

An Investigation of Milk Powder Deposition on Parallel Fins



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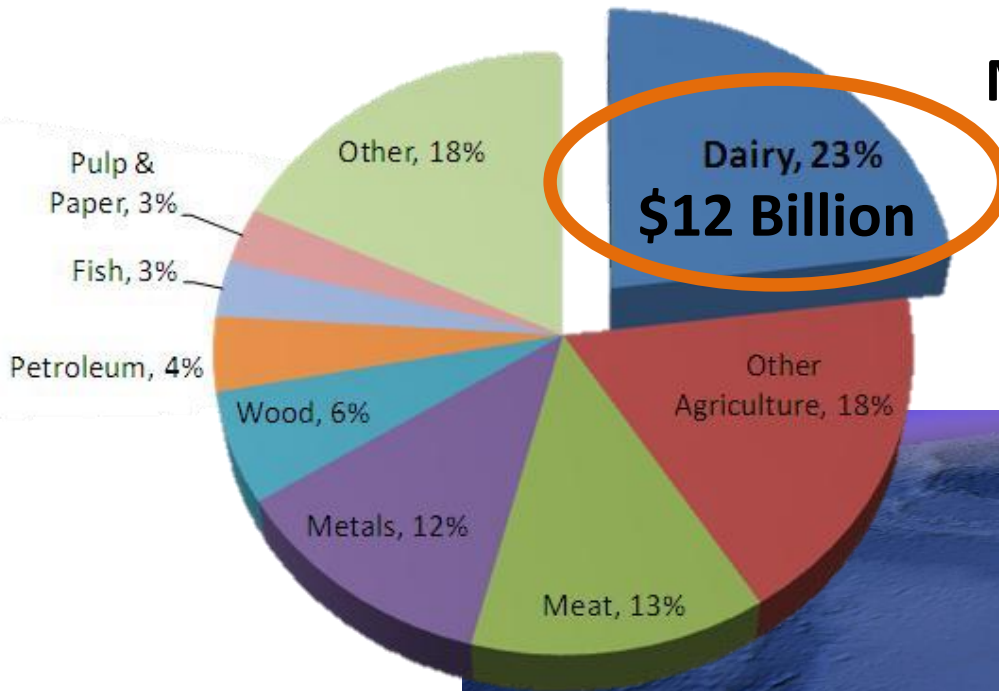
**Energy Research Centre
School of Engineering
University of Waikato
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Outline

- Motive & opportunity
- Challenges facing heat recovery from air
- Methodology
- Fin deposition test results
- Additional experimental work
- Summary

