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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.

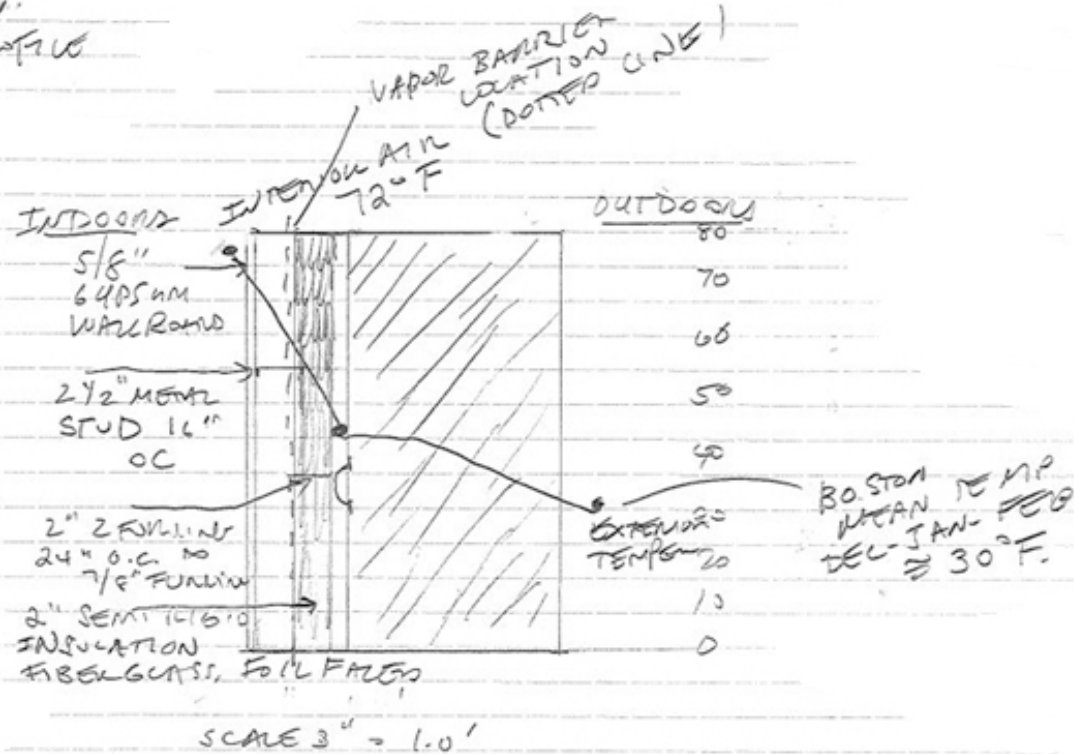
Learning Objectives

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

Old School Hygrothermal Analysis

CITY HALL ANNEX
WALL ASSEMBLY
TEMPERATURE PROFILE

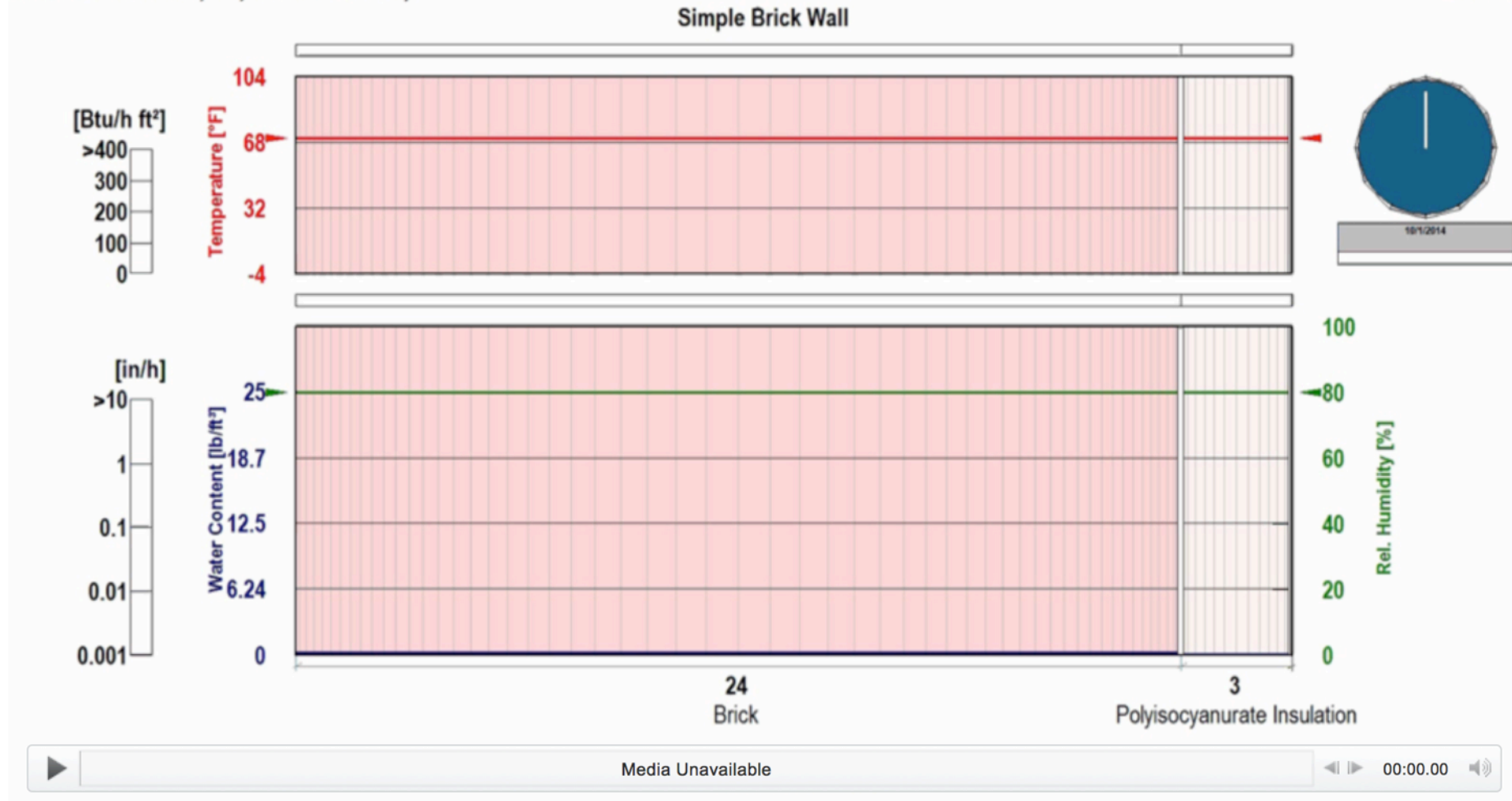


- ⑤ ASSUMING INDOOR CONDITIONS AT 72°F AND 35% RH THE DEW POINT FROM THE PSYCHROMETRIC CHART IS APPROXIMATE 46°F. ANY TEMPERATURE BELOW THE DEW POINT WILL CAUSE CONDENSATION IN THE WALL ASSEMBLY.

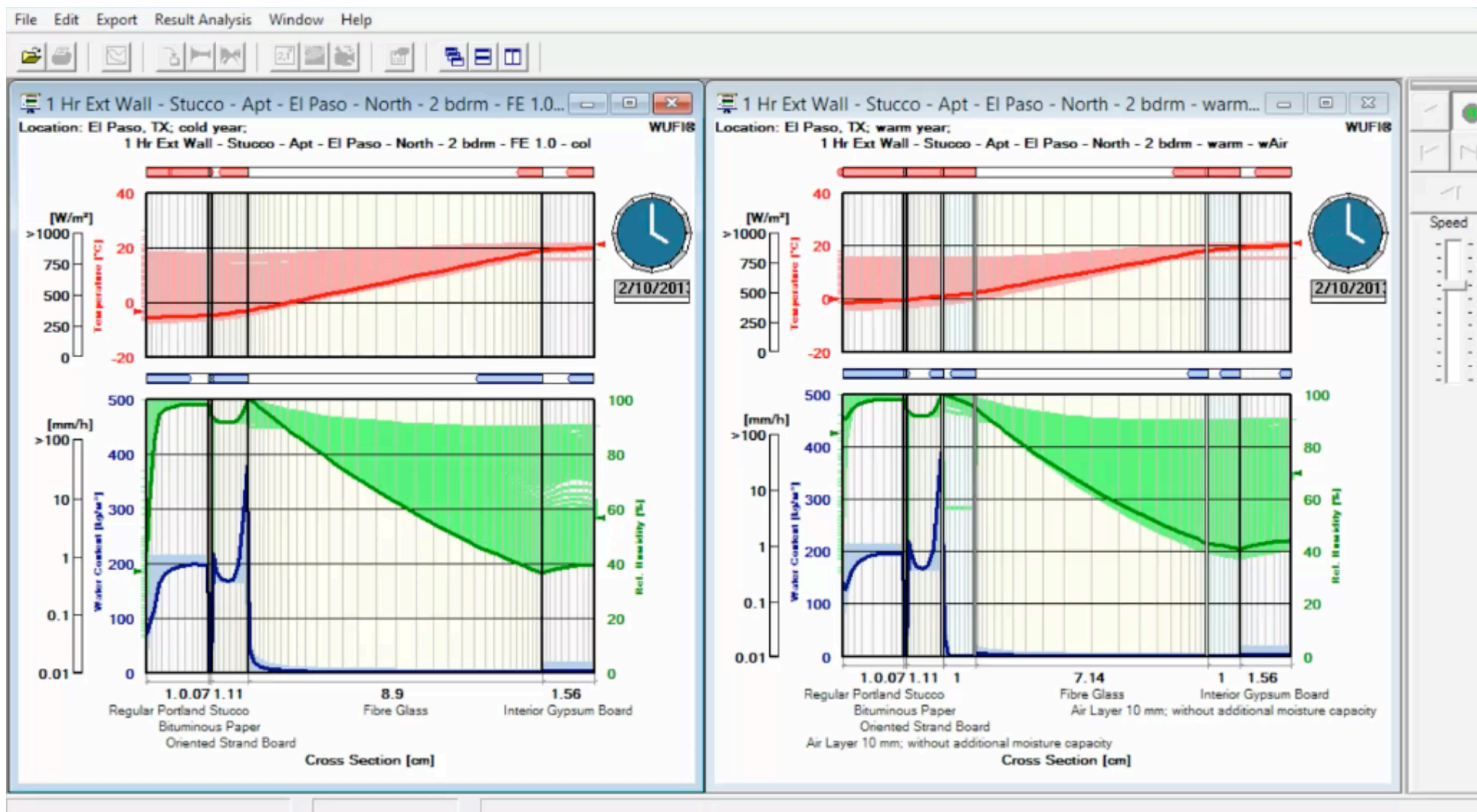
WUFI Pro 1d Simulation (Fraunhofer IBP) Wärme Und Feuchte Instationär

Location: Knoxville, TN; ASHRAE Year 1;

WUFI®



Simultaneous Simulations



Five Required Material Properties (minimum)

Layer/Material Data

Layer/Material Name: Concrete, w/c=0.5

Material Data | Info

Basic Values

Bulk density [lb/ft ³]	143.584
Porosity [ft ³ /ft ³]	0.18
Specific Heat Capacity, Dry [Btu/lb°F]	0.203
Thermal Conductivity, Dry, 50°F [Btu/h ft°F]	0.924
Permeability [perm in]	0.716

Approximation Parameters

Moisture-dep. Thermal Cond. Supplement [%/M.-%]	8.0
Temp-dep. Thermal Cond. Supplement [Btu/h ft°F ²]	0.000064

Typical Built-In Moisture [lb/ft³]: 9.364

Layer thickness [in]: 21

Color: [dropdown]

Hygrothermal Functions

Moisture Storage Function

- Liquid Transport Coefficient, Suction
- Liquid Transport Coefficient, Redistribution
- Permeability, moisture-dependent
- Thermal Conductivity, moisture-dependent
- Thermal Conductivity, temperature-dependent
- Enthalpy, temperature-dependent

Graph | Edit Table | from File...

Approximate

No.	RH [-]	Water Content [lb/ft ³]
1	0.0	0.0
2	0.05	1.68555529
3	0.1	1.99769516
4	0.15	2.12255111
5	0.2	2.18497908
6	0.3	2.30983503
7	0.4	2.49711895

New | Delete | Copy | Insert


Copy

Paste into Material Database | Import... | Export... | OK | Abort | Help

ASHRAE 160-2009

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ANSI/ASHRAE Standard 160-2009




ASHRAE STANDARD

Criteria for Moisture-Control Design Analysis in Buildings

Approved by the ASHRAE Standards Committee on January 24, 2009; by the ASHRAE Board of Directors on January 28, 2009; and by the American National Standards Institute on January 29, 2009.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site, <http://www.ashrae.org>, or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada).

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Provides:

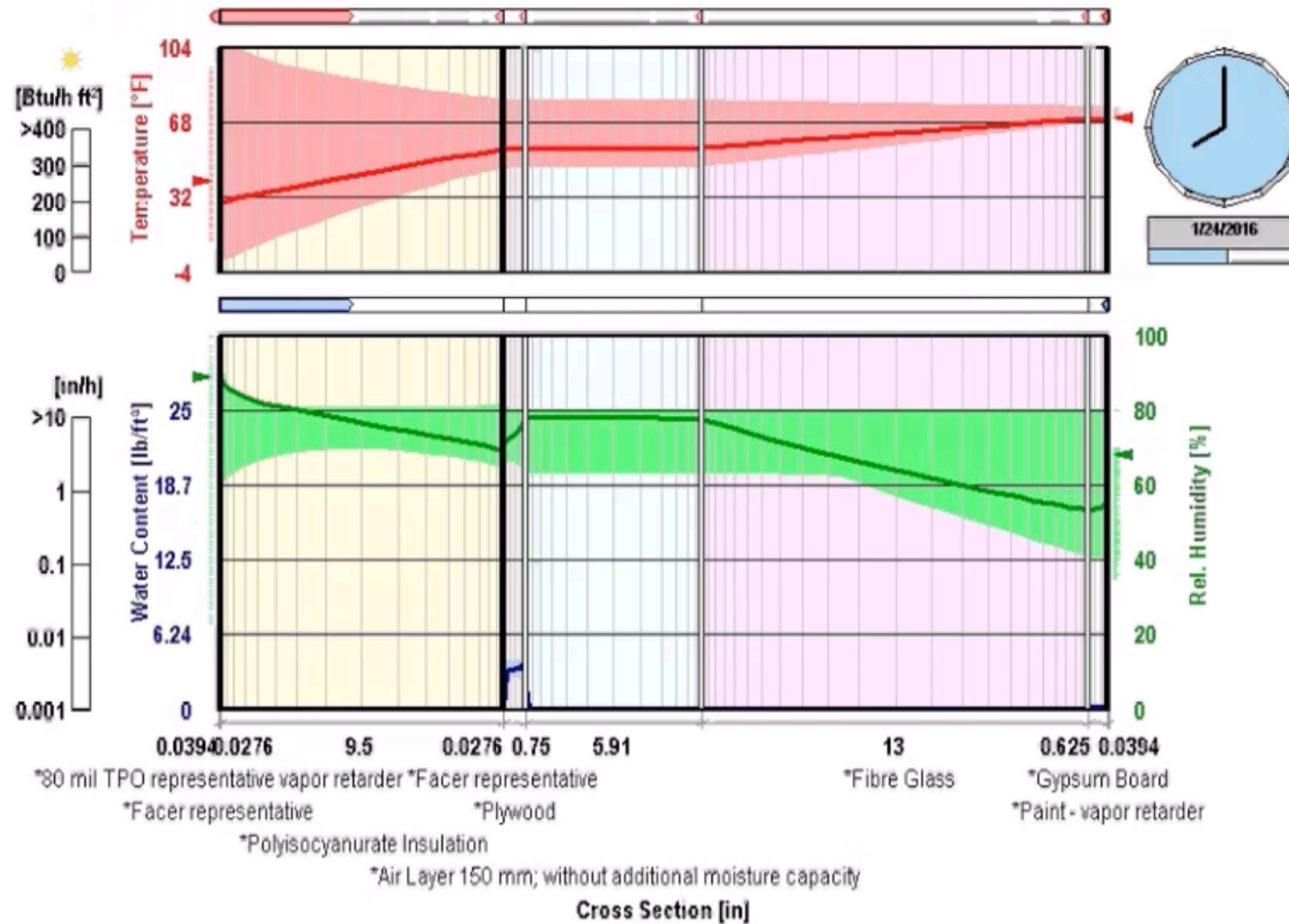
1. Design criteria for materials, climate, conditions, moisture generation, ventilation, pressure differentials, rain loads, etc.
2. Guidelines for minimizing moisture problems associated with mold growth and corrosion
3. Report parameters and guidelines

