2014 INTERNATIONAL OIL SPILL CONFERENCE

Advancing Oil Spill Response in Arctic Conditions: The Arctic Oil Spill Response Technology - Joint Industry Programme

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ABSTRACT 30043:

The oil and gas industry has made significant advances in being able to detect, contain and clean up spills in arctic environments. To further build on existing research and improve the technologies and methodologies for arctic oil spill response, nine oil and gas companies (BP, Chevron, ConocoPhillips, Eni, ExxonMobil, North Caspian Operating Company, Shell, Statoil, and Total) established the Arctic Oil Spill Response Technology Joint Industry Programme (JIP). The goal of the JIP is to advance arctic oil spill response strategies and equipment as well as to increase understanding of potential impacts of oil on the arctic marine environment. Officially launched in January 2012 at the Arctic Frontiers Conference in Tromsø, Norway, the JIP has six technical working groups (TWG) each focusing on a different key area of oil spill response: dispersants; environmental effects; trajectory modeling; remote sensing; mechanical recovery and in-situ burning (ISB). There is also a field research TWG to pursue opportunities for field releases for validation of response technologies and strategies. Each TWG is led by recognized subject matter experts with years of experience in oil spill response research and operations. This JIP is bringing together the world's foremost experts on oil spill response research, development, and operations from across industry, academia, and independent research centres. Research integrity will be ensured through technical peer review and public dissemination of results. This paper describes the scope and current progress of this Joint Industry Program (JIP).

INTRODUCTION:

Oil spill prevention is a top priority for the oil and gas industry and the ability to prevent and respond to oil spills is instrumental for achieving a licence to operate. Oil spill response is a demanding task in any environment, but responding to spills in arctic regions presents different challenges. These include low temperatures, prolonged periods of daylight and darkness, environmental sensitivities, and the presence of seasonal and dynamic sea ice. Industry global practice, years of preparation and lessons from research and incidents are incorporated into present oil spill prevention and response programs. To develop the present capability, experts from industry, government agencies, and academic and independent research organizations have carried out numerous laboratory and tank tests, field experiments and scientific and analytical studies for more than 50 years to develop equipment and methodologies to respond in arctic conditions. (Norcor, 1975; Dickins and Buist, 1981; Sergey and Blackall, 1987, Singsaas et al., 1994; Rytkönen and Sassi, 2001; and Sørstrøm et al., 2010). This sustained and frequently collaborative effort is not commonly known and recognized by those outside the field of oil spill response.

Arctic Oil Spill Response Technology JIP:

To build on existing research and improve the 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 Program 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, to identify technology advances and research needs in industry preparedness, and prioritize identified issues. One outcome was the recommendation to establish the Arctic Oil Spill Response Technology - Joint Industry Programme (JIP) that would undertake specifically targeted research projects identified to improve industry capabilities and coordination in the area of arctic oil spill response. The JIP research is focusing on expanding industry knowledge of and capabilities in arctic oil spill response in Dispersants, Environmental Effects, Trajectory Modelling, Remote Sensing, Mechanical Recovery, and ISB.

Uniting efforts and knowledge in this four-year JIP increases opportunities to develop and test oil spill response technologies and methodologies, conduct large scale field experiments, and raise awareness of existing industry oil spill response capabilities in the Arctic region. The JIP is committed to sharing information on the progress of its projects and to sharing project results with the objective of improving arctic spill response capabilities. Information is available via the dedicated JIP website created specifically for this purpose www.arcticresponsetechnology.org.

Research efforts are currently underway that include laboratory and meso-scale dispersant tank testing to advance the application and understanding of dispersant effectiveness in very cold water, understanding the potential environmental effects of oil spills and spill response technologies, ice and oil spill trajectory modelling, surface/subsea remote sensing, mechanical recovery of oil, and in situ burning in arctic and ice-prone regions. In addition, significant work is being committed to develop a robust information database that will support the use of Net Environmental Benefit Analysis (NEBA) for response decision-making and environmental impact assessments related to the Arctic environment.

