REHAU MONTANA ECOSMART HOUSE PROJECT
Bozeman, MT
RMEH 04 Test Report

Evaluation of Pickup Response Time of Radiant Floor Using Different Water Supply Temperatures

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Executive Summary

Experiment RMEH 04 was conducted at the REAHU Montana Ecosmart House (RMEH) in Bozeman in order to evaluate the pickup response time of the radiant floor heating system at different radiant water supply temperatures and compare the results obtained for different floor configurations. It was determined that it took approximately 50% less time to increase the floor temperatures from 70°F - 90°F with a 120°F HWS compared to 105°F HWS.

Comparison of response time among the three different existing floor configurations at the RMEH is well exemplified in Table 1. The lower level, insulated slab on grade, showed the slowest pickup time where it did not reach 90°F with a HWS temperature of 105°F over the 3-day timeframe. This slab took nearly 30 hours to achieve 90°F from 70°F when the HWS temperature was 120°F. The main level, Amvic AmDeck™ insulated concrete form, provided a pickup time of 53 hours and approximately 22 hours for HWS temperature of 105°F and 120°F, respectively. The upper level, GYP-CRETE® overpour, showed the fastest response time from 70 to 90°F, with pickup times of 19 and 9 hours for HWS temperatures of 105°F and 120°F, respectively.

Area weighted average pickup times for each level and hot water supply (HWS) temperature are summarized in Table 1.

Table 1. Pickup Times for Each Floor Based on HWS Temperature

Pickup Interval (°F)	Lower Level (Slab) Pickup Time (hrs)		Main Level (Amvic) Pickup Time (hrs)		Upper Level (Overpour) Pickup Time (hrs)	
	105°F HWS	120°F HWS	105°F HWS	120°F HWS	105°F HWS	120°F HWS
70 to 72	2.38	1.22	2.31	1.58	0.99	0.67
72 to 74	2.69	1.31	2.51	1.60	1.07	0.69
74 to 76	3.15	1.44	2.78	1.65	1.18	0.72
76 to 78	3.87	1.60	3.17	1.71	1.31	0.75
78 to 80	5.26	1.82	3.75	1.80	1.54	0.81
80 to 82	8.33	2.16	4.74	1.92	2.08	0.87
82 to 84	32.57	2.73	6.71	2.10	4.54	0.96
84 to 86	---	4.12	10.96	2.39	1.60	1.04
86 to 88	---	7.57	11.16	2.96	1.95	1.12
88 to 90	---	5.78	4.93	4.10	2.52	1.28
Total Time	∞	29.76	53.01	21.81	18.78	8.90
Average Time per Two Degrees F	---*	2.98	3.71	2.18	1.88	0.89

*Note: Average was not computed since lower level never achieved 90°F in this configuration

Experiment Description

The purpose of this experiment was to measure the pickup response time of radiant floor heating (RFH) from 60°F to 90°F using a boiler to supply water temperatures of 105°F and 120°F. Starting at 60°F, floor temperatures were raised as quickly as possible and the pickup time from 70°F to 90°F was measured at 2°F increments. Simultaneously, the maximum achievable air temperature was determined. Finally, a

comparison between the three different floor configurations was conducted at the REHAU Montana Ecosmart House (RMEH). Fixed temperatures of 105°F and 120°F were set on the mixing valve to ensure consistent radiant zone supply temperatures. The corresponding buffer tank temperatures were set at 115°F and 130°F with a dead band of 8°F below setpoint. The REHAU Smart Controls (RSC) controlled the radiant supply temperature for each zone. The 105°F experiment was performed over a 3-day period while the 120°F experiment was performed over 2½-days.

The hydronic radiant floor is made of 1/2" Crossed-linked Polyethylene (PEXa) pipe. The three different types of floors in the house are as follows:

1. Basement: Insulated slab on grade.
2. Main floor: 12" Expanded Polystyrene (EPS) blocks deck on 1-5/8"x10" metal joist 16" OC with an over poured 3" reinforced concrete topping slab, finished with a hardwood panel.
3. Upper floor: GYP-CRETE® overpour finished with a hardwood panel.

Results

As expected, the pickup time increased as floor temperatures increased due to the decrease in temperature differential between the slab and HWS temperature. During the 105°F HWS experiment it was observed that the lower level slab was not able to achieve the desired 90°F within the specified 3-day experiment. The lower level slab had a peak temperature of 84°F during this timeframe. Figure 1 shows the space and slab temperatures versus time for the lower level of the RMEH. The slab temperature is expected to slowly approach an upper limit somewhere below the HWS temperature setpoint based on the how steady the heat transfer rate is in the RMEH. During this experiment it was determined that the required pickup time needed to increase the floor temperatures from 70°F - 90°F was approximately 50% less for a 120°F HWS when compared to a 105°F HWS.

