Calciner CFD modelling
An equipment designer's perspective

Damien Grévain and Sam Zakrzewski, Fluid Dynamics specialists, Cement division

One Source

Fluid Dynamics Specialists in Cement Division

FLSMIDTH

	Damien Grévain	Sam Zakrzewski
Started at FLSmidth	2013	2008
Fluid dynamics and CFD experience	+14 years	+15 years
Expertise in	Multi-phase flows, Reacting flows, Particle laden flows	
and	Combustion design	Experimental fluid dynamics HPC systems
Education	M.Sc. in Industrial Thermal System Engineering from IUSTI Marseille, France - 2001	Ph.D. in Mechanical Engineering from University of New South Wales Sydney, Australia - 2002

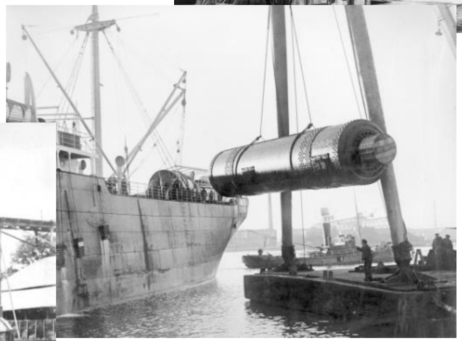
One Source

A One-source supplier to the global minerals and cement industries

- A **leading supplier** of equipment and services to the **global**
  - **minerals** (100+ years of experience)
  - **cement industries** (133 years of experience)

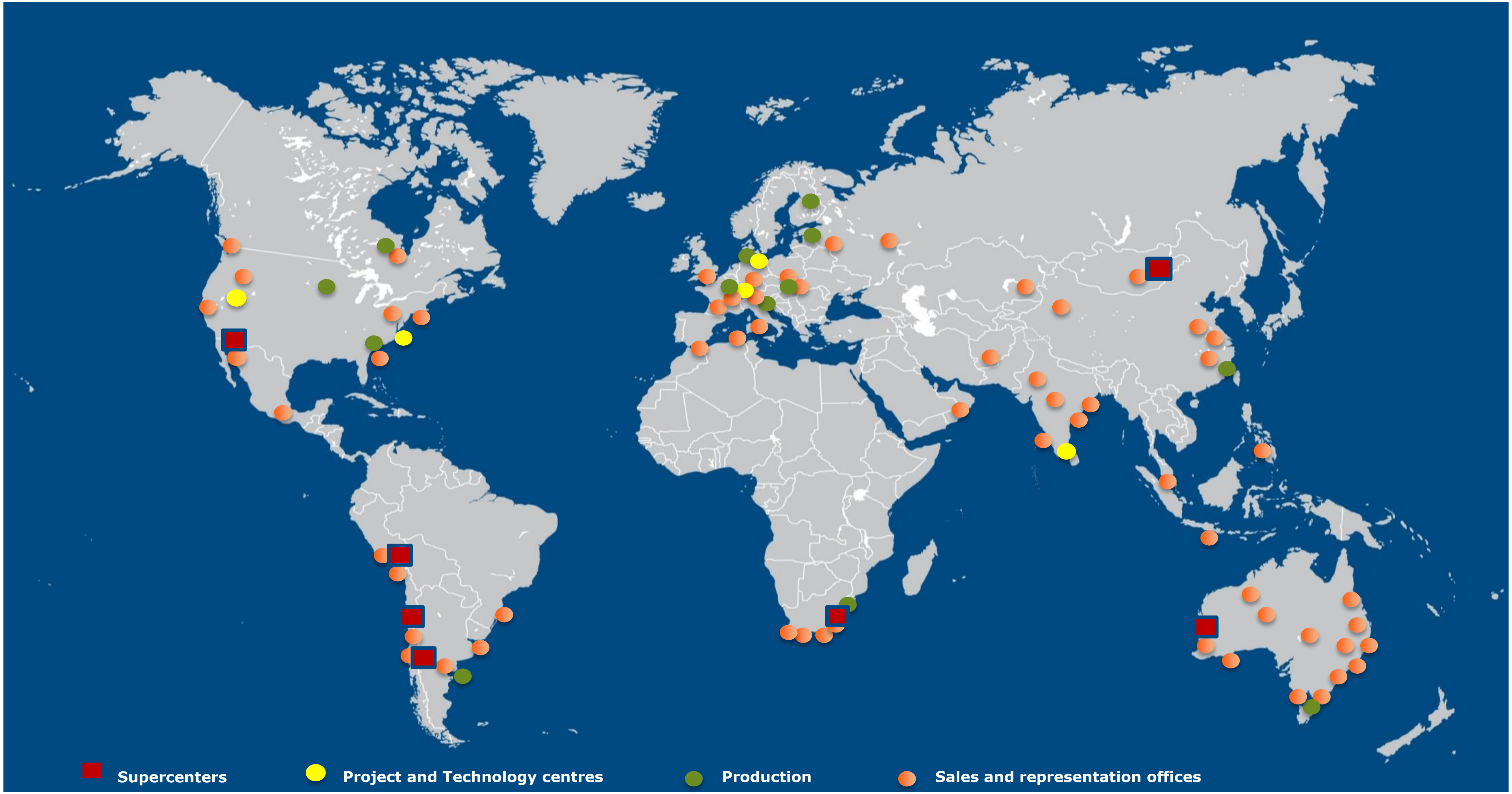
- FLSmidth **supplies everything from single machine units to complete minerals and cement flow sheets** including associated services

- FLSmidth primary focus industries:
  - **Coal**
  - **Iron ore**
  - **Fertilizers**
  - **Copper**
  - **Gold**
  - **Cement**



