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TITLE

MECHANICAL OIL RECOVERY IN ICE-INFESTED WATERS (MORICE)

PHASE 4

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CLIENT(S)

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ABSTRACT

This report describes the work conducted in Phase 4 of the program "Mechanical Oil Recovery in Ice-Infested Waters" (MORICE). The objective of the program is to develop technologies for more effective recovery of oil spills in ice. The specific objectives in Phase 4 were to:

- Design and build a harbour-sized oil recovery prototype based on the two concepts from Phase 3
- Design and build support vessel or work platform
- Test the entire prototype in ice and oil

Most of the construction took place at the Alaska Clean Seas base in Prudhoe Bay. Testing in ice was carried out in the Alaskan Beaufort Sea.

The main conclusion that resulted from the ice testing is that the prototype comprising the Lifting Grated Belt (LGB) ice deflector and Brush/Drums recovery unit installed on the catamaran work platform can effectively process broken ice with level ice thickness up to at least 20 cm (8 inches). However, due to mechanical problems (especially with the hydraulics), the prototype was not considered ready for oil in ice testing.

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SUMMARY

This report describes the work and results of Phase 4 of the program "Mechanical Oil Recovery in Ice-infested Waters" (MORICE). MORICE was initiated in 1995 and was aimed at developing technologies for more effectively recovering oil spills in cold climate waters where ice is also present in the recovery area.

The specific objectives in Phase 4 were to:

- Further develop the two concepts from Phase 3 to a prototype level
- Build a harbour-sized prototype
- Design and build support vessel or work platform
- Test the prototype in ice and oil

Funding limitations made it necessary to reduce activities prior to the final design of the prototype and by not purchasing auxiliary equipment like pumps, air heater, outboard motors, and electric generator. Instead plans were made to utilize nearly all of the auxiliary equipment from the Alaska Clean Seas (ACS) inventory.

All the modifications to the LGB recommended in Phase 3 were carried out, and in early July, a 40-foot container with equipment and components was shipped from Norway to Prudhoe Bay, Alaska, where it arrived in late August.

The construction of work platform and building together the prototype was mainly done at the Alaska Clean Seas base in Prudhoe Bay. In late September, the work platform was float tested with most of the heavy equipment on board, whereafter it was taken back to the workshop again to complete the remaining construction work.

By late October, the prototype was assembled again and tested in Alaskan Beaufort Sea ice for two days, without oil. Most of the members of the Steering Committee were able to observe the prototype in the ice.

The main conclusion that resulted from the ice testing is that the prototype comprising the Lifting Grated Belt and Brush/Drums installed on the catamaran work platform can effectively process broken ice with level ice thickness up to at least 8 inches (20 cm). Single ice pieces with ice thickness up to 15 inches (37 cm) were also processed. Due to mechanical problems, the Brush/Drum recovery unit could not be operated; hence the prototype was not ready for oil in ice testing. Furthermore, the costs incurred were over budget for the project. The decision was made that no further activities should be carried out in this phase. The remaining activities should be defined as part of Phase 5.

Recommendations for next phase

To sum up, the overall recommendations for the next phase are in agreement with the conclusions from the Steering Committee meeting:

- Phase 4 has identified the need for continued development of the prototype. The next phase of the program should continue with further development to ensure reliable operation of all system components. This goes especially for the hydraulic system, pumps for water flushing and transfer of recovered product.
- Extensive systems and ice handling testing should be carried out prior to introducing oil to the entire prototype.
- The project should be approaching skimmer manufacturers to make alternative recovery units for the prototype.

1. INTRODUCTION

1.1 Background

The program for Mechanical Oil Recovery in Ice-infested Waters (MORICE) was initiated in 1995 to develop technologies for the more effective recovery of oil spills in ice-infested waters. Several northern countries face the potential of an oil spill in waters where ice is present, either permanently or during parts of the year.

MORICE is a multinational effort involving Norwegian, Canadian, United States and German researchers. While research activities in this field have generally not been co-ordinated on an international level in the past, a collective international effort is considered essential to achieve a significant improvement in the capability of dealing with oil spills in ice.

Phase 1 of the MORICE Program (Johannessen, B.O. et al, 1996) involved an extensive literature review to identify available information from previous efforts to develop oil-in-ice recovery technologies. Information collected also relates to oil behaviour, ice conditions, historical oil spills in cold areas, and operational experience gained during the recovery of oil in these conditions. Following this review, a series of brainstorming sessions and technical discussions was held to evaluate past work and generate new ideas for potential solutions to the problem. A number of concepts were proposed. The MORICE Technical Committee considered ten of these ideas in detail.

MORICE brainstorming sessions and technical discussions have focused on the following ice conditions:

- Broken ice
- Up to 70% ice concentration on a large scale; locally up to 100%
- 0 - 10 m ice floe diameter
- Small brash and slush ice between ice floes
- Mild dynamic conditions (current, wind)
- Oil within a wide viscosity range

Phase 2 of the program (Johannessen, B.O. et al, 1998) involved qualitative laboratory testing of six of the ten concepts recommended from Phase 1. These concepts included the Lifting Grated Belt, the Submerging Grated Belt, the Brush/Drum, the Grated Plough, and the Auger Drum. The Air Conveyor was also evaluated as a transfer unit for collected materials. This phase started in February 1997 and was completed in late February 1998.

Phase 3 focused on continued development of two concept components that were selected from Phase 2, the Lifting Grated Belt and the Brush/Drum system. Detailed quantitative testing was conducted on these concepts on a larger scale. For example, the LGB tested was 1.5 m wide, 4.5 m long and weighed 450 kg. The purpose of these tests was to evaluate oil recovery and ice processing performance more comprehensively, as well as to provide more details on operating parameters in order to be able to design prototypes in the following Phase 4. Testing took place at the large-scale ship basin facility, Hamburgische Schiffbau-Versuchsanstalt (HSVA), in Hamburg, Germany. This phase also initiated conceptualisation of the vessels and operating platforms for Phase 4 prototypes.

1.2 Objectives

The overall objective of MORICE is to develop technologies for the recovery of oil spills in ice-infested waters.

In Phase 4 the specific objectives were to:

- Further develop the two concepts from Phase 3 to a prototype level
- Build a harbour-sized prototype
- Design and build support vessel or work platform
- Test the prototype in ice and oil

1.3 MORICE Phase 4 Activities

Scheduling of the project was critical in the sense that the testing had to be carried out during freeze-up, which in Prudhoe Bay normally takes place in October.

In late April 1999, the decision was made to formally start Phase 4. By then, the overall design of the work platform had been finished in Norway, and it was decided to undertake most of the construction work at the Alaska Clean Seas (ACS) base in Prudhoe Bay.

Funding limitations made it necessary to reduce the budget to a minimum. This was done by reducing activities prior to the final design of the prototype and by not purchasing auxiliary equipment like pumps, air heater, outboard motors, and electric generator. Instead plans were made to utilize nearly all of the auxiliary equipment from the ACS inventory.

In early July, a 40-foot container with equipment and components was shipped from Norway to Prudhoe Bay, Alaska, where it arrived in late August. The modifications to the LGB recommended in Phase 3 were carried out prior to shipping it to Alaska. The project leader went to Prudhoe Bay to take part in the preparations at the ACS facilities. Some of the detailed design work took place during the construction of the prototypes in Prudhoe Bay.

In late September, the work platform was float tested with most of the heavy equipment on board. After this float test, it was immediately taken back to the workshop again to complete the remaining construction work.

By late October, the prototype was assembled again and tested in Alaskan Beaufort Sea ice for two days, without oil. Most of the members of the Steering Committee were able to observe the prototype in the ice. After the ice testing, a Steering Committee meeting was held in Prudhoe Bay. Based on the costs incurred and the results from the ice testing, the Steering Committee decided to stop the project at this point, and to move the remaining activities to the next phase of the program (Phase 5).

2. PHASE 4 WORK DESCRIPTION

Due to a major reduction in the budget, the plans as outlined in the original proposal had to be reconsidered. Time was short since the shipment of equipment from Norway to Alaska took nearly two months, and the funding of the project was more time-consuming than expected. Instead of doing an extensive portion of the preparations prior to shipment from SINTEF, most of the preparations were carried out at ACS in Prudhoe Bay.

In summary, Phase 4 has focused on the following areas:

Lifting Grated Belt
The Lifting Grated Belt unit tested in Phase 3 was used in the prototype design. However, certain refinements and modifications recommended after the Phase 3 work were carried out to the unit to ensure its functionality for incorporation into the prototype. Some of these changes also relate to improvements to the flushing system, the oil recovery unit, and other mechanical components.

Brush/Drum oil recovery unit
As with the LGB, several aspects of the Brush/Drum System have been refined or modified based on the experience gained during the Phase 3 tests. Specifically, the combination of a large and a small Brush/Drum used during the quantitative tests were included. Sidewalls were also installed to prevent oil leakage.

Operating Platform
A simple catamaran vessel was designed and constructed in Phase 4. The complete unit had the ice processing and oil recovery components installed and was planned to be tested with oil and ice in a land-locked pit in Prudhoe Bay during freeze-up 1999. All equipment, including ice processing and oil recovery components, are modular units that are interchangeable to make it possible to use the same work platform for different recovery concepts.

