Presentation to SolarPACES 2017

Solar Thermal Treatment of Manganese Ores

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Manganese ore processing – current landscape

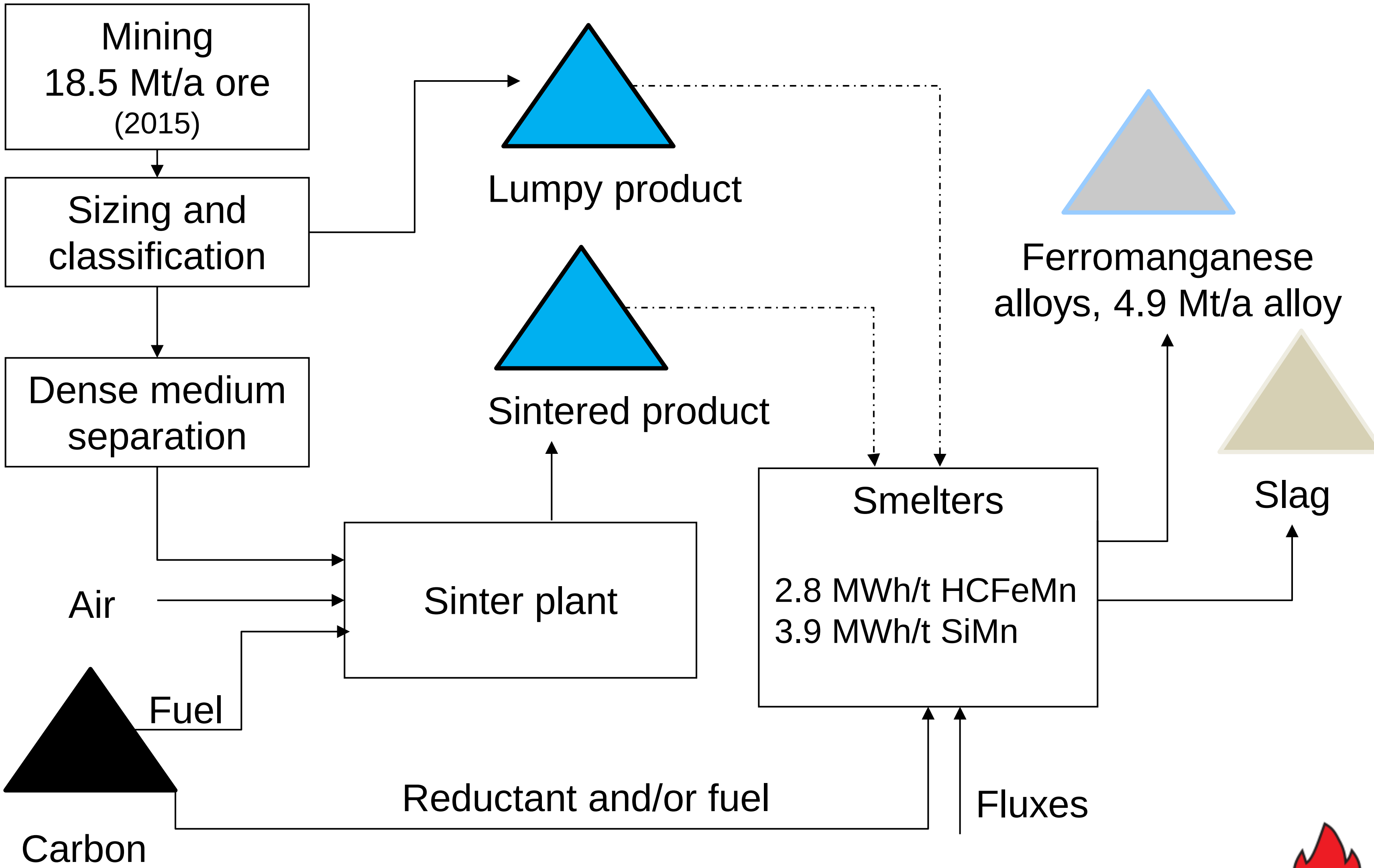

Figure 1. Manganese ore processing

Manganese ore processing – future landscape?

