BUILDING
EXTERIOR
SOLUTIONS

A Terracon COMPANY

Knowledge | Experience | Solutions

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CONTINUING EDUCATION AIA

Course Description

This course will provide a brief introduction to hygrothermal modeling, state of the art software, and relevant standards. We will then investigate several case studies to learn from real world construction examples.

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Learning Objectives

At the end of the this course, participants will:

1. Be aware of the potential of hygrothermal modeling software

2. Learn ANSI/ASHRAE standard's criteria for moisture control design analysis in buildings

3. Learn how hygrothermal modeling software can help designs with extreme conditions

4. Understand how hygrothermal modeling software can help predict buildings future behavior

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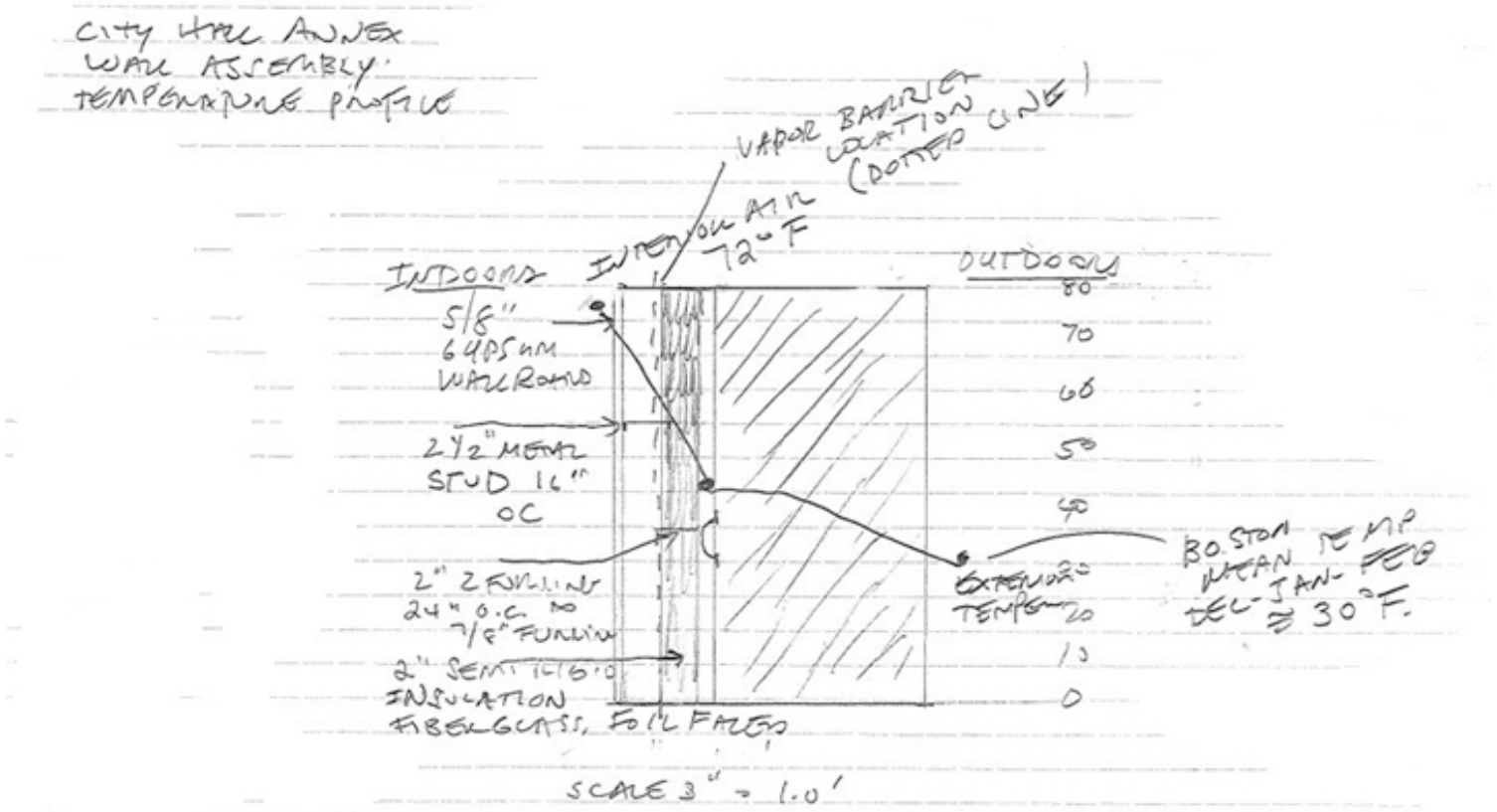
Old School Hygrothermal Analysis



(5) ASSUMING INDOOR CONDITIONS AT 72°F and 35% RH THE DEW POINT FROM THE PSYCHROMETRIC CHART IS APPROXIMATE 46°F. ANY TEMPERATURE BELOW THE DEW POINT WILL CAUSE CONDENSATION IN THE WALL ASSEMBLY.

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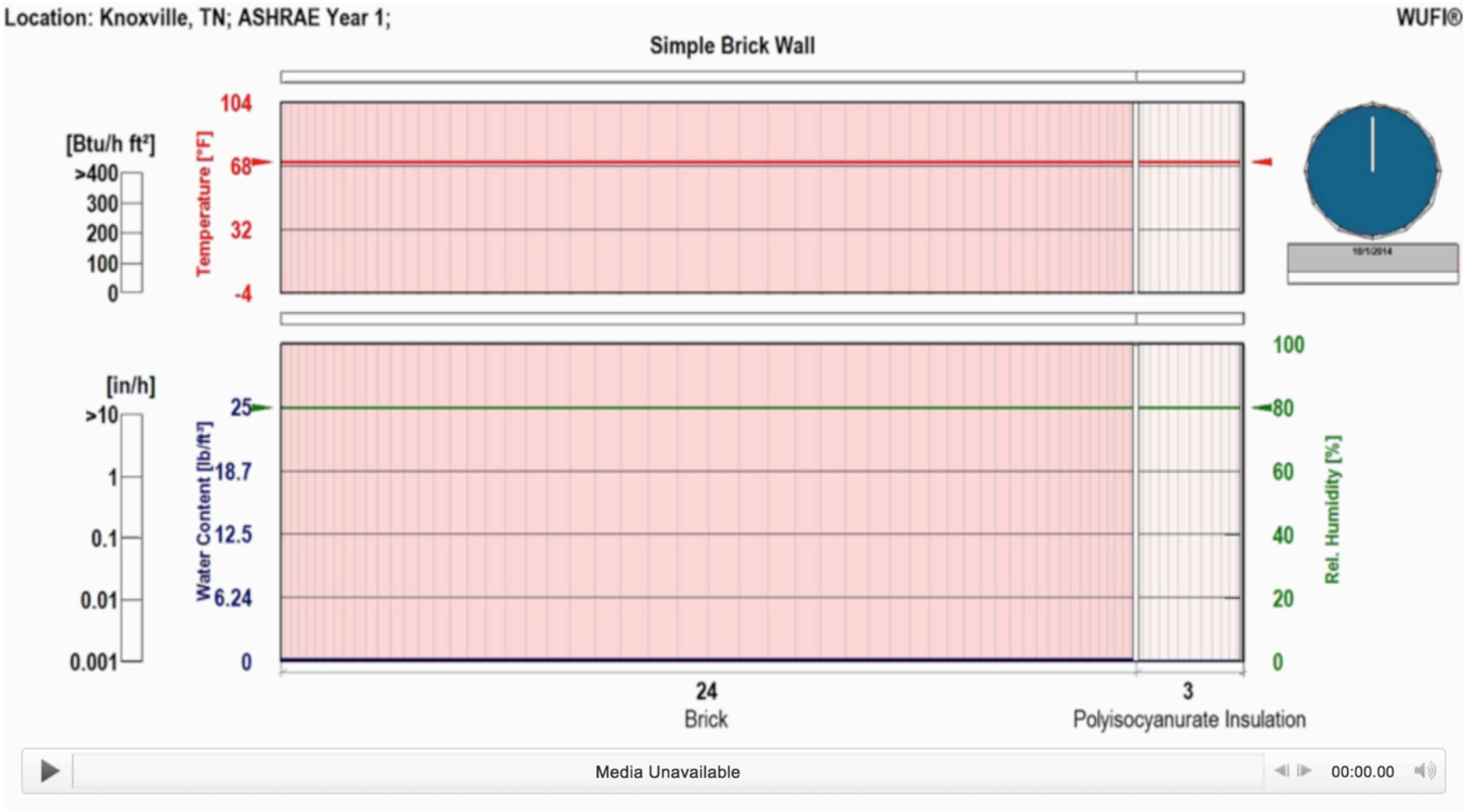
WUFI Pro 1d Simulation (Fraunhofer IBP)
Wärme Und Feuchte Instationär



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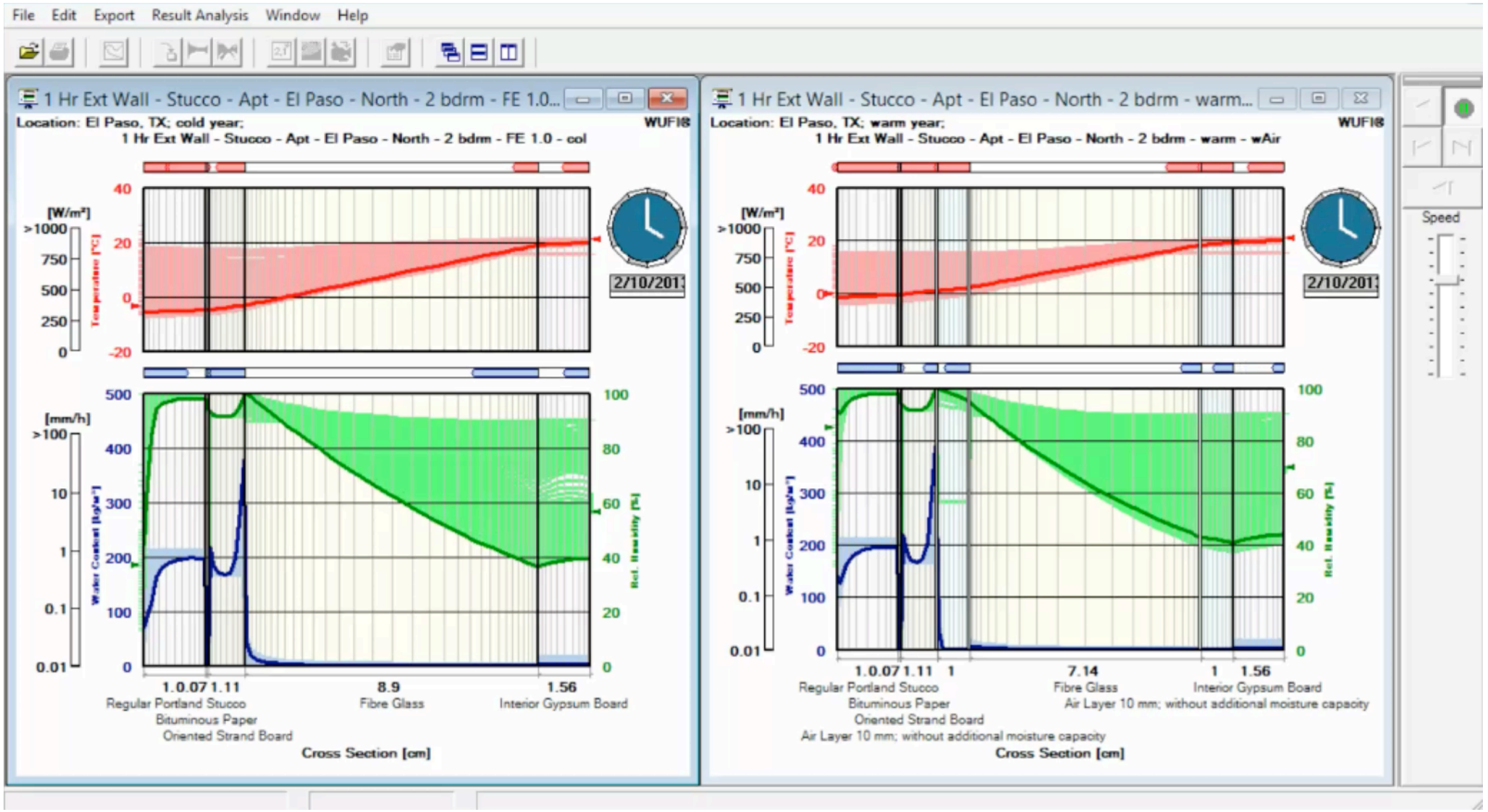
Simultaneous Simulations



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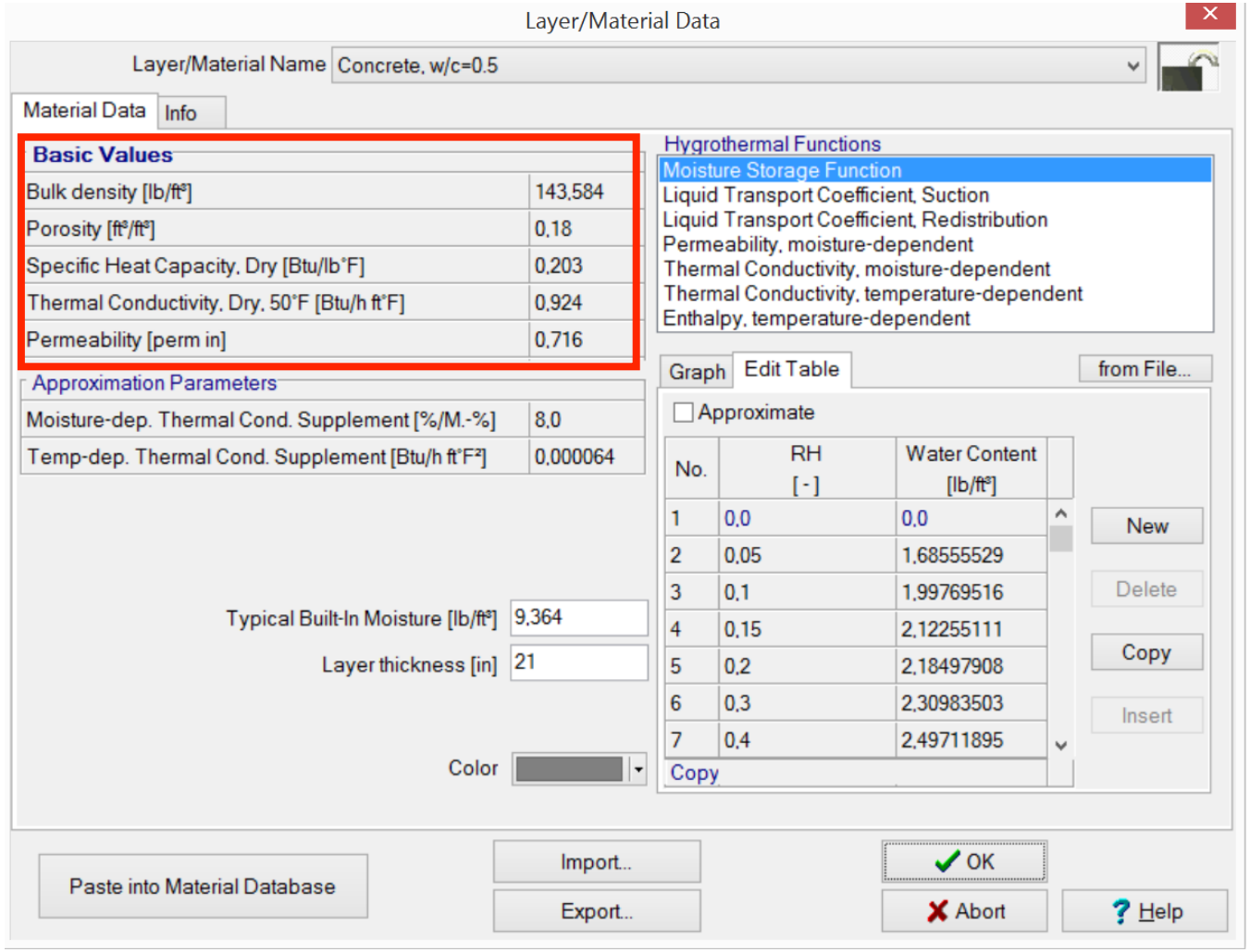
Five Required Material Properties (minimum)



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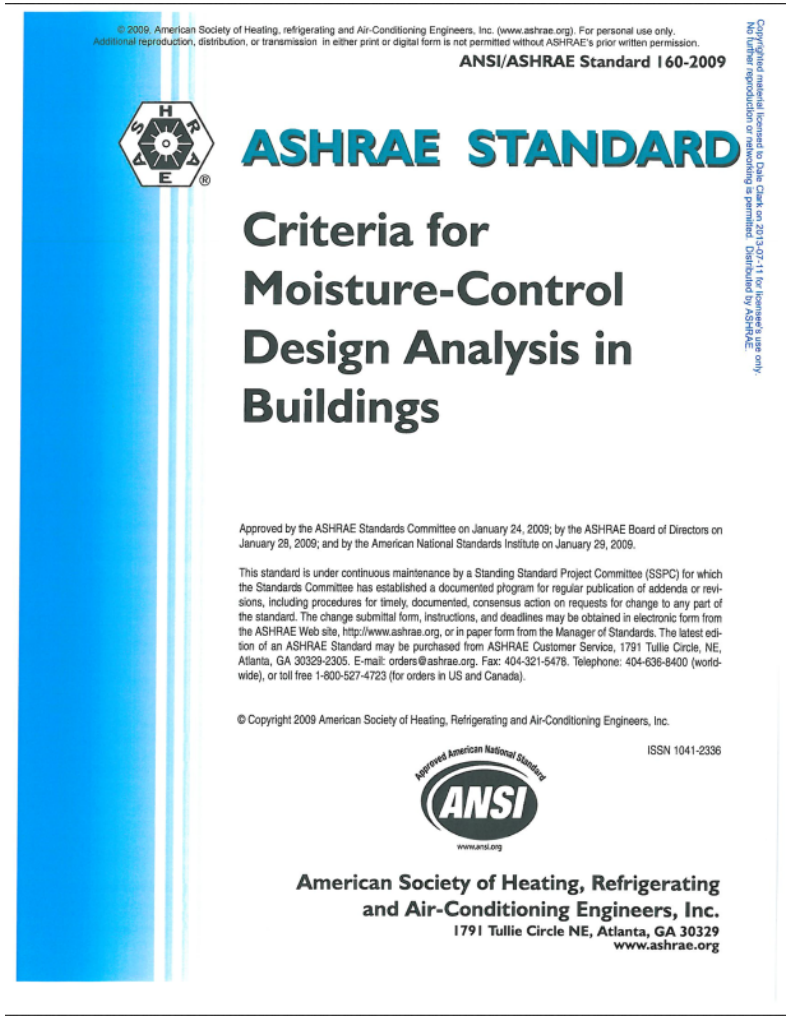
ASHRAE 160-2009



Provides:

1. Design criteria for materials, climate, conditions, moisture generation, ventilation, pressure differentials, rain loads, etc.

