# Field Examples and Mitigation Strategies for Sulphide Mixtures with a High Risk of Self-heating©

*Presentation to MLARD Conference*

*December 2, 2020*

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# This presentation covers

*Assessing Self-heating Risk*

- The FR-2 test & Risk Assessment

*Mitigation and Examples*

- The approach to mitigation
- Neutralizing acid
- Using reactive pastefill
- Chemical treatment
- Excluding oxygen
- Removing moisture
- Control Mineralogy –removing pyrite
- Reactive blast hole modelling – Red Dog

# Characterizing Self-heating Behaviour – the FR-2 test

**<u>Stage A</u>**

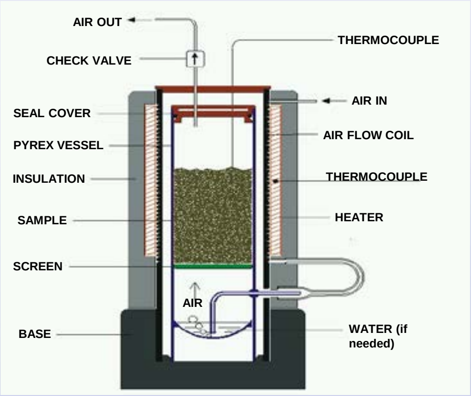
- 6% moisture
- **70 $^{o}$C**
- 48 hrs

An accelerated "weathering" stage

**<u>Stage B</u>**

- Continues from Stage A
- **140 $^{o}$C**
- 48 hrs

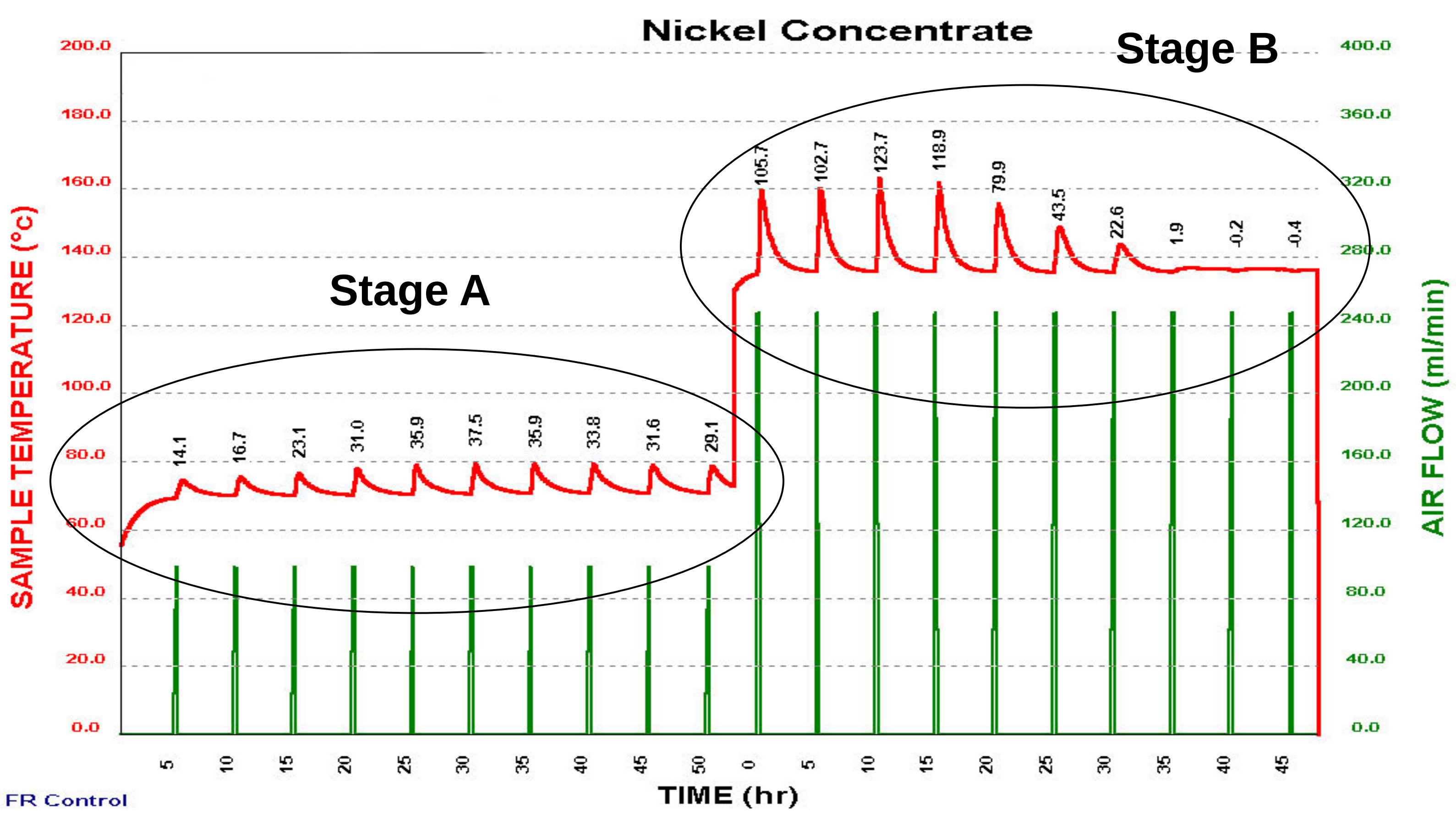
Oxidation at elevated temperature (moisture driven off)




