

INNOVATIVE ENERGY SOLUTIONS

RJM



INTERNATIONAL

Case Study : Combustion Optimisation on an FBC Firing Waste Wood

Document QA

REVISION TABLE

Revision	Date	Document number	Document title	Description
1				

DOCUMENT APPROVAL

	Name	Signature	Date
Prepared By:			
Reviewed By:			
Approved By:			



Fuels and Energy Research Forum

Case study:

COMBUSTION OPTIMISATION ON AN FBC FIRING WASTE WOOD

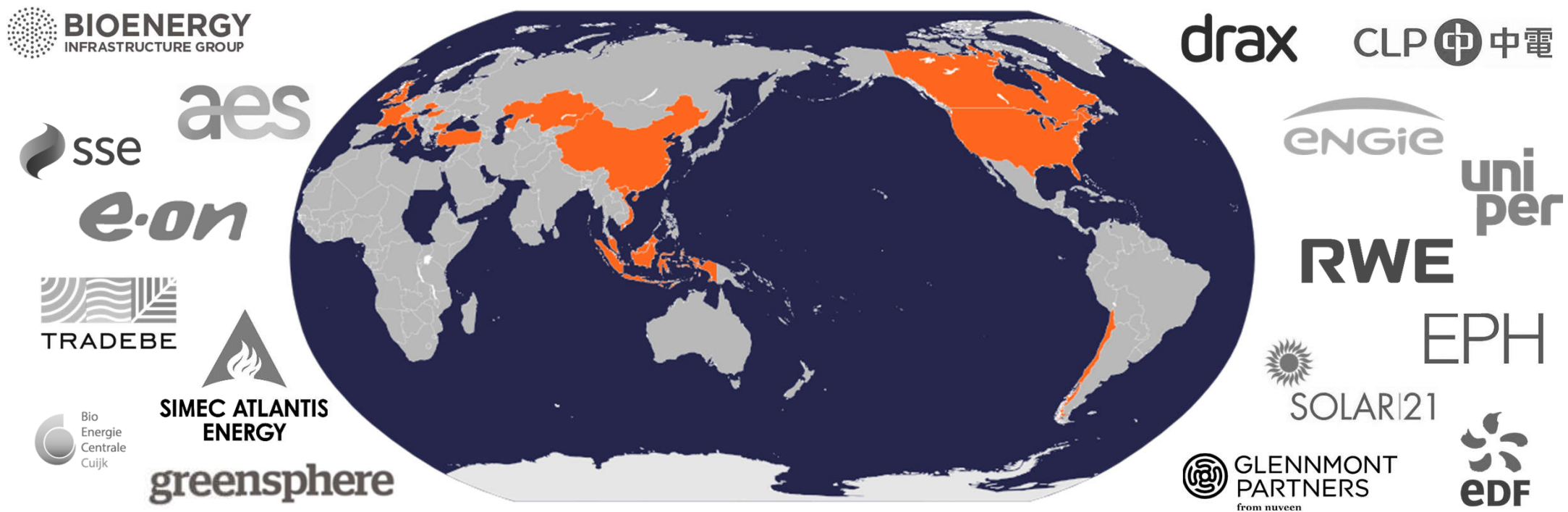


RJM
INTERNATIONAL

Resolving complex combustion and emission challenges for coal, oil, gas, waste and biomass-fired plant through the application of innovative, cost-effective solutions

Global Experience with Global Clients

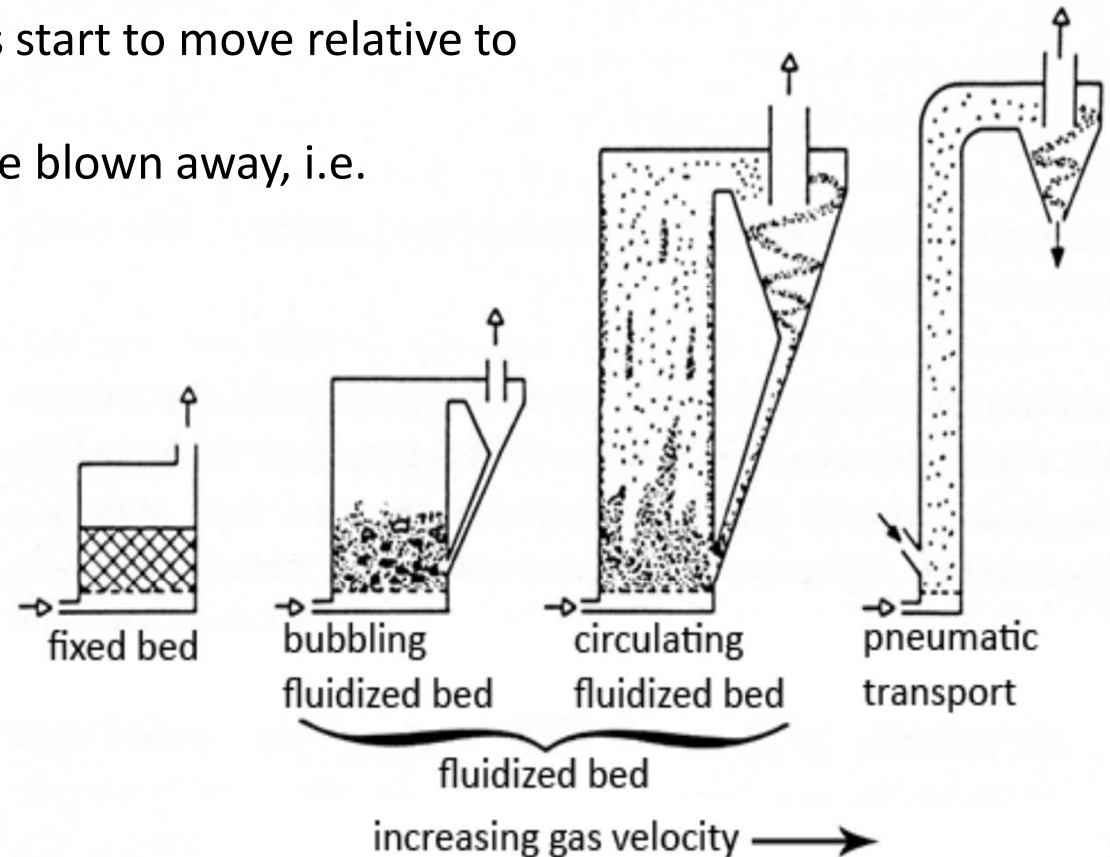
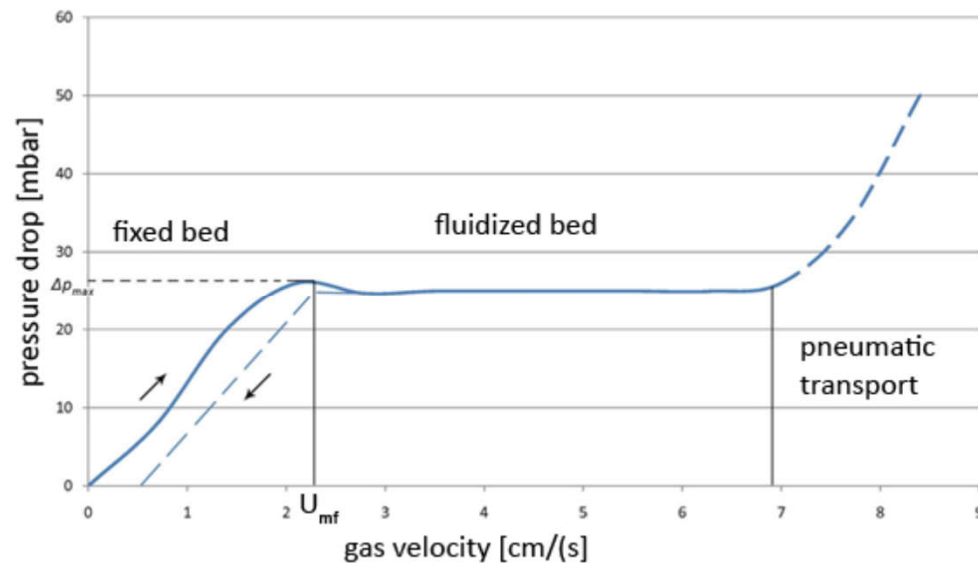
RJM have over 60,000 MWe of capacity across the globe



