INTERACTION BETWEEN MOLTEN SMELT AND GREEN LIQUOR IN RECOVERY BOILER DISSOLVING TANKS – PRACTICAL IMPLICATIONS

Honghi Tran, University of Toronto

INTERACTION BETWEEN MOLTEN SMELT AND GREEN LIQUOR IN RECOVERY BOILER DISSOLVING TANKS – PRACTICAL IMPLICATIONS

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ABSTRACT

In recovery boiler operation, molten smelt, which consists of mostly sodium carbonate and sodium sulphide, continuously flows out of the boiler at 800 - 830°C through smelt spouts. These molten smelt streams are shattered by steam jets into droplets prior to falling into a dissolving tank where they dissolve in water to form green liquor. The interaction between molten smelt and green liquor in the dissolving tank produces loud noise and can be violent. In extreme cases, it can cause catastrophic explosions resulting in equipment damage, personnel injury and costly boiler downtime. As regulations on occupational health and safety become increasingly stringent, safe and effective dissolving tank operation has become a top priority for kraft pulp mills.

A research program has been conducted at the University of Toronto over the past 8 years to investigate the interaction between molten smelt and a steam jet, the interaction between molten smelt and green liquor, the acoustics of a dissolving tank, and the impact of tank hydrodynamics on smelt dissolution. The behaviour of molten smelt droplets at the moment they contact water was documented using a high-speed video camera coupled with a high-quality microphone. The results show that some droplets explode immediately upon contact with water, some explode after a short delay, while others do not explode at all. The probability of a molten smelt droplet exploding depends strongly on water temperature and smelt composition (particularly sulfidity), and to a lesser extent, on smelt temperature and green liquor composition. The height from which molten smelt falls to the liquor surface, the level of agitation in the tank and the presence of an external triggering event can all accelerate droplet explosion. There is a clear evidence that the explosion of one droplet can trigger the explosion of other droplets nearby, leading to a multi-droplet chain explosion. These results, along with mill experience, imply that in order to rapidly and safely dissolve molten smelt in green liquor, it must be shattered into smaller fragments and distributed over a large area in the dissolving tank.

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FINNISH RECOVERY BOILER COMMITTEE

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Interaction between Molten Smelt and Green Liquor in Recovery Boiler Dissolving Tanks – Practical Implications

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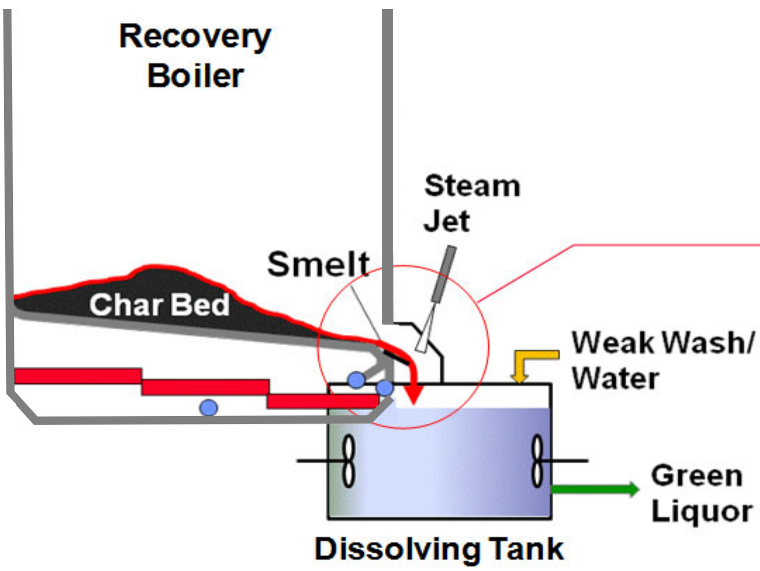
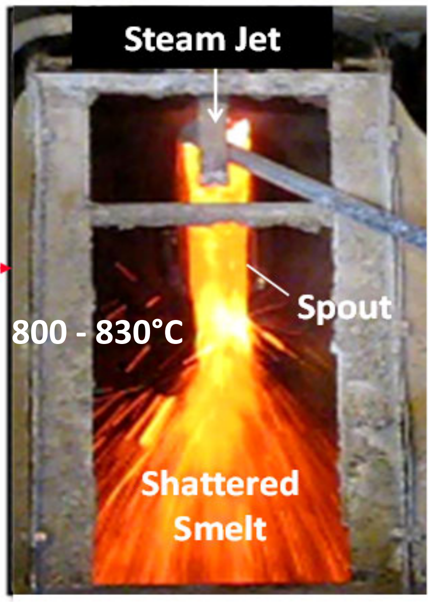
Dissolving Tank Operation





Dissolving Tank Operation

- Requires molten smelt droplets to explode when in contact with liquor
  - Dissolve/disperse quickly
- Undesirable scenarios
  - Uncontrolled explosion: Loud noise, building rumbling, and even tank explosions
  - No explosion: Solidified smelt accumulation at tank bottom $\rightarrow$ heavy scale formation, and poor liquor properties
- Dissolving tank explosion has increasingly become an important safety issue

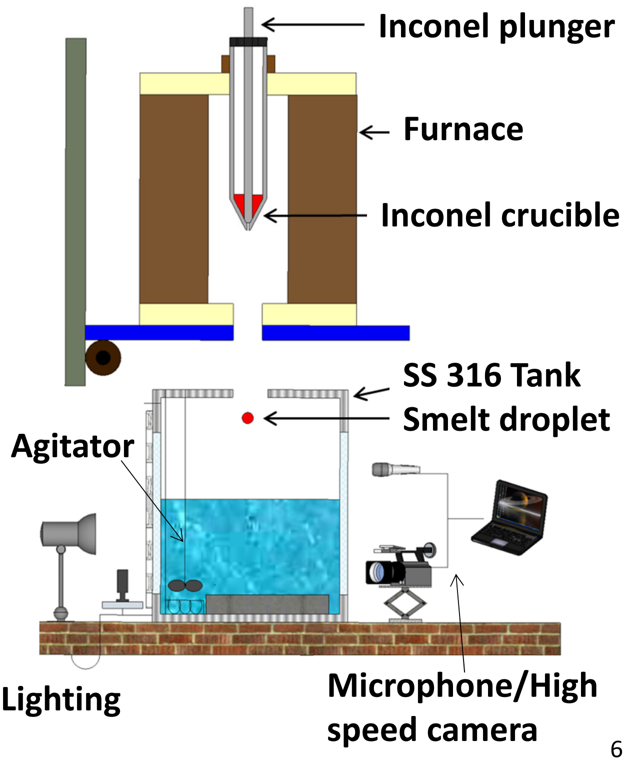
Dissolving Tank Operation

Research at U. of Toronto (Past 8 years)