Auxiliary Equipment
Nearly all of the auxiliary equipment needed for the prototype units was borrowed from the ACS inventory. This equipment included such items as a hydraulic power unit, water pumps, air heater, transfer pump for recovered product, and storage devices. A few items, however, like screw augers for the troughs, were purpose-built for the MORICE program.

2.1 Design of prototype units

Designing the prototype units included designing a vessel to be used as a work platform for the ice deflection and oil recovery components. It also included engineering the lifting/support system for the prototypes on the work platform as well as assembling all of the components into one or more complete prototypes.

Work platform
At an early stage of the Phase 4 planning, Alaska Clean Seas offered to modify an existing catamaran (the SWOMP) for the project. Upon closer examination together with the ACS technical personnel at Prudhoe Bay, however, it was realized that a new and simple work platform designed and built from scratch would be a better and less expensive solution.

To move the Lifting Grated Belt somewhat away from the bow and thus facilitate a better trim of the platform, an ice feeder was designed to ensure that ice and oil would enter the recovery unit.

Lifting Grated Belt (LGB)
The size of the unit was one of the first issues that were evaluated. Since the unit used in Phase 3 worked well and was considered large enough for evaluation under field conditions, it was decided to use the same unit with some modifications to the prototype.

The main design changes of the LGB were associated with widening the unit. During the Phase 3 tests, ice pieces conveyed by the belt with a centre of gravity outside the belt would fall off. It was decided that there should be some means to prevent the loss of this ice. At the same time, oil should be flushed off these ice pieces, like all ice processed. Next, the flushed-off oil should be guided to the recovery area inside the belt for pickup. Designing a combined flushing tray and ice support on either side of the LGB solved these two problems. The tray covering the whole length of the belt was fabricated from steel plates welded together and to the frame of the belt, see Figure 2.1.

Figure 2.1 Lifting Grated Belt

Flushing system
The design of the flushing system for washing oil off the ice had to be reconsidered after the Hamburg tests. In a SINTEF cold laboratory in Trondheim where samples of ice pieces with oil were prepared, several types of nozzles were tested at different settings to find what would be the best choice. The following parameters were altered:

- different nozzle types and sizes
- water temperature from approximately 6-7°C to around 80°C
- water pressure from 2-3 bars up to 70 bars

A spraybar with a maximum of three nozzles and a pressure gauge was used. This spraybar was connected either to a high-pressure washer with hot or cold water, or to a gear pump connected to the tap water.

During these tests it was realized that hot water might not be the key factor for washing off oil from ice. Since hot water will melt ice, it could easily dig grooves into the ice, and deflect the water flush in different directions. The result is that the washing effect is more or less lost. With water temperature not far from the freezing point, however, the melting of ice is at a minimum, and the deflection of the flushing water does not change unless the orientation of the surface to be washed, the interface between oil and ice, changes.

After these tests a type of nozzle that employs low-pressure water and relatively high flow rate was chosen. This requires a pump for pumping seawater to the nozzles.

Brush/Drum recovery unit
During previous work in the program Brush/Drums were used in various configurations and of different size. For Phase 4, a small Brush/Drum recovery unit comprising two small drums was designed, based entirely on the recommendations arising from Phase 3. These included:

- Use two contra-rotating Brush/Drums
- Install troughs with screw augers to convey recovered and scraped off product to the outlet at the middle of the trough
- Install walls to prevent oil from escaping to the sides
- Design a floating unit that will relate to the water surface instead of the LGB. This was to assure that the fairly small tolerances for the draft of the drums would not be exceeded as the draft of the LGB changes with different loads on the work platform (ice load, weight of recovered product stored on deck).

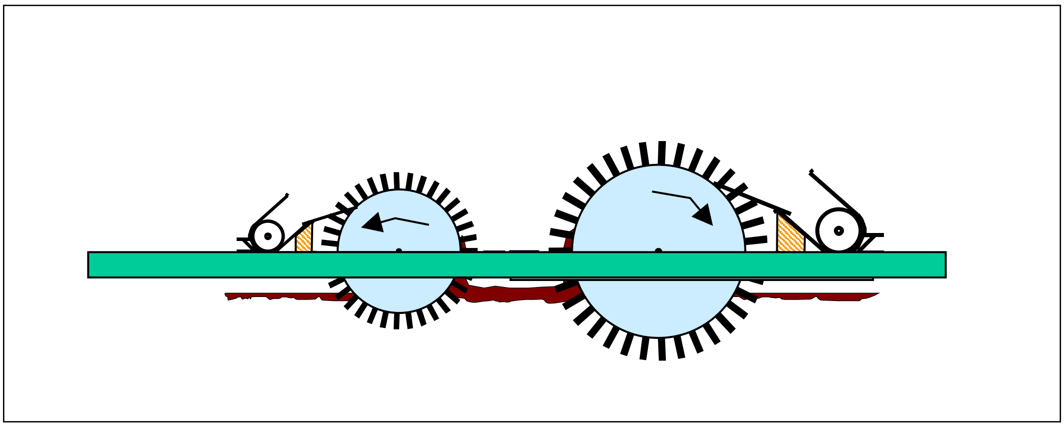

Figure 2.2 Brush/Drum concept used in Phase 4.

What is referred to as the large Brush/Drum system in Phase 3 was intended to operate as a recovery unit without any deflection of larger ice pieces from the recovery path. The final configuration of this concept worked very well during the Hamburg tests, and the recommendations were to prepare a large prototype Brush/Drum system based on the unit used in the previous phase. The design work essentially was limited to modifications of the drums and other components used in Phase 3, and their assembly as a complete prototype unit. Budget cuts forced this recovery concept to have second priority, and although the drums, bristles and other components were shipped to Alaska for evaluation, this large system was not prepared for use on board the work platform.

2.2 Modifications of Ice/Oil Processing Components

The components tested in Hamburg were refined and modified as recommended, before being assembled to comprise the prototype units.

Lifting Grated Belt

The modifications of the LGB comprised:

- Reinforcement of the main frame to resist increased ice loads in the field. This included diagonal braces at the lower horizontal portion of the frame
- Protection of sprockets to avoid ice being jammed between chain and sprocket
- Rearrangement and protection of hydraulic motor and hoses from ice loads
- Reinforcement of rake tines
- Widening rake base plates
- Installing chain adjustment

All of these modifications were carried out at the engineering workshop in Norway that constructed the Lifting Grated Belt for Phase 3. The widening of the unit with a combined flushing tray and support for ice was done at the same time. This increased the weight of the LGB to approximately 800 kg.

Brush/Drum recovery unit

The modifications of the Brush/Drum unit were so extensive that it is probably more correct to call it a new design, although the basic concept remains the same. This new design, described in the previous section, is a scaled-down version of the large Brush/Drum system with one large and one small drum.

Flushing system

The flushing system was redesigned as described in the previous section, and completely new spraybars with nozzles were manufactured in Prudhoe Bay.

2.3 Auxiliary equipment – design, purchase/construction

This activity was planned to go hand-in-hand with the design of the prototype units. As previously mentioned, most of the required auxiliary equipment had been identified in the ACS inventory. Auxiliary equipment included:

- Hydraulic power pack
- High-pressure hot water washer
- Air heater for work platform
- Electric generator
- Transfer method (screw pump, screw auger in troughs)
- Storage of recovered product (small, onboard open-top storage tank)

Hydraulic controls had to be ordered especially for operating several functions of the prototype. A total of seven functions were to be controlled:

- motor to power the ice feeder, and rams for its vertical control
- motor for driving the LGB
- motors for two recovery drums
- motors for two augers in the collection troughs of the drums

