# Paper sludge incineration in BFBC

David Graham
Power Technology, E.ON UK

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# BFBC – Waste to Energy plant

Fuel:

- Primary & Secondary sludge
- De-inking sludge
- Plastics

Capacity:

- Overall CHP plant 80/200 MW
- Waste to Energy component

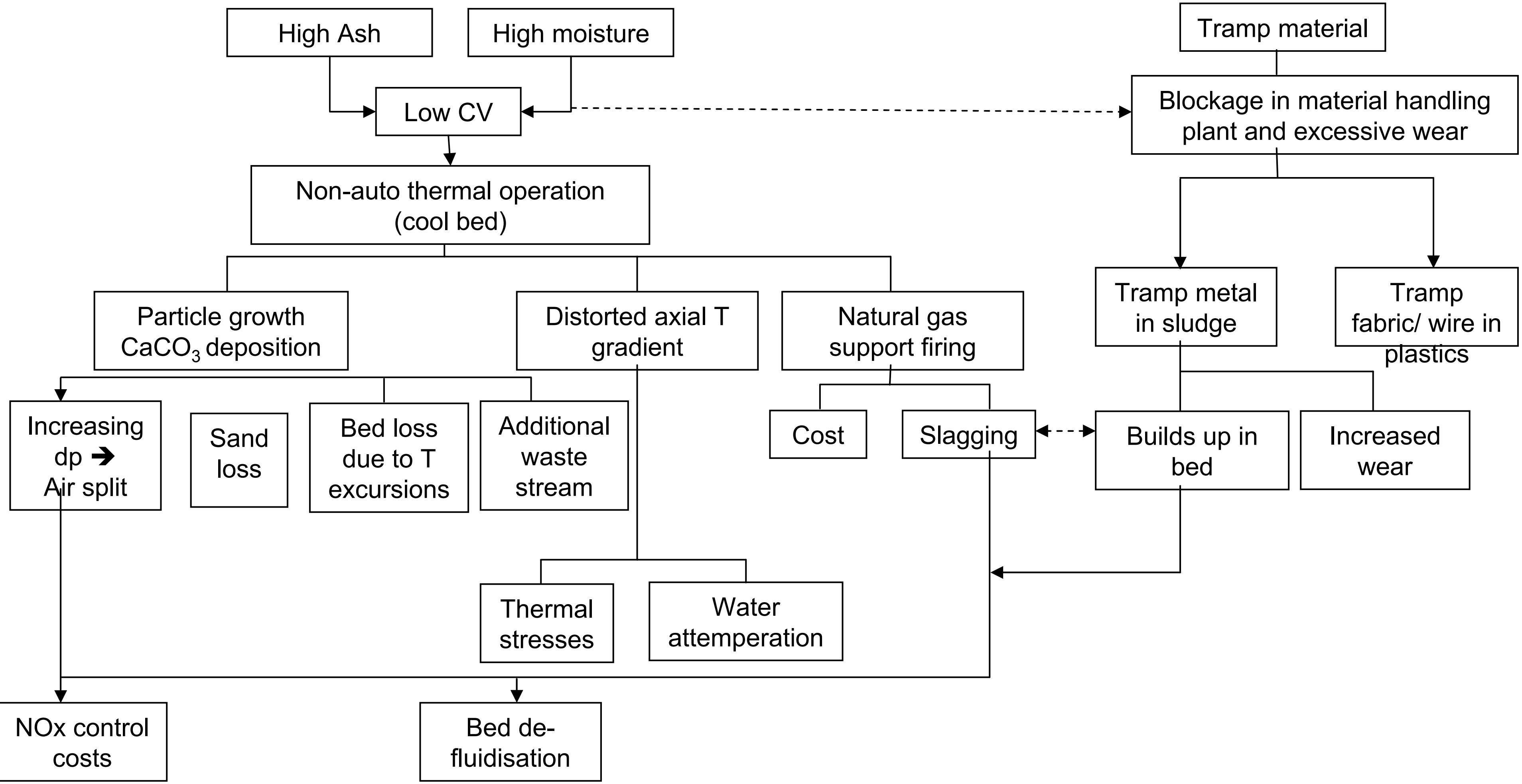
 ~ 20 t/h fuel at ~ 3.5 MJ/kg

 (Design CV >4.6 MJ/kg)

# Fuel composition

| | MIXED FUEL |
|---|---|
| **AS RECEIVED %** | |
| **Moisture** | 57.1 |
| **Ash** | 12.3 |
| **Volatile Matter** | 28.0 |
| **Sulphur** | 0.03 |
| **Chlorine** | 0.06 |
| **CV, MJ/kg Net** | 3.5 |
| **DRY ASH FREE %** | |
| **Carbon** | 48.4 |
| **Hydrogen** | 5.7 |
| **Nitrogen** | 0.6 |
| **Oxygen** | 45.0 |
| **Volatile Matter** | 91.5 |

# Background –Fuel Issues



UK

# Background

## General FBC Issues:

- •Bed Agglomeration (sintering, slagging, tramp material)
- •Fouling/Deposition
- •Corrosion/Erosion

## Impacts:

- Bed de-fluidisation and forced outages (bed dig out)
- Boiler performance and outage frequency
- Tube leaks

# Review

## Impact of increasing fuel CV and bed temperature on :

- Bed Agglomeration
  - sintering due to higher bed temperature
  - sintering due to alkali metals (co-firing)
- Fouling/Deposition
  - changes to ash characteristics
- Corrosion/Erosion
  - increasing chlorine (plastics)
  - increasing alkali metals (co-firing)

