NEUP Cement Calcination Project Updates

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FUTURE

VISION

OPPORTUNITY

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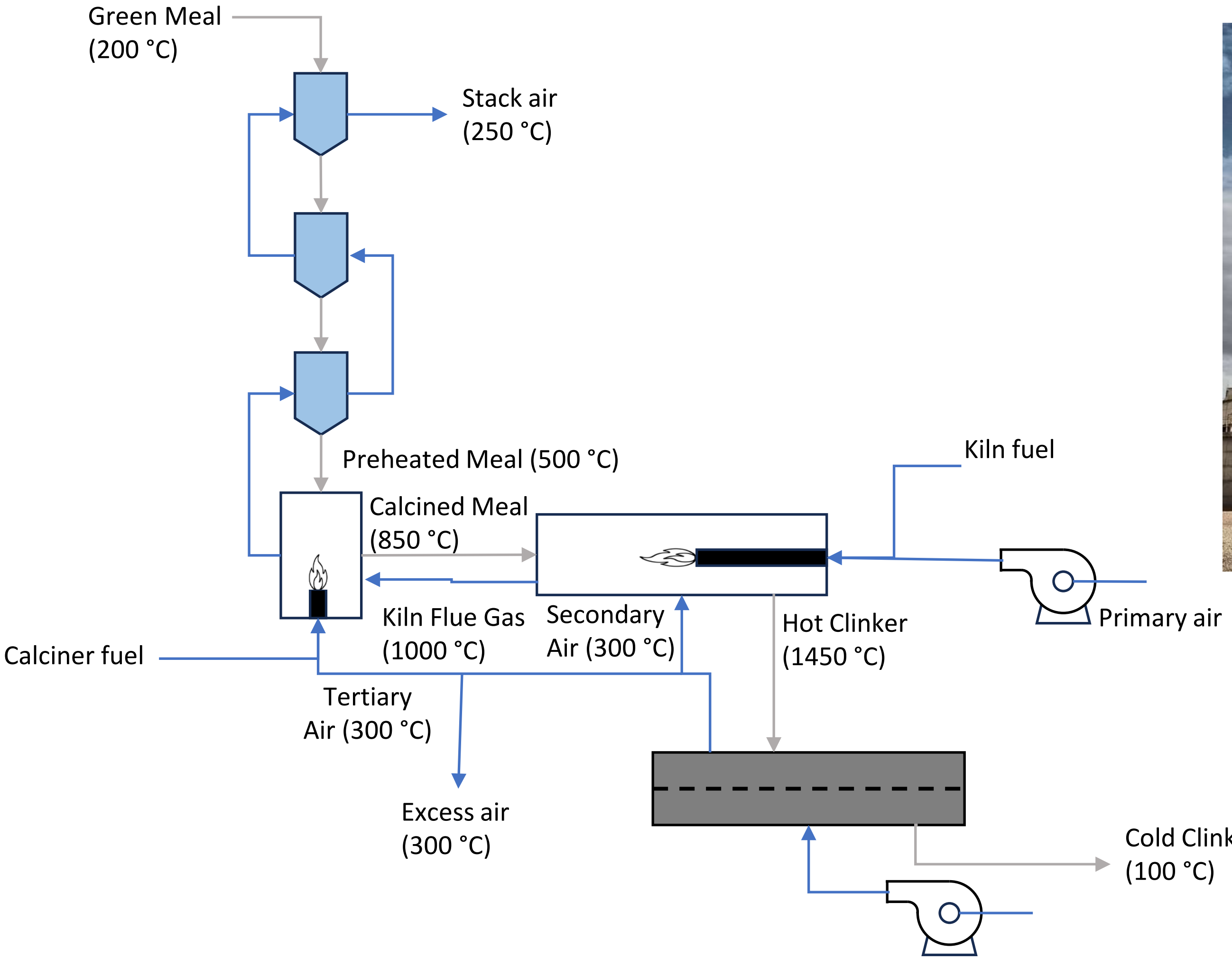
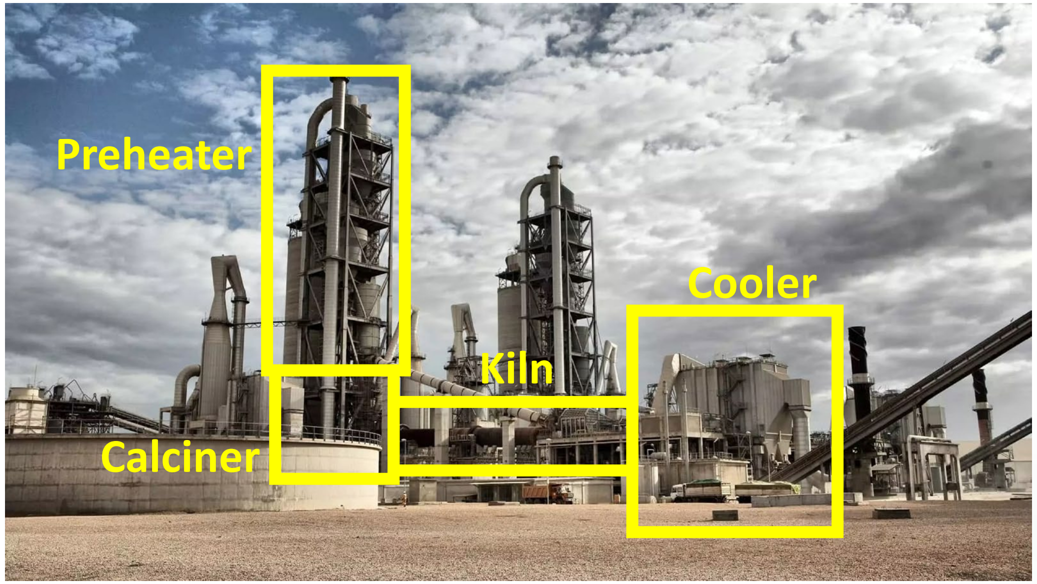
PennState College of Engineering

