Glazing Investigation Report

One Wall Centre, 938 Nelson Street, Vancouver, BC

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1. Executive Summary

The visual clarity of the insulating glazing units supplied by Visionwall has deteriorated to unacceptable levels on the majority of the residential portion of Once Wall Centre. The deterioration of the visual quality is a result of premature condensation forming inside the insulating glass unit and causing corrosion of the low-e coating on the glass. The condensation is caused by an excessive building up of moisture in the desiccant as a result of airflow through discontinuities in the perimeter seals. The discontinuities are a result of defects in the design and manufacturing of the insulating glass unit.

The majority of the insulating glass units (IGUs) reviewed are already exhibiting moderate to severe corrosion of the low-e coating. Many of the minor classed units were clear only a few years ago. The corrosion level on insulating glass units reviewed over multiple years indicates that these units have failed and are continuing to degrade. Test results indicate that the majority of the clear IGUs are near, or at the point where condensation and corrosion will start to occur.

The defective edge seal used on the original insulating glass units will continue to degrade in service and will eventually cause the premature failure of all IGU edge seals on the building. Once the edge seal has failed, the low-e coating and the visual quality on all insulating glass units will continue to deteriorate over time.

The replacement of the Visionwall glazing on the residential portion of the building will be required in order to permanently solve the premature condensation problems and resultant degradation of the visual clarity of the glass. Replacement of 100% of the glazing will also resolve sealant embrittlement issues and will allow the overheating issues to be; mitigated by utilizing a low-e coating with better solar shading properties, and further reduced if dark tinted glass similar to the hotel portion of the building can be used in the replacement insulating glass units.

In-situ repairs such as desiccant tube replacement and sealant injection have already been attempted by the manufacturer and have not been effective at mitigating the problem. Based on the investigation to date it is our opinion that an effective long term in-situ repair of the existing glazing units will not be feasible.

The cost to replace all glazing units on the residential portion of the building is 6.5 million dollars.

Additional investigation of the overheating issue, structural sealant embrittlement, and full scale mock-ups and testing are recommended before re-glazing commences.

2. Introduction

RDH Building Engineering Ltd. was retained by Tim Peters of Jenkins Marzban Logan LLP to investigate the premature fogging of the Insulating Glass Units (IGUs), as well as reports of overheating on the residential floors of One Wall Centre.

2.1. Documents Provided

The following documents were reviewed by the writer as background information for the investigation

- Visionwall Shop Drawings - Wall Centre Phase 2, Dated 99/04/30 (216 pages)
- Background photos from Suite 4702, 2004-2007

2.2. Background Information

Basic Building Statistics

- Completed: 2001
- Number of Floors Total: 48
- Commercial Floors: 30 (1-30)
- Residential Floors: 17 (31-48)
- Number of Residential Suites: 74

The following information was provided to RDH by the strata council:

- Occupants have observed extensive fogging of glazing IGUs particularly during periods of cold weather, since the time of original construction.
- The original contractor has returned to replace desiccant tubes on the entire building on 2 occasions.
- Some locations have had desiccant tubes replaced 3 times.
- A number of severely fogged glazing units have already been replaced by the original contractor.
- Numerous owners have reported overheating issues even during periods in the winter when it is sunny and the air conditioner is operating at full capacity

2.3. Applicable Standards

The following standards apply to the manufacture and installation of the insulating glass units installed on the building.

2.3.1. CAN/CGSB-12.8-97 – Insulating Glass Units

CAN/CGSB-12.8 relates to the assembly of clear, float and laminated glass into a sealed insulating glass unit. Section 3.2 specifies the type and quality of the Glass as follows "The glass used in the units shall conform to CAN/CGSB-12.1, CAN/CGSB-12.3, CAN/CGSB-12.4, CAN/CGSB-12.10, CAN/CGSB-12.11 or of a patterned or obscure glass as specified (par.5.1). The interior cavity glass surfaces of the units shall be clean and there shall be no sealant at a distance greater than 3mm above the spacer."

2.3.2. CAN/CGSB-12.1-M90 – Tempered or Laminated Safety Glass

CAN/CGSB-12.1 relates to the tempering and laminating of clear float glass and references CAN/CGSB-12.3 for the source glass to be tempered.

2.3.3. CAN/CGSB-12.3-M91 – Flat, Clear Float Glass

CAN/CGSB-12.3 relates to the manufacture and use of clear float glass. Paragraph 5.5 classifies the maximum allowable visual defects for different applications and sizes. For conventional 2.5 to $7m^2$ glazing quality glass, defects such as medium and heavy scratches, rubs and process surface defects are not permitted. Medium and heavy scratches, rubs and process surface defects are defined as visible from a distance of 3m when looking through the glass perpendicular to it, using daylight without direct sunlight. Process surface defects viewed in normal light are also considered heavy if they are readily visible as a cloudy surface.

2.4. Curtain Wall System Design

The glazing system installed on One Wall Centre consists of a four-sided structurally glazed unitized curtain wall system supplied by Visionwall Corporation. It incorporates a proprietary three element IGU consisting of an optically clear polyethylene terephtalate (PET) film suspended between 2 lites of glass (Fig. 2.4.1). The curtain wall system is unitized, and as such was prefabricated and glazed into finished panels in the factory. The panels were then shipped to site and sequentially hung on the building during construction.

The Visionwall system utilizes the rainscreen principle to control rain penetration. The exterior water shedding surface consists of the structural silicone sealant and exterior dry gaskets, and the inner air barrier and water resistive barrier consists of the interior dry gaskets and aluminum framing members. The space adjacent to the glazing unit between the exterior water shedding surface and the interior water resistive barrier gaskets is called the glazing rebate. On the Visionwall system the glazing rebate is vented and drained to the exterior in order to moderate the pressure differential across the exterior silicone and dry gaskets (Fig. 2.4.2). During wind driven rain, the wind induced pressure will cause air to enter the vent holes and quickly equalize the pressure across the exterior water-shedding surface reducing the potential for water entry past the exterior seals and allow drainage of any water infiltration that enters the glazing rebate.

The net result of installing IGUs in a rainscreen curtain wall system as discussed above is that the outer edge of the IGU that is fully exposed to the glazing rebate and will therefore be exposed to exterior wind pressures.

The IGU is glazed into the curtain wall assembly using structural silicone adhesive on all four sides (four sided structurally glazed). The exterior lite of the IGU extends 25mm past the spacer bar and interior lite to overlap in front of the mullion. The structural sealant is installed between the exterior lite extension and the vertical aluminum mullion. The interior lite is sealed to the mullion with an interior dry gasket. This glazing method prevents direct visual or physical access to the glazing rebate from both the interior and the exterior of the building unless the IGU is removed from the curtain wall assembly.

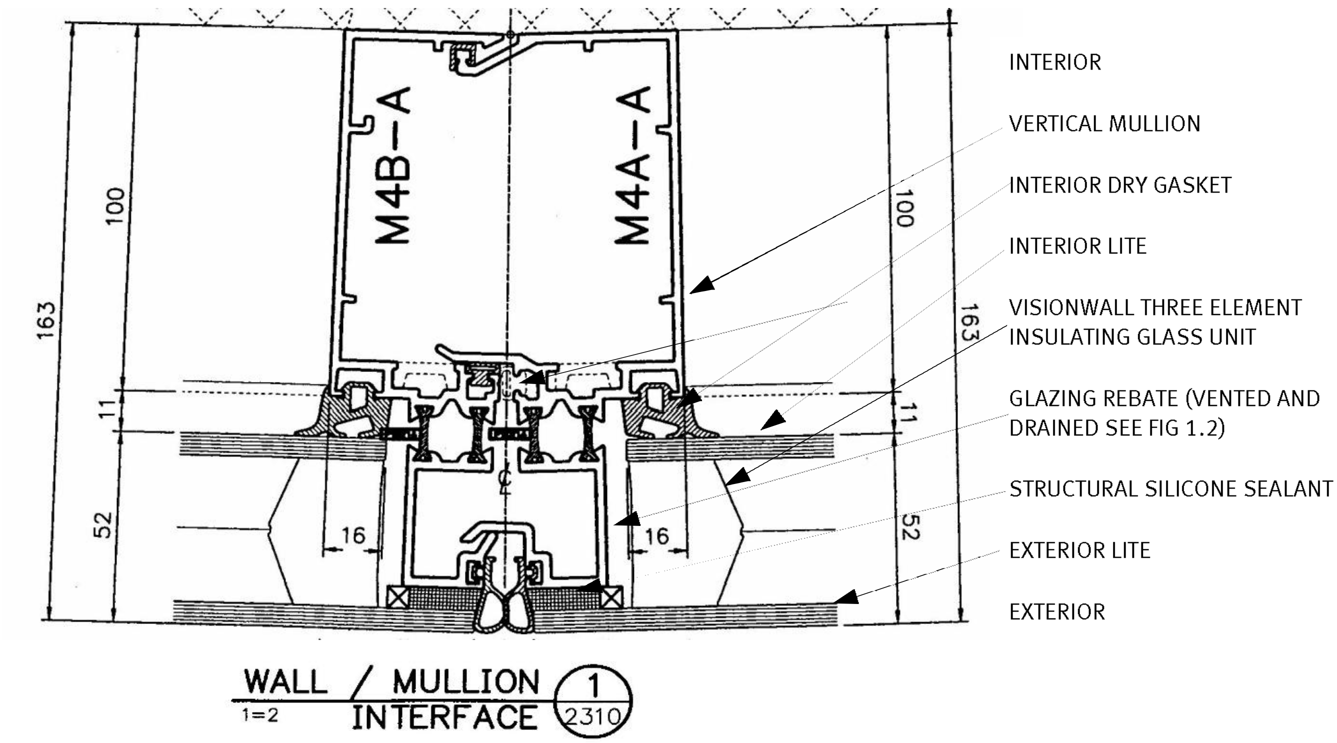


Fig. 2.4.1 Typical Vertical Mullion Detail – Visionwall Shop Drawing # 2702 Dated 99/04/30

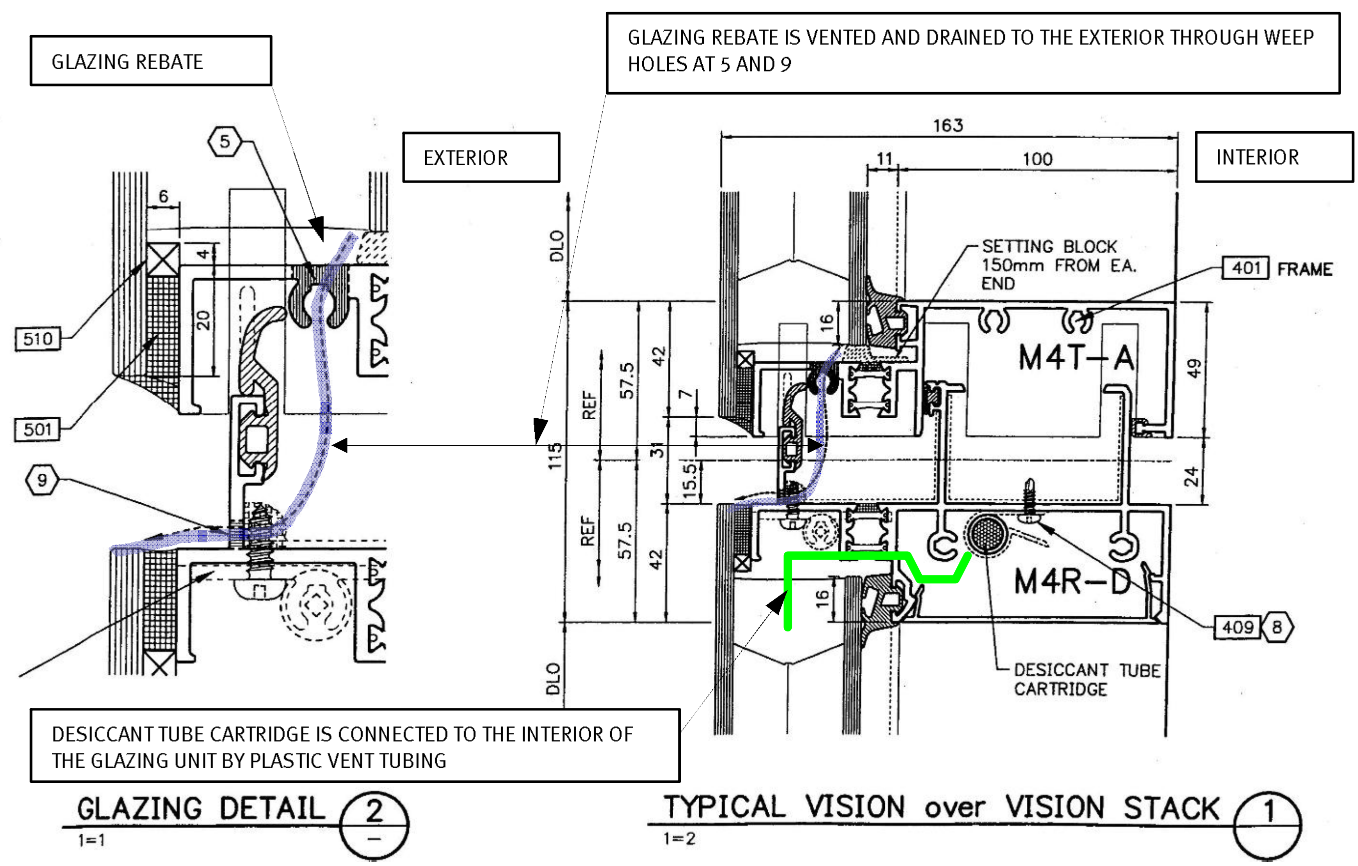


Fig. 2.4.2 Typical Stack Joint and Venting Detail – Visionwall Shop Drawing # 2600a Dated 99/04/30

2.5. Insulating Glass Unit Design

The Visionwall proprietary IGU used on this project has a significantly different design philosophy than conventional structurally glazed Insulating Glass Units (Conventional IGU). Conventional high performance IGUs are hermetically sealed units consisting of 2 or 3 lites of glass separated by spacer bars that are filled with desiccant (Fig. 2.5.1). The two lites of glass are sealed together at the perimeter of the IGU with a primary vapour retarding sealant such as polyisobutylene (PIB) and the aluminum spacer. A secondary structural and weathering sealant such as silicone is provided between the lites of glass to the exterior of the primary seal. The secondary sealant is installed to provide structural attachment and prevent the ingress of air and water. The desiccant installed inside the hollow spacer bar absorbs the moisture from the air between the two lites of glass to prevent fogging. The amount of desiccant installed in the IGU is typically sufficient to absorb the amount of water that diffuses through the perimeter sealants, and gasses that may enter through microscopic pores, over the life of the assembly.

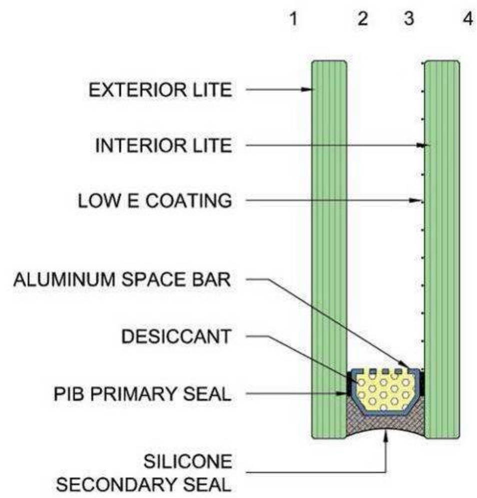


Fig. 2.5.1 Conventional Insulating Glass Unit

The Visionwall IGUs that were originally installed at One Wall Centre are shown in Fig. 2.5.2 and 2.4.2. The Visionwall IGUs have two unique design features that set them apart from conventional IGUs. Firstly, they contain an optically clear PET film that is suspended between the outer and inner lites of glass to increase the thermal insulating performance. The optically clear film is suspended on springs that are attached to the spacer bar. The spacer bar consists of a large desiccant filled PVC thermal break mechanically attached between two aluminum extrusions. The glass is fastened to the aluminum spacer bar extrusions with two sided foam tape. The hermetic seal around the perimeter of the IGU consists of a stainless steel foil or band set into a thin layer of a butyl based thermoplastic sealant. Thermoplastic refers to a class of sealants that soften when heated and return to their original properties when cooled to normal temperatures.

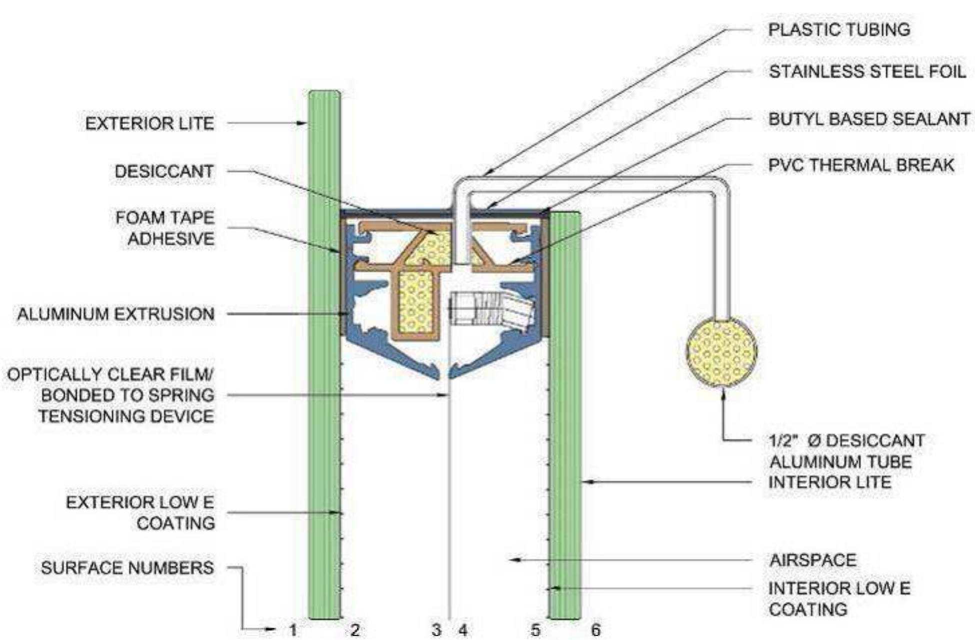


Fig. 2.5.2 Original Visionwall IGU as installed

The second significant departure from conventional IGUs is that Visionwall IGUs are allowed to vent and equalize to the interior of the building. The venting is done through a small breather tube that is attached to a spigot that penetrates through the stainless steel edge band to the interior of the Visionwall IGU. The breather tube is attached to a large aluminum tube filled with desiccant on the interior of the building. When temperature variation, wind pressure and atmospheric pressure change the volume of air inside the Visionwall IGU, these small volumes of air will flow in and out of the unit through the desiccant tube. The theory is that the desiccant tube will allow air movement while absorbing moisture from the interior air entering the system, thus ensuring that no moisture is able to enter the IGU assembly through the breather tube. If small amounts of moisture are able to enter the Visionwall IGU it will be absorbed by the large amount of desiccant located inside the PVC spacer bar extrusion. The volume of desiccant located inside the PVC spacer bar extrusion is several times that which is contained in the desiccant tube. The desiccant in the spacer bar is typically sufficient to absorb the amount of water that diffuses through the perimeter sealants and gasses that may enter through microscopic pores, over the life of the assembly.

The Visionwall IGUs have a Low-e coating on glass surfaces 2 and 5 to improve the thermal performance of the assembly. The shop drawings indicate that the low-e coatings are soft-coat silver coatings on heat-strengthened exterior and tempered interior glass lites manufactured by Viracon.

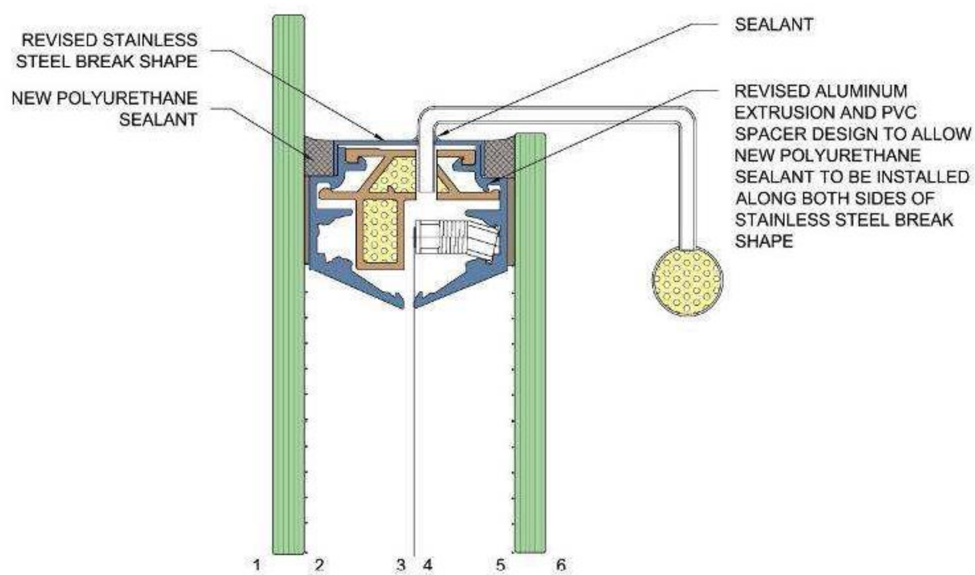


Fig. 2.5.3 New Visionwall IGU

Subsequent to the completion of One Wall Center, Visionwall changed their IGU edge seal design. New Visionwall IGUs delivered to site as replacement units in 2008 have a revised edge seal design. The new edge seal design shown in Fig. 2.5.3 incorporates a revised spacer bar assembly that has a 6mm reveal on both sides. The stainless steel foil strip has been revised into a break shape that fits into the reveal in the spacer and polyurethane caulking is installed to fill the 6mm reveal spanning between the stainless steel break shape and the adjacent glass lites. The new edge seal design incorporates a better sealant profile which will allow more differential movement without causing damage, and incorporates a thermosetting sealant that will be less prone to ridging caused by temperature variations than the original edge seal design.

2.6. IGU Seal Failure Modes

Failure of insulating glass units is generally considered to occur when clear vision through the unit is obscured by condensation (fogging)[1]. The Visionwall IGUs contain a Zeochem Molecular Sieve Type 3A desiccant in the spacer bar and in the desiccant tube that will absorb the initial moisture in the unit at the time of assembly as well as some moisture that enters the IGU through air leakage or vapour diffusion. When the IGU is new, the desiccant will generally have moisture content less than 6% at 20°C[1]. At this moisture content, the desiccant will dry the air inside the IGU to a dew point below -65 °C[2]. The dew point is the temperature to which the air must be cooled for water vapor to condense into water. When the dew point temperature falls below freezing it is often called the frost point, as the water vapor no longer creates dew

[1] Canada Mortgage and Housing Corporation (CMHC), "Predicting Time to Fogging of Insulating Glass Units" Research Highlight 05-117, 2005 http://www.cmhc-schl.gc.ca/odpub/pdf/64911.pdf

[2] Zeochem Molecular Sieve Type 3A Isotherm, 1990 – Refer to Appendix J for further information

but instead creates frost. For the purpose of this report we have used dew point to refer to both the dew and frost point to refer to the temperature that either dew or frost is observed. When the dew point of the air inside the IGU is at -65 °C, moisture will not condense or fog inside the IGU unless exterior air temperature drops below -65 °C and this is not possible in Vancouver where the record low temperature is -17.8 °C[3] and the National Building Code of Canada January 2.5% design temperature is -7 °C. Over the life of the IGU, very small amounts of moisture will move through the perimeter hermetic seal through the process of diffusion, as a gas through microscopic holes, and through the vent tube. As the desiccant absorbs additional water it looses its ability to lower the dew point of the air inside the IGU. For example, when the moisture content of the desiccant is raised to 20% at 20°C, the dew point of the air inside the IGU will be around -5°C. At a dew point of -5°C, condensation will occur on the coldest glass surface exposed to the inside of the IGU (the interior surface of the exterior glass lite, or surface number two) during cold winter months when the exterior temperatures are below this temperature. In Vancouver surface temperatures of -5°C are relatively common during this period, and IGUs with dew points in this range will generally exhibit some condensation during the winter months. Table 2.6.1 summarizes one method of predicting the life span of IGUs based on the measured dew-point values, a study performed by the Canada Mortgage and Housing Corporation (CMHC) [1].

Table 2.6.1 Prediction of IGU Life Based on Measured Frost/Dew Point

Dew Point Temperature (°C)	Prediction of Remaining Life
Less than -62°C	There is almost no moisture in the IGU cavity, thus the IGUs can be expected to have a "very long expected future clear life".
Between -62°C and -18°C	There is some moisture in the cavity, thus the IGUs can be expected to have a future clear life less than units with a dew-point temperature less than -62°C.
Between -18°C and 0°C	There is "considerable" moisture in the air space, thus the IGUs will have a relatively short future life. Estimation of remaining life span requires knowledge of the construction of the units, including the desiccant type and manufacturer.
Above 0°C	Permanent fogging of glass surfaces within the IGU can be expected to develop within two years.

While not directly applicable to the vented Visionwall IGUs, the values in Table 2.6.1 provide a good starting point for the understanding of the relationship between the measured dew point values and the relative condition of the IGU.

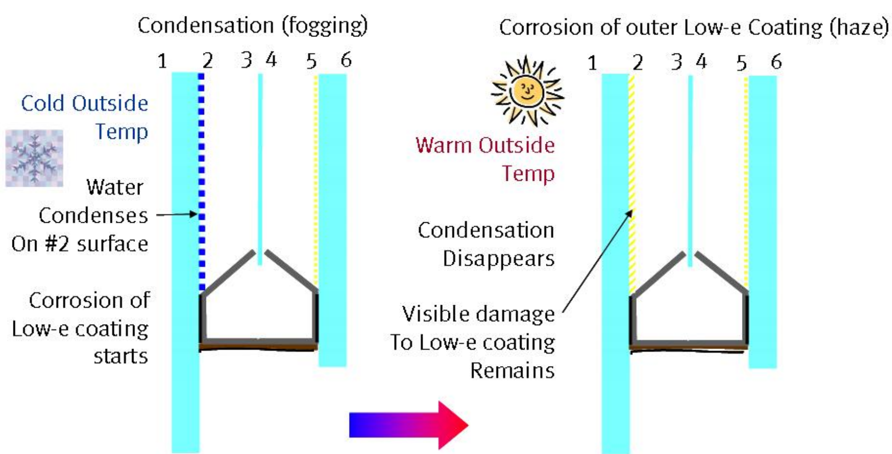


Fig. 2.6.2 Condensation (fogging) vs low-e Corrosion (Haze)

Another factor that influences the time to failure of an IGU is the type of coating applied to the interior glass surfaces. Traditionally an IGU with no coatings that is nearing failure will have visible condensation for only a few days per year, and over a period of years this will increase until the desiccant is saturated and the IGU becomes permanently fogged. The Visionwall IGUs installed on One Wall Centre have a low-e coating on surfaces 2 and 5. Low-e coatings act to reflect radiant heat originating from indoors back to the inside keeping heat inside

[3] Environment Canada Climate Normals, 1971- 2000, http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

in the winter, and infrared radiation from the sun away, keeping it cooler inside during the summer. The low-e coatings within the Visionwall IGUs consist of a very thin layer of silver applied to the glass, and as such, are very prone to corrosion/oxidation if exposed to liquid water even for a short time. When condensation occurs inside a Visionwall IGU, fogging will occur on surface 2 first (Fig. 2.6.2). As soon as the condensation occurs, the low-e coating on surface 2 will begin to corrode resulting in a visible white oxide. As the corrosion progresses the white oxide becomes more visible and results in severe spotting and hazing of the IGU. The corrosion of the low-e coating is permanent and can not be reversed during warmer weather like the initial condensation observed in a non low-e coated IGU nearing failure. IGUs that are constructed with low-e coatings, especially those with the coating on surface 2, will generally exhibit permanent corrosion hazing before the sealed unit becomes permanently fogged due to the condensation of water. Therefore, it is more likely that the service life of the IGUs will be driven by the level of permanent hazing due to low-e corrosion, and this will occur sometime after the first condensation event but long before permanent condensation of the IGUs.

The primary factors influencing the service life of an IGU are as follows:

- Permeability of the perimeter seal - The combined vapour, air tightness and durability of the hermetic perimeter seal. An effective vapour barrier and air barrier are required to limit the transfer of moisture across the perimeter seal for the entire life of the IGU. The desiccant will be quickly saturated if air can enter and exit through discontinuities in the edge seal.
- The type, quantity and effectiveness of the desiccant – A sufficient quantity of desiccant must be installed to absorb the expected moisture over the service life of the IGU.
- The in-service environment – The IGU must be adequately supported and the glazing rebate vented and drained to prevent the buildup of water against the perimeter edge seal.

2.7. Investigation Protocol

On May 15th and 16th, 2008 Dan Chindea from Visionwall and Brian Hubbs, Matt Mulleray, Ryan Gregory, and Graham Finch from RDH met at One Wall Centre to collaboratively agree on a standard test protocol to be used when assessing the glazing units on the residential portion of the building. The visual review and classification system used by RDH during the 2006 and 2007 investigations was used as the visual review protocol so that results from previous years could be compared to future results. The new Visionwall IGUs stored in the parkade were used as a control sample to calibrate the protocol. On May 15th and 16th glazing units in suite 3101 and 4602 were visually reviewed by all present using the collaborative investigation protocol. During this period, frost point testing and pressure testing on selected IGUs was also completed collaboratively. The following collaborative investigation protocol was used as the bases for the IGU investigation to date:

Visual review

The visual review protocol is based on the 3m medium and heavy visual defect intensity guidelines outlined in CAN/CGSB-12.3. to facilitate a qualitative comparison with the severity of the low-e corrosion. For example, if the corrosion of the low-e coating is viable from a distance of 3m or it is readily visible as a cloudy surface it would be visually similar to a heavy intensity process surface defect that would not be generally acceptable for glazing quality glass. All IGUs reviewed are classified according to the following categories:

a. Severe – Any visible condensation, large corrosion spots on low-e coating, large clusters of small spots, or permanent haze visible from 3m,

Visual condensation and corrosion visible from 3m

Large low-e corrosion spots visible from 3m

Permanent haze visible from 3m

Large low-e corrosion spots visible from 3m

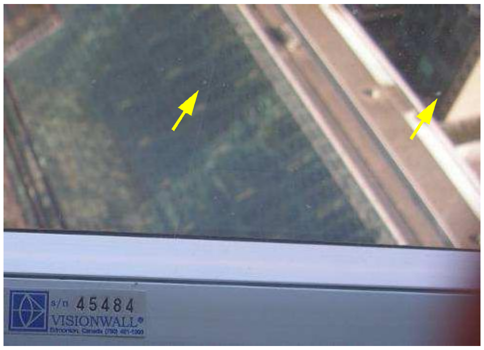
"Scratch" like patterns of frost/corrosion visible from 3m

b. Moderate – Any corrosion/oxidation of the low-e coating visible from 3m,

Moderate corrosion spots visible from 3m

Moderate corrosion spots visible from 3m

c. Minor – Any visible corrosion/oxidation of low-e coating, but not visible from 3m,



Minor corrosion spots only visible from <3m away

Minor corrosion spots only visible from <3m away

d. Clear – No visible corrosion/oxidation of low-e coating or condensation in IGU.

In all cases the condition and presence of low-e corrosion within the IGU was confirmed by closely inspecting the glass for debris or dirt on the exterior or interior surface which may have appeared as low-e corrosion from a greater distance.

Dewpoint Testing

Test the dewpoint of the air inside the glazing unit in general conformance with ASTM E 576 “Standard Test Method for Frost/Dew Point of Sealed Insulating Glass Units in the Vertical Position” with the understanding that it was not possible to gain access to the exterior of the IGU to clean, or condition the IGU at a constant temperature:

a. Record dewpoint temperature with the dewpoint test apparatus,

b. If possible, record the exterior and interior temperature and estimate the temperature of the desiccant.

c. If possible, normalize dewpoint temperature results for all future dew point readings to a standard desiccant temperature (25°C)

d. Obtain exterior climatic data for the 24-hour period prior to the test.

Pressure Decay Test

Perform the following pressure decay test as follows on all clear units and a sample of moderate and severe units.

a. Remove desiccant tube.

b. Pressurize glazing unit to between 250 Pa and 500Pa through the desiccant tube.

c. Monitor pressure in the glazing unit over a 2 to 4 hr period and compare results to a sealed control sample.

3. Investigation and Analysis

3.1. In-Situ Visual Review

Between February 2006 and February 2009 RDH visited the building on several occasions to perform visual reviews of the Visionwall IGUs at One Wall Centre. The raw data from all visual reviews is contained in Appendix C and is summarized in Appendix A. All visual reviews were conducted using the investigation protocol described in section 2.1. Visual review of the Visionwall IGU is the most effective in-situ method of determining if the desiccant has absorbed enough moisture to allow the dew point of the air inside the IGU to exceed the exterior ambient air temperature. As discussed previously, if the dew point inside the IGU reaches the temperature of the inside surface of the exterior glass lite (surface 2), then condensation will occur. Over time this condensation will permanently corrode the low-e coating leaving a telltale corrosion residue on surface 2. The greater the amount and severity of the corrosion residue, the more often the IGU is likely undergoing sustained condensation during colder temperatures. Using careful observation during the visual review, IGUs were identified as minor, moderate or severe if visible corrosion or condensation could be observed on surface #2. IGUs were identified as clear if no corrosion on surface 2 could be observed even if dirt, water stains, smears or other visual anomalies were observed on surfaces 1, 3, 4, 5 and 6.

In 2006 and 2007 RDH visually reviewed a total of 239 Visionwall IGUs in 17 different suites. Suites were located on various floors and elevations making up a representative sample of the residential portion of the building. Of the IGUs reviewed, 17% had a visual rating of severe, 17% a rating of moderate, 23% a rating of minor, and 43% were clear. In 2008 RDH completed a review of 163 IGUs in 8 suites and found that 25% had a visual rating of severe, 31% a rating of moderate, 30% a rating of minor, and 13% clear (Fig. 3.1.2). During the mockup and broken IGU replacement program completed in 2009, RDH completed a visual review of 53 IGUs in 3 suites. Of the suites reviewed in 2009, 59% had a visual rating of severe, 26% a rating of moderate, 15% a rating of minor, and 0% were clear (Fig. 3.1.3).

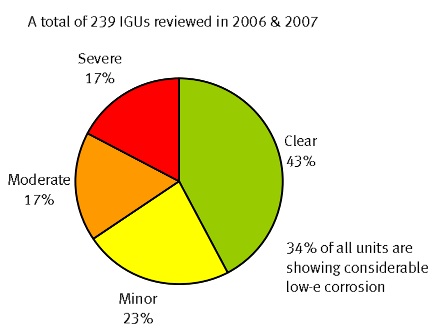


Fig. 3.1.1 2006-2007 Visual Review Summary

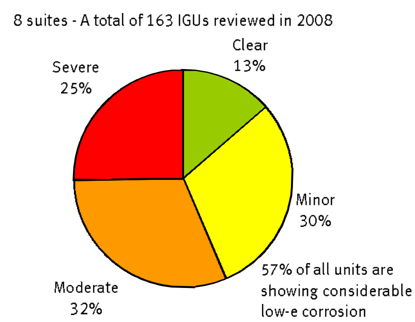


Fig. 3.1.2 2008 Visual Review Summary

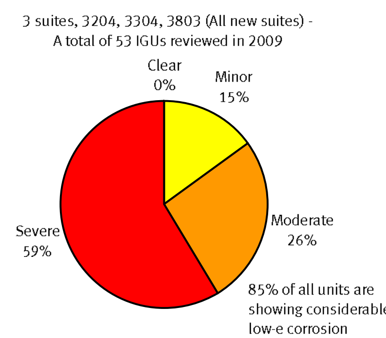


Fig. 3.1.3 2009 Visual Review Summary

Based on all of the visual observations recorded by RDH between 2006 and 2009, the visual condition of the IGUs appears to be rapidly worsening over time. Fig. 3.1.4 and Fig. 3.1.5 compares the visual results from five suites that were reviewed both during the 2006-2007 investigation and again in 2008. When these results are compared, it is clear that rapid progressive failure of the Visionwall units is occurring. In less than two years the number of clear units has halved and the percentage of units showing either moderate or severe damage to the low-e coating doubled. Considering that the visual condition of the IGUs continues to worsen rapidly over time, it is not possible to use all of the visual review data taken between 2006 and 2009 to predict a current overall categorization for the entire residential portion of the building. Instead it would be more accurate to use the results from 2009 or the combined 2009 and 2008 sample to extrapolate the overall building condition at the time this report was written.

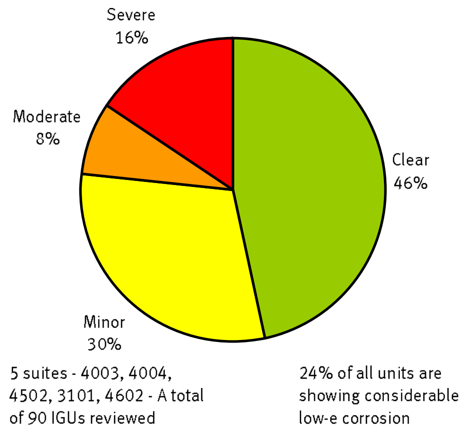


Fig. 3.1.4 2006-2007 Visual Review Summary (Suites 4003,4004,4502,3101,4602 only)

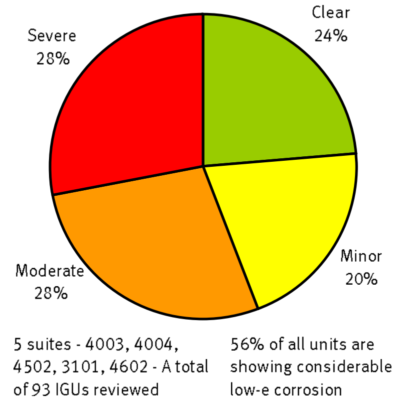


Fig. 3.1.5 2008 Visual Review Summary (Suites 4003,4004,4502,3101,4602 only)

Corrosion of the low-e coating was observed on all elevations and residential floor levels. In Fig. 3.1.6 the visual results from the 2008 review are presented graphically on the 40th floor plan. None of the IGUs were identified as clear, indicating that condensation has occurred within all the IGUs on this floor. The severity of the corrosion is worse on the east and south side of the building where positive and negative wind loads from the prevailing south east winds are higher and more frequent. To a lesser extent the level of deterioration also appears to be affected by the orientation towards the sun and its resultant solar radiation loads. This relationship suggests that the primary cause of the condensation within the IGUs is wind driven air leakage into the IGU through discontinuities in the perimeter edge seal which is exacerbated by the higher thermal cycling on the southern elevations.

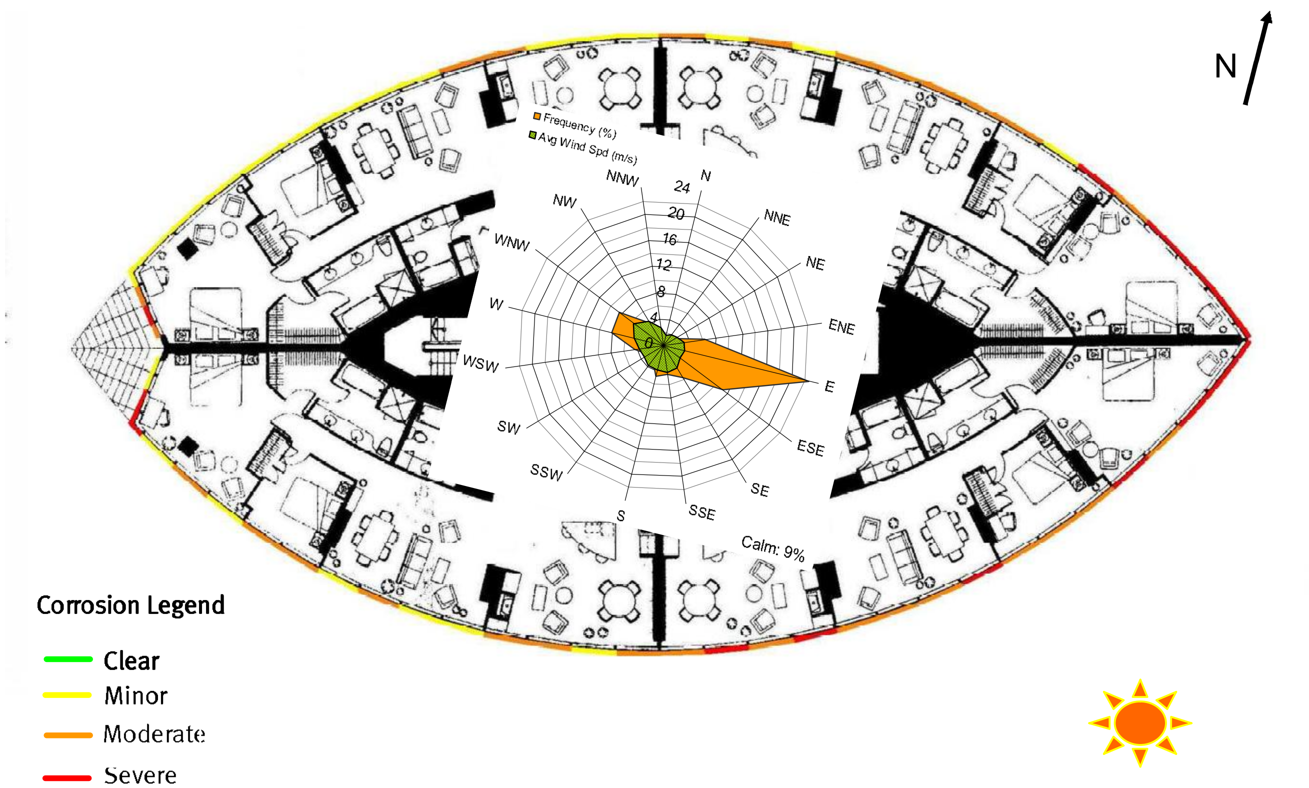


Fig. 3.1.6 2008 Visual Review – 40th Floor Results with local wind speed and direction overlay from YVR wind data

3.2. Dew Point Testing

Dew point testing of a sample of IGUs was performed by RDH in general conformance with the ASTM E 576 Standard Test Method for Frost/Dew Point of Sealed Insulating Glass Units in the Vertical Position, using a Dennis Industries Dew/Frost Point Measuring Apparatus for Sealed Insulating Glass Window. During the testing it was not possible to access the exterior of the glazing units in most locations nor was it possible to condition the IGUs prior to testing. As a result, the exterior surface temperatures of the glass were measured at the closest operable window vent, or the exterior ambient air temperature was recorded along with the interior ambient temperature in order to allow estimation of the desiccant temperature if required.

Table 3.2.1 Water Vapour Equilibrium of Desiccant as a Function of Temperature (Source: Zeochem Molecular Sieve Type 3A Isotherm, 1990, Appendix J)

Desiccant Temperature	Dew Point Temperature (˚C)			
	4%MC*	10%MC*	15%MC*	20%MC*
5˚C	-79	-68	-59	-18
10˚C	-77	-65	-55	-14
20˚C	-72	-58	-46	-4
30˚C	-67	-52	-38	7
40˚C	-61	-45	-30	18
50˚C	-55	-37	-21	29

*Weight of water as a percentage of weight of dry adsorbent

One variable that makes the in-situ field measurement of IGU dewpoint difficult is the capacity the desiccant to absorb moisture varies with temperature (Table 3.2.1). For example if the moisture content of an IGU with a Zeochem 3A desiccant at a moisture content of 20% at 10^{0}C is measured it will have a dewpoint of -14 ^{0}C, if the desiccant in this same unit is raised to 50^{0}C it will have a dewpoint of 29 ^{0}C. A Zeochem 3A desiccant moisture content greater than 20% is approaching saturation for the purpose of preventing fogging in IGUs. Under normal glazing desiccant service temperatures ranging between 5˚C and 50˚C the dewpoint in an IGU with desiccant at 20% moisture content will be between -18˚C and 29˚C respectively. Therefore, for the purpose of this report, in-situ measured dewpoints greater than -18 ^{0}C, regardless of the temperature of the desiccant, are assumed to be close to saturation and at or near the point when condensation will occur within the IGU causing permanent damage the low-e coating. Conversely IGUs with in-situ measured dewpoint less than -62 ^{0}C are assumed to have desiccant with reasonable capacity to absorb additional moisture. IGUs with a measured dewpoint between -62 ^{0}C and -18 ^{0}C are in the cautionary category. These IGUs have absorbed significant moisture and those with dewpoints closer to -62 ^{0}C are assumed to be closer to the new condition while those closer to -18 ^{0}C are assumed to be nearing the saturated condition. Additional analysis and laboratory testing beyond the scope of this report is required to accurately predict the future life of these IGUs.

