Radiant Heating Panel
Thermal Analysis

Prepared by Tim Fleury

Harvard Thermal, Inc.

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Harvard Thermal, Inc.
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Analysis Objective

•Perform a thermal test on a small sample of the concrete panel to determine the Thermal Conductivity and Specific Heat of the concrete

•Generate a thermal model of the panel and heating fluid to determine the heat added to the room per panel

•Document the thermal analysis results

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Major Assumptions

- Plastic housing on concrete constructed of Polystere or equivalent material with thickness of 0.093 inches
- PEX tubing wall thickness = 0.062 inches
- PEX tubing deforms to fill the groove in the concrete
- Sub flooring consists of ½ inch thick plywood with no insulation
- Room temperature remains constant at 68 °F
- No material on top of concrete
- Radiation emissivity is 0.8 for all surfaces

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Thermal Conductivity Test - Procedure

- The purpose of the test was to determine the thermal conductivity of the concrete
- A constant heat load (1.62 Btu/Hr) was applied to one surface of the concrete while the opposite surface was clamped to a coldplate
- Heat load consisted of a resistor attached to a ¼ inch thick aluminum plate
- Thermal grease was used at all interfaces
- The sample was heated to a stabilized temperature of 63.5 °F
- Coldplate was maintained at a constant temperature of 53.7 °F
- A thermal model was generated to verify the test results
- Based on the results, the thermal conductivity of the concrete was calculated to be 0.381 Btu/Hr-ft-°F

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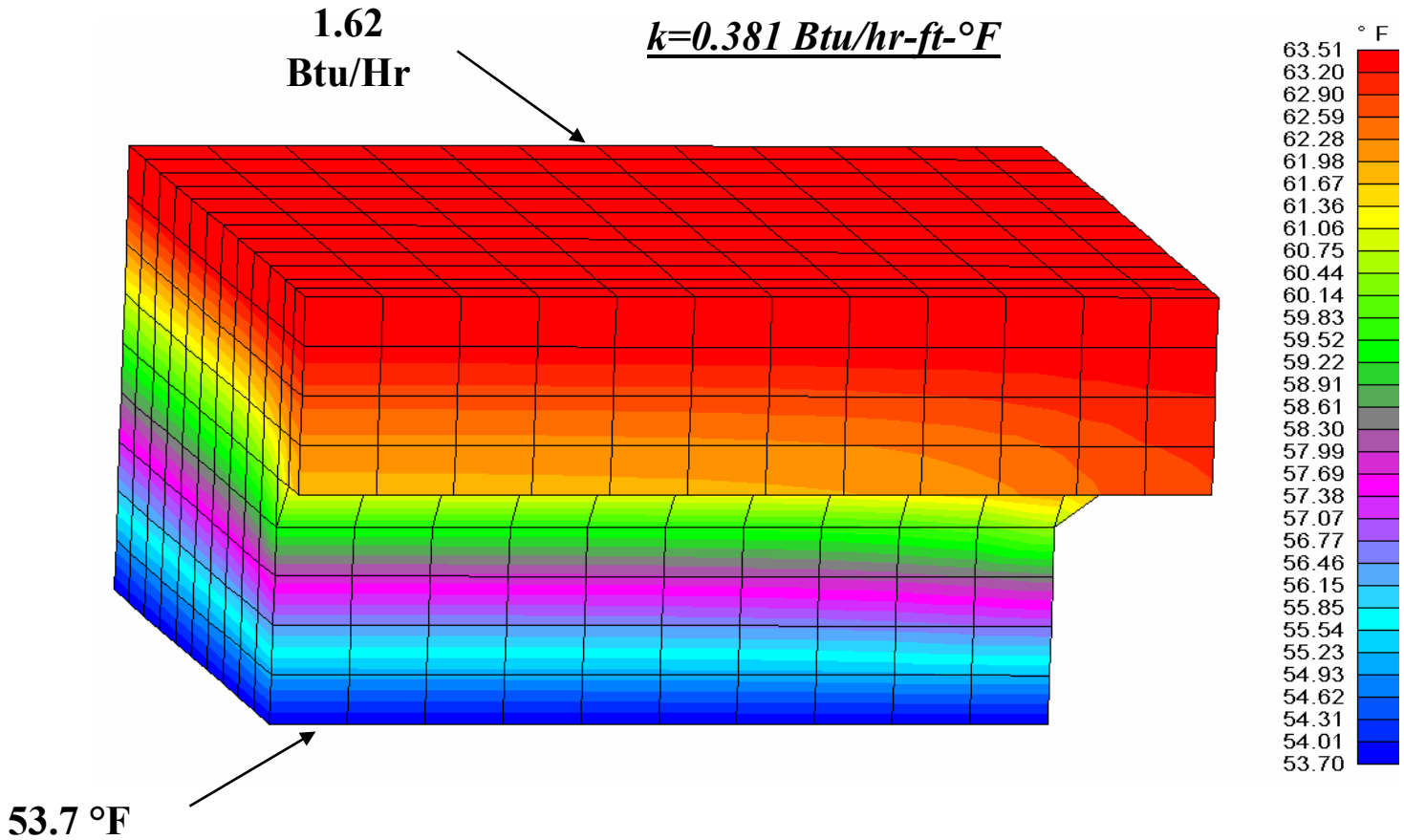
Thermal Conductivity Model