WUFI Pro 1d Simulation (Fraunhofer IBP)

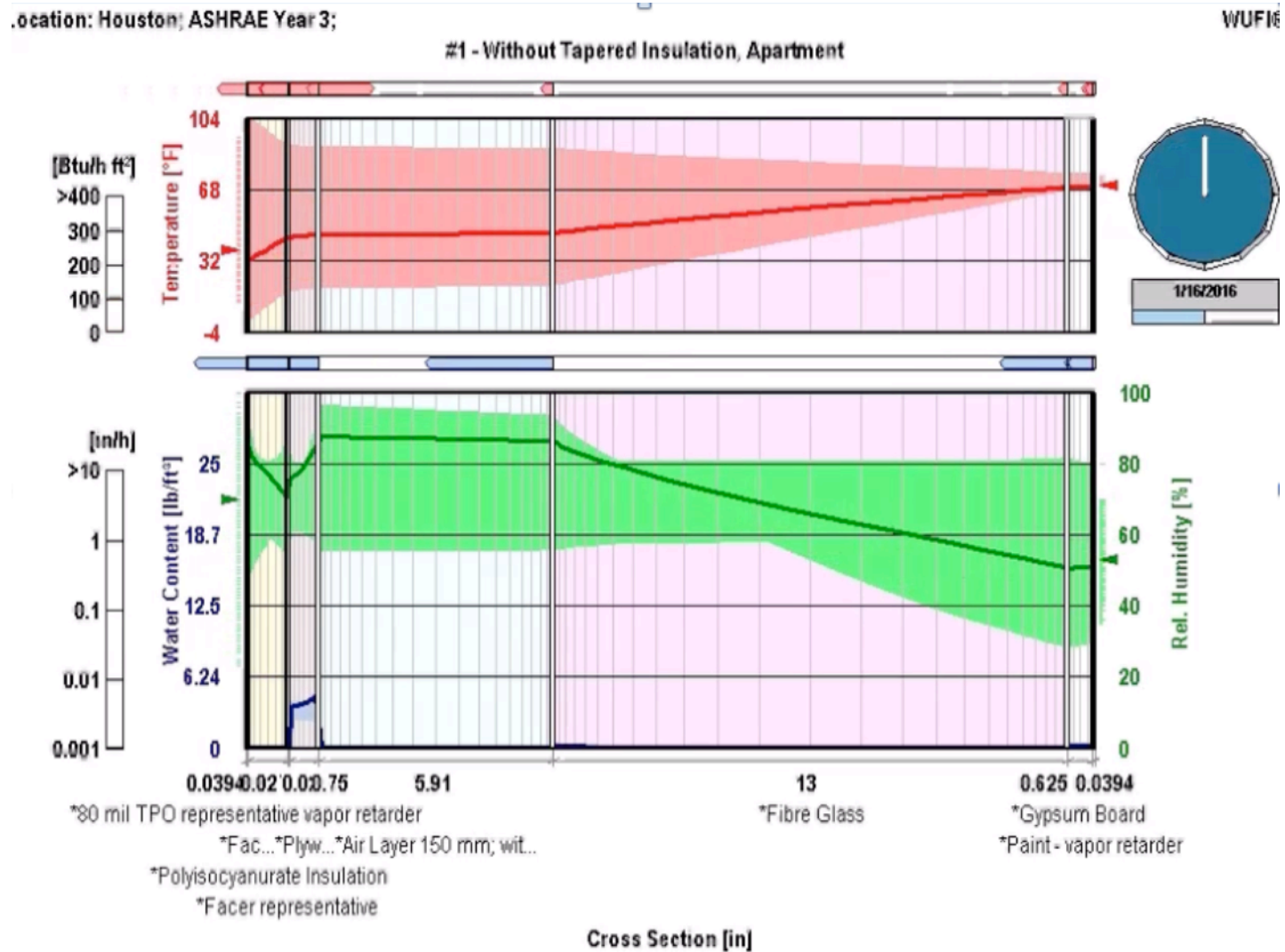
Location: Houston; ASHRAE Year 3;

WUFI

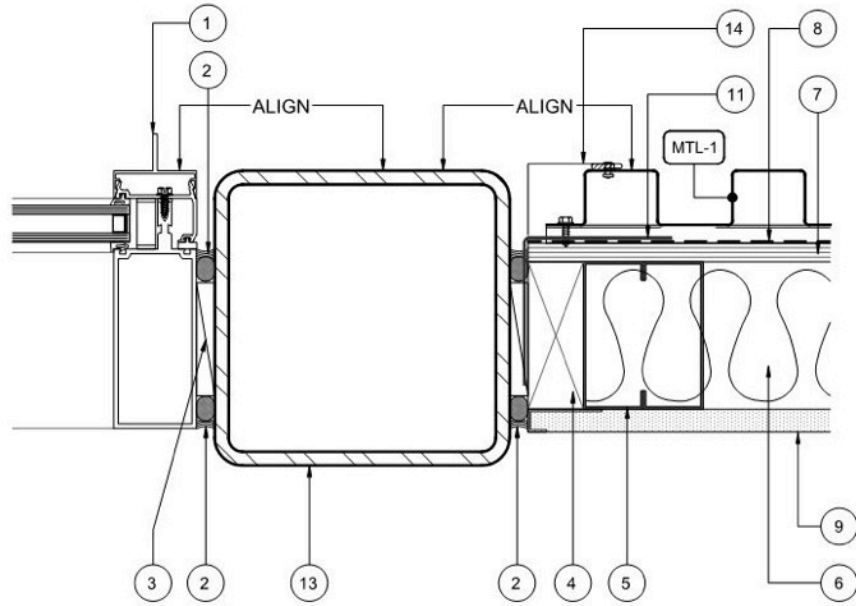
#3 - Max Tapered Insulation, Apartment



WUFI Pro 1d Simulation (Fraunhofer IBP)



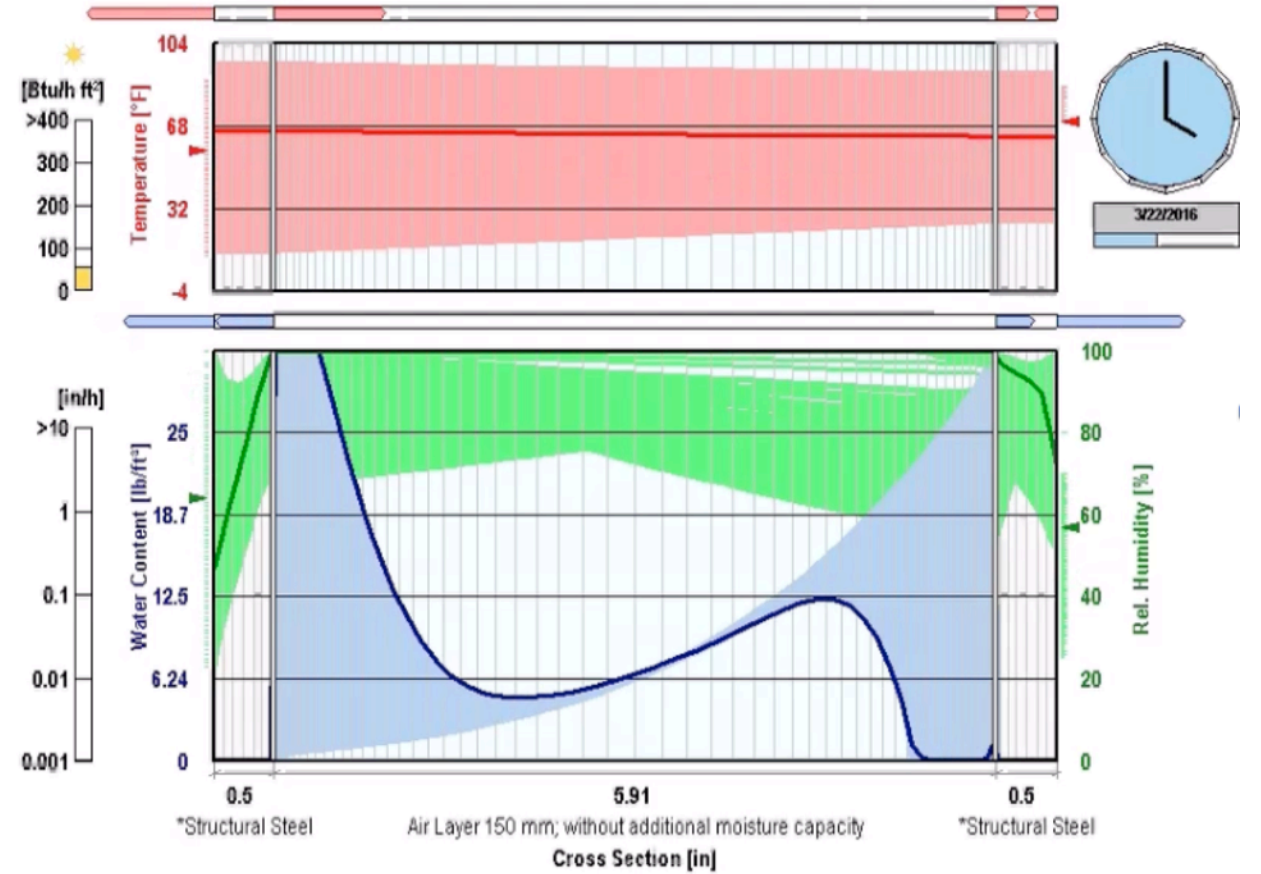
WUFI Pro 1d Simulation (Fraunhofer IBP)



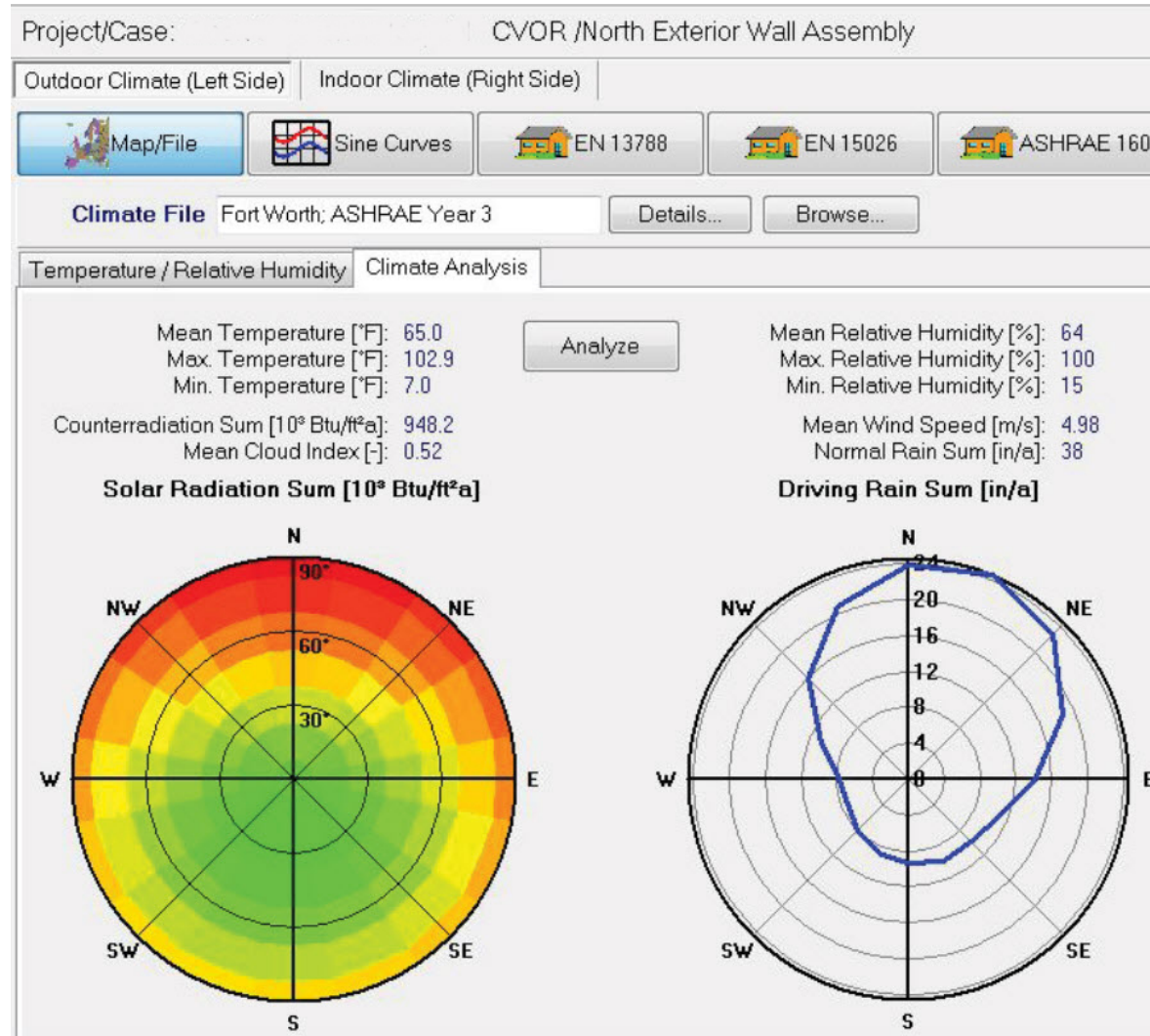
Location: Houston; ASHRAE Year 3;