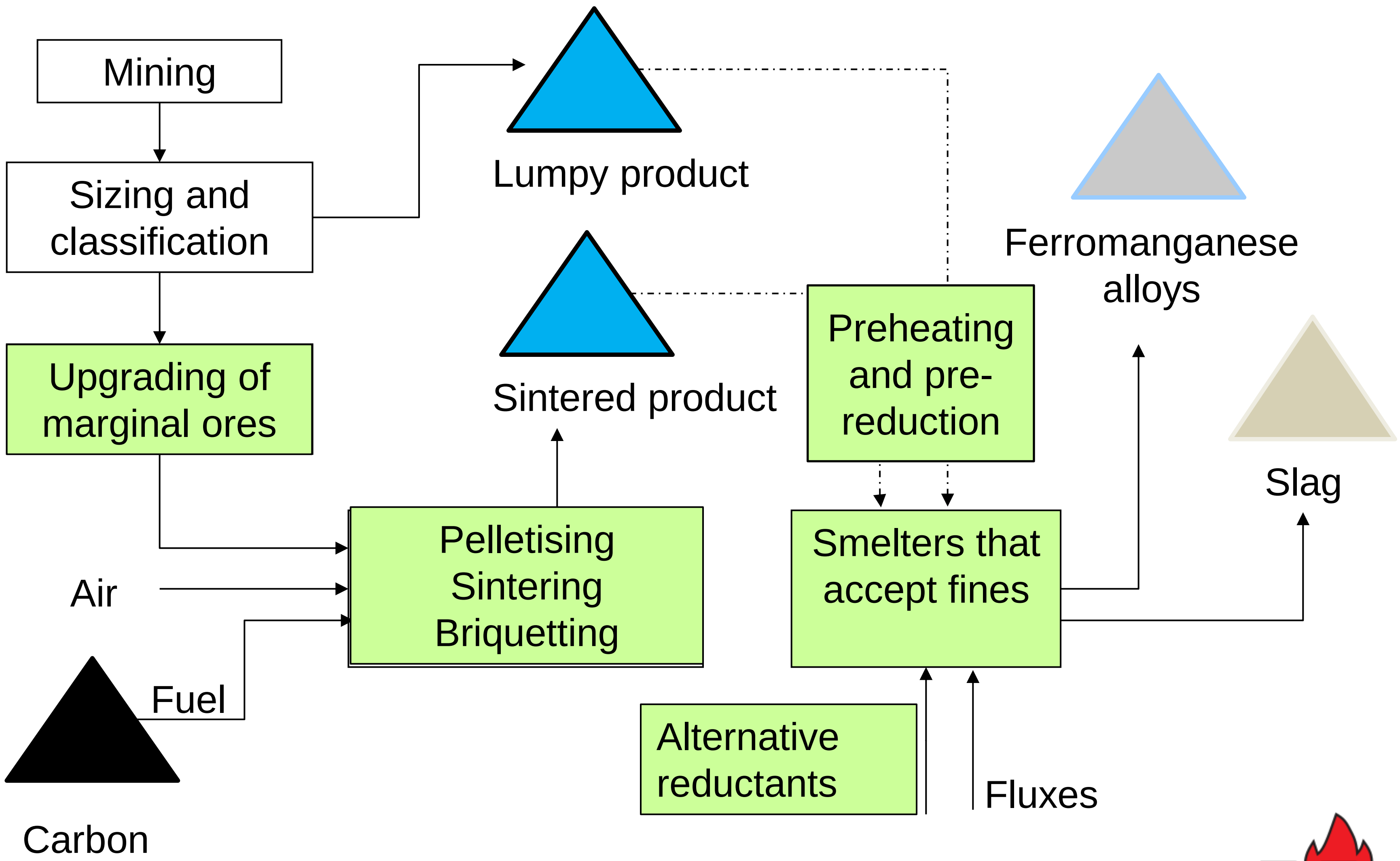

Figure 2. Manganese ore processing tomorrow

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Experiments

Figure 3. STERG solar concentrator

Figure 4. Untreated ore , -6 mm

Figure 5. Pellets, -13 mm + 6 mm

Experimental Set-up – Sample container

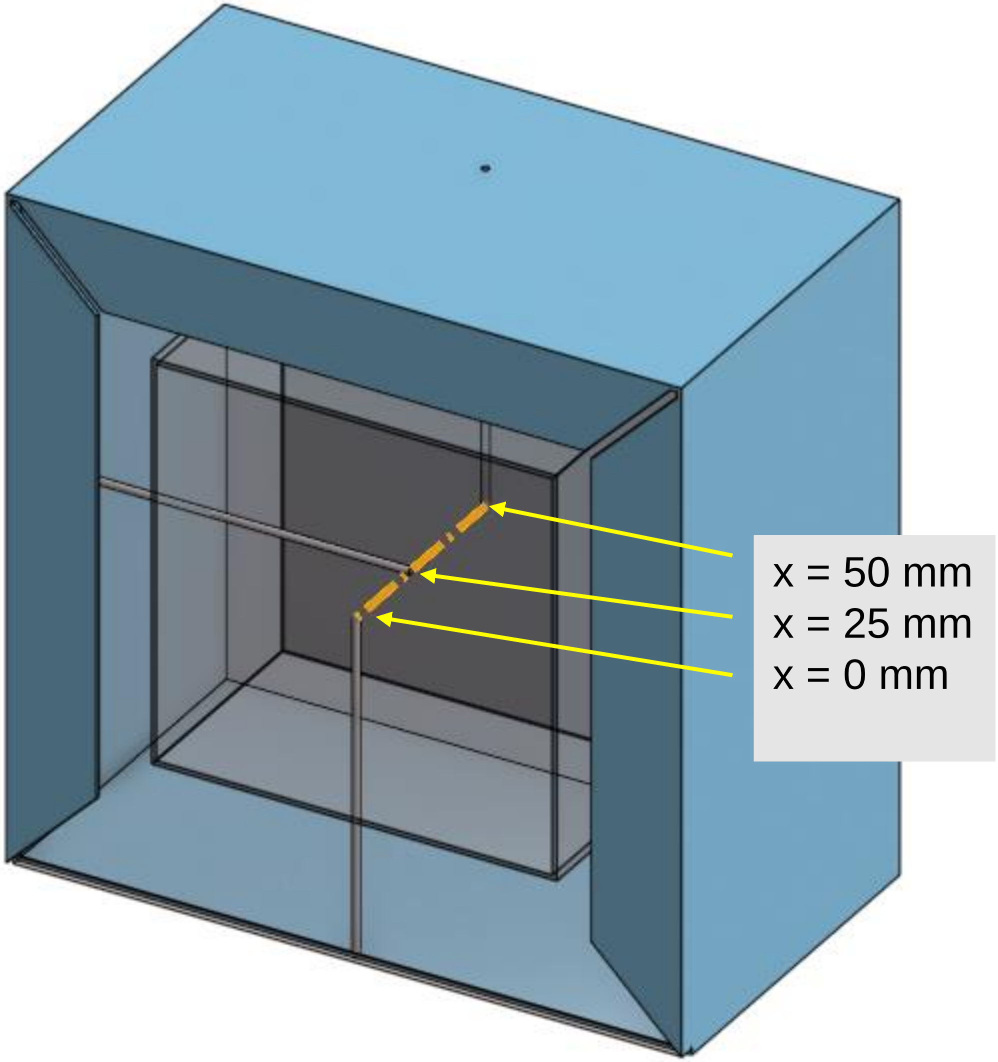


Figure 6. Positions of central thermocouples

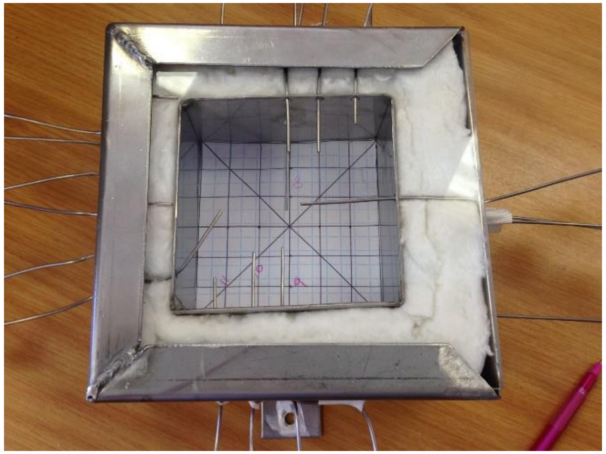


Figure 7. Empty sample container

Figure 8. Full sample container

Results - Thermal

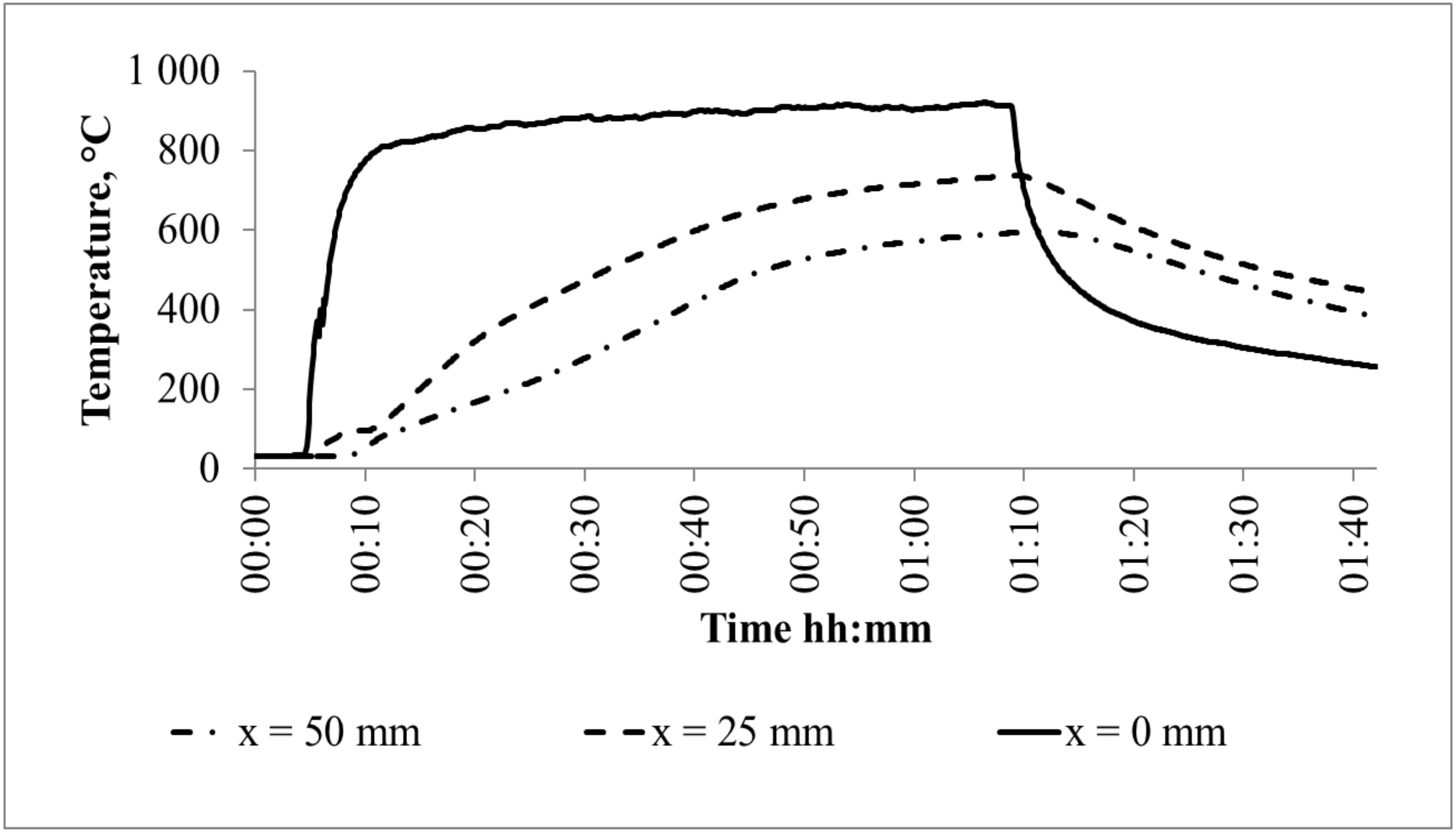


Figure 9. Temperatures recorded, Pellets B +

Assumptions – Heat Transfer Modelling

The assumptions made for the present model include:

- Approximation of the bed as a continuum slab of material with constant and uniform thermal conductivity, effective density, and heat capacity.
- Approximation of the heat transfer mechanism in the bed as one-dimensional (perpendicular to hot face) and transient.
- A single "concentration factor" , η, expressing the concentration ratio between the measured instantaneous direct normal insolation (DNI) and the energy flux experienced at the bed hot face.
- A boundary condition at the hot face expressed in terms of a convective heat transfer coefficient and a surface emissivity, both pre-specified constants.

TABLE 1. Fixed parameters used for all model fitting runs

Parameter	Value	Parameter	Value
δ	0.05 m	ρC_P	1 x 10^6 J/m^3K
h	7.5 W/m^2K	x resolution	100
ε	0.5	t resolution	100
T_A	298 K	T_0	(from test data)