Global reach with presence in 50+ countries

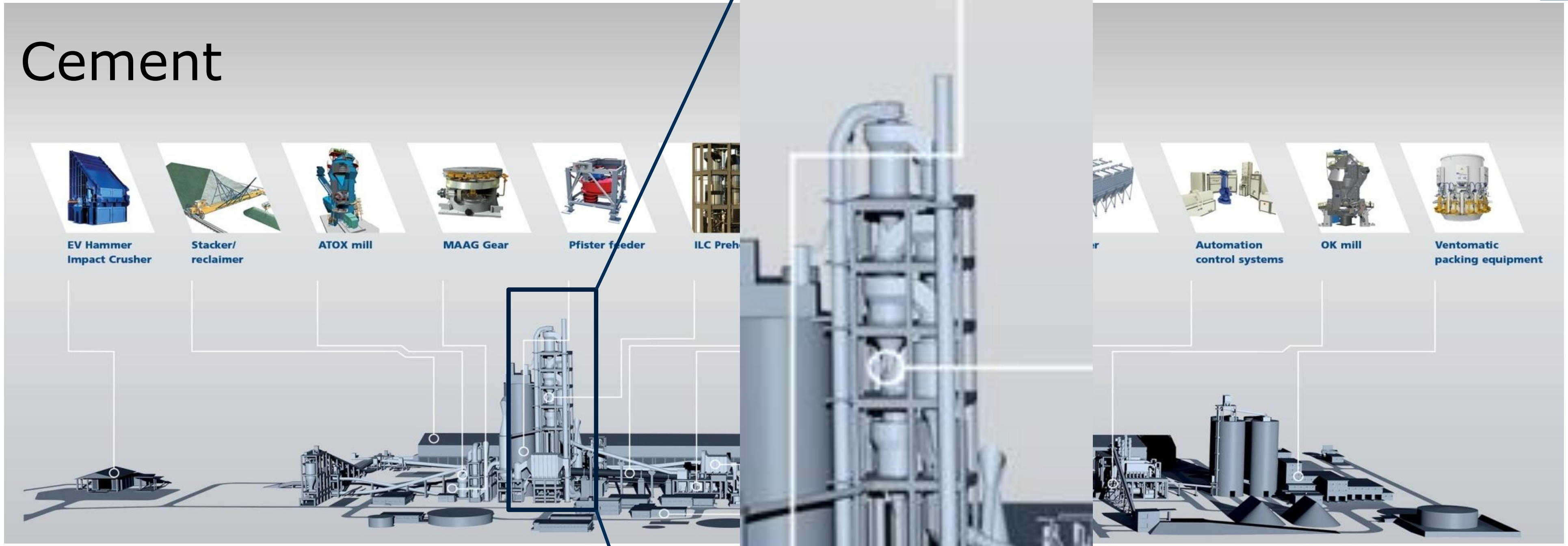
FLSMIDTH



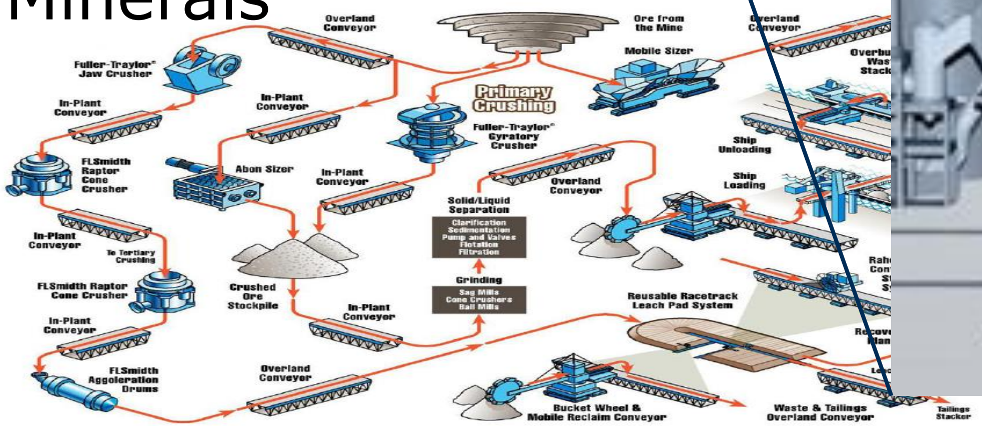
One Source

Product Portfolio

Cement



Minerals

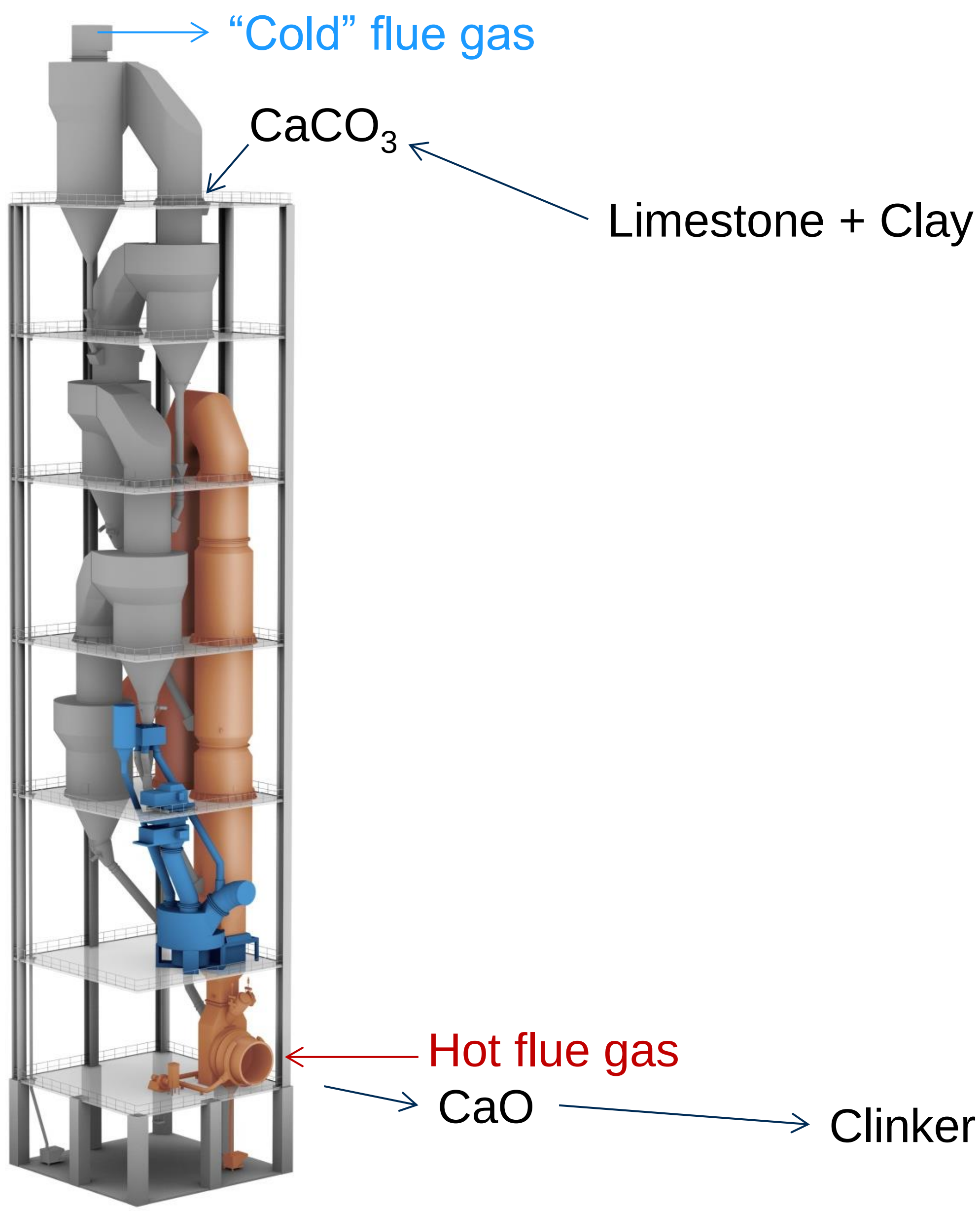


Cement Production
Pre-Calciner

$$CaCO_3 \rightarrow CaO + CO_2$$

Endothermic reaction

1782 kJ/kg $CaCO_3$



Calciner modelling
What are we investigating?

- Temperature profile
- Gas velocity profile and streamlines
- Mixing
- Meal fall through
- By-pass

- Particle residence time
  - Meal
  - Solid fuel
- Fuel burnout
- Alternative fuel combustion
- Calcination degree

One Source

Calciner modelling
Why?

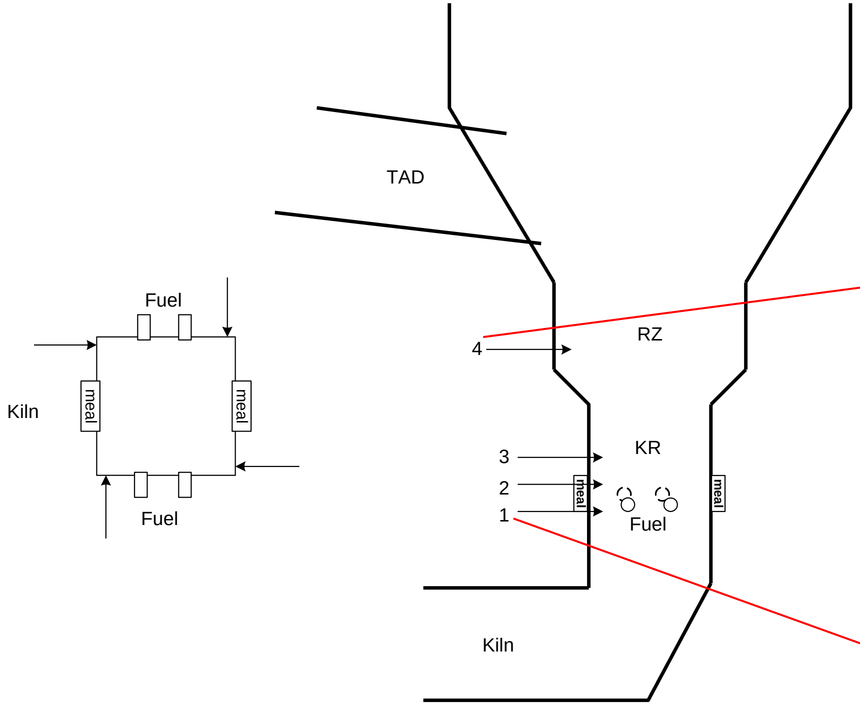
- Product development
- Research
- Sales
- Troubleshooting

→ (all arrows point to)

