4.0 Heat Treated glass

G.James Toughening Furnace, Brisbane

4.1 Introduction

In the Mappae Clavicula (a 9th century book) there is a description of 'unbreakable glass'. It was understood at this early stage that glass could be toughened and made stronger by quenching in hot oil. Similarly 'Prince Rupert's Drops' were produced by dropping molten gobs of glass into water. The result is a teardrop shaped piece of glass, the head of which is strong enough to withstand heavy blows with a hammer. However if the fine tail is snapped off, the complete teardrop explodes with a surprising amount of energy. This phenomenon occurs due to the outer 'skin' of the drop immediately solidifying on contact with the water while the centre cools at a slower rate. Consequently, the centre of the drop is put into tension and pulls inwards on the already hardened outer surface, which is now in compression. Breaking the tail releases the tension, which dissipates through the compressed outer surface. This is a classic demonstration of the principles involved in the toughening process.

In 1879 De La Bastie took this principle further by quenching the glass in a bath of linseed oil and tallow. The resulting product however was closer to what is today termed 'heat strengthened', rather than fully toughened. Both these methods had severe bowing problems which Siemens tried to overcome by quenching the glass between two cast iron blocks. It was not until 1928 that Reunies des Glaces in France invented the vertical electric furnace where large sheets of glass could be processed with minimal bowing. Pilkington (U.K.) followed quickly with their process of quenching by blowing air on both sides of the glass simultaneously.

In essence the process remains the same today and although vertical furnaces are still used, almost all architectural glass is produced on horizontal furnaces.

4.2 Process

Toughened Glass

The cut-to-size glass sheets are fed from the loading conveyer into the furnace where it oscillates back and forth on ceramic rollers until it reaches approximately 620˚C.

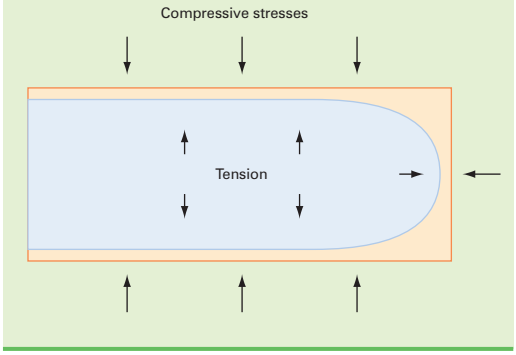
Progressing from the furnace, the glass moves into the quench where it is rapidly cooled by blasting both sides with air.

This 'snap cooling' or quenching induces compressive stresses to the glass surface while the centre remains in tension. Although the physical characteristics remain unchanged, the additional stresses created within the glass increases its strength by 4 - 5 times that of annealed glass of equal thickness.

Heat Strengthened

The process is similar to that of toughening, however in this instance the glass is quenched

Figure 4.2a: Stresses in Heat Treated Glass



at a slower rate. The result is lower compressive stress, increasing the strength to only twice that of annealed glass of equal thickness.

The latest development in technology has been the introduction of gas-fired, forced convection heat processing which has resulted in improvements in the speed of manufacture and quality of heat treated glass.

G.James operates the following heat processing facilities:

Brisbane: Two horizontal furnaces, the largest of which is gas-fired.

Sydney: Three horizontal furnaces (one of which manufactures both flat and curved toughened glass) and one vertical tong furnace for specialty glass.

Melbourne: One horizontal furnace.

Malaysia: One horizontal furnace.

4.3 Properties

Toughened Safety Glass

- Up to five times stronger than annealed glass of the same thickness
- Designated Grade A safety glass as per AS/NZS 2208
- In the event of breakage, the panel will fracture into relatively small harmless particles
- Greater resistance to thermal stress when compared to annealed glass (can be subjected to temperatures ranging from 70˚C to 290˚C)

Because of its mechanical strength it is ideal for creating a 'total vision' concept in all glass assemblies, foyers and entrance ways. It is

The small and relatively harmless fragments of toughened glass

recommended for doors, side panels and low lites, glass balustrades, shower and bath screens, pool fences and glass walled squash courts. It is also used in automotive, marine, rail and land transport as well as furniture applications.

Heat Strengthened

- Twice as strong as annealed glass of equal thickness
- Not designated as a safety glass
- Greater resistance to thermal stress when compared to annealed glass
- Typically breaks into large pieces, which tend to remain in the opening

4.4 Available Sizes

G.James Safety Glass can offer an extensive range of toughened and heat strengthened products and manufacture to the following size specifications:

Brisbane:

- 2100mm x 4500mm @ 3mm - 19mm thick
- 1500mm x 5100mm @ 5mm - 25mm thick

Sydney:

- 2100mm x 4000mm @ 4mm - 25mm thick
- 1500mm x 2400mm @ 4mm - 25mm thick
- 2100mm x 3600mm @ 5mm - 19mm thick
- 20mm diameter min. (vertical)

Melbourne:

- 2100mm x 5000mm @ 4mm - 25mm thick

Malaysia:

- 2440mm x 4200mm @ 4mm - 19mm thick

Height to width ratio limitation on all furnaces is 15:1, while the minimum size on all horizontal furnaces is 350mm x 350mm.

NB: Should your glass requirements approach these maximum or minimum sizes, please consult our technical advisory service.

4.5 Manufacturing Guidelines

As heat treated glass cannot be cut, drilled or edgeworked in any way, it is therefore important to ensure the sizes ordered are correct. If a template is required, it should be full size and of a rigid material such as plywood.

If applicable, and in particular with reflective glasses, the direction of roller-wave should be specified (See Section 4.8). It is recommended the roller-wave run horizontal provided the sizes are within the constraint of the furnace width.

Again due to the heat process involved, toughened glass will contain localised warp or bow which will vary with thickness and colour, particularly reflective glasses including Low E, ceramic painted, sandblasted or figured rolled glass.

Holes

Hole sizes

The following hole sizes are available: 5mm, 6mm, 6.5mm, 7mm, 8mm, 9mm, 10mm, 12mm, 13mm, 14mm, 15mm, 16mm, 17mm, 18mm, 19mm, 20mm, 21mm, 22mm, 23mm, 25mm, 26mm, 28mm, 30mm, 32mm, 35mm, 40mm, 42mm, 45mm, 50mm, 58mm and 80mm.

Due to the dimensional precision required for the various applications of heat processed glass, accurate and detailed diagrams are essential.

To avoid confusion, manufacturing delays and costly replacements, diagrams must comply with the following guidelines:

Diagram Guidelines

- Each item should be drawn separately on A4 size paper
- Each item must be clearly dimensioned with clearly indicated measurements from reference points
- Cut-out or notch positions and sizes must be clearly dimensioned with the measurement preferably to the edge of the cut-out or notch
- Hole sizes indicated and hole positions clearly dimensioned from the edge to the hole centre
- Glass thickness and type indicated
- Edgework requirements indicated to all individual edges
- Stamp position and type indicated
- Square corners indicated on rakes or irregular shapes
- Radii clearly indicated

4.6 Applications

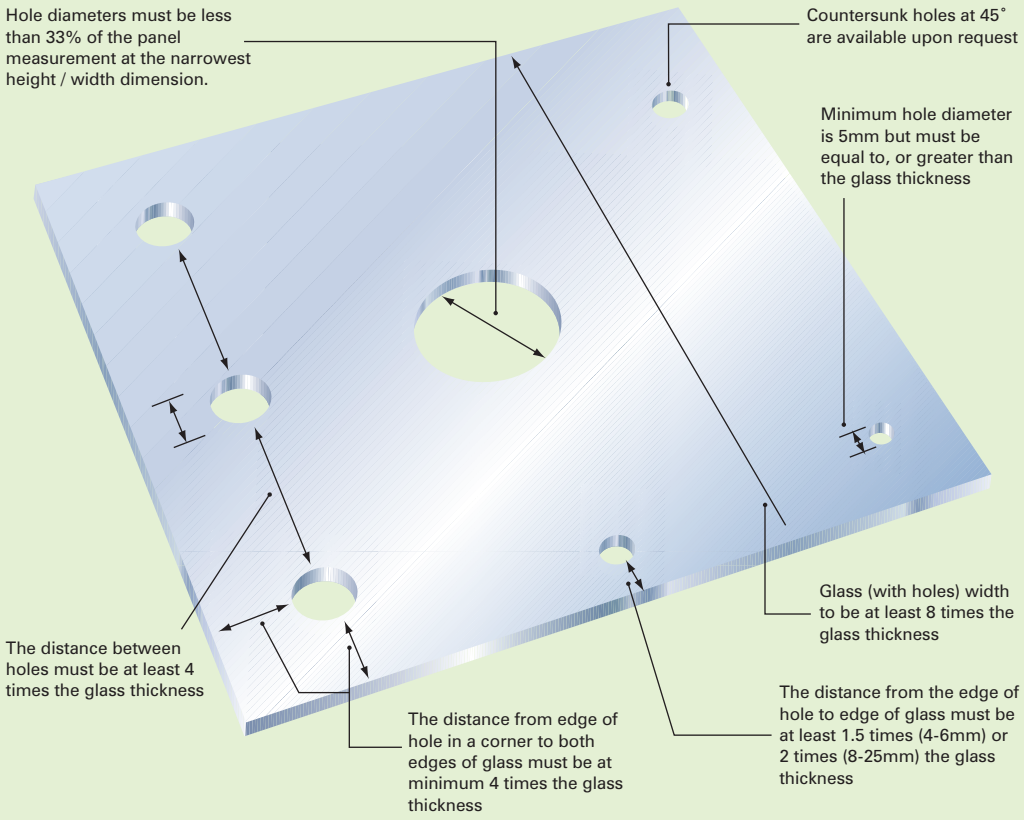
Balustrades

Framed and structural self-supporting balustrades are ideal for use in pool fencing, balcony, staircase and other applications where the ultimate in unobstructed views is desired. Suitable for both commercial and residential situations, these systems provide a low maintenance, stylish and unique balustrade alternative.

