Mock Ups: The Crash Test Dummy for Building Enclosures

Speaker: Brian Stroik

Tremco Commercial Sealants & Waterproofing

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Mock Ups: The Crash Test Dummy for Building Enclosures

Learning Objectives

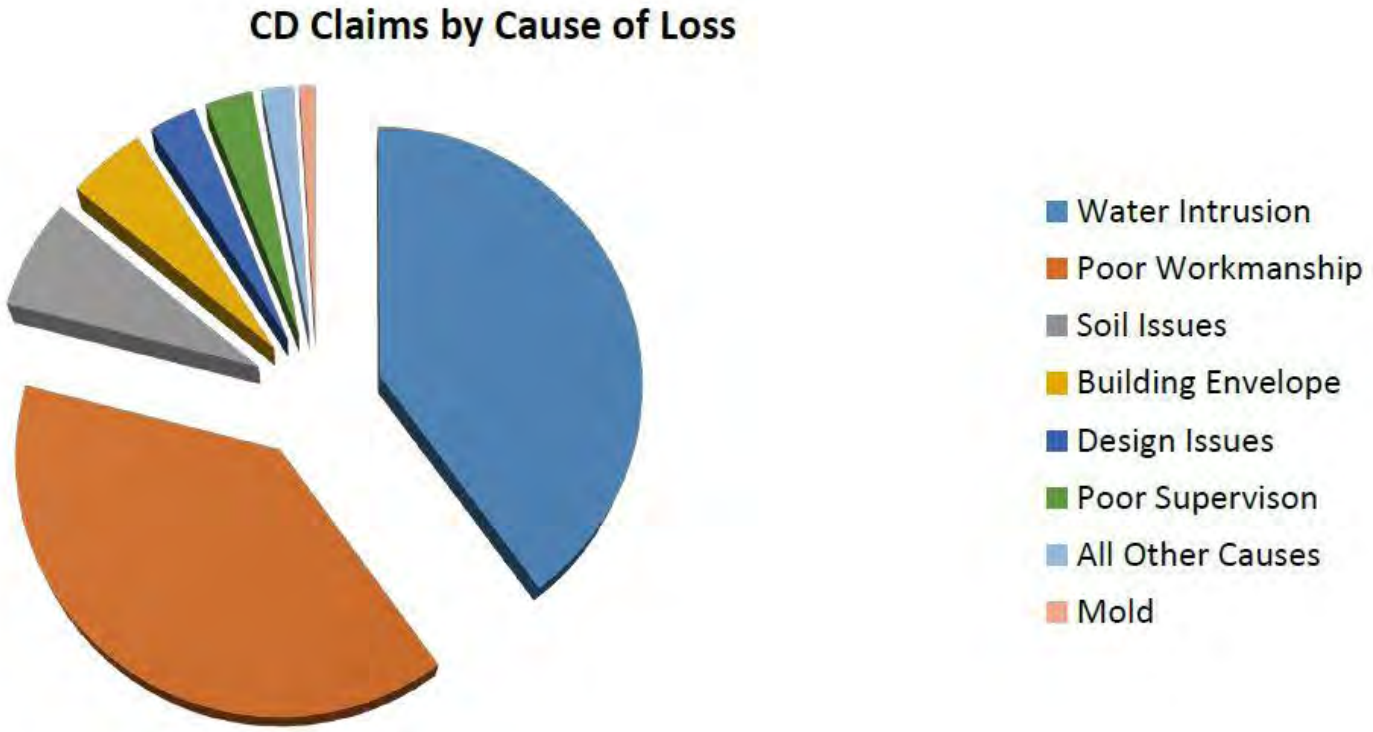
- Discuss building science and why Mock Ups are so important
- Describe and provide examples of various types and sizes of Mock Ups that can be constructed
- Review various ASTM / AAMA tests for Mock Ups
- How do we transfer the knowledge of a Mock Up to our tradesmen

Per Zurich Insurance:

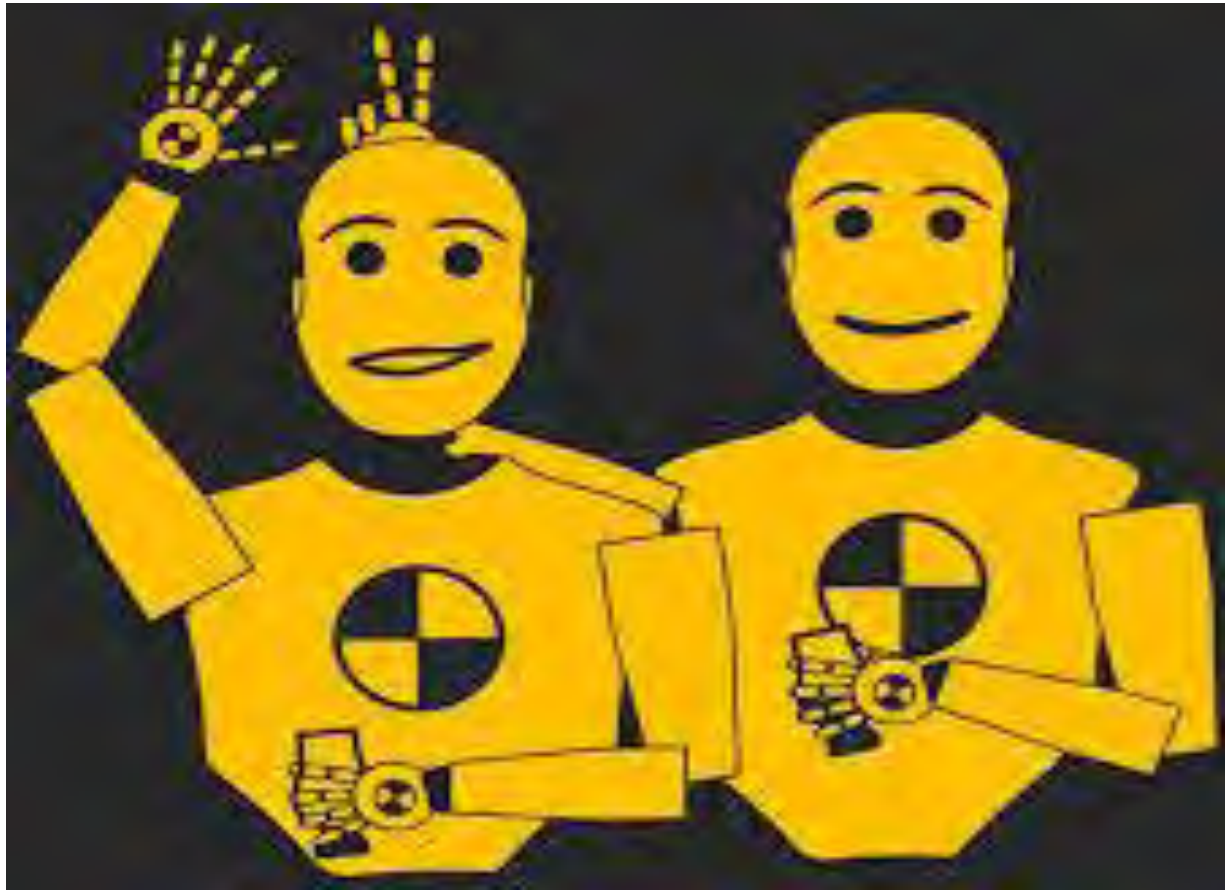
- We pay out **Hundreds of Millions of Dollars every year** in Construction Claims
- **70%** of those are **due to Water and Moisture Issues** in the **Enclosure**

Zurich Construction Defect claims study results

ZURICH



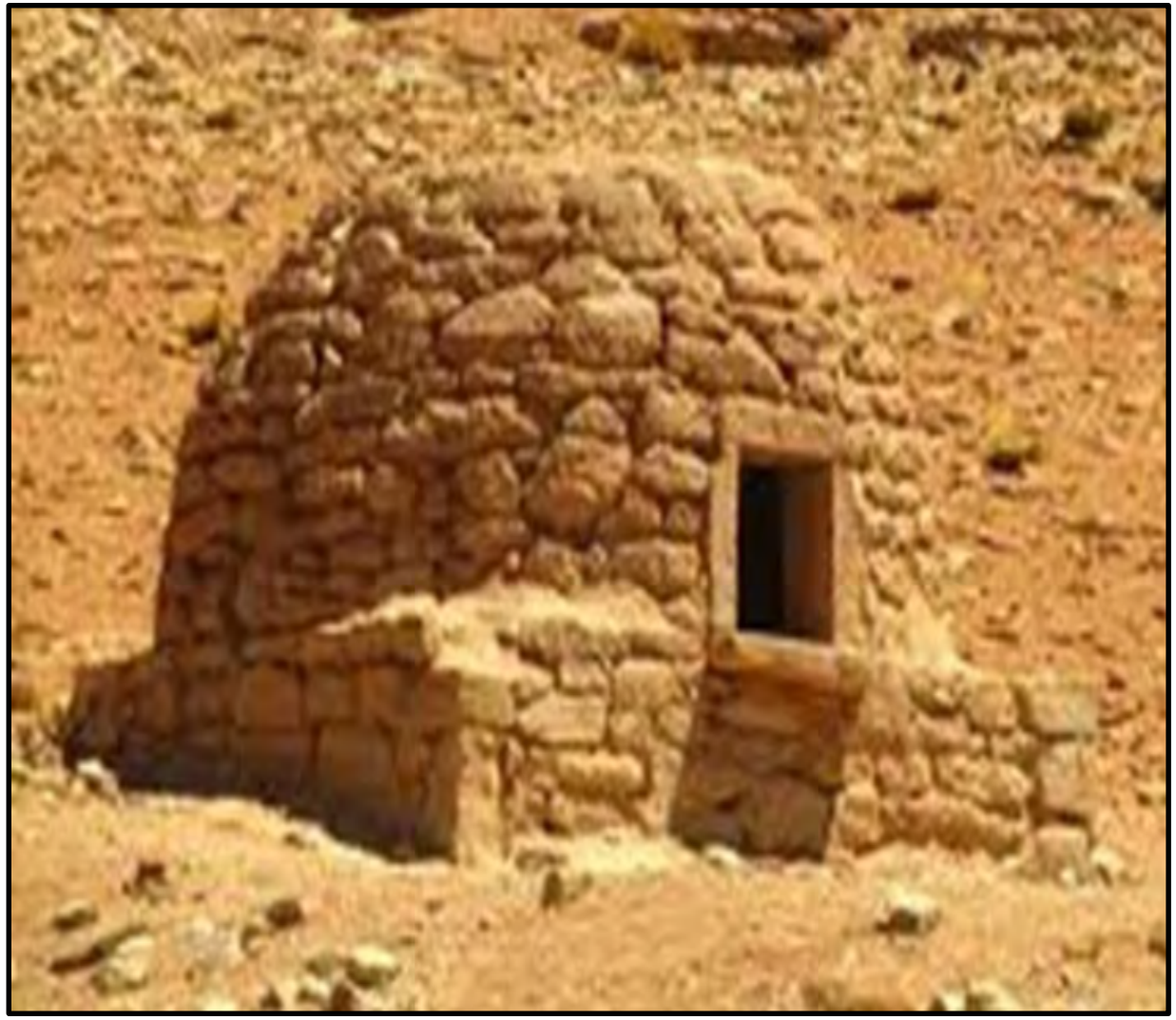
93% of Tested Mock Ups Fail!!!



National Testing Lab 2009

Why Do We Have So Many Issues?

Did These Buildings Work?



Buildings of Today

How Many Products?

- 3 Different Types of Back Up Walls
  - Block, OSB, Exterior Sheathing
- 5 Different Types of AVB
  - Fluid, Self Adhered, SPF, Rigid, Mechanically Fastened
- 4 Different Types of Insulation
  - SPF, Extruded Poly, Poly Iso, Mineral Wool
- 4 Different Types of Exterior Cladding
  - Brick, Metal Panel, EFIS, Cement Board

How Many Products?

OVER 116 **Wall Configurations**

This **DOES NOT** Consider all of the **Different Manufacturers** of each Item

Oil Embargo of 1973 / 1974

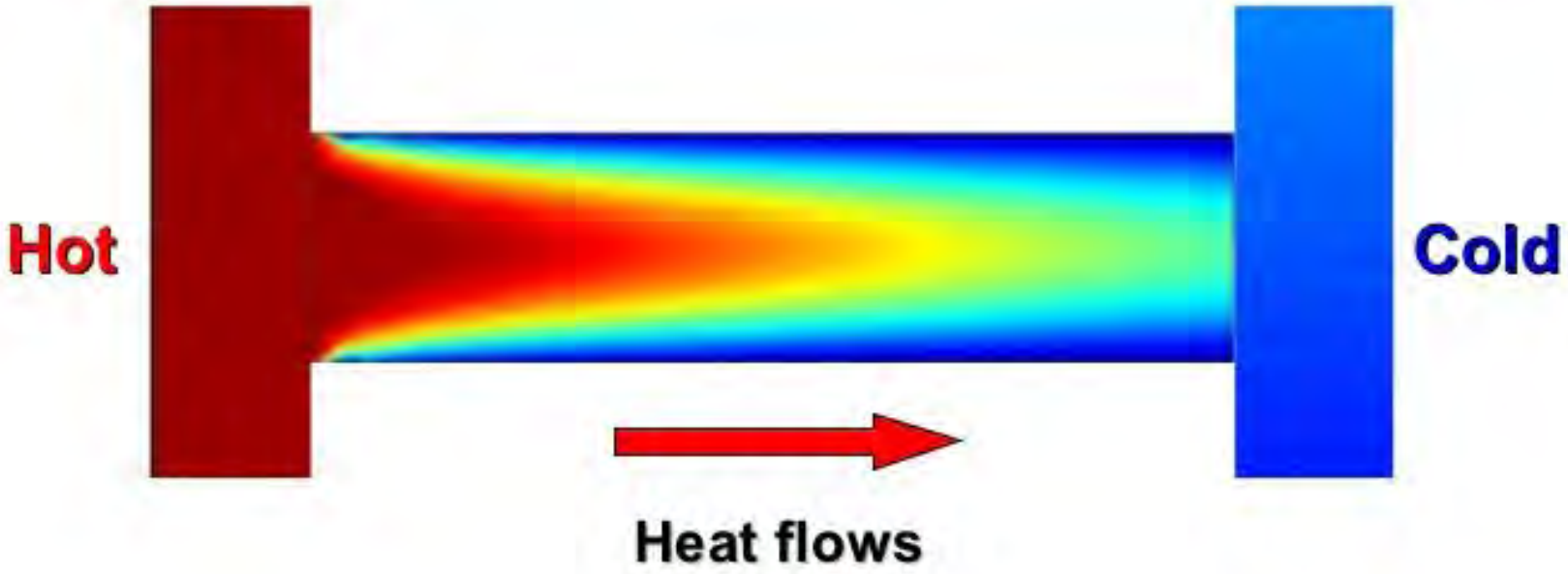
‘74 – ’77 – Federal Energy Administration – Dept of Energy in Oct ‘77

Building Science in it's "Toddler" Stage

Central Air

Brian's Physic's – What I remember from High School

- **Heat** will flow between two bodies as long as there is **temperature difference** between them.



How do I explain to an Owner…. the Value of a Mock Up?

(Our Crash Test Dummy)


05/0


WISCONS


Germantown High School
Germantown, Wisconsin


PARKING
864


CRASH TEST
BELGIAN STYLE TRIPEL
DUMMY
Where Do
We Start?

Mock Up Requirements Specifications

Exhibit 2.1
BUILDING ENVELOPE FUNCTIONAL PERFORMANCE TESTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Functional performance testing requirements for the Building Envelope systems.

1.2 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditi other Division 01 Specification Sections, apply to this Section. Division 07 and 08 Specification Secti apply to this section. Where conflicts arise regarding building envelope testing, this Section shall sup other Sections.

A. Building envelope testing requirements are described in this specification. The following specifi sections are related to the required building envelope testing work:

1. Basic Waterproofing, Roofing, Air Barrier and Insulation Requirements: Refer to Div. 07
2. Basic Fenestrations Requirements: Refer to Division 08

1.3 TESTING AGENCY

A. Contractor shall retain a Building Envelope Testing Agency (BETA) to perform the testing identified b

1.4 ABBREVIATIONS

A. The following are common abbreviations used in the Specifications (definitions are found furthe Section).

1. A/E - Architect and Design Engineers
2. BETA – Building Envelope Testing Agency
3. CM – Construction Manager
4. FPT - Functional Performance Test
5. Tremco – Tremco Sealants and Waterproofing

1.5 DEFINITIONS

A. Approval: Acceptance that a material or system has been properly installed and passed the functional performance testing defined in this section.

B. Architect/Engineer (A/E): Prime consultant (Architect) and sub-consultants who comprise the design team, generally the Architect of Record and any Design Sub-consultants.

C. Contract Documents: Documents binding on parties involved in construction of this project including but not limited to drawings, specifications, change orders, amendments, and contracts.

D. Deficiency: Condition of a building envelope material, system or functional performance test that is not in compliance with Contract Documents, that is, does not perform properly or is not complying with design intent.

E. Functional Performance Test (FPT): Test of performance of building envelope materials and

systems. Systems are tested under various simulated environmental conditions, such as air leakage under pressure differential and water leakage under pressure differential with water spray.

F. Construction Manager: Prime contractor, contracted directly to the Owner, responsible for performing the work per the Construction Documents.

G. Mock-up: The activities where systems or materials are initially constructed and tested. Mock-ups are to be in-place and approved prior to commencing full-scale construction.

H. Simulated Condition: Condition created for testing component or system, such as applying pressure differential across the building envelope concurrent with water spray to simulate a wind-driven rain.

Specifications: Construction specifications of Contract Documents.

Sub-contractor: Contractors of Construction Manager, prime contractor, and their Sub-contractors, who provide and install building envelope components and systems.

COORDINATION

Functional Performance Team Members will consist of:

1. Building Envelope Testing Agent (BETA)
2. Construction Manager (CM)
3. Architect and Design Engineers (A/E)
4. Building Envelope Sub-contractors
5. Tremco

Management: CM shall direct and coordinate the activities of the BETA.

Scheduling:

1. A/E will work with the CM, BETA, and Tremco to establish a functional performance testing schedule.

SUBMITTALS

CM, A/E and Tremco shall review all submittals for Mock Up
1. A/E shall have final approval of submittals
2. Submittals shall be provided to the BETA

1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: Qualified according to ASTM E699 for testing indicated in table below following section 1.10 / C

1.9 DOCUMENTATION, NON-CONFORMANCE, AND APPROVAL OF TESTS

A. Documentation:

1. BETA shall document results of FPT in a report documenting test locations with drawings and photos.

a. Deficiency or non-conformance issues will be noted and reported to CM.

