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Farahani, Hamed Farmahini ; Alva, Ulises; Rangwala, Ali S.; Jomaas, Grunde

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Convection-driven melting in an n-octane pool fire bounded by an ice wall

Hamed Farmahini Farahani, Wilson U. R. Alva, Ali S. Rangwala, Grunde Jomaas

Presentation
by
Hamed Farmahini Farahani

Department of Fire Protection Engineering
Worcester Polytechnic Institute
Worcester, Massachusetts 01609

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Background

In Situ Burning in Marine Environment

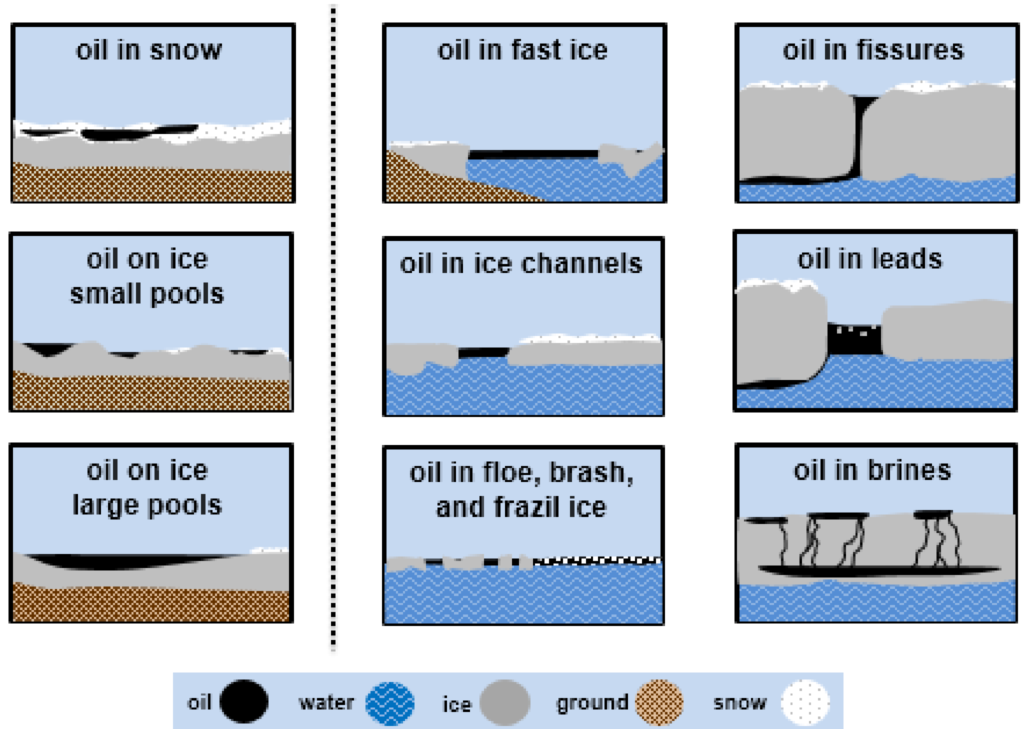
In situ burning after Deepwater Horizon spill 2010

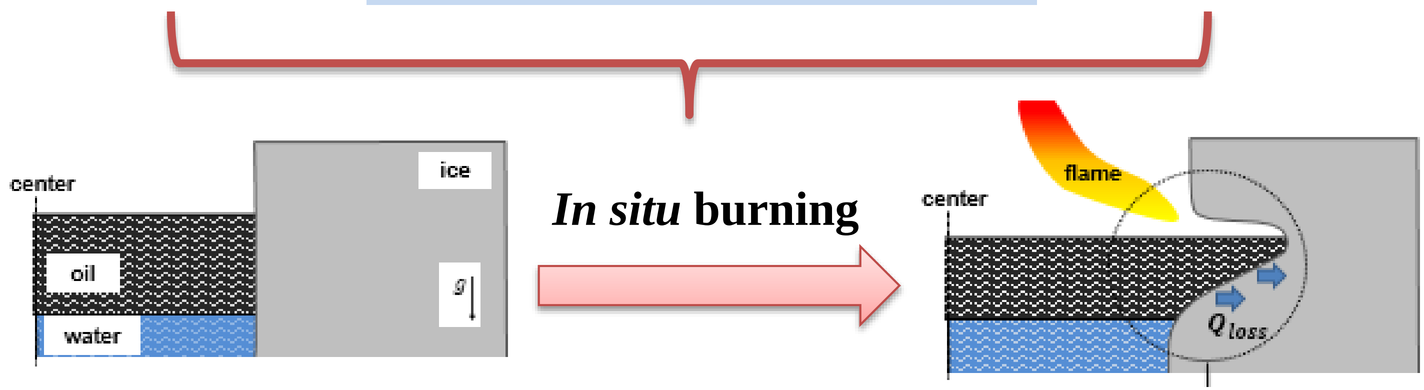
https://www.marinelink.com/news/worst-spill-fire411277

