G. James
is glass

HANDBOOK

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FIRST EDITION

Forward

The G.James Group is the most comprehensive and technologically advanced processor of glass in the Asia Pacific region. Significant investment in training, technology, equipment, business resources, infrastructure, and quality control systems ensure that all processes - including cutting, edging, laminating, toughening, double glazing, curving, coating, profiling and painting - are to world best standards.

Today, G.James operates the only vacuum-coating glass plant in Australia. The Group's impressive in-house capability has led to it being the preferred supplier on many national and international landmark projects.

With its worldwide reputation as an innovator of glass and associated products used in residential, commercial and high rise monumental buildings, G.James is at the forefront of developments within the glass industry.

Glass today is used to perform many functions other than its primary role of allowing light to enter a building. Its applications can be visual, mechanical, structural, decorative, thermal, architectural, artistic or a combination of any or all of these aspects. G.James provides a range of services including design assistance, specification guidelines, product development, testing and assessment to cover all of these elements.

This book has been compiled as a training and reference document for G.James employees, tutors, students, architects, engineers, builders, those within and those entering our industry.

Whatever your interest, we trust we can pass on a greater understanding of this amazing and versatile material - GLASS.

If you require further assistance or information on any of the material contained within this handbook, please contact the G.James Technical Advisory Service on 1800 452 637.

Mr Joseph Saragossi, AO
Chairman of Directors

The G.James Story

The origin of the G.James Group of Companies began when the late George James migrated from England in 1912. He established a glass merchandising business initially at West End, Brisbane and then from the early 1920's at 31 Bridge Street, Fortitude Valley, Brisbane.

The business was based on buying cases of glass from Australian and overseas sources and then selling to timber joiners. He commanded a large market covering Queensland, the northern part of New South Wales and as far south as Taree.

The business remained as such, with the addition of some cutting and processing, until the death of George James in 1958. His son-in-law Mr Joseph Saragossi, together with Joseph's wife Pearle and sister-in-law Gertie Baratin, founded a private company and purchased the G.James business. Joseph Saragossi had served as a Radio Officer in the American Armed Forces. He saw active duty in the South West Pacific and after the war established a successful electrical contracting business. He became the guiding force in building the business from five employees to its present size and diversification.

Market conditions were changing, post war glass quotas were lifted and major customers became major competitors. In addition, aluminium framed joinery was being introduced threatening the existence of the timber joiners, the most traditional and largest group of customers. These circumstances became the motivation in changing the direction from a glass merchant to a diversified wholesale, retail, contracting glass business as well as a manufacturer and installer of aluminium/glass window and door products for use in the building industry (residential, commercial, industrial and monumental).

During the 1960's aluminium largely replaced timber for framed joinery and the company relied heavily on imported extrusions and glass to fulfil its requirements. Economic growth during the late 60's and 70's led to the procurement of custom made extrusions from Australian producers thereby replacing previously imported windows and extrusions from the U.S.A.

As the product range gradually expanded, a small network of regional branches were established and fabrication facilities were increased. However with the limited availability of safety glass from within Australia and the constant reliance on local extruders for aluminium profiles, G.James recognised the need to become more autonomous. So began what would become a perpetual program of capital acquisitions and the establishment of strategically located glass processing and service facilities.

G.James premises at 31 Bridge Street, Fortitude Valley in 1940, the company's home for nearly fifty years.

1977: Glass Toughening Plant commissioned at Smithfield, Sydney
1986: Glass Laminating Facility opens at Narangba, Brisbane
1987: Glass Toughening Plant commissioned at Narangba, Brisbane
1989: Glass Toughening Plant opens at Campbellfield, Melbourne
1994: Glass Laminating Factory commenced in Senai, Malaysia
1996: Gas Convection Furnace (for Heat Processing) installed at Narangba, Brisbane
1998: Insulated Glass Unit Line opens at Eagle Farm, Brisbane
1998: Off-line, Vacuum Coating Glass Plant opens at Eagle Farm, Brisbane
1999: Insulated Glass Unit Line installed at Campbellfield, Melbourne
1999: Curved Toughened Glass Furnace commissioned at Smithfield, Sydney
1999: Glass Toughening Furnace commissioned at Senai, Malaysia

G.James now employs more than 2000 people involved in the manufacture, fabrication, processing and installation of a diverse range of glass and aluminium products.

G.James is today Australia's leading integrated glass and aluminium manufacturer and contractor.

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1.0 Getting to know glass

1.1 A Brief History

Where did it all start?

