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Ice Engineering

U.S. Army Engineer Research and Development Center, Hanover, New Hampshire

Improving Oil Spill Response in Ice-Covered Waters

As the world's appetite for crude oil grows, supplies in easy-to-access areas of the world are dwindling. Exploration, development, and production of oil from ice-covered seas is accelerating: in Alaska the world's first offshore production island has been operating for more than four years and plans are under way to explore existing lease areas farther offshore.

Although modern offshore drilling and production systems are designed and regulated to be very safe, accidents sometimes happen, and oil spills in ice-covered waters present challenges unlike those that occur in open water, thus requiring a different response.

Improving spill response

The U.S. Army Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory (ERDC-CRREL) recently supported two important research programs intended to improve spill response in ice-covered waters: developing new technologies to detect oil trapped under or within solid ice, and testing herding agents as a technique to thicken oil slicks for burning and/or mechanical recovery in situations where ice concentrations hinder the natural formation of thick oil slicks. Both of these projects are highlighted in this technical note as examples of how CRREL's Ice Engineering Facility is being utilized in new ways to address ongoing environmental issues associated with Arctic offshore exploration and development.

BP's Northstar production island in 39 feet of water off Prudhoe Bay, Alaska. (Photo courtesy of David Dickins, DF Dickins Associates, Ltd.)

Concrete Island Drilling System (CIDS), a bottom-founded Arctic structure originally used for exploration wells in the U.S. Beaufort Sea and now serving as the base for ExxonMobil's Orlan production structure in the Sakhalin 1 development. (Photo courtesy of David Dickins, DF Dickins Associates, Ltd.)

Detecting oil under ice

According to the U.S. Department of the Interior, practical oil spill detection continues to be performed primarily by visual observation, photography, and thermal infrared/ultraviolet imaging. These systems are limited to favorable sea and atmospheric conditions and are, therefore, inoperable in rain, fog, or darkness. At present there is no remote sensing system to detect oil spilled under ice—the only viable technique involves drilling holes through the ice sheet to see whether there is oil trapped in or under it.

The first step in efficiently responding to an oil spill is determining its exact location and extent. When a spill occurs in ice-covered waters, such as off the northern coast of Alaska, visual detection is inefficient. Alternative means are needed to delineate the size of the spill and to develop the appropriate response strategies to remove the oil. There is a worldwide need to develop a practical remote sensing system to detect and map oil in ice-covered water to facilitate leak detection and improve spill response capabilities for oil and gas operations in Arctic regions.

In 2004, as part of an effort to evaluate potential remote sensing techniques to detect oil trapped within and under ice, CRREL hosted researchers from DF Dickins Associates Ltd.; Boise State University; University of Glasgow; Exploration Technologies, Inc.; and Shell Global Solutions. The program was sponsored by the U.S. Department of the Interior Minerals Management Service (MMS), Alaska Clean Seas (Prudhoe Bay), and Statoil ASA (Environmental Technology Research Centre, Stavanger, Norway), and is supported by MAR, Inc. (OHMSETT) and CRREL. The research team utilized CRREL's Ice Engineering Facility to determine whether off-the-shelf technologies and sensors can detect oil under ice in a controlled mesoscale environment as a prelude to further development and field testing. The team evaluated two independent technologies: high-frequency pulsed ground-penetrating radar (GPR) and an ethane gas sensor using flux chambers.

In preparation for testing, seven oil containment hoops were placed in CRREL's Environmental Test Basin. Six hoops were frozen in a solid ice sheet cover and one in a brash (broken) ice cover. Measured volumes of crude oil were pumped under the ice into three hoops one week before the test while the ice was growing to allow the oil to become encapsulated by new ice growth beneath the oil. Oil was spilled into the four remaining hoops at the beginning of the test week. The ice cover was then surveyed with the GPR antennas. The "light touch" ethane sensor is capable of detecting parts per trillion ethane, so to isolate the sample volume from background ethane, flux chambers were placed on the ice and ethane gas that seeped through the ice was sampled. In its final report (Dickins et al. 2005), the research team concluded that the project detected oil trapped in and under ice with two completely independent technologies, both of which have potential for further development and large-scale field testing.