What is a fluidised bed?

With increasing gas velocity the bed particles start to move relative to each other and become fluidised.

When the gas velocity is high enough they are blown away, i.e. pneumatic transport.



Bubbling fluidised bed boilers



What is a bubbling fluidised bed boiler?

- A sand bed of 0.5 – 1 m depth.
- Primary air mixed with flue gas blowing through the bed.
- Under stoichiometric combustion in the bed.
- Fuel dropped onto the top of the bed.
- Over fire air (OFA) added over bed.
- Typical bed temperature 700 – 950°C.
- Typical furnace exit temperature 900 – 1000°C.



Why a fluidised bed?

Good points

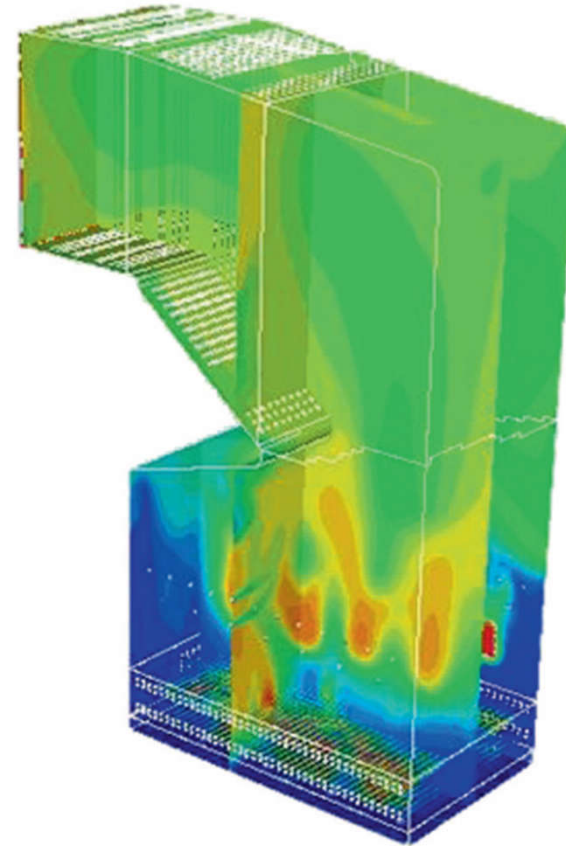
- Possible to run at low temperatures => low NOx
- High level of fuel flexibility (cheap fuels can be used)
- Fuel particles don't need grinding (mills are expensive both to buy and to run)
- Mechanically simple and robust.

Not so good points

- Require high fan pressure.
- Sensitive to bed sintering
- Limited turndown ratio (need to maintain fluidisation)

Common problems

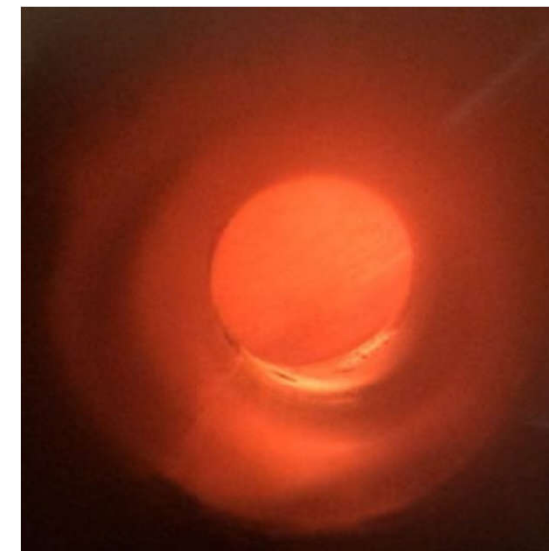
- Uneven fuel flow.
- Fuel blockages.
- Hot spots in the bed.
- High bed or gas temperatures.
- Bed sintering.
- Slagging/fouling.
- Emissions.



What is combustion optimisation?