- Molten smelt – steam jet interaction
  - 3 master's students
- Molten smelt – green liquor interaction
  - 1 PhD student (Eric Jin)
- Dissolving tank noise (acoustic) analysis
  - 1 PhD student
- Dissolving tank hydrodynamics and impact on smelt dissolution
  - 2 master's students

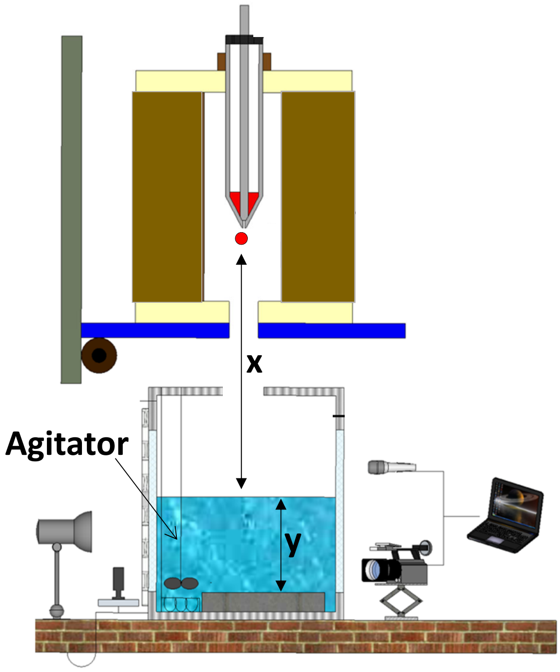
Apparatus and Test Conditions

- Samples
  - Na_2CO_3 and NaCl mixtures
  - Eutectic mixtures of alkali salts
  - Kraft mill smelts
- Droplet size
  - 7 mm
- Water/GL temperature
  - 25 – 100^{o}C
- Smelt temperature
  - 800 – 1000^{o}C
  - 50^{o}C above eutectic temperature



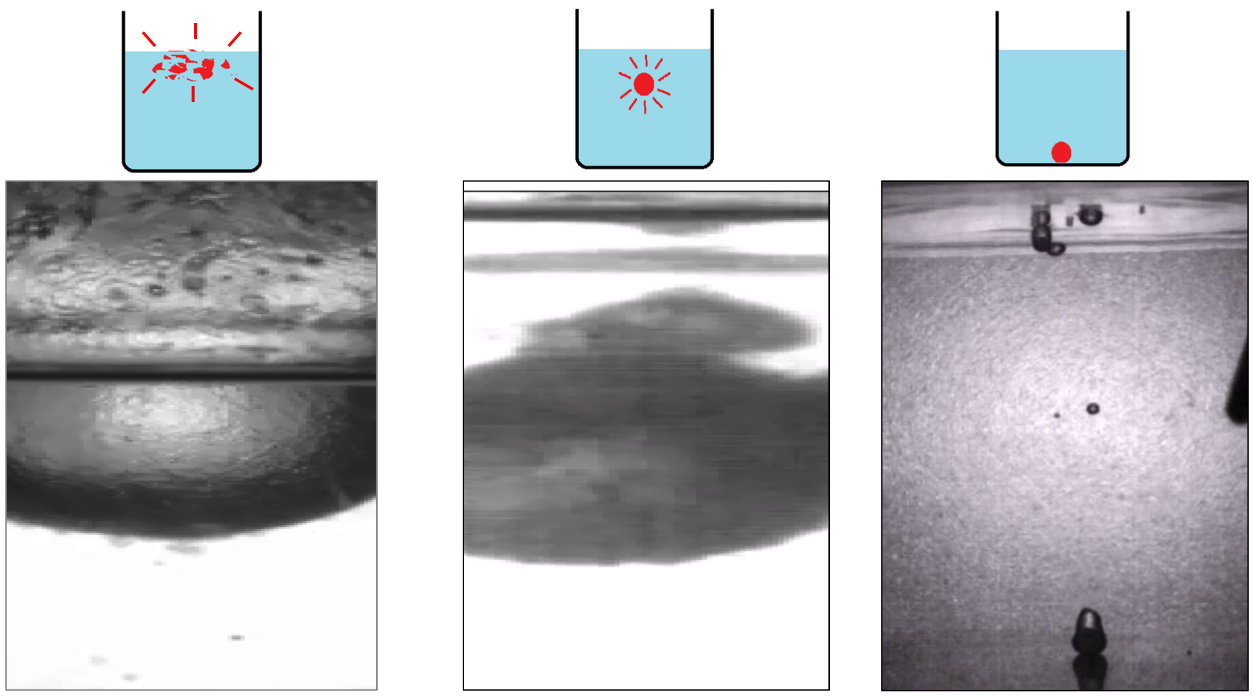
Test Conditions

- Green liquor TTA
  - Boiling point rise
- Smelt composition (sulfidity)
- Smelt falling distance (x)
- Liquor depth (y)
- Agitation
- Disturbance