KEN AND MARY ALICE LINDQUIST DEPARTMENT OF NUCLEAR ENGINEERING

60 NUCLEAR ENGINEERING

Overview of cement process

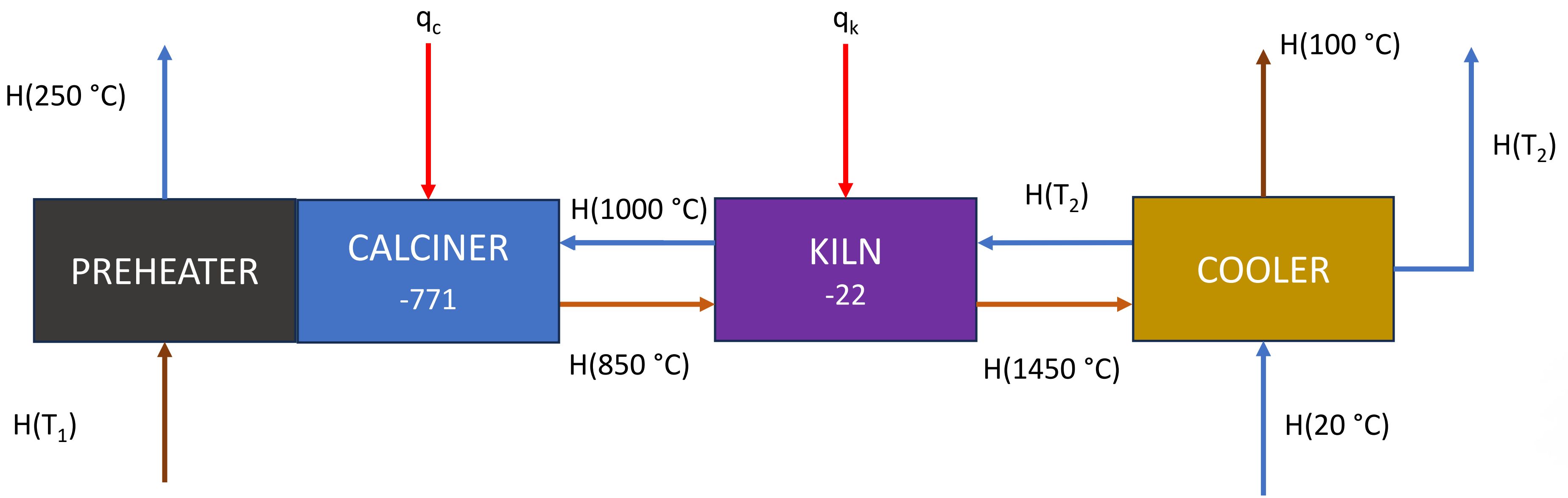




Goals

- Feasibility of nuclear energy insertion in the cement process.
  - Energetic and economic viability.
  - Study of the effect of insertion in calcination chemistry.
  - Identify process integration strategy.

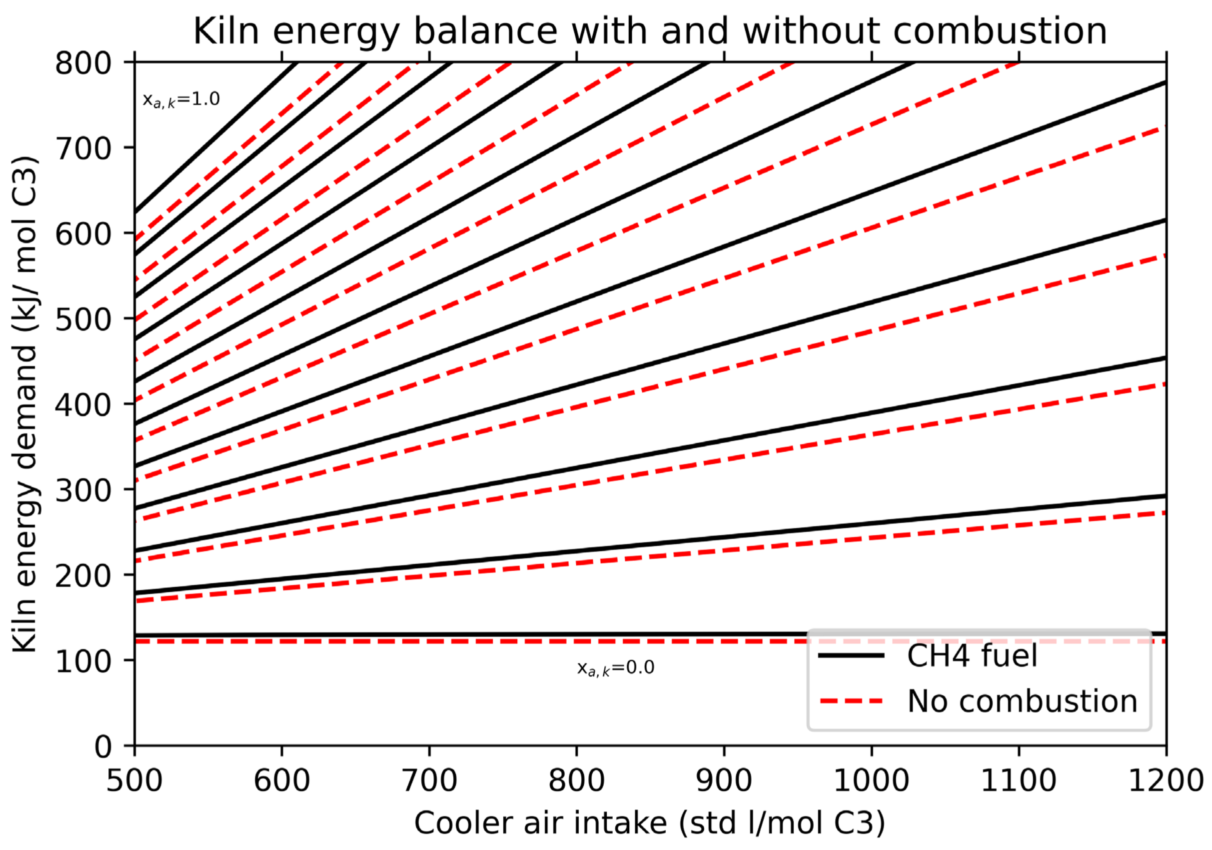
Cement plant energy balance



Assumptions:
- No additional reactions
- Instantaneous reactions at 850 and 1450 °C
- All gases at 1 atm
- Isentalpic operation

