



# **Building Envelope**

## **Technology Symposium**

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# Curtain Wall Failures

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# Karim P. Allana, PE, RRC, RWC

**EDUCATION:** B.S., Civil Engineering, Santa Clara University

**REGISTRATION:** P.E., Civil Engineering, California, Washington, Nevada and Hawaii

**CERTIFICATION:** Registered Roof Consultant (RRC), Roof Consultants Institute, Registered Waterproofing Consultant (RWC), Roof Consultants Institute

## **OVERVIEW:**

- CEO and Senior Principal at Allana Buick & Bers.
- Former Turner Construction Employee (Project Engineering and Superintendent)
- Over 37 years experience providing superior technical standards in all aspects of building technology and energy efficiency.
- Principal consultant in forensic investigations of building assemblies, failure analysis, evaluation and design of building infrastructure and building envelope evaluation and design.
- Expert in all aspects of building envelope technology.
- Completed numerous new construction, addition, rehabilitation, remodel and modernization projects for public and private sector clients.
- Specialization in siding, roofing, cement plaster, wood, water intrusion damage, window assemblies, storefronts, below grade waterproofing, energy efficiency, solar engineering and complex building envelope and mechanical assemblies.



# Presentation Outline

- Typical Curtain Wall Systems
- Common Modes of Failure
- Lessons Learned



# Typical Curtain Wall Systems

- By definition, a wall that carries no weight other than its own
- Load transferred to the edge of the floor slab
- Panels “hang” like a curtain from structural elements
- Commonly in-filled with glass, but can be in-filled with stone veneer, metal panels, operable vents



# The Hallidie Building, SF



One of the Oldest Glass  
Curtain Walls (1918)

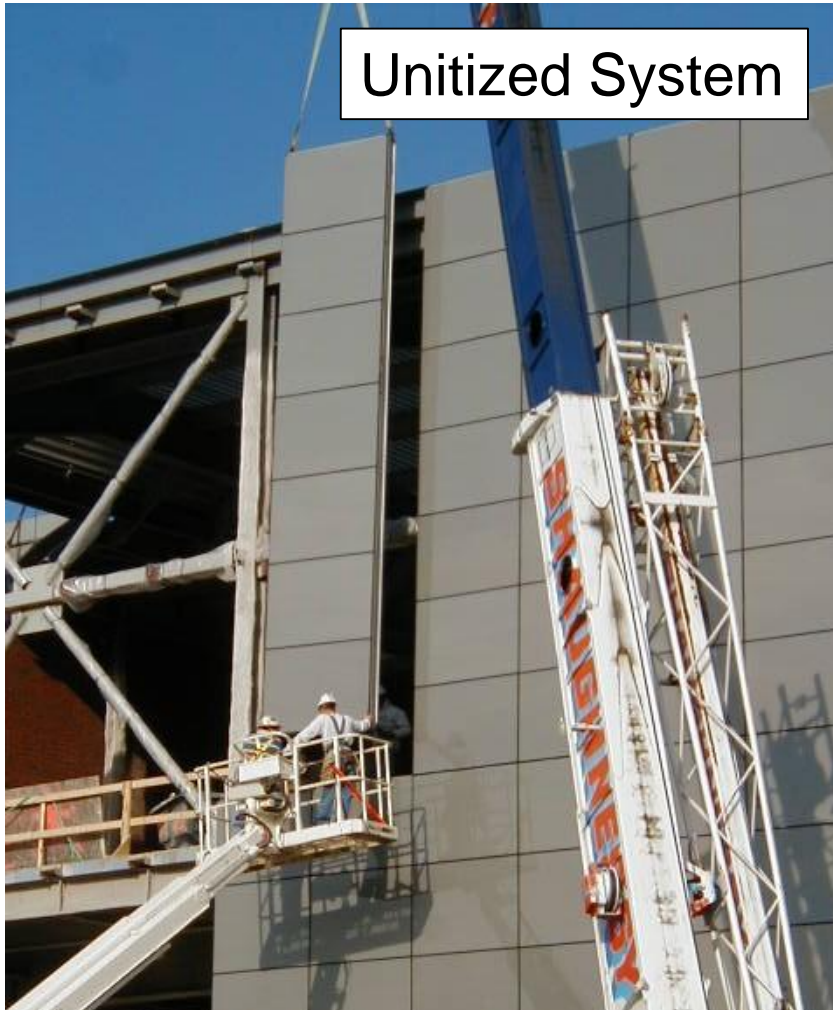


# Typical Curtain Wall Systems

- Can be a stick assembly system or unitized (modular) system for prefabrication
- Oldest curtain walls were built with thick masonry and brick or terra cotta
- In theory, they can perform for decades



# Stick Assembly vs. Unitized System



# Common Modes of Failure

- Gasket Failure
  - Water Intrusion
  - Air infiltration
- Aluminum Coating Failure
  - Missing primers
  - Coating thickness issue
  - Contaminants
- Corrosion of Glass
  - Edge deletion issue
  - Standing water on seals
- IGU Polyisobutylene (PIB) Failure
- Aluminum Thermal Break Failure

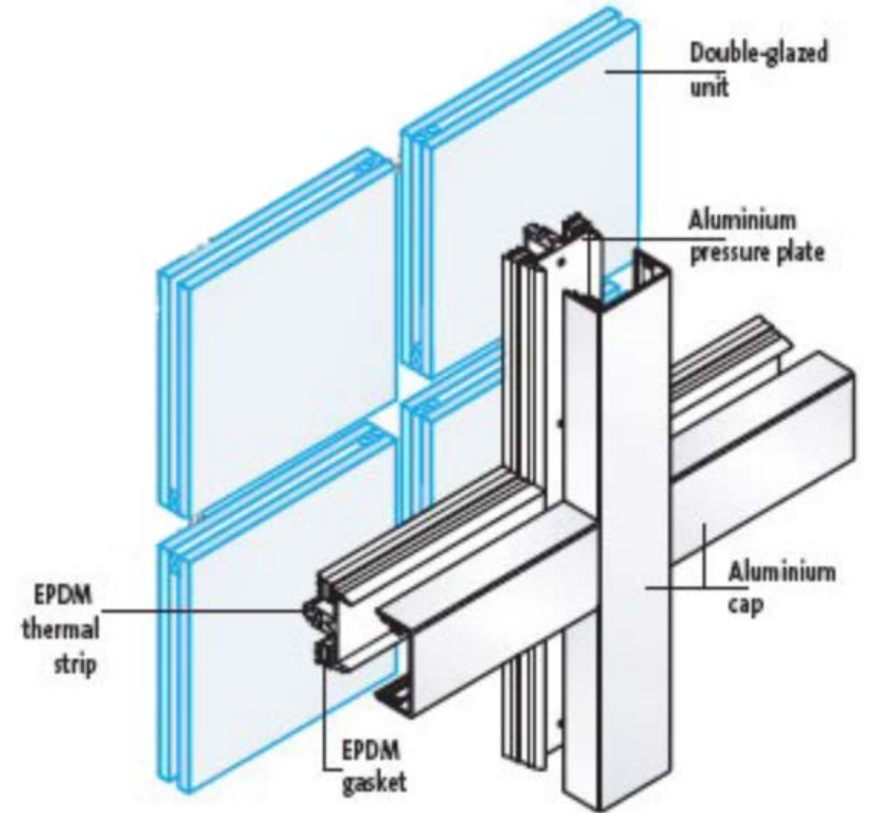


# Gasket Failure



# What is a Gasket?

- Gaskets - strips of synthetic rubber compressed between the glazing and frame or frame to frame
- Generally extruded EPDM
- Can be special ordered with silicone



# Gasket Failures

- Drying out, shrinking and cracking
- Exposure to UV radiation
- Exposure to freeze-thaw cycles
- Improper maintenance