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Specific Heat Test - Procedure

- The purpose of the test was to determine the Specific Heat of the concrete
- Panel sample was heated to a stabilized temperature (63.4 °F) then allowed to cool down with no heat applied
- Coldplate was held to a constant temperature of 53.0 °F
- The heat source was then turned off
- Temperature difference between the heat source area and cold plate interface was monitored during the cool down period
- Based on the results, the Specific Heat (Cp) of the concrete was calculated to be 0.19 Btu/lbm-°F

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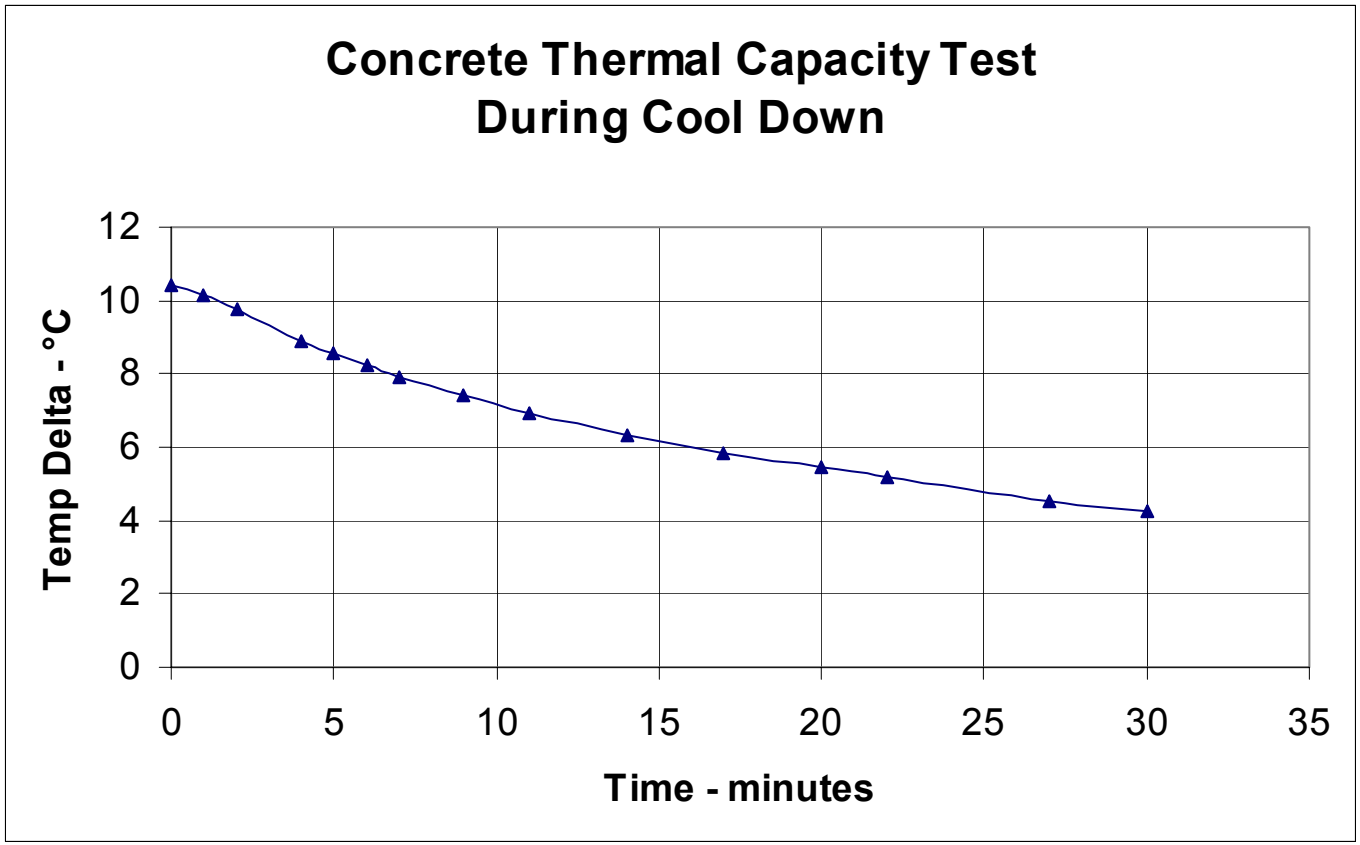
Specific Heat Test Data



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Specific Heat Test - Results

