MODEL INVESTIGATION OF MOLD LEVEL MONITORING WITH THERMOCOUPLES

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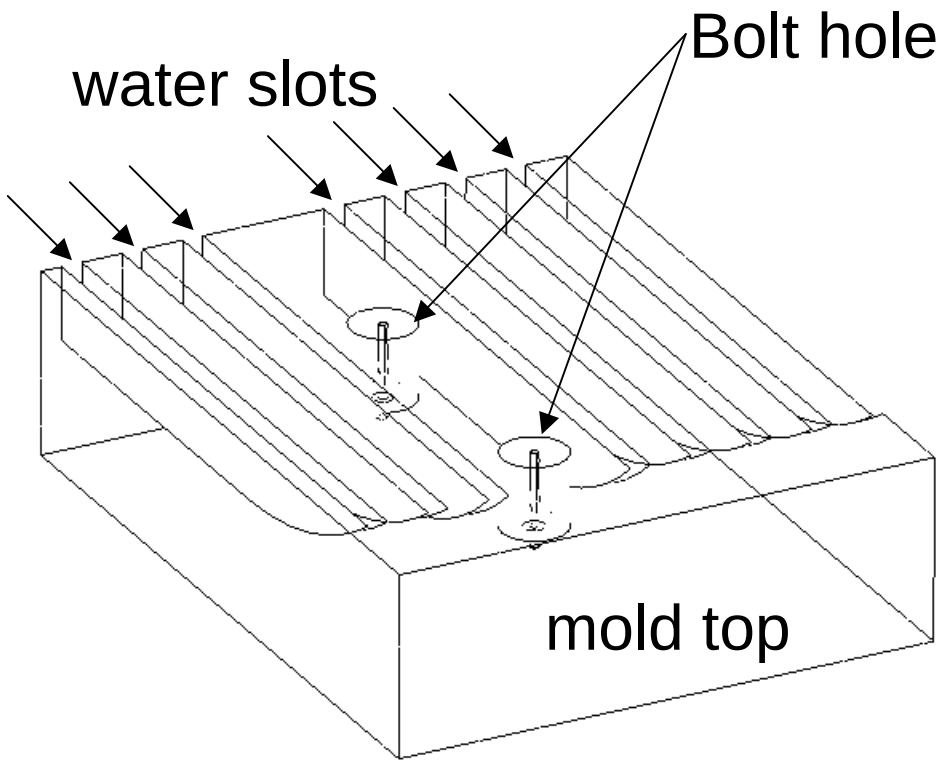
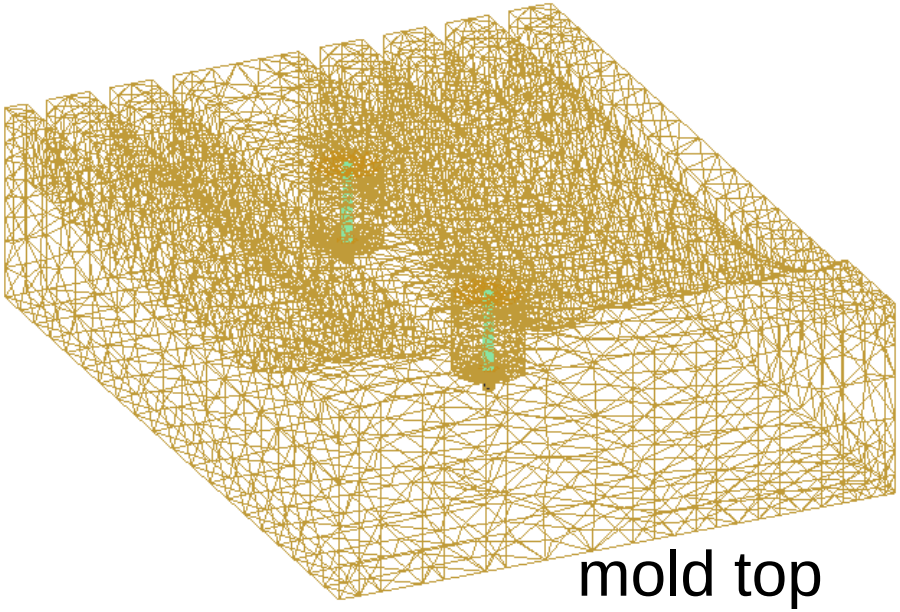
Objectives

- Investigate the potential use of mold thermocouples to detect level fluctuations.
  - Develop 3D transient FEM model
  - Validate with 2D models
  - Validate with plant TC measurements (Columbus Stainless Steel)
  - Simulate TC response to controlled level fluctuations
  - Simulate TC response to oscillation mark movement

3-D Model of Mold Near Meniscus

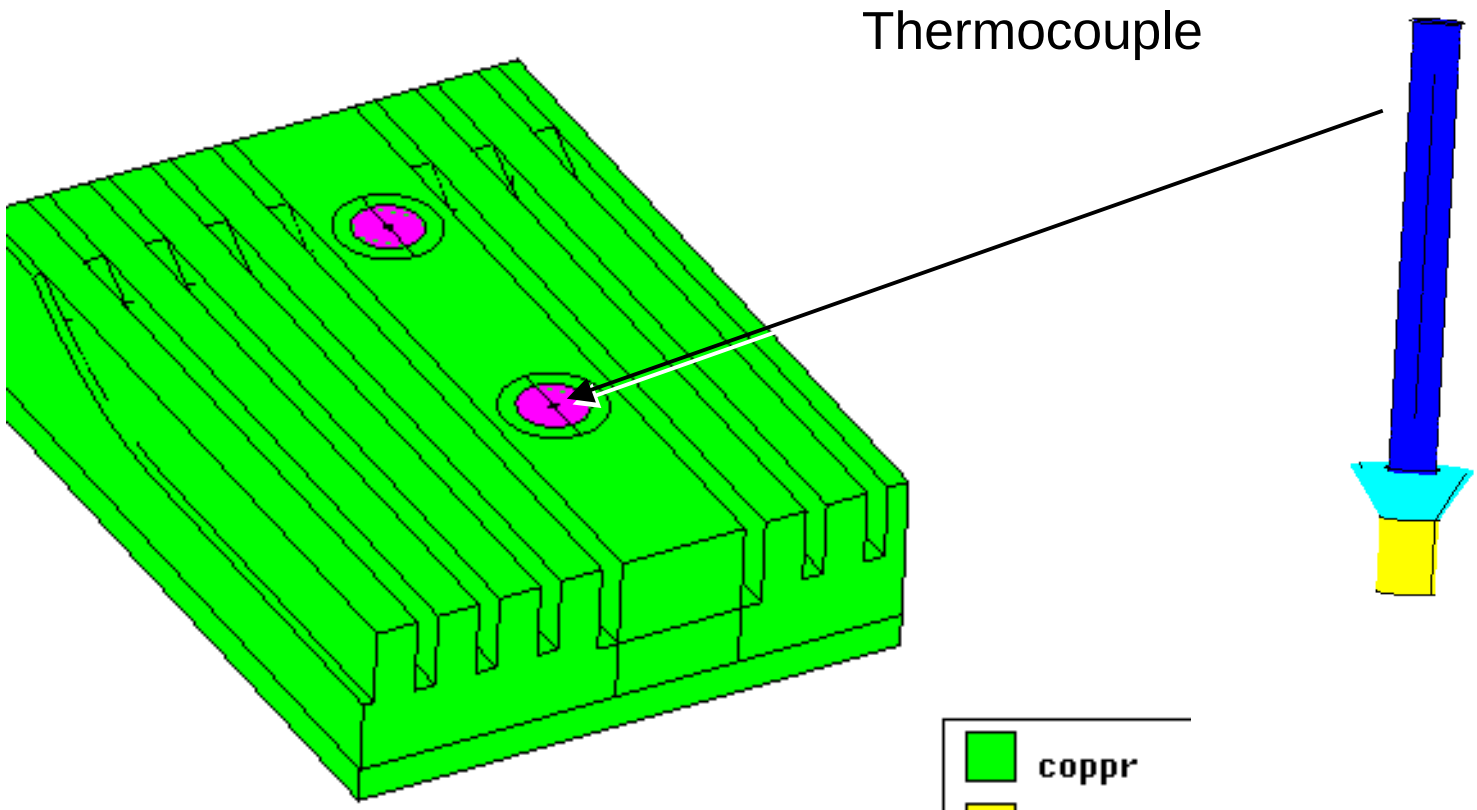


Domain (showing slots)



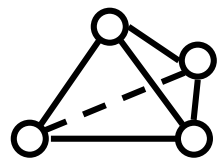
Finite Element Mesh
(4-node tetrahedrons)

3-D Transient Model description



- finite element model

4-node tetrahedral elements:



