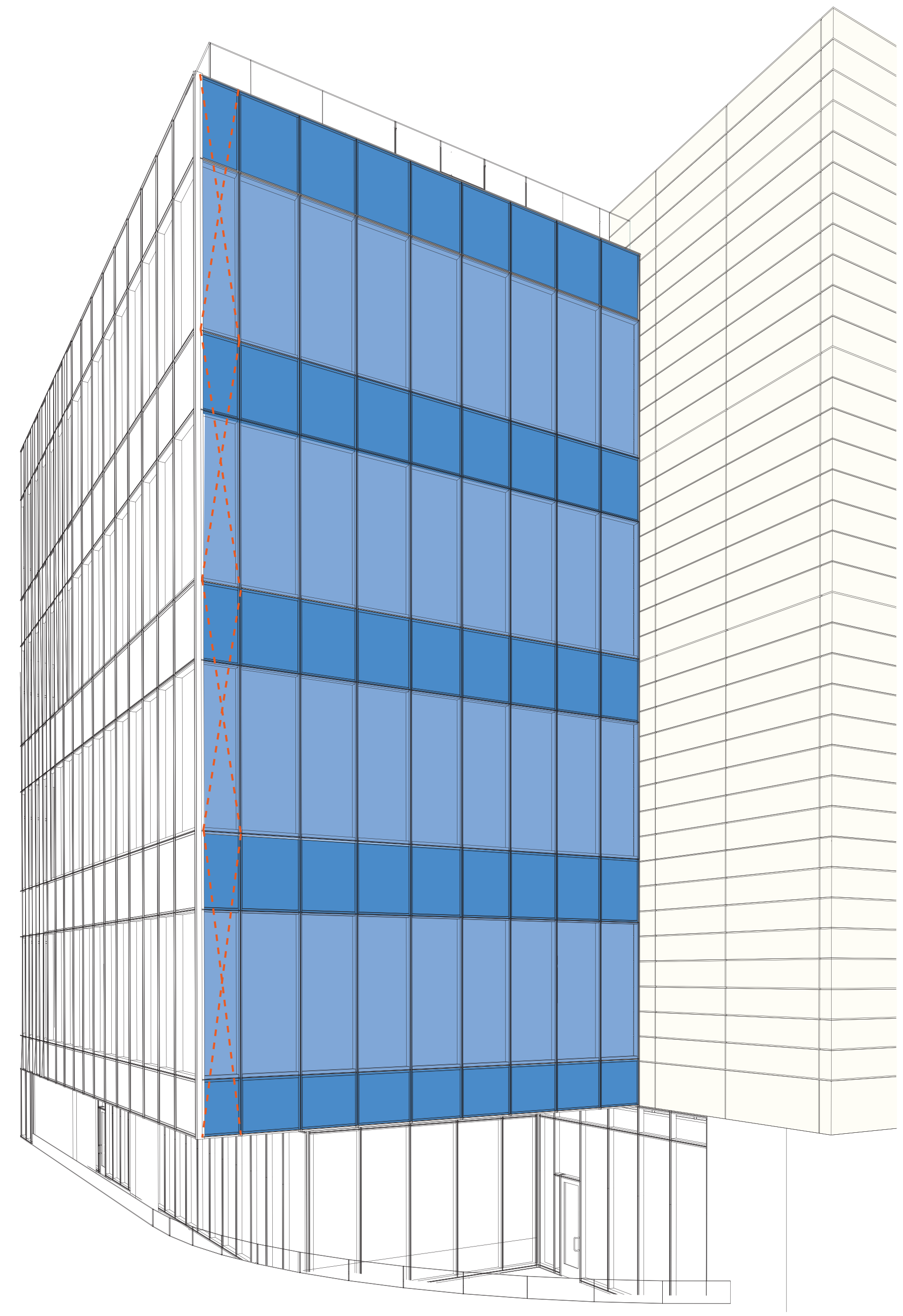
CHAPTER 1

Wall Types

Curtain Wall

A curtain wall system is a thin, lightweight exterior cladding system most commonly made up of aluminum and glass. This wall type is non load bearing and designed to carry its own weight and transfer wind loads and dead loads to the structure of the building. The system is designed to prevent water intrusion by providing drainage and creating a system that resists air and water.



Curtain walls can extend vertically to cover several levels of a building and can cover most or all of the exterior facade of a building without any interruption. The system is designed to mate with itself vertically and horizontally. A curtain wall may not always be straight and rectangular. Walls may be curved, segmented, tapered or sloped. Walls may be interrupted by: doors, canopies, balconies, sunshades, steel, signs and other design elements.

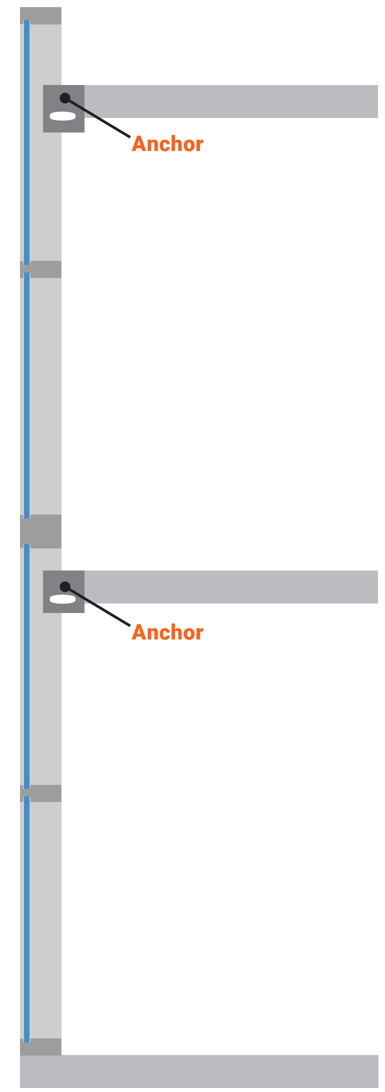
Bay (a.k.a module)
This typically refers to a horizontal span. When referring to the overall building or wall, it usually refers to grid line to grid line. When used within a window or curtain wall, it refers to the distance between vertical mullions.

Unit
Pre-assembled and glazed in the shop. Indicated by dashed X on elevations.

Sill Track
The initial piece of aluminum that is placed underneath the units sitting on a slab.

Unitized curtain walls are built up from individual units that are pre-assembled in the shop and shipped to the field to install. Multiple units stack on top of each other and next to each other to create a curtain wall. A typical curtain wall starts with a sill track with units that span floor to floor anchored at each floor line, and topped with a metal panel parapet cap. Curtain walls can also begin with a soffit condition, where the starter unit is hanging over the outside of the building.

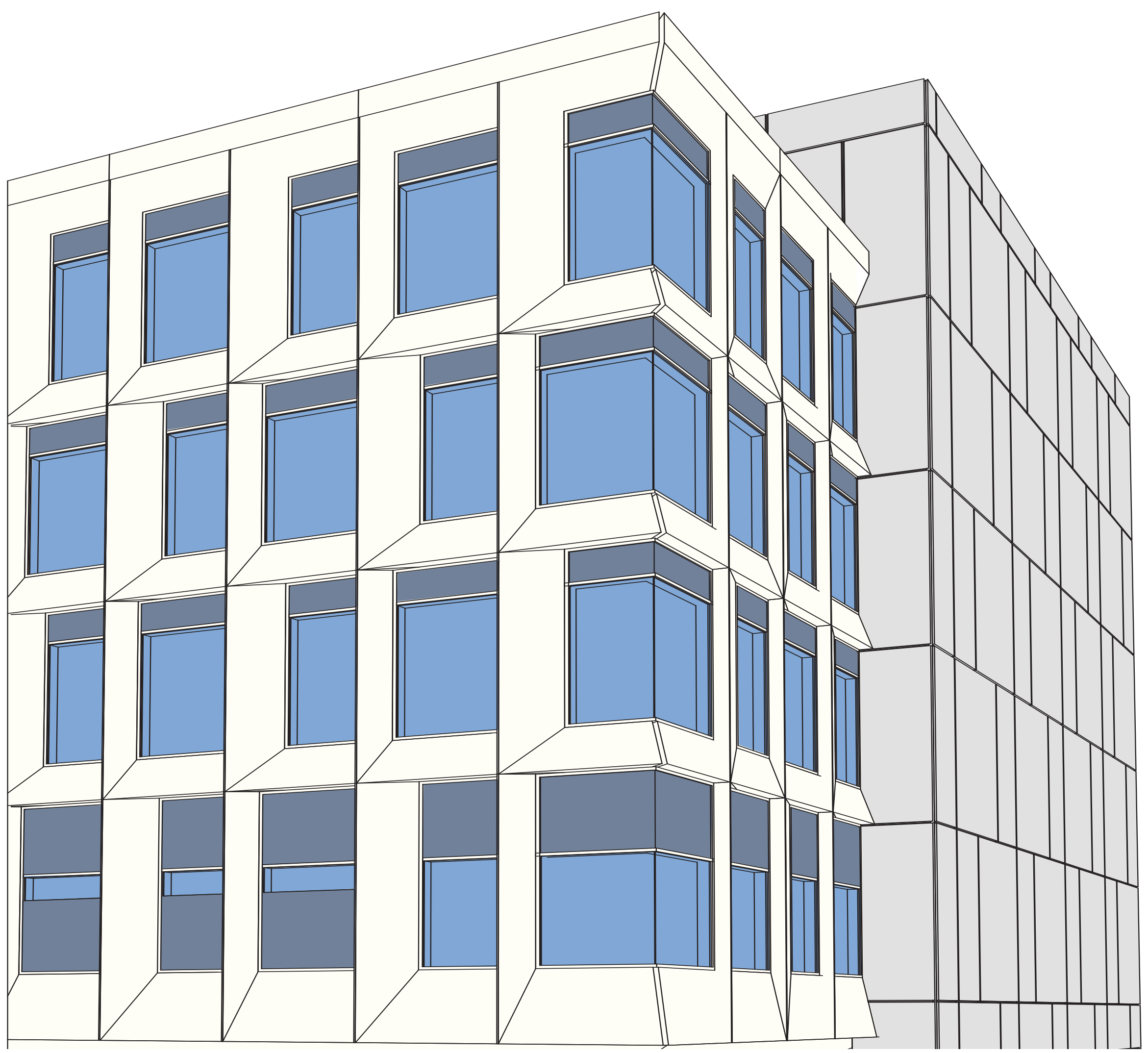
Cladding System
A cladding system refers to the external covering or layer of a building that provides both protection and aesthetic appeal.

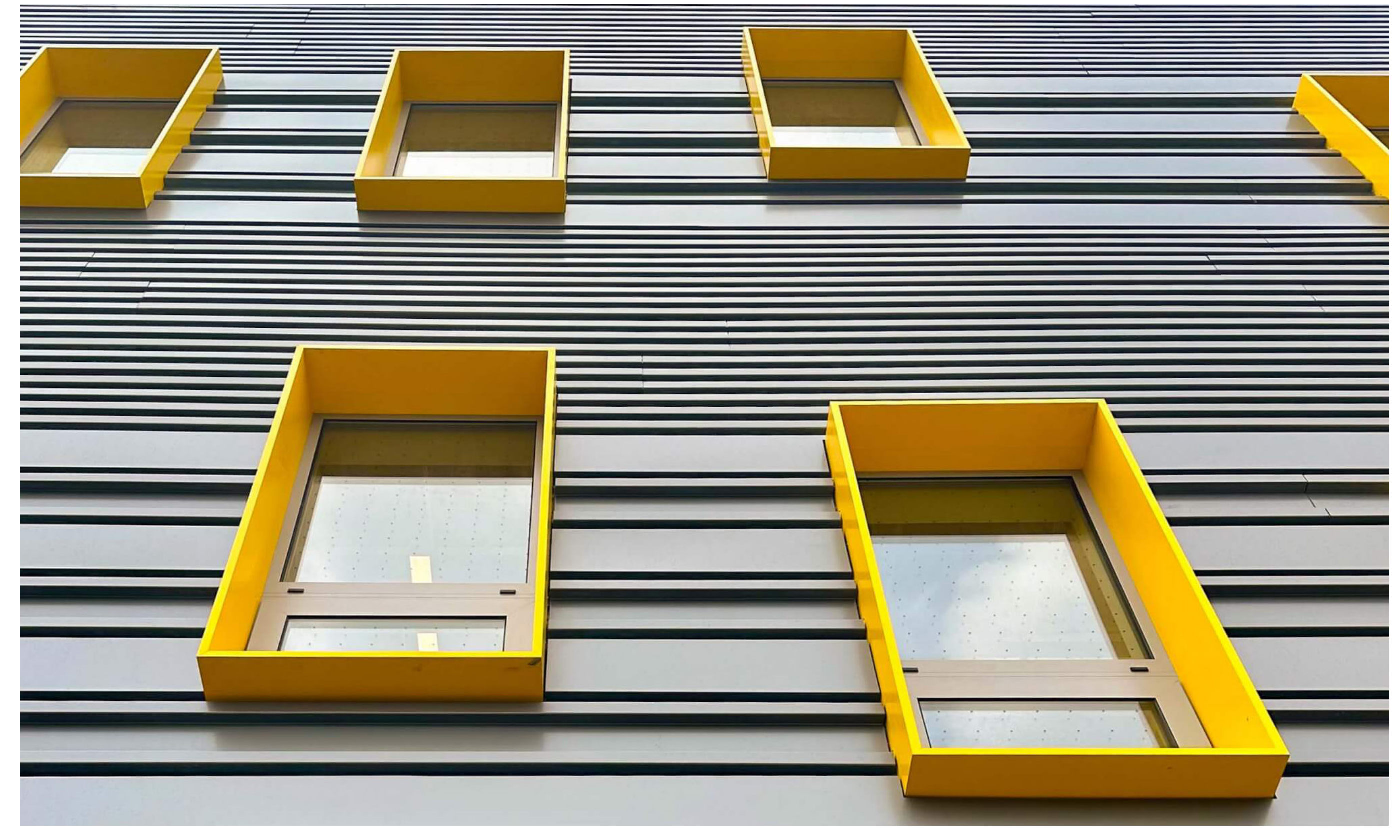


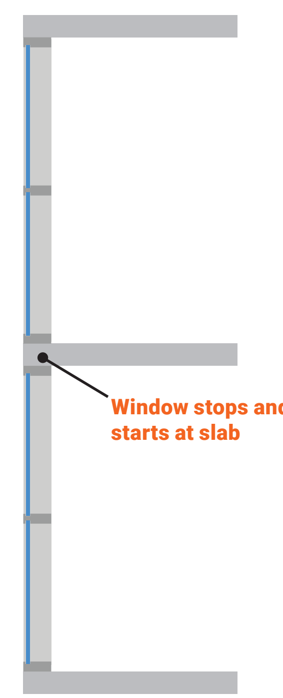
Anchors at each floor attach the curtain wall to the building and allow the system to span multiple floors.

Punched Opening

A punched opening is a single unit or window frame that fits inside an opening. Its components consists of a sill, head, and two jambs. Similar to curtain wall, punched openings utilize a sill track at the bottom of the unit. There may be intermediate vertical mullions that do not split the unit, but give the appearance that there are multiple units. There may also be various horizontals within a punched opening.







These units are wind load anchored at the head and dead loaded at the sill. The anchoring types will vary based on the type of structure provided by the surrounding material.

If a precast subcontractor is providing the perimeter opening, then the glass punched opening units can be pre-installed into the openings in the shop and shipped as a single panel of precast material with windows already installed. This option provides the best scenario for us and our customers to minimize time in the field.

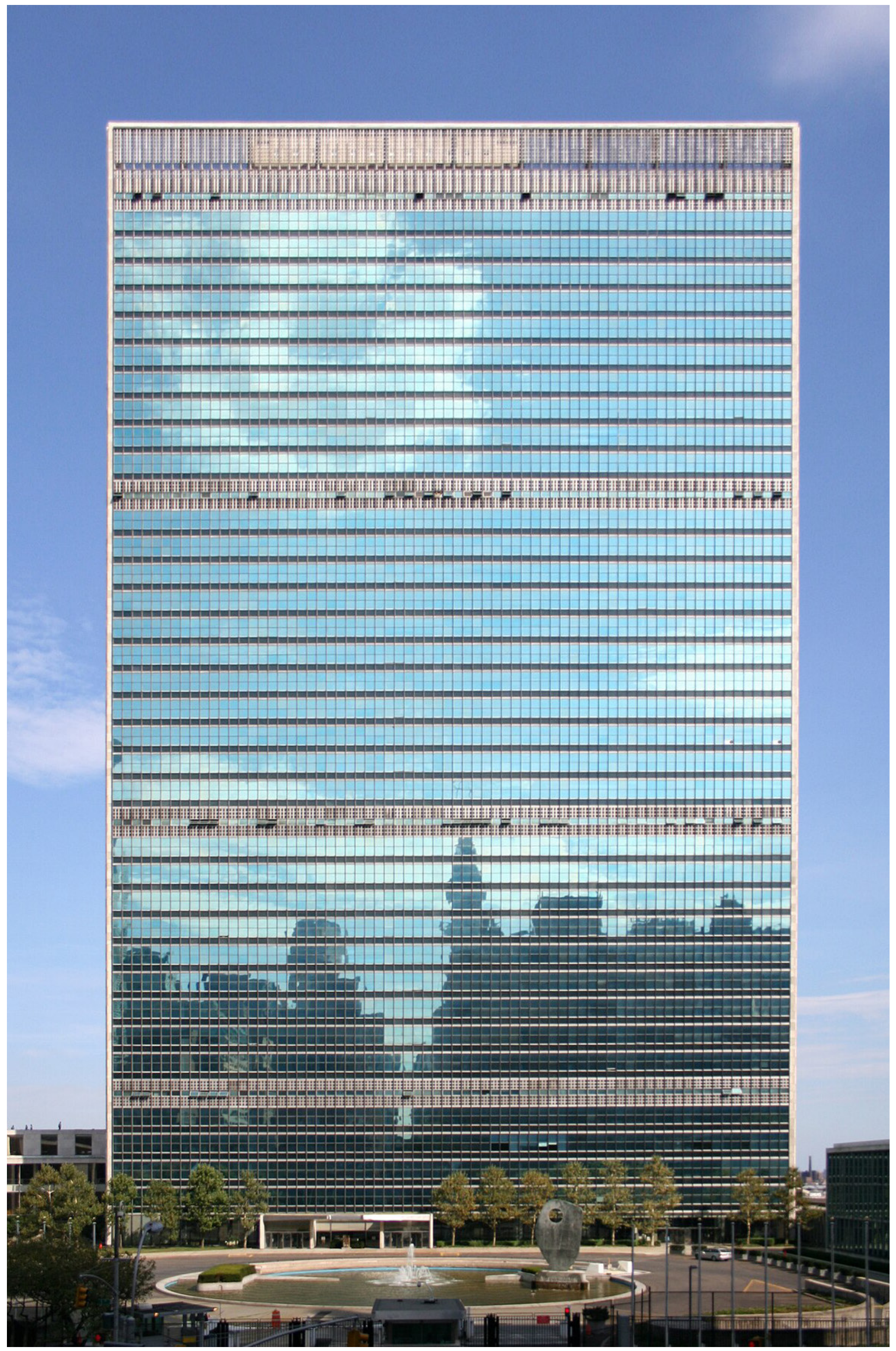
Mullion
This term can be referencing either a horizontal or a vertical member of the curtain wall frame. The most commonly used term in the industry for curtain wall framing. Though horizontal and verticals are made up of multiplied aluminum components, the term mullion encompasses the entire member.

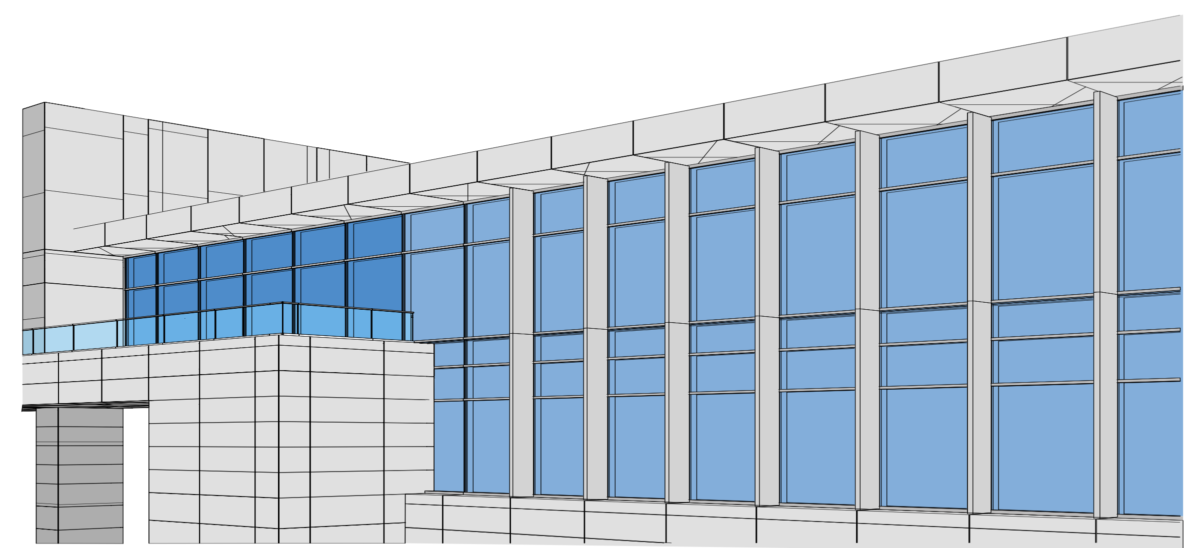
Window Wall

A window wall is a row or strip of two or more units next to each other, without any other units above or below. A strip window has a sill, head, two jambs, verticals, and possibly corners.

There may be various horizontals within a strip window. These units typically are wind load anchored at the head and dead load anchored at the sill. The anchoring types will vary based on the type of structure provided by the surrounding material.

In terms of drainage, window walls are similar to storefronts, in that they always weep at the sill conditions.





Strip windows can butt up to a curtain wall and thus transition from a strip window to a curtain wall. Typically this occurs at balconies and soffit conditions.

Store-front System

A store-front is the facade or entryway of a retail store located on the ground floor or street level of a commercial building. Store-fronts typically include one or more display windows. Considering these systems will not usually span more than one story, store-front can also be referred to as strip window. Store-front systems are typically smaller spans, meaning smaller system sizes can be used at these areas.

The fact that a store-front system is typically used as the main entrance or strictly for retail space is what differentiates it from a High Span system. Store-front systems are site-assembled (stick-built) and are relies heaily on field labor. Glass and infills are set and glazed on site. Store-front systems typically utilize pressure plates and snap caps in order to capture the glazing.

Mullions tend to be shallower, lighter, and less bulky compared to curtain wall mullions.

