Using Herding Surfactants to Thicken Oil Slicks in Drift Ice for *In situ* Burning

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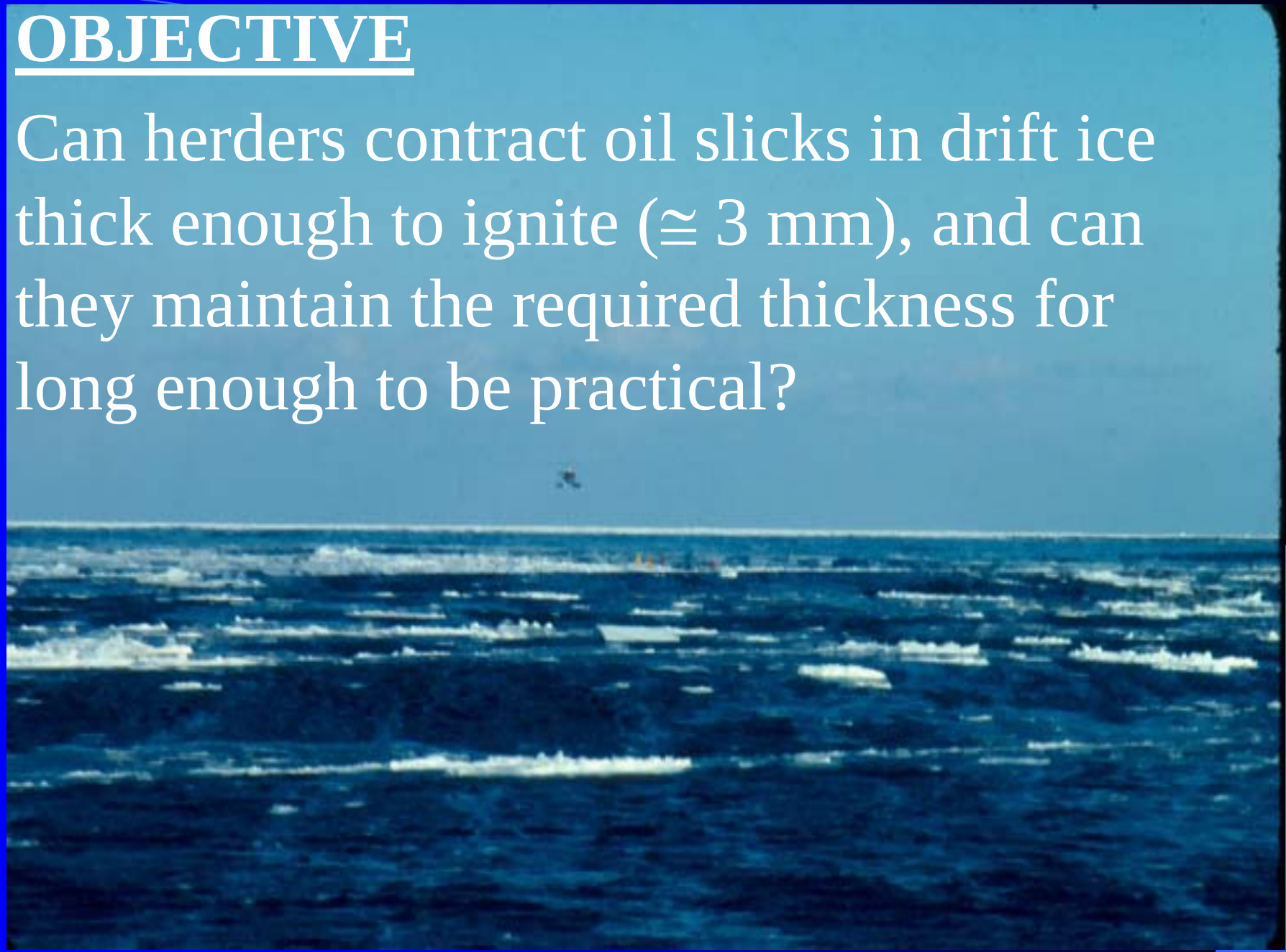
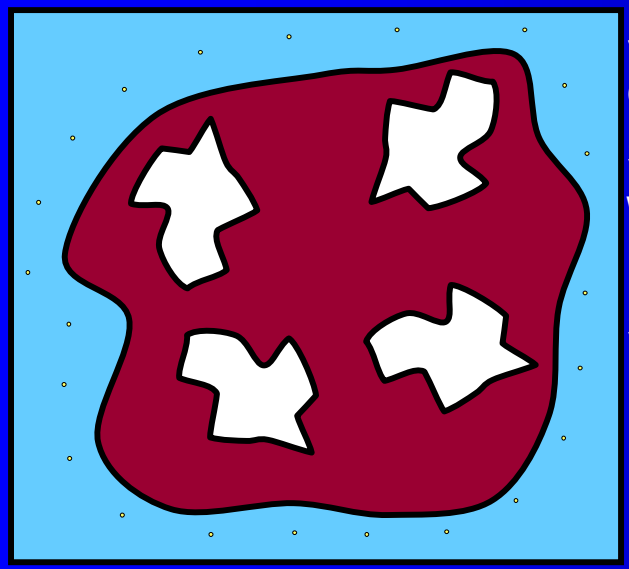
- Alaska Clean Seas