- Validation

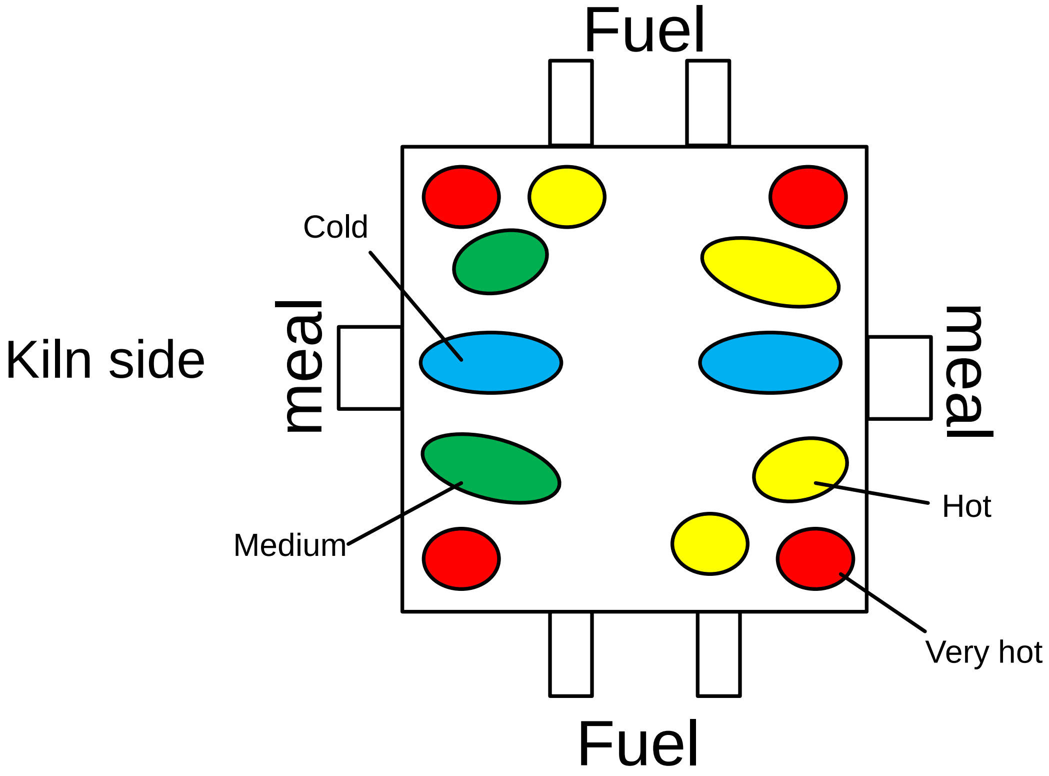
Comparison with measurements
Industrial conditions

- Location of temperature mapping

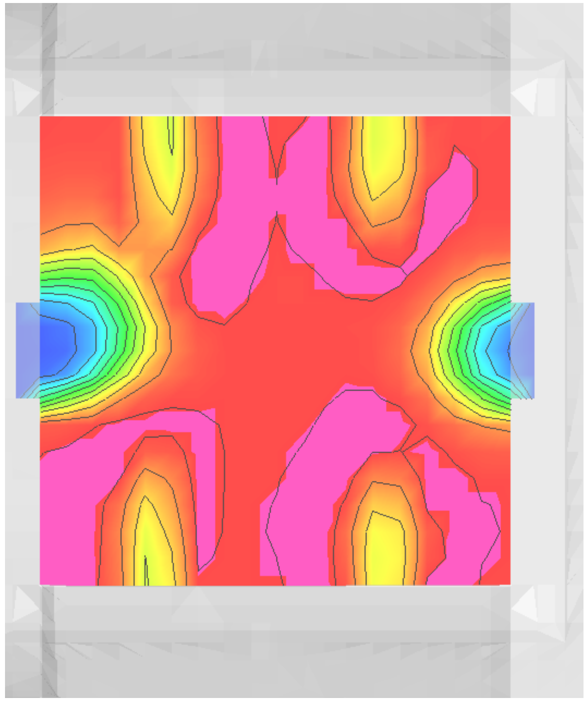


Temperature in riser
Industrial conditions

Measurements

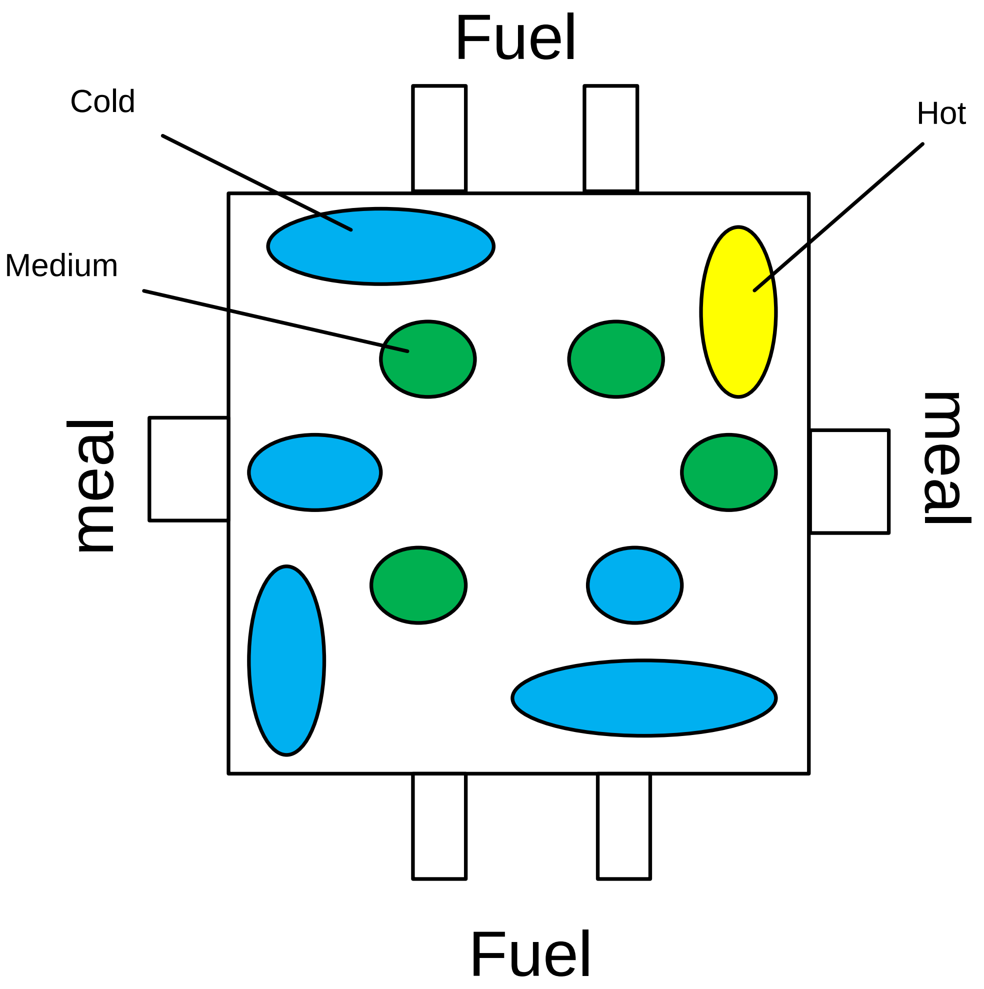


Basecase
EMMS - VR 17.0.1



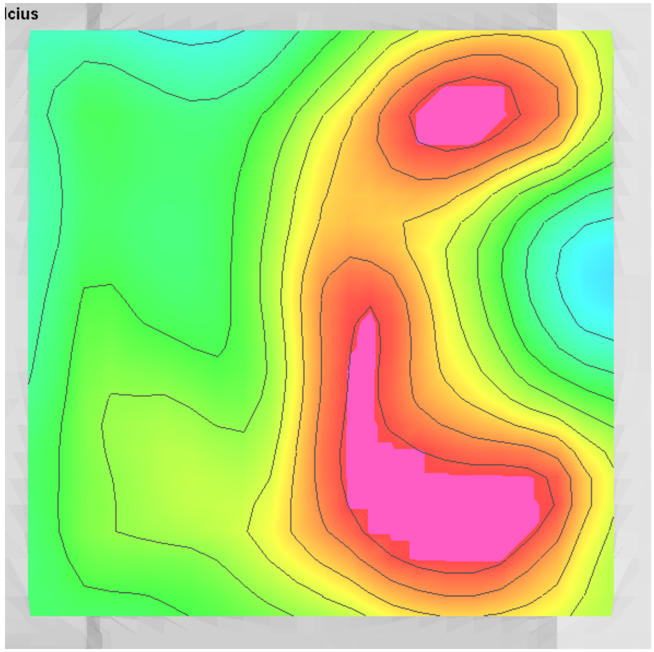
Temperature in calciner bottom duct
Industrial conditions