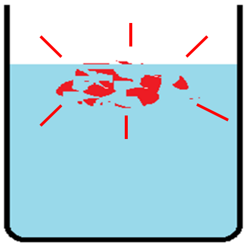


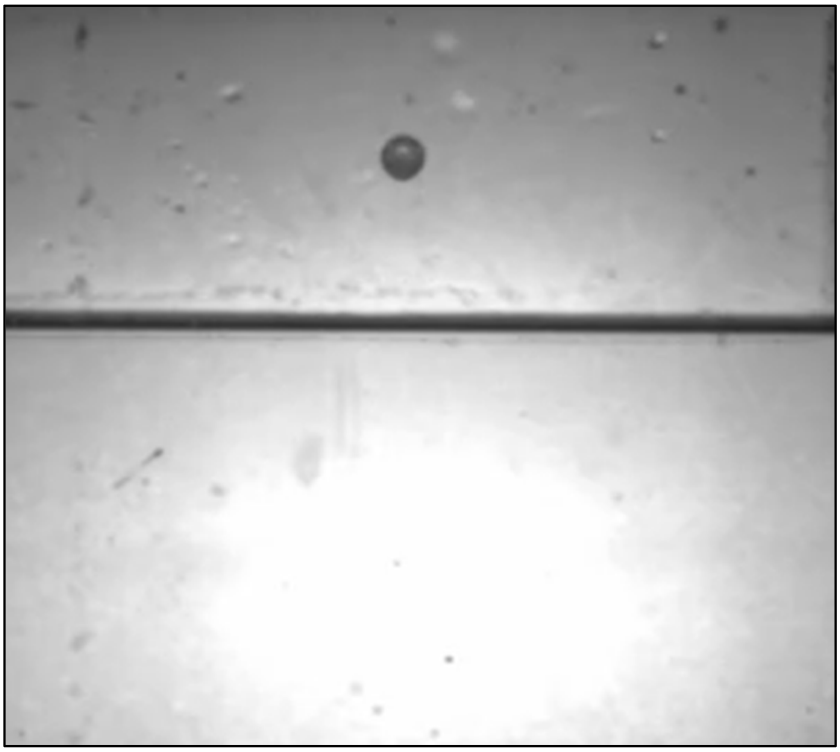
Three Types of Interaction

Immediate Explosion	Delayed Explosion	No Explosion



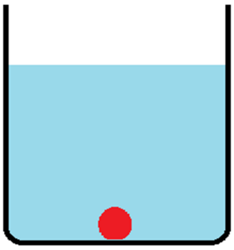
Immediate Explosion

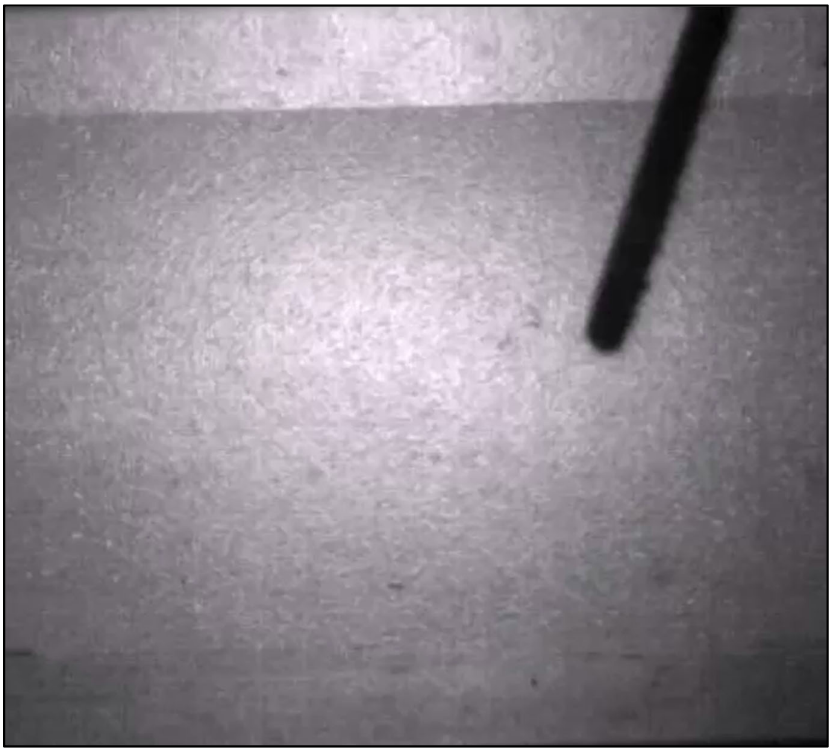




Delayed Explosion

No Explosion





