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, and Registered Waterproofing Consultant (RWC)
- **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.

ABBAE Firm Overview

- Allana Buick & Bers (ABBAE) is an Architectural Engineering firm specializing in Building Envelope Systems
- ABBAE is one of the 5 largest building envelope consultants in the country
- ABBAE has over 33 years of experience & over 12,500 projects
- ABBAE is also a leading Forensic Defect firm with hundreds of forensic projects (litigation)
- Locations – 16 offices across California, Nevada, North Carolina, Oklahoma, Oregon, Texas, Virginia, Washington, Colorado

Staff & In-House Expertise

- Licensed Professional Engineers – Civil, Structural, and Mechanical
- Registered Architects
- Building Enclosure Commissioning Process Providers (BECxPs)
- Registered Building Envelope Consultant (RBEC)
- Registered Roofing Consultants (RRCs)
- Registered Waterproofing Consultants (RWCs)
- Registered Exterior Wall Consultant (REWCs)
- Registered Roof Observers (RROs)
- Certified Exterior Insulation and Finish System (EIFS) inspectors
- Curtain Wall Specialists
- ICC Certified Building Inspectors
- Quality Assurance Monitors
- Water Testing Experts
- Leak Investigation and Diagnosis Experts
- Infrared Imaging and Nuclear Moisture Scanning Experts

ABBAE Building Expertise

- Building Envelope Systems
  - Roofing Systems
    - High-Slope/Low-Slope Roofs
    - Green/Garden Roofs
    - Drainage Systems
    - Pedestrian Plazas
  - Exterior Wall Systems
    - Wall Cladding/Siding/GFRC/pre-cast
    - EIFS/cement plaster/stucco
    - Sheet Metal Flashings
  - Windows and Glazing Systems
    - Punched Windows
    - Curtain Wall/Window Wall Systems
    - Sliding Glass Doors
    - Skylights

- Building Envelope Systems (cont'd)
  - Roofing & Waterproofing Systems
    - Deck/Balcony/Lanai Waterproofing
    - Podium Waterproofing
    - Pool/Spa Deck Waterproofing
    - Above-Grade/Below-Grade Waterproofing
    - All types of low and steep sloped roofing
  - Commissioning BECx
    - OPR/BOD/Commissioning Plan
- Mechanical/HVAC Systems
  - HVAC design
  - Plumbing systems
  - Commissioning and testing

ABBAE Core Services

- Consulting and third-party peer review services
- Engineer of record for building envelope systems
- Contract administration services
- Inspection services (usually direct with owner)
- Air and water performance testing
- Mock-up design, observation, and testing
- Building assessments and forensic investigations
- Litigation support and expert witness services
- Educational seminars with AIA credits

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 that 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

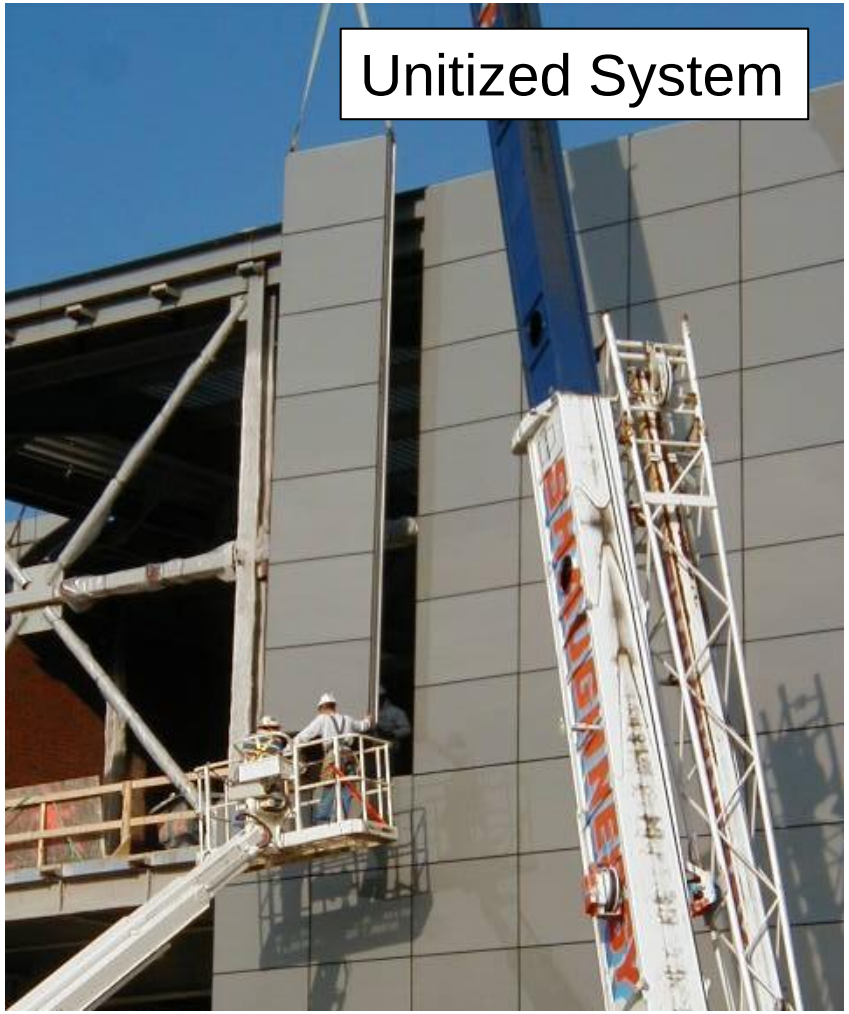
The Hallidie Building, SF

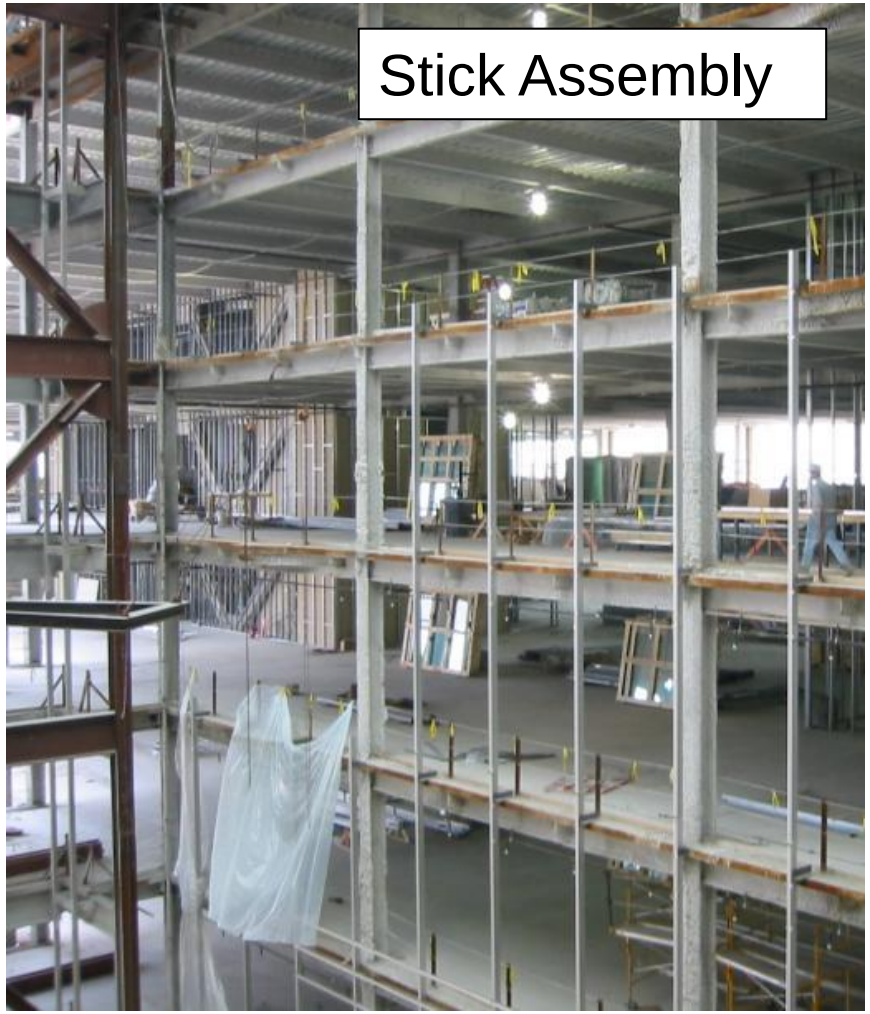
One of the Oldest Glass Curtain Walls (1918)