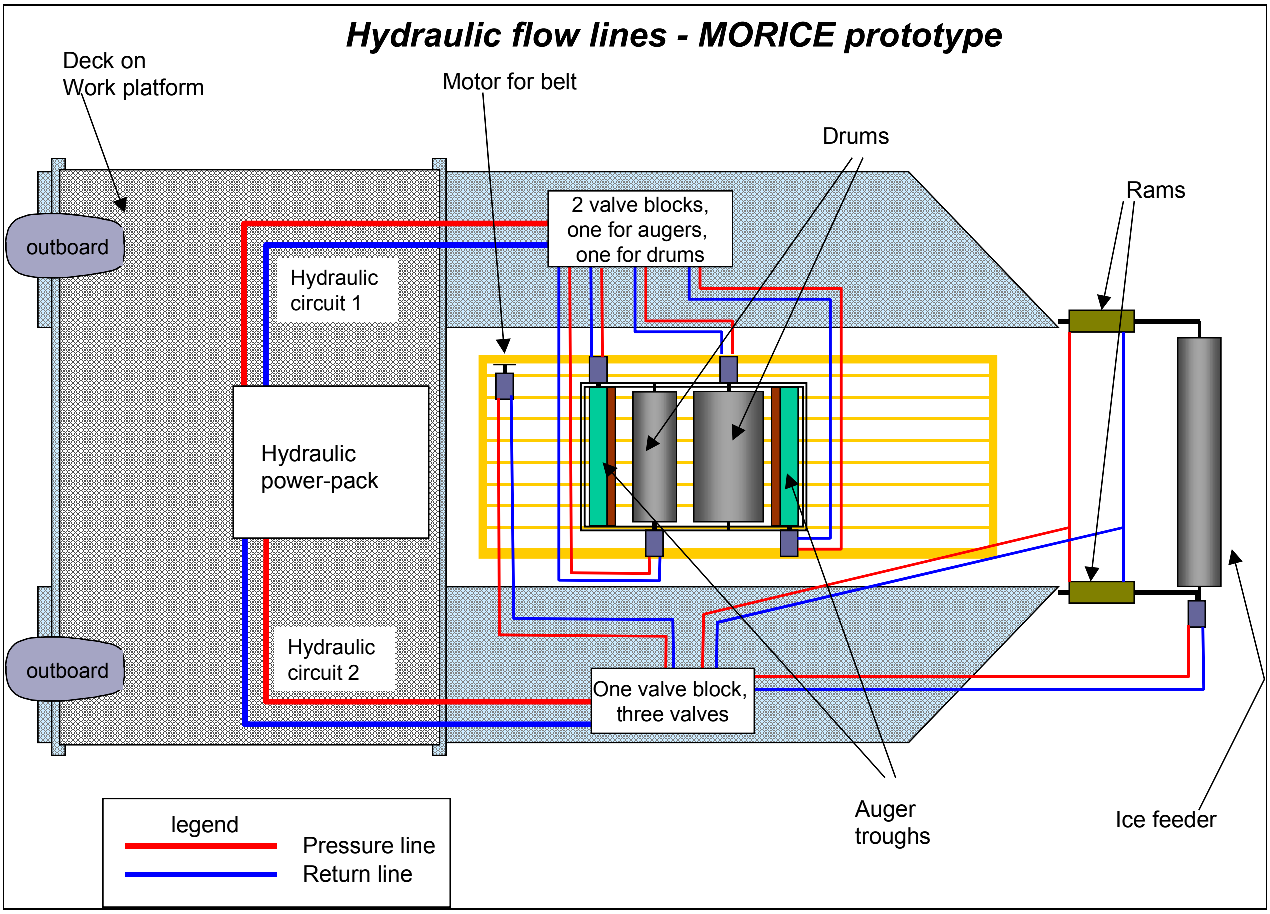

Figure 2.3 Schematics of the hydraulic flowlines.

2.4 Construction of prototype units

This activity included:

- Construction of a sheltered work platform for oil recovery/ice processing units
- Installation of two outboard motors with the controls located at the bow
- Construction of lifting/support system for the Lifting Grated Belt with a Brush/Drum recovery unit installed under the belt
- Assembly of all components into a complete oil recovery prototype

The pontoons for the work platform were built by a US boatbuilder that has specialized in building catamarans. Unfortunately the pontoons were not fabricated according to specifications, and the pontoons had to be modified upon arrival at Prudhoe Bay. The rest of the construction, like beams connecting the hulls, deck and lightweight superstructure made of aluminum channels of various types and sizes covered with tarp, were prepared at the Alaska Clean Seas workshop in Prudhoe Bay.

The lifting/support system for the LGB and recovery unit was also constructed and assembled at ACS. This was time-consuming, but at the same time it offered a high degree of flexibility in the sense that design details of the support structure could be worked out during the construction. A considerable amount of effort was put into the lifting/support system since this is essential for the whole prototype, both regarding strength and functionality.

The recovery unit consisting of two small Brush/Drums with combs and scrapers, and troughs with augers etc. was also put together at the ACS mechanical workshop. The recovery unit was outfitted with pontoons to make it float on the water surface and not be fixed to the LGB.

The construction took more time and involved more work than expected. Apart form being more expensive, the additional time put a certain stress on the last preparations. Most of the problems that occurred during construction were solved satisfactorily, with one important exception: The hydraulic control system designed for the prototype could not be tuned to work properly, and as a result, the recovery unit could not be operated during the ice testing.

2.5 Prototype unit testing

Float test
After a lot of construction work had taken place in-house at the Alaska Clean Seas base in Prudhoe Bay, the work platform and the Lifting Grated Belt were disassembled and brought down to West Dock for a float test. The auxiliary equipment to be used during testing was also put on board the work platform.

Testing in ice
Late October the prototype was tested for two days in ice in the Alaskan Beaufort Sea. By this time it was difficult for the icebreaking barge to break through and negotiate the ice near the West Dock area to reach suitable ice conditions several kilometers away for evaluation of the prototype. The air temperature was around – 15^{o}C, and the ice thickness where the prototype was deployed was typically 7 to 8 inches (18 to 20 cm).

The recovery unit was installed inside the LGB during the ice testing, although the malfunction of the hydraulic controls prevented the operation of the unit.

Full scale testing in oil and ice
Due to problems with the hydraulics as well as the test conditions (i.e., snow and ice cover) in the pit, this part of the test plan could not be carried out.

2.6 ACS facilities in Prudhoe Bay

With their main activities located in Prudhoe Bay, ACS itself has most of the infrastructure and personnel required for carrying out this project. On the other hand, the open water season in Prudhoe Bay is very busy. This year ACS was outfitting and getting operational the icebreaking barge Endeavor with oil combatting equipment. This work was done simultaneously with the construction of the MORICE prototype.

ACS operates out of West Dock with most of their offshore workboats and equipment. With the icebreaking barge Endeavor to be operated in the ice for as long as possible during freeze-up, the prototype could be lifted on board the barge and transported to an area with suitable conditions for the ice testing.

Testing with oil in ice was planned to be carried out in an on-land pit at Prudhoe Bay. Originally a pit that had been used previously for different experiments such as in situ burning of oil was chosen for this. The horizontal dimensions of this pit are 100 by 75 feet (30 by 23 m), and the depth is approximately 6 feet (1.8 m). Later, a larger pit much closer to the ACS base was chosen. The part of the pit to be used was approximately 220 feet by 60 feet (67 by 18 m). This pit was prepared for the oil and ice tests by sealing off part of the pit and filling it from the Seawater Injection Plant (SIP) close by to a depth of approximately 4 feet (1.2 m). More water could be added, but this was considered enough for the work platform to operate in.

Figure 2.4 The ice-breaking barge Endeavor at West Dock, Prudhoe Bay.

Figure 2.5 Test pit with Saltwater Injection Plant in the background.

2.7 Methodology

The models constructed for the previous phase were supposed to be used for the Phase 4 work. This time one or more complete prototypes were to be tested. This called for a whole range of problems of a more practical nature to be sorted out. On the other hand, some of the arrangements would be easier compared to the lab studies: e.g., recovered product from all the troughs could be stored in the same temporary storage container.

The following sections describe the general preparations and methods used for testing of the prototype in Prudhoe Bay. Specific set-ups are described in more detail in Chapter 3.

Float test
After the construction of the work platform had reached a certain point, it was to be put in the water for the first time. The platform had to be disassembled to get it out of the workshop, and the components were transported to the West Dock on trucks and trailers. The platform was put together on the relatively flat deck of a barge, and deployed in the water by using a large crane operated from the ice-breaking barge Endeavor. Nearly all the auxiliary equipment was installed too to assure that vessel stability and operational characteristics were satisfactory. Since the recovery unit would be floating on its own inside the LGB, it was not considered necessary to include it in the open water test. After some manoeuverability tests were conducted, the platform was lifted out of the water, disassembled again and transported back to the ACS mechanical workshop where its construction could be resumed.

Preparation of test oil
For the oil in ice tests it was decided to use weathered North Slope Crude oil. A batch of this oil was weathered until the parent oil had a viscosity of about 1200 cP at 10 s^{-1}, measured at 5^{o}C. The viscosity was checked with a Bohlin Visco 88, which does not have a temperature control. The viscosity of this oil floating between ice floes with an ambient air temperature of say – 15 ^{o}C would be a lot higher. Unless heated by radiation from the sun, the average temperature of the oil would be somewhere between the temperature of the water (approximately –2 ^{o}C) and the air temperature.

Preparation of pit for oil and ice testing
The entire prototype with work platform was to be lifted into and out of the water by a large crane. When not in use, the prototype was to be stored on the flat area next to the pit, kept ice free underneath a parachute warmed by an air heater.

Water was filled with seawater from the SIP and left to freeze. For various reasons, the ice conditions in the pit made it more or less impossible to carry out the testing there. The ice was freezing quickly, and drifting snow accumulated on top of the ice due to the pit being located on flat terrain. As a result, there was far too much ice, slush and snow, and the water was too shallow to float the platform.

Sometimes ice growth can be significantly reduced by relatively simple means such as covering the test area with a tarp or light canvas when not used. In this case, however, a tarp would have created a lot of problems because the test pit is recessed in the terrain.

This has demonstrated very clearly that testing in a pit during freeze-up is very difficult to carry out. At the same time, the filling and emptying/cleaning of the pit is expensive. Future oil in ice testing should be planned differently.

