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Lessons in Insulating Glazing Unit Failures

Failure Mechanisms and Re-Glazing of an all Glass Tower

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Outline

- How do Building Enclosures and Insulating Glazing Units (IGUs) Fail?
- Standard and Innovative In-Situ IGU Testing Methods
- Selection of New IGUs and Replacement in an Occupied Building

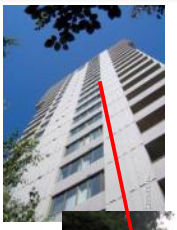
Failed Building Enclosures – Rot and Corrosion

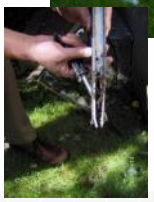






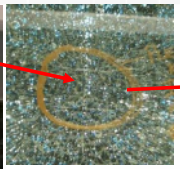
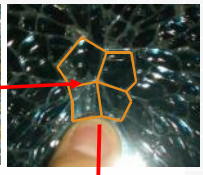
Failed Windows – Corrosion & Wind



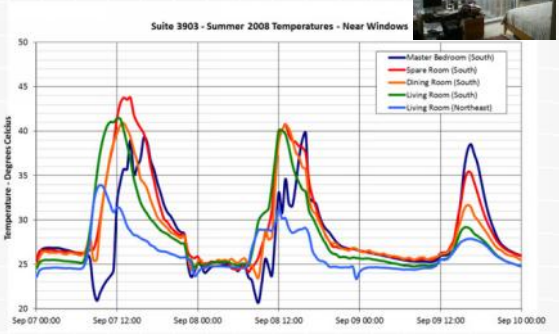



Alright… So What Fails Here?

Failed Tempered Glazing – Nickel Sulphide Inclusions

Overheating in a Cold Climate

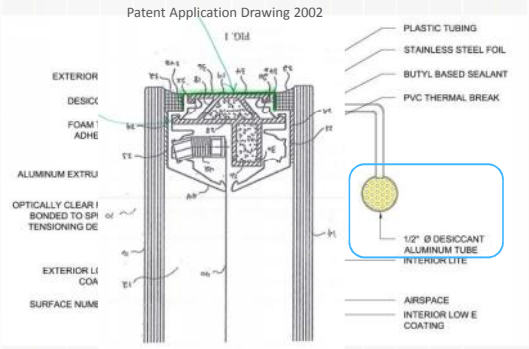


Background – Case Study

- Residential condo building constructed in 2002 – entirely structurally glazed curtainwall – R-5 proprietary triple IGUs
- First fogged IGUs reportedly observed in 2003
  - Contractor replaced all desiccant tubes
  - More fogging persisted
  - Corrosion of low-e noticed
  - More desiccant tubes replaced
- Retained by owners to first investigate in 2006
- Continued investigations through 2007-2008
- Acknowledgement of widespread and worsening problem
- Owners decide to proceed with re-glazing
- Design in 2011 - Re-glazing in 2012

Insulating Glazing Units

Patent Application Drawing 2002

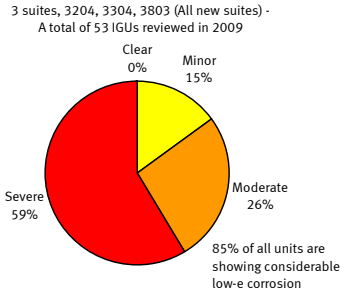


Quantifying IGU Failures in the Field

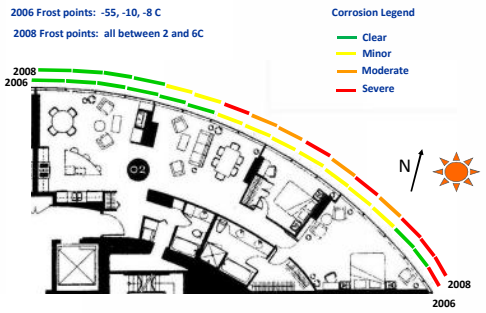
- Visual Review
  - Rating based on visual observation and level of fogging and low-e corrosion damage visible from 10 feet away
- Dew/frost-point testing (ASTM E-576)
  - Measures how dry the IGU airspace is and estimate the saturation level of the desiccant
  - Can estimate remaining service life of IGUs
  - Can quantify failed units and units close to failure

