ARCTIC RESPONSE TECHNOLOGY
OIL SPILL PREPAREDNESS

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North Slope Spill Response

MECHANICAL RECOVERY IN ICE SUMMARY REPORT

ARCTIC OIL SPILL RESPONSE TECHNOLOGY – JOINT INDUSTRY PROGRAMME

The oil and gas industry has made significant advances in the ability to detect, contain, and cleanup oil spills in arctic environments (Potter et al., 2012). Ongoing research continues to build upon more than fifty years of examining all aspects of oil spill preparedness, oil spill behaviour, and available options for oil spill response in the Arctic marine environment. This research has included hundreds of studies, laboratory and basin experiments, and field trials, conducted in the United States, Canada, and Scandinavia. To build on existing research and improve technologies and methodologies for arctic oil spill response, members from the IPIECA-Oil Spill Working Group, Industry Technical Advisory Committee (ITAC) and the American Petroleum Institute-Emergency Preparedness and Response Programme Group formed a joint committee in 2009. The committee's task was to review the oil and gas industry's prior and future work scope on prevention and response to oil spills in ice in order to identify and prioritise technology advances and research needs. One outcome was the recommendation to establish the Arctic Oil Spill Response Technology Joint Industry Programme (JIP) that would undertake targeted research projects identified to improve industry capabilities and coordination in the area of arctic oil spill response.

The JIP was launched in January 2012 and over the course of the programme is carrying out a series of advanced research projects in six key areas: dispersants, environmental effects, trajectory modelling, remote sensing, mechanical recovery, and in situ burning (ISB).

Recognizing the limitations of mechanical recovery systems available today, the JIP Mechanical Recovery research project was initiated with the following objectives:

- Examine results obtained from previous research projects and identify further improvement opportunities for design of mechanical recovery equipment and response strategies for oil spill recovery in ice;
- Develop a selection process by which novel concepts can be rigorously examined; and
- Select and develop the most promising concepts.

SUMMARY

This report examines the JIP's research undertaken to evaluate the feasibility of existing equipment, and looks at potential future development of equipment, to improve effectiveness of Mechanical Recovery in the Arctic.

It provides an overview of mechanical recovery of oil in ice-covered waters and the results of JIP-contracted feasibility evaluations of methods for mechanical recovery in four areas:

1. New Vessel Design Concepts;
2. Remote Recovery Units;
3. On-board Oil-Water-Ice Separation; and
4. On-board Recovered Oil Combustion Systems.

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CHAPTER 1. MECHANICAL RECOVERY IN ICE: BACKGROUND

Mechanical recovery is a technique (along with use of dispersants and in-situ burning) for responding to an oil spill on water. It is the process of removing oil from the water surface utilising a skimming device or direct suction, and pumping recovered fluids to a storage system. The overall system to support the skimmer usually involves deployment of containment booms in a configuration that directs oil toward the skimming system, thereby maximising the amount of oil coming into contact with the skimmer (i.e., oil encounter rate). The system may also involve onboard treatment of recovered fluids and decanting of water to maximise recovered oil storage capacity. A complete mechanical recovery operation includes disposing or recycling of recovered liquids and oil contaminated materials.

Many decades of experience with mechanical recovery under cold climate conditions around the world have advanced understanding of the recovery process and have led to development of specialised equipment and well-practiced response tactics. Ice-strengthened vessels are used in arctic waters where ice may be present. Several configurations of arctic-capable response vessels, both with built-in and over-the-side recovery equipment are currently in operation (Wilkman et al., 2014). Azimuthal Stern Drive (ASD) ice-capable vessels are valuable for arctic oil spill and emergency response due to their high maneuverability in ice and ability to effectively support both mechanical recovery and vessel-based dispersant application operations. High capacity arctic skimmers were also developed and tested for recovery of oil in ice while operating at low temperatures (Sørstrøm, 2010; SL Ross, 2010; Meyer 2014). Finnish researchers developed and tested several skimming and ice processing devices that are suitable for operating in ice conditions of the Baltic Sea region (Wilkman, 2014). Just as with vehicle designs, some mechanical response systems resemble earlier versions, while incorporating significant engineering and design improvements that draw upon real-life experience during laboratory, meso-scale experiments, and actual field trials under extreme conditions. Advanced arctic skimmer designs include improved oil and ice processing; ability to handle larger volumes of cold viscous oil and oil/ice mixtures with low water uptake; and heating of critical components to prevent freezing. Various viscous oil pumping systems and techniques have also been developed to facilitate efficient transfer of cold and viscous oil-water mixtures and small ice pieces (Potter 2007, Hvidbak 2001, Fleming and Hyde Marine 2003). Skimming technology has significantly matured over several decades and further technological improvements likely will be incremental rather than revolutionary.

