6.0  JVOPS WORKSHOP TESTING

This chapter will summarize the approach to the JVOPS Test and will describe the test infrastructure that would achieve the test goals. Following this will be described the modifications to the test infrastructure and test plan that were necessary during testing. Finally will be summarized in chronological order the tests that were carried out with the test results summarized on one Data Collection Sheet for each test.

6.1  Summarized Test Approach

A special approach had been developed for the testing goals of the JVOPS Workshop (see section 4.3). Minimal consumption of clean test hose, fewest possible pump stops, minimal pump decontamination work, and minimal testing time required specific test procedures that will be briefly summarized in the following, and equipment that by the Lead Engineer and the Technical Support Engineer was specially developed for this occasion. For more information, please see the Test Plan in Appendix N.

6.1.1  Order of Test Runs Important to Reduce Hose Consumption

Previous extreme viscosity testing in Canada and Denmark had disclosed that a test hose, which has been subject to very viscous and sticky bitumen oil, cannot be reused for further tests without being completely cleaned first. If all pumps and all flow enhancing techniques, and settings thereof, should be tested under exactly the same conditions, it would require the use of new or completely cleaned test hoses, even for each sub test run of one single test.

It had been found that it is not possible to make a baseline test first (with no flow enhancing technique applied) and then by continued pumping observe the influence of for instance different water lubrication combination types and settings of injected water percentages. The very first test run (without lube water) would immediately have contaminated the test hose with an oil layer of unknown thickness. Consequently the following runs with various WL settings would be carried out with a test hose of unknown “inner diameter” and unknown surface roughness.

If the tests could be carried out in the opposite order, with the expectedly best water lubrication combination first, then the next best, etc. until finally doing the baseline test, the problem with oil sticking to the inner hose wall might be avoided during test runs with lube water applied and only occur in the final run without lube water.

6.1.2  The Water Lubrication Control Stand (WLCS)

A piece of equipment was needed that could control the lube water injection at pump inlet, outlet, or both, and in different percentages of pumped product, while at the same time being able to switch between hot and cold water, even on inlet- and outlet side
simultaneously. A special control stand and arrangement of water supply pumps had to be designed. The Water Lubrication Control Stand (WLCS) in Figure 35 meets the requirements, and the supply pump arrangement (Figure 36) would from hot, tempered, and cold water tanks feed to the WLCS the required type and temperature water.

Figure 35  The Water Lubrication Control Stand (WLCS) hooked up and ready at the top of the USCG Test Tank

Figure 36  Water Lubrication Supply by WL Pump Stand (1) from Hot Lube Water Tank (2), Tempered Lube Water Tank (3), and Cold Lube Water Tank (4).
6.1.3 The Swift Hose Add-on System (SHAS)

The long distance tests at both the CCG and the USCG test line required that the length of test hose was increased 3 times. At the CCG line first from 200 ft to 300 ft, then to 400 ft, and finally to 500 ft. At the USCG line, hose length would be increased from 600 ft to 900 ft, then to 1200 ft, and finally to 1500 ft. This would have required a total of 1400 ft of hose at the Canadian side and 4200 ft at the US side if the pumping would have to be stopped and oiled hoses replaced with clean ones each time the distance was increased.

The SHAS (see section 5.5.6 and Figures 21 and 31) was developed to reduce the amount of test hose needed for the long distance testing. It would allow for adding on up to three additional hose lengths without interrupting the pumping and water lubrication processes. Total consumption for long distance testing at both test lines was brought down from 5600 ft to 2000 ft of hose. This would result in a significant cost reduction since the long distance test at each test line otherwise might have taken two to three days. Enormous lengths of hoses would have had to be cleaned in an around-the-clock decontamination process. By using the SHAS, the long distance testing would be reduced to maximum 30 minutes at each test line.

The availability of the WLCS and the SHAS made it possible, within one test sequence, to switch between WL settings, combinations (in, out, or both), and temperatures and to increase the pump transfer distance up to three times.

6.1.4 Test Support Graphs and Tables

Besides the development of the WLCS and the SHAS some important graphs and tables were produced. These would help the Lead Engineer and the Technical Support Engineer manage each individual test while in progress and would provide directions for the WLCS operators as to the water lubrication settings for each individual test run under a test. All graphs were laminated.

All graphs and two WL operator table examples can be seen in Appendix H, Test Support Graphs and Tables.

6.1.4.1 Apparent Capacity vs. Hydraulic Flow

These graphs were produced for each individual test pump. The calculations for the graphs were based on the displacement per rev. of the hydraulic motor, displacement per rev. of the pump in question, and the approximated volumetric efficiency of the hydraulic motor. An example of an Apparent Capacity vs. Hydraulic Flow graph can be seen in Figure 37.

A positive displacement pump will, as experienced from previous testing, have no volumetric loss when pumping viscous oil, provided it for each revolution is able to drag
in enough oil to fill its displacement volume. Therefore curves can be produced that present the relationship between hydraulic flow and apparent pump capacity. However, the hydraulic motor has some degree of slippage (its volumetric efficiency is less that 1.0). Technical documentation and consultations with hydraulic motor manufacturers provided information that were used to adjust the curves accordingly.

The test Lead Engineer used these graphs to determine the apparent pump capacity from his position on the top of the test tank, where he could read (or be informed of) the hydraulic flow on an in-line gauge. The Lead Engineer also checked the test pump’s discharge pressure on an analog gauge and would instruct the hydraulic power pack (CCG) or remote control stand (USCG) operator to adjust hydraulic flow up or down as required to avoid pressures that were higher than the JVOPS Test maximum of 174 psi or 12 bar.
6.1.4.2 WL Flow vs. Hydraulic Flow and WL Operator In / Out Tables

The hydraulic flow at any time was used by the WLCS operators to set the flows of lube water to the AWIFs. For this purpose graphs were developed for each test pump, which for each pre-determined WL % setting would provide information on the corresponding water flow (Figure 38).

The WL In operator and the WL Out operator would use control valves and an in-line flow meter on the WLCS to accurately adjust the lube water flow rate for a pre-determined lube water % for his AWIF (in or out) in a given test run. The WL Flow vs. Hydraulic Flow graph would allow the operators to immediately adjust the WL flow up or down as required to match the hydraulic flow (and thereby the pump capacity).

Figure 38  Example of Test Support Curves, DOP-250/OMTS315
WL Flow vs. Hydraulic Flow and WL%
6.1.4.3 Hose-fill Time vs. Apparent Capacity

The Hose-fill Time vs. Apparent Capacity curve (Figure 39) was used by the Technical Support Engineer to determine how much time it would take for a new WL setting to be in effect in the full length of the test hose. He would receive information from the Lead Engineer on the apparent capacity. By following the curve for the hose length being tested, he could quickly see the minimum length of time a new set of WL settings should be in force before data should be marked.

Upon a signal from the Technical Support Engineer the Lead Engineer would over the radio system announce: “Mark Data”.

Figure 39  Example of Test Support Curves, Hose Fill Time vs. Apparent Capacity
6.2 Overview of Planned Tests

This section will describe the purposes of the tests that were planned and how the test results from one test would have influence on the following test at the same test line. Proportionality between pump pressure and pumping distance (or the lack of same) would be an important factor in the evaluation of the longest pumping distances possible, both during the JVOPS Workshop and in general for future potentials of viscous oil pumping systems with the most optimal flow enhancing techniques applied.

6.2.1 AWIF Comparison and Cold vs. Tempered Lube Water Test (Test 0)

Before initiating any of the 200,000 and 500,000 cSt oil tests the USCG test line would carry out a test on a lower viscosity oil (25,000 – 50,000 cSt) as a performance comparison test between the existing USCG/US Navy discharge side AWIF for the USCG VOPS DOP-250 and a re-designed AWIF, with a claimed more uniform distribution of the lube water around the oil core. A second purpose of this test was to evaluate tempered lube water against cold lube water for discharge side lubrication. Two DOP-250 pumps would be used in this test, one with the “old” and one with the “new” AWIF.

The best working AWIF would be used for all further testing, and the best of cold or tempered water would be used as “cold” discharge side lubrication water whenever applicable in all the high viscosity tests to be carried out afterwards.

6.2.2 Pre Tests (Tests 1 and 5)

With an oil product in the 200,000 to 500,000 cSt viscosity range, and with an otherwise unknown behavior, it was, based on previous high and extreme viscosity testing (Ref 12), necessary to do the first high viscosity tests on a relatively short hose length. Otherwise it might not even have been possible to reach a flow rate that would allow for the creation of the core annular flow phenomenon. Therefore the length of the 6” test hose for the first CCG test on 500,000 cSt oil was conservatively set to 50 ft and for the first USCG test on 200,000 cSt oil to 100 ft. The longer test hose at the USCG side was due to the lower viscosity.

The first tests on both sides would be used to find the most optimal amount of inlet and outlet lube water and for the USCG line also the best lube water temperature combination. It had up front, based on experience from previous testing in Canada and Denmark, been decided that the CCG GT-185 pump would in all cases need hot water both on inlet and outlet. Here it was more a matter of finding the best working percentages of the hot inlet and outlet lube water.
6.2.3 Master Tests (Tests 2 and 6)

Once the pre tests were complete, the next tests would use longer test hoses (CCG 100 ft, USCG 300 ft) and be the so-called Master Test, where the “best” WL settings from the first tests would be applied and fine tuned. The relations between the results of the pre tests and the Master Tests would serve as basis for an evaluation on the degree of proportionality between pumping distance and required pump pressure when applying core annular flow. This relationship would be used to pre-evaluate the respective pumps’ ability to perform in the long distance testing. The relations between the results of the pre tests and the Master Tests would also provide information on whether additional lube water is required for increased pumping distance.

After fine tuning the water lubrication and trying out some optional settings there would be an opportunity to make a baseline test run without water lubrication (this was removed from the CCG test since it already during prep week was observed that it took the GT-185 pump 65 minutes just to fill a 100 ft long 6” hose (2 USgpm) when no lube water was applied. This was in connection with the hose cleaning test at the CCG test line (see section 5.11.4).

6.2.4 Long Distance Pump Transfer Tests (Tests 3 and 7)

After the Master Tests at both test lines the long distance pump transfer tests would be initiated.

On the CCG side this would involve pumping oil through 200 ft, then 300 ft, then 400 ft, and finally through 500 ft of 6” hose using the best WL settings as found in the previous tests. Time and availability of oil permitting, other WL settings would be tested.

On the USCG side this would involve pumping oil through 600 ft, then 900 ft, then 1200 ft, and finally through 1500 ft of 6” hose using the best WL settings as found in the previous tests. Time and availability of oil permitting, other WL settings would be tested.

6.2.5 Manufacturers’ Tests (Tests 4/(1-4) and 8/(1-4))

The Master Tests (described in section 6.2.2 above) would be repeated with the manufacturers’ pumps (Lamor GT-A 50 and Framo TK-125) under the same conditions, so that the results could be compared. The manufacturers’ pumps would not be subject to long distance testing. Instead their performance under Master Test conditions would be used to calculate their potential long distance performance, based on how the GT-185 and the DOP-250 had performed in their 500 ft, respectively 1500 ft tests. The same would apply for the USCG DOP-160 and the CCG GT-260. They would participate at their own test lines as “manufacturers’” pumps, where the USCG DOP-250 and the CCG GT-185 would participate in the manufacturers' testing respectively at the CCG and the USCG test line.
6.2.6 Local Bulk Heating Tests (Tests 9 and 10)

With all the dedicated water lubrication tests completed it would be time for the Local Bulk Heating tests (see section 3.1.2 for definition). These tests had been scheduled as the last tests since there was a significant risk of heating the test oil too much for further testing, meaning that the viscosity of the test oil at both lines might have dropped more than could be chilled back to the targets within reasonable time.

The local bulk heating tests would use the same test hose lengths at the two test lines as in the respective Master Tests, and would compare the performance of local bulk heating in conjunction with water lubrication (at the previously found most optimal settings) with local bulk heating alone.

6.2.7 Test Overview

Table 1 shows the planned overall test matrix for the JVOPS Workshop testing.

<table>
<thead>
<tr>
<th>Day</th>
<th>USCG 25/200,000 cSt test line</th>
<th>CCG 500,000 cSt test line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1 afternoon</td>
<td>2. Test all functions full scale on water under pressure</td>
<td>1. Test all functions full scale on water under pressure</td>
</tr>
<tr>
<td>Day 2 morning</td>
<td>100 ft AWIF and cold vs. temp WL comparison test with DOP-250 (Test 0)</td>
<td>50 ft optimizing hot water injection combination with GT-185 (Test 5)</td>
</tr>
<tr>
<td>noon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>afternoon</td>
<td>100 ft test, optimizing water injection combination on DOP-250 (Test 1/1)</td>
<td></td>
</tr>
<tr>
<td>Day 3 morning</td>
<td>100 ft test, optimizing water injection on DOP-250 w. best Test 1/1 combination (Test 1/2)</td>
<td>100 ft proportionality verification, Master Test with GT-185 (Test 6)</td>
</tr>
<tr>
<td>afternoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 4 morning</td>
<td>300 ft proportionality verification, Master Test with DOP-250 (Test 2)</td>
<td>200 - 500 ft long distance test with GT-185 or optionally GT-260 (Test 7 or 7 Optional)</td>
</tr>
<tr>
<td>afternoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 5 morning</td>
<td>600 - 1500 ft long distance test with DOP-250 (Test 3)</td>
<td>no testing</td>
</tr>
</tbody>
</table>
Table 1 (continued)

| Day 6  morning | afternoon | Comparative testing with DOP-160 (Test 4/1, as Master Test) | Comparative testing with DOP-250 (Test 8/2, as Master Test) |
| Day 7  morning | afternoon | Comparative testing with LAMOR GT-A (Test 4/3, as Master Test) | Comparative testing with LAMOR GT-A (Test 8/3, as Master Test) |
| Day 8  morning | afternoon | Local bulk heating test with DOP-250 (Test 9) | Local bulk heating test with GT-185 (Test 10) |

6.3 Test Infrastructure Achieving the Test Goals

Details on the major components of the Test Infrastructure are provided in section 5.5 and a complete list of equipment is presented in Appendix F.

Below is a summary of the equipment and supplies that formed the JVOPS Workshop Test Infrastructure. Please refer to Figure 40, which shows the overall layout of the test site including test hose placement and Figure 41, which shows the same overview without test hoses but showing the Data Acquisition cables between the DA central station and the many sensors at the test tanks.

6.3.1 Test Oil and Oil Tanks

Considerations and calculations that were part of the Technical Approach Strategy (TAS) formed the basis for the volumes of test oil that should be available at both test lines as well as for the sizes of the two test tanks.