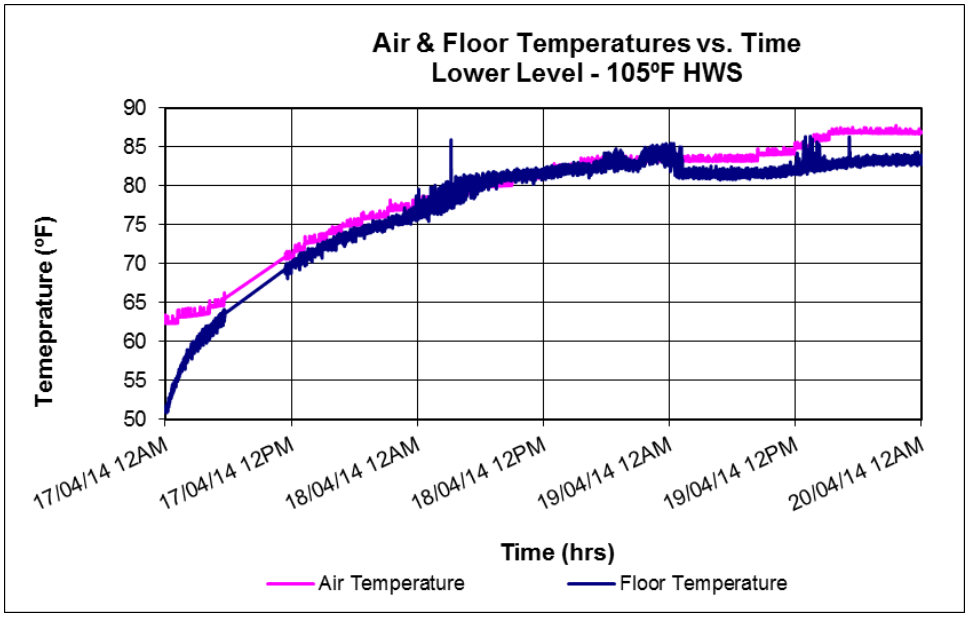

Figure 1. Lower Level Air and Floor Temperatures vs. Time Using 105°F HWS

The main level, constructed with Amvic AmDeck™ insulated concrete forms, took 53 hours to reach 90°F. In contrast, the upper level constructed with a GYP-CRETE® overpour reached 90°F in as little as 8.9 hours

from a 70°F initial temperature. Figure 2 shows the average floor and air temperatures for the main level of the RMEH. Near the end of the experiment the floor and air temperatures began to stabilize due to the limits put in place to prevent the slabs from overheating. RSC was configured this way to avoid structural and floor material stress that could occur from excessive floor temperatures.

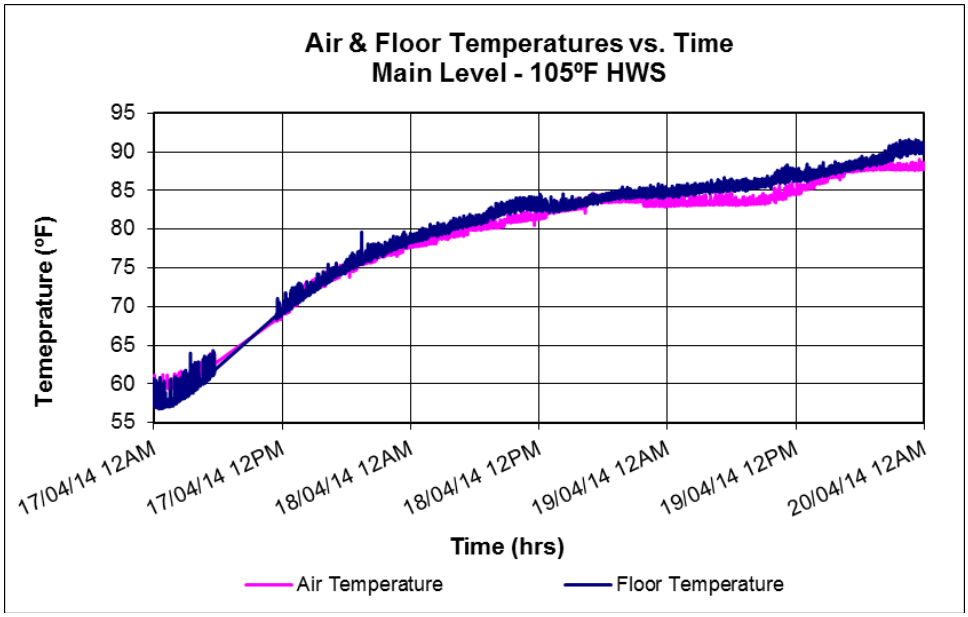

Figure 2. Main Level Air and Floor Temperatures vs. Time Using 105°F HWS

Plots for each floor and HWS temperature combinations are presented in Appendix D. Air temperatures were consistently much closer to floor temperatures during the 105°F HWS experiment. During the 120°F HWS experiment, differences up to 5°F were observed between air and floor temperatures.