2. Guidelines for minimizing moisture problems associated with mold growth and corrosion

3. Report parameters and guidelines

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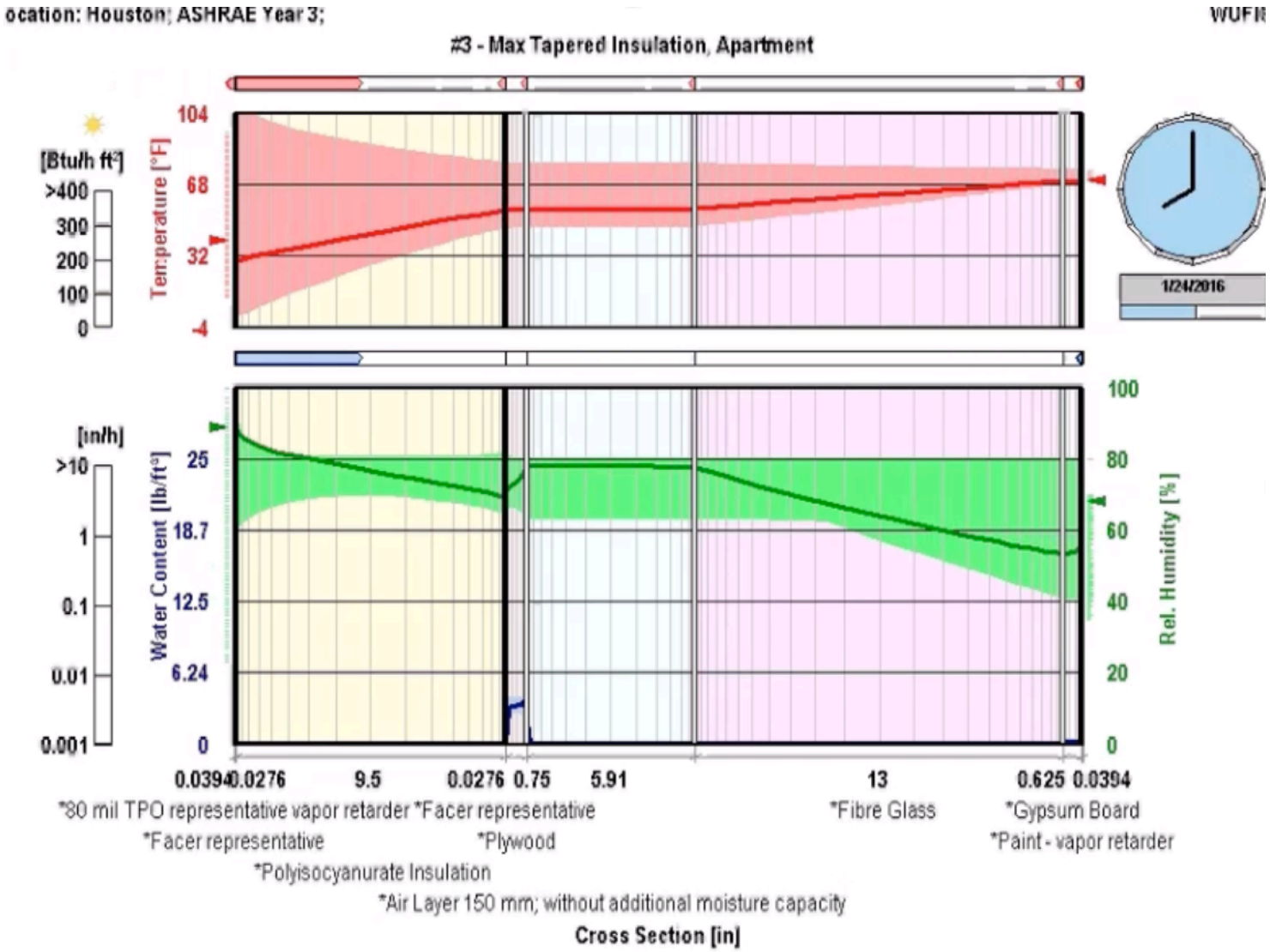
WUFI Pro 1d Simulation (Fraunhofer IBP)



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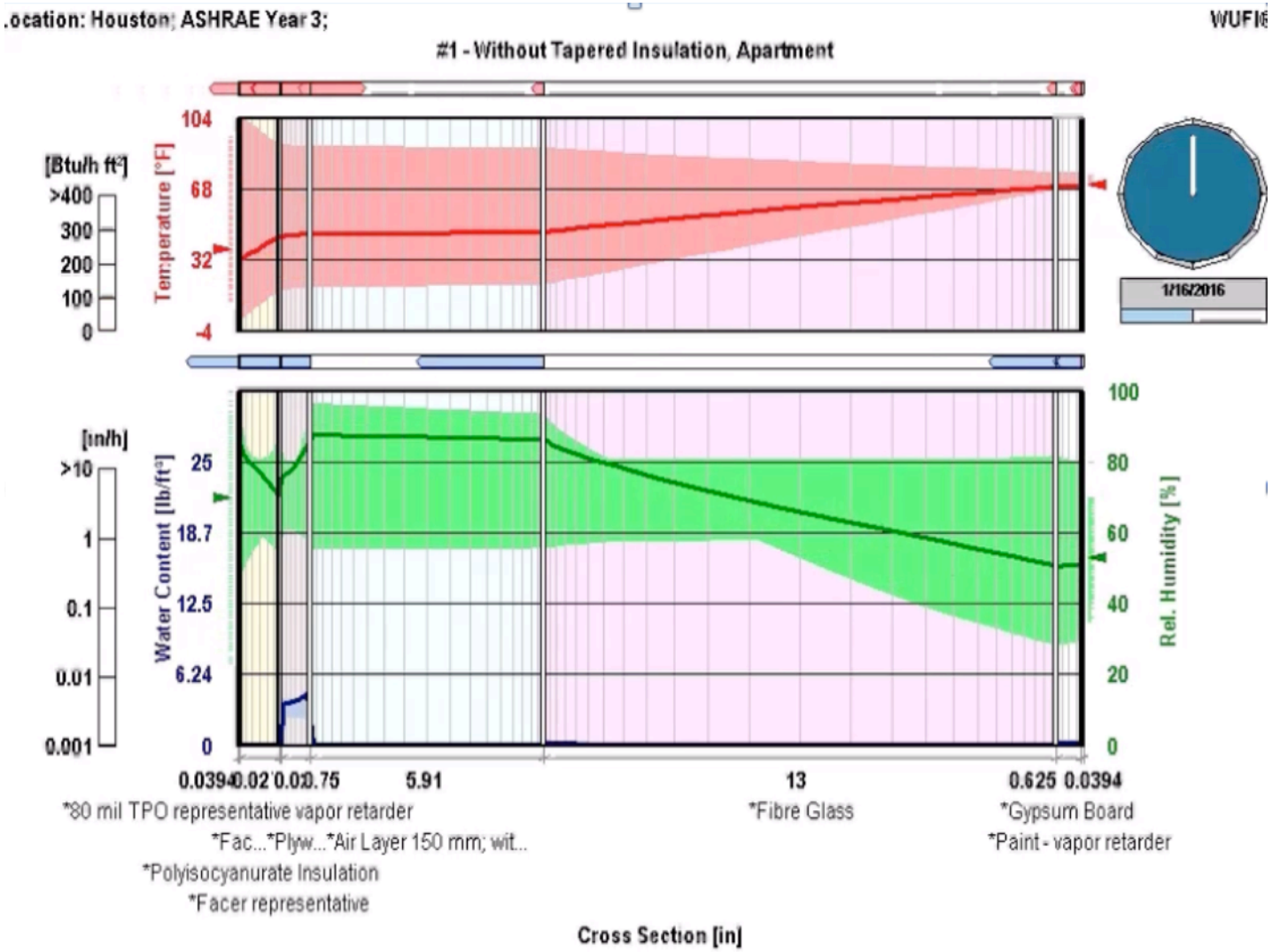
WUFI Pro 1d Simulation (Fraunhofer IBP)



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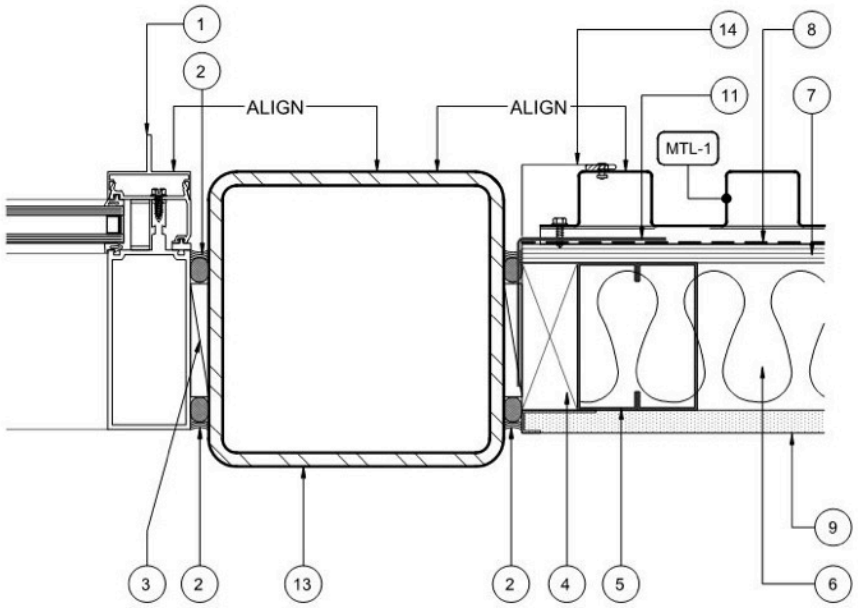
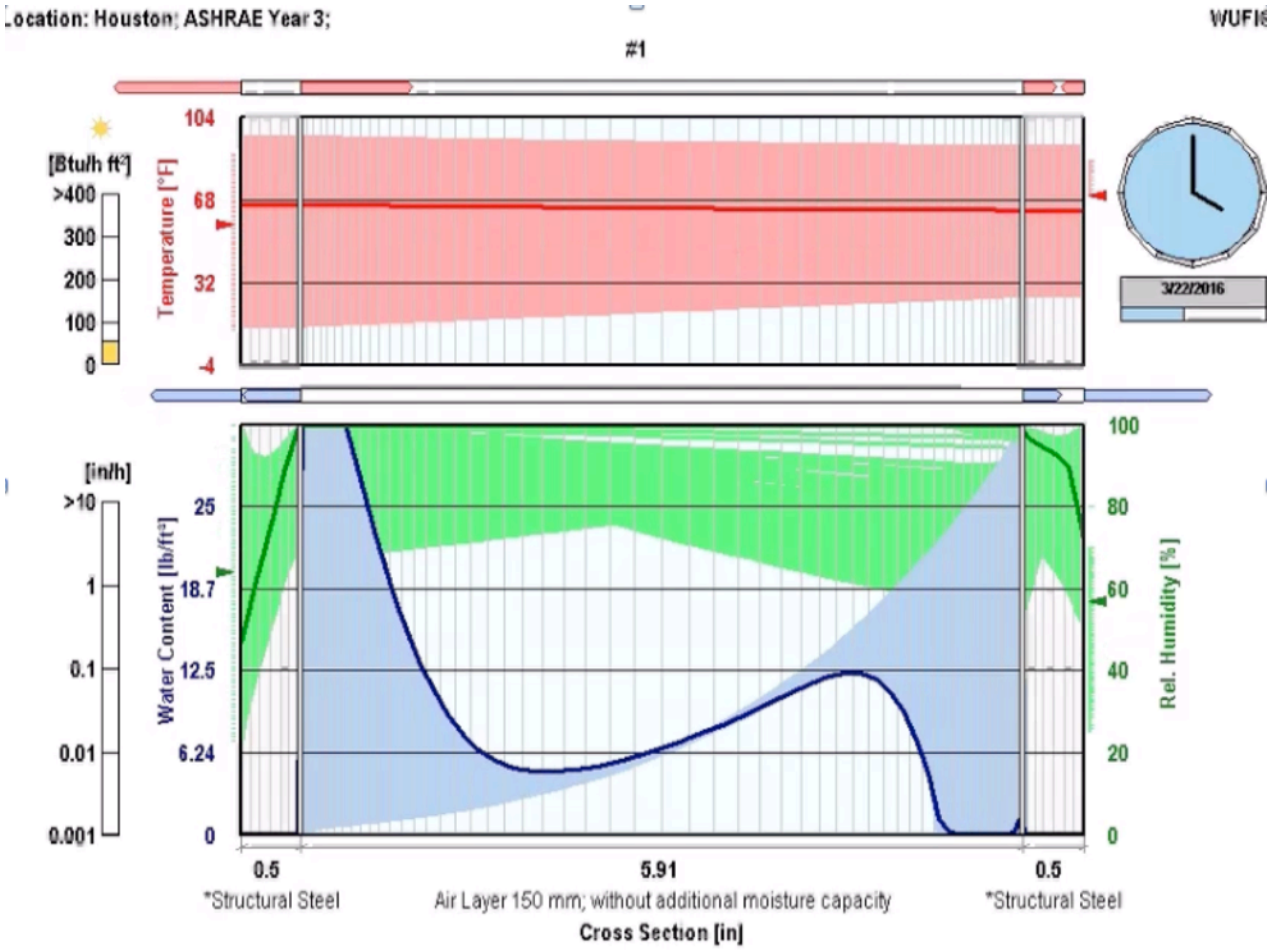
WUFI Pro 1d Simulation (Fraunhofer IBP)





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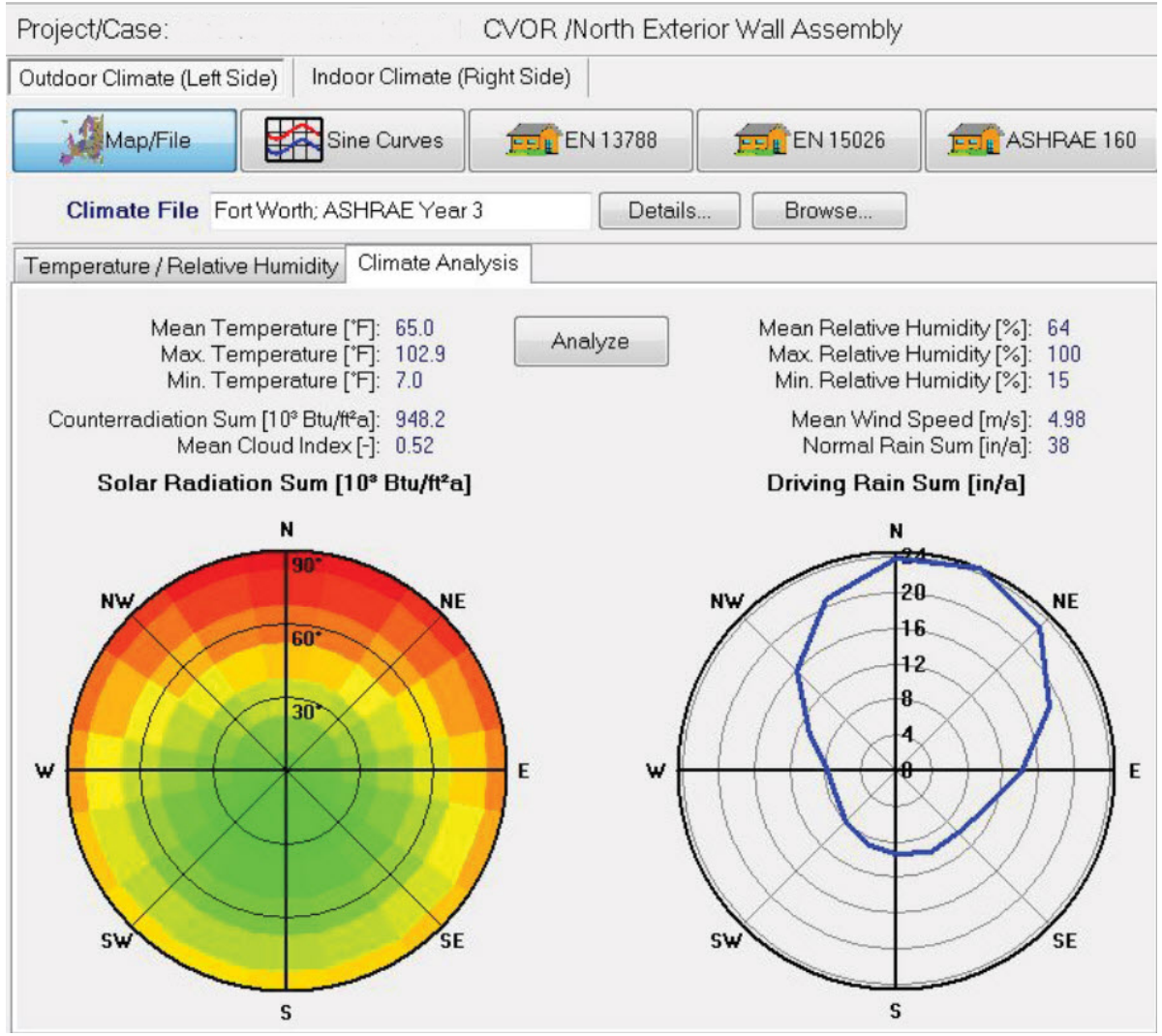
Worst Case Scenario