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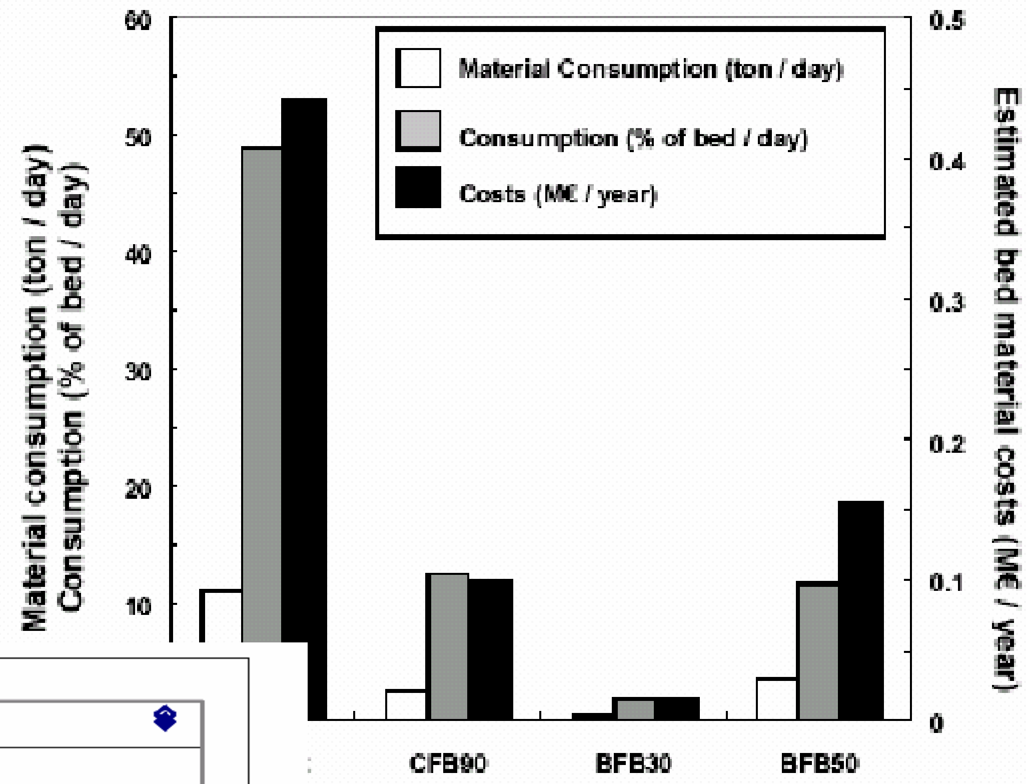
# Bed agglomeration

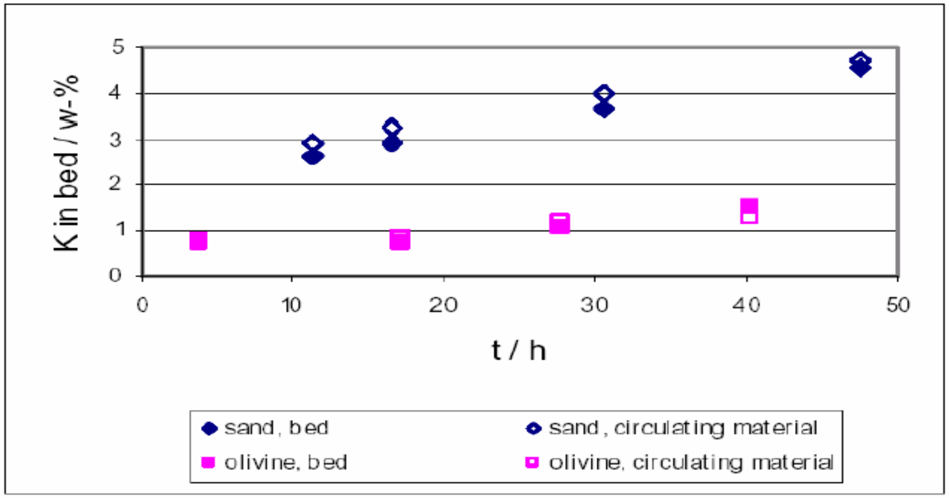
Causes: alkali silicates; low melting point compounds of Pb/Sn

Control strategies:

- Ongoing sand bed replacement
- Alternative bed materials

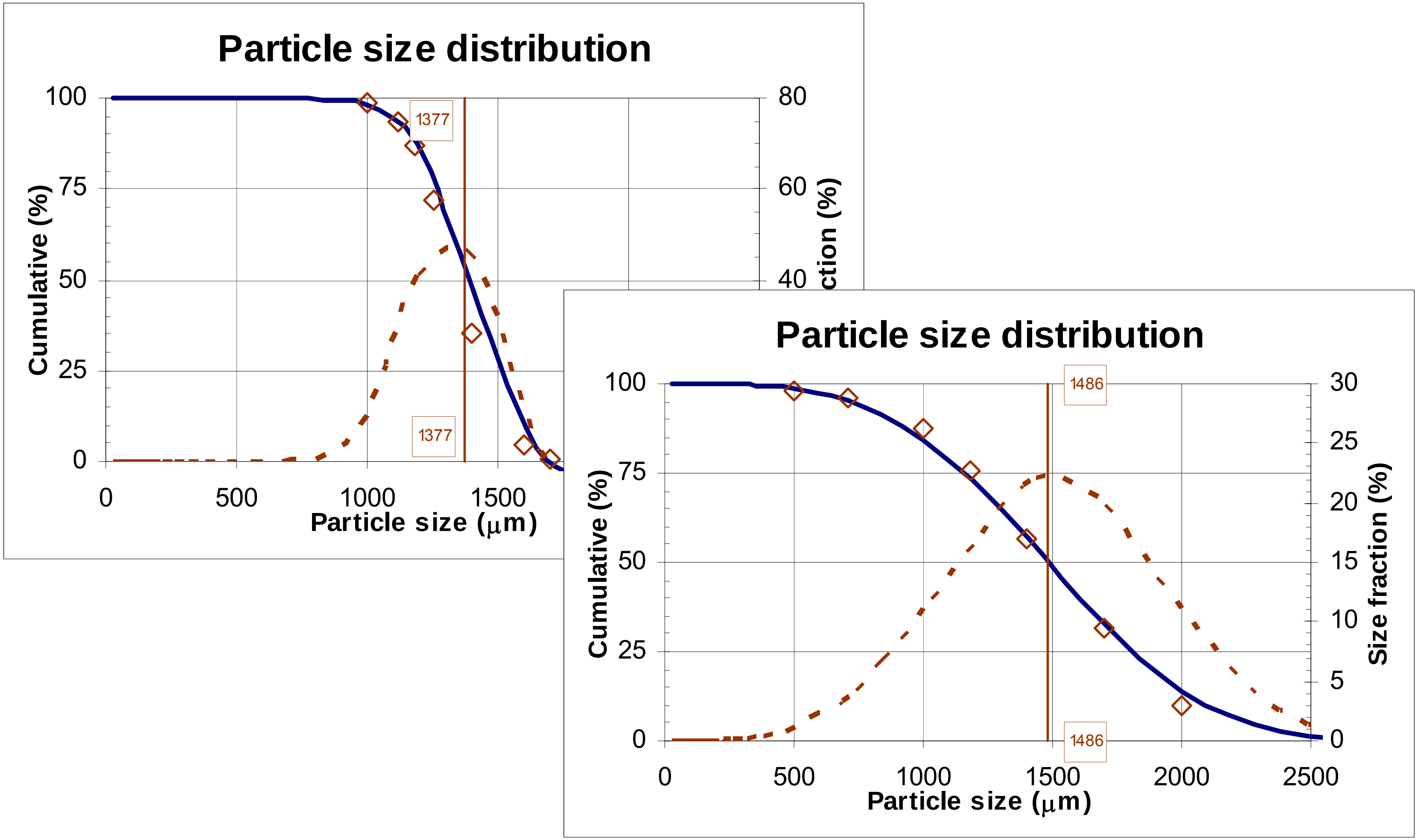



Brus, E., Őhman, M., Nordin, A., Skrifvars, B-J, Backman, R., 'Bed material consumption in biomass fired fluidised bed boilers due to risk of bed agglomeration – coating formation and possibilities for regeneration', IFRF Combustion Journal Article Number 200302, Jun 2003




Almark, M., Hiltunen, M., 'Alternative Bed Materials for High Alkali Fuels', Paper no. FBC2005-78094, 18th International Conference on Fluidised Bed Combustion, Toronto, May 2005