Project 1 - Fate of Dispersed Oil under Ice:

One of the requirements for efficient dispersion is adequate mixing in the water column allowing for a cloud of dispersed oil to rapidly dilute to very low concentration. A key parameter for stable dispersion is the level of turbulence required to keep dispersed oil entrained in the water column. In the Arctic, ice cover dampens energy input from the wind into the ocean (SL Ross Environmental Research Ltd., 2010). This dampening may cause turbulence under the ice to be lower compared to an open ocean environment. Existing numerical models can determine how quickly dispersed oil plumes will rise on the basis of information on ambient turbulence conditions, dispersed oil droplet size distributions, and dispersed oil densities. For these models to predict dispersed oil behaviour under ice, improved understanding of the natural turbulence under a range of ice roughness conditions is required.

The overall goal of this research project is to provide critical information in support of dispersants use in ice-covered marine environments and develop a tool to support contingency planning decisions with respect to dispersant use. The aim is to provide additional evidence to support dispersant use and decision making in ice-covered waters and to determine optimal operational dispersion criteria. The primary research objective is to develop a detailed numerical model that predicts the potential for a dispersed oil plume to resurface and reform a new slick under the ice and then run the model with varying ice concentrations, release types, environmental conditions, oil types, and levels of turbulence. The model will be designed to evaluate whether or not dispersed oil droplets formed under continuous or concentrated ice could resurface under the ice to form a significant accumulation within two days. The first phase will determine what data already exists to support model development.

Progress:

SINTEF was awarded the contract for phase one of this project which is to choose an appropriate existing plume model to describe the resurfacing potential of surface slicks, determine what metocean input parameters will be needed to run the model, and conduct a technology assessment to determine what under ice turbulence/current data sets exist that are suitable for our modelling purposes. The phase one technical report is under review by the Dispersant TWG. If the required data are not available to run the selected model, a second phase of this project will focus on gathering the additional data required to run and validate the model and then to model surface and subsurface dispersant use scenarios.

Project 2 - Dispersant Testing under Realistic Conditions:

Researchers have examined dispersant effectiveness in cold waters with sea ice at both laboratory scale and in wave basin tests using a variety of oils. Laboratory and field tests have demonstrated that oil spilled in ice-covered waters is dispersible (Owens and Belore, 2004; Nedwed, et al., 2006).

Research has also demonstrated that inorganic mineral fines in turbid coastal waters function naturally to form oil mineral aggregates (OMA's) that can remove oil from contaminated shorelines. In 2008, The Department of Fisheries and Oceans, Canada and the Canadian Coast Guard demonstrated through field research that streams of mineral fines slurry combined with mixing energy from vessel prop wash promoted rapid OMA formation and dispersion of oil slicks in ice (SL Ross Environmental Research Ltd., 2010). Use of chemical dispersants and/or mineral fines should provide a response option with high encounter rates, high effectiveness, lower manpower requirements, and greater responder safety than mechanical response. Further, mineral fine treatment may be suitable for use on spills in freshwater.

The overall goal of this research project is to provide additional evidence to support dispersant use in ice-covered waters. The primary objective is to define the operational limits of dispersant and mineral fines in Arctic marine waters with respect to oil type, oil viscosity, ice cover (type and concentration), air temperatures, and mixing energy (natural, water jet and propeller wash). A second objective is to identify the regulatory requirements and permitting process for dispersant and mineral fines use for each Arctic nation/region. This project will be conducted by individual tasks on a phased approach.

Progress:

SINTEF was awarded the contract for this project to conduct a state of knowledge technology assessment that identifies and summarizes state of the art and research conducted to date on the effectiveness of dispersant and mineral fines in ice, Arctic capable delivery systems, and experimental dispersant technologies; to conduct laboratory and meso-scale basin tests on the effectiveness of dispersants and mineral fines with various types of mixing energy; modelling subsea releases of oil treated with dispersants; and to identify and summarize regulatory requirements and permitting process for using dispersants and mineral fines for each Arctic nation. Two tasks have been completed and final reports received:

- **Dispersant Testing Under Realistic Conditions State of the Knowledge Review.** This report identified the literature on previous testing of dispersant effectiveness under Arctic conditions. Important parameters assessed were oil type (naphthenic, asphaltenic, paraffinic, waxy crude or fuel oil), oil viscosity, oil weathering degree, dispersant type, dispersant to oil ratio, salinity, ice coverage, mixing energy, and temperature. The report summarized the scientific literature and identified previous research allowing the TWG to develop a matrix of dispersants effectiveness tests that will not repeat prior studies. The next phase of the work is to perform the actual dispersant effectiveness testing (Lewis, 2013).
- **Dispersant Use in Ice-affected Waters: Status of Regulations and Outreach Opportunities.** This report identified and summarized the regulatory requirements and permitting process for using dispersants and mineral fines for each Arctic nation (SEA 2013).

The main findings from the reports are:

1. Dispersants can work in the Arctic and will, under certain conditions, be more effective in the presence of ice than in open water;
2. In addition to increasing effectiveness, the presence of ice can increase the time window within which dispersants can be used effectively;
3. Except for the UK and the US there is generally an absence of national policies and procedures to approve the use of dispersants during an incident.
4. The findings indicate however, that in some countries there are good regulatory models established for dispersant use.

Project 3 - Environmental Impacts from Arctic Oil Spills and Oil Spill Response Technologies:

The overall goal of this research project is to improve the knowledge base and stakeholder acceptance for using "net environmental benefit analysis" (NEBA) for response decision making and ultimately gain stakeholder acceptance of the role of environmental impact assessment in oil spill response plans and operations. Due to the fundamental role of comparing the effectiveness and impacts of different response options in NEBA, the information base needs to address both the acute and long-term effects of spilled oil as well as the impacts of various response options (e.g., natural attenuation, surface/subsea applied dispersants, in-situ burning, etc.) on Arctic ecosystems. Review and tabulation of published measured effects (e.g., toxicity thresholds and recovery times) is anticipated to be an important part of this project which is being conducted in three phases.

- Perform a comprehensive review on the environmental impacts of Arctic oil spills and from the technologies used to respond to such spills and identify research activities to improve the knowledge base for using NEBA in the Arctic
- Conduct and complete the most crucial research activities identified in phase one. It is envisioned that this work will include laboratory and modelling studies and potentially field research and will be contracted through competitive solicitation(s)
- Organize and conduct two NEBA workshops in key Arctic regions. These workshops will be used to demonstrate how the information base resulting from the review and the data from new studies are used in optimizing the NEBA process

Progress:

NewFields was awarded the contract for phase one. The Environmental Effects TWG is exploring publishing the phase 1 report in an online form, where the individual chapters and the recommendations are linked to the developed literature database to form a web-based education and information tool for Arctic NEBA. The TWG developed and solicited requests for proposals for phase 2 research. Proposals will be reviewed by the TWG and contractors selected in 1Q/2014.

Project 4 – Oil Spill Trajectory Modelling in Ice:

The overall goal of this research project is to conduct research investigations in ice modelling and integrate the results into established industry oil spill trajectory models. Current ice models have intrinsic limitations, such as the flawed assumption of viscous-elastic rheology of the ice, that render them inaccurate. The primary research objective is to advance and expand the oil and gas industry's oil spill trajectory modelling for oil spills in ice affected waters. This project will create or adapt an existing model for predicting ice movement in the marginal and pack ice zones under applied (forecast) wind and current forcing and then integrate the results into established oil spill trajectory models. The new model is expected to provide increased accuracy on the behavior and movement of ice and it is intended that the model will be implementable in any of the leading oil fate and effects models, e.g., OilMap (ASA) and OSCAR (SINTEF). The model may also be applicable beyond the Arctic, for example in non-Arctic but ice-prone areas (e.g., Baltic and Caspian seas).