Pros

Lower material cost

Simple detailing

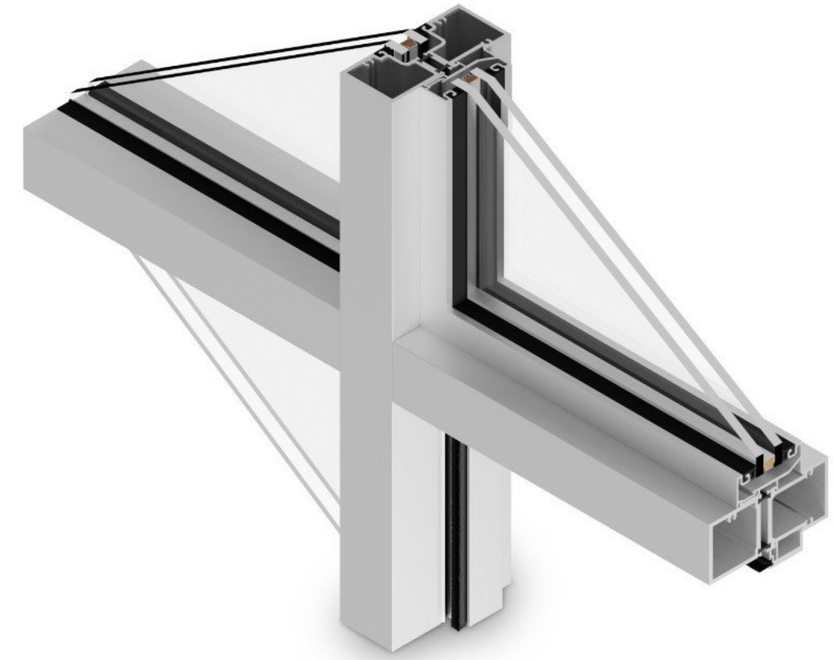
Flexible for small openings

Cons

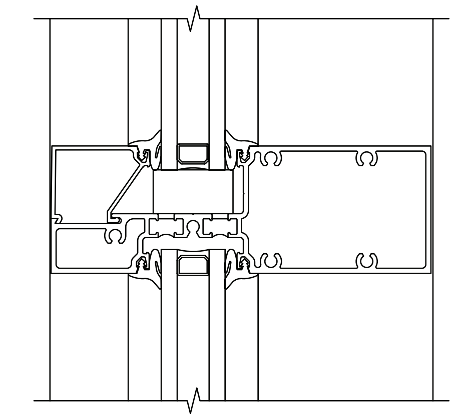
Slower installation

Higher field risk (weather, sealant quality)

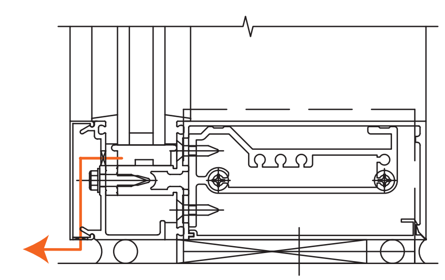
Not ideal for tall or high-performance facades

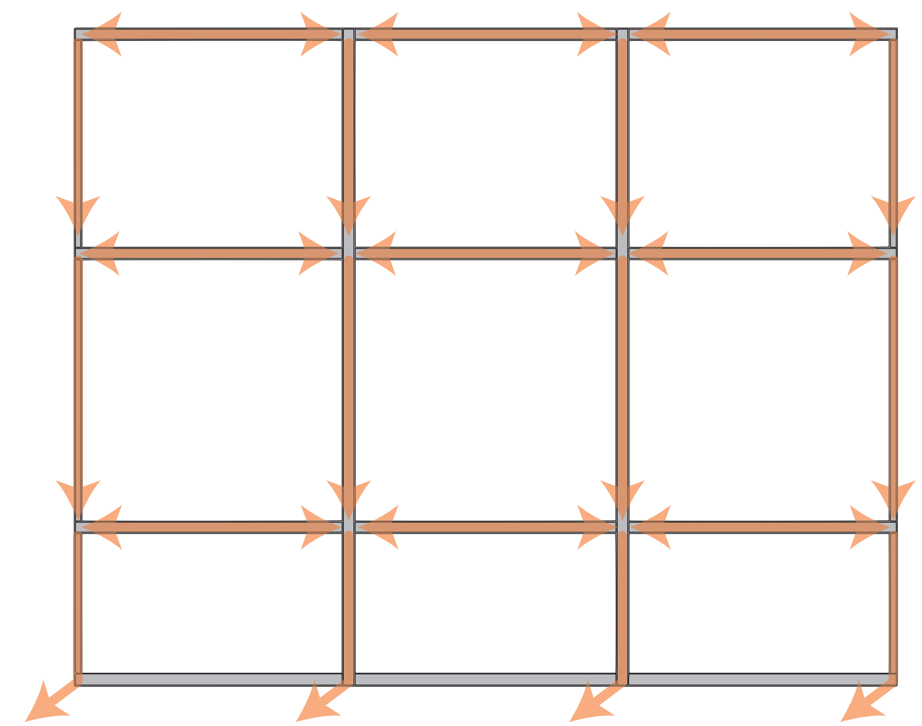


Glass placement usually centers evenly between the exterior and interior edges of the frame. If you notice equal distance from both sides of the glass edge to the front and back, it's likely a storefront system.



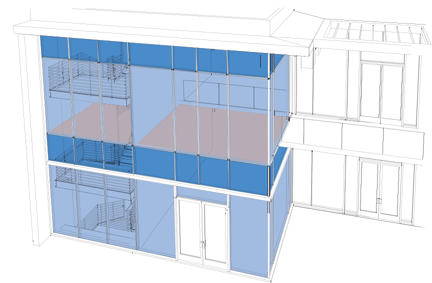
When it comes to drainage, storefront systems always weep at the sill condition.





High Span System

A High Span is a system which spans multiple floors but is not supported by a slab (self supporting). This system is used to create large, open spaces with minimal structural support. The term "high span" refers to the enhanced distance between the window system's structure.



CHAPTER 2

Glazing Systems

Stick-built System

Stick-built systems are window systems that are constructed directly in the field. Tec Wall still requires some prep work in our shop before being shipped to the construction site. Metal must be cut to size and notches must be completed before it's ready to be installed. Pre-cut glass is shipped to the construction site to be glazed into our system after the metal has been installed. Most stick built systems are off-the-shelf products therefore making their material costs relatively low.

Stick-built systems are preferred by some architects based off their aesthetic qualities. Stick-built systems are often revered as being more traditional, giving buildings a more classic look and feel.

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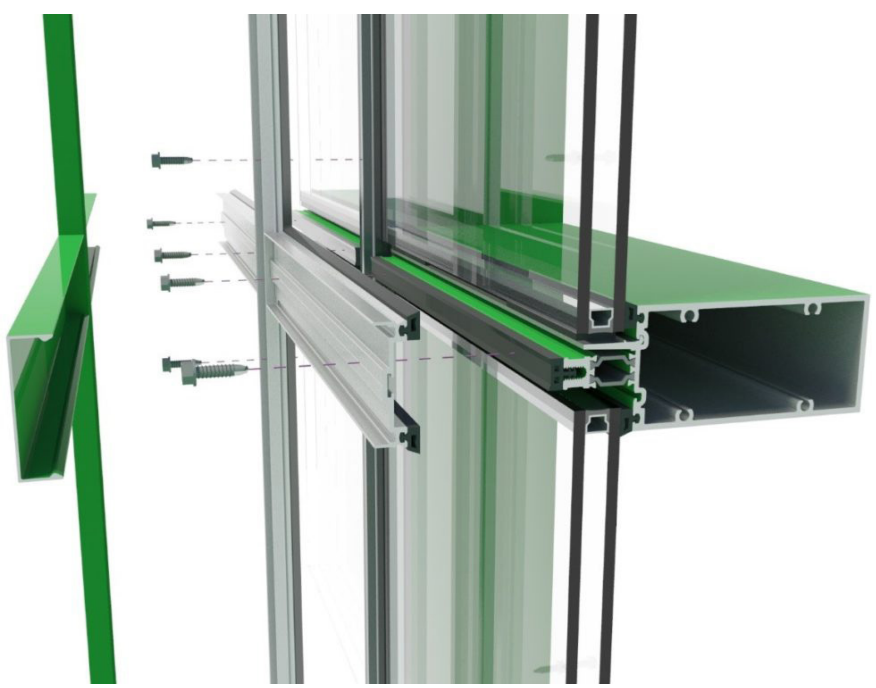
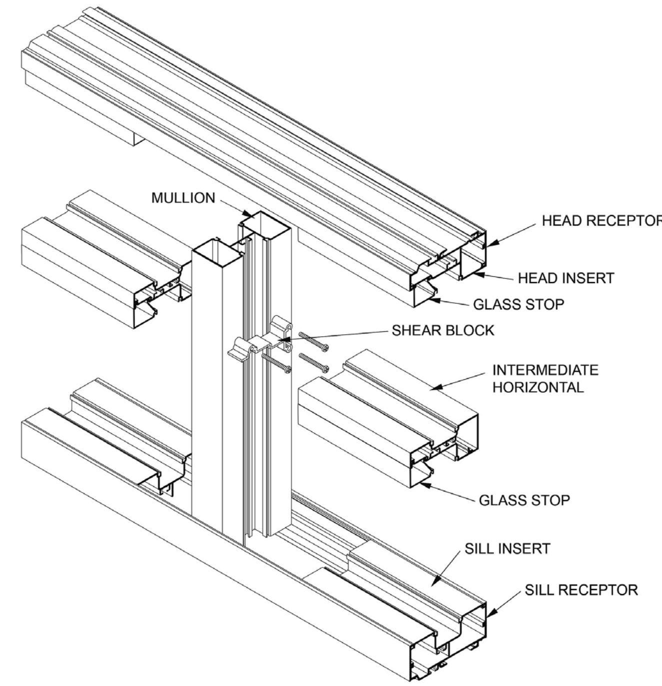


Glazed
Glazing infill set from the exterior of the building.

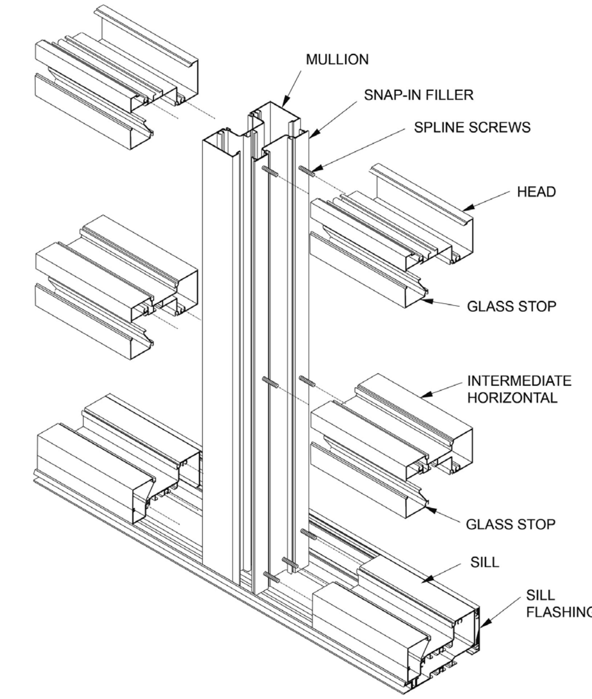
Setting
Placement of lites or panels in sash or frames. Also action of a compound as it becomes more firm after application

Shear Blocks
a.k.a. Joinery clips
An aluminum extrusion that is used to attach framing members to each other. It is typically applied to the verticals and then the horizontals are attached to them.

Pressure Plate
An exterior extrusion that is mechanically fastened to hold the glass in place in curtain wall applications.



The Shear Block system of fabrication allows a frame to be preassembled as a single unit. Horizontals are attached to the verticals with shear



The split vertical in the Screw Spline system allows a frame to be installed from unitized assemblies. Screws are driven through the back of the verticals into splines extruded in the horizontal framing members. The Individual units are then snapped together to form a complete frame.

Setting Verticals

When a Stick-built system is installed, the field will set the pre-cut vertical mullions first.

Setting Horizontals

After all of the vertical mullions have been placed, the crew will come back and install all over the horizontal members.

Setting Glass

Once the aluminum mullions are set into place, the glass is held temporarily in place with fasteners. Next, the crew would come back and complete with pressure plates and snap-on beauty caps.

Cassette System

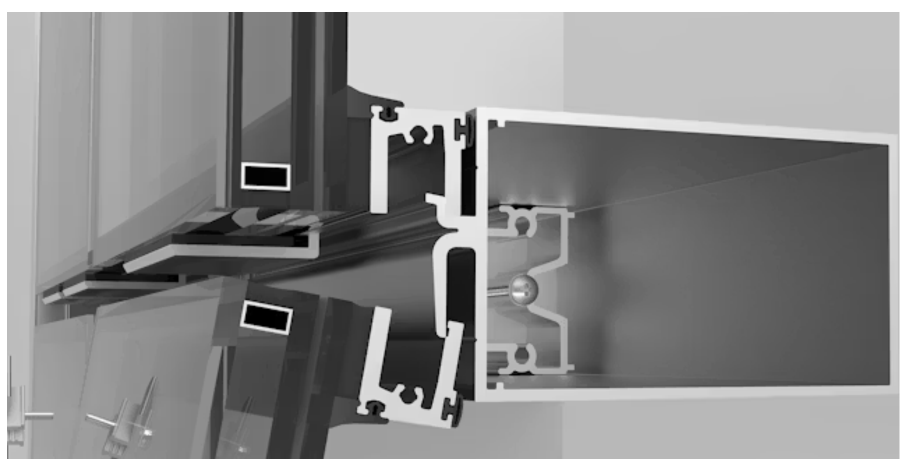
a.k.a Toggle Glazing

A cassette glazing system is a modular facade system that is designed to improve efficiency of assembling unitized facade components on construction sites. Pre-assembled frames are securely fastened between the glass units, allowing for easier installation and replacement of glass.

Gasket
A solid or semi-flexible extruded rubber profile that mechanically locks glass into the frame. Used for water, air and dust control

Glazing Spacer Tape
A compressible, adhesive foam tape applied to framing before the glass is set. Helps to set glass position.

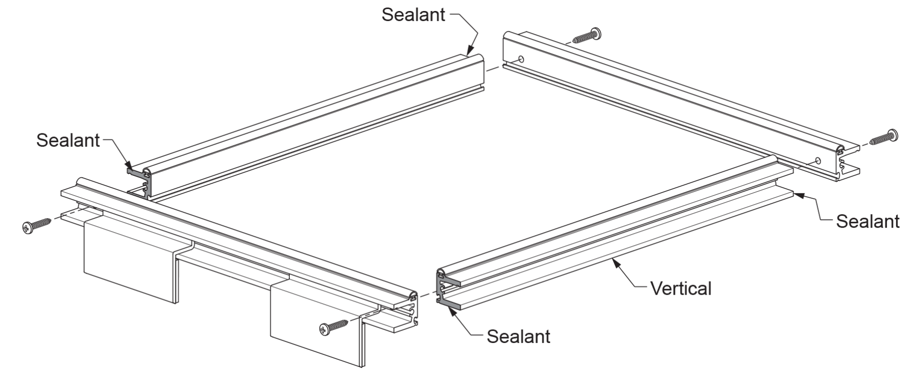
Cassette wall systems utilize sub-assemblies of major framing components and produce pre-glazed, pre-assembled glass and infill systems that can be later assembled without the use of sealants.

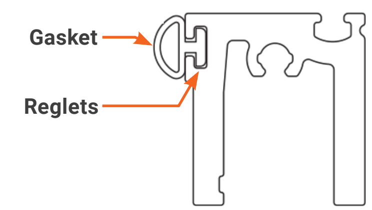


Framing is stick built in the field. Shop glazed cassettes interlock with integral adapters on the horizontals to create full width engagement top and bottom. Vertical sides are toggled to the mullions to complete the mechanical attachment in the field.

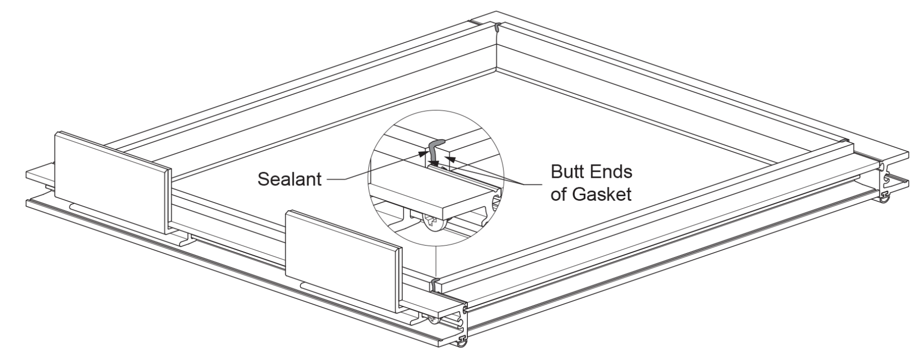
YHC 300 SSG Cassette Curtain Wall System

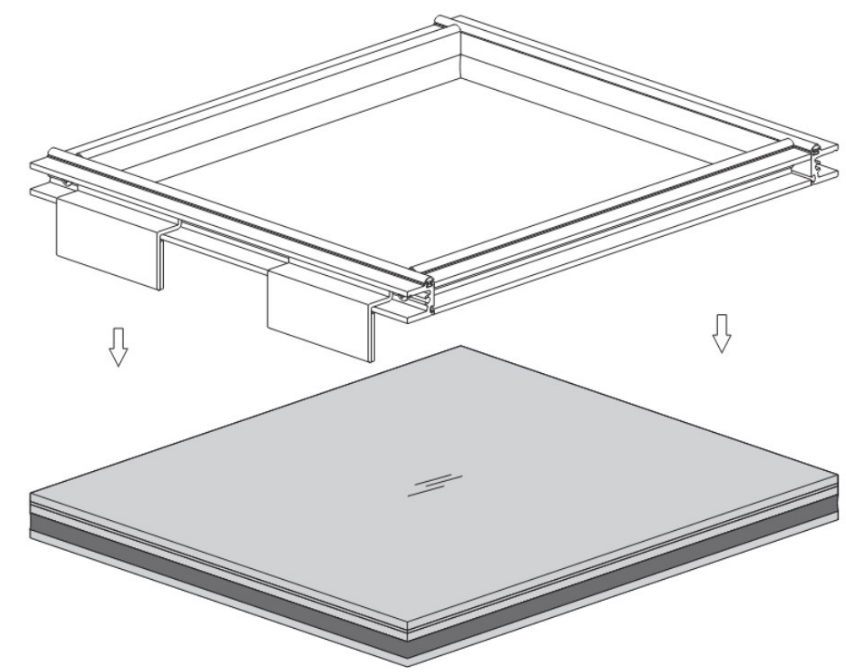
Horizontal and Vertical gaskets are installed into the reglets of the glazing cossette prior to assembling the frame. Setting block chairs are placed at 1/4 points or 1/8 points depending on glass weight. Silicone sealant is applied to both ends of vertical extrusions. The casette unit is assembled with fasteners through holes at the ends of horizontals into the splines of the verticals.





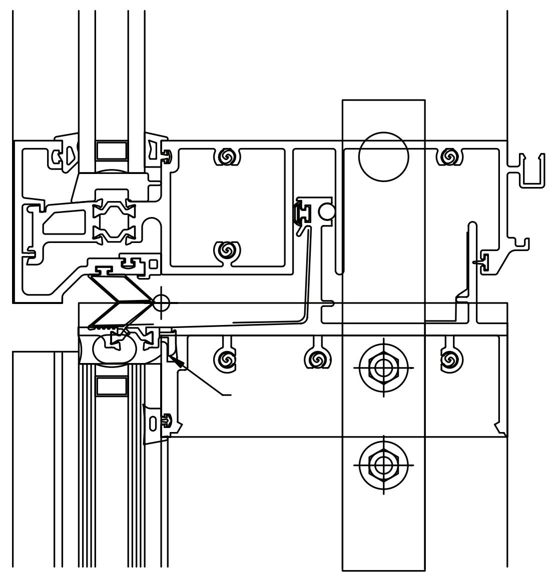
Once the cassette unit is assembled, glazing spacer tape needs to be installed on the exterior face of the unit.



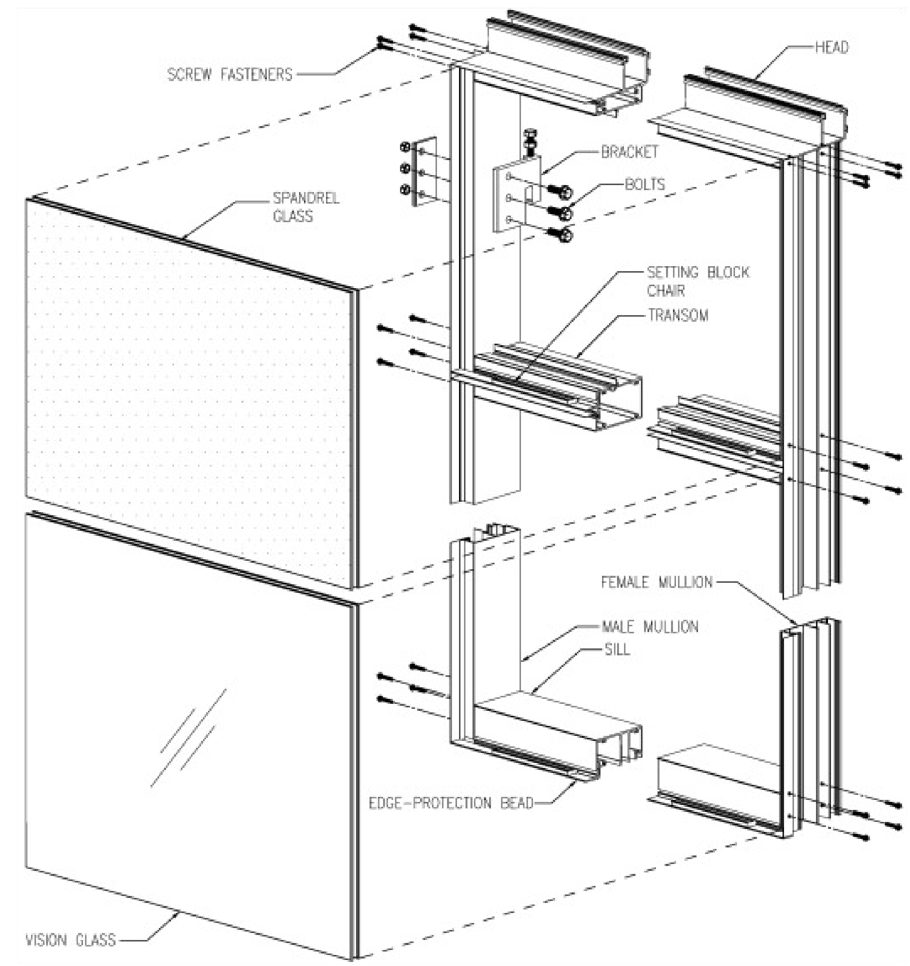


Unitized System

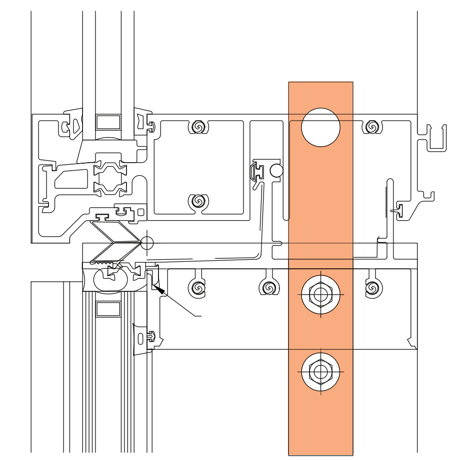
Unitized window systems are prefabricated within a controlled factory environment and then shipped to the field for installation. Unitized systems are pre-assembled into modules, also called units, transported to the field on pallets and installed directly on-site. Each unit is hoisted and installed around the building from the first floor upwards, from right to left. The unit still requires all the work required to make the system waterproof, but this occurs in a controlled factory setting and not in the field.



Since these units are stacking on top of one another, they have a stack joint between the two in order for the system to remain waterproof and to allow for the expected movement of the building's slabs.



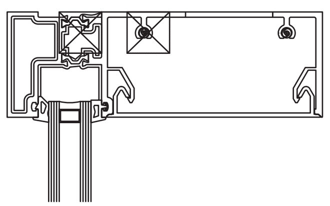
Unitized systems have bayonets attached to each vertical component , allowing a crane to pick it up by these points and hoisting it into position. These bayonets also help align the units one on top of another at a curtain wall and translate most of the wind load at the stack joint. Unitized systems are Walters & Wolf's preference because they are safer, cost effective and the control over the quality of the end product is higher.



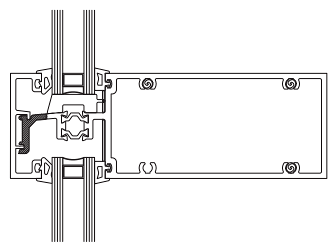
Palletization
When shipping units to the field, they are typically grouped them together in packs of 4-6 units bundled together on wooden pallets.

Unit Makeup

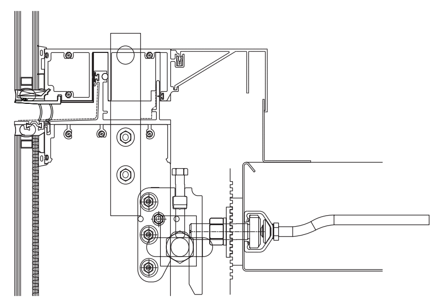
1. Head
Top member of the wall, it can have a parapet cap over the top or uses a sealant joint to perimeter materials. Each unit has a head.