- Based on heat transfer formula:

$$(T-T_{cp})/(T_o-T_{cp}) = e^{-(t/RC)}$$

- At t=30 minutes; Tcp = 53 °F, To = 63.4 °F, T = 57.3 °F
- Thermal resistance of the sample (extracted from thermal conductivity test) = R = 6.0 Hr-°F / Btu (11.4 °C/W)
- The Capacitance, C, = Specific Heat (Cp) x Weight
- Weight of concrete sample = 0.489 lbs (222 gms)
- Based on the results, the Specific Heat (Cp) of the concrete was calculated to be 0.19 Btu/ lbm-°F

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Radiant Panel Model

- A model of the radiant panel was generated using TAS (Thermal Analysis System) software
- Model included the panel, water flow, plywood subfloor, and convection and radiation
- Water inlet conditions were:
    - 0.5 gpm, 90 °F water
    - 0.5 gpm, 140 °F water
    - 2.0 gpm, 90 °F water
    - 2.0 gpm, 140 °F water:

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Material Properties
Thermal Conductivity

Number	1	2	3	4		Units
Description	PEX Tubing	Concrete	Plywood	Polysterene		
X Conductivity	0.018300	0.031750	0.066600	4.580e-003		Btu/(hr-inF)
Y Conductivity	0.018300	0.031750	0.066600	4.580e-003		Btu/(hr-inF)
Z Conductivity	0.018300	0.031750	0.066600	4.580e-003		Btu/(hr-inF)

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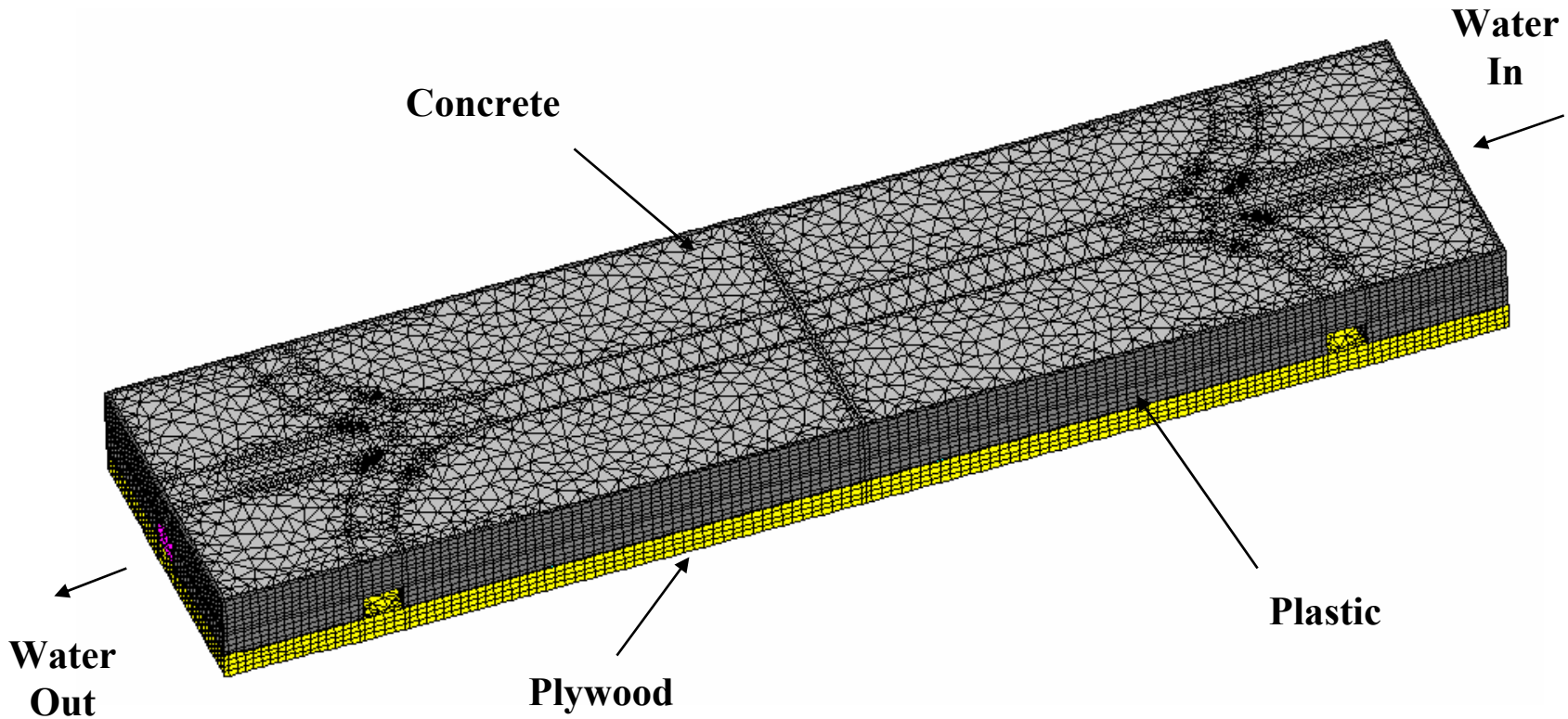
Radiant Panel Model