Background

In Situ Burning in Ice-infested Waters

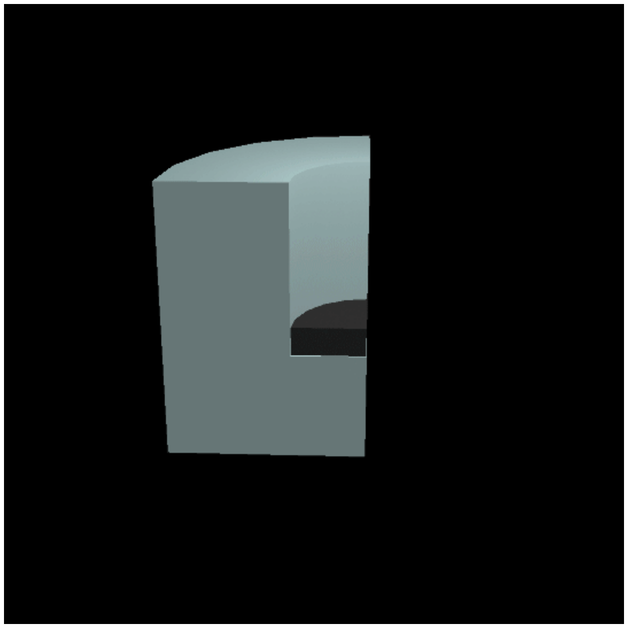
Presence of ice in different forms

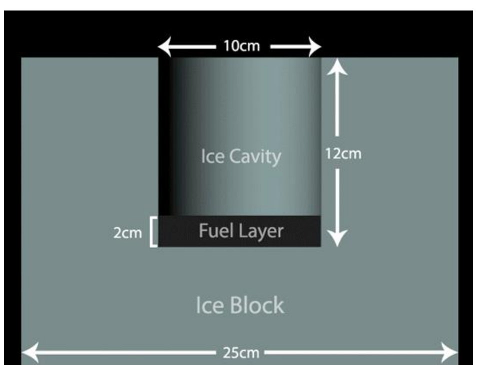




Problem Definition

Geometry Change of Ice and Its Effects





1. Expansion of the pool area
   - ➔ Thinning the fuel layer
   - ➔ Faster extinction
   - ➔ Joining melt pools (multiple small pools adjacent to each other)
   - ➔ Higher burning rates
   - ➔ Deposit of oil residue

Lateral cavity formation

2. Melt-water accumulation
   - ➔ Change in the level of the fuel
   - ➔ Overflow from the top
   - ➔ Faster extinction

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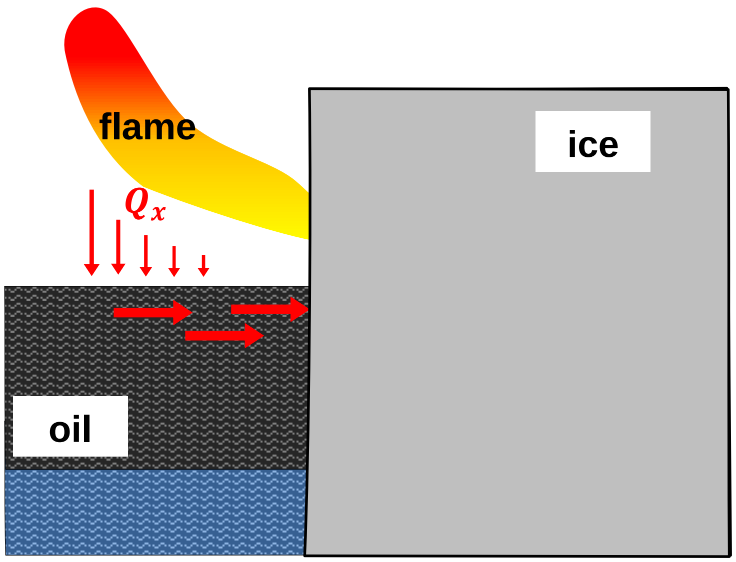
Objective