Material Properties

Material	Thermal Conductivity (W/m °C)	Specific Heat (J/kg-K)	Density (kg/m^3)
Copper (Cu-Ag-0.1P)	364. (Columbus blueprint)	386. (Smithels)	8960. (Smithels)
1026 Steel (shell)	24.6	640.	7200.
Steel (cold support)	50.	500.	7860.
Constantan (for K-thermocouples)	216. (Columbus) (195. Goodfellow)	416. (weighted avg of 55%Cu and 45%Ni) (410. – Marks p4-9)	8900. (Goodfellow)
TC conducting Paste	0.9 (Columbus supplier)	2800. (Marks p4-9 wax)	2100. (Columbus supplier)
Air	0.028 (0.026 @300K – Liquid Air website)	1040. (at 300 K Marks)	1.2 (at STP – Marks p. 4-17)

Geometry & Boundary Conditions

Site	Values
Water slots	$h = 0.045\ W/mm^2\ {}^oC$, $T_\infty = 30^oC$
Heat flux	$q'' = 1.75\ W/mm^2$ (constant case)

copper plate thickness:	43 mm (wide face)	38 mm (narrow face)
TCs located	20mm below hotface (WF)	15 mm below hotface (NF)

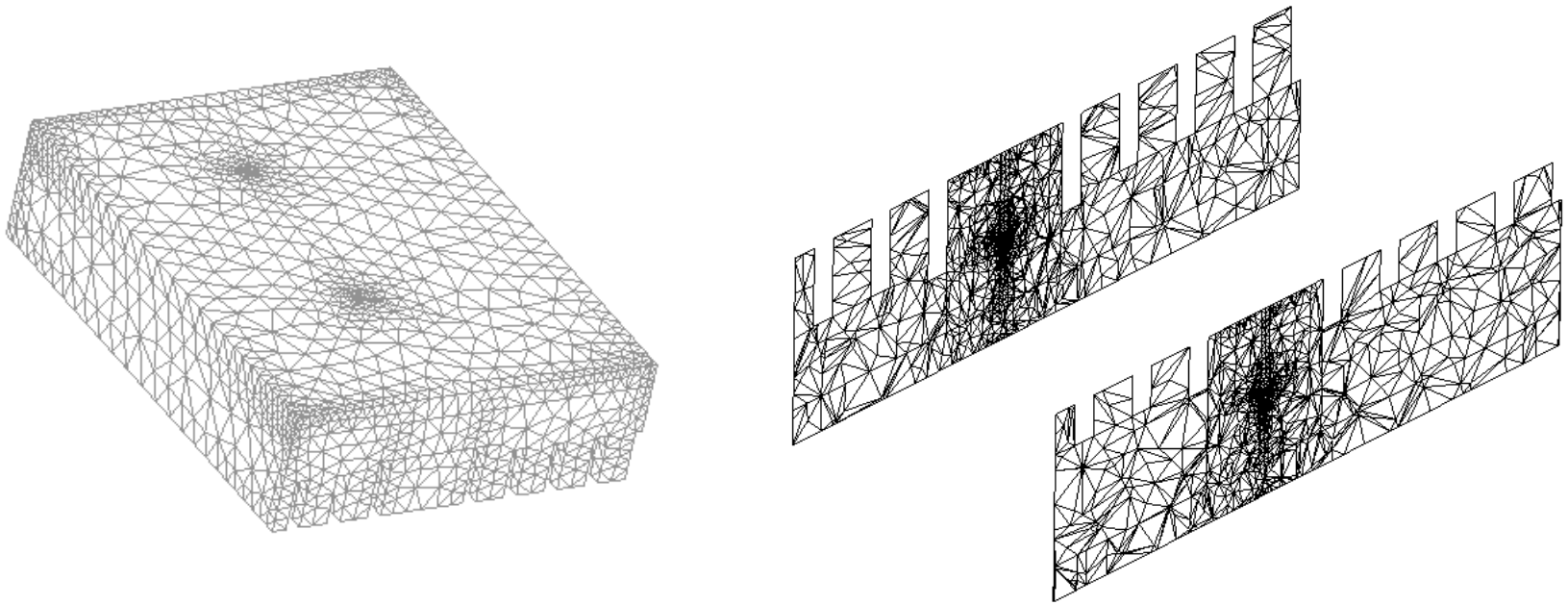
Bolt diameter (16mm with 2mm threads = 20mm total on WF)
Bolt diameter (12mm with 2 mm threads = 16mm total on NF)

Steel grade: 44101 ferritic stainless steel, (prone to clogging and bulging)