*500g sample*

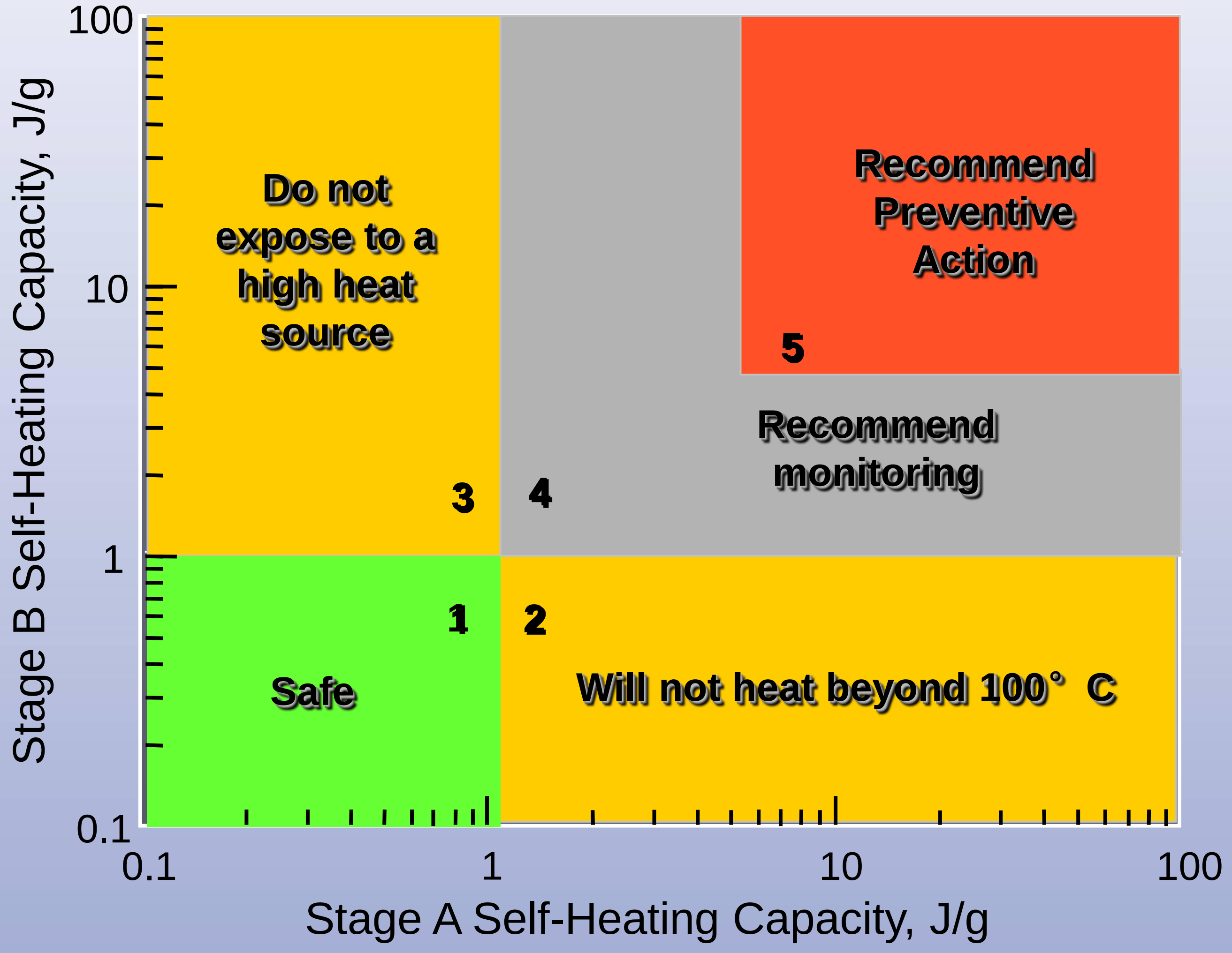
*Air is blown in for 15 min every 5 hours*