Lateral Cavity Formation



A) Heat feedback of the flame to the fuel surface
B) Transport of the flame heat by the liquid fuel toward the ice by convection

➔ Melting of the ice by the arriving liquid

Lateral cavity

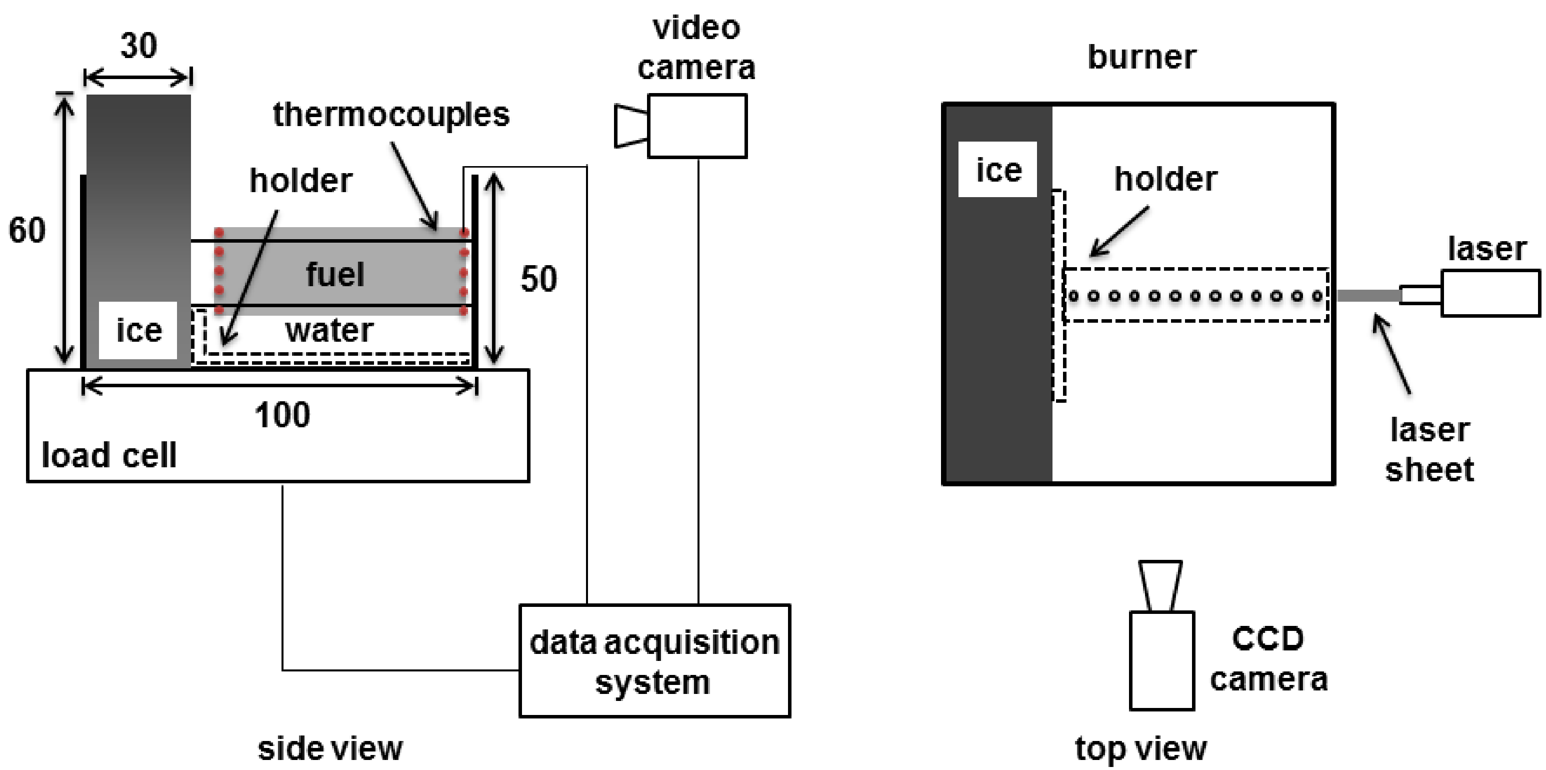
Objectives

- **Visualize** the flow field in liquid fuel and cavity formation
- **Evaluate** the role of convective mechanisms in the melting process