G.James offer a selection of powder coated aluminium framed balustrade or structural self-supporting systems glazed with Grade A safety glass (clear, tinted or decorative).

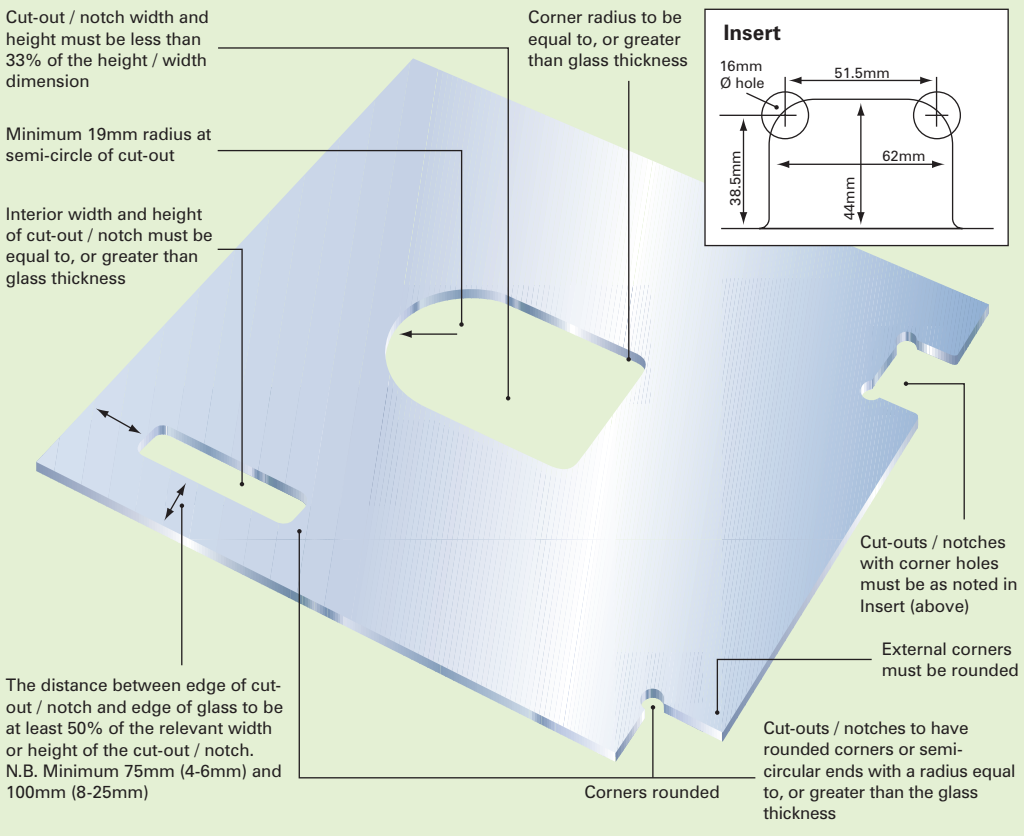
The glass thickness used for such purposes is dependent upon the application with strict compliance to the relevant regulations, codes and standards.

Figure 4.5a: Process Limitations – Holes



NB: Holes will have a ground finish with arris unless otherwise specified.

Figure 4.5b: Process Limitations – Cut-outs and Notches



NB: Cut-outs and notches will have a ground finish with arris. Polished cut-outs and notches are available on request.

Frameless toughened glass showerscreen

Consult the following to ensure compliance:

- AS 1170: Wind Load requirements
- AS 1288: Use of Glass in Buildings
- The Building Code of Australia
- Local Authority requirements
- AS 1926: Fences for Swimming Pools
- AS 2820: Gate Units for Private Swimming Pools

NB: G.James does not recommend monolithic toughened glass be used on the exterior sheer face in elevated locations above trafficable areas.

Frameless Showerscreens

Frameless toughened safety glass showerscreens offer a unique and stylish alternative to aluminium framed screens by creating the illusion of space and a distinct feature in bathrooms and ensuites.

With configurations limited only by the imagination, each screen is custom designed and measured to suit the particular site to ensure structural stability and functionality.

A wide selection of handles (or knobs) and hinges are available in powder coated, chrome or gold plated finishes.

Glass Assemblies

Suspended glass assemblies allow designers to create an impressive feature without the interference of framing, providing greater light and a feel of open space with minimal visual barriers. In principle, the system involves toughened glass panels bolted together at the edges/ends with specially designed fittings and hung from the building structure hence the term 'suspended' glass assemblies.

Toughened glass fins are used at each vertical joint to act as stabilisers and provide stiffness against high wind loads. The panel to panel joints are sealed with silicone and the entire assembly is suspended on adjustable hangers and retained at the bottom and sides in a peripheral channel. This channel, designed with deep glazing pockets, can accommodate a certain amount of movement within the floating facade. An exciting new development in frameless glass assemblies is the use of structural trusses eliminating the need for patch fittings.

Types

Toughened glass assemblies can be designed to incorporate the following systems:

- 'Spider' fittings with cable/bow trusses
- Patch plate fittings
- Countersunk, flush faced patch fittings
- Structural trusses (without the need for holes)

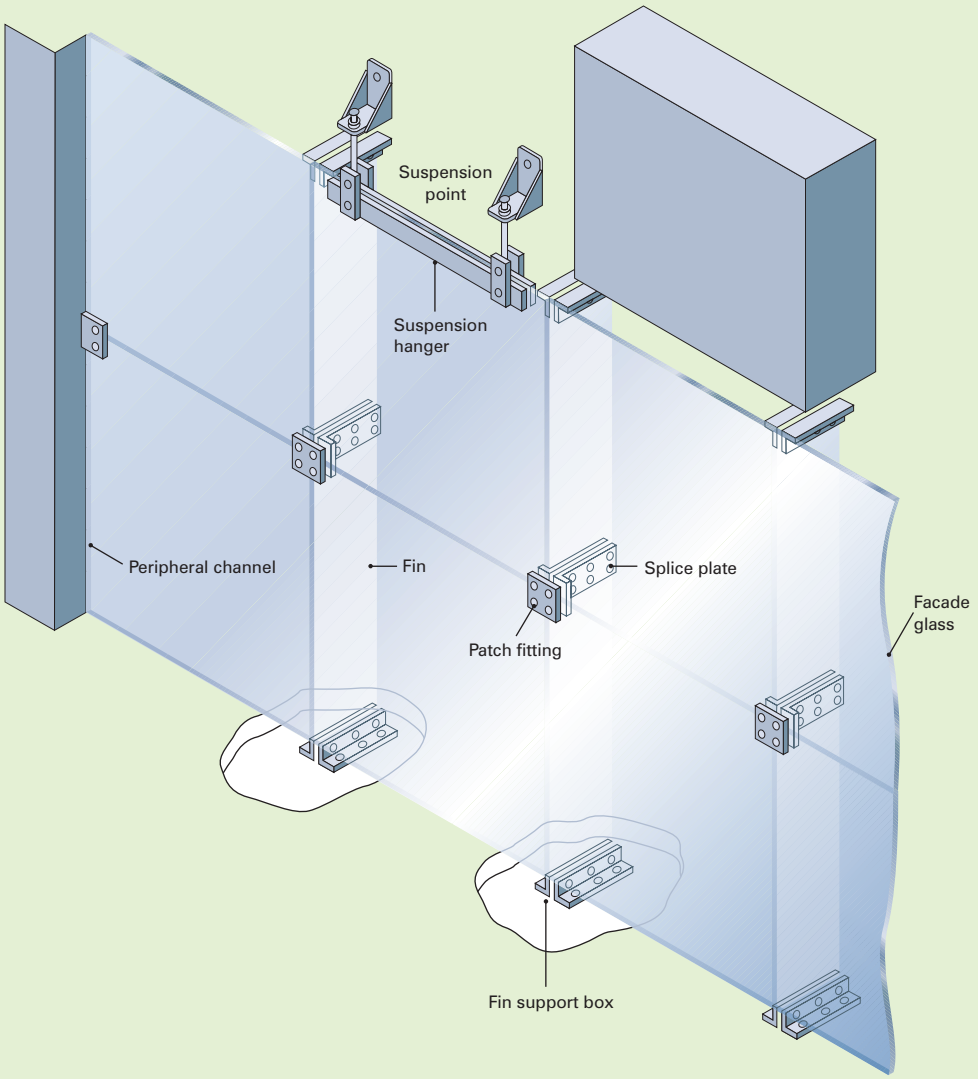
G.James can design assemblies to suit a wide range of applications incorporating either flat or curved toughened glass.

