Wettability Studies: A Tool to Project Dust Control Issues and Develop Engineering Controls in Coal Mining

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Definitions - Dust

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- Dust - *small solid particles, conventionally taken as those particles below 75 µm in diameter, which settle out under their own weight but which may remain suspended for some time (ISO 4225)*

Particles small enough to stay airborne may be **inhaled** through the nose (nasal route) or the mouth (oral route)

- Respirable Dust –
  - Dust of less than 10 microns which is capable of penetrating deep into the alveoli
  - MSHA's definition of respirable dust – Dust with the following size characteristics:

Aerodynamic diameter	Percent
µm	passing
2	90
2.5	75
3.5	50
5	25
10	0

Issues With Dust

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- How is It Generated ?
  - During cutting, drilling, grinding, shearing and general breakage during mining operations
  - During loading, dumping and transferring of mined materials
  - Re - emission of settled dust due to mine activities
- How Does It Affect Us?
  - Health Hazards – eg Silicosis
  - Occupational Hazard - explosion
- How Can We Control It?
  - Ventilation
  - Isolation
  - Protective Gear
  - Dust Capture
    - Dust Collection
    - Wet Dust Suppression - During handling operations
    - Wetting with water sprays

Definitions - Wetting

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- Wetting - Air from the air-solid interface is displaced to form a liquid-solid interface
- Wettability - Probability of particles being wetted
  - particle size,
  - surface properties of coal and,
  - physical and chemical properties of fluid (water).
- Wettability Rates - The amount of coal wetted as a function of time

Wetting rate is considered to be more important than the wettability due to the short contact times

Wetting Concepts

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Hydrophobic Surface
No wetting

Hydrophilic Surface
Complete wetting

It can be engineered such that hydrophilic surfaces are made non-wettable and hydrophobic surfaces are wetted

- Use Chemicals to Change Solid Surfaces
- Use Chemicals to Change Liquid properties
- Change Surface Roughness

Beading on Windshields

Drowning Fleas

Self cleaning of leaves – Lotus Effect

Why Is Size Important?

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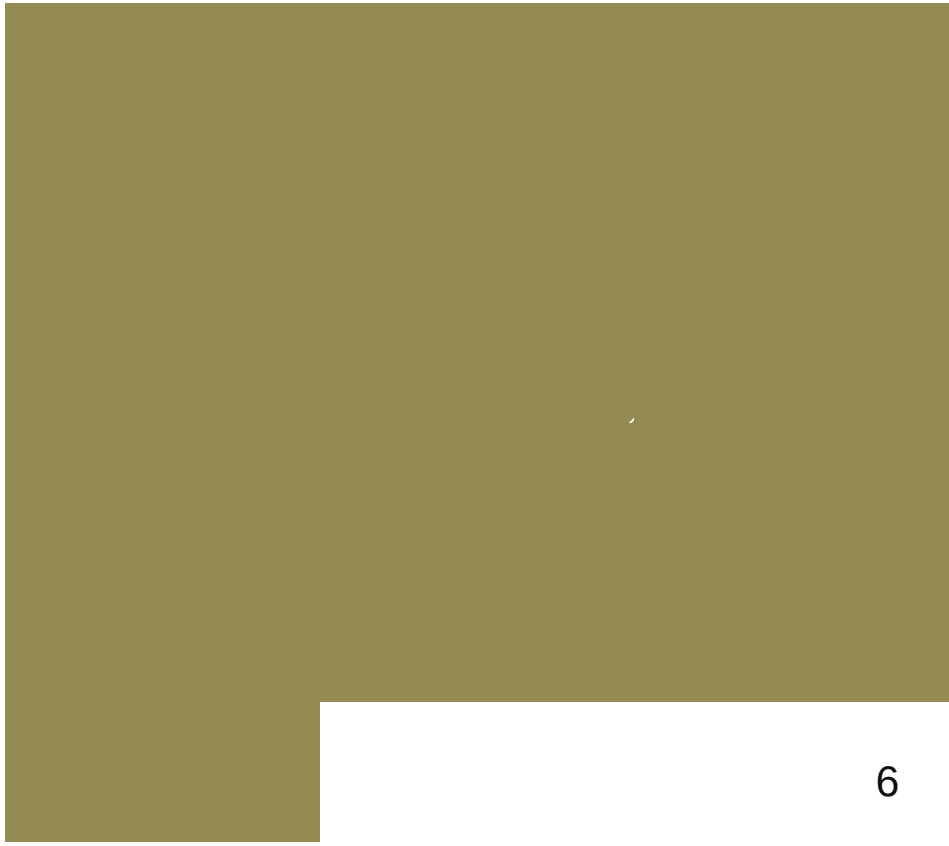
Area needed to be wetted
6 X Length^2

Area needed to be wetted
8 X Length^2



More Wetting Agent Required if Material is Identical

The issue is not the same when materials are different

Wetting

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What We Would Like to Happen

Dust too small compared to water droplet

When Dust Wetting Occurs

When dust is hydrophobic

Key Parameters

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Wetting depends on

- Contact between the dust and the fluid droplets,
  - Relative Particle/Droplet size
  - Air Velocity
  - Nozzle Design – Spray Type
- Wettability of the particles by the wetting fluid, and
  - Solid Surface Properties
  - Surface Tension
  - Surface Roughness
- Wettability rate (due to low contact times)
  - Surface Tension
  - Contact Time
  - Surface Area

Reducing Surface Tension

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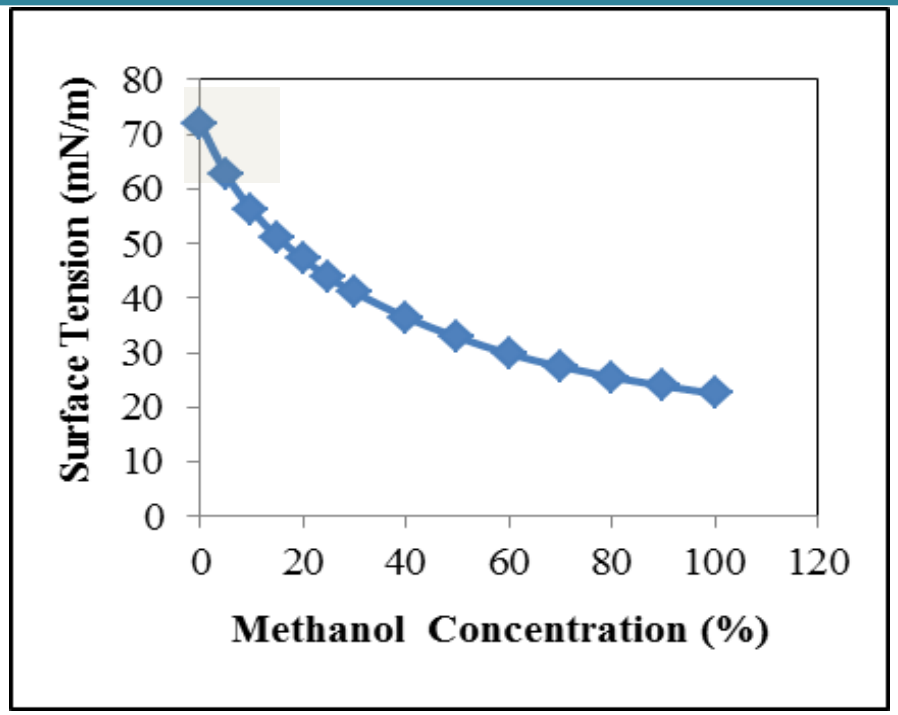
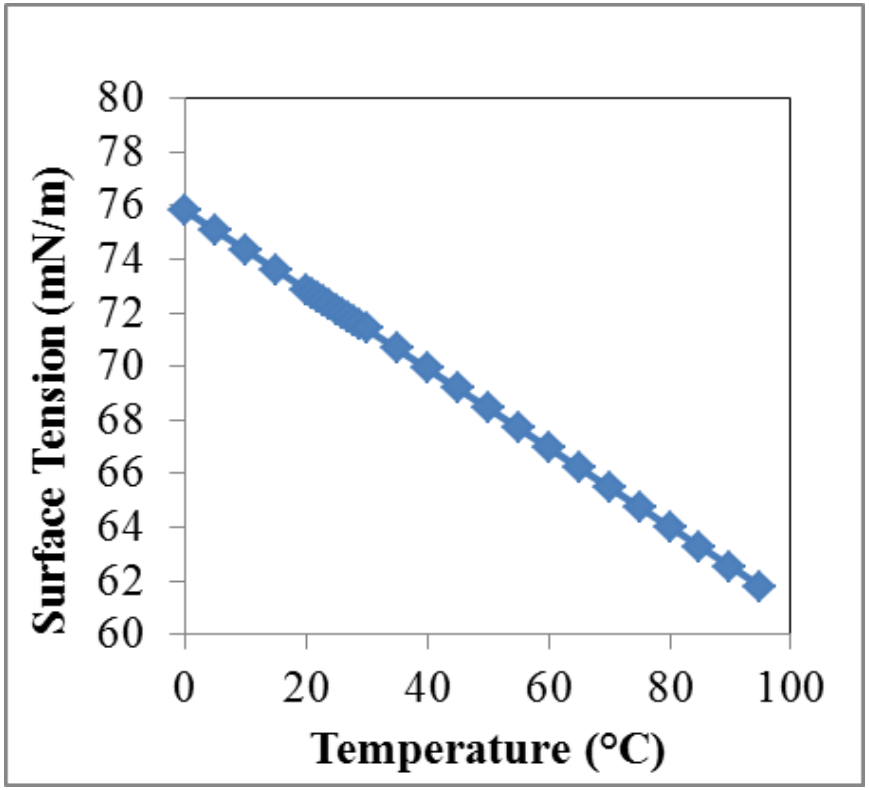