MOTIVE

New Zealand Exports



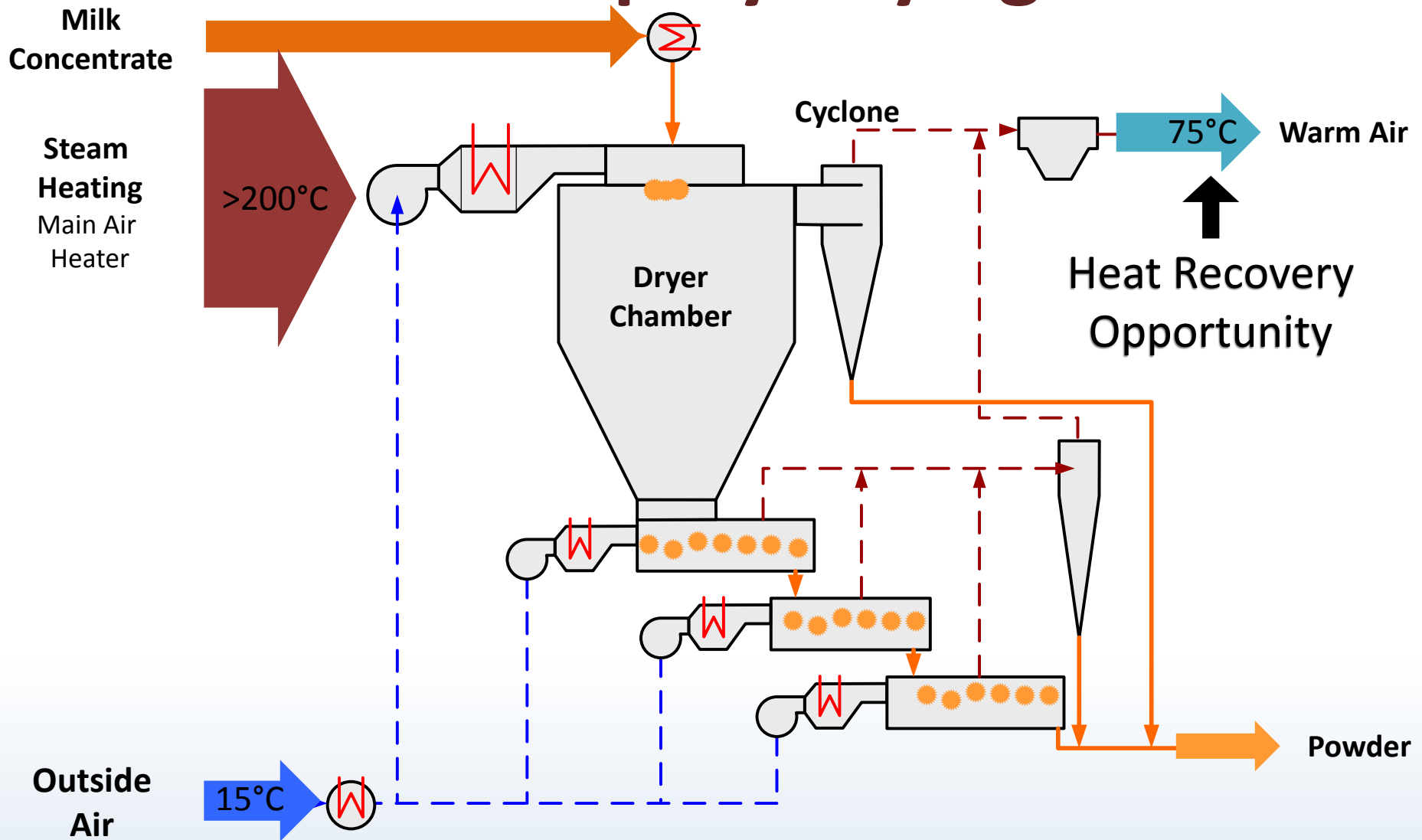
**Milk Powder
>85%**



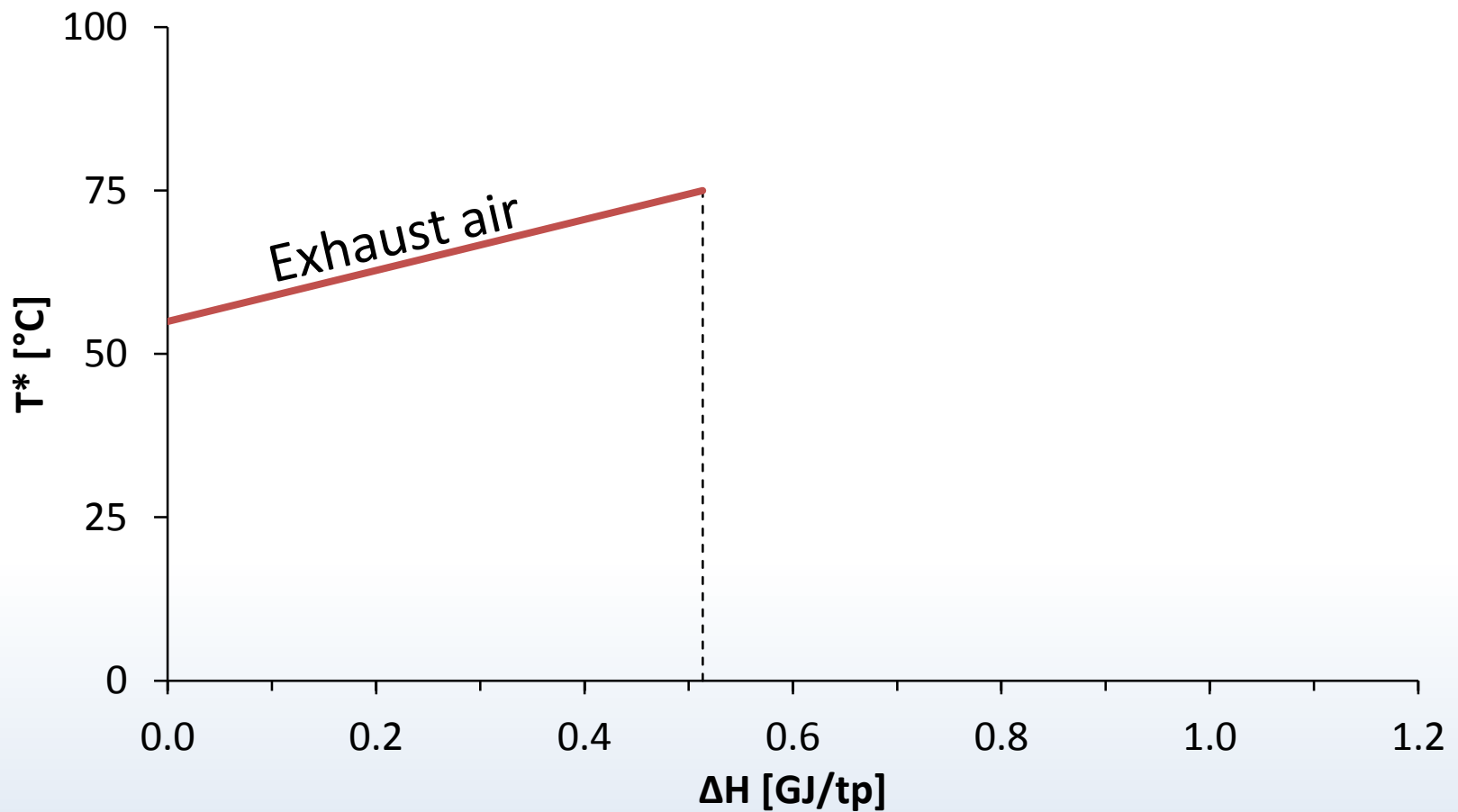
New Zealand Dairy



Milk Spray Drying

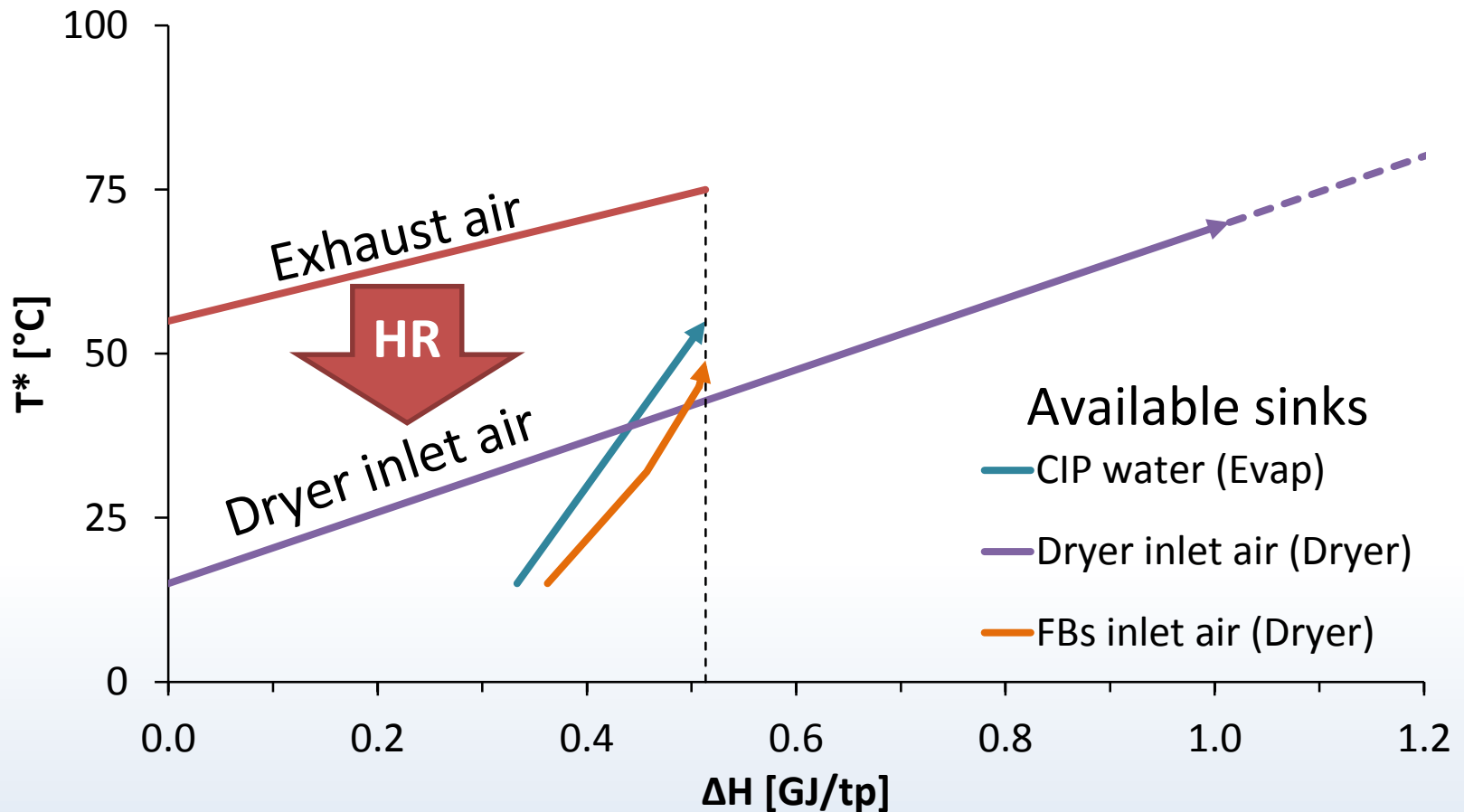


Dryer exhaust heat recovery

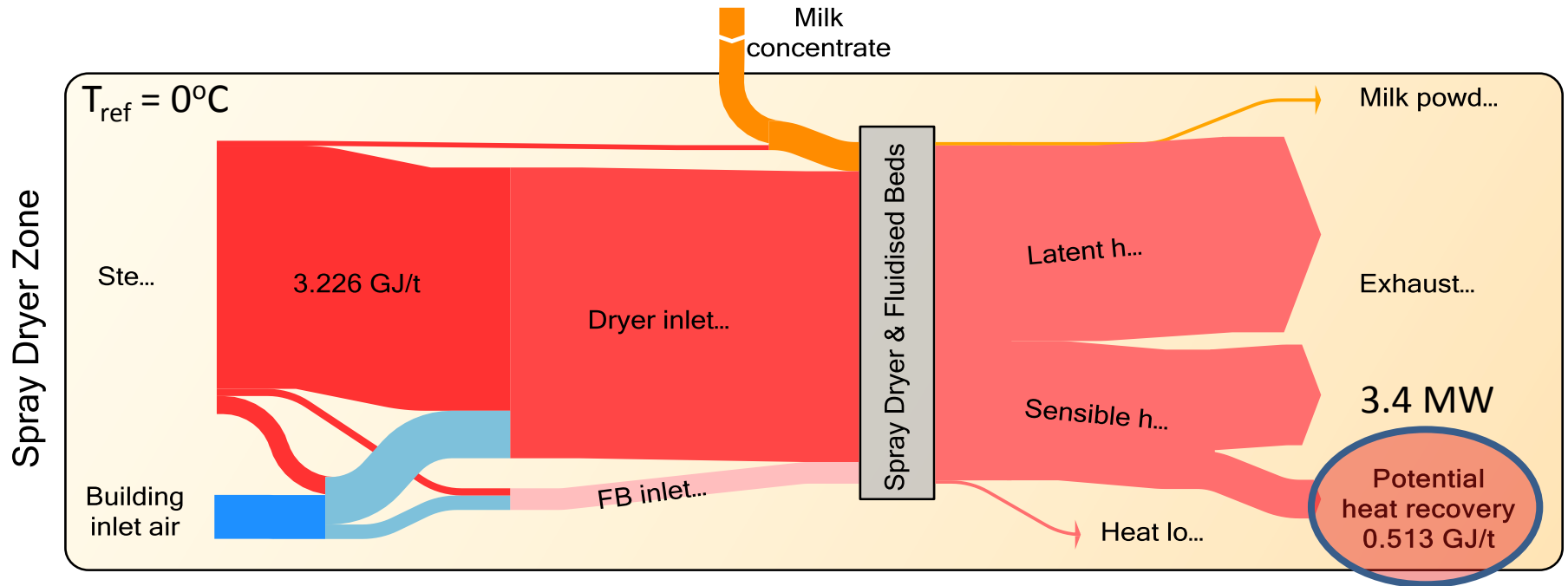


Dryer exhaust heat recovery

Best sink: Dryer inlet air



Sankey: Energy Flows



Exhaust HR (75 to 55°C) = 10% Steam Reduction

Savings for 23 t/h dryer = **\$900,000 per year¹**

¹Savings based on Steam \$30/t, Chilled water \$35/MWh and 6000 hours of production

CHALLENGES

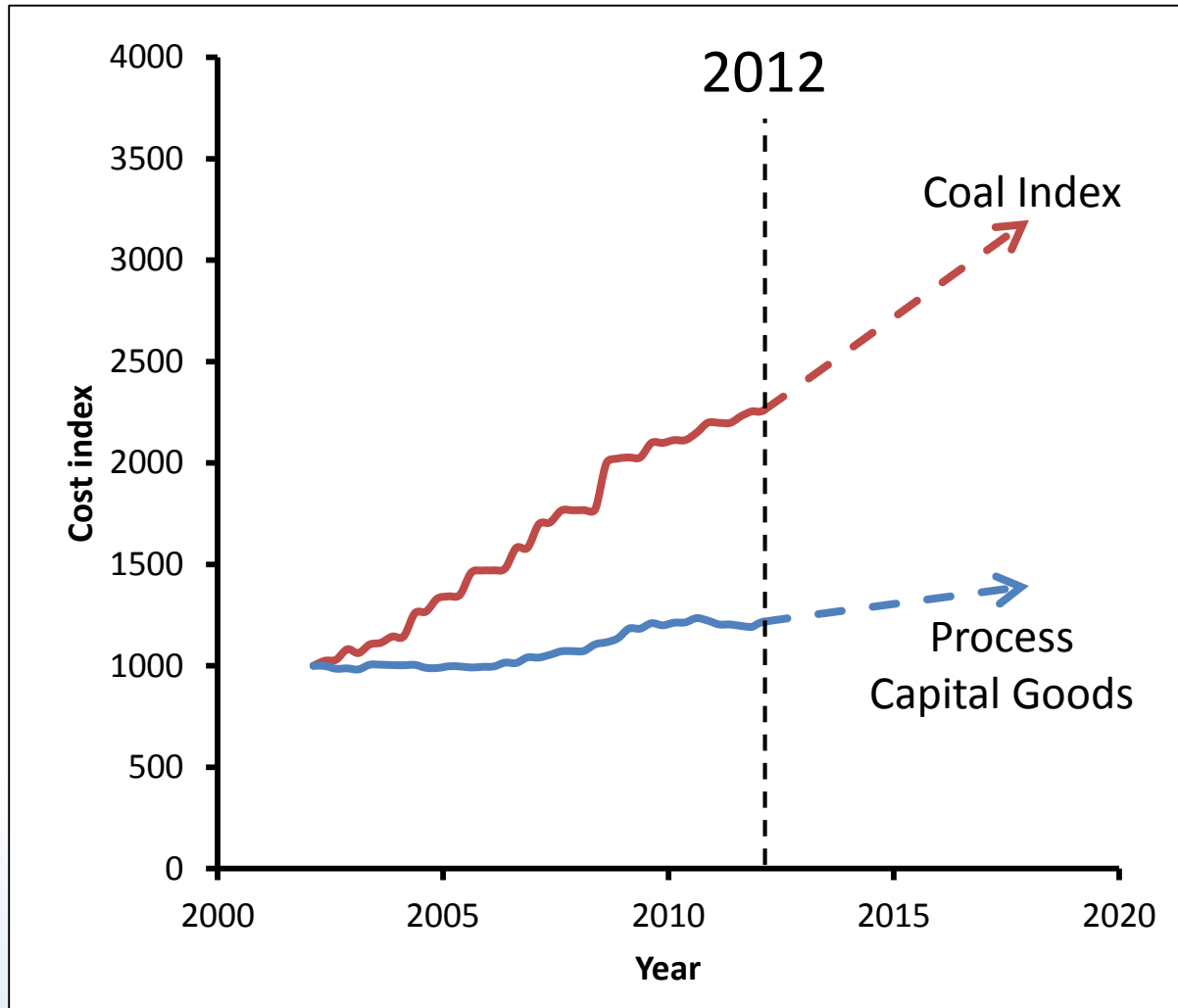
Challenges

- 1) Expensive to recover heat from air – high HT resistance
- 2) Distance between exhaust and inlet ducts
- 3) Particulate fouling

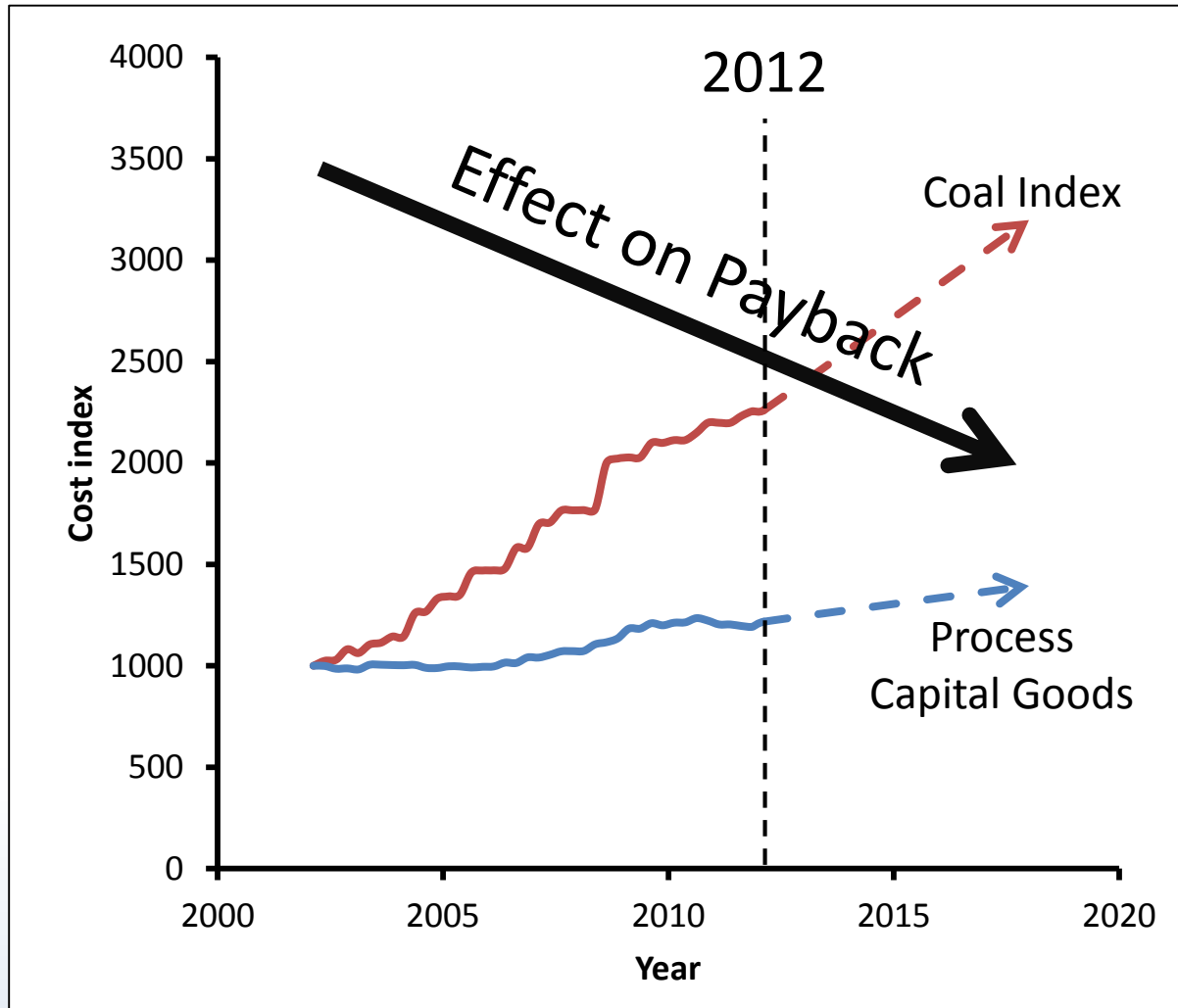
Challenges

- 1) **Expensive to recover heat from air** – high HT resistance
- 2) Distance between exhaust and inlet ducts
- 3) Particulate fouling

Process Heat and Capital



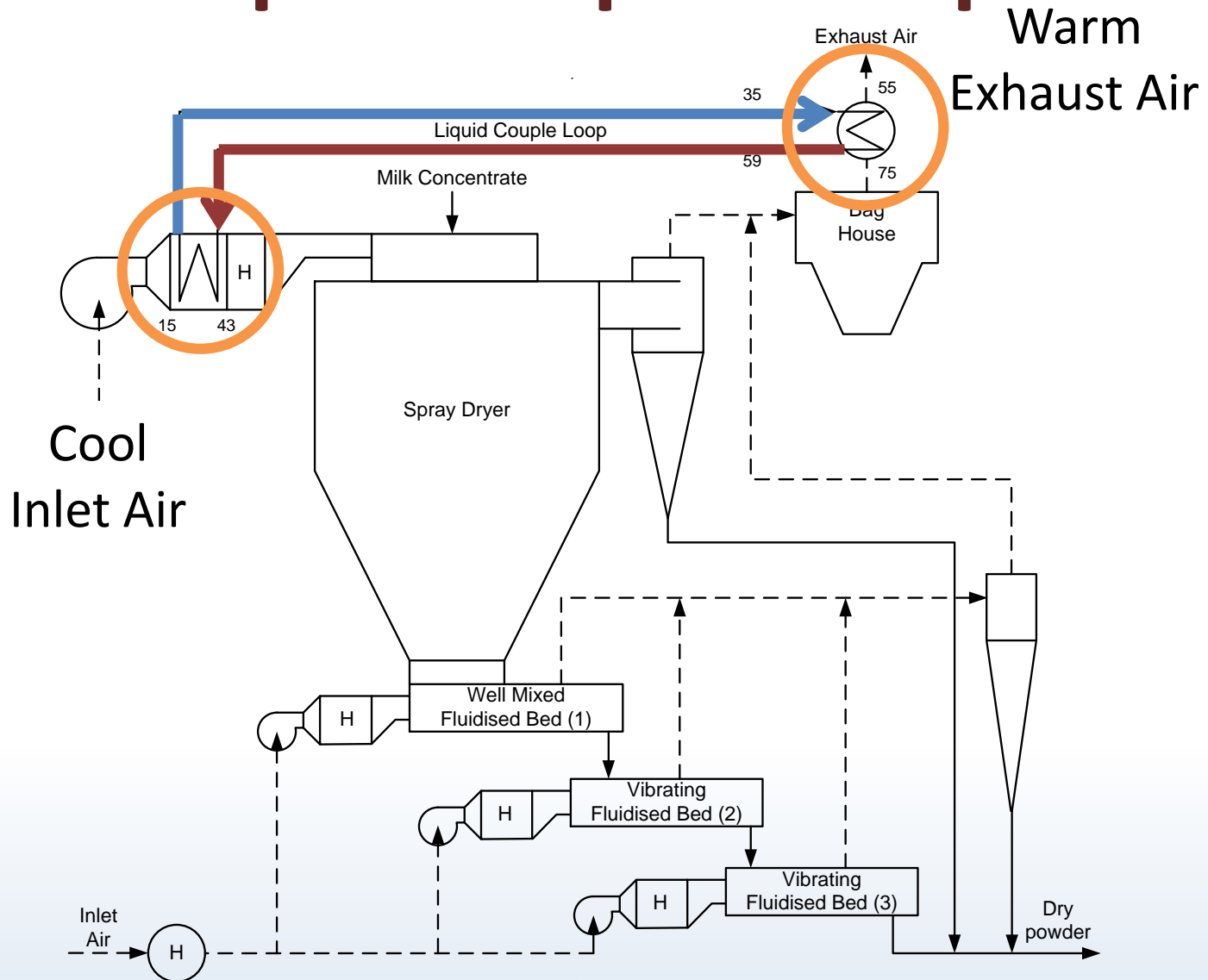
Process Heat and Capital



Challenges

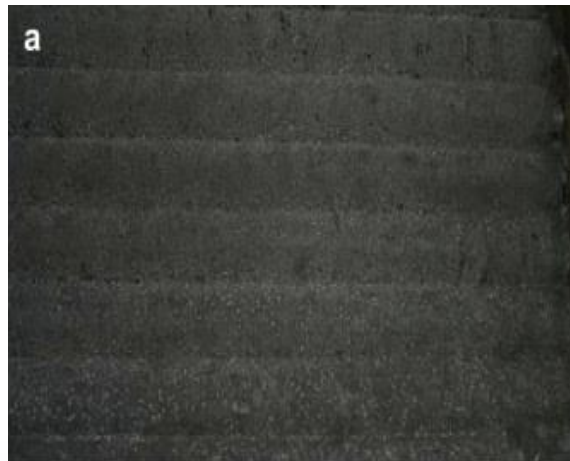
- 1) Expensive to recover heat from air – high HT resistance
- 2) **Distance between exhaust and inlet ducts**
- 3) Particulate fouling