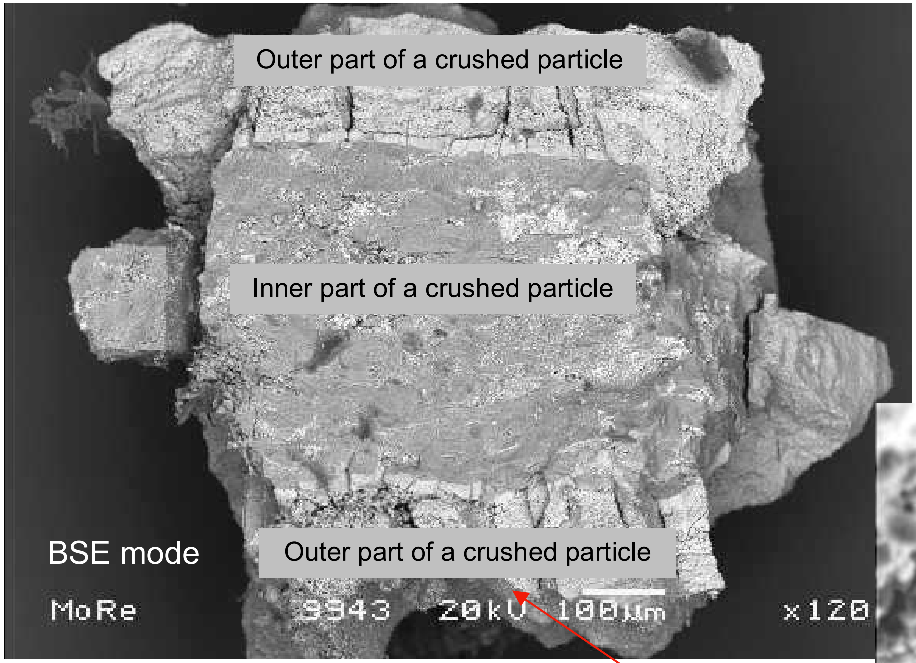
# Particle size

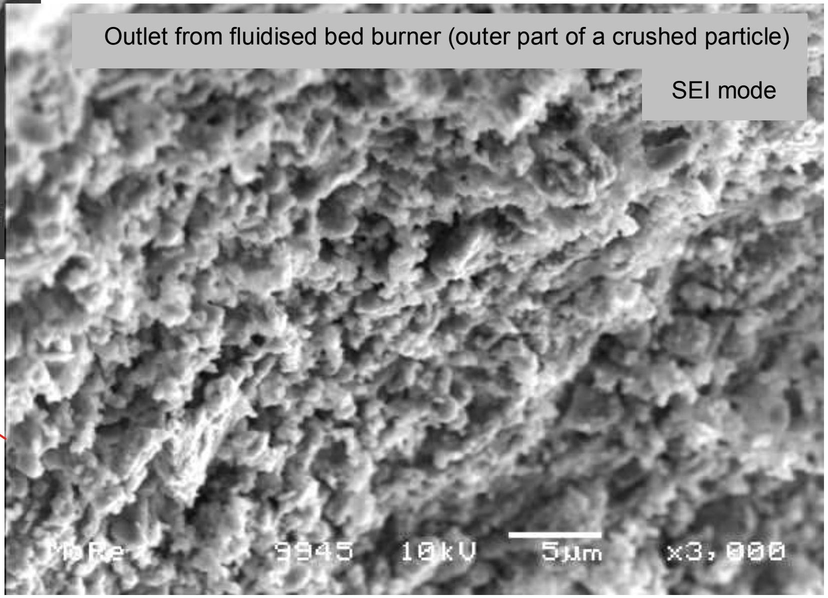



Source: DEFRA, August 2005

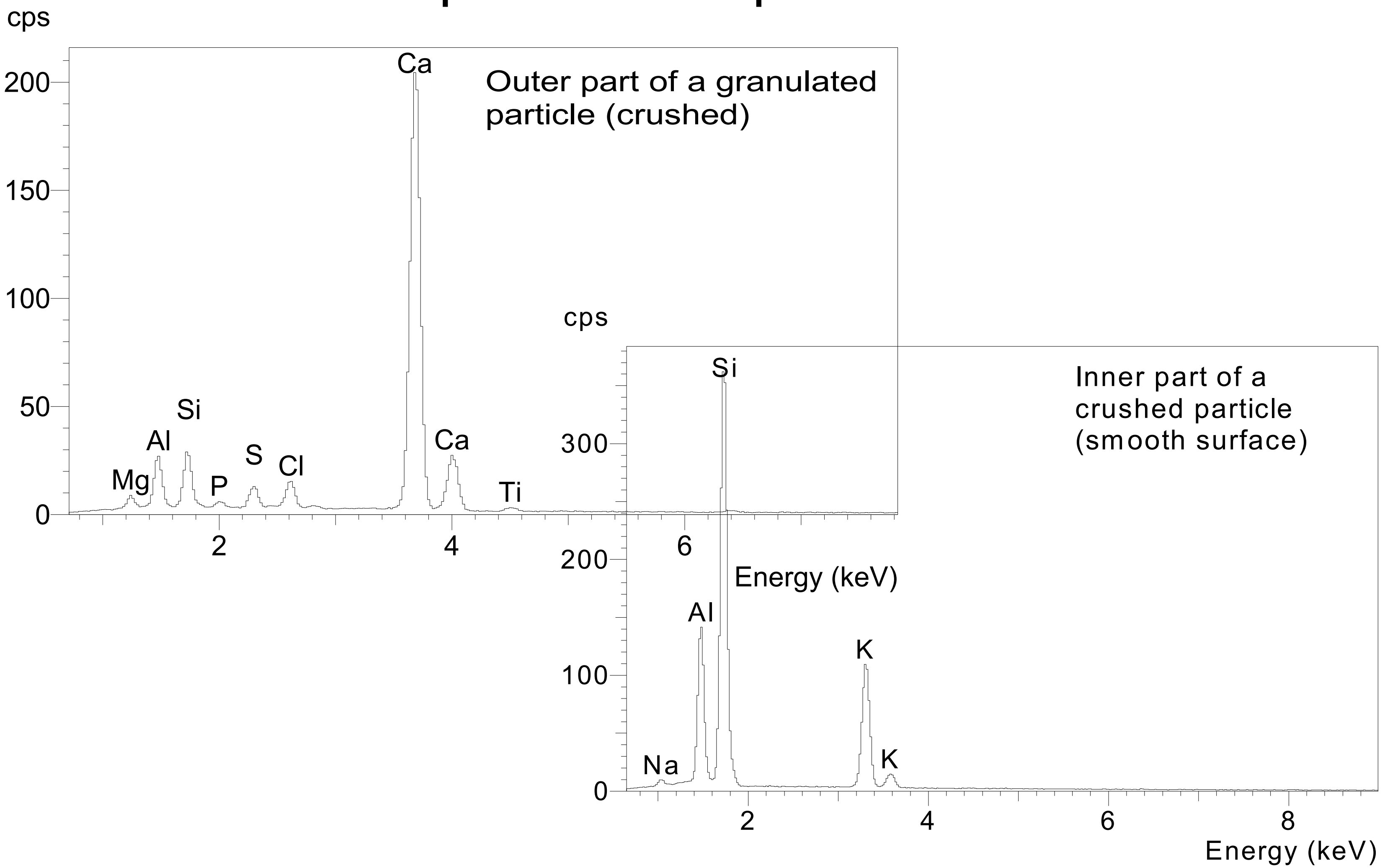
# Bed material

# Bed material – particle structure



# Bed material – particle composition



# Agglomeration Indicators

(Na + K)/(2S + Cl) > 1

Alkali metals > (sulphur + chlorine)