Measurements



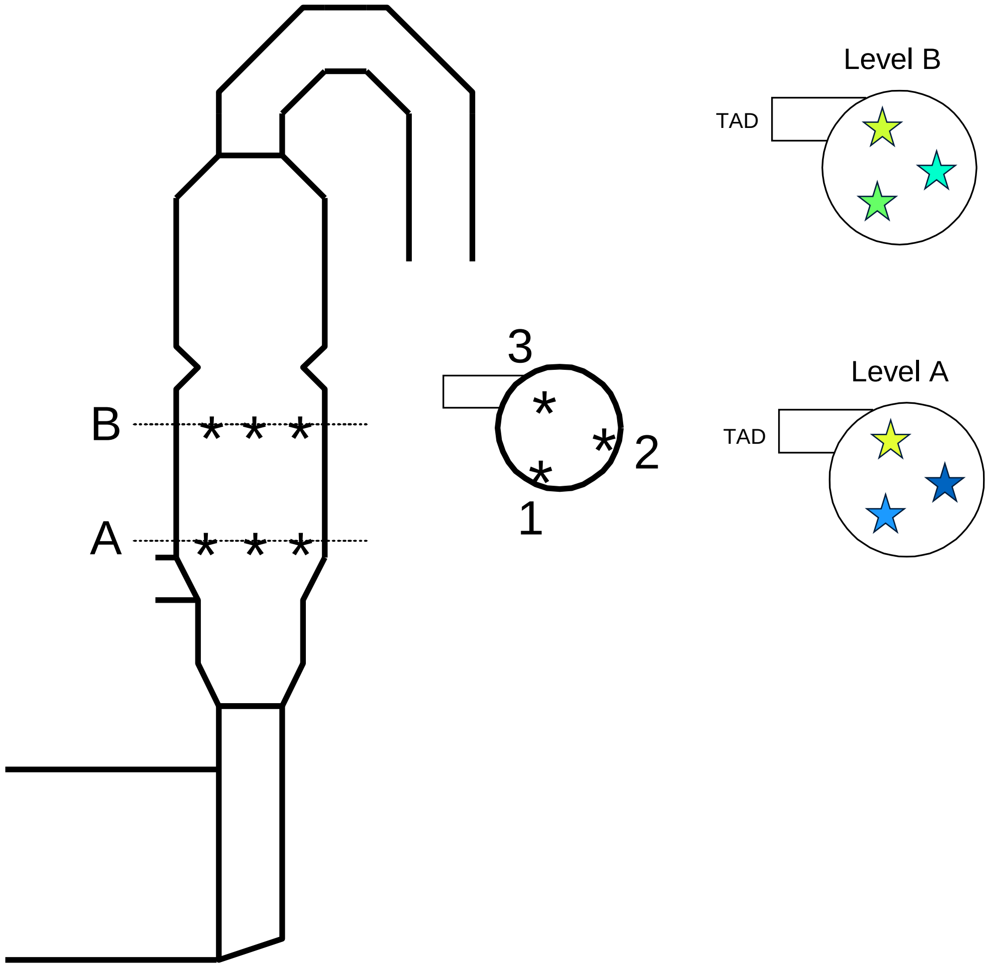
Basecase

EMMS - VR 17.0.1

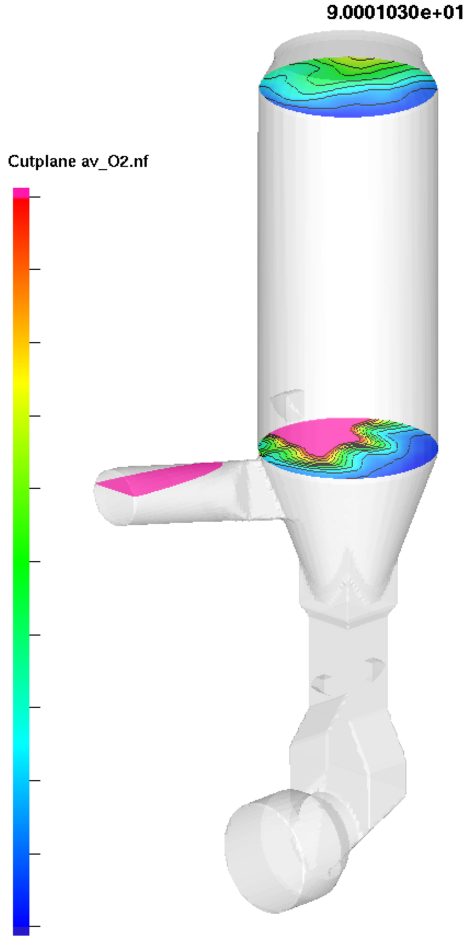


Location of oxygen measurements in calciner
Industrial conditions

Measurements



Basecase
EMMS - VR 17.0.1



Meal streams in industrial conditions
General observation from model

Wen-Yu in VR 17

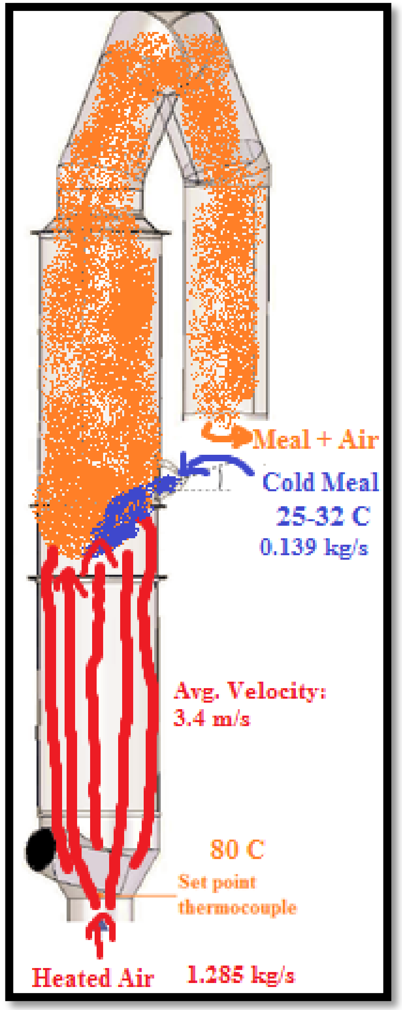
- Meal stream out of spreader box tends to keep close to walls and gather at the bottom of the cone
- Meal falls through riser

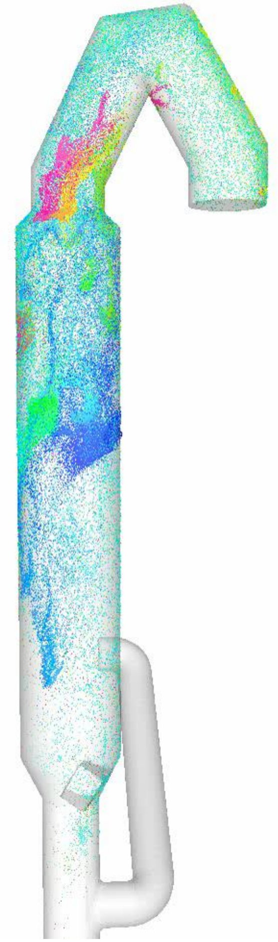
EMMS in VR 17

- Meal stream penetrates better across the calciner and achieves much more meal suspension and dispersion
- Less meal falls through riser

Lab scale measurements

- Cooperation with:
  - DTU KT CHEC
  - MiCeTec
- Test centre
- Scaled down industrial calciner 1:12