NB: It is recommended that glass used in suspended glass assemblies be heat soak tested.

Toughened glass assembly

Toughened glass assembly incorporating spider fittings

Figure 4.6a: Toughened Glass Assemblies



Frameless toughened glass entry

Frameless Entries

For building entrances and shopfront applications, frameless toughened glass entries provide impressive, unobstructed views with design flexibility and functionality.

Types:

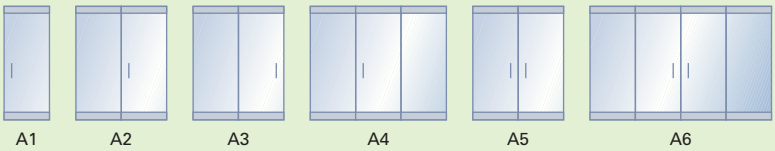
- Heavy-duty floor springs in single or double action with hold open or non-hold open functions
- Automatic pivot systems
- Concealed overhead closers
- Automatic, overhead operators with electric locks, card readers or panic bars

Hardware Options:

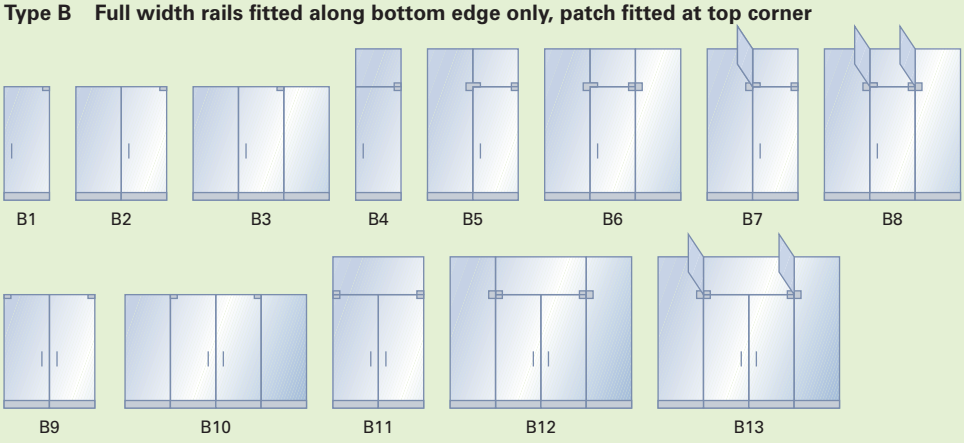
- Locks fitted to the top and/or bottom rails, or at the handle position

Figure 4.6b: Frameless Glass Door Options

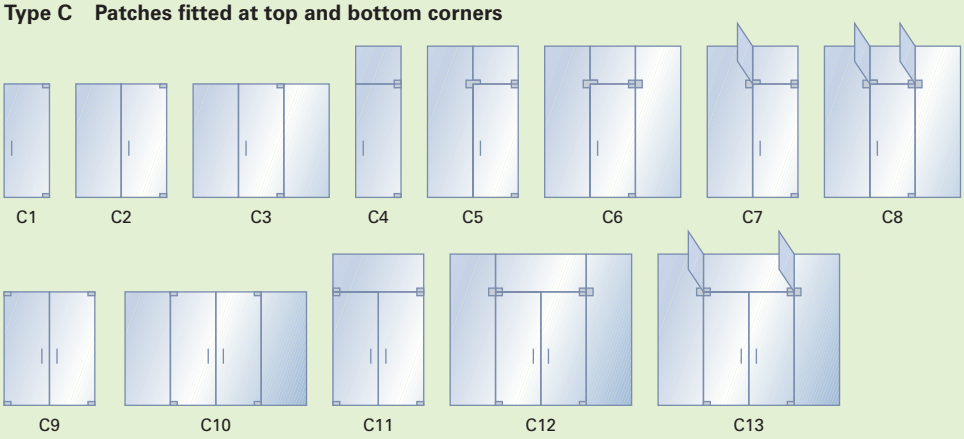
Type A Full width rails fitted along top and bottom edges



Type B Full width rails fitted along bottom edge only, patch fitted at top corner



Type C Patches fitted at top and bottom corners



• Handles in a selection of designs and sizes

All above are available in either brass, polished or satin stainless steel, powder coated or anodised finishes.

Bi-folding and Stacking Doors

Utilising the latest hardware componentry with the features of toughened glass, bi-folding and stacking doors offer a moveable wall system which allows the glass panels to travel in a concertina style folding action. The glass panels can be either framed or frameless and, once completely opened, be totally hidden from public view. This facility allows any commercial operation to have maximum business exposure and full use of all available space making it perfect for cafes, coffee shops etc.

Multi-stacking configurations can be designed to suit residential applications to provide unobstructed views of the city, surrounding countryside or pool area. In addition, bi-folding and stacking systems are capable of incorporating sliding or pivot doors.

NB: Weatherproofing issues need to be considered.

4.7 Colourlite (Ceramic Painted Glass)

The application of fused colour to glass provides architects with the ability to complement or contrast the vision glass used in today's modern buildings. The coloured frit used in this process consists of glassflux (70 - 95%) and ceramic pigment (5 - 30%).

Frameless toughened glass stacking door system

Figure 4.7a: Colourlite Standard Colours

NB: Colours are for illustrative purposes only

Process

The manufacture of Colourlite involves 'screening' the selected coloured ceramic paint onto one side of the glass. This method of application ensures total and complete coverage of the glass surface. Once the colour has been applied, the glass is then heat treated with the heat generated within the furnace sufficient to melt the frit into the glass substrate.

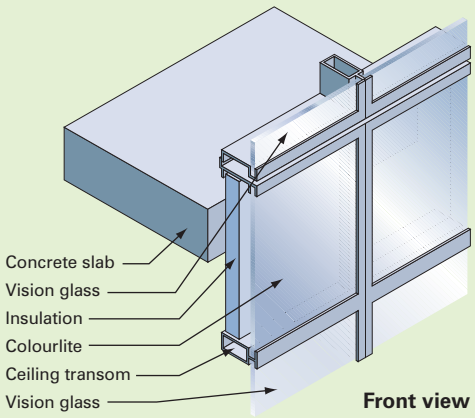
Minimum size: 350mm x 350mm
Maximum size: 1500mm x 2700mm

Properties and Applications

The application of Colourlite bonds the colour to the glass, supplying a permanent non-porous surface with excellent scratch resistance (removal of the colour is not possible without damage to the glass substrate). G.James Colourlite is impervious to weathering and fade resistant.

Colourlite spandrel application

Figure 4.7b: Colourlite Spandrel Application



Variation in perceived colour may occur with any ceramic frit. Such variations however will be more apparent with white or light colours because of unavoidable light transmittance. Further due to inherent variations in the ceramic frit thickness, lighter colours are more influenced by the colours of materials installed behind the glass. Therefore, if white Colourlite is specified, the area behind the glass must be of a uniform light colour to avoid any shadowing effect. It is recommended that full-sized prototypes (incorporating all specified spandrel materials, in particular insulation) are viewed on-site and approved by the client to avoid any oversight in this regard.

Viewing should always be from the glass side and never the painted surface, nor should Colourlite be used in applications where backlighting may occur.

Colourlite's excellent colour stability and aesthetic features means this product is perfect for spandrel panels in high rise/apartment buildings. Choose from the eight standards colours (See Figure 4.7a) or select your own customised colour.

4.8 Characteristics

Roller-wave

An inherent consequence of the heat treatment process is roller-wave which is caused by the heated, slightly softened glass being in continual contact with the oscillating ceramic rollers. This distortion is more noticeable in reflective or dark tinted glasses and if applicable, the direction of roller-wave should be specified. It is recommended the roller-wave run horizontal provided the sizes are within the manufacturing constraints of the furnace.