# Mondavi Gasket Shrinkage / Failure



# Gasket Failure



Gaps created by gasket failure admits air and moisture into the system



# Gasket Failure - San Jose Condo



# Gasket Failure - San Jose Condo



# Gasket Failure- San Jose Condo



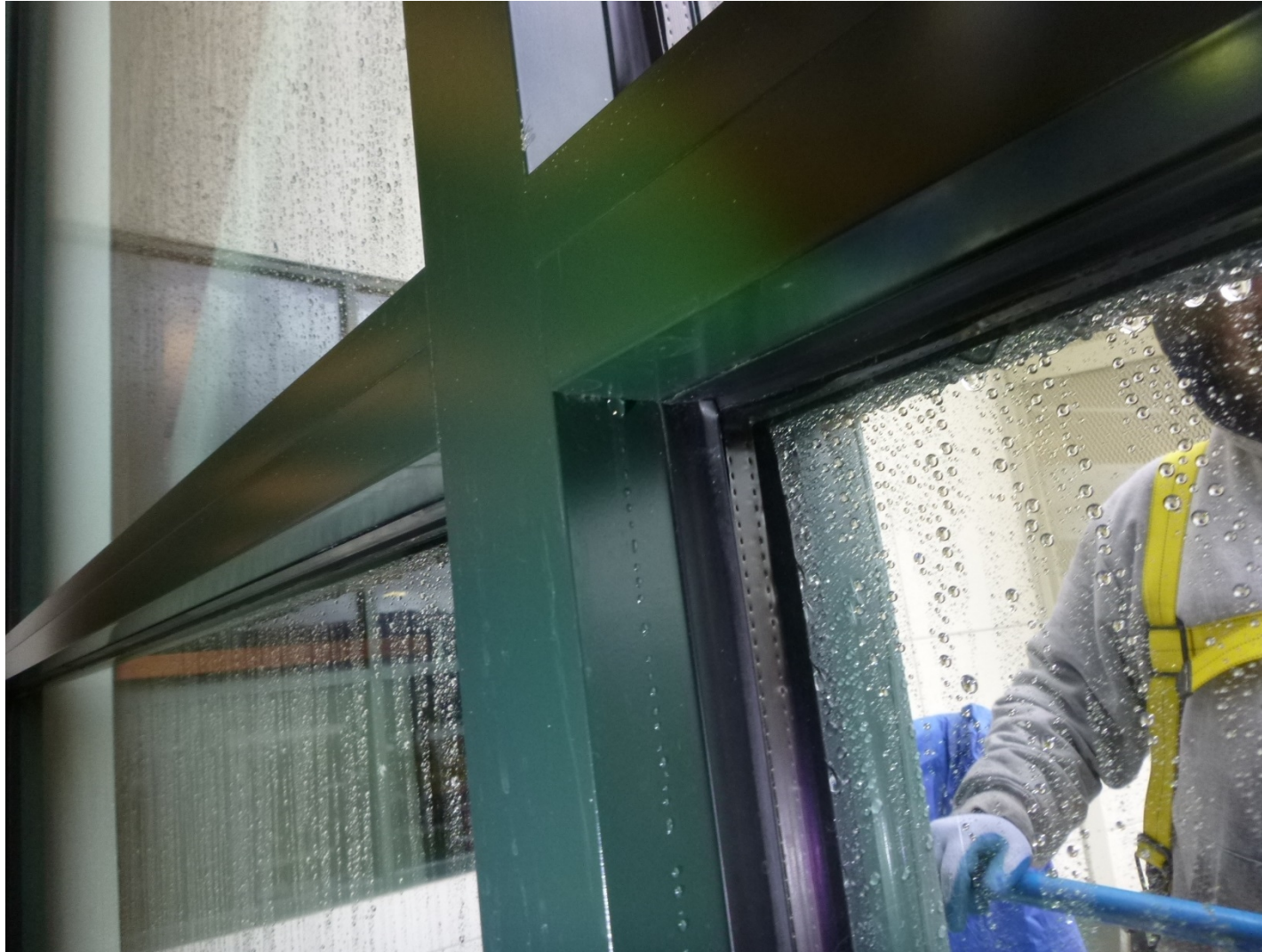
# Gasket Failure- San Jose Condo



# Gasket Failure- SM College Library



# Gasket Failure- Causing Leaks

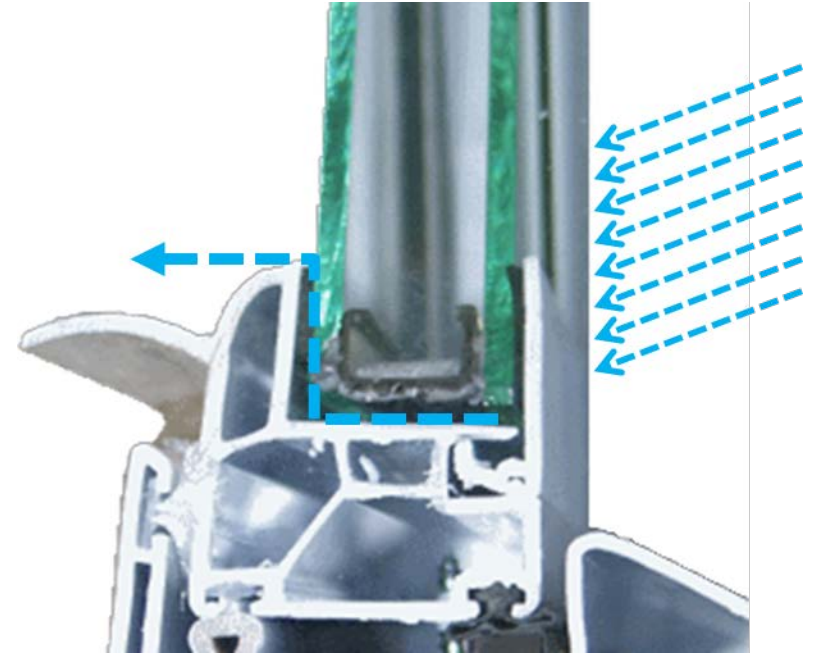


# Gasket Failure- Causing Leaks

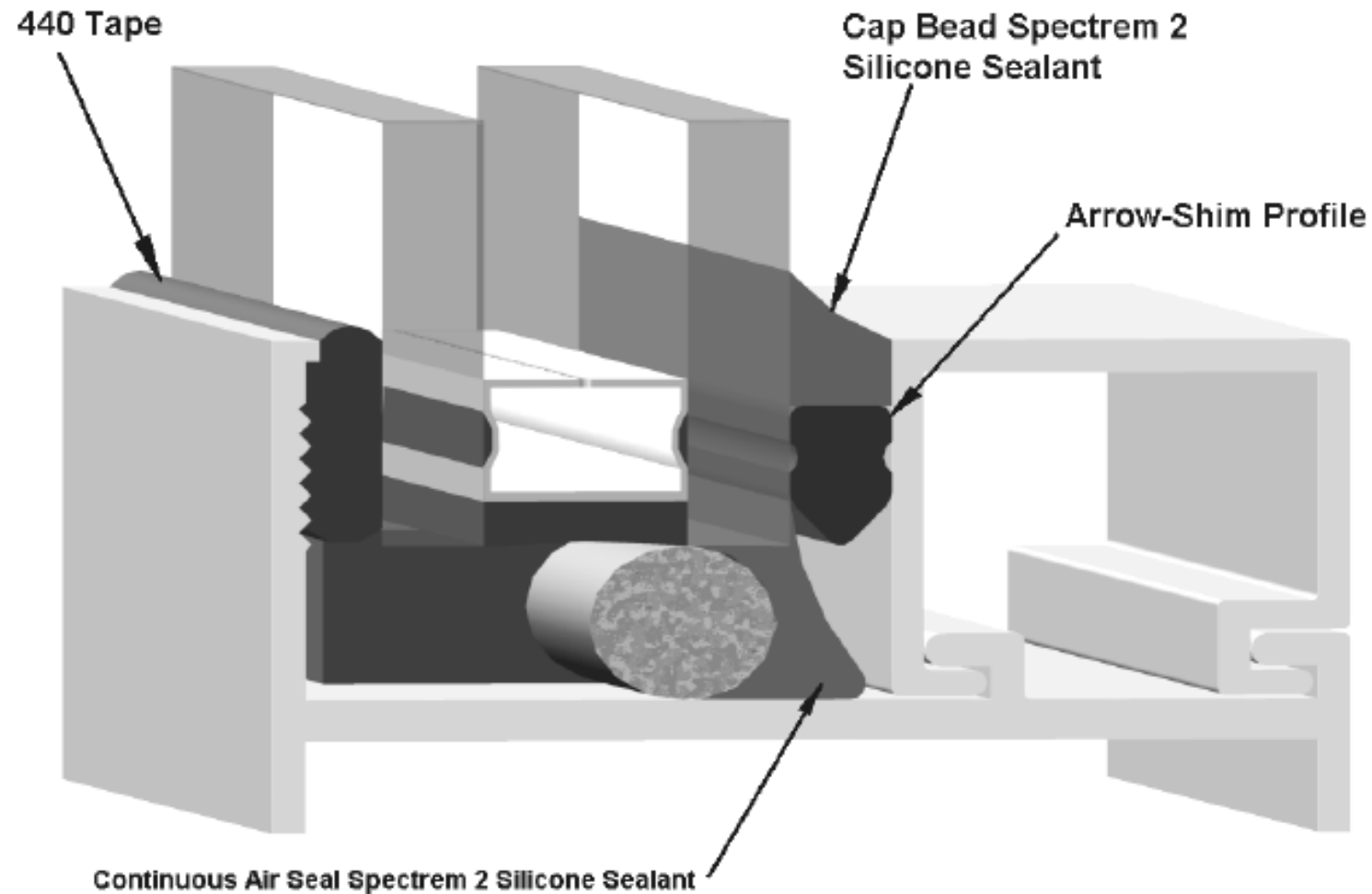


# Leaks Through Window Glazing Seals

- “Glazing seal” refers to the seal between the glass and window sash
- Commercial windows use tape with adhesive backing on two sides and silicone heel or cap beads for glazing seals
- Fin style windows often only use acrylic tape and no wet silicone
- Acrylic tape can break down from UV and water
- In some cases window sashes can overflow with just a light spray