Another variable that affects the correlation between the visual categorization and the measured dew points is the desiccant tube replacement program. The desiccant tubes on the residential potion of the building were replaced by Visionwall after construction in an attempt to mitigate the condensation that was reported on the IGUs. In some cases it is our understanding that these desiccant tubes were replaced up to 3 times on various IGUs. It is possible that condensation occurred after construction, and the new replacement desiccant tubes were successful in temporarily lowering the dewpoint within the IGU. However, the volume of the desiccant contained inside the IGU spacer bar is several times greater than the external desiccant tube. Therefore, we would expect that the replacement tube would only have a relatively short term influence on the dewpoint of the IGU until the moisture source that saturated the main IGU desiccant had the same effect on the much smaller quantity of desiccant in the external desiccant tube.

The dewpoint test is performed by cooling down a small area of the interior glass to a known temperature. As the temperature of the glass is slowly reduced the cooled area is periodically checked for condensation on surface 5 (the exterior surface of the inside glass lite). The dewpoint temperature is measured when condensation first starts to form. Fig. 3.2.2 and Fig. 3.2.3 show the dewpoint testing apparatus, and interstitial condensation formed on surface #5 during a test of an IGU at One-Wall Centre.

Fig. 3.2.2 Dewpoint Test Apparatus and Condensation Indicating Dewpoint Temperature

Fig. 3.2.3 Dewpoint Test Apparatus and Condensation on Surface #5 Indicating the IGU airspace Dewpoint Temperature

The results of the dewpoint testing are contained in Appendix C and summarized in Appendix A and in Table 3.2.2. The dew point measurements taken during 2006 and 2007 follow a trend upwards as the severity of damage to the low-e coating increases. For example, the average measured dewpoint increases from -19.7 ^{0}C for the clear category to -0.9 ^{0}C for the severe category and the amount of IGUs with dewpoint greater than -18 ^{0}C is 100% for both the moderate and severe categories. In 2006 and 2007, 67% of the tested clear IGUs also had a dewpoint greater than -18 ^{0}C. This indicates that a significant percentage of the clear IGUs tested in 2006 and 2007 were close to the point where condensation could occur, and damage the low-e coating. This is consistent with the results from the visual review (Fig 3.1.4 and 3.1.5) where almost half of the clear units from five suites reviewed in 2006 and 2007, were found to have visible low-e corrosion when they were reviewed a second time less than two years later in 2008.

In 2008 the number of IGUs tested with a dewpoint above -18 C was 88%, which is higher than the 2006 value of 83%. There are a few anomalous readings where a low dewpoint was measured on IGUs that exhibited corrosion of the low-e coating. This result is possible if the desiccant was very cold or the solar heat gain at the time of the measurement was so large that it warmed the exterior surface of the interior glass sufficiently to delay the start of condensation. In 2008, 89% of the clear IGUs tested had measured dew points in excess of -18 ^{0}C indicating that the majority of the clear IGUs are at or near the point when condensation can occur and cause damage to the low-e coating.

Table 3.2.2 Dewpoint Test Results by Visual Category

Visual Classification	# of Dew Point Tests		Average Dew Point [°C]		% of Results Greater Than -18°C	
	2006-2007	2008	2006-2007	2008	2006-2007	2008
Clear	12	9	-19.7	-3.9	67%	89%
Minor	6	13	-12.7	-7.6	83%	85%
Moderate	4	18	-3	-4	100%	94%
Severe	7	17	-0.9	-3.7	100%	82%
Total	**29**	**57**	**-11.4**	**-4.8**	**83%**	**88%**

The results of the dewpoint testing indicate that the desiccant inside the IGU is at or near saturation on the majority of the IGUs regardless of their visual classification. In addition, the desiccant is continuing to absorb moisture increasing the level of visual corrosion rapidly over time. The results from the review of suite 4502 are shown graphically in Fig. 3.2.4 to show the level of degradation in both the dewpoint and the visual condition over a two year period.

Suite 4502 -				
Glazing Unit Serial #	Feb 13/2006 Visual Condition	Aug 7/2008 Visual Condition	2006 Dewpoint	2008 Dewpoint
43205	Clear	Clear		-12
43238	Clear	Clear		1
43239	Clear	Clear	-55	-4
45157	Clear	Clear		-1
45458	Clear	Minor		2
45474	Clear	Minor		2
45470	Minor	Severe		3
45466	Minor	Moderate		4
45357	Minor	Moderate		
45459	Minor	Severe		
45456	Minor	Moderate		
45150	Minor	Severe		2
45153	Minor	Moderate		2
45367	Clear	Severe		8
44900	Clear	Severe	-10	4
45484	Severe	Severe	-5	6

Fig. 3.2.4 Results from the 2006 and 2008 visual review and dewpoint testing shown graphically on the floor plan for Suite 4502

In addition to the increase in level of deterioration, Fig. 3.2.4 also shows a similar failure pattern to the 40th floor wherein IGUs more directly affected by wind induced pressures from the south eastern prevailing winds are generally in a more advanced stage of deterioration than those near the centre of the north elevation.

3.3. Desiccant Testing

In addition to the internal desiccant chambers within the IGU, the Visionwall units at One-Wall Centre have replaceable externally mounted desiccant tubes. All external desiccant tubes were replaced by Visionwall in March 2003, and from December 2004 through June 2005 at glazing units which had various visual classifications.

In 2006, RDH removed 8 desiccant tubes from several IGUs to test the moisture content. New desiccant tubes were installed to replace the ones removed for testing. The moisture content of the desiccant was calculated by removing the entire desiccant from the tube, weighing the desiccant, baking the desiccant at 230 ^{o}C and recording the weight of the sample once all weight loss has stopped. The total weight loss is then divided by the total dry weight to achieve the moisture content. The moisture content is then divided by the assumed saturated moisture content of 22% to achieve the percent saturation value. The results of the desiccant testing are shown in table A7 of Appendix A. The moisture content of the desiccant tested was found to be between 15 % and 19 % on six of the eight desiccant tubes tested. On the remaining two clear IGUs the desiccant moisture content was 0.8% and 7.4%, these desiccant tubes were still actively providing dehumidification for the ventilation air into the IGUs. The other six desiccant tubes were close to saturation and therefore were not providing adequate dehumidification of vent tube air leakage.

The majority of the new desiccant tubes tested are close to saturation after less than two years in service. The accelerated saturation of the desiccant tubes indicates that the IGU is not a closed airtight system as designed. Instead, the high moisture levels in the desiccant is likely caused by a discontinuity in the perimeter IGU seal allowing moist air leakage through the perimeter seal, into the IGU, through the desiccant tube, and into the building. The results are also an indication that desiccant tube replacement has not been an effective remedial repair strategy.

3.4. Pressure Testing

Pressure testing is one of the production quality control methods used by Visionwall to check the air tightness of the perimeter seals before the IGUs are assembled into the frames. In the factory, the IGUs are pressurized with a mechanical air compressor and an analog gauge is attached to the breather tube for a few minutes to check for a drop in pressure. If the pressure drops quickly the IGU is sent back to the assembly line for resealing. In 2006 and 2007 a similar pressure test was tried in the field using a hand pump and analog gauge, however, it was found that an adequate volume of air could not be delivered with the hand pump to achieve 500Pa of pressure regardless of how long air was pumped into the IGU, indicating a leak path through the IGU seal. During the testing protocol development on May 15th and 16th, 2008 it was collaboratively agreed that a more accurate measurement of the pressure decay was required. RDH developed a pressure test apparatus and protocol to monitor the pressure inside the IGU over a one hour period. Typically a pressure of up to 250 Pa was applied to the IGU instead of 500 Pa as in most cases the units could not be easily pressurized to 500 Pa due to air-leakage out of the IGUs.

The pressure testing protocol and results are shown in Appendix B. The pressure test results from suite 3903 along with the two new clear IGUs that were located in the storage area are shown in Figure 3.4.1. In Suite 3903 and 4502, the results of the pressure testing correlate well with the visual condition of the IGUs. In these suites the IGUs with high air leakage rates (faster decay time), generally had a higher level of low-e corrosion damage than those with a slow decay time. The apparatus was calibrated with a perfectly sealed container and no pressure loss or decay was observed, therefore, any decay within the IGU is indicative of a small defect in the perimeter edge seal or desiccant tube penetration.

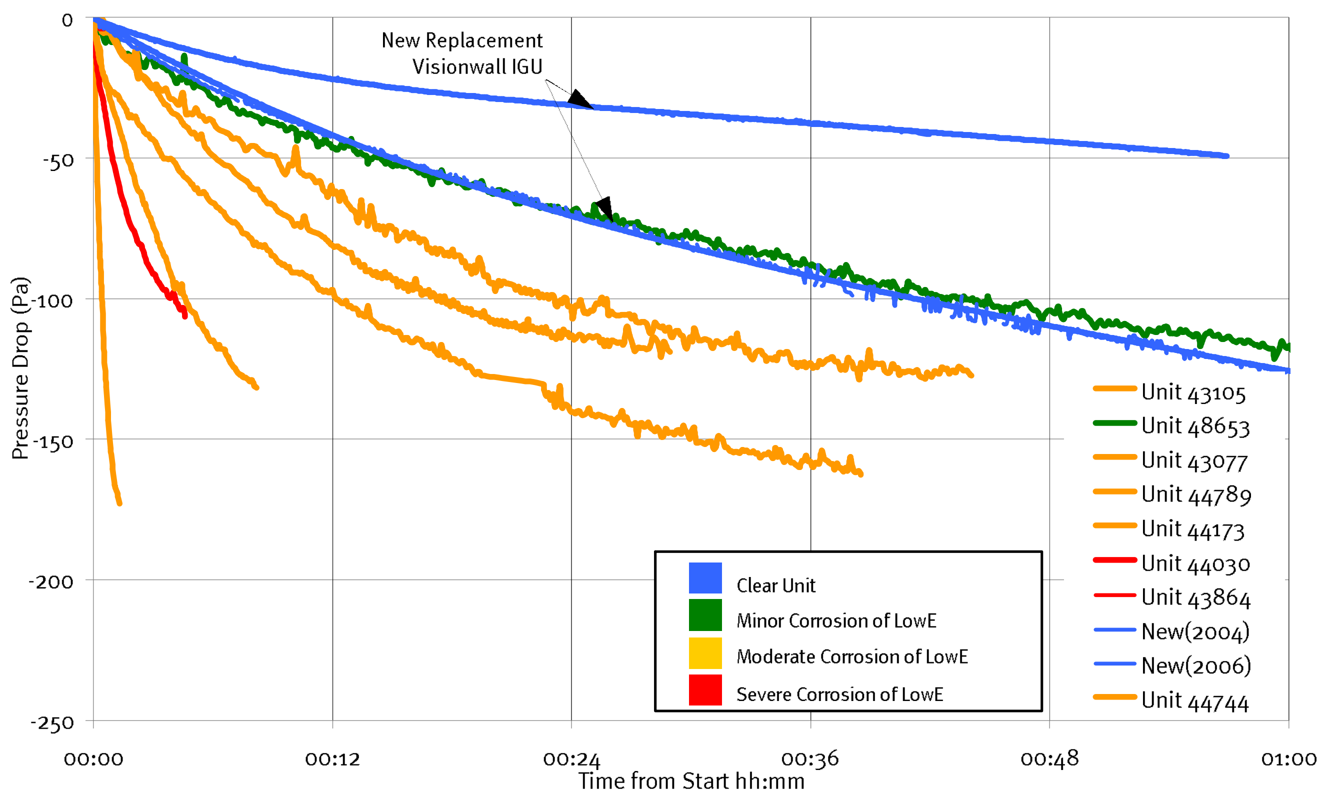


Fig. 3.4.1 Pressure Test Results, Suite 3903 by Visual Classification

A significant observation made during the pressure testing was that the two new replacement IGUs provided by Visionwall in 2004 and 2006 both showed significant pressure decay over the one hour period. This pressure decay suggests that these new IGUs already contain small perimeter seal defects prior to installation. In the case of the new IGU manufactured in 2006, the decay curve was similar to IGU 48653 which was exhibiting minor condensation of the low-e coating. This similar decay curve suggests that if the replacement IGU is installed in the same location, the new IGU will have a similarly unacceptable service life.

All IGUs pressure tested on the 40th floor had either very fast decay curves, or in the case of four of the 10 IGUs tested, no pressure could be built up within the IGU using the high pressure compressor (Appendix B: Figure B23). Of these four IGUs, either the desiccant tube is not attached to the IGU, or the discontinuities in the edge seal are many times larger than the opening area of the desiccant tubing. On the 40th floor, the pressure decay in all IGUs was very fast regardless of their visual condition (only six units tested), and therefore did not correlate as well as the results from 3903 and 4502.

3.5. In-Situ Pressure and Air Flow Testing

In an effort to determine how moisture is entering the Visionwall IGUs from the exterior or interior, and to aid in the development of a prediction method for remaining service life, the pressure and flow rate of air moving through the desiccant tube of several IGUs at suite 4502 and the four suites at the 40th floor were monitored. The pressure and airflow test protocol, apparatus and results are contained in Appendix B.

Wind constantly subjects a building to pressure, depending on the building shape and wind direction, areas of the façade will be under positive or negative pressure, or cause a pressure difference between the exterior and interior of the building. At One Wall Centre, this pressure difference acts across the curtain wall framing and IGUs. As the glass of the IGUs is somewhat flexible, under wind pressure the flexing glass will cause the airspace width to expand and contract. This creates a pumping action whereby air is constantly pulled in and expelled through the desiccant tube and other edge seal discontinuities. To measure this pumping action and airflow, pressure gauges and flow sensors were attached to IGU airspace in five suites to measure the in-situ flow and pressure caused by wind and also solar loading.

The results of the air flow testing show a direct correlation between the wind speed and direction with the pressure within the IGUs and resultant air flow measured through the desiccant tubing. Lesser effects are seen as the result of solar radiation and glazing temperatures. Positive pressures within the IGU airspace (with respect to the interior) cause air to be expelled from the IGU and out of the desiccant tube and other edge seal defects. Negative pressures within the IGU airspace cause air to be drawn into the IGU through the desiccant tube but also through other edge seal defects. Because of the elliptical wing shape of the building, positive or negative pressures are difficult to estimate based on wind-speed or direction, however typically positive pressures result from wind perpendicular to the surface, with negative pressures resulting on the leeward and side walls.

At One Wall Centre, the annual average wind-speed is approximately 6.5 km/hr with the predominant wind direction from the Southeast (as measured by an RDH weather station at 300 ft from ground on top of a nearby high-rise). This almost constant wind pressure on the façade causes a pressure different between the exterior and interior but also between the IGU airspace and the exterior or interior.

Fig. 3.5.2 shows the pressure within five monitored IGUs at the 40th floor and Fig. 3.5.2 shows the resulting airflow through the desiccant tube from the IGU into the suite. As shown, the IGU airspace pressure and airflow measured through the desiccant tube is directly influenced by the wind speed and direction.

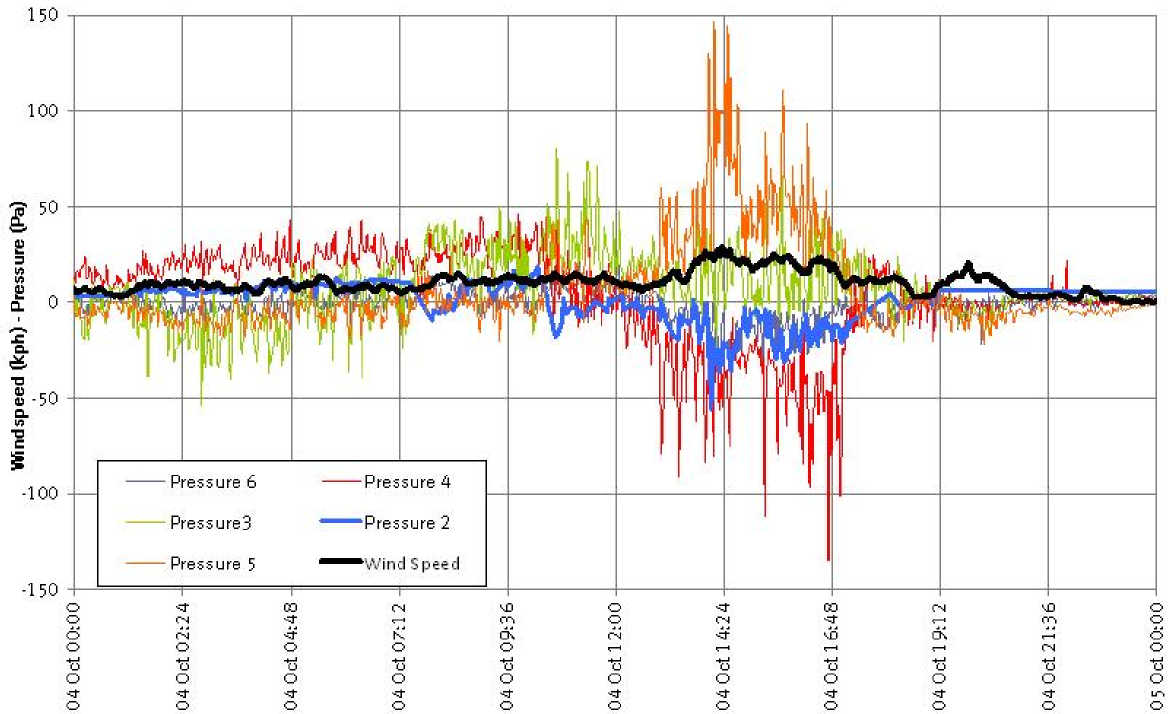


Fig. 3.5.1 Pressure within IGUs at 40th floor over a 24-hour period caused by varying wind-speed and direction.

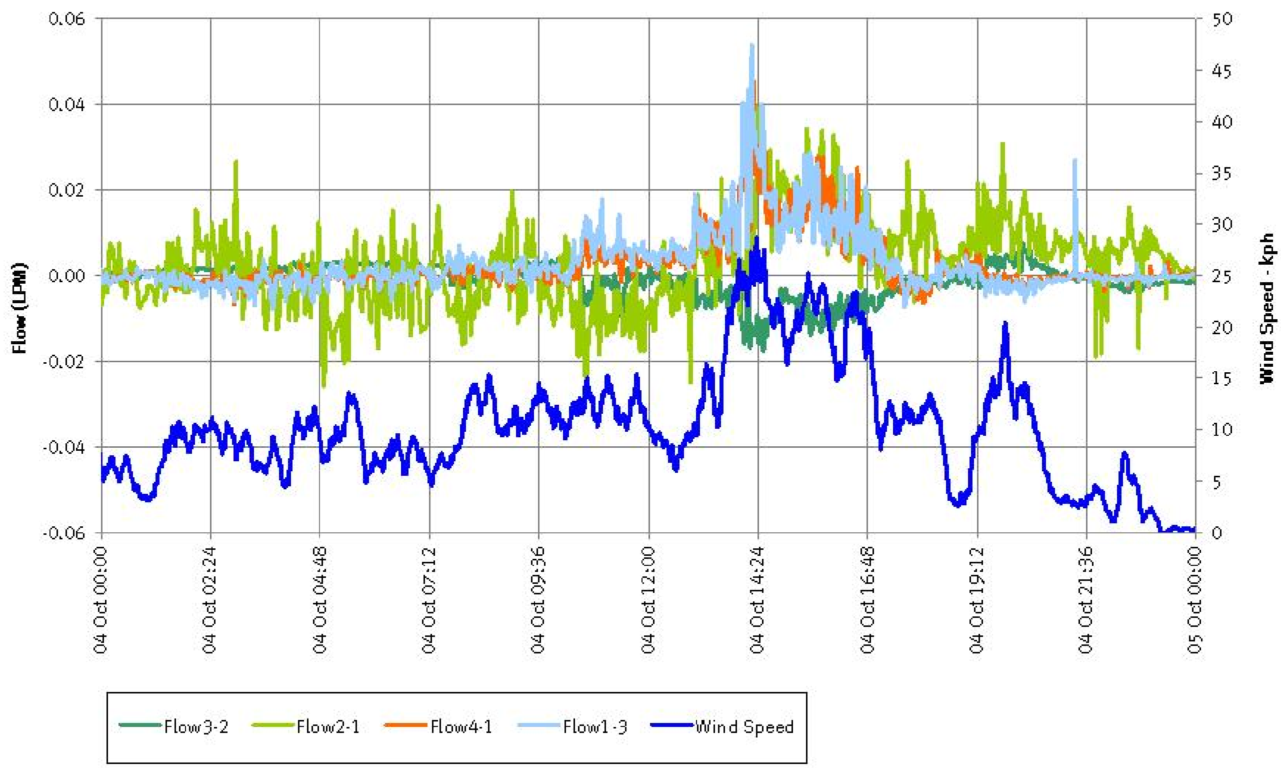


Fig. 3.5.2 Airflow Through Desiccant Tube of IGUs at 40th floor caused by Wind (Wind Direction Variable from East to South)

During light winds, IGU pressures of up to 50 Pa were common, with pressures greater than 100 Pa during larger wind events (up to 30 kph). No storms were recorded during the monitoring period, however much higher pressures of up to 500 Pa within the IGU would typically be experienced during wind-storms with winds greater than 80 kph. These pressures directly have an impact on the flow rate through the desiccant tube, but also flow through other IGU edge seal discontinuities.

On October 4, 2008 a volumetric balance of the airflow measurements through the desiccant tube from the four IGUs was performed. The total airflow (in both directions) as well as the airflow into the desiccant tube from the interior was determined for each IGU. In all cases, the pressure difference across the desiccant tube at the start and end of the monitoring was 0 Pa. Therefore, the volumetric difference between the infiltration and the exfiltration must have been made up from leaks into the IGU from the exterior.

- Flow 2 (Suite 4001, Northwest Corner) – Total flow into and out-of the IGU through the desiccant tube was 11.97 L, and the total flow into the IGU was 3.95 L .
- Flow 1 (Suite 4003, Southeast Corner) – Total flow into and out-of the IGU through the desiccant tube was 6.47 L, and the total flow into the IGU was 4.30 L.
- Flow 4 (Suite 4003, Southeast Corner) – Total flow into and out-of the IGU through the desiccant tube was 5.60 L, and the total flow into the IGU was 3.81 L. Flow 1 and 4 had very similar performance.
- Flow 3 (Suite 4004, Southwest Corner) – Total flow into and out-of the IGU through the desiccant tube was 4.21 L, and the total flow into the IGU was -1.32 L (a net flow out-of the IGU).

In a closed system the total air leaking into the IGU would balance with the air leakage out of the IGU provided that the pressure was the same at the start and end of the monitored period. The difference between the volume of air moving in and out of the desiccant tube over the monitored period indicates that the system is open to the exterior. Provided that the glass is not broken, there are only two locations where openings could exist in the Vision wall IGU; discontinuities in the perimeter seal or the desiccant tube attachment with the IGU.

3.6. Indoor Suite Temperature Monitoring

A preliminary investigation into reported suite overheating was performed by RDH through 2008 in conjunction with our IGU failure investigation. This overheating investigation was not a comprehensive evaluation of the interior environment being maintained within the suites, but was performed in order to corroborate the reports of overheating reported by several suite owners. A more comprehensive study correlating air-conditioning and ventilation provisions, IGU performance, solar effects, and occupant behaviour is required to provide a full picture of all variables affecting the thermal comfort the suites. The data was collected as part of the investigation into the IGU failure. Measurements were recorded in a few locations within each suite, and as such may not be representative of conditions throughout each suite.

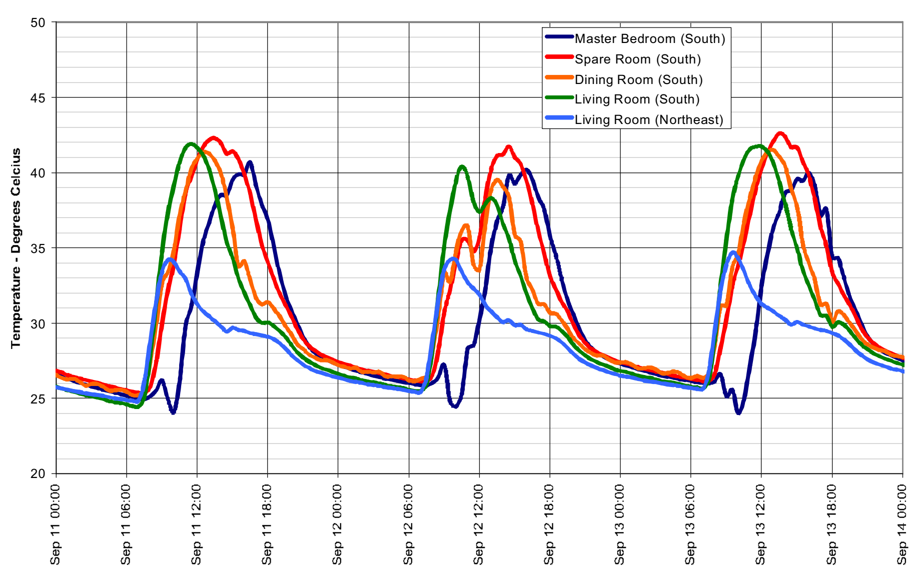


Fig. 3.6.1 Suite 3903 Perimeter air Temperatures, September 11 through 14, 2008

The results of the temperature monitoring are contained in Appendix D. Temperature measurements were taken in Suite 3903, 4001, 4002, 4003 and 4004. In Suite 3903 temperature measurements were taken in 5 locations between July 3 and October 2, 2008 to measure the air temperature near the exterior perimeter. During this period the heating, ventilation and air conditioning (HVAC) system was turned on and set to 21 °C. The perimeter indoor air temperature during three typical sunny days is shown for suite 3903 in Fig. 3.6.1. The temperatures near the windows are uncomfortably warm on sunny days over the entire monitored period and this is consistent the occupant complaints. The warm perimeter temperatures affect the thermal comfort and make it difficult for the HVAC system to equalize the temperature profile throughout the entire suite. The impact of solar heat gain is evident when the north-east facing living room maximum daily temperatures of 35°C is compared to the plus 40°C temperatures experienced in the south facing rooms that that are exposed to the most direct sunlight.

The original design of the HVAC system for the residential suites at One Wall Centre was originally based on the entire tower consisting of dark tinted glass. During construction, the glass on all but one of the residential floors was changed to a clearer glass. The clear glass used in the construction of the Visionwall IGUs allows more solar radiation to enter the building compared to the original dark tinted glass. It is our understanding that a redesign of the mechanical systems were made to offset the additional heat gain expected as a result of the switch to clear. However, it is apparent in Suite 3903 that the combination of glazing properties and HVAC system are ineffective at maintaining a comfortable temperature throughout the suite during clear sunny days.

Temperature monitoring of the suites on the 40^{th} floor indicates that the HVAC system is maintaining ambient temperatures away from the windows in the centre of the suite at relatively comfortable levels when the air-conditioning is running, while the temperatures at the perimeter swing very high due to solar heat gain. Complete results are provided in Appendix D.

Further investigation of the HVAC system, detailed monitoring of the environmental conditions and simulation of the overheating condition is required in order to fully understand the problem and develop appropriate solutions. Replacement of the clear glazing with tinted glass to match the lower portion of the building will likely resolve the overheating problems by reducing the amount of solar energy getting through the glazing to the interior of the building. If clear glazing is used to replace existing failed IGUs, more advanced low-e coatings can be used to lower the solar heat gain coefficient of the IGUs, although this will not be as effective as the tinted glass option, and the colour and opacity of the clear glass will still be noticeably different from the existing IGUs.

3.7. Glazing Removal and Testing

Three new IGUs were ordered from Visionwall in 2007 to be used as mock-up replacement IGUs and to allow a detailed visual review of the perimeter edge seal and subsequent destructive testing and analysis to be performed in a laboratory. Unfortunately, issues with the swing stage followed by problems obtaining a Workman Compensation Board height variance delayed the mock-up removals until 2009. By 2009 one of the mock-up IGUs was reassigned to suite 3903 where it was used to replace IGU 44774 that had spontaneously broken due to a nickel sulphide inclusion. On March 22, 2009 IGU 43882 was removed from suite 3803 and visually reviewed on site, however, when the new replacement IGU was reviewed prior to reinstalling into the building, severe corrosion of the low-e coating of the new IGU was observed indicating that the seal had already failed. In addition, the new IGU was manufactured from two lites of 6mm glass and was structurally unsuitable to replace the original IGU that was constructed of 8mm and 10mm tempered glass. As a result, after IGU 43882 was visually reviewed, it was re-installed in the building. Only one IGU (43161 from suite 3803) was successfully removed from the building on February 28, 2009, replaced with a new IGU, and tested in the laboratory.

3.7.1. Visual Review

The results of the visual review of the three IGUs that were removed from suite 3903 and 3803 are contained in Appendix E. On all three IGUs, numerous large discontinuities were observed in the perimeter edge seal. The most common discontinuity in the perimeter seal was a ripple or “fish mouth” in the stainless steel foil (Fig. 3.7.1.1, Fig. 3.7.1.3 and Fig 3.7.1.4) . At many ripples the stainless steel edge band had pulled away from the butyl sealant allowing a direct path to the joints between the PVC and aluminum extrusion that make up the spacer bar (Fig. 3.7.1.2). Other discontinuities included buckling of the stainless steel along a length of the stainless steel foil (Fig. 3.7.1.5) combined with a small hole between the edge of the stainless steel and the butyl sealant. The largest air leakage path observed was on IGU 43161, removed from suite 3803 where the stainless steel had delaminated from the butyl sealant at large gap in the PVC spacer allowing a direct path to the interior of the IGU (Fig. 3.7.1.6).

During the removal of the IGUs from the building, the curtain wall system was reviewed to examine the as-built drainage and venting provision for the glazing rebate. In all cases the glazing rebate was dry, well vented and drained with no evidence of ponding water or residue blocking the weep-holes.

Fig. 3.7.1.1 Typical ripple or "fish mouth" in the stainless steel edge band. IGU 44774

Fig. 3.7.1.2 Edge band removed at ripple revealing open joint between PVC and aluminum extrusion spacer bar components

Fig. 3.7.1.3 Typical ripple or "fish mouth" in the stainless steel edge band of IGU 43161

Fig. 3.7.1.4 Typical ripple or "fish mouth" in the stainless steel edge band of IGU 43882.

Fig. 3.7.1.5 Typical Buckling of stainless steel edge band of IGU 44774.

Fig. 3.7.1.6 Typical delamination of the stainless steel edge band at a large joint in the PVC spacer between the jamb and corner of IGU 43161.

3.7.2. Air Leakage Testing

Following the visual review on site, IGU 43161 was taken to the RDH laboratory for further testing. The laboratory testing was intended to verify and quantify the air leakage paths prior to disassembly of the IGU to remove samples of the desiccant for moisture content testing. Results from the air leakage testing are summarized in Appendix E.

Prior to verifying the air leakage paths a pressure test performed on the IGU using the pressure testing protocol in Appendix B. In the laboratory, the IGU pressure decayed rapidly from 100 Pa to 0 in less than 1 minute. Following the initial test, the large discontinuity at lower left corner was taped up and the IGU re-tested. When the IGU was retested again it took 10 minutes for the pressure to return to zero. This pressure decay indicates that there are additional discontinuities in the edge seal.

In order to verify the air leakage path through the perimeter edge seal, the IGU was submerged into a water bath and pressurized to 250 Pa above the applied water head (750 Pa). The location and quantity of the bubbles exiting IGU was recorded and used to qualitatively rank the leakage paths. A total of 19 significant discontinuities were confirmed on IGU 43161, of these 5 were minor, 11 were moderate, 2 were major and 1 was very large. At the end of the test, the IGU was pressurized to 750 Pa and the vent tube was removed from the compressor and allowed to free flow out of the IGU under water. The volume of the air bubbles flowing out of the vent tube was similar to the moderate category which was typically caused by a foil ripple. This observation suggests that the air leakage paths through the perimeter edge seal are at least an order of magnitude greater than the airflow possible through the desiccant tube. If the combined leakage paths through the perimeter seal are much larger than the opening in the desiccant tubing, as suggested by the laboratory air leakage test, then much of the air leakage into and out of the IGU will consist of air leakage from the exterior entering and exiting the IGU directly due to changes in temperature, wind pressure and changes in barometric pressure. This air leakage will deposit moisture in the IGU desiccant without flowing through the exterior desiccant tube. This finding indicates that replacement of desiccant tubes will not be an effective

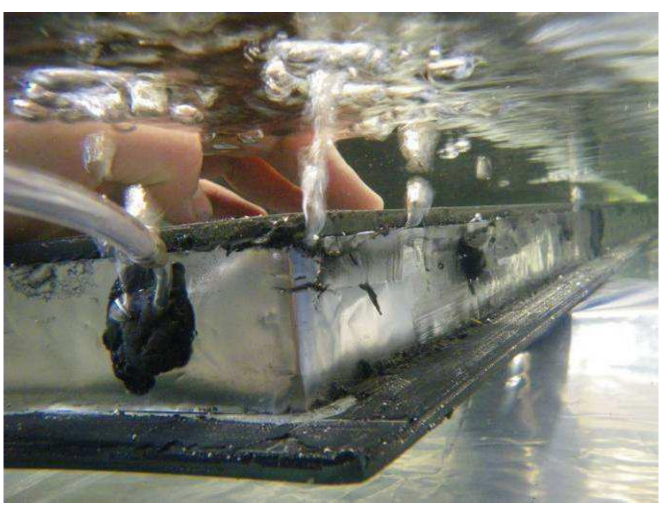


Fig. 3.7.2.1 Confirmed Air Leakage Paths #9, 11, 12, 13, 14, & 15 Moderate and Minor Category

method of preventing or repairing IGUs with high dew points unless all perimeter seal discontinuities can be sealed.

At the end of the air test, a significant quantity of water had leaked into the IGU through several of the edge seal discontinuities. As a result, moisture content testing was not performed on the internal desiccant from this IGU.

3.7.3. Structural Sealant Testing

During the removal of IGU 43161 the structural sealant adhering the IGU to the curtain-wall frames was informally tested for strength and elastic modulus. It was found that the sealant was very brittle. In all cases when the sealant was flexed back on itself or twisted it would break with very little force applied (Fig. 3.7.3.1). RDH reviewed the sealant on several other IGUs removed from the building by the glazing contractor and it was found to be in similar condition. The sealant manufacturer was contacted and on May 22, 2009 Kelly Charbonneau, Technical Services Engineer for Dow Corning Corporation visited the RDH laboratory to view the brittle sealant and participate in the sealant adhesion and cohesion testing on IGU 43161. The results of the investigation and testing are summarized in the Dow Corning Report contained in Appendix G. In summary, the testing revealed that the in-situ sealant has likely been over catalyzed, and as a result, has lost much of its strength. In its current condition, the safety factor of the sealant samples tested varied between 1.6 and 4.0. Four out of the seven tests had a safety factor less than 2.5 as required by ASTM C 1401, although the average safety factor was slightly above this level at 2.7. Dow corning indicated that the material properties would not likely deteriorate further over the remaining service life of the sealant. Additional testing of a larger sample of IGUs is required to determine if and where any additional structural fastening is required.

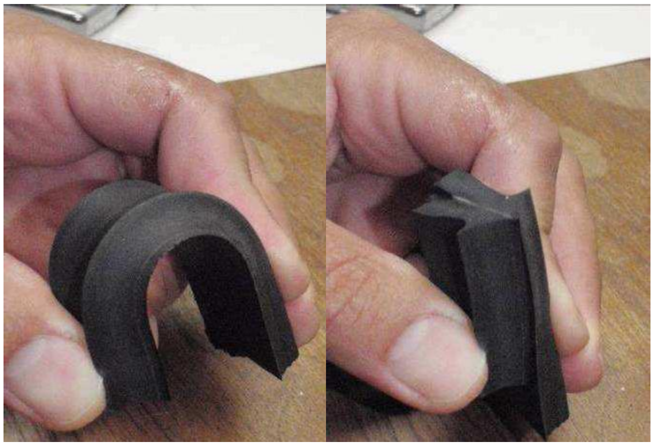


Fig. 3.7.3.1 Brittle Structural Sealant From IGU 43161 Breaking in Half After Being Bent 180 Degrees

RDH obtained quality two control “cup” samples from Visionwall taken around the time when IGU 43161 was assembled into the unitized curtain wall. The quality control sample exhibited the same over catalyzed material properties as the aged sealant that was removed from the building.

3.8. In-Situ IGU Perimeter Seal Repair Observations

On March 15, 2008 the writer visited the Visionwall plant in Edmonton, Alberta to review a mockup of an in-situ repair procedure that was being considered for the remediation of the remaining clear IGUs on the building. The mockup consisted of a complete 600mm x 600mm curtain wall sample with a small hole drilled into the edge of the glazing unit (Fig. 3.8.1). The repair procedure was to inject a flexible 2 part sealant from the head into the glazing rebate, and effectively seal the entire perimeter of the IGU to the curtain wall framing. The Mockup procedure was not successful for the following reasons:

- The sealant was too viscous to completely fill the glazing rebate,
- Air locks were formed in the jambs and sills. After

Fig. 3.8.1 In-Situ Repair Mock-up After Sealant Injection

the sealant was injected under pressure and the tube removed, sealant continued to flow out of the IGU,

- The sealant did not flow around the entire perimeter of the glazing rebate.

Based on the mockup testing we do not believe that it will be feasible to undertake in-situ repairs of the discontinuities in the IGU perimeter seals for the following reasons:

- The IGUs are very large and any liquid injected into the glazing rebate will be under a high hydrostatic pressure at the sills. Any sealant with a low enough viscosity to completely fill all the voids around the IGUs will also flow to the interior of the suites through gaps in the glazing gaskets, and also to the exterior of the building through the weepholes.
- The glazing rebate can not be filled with sealant without eliminating vented cavity that is critical to the water penetration resistance of the system and maintaining the longevity of the IGU seals.
- If the glazing rebate is filled with sealant, racking loads and displacements from the mullions could be transferred to the IGUs and either accelerate seal failure or cause glass breakage.
- The discontinuities in the perimeter edge seal are numerous, very small and located randomly around the unit. The probability of sealing all these discontinuities with a blind injection process is very low.

4. Discussion and Conclusions

The visual clarity of the insulating glazing units supplied by Visionwall on the building has deteriorated to unacceptable levels on the majority of the residential portion of One Wall Centre. The deterioration of the visual quality of the IGUs is a result of condensation and the related low-e coating corrosion inside the IGU. The condensation is caused by a buildup of moisture inside the IGU as a result of temperature changes, pressure differences across the enclosure and fluctuations in barometric pressure forcing moist exterior or interior air through discontinuities in the perimeter seal. There are three air leakage mechanisms contributing to this moisture buildup:

1. When wind blows against the building the glazing system will be under an inward acting pressure. This inward acting pressure will force moist air through the discontinuities in the perimeter edge seal, through the spacer bar where it will be dehumidified by the desiccant, through the airspace of the IGU, into the vent tube, through the desiccant tube, to the interior of the building. The source of moisture for this leakage mechanism is from the exterior.
2. Stack effect and wind induced suction pressures will create an outward acting pressure on the glazing system. An outward acing pressure will force moist air to flow into the desiccant tube where it will be dehumidified by the desiccant, into the vent tube, through the IGU, spacer bar and discontinuities in the perimeter edge seal to the exterior. The source of moisture for this leakage mechanism is from the interior.
3. Temperature changes, fluctuations in barometric pressure and dynamic wind loads all act to cyclically change the pressure inside the IGU with respect to the exterior and interior of the building. As the pressure inside the IGU equalizes with ambient conditions, airflow will move in and out of the IGU through desiccant tube and any discontinuities in the perimeter seal, causing the desiccant to absorb moisture. The source of moisture for this leakage mechanism is both interior and exterior. The ratio of exterior to interior air leakage will be related to the relative size of the air leakage paths. For example, if the leakage paths though the exterior perimeter are larger than the area of the desiccant tubing, then the percentage of the moisture entering the IGU from the exterior will be proportionately larger from the exterior than the interior.

Replacement of the desiccant tubes has been suggested as a possible method to prevent clear and moderate IGUs from getting worse over time. Unfortunately, only air leakage path 2 is affected by a desiccant tube replacement program. Air leakage path 1 transports moisture into the IGU desiccant before the air ever gets to the desiccant tube. With respect to leakage path 3, air testing performed in the laboratory suggests that discontinuities in the edge seal are an order of magnitude larger than the desiccant tubing. Therefore, even a very large desiccant tube attached to the existing tubing, would not have any appreciable effect on reducing the moisture inside the IGU. This is consistent with the negligible impact of the desiccant replacement program undertaken by Visionwall shortly after construction on the condensation resistance of the units.

Discontinuities in the perimeter of the IGUs are caused by a defect in the design and manufacturing of the perimeter edge seal. The design of the edge seal incorporates a PVC thermal break bonded to aluminum extrusions and a stainless steel edge band that is bonded and sealed to the thermal break with a thermoplastic butyl based sealant. The aluminum and PVC spacer have a much higher coefficient of thermal expansion than the stainless steel edge band. When the IGU heats up in the sun, the spacer will expand more than the stainless steel and will tend to stretch the band, conversely when the IGU cools down the spacer will shrink smaller than the edge band. The thermoplastic butyl sealant adhering the edge band to the spacer will change properties as the temperature increases, becoming softer and more pliable at high temperatures and harder at lower temperatures. This process can result in the formation of ridging and fish mouths observed in the stainless steel edge band by acting as “ratchet” allowing some slippage during warm temperatures and locking everything in place during cold temperatures.

Many of the small defects in the perimeter edge seal such as pinholes and open joints between the edge of the edge band and the glass were likely present when the IGUs were manufactured. Pinholes and gaps in perimeter edge seal would have been almost impossible to eliminate using the original edge seal method. Rolling a thin band of stainless steel into a wet bead of butyl based sealant would have been very difficult to make initially airtight, and the butyl sealant joint between the edge of the band and the glass did not have an adequate sealant joint profile to allow a reasonable level of differential movement to occur without damaging the seal. These smaller deficiencies are very difficult if not impossible to visually identify, and the short duration of Visionwall's quality control pressure test is inadequate to identify small air leakage paths. The presence of small initial discontinuities and the lack of adequate quality control testing was evident when the new replacement IGUs provided by Visionwall were found to have measurable air leakage decay curves or had already failed resulting in visible low-e corrosion before the IGUs were installed in the building.

It is likely that Visionwall was aware of the deign and manufacturing defects related to the edge seal design sometime after construction of One Wall Centre when they changed the design of the spacer and perimeter edge seal to incorporate a new stainless steel channel that is sealed to the glass with a properly profiled thermosetting (elastic properties under expected service temperatures) sealant.

The majority of the IGUs reviewed are already exhibiting moderate to severe corrosion of the low-e coating. Many of the minor and moderate classed IGUs were clear only a few years ago. The level of corrosion observed on all IGUs that were reviewed over multiple years indicates that these units have failed and are continuing to degrade. The dew point testing indicates that the majority of the clear units are near, or at the point where condensation and corrosion will start to occur. The defective edge seal used on all of the original units will continue to degrade and will eventually cause the premature failure of all IGU edge seals on the building. The corrosion of the low-e coating and the visual quality on all IGUs will continue to deteriorate over time, severely obstructing the vision through the windows. Based on the collaborative discussions and mockups performed with Visionwall, we do not believe that an effective, repeatable, long term in-situ repair to the edge seal is feasible on a large scale bases.

The replacement of all Visionwall glazing units on the residential portion of the building will be required in order to mitigate the premature condensation and low-e corrosion problems. Replacement of 100% of the glazing will also resolve the sealant embrittlement issues and will allow the overheating issues to be mitigated by utilizing a low-e coating a with better Solar Heat Gain Coefficient, and significantly reduce overheating issues if dark tinted glass, similar to that at the hotel, can be used in the replacement IGUs.

4.1. Glazing Replacement Design

When the full scale glazing replacement program is undertaken, multiple work platforms and crews will be working on the building during periods of inclement weather in order to replace the over 1000 IGUs within a reasonable period of time. The original IGUs relied on a single bead of silicone between the exterior lite and the curtain wall frame to fasten the entire unit to the building. This sealant bead was installed in an environmentally controlled plant, on an accessible horizontal surface from the edge of the glass once the IGU was placed in the framing. In addition, stringent in-plant quality control procedures were in place. On site, there is no access to the edge of the IGU to allow the application of structural sealant after the unit is installed; instead the structural sealant has to be applied to the glass or frame and blindly compressed when the IGU is pushed into place. This work would be performed off swing stages exposed to Vancouver weather. Temporary mechanical anchors would be used to secure the unit in place until the sealant cures. The risk of having an IGU fall out of the building as a result of a QA/QC issue is quite high if this process is repeated over 1000 times by several different crews over many months during varying weather conditions. This risk is unacceptable, and as a result, the re-glazing design should incorporate at least two structural silicone joints and structural clips to hold the IGUs on the building.