Quench Pattern

During the quenching phase of the heat treatment process, the glass is rapidly cooled by high velocity blasts of air. Inevitably this results in slightly higher levels of compression at those areas adjacent to the air nozzles. The consequence of these areas of high compressive stresses is the occasional appearance of a strain pattern of iridescent spots or darkish shadows. This effect is referred to as the 'quench pattern' as it occurs in the furnace quench.

An example of a quench pattern viewed under polarised light

Typically, the pattern is only visible at times of polarised light or by viewing the glass from the inside at acute angles. Similarly, the thicker and more reflective the glass, the more obvious the quench pattern will be.

Nickel Sulphide Inclusion

Toughened glass can on rare occasions shatter for what appears to be no apparent reason. This is sometimes referred to as a 'spontaneous breakage'.

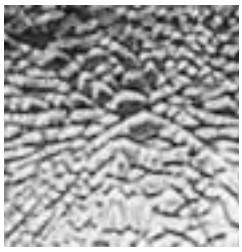
In the early 1960's, the I.C.I. building in Melbourne had extensive breakage in the spandrel panels. Mr Ron Ballantine of the CSIRO investigated the case and discovered the cause was nickel sulphide (NiS) inclusions, a substance that possesses both an Alpha and a Beta phase. Once subjected to heat, as would occur during the toughening process, this phase alters to the more unstable Beta phase. Since the quenching process is very rapid, the structure of NiS does not have time to transform back to the stable Alpha phase. This phase transformation will continue to occur over periods of time ranging from a few minutes to years after glazing.

The cause of spontaneous breakage is not limited to NiS but any foreign particle, even silica stones, which may enter the raw glass mix or float glass manufacturing process. However while other such particles can be found using electronic scanners, to date NiS stones go undetected, only being identified after breakage. Identification is possible by following the fracture radii to the centre point of origin. If there appears two larger fragments shaped like 'butterfly wings', this would typically indicate the presence of NiS. Microscopic examination may reveal a minute black speck or NiS stone in the centre of the glass. Stones of concern are always situated in the central or tensile zone and vary in size upwards from 0.04um in diameter.

While glass manufacturers are extremely careful to ensure that no nickel enters the glass tank, it should be noted that it takes only 0.1 gram of nickel in a 500 tonne tank to produce 50,000 NiS stones.

4.9 Heat Soak Testing

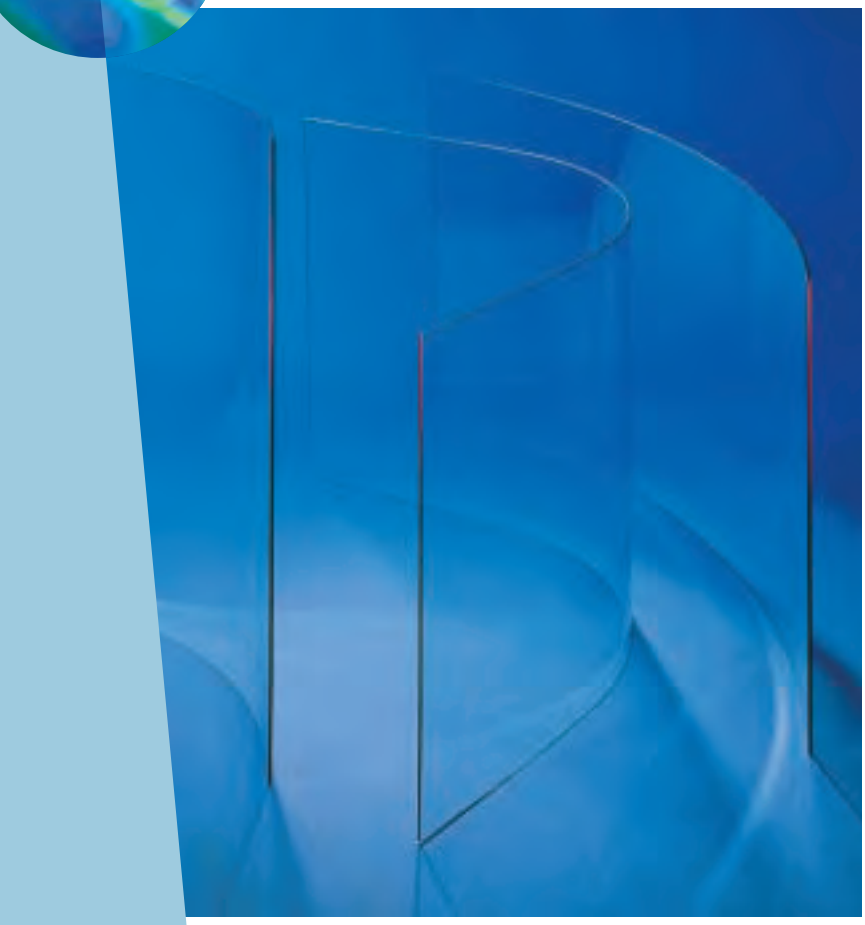
G.James Safety Glass can conduct heat soak testing (HST) on toughened glass if required. Heat soaking is a destructive test which heats the glass for several hours at 280˚C to speed up the Alpha to Beta transformation of any nickel sulphide (NiS) should it be present. This accelerated testing process reduces the likelihood of breakage by a factor of 20 with a 95% conversion rate of potentially damaging nickel sulphide inclusions. Obviously identifying NiS inclusion prior to on-site installation has distinctive cost, safety and security benefits and is therefore strongly recommended for toughened glass assemblies or where the consequence of breakage could result in injury.



Left: Typical failure pattern (butterfly wings) observed after spontaneous breakages of toughened glass due to NiS inclusions

Right: Scanning Electron Micrograph of a typical NiS inclusion observed after the spontaneous failure of toughened glass (about 0.2mm diameter). One can note the rough aspect of the surface, as always seen on dangerous NiS stones

5.0 Curved toughened glass



A range of possible curves

5.1 Introduction

In another first G.James combines the strength of toughening with the latest in curved safety glass technology to offer architects, specifiers and interior designers a range of innovative and exciting design options.

The continuous manufacturing process involves heating, then curving the glass to the required shape before finally toughening. By employing movable platens in the quenching process, the need for expensive press moulds has been eliminated. This technology allows each shape to be precisely moulded to customer specifications providing cost effective building solutions.

5.2 Terminology

To assist designers and clients when seeking quotations or placing orders the following terminology should be used:

Height: The straight edge length of the glass.

Depth: The distance between two parallel lines which enclose the curved glass.

Radius: The distance from the centre of the circle to the circumference of the circle.

Degree: The angle of a segment in a circle expressed in degrees.

Tangent: A straight line extending from the arc of the curve.

Chord: The straight distance between the edges of the curve.

Girth: The distance around the surface of the curve.

(See Figures 5.2a & 5.2b)