Experimental Setup

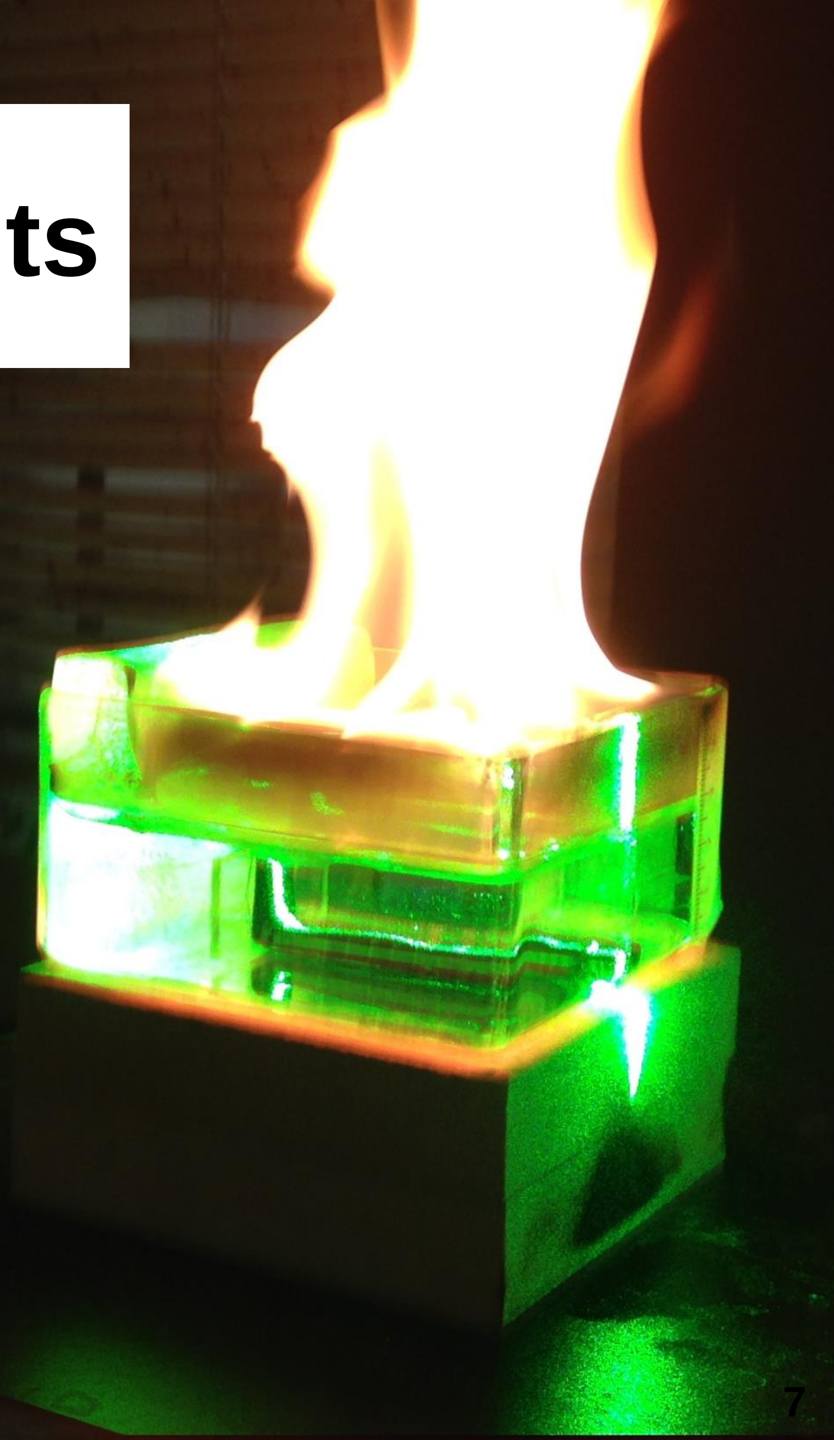
Burning of n-octane adjacent to an ice wall

