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1944 - 2014 70 YEARS OF INNOVATION

Novel Techniques for Controlling Heat Transfer in a Continuous Casting Mould

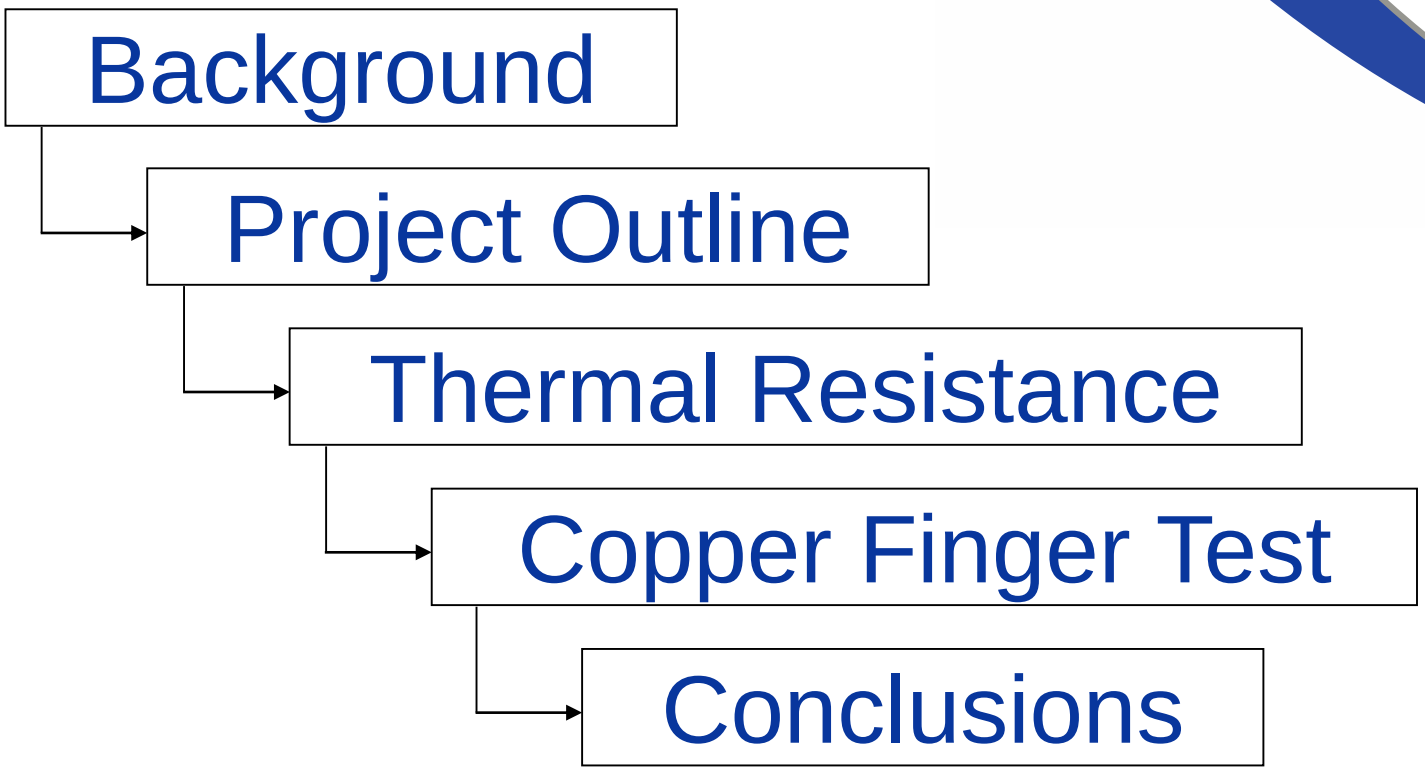
Presenter: Dr Adam Hunt

Director of Studies: Dr Bridget Stewart

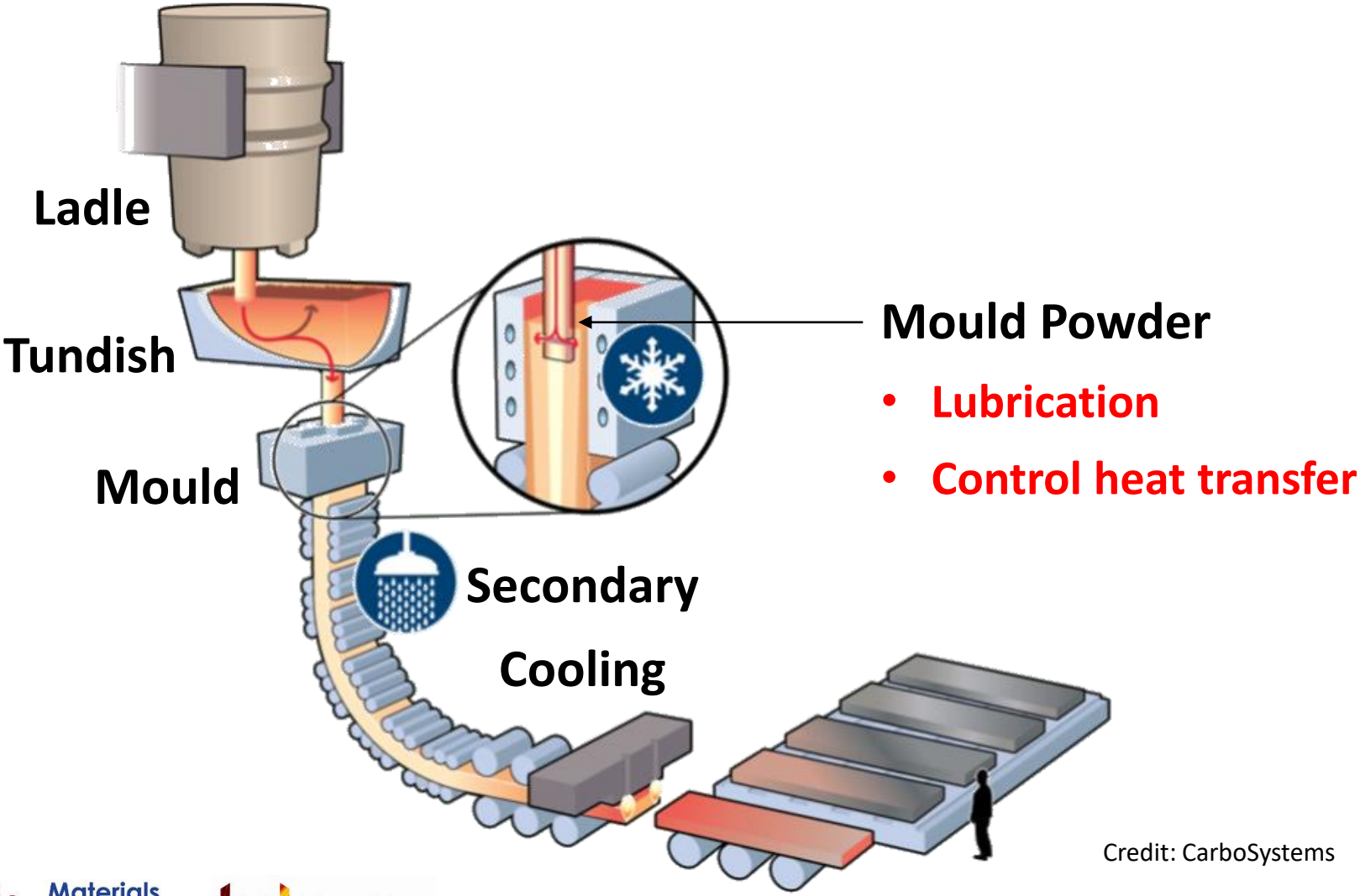
27th February 2018

Excellence in Materials & Process Innovation

Overview


Background
Project Outline
Thermal Resistance
Copper Finger Test
Conclusions

Background – Continuous Casting



Credit: CarboSystems

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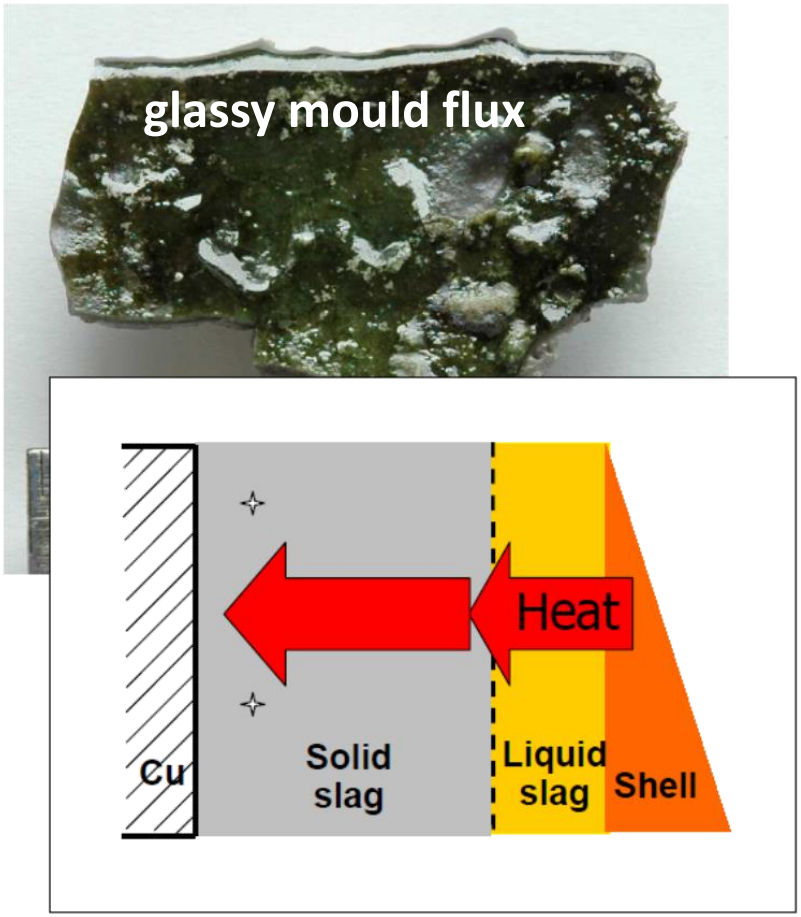
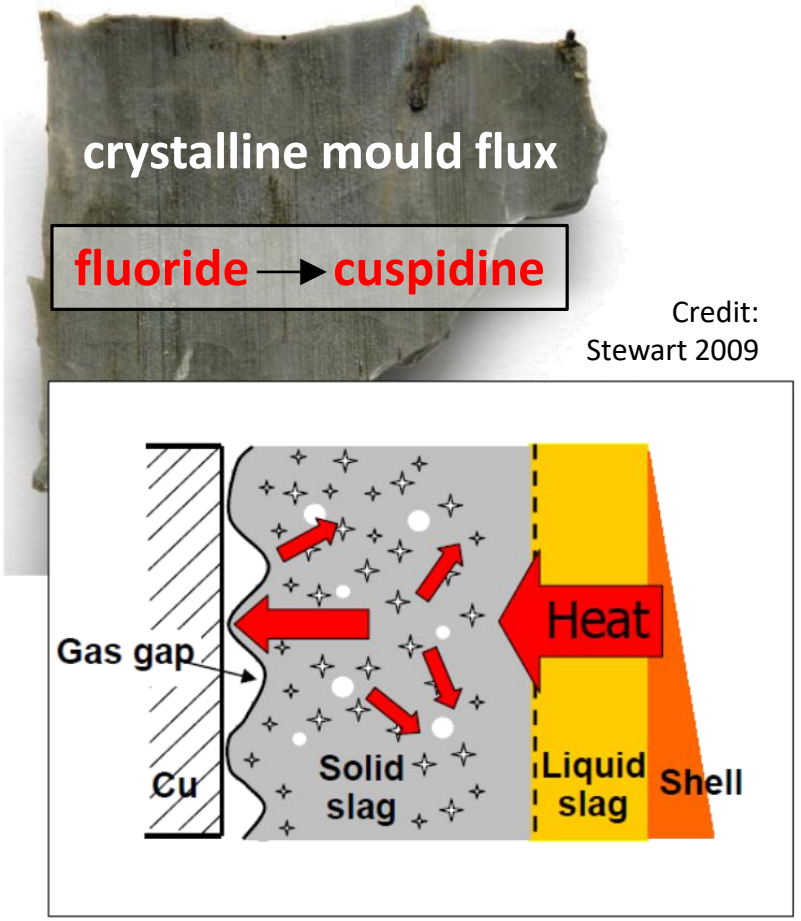
Background – Traditional Heat Transfer