Casting speed: 1.04 m/min
Strand Width: 1290 mm

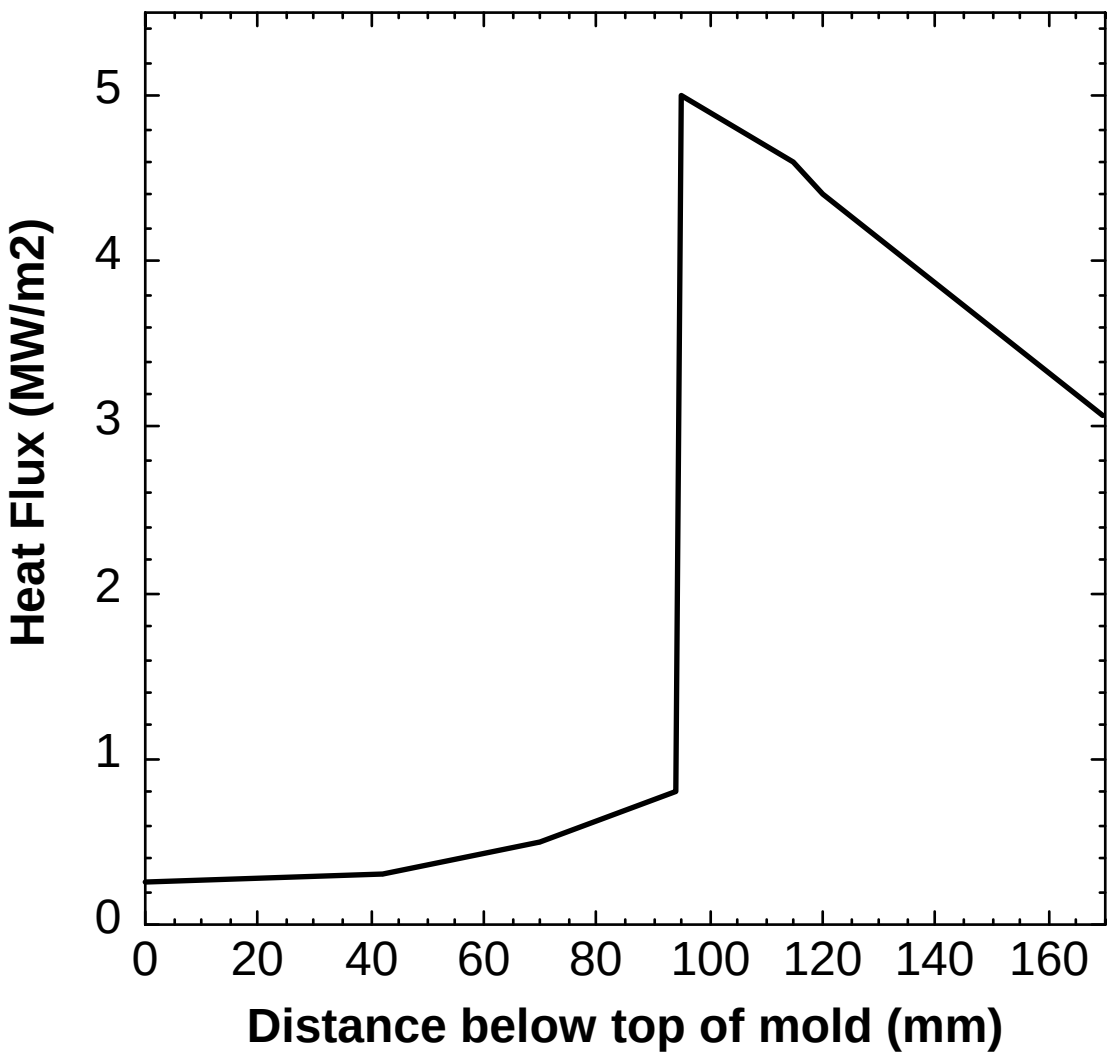
GID3 wide face simulation

Finite Element Mesh

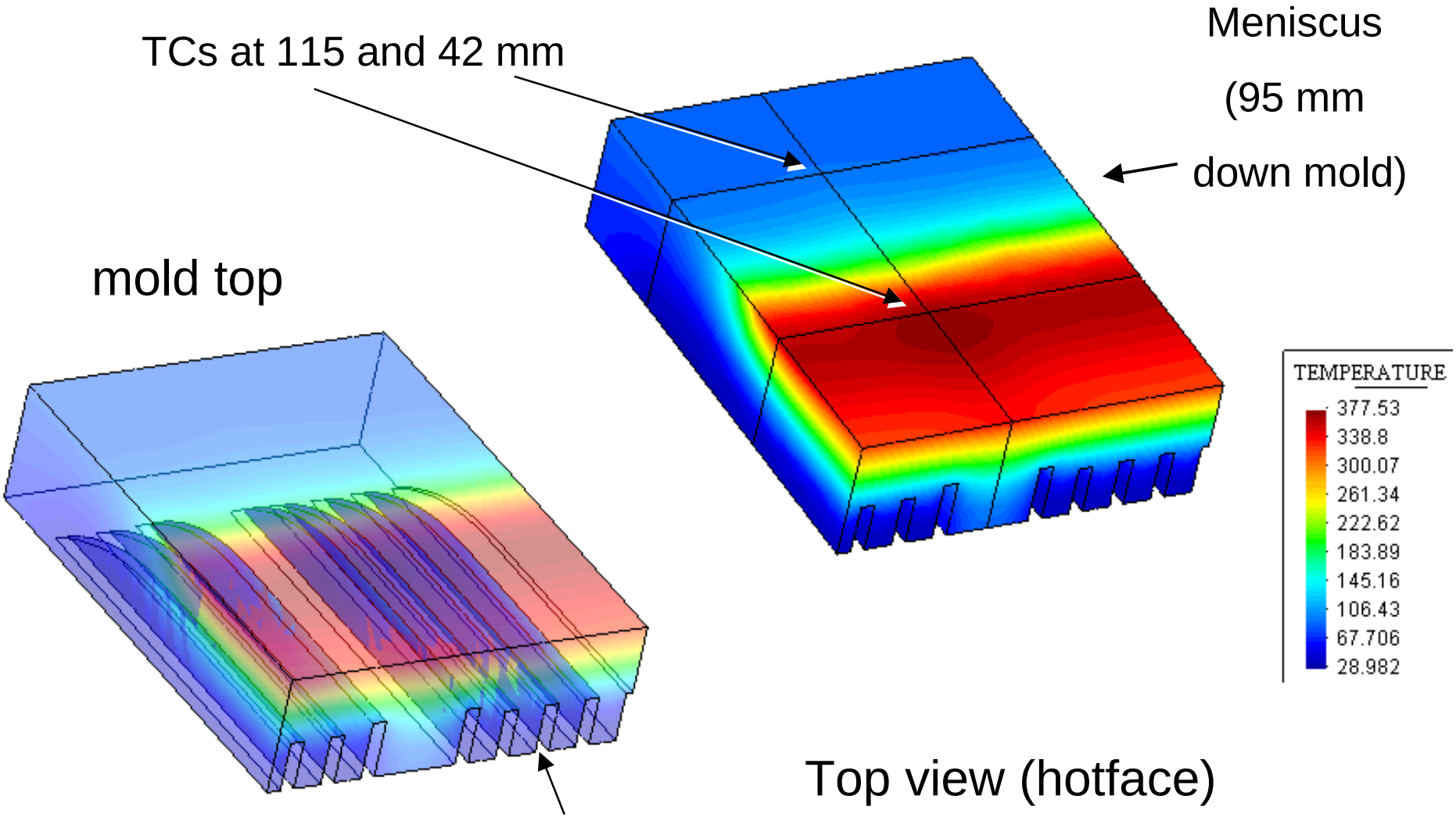


8241 nodes and 38887 tetrahedrons

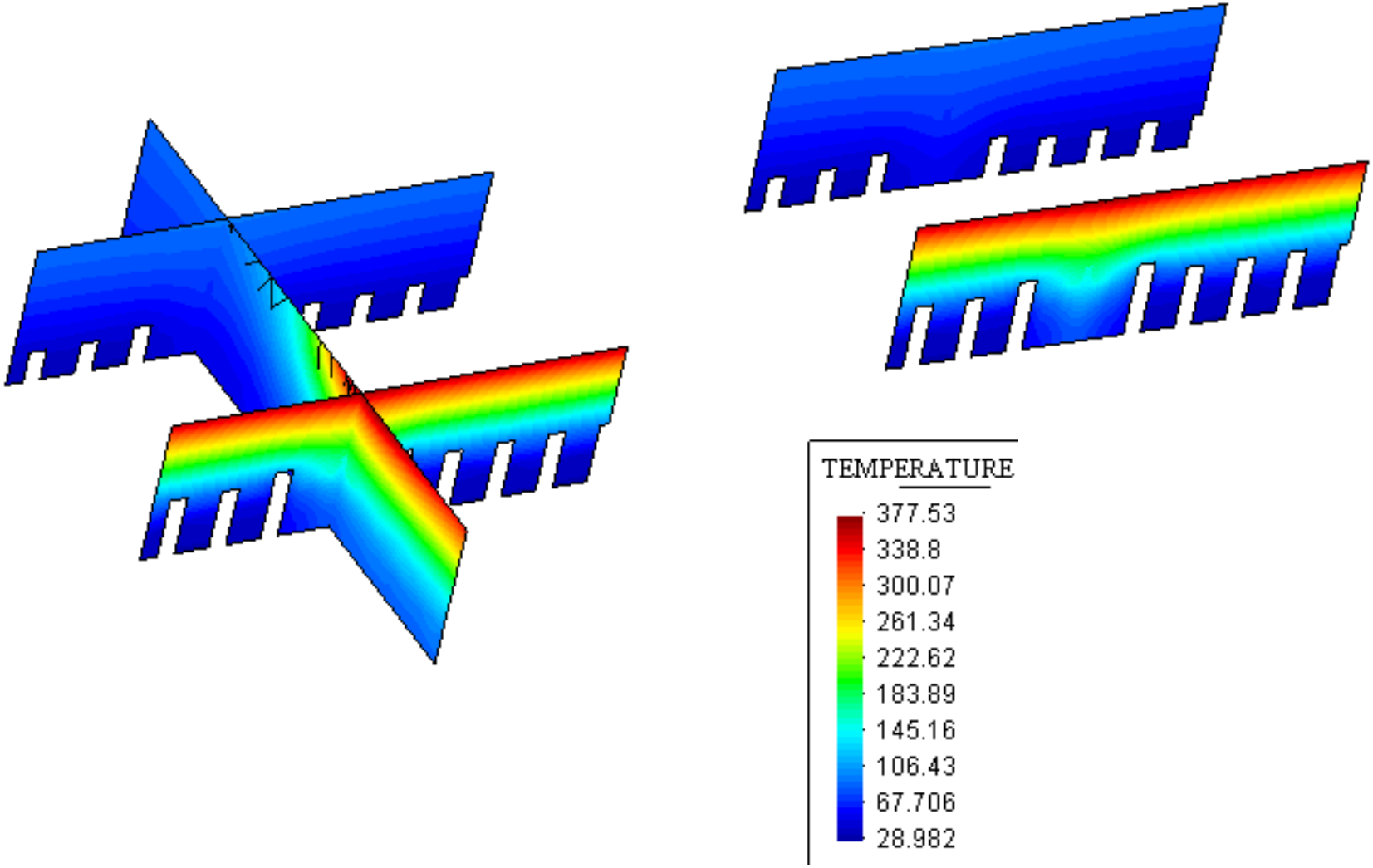
Heat Flux profile (calibrated)



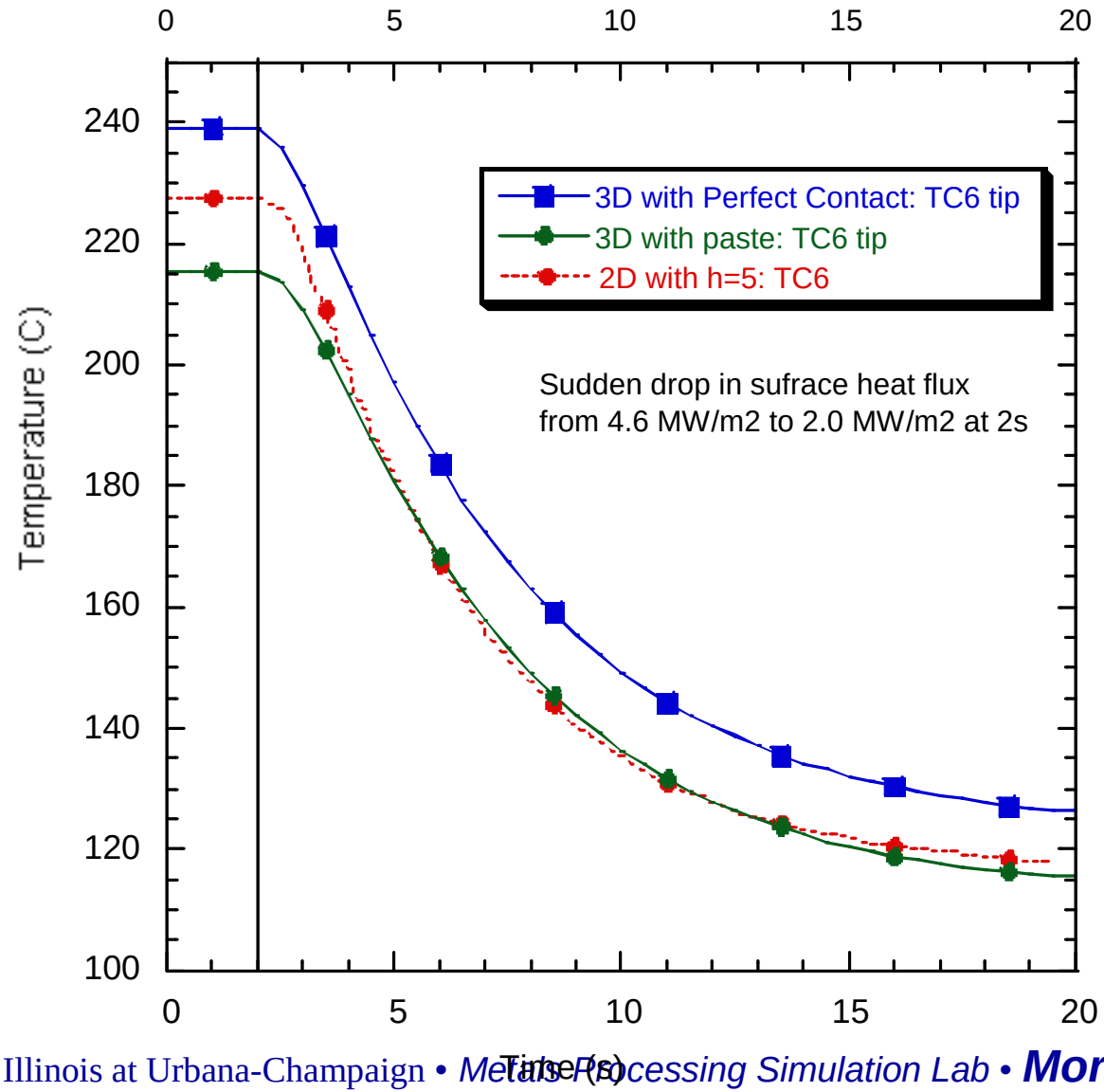
Temperaures (steady state)