Progress:

The Nansen Environmental and Remote Sensing Centre (NERSC), Bergen, Norway was selected as the contractor for this project. NERSC aims to develop a new sea ice model that will be tested/evaluated/validated at a regional scale as well as a new very-high resolution model to simulate sea ice dynamics in the Marginal Ice Zone (MIZ). The project will improve the ice drift and deformation within both the ice pack and the MIZ. These outputs will then be coupled into existing oil spill trajectory models and scenarios run to verify/demonstrate results. The major expected outcome of this project will be an increase of the oil spill trajectory models accuracy in presence of sea ice, along with an estimation of the uncertainties in these trajectories. A project initiation meeting with NERSC was conducted and this project has been initiated.

Project 5 - Oil Spill Detection and Mapping in Low Visibility and Ice:

Remote sensing is an important element for an effective response to marine oil spills. Timely response requires rapid and sustained reconnaissance of the spill site to determine the exact location and extent of oil (particularly the thickest portion of the slick) and update projections of oil slick's movement and fate at sea. Remote detection and mapping are essential to effectively direct spill countermeasures such as mechanical containment and recovery, dispersant application, in situ burning, and for the preparation of resources required for shoreline clean-up. Previous industry and government supported research and development has yielded technologies such as strengthened beacons designed to track the location of oiled ice, ground penetrating radar (GPR) to detect oil in, on, and under ice (Bradford et al., 2010)., laser fluorosensors, and enhanced marine radar. In addition, recent tests have shown that Autonomous Underwater Vehicles or AUV's can carry sensors capable of locating and tracking oil under ice. The overall goal of this project is to expand industry's remote sensing and monitoring capabilities in darkness and low visibility, in pack ice, and under ice. This project is split into two elements: surface remote sensing (i.e. satellite-borne, airborne, ship-borne and on-ice detection technologies) and subsea remote sensing (i.e. mobile-ROV or AUV based and fixed detection technologies) and will be performed in a phased approach. First, a Phase 1 assessment and evaluation of existing and emerging technologies was performed that includes an evaluation of further research and development needs, logistical support requirements, and operational considerations including testing opportunities.

Progress:

C-CORE (surface) and Polar Ocean Service/Woods Hole Oceanographic Institute (POS/WHOI) (subsea) were selected as the contractors for the phase one technical assessment and have completed their research projects. Two final reports were received: The study's primary objective is to define the state-of-the-art for surface remote sensing technologies to monitor oil under varying conditions of ice and visibility.

- **Oil Spill Detection and Mapping in Low Visibility and Ice: Surface Remote Sensing.** The report defined the state-of-the-art for surface remote sensing technologies to monitor oil under varying conditions of ice and visibility (Puestow et al 2013).
- **Oil Spill Detection and Mapping in Low Visibility and Ice: Subsea Remote Sensing.** The report defined the state-of-the-art for subsea remote sensing technologies to monitor oil under varying conditions of ice and visibility (Wilkinson, Maksym, Singh, 2013).

The main findings from the reports are:

1. The current state of technology in remote sensing, confirms that the industry has a range of airborne and surface imaging systems utilized from helicopters, fixed-wing aircraft, vessels and drilling platforms that have been developed and tested for the "oil on open water scenario" that can be used for ice conditions.
2. There are several technologies that exist today capable of, or having the potential for, effective sensing in a broad range of ice and environmental conditions that would be experienced in the Arctic.
3. Unmanned underwater vehicles (UUVs) have been successfully operating in ice-covered waters and are now a viable technology for under sea ice operations.
4. UUVs, and especially autonomous underwater vehicles (AUVs), have the dual advantages of being deployable in a range of ice and weather conditions, and importantly their sensor payloads will have a direct view of oil trapped beneath the ice.

5. For logistical considerations, flexibility of deployment and range, AUVs are likely the most promising underwater platform for oil spill detection.
6. Detection of oil encapsulated within the ice may also be possible with some sensors mounted on UUVs, and possibly more efficiently than with surface and airborne remote sensing methods.

Phase two research experiments will be conducted to test and evaluate the performance of various surface and subsea remote sensing technologies with crude oil on, encapsulated in and under ice, in conditions that include low visibility. The experiments, expected to start in 1Q/2014, will use the climate controlled test basin at the U.S. Army Corps of Engineers-Cold Regions Research and Engineering Laboratory (CRREL) located in Hanover, New Hampshire, USA.