The CCG test line had approx. 60 bbl of oil placed in the 65 bbl test tank. No backup storage was deemed necessary due to less comprehensive testing, higher viscosity, lower capacity CCG primary test pump (GT-185), and shorter test hoses.
The USCG test line had approx. 440 bbl of oil placed in the 500 bbl baker backup tank. The test tank had a maximum content of 125 bbl and would for testing contain 120 bbl of oil that would be transferred from the backup tank. The higher volumes of oil and the backup tank were deemed necessary due to the higher capacity USCG primary test pump (DOP-250), more extensive testing, lower viscosity oil, and longer test hoses.

The USCG test line further differed from the CCG test line by incorporating a 200 bbl buffer tank that would receive the oil and lube water from the USCG tests. Between testing, the oil and water would be transferred to an oil / water separating brush belt skimmer on the backup tank. Oil would enter the baffle section of the backup tank and water would run off into a water receiving tank (see also 6.3.7 below).

Open top water tanks would at both test lines receive the lube water that by the belt skimmers had been separated from the test oil.
JVOPS Workshop
TEST LAYOUT

Figure 40. JVOPS Test Site Layout
Figure 41. JVOPS Test Data Acquisition
6.3.2 Test Hoses

The lengths of the test hoses for the pre-tests and the Master Tests were conservatively determined based on experience from previous extreme viscosity tests in Canada and Denmark.

The target hose lengths for the long distance tests had been more subjectively decided on. The USCG goal was clearly to overcome a pumping distance that would resemble the NEW CARISSA incident off the Coast of Oregon in 1999. This incident had been the incentive to start the series of VOPS Workshops in the following years, and the USCG target for this sixth workshop was clearly to demonstrate that it really is possible to efficiently pump transfer 200,000 cSt oil through at least 1500 ft of hose when using the right equipment and the right techniques. The target pumping distance for the CCG test line was set to 500 ft with respect to the higher viscosity of the test oil (500,000 cSt). A total of 3300 ft of 6” Hydrasearch lay flat hose was available for the JVOPS Workshop.

6.3.3 SHAS and WL System

The Swift Hose Add-on System (SHAS) and the water lubrication system including the Water Lubrication Control Stand (WLCS), the lube water tanks, and the lube water supply pumps were other essential parts of the test infrastructure. The sizes of the various water tanks (hot, tempered, cold) for the lube water system had in the TAS been determined in a similar way as the test tanks.

6.3.4 Test Power Packs

Diesel hydraulic power units (HPUs) would via hydraulic hoses, and in the case of the USCG test line a remote control stand, provide power to the test pumps. Other HPUs would provide power to the mix pumps and oil transfer pumps.

6.3.5 Boiler System

A US Navy Clayton boiler system would be used in conjunction with heat exchangers to heat the hot (and tempered) lube water and to heat the oil in the USCG test tank for Test 0. For the local bulk heating tests (9 & 10) the boiler would provide steam for the heating coils placed in front of or around the test pump.

6.3.6 Chiller System

A rental chiller system including chiller, buffer tank, and heat exchanger would via the heat exchanger provide chilled water for the cold lube water tank and for chilling the sides of the oil tanks when a viscosity increase was required. A rental diesel electric power unit provided power to the chiller.
6.3.7 Oil / Water Separation

Two belt type skimmers were used for separating the applied lube water from test oil.

At the USCG line a LAMOR Brush Chain skimmer (attached to the roof of the baker backup tank) was used between tests. Used test oil/water was pumped from the USCG 200 bbl buffer tank to the backup tank via the skimmer. The oil/water mixture was delivered on the top of the moving belt and water would run off via a tray beneath the brush bank and into a water receiving tank, while the oil was brought upwards to be scraped off into the baffle section of the backup tank. The LAMOR skimmer belt was powered by a 10 Hp HPU that was provided by Hyde Marine, Inc.

At the CCG test line, an ERE steel belt skimmer was placed at the top of the CCG test tank and would separate oil and water continuously during testing. The oil/water mixture was delivered on the top of the moving belt, and water would run off via a tray beneath the belt bank and into a water receiving tank, while the oil was brought upwards to be scraped off into the baffle section of the CCG test tank. The ERE skimmer belt was powered by an ERE HPU.

6.3.8 Hose Cleaning System

A US Navy hose pigging system including compressor, pig launcher, pig catcher, various types pigs, and the necessary controls would be an important part of the test infrastructure because so much test hose had to be decontaminated for reuse and for final return shipment.

The hose cleaning system further consisted of a 120 ft by 20 ft containment berm, two 200 bbl open top containers, one high pressure washer, and misc. pumps for flushing with diesel fuel and with water.

6.3.9 General Decontamination and PPE

General decontamination was provided by a local contractor, Asco Environmental, Inc., Harvey, LA under contract with the US Navy. Their equipment included containment berms, tanks, waste containers, hot water high pressure cleaner, and vacuum trucks for removal of contaminated water. ASCO was also responsible for waste handling, portable toilets, wash stations, and for supplies of various personal protection equipment (PPE).

6.3.10 Miscellaneous Equipment

Misc. portable and self powered pump systems and hose sets were used to pump water from the bayou to the lube water tanks and to circulate chilled water from the chiller station to the two oil tanks (CCG test tank and USCG backup tank).
6.3.11 Data Acquisition

The Data Acquisition setup for the JVOPS Workshop was the most comprehensive system for data recording that has ever been applied in a VOPS workshop. The special test procedure with frequent on-the-go adjustments of various test parameters required continuous logging of vital data throughout each test and not only at specific Mark Data points. So much would rely on the efficiency of this system that wherever possible data were also recorded manually and in some cases electronically for backup. See also section 5.11.3 and in particular Appendix F for full information on the data acquisition system, including specifications on equipment.

The principles of the electronic data acquisition and information on backup data recording and general manual data recording are explained below. The essential recordings that for each test would be recorded electronically by PC based data loggers (Figure 42) were:

- \( Q_{\text{hydr}} \) Hydraulic flow to pump (pump RPM equivalent)
- \( P_{\text{pump}} \) Test pump discharge pressure
- \( T_{\text{wl in}} \) Temperature of inlet side lube water
- \( T_{\text{wl out}} \) Temperature of outlet side lube water
- \( Q_{\text{wl in}} \) Flow rate of inlet side lube water
- \( Q_{\text{wl out}} \) Flow rate of outlet side lube water
- \( T_{\text{oil/inlet A and B}} \) Temperature of test oil at pump intake (2 sensors)
- \( T_{\text{oil/bulk A and B}} \) Temperature of bulk of test oil in safe distance from the test pump (2 sensors in each test tank)

Below is information on the purpose of each reading and on how backup was provided, so that data would not be lost due to failure to the electronic system.
6.3.11.1 Information on test oil temperatures and thereby viscosities

Two electronic bulk oil temperature readings, $T_{(oil/bulk)}$A and B, in each test tank would provide information on the viscosity of the bulk of the test oil before it became subject to any influence from the possible heat applied at the pump (from hot water injection or from local bulk heating).

Two electronic temperature readings of the test oil as it entered the pump, $T_{(oil/inlet)}$A and B, logged by two sensors placed 8 inches from the pump intake, would provide information on any possible decrease in viscosity caused by possible heat injection at the pump.

6.3.11.2 Information on pressure drop in test hose

One electronic pump pressure reading, $P_{(pump)}$, taken at the pump discharge, would record the total pressure drop in the test hose. An additional reading, recorded manually from an analog pressure gauge placed above the oil, a few feet from the pump discharge, would provide manual backup, and would provide instant pump pressure information to the Lead Engineer.

6.3.11.3 Information on hydr. flow and thereby apparent pump capacity

One electronic hydraulic flow reading, $Q_{(hydr)}$, taken by an inline meter on the test tank top would record the hydraulic flow to the test pump (and thereby provide information on the apparent pump capacity). An additional reading, recorded manually from an analog inline meter placed on the test tank top would provide backup, and would provide instant hydraulic flow information to the Lead Engineer, who instantaneously could convert to pump capacity using the conversion sheet, “Apparent Capacity vs. Hydraulic Flow”, for the pump being tested.

6.3.11.4 Information on applied water lubrication

One electronic inlet lube water flow reading, $Q_{(wl in)}$, taken by an inline flow meter sensor in the “INLET AWIF” section of the WLCS, would record the flow of water injected at the inlet side AWIF. A digital display connected to the meter would provide for manual backup readings and would provide information to the WL$_{in}$ Operator on current status.

One electronic outlet lube water flow reading, $Q_{(wl out)}$, taken by an inline flow meter sensor in the “OUTLET AWIF” section of the WLCS, would record the flow of water injected at the discharge side AWIF. A digital display connected to the meter would provide for manual backup readings and would provide information to the WL$_{out}$ Operator on current status.
One in-line electronic inlet lube water temperature sensor, \( T_{(wl\text{ in})} \), placed in the “INLET AWIF” section of WLCS, would record the temperature of water injected at the inlet side AWIF. An analog in-line thermometer placed close to the “INLET AWIF” port would provide for manual backup readings and would provide information to the WL\text{in} Operator on current status.

One in-line electronic outlet lube water temperature sensor, \( T_{(wl\text{ out})} \), placed in the “OUTLET AWIF” section of WLCS, would record the temperature of water injected at the outlet side AWIF. An analog in-line thermometer placed close to the “OUTLET AWIF” port would provide for manual backup readings and would provide information to the WL\text{out} Operator on current status.

### 6.3.11.5 Manual data acquisition

The “Drum fill” pump capacity control (Figure 43) would be a manual control of the apparent pump capacity (that was based on information on the hydraulic flow). An oil drum, hanging from a crane in a special built frame, incorporating a weighing cell, would be moved into the discharging oil flow from the test hose, and the time to fill the drum would be logged manually on a stop watch. The arrangement was developed by SAIC Canada and Environment Canada who had provided it for the JVOPS Workshop. The Drum fill arrangement has a digital display and a reset function: The reset function would compensate for any oil left in the drum after emptying it so that the digital display – after a new drum fill – only would show the weight of the new oil that had entered the drum.

![Drum Fill Pump Capacity Verification](image_url)
After registering the weight of the oil the drum would be emptied. At the USCG test line the oil would be dumped into the 200 bbl buffer tank that was also receiving the oil and lube water from the test hose. At the CCG test line the oil would be dumped on the moving belt of the oil/water separating skimmer.

The drum fill method for verification of apparent pump capacity is not very precise, especially not on high pump capacities. At a pump capacity of 280 USgpm it will take about 5 seconds to fill the drum. The stop watch timing from moving the drum into the oil flow and till it has been moved back out is expected to be up to +/- 1/10 second off at each movement, or totally +/- 0.2 second. The accuracy should therefore in the 280 USgpm range be expected to be within +/- 10%. At 100 USgpm it would be within +/- 4%. Nevertheless it provides a valuable indication on possible serious inflow slippage at the pump intake. The density of the test oil is approximately 1.01, so with an error of about 1% only, the weight of the oil would be converted to volume using a density factor of 1.

Hydraulic supply and return pressures taken at the test HPU would in combination with information on the hydraulic flow provide valuable information on the power delivered by the HPU.

Discharged oil temperature readings taken at the discharge end of the test hose would in combination with the above mentioned bulk oil temperatures and the oil temperatures at the pump intake provide information on the temperature (and thereby viscosity-) development of the oil throughout the entire pumping process.

Bulk oil temperatures, 9 in the USCG backup tank, and 3 in the CCG test tank, taken between tests, would provide information to the Lead Engineer on the viscosity of the test oil and be basis for decisions on chilling or heating the oil.

Lube water tank temperatures (Hot, tempered, and cold) would be recorded to verify that the different lube waters would be of the right temperatures prior to testing and during testing.

Ambient temperatures would be recorded and a general description of the weather conditions be registered since these could have some influence on the test results. Direct sun from clear skies might for instance facilitate the pumping process by adding heat to the discharge hoses. The long distance tests would especially be sensitive to direct sun.

6.3.12 Hose Ramps, Work Platforms, and Gallows

Work platforms were built next to the USCG and CCG test tanks in level with the tank tops and secured a safe work area at these busy spots. A work platform was also built over the 200 bbl USCG buffer tank. Platform frames for the attachment of the SHAS table were built over the CCG test tank and the USCG buffer tank.
Several hose ramps were fabricated to run the test hoses between the tank tops and ground level and back again. At the CCG test tank and at the USCG buffer tank they also reached up to meet with the SHAS that was to be placed over these tanks on the special consoles.

Gallows were built high over the two test tanks and could each hold two fully equipped test pumps in wire slings while data acquisition equipment was attached in preparation for testing. After each test the test pumps would hang in the gallows for drip off prior to being wrapped in plastic sheet and be crane lifted to the decon area.

6.3.13 Crane and Cherry Picker

Heavy lift equipment had to be available throughout the prep phase as well as for testing. A mobile crane and a cherry picker were made available from the host facility, Cenac Towing, as services-in-kind to the project, often off normal working hours.

6.3.14 Portable Light Masts and Light Machines

Several days during setup and testing had to be extended into the dark evenings where portable light masts and generators were essential for the safe and operational work environment. The light equipment was rented from a local supplier.

6.3.15 Command Center

The command center for logistics / administration and the test management, initially provided by USCG Gulf Strike Team and for the test week by Erst O’Brien’s Response Services in New Orleans, was placed away from the turmoil of the test site and provided an excellent place for desk work that required concentration under calm conditions. The command post proved valuable when the Lead Engineer and the principal planning group had to meet to make ad-hoc adjustments to the test plan during the progress of the JVOPS Workshop. These will be described in section 6.4, Chronologic Test Summary, below, in the order that they were required.

6.4 Chronological Test Summary

This section summarizes the time span from 9 through 15 December with notes to describe major test relevant events and observations. It will not go into details regarding the tremendous work that had to be carried by the up to 100 CCG, USCG, US Navy, and Industry responders each day. They were moving heavy equipment around, bringing test hoses in position and removing them again, decontaminating pumps, hoses, and equipment, refueling power packs, operating power packs, remots controls, and skimmers, operating the chiller system, operating the boiler system, transferring oil, doing equipment maintenance and repair, etc. This work represented by far the majority of the work carried out during testing and required more than 90% of the available time.
Just before the actual tests the crews moved to their positions in the many test teams with each their own areas of responsibility. After testing everybody moved back to work breaking down the previous test and setting up for the next, and so on for 10 to 12 hours each day.

Each day started at 07.00 with a morning briefing where new assignments were delegated and general information on the targets of the day were presented. Likewise each day ended with a short debriefing where the accomplishments of the day were summarized. It was important to the test management to keep the level of information on the workshop developments at a high level.

