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# LASS AND ALUMINUM CURTAIN WALL SYSTEMS

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## ABSTRACT

The curtain wall is the most airtight and weather resistant cladding and exterior wall system available. This article provides an overview of the components of modern glass and aluminum curtain walls, their design features, performance and durability characteristics. It also provides the architect or designer with knowledge of the technology of curtain wall design with respect to air leakage control, rain penetration control, heat loss (or gain) control and condensation control. Consideration is given to testing of a new curtain wall system design. This article also provides sample design details of curtain wall connections at grade, soffits, head and sill conditions, parapets and at connections with other cladding and wall systems such as brick or precast exterior cladding and wall systems. This article does not review the structural design of aluminum curtain walls systems nor does it review storefronts, sloped glazing or skylights.

## OBJECTIVES

After reading this article you should understand;

1. What characterizes a glass and aluminum curtain wall and its components.
2. What is the difference between a stick built curtain wall, a unitized curtain wall and a structural glazing curtain wall,
3. What range of climatic and indoor conditions can be supported by a glass and aluminum curtain wall,



**Ontario Association of Architects**



**Fig. 1**  
**Curtain Wall With Granite Spandrel Panels**



HOME TO CANADIANS  
Canada

4. What problems may occur when a glass and aluminum curtain wall leaks air and how air leaks are controlled,
5. How a curtain wall system prevents rain penetration and how the rainscreen principle is applied,
6. How surface condensation is controlled on glazing and curtain wall frames and what is a temperature index,
7. What types of glass and sealed units are used in the vision areas,
8. What are the most common causes of pre-mature insulating glass unit (IGU) failure,
9. What type of glazing or panels may be used in spandrels,
10. How is a glass and aluminum curtain wall tested for air leakage, rain penetration and condensation,
11. How to design a typical curtain wall connection at grade, at a parapet, at a window head or sill and at a soffit.

## INTRODUCTION

The glass and aluminum curtain wall is found in city centres on many new buildings and it is quite popular as a cladding and exterior wall on all types of commercial, industrial, institutional and residential buildings. The curtain wall is characterized with coloured vision and spandrel glass areas, a grid of aluminum caps and most recently with metal or stone spandrel covers (see Fig. 1, page 1). It is also combined with other types of cladding systems such as precast, brick or stone to create attractive and durable building facades.

The curtain wall comprises a complete cladding and exterior wall system with the exception of the indoor finishes. It is generally assembled from aluminum frames, vision glass and spandrel glass (or metal or stone) panels to enclose a building from grade to the roof. It is available in three system types to include the stick built system, the unitized (or panel) system and the structural glazing system (capless vertical joints). The glass and aluminum curtain wall is designed to resist wind and earthquake loads, to limit air leakage, control vapour diffusion, prevent rain penetration, prevent surface and cavity condensation and limit excessive heat loss (or heat gain). It is further designed to resist noise and fire.

## THE STICK BUILT SYSTEM

The oldest curtain wall type is the stick built system. It is a cladding and exterior wall system which is hung on the building structure from floor to floor. It is assembled from various components to include steel or aluminum anchors, mullions (vertical tubes), rails (horizontal mullions), vision glass, spandrel glass, insulation and metal back pans (see Fig. 2 below). In addition, there are various hardware components to include anchors, aluminum connectors, setting blocks, corner blocks, pressure plates, caps, gaskets and sealants.

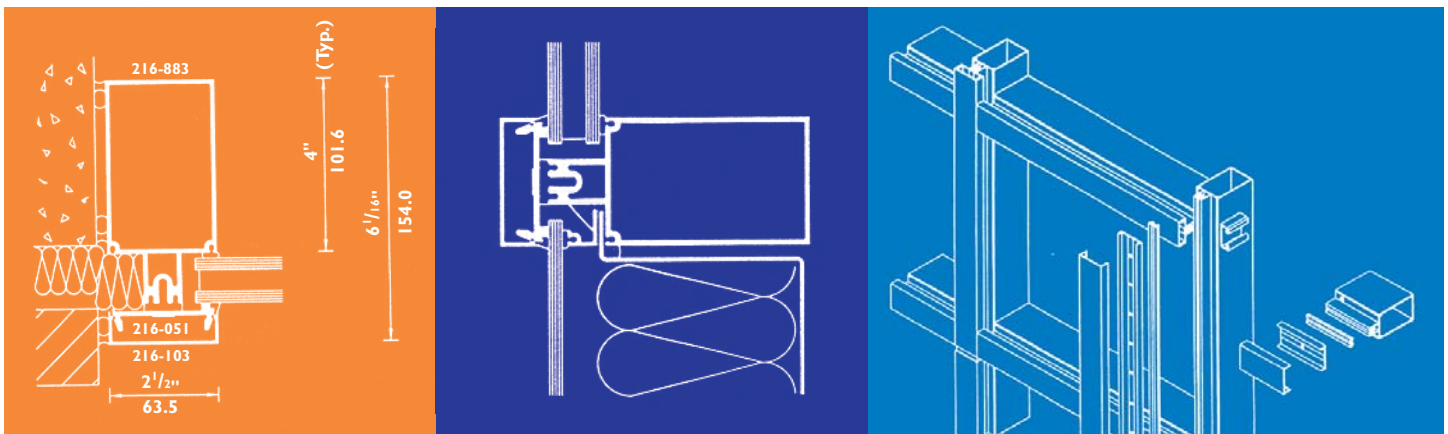


Fig. 2 – Stick Built Curtain Wall System – Ottawa Post Office

The stick built system is installed by hanging the vertical mullion from a floor edge with a steel angle, while sliding the lower end of the vertical mullion over an insert anchor in the vertical mullion attached below. Vertical mullions are spaced from 1.25 metres (4 feet) to about 1.85 metres (6 feet) depending on the spacing of columns, the wind load, and the desired appearance of the facades (see Fig. 3 below). The joint between the vertical mullions is also an expansion joint for the floor-to-floor live load deflections, any concrete structure creep movements as well as a thermal expansion joint for curtain wall components. These joints must be designed on a job-by-job basis. The rails (horizontal mullions) are then attached to the vertical mullions to create frame openings, one frame opening for the vision area to receive an insulating glass unit (IGU) and one frame opening for the spandrel area (to receive the spandrel panel cover (to hide the floor edge, perimeter heating equipment and ceiling plenum areas)).

Vision IGUs are installed in the frame openings between floors. They are always placed in the frame opening on two setting blocks (usually silicone, EPDM or neoprene) spaced about 1/4 of the rail span from each end. The IGU may be air sealed on the inside to the shoulders of the aluminum frame with a gasket (dry seal) or a preshimmed tape and sealant (wet seal). For practical reasons of IGU installation, the glazing method of choice is a dry gasket inside and a wet seal outside. For performance and durability of the IGU, the glazing method of choice would be a wet seal inside and a dry gasket outside. Some systems use a dry/dry glazing method. In the final stage of installation of a glass and aluminum curtain wall, the IGUs and spandrel covers are permanently held in place with full length pressure plates and aluminum snap caps.

The spandrel areas are usually enclosed with a metal backpan (air and vapour barrier), with high density glassfibre or mineral fibre insulation within the backpan. The backpan is then fastened and sealed to the aluminum frame. The spandrel glass is usually monolithic heat strengthened glass with a coloured coating (frit) and polyester film to opacify the spandrel glass and to closely approximate the colour or tint of the vision units. The spandrel covers may also be aluminum, stainless steel or copper panels. In the last few decades, granite panels as well as sealed units have been installed in the spandrel areas of curtain wall systems.



**Fig. 3 – Typical Components of a Stick Built Curtain Wall System**

Stick System—Tubular mullions and transoms with shear block construction. Pressure equalized rain screen design.  
Courtesy of the Kawneer Company

The stick built system can be constructed very air tight and resistant to water penetration. When the aluminum frames are assembled, a corner block is installed at the junction of the vertical mullion and rail. This corner block separates the glazing cavity of the sealed units from the glazing cavity of the spandrel area. It acts both to divert water into the sill cavity of the rail and as a compartment seal for pressure equalization performance. It is important to seal the corner block to the vertical mullion and rail and that it fit tightly behind the pressure plate to prevent water from draining to the IGU or spandrel cavity below.