1.1 Ice Management

Mechanical recovery is dependent upon the skimmer or suction device making direct contact with oil. In ice conditions, relatively small amounts of ice can interfere with flow of oil to the skimmer and result in substantial reduction of oil coming into contact with the skimmer. Maintaining a successful mechanical recovery operation in ice becomes more dependent on ice management than on specific skimmer capabilities. The presence of ice in sufficient concentrations (generally over 30%) has a dampening effect on waves, and in higher ice concentrations, the ice creates a barrier that slows the spread of oil. This natural containment has the advantage of increasing oil thickness and reducing the overall affected area that mechanical recovery equipment needs to access.

Selection of a mechanical recovery system for ice-covered waters is largely determined by the type and concentration of ice cover.

- At 0-30% ice coverage, conventional open water mechanical recovery techniques can be used. As ice concentration increases, the width (or opening) of a containment boom can be adjusted to maneuver around individual ice floes.
- At 30-70% ice coverage, vessel-towed booms can be replaced with short sections of boom connected to a skimming vessel with “outrigger arms.” These narrower systems are easier to maneuver around ice floes, which can help avoid excessive ice concentrations and possible

damage to equipment. Some skimming systems are specially built to process small ice pieces, as well as slush and grease ice between larger ice floes. To facilitate movement and access to oil in such conditions, these skimmers often have their own propulsion system, or they may be lifted and re-positioned by a crane aboard a vessel.

- At ice coverage greater than 70%, specialised skimmers are operated by ice-strengthened response vessels. At high ice concentrations, a boom cannot be used; however, the ice itself often provides containment, preventing oil from spreading on the surface of the water. In this case, oil may be recovered from concentrated oil “pockets” between ice pieces using skimmers deployed from the side of a vessel.

Special ice management and water flushing strategies were developed to facilitate access of mechanical recovery equipment to oil in high ice concentrations. Even with these strategies, the encounter rates are significantly reduced as compared to an open water recovery operation.

1.2 Limitations

Mechanical recovery, both in open water and in ice, is a slow process. In open water, conventional containment boom and recovery systems cannot be towed at speeds greater than one knot. Faster speeds can cause entrainment and the loss of oil under the boom. New innovative designs in boom systems are capable of successfully containing oil at speeds up to three knots. With ice present, encounter rate can be further reduced by presence of ice pieces and limited ability to deploy containment booms.

Mechanical recovery operations for a large spill event require a considerable amount of equipment and logistical support. Vessels, boom, skimmers, and storage are necessary, along with personnel to operate and support the operation. All this requires fuel, food, housing, mechanical support, and waste management, at a minimum. This support can be provided by on-water facilities; but typically comes from land-based facilities. Lack of facilities in remote arctic communities can hamper an effective response. Limited availability of disposal sites approved for temporary or permanent storage of recovered oily waste and lack of port facilities to accept deep-draft vessels are challenges faced in the Arctic. For a spill event far offshore, travel time to and from shore facilities can further reduce effectiveness of a mechanical response.