**(K + Na + Si)/(Ca + P + Mg) > 1**

**(Alkali metals + silica) > Calcium**

After: Visser, H.J.M., ‘The influence of fuel composition on agglomeration behaviour during fluidised-bed combustion’, ECN Technical report ECN-C—04-054, Sep 2004

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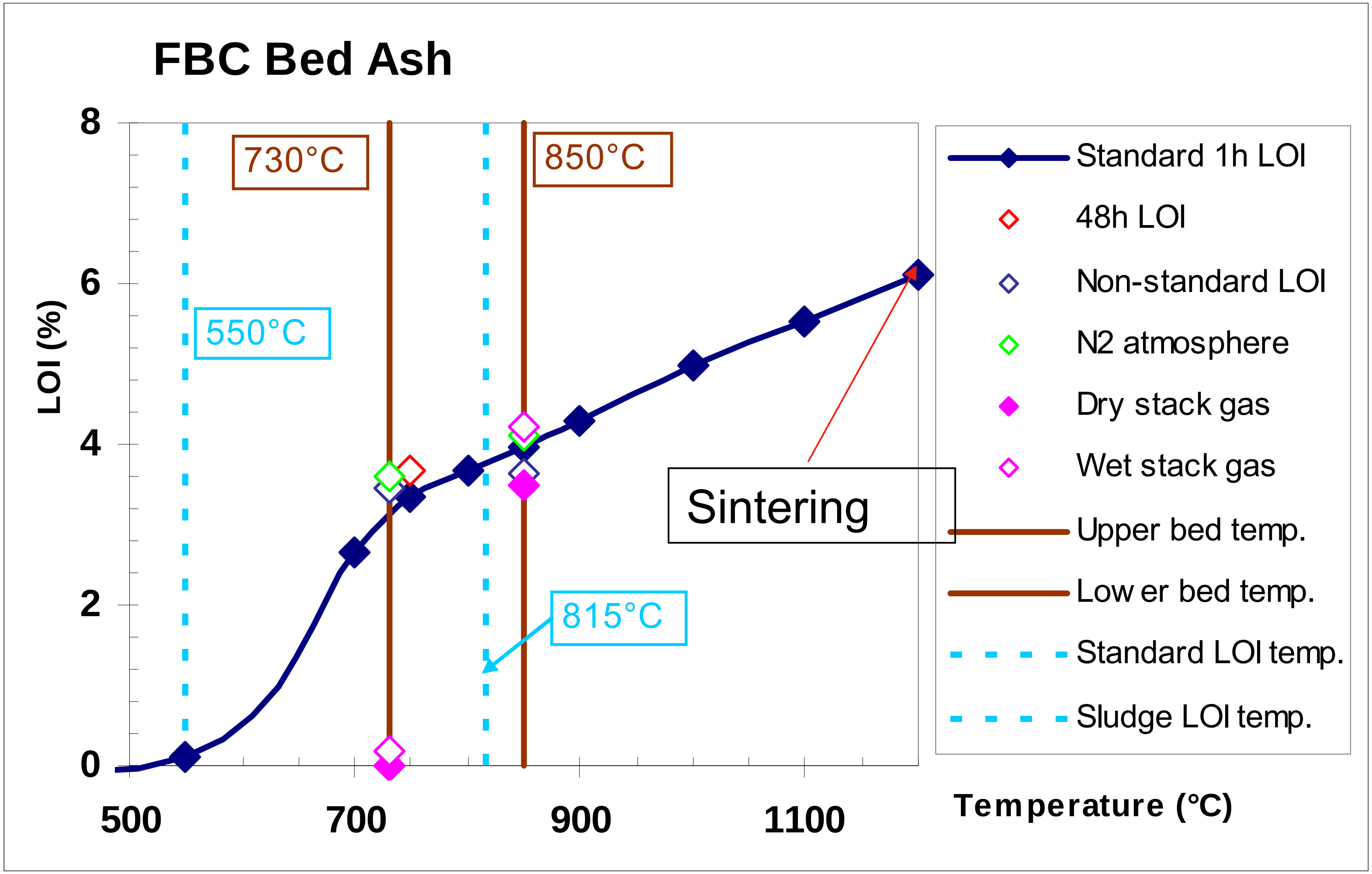
# Fly ash composition