# Glazing Gaskets Enhanced



# Gasket/Seal Failure Effects

- Water intrusion
- Air infiltration
  - Energy loss
  - Condensation



# Leaks Due To Gasket Shrinkage

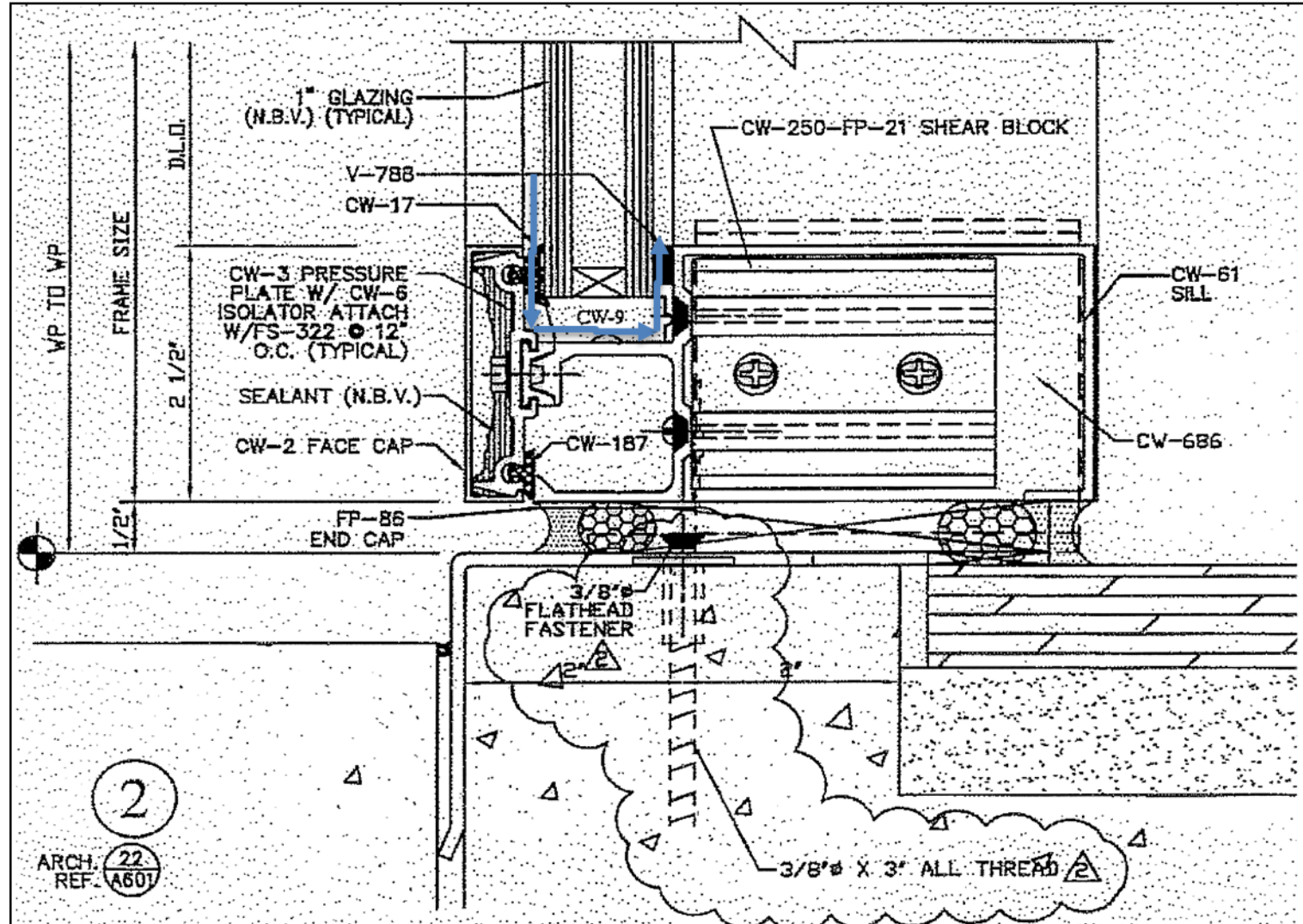


# Leaks Due To Gasket Shrinkage



# Typical EPDM Mullion Gasket Shrinkage

15/16" glazing installed produces a loose seal and leaks



# Gasket Shrinkage Water Intrusion

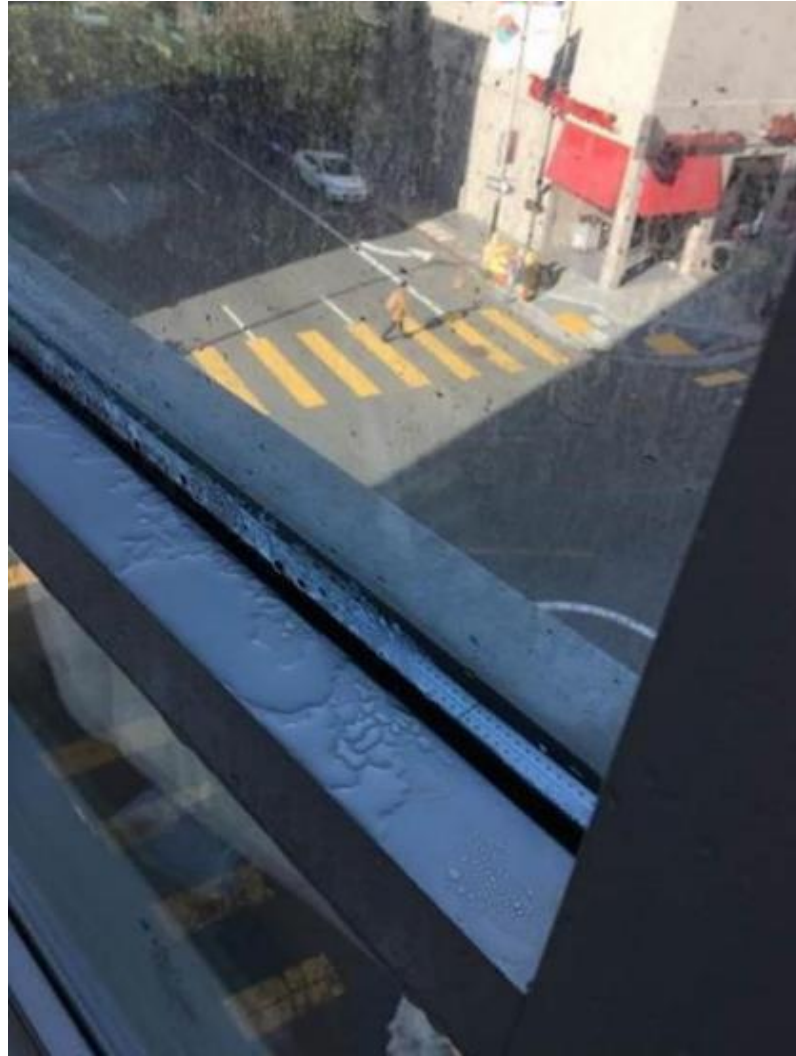


# Air Infiltration Can Cause

- Air Infiltration can lead to:
  - Energy loss
    - Creating an Air Tight Enclosure Makes all the Difference
    - ASHRAE 90.1 User Manual
      - “Controlling infiltration is important to achieving energy- efficient building.”
      - Air infiltration creates additional loading on the mechanical system
      - Newer Codes (2009 IBC) will require Air Barriers and on-site testing
  - Condensation
    - Commonly mistaken for water intrusion

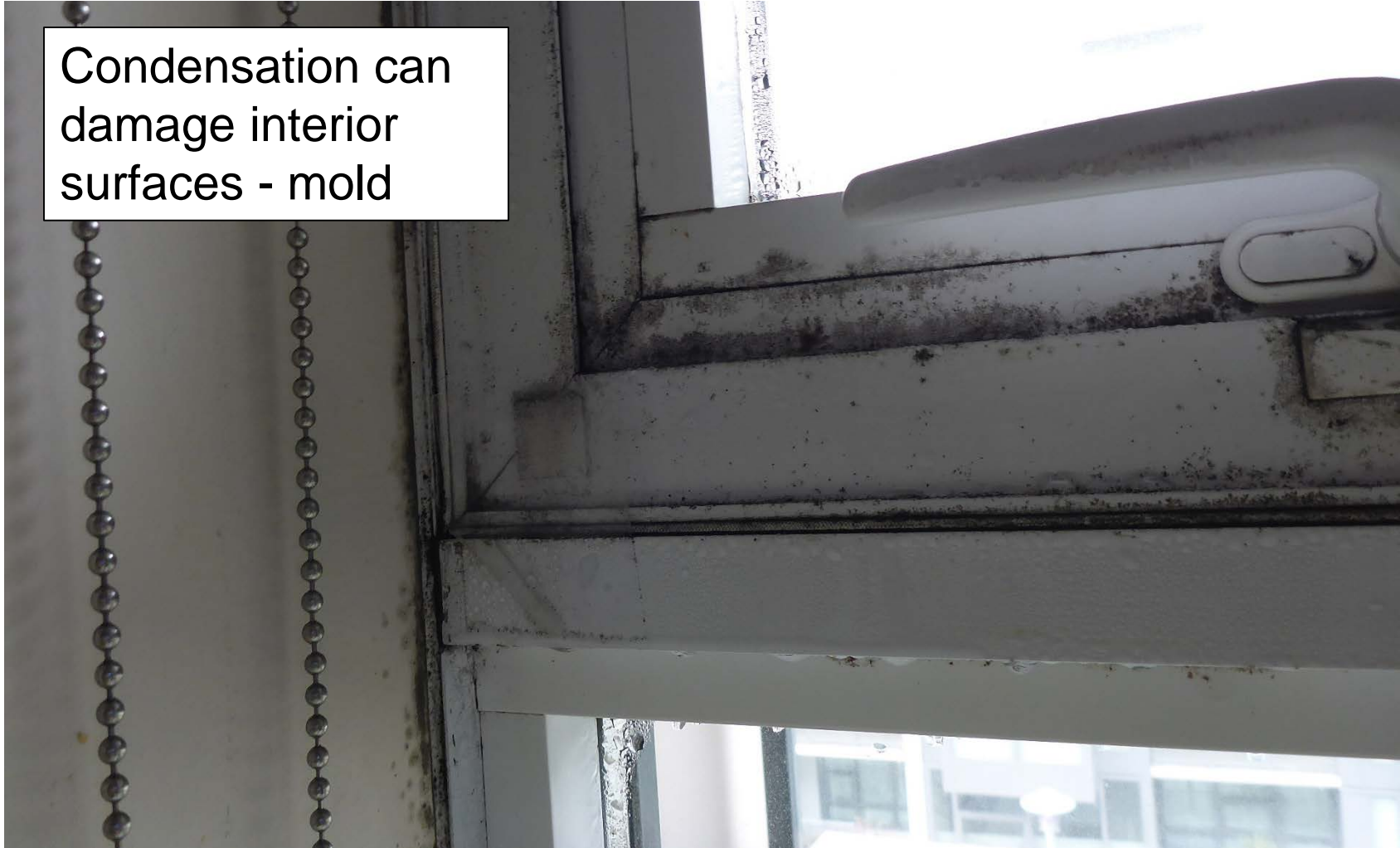


# Condensation Due to Gasket Shrinkage

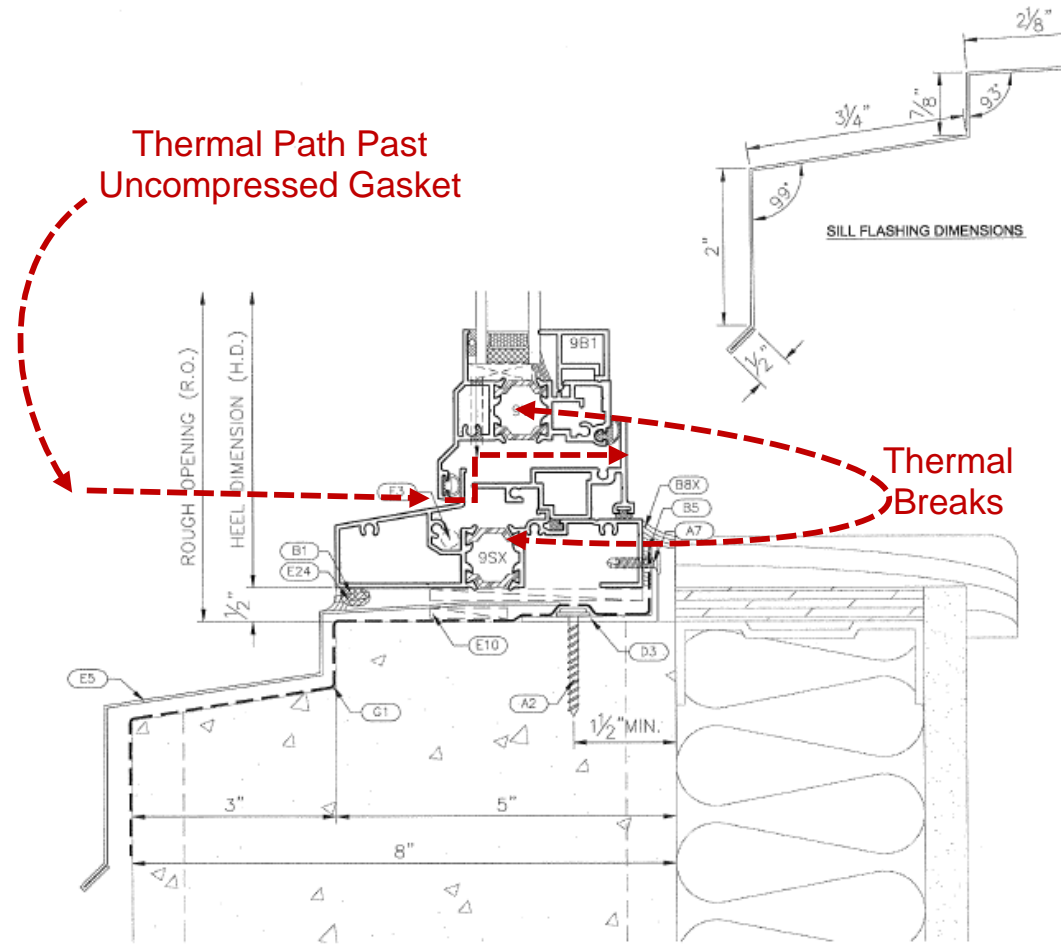


# Condensation Due to Gasket Shrinkage

Condensation can  
damage interior  
surfaces - mold



# How Condensation Can Occur



Thermal  
Path



# Avoiding Gasket Failure

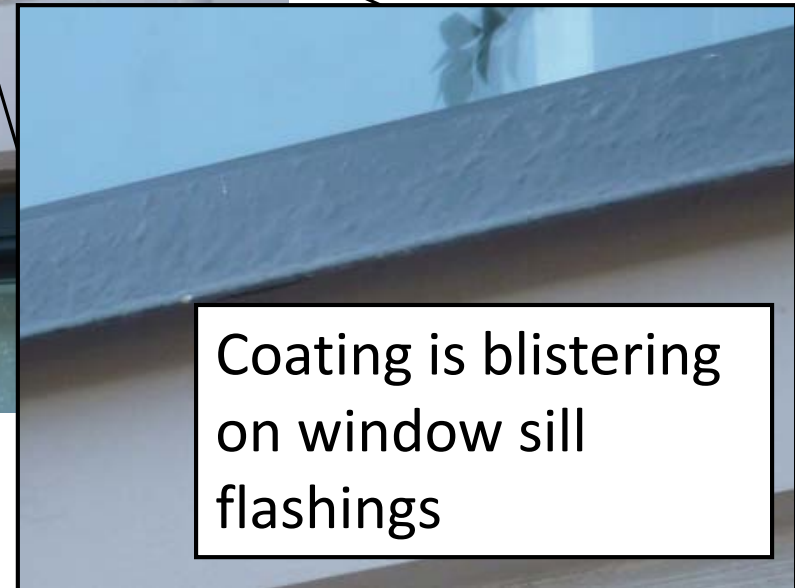
- Specifying high quality gasketing materials
- Quality control testing/commissioning to check for specified materials
- Using wet seals on inside in conjunction with gaskets