The mechanically attached four sided structural glazing concept is shown conceptually on Fig. 4.1.1 and Fig. 4.1.2. Either a modified Visionwall three element glazing unit or a conventional triple glazed sealed insulating glass unit can be used for the re-glazing program. The advantage of the conventional IGU is that it can be purchased from several different sources increasing competition and ensuring a continuous and convenient supply of replacement IGUs. In addition, the conventional sealed units have a good track record and are unlikely to have condensation related problems over the expected service life. If Visionwall IGUs are used for replacement, the design of the perimeter edge seal needs to be improved in order to ensure that the perimeter seal will be air and watertight over the life of the assembly. In addition, a structural clip attachment is required similar to that shown for the conventional triple glazed unit.

Regardless of the type of IGU used, the design of the new replacement IGUs needs to address the overheating issues. Clear glass with a solar reflective low-e coating on surface 5 and 2 will help to reduce the heat gain in the suites. This same unit with tinted glass on the exterior to match the lower portion of the building will significantly reduce the overheating problems.

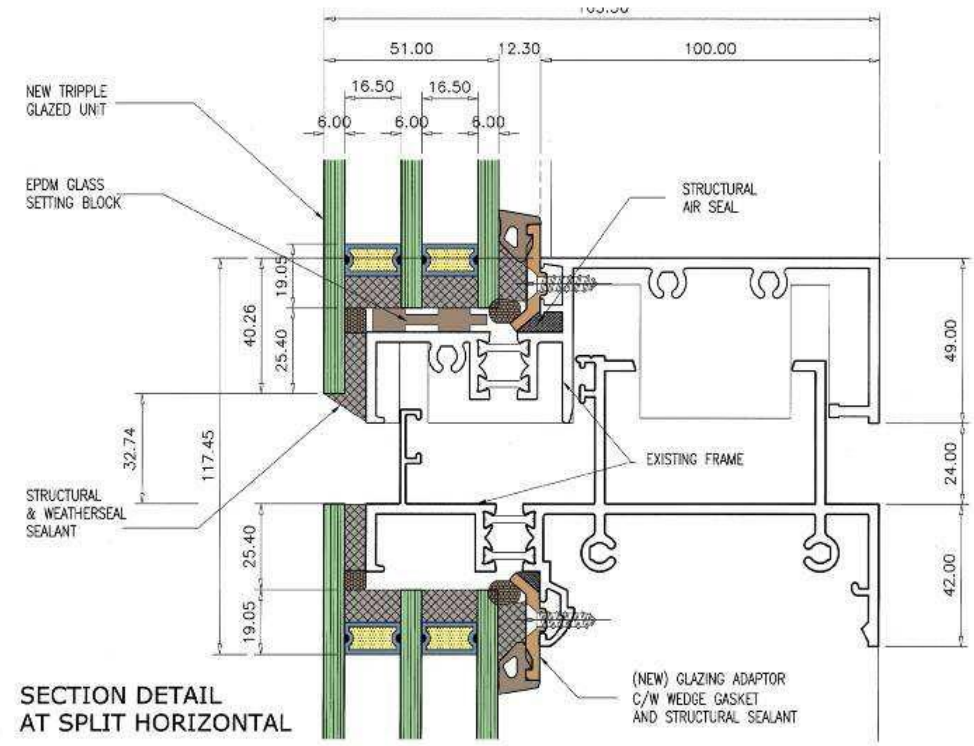


Fig. 4.1.1 Mechanically Attached Four Sided Structural Re-glazing Method – Stack Joint

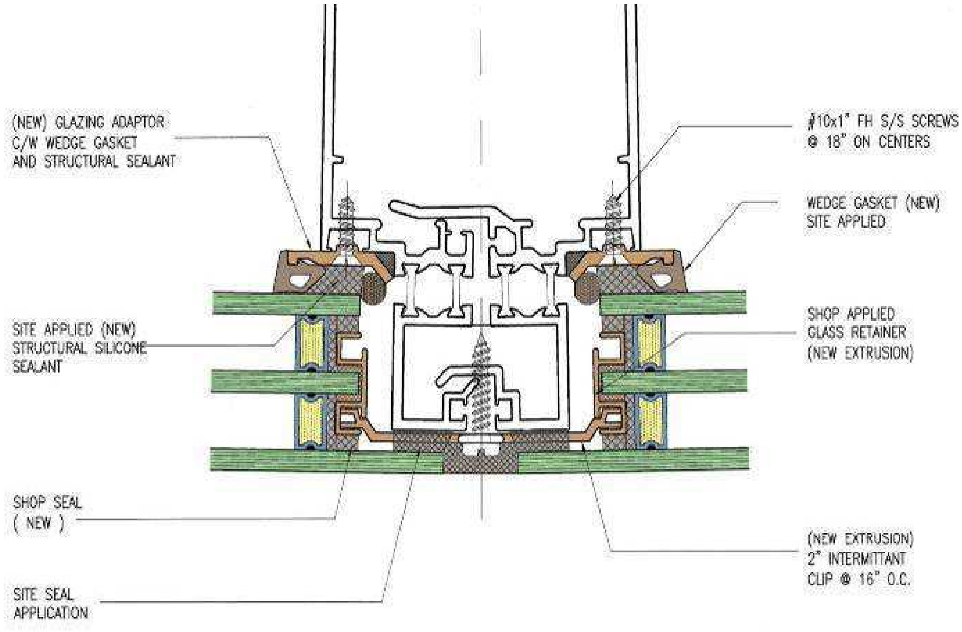


Fig. 4.1.2 Mechanically Attached Four Sided Structural Re-glazing Method – Vertical Mullion

4.2. Glazing Replacement Cost

RDH retained the services of Advanced Glazing Systems Limited (AGS) to provide a cost estimate suitable for tender to re-glaze the entire residential portion of One Wall Centre with new glazing installed in accordance with the glazing design described in section 4.1. AGS was asked to provide a price for installation only and another price to supply and install new glazing units. Both prices include all required modifications and the addition of 4 new work platforms and hoists to the existing swing stage equipment on the roof. The AGS tender price is contained in Appendix H and is summarized below with additional costs for owner contingency, consulting fees, and GST added:

Table 4.2.1 Estimated Cost to Re-glaze All Residential Floors

Option 1 Installation only	
Installation	$3,123,649
Consulting Fees (6%)	$320,704
Owner Contingency (10%)	$312,365
GST	$187,836
Total	**$3,944,554**

Option 2 Supply and Installation	
Installation	$5,345,064
Consulting Fees (6%)	$320,704
Owner Contingency (10%)	$534,506
GST	$310,014
Total	**$6,510,288**

Consulting fees generally include for the preparation of design and tender documents, presentation materials to the City with respect to glazing colour, quality assurance during the construction process, onsite mockup and ongoing quality assurance sealant, air and water testing. Costs for HST have not been included but may be required on all work not implemented by July 2010. Costs for PST have not been included but may be required on all or a portion if this work.

5. Recommendations

We recommend the replacement of all insulating glass units on the residential portion of the building with new insulated glass units at an estimated cost of 6.5 million dollars. We also recommend the following additional investigation be carried out prior to the design and implementation of the re-glazing project:

- Perform a detailed investigation of the overheating problem including an analysis of the HVAC system, monitoring of interior temperatures, and a simulation of the predicted interior conditions using both clear and tinted IGUs.
- Present the tinted glass option to the City and investigate the possibility of matching the residential glass to the lower floors.
- Further investigation of the structural sealant embrittlement on additional IGUs to confirm that exterior clips are not required as a safety issue on other areas of the building (non residential).
- Install a mockup of the new glazing on an area two floors high and five units wide in order to confirm the acceptability of the new glazing, and allow air and water testing prior to proceeding with the work on a full scale basis. The mockup will can be retained as part of the finished work provided that it is acceptable from an aesthetic and performance perspective.

RDH Building Engineering Ltd.

Brian Hubbs, P.Eng

Senior Building Science Specialist, Principal

Graham Finch, MASc, EIT

Building Science Engineer

Appendix A

Visual Review and Dewpoint Testing Data

APPENDIX A: Visual Observations and Dewpoint Testing, 2006 through 2009

Visual Observation and Dewpoint Testing Summary tables and Figures for the Observations and Results are presented within this Appendix, with the raw data and supplemental background information following in Appendix C.

A floor plan of the typical residential suite layout is shown below for all residential floors except 31 through 33, which are configured into 6 suites per floor instead of the typical 4.

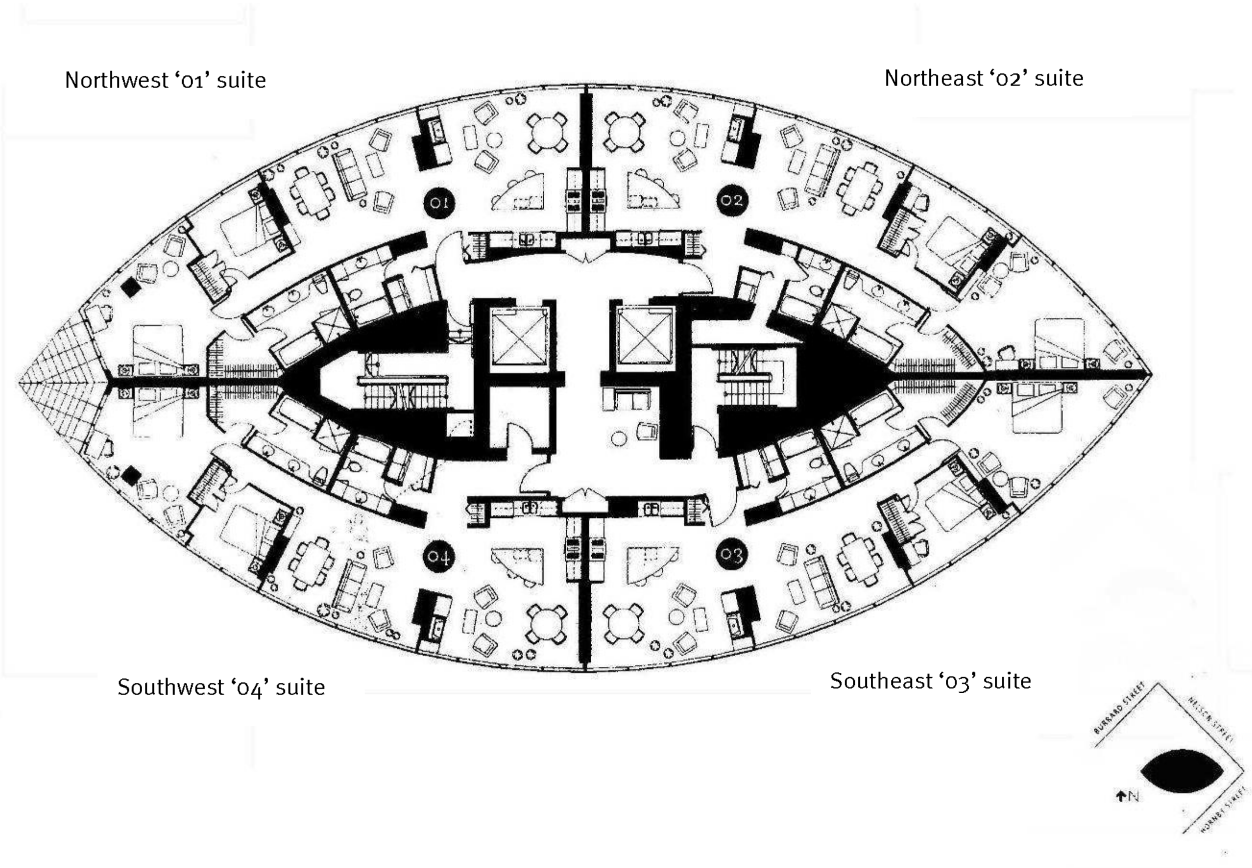


Figure A1: Typical Floor Plan

2006-2007 Visual Review and Dewpoint Testing

Testing performed at One Wall in 2006 and 2007 consisted of the following:

- Visual review of selected IGUs,
- Dewpoint testing of selected IGUs,
- Saturation testing of desiccant from selected IGU desiccant tubes.

Visual observations and dewpoint tests were performed onsite on February 6th and 13th 2006, and April 25th and 26th 2007.

Visual classification was performed in accordance with the visual review protocol outlined in section 2.7 of the report.

- Severe – Any visible condensation, large corrosion spots on low-e coating, large clusters of small spots, or permanent haze visible from 3m,
- Moderate – Any corrosion/oxidation of the low-e coating visible from 3m,
- Minor – Any visible corrosion/oxidation of low-e coating but not visible from 3m,
- Clear – No visible corrosion/oxidation of low-e coating or condensation in IGU.

Table A1 and A2 present a summary of the visual observations for 2006 and 2007. Figures A2 and A3 present a pie chart showing the distribution of observations.

Table A1: February 2006 Visual Observation Results

February 2006 – Suites 4701, 4004, 3804, 4502, 4003, 4501, 4504		
	# Units with visual Classification	% of Units
Clear	38	35%
Minor	40	37%
Moderate	18	17%
Severe	13	12%
Total	109	

Table A2: April 2007 Visual Observation Results

April 2007 – Suites 3501, 3101, 3306, 3703, 3105, 4104, 4803, 4602		
	# Units with visual Classification	% of Units
Clear	63	48%
Minor	16	12%
Moderate	23	18%
Severe	28	22%
Total	130	

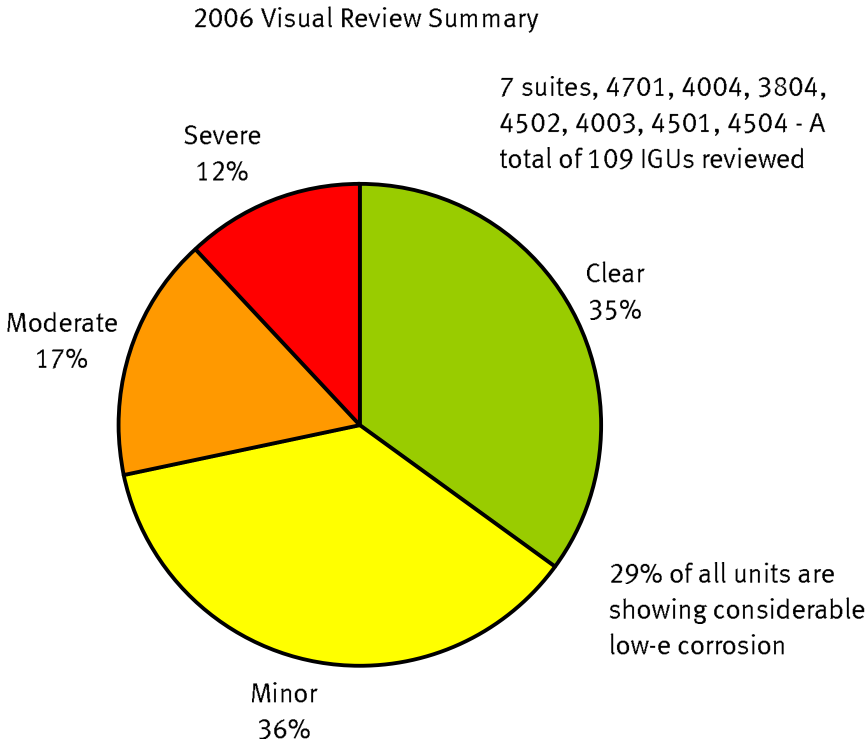


Figure A2: 2006 Visual Review Summary, 109 IGUs

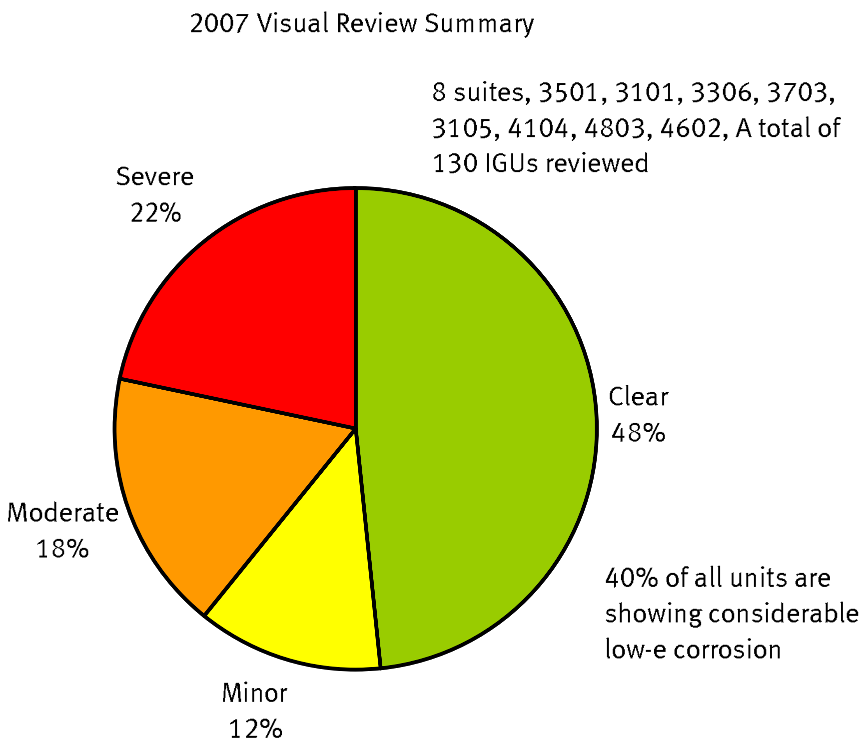


Figure A3: 2007 Visual Review Summary, 130 IGUs

The results from February 2006 and April 2007 were combined together in a previous 2007 RDH report dated June 16, 2007. This data is referred to as 2006-2007 data.

All recorded data from 2006 and 2007 is combined into Table A3, Table A4, and Figure A4.

Table A3: February 2006 and April 2007 Combined Visual Observation Results

2006 and 2007 – All Suites Reviewed		
	# Units with visual Classification	% of Units
Clear	101	42%
Minor	56	23%
Moderate	41	17%
Severe	41	17%
Total	**239**	

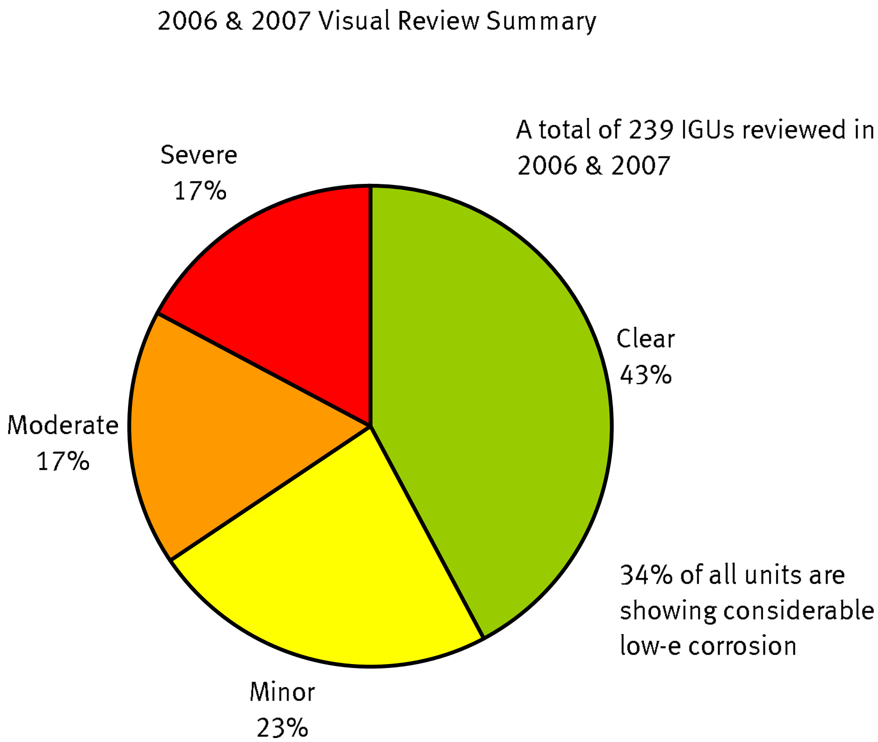


Figure A4: 2006-2007 Visual Review Summary, 239 IGUs

Table A4: February 2006 and April 2007 Combined Visual Observation Results – By Suite

Suite	Orientation	Clear		Minor		Moderate		Severe		TOTAL
4701	Southwest	1	25%	1	25%	1	25%	1	25%	4
4004	Southwest	6	30%	9	45%	4	20%	1	5%	20
3804	Southwest	4	22%	6	33%	7	39%	1	6%	18
4502	Northeast	9	53%	7	41%	0	0%	1	6%	17
4003	Southeast	2	13%	6	38%	2	13%	6	38%	16
4501 & 4504	Northwest & Southwest	16	47%	11	32%	4	12%	3	9%	34
3501	Northwest	13	68%	1	5%	2	11%	3	16%	19
3101	West	15	75%	3	15%	1	5%	1	5%	20
3306	South	3	33%	0	0%	5	56%	1	11%	9
3703	Southeast	1	6%	0	0%	4	22%	13	72%	18
3105	South	10	100%	0	0%	0	0%	0	0%	10
4104	Southwest	3	16%	5	26%	8	42%	3	16%	19
4803	Southeast	8	44%	5	28%	3	17%	2	11%	18
4602	Northeast	10	59%	2	12%	0	0%	5	29%	17
	TOTAL	101	42%	56	23%	41	17%	41	17%	239

Dewpoint testing of several randomly selected IGUs was also performed in February 2006 and April 2007. The results of these dewpoint tests are summarized in Figure A5 and Table A5.

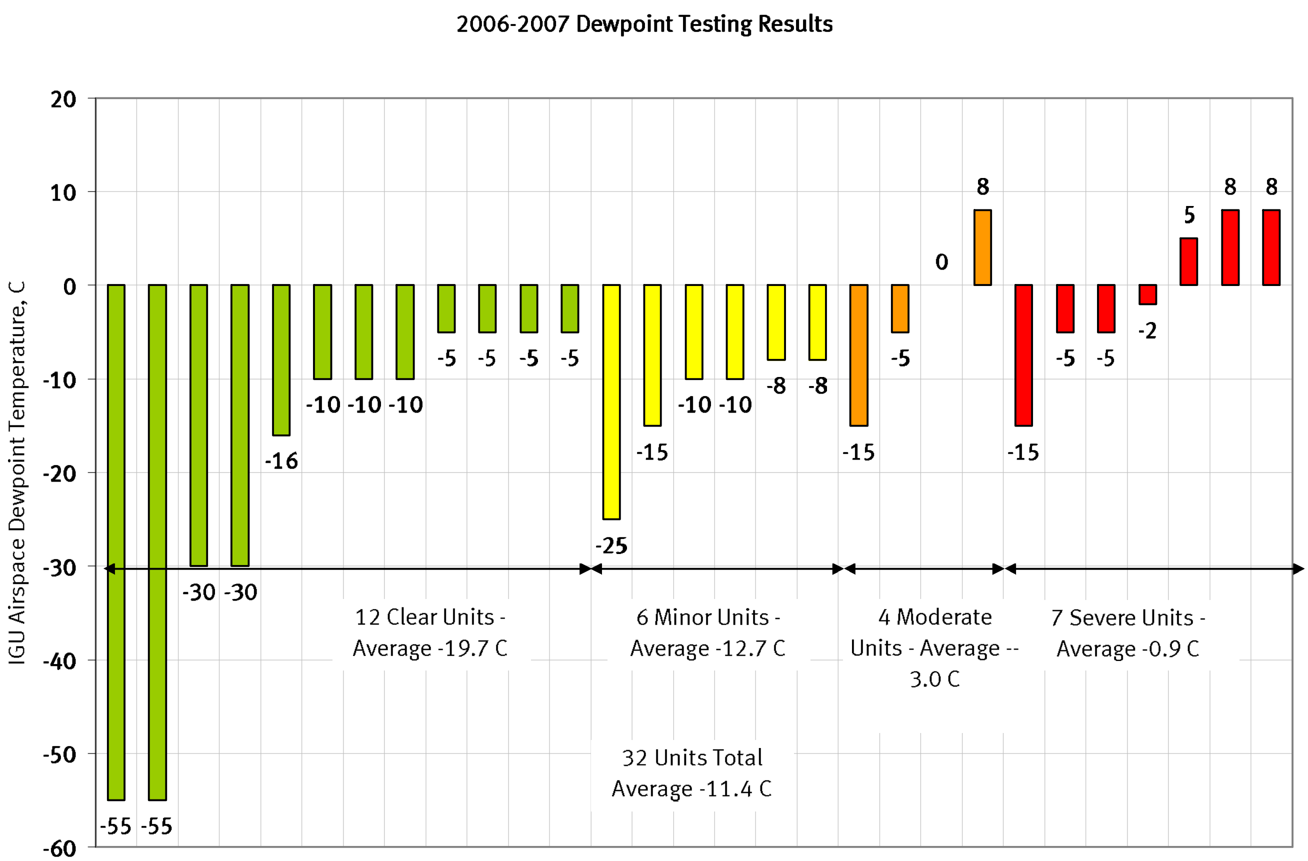


Figure A5: 2006-2007 IGU Dewpoint Testing Summary

Table A5: 2006-2007 IGU Dewpoint Testing Summary

Visual Classification	# of Dew Point Tests	Average Dew Point [°C]	% of Results Greater Than -18°C
Clear	12	-19.7	67%
Minor	6	-12.7	83%
Moderate	4	-3.0	100%
Severe	7	-0.9	100%
Total	**29**	**-11.4**	**83%**

2006-2007 Desiccant Saturation Testing

Desiccant samples were taken from eight Visionwall Unit external desiccant tubes for laboratory testing in February 2006. The moisture content and percent saturation of the desiccant was determined and presented in our letter dated June 16, 2007.

The moisture content of the desiccant was calculated by removing the entire desiccant from the tube, weighing the desiccant, baking the desiccant at 230°C and recording the weight of the sample once all weight loss has stopped. A Raytek Raynger MX infrared temperature gun and a Digi-Sense digital thermometer with T-type thermocouple was used to control the lab oven to approximately 230°C. The total weight loss is then divided by the total dry weight to achieve the moisture content. The moisture content is then divided by the assumed saturated moisture content of 22% to achieve the percent saturation value. A MyWeigh IM01 1000g ±0.01 g laboratory scale with 0.01g precision was used for the weight measurements.

The difference between the wet and dry mass represents the mass of water held by the desiccant. Using these values moisture content was determined:

$$MC_{des} = \frac{M_{h20}}{M_{des}}$$

Using moisture content, saturation was calculated:

$$SAT = \frac{WC_{des}}{WC_{\max}}$$

Table A6 and Table A7 presents a summary of the data.

Table A6: 2006-2007 IGU Dewpoint Testing Summary

Suite	IGU Unit	Moisture Content of Desiccant Sample #				% Saturation	Tube Date	IGU Condition	Pressure Test	Measured Dewpoint
		1 of 3	2 of 3	3 of 3	Average					
3105	38416	15.5	17.8	17.8	17.0	77.3	Oct-04	Clear	Fail	-5°C
3105	38649	2.2	0.0	0.1	0.8	3.6	Oct-04	Clear	Fail	-10°C
3501	43735	19.1	19.3	19.4	19.3	87.7	Feb-05	Clear	Fail	-16°C
3501	43748	18.7	18.6	18.9	18.7	85.0	Feb-05	Minor	Fail	-15°C
3703	43211	18.1	17.5	18.1	17.9	81.4	Nov-04	Moderate	Fail	n/a
3703	43589	18.2	17.9	8.3	15.0	68.2	Nov-04	Severe	Fail	n/a
4104	43656	0.9	3.7	17.7	7.4	33.6	Dec-04	Clear	Pass	n/a
4803	43320	19.0	19.1	19.5	19.2	87.3	Feb-05	Clear	Fail	-5°C

Table A7: 2006-2007 IGU Dewpoint Testing Summary

Suite	IGU Unit	% Moisture Content Average	% Saturation	IGU Condition	Measured Dewpoint
3105	38416	17.0	77.3	Clear	-5°C
3105	38649	0.8	3.6	Clear	-10°C
3501	43735	19.3	87.7	Clear	-16°C
3501	43748	18.7	85.0	Minor	-15°C
3703	43211	17.9	81.4	Moderate	n/a
3703	43589	15.0	68.2	Severe	n/a
4104	43656	7.4	33.6	Clear	n/a
4803	43320	19.2	87.3	Clear	-5°C

2008 Visual Review and Dewpoint Testing

Field Observations during the year 2008 were made on May 15, May 16, July 3, August 7, and October 6. Suites 3101 and 4602 were reviewed May 15 and May 16, Suite 3903 on July 3, 4502 on August 7 and 4001, 4002, 4003, and 4004 on October 6.

Table A8 present a summary of the visual observations for all suites reviewed in 2008. Figure A6 present a pie chart showing the distribution of observations.

Table A8: 2008 Visual Observation Summary

2008 – Suites 4502, 4001, 4002, 4003, 4004, 3101, 4602, 3903		
	# Units with visual Classification	% of Units
Clear	22	13%
Minor	49	30%
Moderate	51	31%
Severe	41	25%
Total	**163**	

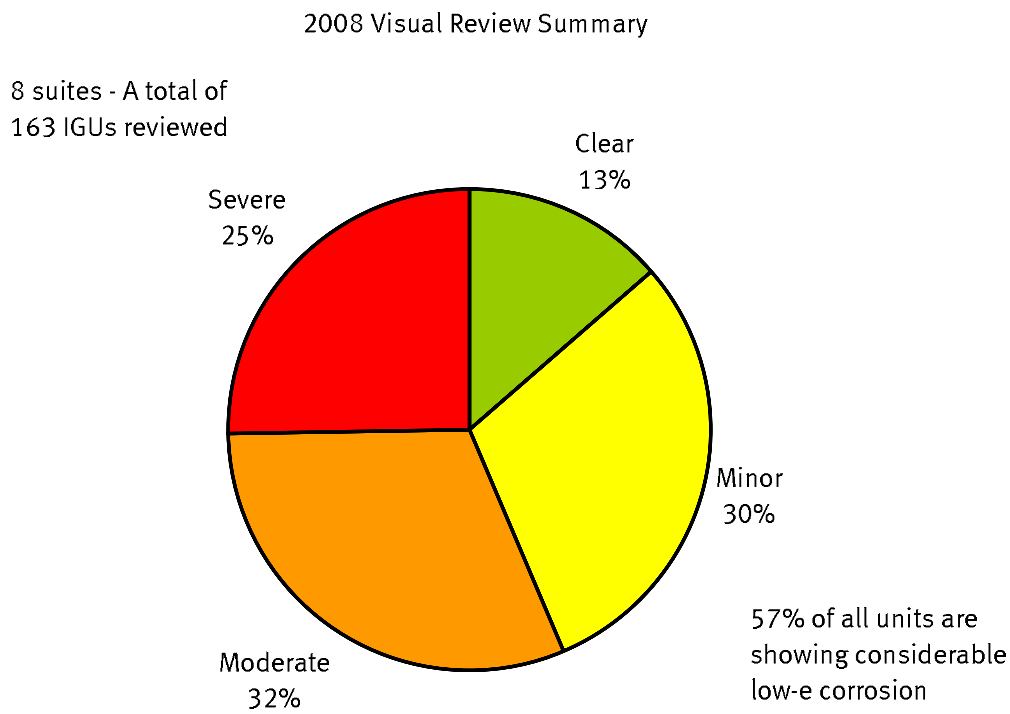


Figure A6: 2008 Visual Observation Summary

Dewpoint testing of several randomly selected IGUs was also performed in 2008. The results of these dewpoint tests are summarized in Figure A5 and Table A5.

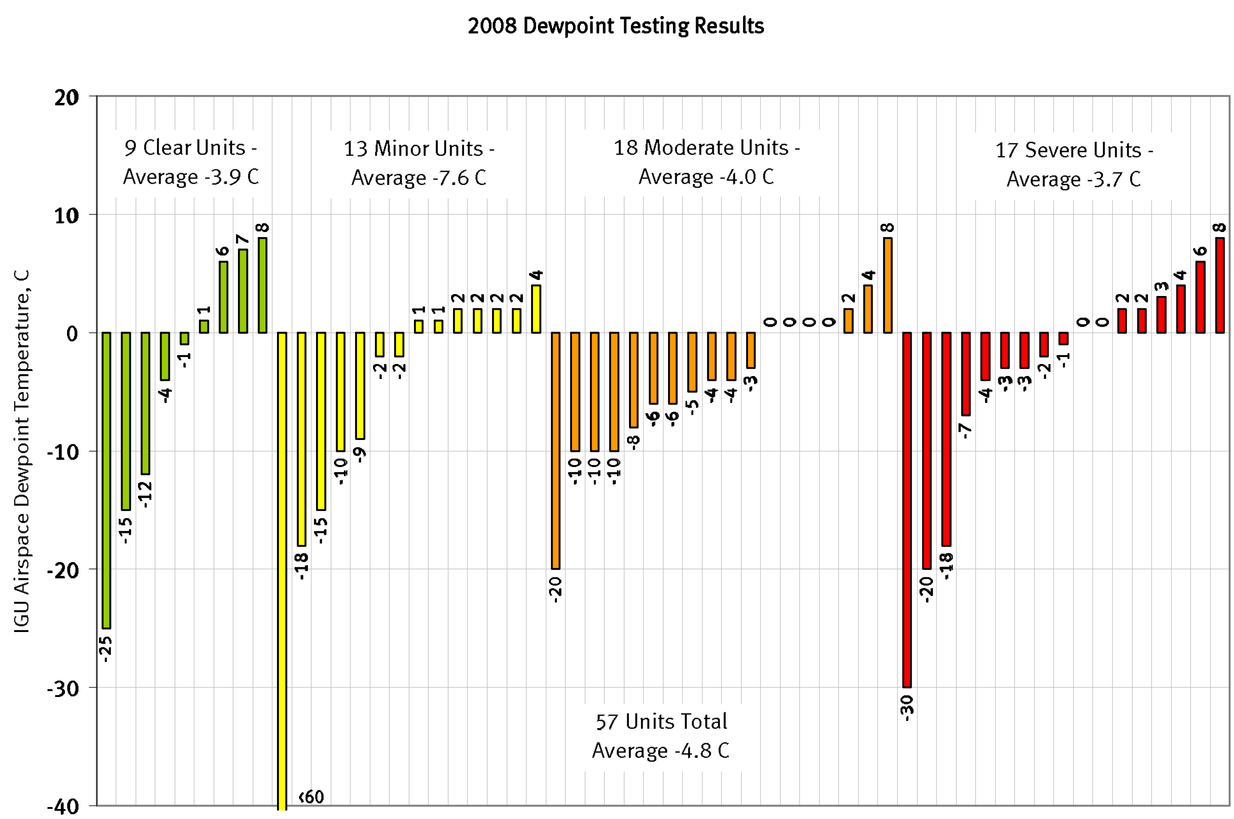


Figure A7: 2008 IGU Dewpoint Testing Summary

Table A9: 2008 IGU Dewpoint Testing Summary

	Average Dewpoint	# Units	% of Units above -18C
Clear	-3.9	9	89%
Minor	-7.6	13	85%
Moderate	-4.0	18	94%
Severe	-3.7	17	82%
Total	-4.8	57	88%

The visual observations for the 40th floor suites are presented in Figure A8, showing the distribution of fogged/corroded IGUs around the building. The highest concentration of fogged/corroded IGUs is near the east corner, and south elevation.

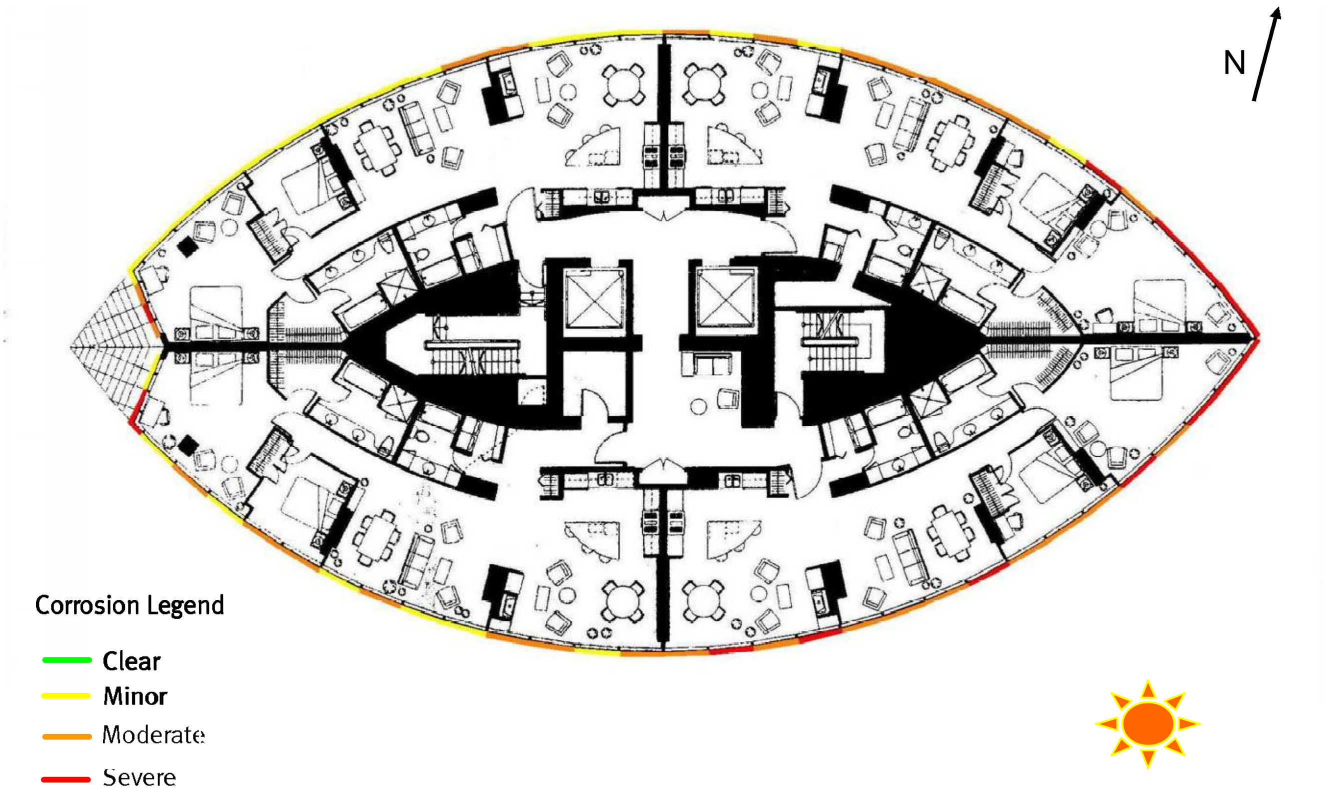


Figure A8: 40th Floor Suites, Visual Observation

2009 Visual Review

Field Observations during the year 2009 were made on February 28 and March 6. Suite 3803 was reviewed on February 28 while removing an IGU for testing, and suites 3204 and 3304 were reviewed on March 6, while locating a suitable IGU for the trial replacement program.

Table A10 present a summary of the visual observations for all suites reviewed in 2009. Figure A9 present a pie chart showing the distribution of observations.

Table A10: 2009 Visual Observation Summary

2009 – Suites 3204, 3304, 3803		
	# Units with visual Classification	% of Units
Clear	0	0%
Minor	8	15%
Moderate	14	26%
Severe	31	58%
Total	**53**	

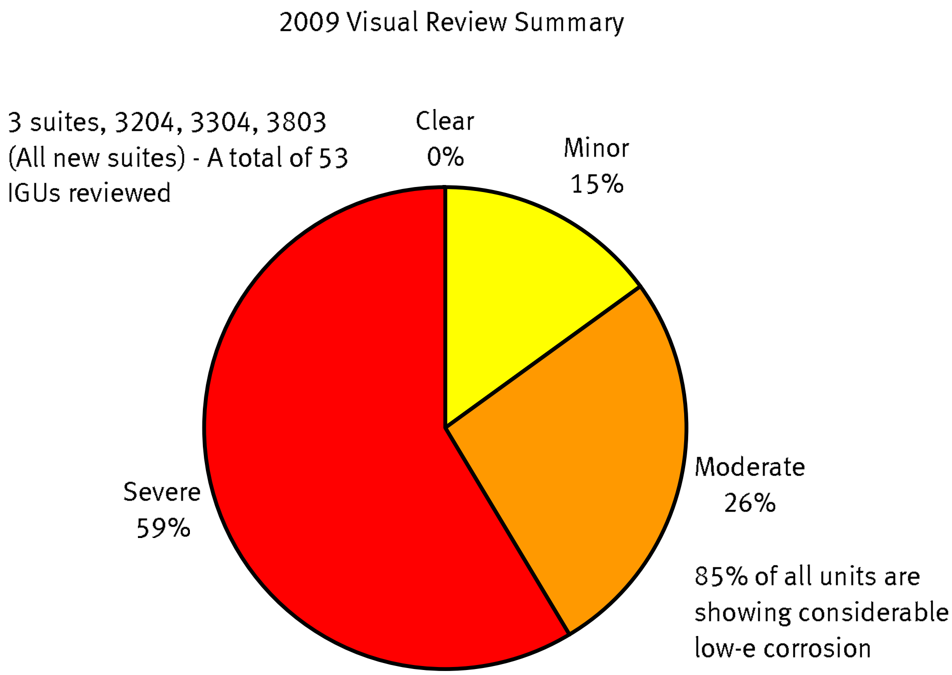


Figure A9: 2009 Visual Observation Summary

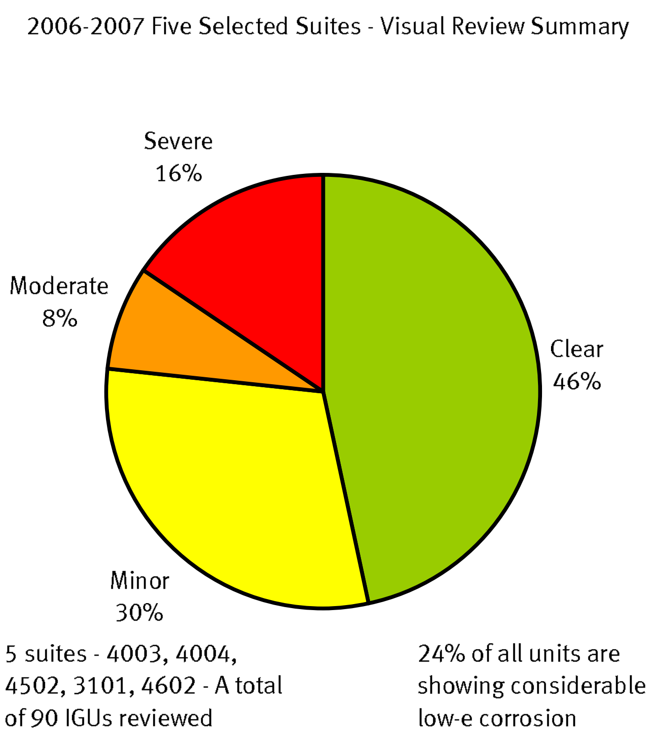
Comparison of Visionwall IGU Condition between 2006/2007 and 2008

A total of 459 IGU condition observations were recorded between 2006 and 2009, 109 in 2006, 130 in 2007, 163 in 2008 and 57 in 2009. Of these 459 visual observations, 90 windows were reviewed on two separate occasions to determine if the condition of the IGUs were continuing to degrade over time. Therefore 369 unique IGU observations were recorded by RDH since 2006. This accounts for approximately 37% of the approximately 1000 IGUs within the residential portion of the building.

Table A11 and Figure A10 compare the visual classification of 90 identical units between 2006/2007 and 2008. These units are within suites 4003, 4004, 4502, 3101, and 4602.