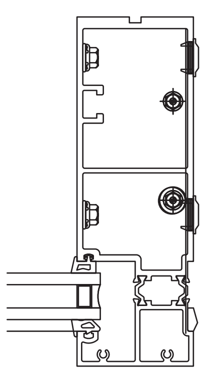
2. Horizontal
Horizontal framing member that attaches to the vertical member on each side. There can be various sizes, types and quantities of horizontals within a unit.



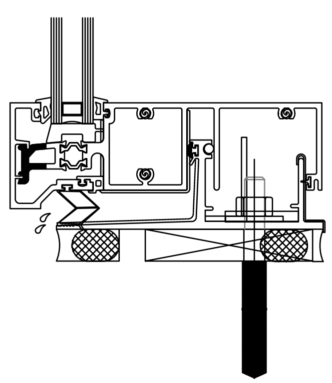
3. Stack Joint
Made up of a unit head and a unit sill. This is the joint where the two units meet and stack on top of each other.



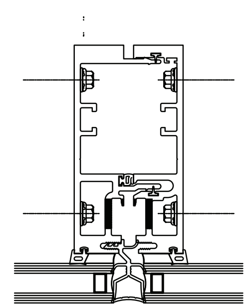
4. Jamb
The vertical member where a curtain wall starts or ends. Jamb units mate with a unit on one side.

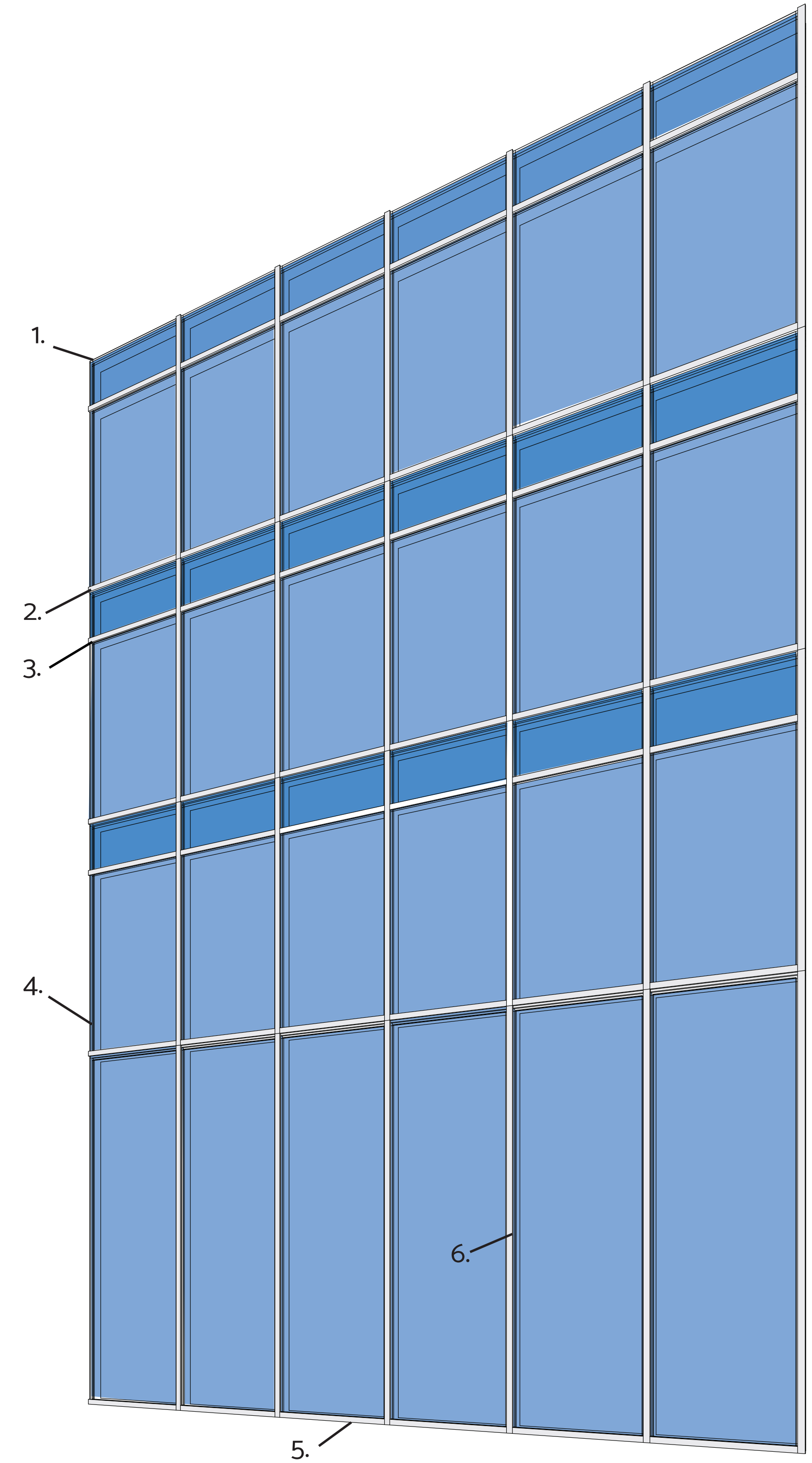


5. Sill & Sill Track
Field use sill tracks are installed first under the sill. The sill is the framing member at the bottom of a unit or wall. Each unit has a sill.



6. Vertical
Made up of two separate units. Each unit has a mullion half that mates with another half on the next unit.





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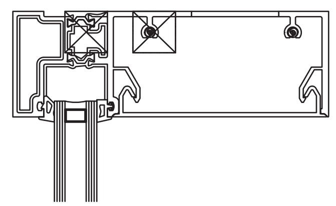

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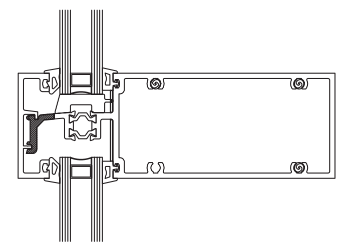

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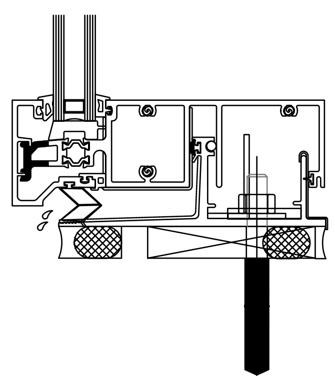

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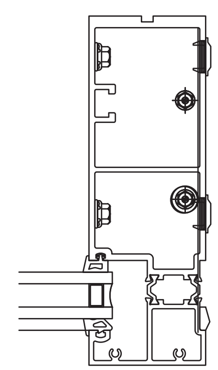
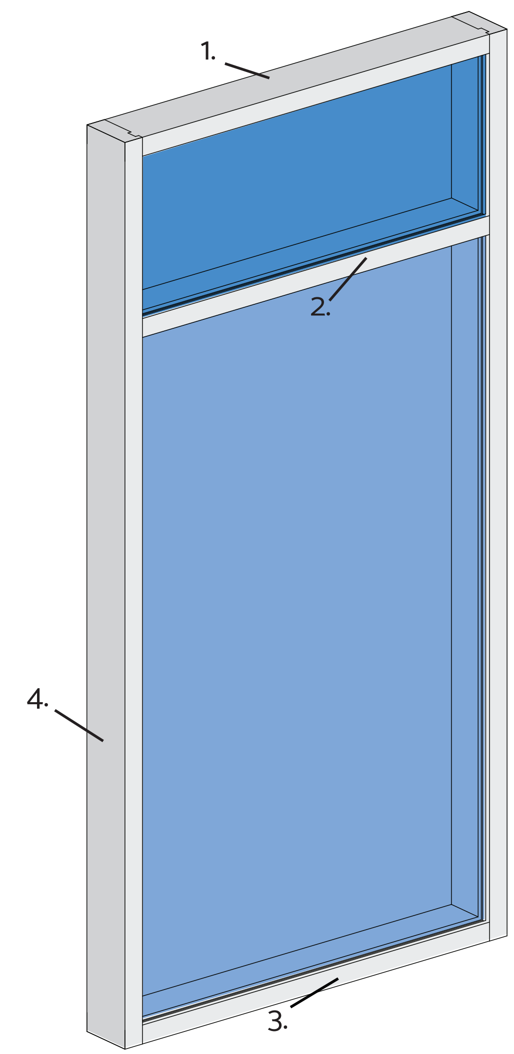


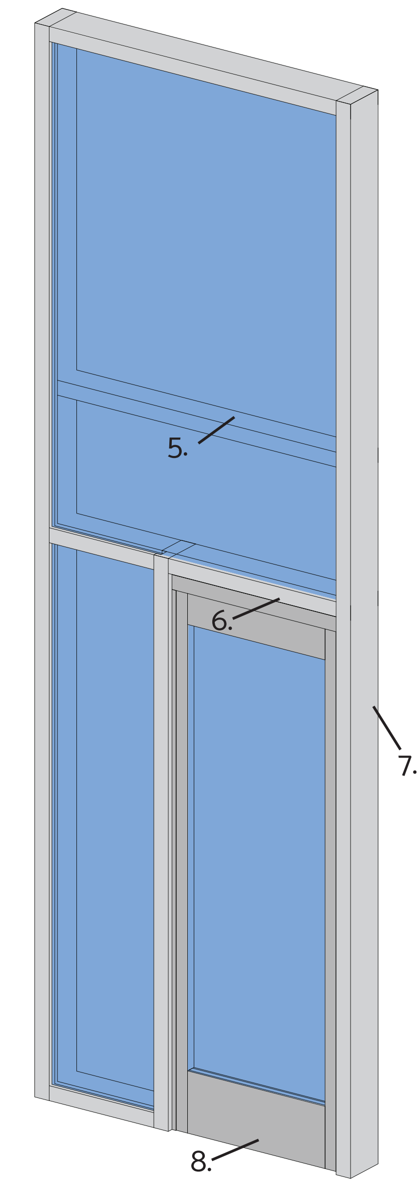
5. Kiss Mullion
This is an aluminum extrusion that runs behind a lite of glass. This piece does not break the glass into two, but rests behind the glass for visual or insulation purposes.

6. Door Header
The top condition on a door opening.

7. Door Jamb
The left or right edge of a door opening.

8. Door Threshold
The bottom condition of a door opening.



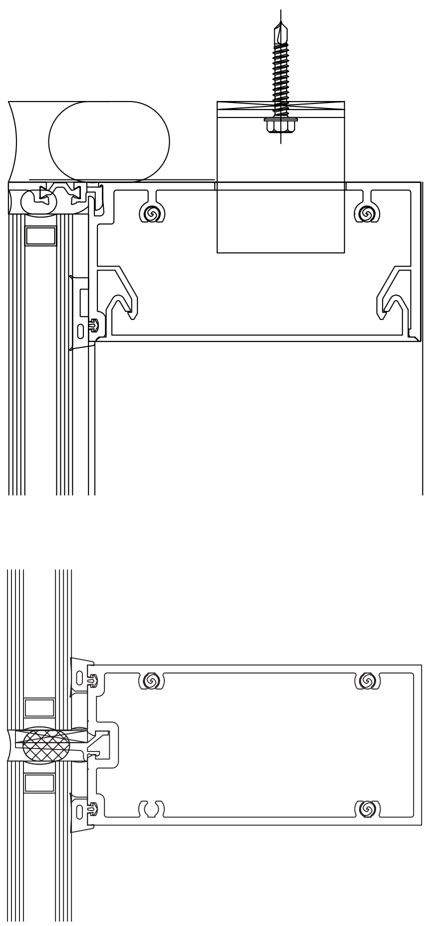


Captured Vs Inviso

Structurally Glazed

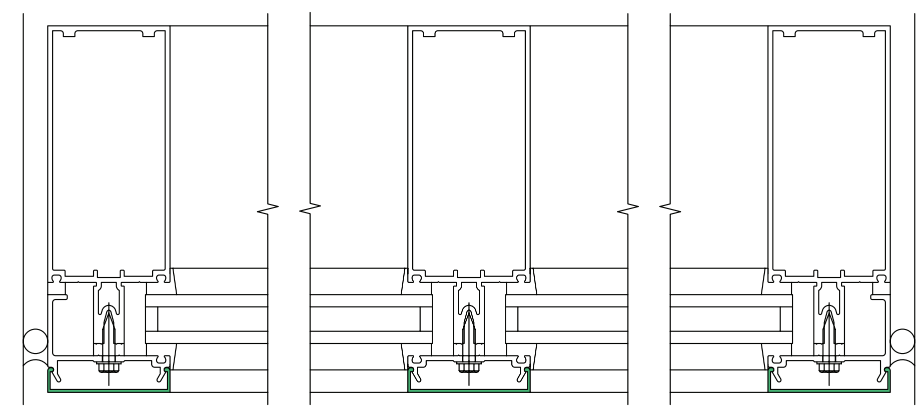
a.k.a inviso

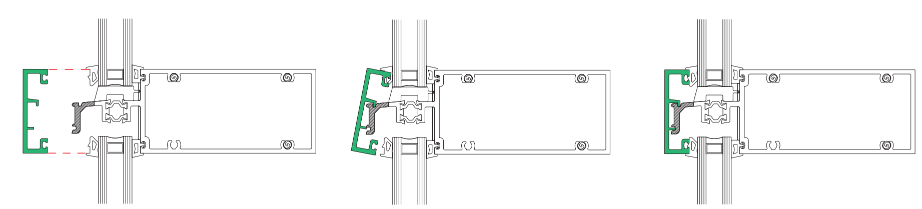
The edges of the glass are anchored to the window frame without any metal cover the edge of the glass. The full perimeter of the glass is visible, giving the illusion that the glass is free standing.

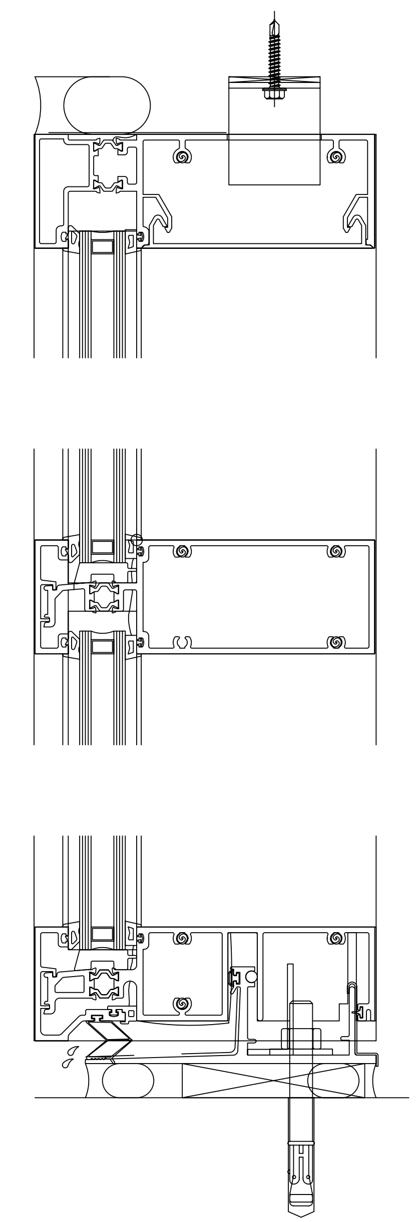


Captured

When the edges of the glass are covered by a metal cover. The glass is tucked inside of a glass poking, creating a metal frame around the glass.







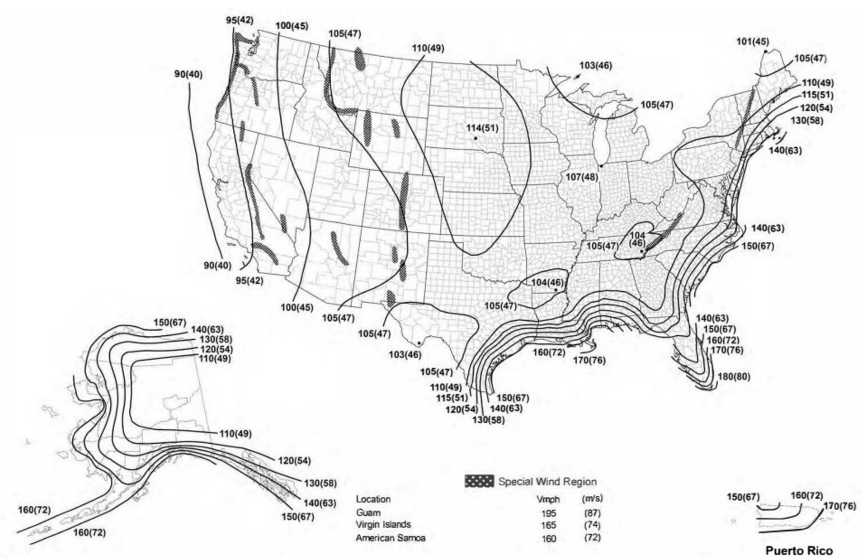
CHAPTER 3

Engineering Glazing Systems

Wind load Information

The basic wind speed in the building code comes from decades of weather data and represents a rare 3-second gust with about a 7% chance of being exceeded over a building's life. It's not a typical wind — it's a safety benchmark."

The American Society of Civil Engineers (ASCE) represents more than 150,000 members of the civil engineering profession in 177 countries. Founded in 1852, ASCE is the nation's oldest engineering society. ASCE 7-16 is the most current set of guidelines that are used in the design of structures for different loading environments.



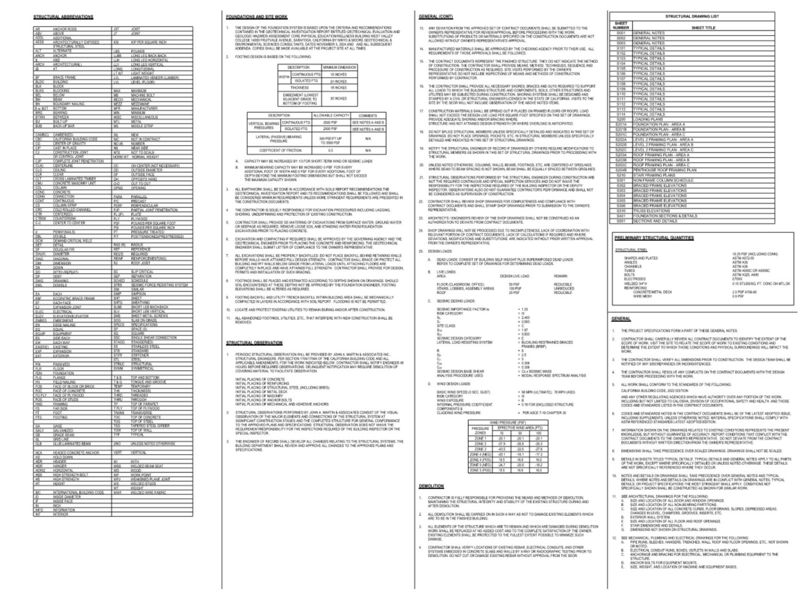
Example of ASCE 7-16 Risk Category II Basic Wind Speed

Information regarding building codes and expected wind loads can be found within the specifications or structural general notes section of a project.

D. WIND DESIGN LOADS:

BASIC WIND SPEED (3 SEC. GUST) = 98 MPH (ULTIMATE); 76 MPH (ASD)
RISK CATEGORY = III
WIND EXPOSURE = B
INTERNAL PRESSURE COEFFICIENT = 0.18 FOR ENCLOSED STRUCTURE
COMPONENTS &
CLADDING WIND PRESSURE = PER ASCE 7-16 CHAPTER 30

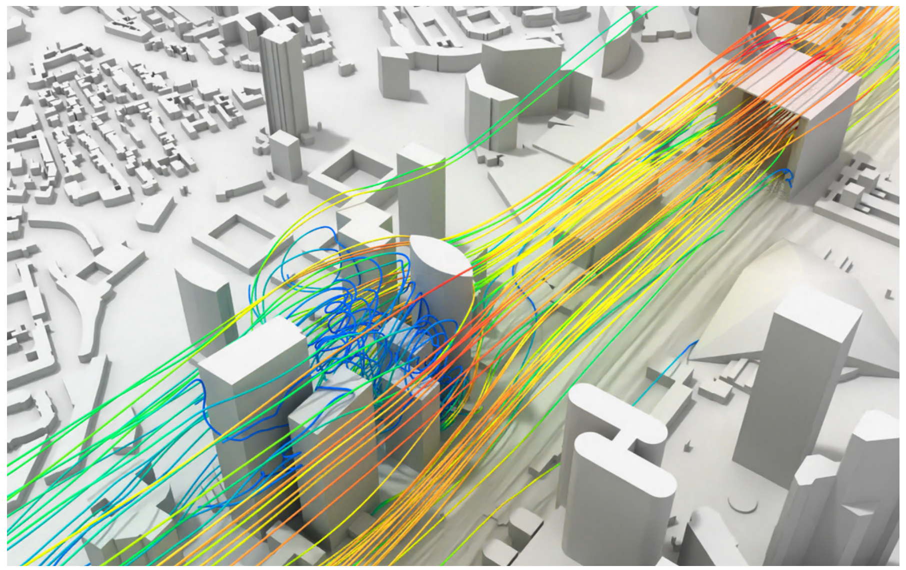
WIND PRESSURE (PSF)			
PRESSURE ZONES	EFFECTIVE WIND AREA (FT2)		
	10	50	100
ZONE 1	-20.1	-20.1	-20.1
ZONE 2	-27.9	-26.8	-26.3
ZONE 3	-43.5	-32.6	-27.9
ZONE 4 (NEG)	-20.1	-18.1	-17.3
ZONE 4 (POS)	18.5	16.6	16.0
ZONE 5 (NEG)	-24.7	-20.9	-19.2
ZONE 5 (POS)	18.5	16.6	16.0

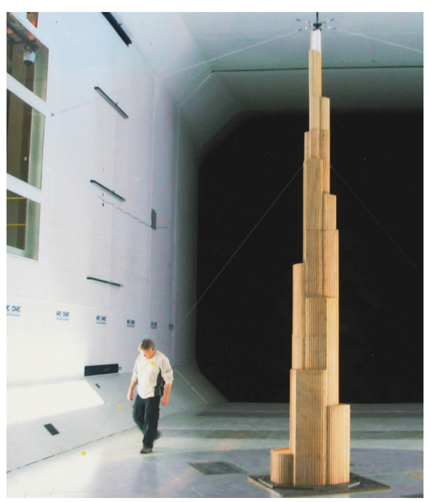


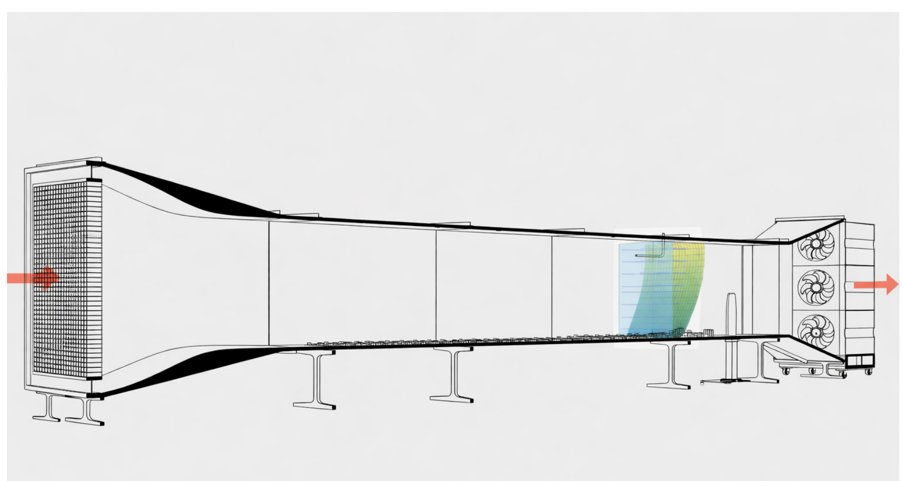
Wind Loads

Wind loads are the primary forces affecting curtain wall systems.

A wind load is a force placed on the exterior structure of all buildings. The force of the wind can cause structures to bend, twist or vibrate. We must consider wind loads first and foremost when designing a glazing system. Wind blowing on a building would like to travel in a straight path. Since there is a building obstructing its path, the wind will hit the building, then force itself around the building to continue its trajectory. This causes a positive pressure to be asserted onto the side of the building the wind is hitting and a negative force on the sides and back of the building.







Wind tunnel studies can be done on specific sites and buildings to determine what the exact conditions on the building. Typically the wind tunnel study will reduce the load that is expected from the code.