Chain Explosion

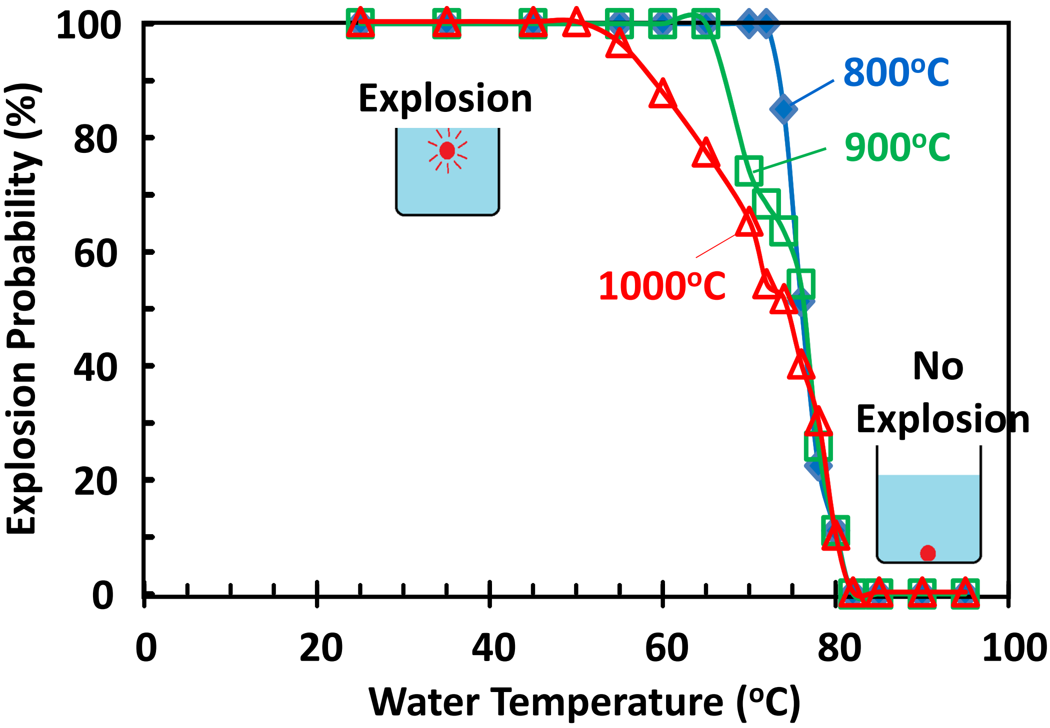
PHANTOM

Camera: Phantom v2512
Resolution:1280x800
Frame Rate: 25000/s

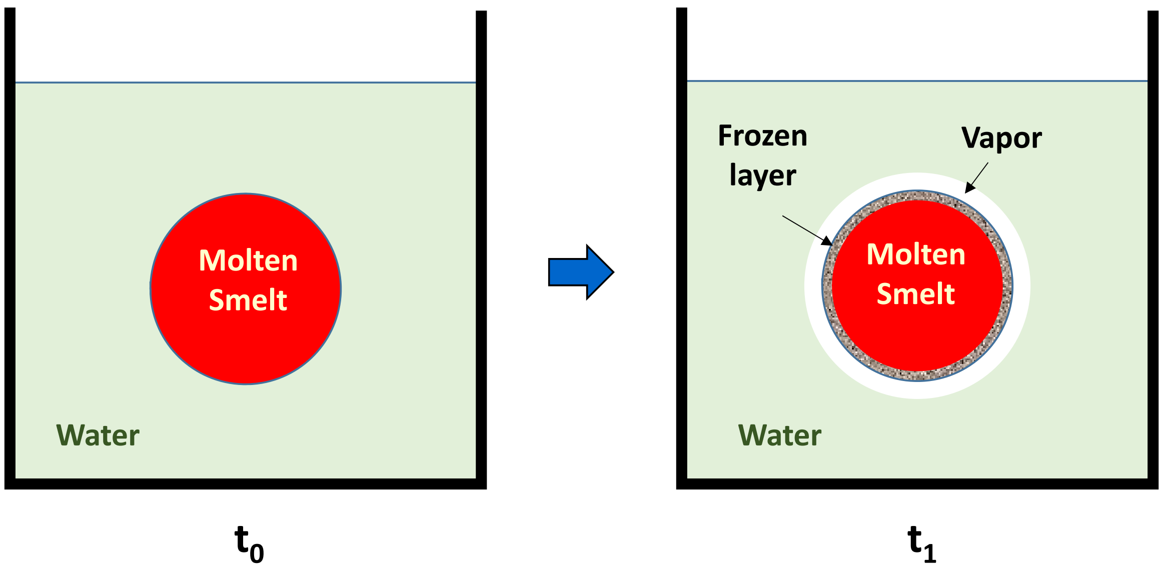
- **Explosion of one droplet can cause other droplets nearby to explode**

Effects of Smelt and Water Temperatures

(80 wt% Na_2CO_3 – 20 wt% NaCl)