CHAPTER 2. JIP MECHANICAL RECOVERY PROJECT

As the initial stage in this project, the JIP Mechanical Recovery Technical Working Group (TWG) conducted a dedicated workshop in collaboration with Alaska Clean Seas (ACS) March 6-8, 2012 in London, UK, to evaluate existing techniques for accessing and recovering oil in ice-covered waters and to identify promising novel recovery concepts. The workshop objective was to allow selected researchers, responders, and manufacturers to devise creative response solutions and proposals for potential future research. To facilitate creative thinking and ensure that all possible solutions were explored, a Counter-Intuitive Problem Solving (CIPS) approach was implemented using professional facilitators to prepare and conduct the workshop. The goals of the workshop were to:

- thoroughly examine results obtained from previous industry-supported projects, as well as other projects relevant to the JIP project scope (e.g. X-Prize project) to identify a number of novel concepts for mechanical recovery, suitable as countermeasure techniques for large offshore oil spills in ice-covered waters (with a focus on improvement of encounter rates); and
- to evaluate existing techniques to access and recover oil from under land fast ice and identify improvement opportunities.

The intent of this effort was to evaluate concepts beyond conventional skimming equipment, consider large scale recovery approaches, and evaluate opportunities from adjacent subject areas such as non-oil materials handling. Four response scenarios were considered:

Scenario 1: Oil mixed with moving new/young ice at freeze-up.

Scenario 2: Oil between thick broken ice floes with concentrations from 5/10th to 9/10th coverage. Surface release scenario - assumes relatively thick slick.

Scenario 3: Oil under moving offshore ice (5/10th to 10/10th coverage). Subsea release (pipeline or blowout) - assumes relatively thin oil slick.

Scenario 4: Oil under stable landfast ice. Subsea release from a pipeline - assumes thick slick and stable ice.

2.1 Workshop Results

Several promising concepts were identified and judged to warrant further feasibility analysis to evaluate their probability of success and better define developmental strategies. Identified concepts were grouped into four key project focus areas:

1. New recovery vessel design concepts.
2. Remote recovery units operating from the “mother ship”.
3. On-board oil-water-ice separation devices.
4. On-board oil incinerators.

These concepts approach improvement of oil recovery efficiency from very different angles and required assessment by specialists with a variety of expertise. After an open competition solicitation and selection process, the following contractors were selected to undertake evaluation of the identified project areas:

1. Aker Arctic - New recovery vessels design concepts.
2. Aker Arctic - Remote recovery units operating from the “mother ship”.
3. Lamor - On-board oil-water-ice separating devices.
4. SL Ross Environmental Research Ltd. - On-board oil incinerators.

The feasibility evaluations were delivered as technical memos that the JIP Technical Working Group (TWG) used in screening ideas and concepts, together with selection of any potential future research and development projects. To ensure transparency of the process, the TWG selected an external contractor, Alaska Clean Seas (ACS), to prepare this summary report consolidating results of the four independent evaluations and highlighting important project findings.

CHAPTER 3. FEASIBILITY EVALUATIONS

3.1 New Vessel Design Concepts

The aim of this high-level feasibility study was to evaluate proposed mechanical recovery methods for spilled oil in ice-covered waters and identify the most promising new vessel design concepts.

In total, twelve different recovery system concepts were evaluated, ranging from new vessel designs to vessel-mounted recovery systems, representing various approaches to separation of oil and ice.

3.1.1 Evaluation and Findings

As mentioned previously, mechanical recovery in ice requires a platform (e.g. a vessel) to transport the skimming system, and a storage system to hold recovered oil. As the percentage of ice coverage increases, the need for ice-capable or ice-strengthened vessels becomes critical.

The vessel may serve as a platform for transporting skimming systems and operating them from the side of the vessel, or it may be designed to provide some assistance with ice management and/or provide a barrier to separate ice from floating oil.

There are three basic concepts for managing ice, as it relates to oil spill response: 1) lifting contaminated ice pieces from the water for cleaning and separation; 2) submerging contaminated ice pieces to separate oil and ice; and 3) cleaning contaminated ice pieces at the water surface.