To prevent excessive heat loss at the vertical mullion or rail pressure plate and cap connections in winter, a thermal break of EPDM rubber or other material, is placed between the pressure plate and the screw spline (slot with linear threads inside) of the vertical and horizontal mullions. This rubber-like material is not insulation, but it does provide sufficient thermal resistance between the cold pressure plate on the outside and the indoor mullion to allow the indoor temperature to warm the indoor part of the mullion above the dewpoint temperature (condensation temperature) of the indoor air.

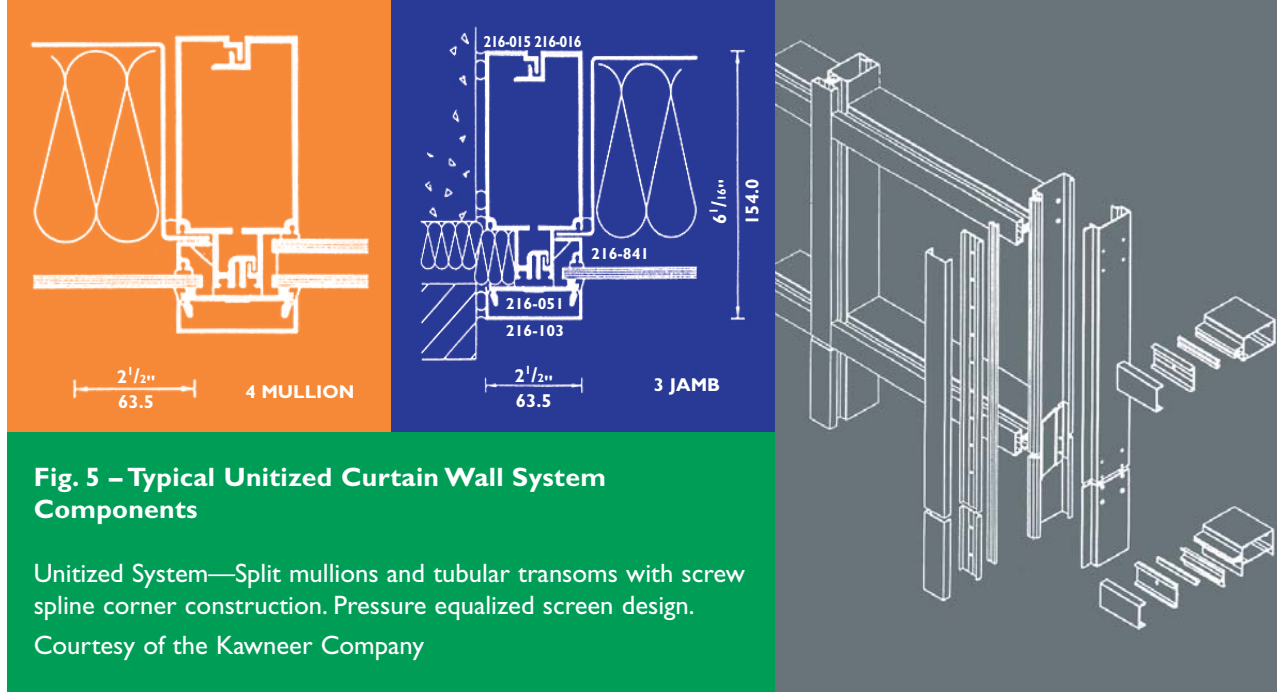
The pressure plate and cap enclose the drainage and vent areas of the glazing or spandrel rainscreen cavities. The pressure plates are usually punched with two drain and vent holes on small units and three holes per window or spandrel opening on larger units. This is because the setting blocks are currently designed and extruded to allow moisture migration past the setting blocks to the drain/vent holes. The holes are 30 mm (1.25 inches) long by 6 mm (1/4 inch) high and punched in line with the surface of the neck of the rail component to allow drainage from the glazing cavity through the pressure plate and into the snap cap. In the snap cap, water is directed to two small holes near the ends of the snap caps, approximately 100 mm (4 inches) from the ends.

## THE UNITIZED CURTAIN WALL

A glass and aluminum curtain wall fabricated and installed as a panel system is referred to as a unitized curtain wall system. A unitized curtain wall will have the same components as a stick built curtain wall system. It will comprise aluminum mullions, an IGU and a spandrel panel mounted in a prefabricated aluminum frame. However, instead of assembling the glass and aluminum curtain wall in the field, most of the system components are assembled in a plant under controlled working conditions. This promotes quality assembly and allows for fabrication lead-time and rapid closure of the building.



Fig. 4 – Unitized Curtain Wall System Installation



**Fig. 5 – Typical Unitized Curtain Wall System Components**

Unitized System—Split mullions and tubular transoms with screw spline corner construction. Pressure equalized screen design.

Courtesy of the Kawneer Company

The unitized system is assembled on the building as panels (see Fig. 4, page 4). The mullions and rails are fabricated as half sections instead of tubular sections, which mate at assembly time to form the curtain wall system. The panels are installed in shingle fashion, starting from the bottom of the building and going around each floor and up the building.

While the unitized system offers many advantages with respect to quality assembly and speed of on building closure, there is one design concern with respect to installed performance and durability. In a stick built system, there are two joints along every mullion and rail. In a unitized system, there are three joints along every mullion and rail. These include the two glass to aluminum joints and a third joint at the junction between the half mullions and half rails. Three joints instead of two increases the potential air and water leaks by 50% over a stick built system. Should an air or water leak develop at the third joint, there is usually no practical method of accessing the in-between panel joint for repair (see Fig. 5) unless the manufacturer has provided a serviceable joint system design. In a unitized system, the manufacturer must rely on qualified installers to ensure that the air seals are properly installed between the split mullions. Nevertheless, the unitized system is now as popular as the stick system according to one manufacturer and it has performed satisfactorily when installed correctly.



**Fig. 6 – Structural Silicone Glazing System**

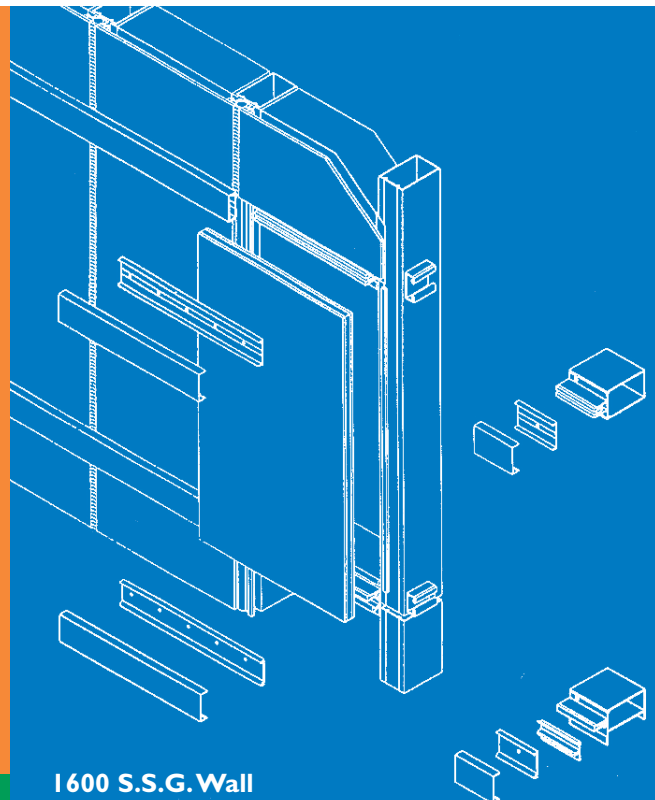
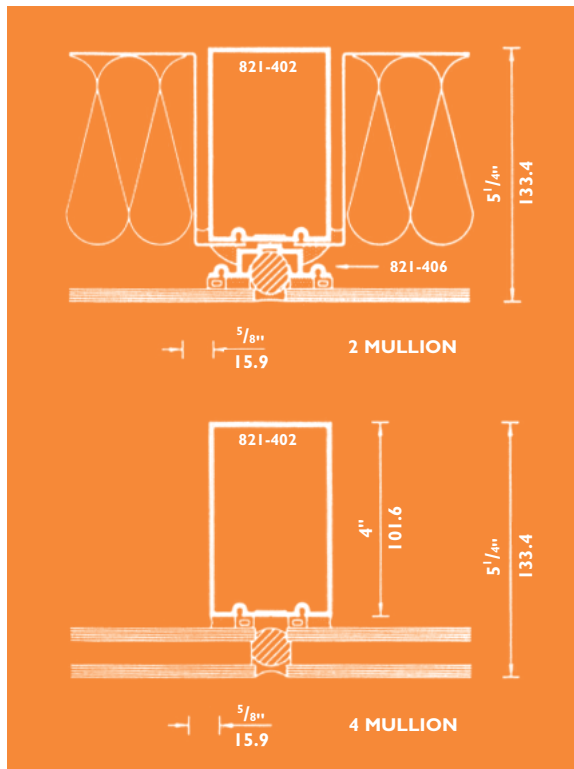
## THE STRUCTURAL GLAZING SYSTEM

Structural glazing curtain wall systems may be found in many cities in Canada and in the United States. It may be found with two or four sided capless glazing applications. In Canada only two sided applications are used with the vertical joints of the IGUs being capless (see Fig. 6, page 6) but there are a few specially designed four sided examples.

