

FINAL REPORT

THE JOINT VISCOUS OIL PUMPING SYSTEM (JVOPS) WORKSHOP

A united effort by the U.S. Coast Guard, Canadian Coast Guard,
U.S. Navy, and Response Community to promote and improve
heavy viscous oil marine lightering response.

Conducted at CENAC TOWING, INC.
Houma, Louisiana, USA

December 1 to 15, 2003

Prepared by:
flemingCo environmental aps
and Hyde Marine, Inc.

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FOREWORD

The present Report on the preparations for and on the events that took place at the Joint Viscous Oil Pumping System (JVOPS) Workshop testing in Houma, Louisiana, USA from 8 to 15 December, 2003 is the result of a tremendous joint effort by personnel from the US Coast Guard and the Canadian Coast Guard, and by members of the international oil spill response community.

In the light of heavy oil disasters in recent years, the International Maritime Organization (IMO) under the United Nations (UN) and Governments throughout the world have requested international co-operation in developing and testing operational high density oil collection and pumping systems.

This Report will document that this request now has been met as to high density oil pumping systems that efficiently can transfer very viscous oil over long distances, a task that previously could not be overcome in most heavy oil incidents.

The US Coast Guard and the Canadian Coast Guard took the lead in this work and provided the majority of the funding. The two Coast Guards teamed up with scientists, responders, response equipment developers, and manufacturers from seven nations and through a two year period with planning and preparations they never lost sight of the target. Several problems threatened the project including funding, availability of an appropriate test oil, and specialized equipment that had to be developed, but they were faced and solutions were found.

Although the Report in general will not focus on individuals and their roles in the project, it is at this place appropriate to mention the three Project Officers that really made a difference: Commander Michael D. Drieu, USCG, Senior Response Officer Ron MacKay, CCG, and Lieutenant Commander Peter C. Nourse, USCG. Their leadership, consistent work, and never failing optimism kept it all together through many difficult phases.

Special thanks to Mr. Benny Cenac, the owner of Cenac Towing, Inc. in Houma, LA, who graciously made land, cranes, personnel, workshop services, and waste oil receiving facilities available to the Workshop. Several other entities within the response community donated services in-kind and include the U.S. Navy Supervisor of Salvage (Washington, D.C.), Hyde Marine, Inc. (Cleveland, OH), Lamor Corp. (Finland), Environmental Recovery Equipment Inc. (Ontario, Canada), The O'Brien's Group (LA, USA), and Clean Caribbean Cooperative (Florida, USA). The co-sponsorships of the Oil Spill Recovery Institute (Cordova, Alaska), Alaska Clean Seas, and the U.S. Navy Supervisor of Salvage are likewise highly appreciated.

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Flemming Hvidbak, JVOPS Lead Engineer
flemingCo environmental aps, Denmark

Senior Project Officers:

Commander Michael D. Drieu
Chief of Response (mor)
Coast Guard District Eight
500 Poydras St.
New Orleans, LA 70130

Ron MacKay
Senior Response Officer, Charlottetown
Rescue, Safety and Environmental Response
1 Queen Street, P.O. box 1236
Charlottetown, PE C1A 7M8

Lieutenant Commander Peter C. Nourse, PE
Special Projects Officer
Response Systems Team
Ocean Engineering Division G-SEC-2
Office of Civil Engineering
U.S. Coast Guard Headquarters
2100 Second St. S.W., Room 6114
Washington, DC 200593

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0.0 A Guide to the JVOPS Workshop Report

The present report can be read from the beginning through the end and will then provide all necessary information on the background, the applied flow enhancing techniques, the workshop planning and preparations, the test infrastructure, the workshop testing with results and conclusions, and finally recommendations for modifications to existing viscous oil pumping systems.

Readers who want to go directly to the JVOPS Workshop testing may jump to Chapter 6, where a brief summary on the test infrastructure and the purpose of each test provide enough background for a study of the summary on all the tests. The analysis of the test results may be studied in Chapter 7.