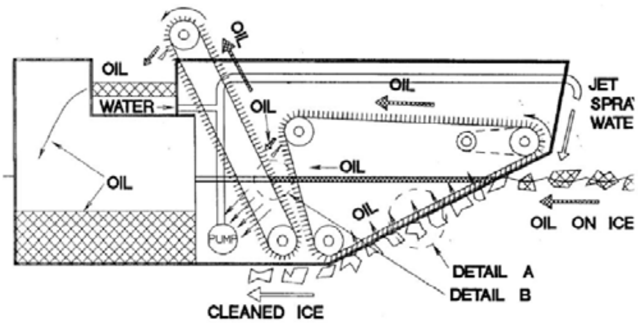
The basic lifting technique utilises a clamshell grab and crane to lift oil-contaminated ice onto the deck of the response vessel. There, ice could be melted on board the vessel or transported to shore for processing. Previous research has shown this method is not efficient, with recovered material containing approximately 7% oil by weight. A suction dredger system has similar drawbacks.

Utilising a semi-submersible heavy lift vessel or a floating dock to collect large amounts of oiled ice on deck for further cleaning and separation was also evaluated; but this concept was ruled out as a feasible method due to practical operational concerns in ice-covered water, as well as concerns for personnel safety.

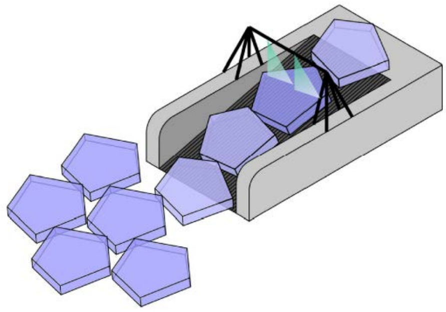
A conveyor belt or inclined plane grid system could carry both ice and oil up on board a vessel to be cleaned and separated. In various concepts, the cleaning of ice pieces is performed by spraying with steam or hot water and recovering oil with traditional skimmers located beneath the conveyer belt or grid. Examples of these types of systems are Arctic Protector, AARC Trimaran, and the MORICE prototype unit.

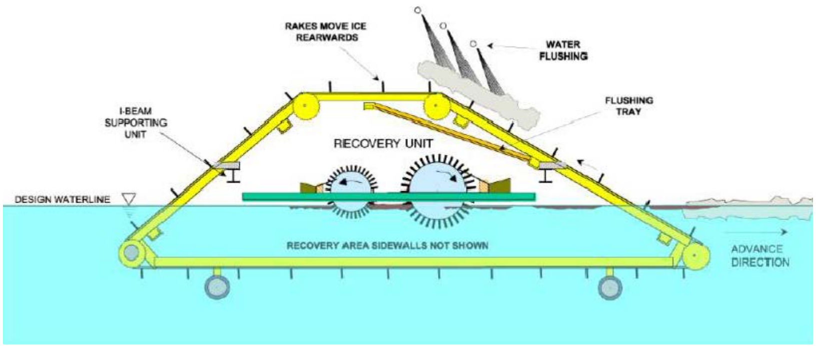
In contrast to raising oiled ice pieces out of the water, a number of systems submerge contaminated ice pieces to release oil from ice by gravity separation and then allow the oil to float up to a skimming system by natural buoyancy. Oil separated from ice in this manner rises through a grid system to a separate skimmer located on the water surface. Figure 1. illustrates some of these concepts.

Sketch of a passive inclined grid



Ice Cleaner flow scheme
(Wartsila Marine, 1988)





Schematic drawing of the lifting grated belt with flushing system

Figure 1. Ice management concepts for oil spill recovery.

There are two major drawbacks to these systems:

- some of the separated oil may return to the environment instead of encountering the skimmer; and
- since it takes time for oil to separate and rise through the water and grid system, the recovery process can be slowed.

Examples of these types of systems are the OilWhale, Ice Cleaner (Lori), and the Lamor Oil Ice Separator. The Lamor system also incorporates a shaker table to enhance separation of oil and ice.