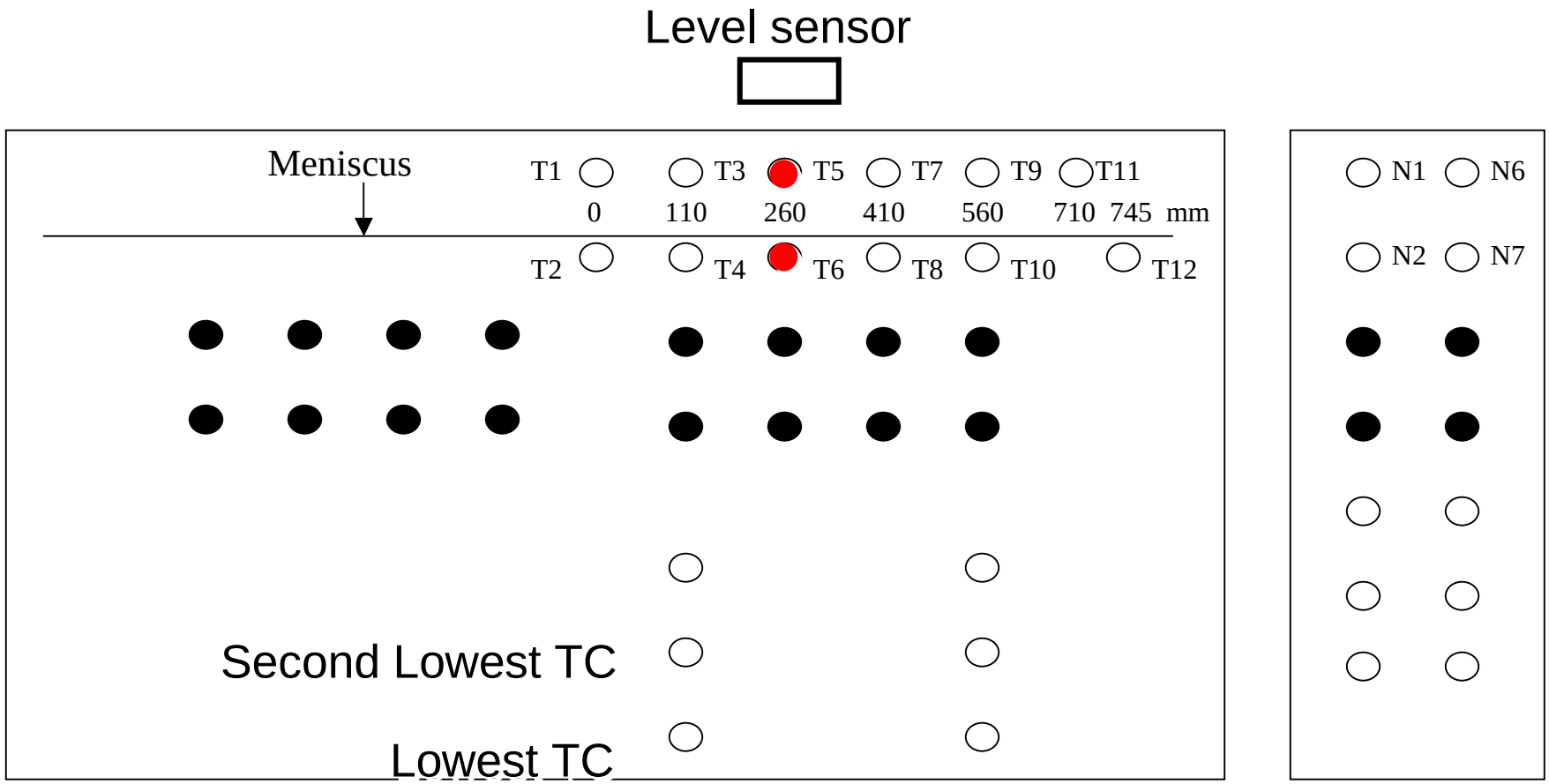
Temperature profiles



Model Validation: compare 2D and 3D calcs

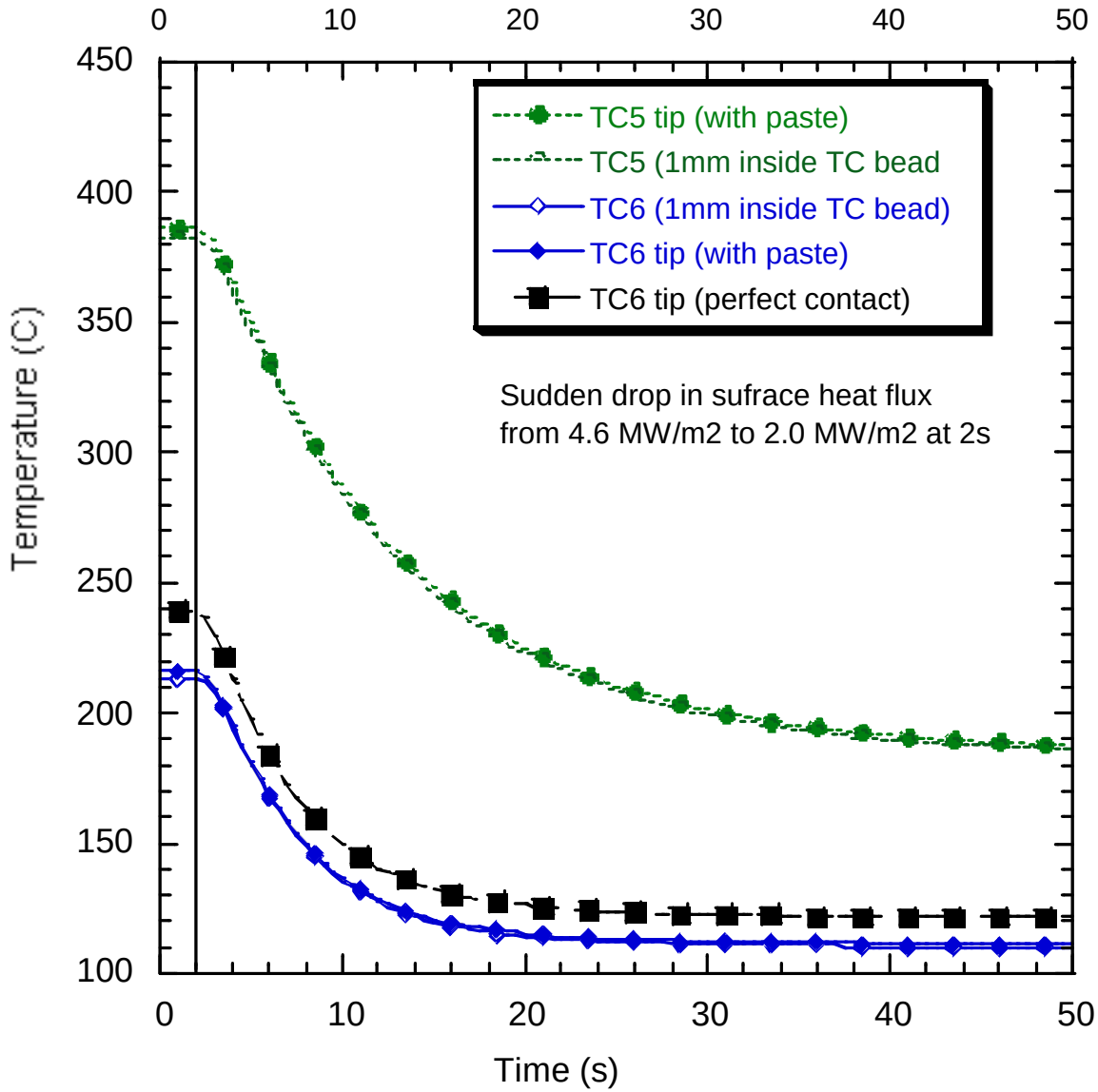


Model Validation: with Columbus instrumented mold (design 2)