Fogged and Corroded Glazing Units (Surface #5)

Visual Review of IGU Conditions, 2006 through 2009

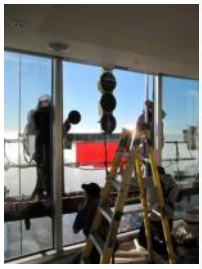


Mapping IGU Degradation with Time

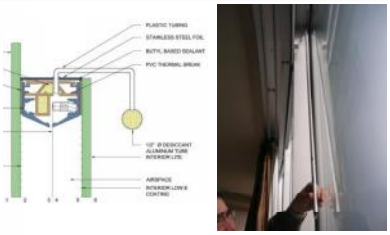


But How and Why are They Failing So Fast?

- Further testing procedures evolved:
  - Desiccant saturation measurement
  - Pressure testing
    - Measure leakage rate of IGUs
  - Flow testing
    - Measure flow through the desiccant tube in service
  - Eventual removal
    - For visual and laboratory testing
    - Delayed for several years to get safety variance to remove IGUs



Desiccant Saturation Testing



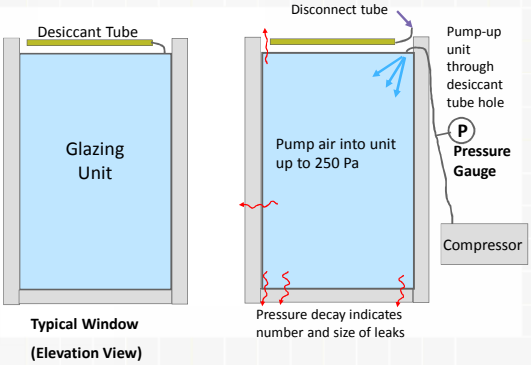
- Once desiccant reaches 80%, it no longer protects IGU from fogging – dewpoint above 0°C (32°F)
- Found saturated desiccant in all fogged units, and drier desiccant in clear IGUs

In-situ IGU Pressure Testing

- Purpose to determine how "sealed" the IGUs actually are
- Built a specialized testing apparatus to measure pressure decay of IGUs in-situ
- Correlate condensation/low-e corrosion with "leakiness" of the IGUs

Pressurize IGU through hole at removable desiccant tube

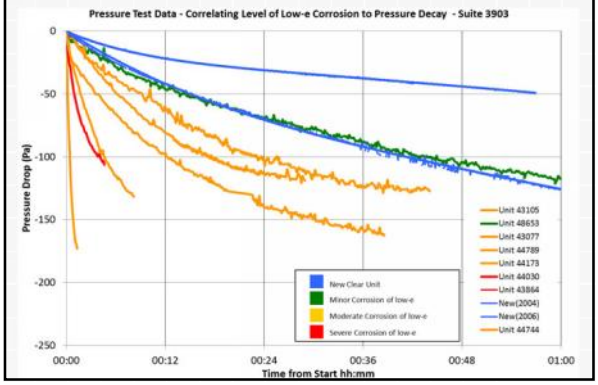
Pressure Testing Apparatus



Pressure Testing Theory

- A completely sealed IGU will retain applied pressure indefinitely (i.e. car tires, basketball etc).
- A leaky unit will exhibit a loss of pressure with time (pressure decay).
  - Air is leaking out through perimeter glazing seal
- The pressure decay can be measured and an approximate leakage area calculated
  - Correlate with corrosion and dewpoint measurement
- Units that cannot be pressurized are very leaky (i.e. like a flat tire)
- Can also use to test new units (originally the IGU company was going to replace all fogged units)

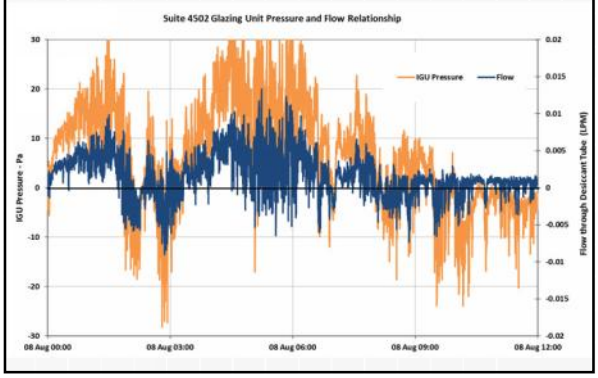
Pressure Decay Testing



Flow Monitoring

- Low Flow sensors connected to open end of desiccant tubes
- Data recorded every second
- Temperature data also collected
- Wind speed and direction data taken from site