Water Temperature Increase Temperature



Methanol Water Mixtures

Add Surfacatants

SIUC Holistic Approach

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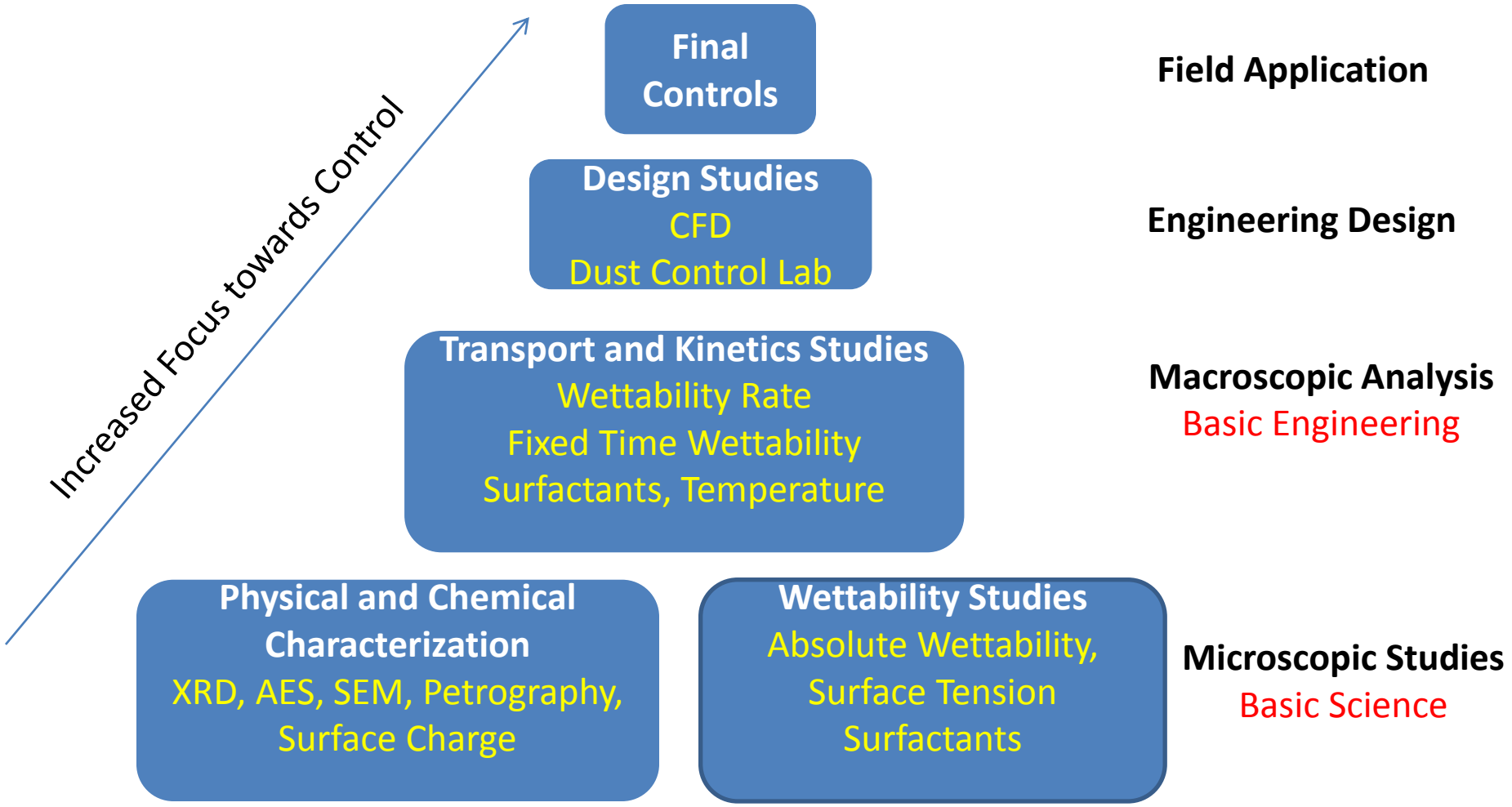

Step 1: Sample Collection

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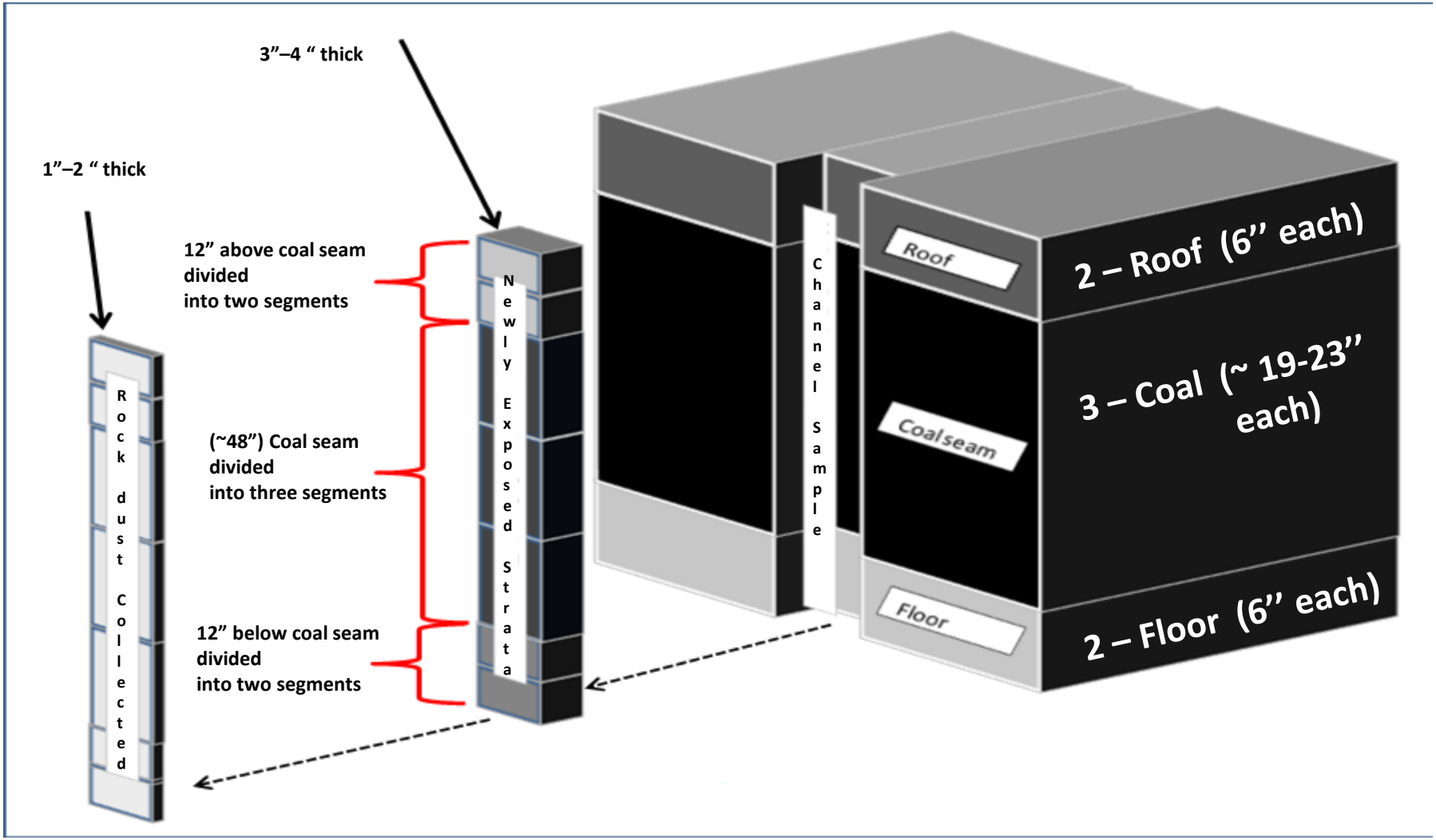