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Hygrothermal Analysis:
unique assemblies

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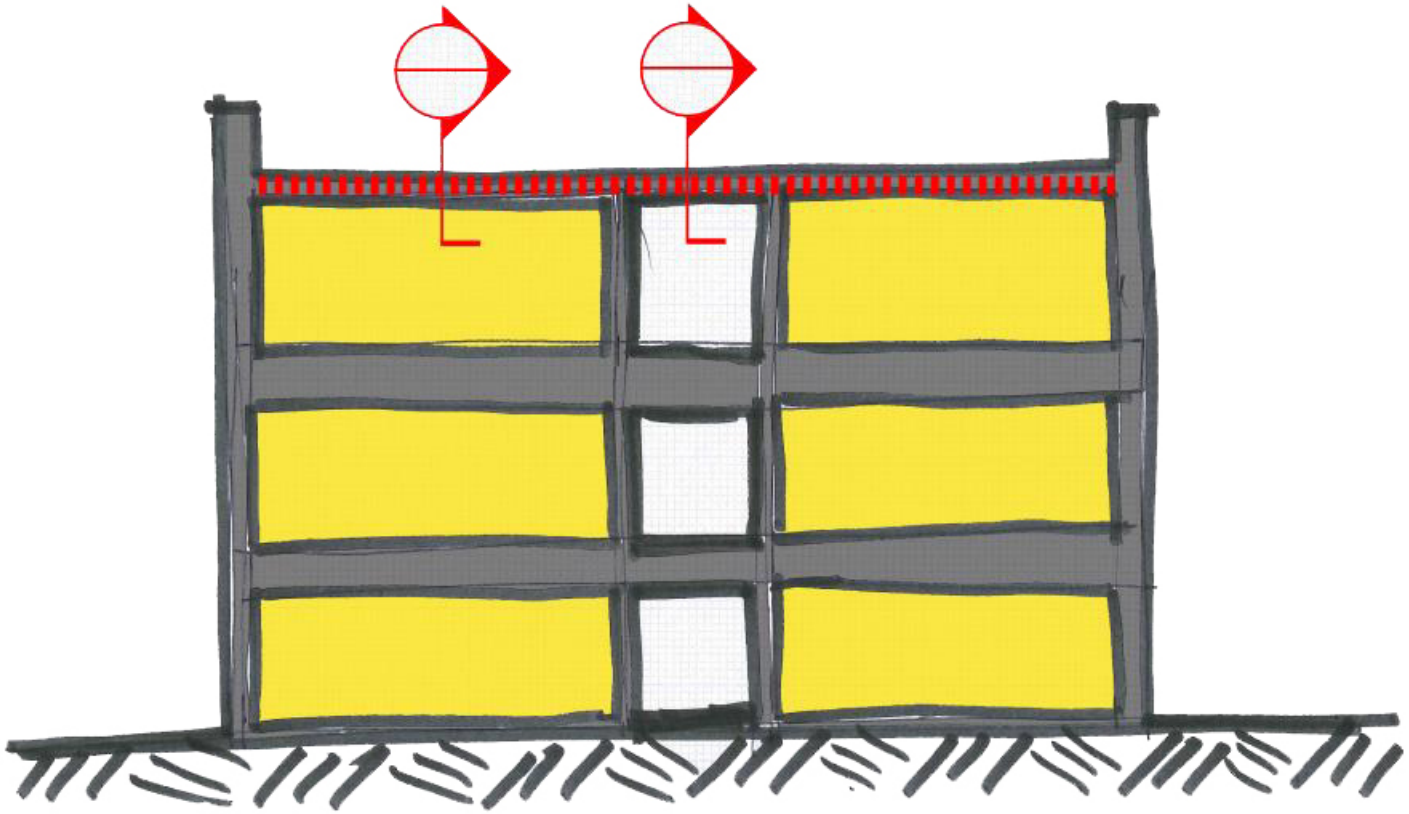
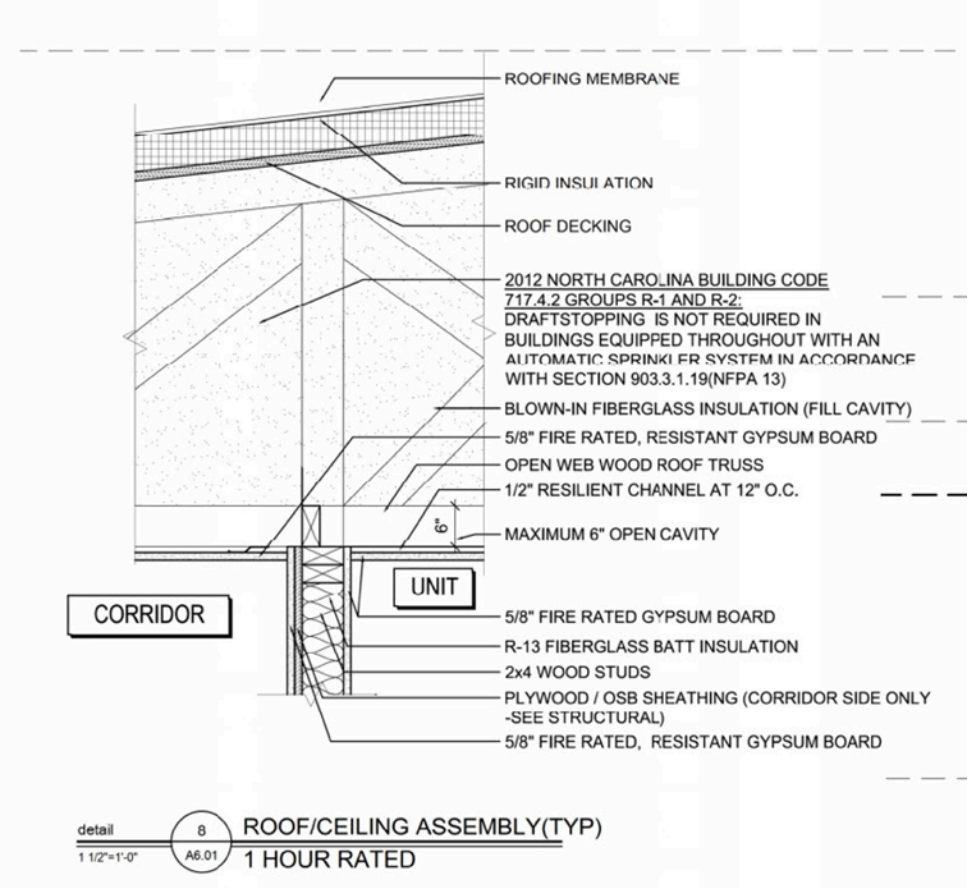
The Challenge





Roof Assembly

- 80-mil Calisle Sureweld TPO reinforced membrane (white)
- 2-inch Calisle SecurShield HD Composite Polyiso
- ¾-inch plywood decking
- R-19 Unfaced Fiberglass Insulation
- Air Layer (thickness varies – simulated as 0.07 ACH and 6-inches thick)
- 6.5-inches fiberglass insulation
- 5/8-inch Gypsum Board
- PPG Latex Paint at Apartments; PPG Acrylic Paint at Hallways (2 coats with primer)

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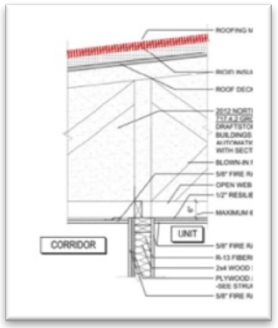
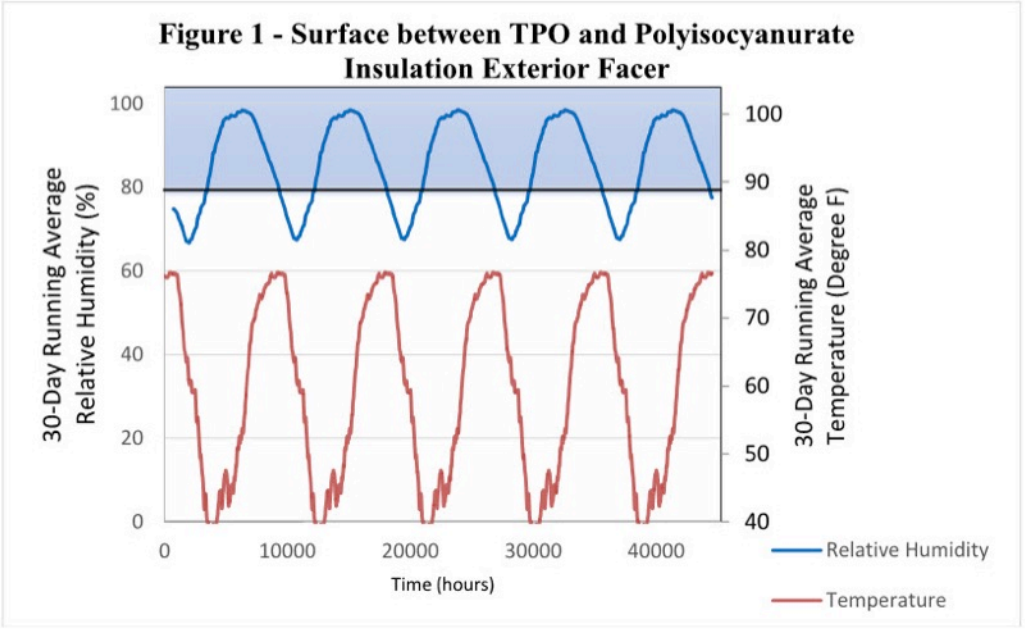
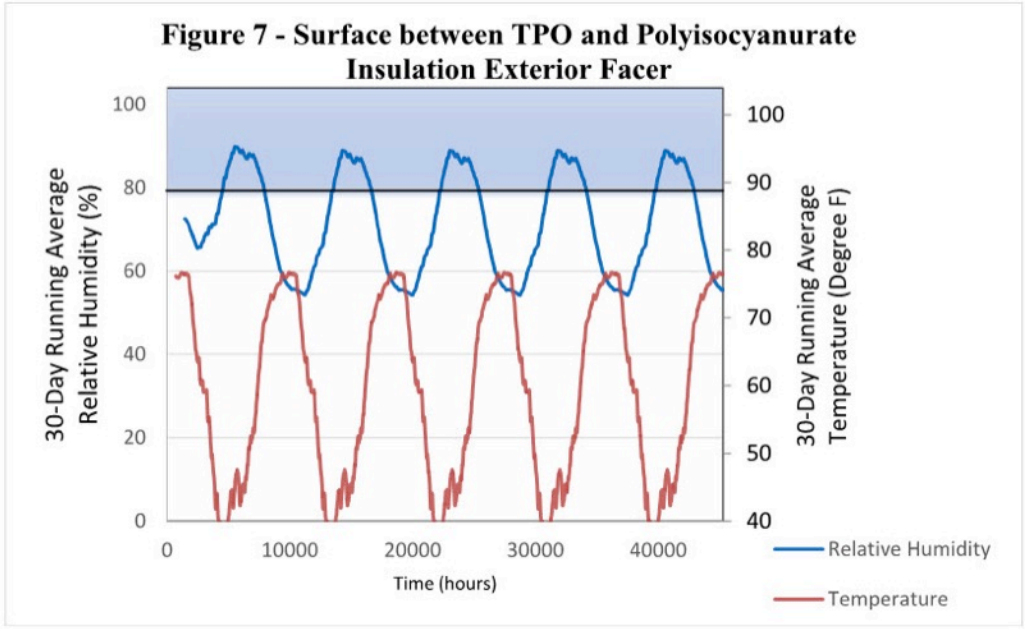


Surface between TPO and ISO

Assembly #1 (over apartment)



Assembly #2 (over breezeway)



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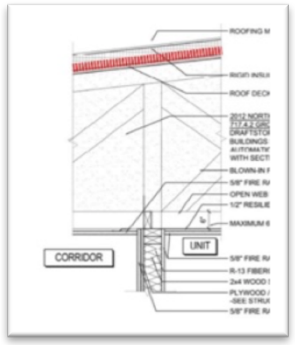
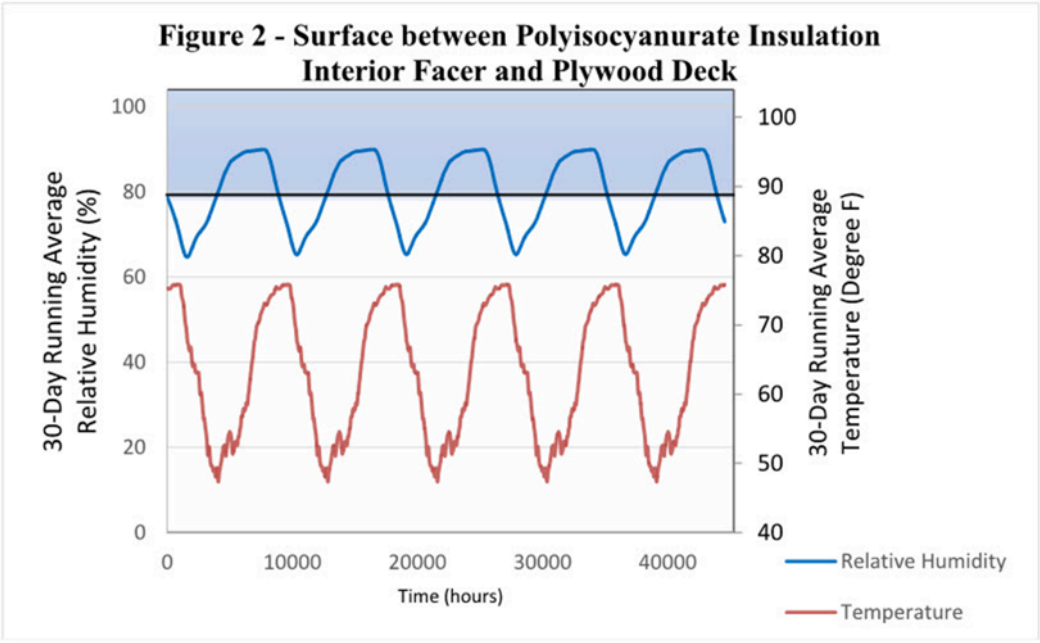
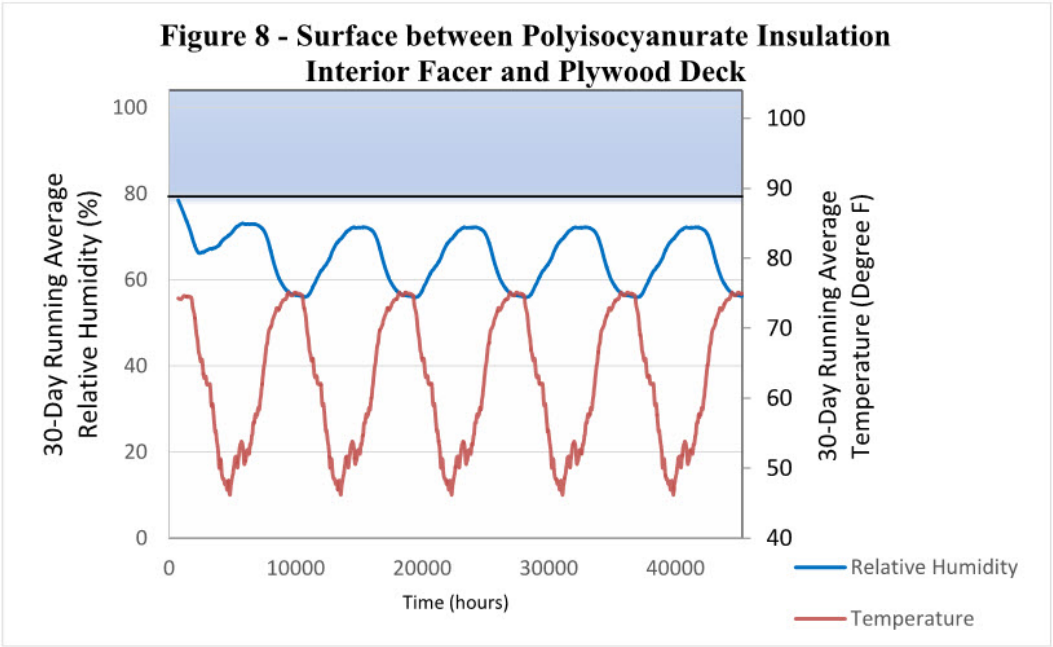


Surface between ISO and Plywood

Assembly #1 (over apartment)



Assembly #2 (over breezeway)