Table A11: Comparison of IGU Visual Classification between 2006/2007 and 2008

Feb 2006 & March 2007 – Suites 4003, 4004, 4502, 3101, 4602		
	# Units with visual Classification	% of Units
Clear	42	47%
Minor	27	30%
Moderate	7	8%
Severe	14	16%
Total	**90**	
May, June, July, August 2008 – Suites 4003, 4004, 4502, 3101, 4602		
	# Units with visual Classification	% of Units
Clear	22	24%
Minor	19	20%
Moderate	26	28%
Severe	26	28%
Total	**93**	
* 3 units reviewed in 2008 within these suites were not reviewed in 2006/2007		



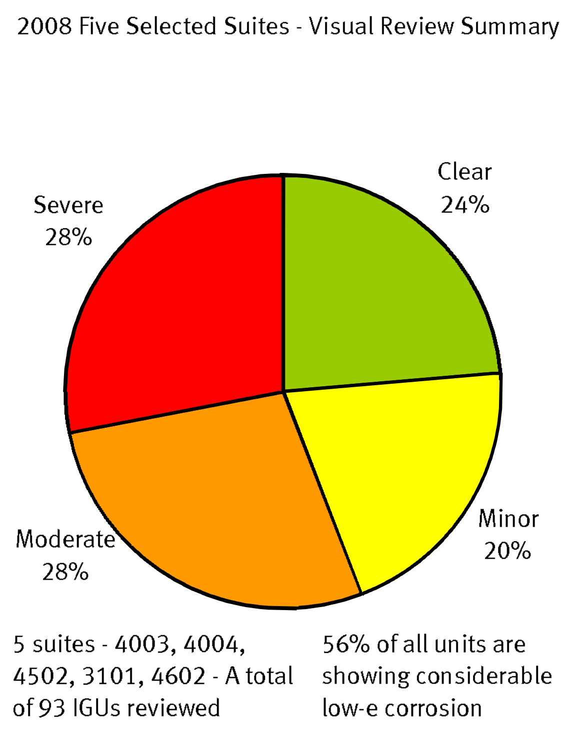


Figure A10: Comparison of IGU Visual Classification between 2006/2007 and 2008

The IGUs specifically within suite 4502 are graphically compared in Figure A11 and summarized in Table A12.

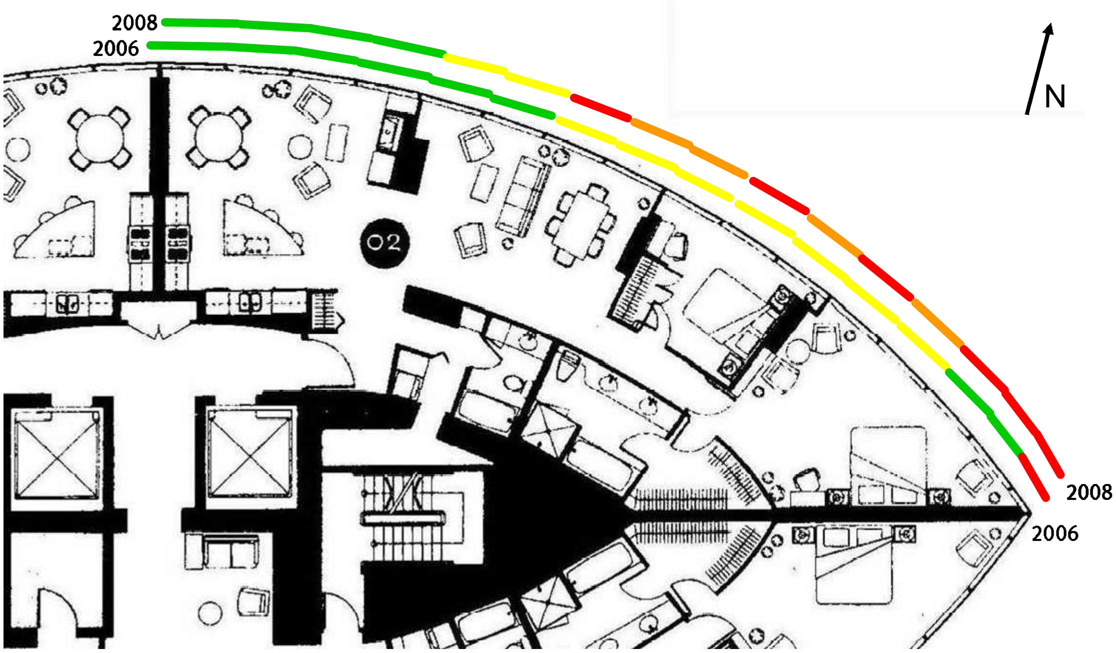


Figure A11: Suite 4502, Degradation of IGU Condition between February 2006 and August 2008 (18 months).

Table A12: Suite 4502, Summary of IGU Conditions between February 2006 and August 2008.

Suite 4502 -				
Glazing Unit Serial #	**Feb 13/2006 Visual Condition**	**Aug 7/2008 Visual Condition**	**2006 Dewpoint**	**2008 Dewpoint**
43205	Clear	Clear		-12
43238	Clear	Clear		1
43239	Clear	Clear	-55	-4
45157	Clear	Clear		-1
45458	Clear	Minor		2
45474	Clear	Minor		2
45470	Minor	Severe		3
45466	Minor	Moderate		4
45357	Minor	Moderate		
45459	Minor	Severe		
45456	Minor	Moderate		
45150	Minor	Severe		2
45153	Minor	Moderate		2
45367	Clear	Severe		8
44900	Clear	Severe	-10	4
45484	Severe	Severe	-5	6

Appendix B

Pressure and Flow Testing Data

APPENDIX B: Pressure and Flow Testing Data

Pressure Testing Protocol

Following the testing protocol development between RDH and Visionwall on May 16th and 17th 2008 it was agreed that a more accurate measurement of the pressure decay was required. Further to the testing, RDH sourced and tested low pressure digital pressure gauges from SMT Research Ltd. which have the capability to measure and data-log the pressures applied during in-situ testing of the glazing units at One Wall Center. Development of a test protocol was developed and the pressure sensors were rigorously tested in our laboratory for suitability for the wide scale testing.

The purpose of pressure testing is to determine the airtightness of the glazing units and the resulting pressure decay and leakage area for leaky units. “Air-leaky” glazing units will require frequent desiccant replacement or will fail prematurely. The intent of pressure testing the units is to correlate pressure decay data with the visual corrosion observation and dewpoint measurement of units to determine a failure criterion. Units which cannot hold pressure (are not air-tight) will require premature replacement or repair.

In theory, the two lites of glass that make up the Visionwall glazing units at One Wall Center are intended to be perfectly sealed to each other around the perimeter. The only hole in the IGU is a small tube through the perimeter edge seal which is connected to an external desiccant tube. Therefore, if one were to pressurize the sealed Visionwall IGU through this small tube and cap it off, the pressure would remain constant until uncapped. In fact, during production of Visionwall units, units along the assembly line are pressurized and checked for edge seal continuity for quality assurance. By connecting a calibrated differential pressure sensor with an airtight connection to the desiccant tube of a pressurized unit, the pressure loss or decay can be measured. Faster decay indicates a leakier unit, and where the unit cannot be pressurized, the size of seal defect or hole is larger in area than the diameter of the desiccant tube connection.

Dan Chindea from Visionwall indicated that an applied test pressure of 250-500 Pa is well below design wind pressures, and will not cause damage the edge seal or cause breakage of the glass; therefore a safe pressure of 250 Pa was applied for the test.

Pressure Test Protocol

- Remove desiccant tube from glazing breather tube.
- Pressurize glazing unit through the breather tube up to 200 Pa using a dry-air compressor. Monitor deflection of the glazing unit (will be less than ½” bow at this pressure) as a secondary backup to reduce the risk of over pressurization.
- Attach digital pressure sensor and data-logger to desiccant tube, and record rate of pressure decay.
- Analyze and compare pressure decay curves and correlate with corrosion and sealed air dewpoint temperature.

In the laboratory, the pressure testing apparatus was calibrated and tested for air leaks. When the pressure sensor and tubing connections were directly connected to a desiccant tube and a perfectly sealed container, no pressure decay or leakage was observed over 24 hours. This confirms that the apparatus is air-tight and any pressure loss measured in the field would be due to leakage through the tested glazing unit. It was also found that barometric pressure changes could affect some longer tests. As a result barometric pressure was also monitored during longer monitoring periods.

A schematic of the pressure testing apparatus is shown in Figure B1 and photographs of the units in use are shown in Figures B2 through B11.

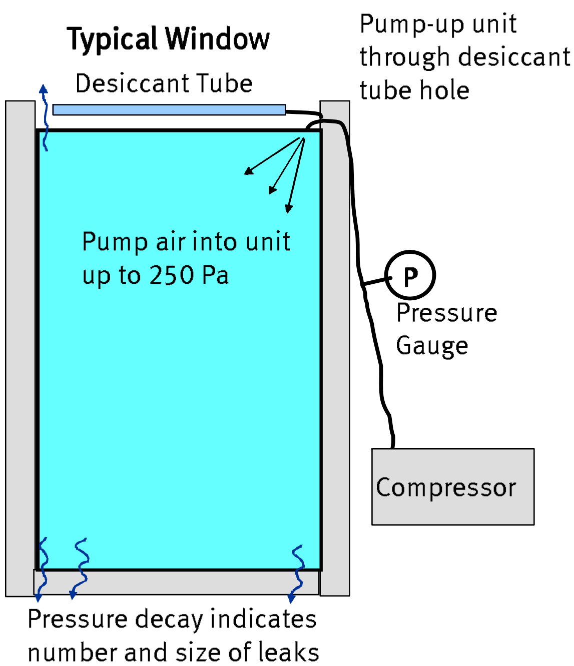


Figure B1: One Wall Pressure Testing Schematic.

To record the pressure measurement the following equipment developed by SMT Research was used.

- The pressure sensor is a Free-Scale differential pressure gauge (Model MPXV7002DP) with an operating range of ±2000 Pa. The free-scale sensor is a Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated. The sensors are factory calibrated and have a 2.5% error when between 10 and 60°C and 6.25% error outside of this range. A maximum pressure of up to 8 kPa can be safely applied to the pressure gauge without causing damage.
- The pressure sensor is housed in an SMT research wireless Industrial Data-logger referred to as a WiDAQ (http://www.smt-research.com/product/IndustrialWiDAQ). Power is applied to the sensor from batteries onboard the WiDAQ and data is recorded using the onboard chipset.
- The wireless data-logger communicates with a SMT Research Building Intelligence Gateway referred to as BiG (http://www.smt-research.com/product/BiG) and resembles a mini-laptop. The data from the pressure sensors is viewed onscreen and is uploaded to SMT's online Analytics software.
- A total of five pressure data-loggers (WiDAQ units) were fabricated for this project, referred to by RDH as Pressure Units #2 through #6. The factory calibrated pressure units were only used for testing at One Wall during the investigation.
- A secondary Dwyer Instruments Capsuhelic 0-5" H_2O analog pressure gauge with a maximum overpressure of 500 psi was used during the testing while filling the IGU with the compressor. The analog provided a secondary calibration of the digital pressure gauges and was used to provide a safeguard against over-pressurizing the IGU.
- Datasheets for the pressure sensors and SMT equipment are provided in Appendix I.

Pressure testing was performed by Graham Finch, MASc, EIT, Brian Hubbs, P.Eng, Ryan Gregory, EIT, and David Sommer of RDH.

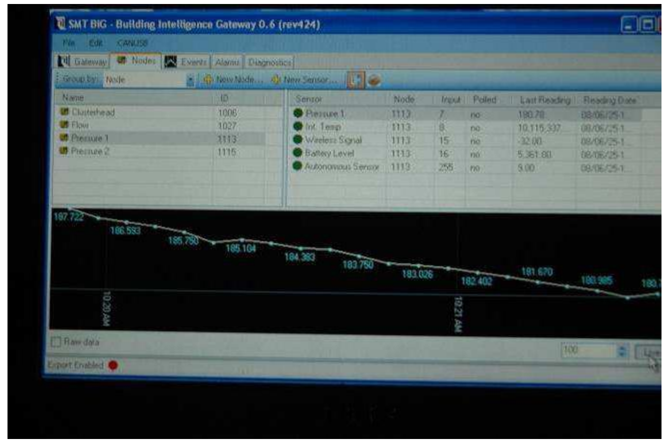


Figure B2: Pressure testing apparatus consisting of compressor and BiG mini-laptop.

Figure B3: View of SMT's Building Intelligence Gateway software showing real-time pressure output

Figure B4: Wireless pressure sensor WiDAQ attached to Visionwall IGU using glazing suction cup.

Figure B5: Pressure testing apparatus including valves and Capsuhelic analog gauge back-up.

Figure B6: Removal of curtainwall framing component to access desiccant tube to attachment of pressure gauge tubing

Figure B7: Desiccant tube attached to IGU through 1/8" clear flexible tubing. Desiccant tube is removed from IGU to all connection of pressure gauge.

Figure B8: Pressure gauge mounted on suction cup, with tube attached to IGU desiccant tube, suite 3903.

Figure B9: Pressure gauges mounted on suction cups, with tube attached to IGU desiccant tube, suite 3903.

Figure B10: Pressure gauge mounted on suction cup, with tube attached to IGU desiccant tube, suite 4502.

Figure B11: Pressure gauge tube attached to desiccant tube IGU tube.

Following successful application and results from the pressure testing apparatus, a flow measurement device was built using the same concept (Figure D12). The intent of the flow testing apparatus was to measure the flow through the desiccant tube (i.e. leakage out of the IGU) through this intentional opening as a source of air leakage into the IGUs. The flow gauge does not measure the flow into/out of the IGU through the edge seal defects identified in the IGU pressurization test.

Flow gauges were installed at six IGUs and monitored in-situ for several weeks. The flow gauges were installed in conjunction with pressure gauges on an adjacent IGU. The purpose was to correlate wind/building pressure effects on the pressure within the IGUs and resulting flow through the desiccant tube as a secondary source of leakage into the IGU and failure. Depending on the flow rate through the desiccant tube to the indoor environment, the time to saturation of the desiccant can potentially be determined.

The external desiccant tube contains only a small amount of molecular sieve desiccant relative to that contained within the vinyl extrusion of the IGU. Assuming that the IGU spacer is completely filled, a rough estimate of the desiccant contained within the external tube is 10-15% of that contained within the four sides of the IGU perimeter edge spacer.

A schematic of the flow testing apparatus is shown in Figure B1.

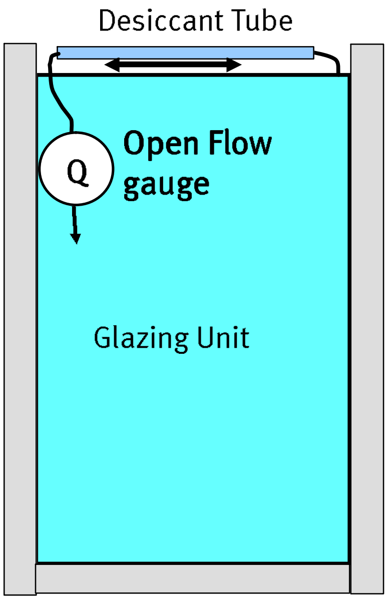


Figure B12: One Wall Flow Measurement Apparatus

To record the airflow measurement the following equipment developed by SMT Research was used.

- The low airflow sensor is an OMRON MEMs flow sensor, model # D6F-P0010A with an operating range of 1 Liter per minute. The sensors are factory calibrated and have a 5% error when between -10 and 60°C. A maximum pressure of up to 50 kPa can be safely applied to the sensor without causing damage.
- The flow sensor is housed in an SMT research wireless Industrial Data-logger referred to as a WiDAQ (http://www.smt-research.com/product/IndustrialWiDAQ). Power is applied to the sensor from batteries onboard the WiDAQ and data is recorded using the onboard chipset.
- The wireless data-logger communicates with a SMT Research Building Intelligence Gateway referred to as BiG (http://www.smt-research.com/product/BiG) and resembles a mini-laptop. The data from the flow sensors is viewed onscreen and is uploaded to SMT's online Analytics software.
- A total of five flow data-loggers (WiDAQ units) were fabricated for this project, referred to by RDH as Flow Units #1 through #5. The factory calibrated flow units were only used for testing at One Wall during the investigation.
- Datasheets for the flow sensors and SMT equipment are provided in Appendix I.

For reference, a Vision Wall IGU edge seal is compared to a traditional IGU edge seal.

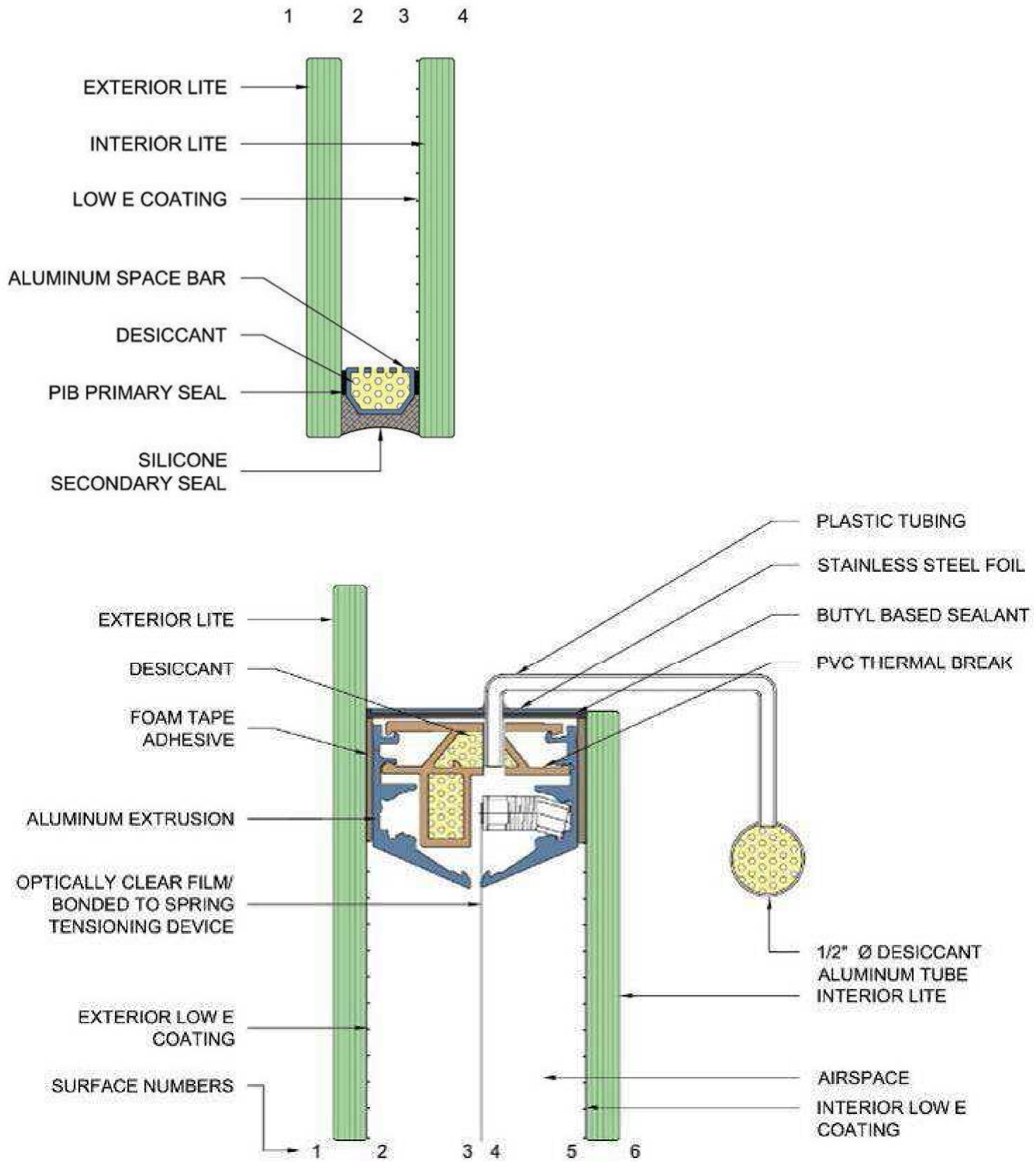


Figure B13: Conventional and Visionwall IGU Edge Seal Construction

2008 Pressure Testing – New Replacement Vision Wall IGUs

On June 25th, 2007 two new Visionwall units were pressure tested. The units were located in storage within the loading bay on pallets ready for installation. Packing slips indicate the new units were produced in 2004 and 2006. No other new units were accessible for testing.

Each of the new units were pressurized to between 180 and 200 Pa and the pressure decay monitored using the previously mentioned equipment. Pressure decay curves indicated relatively air-tight units; however a slow pressure decay was observed, indicating a small amount of air leakage through the edge seal as shown in Figure 6. The results are presented in Figure B14 and B15.

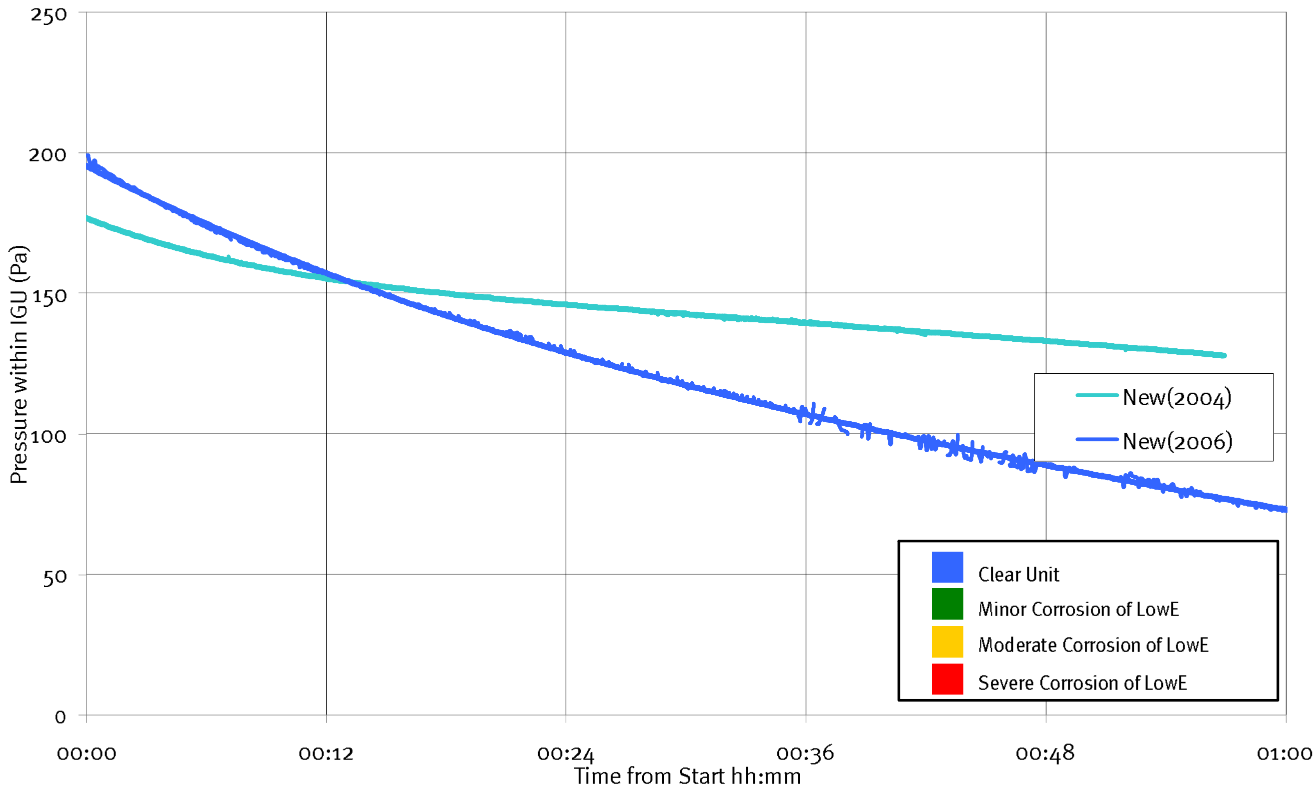


Figure B14: Pressure Decay Curves for Two New Replacement Vision Wall Units.

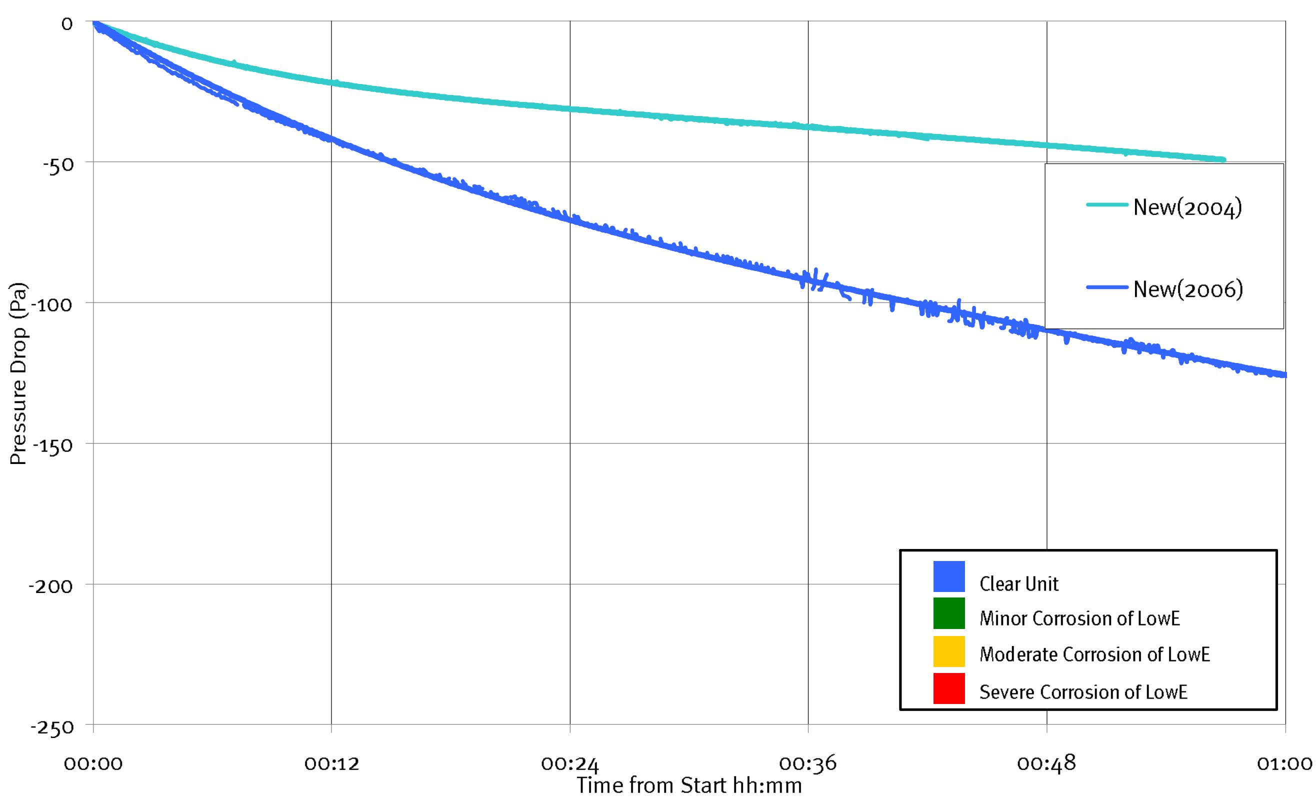


Figure B15: Pressure Decay Drop for Two New Replacement Vision Wall Units.

Testing revealed that the new units are not perfectly air-tight, and the 2006 unit was leakier than the 2004 unit. It should be noted that both of these units were sealed using the original edge seal methodology. No new Visionwall units (post 2006) with the improved edge seal technology were available for testing.

2008 Pressure Testing – Suite 3903

Eight Vision Wall IGUs within suite 3903 were pressure tested on July 3, 2008 using the previously discussed pressure monitoring equipment. The pressure testing was performed in conjunction with a visual review and dewpoint test at the suite. The results of the pressure tests are plotted in Figure B16, with the dewpoint temperature and low-e condition noted for each pressure decay curve.

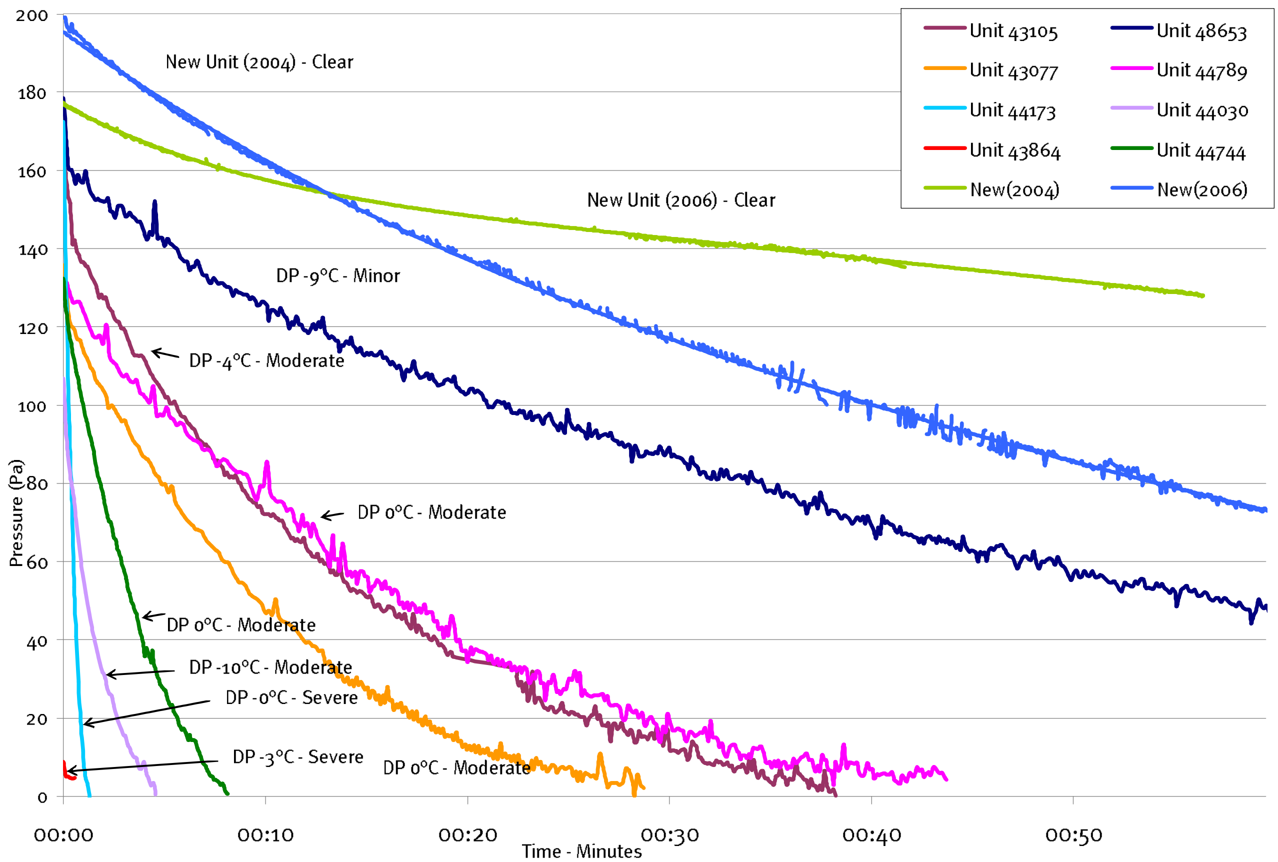


Figure B16: Pressure Test Results for Vision Wall IGUs within suite 3903.

Small variations in the pressure are caused by wind pressures on the IGUs and building pressure fluctuations as the result of wind or HVAC equipment. These did not adversely affect the pressure decay of the sealed IGUs – and pressure decay curves for each of the tests was relatively uniform. Statistical analyses of the curves indicate a repeatable and calculable logarithmic decay.

Unit 43864 (lower left, red line) was the most severely corroded unit within suite 3903 and recorded a very rapid pressure decay. When testing this unit, we found it extremely difficult to pressurize the unit beyond 50 Pa (even after 5-10 minutes) as the size of the edge seal defect is larger in area than the tube inlet used to pressurize the unit. All other units tested, we were able to pressurize to at least 150 Pa and record a pressure decay over minutes. On the opposite end of the spectrum, unit 48653 (navy blue line, 3rd from top) was the clearest unit tested with only very minor corrosion spotting. This unit had a relatively slow decay similar to the new units.

The pressure decay curves correlate well with low-e corrosion damage and partially with the airspace dewpoint temperature. This is due to the fact that the desiccant tubes were replaced in 2004-2005 and have saturated at varying rates (thus impacting the airspace dewpoint temperature), or that the corrosion damage observed may have occurred prior to desiccant tube replacement. What is clearly shown is that the more severely corroded units are quite leaky. This is further shown in Figures B17 and B18 where the ten tested units are colour-coded according to low-e corrosion classification.

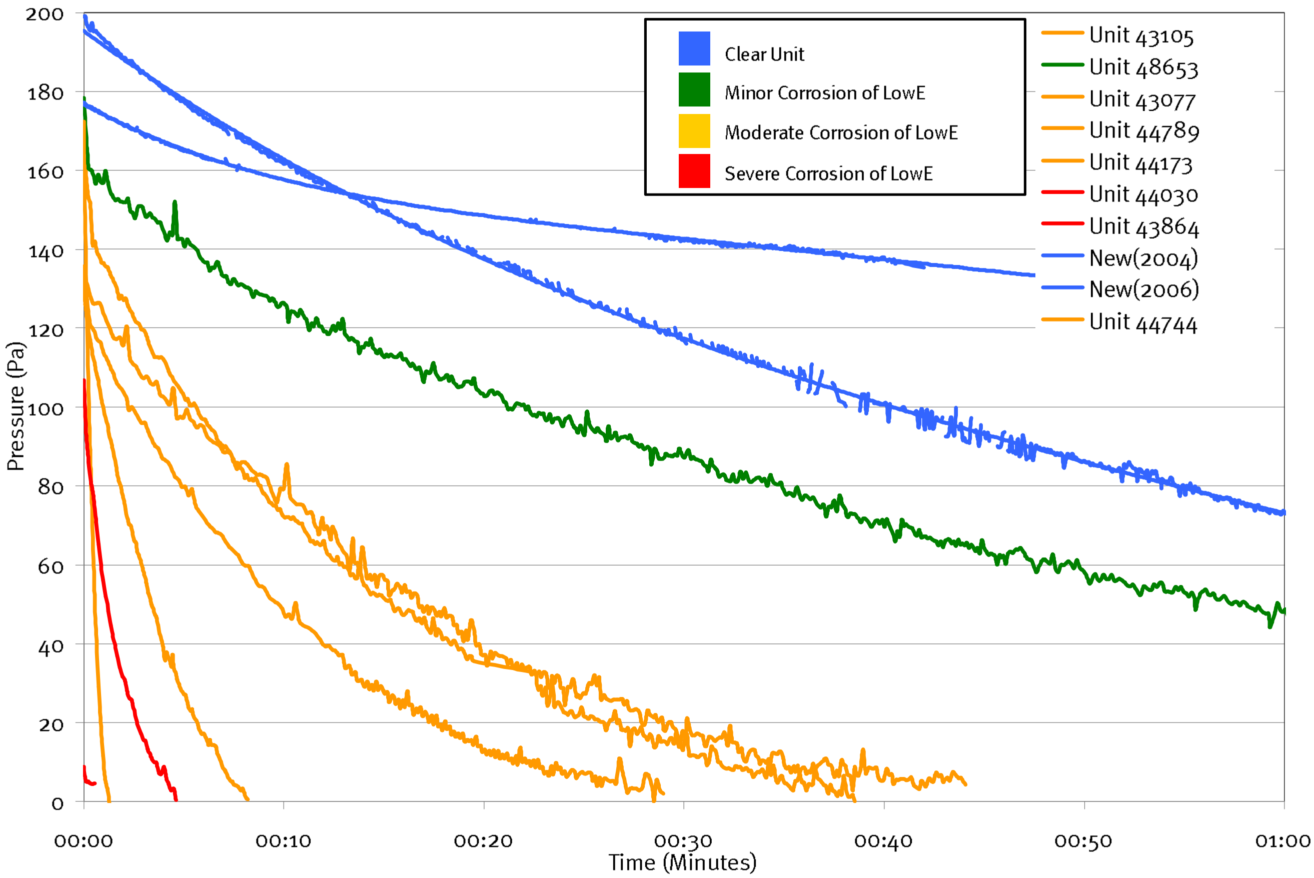


Figure B17: Pressure Test Results, Suite 3903 – Correlated with Low-e Corrosion condition

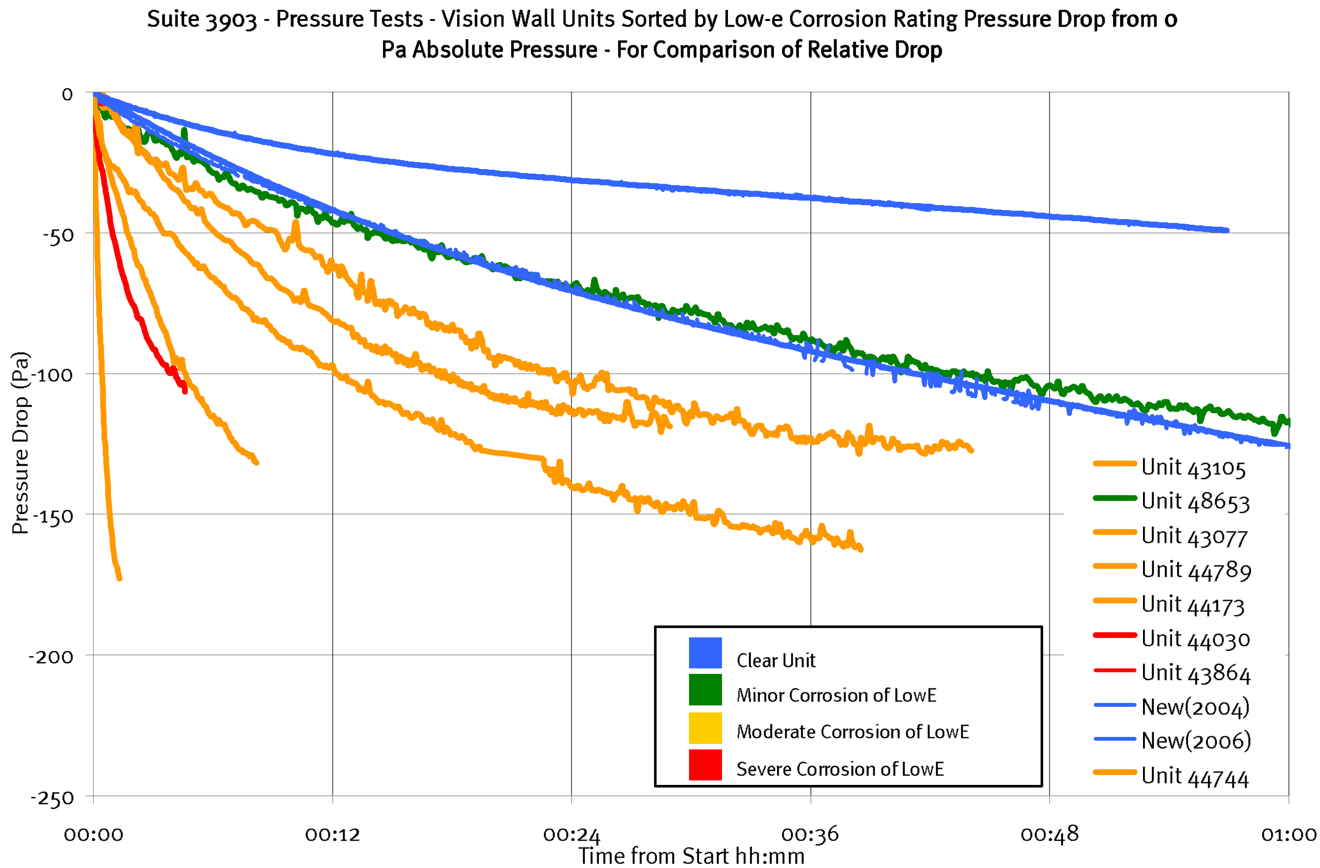


Figure B18: Pressure Test Results, Suite 3903 – Correlated with Low-e Corrosion condition

As shown in the figures, the units with high air leakage rates (faster decay time) had a higher level of low-e corrosion damage, indicative of past or present moisture within the glazing unit.

2008 Pressure Testing – Suite 4502

Thirteen Vision Wall IGUs within suite 4502 were pressure tested on August 7, 2008 using the previously discussed equipment and apparatus. The pressure testing was performed in conjunction with a visual review and dewpoint test. The results of the pressure tests are plotted in Figure B19, with the dewpoint temperature and low-e condition noted for each pressure decay curve.

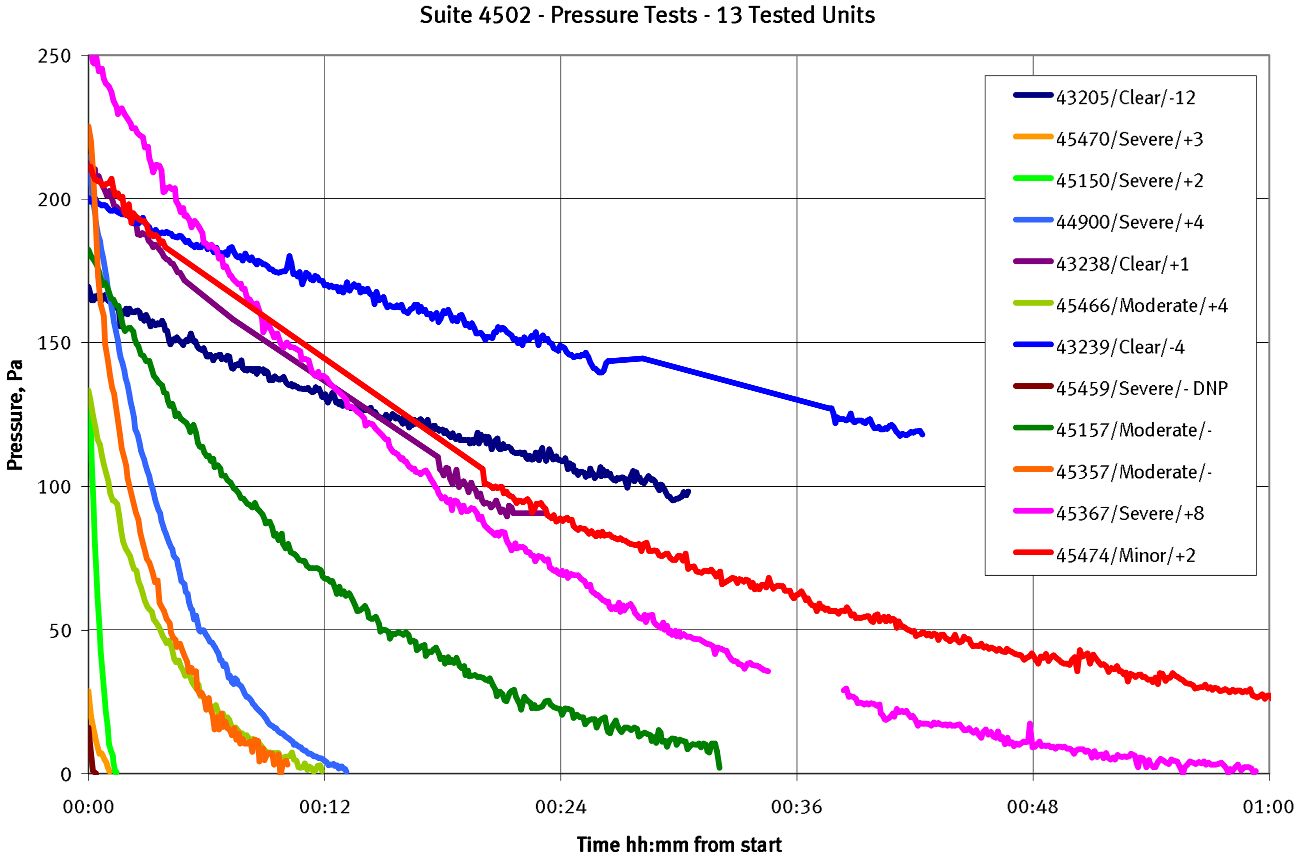


Figure B19: Pressure Test Results for13 Visionwall IGUs within suite 4502.

Similar to pressure testing at suite 3903, more severe low-e corrosion is correlated with a faster decay curve.

The severity of IGU low-e corrosion is correlated with the pressure decay curves in Figure B20 and B21.