2. The A/E, CM and Tremco will witness the FPT and will assist with any required remediation (primarily in the mock-up), and provide documentation, as required.

Mock Up Requirements Specifications

Component	Performance Criteria		Mock Up Testing	In Situ Testing
	Air	Water		
Curtain Wall / Store Front	ASTM E1186 (4.2.6) – No major air leaks. A major leak is defined as air and smoke visible and easily detectable by hand within (1" or 25.4 mm) of the leak location(s)	ASTM E1105 - No water leakage when tested under a pressure per project requirements, but not less than required in the standard	1 (one) area as shown on Mock Up drawing	5-10% Completion: Three (3) areas 35-45% Completion: Three (3) areas 70-80% Completion: Three (3) areas 95-100% Completion: Three (3) areas
	N/A	AAMA 501.2 – No water leakage during testing	Five (5) locations of ten lineal feet (10' or 3 M)	5-10% Completion: Three (3) areas of ten lineal feet (10' or 3 M) 35-45% Completion: Three (3) areas of ten lineal feet (10' or 3 M) 70-80% Completion: Three (3) areas of ten lineal feet (10' or 3 M) 95-100% Completion Three (3) areas of ten lineal feet (10' or 3 M)
	ASTM E330		1 (one) area as shown on mock -up drawing	5-10% Completion: Three (3) areas 35-45% Completion: Three (3) areas 70-80% Completion: Three (3) areas 95-100% Completion: Three (3) areas
	ASTM E783 Air Leakage allowed per standard	N/A	One (1) area; as indicated on Drawings.	5-10% Completion: Three (3) areas 35-45% Completion: Three (3) areas 70-80% Completion: Three (3) areas 95-100% Completion: Three (3) areas

Air Barrier Assemblies (including Water-Resistive Coatings per Section "XXXXX"	ASTM E 1186 (4.2.7) – Pass/fail criteria shall be no bubbles observed in the leak detection liquid	N/A	Five (5) tests of each air barrier and fastener type	5-10% Completion: Five (5) tests of each air barrier and fastener type 35-45% Completion: Five (5) tests of each air barrier and fastener type 70-80% Completion: Five (5) tests of each air barrier and fastener type 95-100% Completion: Five (5) tests of each air barrier and Fastener type
	N/A	ASTM E1105 - No water leakage when tested under a pressure per project requirements, but not less than required in the standard	Two (2) test areas for each air barrier type	5-10% Completion: Three (3) areas 35-45% Completion: Three (3) areas 70-80% Completion: Three (3) areas 95-100% Completion: Three (3) areas
	Adhesion: ASTM D4541 - Not to be less than manufacturers' requirements	N/A	Three (3) tests for each air barrier type	5-10% Completion: Three (3) areas 35-45% Completion: Three (3) areas 70-80% Completion: Three (3) areas 95-100% Completion: Three (3) areas
System Interfaces	N/A	AAMA 501.2 – No water leakage during testing.	Five (5) locations of ten lineal feet (10' or 3 M)	5-10% Completion: Three (3) areas of ten lineal feet (10' or 3 M) 35-45% Completion: Three (3) areas of ten lineal feet (10' or 3 M) 70-80% Completion: Three (3) area of Ten (10') lineal feet
	N/A	ASTM E1105 - No water leakage when tested under a pressure per project requirements, but not less than required in the standard	1 (one) area as shown on mock-up drawing	5-10% Completion: Three (3) areas 35-45% Completion: Three (3) areas 70-80% Completion: Three (3) areas 95-100% Completion: Three (3) areas

Mock Up Requirements Specifications

Roofing	ASTM E1186 (4.2.7) Pass/fail criteria shall be no bubbles observed in the leak detection liquid.		Five (5) locations at seams and or fasteners	5-10% Completion: Ten (10) areas 35-45% Completion: Ten (10) areas 70-80% Completion: Ten (10) areas 95 Te
		ASTM D5957 – No water leakage when tested for a minimum of 48 hours	Test completed roof	Te

D. Water leakage is only acceptable if ALL of the following conditions are satisfied:

1. Water is contained and drained to the exterior.

Where testing indicates that performance requirements are not met, the CM shall repair or repla
section and a re-test shall be conducted. All repairs shall be conducted with inspection by
testing shall be conducted by the BETA. All costs associated with the repair and re-testing shal
responsibility of the CM.

E. In addition to re-testing, failed tests will typically result in testing of an additional specimen at th
of the A/E and Owner and at the cost of the CM. Testing will be concluded only when satisfa
are achieved.

1. Additional Testing: 5 percent, but not less than 2 locations, of additional testing shall be
for each failed test.

F. Installation of related work shall not continue until tests have been successfully completed.

1.11 TEST REQUIREMENTS

A. Mock-up Testing: A building envelope mock-up shall be constructed and tested prior to comm
of installation of building envelope components responsible for providing environmental separat

1. Testing shall be conducted on the installed fenestration, air barrier, and any termination
penetrations through the air barrier such as fasteners but prior to the installation of any
claddings.
2. The mock-up area is indicated on Drawings. The mock-up shall include a junction with
roofing membrane, a building corner condition, and foundation wall intersection.
3. Testing sequence shall be approved by Tremco.
4. The coordination, construction and completion of the mock-up construction are the resp
the CM.

a. The CM shall provide a chamber or closure wall for the mock-up, it is the responsibility of the CM to construct and repair the test chamber as necessary to create an air-tight chamber. Mock-up test chambers are typically constructed of wood or steel framing, exterior sheathing, and a sheet applied air barrier.

Test your Mock Up!

b. Prior to testing, the BETA will pressurize the test chamber while simultaneously supplying smoke to the chamber. Any voids in the chamber air barrier will be identified and sealed to create an air-tight chamber.

c. The CM shall permit inspections of the mock-up to the A/E and BETA and any member of the building envelope testing team throughout construction and testing as required.

B. It is left to the discretion of the A/E to have all exterior insulation, claddings, and other enclosure materials, installed after the completion of mock-up performance testing.

The following test protocol shall be completed after installation of the complete air barrier system, including all flashings, fenestration assemblies, and all penetrations through the air barrier, but prior to installation of exterior cladding.

1. ASTM E1186 method 4.2.7, Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems: Use pressurization and smoke tracers to identify leak locations through the mock-up chamber and the face of the mock-up. All leaks through the mock-up chamber must be sealed prior to commencing ASTM E283 testing.

2. ASTM E1186 method 4.2.6, Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems: Use chamber depressurization and site detection liquid at penetrations through the air barrier (e.g. fastener penetrations). Pass/fail criteria shall be no bubbles observed in the leak detection liquid. A minimum of 5 locations at each type of fastener (fasteners at masonry anchors, girts, or other cladding receptors) shall be tested. Testing may require special installation of any continuous girts or cladding receptors such that dome can be placed completely around girt or receptor (dome has diameter or approximately 18" [457 mm]) This is typically accomplished by installing and fastening a 12" (304.8 mm). portion of the girt or receptor.

3. ASTM E783, Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Window and Doors.

4. ASTM E330, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Diff

5. AAMA 501.2, Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems: Pass/fail criteria shall be no uncontrolled water leakage when tested.

6. ASTM E1105, Standard Test Method for Installed Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure: Pass/fail criteria shall be no water leakage when tested using Procedure B under indicated pressure

7. ASTM C1193, Standard Guide for Use of Joint Sealants

8. ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

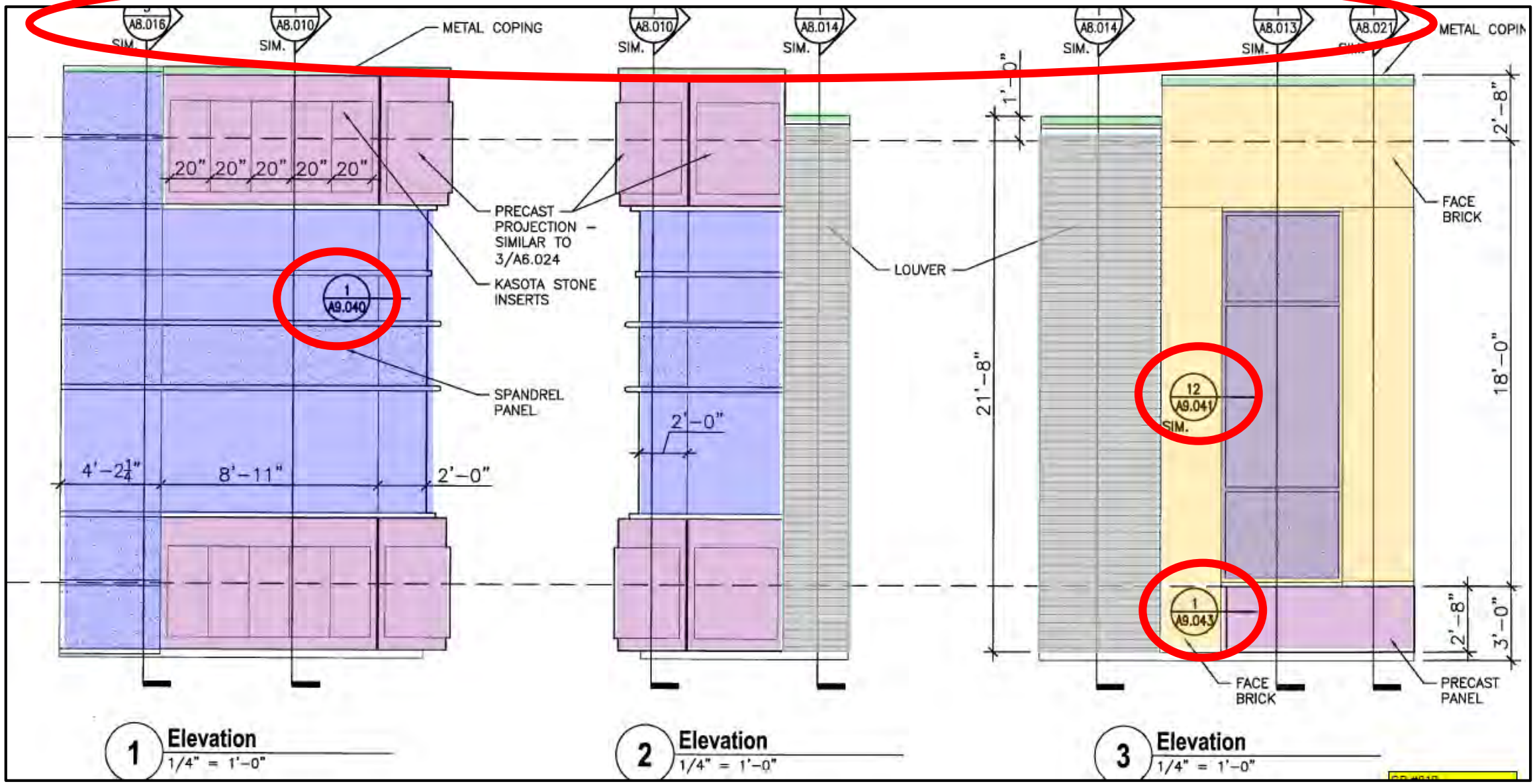
9. ASTM D5957 – Standard Guide for Flood Testing Horizontal Waterproofing Installations. Pass / Fail criteria shall be No water leakage when tested for a minimum of 48 hours

Where testing indicates that performance requirements are not met, the CM shall repair or replace the failed section and a re-test shall be conducted. All repairs shall be conducted with inspection by the A/E. Re-testing shall be conducted by the BETA. All costs associated with the repair, re-testing and re-inspection shall be the responsibility of the CM.

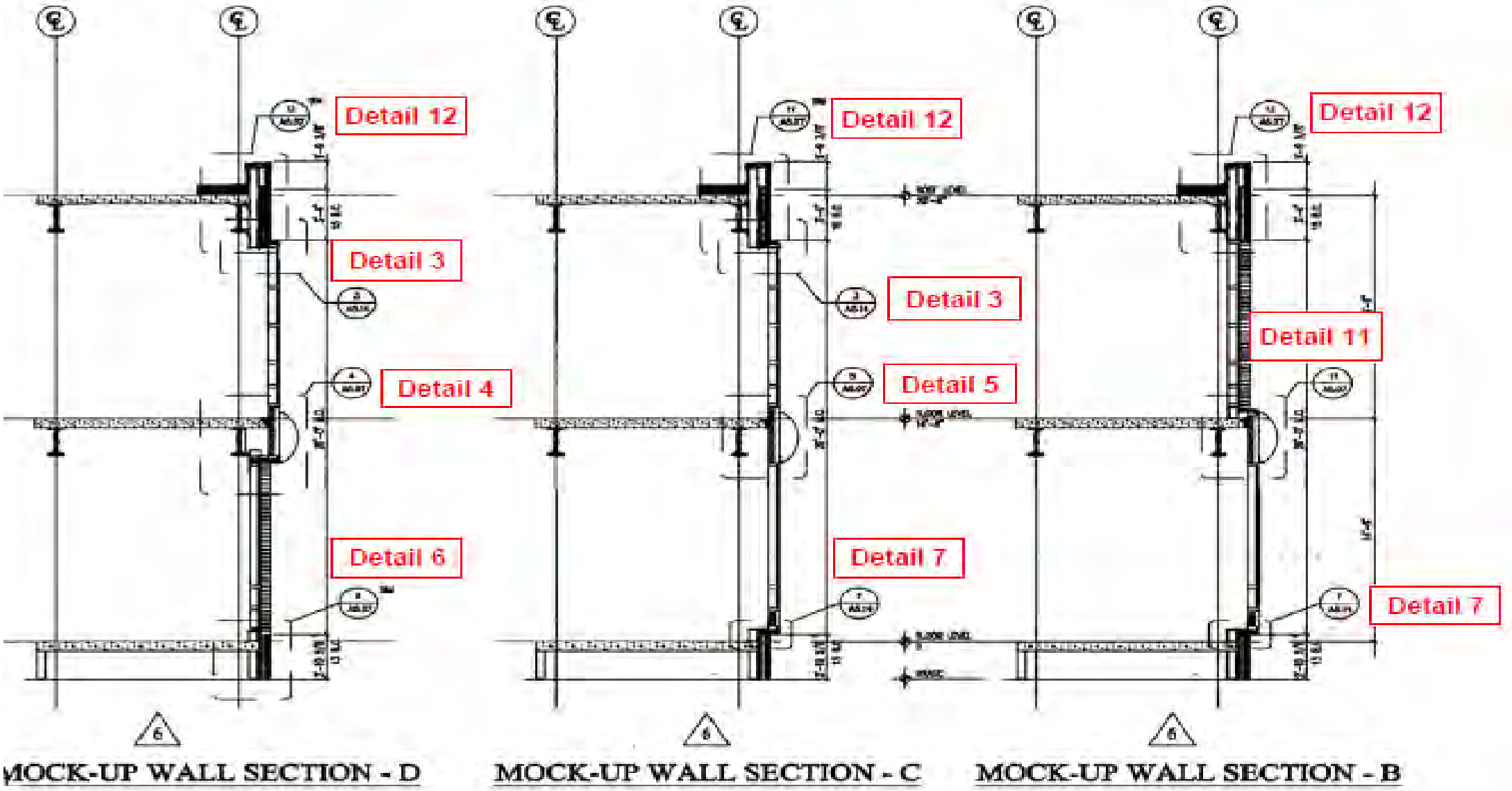
1.12 LESSONS LEARNED PROJECT TRAINING

A. CM is responsible for creating a Lessons Learned Program from the Mock Up, Specifications, Shop Drawings and Details for all aspects of the Exterior. All tradesmen shall go through their respective Lessons Learned immediately after the jobsite Safety Orientation and prior to working on site.