Results of Heat Transfer Model

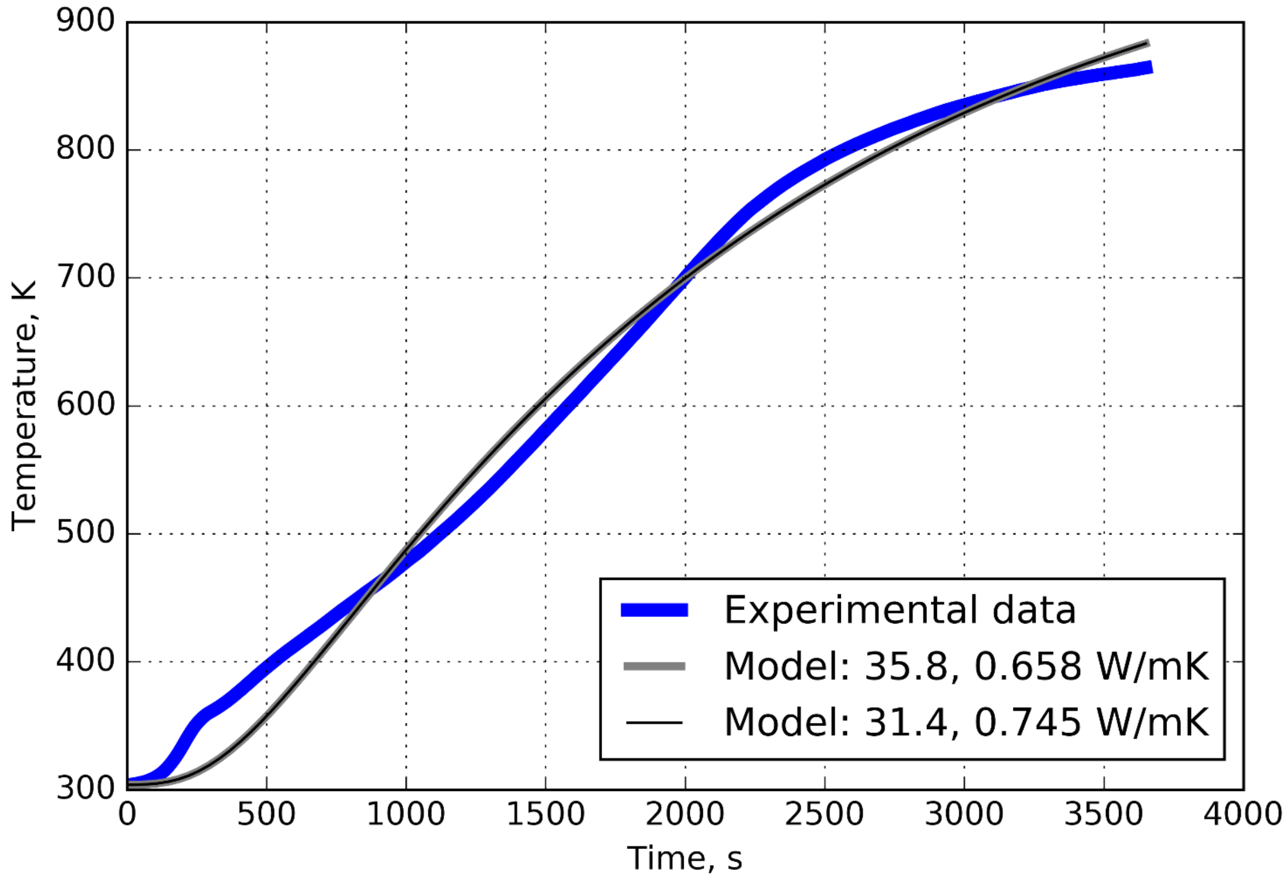


Figure 10. Experimental temperatures and model predicted temperatures

Effective Thermal Conductivity

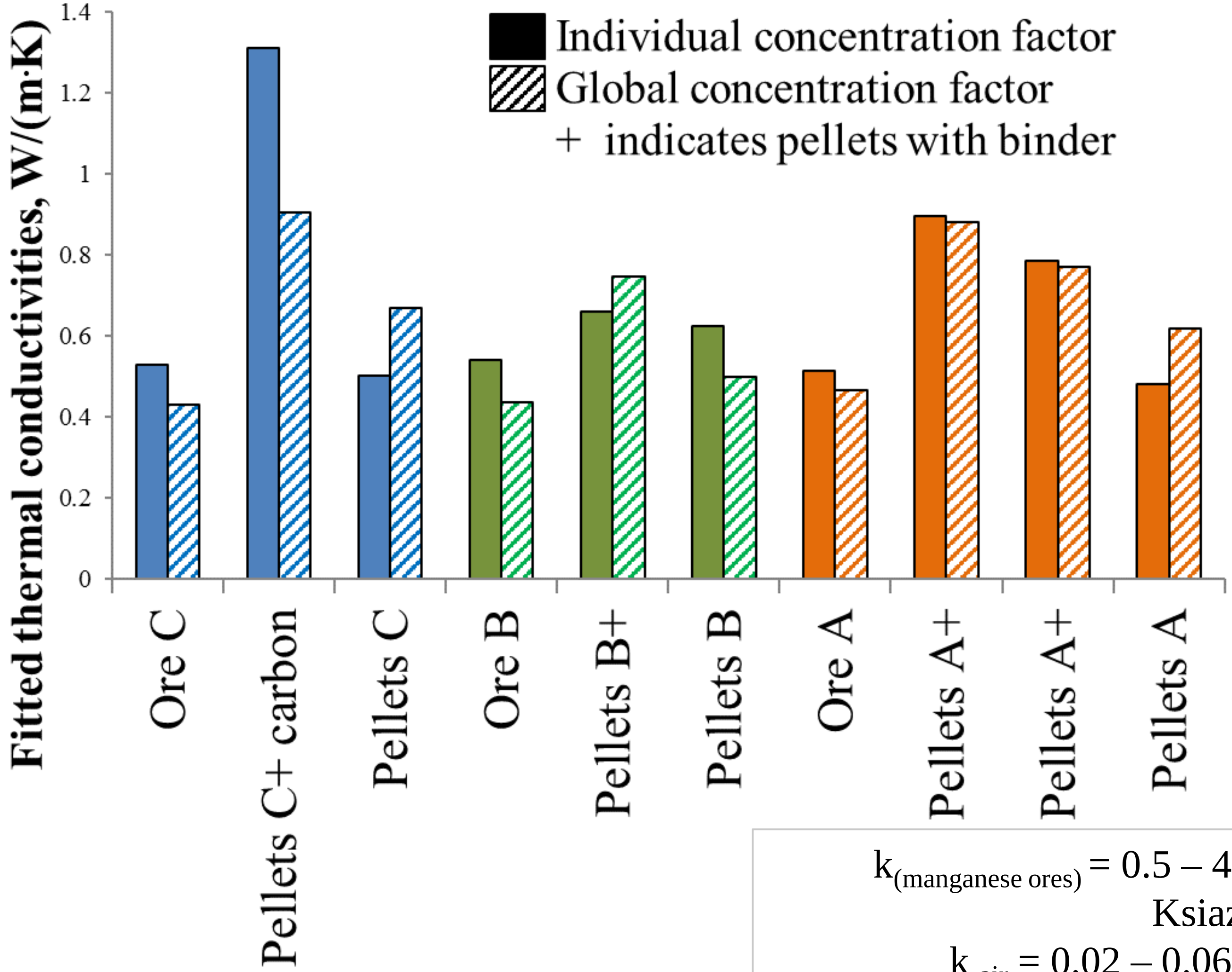
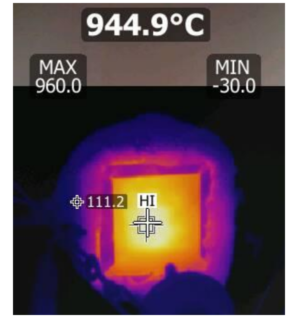


Figure 11. Effective thermal conductivities

$k_{(manganese\ ores)} = 0.5 – 4$ W/(m·K)
Ksiazek, 2012
$k_{air} = 0.02 – 0.06$ W/(m·K)
$k_{graphite} = 25 – 470$ W/(m·K)