Pressure Coefficients
Pressure coefficients are values that represent the pressures on a building's exterior skin caused by the wind. The number represented varies based off wind direction, the building's location and its overall shape.

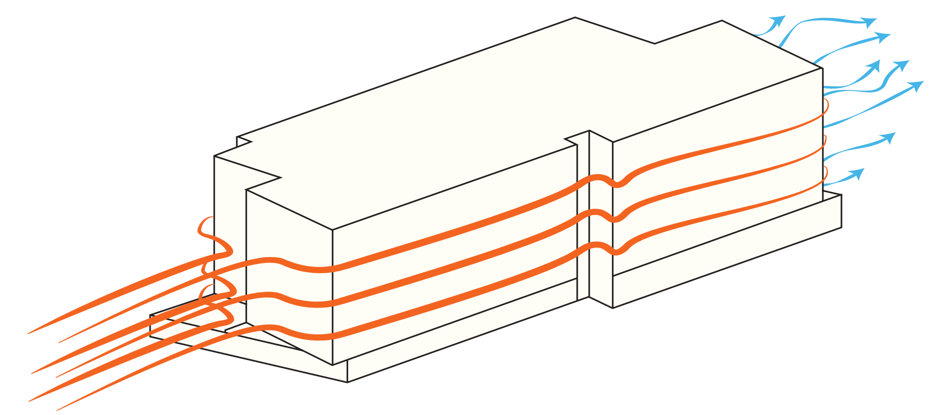
Wind Pressure vs. Suction

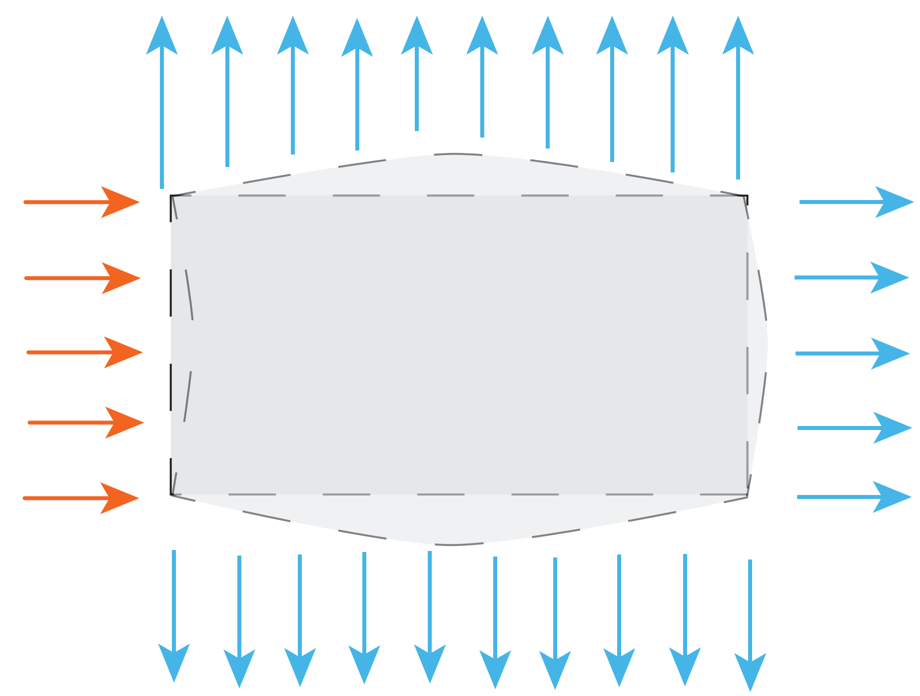
Wind pressure refers to the force exerted by the wind in the direction of the wind flow, pushing against the building's surface. On the other hand, suction or negative pressure refers to the force pulling the building in the opposite direction of the wind.

Pressure exerts a positive force onto left side of building, trying to push the window system inwards.

The positive pressure is always equal to the negative pressure exerted on the other side.

Pressure exerts a negative force onto this opposite side of the building, trying to push the window system outwards.





The backside of our building experiences suction, while the force on the opposite end is experiencing pressure.

Risk Category

The International Building Code (IBC) divided risk categories into four levels: Occupancy Category I, II, III, IV.

The risk category assigned to a building depends on its intended use and the number of people who are expected to occupy the building at any given time. Risk categories are assigned based off the potential hazard to life if the structure were to fail. Higher risked buildings need to have a higher design criteria because they are essential to community services if an emergency were to happen. Risk Category determines load factor for the building itself. The load factor is then applied to the basic wind load to ensure that the calculations are adjusted to account for the importance or risk of the building.
To perform our vertical deflection analysis, we use the risk category wind speed multiplier associated with whatever category our building falls within. Risk category is typically provided in the specification section of our project.

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent low risk to human life in the event of failure	I
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures, the failure of which could pose a substantial risk to human life	III
Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure	
Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released[a]	
Buildings and other structures designated as essential facilities	IV
Buildings and other structures, the failure of which could pose a substantial hazard to the community	
Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released[a]	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures	

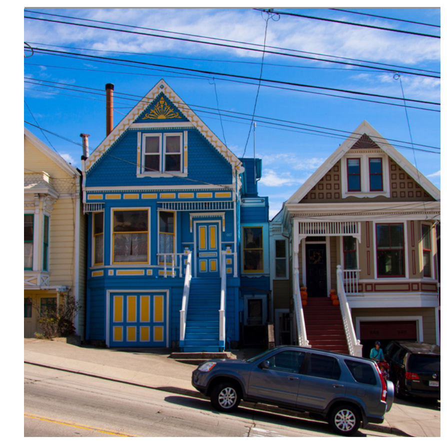
"Risk Category of Buildings and Other Structures" is located in IBC, chapter 16, section 1604.5

Risk Category 1

Lowest hazard to life since they have few or no human occupants. This could include agricultural facilities or minor storage facilities.

Risk Category 2

Standard occupancy within these buildings. Most buildings are considered a risk category 2.



Risk Category 3

Structures with high numbers of occupants and overall larger buildings. This can include public assemblies such as schools or colleges.

Risk Category 4

Essential structures to a community. These can include: hospitals, fire stations, and emergency vehicle garages.

A risk category 1 building, with a load factor of 1.15 would mean that the basic wind load on the building would be multiplied by 1.15 to account for the risk associated with the building.

Risk Category I : .87
Risk Category II: 1.0
Risk Category III: 1.15

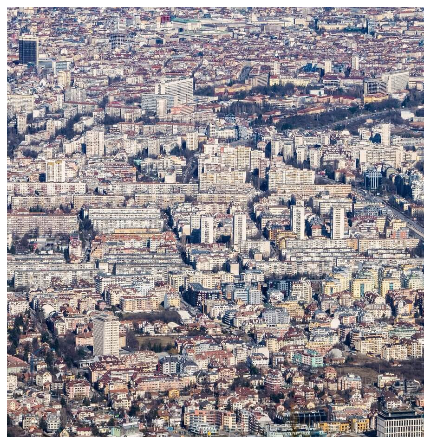
Exposure Category

While risk category categorizes a building based off its occupancy and intended use, exposure category aims to categorize buildings by their surrounding terrain. Exposure categories take into account the vegetation, structures and topography of the are surrounding the proposed building. A building's exposure category is used to determine how a building's surroundings affect the wind speed that the building will be expose to.

If a building is located in a flat, open space (exposure D), we expect the wind loads to be higher than if it was in a dense urban environment because there's nothing to block the wind from hitting the structure

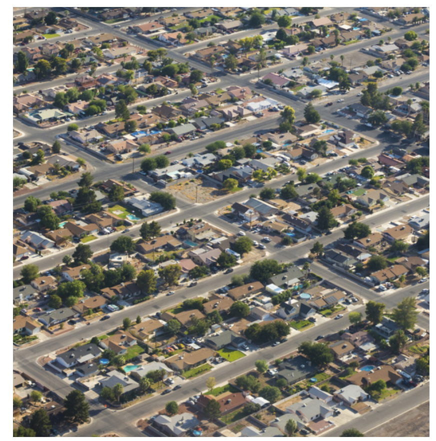
Exposure A

Dense urban environment in which 50% more of the buildings are taller than 70 feet.



Exposure B

Urban or suburban environment with closely spaced homes.



Exposure C

Open terrain with scattered obstructions less than 30 feet.

Exposure D

Flat, unobstructed areas like shorelines.

Corner Zones

When the wind whips around the corners of the building it creates a vortex causing greater positive and negative wind load pressures at the corner zones. Corner zones must be examined to determine if steel reinforcement will be used to strengthen the mullions, or an increase in system size is necessary.

To generate a negative pressure in the corner zone, the wind must first build up pressure on one side of the building and then release into the void on the other side. This release creates a vortex effect, resulting in suction forces exerted on one face of the building that can surpass the positive wind load pressures. However, in the case of small returns on a building where there is limited space for the wind to build up and be released around the corner, the increased negative loads may not be experienced.

The negative wind load pressure at corner zones is always going to be higher than the positive loads.

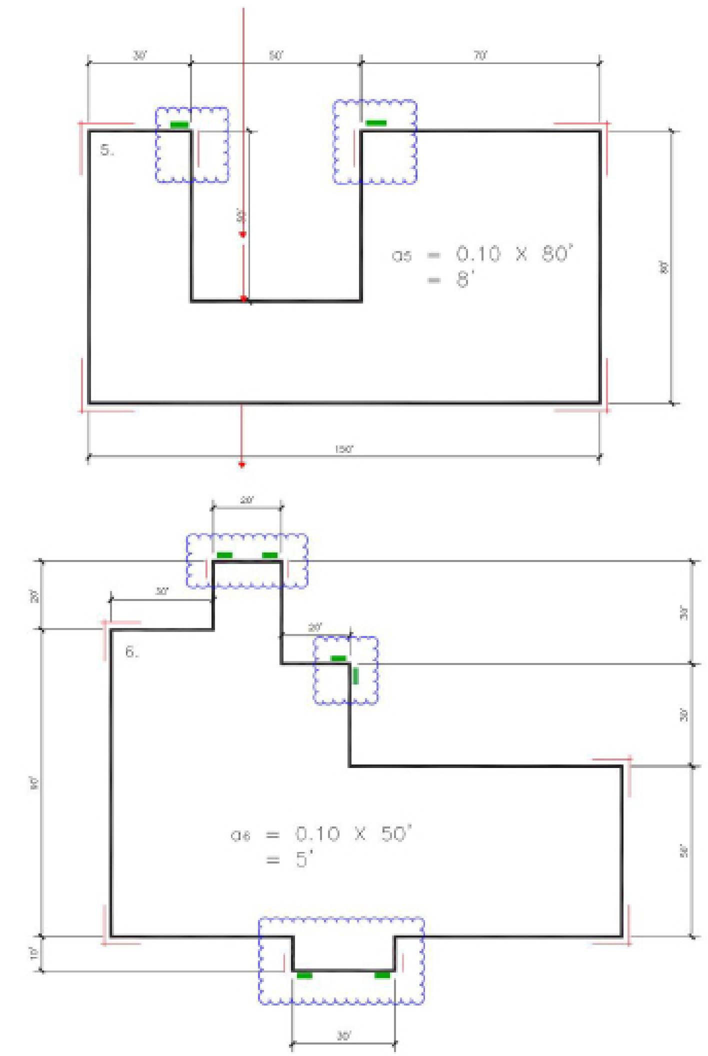
Mean Roof Height
Where the highest slab on the building is located.

Least Building Width
The shortest side of the building looking at it in plan view.

Corner Zones
The areas where the building's exterior

Corner Zones Distance = Least building Width x 10%.

Least Building Width (115 ft) x .10 = Corner Zone Distance (11.5 ft)



You use elevations and floor-plans to determine the locations of the corner zones.

Tributary Area

The tributary area of a curtain wall refers to the specific portion of the wall that transfers its load onto a supporting element.

We use the elevation's tributary area to assess how much of the wind force is transmitted to the anchors and to determine if the vertical mullions might deflect excessively. By analyzing the expected wind loads on the building, we can apply this information to different areas of the curtain wall to ensure the anchors are capable of withstanding the loads and to determine the appropriate size and strength of the curtain wall system. This analysis helps us design a robust and safe curtain wall system that can handle the anticipated loads and maintain structural integrity.

Tributary Area for Anchors

The larger the tributary area of a curtain wall, the higher the loads that will be imposed upon that anchor. By accurately determining the tributary areas, engineers can select the appropriate type of anchors, size them properly, and ensure that they are securely fastened to the building's structure

Curtain wall anchors are connectors that help fasten the system to the structure of the building. Wind hits the glass, then the force travels to the vertical mullions, and then to the anchor. We must ensure the anchors we use are strong enough to handle these forces.

On any given unit, the anchor at the head of the unit is taking the wind load from the top half of the module, while the bottom anchors are experiencing loads from the bottom half of the glass. This is how we know which sort of hook lugs and anchors we need to use at each area. We use the wind loads expected based off our previous analysis (building's location, exposure category, risk category and corner zone analysis) and apply it to the tributary area and make sure that our anchors can withstand the loads.

Tributary Area for Mullions

On a vertical mullion, as we consider it's deflection, it will be half of the width of the bay on either side. This is the area where the wind load is effecting the glass, translating the wind load onto the mullions. Since the tributary area is related to the spacing between vertical and horizontal mullions, it's important to analyse these locations to determine if the wind loads imposed on these areas will make our vertical mullions over deflect, past the allowed deflection for any given project.

Vertical Mullion Deflection

Vertical mullion deflection refers to the amount of bending or deformation that occurs in a vertical support member, known as a mullion, in a building or structure. There will always be an amount of elasticity within our window system, we refer to this as allowable deflection. Allowable deflection is calculated and designed to prevent the building from excessive deflection that may cause discomfort to the occupants or damage to the building. The vertical would bend inward under a positive wind load, and outward under a negative window load at corner zones. If we discover our tributary areas are too large for a given system, we are able to bulk up our system so it is able to resist the stronger loads imposed on it.

Deflection
The amount of bending movement of any part of a structural member under design loads.

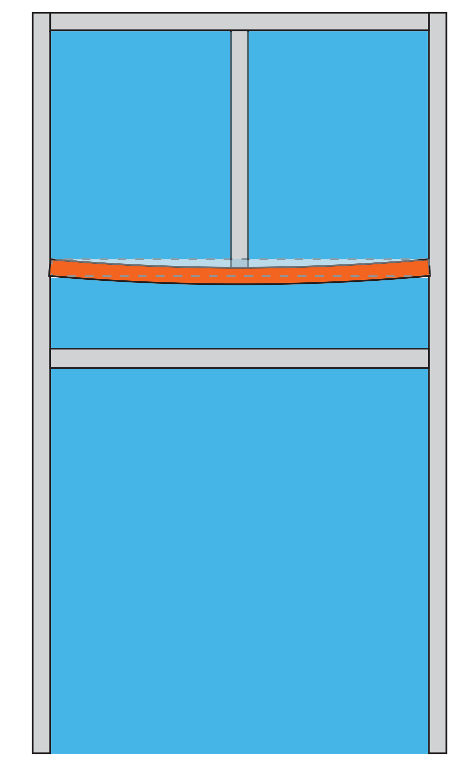
I-values
Refers to a physical property of any shape. It's used to determine whether a shape will be sufficient to withstand the loads applied to it. Higher is stronger.

The amount of deflection is determined by the strength and stiffness of the mullion material, as well as the size and shape of the mullion.

Horizontal Mullion Deflection

In order to determine if your horizontal members will be rigid enough to not over-deflect due to the weight of the glass it's supporting, you must first find the largest piece of glass within your project.

Maximum dead load deflection allowed is L/360 or 1/8" max, where "L" = Length of Aluminum Member. In the case of a vertical mullion spanning 10'-0", the allowable deflection would be 120" divided by 360, or .33 inches.



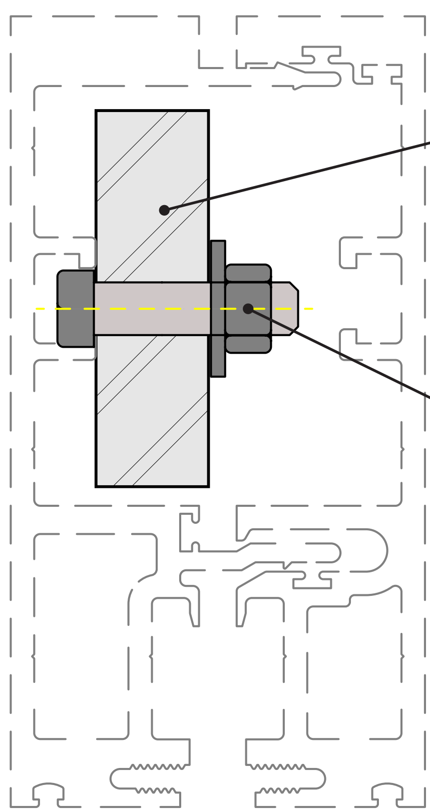
If you have a vertical mullion that is resting on top of your horizontal, this may cause the horizontal to over-deflect. Sometimes you will have to steel reinforce

Steel Reinforcement

Sometimes at corner zone conditions, since the loads can be significantly higher, we reinforce our mullions with tube steel at the corner locations. This allows us to maintain a smaller system size throughout the project, while ensuring that our verticals pass deflection tests at the corners. If there is no steel reinforcing required at corner zones, it is safe to assume that no reinforcement is required on typical zones.

Reinforce
Any material that is added to lend additional structural support. This is typically a steel extrusion.

Aluminum alloys typically have lower yield strengths compared to steel alloys, which is why steel is used as reinforcement. For any given profile, the i-value of steel will be 2.9 times greater than aluminum.



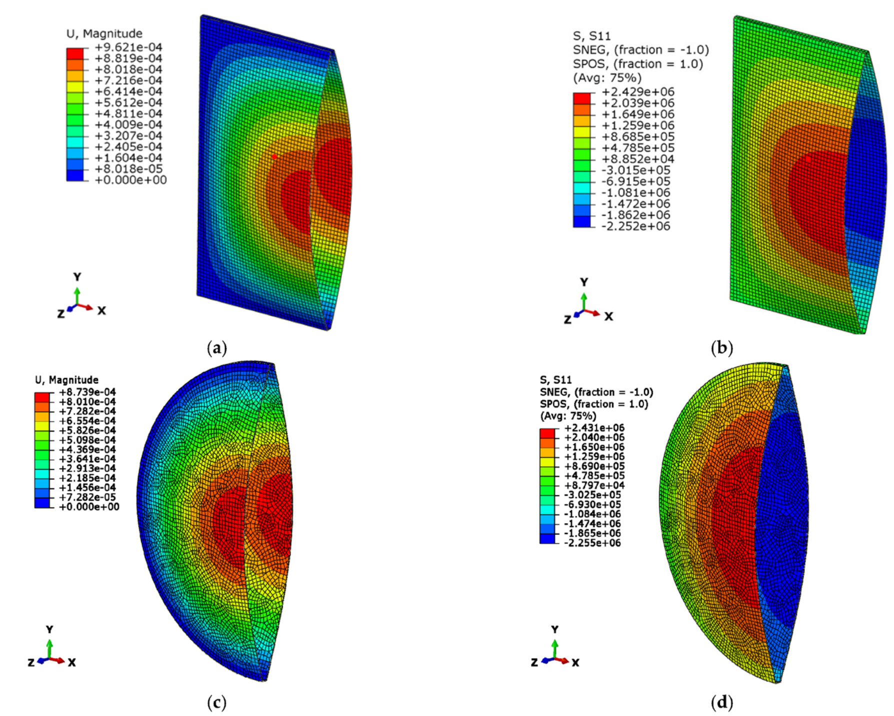
Steel Bar
Centered in vertical span.

Hex Bolt
3 total screws, two 6" from each end of the steel and one in the center.

Center of Glass Deflection

Center of glass deflection is the amount of bending movement at the center of a lite of glass under an applied load. Center of glass deflection must be considered in design because excessive deflection can cause the glass to break or crack. Thermal stress is the main cause of center of glass deflection. Because the outer edges of the glass will heat up faster than the center, the glass has a higher chance of breaking due to this temperature differential. Glass manufacturers don't want the center of the glass to deflect more than ¾" of an inch. .

Small, thick pieces of glass are less likely to deflect than larger, thinner sheets of glass.



Factors that can affect center of glass deflection include the thickness of the glass, the size of the panel, and the type and amount of load applied to the glass.

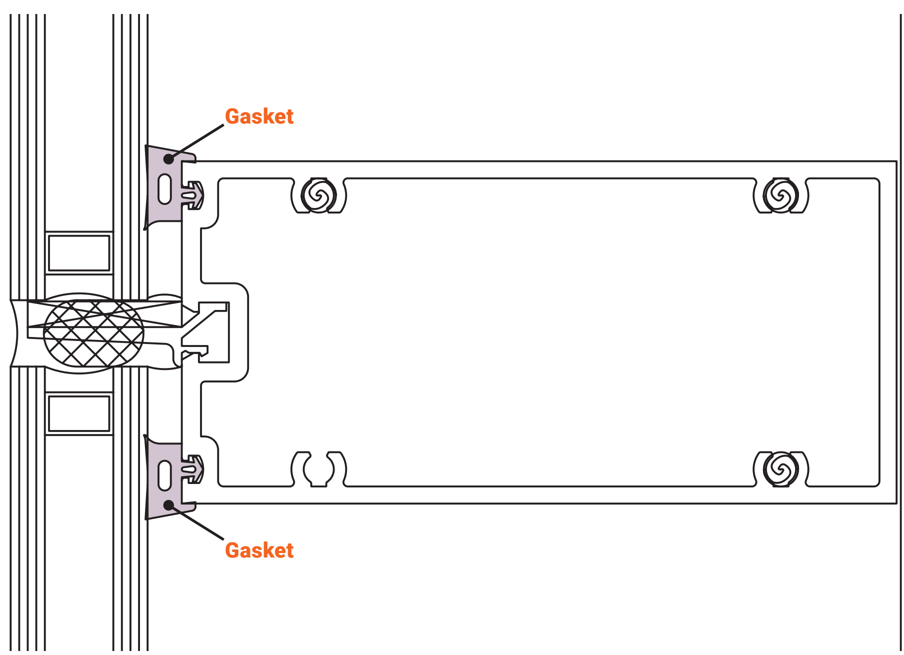
When a large lite of glass is over deflecting, one possible solution would be to place another horizontal within the span in order to breakup the large lite of glass. Another option to decrease the likelihood of over deflecting would be to use laminated glass. Due to the laminates PVB interlayer, the thermal stress is distributed more evenly across the surface; creating a better resilience to center of glass deflection compared to annealed or tempered glass.

Thermal Expansion and Contraction

When designing a curtain wall, it is essential that we bear in mind the constant thermal expansion and contraction of the parts and pieces within the system. Due to fluctuating temperatures in the environment, thermal expansion that can cause stress on glass, joints and anchors. Curtain wall systems are designed for expansion and contraction between temperature ranges from 1 to 180 degrees Fahrenheit. In curtain wall systems, the risk of thermal expansion must be carefully considered for three main components: the glass panels, the aluminum frames, and the joints.

Glass

Glass is a major component of curtain walls, and it is known for its relatively low coefficient of thermal expansion. Although glass expands and contracts due to thermal changes less than aluminum, thermal expansion still occurs as the temperature of the glass increases. When the temperature of glass increases, the molecules within the glass absorb energy and begin to move more quickly, causing the glass to expand. This expansion can cause the glass to become larger in all directions, including length, width, and thickness. An ordinary piece of float glass will expand roughly .03" at 212 F.



In order to manage the inevitable expansion of the glass, a gasket is placed between the frame and our insulated glass to allow the glass to expand into the pocket slightly. This ensures that the glass does not shatter when it's expanding and contracting.

Aluminum

Alloyed aluminum is relatively lightweight, recyclable, durable and strong; but it has a relatively high coefficient of expansion. Meaning the mullions within a curtain wall will expand and contract at a faster rate than the glass does. A high coefficient of expansion means that the aluminum is susceptible to elastic changes due to weather conditions. Considering that aluminum and glass expand and contract at different rates, stress is created at the points where they are connected. Over time, this will results in issues such as sealant failure, water leakage and damage to the curtain wall.

Coefficient of Thermal Expansion
A measure of how much a material expands or contracts in response to a change in temperature.