Photo by Marie Darling, CRREL

Containment hoops were frozen into ice to isolate crude oil placed below the ice cover.

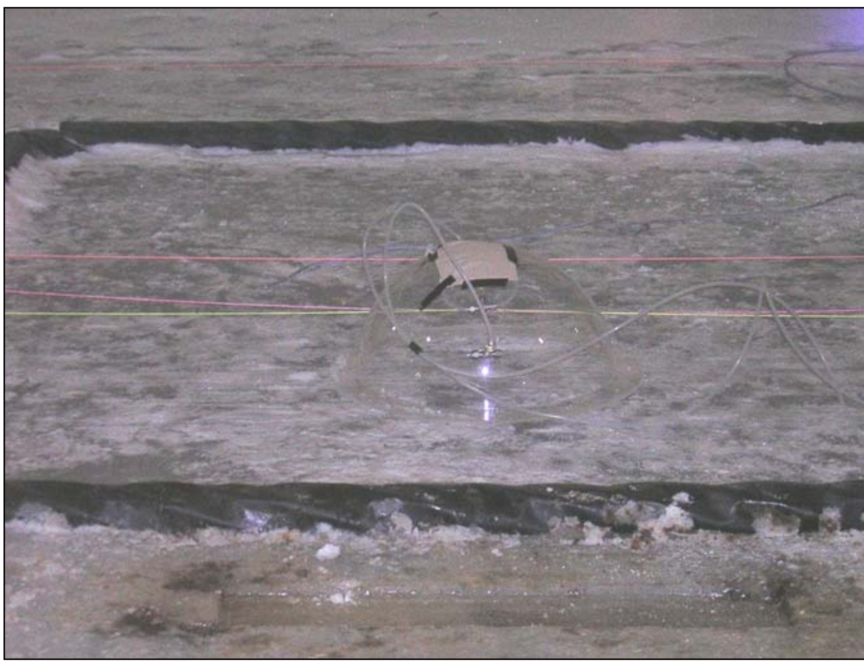

Photo by Marie Darling, CRREL

Flux chambers were placed within the containment hoops to detect ethane transmitted from an oil layer in or beneath the ice.

The results obtained at CRREL led to further research into systems and procedures to detect oil in and under ice utilizing GPR and ethane sensing. Field testing in 2005 at Prudhoe Bay, Alaska, demonstrated the ability of radar hardware to withstand sustained operation in realistic Arctic field conditions and to profile thicker ice sheets. This led to a large-scale field spill in Norway in March 2006 where the GPR successfully detected oil under 65 cm of sea ice. The stage is now set to consider developing an operational system that will address a critical gap in the ability of responders to find oil trapped under solid ice. This positive outcome could not have been achieved without the essential first step of having a suitable controlled mesoscale environment in which to conduct proof-of-concept testing at a reasonable cost.

Herding of oil in ice

There is a technology and knowledge gap related to the mitigation of oil spills in broken ice conditions. In-situ burning may be one of the few viable options to quickly remove oil spilled in loose pack ice. However, a fundamental problem for burning blowout slicks or sub-sea pipeline leaks in pack ice less than 60% to 70% coverage is that the slicks can either initially be too thin or they can thin quickly, resulting in inefficient burns with oil residue remaining. If these slicks could be thickened to the 2- to 5-mm range, effective burns could be carried out (Buist and Morrison 2005).

The use of surface-active agents (also called oil herders or oil collecting agents) to clear and contain oil slicks on a water surface is well known. When applied on water, these agents have the ability to spread rapidly into a monomolecular layer as a result of their high spreading pressure. Consequently, small quantities of these surfactants will quickly clear thin films of oil from large areas of water surface as the oil is contracted into thicker slicks. For application of herders in loose pack ice, the intention would be to herd freely drifting oil slicks to burnable thickness, then ignite them from the air. Burning would be performed without additional mechanical containment.

A program to research herding of oil in ice was undertaken by CRREL and partnering researchers in 2005. This pooled study was funded by SL Ross Environmental Research Ltd., ExxonMobil Upstream Research Company, Sakhalin Energy Investment Company, Agip Kashagan North Caspian Operating Company, Statoil ASA, MMS, and OHMSETT.