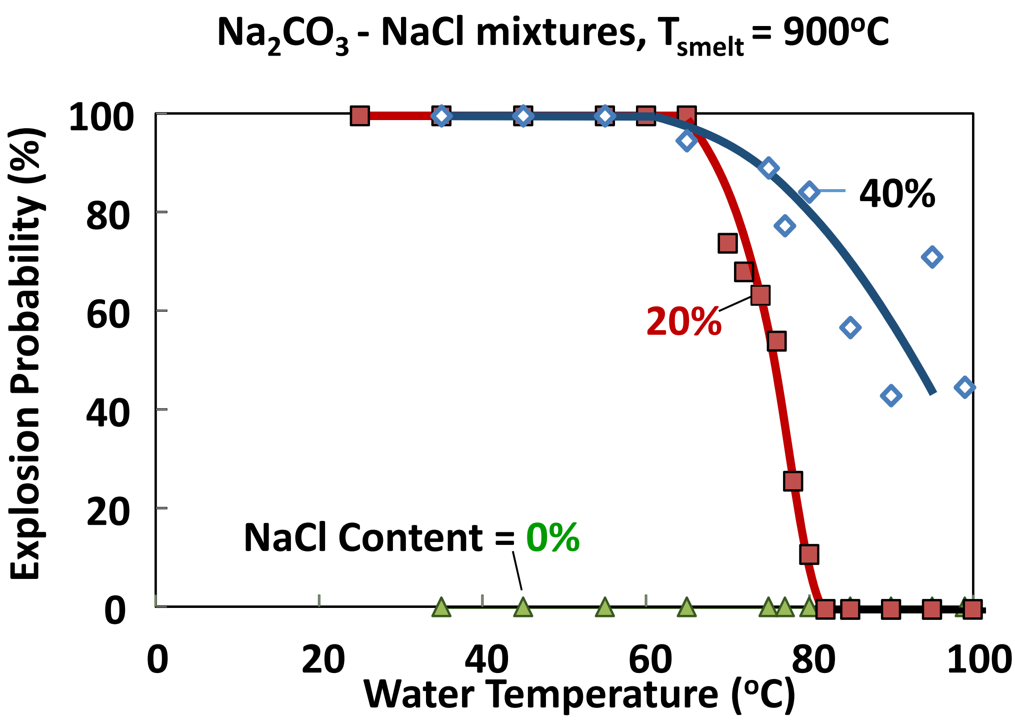


Importance of Vapor Film and Frozen Layer



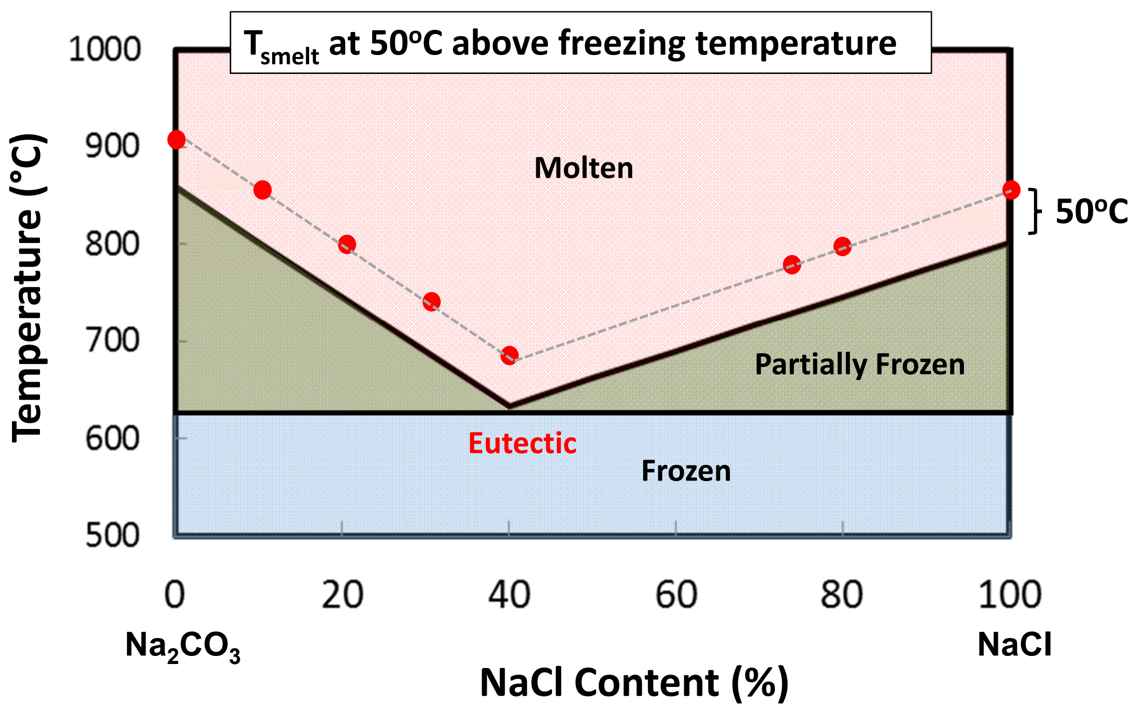
- Vapor film and frozen layer separate molten smelt from water, making it less likely to explode

Effect of Smelt Composition



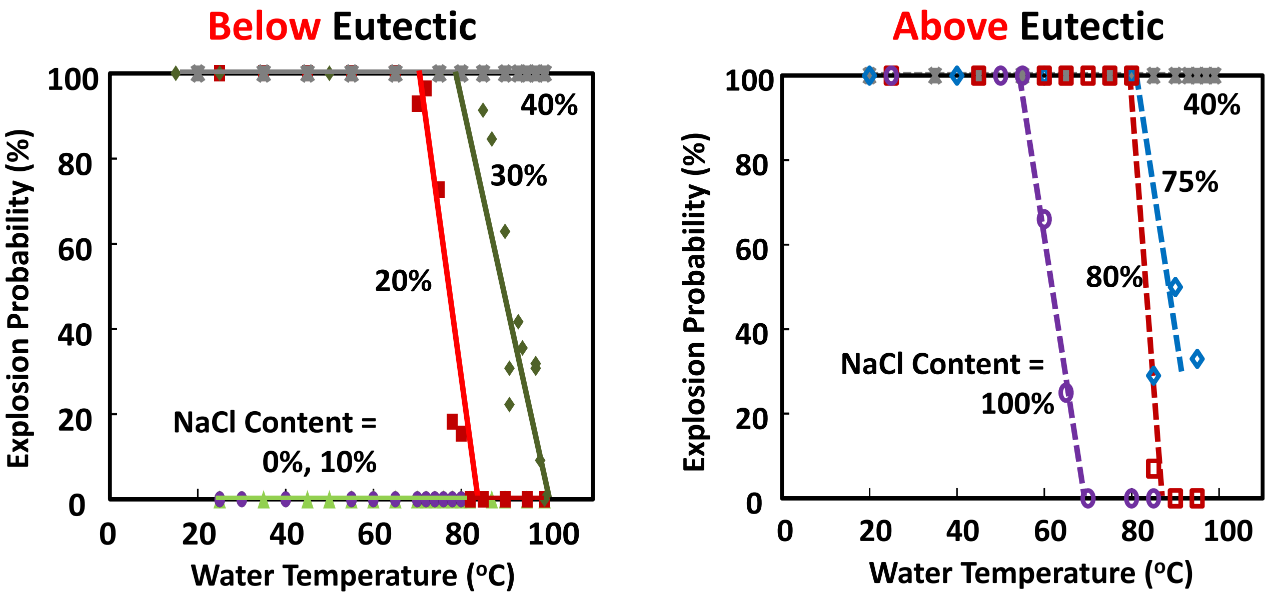
- Higher NaCl content → More likely to explode

