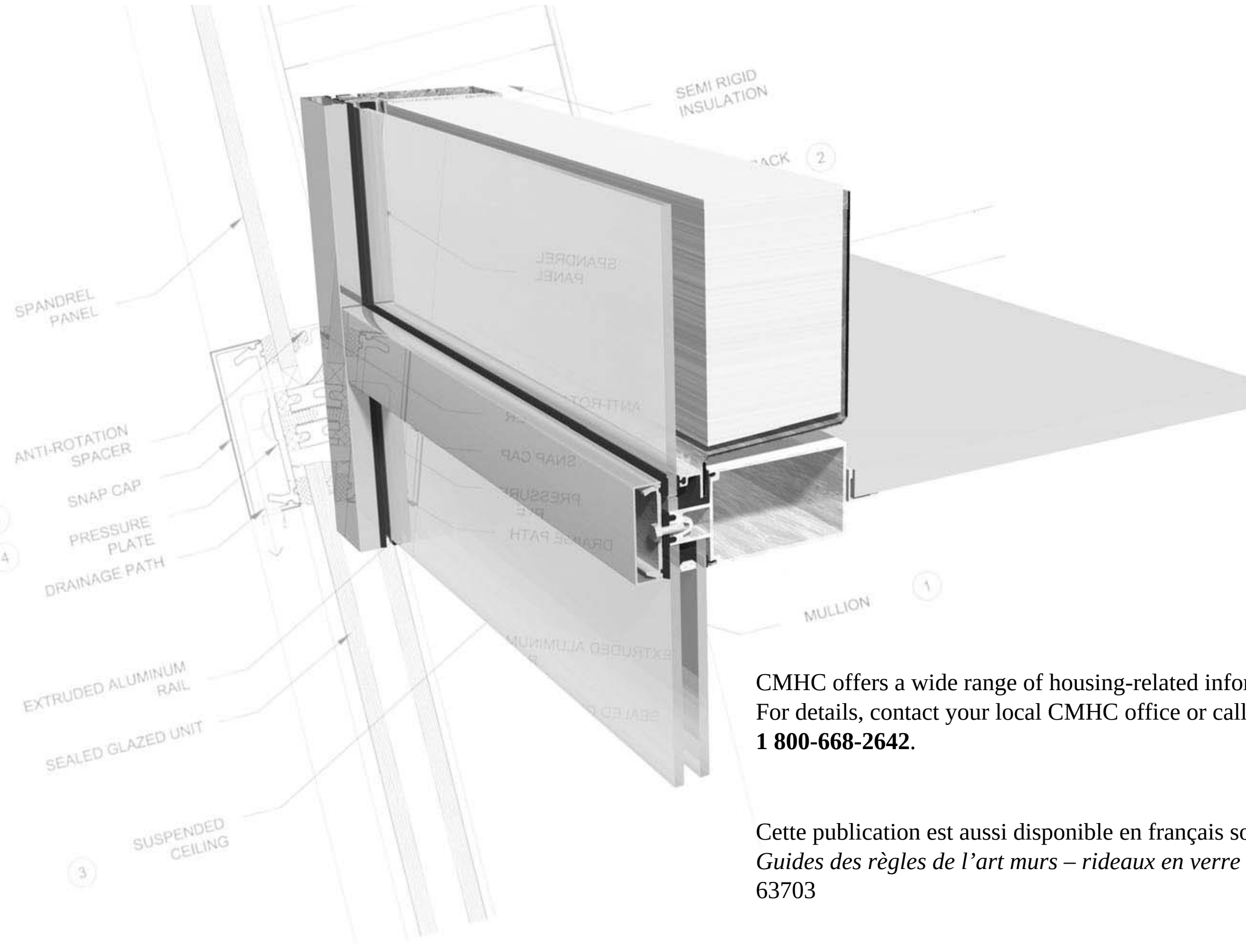
GLASS AND METAL CURTAIN WALLS

BEST PRACTICE GUIDE
BUILDING TECHNOLOGY



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FOREWORD

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INTRODUCTION

This Guide on Glass and Metal Curtain Wall Technology is one of a series of CMHC technical publications that provides practical information on wall system design and performance for building designers, owners and managers.

All wall systems are required to resist many different forces in the provision of a suitable separation of indoor and outdoor environments. They are required to:

- have sufficient structural strength and rigidity
- resist the spread of fire
- be durable
- control odours
- control light
- control sound and vibration
- control heat flow
- control air flow
- control water vapour flow
- control exterior precipitation
- control solar radiation

While each of these requirements is important, history shows that deficiencies in the performance of walls relate to some requirements more frequently than others. Accordingly, these requirements have a greater potential for damage, either physical or financial. The rate of occurrence of defects in certain aspects of wall performance has generated the industry need for reference material such as the Best Practice Guide Series, and has also influenced the topics covered in this *Guide*.

The glass and metal curtain wall, in all its forms ranging from single-storey, storefront applications to towering skyscraper cladding, has become one of the most popular forms of building cladding. Owing to this popularity, the more general term “curtain wall”, while actually defining and encompassing a very broad spectrum of different wall types, has become the everyday reference to glass and metal curtain wall. The two terms will be used interchangeably in this *Guide*.

A modern curtain wall, by its nature, is a highly engineered product based on sophisticated industrial processes and concepts of mass production, standardization, precise tooling and machining. Unlike traditional walls, curtain walls are typically designed, manufactured and installed by one contractor. Much like the modern automobile with “no user serviceable parts”, the curtain wall is often treated as a “black box” and the design professionals actually participate little in the wall design. This lack of detailed design involvement leads to an increased reliance on the curtain wall suppliers for technical expertise and, too often, an inability on the part of the professionals to properly assess the suitability of particular designs proposed by suppliers. This *Guide* is intended to provide assistance to the professional in this regard.

One of the major causes of defects in exterior wall systems is the failure to apply existing knowledge of envelope construction to new buildings and to the repair of existing buildings. The Best Practice Guide Series is intended to encourage state-of-the-art construction by providing detailed descriptions and CAD details of building features that can be adapted and developed by professionals to suit the particular conditions of their buildings.

The *Guide* is organized into nine chapters. Following this introductory chapter, there are eight additional chapters covering various topics, as summarized in the following paragraphs.

A glass and metal curtain wall, in its basic form, consists of a lightweight metal gridwork with some combination of transparent or opaque infill panels. The grid, of either tubular or open shaped pieces can be assembled as individual pieces in the field (stick) or as part of factory preassembled panels (unitized). In either case, the grid is typically attached at discrete points to the floor slab edges, hanging like a curtain down the building. Glass forms one of the most popular infills as vision panels or, when coated, opaque spandrel panels. A wide variety of other materials such as stone, steel, aluminum, composites and plastics are used as curtain wall panels. In Chapters 2 and 3 curtain wall systems and their components are described.

A curtain wall is a unique wall assembly with regards to the number, type and level of performance tests used for its assessment. Regardless of the sophistication of the product or the testing programme, curtain walls must meet the same basic performance criteria as all wall types. The lightweight, thin and non-absorbent nature of glass and metal imposes special constraints on the wall design to meet the basic performance criteria. For example, a metal and glass curtain wall must control water penetration by either a positive seal or by drainage, as it has no ability, like masonry or stone, to absorb and store water for re-evaporation. The modular gridwork layout of a curtain wall creates the potential for pressure-equalized rainscreen performance but this potential is only realized through careful detail design and construction. In Chapter 4 the basic performance aspects of curtain walls are discussed.

As mentioned above, curtain walls are subjected to a greater degree of performance testing than almost any other wall type. The selection of a proper test procedure, the establishment of rational test criteria and knowledgeable interpretation of the test results, are all critical to the usefulness and success of a test programme. In Chapter 5 the test methods used to evaluate wall performance are described.

Chapter 6 contains CAD details to illustrate special features of curtain wall and provide explanatory notes to outline the proper use of the details. An accompanying CD ROM contains AutoCAD files of the details in this chapter.

An adequate quality assurance programme is mandatory to a successful wall installation. Quality assurance impacts not only field installation but all aspects of the wall from design through fabrication, assembly and installation. The repetitive nature of a curtain wall can result in a very small issue being reproduced numerous times throughout a wall area to become a very large problem. A discussion of Quality Assurance along with Quality Control checklists is provided in Chapter 7.

Following the "black box" analogy, performance specifications for curtain wall typically employ a "hands off" approach to curtain wall design. Regrettably, this lack of detail design involvement leads to a reliance on the technical expertise of suppliers with little opportunity for design professionals to properly match a client's needs or specific site requirements to actual wall attributes. A greater understanding of curtain wall detail design can only strengthen curtain wall performance specifications. The CAD details of Chapter 6 are supplemented by an annotated master specification in Chapter 8.

Curtain walls, like all wall systems, do age and require maintenance before eventual renewal. While many of the wall components are inherently durable in most environments, building owners often overlook the large investment they have in renewable components such as sealants and insulating glass and budgets do not allow for timely replacement. Guidance regarding maintenance and renewal can assist design professionals in advising owners. Chapter 9 offers information related to the maintenance and renewal of curtain wall systems.

Finally, a reference section lists other useful publications and web sites along with a glossary of curtain wall terminology.

This Best Practice Guide is intended to be supplemented by the knowledge of the professional engineer or architect and, where prudent, the advice of a specialist consultant. The information contained in the *Guide* is intentionally generic, and must be considered in light of local codes and building practices, with proposed details modified to suit particular conditions. Products shown in this *Guide* are for illustrative purposes only and are not intended to promote any specific product over others available on the market.

Chapter 2

METAL CURTAIN WALL ASSEMBLIES

2.1 BASIC DEFINITIONS

The term “curtain wall” was first used to describe the outer wall of medieval fortifications. Its use in a more contemporary sense is seen in Gothic cathedrals with their large expanses of lightly framed glass walls between load-bearing buttresses. Today the term curtain wall is defined in most literature to be any building wall of any material that is designed to resist lateral loads due to wind or earthquake and its own self weight. In other words, the curtain wall is a non-load-bearing wall.

The American Architectural Manufacturers Association, the most widely referenced industry source with respect to metal curtain walls, provides the following definitions in their Aluminum Curtain Wall Design Guide Manual:

Metal Curtain Wall – An exterior curtain wall which may consist entirely or principally of metal, or may be a combination of metal, glass and other surfacing materials supported by or within a metal framework.

Window Wall – A type of metal curtain wall installed between floors or between floor and roof and typically composed of vertical and horizontal framing members, containing operable sash or ventilators, fixed lights or opaque panels or any combination thereof.

From the above definitions it follows that a metal curtain wall is a particular type of curtain wall and a window wall is a subset of metal curtain wall. For purposes of this document window wall systems, as illustrated in Figure 2-7, are specifically excluded from consideration.

2.2 METAL CURTAIN WALL

A metal curtain wall can be classified in several different ways. One of the common means of identifying different walls is to classify them by type, erection system and glazing method. For example a wall can be described as a custom, unitized, two-sided, structurally glazed system. The following illustrates the categories for classification of a curtain wall in this manner.

WALL TYPE →	ERECTION →	GLAZING METHOD
STANDARD CUSTOM	STICK UNITIZED OTHER	EXTERIOR BATTEN STOP STRUCTURAL SILICONE GLAZING (SSG) OTHER

2.3 ESSENTIAL TERMINOLOGY

To properly understand the specific features of a wall design that permit the classification of the wall, it is first essential to understand some basic terminology used in describing components and features of a wall. The following provides essential terminology in the nomenclature of curtain wall components.

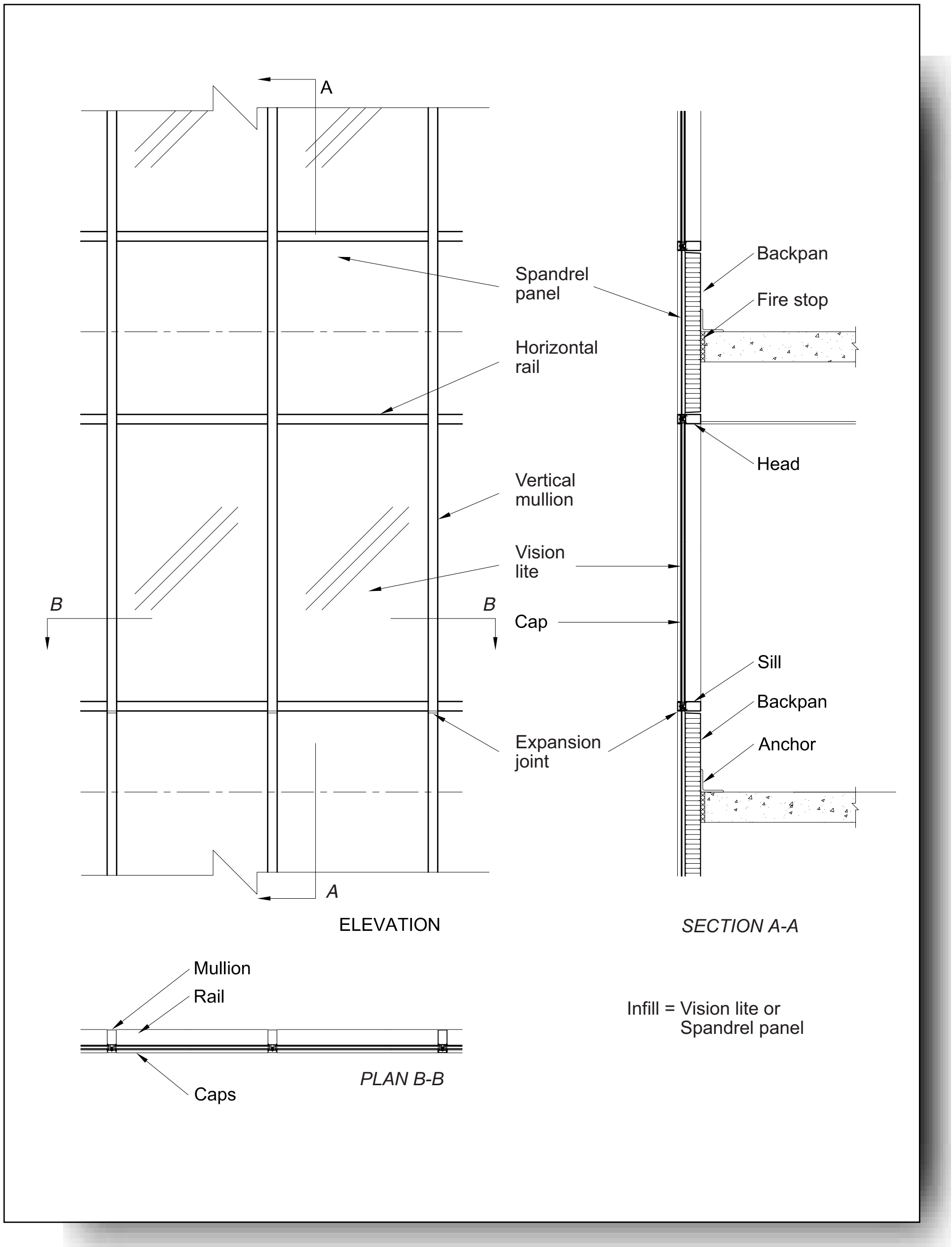


Figure 2.1: *Essential terminology*

The following sections describe the alternatives for classification of a wall within each category.

2.3.1 WALL TYPES

This category for wall classification includes two generic options. A comparison between these two wall types is provided below.

WALL TYPE	CHARACTERISTICS AND FEATURES
STANDARD	• Details and components designed and standardized by manufacturer • Manufacturers sell through a dealer network • Manufacturers stock in standard lengths typically 6.5 to 8.2 m (20 to 27 ft.) in length • Standard finishes although custom finishes available • Typical frame width 50 mm (2 inches) or 63.5 mm (2 ½ inches) , frame depth 75 to 150 mm (3 to 6 inches) • Manufacturers catalogue information readily available • “Standard” designation applies only to components not to potential arrangement of components
CUSTOM	• Details and components designed specifically for a single project or group of projects • Materials generally not available on open market but restricted to single supplier or installer • Minimum size of project required to justify custom extrusions • Allows optimum use of material and flexibility to meet architectural requirements • Component dimensions and cross sections often architecturally distinct

2.3.2 ERECTION

This category for wall classification includes the two most common erection techniques, as well as a third grouping used to mention others that may be encountered on older buildings but are no longer common, nor promoted, for new construction.

ERECTION	CHARACTERISTICS AND FEATURES
STICK	• Likely most common wall system especially on low-rise construction and in smaller population centres • Each component of wall is installed piece by piece in the field. Installed with one- or two-storey mullion lengths and horizontal rails equal in length to width of the infill panels • Field labour intensive and dependent • Often utilize standard system • Minimum requirements for assembly facilities and shipping • Normally short lead time to arrive on-site, but longer erection/close-in time on-site • Difficult to accommodate in-plane movements due to sway or seismic events
UNITIZED	• Most common to large high-rise buildings although found on buildings as low as four stories. System has grown in popularity since 1980 • Large factory assembled framed units complete with spandrel panels and often with vision lites installed. Panels typically one-storey high by width of infill panels • Panels designed for sequential installation with interlocking split vertical mullions and nesting horizontal rails at expansion joint • Significant fabrication facility and shipping requirement. More shop labour dependant and less field dependant than stick system • Normally longer lead time to arrive on-site, but rapid erection with minimum time to close in building once on-site • Design potential to accommodate in-plane movements due to sway and seismic events

OTHER	**Mullion and panel** • Consists of gridwork similar to stick system and prefabricated framed panels installed between. Popular through the 1970s but rarely used today • Combines features of stick and unitized wall systems **Large panel** • Typically consists of steel truss type frame one storey in height by 10 to 15 m (33 to 50 feet) in length. Frame supports all of wall elements • Not as popular due to handling issues. Used on smaller specialized projects **Window wall** • Consists of wall system spanning between floor slabs with slab edge cover. Almost entirely restricted to residential applications • Framing lightweight residential type inside stop glazed. Can utilize either stick or unitized framing. Often use older technology with inherent reliability problems

The following sections illustrate the general erection techniques for the above assemblies of curtain wall. However, the remainder of this *Guide* will focus only on stick and unitized systems which represent the vast majority of curtain wall designs today.

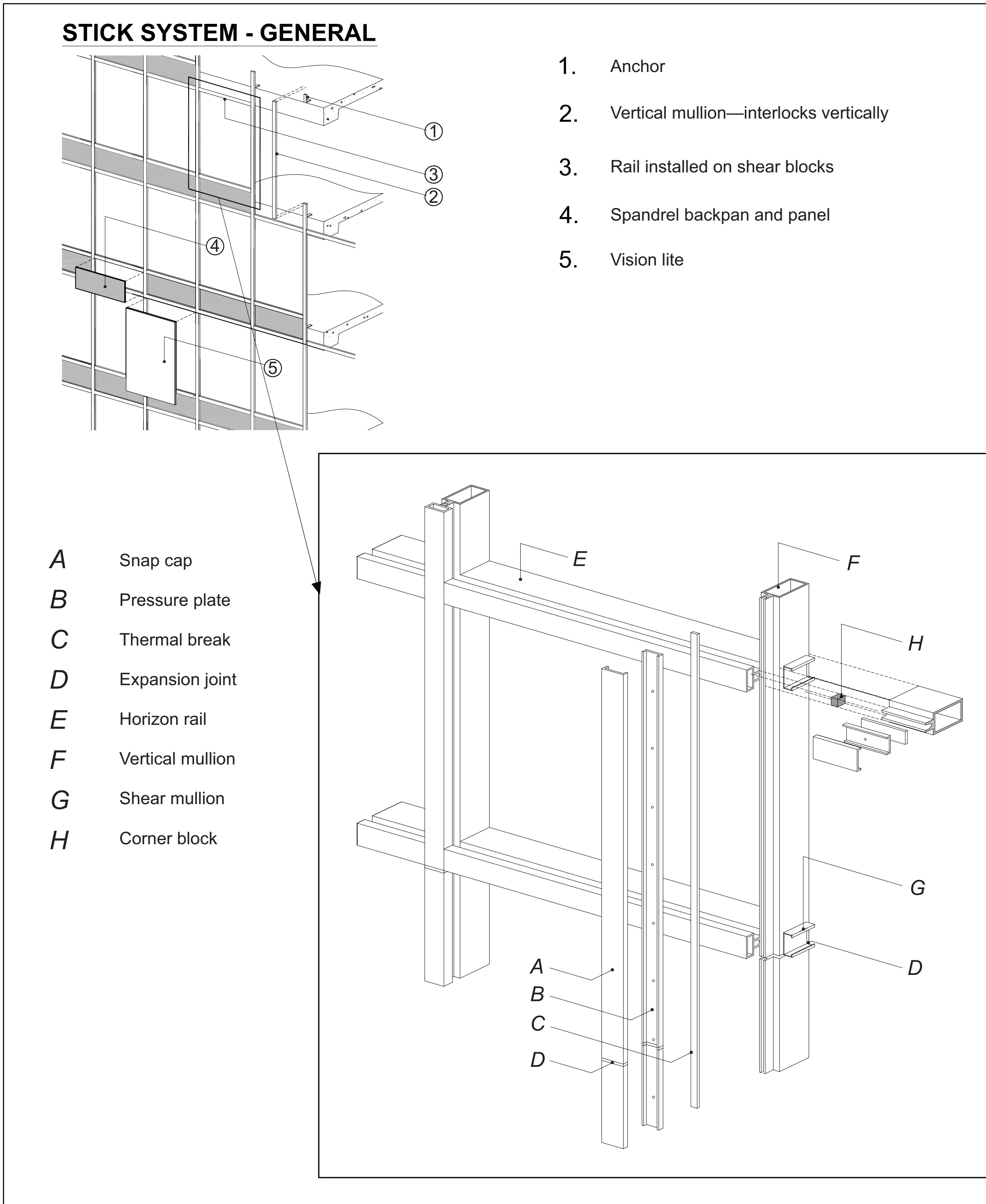
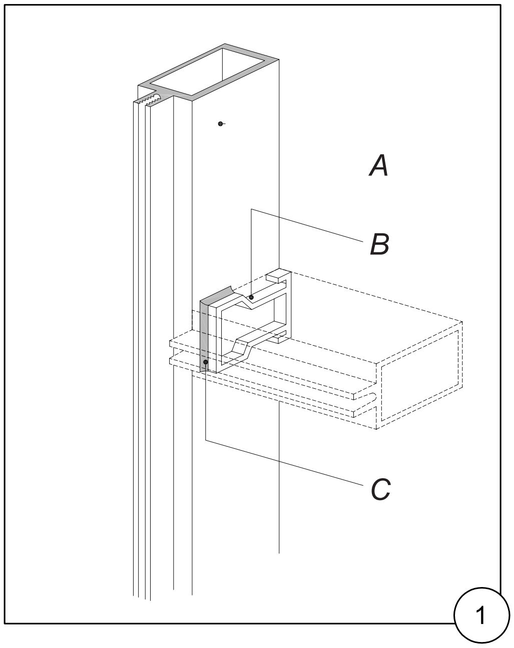
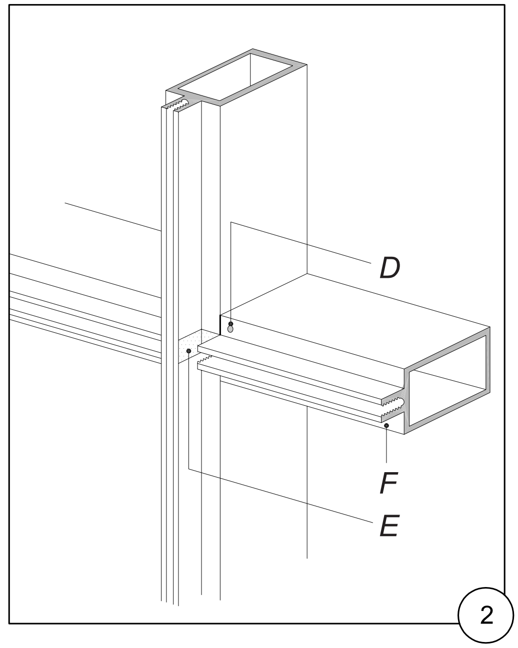


Figure 2.2: *Stick system - general*

STICK SYSTEM - JOINERY





Typical horizontal / vertical connection

- *A* Vertical mullion
- *B* Shear block or spigot (several different designs available)
- *C* Joinery sealant or tape
- *D* Fixing screw
- *E* Bedding sealant for corner block
- *F* Horizontal rail
- *G* Corner block (typically neoprene rubber)
- * Outer surface of corner block extends to the same plane as top of thermal break.

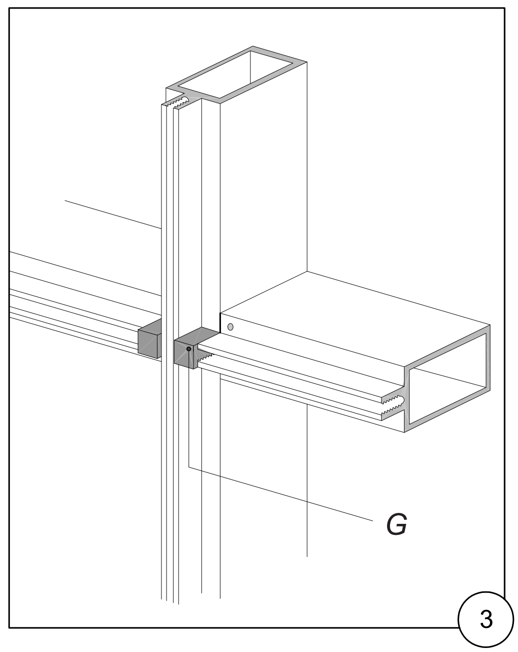
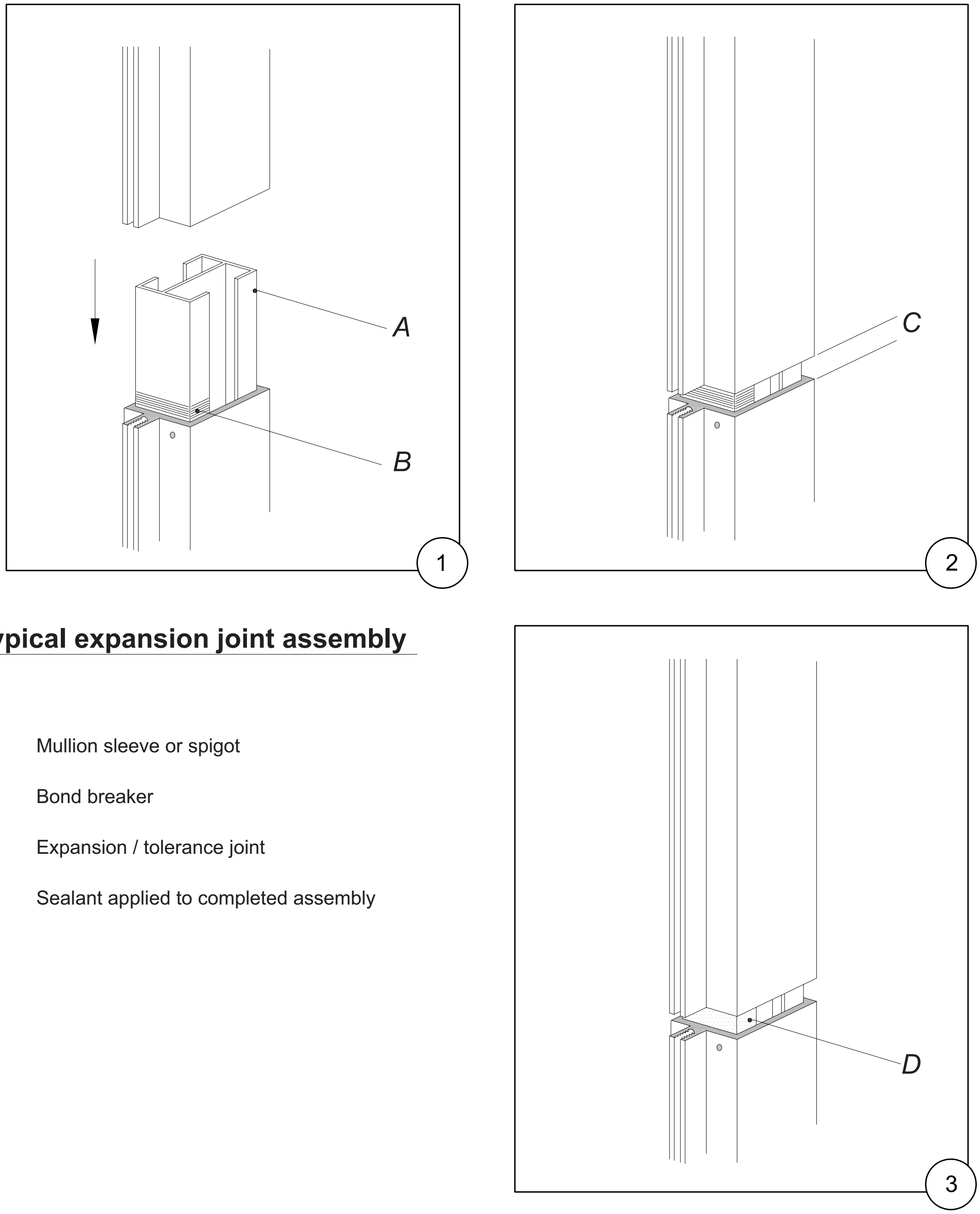


Figure 2.3: *Stick system — joinery — typical horizontal/vertical connection*

STICK SYSTEM - JOINERY

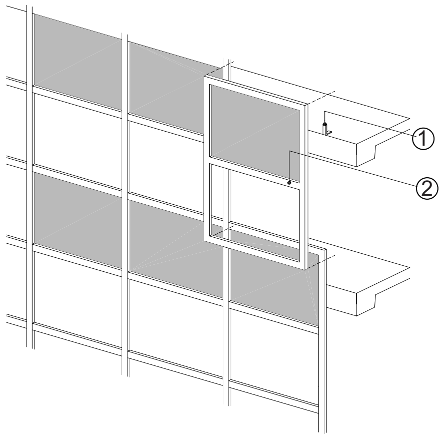


Typical expansion joint assembly

- A Mullion sleeve or spigot
- B Bond breaker
- C Expansion / tolerance joint
- D Sealant applied to completed assembly

Figure 2.4: *Stick system — joinery — typical expansion joint assembly*

UNITIZED SYSTEM - GENERAL



1. Anchor
2. Prefabricated, pre-glazed frame

A Snap cap

B Pressure plate
(May be in two pieces)

C Thermal break

D Expansion joint

E Horizontal rail

F Split mullion

G Mullion sleeve*

* Connection at expansion or stack joint varies widely with different designers

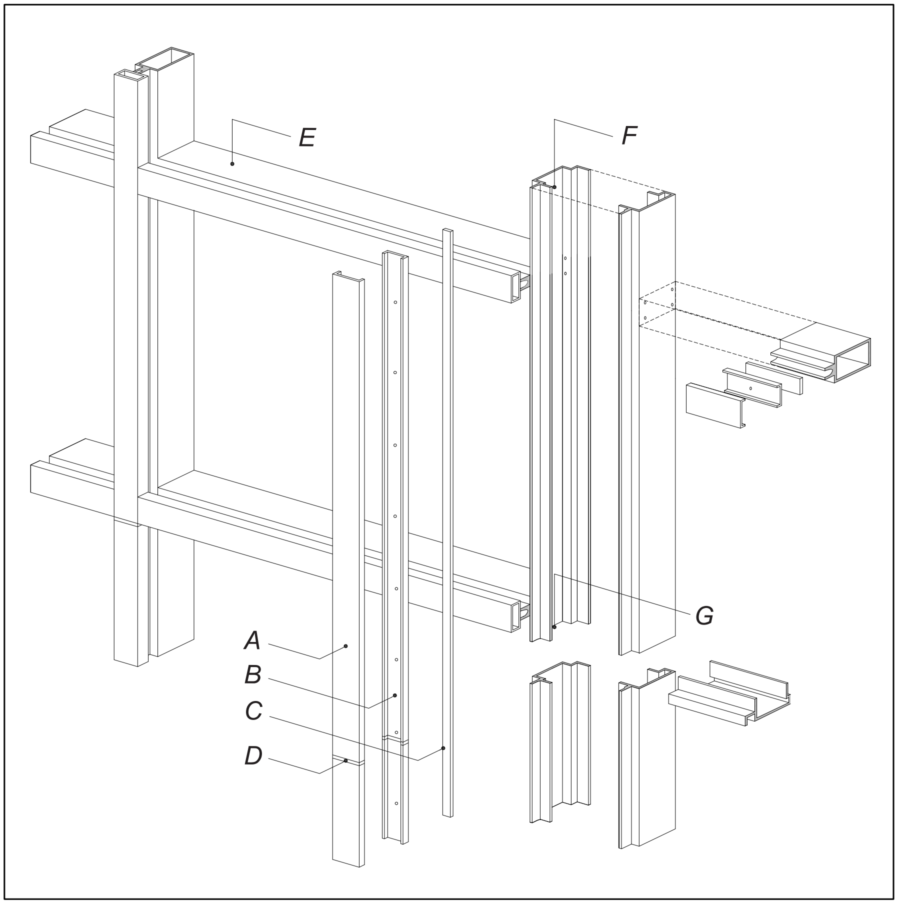
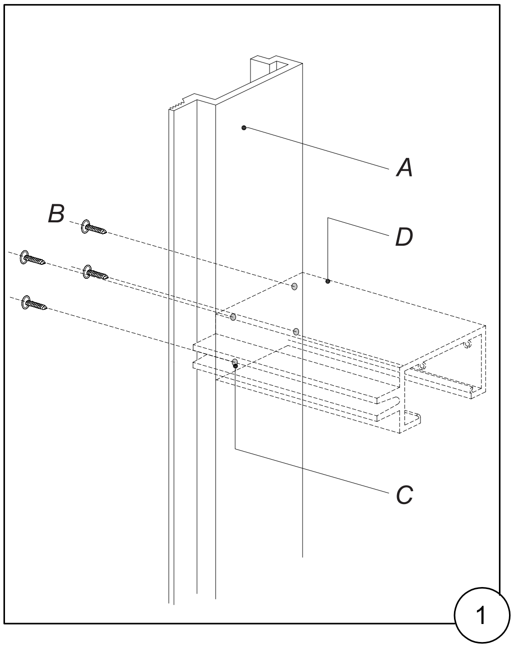
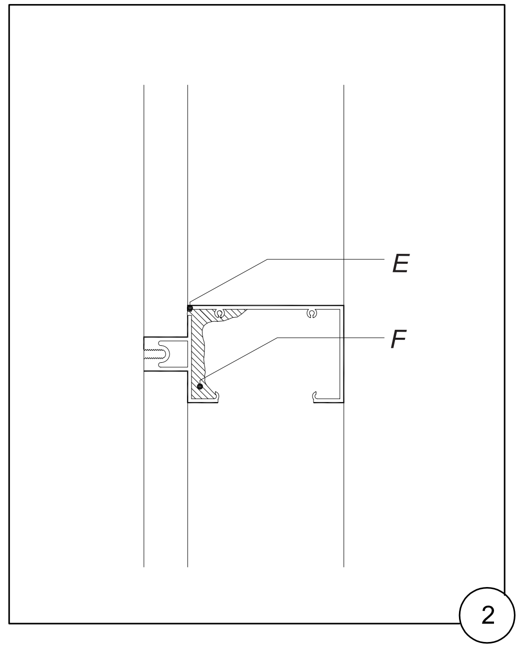


Figure 2.5: *Unitized system — general*

UNITIZED SYSTEM JOINERY





A Split mullion

B Rail fixing

C Predrilled holes

D Horizontal rail, often open section, incorporating screw lots

E Sealant continuity hole

F Sealant applied inside horizontal*

* Closed section horizontals may use butyl tape seals

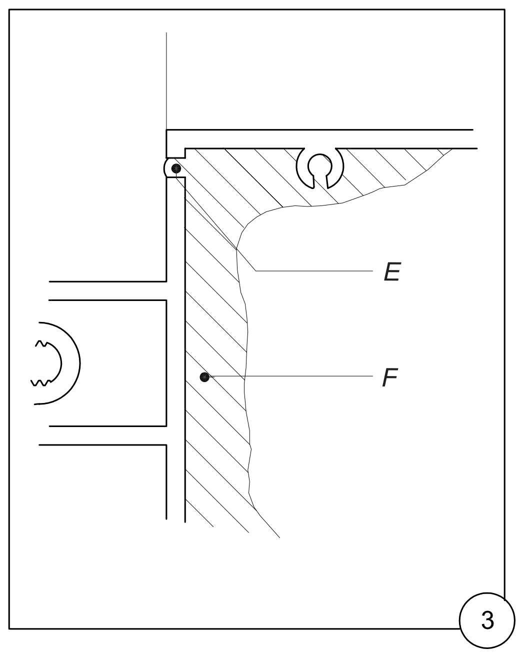
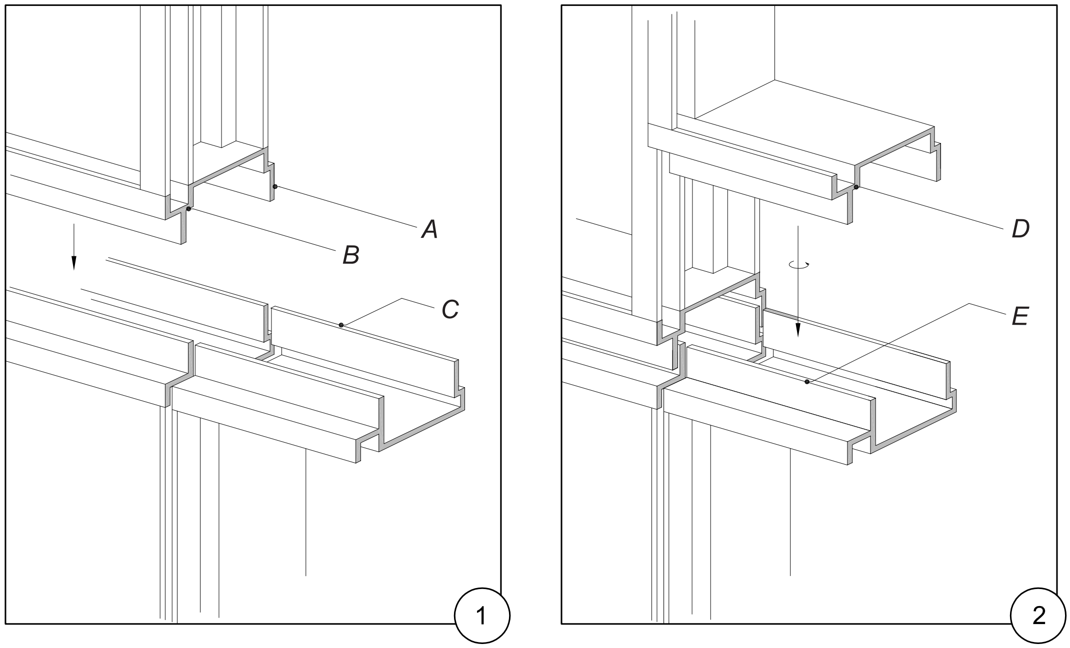


Figure 2.6: *Unitized system — joinery — typical expansion joint assembly*

UNITIZED SYSTEM - GENERAL



Four-way stack joint concept

A	Frame lowered into position onto installed frames
B	Mullion interlock
C	Interlocking rail
D	Mullion interlock is engaged—frame is rotated and lowered into position
E	Airseal gasket

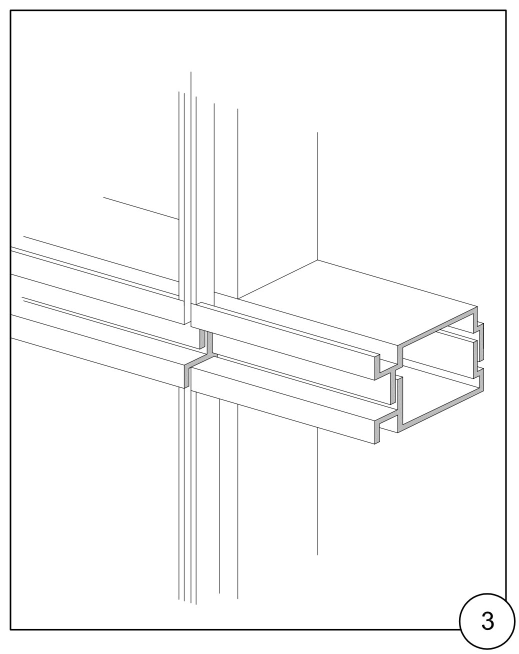


Figure 2.7: *Unitized system — general — four-way stack joint concept*

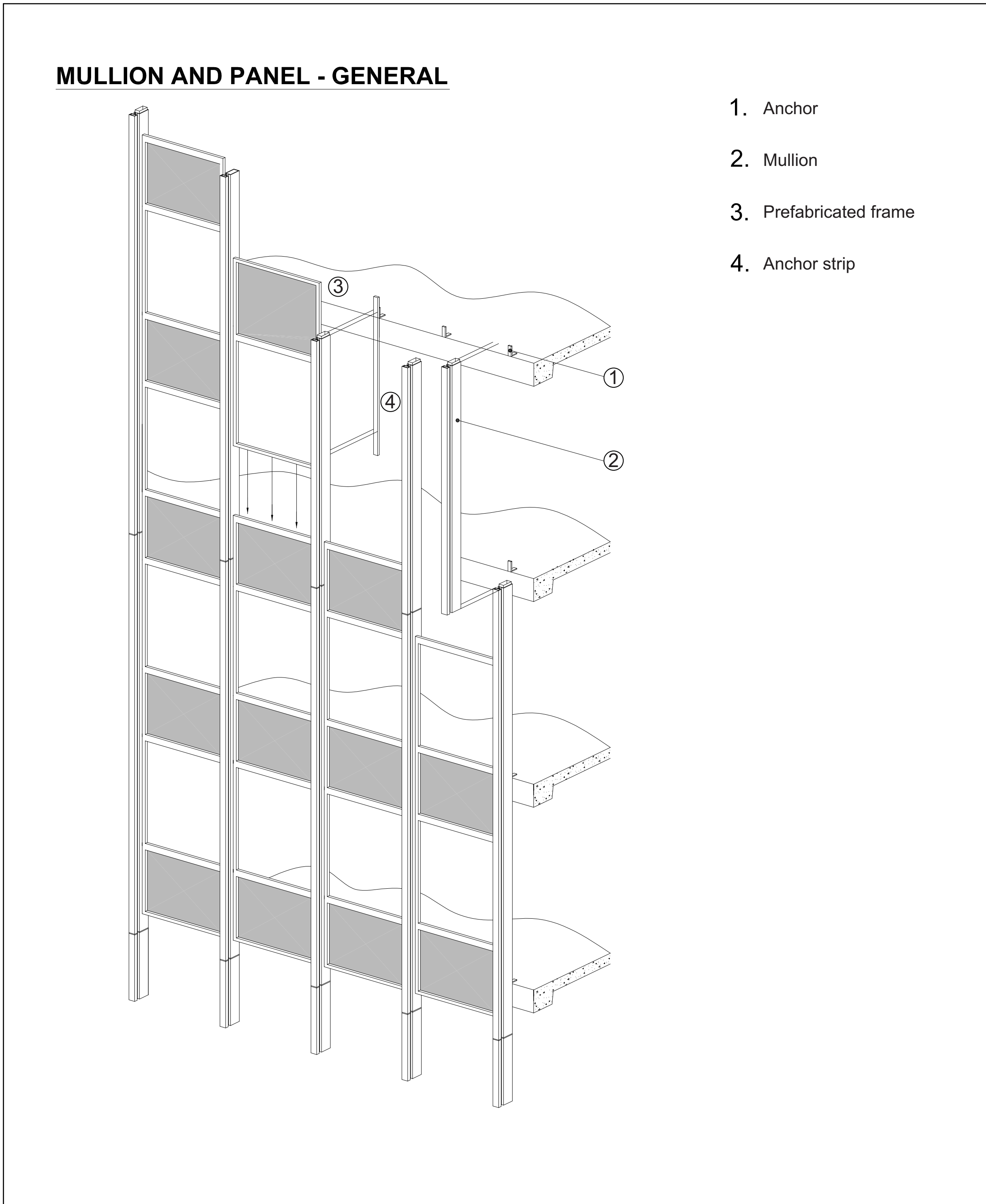


Figure 2.8: Mullion and panel — general

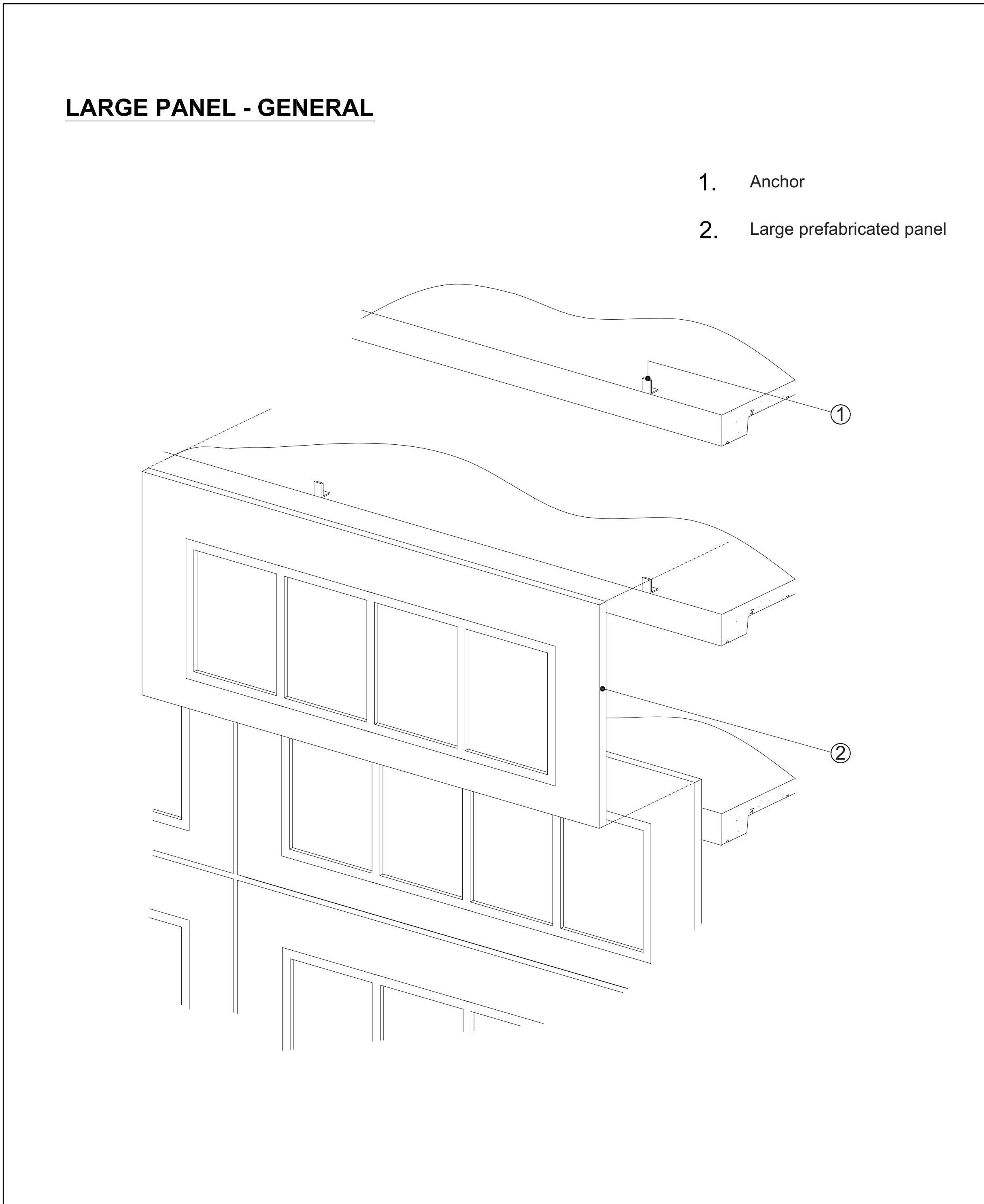


Figure 2.9: *Large panel — general*

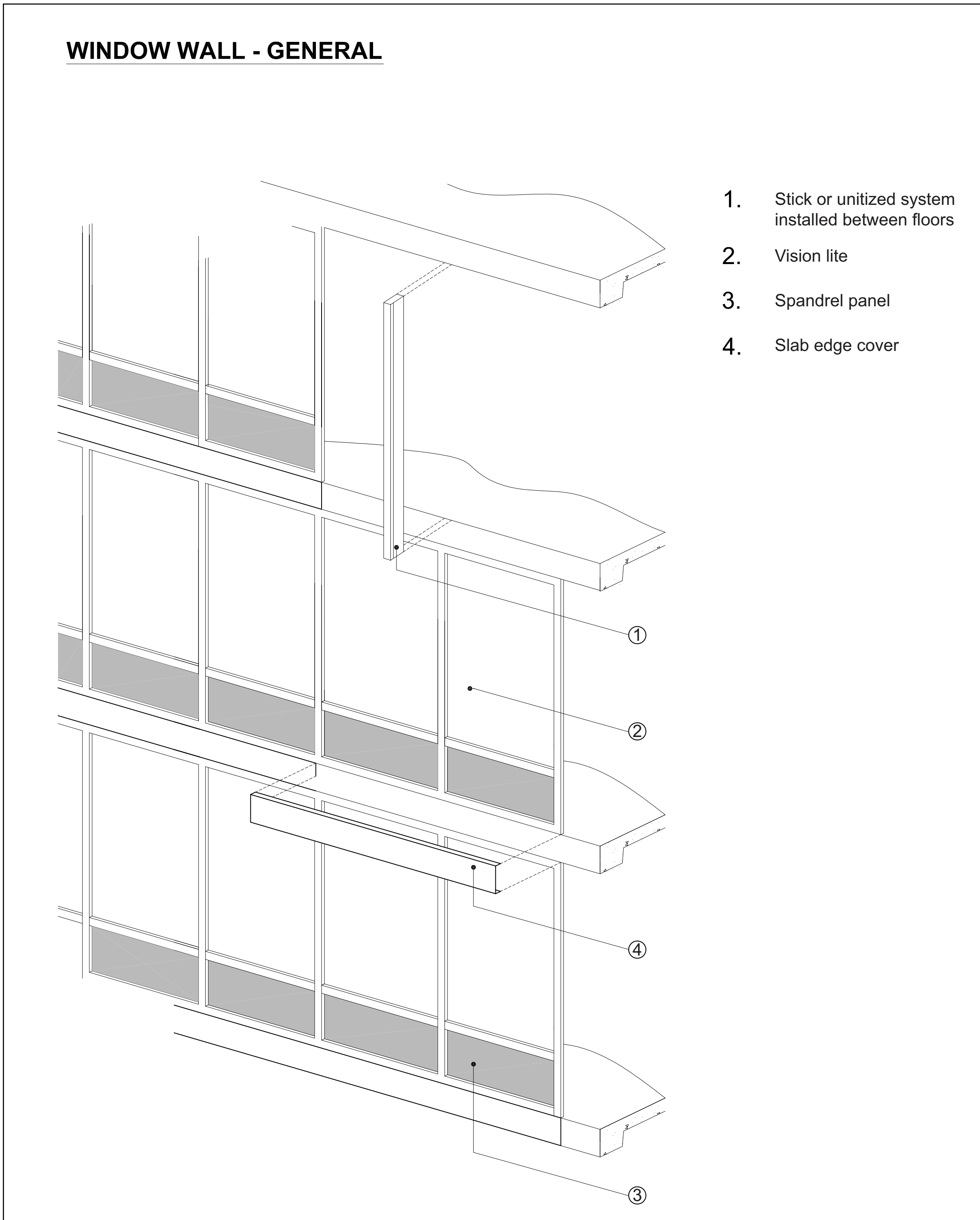
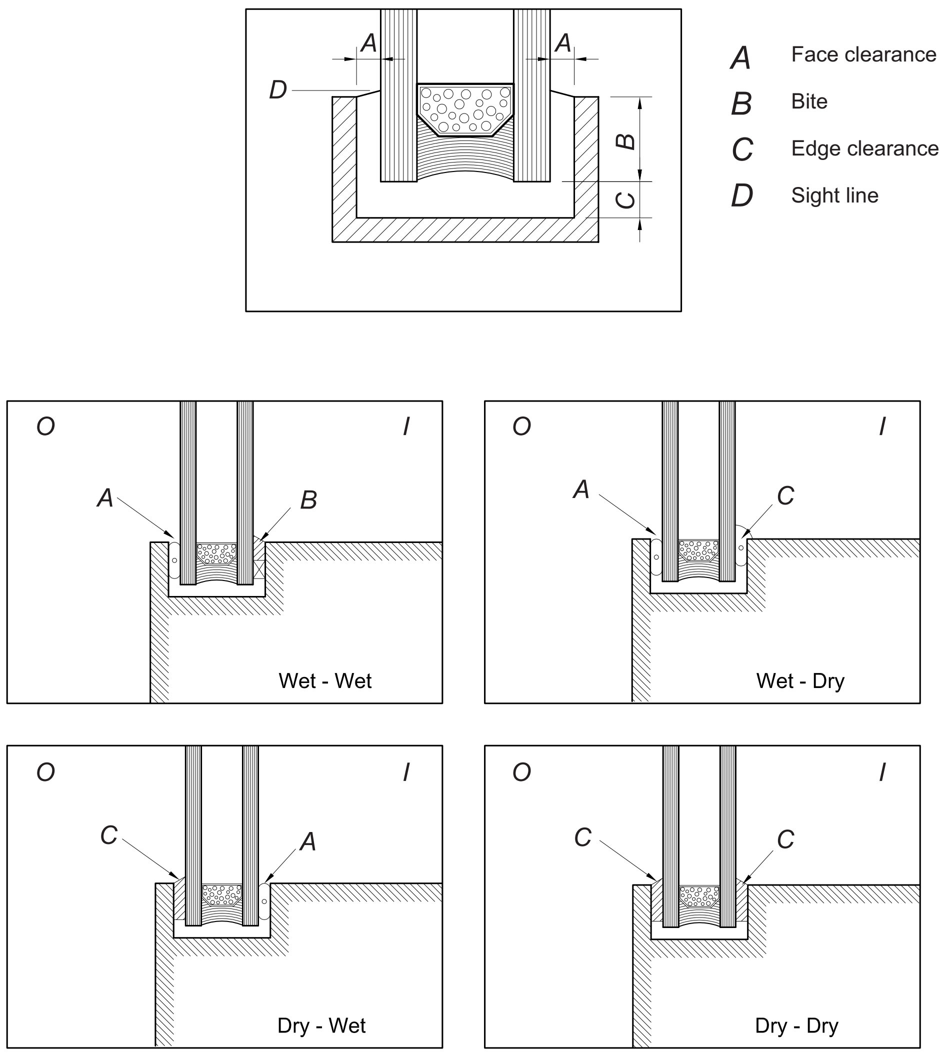


Figure 2.10: *Window wall — general*

The classification of a wall within the Glazing Method category is based on specific details of how infill panels are attached within the openings of a framing grid. Before discussing the various methods of glazing (attaching an infill panel) it is important to review the terminology that will be used to distinguish between components used in the different glazing methods.

GLAZING METHOD - ESSENTIAL TERMINOLOGY



SEAL COMBINATIONS

A - Shimmed glazing tape
B - Gunnable sealant on spacer
C - Rubber gaskets

O - Outside
I - Inside

Figure 2.11: *Glazing method — essential terminology*

2.3.3 GLAZING METHOD

This category for wall classification includes the three most common methods, as well as a fourth grouping used to mention other methods that may be encountered on older buildings but are no longer common, nor promoted, for new construction.

GLAZING METHOD	CHARACTERISTICS AND FEATURES
EXTERIOR BATTEN	• Most commonly used form of glazing method relies on exterior metal batten to hold infill panel against framing member • Batten or pressure plate fixed to framing with cap screws that apply pressure to gaskets or tapes at edge of infill to create seal. Used with either tubular or split mullion • Glass installed from exterior • Exterior gasket is mainly a water intrusion barrier. It is not waterproof • Interior seal (gasket/tape) provides air barrier continuity between frame and sealed unit/backpan • Other gaskets between antirotation spacers provide separation and movement capability

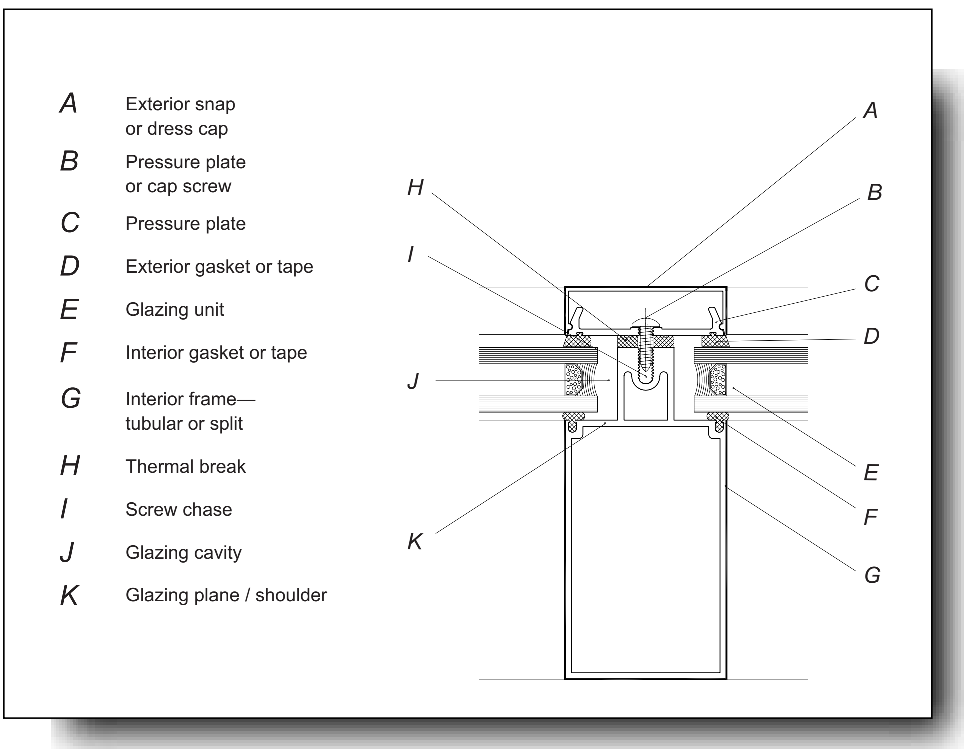


Figure 2.12: *Glazing method — exterior batten*

GLAZING METHOD	CHARACTERISTICS AND FEATURES
STOP	• Interior or exterior removable glazing stop or bead used to force edge of infill against fixed stop. Most common is interior stop • Seal is created with tapes or gaskets compressed by stop. Common method used in window wall assemblies, at operable sash and in some contemporary systems • Glass installed from side of removable stop

A Optional snap cap
B Glazing tape
C Thermal break
D Glazing unit
E "Wedge in" rubber gasket
F Interior removeable stop
G Heel bead or gasket air seal
H Fixed exterior stop

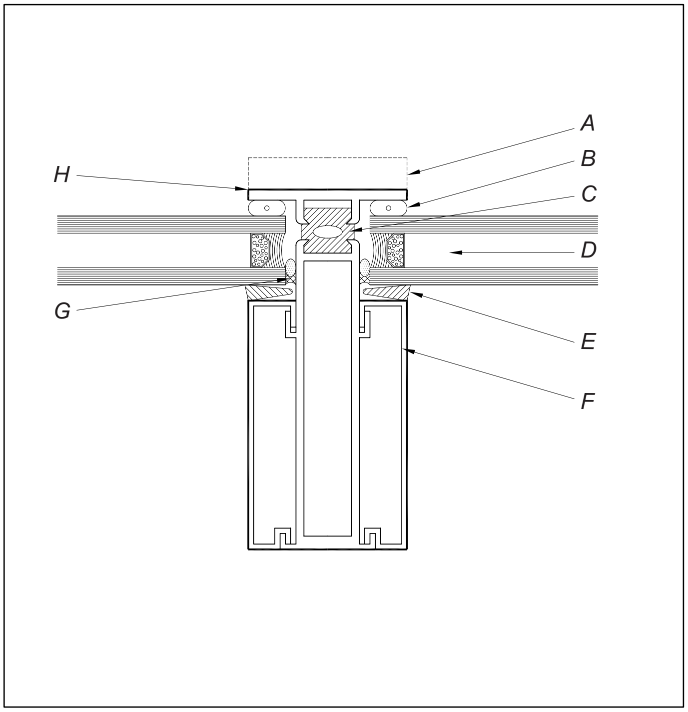


Figure 2.13: *Glazing method — stop*

GLAZING METHOD	CHARACTERISTICS AND FEATURES
STRUCTURAL SILICONE (SSG)	**2-Sided Structural Silicone (2SSG)** • Two edges of infill are adhered to framing with structural silicone sealant and two edges are mechanically fixed usually with pressure plates. Can be field installed **4-Sided Structural Silicone (4SSG)** • Four edges of infill are adhered to framing with structural silicone sealant. Must be shop installed (for quality control) • Dead load of infill is supported on metal fin and setting block

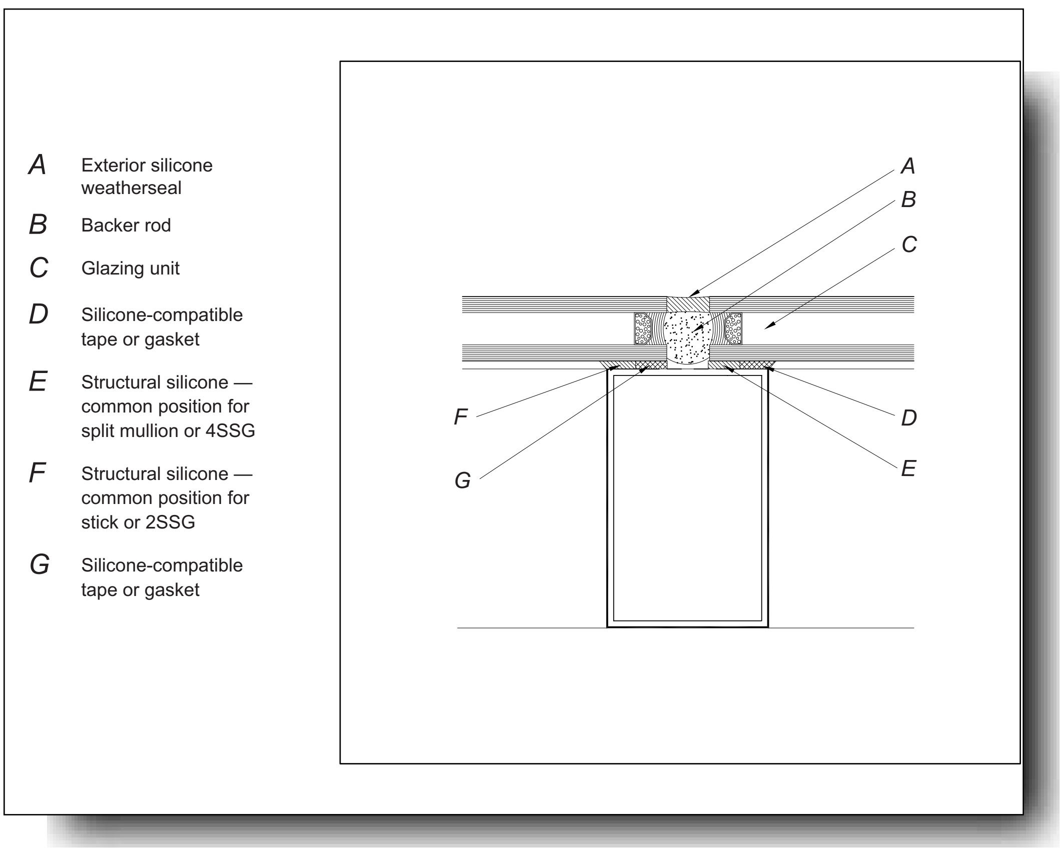


Figure 2.14: *Glazing method — structural silicone (SSG)*

GLAZING METHOD	CHARACTERISTICS AND FEATURES
OTHER	**Channel glazing** • Channel or pocket glazing is modeled off of window sash assembly • Infill panel is maneuvered into oversized channel and fixed in position with wedge in type gaskets • Often used to accommodate unique geometry at building corners and/or to "hide" framing system from exterior at adjacent construction (e.g. framing behind stone sill or jamb)

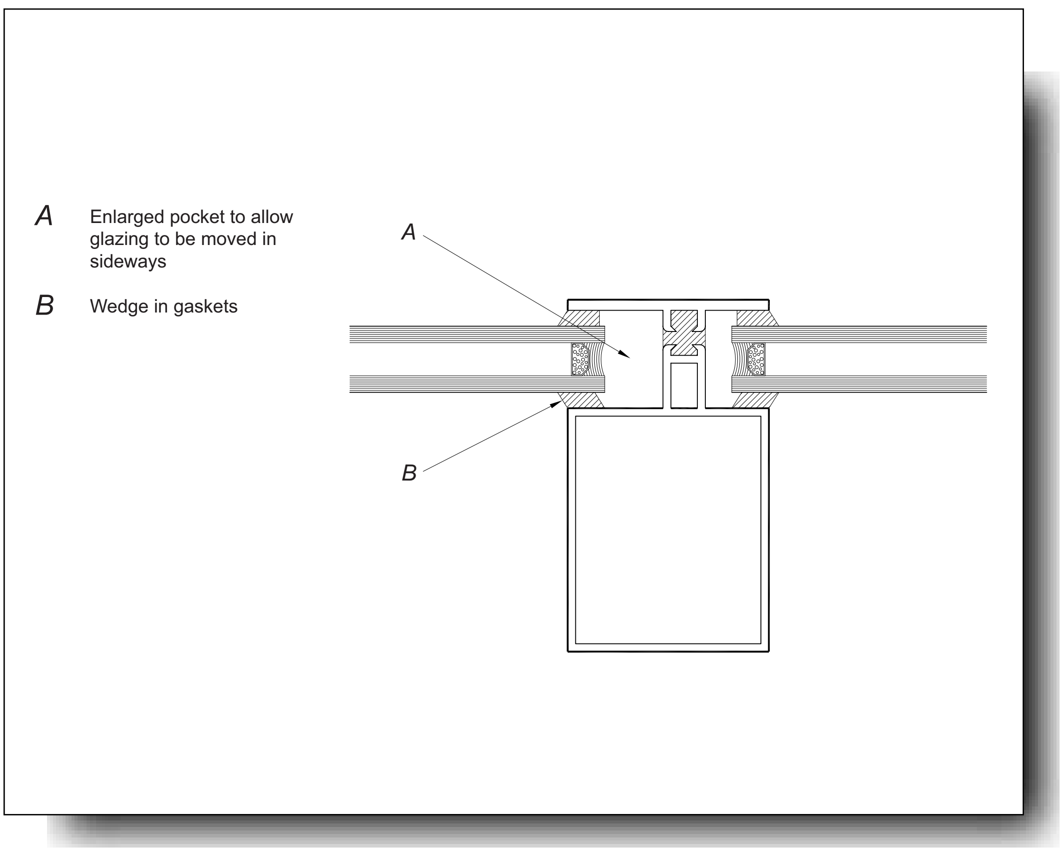


***Figure 2.15:** Glazing method — channel glazing*

GLAZING METHOD	CHARACTERISTICS AND FEATURES
OTHER	**Structural gasket** • Introduced in 1950s by automotive industry and used in many buildings up to late 1960s • Consists of preformed rubber seal with recess where locking strip is inserted • Locking strip exerts pressure on rubber creating seal • Fallen into disuse due to style change and performance problems

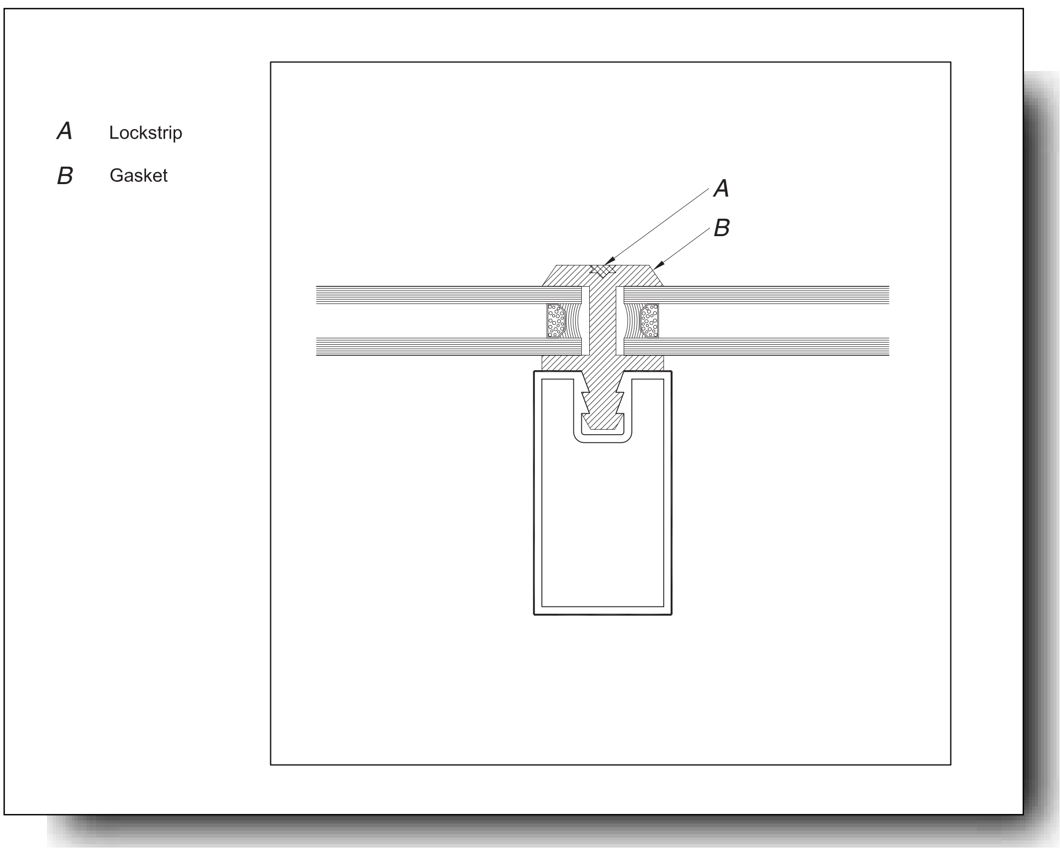


Figure 2.16: *Glazing method — structural gasket*

2.3.4 SELECTION CRITERIA

There are a large number of factors that influence the design and selection of a particular curtain wall system. These factors range from whim to practical reality, from budget constraints to Code compliance.