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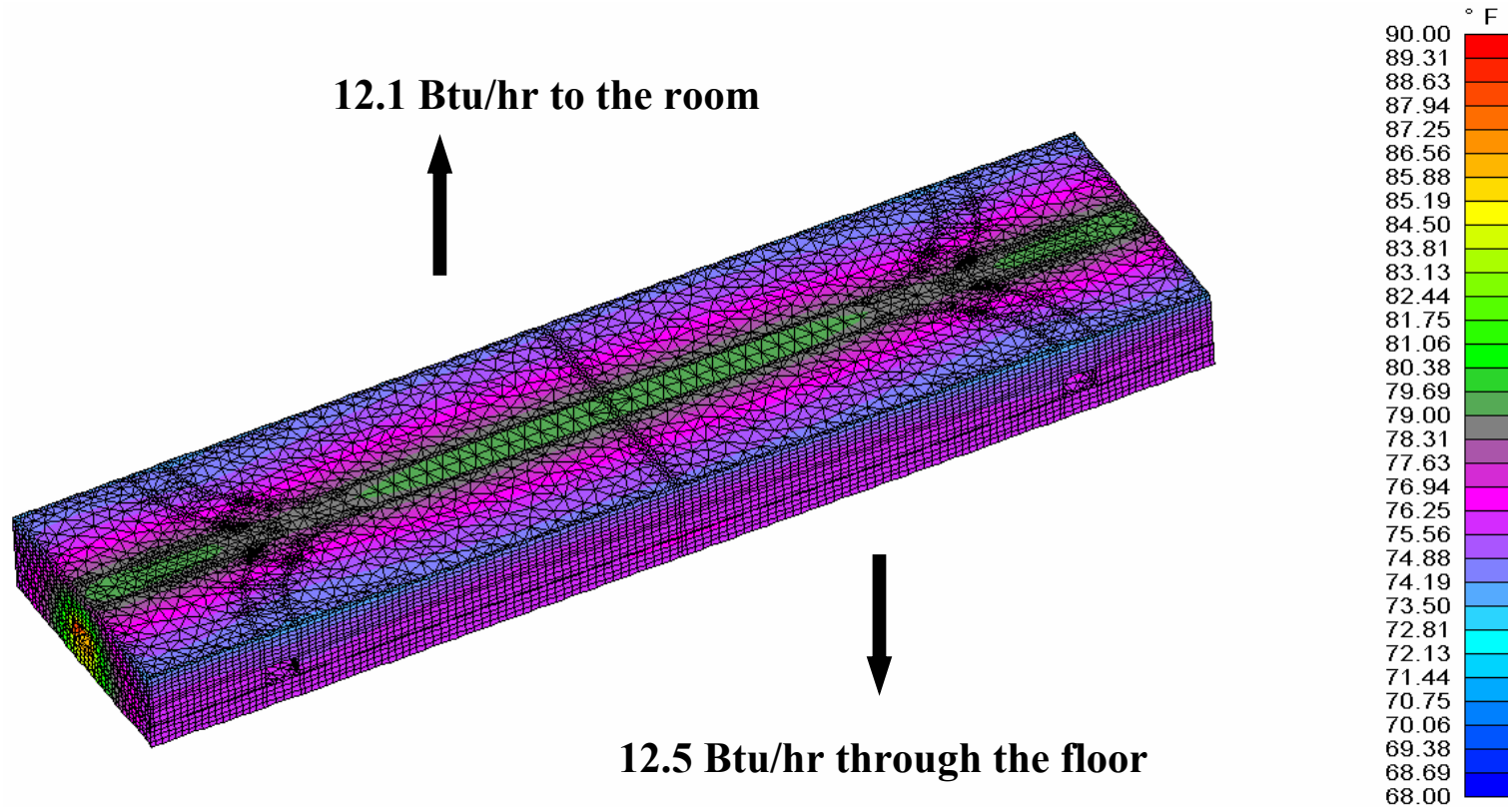
Thermal Results
0.5 GPM, 90 °F