The necessary ad-hoc changes that were made to the Test Plan will be described in the order that they were implemented during the period. The section will finally conclude with a revised “as was” overall test matrix, which will be referred to throughout the remaining sections of this report.

6.4.1 9 December, 2003 – Water Pumping Test

This test was carried out to train the test teams, to check the functionality of the test infrastructure including data acquisition, and to verify equal performance of two DOP-250 pumps that were to be used in Test 0. The test was part of the prep week work and has therefore been described in section 5.11.5. The results of the water pumping test can be found in section 6.5.

6.4.2 10 December – Test 0 and Test 5

Test hoses and pumps for the tests at each test line had already been rigged the day before, the USCG test tank had been filled with test oil, a DOP-160 pump for mixing had been submerged into the test oil, and two Titan heat exchangers had been placed into the oil and connected to the Clayton boiler. Heating the USCG test tank had been applied from 06.00. Target temperature was 95 to 100 F for a viscosity in the 25,000 to 50,000 cSt range, which was reached at 07.30. Heat exchangers were first lifted above the oil to drip off, then removed. Mix pump still working. Sensor rigging for DOP-250 pumps at USCG test tank ongoing. Chilling of cold lube water tank (target 45-50 F) and heating of tempered lube water tank (target 95-100 F). At 09.15 the two DOP-250 pumps for Test 0 were hanging over the oil, hooked up and ready. At 10.00: General data acquisition meeting. At 10.45: Test 0 specific instruction of tank top test teams on USCG tank top.

Test 0/1: USCG “old” outlet AWIF and cold vs. temp lube water comparison test

11.16: Submerged DOP-250 w. old discharge side AWIF in oil while filling riser hose w. temp. lube water for hose priming and to balance static oil pressure. Problem observed w. WLCS or WL pump. Expectedly fixed and test started at 11.33. Three runs completed with approx. 10, 6, and 4 % tempered (87 F) discharge side lube water, but when cold discharge side lube water was to be applied, problems were again observed,
apparently with the cold lube water pump. Test 0/1 stopped at 11.43. Platform for AWIF comparison still intact so decision made not to repeat test and that temp. vs. cold lube water comparison would be accomplished well enough if it could be retrieved from the test with the new AWIF (Test 0/2). Problem with cold lube water was found to be malfunctioning pressure relief valve on WLCS, which was fixed.

Test 0/2: USCG “new” outlet AWIF and cold vs. temp lube water comparison test

13.12: DOP-250 w. new discharge side AWIF submerged in USCG test tank while priming test hose with temp. lube water. Again some delay due to insecurity about WL system, but at 13.20 Test 0/2 started and three runs with tempered (10, 6, and 4%) and three with cold (10, 6, and 4%) were completed, Test stopped at 13.32.

14.00: the GT-185 was hanging ready over the CCG test oil. Hose pigging (w. foam pig) of 100 ft test hose from Test 0/1 while in place at test tank. Hose was then moved to GPC decon berm for one more pigging (scraper pig) and then diesel flushing for 20-30 minutes. Only thin oil film left in hose so at 15.35 the Lead Engineer declared the hose “clean”. This was very promising from the perspective of cleaning the test hoses well enough, even though the oil that had been removed had been slightly warmer than ambient temperatures, i. e. at lower viscosity than could be expected in the remaining tests.

15.40: Final preparations made for Test 5 at CCG test tank. Pump hooked up to hydraulic and test hoses and data sensors connected. 16.25: Found a new problem with WL system. Initially it seemed to be a relief valve problem in the WLCS but was found to be the low pressure hot water pump that could not suck water from feed line that it shared with the high pressure hot water pump. Problem solved by starting low pressure pump first. 1648. Problem to heat hot lube water tank. Temp only 167 F at top and cold at bottom, recirculation with hot water lube pump necessary. Did not solve problem completely. Was only possible to heat the tank to 180 F. Possible problem with boiler system. Decision made to use 180 F as hot water for Test 5 (vs. target 210 F). Rationale was that in field operation 210 F may not be achieved anyway. Minor problem with CCG test HPU solved. 17.45 Turn on light from light masts and ready for Test 5

Test 5, CCG Pre Test w. GT-185 on 50 ft hose for optimal WL settings

18.00: Initial start of Test 5 with pump being submerged in oil while discharge line is being primed with hot discharge side lube water. Small delay by additional WLCS check and test started at 18.07. Seven test runs with various hot water in and out settings were made and test stopped at 18.24. This was the first test in the 500,000 cSt range and the readings indicated fantastic performance.

6.4.3 11 December – Test 1/1 and 1/2 and 100 ft Hose Decon Test

06.00 filling USCG test tank and have boiler working on hot lube water tank. Problem with boiler detected and found to be a piece of rubber in feed line to heating coils in hot lube water tank. From this point on, no problem keeping hot lube water at 200 to 210 F.
08.00 Data acquisition meeting to conclude on Tests 0/1 and 0/2 and on Test 5. Initial analysis of Tests 0/1 and 0/2 revealed no significant difference in performance between old and new AWIF. Likewise no significant difference between colder and more tempered lube water with trend in favour of cold. Decision to use old AWIF in all further USCG testing and to use ambient temperature water as “cold”. Decision on attempting a re-start test run in connection w. Test 1/2 at USCG test line. This was the first change to the test plan. At completion of Test 1/1, which would aim to find the best in/out lube combination as to temperatures, Test 1/2 would start with the same hose as in section 1 after the oil had been left in the hose for minimum 15 minutes to break down the water ring. The baseline run (no lube) of Test 1/1 would be carried out in the beginning of Test 1/2, and after completion it would be attempted to re-establish the core annular flow using a total maximum of 8% water (in + out). If successful, the remaining part of Test 1/2 would follow the original plan and aim to fine tune the amounts of lube water for optimal performance.

Lamor brush conveyor separator fitted with a diverter plate to avoid discharged oil to fall through the brushes and to better spread oil over all four brush chains.

Intensive chilling on CCG test tank. In periods chilling USCG backup tank at the same time.

Test 1/1, USCG Pre Test w. DOP-250 on 100 ft hose for optimal WL combination

13.43: DOP-250 submerged while priming hose w lube water. A pump pressure sensor line had by mistake been disconnected and delayed pump start to 13.49. Eight runs with different lube water combinations were completed and test stopped at 14.00

Test 1/2: USCG Pre Test w. DOP-250 on 100 ft hose, re-start and fine tune WL.

14.26: The DOP-250 pump was started without lube water and moved product at about 75 USgpm at max allowable pressure (174 psi) through the 100 ft test hose (plus riser hose etc.). At 14.29 hot water was applied at both in and outlet AWIF and caused an almost immediate increase in pump RPM (to max. after 30 secs.) and after a small pressure peak to 220 psi the pump pressure dropped rapidly to about 14 psi to level out at 7 to 8 psi when additional lube water was applied at 14.30. As the test continued into six runs with different WL settings, the pressure dropped further and it was verified that the DOP-250 can re-start on about 150,000 cSt oil with an oil filled and contaminated 100 ft hose and that efficient core annular flow can be re-established, almost as well as if it had been on a new clean test hose. The WL settings were 1% hot in and 1% hot out. This altered the test plan as to decon of the DOP-250 between tests. The pump and riser hose were decided to be left at the tank until the next test, where 300 ft of clean hose would be connected for Test 2.

100 ft Hose Decon Test

This afternoon the 100 ft test hose from Test 1 was foam pigged while in place at the USCG test tank and brought to the GPC berm where it was scraper pigged. The hose
was later flushed with diesel and washed inside with water and detergent and was approved “clean”. This was most promising. The new hose decon procedure, as developed by GPC over the last two days, seemed to be able to keep up with hose consumption, provided a couple of “short cuts” could be implemented to the test plan.

These short cuts were decided on by the JVOPS Workgroup the same evening. It was necessary to compensate for the day lost during prep week and even though it now seemed that hose cleaning would work well it was still a concern that it would not be able to meet the continued demand fast enough. The hose pressure drops observed in tests 1 and 5 indicated that the USCG long distance pumping goal of 200,000 cSt through 1500 ft of hose and the CCG goal of 500,000 cSt through 500 ft could be carried out within a safe margin of the maximum pump pressure.

Therefore the Lead Engineer proposed a combination of tests 2 (USCG Master Test on 300 ft hose) and test 3 (USCG long distance) and of test 6 (CCG Master Test on 100 ft) and test 7 (CCG long distance). The master tests should in principle be carried out as planned and instead of stopping and preparing for long distance tests one day later, the tests should right away continue into the long distance tests. The major difference from the originally planned long distance tests would be that the hose lengths added on by using the SHAS in one step would bring the pumping distance up to maximum (in stead of in steps). At the USCG line 1200 ft would be added, and at the CCG test line 400 ft. This approach was accepted by the workgroup and it was further decided to incorporate a re-start test in the USCG Master Test, after baseline testing without lube water to check if it was possible to re-start the core annular flow using cold water on the inlet AWIF. If not, hot water would be applied.

Upon review of the results of the first tests it appeared that 4 % hot water on the inlet AWIF combined with cold water on the outlet AWIF worked well. Combinations using less than the half of this amount of lube water had proved equally efficient, once the core annular flow pumping process had been established with higher amounts of hot lube water to both AWIFs. Without adding in more tests that should start up with the lower percentage settings, it was therefore difficult to determine what actually was the most optimal combinations and settings of lube water. Therefore 4% hot in / 4% hot out was decided to be the start up setting in all remaining tests and that 4% hot in / 4% cold out would be the primary targets for long distance testing at both test lines.

The good results in the first USCG tests with the hot in / cold out combination of lube water to the AWIFs resulted in changes to the approach at the CCG test line. If hot in and cold out would work well in the Master Test, the same setting would be used after adding on the 400 ft of hose for long distance testing. If it worked well, this would be an important step in making the water lubrication concept more operational for future use in the field, since the requirement for hot lube water would be reduced significantly.

The decided changes would modify the use of the SHAS by only adding on one additional hose length at each test line (USCG 1200 ft, CCG 400 ft), but this would still be enough to test the suitability of this equipment.

The decided changes to the Test Plan would bring testing back on schedule.
6.4.4 12 December – Test 6 + 7 and Test 2 + 3

The 300 ft hose section for Test 2 (USCG Master Test) was connected to the DOP-250 and riser hose, which had been left hanging over the USCG test tank after Test 1.

The SHAS was positioned on its console on the CCG test tank. The 100 ft test hose for Test 6 (CCG Master Test) was connected to the GT-185 and riser hose, which had been decontaminated after Test 5. The discharge end was connected to the SHAS position one, and the discharge end of the additional 400 ft for Test 7 was connected to position two on the SHAS manifold. The inlet end of the 400 ft hose was placed close to the SHAS outlet side, ready to be connected to outlet position one, used during the Master Test.

Test 6, CCG Master Test w. GT-185 and 100 ft hose

13.15: The GT-185 was submerged while priming the riser hose with hot discharge side lube water. Shortly after the pump was started it was observed that it did not rotate despite full power was on. The test was therefore stopped at 13.20. The pump had to be lifted out of the oil and it was found that one of the hydraulic supply line quick couplings had been disconnected, probably by touching the tank structure during deployment. A closer review disclosed that the coupling did not meet the JVOPS Test standard, which required locking devices on all hydraulic couplings to be submerged in oil. This delayed the test for 35 minutes while the coupling was being secured, which was difficult work because of the sticky oil on pump and hoses. But it was a valuable lesson for responders, since it so clearly demonstrated that a similar disconnect in a real world lightering operation would have caused a lengthy stop of the operation involving hard and dirty work.

Test 6 on 100 ft test hose was re-started at 13.59 and two runs were completed as scheduled before the additional 400 ft of hose were added on using the SHAS, thus commencing Test 7. The add-on procedure worked well.

Test 7, CCG Long Distance Test w. GT-185 and 500 ft hose

It was observed that the hot in / cold out lube water combination worked well in the 100 ft test, so for the 500 ft test the same settings were maintained for the first run. Two more runs with other settings were carried out before this successful test stopped at 14.24. The GT-185 had pumped the close-to 500,000 cSt oil through 500 ft of hose at almost full pump capacity and at a very low pressure of about 14 psi. The use of the SHAS proved to be a rapid and efficient way of adding on a hose length on the fly, and it seemed not to disturb the core annular flow.

Immediately after the CCG tests the SHAS was wrapped in plastic and crane lifted to the decon area and cleaned. It was then lifted to the USCG buffer tank and fitted on its console. The 300 ft hose from the DOP-250 test pump was connected to the SHAS manifold position one and the discharge end of the 1200 ft hose that would be added on after the Master Test was connected to position two on the manifold. The free end of the hose was then connected to the riser hose.
1200 ft hose was placed close to the SHAS outlet side, ready to be connected to the position one outlet used during the Master Test.

**Test 2, USCG Master Test w. DOP-250 and 300 ft hose**

16.48: DOP-250 submerged in about 200,000 cSt oil while priming riser hose w. hot discharge side lube water and heating pump inlet area and adjacent oil with hot inlet side lube water. The pump was started at 16.51 and three runs were completed with hot in/hot out, hot in/cold out, and cold in/cold out WL combinations to the AWIFs, all of 4% lube water on both in- and outlet. The pump had pumped at about 260 USgpm apparent capacity at a pressure that never exceeded 8 psi with all the applied WL settings. Then all lube water was shut off so that the oil and water in the test hose could be (slowly) pumped out in preparation for the baseline test. This was a process requiring utmost caution by the Lead Engineer and the operator of the hydraulic flow control and despite the careful approach there were observed pump pressure peaks up to 250 psi, which is 70% higher than the manufacturer's specified maximum for the pump. Fortunately the pump could withstand this. The pump was stopped at 17.03. Night lighting was turned on.

At 17.18, after a 15 minutes break to let the oil settle in the hose and to break down the lubricating effect of any water remaining in the test hose, the pump was re-started and baseline testing without lube water was carried out. After retrieving data for the baseline test, it was at 17.21 attempted to re-establish the core annular flow using cold water on both in- and outlet. This had no effect, so at 17.23.30, hot water on the outlet only was applied, but showed up to 17.26 the same result: Pump pressure was at maximum and pump rate remained as without lube water. Hot in and hot out was applied at 17.26 and after 40 seconds (at 17.26.38) the pump pressure started dropping. After 35 more seconds (at 17.27.14) the pump operated at max RPM and the discharge pressure had at 17.28.18, when a full run with 4 % hot in and 4 % hot out had been completed, dropped to 11 psi. Now that core annular flow had been re-established using hot in and hot out, the WL flows were set to 4 % hot in and 4 % cold out as planned, and one test run was carried out with these settings. The pump pressure had increased to 17 psi with the hot in / cold out combination.