OBJECTIVE

Can herders contract oil slicks in drift ice thick enough to ignite (≅ 3 mm), and can they maintain the required thickness for long enough to be practical?

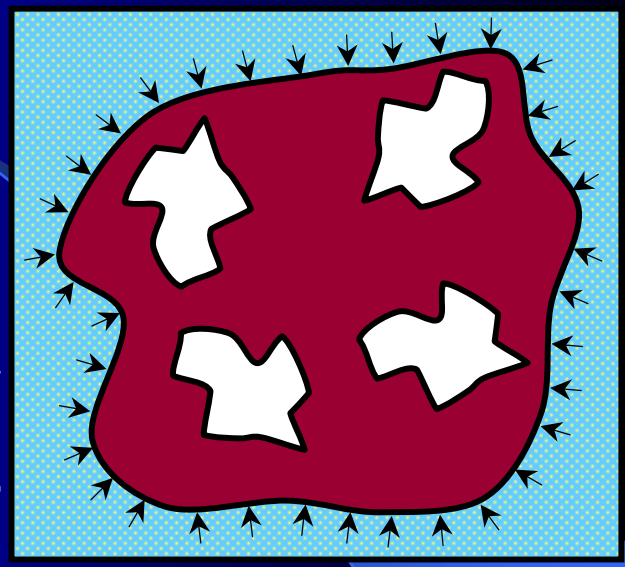


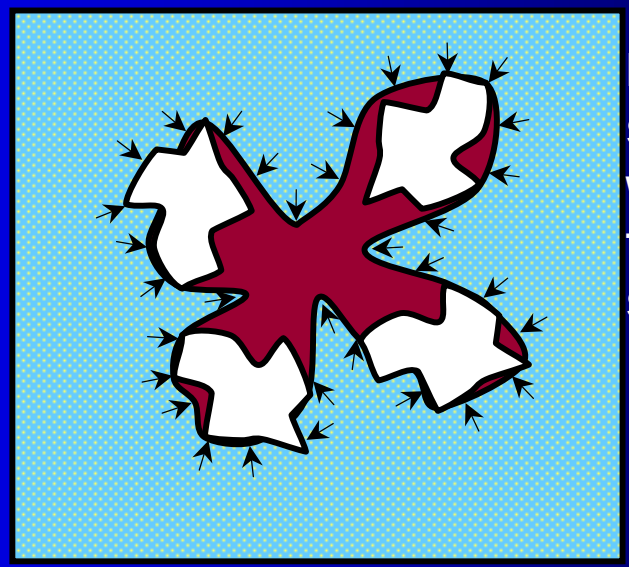
How do herders work?



Small amounts of herder sprayed on water around perimeter of slick

Herder rapidly spreads to form monolayer





Herder changes surface chemistry of water causing slick to contract into smaller area

Summary of Previous Testing

Three series of tests completed so far:

1. Preliminary concept feasibility tests in 2003
2. Small-scale lab tests in 2004
3. Mid-scale tank tests in 2005/06

Preliminary & Small-scale Tests

Conclusions from Preliminary and Small-scale

- Composition of oil plays a strong role in determining the efficacy of herding.
- The USN cold water herder formulation outperformed both the other herders
- A 1.6 m/s wind balanced the effect of the herder on a slick.