Air and floor temperatures for each level were calculated based on an area-weighted average. These values are listed in Table 2. Air temperatures were recorded when the floor temperatures initially hit 90°F and at the end of the experiment. These results provide perspective regarding maximum air temperatures achievable when a floor initially reaches temperature and when it stabilizes at setpoint. Floor temperature limits set within the RSC were accounted for in analysis of this experiment. The cumulative average temperature for the RMEH at the end of the experiment was very close to 90°F for both HWS temperature scenarios. These finding coincide with observations to be expected in radiant floor systems when they achieve near steady-state conditions.

Table 2. Estimation of the Maximum Air Temperature Achievable Simultaneously at the RMEH

Zone	Floor area (ft^2)	Area Ratio	Initial Air Temp When Floor Reached 90°F (°F) (1)		Max Air Temp at End of Experiment (°F) (2)	
			105°F HWS	120°F HWS	105°F HWS	120°F HWS
Rad Zone LL1RAD- Meeting Room	1057.0	0.261	82.00	80.00	88.00	92.00
Rad Zone LL3RAD- Studio / Bathroom	209.0	0.052	82.34	82.64	84.84	88.74
Rad Zone LL6RAD - Storage	165.0	0.041	85.05	87.64	93.73	95.70

Rad Zone ML1RAD - Front Entry and Half Bath	355.0	0.088	87.21	90.68	89.00	92.00
Rad Zone ML3RAD- Study	181.0	0.045	84.97	84.97	95.12	93.51
Rad Zone ML4RAD - Dining and Living Rooms	477.0	0.118	88.00	83.00	89.00	89.00
Rad Zone ML5RAD - Kitchen	198.0	0.049	90.00	89.00	89.00	89.00
Rad Zone ML6RAD - Laundry	112.0	0.028	84.42	81.03	90.92	89.87
Rad Zone UL1RAD - Master Bedroom	191.0	0.047	76.00	73.00	88.00	83.00
Rad Zone UL2RAD - Master Bath	198.0	0.049	75.87	80.07	89.07	91.48
Rad Zone UL3RAD - Daughters Living Area	250.0	0.062	80.00	81.00	89.00	91.00
Rad Zone UL4RAD - Daughters Bed Room	172.0	0.042	86.53	86.09	87.79	89.88
Rad Zone UL5RAD - Guest Bedroom and Bath	232.0	0.057	85.04	86.38	94.64	90.90
Rad Zone UL6RAD - Daughters Bath	76.0	0.019	79.88	80.07	90.88	87.57
Rad Zone UL7RAD - Hallway	176.0	0.043	80.48	80.09	89.56	94.40
Total / Weighted Average	**4049.0**	**1**	**83.5**	**82.8**	**89.3**	**90.8**

Notes: (1) Maximum temperature achieved when floor did not reach 90°F
(2) Floor temperature limit was set to 95°F and 90°F, respectively using RSC

A plot of the radiant supply and return fluid temperatures versus time illustrates the evolution of the average temperature difference (ΔT) for each buffer tank setpoint as seen in Figure 3 and Figure 4. These plots also show that it took approximately 36 hours to effectively reach setpoint temperature in the buffer tank for both the 115°F and 130°F setpoints. The buffer tank achieved average temperatures of 104°F and 120°F after the initial 36 hour ramp up time. These averages are below setpoint by almost 10°F. Even though the buffer tank deadband was set at 8°F in the RSC, the average temperatures were expected to be no more than 4°F less than setpoint. These plots also show how the boiler needed approximately 36 hours to bring the buffer tank to its setpoint temperature while under load from the radiant zones.

