PREMA

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Development of a heat and mass transfer model for a shaft kiln to preheat manganese ore with hot air

SAMBO SN

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Master of Engineering

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PREMA - Energy efficient, primary production of manganese ferroalloys through the application of novel energy systems in the drying and pre-heating of furnace feed materials

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820561

Outline

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- Support study on Prema
- Preheating of Manganese ore

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Methodology

- Characterisation
- Modelling
- Experimental work

Research budget

Research time table

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820561

Background

The PREMA Project

- The Prema project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 820561
- Work Package 2, Research in Solar Thermal Technology (Mintek, DLR, Trabsalloys, Stellenbosch, and SINTEF)
- Task 2.6, Shaft Kiln Design in progress (Mintek).
- This work will introduce concentrating solar thermal into minerals processing.
- The work presented is in support of the shaft kiln design for preheating of manganese ore to 600 ˚C before smelting in a submerged arc furnace

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Background

Preheating of manganese

- 90 percent of manganese (Mn) produced worldwide is used by the steel manufacturing industry, consuming about 7.5 kg Mn per ton of steel produced (Steenkamp and Basson, 2013).
- Prior to treatment in silico-manganese and ferromanganese smelters, Mn ore is pelletized and pre-heated.
- Pre-treatment aims to size, strengthen and give mineralogical upgrade to the furnace charge material.
- Preheating with hot air from CSP system will eliminate the use of electricity and burning of fossil fuel and reducing furnace power required for smelting

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Introduction

Problem Statement

- Furnace feed rate (141 kg/h) and temperature (600 ˚C) must be maintained
- The process is continuous, It is not practical to directly measure the ore particles mean surface temperature across the shaft kiln
- Only the air temperature profile can be obtained with certainty
- The effective control action of the air flow rates can be achieved by measuring the gas temperature at the inlet and exit points of the kiln.
- A model that simulates the heat and mass transfer in the shaft kiln need to be developed to control the kiln to meet furnace feed requirements