Conclusions from Preliminary and Small-scale

- Waves did not detract from immediate effectiveness of the herder; breaking waves dispersed the herder into the water column.
- Herded slicks ignited and burned in open water and in the presence of ice blocks.
- Burn efficiencies were similar to those measured for contained slicks of the same dimensions.

Mid-scale Tests To Date

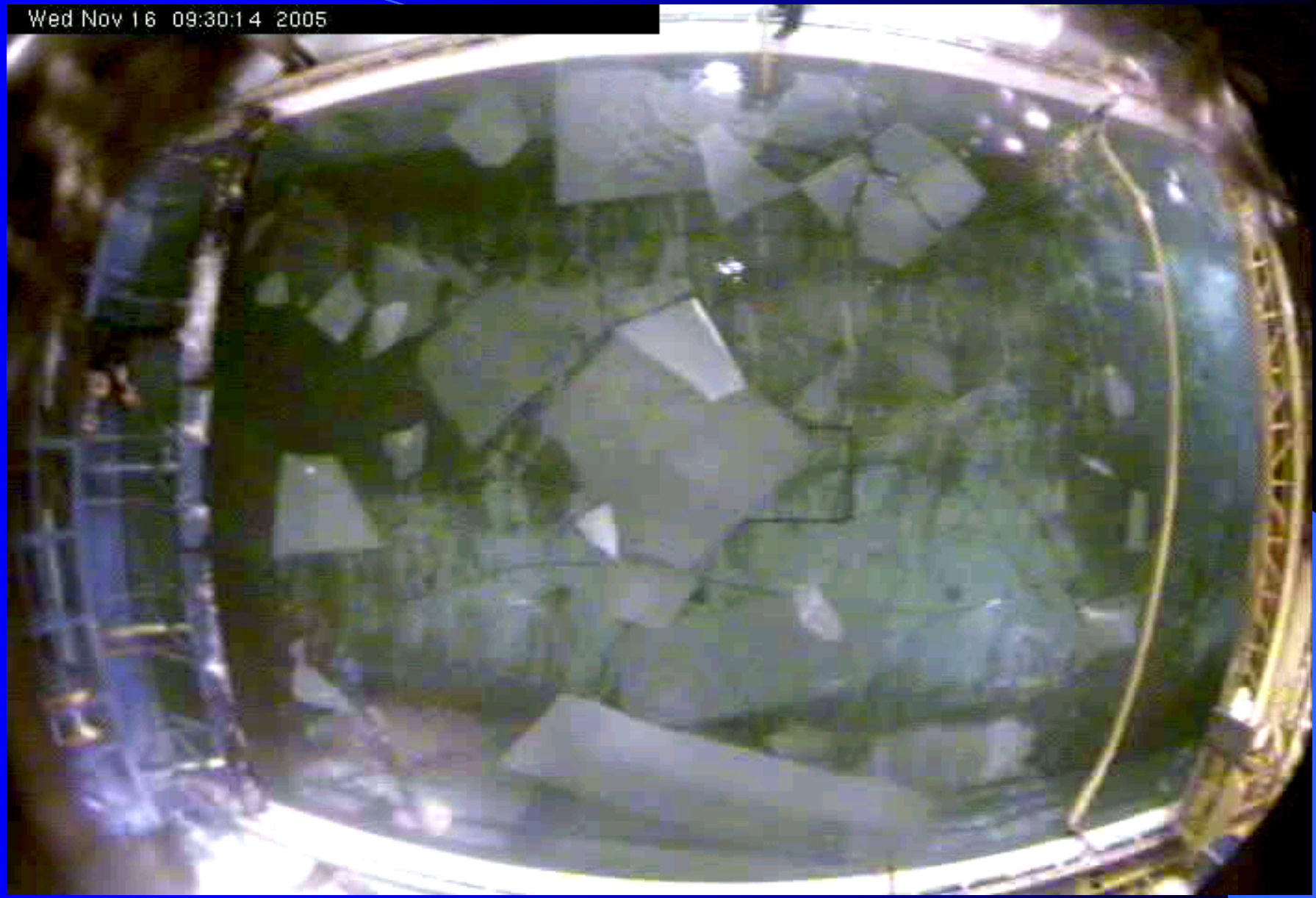
1. A test program at the scale of 100 m^2 in the indoor Ice Engineering Test Basin at the US Army Cold Regions Research and Engineering Laboratory in November 2005.