A structural glazing curtain wall system uses the same aluminum mullion components as the stick built curtain wall except that the mullion nose (neck) of the verticals is omitted to create a capless vertical joint system. The vertical joints between the IGUs are sealed on the outside with silicone sealant for a flush exterior appearance. The horizontal mullions are constructed with standard pressure plates and caps.

To hold the IGU against the aluminum of the vertical mullion, the inner light of the IGU is held apart from the aluminum mullion with a gasket or spacer tape and a structural silicone sealant is applied between the glass and the aluminum. The joint or contact width is about 12.5 mm (or 1/2 inch) (see Fig. 7 below). The structural silicone sealant forms a strong adhesive bond having a minimum strength of 20 psi. When the shop drawings are submitted to a silicone manufacturer, they will often warranty an application for twenty years if it is determined that all materials are compatible by testing.

Silicone sealant is vapour permeable. In high humidity indoor environments, where the structural silicone may be exposed to high humidity during winter, the silicone may require a cap bead of moisture resistant sealant (butyl) to minimize the diffusion of humidity into the structural silicone glazed joint.



**Fig. 7 – Typical Structural Silicone Glazing (SSG) System**

Courtesy of the Kawneer Company

### 1600 S.S.G. Wall

Tubular mullions and horizontals with shear block construction. Pressure equalized rain screen design. Capless vertical glass joints with horizontal pressure plates and caps.

## DESIGN FEATURE I - AIR LEAKAGE CONTROL

To perform satisfactorily, a cladding an exterior wall system must meet several performance requirements. These include air leakage control (the air barrier function), vapour diffusion control (the vapour barrier function – not the same as the air barrier function), heat loss/gain control (insulation and thermal breaks), rain and melt water penetration control (the rainscreen principle). In addition, the curtain wall must accommodate various differential movements. The most critical of the performance requirements is air leakage control.

The leakage of air through a curtain wall system in winter may result in excessive ice build up on aluminum caps, at parapets or soffits. The ice can grow to become a safety hazard to persons and property below. Air leakage also causes condensation in glazing cavities to the detriment of the IGUs and it can corrode backpans and fasteners. Excessive condensation in a glazing cavity may expose an IGU to prolonged edge immersion in water. *While sealed unit edges can resist wetting and drying cycles, immersion in water, even for a few months, will destroy an IGU in a few years.*

Rain will penetrate a curtain wall that is not air tight and sealed correctly and air tight. When wind and rain impinge on a facade, rain water is pushed through imperfections in the outside seals and into glazing cavities by the difference in wind pressure between the outside and the glazing cavity pressure. The rain may accumulate in a cavity until it overflows into the building to appear at a floor, window head or ceiling.

Generally, an aluminum curtain wall is airtight. In a typical stick built curtain wall section, the air barrier plane is continuous and structurally supported. Specifically, the air barrier plane may be traced through a section (see Fig. 8) to include the glass of the IGU, the seal between the glass and the aluminum mullion, the aluminum of the mullion, the seal between the aluminum mullion shoulder and the backpan, the metal liner of the backpan, the seal between the bottom of the metal pan and the shoulder of the mullion below which connects with the glass of the sealed unit below. In plan, the same tracing of the air barrier plane would apply. The leakage of air at the glass aluminum joint is minimized with either a wet or dry seal. In a unitized system, the mullions are split and therefore include an additional air barrier joint between the half mullions. This joint is usually hidden and inaccessible once assembled.

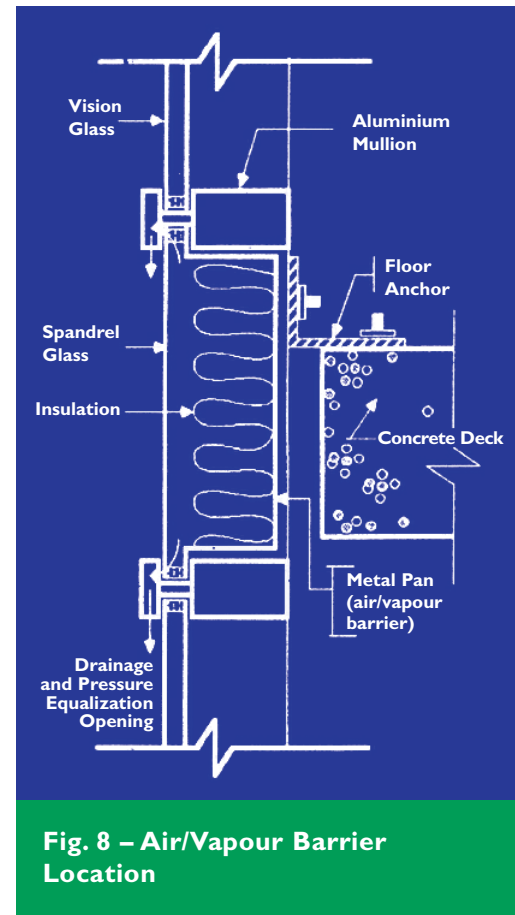


Fig. 8 – Air/Vapour Barrier Location

The air leakage rate through a curtain wall fabricated for the United States market is limited to 0.3 litres/sec\*metre<sup>2</sup> at 75 Pa (0.06 cfm per ft<sup>2</sup> at 1.57 lbs/ft<sup>2</sup>) air pressure difference. In Canada, the air leakage rate is limited to 0.1 litres/sec\*metre<sup>2</sup> at 75 Pa (0.02 cfm per ft<sup>2</sup> at 1.57 #/ft<sup>2</sup>) air pressure difference. The United States air leakage rate limit is related to the loss or gain of energy, heating in winter and air conditioning in summer. The Canadian air leakage rate, which is 3 times more stringent than the allowable leakage rate for the United States market, is related primarily to the control of ice buildup on the exterior of curtain wall components, condensation in glazing cavities and to condensation and rain penetration in wall cavities below a glazing system.

## DESIGN FEATURE 2 - VAPOUR DIFFUSION CONTROL

Vapour diffusion through an exterior wall is sometimes the cause of cavity wall wetness or condensation in winter. However, because a modern curtain wall, whether stick, unitized or structural glazing, has components which are resistant to vapour diffusion (aluminum extrusions, glass, sheet metal panels, gaskets), cavity moisture due to diffusion is not a concern, except for silicone sealants on the inside surface of the IGUs which can be protected with a butyl cap sealant.

## DESIGN FEATURE 3 - RAIN PENETRATION CONTROL

Like any wall system, the curtain wall system must prevent the penetration of rain or melt water to the inside of the building. Being constructed of glass, aluminum, steel, fibrous insulation and sealants, the components have no ability to absorb and release even the most incidental amounts of water penetration. While some types of insulation can absorb moisture, very little moisture enters the backpan area. Also, because most of the materials comprising the curtain wall are corrosion resistant, water does not damage the system materials, except the seals of the IGUs if they remain wetted for long periods of time.