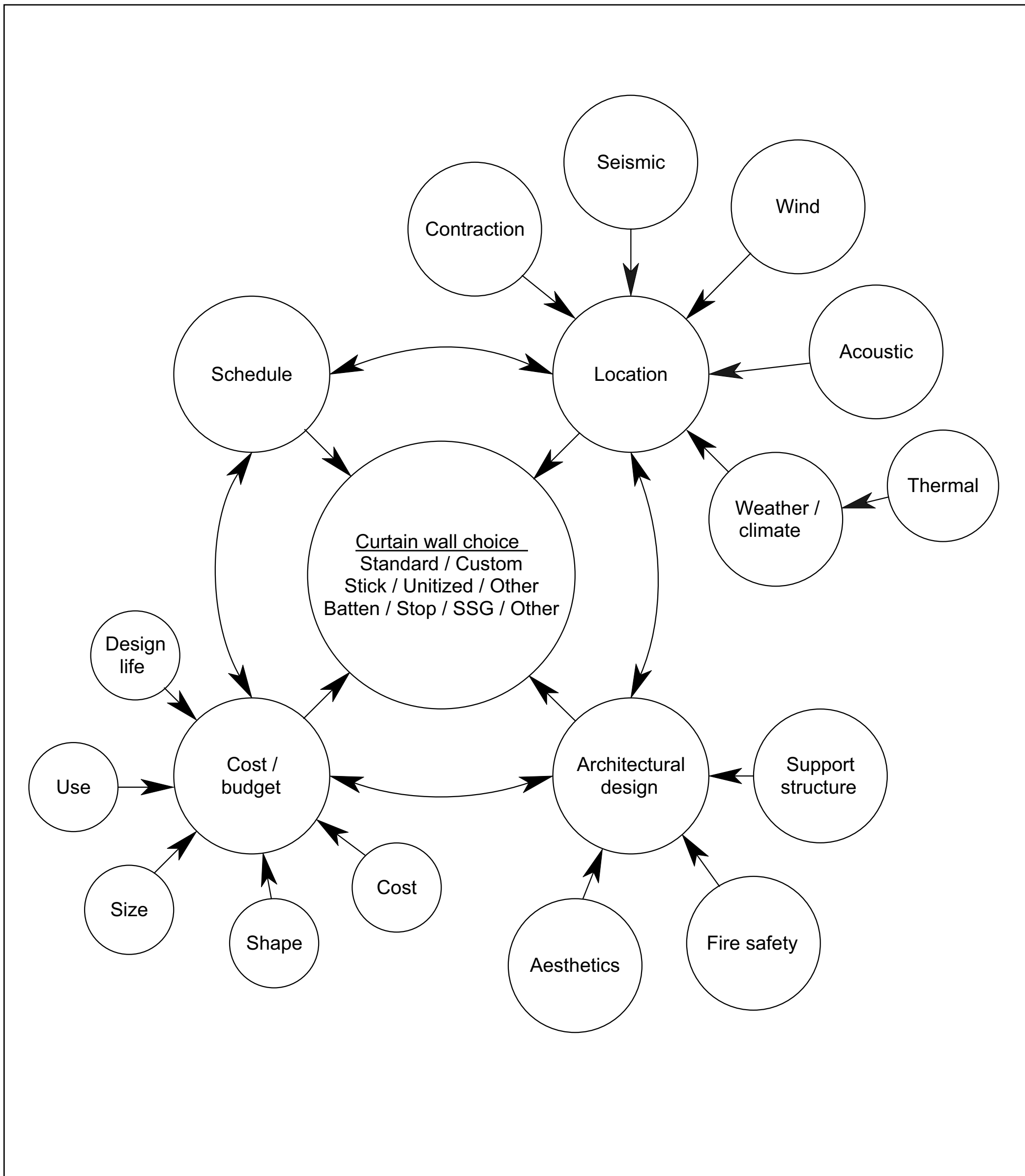


Figure 2.17: *Factors that influence the design and slection of a particular curtain wall system*

Inherent in all of the above are issues of quality and durability.

Given the large number of factors and the interaction of these factors it is very difficult to provide all encompassing guidelines for curtain wall selection. Curtain wall designers are inventive and can adapt systems to accommodate many conditions. However, some guidelines can be provided to assist the professional in selecting a curtain wall type and system once the architectural aesthetic is resolved. The following describes considerations for choosing a wall system from within the wall type and erection categories. The glazing method is most often influenced by architectural concerns.

Choosing a Wall Type — Standard or Custom?

The use of a standard or off-the-shelf type of curtain wall does not imply a restriction to a standard overall design. It only implies the use of standardized components and details. These elements can be arranged in many different ways to produce very unique assemblies. Nonetheless, custom walls might still be the best choice in some situations. The following outlines considerations for choosing between a standard or custom wall type.

Type	Factor	Applicability
Standard or Custom?	Architectural Design	Architectural demands for non-typical sections or unusual arrangements may mandate **custom** extrusions to achieve the proper effect.
	Cost/Budget *Size*	The greater the project size the greater the potential that **custom** extrusions that exactly meet the site conditions will be more economical.
	Cost/Budget *Cost*	Unless there are size-related savings or special requirements custom projects will generally be more expensive than **standard** assemblies.
	Schedule	**Standard** walls can generally go into production faster and arrive on-site sooner. However, early arrival on-site does not ensure an earlier close-in of the building.
	Location *Contractor*	Smaller projects in smaller centres will have less access to custom materials thus favouring **standard** products.
	Location *Weather*	While standard products are available to meet most Canadian conditions, coupling severe exterior and severe interior conditions may require the development of a **custom** system.

Adequate quality and durability can be achieved with either standard or custom walls. Standard walls have the advantage of a product history. Custom assemblies may require greater testing and analysis to evaluate potential durability issues.

Choosing Erection Type — Stick or Unitized?

While there are five or six different generic curtain wall systems, stick and unitized systems form the great majority of systems installed in Canada and North America. Given market pressures and contractor capability stick systems are typically used extensively in lower rise, smaller buildings in both smaller and larger centres. As the building size increases, in either height or footprint, the use of unitized systems to clad these buildings also increases. Most very large or very tall curtain wall clad buildings, constructed in Canada since the mid-1980s, have been clad with unitized systems. The following outlines considerations for choosing between a stick or unitized wall.

Erection	Factor	Applicability
Stick or Unitized?	Architectural Design	Most architectural designs can be executed in either system. Very long spans, especially near ground floor areas, are often more suited to stick systems. 4SSG systems must be pre-glazed unitized systems, making available shop facilities essential.
	Cost/Budget *Size*	The greater the project size, the greater the potential economy in unitized systems. Very small projects are almost exclusively completed using stick systems.
	Cost/Budget *Shape*	Very complex facades with little repetition, varying module size and spans make unitized systems less economical.
	Schedule	Advantages of one system over another depends on particular schedule demands. Standard stick systems can be fabricated and to the field quickly but take longer to close-in. Unitized systems take longer to arrive on-site due to plant assembly but close-in the building quickly once on-site.
	Location *Contractor*	Unitized systems require greater investment in plant and equipment and hence contractors are generally larger and located near major centres.
	Location *Seismic*	Stick systems, due to the sleeving of vertical mullions and the racking induced by lateral movements, are less able to accommodate seismic movements. Properly designed **unitized** systems can typically better accommodate seismic events.

As history has shown, adequate quality and durability can be achieved with either stick or unitized systems. However, due to the inherent quality control achievable in the factory assembly of the unitized system the potential for a higher quality project is increased using a unitized system. This potential is not always realized due to poor joint design to control air and water. Stick systems have problems mainly at the expansion joint where unitized systems add the vertical mullion joint which often compounds the expansion joint problem through the service life of the building.

Chapter 3

COMPONENTS AND MATERIALS

3.1 OVERVIEW

Unlike many other wall assemblies metal curtain walls are assembled from a relatively short list of components. The primary materials are aluminum, steel and glass, along with secondary materials such as sealants, rubbers and insulation products. All of these materials and components are assembled to very close tolerance into a highly engineered product.

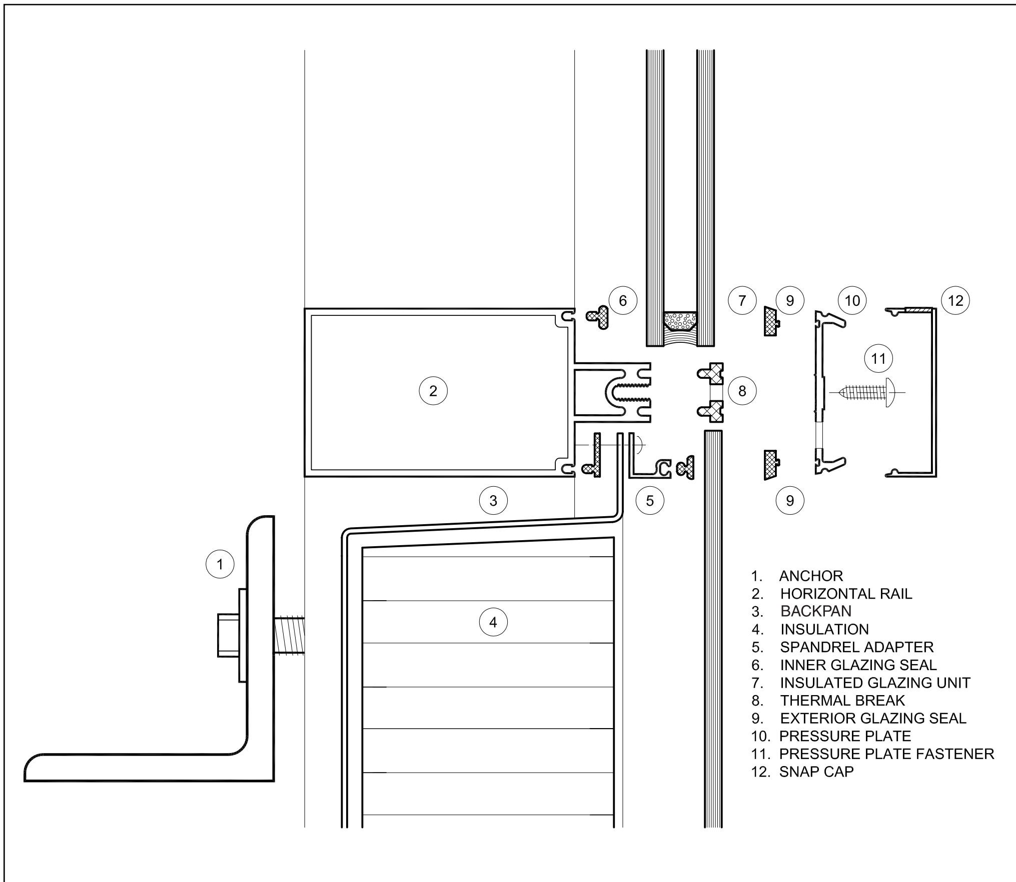


Figure 3.1: *Components and materials*

3.2 ANCHORS

Curtain wall anchors connect the wall to the building and can be broadly grouped as both gravity and lateral load anchors (fixed) or as just lateral load anchors (slotted). Aside from their primary load carrying function anchors must be designed to allow for adjustment to site conditions and, in the case of lateral load anchors, allow adequate vertical movement but no out-of-plane movement.

Curtain wall anchors come in many sizes, shapes and configurations. Each manufacturer has its own favourite anchoring system representative of an ideal combination of material fabrication and field installation cost. However, every anchor has essentially two basic components: an embedded part, cast in or drilled into the floor slab edge; and a mounting lug assembly that fixes to the embed and to the framing.

3.2.1 Concrete Embed

Concrete embeds come in a variety of designs and, aside from a few proprietary anchor systems, there is little standardization across the industry. There is no best type of embed for all conditions. Top edge of slab anchors are the most common (A, B). Anchors cast into pockets are more expensive but when grouted over, simplify floor finishes (B). Slab edge anchors require careful control of slab edge tolerances. Underslab anchors are usually only used at special conditions (D).Given the interior location of the embed, the use of galvanizing is an excessive practice in most instances.

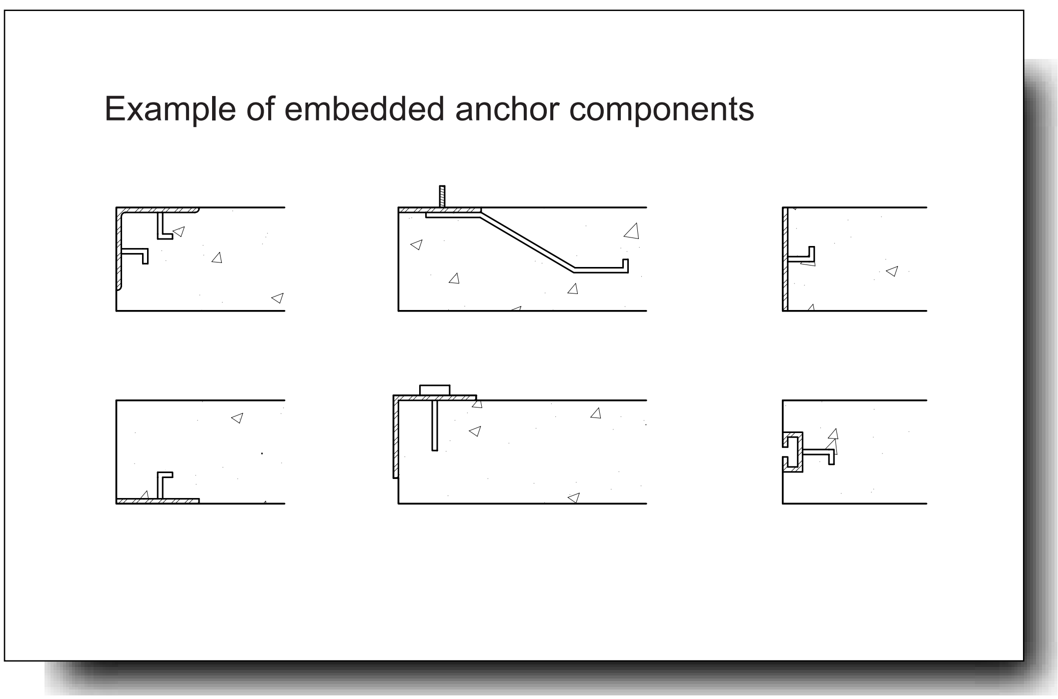


Figure 3.2: *Examples of embedded anchor components*

Critical Path

The design and layout of cast-in embed type anchors are often in the critical path of a building's construction. The anchors must be installed long before the curtain wall is fabricated or even completely designed. Therefore some conservatism must be built into the anchors and decisions on module spacing or special elements must be made early.

3.2.2 Mounting Lug Assembly

The design of the mounting lug assembly is based, in part, on the installation philosophy of the contractor. In Canada, the predominant approach to wall installation is to install the wall as quickly as possible in a temporary position and then adjust and shift components to achieve the proper final position of the wall. The other approach is to spend more time on the initial setting and fixing of the mounting lug, so that framing can be installed with little or no adjustment. This approach is common in Europe and the Far East and is gaining popularity in Canada. Notwithstanding developing philosophies there are a few common lug configurations.

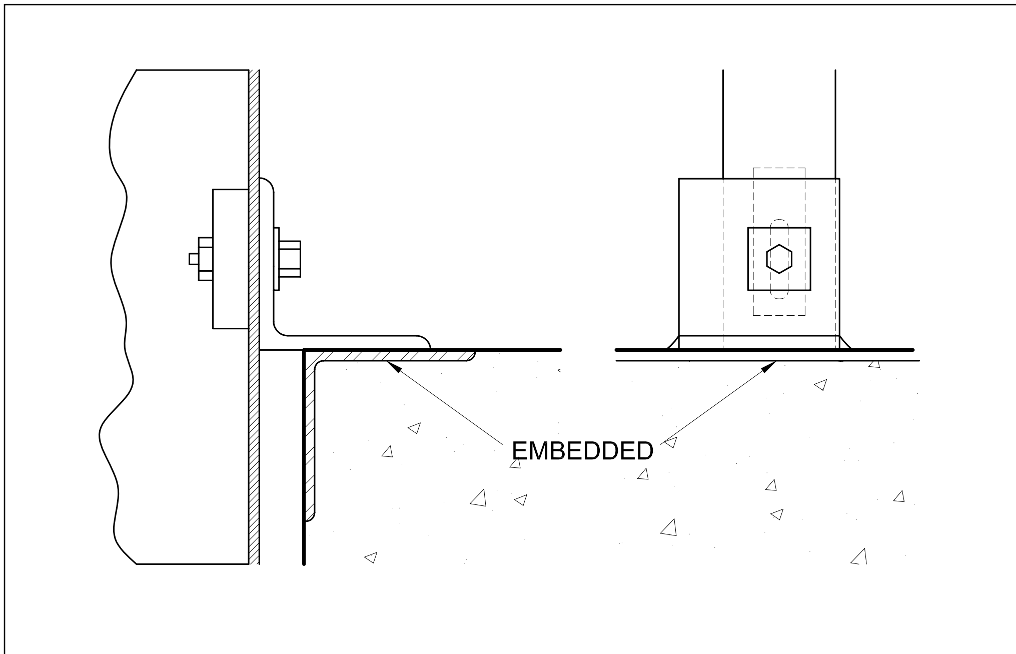


Figure 3.3: *Common anchor in many stick-erected curtain wall systems*

The relatively simple anchor shown above is common in many stick-erected curtain wall systems and has a long record of proven performance. The anchor consists of a cut steel angle welded to the mounting surface of the embed. The angle is roughly positioned and tacked in place during initial layout. The angle has a cut hole in the vertical leg that allows some vertical and lateral movement of the anchor bolt. The anchor bolt is set through an anchor block internal to the mullion tube and through the cut hole in the angle. A rectangular steel washer plate on the anchor bolt is welded in position to fix the bolt and framing position. Welding and locking of the anchor bolt nut are the final activities in the fixing of the anchor. Welds require final inspection as they are a structural element and painting is recommended as minimal corrosion protection.

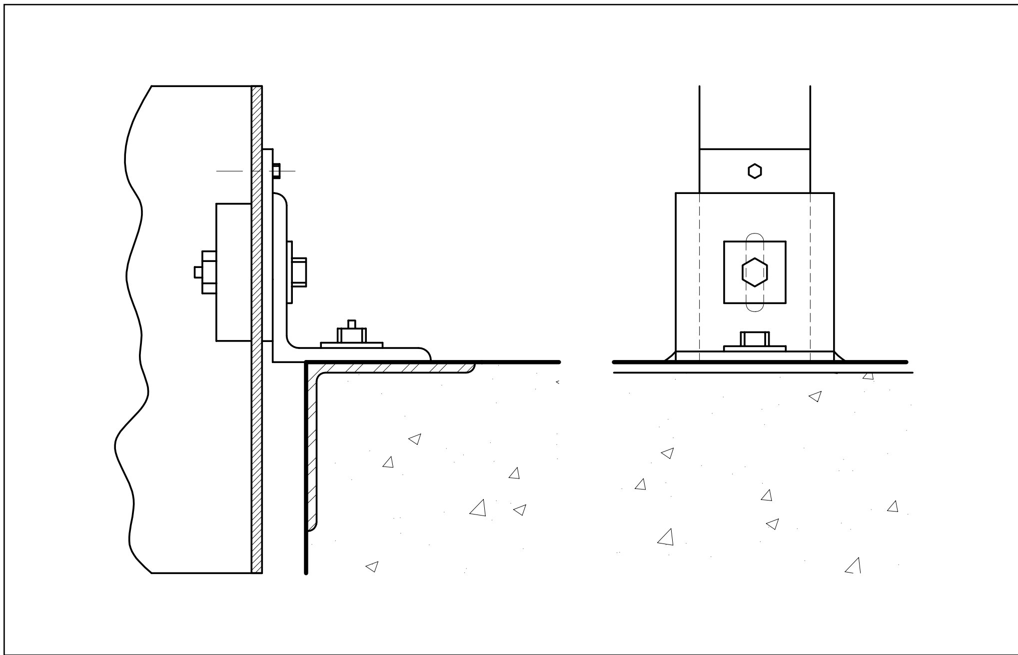


Figure 3.4: *More sophisticated anchor*

The slightly more sophisticated anchor shown above is most commonly found in unitized wall systems. It eliminates field welding through the use of a pre-welded threaded stud on the embed, extruded aluminum mounting lugs and a separate dead load fixing screw.

Aside from typical slab edge anchors, a curtain wall that extends to grade often requires internal anchoring to the structure. These anchors are often cut from aluminum extrusions or may be built-up plate/angle assemblies. Such anchorage must satisfy the same constraints as slab edge anchors. In addition, given the termination of the system, air seal closures require special attention.

Regardless of the actual anchor design, there is a need to account for certain clearances and tolerances associated with the anchor. When reviewing a shop drawing, it is worthwhile to check that the following clearances and tolerances have been incorporated.

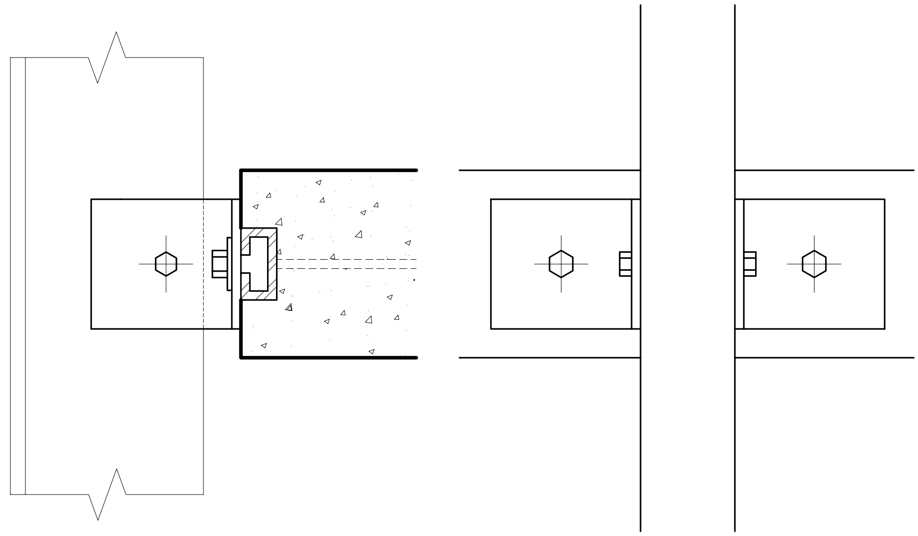
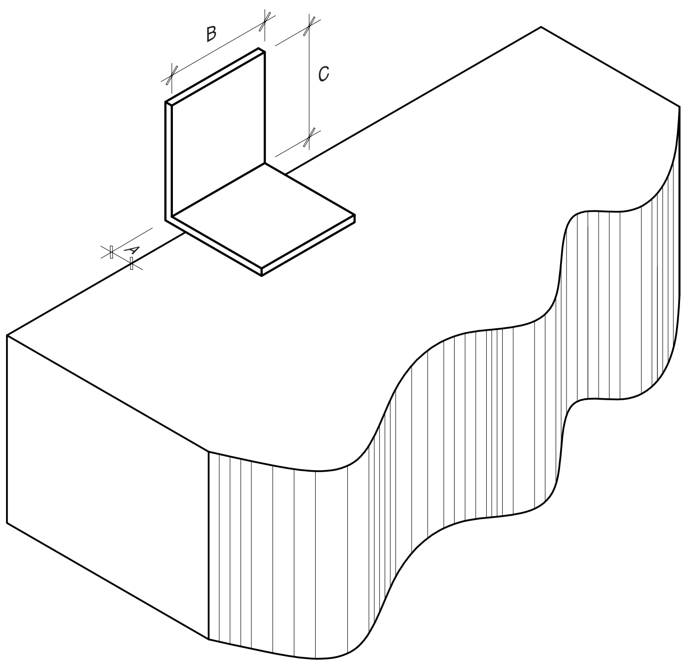


Figure 3.5: Slab edge anchor



Clearance @ A typical 25-50 mm (1 to 2 inches)
Tolerance @ A typically ±25 mm* (1 inch)
Tolerance @ B typically ±12 mm (1/2 inch)
Tolerance @ C typically ±12 mm (1/2 inch)
*Increasing A to 75 mm (3 inches) may require added gusset.

Figure 3.6: Anchor clearances and tolerances

3.2.3 Anchor Loading and Design

Anchor loading is dependent on the module spacing, the materials comprising the wall, the wind load at the particular location and the structural support condition for the wall. Every anchor will have applied lateral loads. Gravity loads will also act at fixed anchors.

Anchor design requires reference to concrete, aluminum and steel standards of practice, along with proprietary information from expansion anchor and stud suppliers. It is important to be aware that many designers/specifiers include a greater than typical factor of safety in their designs, to account for the critical nature of anchors. This factor (1.3) is typically applied in addition to typical live load factors and is intended to account for the following issues:

- The anchor insert is installed by someone other than the curtain wall contractor.
- The anchor insert is not tested in a performance mockup.
- The edge of the concrete slab is often the poorest quality of concrete.
- Concrete embedments are subject to brittle fracture.
- Embedments are often installed prior to completion of the final design.
- Remedial work to embeds is difficult to do.
- The cost of additional factor is generally not significant.

3.3 FRAMING

The following discussion of curtain wall framing includes not only the load-carrying mullion and rails but also the pressure plate, snap cap and stiffening components.

3.3.1 Materials

Aluminum extrusion is the primary framing material for glass and metal curtain wall systems. The principal aluminum alloys and tempers used in curtain wall applications are:

Alloy – Temper	Ultimate Strength (MPa)	Yield Strength (MPa)
6063 – T5	150	110
6063 – T54	230	205
6063 – T6	205	170
6061 – T6	260	240

The listed material strengths decrease dramatically with welding. Other characteristics of each alloy are discussed below.

Alloy 6063

Alloy 6063 is the most common framing alloy in North America. It provides a good combination of mechanical properties and extrudability.

Its extrudability allows the production of intricate profiles and thin walled hollow shapes. It responds well to anodizing, polishing, dyeing and chemical brightening and readily accepts most architectural finishes. It has excellent corrosion resistance to normal atmospheres. T5 and T6 tempers are most common with the decision on temper being governed by strength requirements. T5 is more common for closed shapes and T6 is more common for open shapes. Production of the higher strength T54 alloy requires closer quality control and is only available from select extruders. Exterior pressure plate or interior stop material is typically 6063 aluminum extrusions. Snap caps are also typically extruded 6063 aluminum.

Alloy 6061

Alloy 6061 is a medium strength structural alloy. It is used in sheet, plate and extruded form in applications requiring greater strength than 6063. While frequently used for anchor, splice and lug assemblies, 6061 finds limited application as extruded framing. However, section profiles are typically less intricate than 6063 profiles due to greater difficulty in extruding. Alloy 6061 readily accepts most architectural finishes and provides excellent corrosion resistance to normal atmospheres. T6 is the only temper in common use.

Contact with Dissimilar Materials – Galvanic Series

Pre-painted aluminum generally does not require any further protection even in contact with wood, concrete or steel. Under extreme conditions a heavy coat of bituminous paint prior to installation will provide an insulating barrier.

Heavy Metal Corrosion

While architectural aluminum alloys are inherently corrosion resistant, water coming in contact with aluminum after running over a heavy metal, such as copper, can cause corrosion of the aluminum. Protection must be provided when a curtain wall is adjacent to copper flashings or feature elements as when copper snap caps are used.

Steel Reinforcing

For most common spans, the standard, relatively thin walled, aluminum extrusions have adequate strength. In particular for long span applications, it is more efficient to utilize steel as the framing material with an extruded aluminum glazing adapter or to use steel as reinforcing hidden within an aluminum section. Where the steel is to be left exposed, hollow structural sections (HSS) are frequently used. Where steel is used as hidden reinforcing it can be in the form of HSS, flat plate, angles or built up shapes. Prime painting of steel reinforcing is adequate in most applications. In extreme conditions (high interior RH, low exterior temperature) galvanizing should be considered.

Pultruded Fibreglass

In some specialty applications pultruded fibreglass framing sections are used. The range of sections of this material is quite limited and special orders are frequently required. Pultruded fibreglass is more often used in pressure plate and snap cap components where special corrosion resistance or increased thermal performance is required.

Formed stainless steel; formed copper and pultruded fibreglass are also used in certain snap cap applications.

Pultruded Fibreglass Pressure Plates

While thicker and heavier than aluminum pressure plates, pultruded fibreglass pressure plates can markedly increase the thermal performance of conventional aluminum framing (20 to 40 per cent reduction in U value). They are also ideal where a material potentially corrosive to aluminum, such as copper, is planned for the snap cap.

3.3.2 Profiles

A wide range of cross sections or profiles is available from different manufacturers. Each manufacturer's profile varies somewhat and incorporates different features, although common section widths and depths are found with most suppliers of standard systems.

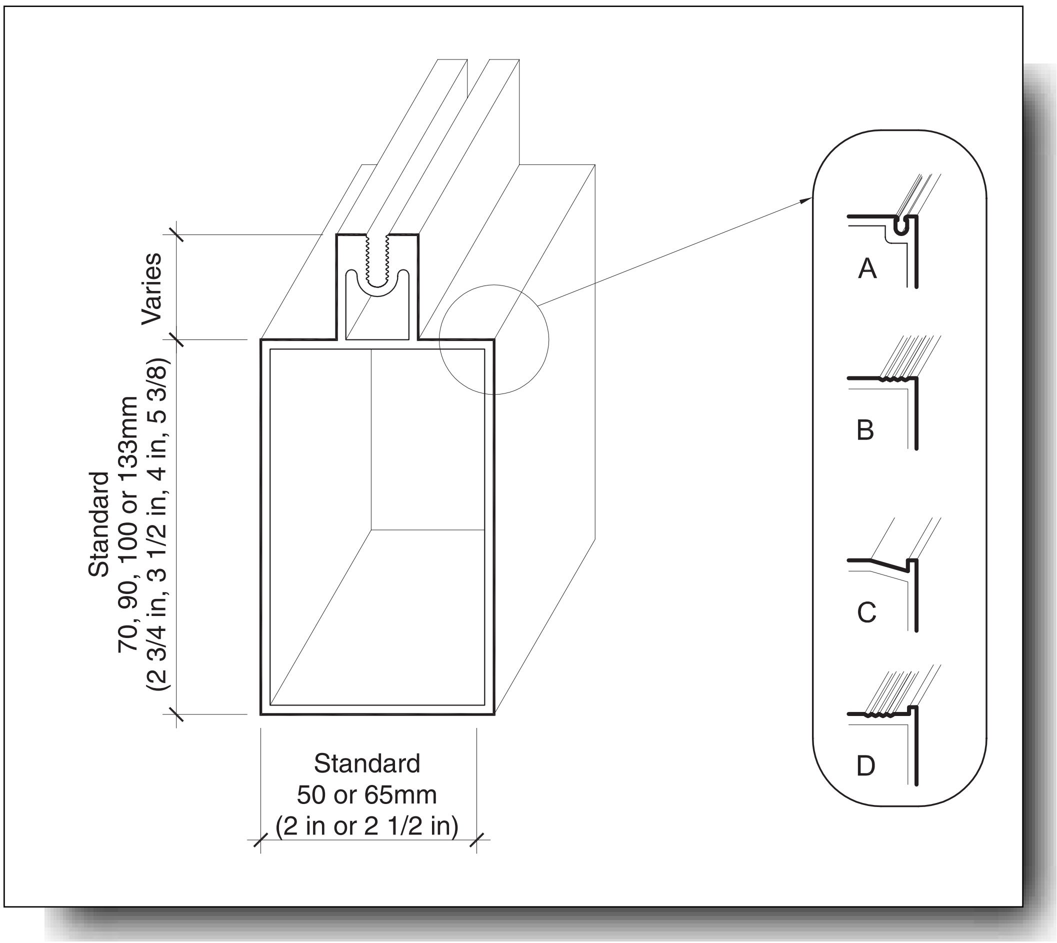


Figure 3.7: *Standard mullion section and shoulder edge detail*

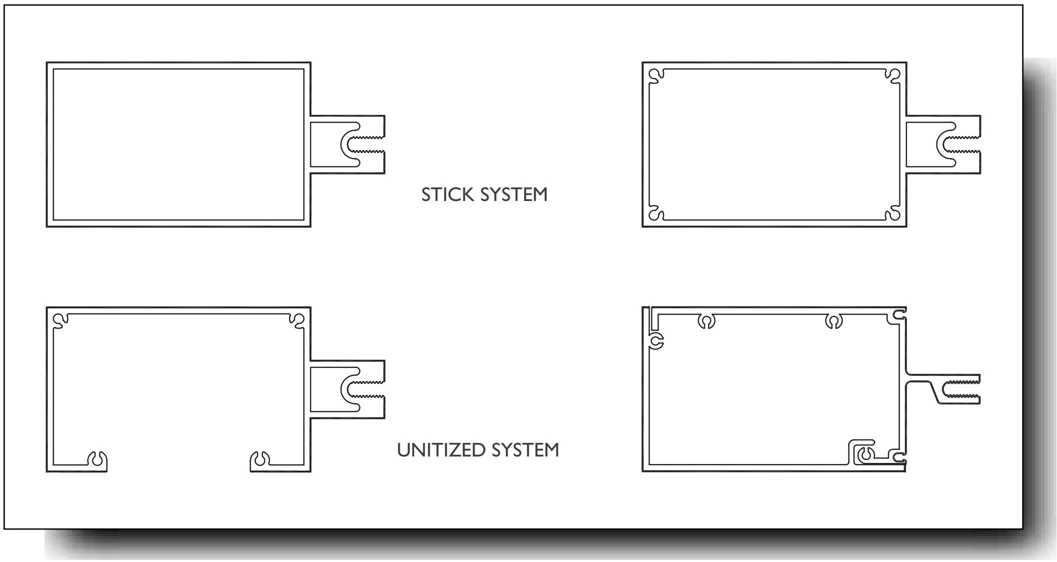


Figure 3.8: *Typical Horizontal rails*

3.3.3 Pressure Plates

As with section profiles, each manufacturer produces its own slightly unique profile of pressure plate. They are typically produced in the same alloys as the main framing members and are not usually finished. All serve the same basic function of clamping the glass or panel into the framing grid. Pressure plate profiles are customized to match the manufacturer's particular sealing system.

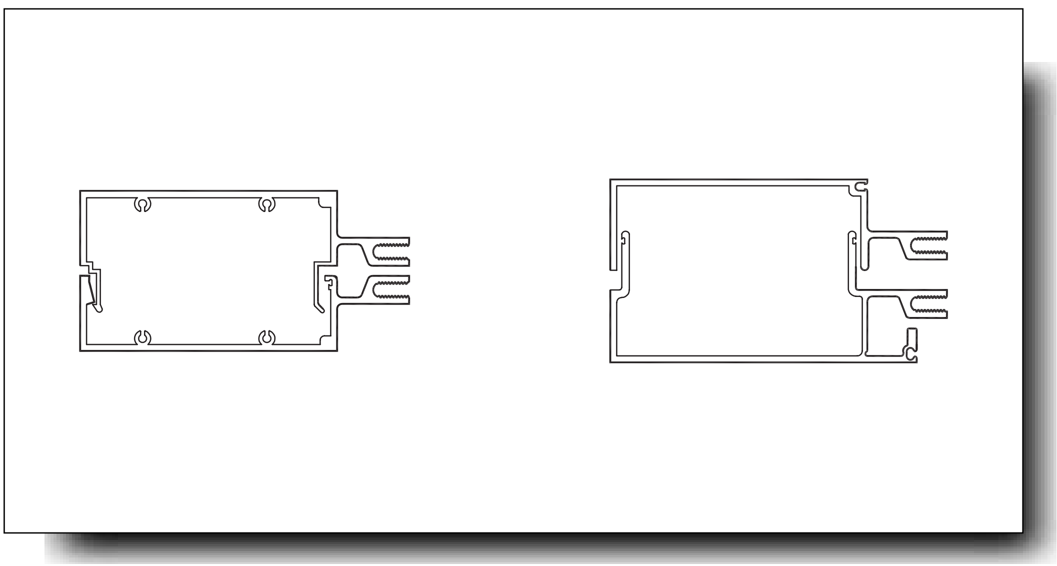


Figure 3.9: *Alternate horizontal rails – Unitized system*

Aside from the typical flat pressure plate, certain standard pressure plates exist to accommodate plan angle changes. With proper gasket selection a standard flat pressure plate can usually accommodate a 5˚ plan angle change.

Pressure plates can also be designed to accommodate sliding guides for use by swing stages. This application has become less common with reliance now placed on discrete point restraints for stage rather than continuous tracks.

Unitized systems employ a typical pressure plate profile for intermediate rail members; however, depending on the interlock system, two-part pressure plates may be used at interlocking vertical and horizontal frame members. Critical to the design of these systems is the ability to drain.

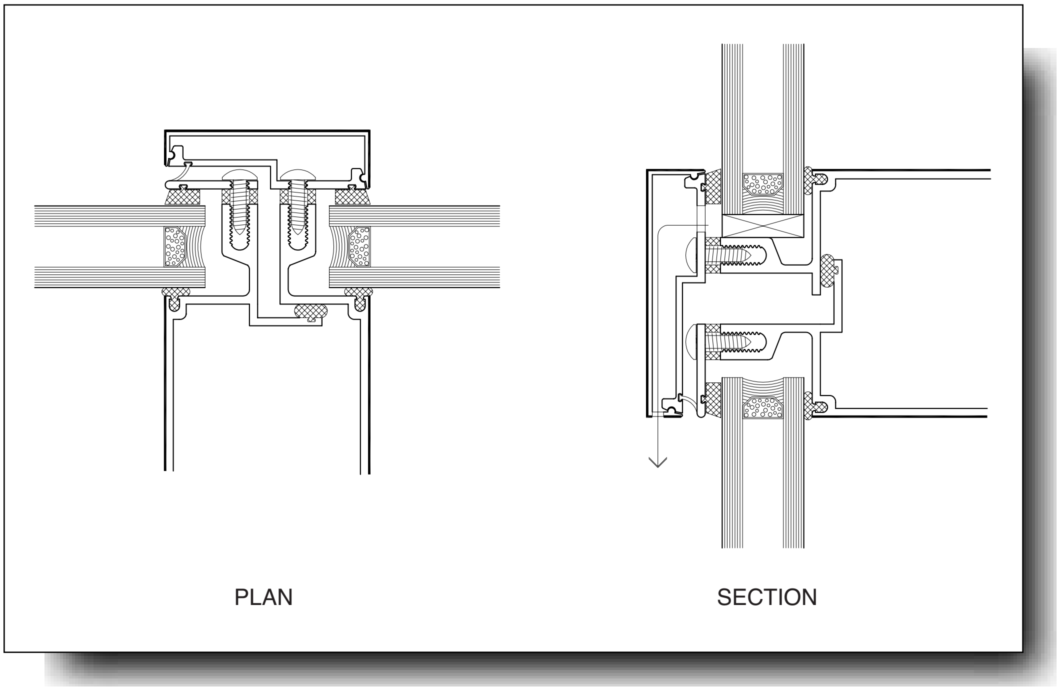


Figure 3.10: *Interlock system two-part pressure plate*

Vertically, pressure plates are typically installed in mullion length segments. Horizontally, pressure plates for the rails are fit between the mullion pressure plates with an expansion gap at each end.

Pressure plates are pre-punched to accept the pressure plate screws. Hole centres vary with applications between 150 and 200 mm (6 to 8 inches) on centre.

In addition to holes for pressure plate screws, ventilation/drainage openings are also punched in the horizontal rail pressure plates. Manufacturers employ a variety of opening sizes and shapes. The size and shape of the vent/drain opening should be based on the specific project design details (see Chapter 4). The preferred shape is an elongated slot, no smaller than 25 mm (1 inch) long and 9 mm (3/8 inch) high. Slots should be positioned at the centre of each module and 50 mm (2 inches) from each end of the pressure plate. Punched circular holes are not recommended for use as drainage openings in the pressure plates as they have a tendency to clog with time.

The bottom edge of any drain slot must align with the top surface of the thermal break or preferably sit slightly below and not be blocked by the placement of setting blocks.

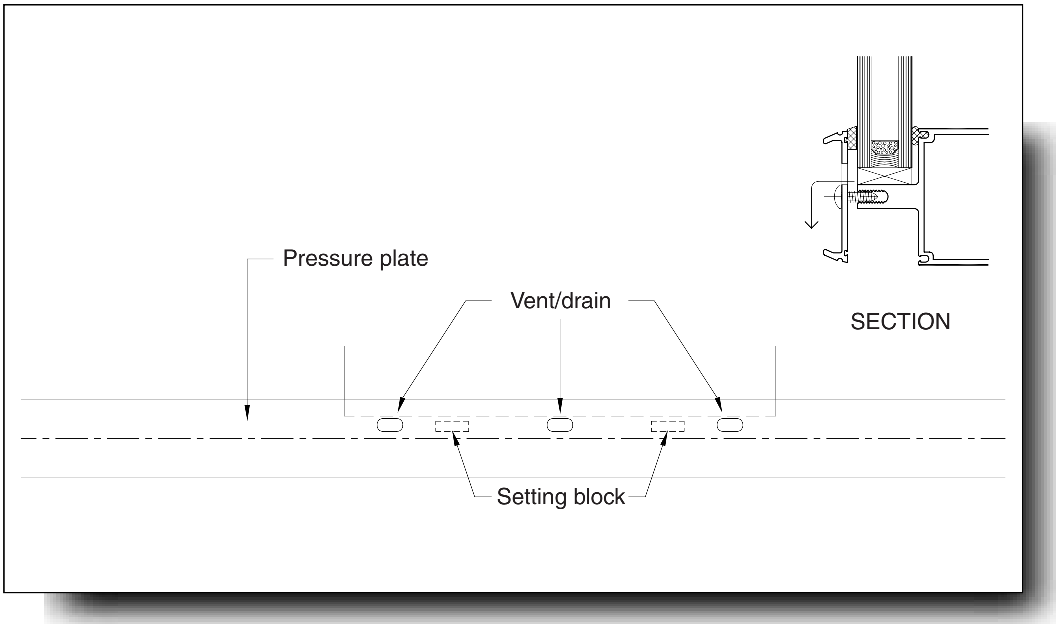


Figure 3.11: *Vent/drain openings*

Drainage Openings

Drainage openings must be sized to allow clear drainage and adequate venting of the glazing cavity. The recommended opening shape is an elongated horizontal slot.

As the drainage opening in the pressure plate is baffled by the snap cap, the openings in the cap must be at least as large as those in the plate if the concern is simply the provision of drainage, or substantially larger if the concern is pressure equalization as well as drainage.

Provision of ventilation openings on the lower half of pressure plates is discouraged due to the potential for water entry by gravity flow into the vent opening. Water entry at this point will sit on top of the glass unit or must drain around the entire perimeter to reach a drainage opening.

3.3.4 Snap Caps

Snap caps or dress caps are firstly a decorative cover over the pressure plate and exposed fasteners, and secondly, more functionally important as a baffle to the drainage openings in the horizontal pressure plate. Snap caps are typically made from extruded aluminum of the same alloy as the main framing member. They may also be made from formed aluminum, formed stainless steel or in some cases, formed copper. Use of formed material requires either a special pressure plate profile or modifications to a standard pressure plate. A variety of standard profiles are available.

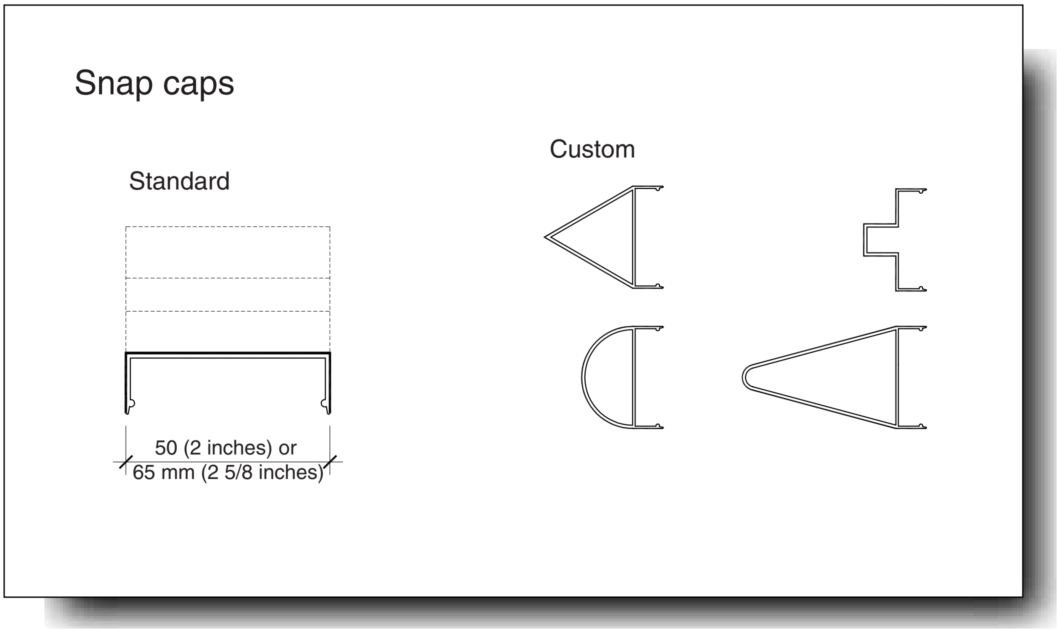


Figure 3.12: *Snap caps*

Custom profiles can be made or produced to suit most architectural design intents. Caution should be exercised with especially deep or non-rectangular caps. The deeper a cap profile the less clamping engagement on the pressure plate. As engagement reduces the potential for cap disengagement in-service increases. Custom designs can be developed to reduce this problem. Nonetheless, deep caps inherently pose a far greater risk for disengagement, and falling from the wall. Deep snap caps also influence thermal performance by connecting more mass outboard of the thermal break. Deep caps can also pose an ice/snow collection hazard and become a roosting location for birds.

Fixing of Snap Caps

High profile snap caps or caps of dissimilar materials should be mechanically fastened to the pressure plate as well as snap connected. Fastening should consist of a minimum of one screw installed at the centre of the cap length. Longer caps should be fixed with two screws at third points installed in slotted holes. Screws are positioned in the side wall of the cap so as to engage extruded legs in the pressure plate. There is a tendency for some snap caps profiles to creep along the pressure plate over time. This is not usually an issue with shorter horizontal caps but can be significant with longer vertical caps. If a cap creeps sufficiently it may start to disengage. As such fixing of one end of the cap is recommended.

Snap cap joints, particularly the mullion caps, must be sized to accommodate actual anticipated thermal movement. The mullion caps will tend to move more than the mullions due to greater thermal cycling. Therefore, folded metal splices must be used at snap cap joints to hide the pressure plate behind and prevent the flow of surface water directly behind the cap. The splice should match the profile of the snap cap and be fixed to the upper end of the lower cap.

3.4 FASTENERS

Mechanical fasteners such as screws and bolts are used in the assembly of the curtain wall framing, the fixing of the pressure plate and the anchorage to the building. A wide variety of fastener types, thread types, coatings and materials are available. The details of fastener selection for the most part concern the structural engineer; as such, this section provides only a broad overview of some issues to be aware of regarding fastener selection.

3.4.1 Materials

Metals used for curtain wall fasteners can be either carbon steel or stainless steel, depending on where the anchor is used in the wall.

The use of carbon steel fasteners should be limited to the wall anchors, and to frame assembly if they will be located to the interior side of the air barrier. All carbon steel fasteners must be plated or polymer coated to provide protection against corrosion.

All fasteners located to the exterior side of the air barrier should be stainless steel. Stainless steel should also be used for pressure plate fastening. Stainless steel fasteners are available in a variety of alloys. The different alloys have differing resistance to corrosion.

Stainless Steel Corrosion Resistance

All stainless steel alloys have good corrosion resistance; however, they are not all equal. For example, Type 316 has better corrosion resistance than Type 304.

There are also other cautions regarding stainless steel fasteners:

Seized Stainless Steel

Stainless steel has a high coefficient of friction and low thermal conductivity; both factors tend to locally heat screw threads and cause seizure. This can lead to shearing off of self-tapping fasteners during power installation.

Painting Screw Heads

Paint finishes do not adhere well to stainless steel fasteners and are often chipped during installation. Attempting to colour match screws should be avoided.

Aluminum fasteners, with the exception of some riveting applications, are not appropriate for use in curtain walls.

3.4.2 Quality Control

Fasteners play a critical role in the integrity of the curtain wall system. It is wise to specify the use of fasteners with proven conformance with standards such as ASTM F606, which provides procedures for lot testing, source inspection, alloy control, heat control, etc.

3.4.3 Fastener Loosening

Fasteners subject to vibration, primarily wind induced, can loosen over time. Prevention of loosening is typically achieved through use of lock washers, nylon nut washers and sometimes chemical adhesives. Not all fasteners require locking devices. Typically, fasteners for main structural connections or anchors and those used in moving parts require lock devices

3.4.4 Fastener Holes, Slots, Chases

Guidance on the position of fastener holes in the aluminum or steel assembly is provided in the appropriate design standards and is primarily the concern of the structural engineer. However, joint design may incorporate reference to oversized or slotted holes to accommodate movement.

No-Friction Connectors

Oversized or slotted holes can be used to allow for movement or temporary fixing only. Fasteners in all permanent fixed connection points must act in bearing against the aluminum material.

In addition to conventional through hole with bearing connections, screw slots and chases are common components of aluminum framing extrusions. Self-tapping screws are driven into slots to assemble framing. Self-tapping screws are also used in screw chases to connect pressure plates.

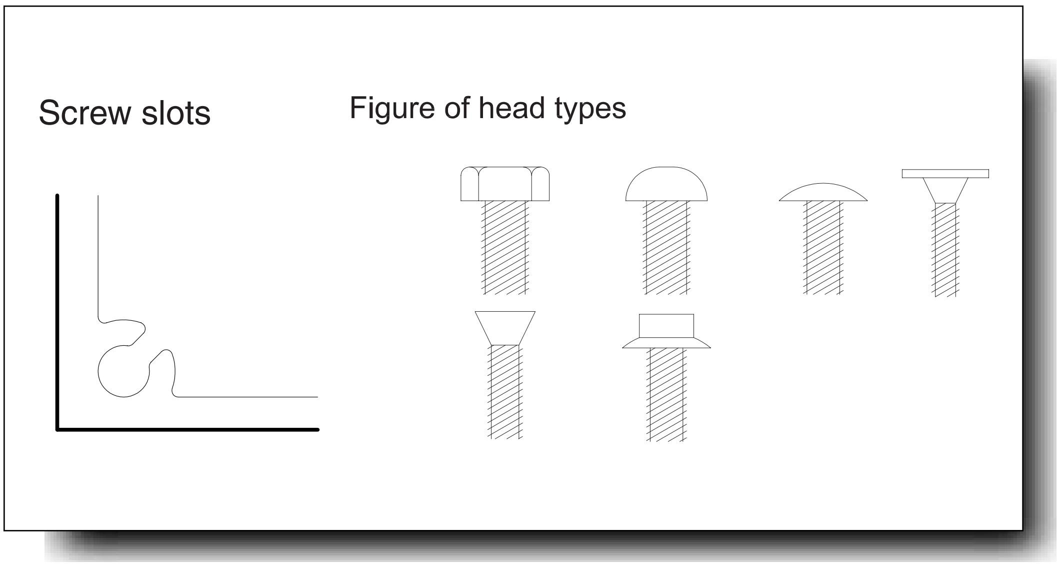


Figure 3.13: *Screw slots*

3.4.5 Fastener Types

Fasteners are described primarily according to size, material and head type. The goal of most curtain wall designers is to use the minimum number of different fastener types on a project.

Despite the widespread use of metric units in the Canadian construction industry much of the curtain wall industry continues to reference fastener size by the imperial designation. For example, the most common size of pressure plate fastener would be called out as a 1/4 inch-20 S.S.P.H. which would indicate a 6 mm (0.25 inch) diameter bolt with 20 threads per inch made from stainless steel with a pan head. The most common sizes of fastener for frame assembly are number 12 and number 10. Fasteners smaller than number 10 are normally only used for fixing non-load bearing elements such as flashing and trim.

As discussed previously, material would be identified as either stainless steel (S.S) or a coated carbon steel. In general, the same alloy of stainless steel would be used throughout a given project.

Head type is selected based on installation, function and appearance factors. Generally hex head and pan head screws are used in load-carrying application; while truss, flat and oval head are used for exposed aesthetic applications.

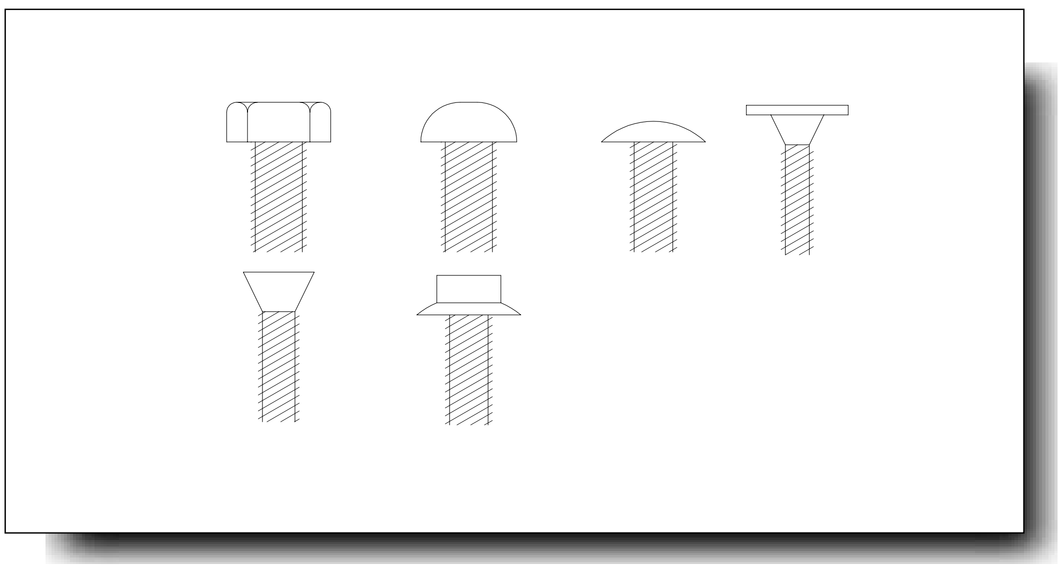


Figure 3.14: *Head types*

3.4.6 Selection Criteria

The selection of fastener type is first governed by load carrying requirements, followed by exposure, function and, finally, appearance as illustrated in the following table.

Parameter(s)	Selection based on:
Size [Diameter, length]	Selection based on shear strength of fastener, bearing capacity of fastened materials, type of hole, length to prevent bottoming out
Material, alloy	Selection based on exposure – generally fasteners outside of air barrier or exposed to water to be stainless steel
Head type	Load-carrying or slotted holes typically warrant hex or pan head. For aesthetic applications use truss or flat head

3.5 GASKETS/TAPES

As discussed in Chapter 2, the type of glazing system (e.g. wet glazing, wet/dry glazing or dry glazing) will influence the type and nature of the gaskets and/or glazing tapes used in a particular application. Whatever system is employed, the gaskets or tapes must work to cushion the glass edge to prevent metal contact that may lead to breakage and to seal at the glass perimeter to prevent water penetration and air leakage.

Gaskets and tapes have been in use in curtain wall for many years and a wide range of standard products are available. Suppliers can produce custom products very quickly to meet special project needs.

3.5.1 Glazing Gaskets

Glazing gaskets are differentiated from glazing tapes on the basis of cure. Gaskets are products generally exhibiting a high degree of cure and elasticity and rely on their elasticity to maintain a seal. Available in a variety of shapes, hardness, density and composition, gaskets are considered compression seals. They are placed in a joint and rely on interface pressure to create a seal.

Gaskets are available in several different rubber materials. The most common materials used in curtain walls are neoprene, ethylene-propylene-diene-monomer (EPDM) and silicone. Silicone-compatible and thermoplastic rubbers are also used. Vinyl chloride gaskets are produced but are not recommended for curtain wall use. High-density polyurethane foam, usually produced with pressure sensitive adhesive on one or two sides, is used as both gasket and spacer in structural silicone glazing. While usually called a glazing tape, on the basis of cure, it is more properly considered a gasket.

Gaskets are produced as both dense and cellular products of varying hardness. The appropriate selection of gasket hardness, particularly in dry/dry glazing systems, is critical to its sealing capability. The most widely used gasket combination for dry/dry glazing is sponge or soft dense gasket on one side of the infill panel with a relatively hard dense gasket on the other. Cellular gaskets are very soft and hardness is not usually quoted. Variations in the apparent hardness of dense gaskets are achieved through the formulation of the material itself or through hollows in the gasket that allow deformation under pressure. Dense gasket hardness varies from Shore A hardness of 40 to 75 depending on application. “Soft” dense gaskets have a hardness of 55±5, while “hard” dense gaskets have a hardness of 70±5.

Aside from the material properties discussed below, material shrinkage — real or apparent, plays a significant role in the performance of glazing gaskets. Actual material shrinkage, both longitudinally and in cross section, has been an issue since the early curtain walls and continues today, although to a much lesser extent. Most apparent shrinkage observed today is not material shrinkage but the creep back of gaskets that have been stretched during installation. Gaskets should be installed such that there is longitudinal compression and a tendency to expand and close joints rather than pull back and open joints.

3.5.1.1 Neoprene and EPDM

Neoprene and EPDM are used interchangeably in many designs and can be produced as both dense and cellular products. Both exhibit good resistance to UV, ozone and, if properly formulated, a low-compression set. In dense gaskets the qualifying feature of neoprene over EPDM is its flame retardant characteristic. This is only significant if the gaskets are large and exposed.

Cellular or sponge neoprene gaskets and tapes are made with a thin impervious skin. They are soft and usually compress 25 per cent to 40 per cent during installation. Sponge neoprene gaskets, particularly when applied as rectangular tapes, have a history of excessive compression set leading to loss of seal. This characteristic has been partially overcome through formulation changes and changes in design.

3.5.1.2 Silicone

Dense gaskets are sometimes manufactured of silicone rubber but generally only for structural glazed applications, due to their higher cost. Silicone rubber provides excellent resistance to UV and ozone. Formulation can provide a very low-compression set.

3.5.1.3 Silicone-Compatible Rubbers/Thermoplastic Rubber

Silicone-compatible rubber and some thermoplastic rubbers are proprietary products developed to provide a less expensive alternative to silicone gaskets in structurally glazed systems. They exhibit good resistance to UV and ozone. They should not be used in large or hollow dense gaskets in compression systems due to their relatively large compression set.

3.5.1.4 Urethane Tape

High density urethane foams, often produced as rectangular sections with pressure sensitive adhesives, are used as gaskets and, when properly tested, as backers for structural silicone glazing. While tested for UV and ozone resistance they are best suited for interior application only.

3.5.1.5 Gasket Corners

The use of extruded or cut gaskets requires the treatment of corners and junctions in the gasket. Typical Canadian curtain walls treatment is required at both the exterior gasket to address water penetration and at the interior gasket to address air leakage. The corners are the most susceptible areas for water or air leakage. The three best corner treatments for use in curtain wall are, in order of increasing performance and durability:

Sealant Corner: Applying a gunnable sealant at the butt corners of a gasket. This method can provide a durable weather tight corner ***if*** the gaskets are properly installed. The most common installation error leading to failure of sealant corners is a gasket cut too short for the opening or a gasket that is stretched on installation. A stretched gasket will eventually creep back opening up a corner. Long-term adhesion of sealants (butyl for neoprene/EPDM, silicone for silicone) to gaskets is often questionable. It is therefore essential that the gaskets be installed such that there is longitudinal compression at the corners and the sealant acts only as a formed-in-place corner gasket.

Glued or Vulcanized Corner: Glued corners are formed by applying cold adhesives to mitre cut gasket lengths usually in a factory setting. When prepared in the factory, glued corners can provide adequate performance and can be useful when a limited number of odd shapes might be required. Cold applied adhesives do not match the performance of hot adhesives. Vulcanized corners are similar to glued corners except that the adhesive is cured at high temperature instead of at ambient temperature. This results in a more durable bond.

Injection Moulded Corners: Injection moulded corners are made by injecting a rubber compound into a mould which holds the two ends of the gasket. The formed corner is then cured under pressure and heat. One of the primary advantages of the approach is the body of solid rubber at the highly stressed corner. All other approaches place the sealed or glued joint at this location. Unfortunately injection moulded corners are considerably more expensive than any of the other methods and incur more assembly and production issues. The use of injection moulded corners is usually restricted to very special projects.

3.5.2 Glazing Tape

Glazing tapes are widely used by the glazing industry. They are commonly provided in two different formats, a butyl rubber-based, stiff, non-shimmed tape for use in non-compression applications such as metal-to-metal lap seals and a softer pre-shimmed polyisobutylene formulation. All modern tapes have good resistance to UV, ozone and heat. As tapes are essentially non-curing sealants the properties of sealants do not apply. Due to their tacky surface tape they do tend to collect dust/dirt which can wash down to soil building panels. However, they do have good adhesion to most building materials. The tapes vary in width from 6 to 25 mm (1/4 to 1 inch) and in thickness from 1.5 to 9 mm (1/32 to 1/8 inch).

3.5.2.1 Non-shimmed Glazing Tape

Due to the size of glass lites and the movement of the wall, non-shimmed glazing tape has little application in curtain wall systems. Their principal application is in non-moving sheet metal joints and in butt connections of framing. Non-shimmed tapes cannot perform in joints subject to significant movement. The tapes perform well in joints with shear movements providing the tape is held in the joint to prevent it from rolling out.

3.5.2.2 Pre-shimmed Glazing Tapes

Pre-shimmed glazing tapes are softer than non-shimmed tapes and due to the cured rubber or plastic shim (rod) in the tape cross section, they can perform in a compression glazing system. Like the non-shimmed tape, shimmed tape can perform under shear movements provided the tape is restrained from rolling from the joint. Restraint is provided by a nib or groove in the aluminum frame or a silicone cap bead.

Curtain wall contractors have often sought a glazing seal system that combines the appearance and durability of an extruded gasket and the wet sealing compliant nature of a glazing tape. Some contractors manually created such a system by combining gaskets and tapes. This demand led to glazing tapes which consist of co-extruded EPDM gasket and polyisobutylene tape. This system has merit if the glazing system is designed specifically to accept the gasket and tape. Improper design can lead to the gasket rolling out of the joint.

Suitability of Co-Extruded Tapes

Co-extruded tapes can only be used with pressure plates or framing sections with specific design features. They should not be used with components that do not incorporate an essential nib to key into the tape.

3.6 GLAZING ACCESSORIES

Glazing accessories include setting blocks, spacer blocks and backers for sealants.

3.6.1 Setting and Spacer Blocks

Setting blocks and spacers must support the weight of the glass units with little or no compression over long periods of time. EPDM, neoprene, silicone and some silicone - compatible rubbers with Shore A hardness of 70 to 90 are suitable for use. While most are provided as simple rectangular blocks, setting blocks may be custom designed to key into a specific glazing system.

3.6.2 Joint Backers

Joint backers are primarily cut or extruded low-density foam rods. The most common materials are closed cell polyethylene and open cell urethane. In theory, both materials serve the purpose as a joint backer but have quite different properties. The choice of one product over another is unfortunately left to the installer of the sealant as the installation of the sealant varies with the type of backer.

Closed cell, low-density polyethylene rods have a smooth skin and do not absorb water. If the skin is punctured during installation there is an outgassing of the blowing agent in the foam. Therefore if a sealant is immediately applied over a punctured rod, bubbles in the sealant will result. This possibility is the major reason some installers prefer open cell rods that, by their nature, do not outgas. However, if puncturing of the backer is avoided then the closed cell nature of the foam is advantageous in keeping water from being held close to the edge of the glass, particularly from sealed insulating glass units.

Open cell urethane foam provides a surface texture that some claim is easier to apply caulking over. Also water can flow through the foam if there is sufficient head. The open cell foams also allow some air circulation to the back of the sealant joint that can promote cure in some sealants. The foam structure will hold some water and there is a potential for water to be held against the edge seals of sealed units.

The joint backer rod will block or at least impede ventilation and water drainage behind a sealant joint. In some systems such as structural silicone glazing, drainage behind the exterior weatherseal joints is essential. In such cases, it is best to avoid the risk associated with a conventional joint backer. One way to avoid the risk is to use framing with a second drainage chamber behind the backer rod. A second way is to use an alternate joint backing material such as a linear, low-density polyethylene sheet. This material, if folded properly into the joint, provides proper sealant profile and a clear drainage/vent path.

3.7 SEALANTS

An overall design intent for contemporary curtain wall systems should be to minimize the reliance on sealants, particularly exterior sealants. Removal of sealants from the exposed exterior of the facade reduces cleaning requirements, removes a workmanship-sensitive element, and with most sealants, eliminates a future maintenance issue.

Nonetheless, there is always a need to seal metal-to-metal joints in framing elements, seal or provide backup seals to gaskets and to use sealants in water shed and remedial functions. Structural silicone glazing is a special case of sealant use (see Section 3.13).

There are many different ways of categorizing sealants. In considering glass and metal curtain walls one of the most important characteristics is the ability to accommodate cyclic movement. In categorizing sealants into low- , medium- , and high-movement ranges it is interesting that longevity and cost often fall into the same divisions. Low cost generally implies low-movement capability and short life.

Low Cost – Short Life

There is a tendency in the curtain wall industry to apply the lowest cost, lowest performance sealants in the location least accessible in the completed wall, for example at internal, sheltered backpan seals. While the internal sheltered seals will last longer than an exposed seal, eventual replacement of failed products is costly.

The following provides commentary on the suitability of sealants from each category for use in curtain wall:

Low-Range Sealants: Low cost, low-movement capability sealants have no place in modern curtain wall construction. These sealants include oil or resin based caulks, bituminous-based mastics and polybutene-based sealants. These sealants are generally composed of mineral fillers.

Medium-Range Sealants: Medium-range sealants have limited applications in curtain wall systems. The sealants used in these applications are the better low shrinkage butyl sealants and some polyurethanes. The use of butyl sealant is firmly entrenched in the curtain wall industry, although its use actually should be limited.

Butyl sealants are among the least expensive commercial grade sealants. They provide good adhesion to most metal substrates and require little surface preparation. Butyl is the only sealant that will reliably adhere to neoprene gaskets. As they are never used in exposed locations, UV resistance, while good, is of little consequence. Butyl sealants are low recovery products in that they accommodate movement by creep and deformation rather than by elastic tension or compression. Therefore they should only be used for non-moving joints such as backpan perimeter seals and joinery seals. Even then, it must be recognized that the current generation of butyl sealants will shrink in the order of 10 per cent to 15 per cent and crack/fissure as they age.

High-Range Sealants: **High-range sealants include silicones and polyurethanes. Silicone sealants are high recovery products accommodating movement by elastic extension and compression. They provide good adhesion to most curtain wall substrates although proper surface preparation is critical. Silicone sealants have excellent UV and ozone resistance and movement capability with some products of up to 100 per cent.**

Despite claims to the contrary, silicone sealants tend to attract atmospheric dust resulting in a dirty appearance. Some silicones release oils that can stain adjacent porous substrates. These issues have led to the development of non-bleed, non-stain silicone sealants. As all non-stain products are not equal, investigation or testing of specific products is warranted for any critical installation.

Urethane sealants are intermediate to high recovery products accommodating movement through a combination of elastic and plastic deformation. Good urethane sealants typically exhibit 70 to 90 per cent recovery. Urethane sealants provide good adhesion to most curtain wall substrates. They have good UV and ozone resistance and movement capability up to 50 per cent.

