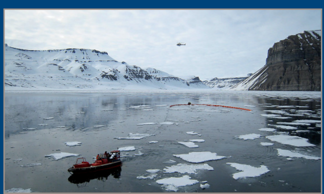
SINTEF A16066 Unrestricted

REPORT



Oil in Ice - JIP

Report no.: 10

Testing of Ro-Clean Desmi Polar Bear Skimmer in SINTEF ice basin. "Oil in ice" JIP, task 3.2: Testing of new concepts and units. Draft

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SINTEF Materials and Chemistry
Marine Environmental Technology
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Preface

SINTEF has in cooperation with SL Ross Environmental Research Ltd and DF Dickins Associates LLC on behalf of the oil companies AGIP KCO, Chevron, ConocoPhillips, Shell, Statoil and Total initiated an extensive R&D program; *Joint industry program on oil spill contingency for Arctic and ice covered waters.* This program was a 3-year program initiated in September 2006 and finalized in December 2009.

The objectives of the program were;

- To improve our ability to protect the Arctic environment against oil spills.
- To provide improved basis for oil spill related decision-making:
- To advance the state-of-the-art in Arctic oil spill response.

The program consisted of the following projects:

- P 1: Fate and Behaviour of Oil Spills in Ice
- P 2: In Situ Burning of Oil Spills in Ice
- P 3: Mechanical Recovery of Oil Spills in Ice
- P 4: Use of Dispersants on Oil Spills in Ice
- P 5: Remote Sensing of Oil Spills in Ice
- P 6: Oil Spill Response Guide
- P 7: Program Administration
- P 8: Field Experiments, Large-Scale Field Experiments in the Barents Sea
- P 9: Oil Distribution and Bioavailability

The program has received additional financial support from the Norwegian Research Council related to technology development (ending December 2010) and financial in kind support from a number of cooperating partners that are presented below. This report presents results from one of the activities under this program.

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Funding Partners

Agip KCO, ConocoPhillips, Chevron, Shell, Total, Statoil

R&D Partners

SL Ross, Dickins

Cooperating Partners

The Research Council of Norway, NOFO, alaska clean seas, UNIS, Kystverket, MMS, Oil Spill Recovery Institute Cordova, Alaska, Coastal Response Research Center at the University of New Hampshire

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TITLE

Testing of Ro-Clean Desmi Polar Bear Skimmer in SINTEF ice basin. "Oil in ice" JIP, task 3.2: Testing of new concepts and units.

A technical report

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CLIENT(S)

Agip KCO; Chevron; ConocoPhillips; Shell; Statoil; Total
Norwegian Research Council's DEMO 2000 Program

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ABSTRACT

This report summarizes the findings of a test program conducted in September 2008 in the SINTEF ice basin of the Polar Bear skimmer manufactured by Ro-Clean Desmi A/S of Denmark.

The Polar Bear skimmer is a mechanical oil recovery device that was designed on the basis of 2007 tests in the SINTEF ice basin of Ro-Clean Desmi's Helix Skimming adapter and Ice Skimmer as well as subsequent field evaluations of the Helix in the Barents Sea in May 2008.

The Polar Bear skimmer is a ruggedly constructed hexagonal device that incorporates one central buoyancy chamber and features six state-of-the-art brush drums and scrapers. It is not self-propelled. The skimmer was determined to tumble small ice pieces (rather than "process" the ice under it) while drawing oil into the brushes. In ice fields exceeding 30%, the skimmer must be repositioned so that oil contacts the brushes. In open water, recovery rate exceeded 30 m^3/h. This reduced to 2-2.5 m^3/h in slush ice. The pump transferred ice without problems; overnight storage at -10°C did not cause any problems.

Further refinements to the brush drums including their size and position relative to the skimmer body were identified as possible means to improve skimmer performance. Maintaining significant and efficient (low water content) performance in ice infestations using the Polar Bear will likely depend on frequent repositioning of the skimmer, operation at low rpm, and its placement in thicker slicks of oils that readily flow.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Mechanical recovery	Mekanisk oppsamling
GROUP 2	Oil spill	Oljesøl
SELECTED BY AUTHOR	Oil recovery skimmers	Oljeopptakere
	Basin testing	Bassengtesting
	Arctic	Arktis

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Executive Summary

A test program was conducted in September 2008 in the SINTEF ice basin of the Polar Bear skimmer manufactured by Ro-Clean Desmi A/S of Denmark. The objective of the evaluation work was to determine the capability of the skimmer in ice as part of the Joint Industry Program to improve cold weather spill countermeasures. Ice basin testing not only allowed performance to be assessed under controlled conditions but also resulted in the identification of improvements to the skimmer to be further examined in field trials planned for May 2009.

The Polar Bear skimmer is a mechanical oil recovery device that was designed on the basis of 2007 tests conducted in the SINTEF ice basin of Ro-Clean Desmi's Helix Skimming adapter and Ice Skimmer as well as subsequent field evaluations of the Helix in the Barents Sea in May 2008.

The Polar Bear is a well-engineered, ruggedly constructed hexagonal skimmer that incorporates one central buoyancy chamber and features six state-of-the-art brush drums and scrapers. It is not self-propelled but must be operated from a crane or a hydraulic arm. The skimmer was determined to be stable in water and could tumble small ice pieces rather than "process" ice under it. It was capable of drawing oil into the brushes. A thick emulsion used during these tests likely contributed to reduced flow of oil to the skimmer in ice. In ice covers exceeding 30%, the skimmer must be repositioned frequently so that oil makes contact with the brushes. In open water, recovery rate exceeded 30 m^3/hr. This reduced to 2-2.5 m^3/h in slush ice. The screw auger pump transferred ice without problems.

Further refinements to the brush drums including their size and position relative to the skimmer body were identified as possible means to improve skimmer performance. Maintaining significant and efficient (low water content) performance in ice infestations using the Polar Bear will likely depend on frequent repositioning of the skimmer, operation at low rpm, and its placement in thicker slicks of oils that readily flow. Good performance in cold weather should be possible.