Credit:
Stewart 2009

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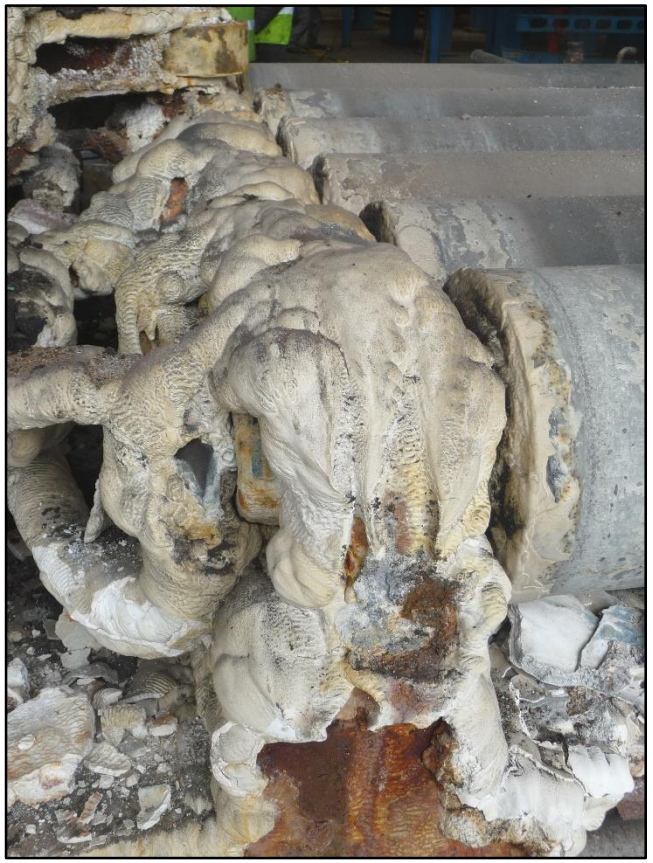
Project Outline – Problems with Fluoride

- **Reduction in equipment life**
- **Uncertainty with the process**
- **Environmental Impact**

- Thermodynamics **limit** the replacement of cuspidine phase



Can heat transfer be controlled without crystallisation?

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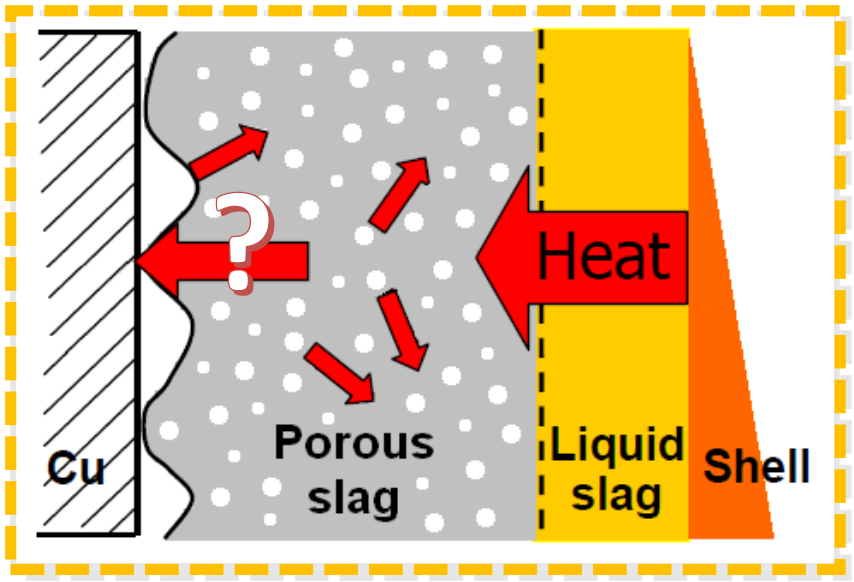
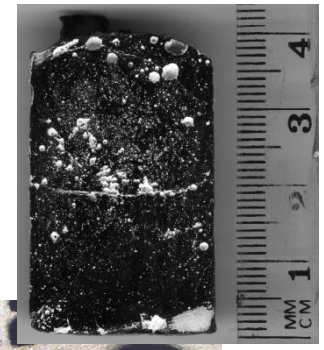
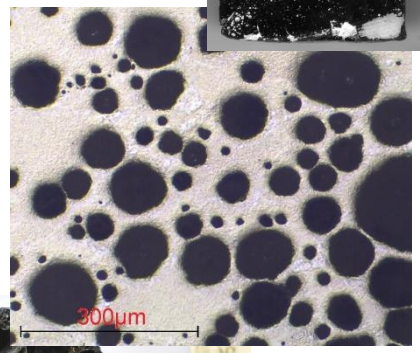
Project Outline – Possible Solutions

Deliberately introduce porosity into the mould-strand gap

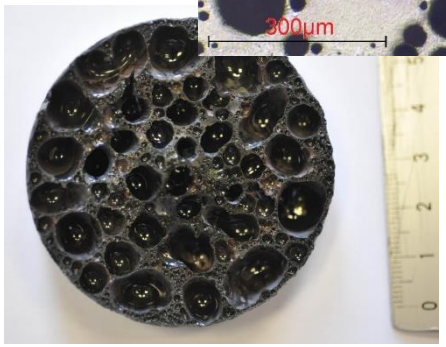




Foaming agents



Microspheres



Gas injection

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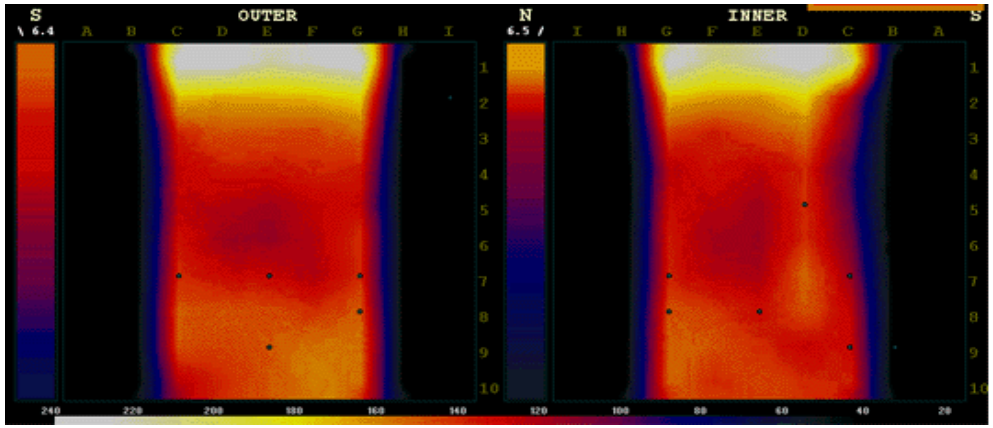
Project Outline – Possible Solutions

- **Where to add:**
- On the steel surface with powder?
- Will it infiltrate into mould-strand gap?
- Effect on lubrication?



Coating on mould wall in the meniscus region

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What does the coating need to do?

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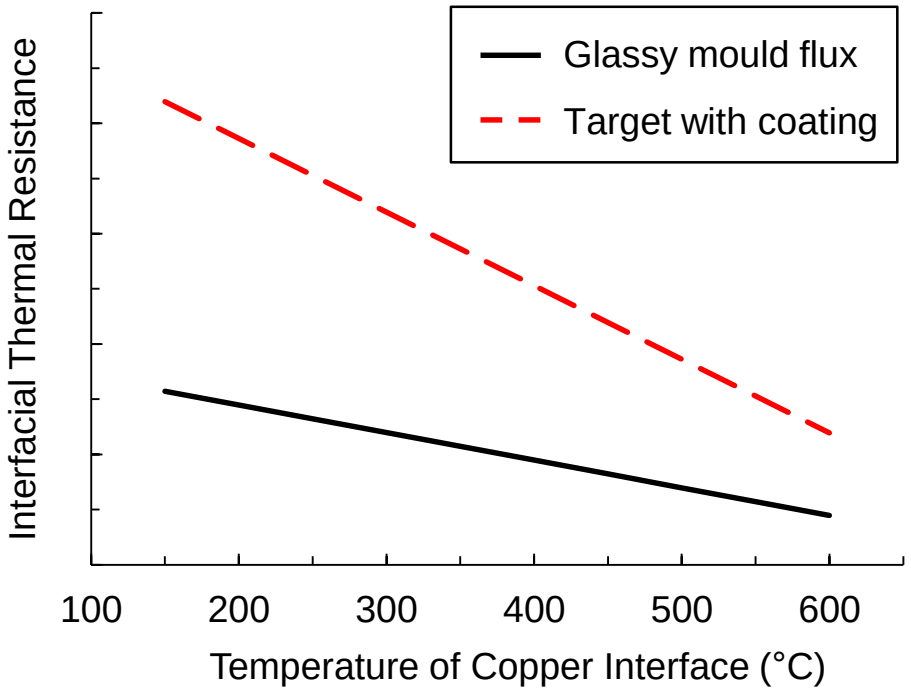
Thermal Resistance – Coating Specification

- Fluoride removal estimated to reduce total thermal resistance by **0.25 $m^2.K.kW^{-1}$**
- Interfacial thermal resistance estimated to be **0.15 $m^2.K.kW^{-1}$** (1)
- Coating must increase thermal resistance by **167 %**



[1] Hanao, M. and Kawamoto, M., Flux film in the mold of high speed continuous casting. *ISIJ International*, vol. 48 (2008), no. 2, pp. 180-185

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How to test the coating performance?