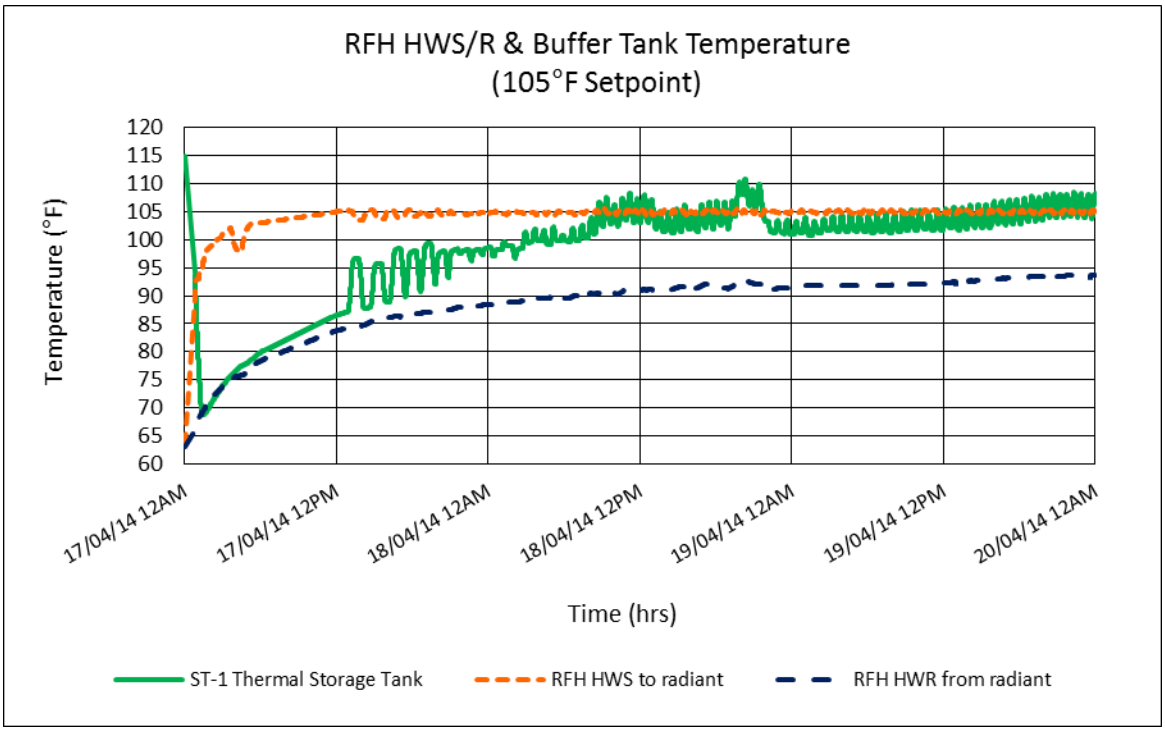

Figure 3. RFH Supply, Return, and Buffer Tank Temperature at 105°F HWS Setpoint

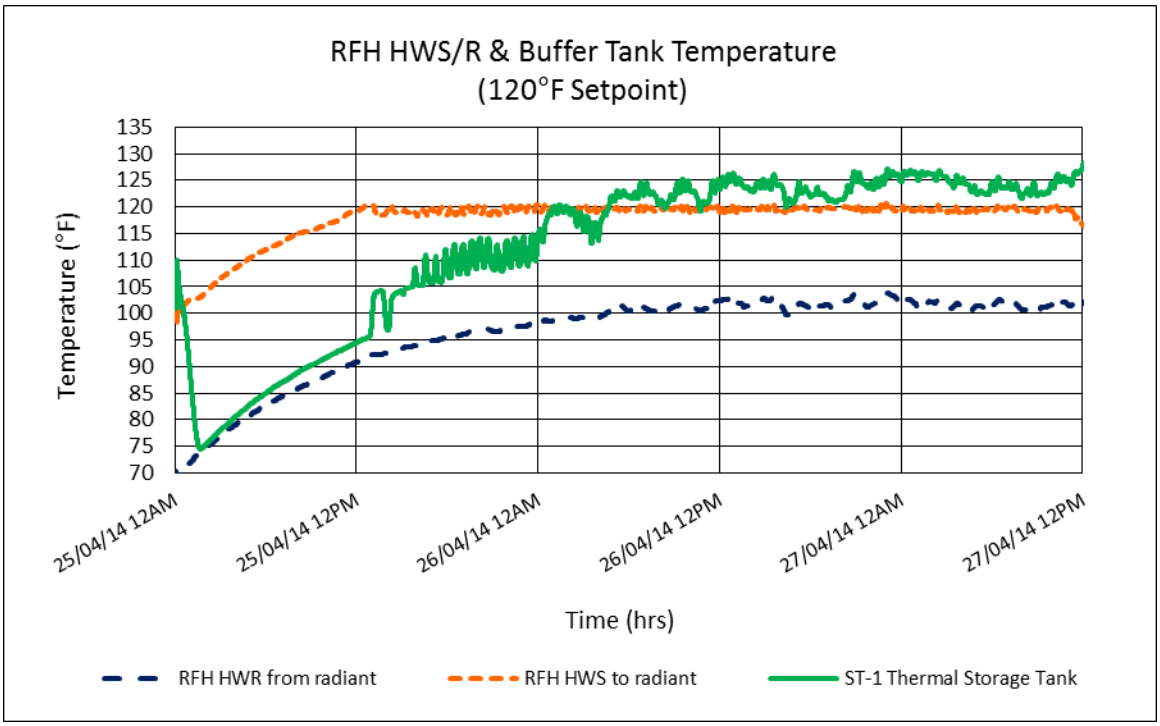

Figure 4. RFH Supply, Return, and Buffer Tank Temperature at 120°F HWS Setpoint

Temperature change between the HWS and HWR versus time was also explored (Figure 5). During the initial startup of the experiment, large temperature differences were observed as the boiler was trying to bring the buffer tank to setpoint. This was expected since the RMEH was cold at startup and the heat exchange rate between the floor and air was at its peak. As each test scenario approached steady state a temperature changes of approximately 11°F and 14°F were calculated for HWS setpoints of 105°F and 120°F, respectively.

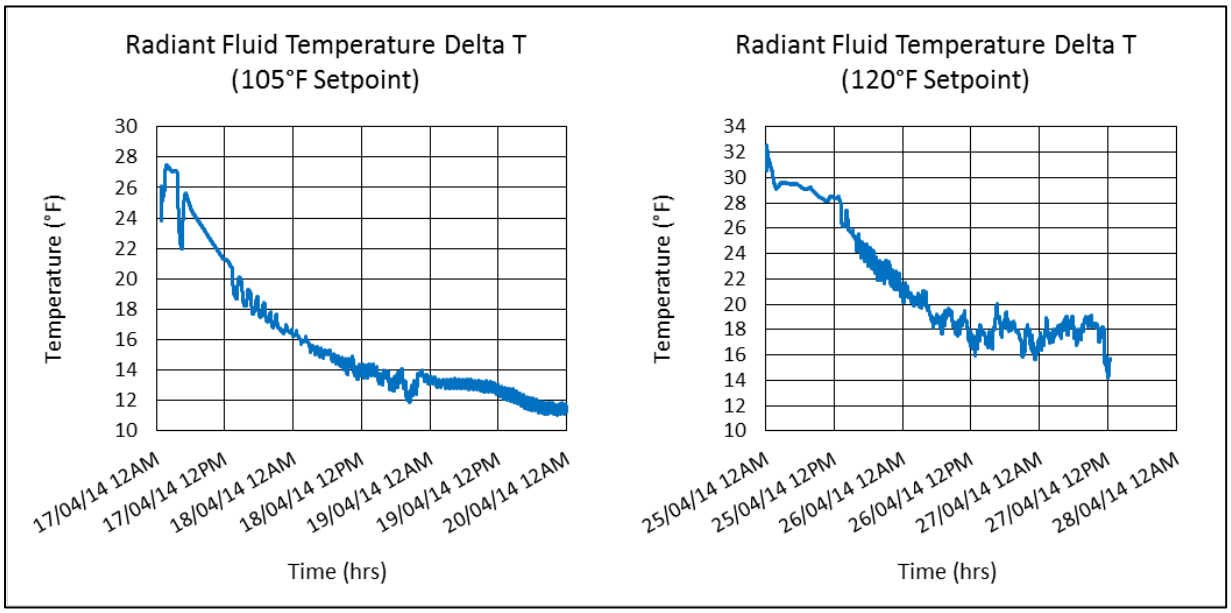

Figure 5. Temperature Change between HWS and HWR vs. Time

Appendix A. Test Schedule Sheet

System Performance
Data Collection

REHAU ECOSMART HOUSE
Bozeman, MT

lee2289

Test Number:	RMEH 04-001	