Silicone sealants are the most common choice for exposed or moving joints, although some curtain wall contractors do favour polyurethane sealants. Recognizing that all organic based sealants will eventually fail, some contractors are using silicone sealants for all joints. Different silicone formulations make this approach more cost effective. In some areas this requires a higher level of care but properly done provides a lower life cycle cost to the curtain wall system.

3.8 GLASS

Glass has a long history dating back to about 3000 B.C. Widespread window glass use began in 1916 with the introduction of the sheet glass process. The industry has evolved such that today essentially all architectural glass is produced by the float process.

The float process began by feeding molten glass into the top of a bath of molten tin. The glass floats in the tin forming a ribbon of uniform thickness and parallel surfaces. The glass is fed off the tin in a continuous ribbon into an annealing lehr where it is cooled at a controlled rate. The cooled glass is cut on leaving the lehr.

Wired glass is used in both vision and spandrel areas of curtain wall where fire ratings are required.

3.8.1 Structural Overview

Glass behaves differently to most other construction materials and as a consequence its design involves a number of special considerations. Glass can be used as a structural member as it is strong and rigid. Glass will behave elastically until failure. However, the brittle nature of glass results in dramatic fracture at either high stress or at a flaw.

The usual application of flat glass in curtain walls involved wind-loading perpendicular to the glass surface with the glass supported on two or four sides. In-plane forces arising from self-weight are relatively small and are carried in bearing or setting blocks. Sufficient edge clearance must be provided to prevent in-plane movements such as sway, racking, thermal movements or deflection from creating in-plane loads on the glass.

Fracture of glass can be caused by impact, bending, point pressure, and/or thermal loads. Given the brittle nature of glass, its load capacity is governed by the presence of cracks, defects and flaws at a point of critical stress.

Wind-Loading Breakage

Very little glass breakage is actually due to wind-loading alone. Examination of the break origin will often provide important clues as to the cause of breakage and the stress level that caused it. Frequently breakage is due to inadequacies in the framing or installation damage to the glass.

3.8.2 Glass Strength

Annealed clear glass is widely used in architectural applications. In many situations it has adequate strength to resist wind loads and some thermal loads. However, when used with coatings, tinted or used in insulating glass assemblies the thermal stresses rise considerably. Increased thermal stresses or inadequate wind load resistance of annealed glass leads to the use of heat-treated glass.

Heat treating of glass involves the controlled heating and cooling of annealed glass to impart residual compressive stresses at the glass surfaces and a compensating tension at the central region. The stresses in the glass are similar in character to that of pre-stressed concrete. All material characteristics remain the same except strength under static uniform load and resistance to thermal stress increases.

Heat-Treated Glass

The most common reason for heat treating glass is the need to increase resistance to thermal breakage. Heat-treated glass behaves as annealed glass with respect to deflection, thermal characteristics, colour, clarity and light transmission.

Heat-treated glasses are classified as heat strengthened or fully tempered. Heat strengthened glass has a surface compression between 24 MPa - 3,500 psi and 51 MPa – 7,500 psi. In the lower half of this range heat strengthened glass breaks like annealed glass into large shards. In the upper half of the range it has strength and breakage patterns characteristic of fully tempered glass.

Fully tempered glass has a surface compression of 10,000 psi – 69 MPa or more. On fracture fully tempered glass breaks into many smaller cubic fragments.

Relative Strength of Primary Glasses

Wired 0.5

Annealed 1.0

Heat strengthened 2.0

Fully tempered 4.0

Other properties to be considered in reviewing heat-treating processes include strain patterns, surface hardness, fabrication and distortions. A strain pattern is inherent in all heat-treated glass. This pattern is readily detected under polarized light conditions. While not a defect, it can detract markedly from the appearance of a facade.

Surface hardness is not altered by heat treatment. All glass fabrication must be completed before glass heat treatment. Cutting, grinding, drilling or sandblasting of glass after heat treatment may result in breakage.

Glass can be heat-treated in either a vertical or horizontal orientation. The horizontal process is most common today, but characteristically produces corrugations or waves in the glass. In the vertical process the glass is clamped by two tongs near one edge, so small indentations are caused by the tongs during the heating process. In either process some bow, warp or kink is inherent in the resultant heat-treated glass. This can be minimized with proper furnace set-up.

Distortion of Heat-Treated Glass

All heat-treated glass has some distortion. Governing standards are very liberal with respect to allowable tolerances for bow, warp or kink. Where these tolerances are not acceptable the specifications should identify closer limits. Heat-treated glass should not be used where undistorted view is critical, such as air traffic control towers.

3.8.3 Thickness Selection

Glass design or thickness selection in Canada is governed by CAN/CGSB-12.20-M89 *Structural Design of Glass for Buildings*. This standard is based on the limit states approach to design, where a factored resistance must be greater than or equal to factored loads. Design information in CAN/CGSB-12.20-M89 is based on four-sided support to the glass, which is the most common condition. Support other than four-sided requires special analysis.

3.8.4 Deflection of Glass

Deflection of glass is influenced by both bending and membrane action. Historically manual methods based on graphical techniques were used to determine glass deflection under loading. However, nearly all glass deflection evaluation is now done by computer simulation. While the deflection limits of glass supporting members are typically specified the actual deflection of the glass is often ignored.

Deflection of glass should be reviewed with respect to the following factors:

Aesthetic/Psychological	Glass deflection under wind load may result in aesthetic issues due to changing reflections on the exterior or feelings of instability by the occupant.
Structural	Excessive glass deflection may affect gasket and framing integrity even causing disengagement of gaskets.
Sealants	Deflection will result in effective span change exceeding the movement capabilities of sealants.
Safety	Deflecting glass may contact other building surfaces or framing elements.
Limits of Deflection	While strength is the primary consideration deflection implication should also be reviewed.

3.8.5 Factors that Impact Glass Performance

A number of factors impact the performance of architectural glass. These factors include:

- surface and edge condition
- size and shape of glass
- glass support
- thermal movement
- deflection of framing
- glass setting
- glass opening tolerances
- improper cushioning
- thermal stresses

Floating Glass

The design intent to maximize glass performance is to have the glass “float” in the framed opening. The glass is not free to move but fully cushioned and supported.

The following sections discuss each of these factors individually.

Surface and Edge Condition

The condition of the glass edge has a great impact on the resistance to thermal breakage of the glass. Under thermal (solar) loading the central portion of a lite of glass tries to expand but is held back by the cooler glass edges. This puts the edges in tension. Clean cut edges provide the greatest edge strength. Even very small defects on the edge of annealed glass lead to failure under thermal loading.

Surface damage due to concrete or weld spatter and wind-blown debris reduces the ability of the glass to resist uniform loading.

Surface and Edge Damage

Surface damage in the central portion of the lite, or within the region between the centre and any corner, results in the greatest strength reduction with respect to uniform load resistance. Edge damage, particularly at the centre of each edge, greatly reduces the lite's resistance to thermally induced stress.

Size and Shape

The greater the area of a lite of glass of given thickness the lower the ability to resist wind load. For a given area of glass load capacity varies with aspect ratio (height/width). The capacity increases as the glass shape becomes more slender. Therefore, to maximize wind load capacity, very large and square glass units should be avoided.

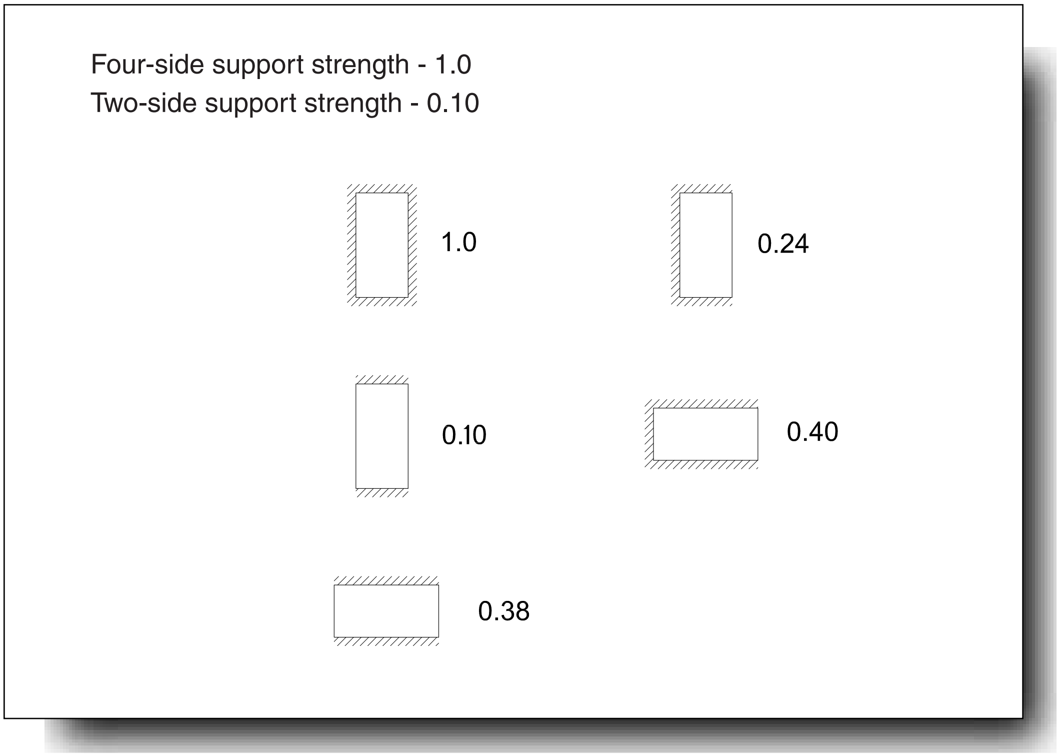


Figure 3.15: *Relative wind load resistance of different support conditions*

Glass Support

Glass resistance to wind loads is affected by the support at the glass edge. Glass supported on all four edges has the greatest resistance to wind load. For example, if one considers a rectangular piece of glass approximately 2.5 m^2 (25 sq. ft.) in area the following table illustrates the relative wind load resistance of different support conditions.

> ***Thermal Movement***
>
> Cyclic heating and cooling of a curtain wall system can result in the glass "walking" laterally in the framing system. This action is more common with dry glazing systems. If the glass moves sufficiently a vertical edge may contact metal framing causing edge damage or actually disengage resulting in a three-sided support condition.

> ***Glass Walking***
>
> Where dry-dry glazing systems are used edge blocks are recommended to limit the lateral "walking" of the glass.

Deflection of Framing Members

Most glass strength information is based on the framing members at the glass edge not deflecting more than the span divided by 175 or 19 mm (3/4 inch), whichever is less. Framing deflections must not exceed this limit or the glass edge begins to behave as unsupported.

In-plane deflection of horizontal framing must be limited to 3 mm (1/8 inch) or 25 per cent of the design edge clearance. Deflections greater than this limit can cause point loading on the glass edge and reduce bite of the glass edge.

Twisting of the horizontal framing must also be limited to prevent mechanical stresses on the glass. In most cases twist is limited to 1˚.

> ***Twisting under Load***
>
> Due to the eccentric nature of glass loading to the horizontal framing member twist under wind and inplane loading must be checked and limited to approximately 1º.

Glass Setting

Glazing guidelines are almost universal in their recommendations with respect to the positioning of setting blocks.

Positioning of the setting blocks along the glass edge as illustrated, has resulted in good glass performance over time. Aside from their position along the glass edge setting blocks must also be positioned to support the entire thickness of the glass, including both lites in an insulating glass unit.

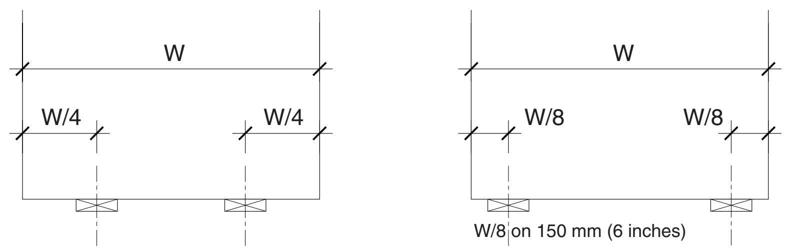


Figure 3.16: *Figure shows position of setting block*

Tolerance of Glass Opening

Corner offset, framing member bow and out-of-square openings can result in mechanical stresses being imposed on the glass and increased probability of breakage. Offsets, between intersecting framing members at the corners, more than 0.75 mm (1/32 inch) can create localized bending stress in the glass. An inherent bow or kink in a framing member in excess of 1 mm (1/25 inch) in a 1 m (3.25 feet) length can also create localized bending stresses or point loading at the glass edge.

Out-of-square openings or "racked" frames can result in uneven bite at the glass edge and, in the extreme, lack of glass edge support. Contact with the metal frame is also possible in a severely racked frame. For typical glass sizes (approx. 2.5-3 m^2 (25 - 30 sq. ft.) differences in diagonal measurements should be limited to 3 mm (1/8 inch)

Glass Cushioning

Face clearance for the glass should be provided by a continuous gasket or spacer. Use of intermittent shims, promoted by some suppliers, should be avoided as they create local pressure points in the glass. The type of gasket or spacer will depend on the type of glazing system chosen.

Thermal Stresses

Thermal stresses, primarily caused by solar exposure but also due to heating and ventilation systems, are one of the major causes of glass breakage. Typically, as the central portion of a lite of glass expands on heating the cooler edges are placed in tension, much as an elastic band around an inflating balloon. The glass's ability to resist breakage is then governed by the condition of the glass edge.

When conditions indicate the potential for high thermal stresses, heat-strengthened glass can be used to reduce the potential for breakage.
Some conditions that lead to increased thermal stresses in glass include:

- **Glass tint** - Heat absorption increases as the degree of glass tint increases. In general glass stress increases as one moves from clear to green to bronze to gray.
- **Glass coatings, add-on films** - Reflective coatings, visible or invisible (low-e), applied to the number 2 or 3 glass surface increase the temperature of the glass by re-radiating heat to the glass. Coatings may double or even triple the glass stress. Analysis of specific combinations of tint and coating is required to assess breakage potential. Add-on films also act to re-radiate heat or increase heat absorption.
- **Excessive bite -** Excessive glass bite can increase thermal stresses by increasing the center-to-edge temperature differential. Increasing the amount of glass that overlaps the framing increases the risk of thermal breakage of the glass.
- **Inadequate face or edge clearance** – Face-and-edge clearance assist in thermally isolating the glass from the framing members. The inherent low conductivity of most exterior gasket materials results in warmer glass edges and less of a temperature differential between the centre of the glass and the edge.
- **Interior heat traps -** When interior air circulation is inadequate to remove heat built up behind the glass a heat trap is created. This can cause a rise in temperature and an increase in thermal stresses.
- **Interior shading and heat outlets -** Interior shading such as Venetian blinds, roller shades and draperies contribute to heat traps. The insulating effect of the air between the glass and the shading reduces the heat the glass can release thus increasing glass temperature.
  At night in cold climates, closed shading results in lower glass temperatures by blocking heat flow to the glass. This can contribute to condensation issues as well as thermal shock when a setback heating system restarts in the morning.
- **Framing system -** Framing systems of low heat capacity, such as aluminum, tend to minimize edge stresses. However, when lightweight framing is thermally connected to materials such as concrete with a high heat capacity greater stresses are created. Of greatest concern is where an aluminum frame is cast into a precast concrete panel.
- **Exterior shading -** Shadows cast by extended snap caps, balconies, canopies, columns, adjacent buildings or intentional shading systems can create a variety of different patterns of shade on the curtain wall glass. The particular pattern and the area of the glass covered, when combined with other factors already discussed, can result in critical thermal stresses.

Glazing manufacturers are willing to assess designs with respect to anticipated thermal stresses. It is prudent to have the above conditions assessed well before a project design is completed.

3.9 FABRICATED GLASS PRODUCTS

The primary fabricated glass products used in curtain wall systems are insulating glass units and laminated glass.

3.9.1 Insulating Glass Units

Sealed insulating glass (IG) units are made of two or more lites of prime glass sandwiching an edge spacer to create an hermetically sealed air space. The air space is dehumidified by a desiccant contained in the edge spacer and may contain either air or an inert gas. Originally developed to avoid cleaning the two surfaces of a double-glazed window, IG units are now the standard vision unit in most Canadian curtain wall systems.

The three basic components which form an IG unit; the glass; the edge spacer; and the edge sealants are available in a wide variety of forms that can be assembled in an even greater variety of combinations. Glass types are selected to provide certain visual effects and performance characteristics. Spacers and sealants are primarily selected based on performance characteristics.

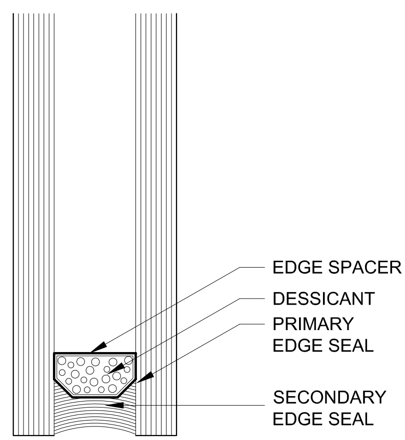


Figure 3.17: *Sealed insulating glass units*

3.9.1.1 Glass

Annealed and heat-strengthened glass are the most common glass types used in IG units. The decision to heat-strengthen is primarily based on either wind-load conditions or thermal loading in the glass created by tints, coatings or shading patterns. Fully tempered glass is used in special applications but should be avoided due to an increased risk of spontaneous breakage due to inclusions, increased distortion and a tendency to fall from the opening when broken. The strain pattern, visible under certain lighting conditions, is an inherent feature of both fully tempered and heat strengthened glass and should not be considered a defect. While not a defect it can detract from the wall appearance and samples should be viewed prior to construction.

Wired glass may be required for fire code compliance. However, IG units using wired glass should be avoided and unsealed double-glazing used in-lieu. Laminated glass is routinely used in IG units with no detrimental effects.

Glass thickness is again primarily based on wind-load considerations — however, varying thickness can change the aesthetic effect of tinted glass. Glass thickness variations in an IG unit can also be used to reduce distortion of reflected images in coated glass and reduce sound transmission by decoupling the natural frequencies of similar thicknesses of glass.

Common glass tints are green, bronze, grey and blue. The depth of tint varies with the thickness of the glass and manufacturer. Tinted glass can be combined with reflective glass to give different appearances.

Coating technology is a rapidly advancing field. Glass coating for IG units consist primarily of very thin pure metal or metal oxide layers applied to the glass. Coatings such as cobalt, iron, chrome and tin are often applied pyrolytically. Pyrolytic coatings are applied to the glass raised to near its melting point and fuse to the glass surface to become part of the glass as it cools. Pyrolytic coatings are termed hard coats and have excellent durability and can be used in single-glazing. Coatings such as silver, copper, chrome, titanium or stainless steel are applied by magnetic sputtered vacuum deposition and are termed soft coats. Soft coats are susceptible to scratching and corrosion and must be sealed within the air space in the IG unit (surface 2 or 3).

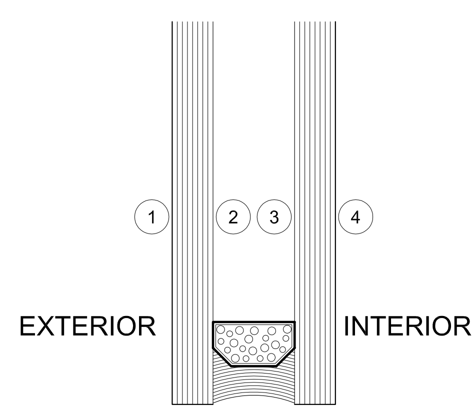


Figure 3.18: *Sealed insulating glass units*

Reflective or low-emissivity coatings can be applied as either hard or soft coat products. Reflective coatings are mirror like and act as solar control products reflecting heat back to the exterior. Low-emissivity products are essentially low-reflective products that reflect heat back to the warmer side whether reducing solar gain or retaining interior heat. The maximum size of coated glass products is 2,435 mm (8 feet) by 3,655 mm (12 feet).

Why Low-Emissivity?

The amount of heat transferred by radiation across an air space depends on the temperature of the two facing surfaces and the emissivity of the surfaces. Emissivity is a measure of the amount of radiation of a specific wavelength given off by a surface when compared to a perfect radiator. If a surface has a low-emissivity the heat loss from the surface by radiation will be reduced.

Why Argon?

About 25 per cent of the heat flow in an IG unit is by conduction. One means of reducing the conduction is to replace the air in the unit with a gas of lower heat conductance. Argon is the most popular gas fill due to its availability, low cost, UV stability and non-corrosive nature. It is colourless and non-toxic. Krypton is the second most common gas used only where narrow air spaces are required.

3.9.1.2 Spacers

A variety of proprietary spacer materials and profiles are produced. The most common is the aluminum spacer with other types including galvanized steel, stainless steel, thermally broken aluminum, fibreglass, silicone foams and organic spacers. The particular shape of the spacer is dictated by the assembly method (automated or manual) and the sealant type. Aluminum spacers are provided in either a standard mill finish or can be clear or colour anodized to match framing elements. Seams of aluminum spacers allow ventilation to the desiccant within the spacer. Corners of spacers are formed by bending or the use of keys.

Research has identified the spacer as a major contributor to heat flow at the unit perimeter. This has led to the development of “warm edge” technology and thermally improved spacers. Aluminum spacers incorporating thermal breaks, single-wall stainless steel spacers and silicone foam spacers have all been developed to address the issue of edge conduction.

Organic spacers are formed from co-extruded butyl based tape with an integral strip spacer and a molecular sieve desiccant. Spacers of this type are not recommended for curtain wall applications.

3.9.1.3 Edge Sealants

Architects routinely specify the type of edge sealant for use in IG units, often with little regard for the characteristic strengths or weaknesses of the different sealants. Common sealants used in IG unit edge seals include:

- polyisobutylene (PIB)
- hot melt butyl
- polysulphide
- polyurethane
- silicone

IG units are produced with both single-and double-seal designs. Single-seal designs rely on a single edge sealant to hold the unit together and to provide a barrier to vapour flow into the unit air space. Hot melt butyl, polysulphide and polyurethane can be used for single seal units. Dual-seal units employ a primary sealant as a barrier to vapour flow and a secondary sealant to hold the unit together. Polyisobutylene (PIB) is the universal primary sealant. Secondary sealants include hot melt butyl, polysulphide, polyurethane and silicone.

As curtain wall and glazing units have evolved single-seal units have become uncommon in the commercial and institutional sector. Hot melt butyl secondary seals are also used primarily in the residential market. As such, the principal secondary sealants in use in contemporary curtain wall are polysulphide, polyurethane and silicone.

3.9.2. Laminated Glass

Laminated glass is formed by bonding two or more plies of prime glass to a clear or coloured plastic interlayer (commonly polyvinyl butral PVB). Although it has other properties, the primary reason for using laminated glass, either alone or as part of an insulating glass unit, is its behaviour after glass breakage. After glass breakage the tough plastic interlayer tends to hold the glass fragments in place reducing the risk of injury. This specific behaviour qualifies laminated glass as safety glazing (CGSB/CAN2-12.1-M).

The post-breakage behaviour of laminated glass is leading to its increased use in curtain walls as a means of reducing injury and property damage as the result of both natural and man-made disasters. For example, laminated glass is seen as a passive response to the risk of bomb blast injury provided the glass is properly glazed into the frame.

Aside from the post-breakage behaviour, laminated glass provides important sound reduction properties that can be useful in curtain wall near airports, train stations or busy streets (see Chapter 4). The plastic interlayer also acts to block UV transmission and is available in colours to provide specific aesthetic effects. Care must be taken to avoid exposing the edges of the glass and the interlayer to silicone or solvent containing sealants (acoustic sealant). Exposure can result in the discolouration of the interlayer and slight delamination.

3.10 SPANDREL GLASS

Spandrel glass is a specific spandrel panel product and likely the most common spandrel material. In accordance with CGSB/CAN2-12.9-M, spandrel glass is classified by type, class, style and form.

Unless overruled by very specific requirements, fully tempered glass should not be used as spandrel glass. Heat-strengthened glass is usually adequate from a wind load and thermal load perspective. Fully tempered glass brings the risk of spontaneous breakage due to inclusions, increased distortion and a tendency to fall from the opening when broken even when a backing scrim is applied. The strain pattern, visible under certain lighting conditions, is an inherent feature of both fully tempered and heat-strengthened glass and should not be considered a defect. Fully tempered glass must have a backing scrim applied to hold the small fragments of glass together after breakage. Scrim should be applied to heat-strengthened glass as an added safety precaution.

Class

In all but very special cases all spandrel glass should be considered Class A - float.

Style

The style of spandrel glass refers to the type of coating applied to the glass. Ceramic coatings (Style 1) are available in a range of colours and are fused at high temperatures into the surface of the glass. Ceramic coatings are very durable but can be subject to thickness variations impacting colour consistency. Reflective coatings (Style 2) are applied to the glass in a similar manner to IG units although a protective film must usually be applied to protect the coating. Reflective coatings are durable but more sensitive to moisture and pollution than ceramic coatings. Organic coatings (Style 3) form the third style and include a variety of paint type products. As many coatings are not truly opaque, a backing film or opacifier (that often doubles as an anti-fallout scrim) is often used to block any reflected light from behind the glass and provide a more consistent colour.

Form

Monolithic (Form M) is the most common form of spandrel glass and the most recommended. It is the simplest and most durable of the spandrel glass products. Form I, which includes insulating glass units, is used where a closer match is sought with the vision lites. However, this closer match is obtained at significantly greater initial cost as well as long-term maintenance cost. Laminated glass (Form L) sees very limited use as spandrel glass in Canadian curtain wall designs.

3.11 SPANDREL PANELS

Opaque spandrel infill panels can be broadly classified as either metal panels, stone panels or other materials such as fibre reinforced plastics, ceramics, etc. In a contemporary curtain wall the spandrel panel is a cladding or screen element and is backed by a ventilated air space, insulation and a metal air vapour barrier system. As such, insulating value is not a prime requirement of the panel. Lightweight panels are generally glazed into the opening in the framing grid much as spandrel glass. Heavier weight panels, such as stone, require separate fixing. As with spandrel glass, the spandrel panel is subject to wind-loading. This loading may be reduced somewhat by partial pressure equalization of the cavity.

3.11.1 Metal Panels

Metal panels form the most common spandrel infill after spandrel glass. The metal panel may exist as either a formed plate such as aluminum on a composite sandwich panel composed of steel or aluminum face and/or back sheets and a core.

Plate Aluminum

Formed, 3 mm (1/8 inch) thick aluminum plate is the most common metal panel material. The aluminum can be supplied anodized or painted to match or contrast the framing grid system. Depending on panel design it is either clamped into place at its edges much like an IG unit or held in place with discrete clips. Panel design varies with application and panel designer but a number of issues require careful monitoring.

Panel size and shape are limited by the maximum plate size and the facilities of the painter and fabricator. As panel size increases, so does the need for stiffeners and potential for panel distortion. Stiffening is done by either folding an edge or by attaching a stiffener rib by welding or by welding aluminum studs and then mechanically fastening the stiffener to the plate. Aluminum stud installation requires close quality control and careful design as failure of the aluminum studs under cyclic loading is not uncommon. Stainless steel nuts must also be used with aluminum studs. Panel stiffening also accentuates potential distortion of the panel.

Waviness or “oil-canning” is a common complaint of solid panels. The distortion is often emphasized by stiffeners and edge clamping. Distortion can also develop over time. Review of the panel design and installation method, along with the construction of a mock-up panel is recommended to help resolve distortion issues early in a project.

The thickness of the plate aluminum results in noticeably radiused corners. This is a function of the material and must be considered in the architectural design.

Composite Sandwich Panels

A wide variety of composite panels are available with cores ranging from 4 mm thick PVC to 100 mm (3/16 to 4 inches) thick aluminum honeycomb. The physical properties of the panels vary widely as does their applicability to certain design and jurisdictions. Two of the more popular composite panel types include solid plastic covered panels and aluminum honeycomb cored panels.

Solid Plastic Cored Panels

Solid plastic cored panels vary in thickness from 4 mm to 8 mm (3/16 to 3/8 inch). The panels are made with coil coated aluminum sheet facing and backing sheets either integrally bonded or adhesively bonded to a rigid plastic core. The coil coating process provides for great consistency of colour. The face sheets are thin and fabrication methods allow for very sharp corners.

The properties of the plastic core vary widely with different manufacturer, particularly with respect to fire resistance. In considering exterior flame spread the thin aluminum face sheet provides little protection to the core material. Most core materials burn when exposed to flame but are self-extinguishing once the flame is removed. Some core materials will continue to burn after ignition. It is important to review the characteristics of the particular cores and ensure compliance with local jurisdictions particularly where high-rise buildings are being considered.

Honeycomb Cored Panels

Aluminum honeycomb cored panels are generally 12 mm to 25 mm (1/2 to 1 inch) in thickness and consist of thin aluminum face and backing sheets adhesively held to the core. These panels can be made very flat, stiff and strong. Oil canning distortion is rare. Specialized fabrication and assembly techniques are employed with this type of panel.

3.11.2 Stone

The most common stone used in curtain wall is granite. More porous stones, such as marble or limestone, are not recommended for curtain wall applications. Granite is available in a range of colours, will take a variety of finishes, has a relatively low coefficient of expansion, and has high strength and hardness. Stone is a natural material and, as such, is subject to faults such as fissures, cracks and inclusions that impact the strength and durability of the stone as well as its appearance.

Unlike other stone cladding assemblies, the overall dimensions of the stone are critical in a curtain wall assembly. The close tolerances of the supporting frame assembly require a close tolerance on the stone dimensions. Thickness is of particular concern. The position of the stone in the frame is usually set from the stone face to ensure proper alignment. Too thin a stone will result in strength loss while too thick a stone may prevent proper alignment.

Depending on the desired architectural appearance the stone panel is either glazed and capped like a piece of spandrel glass or more commonly sits proud of the framing to appear as a continuous band. If the stone is set proud of the framing discrete anchors are used. A designer will select from one of a number of common anchor types, such as kerf anchors, proprietary mechanical anchors and adhesive anchors.

Given the variability in stone strength, all anchor designs must be qualified by physical testing. Normal safety factors associated with stone design must be used. Regardless of claims of pressure equalization, the stone anchors must be designed for the full wind load and checked for seismic inertial loading.

3.12 FINISHES

A variety of different finishes have been and are being used on curtain wall framing and spandrel panels. The primary finish systems include anodizing and organic coatings. Porcelain enamel coatings, once very popular for spandrel panels, still see some use.

3.12.1 Anodizing

Anodizing remains the most popular finish for architectural aluminum. Anodizing is an electrochemical process that converts the surface of aluminum to aluminum oxide. The process creates a coating that is much thicker and harder than the aluminum oxide that naturally occurs on aluminum. Anodized surfaces are available in a range of colours and the finish provides a depth of colour and reflectivity that is not reproduced by other finishes.

The Aluminum Association Designation System for Aluminum Finishes designates two classes of architectural finishes based primarily on coating thickness. Class I finishes have a minimum thickness of 0.017 mm (0.7 mil) and Class II finishes have a thickness of 0.01 to 0.017 mm (0.4 to 0.7 mil). Only Class I finishes are recommended for exterior applications.

Practical considerations for the use of anodized finishes:

<u>Form before anodizing</u> Class I coatings are brittle and except for very thin material forming should precede anodizing. The coating at a fold will crack exposing a bright line, which is the base metal.

<u>Uniformity of appearance</u> Even with careful quality control some variation in appearance should be expected. The translucent nature of the surface reflects light differently when viewed from different angles. As such, panels for example must be installed in the same plane with the same grain or rolling direction to enhance uniform appearance. It is best to ask for a sample range to set a standard.

<u>Welds</u> Welding will generally cause discoloring in and around the weld as well as in the opposite face. This is due to the local effects of heat and alloy change. Welds should be carefully positioned to minimize any visual effects.

<u>Installation damage</u> Alkaline building materials can stain or locally fade anodized finishes if left on the surface for a long time. Like all finishes anodizing can be damaged by harsh chemicals and abrasion.

3.12.2 Organic Coatings

Organic coatings are applied surface finishes as opposed to the integral finish provided by anodizing. The broad definition of organic coatings includes a wide range of products applied as liquids or powders. Given the exterior exposure conditions of curtain walls only high performance coatings complying with AAMA 605.2 *Voluntary Specifications for High Performance Organic Coatings on Architectural Extrusion and Panels* are recommended. The high performance coatings most often recommended are polyvinylidene fluoride (PDVF) based two- ,three- , or four-coat systems. These coatings, also called PVF^2, fluoropolymer and fluorocarbon, are among the most stable resins known and offer high performance, UV resistance, high durability and moderate abrasion resistance. The base resins are manufactured by only a few suppliers and provided only to licensed applicators.

The PDVF coatings are applied by either airless or electrostatic spray to extrusions and small parts, or roller to large sheets or coils of material.

Powder coating, while popular in Europe for over 20 years, is relatively new in North America and currently represents only about 10 per cent of all finishing applications. Powder coating, unlike solvent containing organic coatings, contains no solvents and releases negligible amounts of volatile organic compounds (VOC) into the atmosphere. With the drive to eliminate the release of VOCs and increasingly stringent air pollution control legislation, the use of powder coating is expected to steadily increase. Improvements in powder coating technology have resulted in finishes that rival the durability of PDVF coatings. Powder coatings possess moderate to high abrasion resistance.

Powder coating involves the spraying of a fine, dry plastic powder paint onto the aluminum surface. The paint powder is charged with static electricity that attracts the paint to the metal surface. The coated paint is then heated in an oven where the powder paint melts and flows to a smooth surface.

Practical considerations for the use of organic coatings

Size and length In designing the wall, the size limitation of the painting facility must be considered. Decisions regarding pre- or post-painting of assembled parts should also be made early in the design process. Welded parts must be post-painted.

Design of parts Custom profiles that match an architectural intent may result in uneven paint coating or excessive paint buildup. Deep recesses and sharp inside corners can create difficulties and this should be recognized in the design.

Compatibility and adhesion of sealant The adhesion of sealants, particularly structural silicone glazing, is very dependent on the type and consistency of the finish. It is critical that compatibility and adhesion of sealants be verified in production coating materials. Even changes in colour of a given coating can impact adhesion.

Tests Visual checks of the coating are not a reliable means of assessing the quality of a coating and its application. Quantitative procedures such as film hardness and adhesion, resistance to chemicals, corrosion, weathering and fading and impact resistance must all be specified and verified.

Touch-up The original coating application can usually provide air dry touch-up finishes that provide an appropriate match to the factory applied finish. Some difference in gloss and colour should be expected and touch-up materials do not weather as well as factory applied finishes.

3.12.3 Porcelain Enamel

Porcelain enamel finishes are vitreous inorganic coatings that are bonded to metal by fusion at high temperature (800˚F). Porcelain enamel coatings are the hardest and most durable architectural metal finishes. Due primarily to cost consideration, the use of porcelain enamel for architectural finishes has steadily declined.

Practical consideration for the use of porcelain enamel finishes

Brittle nature The glass-like character of the coating is brittle and lacks flexibility. Any deformation of the panel can result in cracking and spalling. Repair of spalled areas is difficult.

Coverage Uniform coverage of points with sharp corners or inside corners is difficult. Inside corners where the porcelain might accumulate can shrink and crack on firing.

Warpage Due to the high firing temperatures warping of light gauge sheet or parts may occur.

3.13 STRUCTURAL SILICONE GLAZING COMPONENTS

Structural silicone glazing (SSG) is a specific glazing method where the glass is adhesively held in the framing, on either two or four edges, with a structural grade silicone sealant. The method is properly part of a glazing system but many of the components are unique to the system or require more attention than batten or stop glazing.

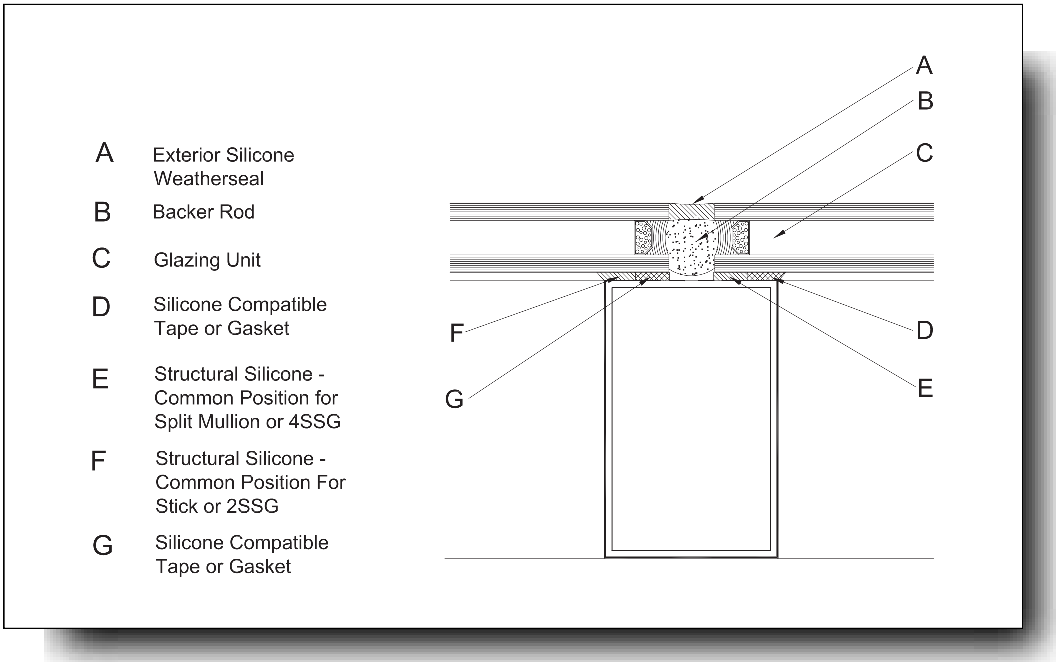


Figure 3.19: *Cross section of SSG for stick and unitized section*

3.13.1 Framing

All of the comments regarding curtain wall framing including alloys, corrosion potential, and galvanic reaction, mentioned in Section 3.3, apply to framing for structural glazing systems. Differences lie in the method of retaining the glass. Stick systems field glazed (two-sided SSG) should be designed for application of sealant from the interior as shown in Figure 14. The finished silicone bead forms the interior gasket. The frame section must present a smooth flat surface for the silicone to bond to along with some means of clamping the glass temporarily until the silicone cures. The cure time varies with sealant and weather conditions. Manufacturer standards recommend 21 days of curing to achieve full strength. Removal of temporary clips prior to 21 days can be done with approval of the sealant manufacturer.

In unitized systems, incorporating either two- or four-sided SSG, the silicone is applied from the outside as there is clear access before the mating sections are joined (Figure 24). In both stick and unitized systems the mullion head must have provisions for either gasket or foam tape application.

3.13.2 Gaskets and Tapes

The primary purpose of gaskets or glazing tapes in an SSG system is that of a spacer to hold the glass at a set distance from the framing. This controls the thickness and, along with the gasket/tape position, the profile of the structural silicone sealant bead. The gasket or tape may also function as a finished edge as in the case of an interior gasket.

The most critical characteristic of the glazing gasket or tape in an SSG system is its chemical compatibility with the structural silicone sealant and the silicone weather seal. Given the importance of the long-term integrity of the structural silicone bead no chemical incompatibility is acceptable. The major silicone manufacturers have developed a series of standard tests to evaluate the potential for chemical incompatibility between the silicone and any contacting material, in this case the gasket or tape. These tests have been formalized into ASTM C-1087-95. The tests are conducted on production run materials and take approximately four weeks to complete.

The most common material for extruded glazing gaskets on SSG systems is silicone. While verification is required, silicone gaskets are of the same basic material as the structural silicone bead and this results in a low-risk of incompatibility. The most common glazing tape is a dense polyurethane foam manufactured with adhesive on one or both sides. The adhesive is used to temporarily hold the tape in position until the glass is installed and the silicone sealant cured. Unlike the silicone gasket, polyurethane is from a different chemical family and only certain formulations provide the necessary compatibility. The major silicone manufacturers prequalify specific polyurethane tapes made by specific manufacturers. Even though some tapes are prequalified, testing of all tapes should still be conducted to verify compatibility.

3.13.3 Glazing Accessories

As with the gaskets in an SSG system, chemical compatibility of all glazing accessories that might contact the silicone sealant is a prime requirement. The setting block and backers to the silicone weather seal are the main elements of concern.

The setting blocks must possess the same qualities as outlined in Section 3.6 in addition to chemical compatibility with the structural silicone. This leads to the use of either silicone or silicone-compatible rubber setting blocks. Compatibility testing is conducted in the same manner as for gaskets and tapes. In addition, it is necessary to confirm compatibility of the setting block with the silicone edge seal of the insulating glass unit.

Backer rods or folded membranes used to support the silicone weather seal also require compatibility testing as outlined above.

3.13.4 Structural Silicone Sealants

As the name of the system, structural silicone glazing, implies **only** structural grade silicone sealants are acceptable for structural glazing. Inorganic silicone sealants are the only materials with the necessary properties of strength, durability and adhesion for use in a load carrying structural role.

Structural silicone adhesives are produced in one- or two-part formulations. One-part sealants are used for field applied two-sided applications and for glass-to-glass weather seals. Two-part sealants are used in shop applied two- or four-sided applications where particular control of cure time is required.

Aside from production issues such as shelf life, tack free time, cure time, gunnability, viscosity, etc., the two characteristics of prime concern with respect to structural silicone are the cohesive and adhesive strengths of the material. The design goal with SSG is to ensure that failure, if it occurs, happens cohesively at a predictable level rather than adhesively at an unpredictable level.

The cohesive strength of the silicone is dependent on the formulation and cure mechanism of the sealant. The strongest sealants are not necessarily the best choice due to their high stiffness and high resultant bond line stresses. Also the cure mechanism of high strength sealants can release volatile compounds into the glazing cavity. Acetoxy cure (vinegar smell) silicones should not be used in structural glazing for this reason.

Adhesive strength is a property dependent on the nature of the sealant but is heavily influenced by the condition and type of surface to which the sealant is applied. Silicone sealants bond tenaciously to clean uncoated glass substrates due in part to the common silica base of the two materials. Adhesive failure, where observed in the field, occurs almost exclusively on the other bonding surface. Contaminants on this surface, along with the type of finish (see Section 3.12), affect the bond.

3.13.5 Fabricated Glass Products

Insulating Glass Units

The edge seal of insulating glass units used in structural silicone glazing vary in two important aspects from non-structural silicone glazing. The secondary seal of the unit must be of silicone sealant. Silicone is the only edge seal material that has demonstrated adequate durability (particularly with respect to UV resistance) and strength for this application. The second variance with typical IG units is the width of the secondary seal. The seal must be designed for a defined portion of the wind load, over and above the dimension needed to accommodate normal internal stresses in the IG unit. This usually results in a secondary seal at least 6 mm (1/4 inch) in width.

The combination of silicone secondary seal and a designed width to accommodate wind loads results in the exclusive use of dual sealed silicone units.

The architectural design intent in the use of SSG is often to present the appearance of larger or continuous lites of glass. The weather seal, IG edge seal and the framing behind creates a dark band at the SSG joint (mullion or rail). The use of standard aluminum edge spacers results in highly visible streaks of light coloured metal at any variation in the width of the primary seal when the wall is in bright sunlight. As such, the use of black anodized spacers is recommended for SSG walls.

Laminated Glass

Laminated glass lites, used either alone or as the inner lite of an IG unit are common in SSG systems. The configurations or constituents of the laminated glass do not change in SSG — however — a caution must be raised regarding the appearance of the edge of the lite at the weather seal where the edge is exposed to view. Most silicone sealants cause minor isolated delaminations of the vinyl interlayer at the glass edge. These delaminations usually only extend 1 to 3 mm (1/25 to 1/8 inch) in from the edge. They are normally not progressive and are of no structural significance. However, the edge imperfections may become a significant aesthetic issue.

Tinted or Coated Glass

Tinting of glass has no effect on SSG. In contrast, coating on glass can have a significant effect on the structural silicone bonding of the glass to the framing and on the edge seal of the unit if the silicone must bond to the coating. If this occurs, the bond of the coating to the glass becomes part of the load path at the unit edge. Given the likelihood of an inconsistent bond of the coating to the glass or of the silicone to the coating, all coatings must be “edge deleted” over the width of the silicone bond line.

At the edge seal of the unit any coating on the inner glass surfaces must also be edge deleted at the bond line of the secondary seal. Also in SSG systems where the edge seal is exposed, coatings should be deleted over the width of the primary seal. Despite manufacturers claims that there is no functional reason to do this, most coatings when in contact with the primary seal reflect light differently and create an aesthetic issue at the glass edge.

3.13.6 Spandrel Glass

Spandrel glass components in an SSG system must comply with all the requirements of spandrel glass in general. In addition, as discussed in 3.13.5, any coating applied to the inside surface of the glass must be edge deleted over the width of the structural silicone seal. Any coating applied to the spandrel glass must also be tested and verified as compatible with the silicone sealant.

SSG and Finishes

Regardless of prior experience with adhesion to a particular coating, laboratory and field adhesion testing of the structural silicone must always be conducted.

3.13.7 Finishes

As the structural silicone sealant must bond to the finish on the framing member, the finish plays a major role in the integrity of the bond. The silicone must bond to the finish and the finish must bond structurally to the aluminum.

In the first case all aluminum used in SSG systems must be finished. The natural oxide surface of mill aluminum is too variable and contaminated with oils to allow consistent silicone bond.

Anodizing and organic coatings form the principal finishes used with SSG systems. In all cases the adhesion to these finishes must be verified by standard testing. This testing is carried out on production run samples in the laboratory before the finish is approved for use and in the field as a continuing quality control procedure.

Adequate adhesion can be obtained with both anodized and coated surfaces. However, it is imperative to always check adhesion. It must not be assumed that because the same type and brand of coating is being used and only the colour is different that proper adhesion will be attained. The different pigments used to produce different colours or shades can markedly change the adhesive strength of the silicone sealant. Changes in coating formulation over time, even of the same colour, can also impact adhesion.

Chapter 4

PERFORMANCE-THEORY AND PITFALLS

4.1 FUNCTION OF WALL

In traditional building facade design the facade is considered a sealed skin or envelope. This envelope separates the variable and uncontrollable exterior environment from the more consistent and controllable interior environment. The efficiency of the envelope is measured by its ability to provide the separation. Most current quantitative standards aim at measuring this efficiency.

The traditional separation or envelope concept of facade design does not truly apply to glass and metal curtain wall nor is it consistent with the growing trend toward green buildings. Green building design considers the building facade more as a *filter* than a *barrier*. It moderates between the external and internal environments, as illustrated in Table 4.1. The concept of the exterior wall as a filter is not new but is achieving a resurgence.

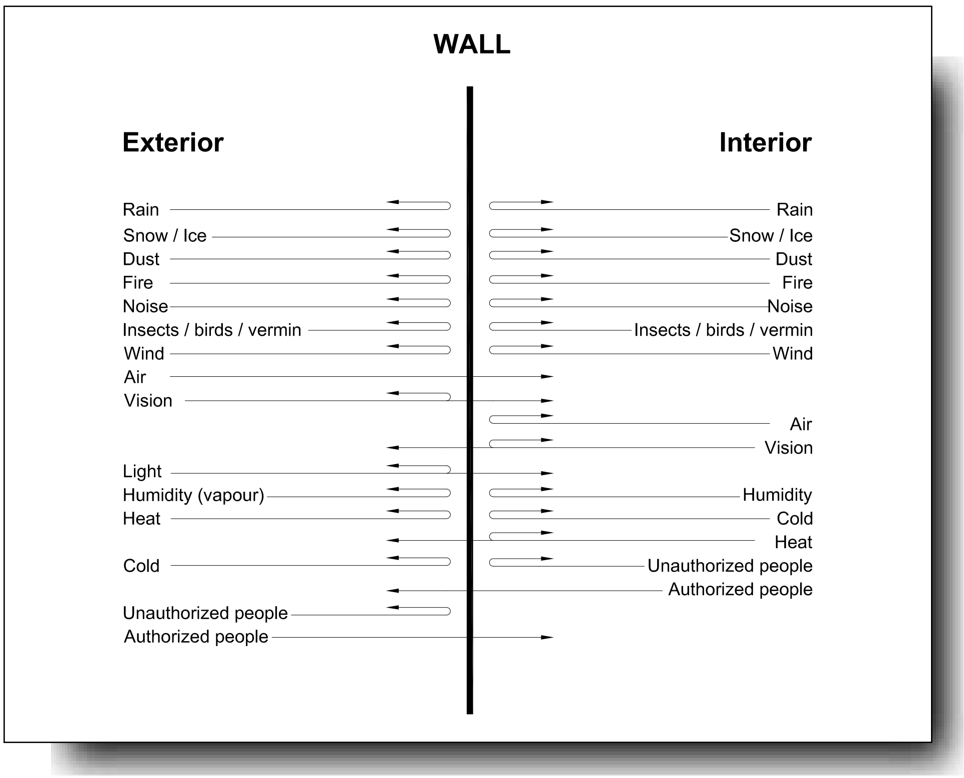


Table 4.1: *Wall as a filter*

Glass and metal curtain wall systems should more properly be considered a *selective* filter as they must provide a barrier to some effects and allow passage of others as illustrated in table 4.1. Glass and metal curtain walls have always filtered light and heat primarily through the glazed portion of the assembly. With spectrally selective glass products this filtering can be controlled and optimized. The addition of operable vent elements further supports the filter concept by allowing local control of air supply and movement. While filtering light, heat and air, the wall must clearly provide a barrier to rain, wind, snow and unauthorized persons.

The concept of the wall as a filter is not unique to metal a curtain wall. However, unique features of metal curtain wall technology mean the design of these walls requires attention to matters which normally receive little attention in traditional wall assemblies. The same physical laws and internal and external loads apply but how they react with, and impact, the wall assembly is often different. As such a discussion of the performance parameters specifically affecting the function and performance of the glass and metal curtain wall must include:

- structural integrity
- control of water penetration
- control of air leakage/air flow
- control of water vapour flow
- control of heat flow
- condensation resistance
- control of sound transmission
- control of fire

4.2 STRUCTURAL INTEGRITY

As structural integrity relates to life safety it is the primary concern of curtain wall design and is one of the few aspects of wall design which is codified in detail. In Canada, the primary standards related to curtain wall design referenced in the National and Provincial building codes are:

CAN/CGSB-12.20-M *Structural Design of Glass for Buildings*
CAN3-S157-M *Strength Design in Aluminum*
CAN3-S16.1-M *Steel Structures for Buildings*

The most commonly used additional references include:

Aluminum Design Manual – Aluminum Association
Metal Curtain Walls – American Architectural Manufacturers Association

The structural design of curtain wall involves the same principles as any other wall design although there are certain special and unique aspects to curtain wall design. For example, most conventional structural designers would not rely on brittle (glass) or elastic (sealants) materials as load carrying elements. In the structural design of curtain walls it is the requirements of stiffness rather than strength that usually govern design. In conjunction with structural design for stiffness and strength, adequate provision for movement also forms an important part of structural integrity.

- The structural design of curtain walls is greatly influenced by the need to limit flexibility and accommodate movement.

Structural design of curtain wall must consider primary loads generated by gravity, or self weight, and by wind action. Secondary loads are also generated by a number of other sources, as shown in Table 4.2.

PRIMARY	SECONDARY
Gravity or dead loads	Seismic
Wind	Impact
	Guard
	Window washing
	Blast
	Sunshades
	Temperature, snow/ice

Table 4.2: *Secondary loads*

The grouping of loads in Table 4.2 is not meant to imply that secondary loads are less important or of lesser magnitude as in many cases they are not. However, dead and wind loads are always present and must be considered in every design. Individual loads in the secondary category may or may not apply.

The incidence of structural failure of curtain wall is far lower than failures where a system fails to provide some other performance characteristic such as weathertightness or condensation resistance. Nonetheless, they do occur. The most common type of failure results from negative wind loads pulling panels or glass out of the wall. Other common failures include dislodging of snap caps and panels due to temperature induced movement, failure of anchors under stacking dead load, disengaging of split mullions under high load and failure of connections and framing under extreme but predictable loading.

4.2.1 Dead Loads

Most glass and metal curtain walls would be classified as lightweight cladding systems. While specific elements within the wall must resist the dead load of the wall components and the overall anchorage of the frame to the building must consider dead load (see 2.1 – Anchors), wind load usually requires more attention.

4.2.2 Wind Loading

Structural design for wind load involves a determination of wind pressures, analysis of the forces in the wall as a result of these pressures and the selection/design of members and components to resist the loads.

Determination of Wind Load

Wind loading is determined by either reference to relevant building codes or through specific modeling in a boundary layer wind tunnel (BLWT). The characteristics of each approach are summarized below:

Code Derived Wind Load – Features and Limitations

- NBCC provides relatively simple procedures for calculating wind load based on building height, shape and location.
- Total load to be resisted by wall is the algebraic sum of external and internal pressures.
- Formulae are provided to calculate external and internal pressures, with special factors included for the design of cladding elements.
- Reference wind velocity pressure for cladding design is based on a probability of being exceeded in any single year of one in ten.
- Procedures only truly apply to regular rectangular shaped buildings. Do not identify peak corner or *hot spot* load locations. Tend to overestimate positive pressures and underestimate negative pressures on high rise buildings. Do not account for special conditions such as crosswind deflection, vortex shedding or instability due to flutter or galloping.

Wind Velocity Pressures

With the rapidly escalating value of the contents of buildings the cladding of many newer buildings is designed for a more stringent, one in thirty, probability of being exceeded in any single year rather than the NBCC requirement of one in ten probability.

BLWT Derived Wind Load – Features and Limitations

- Given the limitations of code derived wind load usage of BLWT has increased steadily since the 1950s.
- Most frequently used on major buildings, building of unusual height or shape and buildings having special design features.
- Increase in number of BLWT available is reducing cost and studies now are done on lower rise buildings.
- By nature BLWT takes into account effects of local topography, surrounding buildings and wind direction.
- BLWT testing provides direct project specific information in lieu of generalized code values.
- BLWT testing provides far more detailed information than code derived procedures. Information allows for optimization of glass and framing design.

Analysis/Design for Wind Effects

Once the wind pressures are determined, analysis can proceed to evaluate the forces that the metal and glass must resist. This analysis is carried out at several levels starting with consideration of the overall grid framework, its connections and anchors and then proceeding to the infill elements such as glass and panels and finally to the fixing of the infill in place in the gridwork.

Wind load charts are produced for standard systems by most of the major curtain wall manufacturers, an example of which is shown in Figure 4.1. Charts are also available that consider in-plane dead loads.

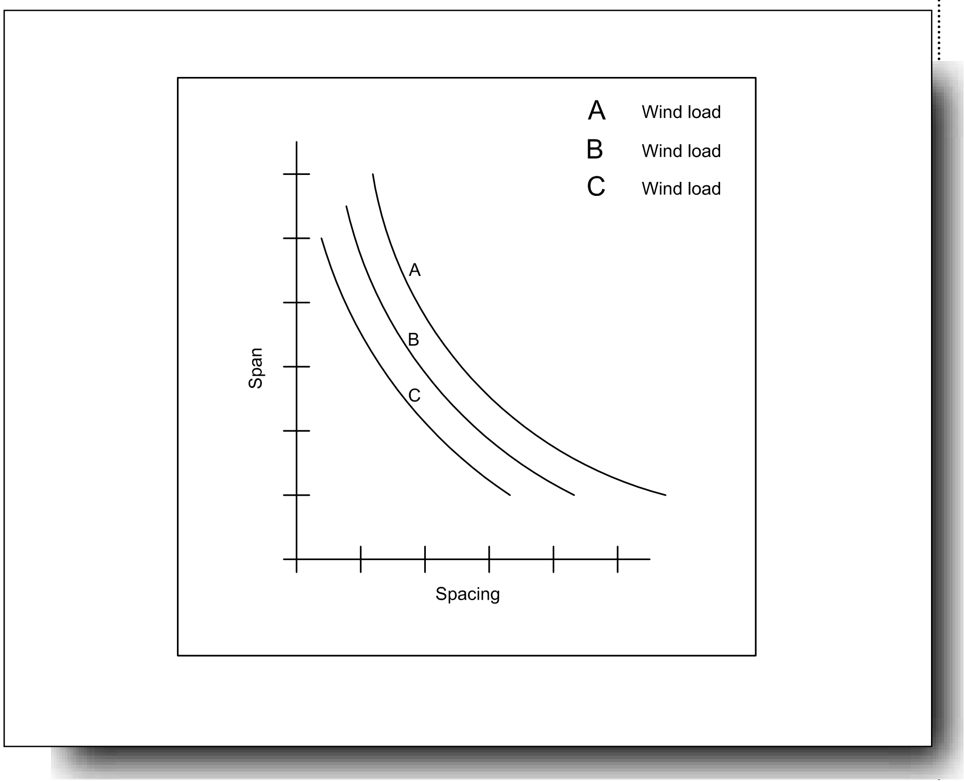


Figure 4.2: *Wind load charts*

Wind load charts can be useful particularly in preliminary design and in some cases can be used in final design. However, all charts contain several limitations that should be considered.

Wind Load Charts – Limitations and Cautions

- Charts are based on simple single spans and are most appropriate to design of horizontal rails.
- Chart values are unique to a specific aluminum alloy. At least three different alloys/tempers are in common use (see Chapter 3-Components).
- Charts are usually based on most liberal deflection limit (L/175).
- Frequently, charts do not consider lateral buckling of mullions (usually not an issue with solid tubular members).
- Well prepared charts are based on specific code. Canadian and USA based manufacturer charts are not the same.

In most instances the horizontal rails are designed as simple beams transferring gravity and lateral loads to the vertical mullions. As such windload charts are most appropriate to horizontal rail design. Any end fixity of the horizontal rails through their connection to the mullions is ignored. However, the horizontal rails do act as lateral braces to the mullions to increase their resistance to lateral buckling.

Wind pressure is typically applied to infill elements as uniform load. Analysis of most infill elements themselves involves a combination of bending and membrane theory discussion of which is beyond the scope of this document. However, resultant loads are transferred to the framing system based on tributary area concepts as illustrated below in Figure 4.3.

The vertical mullions are analyzed in one of three different ways depending on the position of the expansion or stack joint, as illustrated in Figure 4.4.

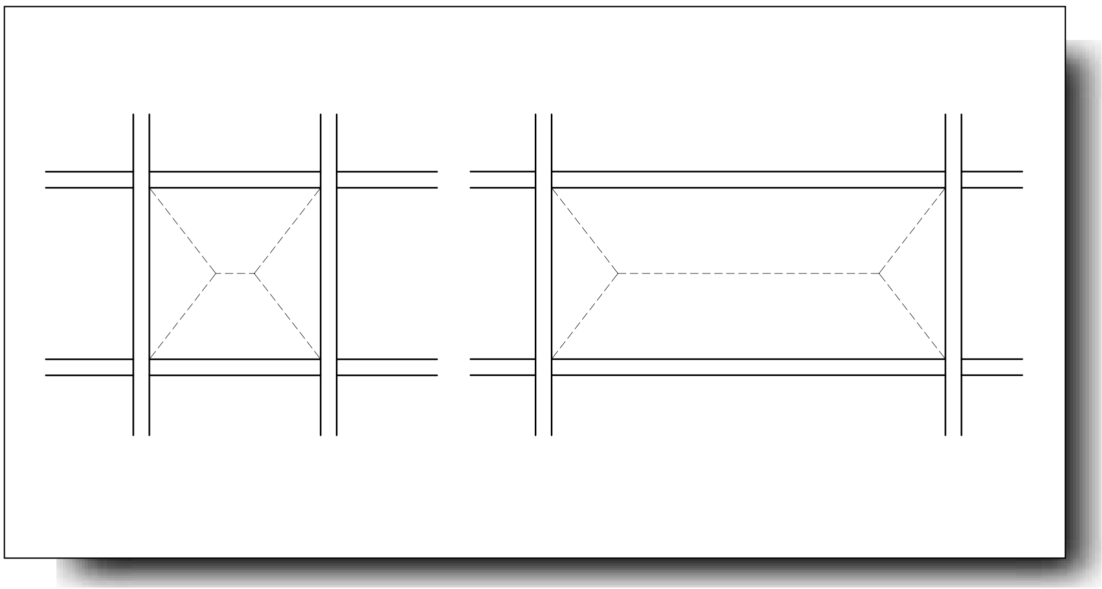


Figure 4.3: *Resultant loads transferred to the framing system*

Simple Span	Continuous with shear connect	Continuous with moment connect
• Span condition dictated by sill rail elevation • Most inefficient structural condition	• Most commonly designed condition • Mullion spigots provide shear connection but permit rotation	• Least common design condition • Most structurally efficient condition • More difficult to install and fabricate

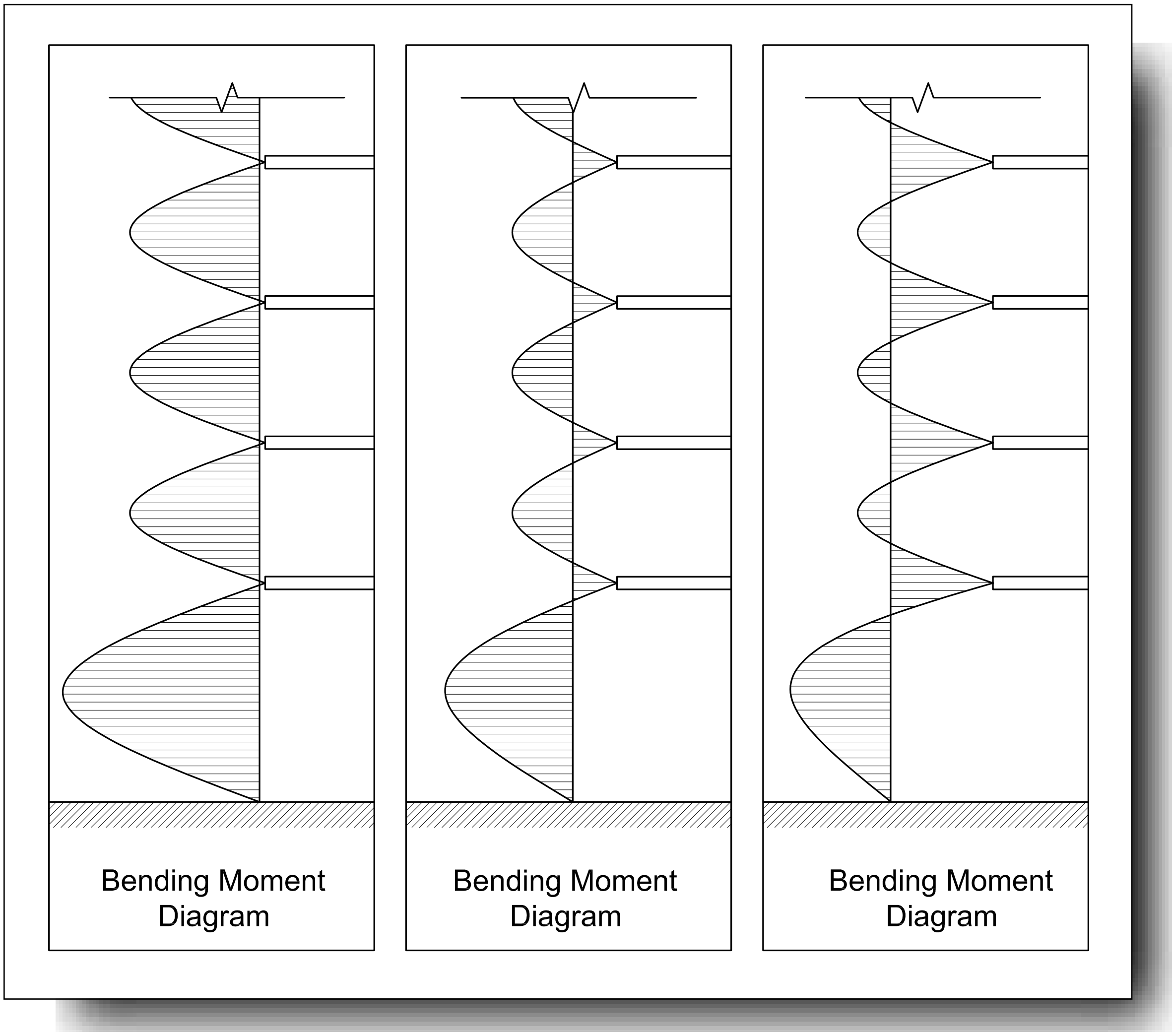


Figure 4.4: *Vertical mullions*

Pressure Equalization and Wind Load Design

Pressure equalization of a curtain wall has **no** bearing on the overall design wind load a wall must resist. However, the use of pressure equalized design principles to reduce the wind load across the outer panel in a rainscreen assembly has been suggested. Standard wind load test procedures and computer modeling indicate a potential decrease in the maximum pressure across a vented outer panel and a very short duration to any maximum pressure.

Except in special cases, most prudent designers **do not** apply any pressure equalization reduced pressures to the **strength** design of a panel or its connections. However, applying the full wind load to a deflection analysis may be unduly conservative particularly with thin panels. Except where snap through, flutter or deflection induced disengagement is an issue, pressure equalization reduced pressures have been successfully used in deflection analysis.

In most curtain wall design it is stiffness that governs the design. Therefore structural analysis often focuses on determining a sufficiently stiff cross section first and then checking strength at critical joints.

For small single story buildings using standard tubular members design for wind load may be based on reference to wind load charts (see cautions above). As building size increases, the complexity of the analysis increases, as does the potential for greater economy in design.

With standard systems, design includes selecting a stock member that meets or slightly exceeds the minimum structural requirements. With a custom system, design the most efficient section that just meets these same structural requirements can be developed

4.2.3 Seismic Loading

Metal and glass curtain walls are subject to two effects during a seismic event. The first are the inertial forces induced in the parts of the wall itself due to its mass. The second is the movement or sway of the building structure during an event.

The NBCC specifies the determination of each of these effects, and provides a maximum allowable interstorey drift. Given their light weight, the inertial forces rarely govern a curtain wall design.

Actual Lateral Drift

Designing a curtain wall to allow for the maximum allowable lateral drift is often overly conservative and onerous. The structural engineer should be asked to provide the actual expected drift not the maximum code allowable for purposes of curtain wall design.

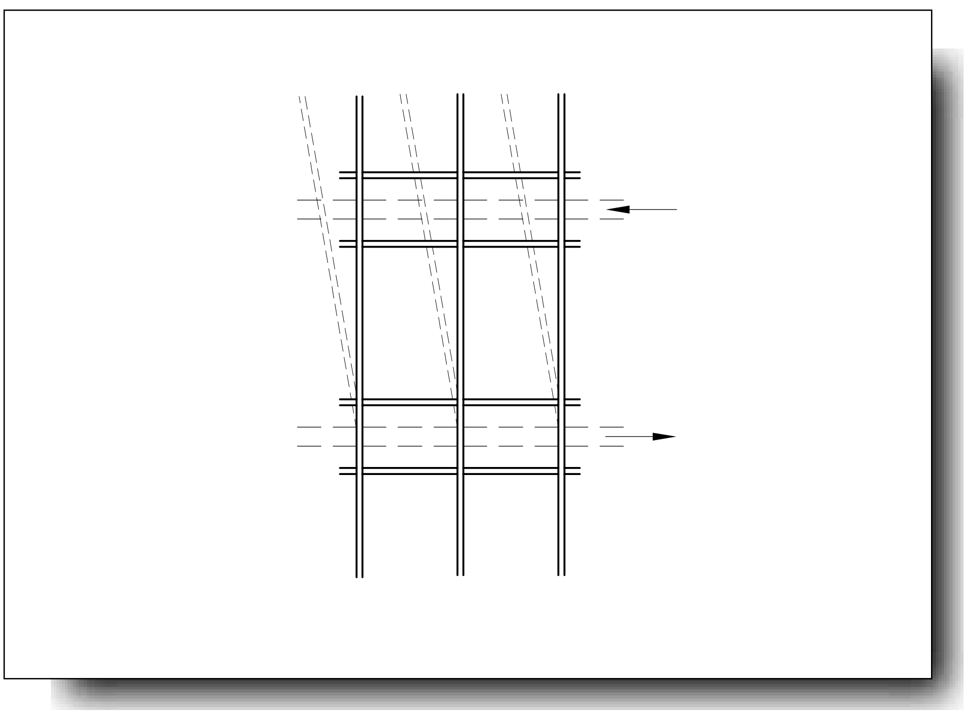


Figure 4.5: *Lateral drift – stick system with mullion splice*

Stick vs. Unitized – Mullion Splice

Typical stick systems and unitized systems with a vertical mullion splice have very little ability to accommodate lateral drift without frame racking and subsequent glass breakage. Stick/vertical splice systems should be limited to discrete strips or avoided in high seismic zones. Unitized systems without mullion splices typically perform well in seismic events.