We need:

- A reliable and even fuel flow.
- Even fuel distribution across the bed.
- Control of bed temperature and agglomeration.
- Good mixing of OFA and combustion gases.
- Emissions under control.
- Low slagging and fouling.
- Understanding of the bed chemistry



How to do it

In theory, it is simple:

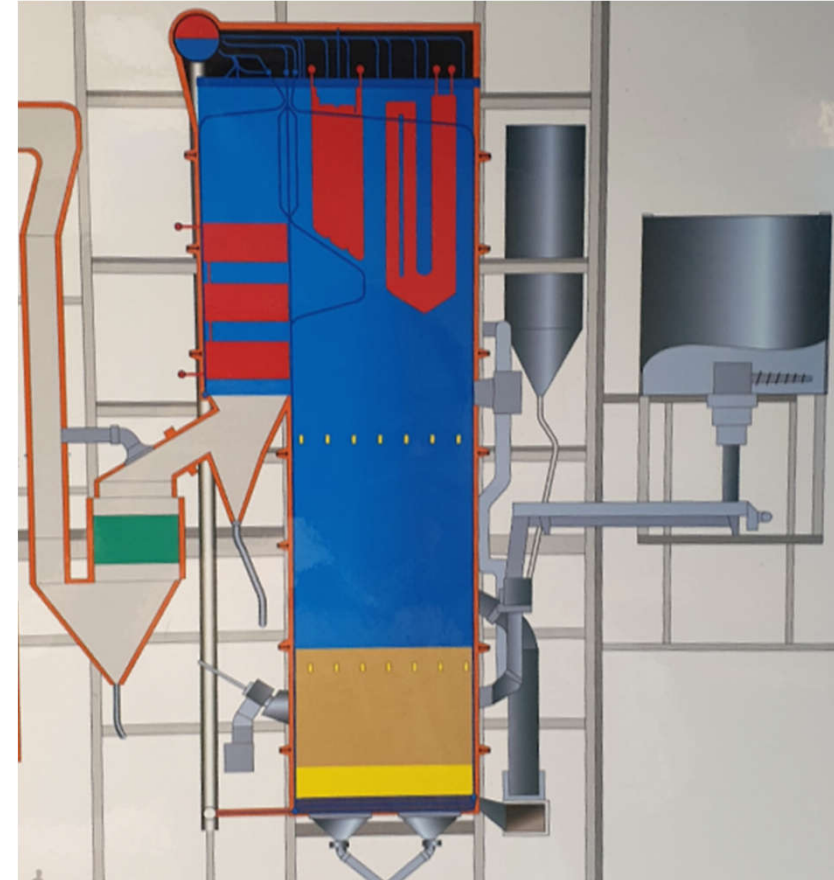
- Control your fuel flow.
- Keep the fuel within the specification.
- Make sure to mix air and combustion gases well.
- Keep gas and bed temperatures within the operational envelope.
- Don't mix materials so they get a lower melting point than the environment you are exposing them to.
- If particles melt:
 - Remove them from the bed.
 - Don't throw them onto the wall.

Practical example

- Plant 1: 80MW_{th}
 - Waste wood
 - Traditional bubbling fluidised bed.
 - 14 SA ports
 - 14 TA ports

Problem:

- Unable to meet emission limits on full load
 - NO_x
 - CO
 - Dust
- Uneven fuel feed and blockages



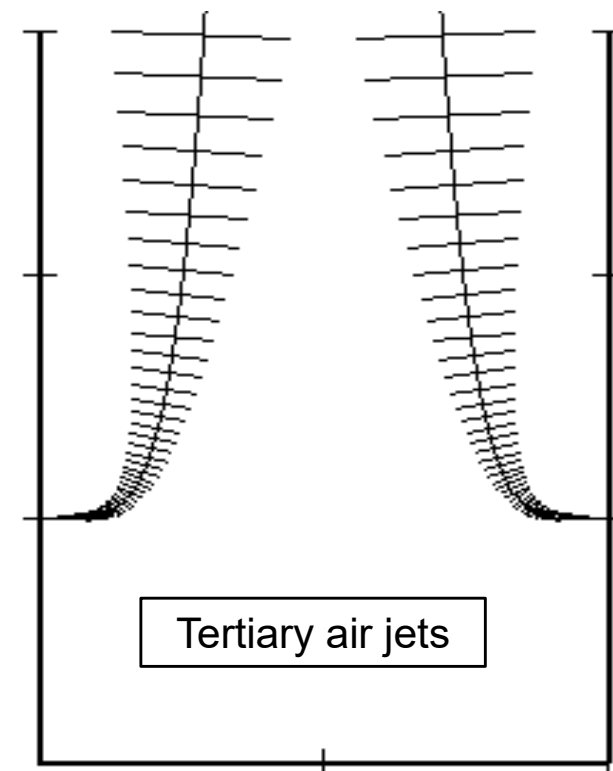
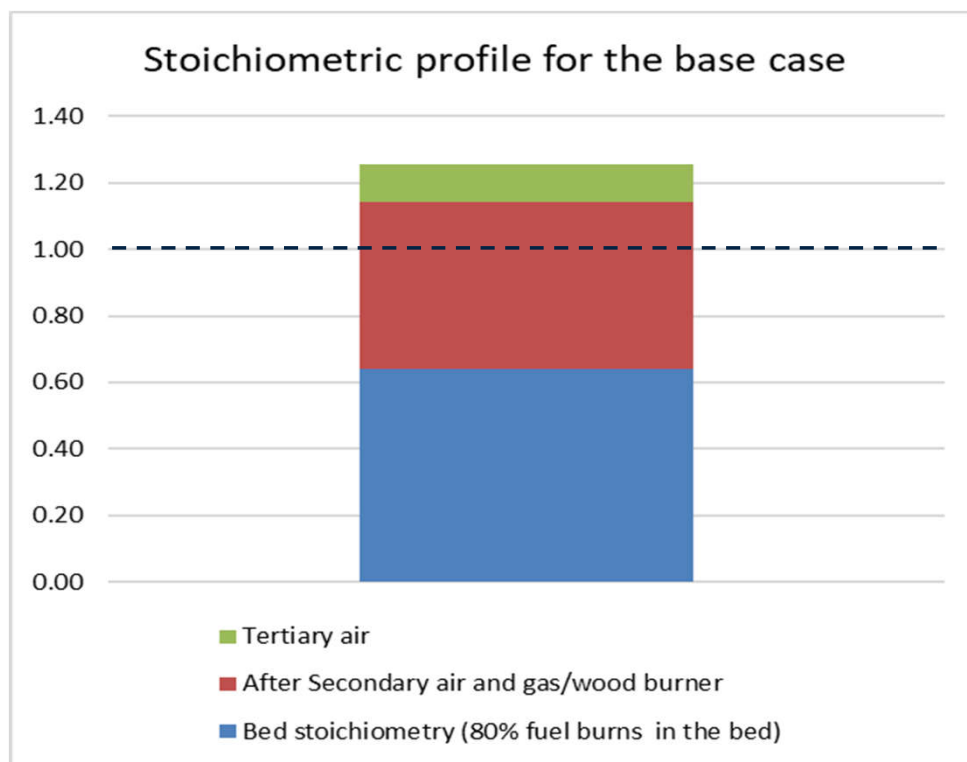
Practical example