Operation of the tested units

The strategy for the testing in ice was simply to move the prototype to ice conditions that were considered suitable for test purposes. The only practical preparation of the ice conditions in this situation was to have the ice-breaking barge break the ice. During an early trip with the Endeavor into the ice field, it was clear that the broken ice produced by the barge was well suited for this test program.

A simple protocol for the ice testing was prepared. The objective was to try and operate the unit just as it was expected to be operated during recovery of oil in the ice. It was the test team's intention to operate all the systems, including handling of recovered product, including water and small ice pieces. This ice test was supposed to be the last step before testing with oil and ice in the pit.

As in the lab tests in Phase 3 the two I-beams supported the LGB in between the two hulls of the work platform. Access was provided to the LGB from all sides, while the lifting system allowed placement of the LGB with its recovery unit at the correct operating depth.

No specific test set-ups were prepared for the ice testing, but a test protocol was prepared to monitor the various conditions under which the operations were performed.

Assessment of performance

Testing included visual observation and assessment of the operation of the unit. Some handheld video recordings were also obtained for later examination.

Ice deflection performance was assessed only through visual observations of the interaction between the test unit and the ice, and its ability to separate large ice forms from smaller ice pieces. For obvious reasons oil recovery performance was not evaluated.

The operation of the ice feeder constructed for these tests was also observed. It had been added during the construction phase of the work at ACS. Its evaluation was based on qualitative assessments rather than numerical quantification of ice pieces moved by it versus ice not being influenced.

3. DESCRIPTION, RESULTS AND DISCUSSION

The evaluations of the prototype were made after two days in the ice field in the Alaskan Beaufort Sea. The air temperature was between –15°C and –20°C, and with a few knots of wind. The ice was broken effectively with the ice-breaking barge prior to launching the work platform in the ice field.

Due to inappropriate hydraulic flow controls, the recovery unit was not used. Because of temperature problems, the flushing system was also inoperable.

3.1 Work platform with ice feeder

3.1.1 Unit description and set-up

The work platform for the prototype testing was designed as a catamaran with simple aluminum pontoons filled with foam, connected by two steel beams in such a way that the distance between the hulls could be varied. This flexibility facilitates the use of the platform for concepts that have different swath widths. Another reason for this modular design of the work platform was that it would make it possible to transport it in a container or on flatbeds for rail or road travel.

To compensate for the lack of a 3-dimensional design tool, a model of the platform in scale 1:10 was made prior to starting its construction, see Figure 3.1. The two pontoons fit side by side into a standard 40 foot (12 m) container. The length of the vessel is approximately 9 m (30 feet), and the total width between the pontoons is a maximum of 3 m (10 feet). The cross section of each pontoon is rectangular, 110 cm (43 in.) wide and 95 cm (37 in.) deep.

The overall design of the platform was submitted to the boatbuilder who constructed the pontoons, and details like strengthening members, framing, etc. for the whole platform were discussed with him to ensure that they had sufficient strength.

Figure 3.1 Scale model of the work platform and LGB.

The conceptual design of the support and lifting system was done together with the design of the pontoons. At each end of the two I-beams supporting the LGB, a hydraulic cylinder supports the system. These hydraulic cylinders have to be strong enough to support the weight of the whole LGB with recovery unit and ice, in any position from the lowermost operating position to the uppermost transport position by just closing the hydraulic circuit. A stroke length of 1000 mm (3 feet) was chosen for the rams.

Figure 3.2 Lifting system, handpump (left), ram protected inside post (right).

Two manually operated pumps were chosen for the rams, and to save weight and costs as well as excessive pumping, very slim rams were chosen. The posts that would support the rams were to be made out of aluminum channels, and the rams could be positioned inside the posts for protection. At the same time, a frame holding the posts in place could be used to form the skeleton of a superstructure on the platform, see Figure 3.3. This frame would be covered by a tarp to make a nearly closed-in area over the LGB and the recovery unit to protect these vital components from exposure to cold wind. An air heater would ensure that the temperature inside the tarp could be kept at above-freezing temperatures.

Figure 3.3 Platform Superstructure under construction.

Ice feeder
At first the LGB was planned to be located so that the rakes lifting the ice would break the water surface at a straight line running between the bows of the catamaran hulls. With a catamaran platform supporting a fairly heavy LGB unit with a recovery unit inside, it would be better to move the LGB a bit further aft due to the trim of the vessel. At the same time, it was important to ensure that the ice and the oil would enter in between the pontoons of the work platform.

Earlier in the program, different ways of feeding the ice towards and/or through a recovery unit had been discussed. Now it was time to try to apply this concept by making an ice feeder that would push the ice in between the pontoons. The ice feeder is shown in Figure 3.4 below.

Figure 3.4 Ice feeder.

The ice feeder is mounted on a frame with its rotational axis approximately 1 m in front of the bow. A hydraulic motor powers it, and the vertical position is adjusted with two rams, one on each side. Including the tines, the diameter of the ice feeder is approximately 14 in. (35 cm). When rotating, the tines act as claws working from above the ice. Depending on the vertical position of the feeder, the ice could either be pushed gently by the feeder, or be submerged. The rotational speed of the feeder decides the rate at which the ice is processed, and it could be reversed if too much ice enters the LGB.

3.1.2 Results and discussion – work platform, ice feeder

The work platform worked well under the conditions encountered. During the Steering Committee meeting after the ice testing, a roundtable discussion was conducted to identify lessons learned in Phase 4 of the program. The following summary highlights the items discussed. The comments are mainly based on observations made during two days of ice testing of the Lifting Grated Belt and work platform in the ice field outside West Dock, hence the evaluations might change after testing with oil in ice.

The following points are discussed in more detail:

- Floatation and stability of work platform
- Operation in ice
- Handling of vessel
- Deck space
- Ice feeder
- Protection of equipment from heat loss

Floatation and stability of work platform

The conclusion after the float test in open water was that the catamaran vessel provides a stable work platform that is relatively simple to disassemble, transport and put together again. Using auxiliary equipment from the ACS stock adds weight to the unit compared to tailor-made equipment. This is not a surprise, and it was expected that the tests could be conducted with the present equipment.

The float test showed that some of the load on the aft deck either had to be reduced, moved forward, or that additional weight should be loaded on the front deck. One important reason for the extra draft at the stern is that a hydraulic power pack with higher capacity had to be used. This added a one ton payload on the aft deck.

In ice the pontoon system proved stable and capable of supporting skimming operations. The total weight of the platform, including auxiliary equipment, LGB and recovery unit was approximately 7.5 tons. The total buoyancy of the pontoons is about 15 tons. Some equipment, like the diesel powered high-pressure hot washer, the pump for recovered product and the temporary storage for recovered product, was not on board during testing in ice. The maximum weight of this equipment would be about 1.5 tons in total, which is considerable for the size of vessel unless the centre of gravity of this weight is located close to the centre of buoyancy of the platform. In other words, the flotation could be less than satisfactory if all this additional weight were needed on board during recovery.

It should be kept in mind that the auxiliary equipment like the hydraulic power pack and air heater weighs a lot more than would off the shelf equipment specifically chosen for this unit. Using standard equipment on the market today with a similar capacity would eliminate the 1.5 tons mentioned above.

Operation in ice
The platform was moving through broken ice with a typical size of approximately 1 to 5 feet (0.3 m to 1.5 m), and with a level ice thickness of about 6 to 8 inches (15 to 20 cm). With enough open water in between the ice it was not difficult to move through the ice field. However, the shape of the bow on the platform is a compromise, and a comment from the observers on the ice-breaking barge was that reshaping pontoon bows might improve lateral ice deflection. This is believed to be correct, but the effect likely would be rather limited. Compared to reshaping the bow an additional, narrow ice feeder attached at the bow outside each pontoon would be more effective for lateral deflection of ice. However, it would add to the complexity as well as the weight, and this is something to consider for an industrialized version, not for the prototype.

This type of vessel, built of aluminum, has inherent weaknesses related to operation in ice. If the ice testing was to be carried out under more dynamic ice conditions where ice pressure is expected, the vessel has to be a lot stronger than this one. Similar to the LGB operated from this vessel, the platform is what we could call a harbour version or size, indicating that the unit could be built in different sizes, as well as materials, depending on its operational purposes.

Handling of vessel
The work platform was operated by a driver positioned at the bow of the starboard pontoon. He had no steering, only forward/reverse and throttle for the two engines. Compared to lab conditions, the advancing speed of the platform varies a lot. This presents much more difficult operating conditions for the LGB and the recovery units. Typically, the speed tends to be much higher than we have used in the lab. The operating conditions in general vary far more in the field compared to operations in a test tank. This represents a significant challenge for the equipment.

The propulsion with the twin 70 hp outboard motors seemed to be adequate, but the manoeuvrability may have been challenged in the case of more wind. Relevant factors include the size of the superstructure, the lack of steering and the deep transom.

The bottom of the pontoons is level all the way to the transom, and the propellers of the outboard motors do not extend below this level. When reversing, this causes the outboard motors to push a lot of water directly into the transom. The result is a reduced effect of the propellers. The original design of the transom was less deep to improve the flow of water when reversing, but unfortunately this feature was not included during construction. A modification of the transom is not considered necessary for the ice testing and oil-in-ice testing aspects of this program.