Step 2 : Sample Preparation

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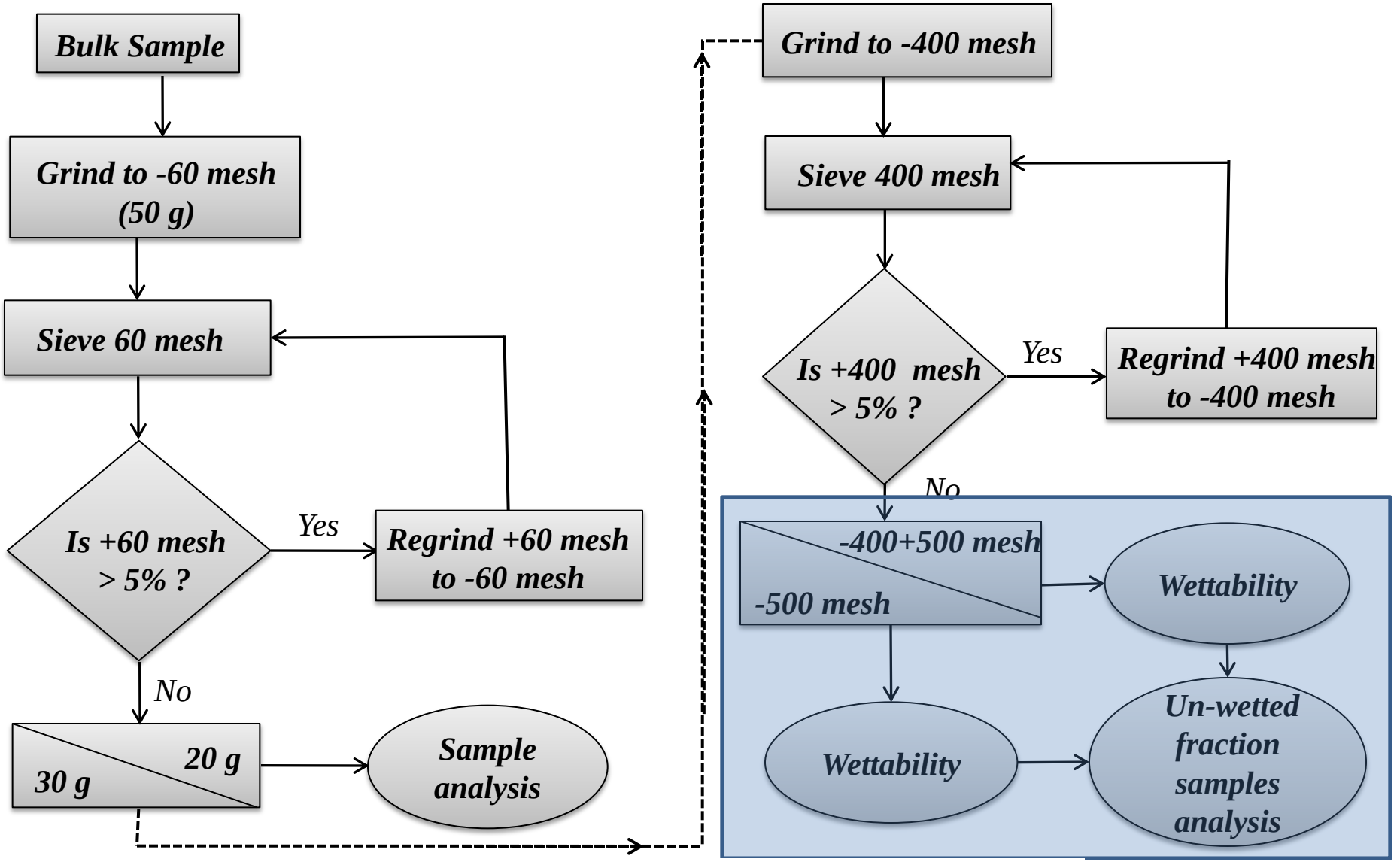

Step 3: Wettability Studies

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- Absolute Wettability
  - Whether a particle is wettable
    - Altering the surface tension of the wetting fluid
      - Mixing water with lower surface tension fluid – methanol
      - Adding surfactant (may alter solid surface characteristics)
- Wetting Kinetics
  - Detailed kinetics at different residence times
    - Methanol water mixture
    - Aqueous solution of surfactant
  - Fixed time wettability (Chugh et al, 2004)
    - Methanol water mixture
    - Altering temperature of water

AW Procedure

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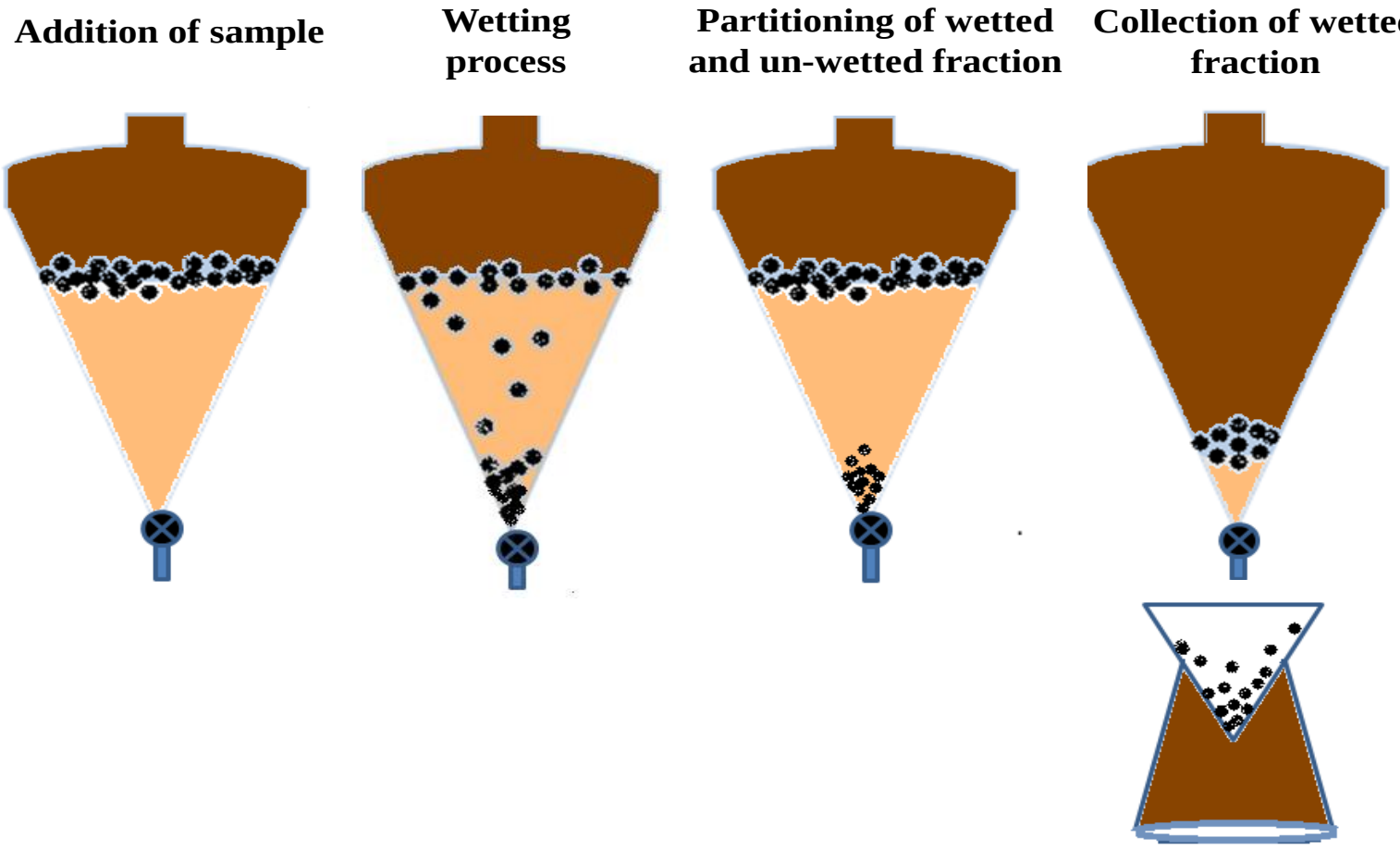
Partitioning of hydrophilic and hydrophobic portions



Same system was also used for the detailed kinetic study

FTW Set-Up

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Wetted and un-wetted fraction