To enhance the rain penetration control of a glass and aluminum curtain wall system, the rainscreen principle is applied. The rainscreen principle incorporates various features to control:

- direct entry of rain or melt water,
- capillary action,
- surface and cavity drainage,
- pressure equalization of the glazing cavities.

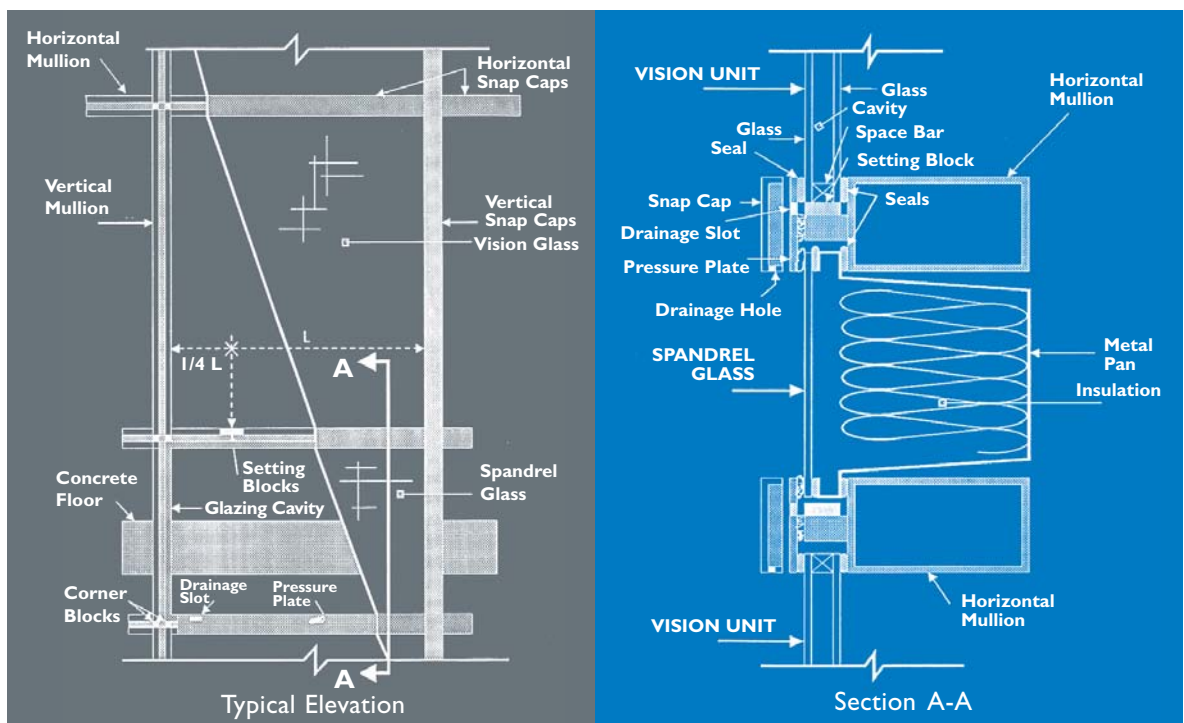
In a stick built system, resistance to the direct entry of rain and melt water penetration is provided by the outside seal or gasket at the glass-to-cap joints. However, should a minor amount of rain or melt water penetrate through the head, jamb or sill gasket or seal of the vision glass, it is channeled sideways and downwards via the jamb cavity to the sill glazing cavity below. The rainwater is then diverted horizontally by the corner blocks (see Figure 9, page 9) to the drain holes in the pressure plates and into the curtain wall snap caps to drain to the outside.



When a sealed glazing unit is installed into a curtain wall frame opening, it is usually placed on two setting blocks (EPDM, silicone or neoprene) placed at the quarter span locations. As these support blocks for the IGUs may impede the drainage of rain or melt water, manufacturers punch a third drain hole in the centre of the pressure plate to drain incidental moisture that may have entered the glazing cavity along the sill between the setting blocks. It is important that the drain holes in the pressure plates be no higher than the bottom of the drainage cavity and that they be unobstructed by debris or excessive sealant.

To support pressure equalization, the glazing cavity must be air sealed on the inside. Air sealing is provided by a gasket or a wet seal between the glass and aluminum surface on the inside. To further enhance the pressure equalization effect, the glazing cavity must also be compartmented. Compartmenting is accomplished by the neck of the vertical and horizontal mullions and the corner blocks. Properly sealed corner blocks preserve the equalization of pressure for each glazing and spandrel cavity.

The spandrel cavity of most curtain wall systems in Canada is also a pressure equalized system. The metal backpans perform the task of the air barrier to contain the wind pressure for pressure equalization. Spandrel cavities are usually vented at the top and bottom to allow for convective drying of the insulation. However, while research<sup>(2)</sup> has shown that the size of the drains and vents in the pressure plates, (6 mm x 30 mm long and 8 mm in diameter) and the holes in the snap caps are adequate for the volume of the glazing cavity, they are inadequate for the dynamic (wind gusts) pressure equalization of the spandrel cavity area. The volume of the spandrel cavity is hundreds of times larger than the glazing cavity, and it is flexible and therefore requires larger vent openings to allow pressure equalization to occur with similar effectiveness. This means that the pressure plate and snap cap drain and vent openings into the spandrel cavity should be larger than the drain and vent openings into the glazing cavity.