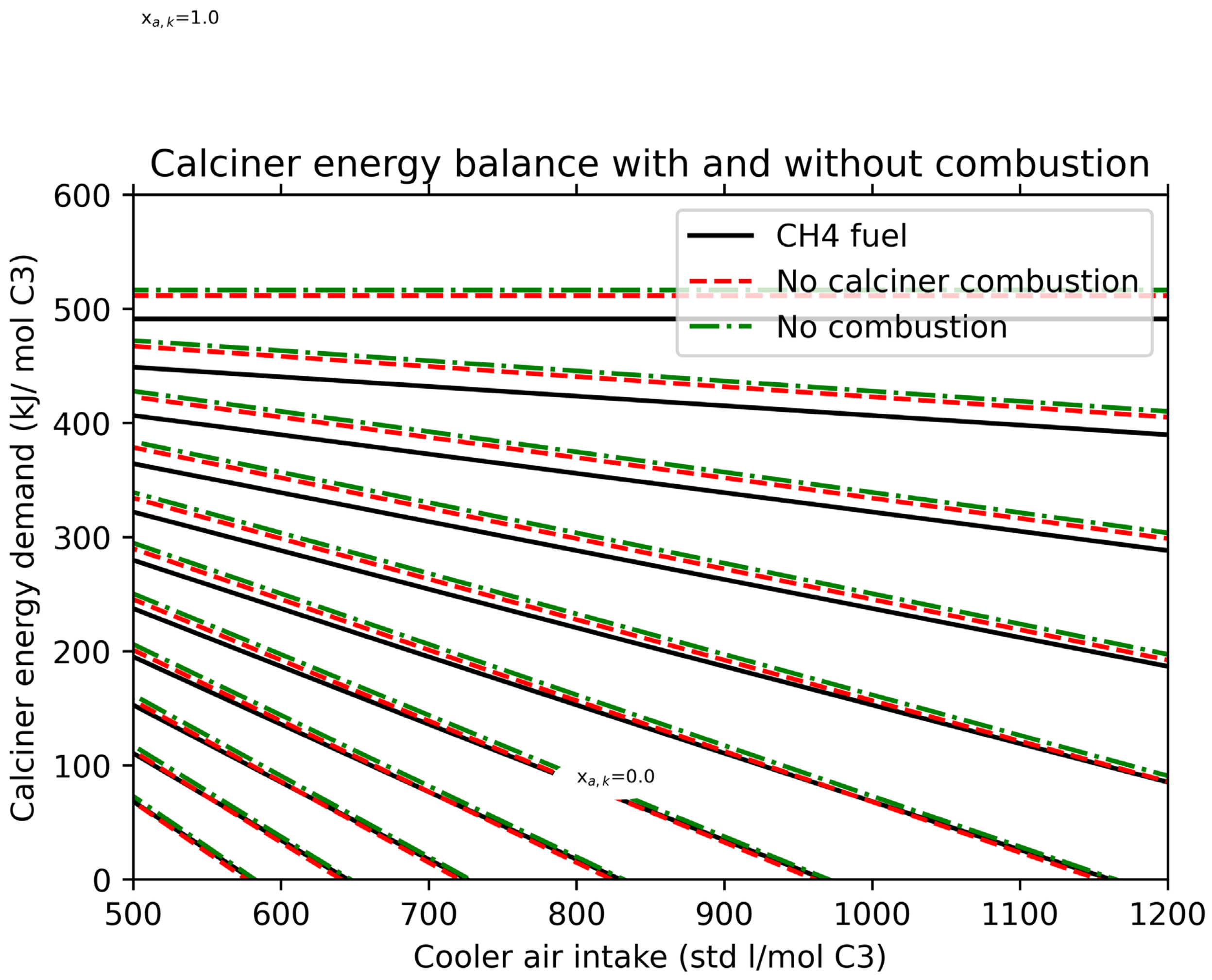
Kiln energy balance

- Kiln operation without combustion requires less energy.
- No need to heat up combustion byproducts.
- Effect is more pronounced for high air flows and high air temperatures.
- Restrictions due to air flow cap on preheater tower.