The outboard motors were installed without steering to make everything as simple as possible. With the two outboard motors separated by more than 4 meters (13 feet), it was expected that individual forward, reverse and throttle controls for the two outboard motors would suffice for manoeuvring the platform. Due to the total weight of the platform, windage, and possibly other factors, this probably should be reconsidered, and the outboard motors should be equipped with steering to improve the manoeuvrability.

The angle of view from the driver's position is not very good and should be improved. When considering the entire platform with the tarp, the ideal position for the driver would be on top of the superstructure. From this location he would be able to see all around the vessel, and be able to direct the recovery operation in the best direction. For the purpose of testing the prototype, however, such a relocation of the driver's controls is not considered necessary. The driver's view will be improved somewhat by reducing the height of the tarp at the bow. In this way the driver will be able to see the entire surface area at the bow where the ice and oil is fed towards the LGB.

Deck space
The deck behind the tarp is approximately 5 m (16 feet) wide and 4 m (13 feet) long. This appears to be a lot of space, until the large equipment is put in place. The first time in the ice the lack of space was a problem because the 20 foot (6 m) long lifting straps made of heavy material were left on the deck. The second day these straps were disconnected and removed from the platform. Still, too much of the deck space was used for the auxiliary equipment.

When discussing this problem afterwards, it was suggested that a rack be installed on top of the hydraulic power pack where the air heater and the electric generator could be positioned. This would result in enough space to provide room for the placement of a temporary storage container for recovered product.

Ice feeder
In general the ice feeder worked as intended, and the strength and control of the feeder seem to be appropriate. Some of the statements from the discussions afterwards are included below:

- Impressive and functional addition to skimmer
- Effectively managed ice into and away from the skimmer
- Longer tines may further improve effectiveness
- Feeder frame should be smoother or raised to prevent interference with ice movement
- Vessel operator should have control of feeder system

Except for the last statement, these comments are fairly consistent with the evaluation made by the project team. Whether the driver should control the feeder is questionable. Since its function is to feed ice to the LGB, the operator of the LGB should probably also operate the ice feeder. Furthermore, the driver normally has to focus on maneuvring the vessel to keep the work platform in the best position for the recovery of oil. The best solution will become apparent once the operation of the platform is more familiar to the crew.

Prior to installation, it was realized that the relatively small diameter of the feeder would limit the ice thickness it could handle. Still, its size should be sufficient to be able to evaluate its usefulness. The possibility of having ice jammed in between the tubes of the frame supporting the feeder was also foreseen. A thin sheet of plywood mounted underneath the frame will eliminate this problem.

Protecting equipment from heat loss
The lightweight superstructure with the closed-in area formed by the tarp functioned as intended. With the air heater providing 150 kW of heat supply, it should be easy to keep the area inside the tarp at above freezing temperatures. This has been considered the most important reason for covering this area, although a side effect is that the crew will have some shelter too. During intended or unintended stops in the operation, it will be possible to keep equipment from freezing and thus being able to be started again. Maintenance of equipment in situ should, to some extent, be possible too.

Other items
Some other items that should be mentioned:

- Personnel working in areas with no railing need safety harnesses.
- A toolbox should be assembled for the platform.
- The noise level of the heater and power pack and/or generator requires hearing protection. An additional result of the noise is that communication between members of the crew is hampered. Handheld radio sets with earplugs would make communication much easier. With a bit of training, however, the need for communication should be reduced.

3.2 Lifting Grated Belt

3.2.1 Unit description and set-up

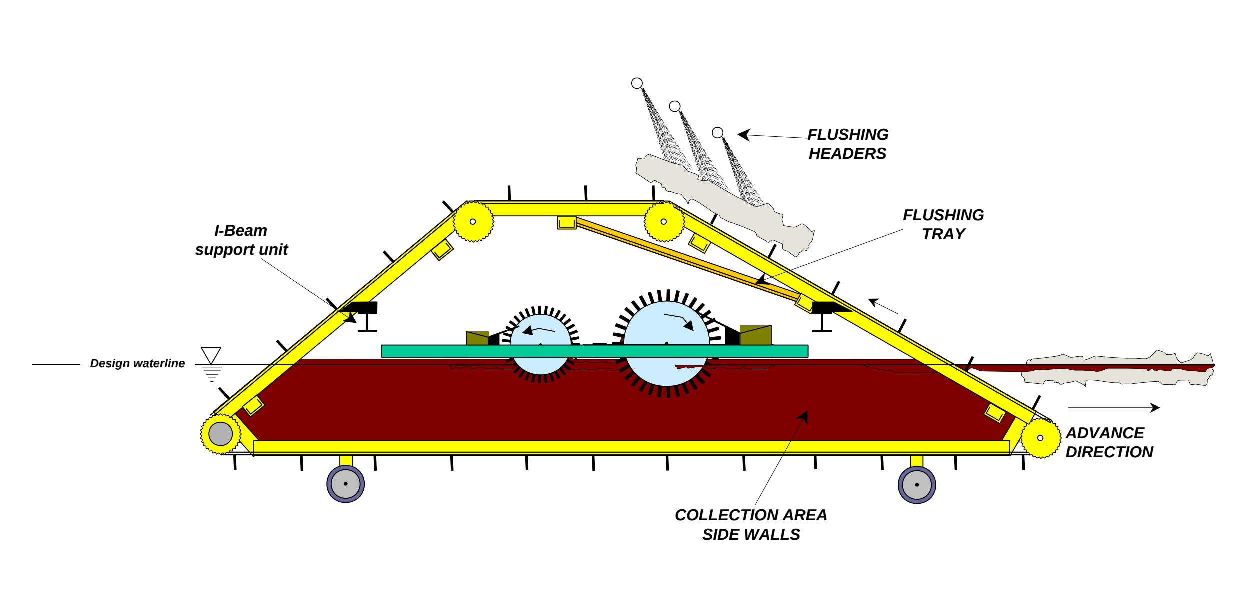

Figure 3.5 Lifting Grated Belt with flushing system and recovery unit.

Figure 3.5 shows the Lifting Grated Belt unit with the flushing booms above the front inclined plane and the oil recovery unit within the frame. The unit advances to the right as ice pieces are lifted and deflected over the grated inclined plane by means of the moving rakes. Oil at the water surface is intended to pass through the grating and into the collection area. Some oil that adheres to the large ice pieces may be removed by the flushing operation on the ascending side of the belt when the ice is lifted out of the water. A flushing tray just below the front section of the moving belt prevents the flushing water from interfering with the oil recovery operation below. A trough at the end of this tray was available to guide the flushing product to the front of the recovery area.

In the collection area, an oil recovery unit can then recover oil from a mixture of oil and small ice. For this phase of the MORICE program, an oil recovery unit for the LGB collection area consisting of two small Brush/Drums was prepared. Oil passes from the front to the rear of the collection area due to the action of the rotating Brush/Drums. Some of the oil adheres to, and is lifted by, each drum. The oil is then scraped off, slides into the trough of each drum and is subsequently transferred by a pump to a temporary storage container on deck.

The modifications recommended for the LGB in the Phase 3 report have been carried out. These modifications are listed in Chapter 2. Additionally the I-beams were put further apart to make the whole set-up more rigid.

The LGB was mounted on the work platform as described in Section 3.1. With the LGB lifted to the upper position, the recovery unit should be able to slide sideways into or out of the LGB for repair or maintenance, on top of the platform deck. When in the lower, operational position, there is a wide opening between the sides of the LGB and the pontoons. A hinged plate at the bow of each pontoon will guide ice and oil onto the grating. In this way, the swath width of the Lifting

Grated Belt is increased from the original 170 cm (67 inches) to 300 cm (118 inches). Sidewalls fastened to the frame of the LGB prevent the ice and oil from escaping to the sides after having entered through the grating.

The flushing system has been modified based on a series of experiments with various types of nozzles, at different water pressures and temperatures. Three spraybars with so-called "power washing nozzles" cover the width of the belt on its ascending side. Individual valves for the three spray bars allow control of the amount of flushing water used. With water pressure of about 3 bars, the maximum flowrate of flushing water is approximately 500 litres/min (130 gpm.).

3.2.2 Results and discussion - Lifting Grated Belt

A comprehensive assessment of the capability of the LGB could not be conducted as the result of the relatively brief testing program in the ice. However, it was possible to determine that the modified Lifting Grated Belt seemed to provide an effective means of deflecting ice to facilitate oil recovery operations under the belt.

The modifications made to the LGB seemed to work well. The most noticeable improvement was the combined support and flushing tray on the sides of the belt. Ice of different size was able to enter the belt guided onto it by the screen. The ice never got stuck or fell over the side of the tray and between the belt and pontoons.

The LGB belt could be operated relatively accurately in the forward direction. In reverse it had no flow control, and this caused too sudden and quick a movement of the belt. The small drums for the recovery unit were equipped with hydraulic motors, but the controls were inadequate. For this reason, the drums were not operated at all. This resulted in build-up of small ice inside the LGB.