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Introduction

Problem Statement

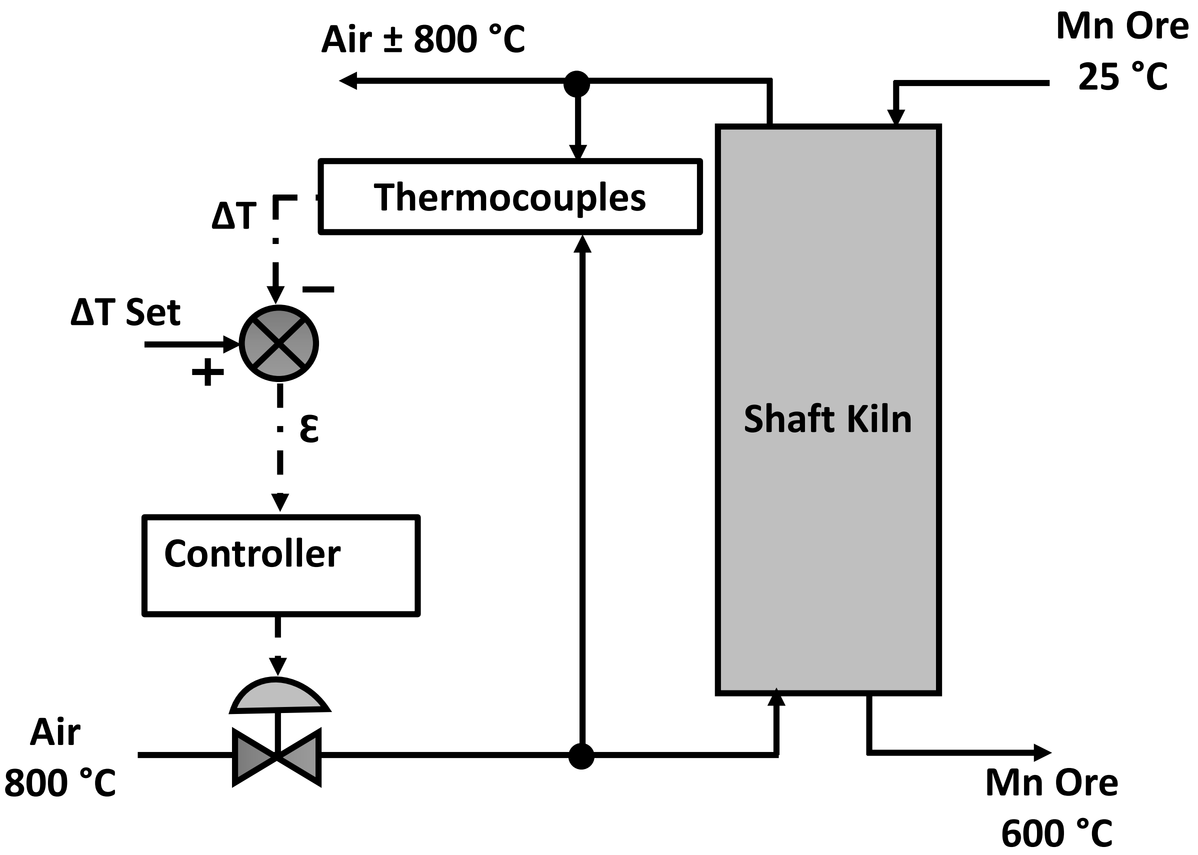

Figure 1: Shaft kiln proposed feedback control loop

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Introduction

Objective

- Develop a heat and mass transfer model that simulate the bed mechanical properties, fluid dynamics, axial and radial temperature profiles, and validate the model with experimental work and published heat and mass transfer correlations, and write a control program in python.

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Introduction

Specific Objectives

a. Obtain Manganese ore (UMK) minerals composition, Thermo-physical properties up to 600 °C, packed bed properties (porosity, packing geometry) and the minerals reaction kinetics up to 600 °C.

b. Develop a fluid-solid oriented heat and mass transfer plug flow model.

c. Validate the model with experiments and theory

d. Write a control program (python)

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Method

Manganese ore characterization

Table1: Manganese (UMK) ore chemical analysis

Analysis	Species	Method
Bulk Mineralogy	hematite (Fe_2O_3), Hausmanite (Mn_3O_4), etc.	MLA and QEMSCAN
Metallic elements	Manganese, iron, Magnesium, etc.	ICP-OES, XRD
LOI	Organics and Hydroxides,	Thermo gravimetric

- Analysis work done by SINTEF (Norway) in Task 3.1 (Characterization of Mn-sources) of work package 3 to be compared with Mintek analysis

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Method

Manganese ore characterization

Table 2. Manganese (UMK) ore Thermo physical properties

Analysis	Method
Thermal diffusivity (α) Specific heat capacity (C_p)	LFA 457 Microflash, Tested at 100 ˚C increments
Thermal conductivity (K)	Calculated using the values of α, C_p and density
Thermal expansion (%)	Push rod dilatometer

- All analysis work done by SINTEF (Norway) in Task 3.1 (Characterization of Mn-sources) of work package 3.

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Method

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Packed bed air flow modelling