Several abbreviations and formulations are used throughout the Report and will as a minimum be explained the first time they occur. A list of abbreviations in alphabetic order and some special formulations (listed with related formulations) have for clarity been listed below.

0.1 Abbreviations:

AWI	Annulus Water Injection
AWIF	Annulus Water Injection Flange (an inlet AWIF is placed at the pump suction intake and a discharge AWIF is placed at or close to the pump discharge outlet)
C	Cold (typically cold lube water)
CCG	Canadian Coast Guard
DL	Data Logger (electronic)
ESSM	Emergency Ship Salvage Material
GPC	A joint venture contracting with US Navy Supsalv
H	Hot (typically hot lube water)
HPU	Hydraulic Power Unit
HSE	Health, Safety & Environment
ICS	Incident Command System, in JVOPS Workshop context modified to Integrated Command Structure
JVOPS Workshop	Joint Viscous Oil Pumping System Workshop
PDAS Pump	Positive Displacement Archimedes' Screw Pump
PPE	Personal Protection Equipment
RC	Remote Control
RPM	Revolutions Per Minute
SAIC	Science Applications International Corporation (Canada)
SHAS	Swift Hose Add-on System
Supsalv	Supervisor of Salvage
T	Tempered (typically tempered lube water)
USCG	United States Coast Guard
USN	US Navy
VOPS	Viscous Oil Pumping System

WL	Water Lubrication
WLCS	Water Lubrication Control Stand
WLSS	Water Lubrication Supply System

0.2 Special Formulations (listed in related order):

Calculated capacity	The pump capacity of a positive displacement pump calculated from data on the hydraulic flow to the pump's hydraulic motor.
Drum fill capacity	The pump capacity measured by the time to fill a drum, and is used to verify the calculated capacity.
Core annular flow	The phenomenon when two immiscible liquids flow concentrically inside a tube or a hose with only the low viscosity liquid touching the inner tube or hose wall.
Water lubrication	Core annular flow using water as lubrication medium for oil and synonymous with AWI. Sometimes mentioned as "lubrication" in this context.
Lube water	Lubrication water, or water supplied to an AWIF or another water lubrication device on a pump in an attempt to create core annular flow.
Cold in	Refers to cold lube water provided to the inlet side AWIF of a pump, normally used in conjunction with a percentage (example: 4% cold in).
Cold out	Refers to cold lube water provided to the discharge side AWIF of a pump, normally used in conjunction with a percentage (example: 4% cold out).
Hot in	Refers to hot lube water provided to the inlet side AWIF of a pump, normally used in conjunction with a percentage (example: 4% hot in).
Hot out	Refers to hot lube water provided to the outlet (AWIF) of a pump, normally used in conjunction with a percentage (example: 4% hot out).
Hot	In the context of water lubrication this means a temperature between 180 and 210 F.
Tempered	In the context of water lubrication this means a temperature of that of the oil or slightly higher.

Cold	In the context of water lubrication this means a temperature that is colder than the oil.
Master Test	Principal test that is conducted over a longer distance than a pre test for proportionality verification and to determine whether more lube water is required for longer pumping distances. The Master Tests use parameters and techniques optimized in pre-tests. The parameters used were repeated in the manufacturers' testing for comparison.
Decon	Decontamination

0.3 Conversion between US and Metric Units

1 inch (")	= 2.54 mm	= 0.0254 m		
1 ft (')	= 0.3048 m		1 m	= 3.2808 ft
1 USgal	= 3.785 l		1 l	= 0.2642 USgal
1 USgpm	= 3.785 l/min	= 0.2271 m ³ /h	1 m ³ /h	= 4.4033 USgpm
1 barrel (bbl)	= 0.15898 m ³		1 m ³	= 6.2901 bbl
1 °F	= 32 + 9/5 °C		1 °C	= 5/9(°F – 32)
1 psi	= 0.069 bar		1 bar	= 14.5 psi
			(1 Pascal = 10 ⁻⁵ bar)	
1 HP	= 0.736 kW		1 kW	= 1.3587 HP
1 BTU/h	= 0.293 x 10 ⁻³ kW		1 kW	= 3412.97 BTU/h
1 acre	= 4047 m ²			