Use Details from Actual Project



Use Details from Actual Project



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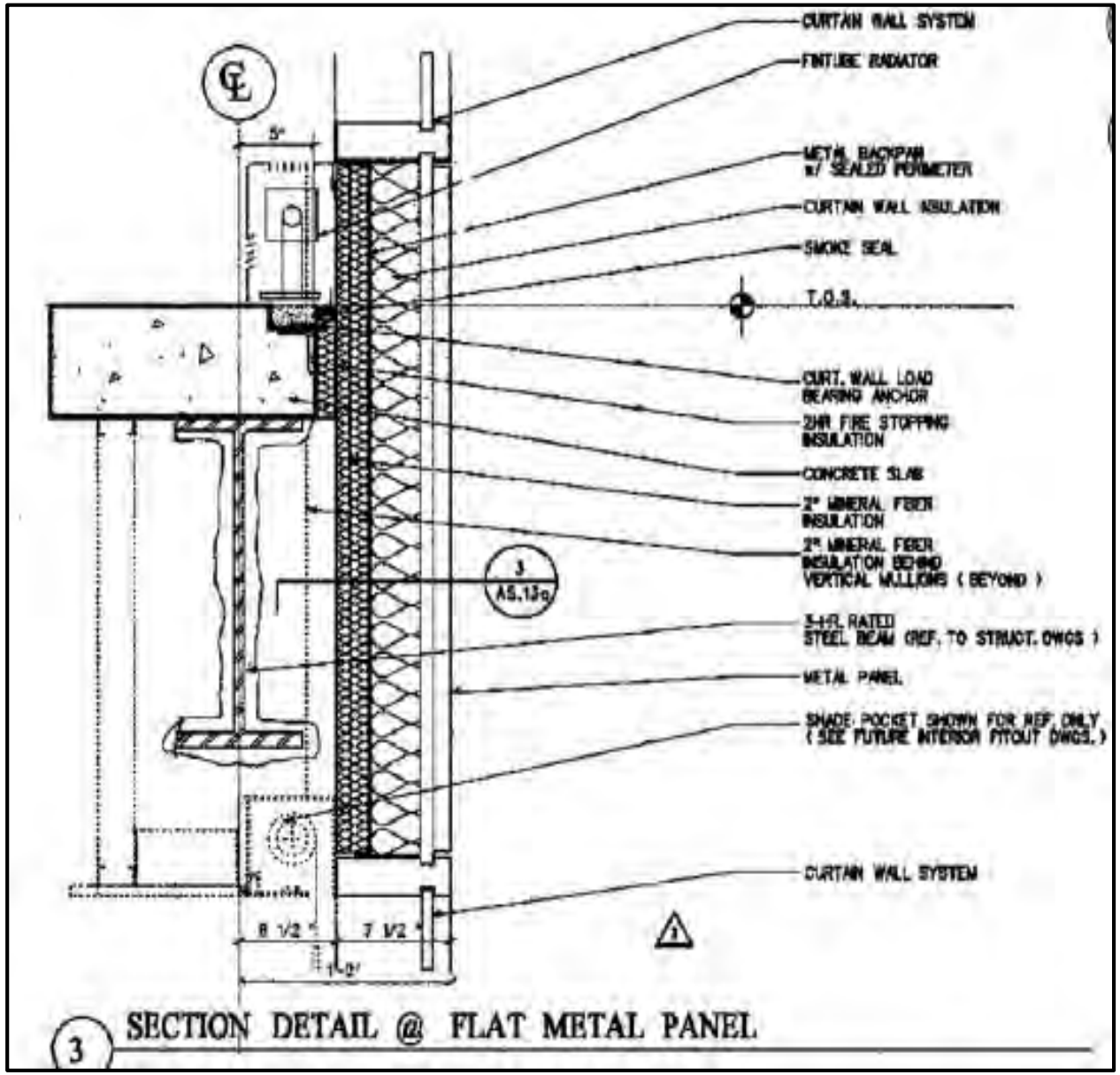
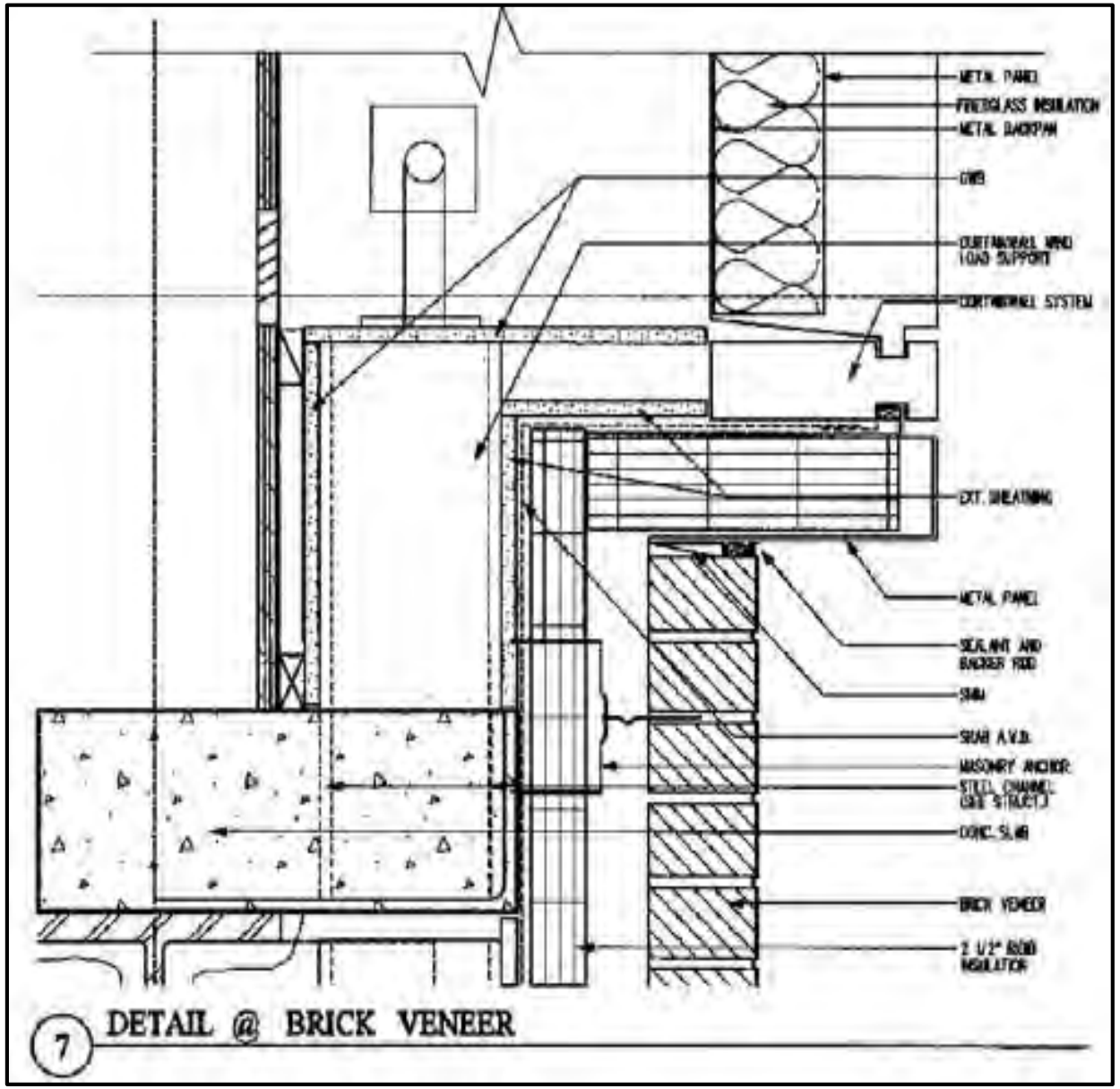




Team Preconstruction Meetings

Job Name:
Meeting Date:

Pre-Construction Meeting Template

IV. Review Project Drawings

Project Drawing	Status (A=Approved NA=Not approved)	Party Responsible for Corrective Action
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

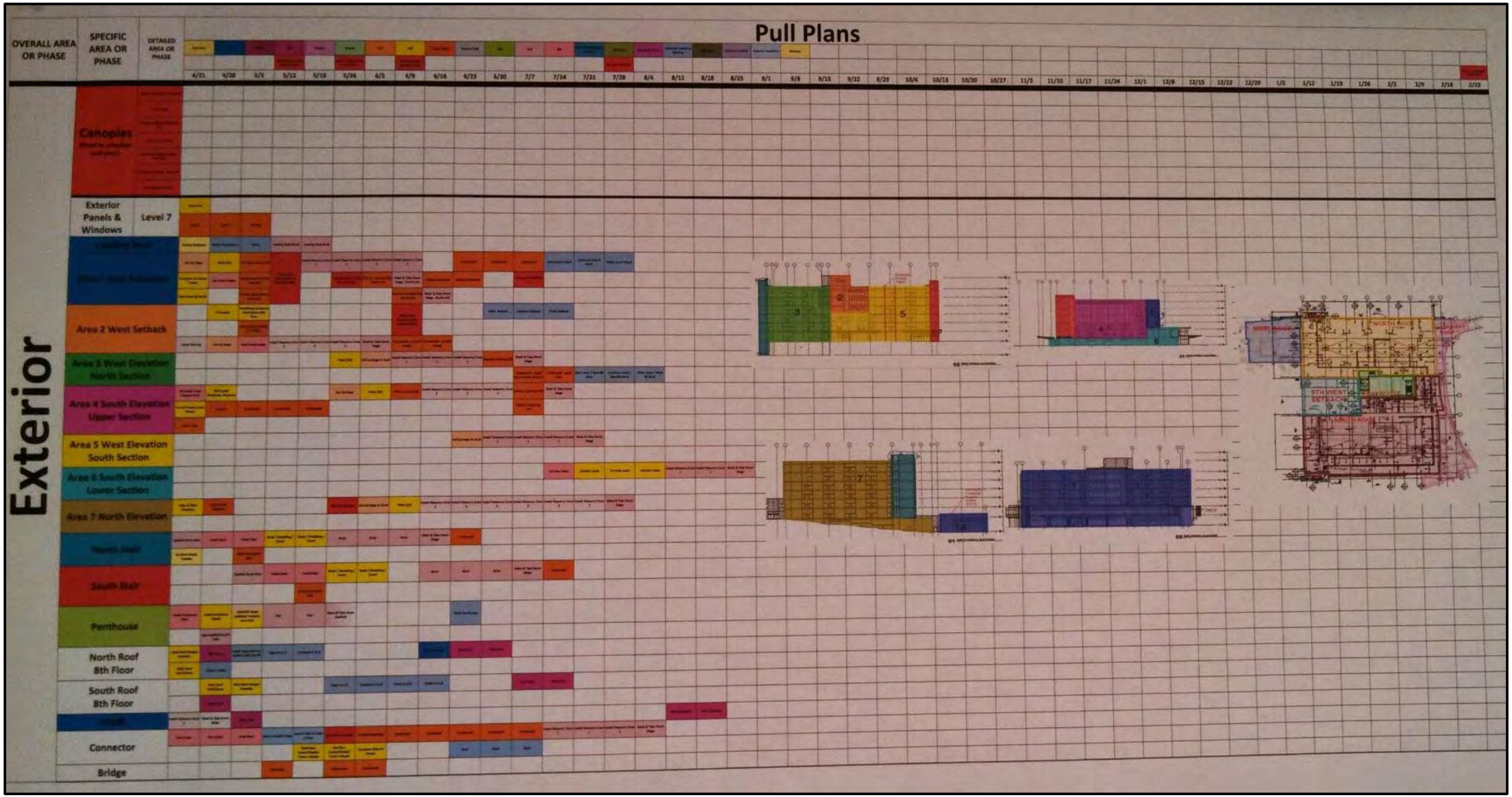
V. Review of Construction Details

Tie-In Area	Contractor Responsible
Walls to doors & windows	
Foundation to walls	
Walls to Louvers	
Different wall systems	
Roofing to walls	
Control joints to walls	
Wall, floor & roof cross-expansion, control/expansion joints	
Utility pipes and ductwork tying into walls	
Wall & roof over unconditioned spaces	
Wall to electrical penetrations	
Other	

VI. Sequencing of the Trades

Work Activity	Trade Responsible for Work
1.	
2.	
3.	
4.	
5.	

Make Sure the Mock Up is Part of Your Schedule!

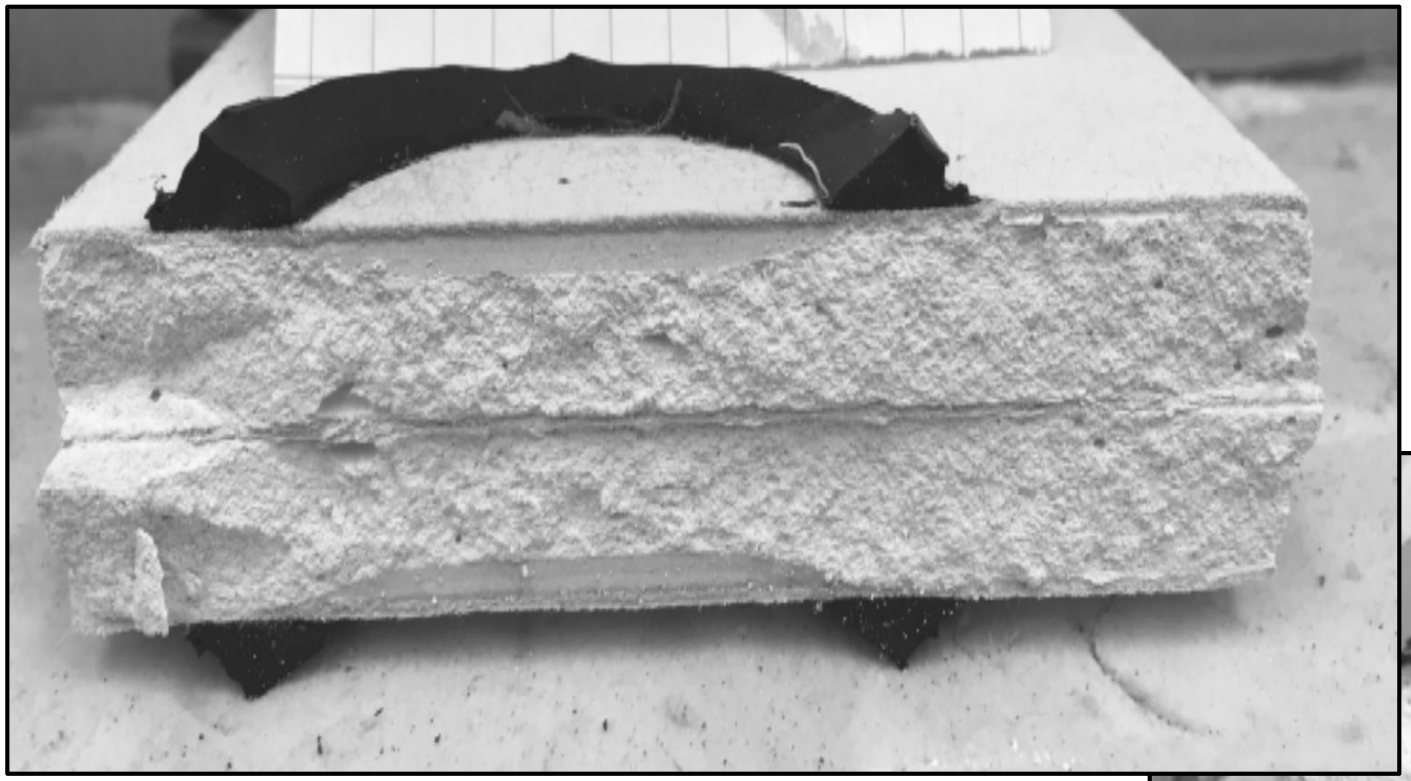


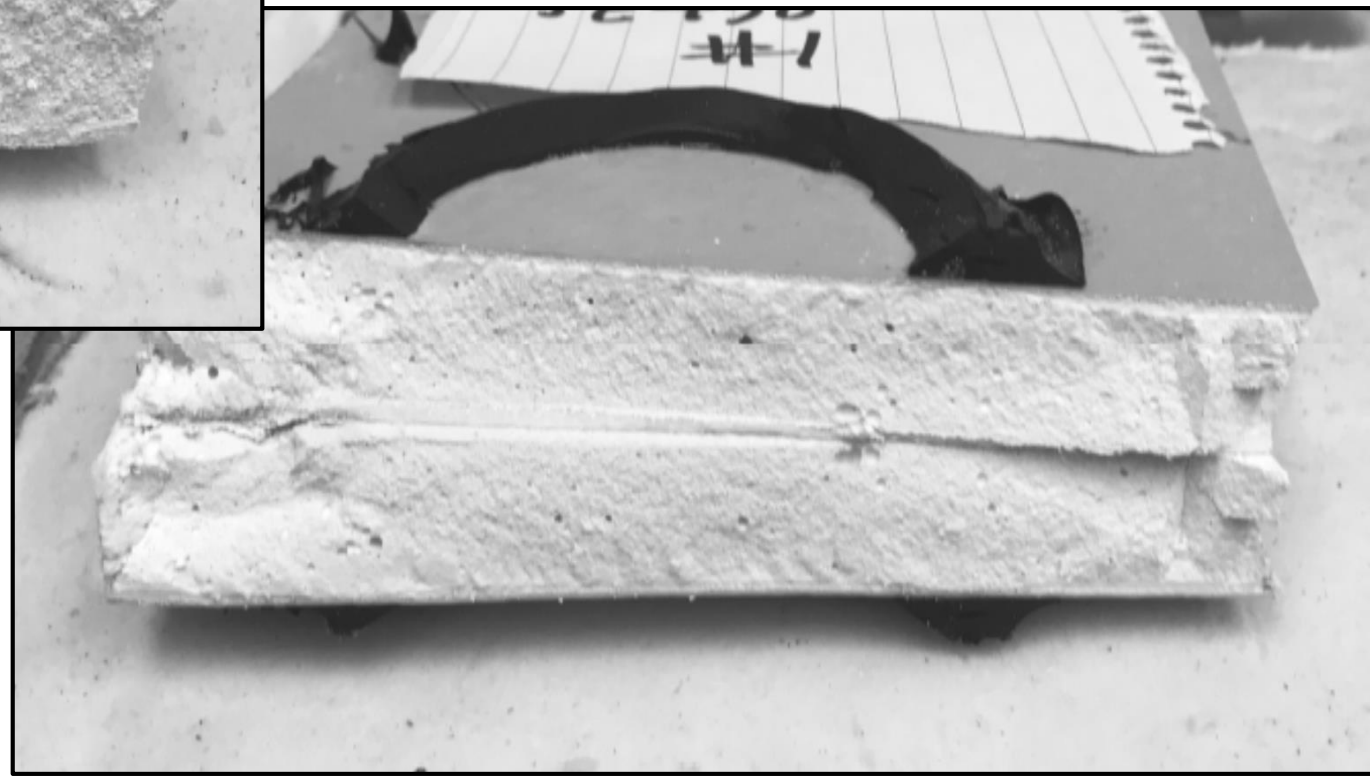
Product / Sequence / Informational Mock Ups

Hey…That looks pretty simple to me…..