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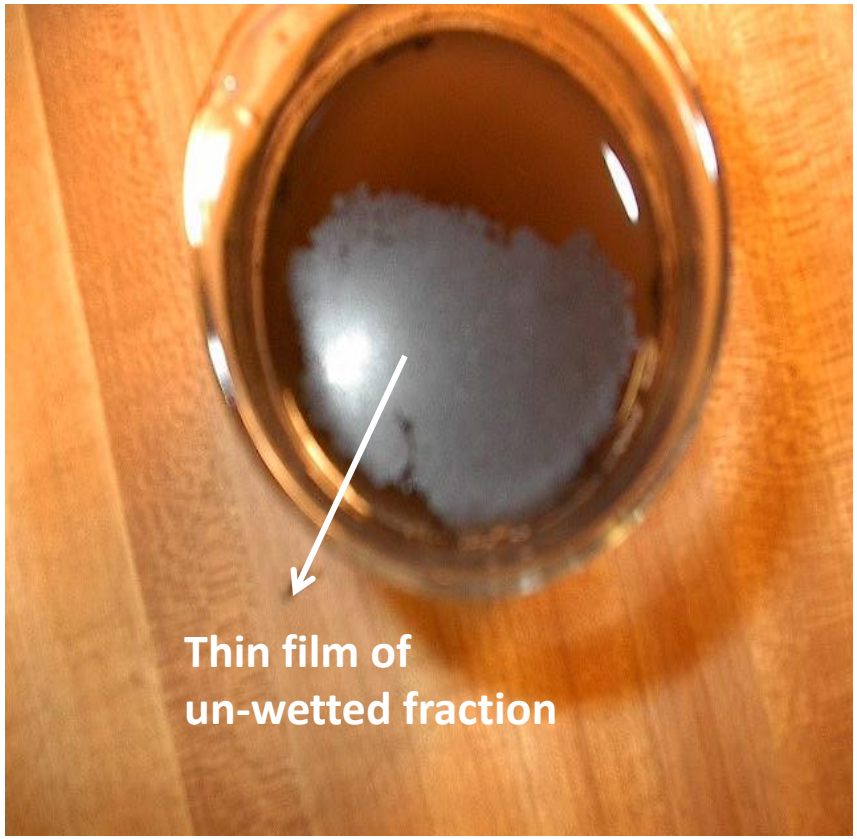

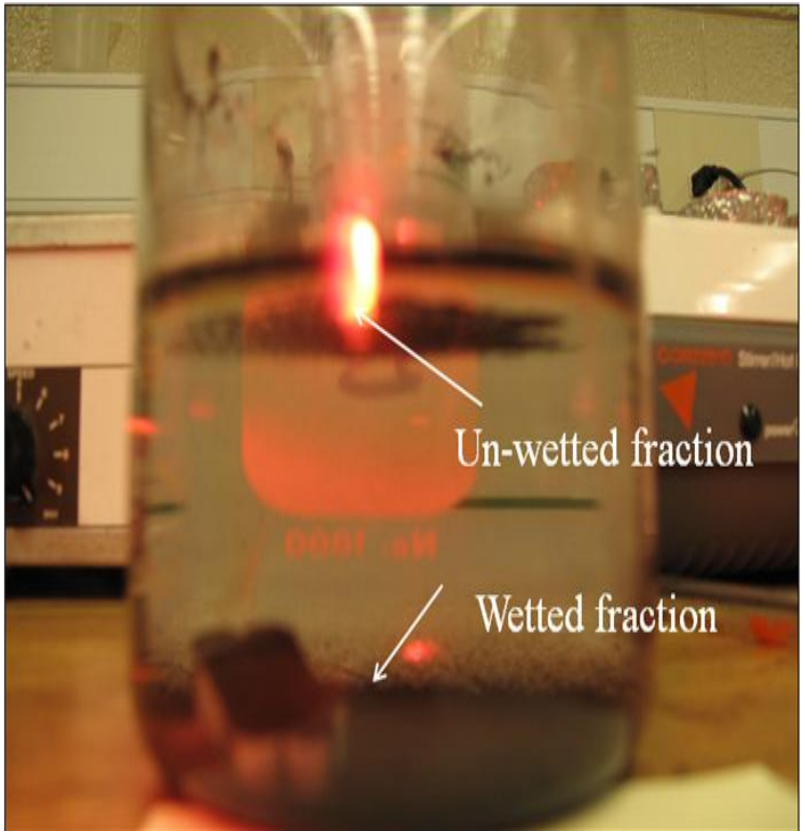

Absolute Wettability – Size effects

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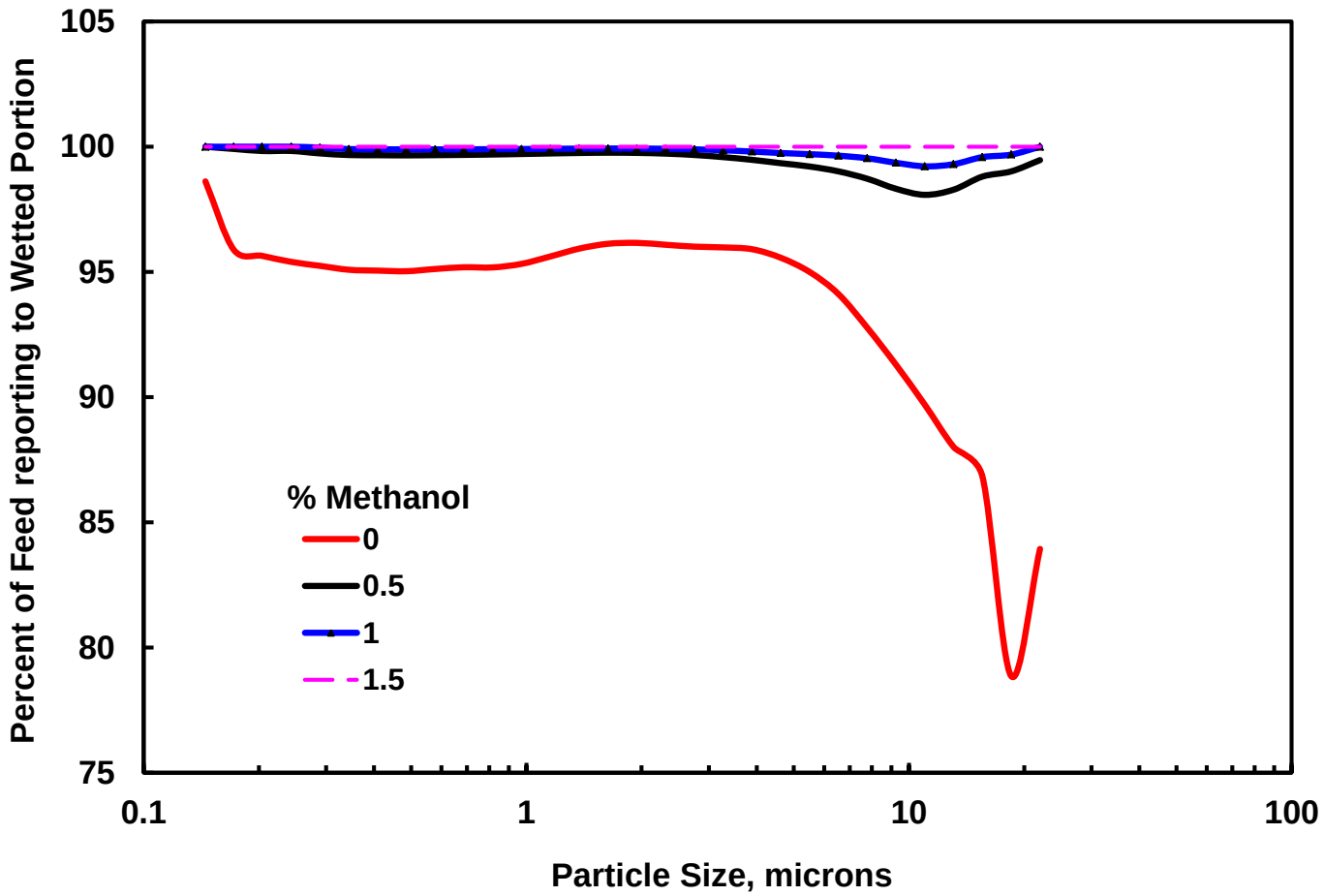
DATA FROM DIFFERENT MINE



The wetted fraction was finer – wetting fluid modifications required for coarser particles