1 Objectives

Based on testing of the Helix 1000 skimmer adapter in the SINTEF ice basin in March 2007 (Singsaas *et al.*, 2008[A]) and during an experimental field trial in May 2008 (Singsaas *et al.*, 2008[B]), Ro-Clean Desmi suggested developing a new skimmer based on the same main principle. A project plan. including drawings of the skimmer was presented to a Reference Group for recommendation and was approved by the Steering Committee for support as part of the Joint Industry Program. The development was also supported by the Norwegian Research Council's DEMO 2000 program. Although not constructed as an ice skimmer, the Helix skimmer adapter proved to be an interesting concept for further development. The Ro-Clean Desmi Polar Bear skimmer is its modified successor. This report describes the testing of the Polar Bear skimmer in the SINTEF test basin in September 2008.

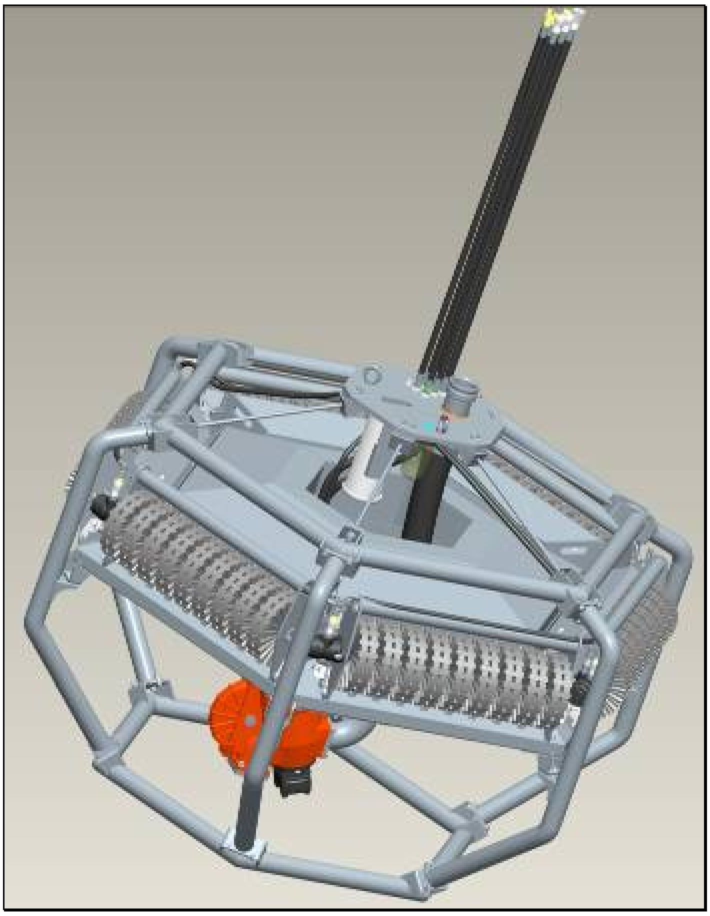

Figure 1.1 Graphic of the Polar Bear skimmer.

The development of the Polar Bear started early in 2008 and in June 2008 the first prototype was tested for floating characteristics including stability in Ålborg harbour (Figure 1.2). The hexagonal-shaped skimmer proved to be stable in the water. The skimmer was equipped with brush drums 30 cm in diameter. Increasing the size somewhat was discussed but the skimmer presented for testing in the ice basin had six brush drums with this diameter. The skimmer prototype was further improved right up to testing in the SINTEF Ice Basin.

Figure 1.2 Testing of floating characteristics in Ålborg harbour.

2 Objectives

The main objective of this project was to document the capability and potential application of the Polar Bear skimmer for recovery of oil in ice. Based on this documentation, SINTEF test personnel together with Ro-Clean Desmi were to identify suggestions for modifications and improvements to be applied to the construction of a final prototype to be tested and verified during the experimental field trial planned for 2009.

3 Experimental setup

The Polar Bear was examined in the SINTEF Sealab test tank September 23rd – 25th 2008. The test tank, testing and measuring parameters and the test scheme are described in the following sections. The technical description of the complete skimming system used, including skimming head, pump, hydraulics, and power pack, is presented in Appendix A.

3.1 The test tank

The test tank at SINTEF Sealab is a 4x11 m basin built within a climate-controlled room with ambient temperatures possible to -20°C. The test setup is shown schematically in Figure 3.1.

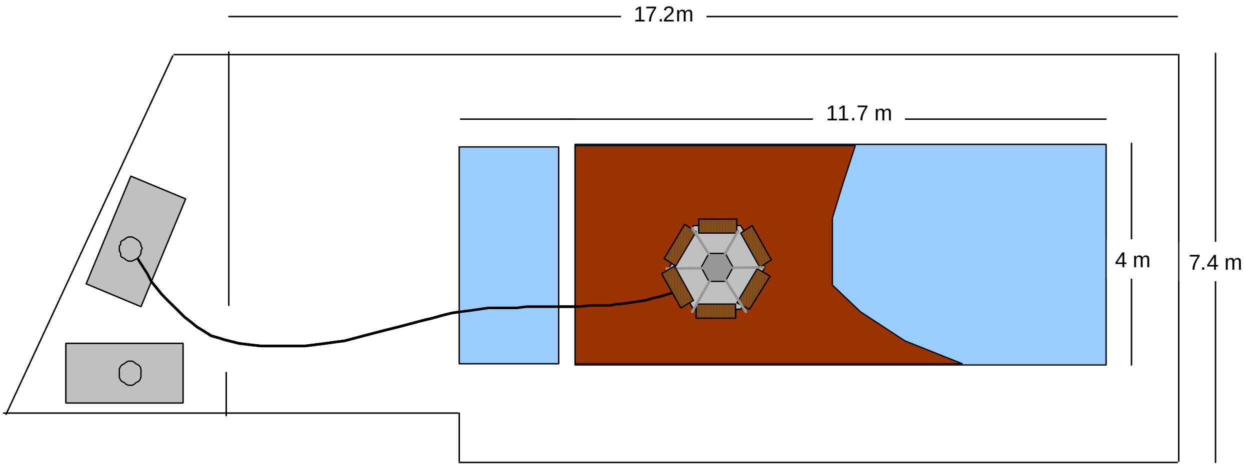

Figure 3.1 Sketch of the ice basin configuration during the testing.

Two 3 m^3 tanks were installed in a heated room next to the ice basin for the storage of emulsion for testing and also for use as recovery tanks so that skimmer performance could be measured.

3.2 Test oil

For phase 1 of the project a 50% emulsion of an IF30 was used for the testing. The oil was purchased from the Esso Slagen refinery. In the first experiments, the emulsion had a viscosity of approximately 6-8.000 mPas. This same oil was used in the field experiments in the Barents Sea in April 2007. The emulsion had proven to be stable in the prior experiments and major variations in physical properties due to gain or loss of water were not expected.