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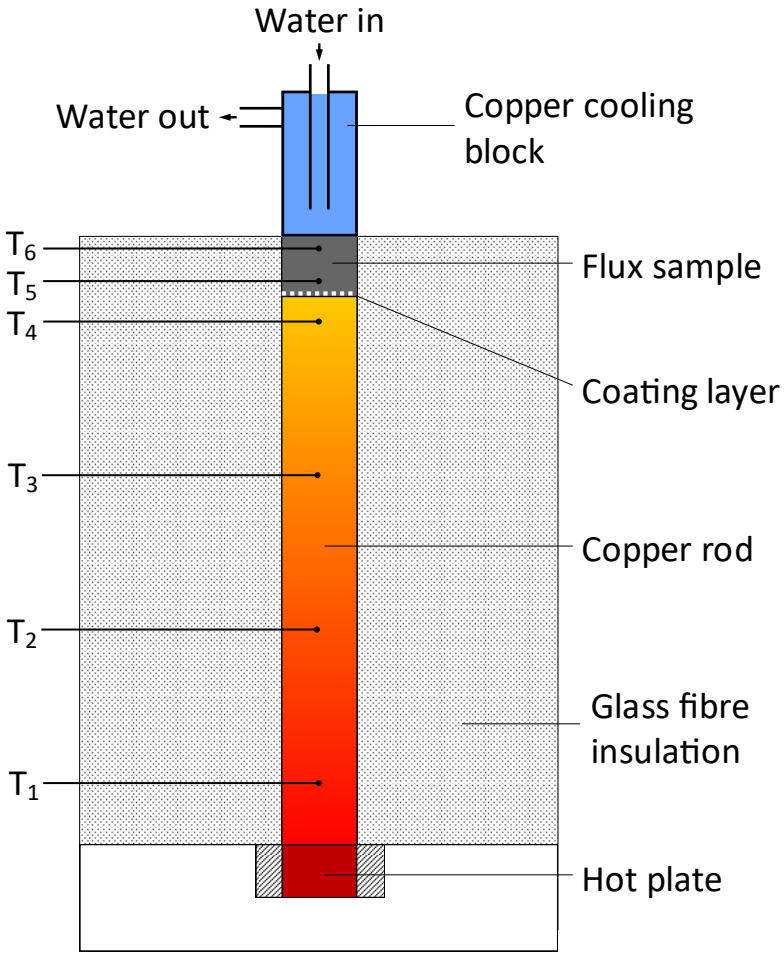
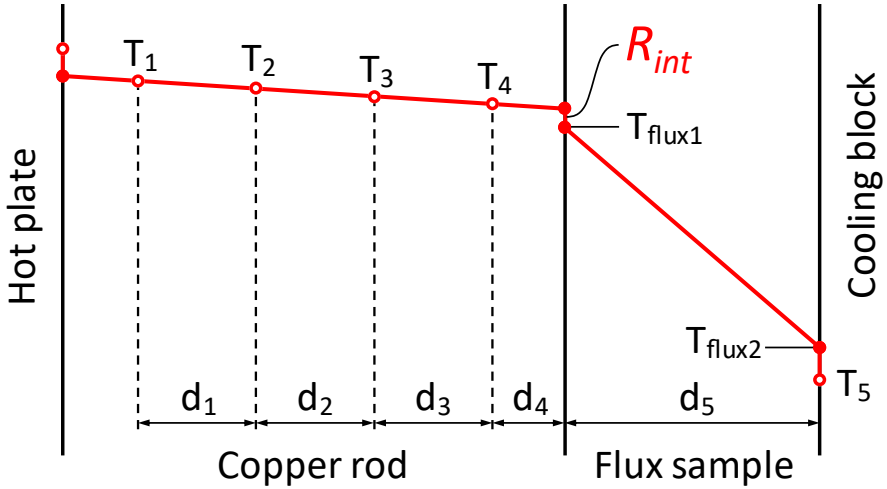
Thermal Resistance – Methodology



- Device was designed and built to measure thermal resistance (R_{int}) and thermal conductivity



- Derivation of Fourier's Law used to calculate R_{int}

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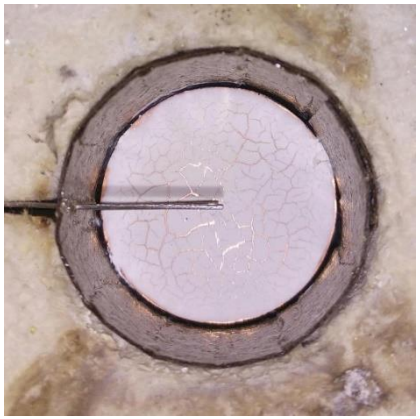
Thermal Resistance – Sample Preparation

- A defined volume of coating solution was applied to the copper surface and left for 12 hours to dry

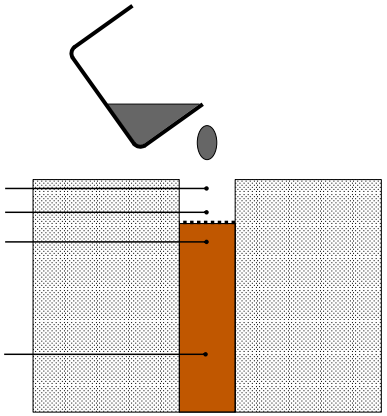
Table I. Coatings used in investigation

Solution	Concentration	Gas Evolved	Amount 1	Amount 2	Amount 3	Amount 4	Amount 5
$MgCO_3$ (aq)	120 g/l	CO_2	0.2 mm	0.4 mm	0.6 mm	-	-
Na_2SiO_3 (aq)	724 g/l	H_2O	0.2 mm	0.4 mm	0.6 mm	0.7 mm	0.8 mm



Magnesium carbonate coating

Waterglass coating



Mould flux preparation

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How did the coatings perform?

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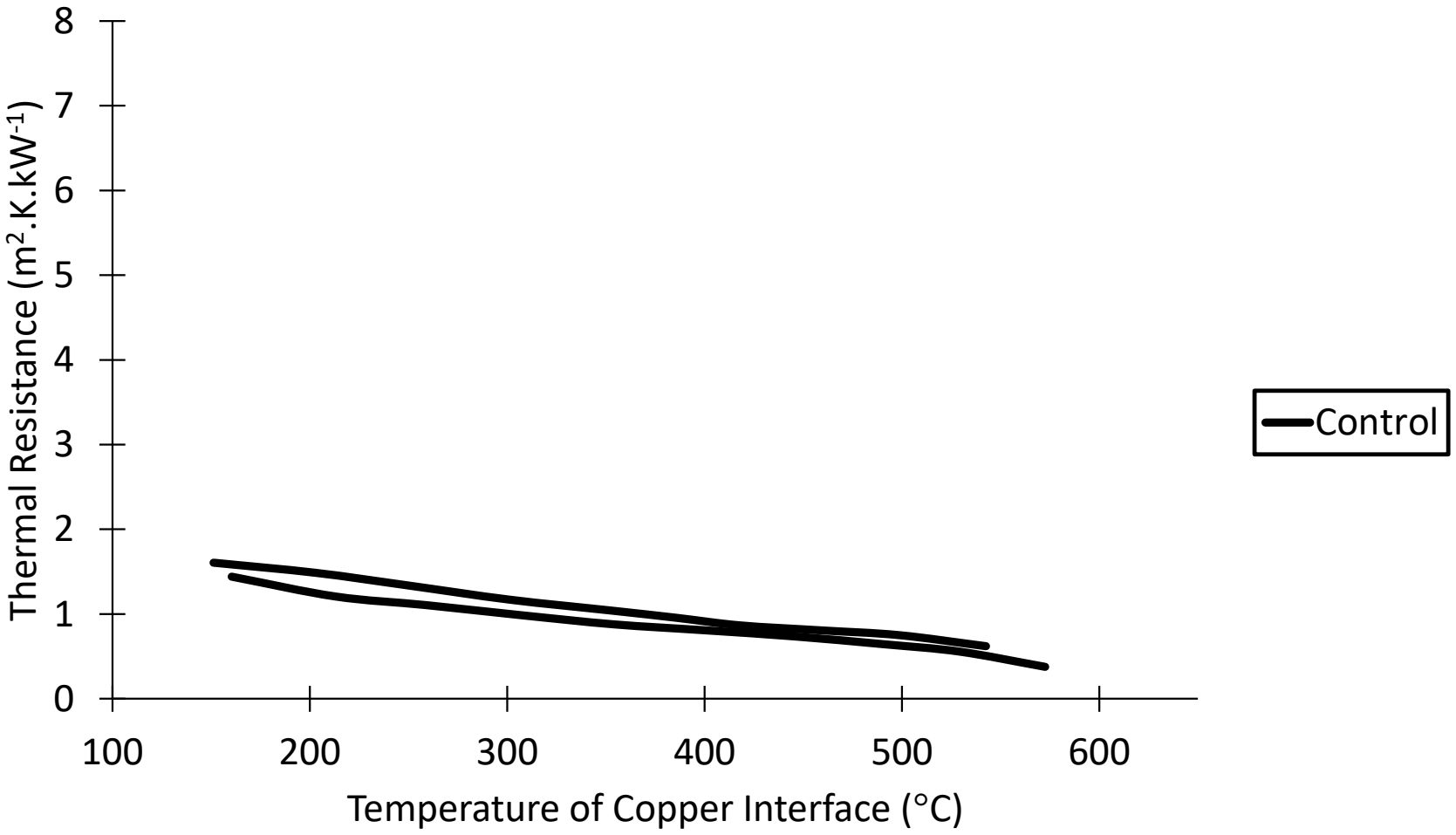
Thermal Resistance – Waterglass Results