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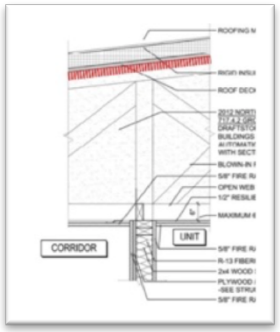
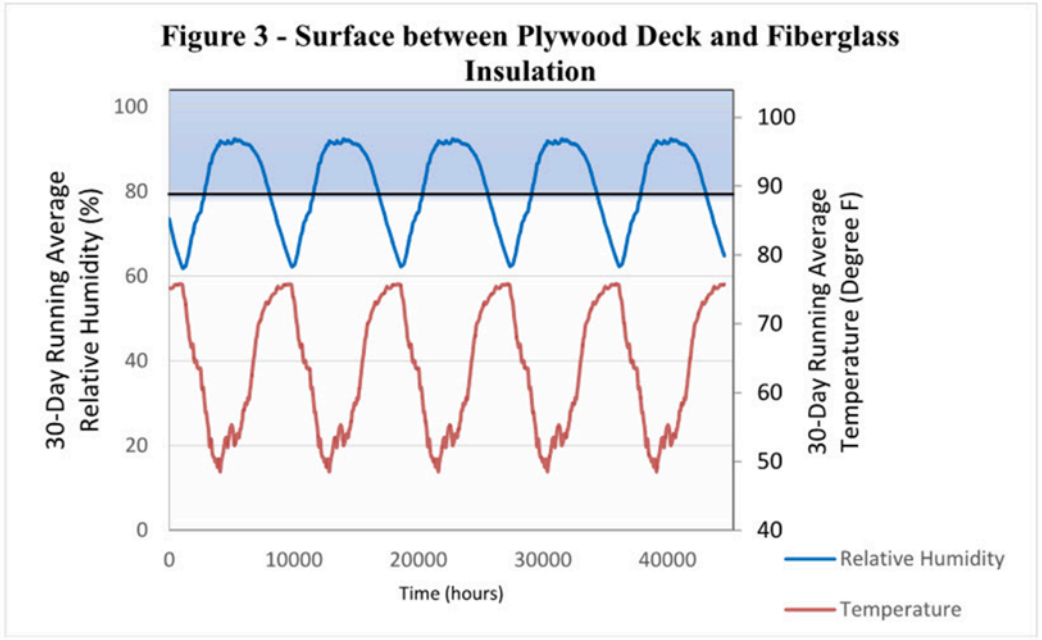
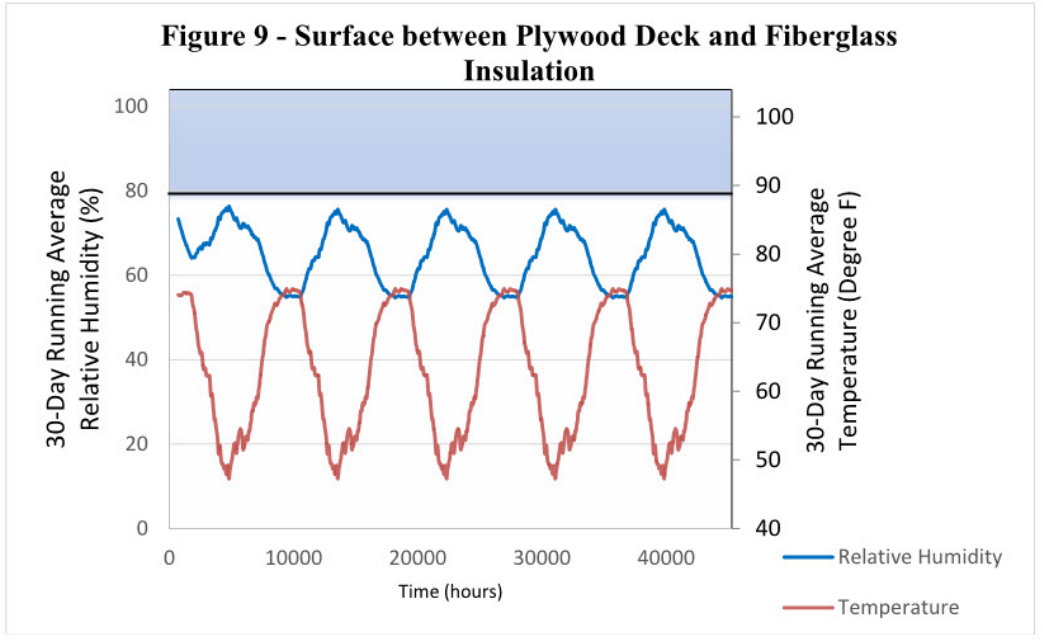


Surface between Plywood and Fiberglass

Assembly #1 (over apartment)



Assembly #2 (over breezeway)



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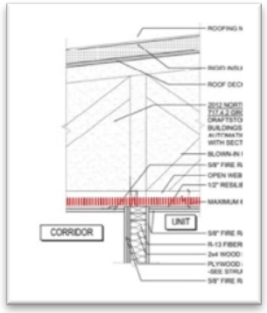
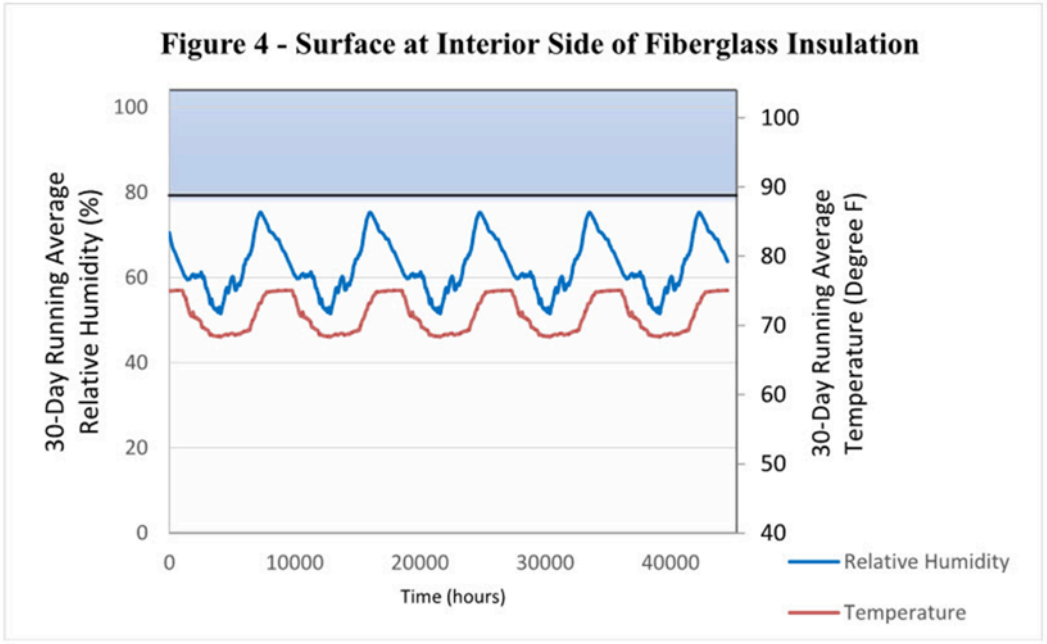
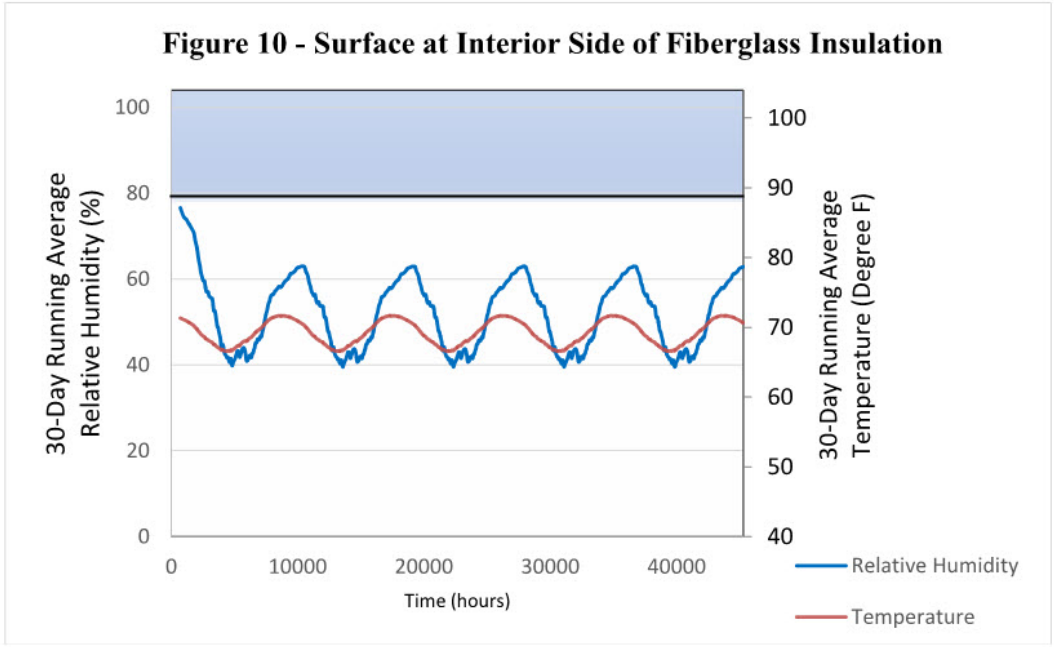


Surface between Fiberglass and Air Layer

Assembly #1 (over apartment)



Assembly #2 (over breezeway)



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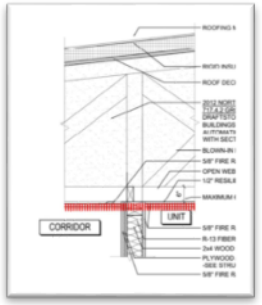
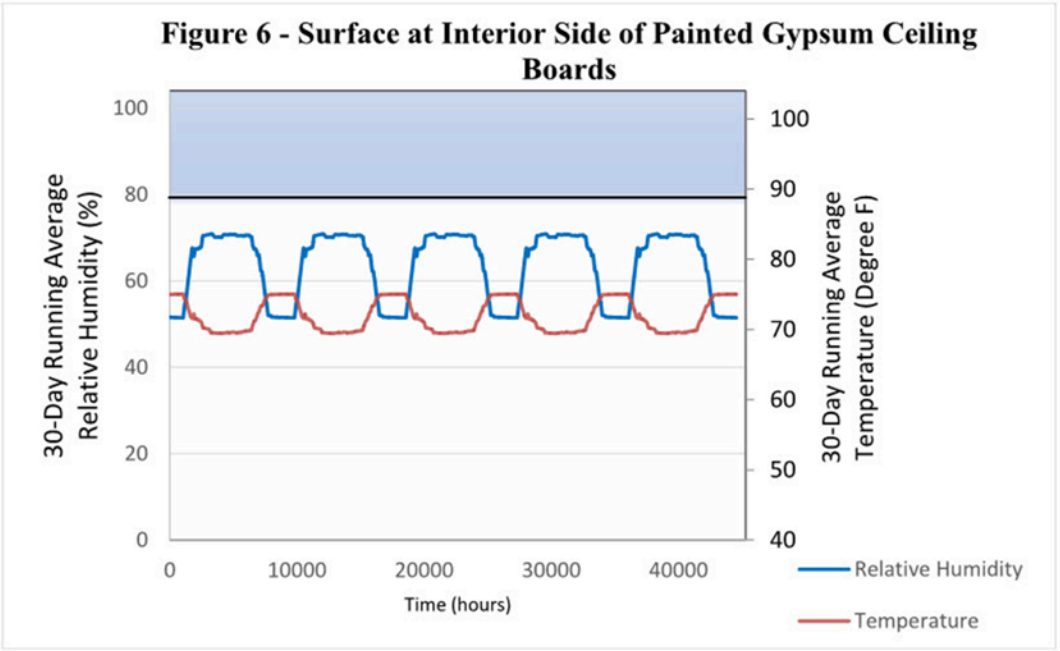
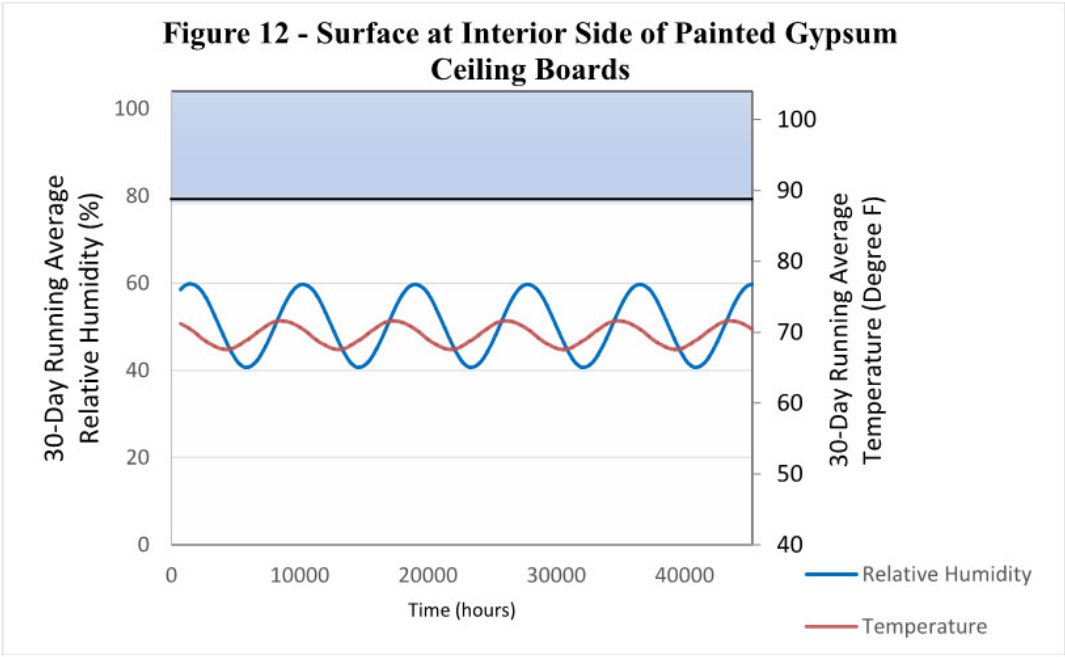


Surface between Gypsum and Paint

Assembly #1 (over apartment)



Assembly #2 (over breezeway)



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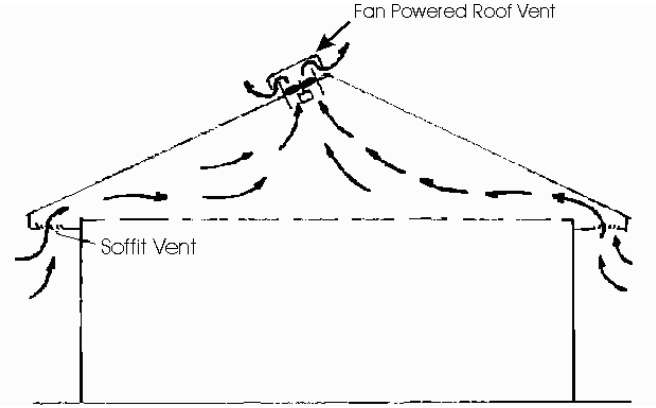
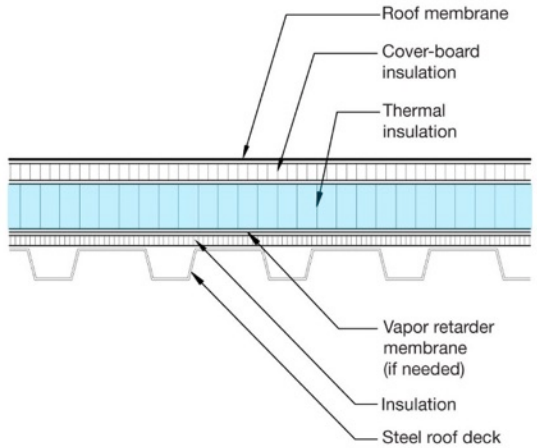
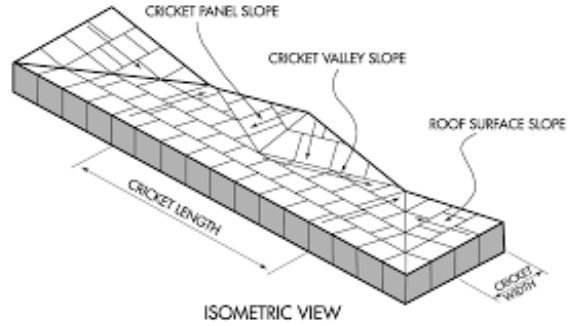




Solutions



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Hygrothermal Analysis:
unique setpoints