Absolute Wettability, contd

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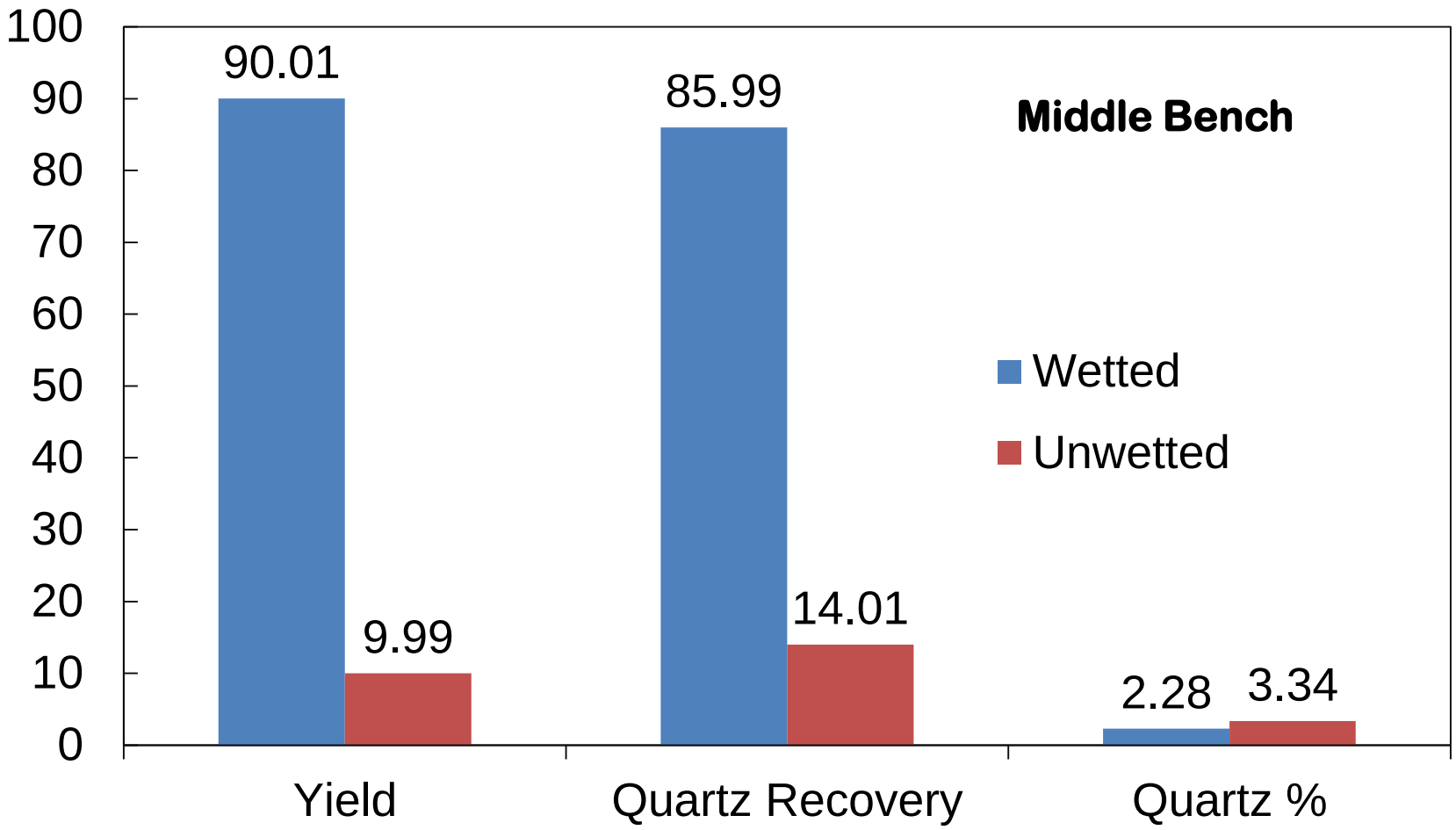

Quartz concentrated in the unwetted fraction

Effect of Surfactant

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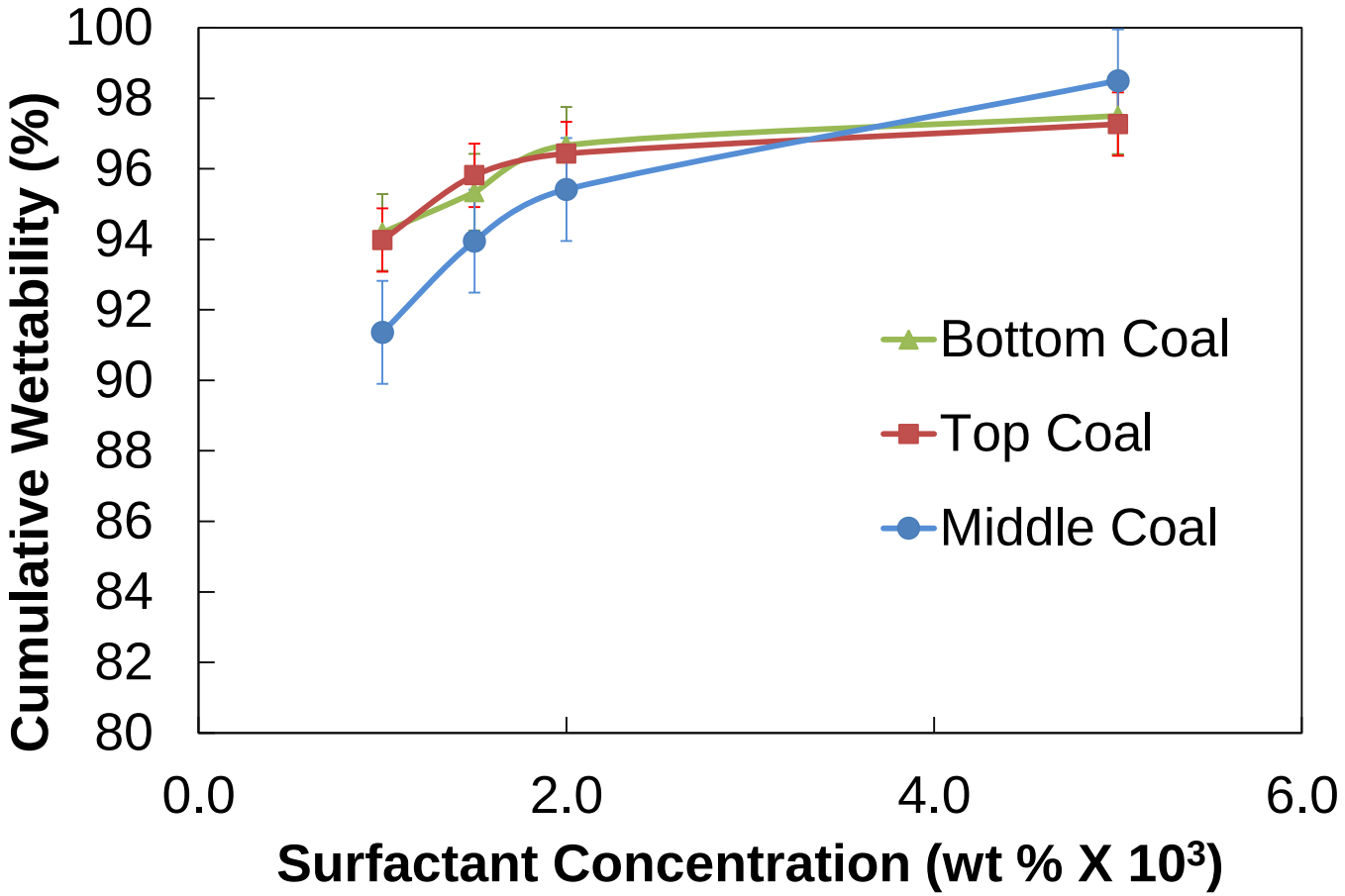