# **Aluminum Coating Failure**



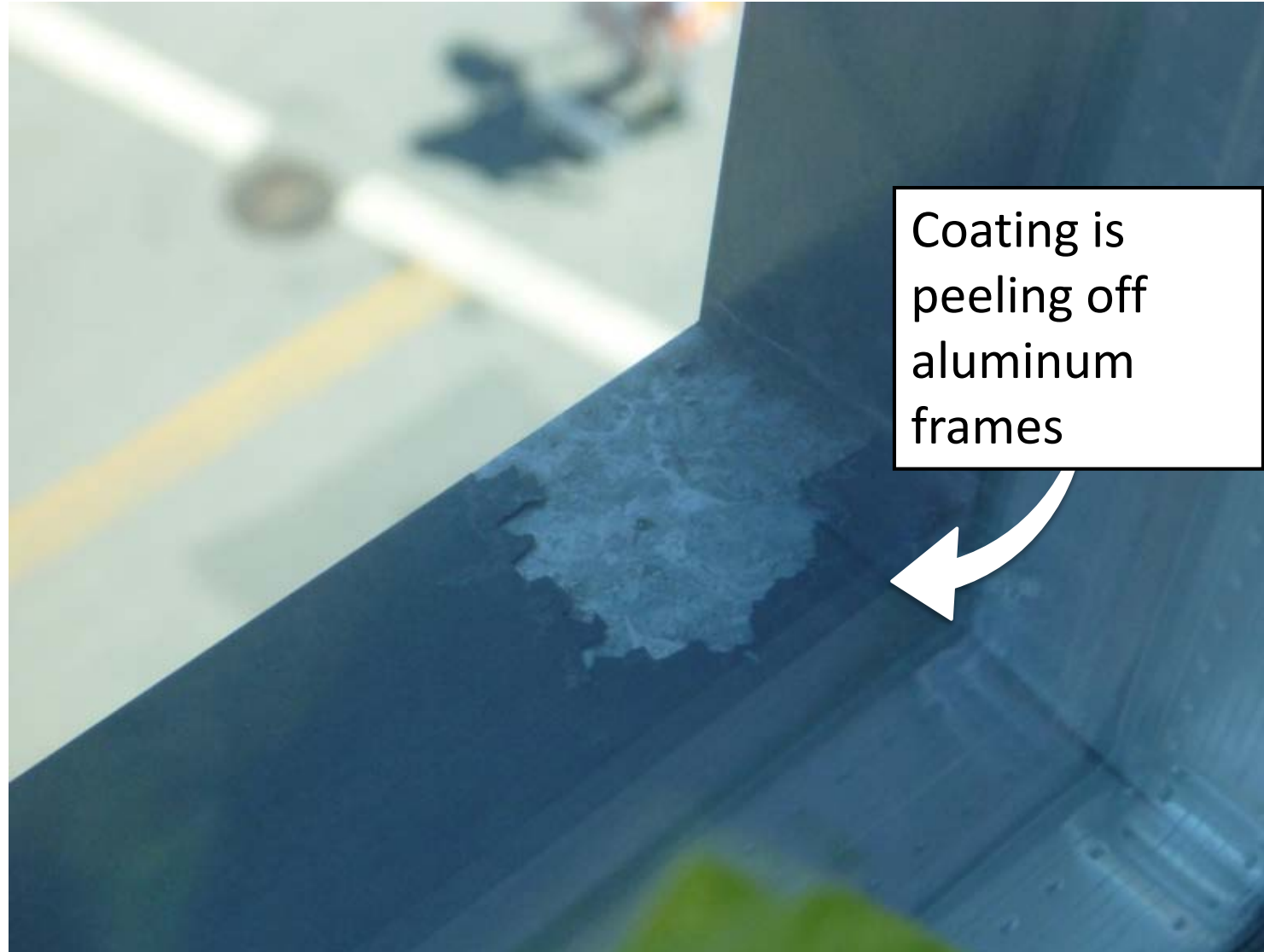
# Aluminum Coating Failure



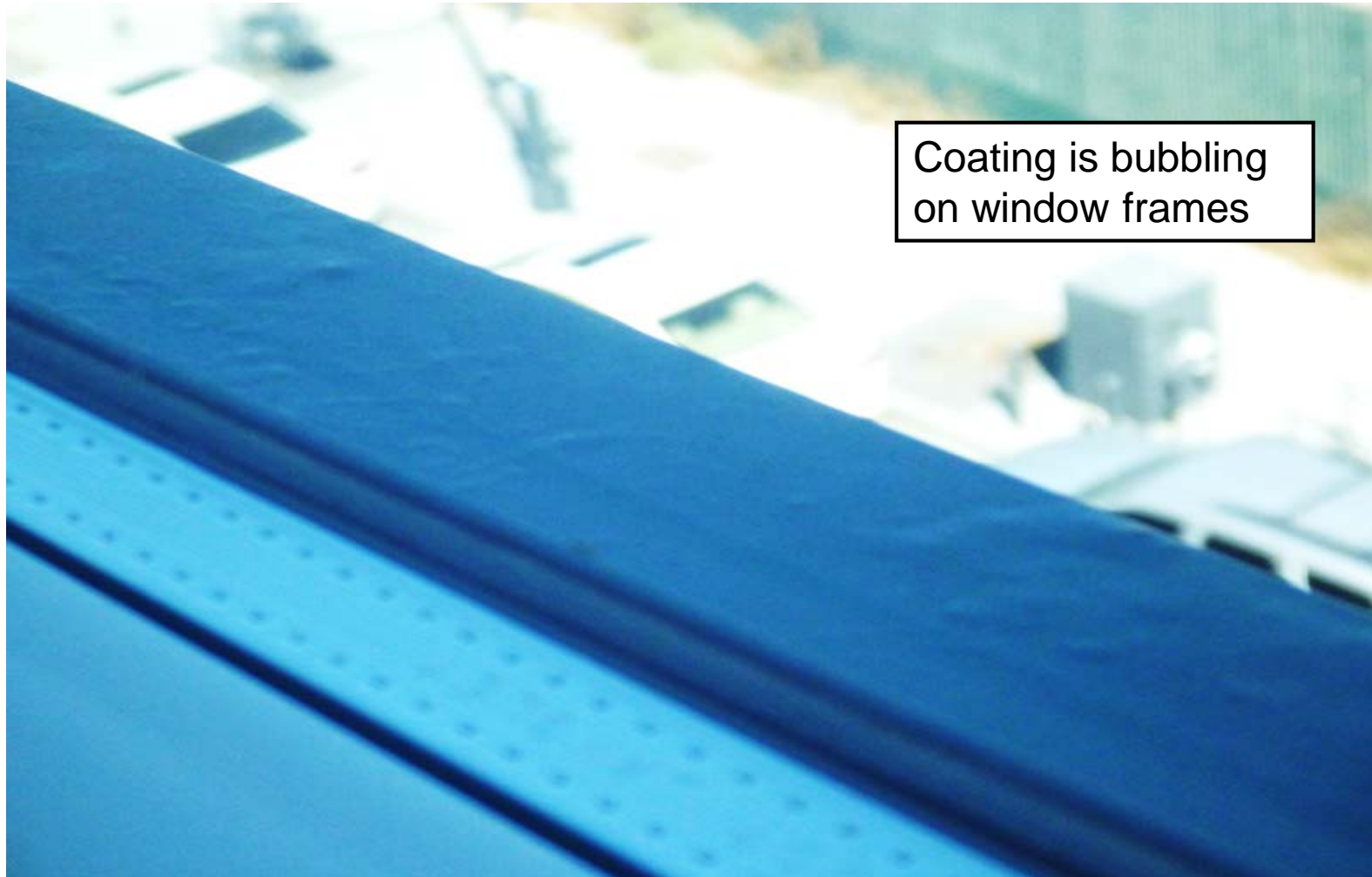
Coating is blistering  
on window sill  
flashings



# Aluminum Coating Failure



# San Francisco Condo #1



Coating is bubbling  
on window frames



# San Francisco Condo #1

Coating is bubbling  
on window sill  
flashings



# San Francisco Condo #2



# San Francisco Condo #2



# San Francisco Condo #2



# Coating Failure Causing Pitting



# Aluminum Coating Failure Causes

- Proper surface preparation and pre-treatments are not followed
  - Missing primer
- Coating requirements are not followed
  - Improper thickness of coating
- Lack of surface prep – leading to trapped contaminants



# Aluminum Coating Failure Prevention

- Proper preparation and coating requirements must be followed
  - Surface preparation, coating thickness requirements
- Use of Fluoropolymer finishes that meet AAMA 2605 certification
- Reviewing coating submittals
- Performing factory visits and verification
- Obtaining samples from factory runs and send for independent testing