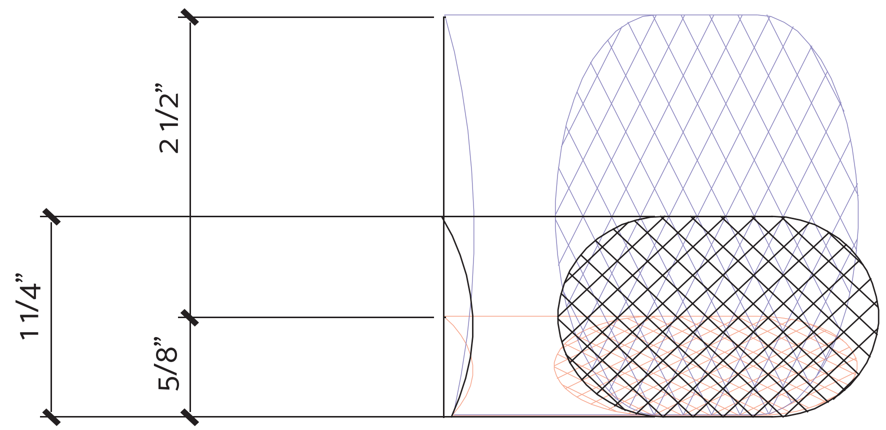
Approximate Coefficients of Thermal Expansion at 20°C		
Material	**α (10^{-6}/°C)**	**β (10^{-6}/°C)**
Aluminum	23	69
Concrete	12	36
Diamond	1	3
Glass	9	27
Stainless Steel	17	51
Water*	69	207

As indicated in this chart, aluminum has a much higher coefficient of expansion than glass does.

Caulk Joints

Caulk is a flexible material that is used to seal gaps and joints between building materials, such as between a window frame and the surrounding wall. However, as the temperature changes, the materials that the caulk is sealing against may expand or contract at different rates. The joint can also be flexed due to changes in live load and seismic movement. This can cause the caulk to become stretched or compressed, which can lead to cracking or failure of the seal.

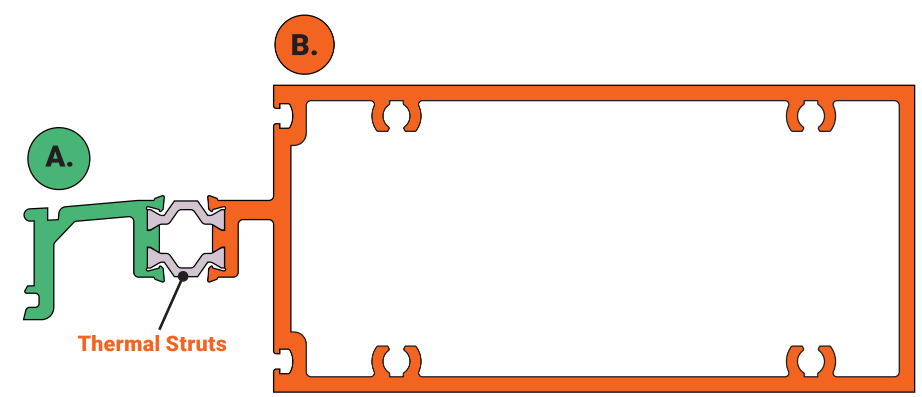
To prevent these problems, it is important to use a caulk that is specifically designed to withstand thermal expansion and contraction. This type of caulk is often referred to as "expansion joint caulk" or "elastomeric caulk." It is more flexible and can expand and contract with the building materials without cracking or failing.



Caulk joints have the ability to stretch and compress 50% in either direction. A standard 1 1/4" caulk joint should be expected to compress to 5/8" and stretch up to 2 1/2" without failure.

Thermally Broken Systems

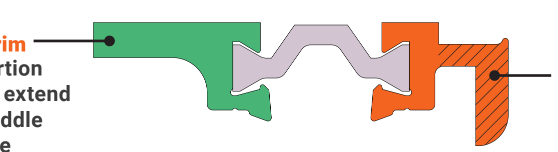
Thermal breaks of low-conductivity materials are often incorporated into façades to improve thermal performance.



Thermal Struts a.k.a iso bars

Made of hard plastic to separate metal from one another. Break between aluminum parts allows for better thermal U-Values These thermal breaks are crimped together by our vendors to hold them in place, so these two extrusions would really be considered as one.

Inviso Trim
Front portion needs to extend to the middle where the verticals meet.



This part of the trim must be notched at daylight so they sit inside of the vertical member.

Live Load and Dead Load

Dead Load

Dead Load is the dead weight of an object or structure, usually measured in pounds per square foot(psf).

Floors, walls, ceilings, columns, staircases, permanent appliances, and any fixed decoration create a static load that does not change over the life of the building. All of these factors would add up to a building's dead load. Precise calculations help ensure that a structure can support all of its components.

Design Considerations

For curtain wall design, the dead load we are most concerned with is the weight of our own unit. The choice of materials is an important consideration when designing a curtain wall system because each material will contribute to the unit's overall weight. It is important to calculate the dead load of our unit in order to ensure our anchors can hold it safely to the structure.

We must also calculate the dead load of our glass to ensure that its weight will not cause our horizontal mullions to over deflect.

1/4" Monolithic	**3.27 psf**
3/8" Monolithic	**4.9 psf**
1/2" Monolithic	**6.54 psf**
5/8" Monolithic	**8.17 psf**
3/4" Monolithic	**9.81 psf**
7/8" Monolithic	**11.45 psf**
1" Insulated	**6.54 psf**

Weight (dead load) of typical monolithic lites of glass. These would be added together based off the inboard and outboard configurations.

Live Load

Live load refers to occupational forces from occupancy and intended use. They represent transient forces that can be moved through the building or act on a particular structural element. People's estimated weights, furniture, appliances, automobiles, and movable equipment are included in live load criteria. It's important to note that dead load is not considered when you get the live load deflection. The live load is the movement after the building has been constructed.

Live load is the maximum deflection between the columns, not a constant around the entire building.

Typical live load deflection is around 3/8" to 1/2" for most buildings.

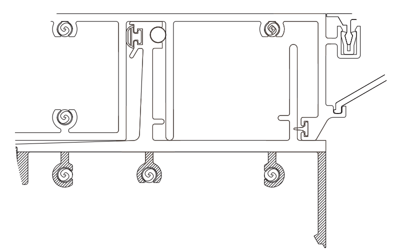
Live load must be considered because it directly effects the anticipated movement of the building's slabs, directly effecting the movement between window units. As more live load, possibly people or machinery, is added to each floor of the building the anticipated movement of the slab will increase. It is important to calculate the live load of the building to ensure we design our systems to allow for the anticipated movement between floors. While there may be a typical live load deflection for the building, it's important to note that there might be particular places on the building where the deflection is greater depending on column spacing and other variables.

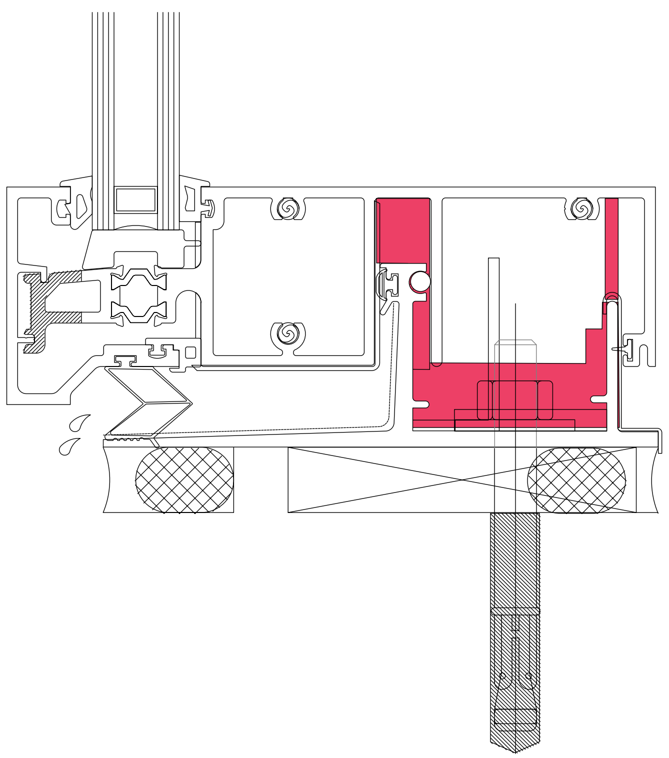
A typical live load requirement is L/360, or the span divided by 360. In the case of a beam spanning 20'-0", the allowable deflection would be 240" divided by 360, or .66 inches.

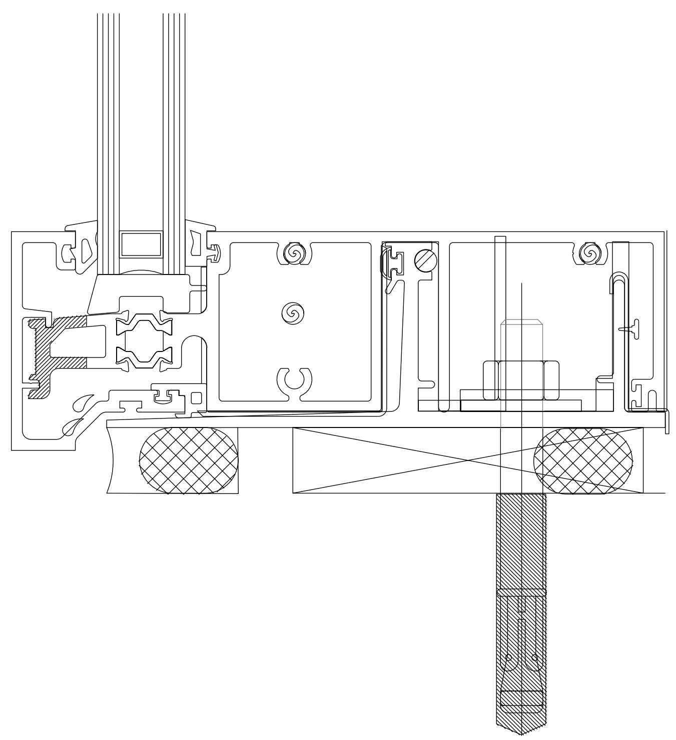
Considerations and impacts on glazing systems

In a wind loaded system, the unit is hanging above the sill track. In order to allow for movement, this space is given so that the unit above can move up and down.

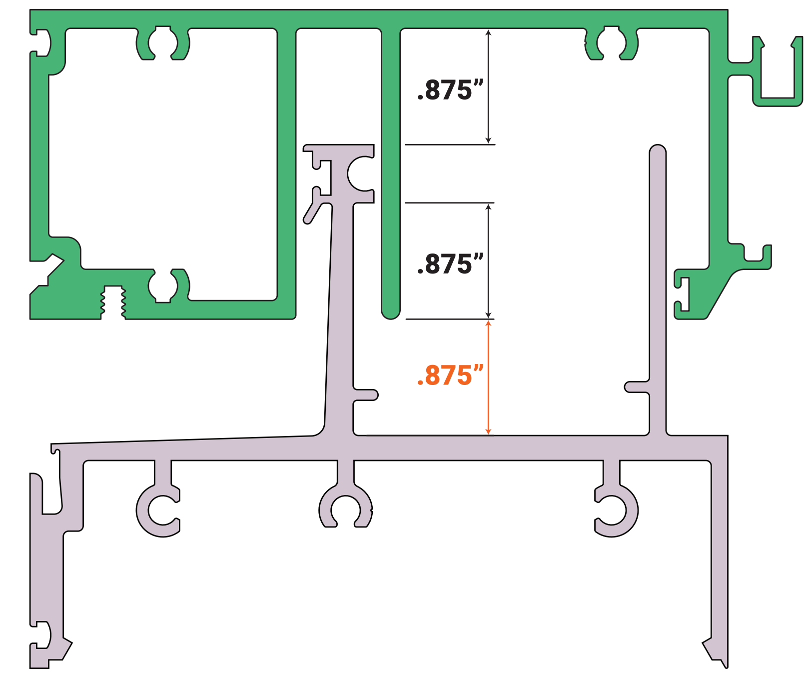
Extrusion lengths must all be equal so that nothing interferes with the Sill Track. There should be no interference with parts if the top member moves down due to the live load. This would be the maximum movement expected and the worst case scenario.



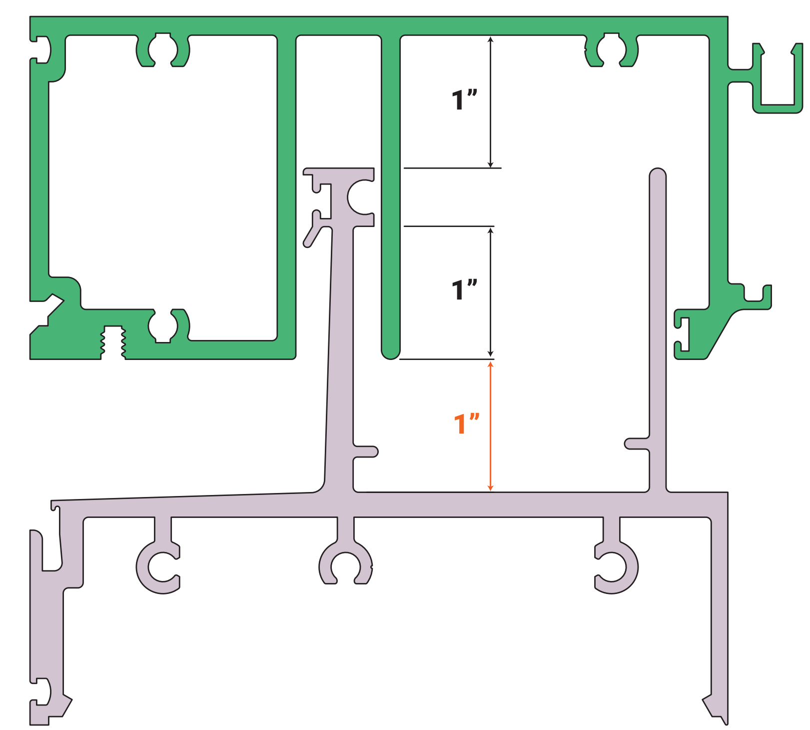




1/2" Live Load



5/8" Live Load



Water Prevention

Mitigating water from buildings is crucial to protect the structural integrity of the building, maintain a comfortable indoor environment, and prevent potential health hazards. Water infiltration and moisture accumulation can lead to various issues such as: structural damage, mold and mildew growth, interior damage and degradation of insulation.

Internal Drainage System

A curtain wall designed with an internal drainage system relies mostly on gravity to mitigate water away from the interior of the building. These systems are generally simpler to design and install compared to a pressure equalized system.

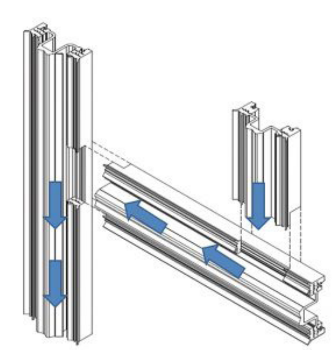
In a water-managed system, weep holes play a crucial role in draining water that enters the glazing pocket. Without weep holes, small amounts of moisture that find their way into the glazing pocket won't have a chance to completely dry out, leading to an increase in relative humidity inside the system.

To prevent minor leaks from entering the building, flashing and collection devices are used to redirect water away from the interior of the building. The system must incorporate drains and weeps in the glazing pocket, allowing any water that gets inside to be effectively drained away.

Glazing Pocket
The space or cavity in a curtain wall or window system where the glass panels are installed

Relative Humidity
A measure of the moisture content in the air relative to the maximum amount of moisture the air can hold at a specific temperature

Flashing
Material used to prevent water from entering into a building by redirecting it away from at risk areas.



Pressure Equalization

Pressure equalization typically provides the highest water resistance and air tightness to a window system. Based around the rain screen principle, pressure equalization requires the a ventilated outer wall surface. This exterior cladding promotes air movement and pressure equalization between the interior and exterior of the window to prevent water from being forced inside. This exterior is backed by drained air spaces, allowing the water to freely exit the system. On the inside faces of glass, interconnecting gaskets or wet seals within the inside face of glass serve as airtight barriers to control the environment inside the building. A pressure-equalization chamber in the glazing pocket reduces water penetration by eliminating (equalizing) the pressure difference across the rain screen. The outside face of the glass, exterior glazing materials, and the outer exposed face of the aluminum framing function as a rain screen that directs water away The pressure-equalized system is particularly effective in regions prone to heavy rainfall and strong winds

Water Barrier
A material or assembly that is used to prevent water penetration through a curtain wall.

Rain Screen Principle
A cladding system that uses an air gap between the exterior cladding and the building's structural frame to allow for drainage and ventilation of any water that penetrates the cladding.

Condensation Resistance

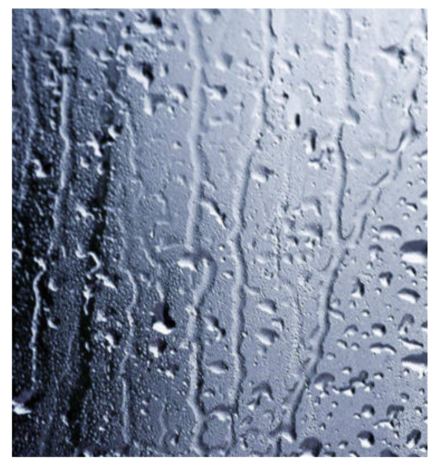
Condensation will form on glass if the temperature of the glass falls below the dew point of the air. When the outside air is filled with water vapor, and it comes into contact with the cold surface of glass, the vapor will turn into a liquid and form small droplets of water. Since insulated glass units have an air space between the two pieces of glass, they are able to greatly reduce heat transfer between panes. This means the IGU stays warmer than a typical piece of glass. Therefore, the glass is much less likely to cool the water particles surrounding it because it will be warmer. Special coatings may be applied to the glass in order to reflect heat into the room, making the surface of glass even warmer than it would typically be. This creates less chances or condensation formation on the glass.

The occurrence of condensation between the pans of insulated glass is an indication of failure; that the hermetic seal of the unit has been breached. Outside moist air infiltrates the air space and condenses on the inter pane surfaces of the glass. Water in contact with the edges of the IG unit promotes degradation of the perimeter sealants, can also result in premature seal failure and glass fogging.

Dew Point
The temperature to which air must be cooled for saturation to occur.

Condensation
Water which collects as droplets on a cold surface when humid air is in contact with it.

Hermetic Seal
Any type of sealing that makes a given object airtight



Building Movement

A glazing system must have the ability to accommodate the anticipated movement of a structure. It's important to follow the specified movement in the structural drawings to confirm that the curtain wall will not fail due to seismic activity. Aluminum glazing systems must be able to withstand the effects of story drift, twist, column shortening, long-term creep and deflection from uniformly concentrated live loads. Curtain walls must also be able to hold out against earthquakes.

Lateral Interstory Drift

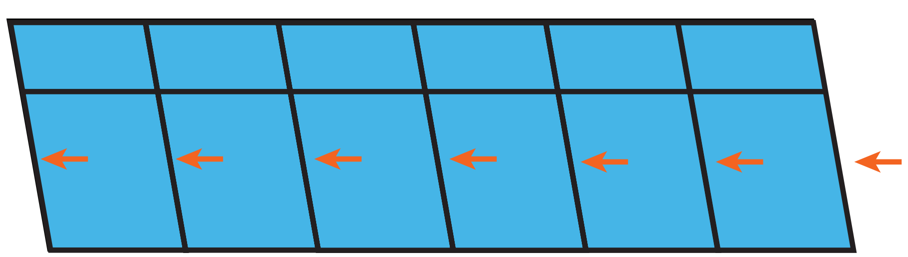
Lateral inter-story drift refers to the reaction of a structure to wind forces or a seismic event. This information is typically presented to designers in two criteria; an elastic or inelastic response. This anticipated displacement is provided by the structural engineer as a percentage of the floor height. On most projects, the greater distance between floors means a larger drift between the floor levels.

Elastic
The ability for a material to move and deform, then return back to their original state. Elasticity is essential for accomodating various forces and movements the building will experience.

Racking
A movement or distortion of sash or frames causing a change in angularity of corners. This can also refer to the type of movement that the system is expected to see under seismic load.

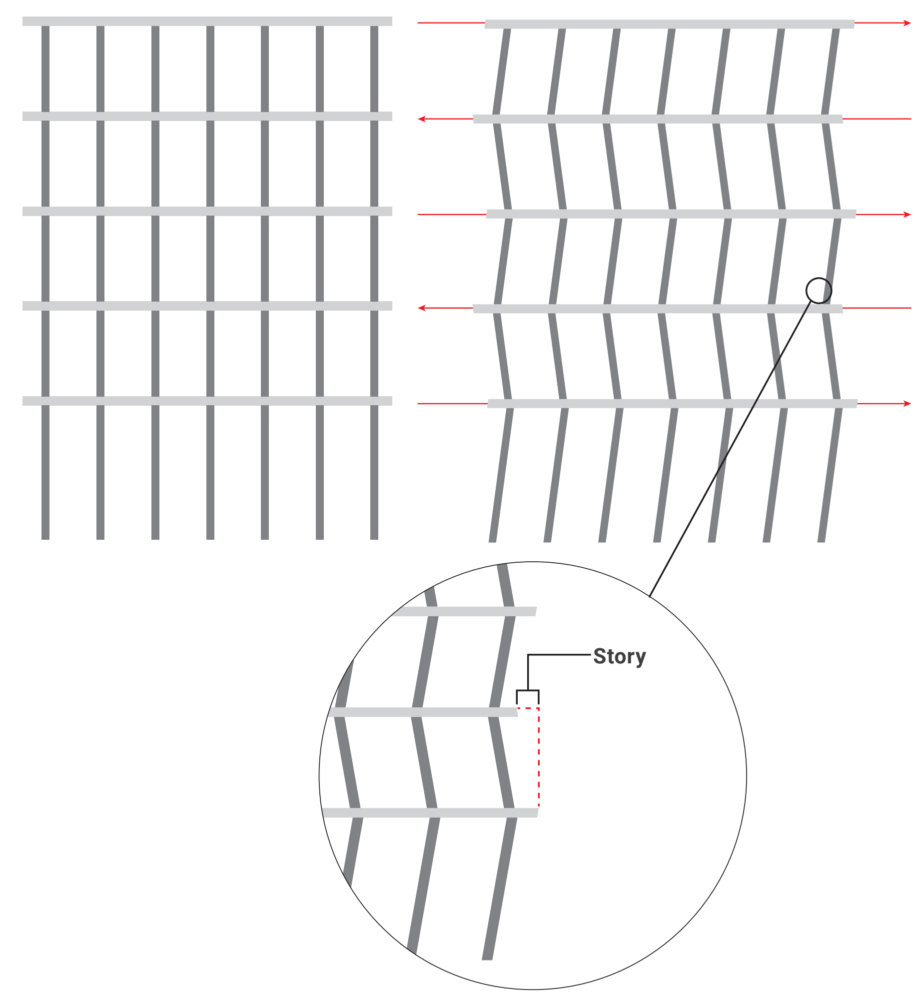
Story Drift
The later displacement of one level relative to the level above.

Seismic Joint
A building joint that allow for movement during seismic events without damaging the skin.



Displacement

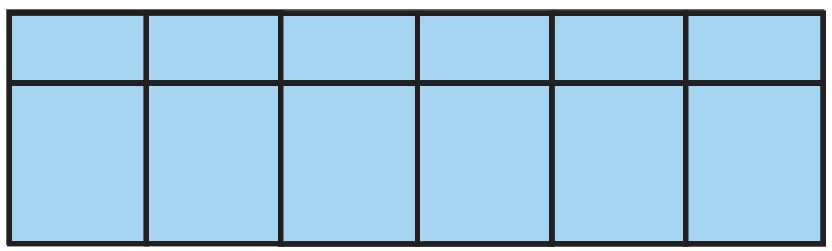
If the distance between floors is 14', and the lateral insterstory drift we are given is 1.5%, the displacement would be: 168"(14') x .015 = 2.52". This means that the top of our verticals can be offset from the bottom by 2.52".



For seismic racking, we must consider that the floors are moving in opposite direction from the floors above and below it.