**Fig. 9 – Drainage Paths within a Typical Curtain Wall System**  
Courtesy of the Kawneer Company



## PSYCHROMETRIC CHART

### NORMAL TEMPERATURES

SI METRIC UNITS  
Barometric Pressure 101.325 kPa  
SEA LEVEL

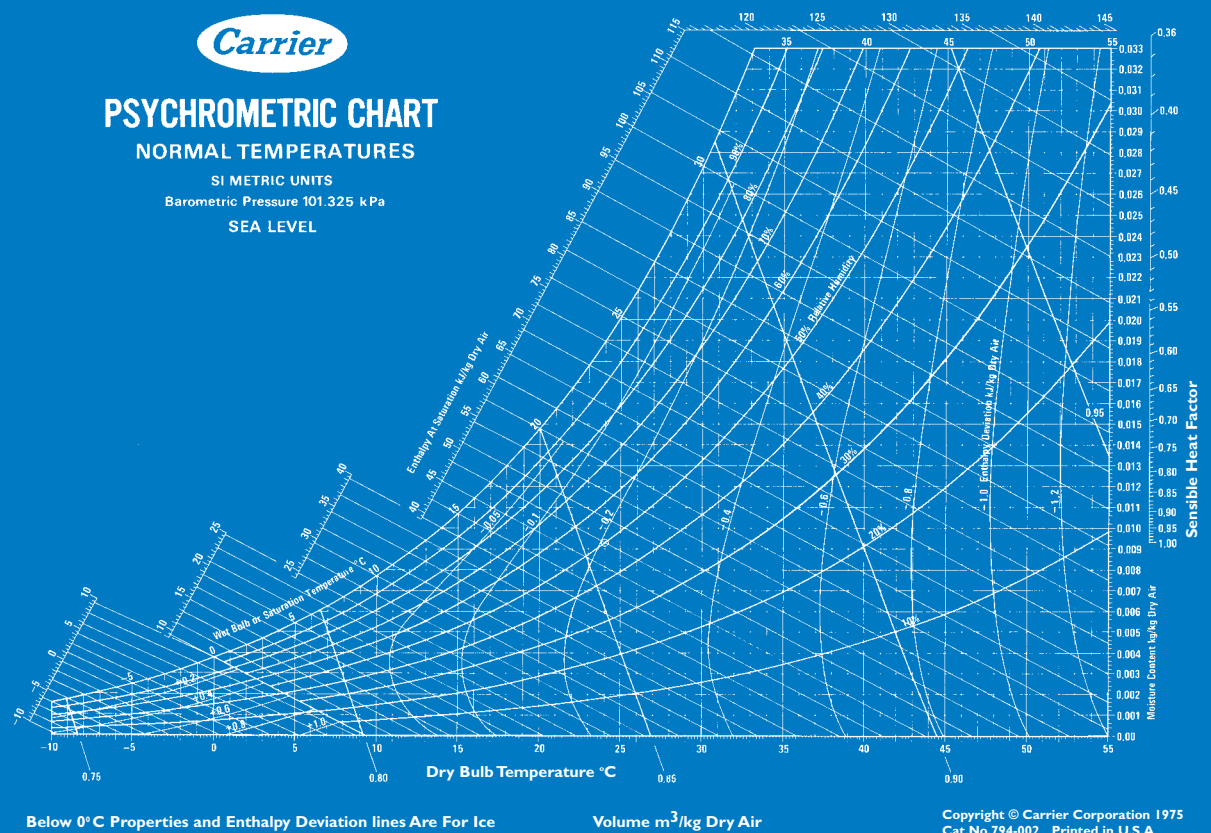


Fig. 10 Psychrometric Chart Courtesy of Carrier Corporation

## DESIGN FEATURE 4 - CONDENSATION CONTROL

The curtain wall is also designed to be resistant to surface condensation. To be resistant however, the aluminum curtain wall must incorporate various features such as quality thermal breaks for the aluminum frames, double or triple glazing for the vision area and an insulated spandrel pan area. Connections and fasteners may also include thermal breaks or thermal separators. The condensation resistance of the aluminum curtain wall in winter is governed by the indoor conditions of temperature and relative humidity and the outdoor temperature. In summer, the condensation resistance of the aluminum curtain wall is governed by the outdoor temperature, the outdoor relative humidity and the indoor air conditioned temperature.

Condensation occurs on the glass or aluminum surfaces when the humidity of the surrounding air comes in contact with a cold surface to change from a vapour to liquid. The temperature at which this change occurs is known as the dewpoint temperature of the surrounding air. To determine the dewpoint temperature of the surrounding air, two conditions must be known or selected (conditions are selected when designing a new project), the (dry bulb or ordinary) temperature and the relative humidity. Using a psychrometric chart (see Fig. 10) the dewpoint (or condensation) temperature of any mass of air at a given temperature and relative humidity may be determined (see ASHRAE Fundamentals).

For example, a new hospital requires an indoor relative humidity of 40% at an indoor temperatures of 23°C during winter. The dewpoint temperature of the indoor air is determined using a psychrometric chart and it is found to be 8.5°C. To prevent condensation from occurring on the glass or aluminum of the curtain wall, the surface temperatures of the glass or aluminum surfaces must not fall below 8.5°C at any outdoor temperature down to winter design temperature (see 1995 National Building Code, Appendix C for winter design temperature of your area).

The next step is to determine the minimum curtain wall indoor surface temperature which will occur for a given outdoor design temperature. For this analysis a new concept is introduced, the temperature index ( $T_{\text{index}}$ ). This is a number, between 0 and 1, which is assigned to a curtain wall or window component based on laboratory measurements or by calculation. This number (or coefficient) indicates the temperature drop which will occur at the surface of a component given a specific outdoor temperature and a specific temperature difference between the inside and the outside. For example, if an IGU in the vision area has a temperature index ( $T_{\text{index}}$ ) of 0.60 and the indoor temperature ( $T_{\text{ind}}$ ) is 23°C and the outdoor design temperature ( $T_{\text{out}}$ ) is -20°C, the temperature at the indoor surface of the glass ( $T_{\text{glass}}$ ) is found by calculation as follows;

$$\begin{aligned} T_{\text{glass}} &= T_{\text{index}} \times (T_{\text{ind}} - T_{\text{out}}) + T_{\text{out}} \\ &= 0.60 \times (23 - (-20)) + (-20) \\ &= 5.8 \text{ }^\circ\text{C} \end{aligned}$$

Therefore the temperature 5.8°C,  $T_{\text{glass}}$ , is below the dewpoint temperature of 8.5°C for the indoor conditions of the hospital and condensation would occur on the glass. To correct this condition, a designer must either prescribe a lower indoor humidity, increase the surface temperature of the glass by means of convection air or radiant energy or select window components with higher temperature indices.

The temperature index is a useful concept. It is used to specify the minimum thermal performance value of an IGU or other curtain wall components. For example, if the indoor design temp ( $T_{\text{ind}}$ ) of the new project is to be 23°C, the dewpoint temperature ( $dt_{\text{ind}}$ ) of the indoor air is to be 8.5°C, and the winter design temperature ( $T_{\text{out}}$ ) is to be -20°C, the **minimum temperature index** ( $T_{\text{index}}$ ) to be specified for the curtain wall, IGU or window should be;

$$\begin{aligned} T_{\text{index}} &= [dt_{\text{ind}} - T_{\text{out}}] / (T_{\text{ind}} - T_{\text{out}}) \\ &= [8.5 - (-20)] / [23 - (-20)] \\ &= \underline{0.66} \end{aligned}$$

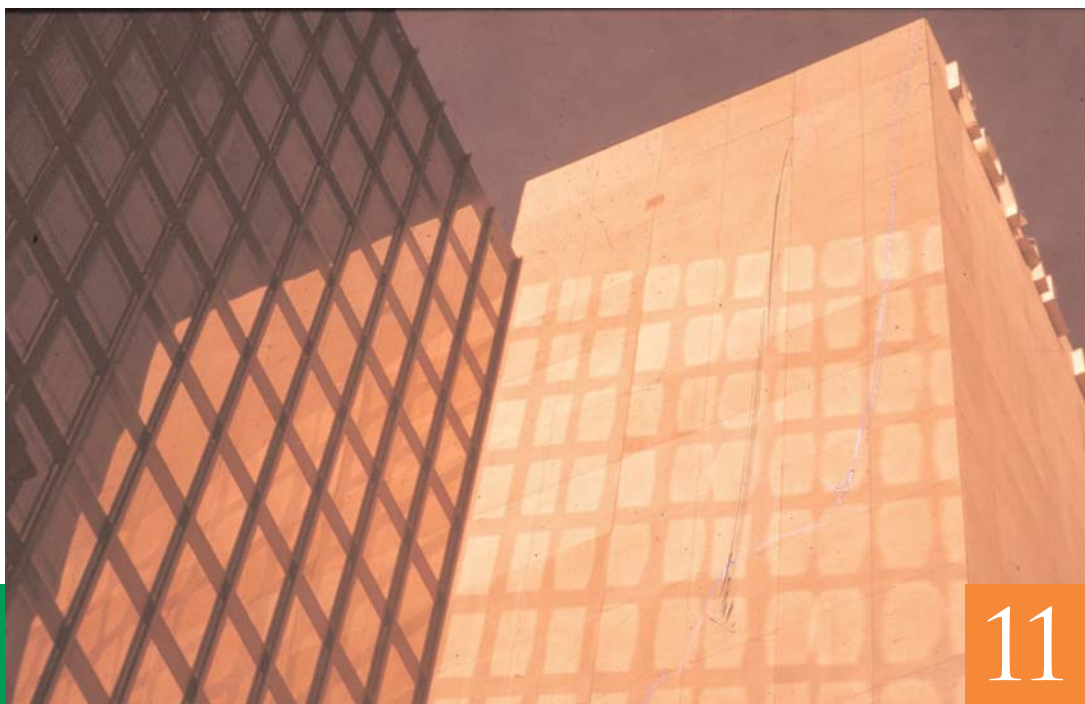


Fig. 11 – Glass Reflections off a Curtain Wall

## GLASS AND GLAZING

Curtain walls often provide the appearance of being all glass. Some are glass with metal spandrel covers and some curtain walls incorporate granite facing panels in the spandrel frames. The glass of vision areas and the glass of spandrels and stone facings are specialty products.

Glass for curtain walls (see Fig. 11, page 11) is available as float, tinted (heat absorbing), wired glass, patterned and cathedral glass. Float glass may be heat treated to become heat strengthened glass or tempered glass to provide greater resistance to thermal and mechanical stresses. For greater safety, laminated glass is also available. Vision glass is usually fabricated from float glass. However, if additional strength or safety is required, then heat strengthened, tempered, laminated or wire glass may be used. Vision glass may be heat absorbing (tinted) or heat reflective (coated). Laminated glass or wire mesh glass are used for impact strength and fire resistance.

Vision glass for a curtain wall may be single, double or triple glazed. In Canada, depending on the severity of wind loads and other factors including solar radiation, cooling and heating requirements, the architect or designer selects either a double or triple glazed IGU. Glazing for curtain wall systems may vary widely with the application. In general, vision glass is clear. It is available in various thicknesses, but is generally between 4 mm and 6 mm thick. It is usually assembled into an IGU to provide heat loss (or heat gain) control and better condensation resistance. To describe glass products, the industry has adopted a standard method of surface identification for single, double and laminated glazing units (see Fig. 12).