Pressure and Flow through Desiccant Tube



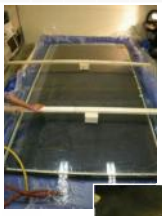
In-Situ Monitoring Results

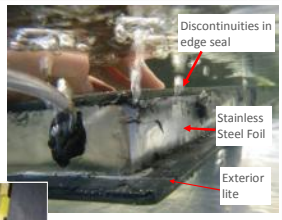
- Air flows from outside into the IGU through edge seal defects then into suite through desiccant tube – driven by wind pressure differences and thermal expansion/contraction
- Desiccant tube flow rate of <0.01 L/min resulting in exchange of 1-5 Liters of air per day just from wind
- Estimated service life of external desiccant tubes with these average flow rates is <5 years to saturation
  - Not accounting for other leaks (as indicated by pressure decay testing)
  - Could this replaceable desiccant tube design have worked in theory? 10x more desiccant by volume within IGU edge seal anyway

Partial IGU Removal – Replace Broken IGU

Eventual (2 year later) IGU removal of Intact IGU

IGU Perimeter Seal Discontinuity Testing





- Over 20 unique leakage locations observed in addition to the desiccant tube hole

Investigation Summary

- Systemic failure of IGUs due to an inadequately sealed "thermally efficient" edge spacer
  - PVC, aluminum, stainless steel foil & hot-melt butyl differential expansion/contraction
  - No real durable structural edge seal
  - Removable desiccant tubes easily overwhelmed in service
  - IGU failure led to frequent fogging and corrosion of silver low-e coating on surface #2
  - All IGUs need to be replaced
- Other units in building with stainless steel (not silver) low-e coating are also fogging but not corroding.
  - Remaining Life?

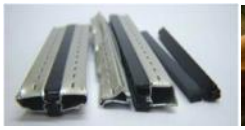
Selecting New Glazing Units

- Criteria: Match existing residential portion plus improve performance
  - Lower SHGC to reduce overheating and issues with undersized AC units
  - All-glass triple vs previous PET suspended film triple
  - Durable edge seal spacer (thin stainless, dual seal with proven track record)
- Original low-e coating not available (old AFG) and hard to match
- Narrowed down hundreds of new alternate options for Owners and City to choose from
- Many plant and site mock-ups for color

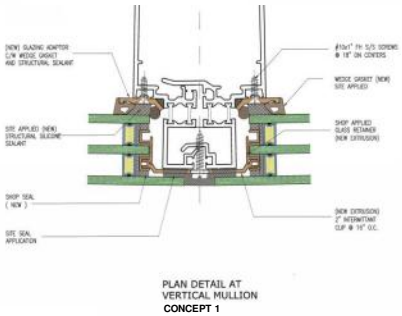
Selecting New Glazing Units

Selection of New IGU Spacers

- Trend towards "thermally broken" edge spacer bars with plastic thermal breaks (polyurethanes, PVC)
- Have investigated the fogging of several brand-new IGUs where VOCs (mainly ethanol and propanol & water) were present in all fogged units but not within any good un-fogged units.
  - Some molecular sieve desiccants are better at absorbing VOCs than others
- Need to be careful with edge seal spacer selection



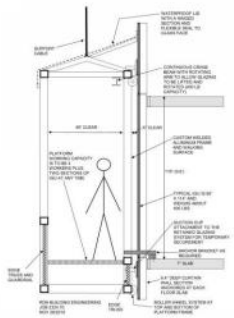
Structural Silicone Sealant Detailing in the Field



PLAN DETAIL AT VERTICAL MULLION
CONCEPT 1

Why More Mock-ups are Performed

Replacing Floor-Ceiling IGUs in a Fully Occupied Condo



Conclusions

- In strive for more energy efficient products and buildings – inevitably some do fail
  - Lessons learned from failures provide valuable lessons in durability
- Edge seal durability very important in thermally efficient IGUs
- In-situ pressure decay testing of IGUs a possible diagnostic tool to test seal integrity (in factory QC and in-situ)
- Mock-ups during Restoration as useful as New Construction

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Discussion

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