The viscosity of the emulsion had increased since the first experiments very likely due to evaporation of the IF30. In the experiments with the Polar Bear skimmer a 50% emulsion of the oil had a viscosity of approximately 15.000 mPas. Neither the viscosity nor the water content varied significantly during the testing.

3.3 Ice conditions

The testing was performed in two different ice conditions. The first target ice scenario was approximately 30% with broken ice pieces and floes with a diameter up to approximately 0,5 m. The ice thickness was approximately 35 cm. This is referred to as the 30% broken ice scenario. The other target ice scenario was a mixture of small ice pieces and slush ice with an ice cover of up to 100%. This scenario is referred to as the slush ice scenario.

3.4 Measuring parameters

Changes in the emulsion properties were monitored continuously throughout the testing. Samples of the emulsion were taken prior to all tests and water content and viscosity were measured. The thickness of the emulsion in the test tank was controlled routinely. Temperatures were recorded in the water, air, and in the surface emulsion.

The volume of fluid in the recovery tanks was measured, and the amount of recovered fluid was calculated. When possible, recovered free water was drained off and measured. For some of the tests, the tank level was continuously measured by a Laser Distance Sensor. This enabled calculation of recovery rate throughout the test.

Photo and video were also taken during all tests.

During testing visual observations were made with special emphasis on:

- Flow of emulsion to the skimmer
- Ice processing
- Separation of emulsion, water, and ice
- Icing/freezing of the equipment

4 Results and discussions

All experiments conducted are listed along with the main results in Table 4.1. The test log with all recorded measurements is presented in Appendix B.

Table 4.1 Results from tests with the Polar Bear skimmer

Test no	Ice scenario	Drum speed (rpm)	Oil thickness (cm)	Duration (min: sec)	Total (litres)	Recovery rate (m^3/h)	Free water (vol %)	Recovery rate emulsion (m^3/h)
1	0	30	14.5	2:52	1230	26	15.5	22
2	0	15	5	1:34	834	32	15.5	27
3	0	5	4-5	12:39	604	2.9	57	1,2
4	30 % broken	8	10/3.5	12:43	910	4.3	28	3.1
5	30 % broken	3	10	35:30	766	1.3	N/D	1.3
6	30 % broken	10	8	10:00	433	2.7	N/D	2.7
7	30 % broken	10	12	10:00	1090	6.5	N/D	6.5
8	30 % broken	10	7	10:00	616	3.7	N/D	3.7
9	30 % broken	15	7-8	10:00	876	5.3	23	4.1
10	30 % broken	15	7-8	10:00	936	5.6	37	3.5
11	30 % broken	10	7-8	10:00	554	3.3	N/Q	3.3
12	100 % slush	10	7-8	10:00	361	2.2	N/Q	2.2
13	100 % slush	20	2-7	8:00	333	2.5	69	0.8
14	100 % slush	5	2/4/9/12.5	10:00	401	2.4	31	1.7

N/D – not visually detected
N/Q- visually detected, but not quantified

4.1 Flow of emulsion to the skimmer

Access to the oil is one of the major challenges of recovering oil in ice-covered waters. The following observations were recorded during this testing:

As noted in Section 3, the viscosity of the emulsion used in these experiments was higher than expected so that oil flow to the skimmer was somewhat limited.

The Polar Bear skimmer is built with one buoyancy element incorporated into the skimmer body rather than several pontoons attached to but separate from the skimmer. This design results in no restrictions of the flow of oil towards the brushes.

Flow of emulsion into the skimmer was, in fact, found to be quite good in the experiments without ice. As ice was added, oil flow became limited. The lack of flow was especially pronounced in the slush ice experiments. Other than repositioning the skimmer, the Polar Bear has no active means (e.g., water flow) for enhancing availability of the oil to it.

Figure 4.1 Flow of emulsion towards the skimmer is limited by ice

4.2 Ice processing

In the context of this project, ice processing is defined as the skimmer's ability to deflect ice for easier access to the oil. The following related observations were made:

The Polar Bear skimmer will process pieces of ice to a certain degree as the brushes tumble them around in the water. Small pieces of ice can even be pushed under the skimmer. The formerly tested Helix skimmer adapter was able to push ice under the brushes, and so processed ice to a certain extent. This ability was somewhat limited for the Polar Bear. This is thought to be due to an edge on the inside and below the brushes obstructing further flow of ice pushed under the brushes as well as the skimmer body itself. The modification of this design feature should be considered for the 2009 field experiments.

The brushes can be controlled so that three of the brushes are rotating at a selected operating speed while the other three are stagnant or rotating at a lower speed. This is thought to enable skimming while moving the skimmer within an ice field. The brushes not in contact with the oil could be turned off to limit the collection of water. In the tests, this seemed to be a satisfactory mode of operation. The rigidity of the hoses, however, made manoeuvring towards oil-covered waters difficult.

The shape of the skimmer is not optimal for negotiating areas of high ice coverage, but tends to result in ice and oil being pushed in front of the skimmer when it is dragged through the water.

Figure ***4.2***2 shows the logged tank volume and calculated recovery rate for test 4 with the 30% broken ice scenario. The figure shows that after repositioning the skimmer (between minutes 8 and 9) a relatively high recovery rate can be obtained, but only for a limited time. Maintaining a high recovery rate over time may depend on frequent movement of the skimmer within the ice. It should be noted that the oil used in testing was of high viscosity, and the periods of high recovery rate after moving the skimmer are expected to be somewhat longer for a less viscous emulsion.

