# Intermediate-Sized Particle (ISP) Formation During Black Liquor Droplet Combustion

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#### **Objectives:**

Understand and propose a formation mechanism of ISP by: Monitoring ISP formation during black liquor droplet combustion processes Quantitatively collecting ISP for the investigation of the effects of liquor type, solids content, and droplet size Analyzing the size and shape of ISP collected with SEM

#### **Background:**

Black liquor combustion in the recovery boiler generates three main types of ash particles: carryover, fume, and ISP. These particles are categorized with the size and formation mechanisms. Carryover particles have the size of  $100 \,\mu$ m or bigger, and are mainly formed by partially burned entrained black liquor or char. Fume particles are < 1  $\mu$ m, and are formed by alkali salts vaporization. ISP has the size range of 5-100  $\mu$ m, and the formation mechanism has not been fully understood yet.

#### **Experimental Instrument and Method:**

- Suspended droplet on a thin wire
- Flat flame burner with 900-1000 °C
- Oxygen content range of 3-15%
- · Camera speed of 60 frames/second
- Water-cooled, nitrogen-quenched collection probe

• Two cyclone separators with 20 µm and 5 µm cutpoints (avoiding fume particles)

• Two 1.6 µm borosilicate filters

#### **Materials and Experimental Cases:**

- Five liquors from different paper mills (two softwood liquors and three softwood/hardwood mixed liquors)
- Two solids contents for each liquor (50% and 70%)
- · Initial droplet size range of
- Total 40-50 droplets burned per each run
- At least 3 replications for each case with different initial droplet size of 5-10 mg, dry basis
- Total droplets burned: >1300

#### Acknowledgement

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Softwood

А

35.5

3.45

5.25

18.8

1.50

0.10

35.4

O - by difference

С

Η

Ν

S

Na

Κ

C1

0

В

32.0

3.40

0.05

5.79

22.0

1.26

0.55

34.95

Analysis for C, D, and E will be done soor

C

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## **Results: Evidence of ISP formation**







A particle formed during drying

## **<u>Results</u>:** Quantitative Analysis

Results from all the experiment runs which included over 1300 droplets burned

2	Average ISP per BLS									
1.5 - 1.4 - 1.4 - 5 1.2 - 1.2						I				
							T			
	F	H			T		f1_			
	F						I		.1	
0.2	L	Liqu	or A		Liqu	or B	Liquor C	Liquor D	Liquor E	







## **Results: SEM Analysis**





irregular shape



agglomerate



6000X, <5µm near fume 15000X, <1µm fume particle

#### Conclusions

500X. 100um

spherical

- ISP are formed during drying but mainly during char burning
- ISP is strongly dependent on liquor type

agglomerate

- Higher solids content liquors generated more ISP, possibly due to longer burning time
- Bigger droplet in the experimental range formed more ISP than small droplet
- SEM images showed ISP with different sizes and surface morphology





E

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Softwood/Hardwood

D