**Test 3, USCG Long Distance Test w. DOP-250 and 1500 ft hose**

At 17.32.44 the SHAS was used to add on 1200 ft of test hose for Test 3 without interrupting the pumping and water lubrication processes from Test 2. The first run of Test 3 maintained the 4% hot in and 4% cold out WL settings from the last run of Test 2, and then one run was completed with 6% cold water on the inlet only. After the 1200 ft of hose had been added, the pumping distance was slightly over 1500 ft, and the pump had still worked at nearly full capacity and the discharge pressure never exceeded 60 psi (compared to max. permissible pressure 174 psi).

Shortly after the USCG long distance test an approach to remove “in situ” the oil from the 1500 ft test hose was initiated. It was attempted to use the test pump at low RPM while simultaneously injecting hot lube water at both the inlet and outlet AWIFs. The approach had been inspired by the previous extreme viscosity tests in Denmark (Ref
12) where a similar technique worked well on 3 million cSt oil and a hose length of 60 ft. However, in this case it did not work. A probable cause was that the inlet side lube water, was slipping backward through leaks between the screw and sealing surfaces. Either much less or no inlet lube water at all should have been applied to enabled the pump to seal very well on the viscous oil that would be dragged into the pump. Hot water on the discharge side only at a high pressure and in conjunction with the pump pressure might have been able to push out the majority of oil in the hose, as was done two days later using high pressure water followed by compressed air and pigs (see 6.4.6).

This was a most encouraging day of oil testing: Both the USCG and CCG main testing targets of long distance pumping of extreme viscosity oil had been reached with overwhelming results.

6.4.5 13 December – No Testing. Re-evaluation of Test Goals

Severe weather made testing impossible and thereby the workshop was again one day behind schedule. The day was instead used to protect the test tanks from rain water contamination, to tear down the long distance test setups, to decon the SHAS and the test pumps, and to rig the two manufacturers’ pumps for testing.

The JVOPS Workgroup met to re-evaluate the test goals considering the available time left. Monday, 15 December would under all circumstances be the last day of testing. This left the group with only two days for the remaining tests, which with reference to the original test matrix in Table 1 would require 3 days, while even adding in one more test (see point 2 below). This would be an impossible task considering both time and the need for chilling the test oil to target viscosities between tests.

Priorities were as follows:

1. Manufacturers’ tests and local bulk heating tests should as a minimum be carried out at one test line (either 200,000 or 500,000 cSt oil).

2. Viscosity verification test. Testing till now indicated that once core annular flow was in full effect, then the viscosity might not matter very much. These observations called for a separate test to verify this.

3. Tests of the smaller DOP-160 and the CCG GT-185 at the USCG test line and the larger GT-260 and the DOP-250 at the CCG test line.

The JVOPS Workgroup decision was as follows:

1. Carry out manufacturer’s tests at the USCG 200,000 cSt test line only.

2. Carry out local bulk heating test with GT-185 at CCG 500,000 cSt test line only.

3. Viscosity verification test with GT-185 pump at USCG test line.
4. No testing of USCG DOP-250 test pump at CCG test line.

5. No testing of the two coast guards’ secondary response pumps. It was based on the findings in the previous tests evaluated that a larger or smaller pump of otherwise similar design would not provide significantly different test results, other than pumping at respectively higher or lower rates.

This led to the last changes that would be made to the Test Plan, and can be seen in Section 6.4.8, Table 2: Overview Matrix of Actual Tests at the JVOPS Workshop.

6.4.6 14 December – 1200 ft Hose Oil Removal/Pigging and Tests 4.3 and 4.4

It was due to the cold weather the day before necessary to heat the USCG test oil in the backup tank about 10 F, from 60 to 70 F. This was done by using the DOP-250 mix pump for a few hours.

1200 ft Hose Pigging

The 1200 ft “add-on” test hose had after Test 3 two days ago been disconnected and capped. Now it was time to see if it the very cold oil (now > 500,000 cSt) could be pushed out. The first approach was to inject hot water at the very high pressure (up to 200 psi) that could be delivered by the hot water discharge side lubrication pump via the WLCS. This concept worked on the hose for about an hour, at which time the WLCS had to be removed and be set up for the first manufacturer’s test. But at the time this approach was stopped, some flow of water and oil had already started discharging from the other end of the 1200 ft hose, that had been connected to the pig catcher mounted over the 200 bbl buffer tank (Figure 44).
Instead, a foam pig, and behind this a scraper pig, were introduced to the hose using the pig launcher (Figure 45) and air pressure in the 120 psi range was applied to push out the oil. At this pressure it took about 1½ hour before the pigs emerged in the pig catcher with a thunderous crash. It is expected that this additional time to push out the oil could have been somewhat reduced if the higher pressure of the WL pump had remained on, but the technique would have developed a large amount of contaminated water.

Pigging the 1200 ft of hose with compressed air was a great success, and this technique develops no oil contaminated water. The principle of this oil removal procedure is expected (with some refinements) to be a recommended approach for the removal of extremely viscous oil from very long transfer hoses.

![Pig Launcher](image)

Figure 45  The "Pig Launcher" of the US Navy Hose Cleaning System.

Important Safety Notice:
The use of compressed air for hose pigging operations involves certain safety issues. If a hose ruptures or a hose connection fails, there is a risk of a high energy explosion or that the cleaning pig could be shot out from the hose, both of which could cause serious injury or death to people. Compressed air hose pigging must be used only under strict safety precautions and with tested pigging equipment and techniques. A safer alternative is to use oil or water under pressure to drive the pig. A hose rupture or disconnect caused by a liquid under pressure could cause a spill but will result in minimal risk to personnel.
Test 4.3, Manufacturer testing, LAMOR GT-A 50 on 300 ft hose

11.57: The GT-A 50 was submerged in the about 200,000 cSt oil while priming the riser hose with hot discharge side lube water for 30 secs. One minute later hot water was applied at inlet and outlet AWIFs for heating pump inlet area and adjacent oil and for hose priming. Pump started at 11.59.30 and was at 12.00 at full capacity at a pump pressure of 5 psi, which continued until 12.10.30 when the pump was stopped as per Lead Engineer request. Excess amounts of lube water had surfaced in the test tank and it was a concern that a lube water line might have come off or were leaking. The pump was lifted out of the oil and the LAMOR representative examined the pump. No lube water line was found to leak.

This interruption of the test was most unfortunate, but was by the Lead Engineer on-the-spot deemed necessary to avoid the risk of a faulty test. The large amount of lube water that had surfaced and that caused the concern was apparently a result of the combination of the lower water density (vs. that of the oil) and the high temperature. This enabled the injected inlet side lube water to rapidly penetrate the oil over the pump and float to the top of the oil. The phenomenon had not been observed in other tests.

The fact that the pump already had been pumping for two minutes (at full RPM for 1.5 minute) meant that the 300 ft test hose had been almost filled with oil and lube water. Therefore, when the pump again was lowered into the oil at 12.12, and testing was restarted, Test 4.3 was not carried out on a clean test hose. Even though the 2 minutes of pumping according to the low pump pressure of 5 psi had been fully water lubricated, the 10 minutes break afterwards would have degraded the water ring and allowed for contact between test oil and hose wall. This was indicated by a pressure peak to over 90 psi lasting for 20 seconds immediately after the pump had been restarted. This type of pressure peak had not been observed in the tests with clean hoses.

The three planned test runs with lube water (4% hot in / 4% hot out, 4% hot in / 4% cold out, and 4% cold in / 4% cold out) were completed at 12.21, where after the oil and lube water carefully was pumped out at low capacity until 12.32 in preparation for baseline testing with no lube water. After a 17 minutes break the pump was at 12.49 restarted for baseline testing at low RPM and was kept close to maximum pump pressure until the test was finished at 12.52.

Test 4.3, Manufacturer testing, FRAMO TK-135 on 300 ft hose

14.45: The TK-125 was submerged in the about 200,000 cSt oil while priming riser hose w. hot discharge side lube water. Shortly after the pump had been brought in position for testing hot inlet and outlet water was again sent to the pump, but the inlet side water injection showed no flow despite pressure was on from the WL pump. The pump had to be lifted out of the oil and it was verified that the TK-125 pump had not been equipped with non return valves in the connections to the water lubrication devices, as recommended by the Test Plan to avoid this type of problem. Highly viscous oil had moved in and formed a plug in the inlet side injection tube (this pump had no inlet AWIF but instead a 3/8" injection tube at the pump intake). The inlet side injection pumps of the WL system were not of high pressure type, so fittings were mounted on the WLCS.
so that the line from the high pressure hot water WL pump could be connected to the TK-125 inlet side injection, and the plug could then be blown out. The pump was deployed again, now with the hot WL injection on at a low rate on both in and outlet to avoid a repetition of the problem with the plug.

The test was finally started at 15.52, and was the most time consuming of all tests. It almost immediately became obvious that this pump would not drag in the oil in the same way as had been observed with the PDAS pumps. The test started with numerous attempts to make the pump drag in the oil and to establish efficient water lubrication. Low as well as high rpm and several water lubrication combinations were tried out. The only type of WL that seemed to have effect was hot water applied at the inlet. Attempts were made to lubricate the inlet with cold water, but immediately the pump pressure rose and in effect caused the pressure relief valve on the power pack to activate (about 3200 psi / 220 bar). This again turned the hydraulic flow to the pump almost to 0. It could seem that the torque of the hydraulic motor was too low for the task. The pump had as the only test pump not been equipped with a high torque motor as recommended by the Test Plan.

It was throughout the test observed that there was visually very little correlation between apparent pumping rate (based on hydraulic flow) and what came out of the discharge end of the test hose. It was not possible to complete any of the test runs in their entirety, but the registered data have been inserted in section 6.5 to provide a picture of the performance. The test was stopped at 16.54 by the manufacturer rep. after the pump for some time had worked with a metallic noise.

6.4.7 15 December – Test 9 + 10 and Test 11

Preparations had in the morning been carried out at the CCG test tank for the local bulk heating test with the GT-185 pump and steam coils, using 500 ft of test hose. The viscosity of the CCG test oil was at 500,000 cSt, which was deemed most suitable for this type of test. However, it was at a very late stage discovered that there was too little oil left in the CCG test tank after Tests 6+7. Almost one third of the test oil had been lost into the water receiving tank under the belt skimmer. This had apparently been caused by the close-to-perfect lubrication of the oil: When discharged from the SHAS outlet the otherwise very sticky oil had been so well lubricated that it would hardly stick to the oil already on the belt or to the belt itself. Instead a large part of the test oil slid down the belt to end up in the recovered lube water tank.

This finding was most unfortunate. There was not enough oil left to carry out the local bulk heating test as planned. The JVOPS Workgroup met do discuss an alternative approach, and it was decided instead to do the test at the USCG test tank, and with 100 ft of hose only. The decision on the reduced hose length was based on a desire to compare results with the viscosity verification test later in the day. This test would also be with the USCG test oil and with the same pump, and the oil viscosities of the two tests would be the same or very close to. The fact that more of the available time for testing and test site break down now had been lost, thus leaving less time for hose cleaning, also played in on the decision on using 100 ft of test hose only.
While oil was transferred from the USCG backup tank to the USCG test tank, the entire setup was moved from the CCG to the USCG test tank and with a delay of several hours the local bulk heating test could start early in the afternoon. It was named Test 9+10 to indicate the merging of the USCG Test 9 and the CCG Test 10, using CCG pumping equipment and USCG test line.

**Test 9+10, Local Bulk Heating Test with GT-185 and steam coils on 100 ft hose**

13.29: The GT-185 with steam coils placed around the pump body was submerged in the oil while priming the riser hose with cold lube water. At 13.35.30 hot inlet lube water injection started and cold outlet lube water and the pump was started 13.36.30. At 13.37 the boiler started sending steam to the coils, the pump was at max. RPM, and hot inlet lube water was shut down while cold outlet lube water was kept at about 4%. Immediately upon shut down of hot inlet water the pump pressure went up from 5 to 75 psi in a few seconds and as the test hose filled up over the next 90 seconds the pressure rose to 172 psi. In that time span it was necessary to cycle the boiler steam power up and down to avoid boiling oil splashing on the test crew on the tank top. It very soon was observed that the heated oil in conjunction with cold outlet lube water did not form a core annular flow.

Experimenting started with different WL settings in an attempt to create core annular flow. Hot water on the inlet seemed best to reduce pump pressure while the steam was on (on and off actually). The test runs started 13.49 and the first run was with steam coils only (no lube water, baseline) and then followed 10 more planned and ad-hoc settings before the test was stopped at 14.27.

The splashing of oil was a surprise to the test management since it was the expectation that the pump would rapidly move away the heated oil. The fact that the boiler was on and off throughout the test might make heat input estimations difficult, thus not providing sufficient data for a fair judgment of the potential of local bulk heating.

After the test the GT-185 was used to transfer the remaining oil to the USCG buffer tank. Then new test oil was transferred to the USCG test tank while the GT pump was decontaminated, the coils were removed from the pump, and the test pump was brought back to the test tank to be hooked up for the final test.

**Test 11: Pressure Drop vs. Viscosity Verification Test with GT-185 pump on 100 ft hose**

16.15: The GT-185 was submerged in the test oil while riser hose was primed with hot outlet lube water and inlet lube water was injected to pre-heat pump intake and adjacent oil. Pump was started and at full RPM at 16.16. Two runs (4% hot in / 4% hot out and 4% hot in / 4% cold out) were carried out that would be directly comparable with the similar settings of the CCG Master Test with oil of a much higher viscosity.

Three more runs were completed with various cold lube water settings before the lube water was stopped in preparation for a re-start test after a short break where the pump was stopped. The usual 15 minutes break was not applied due to time constraints. The
pump re-started at 16.38 and operated without lube water at about 165 psi, peaking to 185 psi after 4 minutes, just before hot inlet water was applied. Pressure then immediately dropped and after 1½ minutes was down to 6 psi. The test stopped at 16.44.

The initial information provided by this test is that (with core annular flow) the pressure drop at about 110 USgpm through approx. 100 ft of 6" hose with 480 k cSt oil is about 8 psi and that it drops to about 4 to 6 psi if the viscosity drops to about 260 k cSt (about half). In both cases with the most optimal lube water combinations, relatively a significant drop, but in a real world scenario the difference would hardly be noticeable.