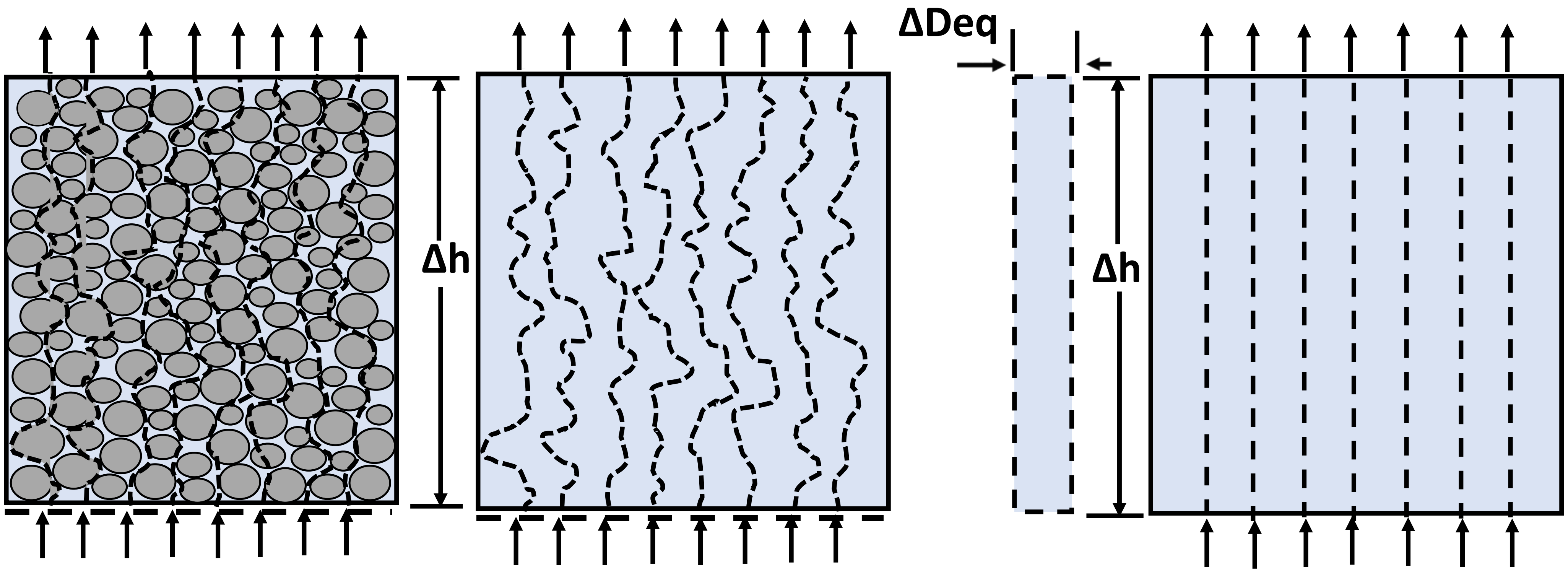

Figure 2. a) Actual packed bed b) packed bed model

- The surface area per volume is equal for both cases
- The flow regime can be used to equate flow rate and pressure drop

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Method

Packed bed air flow correlations

- Laminar flow (Re < 2300) – Kozney Carmen equation
- Transitional flow (2300 < Re < 4000) – Ergums equation
- Turbulent flow (Re > 4000) – Burke Plummer equation