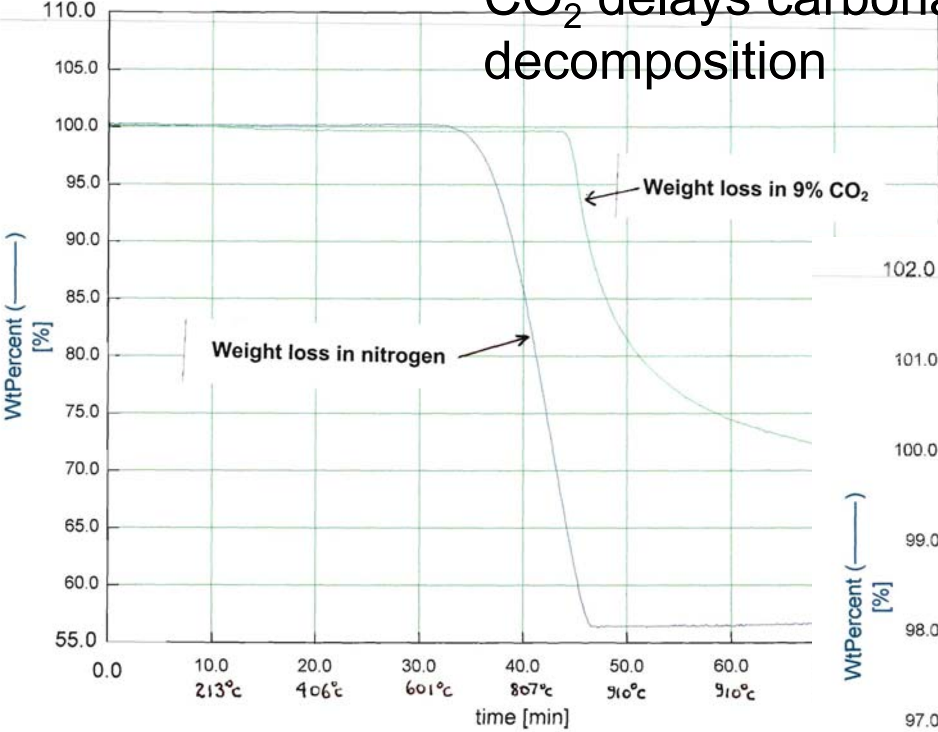
| | |
|---|---|
| **ASH ANALYSIS** | |
| **$SiO_2$** | 12.4 |
| **$Al_2O_3$** | 7.9 |
| **$Fe_2O_3$** | 0.6 |
| **CaO** | 75.5 |
| **MgO** | 1.9 |
| **$K_2O$** | 0.3 |
| **$Na_2O$** | 0.3 |
| **$TiO_2$** | 0.5 |
| **BaO** | 0.01 |
| **$Mn_3O_4$** | 0.03 |
| **$P_2O_5$** | 0.6 |
| **Agglomeration indices** | |
| **(Na + K)/(2S + Cl) > 1** | 0.6 |
| **(K + Na + Si)/(Ca + P + Mg) > 1** | 0.2 |
| **Fouling & corrosion indicies** | |
| **S/Cl < 2** | 0.6 |

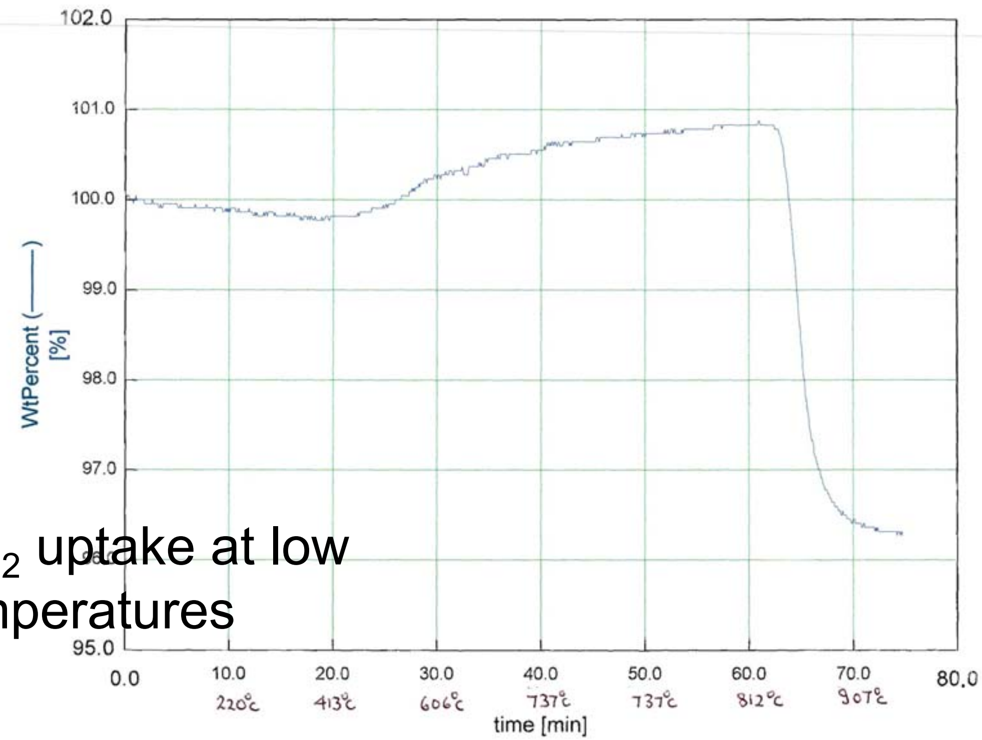
# Bed material – impact of changing temperature



# Bed material – impact of changing temperature (TGA)

$CO_2$ delays carbonate decomposition




$CO_2$ uptake at low temperatures

Source: DEFRA, August 2005

# Conclusions – Fluidised Bed

- Ca forms a protective layer that prevents agglomeration
- Higher bed temperature OK
- Carbonate decomposition must be caused by combustion and/or support firing
- Carbonate levels should be small and less variable at higher T
- Higher bed temperature → more uniform axial profile – better emissions performance

# Fly ash composition

| Ash analysis | | | | | |
|---|---|---|---|---|---|
| | Ex ash | | Ex ash | Ex ash | |
| CaO | $CO_2$ | $LOI_{815°C}$ | $CaCO_3$ | CaO | Ca species |
| 52.2 | 12.0 | 11.2 | 27.2 | 36.9 | 64.1 |
| 53.6 | 14.1 | 13.4 | 32.1 | 35.6 | 67.7 |
| 52.4 | 13.1 | 12.5 | 29.8 | 35.7 | 65.5 |
| 54.5 | 12.5 | 12.3 | 28.5 | 38.6 | 67.0 |