2. A test program at the scale of 1000 m^2 at Ohmsett in February 2006.

CRREL Test Variables

Varied:

1. Ice cover (10, 30, 50 and 70%)
2. Ice type (brash or frazil)
3. Air temperature (0° and –21°C)
4. Waves (calm and small waves)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CRREL Summary

- USN herder significantly contracted Hydrocal slicks to » 3 mm in brash ice ≤ 70%.
- Frazil ice restricted spreading of oil and herder.
- Herded thickness declined slowly over 1 hr.
- Herder seemed to work as well at air temperatures of –21°C as it did at 0°C.
- Short, choppy waves caused herded slick to break up into small slicklets.

Ohmsett Tests

- Test herders at 1000 m^2
- Use free-drifting slicks and ice
- Effect of wind
- Effect of waves
- Effect of evap'd oil

Ohmsett Tests

Ohmsett Summary

- Herder contracted crude oil slicks in loose, free-floating brash ice. Thicknesses > 3 mm achieved with larger volumes of fresh and evaporated crude.
- Herded crude thickness declined slowly.
- Wind caused smaller-volume herded slicks to break up into small slicklets.
- Long waves did not cause herded slick to break up, and may have assisted the process by helping spread the herder over the water.

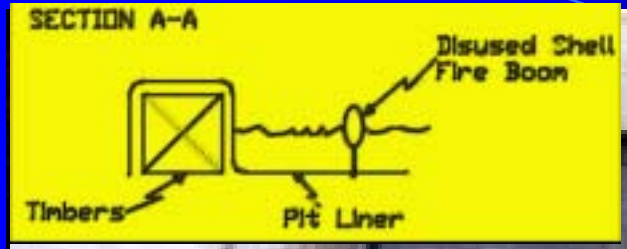
Field Burning Experiments

Prudhoe Bay in November 2006:

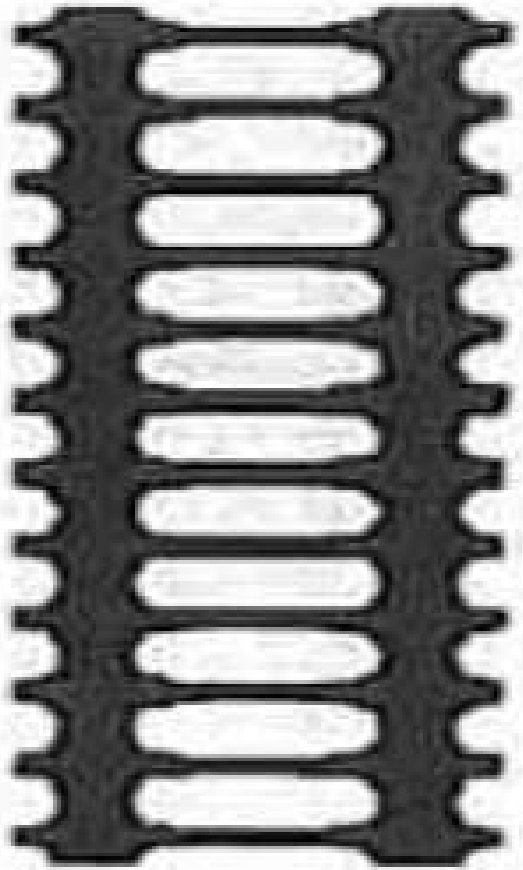
- Researched herding and burning at scale of 30 m^2
- Constructed outdoor test pool at Fire Training Grounds
- Surrounded by windbreak to minimize wind drift
- Used saline ice blocks to simulate brash ice
- Used snow to simulate slush ice