Effect of Smelt Composition



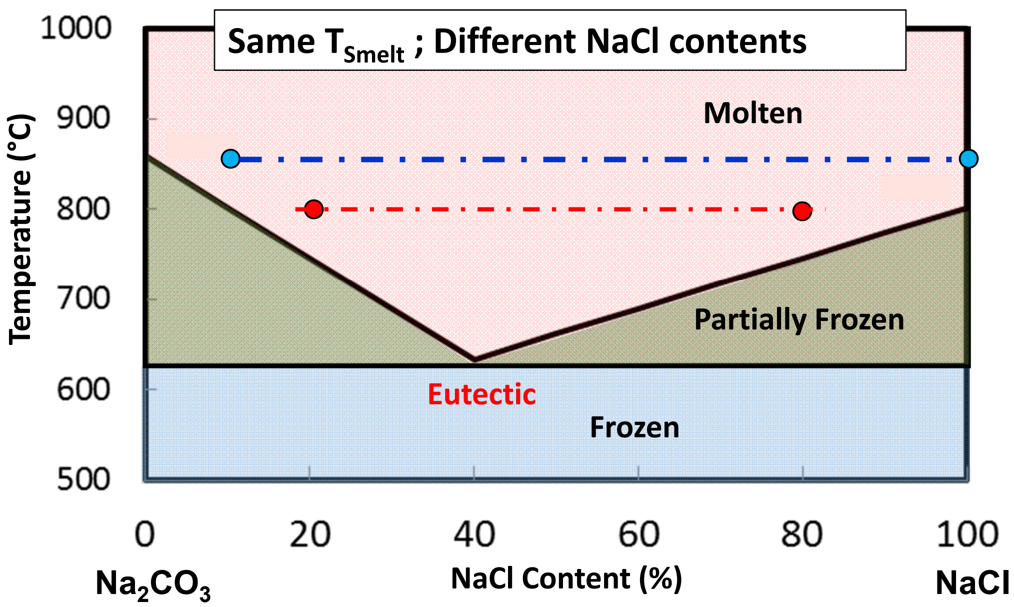
Effect of Smelt Composition

T_{smelt} at 50°C above freezing temperature



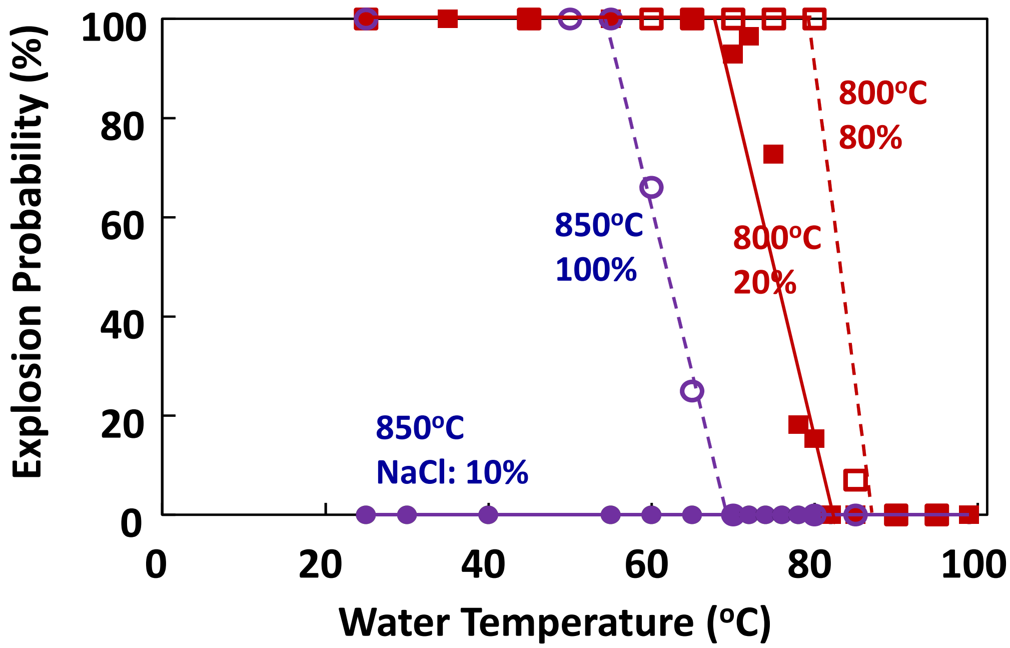
- Closer to eutectic composition → more likely to explode

Effect of Smelt Composition



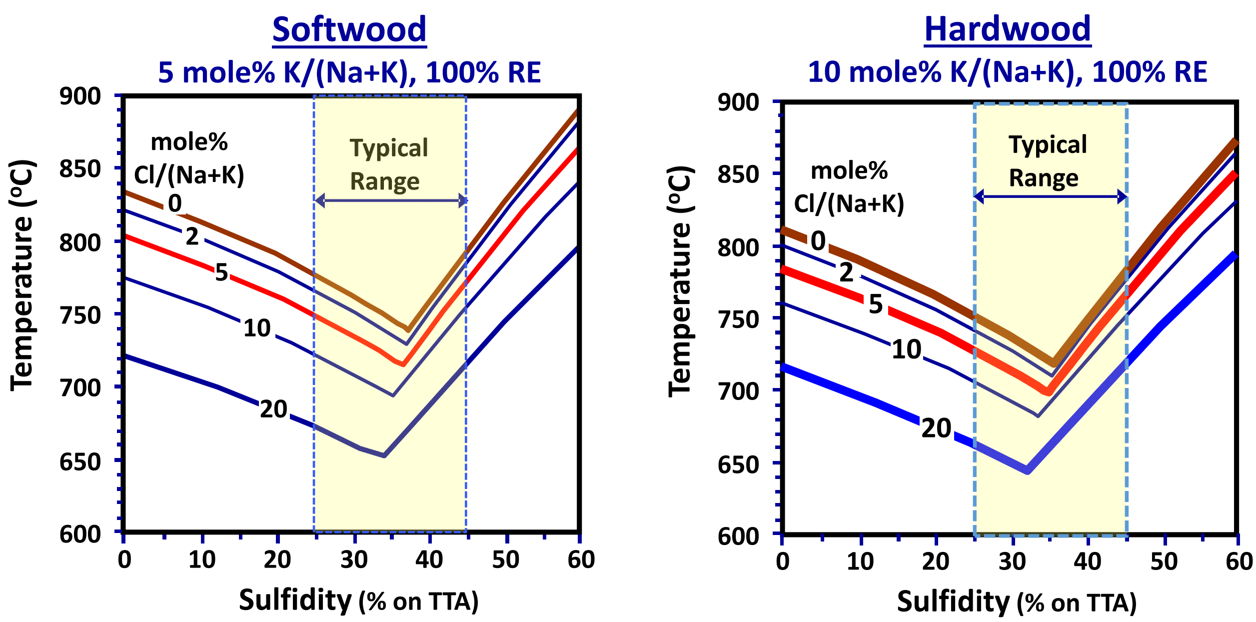
Effect of Smelt Composition

(Same T_{Smelt}, different NaCl content)