Liquid Coupled Loop

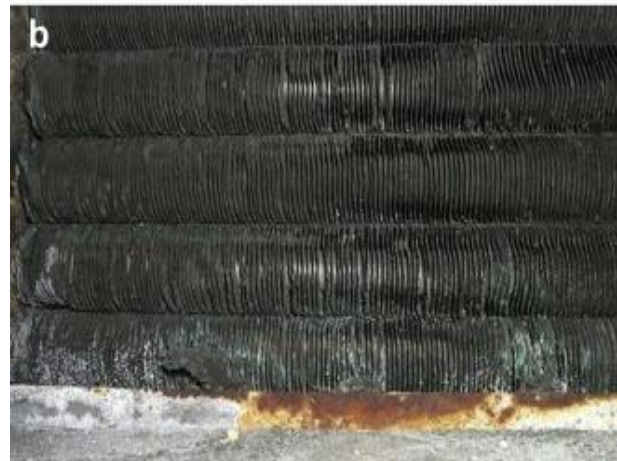


Challenges

- 1) Expensive to recover heat from air – high HT resistance
- 2) Distance between exhaust and inlet ducts
- 3) **Particulate fouling**



Heavily fouled finned tube bank

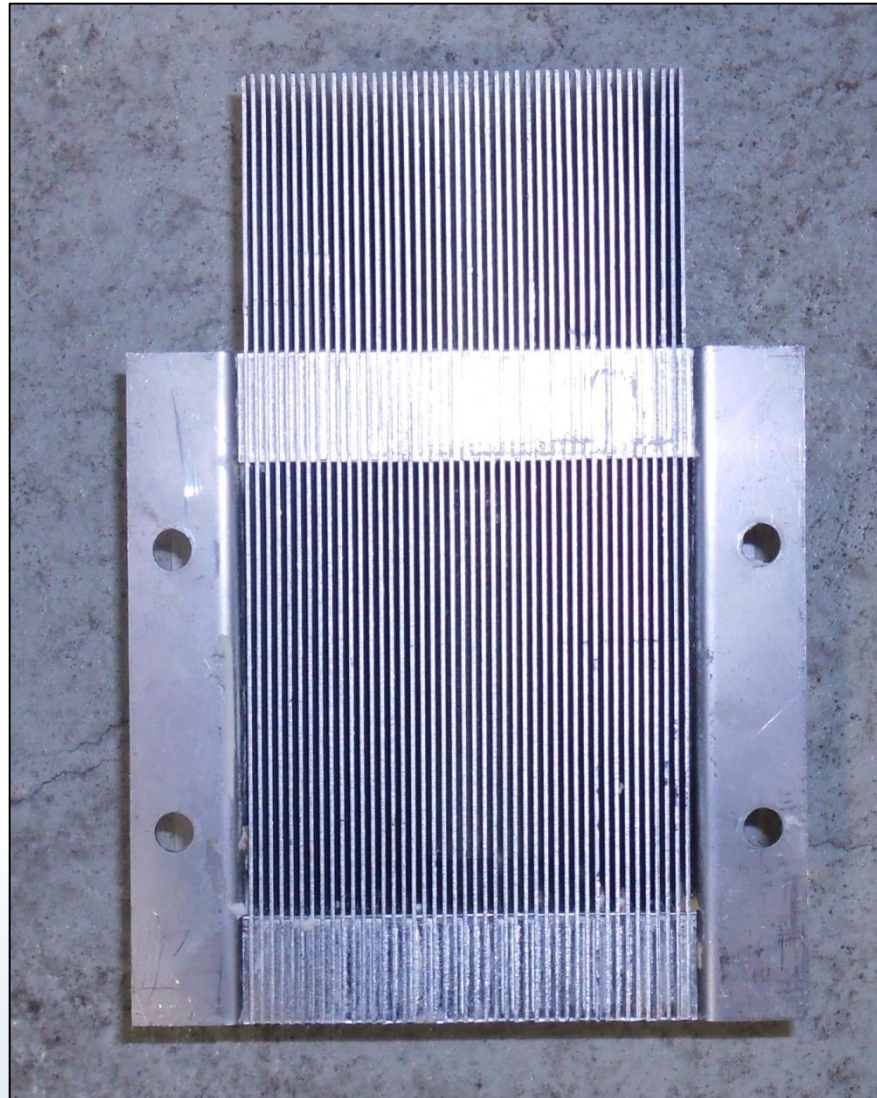


Finned tube bank after cleaning

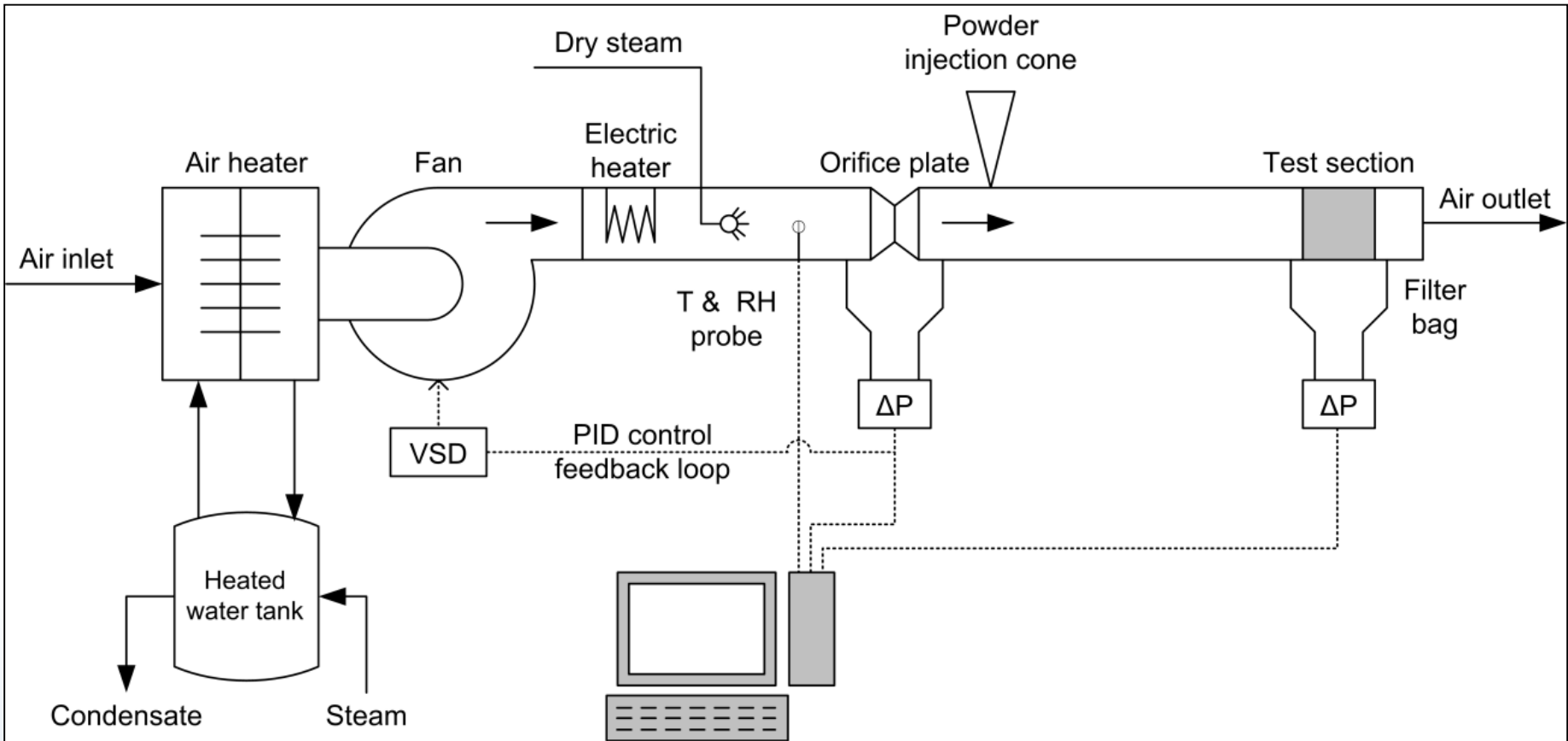
Finned Tube Boiler Recuperator

LAB EXPERIMENTS

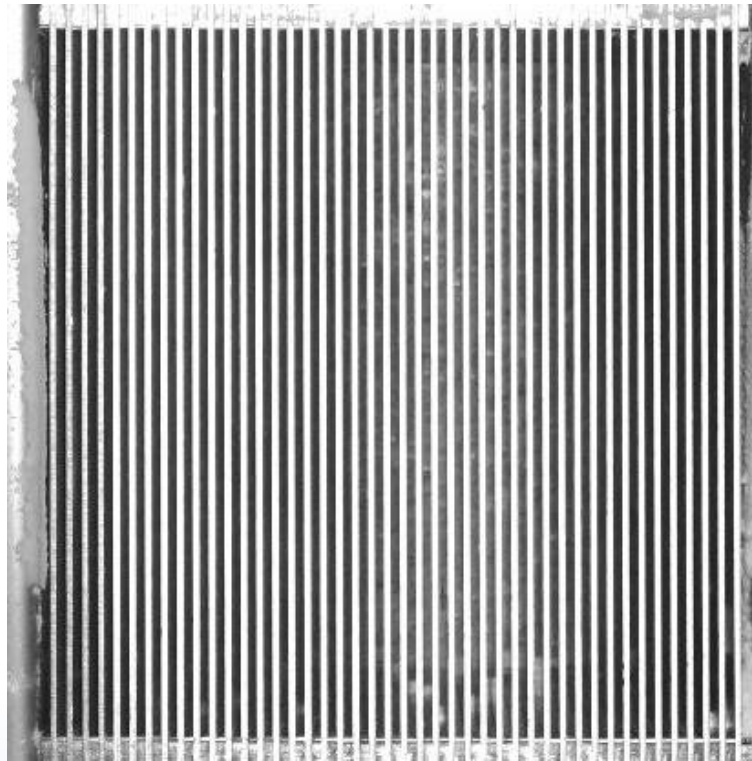
Frontal Deposition on Fins



Test Rig Schematic

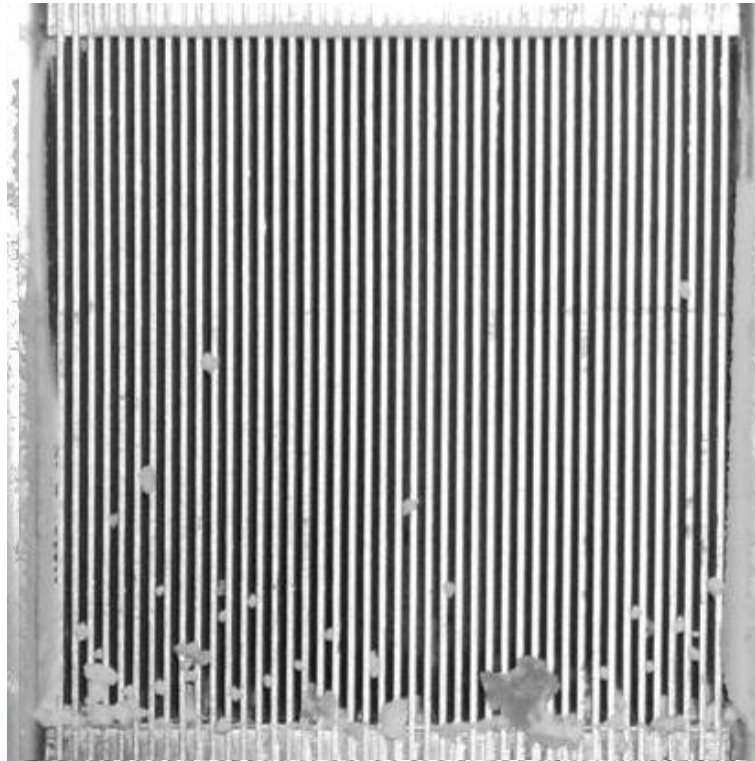


Milk Powder Fouling



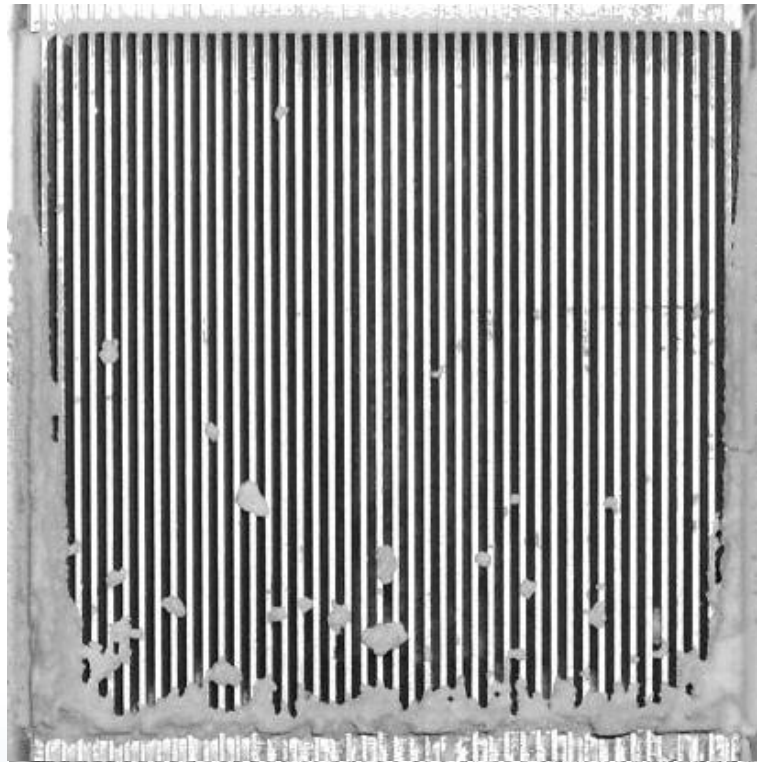
$T=71^{\circ}\text{C}$, $AH = 60 \text{ g/kg}$