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





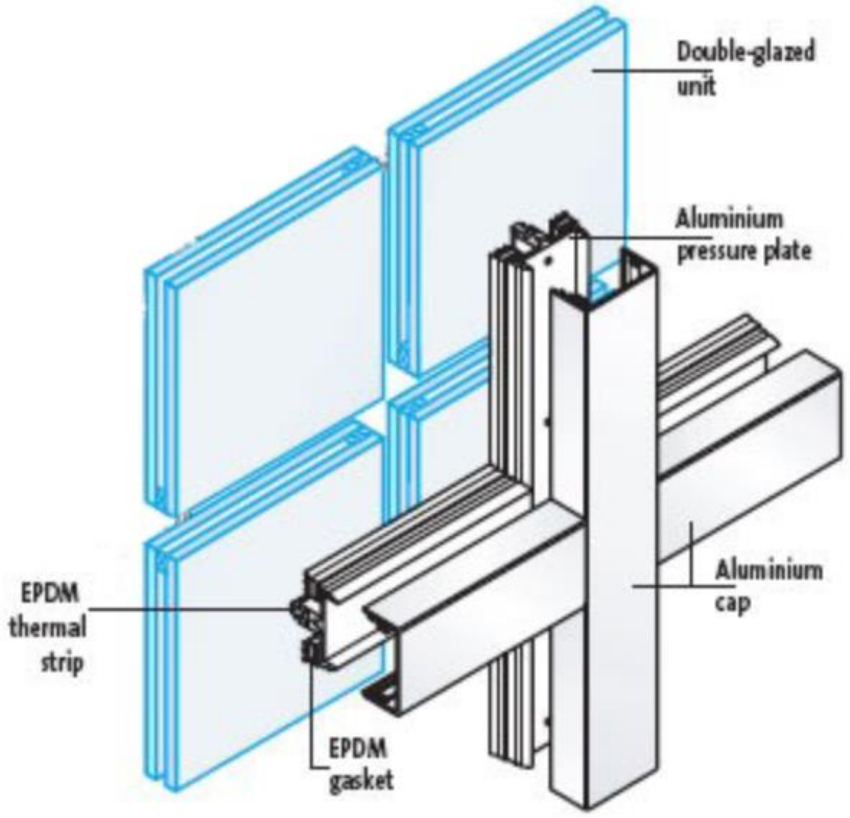
Common Modes of Failure

- 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

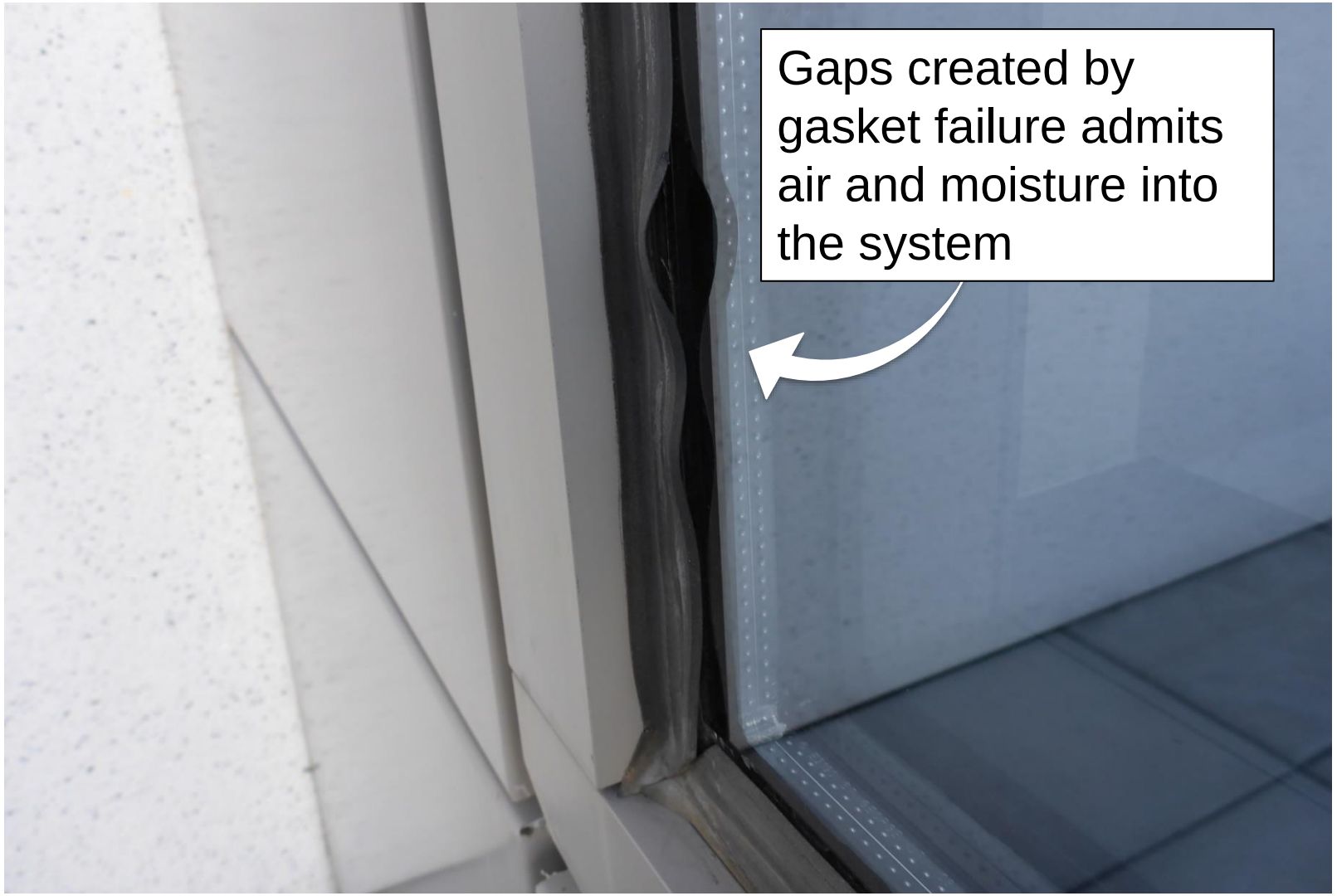


Gasket Failures

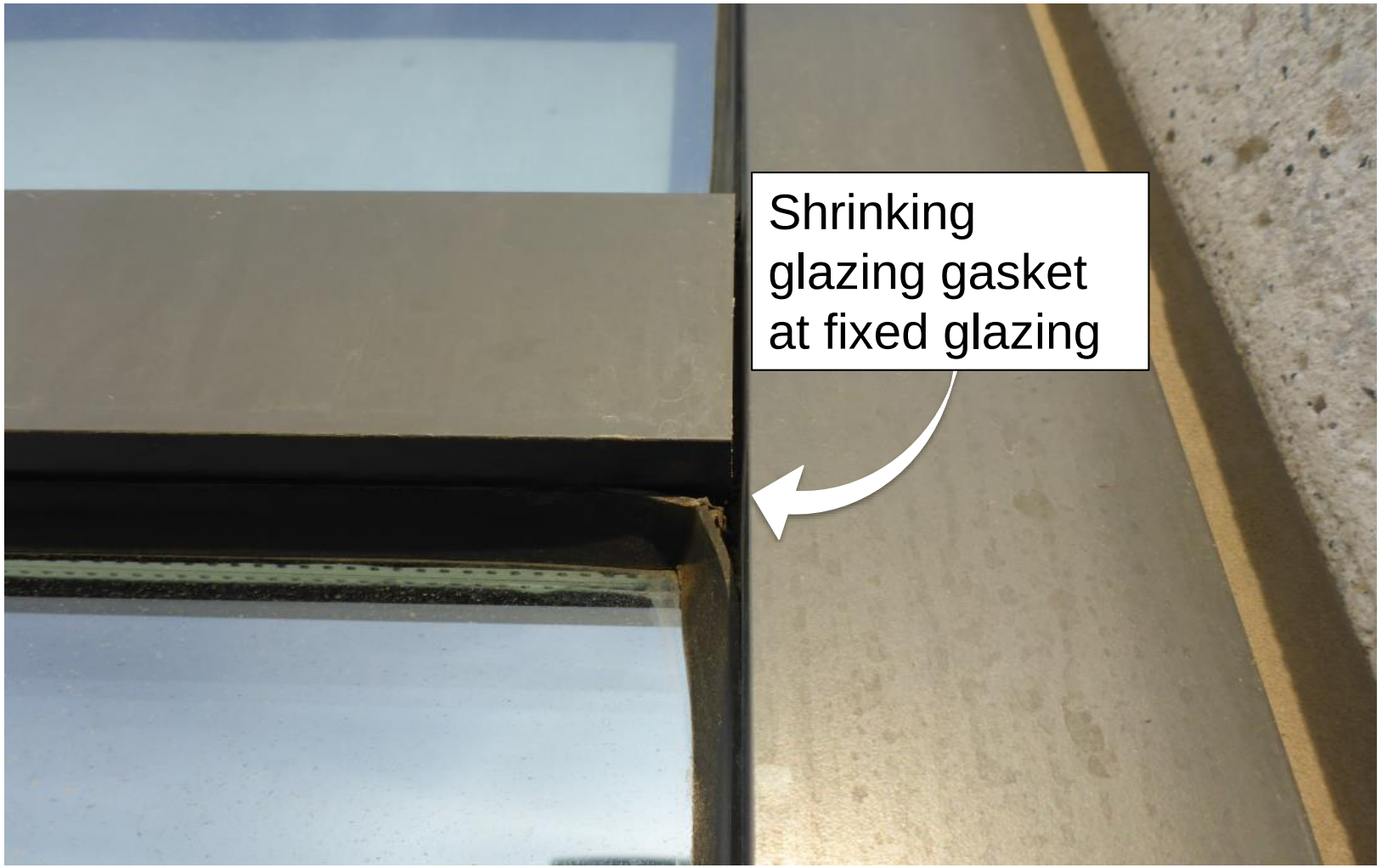
- Drying out, shrinking and cracking
- Exposure to UV radiation
- Exposure to freeze-thaw cycles
- Improper maintenance