Top and bottom coal bench samples - adverse effect of excess surfactant addition

Surfactant affects both the wetting fluid and surface properties

Effect of Surfactant, contd

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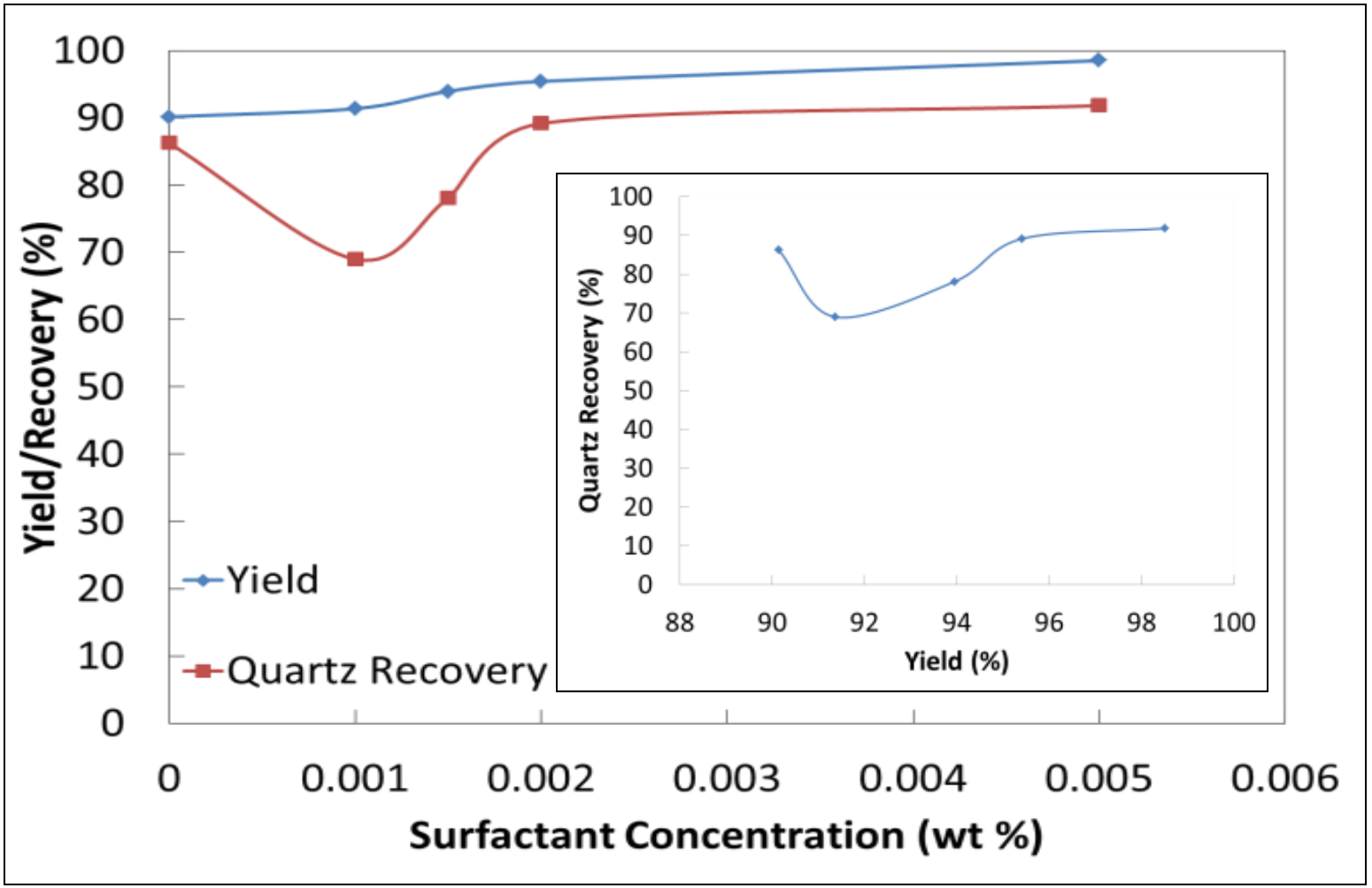

Quartz recovery to the wetted fraction decreases with increasing material recovery

Wettability as a function of contact time

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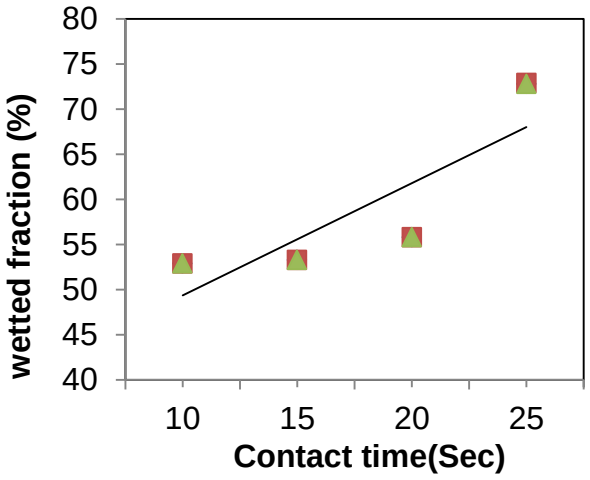
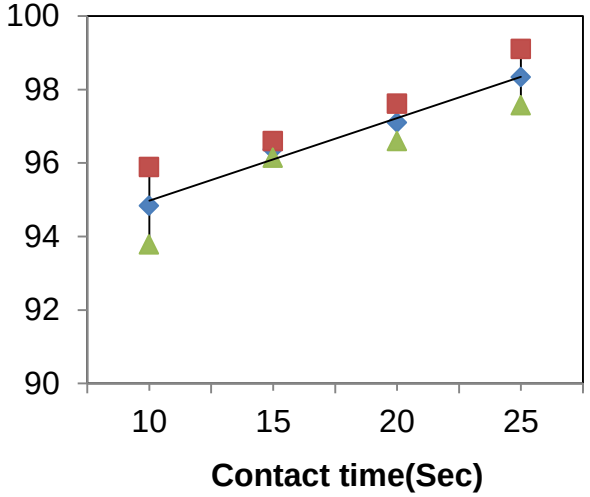
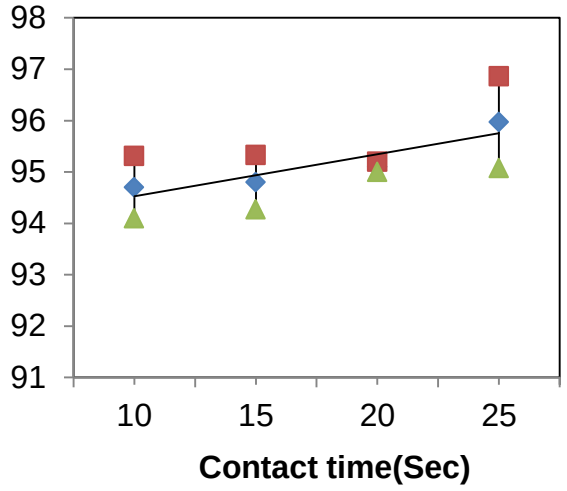
Mine IL 5-1 , -500 C-TB