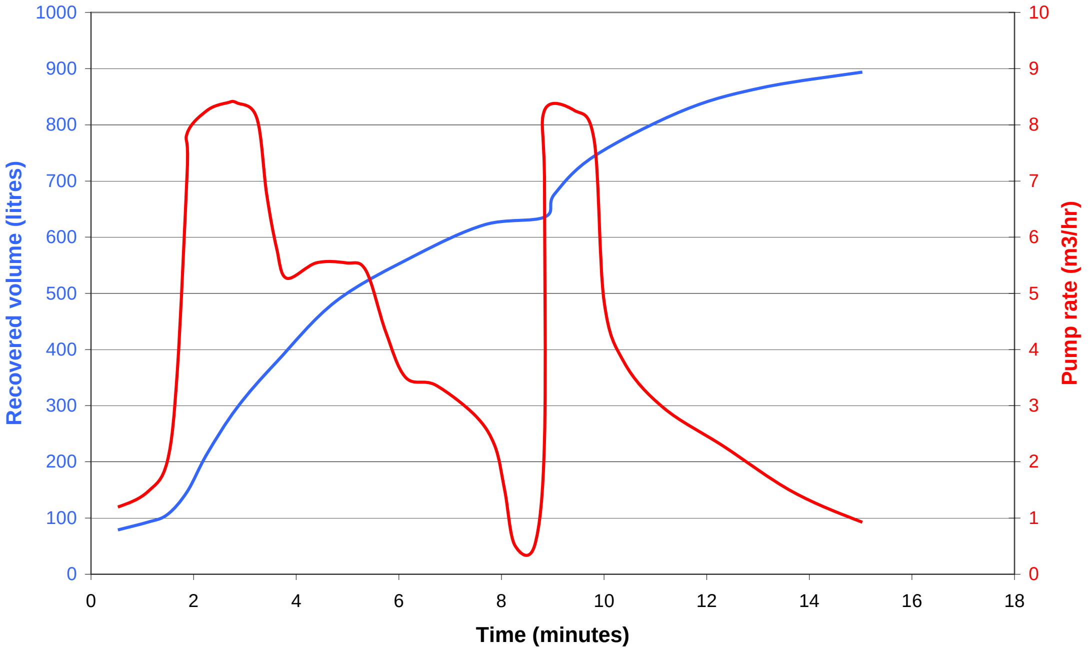

Figure 4.2 Logged tank volume and recovery rate from test 4 -- 30% broken ice scenario.

4.3 Separation of emulsion, water and ice

Based on visual observations, the Polar Bear seemed to separate oil and water satisfactorily in the experiments without ice and in the 30% broken ice scenario. In experiments 1 and 2 the skimmer recovered emulsion at a rate of 26-32 m^3/h with approximately 15% water. These experiments were of short duration and the oil thickness was high throughout the tests. The skimmer was also operated at high drum speeds in these tests (30 rpm and 15 rpm, respectively). In experiment 3 with no ice in the test tank, the skimmer was working most of the time on thin oil. In this test, the average pump rate was 1,2 m^3/h with as much as 57% recovered free water.

In tests 4, 9 and 10 with the 30% broken ice scenario, the skimmer recovery rate was 4,3 to 5,6 m^3/h, of which 23-37% was free water. This is because the skimmer was working in the ice, and the access to oil was limited, with the result that there was more skimming on thin oil and even no oil. The increase in free water was probably due to the lack of oil rather than influence of the ice

In slush ice, the Polar Bear recovered a lot of ice. The pump seemed to transfer the recovered ice without problems. In experiments 12 (10 rpm) and 14 (5 rpm) the amount of recovered water was comparable with the 30% broken ice experiments. In experiment 13 the drum speed was high (20 rpm) with a resulting high volume of recovered free water

Because the emulsion used in testing was viscous, water and ice were more difficult to separate. More specifically, this was due to slush ice and pockets of water being trapped within the emulsion. Somewhat less recovered free water and ice should be expected for an emulsion of lower viscosity.

4.4 Icing / freezing of equipment

After test day 1 and prior to the tests performed with ice, the skimmer was stored overnight at -10°C. This did not influence the start-up of the equipment the following day. The Polar Bear was operated with no mechanical downtime nor related technical problems. The rugged construction of the skimmer should allow it to function without damage in ice-covered waters.

5 References

Singsaas, I., Leirvik, F., Johansen, B., 2008[A]: Testing of Ro-Clean Desmi Ice skimmer and Helix skimmer in SINTEF ice basin. “Oil in ice” JIP, task 3.1: Testing of existing concepts.

Singsaas, I., Leirvik, F., Johansen, B., Resby, J, Solsberg, L., 2008[B]: Testing and verification of oil skimmers during the field experiments in the Barents Sea, May 2008. “Oil in ice” JIP, task 3.1: Testing of existing concepts.

Appendix A Technical description of the skimmer system

A graphic of the Polar Bear skimmer is shown below (Figure A.1) followed by the technical specifications of the skimmer, pumps, and hydraulic power supply. All data are as supplied by Desmi.

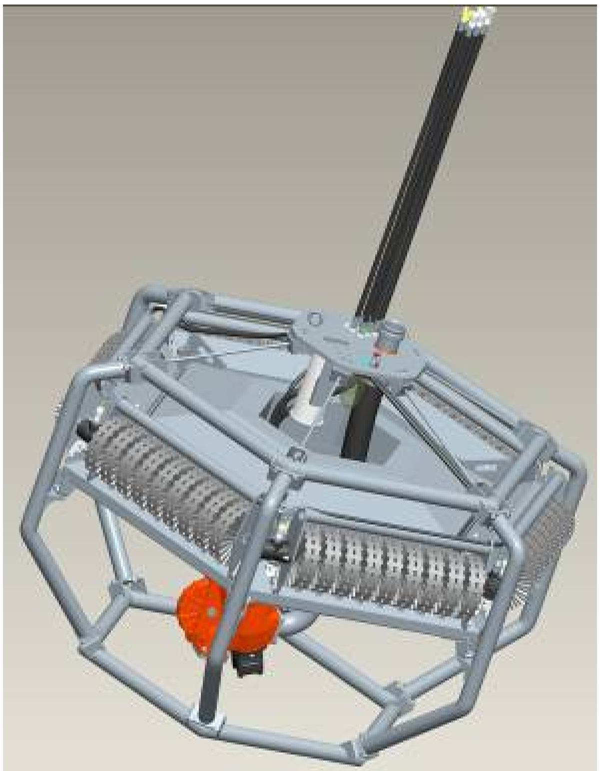

Figure A.1 Graphic of the Polar bear skimmer

POLAR BEAR SKIMMER DIMENSIONS

Length:	2.25 m
Width:	2.50 m
Height:	1.85 m

POLAR BEAR SKIMMER WEIGHT, DRAFT, AND BUOYANCY

Weight	750 kg approx
Draft:	1.0 m
Buoyancy from internal floats	1.05 m^3

BRUSH MODULES

Number of brush modules	6
Number of Brush wheels	9 per module
Outer diameter of brush drums	290 mm
Width of each brush module	900 mm
Bristle length	100 mm
Bristle material	PA 6
Bristle hub material	POM
Scraper/sealing device	Stainless steel/nitrile rubber