# Example Results
# - the Self-heating Thermogram

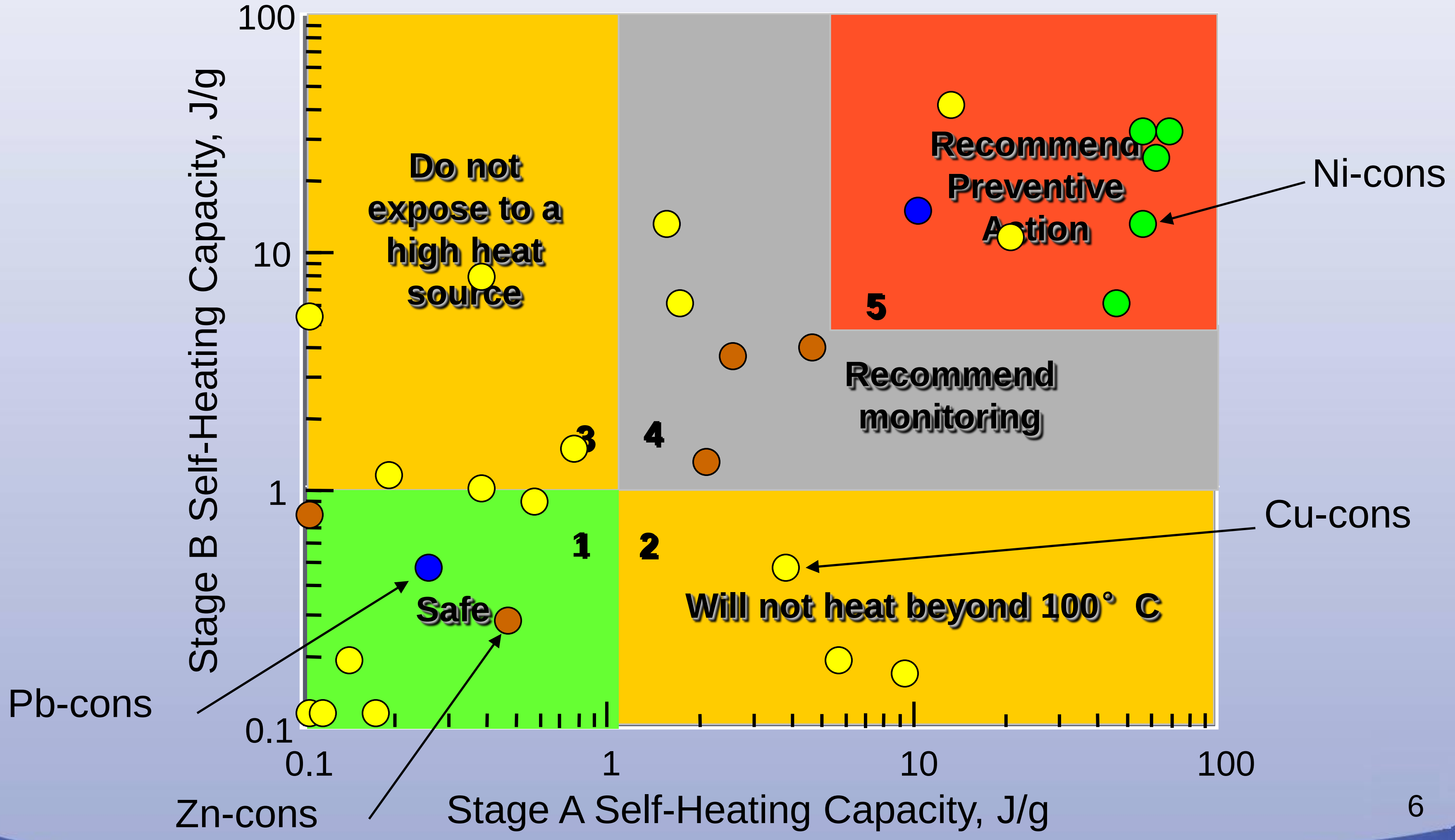



Calculate Stage A and Stage B self-heating capacity (J/g)