In more severe ice conditions, the amount of ice that must be processed becomes a problem in maintaining an acceptable level of efficiency. Structural challenges are present in handling very heavy, thick, and large ice floes. Ice may also quickly clog the systems.

Cleaning contaminated ice pieces at the water surface includes utilisation of brush skimmers deployed from a recovery vessel. For example, the Lamor Arctic Separator (LAS) and the Finnish Environment Institute stern brush system utilise skimming systems with large brushes deployed off the stern of a response vessel (Figure 2.). The brushes rotate on top of the ice and between the ice pieces. The LAS is also equipped with an oil separating grate that pushes broken ice pieces underwater away from the brushes.

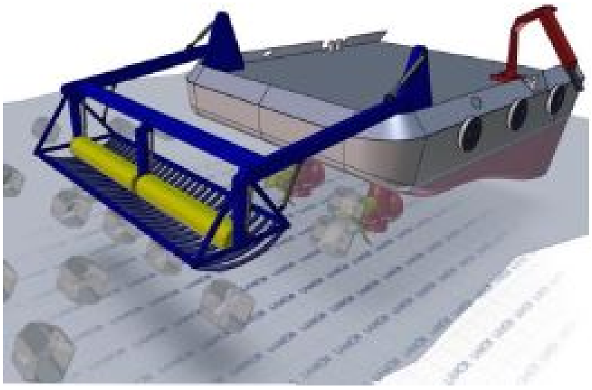


Figure 2. Lamor Arctic Separator.

3.1.2 Conclusions

In general, methods involving submerging ice pieces (limited by size) and separating oil and ice at the water surface were found to have better feasibility for practical application than others.

Out of the total of twelve concepts evaluated, six candidates were considered suitable for further potential development and included the Lamor Arctic Separator; an oblique icebreaker vessel; vacuum tower; stern brushes, trimaran design and Lamor Oil Ice Separator.

3.2 Remote Recovery Units

The aim of this feasibility evaluation was to identify various technologies related to remote recovery units (e.g. units that could be deployed separate from the "mother ship"), and determine feasibility for further research and development. The evaluation consisted of describing and reviewing various methods, products, and concepts related to recovering oil with independent or remotely-operated recovery systems ranging from recovery units to deployment and auxiliary support systems.

3.2.1 Evaluation and Findings

The key to successful mechanical recovery is the skimming unit making contact with oil in the water. Dependent upon location and environmental conditions, skimming systems used in ice-covered waters are deployed from ice-capable vessels or barges. Examples include the Arctic OSR Barge by Lamor Corporation & Crowley Marine Corporation, Navalprogetti's oil spill response barge concept, and the Finnish oil spill response vessel *Louhi*. The skimming systems are deployed either by automatic deployment systems or ship mounted cranes.

Several skimming systems have been developed to address the issue of ice hampering the flow of oil toward the skimming unit. Ice-capable skimmers represent a number of different approaches for recovering oil from ice-covered waters; they typically incorporate a brush or rope mop oleophilic skimmer. These skimmers are deployed via a crane and can be free floating or suspended by the crane in open water between the ice floes. Examples of different brush skimming systems are the Desmi Helix, Desmi Polar Bear, and Lamor Oil Recovery Bucket. The Framo Polaris Skimmer is a self-propelled brush skimming system. Some have a grid system to prevent larger pieces of ice from coming into contact with the skimmer while oil flows through. Examples include the Desmi Ice Skimmer and the LAS. Suspended rope mop skimming systems include the Desmi SeaMop and Hendriksen FoxTail (Figure 3.).

Desmi Helix skimmer

Rendering of the Framo Polaris skimmer

Desmi Polar Bear skimmer

Hendriksen Foxtail VAB 8-14

Figure 3. Ice-capable skimmer configurations.

With all of these systems, as the percentage of ice increases, the ice will impede flow of oil to the skimming system, which requires the system to be picked up and repositioned into other oil pockets within the ice floe. Ice will also impede movement of self-propelled skimmers.