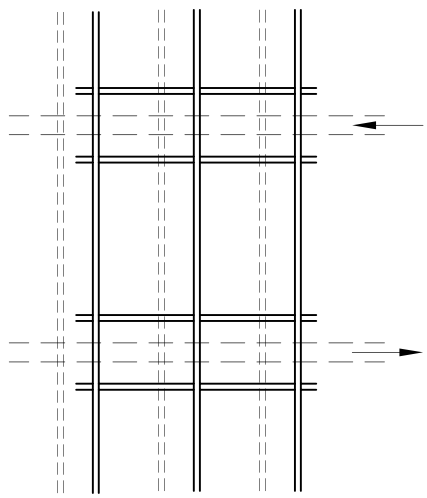


Figure 4.6: *Lateral drift – unitized system without mullion splice*

Structurally Glazed Systems

Two- and four-sided structural silicone glazed systems have performed very well in earthquakes. This is in part due to the lack of metal at the glass perimeter for the glass edge to impact during seismic motions.

Laminated Glass

Most of the injury following an earthquake arises from falling or shattered glass. Laminated glass adhered to the frame is therefore becoming a popular measure to reduce glass related injuries.

Single Mullion Corners

While popular architecturally, outside and inside corners formed with a single vertical member do not perform as well as double corner mullion systems in seismic events. This is due to the greater ability of a double mullion system to accommodate differing lateral movements.

4.2.4 Impact Loading

Except under special conditions curtain walls are not designed for impact loading although they have some inherent impact resistance. The most common impacts to be considered are soft body impact from window washers or occupants and hard body impacts from cleaning equipment and wind borne missiles. Of prime concern are usually the integrity of the glass and the retention of the glass in the frame to minimize the risk of breakage and of subsequent injury from broken glass.

Design to address impact loading has been prompted by the massive property damage claims arising from hurricane events in the southern United States. The use of protective shutters, films and laminated glass in these areas is becoming more common and mandatory in new construction. Extreme wind events are less common in Canada but certain occupancies may demand special attention to this issue.

4.2.5 Guard Loading

Where the floor elevation on one side of a wall, including a wall around a shaft, is more than 600 mm (2 feet) higher than the elevation of the floor or ground on the other side, the wall shall be designed to resist the appropriate lateral design loads prescribed elsewhere in this Section or 0.5 kPa (0.07 psi), whichever produces the greatest effect. (NBC 4.1.10.3.1)

Clearly most curtain walls, with the possible exception of storefront glazing, must act as a guard. While most designs are governed by other specified forces and readily meet the guard loading requirements, it must be noted that the guard loads, as prescribed in relevant Codes, do **not** consider forces generated by someone intentionally trying to impact the wall or particularly the glass.

4.2.6 Window Washing Loading

Window washing is a constantly evolving industry in Canada. The evolution is not in the techniques of washing but in the access equipment and the governing legislation. For the foreseeable future, smaller buildings will continue to be washed by a single worker suspended from a “bosun’s” chair while larger buildings will employ either permanent building or rental swing stages.

Window Washer Loads

- Design special features such as ledges, large protruding snap caps, projecting signs or sunshades to resist man load of 1.1 kN (250 lbf) with a possible impact factor added.
- Design parapets to carry loads generated by support equipment and safety lines. These loads can often be as high as 30 kN (6,720 lbf).
- Design tie back anchors for load of 3 kN (670 lbf) applied in any direction (or as provided by manufacturer.

Window washing by swing stage, along with maintenance activities from a swing stage, imposes loads both perpendicular and parallel to the wall surface. Guidance as to a particular load level should be obtained from equipment suppliers.

In addition to resisting loads arising from window washing operations, curtain walls can be designed to receive equipment. For example, continuous tracks can be incorporated into the vertical mullion pressure plates to accommodate the sliding guide or foot of the stage equipment. Such features are tremendously beneficial to individuals working on the building face. On very tall buildings cables and safety lines should be retained to prevent slapping in high winds.

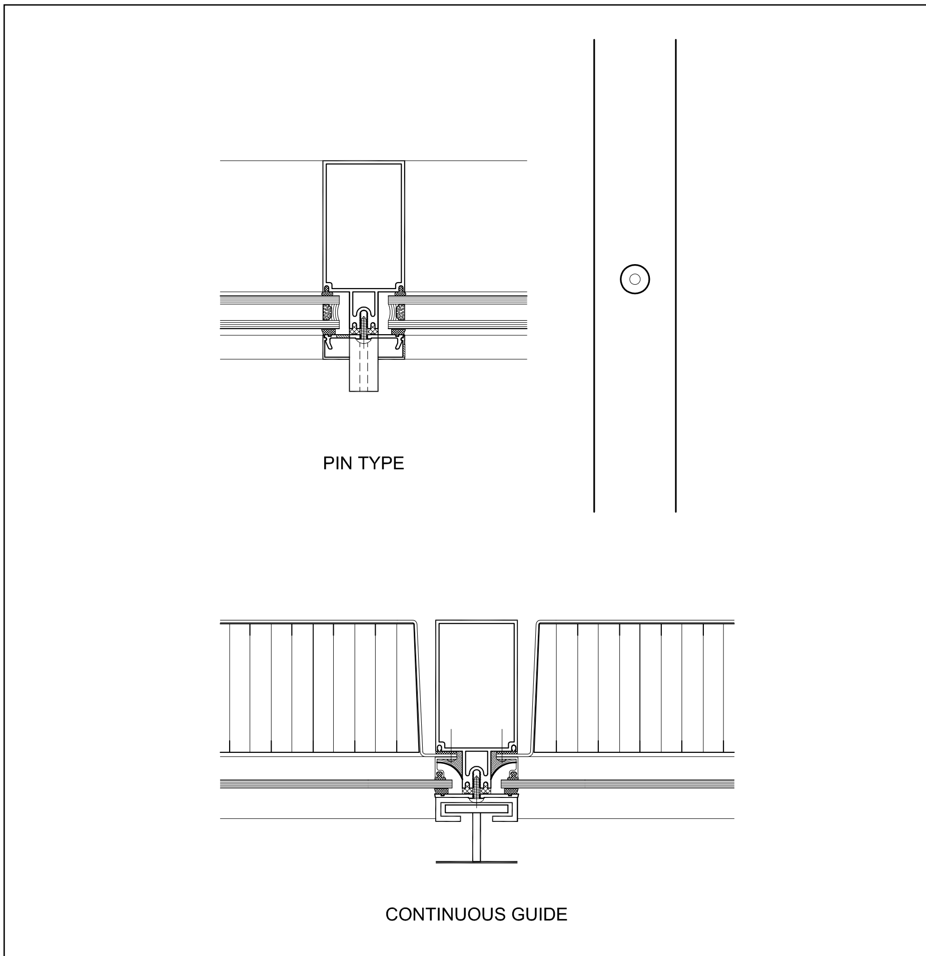


Figure 4.7: *Vertical mullion plates to accommodate the sliding guide or foot of the stage equipment*

4.2.7 Blast Loading

Canada to-date has been spared from large-scale terrorist attacks. As such there is a shortage of Canadian references to this subject. However, the World Trade building bombing of 1993, the Murrah Building (Oklahoma City) bombing of 1995 and the Atlanta Olympic Park bombing of 1996 have raised general awareness of terrorist bombing threats to buildings.

While design information for resistance to ballistic threats is fairly well developed, design information regarding bomb threats on the exterior of buildings is much less developed. General information on the characteristics of a bomb threat to buildings is summarized below.

Bomb Blast Characteristics

- Actual characteristics of blast waves are complex. The behaviour of assemblies subject to blast loading is difficult to predict and full scale testing remains the most reliable means of predicting performance.
- Bombs release very large amounts of energy in the form of an overpressure shock wave followed by a negative pressure shock wave.
- As the shock wave strikes the wall it is reflected resulting in a build-up of pressure at the wall face depending on wall shape and stiffness.
- The face-on pressure on a more flexible wall, such as a glass and metal curtain wall will be less than that on a rigid wall system.
- Overpressure is only one aspect of bomb loading. A car bomb for example generates large numbers of metal fragments propelled by the blast.
- Investigation of the Murrah blast and the explosions at Khobar Towers in Dharan indicate that **50 to 80 per cent** of the injuries resulted from flying glass. Most of the fatalities resulted for shards of glass which flew over 30 m (100 feet) from the buildings.

Design of walls to resist loads of up to 12.5 kPa (250 lb/ft^2) is not uncommon in countries subject to typhoons or increased bomb threat, but is extremely rare in Canada.

Bomb Blast Resistant Design

There are currently no standards relating to curtain wall systems that require assemblies to resist any level of bomb blast. When a security expert identifies a risk to the building due to bomb blast certain minimum measures should be considered. On critical facilities full-scale testing should be implemented.

- Security expert should define level of threat in terms of expected overpressure at wall surface.
- Structural silicone glazing systems offer the best resistance to blasts.

For Installation in New Buildings

- Framing system should be designed using specified overpressure at wall. Glass bite should be minimum 12 mm (1/2 inch).
- Glass units should be attached to framing with structural silicone glazing methods using neutral cure silicone sealant with joints sized to resist specified overpressure. All normal precautions regarding structural silicone sealant to be followed.
- All glazing should consist of laminated glass with minimum 0.76 mm (0.03 inch) thick polyvinyl butyral interlayer.

Replacement Glazing in Existing Buildings

- Should only be carried out if framing is deemed adequate.
- All glazing should consist of laminated glass with minimum 0.76 mm (0.03 inch) thick polyvinyl butyral interlayer.
- Glass should be bonded into frame with a heel bead of silicone sealant around the glass edge if batten glazing method is employed.

Once a bomb threat is identified there is often an urgent need to address it. This has led to temporary measures ranging from parking loaded dump trucks at entrances to a building to applying add-on plastic films to exposed glazing.

Add-on Films – Controversy

There is on-going controversy, primarily between the laminated glass industry and the add-on film industry, regarding the effectiveness of add-on films. Security films, particularly if attached to the frame, can provide some blast resistance under certain circumstances. They do not provide universal protection but can protect against window breakage from a given blast load, at a given time, at a given distance. Test results are available for specific films and specific blast loads.

4.2.8 Sunshade Loading

The green building movement has led to the increased use of passive and active shading devices on curtain wall systems. Aside from weight, sunshades generate additional wind and snow loads on the curtain wall and its anchors. These loads must be incorporated in the overall design of the wall. The devices themselves should also accommodate accidental person loads from window washers or maintenance workers. However, the most significant impact of shade system is often the impact that shade patterns can have on glass stress and breakage. Shade patterns, particularly on coated annealed glass, must be carefully considered as part of glass selection during the design. Considerable additional glass costs can arise to accommodate shade patterns.

4.2.9 Temperature Loading

Temperature loading, primarily due to solar effects, is one of the most significant environmental load factors. Aside from the thermal performance implications, to be discussed elsewhere, changes in temperature results in movements of the wall that must be accommodated at discrete movement joints.

In most cases simplified procedures for predicting temperature induced movements yield results sufficiently accurate for design. Various references exist that allow the designer to determine the air temperature extremes anticipated at a building site. Typically the 2.5 per cent July and January air temperatures used in the design of mechanical systems are used for cladding design. These temperatures must be modified to account for material and surface colour.

With the above information estimates can be made of overall wall and component movements due to temperature loading.

Temperature-Induced Movement

The total temperature-induced movement would consist of an expansion and contraction portion to be split depending on temperature at time of installation or cutting. Temperature-induced movements cause particular problems with snap caps. It is essential to provide sufficient clearance between caps to avoid bowing or disengagement of caps due to temperature-induced movements.

4.2.10 Snow and Ice

Given their vertical orientation, curtain walls do not normally collect sufficient snow or ice for these factors to be considered a load case. However, any protruding element from the wall such as deep caps, canopies, cornices, shades, parapets, signage or other feature can collect snow and ice generating specific concentrated loads on the wall. In the case of signage the ice load can exceed the sign weight by several times.

Aside from load associated with accumulated ice there is an added risk from falling ice.

Falling Ice

Recent ice storms and litigation arising from personal injury cases have highlighted the need to study the potential for ice formation on building facades. Projecting elements, particularly signage and shade systems, along with wide parapet caps are ideal ice collectors. Some form of ice guard system should be incorporated with such design features. The features must also be designed for any increased loads due to retained ice or snow.

4.2.11 Provision for Movement

The lightweight and relatively flexible nature of glass and metal curtain walls, coupled with the use of highly thermally conductive materials, results in a very "dynamic" assembly. Curtain wall systems move more, more frequently and faster than most traditional wall assemblies. There are movements imposed on the wall system such as short- and long-term displacements of the structure due to creep, wind and seismic force. There are also movements within the wall assembly due to wind and solar loading.

Inadequate provision for movement not only results in increased material stress and possibly failure, it also results in noise, fatigue failure, and weatherseal failure. The following table summarizes potential movements and consequences.

Table 4.3: Movement Generator

MOVEMENT GENERATOR		
Cause	**Movement**	**Consequence**
Structure	Slab deflection	Closing of mullion stack joint, loading of anchors
	Column shortening	Closing of mullion stack joint, loading of anchors
Wind	Building sway	Racking of framed opening, release of edge seals
	Flex of mullion	Contact with suspended ceilings, noise
	Flex of metal backpans	Tension on smokeseals, noise on snap-through
Seismic	Lateral drift	Racking of framed opening, release of infill edges, binding on infill corners
Solar loading	Expansion of panels	Bowing of panel, creep from pockets, noise
	Expansion of caps	Bowing of caps, disengagement
	Expansion of mullions	Movement at backpan seals

Stick-and-Slip Movement

Contrary to popular belief, curtain walls do not move smoothly through cycles of expansion and contraction when under solar loading. Assemblies will stick until the movement forces are great enough to overcome friction in the system. Once overcome, the wall will move suddenly to release the stored energy. This sudden movement can generate significant noise and can rupture seals.

Curtain walls must accommodate movement at certain discrete points. The most commonly designed movement joint is the mullion expansion joint or the unitized system stack joint. This joint primarily accommodates differential vertical movement between two consecutive floor levels and two consecutive mullions. A unitized system without mullion splices can also accommodate differential lateral movement between two floor levels.

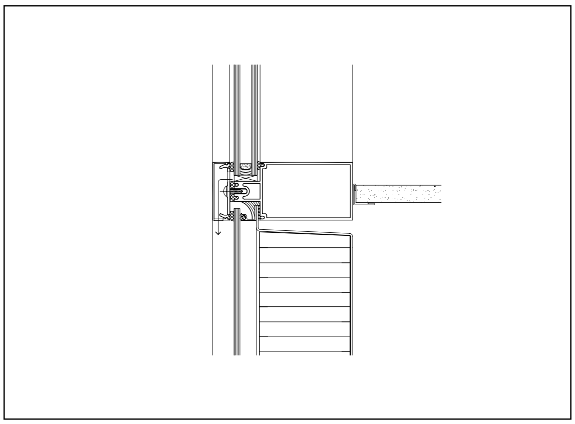


Figure 4.8

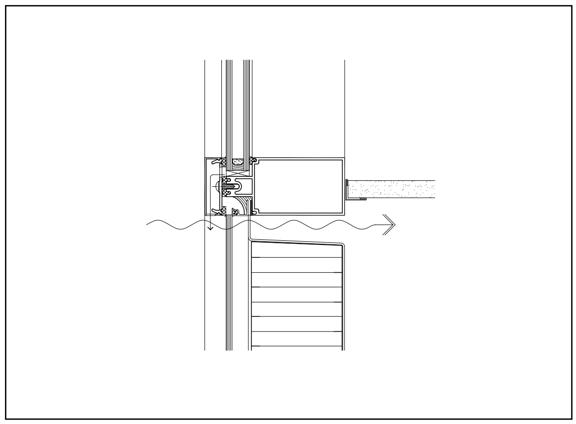


Figure 4.9

Figure 4.8 and 4.9: Illustrate a stick system expansion joint and the impact of improperly sizing this joint.

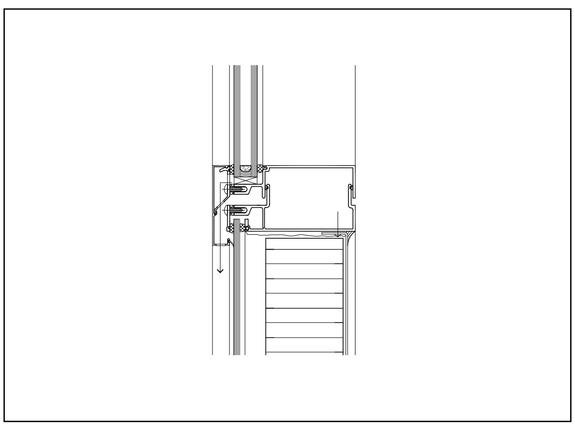


Figure 4.10

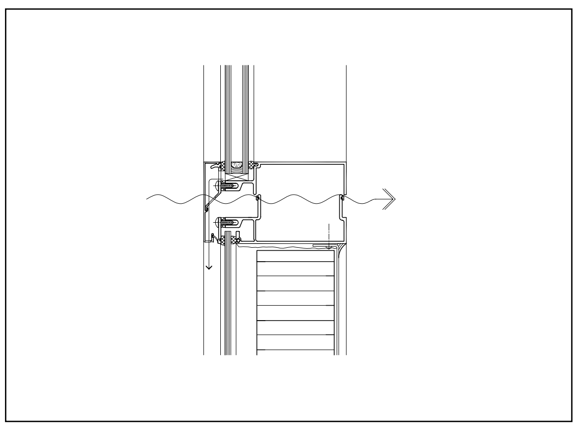


Figure 4.11

Figure 4.10 and 4.11: Illustrate a unitized system stack joint and the impact of undersizing the movement joint.

4.3 CONTROL OF WATER PENETRATION

Water penetration is one of the most persistent performance problems with all wall types. The materials used in traditional walls of masonry and stone have significant capacity to absorb water. This feature often masks a water penetration issue. Most materials in a metal curtain wall are impervious to moisture. This greatly reduces the area subject to water penetration but increases the importance of joints and seals. The impervious nature of the curtain wall materials also eliminates any absorptive storage capacity, therefore any wetted opening rapidly leads to visible water entry. While lacking absorptive water storage capacity typical curtain wall sections do contain cavities that can potentially accumulate water. Accumulated water can damage seals and, in particular, will promote premature failure of insulating glass units.

Three different concepts have been and are still used in metal and glass curtain wall system design to control water penetration.

Design Concepts and Features	
Exterior Face Seal	• Common through 1960s, since that time use has decreased • Used in four-sided SSG and in retrofit of older systems • Relies on integrity of exterior sealant and gaskets • Exterior plane is air barrier
Internal Drainage	• Used through 1960s and into 1970s, rarely seen in Canada after 1980, still common in USA • Recognizes difficulty in maintaining perfect exterior seal, provides backup drainage to exterior • Intentional openings in air barrier can lead to condensation.
Two-Stage Weathertightening or Pressure Equalized Rainscreen (PER)	• Most common contemporary design approaches in Canada • Outer screen, vented air space, air sealed interior barrier • Used since mid-1970s, common on most major buildings since 1980. • PER employs intentional delineation of specific cavities with specific properties (size, stiffness, venting).

Many major office towers built in the 1960s and early 1970s incorporate interior glazed single lites of glass. They rely on exterior sealant or tape seals to control water penetration. The original seals were often butyl or polysulphide based materials which degrade over time. While some seals glass to frame are accessible, framing seals may not be. Many of these towers have been resealed more than once in their lives and newer sealant products are used–particularly inorganic silicone products. Properly installed these products promise a much longer life than their predecessors. Unless a major refit is proposed to the facades, it is often not practical to change from the original face sealed design to a more contemporary design.

While two-stage weathertightening, PER or interior drainage can be incorporated into 4SSG systems they present a design challenge. Small areas of 4SSG are often designed as face sealed systems and reliance is placed on the silicone-to-glass seals. Fortunately the glass edge provides an ideal substrate and the silicone a very durable material for this type of sealing. Cladding of larger buildings should incorporate two-stage weathertightening or PER into any 4SSG system.

Of all of the wall types the metal curtain wall is the most ideal wall to properly apply pressure equalized rainscreen design as advocated by NRC/IRC. The curtain wall is typically composed of a regular grid of small separated rigid walled compartments, convenient to air seal and easy to vent/drain. Typical thermal break and aluminum pressure plates act as compartment seals for each glazing unit/spandrel.

For curtain walls where profiled spandrel panels or column covers are used, specific measures must be taken to compartmentalize the larger cavities. The size of the cavities and the inherent flexibilities in these assemblies often make formal application of PER difficult. But a two-stage weathertightening approach is feasible.

While pressure equalized rainscreen design provides an overall concept to water penetration control, it still occurs more frequently than desired. This is not due to a flaw in the PER concept but to poor execution of details and the failure of designers to properly deal with forces other than air pressure differences that can also cause water penetration.

PER and Water Penetration

It is important to remember that PER design addresses only one component of water penetration–that is it reduces or eliminates the air pressure difference that might drive water through an opening. It does not address other forces such as capillary, kinetic energy, surface tension, and gravity. Good detail design must address these factors regardless whether a PER concept is used or not.

While PER reduces or eliminates water entry due to air pressure differences, curtain wall design must also incorporate in its design a means to eliminate entry due to capillarity, kinetic energy, surface tension and gravity. The design must also provide a means to drain water that will enter the spandrel or glazing cavities. The design intent is to provide a reasonably watertight exterior seal system coupled with adequate venting and drainage paths from the cavities behind. Small quantities of water entering a glazing cavity are re-directed to the first horizontal member below the point of entry and then to the exterior via weep slots. Compressible thermal breaks and corner blocks serve to compartmentalize the cavity and direct water to the weep slots.

Weep slots are typically provided in the horizontal pressure plate so there is drainage between the setting blocks and also between each setting block and the end of the framing member.

The actual size and shape of weep/vent slots is subject to some debate. Most manufacturers use the same size of weep/vent slots regardless of cavity size. While this is not in accordance with PER theory, once a minimum size is provided adequate water penetration resistance is often achieved. This suggests that full pressure equalization, while an admirable target, is not necessary to achieve adequate resistance to water penetration.

A curtain wall system's ability to control water penetration is evaluated by a number of different standard test methods. While some tests have been developed for field use most are meant to be applied to a representative sample of wall installed in a chamber at a testing facility.

ASTM E331 – *Standard test method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference*

ASTM E547 - *Standard test method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Difference*

ASTM E1105 - *Standard test method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference*

AAMA 501.1 – *Standard test method for Metal Curtain Walls for Water Penetration using Dynamic Pressure*

The standard test methods all basically involve applying a water spray to the sample while applying some pressure difference across the wall sample.

It is important to recognize that the referenced test methods provide a common procedure useful in comparing different wall systems. The test methods do not always provide specific test parameters (pressure difference, test duration, number of cycles, wind speed, etc.) or an acceptable pass/fail criteria that might relate the test to expected climatic conditions (see Chapter 5–Design Criteria). Also some tests and sequence of testing are more appropriate to certain wall types. Manufacturers quoting performance supported by specific tests must provide details of the test parameters and the pass/fail criteria for the results to be meaningful.

Unfounded Reliance on Testing

Too frequently designers only specify test procedures without providing the necessary test parameters, or specify test parameters that are not rationally related to the building type or location. An incorrect reliance is placed on a test method to predict in adequate in-service performance.

Pass/Fail Criteria

Most standard water penetration test methods actually allow water penetration within their definition of acceptable performance. The amount of water is limited or the water must not flow onto the floor or adjacent finishes. Designers should recognize that unless a more stringent performance level is specified the test method definition of pass/fail criteria will apply to the test results.

Laboratory vs. Field Performance

Test results obtained in a laboratory setting are a good indication of the achievable performance of a system. However, laboratory performance results from ideal erection conditions, an often unrealistically large and experienced crew, and far more time to erect the wall than allowed in the field. Therefore, there can be little correlation between the laboratory performance and the in-service performance of a wall unless field testing is used as part of the quality assurance programme. An incorrect reliance is placed on laboratory tests to equate to adequate in-service performance.

4.4 CONTROL OF AIR LEAKAGE

The design concepts relied on to control air leakage are interrelated with those to control water penetration. In the face sealed and rainscreen concepts an impermeable plane is theoretically achievable to provide a barrier to air flow. In a face sealed design it is the outer surface of the wall. In a rainscreen wall it is typically the interior surface of the wall (excluding finishes). In the internal drainage concept the most air-tight plane is typically the outer surface; however, there are obvious intentional weepholes. In some designs these weeps are baffled or blocked with open cell foam to reduce air flow. Aside from directly controlling the passage of air through the wall, air leakage control also impacts smoke control, sound transmission, insect control and potential ice buildup on the wall.

Given the impervious nature of the main elements of the curtain wall air leakage is concentrated at joinery, seals and gaskets.

A curtain wall is ability to control air leakage is most frequently evaluated in accordance with **ASTM E283 -** *Standard test method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*. This is a laboratory procedure carried out on a representative sample of curtain wall installed in a test chamber. The air pressure in the chamber is raised or lowered and the net air flow through the wall at a specified air pressure difference is determined. In cases where the chamber or wall-to-chamber seal air leakage is unknown, the gross air leakage of the chamber and sample is first determined. The sample is then masked off so that the extraneous leakage (chamber and seal) can be determined. The difference between the gross and the extraneous air leakage is assigned to the wall sample.

As with water penetration testing, the referenced test method provides a common procedure useful in comparing different wall systems. The test method does not provide specific testing parameters (pressure difference, number of cycles, wind speed, etc.) or a pass/fail criteria that might relate the test to expected climatic conditions (see Design Criteria). Manufacturers quoting performance supported by specific tests must provide the test parameters and the pass/fail criteria for the results to be meaningful.

Testing of walls for air leakage in the field can be done but experimental error is much greater due to the difficulty in isolating extraneous air leakage–particularly lateral and vertical flow in the curtain wall framing.

4.5 CONTROL OF WATER VAPOUR FLOW

The glass and metal components of curtain walls are impervious to both liquid water and to water vapour flow. In a face sealed wall the outer metal and glass surface form a near continuous vapour retarder on the cold side of any insulation with no provision for drainage. In designs where this condition is recognized vapour retarders are also provided on the warm side of the insulation, usually in the form of foil-backed insulation to minimize the risk of condensation formation in the components exterior to the insulation. Some systems with internal drainage similarly incorporate an interior vapour retarder. These systems obviously benefit from the condensation drainage path provided by the internal guttering system but create the risk of corrosion or mold.

Rainscreen systems differ in that the sheet metal backpans function as both air barrier and vapour retarder on the warm side of the insulation and ready drainage is provided to the cavity outboard of the air barrier. As such vapour diffusion is rarely a concern with metal curtain wall systems designed in this way. Water vapour diffusion testing through a completed assembly is rarely carried out although standard test methods may be applied to specific components such as gaskets.

4.6 CONTROL OF HEAT FLOW

Contemporary glass and metal curtain walls are composed of highly conductive materials such as steel, aluminum and glass. The control of heat flow through a curtain wall is dependent on the specific assembly of wall components and the overall size and arrangement of the components. The material assembly and overall layout of the wall have a tremendous influence on the overall wall performance.

From a thermal perspective, most curtain walls can be discussed with regard to three different zones: vision glass area; spandrel area; and framing. The vision glass area is the most complex of the three.

Vision Glass

As discussed in Chapter 3, vision glass in most Canadian curtain walls includes either single glazing or double-glazed IG units. In some projects triple glazing is used. The thermal resistance of IG units is provided chiefly by the multiple air films with some contribution from air or gas filled spaces. Typical resistance values are provided by various different IG manufacturers.

However, as presented in Section 4.1, the curtain wall, and particularly the vision glass, functions more like a filter than a barrier. The IG unit assembly provides a defined resistance to heat flow, calculated much like opaque assemblies, when under night-time conditions. Due to their transparency, IG units allow varying amounts of solar energy to enter the building. Solar heat gain is often the governing design criterion with respect to curtain wall clad buildings. Even in cold climates material features such as tints or coatings are required to control this aspect of heat flow.

The thermal resistance and solar heat gain characteristics listed in manufacturers literature apply to the centre region of the glass unit. The glass edge, a zone 65-75 mm (2 5/8-3 inches) wide about the perimeter of the unit, is in most cases much more conductive than the centre region. This is due to the conductivity of the glass edge spacer. The area weighted average of the characteristics of the centre of glass and edge regions defines the overall thermal performance of the glazing.

Spandrel Area

The spandrel area of the curtain wall is most like traditional walls with an outer cladding, an air space, insulation and a metal backpan. The incorporation of metal stiffeners and the non-typical perimeter condition results in a multi-zone area much like the vision glass. The thermal performance of the spandrel is defined by an area weighted average of the centre and edge zones.

Framing

The highly conductive aluminum framing is usually the weakest thermal element in the curtain wall. The need for thermal breaks in the section to slow heat flow was recognized some time ago and essentially all contemporary framing is thermally broken. The effectiveness of the thermal break varies widely. Thin plastic thermal breaks with wide contact areas perforated with numerous pressure plate screws typically exhibit only a 6 to 10 per cent improvement in thermal performance over a non-thermally broken section. High performance thermal breaks composed of two polyamide webs boast thermal performance approaching that of the centre of glass.

As indicated by the focus on thermal breaks in framing sections the bulk of the heat flow in framing is due to conduction. Therefore, the addition of insulation into the hollow of the framing is of little value.

The overall performance of the wall is described by:

$Uw = \times UiAi/Ag$

Where *Ui* is the U value of a particular element or zone

Ai is the area of a particular element or zone

Ag is the total wall area

The above calculation considers only conduction and not solar effects. Unfortunately this is not the method used to characterize most curtain walls to-date. Traditionally, curtain wall U values have been defined as:

$Uw = (UvAv + UsAs)/Ag$

Where *Uv* is the centre of glass U value

Av is the area of glass

Us is the centre of spandrel U value

As is the area of spandrel

Calculations by this simplified method lead to significant error and should not be used.

4.7 CONDENSATION RESISTANCE

After water penetration, condensation is the most often reported performance issue. The control of heat flow and condensation resistance is closely related. Effective thermal breaks that retard heat flow from warm (interior) to cold (exterior) will help to boost frame surface temperatures. Designs to include as much thermal mass to the interior and exposing or connecting this mass to the interior heat sources also promote higher surface temperatures. Discussion in Chapter 5 outlines test and simulation procedures used to evaluate both thermal performance and condensation resistance.

From the performance perspective, design for condensation resistance is effectively a process of designing to minimize the frequency and extent of condensation formation. It is often not practical to think of obtaining no condensation as there will always be some extreme condition under which condensation will form. It is practical to define an allowable extent of condensation and the specific indoor and outdoor temperatures and indoor relative humidity at which the extent of condensation is to be evaluated.

4.8 CONTROL OF SOUND TRANSMISSION

Traditionally, control of sound transmission has been focused on aircraft/airport noise, traffic noise and railway noise. These three categories of noise pollution still form the focus of most sound transmission investigations. The goal is to provide a curtain wall with an acceptable level of noise reduction. The process involves an:

- assessment of environmental noise
- determination of the minimum acceptable Transmission Loss (TL) or Sound Transmission Class (STC)
- selection of glazing and spandrel type
- design of window frame, installation

There is a variety of different means of assessing environmental noise and establishing a TL or STC rating ranging from simple handbook approaches to more sophisticated analysis. In either case the TL or STC rating is generally determined by an acoustic consultant and the required minimum values provided to the curtain wall designer. With the overall TL or STC value the designer will consider the vision and spandrel areas separately.

Vision Area

The three basic features of glazing design that impact an STC rating are:

- glazing air space thickness and spacer type
- glass thickness
- interlayer damping

Glazing space thickness varies from 6 to 150 mm (1/4 to 6 inches). Spaces between 6 mm (1/4 inch) and 20 mm (3/4 inch) are generally hermetically sealed with desiccant and relatively hard surfaced spacers. Spaces over 20 mm (3/4 inch) are usually not sealed and may have special vented or soft spacers.

Glass thickness for most architectural applications will range 3 to 6 mm (1/8 to 1/4 inch). For some special applications glass up to 12.5 mm (1 inch) thick may be used but this is rare due to higher costs.

Interlayer damping refers to 0.76 to 1.52 mm (1/32 to 1/16 inch) thicknesses of polyvinyl butral laminated between two layers of glass.

STC ratings are established for a number of standard glazing configurations. Modifications to the standard assemblies are generally made by first adding damping, then increasing the air space thickness and finally by increasing the glass thickness. Ratings for specific configurations are obtained by testing glass samples in standard frames. Manufacturers have computer programmes to provide designers with some guidance.

Opaque Spandrel Area

The opaque spandrel portions of the curtain wall contain many of the same elements as a standard opaque wall, however the unique features of the curtain wall (metal backpans, aluminum tubes, etc.) do not make standard handbook values strictly applicable. Where specific STC rating levels must be maintained, testing of mock-up assemblies is often the only way of verifying performance. When an increased rating is required measures such as laminating gypsum wall-board to the interior surface of the backpan or adding weighted sheet products to the mullion tube or spandrel cavity can be effective.

4.9 CONTROL OF FIRE

Curtain walls are most frequently used on buildings required to be of non-combustible construction. Essentially all of the basic materials in a typical curtain wall assembly are non-combustible (aluminum, steel, glass, and stone) and minor combustible components such as sealants and gaskets are permitted in non-combustible construction (NBCC 3.1.5.2.1c). Some panel products such as hard plastic cored composite panels and textured foam plastic cored panels are combustible. They require individual review as some will meet Code requirements while others, seemingly very similar, will not.

The curtain wall must resist fire and smoke migration from floor to floor at the slab edge. As normal vision glass will break within the first few minutes of a significant fire the curtain wall must also resist spread of flame up the exterior of the wall. The behaviour of curtain wall in fire situations is currently the subject of renewed study. Exterior walls are typically not rated assemblies and the fire stop is usually required to have the same rating as the floor slab. Without special modifications it is unlikely that typical firestopping as described below can provide the rating prescribed.

Slab Edge Firestopping

Figure 4.12 illustrates a typical slab edge condition with fire stop and smoke seal in place. Resistance to flame is provided by the compressed inorganic firestop insulation. The depth of the firestop is dictated by the required resistance rating and the width by the dimension slab edge to back of curtain wall. The smoke seal is typically provided by a self-leveling silicone or urethane sealant. The integrity of both of these elements depends on the curtain wall and backpan remaining in place in a fire event.

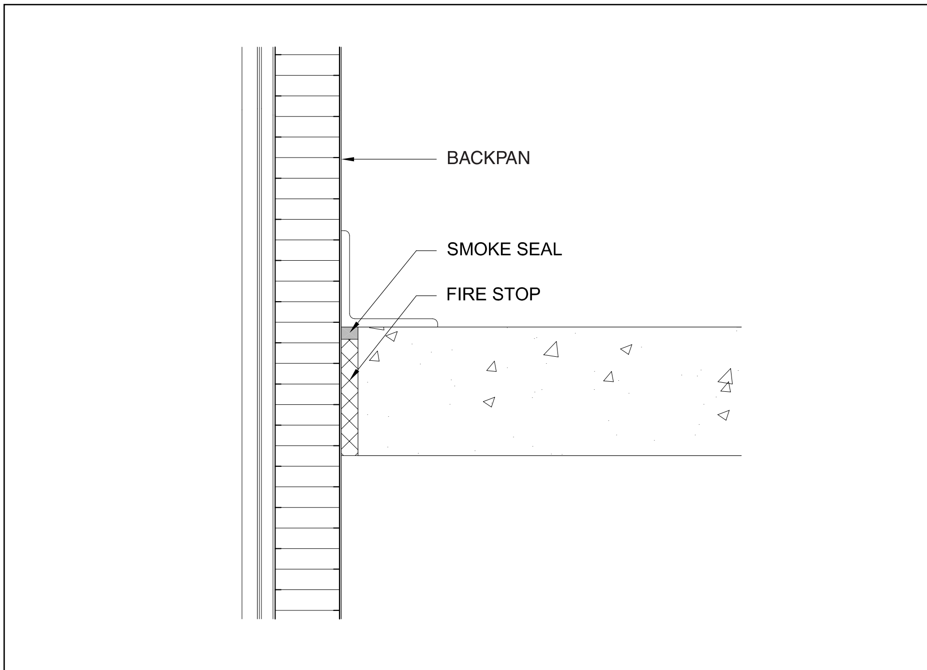


Figure 4.12: *Firestopping and smoke sealing*

While Figure 4.12 illustrates the intent of the firestopping and smoke sealing detail, a plan view in Figure 4.13 illustrates many of the common failings.

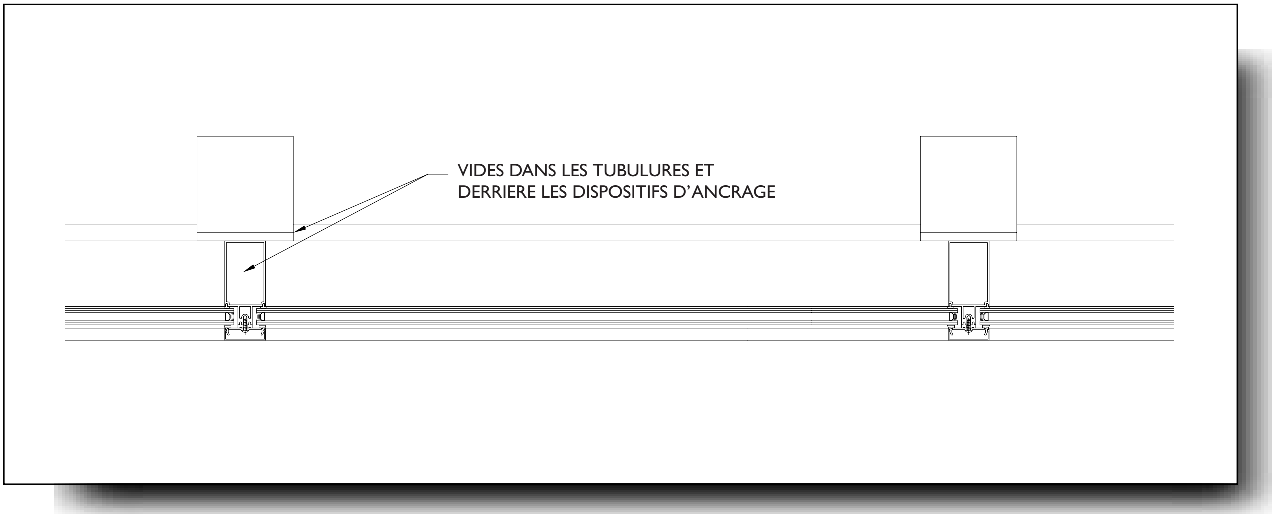


Figure 4.13: *Common failings of firestopping and smoke sealing detail*

Smoke migration is often considered more dangerous than the actual flame and typical faults shown above allow ready passage of smoke from floor to floor.

Backpan Stiffness

Backpan rigidity plays an important role in maintaining fire stop and smoke seal integrity. A flexible backpan may bow under wind load breaking smoke seals and lessening the compression on the firestop. Backpan deflection under full windload is therefore frequently limited to 6 mm (1/4 inch) at the slab level. Another guideline is to limit backpan deflection to 10 per cent of the pan to slab edge dimension.

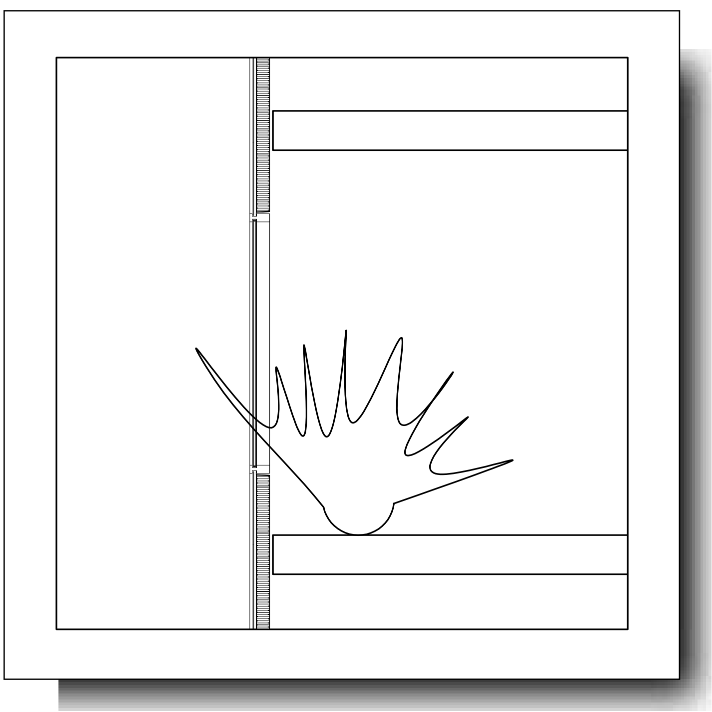


Figure 4.14: *Exterior flame spread*

Exterior Flame Spread

Spandrel cladding elements of glass, stone or solid metal usually do not require special attention. Cladding elements of materials such as FRP or with foamed plastic cores must satisfy requirements of CAN/ULC-S101-M and CAN4-S124-M.

Fire and Aluminum Composite Panels

Aluminum composite panels consist of two thin aluminum sheets sandwiching a hard plastic core. The plastic core is often considered related to foam plastic insulation and hence requirements for the protection of foam plastic are applied to the composite panel cores. The composite panel cores are markedly different materials but individual rulings from fire officials are required to allow their use on buildings over six stories.

4.10 PERFORMANCE AT INTERFACES

Curtain wall performance characteristics discussed previously in this chapter apply to the main field of the wall and do not strictly apply to the interface between the wall and any adjacent material. Adjacent wall areas of different materials/assemblies are covered in other specification sections. The performance required of the interface connections is often a grey area and the physical construction is often ill-defined by both trade responsibility and assembly.

Consistent Performance Requirements

A consistent set of performance criteria should be applied to all wall areas. As such interfaces between wall areas must be designed to the same wind pressures, air leakage rates, water penetration resistance and other performance characteristics common to the main wall areas.

Chapter 5

PERFORMANCE - EVALUATION AND TESTING

5.1 INTRODUCTION

Although testing of wall components was conducted prior to the development of curtain walls, it was the development of curtain walls that first allowed the testing of a complete wall prior to actual construction on site. Today, performance testing of curtain walls is conducted in laboratories for product development or to evaluate specification compliance. It is also conducted in the field as part of a quality assurance programme.

Performance testing of a curtain wall sample prior to production can be a useful tool in identifying fabrication or design weaknesses before they are built into the site wall and difficult to correct. Laboratory testing can involve significant effort and it is important to recognize the reason for testing and how the tests are performed. Insufficient or inadequate test programmes provide little valuable information. Similarly, wholly unnecessary testing is a waste of time and money. Where testing is required sufficient time must be scheduled within the contract to complete the testing and incorporate any changes arising.

In general, if a wall is a new, custom design or a significant departure from a manufacturer's normal work, mock-up testing should be conducted. In some jurisdictions all curtain walls must be tested regardless of design. However, if the wall is a standard design widely used with a history of good performance and a record of previous testing, then a mock-up test programme may be unnecessary.

Initial Failure Common

Despite the best efforts of designers and contractors it is very rare to have a mock-up sample successfully meet all specified performance criteria in the initial attempt. It is important to recognize that testing is not only a qualification process but also a development and learning process for the project team. One must also be aware of what was done initially and what changes were made to pass the tests. Is it practical to achieve the same on site?

There is a perception that only certain test procedures and criteria may be used to evaluate a curtain wall when, in fact, a wide variety of test procedures are available for this purpose.

5.2 MOCK-UP TEST SAMPLES

Inadequacies in a mock-up test programme often begin with the development of the test sample itself. A good mock-up test sample should incorporate the following:

- The extent of the test sample must be clearly indicated in the contract documents and should be of adequate size to include all major elements. This is critical to ensure value in the test programme. Where practical, the sample should be at least four modules wide providing three typical mullions.

- The support conditions for the wall sample must match or be correlated to the actual site support condition. Curtain wall mullions rarely function structurally as simple spans although in many cases they are tested this way.
- The support structure for the wall sample must provide the same stiffness as the actual structure and allow use of project anchorage system.
- The chamber size should consider the test procedures in allowing sufficient space for lateral movements in a racking test or suitable exposed surfaces to permit masking the wall for an air leakage test.
    - The wall should be installed by the same crew or at least the same foreman that will be employed on the site. This allows for an important familiarization with the wall system. The installation process should be reviewed and documented by third party inspection personnel.
    - Visual mock-ups to verify glass and finish aesthetics can be very useful and cost-effective exercises.
    - If the mock-up is to incorporate an operable vent or window the applicable performance standard for this element should be decided early in the test process.

It is becoming increasingly critical to link interior details and mechanical systems to mock-up testing to properly evaluate thermal performance. This is especially important in high humidity environments.

5.3 PERFORMANCE CHARACTERISTICS

Almost any performance characteristic can be evaluated by testing. The most common performance characteristics evaluated by testing in a mock-up test are:

- air leakage
- water penetration resistance
- structural performance

Thermal performance evaluation is important and evaluated by test or simulation. Air leakage and water penetration resistance can only be evaluated by physical testing. Many aspects of structural performance can be evaluated by analysis and calculation. However, the interaction of all elements including deformable gaskets and seals and the indeterminate nature of some assemblies can only be reliably evaluated by tests.

Aside from the most common tests above curtain walls are also tested for:

- condensation resistance
- overall thermal transmittance
- thermal cycling
- seismic racking
- window washing anchors

5.4 BASIC TEST PROCEDURES

There are four basic curtain wall tests widely used to evaluate performance in most mock-up test programmes. These include:

1. Air Leakage – ASTM E283 – *Test for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors*
2. Water Penetration – ASTM E331 – *Test for Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference*
3. Water Penetration – AAMA 501.1, *Standard Test Method for Metal Curtain Walls for Water Penetration Using Dynamic Pressure*
4. Structural Adequacy – ASTM E330 – *Test for Structural Performance of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference*

The above four tests have been used for many years and have become industry standard tests. However, it is important to recognize the limitations of these standard tests.

Standard Test Limitations

- Standard tests were developed as a means of ranking different wall systems to a common standard. There is not necessarily a correlation between a test result and in-service performance.
- Standard tests provide a procedure, but only the minimum parameters to be used in that procedure. Pressure differences, flow rates, durations and pass/fail criteria must be defined by the specifier.
- Standard tests are standard and there is no reason not to specify non-standard tests if they are justified and rational. Testing in Europe and the Far East is much more extensive and onerous than typical North American test programmes.
- Specifiers' reliance on standard procedures and either minimal or irrational parameters drastically limits the usefulness of a mock-up test programme.
- In Canada, there is a tremendous emphasis on pressure-equalized rainscreen technology in the design for water penetration control. However, there are no standard tests that can be used to evaluate actual pressure equalization performance. Neither of the standard water penetration tests permits evaluation of pressure equalization characteristics. To properly evaluate the pressure equalization characteristics of a wall system, testing needs to be conducted without water, using measurements of just air pressure differentials across the air barrier and cladding elements.

In all cases where revisions to standard procedure are considered it is prudent to seek specialist advice.

Aside from the above limitations there are a number of inconsistencies related to curtain wall testing on the building envelope in general that specifiers/architects should be aware of.

Test Inconsistencies

- The curtain wall is tested and often held to a high standard but the interface with the adjacent construction is rarely tested but should form part of the testing.
- The curtain wall is evaluated in accordance with one standard and operable elements within the wall are evaluated to an often lesser standard.

5.4.1 Air Leakage Testing - E283

Air leakage testing to ASTM E283 is common to many building assemblies and components. Basically a pressure difference is created across a wall sample and the flow rate through the wall is measured at this pressure difference. Tests should be conducted to assess both infiltration and exfiltration. The required parameters for the ASTM 283 procedure are the allowable flow rate and the pressure difference, both parameters subject to some controversy.

These are discussed individually in the following sections.

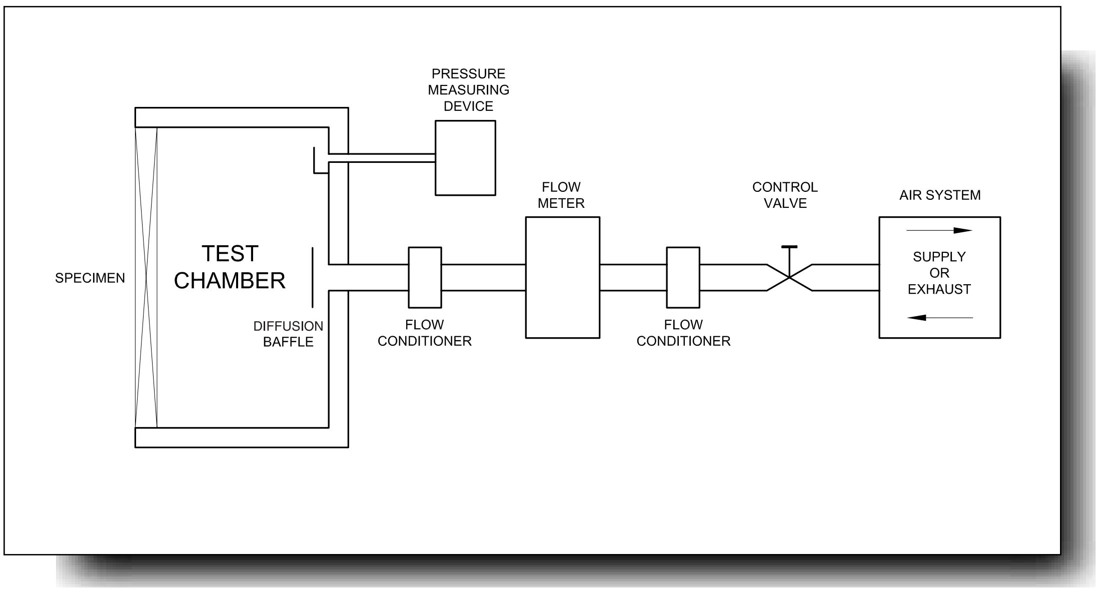


Figure 5.1: *Test pressure apparatus for air leakage*

Allowable Flow Rate

The most common industry reference is AAMA and they recommend an air leakage rate of 0.30 L/s.m^2 @ 75 Pa. Most contemporary curtain wall systems, properly assembled, can easily meet this criterion.

Although not specific to curtain wall, the Appendix of the National Building Code of Canada also provides guidance as to the maximum air leakage rates for exterior wall systems housing different interior conditions.

Warm side relative humidity @ 21˚C	Recommended maximum system air leakage rate (L/s.m²) @ 75 Pa. (gal/min/sq. ft.)
<27 per cent	0.15 (0.22)
27 to 55 per cent	0.10 (0.15)
>55 per cent	0.05 (0.07)

The performance criteria set by AAMA were likely based on energy consumption and levels easily obtained in the industry. The NBCC values reflect the added role of interior humidity as a risk for condensation problems and are therefore more stringent. That is, in the Canadian climate both energy costs and the potential deterioration of materials due to air (and contained moisture) flow are important. Curtain walls are generally less susceptible to moisture damage than other wall systems due primarily to their typically non-absorbent materials. However, icicle and ice lens development represent a serious potential safety hazard. Maximum allowable air leakage rates should be adjusted to reflect the risk posed by moisture accumulation and/or icicle formation in the wall, but should never exceed 0.15 L/s.m². (0.22 gal/min/sq. ft.)

Pressure Difference

The AAMA and NBCC allowable leakage rate criteria are based on a 75 Pa pressure difference. A common test pressure is useful to compare the laboratory performance of assemblies tested at different facilities. However, the 75 Pa pressure does not reflect the long-term applied pressures in high-rise buildings. In many cases, higher pressure differences should be specified. Higher test pressures should reflect the sum of the stack effect, mechanical pressurization and mean wind pressures expected on a particular building. The following paragraphs discuss the pressures created by each of these, individually.

Stack Effect

Pressure differences due to stack effect arise due to temperature differences and therefore density differences between air inside and outside a building. In colder climates, the effect is greatest in the winter months. Air under stack effect alone tends to flow into the building at a lower level and out at higher levels. The stack pressure is commonly estimated as 0.11 Pa/˚C temperature difference per 3 m (30 feet) storey height. In Canada the most significant pressures are observed in the winter months.

In order to establish stack pressures for a particular building the “mean” monthly temperatures, not the more extreme design temperatures, are required. In most cases, a pressure based on the mean January temperature would be appropriate.

Mechanical Pressurization

The level of mechanical pressurization varies widely. Depending on the sophistication of the HVAC systems internal pressures can often be mitigated. However, in many buildings pressurization often acts to lower the neutral plane and increase exfiltration pressure at the upper floors of a building. Information on anticipated mechanical pressurization should be sought from the mechanical engineer and made available to the design team and contractors.

Mean Wind Pressure

Wind pressure data provided in building codes is sufficient for structural design but is not suitable for air leakage evaluation. A reference wind pressure based on the “mean” January wind speed, modified by the exposure and pressure coefficients in the building codes is adequate for a first approximation.

Rational Test Pressure for Air Leakage

Air Leakage Test Pressure = stack effect pressure + mechanical pressure + wind pressure

Where:

- Stack pressure is calculated as 0.11 Pa per ˚C temperature difference (based on mean January temperature) per 3 m height (30 feet)
- Mechanical pressurization is defined by mechanical engineer
- Wind pressure is long-term January pressure based on mean wind speed

5.4.2 Water Penetration - E331

Water penetration testing in accordance with ASTM E331 is common to many building assemblies. Basically a static air pressure difference is applied across the wall sample while a continuous spray of water is provided to the outer surface of the wall. Observers watch for water penetration to the interior during a typical 15 minute test period.

The method of test provided by ASTM E331 was originally based on the assumption of a face-sealed wall. The intent is to provide a continuous film over the wall surface thus placing water at any opening. The pressure difference would then pull water in at the opening. Theoretically, in a rainscreen design no air pressure difference would act across the exterior wall face. However, over 90 per cent of curtain wall assemblies leak water on their first test.

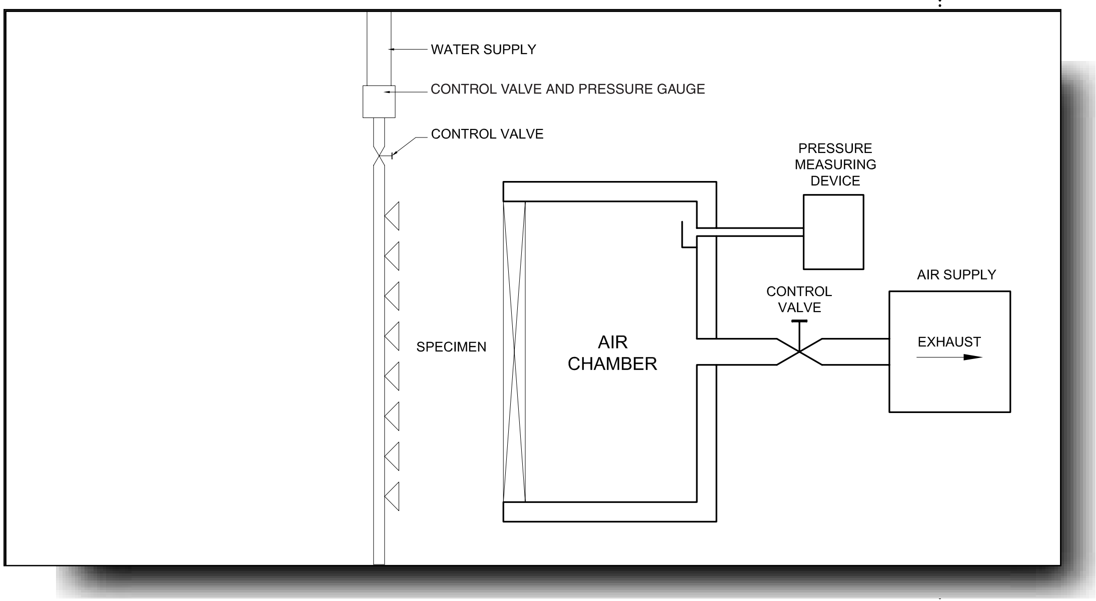


Figure 5.2: *Water penetration test apparatus –ASTM E331*

In order to effectively specify a water penetration test five parameters must be considered. These include:

- pass/fail criteria
- water supply rate
- water supply duration
- pressure difference
- pressure application

These are discussed individually in the following sections.

Pass/Fail Criteria

Reference to either standard procedures or industry recommendations without a separate definition of water leakage may lead to difficulties. ASTM E331 defines water leakage as:

Penetration of water into the plane of the innermost face of the test specimen under specified conditions of air pressure difference across the specimen during a 1 minute test.

AAMA, which is a frequently cited reference with regard to water penetration testing, defines water leakage differently as:

Any uncontrolled water that appears on any normally exposed interior surfaces, that is not contained or drained back to the exterior, or that can cause damage to adjacent materials or finishes. Water contained within drained flashings, gutters, and sills is not considered water leakage. The collection of up to one half ounce of water in a 15 minute test period on top of an interior stop or stoop integral with the wall system shall not be considered water leakage.

Both of the above definitions would allow water entry to the interior and allow the accumulation of water within wall cavities.

The pass/fail criteria should include the requirement for no water penetration inboard of the air barrier plane and rapid drainage resulting in no retained water in wall cavities outboard of the air barrier.

Water Supply Rate

The ASTM E331 specified uniform spray rate of 3.4 L/m^2/min. (300 US gal/min/sq. ft.) is common to several test methods. At first view this appears as a very intense rainfall (50 mm (2 inches) of rain in 15 minutes). However, if one considers a taller building and the accumulation of water flows down the facade during a moderate rain event it is not an unreasonable rainfall. Once the cumulative rundown height exceeds approximately 36 m (120 feet) the effective exposure rate would be greater than 3.4 L/m^2/min. (300 US gal/min/sq.ft.)) for a typical rainfall intensity of 25 mm/15 min. (1 inch/15 min.).

For a curtain wall that does not incorporate absorbent materials, increasing a flow rate above the standard flow rate is of little consequence provided the wall is covered with a uniform film of water using the standard rate. However, if the wall contains water shedding elements or is very articulated, a higher flow rate should be considered.

Water Supply Duration

The origins of the 15 minute water test are unclear and may be tied to the reporting of severe 15 minute design rain events. For curtain walls with very little storage capacity (by either absorption or cavity) this is likely sufficient. It is worth noting however that most countries outside of North America conduct water tests for much greater durations, in some cases more than 90 minutes. Longer durations should be specified for highly sensitive occupancies and very exposed locations.

Pressure Difference

The specification of an appropriate test pressure is critical to the validity and reasonableness of the test. ASTM E331 mandates a minimum test pressure of 137 Pa. AAMA recommends a minimum test pressure of the greater of 300 Pa (0.04 psi) or 20 per cent of the positive design wind load. AAMA also recommends a maximum test pressure of 575 Pa (0.08 psi). Again the origins of the above recommendations are unclear. Review of Canadian climatic data suggests that 20 per cent of the design pressure may not be adequate.

Review of the driving rain wind pressure (DRWP) data developed by Environment Canada indicates that wind pressures between 10 per cent and 100 per cent of the structural design pressure should be expected during rain events. Therefore recommended test pressure should reflect this.

The specifier should also add a load/workmanship factor appropriate for the project to reflect the consequences of water entry under extreme events. The maximum test pressure should also reflect the capability of the test facility. With dry glazed systems it is often prudent to conduct a test cycle with no pressure difference to test resistance with minimum gasket pressure.

ASTM E331 - Test Pressure

- Recommended Test Pressure = (DRWP/Reference Wind Pressure) * Design Wind Pressure
- Minimum test pressure should be 300 Pa (0.04 psi)

Pressure Application

ASTM E331 is, by definition, a static pressure test. Static pressure tests tend to be more severe on stiffer walls and walls with face sealed joints. On critical or custom monumental walls it may be appropriate to apply the static pressure in a stepped manner rather than in a one-step process. This results in a longer test and allows evaluation at varying pressure levels.

5.4.3 Water Penetration - AAMA 501.1

Water penetration testing in accordance with AAMA 501.1 shares many similarities with ASTM E331. In this test however the air pressure difference is created by a moving air stream typically generated by an aircraft engine turning a large diameter propeller.

AAMA 501.1 is claimed to provide some measure of the rainscreen performance of a curtain wall. Given the inconsistency between the frequency of pressure fluctuations generated by the aircraft propeller and natural wind frequency this claim is not valid for most situations. Furthermore, in this test procedure it is impossible to uniquely discern the cause of water leakage, as forces other than air pressure difference are also at play, such as gravity.

Nonetheless this test does still provide important data if conducted and interpreted correctly. The propeller blast rapidly vibrates the curtain wall. This vibration can act to open and close small openings that may admit water. The cycling action can also pump water behind gaskets. In some cases the propeller wash can dislodge exterior capping or decoration.

In addition to the vibration caused by the propeller action, the wind stream distributes the water flow over the wall surface in a variety of directions. Water is driven to vertical channels, up into weepholes, laterally at horizontal projections and into corners. This distribution of water can highlight weaknesses in the curtain wall at exterior junctions and features.

The aircraft engine speed is normally calculated to provide the same air pressure at the surface of the wall sample as that determined for ASTM E331. However, maximum pressures that can safely be attained by the aircraft engine alone are typically 600 Pa (0.08 psi to ?).

If the required test pressure is determined to be greater than the maximum attainable with the aircraft engine alone some specifiers mandate that a static pressure in the chamber is to be used to supplement the aircraft engine wind stream to provide the full test pressure. This practice leads to incorrect, overstated performance evaluations and is not an appropriate way to conduct testing.

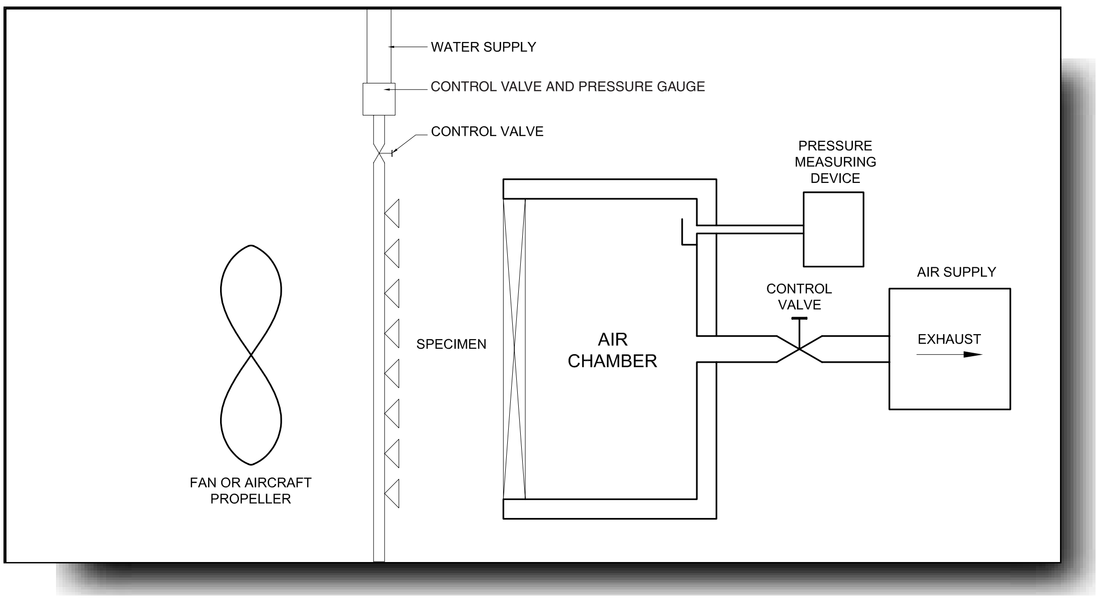


Figure 5.3: *Water penetration test apparatus – AAMA 501.1*

AAMA 501.1 Test Pressure

The maximum test pressure should be limited to the maximum pressure attainable by the aircraft engine alone. Chamber pressure should not be used to supplement the airstream pressure as this pressure will act to reduce vibration and precompress gaskets. It reduces the effectiveness of the test procedures and produces incorrect, overstated performance results.

5.4.4 Structural Adequacy - ASTM E330

The test set-up in accordance with ASTM E330 is very similar to ASTM E283 and ASTM E331. Basically an air pressure difference is applied across the wall sample and measurements of deflection or distortion are made. Like previous tests the test method presupposes a face sealed wall where the air pressure difference is applied across the outer cladding which forms the air barrier. This results in an important limitation with respect to rainscreen wall systems. While ASTM E330 effectively tests the curtain wall framing and anchors to the structure it does not test the structural adequacy of any panels or outer cladding and its attachment (in an interior air sealed rainscreen wall) nor does ASTM E330 test the capacity of any glass in the assembly.

ASTM E330 Test Limitation

Testing a rainscreen wall in accordance with ASTM E330 does not test any elements outside of the air barrier such as spandrel panels, spandrel glass, feature elements or anchors that attach these elements to the mullions or rails. Spandrel panels, etc. require separate tests. It is also important to note that this procedure does not in any way certify any glass.

In order to effectively specify a structural test programme at least three performance parameters are critical. These include:

- design wind/air pressure
- deflection criteria
- overload criteria

These are discussed individually in the following sections.

Design Pressures

Procedures to determine the design wind pressure for testing are well established. Building codes provide information to develop minimum wind pressures and this information can be supplemented by wind tunnel tests. Additive to the wind pressure should be stack and mechanical pressurization pressures previously determined for air leakage testing, although the stack and mechanical pressures are typically very low compared to the design wind pressure. Test pressures are usually applied and held for 10-15 seconds to partially reflect wind gust effects.

Deflection Criteria

Industry recommendations for wall framing deflection tested at the design pressures are L/175 (where L=span). This specification is based primarily on glass edge support conditions. It may result in excessive deflections unless an upper limit on deflection is provided. This limit is determined by the specifier but is often 9 to 12 mm (3/8 to 1/2 inch)

The L/175 deflection criterion is an industry recommendation only and can be altered by the specifier if the project demands. Deflection limits of L/200 are quite common and deflection limits of L/240 are also not unusual. The less the allowable deflection the deeper or heavier the framing and there is an increased cost associated with this.

Most references and specifiers only address the deflection of the aluminum framing. Glass deflection and spandrel backpan deflection can also be an issue. Glass, properly designed for strength, is quite flexible and will deflect substantially during a structural load test. Deflection ratios of L/50 are not uncommon. While glass deflection limits are normally not specified, in cases where there are large lites or public perception is important, the glass deflection specification may be appropriate. Extra attention is typically provided for main floors, observation areas or airport control towers.

Deflection limits for sheet metal backpans are critical. An overly flexible backpan may snap back and forth creating noise, may move to release firestops or load smoke seal sealants or impair the pressure equalization performance of the spandrel cavity. In the case of backpans deflection, ratios are not appropriate and fixed limits should be imposed. Most critical is the deflection at the floor slab level.

Deflection Limits – Sheet Metal Backpans

The deflection of sheet metal backpans at the level of the floor slab should be limited to 6 mm (1/4 inch).

Overload Criteria

The application of the specified test air pressure difference and subsequent measurement of deflections allow the confirmation of a serviceability limit state. The specified load must be applied without exceeding a specified limit state (deflection limit). Testing then normally proceeds to an overload test. This test is conducted at 1.5 times the design pressure.

The 1.5 factor originates in the working stress approach to structural design (WSD) and recognizes test guidelines published by the Aluminum Association. It also reflects a load equivalent to 90 per cent of the minimum factor of safety (1.65) implicit in the WSD method. This coincidentally corresponds to the limit states approach to structural design whereby 90 per cent of the calculated member, or system, resistance must equal or exceed 150 per cent of the calculated load on that member, or system. At the 1.5 times overload condition there is to be no plastic deformation of the structure. In other words the materials stresses stay below the yield point of the aluminum.

However, it is important to recognize that the 1.5 overload condition does not test all components equally as different components have different safety factors. For example the shear failure of an anchor bolt at the 1.5 condition does not indicate a marginally undersized bolt, but a bolt almost 40 per cent undersized. Therefore, the overload test provides useful information on the primary framing members and their interaction but does not truly qualify all components especially anchors, fasteners, welds and glass.

Overload Test Limitation

Overload testing does not ensure a consistent level of safety with respect to all curtain wall components. Typically anchors, fasteners, welds and glass are not fully evaluated in an overload test.

Some specifiers request that testing proceeds to destruction of the sample. Testing to destruction can be useful if information on the post-glass breakage behaviour is required or if concern is expressed regarding the adequacy of anchors. It is often more useful to test anchors or small components in separate, more controlled tests rather than in the large scale mock-up.

Given the inconsistencies in the results of the structural test methods, structural calculations for the curtain wall should also be submitted and reviewed. Historically, calculations were only done in-house by the curtain wall contractor as a rough check on portions of the wall. Today, the calculations form a vital part of project documentation. As such, aside from technical accuracy and completeness, the presentation of the calculations is critical. Unfortunately calculations are often presented in an unorganized haphazard manner and cover only the major building elements. Incomplete or unorganized calculations make the verification of a design more difficult and therefore less likely.

When requesting calculations, the following should be outlined as requirements:

Curtain Wall Calculations

- Calculations must be numbered, preferably in logical groupings that allow the logical insertion of corrected pages. Each page and section should be titled.
- Typed computer output does not guarantee clarity. Often a logically ordered, well referenced hand-written set is far superior (provided handwriting is legible).

- Sketches of the element being analysed help immensely in the understanding of the calculations.
- A clear definition of the imposed loads and their origin is mandatory.
- Analysis should be conducted using accepted techniques and nomenclature common to the applicable design method.
- The basic material properties and allowable stresses/loads should be presented along with their origin.
- Appendices should be included and could contain section properties, bolt data, adhesion data or repetitive form calculations.