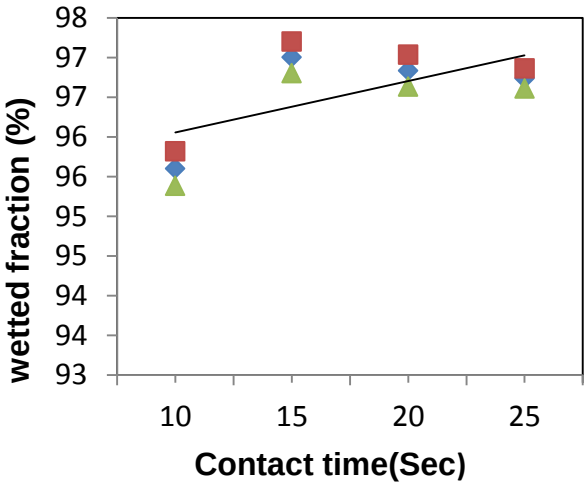
Mine IL 6-1, -500 C-TB



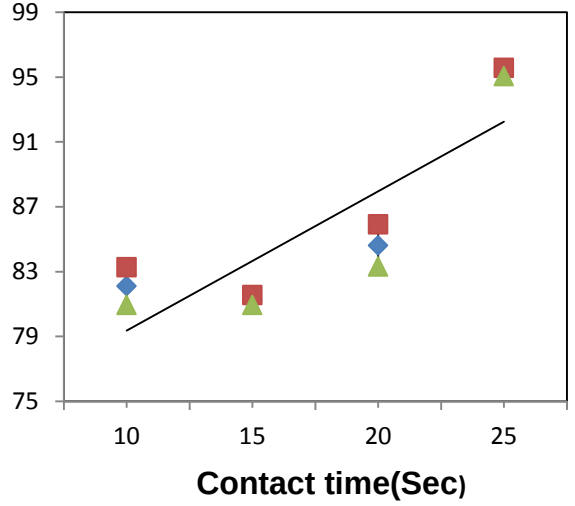
Mine IL 6-7, -500 C-BB



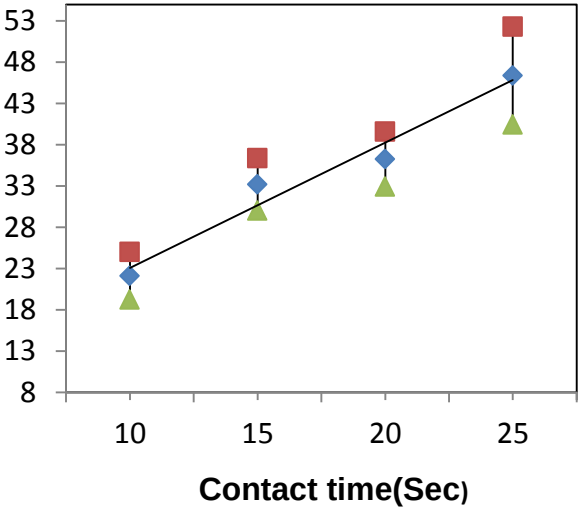
Mine IL 6-2, -500, C-BB



Mine IN 6-1, -400+500, C-TB



Mine IL 5-1 , -400 C-MB



Wettability Rate Studies, contd

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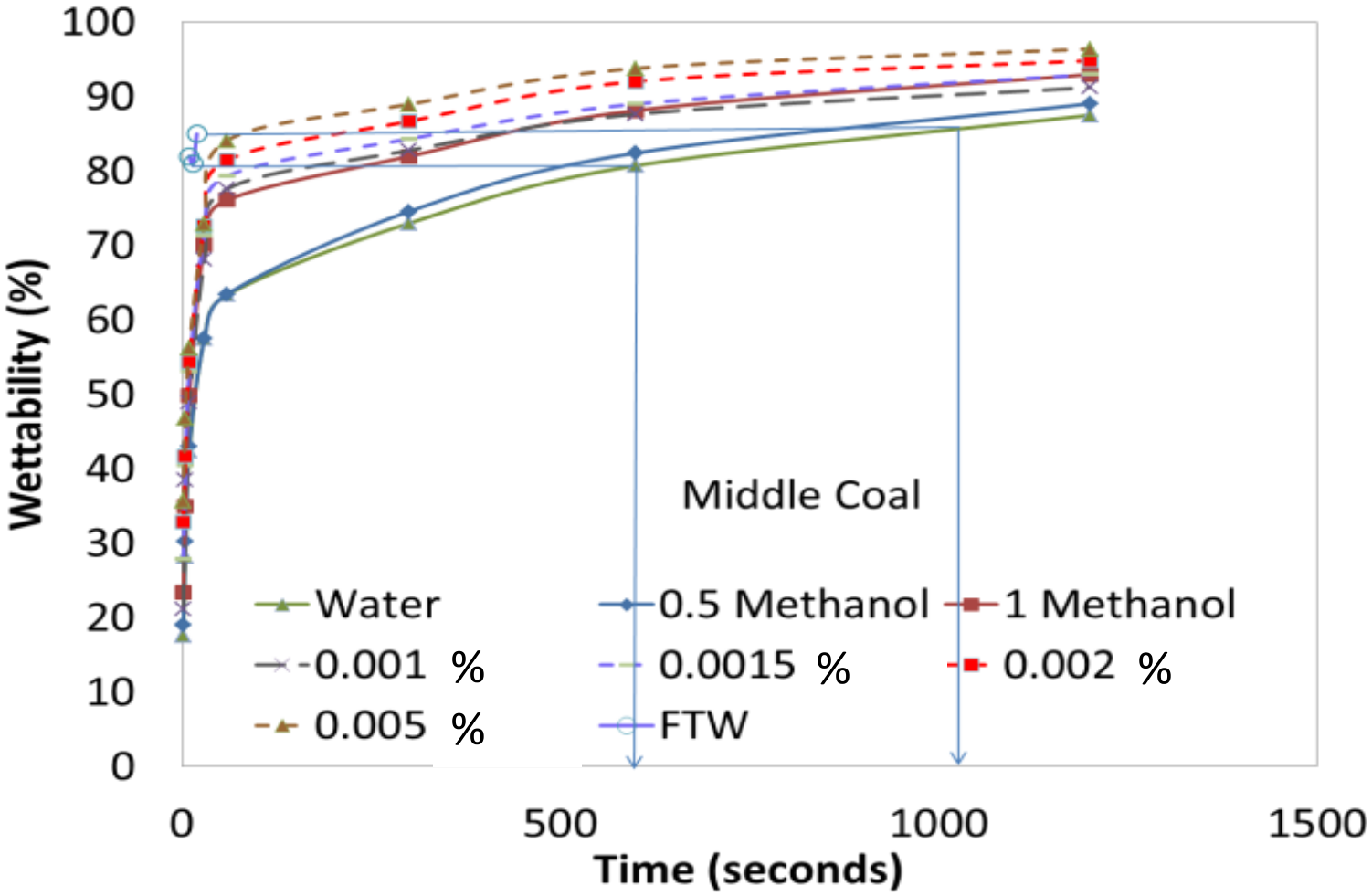

Wetting rates increase with decreasing surface tension, increased amount of surfactant

Correlation between fixed time and absolute wettability

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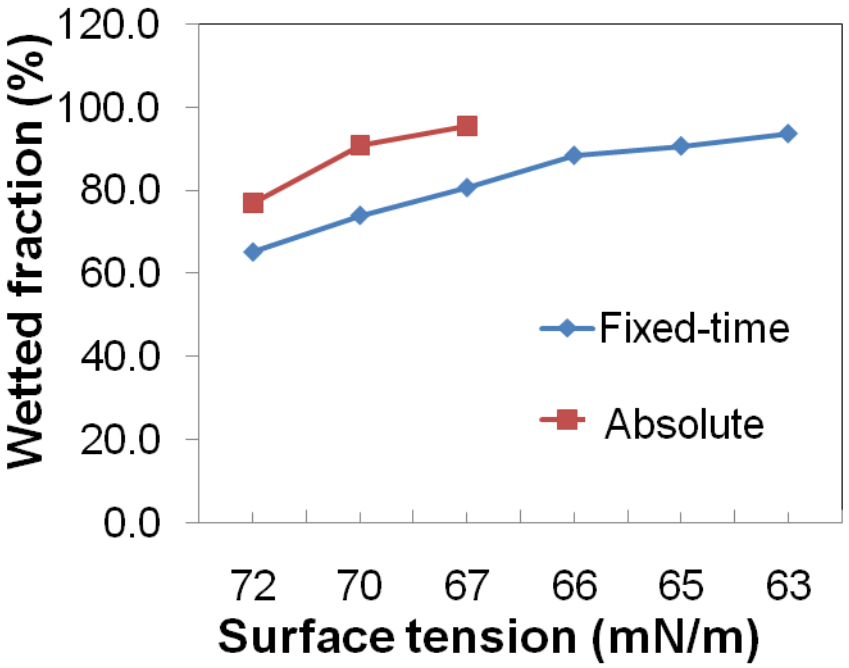
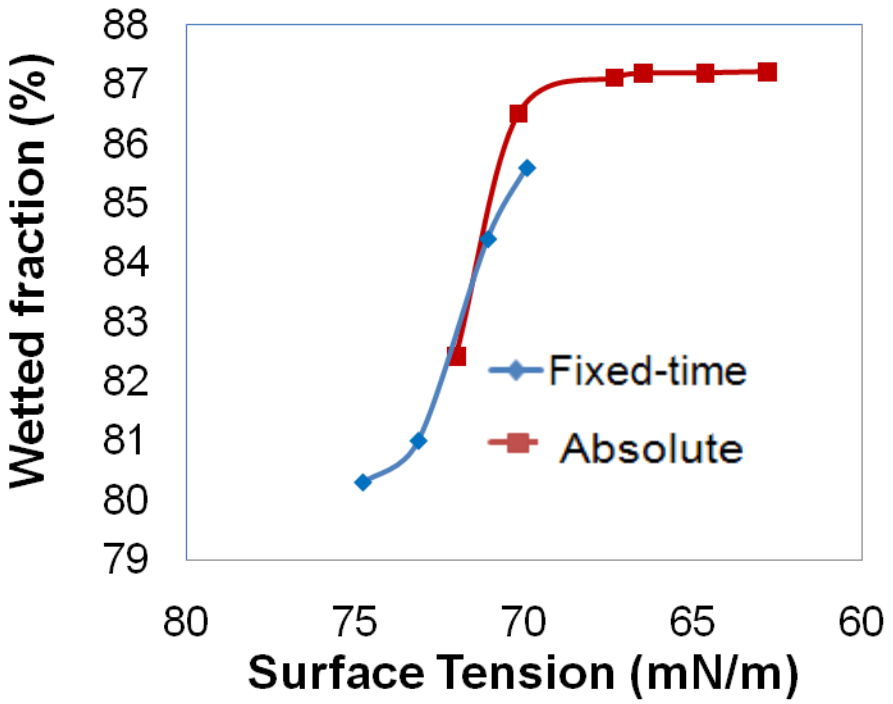
Mine IL 5-2, -500 mesh, C-MB