1.0 EXECUTIVE SUMMARY

The Joint US and Canadian Coast Guard, US Navy, and Industry Viscous Oil Pumping System (JVOPS) Workshop, which had been planned for almost two years, took place at the Cenac Towing Inc. facility in Houma, Louisiana, USA in December 2003. The JVOPS project is the most comprehensive high viscosity oil testing that has ever been carried out. The Workshop was planned and executed by the JVOPS Workgroup, a multi-national group of Government and Industry engineers, scientists, pollution response equipment manufacturers and first responders dedicated to promoting and improving heavy viscous oil response worldwide.

Several marine disasters in recent years have demonstrated the limitations of traditional pump transfer methods, and that innovative techniques are required as to emergency pump transfer of extremely viscous oil. The purpose of the Workshop was therefore to improve the first-response pumping systems of the US and Canadian Coast Guards, the US Navy Supervisor of Salvage, and the international response industry through the evaluation of such systems – in conjunction with their existing and recently developed flow enhancing techniques – in a simulated response scenario of extreme viscosity and pumping distance.

The JVOPS Workshop, which involved about 100 people from 7 nations, targeted pump transfer testing on oil in the critical 200,000 to 500,000+ cSt range and pumping distances up to 1500 ft / 450 m. In addition to testing U.S. (DESMI DOP-250) and Canadian Coast Guard (GT-185) pump systems; Framo of Norway (TK-125) and Lamor of Finland (GT-A 50) also had tests conducted on their systems. The Workshop was a great success with significant positive results reducing hose pressure and increasing flow rates to a degree that must be considered groundbreaking:

1. Annulus Water Injection applied with hot water on the pump inlet and with hot or cold water on the discharge side resulted in some of the tests in a performance improvement of over 200 times when compared to pumping with no water injection.
2. The major USCG target as to a pumping distance of 1500 ft / 450 m on 200,000 cSt oil was achieved at nearly full pump capacity with a pressure drop of only 45 psi / 3 bar (test viscosity: 185,000 cSt).
3. The major CCG target as to a pumping distance of 500 ft / 150 m on 500,000 cSt oil was achieved at nearly full pump capacity with a pressure drop of only 13.6 psi / 0.9 bar (test viscosity: 480,000 cSt).
4. It was verified that re-establishing the fully water lubricated product flow after an unintended pump stop and break down of the water ring was not possible using cold lubrication water, but was successfully accomplished using 4% hot inlet lubrication water and 4% hot outlet water (311 ft / 93 m hose on 210,000 cSt oil).

5. While the combinations of hot inlet lubrication water in conjunction with hot or cold outlet lubrication water were almost equally efficient in testing with clean test hoses, it was observed that the hot in/hot out combination was the most efficient in testing with contaminated test hoses.
6. Inlet side hot water injection was the single most influential flow enhancing technique.
7. The three Positive Displacement Archimedes' Screw pumps tested, DOP-250, GT-185 and GT-A 50, with their respective inlet and outlet water injection devices, can be considered most suitable for pumping oil at these high viscosities.
8. None of the tested pumps can pump the 200,000 and 500,000 cSt oil used in these tests over any operational distance at any operational rate without the assistance from flow enhancing techniques.
9. Hose pigging /decontamination was possible in one step up to 1200 ft / 360 m.

2.0 BACKGROUND FOR PROMOTING HEAVY VISCOUS OIL MARINE RESPONSE PUMP TRANSFER TECHNOLOGY

2.1 Risks Related to Transportation and Use of Heavy Oil

The marine transportation of heavy crude and fuel oils as well as emulsified oil has constantly increased in recent years. Likewise can an increased use of heavy fuel bunker in the modern commercial fleet be observed, which is due to the increasing demand for a continued development of marine engines that can use the heaviest and least expensive fuels. The combination of intensified ship traffic and the use of high density/high viscosity oils pose an increased threat to the marine environment. The characteristics of the oil, including high viscosity and tendency to sink, present particular challenges for clean-up operations in the event of an accidental spill at sea. At the 3rd IMO R&D Forum in Brest, France, 2002 on Response to Spills of High Density Oils, it was concluded that IMO, Governments and industry must improve international co-operation in developing and testing operational high density oil collection and pumping systems.