Project 6 - Mechanical Recovery of Oil in Ice:

The rapid containment and recovery of oil at or near the source is provided by on-site spill response vessels. Mechanical skimmers can be used to remove oil from the water surface and transfer it to a storage vessel. Skimmers work most efficiently on thick oil layers. Floating barriers, including oil booms, are used to collect and contain spilled oil into a thicker layer. In the Arctic offshore, ice itself could act as a boom where the oil is contained in thicker layers between ice floes. A variety of skimmer designs have been optimized for Arctic sea conditions and several have been proven to work well. In most countries, mechanical recovery of oil is the first and preferred response. Mechanical recovery in broken ice is limited by the ability of the skimmer to encounter and remove spilled oil and to function effectively under extremely low temperatures. Another issue related to mechanical recovery is storage, transfer and disposal of the recovered oil/ice/water mixture, which is a special challenge in remote Arctic areas with limited infrastructure. The overall goal of this research project is to improve mechanical recovery of oil spills under Arctic conditions. The objectives are to:

- Thoroughly examine the results obtained from previous research projects and identify a number of novel concepts, which have potential to improve efficiency of mechanical recovery under arctic conditions
- Develop a selection process by which the novel concepts can be rigorously examined
- Select and develop the most promising concepts

Progress:

Utilizing results from an internal workshop conducted in March 2012, novel ideas in four areas will be evaluated (New Vessel Design, Remote Recovery Systems, On Board Oil/Water/Ice Separation, and Onboard Oil Incineration). The objective of this feasibility evaluation is to identify the most promising technologies or equipment designs that can improve recovery of oil in ice and recommend any concepts that can be taken to the ‘proof of concept stage’.

Project 7 - In Situ Burning (ISB) of Oil in Ice-Affected Waters:

In-situ burning (ISB) is a response technique proven very effective for removal of oil in Arctic conditions, especially in snow and dense sea ice. ISB has been used in many field tests over the past 35 years in US, Canada, and Norway with removal efficiencies ~90% (e.g., Norcor 1975, Dickins and Buist 1981, Buist et al 2010). Oil on water or between ice floes can be disposed of quickly, efficiently and safely by controlled burning (API 2012). This technique works most efficiently on thick oil layers as oil is contained by fire-resistant booms or ice. Through burning, an average of about 80-95% of oil volume is eliminated as gas, 1-15% as soot and 1-10% remains as a residue.

The overall goal of this TWG is to ensure in-situ burning (ISB) is available to industry as a response option. This requires ISB to be incorporated into contingency planning and that response organisations have the necessary resources and training. The objective of this research project is to prepare educational materials to raise the awareness of industry, regulators and external stakeholders of the significant body of knowledge that currently exists on all aspects of in-situ burning (ISB). The materials are also intended to inform specialists and stakeholders interested in operational, environmental and technological details of the ISB response technique.

Progress:

SL Ross Environmental Research Ltd. was awarded the contract and this project is actively underway. Two tasks are complete and final reports received.

- **In Situ Burning (ISB) of Oil in Ice-Affected Waters: Technology Summary and Lessons Learned from Key Experiments:** This report provides a summary of relevant scientific studies and experiments as well as previous research efforts on the use of ISB in Arctic environments both offshore and onshore, highlighting key findings and conclusions (Buist et al 2013).
- **In Situ Burning in Ice-Affected Waters: Status of Regulations in Arctic and Sub-Arctic Countries:** This report identified and summarized the regulatory requirements to obtain approval for use of ISB in Arctic nations (Buist et al 2013).

The main findings from the reports are:

1. Confirmation that technology exists to conduct controlled ISB of oil spilled in a wide variety of ice conditions and that ISB is one of the response techniques with the highest potential for oil spill removal in arctic conditions;
2. There is a considerable body of scientific and engineering knowledge on ISB to ensure safe and effective response in open water, broken pack ice and complete ice cover, gleaned from over 40 years of research, including large-scale field experiments;
3. Most of the perceived risks associated with burning oil are easily mitigated by following approved procedures, using trained personnel, and maintaining appropriate separation distances.