A typical IGU consists of two layers of glass with a spacer between the panes. The spacer separates the glass panes to a uniform cavity thickness. The spacer bars may be metal (aluminum) or non-metallic (fiberglass). Fiberglass spacers are used to reduce heat loss at the edge of the IGU or to increase the inside edge glass temperature. They are usually filled with a powder that absorbs humidity (molecular sieve or desiccant) to absorb the residual moisture in the cavity air between the two layers of glass following its fabrication. In general, the powder is placed in all four bars and it lowers the dewpoint temperature of the IGU cavity air to  $-60^{\circ}\text{C}$  or less.

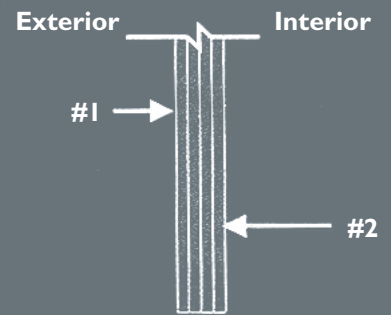


Figure 1  
Monolithic Glass Surfaces

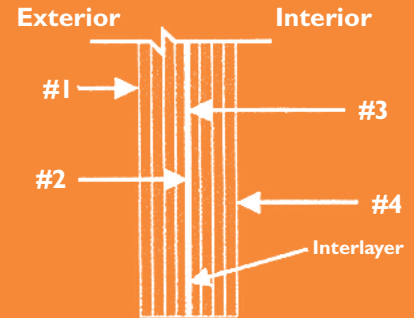


Figure 2  
Laminated Glass Surfaces

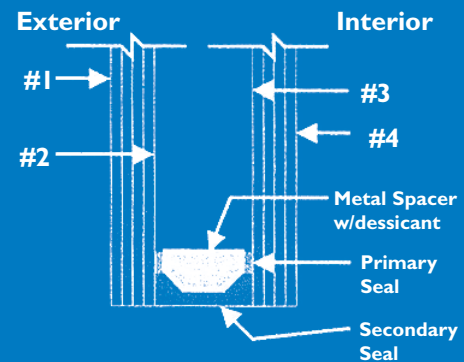


Figure 3  
Insulating Glass Unit Surfaces

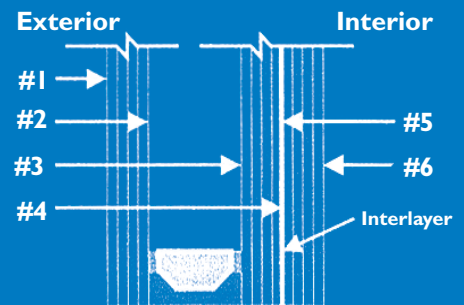


Figure 4  
Laminated Insulating Glass  
Unit Surfaces

Fig. 12 – Insulation Glass Unit  
Surface Numbers

The glass panes are held together with either a single seal of polysulfide, polyurethane or hot-melt butyl or with a dual seal consisting of a primary seal of polyisobutylene (PIB) and a secondary seal of silicone, polysulfide or polyurethane. The primary seal is the vapour barrier seal and the secondary seal holds the glass panes together. The secondary seal may be applied to a depth (glass bite) of 3 mm to 6 mm.

Spandrel glass is often a single layer of heat-strengthened glass with a metallic coating and a polyester opacifying film. The film and coating provide spandrel glass colour and safety in case of breakage. Glass thickness and coatings of monolithic spandrel glass vary with the application. A spandrel area may also be enclosed with an IGU to provide uniform colour matching of the vision and spandrel. While this practice is common in the United States, it is rare in Canada because a spandrel IGU does not provide sufficient thermal resistance in comparison with an insulated metal backpan assembly behind a monolithic layer of spandrel glass.

In Canada, the architect or designer usually specify IGUs for the vision area. The units may be as simple as double glazed clear float glass with a metal spacer and double seal at the edge or one surface of the IGU may be coated with a low E material, it may be gas filled with argon and equipped with a super spacer for increased R value. The type of unit, its purpose and performance requirements should be discussed with your glass supplier.

The installation of an IGU usually requires a clear space of 6 to 10 mm around the perimeter of the glass. The edges must not come in contact with any metal parts and fasteners must not penetrate into the glazing cavity. IGUs are installed on EPDM, silicone, or neoprene setting blocks, 100 mm (minimum) long by 20 mm to 25 mm wide (thickness of IGU) by 6 mm thick. If silicone is used as the secondary seal of an IGU, neoprene setting blocks must not be specified for this application.

Glass usually does not break without a reason. Projectiles, contact with metal at the edge, excessive torquing of pressure plates, high wind load, earthquake load and differential heating are some reasons for breakage. When the outer pane or the inner pane of an IGU breaks, it is sometimes referred to as thermal breakage. Glass breakage of this type occurs when the temperature of the center of the glass rises above the temperature of the edges (sometimes caused by deep shading) by 30°C (55 °F) or more. This can also occur when the sun rises to face a window following a cold night. As the center of the glass warms up faster than the edge, breakage may occur when the temperature difference between the center of the glass and the edge exceed 30°C. Similarly, when the outdoor temperature is cold and the indoor surface of an IGU is heated by convection air the glass-to-edge temperature difference may exceed 30°C. Heat strengthened and tempered glass do not break when subjected to a temperature difference of 30°C.



**Fig. 13 – Failed IGU Fogged with Condensation**

While glass breakage may occur occasionally, the most frequent cause of failure of an IGU is moisture (see Fig. 13, page 13). When the bottom edge of an IGU is immersed in water for an extended period of time, the water attacks the seals and finally allows glazing cavity air to leak into the IGU cavity space, eventually fogging or streaking the surfaces between the glass panes. When this occurs there is no recourse except to replace the IGU. The most frequent causes of excessive wetness are the absence of a drained and vented cavity and/or excessive amounts of sealant in the glazing cavities which block drainage paths to the outside.

## CURTAIN WALL DETAILS AND CONNECTIONS

The aluminum curtain wall system is designed and constructed to meet or exceed the exterior wall performance requirements of most regions in Canada and for general indoor conditions of temperature and humidity. These requirements are partly mandated by the National Building Code of Canada (NBCC) and explained in numerous publications of the Institute for Research in Construction, IRC, (formerly the Division of Building Research) of the National Research Council of Canada (NRCC) and in numerous publications of the Canada Mortgage and Housing Corporation (CMHC) library.

To connect a curtain wall to any other part of the building, the architect/designer must understand these performance requirements, understand the features of curtain walls and understand how to connect like-functions at all connections details. We examine a few typical details to illustrate how this can be accomplished. The details that follow were previously developed and are reproduced here for convenience.<sup>(4)</sup> The details include a grade connection, soffit detail, parapet detail, window sill connection to brick veneer steel stud exterior wall and a sample connection to a rainscreen precast exterior wall.

Consider Figure 14 below. This is a curtain wall connection to the slab-at-grade of a small commercial building. This detail is applicable to stick or unitized curtain walls systems. Note how the air/vapour barrier of the curtain wall is connected from the shoulder of the rail to the top of the slab at grade. Note that the flashing is attached to the cold side of the compression block and that the space in between is insulated to prevent excessive heat loss and a low surface temperature at the slab connection.