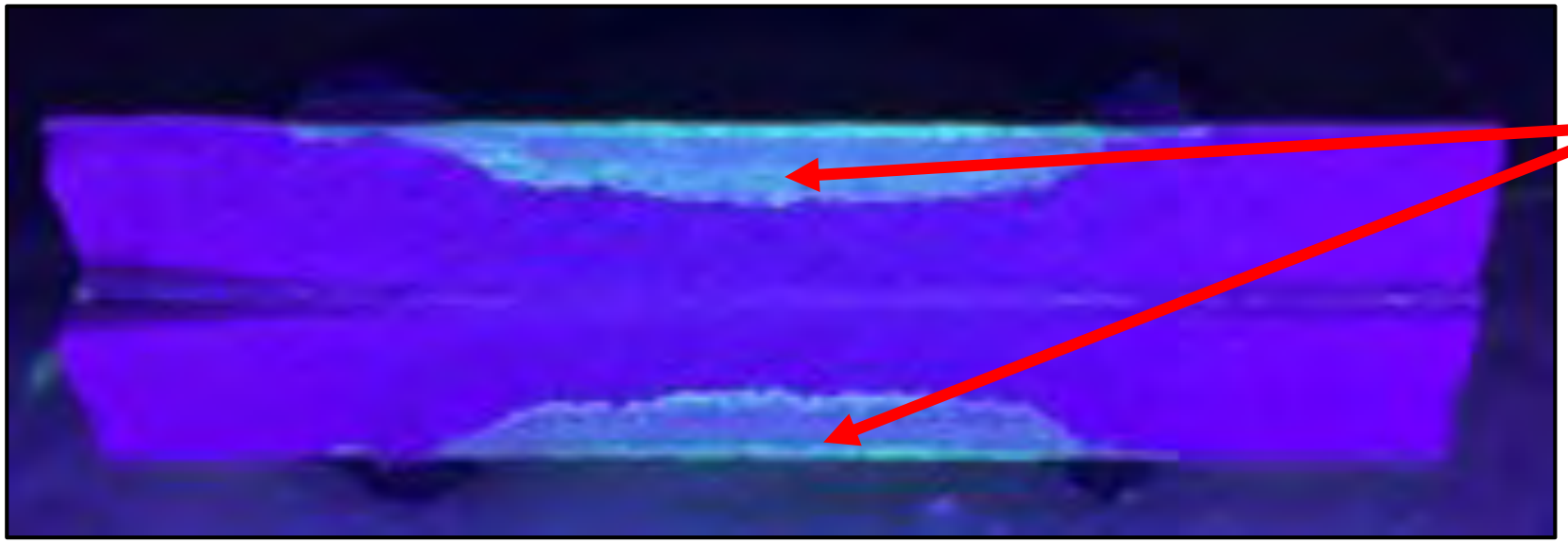
Moisture Infiltration Testing - AATCC 127

Moisture Infiltration Testing - AATCC 127



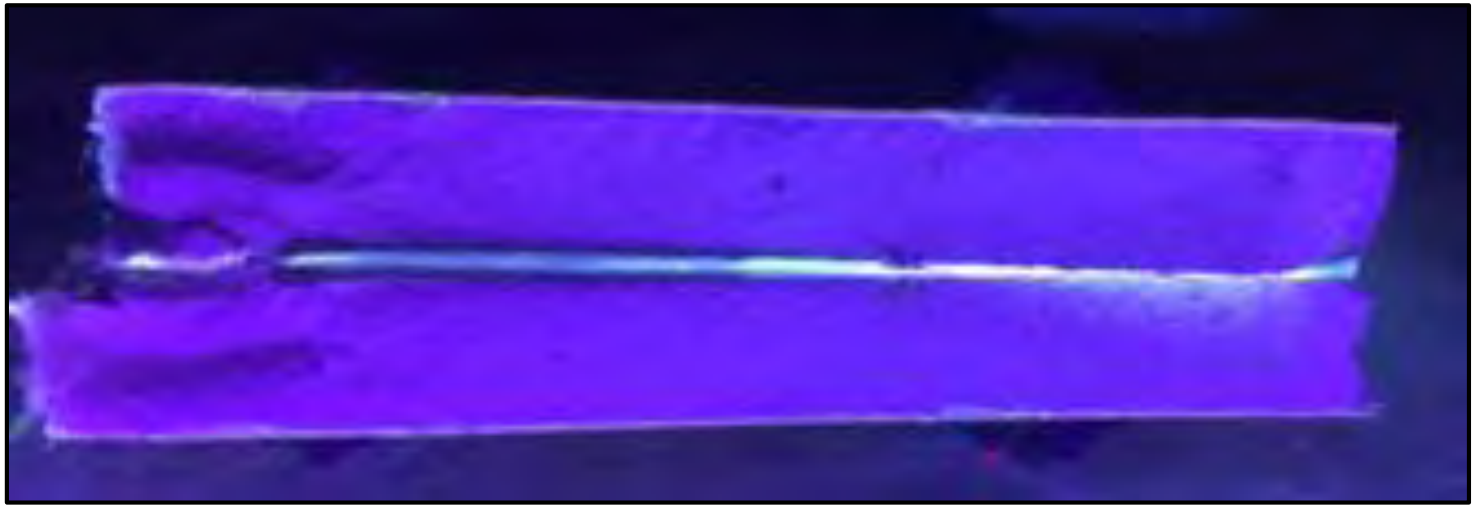


Moisture Infiltration Testing - AATCC 127



Exterior Sheathing Product - Moisture Penetration into Gypsum Core

Membrane over top of Exterior Sheathing - NO Moisture Penetration



Product / Sequence / Informational Mock Ups

Product / Sequence / Informational Mock Ups

Product / Sequence / Informational Mock Ups

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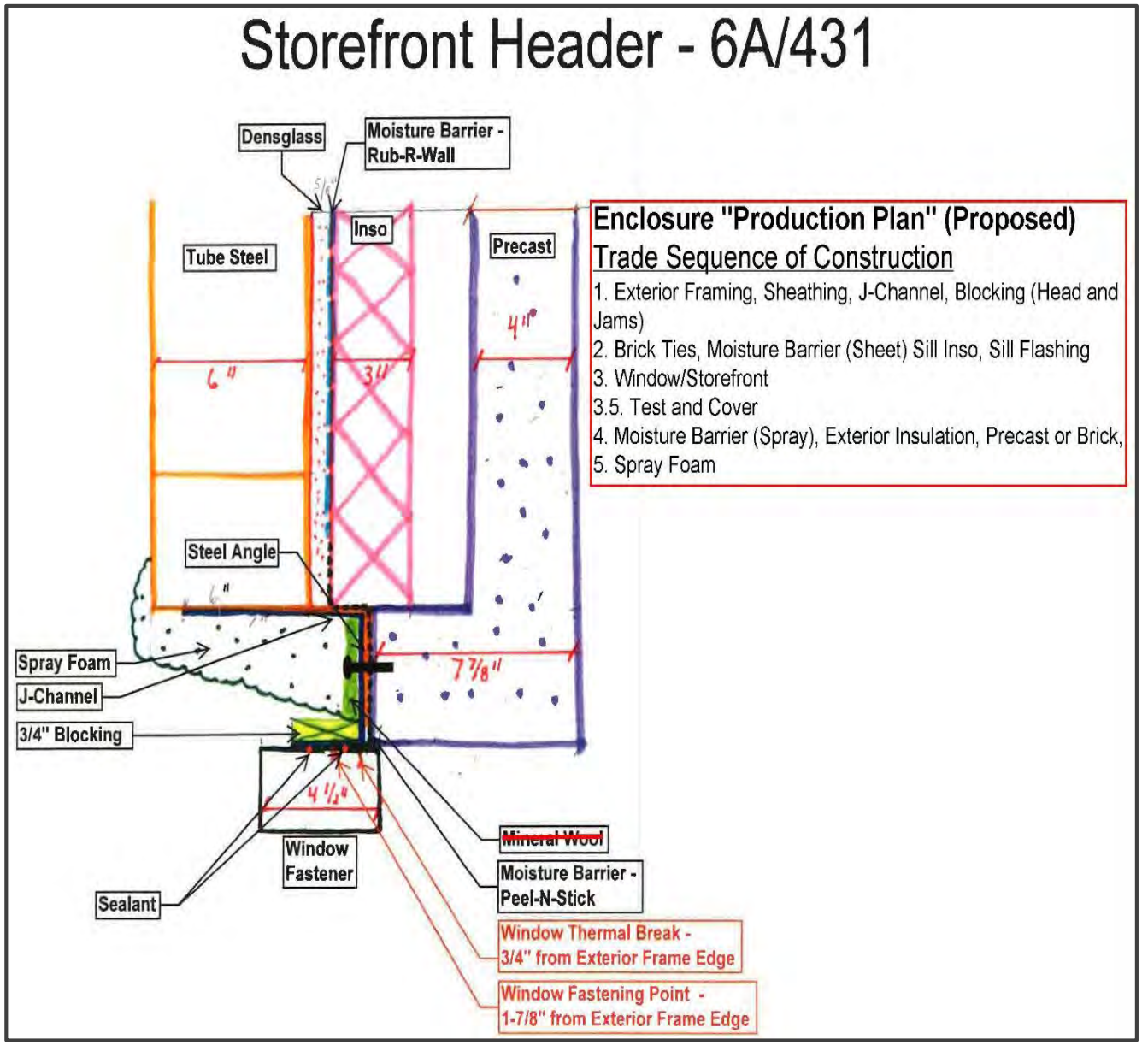
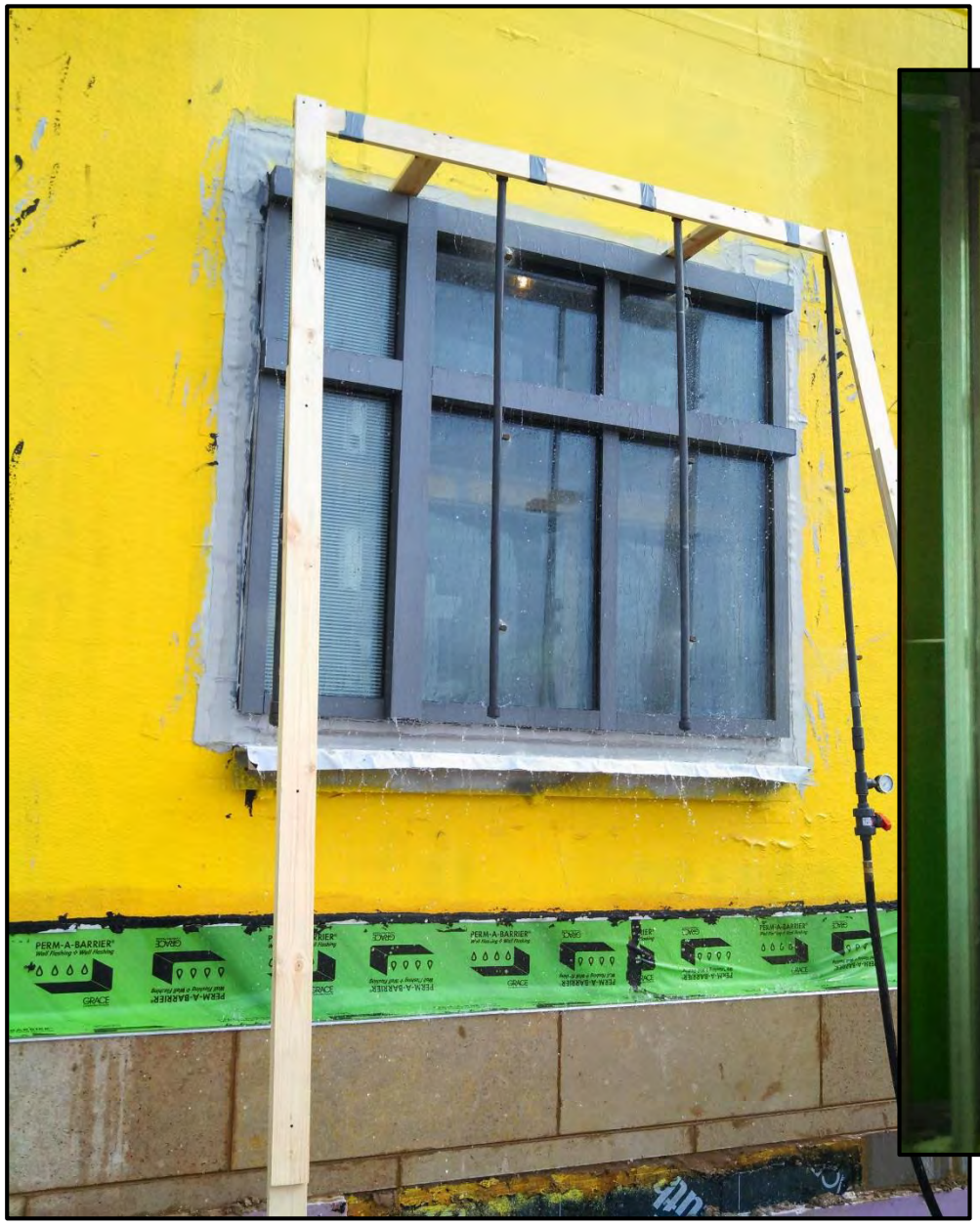
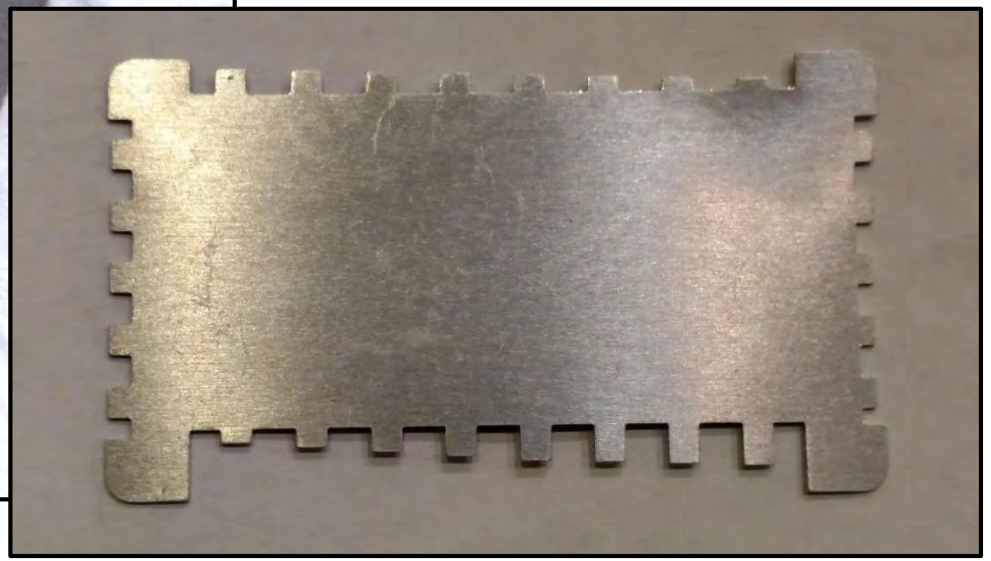