- Uneven fuel feed
 - Waste wood chips
 - Fuel spreader
 - Frequent blockages



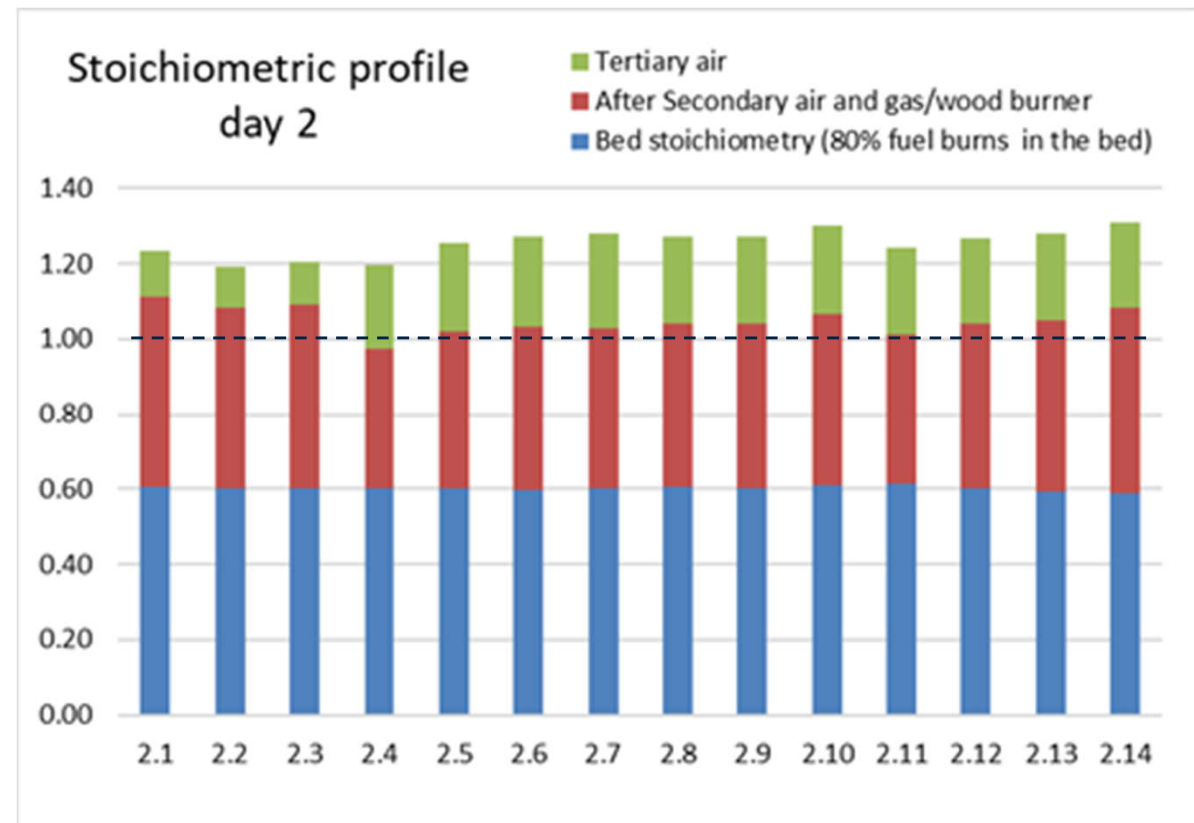
Tertiary air

The situation before we got involved.



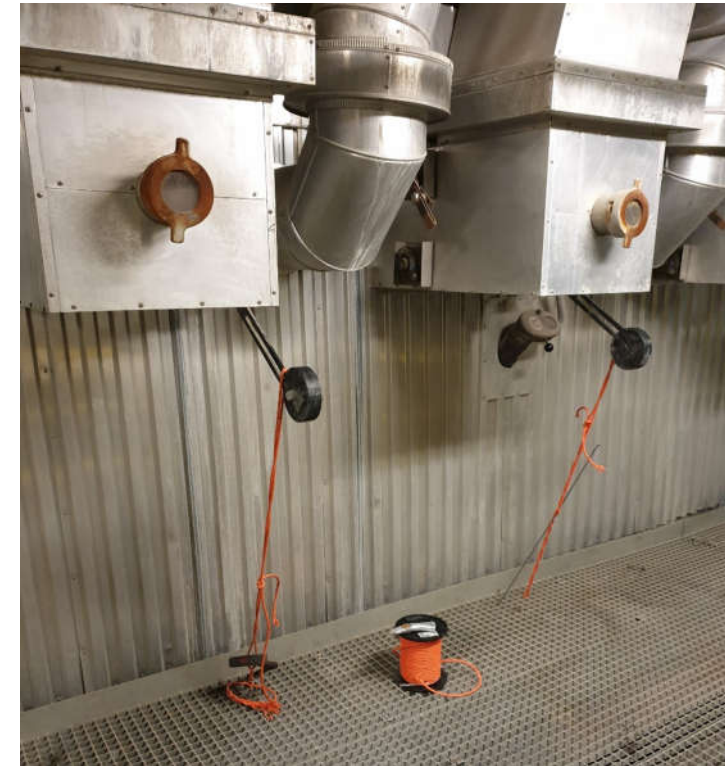
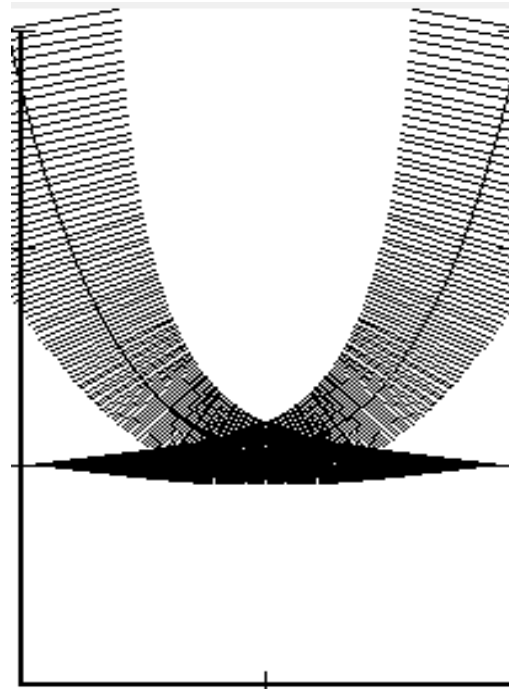
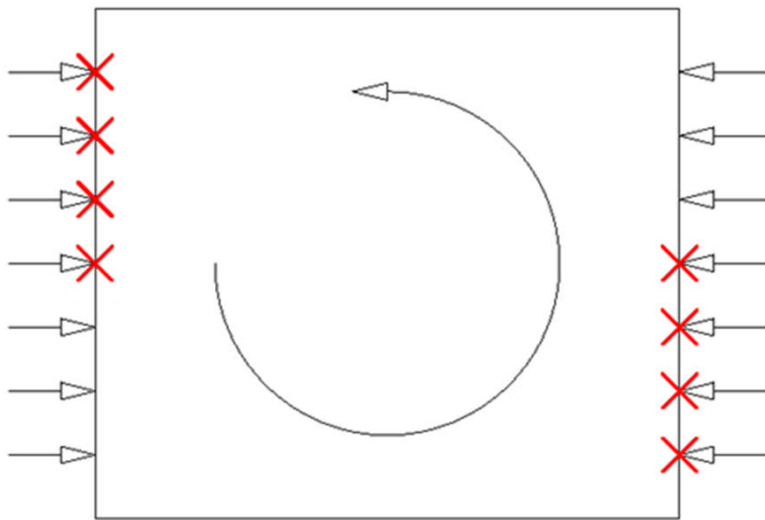
Stoichiometric profile