Figure 5.3a: Available Curves

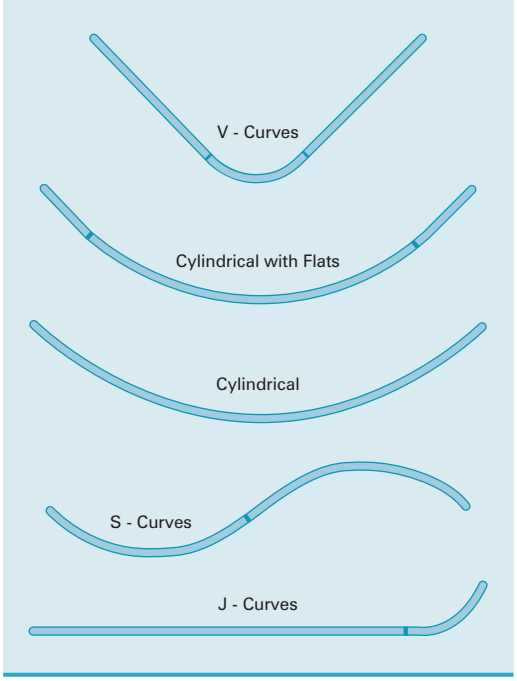


Figure 5.2a: Dimensional Specification No.1

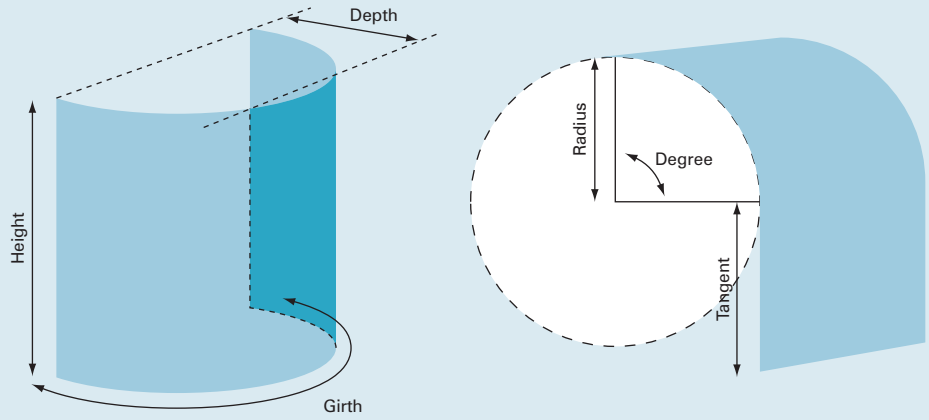


Figure 5.2b: Dimensional Specification No.2

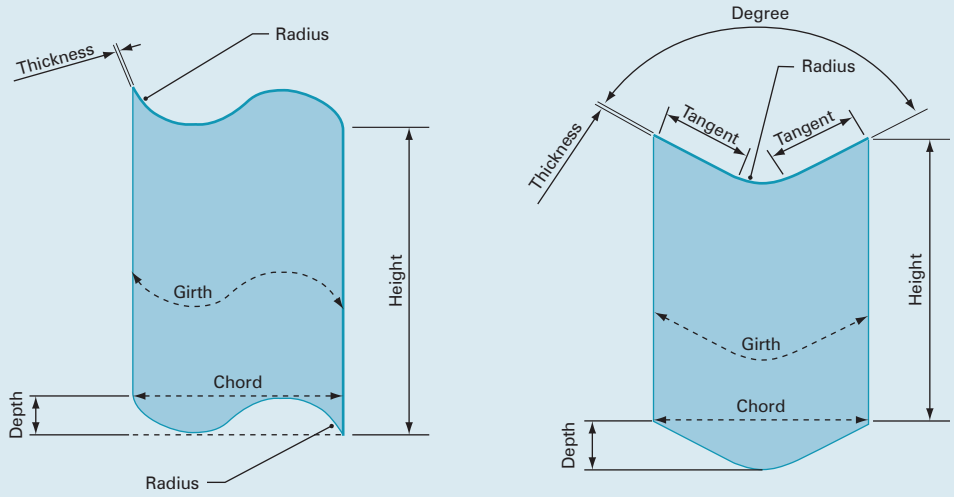


Table 5.4a: Maximum Sizes

Thickness	Glass type	Girth	Height	Minium radius
3mm	Heat Strengthened	2140mm	2500mm	635mm
4mm	Heat Strengthened	2140mm	2500mm	635mm
5mm	Toughened	2140mm	2500mm	635mm
6mm	Toughened	2140mm	3000mm	635mm
8mm	Toughened	2140mm	3000mm	762mm
10mm	Toughened	2140mm	3000mm	762mm
10mm	Toughened	2140mm	3660mm	1525mm
12mm	Toughened	2140mm	3000mm	889mm
12mm	Toughened	2140mm	3660mm	1525mm
15mm	Toughened	1830mm	1830mm	2550mm
19mm	Toughened	1830mm	1830mm	2700mm

G.James' flat and curved glass toughening furnace, Sydney

5.3 Available Curves

(See Figure 5.3a)

It should be noted that the maximum bending angle is 90˚, therefore a full circle (360˚) can only be achieved using four pieces of glass.

5.4 Maximum Sizes

As height increases, the glass becomes more difficult to curve and therefore the minimum radius must be increased. Similarly as the glass weight and thickness increases, the maximum height must be decreased and the minimum radius increased (See Table 5.4a).

5.5 Measuring

Providing accurate dimensions for the purpose of manufacturing curved toughened is crucial to the whole process. In particular, the radius and girth dimension must be clearly stated as being measured from either:

a) the inside edge of the glass,

b) the centre of the glass, or

c) the outside of the glass.

The preferred dimension is the radius from the inside edge of the glass, particularly for cylindrical shapes.

Where the chord and depth dimensions can be supplied, a computer program will be used to print out all necessary dimensions for clients checking and sign off.

Templates would be preferred for cylindrical shapes but are a must for cylindrical shapes with flats. All templates must be of a hard material such as plywood and remember the minimum possible radii as previously listed in Table 5.4a.

5.6 Applications

G.James curved toughened safety glass has many and varied applications including:

- Shopfronts and Internal Partitions
- Balconies, Balustrades and Pool Fencing
- Revolving Doors
- Elevators and Lifts
- Skylights and Covered Walkways
- Bay Windows
- Showerscreens
- Display Cases, Deli bends and Food Cabinets
- Glass Furniture
- Windscreens

It is also possible to incorporate Colourlite onto the surface of curved toughened glass panels.

5.7 Glazing

Please refer Section 11.

G.James can also supply, curved aluminium channels for head and sills if required.

5.8 Acceptance Criteria

Limitations

Curved toughened glass can only be curved in one plane (dimension).

The manufacturing limitations are as follows:

- Maximum girth or curved dimension
  – 2140mm (5mm – 12mm)
- Maximum height
  – 3000mm (6mm/8mm)
  – 3660mm (10mm/12mm)
  For other thicknesses see Table 5.4a
- Minimum height 400mm

Edgework: As per flat toughened glass

Cut-outs: As per flat toughened glass

Holes / Spacings: As per flat toughened glass

Tolerances

Curve: To fit within ± 3mm of the specified shape or 6mm more than the glass thickness.

Local Warpage: At the curved edge: 1.5mm for glass up to 6mm thick and 3mm for glass over 6mm.

5.9 Standards

The appropriate standard for Architectural curved toughened glass covering the thickness range of 5mm – 12mm is AS/NZS 2208. For automotive glasses 5mm – 12mm thick, the appropriate standard is AS 2080.

As 3mm and 4mm are only available in heat strengthened and not fully toughened, such panels are not covered by the above standards as heat strengthened is not classified as a Grade A safety material.

Applications for curved toughened glass

6.0 Reflective & Coated glass

Royal Sun Alliance Building, Auckland

6.1 Introduction

As demand for better performing glass products increased, technology evolved that allowed metallic coatings to be applied to the glass surface. The result was a range of glass products that offer the following benefits:

- A wide choice of external appearances with varying degrees of reflectance
- Superior, all-round performance levels when compared to those of body tinted glass
- A multitude of combinations to satisfy specific aesthetic and performance requirements

6.2 On-line Coatings

On-line coated (or pyrolytic) glass is produced by depositing a metallic oxide onto the glass surface during the float manufacturing process. The result is a series of reflective coatings that are extremely hard and durable, to the extent that they can be heat treated and curved if required. The application process does however limit the range of available colours when compared to off-line coatings.

On-line coated products include Stopsol, Solarcool and Eclipse in addition to Low E types Energy Advantage, K Glass and Sungate 500.

6.3 Solarplus (Off-line Coatings)

Solarplus is G.James' range of Airco (off-line) processed, reflective and Low E solar control glass products.

In this state-of-the-art technology, the material to be sputtered is the cathode in a high voltage electrical circuit. Process gas is fed into a vacuum chamber where a glow discharge (plasma) forms. Electrons are taken from the gas and leave positively charged ions. The ions are attracted to, and collide with the target cathode (the material to be sputtered). This process takes place at very high speed and atoms of the target material are ejected and then recondense on the glass below.

By fine-tuning, the process is capable of uniform coatings on sheets of glass up to 2140mm x 3660mm or as small as 300mm x

G.James coating line

900mm. Almost any non-magnetic alloy or metal can be sputtered, the more common ones being stainless steel, silver and titanium. With argon present in the chamber, a metallic coating is produced. With oxygen or nitrogen either a metallic oxide or metallic nitride layer is produced.

Light transmittance and colour, depend on the coating material and the density of the deposit. G.James Safety Glass has the only architectural glass coating facility in Australia.

Solarplus products are available in either annealed monolithic form (clear and tinted), heat treated or laminated glass or incorporated into a Twin-Glazed unit, depending on the selected coating.

Coating Definitions

The coating description comprises two letters and two numbers, for example TS21. The two letters identify the type of coating and the two numbers indicate the visible light transmittance on 6mm clear glass. The higher the number, the greater the visible light transmittance, conversely the lower the number the better the glass performs in reducing heat transfer. Off-line coatings applied to tinted glass or incorporated into a laminated glass with a tinted interlayer further reduces the visible light transmittance. In these instances the number reference serves as a guide only to the visible light transmittance and may assist in comparing types of glass.