Utilizing the Actual Building - Mock Ups



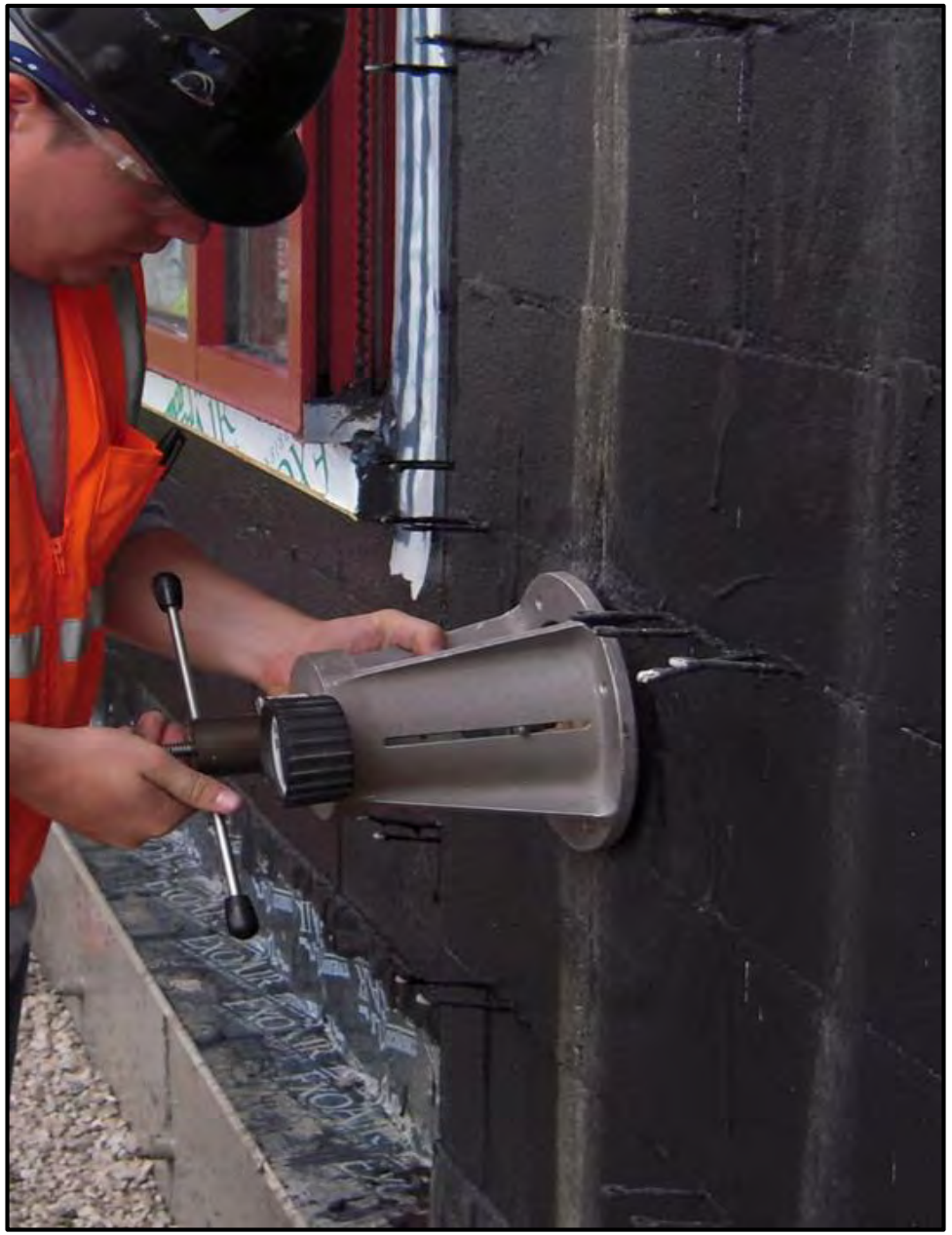
Utilizing the Actual Building

Utilizing the Actual Building



Utilizing the Actual Building

Utilizing the Actual Building

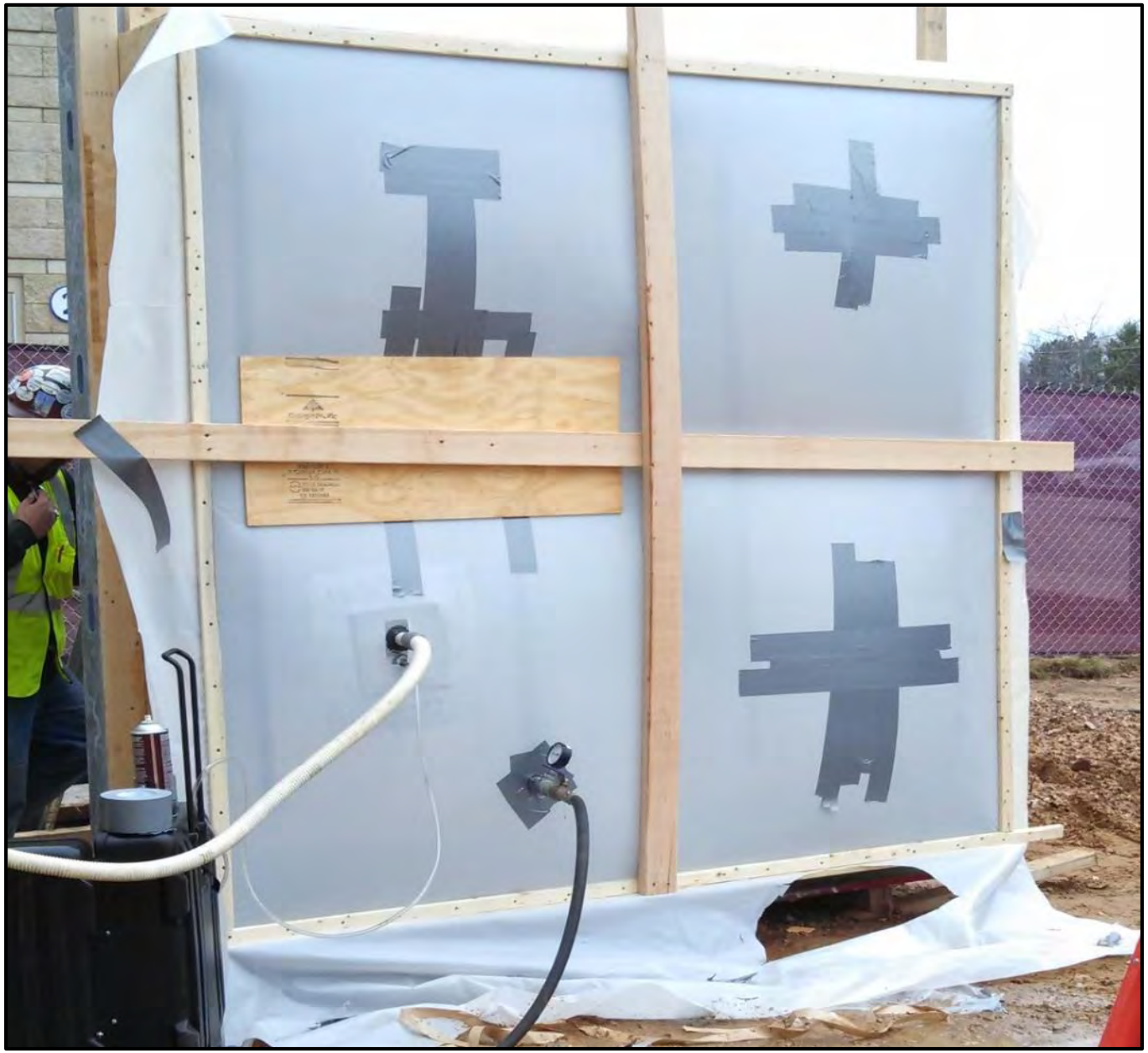


Utilizing the Actual Building

Small Scale On Site - Mock Up

Small Scale On Site

Small Scale On Site



Small Scale On Site

Small Scale On Site

Small Scale On Site

Small Scale On Site

Small Scale On Site

Large Scale Laboratory - Mock Ups

Large Scale Laboratory - Mock Ups

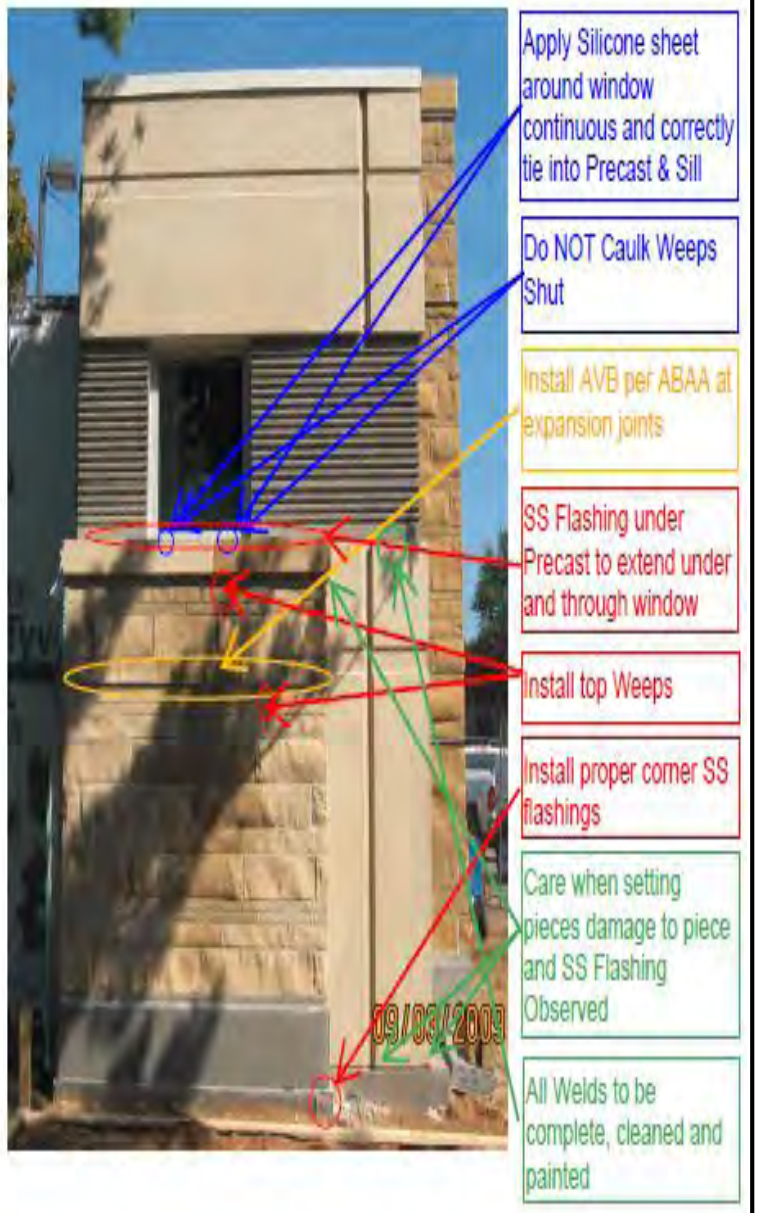
Should We Test The Mock Up???

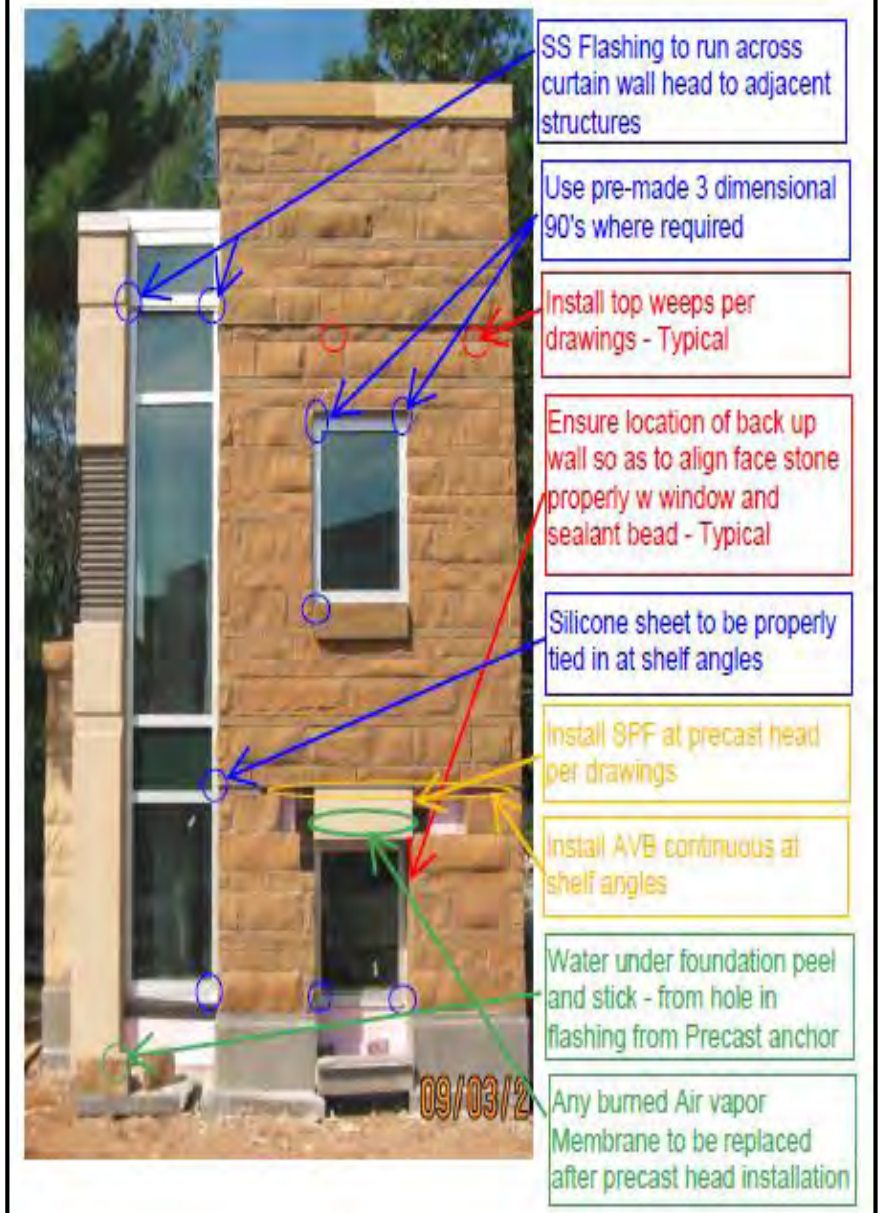

DON'T BE
A DUMMY

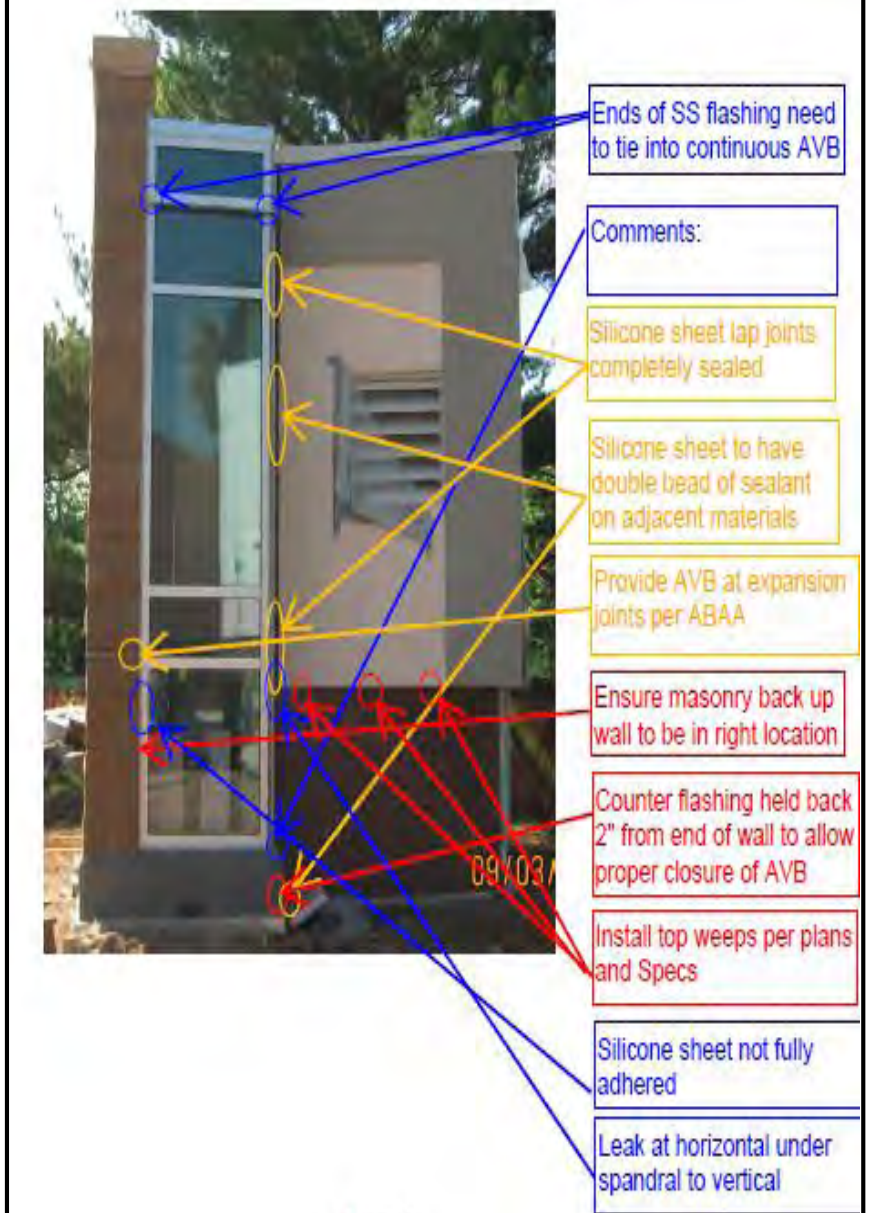
I Get We Need To…But When???

Too Late!!

When Should We Test The Mock Up???

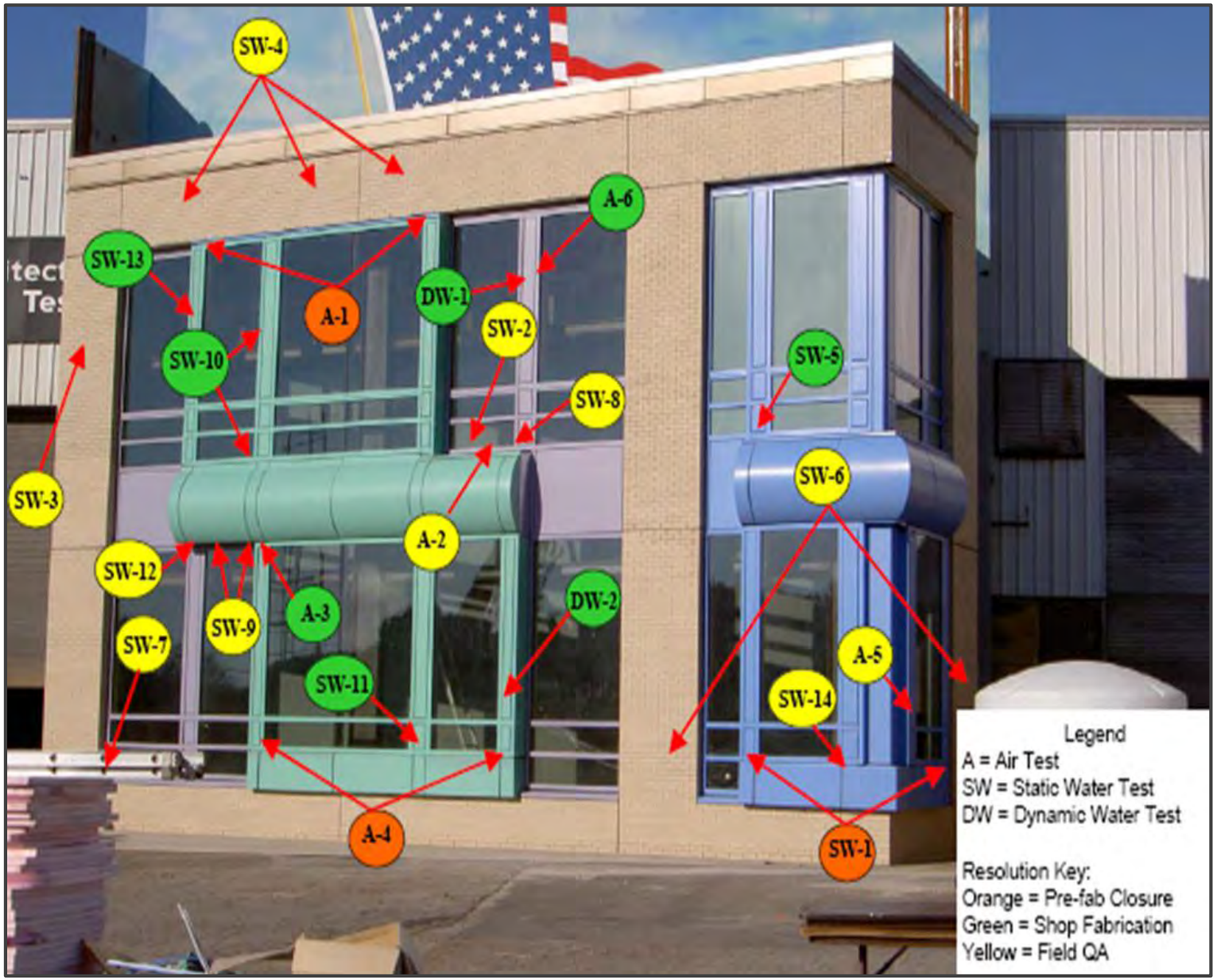






When Should We Test The Mock Up???