# Risk Assessment Chart
## SHC B vs. SHC A: 5 Risk Regions



# Risk Assessment Chart
## Different concentrates



# How to Approach Mitigation

# The Road Map to Mitigation: Interrupting the chain of reactions

$O_2 + H_2O$ + MeS

↓

acid + MeS

↓

$H_2S + S^o$

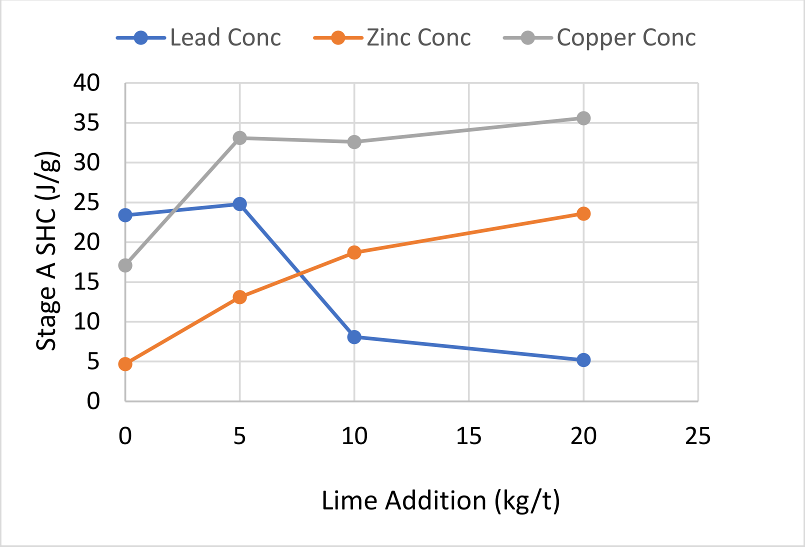
↓

self-heating (A &B)

- Removing &/or controlling air & moisture
- Neutralize acidity to prevent $H_2S$ formation
- Consume $H_2S$, Fast-sulphidation e.g. by adding Cu (as $CuSO_4$)
- Rapid pre-oxidation to coat the surface with hydroxides or sulphates
- Surface Coatings to prevent $H_2O$ **/** $O_2$ contact (organics or inorganics)
- Change the Mineralogy Mix
- Immobilize the $S^o$

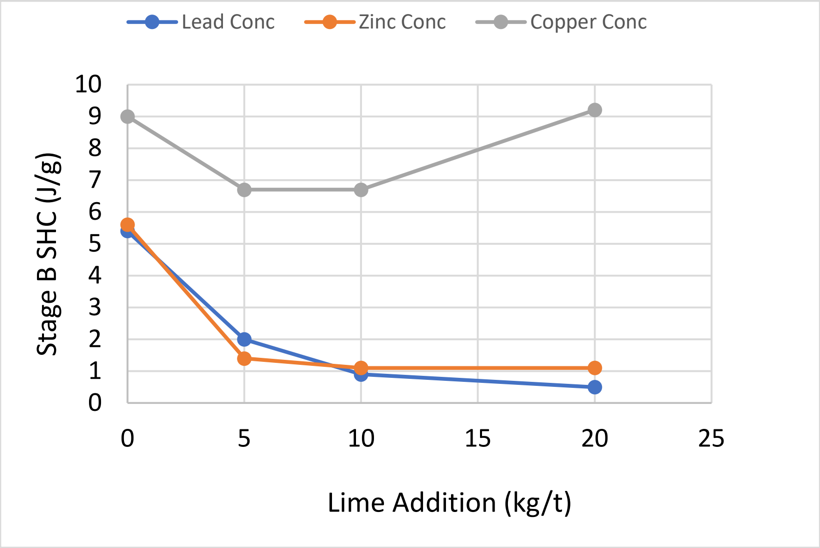
# Effect of Lime Addition on Reducing Self-heating (A and B) in Cu, Pb, Zn Concentrates