- **Burning behavior by a load-cell (balance)**
- **Temperature field by thermocouples**
- **Flow field by PIV**



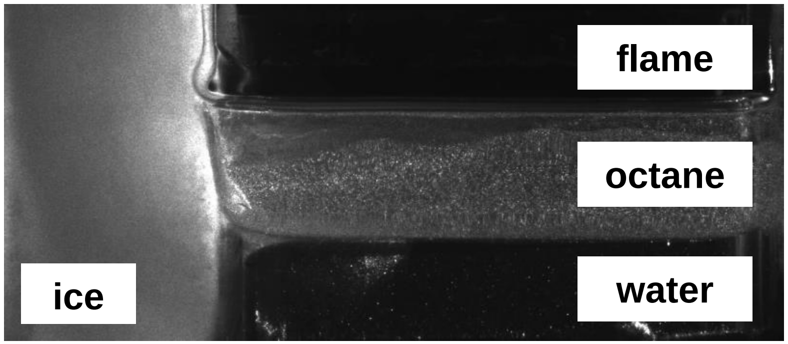
Experimental Results

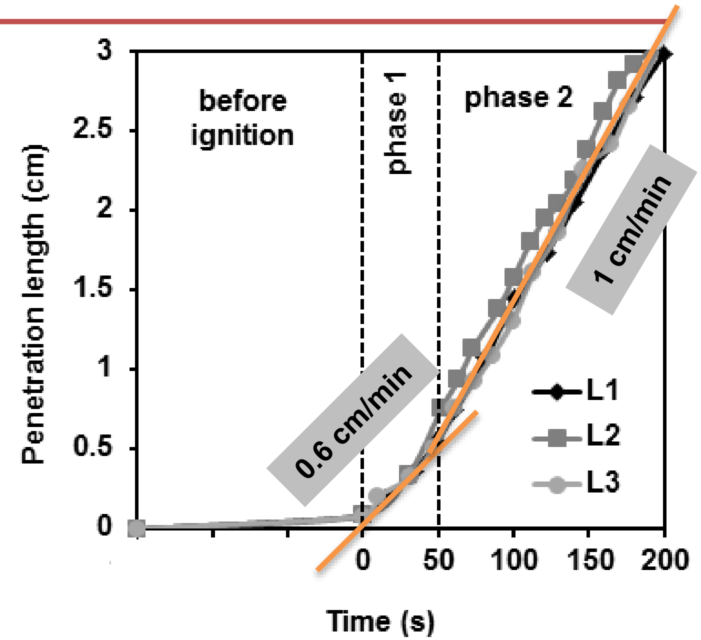
Investigating the effect of heat feedback and convection within the fuel layer on ice melting