Common Tests Performed

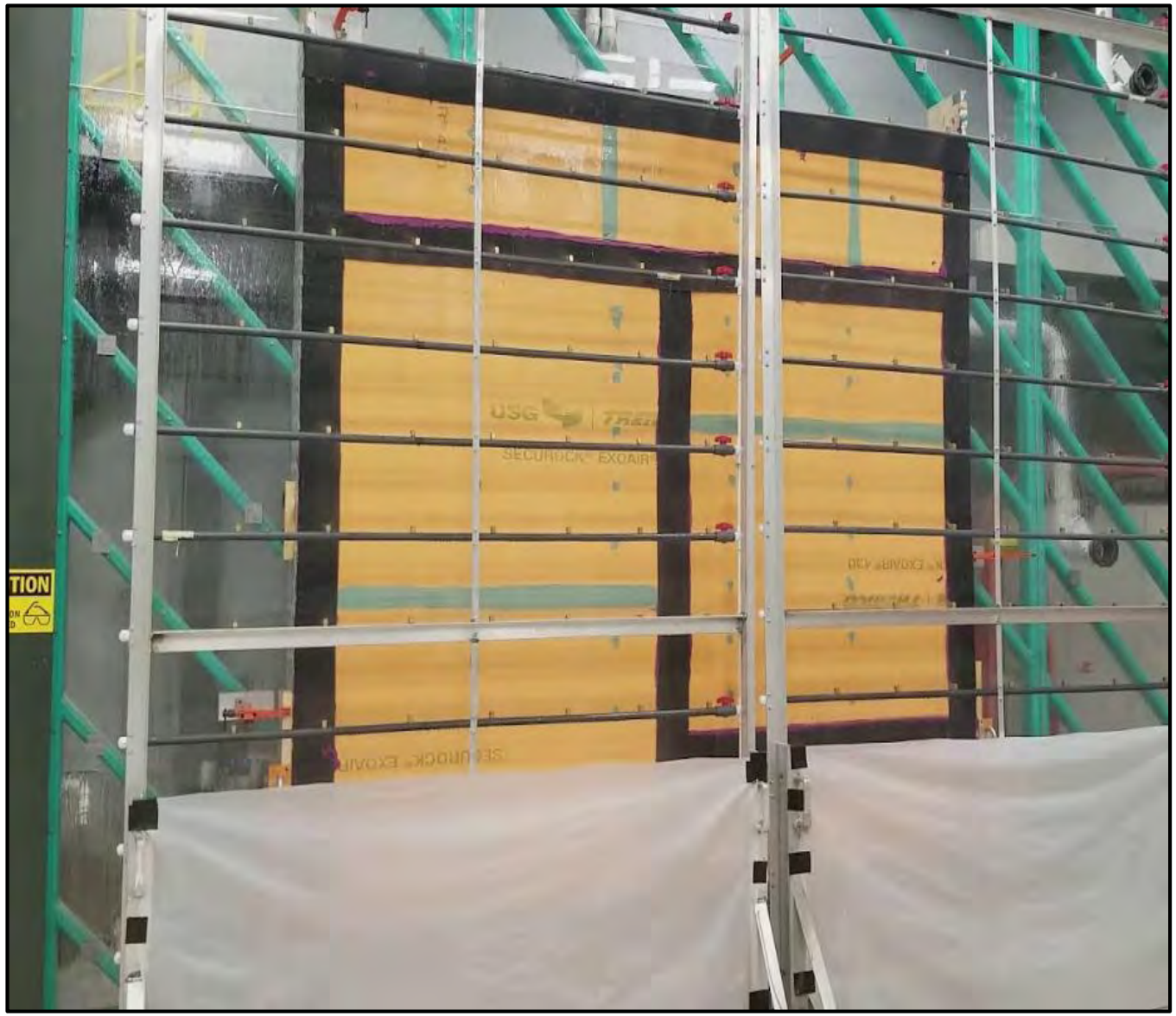


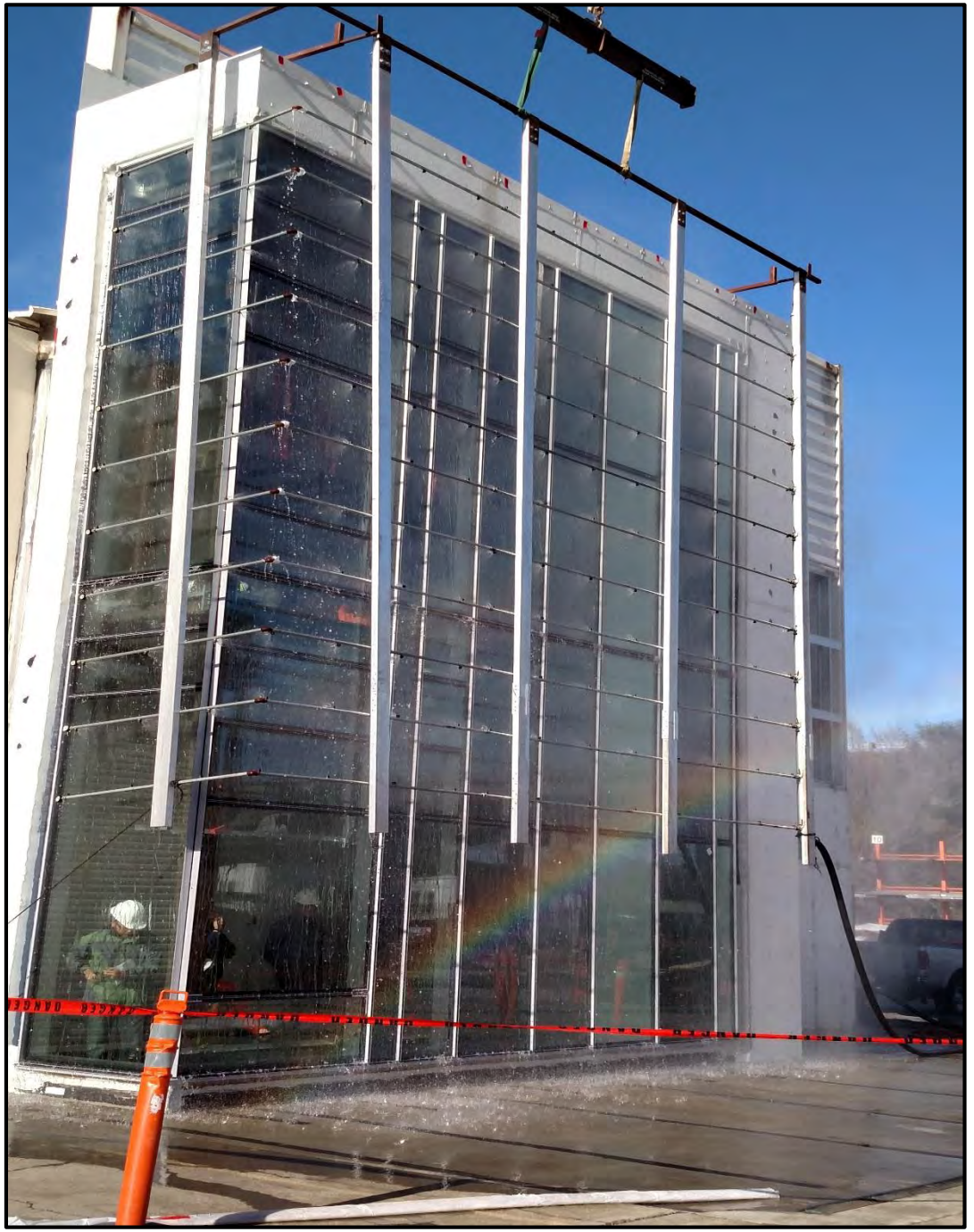
- Air Leakage Windows - ASTM E 283 / ASTM E 783
- Uniform Load Deflection - ASTM E 330
- Static Water - ASTM E 331 / ASTM E1105
- Smoke or Bubble Gun - ASTM E 1186
- Dynamic Water - AAMA 501.1
- Hose Test - AAMA 501.2
- Thermal Cycling - AAMA 501.5
  - Used to Determine Condensation Resistance
- Thermograph - ASTM C 1060
- Sealant Pull Test - ASTM C 1193
- Horizontal Flood Testing (Roof Test) ASTM D 5957
- Air Barrier Adhesion Tests ASTM D 4541
- Lab Mock Up – E 2099
- ASTM Work Standard – Spec and Test Field Mock Ups

Air Leakage - ASTM E283 / E783

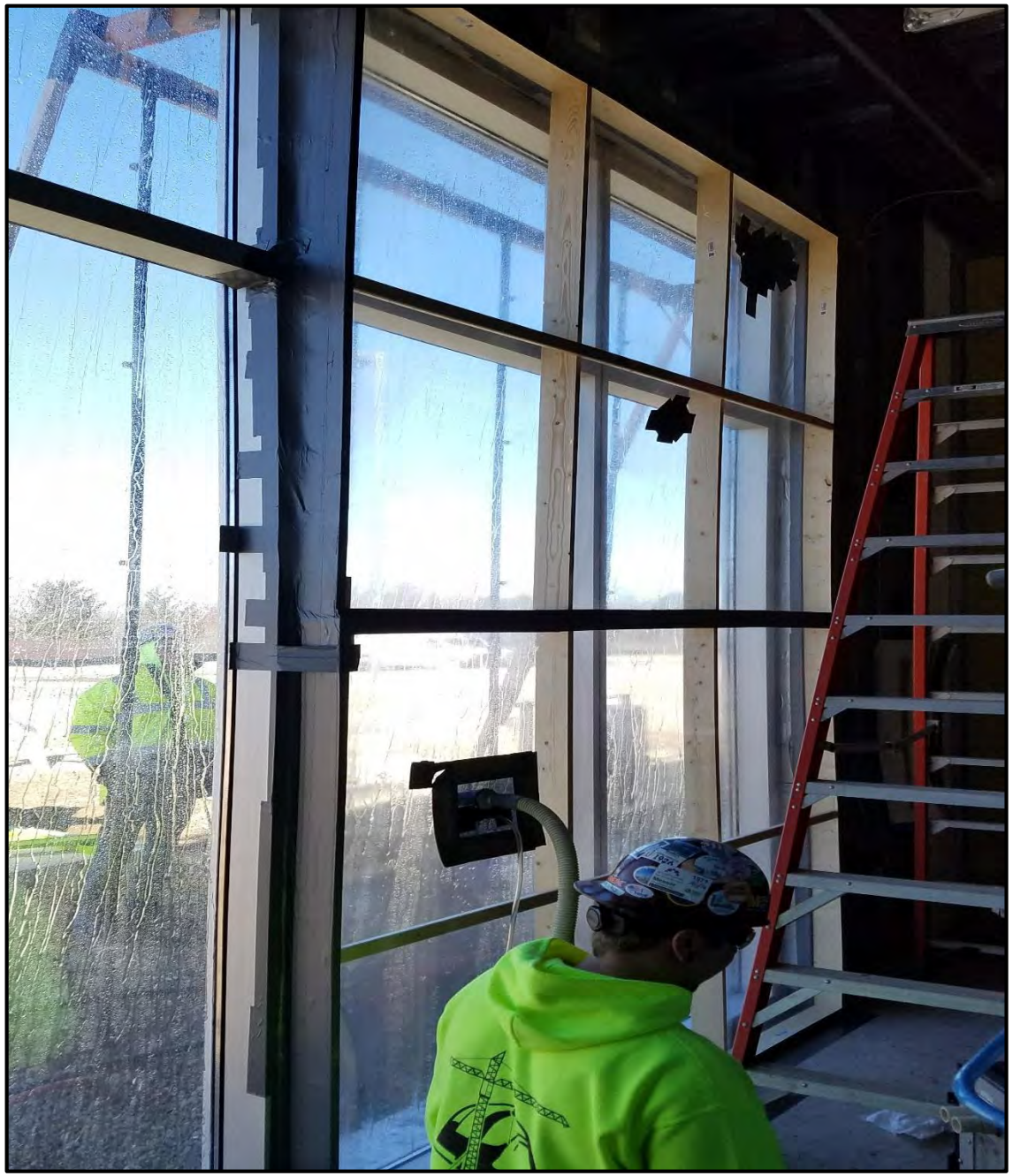
Load Deflection – ASTM E330

Static Water – ASTM E331





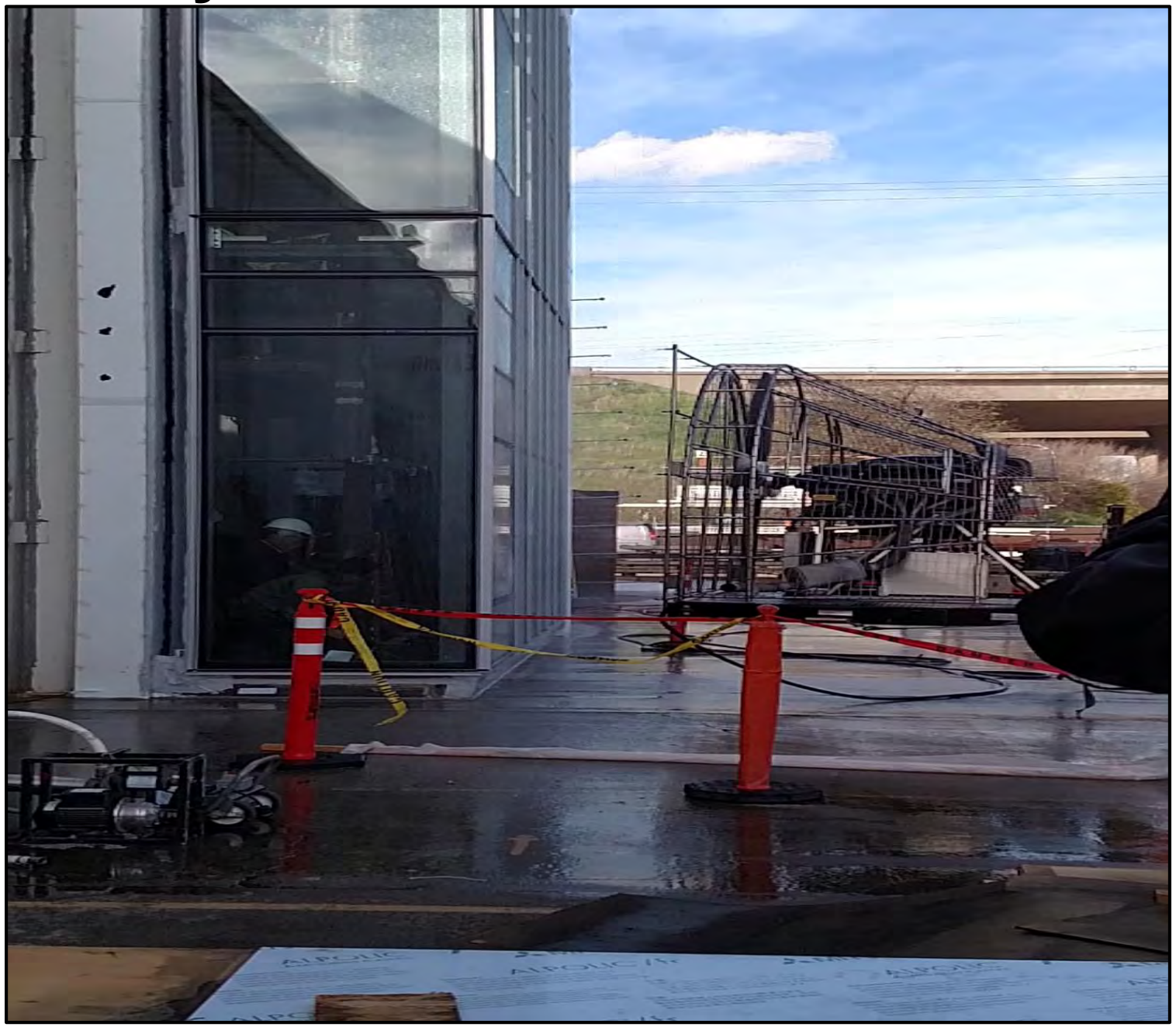
Static Water – ASTM E1105



Tracer Gas (Smoke Test) - ASTM E 1186

Air with Pressurization - ASTM E 1186

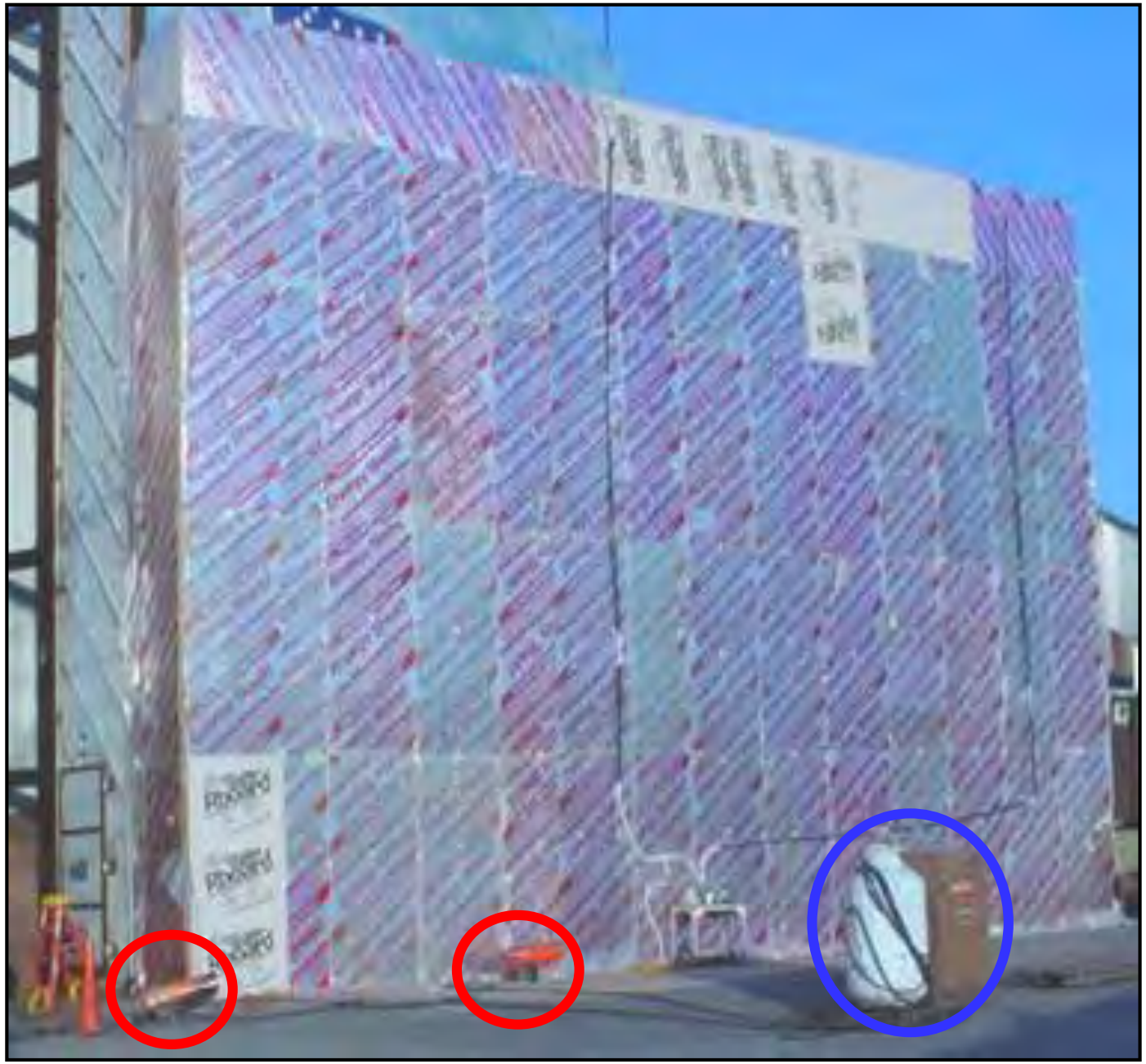
Dynamic Water - AAMA 501.1



Static Water - AAMA 501.2

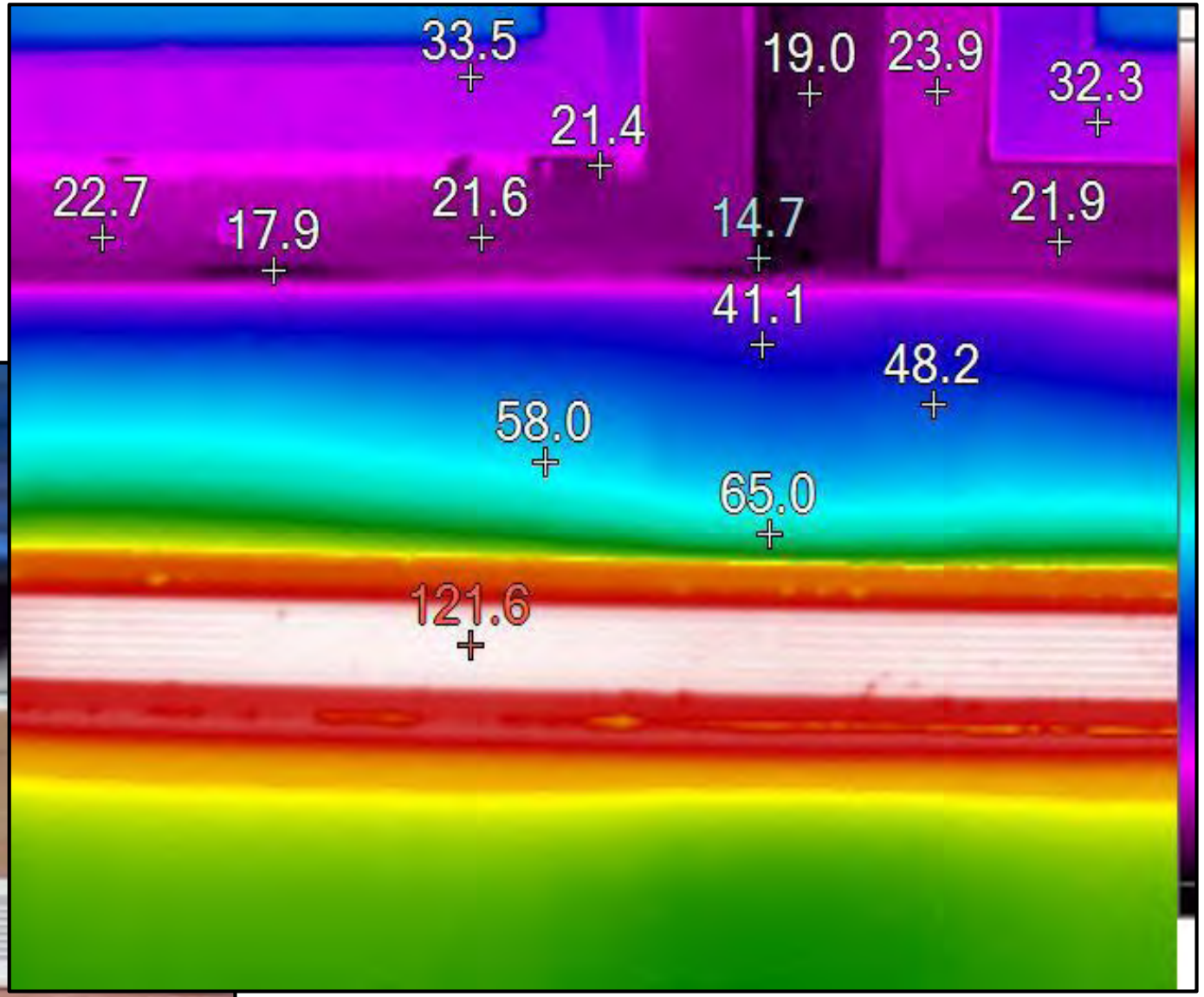
Even a Dummy knows to Start at the Bottom!