2.1.1 Heavy Fuel Oil

High density residual oils, used mostly for power generation, amount to some 600 million tonnes produced and consumed in the world each year. High density fuel oils, also known as heavy fuel oils (HFO), are produced from residues from various refinery processes. Some 140 million tonnes of marine bunker fuel oils are consumed annually, the majority of which is heavy fuel oil. A large ship powered by diesel engines may consume 150 tonnes of fuel oil per day and may carry up to 3,000 to 4,000 tonnes. Heavy fuel oil tends to be cheaper than distillate (lighter) fuel oils, such as diesel (Source: IMO).

The International Tanker Owners' Pollution Federation Limited (ITOPF) has reported that its staff has attended about 450 spills in the last 25 years, of which 40 % involved medium or heavy grades of fuel oil, either carried as cargo or used by larger vessels as bunker fuel. In recent years, about 50% of all oil spills attended have involved heavy fuel oils (Source: IMO).

2.1.2 Heavy Crude Oil

The majority of heavy oil transported at sea is heavy crude oil. Fortunately, the relative amount of accidental heavy crude oil spills is significantly lower than those for heavy fuel oil. Dependent on oil characteristics, it is suspected that heavy crude oil spills may pose similar challenges.

2.1.3 Emulsified Fuel (Orimulsion®)

Since the introduction of the emulsified fuel, Orimulsion®, to the power generation market in the early nineties, significant work has been undertaken studying its behavior when spilled at sea, response to remaining bitumen, and potential cleanup techniques. The studies have in particular been carried out by sponsorships funded by BITOR, the producer of Orimulsion®, but an important part has also been sponsored by Canadian and US government agencies. One of the most recent contributions is the report, “Spills of Emulsified Fuels, Risks and Response” a project under the US National Research Council (NRC).

All existing oil spill preparedness has been based on the fact that a large majority of oils will float when spilled on water, where an Orimulsion® spill will behave differently by initially going into suspension as microscopic bitumen particles in the upper 2-3 meters below the sea surface (dependent on water salinity). After natural or mechanical refloating the particles may – especially in contained areas like harbors and narrow waters – resurface and form a surface layer or patches of very viscous bitumen.

To date there have been no significant spills of Orimulsion® to enable full-scale use, under real life cleanup conditions, of the various conventional and new techniques and technologies, which have been developed and tested for the purpose. Some of these new techniques and technologies, however, formed an important basis for the success of the JVOPS Workshop.

2.2 Heavy Oil Disasters in Recent Years – Spill Response Problems

Although the safety standards of ships continue to improve and accident rates are falling, accidents such as M/V KUROSHIMA (Alaska, 1997), T/B MORRIS J. BERMAN (Puerto Rico, 1994), M/V NEW CARISSA (Oregon, 1999), T/V ERIKA (France, 2001), T/V BALTIC CARRIER (Denmark, 2002), and T/V PRESTIGE (Spain, France, 2002) have confirmed the urgent need for further development and application of techniques that can ensure a more efficient response to spills of high density oils.

These accidents repeatedly demonstrated a serious lack of ability to either recover, pump transfer, or to recover and then pump transfer the very viscous oil. The NEW CARISSA incident was the impetus for the US Coast Guard and Navy to conduct a series of Viscous Oil Pumping System (VOPS) workshops that were conducted in the following years. These workshops culminated with the subject of this report, the Joint Viscous Oil Pumping System (JVOPS) Workshop (#6) in Louisiana, December 2003.