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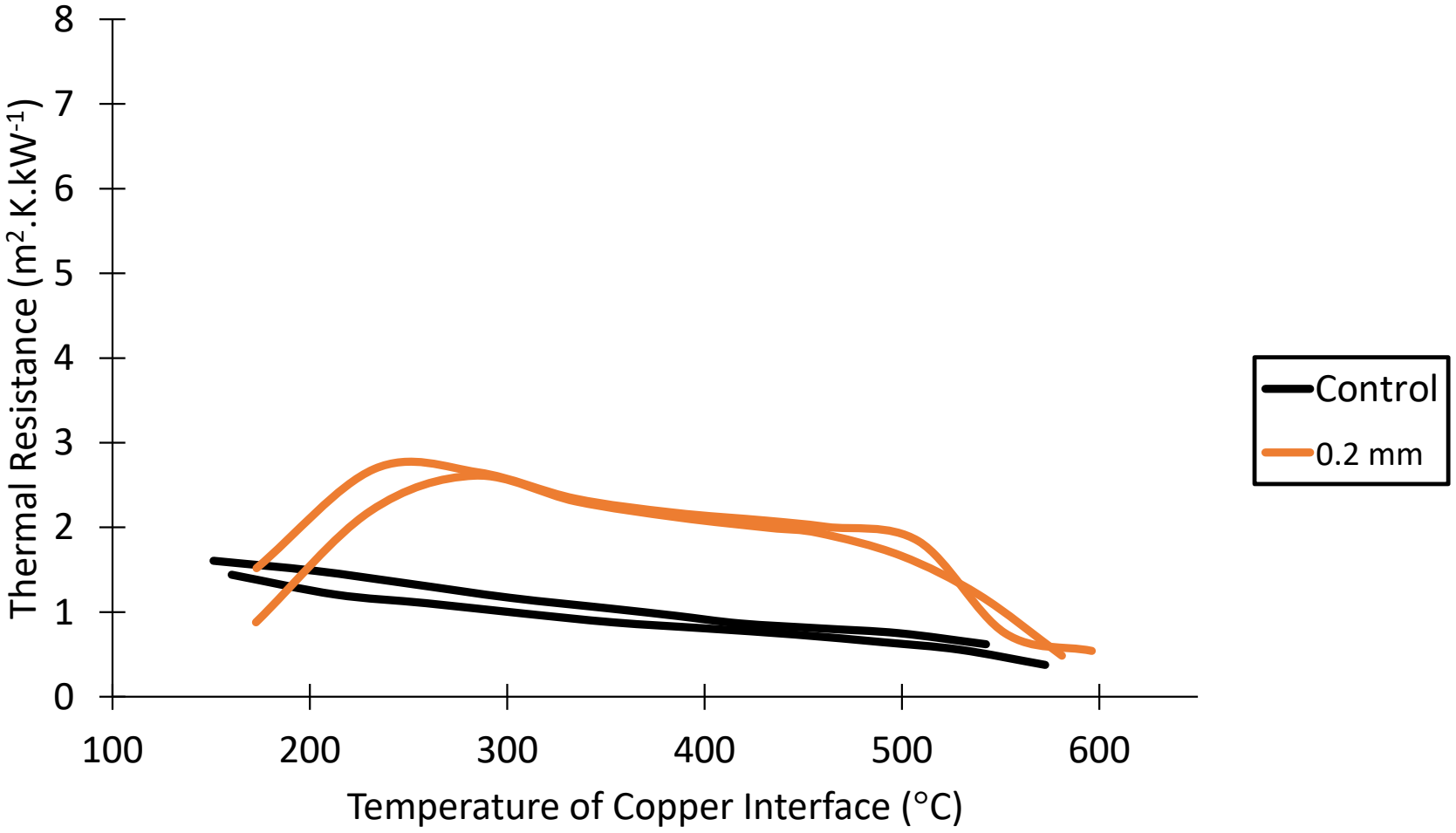
Thermal Resistance – Waterglass Results



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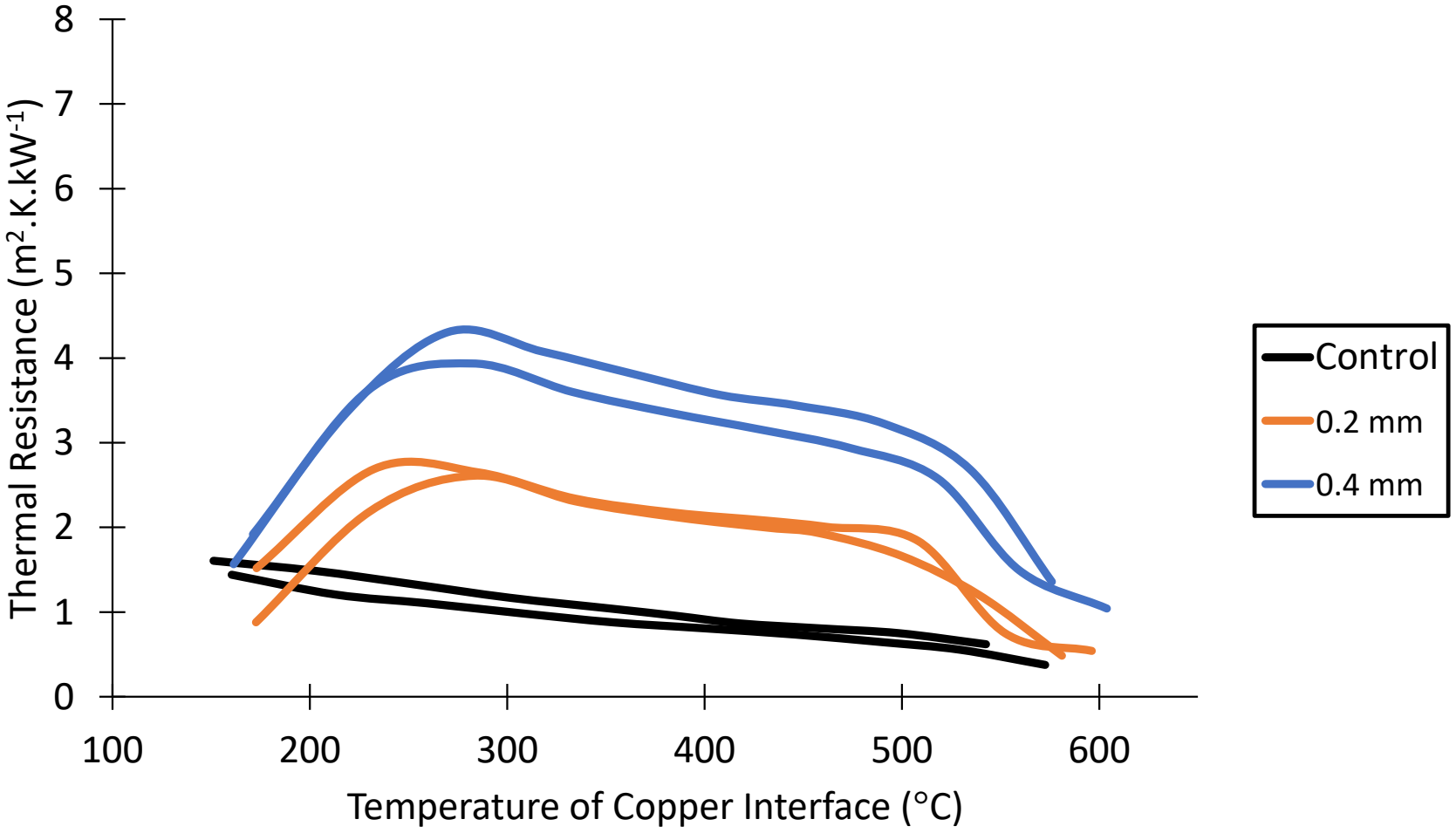
Thermal Resistance – Waterglass Results



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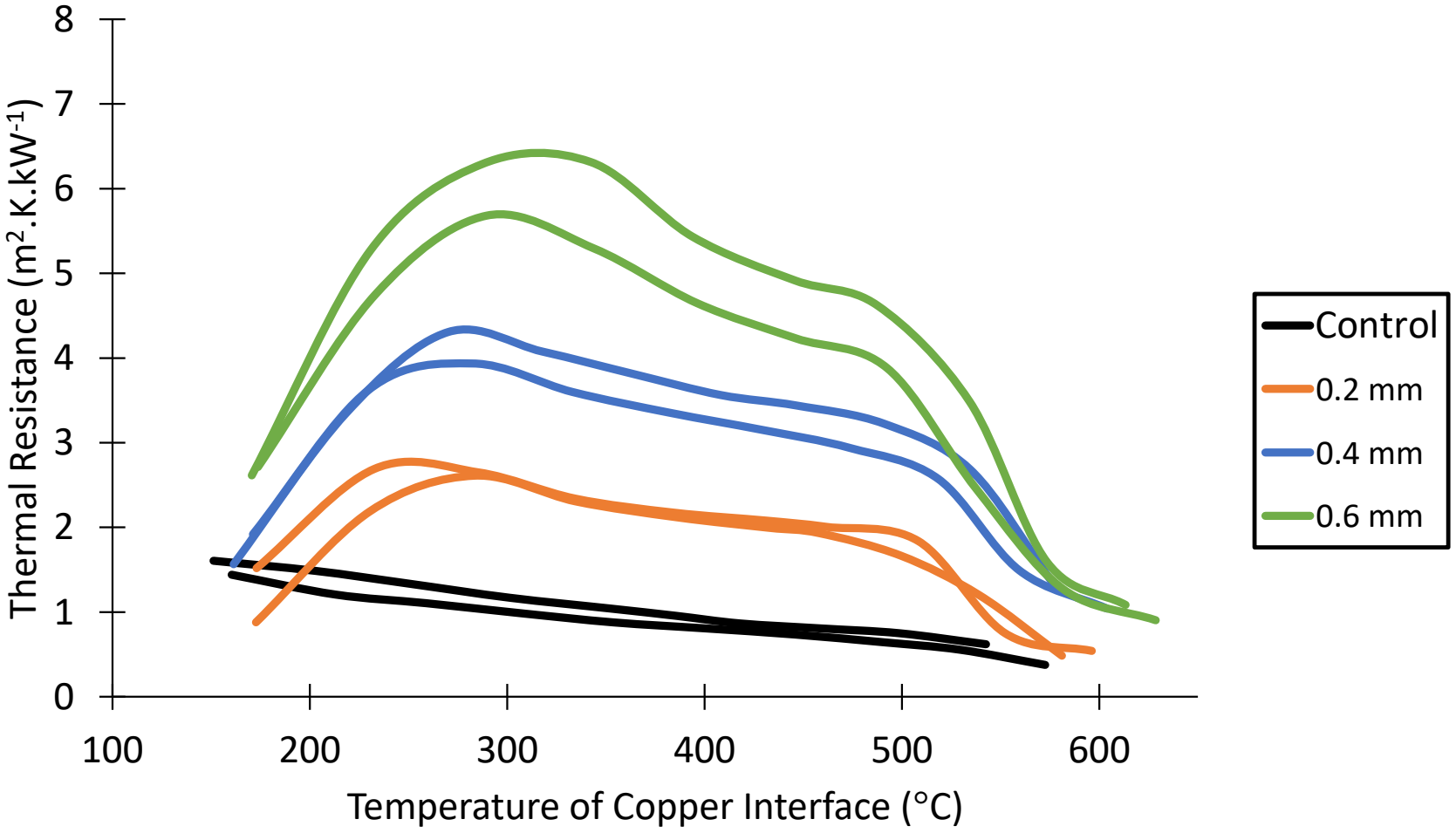
Thermal Resistance – Waterglass Results