A curtain wall connection at a soffit is perhaps one of the most troublesome to design. First, it must be determined whether the soffit is to be heated or unheated. If the soffit is heated then the soffit enclosure must be designed to connect the curtain wall to a soffit closure with a proper air/vapour barrier, insulation and rain penetration control. Figure 15 illustrates one method of providing continuity of the air and vapour barrier, thermal continuity and even rain or melt water

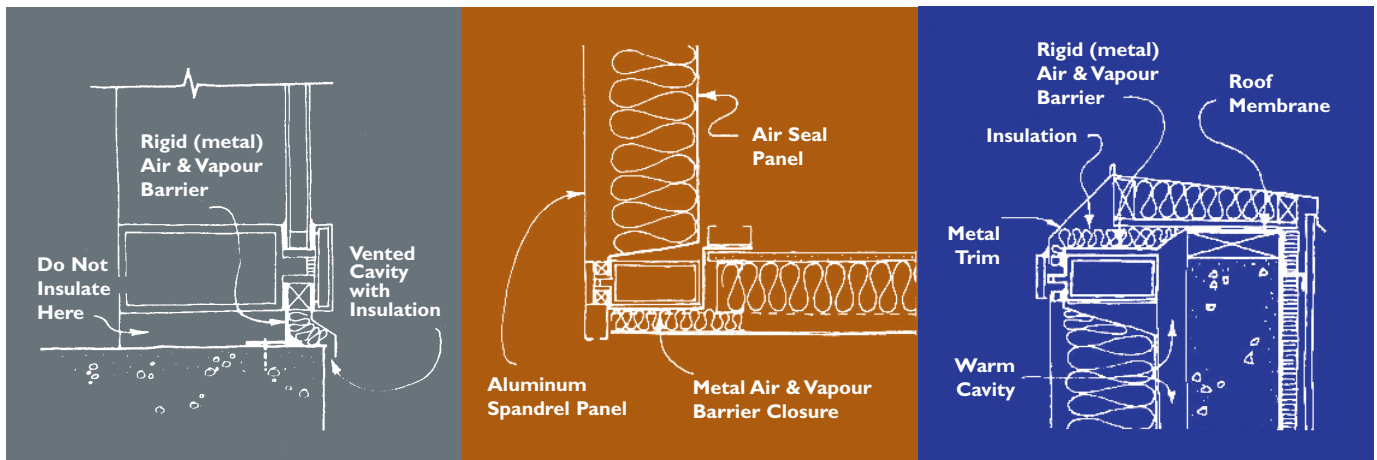


Fig. 14 – Joint Connection at Grade

Fig. 15 – Curtain Wall to Insulated Soffit Joint

Fig. 16 – Curtain Wall Parapet and Roof Connection

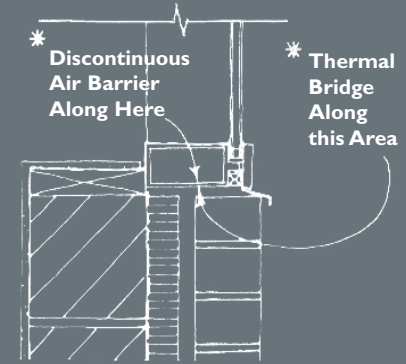
penetration control at the nose of the curtain wall. In the event that the soffit is unheated, it would be prudent to separate the curtain wall system into a heated part and an unheated part. It is designed in this manner so that no vertical mullions extend directly into the cold soffit where infiltration air may enter to cause condensation on the mullion surfaces inside the building.

Figure 16 is a typical curtain wall connection at the roof or parapet of a building. When a curtain wall is designed to extend upwards past the roof line of a building, several potential problems must be considered. Because the vertical mullions are tubes (split tubes in the case of a unitized system) it is important to connect the air barrier of the roof to the glazing cavity of the curtain wall to prevent uncontrolled exfiltration of air through the parapet and to prevent condensation in the parapet area. Further, because the curtain wall mullion, from the thermal break to the inside, should be kept warm, the backside of the curtain wall in the parapet area should be vented to the interior. If these constraints cannot be met practically, consideration should be given to a separation of the curtain wall system at the roof or parapet line. For more information on this area of connection, consult a curtain wall supplier.

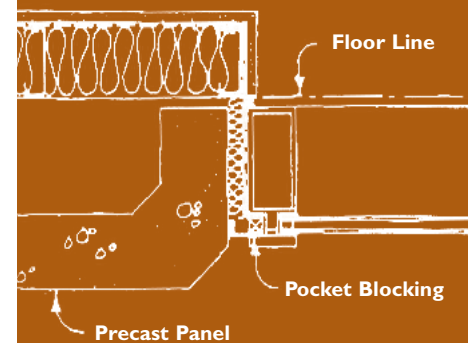
Figure 17 is a curtain wall connection at the sill of a strip window in a brick veneer block backup or steel stud exterior wall. In this example, the placement of the window is made flush with the exterior brick but it does not comply with the requirements of the CSA 440-4 Window standard. The exterior light of the IGU must not extend past the exterior surface of the insulation or the detail must be redesigned to include insulation below the window frame. Note that there is no air barrier connection. This system may experience severe frame condensation. Regardless of the insulation placed below the horizontal mullion, it is necessary to connect an air/vapour barrier on the warm side of the insulation to connect to the air barrier of the exterior wall.

In Figure 18, a curtain wall system is connected to a precast rainscreen exterior wall. In this design, the precast cladding and exterior wall must extend the air/vapour barrier material of the steel stud wall inside the building to the front of the curtain wall glazing cavity. Also, it is best to allow sufficient clearance between the curtain wall jamb and the precast panel for a closure and to accommodate small differential movements. It is noted that the air/vapour barrier of the exterior wall is shown connected to the air/vapour barrier of the curtain wall. The jamb insulation is necessary to warm up the jamb mullion above indoor dewpoint temperature to prevent surface and hidden condensation. The external closure and curtain wall caps provide the necessary rain penetration protection of the joint between the curtain wall and the precast cladding.

The designer must also design the connections of a curtain wall system to the remainder of the building. However, it is recognized that specialized knowledge is required of curtain wall systems to provide correct design detailing to other types of exterior walls. Most curtain wall suppliers provide technical support. Additional information may be obtained from a curtain wall consultant or the curtain wall manufacturer.



**Fig. 17 Curtain Wall Strip Window in Masonry Wall**



**Fig. 18 – Curtain Wall Connection at Precast Cladding**

Courtesy of the National Research Council of Canada

## TESTING CURTAIN WALL SYSTEMS

The performance of aluminum curtain walls is often tested at a laboratory. Testing is undertaken to determine the strength and service deflections, the maximum air leakage rates, the rain penetration resistance under static conditions, the rain penetration under dynamic conditions and the resistance to surface condensation.

To determine the strength and deflection of mullions, rails and glass as well as the failure mode at ultimate load, a curtain wall system may be tested in accordance with a “*Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls and Doors by Uniform Static Pressure Difference*”, an ASTM E-330 procedure. In this method, a sample curtain wall, representative of the materials and spans to be used, is attached to one side of a pressure chamber. Air is then supplied to or extracted from the chamber to exert a pressure difference across the curtain wall system to a prescribed schedule of conditions and exposure times. During the tests, the sample curtain wall is observed (see Fig. 19 below) to record deflections, deformations and the nature of any distress or failure of the sample curtain wall components.

The glass and aluminum curtain wall must not leak air excessively. In the United States, a curtain wall system must not leak more air than 0.3 L/(s.m<sup>2</sup>) at 75 Pa (0.06 cfm/ft<sup>2</sup> at 1.57 lbs/ft<sup>2</sup>). In Canada, due to the consequences of air leakage which include condensation, icicles and energy losses or gains, a curtain wall must not leak more air than 0.1 L/(s.m<sup>2</sup>) at 75 Pa (0.02 cfm/ft<sup>2</sup> at 1.57 lbs/ft<sup>2</sup>). To determine the maximum leakage of air through a curtain wall system, it is tested in accordance with the test method, ASTM E-283, a “*Standard Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen*”. In this method, a sample curtain wall, representative of the materials and spans, is constructed and attached to a pressure chamber and sealed at the perimeter connections. The test wall is then covered with a sheet of polyethylene film and the chamber pressure is depressurized by 75 Pa (1.57 lbs/ft<sup>2</sup>) by an exhaust fan. The leakage of air from the exhaust fan which is also the amount of air leakage into the chamber is then measured and recorded. The polyethylene film is then removed and the test repeated to determine the increase in air leakage. The difference between the two tests is the leakage of air that passed through the curtain wall system. The results are then normalized to a standard reporting format. If the air leakage exceeds the required maximum, repairs may be undertaken and the test repeated.



**Fig. 19 – Glass Failure during Curtain Wall Testing**

Courtesy of Morrison Hershfield Ltd.



