ARCTIC RESPONSE TECHNOLOGY
OIL SPILL PREPAREDNESS

In-Situ Burning in Ice-affected Waters: State Of Knowledge Report

IOSC 2014, Savannah, Georgia

COLLABORATION AMONG TEN COMPANIES

- **International research programme**
- **Builds upon decades of R&D** in arctic oil spill response
- Brings together **experts across industry, academia and independent research centres**
- Research integrity through **technical review and public dissemination** of results

Six areas of research:

- Dispersants
- Environmental Effects
- In-Situ Burning (ISB)
- Mechanical Recovery
- Trajectory Modeling
- Remote Sensing

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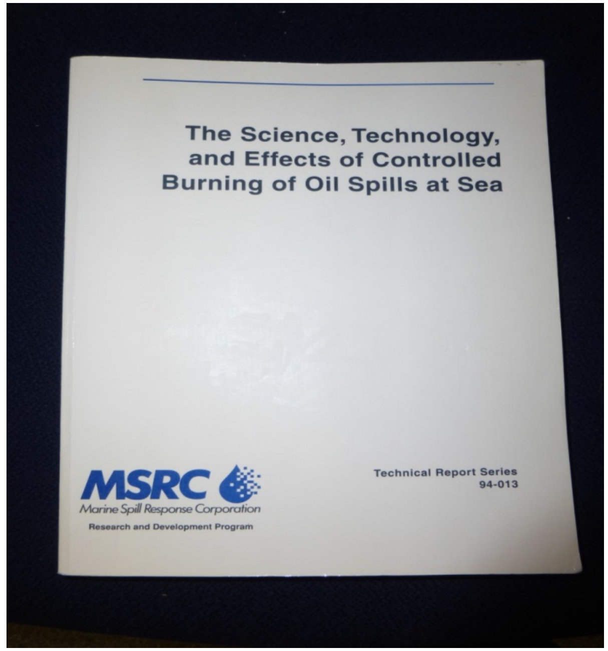
BACKGROUND

- **MSRC funded ISB technical handbook in 1994**
  - Covered science, technology and effects of ISB
  - Covered open water ISB only

Since then:

- **EC open-water guide in 2000**
- **USCG operational manual in 2004**



INTRODUCTION

- **Controlled ISB has been used successfully in Canada, US and Scandinavia since 1970s to remove oil spills in ice conditions**
- **Extensive use during Macondo response in GOM sparked renewed interest**
  - >400 burns removed 220,000 to 310,000 bbls oil
- **State of Knowledge report based on 1994 MSRC report**
  - updated with results of R&D since 1994
  - expanded to include R&D on ISB in ice since 1970

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REPORT CONTENTS

- Brief History of ISB in Ice
- Fate and Behaviour of Oil in Ice re: ISB
- Science behind ISB
- Experimental Studies of ISB in Ice and Actual Spills
- Equipment and Technology
- Environmental and Human Health Aspects
- Operational Aspects

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KEY FINDINGS OF THE REPORT

- **Basic principles of ISB are well understood for a variety of snow and ice conditions**
- **Technology exists to conduct controlled in-situ burns of oil spilled in a wide range of ice conditions**
- **Controlled burning can be done safely and effectively**
- **In almost all situations, ISB provides positive environmental benefits that outweigh the drawbacks**
- **Most perceived risks with burning are easily mitigated by following approved procedures**

BRIEF HISTORY OF ISB IN ICE

- First recorded use in 1958 (burn oil from pipeline spill on Mackenzie River ice near Norman Wells, NWT)
- Since 1970s numerous burns (both experimental and to remove actual spills) have taken place in ice conditions
- Significant research effort in support of Beaufort Sea drilling in the 1970s and 1980s

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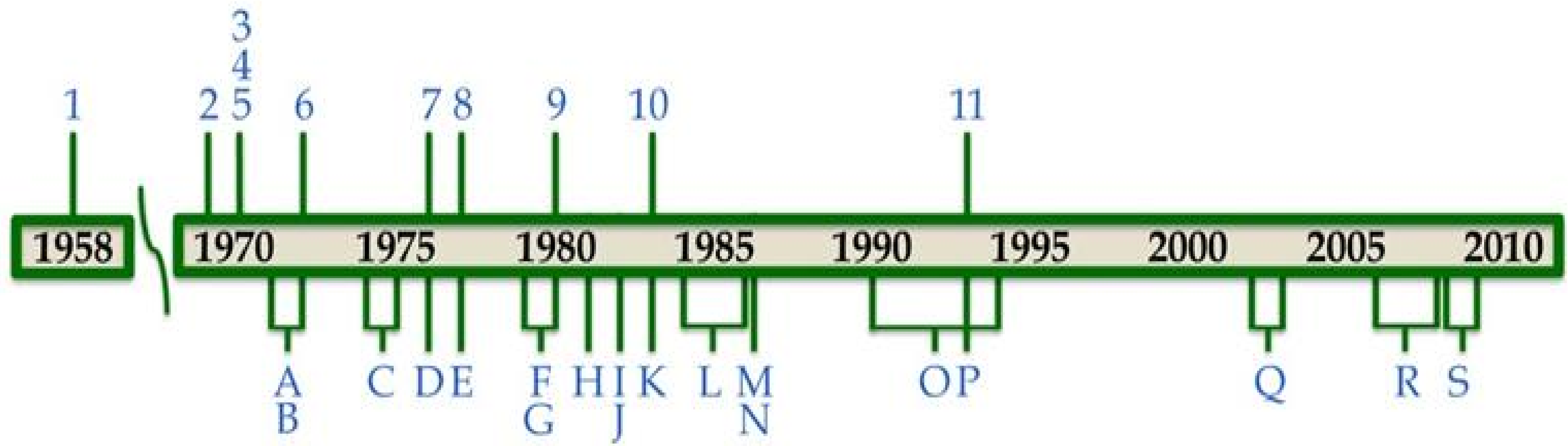
TIMELINE OF BURNS IN ICE SINCE 1958