INTEGRATED OFF-LOADING PUMP

Designation	DOP-DUAL 200
Type	Archimedes screw pump
Pump casing	Seawater resistant aluminum
Pump suction	Free open-end suction
Replaceable sealing discs	10 Polyethylene HD
Sealing ring	Polyethylene HD
Wear plates:	Stainless steel (replaceable)
Plate wheel	High tensile steel
Screw shaft	High tensile steel
Debris size through pump	1½” (Ø 38 mm)
Screw	Ni-seawater-resistant
Cutting knife :	On pump inlet
Screw shaft roller bearings	2 pcs. (oil pressure lubricated)
Capacity :	60 m3/h
Discharge working pressure	13 bar max.
Pump viscosity range	Up to 1 million cSt.
Pump weight	60 kg
Dimensions	L x W x H : 48 x 29 x 55 cm

HYDRAULIC SYSTEM

Brush-Module

Hydraulic motor:	OMP 200 (200 cc) 6 pcs.
Hydraulic flow *):	0-10 l/min
Hydraulic pressure:	210 bar (max)
Hydraulic quick couplings**):	1/2" TEMA male/female (Return/Supply)
Hydraulic motor speed	0-50 rpm

Off-loading pump

Hydraulic motor:	OMTS160 (160 cc)
Hydraulic flow *):	0-130 l/min
Hydraulic pressure:	210 bar (max)
Hydraulic quick couplings**):	3/4" TEMA male/female (Return/Supply) 3/8” TEMA male (Drain)
Hydraulic motor speed	0-800 rpm

Diesel hydraulic power supply

Length	2000 mm
Width	1000 mm
Height	1250 mm
Weight	900 kg (1100 kg full diesel tank)
Hydraulic flow range	0 - 160 l/min
Max. cont. pressure	210 bar
Power	47,6 kW at 2600 rpm (DIN 6271) 50 kW (DIN 70020)

Appendix B Test log Polar Bear skimmer

Test No. 1

Date	September 23, 2008
Time	1147 hrs
Oil thickness	14.5 cm
Test duration	2 minutes 52 seconds
Brush speed	30 rpm
Ice cover	No ice added
Brush depth	5 - 6 cm
Performance	Total liquid collected = 1229 L = 429 L/min = 25.7 m^3/hr.

Pump operated at slow speed results in some oil overflowing skimmer sump.
There is good oil flow into skimmer.
Power pack speed increased to 1500 rpm to provide more power so that pump can be operated to transfer emulsion more effectively from skimmer.
Hose contains liquid (approx 150-160 L) so that this must be taken into account and equilibrium condition achieved when calculating amount of liquid collected by skimmer during a test.

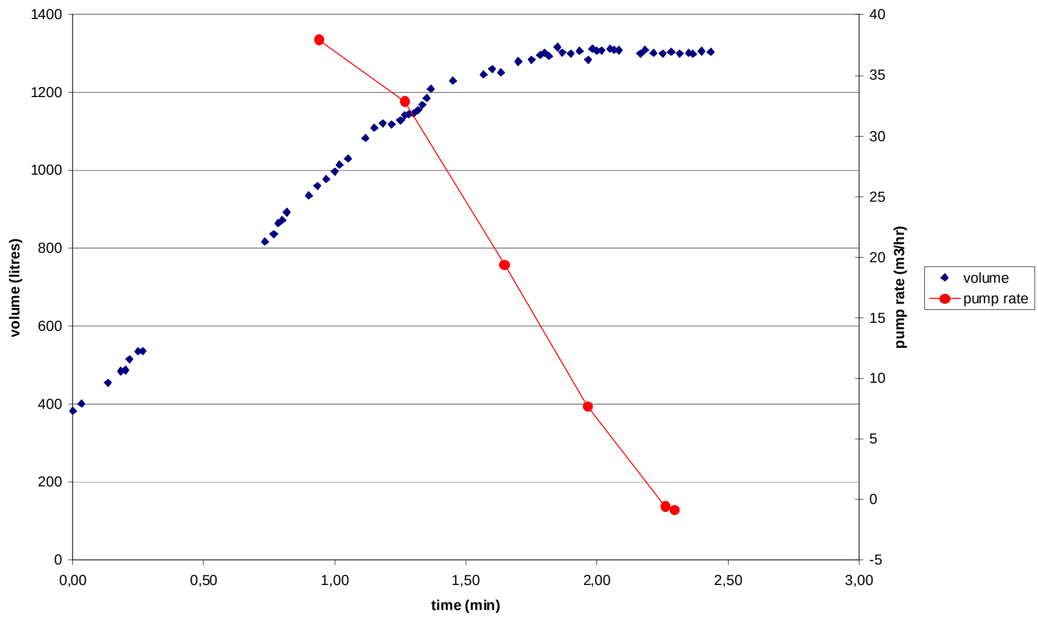

Figure B.1 Logged recovered volume, and calculated recovery rate for test 1

Test No. 2

Date	September 23, 2008
Time	1206 hrs
Test duration	1 minute 34 seconds
Oil thickness	5 cm
Brush speed	15 rpm
Ice cover	No ice added
Brush depth	5 - 6 cm also >100 cm
Performance	Total liquid collected 834 L = 532 L/min = 31.9 m^3/h 2062 L is measured as a combined total of free water from Tests 1 and 2.

Skimmer observed at times to be sitting too low in water (when sump is full) resulting in immersion of skimmer beyond depth of bristles.
There is otherwise good flow of oil into skimmer.
Pumping is conducted intermittently.