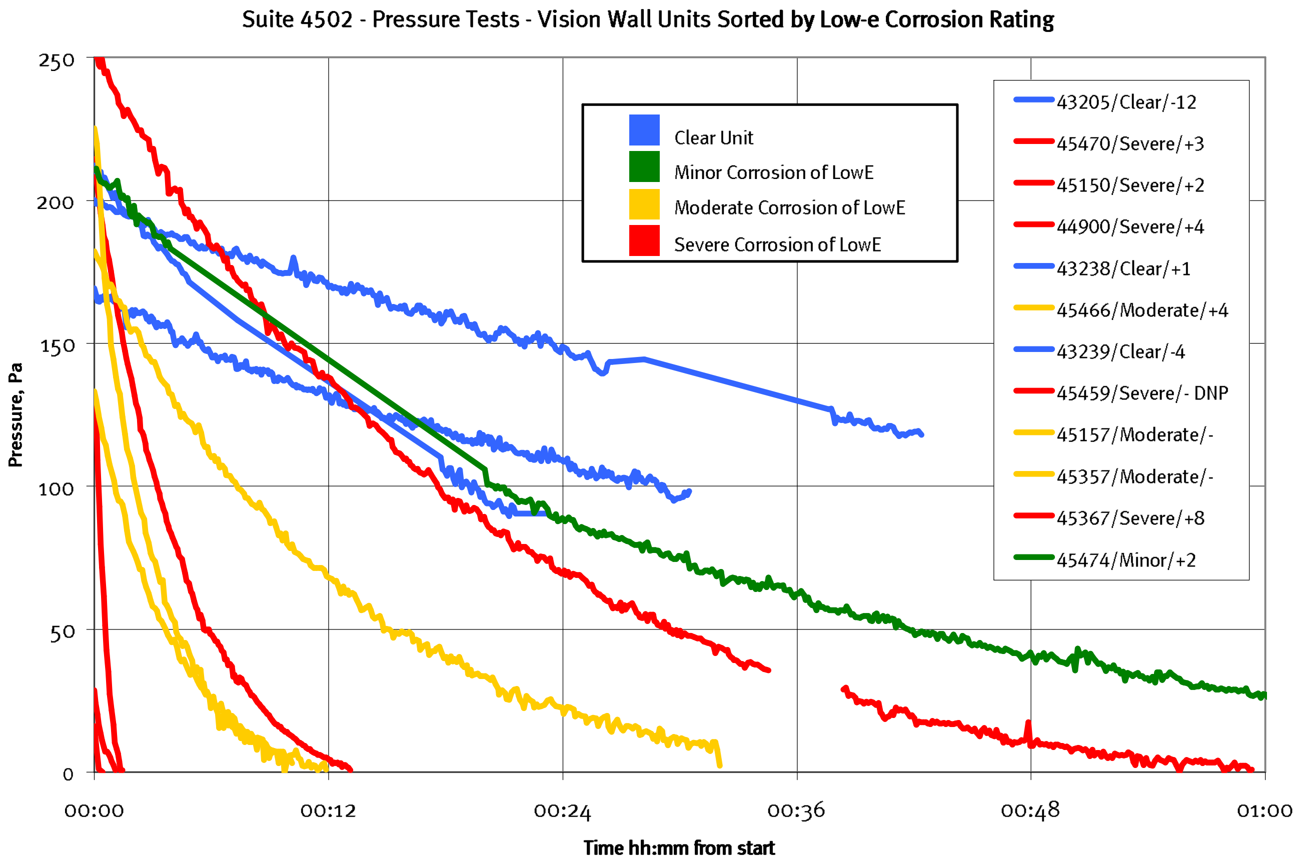


Figure B20: Pressure Test Results, Suite 4502 – Correlated with Low-e Corrosion Condition

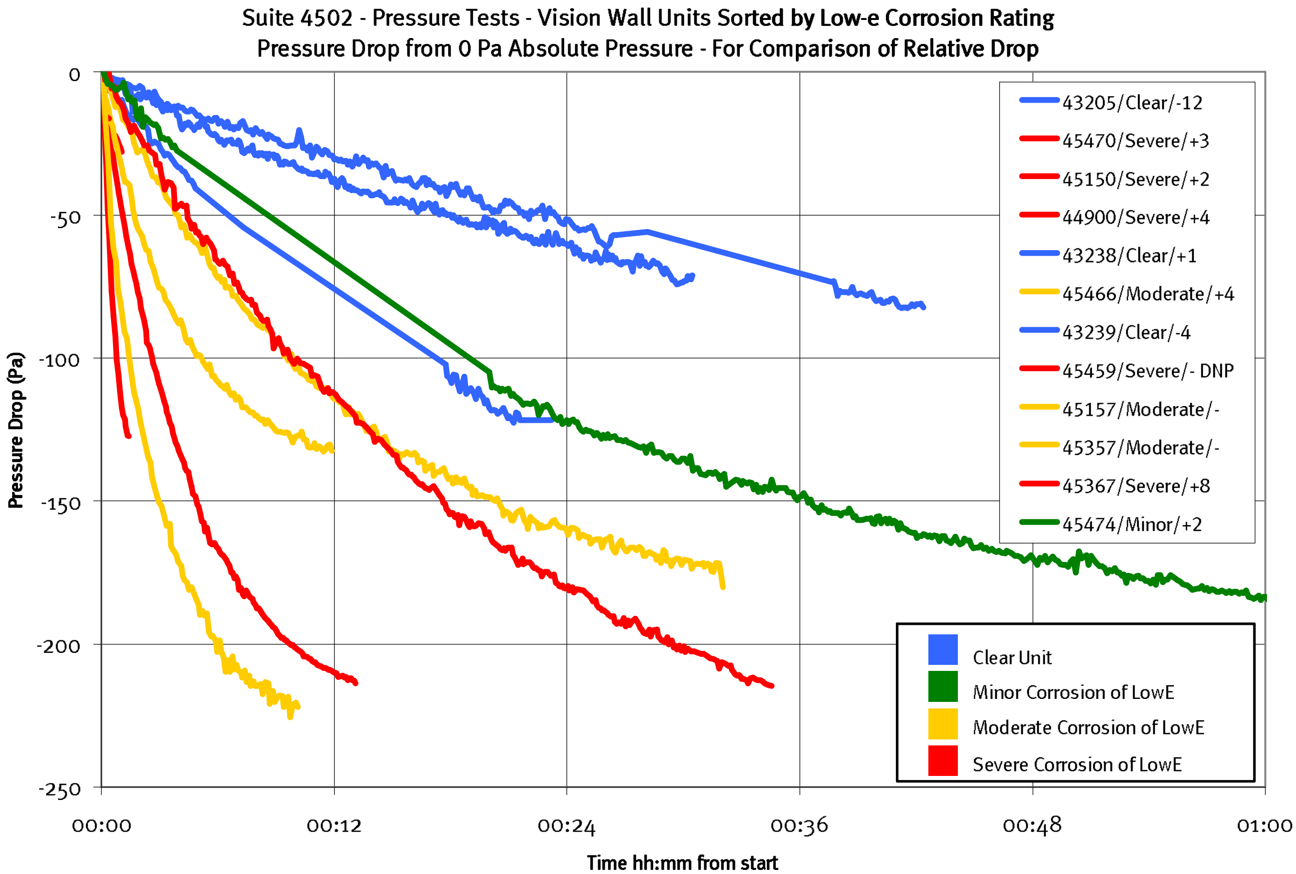


Figure B21: Pressure Test Results, Suite 4502 – Correlated with Low-e Corrosion condition

2008 Pressure Testing – 40th Floor Suites

Ten Vision Wall IGUs at the monitored suites on the 40th floor were pressure tested on October 6, 2008 using the previously discussed pressure testing equipment and apparatus. The pressure testing was performed in conjunction with a visual review, following the pressure and flow monitoring program (see next section). The location of the tested IGUs is presented in Figure B22.

The results of the pressure tests are plotted in Figure D23 and D24, with the dewpoint temperature and low-e condition noted for each pressure decay. Four of the tested IGUs were too leaky to pressurize through the existing desiccant breather tube. Note the difference in the time-scale between Figures B23 and B24.

40th Floor – Pressure & Flow Gauge Locations

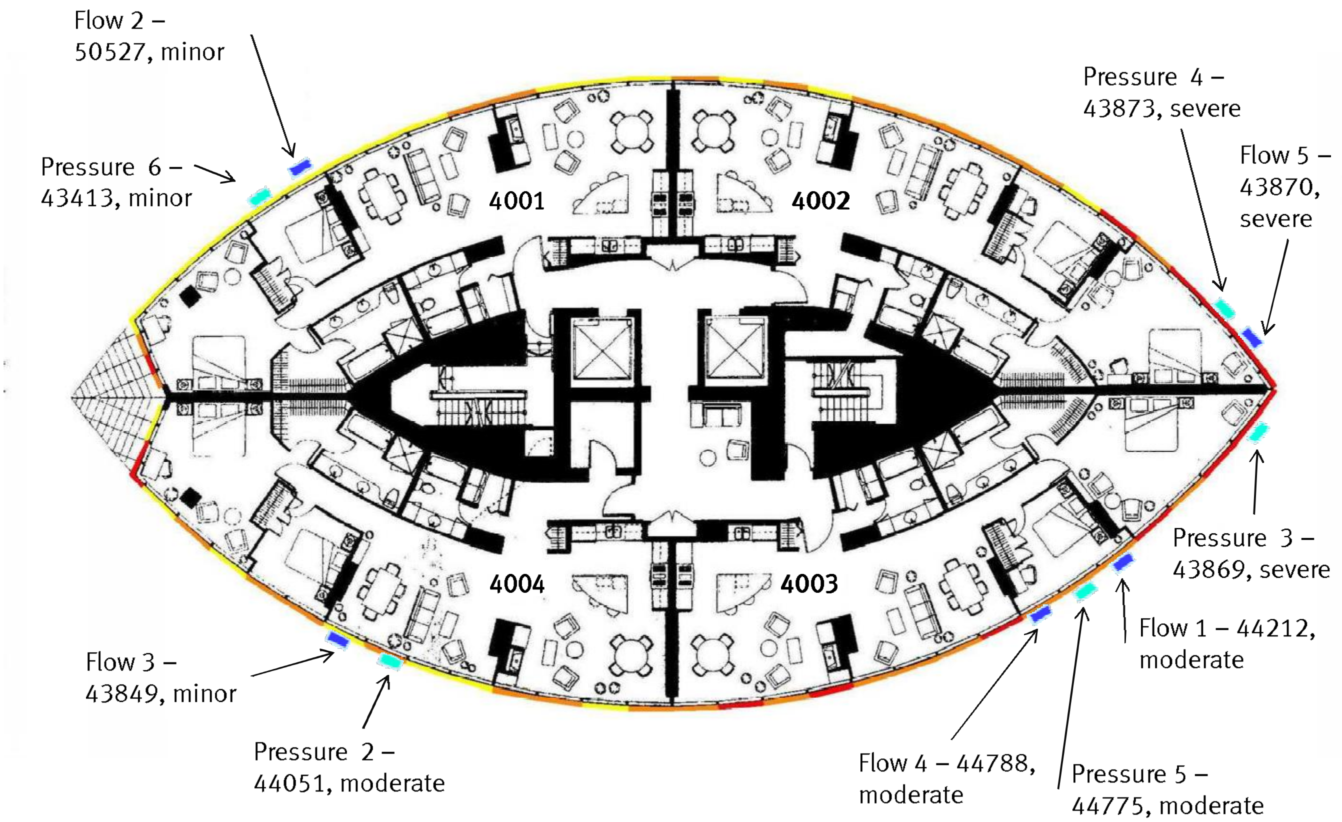


Figure B22: Location of Pressure/Flow sensors and Pressure Tested IGUs at 40th floor.

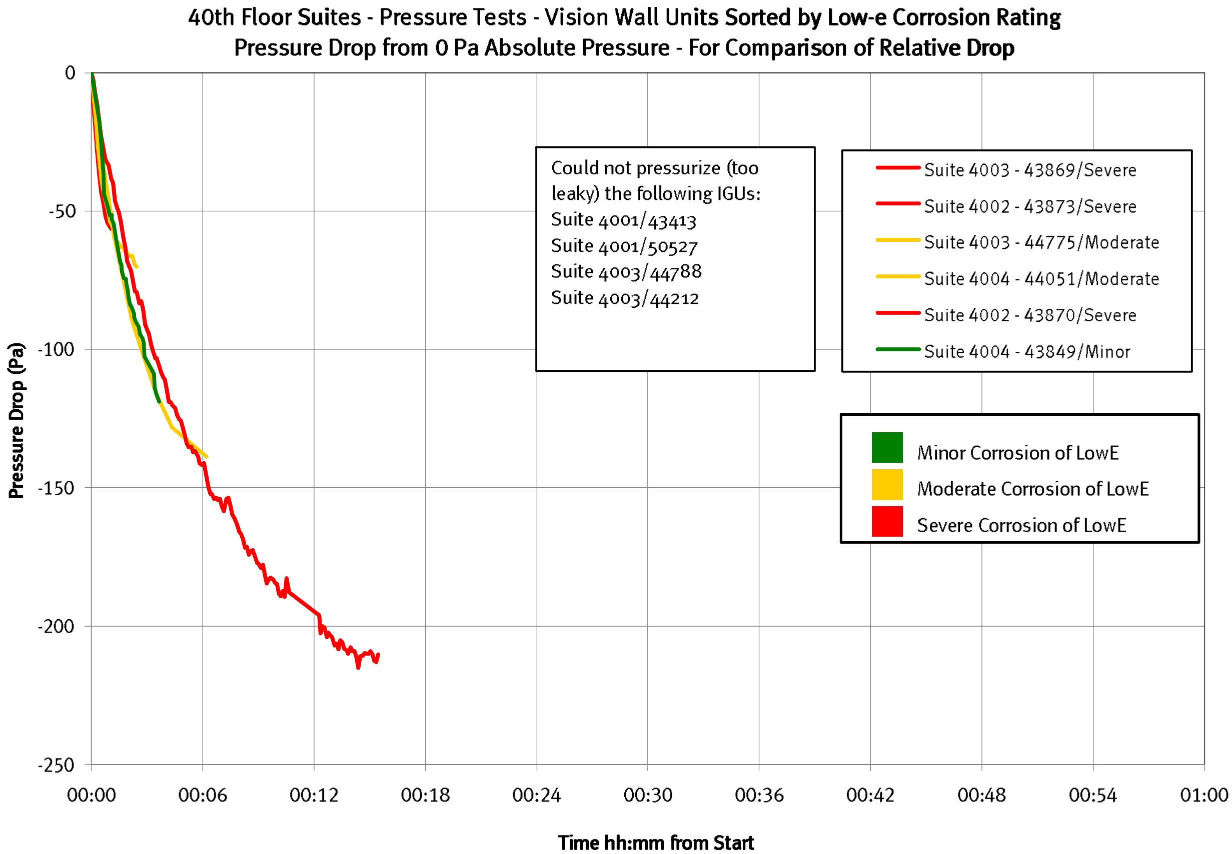


Figure B23: Pressure Test Results, 40[tth] floor suites – Correlated with Low-e Corrosion condition, 0 – 60 minutes

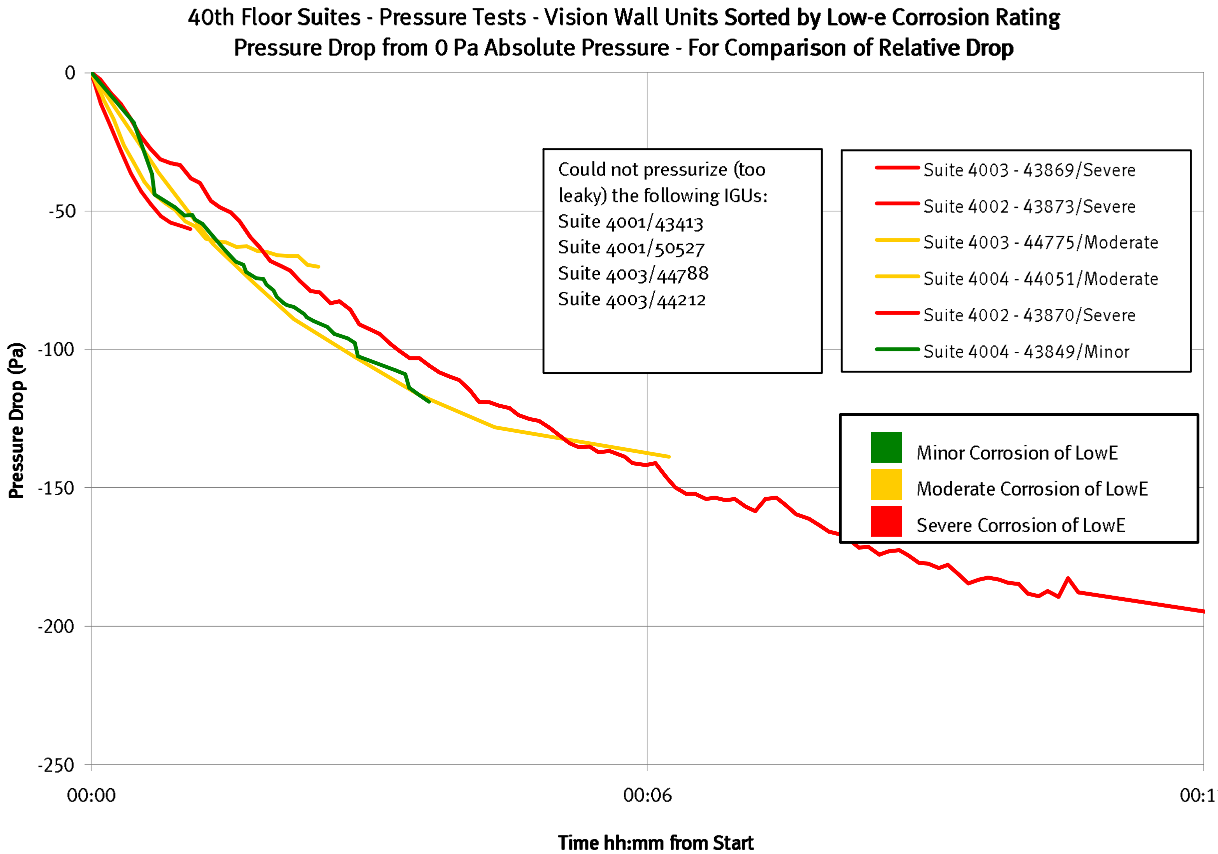


Figure B24: Pressure Test Results, 40tth floor suites – Correlated with Low-e Corrosion condition, 0 – 12 minutes

All six of the pressure tested IGUs showed a very rapid decay, regardless of the severity of the low-e corrosion damage.

2008 Pressure & Flow Monitoring – Suite 4502

A short term monitoring project was implemented at suite 4502 to measure two variables: flow into and out-of an IGU and pressure within an IGU in-situ over a one week period. The purpose was to observe the influence of wind pressures on the pressure within the IGU and secondly to measure the flow out of or into the IGU through the open ended desiccant tube. The monitoring began on August 7th and continued until August 13th. Measurements were taken every 30 seconds by the pressure gauges and recorded by a data-logger.

A weather station, located at the top of a 30-storey high-rise at 388 Drake Street (less than 1-km away) was used for wind and exterior climatic data. The weather station is maintained by RDH and used for several research and monitoring studies. The weather station consists of a professional grade Davis Vantage Pro 2 Plus (http://www.davisnet.com/weather/products/vantagepro.asp) and 5-minute historical and real-time data is available online at http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=IBCVANCO9.

The flow and pressure gauges cannot be hooked up to the same IGU through the same desiccant tube, therefore two adjacent IGUs with a similar visual condition, dewpoint and decay rate were chosen.

The digital flow gauge was hooked up to IGU 44900, and had a severe low-e corrosion/fogging, 4°C dewpoint, with a fast decay.

The pressure gauge was hooked up to IGU 45367, and had a severe low-e corrosion/fogging, 8°C dewpoint, with a fast decay.

The location of the monitored IGUs is shown in Figure B25.

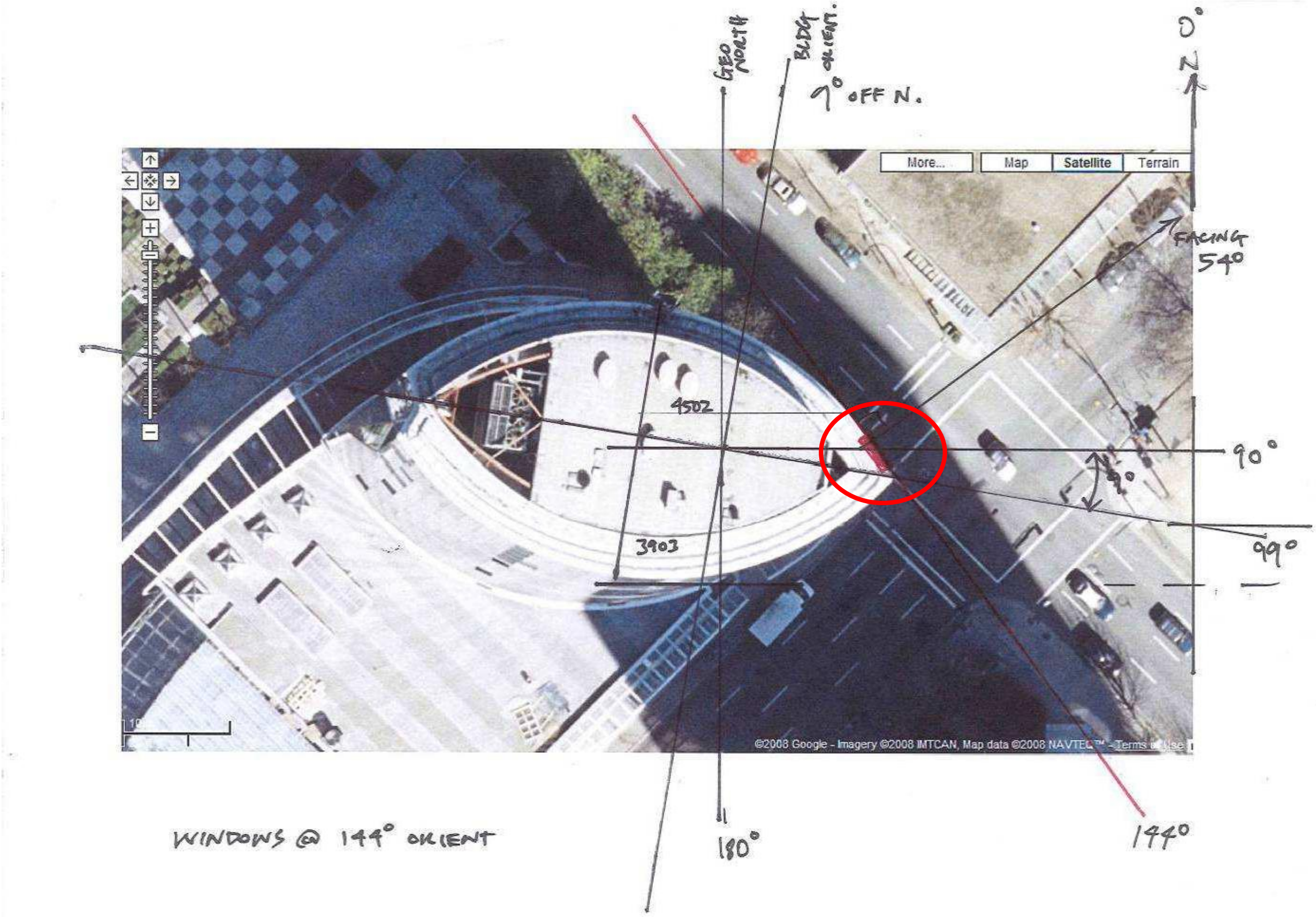


Figure B25: Satellite Image of One- Wall Showing location and orientation of Monitored IGUs at Suite 4502.

Monitored Wind speed and Direction over the period is presented in Figure B26.

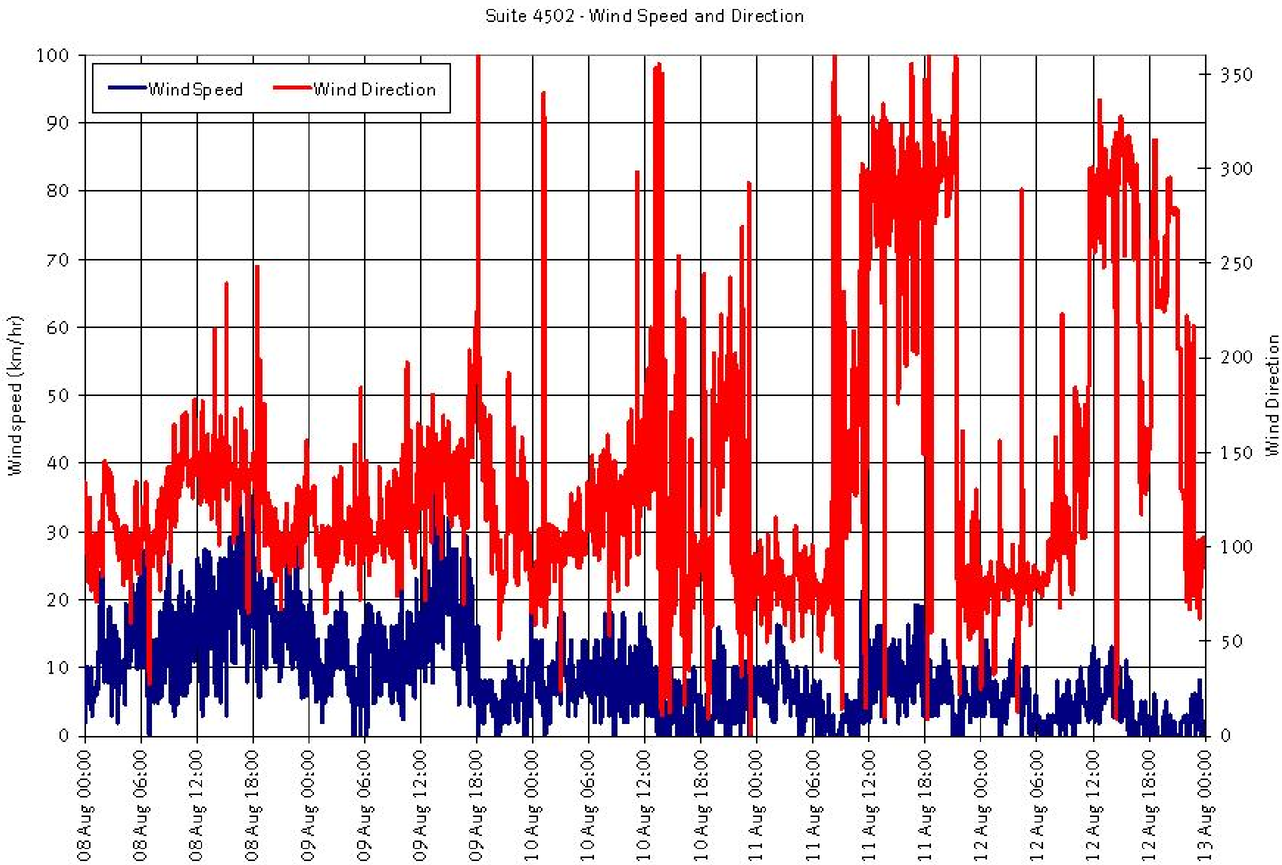


Figure B26: Monitored Wind speed and Direction, August 8 – 13, 2008.

The influence of wind on the pressure within the IGU airspace is plotted in Figure B27 and B28.

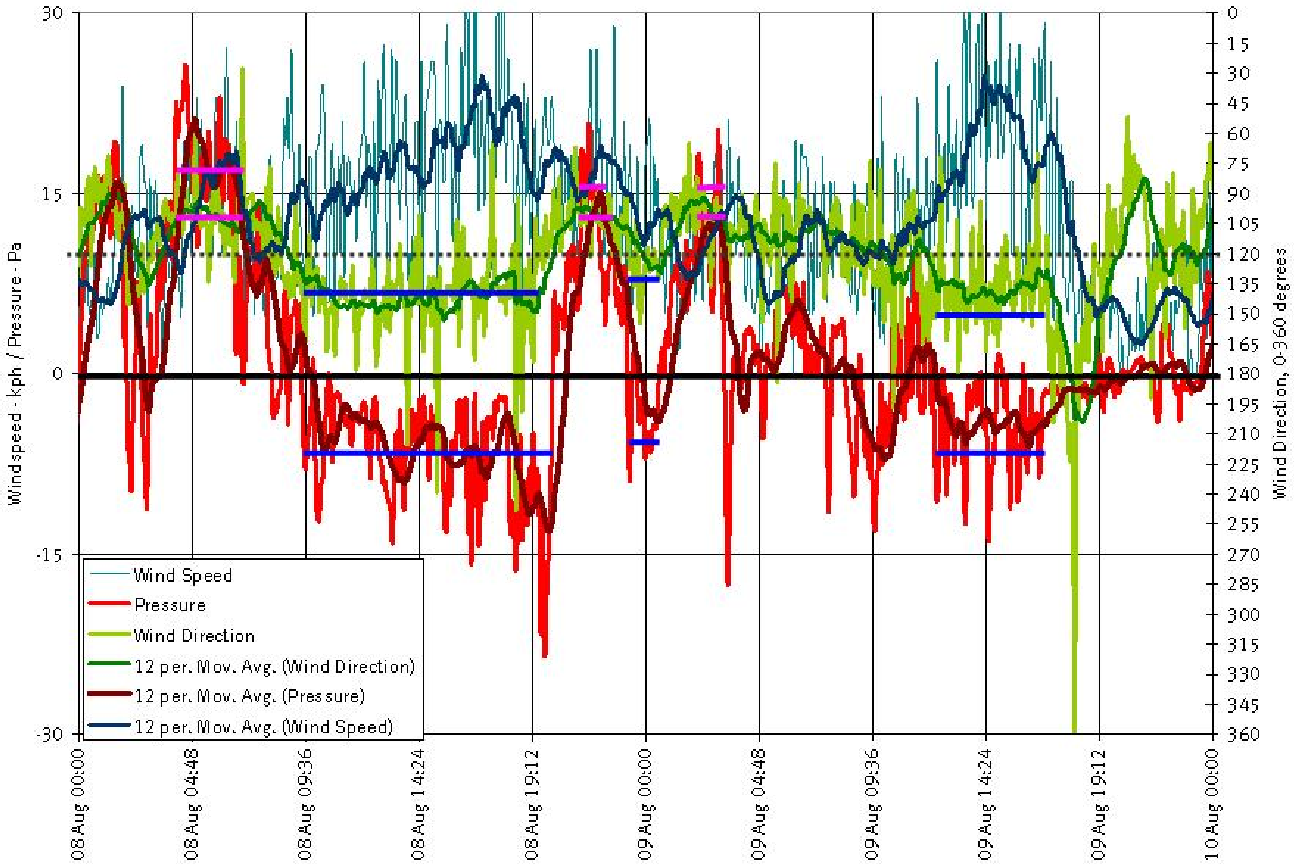


Figure B27: Influence of Wind-speed and Direction on Pressure within IGU 45367.

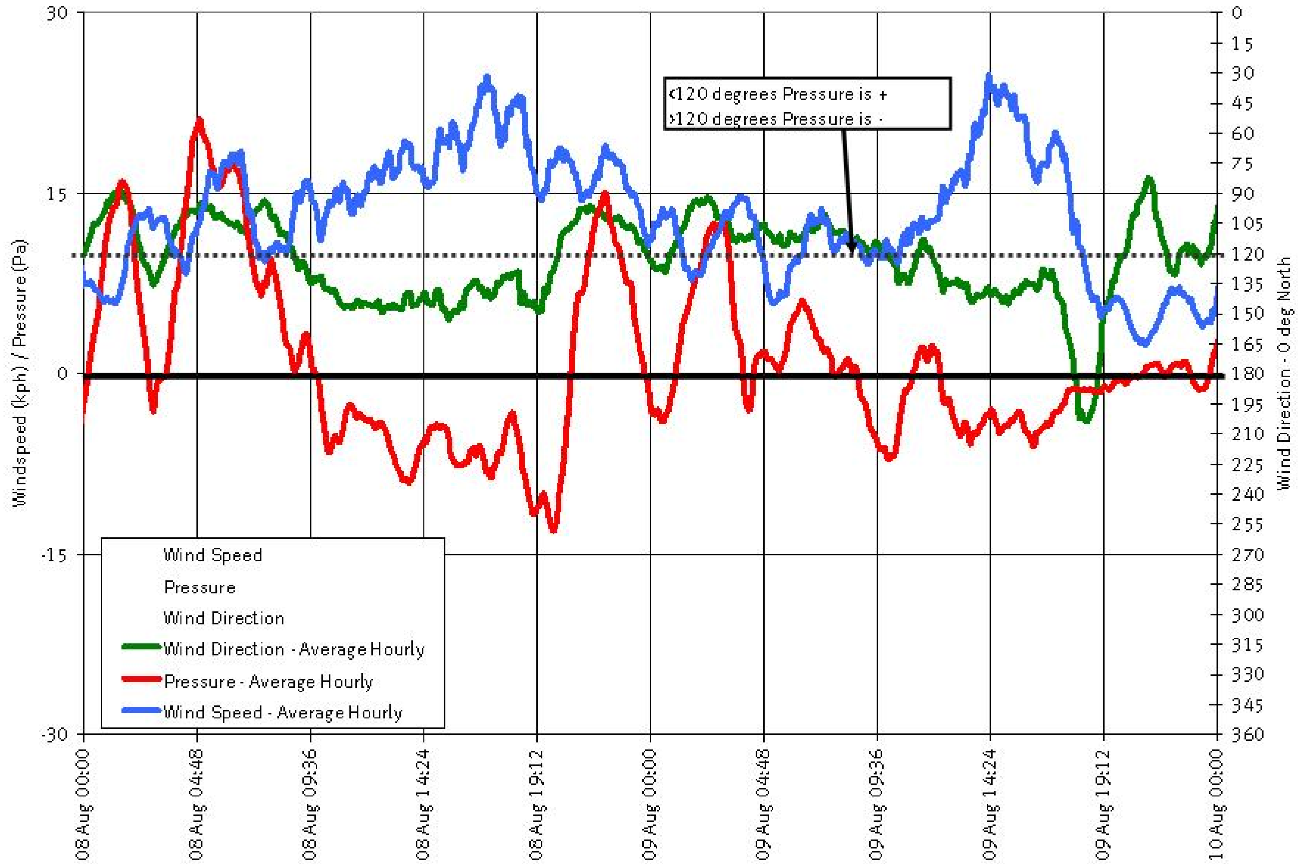


Figure B28: Influence of Wind-speed and Direction on Pressure within IGU – Average Values

Depending on the wind direction – the pressure within the IGU will be positive or negative. A positive pressure will result in airflow out of the IGU and negative pressure will result in airflow into the IGU, should the IGU not be perfectly sealed. As shown, at a wind direction of approximately 120° from north, the pressure within the IGU shifts from positive to negative.

The relationship between this IGU pressure and flow into and out of the IGU is presented in Figures B29 through B31. As shown, the pressure, caused by wind, also results in a flow of air out of or into the IGU through the Desiccant tube. As the desiccant tube makes up only a portion of the IGU leakage, it is assumed that the pressure also causes leakage of the IGUs out of other edge seal deficiencies.

In the following graphs, 5-minute wind data measured atop of the high-rise at 388 Drake is compared to ~5 second pressure and flow data.

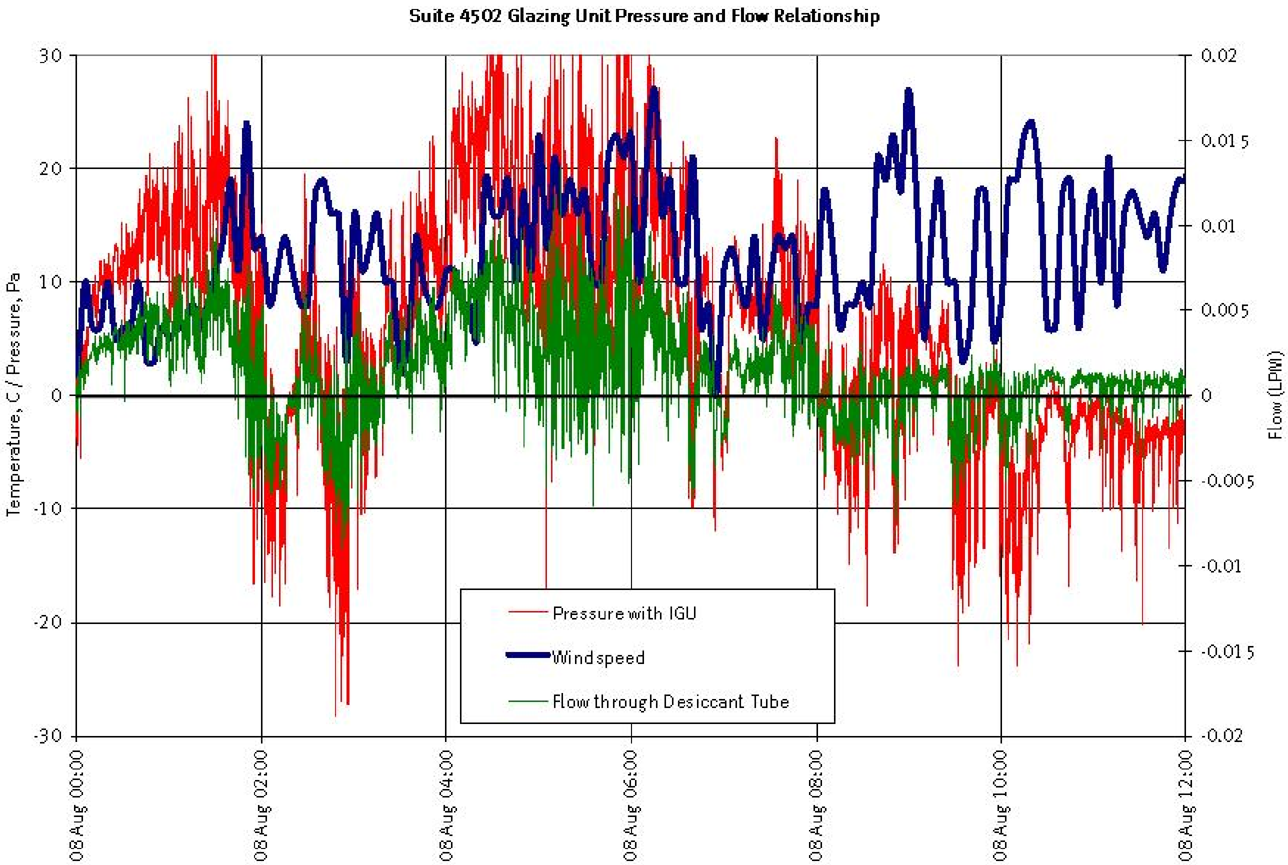


Figure B29: Pressure with IGU 45367 and Flow out of Desiccant Tube at adjacent IGU 44900, 12 hour period. Wind-speed in kph

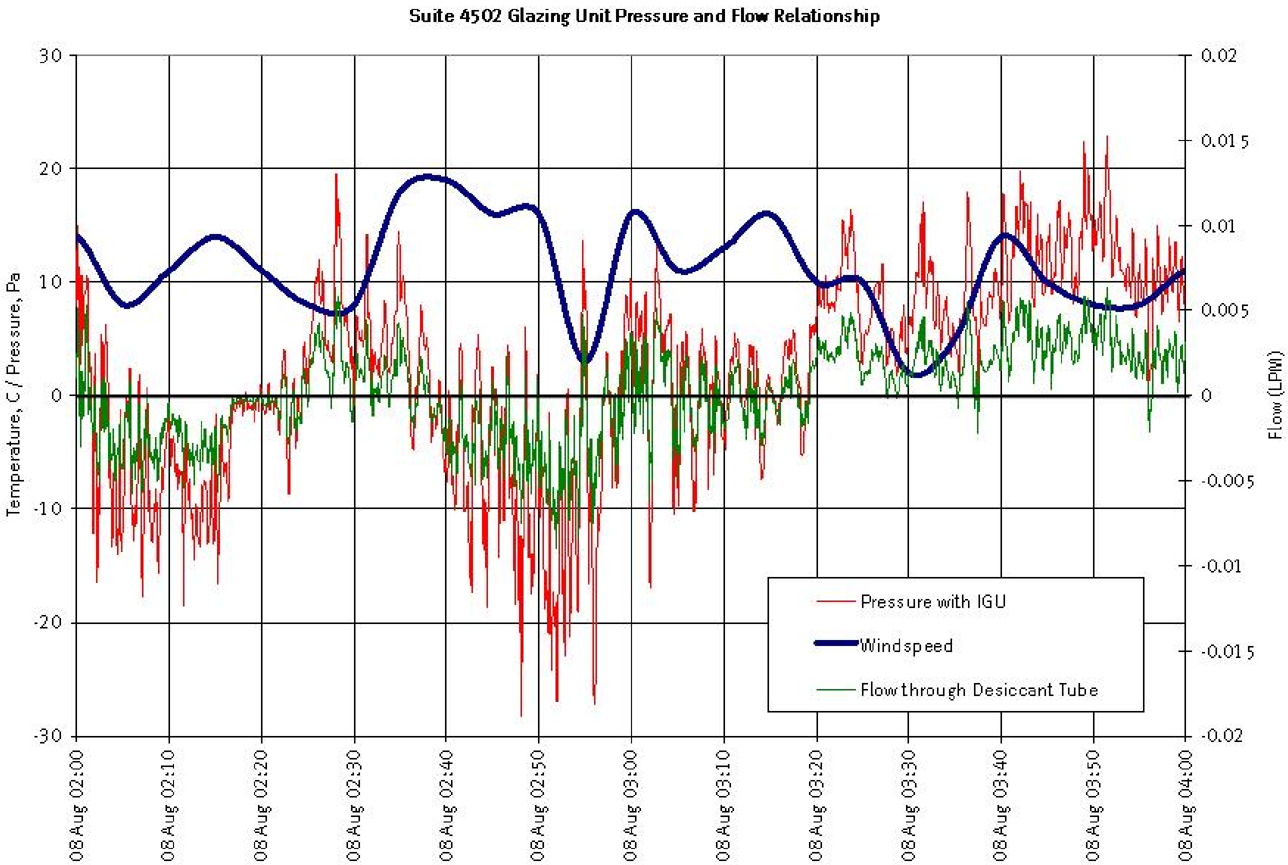


Figure B30: Pressure with IGU 45367 and Flow out of Desiccant Tube at adjacent IGU 44900, 2 hour period. Windspeed in kph.