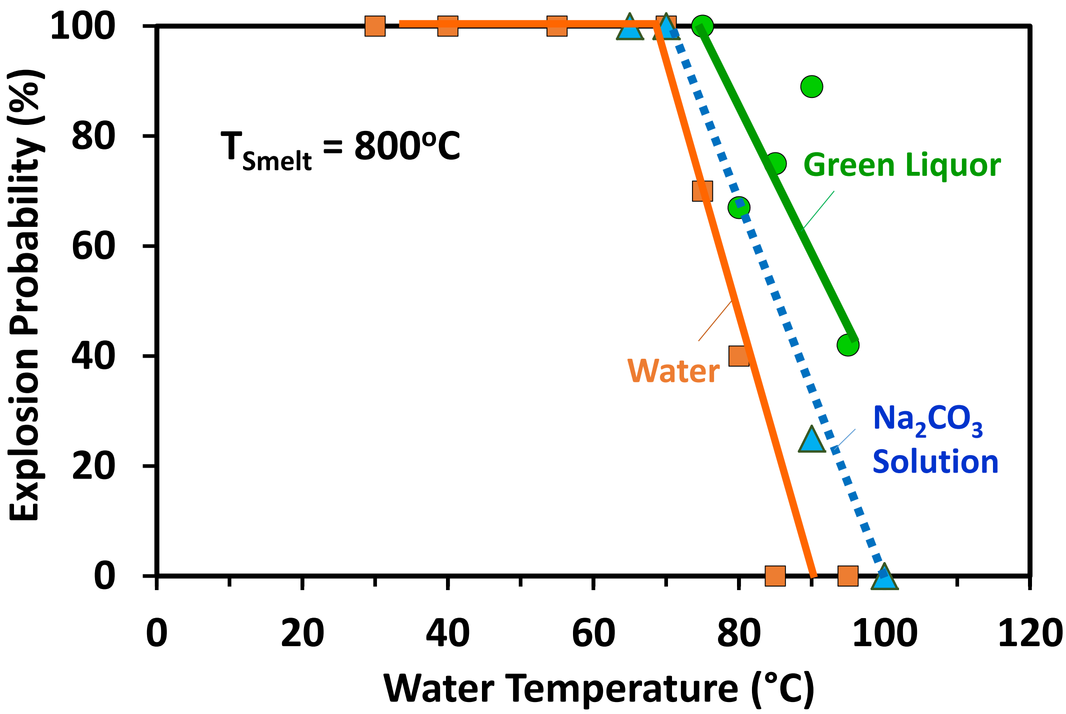


- Higher NaCl content → more likely to explode
  - NaCl has lower k, Cp, ρ values than Na_2CO_3

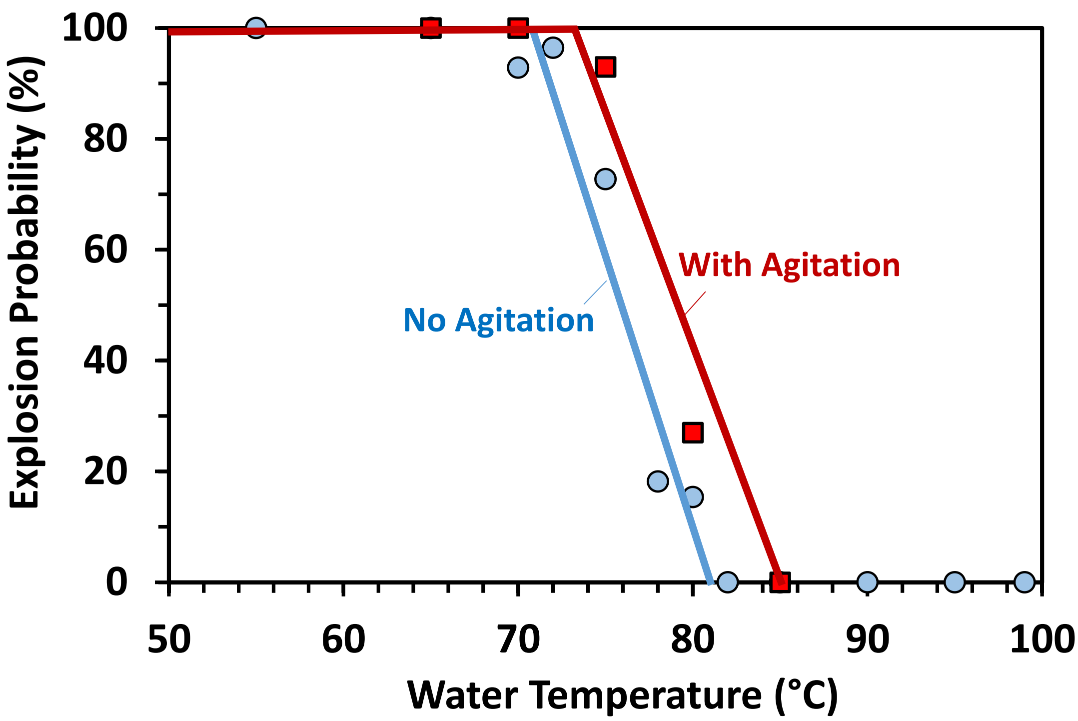
Effect of Sulfidity on Smelt Freezing Temperature