The hydraulic controls for the vertical movement of the LGB worked well, except for the first time in the ice when the belt was stuck before it reached the operating draft. It was lifted and lowered once more, but it stuck once more. Although it was not confirmed, most likely a piece of ice was jammed and caused this problem when the platform was lowered into the ice field by the crane. The hydraulic controls for lowering and raising the belt involved manual operation, requiring a certain coordination of two persons cranking levers at the same time. Some discussion ensued on whether or not this system should have been automated. The second day in the ice, however, one person alone did both the lowering and lifting.

Functionality of ice processing

The ice processing operation functioned well and the lifting design is mechanically sound. The unit lifted and deflected ice pieces up to 15 inches (37 cm) in thickness. As in previous laboratory tests, the angle of ascent (30º) provided effective ice processing, and the angle of the aft incline provided a smooth return of ice pieces back into the water behind the unit. Further refinements to this design aspect are not considered to be required.

Rakes

The tines worked well, but a lot of tines were bent, as were some of the rake bases made of flat iron. This problem was mainly caused by inadequate speed controls for the hydraulic motor driving the belt and specifically the very sudden and quick movement of the belt, especially in reverse (see also below). In this instance, the rakes were the weak link. This can be considered to be an appropriate choice since a bent or worn out length of rake is quick and easy to replace. On the other hand, future unit constructions should consider harder rake steel and/or a greater number of reinforced tines (e.g., every 5-10 tines along the length of the rake). As discussed earlier in the

Phase 3 report, the rake tine length should not be reduced since this would make it more difficult for large ice pieces to pass over the edge at the top of the ascending side of the belt.

Hydraulic power

When handling large amounts of ice, the lifting belt tended to stop and the control valve had to be adjusted to convey the ice. This was not seen during earlier operation in the test tank. The control of the belt motor in the forward direction was acceptable, but in reverse there was only full speed and stop. Whether the apparent lack of forces (i.e., pressure and flow) from the hydraulic motor was also caused by inadequate hydraulic controls is not clear. If the motor proves to be too small, it can easily be replaced. Hydraulic controls are also discussed in conjunction with the Brush/Drum unit (see next section).

Flushing

Major modifications were made to the flushing system, but due to problems with the flushing water pump, it was not possible to operate the flushing system during the ice testing.

Three "trash" pumps were taken from the ACS inventory, and one pump was connected to each of the spray-bars. To reduce the length of the flowlines and distribute the weight on the work platform, these pumps were put at the front of the port pontoon. The pumps are direct-driven by diesel engines with a manual start. Furthermore, the pumps cannot be run dry, and they have to be primed with water before operation. Hence the pump engines could not be started until the platform was in the water. At the ambient temperature encountered during the tests, these pumps were not able to establish suction. There are only a couple of explanations why the pumps wouldn't prime:

1. The most obvious reason is that the intake pipes became plugged with ice because of their position at the bow on the skimmer.
2. Since the pick up lines ran straight up and down, the prime water ran straight out of the pipes and the water didn't stay in the pump. This could be corrected simply by putting a one way check valve in the system.

Even for the limited period of time required for prototype testing, these pumps do not seem to be the appropriate choice. The three spray-bars should be supplied with water from one common pump through a manifold with a valve for each of the spraybars.

Clearing flushing tray of slush

A lot of slush accumulated on the flushing tray. This was not surprising since the flushing was not operated. Without being able to operate the flushing system, several questions remain unanswered:

- Is the nozzle type and size appropriate? At a minimum, the small ice would be flushed off the larger ice pieces.
- Will the flushed product pass through the restriction posed by the glider rod supports and into the trough?
- Do the trough and the hoses connected to it have sufficient capacity for the flushing product at the maximum flow rate and with a lot of small ice to be flushed off?

3.3 Brush/Drum recovery unit

The recovery unit prepared in this phase of the MORICE program has been based entirely on the recommendations from Phase 3.

3.3.1 Unit description and set-up

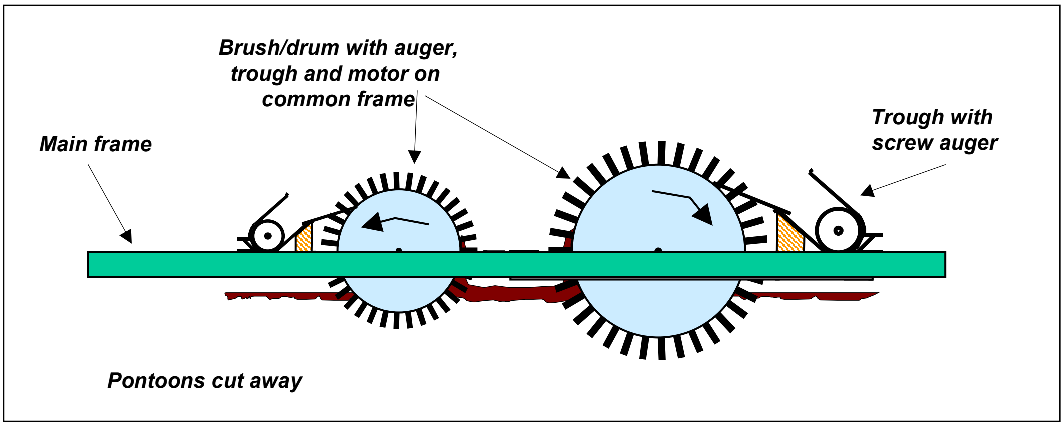

Figure 3.6 The Brush/Drums with one large and one small drum.

A conceptual sketch of the recovery unit prepared for Phase 4 is seen in Figure 3.6. It has a larger drum in the front with a smaller drum placed just behind it. The diameters of the two drums were approximately 45 cm (18 inches), and 32 cm (13 inches), respectively. Hydraulic motors individually powered the drums. Each of the drums has its own scraper and trough to collect recovered product. A screw auger in the trough, powered with a hydraulic motor, conveys the product towards the middle of the trough where a hose for the transfer pump is connected.

The unit is equipped with pontoons for floating under the LGB, see Figure 3.7. A mechanism to adjust the draft of the two drums also had to be in place. Large threaded bolts in each of the four corners of the frame for the drums facilitated this adjustment. In addition to this, there is an individual adjustment of the height for each drum. Several details of the design of the skimming system were worked out during its construction.

All the brushes used were employed earlier in the Phase 3 units. The larger drum in the front has fairly stiff bristles used previously on the large Brush/Drum system (please refer to the Phase 3 report). These bristles are specifically suited for ice deflection. The bristles used on the drum at the rear were used previously on the small drums operated in small ice and oil under the LGB.

The function of the larger drum in the front is both to deflect ice, and to recover oil. The function of the smaller drum is to catch and contain the oil not picked up by the first drum. The smaller drum is normally operated in the opposite direction to the large drum, and the scraper and trough for this drum face the back of the unit. In this way, a pool of oil is formed in the confined area between the two drums. Oil behind the small drum is also drawn into the double drum recovery system.

A significant increase in oil recovery is achieved by briefly reversing the direction of rotation of the smaller drum (clockwise in Figure 3.6) in order to have its descending side make contact with the oil. The rotation is quickly reversed again to scrape the oil into the trough. Rotating the smaller drum for too long in the clockwise direction would result in much of the pooled oil being lost behind the unit. The mechanisms involved in recovering the oil in this configuration are discussed in detail in the Phase 3 report.

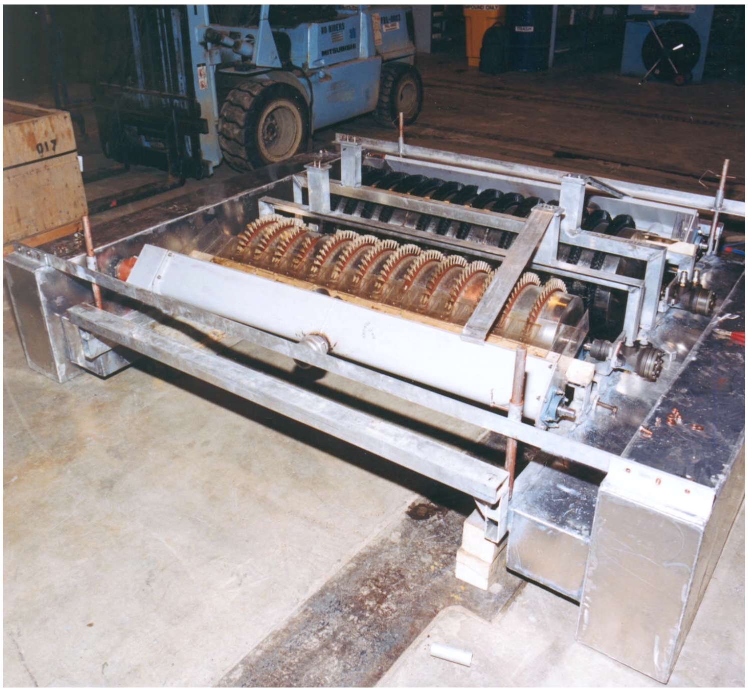

Figure 3.7 Photo of the recovery unit for Phase 4.

With hydraulic operation of the drums, the reversing action of the smaller drum referred to above calls for very good control of the motors. For proper operation, a control system for both manual and automatic operation of the drums was developed.