3.0 SUMMARY OF PREVIOUS HEAVY VISCOUS OIL PUMPING RESEARCH INITIATIVES

Literature and testing on annulus ring water lubrication dates back to 1959 (Ref 1) where research initiatives were started by the heavy oil industry who wanted to facilitate the pumping of very viscous crude oil through pipelines. With the decreasing availability of lighter crude oil, facilitating increased interest in heavy crude and oil fields that previously were not feasible, this work is continuing. The following paragraphs will describe the flow enhancing techniques that presently are available to spill responders and provides a summary of the efforts that have been carried out within the oil spill response community.

3.1 Summary of Flow Enhancing Techniques

The four primary flow enhancing techniques have been described in previous viscous oil pumping literature (Ref 2) and are discussed in the following sections.

3.1.1 Bulk heating

Bulk heating involves the heating of the entire volume of oil in a storage tank, usually through the use of heating coils. There may be a limited temperature increase required to convert the extreme viscosity product to something that is pumpable. For example, bitumen may go from 2 million cSt and down to 200,000 cSt by increasing the temperature from 20 to 30 °C. This would be enough for a Positive Displacement Archimedes' Screw (PDAS) pump to transfer the bitumen at an operational rate over short distances, and further heating would enable several other pump types to be useable. However, since most oil recovery skimmers do not have an on-board tank, they must be able to transfer the recovered product instantly. Bulk heating is not an option. Likewise, in connection with the transfer of cold heavy oil from sunken vessels it may be impossible, or to the best very difficult and expensive, to heat up the entire tank.

3.1.2 Local bulk heating

Local bulk heating involves heating coils wrapped around the transfer pump or placed in front of its intake. A steam/hot water source heats up the coils. The heat from the coils is transferred to the oil adjacent to the pump, thus reducing viscosity locally and facilitating in-flow. Even though the oil outside the local heating area will remain extremely viscous, it will nevertheless gradually sink in and compensate for the oil that is being removed by the pump, so that the transfer process can keep going. As an alternate to heating coils, other types of heat exchangers may be used, as long as they can be placed in the vicinity of the pump intake. A steam heated inlet hopper to the transfer pump in a mechanical feeder skimmer may in some cases be enough to change failure to success.

3.1.3 Discharge side annulus ring water injection

This technique was first investigated in 1959 by the heavy oil industry who wanted to facilitate the pumping of very viscous crude oil through pipelines. The principle of a so-called Annulus Water Injection Flange (AWIF), which injects water as a low viscosity “coating” between the oil and the hose or tube, can be seen in Figure 1.