Glass was probably first discovered by Syrian copper founders between 5000 – 7000 years ago. The dross (or waste) produced by the ores could be described as vitreous pastes with colouring from various metallic oxides. It would of been very similar to obsidian, which is produced naturally through volcanic action. The substance was opaque and did not resemble glass as we know it today in its many forms.

The crown table spinning at the end of the punty

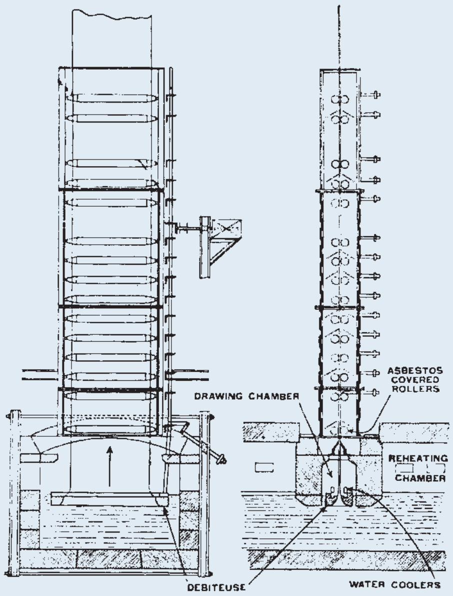
The old cylinder process

The old cylinder process

Pliny's well known story of the shipwrecked Phoenicians lighting a fire on the beach, using blocks of soda to support their pots and subsequently discovering glass the following morning - while being romantic, is not supported by historical facts.

Through conquest the art was taken to Egypt where the oldest relics are dated at 2000 B.C. It is also believed that Alexander the Great was buried in a glass coffin. From Egypt the technique was taken to Rome, from where it spread throughout Europe and continued to develop. Between the 7th and 13th centuries, the 'crown' method of spinning a gob of molten glass on a hollow rod or punty was used. This resulted in a bubble of glass being flattened into a disc approximately one metre in diameter, from which small pieces were cut from the outside, leaving the worst quality in the centre. The bulls-eye or bullion ironically is now the most sought after piece.

Figure 1.1a: Fourcault Process




The Fourcault process in action

Crowns were subsequently replaced by the cylinder blown and later the cylinder drawn process in 1903. In principle a long balloon of glass was blown or drawn; split and flattened and then allowed to cool slowly to avoid stress in the glass, however sizes were again limited.

It was in 1913 that continuous processes such as; the Fourcault process (Belgium); the Colburn - Libbey - Owens process (USA); and the most successful of all, the P.P.G. Pittsburgh process. All involved drawing the glass up vertically out of a tank of molten glass, the edges being held by knurled rollers to retain the ribbon width.

The sheet glass produced by these methods gave a good strong fire finish, but the very action of pulling upwards meant the product contained inherent bands of distortion which resulted in poor optical quality and terrible reflections.

Where true optical quality was required in mirrors or large shopfront windows, a plate glass was needed. The plate process involved sheet glass being ground and polished to achieve the desired quality. By 1938 the process had been developed to the stage where a continuous ribbon of cast glass was ground and polished on both surfaces simultaneously, first with sand then iron oxide. Apart from being extremely messy, the process line was longer than the ocean liner The Queen Mary, and was correspondingly, very costly.

The quantum leap came in late 1958 when Pilkington launched their Float Glass process, which has since been licensed to glassmakers throughout the world. This innovative process involved molten glass being floated on a shallow bath of molten tin, while being heated on the top surface. The resulting product is optically true and requires no further grinding or polishing. While manufacturing methods have changed dramatically over the last century, the basic ingredients used in glass making are still very much the same.


A typical float glass line

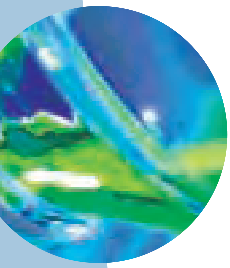
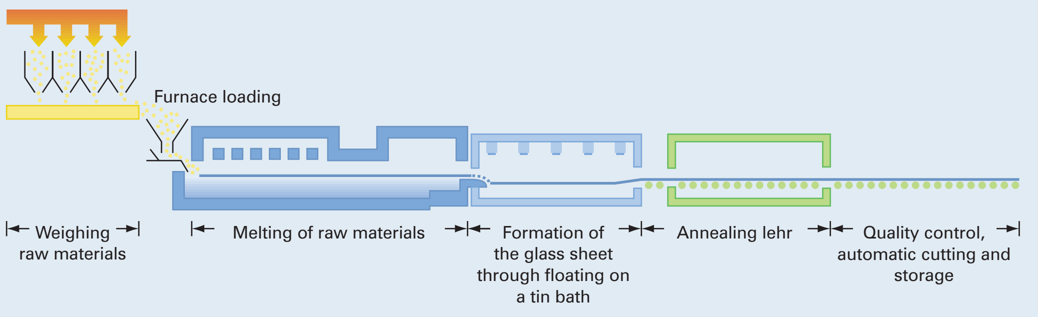