Description:	Measure pickup response time of radiant floor from 60F to 90F using two water temperatures of 105F and 120F, from boiler.	
Objectives:		
	1 Starting at 60F floor temperature, raise floor temperature as quickly as possible	
	2 Measure pick-up time from 60F to 90F at 2F increments starting at 70F	
	3 Measure max air temperature acheivable simultaneously	
	4 Compare overpour versus slab response in Floors 1, 2 & 3 (slab, Amvic, overpour)	
	5	
Data Collection Parameters:	**Description**	**Source**
	1 OA Temp	RSC
	2 Zone Set Point Temp	RSC
	3 Zone Actual Temp	RSC
	4 Slab Sensor Temp	RSC
	5 Slab Set Point Temp	RSC
	6 HDD	MSU
	7 Boiler Gas Usage	MSU
	8 Boiler HWS Temp	RSC
	9 Boiler HWR Temp	RSC
	10 RFH HWS Temp	RSC
	11 RFH HWR Temp	RSC
	12	
	13	
	14	
	15	
	16	
	17	
	18	
Test Duration:		
	Length Each test runs until floor achieves 90F	
	Start Date	
	End Date	
Deliverables:		
	1 Measure pick-up time	
	2 Plot Air Temp v. Floor Temp	
	3 Plot Fluid Temp V. Delta T	
	4 Compare response time of Floor 2 and 3	
	5	
Notes:		
MSU Notes:	testing in January 2014	