6.4.8 Overview of Tests that Were Carried Out at the JVOPS Workshop

The final test schedule “as it was” can be seen in Table 2, Test Overview Matrix of Actual Tests at the JVOPS Workshop. This matrix will be referred to in the remaining part of this report and especially in chapter 7, Evaluation of Test Results.
### Table 2  Overview Matrix of Actual Tests at the JVOPS Workshop

<table>
<thead>
<tr>
<th>Date</th>
<th>USCG 25/200,000 cSt test line</th>
<th>CCG 500,000 cSt test line</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 December, 2003</td>
<td>Water Test</td>
<td>no testing</td>
</tr>
<tr>
<td></td>
<td>Test all functions full scale on water under pressure and carry out performance comparison test of two DOP-250 pumps to be used in Test 0</td>
<td></td>
</tr>
<tr>
<td>10 December, 2003</td>
<td>100 ft test on 25-50 k cSt oil w. “OLD” USCG VOPS AWIF and cold vs. temp WL comparison test w. DOP-250 (Test 0/1)</td>
<td>50 ft pre test, optimizing hot water injection combination with GT-185 (Test 5)</td>
</tr>
<tr>
<td></td>
<td>100 ft test on 25-50 k cSt oil w. “NEW” AWIF and cold vs. temp WL comparison test w. DOP-250 (Test 0/2)</td>
<td></td>
</tr>
<tr>
<td>11 December, 2003</td>
<td>100 ft test, optimizing water injection combination on DOP-250 (Test 1/1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 ft test, re-start and optimizing water injection on DOP-250 w. best Test 1/1 combination (Test 1/2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 ft hose decon test</td>
<td></td>
</tr>
<tr>
<td>12 December, 2003</td>
<td>300 ft proportionality verification, Master Test with DOP-250 (Test 2) including re-start + 1500 ft long distance test with DOP-250 (Test 3 modified)</td>
<td>100 ft proportionality verification, Master Test with GT-185 (Test 6) + 500 ft long distance test with GT-185 (Test 7 modified)</td>
</tr>
<tr>
<td>13 December, 2003</td>
<td>Severe weather conditions, no testing</td>
<td>Severe weather conditions, no testing</td>
</tr>
<tr>
<td>14 December, 2003</td>
<td>1200 ft hose decon test, oil removal / pigging with high pressure hot lube water pump and USN hose pigging system Comparative testing with LAMOR GT-A 50 (Test 4/3, as Master Test) Comparative testing with FRAMO TK-125 (Test 4/4, as Master Test)</td>
<td>no testing</td>
</tr>
<tr>
<td>15 December, 2003</td>
<td>Local bulk heating test on 100 ft hose with GT-185 and steam coils (Test 9+10) Pressure drop vs. viscosity verification test on 100 ft hose with GT-185 (Test 11)</td>
<td>no testing</td>
</tr>
</tbody>
</table>
6.5 Summary of Collected Data

This section contains a Data Collection Sheet for each pump transfer test with the key data on each individual test run. The data have been extracted from the raw data that were retrieved by the electronic data logger system and from manual and backup data. The sheets have brief comments to individual test runs where relevant. More in depth notes of interest can be found in the "Notes" section on page two of each sheet.

Raw data from all tests are presented in Appendix L and in the test results analysis section (Chapter 7) are presented all main data from each test in Excel graph format.

Please note that the water lubrication percentages for Test 4/4 are calculated as

\[ WL \% = \left( \frac{\text{Lube water GPM}}{\text{Drum fill capacity GPM}} \right) \times 100 \% \]

This is due to the large deviation from the apparent pump capacity (based on the hydraulic flow) to the actually measured capacity (by drum fill per time) in this test.

In all other tests water lubrication percentages are calculated as

\[ WL \% = \left( \frac{\text{Lube water GPM}}{\text{Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water}}} \right) \times 100 \% \]

The reason for not relating the WL% to the oil flow is that the total of oil flow plus inlet lube water flow are expressed by the hydraulic flow multiplied by a pump specific factor. In a real world scenario, the hydraulic flow (and thereby oil flow plus inlet lube water flow) is what the responders can read on the hydraulic flow gauge.
Dec. 9 Test on USCG DOP-250 w old AWIF and USN DOP-250 with new AWIF

Water pumping comparison test results

Test of two DOP-250 pumps on water using a fixed valve setting at the discharge end of a 150 ft 6" hose.

Purpose: To verify same degree of sealing capability of the two pumps prior to comparison testing of two different discharge side AWIFs, one on each pump

Test method:
1. Run hydraulic flow to pump up to 40 USgpm, equivalent to 240 USgpm pump capacity with OMTS 315 Hydr. motor (Conversion sheet "DOP-250/OMTS 315 Apparent Capacity vs. Hydraulic Flow").

2. Set valve on discharge end of 150 ft hose so that pressure gauge at discharge shows 150 PSI. Maintain same valve setting while setting hydraulic flow at 30, 20, and 10 USGPM, each time reading pressure. Use same valve setting for second pump.

NOTE: This test was not a water lubrication test, but water lubrication on the two pumps' discharge side was used and logged as an exercise prior to testing with oil, Test 0.

Date and time: December 9, 2003 at 1400 hours.

Manual data pick-up:
- Discharge pressure at hose discharge: Jim Mackey
- Hydraulic flow: Flemming Hvidbak

The test verified that the two pumps have approximately the same sealing characteristics and that they therefore could be used for AWIF comparison testing in Test 0.
<table>
<thead>
<tr>
<th>RUN #</th>
<th>Pump press.</th>
<th>Hour, min, sec</th>
<th>P_{supply-P_{return}}</th>
<th>Psupply</th>
<th>WL</th>
<th>USgpm</th>
<th>hydr.</th>
<th>T_\text{hydr}</th>
<th>P_{supply-P_{return}}</th>
<th>Psupply</th>
<th>WL</th>
<th>USgpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>5</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>6</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks:
- No data for run 4 due to problem with WL system.
- Run not carried out due to problem with WL system.
- Run not carried out due to problem with WL system.

### Test 0/1 Data Collection Sheet

#### USCG Std. Disch. AWIF and Cold vs. Temp. on 100 ft hose / 25-50 k cSt oil

**Date:** 2003-12-10

**Test pump:** USCG VOPS DOP-250/OMTS 315 w. standard USN/USCG discharge side AWIF

**Total 6" hose length:** 100 ft + riser hose arr. = 107.5 ft

**Cold water:** (C) tank: 47 F [45-50 F] from analysis of oil sample: cSt @ 106 F

**Tempered water:** (T) tank: 95 F [100-110 F]

**Weather:** 55 F, clear skies.

Oil viscosity based on Inlet Oil Temperature average: 21,000 cSt @ 106 F (Dec. 03 curve).

**White:** Manual data and calculated data. No bu data: (-). Values in [ ] are target values (may not be used when on target).
Test 0/1 Data Collection Sheet Notes

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100%

The test was carried out in the USCG test tank on heated oil as the first step in a comparison between the standard USN/USCG VOPS discharge side AWIF and a new discharge side AWIF and also had the purpose of comparing tempered and cold discharge side lube water.

The test was stopped after run 3 due to a problem with the cold lube water supply. Tempered vs. cold lube water comparison to be carried out in Test 0/2.

It is not quite clear why the lube water temperatures differed so much from the lube water tank temperatures, which were close to or at targets. Stratification in the tanks may be part of the reason. The WL tank temperatures were at this early stage of testing gauged with a hand held meter in the upper ¼ of the tanks. The WL pumps sucked from the bottom of the tanks. However, stratification would in this way have provided even colder cold (C) lube water, but it did not.
### Test 0/2 Data Collection Sheet

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Hy flow stable</th>
<th>Apparent DOP250 cap. from hydr. vs flow conv. curve – WL_in USgpm</th>
<th>Calculated ‘Drum fill’ measured ~ Σ WL_out USgpm</th>
<th>Bulk Oil Temp Ave.</th>
<th>Inlet Oil Temp Ave.</th>
<th>Disch Oil Temp</th>
<th>P_supply − P_return psi</th>
<th>Time Hour, min, sec</th>
<th>Pump press. psi</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>9 T (92)</td>
<td>0 W (27)</td>
<td>26 W (44)</td>
<td>50</td>
<td>296</td>
<td>n/a</td>
<td>107</td>
<td>95</td>
<td>100</td>
<td>3070</td>
<td>13.22, 34.00</td>
<td>7 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 2</td>
<td>5 T (92)</td>
<td>15 W (13)</td>
<td>48 W (43)</td>
<td>286</td>
<td>n/a</td>
<td>107</td>
<td>97</td>
<td>107</td>
<td>3120</td>
<td>6.3 (0)</td>
<td>13.24, 01.00</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 3</td>
<td>4 T (92)</td>
<td>11 W (12)</td>
<td>48 W (43)</td>
<td>289</td>
<td>n/a</td>
<td>107</td>
<td>98</td>
<td>108</td>
<td>3070</td>
<td>6.3 (0)</td>
<td>13.24, 54.00</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 4</td>
<td>2 T (92)</td>
<td>6 W (7)</td>
<td>48 W (43)</td>
<td>290</td>
<td>n/a</td>
<td>107</td>
<td>99</td>
<td>109</td>
<td>3020</td>
<td>6.2 (0)</td>
<td>13.26, 10.00</td>
<td>(0)</td>
<td></td>
<td>Ad hoc added run</td>
</tr>
<tr>
<td>RUN 5</td>
<td>8 C (62)</td>
<td>24 W (25)</td>
<td>49 W (43)</td>
<td>290</td>
<td>n/a</td>
<td>106</td>
<td>101</td>
<td>110</td>
<td>2980</td>
<td>4.8 (0)</td>
<td>13.27, 21.00</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 6</td>
<td>5 C (66)</td>
<td>15 W (16)</td>
<td>50 W (45)</td>
<td>299</td>
<td>n/a</td>
<td>103</td>
<td>100</td>
<td>112</td>
<td>2820</td>
<td>5.9 (0)</td>
<td>13.28, 10.00</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 7</td>
<td>3 T (72)</td>
<td>10 W (9)</td>
<td>50 W (45)</td>
<td>297</td>
<td>n/a</td>
<td>104</td>
<td>101</td>
<td>107</td>
<td>2830</td>
<td>5.4 (0)</td>
<td>13.29, 00.00</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 8</td>
<td>2 C (82)</td>
<td>5.5 W (6)</td>
<td>50 W (45)</td>
<td>296</td>
<td>n/a</td>
<td>103</td>
<td>101</td>
<td>112</td>
<td>2780</td>
<td>5.5 (0)</td>
<td>13.29, 51.00</td>
<td>(0)</td>
<td></td>
<td>Ad hoc added run</td>
</tr>
<tr>
<td>RUN 9</td>
<td>1 C (86)</td>
<td>2.5 W (2.5)</td>
<td>50 W (45)</td>
<td>297</td>
<td>n/a</td>
<td>102</td>
<td>103</td>
<td>114</td>
<td>2780</td>
<td>6 (0)</td>
<td>13.30, 41.00</td>
<td>6</td>
<td></td>
<td>Ad hoc added run</td>
</tr>
</tbody>
</table>

**Yellow: Datalogger and back-up ( ) readings**  White: Manual data and calculated data.  No bu data: (--).  Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Inlet Oil Temperature average: 30,000 cSt @ 99 F (Dec. 03 curve).

From analysis of oil sample:  cSt @ 99 F

Weather: 55 F, clear skies.  Tempered water (T) tank: 96 F [100-110 F]  Cold water (C) tank: 49 F [45-50 F]

Test pump: USN VOPS DOP-250/OMTS 315 w. new flemingCo discharge side AWIF  Total 6” hose length, 100 ft + riser hose arr. = 107.5 ft
Test 0/2 Data Collection Sheet Notes

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %

The test was carried out in the USCG test tank on heated oil as the second step in a comparison between the standard USN/USCG VOPS discharge side AWIF and a new discharge side AWIF and also had the purpose of comparing tempered and cold discharge side lube water.

It is not quite clear why the lube water temperatures differed so much from the lube water tank temperatures, which were close to or at targets. Stratification in the tanks may be part of the reason. The WL tank temperatures were at this early stage of testing gauged with a hand held meter in the upper ¼ of the tanks. The WL pumps sucked from the bottom of the tanks. However, stratification would in this way have provided even colder cold (C) lube water, but it did not.
## Test 1/1 Data Collection Sheet

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube</th>
<th>Outlet Lube</th>
<th>Inlet Lube</th>
<th>Outlet Lube</th>
<th>Hy flow stable</th>
<th>Apparent DOP250 cap. from hydr. vs flow conv. curve – WL</th>
<th>Calculated ‘Drum fill’ measured ~ Σ WL</th>
<th>Bulk Oil Temp. T&lt;sub&gt;bulk&lt;/sub&gt; °F</th>
<th>Inlet Oil Temp. T&lt;sub&gt;in&lt;/sub&gt; °F</th>
<th>Disch Oil Temp. T&lt;sub&gt;dish&lt;/sub&gt; °F</th>
<th>ΔP Hydr.</th>
<th>Time Hour, min, sec</th>
<th>Pump press.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>4</td>
<td>210 H</td>
<td>4</td>
<td>H (162)</td>
<td>10.5 (11.4)</td>
<td>9.6 (9.6) (-)</td>
<td>264</td>
<td>250 74 73 94</td>
<td>2415</td>
<td>13.52 18</td>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 2</td>
<td>4</td>
<td>210 H</td>
<td>4</td>
<td>C (110)</td>
<td>11 (11.3)</td>
<td>10 (9.4) (-)</td>
<td>265</td>
<td>260 74 73 88</td>
<td>2415</td>
<td>13.53 04</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 3</td>
<td>4</td>
<td>210 H</td>
<td>4</td>
<td>C (98)</td>
<td>11 (-)</td>
<td>10.5 (-) (-)</td>
<td>265</td>
<td>268 74 73 87</td>
<td>2315</td>
<td>13.53 52</td>
<td>5.6</td>
<td>Ad hoc added run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 4</td>
<td>6</td>
<td>210 H</td>
<td>0</td>
<td>n/a</td>
<td>15 (15.1)</td>
<td>0 (0)</td>
<td>262</td>
<td>270 74.5 74 80</td>
<td>2320</td>
<td>13.55 00</td>
<td>5.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 5</td>
<td>0</td>
<td>n/a</td>
<td>6</td>
<td>H (170)</td>
<td>0 (0)</td>
<td>15 (14.8) (-)</td>
<td>262</td>
<td>255 74.5 74 83</td>
<td>2720</td>
<td>13.56 01</td>
<td>5.7</td>
<td>Note ΔP Hydr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 6</td>
<td>4</td>
<td>69 C</td>
<td>4</td>
<td>C (120)</td>
<td>11 (10.2)</td>
<td>11 (10.4) (-)</td>
<td>263</td>
<td>252 74.5 74 85</td>
<td>2270</td>
<td>13.57 05</td>
<td>4.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 7</td>
<td>6</td>
<td>68 C</td>
<td>0</td>
<td>n/a</td>
<td>15 (14.6)</td>
<td>0 (0)</td>
<td>260</td>
<td>254 74.5 75 88</td>
<td>2620</td>
<td>13.58 04</td>
<td>4.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 8</td>
<td>0</td>
<td>n/a</td>
<td>6</td>
<td>C (80)</td>
<td>0 (0)</td>
<td>15 (14.3) (45)</td>
<td>280</td>
<td>253 74.5 75 82</td>
<td>3020</td>
<td>13.58 56</td>
<td>4.5</td>
<td>At 14.00 disch oil temp was 73 F. Note ΔP Hydr. WL and pump stopped 14.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Yellow: Datalogger and back-up ( ) readings**  White: Manual data and calculated data. No bu data: (-). Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Bulk Oil Temperature average at test start: 150,000 cSt @ 74 F (Dec. 03 curve). From analysis of oil sample: cSt @ 74 F

Weather: 55 F, partly cloudy, moderate wind

Hot water (H) tank: 207 F [200-210 F]

Cold water (C) tank: 66 F [ambient F]

Test pump: USCG VOPS DOP-250/OMTS 315 w. flemingCo inlet side AWIF and standard USN/USCG discharge side AWIF

Total 6’ hose length, 100 ft + riser hose arr. = 107.5 ft
**Test 1/1  Data Collection Sheet Notes**

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100%

The purpose of this test was to find the best working combination of WL in and out (or one only) as to lube water temperatures and percentages of injected water.