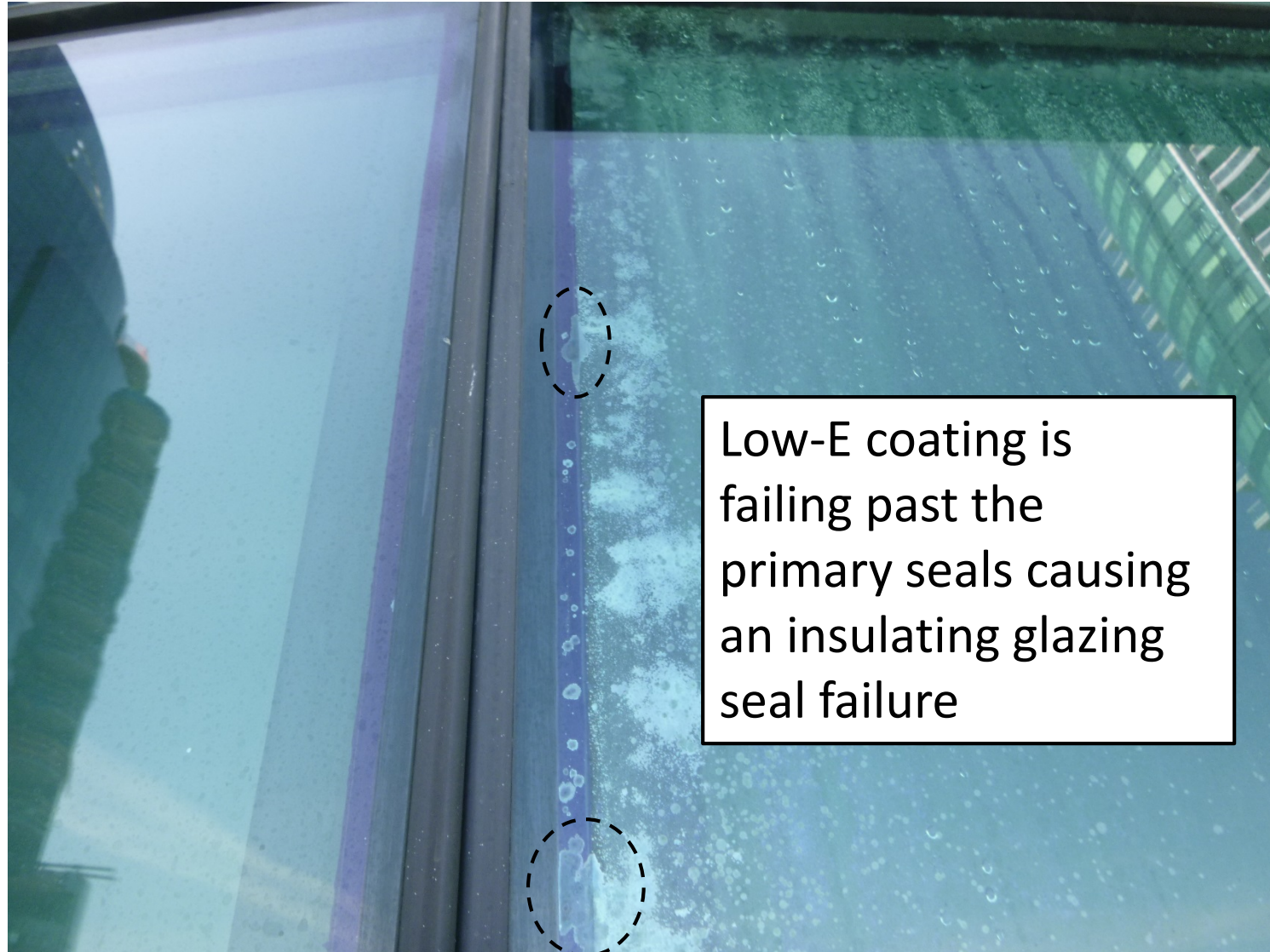
# **Corrosion of Glass**



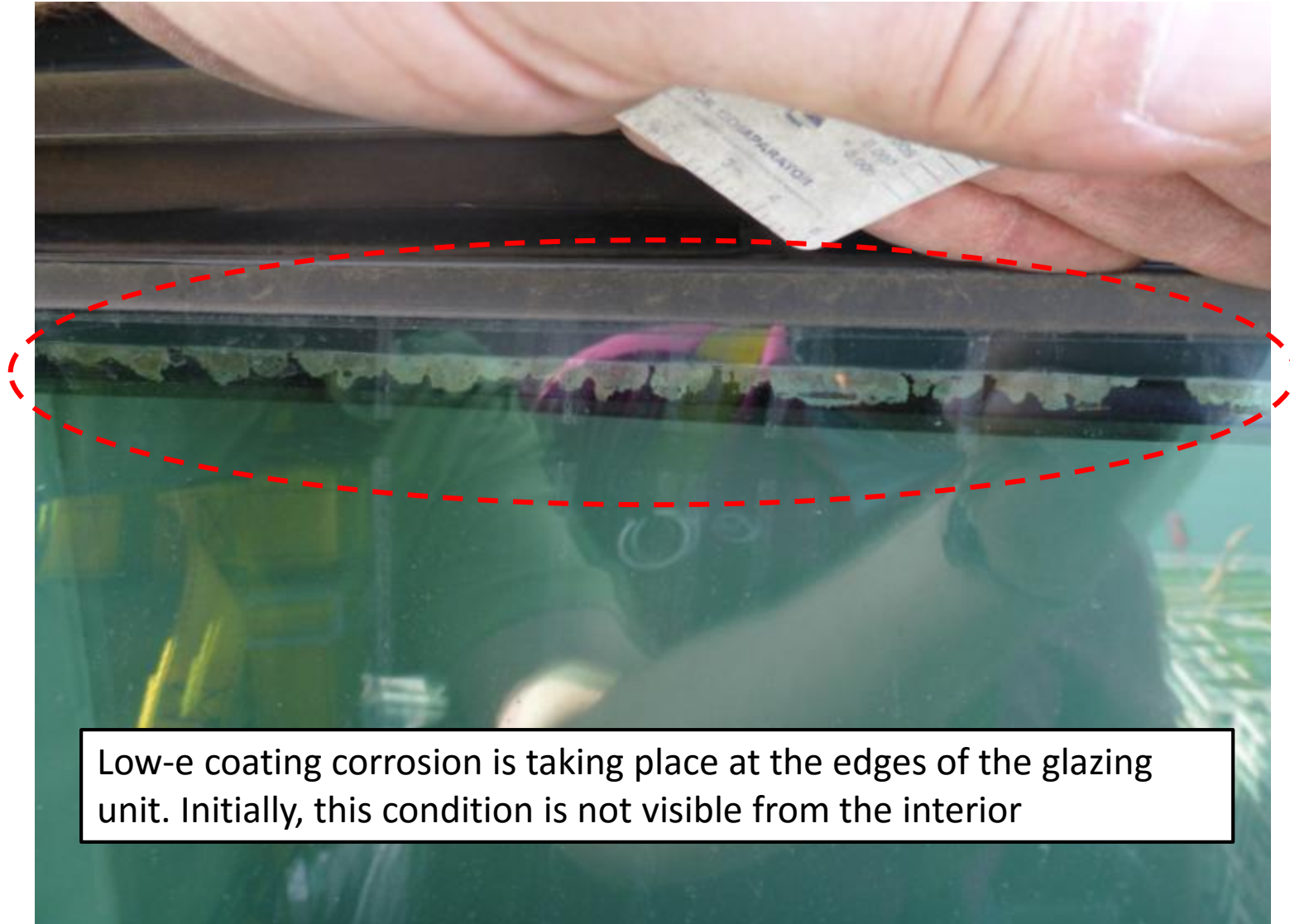
# Corrosion/Tarnishing of Silver Coatings



# Tarnishing of Low-E Silver Coatings



# Start of Low-E Coating Corrosion



Low-e coating corrosion is taking place at the edges of the glazing unit. Initially, this condition is not visible from the interior



# Continuing Low-E Coating Corrosion



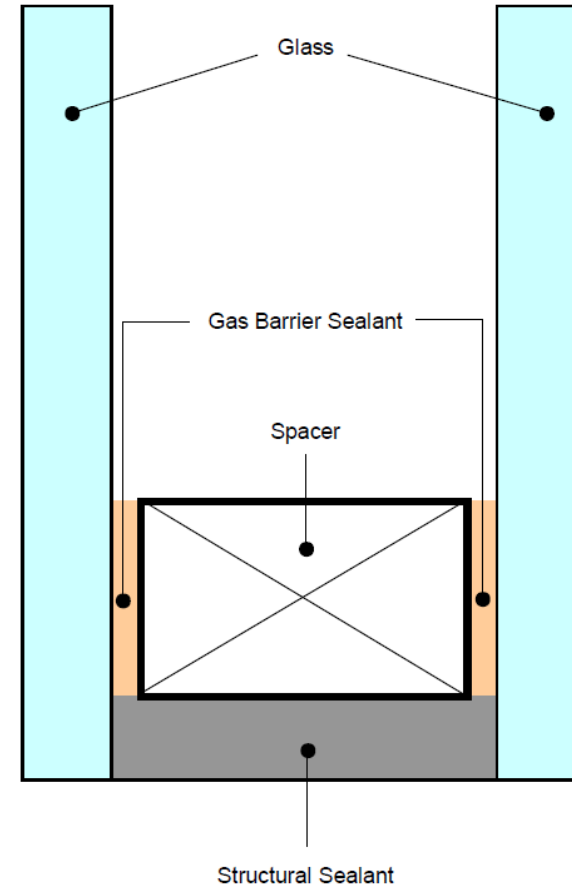
# Causes of Corrosion

- Edge Deletion Failure
  - Leads to IGU glazing failure
- Standing water on top of silicone sealant



# What is an Insulating Glass Unit?

- Insulating Glass Units are sealed with PIB and Silicone combinations of 2 or more lites of glass separated by a dry air space

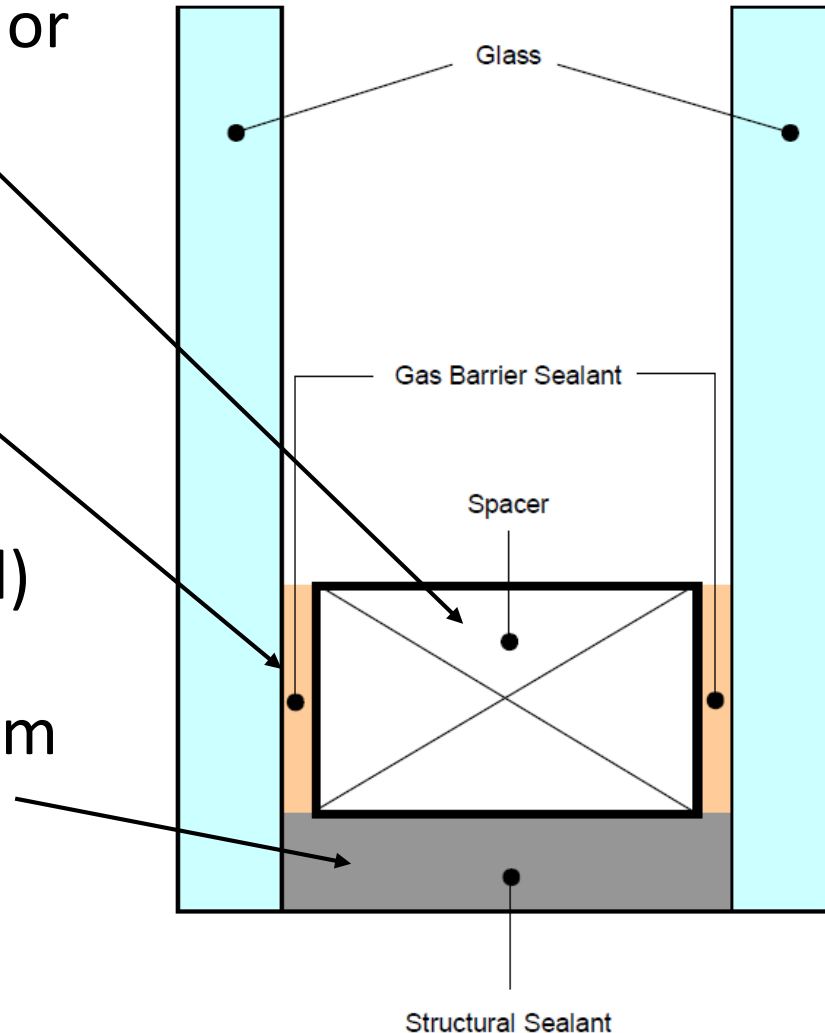


# How Are Dual Glazing Units Sealed?

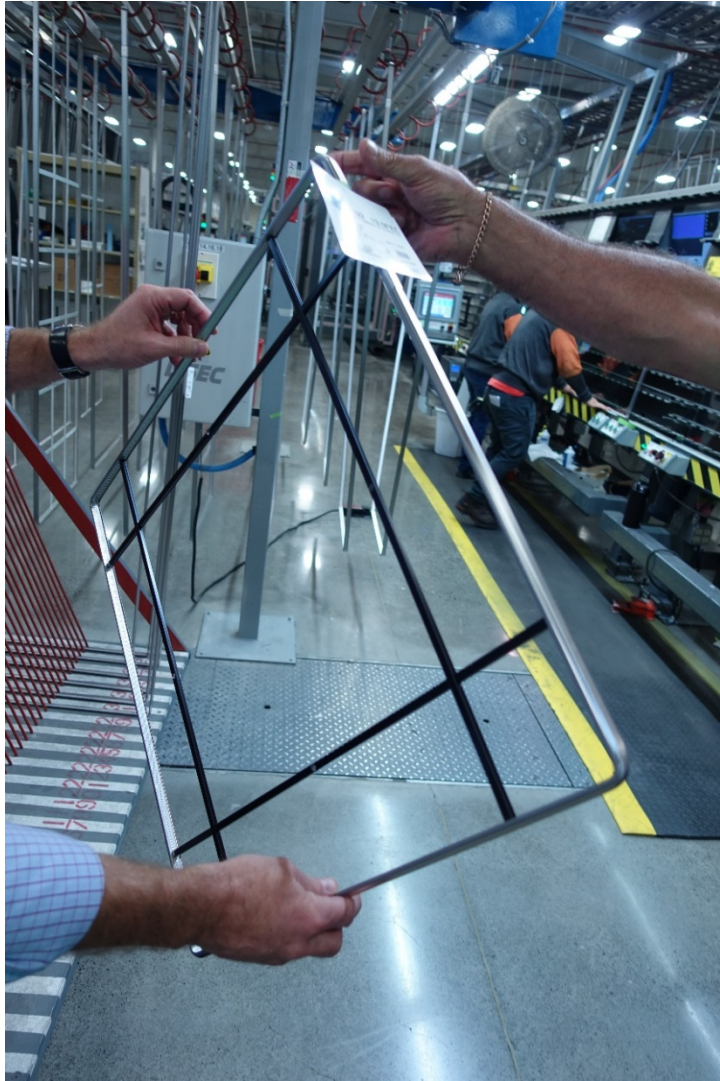
Spacer, usually aluminum or stainless steel

Primary Seal (PIB)  
impermeable to moisture  
diffusion.