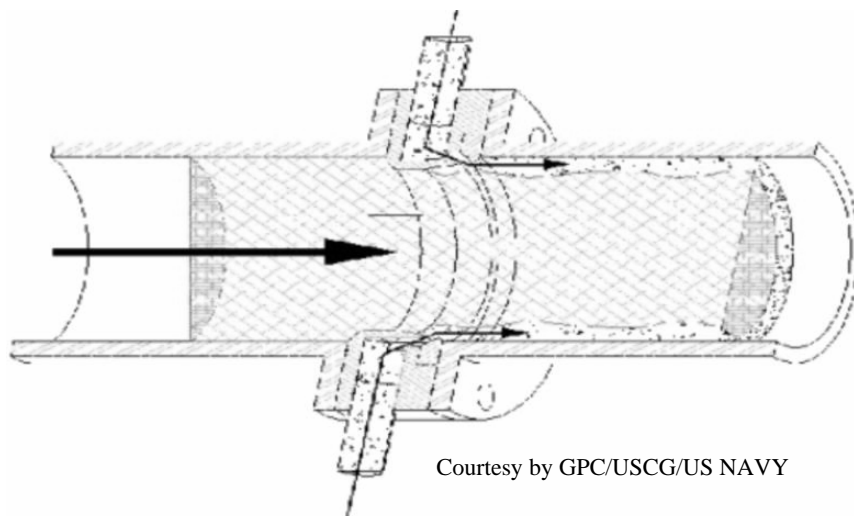


Figure 1. Discharge Annulus Water Injection Flange Cutaway Sketch

FRAMO adopted in the 1990's this technique for use in the emergency off-loading industry. In both cases mainly centrifugal pumps have been used, which is the reason for having the point of injection after the pump. These pump types have a severe decrease in efficiency at a relatively small increase in viscosity. Water lubrication has been able to enhance the efficiency of these pumps, but only by placing the injection flange on the discharge side and a short distance from the pump. Turbulence inside the pump would otherwise mix the oil and water hence creating higher viscosity emulsion and further decreasing pump efficiency. For the PDAS pumps these reasons for positioning the flange after the pump do not apply; there is no turbulence after the pump, and there will be no or little emulsification inside the pump if water is added before the pump.

Traditionally water at ambient temperature has been used for discharge side water lubrication. As previously tested by the Canadian Coast Guard, the injection of hot water may further enhance the flow when pumping extremely viscous oil. But the results were not conclusive.

3.1.4 Inlet side annulus ring steam/hot water injection

Inlet side annulus ring steam- or hot water injection – developed by flemingCo in 2001 for non emulsifying pumps – is an option to local bulk heating, only requiring that the pump be fitted with an injection flange on its intake (Fig. 2).

This is a more portable and compact solution, which – besides the hydraulic power lines – only requires hook-up to a steam source like a standard mobile steam cleaner or to a source of hot water. The injected steam or hot water heats up the pump intake and gradually the entire pump, thus heating up the oil near the pump and creating almost similar conditions as for local bulk heating. The hot water (or the applied steam, which condenses to hot water) is via a circular slot injected to the inside of the pump where it has two functions:

1. It heats up the inner surfaces – including the moving parts – so that the oil touching the surfaces – locally, in a very thin layer – gets heated up. This reduces the viscosity of the thin oil layer, thus significantly reducing friction inside the pump.
2. Friction is further reduced by the lubricating effect of the injected hot water, which also lubricates the discharge line and facilitates the overall transfer of the oil.



Figure 2 DOP-160 with flemingCo inlet side steam/hot water injection AWIF

3.2 CEDRE (France) Testing

In the late 1980's the French Petroleum Institute (IPF) carried out some small scale laboratory testing on flow enhancement by discharge side annular water injection (AWI). The tests were very promising in that optimal performance with a pressure drop reduction of 25 times was obtained at a water rate of 7% of the oil flow. The test found no difference in performance of AWI on two different products, polyisobutane (Napuis D3) and Bunker C fuel. Likewise there was no difference observed between salt water and fresh water as lubrication medium (Ref 3).

These tests led to the first larger scale oil spill response related tests with discharge side AWI at CEDRE's test facility in Brest, France with 4 and 6 inch tubes and hoses, and pump capacities in the 11 to 82 m³/h range. Best performance with Bunker C fuel was a 20 times pressure drop reduction at a water rate of 6% of the oil flow (Ref 3). Viscosities tested were in the lower end (5,000 to 10,000 cSt) in comparison with the JVOPS testing but provided valuable insight in the potential of annular water injection.

However, apart from FRAMO, who had one of their submersible TK5 centrifugal type offloading pumps involved in the CEDRE tests, the oil spill industry was reluctant to adopt the promising techniques, or was unaware of the test results.

3.3 U.S. Coast Guard Efforts

Previous testing of the USCG Viscous Oil Pumping System (VOPS) have clearly demonstrated the importance of using flow enhancing techniques when attempting to pump oil over longer distances. The results obtained so far was a reduction in pressure drop of 10-12 times, or – in other words – an ability to pump transfer oil over a 10-12 times longer distance than if no flow enhancing technique had been used.

The VOPS incorporates the use of annulus ring water lubrication after the discharge from the transfer pump, materialized by a FRAMO/USCG/GPC/US NAVY type Annulus Water Injection Flange (AWIF). A Positive Displacement Pump injects water to the discharge line adjacent to the transfer pump outlet and creates a ring of water that separates the oil from the inner surface of the discharge hose.