Thermal Cycle - AAMA 501.5

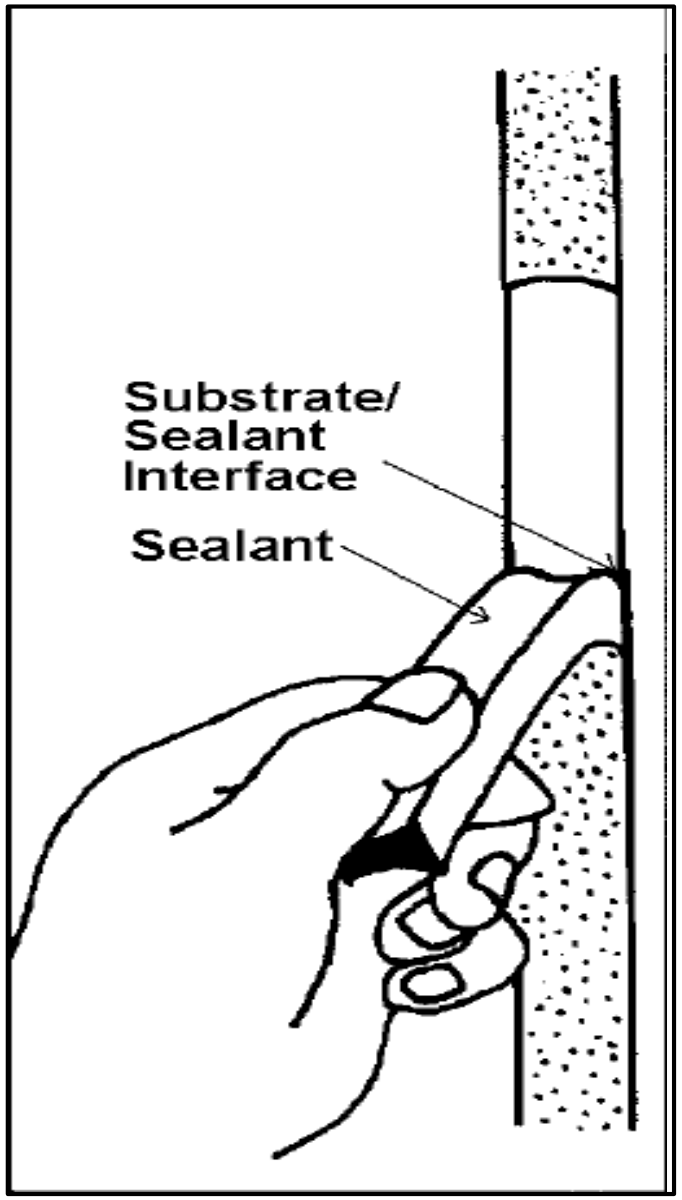


Thermographic Inspection - ASTM C1060

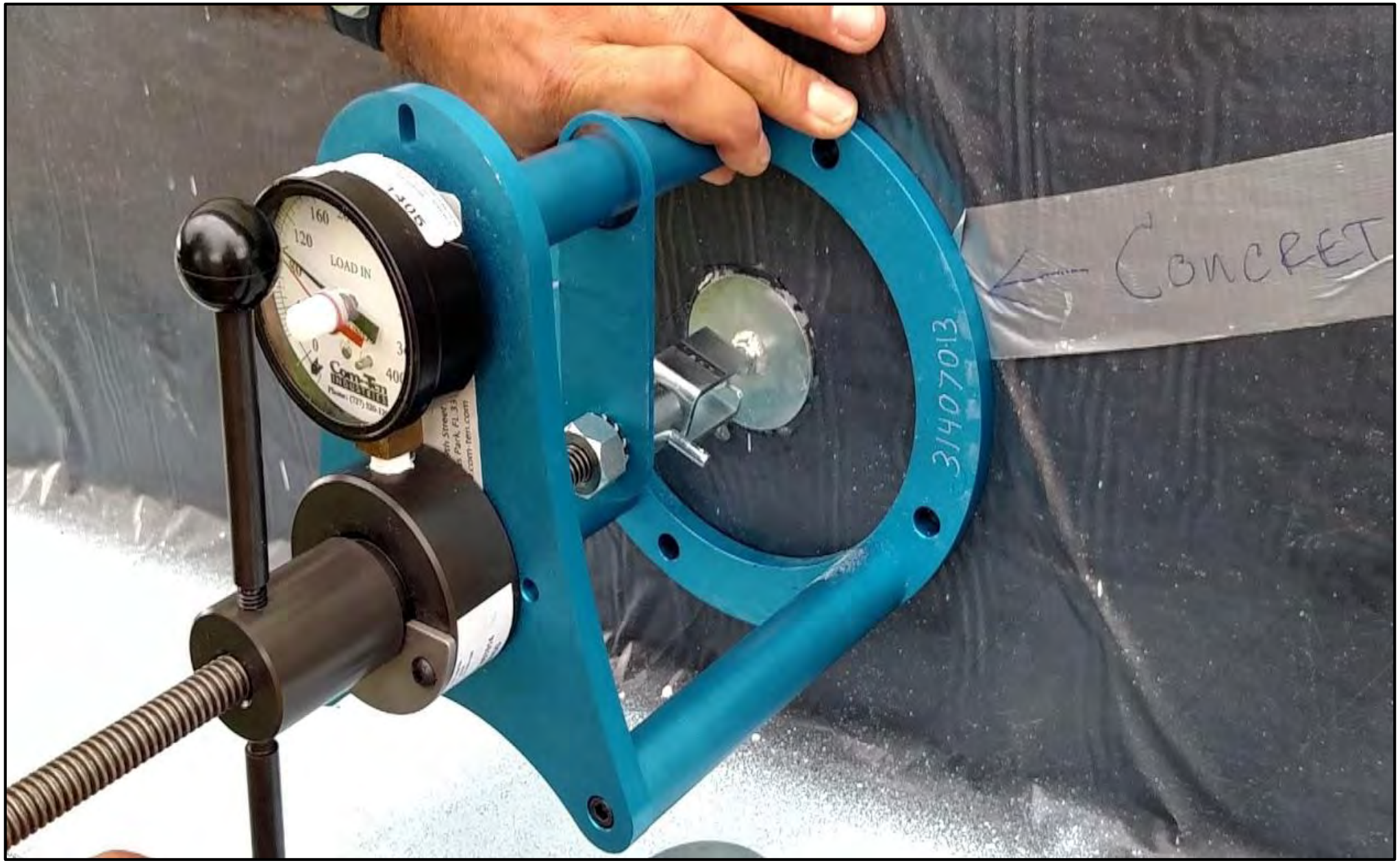
Outside -15F
Inside 73F
RH 26%
Existing Window
Heavy frost



Sealant Pull – ASTM C 1193



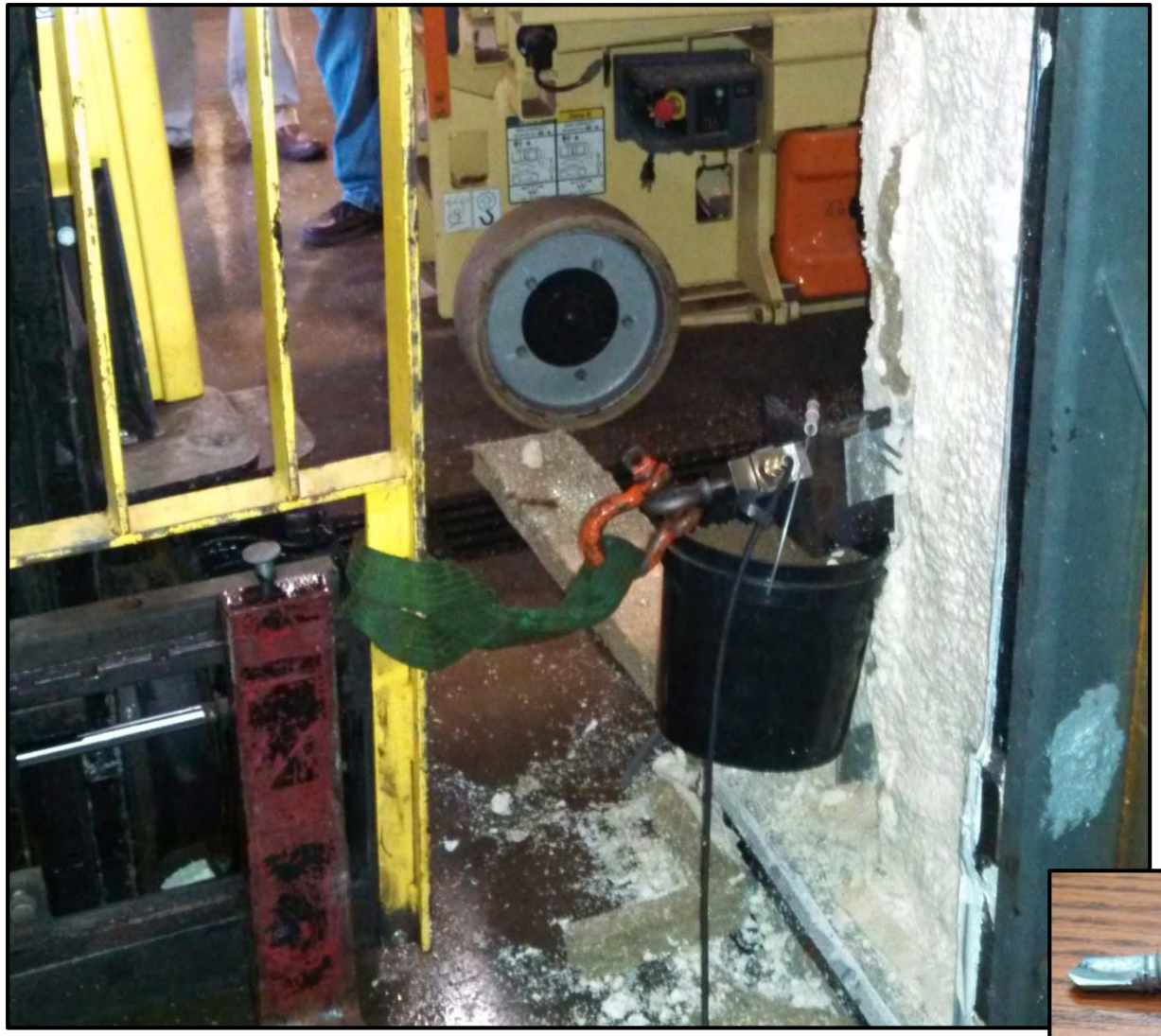
Air Barrier Adhesion - ABAA 002-17 / ASTM D 4541

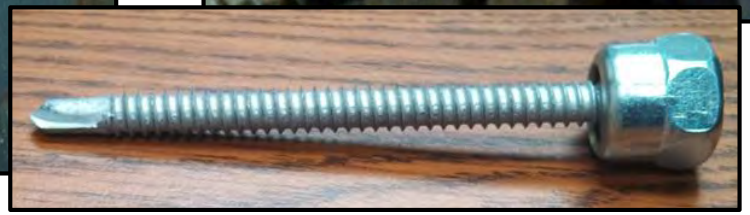


Spray Applied Polyurethane Foam Density - ASTM D 1622

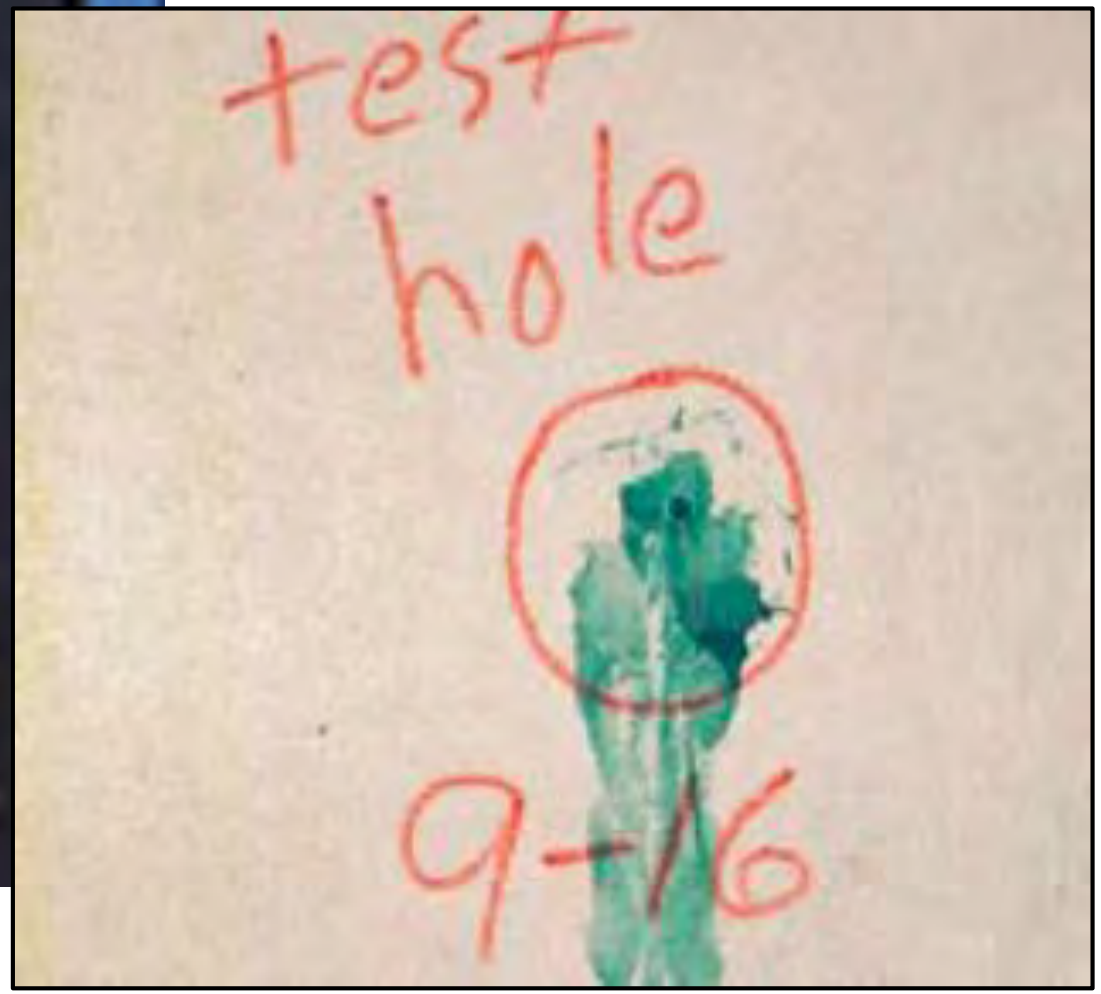
w/v x 1000 / 16 = lbs per ft²

Test Anything You Can Think Of





Test Anything You Can Think Of



Test Anything You Can Think Of

Root Cause Failures, Rework, Retest!