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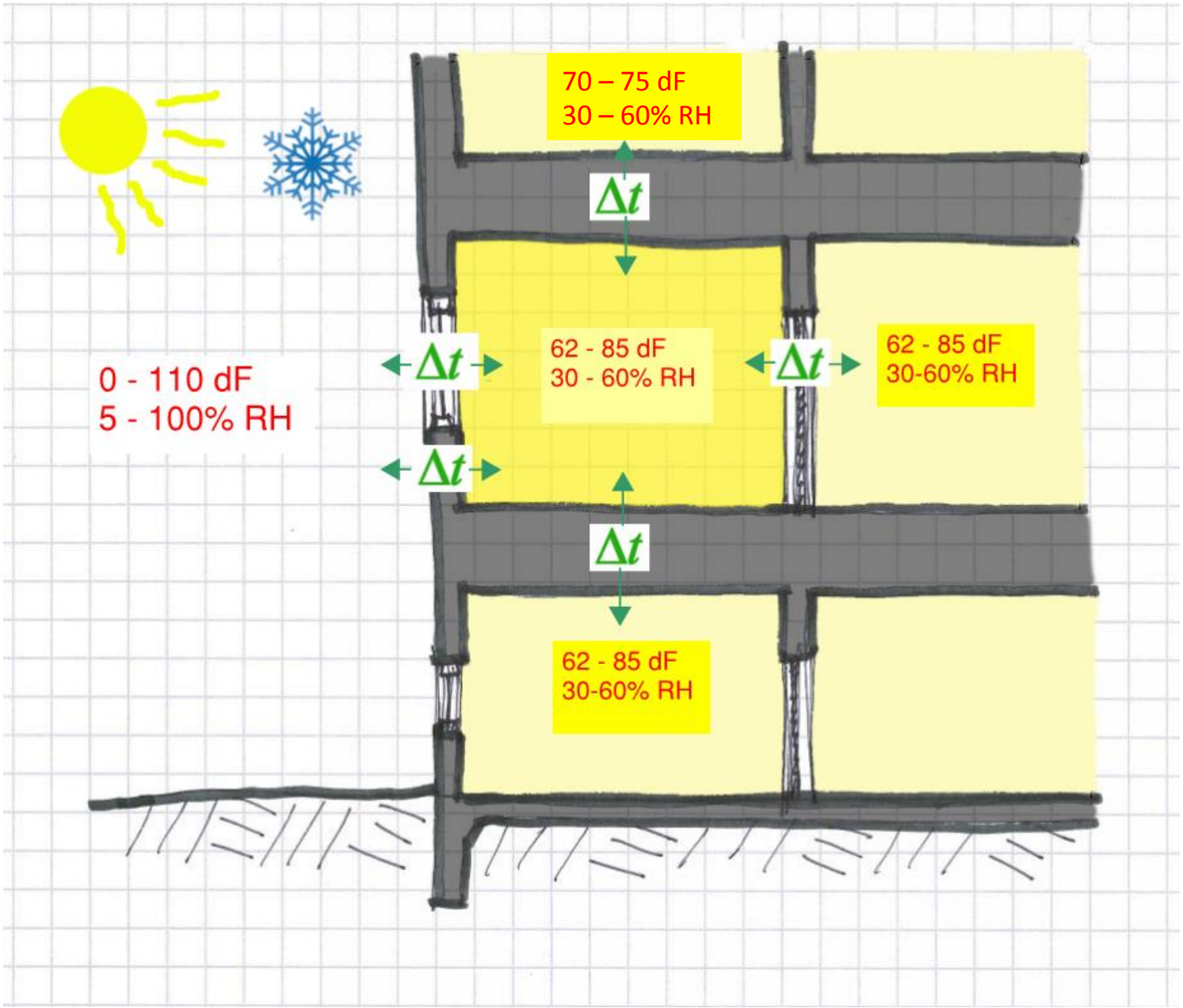
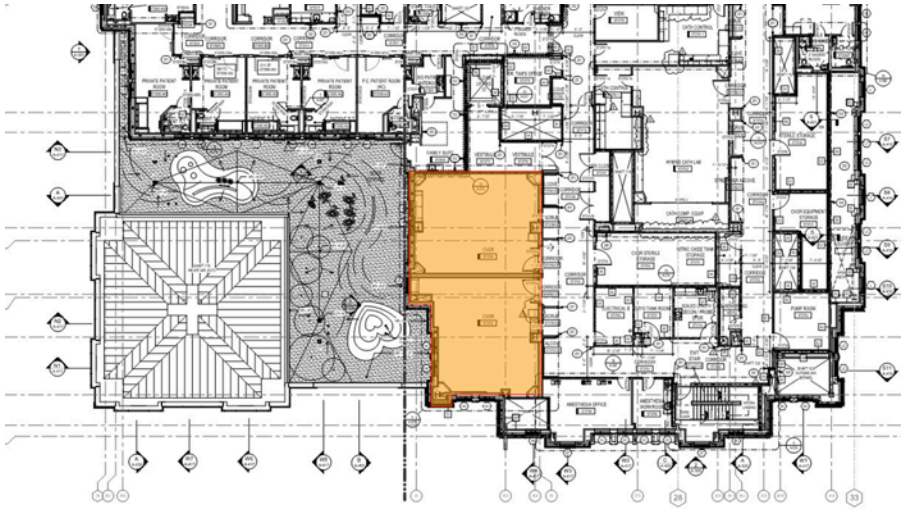
The Challenge


70 – 75 dF
30 – 60% RH
Δt
0 - 110 dF
5 - 100% RH
Δt
62 - 85 dF
30 - 60% RH
Δt
62 - 85 dF
30-60% RH
Δt
62 - 85 dF
30-60% RH



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Simulated Assemblies

North Exterior Wall Assembly 1:

- 3/4-inch clay tile thin brick veneer over 2 1/4" precast concrete panel
- 3-inch extruded polystyrene insulation (XPS)
- 5 1/4-inch precast concrete panel
- 4-inch air cavity
- 3 5/8-inch stud frame cavity with un-faced batt insulation
- 5/8-inch Gypsum Board
- Water based epoxy paint

North Exterior Wall Assembly 2:

- 3/4-inch clay tile thin brick veneer
- 8 1/2-inch precast concrete panel
- 3-inch sprayed polyurethane foam insulation (SPF)
- 1-inch air cavity
- 3 5/8-inch stud frame cavity without insulation
- 5/8-inch Gypsum Board
- Water based epoxy paint

West Exterior Wall Assembly:

- 3/4-inch clay tile thin brick veneer over 2 1/4" precast concrete panel
- 3-inch extruded polystyrene insulation (XPS)
- 5 1/4-inch precast concrete panel
- 4-inch air cavity
- 3 5/8-inch stud frame cavity without insulation
- 5/8-inch Gypsum Board
- Water based epoxy paint

Interior Partition Wall Assembly between Two CVOR:

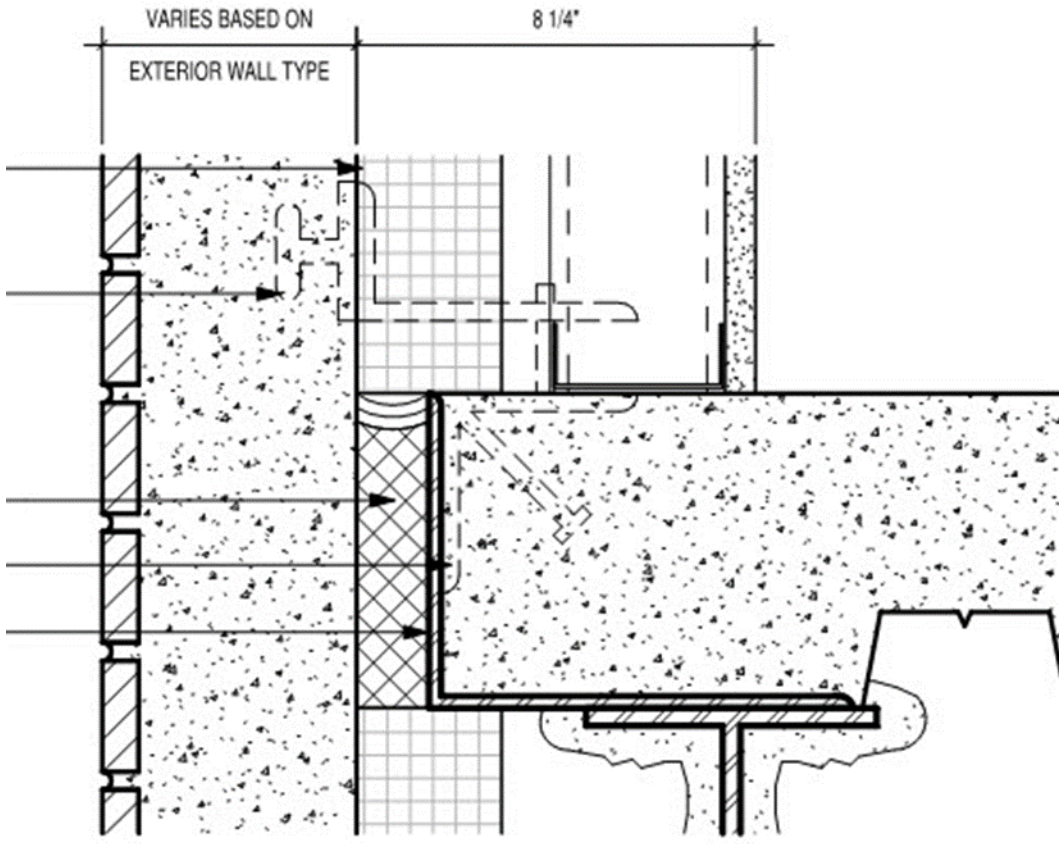
- Water based paint
- 5/8-inch Gypsum Board
- 3 5/8-inch stud frame cavity with un-faced batt insulation
- 4-inch air cavity
- 3 5/8-inch stud frame cavity without insulation
- 5/8-inch Gypsum Board
- Water based epoxy paint

East Interior Partition Wall Assembly between CVOR and Adjacent Corridor:

- Water based epoxy paint
- 5/8-inch Gypsum Board
- 3 5/8-inch stud frame cavity with un-faced batt insulation
- 5/8-inch Gypsum Board
- Water based epoxy paint

Ceiling/Floor Assembly:

- Floor finish (resinous flooring) with elastomeric base coating
- Average 5 1/2-inch concrete slab



Wall Assembly

- 8 ½-inch precast concrete panel with 3-inch XPS
- 3 5/8” stud cavity without insulation
- 5/8-inch gypsum board
- Water based epoxy paint (5-perm vapor retarder)

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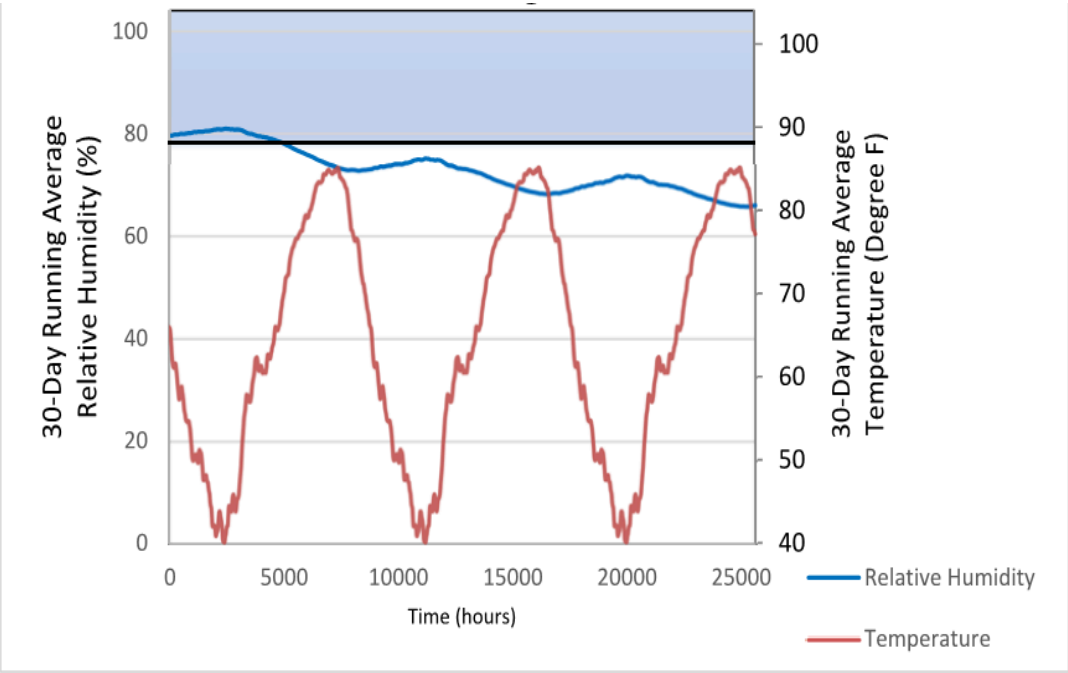
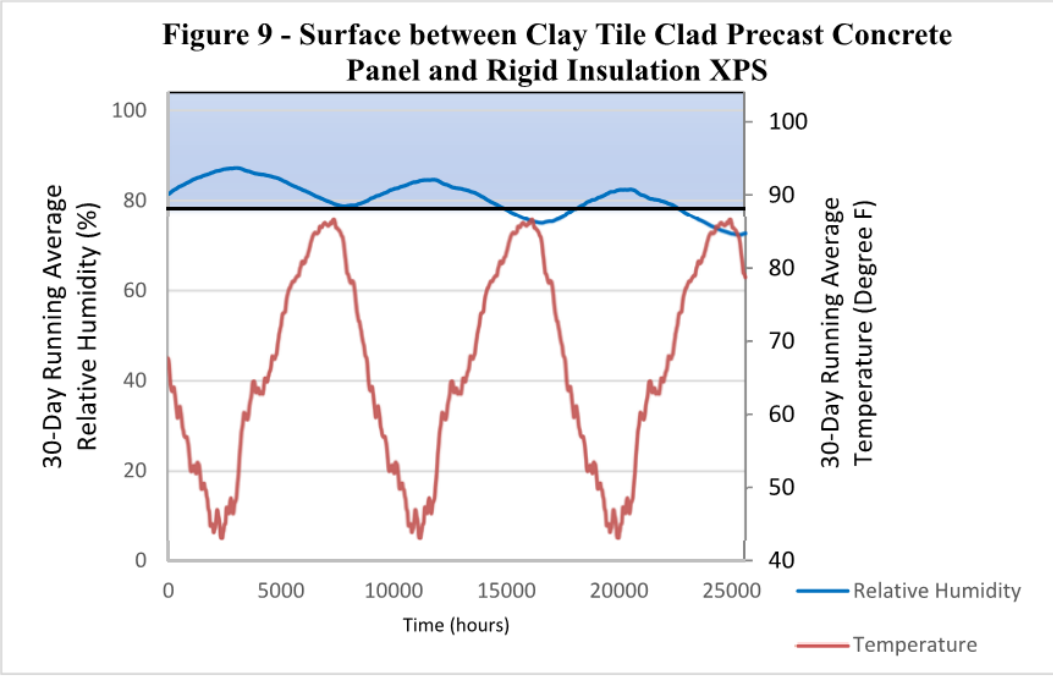
Surface between Clay Tile Precast & XPS

North Exterior Wall Assembly #1



West Exterior Wall Assembly



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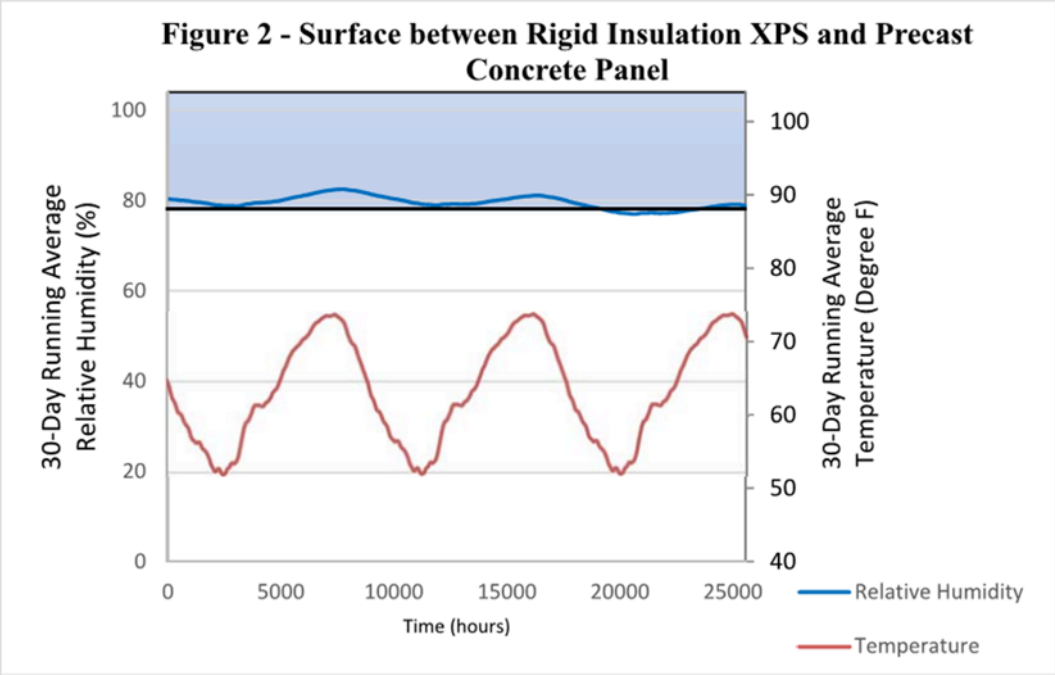
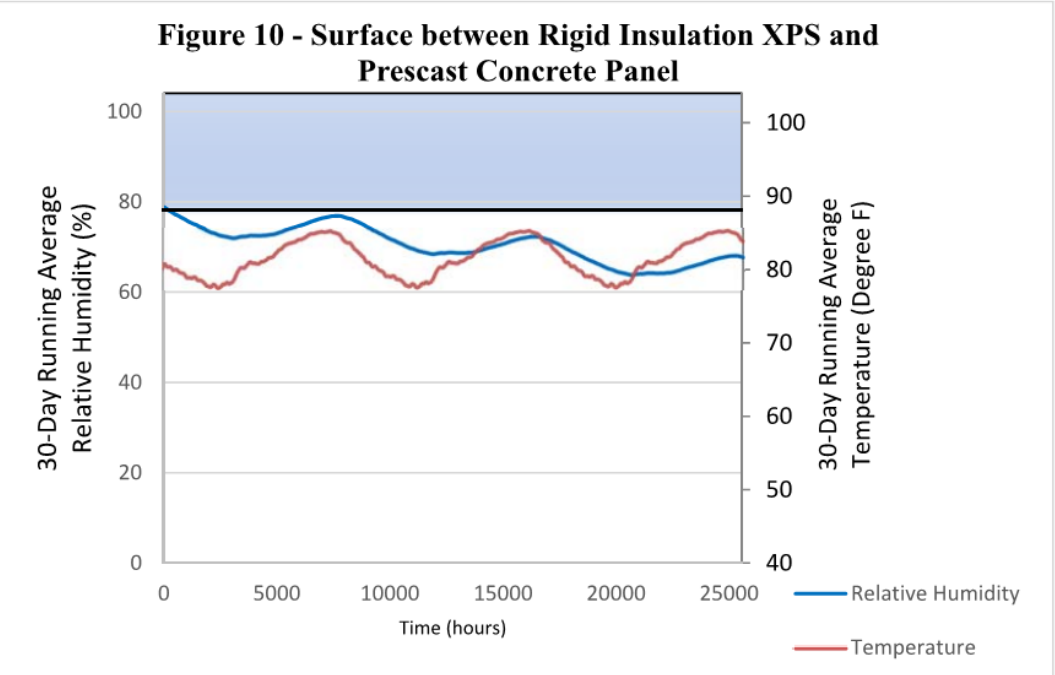
Surface between XPS & Precast Concrete