Data Logger sensor for outlet lube water temperature failed, backup data has been used.

Backup gauging of lube water temperatures seem too low for hot water and too high for cold water. Lube water tanks were on target and were each mixed by circulation via WLCS.
## Test 1/2 Data Collection Sheet

**USCG Pre Test on 100 ft hose / 140 k cSt oil [200 k]**

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Hy flow stable</th>
<th>Apparent DOP250 cap. from hydr. vs flow conv. curve – WL&lt;sub&gt;n&lt;/sub&gt; USgpm</th>
<th>Calculated 'Drum fill' measured – Σ WL&lt;sub&gt;n&lt;/sub&gt; USgpm</th>
<th>Bulk Oil Temp Ave.</th>
<th>Inlet Oil Temp Ave.</th>
<th>Disch Oil Temp Ave.</th>
<th>ΔP Hydr. =</th>
<th>Time</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>12.5/13</td>
<td>80/79/75/75/73</td>
<td>3320/320/165</td>
<td>14.28/13/10.0</td>
<td>205/205/47/47</td>
<td>276/75/75/79</td>
<td>2520/14.30/13</td>
<td>(--)</td>
<td>Restart w/o WL after 25 min stop after test 1/1. Not true baseline, water not removed</td>
</tr>
<tr>
<td>RUN 1A</td>
<td>1/1/3 [H]/(125)</td>
<td>1/1/4 [H]/(150)</td>
<td>1/1/10.2 (10.6)</td>
<td>1/1/10.2 (10.6)</td>
<td>47/44</td>
<td>270/261/75/75/79</td>
<td>2320/230/6.5</td>
<td>14.31/13/30.0</td>
<td>208 H (160)</td>
<td>210 H (174)</td>
<td>47/44/75/75/79</td>
<td>(--)</td>
<td>1% hot in + 1% hot out from 14.28.52. Up to full pump capacity in 30 seconds.</td>
</tr>
<tr>
<td>RUN 4</td>
<td>4/2/5(5.2)</td>
<td>4/2/5(5.2)</td>
<td>4/2/5(5.2)</td>
<td>4/2/5(5.2)</td>
<td>46/45</td>
<td>273/264/75/75/106</td>
<td>2220/220/6.3</td>
<td>14.34/13/54.0</td>
<td>210 H (170)</td>
<td>210 H (170)</td>
<td>47/44/75/75/79</td>
<td>(--)</td>
<td>1% hot in + 1% hot out from 14.28.52. Up to full pump capacity in 30 seconds.</td>
</tr>
<tr>
<td>RUN 5</td>
<td>5/3/0 n/a</td>
<td>5/3/0 n/a</td>
<td>5/3/0 n/a</td>
<td>5/3/0 n/a</td>
<td>46/45</td>
<td>267/261/75/76/106</td>
<td>2175/215/7.7</td>
<td>14.35/13/54.0</td>
<td>210 H (170)</td>
<td>210 H (170)</td>
<td>47/44/75/75/79</td>
<td>(--)</td>
<td>1% hot in + 1% hot out from 14.28.52. Up to full pump capacity in 30 seconds.</td>
</tr>
<tr>
<td>RUN 6</td>
<td>6/2/10.5(10.5)</td>
<td>6/2/10.5(10.5)</td>
<td>6/2/10.5(10.5)</td>
<td>6/2/10.5(10.5)</td>
<td>45/43</td>
<td>261/256/75/77/98</td>
<td>2120/210/6.7</td>
<td>14.37/13/37.21</td>
<td>210 H (180)</td>
<td>210 H (170)</td>
<td>47/44/75/75/79</td>
<td>(--)</td>
<td>1% hot in + 1% hot out from 14.28.52. Up to full pump capacity in 30 seconds.</td>
</tr>
</tbody>
</table>

**Yellow: Datalogger and back-up ( ) readings**

White: Manual data and calculated data. No bu data: (--) Values in [ ] are target values (may not be used when on target).

Oil viscosity based on Bulk Oil Temperature average at test start: 140,000 cSt @ 75 F (Dec. 03 curve). From analysis of oil sample: cSt @ 75 F

Weather: 55 F, partly cloudy, moderate wind

Hot water (H) tank: 210 F [200-210 F]
Cold water (C) tank: 65 F [ambient F]

Test pump: USCG VOPS DOP-250/OMTS 315 w. flemingCo inlet side AWIF and standard USN/USCG discharge side AWIF

Total 6” hose length, 100 ft + riser hose arr. = 107.5 ft
**Test 1/2 Data Collection Sheet Notes**

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100%

The primary purpose of this test was to fine tune WL settings after Test 1/1, which had determined the best combinations of WL in and out. A secondary purpose was to simulate a re-start after an unintended stop for 25 minutes (after Test 1/1). After re-start – and a run without lube water – it would be attempted to re-establish core annular flow using minimal amounts of hot lube water (1% in and 1% out based on max. pump capacity). If successful, it would be deemed not necessary to decontaminate the DOP-250 test pump and riser hose between tests.

Data Logger sensor for outlet lube water temperature failed, backup data has been used.

Backup readings of lube water temperatures seem too low for hot water and too high for cold water. Lube water tanks were on target and were each mixed by circulation via WLCS.
## Test 2 Data Collection Sheet

### USCG Master Test on 300 ft hose / 210 k cSt oil [200 k]

**Date:** 2003-12-12

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Hy flow stable %</th>
<th>Apparent DOP250 cap. from hydr. vs flow conv. curve - WL in USgpm</th>
<th>Calculated 'Drum fill' measured - Σ WL out USgpm</th>
<th>Bulk Oil Temp Ave. T_{in/bulk} °F</th>
<th>Inlet Oil Temp Ave. T_{in/med} °F</th>
<th>Disch Oil Temp Ave. T_{disch} °F</th>
<th>ΔP Hydr. = P_{supply} - P_{return} psi</th>
<th>Time Hour, min, sec</th>
<th>Pump press. P_{pump} psi</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>4 211 H</td>
<td>4 211 H</td>
<td>10.5</td>
<td>9.4</td>
<td>46.4</td>
<td>267</td>
<td>243</td>
<td>70</td>
<td>76</td>
<td>2520</td>
<td>7.1</td>
<td>16.53.47</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>RUN 2</td>
<td>4 211 H</td>
<td>4 64 C</td>
<td>10.5</td>
<td>9.4</td>
<td>46.4</td>
<td>267</td>
<td>243</td>
<td>70</td>
<td>76</td>
<td>2520</td>
<td>7</td>
<td>16.55.58</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>RUN 3</td>
<td>4 64 C</td>
<td>4 64 C</td>
<td>10.5</td>
<td>9.4</td>
<td>46.4</td>
<td>267</td>
<td>243</td>
<td>70</td>
<td>76</td>
<td>2520</td>
<td>7.8</td>
<td>16.57.53</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>RUN 4 Baseline</td>
<td>0 n/a</td>
<td>0 n/a</td>
<td>0</td>
<td>0</td>
<td>4.3</td>
<td>26</td>
<td>no drum fill</td>
<td>71</td>
<td>82</td>
<td>2720</td>
<td>17.21.10</td>
<td>181</td>
<td>17.21.10</td>
<td>0</td>
</tr>
<tr>
<td>Attempts to restart AWI</td>
<td>[4] 64 C</td>
<td>[4] 65 C</td>
<td>10.2</td>
<td>9.2</td>
<td>45.2</td>
<td>10</td>
<td>no drum fill</td>
<td>70</td>
<td>81</td>
<td>3020</td>
<td>17.23.08</td>
<td>151</td>
<td>17.23.08</td>
<td>0</td>
</tr>
<tr>
<td>Run 5 Attempt to restart AWI with 4H/4C (full run)</td>
<td>4 208 H</td>
<td>4 208 H</td>
<td>10.3</td>
<td>9.3</td>
<td>45.2</td>
<td>259</td>
<td>257</td>
<td>71</td>
<td>81</td>
<td>2120</td>
<td>17.28.18</td>
<td>12</td>
<td>17.28.18</td>
<td>0</td>
</tr>
<tr>
<td>Run 6</td>
<td>3.5 209 H</td>
<td>3.5 67 C</td>
<td>8.9</td>
<td>8.2</td>
<td>44.7</td>
<td>259</td>
<td>238</td>
<td>71</td>
<td>82</td>
<td>2122</td>
<td>17.30.44</td>
<td>17</td>
<td>17.30.44</td>
<td>0</td>
</tr>
</tbody>
</table>

**Yellow:** Datalogger and back-up ( ) readings  **White:** Manual data and calculated data.  **No bu data:** (--)  **Values in [ ] are target values (may not be used when on target)**

Oil viscosity based on Bulk Oil Temperature average at test start: 210,000 cSt @ 70 F (Dec. 03 curve).

From analysis of oil sample: cSt @ 70 F


Test pump: USCG VOPS DOP-250/OMTS 315 w. flemingCo inlet side AWIF and standard USN/USCG discharge side AWIF
WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %
## Test 3 Data Collection Sheet

**USCG Long Distance Test on 1500 ft hose / 185 k cSt oil**  
**Date:** 2003-12-12

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>4</td>
<td>207 H</td>
<td>4</td>
<td>66 C</td>
<td>9.7</td>
<td>10.2</td>
<td>45.3</td>
<td>71.5</td>
<td>86</td>
<td>70</td>
<td>12625</td>
<td>17</td>
<td>40 (60)</td>
<td>59</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1200 ft was added to 300 ft at 17.32.42. Pressure dropped to 45 psi at 17.41.40 w. H/H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17.49.40.37 (36)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>43 (40) Sudden hydr. flow increase at 17.47.18 caused pressure increase from 37 to 43 psi.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half way in run 2</td>
<td>6</td>
<td>65 C</td>
<td>0</td>
<td>n/a</td>
<td>16.3 (16.3)</td>
<td>0</td>
<td>44.1</td>
<td>248</td>
<td>225.3</td>
<td>72</td>
<td>84</td>
<td>76</td>
<td>2725</td>
<td>17.45.08.37 (36)</td>
</tr>
<tr>
<td>RUN 2</td>
<td>5</td>
<td>65 C</td>
<td>0</td>
<td>n/a</td>
<td>15 (15.5)</td>
<td>0</td>
<td>47.4</td>
<td>270</td>
<td>257</td>
<td>71.5</td>
<td>83</td>
<td>72</td>
<td>2925</td>
<td>17.49.20.43 (40)</td>
</tr>
</tbody>
</table>

Yellow: Datalogger and back-up ( ) readings  
White: Manual data and calculated data. No bu data: (--). Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Bulk Oil Temperature average at test start: 185,000 cSt @ 71.5 F (Dec. 03 curve). From analysis of oil sample: cSt @ 71.5 F

Weather: 62 F, overcast  
Hot water (H) tank: 210 F [200-210 F]  
Cold water (C) tank: 64 F [ambient F]

Test pump: USCG VOPS DOP-250/=MTS 315 w. flemingCo inlet side AWIF and standard USN/USCG discharge side AWIF

Total pumping distance 1500 ft+riser+2xSHAS = 1514.5 ft
**Test 3 Data Collection Sheet Notes**

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) \times 100 %

This was a continuation of Test 2. 1200 ft of hose were at 17.32.44 added to the 300 ft used in Test 2 to a total of 1500 ft using the SHAS, i.e. without interrupting product flow and core annular flow.

Run 2 with 6% cold water on the inlet has a slightly downwards trend for the pump pressure, which indicates that over time, after the last Mark Point at 17.49.20, the pressure would have dropped further. This in turn indicates that the core annular flow further stabilizes over time, thus becoming more efficient the longer time it is applied. The phenomenon has been difficult to observe for each individual run under the tests with shorter pumping distances because the pressure drops were very low, but here – on more than 1500 ft of 6” hose and with a pressure drop of about 40 psi – it becomes quite obvious. The consequence of this observation may be that – provided sufficient oil and time had been available for each test – the individual test runs in all tests should have been carried out over a longer period of time for a more precise evaluation of the various WL combinations and settings.
### Test 4/3 Data Collection Sheet

**Lamor GT-A 50 Test on 300 ft hose / 210 k cSt oil [200 k]**

**Date:** 2003-12-14

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Run in that was stopped</td>
<td>4</td>
<td>211 H</td>
<td>4</td>
<td>211 H</td>
<td>8.2</td>
<td>8.2</td>
<td>44</td>
<td>205</td>
<td>no drum fill</td>
<td>70</td>
<td>69.5</td>
<td>2515 at 12.00</td>
<td>12.01.29</td>
<td>4.5</td>
</tr>
<tr>
<td>RUN 1</td>
<td>4</td>
<td>209 H</td>
<td>4</td>
<td>209 H</td>
<td>7.9</td>
<td>8.1</td>
<td>44</td>
<td>205</td>
<td>188</td>
<td>70</td>
<td>71</td>
<td>82</td>
<td>2280</td>
<td>12.15.23</td>
</tr>
<tr>
<td>RUN 2</td>
<td>4</td>
<td>211 H</td>
<td>3.5</td>
<td>58 C</td>
<td>8.4</td>
<td>7.2</td>
<td>43.2</td>
<td>(44)</td>
<td>202</td>
<td>178</td>
<td>70</td>
<td>71</td>
<td>82</td>
<td>2280</td>
</tr>
<tr>
<td>RUN 3</td>
<td>4</td>
<td>58 C</td>
<td>4</td>
<td>58 C</td>
<td>8.3</td>
<td>8.4</td>
<td>42</td>
<td>(43)</td>
<td>194</td>
<td>190</td>
<td>70</td>
<td>71</td>
<td>77</td>
<td>2620</td>
</tr>
<tr>
<td>RUN 4 Baseline test</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>0</td>
<td>-1.4</td>
<td>(4)</td>
<td>n/a</td>
<td>26.8</td>
<td>70</td>
<td>72</td>
<td>66</td>
<td>2720</td>
</tr>
</tbody>
</table>

**Remarks:**
- Pump started 11.59.17, at full cap. from 11.59.55, stopped 12.01.33. Possible WL leak.
- Restart after 11 min stop w. hose 88% full of oil. Pressure trend still down at mark point.
- Lowest pressure midrun (8.1). Influence from run 1?
- Trend up at end of run 2.
- Pressure peaked at 55 psi with same WL at 12.20.25 (before mark).
- Pumping out oil and water until 12.32.00 in preparation for baseline test.
- Pump stopped for 17 minutes to let oil in hose settle.
- Pumping out oil and water until 12.32.00 in preparation for baseline test.