Reduced stoichiometry in secondary air zone reduces NO_x, but increases CO.



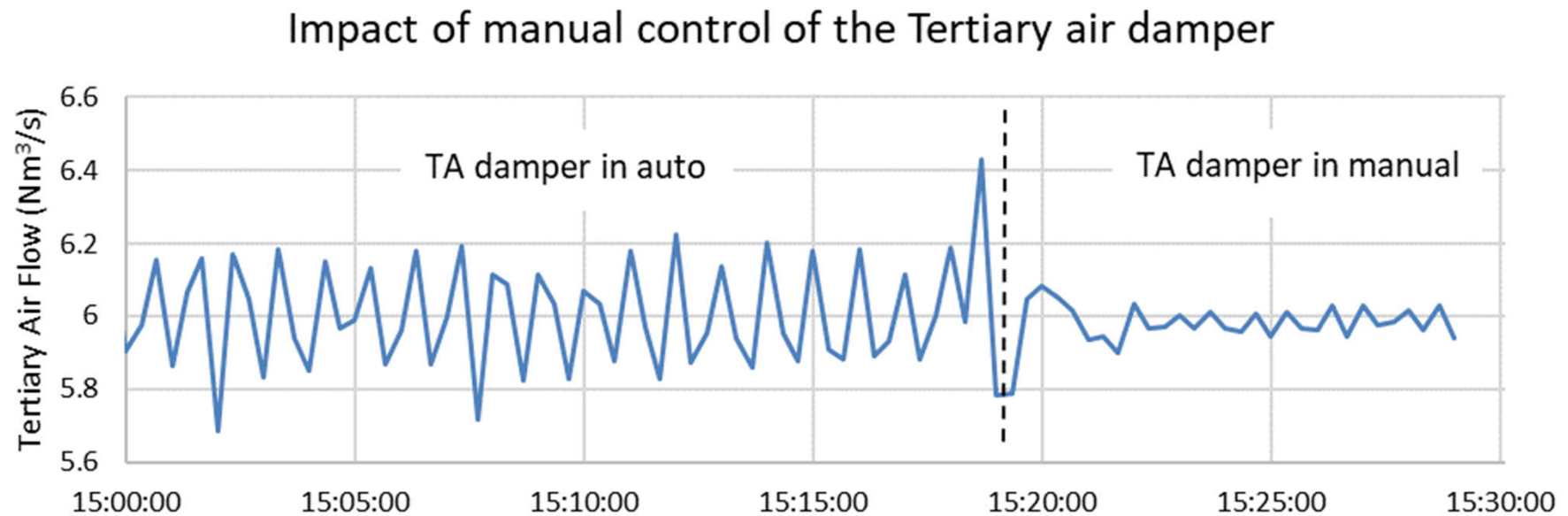
Tertiary air

Fewer TA ports and increased flow gives better penetration and mixing, reducing CO.



Fluctuations

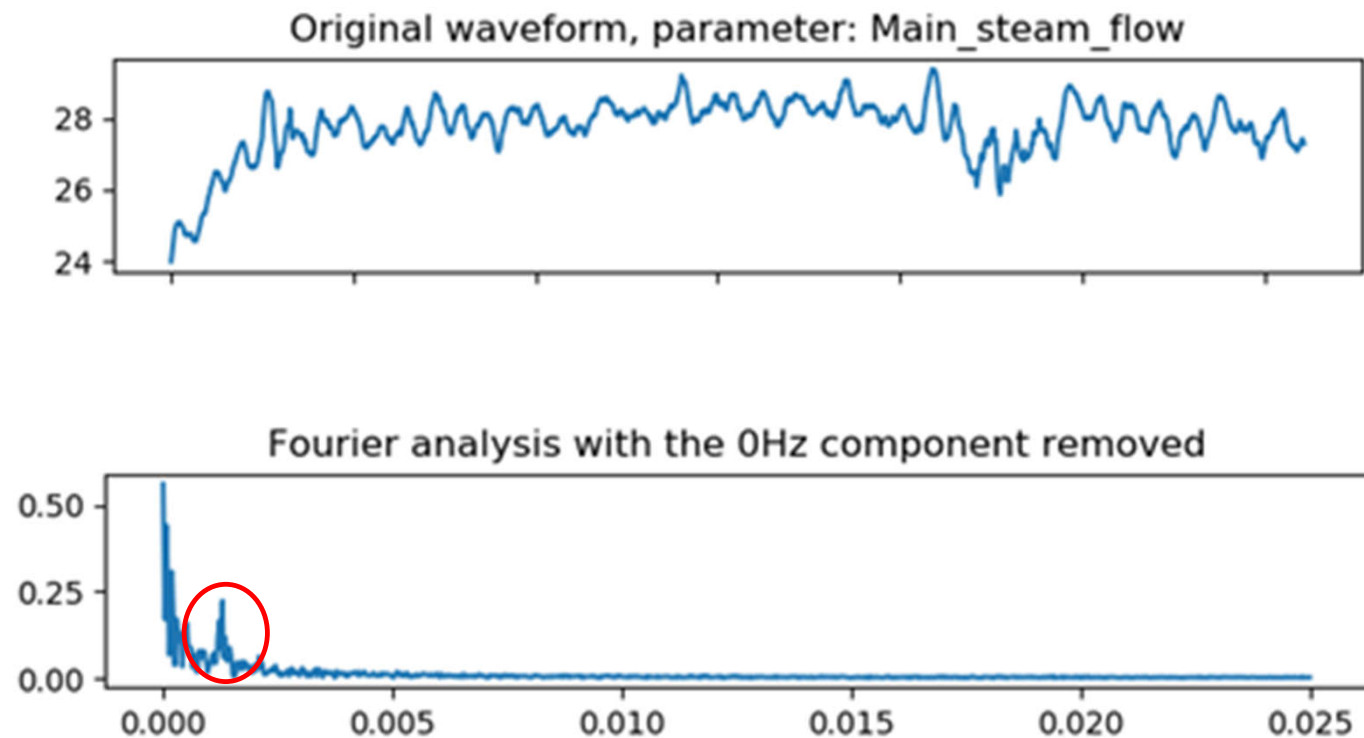
Tertiary air damper clearly not dimensioned correctly



Fluctuations

Periodic variation in steam flow with amplitude 1 kg/s.