North Exterior Wall Assembly #1



West Exterior Wall Assembly



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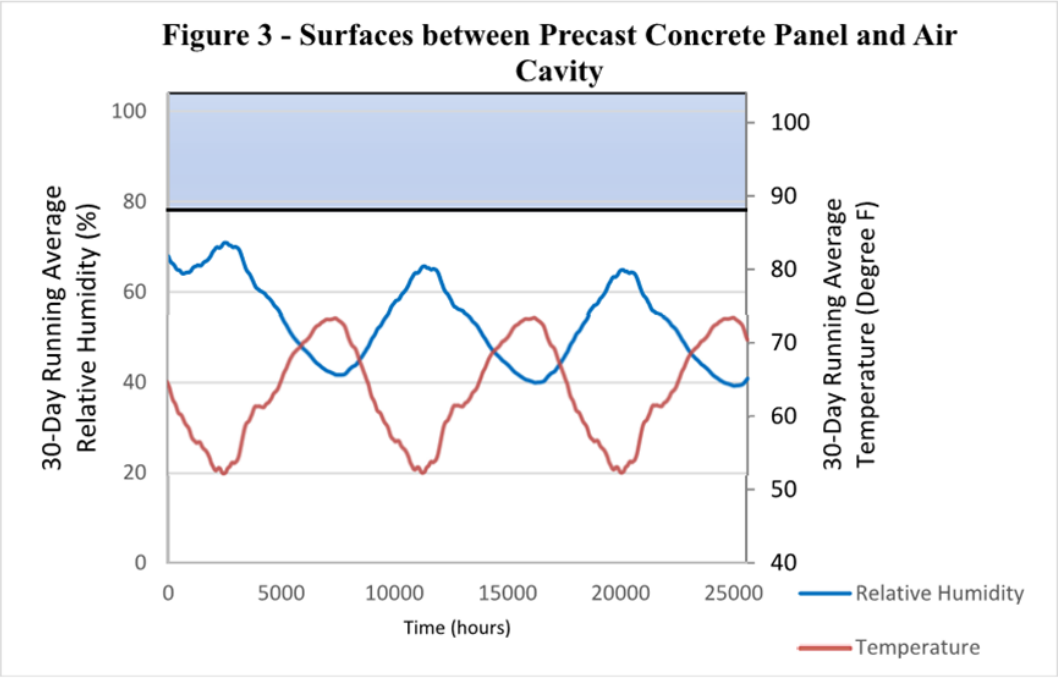
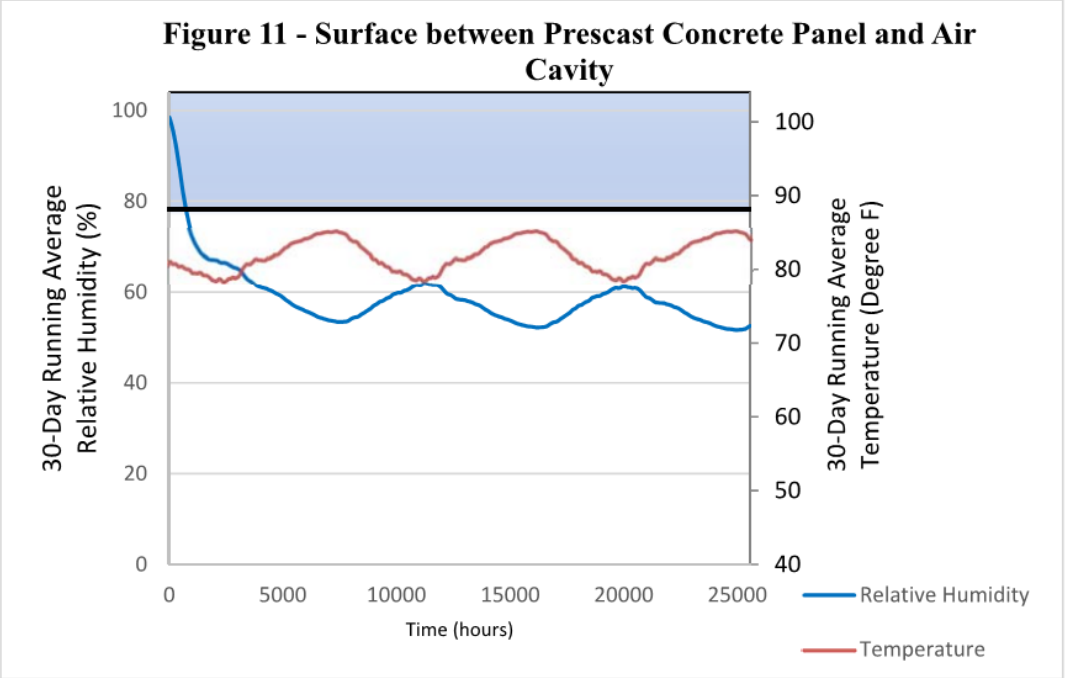
Surface between Precast & Air Cavity

North Exterior Wall Assembly #1



West Exterior Wall Assembly



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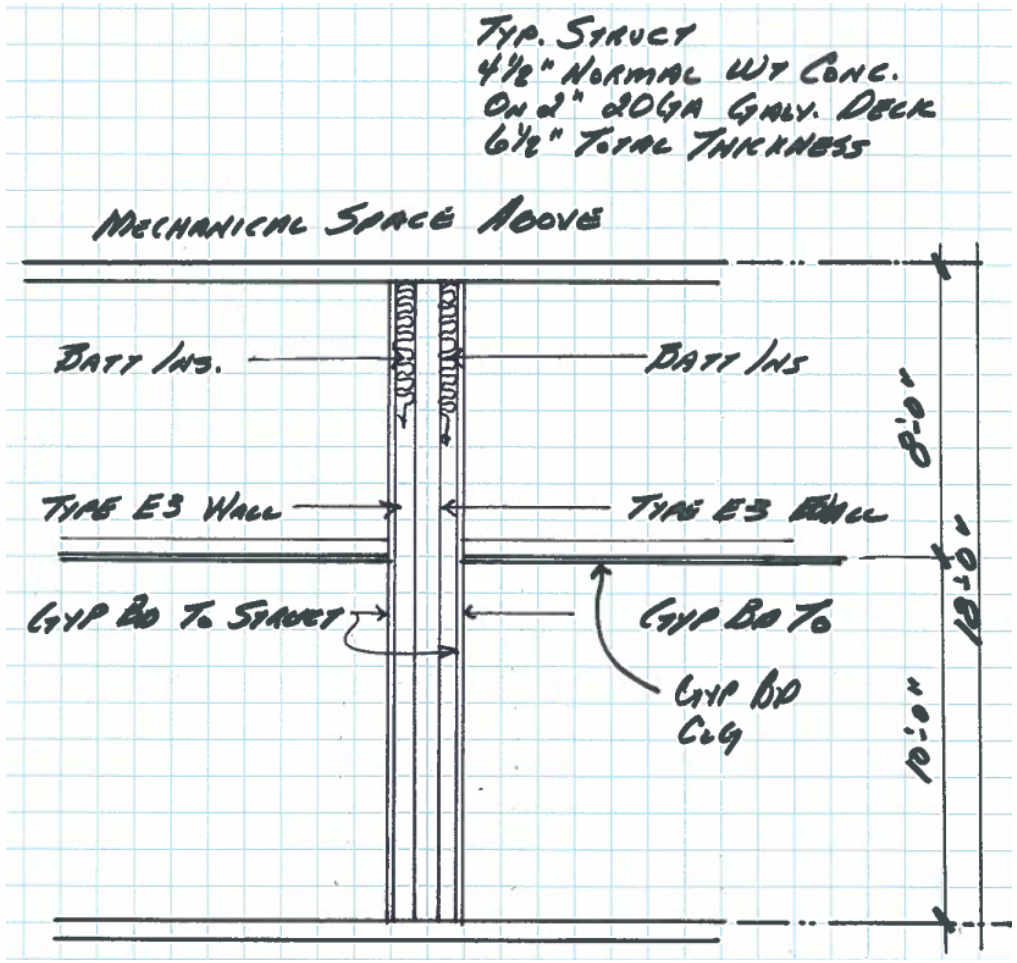
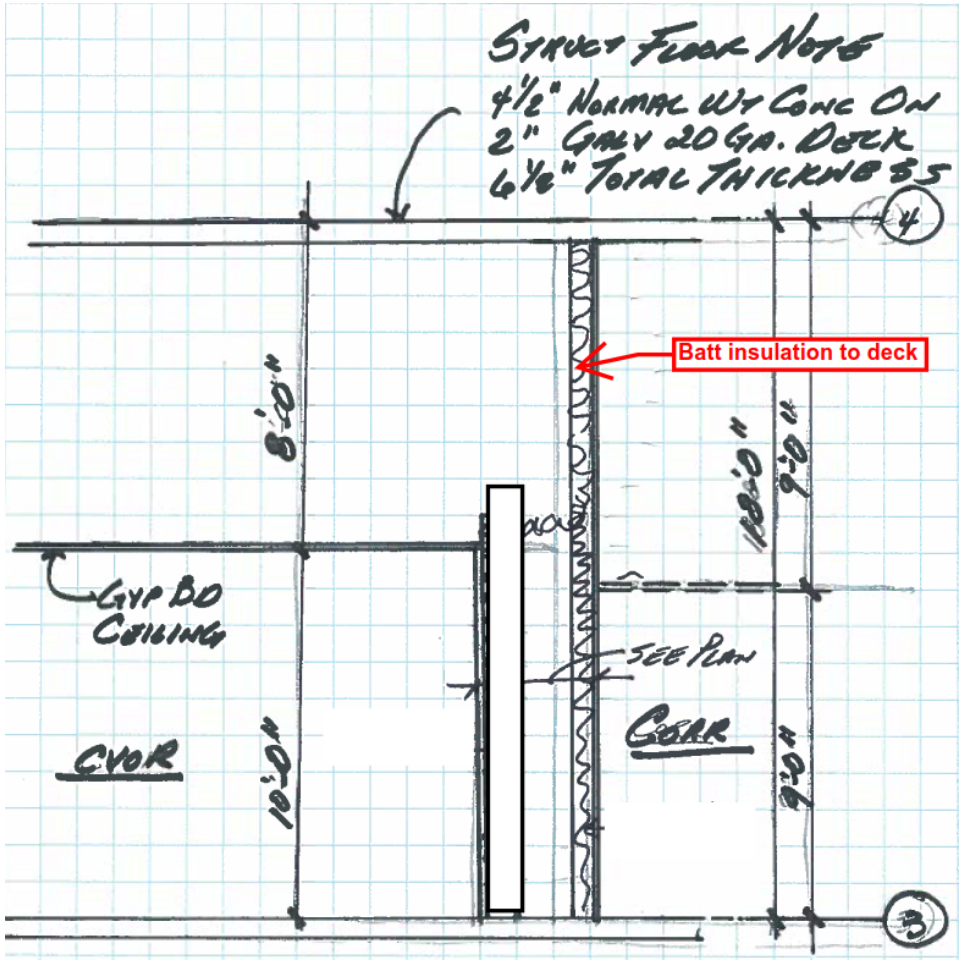
Sketch of Int. Partition Section

Assembly between two CVORs



Assembly CVOR and Corridor



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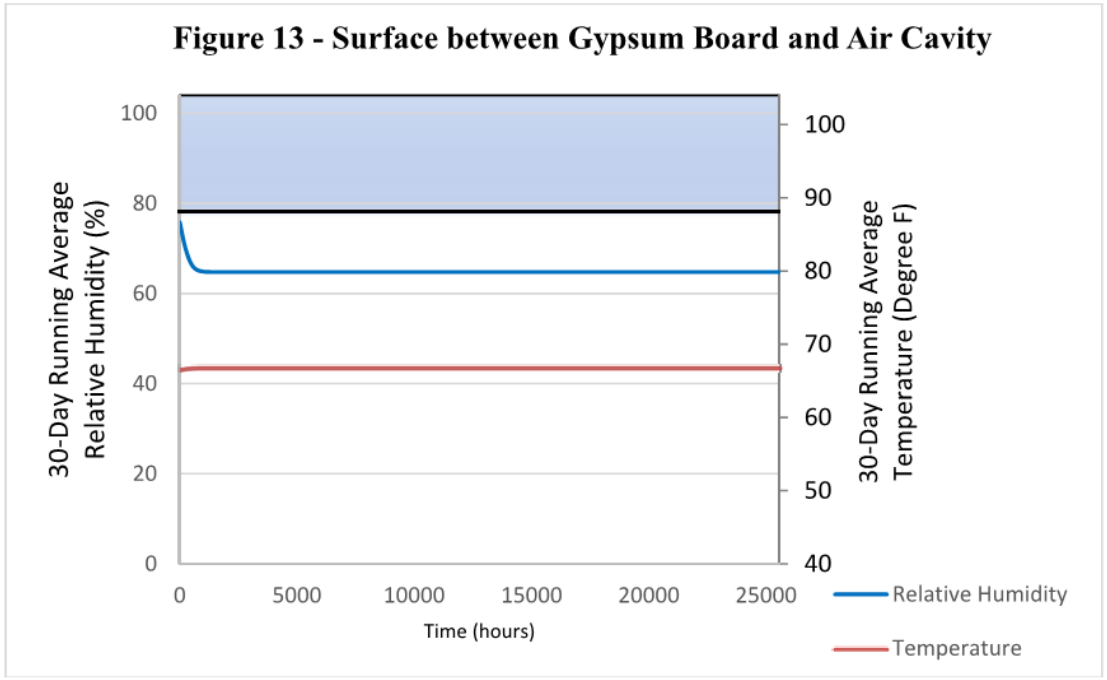
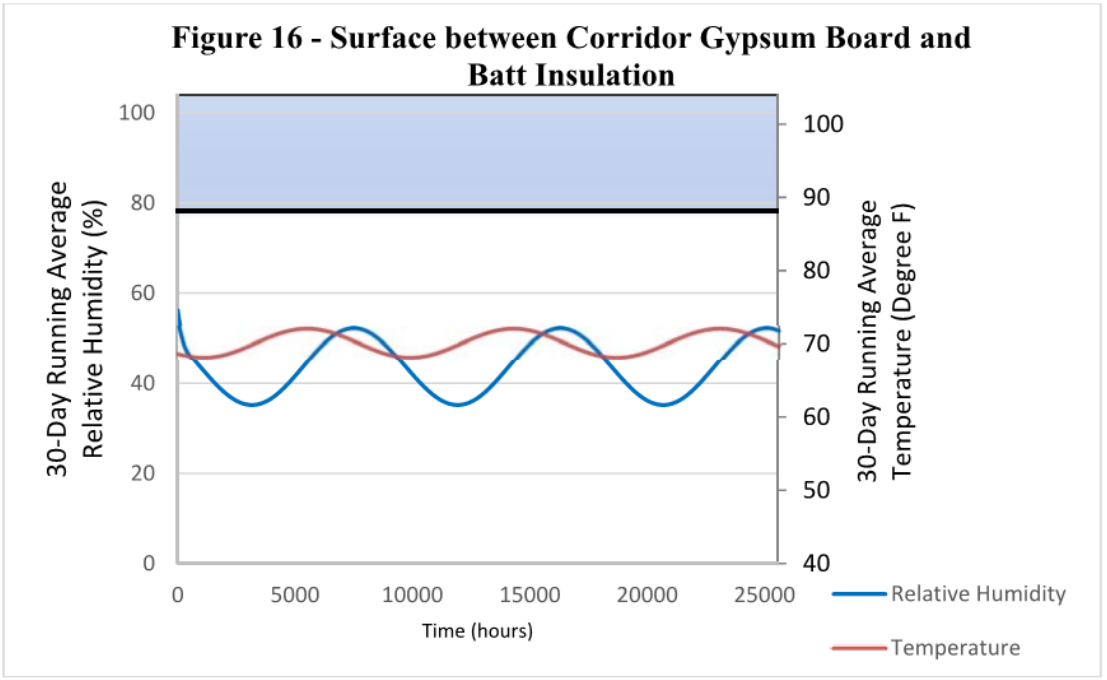
Interior Partitions

Assembly between two CVORs



Assembly CVOR and Corridor



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Ceiling/Floor Assembly (above and below)

- Resinous Flooring Finish (with elastomeric base coating)
- 4.5 to 6.5 inch thick normal weight concrete
- 20 gauge corrugated metal decking