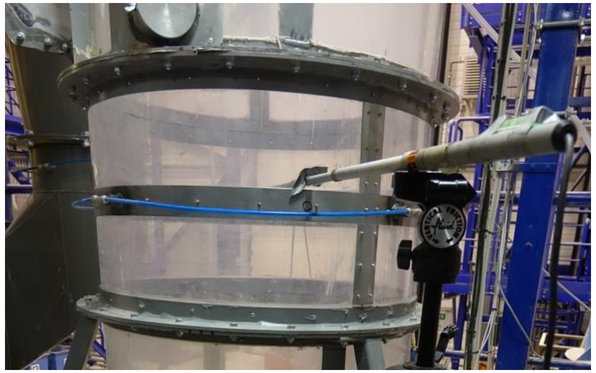




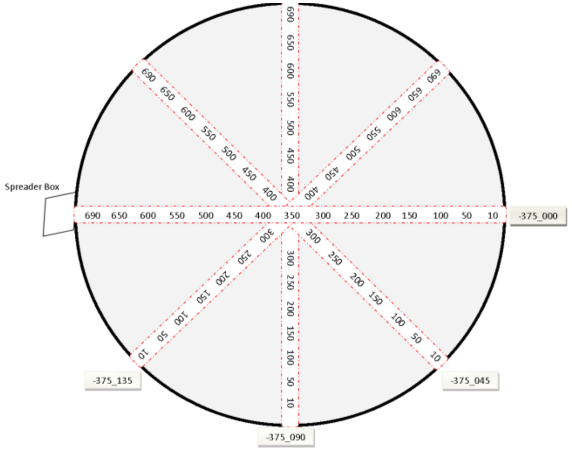
Lab scale measurements
Velocity profile

Single Phase

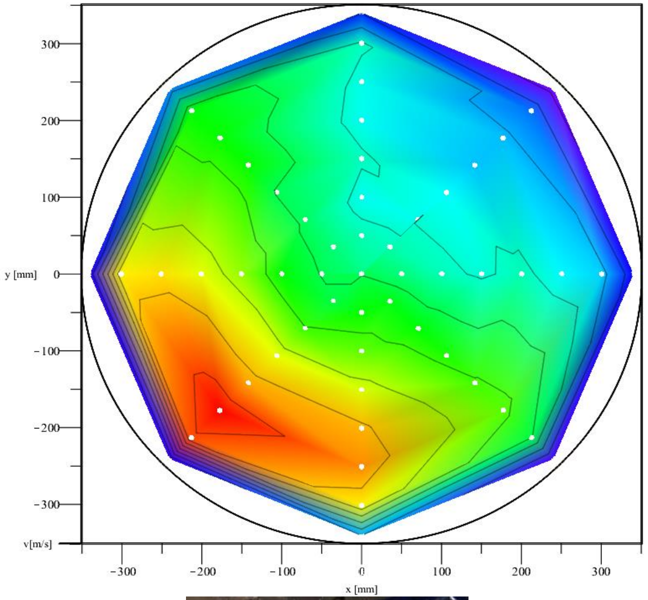
- Upflow velocity with Anemometer



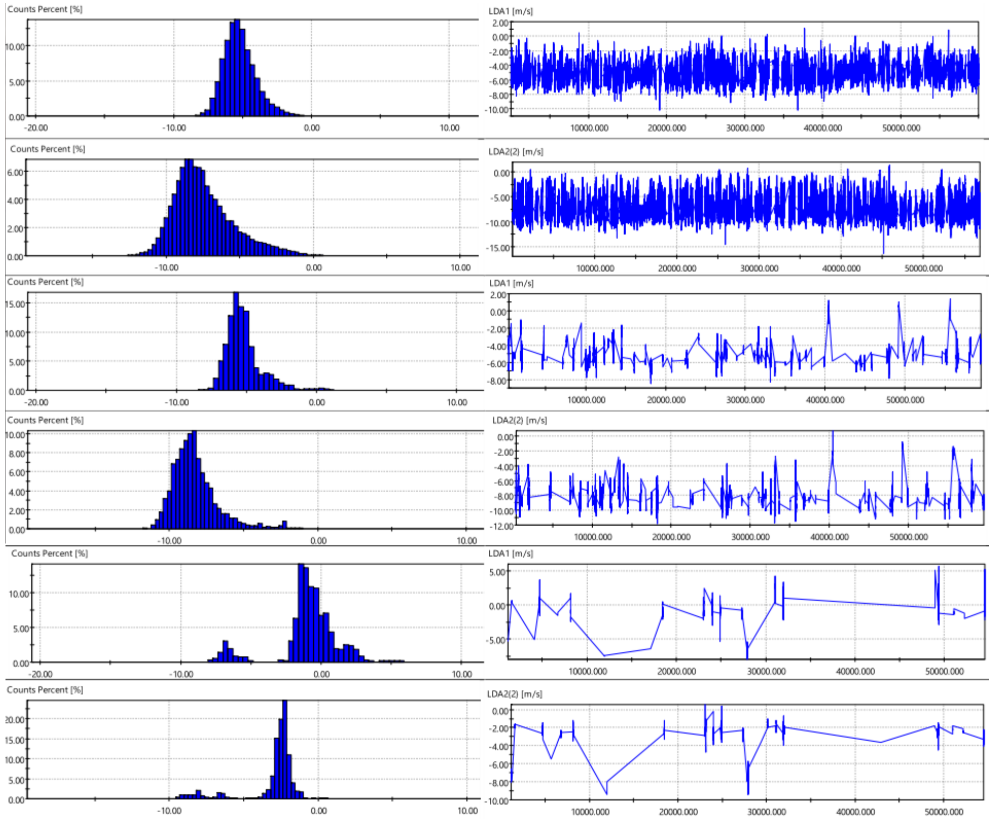
- 375 mm below the top of spreader box

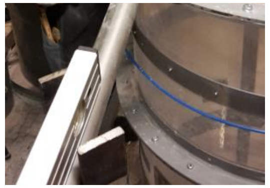


- 60 points measured

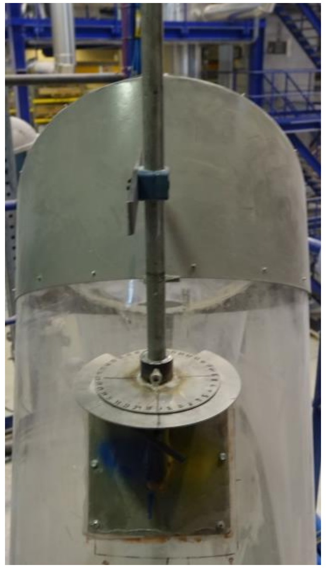


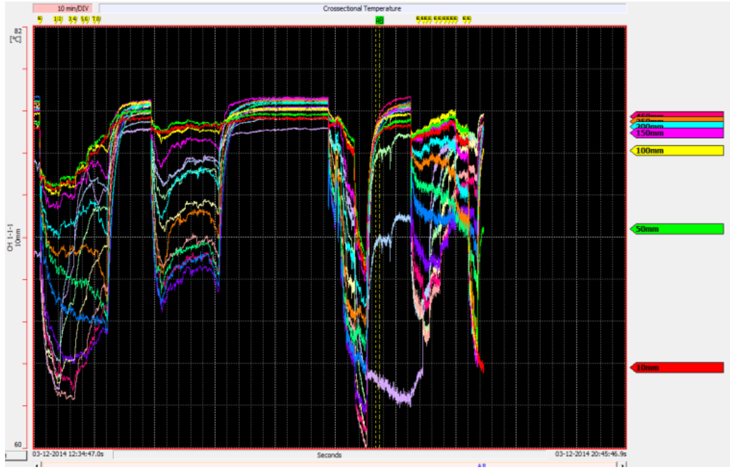
Multi Phase





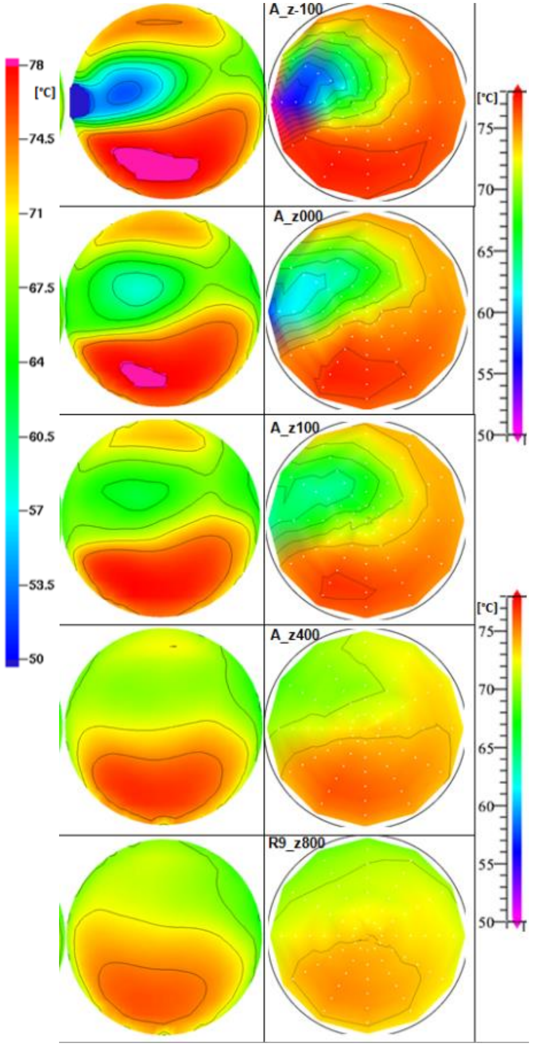
Lab scale measurements
Temperature profile