Prudhoe Bay Experiments

Prudhoe Bay Experiments



Prudhoe Bay Experiments



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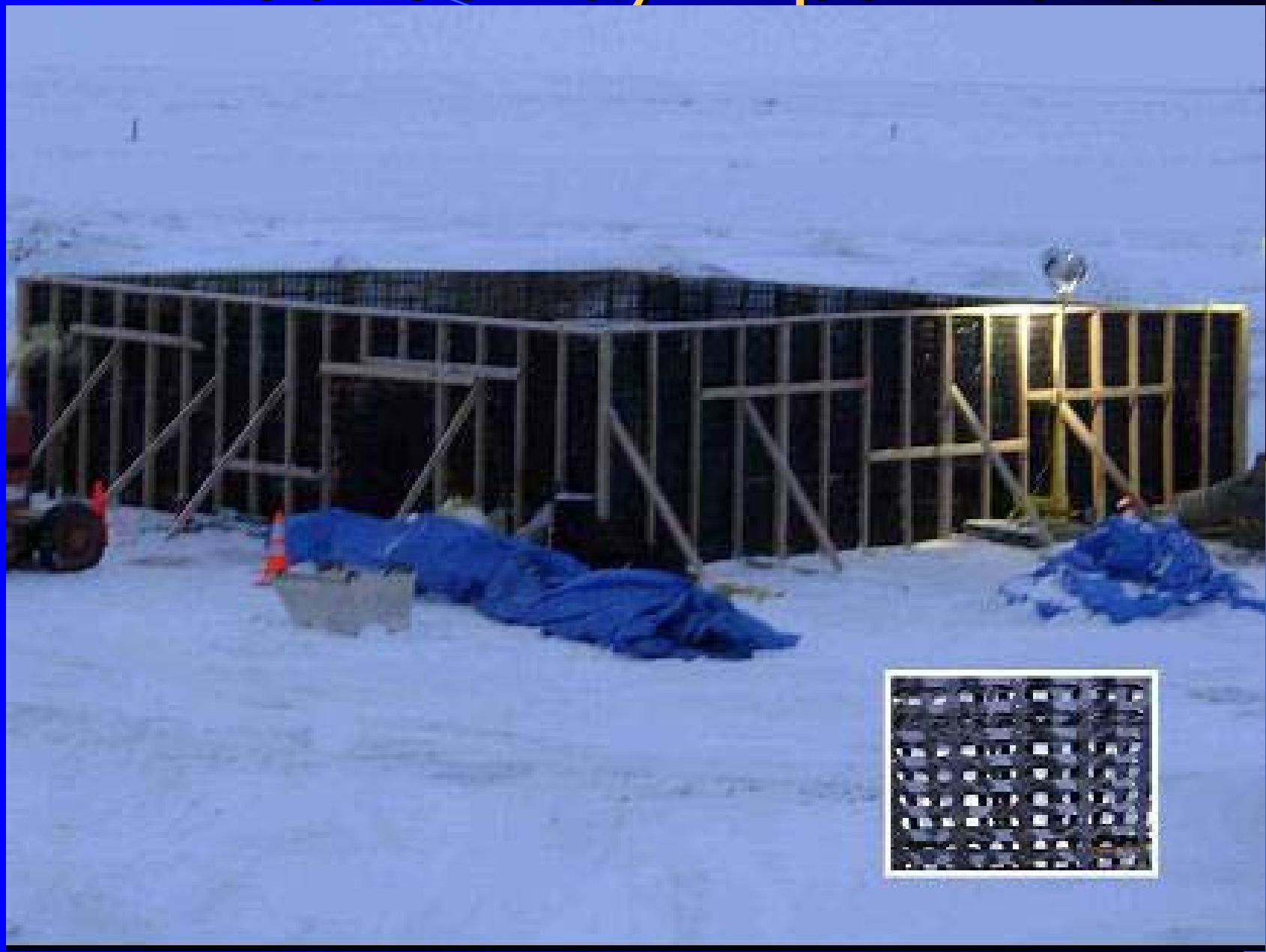