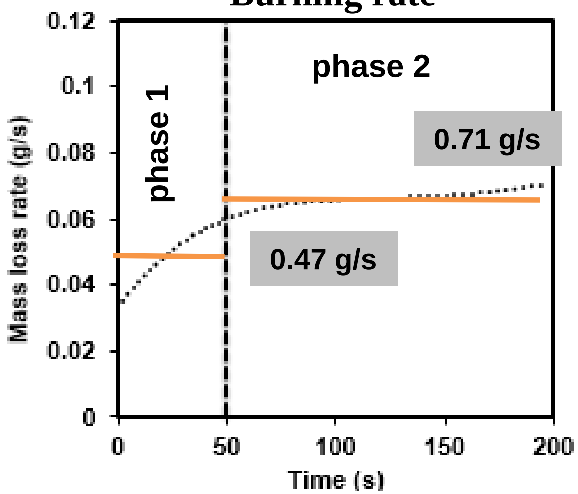
Flame Feedback and Melting

n-octane burning adjacent to 3 cm thick ice

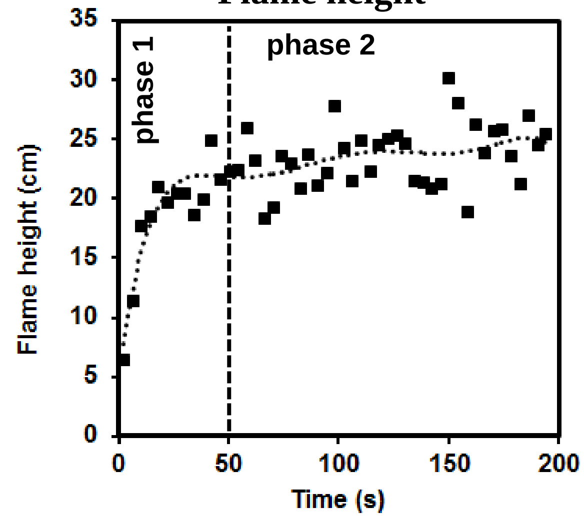




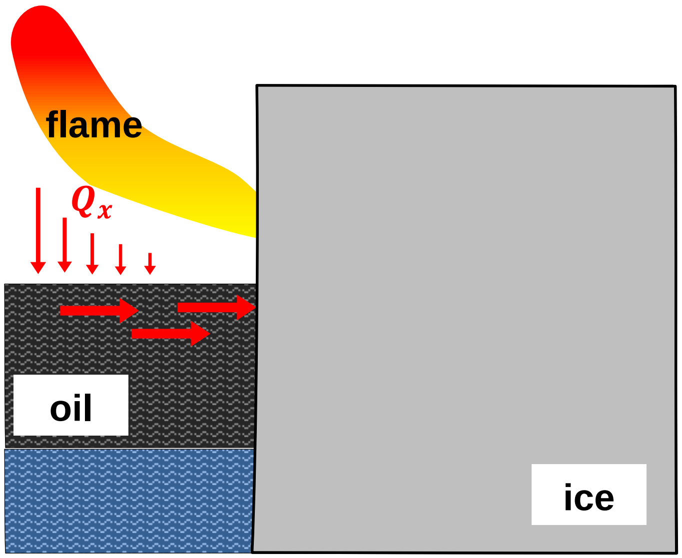
Burning rate



Flame height

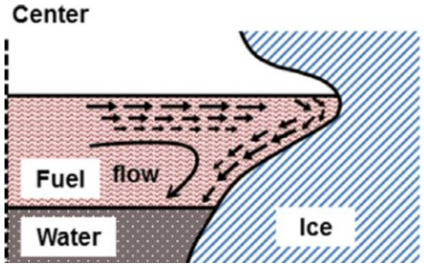


Convection in the Fuel Layer



Transport of the flame heat by the liquid fuel toward the ice by convection to provide the required heat for the melting

Hypothesis:
flows in the fuel layer are driven by the combination of surface tension and buoyancy forces