## *Stage A*




- Decrease heating for Pb
- Increases heating for Zn and Cu

## *Stage B*

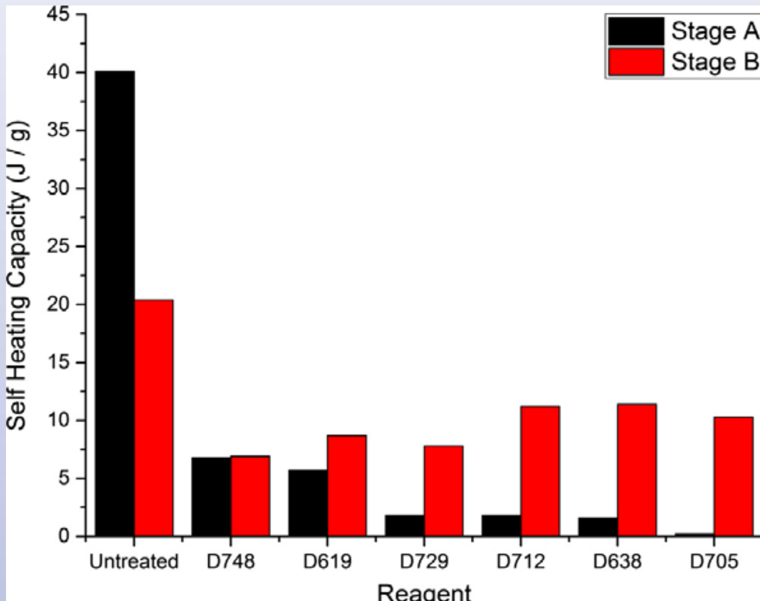



- Decrease heating for Pb and Zn
- Small effect for Cu concentrate

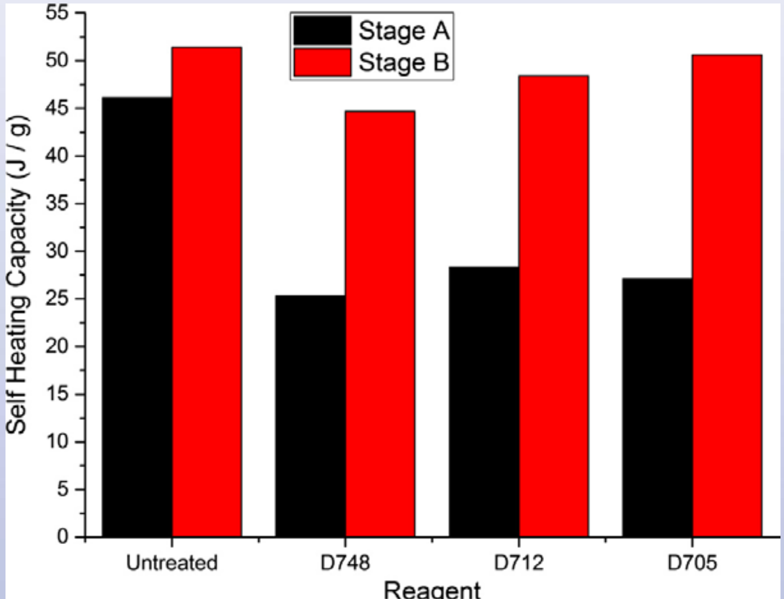
*Polymetallic VMS deposit*

# Effect of Chemical Treatment: Lignosulfonates on Reducing SHC of Ni Ore and Ni Concentrate

*Nickel sulphide ore*



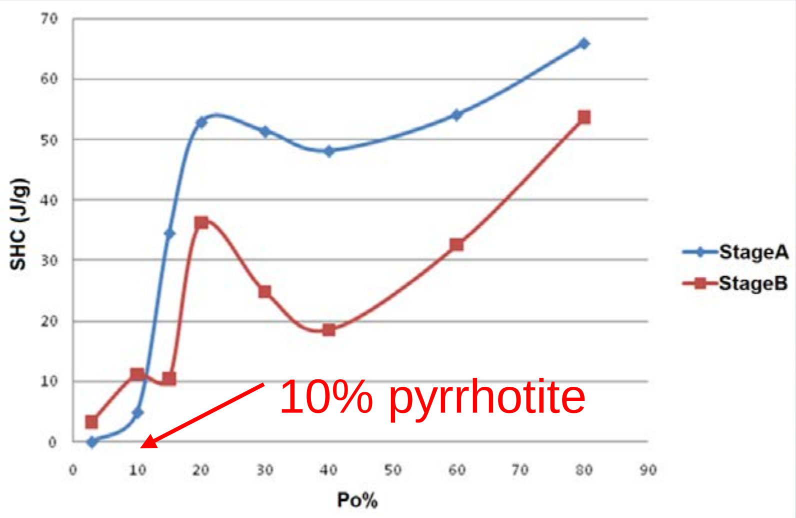

*Nickel sulphide concentrate*

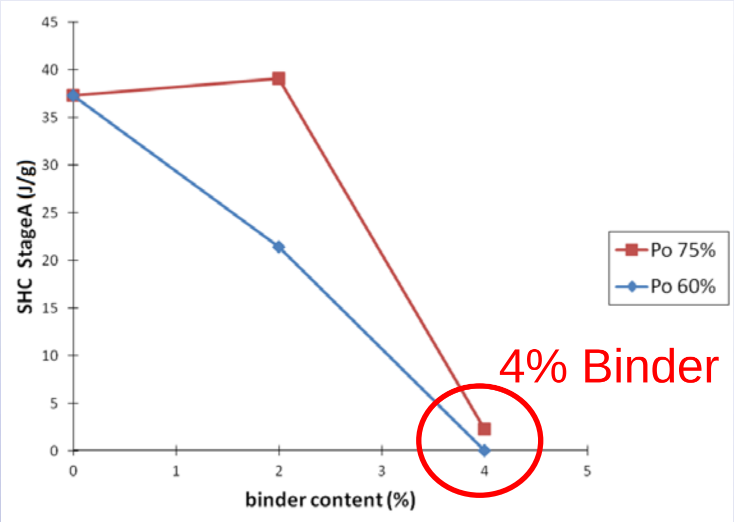



- Very effective on the Ni ore
- Not effective on the Ni concentrate
- Application rate 5kg/t

*Rosenblum et al., Min Eng 2017*

# Reactive Pastefill (Ni ore): Using High Pyrrhotite Tailings




Pyrrhotite content >10% (wt) results in very high self-heating rates in tailings

Binder addition 9:1 slag to cement, 0.5% anhydrous sodium silicate $Na_2SiO_3$

*Zarassi & Hassani, 2011, 2014*

