ENHANCEMENTS TO STOCK CCG TRANSFER PUMPS/ SKIMMER UNITS

D. Cooper
R. MacKay
C. Brown
SAIC Canada
Canadian Coast Guard
Environment Canada
Ottawa, Ontario, Canada
Charlottetown, P.E.I., Canada
Ottawa, Ontario, Canada

ABSTRACT

A number of modifications and enhancements of the two primary transfer pump/skimmer units, specifically the GT-185 and GT-260 stocked by the Canadian Coast Guard have been proposed over the past few years. Much of the focus of the testing during this time has centered on dealing with very viscous oils, but the proposed changes will impact the performance of these devices when dealing with any oil.

This paper details the development of a collaborative series of projects supported by Environment Canada and the Canadian Coast Guard over the past six years. It provides background information on the original problems or design limitations of the oil spill recovery equipment. Descriptions of the subsequent modifications are presented, along with performance information which quantifies any improvements to performance. The work has evolved to include partnerships with federal government organizations from Canada and the United States, along with contributions by manufacturers of similar spill response equipment during testing trials.

INTRODUCTION

The pumping of heavy, viscous oil remains one of the many challenges facing response efforts today. The tendency of most oils to quickly weather and form emulsions in rough seas exacerbates the situation—often resulting in an extremely viscous product that can be difficult to handle even under "ideal" conditions. One extreme case, which has been undergoing investigations in recent years, involves spills of Orimulsion®. Such spills can lead to the formation of pools of extremely viscous bitumen, whose properties can surpass the capabilities of commonly used pumping equipment.

BACKGROUND

SAIC Canada, under contract from Environment Canada's Emergencies Engineering Technologies Office (EETO), develops and performs studies to evaluate new and existing oil spill recovery and containment equipment in order to assist in the advancement of these technologies. The Canadian Coast Guard (CCG), Environmental Response Branch, has extensive expertise in identifying, analyzing and developing the preparedness and response activities essential to an efficient and dependable response system. CCG recently initiated a program and partnered with EETO/SAIC Canada to test the viscous oil capabilities of currently stocked skimmers at CCG bases in Eastern Canada. Under this program, a number of evaluation studies were developed involving innovative equipment that were designed to assist in the recovery of extremely viscous products.

DISCUSSION

Phase 1—Initial Performance Testing of Stock Equipment

The first phase of this program began at the time that Orimulsion®, a bitumen based fuel product from Venezuela, was first being shipped into Canada. Spill responders quickly discovered that the behaviour of this product when spilled in water was unique when compared to traditional crude based oils. Conventional equipment stocked by responders in Canada was deemed inadequate to handle the extremely viscous bitumen that could coalesce and form slicks following a spill. Due to these factors research and testing was undertaken to identify new and innovative equipment that could be used to help remediate such a spill.

The primary focus was the determination of a method or technique that could be employed to contain the spill. The risk of a spill at dockside during offloading operations was identified as a potential threat to the environment, and traditional booms and skimmers were rendered ineffective due to the behaviour of the product when introduced to the water column. Pre-deployed deep skirted booms were identified as a means of possible containment—but the problem with the bitumen being distributed in the water column remained.

Initial testing encompassed the refloatation of spilled Orimulsion® in a flume tank. A prototype Refloater was operated in a variety of modes, simulating a small dockside spill scenario. Factors such as temperature, salinity, concentration of bitumen, and time were incorporated into a testing scenario. Fresh water test runs showed up to 34% removal of bitumen droplets from the water column, compared to 4% which naturally refloated during the test period. During saltwater testing, the refloater was able to remove up to 90% of the bitumen, having an immediate impact on refloating the suspended droplets. Allowing the bitumen droplets to naturally coalesce and rise to the surface of a 3% saltwater test tank resulted in a decrease of up to 37% of the suspended bitumen droplets in the water column over the same testing period.

Testing of a qualitative nature was performed with the suite of skimmers, including a Canadian Coast Guard stocked GT 185 skimmer, to determine if any would be able to process the refloated bitumen. While some designs were inherently better at collecting the extremely viscous product, it was felt that modifications would be warranted in order to actually move the recovered product from their respective holding reservoirs through a recovery hose.

The primary skimmer of interest to the Canadian Coast Guard, the GT 185 skimmer, was not able to process the refloated bitumen by itself since the bitumen would take too long to "flow" into the weir mechanism. Manually pulling the refloated bitumen into the weir was attempted in order to determine the pumping capabilities of the unit. Testing showed that pumping through the approximately 4 metres of 10.2 cm (4") hose attached to the skimmer would be a taxing chore for the pump, as flow rates during testing were extremely low. Enhancements to the pumping capability became the focus for the next phase of testing.