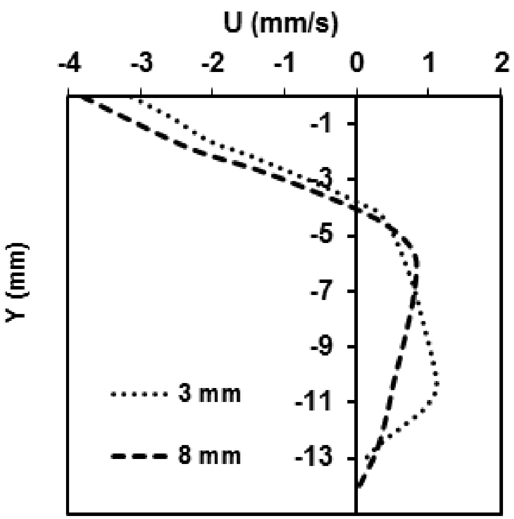


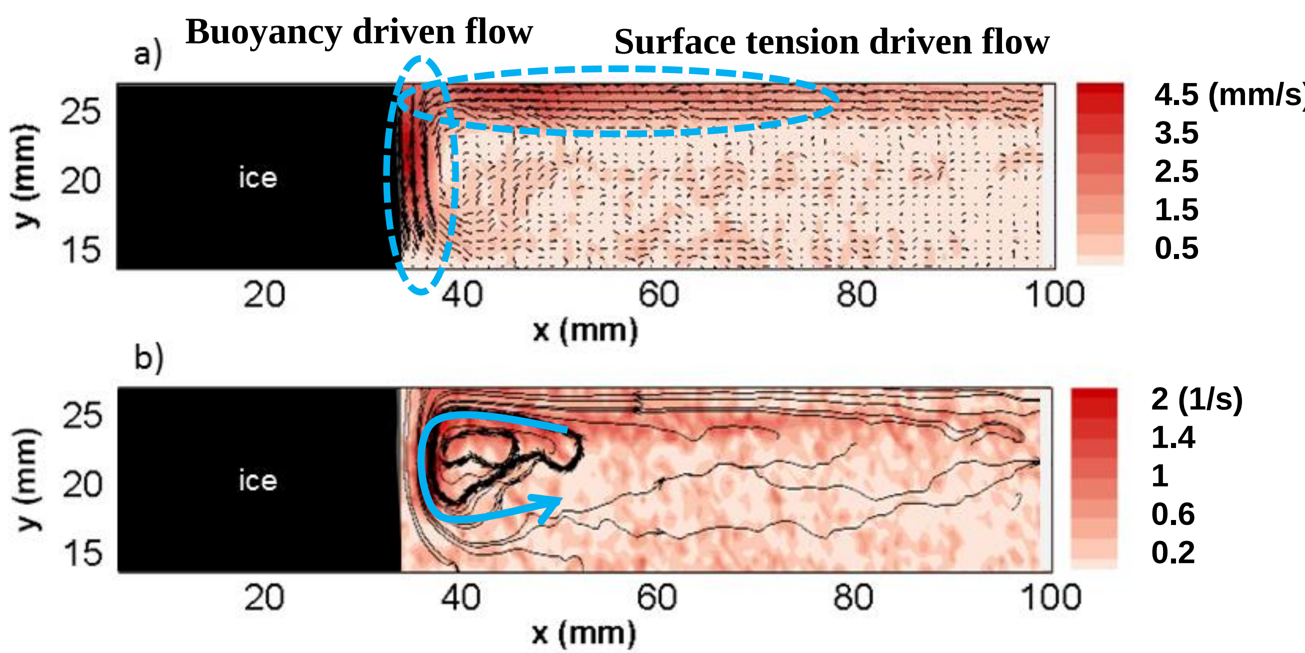
Convection in the Fuel Layer

PIV Results - Before Ignition

- **n-octane temperature is 10-12 °C.**
- **Ice temperature is below 0 °C.**

- **Before ignition**



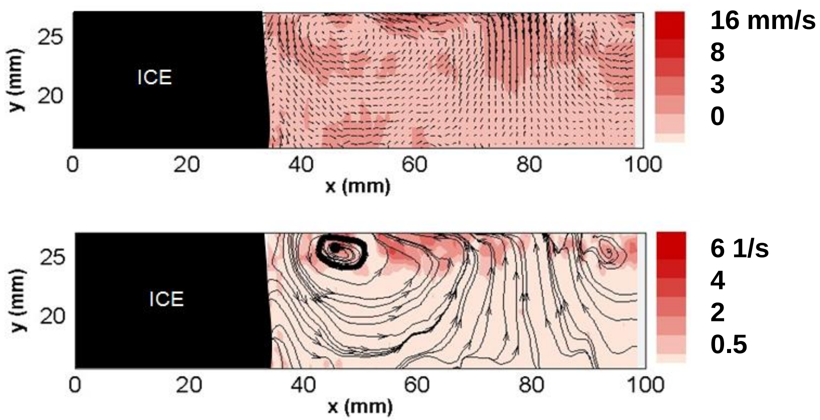


Combined one roll structure

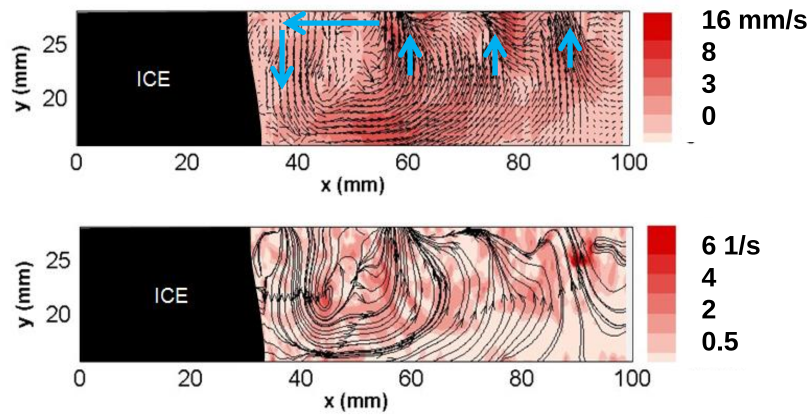
Convection in the Fuel Layer

PIV Results - After Ignition (Phase 1)