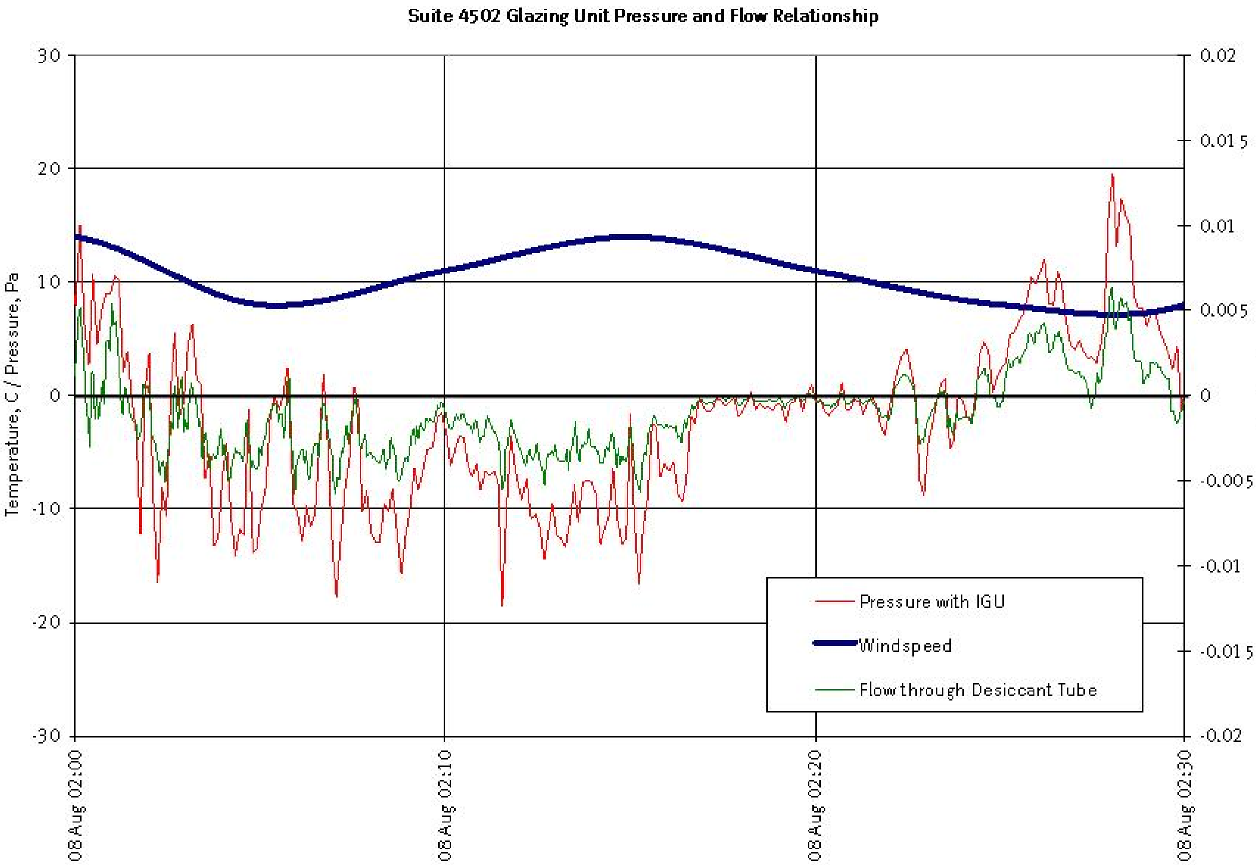


Figure B31: Pressure with IGU 45367 and Flow out of Desiccant Tube at adjacent IGU 44900, 0.5 hour period. Windspeed in kph

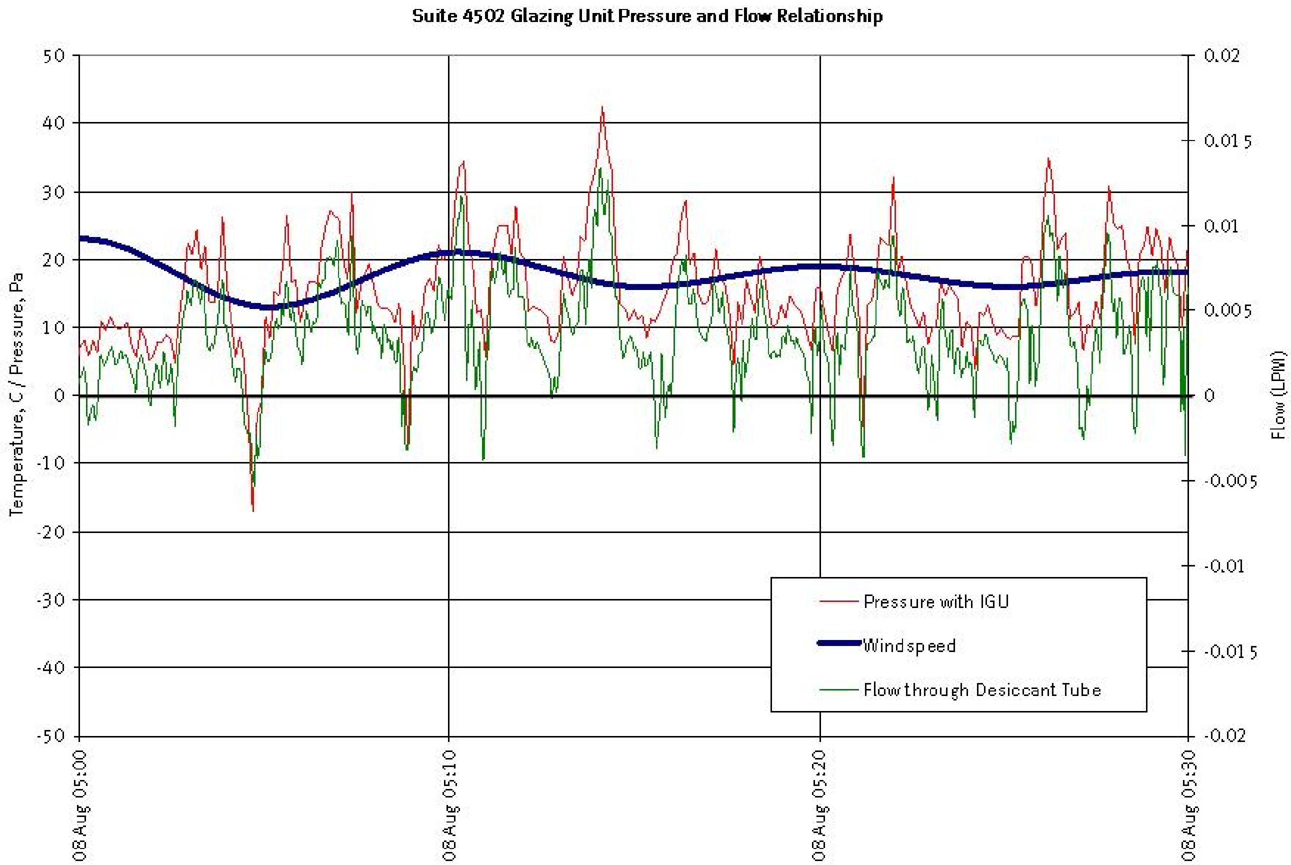


Figure B32: Pressure with IGU 45367 and Flow out of Desiccant Tube at adjacent IGU 44900, 0.5 hour period

During the monitored period between August 7th and 11th 2008 the maximum negative pressure measured was -59 Pa, and the maximum positive pressure was +42 Pa.

Between August 7th at 12:34 pm (start of monitoring) and August 8th at 12:34 pm (24 hours later) a total flow of 2.56 L was measured into and out of the IGU through the desiccant tube. Flow into the IGU at that time was 1.69 L.

Between August 7th at 12:34 pm (start of monitoring) and August 11th at 1:04 am (85 hours later, 5083 minutes) a total flow of 7.25 L was measured into and out of the IGU through the desiccant tube. Flow into the IGU at that time was 2.11 L, flow out was 5.14 L through the desiccant tube. As the pressure difference between the start and finish is 0 Pa, the remaining volume of air would have to be made up from leaks into the IGU from the exterior.

An average flow rate of 0.09 L/hour is determined from this data. A maximum flow rate of 0.04 L/minute was measured during one high wind pressure event.

2008 Pressure & Flow Monitoring – 40th Floor Suites

Based on the trial in-situ pressure and flow monitoring results at suite 4502 – a large scale monitoring program was implemented at the four suites of the 40th floor. Pressure and Flow sensors were installed at five locations and monitored from September 18th through October 6th, 2008 shown in Figure B33.

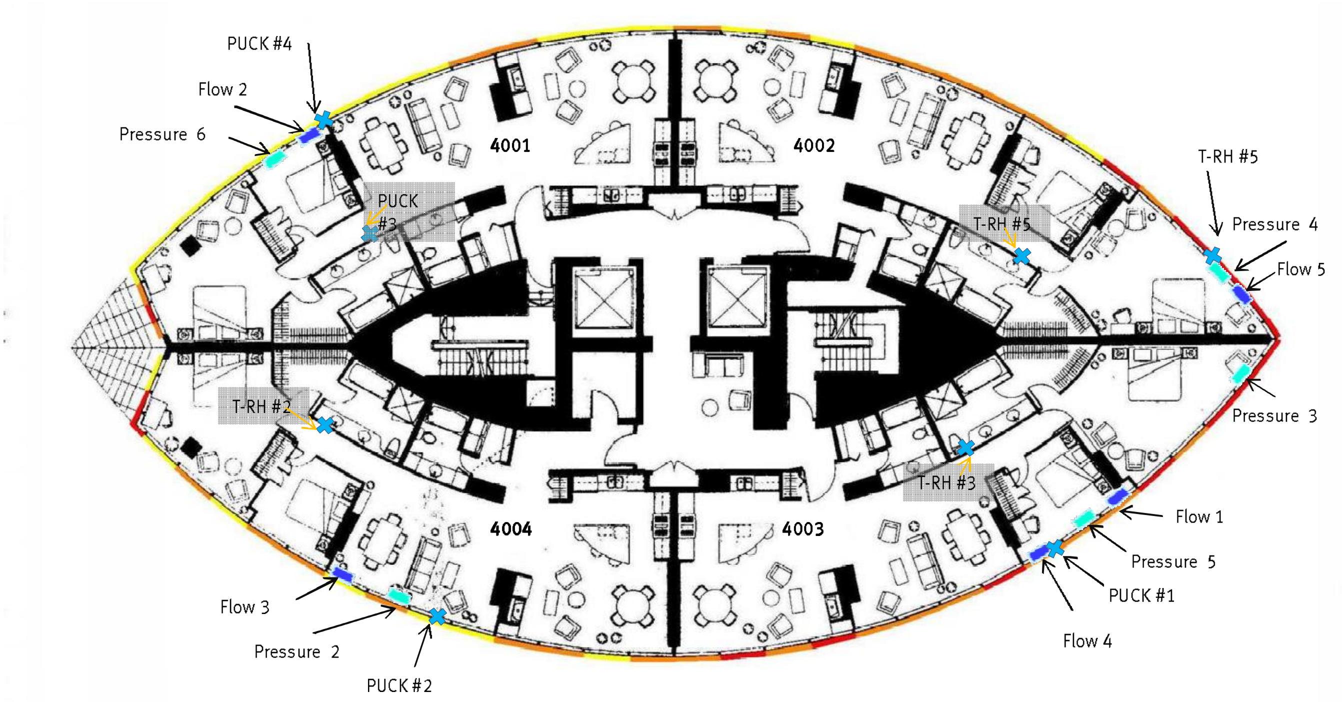


Figure B33: Location of Pressure and Flow Sensors at 40th floor

Pressure data for each of the 5 IGU pressure sensors (Numbered #2 through #6) is plotted in Figure B34.

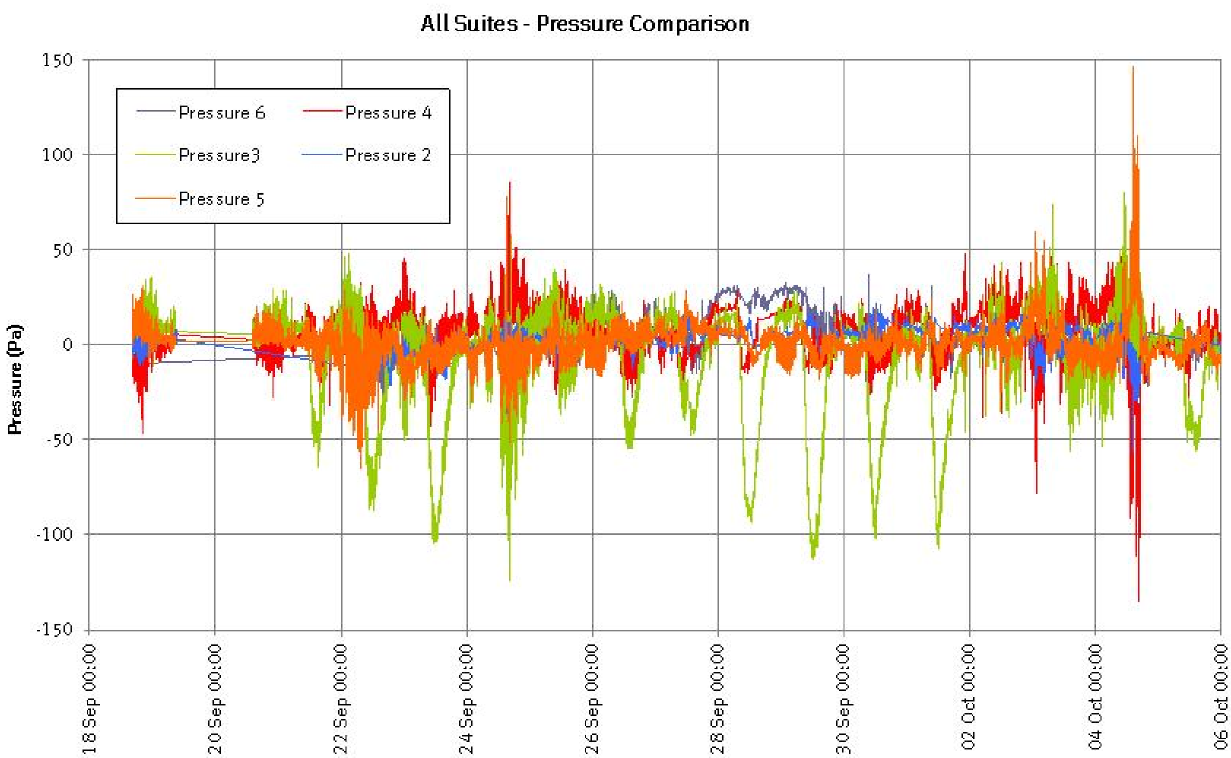


Figure B34: Pressure data for 5 monitored IGUs, September 8th through October 6th.

In general the IGU pressure is influenced by wind pressures on the building. It is suspected the setup for Pressure Gauge #3 was adversely affected by solar heating and hence produced some potentially erroneous results (green line above) – however the remaining 4 pressure gauges provide a good indication of the pressure within the IGUs. Figure B35 presents data for October 4, with wind-speed in kph shown.

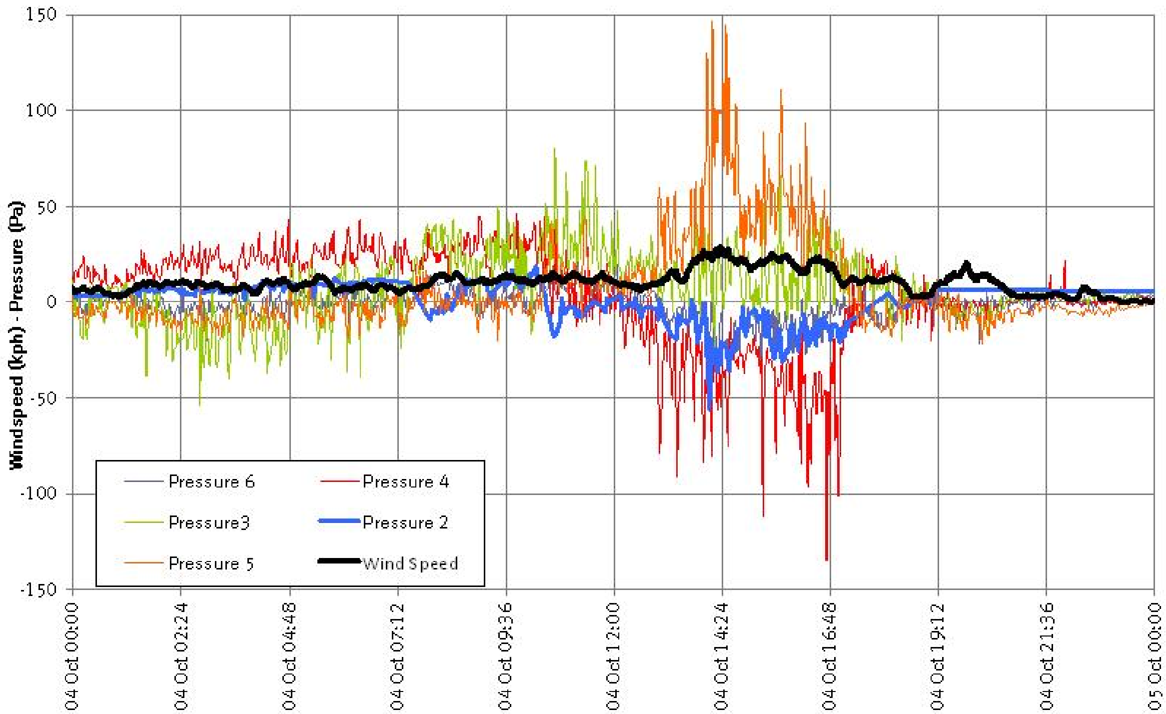


Figure B35: Pressure data vs Wind-speed for 5 monitored IGUs, October 4, 2008

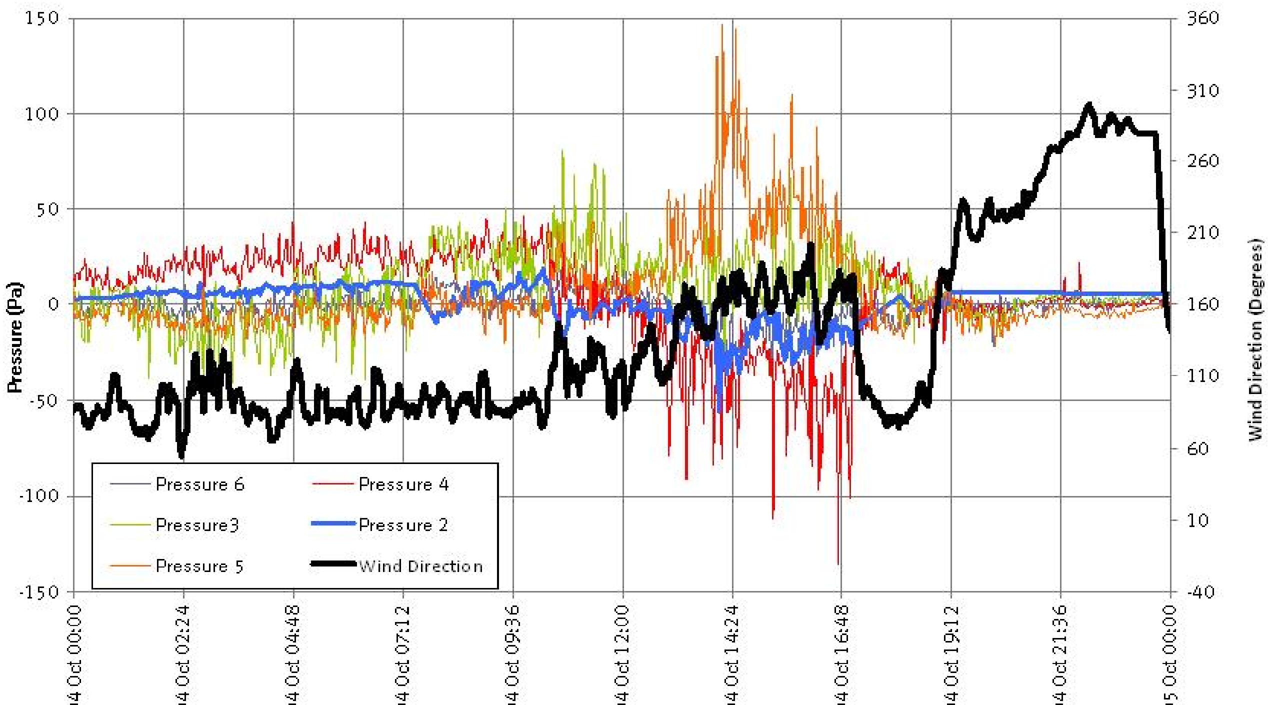


Figure B35: Pressure data vs Wind-direction for 5 monitored IGUs, October 4, 2008

Flow data for IGUs is presented in Figure B36 for the entire period and in Figure B37 for October 4th. Flow Sensor 5 at suite 4002 malfunctioned during the testing and did not record and is excluded from the plot.

Sensor data is broken down in up to 3 parts (i.e Flow 3-1 and Flow 3-2 etc) to fit the data-points recorded every 30 seconds onto one continuous data plot.

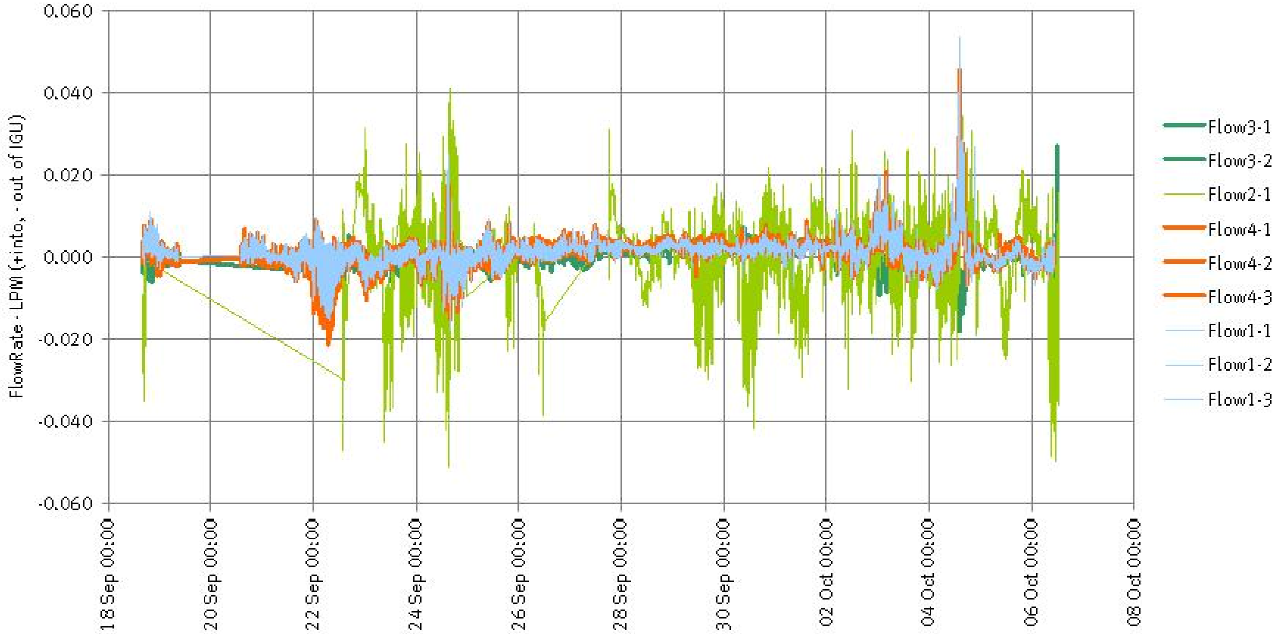
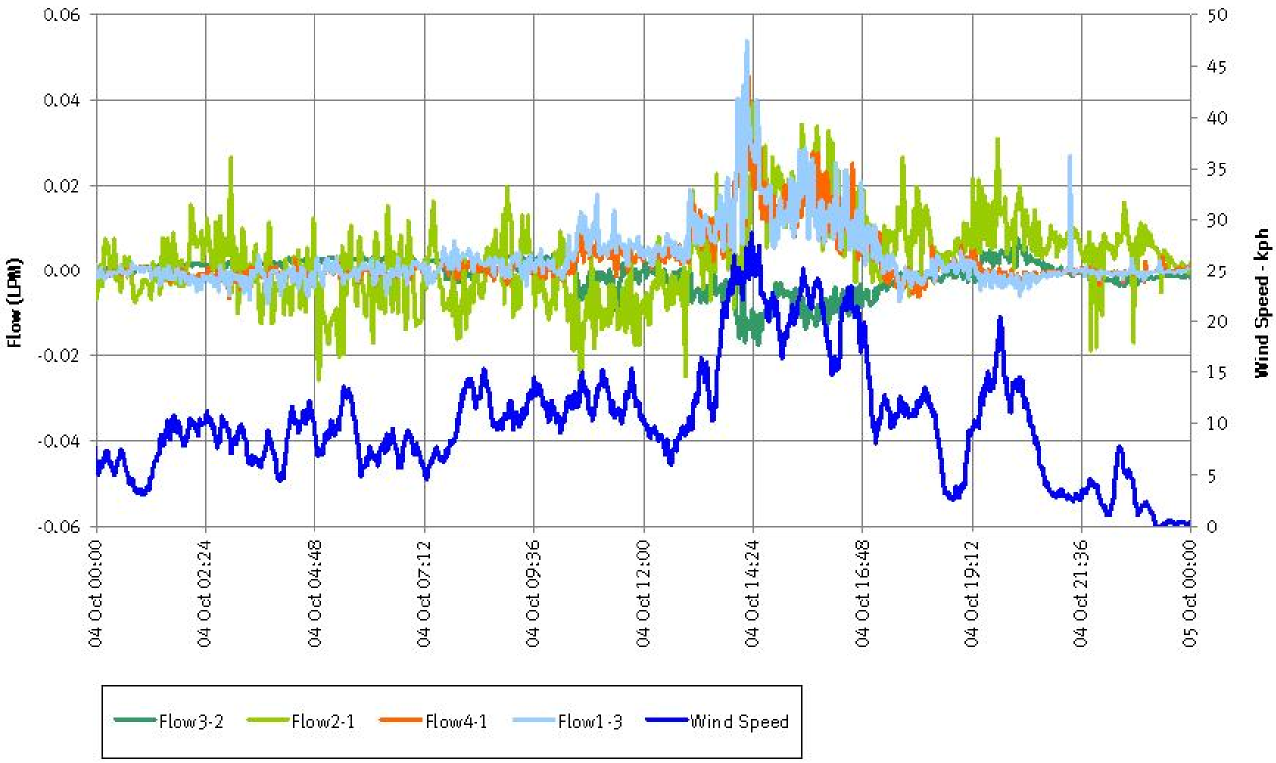


Figure B36: Flow through IGU Tube, September 18 through October 8, 2008.



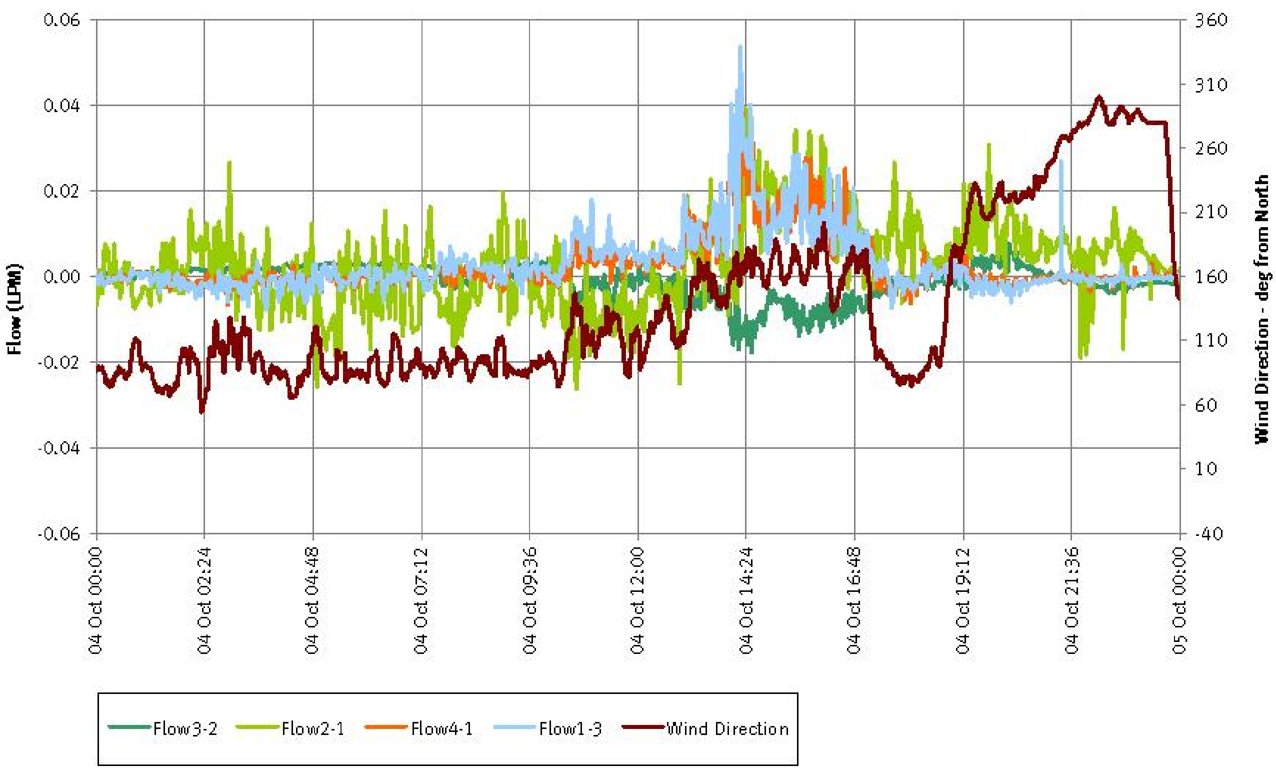


Figure B37: Flow into and out of Desiccant Tubes - October 4, 2008.

Flow units #1 and #4 are located within the same suite (4003) on the same orientation exposed to the prominent wind direction and have very similar behaviour. Flow unit #2 is at suite 4002 and subject to varying wind pressures on the prominently leeward side of the building. Flow unit #3 is at suite 4004 and subject to varying wind pressures on the shear wind side of the building.

Total flow rates into and out-of and into the four monitored IGUs on October 4th are as follows.

- Flow 2 (Suite 4001, Northwest Corner) – Total flow into and out-of the IGU was 11.97 L, and the total flow into the IGU was 3.95 L.
- Flow 1 (Suite 4003, Southeast Corner) – Total flow into and out-of the IGU was 6.47 L, and the total flow into the IGU was 4.30 L.
- Flow 4 (Suite 4003, Southeast Corner) – Total flow into and out-of the IGU was 5.60 L, and the total flow into the IGU was 3.81 L. Flow 1 and 4 had very similar performance.
- Flow 3 (Suite 4004, Southwest Corner) – Total flow into and out-of the IGU was 4.21 L, and the total flow into the IGU was -1.32 L (or a net flow out-of the IGU on October 4th).

Appendix C

Raw Data

APPENDIX C: Raw Data, 2006 through 2009

Raw data from the visual reviews and frost/dew point testing is provided in this appendix. Dewpoint testing was performed using the same Dennis Industries Dew/Frost Point Measuring Apparatus for all tests in all years.

2006-2007 Visual Review and Dewpoint Testing Observations and Results – Raw Data

Visual review and dew-point testing performed by Matt Mulleray, P.Eng and Brian Hubbs, P.Eng of RDH in 2006-2007.

Date of Review	Suite	IGU Unit	Visual Classification	Dew-Frost Point Result	Pressure Test Result (by hand)
Feb 06/06	4701	45820	Severe	5	
Feb 06/06	4701	45659	Clear	-5	
Feb 06/06	4701	45817	Moderate	0	
Feb 06/06	4701	45905	Minor	-8	
Feb 06/06	4004	44052	Minor	-8	
Feb 06/06	4004	43929	Severe	-2	
Feb 06/06	4004	43093	Moderate		
Feb 06/06	4004	43089	Clear		
Feb 06/06	4004	43118	Moderate		
Feb 06/06	4004	44158	Minor		
Feb 06/06	4004	44811	Minor		
Feb 06/06	4004	43654	Minor		
Feb 06/06	4004	44051	Minor		
Feb 06/06	4004	43849	Minor		
Feb 06/06	4004	44048	Clear		
Feb 06/06	4004	44776	Minor		
Feb 06/06	4004	44777	Clear		
Feb 06/06	4004	44825	Minor		
Feb 06/06	4004	43644	Clear		
Feb 06/06	4004	44823	Minor		
Feb 06/06	4004	43659	Moderate		
Feb 06/06	4004	43916	Moderate		
Feb 06/06	4004	44756	Clear		
Feb 06/06	4004	44220	Clear		
Feb 06/06	3804	43221	Moderate	-5	
Feb 06/06	3804	43224	Clear	-5	
Feb 06/06	3804	43164	Moderate		
Feb 06/06	3804	44149	Moderate		
Feb 06/06	3804	44145	Moderate		
Feb 06/06	3804	43586	Minor		
Feb 06/06	3804	44043	Moderate		
Feb 06/06	3804	44040	Minor		
Feb 06/06	3804	43853	Minor		
Feb 06/06	3804	43854	Minor		
Feb 06/06	3804	43365	Minor		
Feb 06/06	3804	43725	Minor		

Feb 06/06	3804	44161	Moderate		
Feb 06/06	3804	44162	Moderate		
Feb 06/06	3804	43926	Severe		
Feb 06/06	3804	43960	Clear		
Feb 06/06	3804	43893	Clear		
Feb 06/06	3804	43890	Clear		
Feb 13/06	4502	43239	Clear	-55	
Feb 13/06	4502	45470	Minor	-10	
Feb 13/06	4502	45484	Severe	-5	
Feb 13/06	4502	43205	Clear		
Feb 13/06	4502	43238	Clear		
Feb 13/06	4502	45157	Clear		
Feb 13/06	4502	45458	Clear		
Feb 13/06	4502	45474	Clear		
Feb 13/06	4502	45466	Minor		
Feb 13/06	4502	45357	Minor		
Feb 13/06	4502	45459	Minor		
Feb 13/06	4502	45456	Minor		
Feb 13/06	4502	45150	Minor		
Feb 13/06	4502	45135	Clear		
Feb 13/06	4502	45153	Minor		
Feb 13/06	4502	45367	Clear		
Feb 13/06	4502	44900	Clear		
Feb 13/06	4003	43092	Moderate	8	
Feb 13/06	4003	59922	Clear	-55	
Feb 13/06	4003	54707	Clear		
Feb 13/06	4003	44720	Moderate		
Feb 13/06	4003	44003	Minor		
Feb 13/06	4003	44050	Severe	8	
Feb 13/06	4003	44053	Minor		
Feb 13/06	4003	44049	Minor		
Feb 13/06	4003	44768	Minor		
Feb 13/06	4003	44775	Minor		
Feb 13/06	4003	44212	Severe		
Feb 13/06	4003	44730	Severe	8	Fail
Feb 13/06	4003	44737	Minor	-10	
Feb 13/06	4003	53061	Severe		
Feb 13/06	4003	43869	Severe		
Feb 13/06	4003	48645	Severe		
Feb 13/06	4501/4504	45475	Severe	-15	
Feb 13/06	4501/4505	59916	Moderate	-15	
Feb 13/06	4501/4506	59917	Clear	-30	
Feb 13/06	4501/4507	45160	Clear	-30	
Feb 13/06	4501/4508	43088	Moderate		
Feb 13/06	4501/4509	43198	Minor		
Feb 13/06	4501/4510	43066	Minor		
Feb 13/06	4501/4511	45158	Clear		

Feb 13/06	4501/4512	45454	Moderate		
Feb 13/06	4501/4513	45473	Minor		
Feb 13/06	4501/4514	45469	Minor		
Feb 13/06	4501/4515	45471	Minor		
Feb 13/06	4501/4516	45472	Minor		
Feb 13/06	4501/4517	45356	Moderate		
Feb 13/06	4501/4518	45145	Minor		
Feb 13/06	4501/4519	45143	Minor		
Feb 13/06	4501/4520	44764	Severe		
Feb 13/06	4501/4521	44771	Clear		
Feb 13/06	4501/4522	59919	Clear		
Feb 13/06	4501/4523	45451	Minor		
Feb 13/06	4501/4524	44762	Severe		
Feb 13/06	4501/4525	44768	Minor		
Feb 13/06	4501/4526	45149	Clear		
Feb 13/06	4501/4527	45144	Clear		
Feb 13/06	4501/4528	43381	Clear		
Feb 13/06	4501/4529	43379	Clear		
Feb 13/06	4501/4530	43349	Clear		
Feb 13/06	4501/4531	43176	Clear		
Feb 13/06	4501/4532	43340	Clear		
Feb 13/06	4501/4533	43174	Clear		
Feb 13/06	4501/4534	45159	Clear		
Feb 13/06	4501/4535	43165	Clear		
Feb 13/06	4501/4536	43064	Clear		
Feb 13/06	4501/4537	43166	Minor		
Apr 25/07	3501	43242	Clear		
Apr 25/07	3501	43324	Clear		
Apr 25/07	3501	43155	Clear		
Apr 25/07	3501	44001	Clear		
Apr 25/07	3501	43757	Clear		
Apr 25/07	3501	43332	Clear		
Apr 25/07	3501	43173	Clear		
Apr 25/07	3501	43183	Clear		
Apr 25/07	3501	43070	Clear		
Apr 25/07	3501	43364	Clear		
Apr 25/07	3501	43374	Clear		
Apr 25/07	3501	43735	Clear	-16	Fail
Apr 25/07	3501	43525	Moderate		
Apr 25/07	3501	43748	Minor	-15	Fail
Apr 25/07	3501	43647	Clear		
Apr 25/07	3501	43927	Moderate		
Apr 25/07	3501	43911	Severe		
Apr 25/07	3501	43904	Severe		
Apr 25/07	3501	43888	Severe		
Apr 25/07	3101	38420	Clear		
Apr 25/07	3101	38645	Clear		

Apr 25/07	3101	38626	Clear	-10	Fail
Apr 25/07	3101	38515	Clear		
Apr 25/07	3101	38854	Clear		
Apr 25/07	3101	47081	Clear		
Apr 25/07	3101	38848	Clear		
Apr 25/07	3101	42502	Clear		
Apr 25/07	3101	44168	Minor		
Apr 25/07	3101	44166	Severe		
Apr 25/07	3101	47088	Minor		
Apr 25/07	3101	44170	Moderate		
Apr 25/07	3101	42394	Clear		
Apr 25/07	3101	38498	Clear		
Apr 25/07	3101	40069	Clear		
Apr 25/07	3101	38496	Clear		
Apr 25/07	3101	40056	Clear		
Apr 25/07	3101	38408	Minor	-25	Fail
Apr 25/07	3101	38624	Clear		
Apr 25/07	3101	38632	Clear		
Apr 25/07	3306	47058	Severe		
Apr 25/07	3306	43264	Moderate		
Apr 25/07	3306	43292	Moderate		
Apr 25/07	3306	43453	Clear	-10	Fail
Apr 25/07	3306	43532	Clear		
Apr 25/07	3306	47064	Clear		
Apr 25/07	3306	47051	Moderate		
Apr 25/07	3306	47053	Moderate		
Apr 25/07	3306	47052	Moderate		
Apr 25/07	3703	47214	Moderate		
Apr 25/07	3703	43211	Moderate		Fail
Apr 25/07	3703	43213	Moderate		
Apr 25/07	3703	43856	Severe		
Apr 25/07	3703	44146	Severe		
Apr 25/07	3703	43441	Severe		
Apr 25/07	3703	43719	Severe		
Apr 25/07	3703	43119	Severe		
Apr 25/07	3703	43724	Moderate		
Apr 25/07	3703	43589	Severe		Fail
Apr 25/07	3703	43367	Severe		
Apr 25/07	3703	44135	Severe		
Apr 25/07	3703	44017	Clear		
Apr 25/07	3703	44137	Severe		
Apr 25/07	3703	44018	Severe		
Apr 25/07	3703	43884	Severe		
Apr 25/07	3703	43865	Severe		
Apr 25/07	3703	1/2 Unit	Severe		
Apr 26/07	3105	38649	Clear	-10	Fail
Apr 26/07	3105	38672	Clear		

Apr 26/07	3105	38644	Clear		
Apr 26/07	3105	38514	Clear		
Apr 26/07	3105	38850	Clear		
Apr 26/07	3105	38494	Clear		
Apr 26/07	3105	40039	Clear		
Apr 26/07	3105	38383	Clear		
Apr 26/07	3105	38416	Clear	-5	Fail
Apr 26/07	3105	38427	Clear		
Apr 26/07	4104	43123	Minor		
Apr 26/07	4104	43120	Moderate		
Apr 26/07	4104	43117	Moderate		
Apr 26/07	4104	44818	Clear		
Apr 26/07	4104	44812	Moderate		
Apr 26/07	4104	44038	Moderate		
Apr 26/07	4104	44036	Minor		
Apr 26/07	4104	44035	Minor		
Apr 26/07	4104	44034	Moderate		
Apr 26/07	4104	44211	Moderate		
Apr 26/07	4104	44208	Severe		
Apr 26/07	4104	44824	Moderate		
Apr 26/07	4104	43658	Severe		
Apr 26/07	4104	44821	Minor		
Apr 26/07	4104	43656	Clear		Pass
Apr 26/07	4104	43923	Severe		
Apr 26/07	4104	43959	Moderate		
Apr 26/07	4104	44753	Clear		
Apr 26/07	4104	44752	Minor		
Apr 26/07	4803	43193	Clear		
Apr 26/07	4803	43259	Minor		
Apr 26/07	4803	43320	Clear	-5	Fail
Apr 26/07	4803	45758	Clear		
Apr 26/07	4803	45795	Moderate		
Apr 26/07	4803	45687	Clear		
Apr 26/07	4803	43245	Moderate		
Apr 26/07	4803	43247	Minor		
Apr 26/07	4803	43153	Clear		
Apr 26/07	4803	45724	Minor		
Apr 26/07	4803	45734	Moderate		
Apr 26/07	4803	45738	Severe	-5	
Apr 26/07	4803	46041	Clear		
Apr 26/07	4803	45744	Severe		
Apr 26/07	4803	46040	Clear		
Apr 26/07	4803	45743	Clear		
Apr 26/07	4803	45821	Minor		
Apr 26/07	4803	44898	Minor		
Apr 26/07	4602	43206	Clear		
Apr 26/07	4602	43229	Clear		

Apr 26/07	4602	43207	Clear		
Apr 26/07	4602	45161	Clear		
Apr 26/07	4602	45537	Clear		
Apr 26/07	4602	45447	Minor		Fail
Apr 26/07	4602	45648	Minor		
Apr 26/07	4602	45649	Clear		
Apr 26/07	4602	47216	Clear		
Apr 26/07	4602	45654	Clear		
Apr 26/07	4602	45651	Clear		
Apr 26/07	4602	45650	Clear		
Apr 26/07	4602	corner	Severe		
Apr 26/07	4602	45661	Severe		
Apr 26/07	4602	45665	Severe		
Apr 26/07	4602	45895	Severe		
Apr 26/07	4602	45488	Severe		
			* - Indicates new (replaced) glazing unit		

2008 Visual Review and Dewpoint Testing Observations and Results – Raw Data

Visual review and dew-point testing performed by Matt Mulleray, P.Eng, Brian Hubbs, P.Eng, Graham Finch, MASc, EIT and Ryan Gregory, EIT of RDH in 2008.