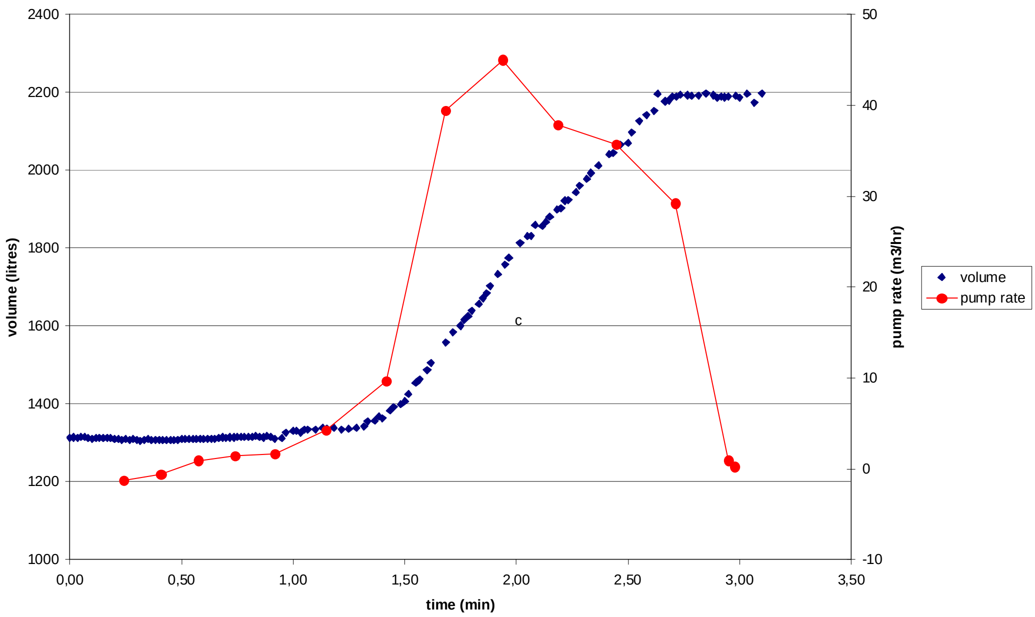

Figure B.2 Logged recovered volume, and calculated recovery rate for test 2

Test No. 3

Date	September 23, 2008	
Time	1233 hrs	
Test duration	12 minutes 39 seconds	
Brush speed	5 rpm	
Brush depth	5 cm.	
Oil thickness	4-5 cm	
Oil temp	0.4°C	
Water temp	0.4°C	
Ice cover	No ice added	
Performance	Total liquid recovered	604 L = 48 L/min = 2.9 m^3/h
	Emulsion	261 L = 21 L/min = 1.2m^3/h

Skimmer is repositioned (lifted and then placed back into tank) to contact and draw oil into it.
Usually one bank of brushes is seen to be operating in the oil.
Skimming is intermittent
Pumping is now achieved at steady rate.
Tank is mostly cleared of oil.

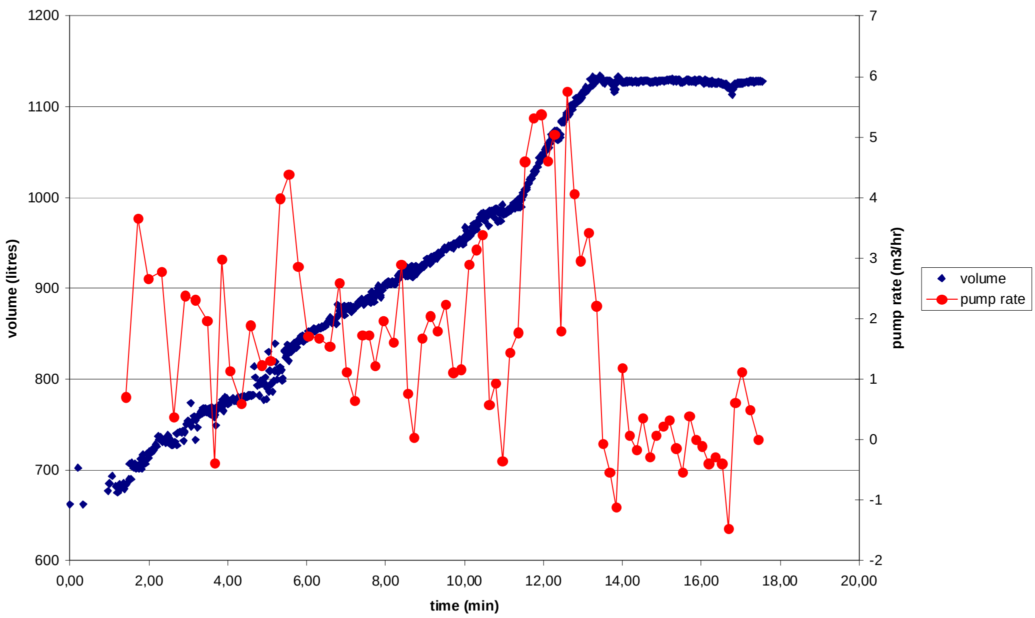

Figure B.3 Logged recovered volume, and calculated recovery rate for test 3

Test No. 4

Date	September 23, 2008
Time	1534 hrs
Test duration	12 minutes 43 seconds
Brush speed	8 rpm
Brush depth	5 cm
Oil thickness	10 cm (varies down to 3.5 cm in some places)
Oil temp	-0.7°C
Water temp	-0.5°C
Air temp	-7.0°C
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm
Performance	Total liquid recovered 910 L = 72 L/min = 4.3 m^3/h
	Emulsion 56 L = 52 L/min = 3.1 m^3/h
	Free water 254 L (28%)

It appears that when brushes contact oil, the oil is drawn into skimmer, usually just to a portion of any one brush pack.
Ice impedes operation of skimmer when it moves into the skimmer with oil.
Clear areas are quickly created when oil is removed.
The skimmer is lifted out of the water for repositioning during this run for at least 1 minute.
Machine continues to run smoothly – both brush packs and the pump.