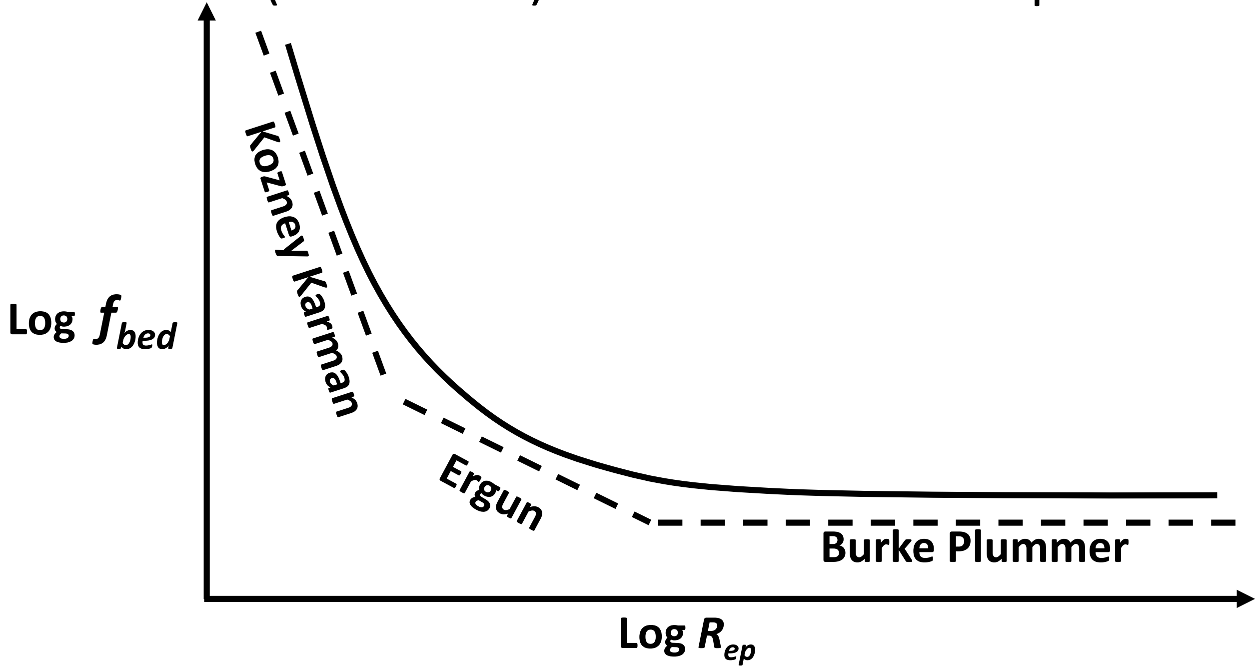

Figure 3. Packed beds flow correlations

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Method

Heat and mass transfer

- Forced convection, radiation, (Air temperature above 400 ˚C, Rickelt (2011)), and conduction

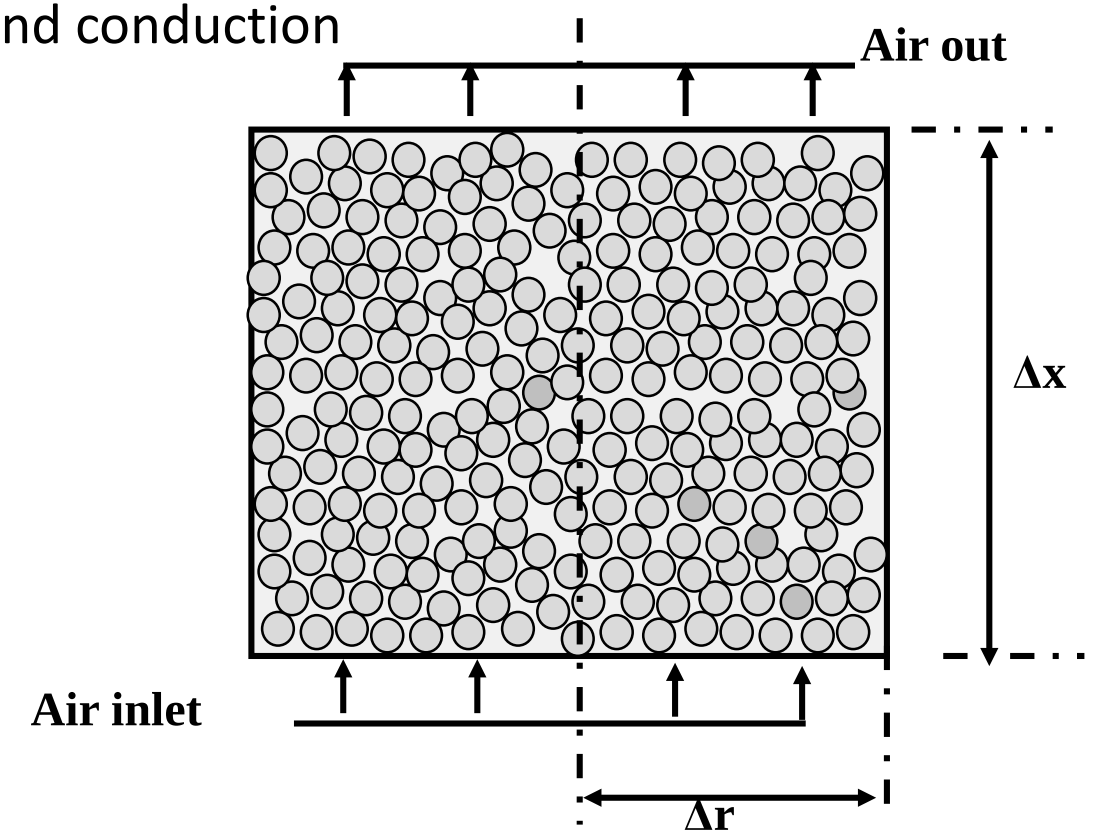

Figure 4. Axial and radial temperature evaluation

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Method

Heat and mass transfer

- The change in minerals composition under oxidizing conditions to be studied with Factsage7.2 Equilibrium model
- HSC Sim will give the reaction rates for the decomposition of carbonates and phase change reactions