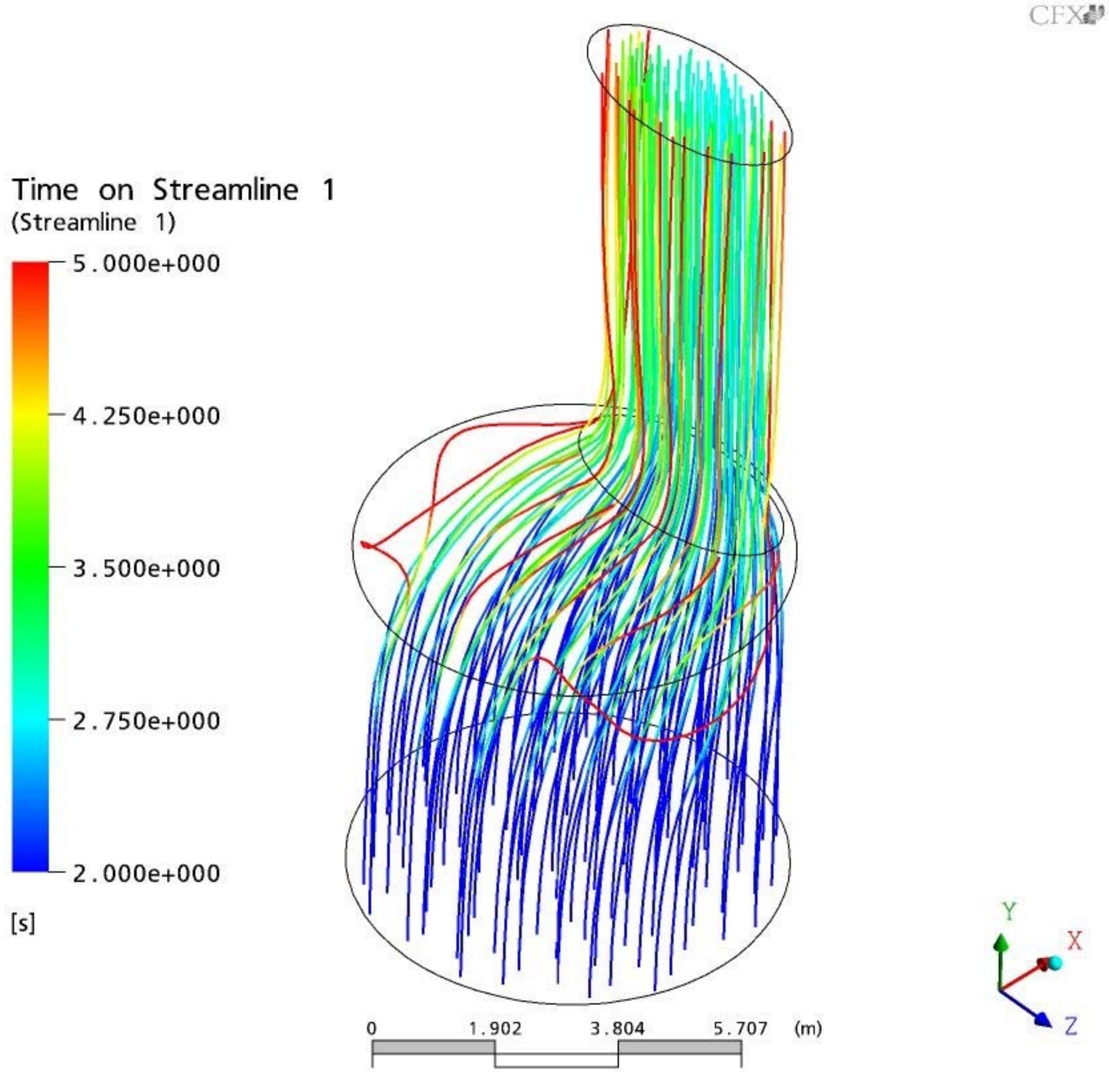
How will this be affected by changing operating conditions?

- axial temperature profile  (peak temperatures lower)