3.3.2 Results and discussion - Brush/Drum

Due to insufficient control of the hydraulic motors, the recovery unit was not operational during the testing in ice. Therefore there are no results to discuss from operation of the unit in ice. Instead, the set-up of the hydraulic system is outlined and the problems associated with it are discussed.

Hydraulics
The hydraulic system has been organized as two separate circuits connected to the same hydraulic power pack, see Figure 2.3:
- one circuit on the starboard side of the platform with control valves for LGB and ice feeder (up/down and forward/reverse)
- one circuit on the port side with control valves for two Brush/Drums and two screw augers.

All hydraulic motors should have both forward and reverse as well as speed controls. Except for the augers, all the functions (drums, belt) need precise flow control at low rpms. During the ice testing in Phase 4, the hydraulic control system was not satisfactory:

- The larger hydraulic power pack is intended for use with a Desmi DOP 250 pump (max. 160 l/min (42 gpm) and max. 210 bar (3000 psi) continuously), and should have sufficient capacity for its application in the MORICE program. Specifications for the two separate outlets at the power pack were not available, and the controls had some peculiarities that should be corrected.
- Flow controls for all of the hydraulically driven components were insufficient, especially for the drums.
- A valve distributing flow between drums and screw augers complicated the control of the system.

As a conclusion to this aspect of the MORICE skimming vessel, the entire hydraulic system (power pack, motors, and controls) has to be reviewed, and the necessary modifications carried out to make all components fully functional prior to further testing.

4. CONCLUSIONS AND RECOMMENDATIONS

An oil-in-ice recovery prototype comprising the Lifting Grated Belt and the Brush/Drum concepts has been developed with its own work platform. During two days, the prototype was tested in an ice field in the Alaskan Beaufort Sea, without oil. Due to problems with the hydraulic system for the recovery unit, only the ice-handling capabilities of the work platform and the Lifting Grated Belt could be assessed.

After the two days of testing in the ice, it was concluded that the prototype was not ready for oil in ice testing. Furthermore, the costs incurred were over budget for the project, and hence no further activities were planned for this phase of the program.

The following specific conclusions and recommendations apply to each of the concepts studied, as indicated:

Work platform

- The work platform worked well under the ice conditions encountered with typical size of ice approximately 1 to 5 feet in diameter, and with a level ice thickness of about 6 to 8 inches.
- The ice feeder worked as intended, and effectively managed ice into and away from the LGB.
- It should be kept in mind that the auxiliary equipment weighs a lot more than would off the shelf equipment specifically chosen for this unit. Using standard equipment on the market today with a similar capacity would eliminate approximately 1.5 tons of this weight.
- Too much of the deck space was used for auxiliary equipment. To save space, a rack should be installed on top of the hydraulic power pack where the air heater and the electric generator could be positioned.
- The propulsion with the twin 70 hp outboard motors seemed to be adequate, but the manoeuvrability may have been challenged in the case of more wind. Steering should be added to the outboard motors to improve manoeuvrability.

Lifting Grated Belt

- The modifications made to the LGB worked well. The most noticeable improvement was the combined support and flushing tray on the sides of the belt.
- The unit lifted and deflected ice pieces up to 15 inches (37 cm) in thickness.
- The tines worked well, but a lot of tines were bent, as were some of the rake bases made of flat iron. Future unit constructions should consider harder rake steel and/or a greater number of reinforced tines.
- The hydraulic flowlines were neatly prepared, but the hydraulic controls in general were not designed for the fully functional operation of the hydraulic motors. The entire hydraulic system has to be modified.
- The redesigned flushing system could not be tested in the field due to problems with the water pumps. A single, appropriate pump that can be operated at below-freezing temperatures should be selected.

Brush/Drum recovery unit

- The recovery unit prepared in this phase has been based entirely on the recommendations from Phase 3.
- The oil recovery unit used in the collection area of the LGB was installed, but the recovery unit was not operational during the testing in ice, hence there are no results to discuss from operation of the unit in ice.

Recommendations for next phase
To sum up, the overall recommendations for the next phase are in agreement with the conclusions from the Steering Committee meeting:

- Phase 4 has identified the need for continued development of the prototype. The next phase of the program should continue with further development to ensure reliable operation of all system components. This goes especially for the hydraulic system, pumps for water flushing and transfer of recovered product.
- Extensive systems and ice handling testing should be carried out prior to introducing oil to the entire prototype.
- The project should be approaching skimmer manufacturers to make alternative recovery units for the prototype.

5. REFERENCES

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Appendix A – Log

MORICE Sea Trials

Date:	October 22, 1999
Time:	1900 hrs
Air Temperature:	3^{o}C
Wind:	calm
Ice:	variable thickness to 30 cm (12 in.), up to several feet across (1+ m)
Deployment:	by crane from Arctic Endeavor into broken ice created by barge/tugs
Personnel on board:	Hans Jensen, Fred McAdams, Dennis Parker, Laurie Solsberg
Equipment on board:	Hydraulic power pack, 3 water pumps, electric generator, air heater, lifting straps from crane

Observations:

- Draft 17 in. (43 cm) aft 18 in. (46 cm) forward (port and starboard)
- Drum/belt system could not be lowered to operational level
- Belt was run but could not retrieve ice properly due to insufficient draft
- Ice feeder was lowered and run
- Ice feeder processed ice well, some pieces hit support frame
- Large pieces that did reach belt stopped it
- Ice deflectors appeared to function well
- The exhaust gas from air heater produced sooty smoke that affected personnel
- Machinery was noisy (hearing protection required)
- Water pumps could not be started after being primed
- Water pumps that were primed were drained after this
- Maneuverability and stability were satisfactory
- Operator view was obstructed
- Deck space was very limited
- Starboard propeller was damaged when vessel backed up against ice
- Catamaran hulls pushed some ice ahead of unit
- After one hour, skimmer was lifted back on board the Arctic Endeavor

MORICE Sea Trials

Date:	October 23, 1999
Time:	1315 hrs
Air Temperature:	inside enclosure -11.6°C outside -13.5°C
Wind:	northerly, 10 knots
Ice:	variable thickness to 38 cm (15 in.), up to 5 feet (1 -2 m) across
Deployment:	by crane from Arctic Endeavor into broken ice created by barge/tugs
Personnel on board:	Hans Jensen, Fred McAdams, Tommy Cumming, Dennis Parker, Laurie Solsberg
Equipment on board:	Hydraulic power pack, 3 water pumps, electric generator, different air heater

Observations:

- Draft 17 in. (43 cm) aft 12 in. (30 cm) forward (port and starboard)
- Drum/belt system was lowered to working level before deployment
- Belt was run and picked up large pieces
- Belt speed was difficult to control (full speed in reverse)
- Large ice pieces stopped belt
- Piece of ice was jammed in underside of belt frame
- Reversing belt and/or jammed ice resulted in belt jumping
- Belt chain jumped off sprocket and stopped operation
- Tines bent as well as rake (along its length)
- Water pumps were started after being primed
- Water pump intakes were clogged and could not be run
- Ice feeder was used to move ice to and away from belt
- Stopping feeder allowed belt to process large ice pieces
- Feeder also was able to submerge ice
- Feeder was also seen to rotate in ice without moving it
- Positioning and speed control for feeder were possible
- Hydraulic connections were tightened. Jensen was tethered to make this repair
- Support frame hit some ice
- Air heater was not run
- Machinery was noisy (hearing protection required)
- Maneuverability, stability were satisfactory even in wind
- Operator view was obstructed as before but operator now has radio
- Deck space was limited but improved over 1st deployment
- Propellers were not damaged
- After one hour, skimmer was lifted back on board the Arctic Endeavor

Appendix B – Photos

Scale model of work platform with Lifting Grated Belt (yellow), support structure (red) and work deck(green).

Platform under construction at Alaska Clean Seas base in Prudhoe Bay.

Lifting Grated Belt installed and lifted above seawater line.

Work platform ready for a float test.

Seen from behind, working deck is ready, outboards installed.

Bow with console for outboard controls.

Platform pontoons transported to West Dock for float testing.

Lifting pontoon on board barge for assembly prior to launching.

Work platform and Lifting Grated Belt put together on barge. Auxiliary equipment (hydraulic power pack, air heater, water pumps, electric generator, hot water pressure washer) is also stored on board.

Work platform lifted for deployment.

How will it float?

Platform with Lifting Grated belt and a 2 ton hydraulic power pack on deck. The next pictures are with this load.

Maneuvering the work platform only with gear and trottle, no steering. The superstructure will be covered by a tarp to reduce heat loss.

Work platform with all auxiliary equipment on deck.

Same as above, seen from the side. Some of the load on the deck has to be reduced, or moved forward. Reserve buoyancy is not a problem.

Preparing oil on ice for testing flushing water nozzles.

Various nozzles were tried, and different water temperatures and pressure.

Hot water spray melted a lot of ice before cleaning it.