# Excluding All the Air (oxygen)

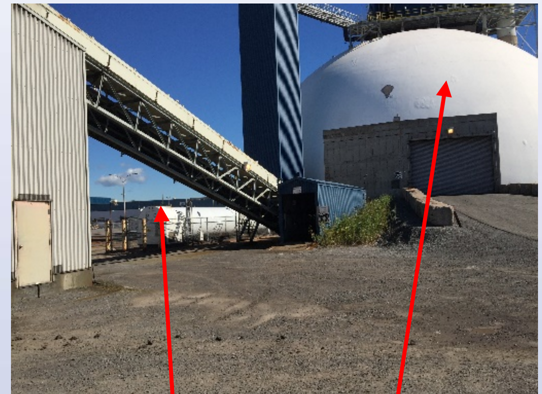
Membrane covers
(exclude all air)

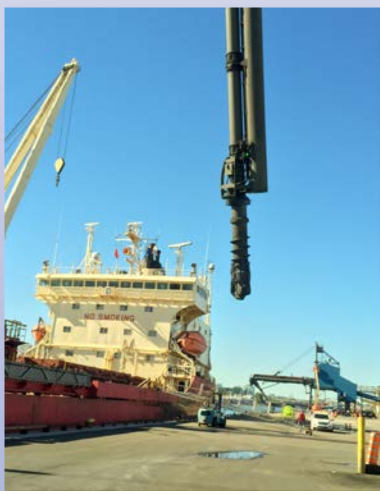
Totes in fully sealed
shipping containers


Plastic lined and
fully-sealed tote
bags

# Excluding Moisture from Ni Concentrate (Raglan Cu-Ni mine)

- % moisture must be below 1% to prevent self-heating
- Operating criteria is <0.5%
- Very close operating controls required





- Sealed dome storage at Raglan site and Port of Quebec
- Liquid $CO_2$ fire suppression
- Sealed ,bottom-discharge railcars

- Concentrate is moved by special augers and air-slide conveyors

# Predicting Rock Reactivity (Red Dog Pb-Zn mine, Alaska

Issue: Drill cuttings react with blasting agent in DH before detonation

Paley and Pickett , 2020

Approach: Construct a predictive model based on mineralogy (assays) and SHC tests from ~50 bench samples