Computation EMMS

Experiment

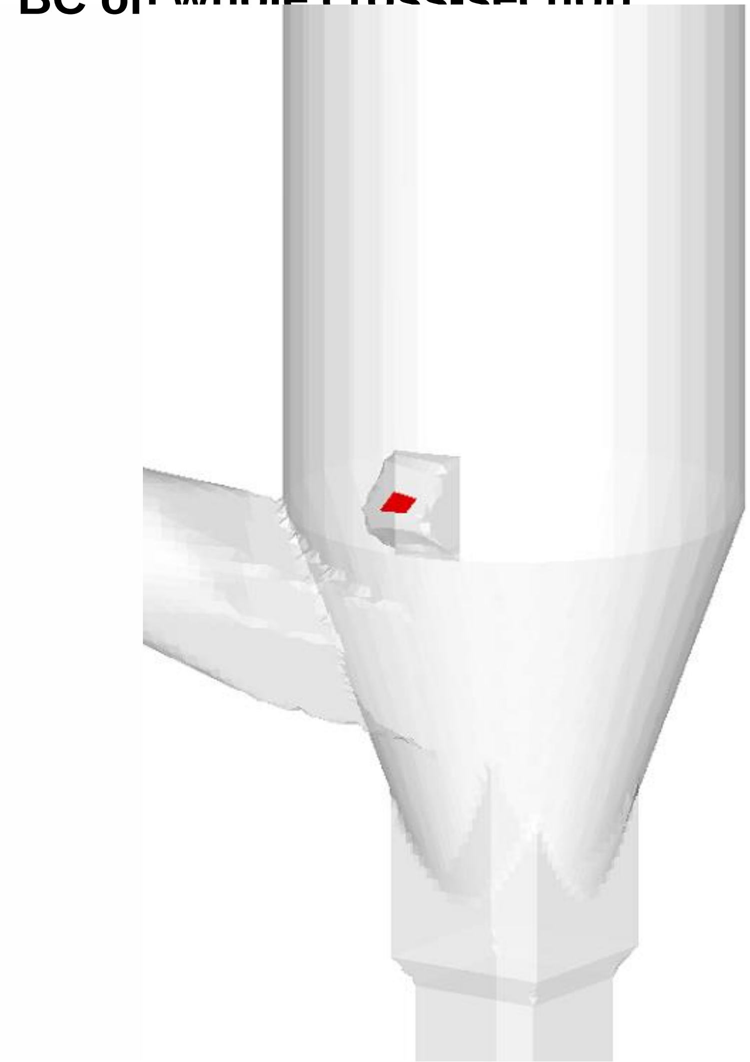


Define Boundary Conditions
Meal flow in pipes

VR 16.0.5 / Wen-Yu
Meal pipe included
BC on whole cross-section

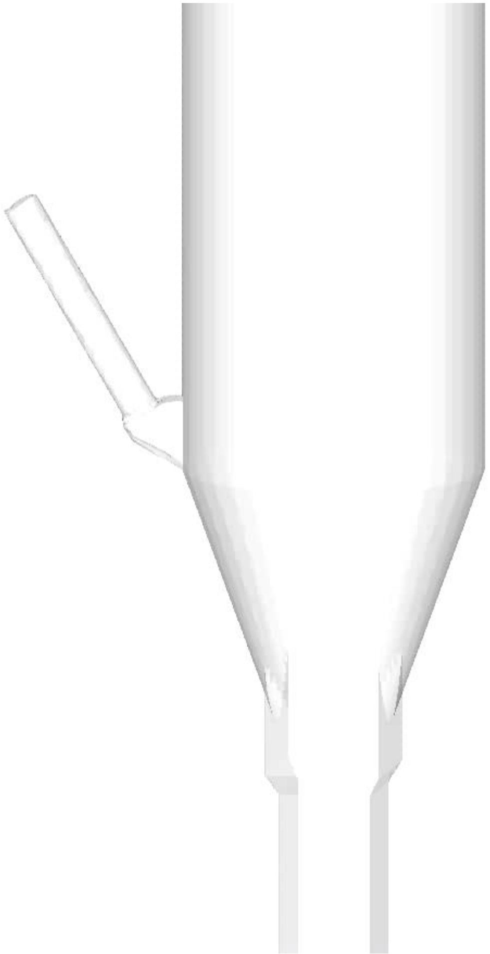
Meal pipe removed
BC on few cells

FLSmidth

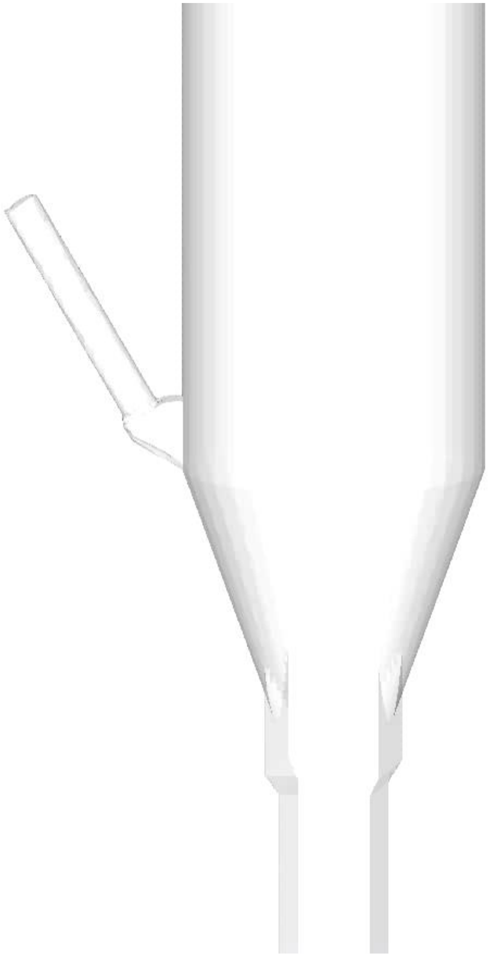


Meal flow in pipes
VR 17.0.3 / EMMS – Different results

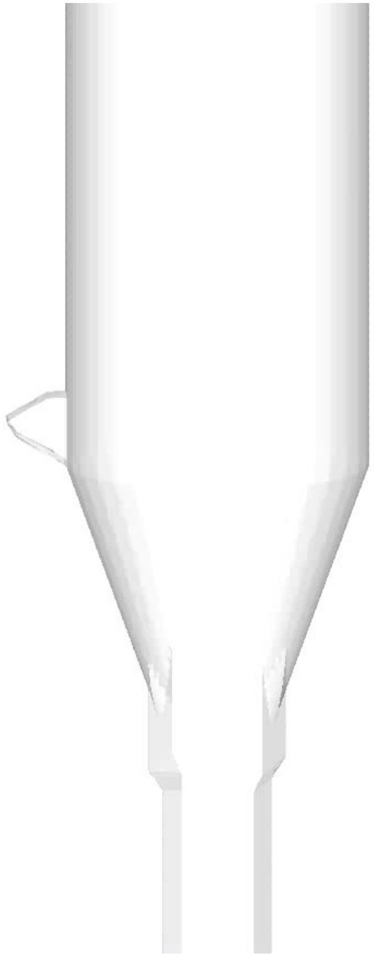
BC on whole cross-section



BC on 4 cells



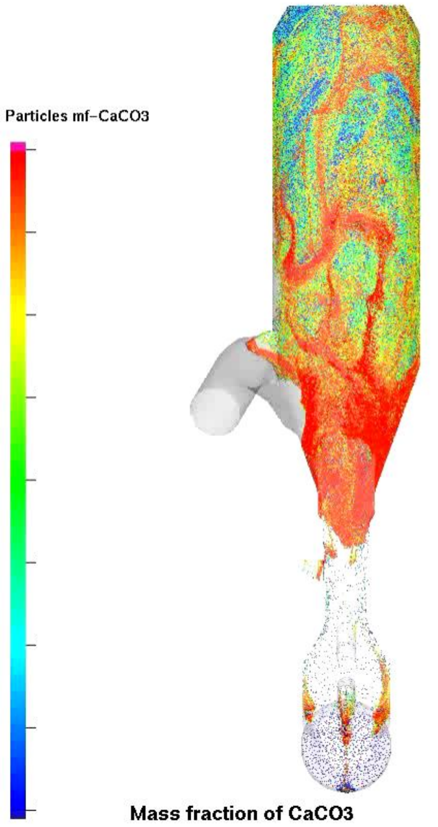
BC on spreader box: 4 cells

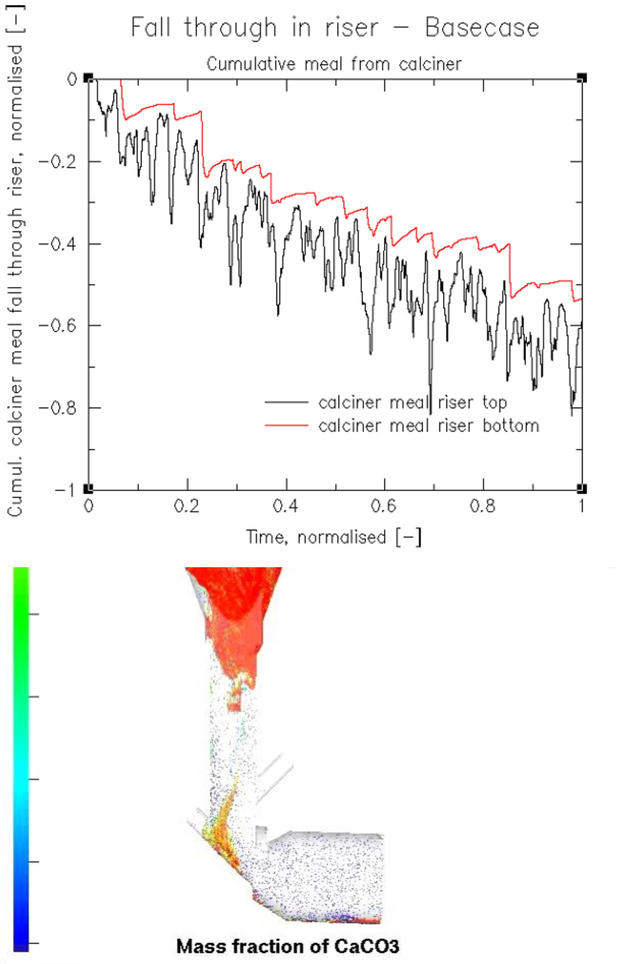


One Source

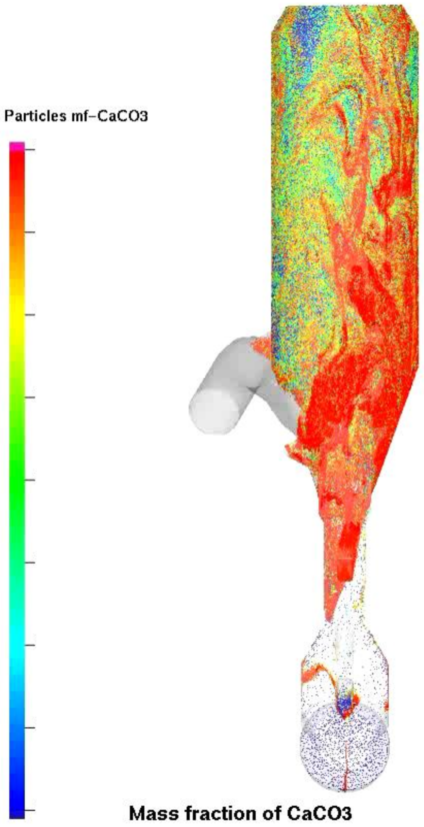
Calciner modelling - Meal fall-through

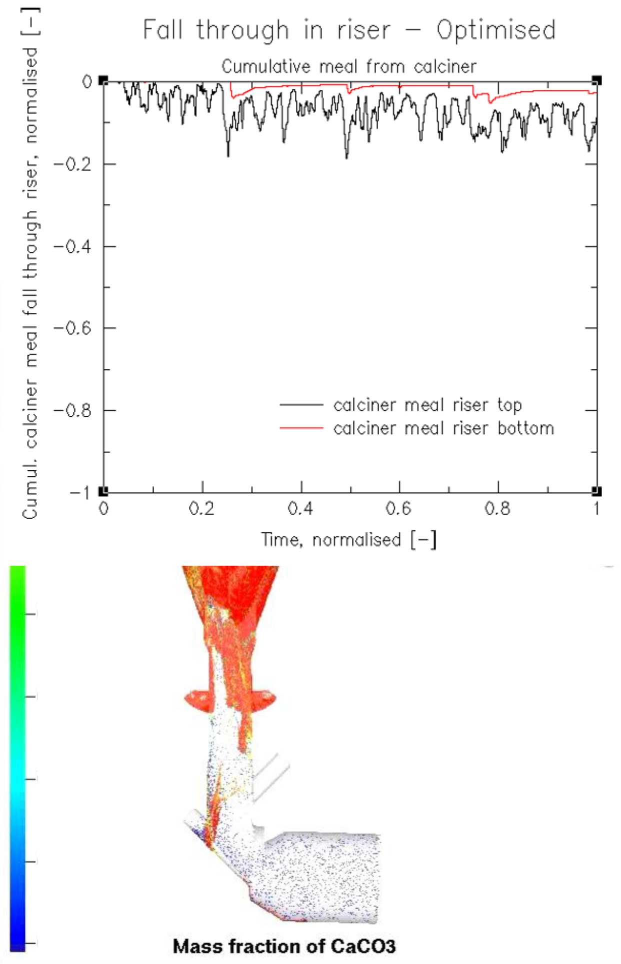
Basecase





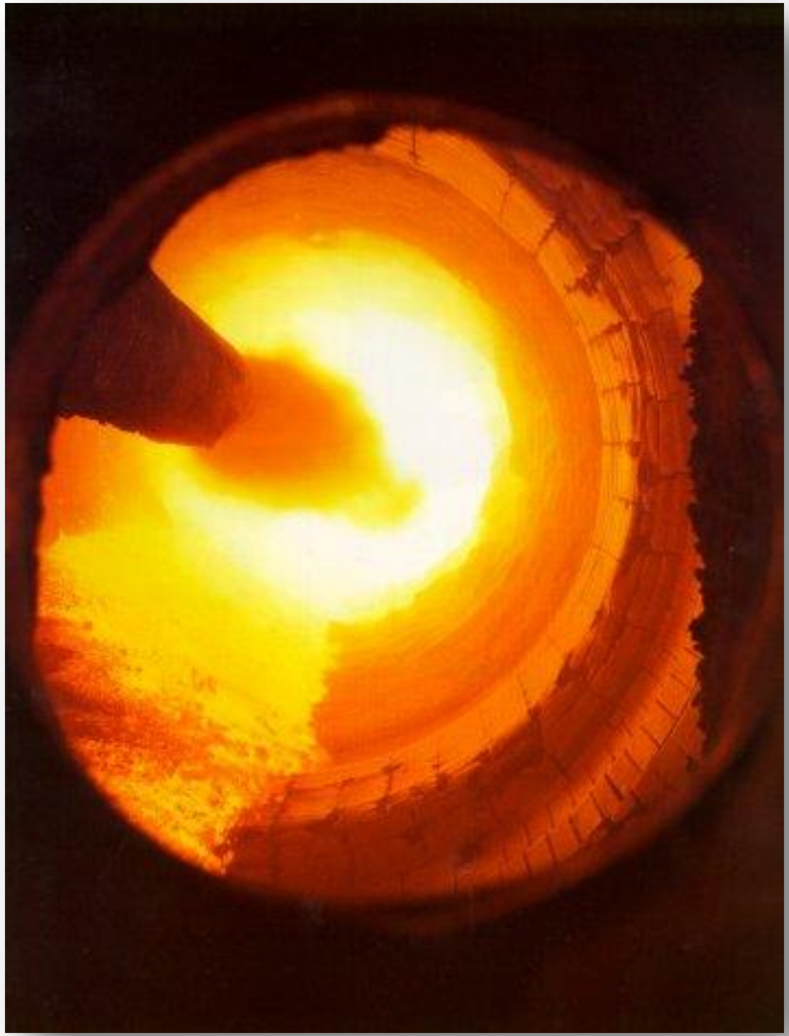
Optimised



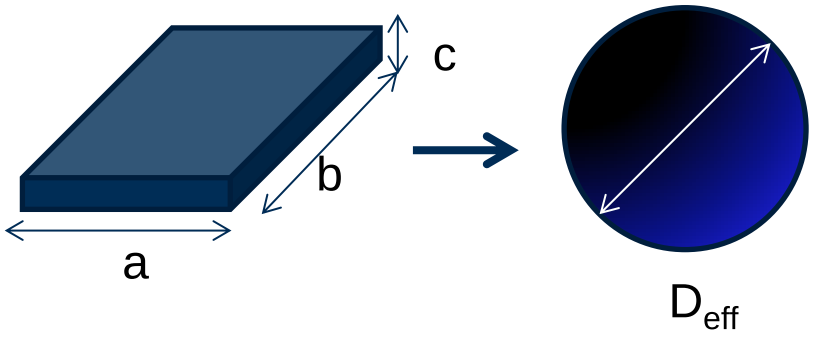


Challenges
Alternative Fuels

Dry sewage sludge

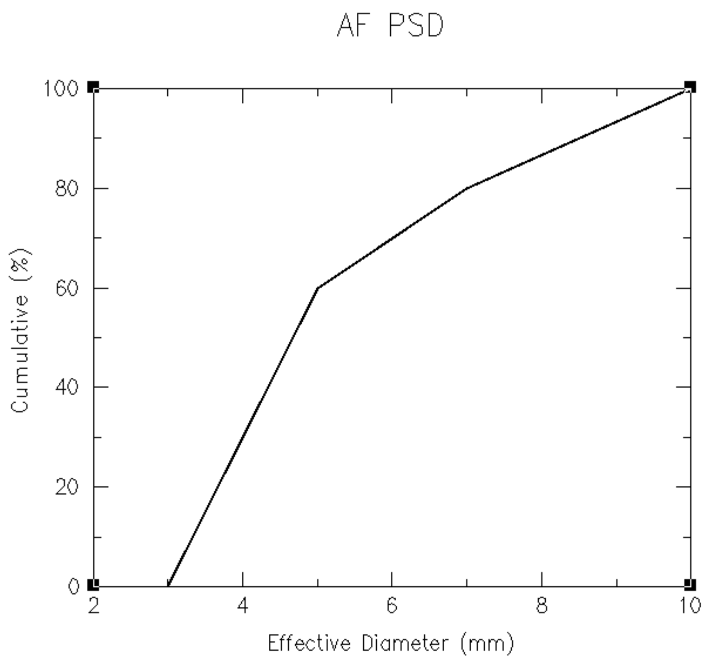


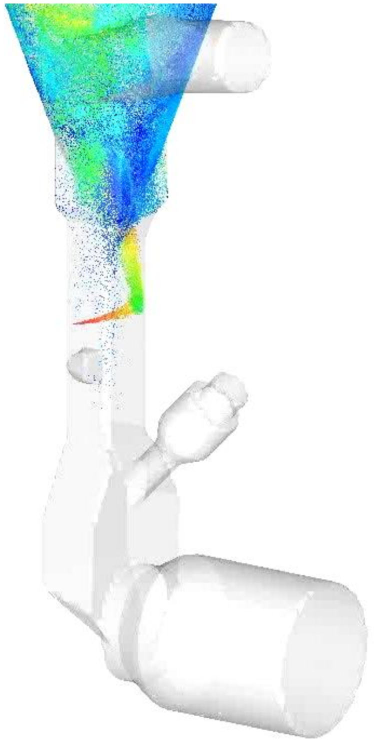
Challenges
Alternative Fuels



a mm	b mm	c mm	Vol mm3	D eff mm
10	10	0.5	50	4.57
20	20	0.5	200	7.26
30	30	0.5	450	9.51

$$D_{eff} = \sqrt[3]{\frac{6 \cdot VOL}{\pi}}$$