Milk Powder Fouling



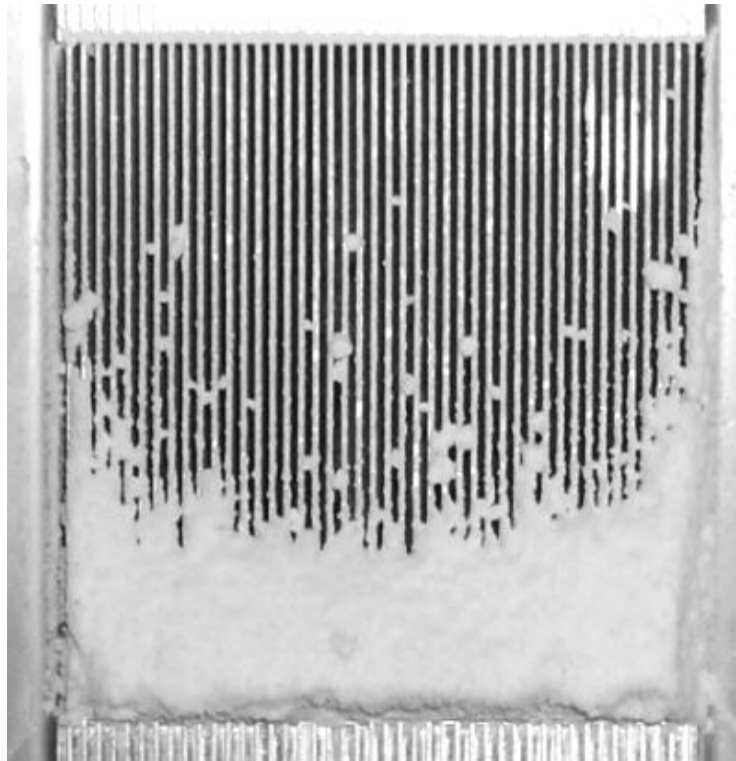
$T=59^{\circ}\text{C}$, $AH = 60 \text{ g/kg}$

Milk Powder Fouling



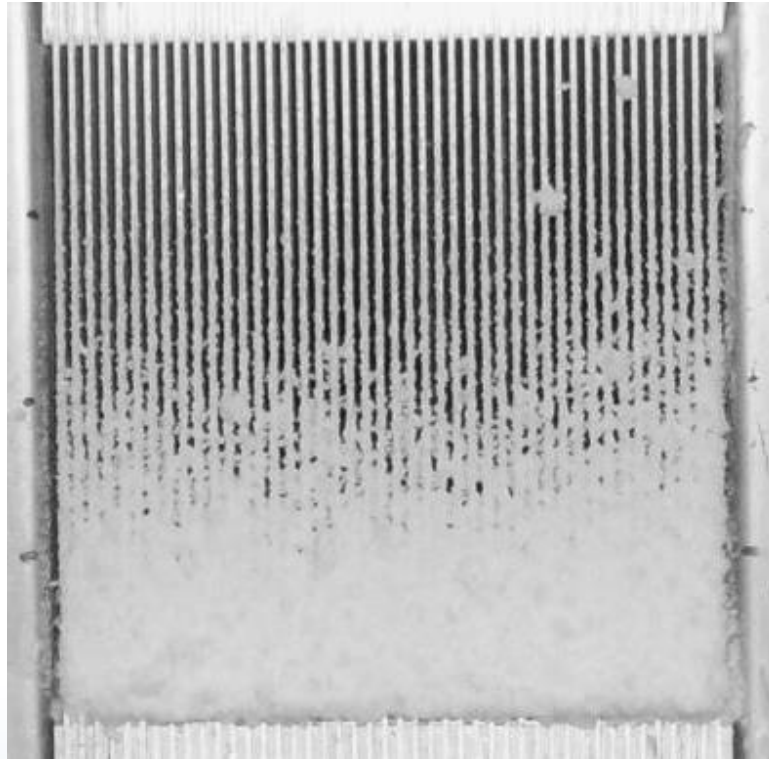
$T=55^{\circ}\text{C}$, $AH = 60 \text{ g/kg}$

Milk Powder Fouling



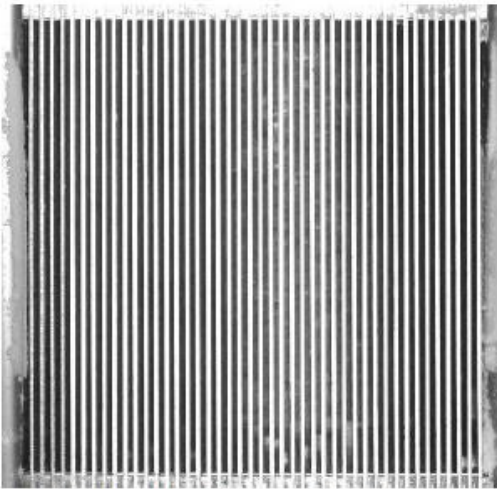
$T=52^{\circ}\text{C}$, $AH = 60 \text{ g/kg}$

Milk Powder Fouling

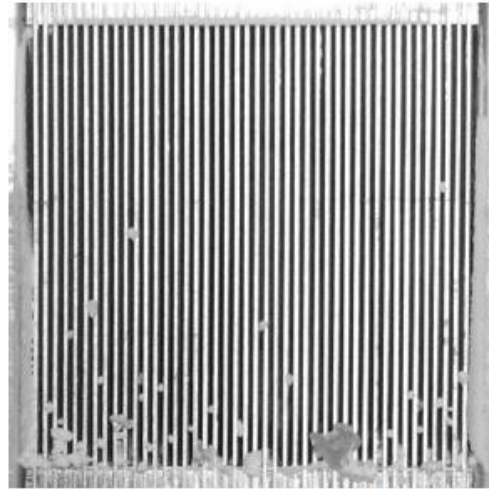


$T=49^{\circ}\text{C}$, $AH = 60 \text{ g/kg}$

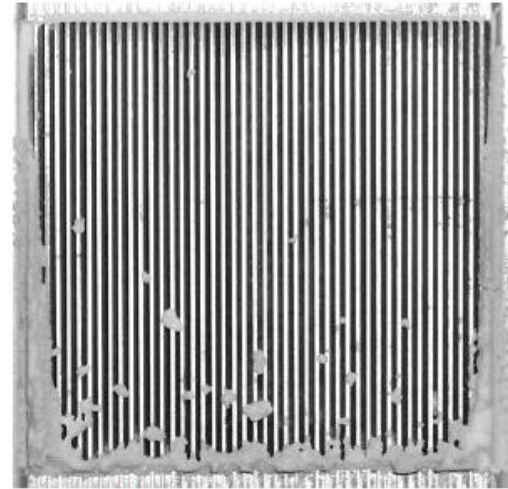
Milk Powder Fouling



(A) $T=71\text{ }^{\circ}\text{C}$, $\phi=0.67$



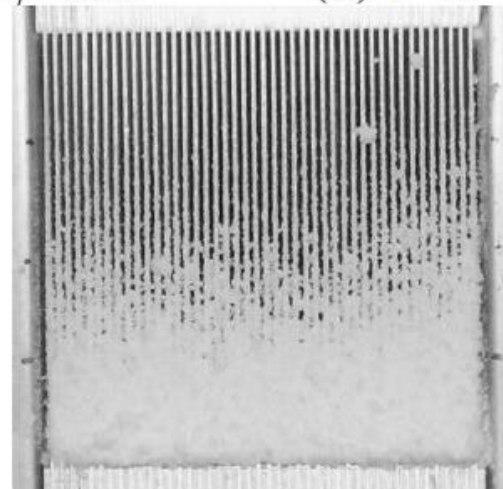
(B) $T=59\text{ }^{\circ}\text{C}$, $\phi=0.66$