**Yellow:** Datalogger and back-up ( ) readings  White: Manual data and calculated data. No bu data: (--)  Values in [ ] are target values (may not be used when on target)  Oil viscosity based on Bulk Oil Temperature average at test start: 210,000 cSt @ 70 F (Dec. 03 curve). From analysis of oil sample: cSt @ 70 F

- Weather: 55 F, partly overcast  Hot water (H) tank: 211 F [200-210 F]  Cold water (C) tank: 55 F [ambient F]
- Test Pump: Lamor GT-A 50/OMTS 200 w. flemingCo inlet AWIF (integral) and flemingCo outlet AWIF (integrated in 6" Hydrasearch type male coupling).
- Total 6" hose length, 300 ft + riser hose arr. = 308.5 ft
**Test 4/3 Data Collection Sheet Notes**

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %

WL BU readings out of timing.

Pump was stopped during run in at 12.01.33 due to large amount of lube water surfacing in tank, which could be a possible leak from WL line. At that time the test hose would be at least ¾ full of oil. Pump lifted out of oil. No leak was found. Test started again after 11 minutes break. Concern that the oil in the hose at that time might have started sticking to hose wall. Possibly this test should be compared with Test 2, runs 5 and 6.
**Test 4/4 Data Collection Sheet**

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water %</th>
<th>Outlet Lube Water %</th>
<th>Inlet Lube Water °F</th>
<th>Outlet Lube Water °F</th>
<th>Hy flow stable</th>
<th>Apparent TK-125 cap. from hydr. vs flow conv. curve - WL_in USgpm</th>
<th>Calculated &quot;Drum fill&quot; measured - ∆ WL_in USgpm</th>
<th>Bulk Oil Temp Ave. °F</th>
<th>Inlet Oil Temp Ave. °F</th>
<th>Disch Oil Temp °F</th>
<th>∆P Hydr. = P_in - P_return psi</th>
<th>Time Hour, min, sec</th>
<th>Pump P_stable psi</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-in period</td>
<td>?</td>
<td>?</td>
<td>207 H</td>
<td>207 H</td>
<td>5.3</td>
<td>8.3</td>
<td>32.3</td>
<td>227</td>
<td>No drumfill</td>
<td>71</td>
<td>72</td>
<td>95</td>
<td>1720</td>
<td>16.09.00.</td>
</tr>
<tr>
<td>RUN 1</td>
<td>9</td>
<td>8</td>
<td>207 H</td>
<td>207 H</td>
<td>4.5</td>
<td>4</td>
<td>32.6</td>
<td>228</td>
<td>47 (21%)</td>
<td>71</td>
<td>72</td>
<td>115</td>
<td>1720</td>
<td>16.11.37</td>
</tr>
<tr>
<td>RUN 2</td>
<td>7</td>
<td>7</td>
<td>208 H</td>
<td>67 C</td>
<td>4</td>
<td>4</td>
<td>32.5</td>
<td>228</td>
<td>54 (24%)</td>
<td>71</td>
<td>73</td>
<td>92</td>
<td>1620</td>
<td>16.21.28</td>
</tr>
<tr>
<td>RUN 3</td>
<td>7</td>
<td>7</td>
<td>204 H</td>
<td>201 H</td>
<td>4</td>
<td>4.5</td>
<td>32.5</td>
<td>229</td>
<td>54 (23%)</td>
<td>71</td>
<td>74</td>
<td>86</td>
<td>1620</td>
<td>16.31.42</td>
</tr>
<tr>
<td>Attempt to run C/C</td>
<td>62</td>
<td>77 C</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>14</td>
<td>No drumfill</td>
<td>71</td>
<td>75</td>
<td>110</td>
<td>3035</td>
<td>16.39.17</td>
<td>28</td>
<td>(12)</td>
</tr>
<tr>
<td>Attempt w. no WL</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.4</td>
<td>25</td>
<td>No drumfill</td>
<td>71</td>
<td>75</td>
<td>108</td>
<td>No data, but expected to be as just above.</td>
<td>16.42.56</td>
<td>40</td>
<td>(22)</td>
</tr>
</tbody>
</table>

Yellow: Data logger and back-up ( ) readings
White: Manual data and calculated data. No bu data: (-->). Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Bulk Oil Temperature average at test start: 190,000 cSt @ 71 F (Dec. 03 curve).

Weather: 55 F, sunny
Hot water (H) tank: 210 F [200-210 F]
Cold water (C) tank: 60 F [ambient F]

Test Pump: Framo TK-125/standard hydraulic motor, with 3/8" inlet injection tube and Framo outlet AWIF.

Total 6' hose length, 300 ft + riser hose arr. = 307 ft
**Test 4/4 Data Collection Sheet Notes**

NOTE: Due to the low measured pump capacity when compared to apparent capacity it has for this pump been necessary to determine the WL percentage as:

\[ WL \% = \left( \frac{\text{Lube water GPM}}{\text{Drum fill capacity GPM}} \right) \times 100 \% \]

Numerous attempts were over a very long run in period made to enable the pump to drag in the oil. The “runs” in the data sheet are examples from relative stable situations although complete runs never were completed due to time constraints. It is not likely that full runs would have changed the picture.

A sudden hot w in at 16.39.51 jump starts the pump, which apparently have been close to be killed by internal friction. Hy flow jumps up (from 2.4 to 51 gpm) instantaneously, but the same does the pump pressure (from 30 to 66 psi), which in turn kills the pump again (or rather blows the HPU check valve). This significantly indicates that the hydraulic motor has too little torque for working with this type of oil.

After some attempts to get the flow going again after 16.42.56 using hot w on outlet, hot water is again injected shortly on the inlet at 16.45. , which repeats above situation but now with pressures up to 92 psi. A more steady supply of inlet hot water (6 gpm) from 16.49.33 with 2 gpm hot on outlet enable hydraulic flow to get back up to 30-32 gpm with a disch pressure peaking at 88 psi. From 16.50.41 pressure drops rapidly while hydraulic flow remains above 30 gpm. WL has gradually been established again. Test was stopped by manufacturer at 16.55 due to severe noise from pump.

The inlet opening of the TK-125 seems to be too small for this type of oil. Inflow is only possible – and only at a rate equivalent to max. 25% of the pump’s rated capacity – with aid from hot water injected via the inlet side injection tube. In addition the cavities inside the pump are relatively small, and the screws rotate tight against each other. This develops very high friction with this type of oil, unless the oil is accompanied with hot water. Unfortunately this type of pump is for design reasons not suitable for water pumping and with inlet water injection it cannot be avoided that the pump sometimes must pump pure water.

The pump cannot be considered suitable for pumping this type of oil, even with the aid from water lubrication. Whether it can pump other products of the same viscosity is unknown.
## Test 5 Data Collection Sheet

**CCG Pre-Test on 50 ft hose / 530 k cSt oil [500 k]**  
**Date: 2003-12-10**

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Hy flow stable</th>
<th>Apparent GT-185 cap. from hydr. vs flow conv. curve – WLout USgpm</th>
<th>Bulk Oil Temp Ave. °F</th>
<th>Inlet Oil Temp Ave. °F</th>
<th>Disch Oil Temp °F</th>
<th>Tdisch flow</th>
<th>Ppump = Psupply - Preturn psi</th>
<th>Time</th>
<th>Pump press. psi</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>8</td>
<td>177 H (156)</td>
<td>7</td>
<td>177 H (174)</td>
<td>8.5 (8.5)</td>
<td>7 (9) (21)</td>
<td>105</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>1700</td>
<td>18.11.08</td>
<td>4.6</td>
<td>Lube water coming crystal clear out of test hose end</td>
</tr>
<tr>
<td>RUN 2</td>
<td>6</td>
<td>177 H (156)</td>
<td>6</td>
<td>177 H (174)</td>
<td>6.1 (8)</td>
<td>6.2 (7.3) (21)</td>
<td>106</td>
<td>60</td>
<td>61</td>
<td>66</td>
<td>1800</td>
<td>18.12.57</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>RUN 3</td>
<td>3</td>
<td>175 H (156)</td>
<td>7</td>
<td>178 H (174)</td>
<td>3.5 (3.6)</td>
<td>8.1 (7.8) (23)</td>
<td>109</td>
<td>60</td>
<td>76</td>
<td>73</td>
<td>1900</td>
<td>18.14.47</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>RUN 4</td>
<td>6</td>
<td>178 H (156)</td>
<td>4.5</td>
<td>178 H (174)</td>
<td>6.5 (6.4)</td>
<td>5.2 (5.3) (24)</td>
<td>110</td>
<td>60</td>
<td>62</td>
<td>77</td>
<td>1900</td>
<td>18.16.08</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>RUN 5</td>
<td>4</td>
<td>178 H (166)</td>
<td>4</td>
<td>178 H (174)</td>
<td>4.8 (-)</td>
<td>4.9 (-) (25)</td>
<td>115</td>
<td>60</td>
<td>62</td>
<td>73</td>
<td>1900</td>
<td>18.17.28</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>RUN 6</td>
<td>3</td>
<td>178 H (166)</td>
<td>4</td>
<td>178 H (174)</td>
<td>3.4 (-)</td>
<td>4.9 (-) (25)</td>
<td>122</td>
<td>60</td>
<td>68</td>
<td>75</td>
<td>1900</td>
<td>18.18.40</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>RUN 7</td>
<td>1.7</td>
<td>177 H (168)</td>
<td>1.7</td>
<td>177 H (174)</td>
<td>2.1 (-)</td>
<td>2 (-) (25)</td>
<td>103</td>
<td>60</td>
<td>74</td>
<td>79</td>
<td>1900</td>
<td>18.20.05</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Run 8</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>0</td>
<td>99</td>
<td>60</td>
<td>68</td>
<td>87</td>
<td>2300</td>
<td>18.21.20</td>
<td>5.5</td>
<td></td>
</tr>
</tbody>
</table>

**Yellow:** Datalogger and back-up ( ) readings   **White:** Manual data and calculated data. No bu data: (-). Values in [ ] are target values (may not be used when on target)

- Oil viscosity based on Bulk Oil Temperature average at test start: 530,000 cSt @ 60 F (Dec. 03 curve).  
- From analysis of oil sample: cSt @ 60 F
- Weather: 60 F, sunny, moderate wind  
- Hot water (H) tank: 182 F [200-210 F]

Test Pump: CCG GT-185/Ross Series ME 15 motor, w. flemingCo inlet and outlet AWIFs and high temperature / high pressure plate wheel.

Total 6' hose length, 50 ft + riser hose arr. + U-bend = 68.5 ft

Static lift: 5 ft, or equivalent to 2 psi must be deducted from above pressures to find real pressure drop.
**Test 5 Data Collection Sheet Notes**

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %

Data Logger: No electronic recordings of hydraulic flow, use manual bu data.

ΔP Hydraulic: Hydraulic supply pressure only, return pressure manual readings are invalid.
## Test 6+7 Data Collection Sheet

**CCG Master Test on 100 ft hose / 480 k cSt oil and 500 ft Long Distance Test**

**Date:** 2003-12-12

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Hy flow stable</th>
<th>Apparent GT-185 cap. from hydr. vs flow conv. curve – WL_{in} USgpm</th>
<th>Calculated 'Drum fill' measured – Σ WL USgpm</th>
<th>Bulk Oil Temp Ave. T_{bulk} °F</th>
<th>Inlet Oil Temp Ave. T_{inlet} °F</th>
<th>Disch Oil Temp Ave. T_{disch} °F</th>
<th>P_supply – P_{return} psi</th>
<th>Time (Hour, min, sec)</th>
<th>Pump press. (psi)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>100 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>210 H (160)</td>
<td>203 H (200)</td>
<td>4.6 (3.6)</td>
<td>4.5</td>
<td>25.1</td>
<td>117</td>
<td>115</td>
<td>61</td>
<td>59</td>
<td>65</td>
<td>1900</td>
<td>14.02</td>
<td>12 (16)</td>
</tr>
<tr>
<td>RUN 2</td>
<td>100 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>210 H (164)</td>
<td>67 C (74)</td>
<td>4.9 (5.3)</td>
<td>5</td>
<td>25.2</td>
<td>118</td>
<td>120</td>
<td>61</td>
<td>62</td>
<td>71</td>
<td>1900</td>
<td>14.04</td>
<td>12 (8)</td>
</tr>
<tr>
<td>Hose</td>
<td>add on. Now:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>500 ft</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUN 3</td>
<td>500 ft</td>
<td>3.5 [4]</td>
<td>210 H (164)</td>
<td>65 C (70)</td>
<td>4.2</td>
<td>23.6</td>
<td>113</td>
<td>61</td>
<td>67</td>
<td>69</td>
<td>1880</td>
<td>14.12</td>
<td>13.6 (10)</td>
<td></td>
</tr>
<tr>
<td>RUN 4</td>
<td>500 ft</td>
<td>2</td>
<td>210 H (182)</td>
<td>65 C (64)</td>
<td>2.2</td>
<td>No DL</td>
<td>123</td>
<td>62</td>
<td>61</td>
<td>73</td>
<td>1890</td>
<td>14.18</td>
<td>13.6 (10)</td>
<td></td>
</tr>
<tr>
<td>RUN 5</td>
<td>500 ft</td>
<td>3.5 [4]</td>
<td>209 H (186)</td>
<td>0 n/a</td>
<td>4.4</td>
<td>No DL</td>
<td>117</td>
<td>63</td>
<td>65</td>
<td>74</td>
<td>1890</td>
<td>14.23</td>
<td>11.9 (10)</td>
<td></td>
</tr>
<tr>
<td>End of</td>
<td>test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Yellow: Datalogger and back-up ( ) readings** White: Manual data and calculated data. No bu data: (---). Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Bulk Oil Temperature average at Test 6 start: 480,000 cSt @ 61 F (Dec. 03 curve).