Mondavi Gasket Shrinkage / Failure

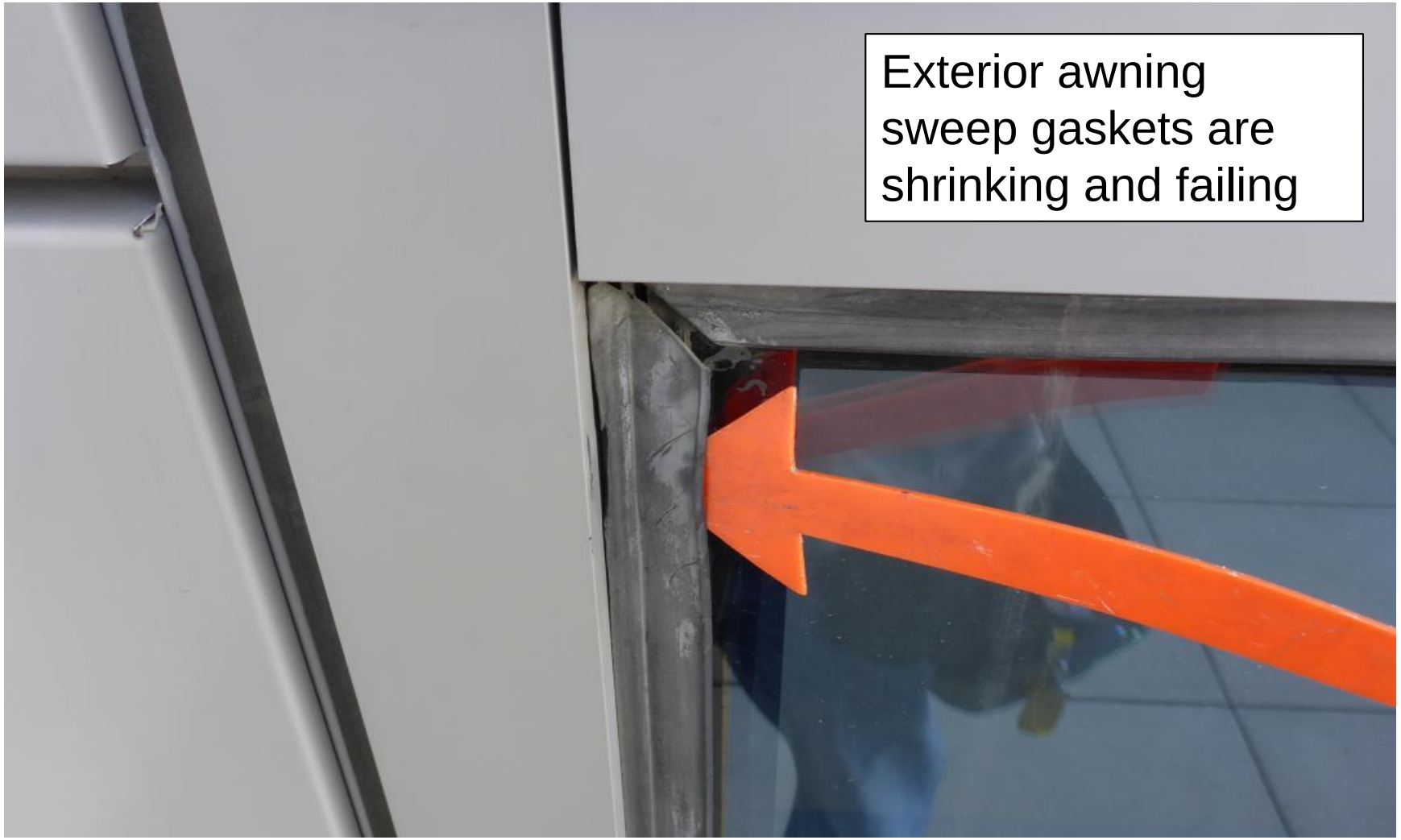
Gasket Failure



Gasket Failure - San Jose Condo



Gasket Failure - San Jose Condo



Gasket Failure- San Jose Condo

Gasket Failure- San Jose Condo

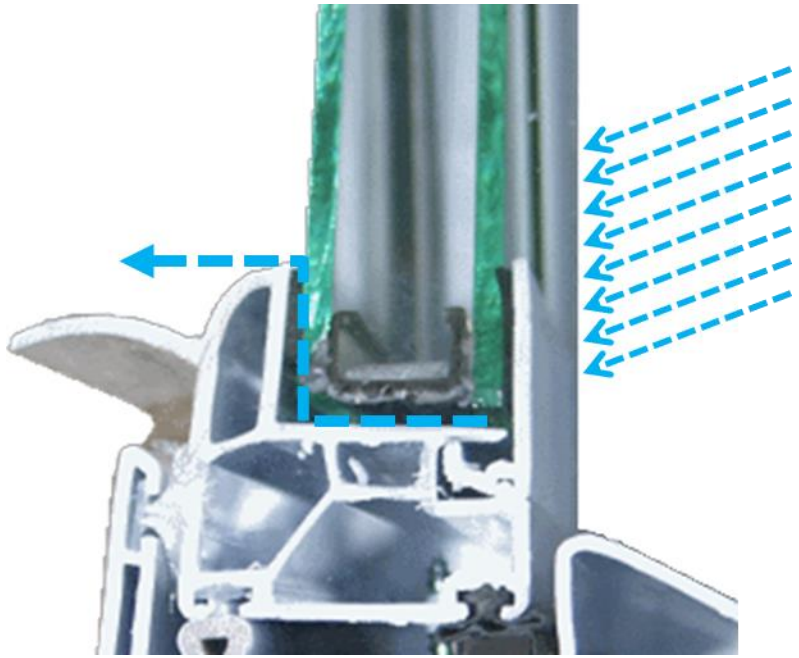
Gasket Failure- SM College Library

Gasket Failure- Causing Leaks

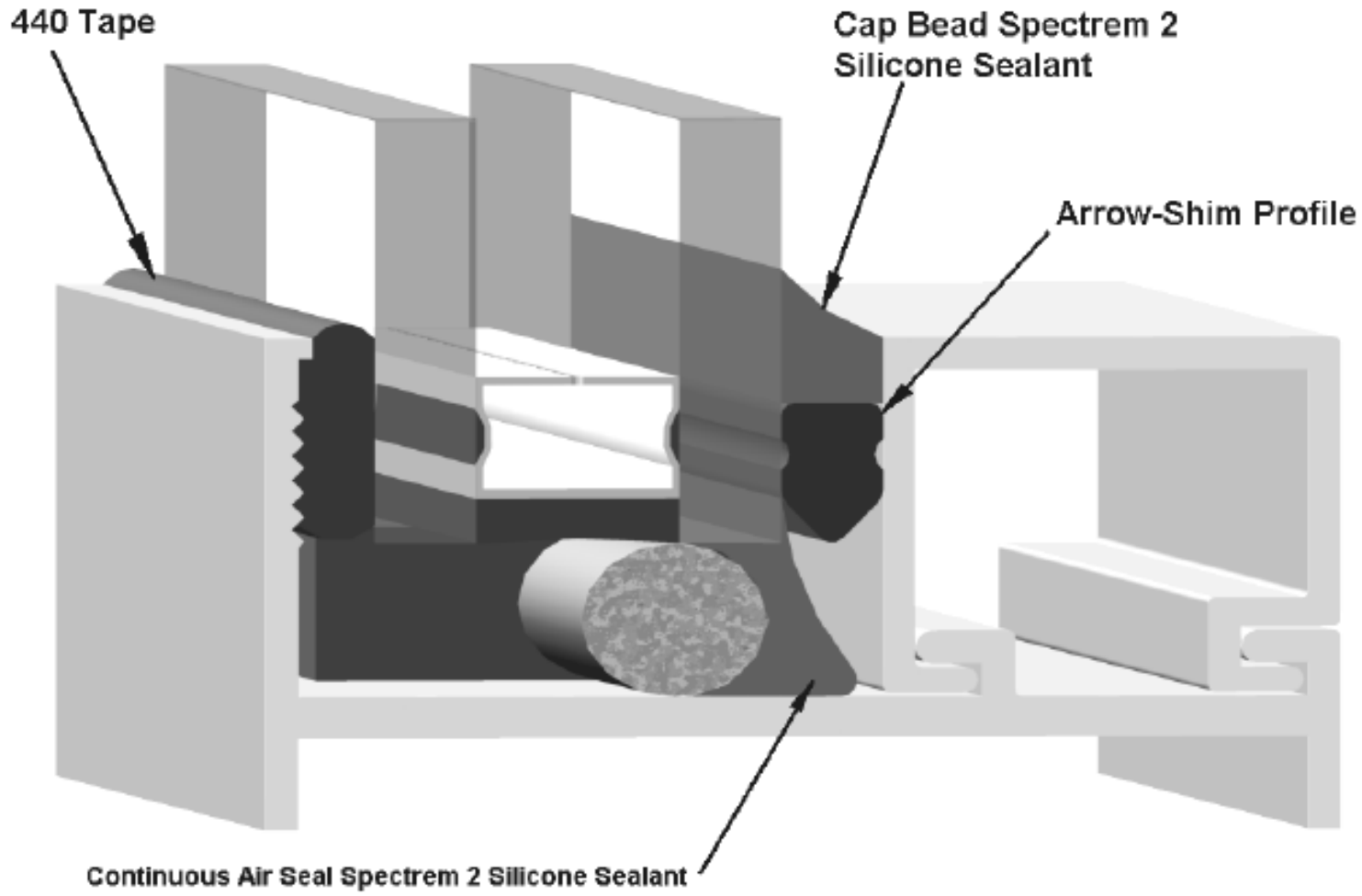
Gasket Failure- Causing Leaks

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

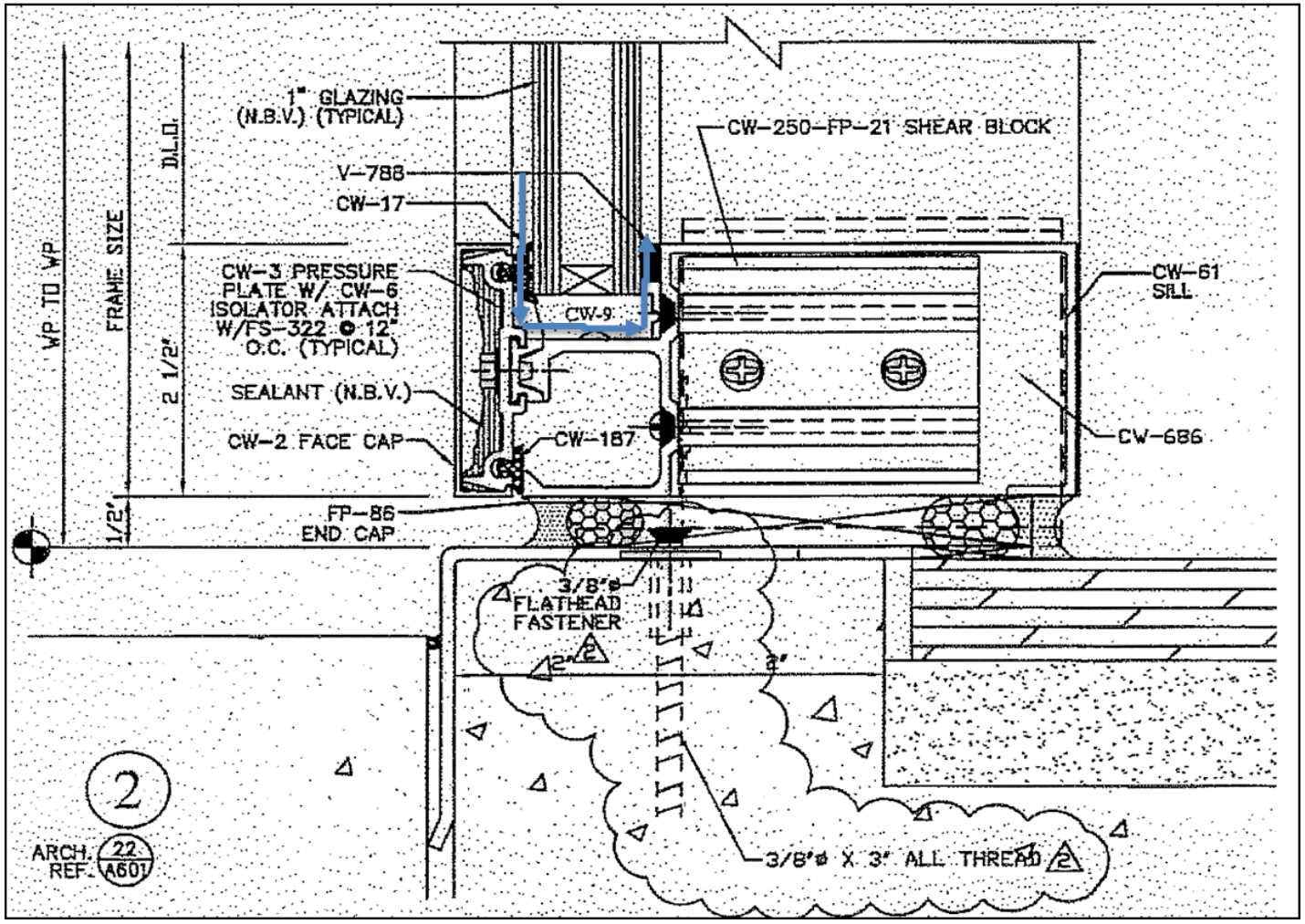
- Water intrusion
- Air infiltration
  - Energy loss
  - Condensation