(C) $T=55\text{ }^{\circ}\text{C}$, $\phi=0.60$

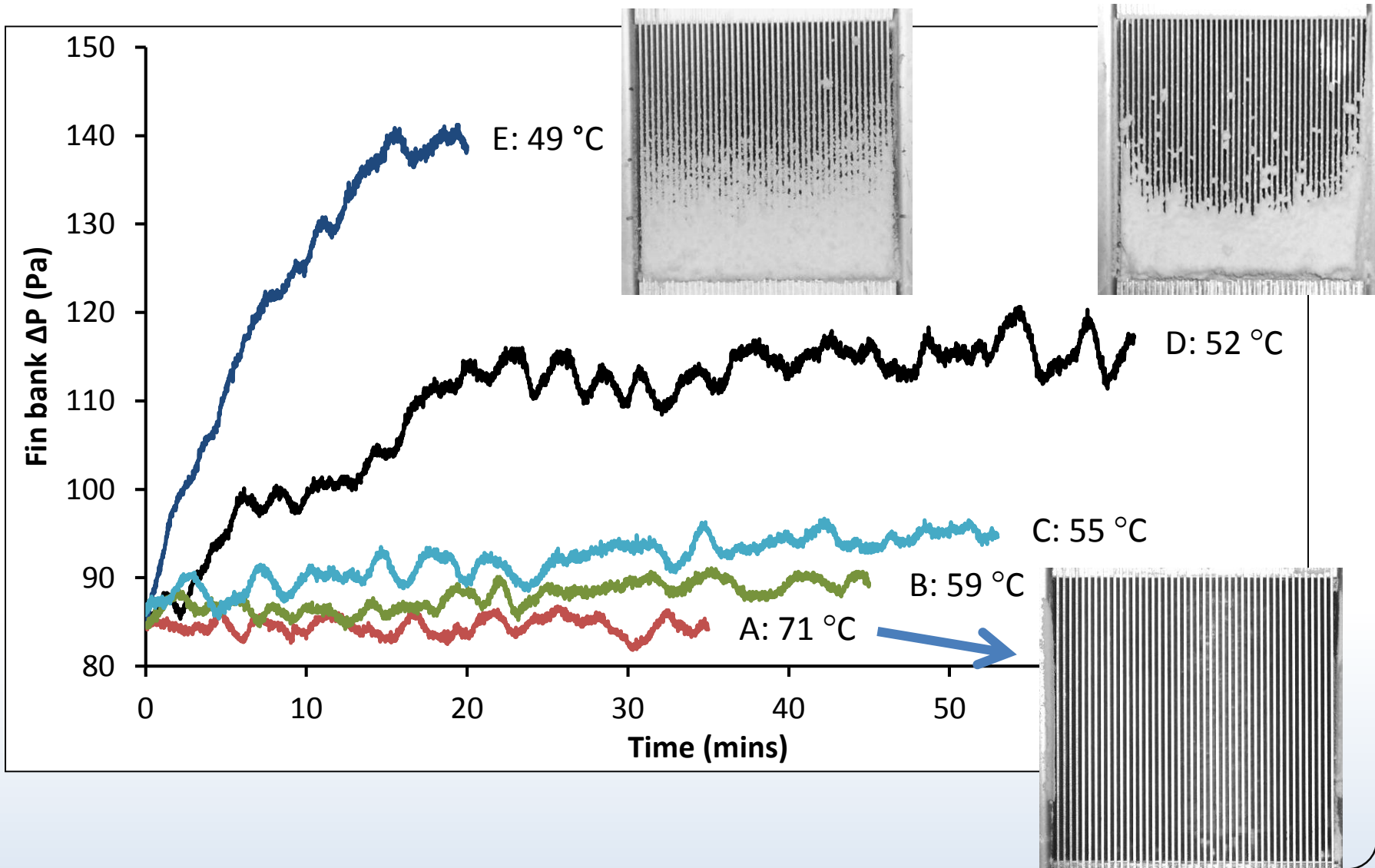


(D) $T=52\text{ }^{\circ}\text{C}$, $\phi=0.44$

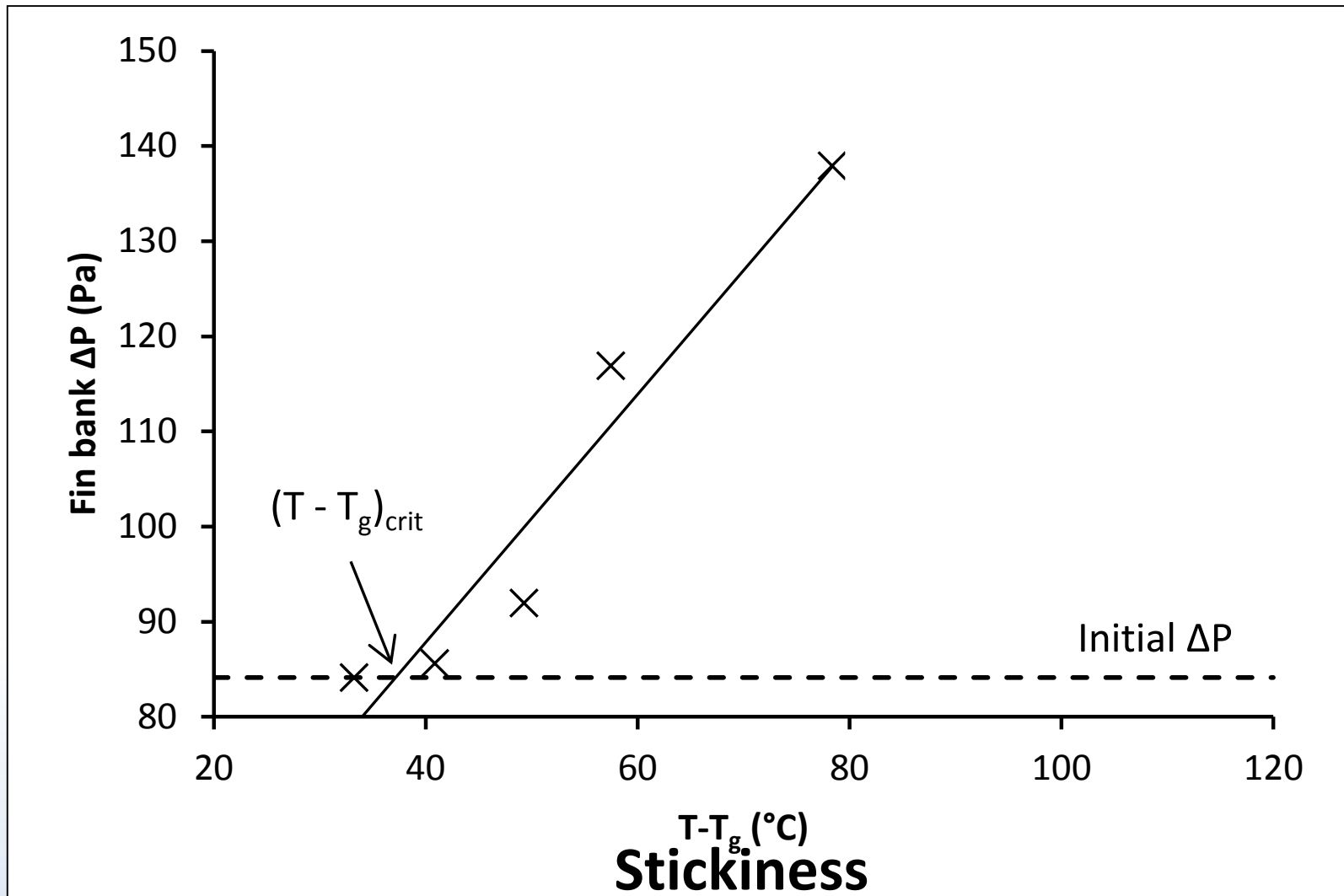


(E) $T=49\text{ }^{\circ}\text{C}$, $\phi=0.35$

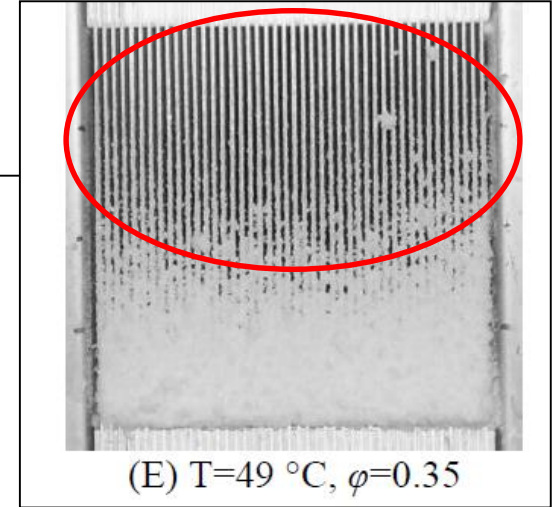
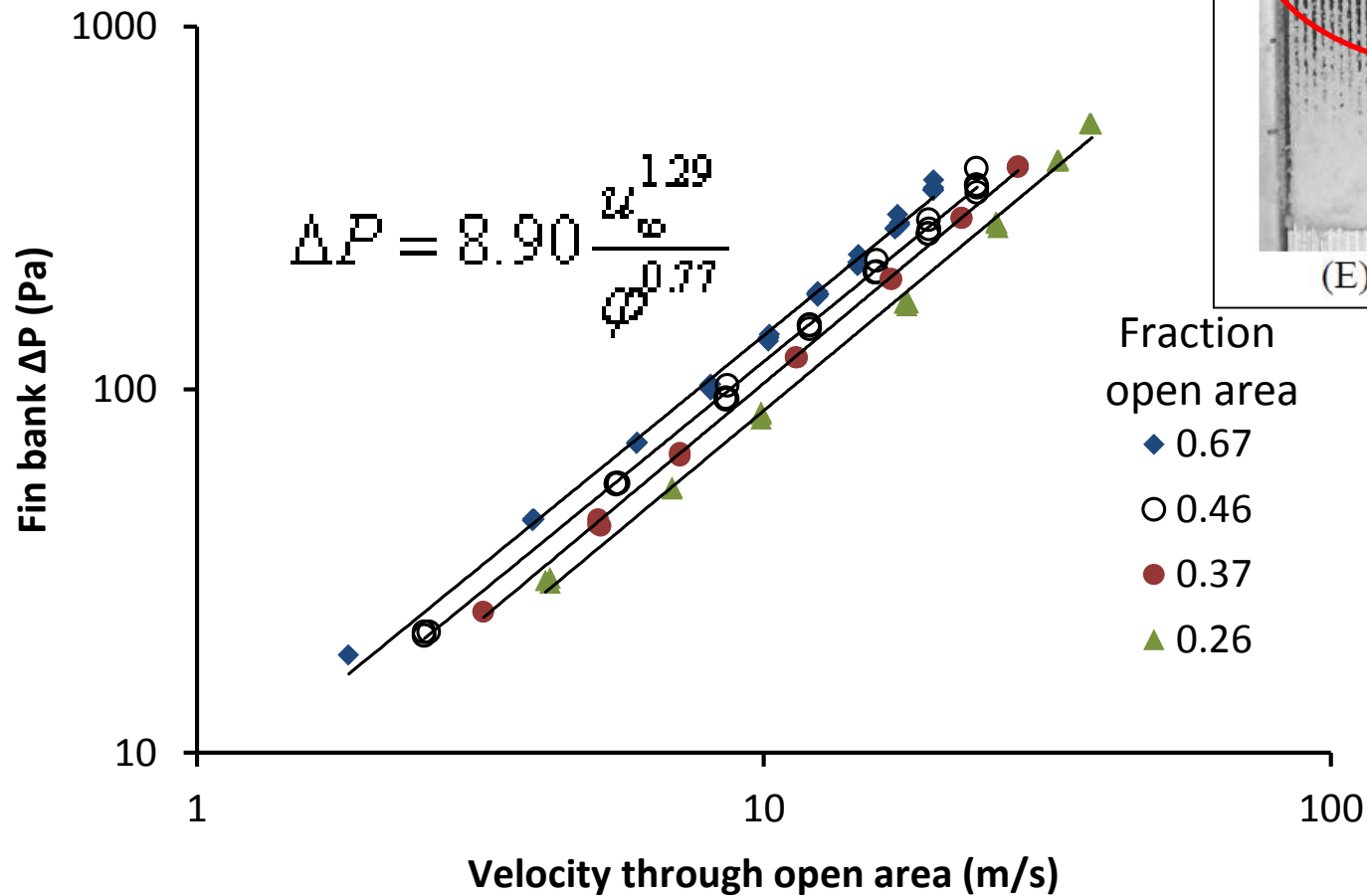
Effect on Pressure Drop



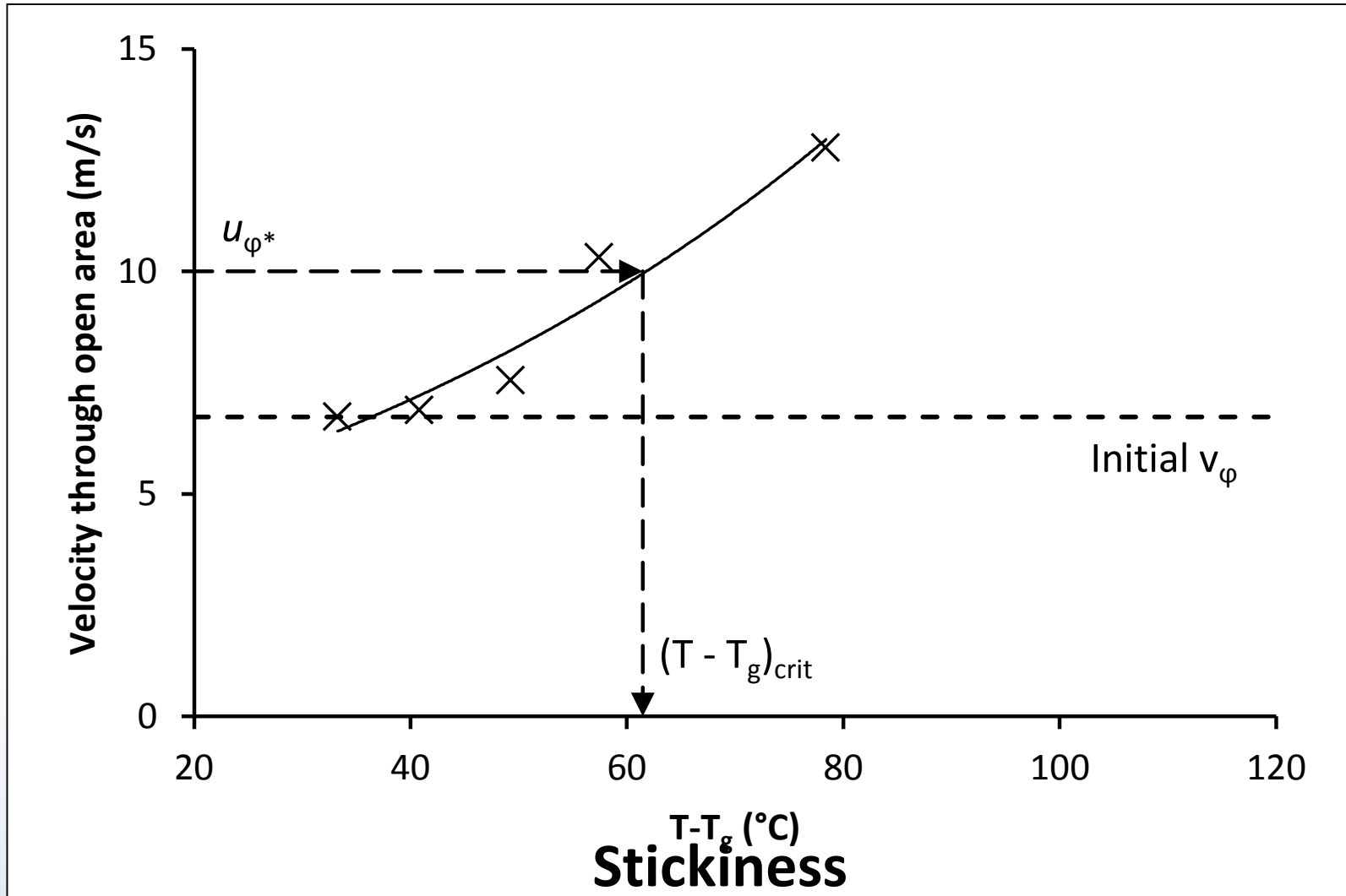
Pressure Drop and Stickiness



Velocity and Pressure Drop



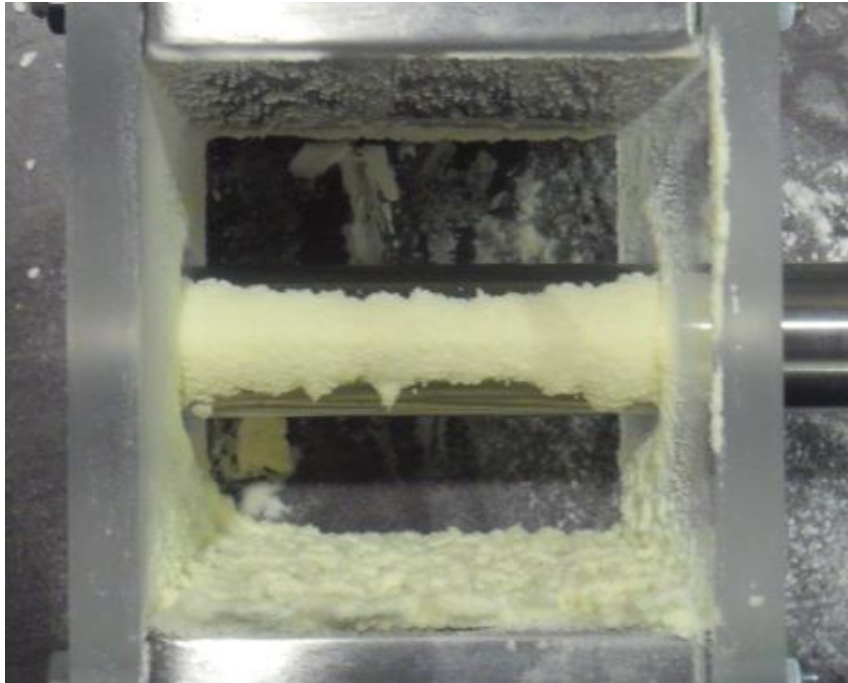
Critical stickiness and velocity



ADDITIONAL EXPERIMENTS

Preliminary Experimental Results

Round Tube



Elliptical Tube



Same air velocity, temperature and relative humidity

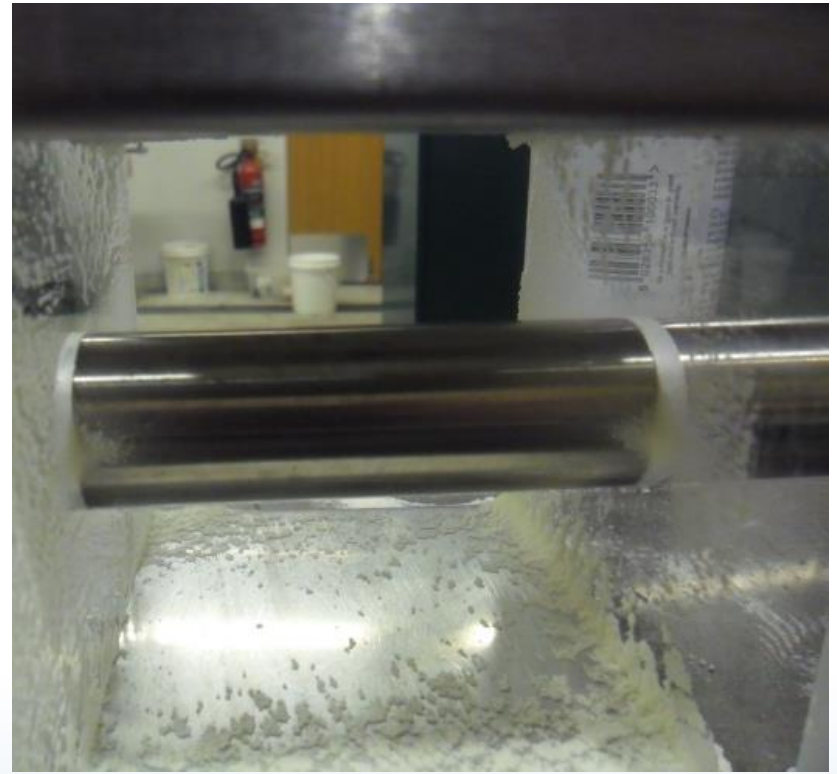
- Air temp / RH determine particulate surface stickiness
- Similar particle loading and time (equilibrium)