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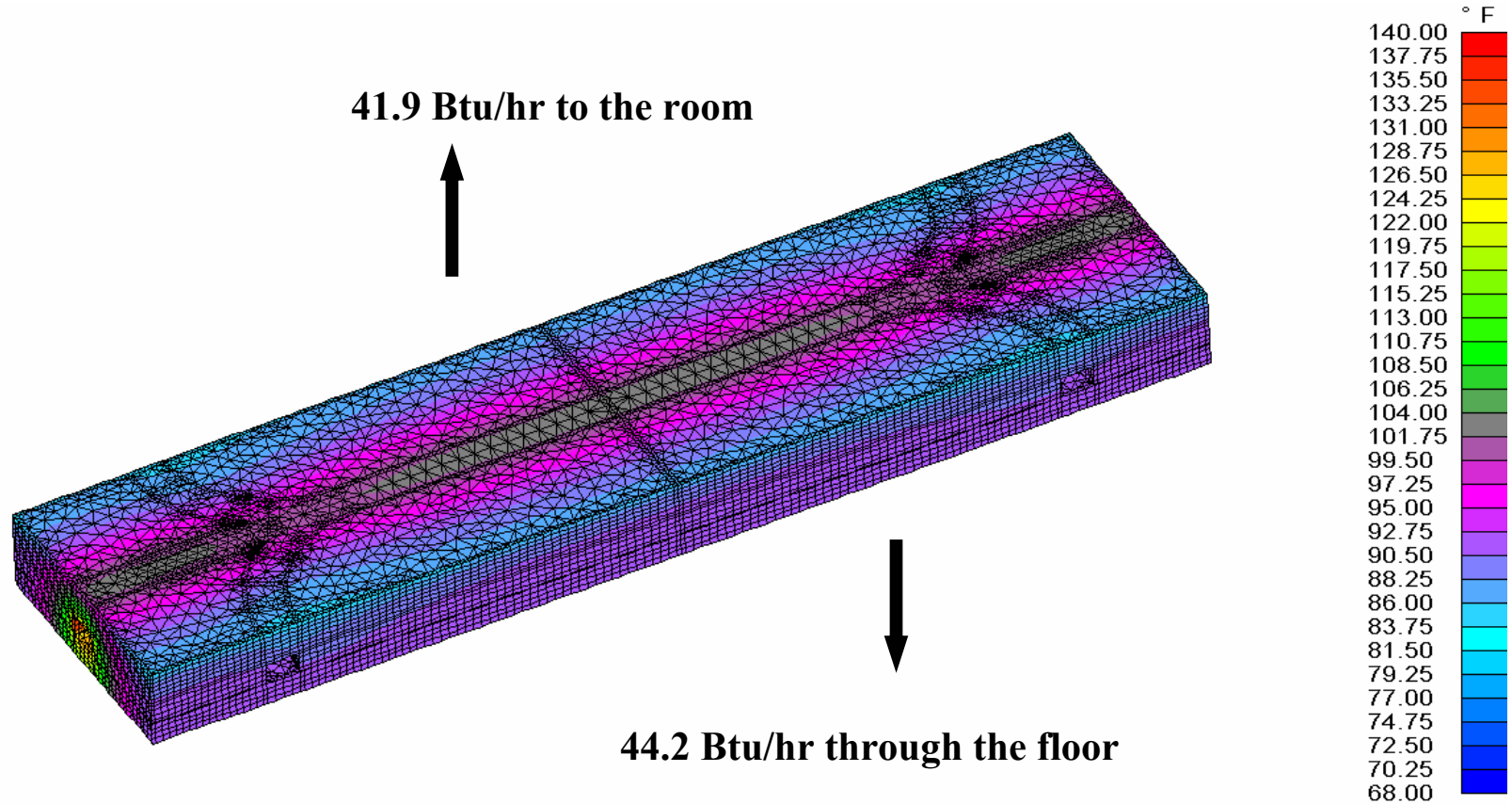
Thermal Results
0.5 GPM, 140 °F