Phase 2—Testing Preliminary Modifications

The performance results of the initial phase of testing were a bit disappointing. One of the easiest modifications considered and ultimately tested was the installation of higher torque motors. Even with this modification, however, the flowrates generated by the skimmers remained disappointedly low. Additional modifications were warranted.

The next step in the research related to the recovery and pumping of viscous oil centered on the performance enhancement developed by the addition of annular water injection at the discharge end of stocked Canadian Coast Guard pumps—both the GT 185 and GT 260. They provide a means of injecting water into the flow of oil being pumped in such a way as to create a "ring" of water surrounding the oil flowing in the hose.

Baseline testing consisted of the entire skimmer assembly being submerged in oil—essentially acting as a transfer pump moving oil around a test loop of approximately 45 m in length while sensors measured pressure and temperature. Flows were left to stabilize for minimum periods of 10 minutes before measurements were recorded. The time required to pump the liquid into a container of known volume was then measured, and the flowrate was calculated. The speed of the skimmer was then changed, and the system was again left to stabilize for approximately 10-15 minutes. This scenario was repeated until four speeds were recorded. Data from this series of runs is presented in Table 1, while a picture of a GT 185 unit used during testing is presented in Figure 1.

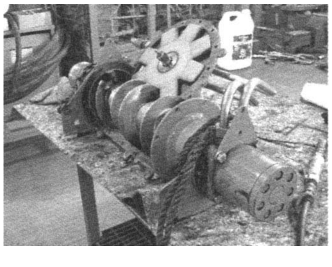

FIGURE 1: GT 185 PUMPS

As expected, loop pressure drop and inlet pressures increased as the flowrate was increased.

Table 1: Bunker C (weathered) in a 10.2 cm (4") loop (GT 185)*

Test Run	Volumetric Flow Rate (m^3/hr)	Linear Speed Within Hose (m/s)	Inlet Pressure bar (psig)	Loop Pressure Drop bar (psig)
1	3.74	0.129	2.72 (39)	2.23 (32)
2	3.13	0.107	2.27 (33)	1.86 (27)
3	4.61	0.158	3.10 (45)	2.55 (37)
4	6.19	0.212	4.00 (58)	3.31 (48)

*Measured viscosity: 17,000 cP

Testing with the annular water injection ring produced an interesting result. The system was run without water injection up to an inlet pressure of approximately 4 bar (60 psi) and left to stabilize. The skimmer was then momentarily stopped and the water injection ring was engaged. The skimmer was then brought back online and the system was left to stabilize. As the system stabilized, the pressure drop was dramatic as shown in Table 2. A reduction of over 90% of the pressure was observed, indicating a significant contribution from the water ring. The quantity of water added to the system was not insignificant due to limitations on the test equipment and the ability to throttle back the quantity of water being delivered to the system; however, this test run did aptly demonstrate the benefits of using annular water injection techniques and formed the basis of future work.

Table 2: Bunker C with Annular Water Injection (GT 185)*

Test Run	Volumetric Flow Rate (m^3/hr)	Linear Speed Within Hose (m/s)	Inlet Pressure (psig)	Loop Pressure Drop (psig)
Mix	20.2	0.694	0.28 (4)	0.21 (3)
Bitumen	13.2			
Water	7.0		1.31 (19)	

*Measured viscosity: 17,000 cP

A shortened section of the 10.2 cm (4") loop (19 m total length) was used for the highly viscous bitumen runs. Once bitumen filled the test loop, the system was left to circulate and stabilize for approximately 25 minutes to ensure a homogeneous liquid. The test runs were performed in a similar fashion to the Bunker C runs, with pressure and flowrates being measured and recorded. This scenario was also repeated until four speeds were recorded. Data from this series of runs are presented in Table 3. Again, as expected, inlet and loop pressures increased as flowrates increased.

Testing with the annular water injection ring produced also provided interesting results. The system was run up to an inlet pressure of approximately 4.4 bar (64 psi) and left to stabilize. The skimmer was then momentarily stopped and the water injection ring was engaged. The skimmer was then brought back online and the system was left to stabilize. As the system stabilized, the pressure drop was slower to stabilize, but levelled off within minutes. A flowrate measurement was performed and flows were recorded as shown in Table 4.