Figure 6.3a: 3 Chamber Off-line Coating System

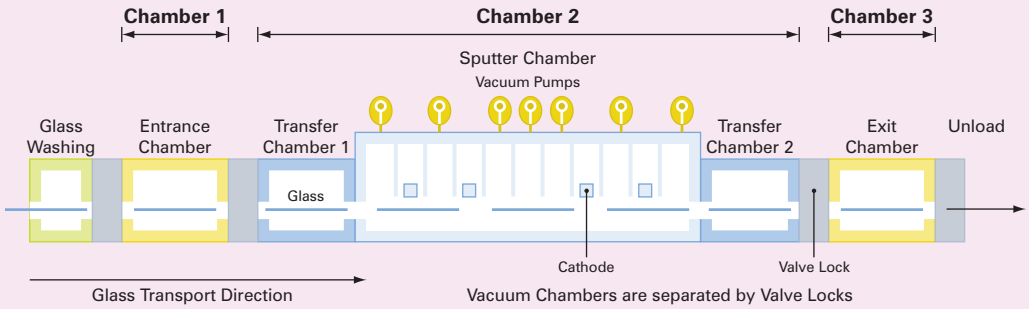
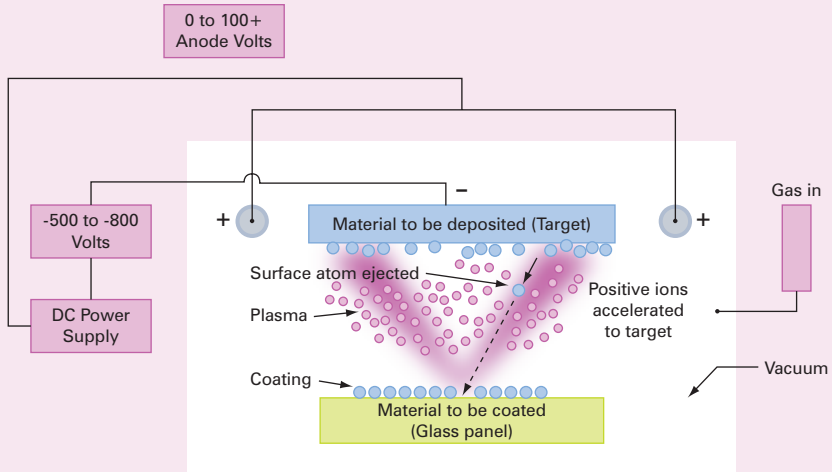


Figure 6.3b: The Sputtering Process



How glass is coated? The Sputtering Process

Glass is conveyed into a vacuum chamber which houses a proprietary AIRCO cathode and a 'target' (bar of the material to be deposited onto the glass). A controlled amount of gas is fed into the chamber, and a negative charge is applied to the cathode, resulting in a glow discharge (plasma) within the magnetic field created by permanent magnets in place behind the target.This plasma creates positive ions which are attracted to the negatively charged target, bombarding the target with such force that atoms of the target are ejected and deposited, atom by atom, onto the glass panel being coated. This cathode technique, developed by AIRCO scientists, is 10 – 100 times more efficient than previous sputtering processes.

Plasma glow during the sputtering process

Solarplus Coatings

TS Series

External Appearance*: Silver Blue to Deep Blue
Product Code: TS21, TS30, TS35***, TS40 and TS50***

TE Series

External Appearance*: Earth
Product Code: TE10

SS Series

External Appearance*: Neutral Silver
Product Code: SS08, SS14*** and SS22

SC Series

External Appearance*: Pewter (Antique Silver)
Product Code: SC22**, SC30*** and SC40***

SL Series (Laminated glass only)

External Appearance**: Silver
Product Code: SL10***, SL20 and SL30***

Notes:
*External appearance based on clear glass.
**External appearance based on clear glass with clear PVB.
***Non Standard coating (surcharge may apply).

As with all solar control glass products, a thermal safety assessment is recommended to determine if heat treatment is required to avoid thermal breakage.

6.4 Handling Criteria

Delivery & Storage

Do

- Make sure the glass is always supported
- Protect from knocks, abrasions and excessive pressure - especially on edges
- Keep surfaces dry, clean and interleaved with polyfoam

Don't

- Bend
- Store in direct sunlight or unventilated spaces

Handling

Do

- Handle glass manually, or with clean, oil-free vacuum pads

Don't

- Use gloves or vacuum pads which are dirty or contaminated

Installation

Do

- Take care not to damage the coating when fitting into the frame, or with glazing tools, sealant guns etc., or by leaning materials against the coated surface
- Glaze with coated surface to the INSIDE of the building (monolithic form only)
- Remove excess lubricants immediately and check regularly for any reappearance
- Clean up splashes from plaster, mortar or concrete before they harden
- Minimise damage by hanging protective plastic drapes over (but not touching) glazed panels once completed

Don't

- Glaze sheets with damaged edges
- Use glass with vented or severely feathered edges
- Glaze with coating exposed to weather

Cleaning

Do

- Clean panels as soon as possible after installation, especially if there is a risk of leaching, run-off or spattering from other materials
- Use ammonia and water or well-diluted mild detergent for routine cleaning

Don't

- Use abrasive cleaners

General

Don't

- Apply protective films to any coated surface
- Mark or label the coated surface

6.5 Low E (Low Emissivity)

All materials lose heat, but some more quickly than others. The rate of heat loss depends on the surface emissivity of the material. For example, a silver teapot will retain the fluid temperature far longer than a glass teapot because the surface of silver has a much lower 'emissivity'. Emissivity is defined as the rate of emitting (radiating) absorbed energy.

The radiant energy is long wave infra-red, which is in effect re-radiated back towards the heat source.

A black body is the perfect emitter with a surface emissivity of 1.0. Comparatively, ordinary clear glass has a surface emissivity level of 0.84, meaning 84% of the absorbed heat is emitted from the surface. When Low E coatings are applied to the glass, the surface emissivity is reduced to less than 0.20. Therefore the lower the surface emissivity, the better the glass reduces heat gain or heat loss. For assessment purposes, heat gain or loss is measured in U-value (W/m^2K) with the lower the number, the better the performance of the glass.

Solarplus Low E

In terms of visible light transmission and thermal insulation, Solarplus Low E is the optimum glass product. These off-line sputtered coatings are transparent layers of silver and metal oxide deposited onto the glass surface. The metal oxides, which surround the silver, protects and suppresses the visible reflectance of the silver. This range of coatings can only be supplied on glass that will form part of a Twin-Glaze unit (edge deletion required).

G.James produce two off-line Low E coatings, namely LE80 and LE54 as part of the Solarplus Low E range.

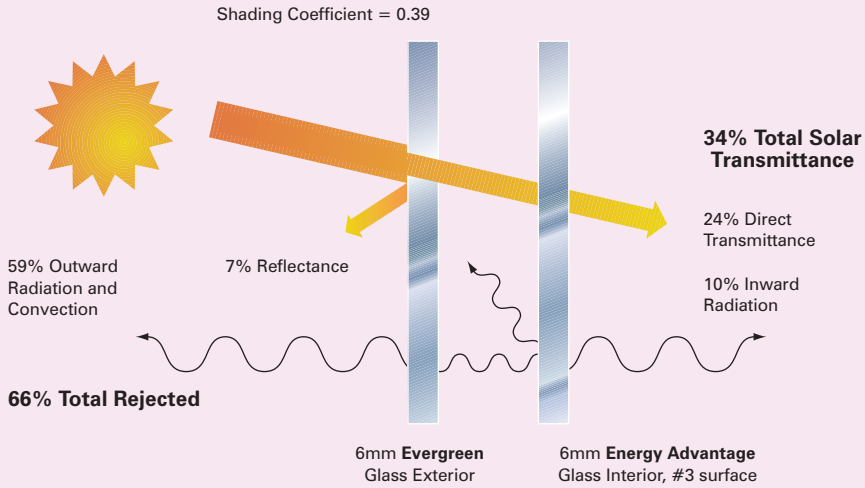
Solarplus Low E LE80 has a neutral colour in both reflection and transmission. This is accompanied by very high light transmission which, when combined with a high performance reflective or body tinted glass and incorporated into a Twin-Glaze unit, results in a thermally efficient window with both a low shading coefficient and U-value.

Solarplus Low E LE54 is a tinted coating which is ideal for use in warm climates, as it offers a balance between light transmission and solar energy control. By combining this coating with a body tinted glass in a Twin-Glaze unit, a desirable shading coefficient is achieved while maintaining good light transmittance, minimal external reflectance and low U-value.

G.James also stock a range of on-line coated Low E glass which can be cut, toughened, laminated or curved in the same way as ordinary annealed glass and requires no edge deletion for fabrication. This range of coated products has very high light transmission, low reflectance and is only available on clear glass. When incorporated with a solar control glass in a laminate (Optilight) or a Twin-Glaze unit, a desirable shading coefficient and a reduction in U-value can be achieved.

NB: Please refer to Section 15 for performance figures

Figure 6.5a: Low E Glass



7.0 Insulated glass units

Russell Offices, Canberra

7.1 Introduction

By nature, a single piece of glass has little resistance to either heat gain or loss, primarily because it is a good conductor and a very poor insulator. Recognising this problem, T.D. Stetson (USA) registered the patent for insulated glass in 1865. Stetson discovered that by adding a second panel of glass separated by still, dry air the insulating properties of glass could be improved. The improved performance of this insulated glass is attributed to the low thermal conductivity of the air pocket. It was not until after World War One that commercial production of the 'bonded units' commenced, with manufacturing techniques improving throughout the 1950's in Europe and the USA.