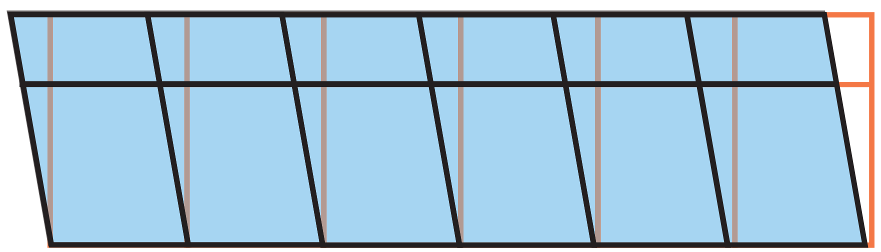
Racking - Stick Frame vs. Unitized

Static



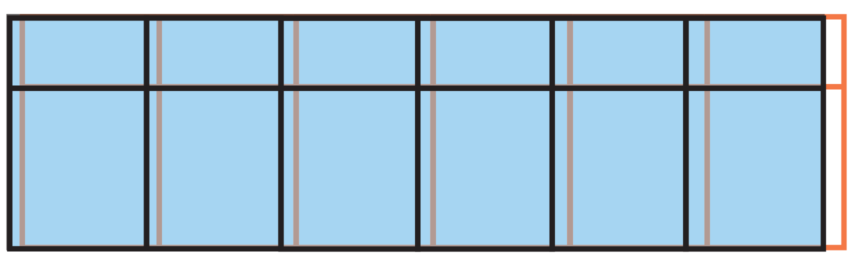
Stick walls do not rack, they tend to lean over. The horizontals will stay horizontal creating non-rectangular openings for the glass to sit inside. We have to make sure that there is enough room in the glazing pocket, the glass that is rectangular will stay within the parallelogram of the frame.

Unitized - Rocking

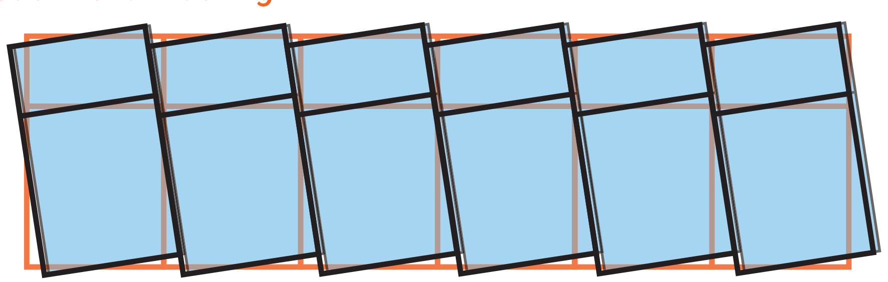


Unitized curtain walls allow the frame to rotate completely, maintaining its rectangular position. These units require the mating of female with male verticals and anti-walk blocks.

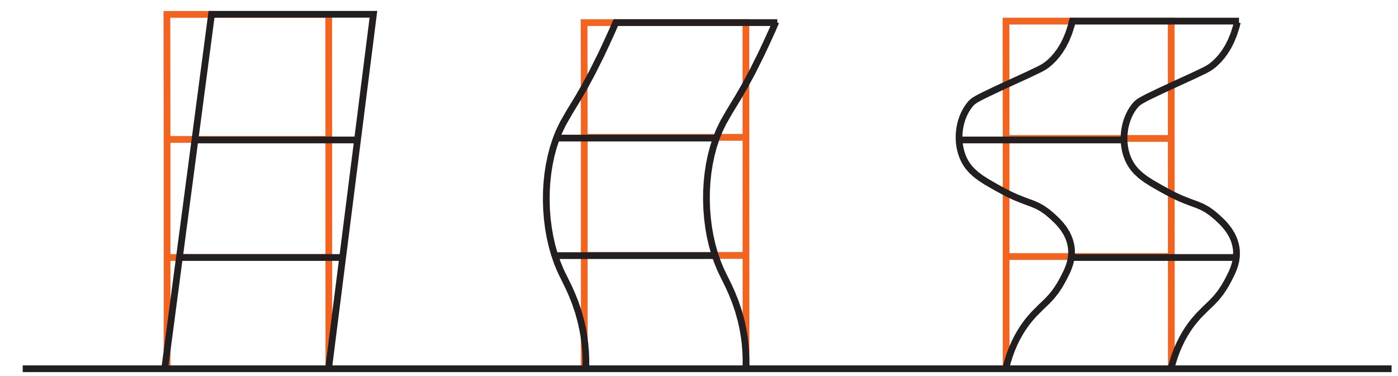
Unitized - Sliding



Stick Built - Racking



Seismic Movement



First Mode

First mode of movement is the initial movement that the building will experience during an earthquake.

Second Mode

As the frequency of the wave slows down, the building enters the second and the third mode.

Third Mode

We usually test to the third mode, the drift is a lot higher in the third mode than the first or second

All That Glass

CHAPTER 4

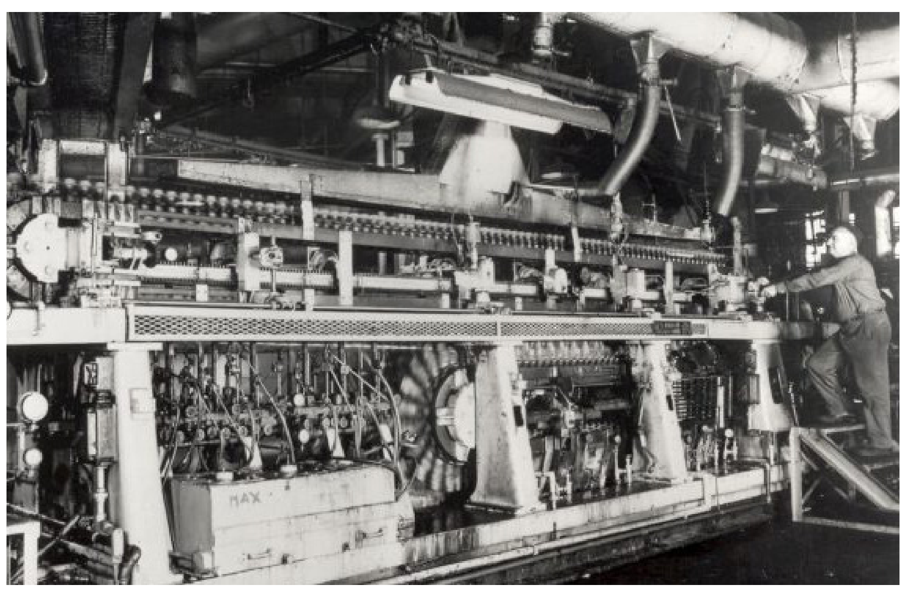
History of Glass

1.

History Of Glass

The Sumerian's of Mesopotamia were the first known human civilization to create glass. Historians believe they principally used the raw materials for glass to glaze pots and vases. Glass was then passed down to the Egyptians who advanced the process to create a large variety of vases and bottles.
Over time, the process of glass-making evolved and by the first century BCE, the blowing of glass had been developed.
Glass-making spread throughout the ancient world, and by the Roman Empire, glass was being produced on an industrial scale.
During the Middle Ages, the production of glass became a major industry all over the world, with large-scale glass-making centers established in cities from Venice to Istanbul.

The industrial revolution of the 19th century brought further advancements in glass making, including the development of the continuous ribbon machine, which allowed for the mass production of flat glass. This paved the way for the widespread use of glass in architecture and other applications, and led to the creation of new and innovative forms of glass.



2.

Plate Glass

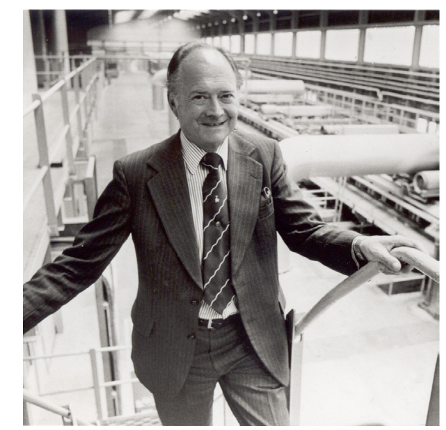
The first recorded instance of large-scale production of plate glass dates back to the 17th century in France. Prior to the invention of plate glass, the most common type of glass was window glass, which was made by blowing a cylinder of molten glass and then cutting it open and flattening it. This method produced a wavy, uneven surface that limited its use for applications that required a flat and clear surface. Plate glass is made by a rolling process, where molten hot glass is rolled out into a large flat sheets and polished into a flat and smooth surface.

The ability to produce large sheets of plate glass made it possible to construct bigger and taller buildings, leading to a significant increase in the number of high-rise buildings in cities. Over time, improvements were made to the manufacturing process of glass. During the 1950's an Englishman by name of Sir Alakstair Pilkington developed a new method to produce glass. the float process.

3.

Float Glass

Over time, improvements were made to the manufacturing process of glass. During the 1950's an Englishman by name of Sir Alakstair Pilkington developed a new method to produce glass. the float process.



All float glass can be considered plate glass. The terms can be used interchangeably.

Float glass is manufactured on a production line where a molten ribbon of glass is made by "floating" the liquid glass mixture over a bed of molten tin. The floating molten glass is transfered onto ceramic rollers where it slowly cools. The cooling process is referred to as annealing. All heat-strengthened, tempered, laminated, insulated and wire glass are made directly from large sheets of float glass. Compared with the process for manufacturing plate glass, the float glass process was a much more efficient and cost-effective process for producing large, flat sheets of glass.

Glazing
a.k.a Glass, I.G.U, Lite, Spandrel, Panel
The term glazing is refers to the action of installing a window, but can also be referring to the single piece of material that is going to be installed into an opening.

Monolithic
Refers to a single piece of glass

Composition Of Float Glass

Float glass is made primarily of silica, which is the primary component of sand. Other ingredients include soda ash, limestone, and dolomite, which are added to the mixture to control the viscosity and chemical properties of the glass. Tinted glass is produced by adding metal oxides to the float glass during manufacturing, producing gray, green, blue or bronze colored glass. Composition of float glass can vary depending on the manufacturing process and the

Manufacturing Float Glass

Glass plants run 24 hours a day, 365 days a year. Manufacturing plants have the ability to produce hundreds of tons of glass per day. There are about 450 float lines around the world, each producing millions of tons of float glass.

1. Silica sand, soda ash, dolomite, limestone, nepheline syenite, salt cake and recycled glass (cullet) are dumped together in a hopper.

2. These materials are then fed in a continuous stream into the filling end of a natural gas furnace.

3. The materials are melted, refined and homogenized in separate zones of the furnace.

4. The molten glass is channeled to the heart of the process, where it is poured on to a bath of dense liquid tin onto which it floats. Like oil on water, the glass simply floats on top.

5. The glass is rolled on rollers, gradually cooling along the way. This process is called annealing. It goes from being 1,100 F to room temperature.

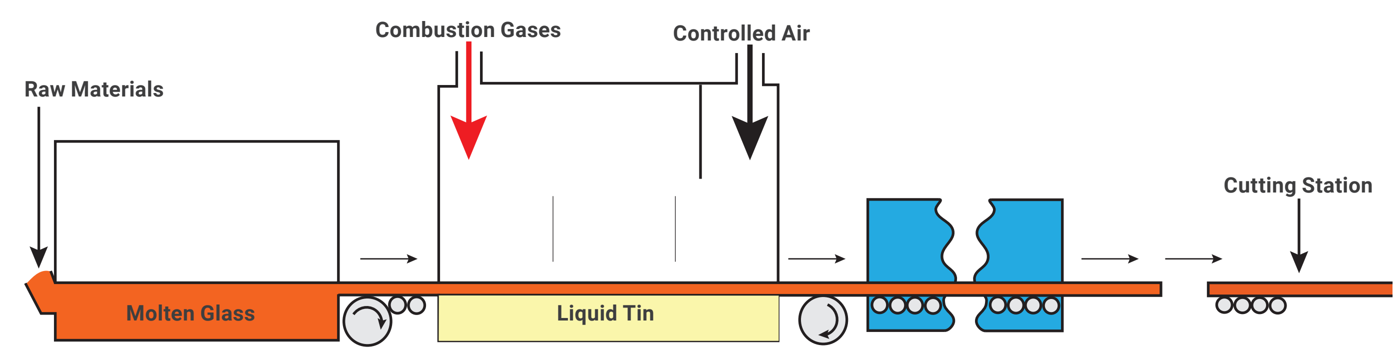
6. After the glass has been cooled and checked, an ultra hard tungsten carbide makes a large longitudinal score before the glass can be cut.

7. Now they proceed with transverse scoring made specific customer dimensions. It can then be snapped or split to predetermined sizes.

8. They're separated and then continue along the conveyor where the sides are cut by roller breakers, this cullet is then sent to be reintroduced to the beginning of the process.

9. Rubber covered rollers bring the finished glass to the inspection section of the shop. The glass is inspected and stored vertically

Cullet
Broken glass, excess glass from a previous melt or edges trimmed off when cutting glass to size. Helps to facilitates melting.



Glass Types

Annealed Glass

Annealed glass is a type of flat glass that has been slowly cooled from its molten state to room temperature in a controlled environment, allowing it to cool uniformly and avoid the formation of internal stress points. This process is known as annealing, and it results in glass that is stronger and more durable than glass that has not been annealed.
The process of controlled cooling decreases 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. Annealed glass goes from being 1,100° Fahrenheit to room temperature.

Physical Properties
Can be easily cut, drilled and shaped without the risk of cracking.

Common Applications
Considered to be a versatile and cost-effective option for many applications where strength and safety are not the primary concerns

Post Breakage
Annealed glass breaks into large, sharp fragments that can cause injury and damage to its surroundings.

Annealed glass is not as strong as heat strengthened glass.

Heat Strengthened

The manufacturing process for heat-strengthened glass involves heating the annealed glass to a temperature of about 1292° F and then quickly cooling it, either by air-cooling or by plunging it into a cold-water bath. This process causes the surface of the glass to cool more quickly than the core, creating a state of compression on the surface and tension in the core. This makes the glass about two times stronger than normal annealed glass.

Physical Properties
Can be easily cut, drilled and shaped without the risk of cracking.

Post Breakage
Annealed glass breaks into large, sharp fragments that can cause injury and damage to its surroundings.

Common Applications
Considered to be a versatile and cost-effective option for many applications where strength and safety are not the primary concerns

Heat Stengthened glass is not as strong as tempered glass.

Tempered Glass

The manufacturing process for tempered glass is similar to heat strengthened, but with an additional step. After heating and cooling the annealed glass to create heat-strengthened glass, the glass is then reheated to a temperature of about 1000° F. As the glass is heated, it is subjected to a uniform thermal compression, which makes tempered glass even stronger.
Once tempered glass has been treated, it cannot be cut, drilled, or otherwise modified, as this will weaken the internal compressive stress points and increase the risk of breakage. As a result, tempered glass must be cut and shaped to the desired size and shape before it is tempered.

Physical Properties
Considered to be roughly four times as strong as plate glass.

Post Breakage
Tempered glass breaks into small, rounded fragments, rather than sharp shards, making it a safer option for applications where the risk of breakage is high.

Common Applications
Commonly used at locations on the building that require “safety glass”. Tempered glass is used at doors and side lite locations around the building.

Tempered glass is stronger than annealed and heat strengthened glass.

Laminated

Made with two pieces of glass with a thick layer of plastic set between them. Most commonly, laminated glass has a layer of PVB in between the two lites. This this sheet of PVB is placed between the glass panes, then a combination of heat and pressure is applied within an autoclave to create on laminated piece of glass.

Physical Properties
Using different sizes of glass on either side of a PVB inner-layer can greatly improve the sound proofing of glass.

Post Breakage
Laminated glass breaks into large sheets of glass that are held together loosely with the PVB interlayer.

Common Applications
Laminated glass blocks all UV rays from entering the building, therefore it is a useful application for security areas, sound sensitive rooms, and museums. Laminated glass is most often used for automobile windshield . Guardrails, canopies and sloped walls all tend to use laminated glass due to the safety factors related to these areas.

Autoclave
A high-pressure and heat vessel that produces a bond between glass and PVB sheet, resulting in a laminated glass product.

Dice
The more or less cubical pattern of fracture of fully tempered glass

PVB
Poly Vinyl Butyral (PVB) is a tough plastic resin that is used in between two panes of glass to bond them together.

Solar Spectrum

Solar Heat

Energy is released from our sun in the form of light. The light omitted comes in three forms; Ultraviolet (UV) light, visible light and infrared (IR) light. All three of these types of light occupy different parts of the entire solar spectrum of the sun. The difference between all three are determined by their wavelengths,

Wavelengths
The length of one complete wave cycle. Wavelengths are typically measured in nanometers.

Ultraviolet Light

Wavelength: 0.01 -0.38 microns

Contributes to the fading of interior materials such as fabrics and paintings. Can degrade sealants and gaskets, leading to potential water infiltration.

Visible Light

Wavelength: 0.38 -0.75 microns

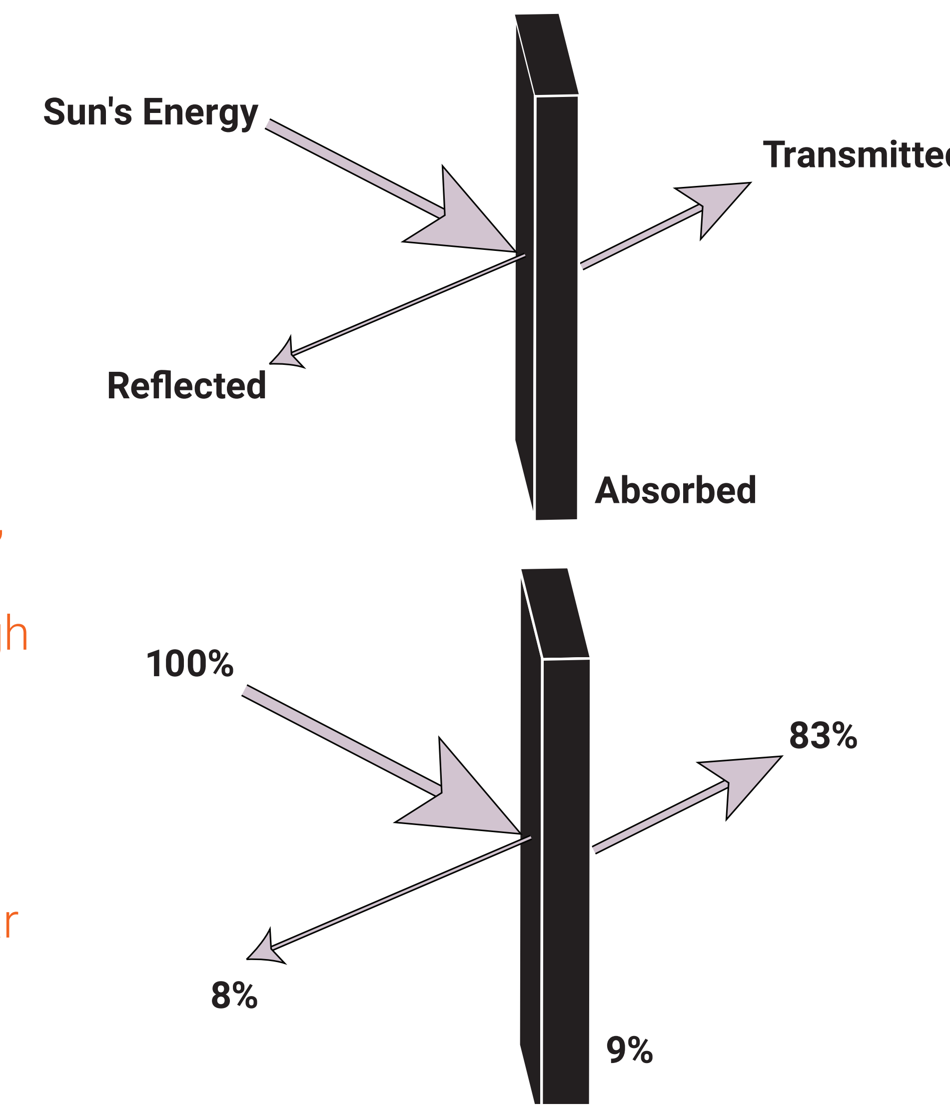
Visible light is color that can be detected by the human eye. The colors of visible light, in order of increasing wavelength, are violet, blue, green, yellow, orange, and red.

Infrared Light

Wavelength: 0.75 -3 microns

Infrared light should be thought of as the heat from the sun. This energy contributes the most to heat gain within a building. Low-e coatings are commonly applied to reduce infrared light penetration.

When light from the sun hits glass, a portion of the energy is reflected, absorbed, and transmitted through the pane. By using the RAT equation, we are able to account for 100 percent of the solar energy hitting our window.



Solar Energy (100%) = R + A + T

There are two industry standard methods for measuring the energy thats transferred through glass, Solar Heat Gain and Shading Coefficient.

Solar Heat Gain (SHGC)

The solar heat gain of a window is the amount of solar radiation that passes through it into the building. This energy comes from both infrared light passing through the glass(A.) and through absorption(B.) re-radiated into the interior space. The SHGC can be affected by sunshades, window coatings, tints, etc.

Shading Coefficient

Higher shading coefficient value means that more solar radiation is penetrating through the glass. Glass with a high shading coefficient is often used in longer winter areas. Glass with a lower shading coefficient is often used in warmer climates.

Shading coefficient is the ratio of the solar heat gain through a specific glass product, compared to the solar heat gain through a lite of 1/8" (3mm) clear glass. This is to show the glass performance in reducing heat. Glass of 1/8" (3mm) thickness is given a value of 1.0. The solar radiation energy through a 3mm piece of transparent glass is 630w/m2 (watts per square meter). As shading coefficient decreases, heat gain is reduced, meaning a better performing product.

Transmittance
The ability of the glass to pass light and/or heat, usually expressed in percentages (visible transmittance, thermal transmittance, etc.)

U-Values

The overall thermal performance of a curtain wall depends on the framing material, glazing infill, construction area and perimeter details. Every component of your system has a different U-Factor. Added together, these components combine into a window's overall system U-Factor. We consider the glazing component, frame component, and the spacer component when figuring out a unit's U-Factor. NFRC, National Fenestration Rating Council, which determines the guidelines for energy ratings such as U-Factors

U-Values typically range from 0.1 (very little heat loss) to 1.0 (high heat loss). The lower the U-Factor, the better for thermal performance.

Summer Daytime U-Value
Measures environmental conditions of a hot outside temperature and direct light. The lower the summer daytime U-value, the better it is at blocking re-radiated heat.

Winter Night-time U-Value
Measures the environmental conditions of a hot outside temperature and direct light. A lower winter nighttime U-value means the glass is better at keeping the heat inside.

U-values vs. R-Values

U-values are used to measure the performance of assemblies, such as window units, while R-values are used to measure the performance of other parts of the building such as walls, floors, and roofs. The R-value is the inverse of the U-value. The higher the R-value, the better for thermal performance.

To calculate U-value, divide 1 by the R-value.
A U-value of 0.10 equals an R-value of 10 (1 divided by 0.10)

Improving U-values

There are many different ways to improving a window system's overall U-Values. Some examples of how engineers attempt to improve the thermal transmittance of their window systems are: using a noble gas, such as argon . Using low-e coatings. Optimize the cavity size between the lites. Specifying warm-edge spacer that create an effective thermal barrier

Low-e Coatings

Low-E (low-emissivity) coatings are designed to transmit energy from the visible portion of the solar spectrum into buildings, while minimizing the amount of ultraviolet and infrared light that passes through. By reflecting the sun's infrared light back out of the building maintains a comfortable temperature in the buildings and increase the insulating value of the window. When the interior is warmer than the exterior temperatures, the low-e coatings help reflect the heat inside of the building. Reversely, when it is warmer outside than in, it trys to reflect heat outside of the building. Coatings are compromised of thin chemical layers of microscopic components of silver and ceramic materials. By controlling the thickness and composition of the materials in a coating, engineers can control the visual and thermal properties of the facade.

Solar Heat Gain Coefficient
The solar heat gain of a window is the amount of solar radiation that passes through it into the building. The SHGC can be affected by sunshades, window coatings, tints, etc.

Visible Transmittance (VT)
The visible light transmittance of glass is a measure of how much visible light comes through the window.

Air Infiltration
Air entering the building through joints or seams can have a negative impact on the thermal performance of the building and HVAC systems.