#1

WUFI

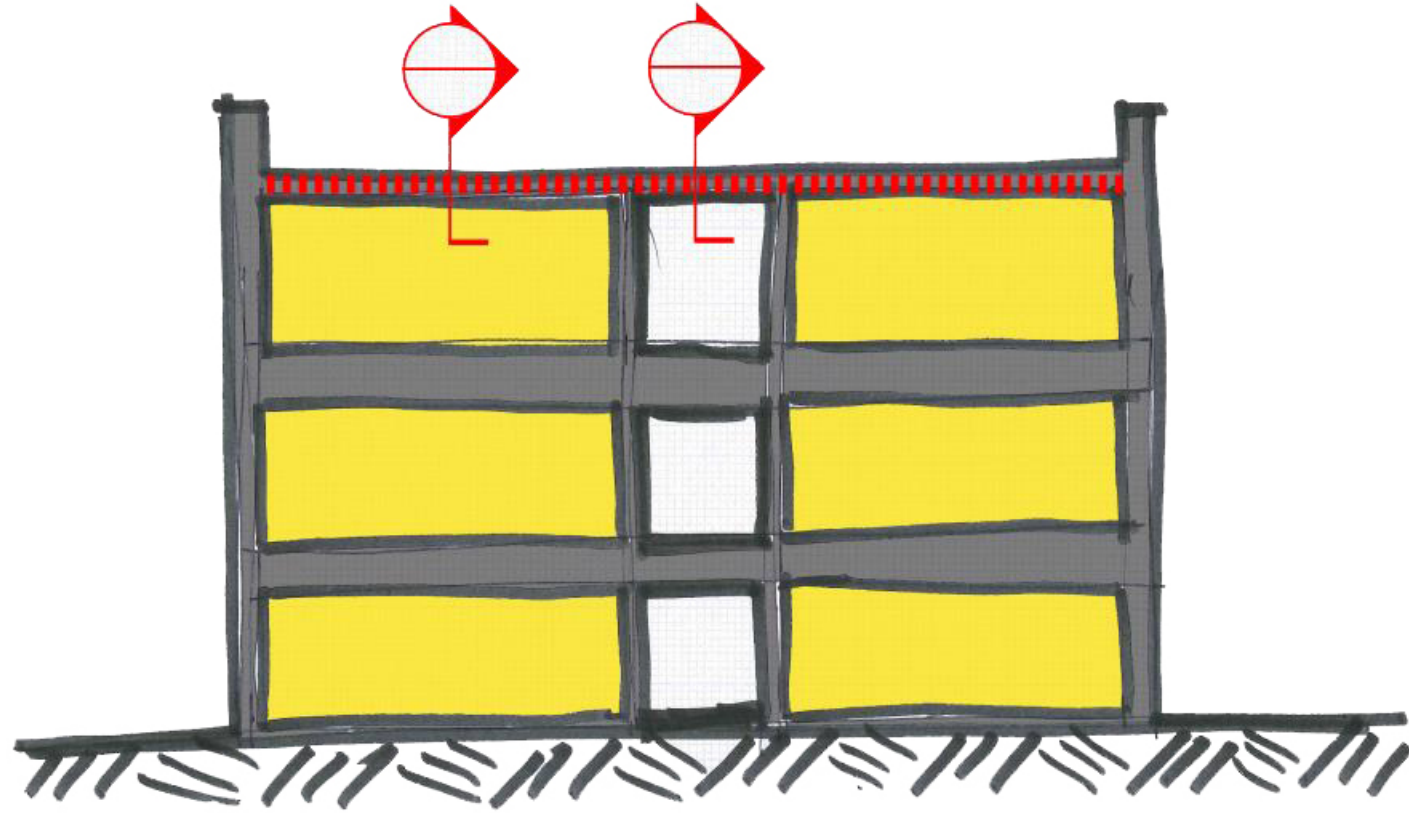


Worst Case Scenario

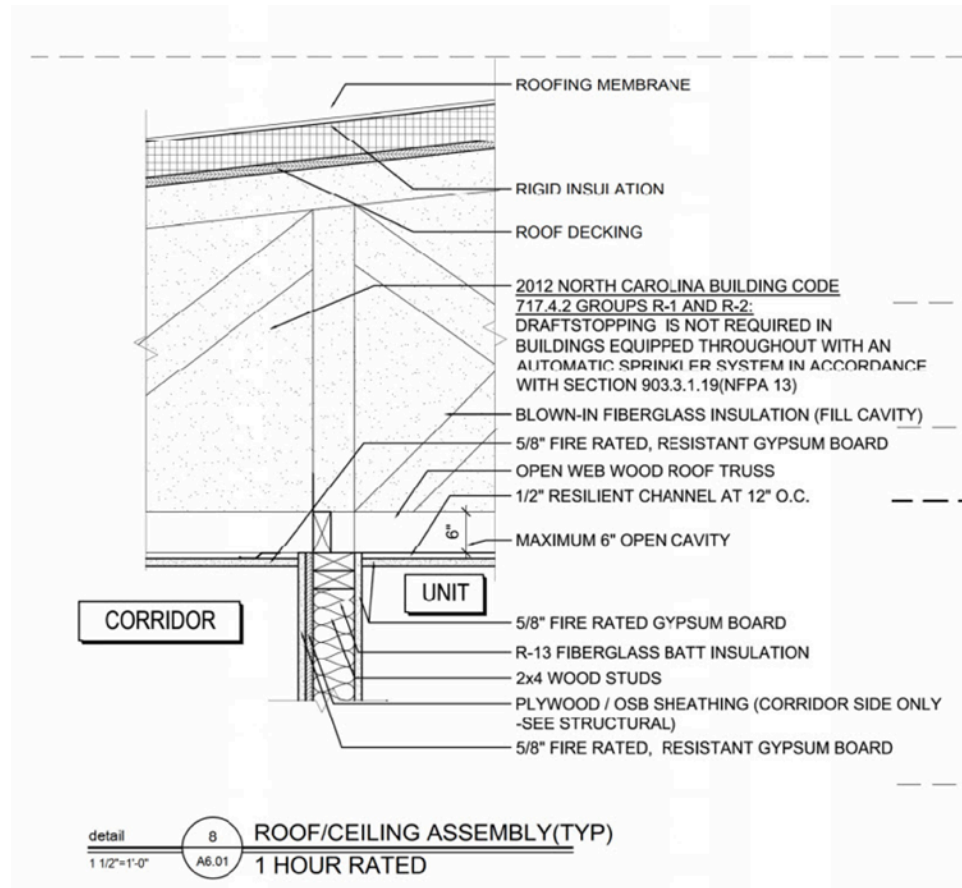


Hygrothermal Analysis: unique assemblies

The Challenge

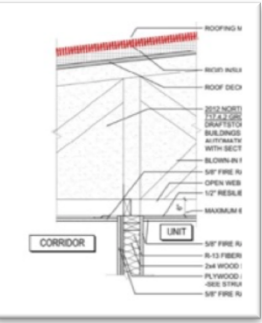


Roof Assembly

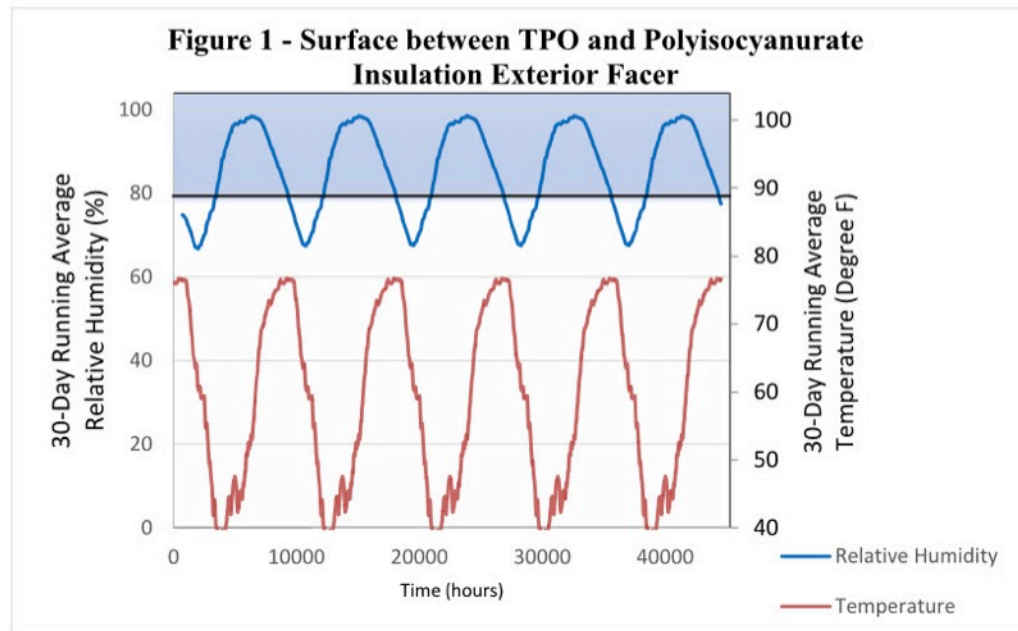


- 80-mil Calisle Sureweld TPO reinforced membrane (white)
- 2-inch Calisle SecurShield HD Composite Polyiso
- 3/4-inch plywood decking
- R-19 Unfaced Fiberglass Insulation
- Air Layer (thickness varies – simulated as 0.07 ACH and 6-inches thick)
- 6.5-inches fiberglass insulation
- 5/8-inch Gypsum Board
- PPG Latex Paint at Apartments; PPG Acrylic Paint at Hallways (2 coats with primer)

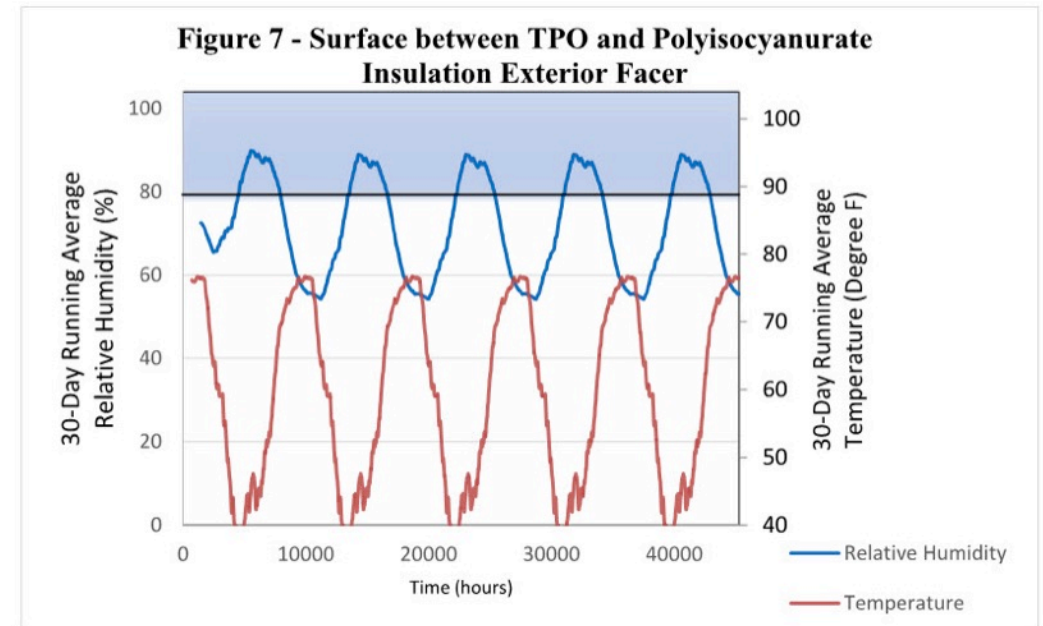
Surface between TPO and ISO



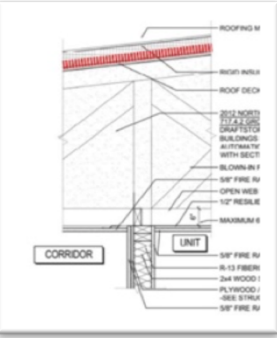
Assembly #1 (over apartment)



Assembly #2 (over breezeway)

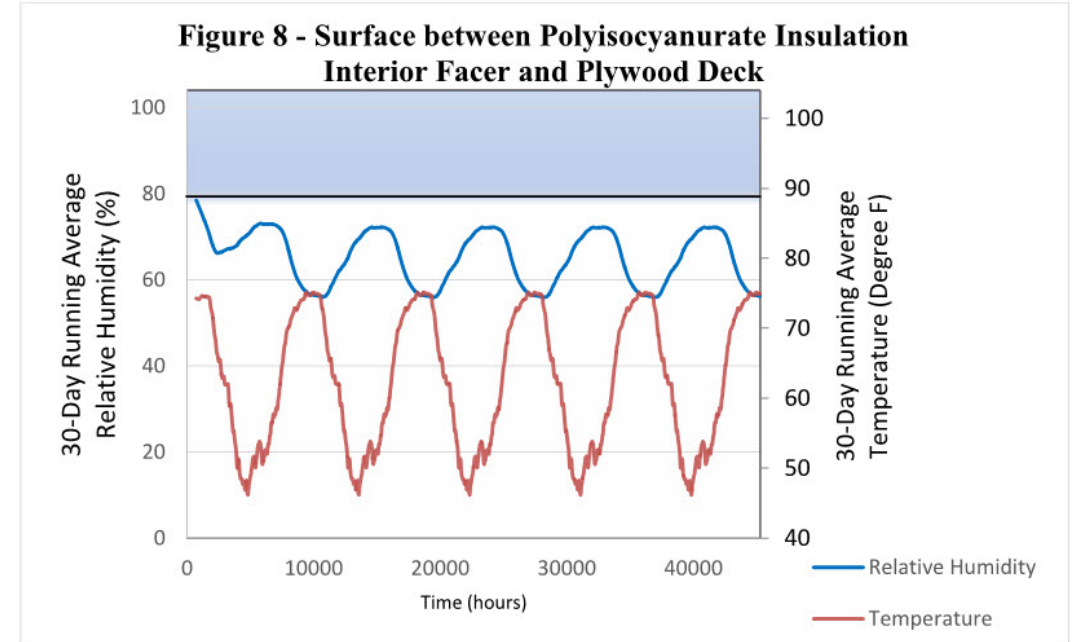
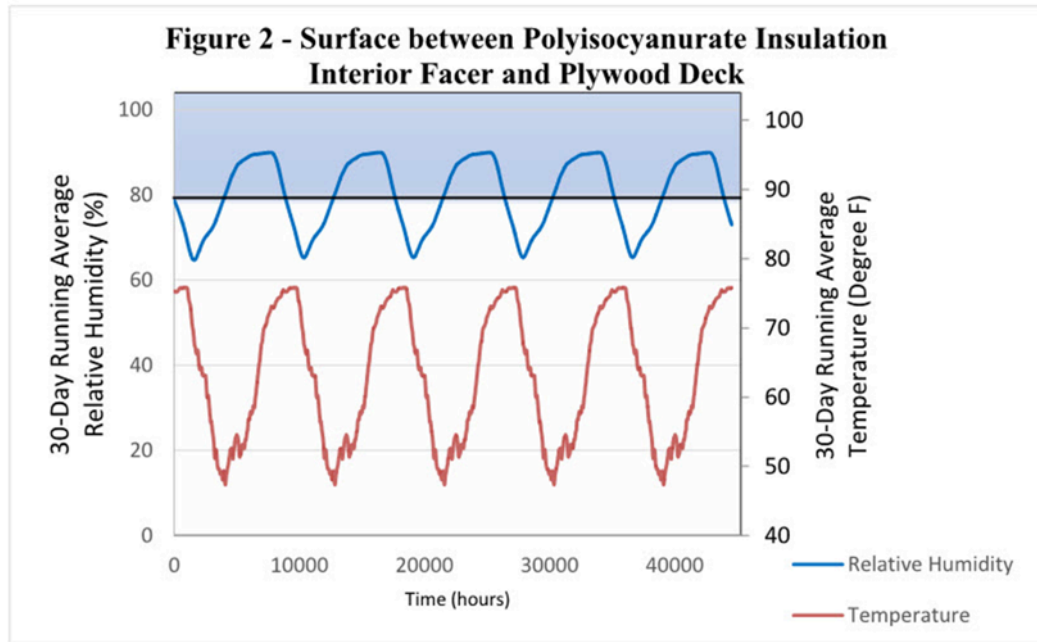


Surface between ISO and Plywood

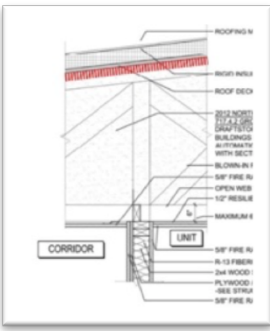


Assembly #1 (over apartment)