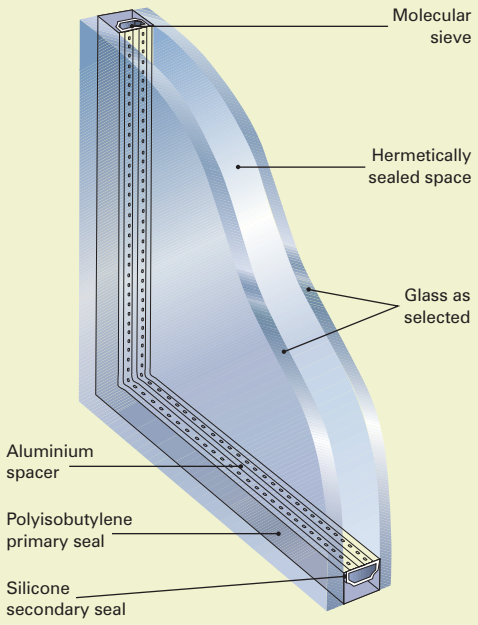
Methods used to seal the unit have progressed over time from the original metal to metal, to metal soldered, then glass fused and finally, to the current day, double sealed system.

G.James began manufacturing IG units in 1991 and registered the name 'Twin-Glaze' under which it markets this product.

7.2 Process

Cut-to-size glass is moved vertically along a conveyor through a washing and inspection process which ensures the glass is thoroughly clean and free of defects. The hollow aluminium spacer is then shaped to suit with a strip of Polyisobutylene applied to both sides providing the primary seal and an excellent vapour barrier. The spacer, which is filled with molecular sieve (desiccant) to prevent condensation from forming after sealing, is positioned between the two panels of glass

Figure 7.2a: Typical Twin-Glaze Unit



G.James Twin-Glaze Line

and then pressed together. Finally the silicone secondary seal is applied to the perimeter void around the unit.

Application of the secondary seal provides the following benefits:

- Good tensile strength to the glass to glass edge
- Low vapour and gas diffusion
- Excellent adhesion between the glass and the metal spacer with short curing times
- Superior structural bonding for the total unit

Today's automated systems such as the Lisec machines operated by G.James provide computerised washing, spacer bending, pressing and sealing with state-of-the-art robotic equipment. G.James is an accredited member of the Insulated Glass Manufacturers Association (IGMA) and complies with BS5713:1979 and CAN/CGSB - 12.8-M90.

7.3 Manufacturing Guidelines

Spacer Widths Available: 6mm, 8mm, 9mm, 10mm, 12mm, 14mm, 15mm, 16mm, 18mm, 19mm, 20mm, 22mm and 24mm.

7.4 Properties and Applications

The principle function of a Twin-Glaze unit is to improve the building occupant's comfort and reduced heating and cooling costs by minimising the flow of heat from the inside to the outside, or outside to inside - depending on the season. This is achieved by the airspace diffusing the transfer of heat creating insulation properties almost twice that of a single panel of glass.

The insulation value (U-value) is dependent on the unit configuration this includes the glass type/s, glass thickness and spacer width. Twin-Glaze units incorporating solar control

Table 7.3a: Size Limitations

Twin-Glaze units incorporating	Available Thickness	Minimum Sizes	Maximum Sizes
Annealed glass	Various	400mm x 400mm	2400mm x 3500mm
Heat Strengthened glass	Various	400mm x 400mm	2100mm x 3500mm
Toughened glass	Various	400mm x 400mm	2100mm x 3500mm
Laminated glass	Various	400mm x 400mm	2400mm x 3500mm

NB: Minimum/maximum sizes will be dependent on human impact/wind loading requirements. Maximum size will be dependent on weight (max. 225kg) and unit configuration.

products such as Solarplus significantly reduce solar heat gain, while certain combinations can provide superior solar and glare control, reduced air conditioning costs, improved noise reduction, greater fire resistance and increased security.

In colder climates where solar energy transmittance is encouraged, a combination of clear glass and Low E (inner) will ensure high light and energy transmittance while the Low E ensures it stays 'trapped' inside. In warmer, tropical climates this same combination helps reflect and prevent the near infra-red (heat) from transferring through to the interior.

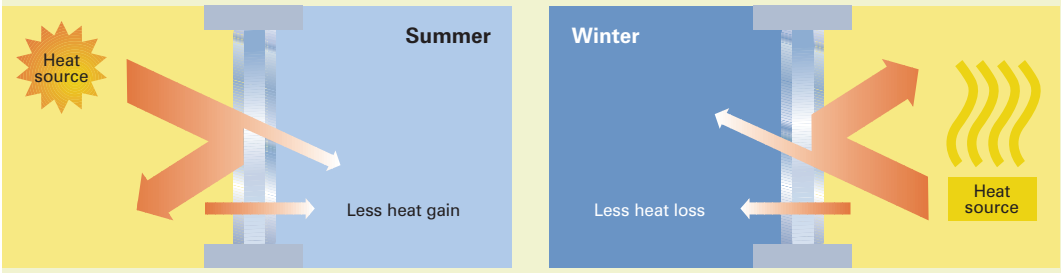
Twin-Glaze units can incorporate combinations of processed clear, tinted, reflective, low emittance (Low E) or Colourlite glass.

A thermal stress analysis is strongly recommended where solar control glass is involved - in particular Low E and high performance glass.

7.5 Condensation

Air comprises a mixture of gases including water vapour. At any given temperature, air reaches a 'saturation point' where it cannot hold any more water. Should air with excess

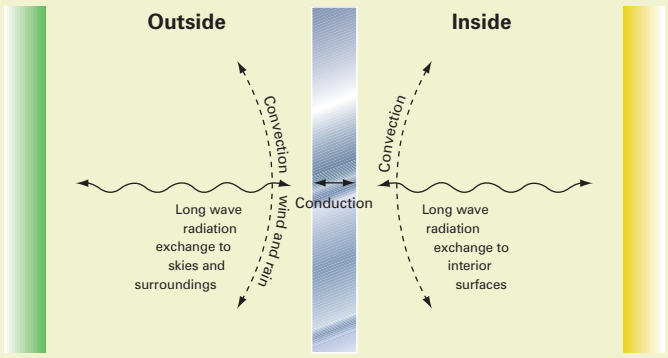
Figure 7.4a: Solar Control



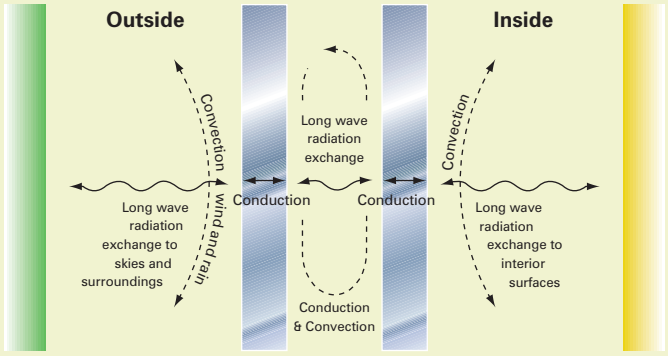
Low E glass helps prevent heat from entering in the summer

Low E glass helps prevent heat from escaping in the winter

Figure 7.4b: Heat Gain/Loss – Single Glass vs Twin-Glaze Unit



As single glass is a poor insulator and easily conducts heat, there is minimal resistance to heat gain/loss.



An air space between two panels of glass significantly improves insulation due to the low thermal conductivity of air (compared to glass). The second panel further assists with thermal resistance.

water vapour come into contact with a colder surface, condensation will form on this surface. The temperature at which condensation occurs is known as the 'dew point'.

In colder climates, condensation can develop on the inside of windows when the outside temperature is significantly lower than the inside temperature thereby reducing the surface temperature of the glass. To overcome this temperature variation, Twin-Glaze units should be selected to provide a thermal barrier between the inside and the outside, thereby minimising the occurrence of condensation.

7.6 Characteristics

There are three main optical effects that can occur with Twin-Glaze units:

Distortion and Reflection

All buildings are subject to constant interior and exterior changes in temperature and pressure. These naturally occurring changes although quite small at times, are sufficient to cause the glass to deflect or bow, resulting in a distorted, reflected image. This distortion known as 'pillowing' is visible mainly in the corners of the unit when viewed from a distance and can be either convex (where the glass bows outwards) or concave (inward bowing). This unavoidable effect is more noticeable with reflective type glasses.

Newtons Rings

With changes in atmospheric pressure, the glass in large Twin-Glaze units may deflect to the extreme where they touch in the centre of the unit, creating irregular, coloured circles similar to an oil stain effect. If either panel is pushed, the rings will move and change shape. Once the unit has pressure equalised, the effect of Newton Rings will disappear however it can be avoided by limiting the size of the unit and/or using thicker glass.