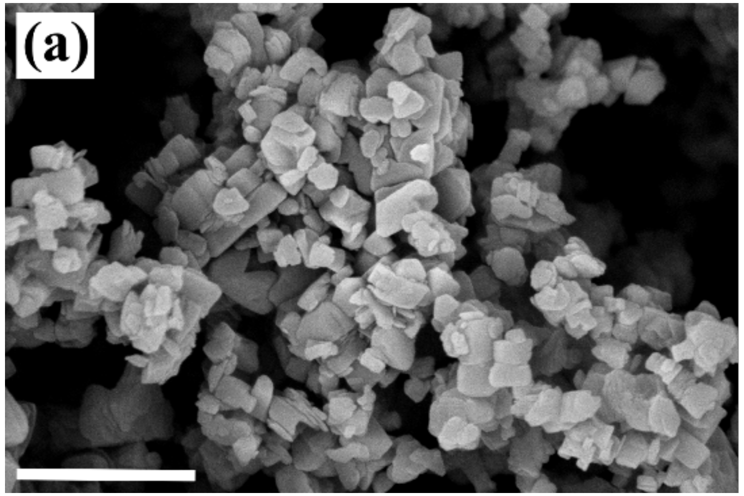


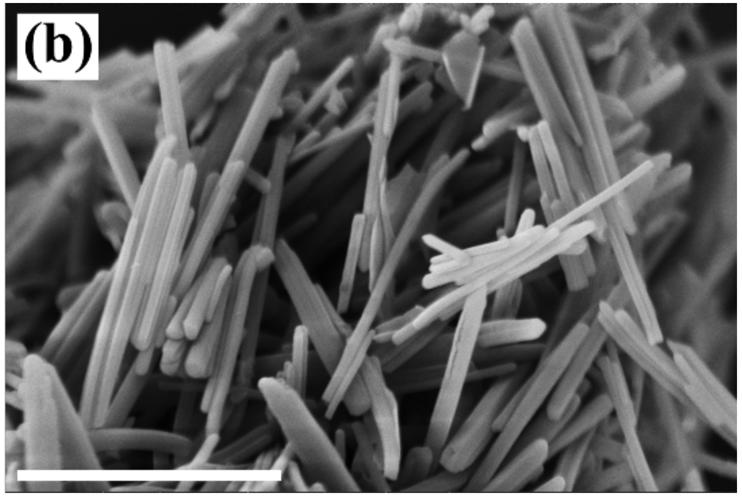
Calciner energy balance

- More air flow, less fuel, since now gas provides heating.
- Insensitive to inlet composition.
- The combustion system has slightly less energy demand.



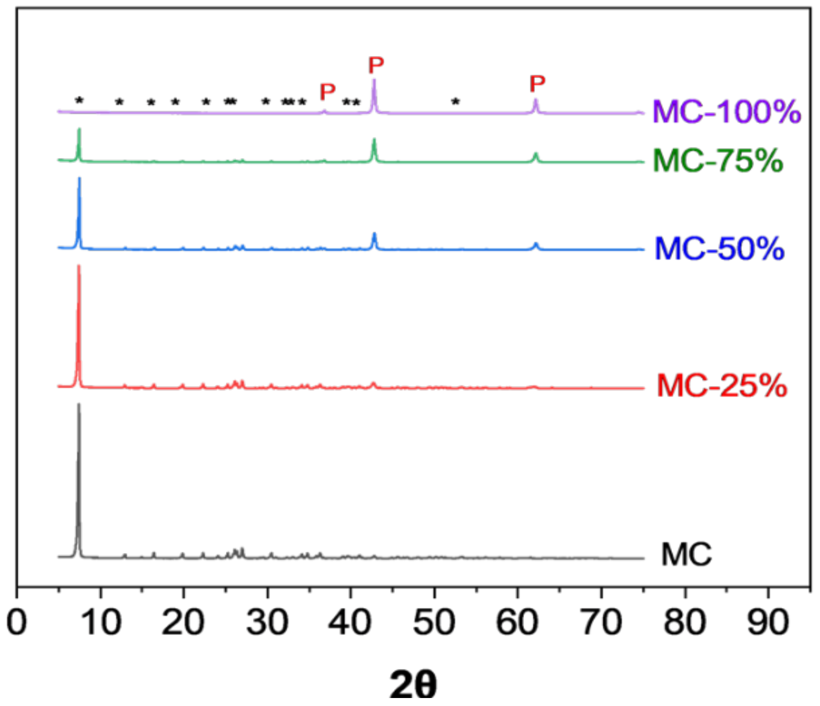
Mineral models stagnant calcination benchmark

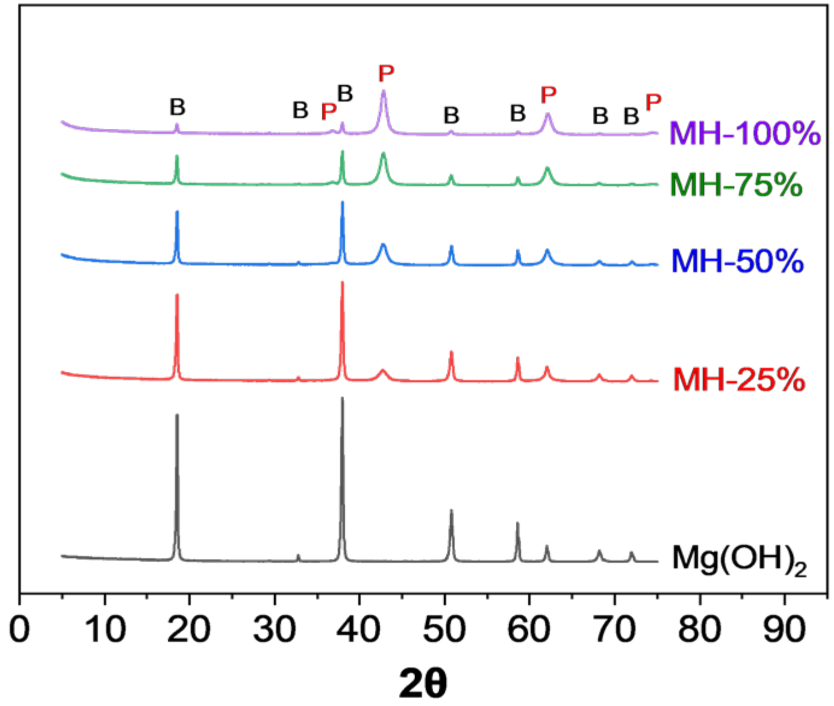




- Secondary Electron (SE) Micrographs of (a) Mg(OH)2 and (b) Mg5(CO3)4(OH)2∘5-6H2O Calcined Raw Materials. Scale bars within each image correspond to the following lengths: (a) 1 μm and (b) 3 μm.
- The hydroxide starting material was composed of 99.9 % Mg(OH)2 (brucite) and 0.1 % MgO (periclase) as evidenced by the Rietveld-refined, X-ray diffraction (XRD) pattern.