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



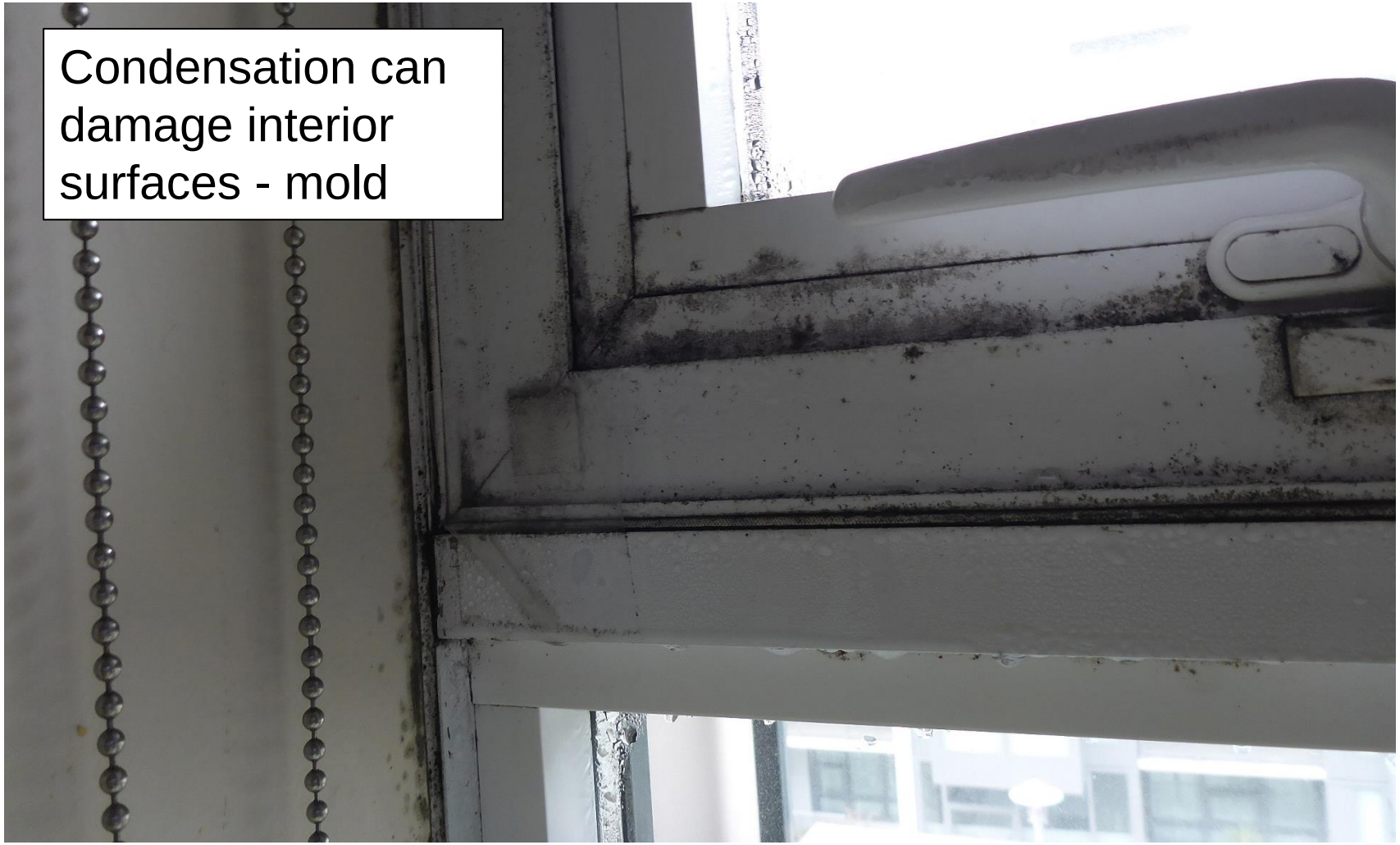
Gasket Shrinkage Water Intrusion

Air Infiltration Can Cause

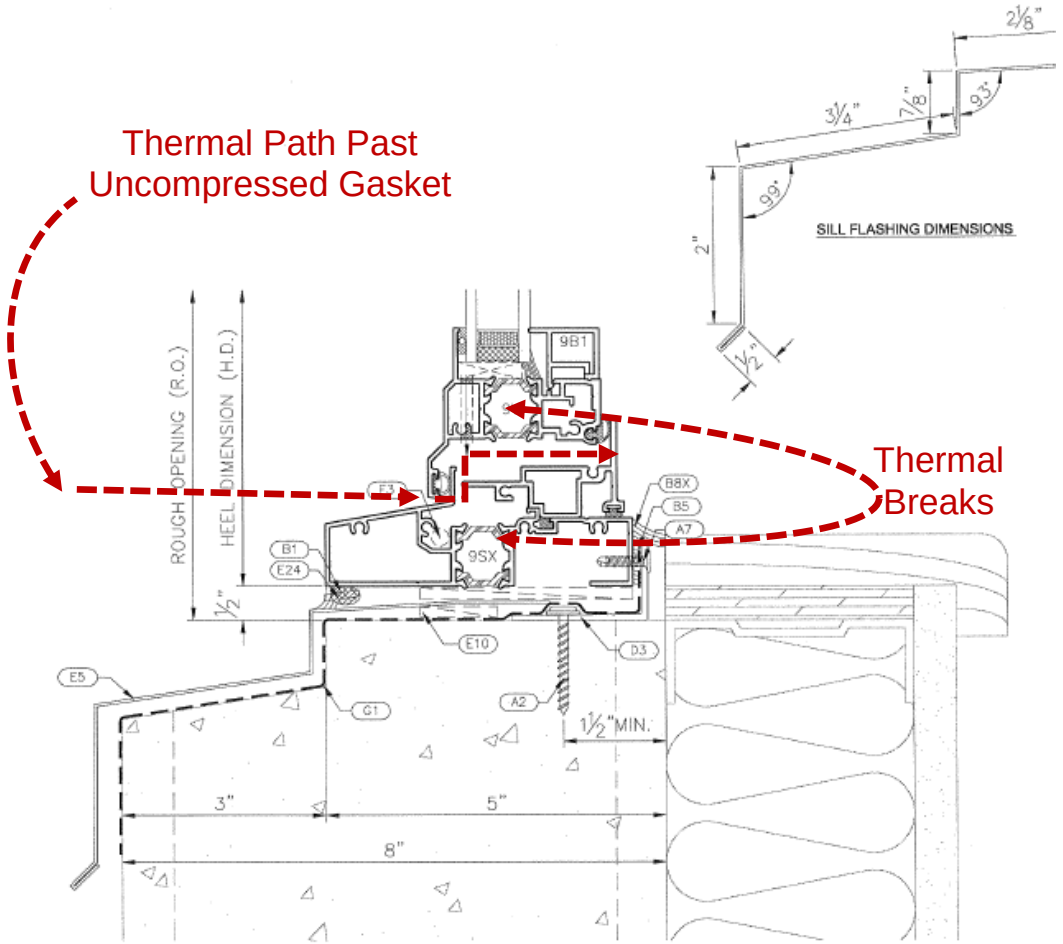
- Air Infiltration can lead to:
  - Energy loss
    - Creating an Air Tight Enclosure Makes all the Difference
    - ASHRAE 90.1 User Manual
      - “Controlling infiltration is important to achieving energy- efficient building.”
      - Air infiltration creates additional loading on the mechanical system
      - 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



How Condensation Can Occur



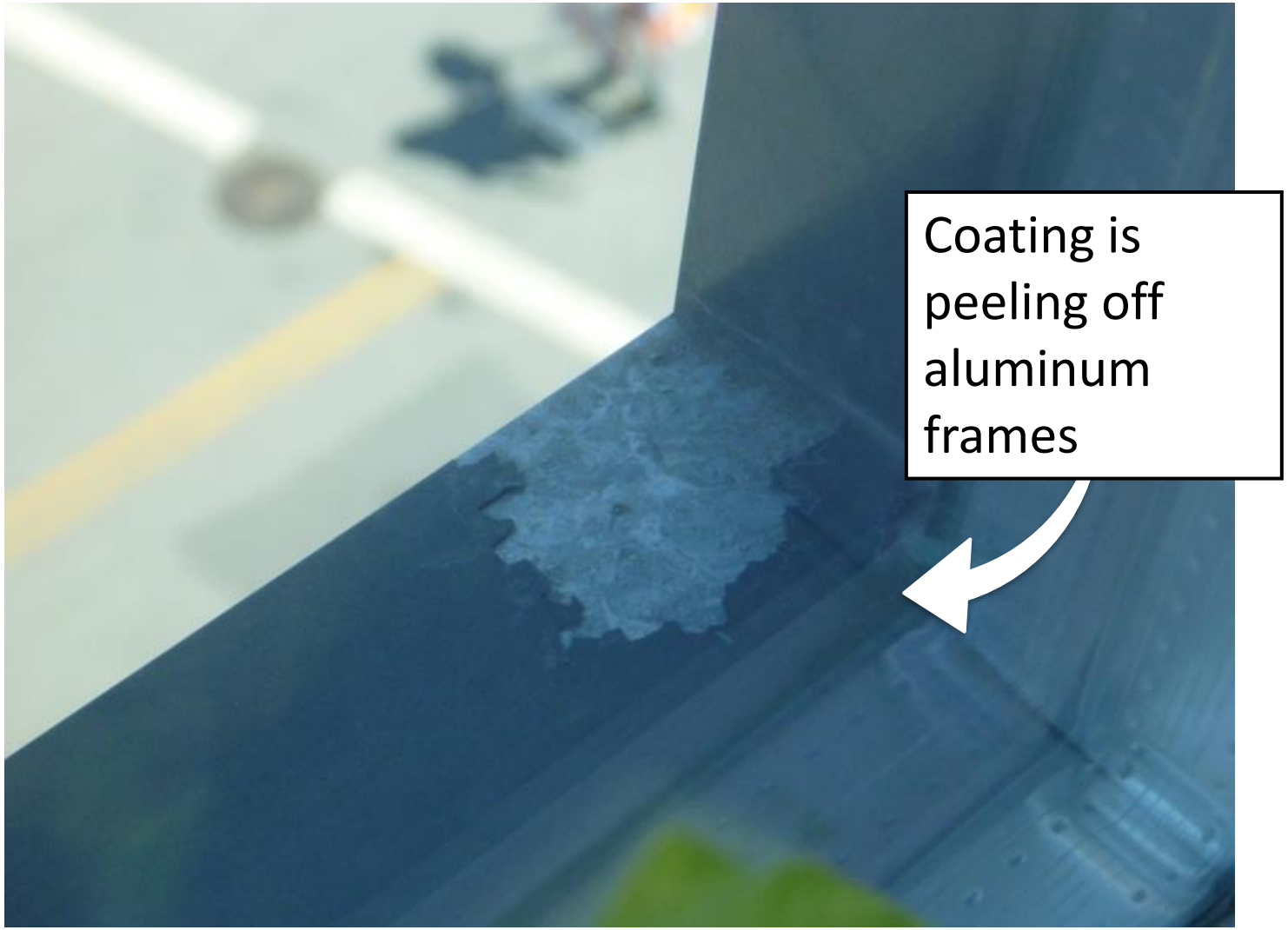
Avoiding Gasket Failure

- 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

Aluminum Coating Failure



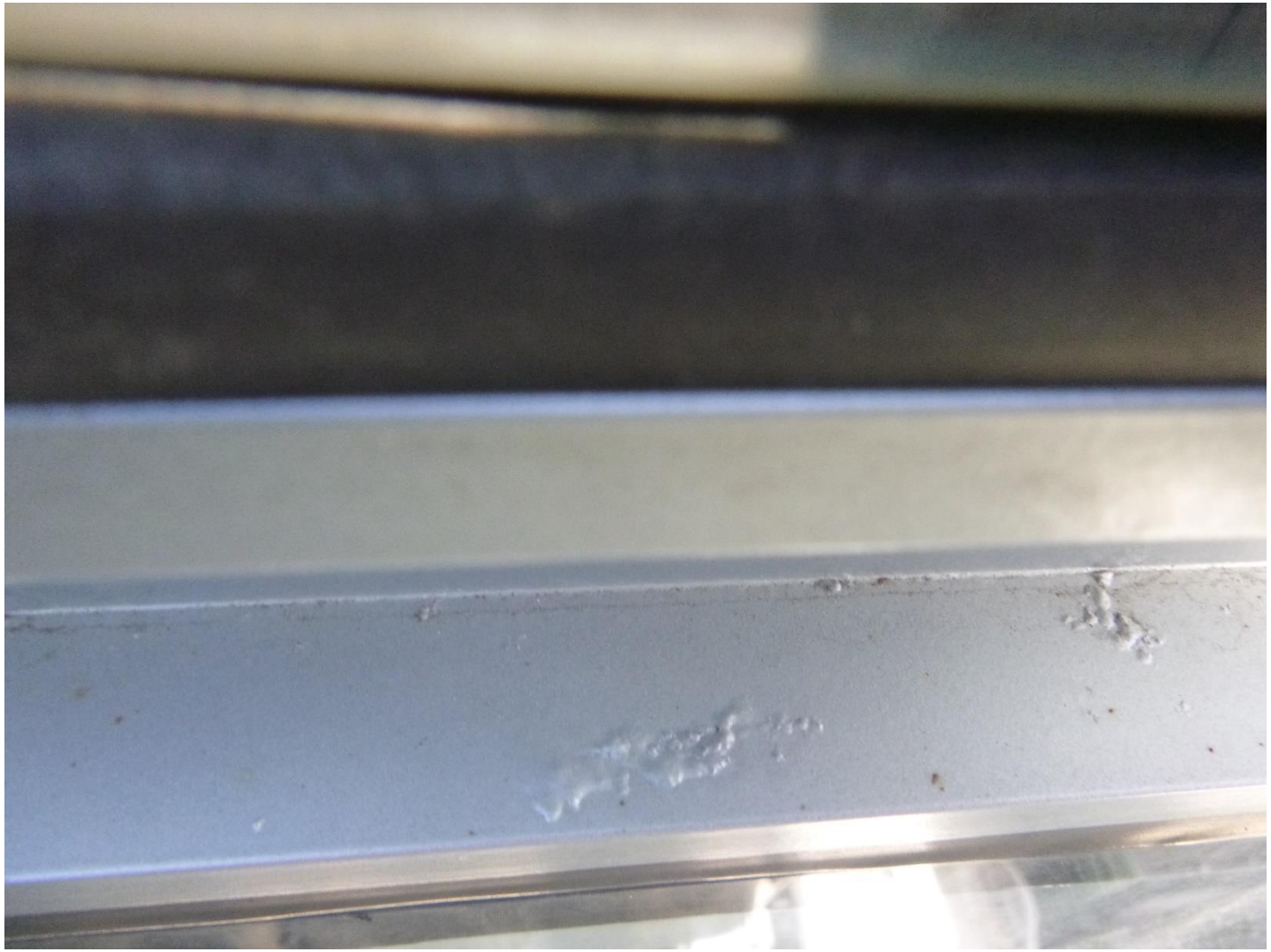
San Francisco Condo #1

San Francisco Condo #1

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

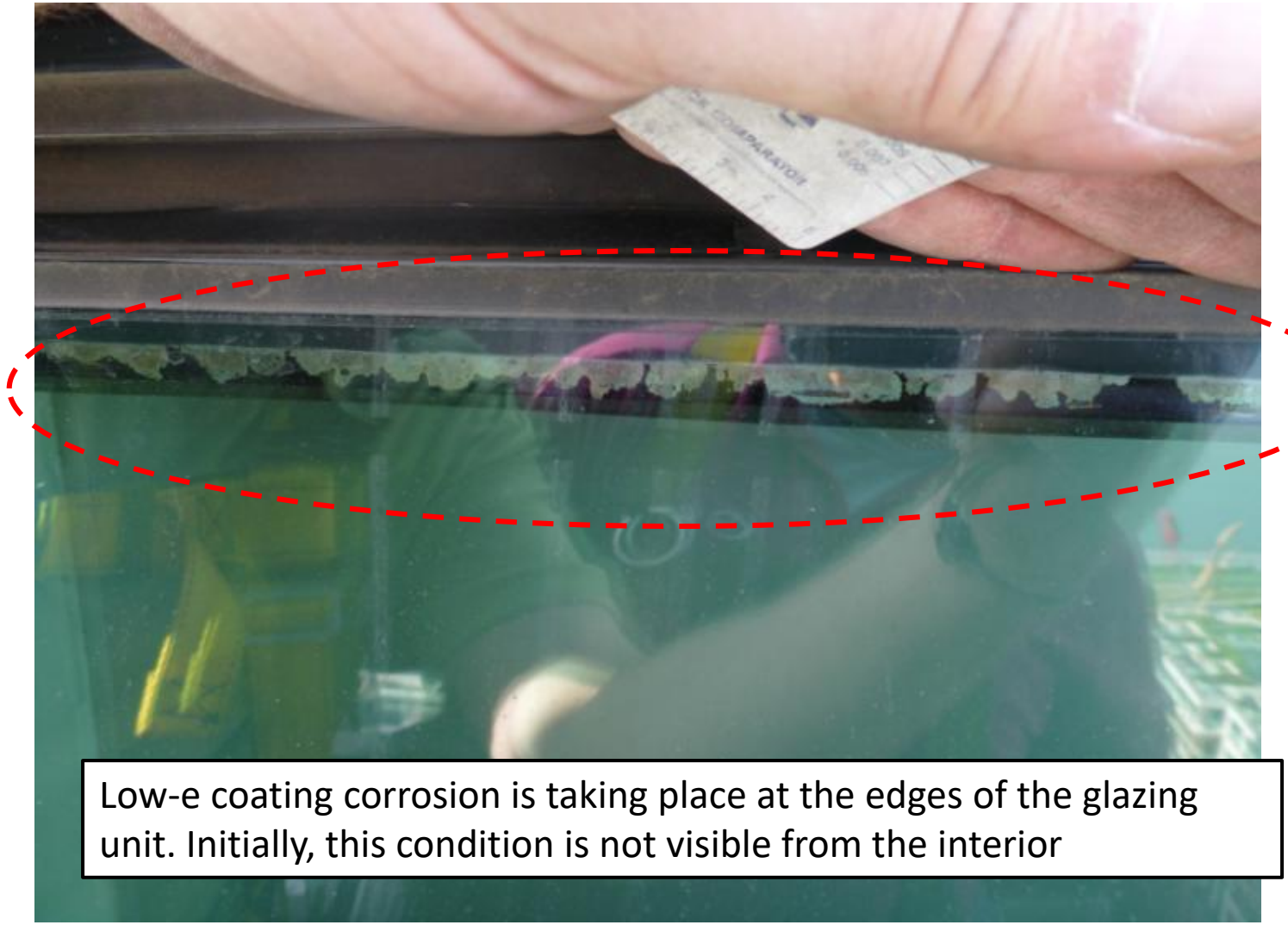
- Proper preparation and coating requirements must be followed
  - Surface preparation, coating thickness requirements
- Use of Fluoropolymer finishes that meet AAMA 2605 certification
- Reviewing coating submittals
- Performing factory visits and verification
- Obtaining samples from factory runs and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