Several skimming support systems such as articulated amphibious vehicles, automatic deployment systems, cranes, auxiliary workboats, and containerised systems such as balloons, aerostats, and other lighter-than-air vehicles, were also considered in the evaluation.

For oil recovery from under ice, Remote Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) based recovery systems were discussed along with use of active containment boom and pressurised air to collect and recover oil using the JML Ice Scraper.

Of special note, a long-reaching hydraulic system similar to those used by cement trucks was mentioned in the evaluation (Figure 4.). A similar type of design could be used for carrying the umbilical hose from the vessel to a floating skimmer. This could greatly extend the reach of a skimming system from the response vessel and assist in safely placing the skimmer in the thickest oil patches, ultimately improving oil encounter and recovery rate of a skimming system.

3.2.2 Conclusions

In general, evaluation of remote recovery techniques recommended continuous development in arctic skimming systems and evaluation of ROVs and AUVs for oil recovery from under ice.

Of most interest for further evaluation was the use of a long-reaching hydraulic system similar to those used by cement trucks (Figure 4.). A similar type of design could be used for carrying the umbilical hose from the vessel to a floating skimmer. This could greatly extend the reach of a skimming system from the response vessel and assist in safely placing the skimmer in the thickest oil patches, ultimately improving oil encounter and recovery rate of a skimming system.

Figure 4. Cement truck pouring cement with a hydraulic arm (photograph by Peter Y. Chou).

3.3 On-Board Oil - Water - Ice Separation

The aim of this high-level feasibility evaluation was focused on Oil-Water-Ice Separation onboard a vessel during an oil spill response operation. Availability of sufficient onboard storage for recovered fluids during a spill event can become critical especially in remote arctic conditions. Optimising storage by separating recovered oil from ice and water is beneficial; but challenging due to large volume of water and ice that can be recovered along with oil, and a wide variety of ice shapes and sizes that may be encountered.

3.3.1 Evaluation and Findings

The evaluation acknowledged that separation can take place in three phases: 1) separation on the waterline (at the water surface), 2) initial (coarse) on-board separation, and 3) secondary (more refined) on-board separation.

Techniques available for separation of oil, ice, and water at the water surface were a focus of mechanical recovery research and development for several decades and were also discussed in the evaluations for new vessel design concepts and remote recovery units. These systems include clamshell, Oil Ice Separator – LOIS, Lamor Oil recovery bucket skimmer, LAS / grid skimmer units, and ship-mounted ice-cleaning brush wheels, among others. Most of these systems require a large vessel to deploy the system and are tailored to handle only very small ice floes typically found in frequently travelled shipping channels such as those in the Baltic Sea region.

There are some concepts for managing ice after oil and ice are brought aboard the vessel. One concept is the Lamor Oil Water Ice (LOWI) Separator Basin. It consists of a clamshell bucket recovering oil and ice from the water surface and placing it in a basin, which uses ice submergence, heating, and pressure washing to separate oil from ice. It requires a 20-foot X 40-foot footprint onboard a vessel. Another concept is the Lamor Shaker, which would utilise the clamshell bucket to recover oil and ice from the water surface and place it into a shaker system (Figure 5.).