Effect of Liquor Composition

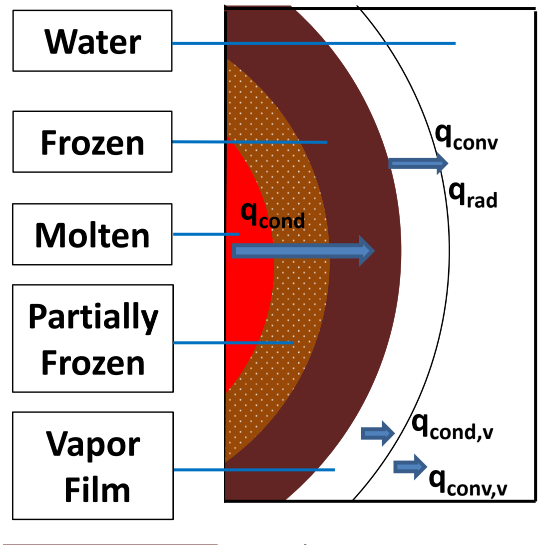


Effect of Agitation



- Agitation disrupts the vapor film promoting explosion

1D Heat Transfer Model

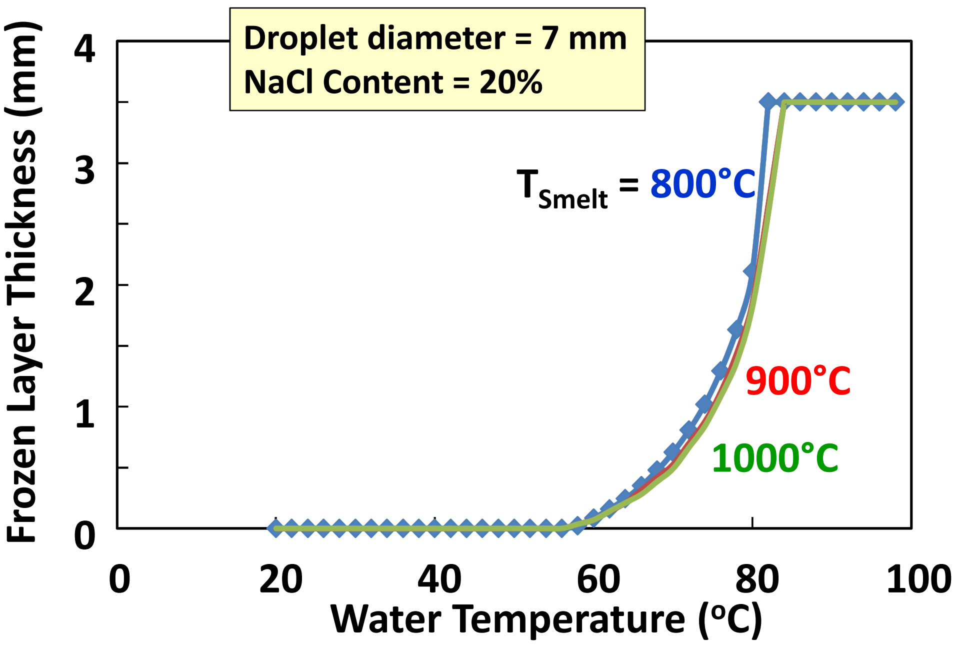


- **Model Input:**
  - T_{water}
  - T_{smelt}
  - **Smelt droplet diameter**
  - **Melting temperature**
  - **Thermal conductivity**
  - **Heat capacity**
  - **Density**

  Affected by Composition (Melting temperature, Thermal conductivity, Heat capacity, Density)

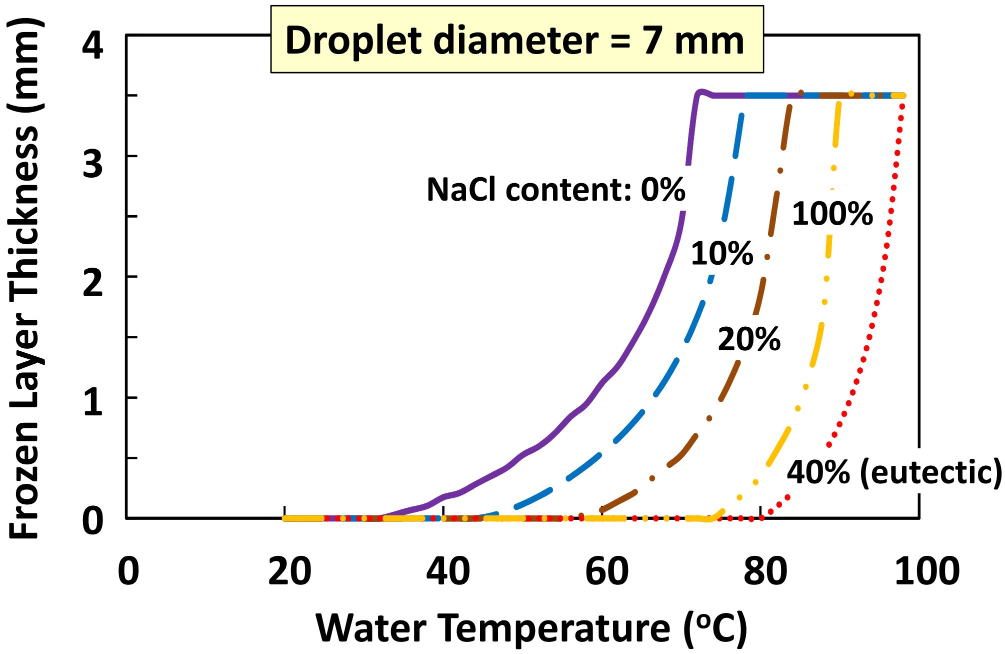
- **Model Output:**
  - **Solidified layer thickness at $t_{collapse}$**

Predicted Frozen Layer Thickness



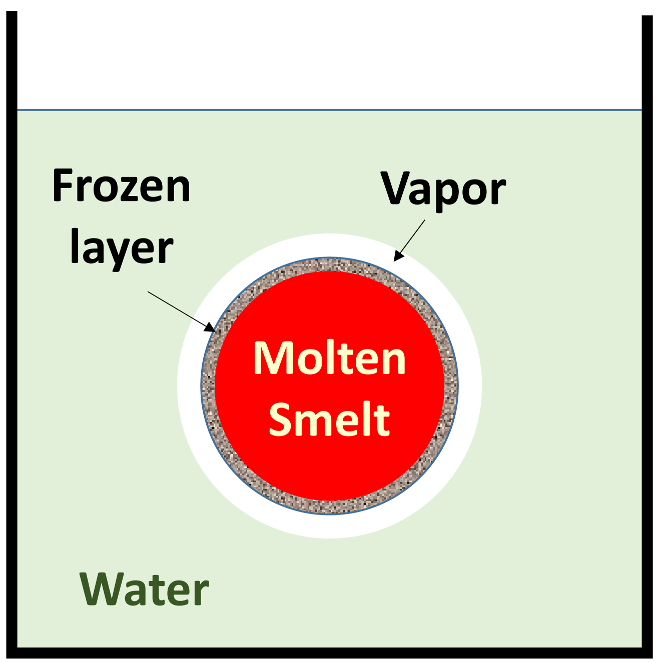
- ***Higher T_{water} → Thicker frozen layer → Less likely to explode***
- ***T_{smelt} has little effect***

Predicted Frozen Layer Thickness



- *Closer to eutectic composition → Thinner layer → More likely to explode*

Importance of Frozen Layer Thickness at the Time when Vapor Film collapses



Conclusions and Practical Implications

- **Explosion is needed in order for smelt to effectively dissolve and disperse;**
- **Some molten smelt droplets explode immediately upon contact with water, some explode after a short delay, while others do not explode at all;**
- **Explosion of one droplet can trigger explosion of other droplets nearby, leading to a multi-droplet chain explosion.**

Conclusions and Practical Implications

- **Explosion occurs more likely with**
  - **Lower liquor temperature**
  - **Larger droplet size**
  - **Higher liquor TTA**
  - **Smelt sulfidity at around 35% (on TTA)**
  - **Higher Cl and K contents in smelt**
  - **Greater disturbance**

Acknowledgements

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