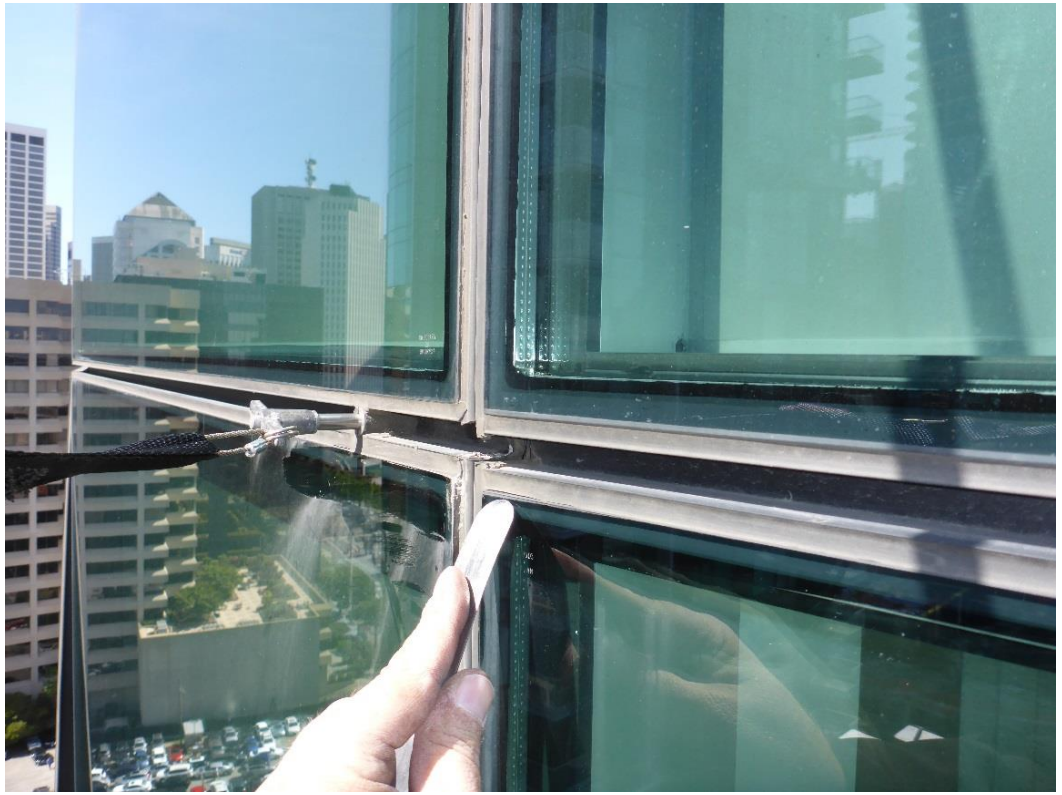
Continuing Low-E Coating Corrosion

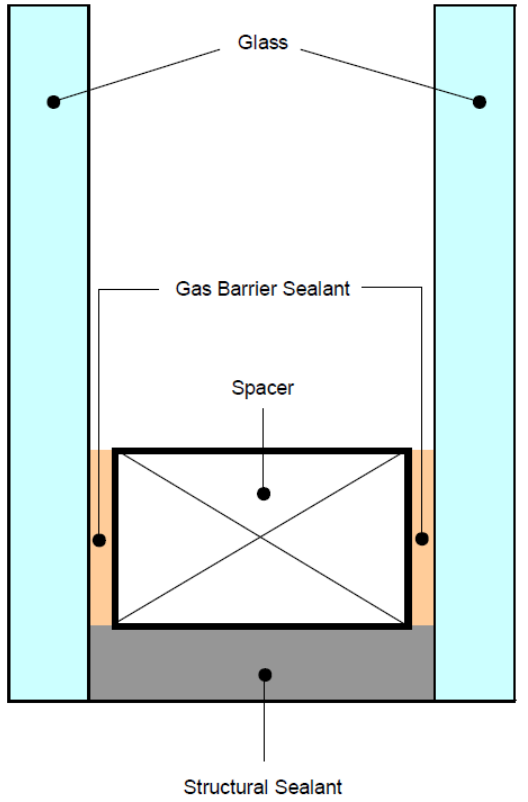
Causes of Corrosion

- 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



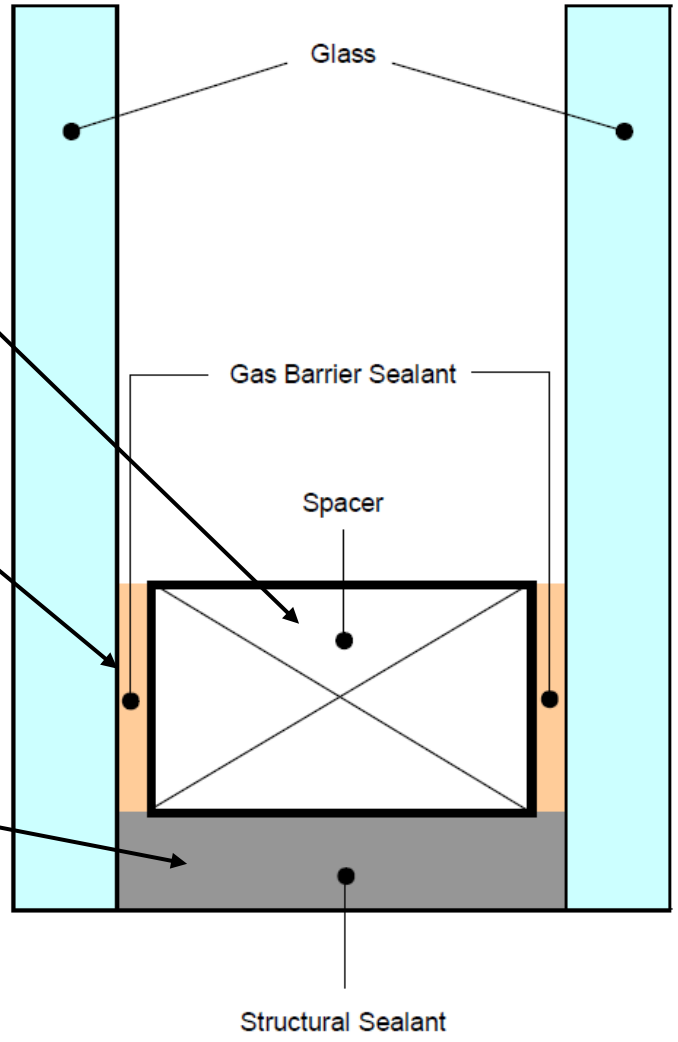


How Are Dual Glazing Units Sealed?

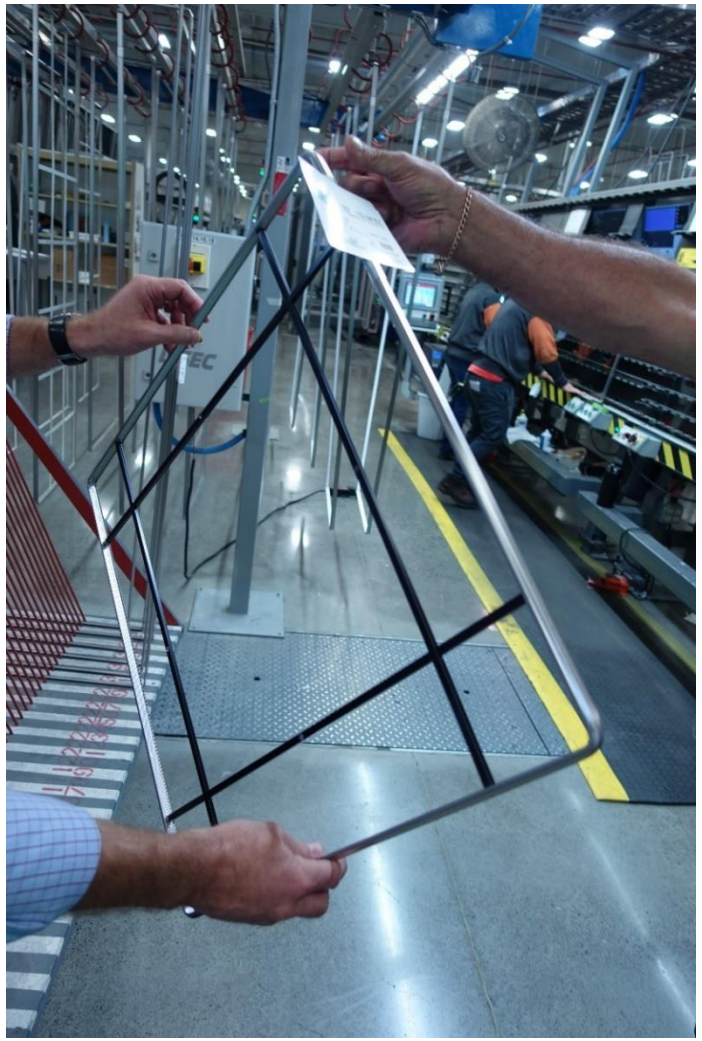
Spacer, usually aluminum or stainless steel

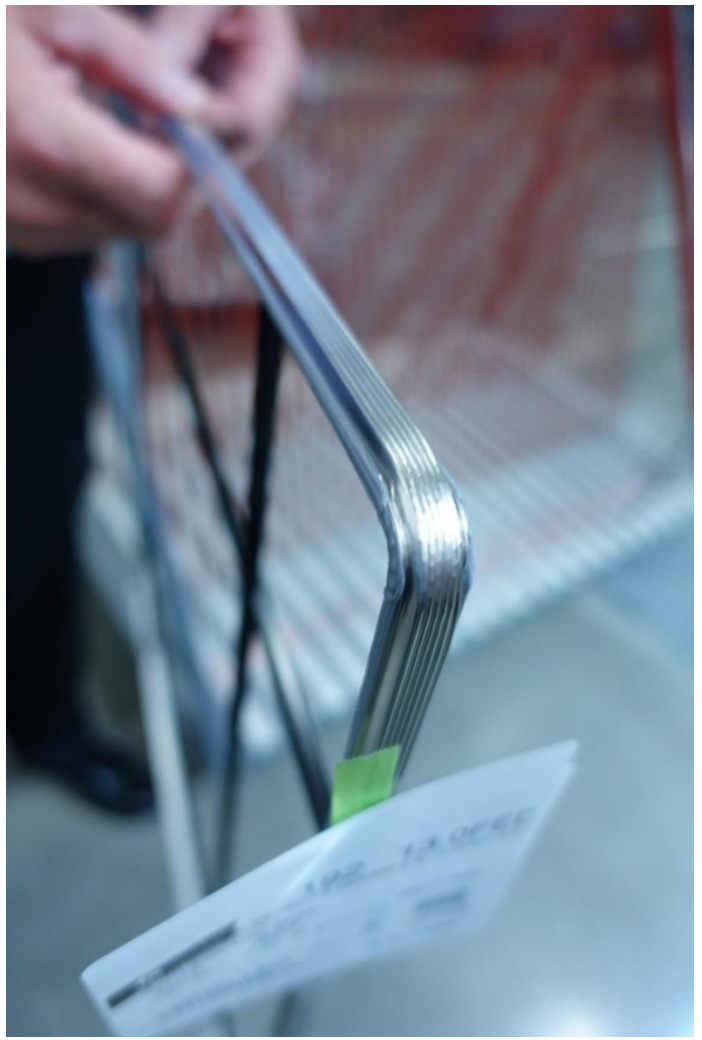
Primary Seal (PIB) impermeable to moisture diffusion.