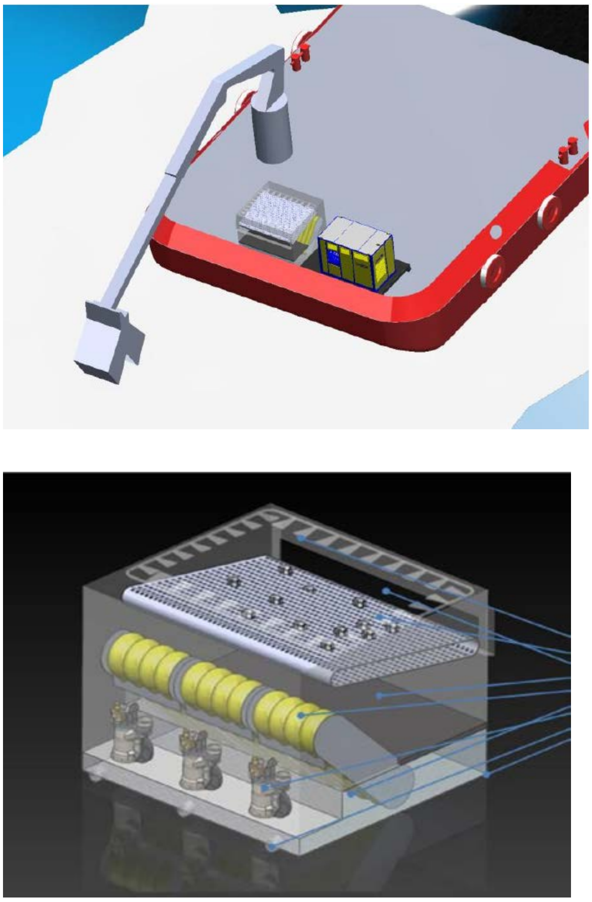


Figure 5. On-board separation concepts (Lamor).

A variety of oil-water separation techniques and equipment types were considered in the evaluation. Most of the separation technologies available commercially on the market are designed to purify oily water from large volumes of water with small concentrations of oil. The purification process in most technologies is aimed at fluids with very low concentrations of oil measured in parts-per-million (ppm). The separation technologies are mainly intended for use with no solid particles present. Some technologies are capable of processing solids, but none are designed to handle ice in different sizes and forms (large, medium, small sized ice blocks and slush ice, etc.).

The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex I regulations regarding water pollutants can be considered an optimum standard for any oil-water separation technology. These regulations specify 50 ppm for general open water areas and 15 ppm for especially sensitive areas. During a large spill event, significant amounts of oil and water mixture are collected; oil-water separators could become a choke point in mechanical response operations. Currently, separators are unable to process recovered fluids fast enough to maintain reasonable response operations.

3.3.2 Conclusions

For separation purposes, melting ice pieces in large volumes is not feasible, due to large amounts of energy required. This finding echoes conclusions of other evaluations in this project (e.g., new vessel designs and remote recovery units), which indicate that due to the complexity of the overall process, including variety in shapes and sizes of ice pieces encountered and large volume of recovered water relative to small volume of encountered oil, the separation of oil from ice and water can be most efficiently conducted at the water surface.

3.4 On-Board Recovered Oil Incinerator

The aim of this high-level feasibility study was to evaluate recovered oil combustion systems to facilitate mechanical recovery of oil in offshore arctic waters. This method provides for an incinerator on the storage vessel that burns recovered oil, thereby freeing up storage space and decreasing the need to transport recovered fluids to another storage location.

3.4.1 Evaluation and Findings

In the 1970s and 1980s, flaring burner disposal systems were studied for the disposal of recovered oil. This effort was intended to address storage limitations during spill response in remote areas or ice-covered waters. The first concept evaluated was pneumatic atomisation systems, which use a modified conventional flaring system used for well testing from an offshore oil exploration vessel. The second evaluation involved burners utilising a rotary cup atomisation system.

With today’s technology there are three concepts to consider: Pneumatic Flare, Rotary Cup Burner, and Augmented Burner.

The Pneumatic Flare design concept operates in a manner similar to flare systems currently used in offshore well testing. It utilises pressurised flow through nozzles to atomise the oil, thus forming more surface area to sustain a burn. The system and supporting components would be mounted onboard a barge trailing oil skimming operations.

The Rotary Cup Burner (Figure 6.) concept consists of a modified helicopter-transportable burner system for floating or at-sea operations. This system utilises a high-speed rotating cup to produce a thin layer of fuel at the lip of the cup, which is then atomised by air blown past the edge of the cup by an integral fan. Rotary cup burners are lighter in weight and require less ancillary equipment than pneumatic atomising flare burners.

The Augmented Burner concept is a chimney-style floating burner, which utilises a pan to hold oil in a pool burn, aided by a chimney and compressed air injection for inducing enhanced burning and more complete combustion (Figure 7.).