Date	Suite	Facing Direction	Unit #	Visual Classification	Dew Point (°C)	Pressure Test
15 May 2008	3101	W	38848	Clear		
15 May 2008	3101	W	47081	Clear		
15 May 2008	3101	W	38420	Clear		
15 May 2008	3101	W	38645	Clear		
15 May 2008	3101	W	38625	Clear		
15 May 2008	3101	W	38518	Clear		
15 May 2008	3101	W	38854	Clear		
15 May 2008	3101	W	42502	Minor		
15 May 2008	3101	W	44168	Moderate	0	3/4" water, 0" in 20 min
15 May 2008	3101	W	44166	Severe	2	3/4" water, 0" in 1 min
15 May 2008	3101	W	47088	Severe		
15 May 2008	3101	W	44170	Moderate		
15 May 2008	3101	W	42394	Clear		
15 May 2008	3101	W	38498	Clear		
15 May 2008	3101	W	40069	Clear		
15 May 2008	3101	W	38496	Clear		
15 May 2008	3101	W	40056	Clear		
15 May 2008	3101	W	38408	Clear	-25	
15 May 2008	3101	W	38624	Clear	-15	
15 May 2008	3101	W	38632	Clear		
15 May 2008	4602	N	43206	Minor	2	

15 May 2008	4602	N	43229	Minor	1	
15 May 2008	4602	N	43207	Minor	1	
15 May 2008	4602	N	45161	Moderate	8	
15 May 2008	4602	N	45537	Minor	2	
15 May 2008	4602	N	45447	Clear	6	
15 May 2008	4602	N	45648	Minor	4	
15 May 2008	4602	N	45647	Clear	8	
15 May 2008	4602	N	47216	Clear	7	
15 May 2008	4602	N	45654	Minor	-2	
15 May 2008	4602	N	45651	Minor	-2	
15 May 2008	4602	N	45650	Moderate	-6	
15 May 2008	4602	N	45663	Moderate	-4	
15 May 2008	4602	N	45695	Severe	-2	
15 May 2008	4602	N	45661	Moderate	-3	
15 May 2008	4602	N	45696	Severe	-4	
15 May 2008	4602	N	45665	Severe	-3	
15 May 2008	4602	N	44895	Severe	0	
15 May 2008	4602	N	45483	Severe	-1	
03 Jul 2008	3903	SE	43097	Moderate	-6	
03 Jul 2008	3903	SE	43077	Moderate	0	Yes #5 - 11:07
03 Jul 2008	3903	SE	43105	Moderate	0	Yes #4 - 11:26
03 Jul 2008	3903	SE	44006	Moderate		
03 Jul 2008	3903	SE	44714	Moderate		
03 Jul 2008	3903	SE	44030	Severe	0	Yes #6 - 11:46
03 Jul 2008	3903	SE	44032	Severe		
03 Jul 2008	3903	SE	44031	Moderate		
03 Jul 2008	3903	SE	44789	Moderate	-4	Yes #5 - 12:29
03 Jul 2008	3903	SE	48653	Minor	-9	Yes #6 - 12:41
03 Jul 2008	3903	SE	44744	Moderate	0	Yes #2 - 12:54
03 Jul 2008	3903	SE	44173	Moderate	-10	Yes #4 x4 - 1:00
03 Jul 2008	3903	SE	43881	Severe		
03 Jul 2008	3903	SE	43864	Severe	-3	Yes #3 1:25, could not pressurize
03 Jul 2008	3903	SE	45834	Severe	-7	
03 Jul 2008	3903	NE	45831	Moderate		
03 Jul 2008	3903	NE	43868	Severe		
03 Jul 2008	3903	NE	43883	Moderate		
03 Jul 2008	3903	NE	44746	Minor		
03 Jul 2008	3903	NE	44745	Minor		
03 Jul 2008	3903	NE	43391	Minor		
03 Jul 2008	3903	NE	43408	Minor		
03 Jul 2008	3903	NE	43406	Minor		
03 Jul 2008	3903	NE	44178	Severe		
03 Jul 2008	3903	NE	44046	Minor		
03 Jul 2008	3903	NE	43847	Minor		
03 Jul 2008	3903	NE	44721	Minor		
03 Jul 2008	3903	NE	44156	Minor		
03 Jul 2008	3903	NE	43127	Minor		

03 Jul 2008	3903	NE	43145	Minor		
03 Jul 2008	3903	NE	43143	Minor		

Suite 4001	Recorded on 10/6/2008						
Glazing Unit Serial #	**Pressure/Flow Sensor #**	**Room**	**Orientation**	**Approx Degree from 0 deg North**	**Size Unit**	**Visual Condition**	**Dewpoint (°C)**
44755		Bedroom	Northwest		Full height	Moderate	
44219		Bedroom	Northwest		Full height	Severe	
43903		Bedroom	Northwest		Full height	Moderate	
43924		Bedroom	Northwest		Full height	Minor	
44742		Bedroom	Northwest		2/3 - w/ operable	Minor	
43607		Bedroom	Northwest		2/3 - w/ operable	Moderate	
44739		Bedroom	Northwest		2/3 - w/ operable	Minor	
43621		Bedroom	Northwest		2/3 - w/ operable	Minor	
43410		Bedroom	Northwest		Full height	Minor	
43413	Pressure 6	Office	Northwest	347	Full height	Minor	-15
50527	Flow 2	Office	Northwest	347	Full height	Minor	-65
50528		Living Room	Northwest		Full height	Minor	
43352		Living Room	Northwest		Full height	Minor	
43350		Living Room	Northwest		Full height	Minor	
44160		Living Room	Northwest		2/3 - w/ operable	Moderate	
43618		Living Room	Northwest		2/3 - w/ operable	Minor	
44157		Dining Room/Kitchen	Northwest		Full height	Moderate	
43195		Dining Room/Kitchen	Northwest		Full height	Minor	
43090		Dining Room/Kitchen	Northwest		Full height	Minor	
43160		Dining Room/Kitchen	Northwest		Full height	Minor	

Suite 4002	Recorded on 10/6/2008						
Glazing Unit Serial #	**Sensor #**	**Room**	**Orientation**	**Approx Degree from 0 deg North**	**Size Unit**	**Visual Condition**	**Dewpoint (°C)**
45822		Bedroom	Northeast		Full height	Severe	
43870	Flow 5	Bedroom	Northeast	52	Full height	Severe	-30
43873	Pressure 4	Bedroom	Northeast	52	Full height	Severe	-18
44736		Bedroom	Northeast		2/3 - w/ operable	Severe	

44026		Bedroom	Northeast		2/3 - w/ operable	Severe	
44738		Bedroom	Northeast		2/3 - w/ operable	Moderate	
44016		Bedroom	Northeast		2/3 - w/ operable	Severe	
44214		Office	Northeast		Full height	Severe	
44773		Office	Northeast		Full height	Minor	
44215		Office	Northeast		Full height	Moderate	
44029		Living Room	Northeast		Full height	Moderate	
43846		Living Room	Northeast		Full height	Moderate	
44041		Living Room	Northeast		Full height	Moderate	
44150		Living Room	Northeast		2/3 - w/ operable	Moderate	
43648		Living Room	Northeast		2/3 - w/ operable	Moderate	
44718		Dining Room/Kitchen	Northeast		Full height	Minor	
43223		Dining Room/Kitchen	Northeast		Full height	Moderate	
43200		Dining Room/Kitchen	Northeast		Full height	Minor	
Corner Unit		Dining Room/Kitchen	Northeast		Full height	Moderate	

Suite 4003	Recorded on 10/6/2008						
Glazing Unit Serial #	**Sensor #**	**Room**	**Orientation**	**Approx Degree from 0 deg North**	**Size Unit**	**Visual Condition**	**Dewpoint (°C)**
Corner Unit		Bedroom	Southeast		Full height	Severe	
43869	Pressure 3	Bedroom	Southeast	155	Full height	Severe	-20
53061		Bedroom	Southeast		Full height	Severe	
44737		Bedroom	Southeast		2/3 - w/ operable	Moderate	
44020		Bedroom	Southeast		2/3 - w/ operable	Severe	
44730		Bedroom	Southeast		2/3 - w/ operable	Severe	
44027		Bedroom	Southeast		2/3 - w/ operable	Severe	
44212	Flow 1	Office	Southeast	155	Full height	Moderate	-20
44775	Pressure 5	Office	Southeast	155	Full height	Moderate	-10
44788	Flow 4	Office	Southeast	155	Full height	Moderate	-10
44049		Living Room	Southeast		Full height	Severe	
44053		Living Room	Southeast		Full height	Moderate	
44050		Living Room	Southeast		Full height	Moderate	
44003		Living Room	Southeast		2/3 - w/ operable	Moderate	
43550		Living Room	Southeast		2/3 - w/ operable	Severe	

44720		Dining Room/Kitchen	Southeast		Full height	Severe	
54707		Dining Room/Kitchen	Southeast		Full height	Moderate	
59922		Dining Room/Kitchen	Southeast		Full height	Severe	
43092		Dining Room/Kitchen	Southeast		Full height	Moderate	

Suite 4004	Recorded on 10/6/2008						
Glazing Unit Serial #	**Sensor #**	**Room**	**Orientation**	**Approx Degree from 0 deg North**	**Size Unit**	**Visual Condition**	**Dewpoint (°C)**
44220		Bedroom	Southwest		Full height	Minor	
44756		Bedroom	Southwest		Full height	Minor	
43916		Bedroom	Southwest		Full height	Severe	
43929		Bedroom	Southwest		Full height	Severe	
44823		Bedroom	Southwest		2/3 - w/ operable	Minor	
43659		Bedroom	Southwest		2/3 - w/ operable	Severe	
44825		Bedroom	Southwest		2/3 - w/ operable	Moderate	
43644		Bedroom	Southwest		2/3 - w/ operable	Minor	
44777		Bedroom	Southwest		Full height	Minor	
44776		Office	Southwest		Full height	Moderate	
44048		Office	Southwest		Full height	Moderate	
43849	Flow 3	Living Room	Southwest	210	Full height	Minor	-10
44051	Pressure 2	Living Room	Southwest	210	Full height	Moderate	-8
44052		Living Room	Southwest		Full height	Minor	
44811		Living Room	Southwest		2/3 - w/ operable	Minor	
43654		Living Room	Southwest		2/3 - w/ operable	Minor	
44158		Dining Room/Kitchen	Southwest		Full height	Moderate	
43118		Dining Room/Kitchen	Southwest		Full height	Moderate	
43089		Dining Room/Kitchen	Southwest		Full height	Minor	-18
43093		Dining Room/Kitchen	Southwest		Full height	Moderate	-5

Suite 4502 - August 7th, 2008							
Glazing Unit Serial #	Room	Orientation	Size Unit	Feb 13/2006 Visual Condition	Aug 7/2008 Visual Condition	2006 Dewpoint	2008 Dewpoint
43205	Kitchen	North	Full height	Clear	Clear		-12
43238	Kitchen	North	Full height	Clear	Clear		1
43239	Kitchen	North	Full height	Clear	Clear	-55	-4
45157	Kitchen	North	2/3 - w/ operable	Clear	Clear		-1
45458	Living Room	Northeast	2/3 - w/ operable	Clear	Minor		2
45474	Living Room	Northeast	Full height	Clear	Minor		2
45470	Living Room	Northeast	Full height	Minor	Severe		3
45466	Living Room	Northeast	Full height	Minor	Moderate		4
45357	Office	Northeast	Full height	Minor	Moderate		
45459	Office	Northeast	Full height	Minor	Severe		
45456	Office	Northeast	Full height	Minor	Moderate		
45150	Bedroom	East	2/3 - w/ operable	Minor	Severe		2
45153	Bedroom	East	2/3 - w/ operable	Minor	Moderate		2
45367	Bedroom	East	Full height	Clear	Severe		8
44900	Bedroom	East	Full height	Clear	Severe	-10	4
45484	Bedroom	East	Full height	Severe	Severe - Opaque	-5	6

4502 - 2008 Summary		
	# Units	%
Clear	4	25%
Minor	2	13%
Moderate	4	25%
Severe	6	38%
Total	**16**	

4001,4002,4003,4001 - 2008 Summary		
	#units	% units
clear	0	0
minor	27	35%
moderate	30	38%
severe	21	27%
total	**78**	

3101, 4602, 3903 - 2008 Summary		
Clear	18	26%
Minor	20	29%
Moderate	17	25%
Severe	14	20%
Total	**69**	

2008 Summary - All Units		
Clear	22	13%
Minor	49	30%
Moderate	51	31%
Severe	41	25%
Total	**163**	

2009 Visual Review Observations– Raw Data

Visual review performed by Brian Hubbs, P.Eng and Graham Finch, MASc, EIT of RDH in 2009.

Suite 3803		Recorded on February 28/2009 During removal of IGU in suite			
Glazing Unit Serial #		**Room**	**Orientation**	**Size Unit**	**Visual Condition**
43161	1	dining	Southeast	Full height	Severe
43065	2	dining	Southeast	Full height	Minor
43067	3	dining	Southeast	Full height	Minor
44147	4	dining	Southeast	2/3 height	Moderate
43997	5	living	Southeast	2/3 - w/ operable, upper	Moderate
43606	6	living	Southeast	2/3 - w/ operable, lower	Severe
43831	7	living	Southeast	Full height	Moderate
43852	8	living	Southeast	Full height	Severe
43829	9	living	Southeast	Full height	Moderate
43405	10	guest bedroom	Southeast	Full height	Moderate
43403	11	guest bedroom	Southeast	Full height	Severe
43389	12	guest bedroom	Southeast	Full height	Severe
44022	13	master bedroom	Southeast	2/3 - w/ operable, lower	Severe
44144	14	master bedroom	Southeast	2/3 - w/ operable, upper	Severe
44021	15	master bedroom	Southeast	2/3 - w/ operable, lower	Severe
44142	16	master bedroom	Southeast	2/3 - w/ operable, upper	Severe
43882	17	master bedroom	Southeast	Full height	Severe
43862	18	master bedroom	Southeast	Full height	Severe
corner?	19	master bedroom	Southeast	Full height	Severe
			Southeast	Full height	

Suite 3803 Summary		
	# Units	% Units
Clear	0	0%
Minor	2	11%
Moderate	5	26%
Severe	12	63%
Total	**19**	

Suite 3204		Recorded on March 6, 2009 to locate replacement IGU location		
Glazing Unit Serial #		**Room**	**Orientation**	**Visual Condition**
south, western most	1	Master bedroom	Southeast	Moderate
south	2	Master bedroom	Southeast	Moderate
south	3	Master bedroom	Southeast	Severe
south	4	Living	Southeast	Severe
south	5	Living	Southeast	Severe
south, 47077	6	Living	Southeast	Moderate
south	7	Living	Southeast	Severe
south corner, half	8	Living	Southeast	Severe
north corner, half	9	Living	Northeast	Severe
north	10	Living	Northeast	Severe
north	11	Living	Northeast	Severe
north	12	Kitchen	Northeast	Moderate
north	13	Kitchen	Northeast	Moderate
north	14	Kitchen	Northeast	Moderate
north	15	Office	Northeast	Minor
north	16	Office	Northeast	Minor
north, western most	17	Office	Northeast	Minor

Suite 3304		Recorded on March 6, 2009 to locate replacement igu location		
Glazing Unit Serial #		**Room**	**Orientation**	**Visual Condition**
south, western most	1	Master bedroom	Southeast	Severe
south	2	Master bedroom	Southeast	Severe
south	3	Master bedroom	Southeast	Severe
south	4	Living	Southeast	Severe
south	5	Living	Southeast	Severe
south, 47077	6	Living	Southeast	Severe
south	7	Living	Southeast	Severe
south corner, half	8	Living	Southeast	Severe
north corner, half	9	Living	Northeast	Severe
north	10	Living	Northeast	Severe
north	11	Living	Northeast	Severe
north	12	Kitchen	Northeast	Moderate
north	13	Kitchen	Northeast	Moderate
north	14	Kitchen	Northeast	Moderate
north	15	Office	Northeast	Minor
north	16	Office	Northeast	Minor
north, western most, 43425	17	Office	Northeast	Minor

Suites 3204 and 3304, East Facing Units		
	# Units	%
Clear	0	0%
Minor	6	18%
Moderate	9	26%
Severe	19	56%
Total	**34**	

2009 Summary - Suite 3204, 3304, 3803		
	# Units	%
Clear	0	0%
Minor	8	15%
Moderate	14	26%
Severe	31	58%
Total	**53**	

2006 through 2009 Vancouver Climate Data prior and during Visual Observations – Raw Data

ASTM Standard E576, "Standard Test Method for Frost/Dew Point of Sealed Insulating Glass Units in the Vertical Position" recommends obtaining climatic data records for the 24 hour period prior to performing a dewpoint test.

Dewpoint tests were performed during visual reviews in 2006, 2007 and 2008 on the following dates: 6 Feb 2006, 13 Feb 2006, 25 Apr 2007, 26 Apr 2007, 15 May 2008, 3 July 2008, 6 Oct 2008, 7 Aug 2008. Visual observations only were performed in 2009 during IGU replacements on 28 Feb 2009 and 6 Mar 2009.

Vancouver Airport (YVR) climate data for the visual review dates and the day prior are presented in the following table. YVR data provides the most complete dataset with visual weather observations during the investigation period. Complete historical data is available at the Environment Canada, National Climate and Information Archive: http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Hourly Data Report for February 5, 2006								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	**°C**	**°C**	**%**	**10's deg**	**km/h**	**km**	**kPa**	
m								
e								
0:00	5.8	0.7	70	29	39	24.1	102.06	Mostly Cloudy
1:00	5	-0.2	69	29	39	24.1	102.19	Mainly Clear
2:00	5.3	-1	64	28	26	24.1	102.37	Mainly Clear
3:00	5.7	-1.6	59	28	35	24.1	102.52	Cloudy
4:00	5.4	-2.2	58	27	26	24.1	102.57	Mostly Cloudy
5:00	4.6	-2	62	27	24	24.1	102.65	Mainly Clear
6:00	5.5	-0.5	65	26	22	24.1	102.75	Mostly Cloudy
7:00	5.4	-1.4	62	27	19	24.1	102.85	Mostly Cloudy
8:00	4.6	-1.5	65	27	15	32.2	102.9	Mostly Cloudy

9:00	2.8	0.3	84	8	6	48.3	102.94	Mostly Cloudy
10:00	3.4	0.6	82	11	11	48.3	103.01	Mostly Cloudy
11:00	5.5	0.2	69	9	11	48.3	103.02	Mostly Cloudy
12:00	7	-1.2	56	11	6	48.3	103.01	Mostly Cloudy
13:00	7.3	-1.6	53		0	48.3	102.96	Mostly Cloudy
14:00	8.3	-1.5	50	23	7	48.3	102.92	Mostly Cloudy
15:00	7.1	-1.2	55	30	4	48.3	102.91	Mostly Cloudy
16:00	6.2	0.4	66		0	48.3	102.89	Mostly Cloudy
17:00	5.5	-1	63	36	4	48.3	102.86	Cloudy
18:00	3.9	-0.7	72	36	7	32.2	102.82	Mostly Cloudy
19:00	4.4	-0.7	69	2	6	32.2	102.73	Cloudy
20:00	4.4	0.2	74	7	9	32.2	102.66	Cloudy
21:00	4.1	0.3	76	4	7	32.2	102.62	Mostly Cloudy
22:00	3.6	-0.3	76		0	32.2	102.6	Mostly Cloudy
23:00	3.1	-0.3	78	5	4	32.2	102.53	Mostly Cloudy
Hourly Data Report for February 6, 2006								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	3.1	0.3	82	7	6	32.2	102.49	Cloudy
1:00	4	-0.3	74	8	6	32.2	102.49	Cloudy
2:00	3.8	0.7	80		0	32.2	102.41	Cloudy
3:00	3.6	0.3	79	11	4	32.2	102.42	Cloudy
4:00	2.9	0.3	83	9	4	32.2	102.4	Cloudy
5:00	3.4	0.4	81	13	7	32.2	102.37	Cloudy
6:00	3.7	0.1	77		0	32.2	102.38	Cloudy
7:00	3.4	0.1	79		0	32.2	102.38	Cloudy
8:00	3	-0.2	79	10	4	48.3	102.42	Mainly Clear
9:00	5.2	0.6	72	36	4	48.3	102.47	Mostly Cloudy
10:00	6.6	0.3	64	28	6	48.3	102.5	Mostly Cloudy
11:00	5.9	1	71	27	4	48.3	102.52	Mostly Cloudy
12:00	7.3	-0.4	58	31	11	48.3	102.51	Mostly Cloudy
13:00	6.8	2.4	73	26	9	48.3	102.49	Cloudy
14:00	6.9	2.4	73	29	9	48.3	102.47	Cloudy
15:00	6.6	2.8	77	30	9	48.3	102.47	Cloudy
16:00	6.2	2.7	78	29	11	48.3	102.49	Mostly Cloudy
17:00	5.4	2.6	82	27	9	48.3	102.49	Mostly Cloudy
18:00	5	3.1	87	30	7	32.2	102.5	Cloudy
19:00	5.7	3.5	86	34	4	32.2	102.53	Cloudy
20:00	5.9	2.9	81	7	6	32.2	102.49	Mostly Cloudy
21:00	5.3	2.7	83	9	11	32.2	102.46	Cloudy
22:00	5.5	2.7	82	11	6	32.2	102.49	Mostly Cloudy
23:00	5.9	2.6	79	3	4	32.2	102.5	Cloudy
Hourly Data Report for February 12, 2006								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								

e								
0:00	4.1	0	75	17	7	32.2	103.3	Mostly Cloudy
1:00	2.9	1.1	88	26	4	32.2	103.39	Cloudy
2:00	3.7	1.2	84	2	9	32.2	103.41	Cloudy
3:00	4.9	1	76	11	9	32.2	103.4	Cloudy
4:00	4.4	0.5	76	11	9	32.2	103.41	Cloudy
5:00	3.7	0.6	80	9	15	32.2	103.41	Cloudy
6:00	4	1.1	81	11	6	32.2	103.47	Cloudy
7:00	4.9	0.3	72	15	6	32.2	103.51	Mostly Cloudy
8:00	4.7	1.2	78	9	9	32.2	103.54	Mostly Cloudy
9:00	5.8	1.2	72	9	13	48.3	103.59	Mostly Cloudy
10:00	7.2	0.9	64	10	11	48.3	103.65	Cloudy
11:00	8.4	1.2	60	10	19	48.3	103.64	Mostly Cloudy
12:00	9.5	1.5	57	10	19	48.3	103.61	Mostly Cloudy
13:00	10.3	2.1	57	12	9	48.3	103.58	Mostly Cloudy
14:00	10.2	1.6	55	14	9	48.3	103.51	Mostly Cloudy
15:00	10.3	0.9	52	12	15	32.2	103.46	Mostly Cloudy
16:00	10.5	1	52	10	9	32.2	103.43	Mostly Cloudy
17:00	10.1	0.4	51	11	9	32.2	103.4	Mostly Cloudy
18:00	9.7	1.7	57	14	7	24.1	103.36	Cloudy
19:00	9	1.1	58	11	6	24.1	103.39	Cloudy
20:00	8.6	2.1	64	5	11	24.1	103.35	Rain Showers
21:00	8.7	2.6	65	5	13	24.1	103.37	Rain Showers
22:00	7.3	4.7	84	5	9	19.3	103.4	Rain Showers
23:00	6.6	5.4	92	8	9	19.3	103.41	Rain

Hourly Data Report for February 13, 2006

T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	kPa	
m								
e								
0:00	6.5	5.3	92	35	6	19.3	103.38	Rain
1:00	6.3	5.5	95	29	11	19.3	103.38	Rain
2:00	6.4	5.7	95	30	15	24.1	103.36	Rain
3:00	6.4	5.2	92	29	24	24.1	103.31	Cloudy
4:00	6.3	5	91	29	30	24.1	103.28	Rain Showers
5:00	6.2	4.5	89	30	30	24.1	103.25	Cloudy
6:00	6.2	4.2	87	29	44	24.1	103.21	Cloudy
7:00	6.2	3.6	83	30	43	24.1	103.15	Cloudy
8:00	5.9	2.8	80	30	39	32.2	103.14	Mostly Cloudy
9:00	6.1	2.3	77	29	54	32.2	103.09	Mostly Cloudy
10:00	6	1.3	72	29	54	32.2	103.07	Mostly Cloudy
11:00	6.4	1.6	71	29	52	32.2	103.02	Mainly Clear
12:00	7.2	1.9	69	29	65	32.2	102.96	Mainly Clear
13:00	7.7	0.7	61	29	67	48.3	102.87	Mainly Clear
14:00	7.8	0.3	59	29	57	48.3	102.8	Mainly Clear
15:00	7.7	0.9	62	29	59	48.3	102.78	Mainly Clear
16:00	6.9	-0.3	60	23	59	48.3	102.77	Mainly Clear
17:00	6.2	0	64	30	50	48.3	102.72	Mainly Clear
18:00	5.9	-0.7	63	30	52	48.3	102.63	Mainly Clear
19:00	5.9	-1.7	58	30	54	32.2	102.57	Mainly Clear

20:00	5.1	-1	65	30	52	32.2	102.6	Mainly Clear
21:00	4.9	-1.6	63	29	54	32.2	102.6	Clear
22:00	4.7	-1.3	65	30	48	32.2	102.57	Mainly Clear
23:00	4.1	0.1	75	29	41	32.2	102.55	Mainly Clear
Hourly Data Report for April 24, 2007								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	10's deg	km/h	km	kPa	
m								
e								
0:00	11.8	8.2	79	13	11	19.3	101.98	Rain Showers
1:00	11.1	9	87		0	19.3	101.97	Rain Showers
2:00	10.5	8.3	86	9	7	16.1	102.02	Rain
3:00	10.2	8.9	92	9	4	12.9	102.01	Rain
4:00	9.9	8.9	93	32	9	12.9	102.02	Rain
5:00	8.9	7.3	90	29	4	12.9	102.03	Rain
6:00	9.3	7.7	90		0	16.1	102.03	Rain
7:00	9.4	7.2	86	9	9	16.1	102.05	Rain Showers
8:00	9.7	8	89	12	17	24.1	102.11	Rain Showers
9:00	9.6	8.4	92	12	28	24.1	102.12	Rain Showers
10:00	9.7	8	89	13	30	24.1	102.14	Rain Showers
11:00	10.2	8.3	88	14	24	19.3	102.19	Rain Showers
12:00	10.6	8.6	87	14	22	19.3	102.18	Rain Showers
13:00	11.5	9	85	16	28	24.1	102.2	Cloudy
14:00	12	8.4	79	17	28	24.1	102.22	Cloudy
15:00	12.9	8.9	77	18	26	24.1	102.22	Cloudy
16:00	13.3	8.6	73	17	17	24.1	102.21	Mostly Cloudy
17:00	13.6	7.6	67	16	17	24.1	102.21	Cloudy
18:00	13	7.3	68	17	9	32.2	102.18	Mostly Cloudy
19:00	11.3	8.7	84	10	15	32.2	102.15	Mostly Cloudy
20:00	10.8	8.4	85	12	15	32.2	102.19	Mostly Cloudy
21:00	8.9	7.1	88	9	11	32.2	102.23	Mostly Cloudy
22:00	9.9	4.7	70	29	9	32.2	102.23	Mostly Cloudy
23:00	9.7	4.7	71	21	7	32.2	102.24	Mostly Cloudy
Hourly Data Report for April 25, 2007								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	10's deg	km/h	km	kPa	
m								
e								
0:00	8.7	4.7	76	17	13	32.2	102.22	Mostly Cloudy
1:00	8.8	4.5	74	13	13	32.2	102.22	Mostly Cloudy
2:00	6.3	4.1	86	10	17	32.2	102.23	Mostly Cloudy
3:00	6.4	4.7	89	10	17	32.2	102.23	Mostly Cloudy
4:00	6.9	4.9	87	10	17	24.1	102.21	Mostly Cloudy
5:00	7.1	4.8	85	9	17	24.1	102.22	Mostly Cloudy
6:00	7.7	4.8	82	10	15	24.1	102.23	Cloudy
7:00	8.5	5.2	80	9	17	24.1	102.25	Cloudy
8:00	9.3	6.1	80	13	15	24.1	102.27	Cloudy
9:00	9.7	6.2	79	14	13	19.3	102.29	Rain Showers

10:00	10	5.5	74	20	13	19.3	102.29	Rain Showers
11:00	10.4	4.3	66	19	13	24.1	102.28	Rain Showers
12:00	10.6	4.9	68	13	9	24.1	102.26	Rain Showers
13:00	10.1	6	76	15	7	19.3	102.25	Rain Showers
14:00	10.1	6.5	78	11	13	19.3	102.21	Rain
15:00	9.5	6.8	83	9	19	19.3	102.21	Rain
16:00	9.5	6.8	83	9	13	19.3	102.19	Rain
17:00	9.3	7.1	86	8	11	19.3	102.19	Rain
18:00	8.8	7	88	7	19	19.3	102.16	Rain Showers
19:00	8.1	6.7	91	8	17	19.3	102.12	Rain Showers
20:00	8.1	6.6	90	9	15	24.1	102.12	Rain Showers
21:00	8.1	6.6	90	8	19	24.1	102.13	Cloudy
22:00	8.1	6.7	91	8	17	24.1	102.15	Cloudy
23:00	8.4	7.2	92	8	20	19.3	102.12	Rain Showers
Hourly Data Report for April 26, 2007								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	kPa	
m								
e								
0:00	8.2	7.2	93	10	19	19.3	102.09	Rain Showers
1:00	8	7.4	96	11	17	19.3	102.1	Rain Showers
2:00	8.1	7.7	97	12	15	16.1	102.07	Rain Showers
3:00	8.7	8	95	13	19	16.1	102.04	Rain Showers
4:00	8.7	7.9	95	14	17	12.9	102.04	Rain
5:00	8.8	8.1	95	13	17	12.9	102.02	Rain
6:00	9	8.5	97	14	24	12.9	102.03	Rain
7:00	9.2	8.4	95	15	19	12.9	102.06	Rain
8:00	9.3	8.6	95	14	22	16.1	102.05	Rain Showers
9:00	9.7	8.8	94	14	24	16.1	102.08	Rain Showers
10:00	9.9	8.8	93	14	22	16.1	102.08	Rain Showers
11:00	10	8.9	93	13	24	16.1	102.07	Rain
12:00	10.2	9	92	14	24	16.1	102.04	Rain
13:00	10.2	8.9	92	13	19	16.1	102.04	Rain
14:00	10.3	9.2	93	14	22	19.3	102	Rain
15:00	10.7	9.1	90	14	20	19.3	102.08	Cloudy
16:00	10.9	8.9	87	14	22	19.3	101.99	Rain
17:00	10.9	8.8	87	14	17	19.3	101.98	Rain Showers
18:00	10.5	9.3	92	11	17	19.3	101.96	Rain Showers
19:00	10.1	9.2	94	10	17	19.3	101.94	Rain Showers
20:00	10.1	9.1	93	10	15	16.1	101.95	Rain Showers
21:00	10.1	9.3	95	11	15	12.9	101.98	Rain Showers
22:00	10.2	9.4	95	9	17	12.9	101.99	Rain Showers
23:00	10.4	9	91	12	13	12.9	101.98	Rain Showers
Hourly Data Report for May 14, 2008								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	kPa	
m								
e								

0:00	9.5	8.1	91	9	11	4.8	102.14	Rain, Fog
1:00	9.4	8.1	92	9	11	6.4	102.19	Rain, Fog
2:00	9.4	8.3	93	10	11	8	102.23	Rain, Fog
3:00	9.4	8.3	93	11	11	8	102.29	Rain, Fog
4:00	9.2	8	92	11	9	6.4	102.38	Rain, Fog
5:00	9.3	8.1	92	10	13	4	102.41	Rain, Fog
6:00	9.5	8.3	92	10	15	3.6	102.5	Rain, Fog
7:00	10	8.9	93	10	15	3.2	102.58	Drizzle, Fog
8:00	10.9	9.6	92	10	19	3.2	102.65	Drizzle, Fog
9:00	11.4	10.2	92	9	15	3.6	102.73	Drizzle, Fog
10:00	11.7	10.3	91	11	13	3.2	102.79	Drizzle, Fog
11:00	12.6	11.2	91	11	13	4	102.87	Drizzle, Fog
12:00	12.9	11.4	91	13	15	4.8	102.96	Drizzle, Fog
13:00	13.3	11.7	90	13	9	8	103.03	Fog
14:00	13.4	11.2	87	14	11	19.3	103.1	Cloudy
15:00	14.3	11.3	82	13	6	19.3	103.14	Cloudy
16:00	13.1	10.4	84	26	9	19.3	103.17	Cloudy
17:00	14.5	11.5	82	29	11	24.1	103.17	Mostly Cloudy
18:00	13.7	10.6	82	31	9	24.1	103.19	Mainly Clear
19:00	12.7	10	84	29	7	24.1	103.21	Mainly Clear
20:00	11.9	9.9	88	30	7	24.1	103.24	Mostly Cloudy
21:00	11.9	10.1	89	32	4	24.1	103.31	Cloudy
22:00	12.6	10.3	86	5	6	24.1	103.32	Cloudy
23:00	12.9	10.5	85		0	24.1	103.31	Cloudy

Hourly Data Report for May 15, 2008

T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	10's deg	km/h	km	kPa	
m								
e								
0:00	13.2	10.9	86	4	4	24.1	103.31	Cloudy
1:00	12.4	10.1	86	30	4	24.1	103.33	Cloudy
2:00	12	10.3	89	30	7	24.1	103.31	Cloudy
3:00	12	10.4	90	32	7	24.1	103.31	Cloudy
4:00	12	10.1	88	31	11	24.1	103.28	Cloudy
5:00	11.9	10.3	90	29	13	24.1	103.27	Cloudy
6:00	12.2	10.6	90	31	11	24.1	103.29	Cloudy
7:00	12.8	10.4	85	30	13	24.1	103.3	Cloudy
8:00	13	11	88	31	11	24.1	103.29	Cloudy
9:00	13.8	10.4	80	31	13	24.1	103.27	Cloudy
10:00	14.2	11	81	30	17	32.2	103.23	Cloudy
11:00	15	11.9	82	30	15	32.2	103.16	Mostly Cloudy
12:00	15.3	11.9	80	30	24	32.2	103.11	Mainly Clear
13:00	15.6	11.8	78	29	24	32.2	103.05	Mainly Clear
14:00	15.5	11.5	77	30	26	48.3	102.99	Mainly Clear
15:00	15.5	11.2	76	30	26	48.3	102.92	Mainly Clear
16:00	15.3	11	76	31	20	48.3	102.82	Clear
17:00	15.3	11.4	78	32	20	48.3	102.74	Clear
18:00	15.3	11.4	78	32	15	48.3	102.65	Clear
19:00	14.2	10.8	80	30	9	48.3	102.57	Clear
20:00	12.3	9.9	85	31	13	48.3	102.53	Clear

21:00	12.4	10.1	86	32	7	48.3	102.53	Clear
22:00	13.1	10.1	82	36	6	48.3	102.5	Clear
23:00	12.6	9.6	82	21	4	48.3	102.46	Clear
Hourly Data Report for July 2, 2008								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	17.1	11.4	69	15	13	32.2	101.4	Clear
1:00	16.3	11.3	72	13	6	32.2	101.39	Clear
2:00	15.7	10.6	72	13	17	32.2	101.38	Clear
3:00	13.6	10.1	79	10	13	32.2	101.41	Clear
4:00	14.5	10.5	77	11	9	32.2	101.43	Mainly Clear
5:00	13.6	10.1	79	10	13	32.2	101.41	Mainly Clear
6:00	15.6	11	74	13	6	32.2	101.39	Mainly Clear
7:00	17.2	11	67	16	9	24.1	101.41	Mainly Clear
8:00	18.5	11.2	62	26	7	24.1	101.38	Mainly Clear
9:00	19.5	13.2	67	24	11	24.1	101.35	Mainly Clear
10:00	20.8	13.5	63	23	13	24.1	101.34	Mainly Clear
11:00	21.2	14.3	65	26	9	24.1	101.29	Mostly Cloudy
12:00	22.2	13.2	57	29	11	24.1	101.21	Mostly Cloudy
13:00	22.4	14.8	62	29	15	24.1	101.16	Mostly Cloudy
14:00	23	13.7	56	31	13	24.1	101.07	Mostly Cloudy
15:00	23.5	14.9	59	31	13	24.1	101	Mostly Cloudy
16:00	22.7	15	62	29	15	24.1	100.95	Mostly Cloudy
17:00	20.7	15.2	71	27	15	24.1	100.9	Mostly Cloudy
18:00	21.4	16.1	72	30	9	24.1	100.81	Mostly Cloudy
19:00	20.6	16.1	75	24	11	24.1	100.78	Mostly Cloudy
20:00	20.1	15.4	74	25	7	24.1	100.8	Mostly Cloudy
21:00	19.7	12.1	62	14	26	24.1	101.01	Cloudy
22:00	19.7	13.4	67	9	17	24.1	101.06	Mostly Cloudy
23:00	20.8	14.2	66	8	9	24.1	100.98	Mostly Cloudy
Hourly Data Report for July 3, 2008								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	20.3	13.5	65	14	4	24.1	101	Mostly Cloudy
1:00	19.6	14.2	71	22	9	24.1	101.08	Mostly Cloudy
2:00	17.5	13.4	77	14	9	24.1	101.04	Mostly Cloudy
3:00	16.4	12.6	78	14	17	24.1	101.09	Mostly Cloudy
4:00	17.1	13	77	10	15	24.1	101.11	Mostly Cloudy
5:00	16.7	12.4	76	11	24	24.1	101.14	Cloudy
6:00	17.9	13.4	75	10	15	24.1	101.13	Cloudy
7:00	18.4	12.2	67	13	15	24.1	101.18	Rain Showers
8:00	18.2	11.1	63	16	19	24.1	101.23	Cloudy
9:00	17.6	12.4	72	12	15	24.1	101.23	Cloudy
10:00	18.4	12.9	70	11	13	24.1	101.21	Cloudy

11:00	20.4	13.2	63	16	15	24.1	101.22	Cloudy
12:00	20.1	13.1	64	12	7	24.1	101.22	Cloudy
13:00	20.6	13.7	65	12	11	24.1	101.19	Cloudy
14:00	21.5	14.7	65	16	15	24.1	101.14	Mostly Cloudy
15:00	21.5	15.4	68	15	15	24.1	101.14	Mostly Cloudy
16:00	21.2	15	68	15	24	24.1	101.13	Mostly Cloudy
17:00	20	13.8	67	16	20	24.1	101.05	Mostly Cloudy
18:00	18.6	13.1	70	14	19	24.1	101.05	Mostly Cloudy
19:00	18	12.1	68	14	22	24.1	101.03	Mostly Cloudy
20:00	16.5	11.3	71	13	17	24.1	101.03	Mostly Cloudy
21:00	16.4	11.7	74	12	22	24.1	101.06	Mostly Cloudy
22:00	16.6	12	74	10	17	24.1	101.05	Mostly Cloudy
23:00	17.3	12.3	72	11	19	24.1	101.05	Mostly Cloudy
Hourly Data Report for August 6, 2008								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	18.2	12.9	71	5	4	48.3	101.33	Mainly Clear
1:00	17.5	12.6	73		0	48.3	101.34	Clear
2:00	17	12.9	77		0	48.3	101.35	Clear
3:00	17.4	13.6	78	21	6	48.3	101.38	Clear
4:00	17.5	13.7	78	30	19	48.3	101.4	Mainly Clear
5:00	16	13.4	85	33	9	48.3	101.41	Mainly Clear
6:00	17.8	14.5	81	32	4	48.3	101.44	Mostly Cloudy
7:00	20	13.6	67		0	48.3	101.4	Mainly Clear
8:00	21.2	14.2	64	29	6	48.3	101.4	Mostly Cloudy
9:00	21.5	14.3	64	30	19	48.3	101.41	Mostly Cloudy
10:00	23.7	14.2	55	29	15	48.3	101.41	Mostly Cloudy
11:00	23.3	14.5	58	29	13	48.3	101.38	Mostly Cloudy
12:00	23.9	12.6	49	30	11	48.3	101.33	Mostly Cloudy
13:00	24.8	13.5	49	29	11	48.3	101.29	Cloudy
14:00	25.5	15.5	54	30	9	48.3	101.24	Cloudy
15:00	26.1	14.8	50	23	7	48.3	101.21	Cloudy
16:00	26	15.8	53	23	6	48.3	101.17	Cloudy
17:00	26.7	15.6	51	24	7	48.3	101.13	Cloudy
18:00	26.4	13.8	46	18	11	48.3	101.15	Mainly Clear
19:00	24.1	13.9	53	13	17	48.3	101.18	Mainly Clear
20:00	20.9	13.7	63	9	15	48.3	101.2	Mainly Clear
21:00	20.3	12.8	62	9	15	48.3	101.2	Mainly Clear
22:00	22.3	13.2	56	9	22	32.2	101.19	Mainly Clear
23:00	21.2	13.4	61	9	17	32.2	101.16	Mainly Clear
Hourly Data Report for August 7, 2008								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	20.9	13.6	63	11	13	32.2	101.16	Mostly Cloudy

1:00	20.1	13.1	64	14	17	32.2	101.16	Mostly Cloudy
2:00	17.1	11.6	70	14	19	32.2	101.2	Mainly Clear
3:00	15.6	11	74	10	17	32.2	101.19	Mainly Clear
4:00	14.9	11.3	79	12	13	32.2	101.2	Mainly Clear
5:00	15.1	11.1	77	14	17	48.3	101.23	Mainly Clear
6:00	16	10.5	70	13	15	48.3	101.26	Mainly Clear
7:00	16.7	10.1	65	12	20	48.3	101.27	Mainly Clear
8:00	17.7	10.6	63	14	22	48.3	101.29	Mainly Clear
9:00	19.6	10.7	56	13	24	48.3	101.28	Mainly Clear
10:00	21.4	12	55	11	15	48.3	101.26	Mainly Clear
11:00	22.8	13.3	55	17	13	48.3	101.26	Mainly Clear
12:00	24	12.6	49	23	13	48.3	101.21	Mainly Clear
13:00	25.8	13	45	23	11	48.3	101.15	Clear
14:00	26.8	12.6	41	23	17	48.3	101.08	Clear
15:00	26.9	15	48	23	17	48.3	101.01	Clear
16:00	23.2	16.1	64	27	11	48.3	100.94	Mainly Clear
17:00	21.7	15.6	68	26	11	48.3	100.88	Mainly Clear
18:00	24.1	15	57	20	13	48.3	100.81	Clear
19:00	22.7	13.7	57	15	7	48.3	100.77	Clear
20:00	19.5	13.9	70	11	17	48.3	100.75	Clear
21:00	18.2	13.2	73	11	17	48.3	100.78	Clear
22:00	17	12.7	76	11	13	32.2	100.79	Clear
23:00	16.6	13.1	80	11	20	32.2	100.8	Clear
Hourly Data Report for October 5, 2008								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	kPa	
m								
e								
0:00	10.4	8.3	87	11	6	24.1	100.73	Cloudy
1:00	11.6	7.7	77	21	17	24.1	100.8	Cloudy
2:00	11.6	6.6	71	21	20	24.1	100.84	Mostly Cloudy
3:00	10.9	6.1	72	22	19	24.1	100.89	Mostly Cloudy
4:00	10.5	6.1	74	22	15	24.1	100.95	Mainly Clear
5:00	8.8	5.8	81	22	17	24.1	101.05	Mainly Clear
6:00	7.5	5.6	88	8	7	24.1	101.08	Mostly Cloudy
7:00	8.4	6.2	86	10	7	24.1	101.16	Mostly Cloudy
8:00	9.8	7.8	87	10	13	24.1	101.2	Cloudy
9:00	11.9	8.5	80	11	11	24.1	101.24	Mostly Cloudy
10:00	13.1	8.8	75	20	7	24.1	101.28	Mostly Cloudy
11:00	13.3	7.5	68	21	17	24.1	101.3	Mostly Cloudy
12:00	13.8	7.4	65	18	22	24.1	101.31	Mainly Clear
13:00	14.2	6.8	61	20	20	24.1	101.35	Mostly Cloudy
14:00	13.3	7.8	69	17	13	24.1	101.39	Mostly Cloudy
15:00	13.4	7.4	67	16	13	24.1	101.38	Cloudy
16:00	13.1	8.4	73	14	11	24.1	101.42	Rain Showers
17:00	12.8	8.3	74	12	9	24.1	101.47	Rain Showers
18:00	12	9.3	84	11	7	24.1	101.51	Rain Showers
19:00	12.2	8.5	78	3	4	24.1	101.57	Rain Showers
20:00	11.7	9	83	3	13	24.1	101.57	Rain Showers
21:00	11.3	8.6	83	8	11	24.1	101.63	Rain Showers

22:00	10.7	7.7	82	1	4	24.1	101.69	Rain Showers
23:00	10.3	8	86	36	6	24.1	101.71	Rain Showers

Hourly Data Report for October 6, 2008

T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	10.4	8	85	9	9	24.1	101.74	Cloudy
1:00	10.4	8.1	86	9	6	24.1	101.78	Cloudy
2:00	10.4	8.1	86	8	15	24.1	101.74	Cloudy
3:00	10.5	7.9	84	9	11	24.1	101.73	Cloudy
4:00	10	8.2	89		0	24.1	101.76	Cloudy
5:00	10.3	7.9	85	31	6	24.1	101.79	Cloudy
6:00	9.9	7.4	84	1	7	32.2	101.73	Mostly Cloudy
7:00	10.3	8.2	87	8	7	32.2	101.73	Cloudy
8:00	11.6	8.2	80		0	32.2	101.74	Mostly Cloudy
9:00	12.1	8.8	80	12	7	32.2	101.63	Cloudy
10:00	12.5	8.4	76	14	7	32.2	101.63	Cloudy
11:00	12.9	8.1	73	5	7	24.1	101.59	Cloudy
12:00	13.1	8.8	75	9	7	24.1	101.53	Cloudy
13:00	13.2	8.2	72	12	13	24.1	101.55	Rain Showers
14:00	12.5	9.2	80	13	11	16.1	101.51	Rain Showers
15:00	11.7	9.8	88	7	26	16.1	101.39	Rain Showers
16:00	11.7	9.5	86	8	24	24.1	101.27	Rain Showers
17:00	12.3	9.6	84	7	22	24.1	101.06	Rain
18:00	12.4	9.7	84	10	22	24.1	101	Rain Showers
19:00	12.4	9.6	83	9	32	24.1	100.86	Rain Showers
20:00	12	10.1	88	11	32	16.1	100.85	Rain Showers
21:00	12.1	10.3	89	11	22	16.1	100.84	Rain Showers
22:00	13.1	10.9	86	13	22	24.1	100.79	Cloudy
23:00	13.6	10.6	82	16	28	19.3	100.83	Rain Showers

Hourly Data Report for February 27, 2009

T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	**kPa**	
m								
e								
0:00	0.7	-4.6	68	11	13	32.2	102.72	Cloudy
1:00	0.7	-4	71	9	11	32.2	102.77	Cloudy
2:00	1.1	-4.3	67	8	13	32.2	102.76	Cloudy
3:00	0.7	-3.5	73	8	11	32.2	102.76	Cloudy
4:00	0.6	-3.1	76	10	11	32.2	102.75	Cloudy
5:00	0.7	-2.8	77	10	13	32.2	102.77	Cloudy
6:00	0.7	-2.6	79	10	11	32.2	102.79	Snow
7:00	0.9	-2.7	77	10	11	24.1	102.79	Cloudy
8:00	1.1	-2.5	77	11	11	24.1	102.78	Cloudy
9:00	2.4	-2	73	8	9	24.1	102.75	Mostly Cloudy
10:00	3.7	-1.6	68	11	9	24.1	102.73	Mostly Cloudy
11:00	5	-3.5	54	10	13	32.2	102.69	Mainly Clear