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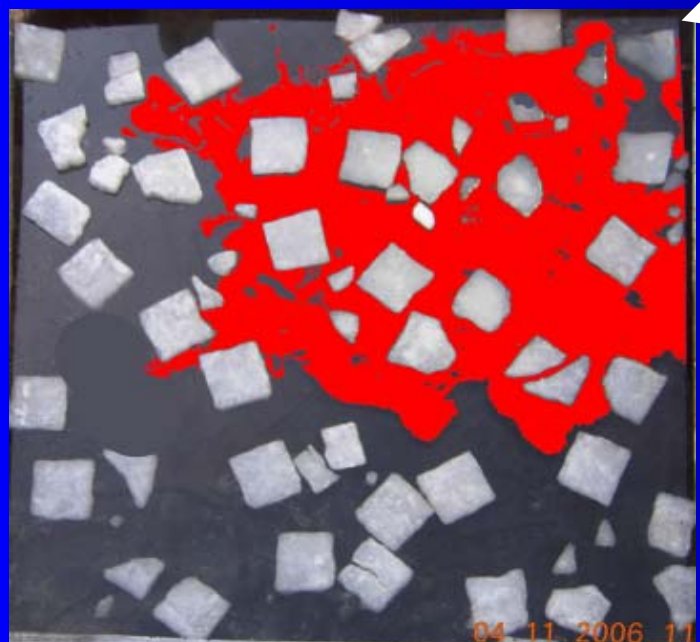

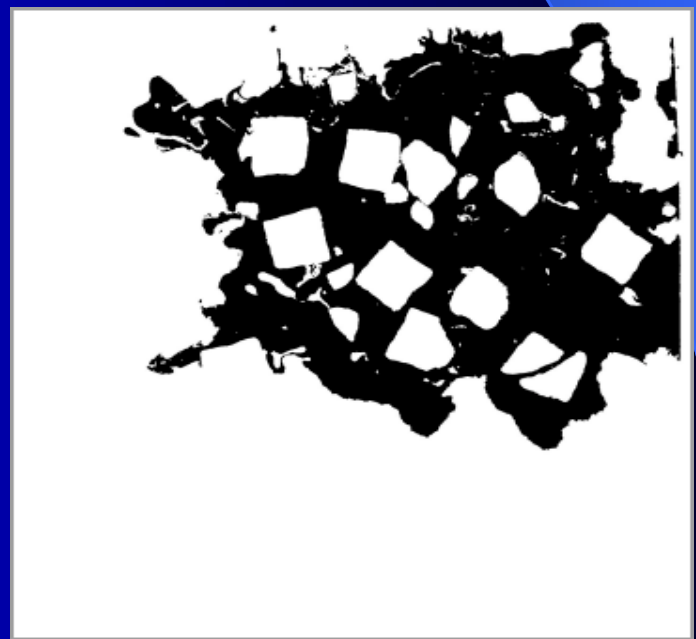

Prudhoe Bay Experiments

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Prudhoe Bay Test Matrix

- Varied:
  - Ice type (brash, slush, open water)
  - Ice concentration (0, 10% and 30%)
  - Oil volume (7.5 and 15 L)
  - Ice grounded vs. floating
  - Waves (small)
- Completed 21 tests with Kuparuk crude