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

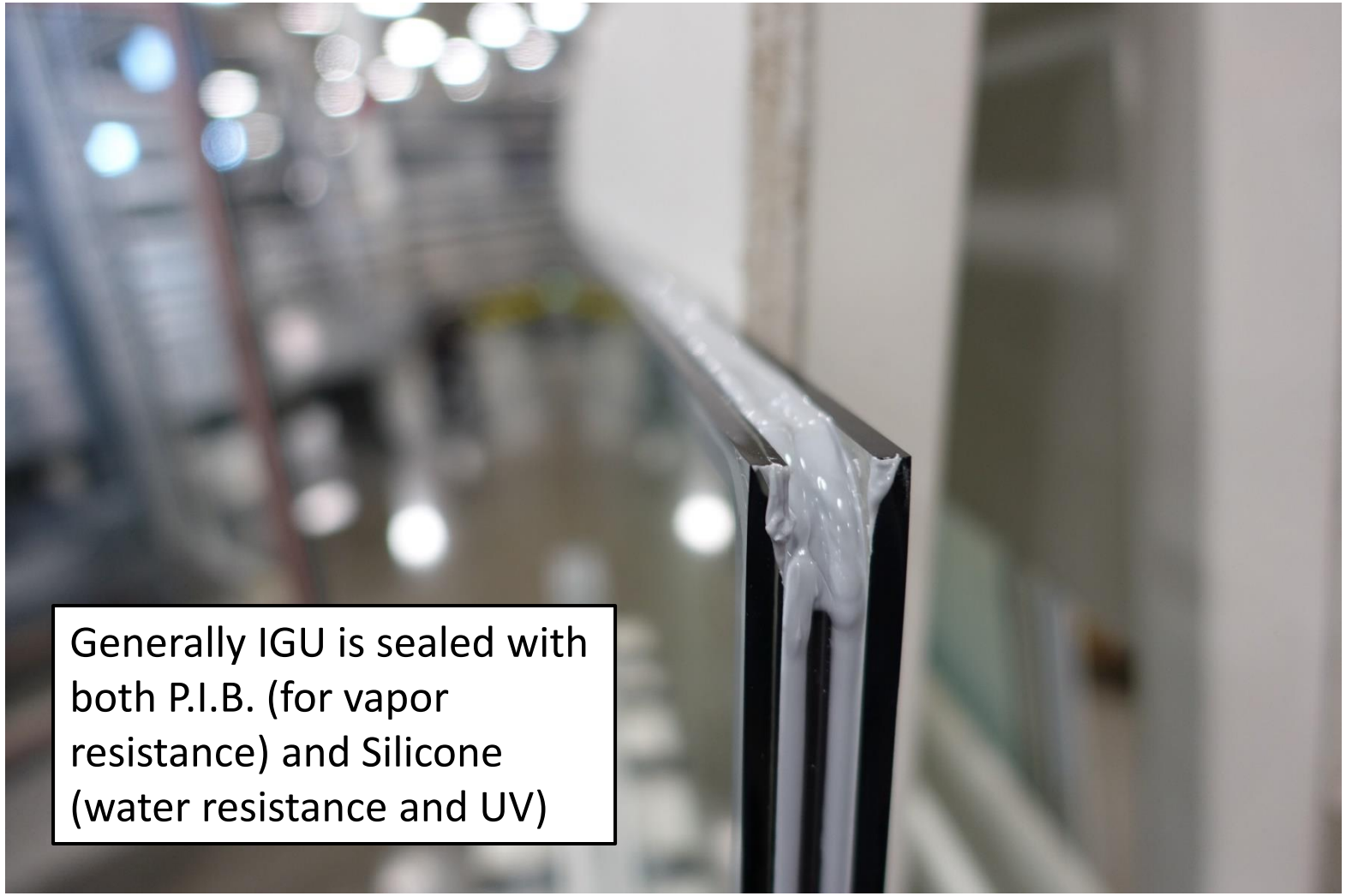


IGU Seals, Stainless Spacers Last Longer



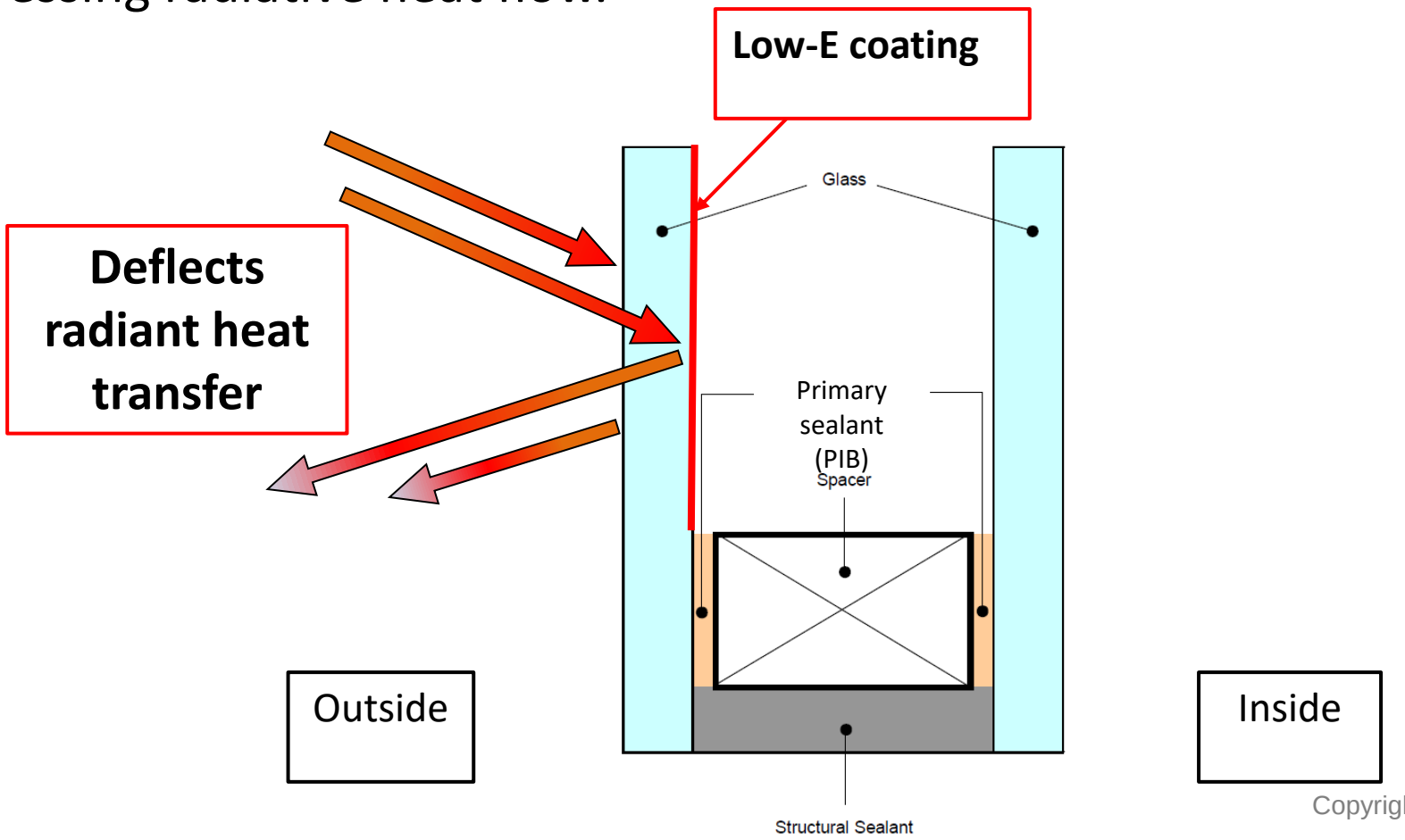


IGU Units Sealed With Dual Sealants



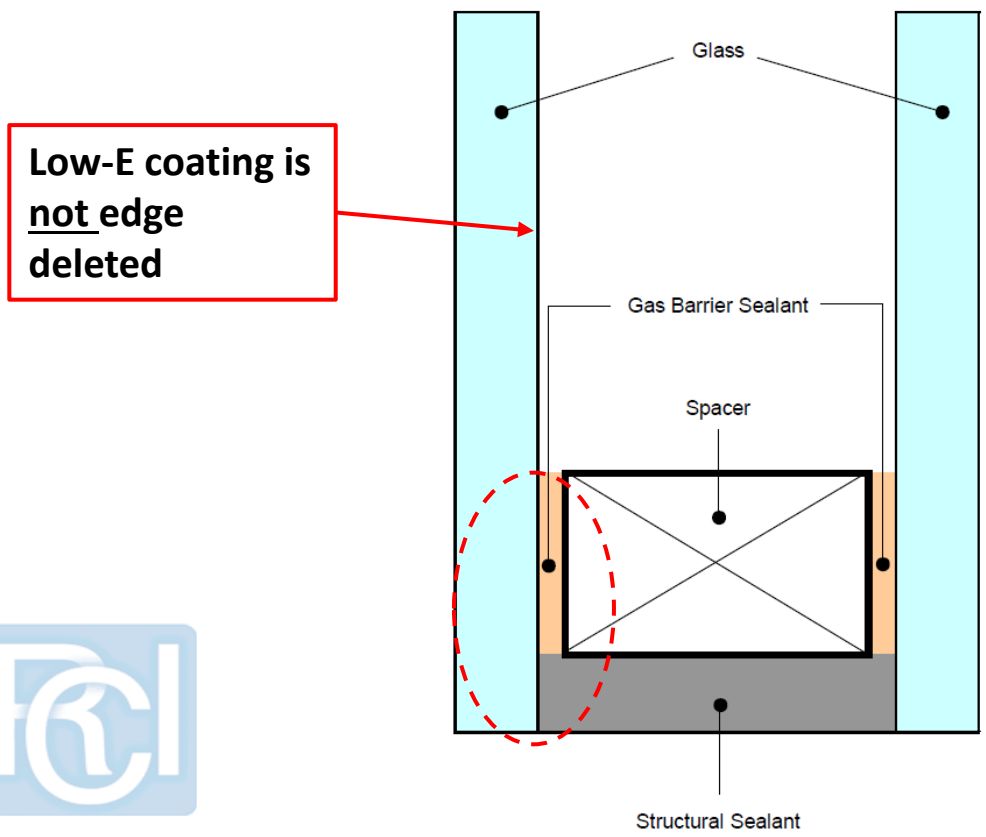
Low-E Coating: What is it?

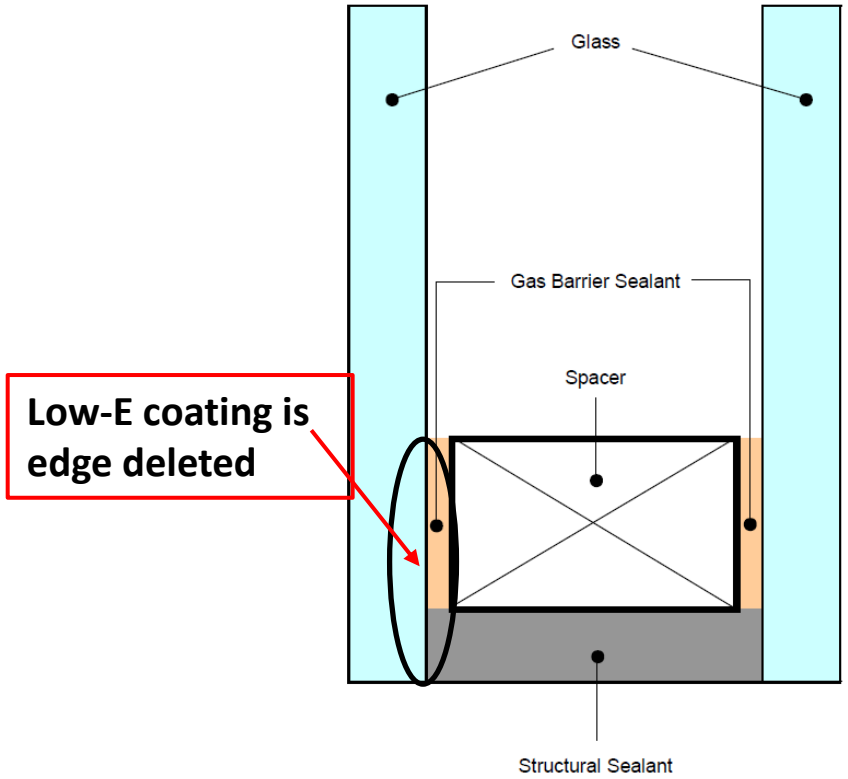
- Microscopically thin and virtually invisible metal or metallic oxide layers (silver) deposited on the glass to reduce the U-factor and (SHGC) Solar heat gain by suppressing radiative heat flow.