Mathematical models have shown that the hose considers the pumped medium almost as if it was water. Consequently the pressure drop should be significantly reduced, which in full scale was demonstrated at the first VOPS workshop in Seattle, 1999 (Northwest Workshop). Oil in the 18,000 cSt range could be pumped through 90 m / 300 ft of 6" hose with a friction reduction factor up to 12 when applying the discharge side water lubrication in a rate of 5 to 6% of product flow (Ref 4).

Four more VOPS workshops were carried out from 1999 to 2002 and have been summarized below:

3.3.1 Workshop at OHMSETT November 1999

This workshop was a simulation of a lightering operation using the prototype VOPS developed after the Seattle workshop. Apart from the longer pumping distances it was in principle a repetition of the Northwest Workshop two months earlier and cemented with pumping distances up to 400 m / 1300 ft and oil viscosities in the 13,000 to 20,000 cSt range the findings of that test. However, in the best cases the pressure reduction factor reached 14 (Ref 5). This test led to the desire for longer distances and higher viscosities as well as for testing under arctic conditions.

3.3.2 Workshop at OHMSETT March 2000

This test had been planned for viscosities in the 60,000 to 400,000 cSt range but the test oil turned out to be in the 13,000 to 44,000 cSt range due to unexpected warm weather conditions. In addition to being an excellent training opportunity for the USCG and Navy VOPS Teams the test again underlined the importance of using annulus water injection when pumping oil over long distances.

The testing verified the limitations of centrifugal pumps on oil viscosities of any significance and confirmed the suitability of PDAS pumps for viscous oil. The important relationship between the size of a PDAS pump and the required torque of its hydraulic motor when pumping viscous oil was verified (Ref 6). The testing further provided valuable insight to the large potential of local bulk heating using steam generators, steam lances and coils.

3.3.3 Workshop at Alaska Clean Seas, October 2000

This workshop tested the standard USCG VOPS discharge side AWI system with a weathered crude oil, and the same oil emulsified to 40% and 60% water by volume, resulting in a viscosity range of 1,000 to 50,000 cSt at 1 s^{-1} . Tests were done both with and without the use of AWI to compare the effect. Tests were also carried out using alternative AWI fluids: a 50/50 glycol/water solution, diesel, and diesel with emulsion breaker. For all tests with AWI the injection rate was nominally 5% of the emulsion flow rate.

Use of the AWI system with water as the injection fluid dropped the line pressure significantly, from a maximum of 108 psi at a pumping rate of 600 bbl/h, to 12 psi at the same flow rate. Use of the glycol/water solution produced similar, but slightly better, results. The use of diesel was not as successful because the diesel seemed to quickly mix with the emulsion. Even though the pressure dropped by a 4:1 ratio it did not have the dramatic effect characteristic of the annular water injection concept.

A final test was performed with emulsion breaker added to the diesel AWI fluid. The demulsifier had a rapid and dramatic effect after only a short period of recirculation. The water content of the emulsion was quickly reduced to near zero and the viscosity was reduced to that of the parent oil (Ref 7).

3.3.4 Workshop at Cenac Towing, Inc., Houma, Louisiana, May 2002

This workshop was characterized by a very realistic work environment, which resembled the emergency offloading of oil from a grounded barge. It was excellent training for the USCG Strike Team responders and provided a realistic insight in the complexity of a lightering operation (Ref 8). The oil that was unloaded from a barge was not homogeneous. The viscosity varied from a few hundred cSt to almost solid product with a viscosity beyond what could be measured. An inlet side lubrication flange on a DOP-160 pump was used for the first time by the Strike Teams during this workshop.

The five previous VOPS workshops have familiarized the USCG Strike Teams with viscous oil lightening techniques and their results have provided valuable information to the oil spill response community that cannot be overestimated. However, the tests have never been with oil in the critical heavy oil viscosity range of 200,000 to >500,000 cSt that can also be met in the field.