Letters denote experimental spills - Numbers denote actual spills

LOCATIONS OF BURNS IN ICE SINCE 1958

Letters denote experimental spills - Numbers denote actual spills

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FATE AND BEHAVIOUR OF OIL IN ICE RE: ISB

Behaviour of oil in ice governed largely by:

- Ice concentration in pack ice; and,
- Processes of encapsulation and subsequent appearance in spring for close pack/fast ice.

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FATE AND BEHAVIOUR OF OIL IN ICE

Each ice season presents different challenges and opportunities for controlled in-situ burning:

Transition periods (freeze-up and break-up) drifting ice and limited site access tend to restrict ISB response options and reduce removal effectiveness

FATE AND BEHAVIOUR OF OIL IN ICE

Mid-winter and early spring provide more stable ice conditions that naturally contain oil within a relatively small area and provide a safer working platform for surface oil removal

- Spills under or on landfast ice, offer a range of effective burning options with very high ISB effectiveness.
- ISB options for spills in moving pack ice offshore are limited by responder safety concerns
  - highly variable removal efficiencies, depending on circumstances of the spill
  - often only possible to track the oil until it is released from the ice in spring

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SCIENCE OF ISB

- Study presents a treatise on the science of in-situ burning:
  - Detailed literature review
  - Summary of key physical and chemical processes involved in in-situ burning
  - Discussion of factors that control ignitability and combustibility of oil on water
- Special attention paid to how oil weathering affects ignition and burning processes, e.g., water-in-oil emulsification, evaporation

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SCIENCE OF ISB

- Present understanding of ISB is summarized in “rules-of-thumb” for:
  - Minimum ignitable thickness for various oils and degrees of weathering
  - Burn rates for various oils
  - Residue thickness as a function of oil type and initial slick thickness
  - Effects of emulsification
  - Effects of brash and frazil ice on minimum ignitable thickness, flame spreading, burn rate and residue thickness

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LITERATURE REVIEW OF EXPERIMENTAL AND ACTUAL SPILLS

- In-depth review of literature on ISB in wide range of ice conditions
- Particular focus on larger test tank and field experiments
- Broken into three categories:
    1. ISB on ice
    2. ISB in snow
    3. ISB in slush, brash, drift and pack ice

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EXPERIMENTAL SPILLS

A: USCG experiments near Barrow, AK, 1971-72
B: Experiments by McMinn near Barrow, AK, 1971-72
C: Experimental spill in Balaena Bay, Canada, 1974-75
D: Experiments in Yellowknife, Canada, 1976
E: Experiments by Energetex in Waterloo, Canada, 1977
F: Experiments at McKinley Bay, Canada, 1979-80
G: Experiments by Energetex at Mckinley Bay, Canada, 1979-80
H: Experiments at McKinley Bay, Canada, 1981
I: Experiments at Prudhoe Bay, AK, 1982
J: Experiments at McKinley Bay, Canada, 1982
K: Tier II burn tests at Prudhoe Bay, AK, 1983
L: Experiments at OHMSETT, NJ, 1984-86
M: Experiments at Cape Breton, Canada, 1986
N: Experiments in Calgary, Canada, 1986
O: Experiments at Svalbard, Norway, 1990-94
P: Experiments in Barents Sea, 1993
Q: Experiments at Prudhoe Bay, AK, 2002-03
R: Experiments at Svalbard, Norway, 2006-08
S: Experiments in Barents Sea, 2008-09