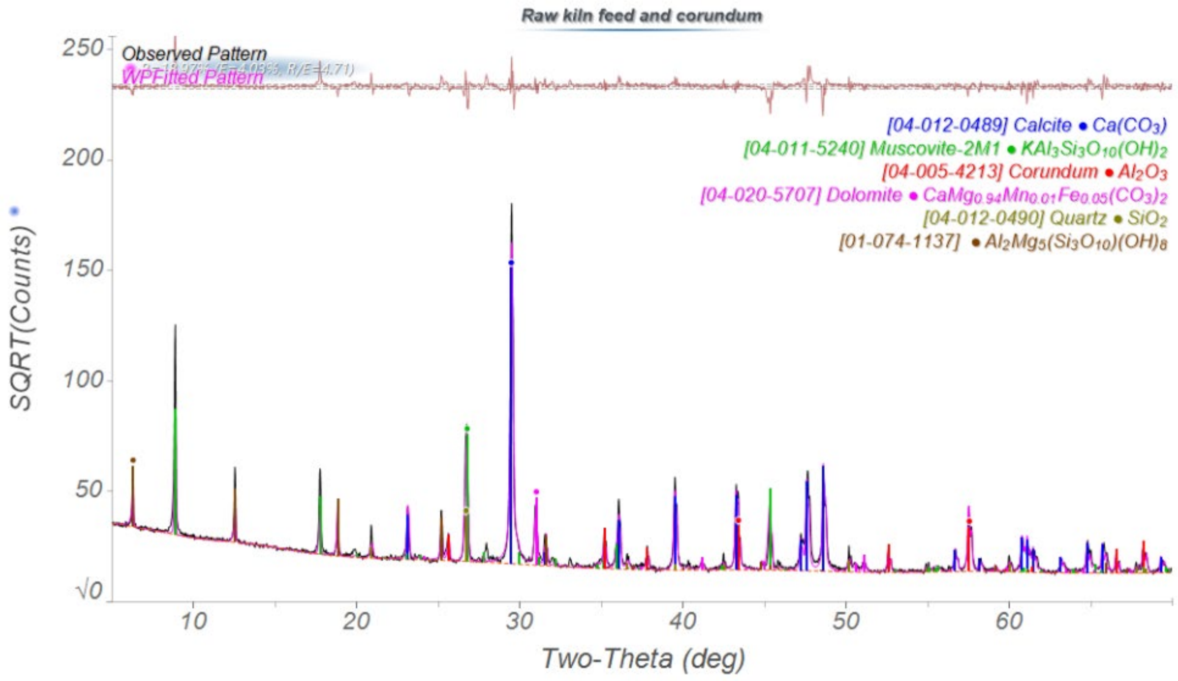
Effect of MgO nanocrystallites agglomeration on thermal decomposition





Compared to HMC calcination, MH calcination formed smaller MgO clusters particles with median sizes 6.37 – 6.41 µm and larger surface areas (40.8 – 149.7 m^2/g). As the calcination degree increased from 26.6% to 90.6%, MgO agglomerates with similar size and an increasing surface area formed.

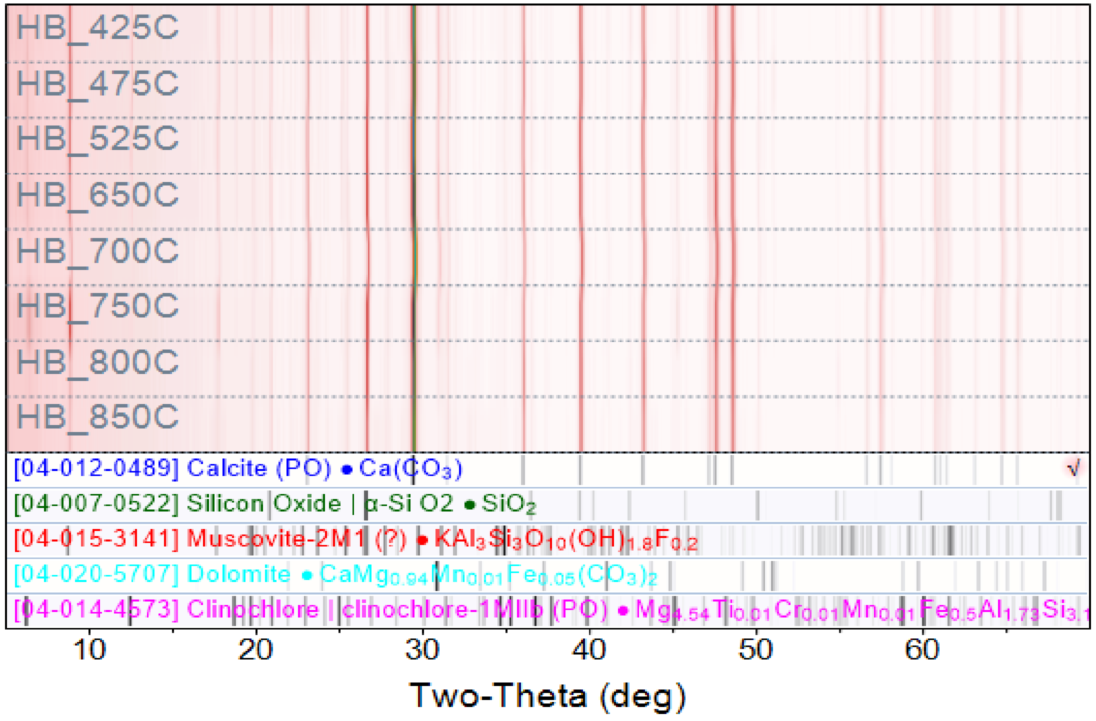
Actual kiln feed characterization



- The initial mineralogy (shown in Figure) of the kiln feed shows a significant calcite, CaCO3, (68.2 wt.%), content and secondary contents of muscovite, K-Al3Si3O10(OH)2, (9.5 wt.%) and dolomite, Ca,MgCO3, (3.4wt.%).