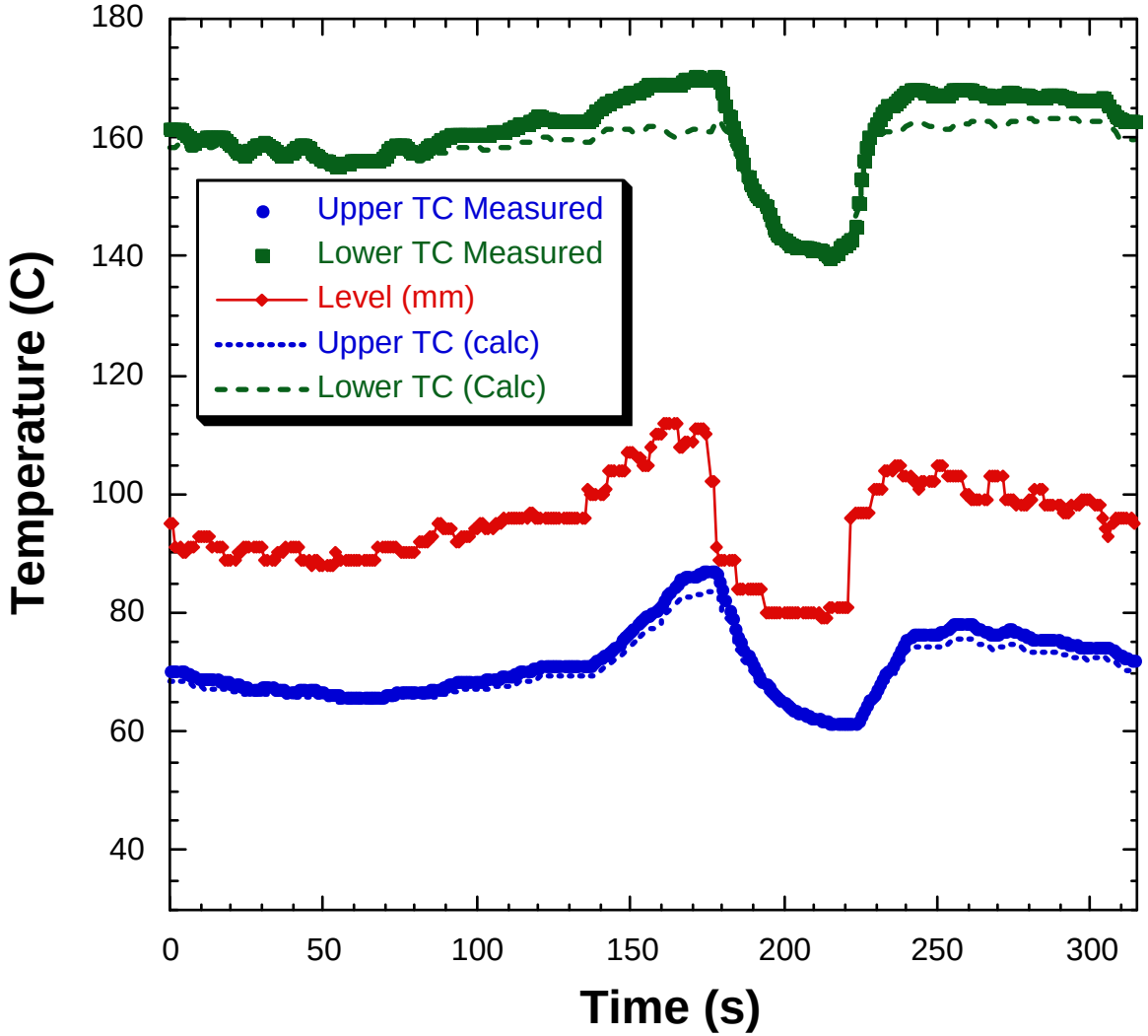


Legend: BOPS ● New T's ○

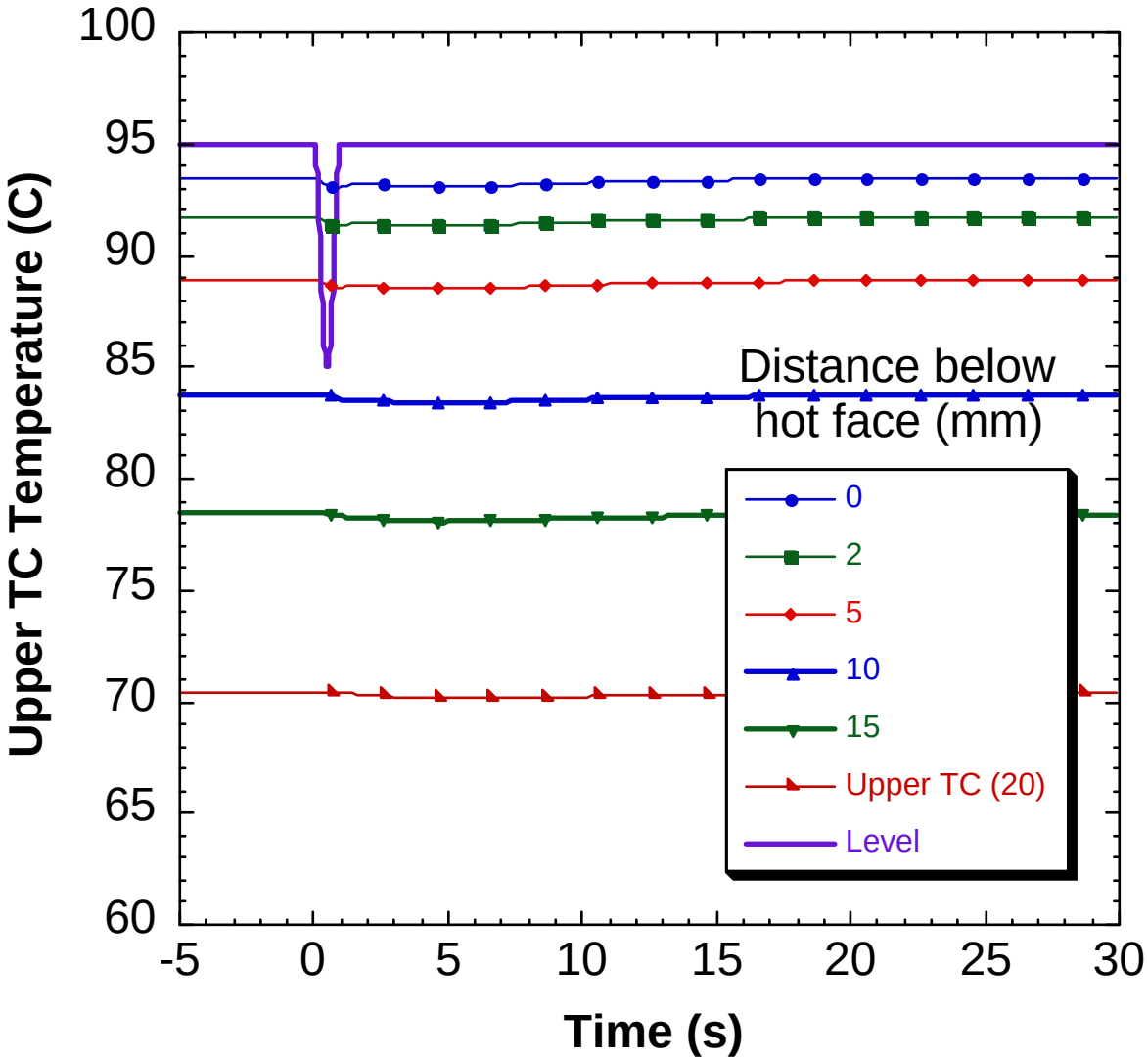
Effect of TC - Cu plate contact condition