3.4 Canadian Coast Guard Efforts

Since 1999 The Canadian Coast Guard (CCG) has carried out testing of skimmers and pumps on "refloated bitumen", which will be the product to deal with after a spill of Orimulsion, where mechanical refloating may have been applied. Testing in 1999 verified that a number of mechanical feeder skimmers can recover very viscous bitumen of about 2 million cSt (Ref 9). It also became clear, however, that skimmer on-board transfer pumps were unable to move the recovered product.

These findings led to testing in 2001 with the GT-185 and GT-260 PDAS pumps equipped with discharge side annulus water injection flanges (AWIF) of the USCG VOPS type. The testing confirmed the USCG findings on bunker oil as to reduction in discharge line pressure drop, but testing with bitumen in the 200,000 to 900,000 cSt range did not demonstrate any operational performance for any of the pumps (Ref 10).

In 2002 the testing continued with a modified GT-185 PDAS pump, equipped with both inlet and outlet lubrication devices. The applied lubrication water was close to the boiling point vs. the ambient temperature water used in previous testing. The test results were most promising: Bitumen with a viscosity of about 2 million cSt could be pumped at an operational rate and over operational distances (Ref 11). The improvement in performance was more than 40 times, but the quantification of lube water – in percent of pumped product – was not optimized due to time constraints.

However, the Canadian results were obtained over a relatively short pumping distance of 40 ft / 12 m compared to the USCG VOPS testing that had pumped oil up to 1300 ft / 400 m. Thus, the CCG had the high viscosity results over shorter distances, and the USCG had the long distance results, using lower viscosities.

3.5 Private Industry Efforts

Beginning in 2001, small scale testing of pump transfer of extremely viscous product has been carried out at response equipment manufacturers' facilities:

3.5.1 Testing at DESMI, Denmark

The Canadian application of hot water injection on the inlet side had been inspired by some testing carried out in Denmark in 2001 where promising results had been obtained by the application of an inlet side steam/hot water lubrication flange on a DESMI DOP-250 pump, the key heavy oil transfer pump type in the USCG VOPS

packages. The tests were sponsored by BITOR and Ro-Clean DESMI and incorporated for the first time the application of the flemingCo concept of inlet side steam/hot water injection. A bitumen test product of 3 million cSt was pumped at a rate of 198 USgpm / 45 m³/hr through 60 ft / 20 m of 6" hose at a pressure of only 29 psi / 2 bar using 2% hot water injected at the inlet side of the pump only (Ref 12).

3.5.2 Testing at Environment Recovery Equipment (ERE), Canada

The FOILEX TDS 150 PDAS pump with steam/hot water injection devices on inlet- and discharge side was tested on bitumen at Environment Recovery Equipment (ERE), Canada in spring 2002 (Ref 13). The test was witnessed by representatives from the US and Canadian Coast Guards. The ERE skimmer recovered about 3 million cSt (16 °C) bitumen to a small buffer tank from where the TDS 150 pumped it through 90 ft / 30 m of 4" hose, back to the test tank in front of the skimmer. Evaluation of performance was visual only. Some difficulties with the inlet side injection on the Foilex pump was observed. Nevertheless the test adds to the picture of the effect of flow enhancing techniques; they can enable some pumps to handle extreme viscosity oil at operational rates.

3.5.3 Testing at LAMOR, Finland

The LAMOR GT-A 50 pump with its integrated flemingCo inlet side steam/hot water injection system was tested in-house at LAMOR, Finland early in 2003 (Ref 14). The LAMOR GT-A 50 was tested as a transfer pump on a LAMOR brush belt skimmer. The skimmer recovered floating bitumen from the test tank and scraped it off into a steam-heated hopper, which guided the product into the inlet of the pump. The viscosity was about 3 million cSt (15 °C) and the pump could match up with the skimmer by instantly transferring the recovered product through the discharge hose – fully water lubricated. Evaluation of performance was visual only. Nevertheless the test proved once more that flow enhancing techniques can enable some pumps to handle extreme viscosity oil at operational rates.