- The particle size distribution of the kiln-feed sample exhibits a median diameter (D50) of 26.9 μm, with its fines and coarse tails extending from 3.59 μm (D10) to 142 μm (D90)

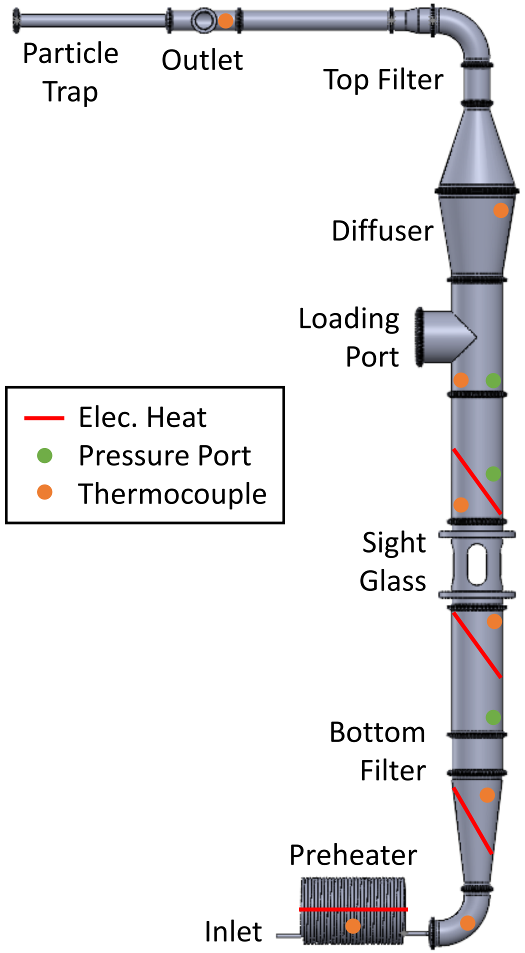
Kiln feed static calcination experiments



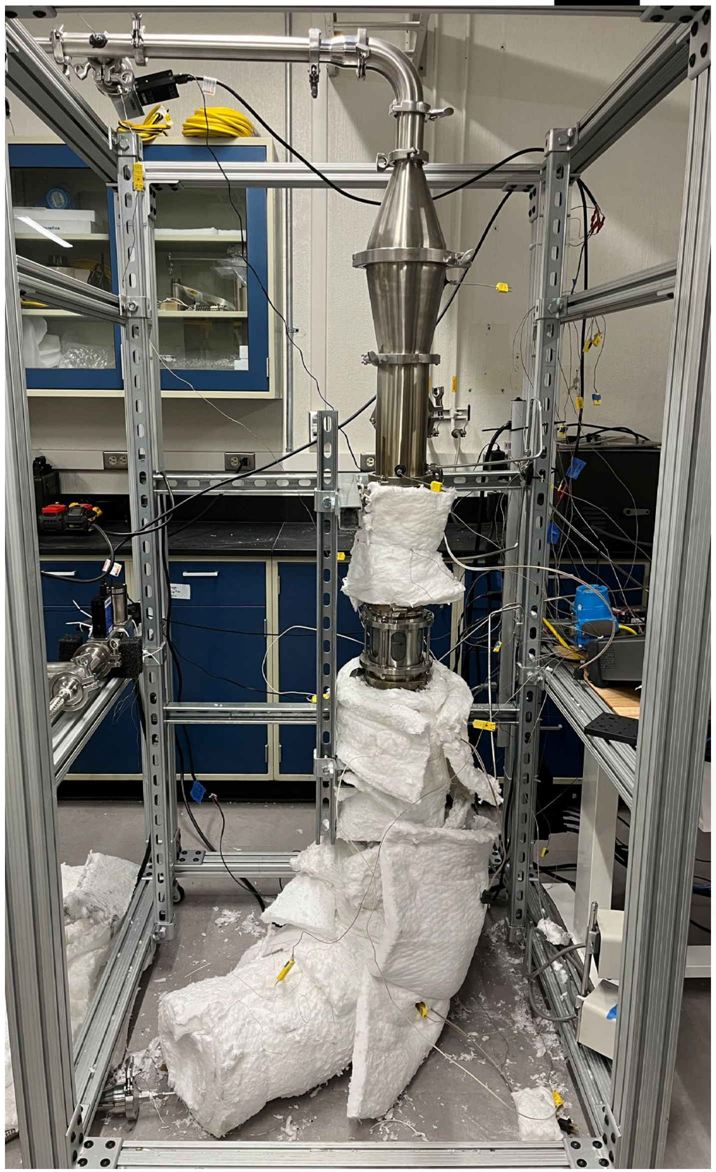
- From 425 °C to 525 °C, the kiln feed is effectively inert, with conversion stuck below 0.2 % and BET surface area steady near 2.7 $m^2\,g^{-1}$, so the preheater contributes little beyond moisture removal
- Meaningful calcination only begins above ~700 °C, and the balance between sintering and gas-driven porosity will ultimately dictate kiln energy efficiency and clinker reactivity.

State of System Design

- Two gas inlet (air and CO2) with oscillation capabilities
- 24” x 4” OD test section
- Designed for 800 °C at 10-20 SLM
- CO2 exit concentration monitoring up to 20 v%
- 17 thermocouple measurements
- Gauge and differential pressure measurements of test section