Effective concentration ratio



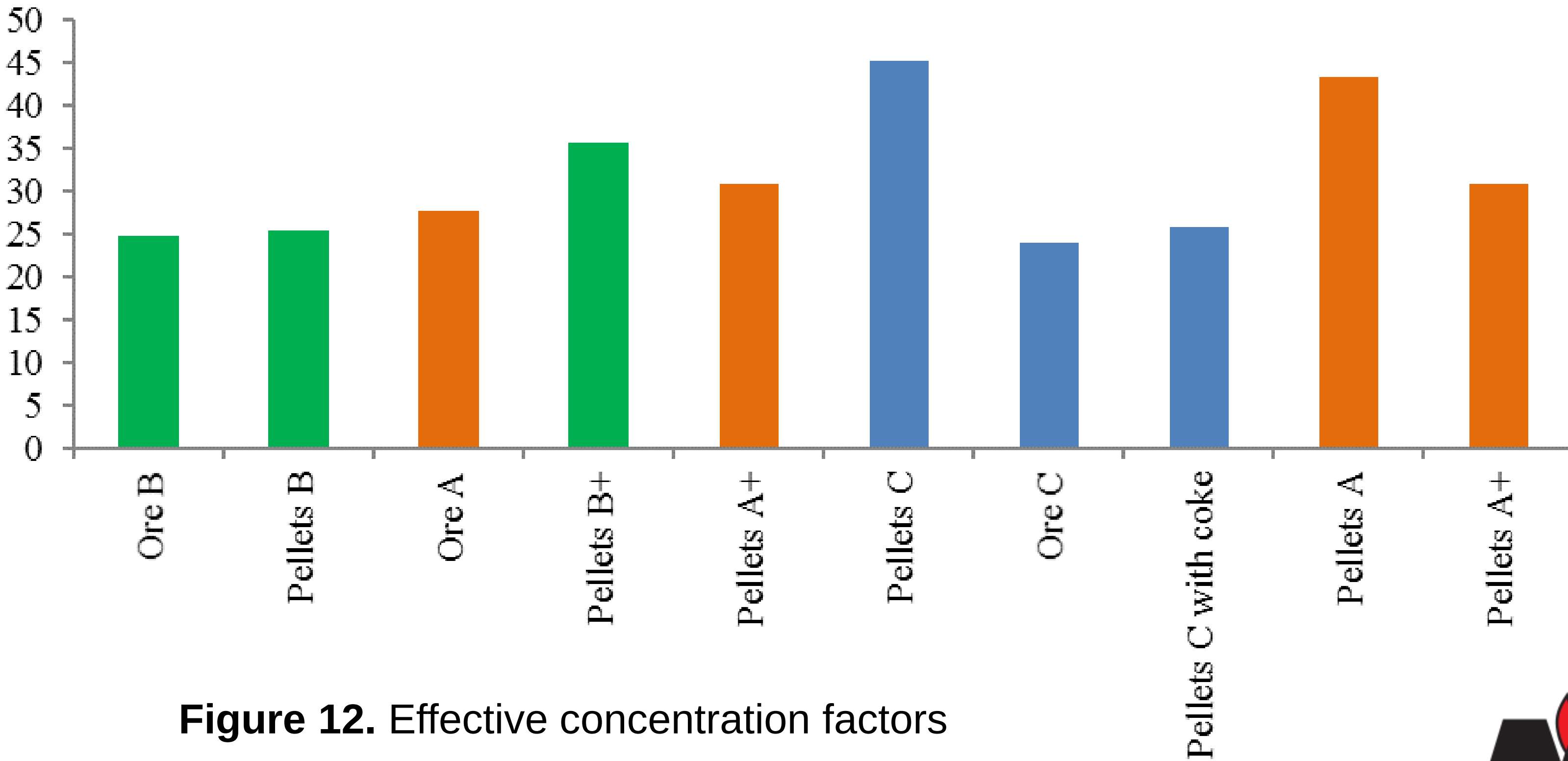


Figure 12. Effective concentration factors

Thermodynamic Modelling

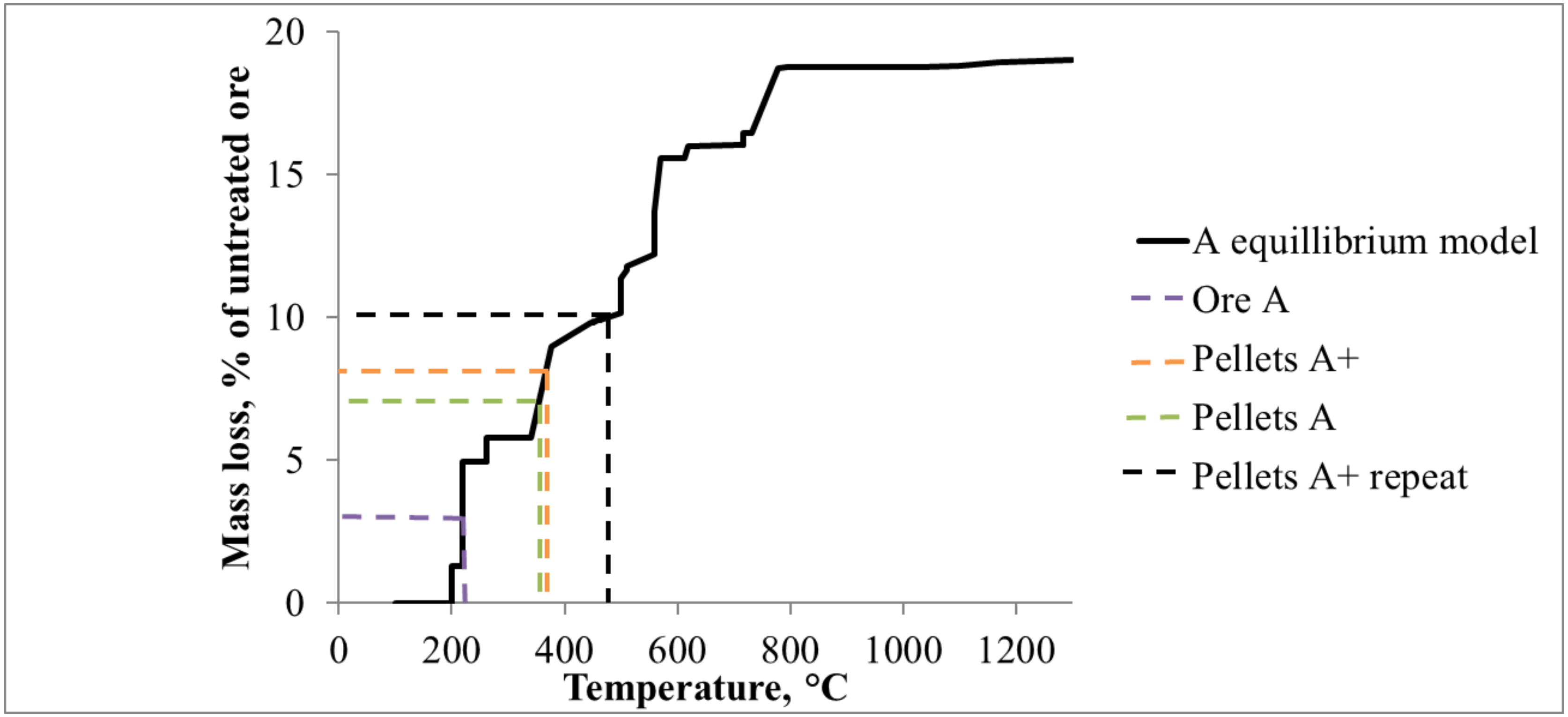


Figure 13. Thermodynamic equilibrium model - A

Thermodynamic Modelling

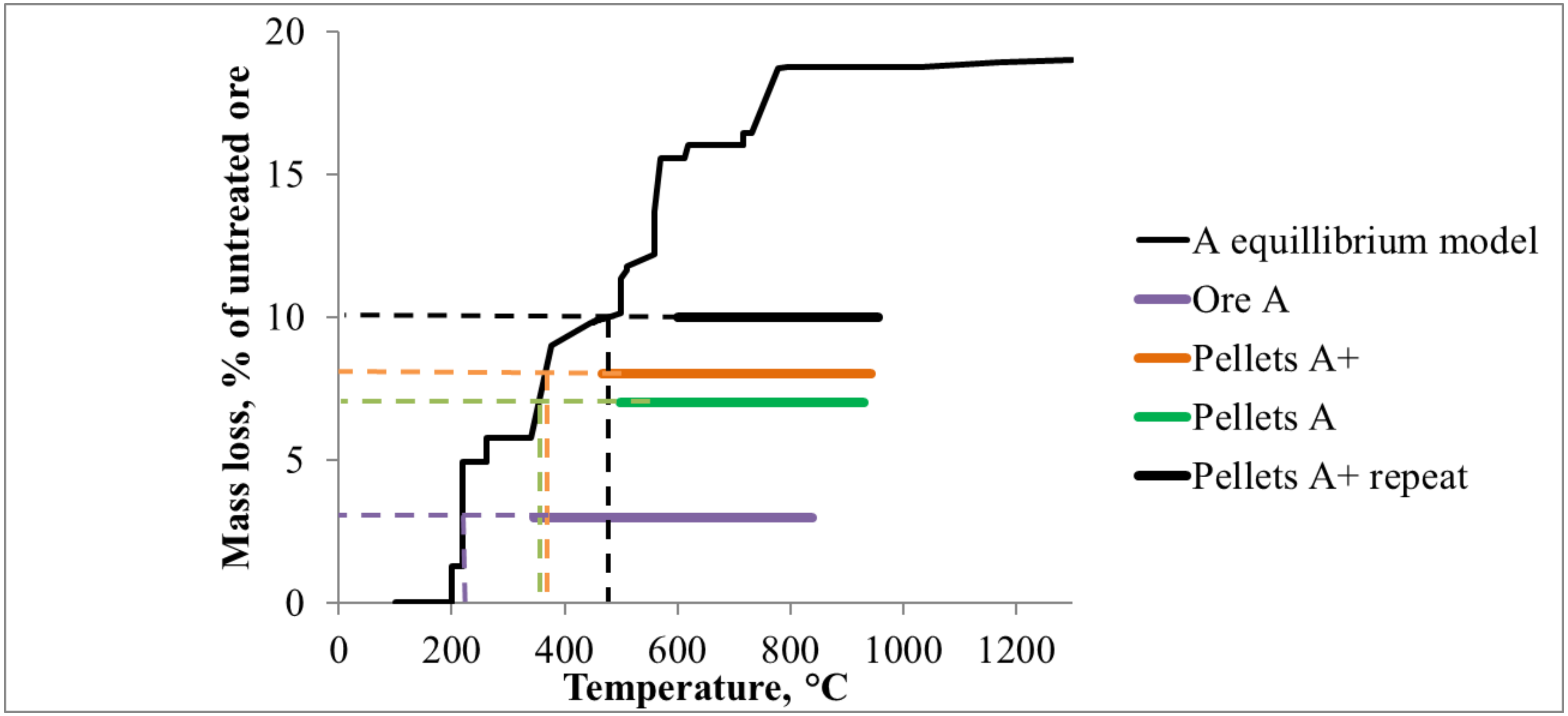


Figure 13. Thermodynamic equilibrium model - A

Thermodynamic Modelling

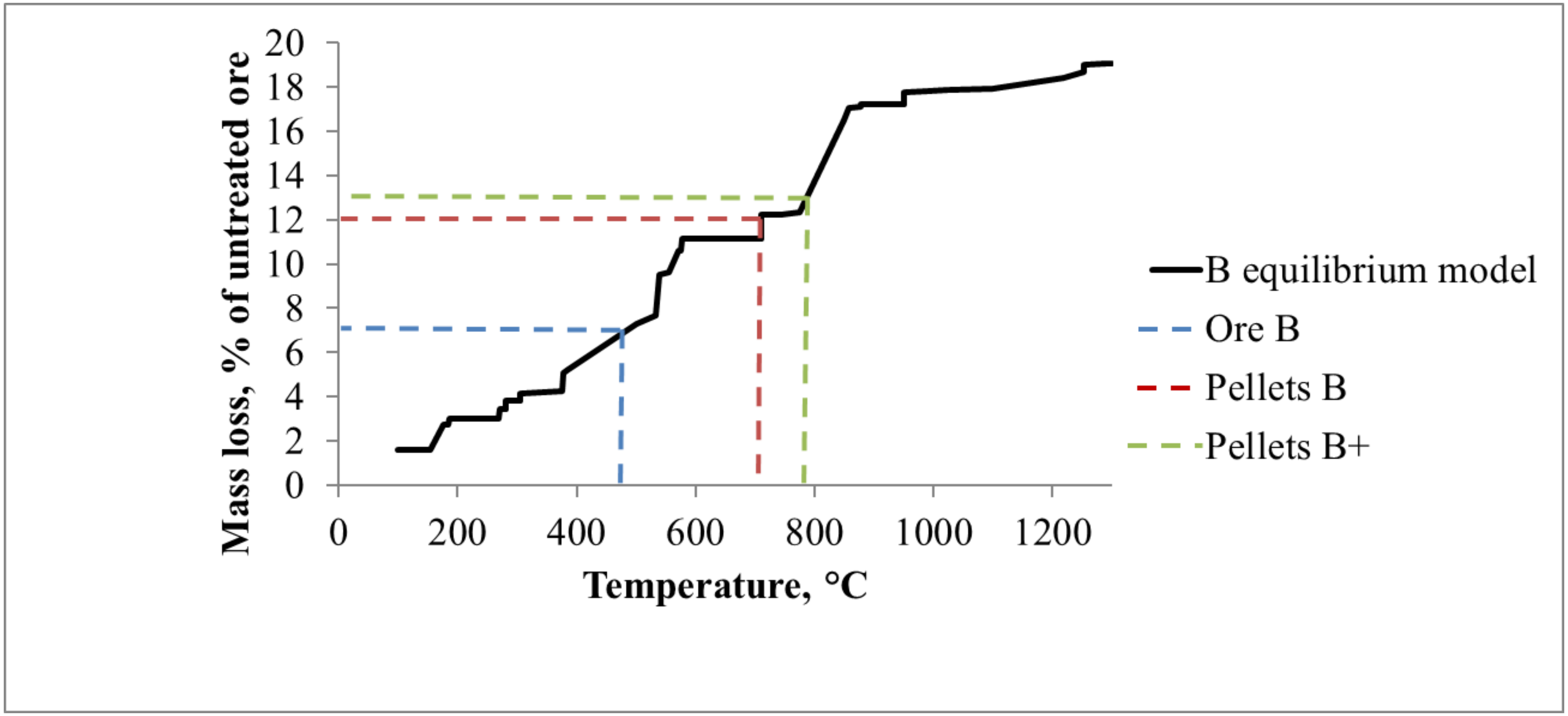


Figure 14. Thermodynamic equilibrium model - B

Thermodynamic Modelling

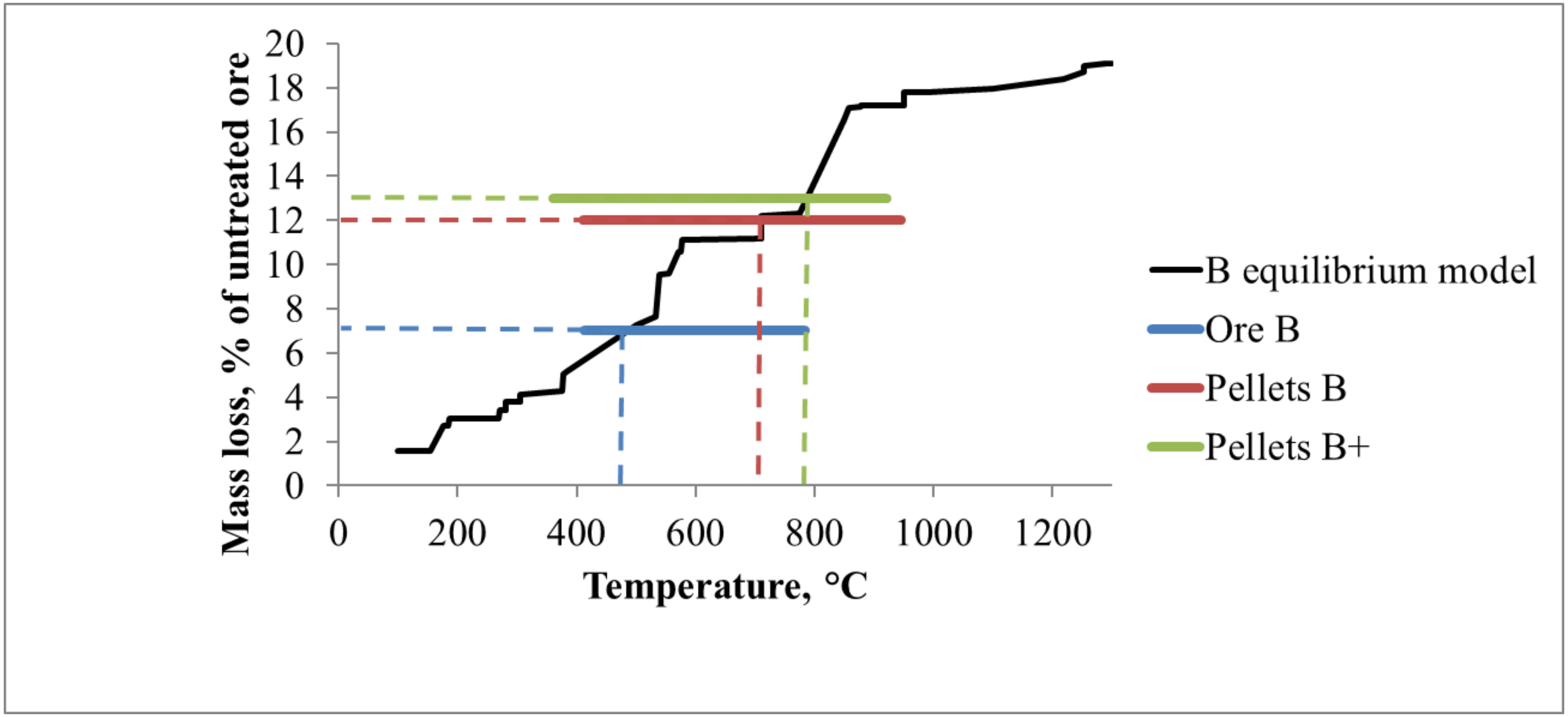