Assembly #2 (over breezeway)

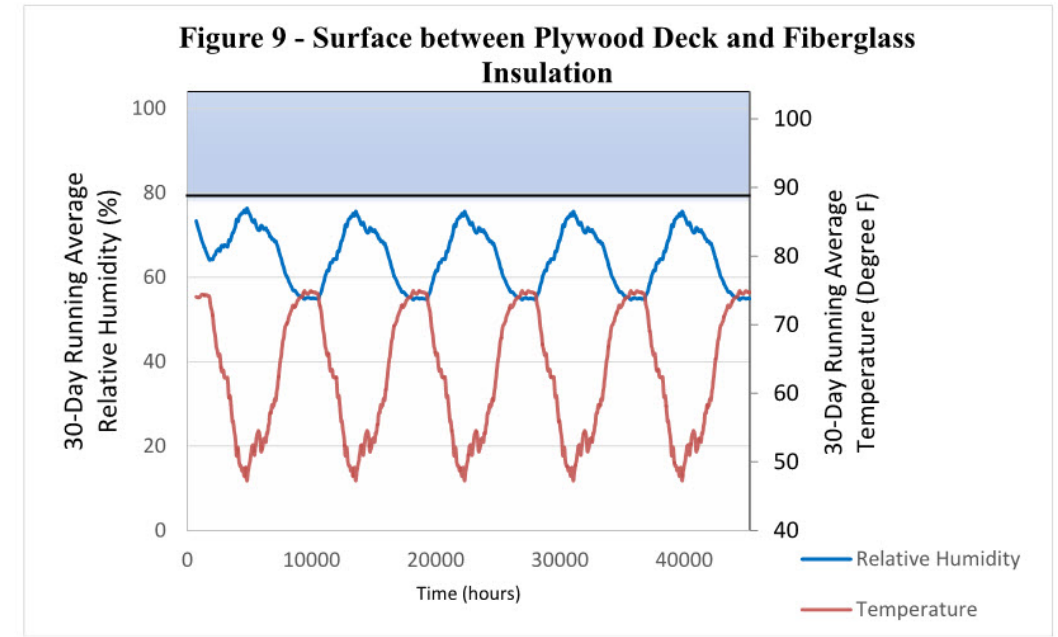
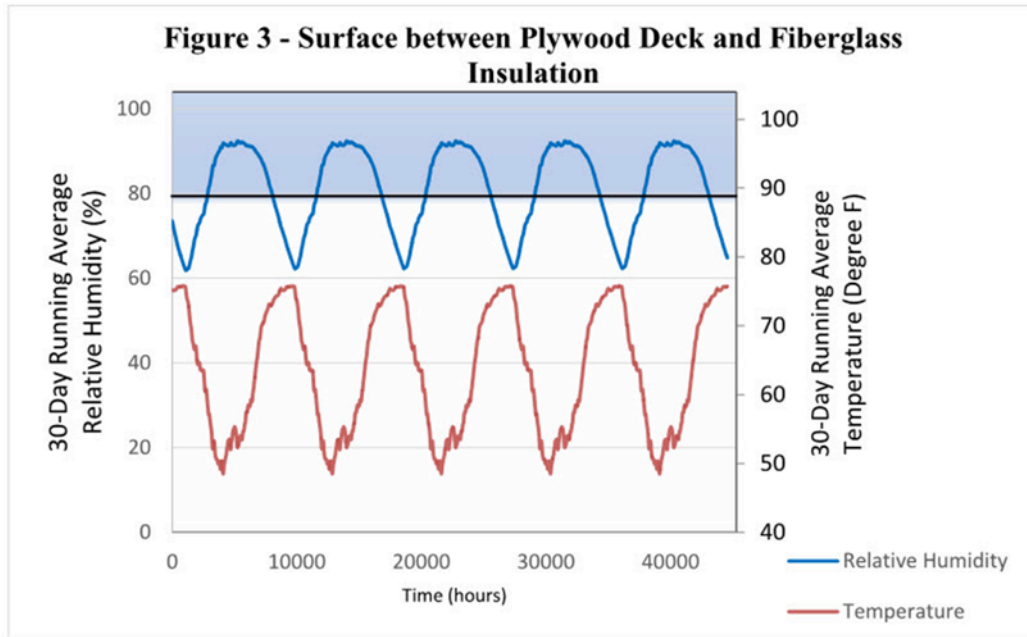


Surface between Plywood and Fiberglass

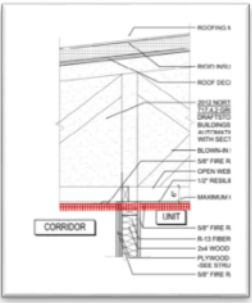


Assembly #1 (over apartment)

Assembly #2 (over breezeway)

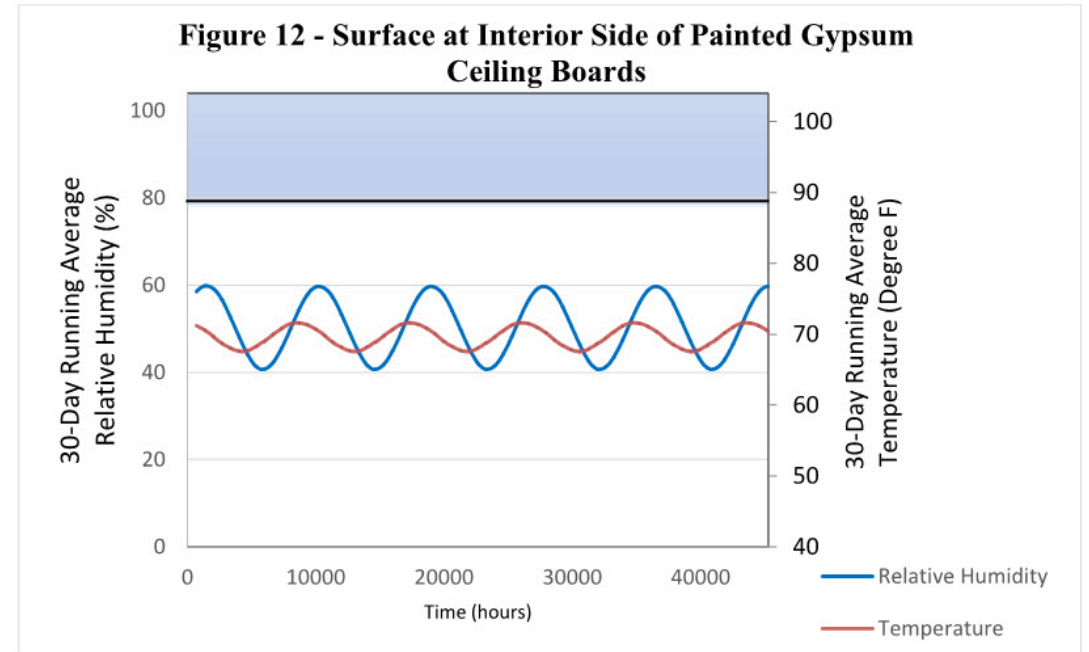
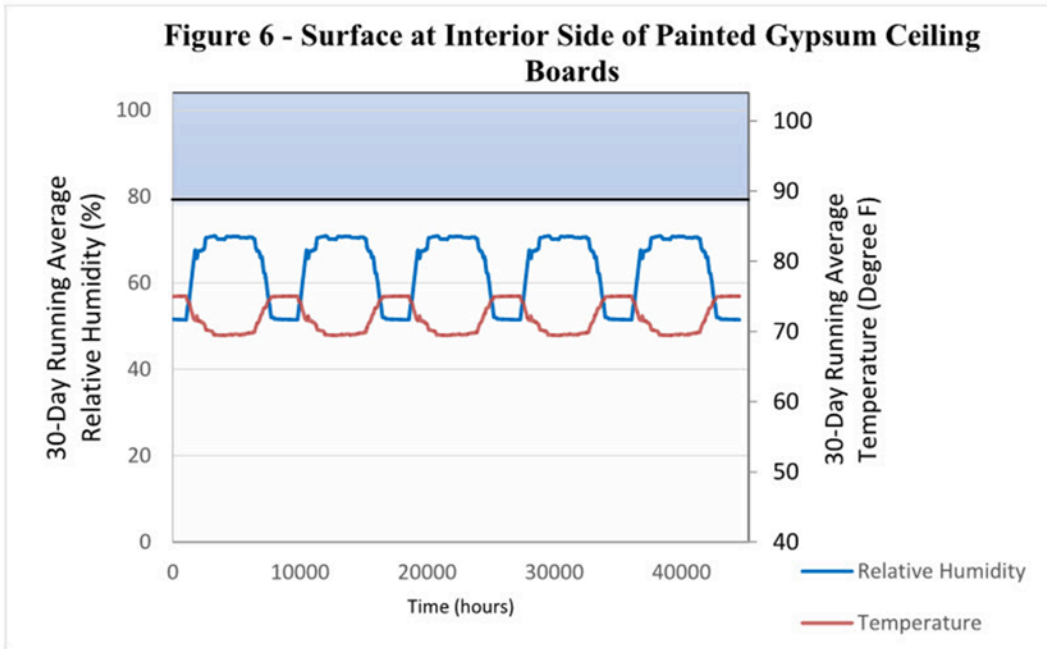


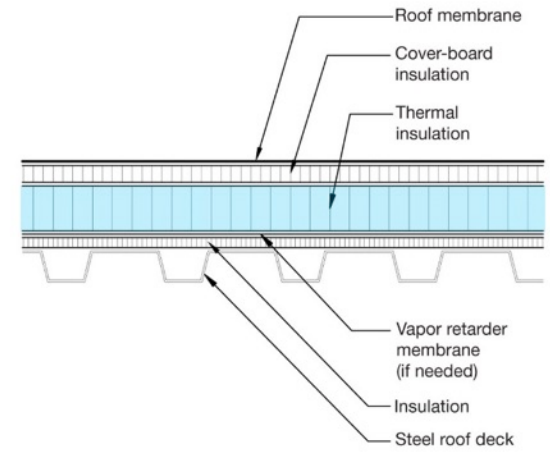
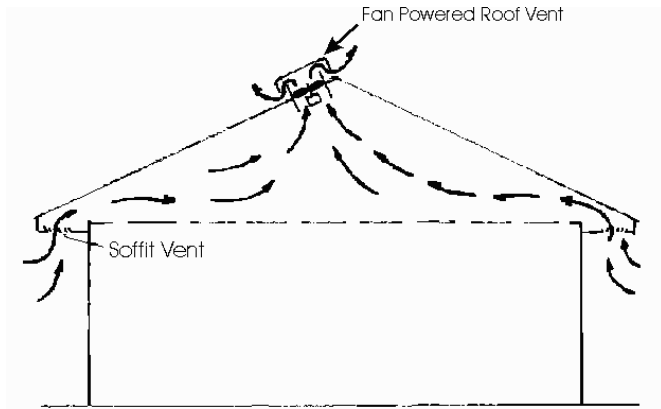
Surface between Gypsum and Paint



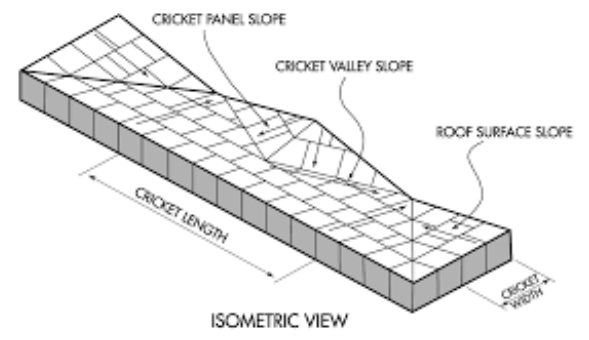
Assembly #1 (over apartment)

Assembly #2 (over breezeway)





Solutions

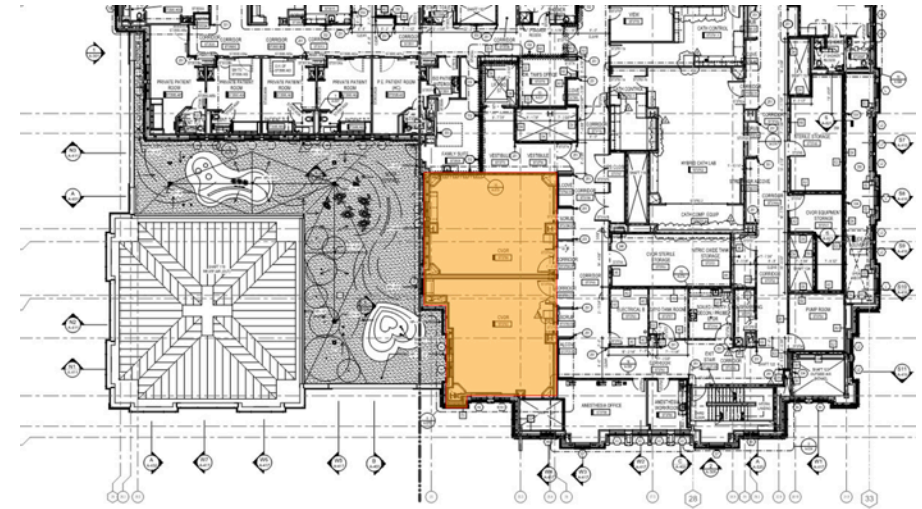
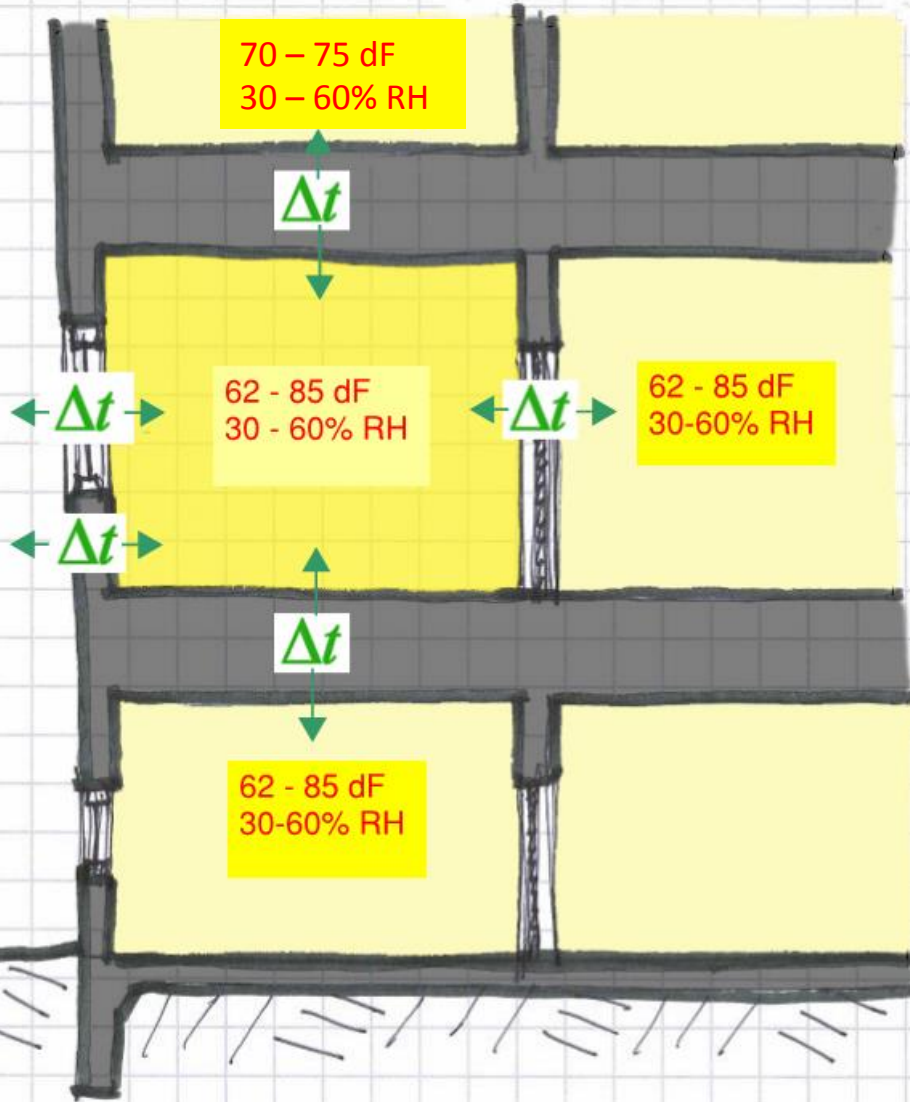