Round: Front vs Back

Front

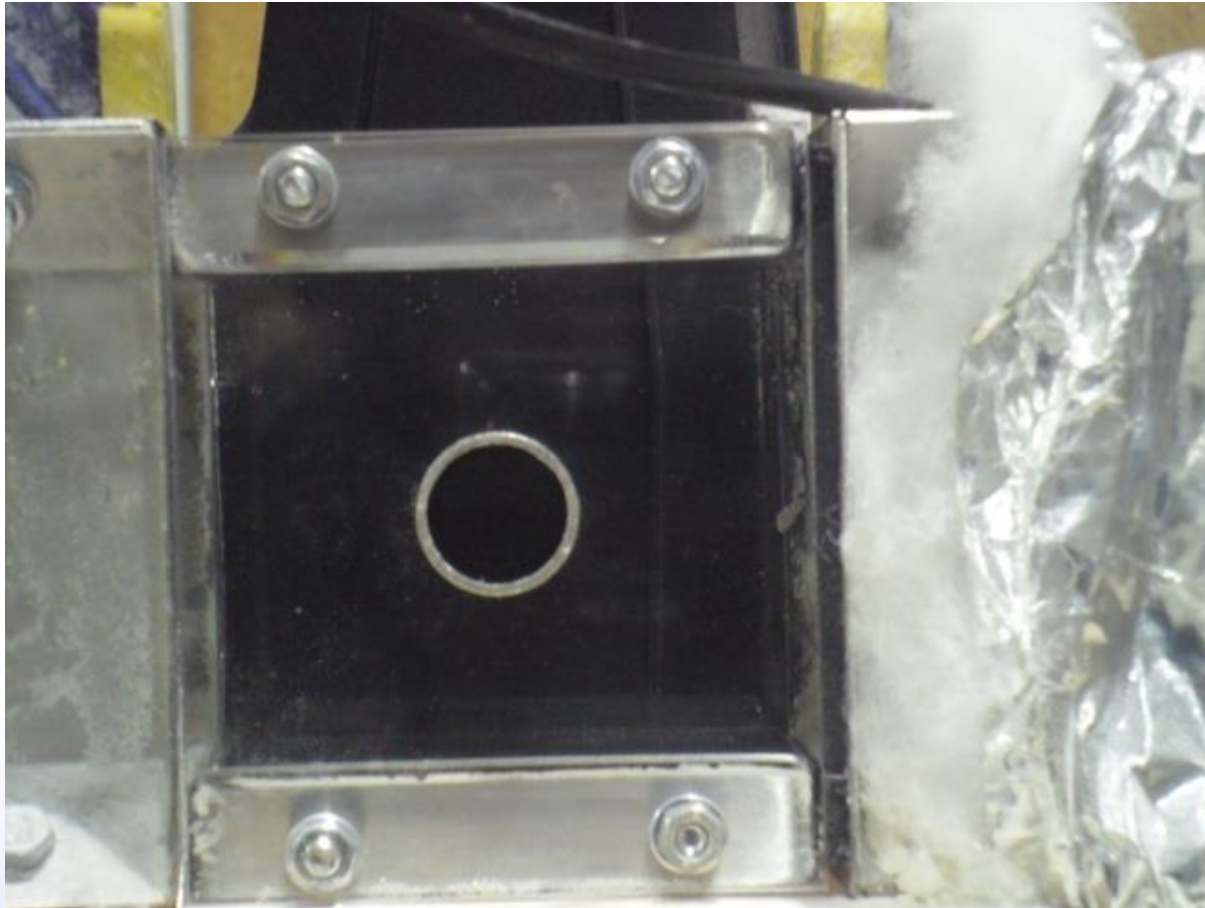


Back

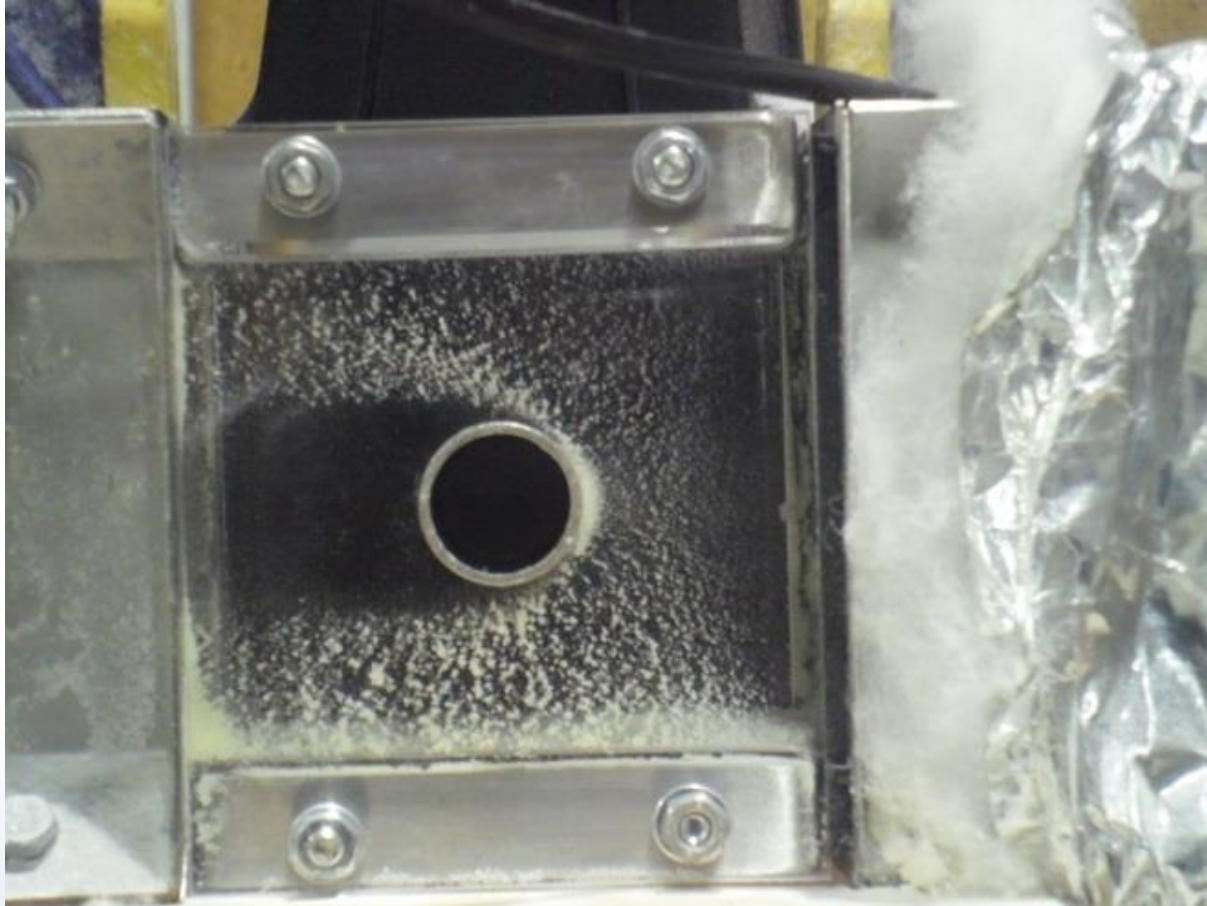


Testing in Fastforward

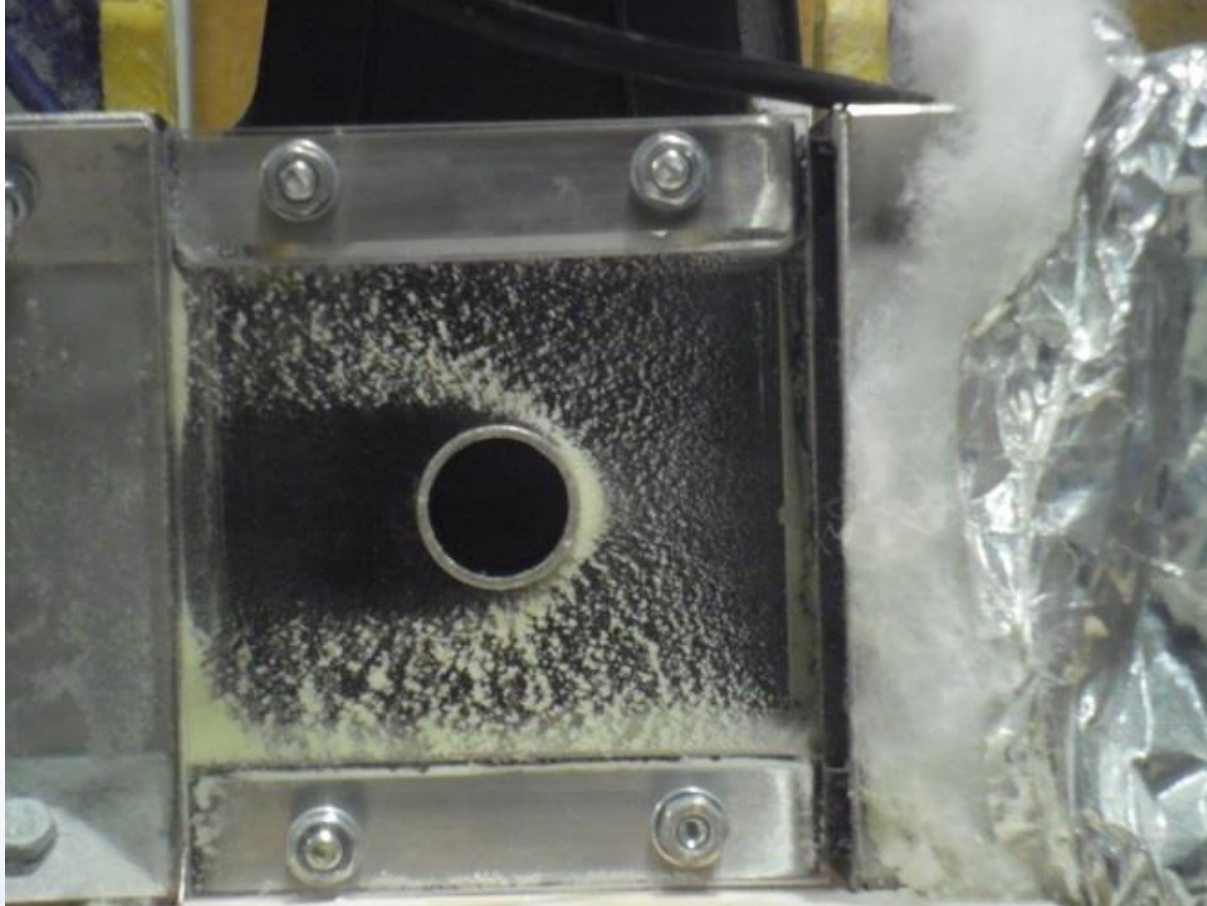
Start



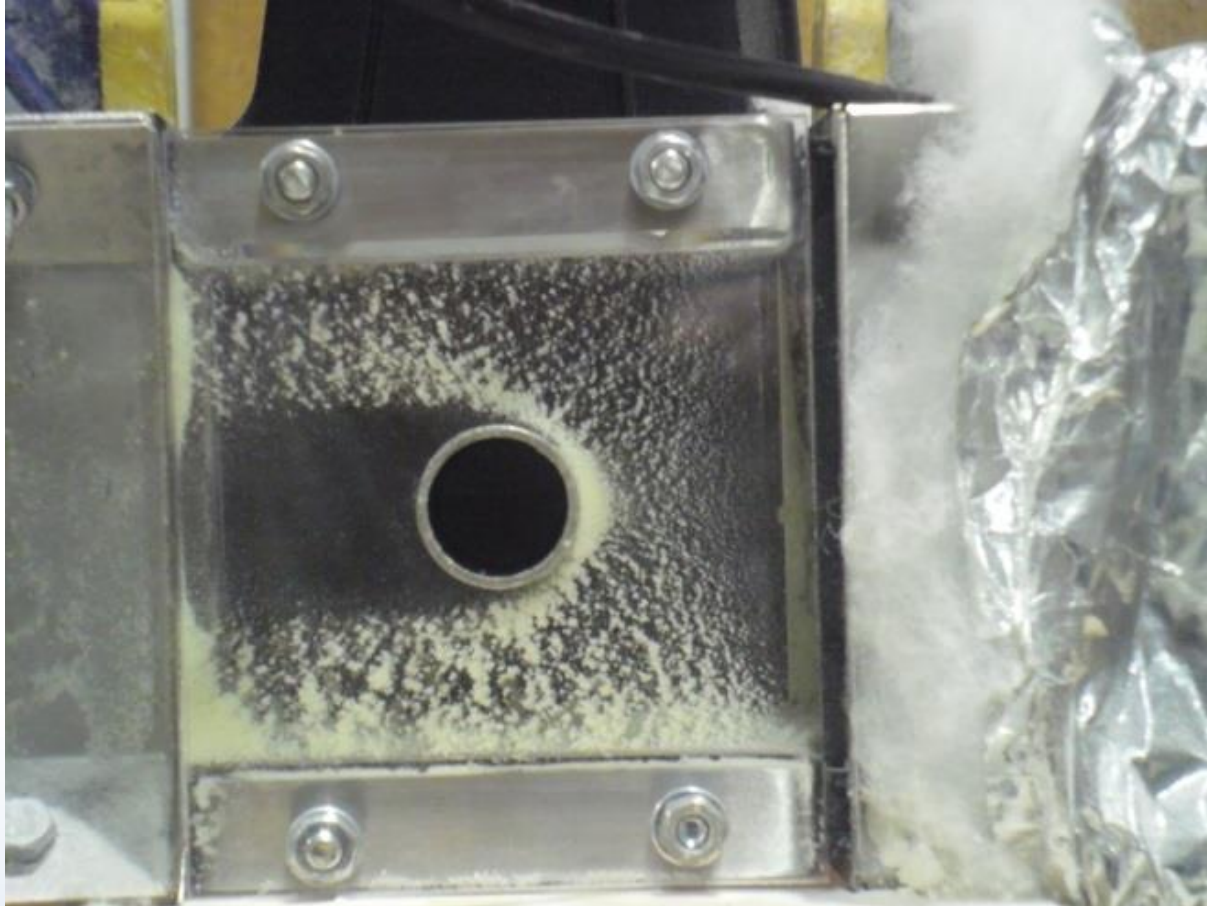
Testing in Fastforward 5 mins



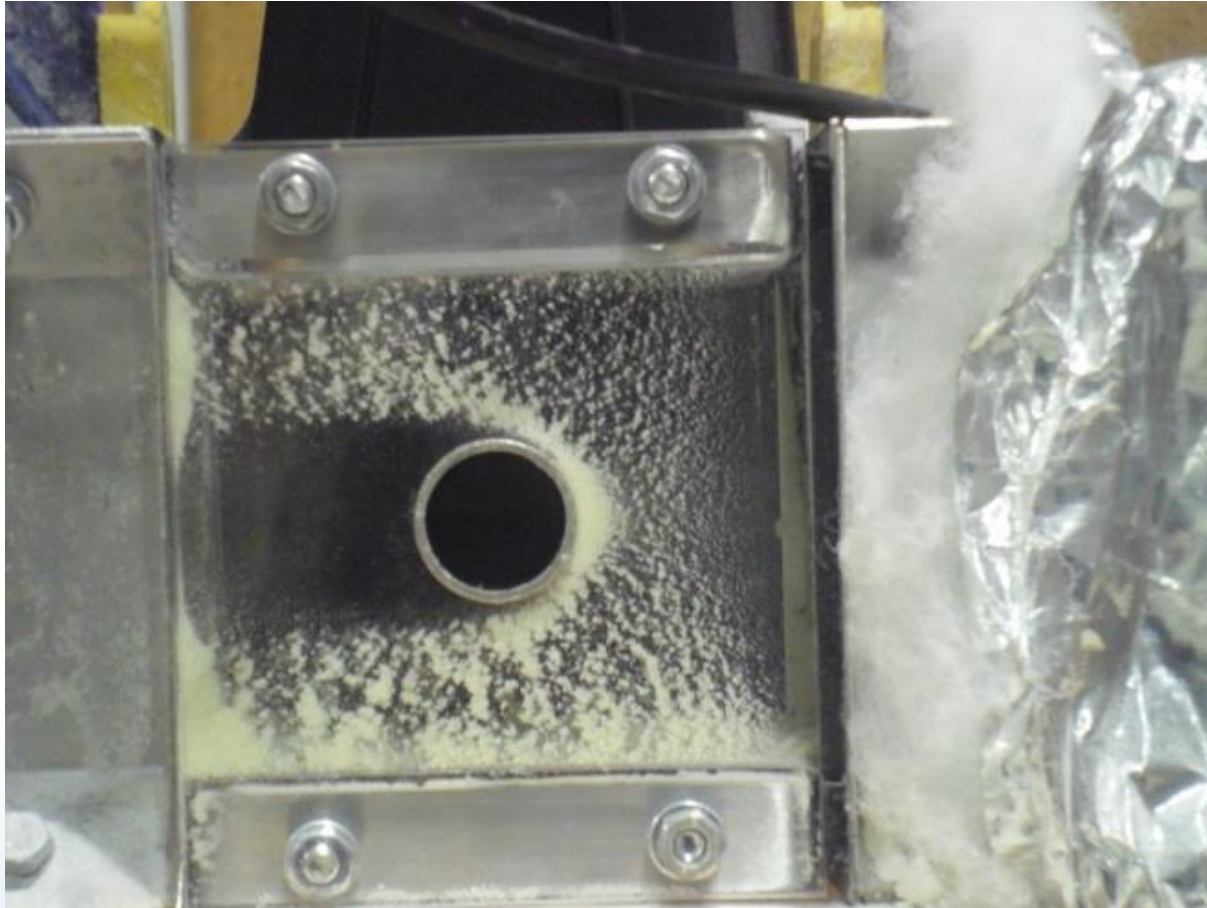
Testing in Fastforward 10 mins



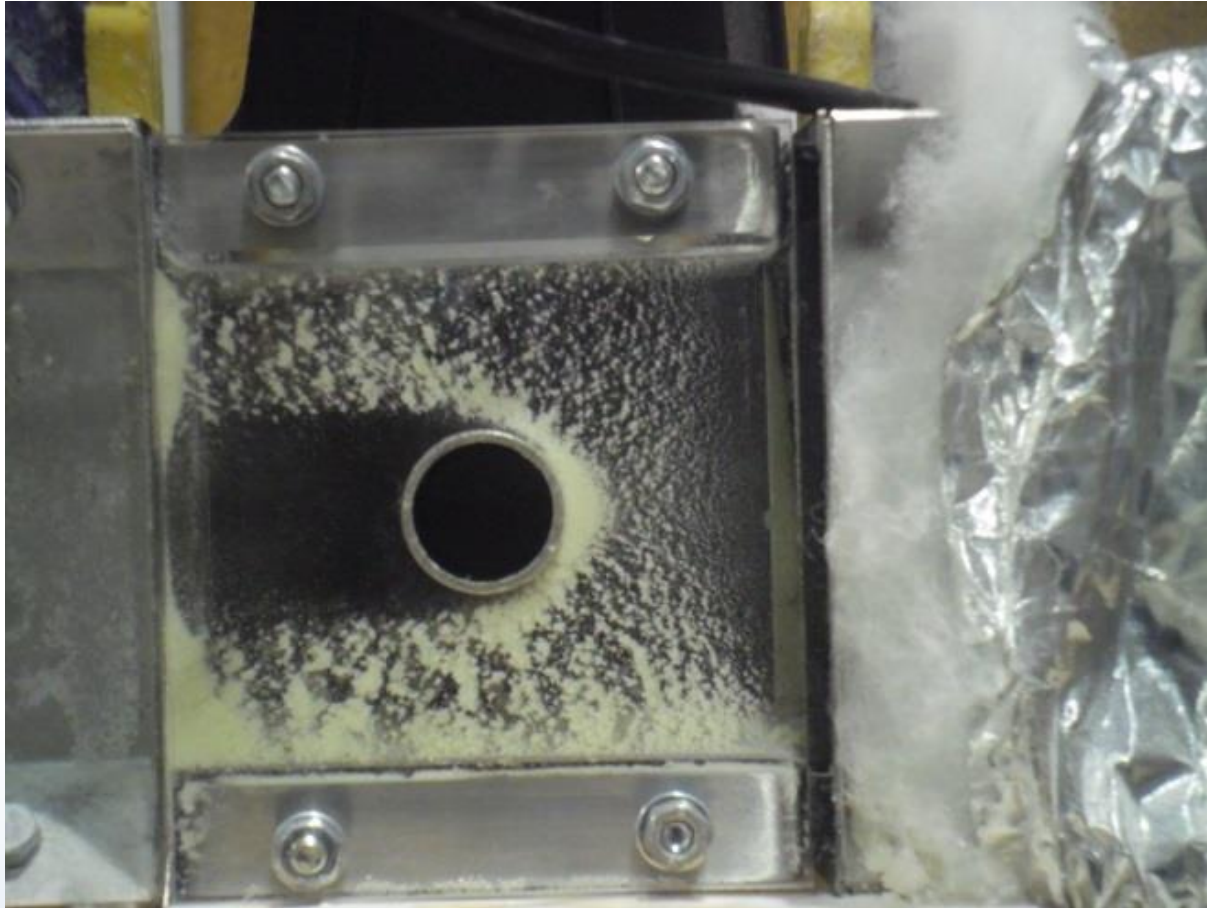
Testing in Fastforward 15 mins