Prudhoe Bay Results - Herding

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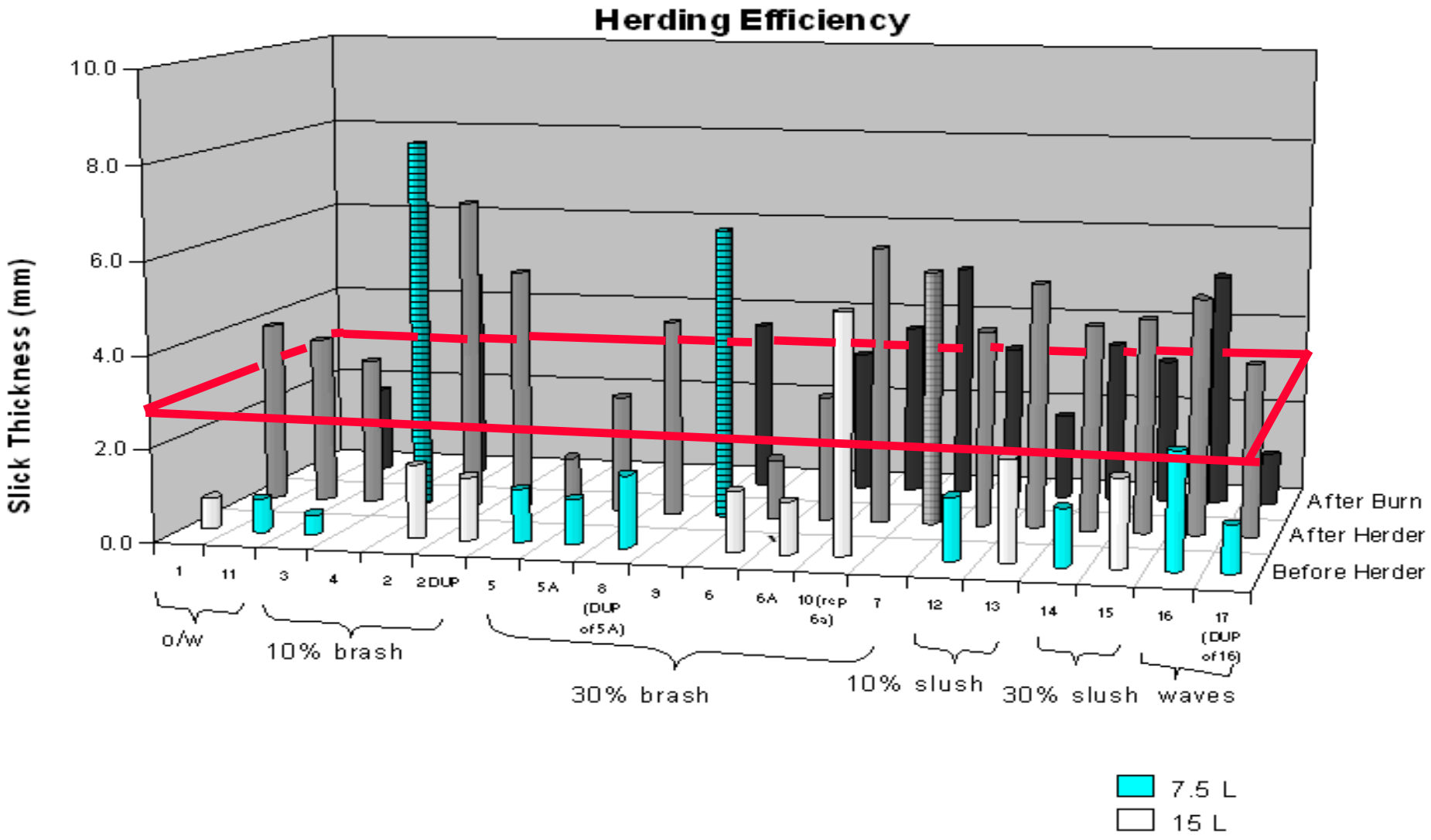
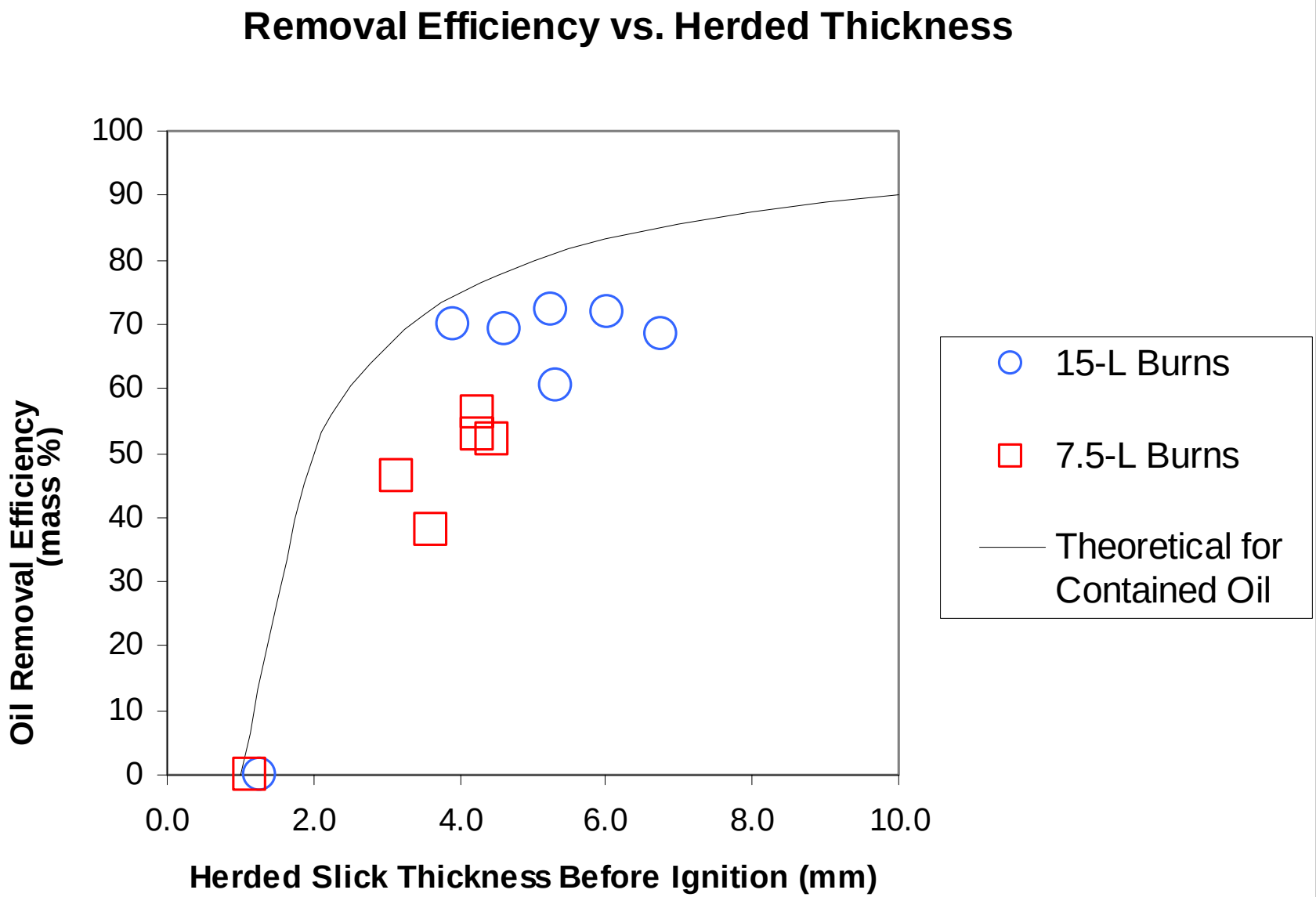