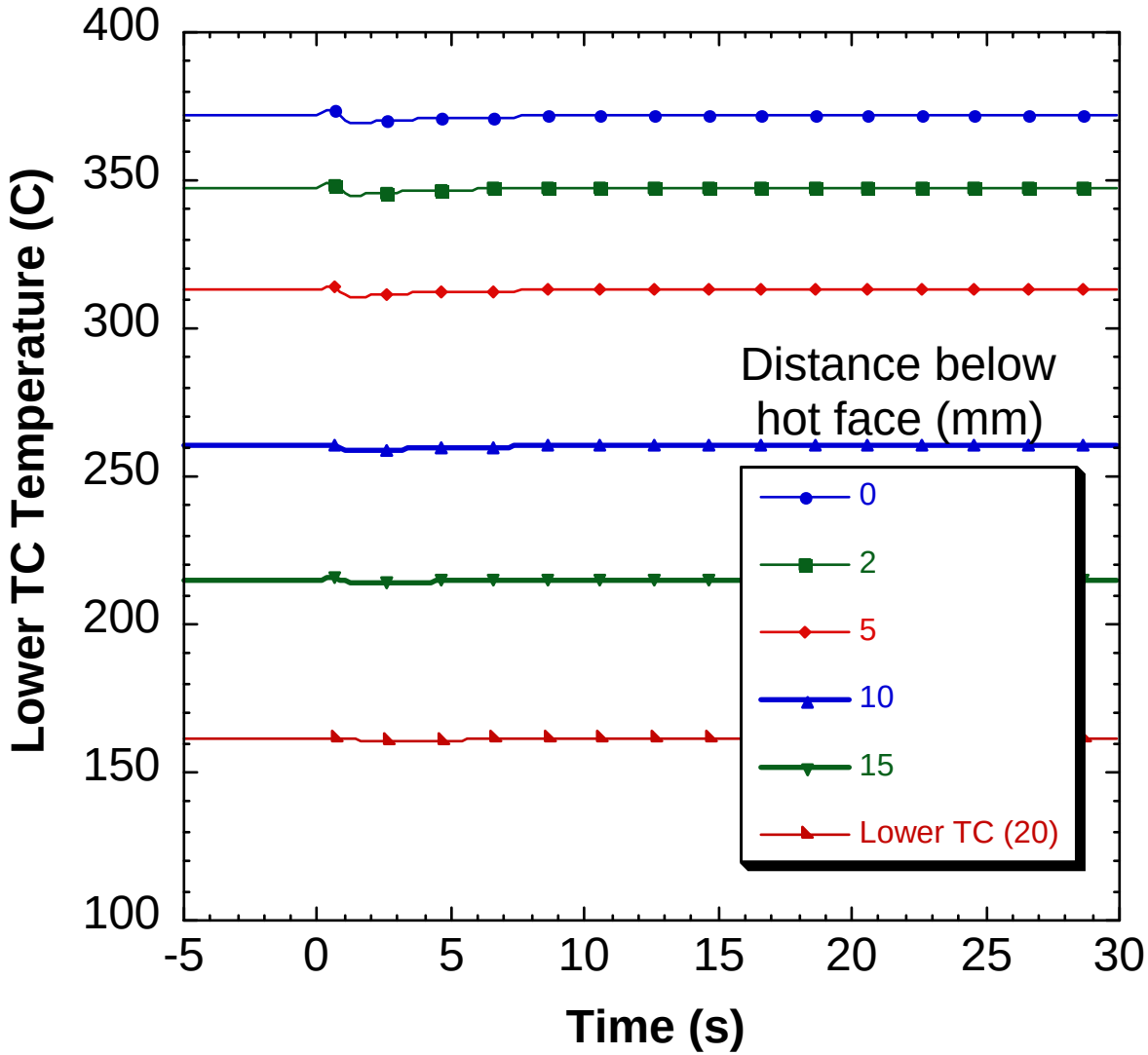
Validation: comparison with measured TC and level histories



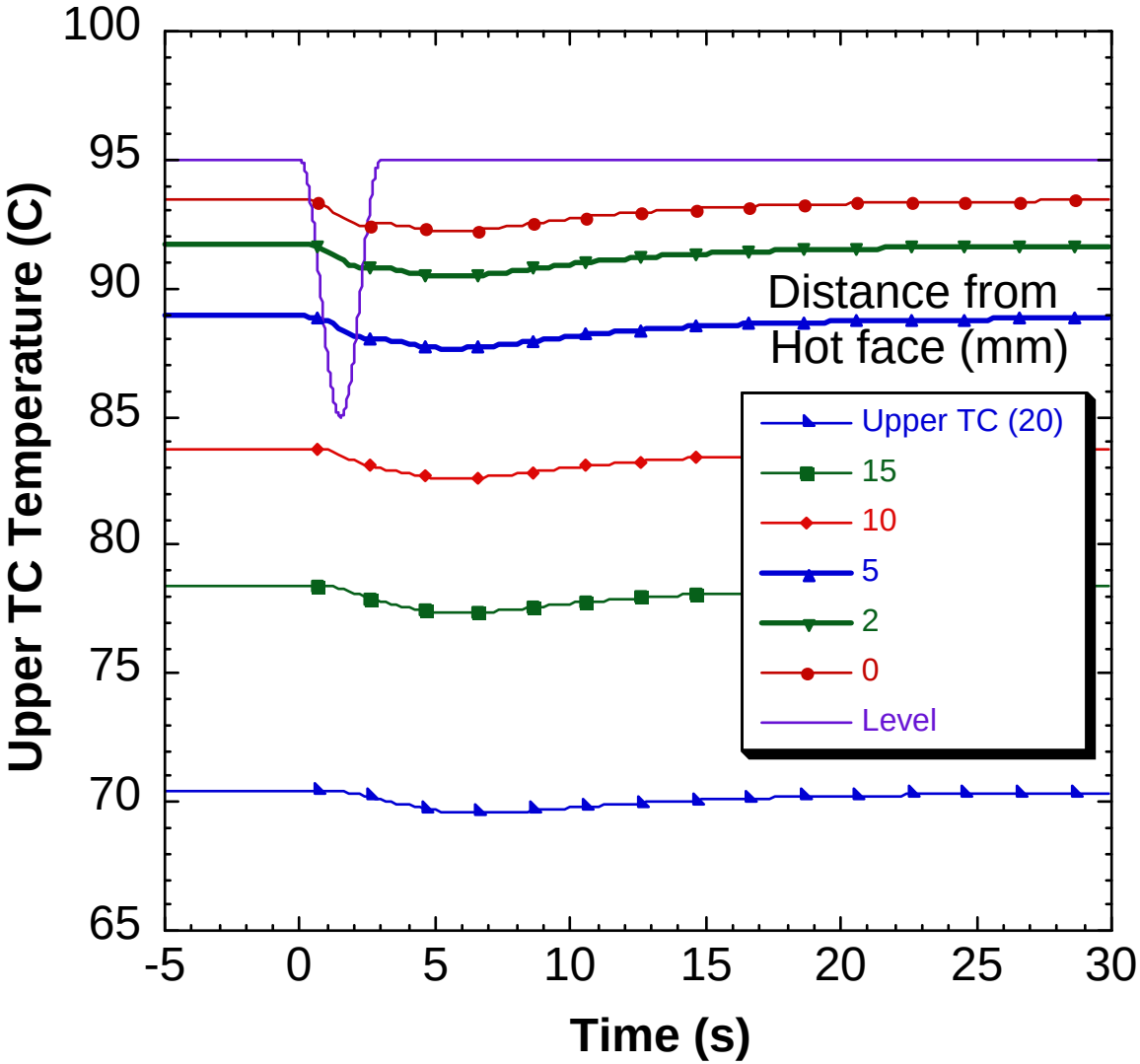
Controled Level Fluctuation: 10mm for 1s



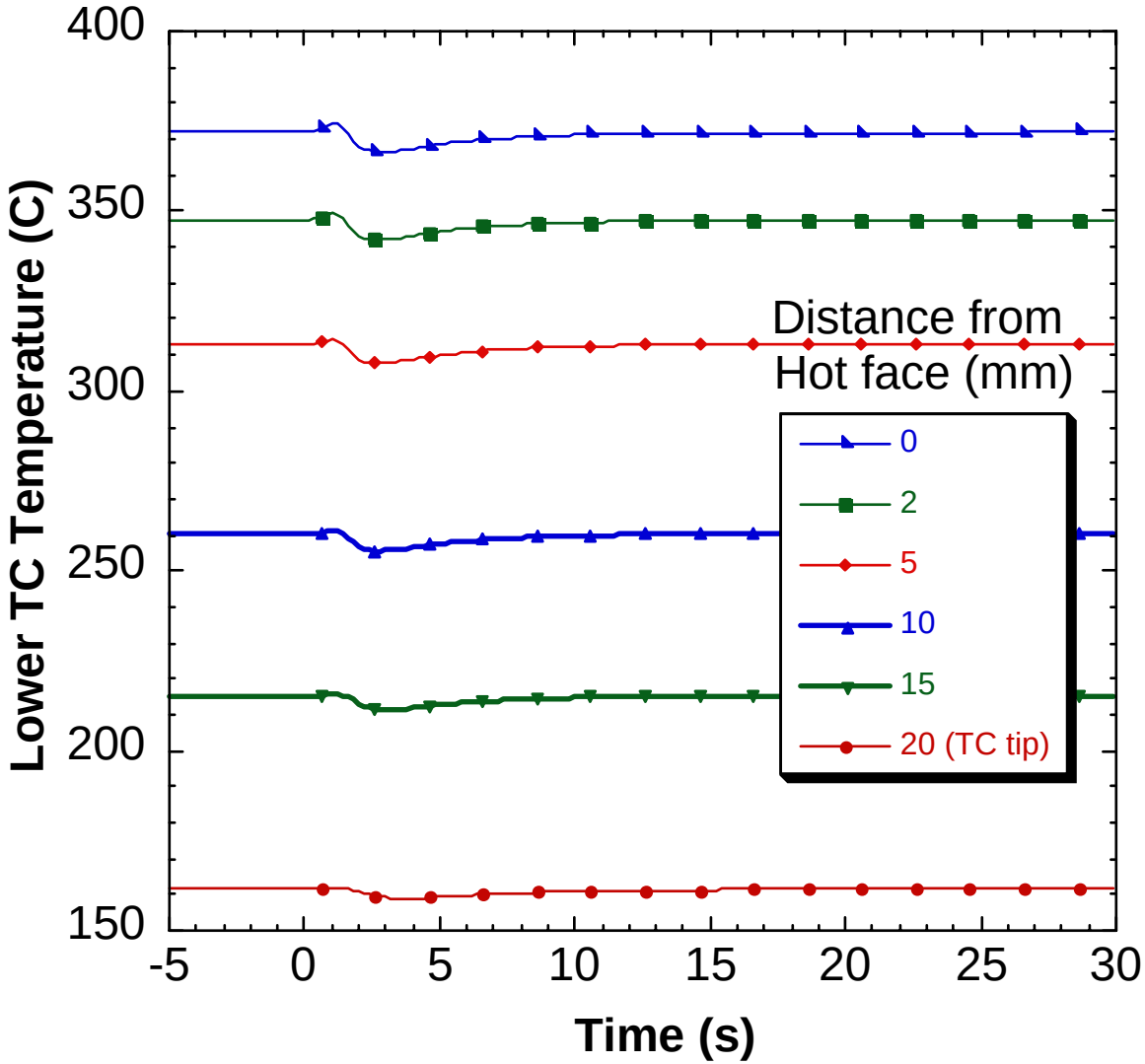
Controled Level Fluctuation: 10mm for 1s