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

Low-E coating has been deleted around the edges of glass to allow for IGU seals to perform better

Case Study – SF Condo

Replacing failed glazing on 650 unit high-rise building can cost over $100MM

Replacing Glass, Slow and Tedious

2 guys on window washing rigs

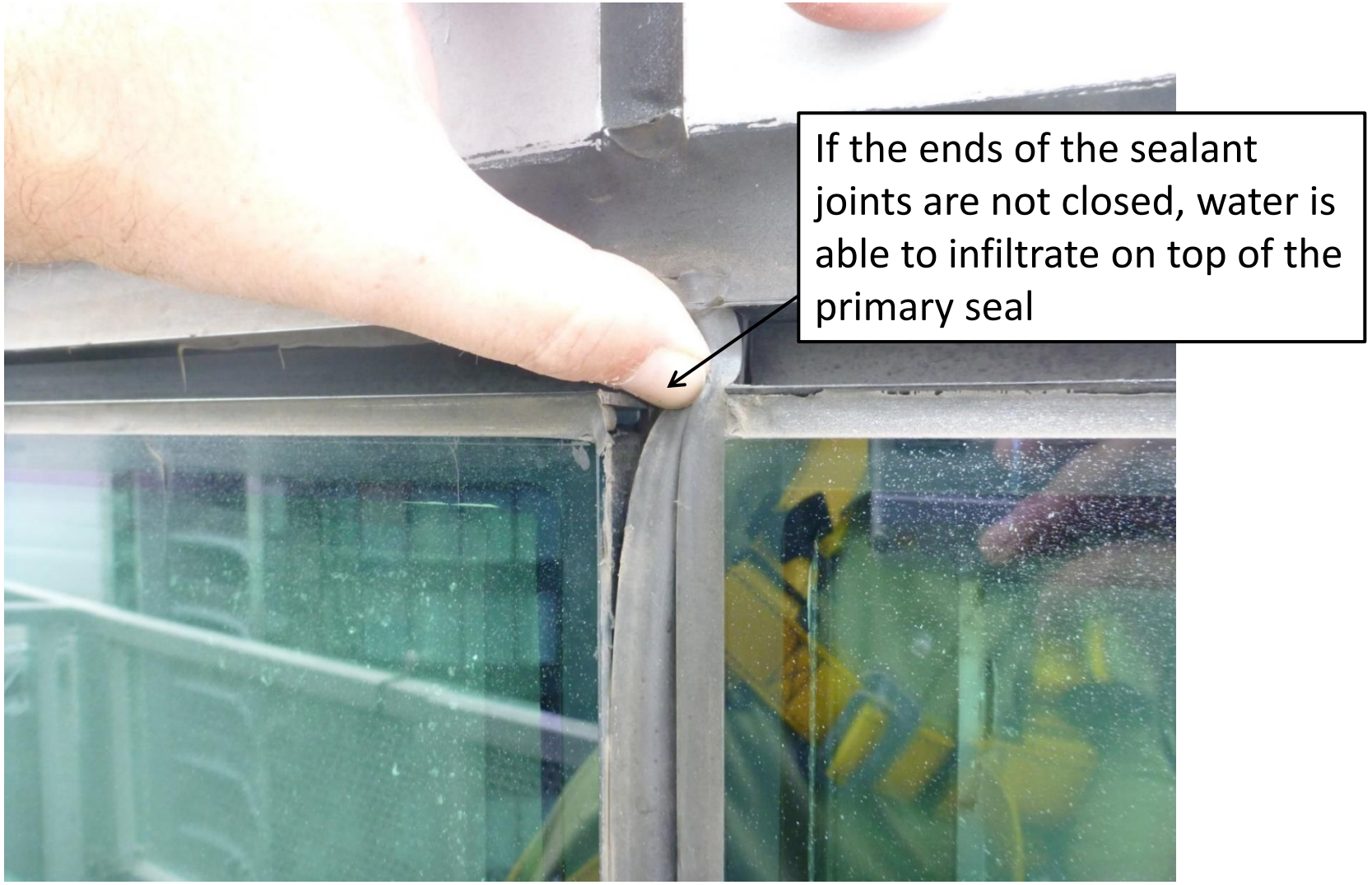
3 guys on the inside handling glass

Replacing Glass, Slow and Tedious

Removed glass from site

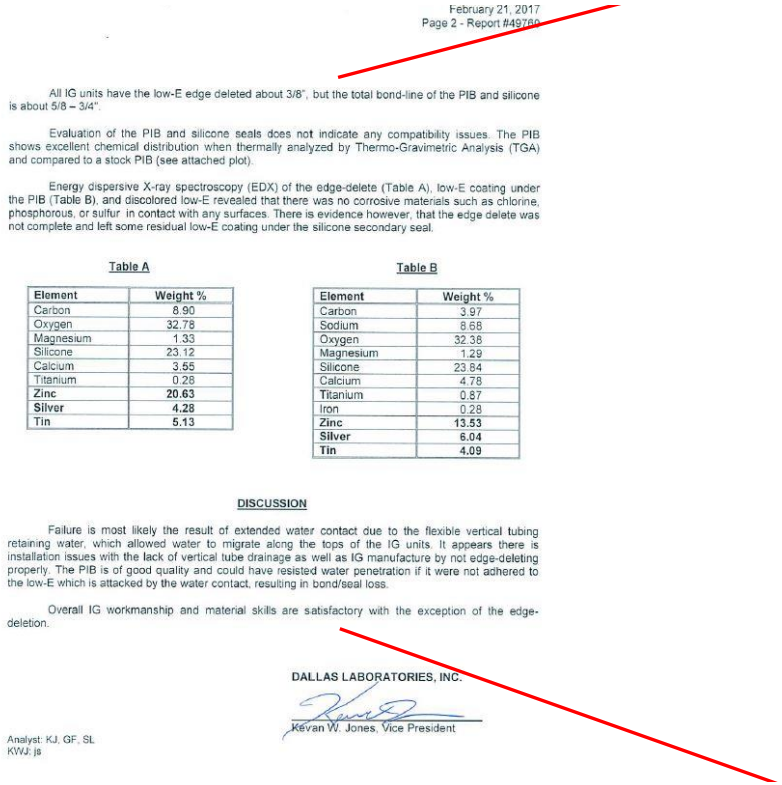
Labeled and crated, shipped to lab

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 ¾”



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, phosphorous, 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	0.28
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	0.28
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.

Kevan 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

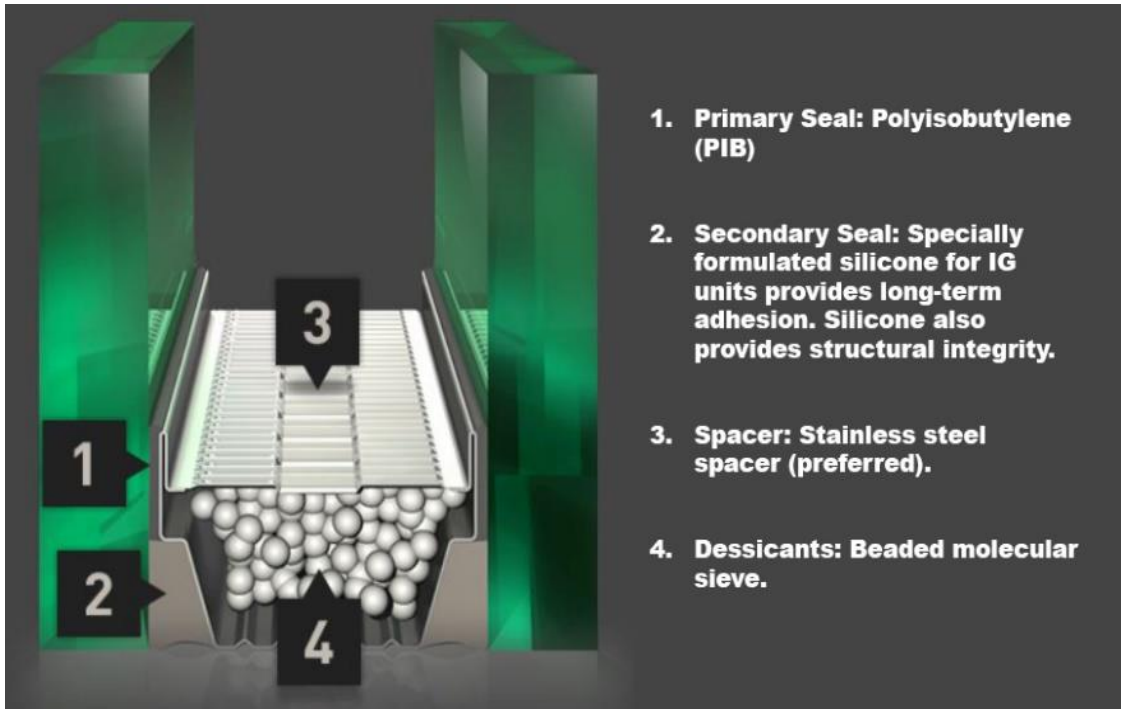
Prevention

- Proper edge deletion needs to occur during the manufacturing process to ensure proper bonding of the IGU sealants
- Design of he 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