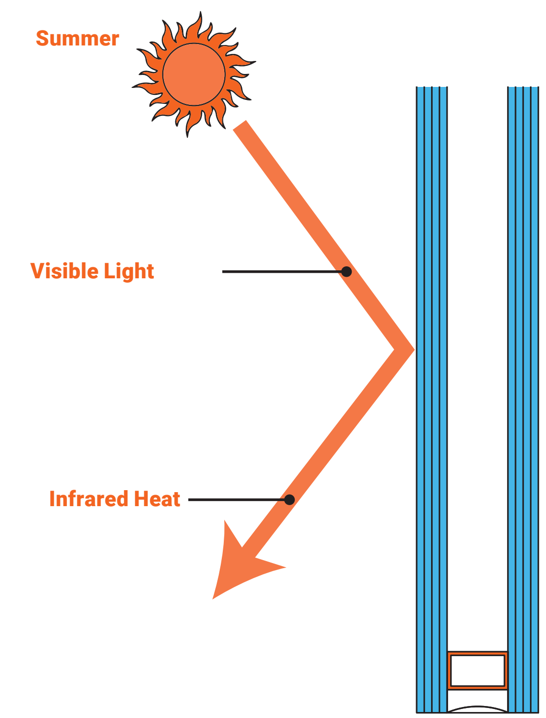
Transmittance
The ability of the glass to pass light and/or heat, usually expressed in percentages (visible transmittance, thermal transmittance, etc.)

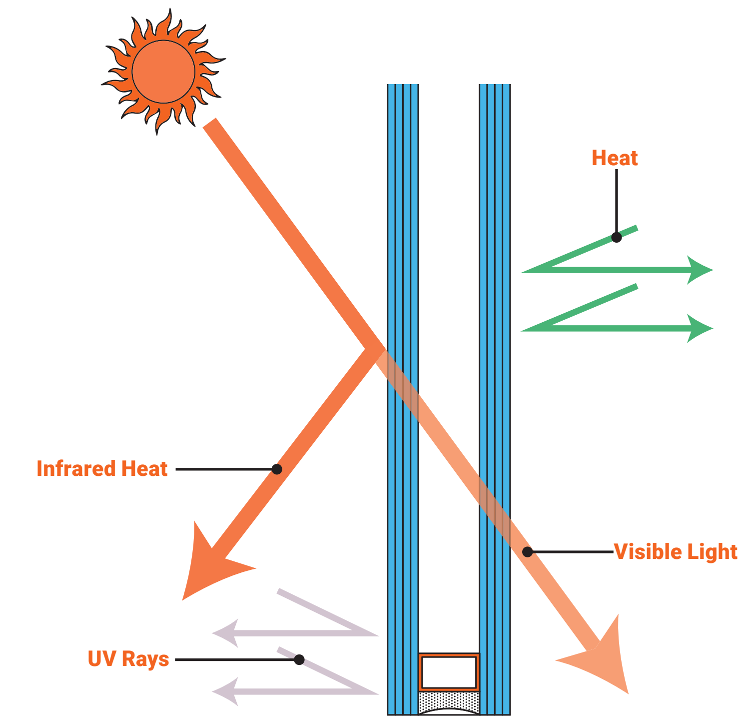
Passive vs Solar Control

Passive low-e coatings
Designed to maximize the amount of solar heat gain that is allowed into a building. The purpose is to allow for less reliance on artificial heaters.

Solar Control low-e coatings
Used to limit the amount of solar heat gain that is allowed into a building.

Both types of low-e glass can be used in combination with other types of glass to provide optimal thermal performance and energy efficiency.





Low-E Coating Types

Single-Silver Coatings
Earliest of the low-e coatings; composed of one layer of silver and two ceramic layers.

Double-Silver Coatings
Created in the 1990's, these coatings have two layers of silver and multiple micro-thin layers of performance materials. This increased their ability to block solar heat gain by 30 percent.

Triple-Silver Coatings
In 2005, these state of the art coatings were created containing three layers of silver with over 12 layer stacks of ceramic material. Triple-silver low-e coated glasses can transmit nearly 70 percent of the sun's available light into a building while blocking up to 75 percent of its infrared and ultraviolet energy.

Quad-Silver Coatings
Introduced in 2016, can block nearly 80 percent of the sun's radiant energy while transmitting more than 50 percent of available sunlight.

Low-e Application Process

Soft Coat
A.k.a. Pyrolytic Process

Became popular in the 1970's. The coating is applied to the glass ribbon while it is being produced on the float line. The coating then "fuses" to the hot glass surface, creating a strong bond that is very durable for glass processing during fabrication.

Hard Coat
A.k.a. Magnetron Sputter Vacuum Deposition

Became popular in the 1980's. The coating is applied off-line to pre-cut glass in a vacuum chambers at room temperature.

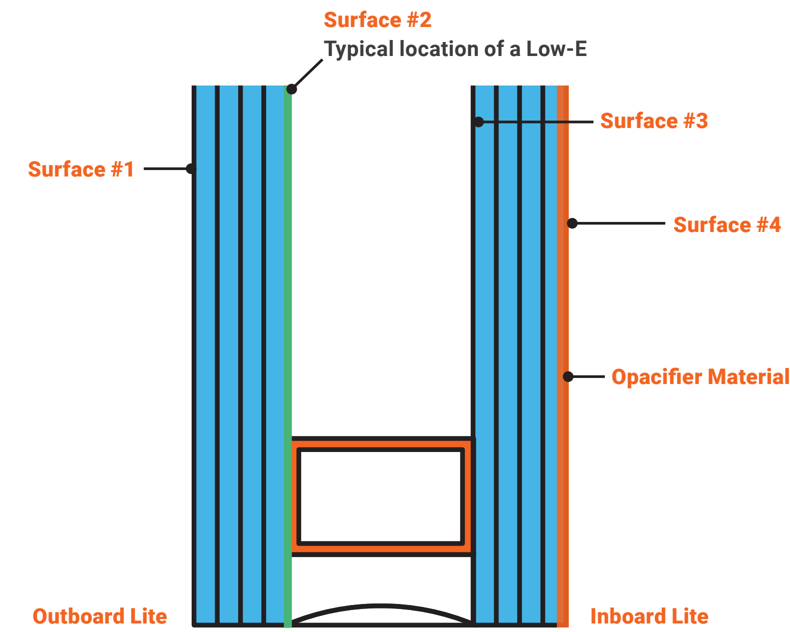
Hard coatings are not as good at insulating our glass compared with soft coated low-e.

Solar Reflective Coatings

By using a coating on the glass that is highly reflective, the amount of visible and infrared light that penetrates through the glass can be controlled. These coatings give glass a mirror-like aesthetic. While these coatings are great for solar heat gain control, they do not provide as much light transmission through the glass.

Spandrel Coatings

Designed to be opaque in order to help hide features between the floors of the building. Typically found below the floor line to hide wiring, ducts, slab, etc. Spandrel glass is created by applying an opacifier to the indoor (#4 surface) of a glass lite. They place it on the innermost surface to avoid potential release of volatile organic compounds (VOCs) inside the IGU. Spandrel glass is created by applying an opacifier to the indoor (#4 surface) of a glass lite. They place it on the innermost surface to avoid potential release of VOCs inside the IGU.



Coating Locations

In a standard double panel insulated glass unit (IGU) there are four potential surfaces to which coatings can be applied. Passive low-e coatings function best when on the third or fourth surface (furthest away from the sun). While solar control low-e coatings function best when on the lite closest to the sun, typically the second surface.

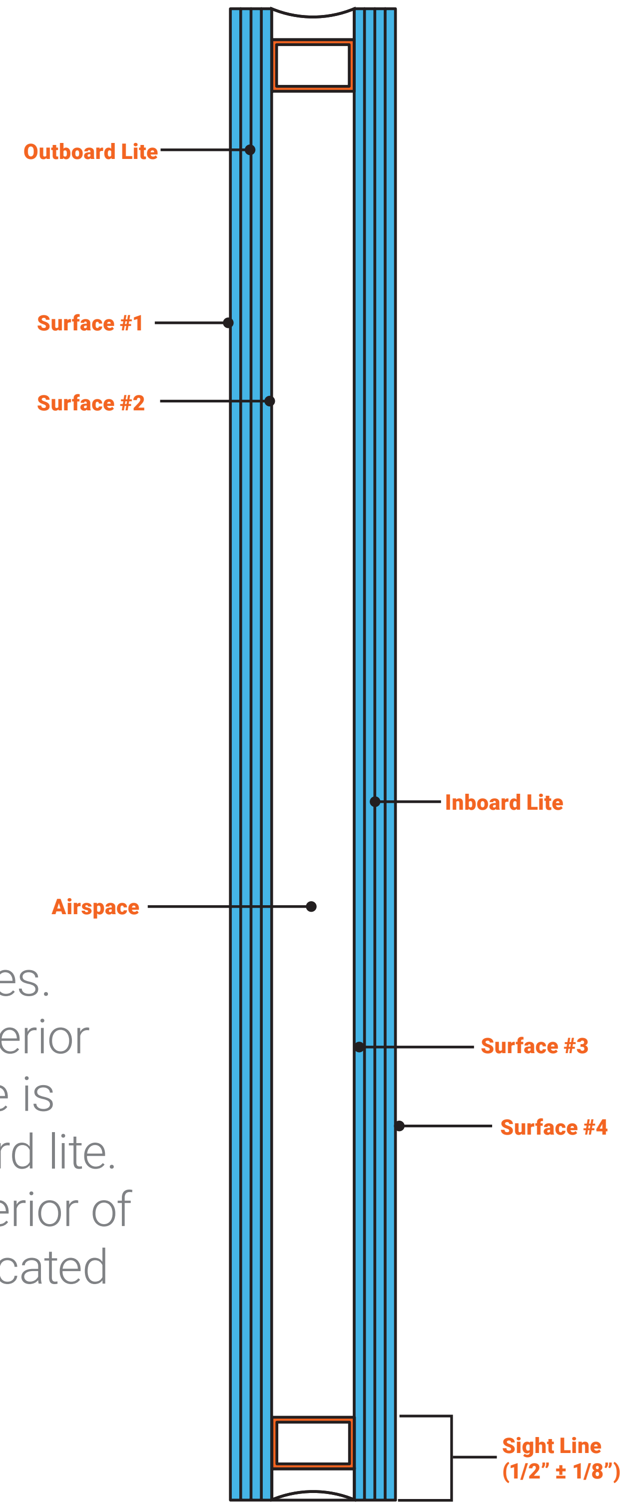
Opacifier
A substance added to materials like paints, cosmetics, plastics, or ceramic glazes to make them opaque (not see-through) by scattering or reflecting light, often creating white, creamy, or pearlescent effects.

Insulated Glass

IGU

Insulated glass units typically consist of an outboard lite of glass, with another lite of glass on the inboard with an airspace in the middle, before it is tempered. Due to the use of air between the lites of glass, IGU's have better thermal properties compared to using a single lite of glass in a similar condition. The air between the glass sheets is thoroughly dried and the space sealed, eliminating condensation and providing superior insulating properties. IGU's also have the advantage of sound dampening, due to the ability to create three separate depths of material (glass thickness of exterior lite, thickness of air spacer, and the thickness of the interior lite of glass The hollow metal spacer within an IGU separates the glass plates, holds a desiccant and provides the structure for the sealed air space.

Insulated glass would have 4 surfaces. The #1 surface is located on the exterior of outboard lite, while the #2 surface is located on the interior of the outboard lite. The #3 surface is located on the interior of the inboard lite. The #4 surface is located on the exterior of the inboard lite.



Airspace

Since insulated glass units have an air space between the two pieces of glass, resulting in a more stabilized internal temperature. 1/2" airspace is optimal for thermal performance. Common spacers used are mill finished and black anodized spacers.

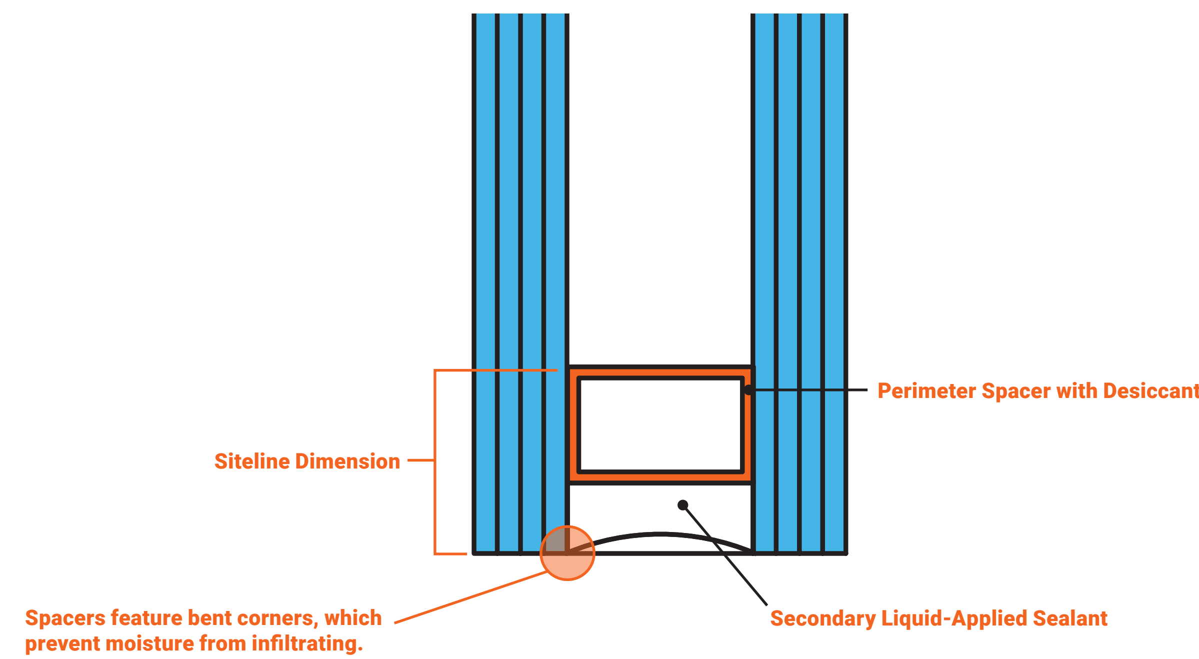
When the airspace increases to above 1/2" the air inside of the insulated glass unit is large enough that the air actually moves and heats itself through convention.

Lite
A single monolithic piece of glass

Desciccant
A substance that is used to absorb any moisture that might get trapped inside insulated glass during the manufacturing process.

Airspace
In an insulated lite of glass, the space between the inboard and outboard panes. This space can vary depending upon the specifications required

Cut Sizes
Glass cut to specified width and length.



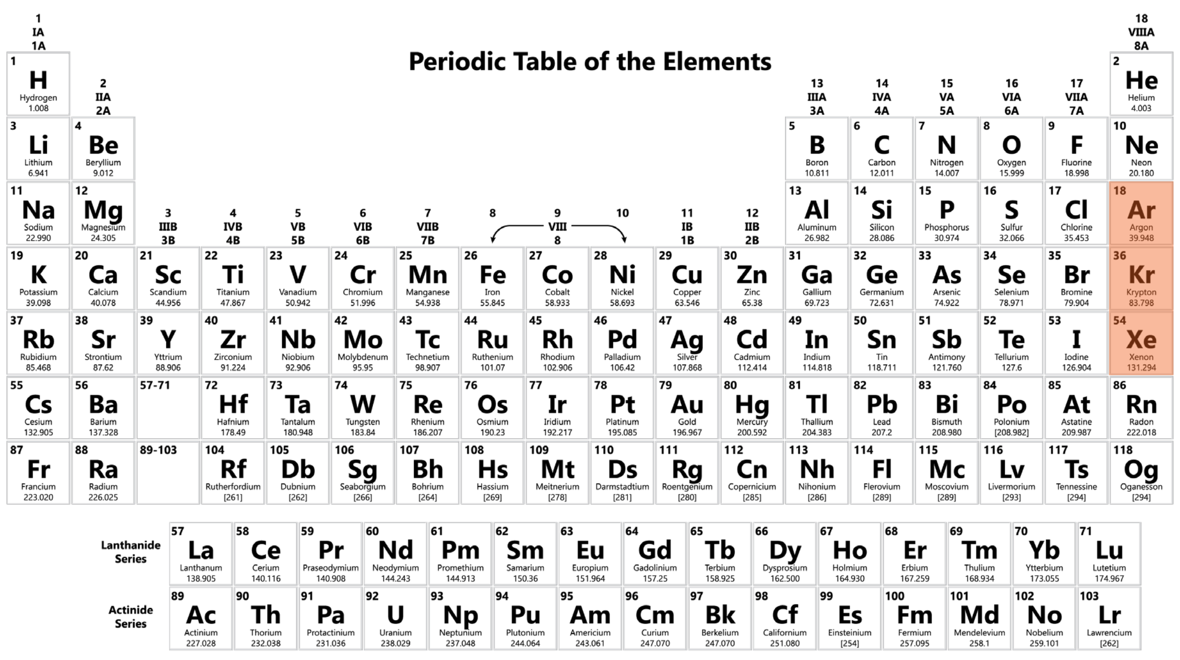
Noble Gases

Inert, orderless gases are used to fill the spaces between glass units. They help to displace the air between the windows, making them less conductive and more effective in blocking heat transfer between panes.

Argon
The most widely used gas that is filled within an IGU.

Krypton
Typically used when the unit's thickness must be minimized but the overall U-value must not change.

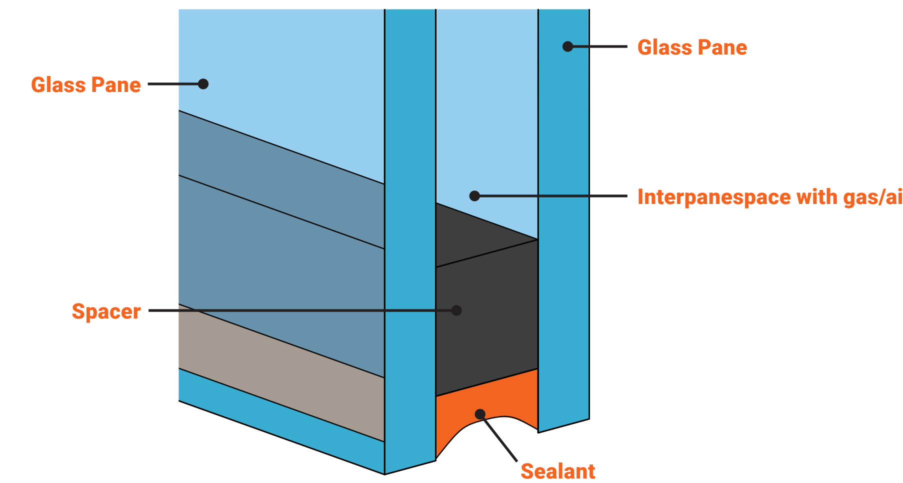
Xenon
Much more expensive than Argon and Kyrpton, used in much larger expanses of glass typically.



Window Spacers

Window spacers are strips of plastic, metal or foam that separates the inboard and outboard lite from one another in an IGU. The spacer is then bonded between the glass panes with sealing material which creates an air-tight, hermetic seal.

The primary function of a spacer is to reduce water vapor and gas-leakage from the IGU. Over a one year period, a typical IGU will leak as much as 1% of their gas per year.



It's important to note that the longevity of peak performance of a window spacer is of the utmost consideration. If the spacer does not provide an enduring seal over a long period of time, it is essentially useless.

Warm Edge Technology (WET)

Warm edge refers to the thermal interaction between multiple panes of glass, the window frame and the spacer.

The warmer the spacer edge, the lower the heat loss through a sealed unit.

Metal
Typically made from aluminum or stainless steel, these spacers are more prone to sealant failure due to their rigidity. Metal spacers are considered the strongest spacers, giving the IGU uninterrupted sight-lines, as well.

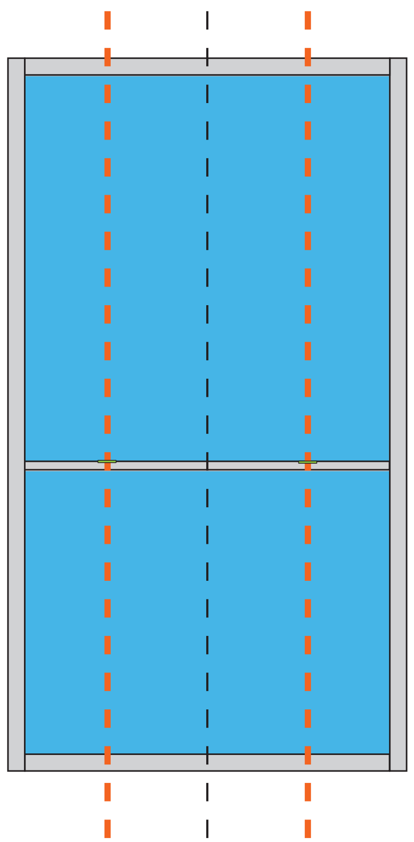
Composite
Plastic material is less conductive to metal, making these spacers have greater insulating properties. These plastic spacers also come in a larger variety of color options.

Structural Foam Spacers
Silcone foam spacers contain no metal components, making them the most energy-efficient spacer. Foam spacers are also more suited to expansion and contraction, making them less prone to sealant movement and more prone to gas retention. They come in either t-shaped or u-shaped configurations.

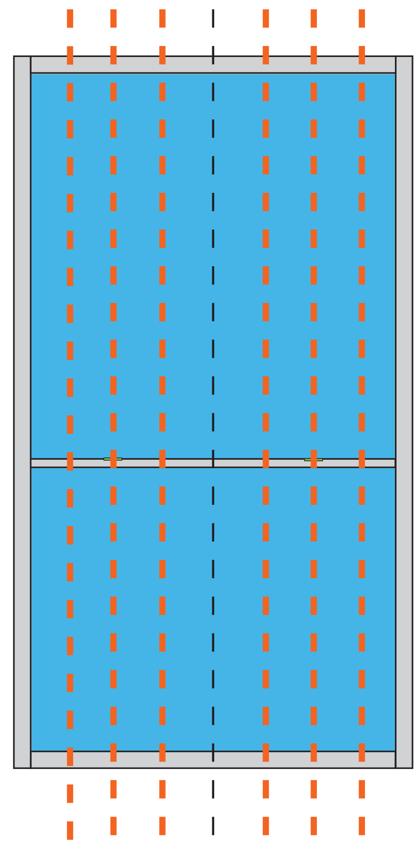
Setting Blocks

All insulated glass units must be supported by at least two silicone setting blocks. These blocks are set at incremental distances across the width of the IGU. Most commonly, these blocks are sat at quarter points, occasionally the weight of the IGU will require more setting blocks to be placed at eighth points.

Recommended minimum face clearance is 3/16" and a minimum edge clearance of 1/4". Inadequate edge clearances can cause glass breakages as a results of glass-to-frame contact.



1/4 Point Placement



1/8 Point Placement

Glass Size Selection

Often times, when selecting glass thicknesses for a project, you want to create one uniform thickness throughout. This is because when there are multiple glass thicknesses on a project more dies, gaskets and other materials are going to be required for the building. This complicates orders, causes errors and problems with vendors. There are typically smaller extrusion quantities for multiple parts, which is less desirable.

Glass should have a uniform thickness on most large commercial glazing projects. The typical thickness of an IGU is 1" or 1 1/4".
While the actual glass sickness on the drawings show a 1 1/4" thickness, the glass received from the manufacturer measures at 1.19" with calipers. For this reason, our glass pockets need to accommodate 1 3/16"

1/4" Monolithic	**3.27 psf**
3/8" Monolithic	**4.9 psf**
1/2" Monolithic	**6.54 psf**
5/8" Monolithic	**8.17 psf**
3/4" Monolithic	**9.81 psf**
7/8" Monolithic	**11.45 psf**
1" Insulated	**6.54 psf**

Effect of aspect ration on glass strength

The aspect ratio can have an effect on the strength of glass, as the strength of glass is influenced by the distribution of stress within the material.

In general, the higher the aspect ratio, the lower the strength of the glass. This is because when the height of the glass is reduced, the stress is concentrated at the corners, which can lead to brittle failure. On the other hand, when the width of the glass is reduced, the stress is spread out over a smaller area, which can lead to plastic deformation.

Effect of aspect ration on glass strength

STC refers to a single number rating derived from individual transmission losses at specified test frequencies. It is used for interior walls, ceilings and floors and in the past was also used for preliminary comparison of the performance of various glazing materials. Different inboard and outboard glass thicknesses will have a positive impact on a system's STC value.