$$MgCO_3\,(s) \rightarrow MgO\,(s) + CO_2\,(g)$$

$$H_2O\,(l) \rightarrow H_2O\,(g)$$

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Method

Experimental work

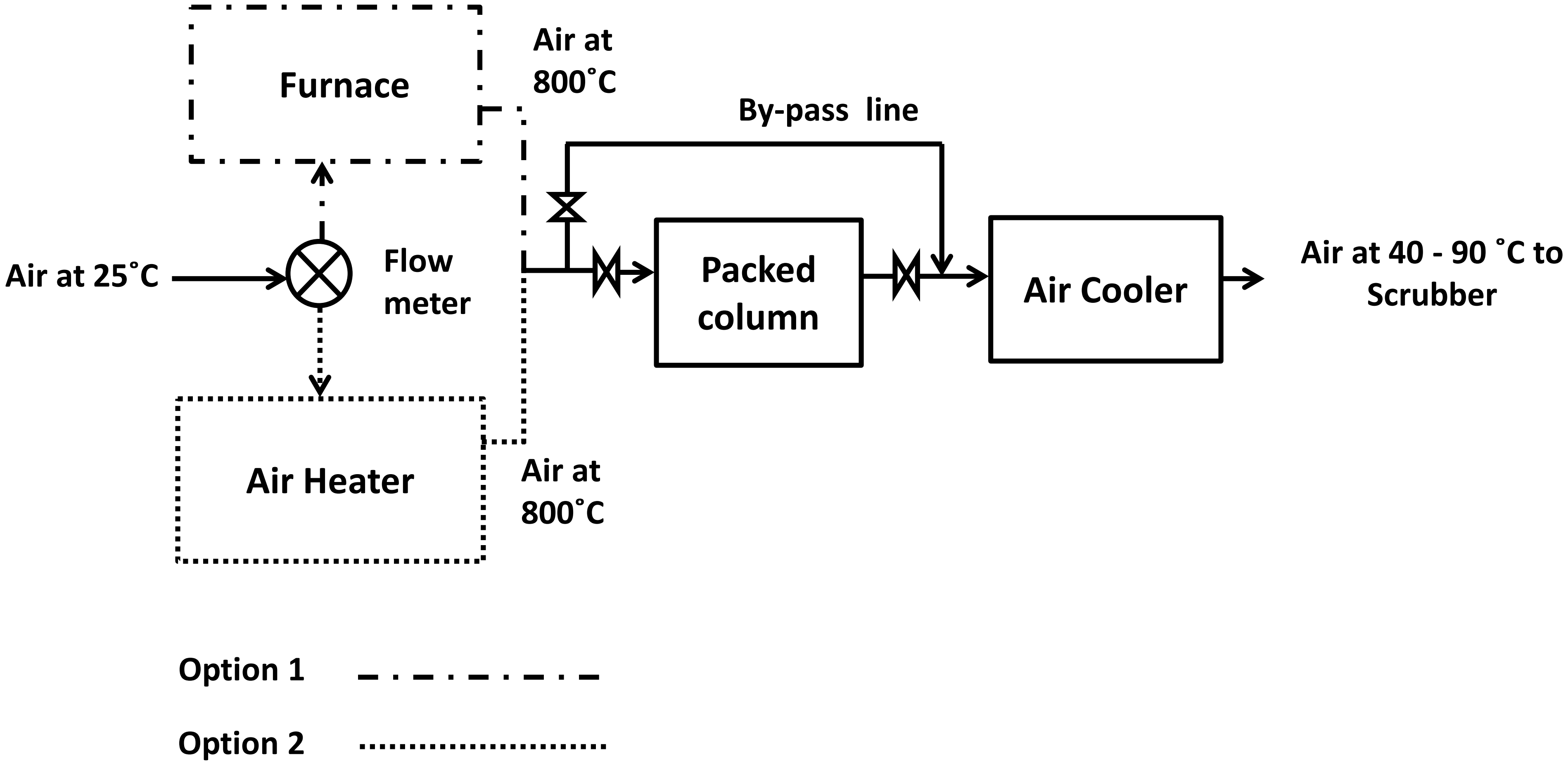

Figure 5. Block diagram with two air heating options

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Method

Experimental work

- 200 mm D, 1200 mm column height
- 6-20 mm particle diameter
- 11 thermocouples
- Non dimensional analysis used for scaling up