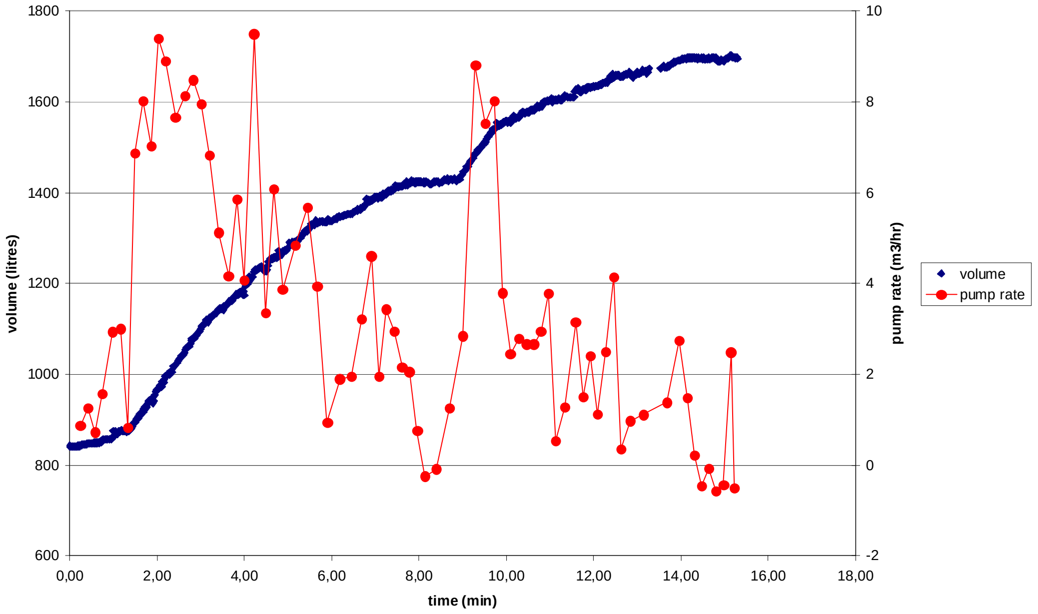

Figure B.4 Logged recovered volume, and calculated recovery rate for test 4

Test No. 5

Date	September 23, 2008
Time	1612 hrs
Test duration	35 minutes 30 seconds
Brush Speed	3 rpm
Brush depth	5 - 6 cm
Oil thickness	10 cm (varies down to 3.5 cm in some places)
Oil temp	-0.4^{o}C
Water temp	-0.5^{o}C
Air temp	-6.9^{o}C
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm

Performance	Total liquid recovered	766 L = 22 L/min = 1.3 m^3/h
	Emulsion	56 L = 52 L/min = 3.1 m^3/h
	Free water	254 L (28%)

Brush packs are raised slightly during operation of skimmer to see if this adjustment draws oil into skimmer more effectively.
Skimmer is again taken out of water and repositioned during this test.
It is possible to position skimmer so that one brush pack seems to be the means of recovering the oil (not all brush packs contact oil after test start-up).
Oil was raked and pushed to skimmer during this test, particularly during the latter half.
Ice was also moved away from the skimmer.
Ice pieces tended to ride up against the brush packs preventing them from recovering oil if the skimmer was left in place.
Continued excellent operation of the pump and brush packs (no interruptions).
I brush pack is positioned toward end of tank in thick oil to remove the slick.

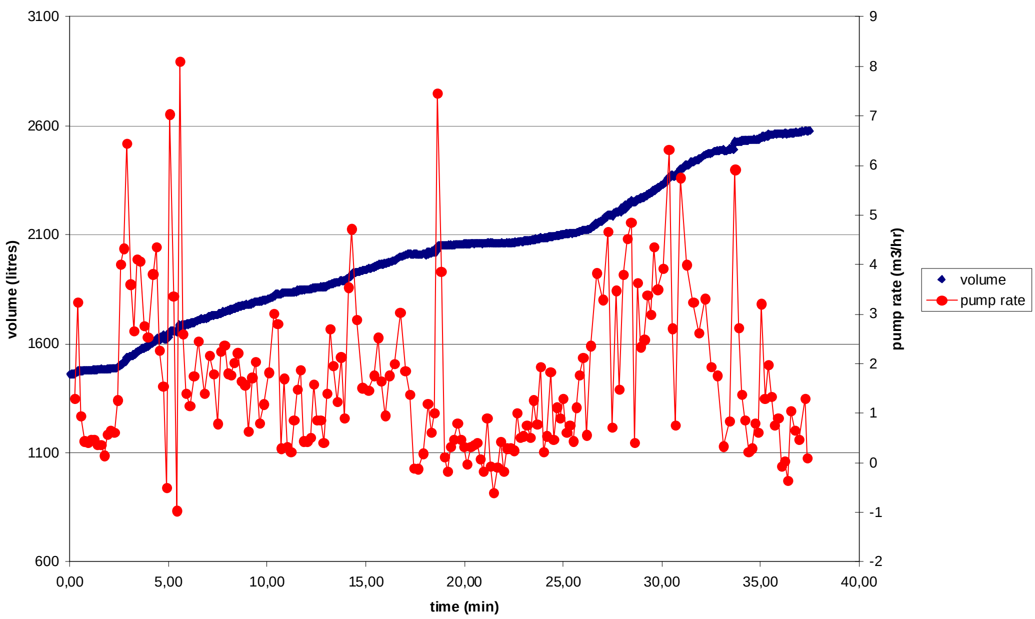

Figure B.5 Logged recovered volume, and calculated recovery rate for test 5

Test No. 6

Date	September 24, 2008
Time	1020 hrs
Test duration	10 minutes
Brush Speed	10 rpm
Brush depth	5 cm
Oil thickness	8 cm (varies)
Oil temp	0.9-1.8°C
Water temp	-0.8°C
Air temp	-3.3°C
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm
Performance	Total liquid recovered 443 L = 44 L/min = 2.7 m^3/h
	Emulsion
	Free water
Oil added	1130 L emulsion

Float height is adjusted prior to these tests in 30 minutes.
Oil initially flows well into skimmer, usually one brush pack that is not in contact with the ice.
Ice then impedes flow of slick into the brush packs.
Skimmer is lifted and repositioned.
Partial brush packs contribute to skimming when these are not blocked by ice pieces.

Test No. 7

Date	September 24, 2008
Time	1058 hrs
Test duration	10 minutes
Brush Speed	10 rpm
Brush depth	5 cm
Oil thickness	12 cm (varies)
Oil temp	0.9-1.8°C
Water temp	-0.8°C
Air temp	-7°C
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm
Performance	Total liquid recovered 1085 L = 109 L/min = 6.5 m^3/h
	Emulsion
	Free water
Oil added	additional 160 L emulsion to compensate for oil in hose

Skimmer initially recovers oil quickly and sump fills with liquid.
There is good flow of oil into skimmer.
Skimmer is moved when it is still in water.
There is initial quick movement of oil into brushes when skimmer is moved.
Clear patches of water quickly appear where oil has been removed.
Skimmer pushes ice when it is moved in the tank.
Skimmer is lifted from tank and then repositioned during this test.
A 2x4 is also used to rotate skimmer and position it so that better contact with oil is made.
Sump fills with liquid a second time during this test.
Where an oil/ice mixture exists, then this does not allow the movement of oil into the skimmer.