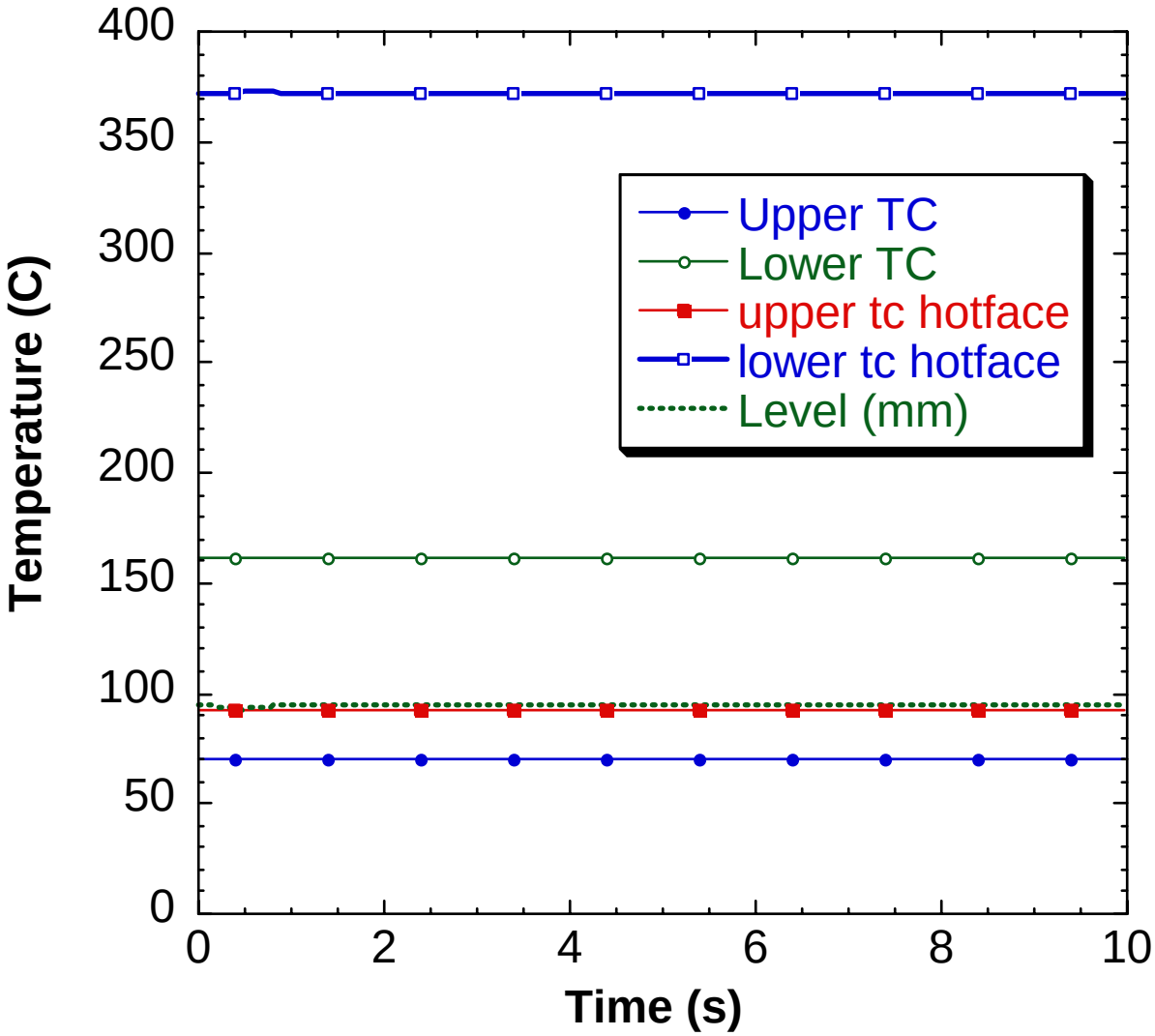
Controled Level Fluctuation: 10mm for 3s