- Frequency spectra revealed a spike with a period of 13 minutes.
- This was caused by a level control in the chute between day silo and main fuel screw.



Identified problems

- Blockages in fuel spreader
- Unfavourable vertical stoichiometric profile
- Poor mixing
- Unstable TA damper
- Fuel fluctuations causing steam fluctuation



Addressing these problems allowed operation at a higher load within emission limits

What is causing deposits and agglomeration?

- High temperatures.
- Low melting ash components and ash/bed material.
- Bed/ash particles entrained by combustion gases leaving the bed.

Simple rule:

- If you put a particle in an environment that is hotter than its melting point, it will melt.
 - If this particle hits a surface, it will stick. => Slag
 - If it stays in the bed => agglomeration



What is causing bed agglomeration?

- The combination of bed material and ash components can form low melting components.
 - High alkali biomass + silica sand => alkali silicates ($K_2O \cdot 4 \cdot SiO_2$ start melting at $750^\circ C$)
- High temperatures in the bed.
- Uneven flow in the bed.
- Accumulation of ash material in the bed.

How does it happen?

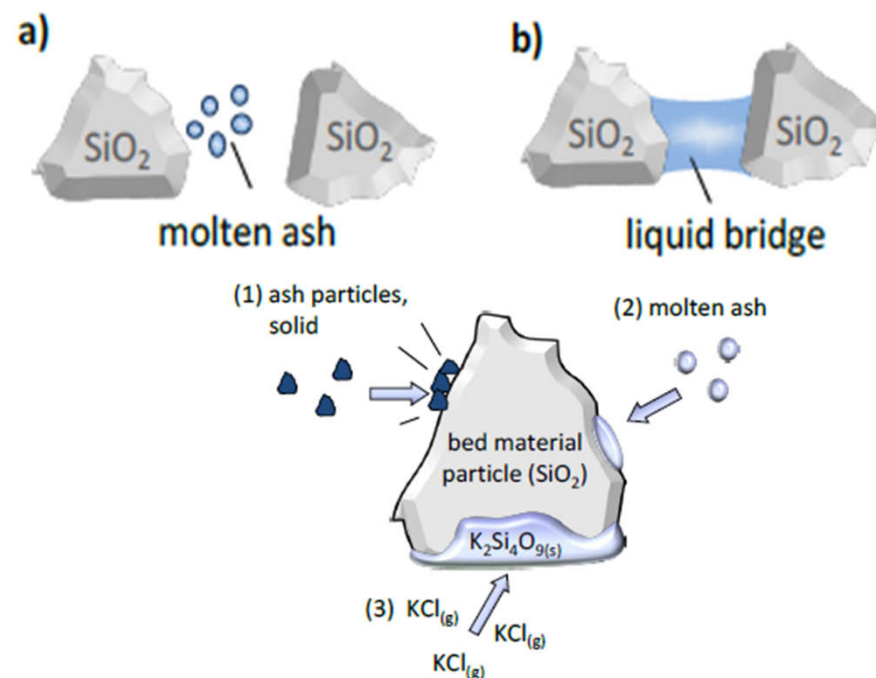
Fully or partially melted material glue bed particles together

Melt induced agglomeration

Formation of a liquid bridge

Coating induced agglomeration.

Particle surface coated by melt.