Figure 1.1b: Float Glass Process



A typical batch mix would consist of: 1000 parts silica (sand) + 310 parts soda ash + 295 parts limestone/dolomite + 60 parts feldspar and 400 parts cullet. Hence window glass is known as a soda/lime/silica. Glass may also be formed by mixing soda ash and silica. This product is referred to as 'water glass' because it is soluble in water. It is the limestone/dolomite that is required to stabilise the glass into a durable product.

1.2 Glass Properties

The general physical characteristics of soda/lime/silica glass for building purposes are:

Mass (kg): Area x Thickness(mm) x 2.6

Density: 2600 kg/m^3

Specific gravity: Approximately 2.60. Glass used for building purposes has a specific gravity comparable with that of aluminium which is approximately 2.70.

Coefficient of linear thermal expansion: 88 x 10^{-7}/°C. Glass has a much lower coefficient of linear thermal expansion than most metals.

Thermal conductivity: (K value) 1.05 W/m°C. The difference between various types of flat glass is small enough to be negligible.

Thermal endurance: 6mm glass heated to a higher temperature and plunged into water at 21°C will rupture at approximately 55°C differential.

Softening point: Approximately 730°C.

Modulus of elasticity: Young's modulus 70 GPa (70 x 10^9 Pa). The modulus of elasticity for glass is similar to that of aluminium.

Poisson's ratio: Float glass .22 to .23. Glass conforms to the elastic theory to the point of fracture.

Compressive strength: 25mm cube: 248MPa (248 x 10^6 Pa).

Tensile strength: For sustained loading 19.3 to 28.4 MPa. Determined as modulus of rupture.

Hardness scale: Moh's scale: diamond 10, sapphire 9, glass 6.5 – 5.5, gypsum 2.

Dielectric constant: 6mm glass at 21°C.

- 1,000,000,000 cycles per sec 6.0
- 10,000,000 cycles per sec 6.5
- 1,000 cycles per sec 7.4
- 10 cycles per sec 30.0

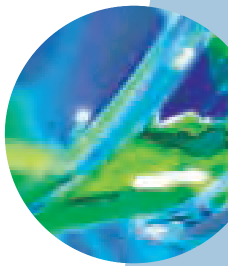
Refractive index: 1.52.
Refractive index varies for light of different wavelengths.

Reflection loss: Approximately 8 to 10% per panel (no absorption) normal incidence. Light is always reflected when it passes from a medium of one refractive index to a medium of another refractive index. The loss is a function of both the refractive indices of the medium and the angle of incidence of the light.

Thermal transmittance (U-value): 5.8 W/m^2°C for summer - 6.2 W/m^2°C for winter. This U-value is for a single panel of 6mm glass and is based on standard ASHRAE conditions. However, for most purposes a U-value of 6 is used.

Visible light transmittance: Sheet 85%, Plate/Float 87%, Rough Cast 80%, Wired Cast 75%, Translucent 70 - 85% dependent on pattern. These are approximate values for 6mm glass based on diffused (non-direct) light.

Infra-red transmittance: Ordinary glass has the property of being relatively transparent to short wave infra-red rays, but opaque to the longer wavelengths. This is the reason why horticultural glass houses accumulate heat from the sun's rays - radiation of short wavelength from the sun is passed through



the glass, and is absorbed by the plants, benches, walls, etc, inside the house. These become hot and in turn re-radiate heat but of longer wavelength which cannot pass through the glass and is reflected back to the interior.

Ultra-violet transmittance: Ordinary glass transmits a very small proportion of the sun's ultra-violet rays. At 315nm less than 1%, at 340nm 41%.

Chemical resistance: Glass will resist most acids except hydrofluoric and at high temperature, phosphoric. Alkalis, however will attack the surface of glass. When glazed into concrete framing, alkalis released from the concrete by rain may be leached onto the glass causing staining, or etching of the glass surface. Weathering steels can deposit soluble sulphates, which may be difficult to remove from glass. Should this occur, any deposits should be removed as soon as possible.