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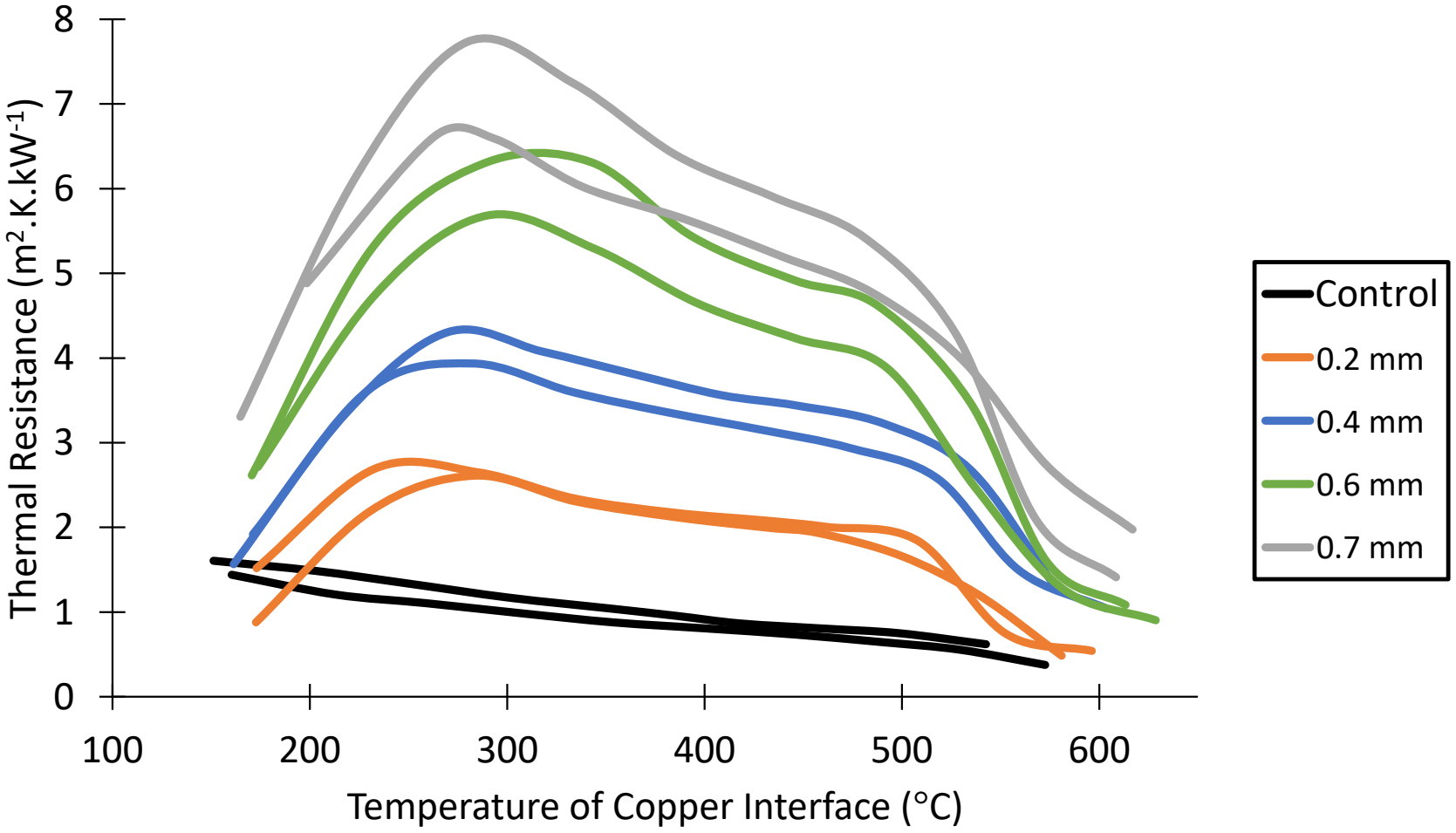
Thermal Resistance – Waterglass Results



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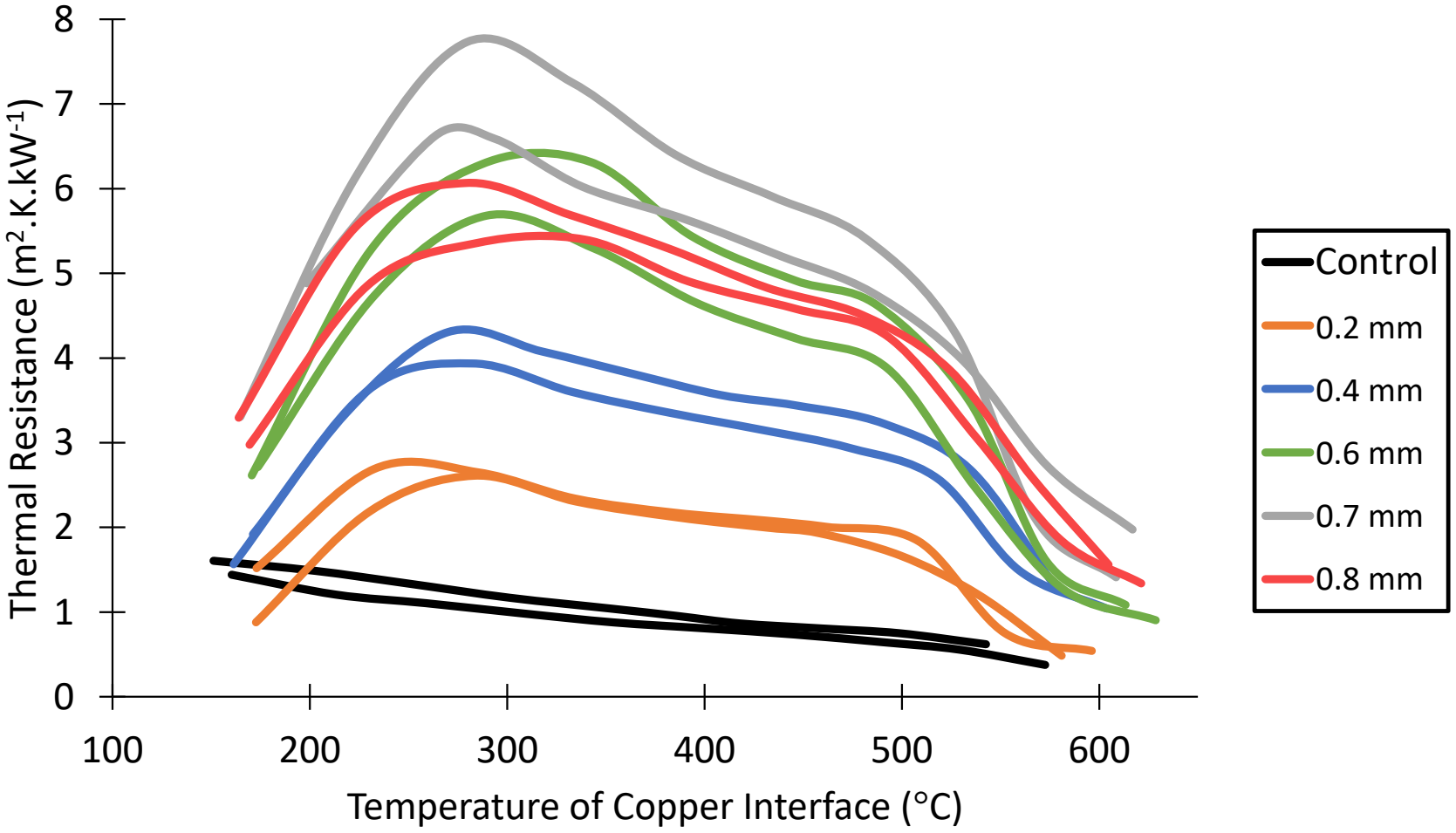
Thermal Resistance – Waterglass Results