19 Key Studies

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ACTUAL SPILLS

1: Pipeline Spill, Near Normal Wells, Mackenzie River, Canada, 1958
2: Tanker *Raphael* spill, Finland, 1969
3: Tank farm accident in Deception Bay, Canada, 1970
4: Tanker *Arrow* spill, Chedabucto Bay, Canada, 1970
5: Collision of *Othello* and *Katelysia*, Tralhavet Bay, Sweden, 1970
6: Diesel spill in ice choked river, Sweden, 1972
7: *Imperial St. Claire* spill in Lake Huron/Georgian Bay, Canada, 1976
8: Barge *Bouchard #65* accident in Buzzards Bay, MA, 1977
9: Cargo vessel *Edgar Jourdain* spill, Hall Beach, Canada, 1980
10: Storage tank leak, Warwick Lake, Canada, 1983
11: Tank farm release, ME, 1993

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LITERATURE REVIEW OF EXPERIMENTAL AND ACTUAL SPILLS

- The review showed that there is sufficient information from laboratory, test tank, and field trials to understand the basic principles of burning oil in wide variety of snow and ice conditions

EQUIPMENT AND TECHNOLOGY

Includes reviews of:

- Ignition systems
- Fire-resistant booms
- Floating burners
- Additives:
  - Ignition and burn promoters
  - Smoke suppressors
- Herding agents

History of each technology presented, along with detailed descriptions and data on existing ISB equipment

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EQUIPMENT AND TECHNOLOGY

ISB equipment commercially available for controlled in-situ burning operations in ice:

- Two kinds of hand-held igniters for surface deployment into oil contained in fire booms
- One aerial ignition system specifically designed for oil among and on ice
- Four types of fire boom for use in open water and light drift ice
- Two herding agents for thickening oil for ignition and uncontained burning in pack ice

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ENVIRONMENTAL AND HUMAN-HEALTH ASPECTS

- ISB removes surface oil by driving much of it into the atmosphere in the form of combustion gases and soot
- This reduces environmental threat of the oil slick, at the cost of increasing the threat posed by the airborne plume
- ISB leaves a residue on the water; however, the residue is usually a small fraction of the original oil volume and is less harmful than the unburned oil

ENVIRONMENTAL AND HUMAN-HEALTH ASPECTS

- Challenge - compare effects of burning vs. not burning
- Select option that provides greater net benefit to environment (NEBA)

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ENVIRONMENTAL AND HUMAN-HEALTH ASPECTS

Studies have examined the composition and environmental fate of burn emissions (e.g., NOBE):

- Showed some emissions (e.g., particulate carbon) could pose a threat to human health or wildlife in immediate downwind vicinity
- Surface-level exposure concentrations would be below threshold levels within a few kilometres directly downwind of the burn
- Air samples taken during the Macondo controlled burning operations corroborate this

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ENVIRONMENTAL AND HUMAN-HEALTH ASPECTS

- Burn residues appear to pose little toxicity threat to aquatic resources and human use of water resources
- Residue could possibly sink and foul fishing gear
- Volume of residue left after an efficient burn would be considerably less than original slick

ENVIRONMENTAL AND HUMAN-HEALTH ASPECTS

- Case studies of burns in major spills have revealed no significant impacts to human or ecological resources
- In two cases, burn residues sank after extinguishing and cooling and caused impacts on fish harvesting operations
- The most significant oil burn event ever experienced, the Kuwait oil fires of 1991, does not appear to have caused lasting environmental or human health impacts

ENVIRONMENTAL AND HUMAN-HEALTH ASPECTS

- Study includes a detailed evaluation to estimate the sensitivity of resources and characterize potential effects
- Compared “burn” versus “no-burn” decision
- In almost all circumstances burning crude oil in ice-affected waters reduces potential risks to humans and the environment, compared with leaving the same oil unburned.

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OPERATIONAL CONSIDERATIONS

Summary of the issues and criteria for planning and implementing a safe and effective burn of spilled oil in ice-affected waters:

- The feasibility of burning
- The resources necessary to carry out a successful burn
- Avoiding or minimizing health risks and environmental impacts

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OPERATIONAL CONSIDERATIONS

Potential Arctic spill scenarios:

- Open water
- Various concentrations of drift and pack ice
- Solid or near-solid ice cover

Different ISB tactics selected to suit the specifics of the scenario

TACTICS FOR BROKEN ICE CONDITIONS

- 0 to 3 tenths
  - Oil spread and movement not affected much by ice
  - Use open-water techniques (fire-resistant booms, etc.)
- 3 to 6-7 tenths
  - Oil spread slowed by ice pieces
  - Difficult to maneuver booms
  - Attempt uncontained burning of thick slicks
  - Use herders to concentrate oil
- 6-7 to 9+ tenths
  - Floes touching, oil contained, thick slicks easy to burn

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SUMMARY: KEY FINDINGS

- Basic principles of ISB are well understood for a variety of snow and ice conditions
- Technology exists to conduct controlled in-situ burns of oil spilled in a wide range of ice conditions
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- In almost all situations, ISB provides positive environmental benefits that outweigh the drawbacks
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THANK YOU

QUESTIONS?

www.arcticresponsetechnology.org