Glass Strength

Glass in its pure form is an extremely strong, perfectly elastic non-crystalline brittle solid. In commercially available float products, its flexural or bending strength is limited by the surface tensile strength of the inevitable microscopic defects, flaws or cracks. These defects reduce the glass strength by a factor in excess of 100 compared to the strength of pure glass.

The property of pure elasticity with brittleness means that glass can not be permanently deformed by load as is the case for most solids such as metals and plastics, and that it fails without warning. Other phenomena affecting the surface flaws and thus the strength of the glass relate to the manufacturing process (with different strengths produced on the tin side and the air side), the duration of the load and presence of water which leads to static fatigue, the physical environment and cleaning processes used.

As annealed glass is quite variable in strength, a design safety factor of 2.5 is used for assessing the glass strength for structural performance. This still leads to an approximate expected failure rate of 8 in 1000 or nearly 1% which is much less than for other materials used in the engineering design processes in buildings.

Glass strength (not stiffness) can be altered by other processes including laminating, heat treating and/or using two pieces in a single hermetically sealed insulated glass unit.

The structural characteristics of these glass types are nominated in AS 1288 but they are summarised as follows:-

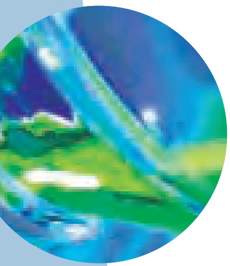
Laminated glass: This process does not significantly affect the strength of the glass but it does improve the safety of the glass as laminated glass typically remains intact and retains some strength even after fracture. For this reason, it is possible that future practice may allow higher stresses for such glass.

Heat treated glass: Both heat strengthened and fully toughened have a surface compression induced by a temperature increase and sudden quenching. The existence of the surface compression means that it must be overcome by load before any surface tensile stress is achieved. The magnitude of the surface compression is of the order of 3 to 6 times the typical stress values used in annealed glass design. This leads to a similar strength increase without any affect on the glass stiffness and deflections.

Insulated glass units: The hermetically sealed air or gas in the space between the glass units by virtue of Boyle's law ensures that the individual pieces of glass share the applied load approximately in proportion to their stiffnesses. Therefore for two pieces of equal thickness glass, the load is shared about 50:50.

Glass Strength Design

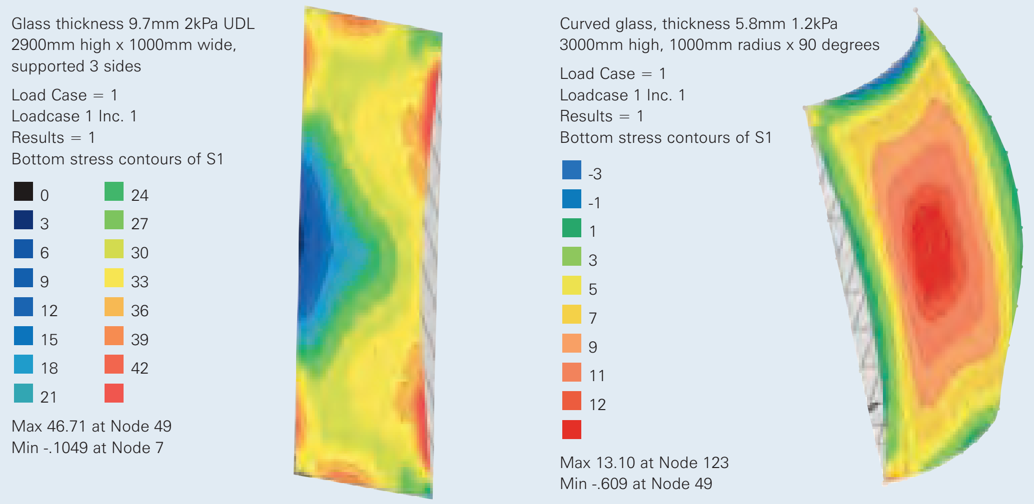
Refer to AS 1288 for specific design provisions. There has been significant improvement in the understanding of, and design methods for glass design since the 1980's. Glass (supported on all sides) under wind loading typically deflects more than its thickness and sometimes for the heat treated glass, many times more than their thickness. This large deflection behaviour introduces non-linearity i.e. The deflections are not directly proportional to the applied load. Because of the membrane stresses in the glass, it appears to stiffen with increased load and thus deflects less for each additional increase in load.



case of simple span glass plates supported on 2 opposite sides, any analysis of glass under load must be carried out using a non-linear analysis method such as finite difference or finite element to determine the glass stresses and deflections. The correct application of a suitable failure prediction model is currently under debate. The extremely common case of a rectangular piece of glass with all four sides simply supported under uniform load has been well analysed and is the basis of the present glass design thickness recommendations of the ASTM and other bodies.