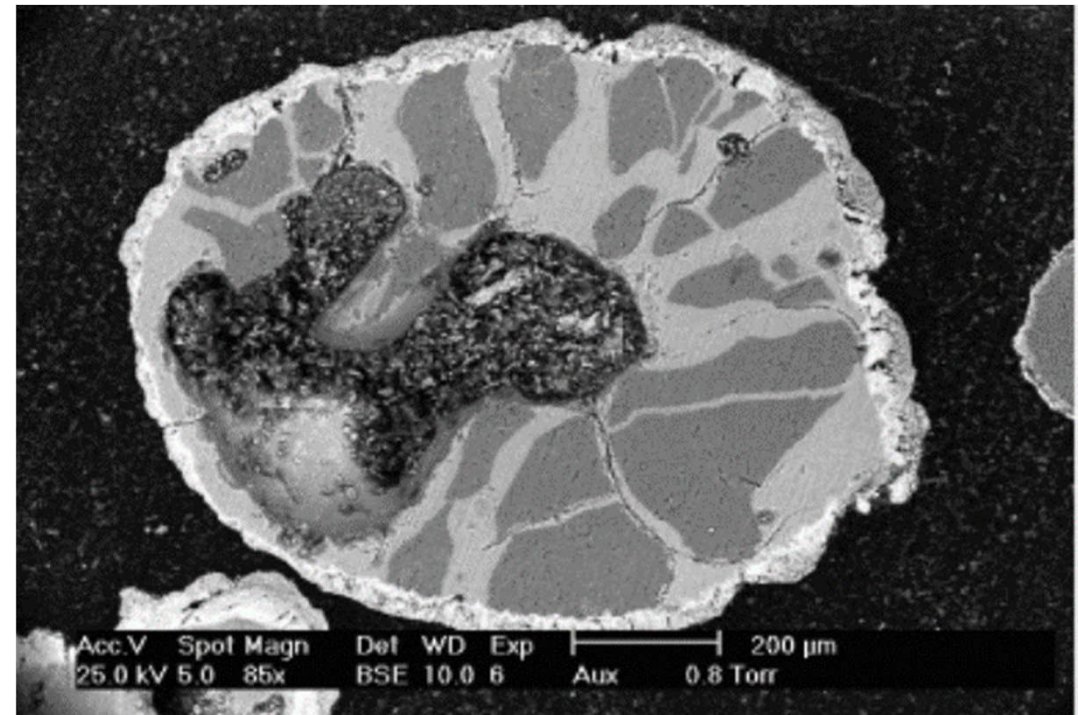


Agglomeration

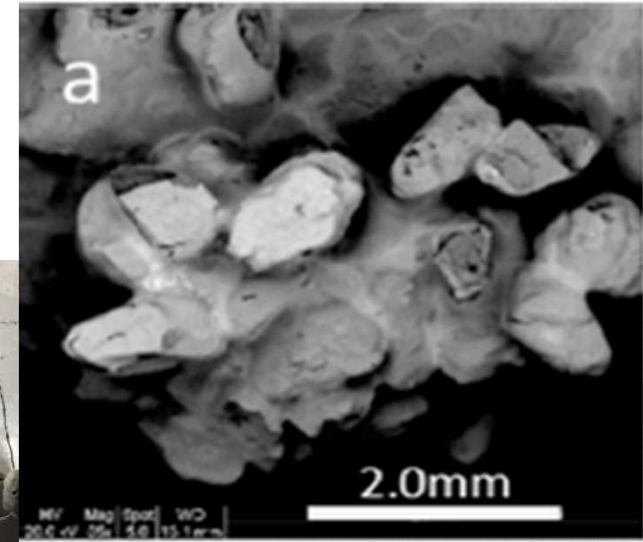
Bed material react with products from the combustion

Bed particle of silica sand after spending 6 months in a bubbling bed burning biomass.

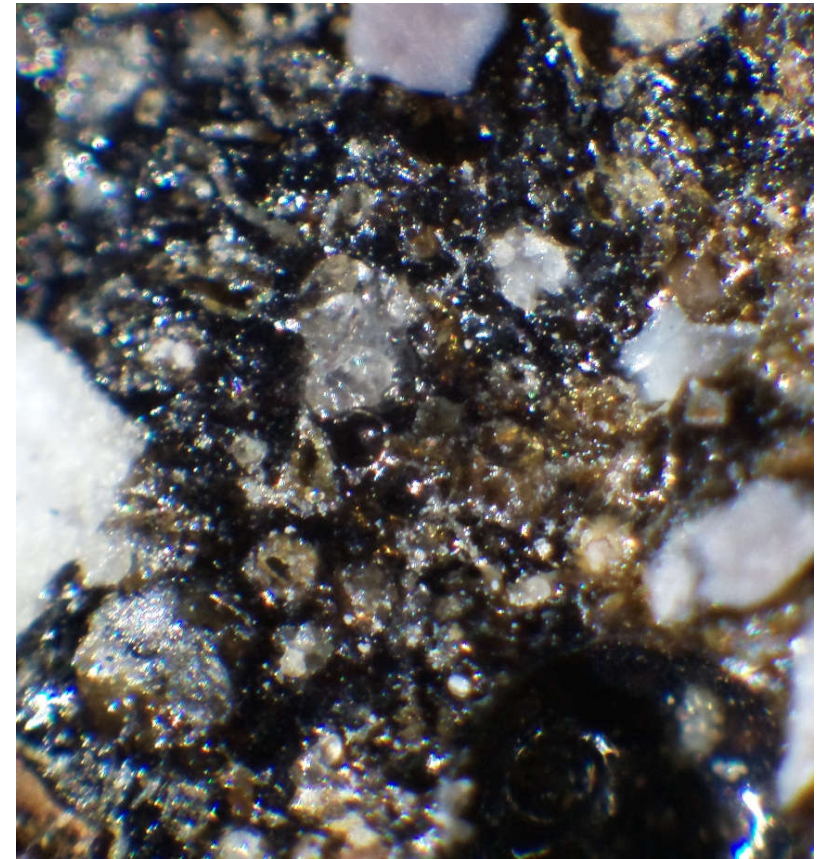
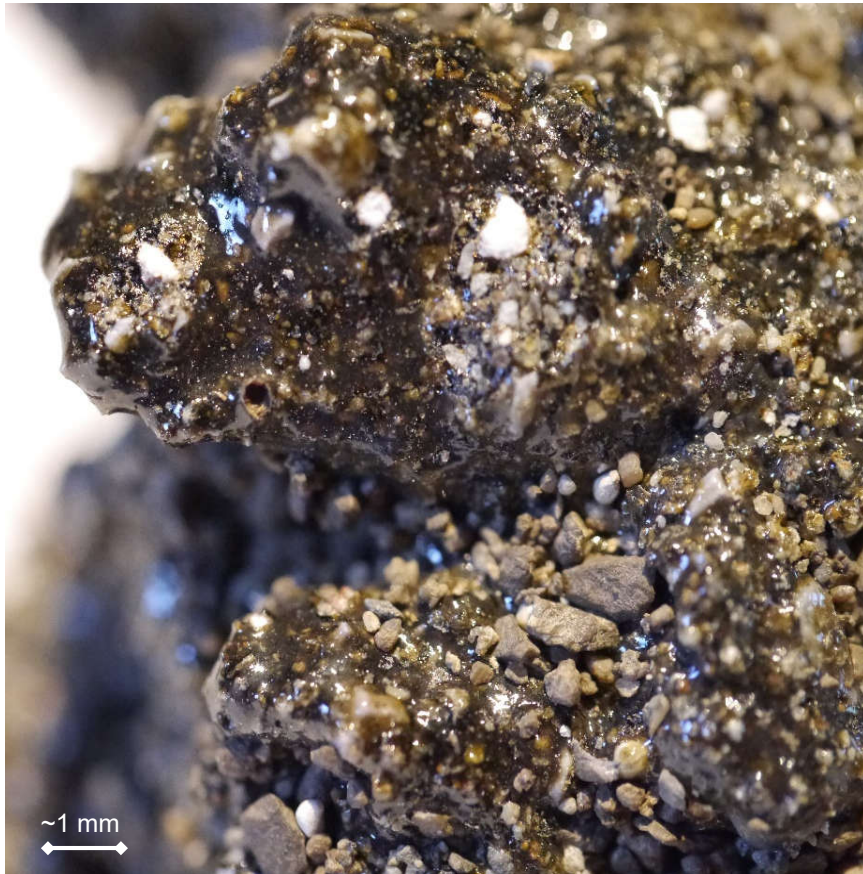
The light grey is potassium silicate, the dark grey is the original silica bed material.



Is slagging and bed agglomeration a problem?