Hygrothermal Analysis: unique setpoints

The Challenge



0 - 110 dF
5 - 100% RH



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

Simulated Assemblies

Interior Partition Wall Assembly between Two CVOR:

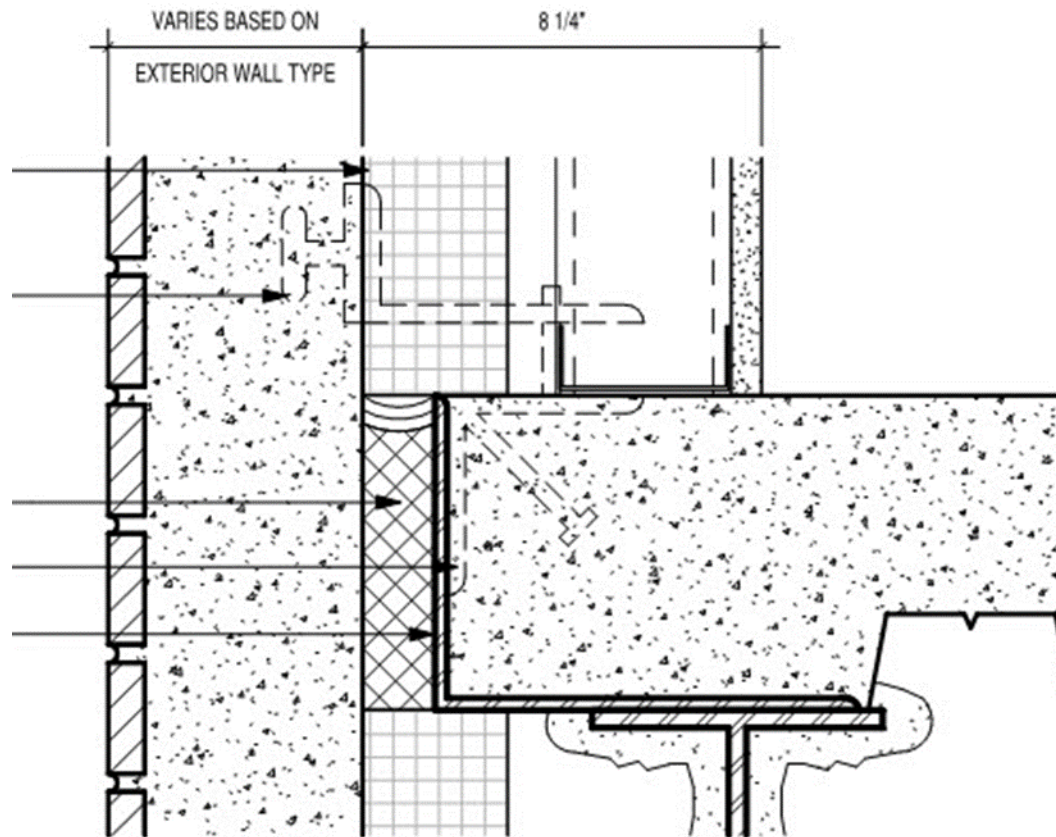
- Water based paint
- 5/8-inch Gypsum Board
- 3 5/8-inch stud frame cavity with un-faced batt insulation
- 4-inch air cavity
- 3 5/8-inch stud frame cavity without insulation
- 5/8-inch Gypsum Board
- Water based epoxy paint

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

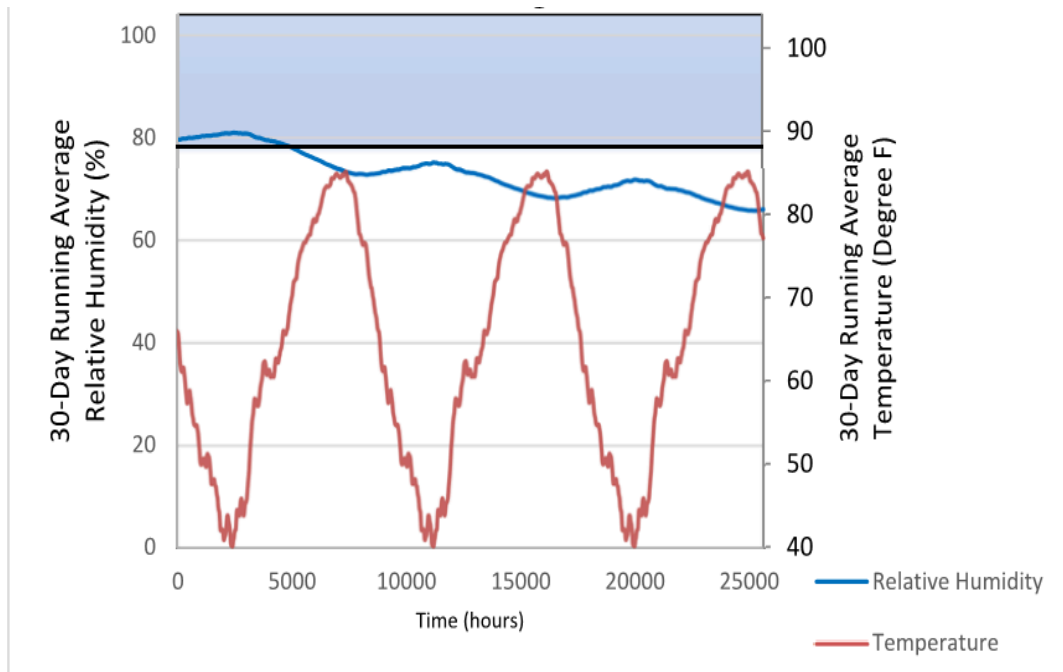


Wall Assembly

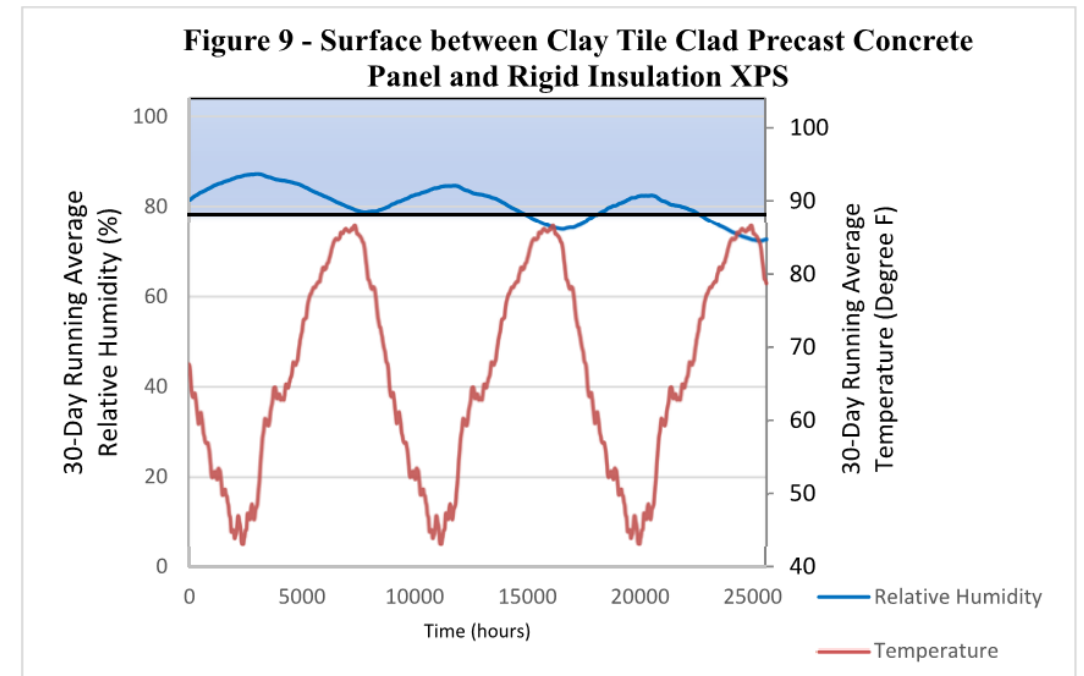
- 8 1/2-inch precast concrete panel with 3-inch XPS
- 3 5/8" stud cavity without insulation
- 5/8-inch gypsum board
- Water based epoxy paint (5-perm vapor retarder)