Mine IL 5-1, -400 mesh, C-TB



Wettability Rate Studies, contd

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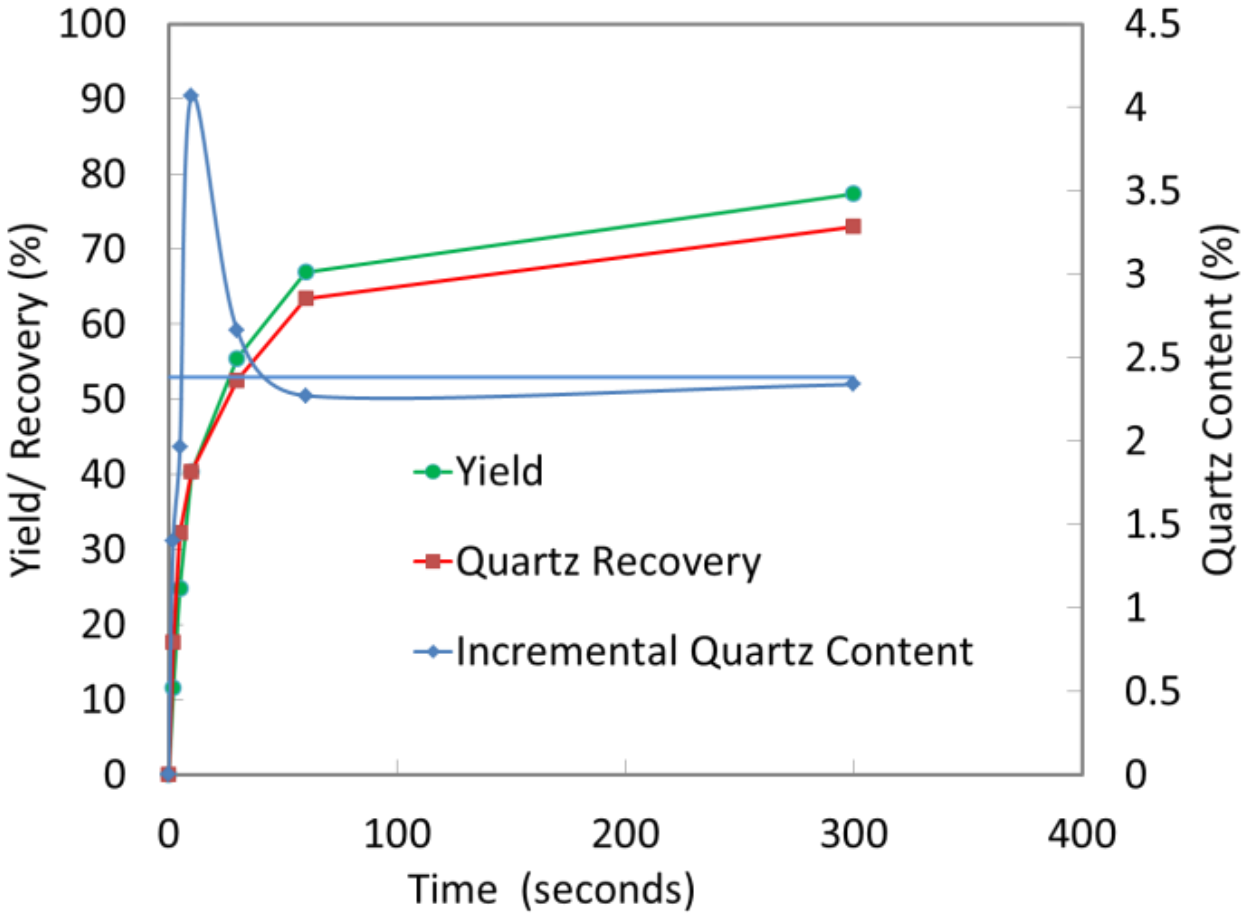

Incremental quartz content in the wetted fraction increases initially

Wettability Rate Studies, contd

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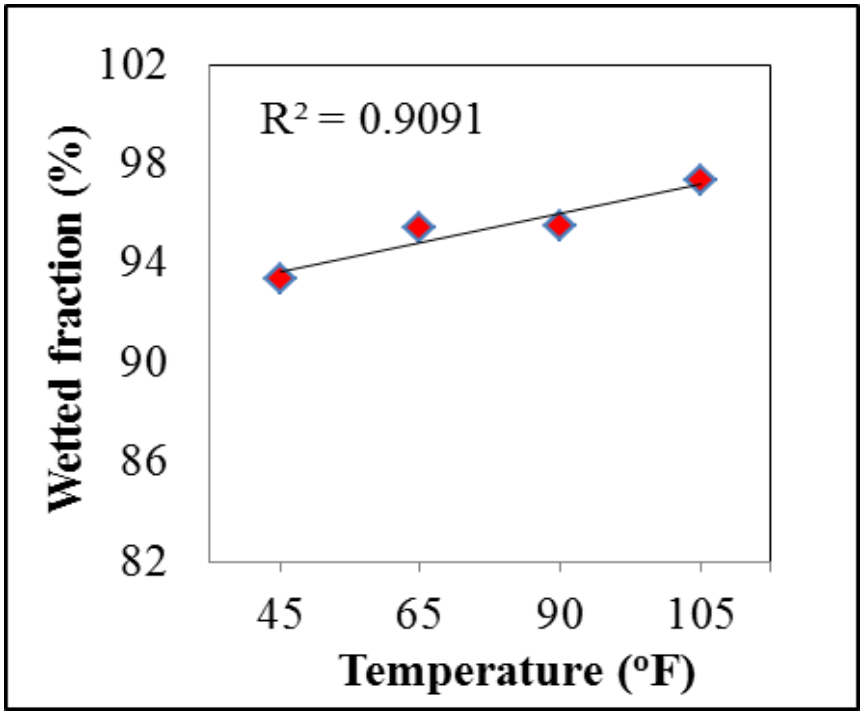
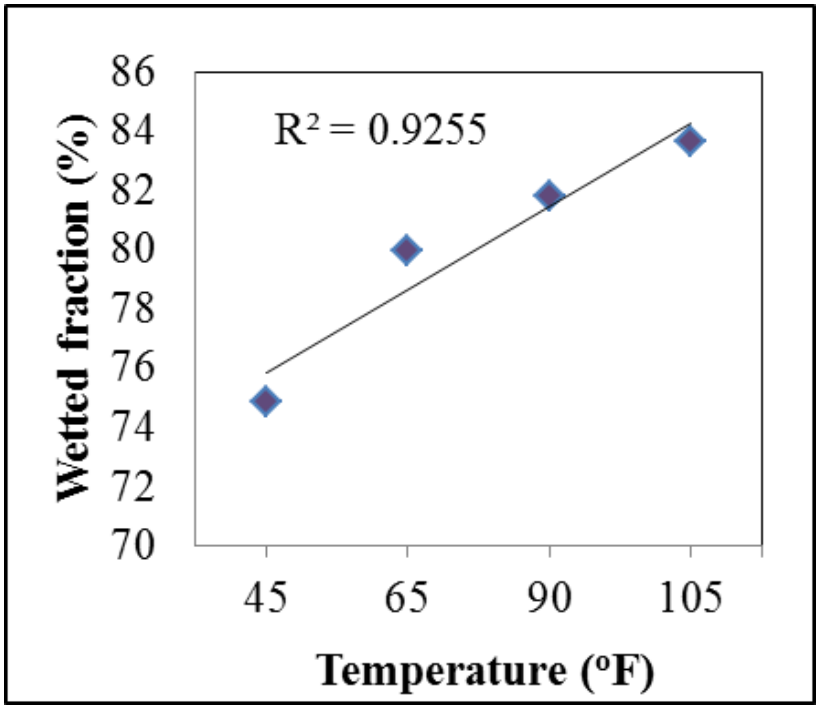
Impact of Temperature on Wettability Rates - FTW





Increasing wetting fluid temperature increases degree of wetting and wetting rates

In Mine Sample Wettability

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Mesh Size	Wetted fraction (%)
	IN 6-1
-400+500 (25 µm - 37 µm)	94.5
-500+635 (20 µm - 25µm)	95.2
-635 (< 20 µm)	98.2

Finer Size fractions were more wettable

Summary

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- Recovery to the wetted fraction is higher for finer fractions.
  - Wetting fluid modifications target coarser fractions.
- Quartz appears to be more concentrated in the wetted fractions.
- Wettability may be suppressed at high surfactant concentrations.
- Quartz recovery decreases with initial increase in surfactant concentration
  - ??
- Surfactant affects both the wetting fluid and the solid surface.
- Wettability rates increase with
  - Temperature
  - Surfactant addition
- **FTW gives a quick estimate of the degree of wetting and wetting rates.**
- Quartz recovery increases at lower contact times and then decreases.
- **WETTING RATE IS A KEY FACTOR IN MINE CONDITIONS**

Information for Engineering controls SIUC

- Wettability as a function of
  - surface tension
  - size distribution
- Wettability rates as a function
  - surface tension
  - size distribution
- Quartz recovery as a function of contact time

Quartz control data from field studies

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Mine IL 6-8 (% Quartz)		
Location	**Unmodified Miner**	**Modified Miner**
Miner Operator	3.5	2.8
Haulage unit Operator	3.7	4.3
Return	3.9	3.3
Full Shift Sample	3.7	3

Mine IL 5-2 (% Quartz)		
Location	**Unmodified Miner**	**Modified Miner**
Miner Operator	3.3	2.1
Haulage unit Operator	2.5	2.3
Return	2.7	2.25

Mine IL 5-2 (% Quartz)		
Location	**Unmodified Miner**	**Modified Miner**
Miner Operator	-	2.5
Haulage unit Operator	-	4.2
Return	7	4.8

SIUC Innovative Spray System- Progress Update

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- Currently, 17 continuous miners are operating on the developed system with very good results.
- We will be performing in-mine sampling studies on another modified miner (fitted with SIUC Spray System designed for 9-ft mining height) in middle of September.
- SIUC is currently designing spray system for 14-ft mining heights. That will be tested in the next 6-months.

Acknowledgements

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Questions ??