The glass and aluminum curtain wall must not leak rain or melt water to the interior of a building. Most glass and aluminum curtain wall designed for use in Canada are of the pressure equalized rainscreen type. To determine the resistance of the curtain wall system to rain or melt water penetration, it is tested in accordance with the test method, ASTM E-331, “*Standard test method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Static Air Pressure Differential*”. In this method, a sample curtain wall, representative of the materials and spans of the installation, is attached to a pressure chamber. Using a rack constructed of spray nozzles, water is sprayed at the curtain wall sample for 15 minutes while an air pressure difference of 137 Pa (2.86 lbs/ft<sup>2</sup>) is applied across the wall. To determine the proper air pressure difference for your geographic location, we refer you to the Can/CSA A440.1 User’s Guide. When the test is stopped, the wall is inspected on the interior for any water leaks.

There are two other rain penetration tests for curtain walls. These include the ASTM E-547, *Standard test method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Differential*. This method is the same as method ASTM E-331 except that the wall will be subject to four cycles of air pressure difference, a cycle being 5 min. on and 1 min. off. It also includes the AAMA 501-4 Dynamic Rain Penetration Test. In this test, an aircraft engine is used to create high wind conditions at the surface of a wall specimen subjected to wetting by spray rack.

In addition to the above and for specific curtain wall projects it may be necessary to determine the indoor surface condensation resistance of the curtain wall system. This test requires that the supplier establish the temperature index (coefficient of performance used to predict indoor surface temperature) of the curtain wall components including the frames and the IGUs. The sample wall is then enclosed on both side with one side maintained at ambient indoor temperature and at a specified relative humidity and the outside surface is exposed to the desired outdoor design temperature. When the condition are attained and stabilized, the inside surface of the curtain wall is examined for condensation, observations noted and or the relative humidity is increased.

Not all curtain wall projects require testing. For small building projects it is rare to specify testing as long as performance data of the curtain wall system is available from the curtain wall manufacturer. In the case of large building projects, testing is often required to verify that all details meet or exceed the performance requirements of the particular design application.

## SOURCES OF INFORMATION

There are various sources of information on curtain wall technology but the most common include AAMA, GANA, and the CSA/CGSB Standards.

AAMA is the American Architectural Manufacturers Association. It is made up of representatives from manufacturing companies from across the US, Canada, Mexico and other countries around the world. They address issue of concerns to member manufacturers but they also set minimum standards of performance and recommended installation, testing and design methods. The AAMA publishes minimum standards with respect to curtain wall performance and quality which can be found in the *Methods of Test for Exterior Walls, AAMA 501-94*. This publication includes laboratory and field test specifications for aluminum curtain walls including performance characteristics, test specimens, methods, recommended practices, test apparatus and testing procedures. It also includes the 501.1. dynamic testing, and 501.2 hose testing procedures.

The AAMA maintains a library of window, door, skylight and curtain wall information in their book store. Numerous titles are available and may be viewed on a web site and purchased from the AAMA corporation. For further information on the AAMA books and articles visit their web site at ;

**[www.aamanet.org](http://www.aamanet.org)** or call or write AAMA at;  
Tel. (847)303-5664; Fax (847) 303-5774  
1827 Walden Office Square, Suite 104  
Schaumburg, Illinois, 60173.

GANA is the Glass Association of North America. It produces an excellent glazing manual which may be obtained by calling GANA, in Topeka Kansas, at (785) 266-7013 or by faxing to (785) 266-0272.

Curtain wall manufacturers such as Kawneer, LBL and glass suppliers such as AFG Glass offer much information and in house expertise which is available to architects and building designers.

## CONCLUSIONS

The glass and aluminum curtain wall system is a marvel of engineering and architecture. A totally non combustible system of glass and aluminum requiring minimal maintenance and providing years of aesthetic quality and building envelope performance. It is the most advanced exterior window wall system available for buildings. Most curtain wall suppliers and glazing companies provide the necessary expertise and production capabilities to construct a quality building. However, no architect/designer should design or prescribe a curtain wall system without a general understanding of the characteristics of glass and aluminum curtain wall technology, in particular the assembly requirements, scheduling and testing of the curtain wall in situ or in a laboratory.

## QUESTIONS

- Question 1** How many types of curtain walls are there and what are they?
- Question 2** What is the purpose of a corner block in a stick built curtain wall system?
- Question 3** What is the purpose of the three slots above the line of screw holes in a horizontal pressure plate?
- Question 4** What is the recommended distance for the positioning of the setting blocks below an IGU of a curtain wall?
- Question 5** What is a dual seal IGU ? What products are used in the fabrication of dual seals?
- Question 6** Which component of the spandrel area in rainscreen curtain wall system is designed to support the wind load?
- Question 7** What is the temperature index of a curtain wall aluminum mullion, if the mullion surface temperature is 12°C, the indoor temperature is 21°C and the outdoor temperature is -25°C?
- Question 8** What is the purpose of a polyester film on the back of a monolithic layer of spandrel glass? Can you identify three functions?
- Question 9** Why is a curtain wall system that is extended into a parapet exposed to indoor conditions of temperature in winter?
- Question 10** What is the maximum leakage rate to specify for a curtain wall system design for a building in Canada? What curtain wall test must be prescribed to determine the leakage rate of air through a new curtain wall system design?

## ANSWERS

- Answer 1** There are three types of curtain walls systems. These are the stick built, the unitized system and the structural glazing system.
- Answer 2** The corner block of a stick built curtain wall ensures the continuity of the glazing cavity between the jamb glazing cavity and the sill glazing cavity. It also diverts drainage water from the head or jamb areas to the sill drainage openings and it provides compartmentalization for pressure equalization of the glazing cavity.
- Answer 3** The three slots in the pressure plate above the screw holes drain rain or melt water intrusion from the sill glazing cavity to the outside. The two outer slots drain the jamb moisture and the center slot drains the center area of the sill.
- Answer 4** Setting blocks must be positioned 1/4 of the length of the rail from each corner. This is for weight distribution and to allow adequate drainage area from the sill glazing cavity.
- Answer 5** A dual seal IGU consists of a primary seal of polyisobutylene (PIB) and a secondary seal of silicone, polysulfide or polyurethane. The primary seal is the vapour barrier seal and the secondary seal holds the glass panes together.
- Answer 6** In a rainscreen curtain wall system, the metal backpan is the air/vapour barrier. For this reason, it is designed to support the wind load which will penetrate through the vent openings in the cap and pressure plates.
- Answer 7** The temperature index of the mullion is calculated as follows;
- $$\begin{aligned} T_{\text{index}} &= [t_{\text{surf}} - T_{\text{out}}] / (T_{\text{ind}} - T_{\text{out}}) \\ &= [12 - (-25)] / [21 - (-25)] \\ &= \underline{0.80} \end{aligned}$$
- Answer 8** The polyester film provides three functions. These include to opacify the spandrel glass to hide the interior construction, to provide color to the spandrel glass and to hold the glass together should it break.
- Answer 9** To prevent condensation from occurring on the backside of a in curtain wall system in a parapet design, sufficient heat must be allowed into the parapet to raise the backside surface temperature above the dew point temperature of the indoor air.
- Answer 10** The maximum leakage rate for a curtain wall system for buildings in Canada is 0.1 L/s.m<sup>2</sup> at 75 Pa. ASTM E-283 is the test method prescribed to determine the maximum air leakage of a glass and aluminum curtain wall system.

## REFERENCES

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4. *Kawneer Product Manual*, An Alcoa Company, the Kawneer Company Canada Ltd., 1051 Ellesmere Road, Scarborough, Ontario, M1P 2X1, Tel. (416) 755-7751.
5. *American Architectural Manufacturers Association*, World Wide Web: [www.aamnet.org](http://www.aamnet.org), 1827 Walden Office Square, Suite 104, Schaumburg, Illinois, 60173.
6. *Aluminum Curtain Wall Design Guide Manual*, (CW-DG-1-96), see AAMA book store at web site on Curtain Walls and storefronts,
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10. *ASTM E-330-90, Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls and Doors by Uniform Static Pressure Difference*, from the Book of ASTM Standards, Vol. 04.07.
11. *ASTM E-331-93, Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference*, from the Book of ASTM Standards, Vol. 04.07.