5.4.5 Alternate Test Procedures

The basic test procedures outlined above are the most common test procedures and provide information useful in the comparison of different curtain walls. There are a number of other procedures that are also applicable in testing the basic air leakage, water penetration resistance and structural performance of curtain wall systems. Advice should be sought from a specialist consultant in the specifics of these procedures.

ASTM E547- *Water Penetration of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Differential.*

ASTM E1233 - *Structural Performance of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Differential.*

ASTM E1424 - *Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors under Specified Pressure and Temperature Difference Across the Specimen.*

5.5 SUPPLEMENTARY TEST PROCEDURES

Aside from the basic test procedures outlined in Section 5.3 further testing is often conducted when a formal mockup is prepared. Unlike the tests referenced in Section 5.3, these supplementary tests are not all subject to consistent test standards or procedures.

1. Condensation resistance
2. Overall thermal transmittance
3. Thermal cycling
4. Seismic racking
5. Window washing anchor

5.5.1 Condensation Resistance

The resistance of highly conductive curtain wall framing to condensation under winter conditions is of significant interest in a cold climate. Testing or analysis to assess the condensation potential of a curtain wall system is carried out by one of three different means, each with its own limitations. These means include a simple, large chamber test, a formal thermal chamber test and computer simulation.

A simple, large chamber test is the most frequently used test method and arguably the least accurate. The method is often incorporated into an overall test programme and utilizes the same chamber and wall sample used for basic testing. This is its principal advantage.

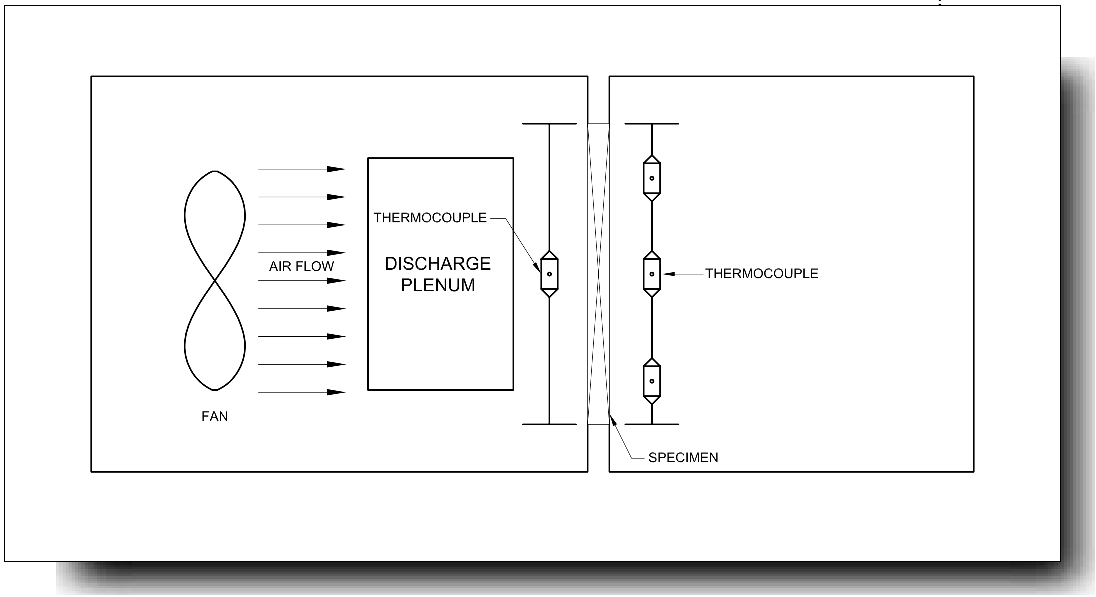


Figure 5.4: *Simple large chamber test*

In this test the mockup chamber is maintained as the warm chamber. An insulated chamber (referred to as a "cold" box) is placed on the exterior of the wall and the temperature is lowered to the design condition. Thermocouples placed on the interior surfaces of the wall record surface temperatures for given cold chamber conditions. The recorded surface temperatures are reviewed with reference to a psychrometric chart to assess condensation potential.

The test is useful in comparing, to a point, the performance of competing products. It has limitations, however, that must be recognized.

Simple Test Procedure Limitations

- No forced air circulation occurs in the cold chamber. Therefore the effect of wind in cooling the frames is minimized.
- The interior surface of the wall is fully exposed to interior heat. This will not be the case on-site and therefore interior surface temperatures are effectively increased.
- The complete lack of interior structure and finishes promotes better air circulation and heat distribution over what would be present on a building site.
- These three limitations all result in an overstatement of the condensation resistance that will actually be achieved in the building installation.

The formal test chamber approach is very similar to the simple, large chamber test. The principal difference in this test method over the simple, large chamber test is the use of a wind generator in the “cold” box. A fan and flow straightening tubes provide an air flow perpendicular to the wall face. Thermocouples strategically placed measure surface temperature for review with psychrometric tables.

Formal Chamber Test

Formal Chamber Procedure Limitations

- The principal limitation of the formal chamber is the size of the sample. Originally developed to test windows most chambers cannot accommodate samples larger than 2.5 m square (8 foot by 8 foot).
- The limitations of the simple procedure with respect to the lack of interior structure and finishes still apply to the formal procedure, and will result in an overstatement of actual condensation resistance that will be achieved in the building installation.

The formal chamber approach reduces errors by providing a controlled air flow but introduces errors by forcing a reduction in frame arrangement to fit the chamber.

Computer Simulations

Computer simulation is rapidly becoming the most popular means of assessing condensation potential. Using finite difference programs, such as *Frame* (by Enermodal Engineering), curtain wall cross sections can be modeled and thermal performances simulated. The modeling procedure is relatively simple involving the drawing of the frame section (complete with gaskets, thermal breaks and glass) within the program and then applying a temperature difference. The program considers the conductivities of the model elements and estimates the surface temperatures for later comparison to psychrometric charts.

While the creation of the models is a simple drawing exercise, the proper use and interpretation of the output from a computer simulation requires some experience. Comparison of simulated results with physical test data sometimes reveals considerable error. However, proper use of the program is very effective in evaluating the relative impact of changes on the thermal performance and the ranking of different designs. Simulation data should be used with caution in predicting condensation potentials.

Even with accurate modeling, experience indicates that simulated surface temperature results should be reduced by 2˚C (±10˚F) for evaluation of condensation potentials using psychrometric charts. For critical installations an even greater correction should be considered.

Again these simulations do not normally consider interior finishes, or significant three-dimensional heat flow, that can have a significant impact on surface temperatures of the curtain wall.

5.5.2 Overall Thermal Transmittance

The overall coefficient of heat transfer (U-value) is an important property of a curtain wall system. When compared with the solar heat gain coefficient (SHGC) of the glazing an overall energy performance level can be determined. A test for thermal transmittance means heat flow due to conduction, radiation and convection. A number of standard test methods are commonly referenced.

AAMA – 1503.1 - *Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections*

ASTM C177 - *Standard Test Method for Steady State Heat Flex Measurements and Thermal Transmission Properties by Means of the Guarded Hot Plate Apparatus*

ASTM C1199 - *Standard Test Method for Measuring the Steady State and Thermal Transmittance of Fenestration System Using Hot Box Methods*

ASTM E1423 - *Standard Practice for Determining the Steady State Thermal Transmittance of Fenestration Systems*

The test procedure set up is similar to the schematic shown for the assessment of condensation resistance. Through the recording of temperature differences at specific locations and the power flow to a roomside calorimeter overall thermal resistance and transmittance values can be obtained.

As with previously discussed thermal testing the principal limitation of this method is the size of the sample. Full curtain wall modules can rarely be accommodated in testing laboratory chambers.

As a result, computer simulation combined with standard test results from glass products is being used more frequently to determine U-values. Analytical procedures include consideration of an overall U-value based on an area weighted U-values of the framing, the glass edge and the centre of glass region.

5.5.3 Thermal Cycling

A sequence of thermal cycling is frequently included in a test programme which incorporates a simple large thermal chamber. The intent of this test is to cycle the wall through a range of exterior temperatures representative of the temperature extremes the wall is likely to be exposed to.

The temperature cycles induce movements in the wall and follow up air leakage and water penetration tests can then provide some indication on the potential effect of these movements. To be effective at least five cycles should be completed. The length of each cycle will depend on the features of the wall as more massive walls require longer to stabilize temperatures. Thermal cycling is not normally conducted on smaller formal test chamber samples as the components are generally too small to move sufficiently.

5.5.4 Seismic Racking

Basic structural testing to ASTM E330 does not impose any in-plane loading or differential out-of-plane loading as would be generated in a seismic event. Nor does it impact any rapid cyclic loading.

While curtain wall design for high risk seismic areas on monumental buildings requires specialist input, most contemporary walls are evaluated based on their ability to accommodate movements from moderate events and their breakage behaviour in extreme events.

Anticipated differential floor slab movements, as can be supplied by the structural designer of the building frame, can be applied to the wall using hydraulic jacks. Initial movements should be representative of a more likely moderate event. Air and water leakage testing would be conducted after this level of loading. After all other testing is complete a final extreme movement can be applied to assess modes of failure.

5.5.5 Window Washing Anchors

Various designs of window washing tie backs are often incorporated into the curtain wall design. While qualified initially by calculation, tests of the anchor in a representative sample of framing may be warranted. Loading must be applied in the direction causing the most severe stress condition in the anchor.

5.6 TEST SEQUENCE

The performance of an individual test can be affected by the sequence of the testing. For example, air leakage testing after water penetration testing will often reveal better results due to the sealing effect of the water. Loading should also be provided in a progressively increasing manner so as not to prejudice a subsequent test.

A typical basic test sequence would consist of:

1. Pre-load to remove construction slack (10 per cent to 50 per cent of design load)
2. Air leakage test (infiltration/exfiltration)
3. Static water penetration test
4. Dynamic water penetration test
5. Structural performance test to 100 per cent of design loads
6. Repeat air leakage test (to assess if structural movements affected air seals)
7. Repeat static water penetration test (to assess if structural loading affected water seals)
8. Structural performance, overload test to 150 per cent of design loads

If large sample thermal cycling is to be conducted the test sequence would change as indicated below:

1. Pre-load to remove construction slack (10 per cent to 50 per cent of design load)
2. Air leakage test (infiltration/exfiltration)
3. Static water penetration test
4. Dynamic water penetration test
5. Structural performance test to 100 per cent of design loads

6. Repeat air leakage test (to assess if structural movements affected air seals)
7. Repeat static water penetration test (to assess if structural loading affected water seals)
8. Thermal cycling test with one cycle used to assess condensation resistance
9. Repeat air leakage test (to assess if thermal cycling movements affected air seals)
10. Repeat static water penetration test (to assess if thermal cycling movements affected water seals)
11. Structural performance, overload test to 150 per cent of design loads

While the above examples represent normal basic procedures there is no restriction on adding additional tests or specially developed tests provided they are identified in the contract documents at time of bid. The services of a specialist consultant early in the design process can be of benefit to the specifier in setting requirements.

5.7 FIELD TESTING

Field testing of curtain wall systems is generally conducted as part of a quality assurance programme in new construction or as part of an investigative programme in existing assemblies. The most frequent field test is for water penetration resistance. Field air leakage tests are also conducted. Structural performance verification can be conducted but is far less common. Verification of thermal performance with respect to surface temperatures by remote monitoring is becoming more common.

5.7.1 Field Water Penetration Testing

Field water penetration testing is conducted using either the “chamber” or the “hose” method. Field testing using the chamber method is based on:

ASTM E1105 - *Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls and Doors by Uniform or Cyclic Static Air Pressure Differences.*

This test procedure is basically a field version of ASTM E331. In this method the same basic parameters are used as in the laboratory procedure ASTM E331. The chamber can sometimes be in the form of a polyethylene sheet to avoid the construction of a plywood box as the chamber. Attention must be paid to minimizing any lateral air flow from the test area to adjacent wall areas in order to achieve adequate test pressures. It is generally not too difficult to conduct this test on a building under construction; however, once ceilings and finishes are installed it is much more difficult to access the interior of the wall to seal a chamber. High volume door fans can be used to overcome this difficulty if full-height (slab to slab) room partitions are available.

Field testing with an imposed air pressure difference is a reliable means of assessing water penetration resistance. However, the test method and results are subject to the effects of wind and temperature differences that are inherent in a field test.

The hose test is conducted in accordance with AAMA 501.2 – *Field Check of Metal Storefronts, Curtain Walls and Sloped Glazing Systems for Water Leakage*. This method requires a 19 mm (3/4 inch) diameter hose, a pressure gauge and a specific spray nozzle (Monarch Manufacturing Type B-25 #6.030 brass). The procedure involves progressively spraying a 1.5 m (5 feet) length of curtain wall joinery for 5 minutes in a back and forth manner with the nozzle perpendicular and 300 mm (1 foot) from the wall surface. If no leakage is detected one moves to the next 1.5 m (5 feet) length.

The hose test is a simple test requiring no set up of a chamber and no complicated test equipment. However, it is limited in its usefulness. On a rainscreen wall it can test the tightness of the exterior screen and possibly the drainage characteristics of the wall.

5.7.2 Field Air Leakage Testing

Quantitative field air leakage testing is frequently specified with reference to either ASTM 283 or ASTM 783 – *Field Measurement of Air Leakage Through Installed Exterior Windows and Doors*.

While the procedures for field air leakage tests are conceptually simple the nature of most curtain wall assemblies makes reliable quantitative results difficult to achieve. The potential for lateral and vertical airflow or extraneous leakage occurring in the system is high and contributes to errors in the test procedure. Efforts to seal off this airflow using expanding foams can be attempted but the foam is applied to a hidden cavity and even small voids can result in significant errors. As such unless the curtain wall assembly can be isolated with respect to extraneous airflow, quantitative field air leakage testing should be avoided and any results be subject to critical review.

Qualitative field air leakage testing can be conducted using a chamber similar to that erected for a water penetration test. Using a fog generator, a helpful visual indication of air leakage can be achieved. The use of smoke bombs in lieu of fog generators should be avoided.

5.7.3 Field Structural Performance

Field verification of structural performance can be conducted in a similar manner to ASTM 331 discussed previously. It is feasible to conduct this testing on an installed wall in new construction but it becomes more difficult once interior finishes are installed. It is often better to test specific elements of the wall with discrete jacks or pumps in place of an overall air pressure difference type test.

5.7.4 Field Monitoring of Thermal Performance

The monitoring of field thermal performance using thermocouples and remote data acquisition equipment is the most reliable measure of thermal performance. A monitoring set-up requires not only recording of curtain wall surface temperatures but also outside conditions (temperature, wind speed) and interior conditions (temperature, relative humidity). Monitoring of an installed system provides the most reliable measure of performance as all of the elements impacting performance are in place (finishes, heat supply, actual air circulation, etc.). Unfortunately this information is available too late to assist with the original design of the wall system, but can provide insight for modification of future, similar designs.

5.7.5 Thermography

Infrared thermography has become a useful tool in qualitatively reviewing building envelope performance and, used properly, can be valuable in assessing curtain wall performance. Unlike many other wall types, glass and metal curtain walls are lightweight structures with highly conductive components. The sensitivity of most modern scanning equipment can lead to mis-diagnosis of small thermal bridges and air leaks. As such a specific scanning protocol is recommended.

The preferred scanning protocol includes a two-pass procedure. The first pass is conducted with the building at as negative an internal air pressure as attainable. The second pass is conducted with the building at as positive an internal air pressure as attainable. The variation in air pressures allows the isolation of thermal bridging and air leakage.

Scanning is also useful in quality assurance programmes particularly where coated glass products are used. The slight surface temperature differences detectable on glass surfaces allow the detection of units installed backward or with missing coatings.

Chapter 6

DETAILS

INTRODUCTION

This chapter introduces CAD details that synthesize the information presented in the previous chapters concerning material selection and building science principles. The details represent a Best Practice Guide in Glass and Metal Wall Construction. CMHC expects the professional designer to modify the details to accommodate local climate and construction practices; aesthetic, performance and structural criteria; and cost factors. Therefore, CMHC does not guarantee in any way the performance of walls described. The professional designer must assume all liability in the use and modification of these details.

Each CAD detail is accompanied with a facing text page in which a checklist of the elements forming the air, water, vapour and heat flow resistance of the section is presented, along with specific comments regarding components of the assembly.

DETAIL 1 - TERMINATION AT GRADE

Provide a waterproofed concrete curb to raise the base of the curtain wall at least 200 mm (8 inch) above any exterior drainage plane. Raising the base of the wall above a drainage plane reduces the potential for water entry due to surface water flow and reduces the potential for physical damage due to snow clearing or salt distribution.

Air Barrier continuity between the concrete curb and the curtain wall is provided by a membrane, supported by sheet metal backing over longer spans.

Thermal Barrier continuity is provided by rigid insulation.

Water Penetration control is provided by the membrane protected by the formed metal base flashing.

① **Concrete Curb**

Positioning the wall on top of a curb avoids the need for supplementary support steel. Air barrier and vapour retarder seals are simplified, insulation and air barrier planes are more readily continuous and the curb provides inherent protection to the wall.

② **Waterproofing Membrane**

Foundation waterproofing membrane to extend up and onto top of curb

③ **Aluminum Mullion**

Anchored to curb with discrete anchors positioned at mullion centre line

④ **Membrane**

Membrane compatible with curb waterproofing ensures continuity of air barrier between waterproofing and sill rail of curtain wall. The membrane is clamped and adhered to sill rail onto primed surface. Where the gap between the curb and the sill rail exceeds 19 mm (3/4 inch) a sheet metal backing must be provided to the membrane.

⑤ **Rigid Insulation**

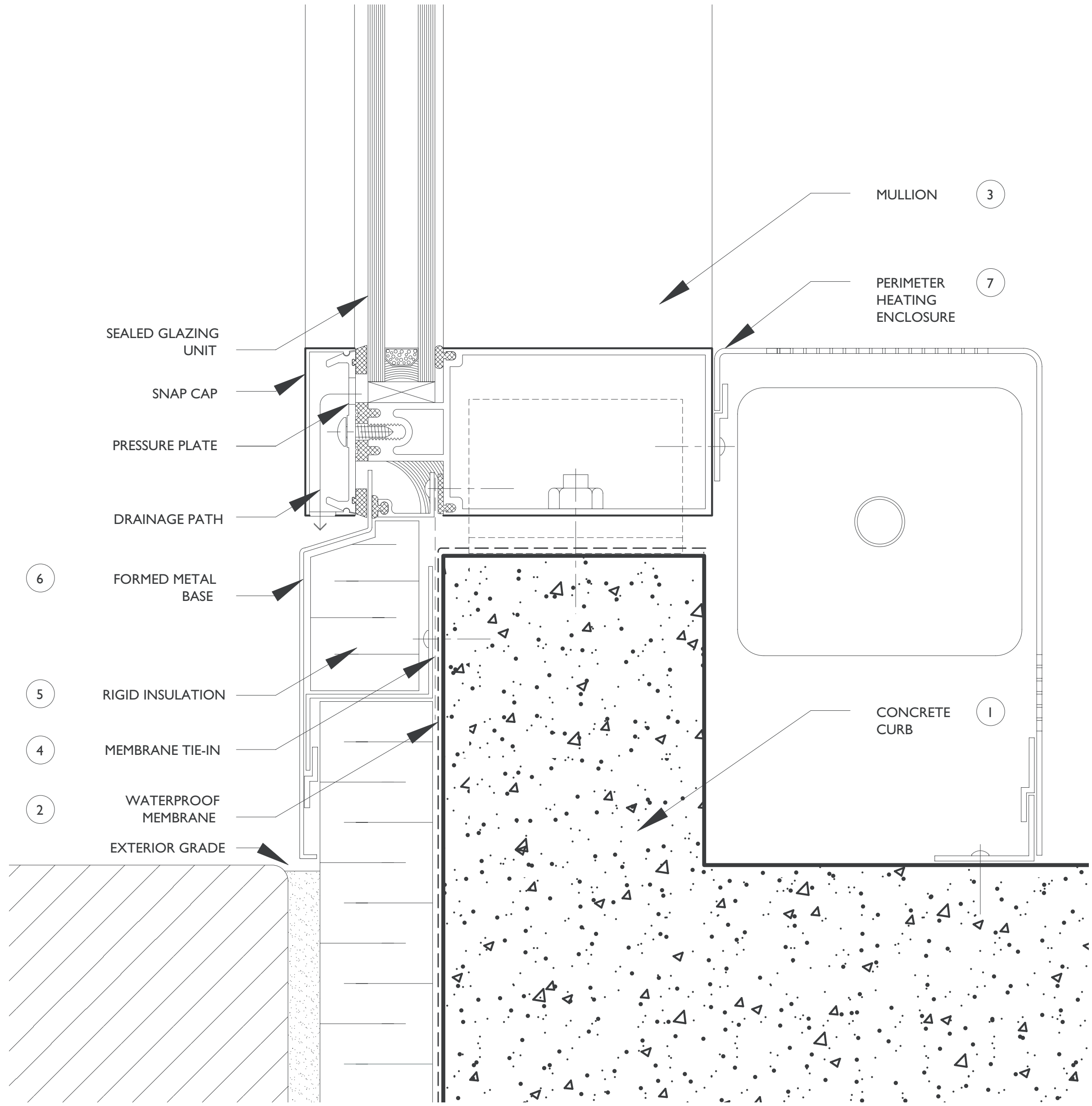
Rigid insulation (Type 4) on the exterior provides continuity of thermal protection.

⑥ **Base Flashing**

A separate formed heavy gauge metal flashing allows easy replacement as the material is weathered or damaged by snow removal and de-icing salts. The drainage space between the snap cap and flashing must be left clear of sealant to promote proper drainage.

⑦ **Perimeter Heating Enclosure**

Providing a thermal connection between the curtain wall sill rail and the heating element enclosure enhances the condensation resistance of the curtain wall framing. Fastening for enclosure shall not penetrate any air seal elements.



Detail 1: *Termination at grade*

DETAIL 2 - TERMINATION AT SOFFIT

The termination of a curtain wall at a cold soffit is an area often overlooked with respect to air sealing and continuity of thermal insulation. Provide a continuous metal closure from the shoulder of the lowest horizontal rail back up to the underside of the slab. This ensures that gaps between the backpan and the mullion and the mullion tubes themselves are well sealed. Thermal insulation to the backside of the wall, particularly the mullion tubes, should be continuous. The end of the wall is often under-insulated due to the desire to maintain a sight-line matching the lowest snap cap.

Air Barrier continuity between the underside of the slab and the lower rail

> In high humidity buildings a heated soffit should be considered to avoid condensation in the assembly.

of the curtain wall is provided by the membrane supported by a sheet metal backing sheet. The backing sheet is mechanically fastened to the underside of the slab, the mullions and the lower rail.

Thermal Barrier continuity is provided by semi-rigid insulation held with straps or stick pins tight to the air barrier closure to prevent air circulation between the air barrier and the insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the sealed membrane and the drainage inherent in the curtain wall system.

(1) Continuous Metal Membrane Support

A continuous sheet metal closure connecting the shoulder of the lowest horizontal rail to the underside of the slab ensures full support to any membrane work and bridges any small gaps such as that between the backpan and the side of the mullion.

(2) Membrane

Either a continuous membrane or membrane strips at all seams and terminations completes the air seal between the slab and the end of the curtain wall.

(3) Metal Backpan

The preformed metal backpan is glazed into the curtain wall framing much as a piece of glass. The backpan detailing at the soffit is the same as at typical spandrel conditions. Where the insulation thickness does not provide full coverage of the sides of the backpan wider strips of insulation should be provided about the backpan perimeter to enhance condensation resistance.

(4) Suspended Metal Soffit

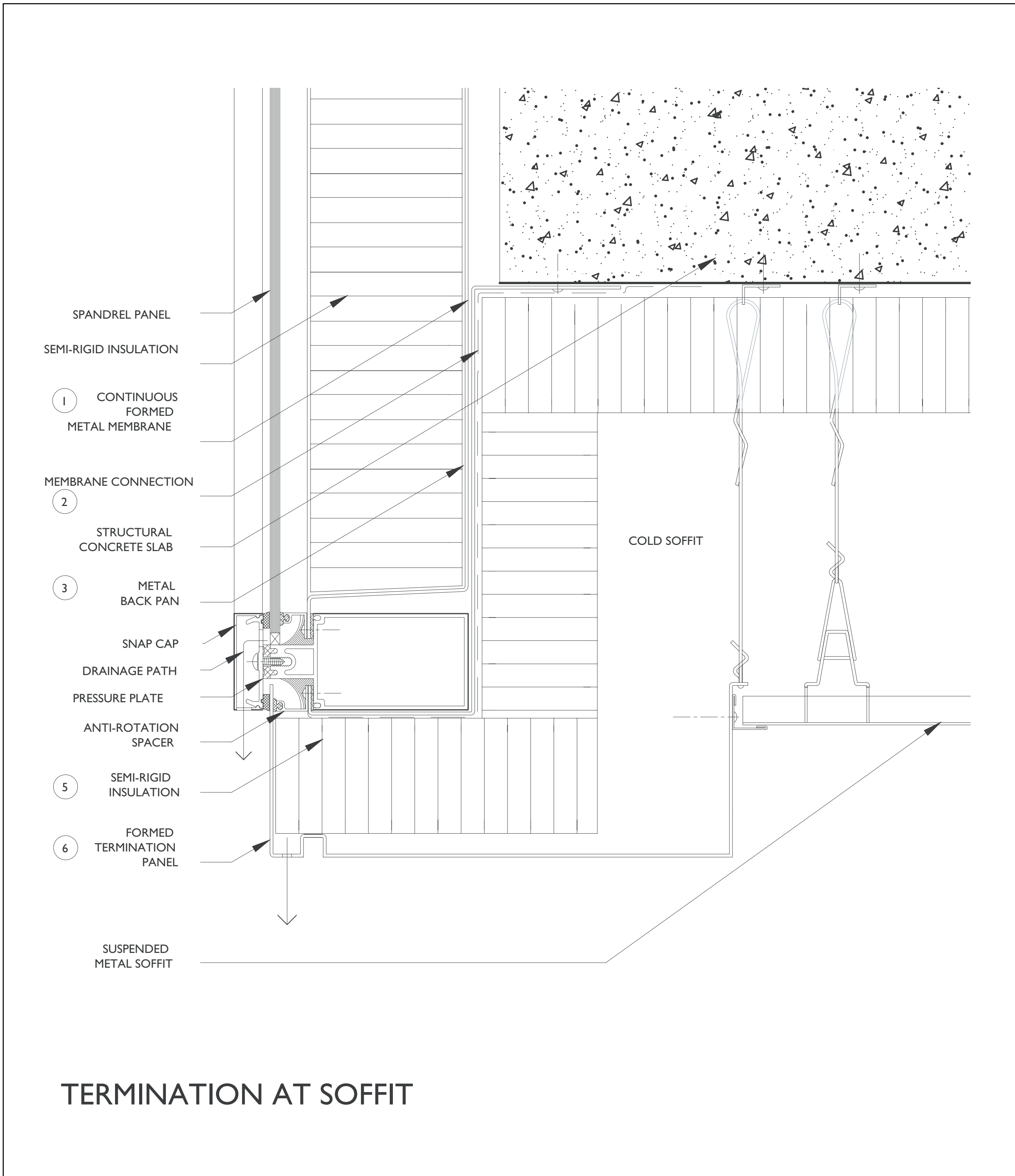
In many cases the section of stick built curtain wall terminating at a soffit actually extends up past two floor-slabs and is fixed against vertical movement at the second slab level. As such differential movement between the wall and the first floor slab and suspended soffit will be maximized. As shown, the suspended soffit should not fix directly to the curtain wall.

(5) Semi-Rigid Insulation

Semi-rigid insulation as used on the underside of the soffit should be continued along the back and end of the curtain wall. Where the thickness of the insulation at the termination of the curtain wall is restricted even a very thin layer of rigid insulation can be very effective.

(6) Termination Panel

The formed metal termination panel should ideally contain a drip edge and integrated with the suspended metal soffit.



Detail 2: *Termination at soffit*

DETAIL 3 - TERMINATION AT PARAPET

Provide a waterproofed curb to raise the top of the curtain wall at least 200 mm (8 inches) above top surface of any roofing. Raising the top of the wall above the roof level reduces the potential for water entry due to roof water flow and reduces the potential for physical damage due to maintenance activities. Also create a continuous formed metal air barrier closure to seal between the top of the curb and the glazing shoulder of the top rail. This detail applies to relatively short parapets where adequate air circulation and heat supply to the space between the curb and the back of the curtain wall can be ensured.

Air Barrier continuity is provided between the top rail of the curtain wall and the roofing by the membrane supported on sheet steel.

Thermal Barrier continuity is provided by semi-rigid insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weepholes in an intermediate horizontal.

(1) Extruded Aluminum Member

A typical horizontal rail at the top of the wall must receive an air barrier closure continuous with the roofing membrane and accept the outside edge of the coping.

(2) Metal Backpan

(3) Spandrel Panel

Spandrel panels are most frequently monolithic glass or sheet metal. Insulating glass, stone, plastics and combinations of these materials are also used.

(4) Structural Concrete Slab

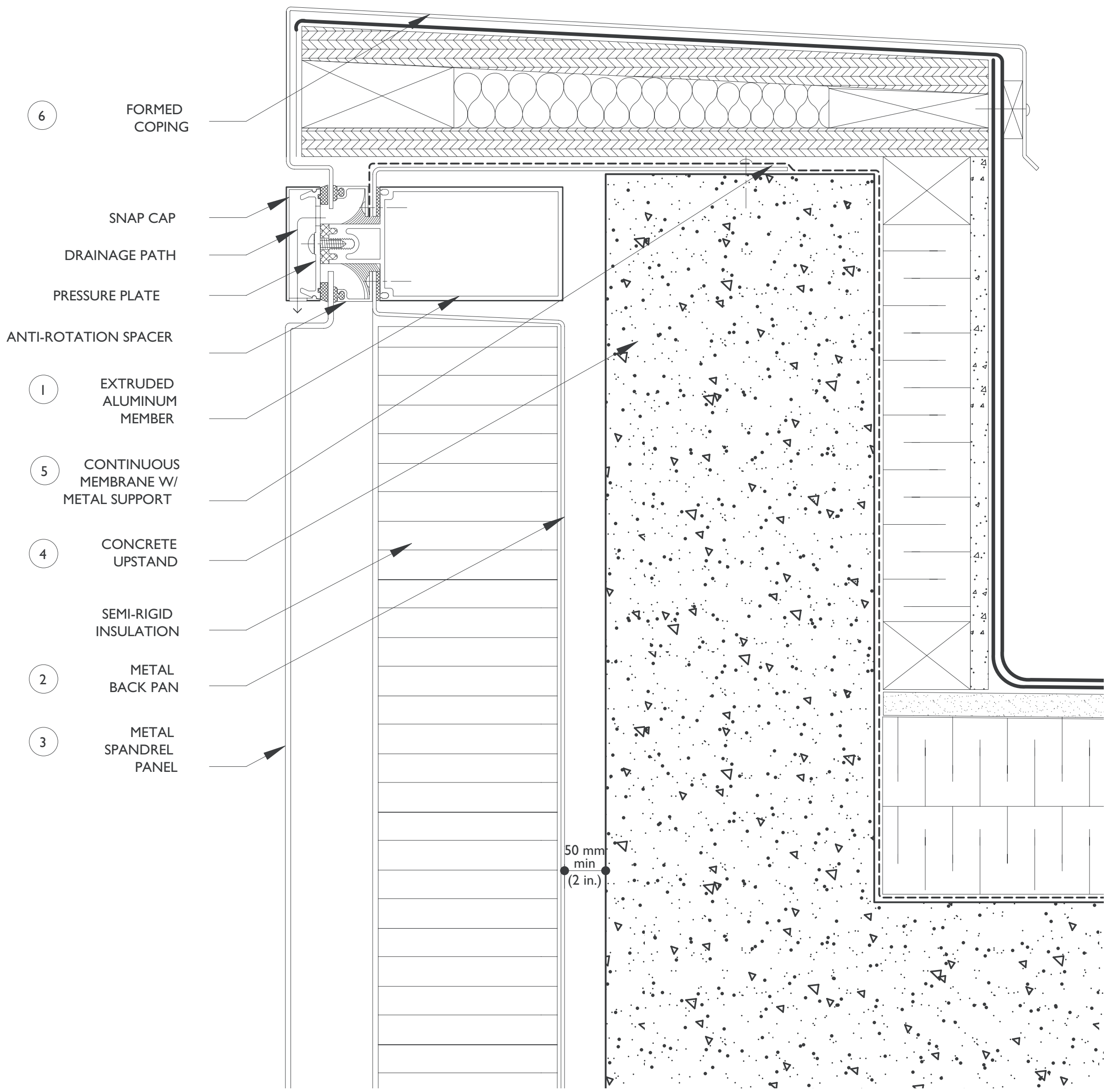
The use of a thermally massive concrete slab with its high heat capacity provides some heat to the upper end of the curtain wall enhancing condensation resistance. Use of the curb avoids the need for supplementary support steel, air barrier and vapour retarder seals are simplified, insulation and air barrier planes are more readily continuous and the curb provides inherent protection to the wall.

(5) Continuous Formed Metal Membrane Support

The open top ends of the mullion tubes, the interface of the wall and the top of the roof curb must be effectively sealed as they can be locations of severe air leakage. Water condensing out of the exiting air most often appears as dripping water at the ceiling level and may be mistaken for roof leaks. A continuous metal closure extending from the top rail to the top of the curb, topped with membrane forms an effective structural air seal.

(6) Coping

The coping of any roof perimeter may be subject to load from window washing and maintenance activities and as such heavier gauge or plate aluminum is often required. The blocking below the coping must not only backup the exposed metal but also provide some thermal insulation to the top end of the curtain wall. Coordination of wall and roof contractors is required to match finishes.



TERMINATION AT PARAPET

Detail 3: *Termination at parapet*

DETAIL 4 - INTERMEDIATE HORIZONTAL

While the exact configuration of stick system horizontal rail varies from manufacturer to manufacturer, the curtain wall industry has settled on a relatively standard range of products.Where differences exist they are often found in the size and shape of the screw chase and thermal break, the type of glazing gasket or tape used and the chases or surfaces into or onto which the gaskets or tapes are placed. To some degree, members of different manufacturers are interchangeable. However, care must be taken to ensure that the mullion can accommodate the appropriate glazing accessories. In many framing configurations the horizontal rail is the same width and depth as the vertical mullion. However, this is not a mandatory condition.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the rail and joinery sealants.

Thermal Barrier continuity is provided by the thermal break.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weepholes in the intermediate horizontal.

① Extruded Aluminum Member

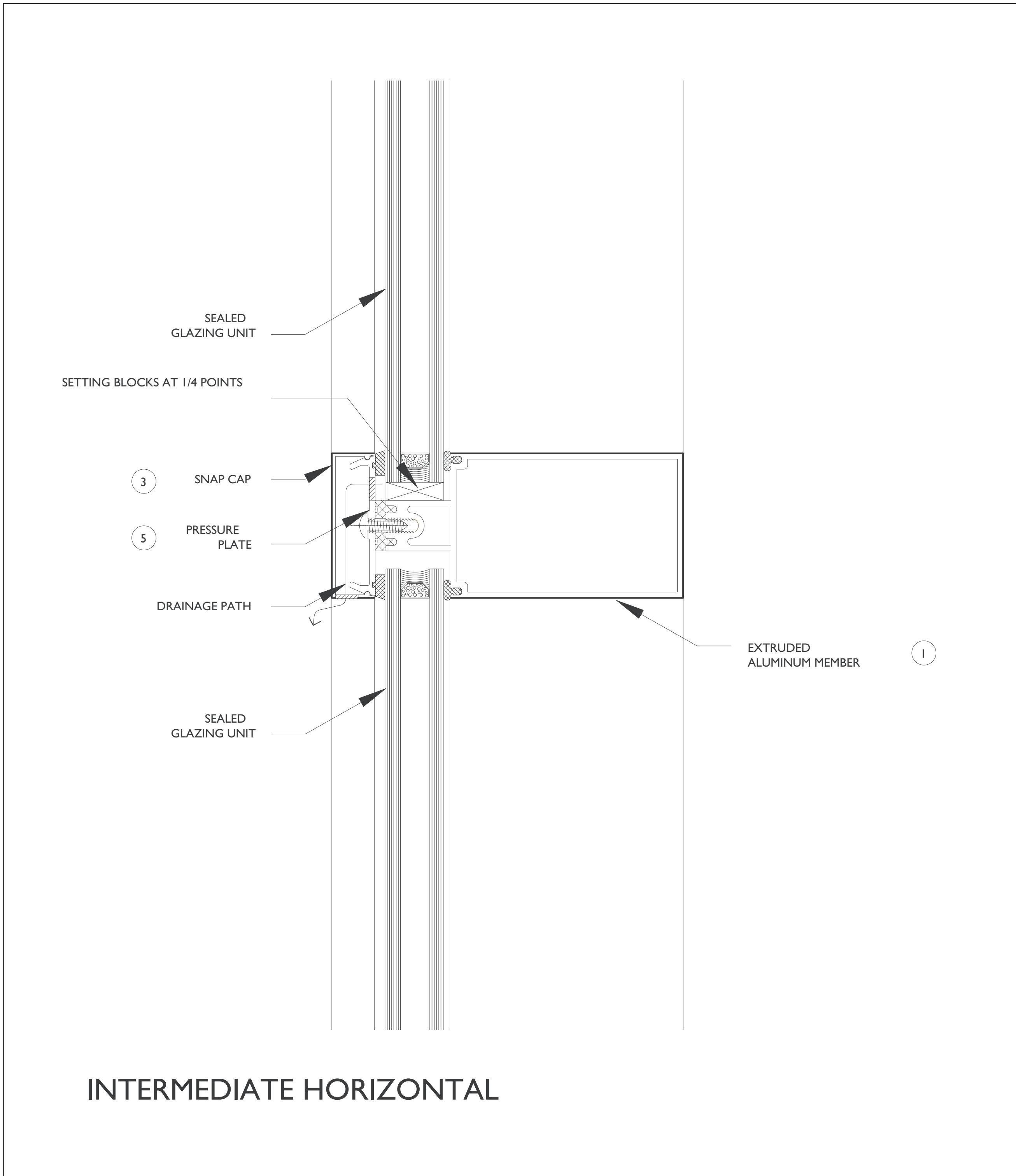
As indicated, basic profiles of aluminum stick system members have become standardized within the industry. Profile must match gasket/tape type and pressure plate configuration. The end of the horizontal rail must be sealed to the sidewall of the mullion at the glazing plane during installation. The rail must be attached to the mullion to sit square without any twist.

② Pressure Plate

As with the snap cap and the aluminum rail a variety of standardized pressure plates exist. Pressure plates must provide adequate compression to the glazing gaskets through the proper tightening of pressure plate screws. At least three weep slots are provided to drain the glazing cavity. Pressure plates are installed after the mullion pressure plates and are shorter than the opening to allow for expansion. The expansion gap is to be carefully sealed avoiding excess sealant flowing into glazing cavity.

③ Snap Cap

Snap caps are designed to engage properly onto a specific type of pressure plate. When caps are manufactured within tolerances, reliable engagement is obtained and cap removal does not result in any cap damage. However use of non-mating snap caps and pressure plates, out-of-tolerance materials or custom caps may result in a progressive loss of cap engagement over time with thermal cycling. Snap cap length must allow for thermal expansion without binding. On custom caps, particularly very deep caps, a fixing screw at one location along the cap length is recommended. Splice plates at expansion joints should also be detailed to prevent excess water entry to the glazing cavities. Of particular concern with deep horizontal caps are additional loads imposed by window washing and other maintenance activities. The area of snap cap weepholes should be twice as great as the area of pressure plate weepholes.



Detail 4: *Intermediate horizontal*

DETAIL 5 – STICK FRAME SYSTEM HORIZONTAL AT EXPANSION JOINT

The exact configuration of a common stick system stack joints, as illustrated in Chapter 2, varies little from manufacturer to manufacturer. The common sleeve joint contains inherent weaknesses with respect to long-term movement capability and sealing. Some manufacturers have recognized this and have introduced improved designs. The adjacent detail illustrates a stack joint assembly that isolates the joint movement to a continuous flexible membrane or gasket instead of relying on metal or glass sliding against a gasket as in the common detail.

Air Barrier continuity is provided by the interior glass surface, perimeter gaskets, the aluminum framing across the head of the sill rail, the air seal gasket/membrane, the sidewall of the head rail and the sheet metal backpan.

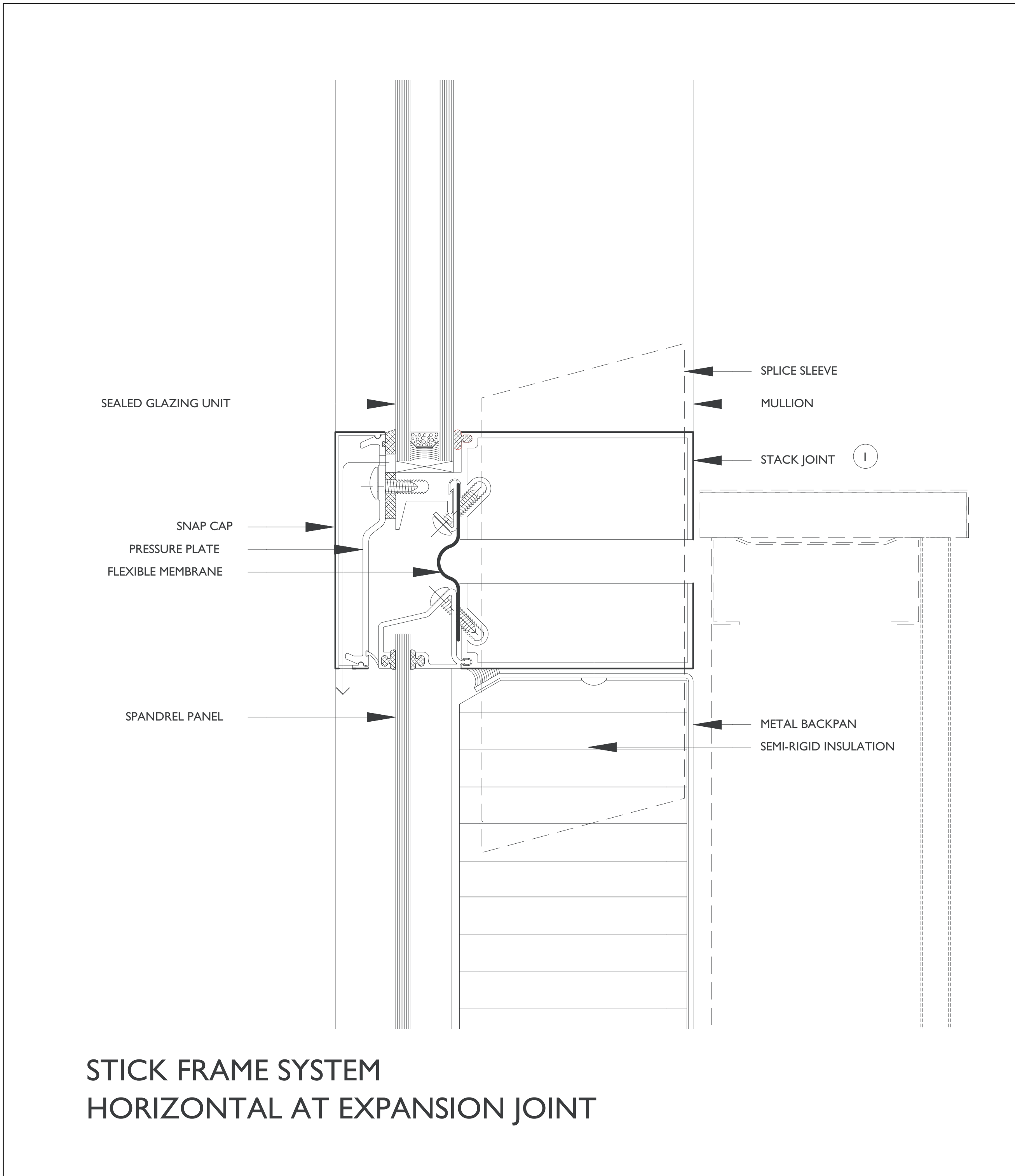
Thermal Barrier continuity is provided by the gaskets and silicone seal and the semi-rigid insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system behind the caps that direct water out at gaps in the sweep gasket.

(1) Extruded Aluminum Rails

Sill and head rails are mating sections that allow for vertical differential movement while sleeves lock lateral movement. The air seal membrane must be continuous and the outboard sweep gasket must allow drainage. The rails must incorporate splines to accept cap screws and a chase to accept a gasket. Components that extend to the exterior must be thermally broken from the main rail section. The use of plastic shielding components also enhances thermal performance.



Detail 5: *Stick frame system horizontal at expansion joint*

DETAIL 6 - HORIZONTAL AT CEILING

As with all detailing the intent at the curtain wall-to-ceiling interface is to expose as much as possible the aluminum section to the interior. This maximizes heat transfer from the interior air to the aluminum framing.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the mullion and joinery sealants, and the sheet metal backpan.

Thermal Barrier continuity is provided by the thermal break and the semi-rigid insulation in the backpans.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weepholes in an intermediate horizontal.

(1) Spandrel Panel

Spandrel panels are most frequently monolithic glass or sheet metal. Insulating glass, stone, plastics and combinations of these materials are also used. Monolithic spandrel glass is usually heat strengthened and is covered on the backside with a scrim which both opacifies and will tend to hold a broken lite of glass together until it can be removed.

(2) Metal Backpan

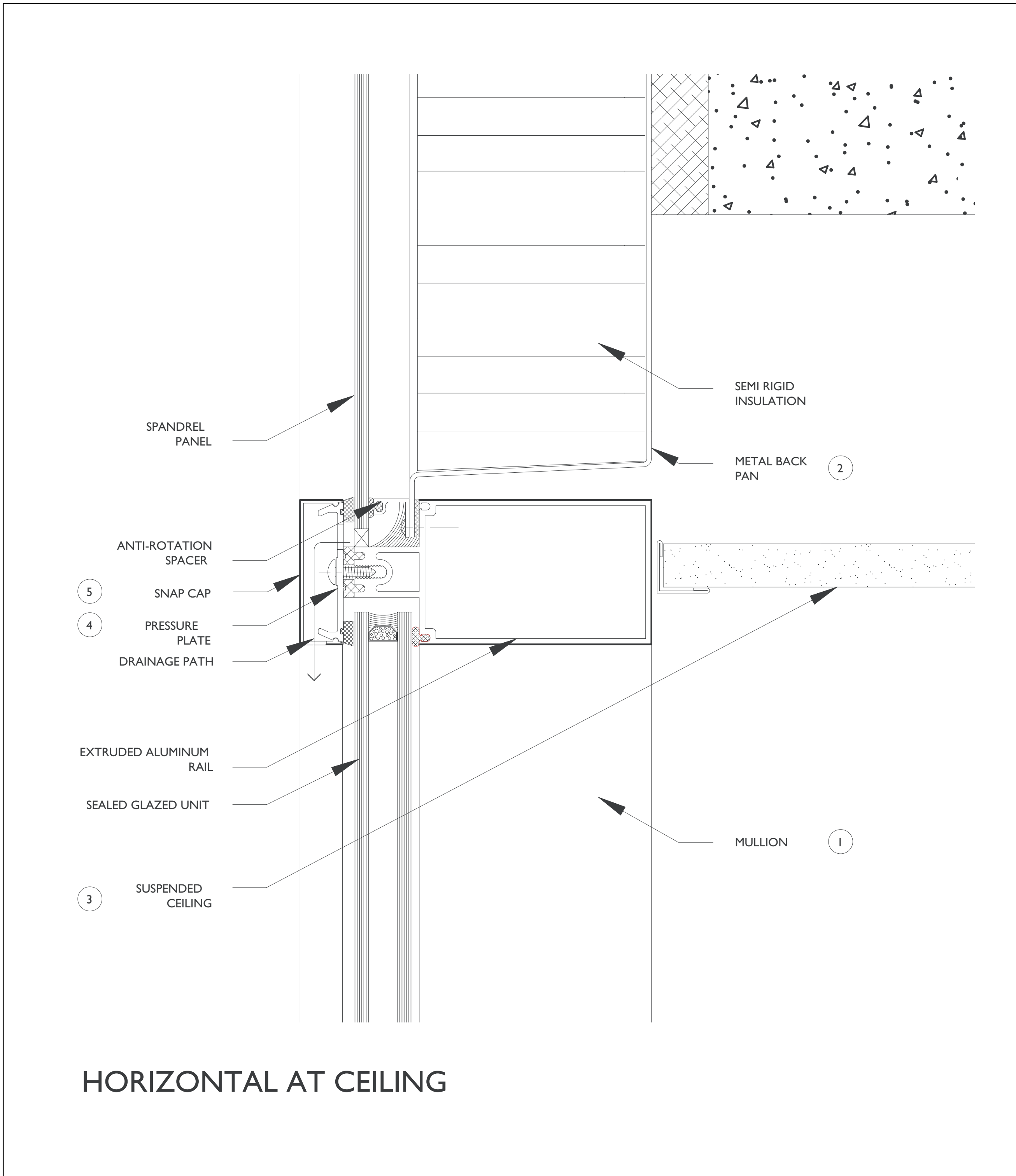
Overall backpan configuration and installation is similar between manufacturers. Differences appear primarily at the perimeter. Extruded adapters tend to be more reliable as folded edges have been known to corrode, provide an uneven surface for a glazing tape and be more susceptible to field damage before installation.

(3) Suspended Ceiling

Suspended ceilings, particularly their support grid, should not be fixed directly to the curtain wall. Wall movement due to gravity or wind loads can result in noise transfer and dislodging of ceiling systems. Fasteners for a support grid should never be drilled into a sheet metal backpan.

(4) Pressure Plate

Pressure plates must provide adequate compression to the glazing gaskets through the proper tightening of pressure plate screws. At least three weep slots are provided to drain the glazing cavity. Pressure plates are installed after the mullion pressure plates and are shorter than the opening to allow for expansion. The expansion gap is to be carefully sealed avoiding excess sealant flowing into glazing cavity.



Detail 6: *Horizontal at ceiling*

DETAIL 7 - INTERMEDIATE VERTICAL

While the exact configuration of stick system vertical mullions varies from manufacturer to manufacturer the curtain wall industry has settled on a relatively standard range of products. Where differences exist they are often found in the size and shape of the screw chase and thermal break, the type of glazing gasket or tape used and the chases or surfaces into or onto which the gaskets or tapes are placed. To some degree, members of different manufacturers are interchangeable. However, care must be taken to ensure that the mullion can accommodate the appropriate glazing accessories.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the mullion and joiner sealants.

Thermal Barrier continuity is provided by the thermal break.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weepholes in an intermediate horizontal.

① Extruded Aluminum Mullion

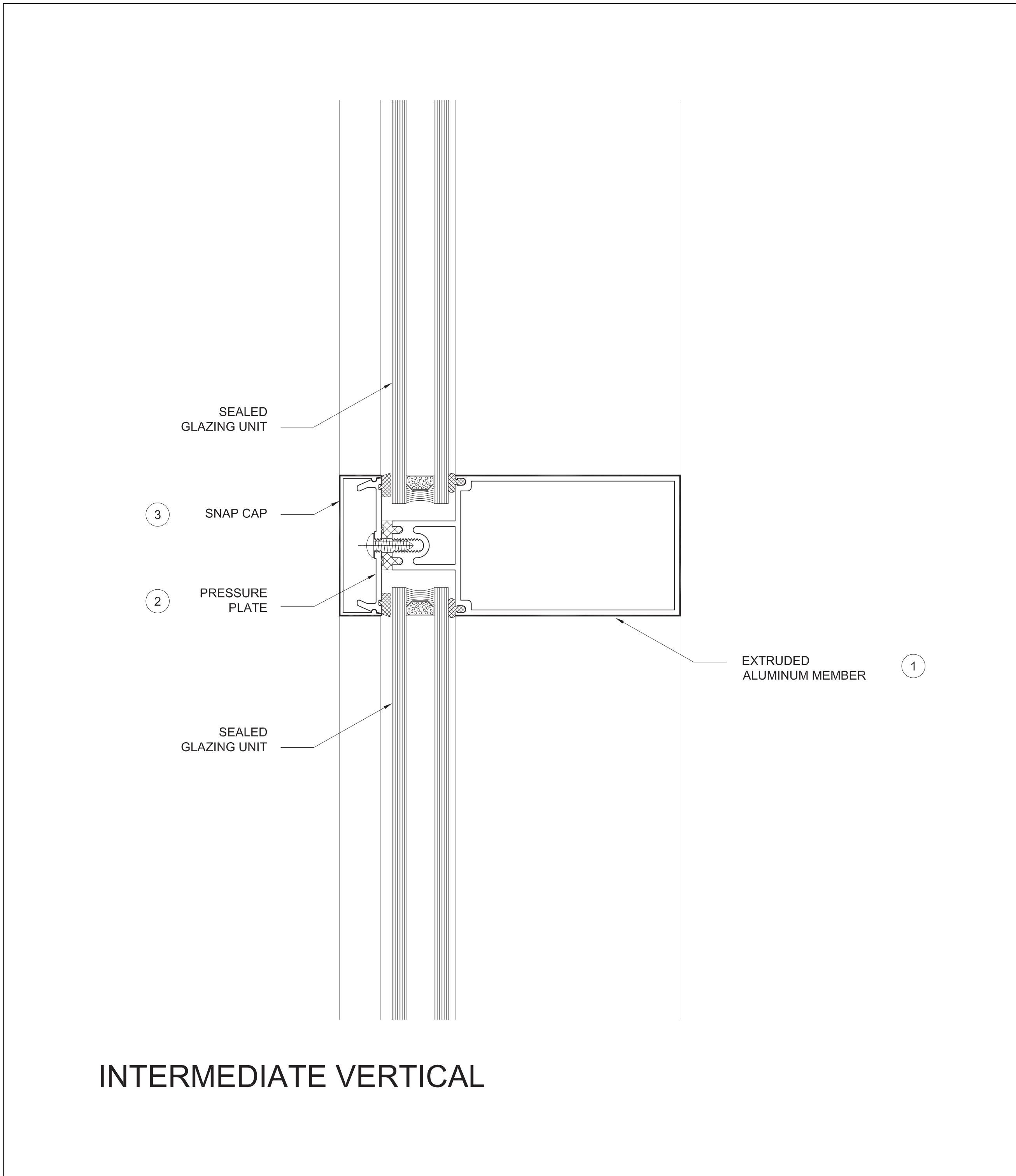
As indicated, basic profiles of aluminum stick system mullions have become standardized within the industry. Mullion profile must match gasket/tape type and pressure plate configuration. Thermal performance of standardized mullions can vary as much as 10 per cent from manufacturer to manufacturer.

② Pressure Plate

Pressure plates must provide adequate compression to the glazing gaskets through the proper tightening of pressure plate screws. At least three weep slots are provided to drain the glazing cavity. Pressure plates are installed after the mullion pressure plates and are shorter than the opening to allow for expansion. The expansion gap is to be carefully sealed avoiding excess sealant flowing into glazing cavity.

③ Snap Cap

Snap caps are designed to engage properly onto a specific type of pressure plate. When caps are manufactured within tolerances, reliable engagement is obtained and cap removal does not result in any cap damage. However, use of non-mating snap caps and pressure plates, out-of-tolerance materials or custom caps may result in a progressive loss of cap engagement over time with thermal cycling. For custom caps, particularly very deep caps, fixing screws at one end of the cap length is recommended. Splice plates at expansion joints must also be detailed to prevent excess water entry to the glazing cavities and allow for movement.



Detail 7: *Intermediate vertical*

DETAIL 8 - INSIDE VERTICAL CORNER

Inside vertical corners present several architectural and construction challenges. The use of dual vertical framing members at the corner allows for standard components, easy glass installation, common floor slab anchors and a location for correcting for building tolerances. The disadvantages include a wide visual appearance and large openings at floor slab level for firestopping. Single corner mullion assemblies are available utilizing single snap caps and pressure plates.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the mullion and the formed corner backpan.

Thermal Barrier continuity is provided by the thermal break in the curtain wall and the rigid insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weepholes in an intermediate horizontal.

① **Extruded Aluminum Member**

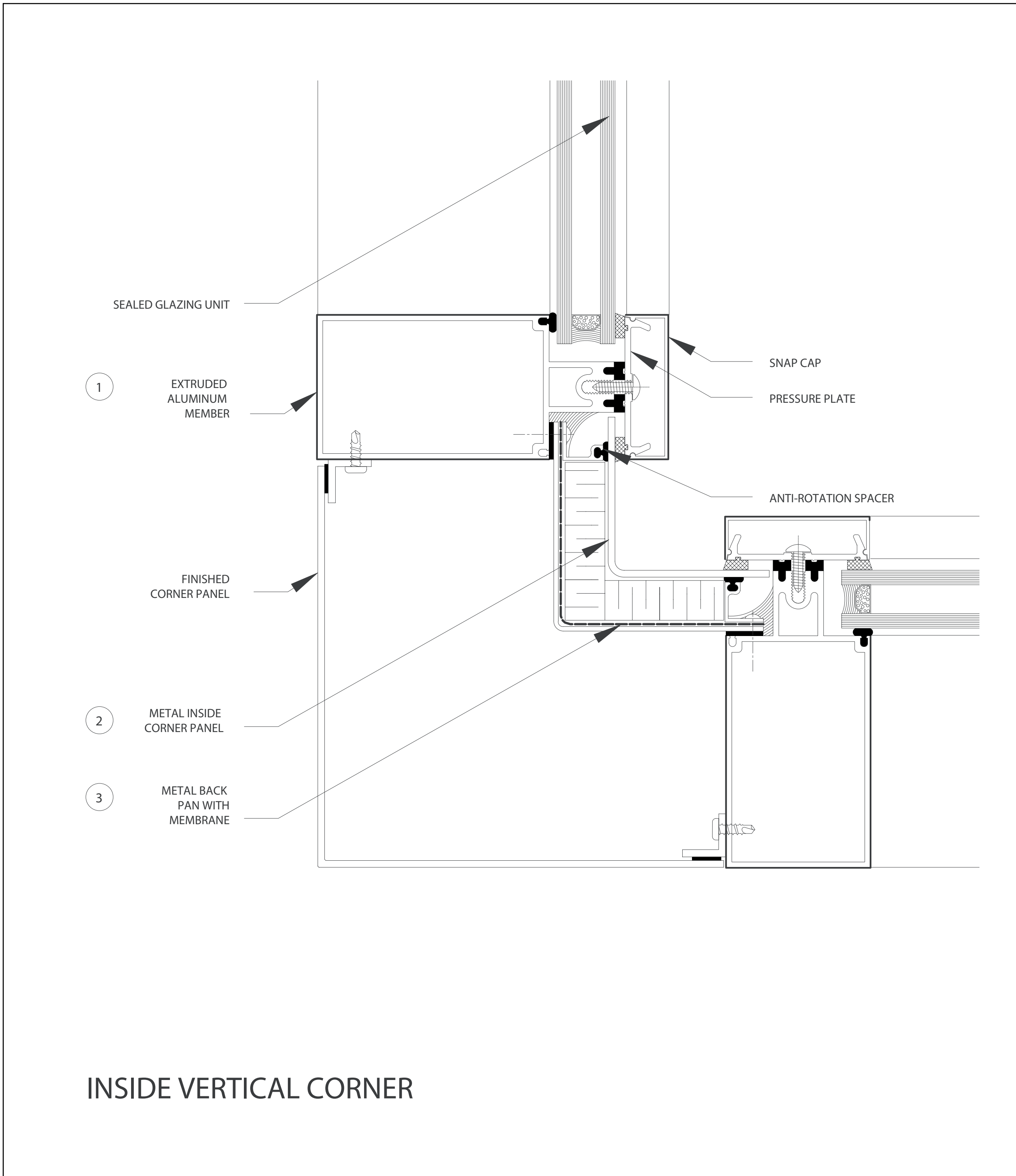
Aluminum framing at dual member corners are typical vertical mullions.

② **Metal Inside Corner Panel**

Prefinished inside corner panels can be trimmed on-site to accommodate overall building tolerances.

③ **Metal Backpan**

The metal backpan, shown in its simplest form, allows continuity of air and vapour barrier functions from mullion to mullion. The space available for insulation is limited.



Detail 8: *Inside vertical corner*

DETAIL 9 - VERTICAL JAMB (MASONRY)

The termination of a curtain wall at a jamb condition adjacent to a masonry cavity wall must include for continuity of thermal and air barrier planes as well to as termination in the flashing of the masonry wall. Membrane from the wall can be carried directly into the glazing pocket, over sheet metal if the span is greater than 19 mm (3/4 inch) Design of the flashing in the masonry wall should be detailed to provide an end dam to effectively redirect any water out of the cavity rather than allowing it to drain vertically down the side of the aluminum mullion.

Air Barrier continuity between the masonry wall and the curtain wall is provided by membrane, supported by sheet metal backing over longer spans.

Thermal Barrier continuity is provided by the cavity wall insulation and the curtain wall thermal breaks.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the flashings in the masonry wall and the drainage inherent in the curtain wall system.

① **Extruded Aluminum Member**

Care should be taken to ensure that the member is positioned to minimize exterior exposure and to maximize interior exposure. In this case the exterior is protected by continuous insulation and the interior is exposed by the positioning of the interior finish to one extreme side.

② **Membrane**

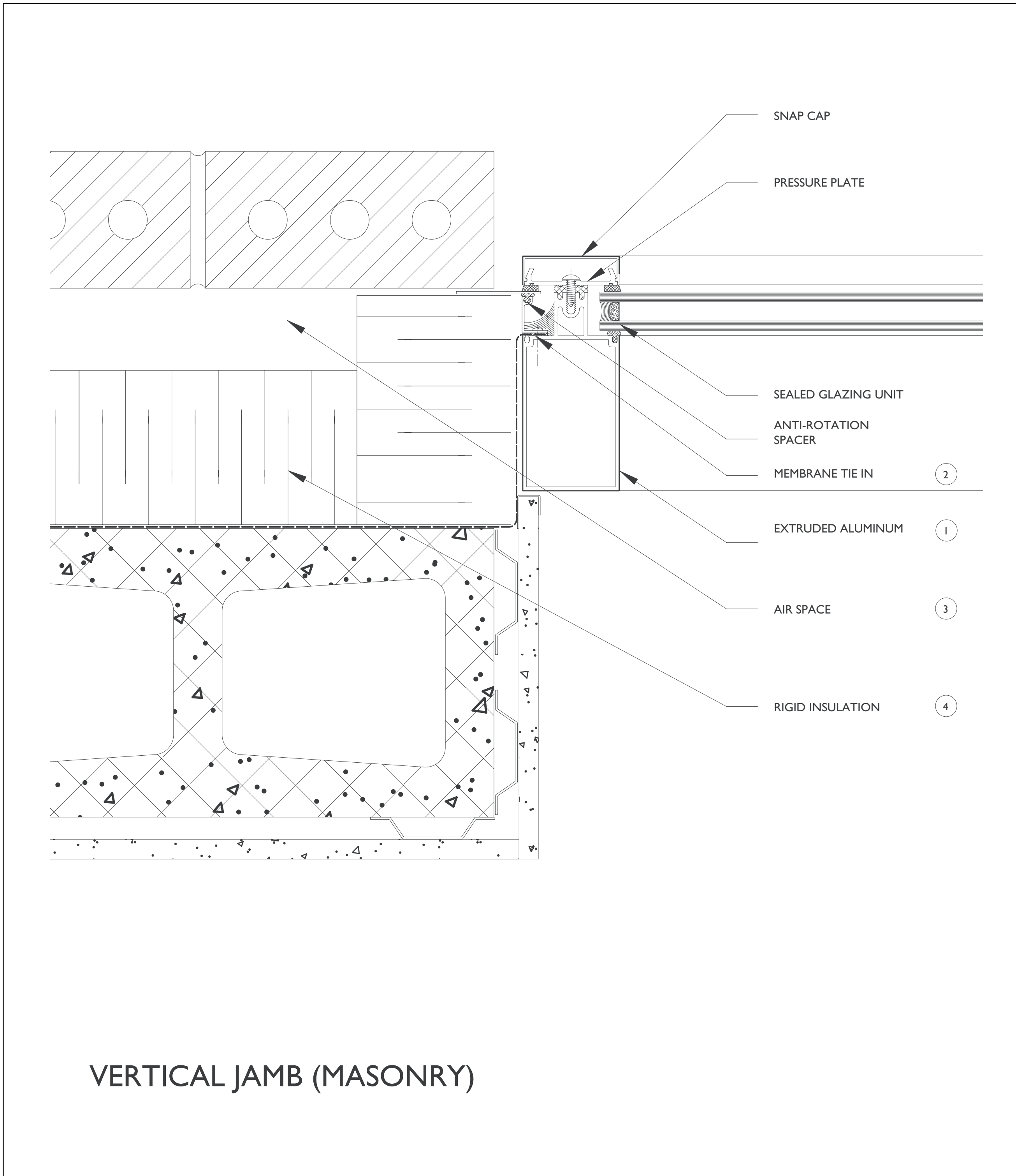
A membrane compatible with the wall membrane ensures continuity of air barrier between the masonry wall and mullion of the curtain wall. The membrane is clamped and adhered to the mullion. Where the gap between the masonry and the mullion exceeds 19 mm (3/4 inch) a sheet metal backing must be provided to the membrane.

③ **Air Space**

The curtain wall framing should be protected from exposure to the air space in the masonry cavity wall. Any masonry wall flashing in the cavity should be terminated at the curtain wall with an end dam.

④ **Rigid Insulation**

The cavity wall rigid or semi-rigid insulation must tightly abut the air barrier closure. Any gaps in the thermal insulation at the air barrier closure should be filled with polyurethane foam or compressible insulation.



Detail 9: *Vertical jamb (masonry)*

DETAIL 10 - VERTICAL JAMB (METAL PANEL)

The termination of a curtain wall at a jamb condition adjacent to a metal panel cavity wall must include for continuity of thermal and air barrier planes as well as termination in the flashing of the panel wall. Membrane from the wall can be carried directly into the glazing pocket, over sheet metal if the span is greater than 19 mm (3/4 inch). Design of the flashing in the panel wall should be detailed to provide an end dam to effectively redirect any water out of the cavity rather than allowing it to drain vertically down the side of the aluminum mullion.

Air Barrier continuity between the metal panel wall and the curtain wall is provided by the membrane, supported by sheet metal backing over longer spans.

Thermal Barrier continuity is provided by the cavity wall insulation and the curtain wall thermal breaks.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the flashings in the panel wall and the drainage inherent in the curtain wall system.

① Extruded Aluminum Member

Care should be taken to ensure that the member is positioned to minimize exterior exposure and to maximize interior exposure. In this case the exterior is protected by continuous insulation and the interior is exposed by the positioning of the interior finish to one extreme side.

② Membrane

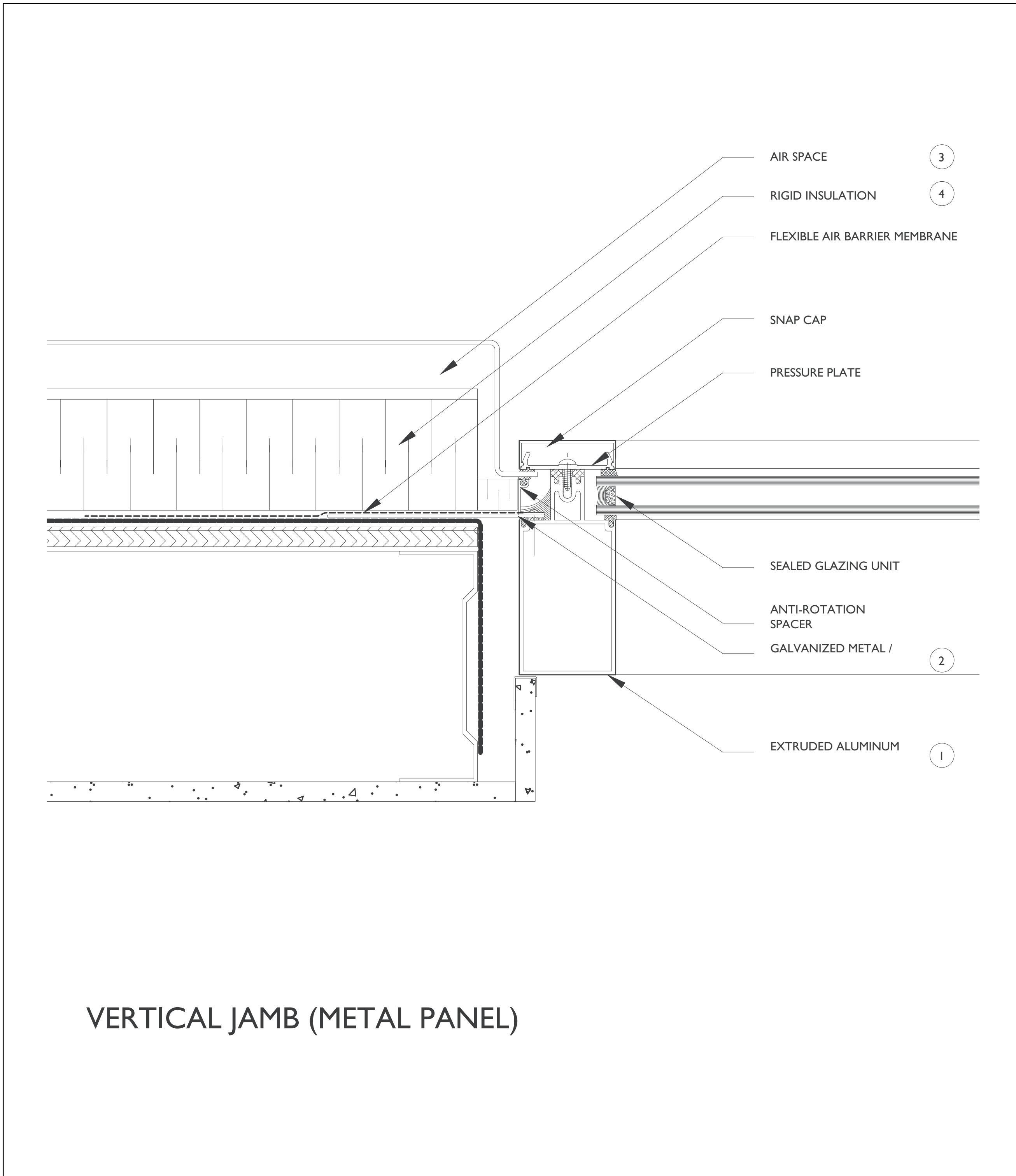
A membrane compatible with the wall membrane ensures continuity of air barrier between the panel wall and mullion of the curtain wall. The membrane is clamped and adhered to the mullion. Where the gap between the panel liner plane and the mullion exceeds 19 mm (3/4 inch) a sheet metal backing must be provided to the membrane.