From analysis of oil sample: cSt @ 60 F

Oil viscosity based on Bulk Oil Temperature average at Test 7 start: 480,000 cSt @ 61 F (Dec. 03 curve).

Target viscosities: 500 k cSt

Weather: 67 F, fair skies, low wind

Hot water (H) tank: 210 F [200-210 F]

Cold water (C) tank: 67 F [ambient F]

Test Pump: CCG GT-185/Ross Series ME 15 motor, w. flemingCo inlet and outlet AWIFs and high temperature / high pressure plate wheel.

Test 6: Total pumping distance = 100 ft + riser + SHAS = 111.5 ft

Test 7: Total pumping distance = 500 ft + riser + 2xSHAS = 515 ft

Static lift: 5 ft, or equivalent to 2 psi must be deducted from above pressures to find real pressure drop.
Test 6+7 Data Collection Sheet Notes

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %

ΔP Hydraulic: Hydraulic supply pressure only, return pressure manual readings are invalid.

WL in and out BU temps are unclear as to Mark points and observation frequency. WL in and out BU flows are unclear as to Mark points and observation frequency.
**Test 9+10 Data Collection Sheet**

**Local Bulk Heating Test on 100 ft hose / 250 k cSt oil**

**Date:** 2003-12-15

<table>
<thead>
<tr>
<th>RUN #</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Inlet Lube Water</th>
<th>Outlet Lube Water</th>
<th>Hy flow stable</th>
<th>Apparent GT-185 cap. from hydr. vs flow conv. curve - WL\textsubscript{in} USgpm</th>
<th>Calculated 'Drum fill' measured \textsuperscript{-} \Sigma WL USgpm</th>
<th>Bulk Oil Temp Ave.</th>
<th>Inlet Oil Temp Ave.</th>
<th>Disch Oil Temp</th>
<th>( \Delta P ) Hydr.</th>
<th>Time</th>
<th>Pump press.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>Baseline, Coil only</td>
<td>0 ( ^\circ F )</td>
<td>0 ( ^\circ F )</td>
<td>0</td>
<td>0</td>
<td>15.5</td>
<td>78</td>
<td>79</td>
<td>68</td>
<td>77</td>
<td>80</td>
<td>2930</td>
<td>13.</td>
<td>51.</td>
</tr>
<tr>
<td>RUN 2</td>
<td>13</td>
<td>61 ( ^\circ C )</td>
<td>0</td>
<td>9.5</td>
<td>0</td>
<td>14.3</td>
<td>64</td>
<td>61</td>
<td>68</td>
<td>68</td>
<td>80</td>
<td>2530</td>
<td>13.</td>
<td>55.</td>
</tr>
<tr>
<td>RUN 3</td>
<td>10</td>
<td>61 ( ^\circ C )</td>
<td>6.5</td>
<td>61 ( ^\circ C )</td>
<td>10</td>
<td>6.5</td>
<td>19.5</td>
<td>88</td>
<td>79</td>
<td>68</td>
<td>68</td>
<td>79</td>
<td>2880</td>
<td>13.</td>
</tr>
<tr>
<td>RUN 4</td>
<td>9</td>
<td>181 ( ^\circ H )</td>
<td>9.5</td>
<td>61 ( ^\circ C )</td>
<td>8.5</td>
<td>9.2</td>
<td>19.3</td>
<td>88</td>
<td>101</td>
<td>68</td>
<td>112</td>
<td>80</td>
<td>1430</td>
<td>14.</td>
</tr>
<tr>
<td>RUN 5</td>
<td>8</td>
<td>181 ( ^\circ H )</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>19.3</td>
<td>89</td>
<td>103</td>
<td>68</td>
<td>115</td>
<td>86</td>
<td>1430</td>
<td>14.</td>
<td>02.</td>
</tr>
<tr>
<td>RUN 6</td>
<td>4.5</td>
<td>180 ( ^\circ H )</td>
<td>0</td>
<td>4.3</td>
<td>0</td>
<td>19.6</td>
<td>92</td>
<td>105</td>
<td>68</td>
<td>95</td>
<td>96</td>
<td>1430</td>
<td>14.</td>
<td>05.</td>
</tr>
<tr>
<td>RUN 7</td>
<td>4</td>
<td>179 ( ^\circ H )</td>
<td>4</td>
<td>62 ( ^\circ C )</td>
<td>4</td>
<td>4</td>
<td>19.6</td>
<td>92</td>
<td>108</td>
<td>68</td>
<td>90</td>
<td>95</td>
<td>1430</td>
<td>14.</td>
</tr>
<tr>
<td>RUN 8</td>
<td>4</td>
<td>179 ( ^\circ H )</td>
<td>0</td>
<td>n/a</td>
<td>4</td>
<td>0</td>
<td>19.8</td>
<td>93</td>
<td>106</td>
<td>68</td>
<td>104</td>
<td>89</td>
<td>1480</td>
<td>14.</td>
</tr>
<tr>
<td>RUN 9</td>
<td>4</td>
<td>63 ( ^\circ C )</td>
<td>4</td>
<td>63 ( ^\circ C )</td>
<td>4</td>
<td>4</td>
<td>20</td>
<td>94</td>
<td>89</td>
<td>68</td>
<td>80</td>
<td>87</td>
<td>2625</td>
<td>14.</td>
</tr>
<tr>
<td>RUN 10</td>
<td>0</td>
<td>n/a</td>
<td>6</td>
<td>63 ( ^\circ C )</td>
<td>0</td>
<td>6.5</td>
<td>21.5</td>
<td>107</td>
<td>99</td>
<td>68</td>
<td>75</td>
<td>80</td>
<td>2930</td>
<td>14.</td>
</tr>
<tr>
<td>RUN 11</td>
<td>4</td>
<td>177 ( ^\circ H )</td>
<td>0</td>
<td>n/a</td>
<td>4.3</td>
<td>0</td>
<td>20.5</td>
<td>98</td>
<td>108</td>
<td>68</td>
<td>109</td>
<td>79</td>
<td>1430</td>
<td>14.</td>
</tr>
</tbody>
</table>
Yellow: Datalogger and back-up ( ) readings

White: Manual data and calculated data. No bu data: (---). Values in [ ] are target values (may not be used when on target)

Yellow, Datalogger and back-up ( ) readings

White: Manual data and calculated data. No bu data: (---). Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Bulk Oil Temperature average at test start: 250,000 cSt @ 68 F (Dec. 03 curve).

From analysis of oil sample: cSt @ 68 F

Weather: 60 F, clear skies, low wind

Hot water (H) tank: 182 F [200-210 F]

Cold water (C) tank: 60 F [ambient F]

Test Pump: GT-185/Ross Series ME 15, w. flemingCo inlet and outlet AWIFs and high temperature/ high pressure plate wheel. Coils were wrapped around the pump.

Total 6" hose length, 100 ft + riser hose arr. = 108 ft

Test 9+10 Data Collection Sheet Notes

WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %

Inlet oil temp sensors A and B were placed close to inlet water lube device with sensor A closest to the steam coils. This positioning of the sensors was – due to limited space between pump and coils – the only alternative to placing them close to the steam coils. Sensor A readings have not been used due to severe fluctuations as steam came on and off. The position of sensor B close to the inlet WL device on the pump results apparently in the recording of too high inlet oil temps, which especially can be seen when hot inlet water is used. Consequently the inlet oil temps are not reliable, but in order to verify the influence of the steam coils on inlet oil temperatures, it is recommended to consider the discharged oil temps. Considering the heat impact of hot water on the inlet and comparing with runs without hot inlet water, it could seem as if the coils never heated the inlet oil to more than 80 F, which resulted in an increase of about 12 F only.

The steam to the coils had to be switched on and off frequently (averagely twice per minute from 13.48 to 14.08.12 (or for runs 1 to 7) and was only on for a few seconds at a time to avoid splashing over the tank top and test personnel from boiling oil. It is therefore unclear exactly how much heat was induced via the coils. Steam was not supplied to the coils after run 7. The effect of the steam coils in runs 2 to 7 must therefore have been very limited. This can be seen by comparing runs 7, 8, and 11 where only run 7 has been assisted by heat from the coils. The parameters of these runs are almost the same, but the same are performance and power requirement (differential hydraulic pressure).

In a real world situation it would not be required to switch the coils on and off to avoid splashing, and in future testing the test tank should be covered so that splashing will not matter for personnel and environment. The coils were designed for a pump with about the double capacity of the GT-185, the DOP-250. This pump might better have been able to remove the oil heated by the coils in step with the applied heat from the steam.

It must be concluded that this test has limited value for the evaluation of local bulk heating as a flow enhancing technique. Not even the baseline test shows some merit since the GT-185 pump probably could have pumped the test oil at the rate of 78 gpm without assistance from the coils (see Test 11, run 7).
### Test 11 Data Collection Sheet

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>4 199 H %</td>
<td>4 200 H %</td>
<td>4.5</td>
<td>4.5</td>
<td>23 (23)</td>
<td>109</td>
<td>112</td>
<td>67.5</td>
<td>67</td>
<td>92</td>
<td>(-)</td>
<td>16.21.23</td>
<td>4.6</td>
<td>(-)</td>
</tr>
<tr>
<td>RUN 2</td>
<td>4 198 H %</td>
<td>4 75 [C]</td>
<td>4.3</td>
<td>4.6</td>
<td>23 (23)</td>
<td>109</td>
<td>113</td>
<td>67.5</td>
<td>66</td>
<td>108</td>
<td>(-)</td>
<td>16.23.45</td>
<td>4.1</td>
<td>(-)</td>
</tr>
<tr>
<td>RUN 3</td>
<td>4 62 C</td>
<td>4 70 C</td>
<td>4.3</td>
<td>4.6</td>
<td>23 (23)</td>
<td>199 (109)</td>
<td>102</td>
<td>67.5</td>
<td>66.5</td>
<td>82</td>
<td>(-)</td>
<td>16.25.50</td>
<td>6.5</td>
<td>(-)</td>
</tr>
<tr>
<td>RUN 4</td>
<td>4 61 C</td>
<td>4 69 C</td>
<td>4.2</td>
<td>4.5</td>
<td>24 (24)</td>
<td>113</td>
<td>104</td>
<td>67.5</td>
<td>67</td>
<td>80</td>
<td>(-)</td>
<td>16.27.35</td>
<td>7.2</td>
<td>(-)</td>
</tr>
<tr>
<td>RUN 5</td>
<td>0 n/a</td>
<td>4 68 C</td>
<td>0</td>
<td>4.6</td>
<td>25 (25)</td>
<td>121</td>
<td>106</td>
<td>67.5</td>
<td>67</td>
<td>77</td>
<td>(-)</td>
<td>16.29.33</td>
<td>5.5</td>
<td>(-)</td>
</tr>
<tr>
<td>RUN 6</td>
<td>0 n/a</td>
<td>2 71 C</td>
<td>0</td>
<td>2.5</td>
<td>23 (23)</td>
<td>113</td>
<td>104</td>
<td>67.5</td>
<td>67</td>
<td>75</td>
<td>(-)</td>
<td>16.31.45</td>
<td>4.5</td>
<td>(-)</td>
</tr>
</tbody>
</table>

**Pump out oil/w:** All WL stopped at 16.32.26. Pressure to 162 psi in 75 sec

**Break w. pump stopped:** Pump stopped at 16.33.46 and re-started at 16.36.00. Break short due to time limit.

**RUN 7 Not real baseline** No data: (-) Max. pressure 184 psi before hot inlet WL was applied and pres. rapidly dropped to 6 psi

---

**Yellow: Datalogger and back-up ( ) readings** White: Manual data and calculated data. No bu data: (-). Values in [ ] are target values (may not be used when on target)

Oil viscosity based on Bulk Oil Temperature average at test start: 260,000 cSt @ 67.5 F (Dec. 03 curve). From analysis of oil sample: 260,000 cSt @ 67.5 F

Weather: 54 F, clear skies, moderate wind Hot water (H) tank: 198 F [200-210 F] Cold water (C) tank: 60 F [ambient F]

Test Pump: GT-185/ME 15, w. flemingCo inlet and outlet AWIFs and high temperature/ high pressure plate wheel. Total 6' hose length, 100 ft + riser hose arr. = 108 ft
Test 11 Data Collection Sheet Notes

The purpose of this test was to compare hose pressure drop and power consumption on 200 k cSt oil with these of Test 6 on 480 k cSt oil, using the same pumping distance and same WL parameters. As secondary purpose was to check if the GT-185 pump could re-start on this “lower” viscosity oil and whether core annular flow could be re-established.

1. WL % = (Lube water GPM / Apparent capacity GPM (based on hydraulic flow and inclusive of possible inlet lube water)) x 100 %
2. Inlet oil temp sensor B has been disregarded. Was for unknown reason placed on inlet lube device and therefore subject to inlet WL temps.
3. Bulk oil sensor B (backup) has been disregarded due to possible malreading. It consistently shows higher temperatures than inlet oil temp sensor A.
4. DL hydr. flow fails from 16.24.56. Thereafter manual backup data has been used.
5. No hydraulic supply pressure data available (manual data). This invalidates the test to some degree since it otherwise would have been possible to compare power consumption on 260 k cSt oil with that of 480 k cSt oil from Test 6, with all other parameters the same.
6. Sudden rise of outlet WL temp at 16.32.33 and high temp throughout rest of test could indicate seeping hot water not detected by DL outlet WL flow sensor.
7. Timeline relation between DL temps, DL flow data are 2 minutes apart. Mark Data points follow temperature timeline. Add 2 minutes to all times in the pressure-flow recordings.
8. Run 7 is not a true baseline test. The break was due to time constraints too short to ensure total breakdown of lubricating effect of any remaining water, but is still a good indication, which points at that the GT-185 can drag in 260 k cSt product and pump it (at a low rate), while it barely can drag in product in the 500 k cSt range.
9. After run 7, at 16.42.43, an attempt to re-establish core annular flow by hot inlet lube water (4.5 USgpm) successfully brought pump pressure down from 184 psi to 6 psi in 96 seconds.
10. Manual backup data on pump pressure are not reliable.