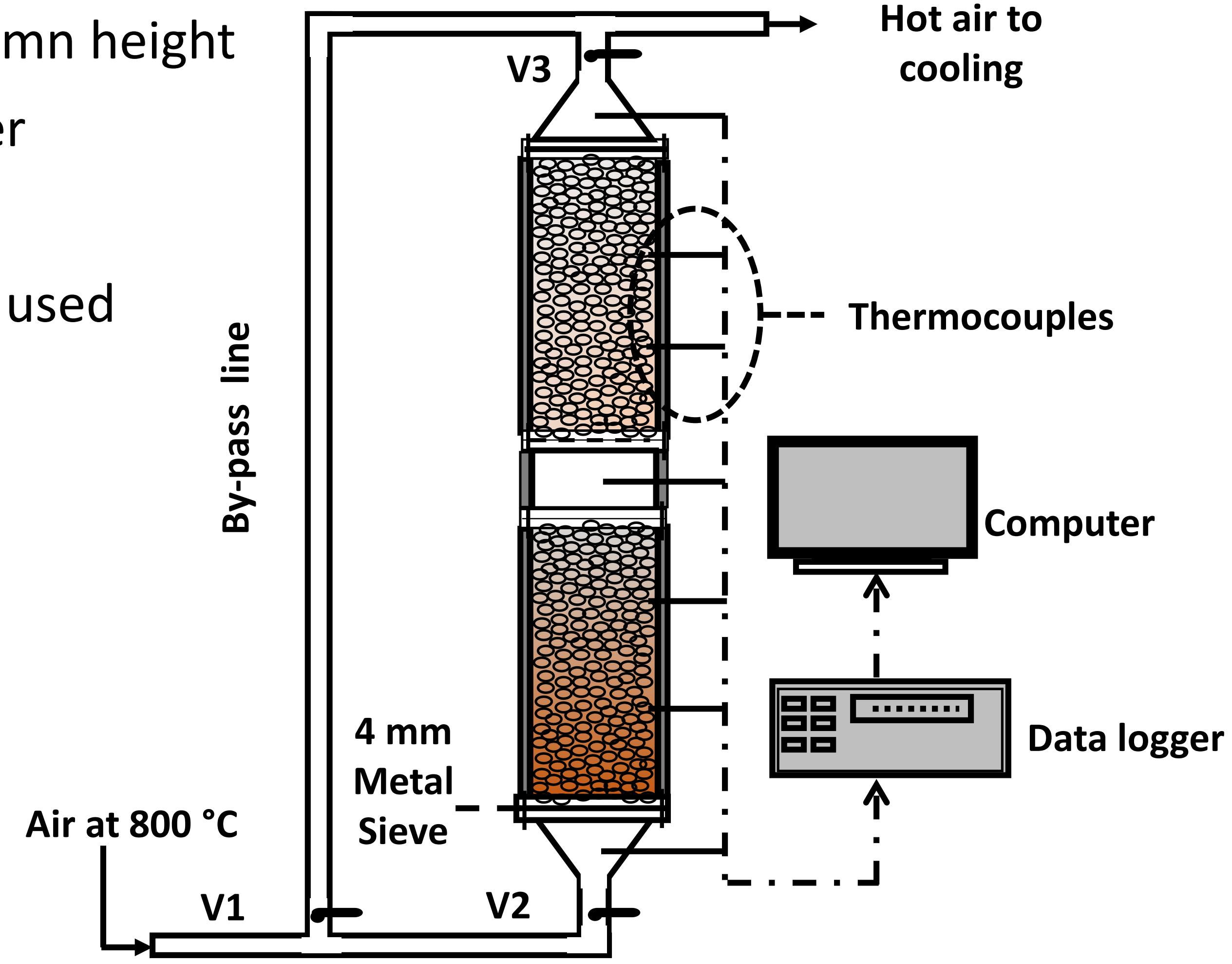

Figure 6. Test rig

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Thank you

Questions and inputs?

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