Controled Level Fluctuation: 10mm for 3s

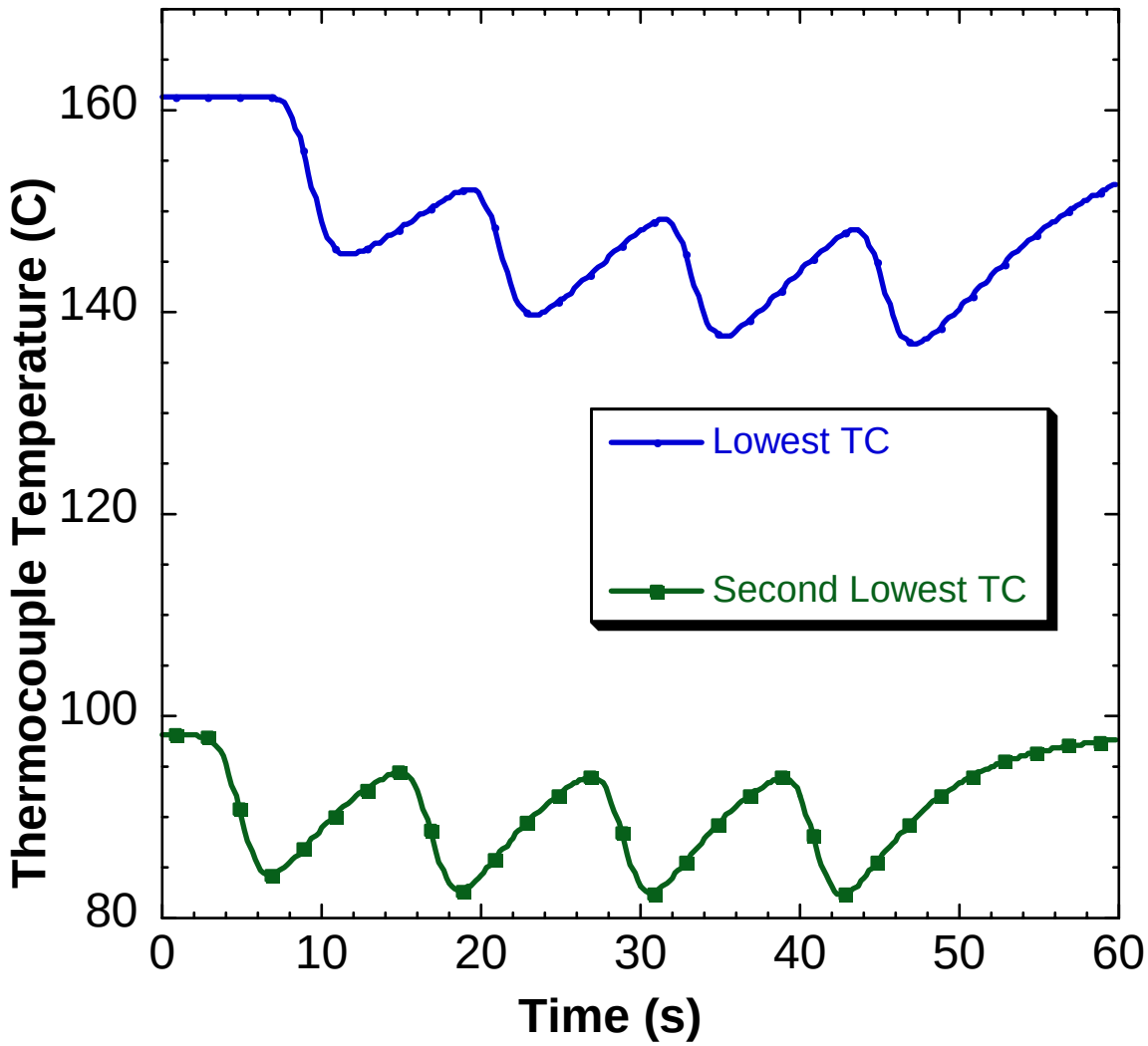


Controled Level Fluctuation: 2mm for 1s



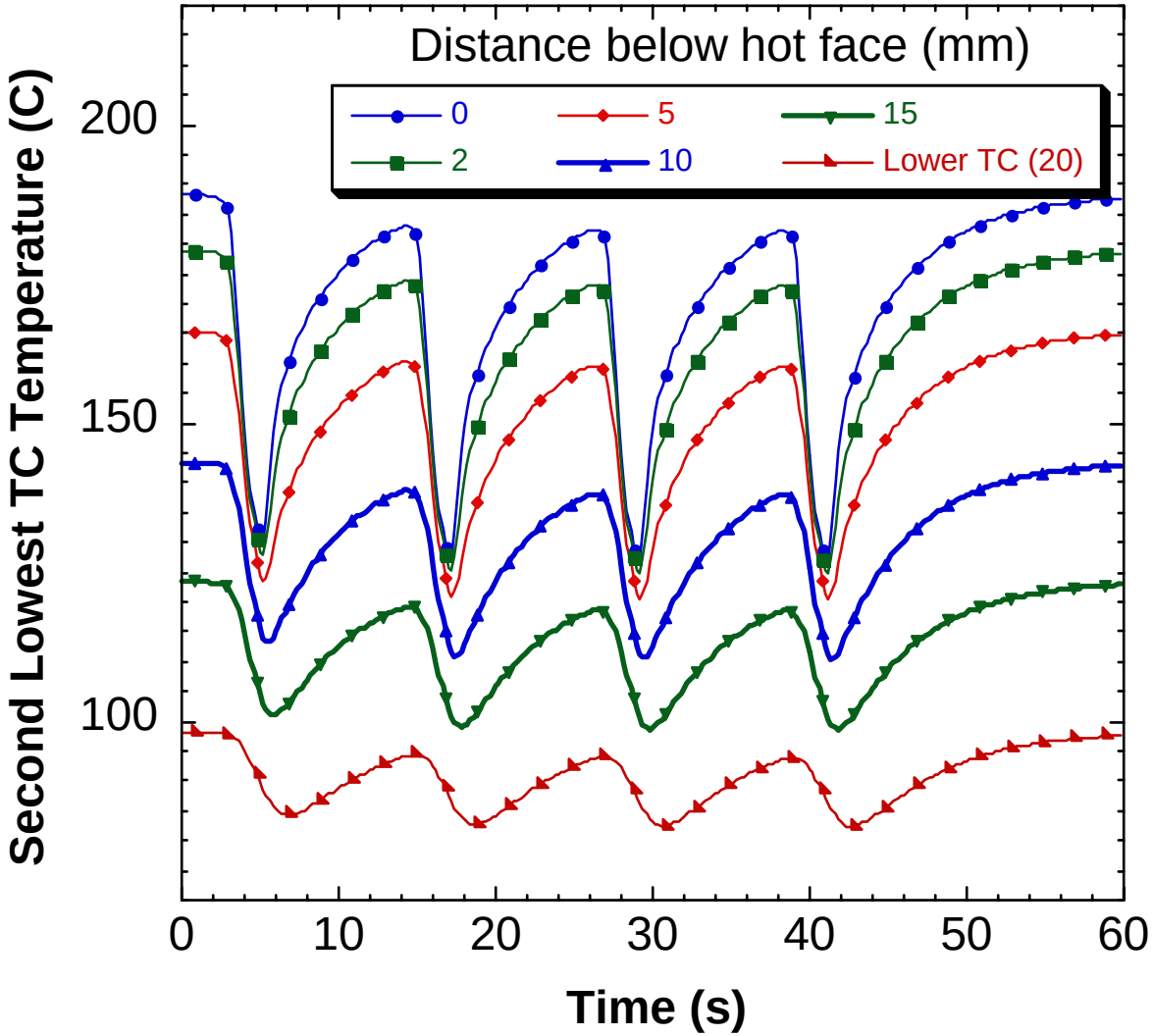
Indetectable !

Severe Oscillation marks passing mold bottom



Alternate between:
1.7 MW/m^2 for 10s
0.2 MW/m^2 for 2s

Severe Oscillation marks passing mold bottom



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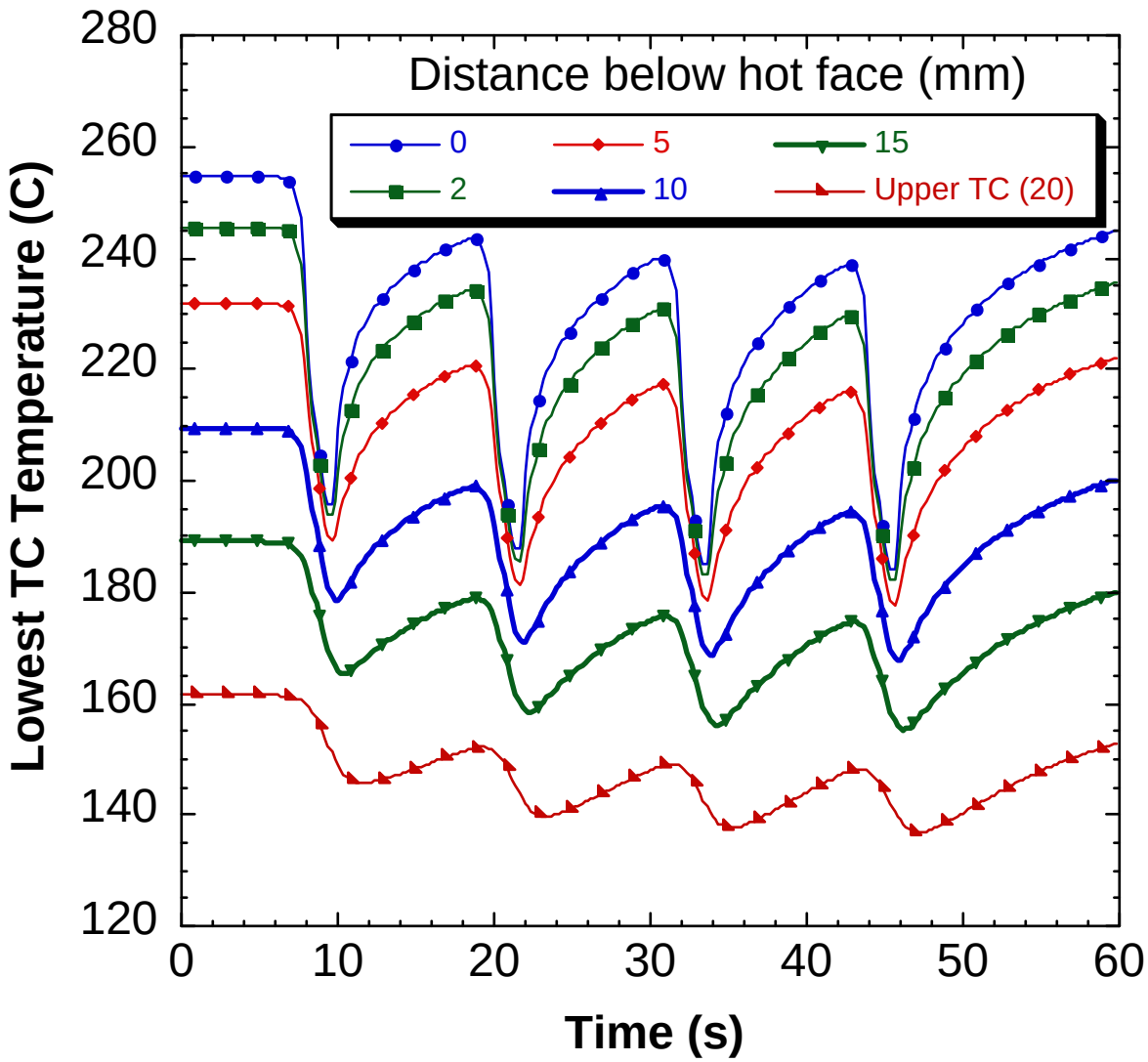
Severe Oscillation marks passing mold bottom



Alternate between:
1.7 MW/m^2 for 10s
0.2 MW/m^2 for 2s

Conclusions

- Compuated TC signals match measurements well
- TC signals drop with imperfect contact to mold Cu
- Thermocouples near meniscus (both above and below) **are** able to detect major level fluctuations
- Small level fluctuations produce very minor changes in TC readings and tinyones (2mm for 1s) are not detectible
- TCs near to hot face can detect minor level fluctuations better
- TC temperature fluctuations lower in mold of 10-20 deg C indicate severe heat flux variations (eg. due to flux layer breakage and alternating air gaps)