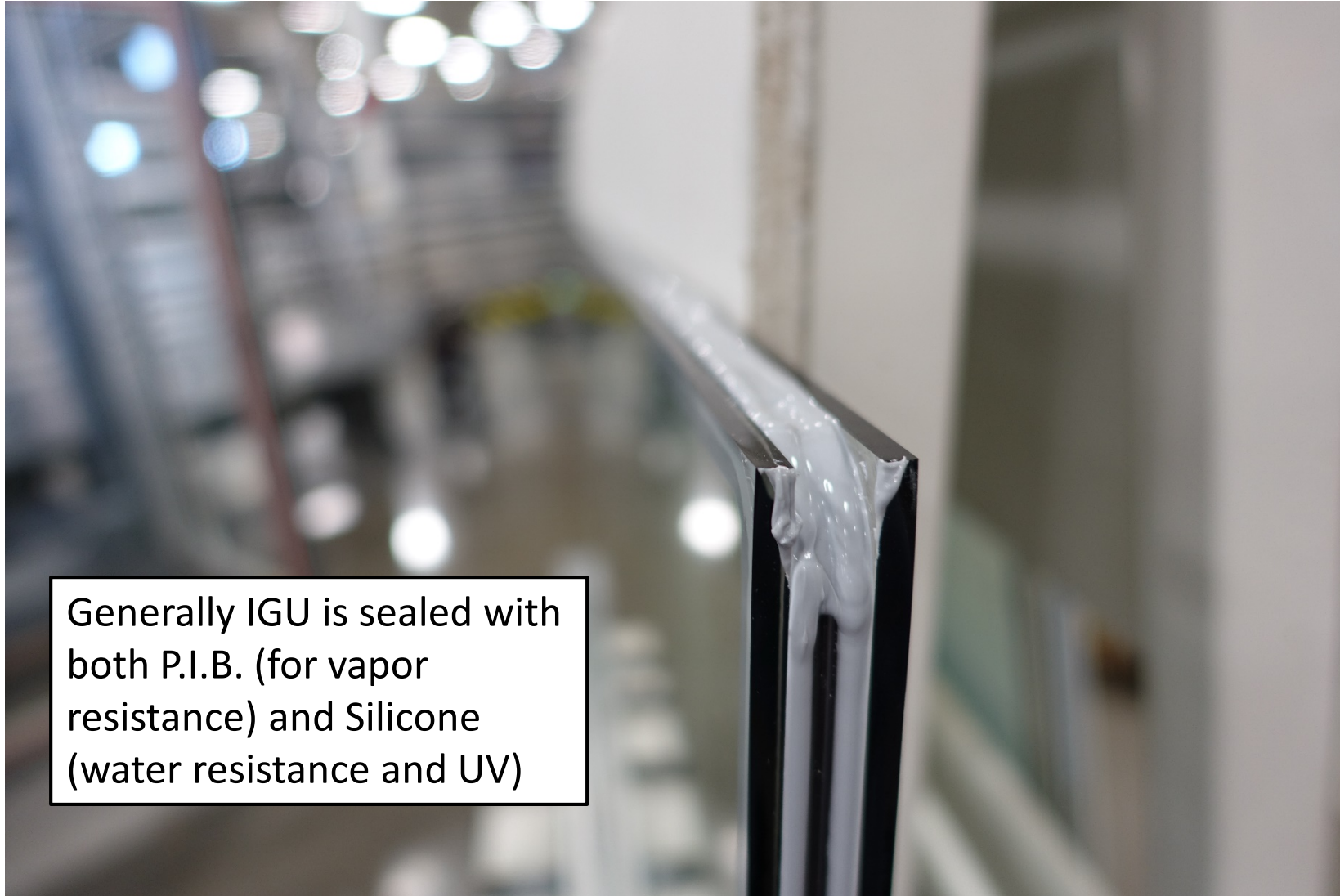
Secondary Seal (structural)  
and selected to hold unit  
together through long-term  
weathering (UV) and  
prevent water infiltration



# IGU Seals, Stainless Spacers Last Longer



# IGU Units Sealed With Dual Sealants

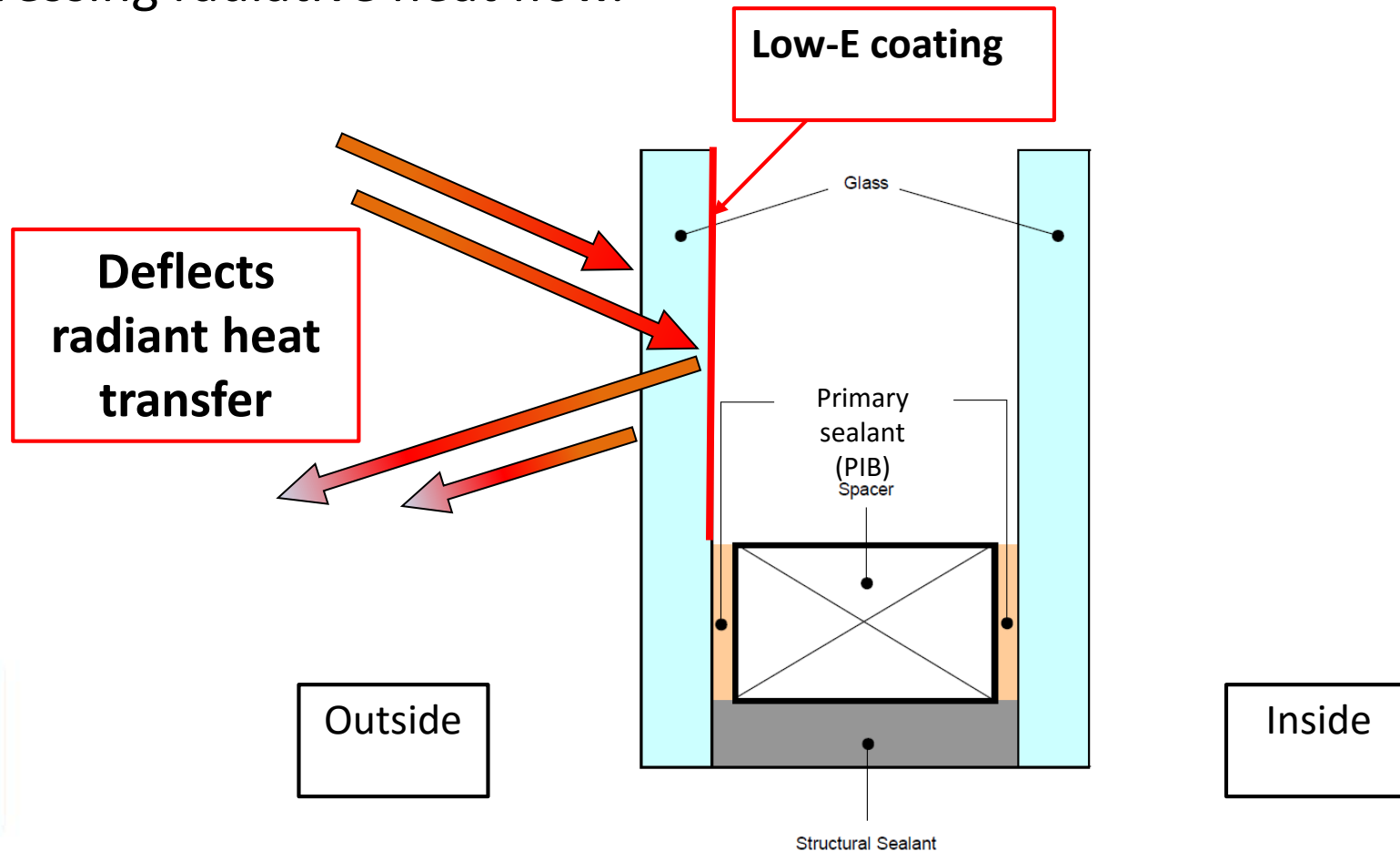


Generally IGU is sealed with both P.I.B. (for vapor resistance) and Silicone (water resistance and UV)



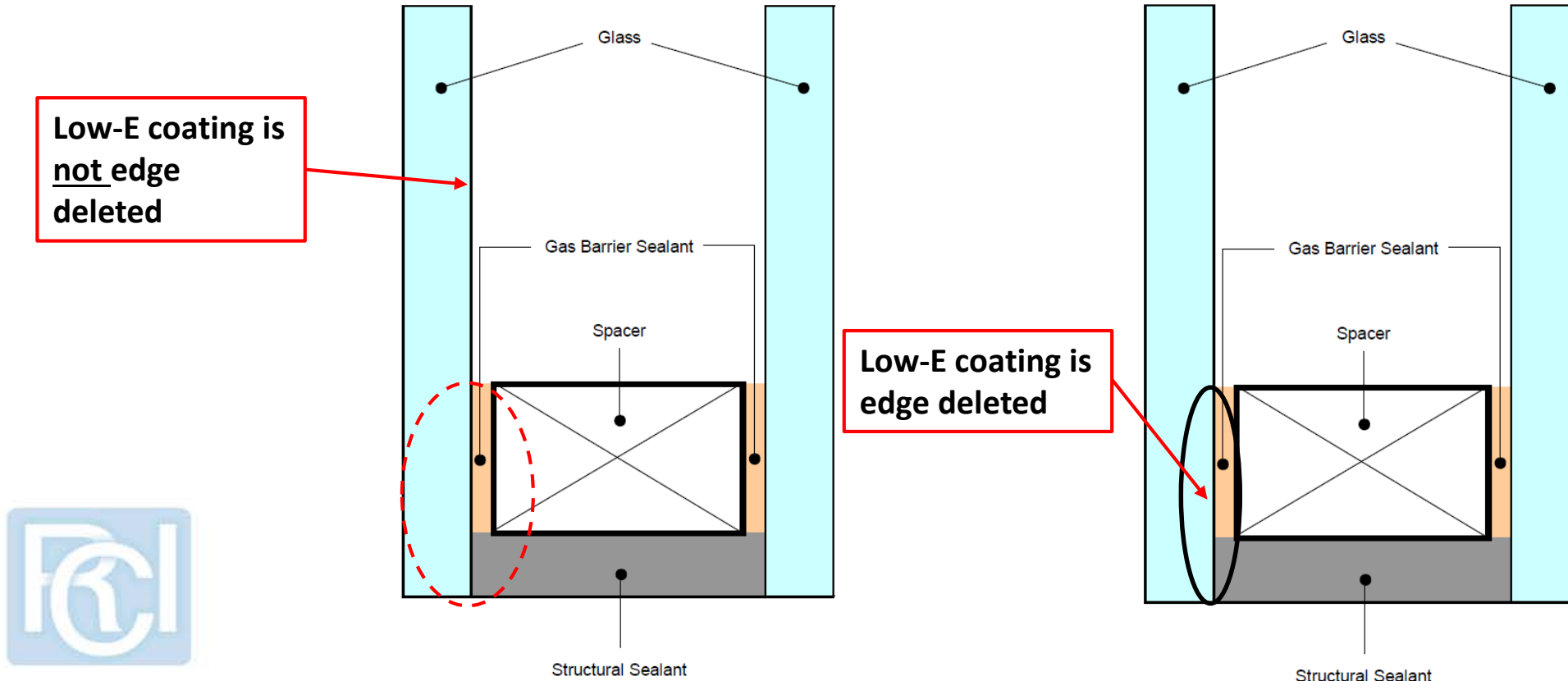
# Low-E Coating: What is it?