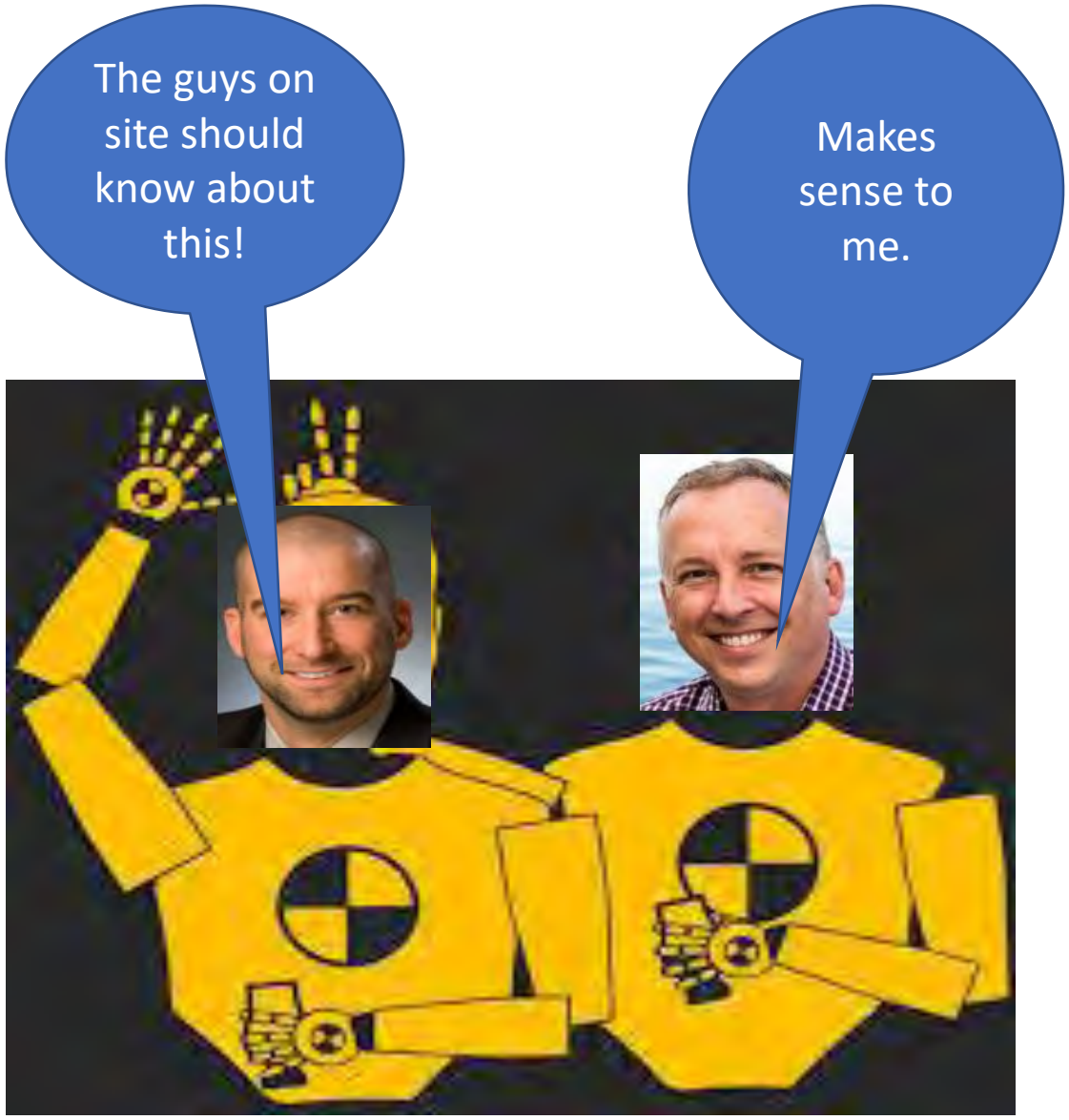
Root Cause Failures, Rework, Retest!

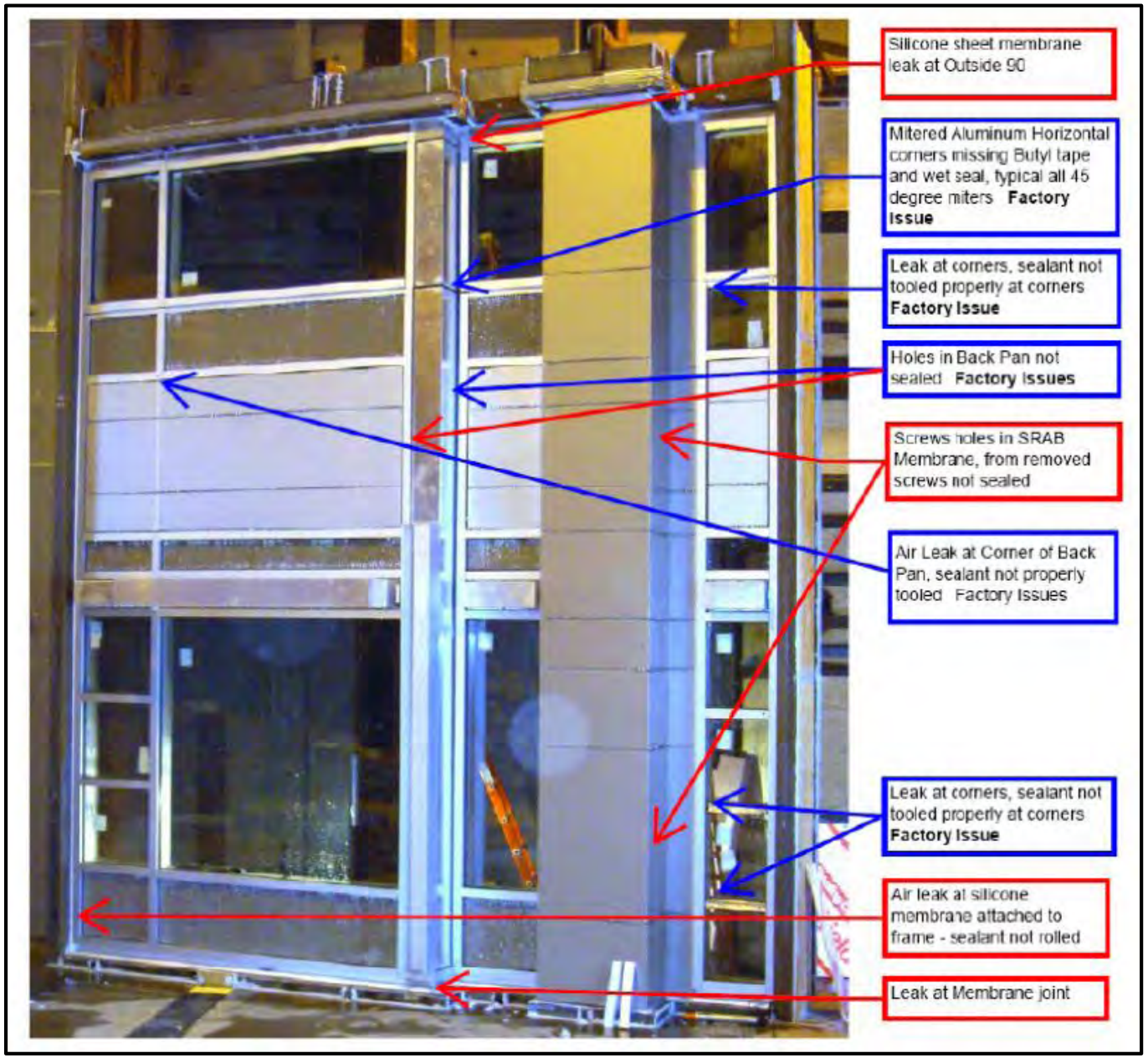
Root Cause Failures, Rework, Retest!

Project Specific Review

We Built…….
We Tested…….
We Passed……. Eventually
So What????

EDUCATE!!!!!

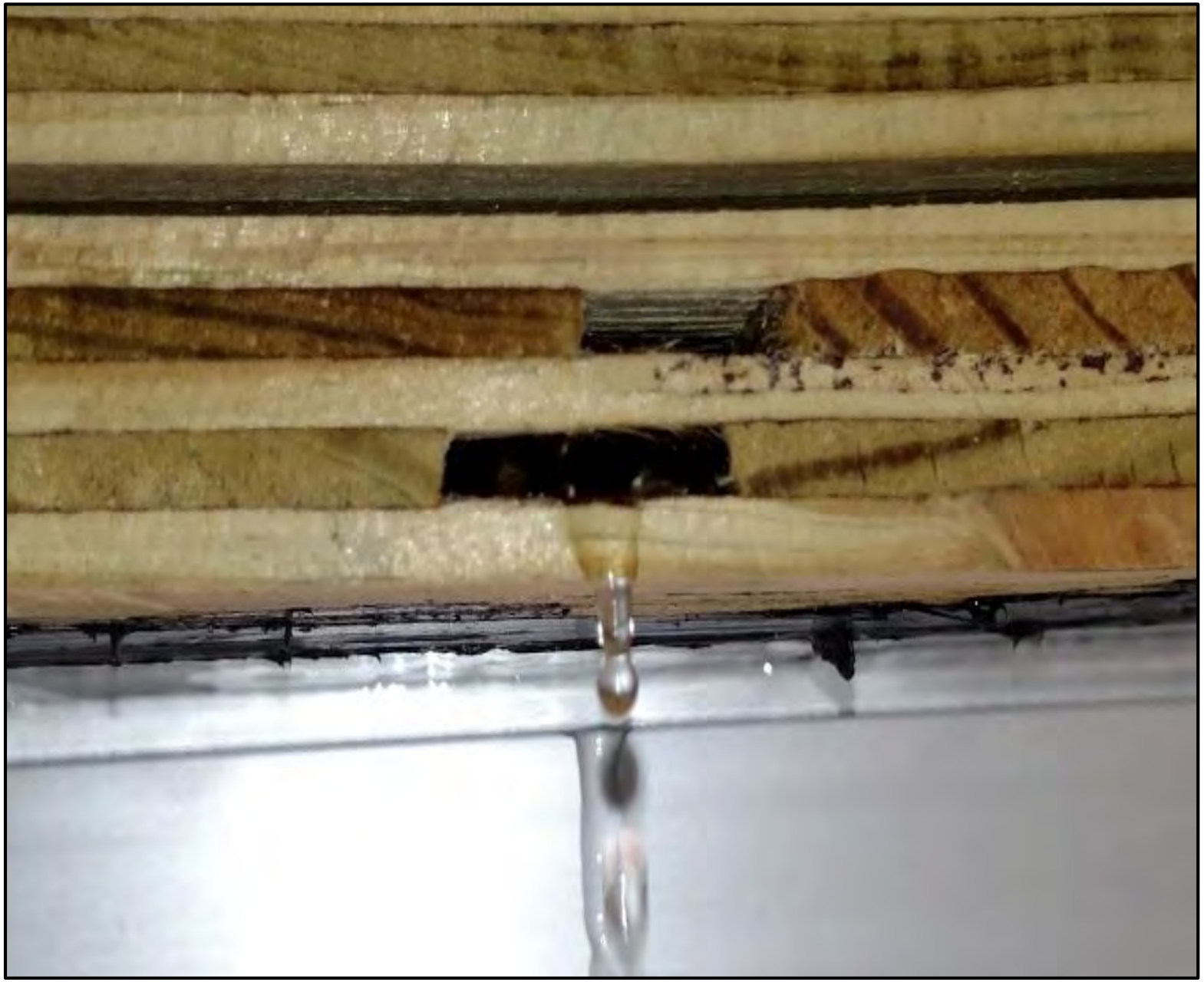

The guys on site should know about this!
Makes sense to me.


Silicone sheet membrane leak at Outside 90
Mitered Aluminum Horizontal corners missing Butyl tape and wet seal, typical all 45 degree miters **Factory Issue**
Leak at corners, sealant not tooled properly at corners **Factory Issue**
Holes in Back Pan not sealed **Factory Issues**
Screws holes in SRAB Membrane, from removed screws not sealed
Air Leak at Corner of Back Pan, sealant not properly tooled Factory Issues
Leak at corners, sealant not tooled properly at corners **Factory Issue**
Air leak at silicone membrane attached to frame - sealant not rolled
Leak at Membrane joint

Project Specific Review

Project Specific Review

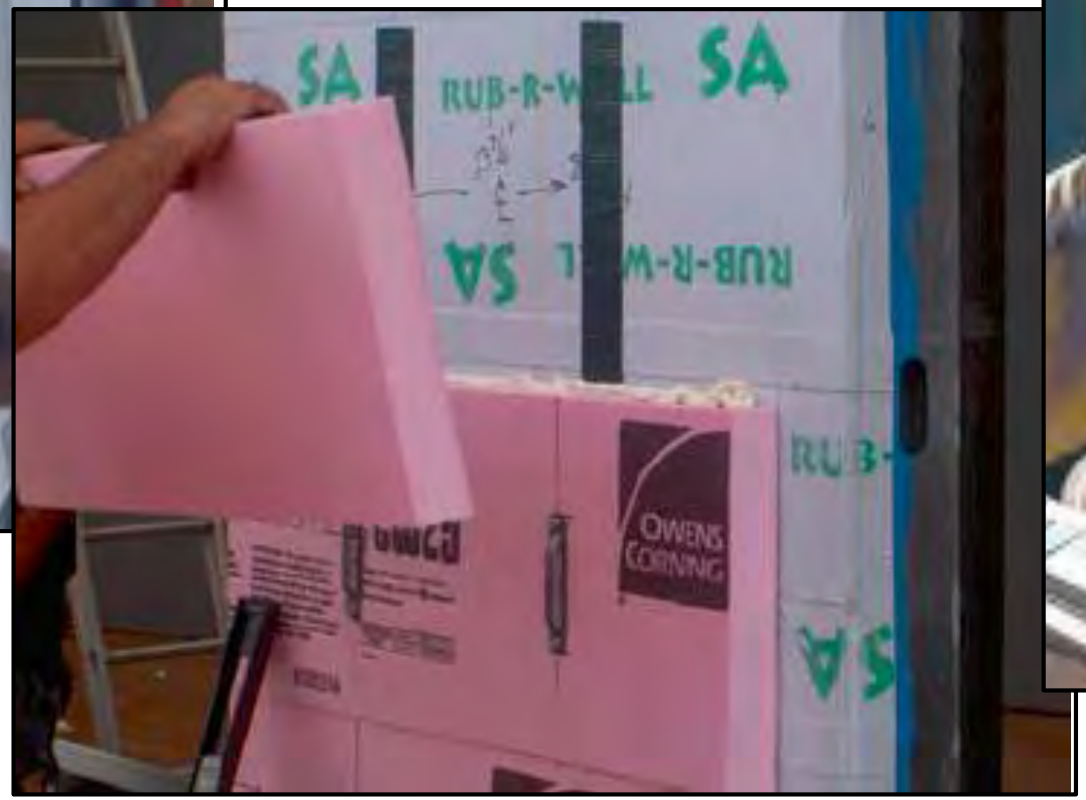
Project Specific Review



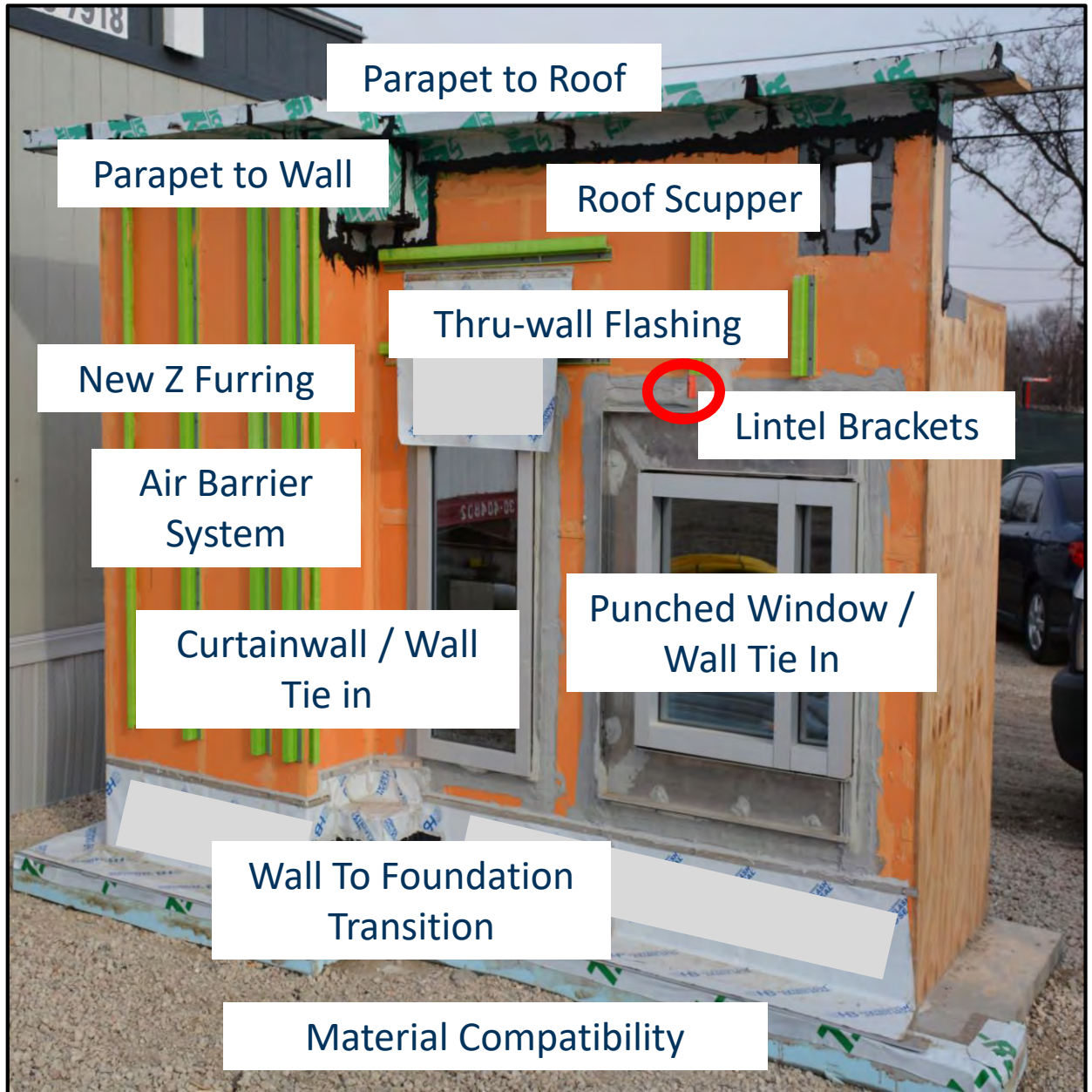
Project Specific Review

Project Specific Review

Project Specific Review



Let's Do Some "Brian" Math – Simple #'s



$14 M Project

On Site Simple Wall Mock Up = $12,500.

Mock Up = 0.09% of Construction Costs

This makes sense – kinda like cheap insurance

Wonder if my room has a bear skin rug????

I like to cuddle

Mock Ups: The Crash Test Dummy for Building Enclosures

Its about time – FINALLY he's done!

I bet Andrew's drink is empty too

Mock Ups: The Crash Test Dummy for Building Enclosures

Thank You!!!!

Questions????

- **Presenter: Brian Stroik**
- Manager – Building Envelope Solutions Team
- Tremco Sealants & Waterproofing
- Vice Chair – Air Barrier Association of America
- Past Chair National Building Enclosure Council
- Co-Chair BEC WI