Less sound will travel into the building if the IGU is made up of different depths of material the sound has to go through. Sound transmission is especially important when a building is situated near a busy freeway, airport, or other noisy environments.

Acoustics

Sound consultants spend at least a week on site, measuring the sounds of nearby area of the building. The consultant will then use a computer model to predict what STC values would be appropriate for each location of the building.

A typical 1" IGU will have an STC value of 32.

Nominal Thickness
The design thickness with a tolerance of plus or minus (n x .2mm) where n equals the number of glass layers in the glazing.

Brittle Failure
a type of fracture that occurs when a crack begins to propagate rapidly, leading to sudden breakage of the material.

Plastic Deformation
relates to the permanent change in a material's shape. It is characterized by a material being able to absorb energy and deform without breaking.

STC
Sound transmission class.

Glass Defects

Breakage is a type of defect that can cause the glass to fracture or shatter into pieces. It can be caused by improper handling, exposure to high temperatures, or impact damage.

Roll marks are surface defects that can cause the glass to appear scratched or scored. They are typically caused by mechanical abrasion during the rolling process used to produce flat glass.

Seeds are small bubbles or inclusions in the glass that can cause a hazy or cloudy appearance. They are typically caused by impurities in the raw materials used to produce the glass or by poor mixing of the glass batch. Seeds are considered to be bubbles that are less than 1/32” in diameter.

Stones are large inclusions or particles in the glass that can cause visible defects in the surface of the glass. They are typically caused by impurities in the raw materials or by poor mixing of the glass batch.

Scratches are surface defects that can cause the glass to appear cloudy or hazy. They can be caused by mechanical abrasion during handling or processing of the glass.

Knots are small, localized defects in the glass that can cause visible cracks or bubbles. They are typically caused by cooling the glass too quickly.

Delamination is a type of defect that occurs when the layers of laminated glass separate, causing the glass to become cloudy or hazy. It can be caused by improper bonding between the layers, exposure to high temperatures, or impact damage.

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 1/32” in diameter glass batch.

Wave distortion is a type of surface defect that can cause the glass to appear wavy or curved. It is typically caused by temperature gradients during the glass-forming process or by cooling the glass too quickly.

Spontaneous Breakage in Glass

There are a few reasons that glass would break without impact and the two main ones are nickel sulphide inclusions or thermal stress.

During glass production, small nickel sulphide stones can form within the glass. This random, rare occurrence can sit within a piece of glass, dormant for years. When the glass is cooled, these nickel sulphide stones become trapped inside of the glass. Over time, these pieces of nickel sulphide try to expand back to their original state, causing the glass the shatter spontaneously.

Often times, when selecting glass thicknesses for a project, you want to create one uniform thickness throughout. This is because when there are multiple glass thicknesses on a project more dies, gaskets and other materials are going to be required for the building. This complicates orders, causes errors and problems with vendors. There are typically smaller extrusion quantities for multiple parts, which is less desirable.

Glass should have a uniform thickness on most large commercial glazing projects. The typical thickness of an IGU is 1” or 1 1/4”.
When environmental temperature changes occur, glass begins to expand or contract. If the difference in temperatures at the edge of the glass and the center of the glass differ severely, the glass is put under too much thermal stress and breaks.

Preventing Breakage

Although there is no guarantee of 100% exclusion of nickel sulphide, there are two methods to reduce the possibility of spontaneous breakage in glass. Using toughened glass or heat soaked glass are two options to minimize chances of nickel sulphide expansion in glass.

Heat soaked glass accelerates the nickel sulphide expansion that would normally occurs over time, showcasing weak panes of glass early.

Toughened glass helps reduce thermal shock within the glass. The rapid heating and cooling process leaves glazing 5x's stronger than standard float glass.

CHAPTER 5

Aluminum

Aluminum Extrusions

Extrusions of aluminum, either mill finished, painted, or anodized, that can be used in a variety of applications. 600 Series alloy is the predominant aluminum extrusion produced in North America. Aluminum ingots are converted into billets of aluminum which are then transformed into our aluminum extrusions. During this transformation from ingots to billets is when alloys are added into the mixture.

13
Al
ALUMINUM
26.981

Manufacturing Extrusions

1. Production starts with extracting aluminum from the ground. The aluminum billets must be transported to the extruding plant.

2. A preheated furnace raises the temperature of the billet to a predetermined level depending on its alloy.

3. The billet is then placed in a hydraulic press which pushes the aluminum through a heated steel die to form the desired shape.
4. The extrusions are cooled by air or quenched in water dependent on their desired final properties.

5. The extrusion is then clamped and stretched to straighten out its profile.

6. The staightened lengths are cut to size and then typically aged in an aging oven to the desired temperature.

7. The profile lengths are then shipped to be painted or anodized.

Extrusion
Typically vinyl or aluminum shapes produced by the process of forcing heated material through an orifice in a die

Alloy
A substance composed of two or more metals

Midwest Premiums
The price to deliver a billet of aluminum to the middle mart of the United States. This price can go up due to increased energy costs.

Extruding Costs
The price of gas for transportation combined with the price of gas for creating aluminum billets from ingots.

Recycling Aluminum

Aluminum extrusions are though as highly recyclable. It is used and reused numerous times via a well-established infrastructure. At the end of it's life, aluminum is sold to smelting operations to recreate billets for the extruder. Extruded aluminum products in North America contain a large portion of aluminum scrap metal. Roughly 50% of the metal's composition is from post-industrial and post-consumer use. Production scrap that is generated during the extrusion processes is collected and either sent to the company's cast house or to the proper recycling companies. There is no relevant chemical composition differences between 100% primary aluminum and nearly 100% aluminum scrap.

Post Consumer Scrap
Scrap metal that has been used for an intended purpose and then recycled. This includes automobile wheels, wire and reclaimed building materials.

Post Industrial Scrap
Refers to extrusion drop-offs from cutting, and scrap generated by the extruder or customers.

Die Drawing
The drawing which shows the precise measurements of the cross-section of an aluminum extrusion. Used by the extruder to make the orifice into which they push the heated aluminum metal through.

Die Design

Standard wall thickness: 0.125

System to accommodate 3/4" of movement as a minimum

Dies with 'legs' are to have equal legs to lay flat on machines

Assembly screws are to have silicone washers - no more caulking
All verticals are to be designed to allow for bayonet

All parts are to be thermally broken

The maximum stock length size for an aluminum extrusion is 300".

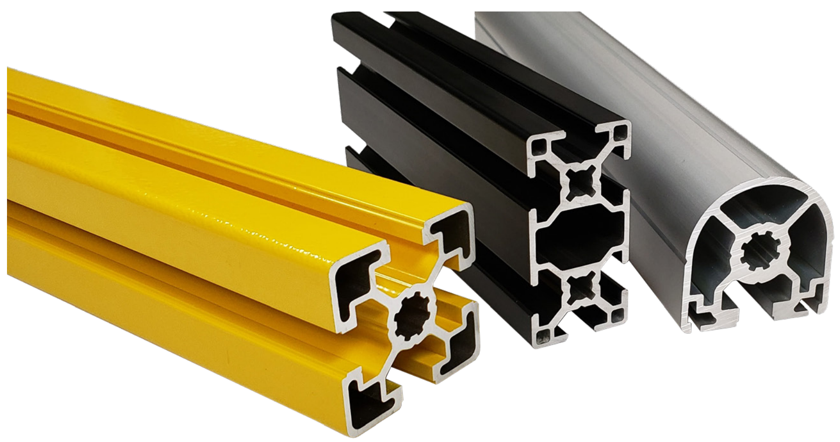
The minimum stock length size for an aluminum extrusion is 14'.

Paint and Finishes

Painting Extrusions

Before aluminum extrusions are painted, they are first cleaned and given an acid etch and rince in order to dissolve the magnesium and silicon alloying elements present on the surface of the extrusion. Afterwards, they are treated with a pre-coat in either a vertical or horizontal spray booth (a variety of pre-coats and primers may be used during this process, dependent on the paint performance desired).

Aluminum extrusions must be painted because silicone is unable to be caulked to milled aluminum . We need a slight bend to the inside edges of convex angled mullions so that the paint adheres to the entire face of the mullion. If it's too sharp of a corner, those paint droplets can stick to one another before making their way into the corner. This causes cracking eventually.



Pretreatment

The pretreatment process is used to prevent rust b uild up and increase the adhesion of the paint to the aluminum. Typically the mullion goes through an anti-ocxidation treatment and a chromate treatment, which clears oil, dust and rust fromt he aluminum's plate surface.

Paint Types

All paints, regardless if they are liquid or powder, are made of two ingredients; a resin and pigment. The resin itself is what gives it mechanical characteristics such as resistance to abrasions or a glossy effect. Pigments are the ingedient that helps provide the color. The quality of pigment is the main cause of fading or color change over time. As long as the resin and pigmnet chemistry are comparable between a powder and a liquid coating, their performances should be similar.

Common resins available for coating aluminum include: Acrylics, Urethanes, Polyurethanes, Polyesters, Silicon Polyesters, Polyester TGICs, PVDF, etc. Only a few of these coating systems will last for more than five years in exterior architectural applications.

3-Coat Finish
Refers to a paint finish where a top coat is added either to improve the longevity or protect the color from fading.

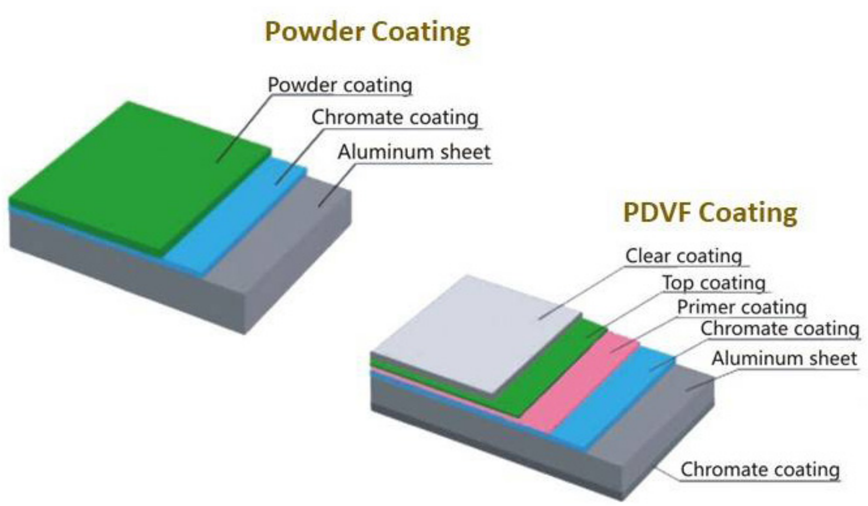
PVDF
Polyvinylidene fluoride, a class of material characterized by its high thermal stability and chemical resistance.

PVDF Coating

Due to PVDF's weather-resistance and its performance against UV light it is the industry standard coating used on curtain walls. It has also proven to pass AAMA 2605-17a in a large variety of colors. PVDF coatings are usually formulated as 70% PVDF and 30% other resins. Today, the most common PVDF coatings are trademarked as Hylar 5000 and Kynar 500. PVDF coatings will outlast anodized aluminum if they are both placed within similar corrosive enviroments. PVDFs have been traditionally manufactured as a liquid coating and not a poswer coating.

Powder Coatings
Applied to aluminum as a finely ground form without an solvents. It is made up of only the resin and pigment powder, not the solvent. The main advantage that podwer pigment has over liquid is the reduction in air pollution. When powder coatings are cured, they release no VOC's. One disadvantage is that you must create a large batch size in order to use powder coatings.

Liquid Coating
Composed of resin, pigment and a solvent. Between 70 and 80% of each gallon of liquid coating is evaporated into the air during the paint curing process. Hydrocarbons are released into the air, a precursor to ozone formation, similar to automobile exhaust.



Paint Application

Spray Coating

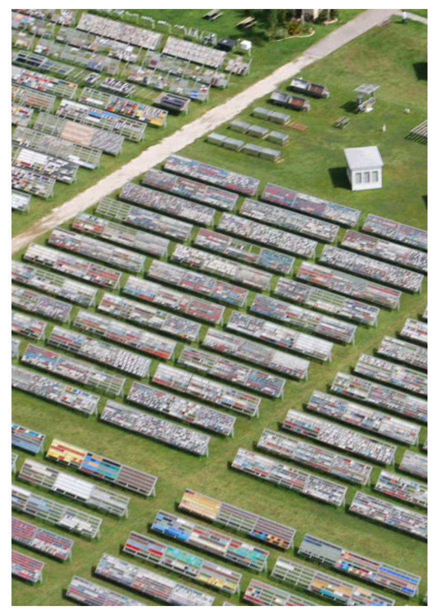
Applied to aluminum mullions using a spray gun. The paint must be atomized into tiny droplets and then sprayed on to the prepared aluminum. This can be typically done through automated methods or possibly manual labor.

A vertical paint line where extrusions are lined up to be coated.

In order to provide color consistency, all the extrusions for a project should be painted by the same applicator within one setup.

Paint Performance

The AAMA standards for weathering are perfomred in Southern Florida, considering one year of the region's sunshine can equate to several years of sun for other parts of the world. This provides engineers with an accelerated timeline upon which to measure a paint's weathering abilities. According to AAMA 2605-17a, approved coatings must withstand at least ten years of sun exposure in Southern Florida.



Q-lab testing facility in Southern Florida where paint performances are measured.

The most significant influence on a coating's long-term performance is determined by its reistance against ultraviolet light.

Anodization

Only some aluminum alloys are suitable for anodizing. Anodizing-friendly alloys include 5005 or 6063 aluminum. Other alloys such as 6061 or 5052 may streak or turn yellow. If aluminum extrusions are to be anodized, they must be properly cleaned and etched in a series of baths. They are immersed in an acid electyolte bath and an electircal current is passed through the solution. This subsequently creates a durable aluminum oxide layer with the aluminum. Aluminum oxide is a durable weather-resitant substance that helps protect the base metal. Due to its increased durability, a lot of storefront locations will be anodized because of their increased risk of accidental damage from pedesstrians. The final stage for anodizing aluminum would be to properly seal it, to enhance durability.

Coating thickness is the determining factor for the overall durability of an anodized piece of metal. A Class I coating is twice as thick as a Class II coating and will last for twice as long in the field.

Anodizing is less expensive than painting and harder than industry standard painted coatings. Anodizing is also unaffected by sunlight, giving it longevity. A downside of anodizing is that it can succumb to acid pollutants found within the air. Eventually, these pollutants can accumulate on the surface of the metal requiring them to be cleaned. Anodized metal can often be restored back to its original state after it appears to be damaged.

CHAPTER 6

Anchors

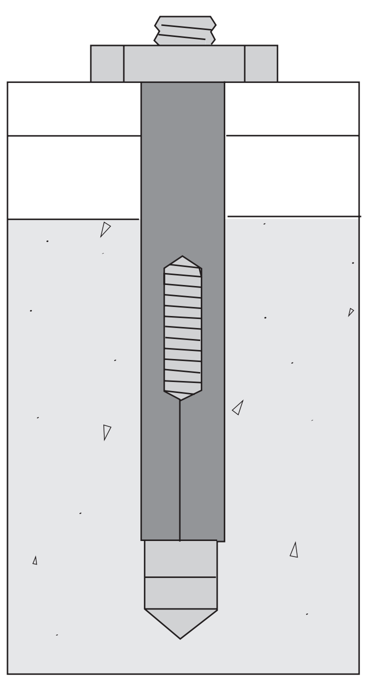
Anchor Types

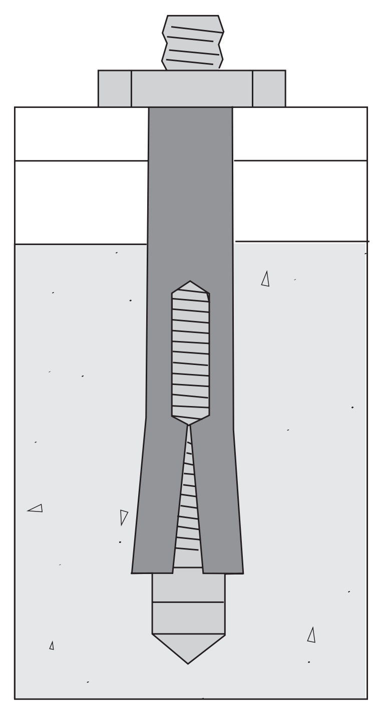
In order for a window system to be successfully installed, there must be parts and pieces that physically attach it to the structure of the building. In the glazing industry, these connections are referred to as anchors.

Anchor Bolts

If we do not have a curb at the floor line we anchor the sill track using a bolt that expands into the concrete. H4L and D2L are two common type of stud concrete anchor used to anchor embeds into

Concrete needs to be at least 8” wide for us to use an anchor bolt. If the curb is smaller than 8” wide, we must use a tube steel embed into the concrete





F&T Clips

F&T clips are used to anchor the head and sill of a typical curtain wall system. The legs of the clips slide into the open ends of the vertical mullions. The F clips which only have 1 anchoring leg and are used at the jambs, while the T clips have both anchoring legs and are used at intermediate verticals. F perimeter is an aluminum extrusion that can be used at curtain wall jambs. These perimeter anchors help limit deflection of the jamb and keep the joint sizes minimal.

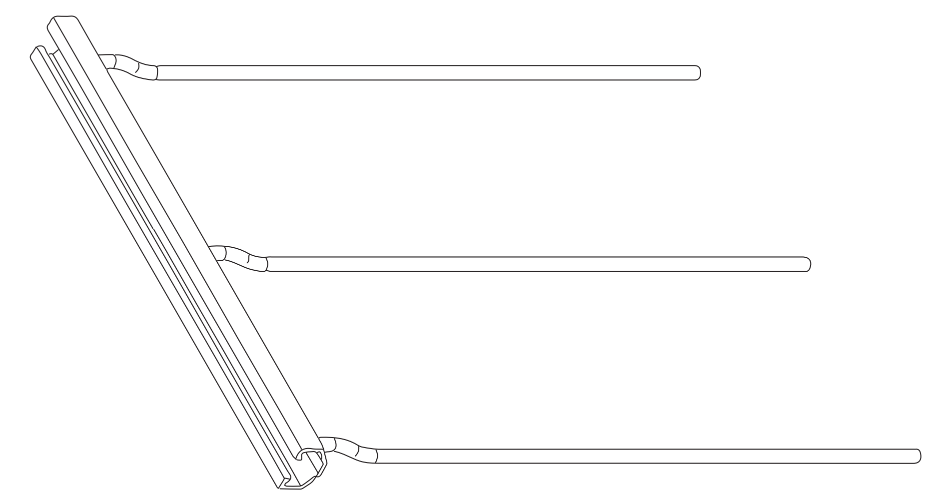
Anchor
A manufactured component that allows for a secure connection to the building.

Embed
Any steel shape that is placed in forms before concrete is poured so that it can be used as an anchor location. The concrete then secures the embed in place.

Embedment
The depth that a concrete anchor must penetrate the surface of the concrete in order to reach specified loads.

Embed Anchors

Embed anchors are worth mentioning, even though the embeds do not actually attach to the glazing system members. Embeds are cast in place anchors that are set into the concrete while it is being poured. All types of system clips can be attached to them by mechanical and welding means.

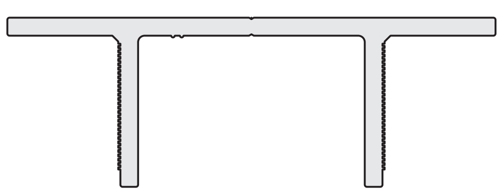


MAC Clips

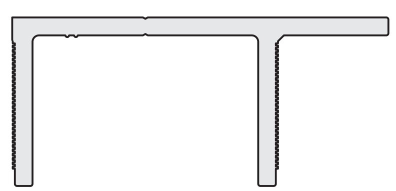
Hilti and Halfen

Hilti Embeds typically have 2 1/4" dimension from edge of embed to edge of slab. The following adjustable clips will accommodate vertical mullions up to 3" wide.

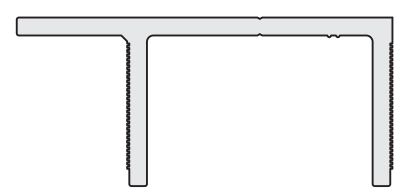
MAC-11



MAC-12



MAC-13



Steel Tube Embeds

If we have a curb, we use a tube anchor to fasten the sill track into the concrete slab. Tube embeds are typically placed at 18” on center of the vertical mullions. Tube Embeds are typically set at the day lite opening of a unit. Tube Embeds are typically 2” dimension from edge of slab at outside corners. At door locations, it is typically to have edge of embed at day lite opening for zurn drain.

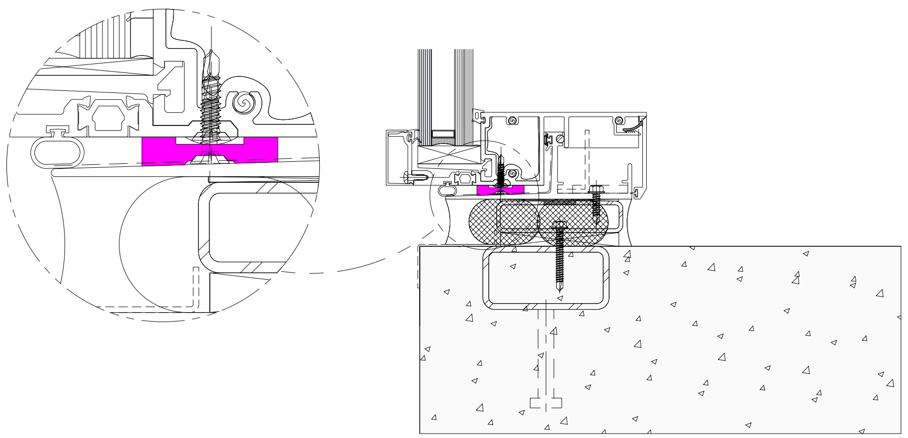
Red oxide metal primer acts as a preparatory or protective coating that prevents rust formation on the metal surfaces exposed to humidity and air.

These embeds are typically placed centered on verticals and aligned to the caulk joint’s on the jambs.

Hard Shimmed

We need to install a hard shim on our system if the weight of the glass has any probability of making the sill member over deflect due to the weight of the glass. A hard shim is placed at each setting block location.

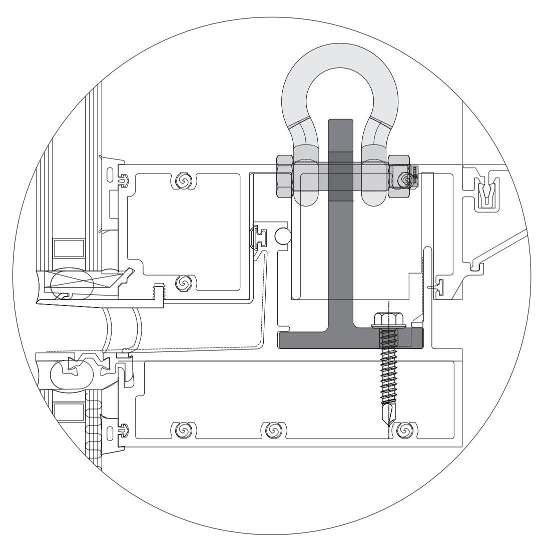
The length of these shims will equal the length of the setting blocks used in these locations.



Lifting Lug

In situations where the field does not have access to bayonets for installing a unit and a crane cannot be utilized due to specific conditions like a soffit setup, an alternative approach is to modify the top anchor to incorporate lifting lugs. This adjustment allows for easier lifting and placement of the unit without relying on bayonets or crane assistance.

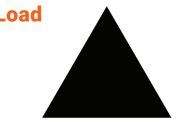
When the mullions don't align with one another. With a bayonet, the units must align. If the verticals are offset, bayonets will not work.



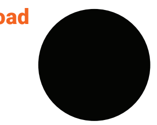
Wind load and Dead Load Clips

When curtain walls span multiple floors they need to be anchored at the floor lines. This can happen at the slab edge, or a structural member such as an I-beam. Depending on the direction of the design team, and engineers the clips will either need to be slotted (wind load) or through bolted (dead load). If the clips are slotted they allow movement while still resisting wind loading. This also allows the floors to move independently of the glazing system. For dead load or through bolted clips the movement must be allowed in the system through working splices.

Dead Load



Wind Load



Stick Built systems are almost always going to be dead loaded at the bottom and wind loaded at the top of the system.