Sky Tower, Auckland

Brewsters Fringes

Only possible with very high quality float glass, this rare and temporary occurrence is a consequence of using two glasses of exactly the same thickness with precise parallel surfaces. The reflected light within one glass blends with the reflection within the other glass to form faint coloured streaks. Brewsters Fringes can appear anywhere over the glass surface and can be avoided by using different glass thicknesses.

8.0 Safety and Security glass

Bullet resistant glass under attack

8.1 Introduction

With safety and security becoming an increasingly important feature in modern building design, G.James has developed the ArmaClear range of specialty glass products to ensure optimum protection should the need arise.

These high impact products are visually similar to ordinary glass (of the same thickness) providing an unobtrusive barrier against most forms of attack. ArmaClear has been installed in a variety of safety and security sensitive applications throughout Australia and overseas, having proved their effectiveness after extensive testing and in-situ service.

8.2 ArmaClear – Bullet Resistant (BR) Glass

The Process

ArmaClear Bullet Resistant (BR) glass is manufactured employing G.James' laminating process where multiple layers of glass and polycarbonate are subjected to tremendous heat and pressure, permanently bonding the individual components into one complete panel. Bullet resistant glass construction can be customised to include tinted glass, tinted or obscure interlayers, reflective coatings and one-way mirror, with certain curved configurations also possible.

Holes, cut-outs and shapes are available but may involve some limitations.

G.James has the manufacturing capabilities and technological experience to satisfy a wide range of specifications, from small hand guns to high-powered rifles and shotguns. The G.James Technical Advisory Service is available to assist with reliable and confidential advice.

Properties and Applications

ArmaClear BR products are multi-ply laminates ranging in thickness from 32mm to 45mm and may consist of an all glass construction or incorporate a combination of glass and polycarbonate. The multiple layers of glass used on the attack side deform and slow the bullet, while the polycarbonate absorbs the force of impact. The actual product thickness and configuration is totally dependent upon

Range of weapons

Table 8.2a: ArmaClear Bullet Resistant Products

Level	Weapon and calibre	Ammunition	Range	Number of strikes	Thickness (mm)	Weight (kg/m²)
G0	Handgun 9mm military	Mk 2Z standard 9mm 7.4 metal case bullet	3m	3	35	82
G1	Handgun 357 magnum	10.2g soft point semi-jacketed, flat nose	3m	3	32	70
G2	Handgun 44 magnum	15.6 soft point semi-jacketed, flat nose	3m	3	34	73
S0	Shotgun 12 gauge	12 gauge 70mm, high velocity magnum 32g SG shot	3m	2	34	73
S1	Shotgun 12 gauge	12 gauge 70mm 28.35g single slug	3m	2	38	86
R1	Rifle 5.56mm	M 193 5.56mm 3.6 full metal case	10m	3	38	86
R2	Rifle 7.62mm	NATO standard 7.62mm 9.3g full metal case	10m	3	45	98

the nominated calibre of weapon correlating to a specific level of protection (See Table 8.2a).

The components used in the manufacture of ArmaClear BR ensure normal vision is maintained. The final product is resistant to abrasion while also providing superior sound insulation. The strength and appearance of this product is unaffected by exposure to sunlight however a thermal safety assessment is recommended where tinted or reflective components are incorporated. Care must be taken to avoid edge damage.

In the event of an attack, ArmaClear will maintain a protective barrier and degree of visibility, except around the area of bullet impact. It is ideal for installation in banks, prisons, armoured vehicles, embassies, payroll offices, police stations, airports, public buildings, government offices and special defence vehicles.

Framing and Accessories

It should be emphasised that the surrounding frame and support structure are equally important as the glass, and must be of a strong construction and capable of providing the same level of protection to that of the bullet resistant glass.

For this reason, G.James has developed framing systems to complement all ArmaClear BR products, including the supply of document trays and voice transfer louvres. Installation can also be provided if required.

ArmaClear bullet resistant glass, framing and accessories

Performance

Standards Australia issued AS 2343 to ensure high standards of performance and detail strict guidelines for bullet resistant glazing.

The Standard defines three broad attack categories:

- 'G' - Resistant to hand gun attack
- 'S' - Resistant to shotgun attack
- 'R' - Resistant to rifle attack

ArmaClear BR products have been tested and certified by an independent, accredited NATA laboratory to ensure compliance with the various parameters outlined in Table 8.2a. Test certificates can be supplied upon request.

NB: NATA - National Association of Testing Authorities.

8.3 ArmaClear – Physical Attack (PA) Glass

G.James' ArmaClear Physical Attack (PA) glass has a remarkable resistance to human attack and penetration.

The Process

ArmaClear PA is manufactured using modern laminating processes where the multiple layers of glass and polycarbonate are subjected to tremendous heat and pressure, permanently bonding the multiple layers of material into one complete pane. Physical Attack glass construction can be customised to include tinted glass, tinted or obscure interlayers, reflective coatings and one-way mirror with certain curved configurations also possible.

ArmaClear PA glass is made-to-order with holes, cut-outs and shapes available if required, however due to the product configuration processing limitations do apply.

G.James has the manufacturing capabilities and expertise to meet the various criteria for intruder resistance and levels of attack. The G.James Technical Advisory Service is available to assist with reliable and confidential advice.

Properties and Applications

ArmaClear PA products comprise an all glass construction or incorporate a combination of glass and polycarbonate with the multi-ply construction resisting penetration even after the glasses within the composite are broken. The multiple glass layers used on the attack side absorb the force inflicted by various hand held implements, making the progress of penetration slow with the attacker quickly tiring and eventually ceasing the attack.

The components used in the manufacture of ArmaClear PA are resistant to abrasion and also provide excellent sound insulation. The strength and appearance of this product is unaffected by exposure to sunlight however a thermal safety assessment is recommended where tinted or reflective components are incorporated. Care must be taken to avoid edge damage.

In the event of an attack, ArmaClear PA will maintain a protective barrier and degree of visibility, except around the area of impact. It is ideal for use in prisons, detention centres, mental health facilities, police stations, shopfronts (jewellery stores etc.), computer installations and other associated establishments.

ArmaClear physical attack glass – Mental health facility

Table 8.3a: ArmaClear PA Products

Product	Thickness	Minimum Size (mm)	Maximum Size (mm)
PA4H3P4H	12.26mm	100 x 400	1100 x 2200
PA6H4P6H	17.76mm	100 x 400	1100 x 2200
PA6H6P6H	19.26mm	100 x 400	1100 x 2200
PA6H9P6H	22.76mm	100 x 400	1100 x 2200

Framing

It should be noted that the surrounding frame and support structure are of equal importance and must be of a strong construction and capable of providing a level of protection similar to that of the PA glass.

To complement the range of ArmaClear PA glass, G.James offer associated framing systems which can be supplied knock-down condition (KDC) or fully installed.

Performance

Standards Australia issued AS 3555 to maintain high levels of performance and outline the guidelines for physical attack glazing.

Extensive testing of ArmaClear PA products subjected to attacks from sledgehammers, jemmy bars, bricks and axes have far exceeded industry standards and expectations. For security reasons, test performance figures are not published but are available on request against a specific project enquiry.

8.4 ArmaClear – Prison Shield (PS) Glass

G.James ArmaClear Prison Shield (PS) is a range of thin, lightweight anti-intruder laminated glass products which has been specifically introduced for low security applications where intrusion is of concern.

ArmaClear PS is constructed using a combination of toughened safety glass, heat - strengthened glass and polyvinyl butyral interlayer between the two glasses. This configuration provides initial strength in addition to continued strength even after one or both of the glass skins have been broken, making it well suited for watch houses, lock-ups, detention centres and police stations. Customised to suit individual requirements, ArmaClear Prison Shield can be manufactured to incorporate tinted glass, tinted or obscure interlayer, reflective coating or one-way mirror.

Table 8.4a: ArmaClear PS Products

Product	Thickness	Minimum Size (mm)	Maximum Size (mm)
PS6H26H	14.28mm	100 x 400	2100 x 3660
PS10H310T	23.04mm	100 x 400	2100 x 3660
PS5H25H	12.28mm	100 x 400	2100 x 3660

G.James is the chosen supplier to QR tilt trains

8.5 Train and Special Purpose Windows

The development of G.James' security products has been extended to include a range of dedicated window products for the transport and railway industries. With extensive in-house design and manufacturing capabilities, G.James can supply fully fabricated, special purpose windows incorporating high impact laminated glass and aluminium perimeter frames.

Of particular mention is the range of railway window systems which includes forward facing windscreens, driver's cab side windows, saloon side windows. These systems have undergone extensive testing and comply with British Standard BRB 566 and the Federal Railroad Administration (FRA) Standards.