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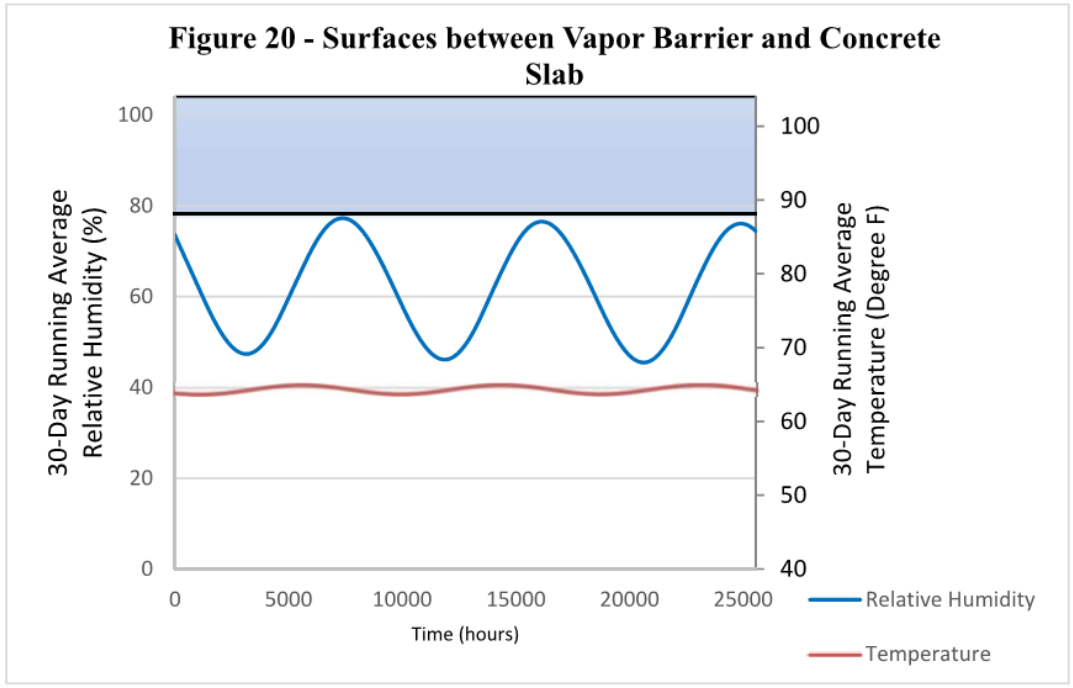
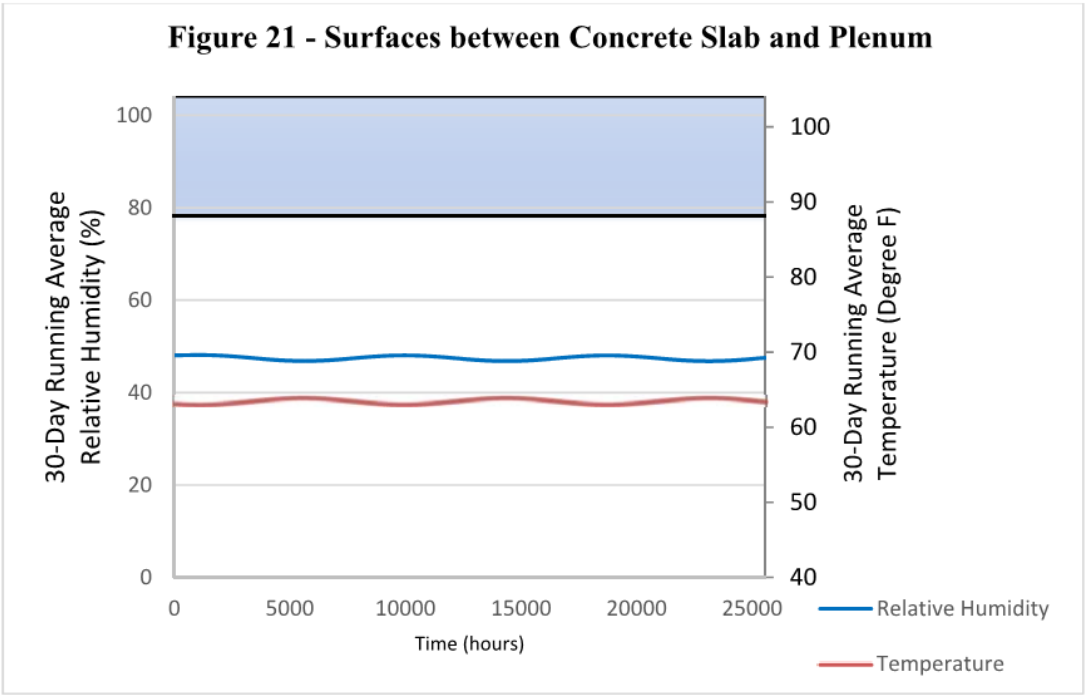
Ceiling Assembly – CVOR to Mech. Rm.

Surface: Flooring and Concrete



Surface: Concrete & Plenum



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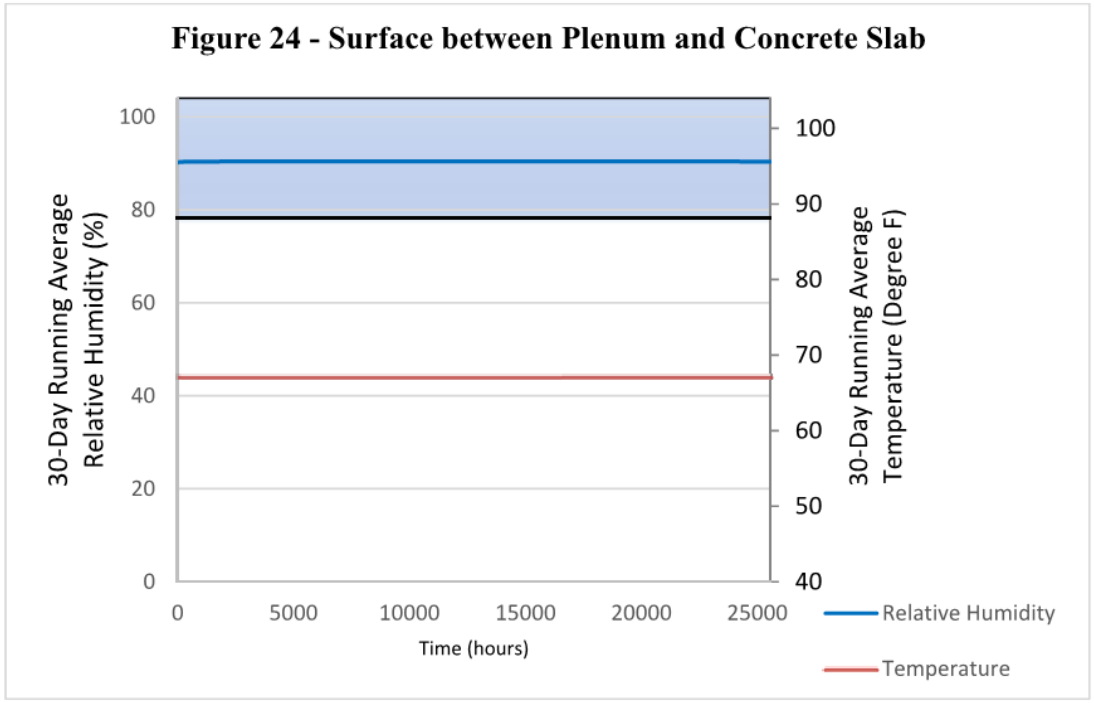
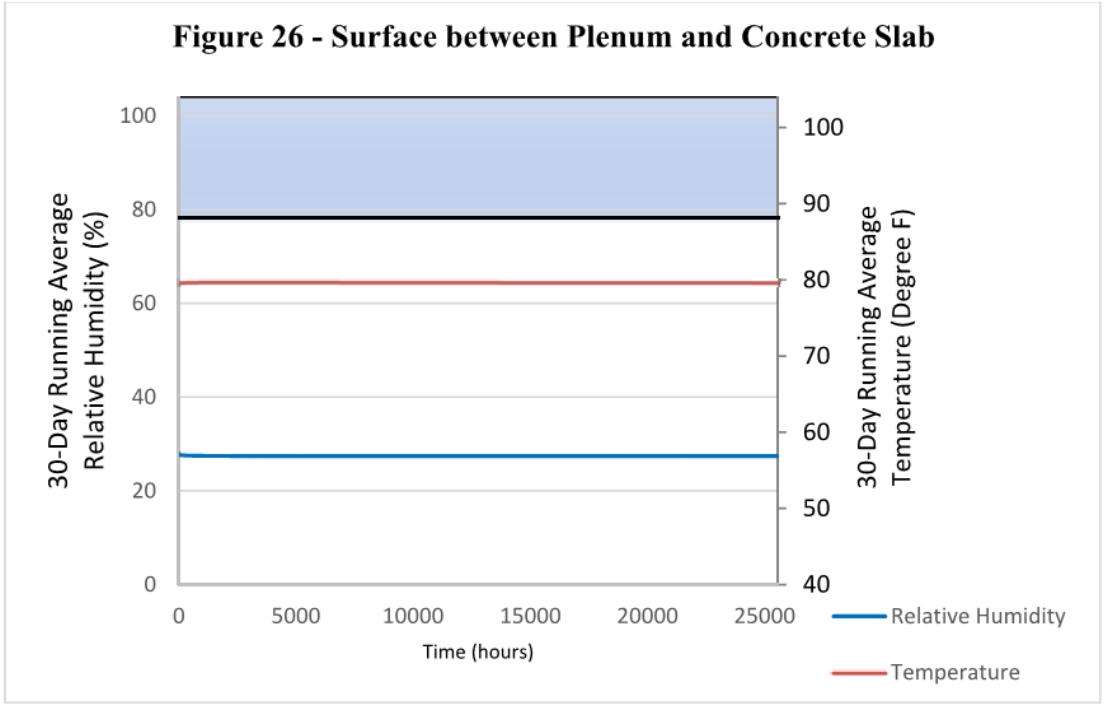
Flooring Assembly

Plenum and Concrete Case #1



Concrete & Plenum Case #2



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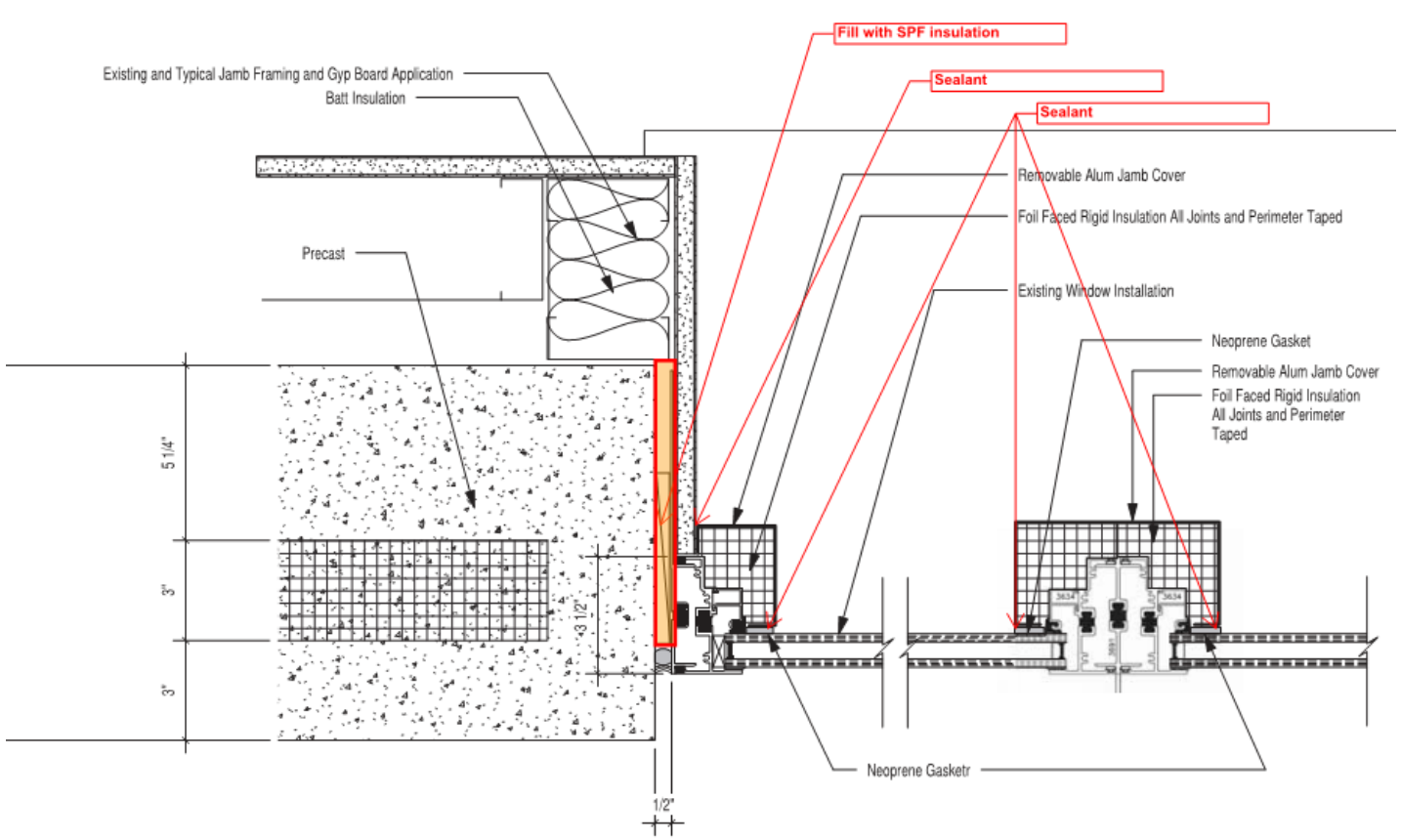
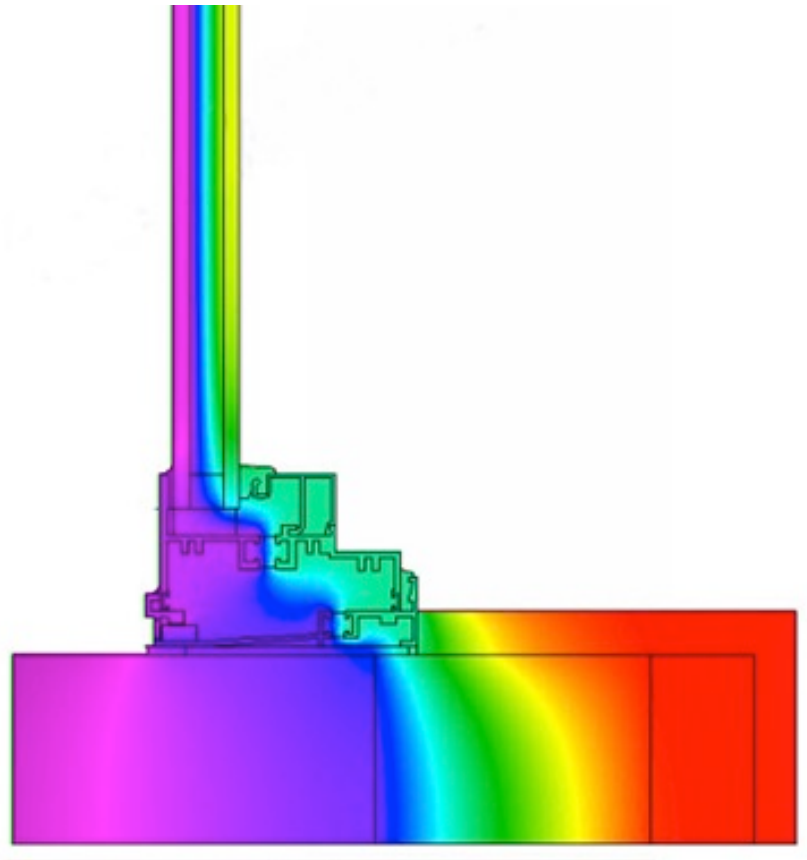
Solutions

$$\Theta_{si} = \Theta_i - U * R_{si} * (\Theta_i - \Theta_e)$$





Solutions

Hygrothermal Analysis:
forensics

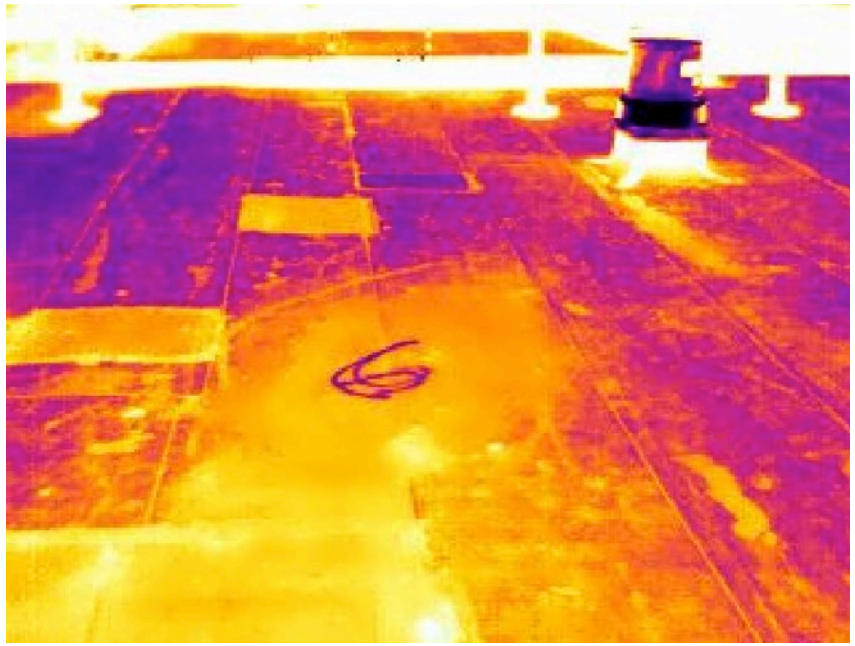
The Challenge

Roof Assembly

- 1 ply Firestone SBS FR Cap - White
- 1 ply Firestone SBS PolyBase
- ½-inch DensDeck Prime Roof Board
- Two layers 2-inch Firestone ISO 95+ GL polyisocyanurate insulation (insulation facers simulated with layers of #15 felt)
- 2-inch thick structural concrete supported by 24-inch concrete beams @ 5-foot OC (w/c = 0.5)

Calcium Chloride results 8/31/15

1N	8/28	8/31		
T	11:34	7:56	68 hrs	1.61 lbs
W	30 g	31g	1 gram	
2N	8/28	8/31		
T	11:34	8:21	68 hrs	3.2 lbs
W	29 g	31g	2 gram	
4N	8/28	8/31		
T	11:54	8:15	68 hrs	4.8 lbs
W	29 g	32g	3 gram	
5N	8/28	8/31		
T	12:01	8:27	68 hrs	6.49 lbs
W	28 g	32g	4 gram	
1S	8/28	8/31		
T	12:15	8:30	68 hrs	1.61 lbs
W	30 g	31g	1 gram	
2S	8/28	8/31		
T	1:08	8:33	67 hrs	6..49 lbs
W	29 g	33g	4 gram	
3S	8/28	8/31		
T	1:15	8:35	67 hrs	6.49 lbs
W	30 g	34g	1 gram	
4S	8/28	8/31		
T	1:21	8:51	67 hrs	6.49 lbs
W	29 g	33g	4 gram	
5S	8/28	8/31		
T	1:24	8.52	67 hrs	6.49 lbs
W	28 g	32g	1 gram	