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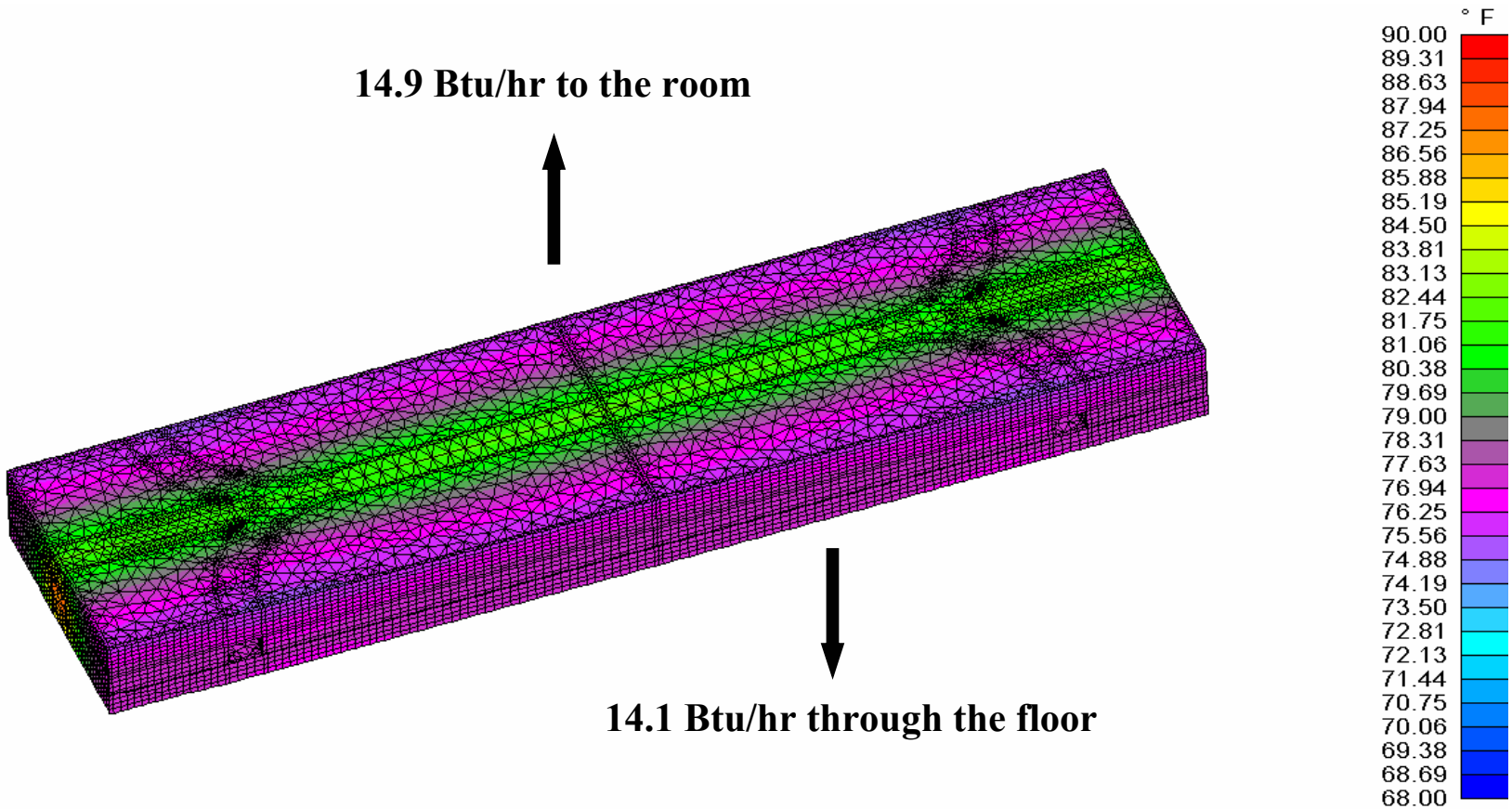
Thermal Results
2.0 GPM, 90 °F



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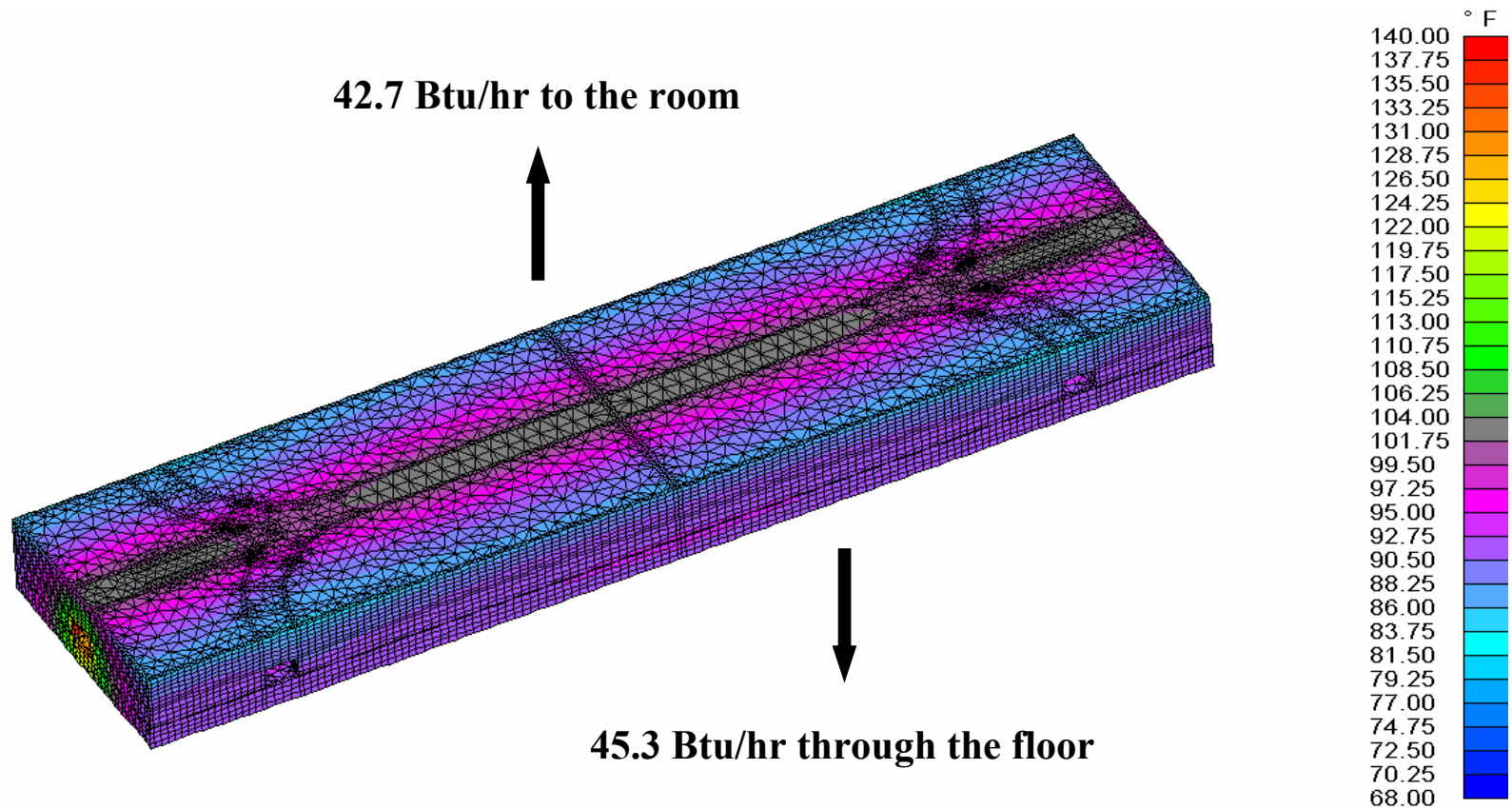
Thermal Results
2.0 GPM, 140 °F