③ Air Space

The curtain wall framing should be protected from exposure to the air space in the metal panel wall. Any panel wall flashing in the cavity should be terminated at the curtain wall with an end dam.

④ Rigid Insulation

The cavity wall rigid or semi-rigid insulation must tightly abut the air barrier closure. Any gaps in the thermal insulation at the air barrier closure should be filled with polyurethane foam or compressible insulation. Avoid foaming the gap between the mullion and the rough opening.



Detail 10: *Vertical jamb (metal panel)*

DETAIL 11 - VERTICAL JAMB (PRECAST CONCRETE)

The termination of a curtain wall at a jamb condition adjacent to a precast concrete cavity wall must include for continuity of thermal and air barrier planes as well as termination in the flashing of the concrete wall. Membrane from the wall can be carried directly into the glazing pocket, over sheet metal if the span is greater than 19 mm (3/4 inch). Design of the flashing in the concrete wall should be detailed to provide an end dam to effectively redirect any water out of the cavity rather than allowing it to drain vertically down the side of the aluminum mullion.

Air Barrier continuity between the precast concrete cavity wall and the curtain wall is provided by the membrane, supported by sheet metal backing over longer spans.

Thermal Barrier continuity is provided by the cavity wall insulation and the curtain wall thermal breaks.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the flashings in the concrete wall and the drainage inherent in the curtain wall system.

(1) Extruded Aluminum Member

Care should be taken to ensure that the member is positioned to minimize exterior exposure and to maximize interior exposure. In this case the exterior is protected by continuous insulation and the interior is exposed by the positioning of the interior finish to one extreme side.

(2) Membrane

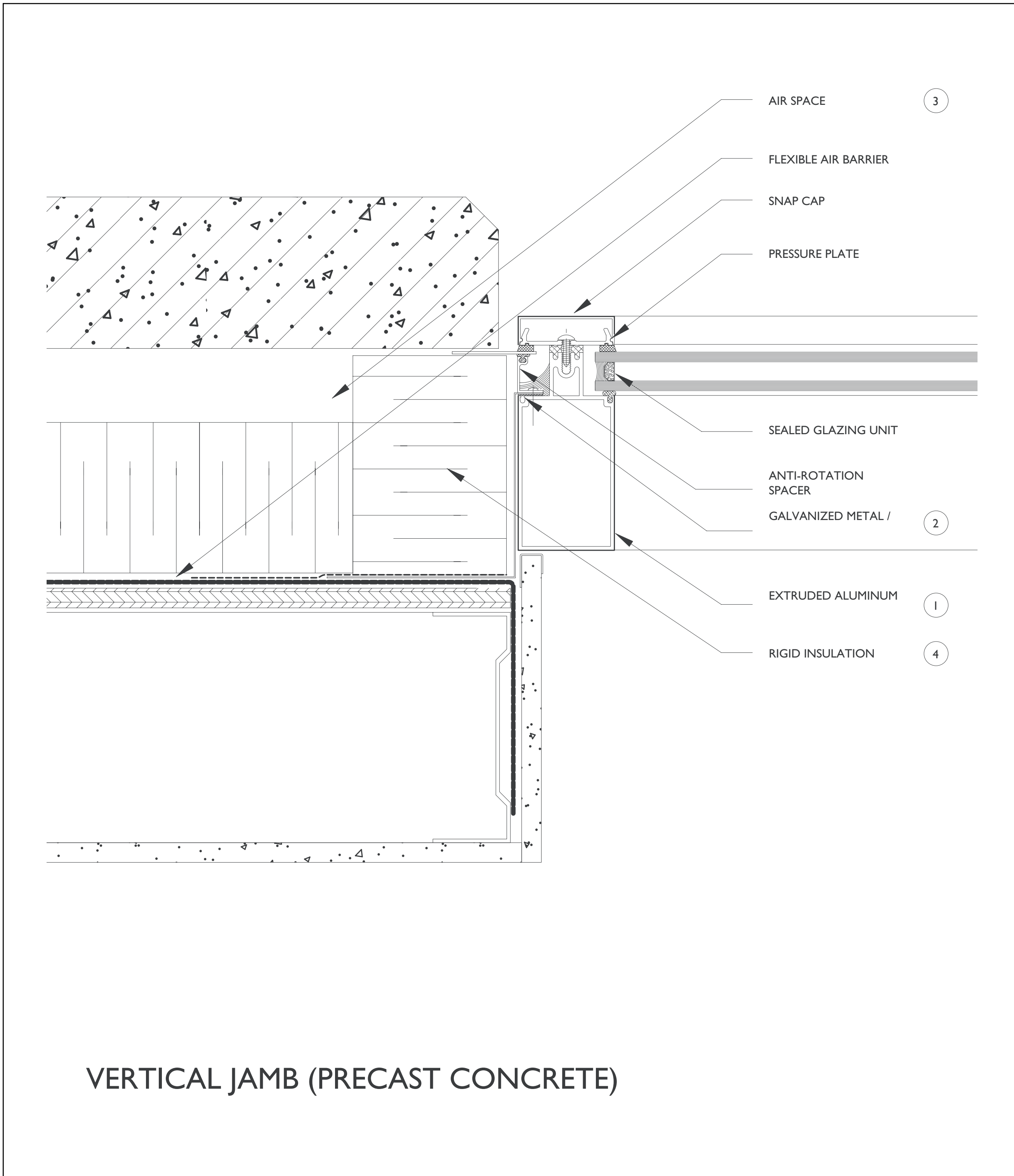
A membrane compatible with the wall membrane ensures continuity of air barrier between the concrete wall and mullion of the curtain wall. The membrane is clamped and adhered to the mullion. Where the gap between the concrete liner plane and the mullion exceeds 19 mm (3/4 inch) a sheet metal backing must be provided to the membrane.

(3) Air Space

The curtain wall framing should be protected from exposure to the air space in the masonry cavity wall. Any concrete wall flashing in the cavity should be terminated at the curtain wall with an end dam.

(4) Rigid Insulation

The cavity wall rigid or semi-rigid insulation must tightly abut the air barrier closure. Any gaps in the thermal insulation at the air barrier closure should be filled with polyurethane foam or compressible insulation.



Detail 11: *Vertical jamb (precast concrete)*

DETAIL 12 - OPERABLE VENT HEAD/SILL

The concept most often utilized with respect to operable vent elements (ventilation, smoke relief, access panels) incorporated into the fixed portions of the curtain wall is to glaze the vent into the wall as a lite of glass. In other words, the perimeter flange of the vent must be sized to fit a standard glazing pocket. It is important to note that the design of most vents will be governed by the CSA A440 *Windows* standard and the performance and specification of the vent is considered separately to the fixed portions of the wall.

Air Barrier continuity between the operable vent frame and the curtain wall is provided by a combination of gaskets, tapes or sealants applied at the interface.

Thermal Barrier continuity is provided by thermal breaks in the vent sash, the vent frame and the curtain wall framing.

Vapour Retarder function is provided by the inherent resistance of the materials.

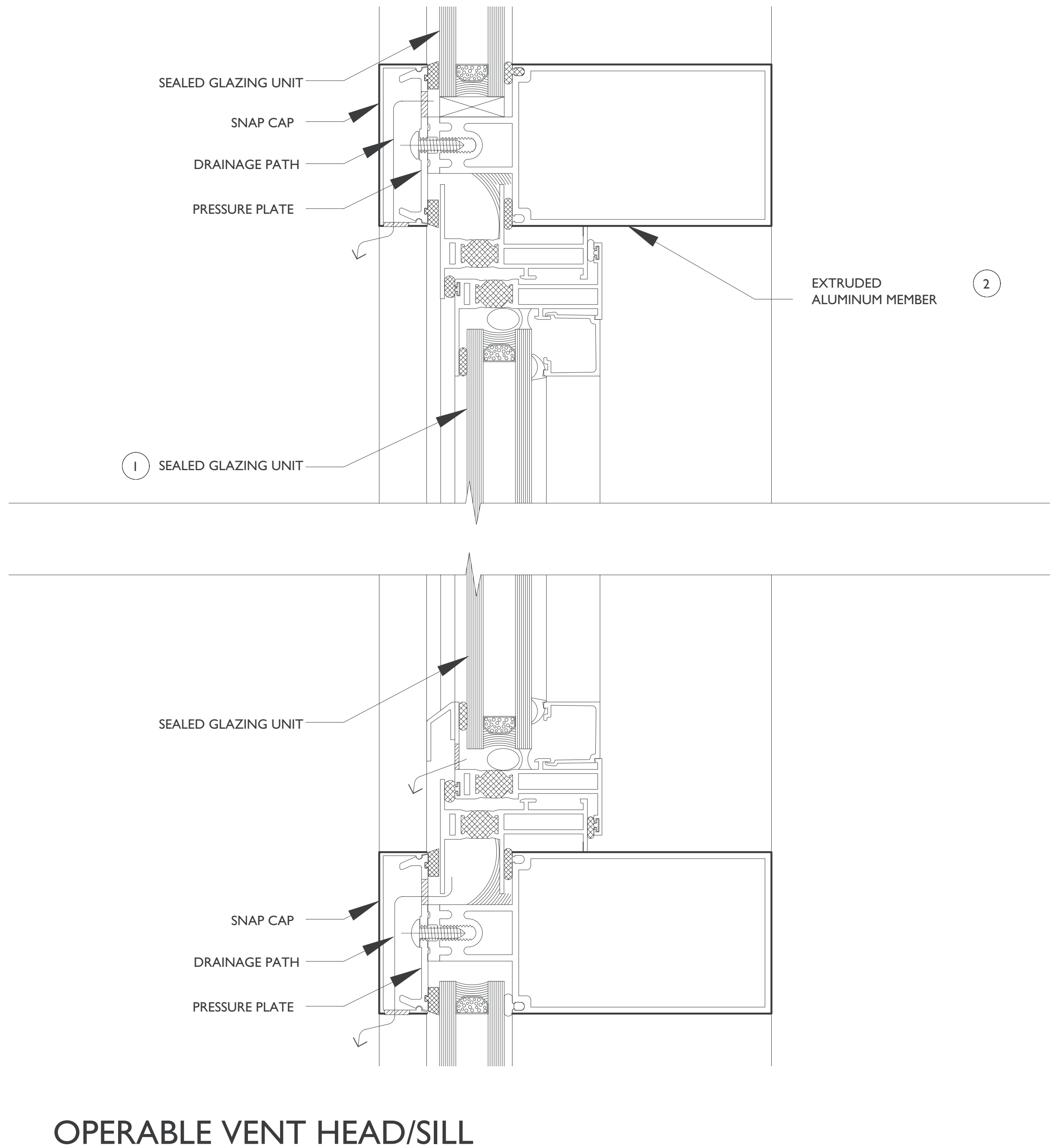
Water Penetration control is provided by the drainage inherent in the vent and the curtain wall system.

(1) Sealed Glazing Unit/Vent Assembly

In most cases the glazing within the vent assembly must match the glazing in the fixed portions of the wall. As such vent frames must be able to accommodate standard sealed glazing units. Operable vents are usually the weakest portion of the wall with respect to water penetration resistance and special measures should be taken where possible to maximize the performance of the vent. Vents are frequently interior glazed and as such to obtain a drained and vented cavity a continuous heel bead about the glass must be used and the glazing cavity drained into the glazing pocket of the curtain wall.

(2) Extruded Aluminum Member

The extruded aluminum framing about an operable vent are intended to be the same members that would be used about a vision unit. Care must be taken to ensure that any mechanical fastening used to position the vent is effectively sealed.



***Detail 12:** Operable vent head/sill*

DETAIL 13 - STICK FRAME SYSTEM SSG INTERMEDIATE HORIZONTAL

The exact configuration of stick frame system horizontal rails varies from manufacturer to manufacturer. Attachment of rail to mullion is as with capped stick system. Exact profiles vary but all include the same basic elements.

Air Barrier continuity is provided by the interior glass surface, perimeter structural silicone seal, and the aluminum framing across the head of the rail.

Thermal Barrier continuity is provided by the thermal break created by the gaskets and structural silicone bead.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the continuous silicone weather seal and drainage cavities in the system directing water to the mullion vertical drainage cavities.

(1) Extruded Aluminum Mullion

A stick framed SSG system can only employ two-sided structural silicone glazing. As such the mullion must be conventionally capped. Weepholes are avoided in the rail. Therefore the mullions must provide a clear drainage path to weepholes at a lower level.

(2) Extruded Aluminum Rail

The horizontal rail must incorporate a bond surface for the structural silicone bead (4) and a chase to accept a gasket (3). Most sections include a chase that will accept an adaptor to support the setting block and accept cap screws necessary to temporarily hold the glass tight to the structural silicone bead until it adequately cures. The rails are fixed to the mullion with shear block or spigot joinery.

(3) Glazing Gasket

As shown, the glazing gasket is frequently positioned inboard of the structural silicone bead. This allows the silicone to be installed from the floor in a manner that is visible to the installer and reviewer. The gasket may be an extruded silicone or silicone-compatible rubber as shown or an adhesive compatible foam tape. Care must be taken to ensure the gasket of the horizontal rail meets and seals to the gasket of the mullion.

(4) Structural Silicone Bead

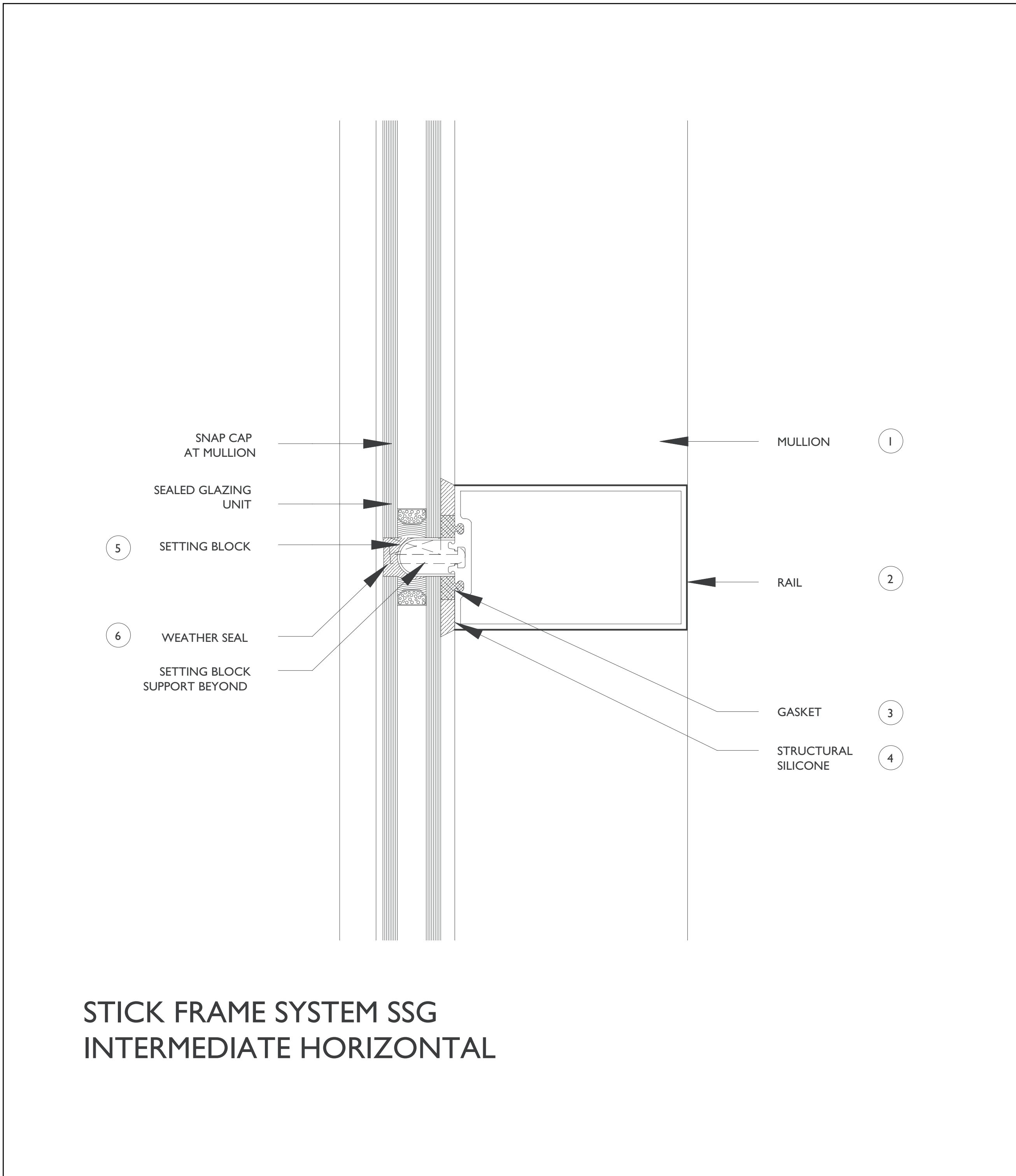
The structural silicone bead is sized to meet the wind loads of the particular application. It has a minimum thickness of 5 mm (1/4 inch) and a typical width of 12 mm (1/2 inch). The bonding surface on the rail must be tested for long-term silicone adhesion and compatiblity.

(5) Setting Block

The setting block must be of silicone or silicone-compatible rubber and must be positioned to support at least half the thickness of the outer lite of glass in an IG unit.

(6) Weather Seal

The silicone weather seal is applied over a backer sheet to create a slightly hour-glass shaped bead. Sizing of the backer is critical to avoid blocking drainage within the rail. The bonding surfaces at the edge of the glass must be cleaned of all sealant residues.



Detail 13: *Stick frame system SSG intermediate horizontal*

DETAIL 14 - STICK FRAME SYSTEM SSG MULLION

The exact configuration of stick frame system mullions varies from manufacturer to manufacturer. Attachment of rail to mullion is as with capped stick system. Exact profiles vary but all include the same basic elements.

Air Barrier continuity is provided by the interior glass surface, perimeter structural silicone seal, and the aluminum framing across the head of the rail.

Thermal Barrier continuity is provided by the thermal break created by the gaskets and structural silicone bead.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the continuous silicone weather seal and drainage cavities in the system directing water to the mullion vertical drainage cavities.

(1) Extruded Aluminum Mullion

A stick framed SSG system can only employ two-sided structural silicone glazing. As such the horizontal rail must be conventionally capped. Weep slots are provided in the rail. Therefore, the mullions must provide a clear drainage path to weep slots at a lower level rail. The mullion must incorporate a bond surface for the structural silicone bead (4) and a chase to accept a gasket (3). Most sections include a chase that will accept cap screws necessary to temporarily hold the glass tight to the structural silicone bead until it adequately cures.

(2) Extruded Aluminum Rail

The rails are conventionally capped and fixed to the mullion with shear block or spigot joinery.

(3) Glazing Gasket

As shown, the glazing gasket is frequently positioned inboard of the structural silicone bead. This allows the silicone to be installed from the floor in a manner that is visible to the installer and reviewer. The gasket may be an extruded silicone or silicone-compatible rubber as shown or an adhesive-compatible foam tape. Care must be taken to ensure the gasket of the horizontal rail meets and seals to the gasket of the mullion.

(4) Structural Silicone Bead

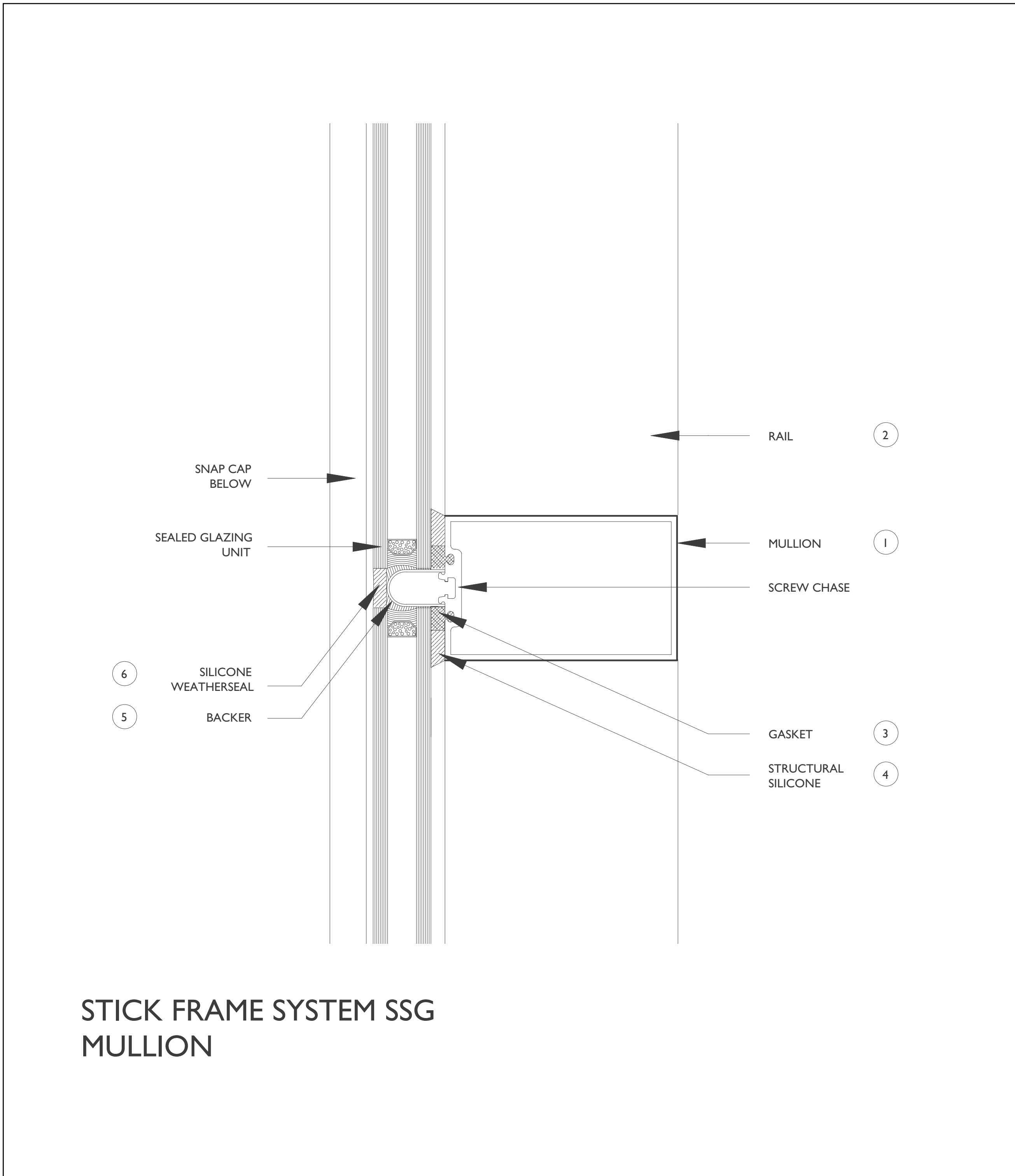
The structural silicone bead is sized to meet the wind loads of the particular application. It has a minimum thickness of 5 mm (1/4 inch) and a typical width of 12 mm (1/2 inch). The bonding surface on the rail must be tested for long-term silicone adhesion and compatiblity.

(5) Weather Seal Backer

The type and sizing of the weather seal backer is critical to the drainage performance of the system. Oversized backer rods can completely block the glazing drainage cavity. A folded polyethylene sheet, as shown, will provide a clear drainage cavity and venting to the back of the sealant bead.

(6) Weather Seal

The silicone weather seal is applied over a backer rod or sheet to create a slightly hour-glass shaped bead. The bonding surfaces at the edge of the glass must be cleaned of all sealant residues.



Detail 14: *Stick frame system SSG mullion*

DETAIL 15 - STICK FRAME SYSTEM SSG OUTSIDE CORNER MULLION (ALTERNATIVE 1)

The exact configuration of stick frame system corner mullion varies from manufacturer to manufacturer. Attachment of rail to mullion is as with capped stick system. Exact profiles vary but all include the same basic elements.

Air Barrier continuity is provided by the interior glass surface, perimeter structural silicone seal, and the aluminum framing across the head of the rail. On the spandrel side,the sheet metal backpan replaces the interior glass surface as the air barrier plane.

Thermal Barrier continuity is provided by the thermal break created by the gaskets and structural silicone bead.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the continuous silicone weather seal and drainage cavities in the system directing water to the mullion vertical drainage cavities.

(1) Extruded Aluminum Mullion

A stick framed SSG system can only employ two-sided structural silicone glazing. As such the horizontal rail must be conventionally capped. Weep slots are provided in the rail. Therefore the mullions must provide a clear drainage path to weep slots at a lower level rail. The mullion must incorporate a bond surface for the structural silicone bead (4) and a chase to accept a gasket (3). Most sections include a chase that will accept cap screws necessary to temporarily hold the glass tight to the structural silicone bead until it adequately cures.

(2) Extruded Aluminum Rail

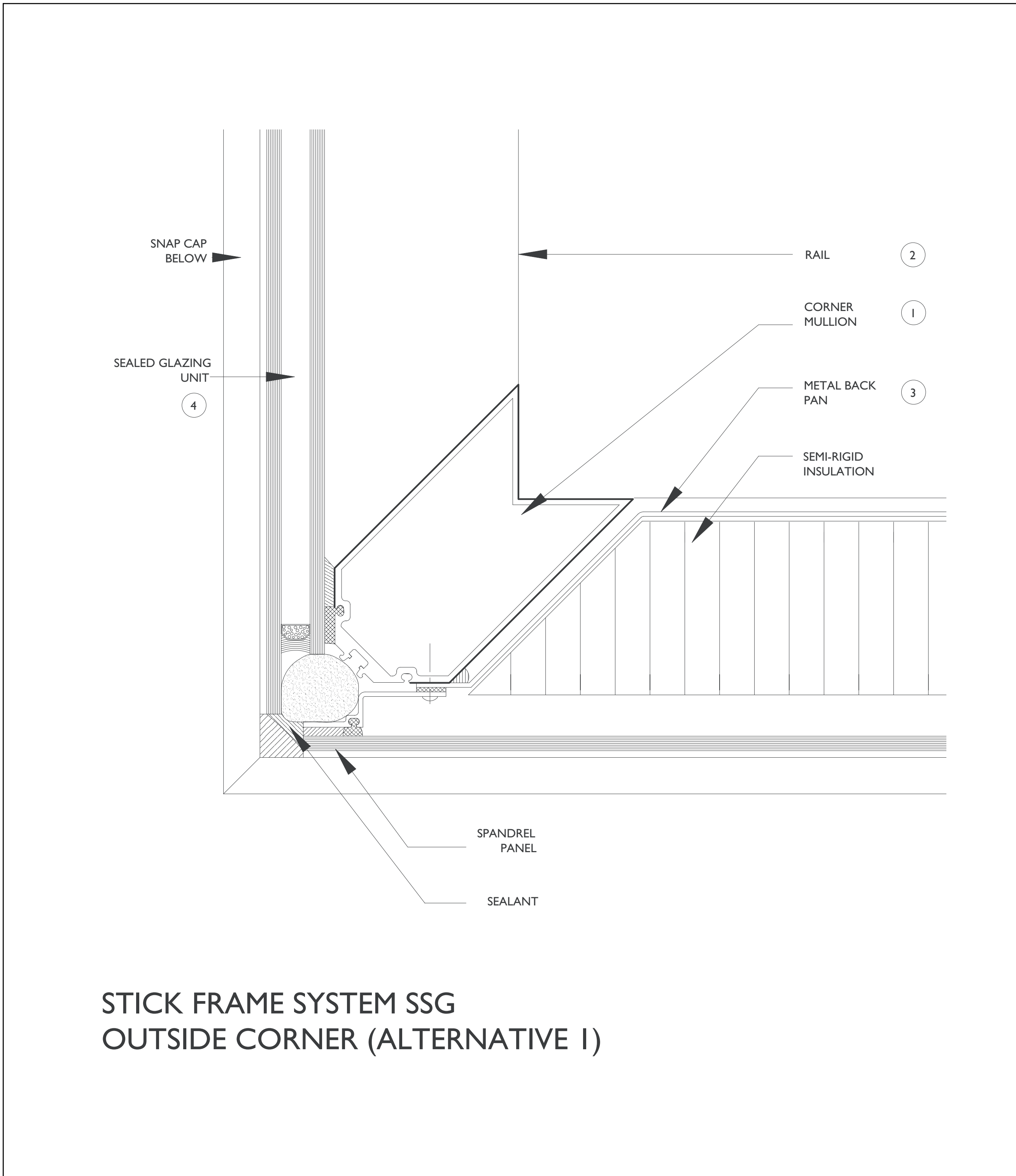
The rails are conventionally capped and fixed to the mullion with shear block or spigot joinery.

(3) Glazing Gasket

As shown, the glazing gasket is frequently positioned inboard of the structural silicone bead. This allows the silicone to be installed from the floor in a manner that is visible to the installer and reviewer. The gasket must be an extruded silicone or silicone-compatible rubber as shown or an adhesive-compatible foam tape. Care must be taken to ensure the gasket of the horizontal rail meets and seals to the gasket of the mullion.

(4) Offset Glass Edge

The use of an offset outer lite of glass at the corner creates the appearance of an all glass corner but at the risk of premature glass breakage due to impact at the glass edge. The quality of the corner is very dependent on the appearance of the corner silicone sealant bead. Unless reflective glass is used the mass of sealant, backer, gaskets and mullion at the corner suggests the use of an alternate detail.



Detail 15: *Stick frame system SSG outside corner (alternative 1)*

DETAIL 16 – STICK FRAME SYSTEM SSG OUTSIDE CORNER MULLION (ALTERNATIVE 2)

The exact configuration of stick frame system corner mullion varies from manufacturer to manufacturer. Attachment of rail to mullion is as with capped stick system. Exact profiles vary but all include the same basic elements.

Air Barrier continuity is provided by the interior glass surface, perimeter structural silicone seal, and the aluminum framing across the head of the rail. On the spandrel side the sheet metal backpan replaces the interior glass surface as the air barrier plane.

Thermal Barrier continuity is provided by the thermal break created by the gaskets and structural silicone bead.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the continuous silicone weather seal and drainage cavities in the system directing water to the mullion vertical drainage cavities.

① **Extruded Aluminum Mullion**

A stick framed SSG system can only employ two-sided structural silicone glazing. As such the horizontal rail must be conventionally capped. Weep slots are provided in the rail. Therefore the mullions must provide a clear drainage path to weep slots at a lower level rail. The mullion must incorporate a bond surface for the structural silicone bead (4) and a chase to accept a gasket (3). Most sections include a chase that will accept cap screws necessary to temporarily hold the glass tight to the structural silicone bead until it adequately cures.

② **Extruded Aluminum Rail**

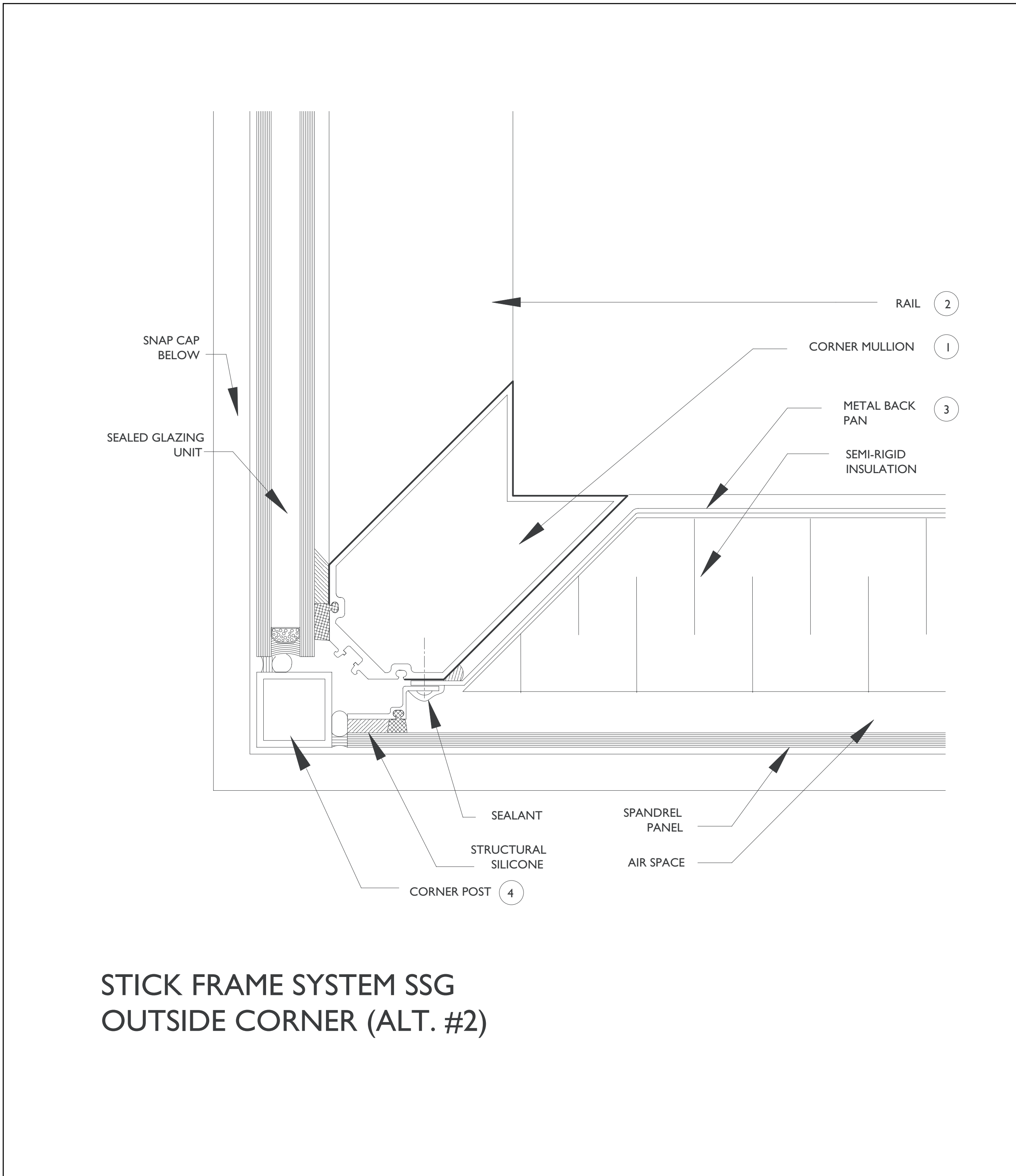
The rails are conventionally capped and fixed to the mullion with shear block or spigot joinery.

③ **Metal Backpan**

As shown, the sheet metal backpan behind the spandrel panel is manufactured as a cassette that is inserted or glazed into the framed opening. The backpan must incorporate a flange to allow mounting and sealing to the framing.

④ **Corner Post**

The exterior corner post provides a clean corner without the need for special glass fabrication and reduces the risk of glass breakage. Finished black or in the colour of the weather seal, the corner post often blends with the mass of the edge seal. The sharp outer corner also provides a smooth surface for the horizontal caps to terminate onto.



Detail 16: *Stick frame system SSG outside corner (alternative 2)*

DETAIL 17 – UNITIZED SYSTEM TERMINATION AT GRADE

Provide a waterproofed concrete curb to raise the base of the curtain wall at least 200 mm (8 inches) above any exterior drainage plane. Raising the base of the wall above a drainage plane reduces the potential for water entry due to surface water flow and reduces the potential for physical damage due to snow clearing or salt distribution.

Air Barrier continuity between the concrete curb and the curtain wall is provided by the membrane, supported by sheet metal backing over longer spans.
Thermal Barrier continuity is provided by rigid insulation.
Water Penetration control is provided by the membrane protected by the formed metal base flashing.

① **Concrete Curb**

Positioning the wall on top of a curb avoids the need for supplementary support steel. Air barrier and vapour retarder seals are simplified, insulation and air barrier planes are more readily continuous and the curb provides inherent protection to the wall.

② **Waterproofing Membrane**

The foundation waterproofing is the membrane to extend up and onto top of curb.

③ **Aluminum Starter Track**

An aluminum starter track is mechanically fastened to curb and all joints are sealed with splice sleeves.

④ **Mullion**

Mullion and frame lowers over and engages starter track. Frame is either suspended from floor above (as shown) or would bear down on solid shim to make this joint non-moving.

⑤ **Membrane**

Membrane compatible with curb waterproofing ensures continuity of air barrier between waterproofing and sill rail of curtain wall. The membrane is clamped and adhered to starter tracker. Where the gap between the curb and the sill rail exceeds 19 mm (3/4 inch) a sheet metal backing must be provided to the membrane.

⑥ **Rigid Insulation**

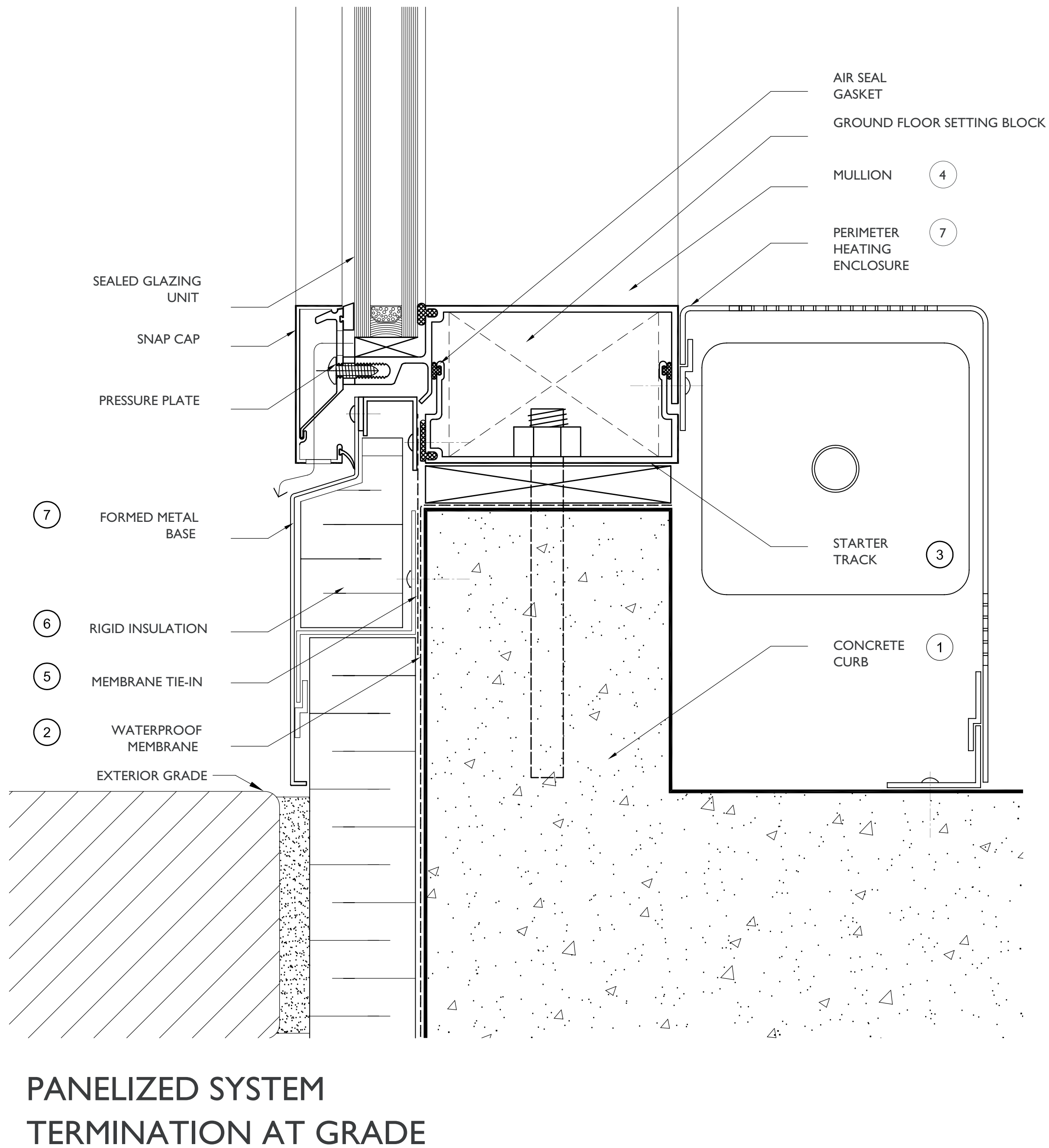
Rigid insulation (Type 4) on the exterior provides continuity of thermal protection.

⑦ **Base Flashing**

A separate formed heavy gauge metal flashing allows easy replacement as the material is weathered or damaged by snow removal and de-icing salts. The drainage space between the snap cap and flashing must be left clear of sealant to promote proper drainage.

⑧ **Perimeter Heating Enclosure**

Providing a thermal connection between the curtain wall sill rail and the heating element enclosure enhances the condensation resistance of the curtain wall framing. Fastening for enclosure shall not penetrate any air seal elements.



Detail 17: *Panelized system termination at grade*

DETAIL 18 – UNITIZED SYSTEM TERMINATION AT UNDERSIDE OF CONCRETE SLAB

Curtain wall termination at the underside of a slab involves a different connection detail and provisions for movement due to slab deflection and curtain wall expansion/contraction. The soffit is designed as a cold soffit.

Air Barrier continuity between the underside of the slab and the head rail of the curtain wall is provided by a self-adhesive membrane supported by a sheet metal backing sheet. The backing sheet is mechanically fastened to the underside of the slab, the mullions and the head rail. Flexibility must be provided by a profile bend to allow for differential movements between the curtain wall and the slab.

Thermal Barrier continuity is provided by semi-rigid insulation held with straps or stick pins tight to the air barrier closure to prevent air circulation between the air barrier and the insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the sealed membrane and the drainage inherent in the curtain wall system.

(1) Structural Concrete Slab (air barrier, structure)

A flat-plate concrete slab presents an ideal substrate for fixing and sealing to the underside.

(2) Vertical Mullion Anchor (structural)

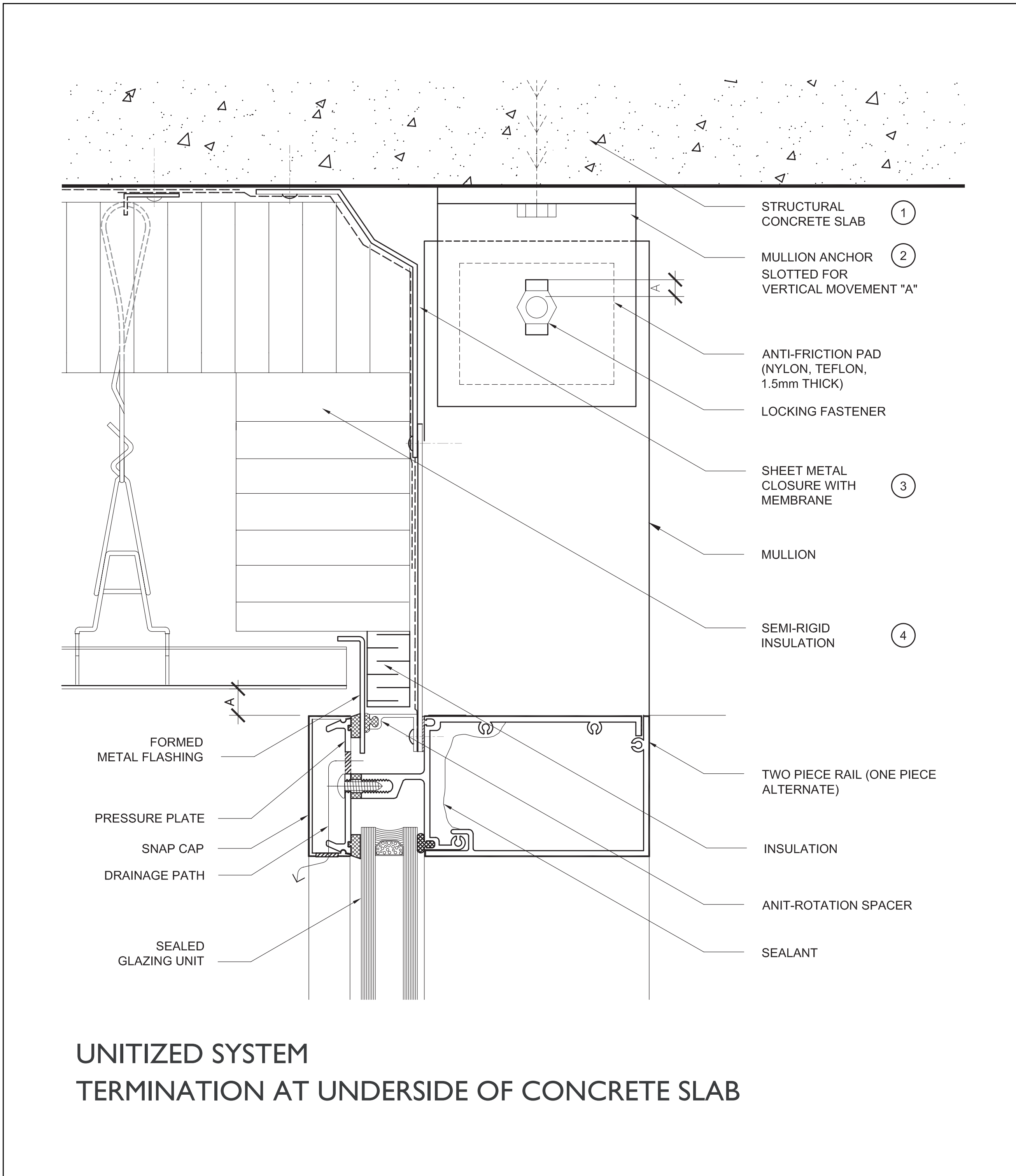
The structural anchor at the top of the curtain wall can take several forms ranging from an extruded aluminum insert to a cut piece of steel angle fixed to the back of the wall. Common to any anchor however, there must be vertically slotted holes to accommodate long-term deflections of the slab and differential movement of the wall and the slab. Fasteners in the moving joint must be provided with locknuts or washers to prevent loosening. Dimension A must equal the anticipated differential movement. The anchor resists wind load only.

(3) Formed Closure Panel and Membrane (air barrier)

The formed closure panel or backpan extension provides back-up for the membrane air barrier between the top horizontal rail and the underside of the slab. The panel should have a break or flexible link to allow for differential movement of the slab and the wall without distress. The screw chase on the vertical mullion is milled off above the horizontal rail to minimize the number of seams required and eliminate the potential opening between the end of the mullion and the slab.

(4) Semi-Rigid Insulation (thermal barrier)

Insulation provided to the metal closure ensures continuity of thermal protection between the floor slab and the wall.



Detail 18: *Unitized system termination at underside of concrete slab*

DETAIL 19 – UNITIZED SYSTEM INTERMEDIATE HORIZONTAL

The exact configuration of unitized system horizontal rails varies from manufacturer to manufacturer. Many differences can exist and sections are rarely interchangeable between different manufacturers. Intermediate horizontal rails span between the mullions.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the rail and joinery sealants.

Thermal Barrier continuity is provided by the thermal break.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weep slots in the pressure plate.

(1) Extruded Aluminum Two-Piece Rail

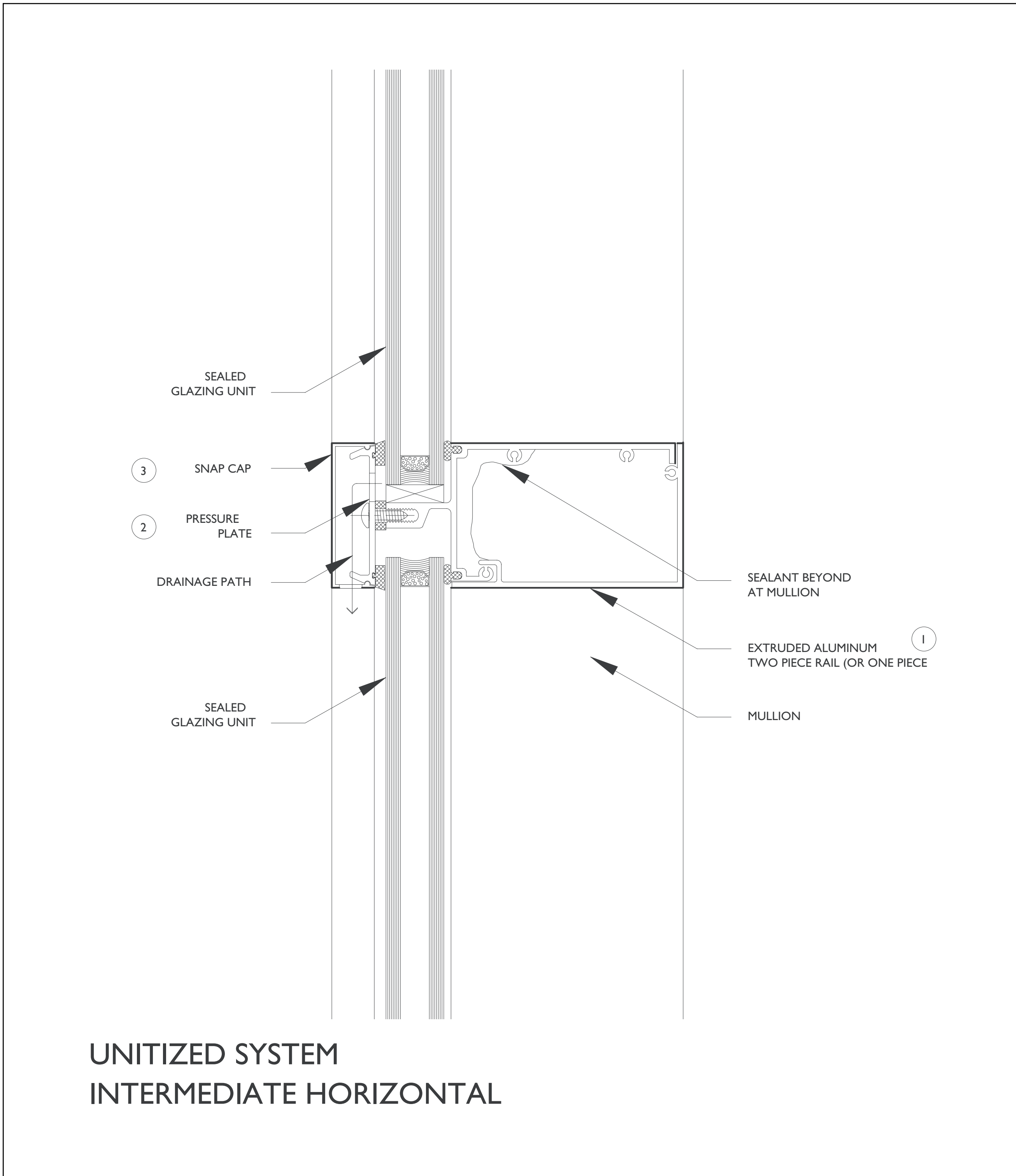
Two-piece sections have some advantages over one-piece tubular sections although their use demands tight tolerances only attainable in shop fabrication. Two-piece sections also require more sophisticated engineering analysis. Two-piece sections allow for interior sealing with a substantial sealant bead which is covered by the second closure section. Sealant continuity holes at the metal to metal joints prevent water leakage at this interface. Corner blocks must be provided between the end of the screw chase in the rail and the mullion screw chase to promote rapid drainage and enhance pressure equalization. A compatible sealant heel bead across the head of the IG unit and returning down the sides enhances water penetration resistance.

(2) Pressure Plate

Pressure plates must provide adequate compression to the glazing gaskets through the proper tightening of pressure plate screws. At least three weep slots should be provided to drain the glazing cavity. One slot should be positioned at the centre of the pressure plate and one at each end.

(3) Snap Cap

Snap caps are designed to engage properly onto a specific type of pressure plate. When caps are manufactured within tolerances, reliable engagement is obtained and cap removal does not result in any cap damage. However, use of non-mating snap caps and pressure plates, out of tolerance materials or custom caps may result in a progressive loss of cap engagement over time with thermal cycling. Snap cap length must allow for thermal expansion without binding. On custom caps, particularly very deep caps, a fixing screw at one location along the cap length is recommended. Of particular concern with deep horizontal caps are additional loads imposed by window washing and other maintenance activities. The area of snap cap weepholes should be twice as great as the area of pressure plate weepholes.



Detail 19: *Unitized system intermediate horizontal*

DETAIL 20 – SECTION: STACK JOINT CAPPED PANEL

The exact configuration of unitized system stack joints varies from manufacturer to manufacturer. Many differences can exist and sections are rarely interchangeable between different manufacturers. The air seal is typically formed by a compressed continuous gasket.

Air Barrier continuity is provided by the interior glass surface, perimeter gasket, the aluminum framing across the head of the sill rail, the sidewall of the head rail and the sheet metal backpan.

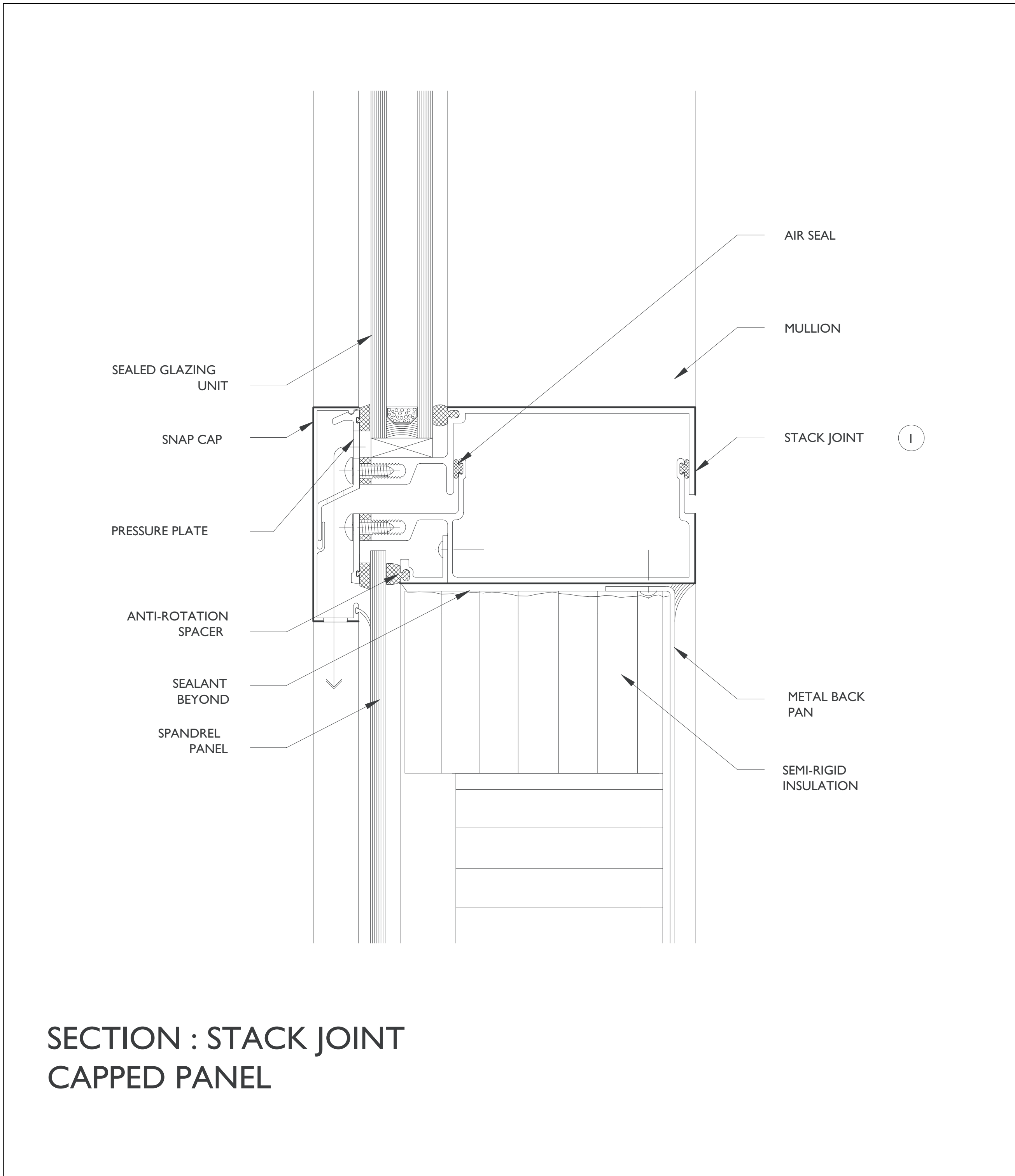
Thermal Barrier continuity is provided by the gaskets, thermal breaks and the semi-rigid insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system behind the caps that direct water out at gaps in the sweep gasket.

(1) **Extruded Aluminum Mullion**

As indicated basic, profiles of aluminum unitized system mullions vary with manufacturer. Sill and head rails are mating sections that allow for vertical differential movement and some lateral movement depending on the system design. The air seal engagement must be continuous and the outboard sweep gasket must allow drainage. The rails must incorporate a chase to accept a gasket. Components that extend to the exterior must be thermally broken from the main rail section. The use of plastic shielding components also enhances thermal performance. An often seen variation on this detail is the use of SSG on the head of the spandrel lite to remove the need for the lower pressure plate.



Detail 20: *Section: stack joint capped panel*

DETAIL 21 – UNITIZED SYSTEM VERTICAL MULLION AT PANEL JOINT

The exact configuration of unitized system vertical mullions varies from manufacturer to manufacturer. Many differences can exist and sections are rarely interchangeable between different manufacturers. The air seal is typically formed by a compressed continuous gasket.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the mullion and the continuous vertical gasket.

Thermal Barrier continuity is provided by the thermal break.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weepholes in an intermediate horizontal.

① Extruded Aluminum Mullion

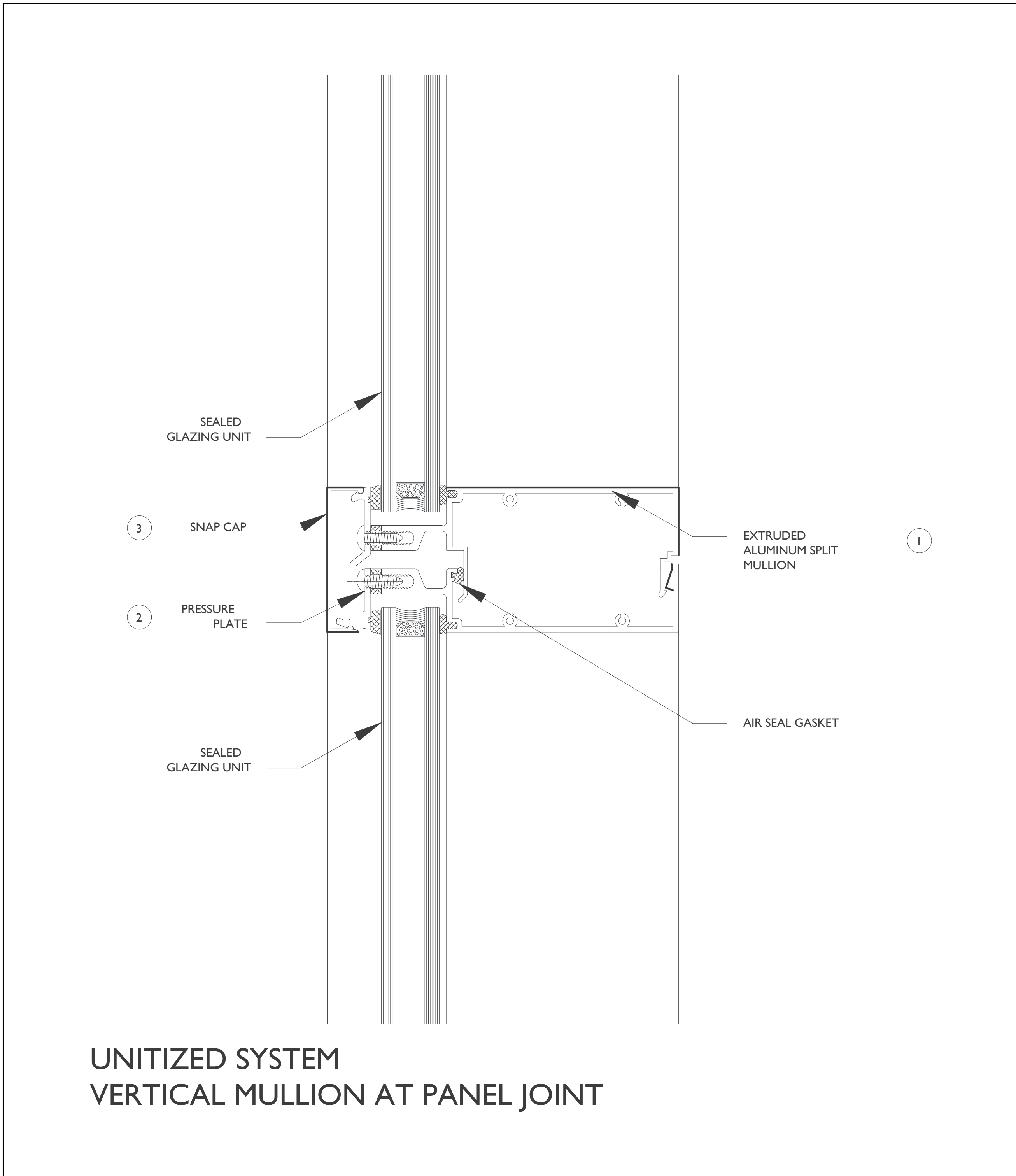
As indicated, basic profiles of aluminum unitized system mullions vary with manufacturer. Mating sections include an outboard engagement, which provides alignment and compression to the air seal gasket and an inboard snap lock that prevents buckling of the mating halves under high load. The air seal engagement must be continuous while the inboard snap lock may be either continuous or discrete. Mullions may span between horizontals as illustrated or may span directly mullion to mullion.

② Pressure Plate

Framing systems may incorporate a double pressure plate as shown or a single pressure plate that engages the adjacent glass edge on installation.

③ Snap Cap

Snap caps are designed to engage properly onto a specific type of pressure plate. When caps are manufactured within tolerances, reliable engagement is obtained and cap removal does not result in any cap damage. However, use of non-mating snap caps and pressure plates, out-of-tolerance materials or custom caps may result in a progressive loss of cap engagement over time with thermal cycling. For custom caps, particularly very deep caps, fixing screw at one end of the cap length is recommended.



Detail 21: *Unitized system vertical mullion at panel joint*

DETAIL 22 – UNITIZED SYSTEM OUTSIDE CORNER CAPPED

The exact configuration of unitized system vertical mullions varies from manufacturer to manufacturer. Many differences can exist and sections are rarely interchangeable between different manufacturers. The air seal is typically formed by a compressed continuous gasket.

Air Barrier continuity is provided by the interior glass surface, perimeter structural silicone seal, and the aluminum framing across the head of the rail. On the spandrel side the sheet metal backpan replaces the interior glass surface as the air barrier plane.

Thermal Barrier continuity is provided by the semi-rigid insulation, gaskets and silicone seal.

Vapour Retarder function is provided by the inherent resistance of the materials.

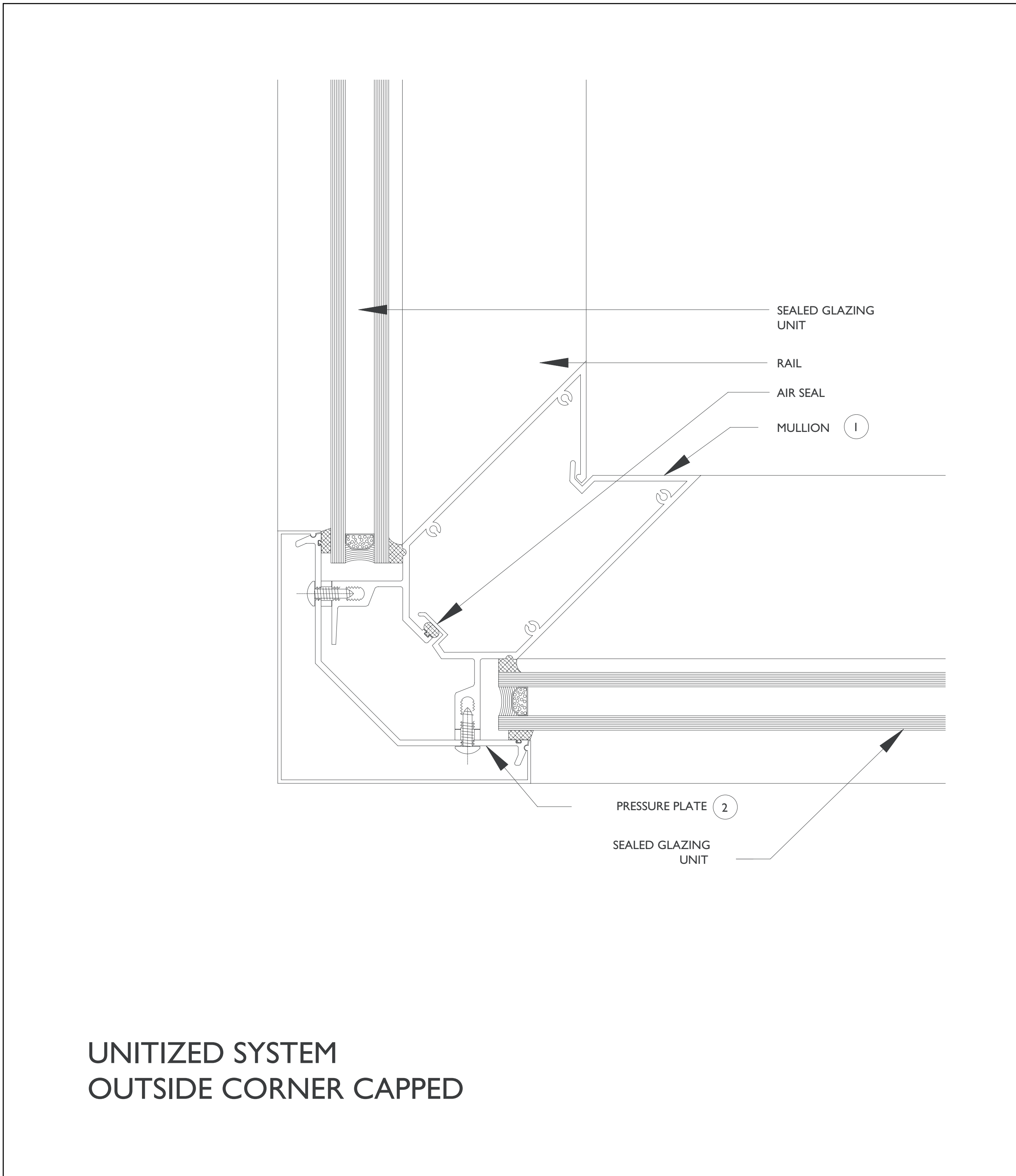
Water Penetration control is provided by the drainage cavities in the system behind the structural silicone sealant directing water to weepholes at the stack joint.

(1) Extruded Aluminum Mullion

As indicated, basic profiles of aluminum unitized system mullions vary with manufacturers. Mating sections include an outboard engagement, which provides alignment and compression to the air seal gasket and an inboard snap lock that prevents buckling of the mating halves under high load. The air seal engagement must be continuous while the inboard snap lock may be either continuous or intermittent. The mullion must incorporate screw splines to accept the cap screws and a chase to accept gasket.

(2) Pressure Plate/Snap Cap

A custom one- or two-piece pressure plate retains the glass units in a conventional manner. One-piece pressure plates provide more reliable sections to engage a one-piece snap cap. Large wide snap caps do not provide the same engagement clamping as smaller typical snap caps and clamping engagement should be supplemented with mechanical fixing.