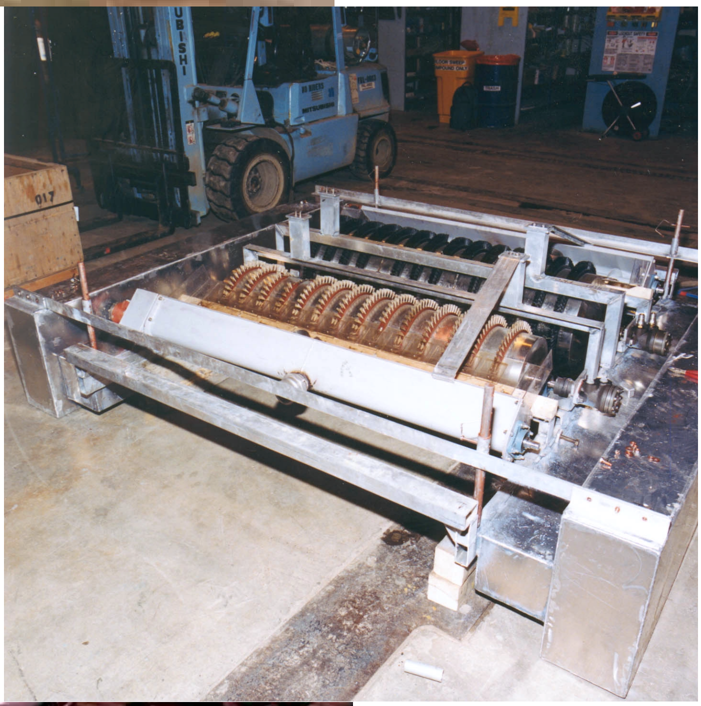
Nozzles with high flowrate, low pressure and low temperature.

Chosen nozzles installed on spraybar.

Phase 4 – Choosing nozzles for water flushing.

Drum and trough with screw auger under construction.

Recovery unit nearly ready.



Lifting recovery unit on board work platform.

Test pit with Saltwater Injection Plant (SIP) in background.

Only closer part of pit to be used.

Trying to remove heavy snow from ice on pit.

Essembling entire prototype for ice testing.

Complete unit lifted on board ice-breaking barge Endeavor.

Getting a lift to more suitable ice conditions.

Tugs pushing ice-breaking barge.

Ready for deployment.

First time in the ice field.

Ice feeder at the bow.

Mowing ice up the
Lifting Grated
Belt.

Various sizes of ice in front of belt.

Small ice under grating, resting on flushing tray.

Small ice on Brush/Drum and in through.

Backing up the outboard.

Rakes bent during ice testing.

Hauling entire unit ashore after ice testing.

Back on land.

Moving prototype to storage for the winter.

Appendix C – From Steering Committee meeting

Many of the issues raised during the Steering Committee meeting in Prudhoe Bay on 23 October 1999 are important to the MORICE program and have been reproduced here.

LESSONS LEARNED, EXPECTATIONS

A roundtable discussion was conducted to identify lessons learned during Phase 4 of the program. The following summary highlights the items discussed. The comments are mainly based on observations during two days of ice testing of the Lifting Grated Belt and work platform in the ice field offshore of West Dock, hence oil in ice recovery may not have been taken into consideration. The statements do not necessarily reflect the opinion of the project team, but have been used as a basis for discussion in this project report.

General comments

- Phase 4 testing has showed improvements and promise for continued development of devices developed under the auspices of the MORICE program.
- Systems developed as a result of this work could clearly fill a void in cold region spill response inventories.
- More development is required to ensure reliable operation of all system components.
- Commercial development will require design input from a marine architect/engineer.

Work platform (catamaran)

- Pontoon system proved stable and capable of supporting skimming operations in ice.
- Reshaping pontoon bows may improve lateral ice deflection
- Propulsion with the twin 70 hp outboard motors was adequate, but the manoeuvrability of the vessel may have been challenged in the case of more wind
- Operator angle of view needs to be improved
- Personnel working in areas with no railing need safety harnesses
- Deck space throughout the vessel was congested with support equipment and supplies
- A tool box needs to be assembled specifically for the platform
- ACS auxiliary equipment served the initial purpose, but a purpose-built power pack could operate all hydraulic, air, electrical and pump needs

Ice feeder device

- Impressive and functional addition to skimmer
- Effectively managed ice into and away from the skimmer
- Longer tines may further improve effectiveness
- Feeder frame should be smoother or raised to prevent interference with ice movement
- Vessel operator should have control of feeder system
- The ice feeder should be safely stowed when the vessel is retrieved and placed on land so that the sharp tines do not cause injuries.

Lifting Grated Belt (LGB)

- LGB handled ice very well
- Flow control in both directions is not adequate and needs to be corrected

- Raising and lowering the LGB was cumbersome, motorized hydraulics should be considered.
- The tine system of the LGB should be improved to prevent bending and ice slippage
- There is a need to investigate and correct stalling of the LGB due to problems with the hydraulics.

Flushing system

- The system was not tested during field trials due to problems with pumping systems.
- The pumping system requires modification.

Brush/Drum recovery system

- Problems were encountered with rotating drums; improvement of the hydraulic system is needed.
- Not tested with oil during field trials
- Offloading and screw auger systems were not tried and therefore their capability remains unknown.

Following this discussion, the Chairman stated that four out of five tasks of the project had been carried out so far, the oil and ice testing had not been done. He briefly indicated that the costs had been higher than budgeted, which means that oil and ice testing would not be possible to do within the existing budget. He therefore asked for everybody to express whether their expectations to this phase of the project had been met. Answers from the participants are summarized below:

Mineral Management Service:

- Regarding moving ice we saw what we came to see
- The ice feeder shows promise
- Had hoped to see more of the components working (more oil processing, Brush/Drums, auger system)

Saga Petroleum/Norsk Hydro:

- Happy with what we have seen
- Think we will be able to have something working under real conditions
- Would have liked to have seen everything working together (ice processing, oil recovery)

Oil Spill Recovery Institute:

- This could be a useable arrangement
- More R&D to be done to make everything work (work out bugs)

Canadian Coast Guard:

- Happy to have seen it out in the ice field under real conditions, it really processes ice
- The ice feeder is a really good idea
- Would have liked to see some actual recovery of oil

The Chairman summed up these statements by concluding that some expectations remain. Before inviting the Steering Committee to discuss how to proceed from here, and how to fund such a continuation, the budgetary situation for the project was reviewed.

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The Steering Committee agreed that Phase 4 testing and modifications should be considered complete. The remaining work of the project should be associated with reporting.

CONTINUATION OF MORICE

The Chairman again asked the attendees to come up with ideas on how to continue the development. A summary of suggestions and views that came up during this discussion is given below:

- CISPRI (Cook Inlet Spill Prevention & Response Inc.) has invited the project to come to Cook Inlet with the MORICE prototype and test it in their ice conditions (December through February) which may be more appropriate than Prudhoe Bay ice with the exception of dynamic ice in Cook Inlet.
- The prototype is not ready for oil in ice testing at the moment. First we should work out the bugs related to the hydraulics and make the complete system work only with ice.
- Carry out oil and ice testing in the pit in Prudhoe Bay during springtime next year.
- The Project Manager also reminded the Steering Committee about the overall plan to finalize the program by doing a field experiment in the Barents Sea with real oil in ice. In case such an experiment should be carried out, the planning of this activity should be started at least a year in advance. After a brief discussion it was concluded that a final test under more controlled conditions would be preferable. The cost/benefit of this approach was also considered to be more favourable.
- Walter Cox, OSRI, would like to see all systems working the sooner the better. From this point of view, he suggested that we accept the invitation from CISPRI and go to Cook Inlet for further trials in real ice conditions.
- Joe Mullin, MMS, offered access to the OHMSETT test tank facility to conduct oil and ice experiments with the entire system in Phase 5. This test facility has sufficient size to make it possible to use the prototype as a self-propelled unit. Freezing conditions at OHMSETT normally occur during January and February. Larger ice pieces for the test will have to be imported to the tank facility.
- Towards the end of the discussion it was suggested that several skimmer manufacturers be asked to make prototypes for oil recovery in the recovery area under the Lifting Grated Belt. The recovery capability of these units could then be investigated through comparative tests under controlled conditions.
- The Project Manager indicated that the EU Large Scale Facility Program at the Hamburg Ship Model Basin (HSVA) has been extended by three more years beginning from January 2000. This might be an opportunity to carry out tests with oil in small ice to compare the recovery capability of different recovery units.

The Chairman summed up the discussion as follows:

- The test activities of Phase 4 have been finished. The OSRI representative would like to continue with further tests in Cook Inlet this winter season, but he accepted the decision made by the majority to stop the evaluation of the prototype vessel at this point.

- Phase 4 has identified the need for continued development of the prototype. In general, all attendees expressed that the next phase of the program should continue with extensive systems and ice handling testing prior to introducing oil to the entire prototype.
- Phase 5 should be modified according to suggestions made during the discussion.
- The idea of approaching skimmer manufacturers to make alternative recovery units for the prototype was accepted.

It was recommended that a Phase 5 proposal should be drafted for review by the Steering Committee prior to initiating a funding campaign. The Project Manager will collaborate with Alaska Clean Seas on the proposal and distribute it for review within three weeks.