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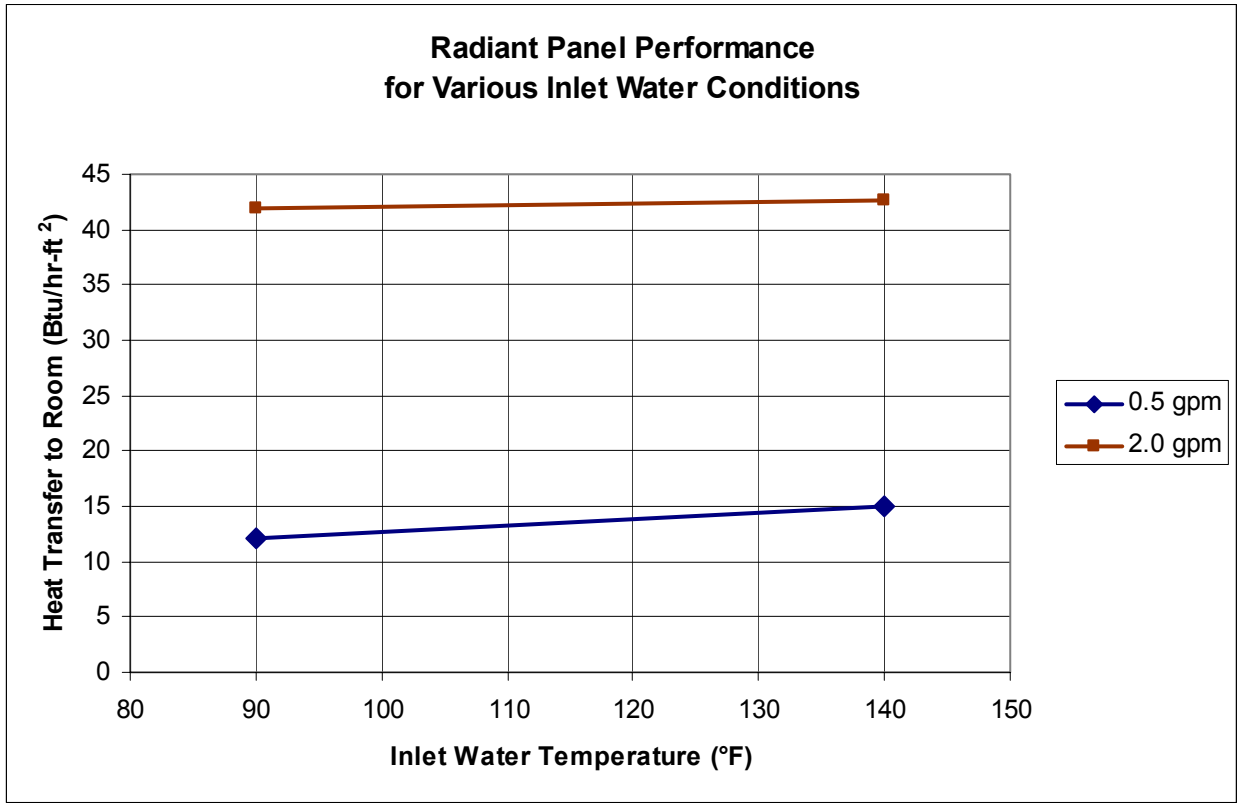
Radiant Panel Performance Summary