Detail 22: *Unitized system outside corner capped*

DETAIL 23 – UNITIZED SYSTEM SSG HORIZONTAL RAIL AT CEILING

As with all detailing, the intent at the curtain wall-to-ceiling interface is to expose as much as possible of the aluminum section to the interior. This maximizes heat transfer from the interior air to the aluminum framing.

Air Barrier continuity is provided by the interior glass surface, perimeter glazing gaskets, the aluminum framing across the head of the mullion, joinery sealants, and the sheet metal backpan.

Thermal Barrier continuity is provided by the thermal break and the semi-rigid insulation in the backpans.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system directing water to weep slots in the pressure plate.

① Spandrel Panel

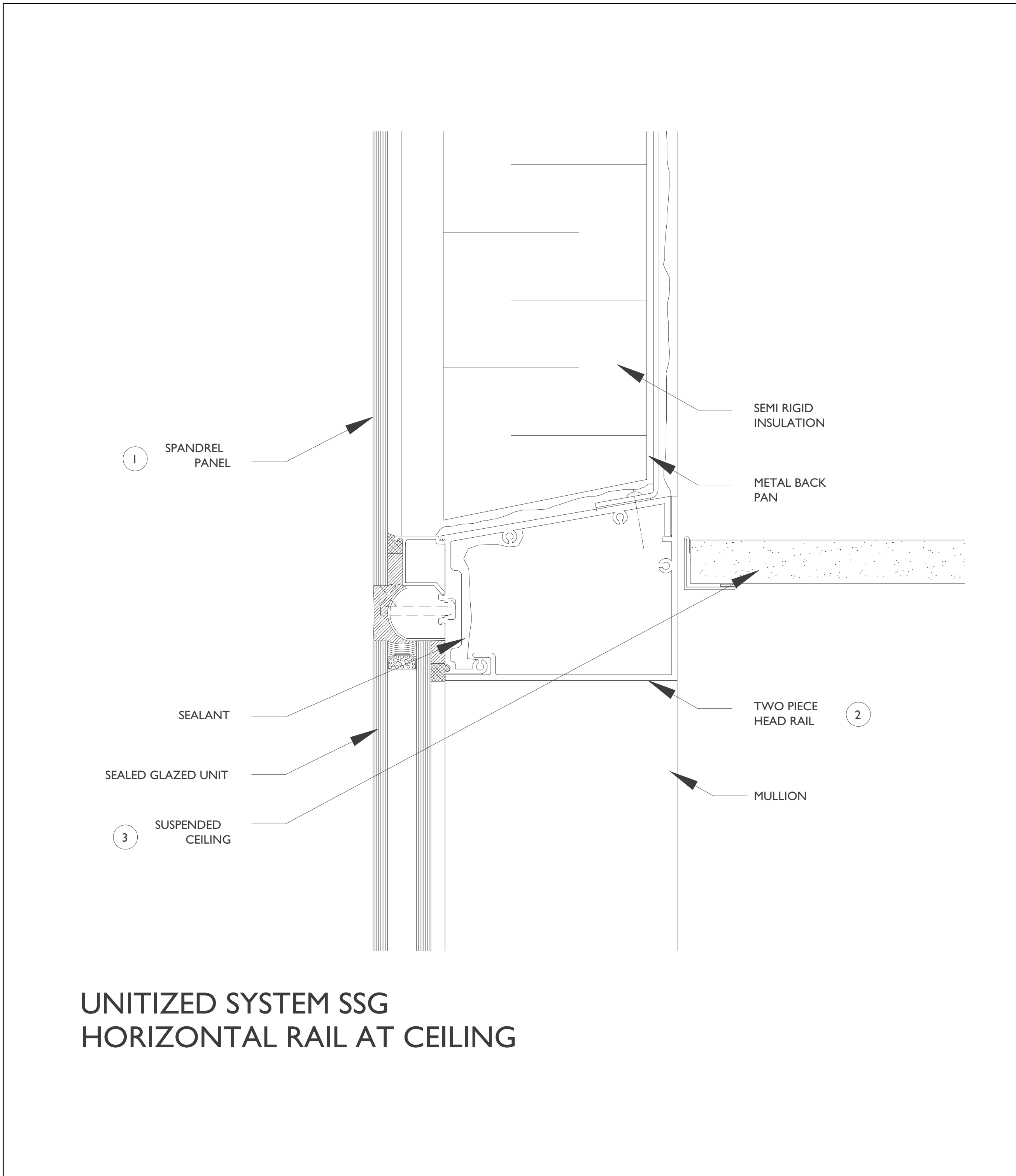
Spandrel panels are most frequently monolithic glass or sheet metal. Insulating glass, stone, plastics and combinations of these materials are also used. Monolithic spandrel glass is usually heat strengthened and is covered on the backside with a scrim which both opacifies and will tend to hold a broken lite of glass together until it can be removed.

② Metal Backpan and Two-Piece Head Rail

The spandrel backpan is formed by the sheet metal backpan bounded by the mullion and rail sidewalls. The horizontal rail at the base of the spandrel cavity spans between the mullions and has a canted upper section to promote drainage. Two-piece sections have some advantages over one-piece tubular sections although their use demands tight tolerances only attainable in shop fabrication. Two-piece sections also require more sophisticated engineering analysis. Two-piece sections allow for interior sealing with a substantial sealant bead which is covered by the second closure section. Sealant continuity holes at the metal to metal joints prevent water leakage at this interface. Insulation completely protects the sidewalls of the rail. Provide a clear 25 mm (1 inch) cavity between the spandrel panel and the face of the insulation.

③ Suspended Ceiling

Suspended ceilings, particularly their support grid, should not be fixed directly to the curtain wall. Wall movement due to gravity or wind loads can result in noise transfer and dislodging of ceiling systems. Fasteners for a support grid should never be drilled into a sheet metal backpan.



Detail 23: *Unitized system SSG horizontal rail at ceiling*

DETAIL 24 – UNITIZED SYSTEM SSG STACK JOINT (ALT. AIR SEAL)

The exact configuration of unitized system stack joints varies from manufacturer to manufacturer. Many differences can exist and sections are rarely interchangeable between different manufacturers. The air seal is typically formed by a compressed continuous gasket.

The use of the double chamber requires specific analysis to ensure thermal performance.

Air Barrier continuity is provided by the interior glass surface, perimeter structural silicone seal, the aluminum framing across the head of the sill rail, the air seal gasket, the sidewall of the head rail and the sheet metal backpan.

Thermal Barrier continuity is provided by the gaskets and silicone seal and the semi-rigid insulation.

Vapour Retarder function is provided by the inherent resistance of the materials.

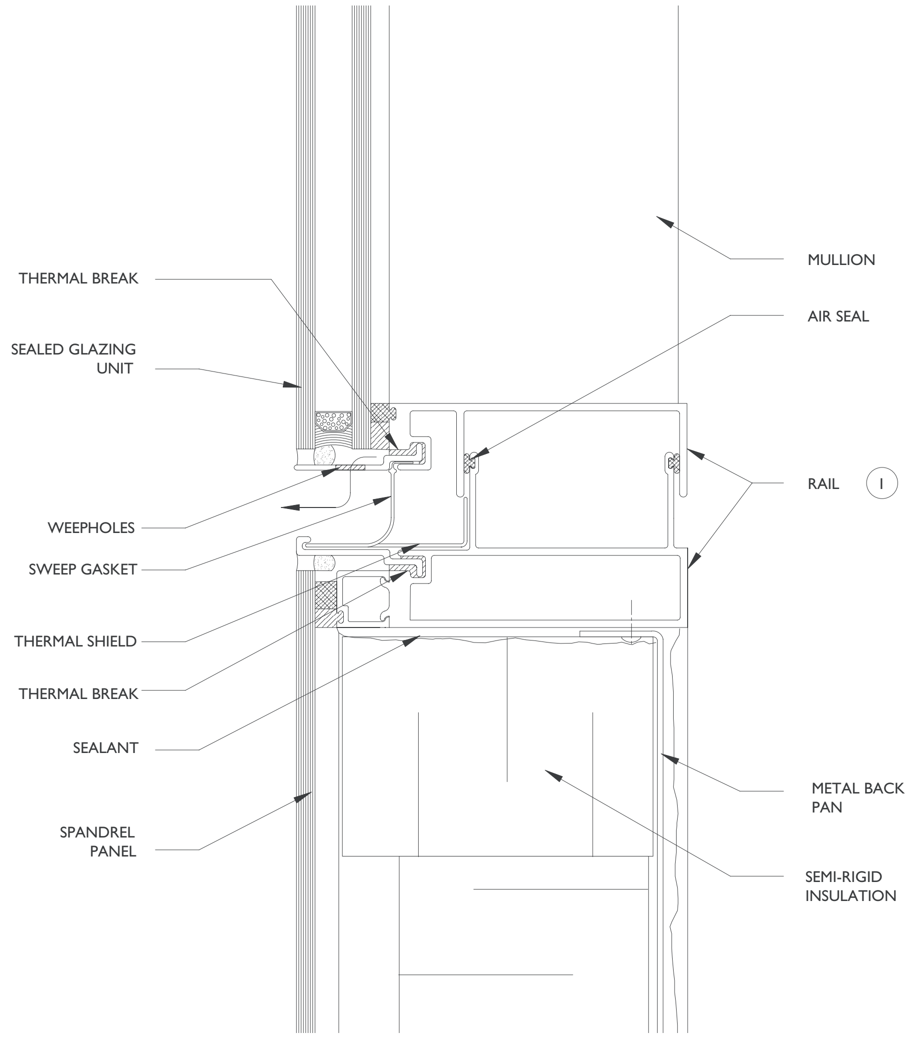
Water Penetration control is provided by the drainage cavities in the system behind the structural silicone sealant that direct water out at gaps in the sweep gasket.

(1) Extruded Aluminum Rails

As indicated, basic profiles of aluminum unitized system mullions vary with manufacturers. Sill and head rails are mating sections that allow for vertical differential movement and some lateral movement depending on system design. The air seal engagement must be continuous and the outboard sweep gasket must allow drainage. The rails must incorporate a bond surface for the structural silicone bead and a chase to accept a gasket. Components that extend to the exterior must be thermally broken from the main rail section. The use of plastic shielding components also enhances thermal performance.

(2) Semi-Rigid Insulation (thermal barrier)

Insulation provided to the metal closure ensures continuity of thermal protection between the floor slab and the wall.



UNITIZED SYSTEM SSG
STACK JOINT

THIS TYPE OF DETAIL REQUIRES SPECIFIC ANALYSIS TO ENSURE THERMAL PERFORMANCE

Detail 24: *Unitized system SSG stack joint (alternate air seal)*

DETAIL 25 – UNITIZED SYSTEM SSG MULLION (ALT. AIR SEAL LOCATION)

The exact configuration of unitized system vertical mullions varies from manufacturer to manufacturer. Many differences can exist and sections are rarely interchangeable between different manufacturers. The air seal is typically formed by a compressed continuous gasket.

> The use of the double chamber requires specific analysis to ensure thermal performance.

Air Barrier continuity is provided by the interior glass surface, structural silicone seal, the aluminum framing across the head of the mullion and the continuous vertical gasket.

Thermal Barrier continuity is provided by the gaskets and silicone seal.

Vapour Retarder function is provided by the inherent resistance of the materials.

Water Penetration control is provided by the drainage cavities in the system behind the structural silicone sealant directing water to weepholes at the stack joint.

(1) Extruded Aluminum Mullion

As indicated, basic profiles of aluminum unitized system mullions vary with manufacturers. Mating sections include an outboard engagement, which provides alignment and compression to the air seal gasket and an inboard snap lock that prevents buckling of the mating halves under high load. The air seal engagement must be continuous while the inboard snap lock may be either continuous or intermittent. The mullion must incorporate a bond surface for the structural silicone bead (2) and a chase to accept a gasket (3).

(2) Glazing Gasket

As shown, the glazing gasket is frequently positioned outboard of the structural silicone bead. This allows the silicone to be installed from the outside edge of panel frame. The gasket may be an extruded silicone or silicone-compatible rubber as shown or an adhesive-compatible foam tape. Care must be taken to ensure the gasket of the horizontal rail meets and seals to the gasket of the mullion.

(3) Structural Silicone Bead

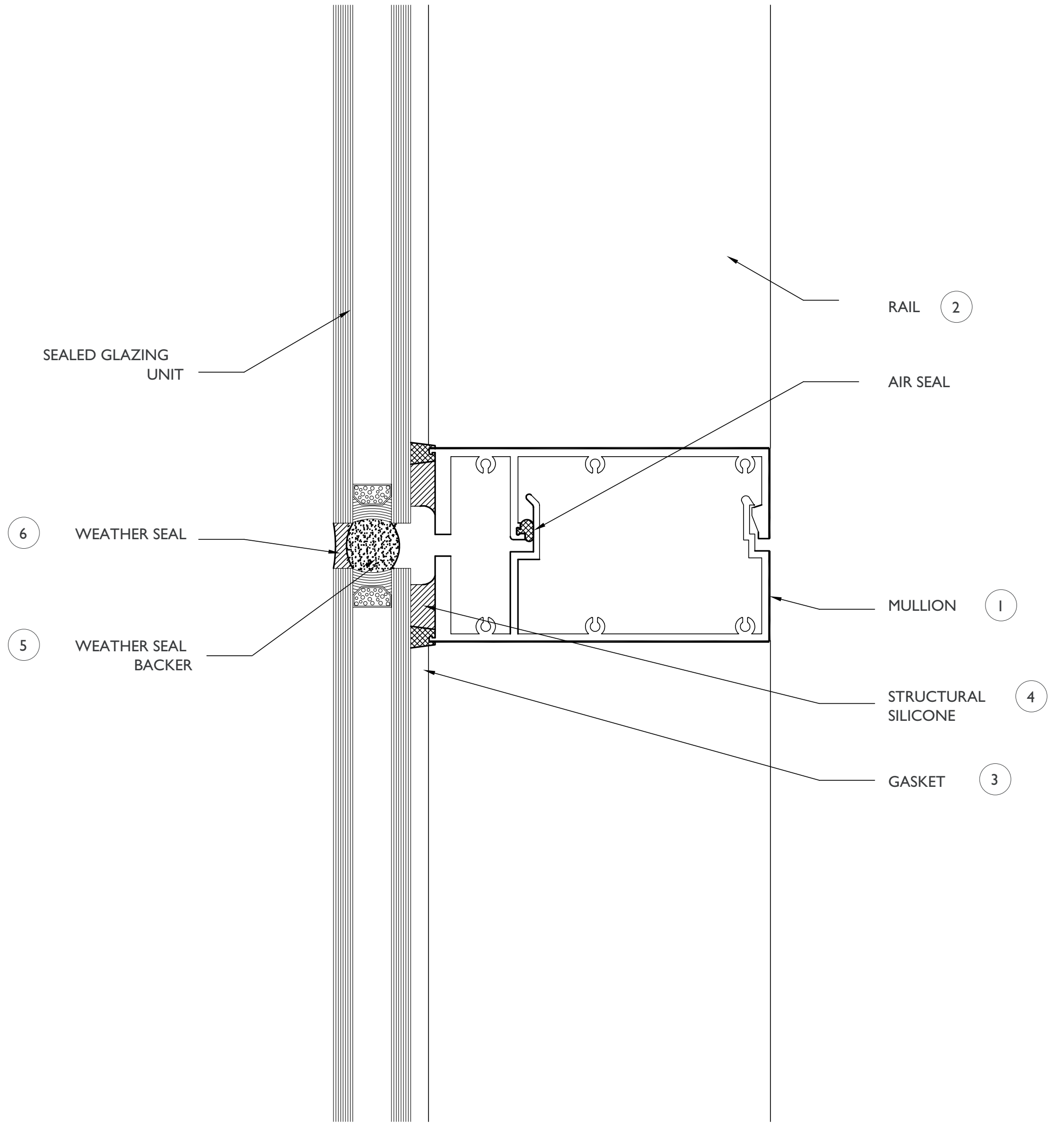
The structural silicone bead is sized to meet the wind loads of the particular application. It has a minimum thickness of 5 mm (1/4 inch) and a typical width of 12 mm (1/2 inch). The bonding surface on the rail must be tested for long term silicone adhesion and compatiblity.

(4) Weather Seal Backer

The type and sizing of the weather seal backer is less critical to the drainage performance of the system where a backup drainage chamber is used.

(5) Weather Seal

The silicone weather seal is applied over a backer rod or sheet to create a near rectangular or slightly hour-glass shaped bead. The bonding surfaces at the edge of the glass must be cleaned of all sealant residues.



UNITIZED SYSTEM SSG
MULLION-ALTERNATE AIR SEAL LOCATION

THIS TYPE OF DETAIL REQUIRES SPECIFIC ANALYSIS TO ENSURE THERMAL PERFORMANCE

Detail 25: *Unitized system SSG mullion-alternate air seal location*

QUALITY ASSURANCE VS QUALITY CONTROL

The terms “Quality Assurance” and “Quality Control” are often used interchangeably and incorrectly as they have specific meanings. There are various different definitions but the terms can be broadly defined as:

“Quality assurance” concerns the establishing and monitoring of an appropriate set of standards and procedures necessary to achieve quality.

“Quality control” consists of conformance to the standards and procedures by all members of the project team.

Standards and procedures are established by the project specification and architectural drawings. The development of the specification is therefore a critical step in a quality assurance programme. In all the steps that follow including shop drawing production and review, mock-up and field testing, fabrication and assembly and curtain wall installation, there are elements of quality control and quality assurance.

In almost all Canadian construction the Contractor is responsible for quality control and the design professionals are responsible for quality assurance.

7.1 SPECIFICATIONS AND DRAWINGS

As indicated, the proper development of the specifications and drawings is essential to the overall success of the project and the quality assurance programme. Despite this importance, curtain wall specification and detailing is frequently considered too lightly, due in part, to the means of procuring the curtain wall as discussed in Chapter 1. Frequent problems found in the review of architectural specifications and drawings include:

Specification/Drawing Blunders

- Specified products cannot be combined to meet the specified performance. This is especially common with respect to thermal performance.
- Wall is required to meet specified standards, but no parameters are specified to precisely define required performance levels.
- Performance requirements are not determined rationally resulting in either the under or over specifying of components. The basing of specification on one manufacturer’s product or the naming of one manufacturer along with a listing of other approved manufacturers that do not produce similar products.
- Detailing of spans or modules spacing that are inconsistent with the structural capability defined by the detailed member depths and widths.
- Inadequate provisions for tolerances and clearances along with a lack of recognition of movement requirements at stack joints
- Reference to residential based window standards in the specification of curtain wall
- The inappropriate inclusion of sloped glazing in curtain wall specification

The above is just a short listing of issues often arising in the review of architectural specifications and drawings. Specifications are discussed in Chapter 8. General procedures and aspects of detailing that enhance the quality of the architectural documents are discussed below.

7.1.1 Early Advice

Early advice, sought from competent council, can add immeasurably to the success of a curtain wall project. One cannot be expert at all things and successful projects are the result of teamwork between the architect, specialty consultant, general contractor and curtain wall manufacturer/contractor.

Manufacturers are typically eager to offer advice on the feasibility, practicality and cost of preliminary designs. Specialty consultants can provide this advice along with input to specification and performance matters. The earlier this advice is sought, the greater value it can be. Initial input before the design is finalized can often result in cost savings or greater value for a given cost, or can serve to avoid large claims for required changes to a contract based on inappropriate details, specifications, etc.

The architect should be aware that while manufacturers can provide very valuable input, they are in a competitive business and are naturally seeking any advantage possible. A given manufacturer may have specific assembly details, installation details or standard sections that, if reflected too closely in the architectural documents, may restrict other manufacturers. Specialty consultants are not all equal and the architect should be very specific with respect to experience and expertise requirements prior to engaging one.

7.1.2 Architectural Detailing

The architectural drawings serve as the basis for the curtain wall shop drawings. The level of detailing varies widely from architect to architect, from project to project and from wall type to wall type. Generally, the level of detailing should increase with the complexity of the design and the custom nature of the wall. Unfortunately, there is a tendency to provide a minimal amount of detailing (possibly driven by budget or liability concerns) and to rely on the curtain wall contractor to resolve the more difficult details. While it is not expected that the architect resolves all the detailed curtain wall design issues, some attention should be paid to the special conditions that exist on a project.

For the simplest of wall designs, based on standard manufacturer's sections, the essential elements of the architectural drawings include:

- Elevation drawings, sufficient to establish the wall pattern and locate the principal framing members, support locations, operable vents, doors, expansion joints
- Designation of different infill materials (vision glass, spandrel panels) and the finishes required
- Designation of the type and size of operable elements
- Large-scale details of all interfaces with adjacent construction (grade, roof, adjacent walls) indicating responsibility for connection, materials, movement requirements, continuity of air leakage control, thermal and moisture protection
- A generalized cross-section of framing members supported by a structural verification of member sizes

As curtain wall complexity increases, and certainly with the use of custom wall sections, the level of detailing must increase. The extent of the increase depends on the approach to the awarding of the contract. The architect may produce drawings that detail primarily the aesthetic requirements and the general methods of anchorage, the glazing method etc., but not the complete detailing of the wall. From these drawings “proposals” are solicited from acceptable contractors. The proposals are to meet the general intent of the architectural drawings but will vary to allow the individual contractors to include their “best” way of approximating the design. Drawings submitted at the bid stage will only include typical representative details with remaining details to be developed later.

The proposal procedure requires less detailing by the architect but does require flexibility in the acceptance of details to be developed. An essential element of this approach is the clear and accurate definition of performance requirements from the outset. It also requires the architect to be able to critically review the proposals, initially independent of cost, in order to assess the performance levels achieved, and to select the most attractive and durable option. The proposal approach can work well with a highly qualified contractor and knowledgeable architect but can be fraught with problems if the contractor or architect has less experience than the project demands.

The alternative to the proposal approach is to produce a more complete set of details to which all bidders are to conform. The level of detail is not that of shop drawings but is considerably greater than that required for the proposal approach. Even with the greater detailing some changes should be anticipated once a contract is awarded. The major disadvantage of this approach is that each manufacturer has established standard design detailing. However, the standard detailing, and even the approach to resolving special conditions, varies between different manufacturers. As a result, this approach commonly ends up more like the “proposal” approach as different bidders propose their modifications to the original details.

7.1.3 Tolerances and Clearances

Architectural detailing frequently does not provide adequate tolerances or clearances, as defined below:

Tolerance – permissible variation from a specified or nominal characteristic (dimension, colour, shape, composition, etc.)

Clearance – space or distance purposely provided between adjacent parts to allow for movement, tolerances or working space.

The most prevalent tolerance or clearance issues develop with respect to building frame tolerances. The methods of fabrication of curtain wall result in tolerances often less than 3 mm (1/8 inch). Building frame tolerances are typically specified in the order of 6 to 25 mm (1/4 to 1 inch) and are often found to exceed 50 mm (2 inches). Specifying tighter building tolerances may be appropriate in specific buildings but it is generally less expensive to recognize these issues in the detailing of curtain wall.

The almost universal architectural desire for small or narrow joints leads to the second most frequent tolerance and clearance issue. Almost any interlocking type joint requires some clearance in order to properly engage, yet detailing commonly asks for impractical joint widths at interlocks.

7.2 SHOP DRAWINGS

Shop drawings, prepared by the curtain wall contractor, start as an illustration of the contractor's interpretation of the architect's intent. They are used by the architect to verify that the contractor understands the design intent but also by the owner for information and leasing, by third party inspection companies to verify compliance, by the field installation crews as a guide to construction and eventually by building operations to assist in maintenance. As such, they are critical documents in the construction of the curtain wall. Far too often the shop drawings are treated with less respect than the original architectural plans, yet with respect to any future work on the wall, the shop drawings are far more valuable. It is more important, and more helpful, for building owners to receive accurate shop drawings for a curtain wall than original architectural drawings giving only a general illustration of the curtain wall.

Aside from elevation and plan views to provide overall dimension and layout, the shop drawings should provide comprehensive and clear details of all the work in the contract and the adjacent interfacing work not in the contract. The interfaces, along with the anchoring and fastening methods, are especially important. Clear interface details are important to establish responsibility and required sequencing for continuity at interfaces.

While the level of detail and the overall quality of shop drawings varies widely, review often reveals a number of issues common to many shop drawings.

Common Shop Drawing Issues

- Installation issues are not fully resolved leading to a lack of fit in the field. Insufficient consideration of clearances and tolerances
- Tendency to detail only typical conditions leaving most complex special conditions for field ad hoc resolution
- Production of details at too small a scale. Details should be full size
- Substitution of specified materials with unqualified products
- Lack of detailing of fasteners, welds or sealant joints that may affect aesthetics
- Inadequate detailing of rain screen details such as compartment seals or drain openings

For the design professional, the review of the shop drawings is a critical phase in the quality assurance programme. Design offices often develop checklists for staff reviewing drawing submission from different trades. A sample checklist for curtain wall shop drawings would include:

Overview	**Plans and elevations**	Confirm scope and extent
		Verify layout and dimensions
		Verify provision and location of movement joints in wall
		Verify location of operable elements
		Verify distribution of glass and spandrels types
		Resolve work labeled “by others”
		Review sequencing of connections to adjacent systems
Materials	**General notes**	Verify aluminum alloy and temper
		Verify anchor and reinforcing steel grade and protection
		Verify fastener types, materials, protection
		Confirm sealant types (same manufacturer)
		Confirm sealant accessory compatibility
		Verify glass types, thicknesses, heat treatments
		Verify glass coatings, edge sealants, edge spacer
		Confirm gauge and treatment of metal backpans
		Confirm finish types and colour numbers
		Confirm stone type, thickness, colour and finish
Details	**Anchors**	Verify anchors meet design assumptions (fixed, sliding, wind only)
		Confirm dead and live loads and directions shown on drawings
		Confirm permissible tolerance and clearance
		Verify grade and treatment of embed steel
		Review anchors for special conditions (outside columns, at atriums
		Confirm alloy type for extruded anchor parts
		Verify corrosion protection
	Framing	Review overall dimensions, tolerances, clearances
		Locate reinforcing, confirm sections, treatment
		Identify slab edge firestop and smoke seal continuity
		Verify mullion tube smoke seal continuity at slab edge
		Review tolerances in split mullion assembly.
		Confirm free movement of stack joint rails (attachments)
	Glazing Details	Confirm adequate bite, edge clearance, face clearance, cap coverage
		Identify required dimension for structural silicone beads
		Review drainage and venting provisions. Ensure drainage paths are clearly shown on details
		Identify and confirm compartmentalization of glazing cavities
		Identify and confirm compartmentalization of spandrel cavities
		Identify and confirm continuity of air barrier plane within wall and to adjacent surfaces
		Confirm attachment and sealing of metal backpans
		Verify stiffener requirements for metal backpan
		Verify free venting and drainage of spandrel cavities
		Identify means of securing insulation to backpan
		Review fixing of spandrel panels
		Confirm fixing of stone spandrels to allow for shipping
		Verify sealing of kerfs to prevent trapping of water
		Verify sealant types at adjacent stone or porous materials
		Confirm adequate detailing of responsibility with respect to adjacent envelope system connections

Cross-checking	**Structural**	Confirm structural support conditions
		Confirm compatible deflections at anchors
	Mechanical	Confirm duct locations and sizes, louvers
		Confirm air distribution to interior face
		Confirm heat distribution to interior face
	Electrical	Verify location of electrical penetrations

Aside from shop drawings the contractor may produce other drawings such as glass cut sheets, fabrication drawings and assembly/installation drawings. These drawings are prepared primarily for the contractor's own internal use and are rarely submitted for review by the architect. In special cases, it may be useful to review specific aspects of these drawings if questions arise regarding aspects of the wall.

7.3 MOCK-UP AND FIELD TESTING

A detailed discussion of mock-up testing issues is provided in Chapter 5. Laboratory mock-up testing of a prototype section of wall should be considered as quality assurance related to the wall system design. Field testing should be considered as quality assurance related to the workmanship, both in assembly and installation.

Formal laboratory mock-up testing provides a measure of verification to the wall design but given the artificial laboratory conditions it is not a complete verification. If a mock-up sample leaks profusely it would be expected that the field installation would demonstrate even worse performance. However, if a mock-up sample exhibits no leakage, this does not mean that a field installed sample would not leak. It only indicates that the particular system can be assembled such that no leakage occurs under a given test condition.

Field testing, as part of quality assurance, can also provide only a measure of verification given the test methods and the smaller areas tested. If a field sample leaks but the laboratory mock-up sample did not, an assembly or installation fault is anticipated. Further investigative testing is required to identify and isolate the leak source.

7.4 FABRICATION AND ASSEMBLY

Fabrication and assembly practices vary with different contractors but more significantly with different system types. Fabrication of a stick system consists of cutting painted stock material (mullions, rails, pressure plates and snap caps) to proper lengths and predrilling holes for the attachment of shear blocks. Assembly of the system is actually carried out in the installation phase of the work. The only components typically preassembled are operable vents, doors and specialty components. These are often bought-out elements for the curtain wall contractor.

Quality issues in the fabrication of a stick system lie primarily in the accurate cutting and drilling of materials. A high degree of accuracy can be achieved with proper machine shop practices but a great number of small-scale stick systems are fabricated with only rudimentary machinery. The most common issues arising include improper miter angles, mispositioned shear blocks, twisted or distorted framing, improperly sized drainage/ventilation openings, and an overall lack of proper fit.

Unitized systems require the same cutting and drilling of materials as stick systems but also include preassembly of frames in the factory. Sealing of joinery, connection and fixing of framing members, installation of insulation into sealed backpans, glazing, and finishing are all factory operations. Given the high degree of preassembly, quality assurance with respect to a unitized system must focus on the factory activities. Factory review checklists should include:

Organization	**Tagging**	Ensure a means of tagging defective components is in place and responsibility of correction is assigned
		Ensure quality assurance procedures are in place and recognized by team
Materials	**General**	Verify aluminum alloy and temper (certificates)
		Verify anchor and reinforcing steel grade and protection
		Verify fastener types, materials, protection
		Confirm sealant types (same manufacturer)
		Confirm sealant accessory compatibility
		Verify glass types, thicknesses, heat treatments
		Verify glass coatings, edge sealants, edge spacer
		Confirm gauge and treatment of metal backpans
		Confirm finish, type, colour, runs, sags, coverage
		Confirm stone type, thickness, colour, inclusions, and finish
Framing	**Assembly**	Verify fit and fixing of framing elements
		Verify twist within tolerance
		Confirm overall dimensions, squareness
		Confirm sealing of joinery including continuity across wall thicknesses
	Accessories	Confirm fixing of anchor components, position of major load bearing holes, bolt fixing
		Verify position and fixing of outrigger elements
Backpans	**Fabrication**	Confirm overall fit of backpan within frame
		Verify stiffener installation and sealing
		Verify positive sealing of backpan corners
		Verify slopes to ensure drainage of backpans
		Confirm continuity of perimeter sealants
	Insulation	Confirm type and thickness of insulation
		Verify snug fit of insulation with no gaps and minimum number of pieces
		Confirm retention of insulation within backpan
Glazing	**Glazing Details**	Verify condition of glass edges and edge sealant coverage
		Confirm overall size and thickness
		Verify proper orientation (inside/outside)
		Confirm adequate bite, edge clearance, face clearance, cap coverage
		Review drainage and venting provisions
		Confirm positioning of setting blocks and locking in position

SSG	**Glazing Details**	Verify QC procedures in place
		Verify positive results of snap, butterfly and adhesion testing
		Verify substrate cleaning and dust free conditions
		Confirm proper sealant application and curing
		Confirm manufacturer inspection of application
Spandrel	**General**	Verify free venting and drainage of spandrel cavities
		Review condition of fabricated panels, finish, corners, flatness
		Review fixing of spandrel panels
	Stone	Confirm position and fixing of anchors
		Confirm pot life and adhesion of epoxy type anchors, witness testing
		Confirm fixing of stone spandrels to allow for shipping
Gaskets		Confirm placement, sealing and securing of all interlock and glazing gaskets
Packing	**General**	Verify packing and crating provide adequate protection
		Confirm packing will prevent movement of components such as stone during shipment
		Confirm frames adequately labeled

7.5 INSTALLATION

While a poorly designed wall cannot be remedied by even the best installer, a well designed and fabricated wall can be easily degraded by poor installation. Glass and metal curtain walls are highly engineered and factory built to close tolerances. Installation requires the placement of these precision built parts on a structure built to much greater dimensional tolerances. As such, proper and timely communication between the members of the project team is the essential requirement of a successful installation.

A great many factors impact the quality of a curtain wall installation. Many of these originate in the architectural design and specifications. Examples include:

- Design wall to be installed from the floor slab and not from stages or scaffold
- Insisting or permitting installation in inappropriate weather. Extreme cold and extreme heat are both very problematic for workers dealing with a system designed to close tolerances, when the weather has such a significant effect on both the worker and the materials being handled/assembled.
- Recognize that curtain walls are shipped to the site by truck and must be hoisted to the work location. This imposes constraints on size but also introduces constraints with respect to loading storage in downtown locations, handling, etc.
- The best approach is to minimize the number of trades required to complete the wall. Careful use of terminology on drawings used to describe the wall can avoid jurisdictional disputes.

- A curtain wall is based on tremendous repetition of standardized details, with little on-site fabrication of custom components. Frequent variations in the standard detailing greatly increase the chances that custom components are required to adjust the wall. This increases the risk of poor quality construction.

As the project moves from design to construction scheduling becomes a significant task. An unrealistic schedule and attempts to enforce it can result in poor coordination of work and a decrease in the quality of the work. Scheduling must consider:

- Adequate time for preparation and review of shop drawings and sample.
- Adequate time to conduct and obtain all material and system test results
- Weather conditions expected during installation
- Time for procurement of specialty items and their fabrication
- Time for design, construction, and testing of mock-up if required
- Time for design and fabrication of cast in components
- Time for review and acceptance of special colours and finishes

Attempting to install the curtain wall before the structure is complete or not sufficiently advanced to accept it adds costs, safety concerns and a potential reduction in work quality. Scheduling must reflect the progress of associated work, such as

- Fabrication and installation of cast in components
- Placing of concrete for structure and slabs
- Removal of slab shoring and form work
- Backfilling for grade or lower level work
- On-going associated or adjacent operations that will cause physical damage to curtain wall components (e.g. welding, laying masonry)

Like many other trades, the curtain wall contractor relies on offset lines and benchmarks set by the general contractor. Any error in the setting of these marks will impact the installation of the wall. All such marks should be set well in advance of the curtain wall installation to allow cross checking and preparation by the curtain wall contractor.

The greatest quality issues related to glass and metal curtain wall installation are tolerances and clearances. Failure to properly control tolerances and clearances is the reason for most curtain wall installation problems. Four different tolerances must be considered. These include building frame tolerances, installation tolerances, material tolerances and fabrication and assembly tolerances.

Building frame tolerances are most significant. It is not uncommon to find floor slabs 50 mm (2 inches) above or below a specified elevation, slab edges out of alignment by 40 mm (1 1/2 inch) or columns 25 mm (1 inch) out of plumb over a storey height. Despite these irregularities, curtain walls are to be installed plumb and at the correct elevation. It is therefore essential that specifications require the proper alignment and location of all materials related to the wall and that these requirements be enforced. Installation tolerances depend on the building tolerances. If the building frame is outside of specified tolerances, modifications to anchors can be expected.

Basic material tolerances refer to extrusion thickness, overall sizes and thickness of panels, length of extrusion. These tolerances must be recognized in joint width and location.

Fabrication and assembly tolerances are normally noticed at joints where, for example, a miter cut does not match or a butt joint is not closed.

Inadequate clearances arise most frequently due to building tolerances. Clearances are essential to allow proper working of sealant joints, to allow differential movement, to allow access for fixing and for possible size tolerance. Clearance issues are most often noted at non-typical anchors. In general, these should be at least 50 mm (2 inches) plus outward tolerance provided.

Delivery, Handling, Storage

Delivery of materials to the site should be made in accordance with a pre-agreed schedule. As delivery is almost always by truck, adequate road access and hoisting equipment should be available. Whenever possible finished material should be hoisted directly from the truck to the floor where installation is to take place. Storage on the floor slabs, while requiring coordination to avoid conflict with other trades, is ideal as it avoids multiple material moves, is generally dry and well ventilated. If the material must be stored in a marshalling area prior to lifting to specific floors the area should be:

- Level, clear of debris and well drained
- Graded areas should be packed to avoid settlement of crates and potential racking of frames
- Located to allow clear future access to crates and prohibit other site traffic from close proximity to crates
- Crates and exposed materials should be protected from mortar, lime, acids, tars and chemical splatter
- If stored indoors where temporary heat might be used, the crates must be ventilated to avoid condensation on the aluminum

As the assemblies are moved from storage to work area handling precautions must include:

- Material should be lifted and handled to avoid bending, twisting, racking or otherwise distorting the material
- Special racks or dollies to store or transport materials should be used
- Care should be taken to avoid climbing, standing or walking on materials
- Finished aluminum parts should not be used to support scaffold, board, walkway or ladders

Construction Elevators

Exterior construction elevators are common to most multi-storey construction projects. The elevators stay in place for a significant portion of the construction schedule, often for several months after the curtain wall is installed. As such, a “unitized” bay or a hoist way opening must be left in the wall. This unitized bay is completed once the elevator is removed. The number and location of hoist ways should be identified on the project specifications.

In order to minimize the potential impact of the leave-out bay on the quality of the completed wall the following should be recognized:

- The wall area at the leave-out bay must be specially detailed to allow installation after the rest of the wall is complete. This is especially important with unitized wall systems.
- The wall areas adjacent to the elevators are subject to soiling and damage. Protection must be considered.
- As the elevator leave-out bay is completed, the newly installed material may not initially match the already completed areas due to the weathering of the installed material.

Anchors

Field installation begins with the layout and installation of anchors. Again the quality of the anchor installation begins with the architectural design and the shop drawing development of the design. Anchor designs will vary with designer and building but several principles can be followed to enhance quality.

- Whenever possible, the anchor should be installed on top of the slab, regardless of structure type. Anchors at the slab edges can be feasible but Canadian assembly and concrete placing practices often make this location problematic. Locating anchors on the underside of the slab should be avoided, as it is difficult overhead work requiring scaffold or ladders.
- Regardless of the anchor detail, the anchor should be large enough to allow 3-way adjustability and rapid field connection.
- On concrete slabs, the anchors should be set into pockets and grouted later to allow full use of floor space
- Whenever possible, concrete embeds should be used in place of drill-in type anchors.
- Where possible, fireproofing should follow anchor installation in steel frames.
- Where fixing is to a steel element, welding is preferred over field drilling and bolting. Where bolting must be used, bolt holes on the steel should be predrilled.
- Anchors should be installed by the curtain wall contractor not by the steel or miscellaneous metal contractor. Embedded parts should be fabricated by the curtain wall contractor and supplied to the general contractor for casting into the slabs. These parts must be issued early in the construction process along with shop drawings showing their position.

Despite the following of the above principles, field issues still develop where the shop drawings are not followed.

Mislocation of Slab Edge

The most common field variance is the concrete slab edge being too far in or out from theoretical position. The position of the slab edge may exceed the movement tolerances designed for the anchor. If the slab edge is too far, excessive bending forces in the cantilevering anchor and tensile forces in bolts may develop. Excessive shimming or excessively long bolts will weaken the connection. All non-typical anchors require an engineer's review and sign off.

Mislocated, Missed or Incorrect Embedments

The proper installation of embeds requires the early issue of separate shop drawings and the careful coordination of their installation. Errors will occur and special modifications again require the review of the curtain wall contractor's engineer.

Inadequate Structure at Anchor Points

Anchorage to a steel structure, provided the beam sizes conform to the structural steel drawings, are typically less of a concern than anchorage to concrete slab edges. Voids or honeycombing of concrete, particularly at groups of embedments, at slab transitions, corners and columns. Inspection of the concrete at embedments should precede anchor installation.

Excessive Shimming – Inadequate Bolt Engagement

Variances in the elevation of embedments often result in excessive shimming. Shimming almost always has a negative impact on the strength of connections. Lateral loads generate bending as well as shear loads in bolts and thread engagement is reduced. Where expansion type anchors are used, unless the length is corrected, embedment is reduced and strength is significantly reduced.

Installation checklists will vary with the system type but would include:

Organization	**Drawings**	Ensure reviewed shop drawings and issued for construction documents available on-site
		Ensure quality assurance procedures are in place and recognized by team
		Ensure communication channels are clearly established for all parties involved with wall construction
		Verify responsibilities for connections to adjacent envelope systems, and review required sequencing
Anchors	**Embeds**	Verify placement of embeds as required.
		Confirm embed is level and square to wall
		Confirm sound concrete at slab edg.
		Confirm offsets within limits; obtain P. Eng. review for excessive offsets
		Review field modifications/non-standard anchors; obtain P. Eng. review for modifications
		Verify protection as specified
		Confirm adequacy of field welding, corrosion protection
		Confirm locking of nuts and bolts to prevent loosening. Confirm installation of slip materials

Framing		Confirm no framing damage from shipping
		Verify framing installed square and plumb
		Confirm positive frame interlock and gasket engagement
		Confirm sealing of joinery including continuity across wall thicknesses
		Confirm proper stack joint height, verify removal of temporary shims
		Verify splice seals in place prior to positioning subsequent frames
		Installation of slab edge and mullion tube firestopping and smoke seal
Glazing	**Glazing Details**	Verify condition of glass edges and edge sealant coverage
		Confirm overall size and thickness
		Verify proper orientation (inside/outside)
		Confirm adequate bite, edge clearance, face clearance, cap coverage
		Review drainage and venting provisions. Sample to check that installation procedures do not restrict designed drainage paths
		Confirm positioning of setting blocks and locking in position
SSG	**Glazing Details**	Verify QC procedures in plac.
		Verify positive results of adhesion testing
		Verify substrate cleaning and dust free conditions
		Confirm proper sealant application and curing
		Confirm manufacturer inspection of application
Spandrel	**General**	Verify free venting and drainage of spandrel cavities
		Review condition of fabricated panels, finish, corners, flatness
		Review backpan seals and suitable retention of insulation within backpan
		Review fixing of spandrel panels
Sealants		Verify proper position and placement of field sealants
Protection	**General**	Review procedures to protect installed curtain wall from damage until project complete
		Constantly monitor and immediately clean any concrete or tar splatter to glass
		Enforce procedures to protect glass from welding or metal cutting sparks

With respect to the work of the curtain wall tradespeople, installation problems are not likely to become significant if they are resolved early on in the installation process. Once the crews are in full production, a tremendous number of identical problems can be created over a short—time resolve problems prior to full production in the field. An investment of a relatively small amount of non-productive time at the beginning of the work can result in a far superior, problem-free installation.

8.1 OVERVIEW

The drawings and specifications are complementary documents used by the architect to describe the building project and by the contractor to develop an understanding of the architect's intent.The curtain wall interfaces with many other building elements, as such the documents must precisely define the extent of the work. Curtain wall systems clad buildings of all types and sizes. On high-rise structures the ground floor is usually different from the upper floors. The storefronts and entrances may be installed by the curtain wall contractor but usually this work is done by another contractor. As such, delineation should be made between the entrance and storefront areas and the curtain wall proper.

8.2 ANNOTATED 08920 SPECIFICATION

The following annotated specification is based on NMS08920 Canadian National Master Construction Specification for Glazed (Aluminum) Curtain Walls dated 2000-12-31. This three-part specification serves as the model for many architects and specification writers. Comments indicated in italics and denoted BPG NOTE are intended to elaborate on the master specification or to direct attention to specific issues. Careful reading and coordination of the specification with the characteristics of a specific project are required prior to the specifications direct use.

A-NMS08920++

Canadian National Master Construction Specification	Glazed [Aluminum] Curtain Walls	Section 08920 Page 1 2000-12-31

SPEC NOTE: DESCRIPTION: This Section specifies tubular aluminum exterior curtain wall system for multi-story cladding; site assembled "stick" frame or shop fabricated "unitized" subassemblies; factory prefinished, vision glass, glass or insulated metal panel infill, column covers, louvres and glazing.With moderate editing, this section could be utilized for bronze or stainless steel systems or could incorporate granite, marble or stone panels. Air barriers, vapour retarders, intake or exhaust louvres, each integral with the curtain wall system, should be included in this section.

BPG NOTE: Curtain wall sections are not necessarily tubular. It may be prudent to specify unitized systems at the onset where the project demands, such as where four-sided structural glazing is used or where specific aspects of the project warrant a unitized system. Where unitized systems are specified infill such as glass units or stone panels are specified in this section and referenced in others. Bronze (08940), Stainless Steel (08930) and Structural Glass Curtain Walls (08970) are *specialty systems that should not be incorporated within this section. *Marble is generally not a good material choice for exterior curtain wall application.*

SPEC NOTE: ENVIRONMENTAL: This section specifies environmentally responsible material choices, including recycling and reuse options, and generally available disposal.

BPG NOTE: Where environmentally responsible material choices are selected, special investigations should be made into durability and compatibility characteristics. Recycling of IG units is not justified on the basis of energy consumption, and is not supported in the industry.

SPEC NOTE: This section is not specifically structured for special or custom configured wall systems. Glass and glazing is referenced to Section 08800 - Glazing. Sealants are referenced to Section 07900 - Joint Sealers. Stone panels within the curtain wall system will be specified in Division 4.

BPG NOTE: Unless a unitized system is specified, glass and glazing, sealants and stone within the curtain wall should be specified generically in their respective sections but special requirements should be included in this section. Stone panels for use in curtain wall must be designed, supplied, fabricated and installed as part of this section.

PART 1 - GENERAL

BPG NOTE: Most contemporary specifications incorporate a work-included clause prior to related sections.Work included can be described in clause 1.3 System Description.

1.1 Related Sections

SPEC NOTE: Curtain wall testing can be identified in a special section or included in this one.

.1 Section [______]: Testing and thermographic scan

BPG NOTE: Testing usually implies laboratory or field physical testing for air leakage, water penetration or structural performance. Thermographic scanning is considered part of quality assurance to be conducted after project completion. As such they should not be combined in the same section.

.2 Section [______]: [stone] [Marble] [Granite] for infill panels

*BPG NOTE: Stone for use in curtain wall is cut and finished in accordance with the requirements of Section 044XX. However, requirements specific to the curtain wall application such as edge preparation, thickness, anchor type and attachment, etc. must be specified in this section. *Marble is not a good material choice for curtain wall applications.*

.3 Section [05500 - Metal Fabrications]: Metal fabricated [attachment devices] [framed openings] [structural support framing for sloped glazing]

.4 Section [07840 - Fire Stopping]: Fire safing between floor edge and curtain wall system

BPG NOTE: As important as fire stopping is the use of smoke seals at the floor edge and within the curtain wall itself.

.5 Section [07900 - Joint Sealers]: System perimeter sealant and back-up materials

.6 Section [08120 - Aluminum Doors and Frames]: Entrance doors, frames and glazed lights

.7 Section [08500 - [______] Windows]: Openings in curtain wall system

BPG NOTE: Windows to be incorporated within a curtain wall are to be designed, supplied, fabricated and installed as part of this section.

.8 Section [08800 - Glazing]

BPG NOTE: Glass to be incorporated within a curtain wall is to be designed, supplied, fabricated and installed as part of this section. Where a stick system is used the glass is normally specified in Section 08800. Where a unitized system is used, the glass is frequently specified within Section 08920 as it is preglazed in the factory.

.9 Section [09911 - Interior Painting]: Field painting of interior surface of infill panel [and [______]] surfaces

BPG NOTE: Where the interior surface of an infill panel (the backpan) is to be exposed, prepainting of the panel should be investigated to avoid the use of a separate trade.

.10 Section [______]: Window washing equipment requirements

BPG NOTE: Window washing elements incorporated within the curtain wall system (tie back pins) are to be designed, supplied, fabricated and installed as part of this section.

.11 Section [______]: Security systems

BPG NOTE: Other work that is often considered as related to the curtain wall installation includes:

Section [07191] Vapour Retarder

Section [07196] Air Barrier

Section [08470] Revolving Doors

Section [08710] Door Hardware

Other sections which may be incorporated into this section or carried as a standalone section include:

Section [ ] Curtain Wall Testing

Section [ ] Structural Silicone Glazing System

Section [ ] Curtain Wall Field Inspection

1.2 References

SPEC NOTE: Edit list of standards to include only those standards referenced in project specification

.1 Aluminum Association Designation System For Aluminum Finishes (AA)-[1997]

  .1 DAF 45 [1997], Designation System For Aluminum Finishes

.2 Architectural Aluminum Manufacturers Association (AAMA)

  .1 AAMA CW-DG-1-[96], Aluminum Curtain Wall Design Guide Manual

  .2 AAMA CW-10-[97], Curtain Wall Manual #10 Care and Handling of Architectural Aluminum >From Shop to Site

  .3 AAMA CW-11-[85], Curtain Wall Manual - Design Windloads for Buildings and Boundary Layer Wind Tunnel Testing

  .4 AAMA T1R-A1-[75], Sound Control for Aluminum Curtain Walls and Windows

  .5 AAMA 501-[94], Methods of Test for Exterior Walls

  .6 AAMA 503-[92], Voluntary Specification for Field Testing of Metal Storefronts, Curtain Wall and Sloped Glazing Systems

  .7 AAMA 606.1-[76], Specifications and Inspection Methods for Integral Colour Anodic Finishes for Architectural Aluminum

  .8 AAMA 607.1-[76], Specifications and Inspection Methods for Clear Anodic Finishes for Architectural Aluminum

  .9 AAMA 608.1-[77], Specification and Inspection Methods for Electrolytically Deposited Colour Anodic Finishes for Architectural Aluminum

  .10 AAMA 2603-[98], Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels

  .11 AAMA 2604-[98], Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels

.3 American Society for Testing and Materials (ASTM)

  .1 ASTM A 36/A 36M-[97ae1], Specification for Structural Steel

  .2 ASTM A 123M-[97ae1], Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

  .3 ASTM A 167-[99], Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

.4 ASTM B 209M-[95], Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]

.5 ASTM B 221M-[96], Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles and Tubes

.6 ASTM E 283-[91], Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen

.7 ASTM E 330-[97e1], Test Method for Structural Performance of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference

.8 ASTM E 331-[96], Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform Static Air Pressure Difference

.9 ASTM E 413-[87(1999)], Classification for Rating Sound Insulation

.10 ASTM E 1105-[96], Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls and Doors by Uniform or Cyclic Static Air Pressure Difference

.4 Canadian General Standards Board (CGSB)

.1 CAN/CGSB 1.108-[M89], Bituminous Solvent Type Paint

.2 CAN/CGSB-12.20-[M89], Structural Design of Glass for Buildings

.5 Canadian Standards Association (CSA)

.1 CSA G40.20/G40.21-[98], General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steels

.2 CAN/CSA-G164-[M92], Hot Dip Galvanizing of Irregularly Shaped Articles

.3 CAN/CSA-S136-[M95], Cold Formed Steel Structural Members

.4 CAN/CSA-S157-[M83], Strength Design in Aluminum

.5 CSA W59.2-[M1991(1998)], Welded Aluminum Construction

.6 Environmental Choice Program (ECP)

.1 ECP-45-[92], Sealants and Caulking Compounds

.2 ECP-67-[95], Recycled Water-Borne Surface Coatings

.3 ECP-76-[1998], Surface Coatings

.7 Steel Structures Painting Council (SSPC)

.1 SSPC - Paint 20 Zinc Rich Coating

.2 SSPC - Paint 25 Red Iron Oxide, Zinc Oxide, Raw Linseed Oil and Alkyd Primer (Without Lead and Chromate Pigments)

BPG NOTE: The standards listed above mandate certain minimum levels of performance. In certain cases this minimum may not be acceptable and more stringent limits require specification. This is especially true of aesthetic issues such as glass colour, flatness, spacer position, etc.

1.3 System Description

SPEC NOTE: Specify in the following paragraph statements that describe the combined result of the components used to assemble the system.

.1 Vertical glazed aluminum curtain wall system includes thermally broken tubular aluminum sections with [self supporting] [supplementary support] framing, shop fabricated, factory prefinished, vision glass, [insulated metal panel] spandrel infill, [column covers,] [and louvres]; related flashings, anchorage and attachment devices.

BPG NOTE: Most contemporary specifications incorporate a much more detailed and comprehensive description of the system and what is included in the work of this section. Items often included in the description are:

- *Firestop and smoke seal between concrete floor slab and curtain wall*
- *Design, supply, fabrication and installation of stone that is part of curtain wall*
- *Sheet metal air/vapour barrier closures and finish closures*
- *Insulation and air/vapour barrier seals between work of this section and adjacent construction*
- *Sealants for work of this section and between work of this section and adjacent construction*
- *Supply and installation of finish hardware for work of this section*
- *Prefabricated expansion joint assemblies*

SPEC NOTE: An adjacent sloped glazing system which integrates or is joined with the curtain wall system may be edited into this section so as to function together or alternately, may be prepared as a separate section. The sloped glazing system may be self-supporting or supported by structural mullion framing.

BPG NOTE: It is strongly recommended that sloped glazing always be specified in Section 08960 and never included in the curtain wall section. Sloped glazing is a specialty product and many failures have resulted from the attempted use of curtain wall sections in sloped applications. Sloped glazing is subject to unique loadings and performance requirements.

.2 Sloped glazing system includes thermally broken tubular aluminum sections with [self-supporting] [supplementary support] framing, shop fabricated, factory prefinished, vision [glass] [plastic], [insulated metal panel] infill; related flashings, anchorage and attachment devices.

.3 Assembled system to permit re-glazing of individual glass (and infill panel) units without requiring removal of structural mullion sections.

1.4 Performance Requirements

SPEC NOTE: Specify in the following paragraph statements that identify system performance requirements or function criteria only. Delete paragraphs not appropriate to project. Performance specifying permits system manufacturers the latitude to adjust or redesign proprietary systems to achieve specified requirements. Edit those statements appropriate to sloped glazing or delete same if not required.

BPG NOTE: This section is the most important section of the curtain wall specifications. The specification of performance criteria defines the level of engineering work required and the ultimate quality required of the installation. Structural performance can usually be adequately defined by calculation. Most other performance parameters require physical testing. Testing involves time and expense that is justified in the case of a new unproven design on a major building but may not be justified where a standard system is used on a smaller structure. Reference to existing test reports may be sufficient. Where testing is required refer to Chapter 5.

SPEC NOTE: Use the following paragraph as the basis for curtain wall system specifying; minimize the material and component statements so not to conflict with performance criteria. The following paragraphs represent a suggested listing of criteria. If more stringent criteria or mock-up testing is being considered, refer to AAMA and ASTM test methods and associated documents for guidance.

.1 Design and size components to withstand dead and live loads caused by pressure and suction of wind, [snow and hail for sloped glazing,] acting normal to plane of system [as calculated in accordance with NBC.] [to a design pressure of [______] kPa.] [as measured in accordance with [AAMA Series No.11][ASTM E 330].]

BPG NOTE: The above is a very simplistic statement that misses many critical loading elements and provides little guidance. Dead loads are not caused by wind loads but by the mass of the wall components. Dead loads generally act in the plane of the wall and result in bending of frame members. Maximum permissible deflection limits of support framing must be specified. Particular attention must be paid to the deflection of members supporting heavy rigid elements such as stone or concrete spandrels. Dead loads may also result in twisting of framing members depending on their method of attachment. Maximum degree of twist should be specified.

Wind loads act perpendicular to the wall may be defined in accordance with the NBC or the results of a wind tunnel study. In most cases it is advisable to specify a minimum acceptable wind load. Internal air pressure loading generated by stack effects and mechanical pressurization must be added to the design wind loads. Wind loads should also consider the effects of glass breakage on one elevation of the building in a storm event. Deflection limits due to wind load are specified in .3 below. Maximum permissible deflections are L/175 for mullions/rails and 2L/175 for cantilevered members at parapets or soffits.

Other structural loads that should be specified include loads generated by window washing operations and loads arising from ice accumulation.

.2 Design and size components to withstand seismic loads and sway displacement as calculated in accordance with NBC.

BPG NOTE: Seismic loads rarely govern a glass and metal curtain wall design but seismic and wind-induced drift can cause significant difficulties. In seismically active areas the structural engineer should provide the range of lateral movements anticipated based on the loading and the structure. Monitoring of actual seismic events indicate that code provisions may not be adequate.

SPEC NOTE: Specify in the following paragraph mullion corner, special change of wall plane conditions and other special conditions; edit accordingly.

.3 Limit mullion deflection to [flexure limit of glass] [[19]mm (3/4 inch)] [L/175] [L/200] [L/240]; with full recovery of glazing materials.

BPG NOTE: This statement applies to wind-induced deflection only. Deflection due to other causes and dead load deflection must also be specified.

BPG NOTE: Flatness criteria for panel elements must be specified especially where panels are large and highly exposed.

.4 Size glass units and glass dimensions to limits established in CAN/CGSB-12.20.

.5 Provide system to accommodate, without damage to components or deterioration of seals:

- .1 Movement within system
- .2 Movement between system and perimeter framing components
- .3 Dynamic loading and release of loads
- .4 Deflection of structural support framing
- .5 Shortening of building concrete structural columns
- .6 Creep of concrete structural members
- .7 A mid-span slab edge deflection of [______] mm

BPG NOTE: The above clause basically identifies common causes of movements. Thermal movements within the system and at the system perimeter framing are most significant. The degree of movement depends on finish colour, air temperature and solar loading. Upper and lower temperature limits of the exposed framing should be specified. These limits should incorporate solar gain and night-time clear sky radiation effects. See .11 below.

SPEC NOTE: Delete the following paragraph if glass thermal resistance is specified in Section 08800 - Glazing

BPG NOTE: The following paragraph cannot be deleted as data in Section 08800 applies only to the vision glass not the whole wall system.

.6 Thermal Resistance of:

- .1 System (excluding vision areas): RSI of [______]
- .2 Vision glass areas: RSI of [______]

BPG NOTE: Thermal resistance of curtain walls has historically been weakly specified. The above statement is frequently used to quote merely the nominal thermal resistance values for centre of panel. In reality, the realistic, overall thermal resistance is based on an area weighted average of the resistances of the framing, the edge of glass, the centre of glass, the edge of spandrel and the centre of spandrel. Actual values obtained are much lower than simplistic centre of panel calculations.

In addition to overall thermal resistance, a major concern with glass and metal walls in cold climates is condensation resistance and thermal shock to the glass. Condensation resistance should be specified in terms of a quantifiable amount of condensation/no condensation for a given set of exterior temperature, wind, interior temperature and interior relative humidity. In order to properly design the curtain wall for thermal loading, the summer and winter design temperatures must be provided along with the interior design relative humidity.

Extreme temperature gradients between the frame and the glass can lead to glass breakage. Maximum limits are to be obtained from the glass suppliers.

SPEC NOTE: Local regulatory agencies may dictate sound attenuation criteria.

.7 Sound attenuation through wall system (exterior to interior): STC [45], measured in accordance with [AAMA T1R - A1] [ASTM E 413]

BPG NOTE: If a building is located near an airport, train station, heavily traveled highway or some other major noise generator, special requirements for performance at different frequencies than the STC ratings measure may be required. The special requirements would be determined by making sound measurements at the building site.

SPEC NOTE: Air infiltration in both the AAMA 501 and ASTM E 283 standards are measured in m/s/min in lieu of the preferred designation of l/s/m. Refer to CSC TEK.AID 07195 - Air Barriers for discussion on air infiltration.

.8 Limit air infiltration through assembly to [0.0003] $m^3/s/m^2$ (.44 U.S.gal/min/sq. ft.)of wall area, measured at a reference differential pressure across assembly of [75] Pa as measured in accordance with [AAMA 501] [ASTM E 283].

BPG NOTE: The above statement represents an air leakage rate indicative of late 1960s curtain wall construction. Most contemporary curtain walls can readily achieve air leakage rates of less than 0.0001$m^3/s/m^2$ (.15 U.S.gal/min/sq. ft.) at pressure differences greater than 75 Pa. Air infiltration and exfiltration rates should be specified to reflect industry normals and pressure differences to reflect actual building pressures (see Chapter 5).

.9 Vapour seal with interior atmospheric pressure of 25mm sp, 22C, 40 per cent RH: No failure

.10 Water leakage: none, when measured in accordance with [AAMA 501] [ASTM E 331] [ASTM E 1105]

BPG NOTE: Water penetration resistance is measured by performance under test conditions. The above sentence references only the test procedure but provides none of the critical parameters. The most critical parameters are the definition of no water leakage and the test pressure. The test procedures usually accept some water penetration in their definition of no water leakage. This should be clarified in the specification. The test pressure should reflect local weather conditions at the project, wind tunnel data and the consequence of water entry. Note that standard tests do not evaluate rainscreen performance. If pressure-equalization performance requirements are specified elsewhere in this section, it is imperative to properly specify additional tests that will specifically assess these characteristics.

SPEC NOTE: Edit the following paragraph to specify differing expansion and contraction coefficient for dark versus light coloured surfaces.

.11 System to provide for expansion and contraction within system components caused by a cycling temperature range of [95]˚C [140˚F] over a [12] hour period without causing detrimental affect to system components

BPG NOTE: While not the intent of this clause, facing panels should remain flat under thermal loading of the wall.

.12 Drain water entering joints, condensation occurring in glazing channels, or migrating moisture occurring within system, to the exterior by a weep drainage network

BPG NOTE: It is not clear in the above statement but all the water being drained is outboard of the air barrier plane in the system. There must never be drainage of internal condensation (that is, condensation that might form on interior surfaces of the wall to the exterior as this would mean holes in the air barrier system).

.13 Maintain continuous air barrier and vapour retarder throughout assembly, primarily in line with [inside] pane of glass and heel bead of glazing compound. [Position thermal insulation on exterior surface of air barrier and vapour retarder.]

BPG NOTE: The location of the air barrier plane mentioned above applies only at the vision glass area. In an insulated spandrel the air barrier plane moves inboard to the plane of the metal backpan.

.14 Ensure no vibration harmonics, wind whistles, noises caused by thermal movement, thermal movement transmitted to other building elements, loosening, weakening, or fracturing of attachments or components of system occur

.15 Reinforce curtain wall system to accommodate window washing guide rails. [Provide anchors sufficiently rigid to resist loads caused by equipment platform, without damage to wall system]

BPG NOTE: Conspicuous by its absence is a reference to rainscreen design. The above test procedures can all be met with a face sealed curtain wall system. The reference to water drainage does not imply a rainscreen system. Given the acceptance of rainscreen design in the curtain wall, industry specifications should mandate its use for controlling water penetration. In addition, insurers of architects may not provide coverage on projects with barrier or face sealed walls.

Rainscreen design, when it is specified, is usually done through a reference to NRC definitions. Unfortunately NRC references are not definitive, do not necessarily require pressure-equalized detailing and are constantly evolving. Without being prescriptive, specifications should mandate the use of compartmentalization, cavity stiffness, vent sizes, and specialized test procedures to ensure pressure-equalized rainscreen designs are developed.

BPG NOTE: Where operable vents are incorporated into the curtain wall system they must be uniquely specified. There is some controversy with respect to the form of the performance specification for an operable vent. In some cases the vent is specified as a window installed in an opening in accordance with CSA-A440. In other cases the operable vent is subject to the same test criteria as the wall in general. Given the increased propensity for water penetration at operable vent, it is prudent to demand performance at least equal to that required of the wall in general.

1.5 Product Data

.1 Submit product data in accordance with Section [01330 - Submittal Procedures]

.2 Provide component dimensions, describe components within assembly, anchorage and fasteners, glass and infill, internal drainage details and [water flow diagrams]

1.6 Shop Drawings

.1 Submit shop drawings in accordance with Section [01330 - Submittal Procedures]

.2 Indicate system dimensions, framed opening requirements and tolerances, adjacent construction, anticipated deflection under load, affected related work, weep drainage network, expansion and contraction joint location and details, and field welding required

BPG NOTE: Shop drawings should bear the stamp of a professional engineer registered in the area the wall is to be installed, and trained and experienced in the design of structures and curtain wall systems.

BPG NOTE: Shop drawings shall show in either full scale or half scale details of the curtain wall, including sections, assemblies, materials, finishes, methods of joining, methods of anchoring, types of sealants, gaskets, insulation, infill, thermal breaks, provision for expansion and contraction, drainage, pressure equalization compartments and all adjacent construction.

1.7 Samples

.1 Submit samples in accordance with Section [01330 - Submittal Procedures]

SPEC NOTE: Use the following paragraph for submission of physical samples for selection of finish, colour, and texture

.2 Submit [two] samples [______] x [______] mm in size illustrating prefinished aluminum surface, specified glass [units], insulated infill panels, glazing materials illustrating edge and corner

BPG NOTE: Finish samples are often submitted on business card size coupons of metal which are practically useless for an owner/architect to select a colour. Finish samples should be submitted on 300 x 300 mm (1 ft. x 1 ft.) size sheets. All samples must be labeled, and in the case of samples for colour selection, should represent the range of colours anticipated.

1.8 Design Data

.1 Submit design data in accordance with Section [01330 - Submittal Procedures]

.2 Provide framing member structural and physical characteristics, [calculations,] dimensional limitations, special installation requirements

BPG NOTE: Calculations should be prepared by a professional engineer registered in the area the wall is to be installed, and trained and experienced in the design of structures and curtain wall systems. Calculations should be prepared in accordance with Chapter 5.

BPG NOTE: Calculations should include elements beyond the aluminum framing such as the glass, metal panels, inserts, anchors and structural silicone sealant.

1.9 Test Reports

.1 Submit test reports in accordance with Section [01330 - Submittal Procedures]

SPEC NOTE: Specify the following paragraph to permit submission of results of pre-tested existing curtain wall designs

.2 Submit substantiating engineering data, test results of previous tests [by independent laboratory] which purport to meet performance criteria and other supportive data

BPG NOTE: In addition to test reports on the overall performance of the curtain wall system test reports should also be solicited from the manufacturer of the major component parts such as insulating glass or insert vents.

BPG NOTE: If the project is to be structurally glazed, test reports on adhesion to glass and metal, compatibility with adjacent materials and sealant strength must be submitted for the products to be used.

1.10 Regulatory Requirements

SPEC NOTE: Only include the following paragraph when required by applicable code criteria.

.1 Conform to applicable code for [acoustic attenuation,] [sound transmission,] [and] [______] requirements

1.11 Mock-ups

SPEC NOTE: Use the following paragraph for assessing full sized erected assemblies for review of construction, coordination of work of several sections, testing or observation of operation. A mock-up may also be used for assessing field-applied finishes.

.1 Construct mock-ups in accordance with Section [01450 - Quality Control]

.2 Provide [______] x [______] mm mock-up including intermediate mullion, [corner mullion,] [sill muntin,] [column cover,] vision glass light, and [insulated] infill [panel] [glass]. Assemble to illustrate component assembly including glazing materials, weep drainage system, attachments, anchors and perimeter sealant

BPG NOTE: The mock-up area should be blocked out on the elevation drawings and the purpose of the mock-up should be clearly defined.

SPEC NOTE: Specify the following paragraph for sloped glazed systems.

.3 Mock-up to include sloped glazed system [and junction with vertical curtain wall and other vertical work] mullions, muntins, [structural member covers,] vision glass light, and [insulated] [panel] [glass]. Assemble to illustrate component assembly including glazing materials, weep drainage system, attachments, anchors, and perimeter sealant

BPG NOTE: Sloped glazing should not be specified in this section.

.4 Locate [where directed]

.5 Allow [24] hours for inspection of mock-up by [engineer] [consultant] before proceeding with work

.6 When accepted, mock-up will demonstrate minimum standard for this work. Mock-up may [not] remain as part of finished work

BPG NOTE: Refer to Chapter 5 for guidance on performance testing.

1.12 Pre-installation Meeting

.1 Convene [one] week before starting work of this section

BPG NOTE: Pre-installation meetings are an excellent and beneficial exercise, frequently resulting in the avoidance of widespread problems that would otherwise result from a simple lack of understanding. The value of such meetings increases with the number of trades people attending the meeting.

1.13 Delivery, Storage and Handling

.1 Deliver, store, handle and protect materials in accordance with Section [01610 - Basic Product Requirements]

.2 Handle work of this section in accordance with AAMA CW-10

.3 Protect prefinished aluminum surfaces with [wrapping] [strippable coating]. Do not use adhesive papers or sprayed coatings which bond when exposed to sunlight or weather.

1.14 Environmental Requirements

SPEC NOTE: Edit the following two paragraphs based on sealant type being specified; the higher performance sealants may be successfully applied at lower temperatures.

.1 Do not install sealants when ambient [and surface] temperature is less than [5]˚C [40˚F]

.2 Maintain this minimum temperature during and after installation of sealants

1.15 Sequencing

SPEC NOTE: Include in the following paragraph, firestopping and air barrier and vapour retarder option statements if that work is specified in another section

.1 Coordinate work of this section with installation of [firestopping,] [air barrier placement,] [vapour retarder placement,] [flashing placement,] [installing ductwork to rear of louvres,] [and] [______] components or materials.

1.16 Warranty

SPEC NOTE: Use the following paragraph for federal government projects.