Relative Humidity Probe Results

8/31/15

	Deck Surface	Slab Temp	Humidity
1S	75.6	70	78%
2S	74.4	76	75%
3S	77.2	79	85%
4S	77.4	78	81%
5S	75.4	77	78%
1N	75.6	79	79%
3N	77	74	71%
4N	73.2	77	82%
5N	78.2	79	78%

Roof Cores

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Summary of Gravimetric Analysis

	A	B	C	D	E	F
Core Number and Sample Name	TARE WEIGHT	TARE + SAMPLE	TARE + SAMPLE "DRIED"	WEIGHT OF ORIGINAL SAMPLE	WEIGHT OF DRIED SAMPLE	PERCENT MOISTURE BY DRY WEIGHT
C1-Dense Prime	None	None	None	654.8	650.5	0.66%
C1-ISO	None	None	None	79	78.6	0.50%
C2-Dense Prime	None	None	None	323.9	320.1	1.18%
C2-ISO	None	None	None	82.5	80	3.12%
C3-Dense Prime	None	None	None	266.7	264	1.02%
C3-ISO	None	None	None	160.1	158.7	0.88%
C4-Dense Prime	None	None	None	370.7	368.1	0.70%
C4-ISO	None	None	None	71.8	71.5	0.42%

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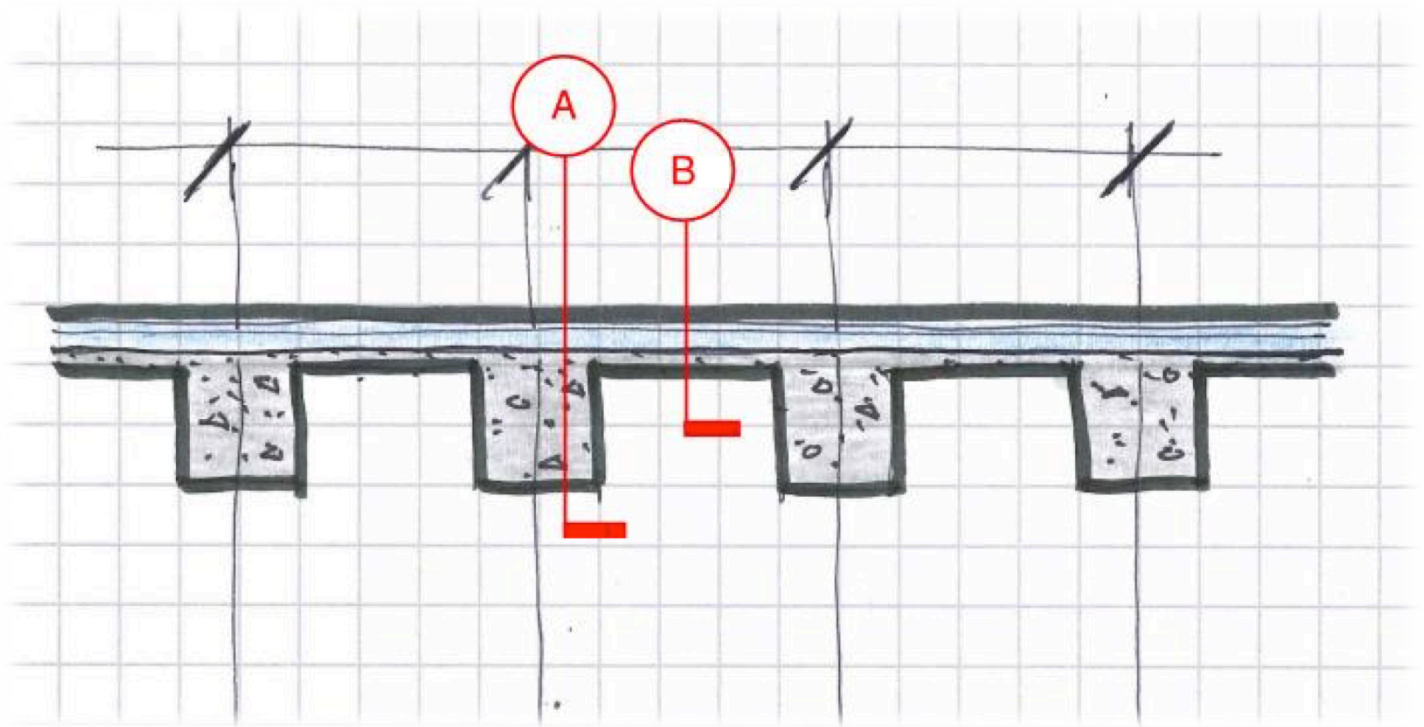
Initial Conditions

- **Initial Conditions: 80% RH typical, but structural concrete varied**
- **5-year simulation**
- **Interior setpoints matching exterior setpoints**
- **Base Case 1: Not at Beam**
  - 100% RH Concrete Deck
- **Base Case 2: At Beam**
  - 100% RH top 4-inches, 80% RH for 22-inches



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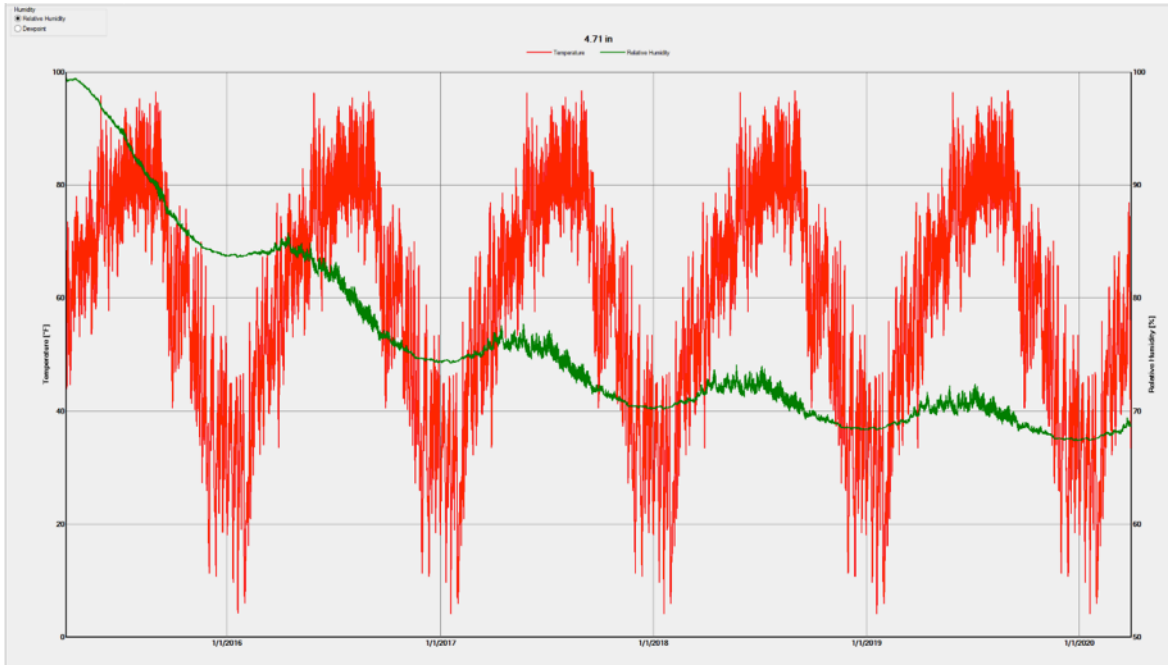
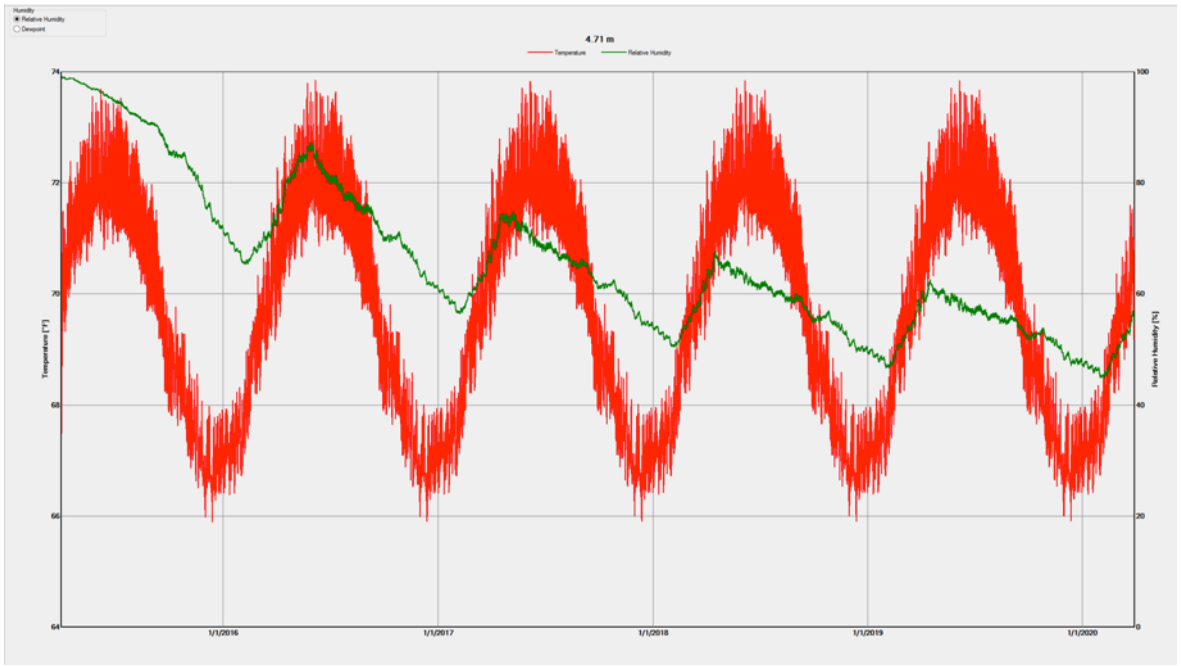
Not at Beam; **No A/C;** 100% RH



Not at Beam; **with A/C & Heating;** 100% RH



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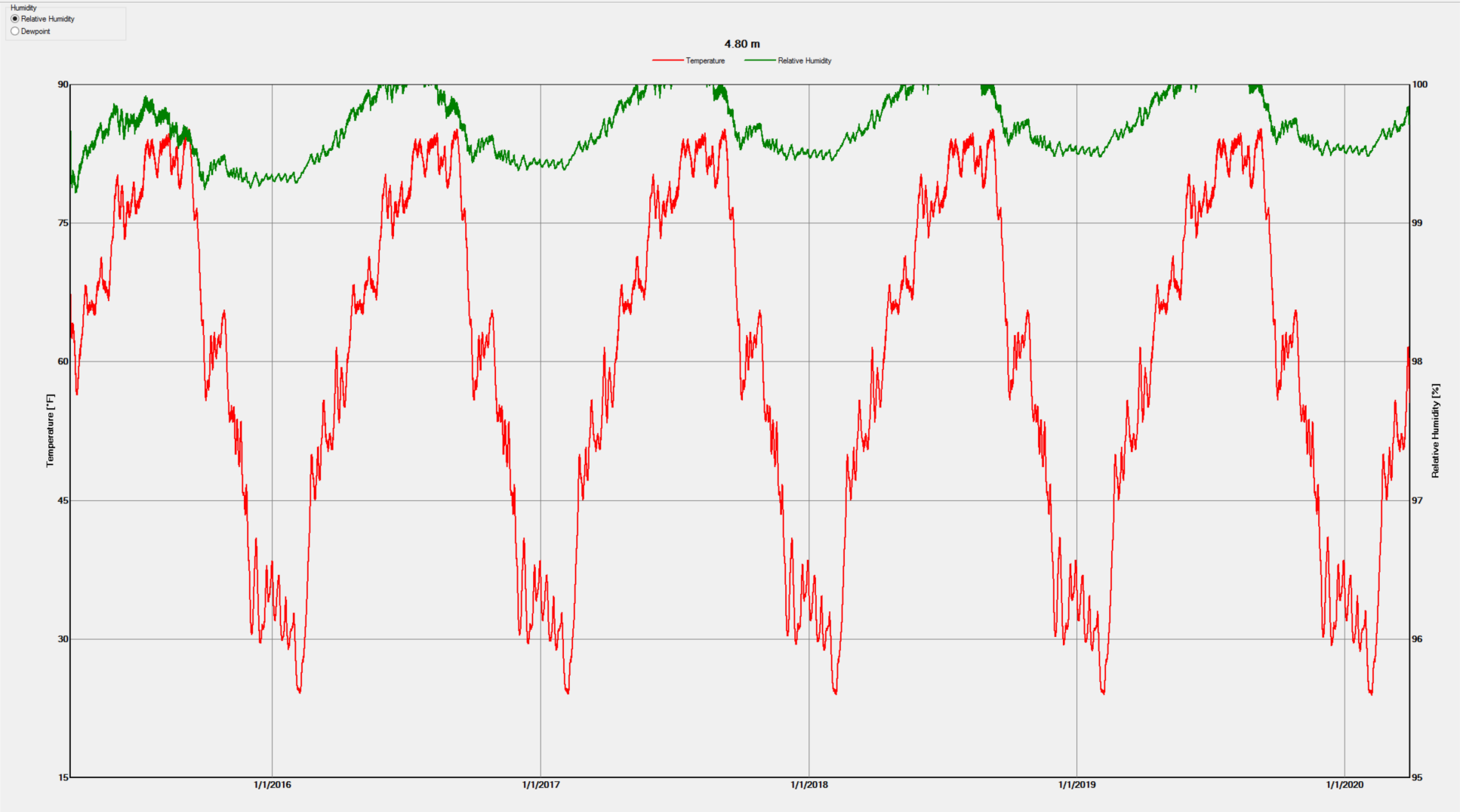
At Beam; No A/C; 100% RH



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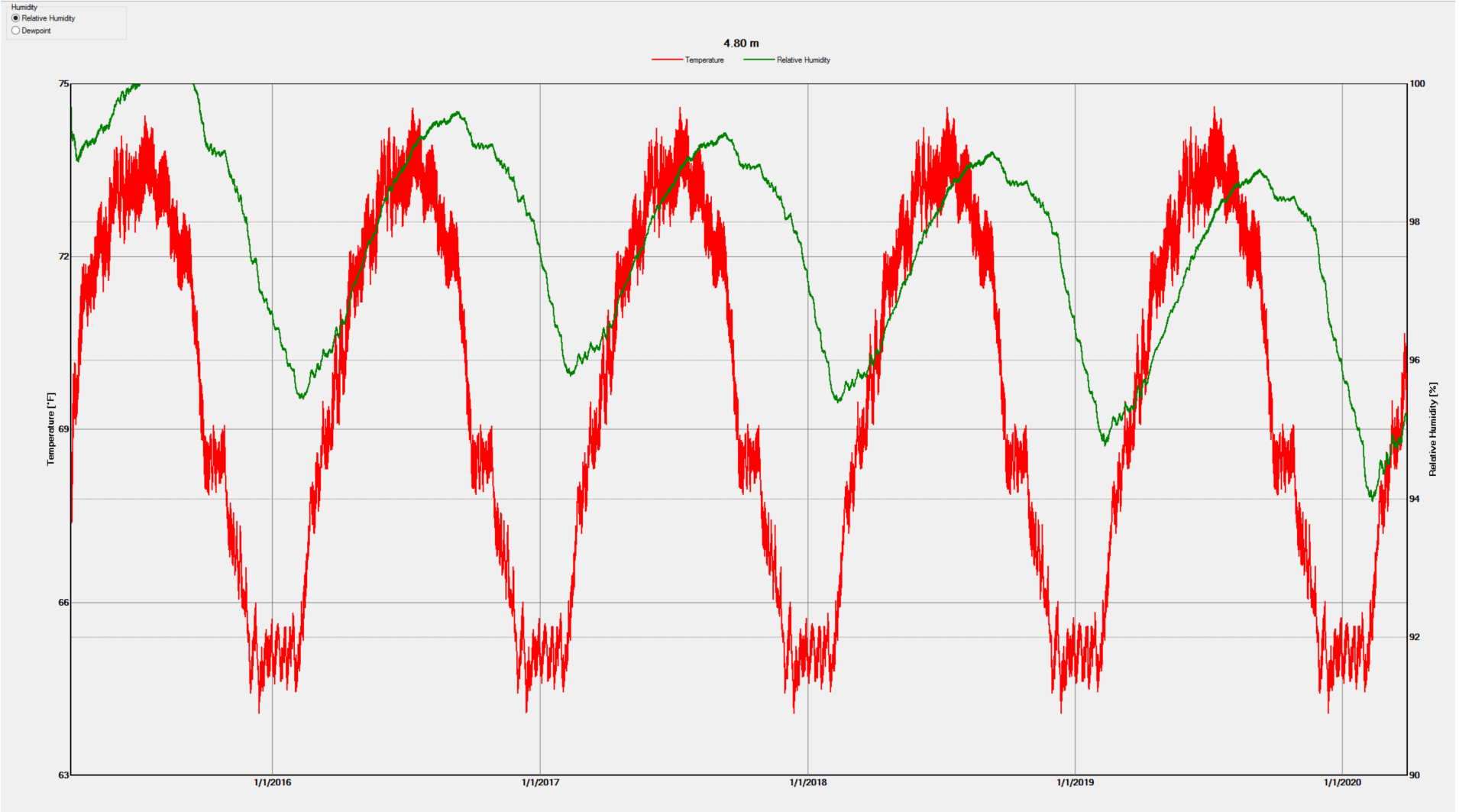
At Beam with A/C; 100% RH 8” Conc



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At Beam; No A/C; 100% RH 4” Conc

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Conclusions

- Sections through the concrete deck (not at beams), dry out efficiently
- If substrate is heavily saturated, potential exists for water to condense on surface of concrete slab during summer months for first few years
- Actual behavior of roofing assembly likely to be between results of Case 1 and Case 2

This concludes The American Institute of Architects
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