Appendix B. Experiment Notes

Data for experiment RMEH 04-001 was collected during the following dates:

- Scenario 1 – 105°F Water Supply Temperature: 4/17/2014 – 4/20/2014
- Scenario 2 – 120°F Water Supply Temperature: 4/24/2014 – 4/27/2014

Appendix C. Data Collection Parameters

RSC and National Instruments (NI) data acquisition systems were used to collect data for this experiment. Data was collected for the following points:

RSC Data Points

- Outdoor Air Temperature
- Zone Setpoint Temperature
- Zone Actual Temperature
- Slab Sensor Temperature
- Slab Set Point Temperature
- Boiler HWS/HWR Temperature
- RFH HWS/HWR Temperature
- Buffer Tank Temperature

NI Data Points

- Gas Consumption from Boiler

Appendix D. Additional Figures

Air & Floor Temperature vs. Time

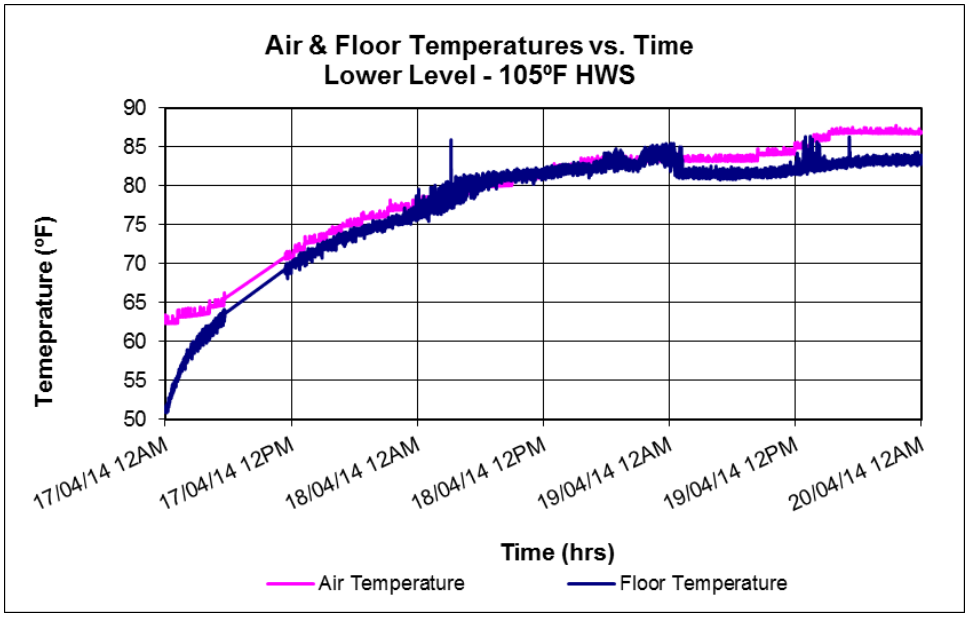

Figure 6. Lower Level Air and Floor Temperatures vs. Time Using 105°F HWS

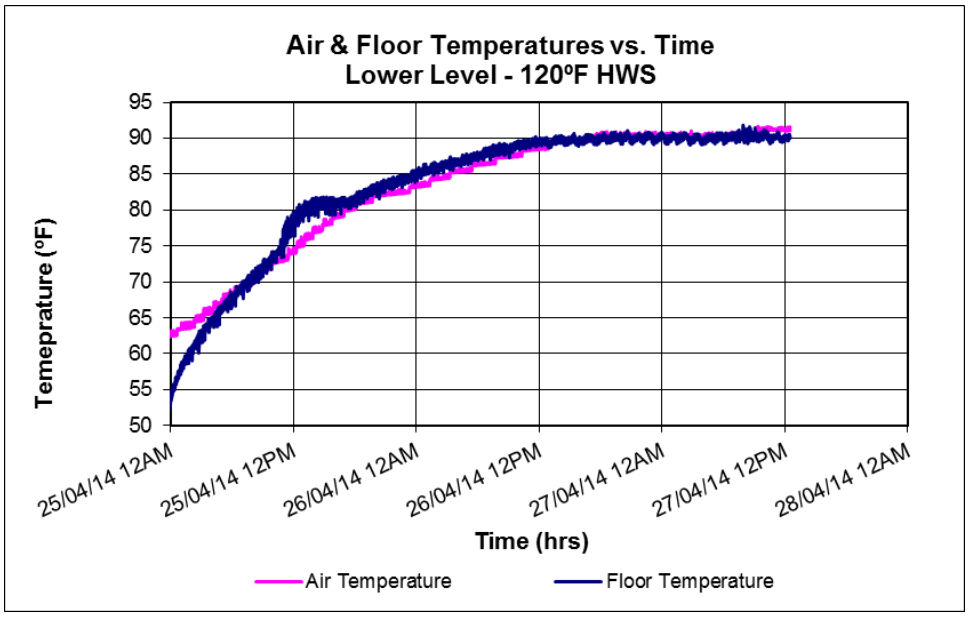

Figure 7. Lower Level Air and Floor Temperatures vs. Time Using 120°F HWS

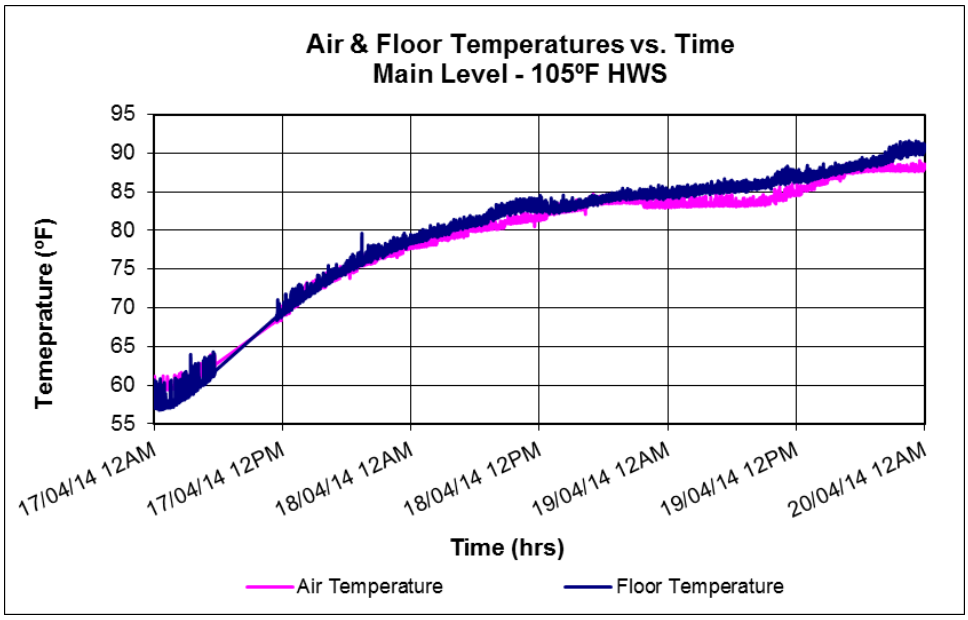

Figure 8. Main Level Air and Floor Temperatures vs. Time Using 105°F HWS

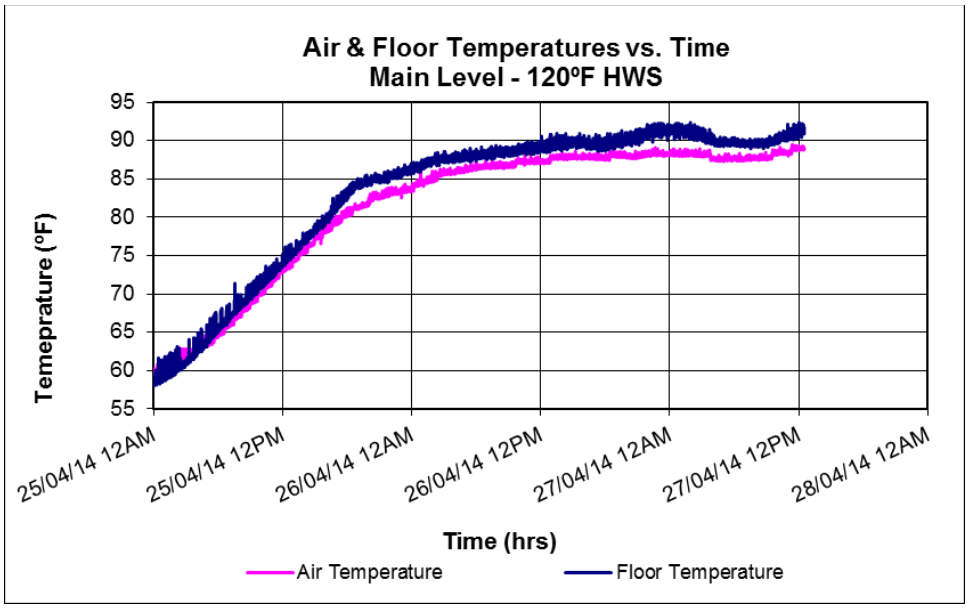