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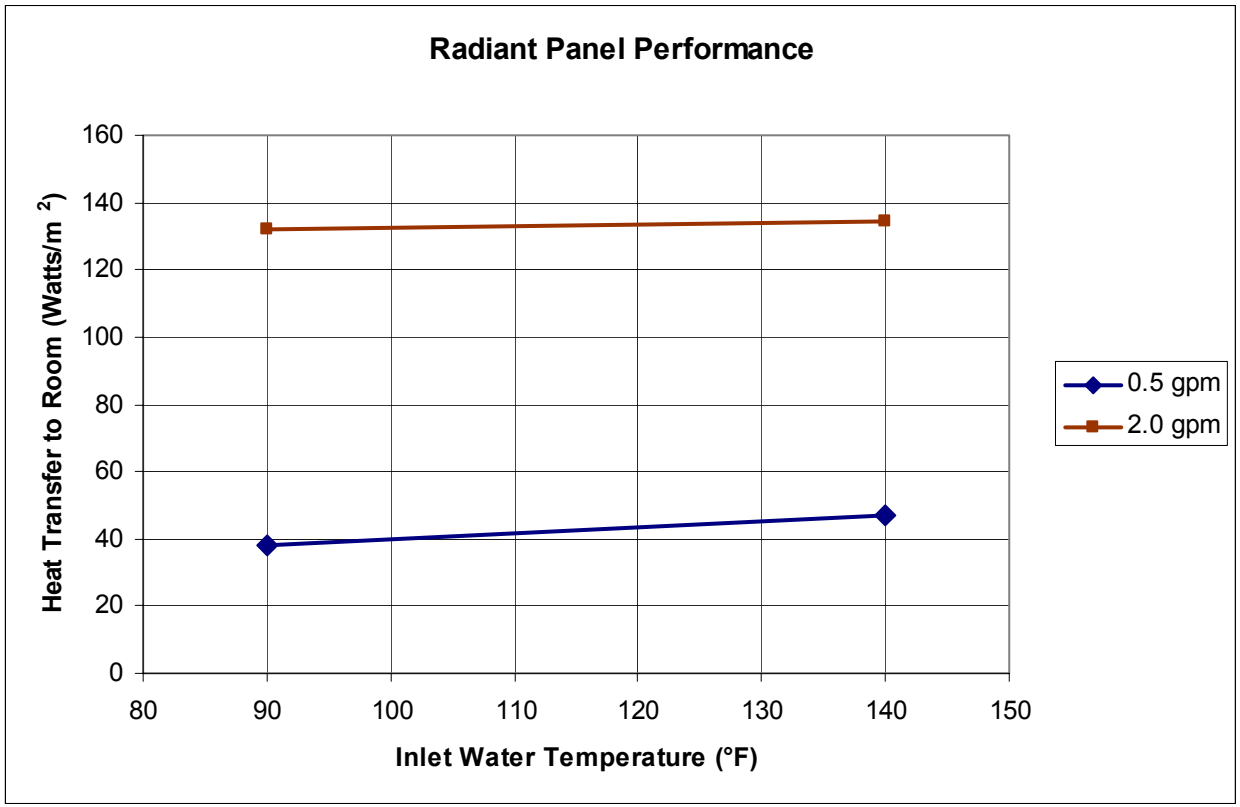
Radiant Panel Performance Summary
SI Units



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Summary

- The Thermal Conductivity (k) of the concrete was tested to be:

  k = 0.381 Btu/hr-ft-°F

- The Specific Heat (Cp) of the concrete was tested to be:

  Cp = 0.19 Btu/lbm-°F

- The heat transfer rate to the room, per panel, was analyzed to be:

0.5 gpm, 90 °F water:	12.1 Btu/hr-ft^2	(38 W/m^2)
0.5 gpm, 140 °F water:	41.9 Btu/hr-ft^2	(132 W/m^2)
2.0 gpm, 90 °F water:	14.9 Btu/hr-ft^2	(47 W/m^2)
2.0 gpm, 140 °F water:	42.7 Btu/hr-ft^2	(135 W/m^2)

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Summary (continued)

- The equivalent heat transfer coefficient to the room, per panel, based on a temperature differential between the inlet water temperature and room temperature:

  0.5 gpm, 90 °F water: 0.551 Btu/hr-ft^2-°F (3.13 W/m^2-°C)

  0.5 gpm, 140 °F water: 1.905 Btu/hr-ft^2-°F (3.30 W/m^2-°C)

  2.0 gpm, 90 °F water: 0.679 Btu/hr-ft^2-°F (3.85 W/m^2-°C)

  2.0 gpm, 140 °F water: 1.941 Btu/hr-ft^2-°F (3.37 W/m^2-°C)

- Half of the heat is transferred through the subfloor
- Adding insulation to the subfloor will improve the heat rate to the room

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