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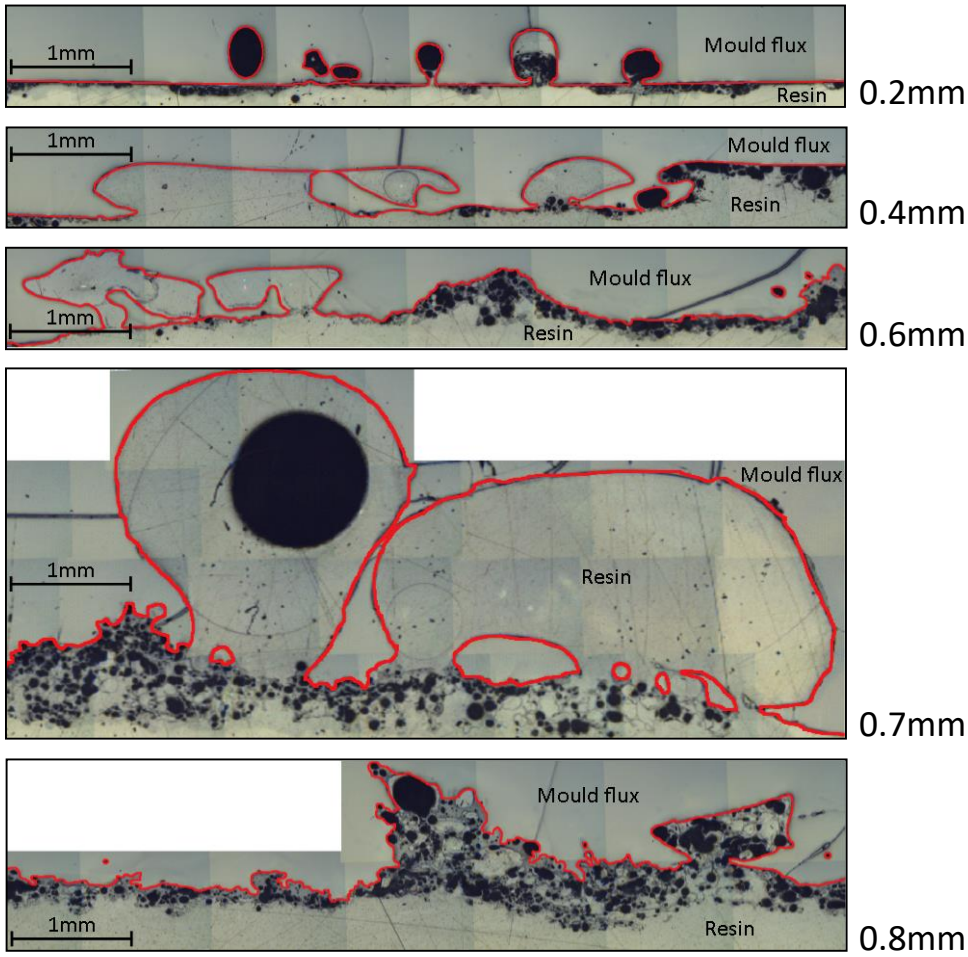
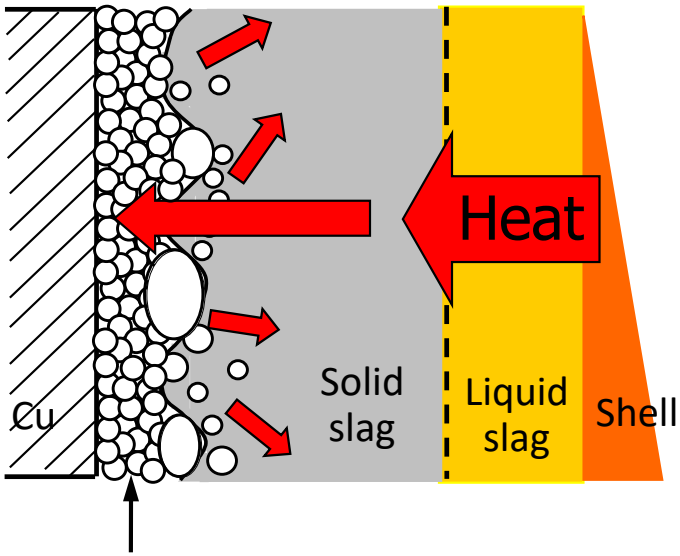
Thermal Resistance – Waterglass Results





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Did the waterglass coating meet the target?

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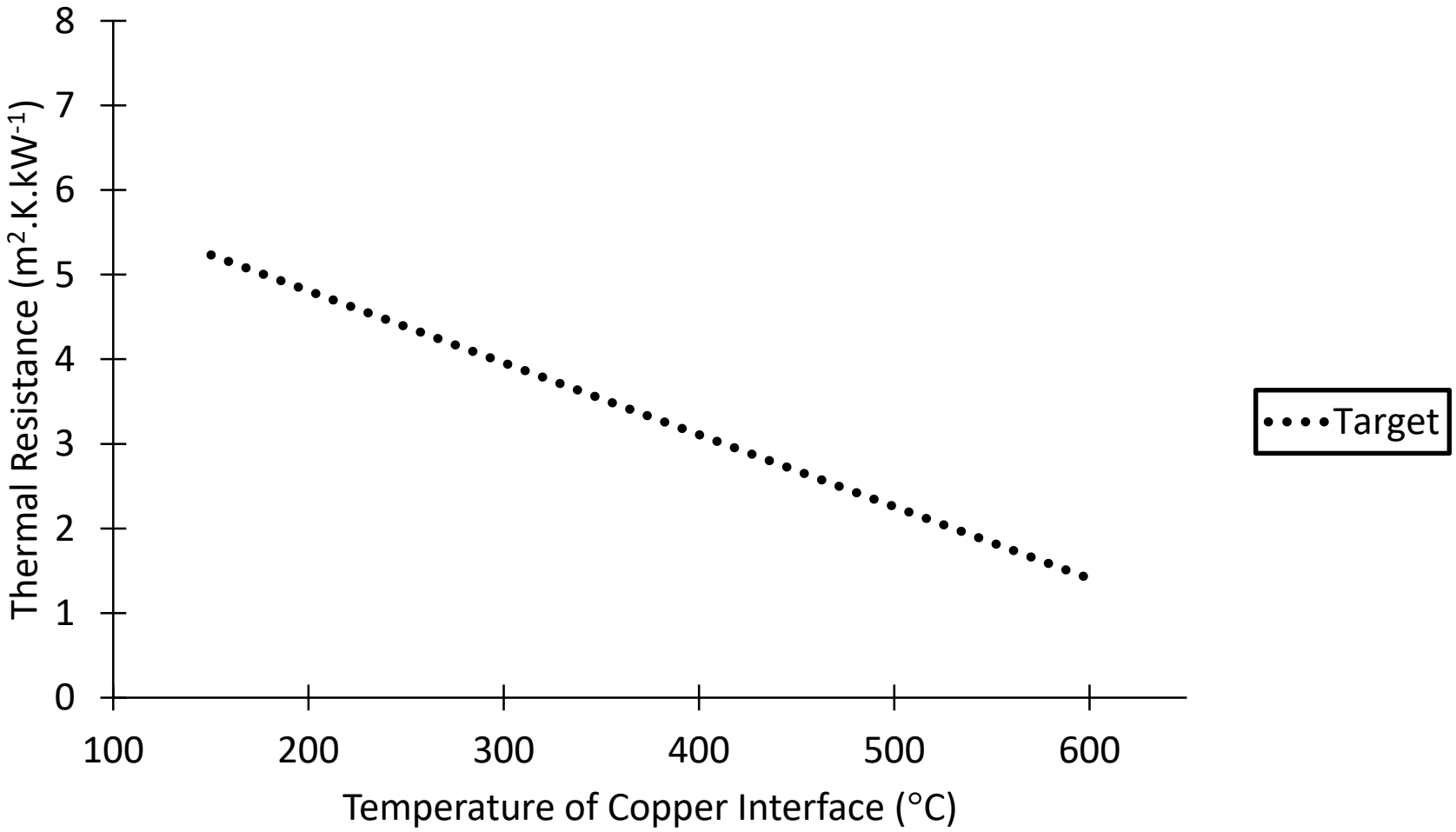
Thermal Resistance – Waterglass Results



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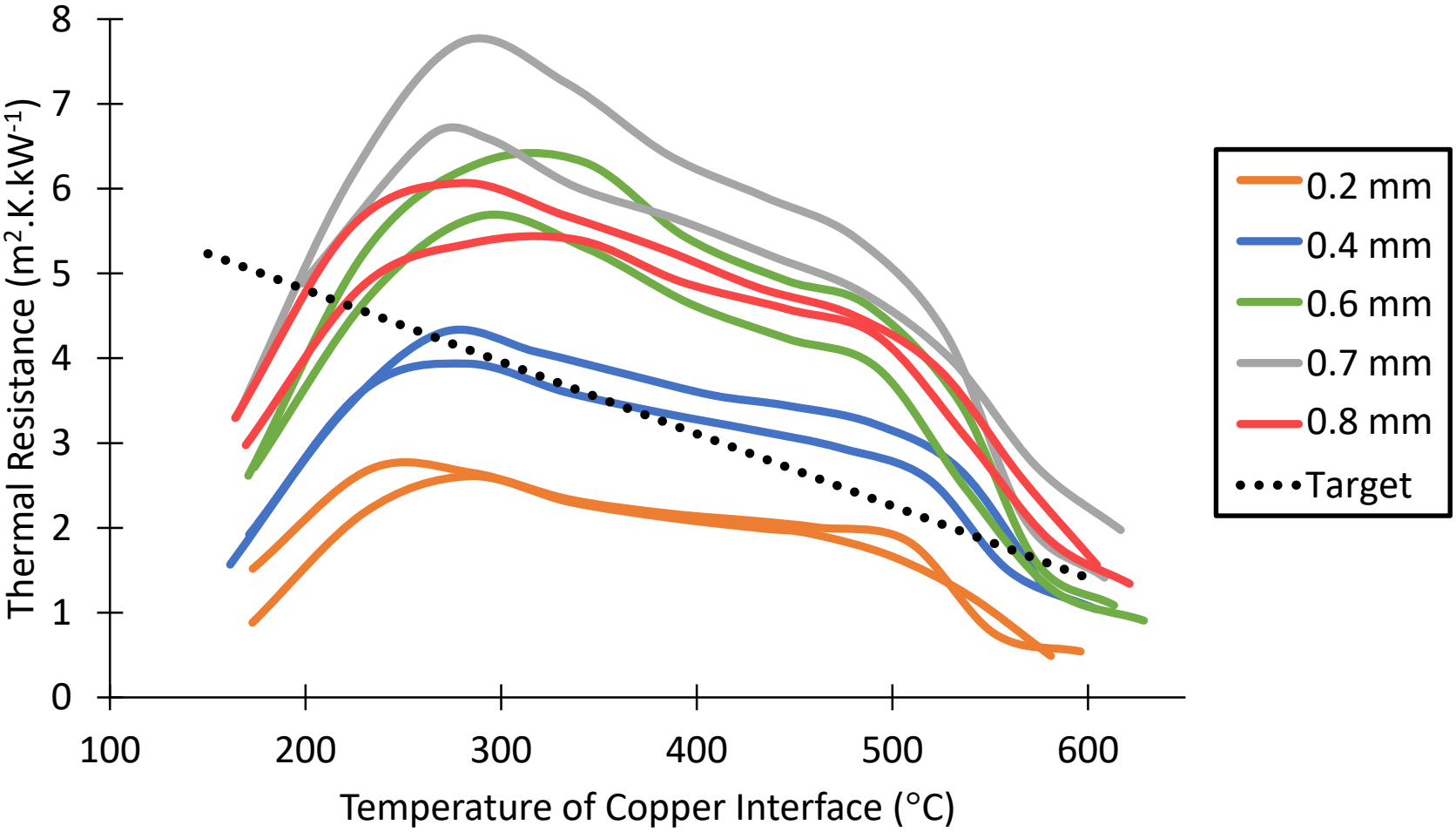
Thermal Resistance – Waterglass Results