# Predicting Rock Reactivity with Blasting Agents (Red Dog mine)

Method: Assays →Mineralogy → SHC & Reactivity with blasting agents → Domains of reactivity (regression) models → Populate the geologic block models → used as basis for loading procedures

Stage A = -1.33 + 0.0614 x Pyr + 0.3 x Sph - 0.00847 x $Sph^2$ + 0.0115 x Pyr x Sph
Stage B = -6.56 + 0.896 x Pyr - 0.00588 x $Py^{r2}$ (j

No instance of rock reactivity with blasting agents has been recorded since these models and new procedures put in place

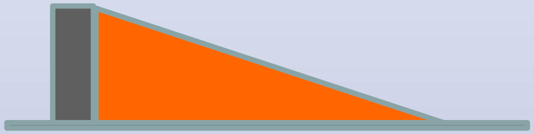
Paley and Pickett , 2020

# Pile Management: Concentrates

- Compact (reduce permeability) with loader in walled (3 sides) bunkers
- Avoid peaked piles (keep low profile). New material on top
- FIFO principle for bunkers (minimize storage time)
- Remove “hot spot” material and re-blend with cooler material
- Prevent increased relative humidity and air temperature by low velocity ventilation
- Use of sensors/cameras and training

air)

*Compacting with Loader*



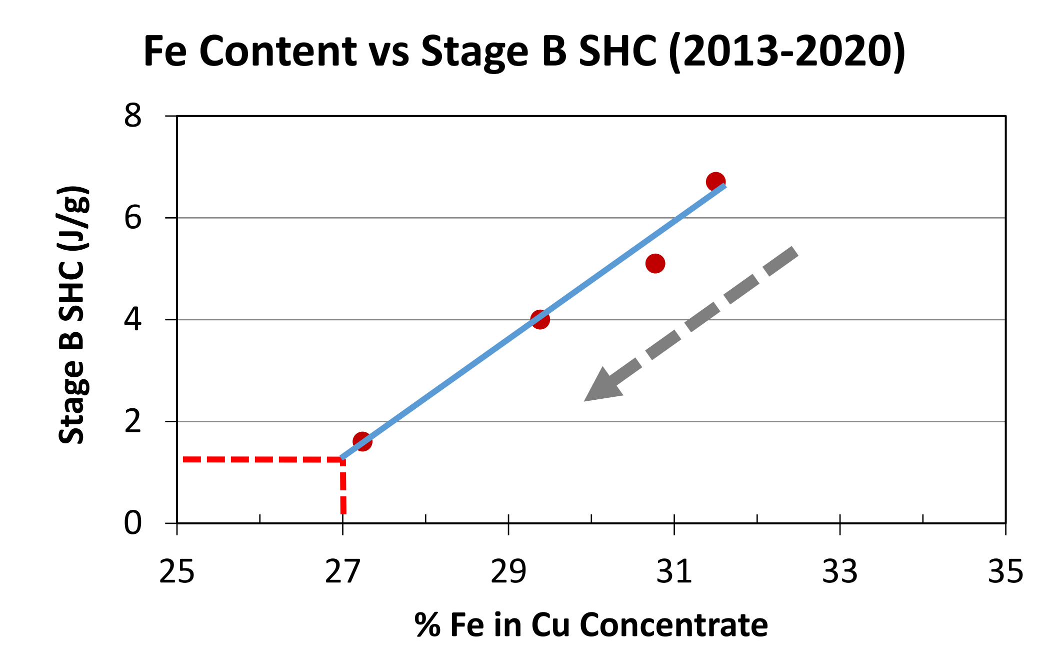
*Low Profile (no peaks)*

*$SO_2$ sensor*

*Infra-Red cameras*

# Change the Mineralogy: example by Removing Pyrite (%Fe)

- Decreasing Fe content of the concentrate drops the %Fe and reduces the self-heating risk to a Safe Designation (< SHC=1 J/g)




Membrane covers (exclude <u>all</u> air)

# Summary of Key Mitigation Concepts

- Lime addition or chemical additives can be effective for some mineral mixtures but not all
- Excluding <u>all</u> moisture or air is effective
- Pile management practice, monitoring and training are the key mitigation controls for safe handling and storage of reactive sulphides
- Understanding the mineralogy-self-heating link can lead to improved control of self-heating
- No cost-effective "magic-treatments" have yet been found