Surface between Clay Tile Precast & XPS

North Exterior Wall Assembly #1

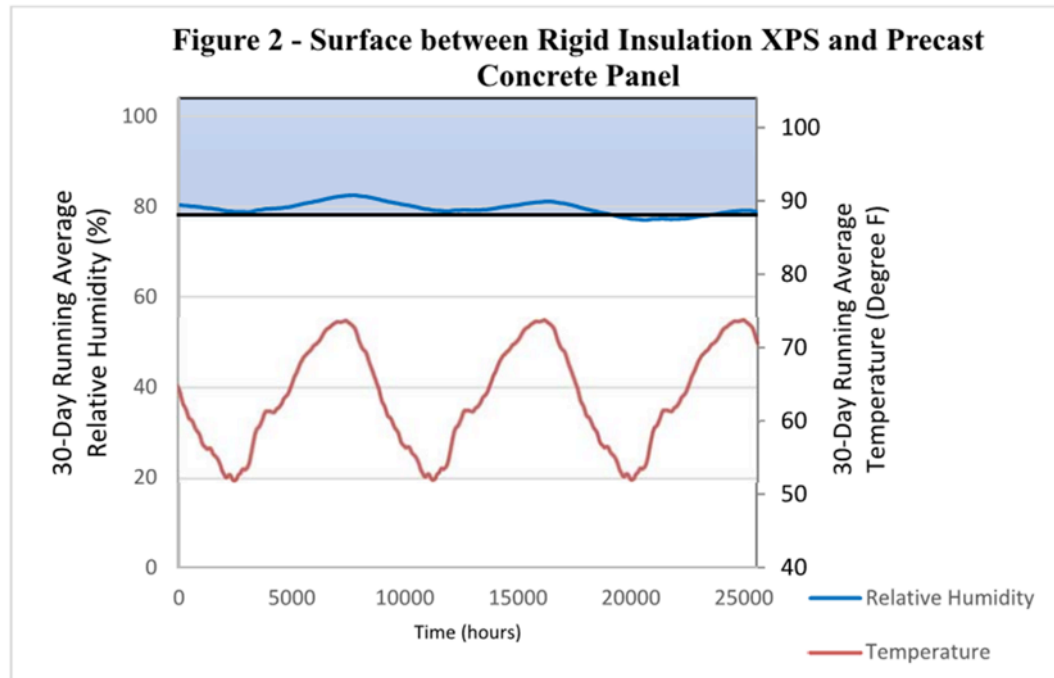


West Exterior Wall Assembly

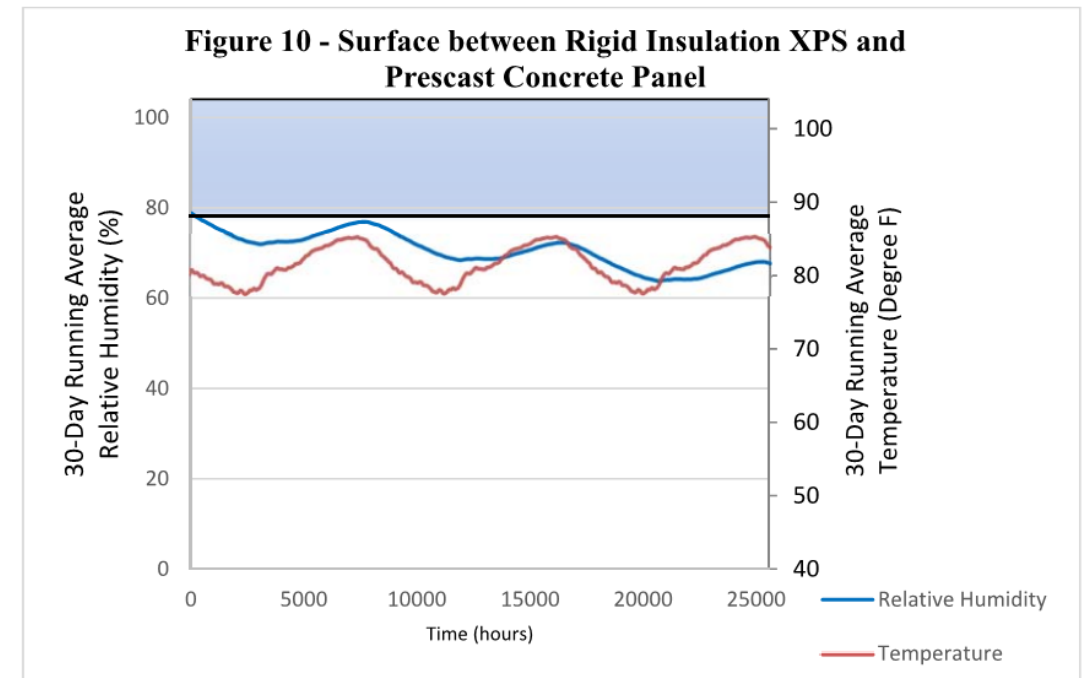


Surface between XPS & Precast Concrete

North Exterior Wall Assembly #1

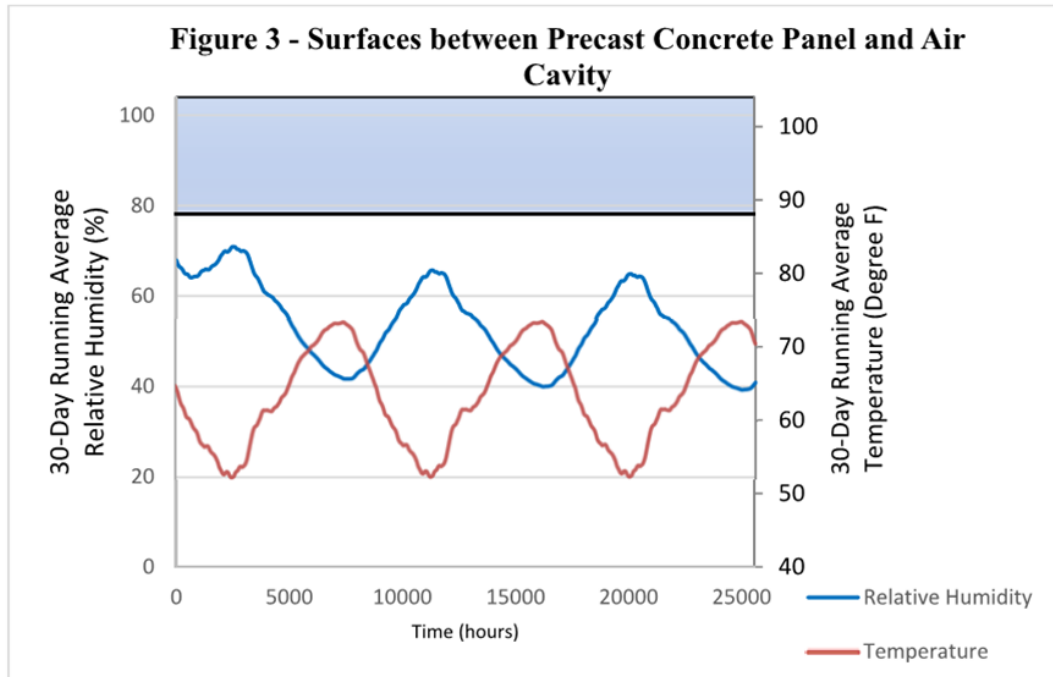


West Exterior Wall Assembly

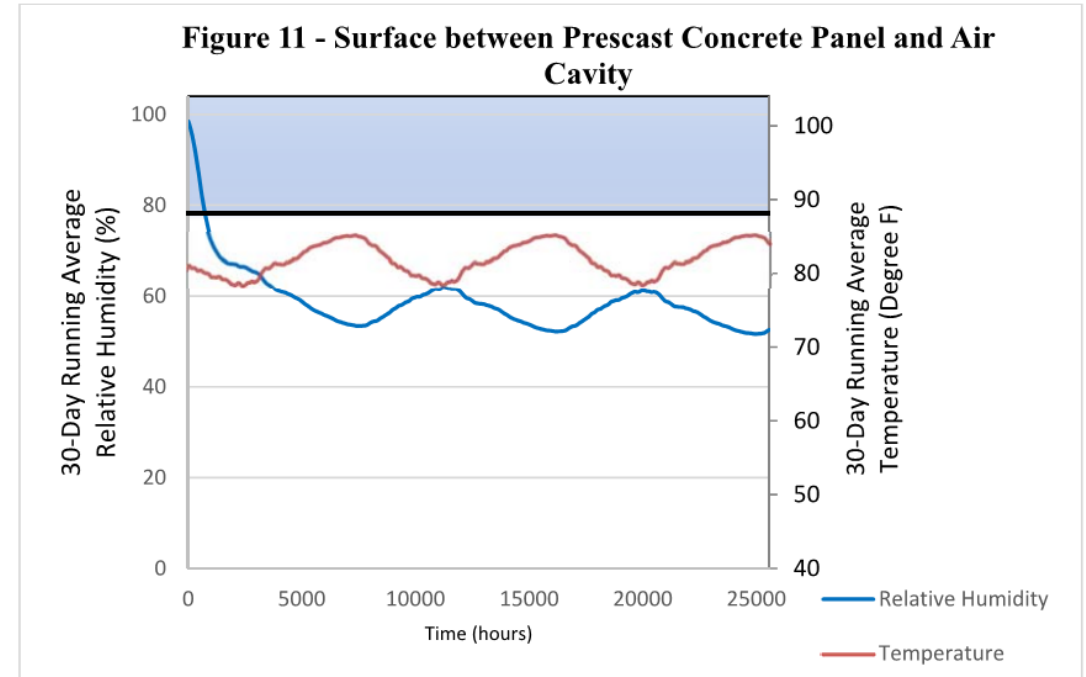


Surface between Precast & Air Cavity

North Exterior Wall Assembly #1

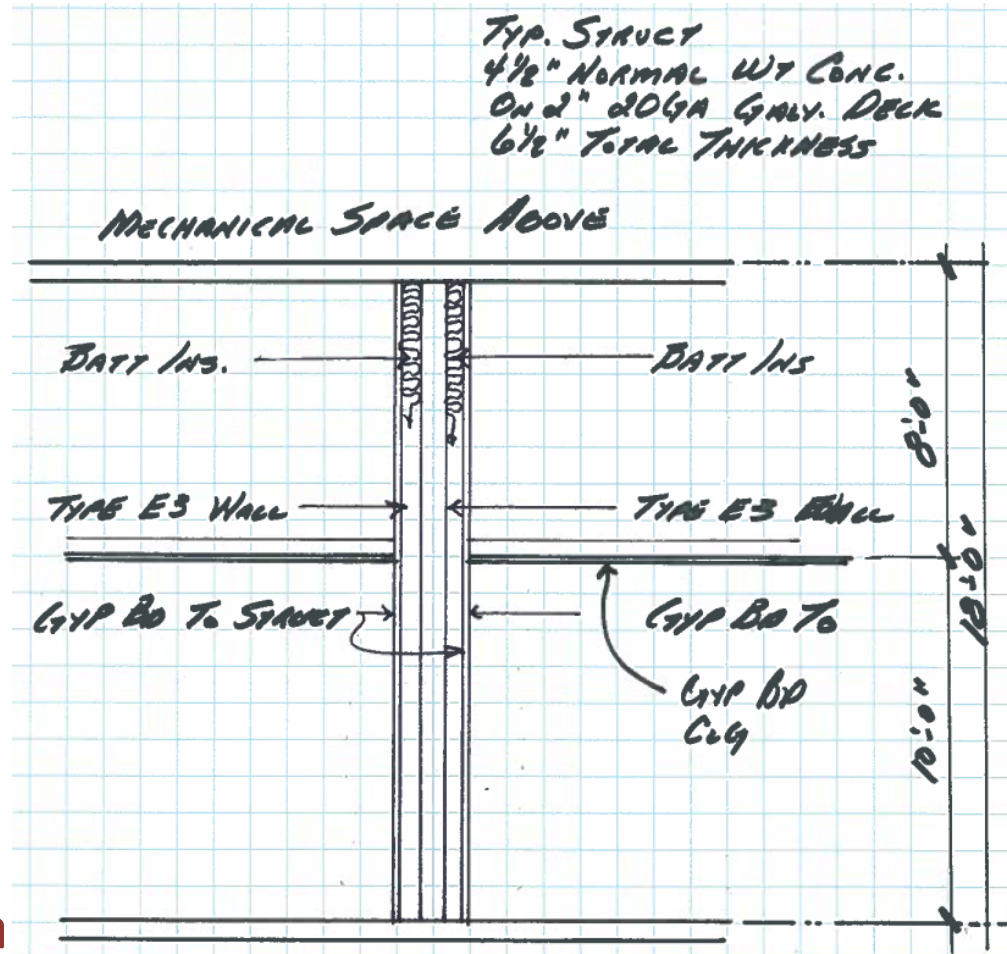


West Exterior Wall Assembly

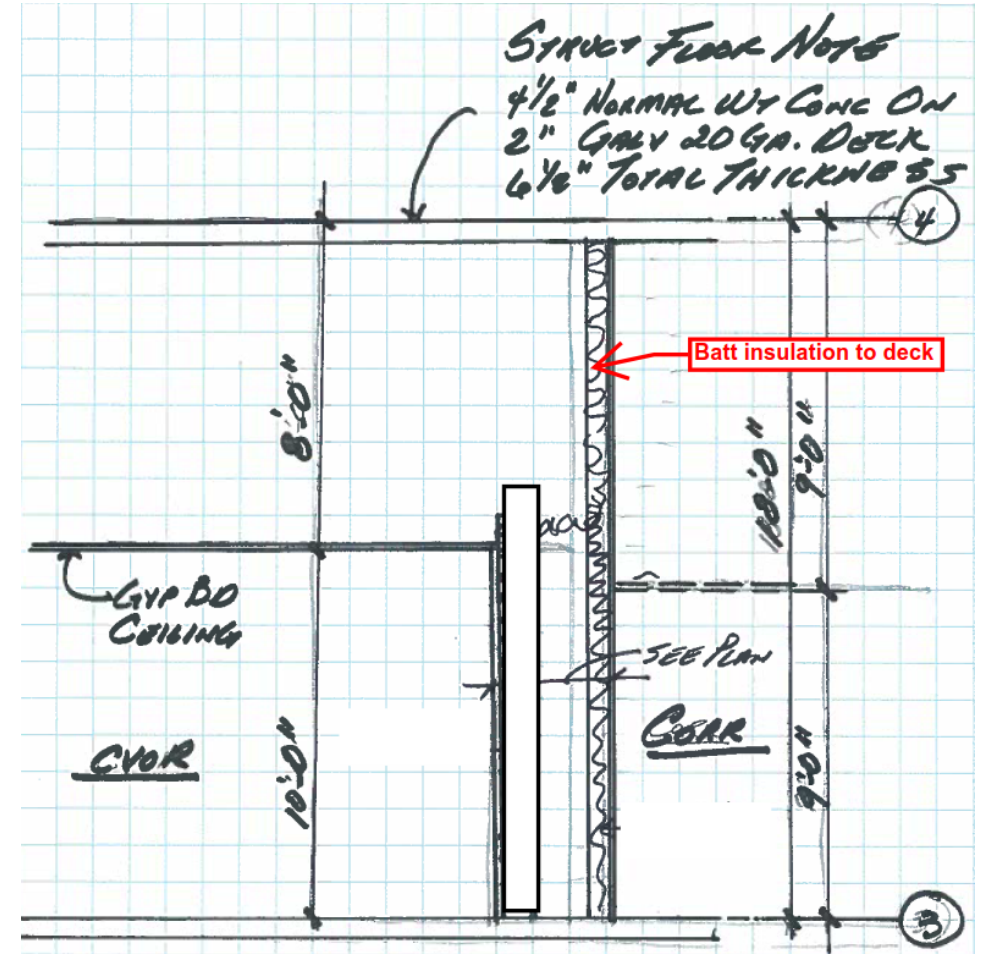


Sketch of Int. Partition Section

Assembly between two CVORs

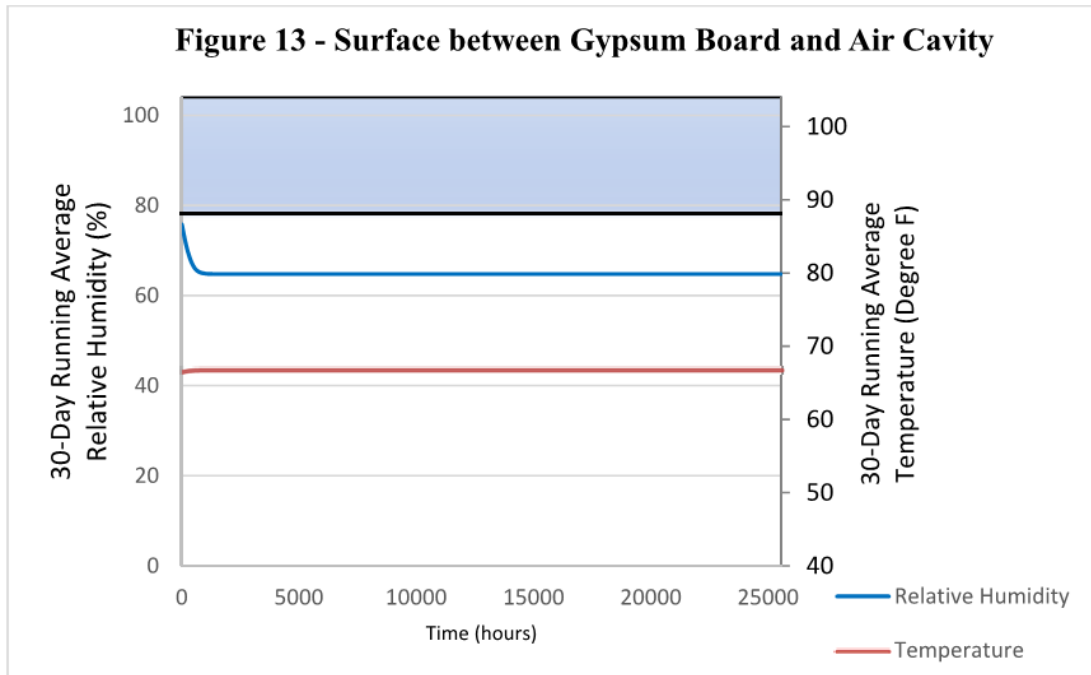


Assembly CVOR and Corridor

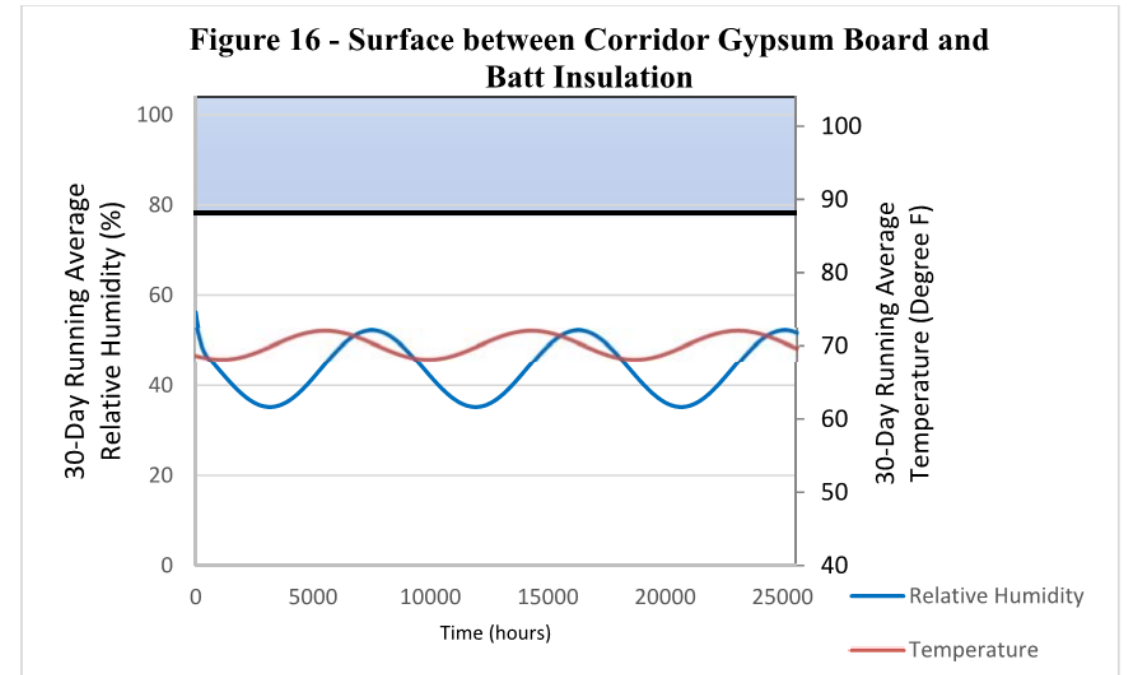


Interior Partitions

Assembly between two CVORs



Assembly CVOR and Corridor

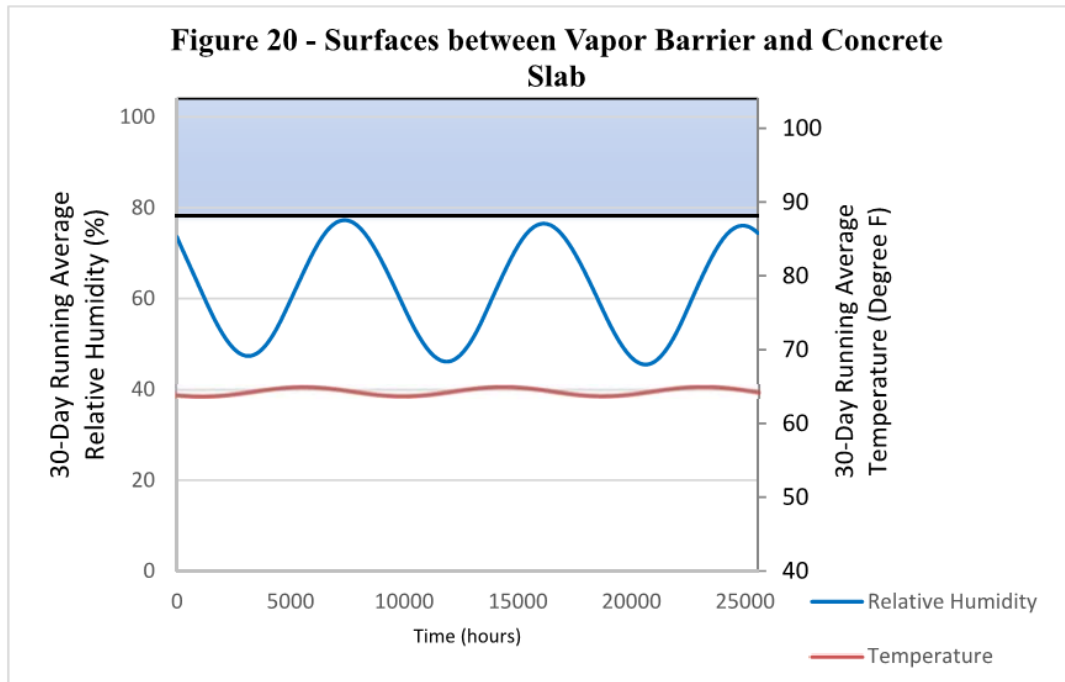


Ceiling/Floor Assembly (above and below)