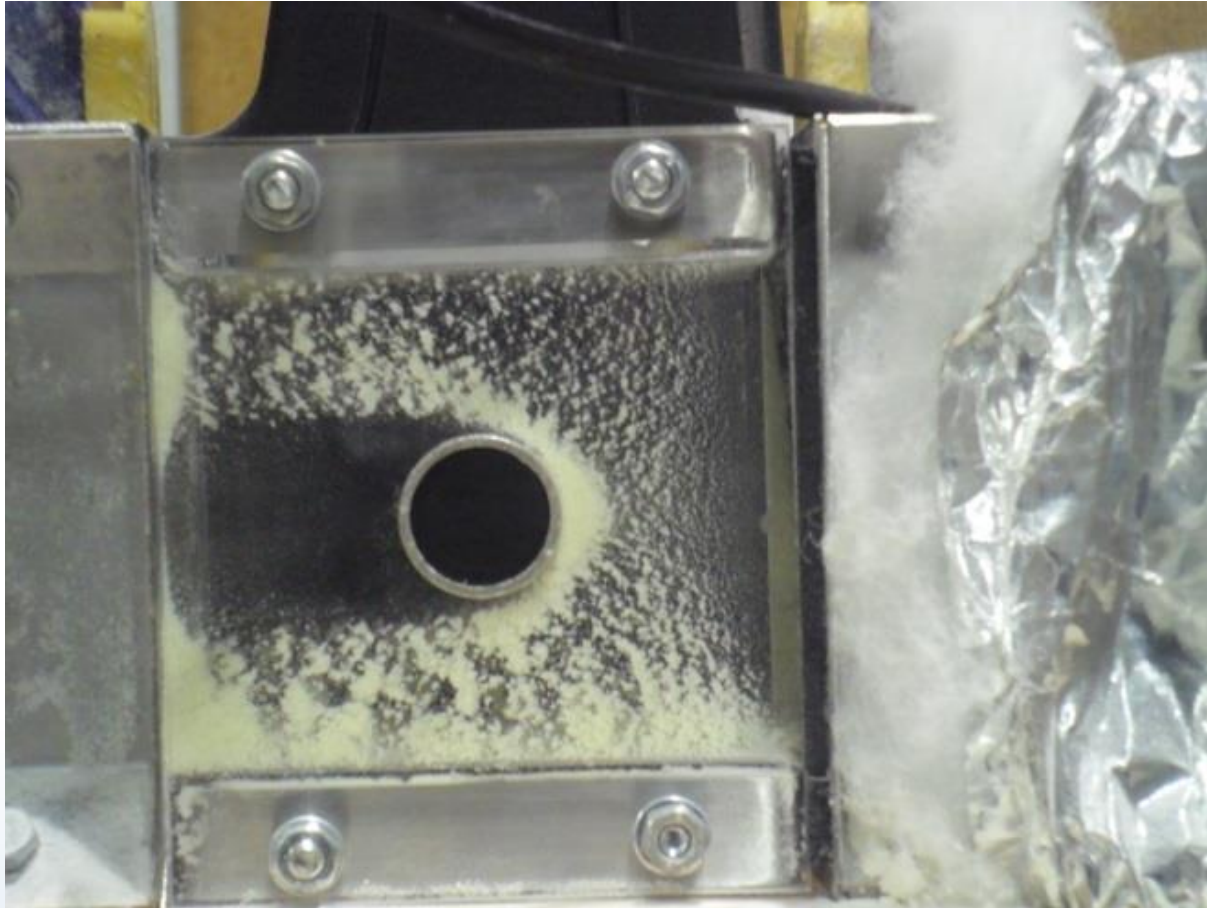
Testing in Fastforward ^{20 mins}



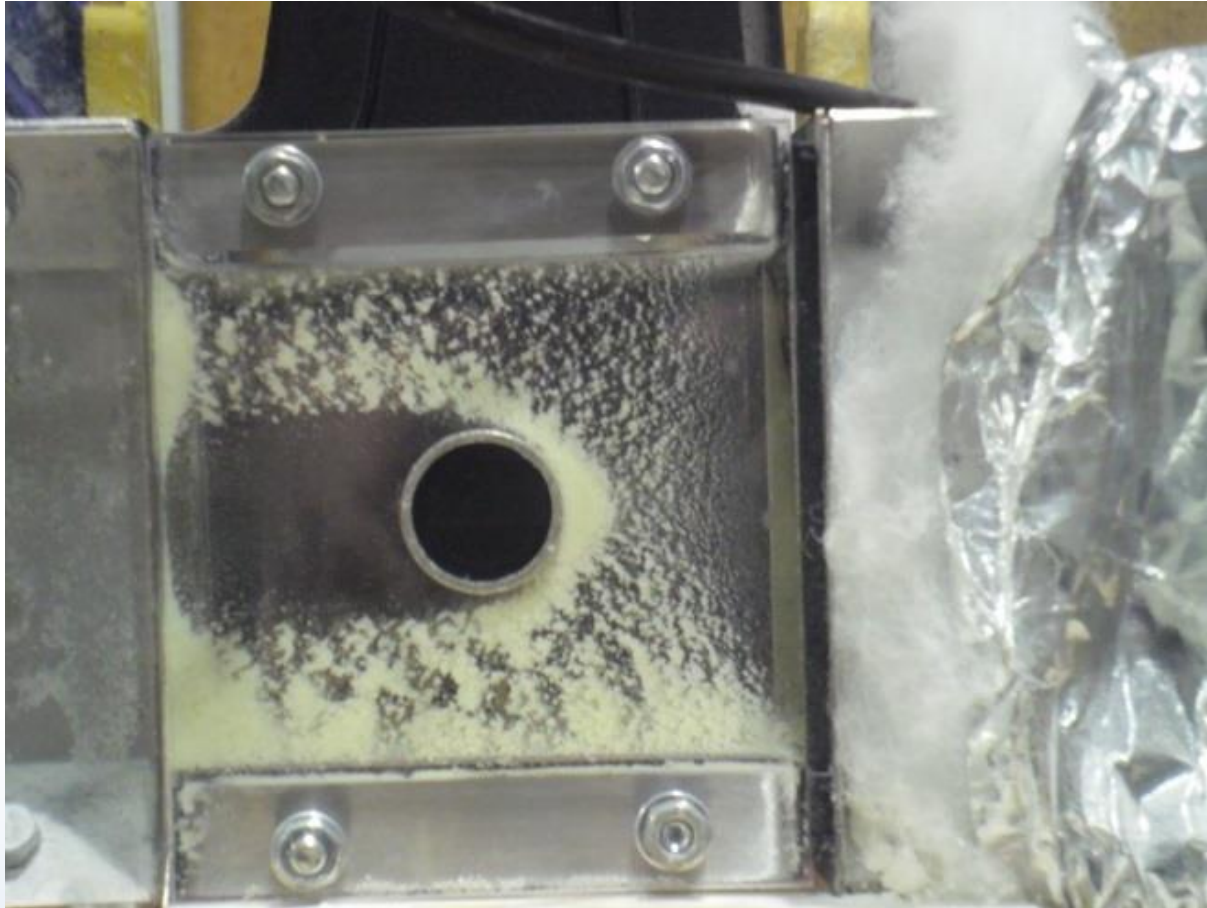
Testing in Fastforward ^{25 mins}



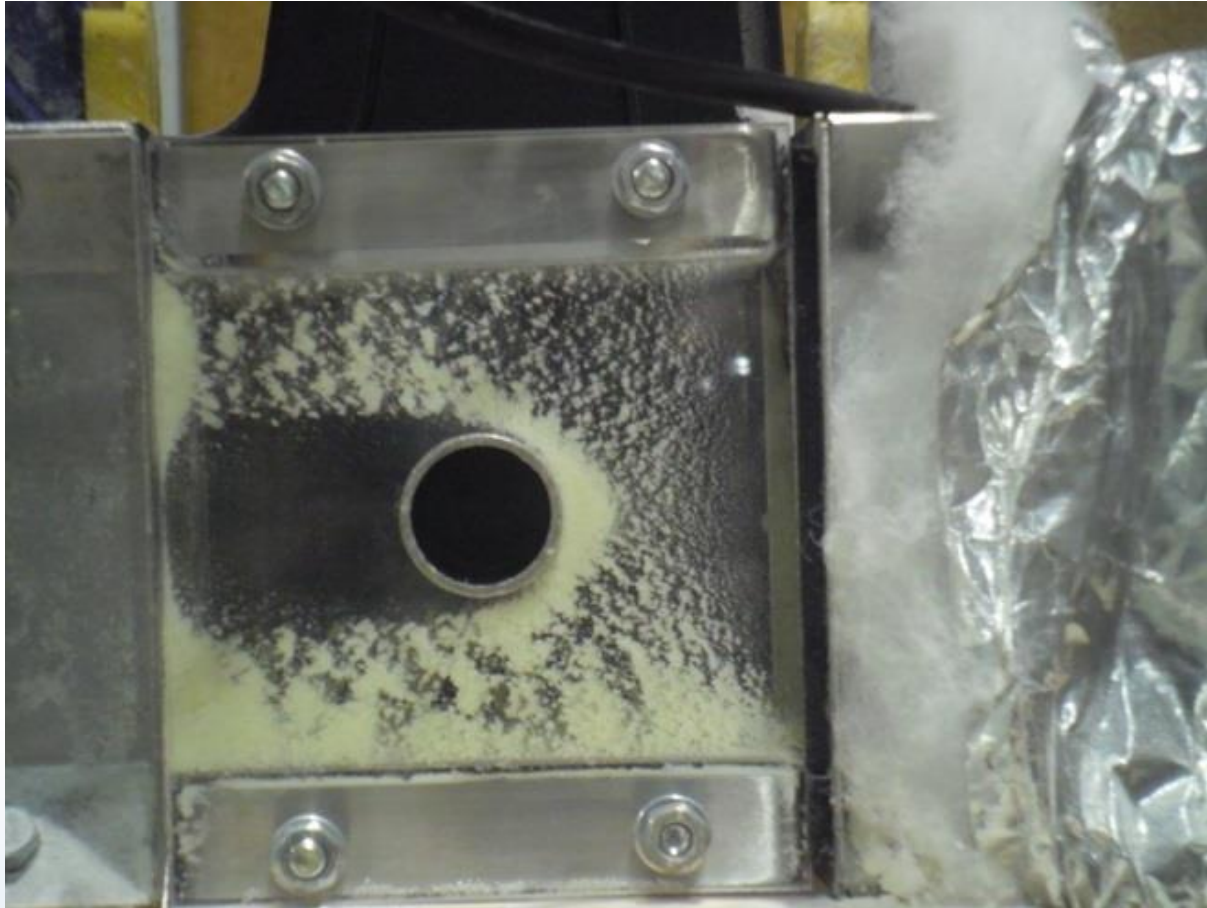
Testing in Fastforward 30 mins



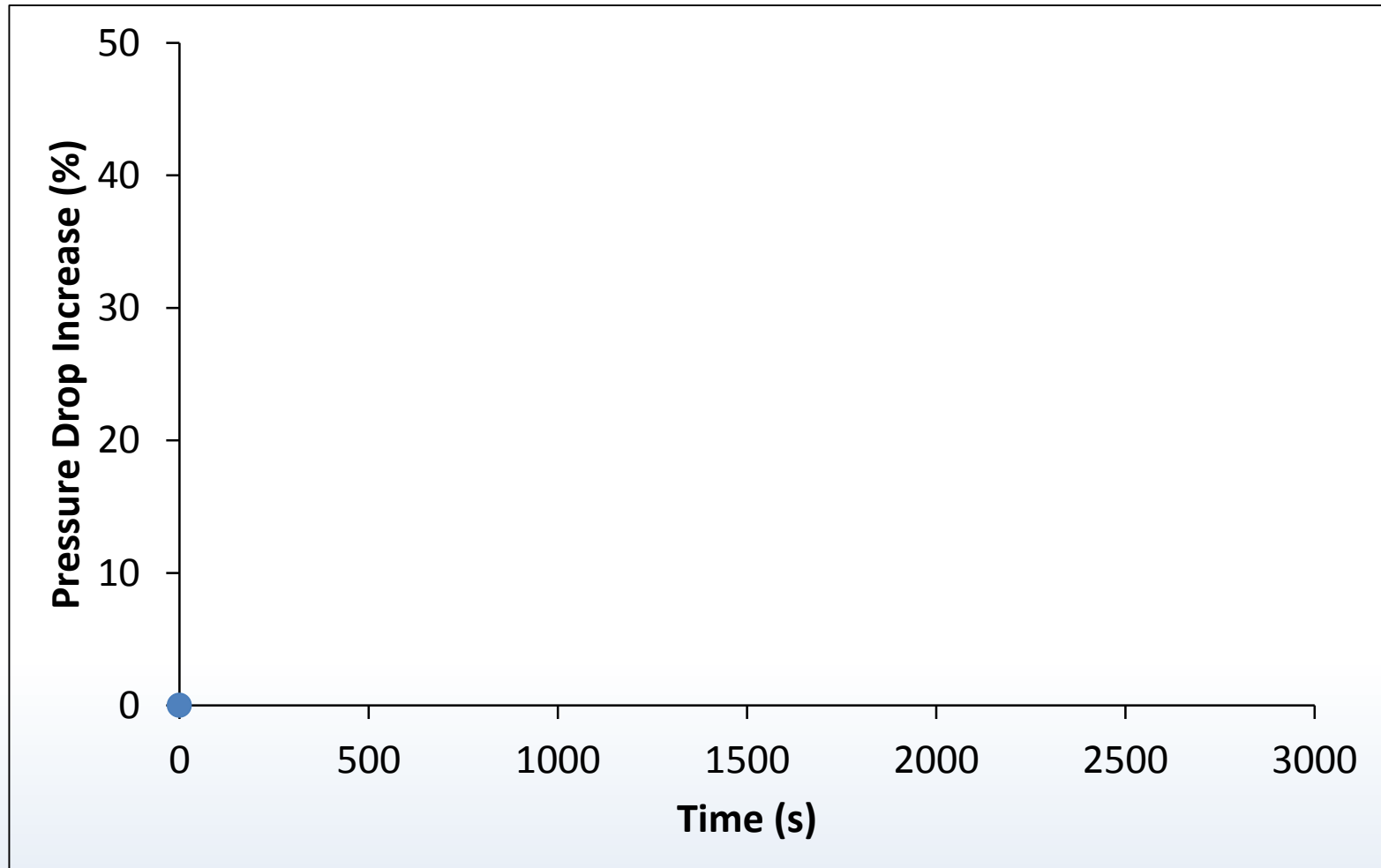
Testing in Fastforward 35 mins



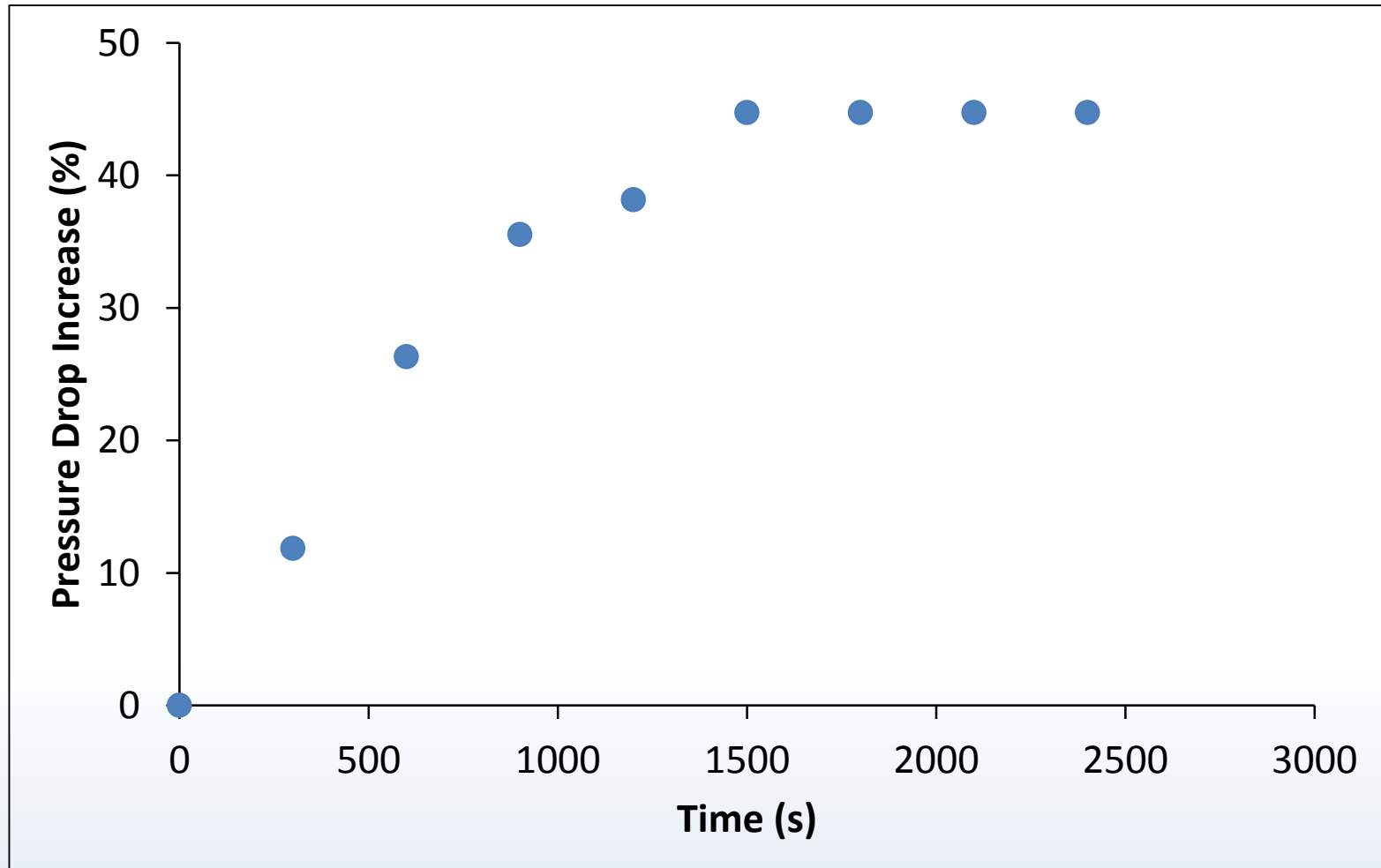
Testing in Fastforward 40 mins



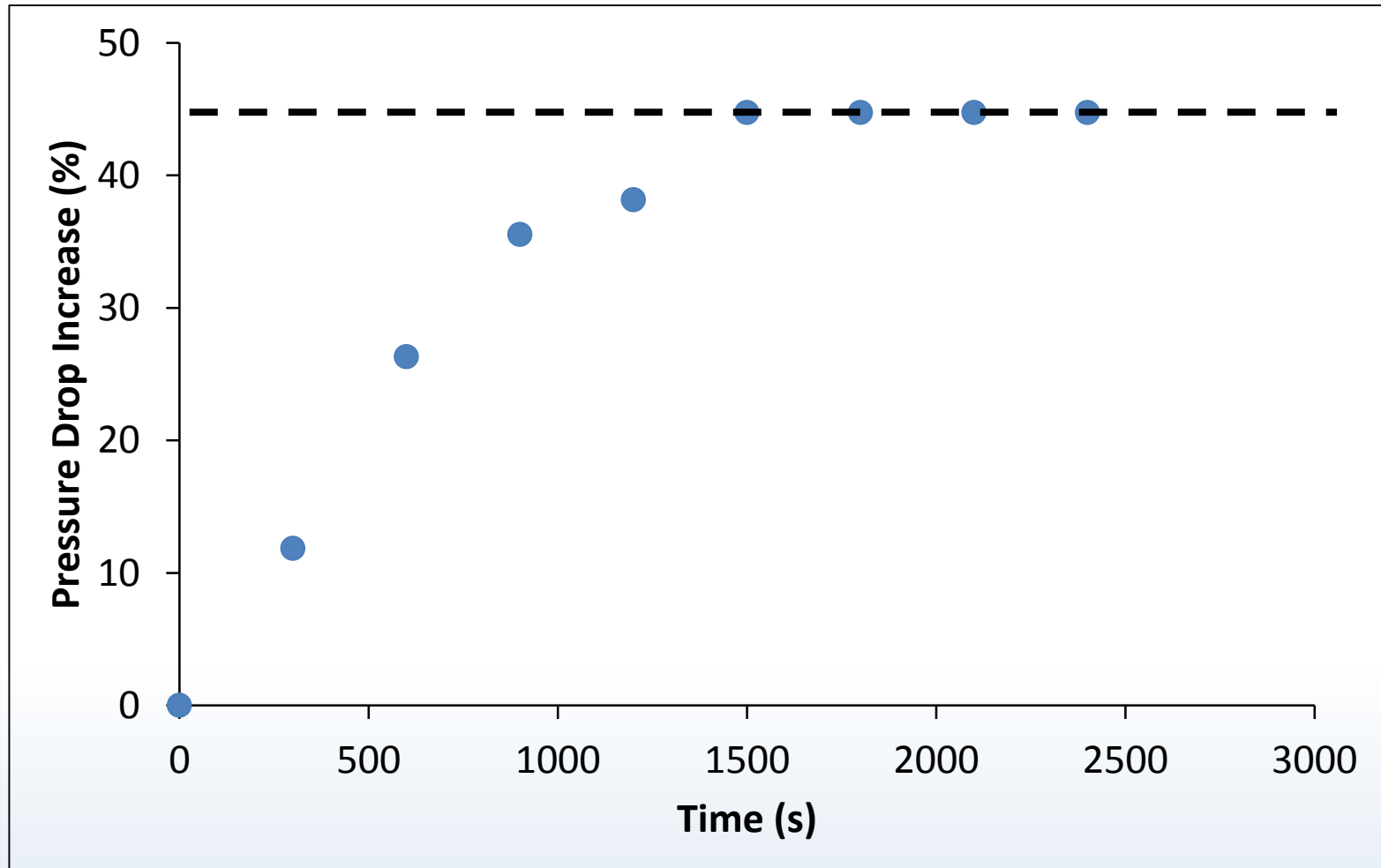
Pressure Drop Increase Due to Fouling



Pressure Drop Increase Due to Fouling



Pressure Drop Increase Due to Fouling



Summary

- Heat recovery from gas streams is important for high energy efficiency and it will be economic, one day
- Tests show a rapid transition to heavy deposition
- Fouling limiting air velocities are correlated to powder stickiness
- The tube selection can also minimise fouling