- **10 seconds After ignition**



- **40 seconds After ignition**

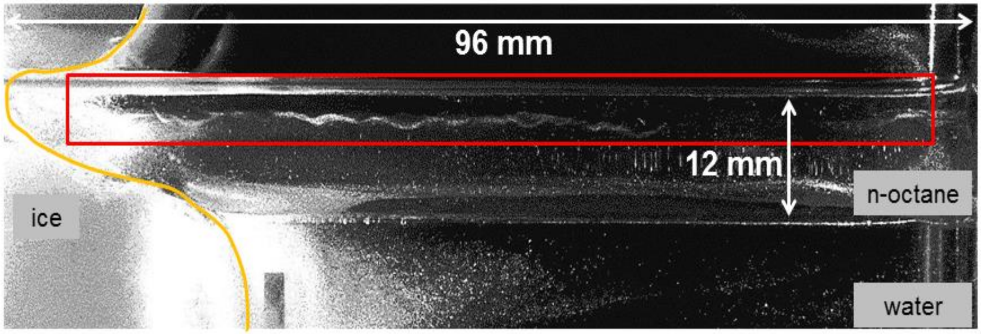


- **Increase in the magnitude of velocity and vorticity over time**
- **Transition from one roll to multi-roll structure**
- **Quality of PIV measurements after phase 1 became low**

Convection in the Fuel Layer

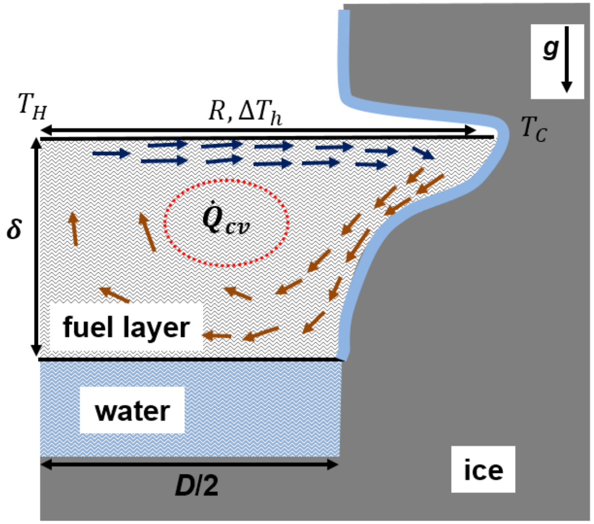
PIV Results - After Ignition (Phase 2)

- **The PIV images lost quality due to the out of plane motions, high temperature differences causing refractive index variation, loss of tracer particles near the surface**
- **The top layer without particles indicate the presence of small recirculation zones known as multi-roll structure**



$$Ma = \frac{\partial \sigma}{\partial T} \frac{\Delta T_h R}{\mu \alpha}$$

$$Gr = \frac{\partial \rho}{\partial T} \frac{g \Delta T_v \delta^3}{\vartheta \mu}$$



Regime		Grashof and Marangoni
before ignition		$Gr_0 \sim 2.6\times10^5$ $Ma_0 \sim 3.2\times10^5$
after ignition	Phase 1	$Gr_1 \sim 1.7\times10^6$ $Ma_1 \sim 5.3\times10^6$
	Phase 2	$Gr_2 \sim 2.1\times10^6$ $Ma_2 \sim 1.2\times10^7$

Conclusions

- Two burning phases were associated with the melting velocity
- The heat pathway from the flame to the ice wall was identified to be the cause for melting the ice
- One roll structure with relatively low velocities were observed before ignition due to the initial low temperature difference
- After the ignition (increase of the temperature difference in the fuel layer) flow field transitioned to an unsteady state with multi-roll structure
- The flow field within the liquid fuel determined the melting

Findings of this study may be applied towards the problems that are related to ice melting caused by global warming

Meet Our Team

Project: In Situ Burning of Oil

http://www.isboil.dtu.dk/

Janne Fritt-Rasmussen

Grunde Jomaas

Ali S. Rangwala

Laurens van Gelderen (Ph.D. Student)

Hamed F. Farahani (Ph.D. Student)

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Thanks

- Questions?

Temperature field