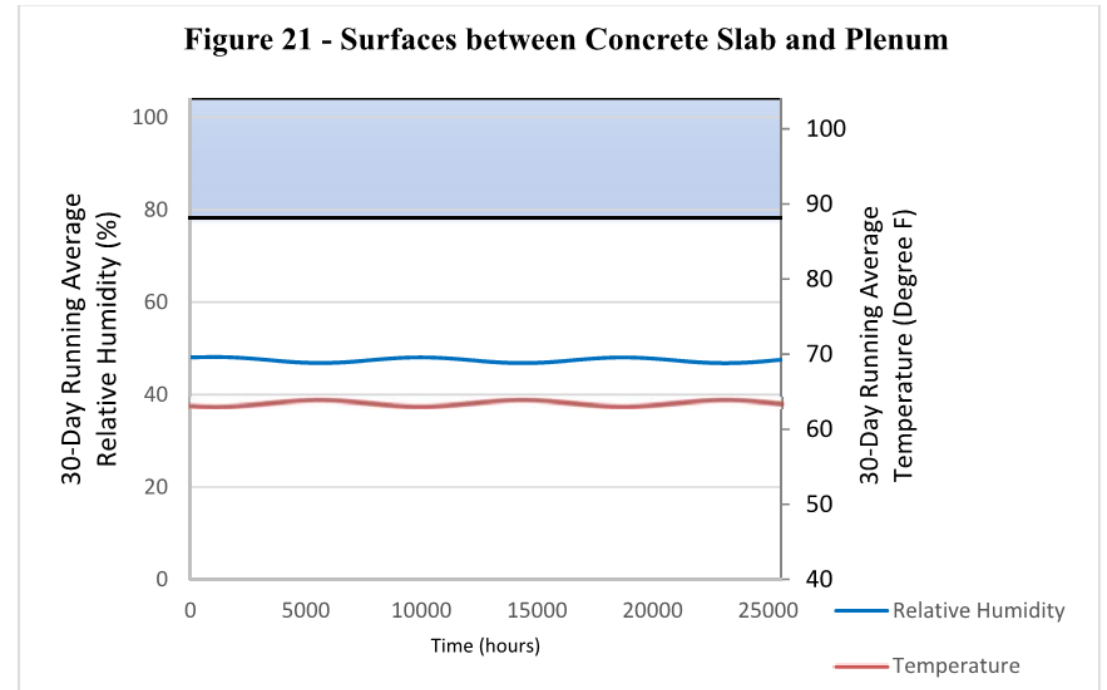
- Resinous Flooring Finish (with elastomeric base coating)
- 4.5 to 6.5 inch thick normal weight concrete
- 20 gauge corrugated metal decking

Ceiling Assembly – CVOR to Mech. Rm.

Surface: Flooring and Concrete



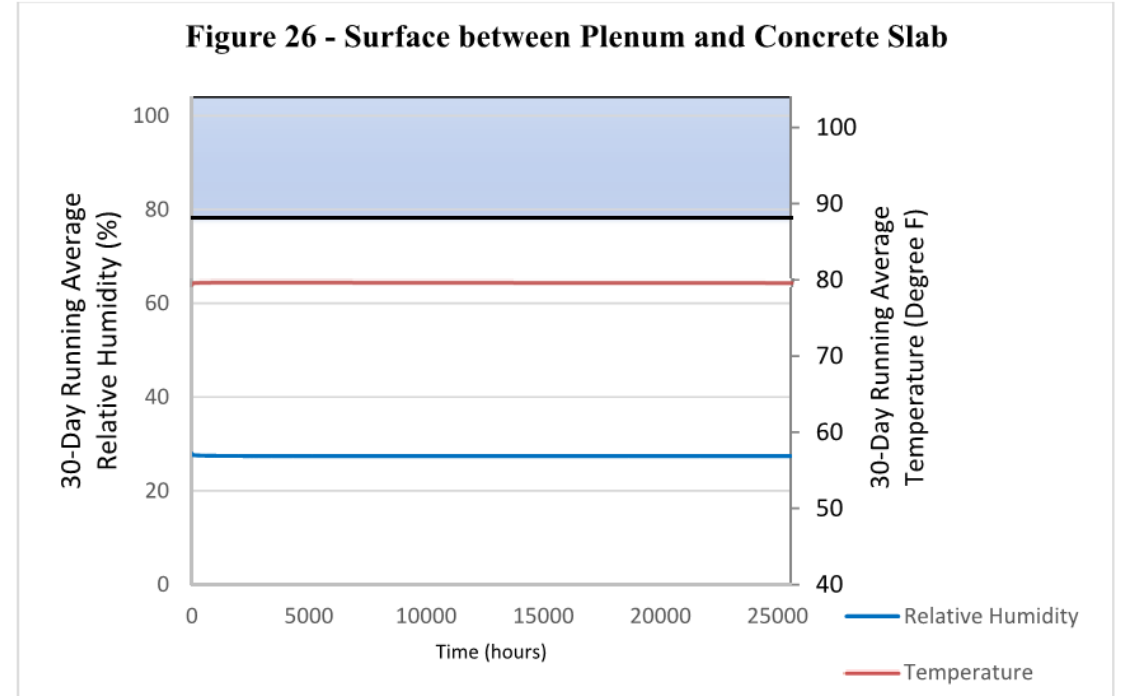
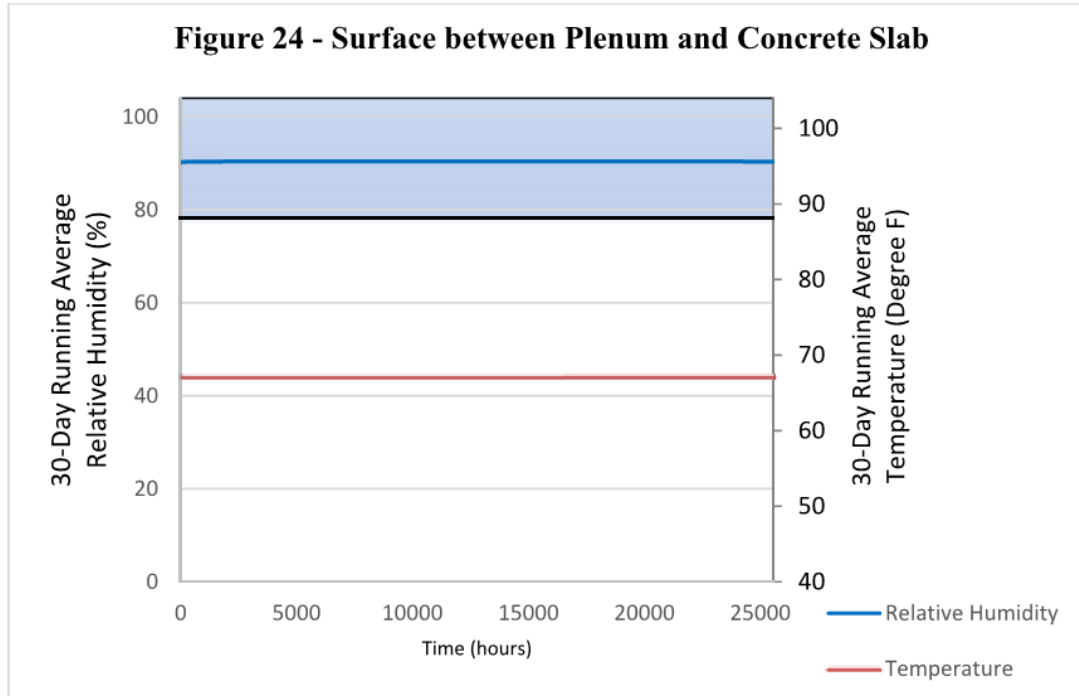
Surface: Concrete & Plenum



Flooring Assembly

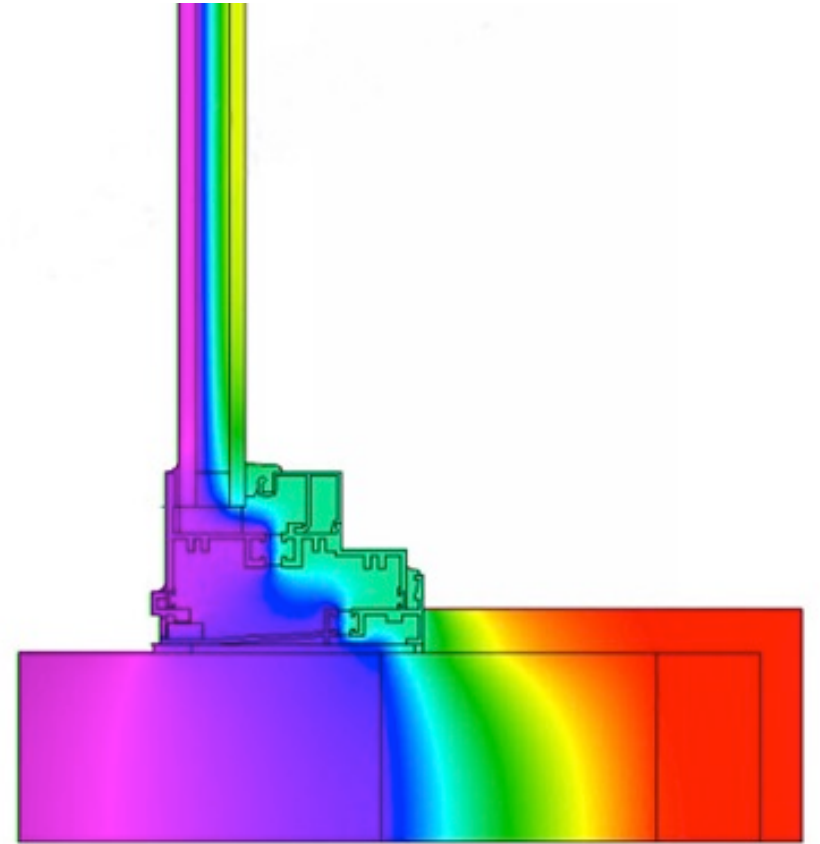
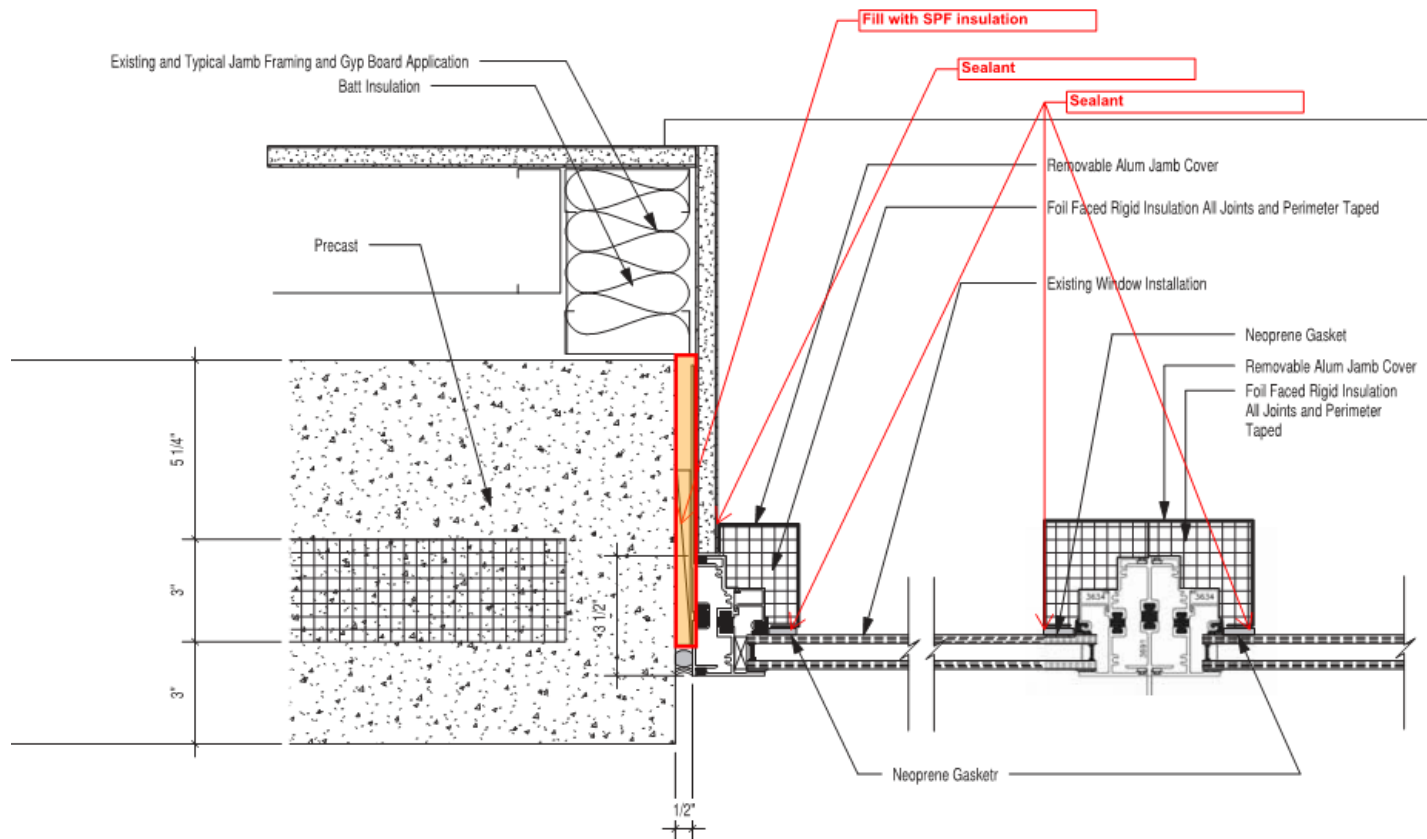
Plenum and Concrete Case #1