Prudhoe Bay Results – Herding in Waves

Prudhoe Bay Experiments

Prudhoe Bay Results - Burns



Prudhoe Bay Summary

- **Herder contracted crude in brash & slush ice ≤ 30% to thicknesses routinely > 3 mm.**
- **Frazil ice restricted spreading of oil & herder.**
- **Short, choppy waves caused herded slick to break up into small slicklets (relatively small volumes of oil may be explanation)**
- **Longer, non-breaking waves did not cause slick to break up.**

Prudhoe Bay Summary

- **Herded slicks ignited & burned in brash and slush ice ≤ 30% at air temperatures ≥ -17°C.**
- **Removal efficiencies averaged 50% for 7.5-L slicks & 70% for 15-L slicks.**
- **Type of ice (brash vs. slush) did not significantly affect removal efficiency.**
- **Burning slicks spread slightly, but as flames began to die down, residue re-herded.**
- **Generally not possible to reignite residue.**

Prudhoe Bay Summary

- **Steeper, cresting waves detracted from burn efficiency - longer, non-breaking waves did not.**
- **Removal efficiencies for herded slicks close to but slightly less than theoretical for equivalent-sized contained slicks.**
- **Removal rate for the slicks in the range expected for equivalent-sized contained slicks.**

What's Next

- Lab-scale experiments to identify other cold-water surfactants more effective, or longer-lasting, than USN.
- Improve the cold-weather handling characteristics of the best herder.
- Experiments to explore if herding agents might enhance mechanical recovery in pack ice or chemical dispersion.
- Preliminary experiments to explore if herding agents might help in clearing oil from salt mashes.
- Develop application system for large-scale herder use.
- Full-scale field trial of herding **&** burning crude oil in pack ice planned for Svalbard in 2008 and/or 2009 as part of SINTEF Oil in Ice JIP.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