Figure 9. Main Level Air and Floor Temperatures vs. Time Using 120°F HWS

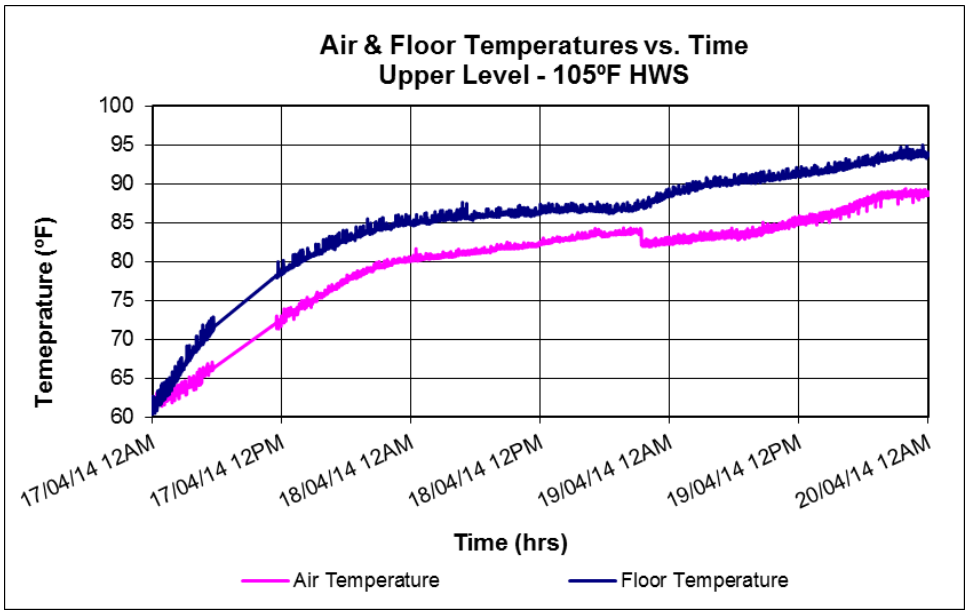

Figure 10. Upper Level Air and Floor Temperatures vs. Time Using 105°F HWS

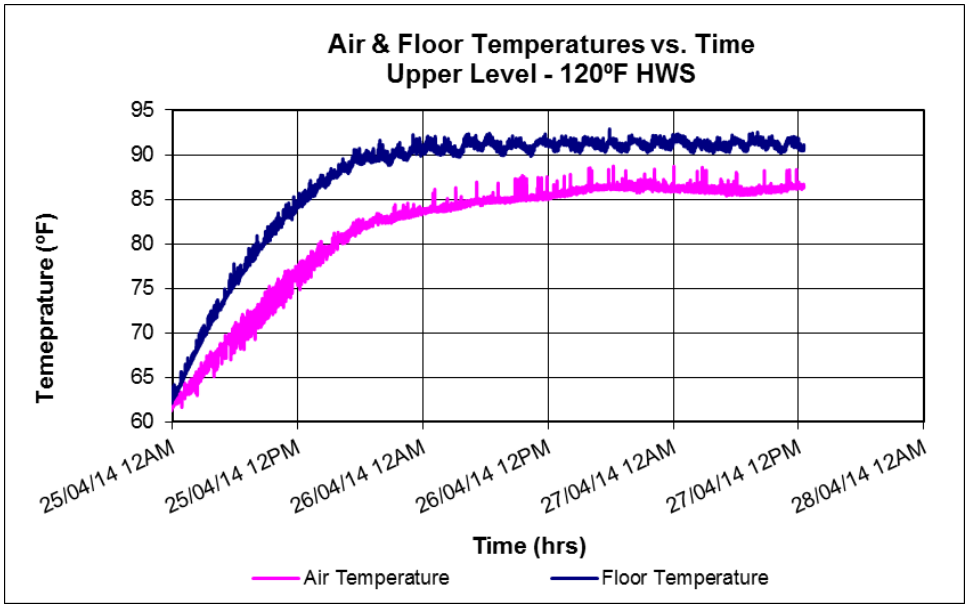

Figure 11. Upper Level Air and Floor Temperatures vs. Time Using 120°F HWS

Appendix F. References

1. REHAU United Polymer Solutions (2013, May). *REHAU Radiant Heating Systems. Design Guide*. Retrieved from http://www.rehau.com/download/869560/radiant-heating-systems-design-guide.pdf

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