Figure 6. Saacke burner shown in use on a remote shoreline.

Figure 7. Chimney style burner.

3.4.2 Conclusions

Evaluation concluded that the Augmented Burner has some obvious advantages due to its comparatively small demands on ancillary equipment and simplicity; however, the unit is still undergoing research and development to see if larger scale performance and future design evolutions are likely. If a high capacity recovered oil system is required (e.g. on the order of 10,000 barrels of oil per day [BOPD] burn capacity), then the Pneumatic Flare is best suited at present. However, if disposal requirements are on the order of hundreds of BOPD burn capacity, then the Rotary Cup Burner modified for use on the aft deck of an ice-strengthened supply boat could be a better option for flaring of recovered oil.

CHAPTER 4. SUMMARY

Mechanical recovery is one technique, along with dispersants use and in-situ burning, proven effective for responding to an oil spill on water. Mechanical recovery during an open water response is challenging; when ice is present, the process is more complex. Ice can restrict access to oil and impede oil movement toward the skimming system. At the same time, ice can assist the response by dampening sea state (e.g., waves) and acting as a containment barrier to slow the spread of oil.

Mechanical recovery is not necessarily the single best response technique to utilise, particularly when dealing with a large volume spill. Mechanical recovery has limitations in terms of oil encounter rate when performed in ice-covered waters. Depending upon the spill location, weather and sea conditions, oil thickness and degree of weathering, ice conditions, available support infrastructure and recovered fluids storage, other techniques such as in-situ burning and dispersants use can be more effective. A combination of these techniques may be the optimal strategy to successfully address overall spill response. Spill responders need flexibility to rapidly employ the most effective response techniques in any given situation.

4.1 Conclusions

In reviewing the technology evaluations in four different areas, no feasible “game changing” spill response technology was identified, despite the best efforts of a large variety of specialists who contributed to the project.

Future Recovery Vessel Design Concepts:

In general, methods involving submerging ice pieces (limited by size) and separating oil and ice at the water surface were found to have better feasibility for practical application than others.

Out of the total of twelve concepts evaluated, six candidates were considered suitable for further potential development and included the Lamor Arctic Separator; an oblique icebreaker vessel; vacuum tower; stern brushes, Trimaran design and Lamor Oil Ice Separator.

Remote Recovery Units

In general, evaluation of remote recovery techniques recommended continuous development in arctic skimming systems and evaluation of ROVs and AUVs for oil recovery from under ice.

Of most interest for further evaluation was the use of a long-reaching hydraulic system similar to those used by cement trucks. A similar type of design could be used for carrying the umbilical hose from the vessel to a floating skimmer. This could greatly extend the reach of a skimming system from the response vessel and assist in safely placing the skimmer in the thickest oil patches, ultimately improving oil encounter and recovery rate of a skimming system.

Onboard Oil-Water-Ice Separation

For separation purposes, melting ice pieces in large volumes is not feasible, due to large amounts of energy required. Due to the complexity of the overall process, including variety in shapes and sizes of ice pieces encountered and large volume of recovered water relative to small volume of encountered oil, separation of oil from ice and water can be most efficiently conducted at the water surface.

Onboard Recovered Oil Combustion Systems

The Augmented Burner has some obvious advantages due to its comparatively small demands on ancillary equipment and simplicity; however, the unit is still undergoing research and the development of larger scale performance and future design evolutions are likely. If a high capacity recovered oil system is required, then the Pneumatic Flare is best suited. If disposal requirements are on the order of hundreds of BOPD burn capacity, then the Rotary Cup Burner modified for use on the aft deck of an ice-strengthened supply boat could be a better option for flaring of recovered oil.

4.2 Recommendations

Ongoing efforts in improving mechanical recovery equipment access to oil (e.g. oil encounter rate) and enhancing capabilities of arctic skimmers should continue. These techniques should improve oil-water-ice separation at the water surface and should avoid bringing large volumes of water and ice on board a vessel.

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