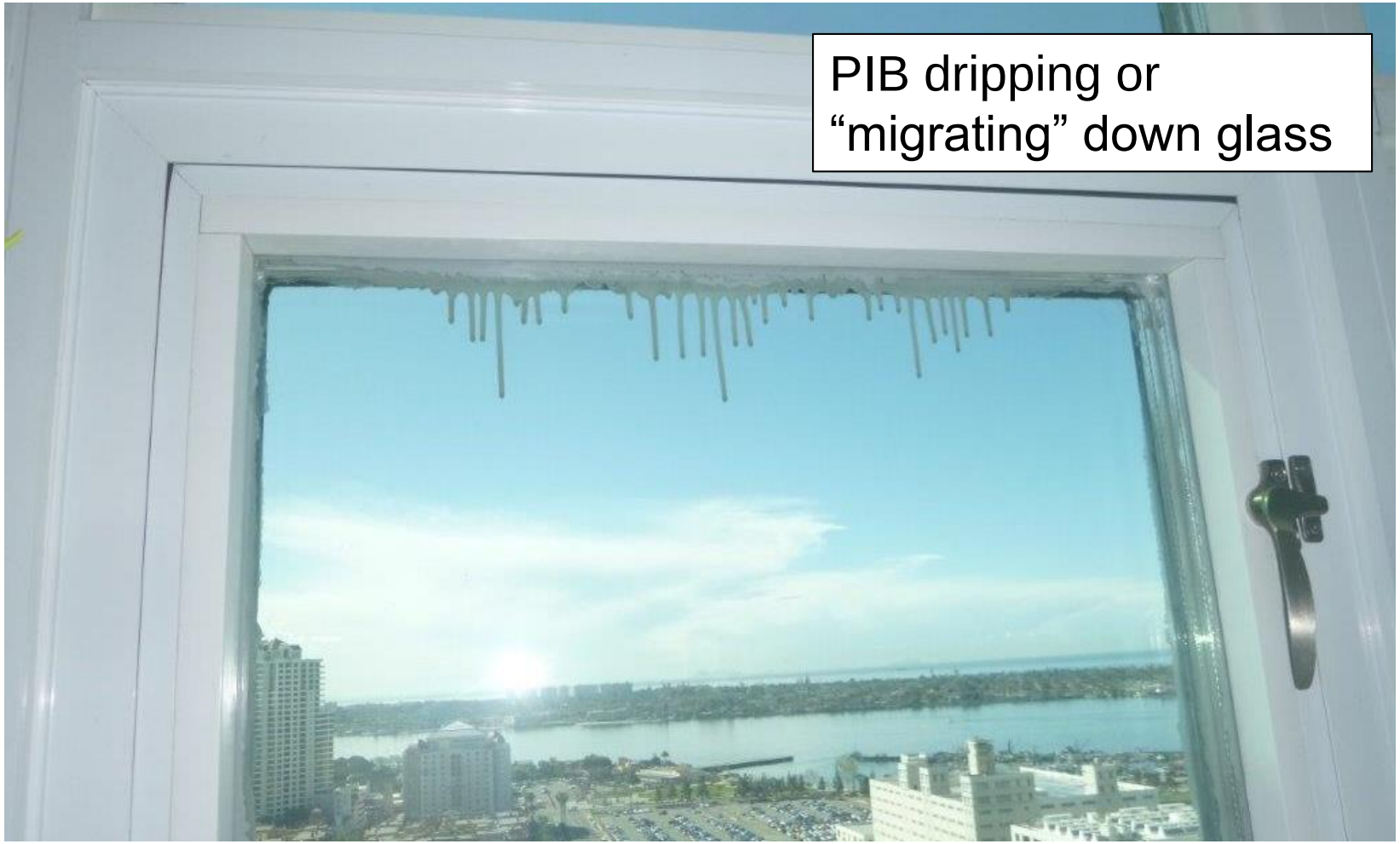
Polyisobutylene (PIB) Migration

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

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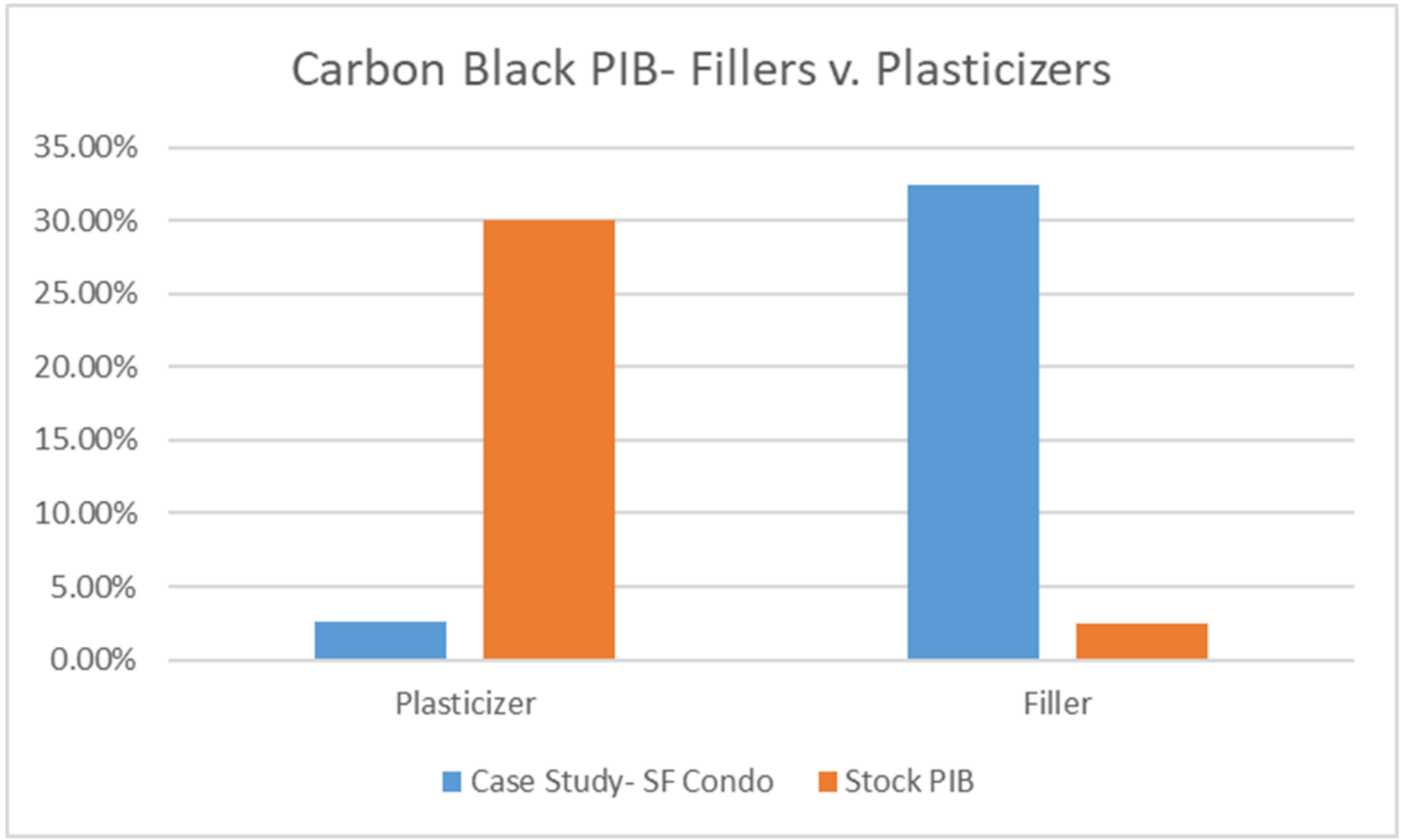
Case Study- SF Condo w/ PIB Migration



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

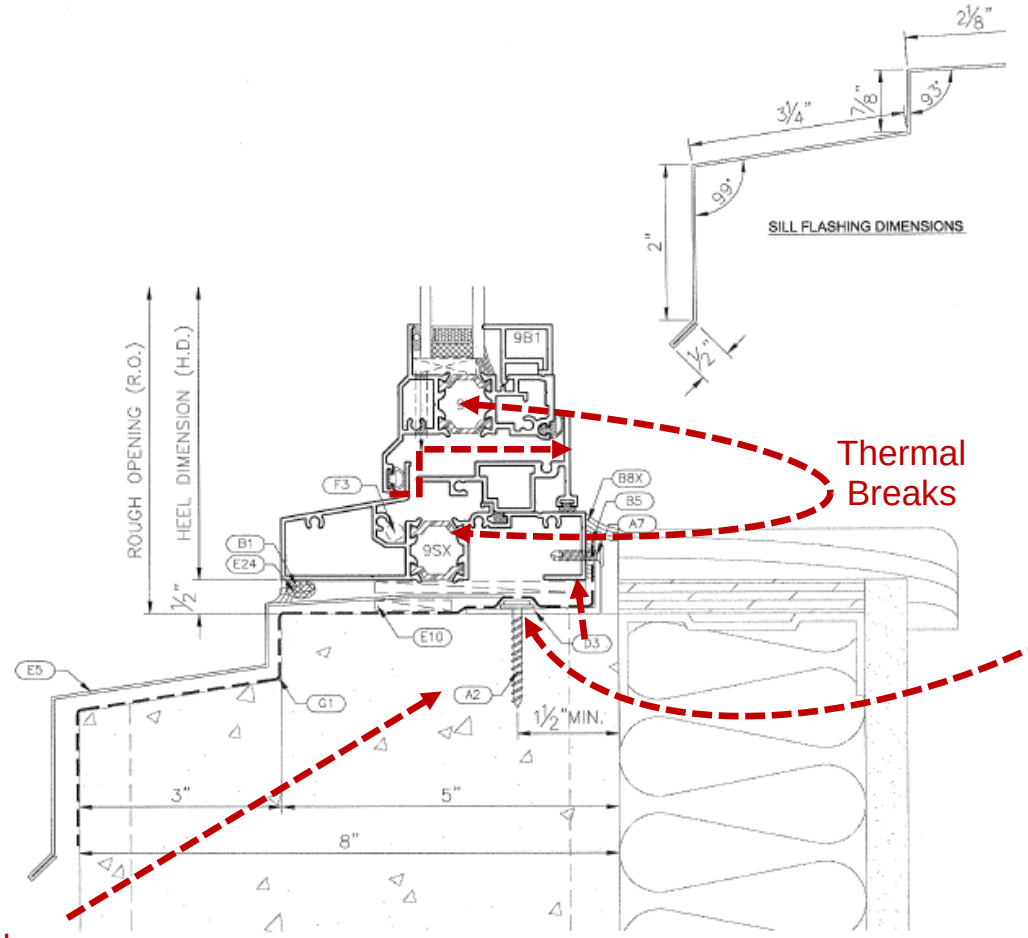
SF Condo

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

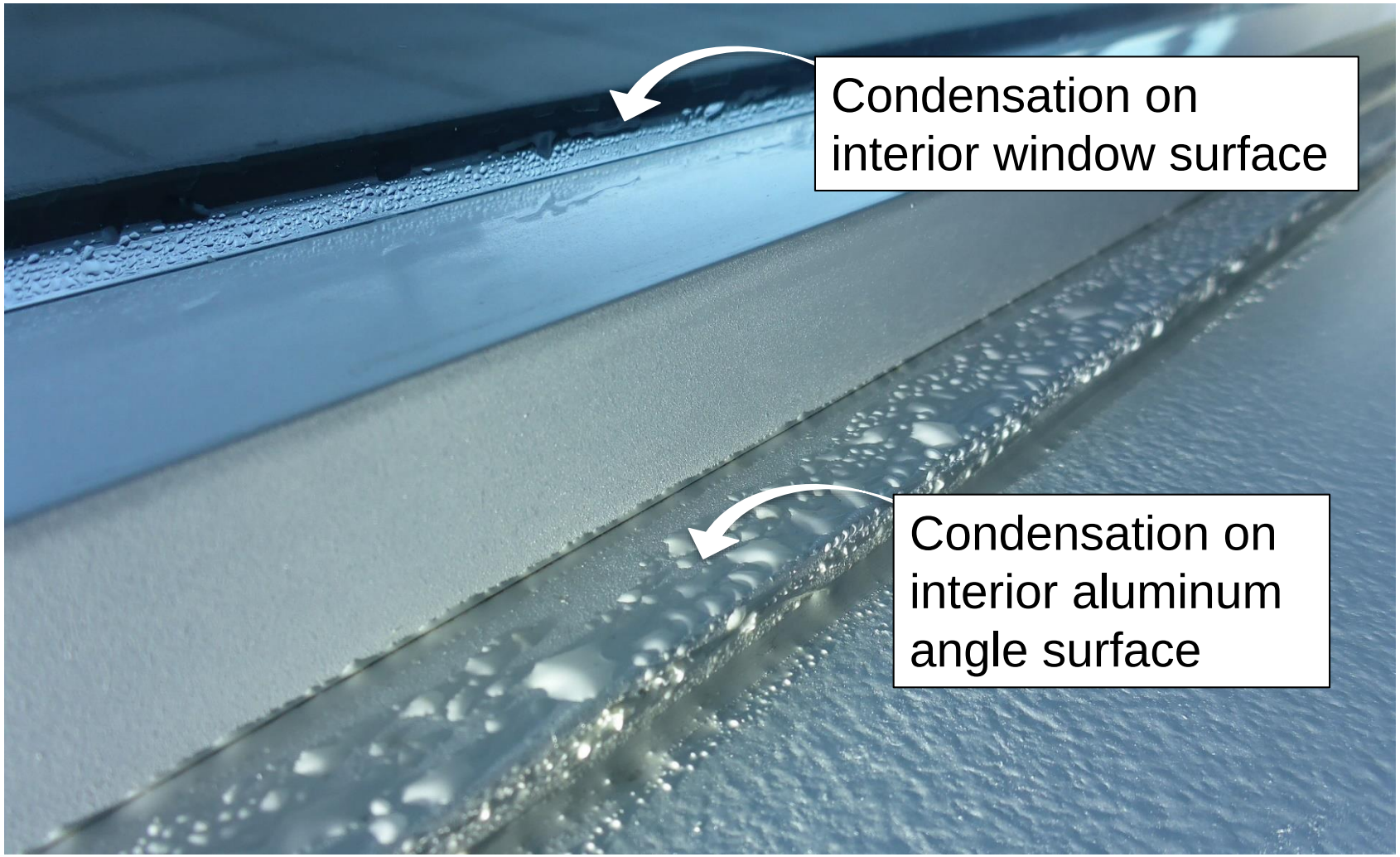


Thermal Breaks

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 perimerter flashing conditions

Lessons Learned

- Conscientious Design
  - Understansing 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 commisioning 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