Table 3: Bitumen in a 10.2 cm (4") diameter loop (GT 185)*

Test Run	Volumetric Flow Rate (m^3/hr)	Linear Speed Within Hose (m/s)	Inlet Pressure bar (psig)	Loop Pressure Drop bar (psig)
5	1.15	0.039	4.07 (59)	3.31 (48)
6	1.30	0.044	4.41 (64)	3.42 (50)
7	0.79	0.027	2.83 (41)	2.14 (31)
8	1.44	0.050	4.48 (66)	3.45 (50)

*Measured viscosity: 200,000 cP

An observed inlet pressure reduction of approximately 45% was recorded with the annular water ring operating. It should be noted, however, flowrates remained relatively low, and that no annular flow was observed to have developed through the outlet during the relatively short run time. It was expected that a larger drop in initial and loop pressure would be observed if the annular water ring was established. Output from the hose seemed to indi-

Table 4: Bitumen with Annular Water Injection (GT 185)*

Test Run	Volumetric Flow Rate (m^3/hr)	Linear Speed Within Hose (m/s)	Inlet Pressure (psig)	Loop Pressure Drop (psig)
Mix	9.32	0.320	2.48 (36)	1.65 (24)
Bitumen	2.23			
Water	7.09		3.65 (53)	

*Measured viscosity: 200,000 cP

cate some mixing of the oil and water was occurring but readily separated once discharged. The reduction in pressure requirements could be attributed to two phased flow within the test loop, as opposed to the formation of an annular ring.

Based upon the results obtained from this series of tests it was determined that the annular water injection ring did have a strong effect on the Bunker C results; however the results for pumping the bitumen were inconclusive. Relatively short test runs imposed by the limited quantity of available bitumen may not have provided sufficient time for annular flow to fully develop within the test circuit.

Phase 3—Testing of Refined Modifications

This next phase of testing involved longer tests designed to identify possible operational compatibility problems due to the stresses imparted by pumping extremely viscous oil. Additional techniques including the injection of hot water at the inlet hopper of the pump was also attempted—subjecting the internals of the pumps to elevated operating temperatures. Testing during this third phase was performed using three test liquids: Bunker C, a viscous oil (bitumen) and water for baseline testing. Figure 2 below shows the operation of baseline testing using water as a test liquid while accurate flowrates are being measured. Table 5 provides properties of the oils used during testing.

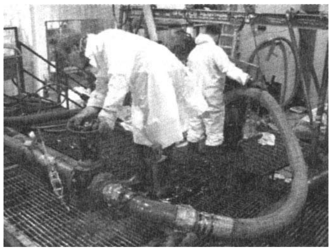

FIGURE 2: TEST LOOP

Table 5: Test Liquid Viscosities

Test Liquid	Viscosity, cP	Temperature, °C
Bunker C	8,700	21.3
Bitumen	930,000	20.0
Bitumen	700,000	23.4
Bitumen	200,000	30.0

An initial test in Bunker C was performed to determine the performance levels obtainable while pumping a common product. Measurements were taken for all hydraulic system and pumping parameters for each measured flowrate, typically starting at 0 psi system pressure and working up by 10 psi increments until the pump reaches its maximum operating pressure, or 100 psi. System flowrates were manually measured at each operating pressure increment.

Bitumen tests were effectively pump weathering tests run for three time periods (3 hours, 5 hours, 9 hours) with water baseline tests being performed after each run to determine if slippage and/or wear within the pump was increasing (shown by a drop in performance measured by flowrate obtained while pumping under specific system pressures and by the maximum pressure obtained when temporarily pumping water against a closed valve).

The results of the testing of two stock GT 185 systems "1153" and "1165" with the three labeled plate wheels is shown below in Table 6.

Table 6: Initial Baseline Testing

Test Number	Plate Wheel ID	Hydraulic Flow Rate (lpm)	Flow rate @ 0 bar/psi (m^3/hr)	Flow rate @ 0.69 bar 10 psi (m^3/hr)	Flow rate @ 1.38 bar 20 psi (m^3/hr)	Flow rate @ 2.07 bar 30 psi (m^3/hr)	Flow rate @ 2.76 bar 40 psi (m^3/hr)	Flow rate @ 3.45 bar 50 psi (m^3/hr)	Flow rate @ 4.14 bar 60 psi (m^3/hr)	Flow rate @ 4.83 bar 70 psi (m^3/hr)	Flow rate @ 5.52 bar 80 psi (m^3/hr)	Flow rate @ 6.21 bar 90 psi (m^3/hr)	Flow rate @ 6.89 bar 100 psi (m^3/hr)	Max pressure: bar (psi)
9.	1165-1	68.5	30.2	16.7	10.3	4.7	--	--	--	--	--	--	--	2.90 (42)
10.	1153-2	68.5	34.9	26.8	22.3	18.5	15.6	12.1	9.5	--	--	--	--	6.00 (87)
11.	1165-2	68.5	31.1	21.5	16.0	12.2	7.8	4.6	--	--	--	--	--	4.34 (63)

An inspection of the stock plate wheels did show some wear during this series of testing, as shown in Figure 3. In spite of the reasonable flowrates that were obtained during the course of testing—concern was raised as to the expected lifespan of the platewheels if they were to be subjected to long term operation in extremely viscous product. This concern was also due, in part, to a failure of a platewheel that occurred while hot water injection at the inlet hopper was activated in separate pumping tests. The materials of construction of the stock platewheels were not proving to be robust enough for the stresses and elevated temperatures that would be expected during actual response efforts for spills of bitumen or other viscous products. These concerns triggered the Canadian Coast Guard to seek a design for replacement platewheels and backing plates for the GT 185 and GT 260 line of pumps.