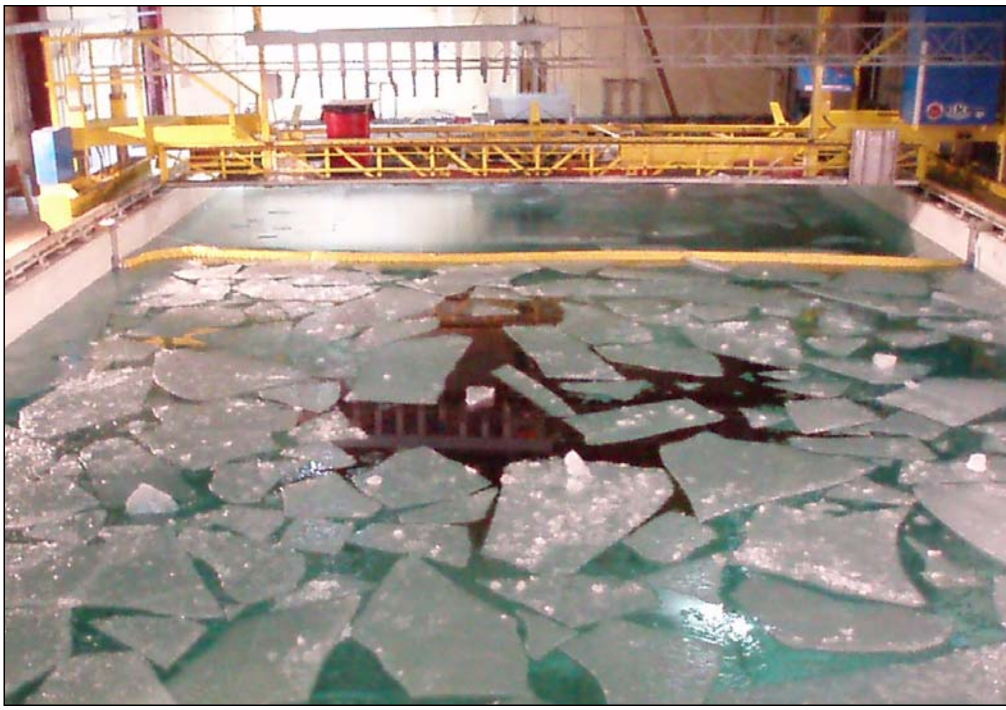

Photo by Paul Meyer, OHMSETT

Conducting oil herding tests in CRREL's Environmental Test Basin.

A series of mid-scale experiments was conducted in CRREL's Environmental Test Basin. The test variables included the following:

- Ice coverage (10, 30, 50, and 70% surface coverage)
- Ice type (brash vs. frazil)
- Air temperature (0° vs. –21°C)
- Herder application time (post-spill vs. pre-spill)
- Waves (calm vs. small waves)

Seventeen tests were conducted over a two-week period. Although conclusions cannot be drawn at this point because the data analysis is ongoing, the results to date show that there is still considerable promise for the application of chemical herders to contract oil slicks in pack ice to thicknesses conducive to efficient in-situ burning, particularly in light wind conditions.

The innovative nature of the testing led CRREL to host a Visitor's Day in November 2005 to showcase mitigation of oil spills in ice-covered waters. Observers from government, industry, and academia viewed oil herding tests in CRREL's Environmental Test Basin.

Ian Buist, SL Ross Environmental Research Ltd., applies herding agent around the periphery of a test slick among broken ice in CRREL's test basin. (Photo courtesy of Ian Buist)

Photo by Tom Tantillo, CRREL

Visitor's Day, November 2005. Left to right: Joseph Mullin and Sharon Buffington, Mineral Management Service, U.S. Department of the Interior; Dr. Kim Newman, Coastal Response Research Center, University of New Hampshire; Jim Wuebben, Acting Director, CRREL; Rich Lougee, Congressional Staffer to New Hampshire Senator Gregg; Laura Ray, Assistant Professor, Dartmouth College; and Bill Schmidt, Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT).

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Ice Engineering

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