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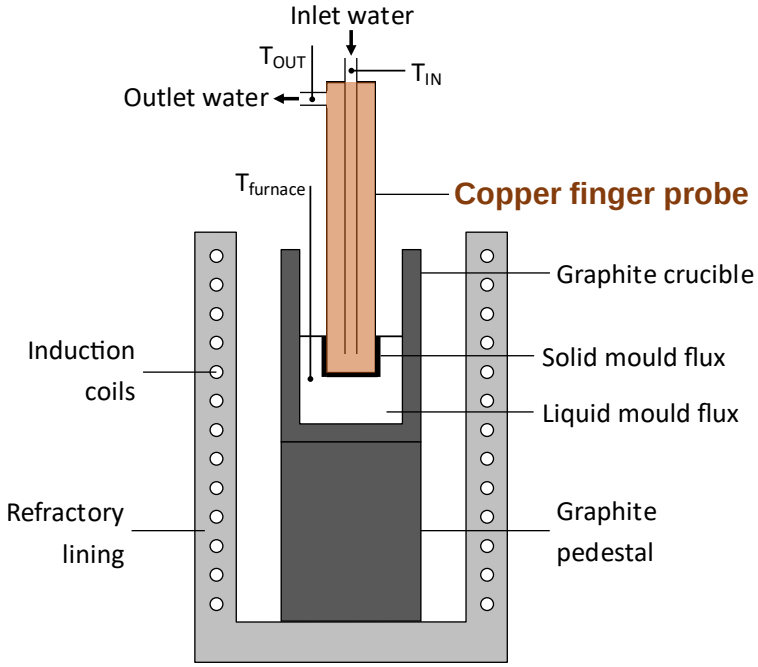
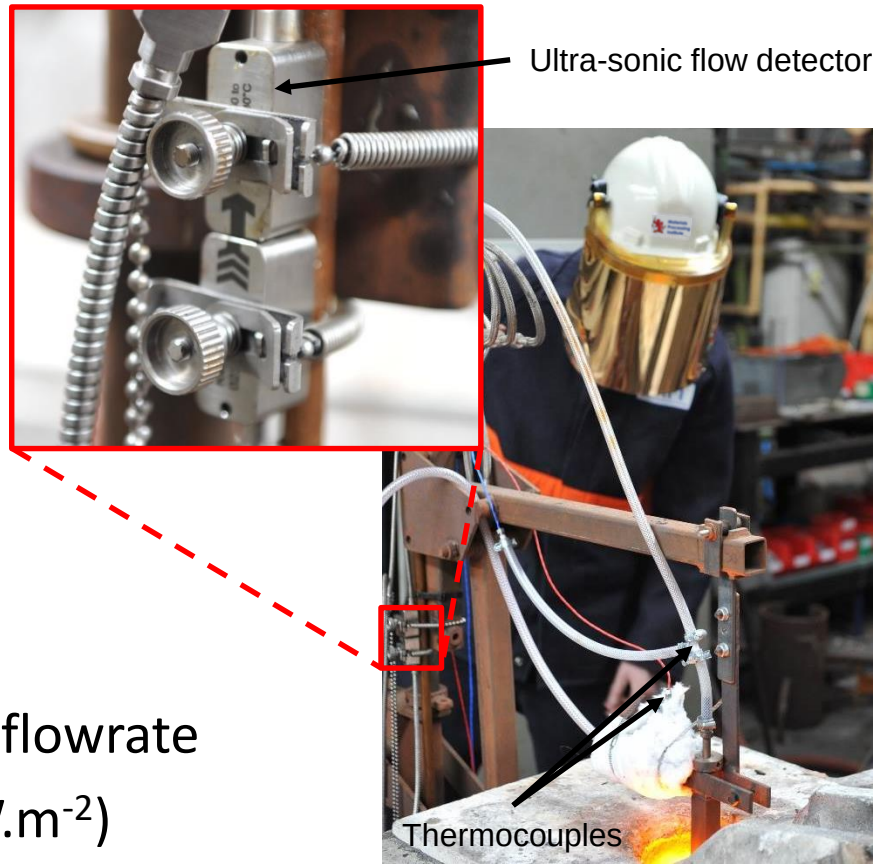
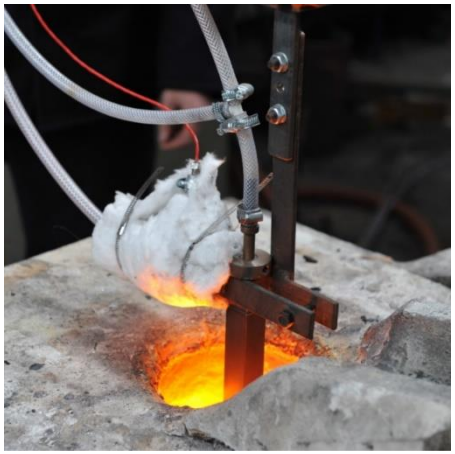
Copper Finger – Methodology

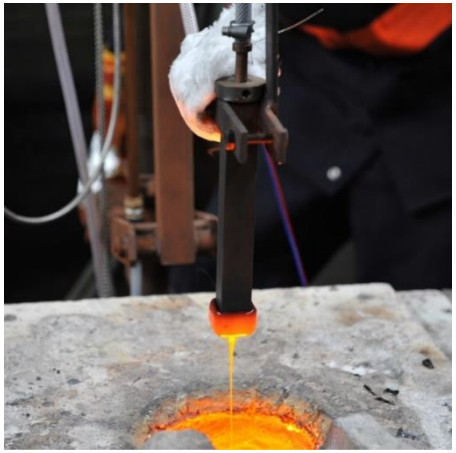


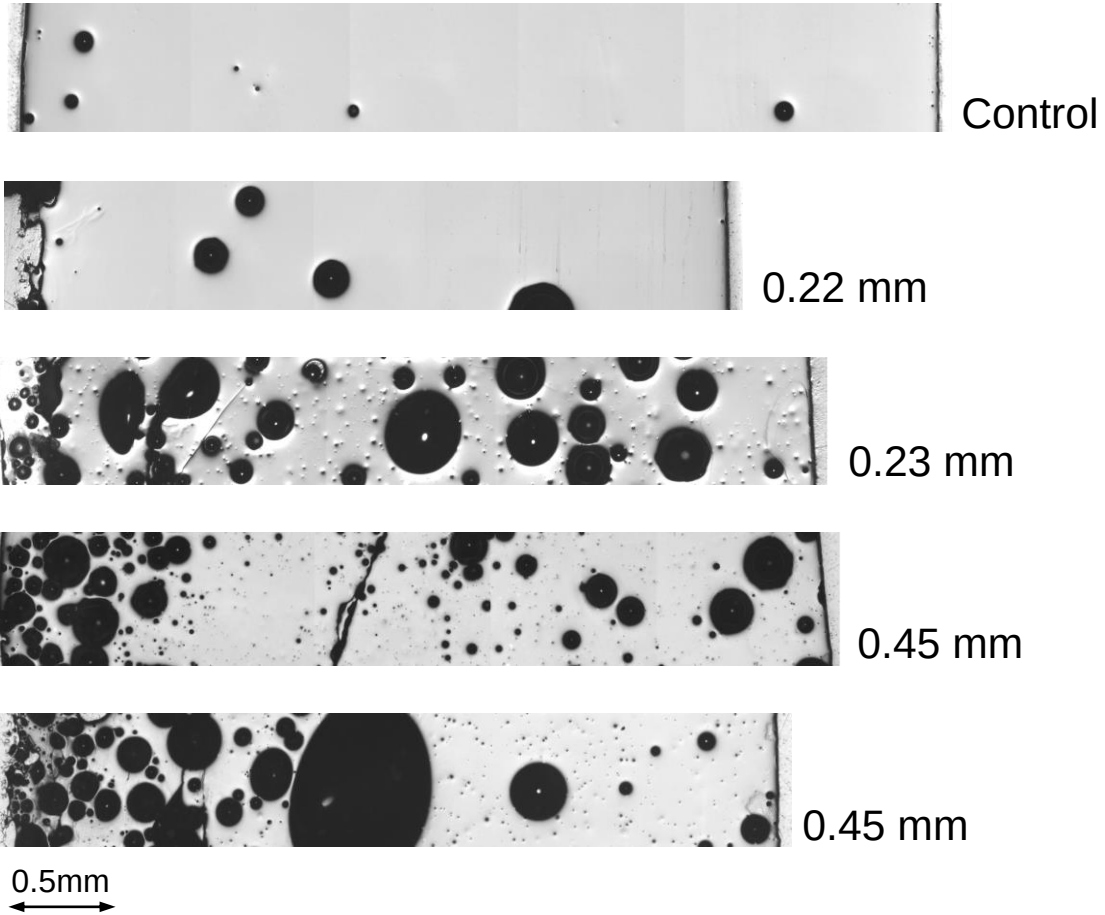


- ΔT of cooling water and water flowrate used to calculate heat flux ($kW.m^{-2}$)