.1 For the work of this section [08920 - Glazed [Aluminum] Curtain Wall], the 12-month warranty period prescribed in subsection GC 32.1 of General Conditions “C” is extended to [24] [60] months.

BPG NOTE: If warranty requirements for glazing units are included here, it is possible to obtain warranty coverage well in excess of 60 months.

SPEC NOTE: Use the following paragraph for private sector projects

.2 Contractor hereby warrants that Glazed [Aluminum] Curtain Wall will stay in place and remain leakproof including coverage for complete system failure in accordance with GC 24, but for [24] [60] months.

BPG NOTE: Unless listed elsewhere, warranties should include aspects of performance other than structural stability and water penetration. Warranties for specific elements may be transferred to the owner (insulating glass units, sealant).

1.17 Extra Materials

SPEC NOTE: Use the following paragraph to specify extra glass units the owner may wish to inventory for future use; edit this article after consultation with the owner.

.1 Provide extra materials of glass units in accordance with Section [01780 - Closeout Submittals].

.2 Provide [______] extra sealed glass units of [each size] required.

.3 Provide [______] extra insulated infill panels of [each size] required.

.4 Provide protected and packaged in wood crates suitable for storage. Clearly identify each crate.

.5 Deliver to [engineer] [consultant], upon completion of the work of this section.

.6 Store where directed by [engineer] [consultant].

1.18 Waste Management and Disposal

SPEC NOTE: ENVIRONMENTAL: The disposal of packing waste into landfill site demonstrates an inefficient use of natural resources and consumes valuable landfill space.

.1 Remove from site and dispose of all packaging materials at appropriate recycling facilities.

.2 Dispose of all [corrugated cardboard] [polystyrene] [plastic] packaging material in appropriate on-site bin for recycling in accordance with site waste management program.

1.19 Tolerances

BPG NOTE: Tolerances and clearances are critical to a successful curtain wall installation. As such a specific clause should be included in Part 1. This clause must outline fabrication and erection tolerances relative to the building grid and each individual assembly. Limits must be imposed on vertical position, horizontal position, deviation from plumb, racking, offset, expansion/stack joint width. Tolerance shall not be cumulative.

1.20 Quality Assurance

BPG NOTE: The quality control measures to be implemented by the contractor throughout the design, testing, fabrication, assembly and installation should be documented and submitted. This is especially important in structural glazing applications. The quality control manual is used by the design team including third party inspectors and testing agencies to provide a quality assurance programme.

PART 2 - PRODUCTS

SPEC NOTE: Edit the following descriptive specifications to identify project requirements.

2.1 Materials

.1 Extruded aluminum: [ASTM B 221M]

BPG NOTE: 6063-T5, 6063-T54, and 6063-T6 are the most common alloys for extrusions. 6061-T6 is common of heavier components such as anchors plates and angles.

.2 Sheet aluminum: [ASTM B 209M]

.3 Sheet steel: [CAN/CSA-S136M] [ASTM A 446/A 446M]; galvanized in accordance with [______]

.4 Steel sections: [CAN/CSA-G40.21M] [ASTM A 36/A 36M] [ASTM A 167 Type 304 stainless]; shaped to suit mullion sections

BPG NOTE: If steel sections to be used as reinforcing are to be finished/galvanized this must be specified.

.5 Fasteners: [[stainless][galvanized]steel] [aluminum]

BPG NOTE: Various types and grades of steel are used for fasteners and their use should be carefully controlled. Fasteners that are outboard of the air barrier or might be exposed to moisture require a high degree of corrosion protection (stainless). Fasteners on the inboard side of the air barrier plane not exposed to moisture need not be stainless but should be treated. Aluminum fasteners are rarely used. In addition to the fastener type, nuts, washers, locking nuts, etc. must also be specified.

SPEC NOTE: ENVIRONMENTAL: Every year, thousands of tonnes of volatile organic compounds (VOCs) are released into the atmosphere. These VOCs react with nitrogen oxides in the presence of sunlight to produce ground level ozone and photochemical smog. The specification of low-VOC surface coatings will improve indoor air quality and reduce environmental impacts. The Environmental Choice Program guidelines ECP-45, ECP-67, and ECP-76 provide acceptable standards.

.6 Bituminous paint: CAN/CGSB 1.108, Type [1] [2], without thinner

SPEC NOTE: Insert appropriate text from Section 08800 - Glazing.

.7 Vertical glass units:

- .1 Glass in exterior lights: Type [______]
- .2 Glass in [entrance] lights: Type [______]
- .3 Glass Infill Panels: Type [______]

BPG NOTE: Where the wall is a unitized system the glass should be completely specified in this section.

SPEC NOTE: Insert appropriate text from Section 07900 - Joint Sealers

SPEC NOTE: ENVIRONMENTAL: The application of caulkings releases volatile organic compounds (VOCs) into the atmosphere. VOCs contribute to numerous environmental problems including the degradation of indoor air quality, the formation of ground level ozone and photochemical smog. The specification of caulkings and sealants that have a low-VOC content and reduced toxicity will help to protect the environment and reduce possible adverse health effects. The specification of products that are certified to meet the specification of the Environmental Choice Program ECP-45 will provide reduced environmental impacts.

.8 Sealant:

- .1 Perimeter sealant: Type [______]
- .2 Sealant used within system (not used for Glazing): Type [______]
- .3 Acceptable material: [EPC-45]

BPG NOTE: Numerous common materials are missing from the above listing. The list below should be added/deleted as the project demands.
Thermal breaks
Gasket

Waterproofing/air barrier membrane
Shims, spacers, tapes, glazing, gaskets
Setting blocks, sealants
Spandrel glass
Spandrel and cavity insulation, stick pins, adhesives
Joint backers
Structural sealant

2.2 Components

SPEC NOTE: Use the following paragraph to specify the nominal dimensions of the primary framing members. If performance specifying, ensure no conflict exists.

.1 Mullion profile: [______] x [______] mm nominal dimension for vertical members, [______] x [______] mm nominal dimension for horizontal members; [thermally broken with interior tubular section insulated from exterior pressure plate;] matching stops and pressure plate of sufficient size and strength to provide adequate bite on glass [and infill panels]; drainage holes, deflector plates and internal flashings to accommodate internal weep drainage system; internal mullion baffles to eliminate “stack effect” air movement within internal spaces.

BPG NOTE: Mullion size should be independently verified and coordinated with the specified wind load. Internal mullion seals, not baffles should be provided to reduce stack effect and smoke flow.

.2 Sloped glazing mullion profile: [______] x [______] mm nominal dimension for members parallel with slope, [______] x [______] mm nominal dimension for members across the slope; [thermally broken with interior tubular section insulated from exterior pressure plate;] matching sloped stops and pressure plate of sufficient size and strength to provide bite on glass [and infill panels]; drainage holes, deflector plates and internal flashings to accommodate internal weep drainage system; internal baffles to eliminate “stack effect” air movement within internal spaces.

BPG NOTE: Sloped glazing does not have mullions and rails but rafters and purlins. As indicated before sloped glazing should not be specified in this section.

.3 Reinforced mullion: [______] x [______] mm profile of [extruded] [sheet] aluminum cladding with internal reinforcement of shaped steel structural section

SPEC NOTE: Use the following paragraph for wall systems with insulated infill panels.

.4 Infill panel: internally reinforced, glazing edge [sealed] [unsealed] permitting internal air movement to glazing space, outside air barrier line [,structurally sufficient to support wall fin radiation saddles]:

BPG NOTE: Interior accessories such as wall fin radiation saddles should never be attached to the sheet metal backpan. If necessary they can be attached to the mullions.

.1 Outer face: [______] mm thick [aluminum]

.2 Core: [glass fibre] [rigid polystyrene] [rigid polyurethane] insulation core with RSI of [______]

.3 Inner face: [______] mm thick [aluminum]

BPG NOTE: Foam cored aluminum skinned panels as described above are rarely used as curtain wall infill. This is partly due to the combustible nature of the panels. A metal faced spandrel panel is more likely to consist of a thicker metal face panel, an air space, fibrous insulation and a sheet metal backpan. Aluminum composite panels are used as a replacement for the thicker aluminum face panel but only where fire regulations allow.

SPEC NOTE: Use the following paragraph for wall systems with stone infill panels.

.5 Infill panel: [stone] [granite] [marble] specified in Section [______]; [______] mm average thickness panel, [______] mm thick at glazing edge

BPG NOTE: The most common stone infill is granite. Marble is rarely used and not recommended. 32-34 mm thick granite panels are either retained in the opening much like a piece of glass (capped on four sides) or supported on independent anchors fixed to the mullions.

SPEC NOTE: Specify in the following paragraph stiffening column covers at grade where public abuse is likely

.6 Column [and sloped beam] covers: [______] mm thick [aluminum], full contact pressure bonded to [______], ensuring flat surface, [______] finish [as selected.] [to match curtain wall mullion sections.]

.7 Flashings: [______] mm thick [aluminum,] [stainless steel,] [galvanized steel,] [______] finish [as selected,] [to match curtain wall mullion sections where exposed,] secured with [concealed] fastening method

.8 Louvres: [extruded aluminum] [______] blade and frame, [100] [______] mm deep, [45] [______]-degree slope with [weatherstop] [______] dam; [aluminum] [sheet steel] blank-off panel, [black] [______] colour, at rear for field cutting and sizing to suit mechanical duct attachment, [______] finish [as selected] [same as curtain wall mullion sections]. Fabricate rigid to eliminate blade flutter

.9 Louvre screening: provide [bird] [______] screen of [______] size at exhaust and [insect] [______] screen of [______] size at intake air louvre inside surface

SPEC NOTE: Integral operable windows can be specified in another section or can be described in detail in this section; operable sash should not be used in sloped glazing. Edit the following paragraph accordingly.

.10 Operable sash: specified in Section [08500 - [______] Windows]

BPG NOTE: As indicated above, an operable sash within a curtain wall system should be specified in this section to performance parameters at least the same as the wall in general.

SPEC NOTE: Integral air barriers and vapour retarders can be specified in another section or can be described in detail in this section. Edit the following paragraph accordingly.

.11 Vapour retarder: specified in Section [07160 - Sheet Vapour Barriers]

.12 Air barrier: specified in Section [07271 - Air Barrier] [07272 - Air Barriers]

BPG NOTE: The integral air and vapour barrier in a contemporary curtain wall is the sheet metal backpan. This component is always specified in this section.

2.3 Fabrication

.1 Fabricate system components with minimum clearances and shim spacing around perimeter of assembly, yet enabling installation and dynamic movement of perimeter seal

.2 Accurately fit and secure joints and corners. Make joints flush, hairline, [and weatherproof]

.3 Prepare components to receive anchor devices. Install anchors

.4 Arrange fasteners and attachments to ensure concealment from view

.5 Prepare system components to receive [exterior doors,] [revolving doors,] [and] [hardware] specified in section [______]

.6 Reinforce interior horizontal head rail to receive [drapery] track brackets and attachments

.7 Reinforce framing members for external imposed loads

.8 Visible manufacturer’s identification labels not permitted

2.4 Fabrication: Infill Panels

SPEC NOTE: Use only where metal clad insulated infill panels are required in the system.

.1 Fabricate infill panels with metal covered edge seals around perimeter of panel assembly, enabling installation and minor movement of perimeter seal

.2 Reinforce interior surface of exterior panel sheet from deflection caused by wind and suction loads

BPG NOTE: Special attention must be paid to reinforcing schemes as oil canning and read through of fasteners often results.

.3 Accurately fit and secure joints and corners. Make joints flush, hairline, and weatherproof

.4 Place insulation within panel, adhered to exterior face of interior panel sheet over entire area of sheet with impale fasteners

.5 Ventilate and pressure equalize the air space outside the exterior surface of the insulation, to the exterior

.6 Arrange fasteners and attachments to ensure concealment from view

.7 [Reinforce panel to receive [convector cabinet]brackets and attachments.]

2.5 Finishes

SPEC NOTE: The wide variety of finishes for aluminum preclude listing all the available options; the following paragraphs offer the commonly specified finishes. Specify the finish colour whenever possible, as the cost varies considerably between colours. One issue that is not specified in this section, nor is it easy to address, is finish colour variations.

SPEC NOTE: Reference to aluminum finishes can be AA or AAMA (which have very similar designations) or by generic or proprietary description. Before specifying either the M series (mechanical) or C series (chemical) pretreatment to aluminum, confirm the treatment required in conjunction with the final finish. These pretreatment processes can also be utilized in conjunction with organic coatings or other finishes.

SPEC NOTE: The AAMA A40 series finishes are anodized 127 gm/m2 (0.7 mils) thick or greater (termed Architectural Class I); A41 is clear, A42 has integral colour, A43 has impregnated colour, A44 is anodized in two steps. The A20 and A30 series coatings are thinner. Resinous, vitreous and electroplated coatings are also available. Only include the following paragraph when project conditions warrant or a custom finish is specified.

.1 Finish coatings: conform to [AAMA 2603.8.] [AAMA 2605.2.] [AAMA 606.1.] [AAMA 607.1.] [AAMA 608.1.] [AA designations.]

.2 Exterior exposed aluminum surfaces: [AAMA] [AA] [A41] [A42] [A43] [A44] anodized to [215-R1], [______] mm thickness, prepared with a [mechanical M [______]] [chemical C [______]] pre-treatment, anodized to [clear] [______] colour.

.3 Exterior exposed aluminum surfaces: prepare surface with [AAMA] [AA] [mechanical M [______]] [chemical C [______]] pretreatment, [[fluoropolymer][siliconized acrylic][polyester]coating to [______] colour [as selected]].

SPEC NOTE: Select either of the next two paragraphs.

.4 Exterior exposed infill panel surfaces: [AAMA] [AA] [A41] [A42] [A43] [A44] anodized to [215-R1], [______] mm thickness, prepared with a [mechanical M [______]] [chemical C [______]] pretreatment, anodized to [clear] [______] colour.

.5 Exterior exposed infill panel surfaces: Prepare surface with [AAMA] [AA] [mechanical M [______]] [chemical C [______]] pretreatment, [[fluoropolymer][siliconized acrylic][polyester]coating to [______] colour [as selected]].

SPEC NOTE: Select either of the next two paragraphs.

.6 Exterior exposed aluminum column covers: [AAMA] [AA] [A41] [A42] [A43] [A44] anodized to [215-R1], [______] mm thickness, prepared with a [mechanical M [______]] [chemical C [______]] pretreatment, anodized to [______] colour.

.7 Exterior exposed aluminum column covers: prepare surface with [AAMA] [AA] [mechanical M [______]] [chemical C [______]] pretreatment, [[fluoropolymer][siliconized acrylic][polyester]coating to [______] colour [as selected]].

SPEC NOTE: Select either of the next two paragraphs.

.8 Interior exposed aluminum surfaces: [AAMA] [AA] [A41] [A42] [A43] [A44] anodized to [215-R1], [______] mm thickness, prepared with a [mechanical M [______]] [chemical C [______]] pretreatment, anodized to [clear] [______] colour.

.9 Interior exposed aluminum surfaces: prepare surface with [AAMA] [AA] [mechanical M [______]] [chemical C [______]] pretreatment, [[fluoropolymer][siliconized acrylic][polyester]coating to [______] colour [as selected]].

.10 Interior surface of infill panel surfaces: [field painted in accordance with Section [09911 - Interior Painting]] [anodized to [clear][______] colour] [Enamelled to [______] colour [as selected]].

SPEC NOTE: Select either of the next two paragraphs.

.11 Interior exposed aluminum column [and sloped beam] covers: [AAMA] [AA] [A41] [A42] [A43] [A44] anodized to [215-R1], [______] mm thickness, prepared with a [mechanical M [______]] [chemical C [______]] pretreatment, anodized to [clear] [______] colour.

.12 Interior exposed aluminum column [and sloped beam] covers: prepare surface with [AAMA] [AA] [mechanical M [______]] [chemical C [______]] pretreatment, [[fluoropolymer][siliconized acrylic][polyester]coating to [______] colour [as selected]].

SPEC NOTE: Select one of the next four paragraphs for the primer type required. Select a primer compatible with finish material. For a high performance finish, careful selection of the primer is required.

.13 Shop and touch-up primer for steel components: [SSPC 25 Paint red oxide.] [______]

.14 Touch-up primer for galvanized steel surfaces: [SSPC 20 Paint zinc rich.]

.15 Concealed steel items: [galvanized in accordance with [CSA G164M][ASTM A 123]to [600]gm/m^2 (33 mils)]. [Primed with iron oxide paint.]

.16 Apply [one coat] [[______] coats] of bituminous paint to concealed aluminum [and steel] surfaces in contact with cementitious or dissimilar materials.

2.6 Source Quality Control

SPEC NOTE: Identify in the following paragraph reference documents that are intended for vertical glazed systems; modify criteria or delete statements for sloped glazed systems.

.1 Perform work in accordance with [AAMA GSM-1] [AAMA CW-I-9]. Maintain [one copy] [[______] copies] on site.

.2 Manufacturer qualifications: company specializing in manufacturing the products specified in this section with minimum [three] years [documented] experience.

.3 Installer qualifications: company specializing in performing the work of this section [with minimum [______] years [documented]experience] [approved by manufacturer].

.4 Design structural support framing components [to CAN/CSA-S157] under direct supervision of a professional structural engineer experienced in design of this work and licensed [at the place where the project is located.] [in the province of [______].]

BPG NOTE: CSA-S157 applies to the design of aluminum elements. The structural support framing should be designed to CSA S16:

.5 Perform welding work in accordance with CSA W59.2.

PART 3 - EXECUTION

3.1 Examination

.1 Verify dimensions, tolerances and method of attachment with other work.

.2 Verify wall openings and adjoining air barrier and vapour retarder materials are ready to receive work of this section.

3.2 Installation

.1 Install curtain wall [and sloped glazing] system in accordance with manufacturer’s instructions.

BPG NOTE: Delete reference to sloped glazing.

.2 Attach to structure to permit sufficient adjustment to accommodate construction tolerances and other irregularities.

.3 Provide alignment attachments and shims to permanently fasten system to building structure. Clean weld surfaces; apply protective primer to field welds and adjacent surfaces.

.4 Align assembly plumb and level, free of warp or twist. Maintain assembly dimensional tolerances [and align with adjacent work].

.5 Provide thermal isolation where components penetrate or disrupt building insulation.

.6 Install [sill] flashings.

.7 [Install [eave edge]flashings at sloped glazing system.]

.8 Coordinate installation of fire stop insulation, specified in Section [______], at each floor slab edge [and intersection with vertical construction where indicated].

.9 Coordinate attachment and seal of perimeter air barrier and vapour retarder materials.

.10 Pack fibrous insulation in shim spaces at perimeter of assembly to maintain continuity of thermal barrier.

BPG NOTE: Insulation at perimeter of assembly does not need to be, and often should not be, fibrous.

.11 Install operating sash in accordance with Section [08800 - Glazing], to [glazing method required to achieve performance criteria] [exterior [wet/dry]method of glazing].

.12 [Install louvres, associated flashings, blank-off plates and screening. Fit blank-off plates tight to ductwork.]

SPEC NOTE: The glazing method chosen for sloped glazing is critical to the success of the system. Placing sealant on the up-slope side of the pressure plate cap is optional, depending on the proprietary glazing system used and the design of the cap and pressure plate.

BPG NOTE: Above SPEC NOTE does not apply as sloped glazing is specified in another section.

.13 Install glass [and infill panels] in accordance with Section [08800 - Glazing], to [glazing method required to achieve performance criteria] [exterior [wet/dry][______] method of glazing]. [Place sealant on the up-slope side of the pressure plate cover caps; finish the surface with a slope to encourage drainage over the cap.]

SPEC NOTE: This paragraph specifies installation of perimeter sealant materials as part of this section. Edit accordingly or delete and retain in Section 07900 - Joint Sealers.

.14 Install perimeter sealant [to method required to achieve performance criteria]. [Type [______], backing materials, and installation criteria in accordance with Section [07900 - Joint Sealers].]

3.3 Site Tolerances

.1 Maximum variation from plumb: [1.5] mm/m (0.2 feet) non-cumulative or [12] mm/30 m (1/2 inch / 100 feet), whichever is less.

.2 Maximum misalignment of two adjoining members abutting in plane: [0.8] mm (1/32 inch).

.3 Maximum sealant space between curtain wall and adjacent construction: [13] mm (1/2 inch).

BPG NOTE: Tolerances and clearances are impacted by fabrication, assembly and site installation. As such it is recommended that tolerances be discussed in Part 1.

3.4 Field Quality Control

SPEC NOTE: Only include the following paragraph if special field inspection services will be involved.

.1 Inspection will monitor quality of installation and glazing.

.2 Test to [AAMA 501,] [ASTM E 1105,] [and] [AAMA 501].

BPG NOTE: The owner may engage independent third party inspection and testing agencies to carry out inspection and testing of the work. The contractor is to cooperate with this agency in providing access at reasonable times. The cost of such inspection will be paid for by the owner. Costs due to reinspection due to deficient work will be backcharged to the contractor.

BPG NOTE: It is not sufficient to list applicable test procedures without listing the test parameters, pass/fail criteria and listing the consequences of failure. It should be stated that where testing reveals weaknesses in the installation, testing will be repeated until repairs/adjustments to the curtain wall provide adequate performance. All similar locations are to be repaired as per the remediated area. All costs associated with this remedial work are to be borne by the contractor along with charges from the testing agency for retesting.

SPEC NOTE: Only include the following paragraph if a thermoscan analysis will be required.

.3 [Evaluate installed system by thermo-photographic scan.]

BPG NOTE: Thermographic scans are also conducted by independent third party agencies. Scans are qualitative and while identifying thermal anomalies are not definitive in defining deficient work. The results of a scan require careful review by professionals familiar with both thermographic scanning and curtain wall systems.

Also, thermographic scans of entire buildings are only of value if the pressure differential across the exterior wall can be controlled. For new construction projects, this usually requires HVAC commissioning to be complete, by which time it is too late to use thermographic scans to prevent problems. As a proactive quality assurance tool, consider specifying a thermographic scan of a much smaller portion of wall area completed at the beginning of construction. An interior air chamber must be specified to control pressures in the test wall area.

3.5 Manufacturer's Field Services

SPEC NOTE: The following paragraph is included to assist in field quality control of work being installed. The legal affect of this type of article is questionable and will not relieve the design professional of legal responsibility for the work described in this section.

.1 [Curtain wall] [Glass] product manufacturers to provide field surveillance of the installation of their products.

.2 Monitor and report installation procedures, unacceptable conditions and [______].

BPG NOTE: Notwithstanding the lack of legal strength, it is prudent to involve the material/component experts in the review of the curtain wall. These would especially include the glass unit suppliers and the sealant suppliers. Written reports should be requested from each supplier.

3.6 Adjusting

SPEC NOTE: Only include the following paragraph if operable sash is specified.

.1 Adjust operating sash for smooth operation.

BPG NOTE: While it may be obvious, adjustments should be made while maintaining the specified performance criteria. Often adjustments made to ease operation reduce air and watertightness.

3.7 Cleaning

.1 Remove protective material from prefinished aluminum surfaces.

.2 Wash down surfaces with a solution of mild detergent in warm water, applied with soft, clean wiping cloths. Take care to remove dirt from corners. Wipe surfaces clean.

.3 Remove excess sealant by moderate use of mineral spirits or other solvent acceptable to sealant manufacturer.

BPG NOTE: Final cleaning is frequently negotiated out of the curtain wall contractor's contract. Independent cleaners must be made aware of any special precautions that are required in cleaning the wall. Special attention must be paid to sealants that might still be curing.

3.8 Protection

.1 Protect finished work from damage.

BPG NOTE: Who protects the finished work is often a controversial question. The curtain wall contractor may be off-site for some time before the building is finished and usually feels that once he leaves, the wall belongs to the general contractor or the owner. Depending on the work to follow, substantial completion of the wall special protection measures must be specified.

BPG NOTE: Protection in the course of the work is also required particularly when welding or masonry work is carried out nearby. Weld splatter often causes irreparable damage to glass and finishes.

Chapter 9

MAINTENANCE AND RENEWAL

9.1 OVERVIEW

Glass and metal curtain walls are composed of a limited number of materials and components, which piece together in a very specific manner to achieve a desired level of overall wall performance. Solely on the basis of durability, the materials each have a service life, at the end of which they will require renewal or replacement. The degradation of a material means that it no longer performs an intended function, and this represents the end of service life. However, with the passage of time, some materials or components used in a curtain will fail to function adequately even though there has been no significant material degradation. This condition also represents the end of service life.

The range of anticipated service life for materials and components used in a curtain wall is considerable, and can even be different for the same material used in different locations. In reality, the anticipated service life of some of the primary materials is so long, that the replacement of the material is rarely considered in any long-term asset planning (e.g. replacement of aluminum framing members). In other cases, the service life of a material or component can be sufficiently short that regular renewal or replacement is not practical, and maintenance is essential to extend service life.

This chapter outlines the maintenance that should be planned for a curtain wall to maximize the time between renewal or replacement of materials or components. It also outlines the renewal or replacement requirements that must be considered in the management of a curtain wall system.

9.2 Maintenance

Maintenance measures are aimed at extending the life of curtain wall materials or components, or at ensuring the wall system is visually acceptable.

9.2.1 Exterior Cleaning

Perhaps the most common maintenance that is regularly performed on a curtain wall is washing of the exterior of the vision units. On most commercial office buildings this washing is conducted at least twice per year. This washing is primarily focussed on maintaining a clear view through the units from within the building. However, if conducted with sufficient frequency, the exterior washing can also help prevent or reduce permanent damage to the glass due to etching.

While washing of the vision units is routine on most buildings, the similar washing of finished metal components such as snap caps, spandrel panels and trim is far less common. Obviously there is no clear view to be concerned with for these opaque wall elements. However, ignoring the deposition of atmospheric pollution on the exterior of metal components invites more rapid deterioration and staining of the finish. Ultimately, this reduces the time before the finish requires complete renewal. It is therefore advisable to include all finished metal components in regular exterior washing maintenance for a curtain wall.

9.2.2. Exterior Seals

As is discussed elsewhere, the seals exposed on the exterior face of a curtain wall can be sealant, as in the case of structural silicone glazing systems, preformed tape, or dry gasket. Although these exterior seals are not intended to completely prevent the passage of air and water, curtain wall designs are premised on the exterior seals restricting most exterior precipitation from entering the wall, by keeping the size of openings in the wall face to a minimum. When too much water passes through the exterior face of a wall, the risk of a failure within the system greatly increases. The failure might be a premature requirement to replace vision units, or the failure of seals at framing joinery seams, but inevitably the failure results in some maintenance or renewal requirement. Clearly then, it is very important to keep exterior seals in good condition.

From initial construction to first maintenance, preformed tape and dry gasket are the most common form of exterior seal on most modern curtain walls. While these products have a number of advantages over sealant, one notable disadvantage is the tendency for tapes and gaskets to shrink. Much of the initial shrinkage of gaskets results because the installer stretched the material during installation. Most gasket materials have sufficient “memory” that they will return to their unstretched length following installation. Frequently this results in significant openings in the exterior seal of a wall, commonly at the corners of the infill panels. For walls utilizing preformed tape or dry gasket as exterior seals, it is good practice to review the seals within the first few years following construction, and conduct maintenance as is required. The most cost-effective maintenance of these seals is often the simple application of sealant at the open joint.

For wall systems that originally rely on exposed exterior sealants, or for walls where cap beads have previously been applied over the exposed exterior seals, it is advisable to plan on localized maintenance repairs to the sealants on a three to five year cycle. Such maintenance work is normally conducted in conjunction with regular cleaning of the wall.

9.2.3 Drainage

The long-term performance of a curtain wall system will be greatly improved if exterior seals are maintained to limit water entry into the wall, and if drainage is maintained to permit drainage out of the wall. To fully maintain all elements of the drainage path in a curtain wall would involve the temporary removal of at least the caps and plates on horizontal rails. There is rarely justification for this degree of regular maintenance work, as it is more logical to include internal drainage repairs with other work required to renew or replace other wall components. However, water will ultimately drain from most walls through weepholes in the underside of the caps on horizontal rails. As part of routine maintenance, it is good practice to clean these holes to remove such potential blockages as insect nests or webs and accumulated airborne dirt.

9.2.4 Pressure Plate Fastening

When pressure plates are used to mechanically clamp edges of panels within frame openings, the tightening of the pressure plate fasteners compresses a number of materials and components together. These include an exterior seal, a vision unit or spandrel panel/backpan assembly, and an interior seal. It is extremely rare that the pressure plate fasteners become loose over time, leading to a maintenance requirement to tighten the fasteners. Therefore, there is normally no need to conduct maintenance work on a curtain wall solely for the purpose of re-tightening pressure plate fasteners.

When it is determined that pressure plate fasteners are loose, it is more commonly due to an original construction flaw that needs replacement for rectification.

9.3 Renewal or Replacement

Aside from elective work to address market pressures, renewal or replacement is required when curtain wall materials or components have reached the end of their service life, and maintenance can no longer be undertaken to extend that life.

9.3.1 Vision Units

In virtually all modern curtain walls, the vision units are insulating glass units fabricated with two or three lites of glass. As is described elsewhere, the lites in these units are sealed together at a fixed separation, creating an isolated space between the pieces of glass. These units can take on a constant dirty appearance, or the view through these units can become obscured, when an excessive amount of moisture enters into the isolated space, or a sufficient amount of moisture enters to cause degradation of coatings on the glass. This condition is commonly referred to as a "failed unit."

While a limited number of units will exhibit this sort of condition in a relatively short time period after installation, due to fabrication problems, most units will provide years of service before the onset of these conditions. Even though the manufacturers of these units are currently offering warranty coverage for periods up to 10 years, many people expect a service life of 20 to 30 years for insulating glass units. In fact, the industry experience is that the service life of most units will fall somewhere in the 20- to 30- year range. Although a specific service life cannot be defined, it is inevitable that the vision units in a curtain wall will require replacement, after approximately 25 years of service.

Far too often the need to replace large numbers of failed units arises quite suddenly. That is, the rate of failure of units increases very sharply once the first few units reach the end of their service life. Unfortunately, the wholesale replacement of units is rarely planned in advance, and budgets are often available to meet the replacement requirements. This results in the unattractive checkerboard phenomena where on one building face there are failed units mixed with original units as well as with different vintages of replacement units. Depending on the coatings applied to the glass, the same product can have differing visual appearance from different production runs.

The most important aspect of renewal and replacement for a curtain wall is therefore to establish a plan and budget for replacement of the vision units on a cycle of approximately 25 years.

9.3.2 Spandrel Panels

Glass panels used in the spandrel areas of a curtain wall may be either monolithic glass or IG units. IG units used as spandrel panels fail in a similar manner as vision units although they frequently have a shorter clear life. This is due to the more extreme conditions of temperature and moisture in the spandrel cavity. Monolithic spandrel glass is not subject to the same service life constraints as vision glass with respect to failure of an insulating glass unit.

Spandrel glass can be coated for colour and reflectivity, and will also typically have a film applied as a safety opacifier for the glass. Therefore, with the passage of time and exposure to moisture, high temperatures and atmospheric pollution, it is quite possible that coatings or film on the glass begin to deteriorate. The rate of deterioration will depend on the coating type. A ceramic frit is extremely durable with a life of 40 to 50 years, while metallic reflective coatings would be expected to have a shorter life. While the need to replace spandrel glass is certainly not inevitable in the same timeframe as the vision units, it is advisable to consider the type of spandrel glass and plan for its replacement in due course.

Thin stone spandrels do not have a long history of performance but should be expected to have a lifetime approaching that of the aluminum framing. Failure of metal panels is dependent on the metal type, finish and installation detail. Metal panels are subject to corrosion if improperly detailed.

9.3.3 Interior Seals

The interior seals around infill panels are sheltered from the exterior environmental effects, and normally exhibit very little deterioration. Typically, until the infill panels are removed, there is no need to renew or replace the interior seals. Of course, when vision units are replaced, as described previously, any wet interior seals are automatically replaced as part of the work. If the interior seals are dry, it would be prudent to check for, and replace, any gaskets exhibiting shrinkage. Otherwise, it is unlikely that dry gaskets will require replacement.

9.3.4 Drainage

As previously discussed, the internal drainage path in a curtain wall is deserving of attention when the temporary removal of at least the caps and plates on horizontal rails is undertaken for other reasons. Therefore, as part of a project involving glass replacement, it is advisable to re-seal all corner blocks at the bottom corners of the frame openings to receive new glass. This will take full advantage of the natural drainage compartmentalization of the wall system. However, if only a limited number of glass units are to be replaced, but accumulated dirt and debris can be seen obstructing drainage, particularly around the bottom corners of vision units, it is often more appropriate to completely remove the corner blocks than to try to clean and re-seal the drainage path.

9.3.5 Joinery Seals

Previous chapters have described how the seams between aluminum framing members are sealed to maintain watertightness. In the layout of the framing, these joinery seams between members occur at the corners of the frame openings. Unfortunately, water flow patterns on the face of a curtain wall, the designed drainage path around vision units and the most likely location for exterior seal openings due to shrinking gaskets all result in a concentration of water within the wall, and at the corners of frame openings. As a result, an adequate seal in the joinery seams is critical to the wall performance.

On occasion, it becomes necessary to access the joinery seams and conduct remedial re-sealing before any other wall components require attention.

However, regardless of other previous repair requirements, it is advisable to include a re-sealing of joinery seams in any glazing replacement project. The work involved is directly associated with the work of re-sealing, or removing, the corner blocks. To conduct this work properly does not require any significant amount of material, but does require patient removal and careful application of old and new sealant materials, respectively.

9.3.6 Backpan Corners

In some wall system designs, the backpans located inboard of the spandrel panels rely on a sealant to maintain air and watertightness at seams in, or around, the pan. As is true with the interior seals, these backpan seals are not exposed to the full external environmental effects and, therefore normally have a very long service life. Nonetheless, in conjunction with a spandrel glass replacement project, it is advisable to at least check the condition of any backpan corner seals, and replace all seals that exhibit any deterioration, or loss of adhesion.

9.3.7 Pressure Plate Fastening

Pressure plate fasteners might be found to be in one, or both, of two conditions that warrant replacement work. These two conditions are loose fasteners, or corroding fasteners.

Pressure plate fasteners that are loose rarely require a simple re-tightening as a form of maintenance. It is more likely that the fasteners are loose because of their incorrect length (and simply can't be tightened sufficiently before the fastener "bottoms out") or the thermal break material is inappropriate (either far too hard, or exhibits excessive compression set). In both cases, the correction of the loose fastener problem requires a replacement, either of the fasteners or of the thermal break material, or both.

If pressure plate fasteners are found to be corroded, it could simply be the result of an incorrect material selection for the fasteners. However, in order for the corrosion to occur, it is also quite likely that the thermal break is not adequately compressed. Therefore, the same factors governing loose fasteners will often influence corroding fasteners. When corroded fasteners are encountered, replacement work might need to include new thermal break as well as new fasteners.

9.3.8 Finished Metal Components

Although the durability of metal finishes has improved greatly, the metal components used on the exposed face of a curtain wall system will often become stained, dulled, scratched (by window cleaning operations) with time. This deterioration of the finish on snap caps, spandrel panels and trim can progress to the point that the metal components detract from the overall appearance of the wall system, and give the appearance of a tired and worn wall that has not been maintained.

Fortunately, if the finish of metal components deteriorates to this stage, the finish can be renewed. For painted finishes, there are several systems available for re-coating the metal. Some of these systems can be applied to the metal components on the wall. This offers the advantage that the costs for removal and replacement are avoided, but inevitably leaves small areas that cannot be refinished (e.g. clamped edges of a spandrel panel). Alternately, metal components can be removed from the wall on a short-term basis, and repainted in a temporary field set-up, or in a shop.

For finishes other than paint, the metal components need to be temporarily removed from the wall and renewed in a shop setting.

Renewal of the finishes of metal components of a curtain wall can rejuvenate the overall wall appearance, without incurring the relatively high cost for new metal components.

9.3.9 Snap Cap Engagement

Commonly, the reliability of the engagement between the snap caps and pressure plates on a curtain wall is reduced if the caps and plates have been removed, especially as the depth of the caps increases. Therefore, whenever a glass unit is replaced, requiring the temporary removal of snap caps and pressure plates, it is advisable to include some form of mechanical or adhesive fastening between the caps and the plates upon re-installation of these components. This is a very inexpensive way to greatly reduce potential safety hazards posed by caps that can otherwise fall from the wall due to wind or minor contact by window washing equipment.

GLOSSARY

Adhesion That property of a coating or sealant which measures its ability to stick or bond to the surface to which it is applied.

Adhesion failure Failure of a compound by pulling away from the surface with which it is in contact. (See "cohesive failure").

Adhesion peel test The separation of a bond, whereby the material is pulled away from the mating surface at a 90-degree angle or at a 180-degree angle to the plane to which it is adhered. Values are generally expressed in pounds per inch width and as to whether failure was adhesive or cohesive.

Air infiltration The amount of air leaking in and out of a building through cracks in walls, windows and doors.

Anchor Any device used to secure a building part or component to the adjoining construction or supporting member.

Annealing In the manufacturing of float glass, it is the process of controlled cooling done in a lehr to prevent residual stresses in the glass. Re-annealing is the process of removing objectionable stresses in glass by re-heating to a suitable temperature followed by controlled cooling.

Anodized finish An aluminum surface finish resulting from anodizing. Coatings may be clear, integral colour or electrolytically deposited colour.

Anodize To provide an aluminum oxide coating by electrolytic action.

Anti-walk blocks Elastomeric blocks that limit lateral glass movement in the glazing channel which may result from thermal, seismic, wind load effects, building movement, and other forces that may apply.

Aspect ratio The quotient of the long side of a glazing lite over the short side of that lite.

Backer rod A polyethylene or polyurethane foam material installed under compression and used to control sealant joint depth, provide a surface for sealant tooling, serve as a bond breaker to prevent three-sided adhesion, and provide an hour-glass contour of the finished bead.

Back-up A material placed into a joint, primarily to control the depth of the sealant.

Batten A plate or strip, usually metal, used on the exterior of a mullion to hold infill panel in place against the mullion framing.

Bead	A sealant or compound after application in a joint irrespective of the method of application, such as caulking bead, glazing bead, etc. Also a molding or stop used to hold glass or panels in position.
Bed or bedding	In glazing, the bead of compound or sealant applied between a lite of glass or panel and the stationary stop or sight bar of the sash or frame. It is usually the first bead of compound or sealant to be applied when setting glass or panels.
Bedding of stop	In glazing, the application of compound or sealant at the base of the channel, just before the stop is placed in position, or buttered (see buttering) on the inside face of the stop.
Bent glass	Flat glass that has been shaped while hot into curved shapes.
Bevelling	The process of edge finishing flat glass to a bevel angle.
Bite	The dimension by which the inner edge of the stop overlaps the edge of the glass.
Bleeding	The absorption of oil or vehicle from a compound into an adjacent porous surface, and different from migration, which is the spreading or creeping of oil or vehicle from a compound out onto an adjacent non-porous surface.
Blistering	Bubbling of installed sealant often caused by expansion of gas below the sealant surface.
Block	Rectangular, cured section of EPDM, neoprene, silicone or other suitable material, used to position the glass product in the glazing channel.
Bond breaker	A material, usually foam or plastic tape, used to prevent three-sided adhesion in a sealant joint.
Bow (and warp)	A curve, bend or other deviation from flatness in glass.
Breather tube units	An insulating glass unit with a tube factory-placed units into the unit's spacer to accommodate pressure differences encountered in shipping due to change in elevation. These tubes are to be sealed on the jobsite prior to unit installation. (See also "capillary tubes.")
Bubbles	In laminated glass, a gas pocket in the interlayer material or between the glass and the interlayer from ASTM C1172). In float glass, a gaseous inclusion greater than .7 mm (1/32 inch) diameter.
Bullet-resistant glass	A multiple lamination of glass or glass and plastic that is designed to resist penetration from medium- to super-power small arms and high-power rifles.
Buttering	Application of sealant or compound to the flat surface of some member before placing the member in position, such as the buttering of a removable stop before fastening the stop in place.

Butt glazing	The butting together of typically vertical edges of two lites of glass and sealing with silicone sealant.
Butyl	A synthetic rubber formed from isobutylene and isoprene, used in either a curing or non-curing form.
Capillary tube units (See also “breather tubes”)	An insulating glass unit with a very small metal tube of specific length and inside diameter factory-placed into the unit’s spacer to accommodate pressure differences encountered in shipping because of substantial changes in elevation and the pressure differences encountered daily after installation. Capillary tubes may or may not require sealing prior to installation. Consult IG unit fabricator.
Cap screws	Screws used to attach pressure plate or batten to mullion
Caulk	(v) The application of a sealant to a joint, crack or crevice (n) A compound used for sealing that has minimum joint movement capability; sometimes called low-performance sealant.
Channel	A three-sided, U-shaped opening in sash or frame to receive light or panel, with or without removable stop or stops. Contrasted to a rabbet, which is a two-sided, L-shaped section, as with face glazed window sash.
Channel depth	The measurement from the bottom of the channel to the top of the stop, or measurement from sight-line to base of channel.
Channel glazing	The sealing of the joints around glass or panels set in a U-shaped channel employing removable stops.
Channel width	The measurement between stationary stops (or stationary stop and removable stop) in a U-shaped channel.
Chipped edge	An imperfection due to breakage of a small fragment from the cut edge of the glass.
Cohesive failure	Splitting and opening of a compound resulting from over-extension of the compound caused by excessive movement. (See adhesion failure)
Compatibility	The ability of two or more materials to exist in close and permanent association for an indefinite period with no adverse effect of one on the other.
Compatible	Two or more substances which can be mixed, blended together, or can be in direct contact without separating, reacting, or affecting the materials adversely.
Compound	A chemical formulation of ingredients used to produce a caulking, elastomeric joint sealant, etc.
Compression	Pressure exerted on a compound in a joint, as by placing a lite or panel in place against bedding, or placing a stop in position against a bead of compounds.
Compression gasket	A gasket designed to function under compression.

Compression set	The loss of compression force exerted by a gasket due to time-dependent shrinkage or creep of material.
Concave bead	Bead of compound with a concave exposed surface
Condensation	The appearance of moisture (water vapour) on the surface of an object caused by warm moist air coming into contact with a colder object.
Consistency	Degree of softness or firmness of a compound as supplied in the container and varying according to method of application, such as gun, knife, tool, etc.
Convection	A natural or forced circulation of air downward against a cold surface and upward against a warm surface.
Convex bead	Bead of compound with a convex exposed surface.
Curtain wall	Any wall designed to resist lateral loads, but no superimposed vertical loads.
Cut sizes	Glass cut to specified width and length.
Deflection (framing member)	The amount of bending movement of any part of a structural member perpendicular to the axis of the member under an applied load.
Deflection (center of glass)	The amount of bending movement of the center of a glass lite perpendicular to the plane of the glass surface under an applied load.
Desiccant	A material used in IG units to adsorb water vapour and certain volatile gases from the hermetically sealed air space.
Design pressure	Specified pressure a product is designed to withstand.
Distortion	Alteration of viewed images caused by variations in glass flatness or inhomogeneous portions within the glass. An inherent characteristic of heat-treated glass.
Double strength	In float glass, approximately 3 mm (1/8 inch) thick
Dry glazing	A method of securing glass in a frame by use of dry, preformed resilient gaskets without sealants.
Dry seal	Accomplishment of weather seal between glass and sash by use of strips or gaskets of Neoprene, EPDM, silicone or other flexible material. A dry seal may not be completely wateright.
Durometer	A machine to measure Shore hardness. (See “shore hardness”)
EPDM	Ethylene Propylene Diene Monomer, a synthetic rubber.
Edge block	(See “anti-walk block.”)
Edge clearance	Nominal spacing between the edge of the glass product and the bottom of the glazing pocket (channel).

Elastomeric material An elastic, rubber-like substance capable of stretching easily and having the ability to recover to its original configuration.

Elongation Normally, it is the strain at break of laboratory samples. (Consult manufacturers for maximum recommended movement in shear, compression and extension for each sealant as used in glazing detail.)

Elongation at rupture test The amount a material has stretched at the time it breaks apart. Test to be run at specified conditions.

Embrittlement The hardening of glazing tapes and gaskets over time due primarily to solvent loss or UV exposure

Emissivity The measure of a surface's ability to emit long-wave infrared radiation.

Exterior glazed Glass set from the exterior of the building.

Exterior stop The removable molding or bead that holds the glass or panel in place when it is on the exterior side of the glass or panel, as contrasted to an interior stop located on the interior side of the glass.

Extruded Formed by forcing plastic or metal through a die

Facade A face or elevation of a building.

Face Glazing On rabbeted sash without stops, the triangular bead of compound applied with a glazing knife after bedding, setting and clipping the glass in place.

Face Sealed A wall system sealed on its exterior surface to prevent water and air leakage.

Fenestration Any glass panel, window, door, curtain wall or skylight unit on the exterior of a building.

Fillet bead Caulking or sealant placed in such a manner that it forms an angle between the materials being caulked.

Flat glass A general term that describes float glass, sheet glass, plate glass and rolled glass.

Float glass Glass formed on a bath of molten tin. The surface in contact with the tin is known as the tin surface or tin side. The top surface is known as the atmosphere surface or air side.

Flush glazing (pocket glazing) The setting of a lite of glass or panel into a four-sided sash or frame opening containing a recessed U-shaped channel without removable stop on three sides of the sash or frame and one channel with a removable stop along the fourth side.

Frame An assembly of members to support glazing or spandrel infill.

Fully tempered glass	Flat or bend glass that has been heat-treated to a high surface and/or edge compression to meet the requirements of ASTM C 1048, kind FT. Fully tempered glass, if broken, will fracture into many small pieces (dice) which are more or less cubical. Fully tempered glass is approximately four times stronger than annealed glass of the same thickness when exposed to uniform static pressure loads. Outside of North America, sometimes call "toughened glass."
Gas-filled units	Insulating glass units with a gas other than air in the air space to decrease the unit's thermal conductivity (U-value) or to increase the unit's sound insulating value.
Gasket	Pre-formed shapes, such as strips, grommets, etc., of rubber and rubber-like composition, used to fill and seal a joint or opening either alone or in conjunction with a supplemental application of a sealant.
Glass	A hard brittle substance, usually transparent, made by fusing silicates, under high temperature, with soda, lime, etc.
Glass clad polycarbonate	One or more lites of flat glass bonded with an aliphatic urethane interlayer to one or more sheets of extruded polycarbonate in a pressure/temperature/vacuum laminating process.
Glass stop	A glazing bead which is either applied to, or is an integral part of the frame.
Glaze	To install glass lites or infill material.
Glazing	(n) A generic term used to describe an infill material such as glass, panels, etc. (v) The process of installing an infill material into a prepared opening in windows, door panels, partitions, etc.
Glazing bead	A light member applied to a frame to hold glass or infill in a fixed position.
Glazing channel	A three-sided, U-shaped sash detail into which a glass product is installed and retained.
Glazing gasket	Preformed elastomeric or plastic material applied between face of glass and framing to provide a resilient support and prevent passage of air and water.
Gun consistency	Compound formulated in a degree of softness suitable for application through the nozzle of a caulking gun.
HVAC	Heating Ventilating and Air Conditioning.
Heat-absorbing glass	Glass that absorbs an appreciable amount of solar energy.
Heat-resisting glass	Glass able to withstand high thermal shock, generally because of a low coefficient of expansion.

Heat-strengthened glass Flat or bent glass that has been heat-treated to a specific surface and/or edge compression range to meet the requirements of ASTM C 1048, kind HS. Heat-strengthened glass is approximately two times as strong as annealed glass of the same thickness when exposed to uniform static pressure loads. Heat-strengthened glass is not considered safety glass and will not completely dice as will fully tempered glass.

Heat-treated Term used for both fully tempered glass and heat-strengthened glass.

Heel bead Sealant applied at the base of channel, after setting glass or panel and before the removable stop is installed, one of its purposes being to prevent leakage past the stop. Sealant must bridge the gap between the glass and frame.

IG unit Insulating Glass unit formed by two or more lites of glass sandwiching a spacer creating a hermetically sealed air space.

Infill Various materials glazed into a framing system.

Insulating glass unit Two or more lites of glass spaced apart and hermetically sealed to form a single-glazed unit with an air space between each lite. (Commonly called IG units.)

Interior glazed Glass set from the interior of the building.

Interior stop The removable molding or bead that holds the glass in place, when it is on the interior side of the glass, as contrasted to an exterior stop which is located on the exterior side of a glass or panel.

Interlayer Any material used to bond two lites of glass and/or plastic together to form a laminate.

Internal drainage A system of design incorporating gutters inboard of the face seal intended to direct water out through discrete weep holes.

Jamb The vertical edge of framed opening.

Jambs The vertical members of a frame adjacent to the structural members of a building.

Laminated glass Two or more lites of glass permanently bonded together with one or more interlayers.

Lite A pane of glass or a sealed insulating unit.

Live load Loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, ice load, rain load, seismic load or dead load.

Locking strip A hard rubber or plastic insert used in a lock-strip gaskets to create a compressive seal.

Low-e	A thin metal coating applied to a glass surface to reduce its emissivity. Usually enclosed in an IG unit.
Luminous efficacy (light-to-solar gain ratio)	The visible transmittance of a glazing system divided by the solar heat gain coefficient (or shading coefficient). This ratio is helpful in selecting glazing products for different climates in terms of those that transmit more heat than light and those that transmit more light than heat.
Migration	Spreading or creeping of oil or vehicle from a compound out onto adjacent non-porous surfaces, as contrasted to bleeding which refers to absorption into adjacent porous surfaces.
Mill finish	Unfinished aluminum having only received initial cleaning after extruding.
Mitred corners	Usually a 45-degree mitred joint produced in some sash where vertical jamb members meet horizontal head and sill members.
Mullion	A vertical or horizontal framing member separating fixed lites of glass or infill.
Mullion	A horizontal or vertical member that holds together two adjacent lights of glass or units of sash or sections of curtain wall.
Mullion head	The top or front surface of a mullion containing screw spline and gasket rebates.
Muntin	A secondary member separating lites of glass or infill.
Muntin	In sash having horizontal and vertical bars that divide the window into smaller lights of glass, the bars are termed muntin bars. Similar to mullion but lighter weight.
Needle glazing or bead	Application of a small bead of compound at the sight-line by means of a gun nozzle about 1/8 in opening size.
Neoprene	A synthetic rubber with properties much like natural rubber, extruded in gasket form or cut from sheets
Non-drying	Descriptive of a compound that does not set up hard.
Non-oxidizing	Descriptive of a compound that withstands accelerated weathering, the equivalent of 20 years of normal weathering without oxidizing. Does not become hard after exterior exposure.
Non-skinning	Descriptive of a product that does not form a surface skin after application. Usually remains tacky or sticky.
Non-staining	Characteristic of a compound which will not stain a surface by bleeding or migration of its oils or vehicle content.
Non-volatile	Any substance which does not evaporate or volatize under normal conditions of temperature and pressure.

OITC (Outside-Inside Transmission Class)	A rating used to classify the performance of glazing in exterior application. For more information see ASTM E-1332 and ASTM E-1425.)
Oil exudation	The exudation of oils from glazing tapes, due primarily to mis-formulation.
Permanent set	The amount by which a material fails to return to its original dimensions after being deformed by an applied force or load.
Pocket (channel)	A three-sided, U-shaped opening in a sash or frame to receive glazing infill. Contrasted to a rabbet, which is a two-sided, L-shaped section, as with face-glazed window sash.
Pocket (channel) depth	The inside dimension from the bottom of the pocket to the top. Pocket depth equals the bite plus the edge clearance.
Pocket glazing	(See “flush glazing”)
Pocket (channel) width	The measurement between stationary stops (or stationary stop and removable stop) in a U-shaped channel.
Polyisobutylene	Polymer manufactured from gaseous hydrocarbons. The polymer is a major portion of butyl rubber which also contains a small per cent of isoprene.
Polymer	A high molecular weight chemical structure consisting of a long chain of small molecular units.
Polysulfide	Polysulfide liquid polymers are mercaptan-terminated, long-chain aliphatic polymers containing disulfide linkages. They can be converted to rubbers at room temperature without shrinkage, chemically or with the addition of a curing agent.
Polysulfide base	Compounds made from polysulfide synthetic rubber
Polysulfide sealant	Polysulfide liquid polymer sealant which are mercaptan-terminated, long-chain aliphatic polymers containing disulfide linkages. They can be converted to rubbers at room temperature without shrinkage upon addition of a curing agent.
Polyurethane sealant	An organic compound formed by the reaction of a glycol with an isocyanate.
Pot life	The time interval following the addition of an accelerator or curing agent before a chemically curing material will become too viscous to apply satisfactorily. Synonymous with working life.
Pre-shimmed tape sealant	A sealant having a pre-formed shape containing solids or discrete particles that limit its deformation under compression.

Pressure plate	A plate or strip, usually metal, used on the exterior of a mullion to hold infill panel in place against the mullion framing.
Priming	Sealing of a porous surface so that compound will not stain, lose elasticity, shrink excessively, etc. because of loss of oil or vehicle into the surround. A sealant primer or surface conditioner may be used to promote adhesion of a curing type sealant to certain surfaces.
Pumping	The forcing of glazing tape or sealant from a joint due to cyclic wind movement of infill.
Rabbet	A two-sided L-shaped recess in sash or frame to receive glass or panels. When no stop or molding is added, such rabbets are face glazed. Addition of a removable stop produces a three-sided U-shaped channel.
Racking	In plane distortion or movement of frames.
Racking	Movement and distortion of sash or frames because of lack of rigidity, or caused by adjustment of ventilator sections. Puts excessive strain on the sealant and may result in joint failure.
Radiant heat loss/gain	The loss or gain of heat to a body by radiation or radiant heat transfer, as opposed to conductive or convective transfer.
Rainscreen	A design method of preventing water penetration relying on an exterior deterrent seal and an inner primary air seal, coupled with a drained and pressure equalized (to the exterior) cavity between.
Reflective glass	Glass with a metallic coating to reduce solar heat gain. (See also “solar control glass.”)
Relative heat gain	The amount of heat gain through a glass product taking into consideration the effects of solar heat gain (shading coefficient) and conductive heat gain (U-value). The value is expressed in Btu/hr/ft2 (W/m2).
Removable double glazing (RDG)	A removable glazed panel or sash on the inside or outside of an existing sash or window, such as a storm panel, used for additional insulation and protection against the elements.
Resilient tape	A pre-shaped sealing material incorporating reinforcing to prevent excessive deformation.
Resilient tape	A pre-shaped, rubbery sealing material furnished in varying thicknesses and widths, in roll form. May be plain or reinforced with scrim, twine, rubber or other materials.
Rod shim	A plastic or cured rubber shim integral to glazing tape to prevent excessive deformation of the tape under compression.

Roll (or roller) distortion Waviness imparted to horizontal heat-treated glass while the glass is transported through the furnace on a roller conveyor. The waves produce a distortion when the glass is viewed in reflection.

Rough opening The opening in a wall into which a door or window is to be installed.

R-value The thermal resistance of a glazing system expressed $ft^2/hr/^\circ F/Btu$ ($m^2/W/^\circ C$). The R-value is the reciprocal of the U-value. The higher the R-value, the less heat is transmitted throughout the glazing material.

STC (Sound Transmission Class) (Sound A single number rating derived from individual transmission losses at specified test frequencies (for more information see ASTM E 90 and ASTM E 413). It is used for interior walls, ceiling and floors and in the past was also used for preliminary comparison of the performance of various glazing materials.

Sash A fixed frame about the perimeter of a lite of glass. Can be either stop or channel glazed.

Screw spline A part of an extrusion into which screws engage.

Scrim A coating or material applied to the back of spandrel glass to hold the glass together after breakage and to render the glass opaque.

Sealant An elastomeric material with adhesive qualities used to seal joints.

Sealant Compound used to fill and seal a joint or opening, as contrasted to a sealer which is a liquid used to seal a porous surface.

Separator sheet An inert sheet material used to separate two either moving or incompatible surfaces.

Setting block Small blocks of Neoprene, etc. placed under bottom edge of glass or panel to prevent its setting down onto bottom rabbet or channel after setting, thus distorting the sealant.

Setting time A term used rather loosely to describe that period when a material has either dried sufficiently through solvent release, or cured sufficiently through chemical reaction, to reach either a specified condition or a condition resulting from either of the two processes.

Shadow box A special form of spandrel panel construction used to create various shadow patterns with varying sun angles.

Shading coefficient The ratio of the solar heat gain through a specific glass product to the solar heat gain through a lite of 3 mm (1/8 inch) clear glass. Glass of 3 mm (1/8 inch) thickness is given a value of 1.0, therefore, the shading coefficient of a glass product is calculated as follows:
S.C. =Solar Heat Gain of the Glass in Question
Solar Heat Gain of 3 mm (1/8 inch) Clear Glass

Shore "A" hardness	Measure of firmness of a compound by means of a Durometer Hardness Gauge. (Range of 20-25 is about the firmness of an art gum eraser. Range of 90 is about the firmness of a rubber heel.)
Sight line	Imaginary line along perimeter of glass or panels corresponding to the top edge of stationary and removable stops, and the line to which sealant contacting the glass or panels are sometimes finished off.
Silicone	An inorganic sealant based on a silicon-oxygen formulation.
Sill	The bottom horizontal frame member.
Sight lines	A line about the perimeter of a lite corresponding to the top edge of any fixed or stationary stop.
Slip sheet	See separator sheet.
Soffit	The underside of elements in a building, such as roof overhangs and the underside of first floor slabs overhanging ground floor lobby areas.
Solar control glass	Tinted and/or coated glass that reduces the amount of solar heat gain transmitted through a glazed product.
Solar heat gain coefficient	The ratio of the solar heat gain entering the space area through the fenestration product to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation which is then reradiated, conducted, or convected into the space.
Spacer	A metal, plastic, or foam strip used to separate two lites of glass in an IG unit.
Spacers	Small blocks of composition, Neoprene, etc. placed on each face of glass or panels to centre them in the channel and maintain uniform width of sealant beads, preventing excessive sealant distortion.
Spandrel	The panel(s) of a wall located between vision areas of windows which conceal structural columns, floors and shear walls.
Spandrel panel	A generally opaque panel used to cover slab edges or columns in non-vision areas of a wall.
Splice plate	A plate or fitting used to maintain continuity of seal between adjoining mullions or snap caps.
Stack effect	As temperature in a building differs from the exterior, pressure differences occur between the interior and exterior due to the difference in the density of the air. This called chimney or stack effect.
Stationary stop	The permanent stop or lip of a rabbet on the side opposite the side on which glass or panels are set.
Stick built	A wall system where generally horizontal and vertical framing members are installed onto the building frame piece by piece. Infill of vision glass and spandrel panel is then added to the framing system.

Stop Either the stationary lip at the back of a rabbet or the removable molding at the front of the rabbet, either or both serving to hold the glass or panel in sash or frame, with the help of spacers.

Strain pattern A specific geometric pattern of iridescence or darkish shadows that may appear under certain lighting conditions, particularly in the presence of polarized light (also called quence marks). The phenomenon is caused by the localized stresses imparted by the rapid air cooling of the tempering operation. Strain pattern is characteristic of heat-treated glass.

Stress (residual) Any condition of tension or compression existing within the glass, particularly due to incomplete annealing, temperature gradient, or inhomogeneity.

Structural glazing gaskets Cured elastomeric channel-shaped extrusions used in place of a conventional sash to install glass products onto structurally supporting sub-frames, with the pressure of sealing exerted by the insertion of separate lockstrip wedging splines.

Structural silicone glazing The use of a silicone sealant for the structural transfer of loads from the glass to its perimeter support system and retention of the glass in the opening.

Structural rubber gaskets A synthetic rubber section designed to engage the edge of glass or other sheet material in a surrounding frame by forcing an interlocking filler strip into a grooved recess in the face of the gasket.

Tempered A full heat treatment process for glass imparting compressive stresses in the glass surfaces and forcing a characteristic cube-like breakage pattern.

Thermal Break An element of low-heat conductivity incorporated into an assembly to reduce heat flow.

Thermoplastic A class of materials, including plastics, foams and adhesives, that soften on heating and harden on cooling and undergo no chemical changes in the process.

Thermosetting A class of materials that, once shaped into their permanent form usually by heat and pressure, cannot be remelted and reshaped due to a basic change in their chemical structure.

Three-sided adhesion In joints, sealant that is adhered to three surfaces and therefore restricted in movement capability.

Toe bead Sealant applied at the intersection of the outboard glazing stop and the bottom of the glazing channel; must be sized to also provide a seal to the edge of the glass.

Tong marks Small, surface indentations near and parallel to one edge of vertically-tempered or vertically heat-strengthened glass resulting from the tongs used to suspend the glass during the heat treating process.

Tooling — Operation of pressing in and striking a compound in a joint in order to press compound against the sides of a joint and secure good adhesion. Also the finishing off of the surface of a compound in a joint so that it is flush with the surface. A narrow, blunt bladed tool is used for this purpose.

Two-sided adhesion — In joints, sealant that is adhered to two opposing surfaces and therefore allowed to extend freely.

Unit — Term normally used to refer to one single assembly of insulating glass.

United inches — The sum of the dimensions of one length and one width of a lite of glass.

Unitized — A wall system composed of large factory assembled panels that are systematically placed on the building frame, often to interlock horizontally and vertically.

U-value — As measure of air-to-air heat transmission (loss or gain) due to the thermal conductance and the difference in indoor and outdoor temperatures. As the U-value decreases, so does the amount of heat that is transferred through the glazing material. The lower the U-value, the more restrictive the fenestration product is to heat transfer. Reciprocal of R-value.

Venting — Providing circulation of air or ventilation between various layers in a wall assembly. Accomplished by vents, breather tubes or other openings.

Venting — Providing circulation of air or ventilation between two walls or partitions. Venting accomplished by use of tubes, breather vents or openings left in wall

Visible light transmittance — The percentage of visible light (390 to 770 nanometers) within the solar spectrum that is transmitted through glass.

Vision unit — Single lite or IG unit used in the vision area of a wall.

Volatile — The property of liquids to change into a gas and pass away by evaporation, under normal atmospheric conditions.

Warm edge technology (WET) — Various technologies aimed at increasing the edge surface temperature of IG units primarily through the use of low conductivity spacers.

Weather-stripping — A material or device used to seal the opening between sash and/or sash and frame.

Wedge gasket — A formed gasket forced between a glazing stop and the glass to create a compression seal.

Weeps (or weepholes) — Drain holes or slots in the sash or framing member to prevent accumulation of condensation and water.

Wet glazing — The sealing of glass or infill in a frame by use of sealant.

Wet seal — Application of an elastomeric sealant between the glass and sash to form a weather-tight seal.

Window An opening constructed in a wall or roof and functioning to admit light or air to an enclosure, usually framed and spanned with glass mounted to permit opening and closing.

Wired glass Rolled glass having a layer of meshed or stranded wire completely imbedded as nearly as possible to the center of thickness of the lite. This glass is available as polished glass (one or both surfaces) and patterned glass. Approved polished wired glass is used as transparent or translucent fire protection rated glazing. Patterned wired glass is sometimes used as decorative glass. It breaks more easily than unwired glass of the same thickness, but the wire restrains the fragments from falling out of the frame when broken.

Appendix B

REFERENCES

REFERENCE ORGANIZATIONS

ORGANIZATION	WEB SITE	ACRONYM
The Aluminum Association	www.aluminum.org	AA
American Architectural Manufacturers Association	www.aamanet.org	AAMA
American Institute of Steel Construction	www.aiscweb.com	AISC
American Iron and Steel Institute	www.steel.org	AISI
American National Standards Institute	www.ansi.org	ANSI
American Society of Heating, Refrigerating, and Air-Conditioning Engineers	www.ashrae.org	ASHRAE
American Society for Testing and Materials	www.astm.org	ASTM
Building Officials and Code Administrators	www.bocai.org	BOCA
Canadian General Standards Board	www.pwgsc.gc.ca/cgsb	CGSB
Canadian Standards Association	www.csa-international.org	CSA
Canadian Window and Door Manufacturers Association	www.cwdma.ca	CWDMA
Construction Specifications Institute	www.csinet.org	CSI
Glass Association of North America (Distribution/Installation Div., Laminating Div. and Tempering Division)	www.glasswebsite.com/gana.html	GANA
Institute for Research in Construction, National Research Council Canada	www.nrc.ca/irc	IRC, NRC
Insulating Glass Certification Council	www.igcc.org	IGCC
Insulating Glass Manufacturers Alliance	www.igmaonline.org	IGMA
International Conference of Building Officials	www.ICBO.org	ICBO
MASTERSPEC®	www.arcomet.com	MASTERSPEC®
National Association of Architectural Metal Manufacturers	www.gss.net/naamm	NAAMM

ORGANIZATION	WEB SITE	ACRONYM
National Fenestration Ratings Council	www.nfrc.org	NFPA
National Wood Window and Door Association	www.nwwda.org	NWWDA
National Glass Association	www.glass.org	NGA
Primary Glass Manufacturers Council	www.glasswebsite.com/pgmc.html	PGMC
Quebec Building Envelope Council	www.cebq.org	QBEC/CEBQ
Safety Glazing Certification Council	www.sggc.org	SGCC
Sealed Insulating Glass Manufacturers Association	www.signma@sba.com	SIGMA
Steel Window Institute	www.steelwindows.com	SWI

REFERENCE DOCUMENTS

DOCUMENT	TITLE
AAMA 501	Methods of Test for Exterior Walls
AAMA 503	Voluntary Specification for Field Testing of Metal Storefronts, Curtain Walls and Sloped Glazing Systems
AAMA 850	Fenestration Sealants Guide Manual
AAMA 1503.1	Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections
AAMA 1504	Voluntary Standard for Thermal Performance of Windows, Doors and Glazed Walls
AAMA AFPA	Anodic Finishes/Painted Aluminum
AAMA CW-DG-1	Aluminum Curtain Wall Design Guide Manual
AAMA CW-RS-1	Rain Screen Principle and Pressure Equalization
AAMA FSCOM-1	Fire Safety in High-Rise Curtain Walls
AAMA JS-1	Joint Sealants
AAMA CW-11	Design Wind Loads and Boundary Layer Wind Tunnel Testing
AAMA CW-12	Structural Properties of Glass
AAMA CW-13	Structural Sealant Glazing Systems
AAMA CWG-1	Installation of Aluminum Curtain Walls
AAMA GAG-1	Glass and Glazing
AAMA MCWM-1	Metal Curtain Wall Manual
AAMA TIR-A9	Metal Curtain Wall Fasteners
AIA	MASTERSPEC®
ANSI Z97.1	Performance Specifications and Methods of Test for Safety Glazing Materials Used in Buildings
ASCE 7	Minimum Design Loads for Buildings and Other Structures
ASTM C 509	Standard Specification for Cellular Elastomeric Preformed Gasket and Sealing Material
ASTM C 510	Standard Test Method for Staining and Colour Change of Single or Multicomponent Joint Sealants
ASTM C 542	Standard Specification for Lock-Strip Gaskets
ASTM C 920	Standard Specification for Elastomeric Joint Sealants
ASTM C 962	Standard Guide for Use of Elastomeric Joint Sealants

DOCUMENT	TITLE
ASTM C 1036	Standard Specification for Flat Glass (Replaced DD-G-451 (d))
ASTM C 1048	Standard Specification for Heat-Treated Flat Glass – Kind HS, Kind FT Coated and Uncoated (Replaced Federal Specification DD-G-1403 (b) and (c))
ASTM C 1135	Standard Test Method for Determining Tensile Adhesion Properties of Structural Sealants
ASTM C 1172	Standard Specification for Laminated Architectural Flat Glass
ASTM C 1184	Standard Specification for Structural Silicone Sealants
ASTM C 1193	Standard Guide for Use of Joint Sealants
ASTM C 1249	Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications
ASTM C 1281	Standard Specification for Preformed Tape Sealants for Glazing Applications
ASTM E 90	Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions
ASTM E 283	Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Wall, and Doors
ASTM E 330	Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference
ASTM E 331	Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference
ASTM E 546	Standard Test Method for Frost Point of Sealed Insulating Glass Units
ASTM E 547	Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential
ASTM E 783	Standard Method For Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
ASTM E 997	Standard Test Method for Structural Performance of Glass in Exterior Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Destructive methods
ASTM E 998	Standard Test Method for Structural Performance of Glass in Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Nondestructive Method
ASTM E 1233	Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential

DOCUMENT	TITLE
ASTM E 1300	Standard Practice for Determining the Minimum Thickness of Annealed Glass Required to Resist a Specified Load
ASTM E 1332	Standard Classification for Determination of Outdoor-Indoor Transmission Class
CEBQ	Murs-rideaux – Guide de conception et d'installation
CPSC 16 CFR 1201	Safety Standard for Architectural Glazing Materials
GANA	Laminated Glass Design Guide
GANA	Sealant Manual
GANA	(Tempered Glass) Engineering Standards Manual
NFRC 100	Procedure for Determining Fenestration Product Thermal Properties
NFRC 200	Procedure for Determining Solar Heat Gain Coefficients at Normal Incidence
NFRC 300	Procedure for Determining Solar Optical Properties for Simple Fenestration Products
NFRC 301	Standard Test Method for Emittance of Specular Surfaces Using Spectrometric Measurements
NFRC 400	Procedure for Determining Product Air Leakage