A third report is in development that will provide a detailed state of knowledge that summarizes the role, function, benefits and limitations of ISB as a response option in the Arctic offshore environment and is intended to cover all planning and operational aspects of ISB, including the potential impacts on human health and the environment. The report will be available in 1Q/2014.

Project 8 - Aerial Ignition Systems for In Situ Burning:

The vast majority of experience with ISB is with terrestrial spills, which can be ignited by hand using simple tools (e.g., flares, drip torches, or breakable bottles of gelled gasoline). In-situ burning was used with great success offshore during the 2010 Gulf of Mexico oil spill. An estimated 11,000,000 gallons of oil was safely ignited and burned during the response (Federal Interagency Solutions Group 2010). Spills to smaller water bodies, which are easy to reach, can be similarly ignited. An alternative is needed to ignite spilled oil in areas with difficult / restricted access.

For the Arctic region such areas include drift and pack sea ice and open waters. Flares and gelled gasoline can be deployed by hand or mechanically from an aerial platform at low altitudes or from a nearby vessel. Safety concerns could often constrain these options. A torch can be suspended beneath a helicopter (under-slung Helitorches) for more precise targeting, but there are associated aviation safety concerns and greater training needed for this option. Helitorches have often been used for ignition on land. While this technique may work well especially for the difficult-to-access spills in broken ice, helicopters have limited distance range and use for the ignition of oil spills 150 miles offshore may be problematic. Alternatively, fixed-wing aircraft have much greater range however; they do not have accurate targeting capability at their operational speeds and, consequently, are not currently considered for ISB.

The overall goal of this research project is to develop improved ignition systems to facilitate the use of ISB in offshore Arctic environments, including ice when the presence of sea ice restricts use of vessels as a platform for this response option. To accomplish this effort we will involve both internal and external company aviation experts in the evaluation of ignition options by enlisting recommendations for improved ignition systems, and subsequent development, testing and certification of an improved aerial ignition system.

This project is designed to align with its sister project under the American Petroleum Institute (API) ISB Program. The mutual research objective is to jointly generate a robust dataset on useful igniters, their launch equipment, and release platforms to support improved capability for aerial ignition. The intent is to evaluate the performance of the existing array of ignition systems used by the US Fire Service, US Dept. of Agriculture, US Bureau of Indian Affairs, US Bureau of Land Management, and US National Park Service and state agencies for reliability, safety, and targeting precision/accuracy. Based on initial results, conduct bench scale tests and then modify ignition systems working with manufacturers and conduct meso-scale tests.

Progress:

A seven member aviation advisory group has been established, of which five are from the International Association of Oil and Gas Producers (OGP) Aviation Subcommittee. A five member ignition advisory group was also established composed of US government and industry fire experts). The project is expected to commence in 1Q/2014.

Project 9 - Chemical Herders and In Situ Burning:

Chemical herders can provide an additional tool to support oil spill response in ice and open water. ISB herding agents can be useful in thickening oil in the 30-70 percent ice concentration range so that in situ burning can be effective (SL Ross 2007). The use of chemical herders to thicken on-water slicks among drift ice for subsequent burning has been studied for a number of years (API 2012). Two field experiments using chemical herders, conducted during the SINTEF Oil in Ice JIP, were effective with greater than 90 percent removal efficiencies observed (Buist et al 2011). The overall goals of this research project are to advance the knowledge of chemical herder fate, effects, and performance to expand the operational utility of ISB in open water and in ice-affected waters.

Progress:

The TWG is developing scopes of work to be incorporated into requests for proposals that will be issued for solicitation in 1Q/2014.

CONCLUSION:

While prevention of oil spills remains a top priority for the oil and gas industry, this program demonstrates a broad, industry commitment to responsible arctic exploration and development by creating international research projects to further knowledge and capabilities in the area of arctic oil spill response. The initial reports for the JIP have been developed by some of the world's foremost experts across industry, academia, and independent research centers, using all relevant scientific studies and experiments, case studies, and previous research efforts in Arctic environments both offshore and onshore. These reports and additional project information are available on the on the JIP website www.arcticresponsetechnology.org.

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