- Microscopically thin and virtually invisible metal or metallic oxide layers (silver) deposited on the glass to reduce the U-factor and (SHGC) Solar heat gain by suppressing radiative heat flow.



# What Edge Deletion?

- Low-E coating needs to be edge deleted. If not edge deleted, the exposed edge could start corrosion and spread to inside
- Once corrosion starts, it breaks down the seals causing overall unit failure



# Edge Deletion During Manufacturing



# Case Study – SF Condo



# Replacing Glass, Slow and Tedious



2 guys on window  
washing rigs

3 guys on the inside  
handling glass



# Replacing Glass, Slow and Tedious

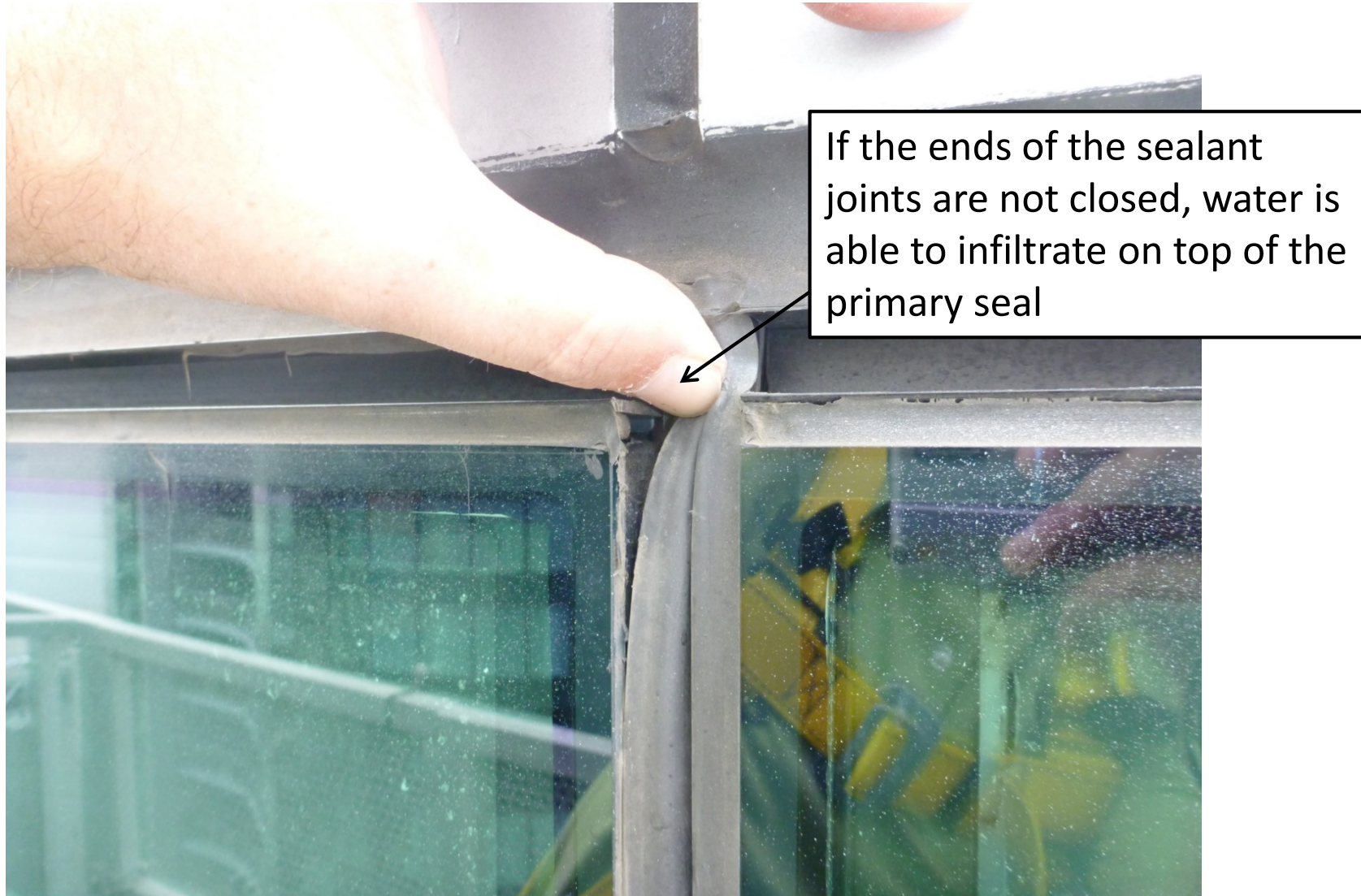


Removed glass  
from site

Labeled and crated,  
shipped to lab



# Water Infiltration at Head Stands on IGU Seal



# Laboratory Conclusion of Failure

All IG units have low-E deleted only about 3/8" but the total bond line of the PIB and silicone is about 5/8" to 3/4"

February 21, 2017  
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All IG units have the low-E edge deleted about 3/8", but the total bond-line of the PIB and silicone is about 5/8" - 3/4".

Evaluation of the PIB and silicone seals does not indicate any compatibility issues. The PIB shows excellent chemical distribution when thermally analyzed by Thermo-Gravimetric Analysis (TGA) and compared to a stock PIB (see attached plot).

Energy dispersive X-ray spectroscopy (EDX) of the edge-delete (Table A), low-E coating under the PIB (Table B), and discolored low-E revealed that there was no corrosive materials such as chlorine, phosphorus, or sulfur in contact with any surfaces. There is evidence however, that the edge delete was not complete and left some residual low-E coating under the silicone secondary seal.

Table A

Element	Weight %
Carbon	8.90
Oxygen	32.78
Magnesium	1.33
Silicone	23.12
Calcium	3.55
Titanium	0.25
Zinc	20.63
Silver	4.28
Tin	5.13

Table B

Element	Weight %
Carbon	3.97
Sodium	8.68
Oxygen	32.38
Magnesium	1.29
Silicone	23.84
Calcium	4.78
Titanium	0.87
Iron	0.25
Zinc	13.53
Silver	6.04
Tin	4.09

## DISCUSSION

Failure is most likely the result of extended water contact due to the flexible vertical tubing retaining water, which allowed water to migrate along the tops of the IG units. It appears there is installation issues with the lack of vertical tube drainage as well as IG manufacture by not edge-deleting properly. The PIB is of good quality and could have resisted water penetration if it were not adhered to the low-E which is attacked by the water contact, resulting in bond/seal loss.

Overall IG workmanship and material skills are satisfactory with the exception of the edge-deletion.

DALLAS LABORATORIES, INC.

  
Kevin W. Jones, Vice President

Analyst: KJ, GF, SL  
KWJ: js



Overall IG workmanship and material skills are satisfactory with the exception of the edge deletion

# Prevention

- Proper edge deletion needs to occur during the manufacturing process to ensure proper bonding of the IGU sealants
- Design of the glazing and curtain wall assembly should not allow water to stand on top of the silicone sealant because, silicone is permeable
- Design installation of glass should be on blocks and properly drained to prevent dual glazing to sit in water

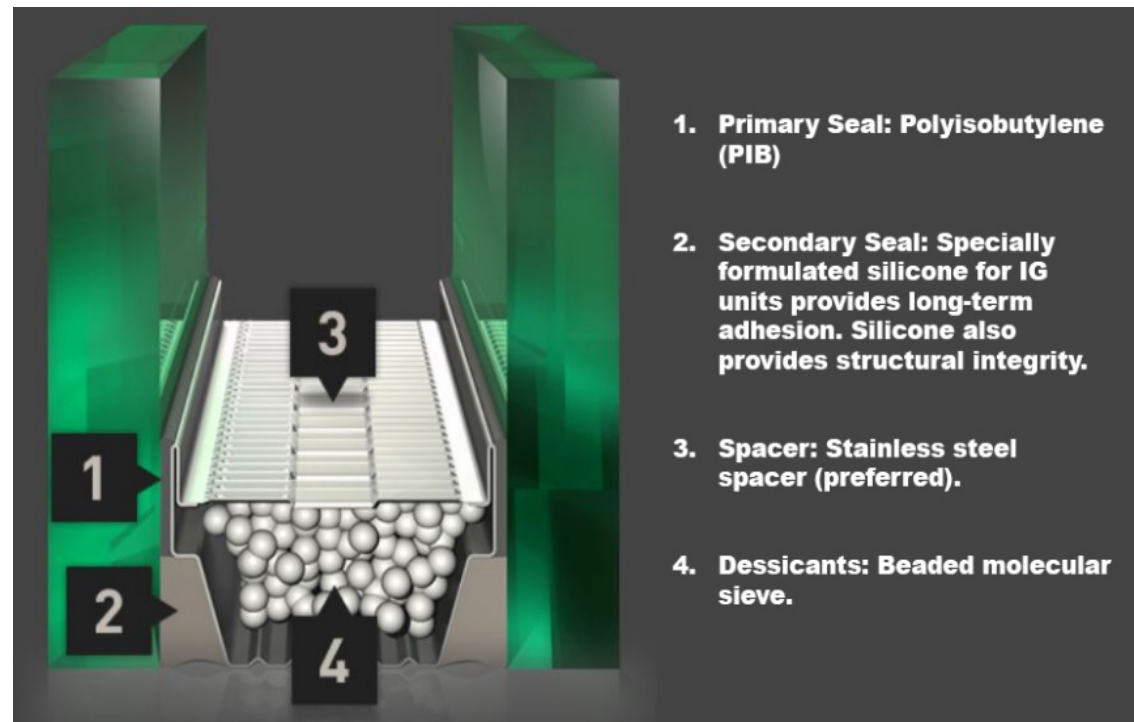


# **Polyisobutylene (PIB) Migration**



# PIB Migration

- PIB (primary) and secondary sealants prevent air/ water infiltration in IGU airspace
- PIB moves from window edge, obscuring vision