Challenges

- Capture fall-through of solid particles in riser
  - Minimum cell resolution required in the riser
  - Small cells → small time-steps → long computational time
    - CPU only: 12-18 days for 80 simulation seconds
    - GPU 17.0.2: 4-8 days for 90 simulation seconds
- Postprocessing
  - Missing streamlines and pathlines in GMW
    - Needs VisIT, Ensight, Paraview, etc…
- Storage and Back-up
  - We generate 1 to 2 TB/month

Challenges

Measurements

- Validation data difficult to obtain
  - Visual inspection
  - Estimation based on experience
  - Integral measurements
    - Temperature
    - O_2 contents
    - LOI
    - Mass balance

Modelling

- How to best define BC of raw meal?
- Predicted meal flow dependent of
  - Velocity
  - Distribution
  - pVolF
  - Restitution coefficients (wall-particle)
  - Sensitive to inlet area

Wishes for the next Barracuda

- Interpolate initialisation data from an IC file
  - save days of calculations with modified project

- Rotating domain (separators, crushers)

- Better capturing of complex internal geometry

- More predictable particle/wall interaction

- Better local mesh fineness control
  Meshing is improved in VR17… still some “surprises”
  - Meal distribution box
  - Kiln feed from bottom stage

- Post-process results in CFD Post (ANSYS)
  - Export data as CGNS

One Source

Conclusions

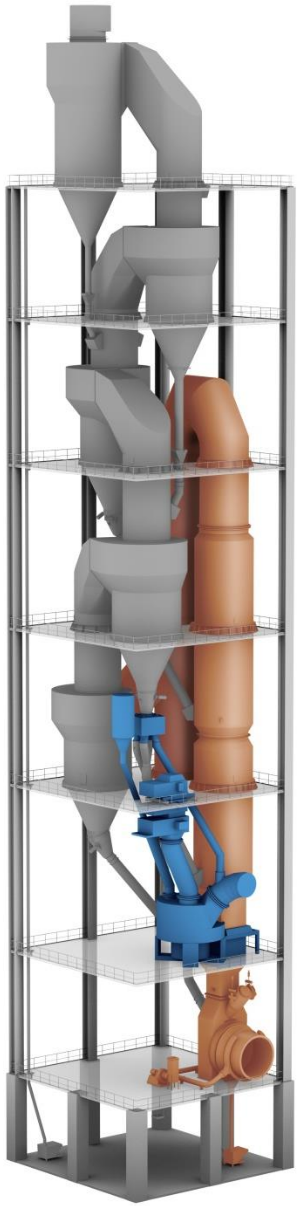
FLSmidth

- Barracuda used to make design decisions based on relative analysis
- Good collaboration with CPFD support
- Validation imperative
- Challenges with alternative fuels modelling
- Acquire more confidence in
  - Particle drag model
  - Meal inlet BC

  … before improving combustion model for sub stoichiometric conditions

- Drag model
  - EMMS delivers promising predictions. Compares best to measurements on
    - Lab-scale setup (without reactions)
  - Limited data available for industrial scale
    - Meal stream velocity and entrainment at site
  - Difficult to state that EMMS is the most adequate for industrial conditions
  - EMMS very sensitive to particle volume fraction
    - Meal blocks-up at vol. fraction well bellow max packing fraction

Thank you!
Any Questions?



One Source