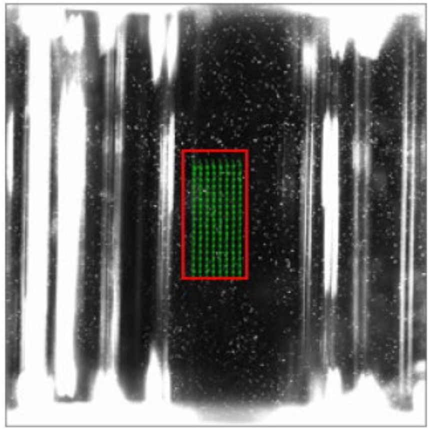
CAD Model of System



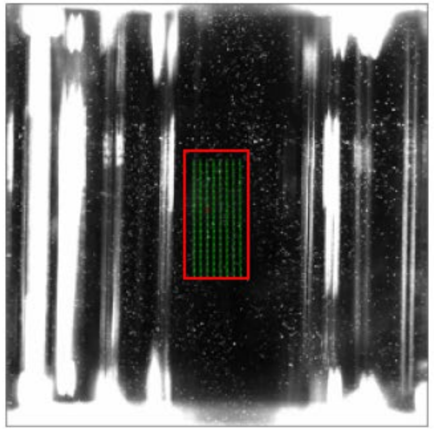
Partially Insulated Experimental Setup

Fluidization Testing

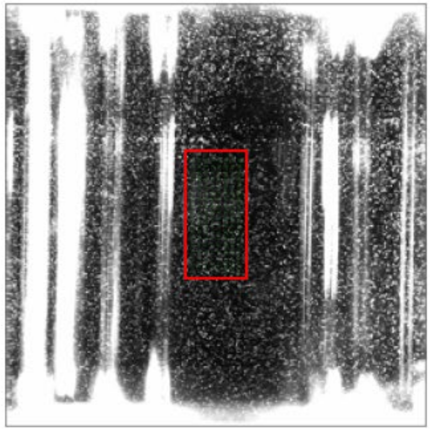
- First tests with silver coated hollow glass particles at room temp.
- Expected velocities
  - $U_{min.\,fluidization}$ = 1.35 mm/s
  - 7.2 mm/s < $U_{turb.\,fluidization}$ < 9.3 mm/s
- Photron NOVA high speed camera at 50 FPS, 12.3 px/mm
- Frame is 84 mm wide (83% of test section)
- ROI is centered on test section, 12.7 x 25.4 mm



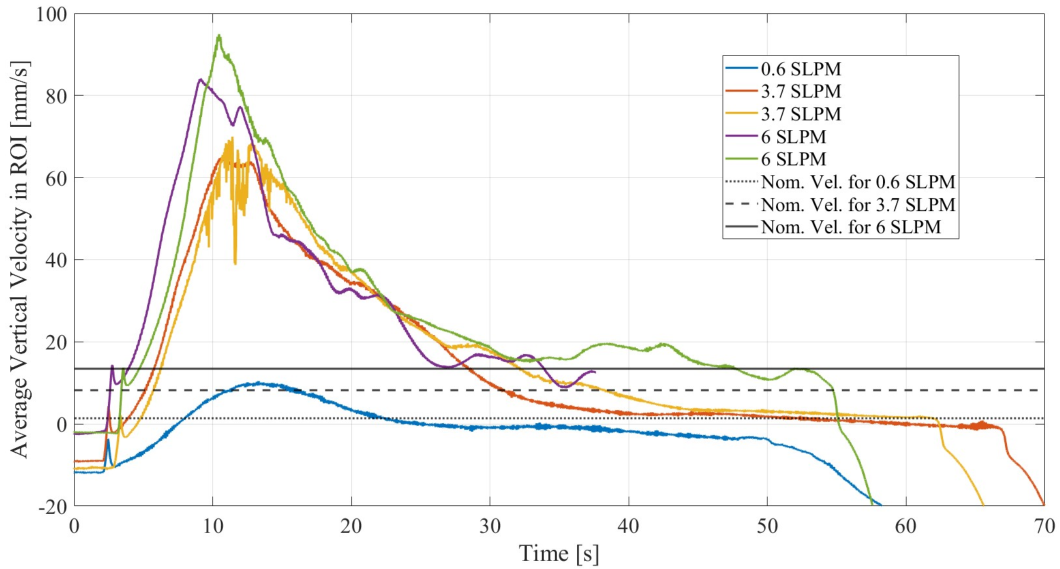
0.6 SLPM (1.34 mm/s avg.)