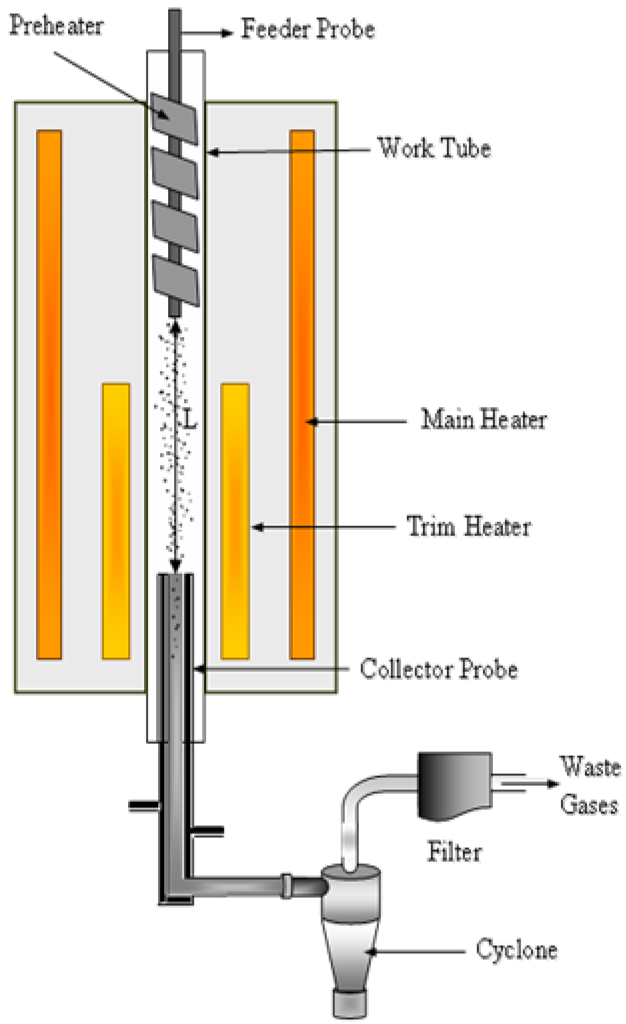
- residence times

- $CO_2$ re-absorption

# RTD

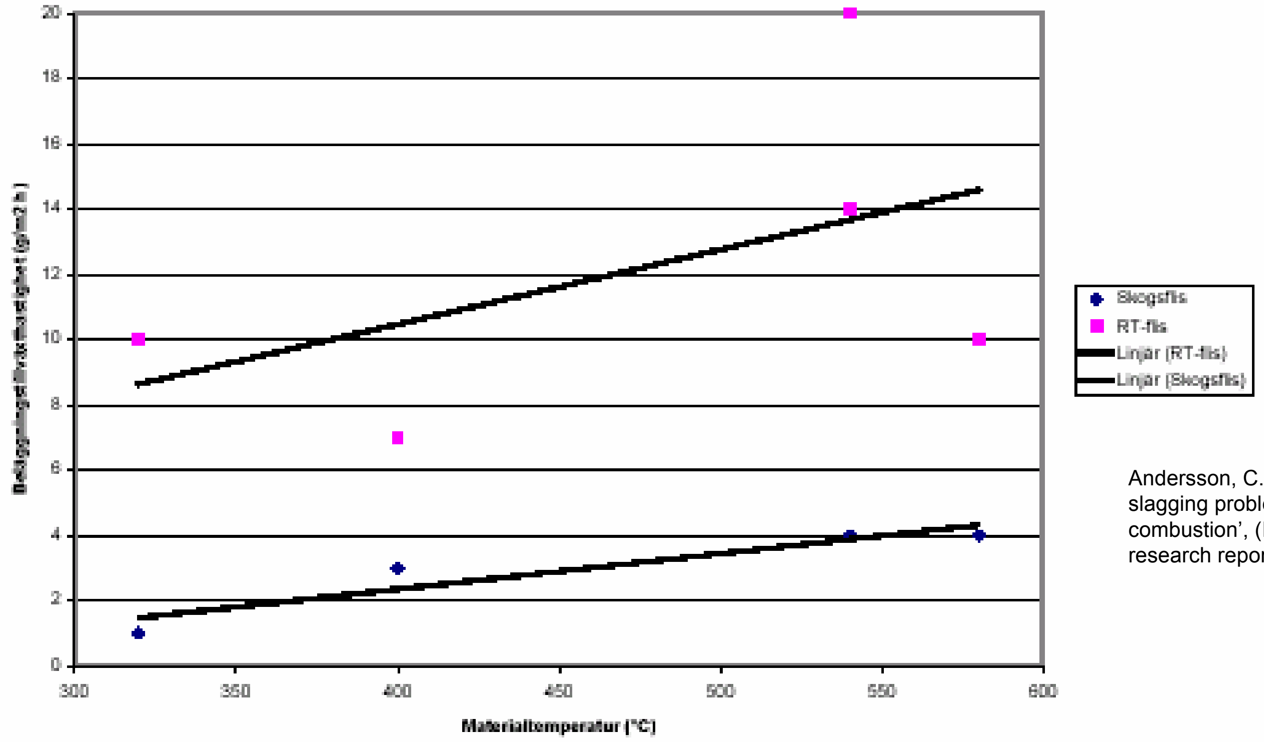

CFX
Time on Streamline 1
(Streamline 1)
5.000e+000
4.250e+000
3.500e+000
2.750e+000
2.000e+000
[s]
0
1.902
3.804
5.707
(m)
Y
X
Z

# Fly ash – changing temperature – drop tube furnace




| Temp. °C | Res. time s | LOI 815°C % wt. loss |
|---|---|---|
| 730 | 1 | 37.25 |
| | 2 | 36.61 |
| | 3 | 34.69 |
| 850 | 1 | 36.46 |
| | 2 | 35.01 |
| 1000 | 1 | 25.46 |
| | 2 | 15.45 |

# Fouling in FBCs – alkali metals




Andersson, C., Hoegberg, J., ‘Fouling and slagging problems at recovered wood fuel combustion’, (In Swedish) Vattenfall research report F9-821, Mar 2001.

Fouling aggravated by alkali metals when S/Cl < 2

(Only trace levels of alkali metals and not seen to be a problem )

# Conclusions - fouling and corrosion - co-firing

- Avoid fuels high in alkali metals since the bed will not absorb these – doping with sulphur would be required
- Past corrosion mostly attributed to chlorine (plastics) - increase would need corrosion trial
- Fossil fuels may aggravate fouling but calcium oxide may be sufficient to absorb the $SO_2$
- Dry, clean, woody biomass is preferred for co-firing
- Plant trials or pilot trials are advisable when changing fuel mix.