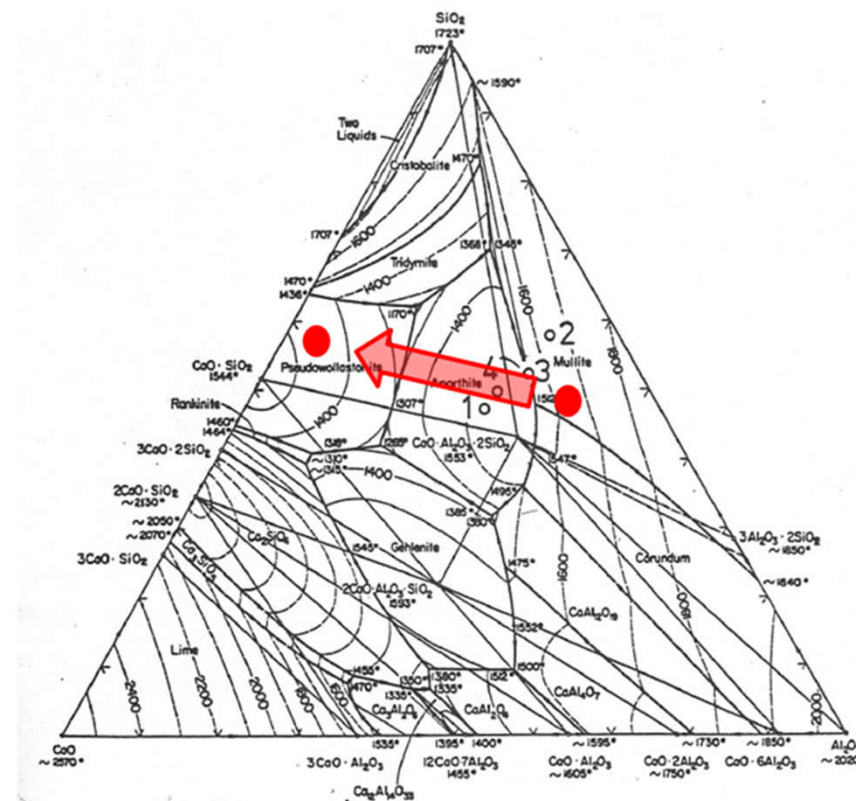


Is slagging and bed agglomeration a problem?



Bed chemistry

- The composition of the sand bed will change over time during operation:
 - Ash accumulation
 - Consumption of some bed element
 - Reactions between bed material and ash
- This phase diagram show how the average composition of the bed moves from 1600°C melting point to an area with much lower melting temperature.
- Add the impact of potassium and sodium to this and extremely low melting points can be the result.



Bed chemistry

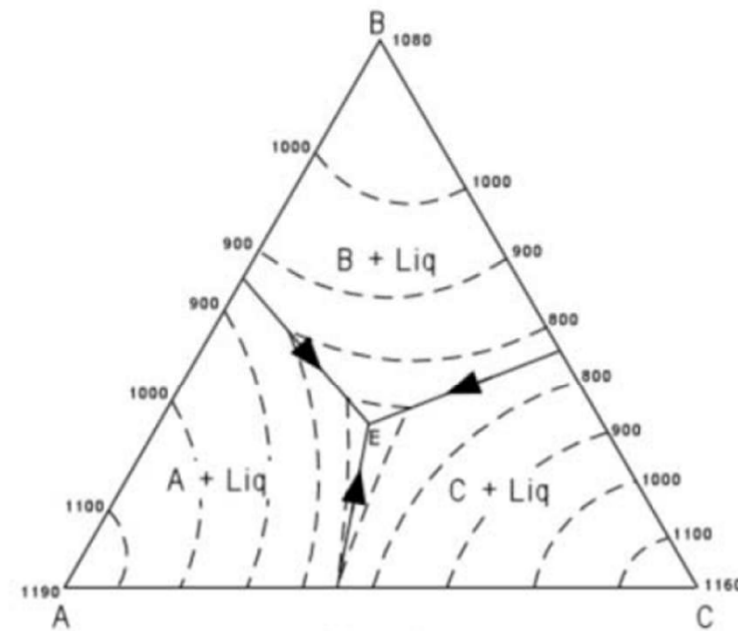
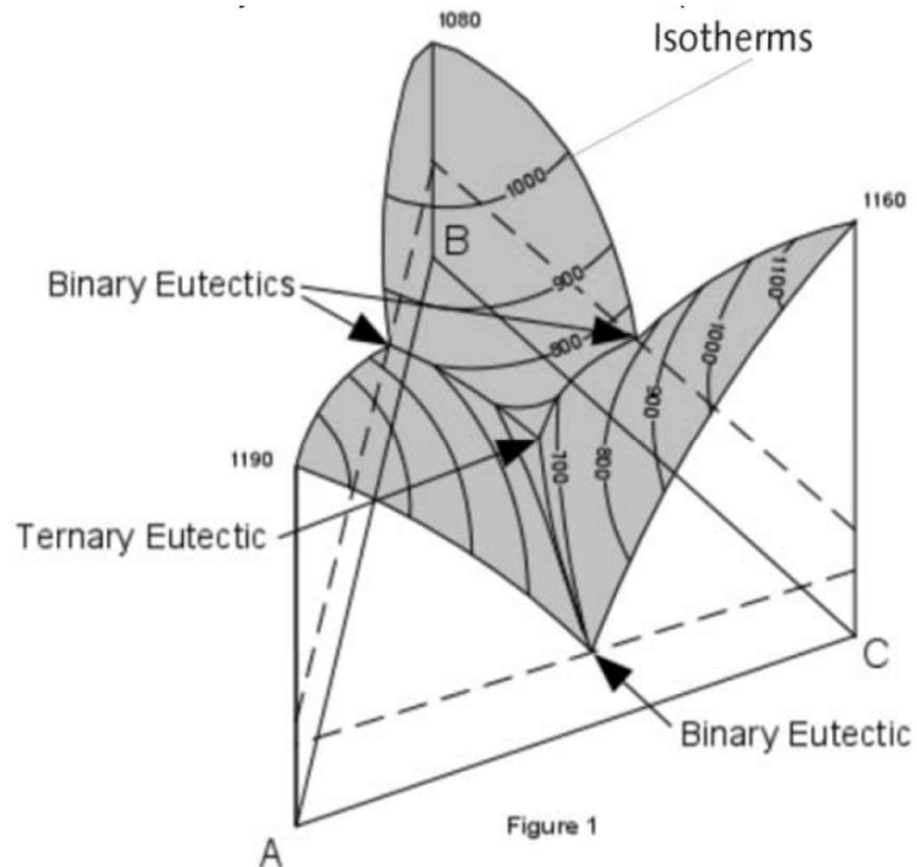


Figure 2

Bed temperature

- Poor ability to control the bed temperature result in bed agglomeration.
- Bed temperature is often controlled by varying the amount of FGR mixed with air for bed fluidisation.