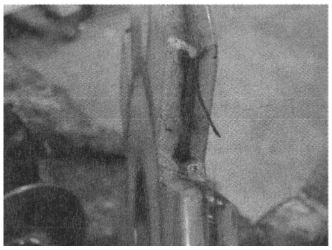

FIGURE 3: STOCK PLATEWHEEL AFTER BITUMEN TESTING

The platewheel prototype and modified GT 185 casing with enhanced backing plate were tested using the 3-hour bitumen protocol. Testing in bitumen for a 3-hour period did not seem to have caused any problems for the new disk and backing plate design. The unit was able to attain pressures in excess of 6.9 bar (100 psi) (the upper limit imposed by the test plan due to limitation of the test loop) at which point the test runs were stopped.

The new prototype plate wheel, as shown in Figure 4, and backing plate combination was able to provide impressive results, surpassing stock equipment for maximum pressures attained during baseline water testing. After hot water "degradation" testing the prototype system did not show any appreciable drop in performance—which is impressive when compared to the failure of the stock disk wheel which jammed within the GT 185 casing shortly after the hot water "degradation" testing began.

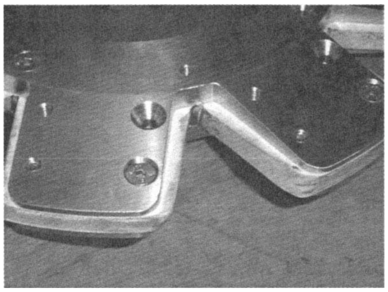

FIGURE 4: PROTOTYPE PLATE WHEEL

Additional testing of the larger GT 260 was performed in 2003. Again, the stock plate wheel and backing plates were replaced with prototype upgrades. Testing with the new components showed that the pump was able to attain upwards of 6.6 bar (95 psi) pressure using a test water loop which compares favourably to the stock set-up. Degradation testing in a hot water tank had a small impact on performance. The GT 260 was able to attain 5.9 bar (86 psi) following the hot water testing.

The stock disk wheels did not stand up well to the testing. As a result of the these findings problems should be expected if the stock disk wheels are used while attempting to pump highly viscous product such as bitumen. Additionally, hot water injection at the inlet side of the pump which may be attempted in order to overcome some of the difficulties in moving the bitumen is not recommended due to the degradation of the stock disk wheel witnessed during our testing.

Phase 4—Field Testing of Refined Modifications

A field evaluation of innovative water injection systems using a range of long hose lengths with extremely viscous fuels to determine the performance of the pumps was performed in late 2003 at the CENAC facility in Houma, Louisiana. This location was selected in part because of the logistical support and infrastructure for securing and storing large quantities of test liquids. Pumps from the inventory of the Canadian Coast Guard, U.S. Coast Guard, and other manufacturers with equipment designed to handle viscous product were selected for testing.

The GT 185 was fitted with a high torque capacity hydraulic pump which limited the throughput to approximately 27 m^3/hr. A number of tests were performed as listed below in Table 7.

Table 7: Long Distance Pump Testing

Test Number	Hose Length (m)	Viscosity (cSt)	Inlet Water (%)	Outlet Water (%)	Drum-fill capacity (m^3/hr)
5	20.6	530,000	1.7 @80°C	1.7 @80°C	23.4
6	32.4	480,000	4 @98°C	4 @19°C	27.0
7	152.4	480,000	4 @98°C	4 @19°C	25.5
11	32.4	260,000	4 @93°C	4 @35°C	25.7

As shown by these results, the system performed extremely well. The penalty of having to deal with the injected water pales in comparison to the benefit of provided performance close to the theoretical maximum of the pump while pumping an extremely viscous product. The modifications and equipment which have been designed and implemented by researchers, engineers and technicians represent a truly global effort to help solve this pumping challenge.

Additional testing is planned for the winter of 2004/2005 which will determine the performance enhancement of a brush modification mounted to the hopper of the skimmer. This enhancement will enable the GT 185 to be operated as a skimmer as opposed to a transfer pump when dealing with viscous product. This mode of operation will allow the unit to be put into operation earlier during response efforts and dramatically extend the capabilities of the stocked equipment of the Canadian Coast Guard.

BIOGRAPHY

Mr. Cooper is a professional Engineer with over fourteen years of experience testing and evaluating equipment and techniques used in the remediation of chemical and oil spills. He has experience performing bench and pilot scale studies in North America and Europe, and is actively involved with the development of new international standards for testing with the American Society for Testing and Materials International organization, specifically the ASTM F-20 Technical Committee on Hazardous Substances and Oil Spill Response.

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