Concrete & Plenum Case #2



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



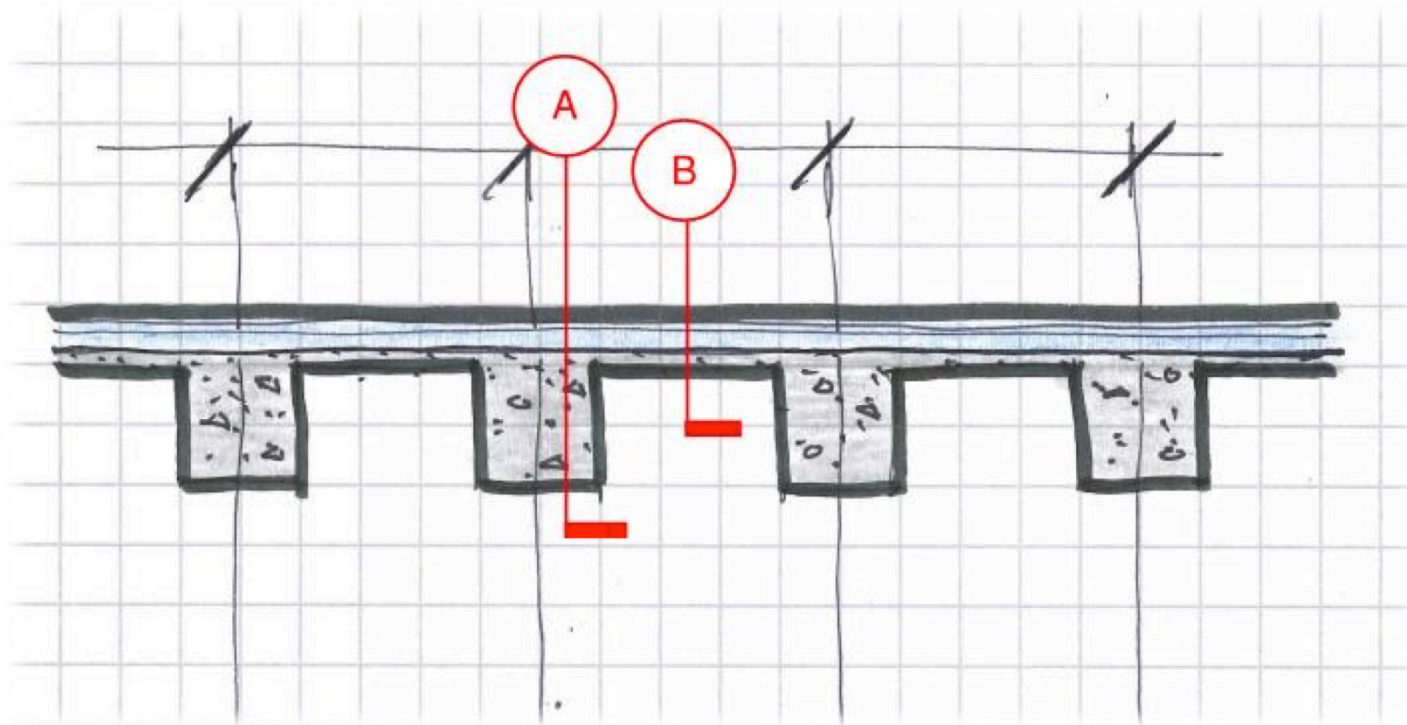
Summary of Gravimetric Analysis

	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%

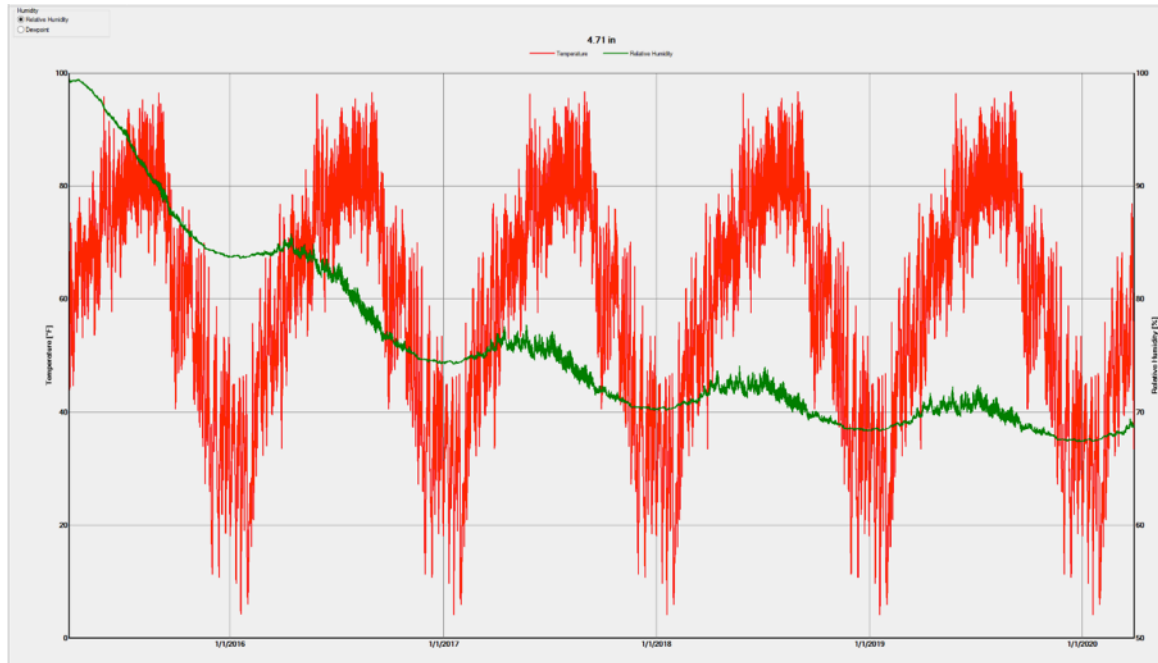
Initial Conditions

- **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

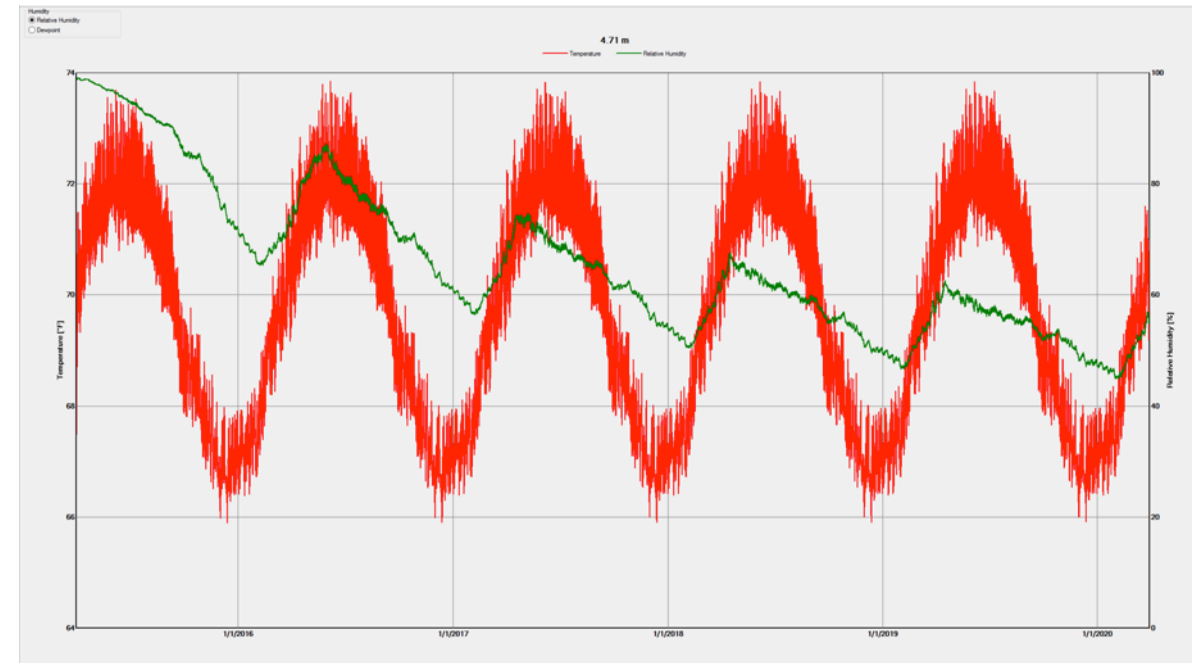




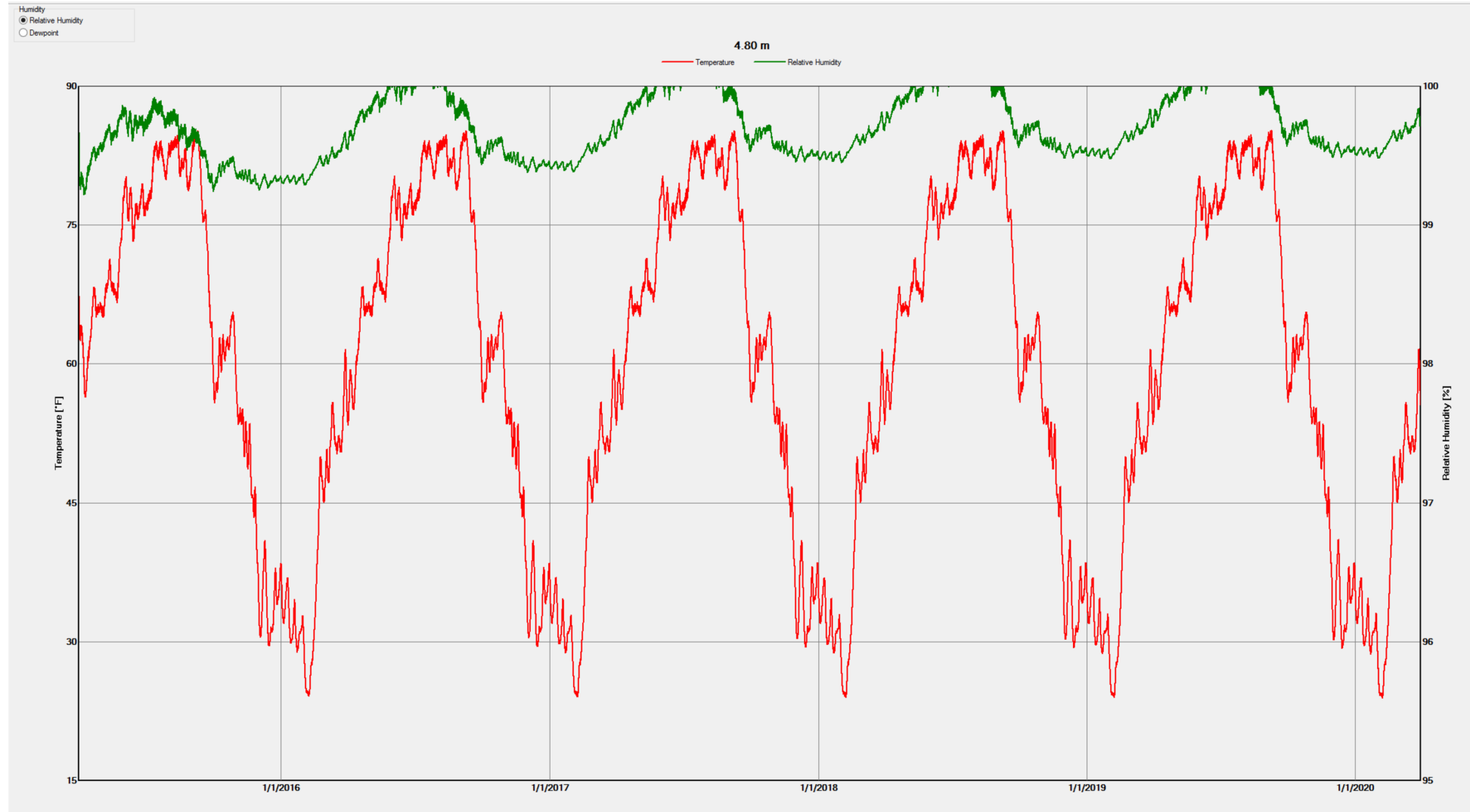
Not at Beam; **No A/C**; 100% RH



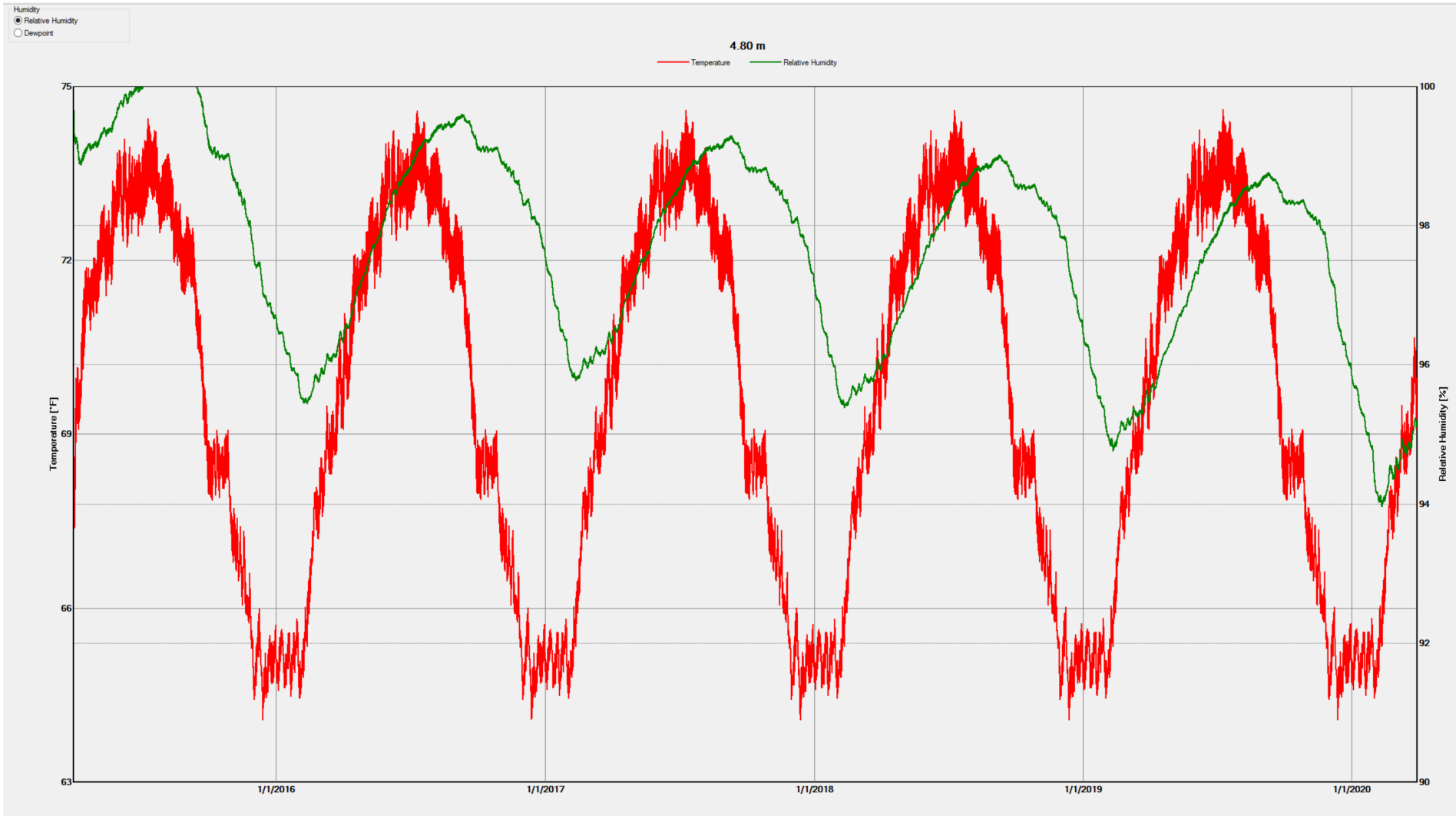
Not at Beam; **with A/C & Heating**; 100% RH



At Beam; No A/C; 100% RH



At Beam with A/C; 100% RH 8" Conc



At Beam; No A/C; 100% RH 4" Conc



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
Continuing Education Systems Course



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