Figure 14. Thermodynamic equilibrium model - B

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Thermodynamic Modelling

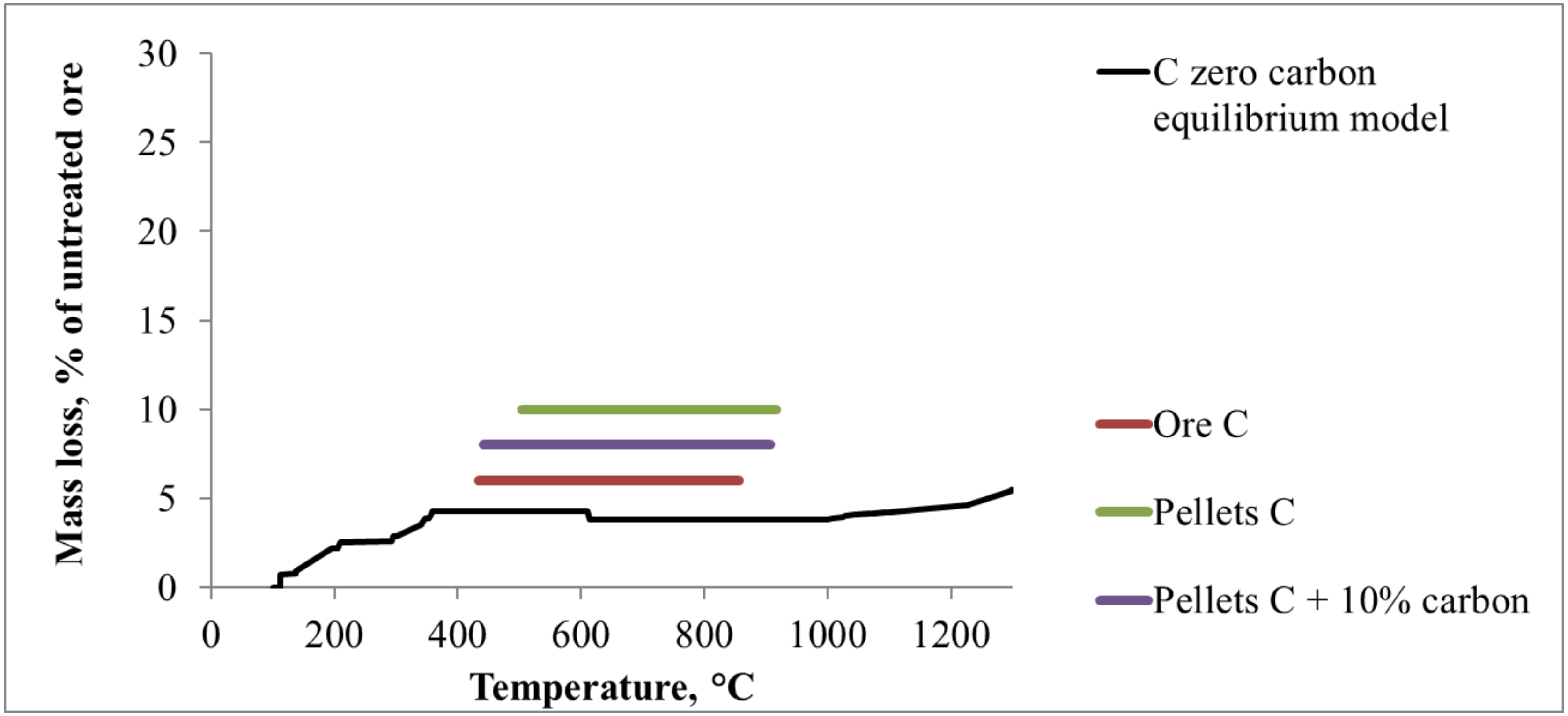

Figure 15. Thermodynamic equilibrium model - C

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Thermodynamic Modelling

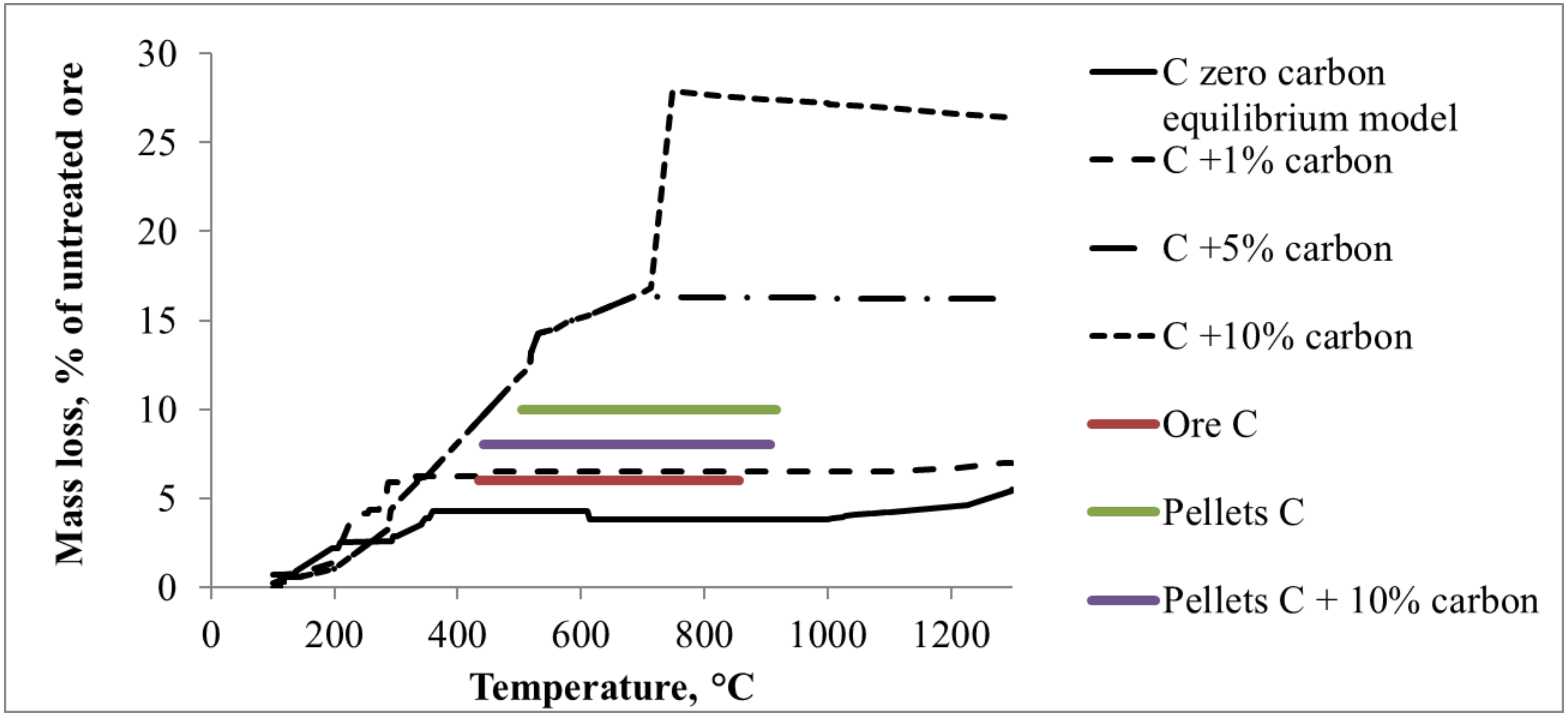

Figure 15. Thermodynamic equilibrium model - C

Future studies

- Modify set-up to investigate forced convection
- Take measures to improve concentrator efficiency
- Expand heat transfer model to include chemical reactions and variable convection
- Review implications of results on economic model

Figure 16. How to avoid sunburn

Conclusions

- Heating and thermal decomposition of manganese ores has been demonstrated
- Effective thermal conductivities has been determined for test materials in air
- The effective concentration ratio has been determined for the concentrator
- Empirical results when compared to thermodynamic equilibrium models indicate that kinetics factors are limiting decomposition
- Organic content in ore C facilitated higher mass loss by acting as a reductant

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Acknowledgements

- MINTEK
- STERG
- Southern African Universities Radiometric Network, SAURAN
- Transalloys

Figure 17. SAURAN station on adjacent rooftop

M.J. Brooks, S. du Clou, J.L. van Niekerk, P. Gauche, C. Leonard, M.J. Mouzouris, A.J. Meyer, N. van der Westhuizen, E.E. van Dyk, and F. Vorster. Sauran: A new resource for solar radiometric data in southern africa. *Journal of Energy in Southern Africa*, 26:2–10, 2015.

Thank You

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