12:00	5.9	-3.2	52	9	13	32.2	102.65	Mainly Clear
13:00	6.1	-4.3	47	17	9	32.2	102.59	Mainly Clear
14:00	5.7	-2.6	55	31	15	32.2	102.57	Mostly Cloudy
15:00	5.1	-2.8	57	25	13	32.2	102.58	Mostly Cloudy
16:00	4.9	-4.4	51	25	15	48.3	102.59	Mostly Cloudy
17:00	4.9	-4.2	52	25	7	48.3	102.57	Mainly Clear
18:00	3.9	-6	48		0	48.3	102.55	Mainly Clear
19:00	3.6	-5.3	52		0	48.3	102.62	Mainly Clear
20:00	1.8	-5	61	3	9	48.3	102.66	Mainly Clear
21:00	2.8	-1.9	71	5	13	48.3	102.66	Mostly Cloudy
22:00	3	-1.7	71	8	13	48.3	102.67	Mostly Cloudy
23:00	3.1	-1.8	70	10	9	32.2	102.71	Mostly Cloudy
Hourly Data Report for February 28, 2009								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	10's deg	km/h	km	kPa	
m								
e								
0:00	3	-2	70	11	4	32.2	102.73	Mostly Cloudy
1:00	3	-2	70	11	7	32.2	102.72	Mostly Cloudy
2:00	2.9	-1.8	71		0	32.2	102.7	Rain Showers
3:00	2.9	-1.8	71	32	4	32.2	102.62	Cloudy
4:00	2.1	-1.7	76	11	6	32.2	102.57	Cloudy
5:00	1.9	-2.1	75		0	32.2	102.53	Mostly Cloudy
6:00	2.2	-1.7	75	19	7	32.2	102.52	Mostly Cloudy
7:00	2.2	-2	74	18	6	48.3	102.46	Mainly Clear
8:00	2.1	-1.8	75	11	6	48.3	102.43	Mostly Cloudy
9:00	3	-1.3	73	17	7	48.3	102.46	Mostly Cloudy
10:00	5	-1	65	18	6	48.3	102.41	Mostly Cloudy
11:00	5.1	-1.6	62	27	6	48.3	102.35	Cloudy
12:00	5	-0.9	66	26	9	48.3	102.28	Cloudy
13:00	5.2	-0.6	66	24	11	48.3	102.16	Cloudy
14:00	5.3	-0.8	65	30	11	48.3	102.13	Cloudy
15:00	5.8	-1.5	59	32	9	48.3	102.07	Cloudy
16:00	6.1	-0.7	62	33	11	48.3	101.97	Cloudy
17:00	6.5	-0.6	60	16	9	48.3	101.87	Cloudy
18:00	6.6	0.1	63	36	6	32.2	101.77	Cloudy
19:00	5.2	1.4	76	30	13	24.1	101.76	Rain Showers
20:00	5.1	1.9	80	32	6	24.1	101.65	Rain Showers
21:00	6.1	2.3	77	15	7	24.1	101.58	Rain Showers
22:00	6	2	75	16	7	24.1	101.58	Rain Showers
23:00	5.1	2.5	83	21	4	19.3	101.53	Rain Showers
Hourly Data Report for March 5, 2009								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	10's deg	km/h	km	kPa	
m								
e								
0:00	5	1.3	77	27	33	24.1	100.79	Rain Showers
1:00	5.1	0.4	72	29	41	24.1	100.75	Mostly Cloudy

2:00	5.3	0.2	70	28	54	24.1	100.71	Mostly Cloudy
3:00	4.7	0.2	73	29	46	32.2	100.71	Mainly Clear
4:00	4.6	-0.2	71	29	46	32.2	100.68	Mostly Cloudy
5:00	4.5	0.3	74	29	41	32.2	100.75	Mostly Cloudy
6:00	4.5	0	73	32	24	32.2	100.8	Mostly Cloudy
7:00	4.3	0.2	75	31	33	32.2	100.8	Mostly Cloudy
8:00	4	0.2	76	11	6	32.2	100.9	Mostly Cloudy
9:00	5.3	0.9	73	28	9	32.2	100.96	Mostly Cloudy
10:00	5.9	1.7	74	27	7	32.2	101.01	Mostly Cloudy
11:00	7.1	1.9	69	31	15	32.2	101.04	Mainly Clear
12:00	7.7	-2.6	48	31	20	32.2	101.08	Mainly Clear
13:00	8.4	3.8	73	34	20	32.2	101.08	Mainly Clear
14:00	8.8	-8.2	29	32	24	32.2	101.11	Mainly Clear
15:00	8.5	-3.6	42	13	11	32.2	101.16	Mostly Cloudy
16:00	8	-2.4	48		0	32.2	101.25	Mainly Clear
17:00	7.6	-8.9	30	34	24	32.2	101.31	Mainly Clear
18:00	6.3	-11.2	27	35	20	32.2	101.38	Mainly Clear
19:00	5.4	-11.6	28	4	11	32.2	101.49	Mainly Clear
20:00	4.3	-8.3	39	12	15	32.2	101.6	Mainly Clear
21:00	2.6	-8.9	42	11	15	32.2	101.7	Clear
22:00	0.2	-8.6	52	11	9	32.2	101.79	Clear
23:00	0.8	-9.8	45	11	15	32.2	101.88	Clear
Hourly Data Report for March 6, 2009								
T	Temp	Dew Point Temp	Rel Hum	Wind Dir	Wind Spd	Visibility	Stn Press	Weather
i	°C	°C	%	**10's deg**	km/h	km	kPa	
m								
e								
0:00	0.4	-10.8	43	12	11	32.2	101.95	Clear
1:00	0	-10.9	44	10	9	32.2	102	Clear
2:00	-0.2	-11.2	43	8	7	32.2	102.02	Mainly Clear
3:00	-0.4	-11.5	43	3	6	32.2	102.07	Clear
4:00	-1.2	-10.8	48		0	32.2	102.08	Clear
5:00	-0.5	-10.2	48		0	32.2	102.13	Mainly Clear
6:00	-1.4	-9.3	55	9	6	32.2	102.15	Mainly Clear
7:00	-1.9	-9.4	56	10	7	48.3	102.19	Mainly Clear
8:00	0.6	-8.3	51	10	7	48.3	102.25	Mainly Clear
9:00	1.8	-9.4	43	11	7	48.3	102.3	Mainly Clear
10:00	3	-8.5	43	13	9	48.3	102.34	Mainly Clear
11:00	4.8	-9.3	35	21	4	48.3	102.34	Mainly Clear
12:00	5.6	-8.9	34		0	48.3	102.34	Mainly Clear
13:00	5.6	-9.7	32	17	7	48.3	102.34	Mainly Clear
14:00	6.4	-8.9	32	24	6	48.3	102.29	Mainly Clear
15:00	6.9	-7.9	34	17	6	48.3	102.27	Mainly Clear
16:00	6.8	-7.2	36	16	15	48.3	102.25	Mainly Clear
17:00	6	-7.6	37	17	11	48.3	102.24	Mostly Cloudy
18:00	5.7	-6.9	40	13	11	48.3	102.22	Mostly Cloudy
19:00	5.2	-5.1	47	12	13	48.3	102.21	Mostly Cloudy
20:00	4.7	-4.7	50	10	9	48.3	102.19	Mostly Cloudy
21:00	3.7	-6.1	49	9	17	48.3	102.06	Mainly Clear
22:00	4.2	-5.6	49	9	15	32.2	102.06	Mostly Cloudy

23:00	4.4	-6	47	10	19	32.2	101.98	Mostly Cloudy

Appendix D

Indoor Temperature Data

APPENDIX D: Interior Suite Temperature Data

Suite 3903 – July 3 through October 5, 2008

5 Hobo Pro data loggers (Model # U12-013) were installed within suite 3903 by RDH from July 3 through October 5, 2008 to measure suite temperatures adjacent to the windows – to assess thermal comfort for the occupants. The data loggers were installed within the master bedroom, guest bedroom, dining room, and living room (north and south elevation. The typical sensor placement in the suite is shown in Figures D1 and D2 at the drop ceiling valence near the windows. At request of the owners, the placement of the loggers was in a location not visible within the suite.

Figure D1: Location of Installed data-loggers, at ceiling valence approximately 12" from window.

Figure D2: Location of installed data-logger, behind curtains at ceiling valence.

Temperatures plotted throughout the monitored period are presented in Figures D3 through D7. Four of the data-loggers are located on the south elevation, with one of the north. The data-logger on the north is located in a shaded location and does not receive direct sunlight, and is more representative of temperatures within the suite away from the solar heated windows. The sensors located on the south are shaded from direct sunlight, but on the sunny side of the building for the majority of the day until evening when the sun is lower in the sky. The interior blinds, even in the open position shade the sensors from direct sunlight.

Suite 3903 consists of a 02 and a 03 unit joined together. Two air-conditioning units are used within the suite. The occupants frequently report overheating from the spring through fall months within their suite even with air-conditioning on. The occupants reportedly use their interior blinds particularly on the south elevation. Air conditioner set-point at the time of installation was 21°C and reportedly kept at this temperature for the summer months, due to the overheating issues.

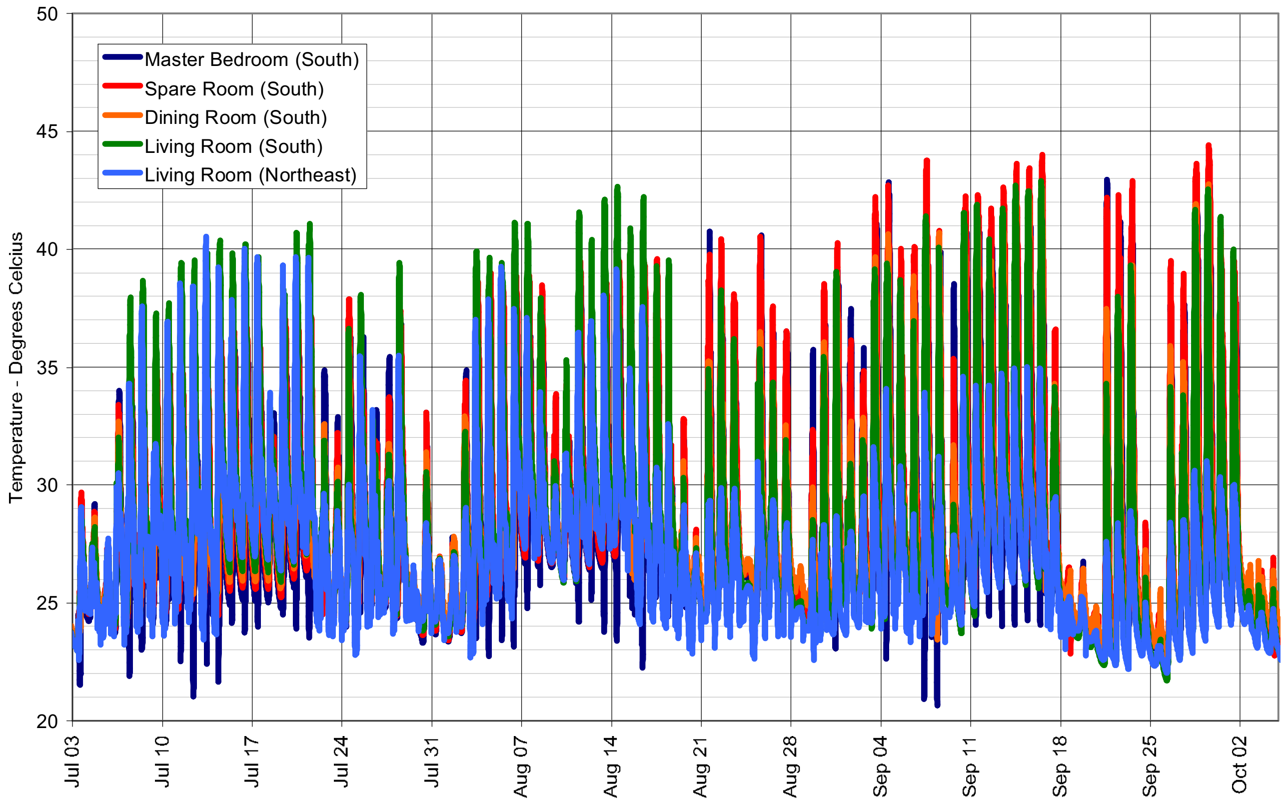


Figure D3: Suite 3903 - Near Window Indoor Air Temperature, July 3 through October 5, 2008

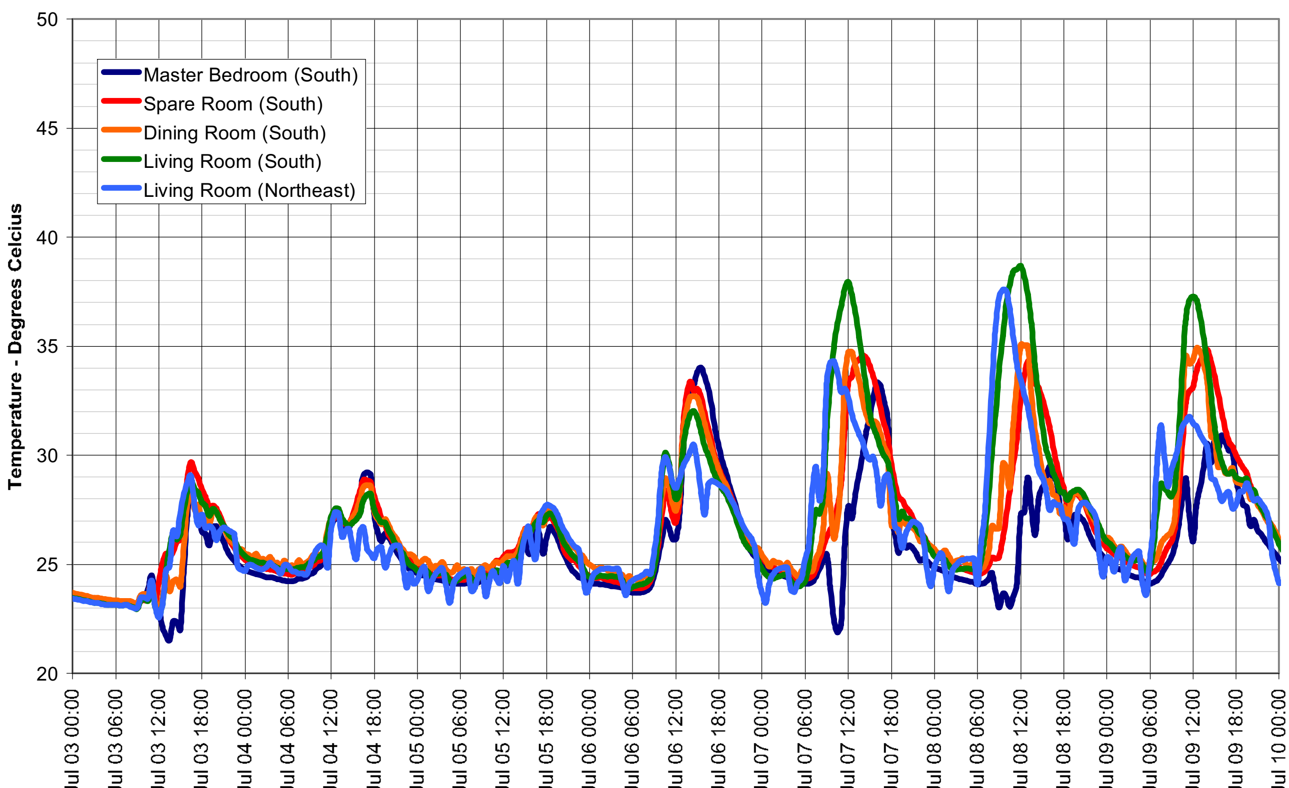


Figure D4: Suite 3903 - Near Window Indoor Air Temperature, July 3 through 10, 2008

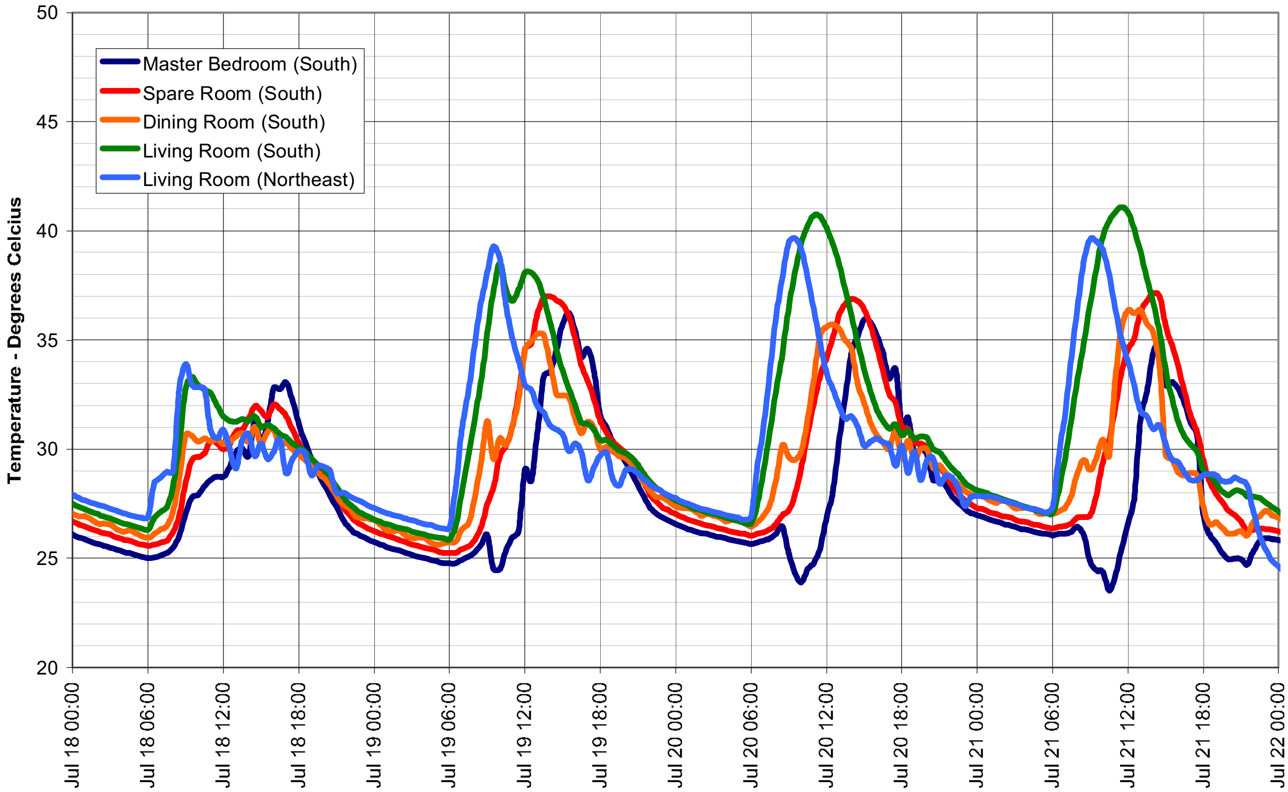


Figure D5: Suite 3903 - Near Window Indoor Air Temperature, July 18 through 22, 2009-08-21

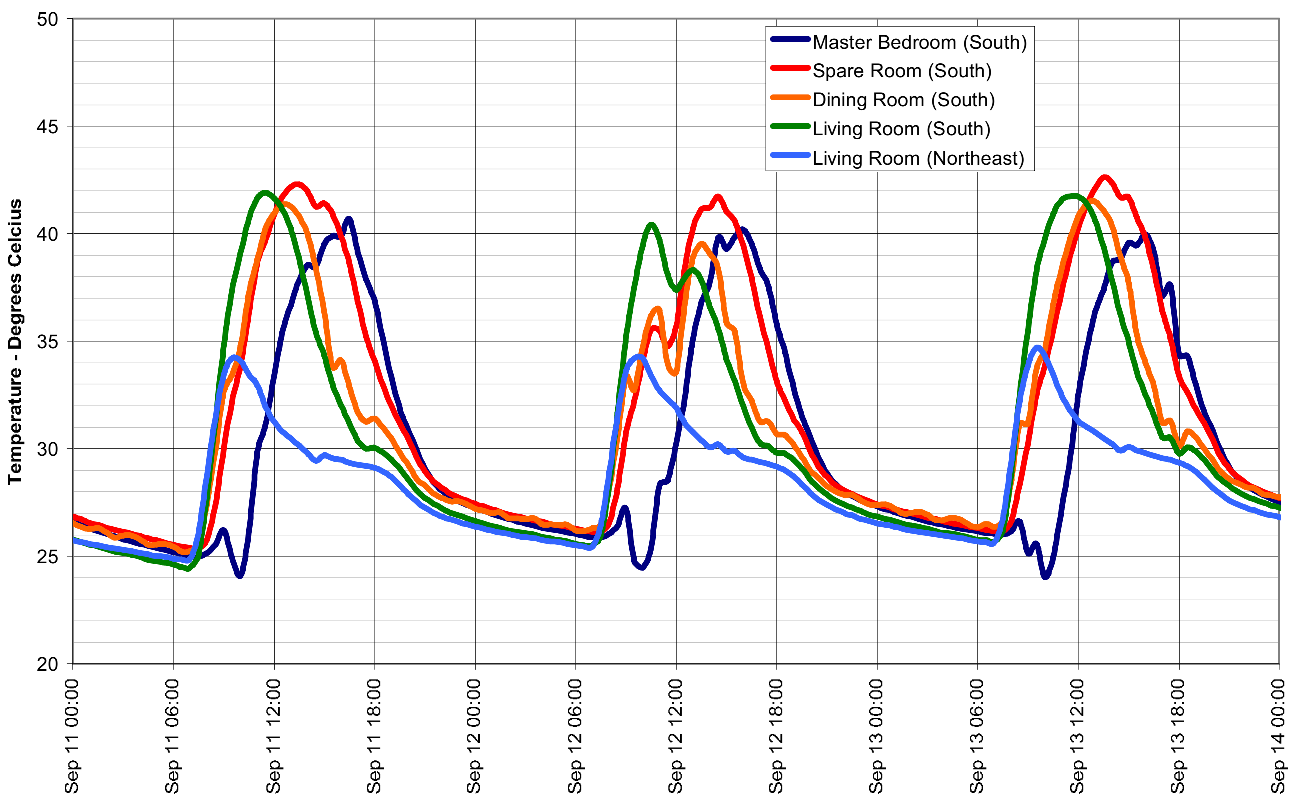


Figure D6: Suite 3903 - Near Window Indoor Air Temperature, September 11 through 14, 2008

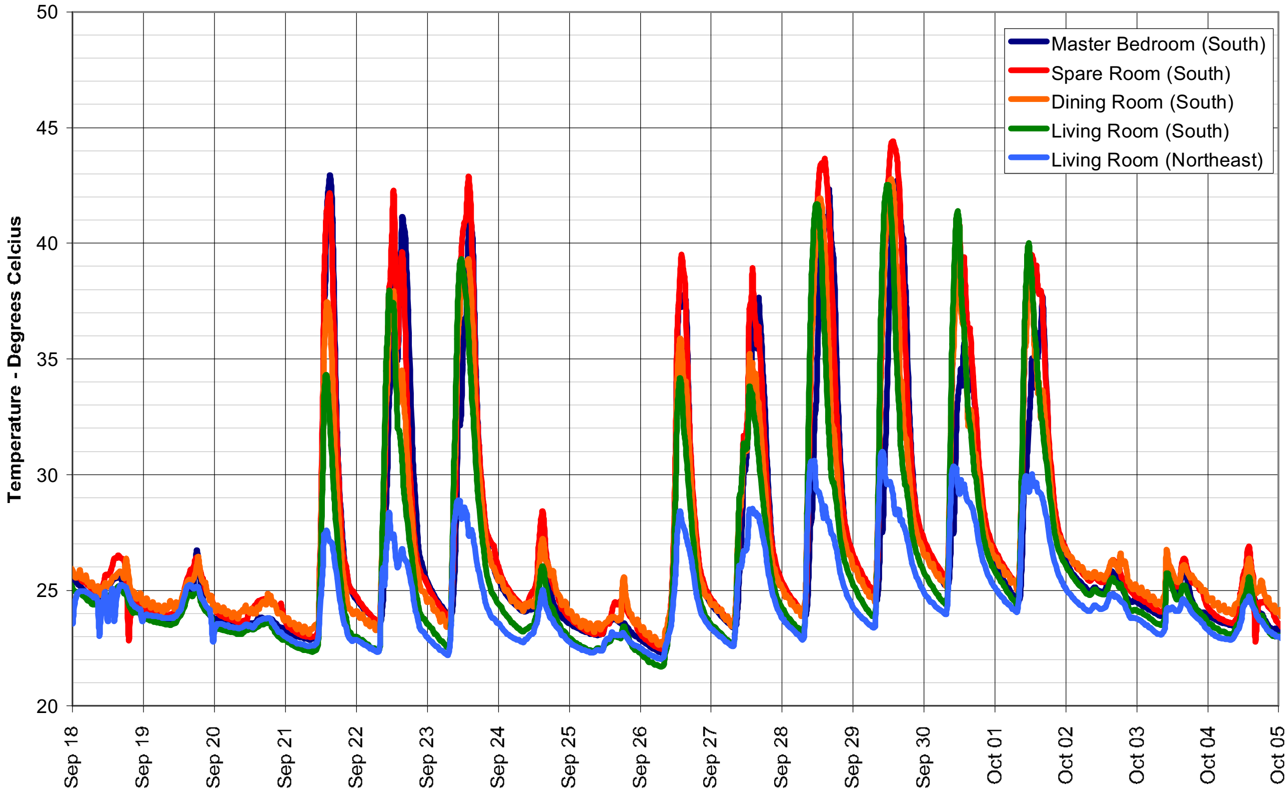


Figure D7: Suite 3903 - Near Window Indoor Air Temperature, September 18 through October 5

Temperatures near the windows are uncomfortably hot over the entire monitored period (up to above 40°C), and this is consistent with the occupant complaints. The warm window temperatures affect the thermal comfort within the suite and required energy to air-condition the suite. Temperatures at the north side of the suite in the afternoon indicate temperatures within the suite are regularly around 30°C, even with the air-conditioning system running. Night-time temperatures are frequently above 25°C, which may be uncomfortable to some people.

40th Floor Suites – September 17 through October 5, 2008

HOBO Pro data-loggers (Model # U12-013) were installed within suites 4001, 4002, 4003, and 4004 from September 17th through October 5th 2008. The data-loggers were installed in conjunction with the pressure and flow gauges attached to the Vision Wall IGUs. The data loggers were installed to measure interior glazing and window frame temperature (using HOBO TMC6-HD thermocouples), and ambient air temperature away from the windows within the suite. The location of the temperature sensors is shown in Figure D8. Temperature data is shown in Figures D9 through D13.

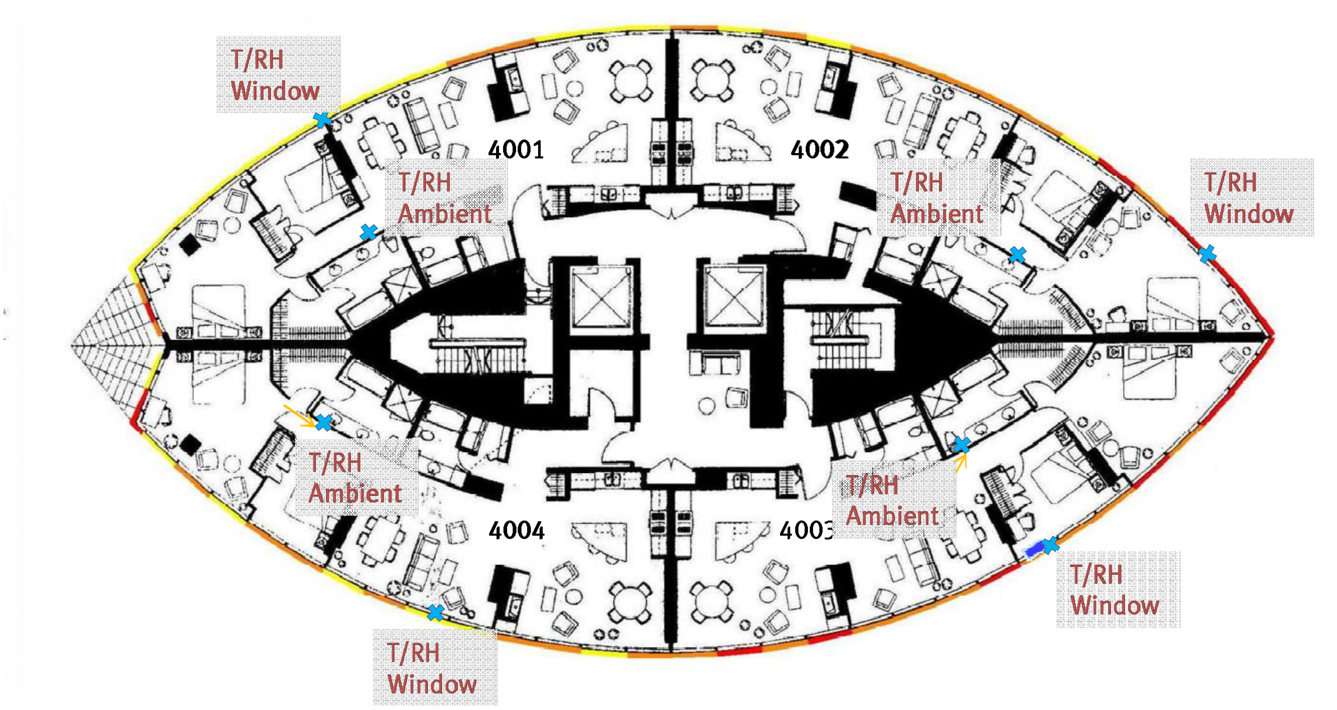


Figure D8: Location of temperature sensors within 40th floor suites.

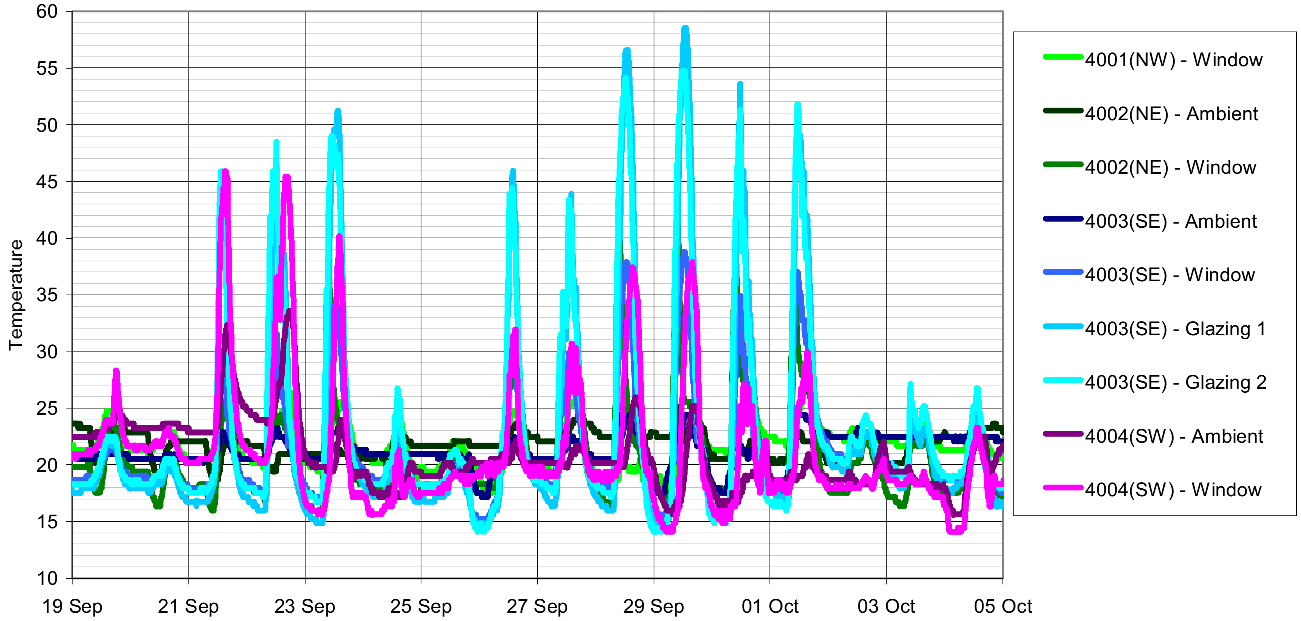


Figure D9: 40th Floor Suites- Window Sill, Glazing Surface, and Suite Ambient Air Temperatures

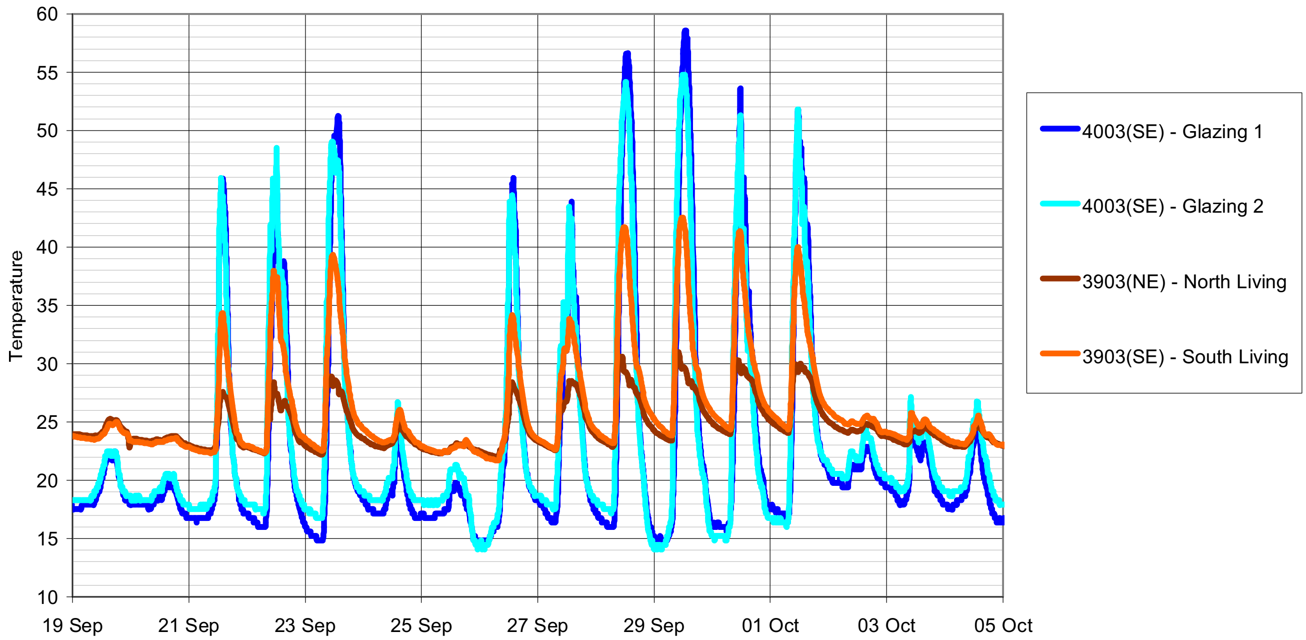


Figure D10: Comparison of Suite 3903 near window temperature and 4003 glazing surface temperature

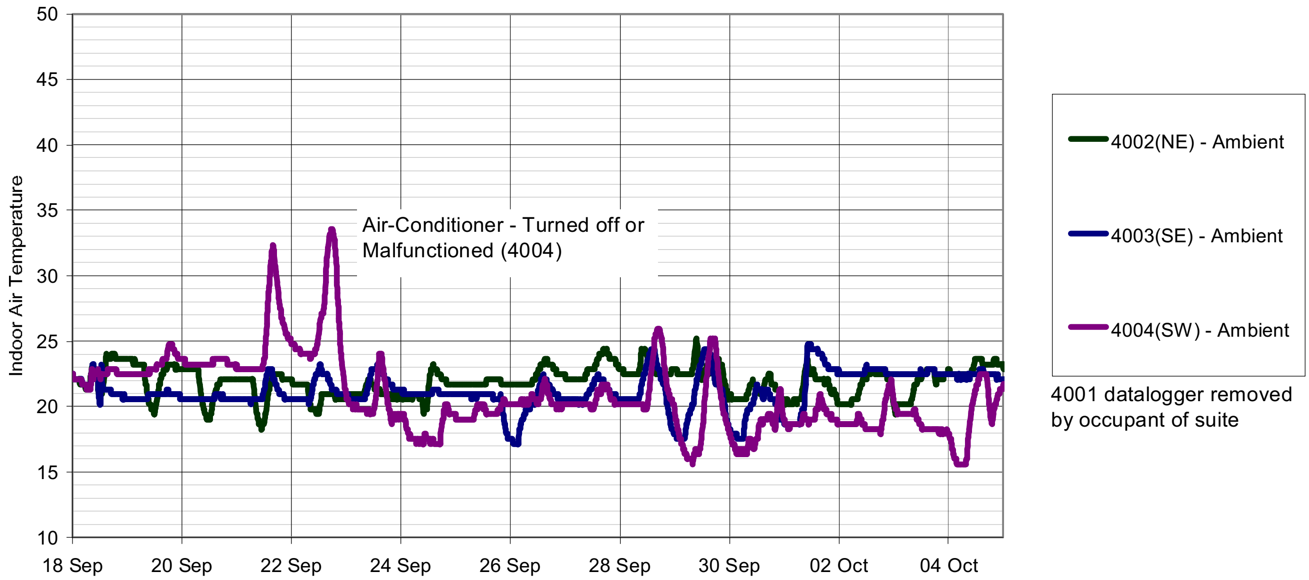


Figure D11: 40th Floor Ambient Suite Temperatures, September 18 – October 5, 2008

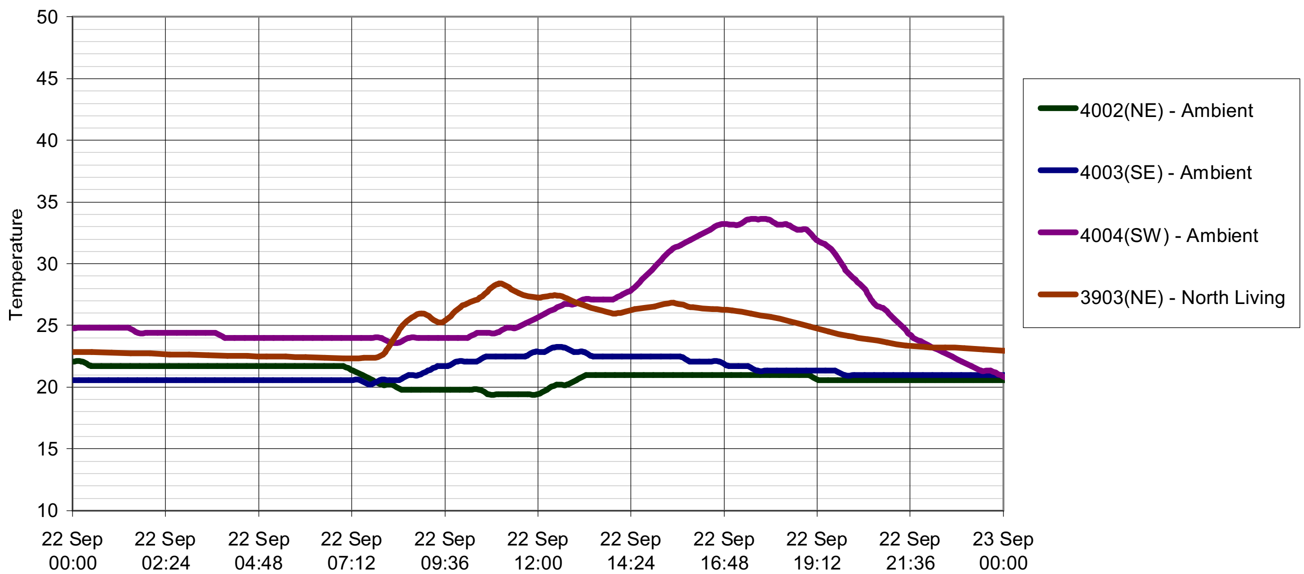


Figure D12: Overheating of Suite 4004 on September 22, 2008, when air-conditioning unit not working, compared to adjacent suites

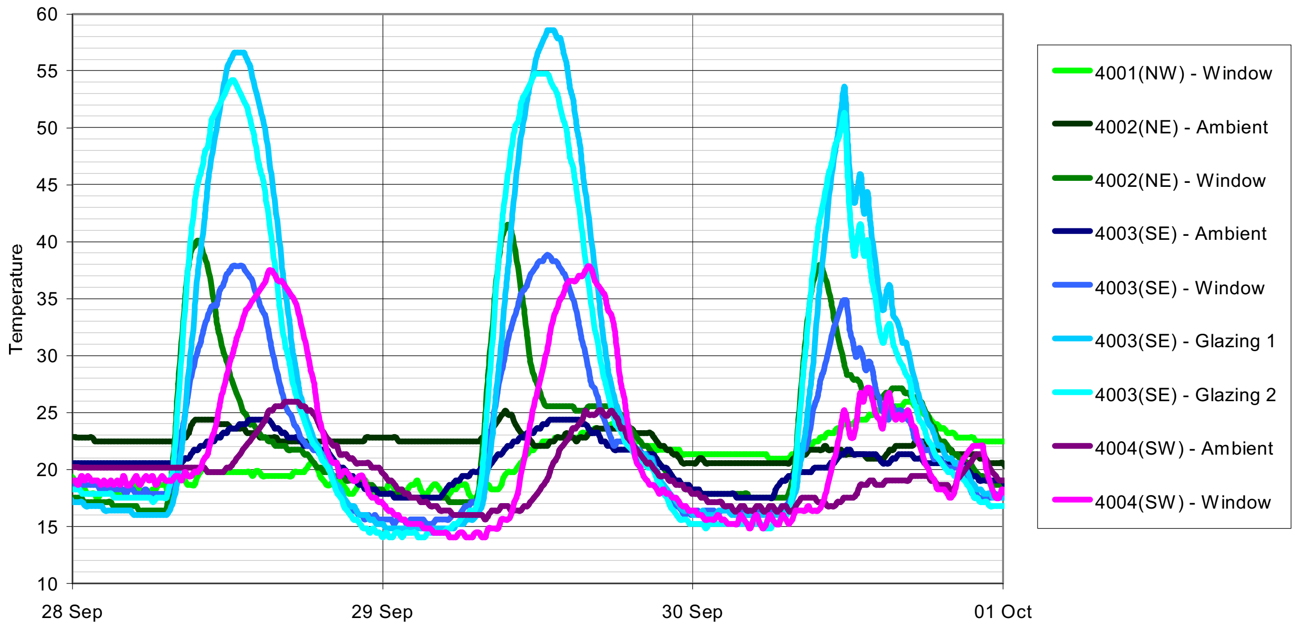


Figure D13: 40th Floor, Peak Solar Heating Events from September 28 through October 1, 2008

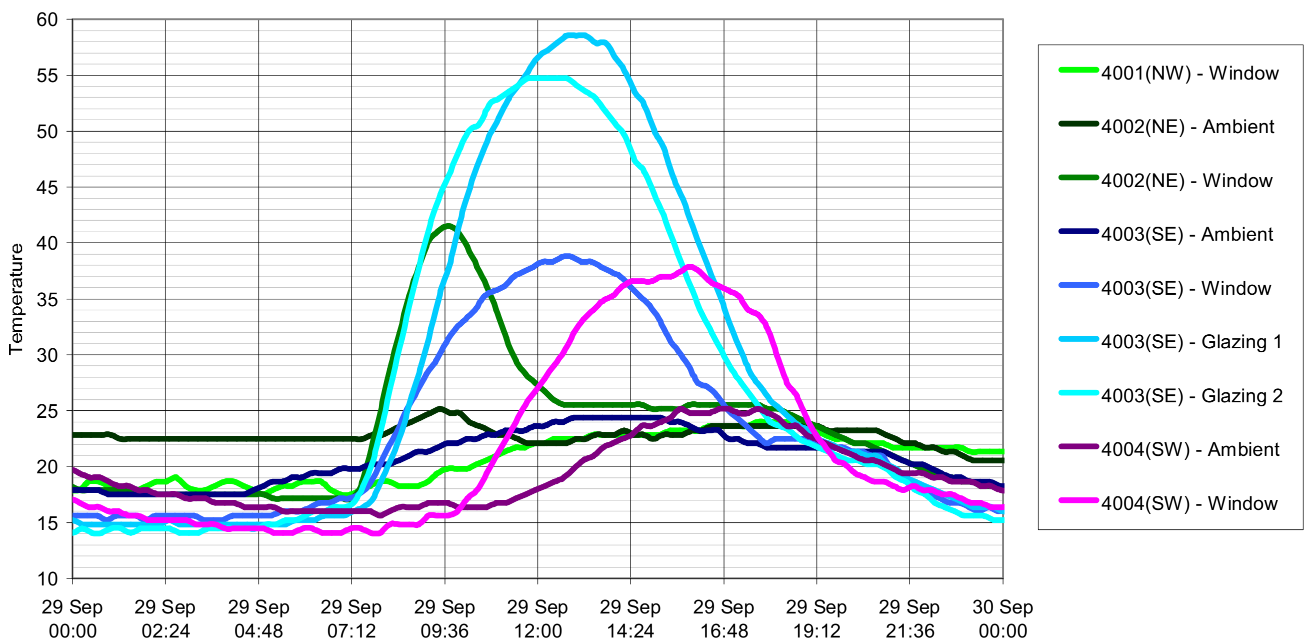


Figure D14: 40th Floor, Peak Solar Heating Event on September 29, 2008.