Test No. 8

Date	September 24, 2008	
Time	1137 hrs	
Test duration	10 minutes	
Brush Speed	10 rpm	
Brush depth	5 cm	
Oil thickness	7 cm (varies)	
Oil temp	0.9-1.8^{o}C	
Water temp	-0.8^{o}C	
Air temp	-7^{o}C	
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm	
Performance	Total liquid recovered	616 L = 62 L/min = 3.7 m^3/h
	Emulsion	
	Free water	
Oil added		

Initial quick recovery of oil by skimmer.
Skimmer is lifted out of tank and repositioned after 3 minutes of operation.
Brush packs contact some oil when the skimmer is moved within the tank.
Some emulsion is frozen, thickened and does not move well toward skimmer.
Skimmer is lifted out of tank a second time and repositioned during this test.
The skimmer remains out of tank for extended periods during this test when it is being repositioned.

Test No. 9

Date	September 24, 2008	
Time	1255 hrs	
Test duration	10 minutes	
Brush Speed	15 rpm	
Brush depth	5 cm	
Oil thickness	7-8 cm (varies)	
Oil temp	0.9-1.8^{o}C	
Water temp	-0.8^{o}C	
Air temp	-9.7^{o}C	
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm	
Performance	Total liquid recovered	876 L = 88 L/min = 5.3 m^3/h
	Emulsion	678 L = 68 L/min = 4.1 m^3/h
	Free water	198 L (23%)
Oil added	160 L additional emulsion (to compensate for oil in hose)	

Skimmer is lifted out of water twice within 4 minutes of starting test.
Oil moves quickly into brushes initially (less than 1 minute).
Water patches appear where oil has been removed.
The 2x4 s used to rotate the skimmer and position it in the oil.
Skimmer position appears to be critical so that oil is in contact with it and skimming can occur.
Up to 2 partial banks of brushes collect oil at any one time after initial placement of skimmer in tank.
Free water is observed in liquid that is pumped back into the tank after this test.

Test No. 10

Date	September 24, 2008	
Time	1328 hrs	
Test duration	10 minutes	
Brush Speed	15 rpm	
Brush depth	5 cm	
Oil thickness	7-8 cm (varies)	
Oil temp	0.9-1.8°C	
Water temp	-0.8°C	
Air temp	-8.7°C	
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm	
Performance	Total liquid recovered	936 L = 894 L/min = 5.6 m^3/h
	Emulsion	585 L = 58 L/min = 3.5 m^3/h
	Free water	351 L (37%)

When started, skimmer initially clears area adjacent to of it of oil very quickly.
Skimmer is lifted out of tank and repositioned within 2 minutes.
Some oil is seen to move between ice pieces into skimmer.
Ice becomes trapped against and under skimmer at 7-8 minutes into test.

Test No. 11

Date	September 24, 2008	
Time	1401 hrs	
Test duration	10 minutes	
Brush Speed	10 rpm	
Brush depth	5 cm	
Oil thickness	7-8 cm (varies)	
Oil temp	0.9-1.8°C	
Water temp	-0.8°C	
Air temp	-8.7°C	
Ice cover	30% ice blocks approx 80 cm x 60 cm x 40 cm	
Performance	Total liquid recovered	554 L = 55 L/min = 3.3 m^3/h
	Emulsion	585 L = 58 L/min = 3.5 m^3/h
	Free water	351 L (37%)

Skimmer is held in stationary position for this test.
Oil initially moves into brushes.
Ice also moves into the brushes.
Ice then impedes oil flow into the brushes.
Skimmer is rotated with the 2x4 to contact oil and move brushes away from ice.

Tank is then cleared of ice pieces by 1630.

Test No. 12

Date	September 25, 2008
Time	1051 hrs
Test duration	10 minutes
Brush Speed	10 rpm
Brush depth	5 cm
Oil thickness	10-15 cm (with ice, oil likely approx 5 cm)
Oil temp	-1.1°C
Water temp	0.2°C

Air temp	-4°C
Ice cover	100% ice pieces of various sizes (slush to 5-15 cm)
Performance	Total liquid recovered 361 L = 36 L/min = 2.2 m^3/h
Oil added	800 L emulsion

There is quick initial movement of oil into skimmer and then oil flow stops.
Skimmer is then moved into the oil/ice mixture.
Some oil then moves into the brushes and is recovered by them.
Skimmer is raised so that submergence depth of brushes is reduced but there is no obvious improvement in skimmer performance in doing this in the oil/ice mixture.

Test No. 13

Date	September 25, 2008	
Time	1137 hrs	
Test duration	8 minutes	
Brush Speed	20 rpm	
Brush depth	5 cm	
Oil thickness	2-7 cm (varies)	
Oil temp	0.9-1.8°C	
Water temp	0.2°C	
Air temp	-4°C	
Ice cover	100% ice pieces varying in size (slush to 5-15 cm); small amount of ice added	
Performance	Total liquid recovered	333 L = 42 L/min = 2.5 m^3/h
	Emulsion	104 L = 13/L/min = 0.8 m^3/h
	Free water	229 (69%)
Oil added	0 L	

Initial oil pickup very quick and of short duration and then no oil recovery occurs.
There is some oil recovery when the skimmer is advanced into the oil/ice mixture.
Ice does not appear to be moved or otherwise "processed" by the skimmer.
The skimmer is lifted and repositioned.
Hose becomes blocked with ice at its discharge point.

Test No. 14

Date	September 25, 2008	
Time	1137 hrs	
Test duration	10 minutes	
Brush Speed	5 rpm	
Brush depth	5 cm	
Oil thickness	2, 4, 9, 12.5 cm (varies)	
Oil temp	0.9-1.8°C	
Water temp	0.2°C	
Air temp	-7.4°C	
Ice cover	100% ice pieces of various sizes (slush to 5-15 cm)	
Performance	Total liquid recovered	401 L = 40 L/min = 2.4 m^3/h
	Emulsion	276 L = 28/L/min = 1.7 m^3/h
	Free water	125 (31%)
Oil added	0 L	

Significant initial movement of oil into the skimmer is observed.
Ice then impedes performance of skimmer.
Skimmer is repositioned and the similar initial movement of oil into the brushes occurs.

The skimmer is then moved within the ice, at first when the hose fills and moves the skimmer.
The skimmer is then raised and repositioned.
There is little change in skimming: quick limited ingress of oil and then no recovery.
The emulsion appears to be relatively thick; it flows but less readily than in day 1 of tests.