# PIB Migration/Failure in IGU



# PIB Migration, Moving/Walking Up



# PIB Migration



# Case Study- SF Condo w/ PIB Migration



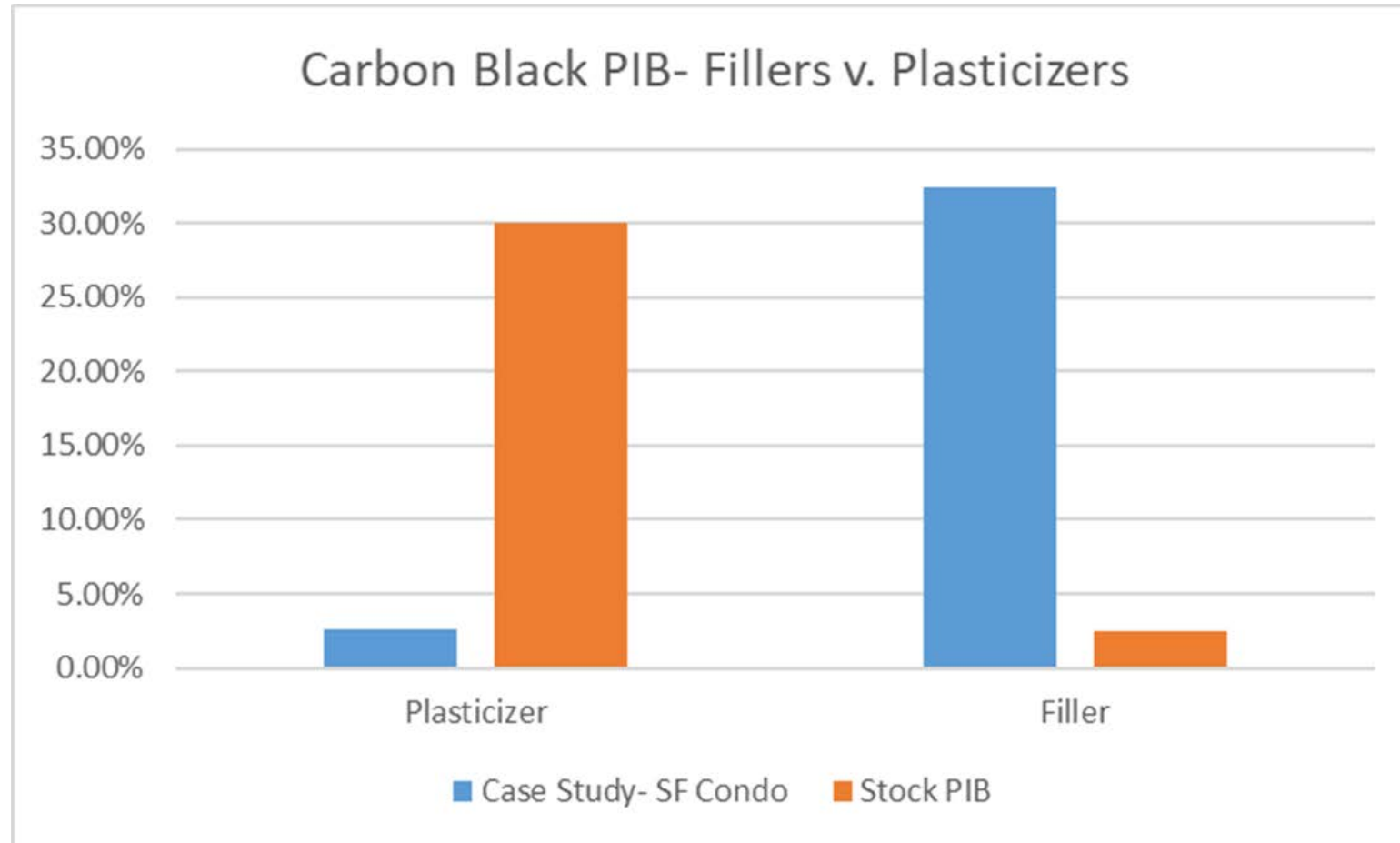
# Case Study- SF Condo w/ PIB Migration



# Case Study- SF Condo w/ PIB Migration



# Case Study- SF Condo w/ PIB Migration



# PIB Migration Mitigation

- Requires glazing replacement
- Limited to gray PIB
- Gray PIB contains 64.8% polymer with plasticizers as low as 2.6%
  - PIB control samples are 97.5% polymer and 30% plasticizer



# **Thermal Break Failure**



# SF Condo



# SF Condo



# SF Condo

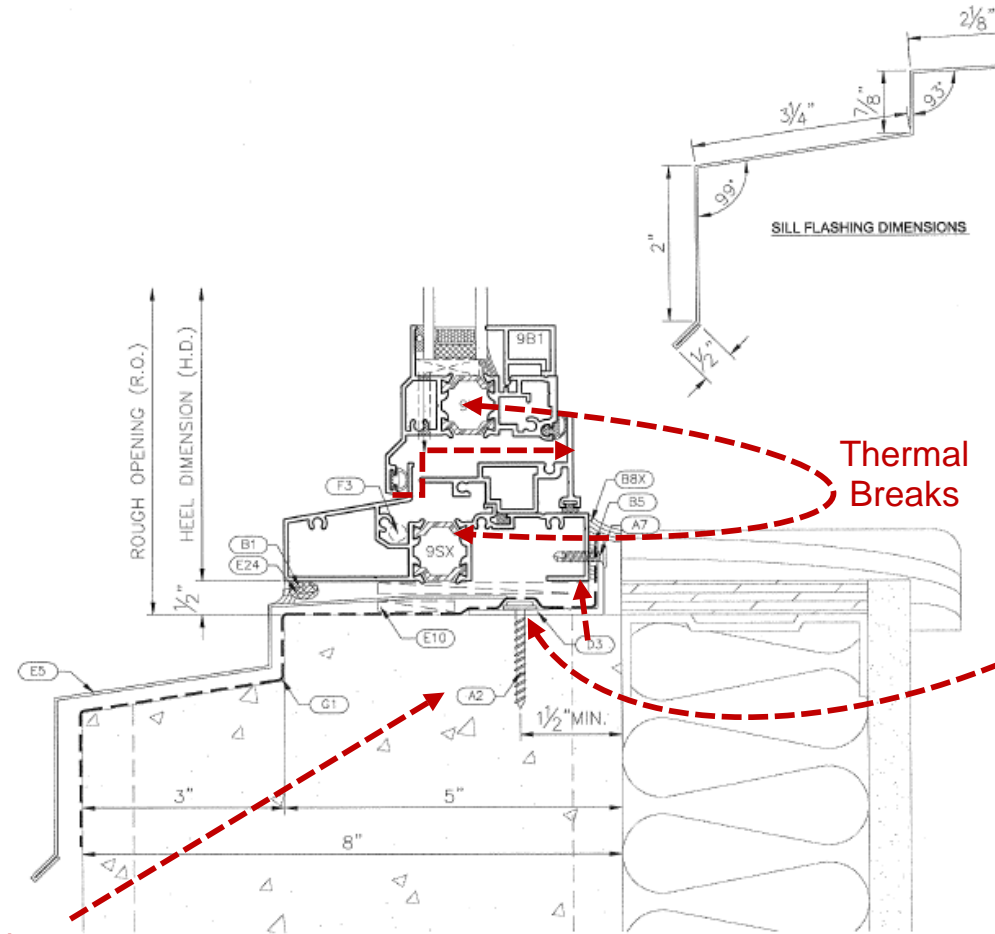


# Thermal Break Failure

- Can cause condensation on frame
- Aluminum frame in contact with concrete
- Occurs when thermal breaks are missing or bypassed



# How Condensation Can Occur

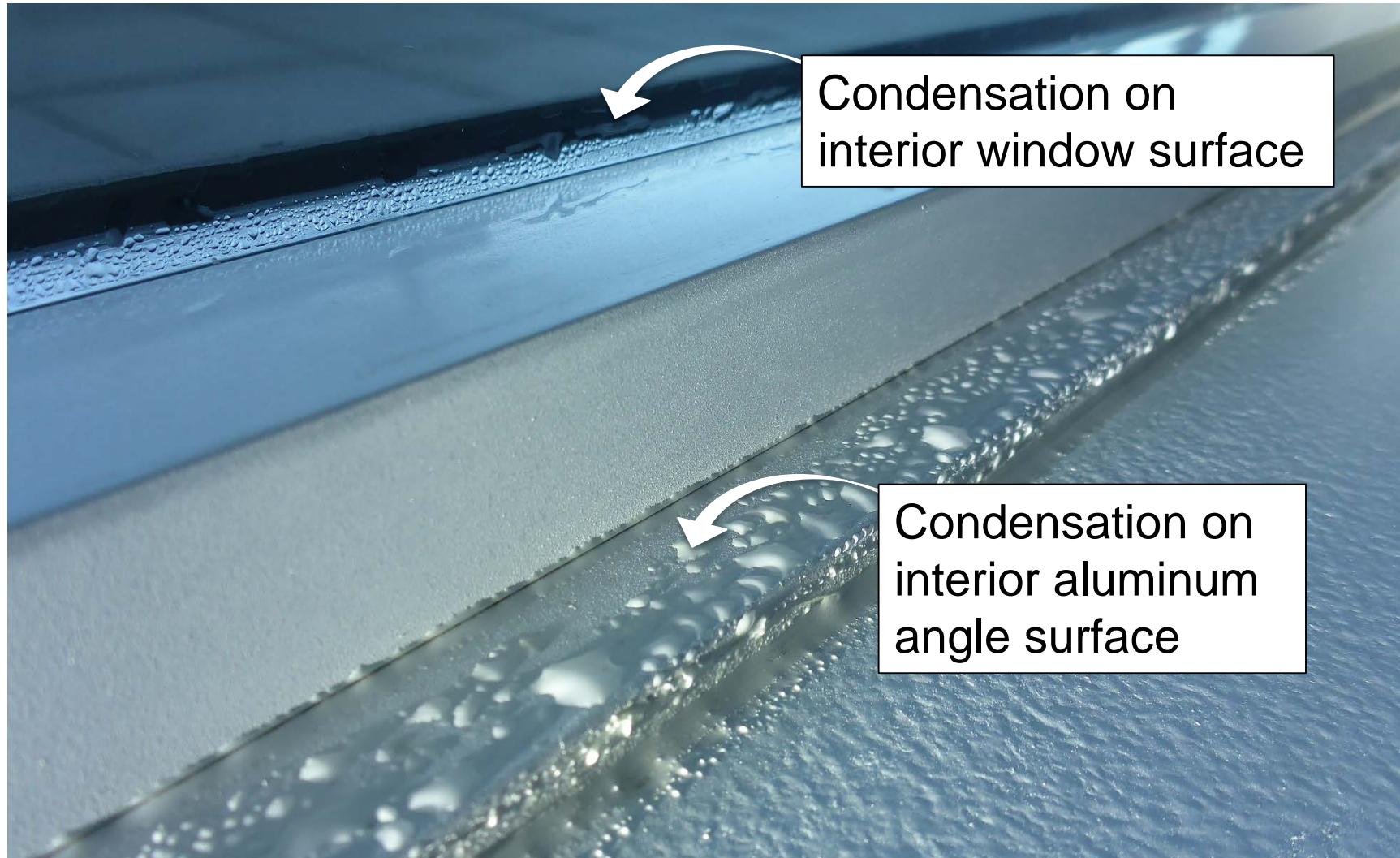


Aluminum back angle in contact with concrete; and in contact with back side of aluminum frame is a thermal bridge. Both the angle and frame are condensing

Thermal  
Path  
Through  
Concrete



# Condensation



# Thermal Break Failure-Condensation

- When the frame reaches dew point, water vapor condenses
- Condensation Resistance Factor (CRF) should match heat/humidity/building use requirements
- Modern curtain walls use thermal breaks prevent condensation



# Avoiding Condensation

- Window design should include thermally broken systems
- Design considerations include:
  - Carefully design thermal breaks in and around glazing elements and rough openings in walls
  - Hygrothermal modeling to determine CRF requirements
  - Avoiding thermal bridges in design
  - Descriptive and fully illustrated perimeter flashing conditions



# Lessons Learned

- Conscientious Design
  - Understanding modes of failures
  - Proper material selection of internal seals, water pathways and sealants is key
  - Specifying design issues like edge deletion, and "wet" pockets of glazing
  - Learn from new modes of failures
  - Quality control and commissioning to ensure performance
- Evaluation and Testing
  - For both new construction and remediation
  - Material testing of system sub-components such as coatings, seals, and construction



**The End**