Copper Finger – Waterglass Results







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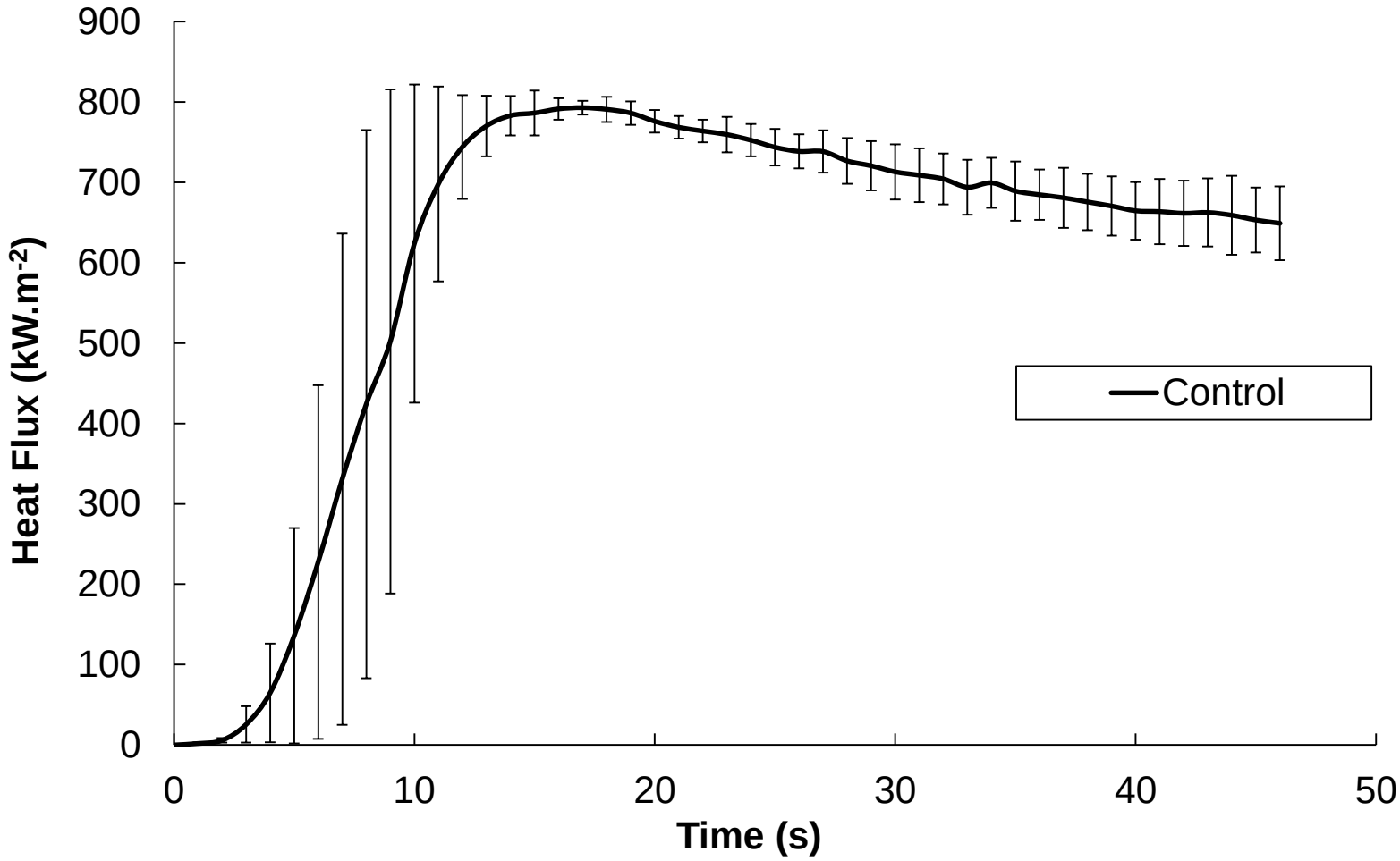
Copper Finger – Waterglass Results



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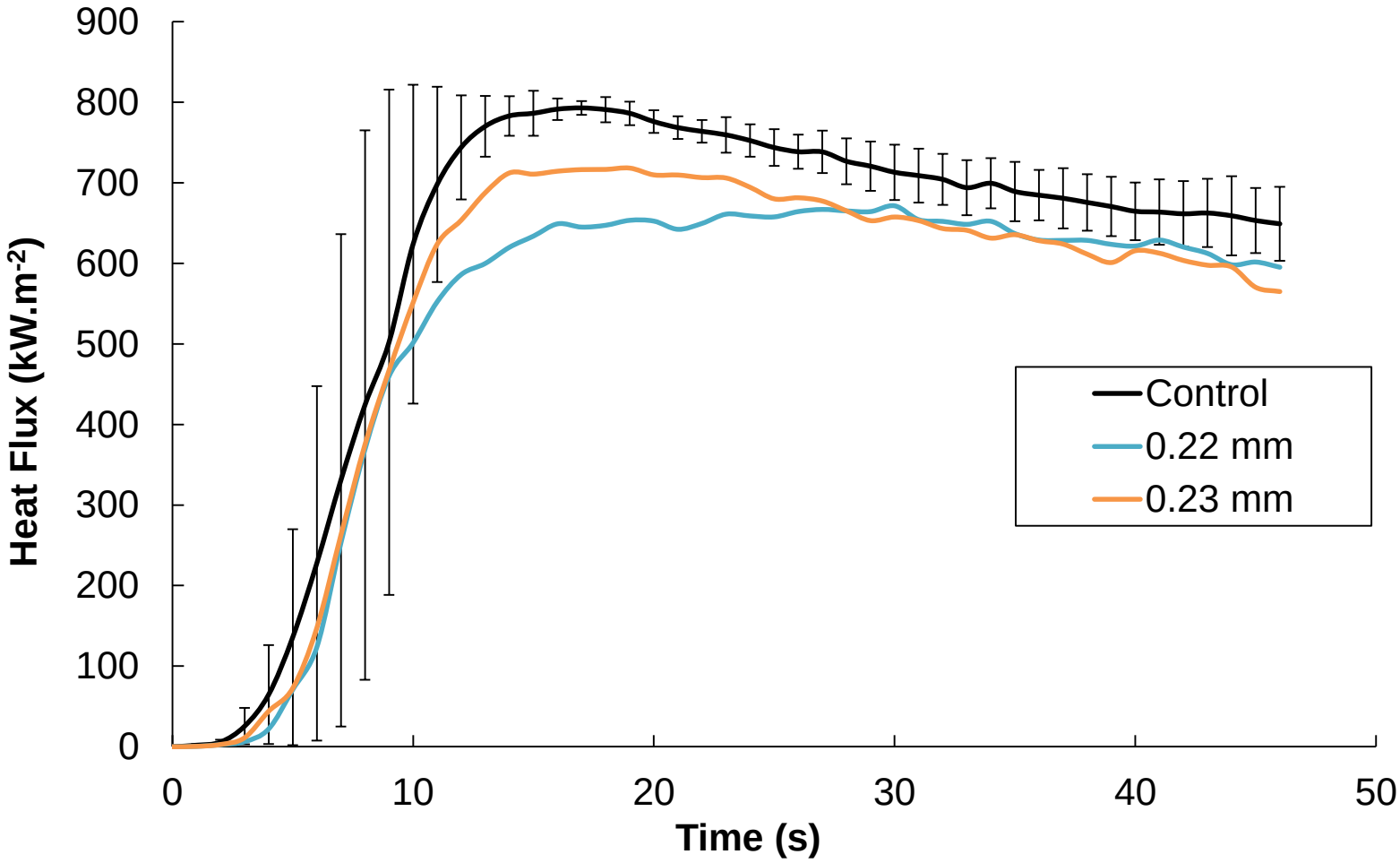
Copper Finger – Waterglass Results



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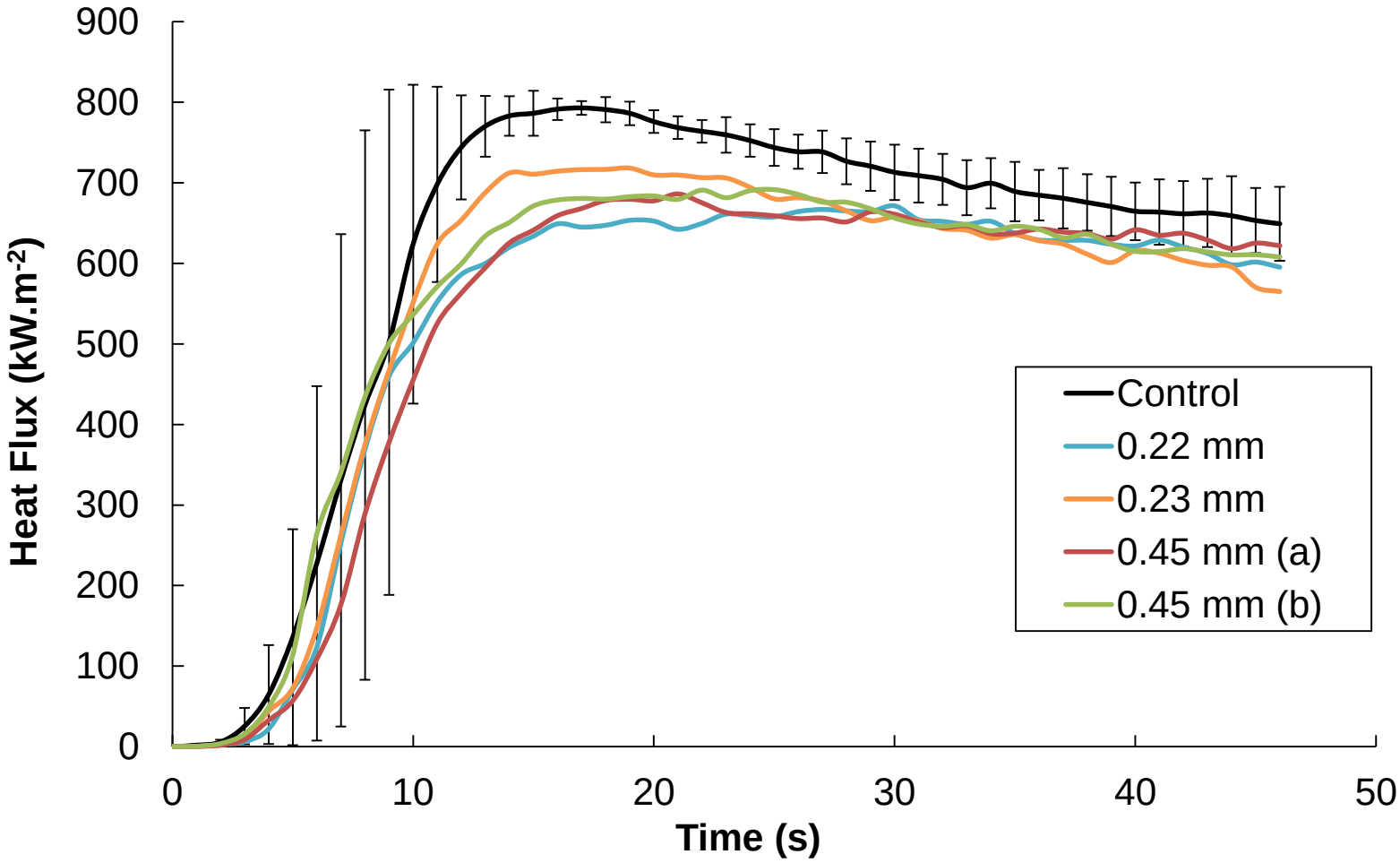

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Further Work

- **Patent application** submitted May 2016, published and awaiting final grant
- Discussion of **European collaboration** to develop coatings further
- **Pilot plant trials** to assess durability and effect of ferro-static pressure
- **Optimisation** of coating composition

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Conclusions

- Introduction of **porosity** into a glassy mould flux can be used to control heat transfer during continuous casting
- To use glassy mould fluxes with crack prone steel grades, reactive coatings must increase interfacial thermal resistance by **167 %**
- Waterglass coating **met and exceeded** target value
- Waterglass shown to create **significant** porosity in mould flux at casting temperatures

Acknowledgments

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- **Technical Discussions:**
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- Alan Scholes, *Materials Processing Institute*
- Prof Ken Mills, *Imperial College*
- Dr Arghya Dey, *Tata Steel*

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Thank You

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