3.7 SLPM (8.28 mm/s avg.)



6.0 SLPM (13.4 mm/s avg.)



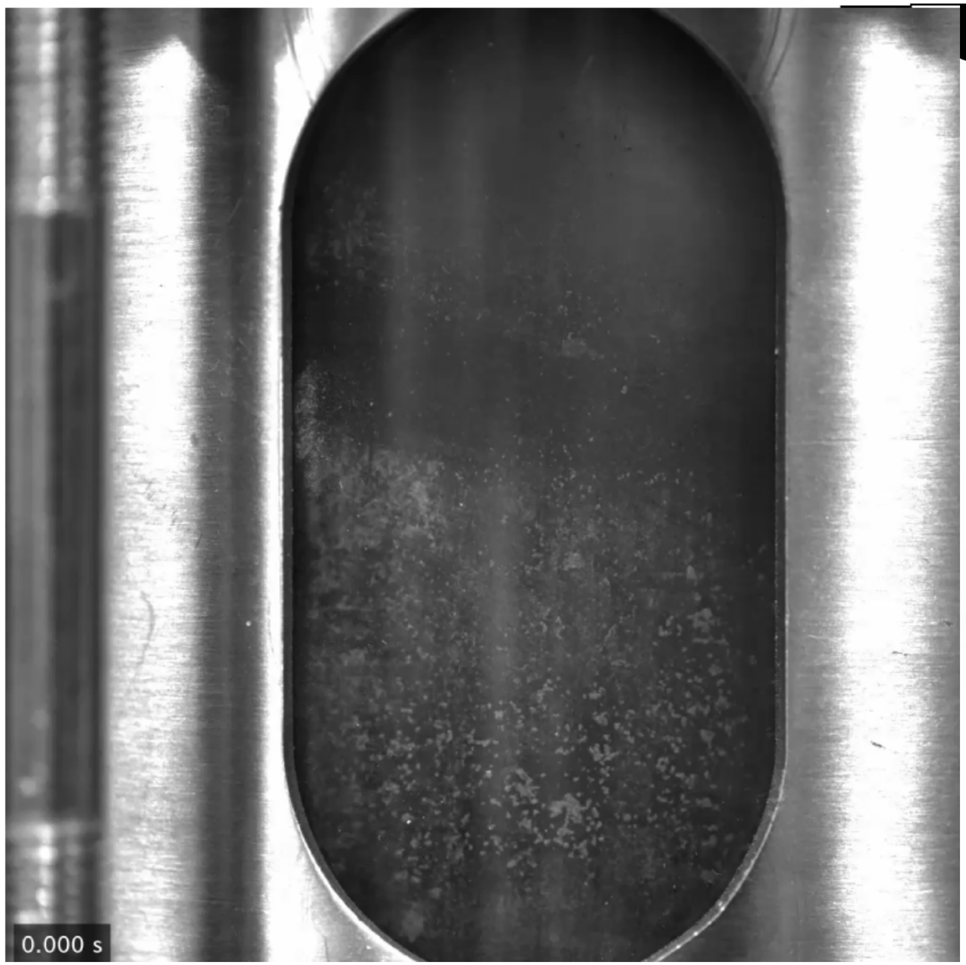
PIV Average Vertical Velocity in ROI

- Particle velocity agrees well with 6 SLPM case → beyond fluidization particles track with air
- Particle velocity below prediction for 3.7 SLPM case → fluidization
- Particle velocity is negligible for 0.6 SLPM case → very little fluidization

Results presented at NURETH-21 in Busan, South Korea

Fluidization Testing

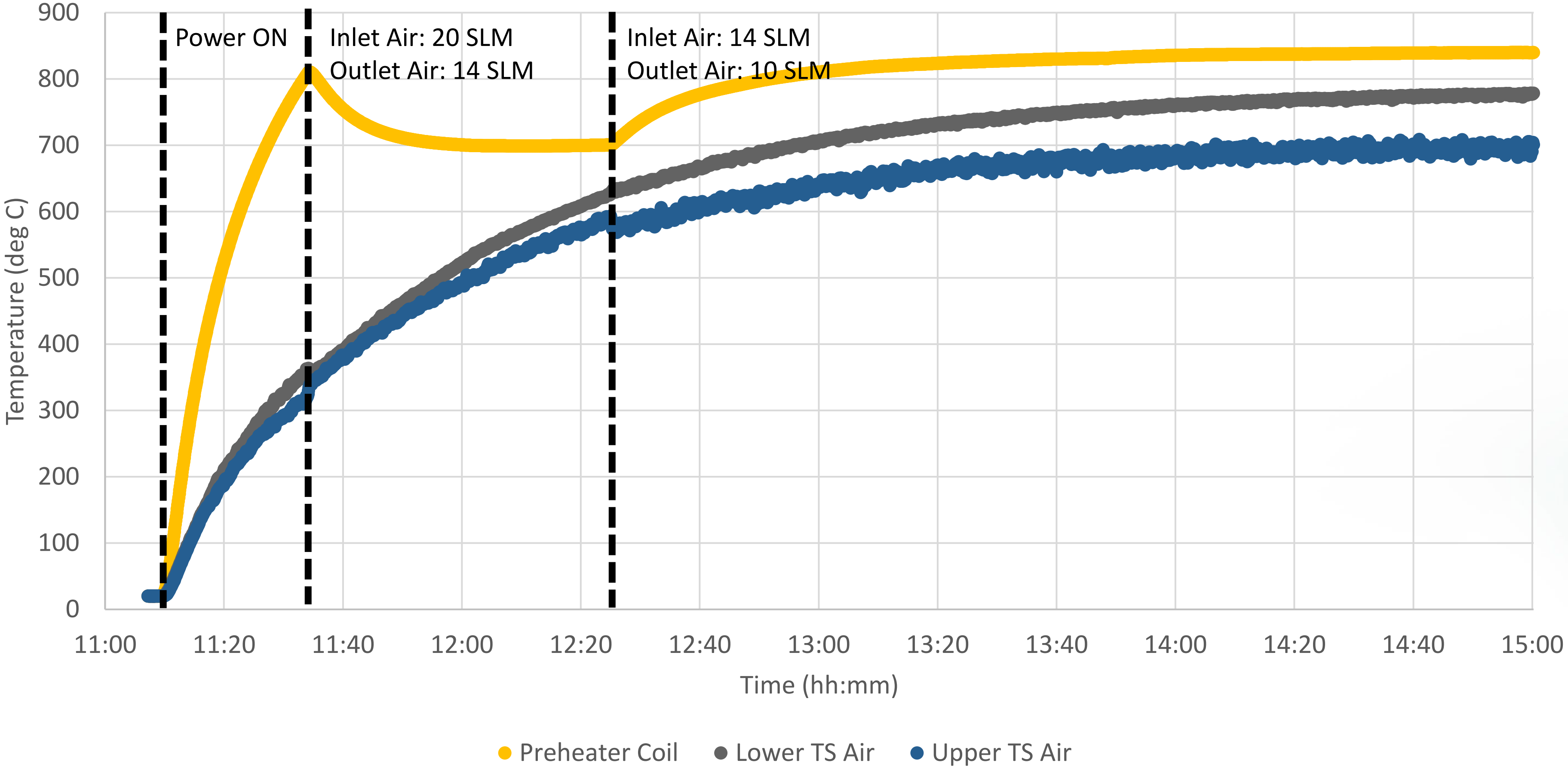
- Move to room temperature tests with real calciner feed particles from Heidelberg Materials plant in Nazareth, PA
- Fluidization is proving difficult due to particle size and tunneling effects
- Currently exploring optimizing flow oscillations to promote fluidization



25 SLM Gas Flow, 250 FPS at 0.2x speed

Moving to High Temperature

- System goal of 800 °C operation
- Sealing the sight glass at high temperatures is proving to be difficult



High Temperature Shakedown with No Particle Loading

Next steps

- Process simulation with varying proportions of primary, secondary, and tertiary air, as well as introduction of n0-combustion heat input to the kiln (nucleoelectric).
- Process optimization.
- Economical feasibility evaluation.
- Testing of experimental column at high temperature and calcination kinetics evaluation with different CO2 feed contents.

Acknowledgements

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