The advances in computer technology with dramatic reductions in computer costs now allows for the analyses of more complex shapes, support conditions and load patterns to be economically achieved. Two examples of typical analyses are illustrated in Figure 1.2a.

Figure 1.2a: Finite Element Analysis

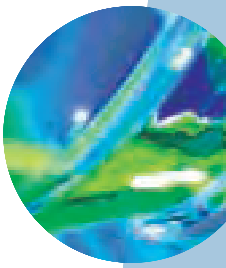


1.3 Thickness Tolerances for Glass

Table 1.3a: Thickness Tolerances

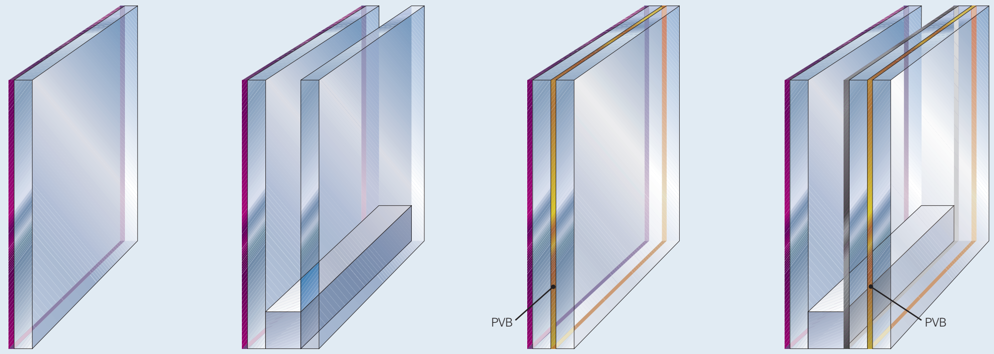
	Nominal Thickness	Tolerance	Range
Float	3mm	±0.2mm	2.8 - 3.2mm
	4mm	±0.2mm	3.8 - 4.2mm
	5mm	±0.2mm	4.8 - 5.2mm
	6mm	±0.2mm	5.8 - 6.2mm
	8mm	±0.3mm	7.7 - 8.3mm
	10mm	±0.3mm	9.7 - 10.3mm
	12mm	±0.3mm	11.7 - 12.3mm
	15mm	±0.5mm	14.5 - 15.5mm
	19mm	±1.0mm	18.0 - 20.0mm
	25mm	±1.5mm	23.5 - 26.5mm
Obscure/Figured Roll	3mm	+0.9mm, –0.5mm	2.5 - 3.9mm
	4mm	±0.5mm	3.5 - 4.5mm
	5mm	±0.5mm	4.5 - 5.5mm
	6mm	+1.0mm, –0.5mm	5.5 - 7.0mm
Wired	6mm	±1.0mm	5.0 - 7.0mm
PVB Laminate	5.38mm	–	4.95 - 5.81mm
	6.38mm	–	5.95 - 6.81mm
	8.38mm	–	7.95 - 8.81mm
	10.38mm	–	9.95 - 10.81mm
	12.38mm	–	11.95 - 12.81mm

NB: These figures are accepted Australian Industry Tolerances. Tolerance of non-standard thicknesses may fall outside the ranges stated above.



1.4 Glass Surface Numbers

Figure 1.4a: Glass Surface Identification



NB: Surface 1 = Exterior Surface

1.5 Identifying the Coated Surface

Figure 1.5a: Monolithic Reflective Glass

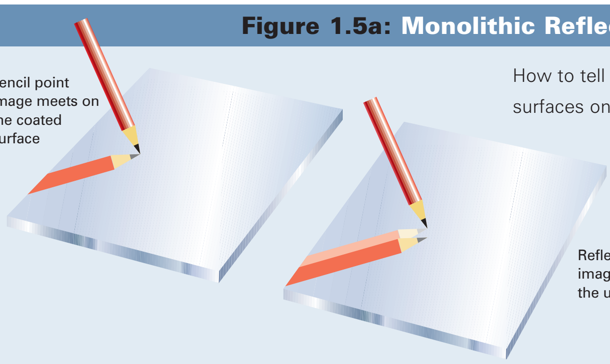
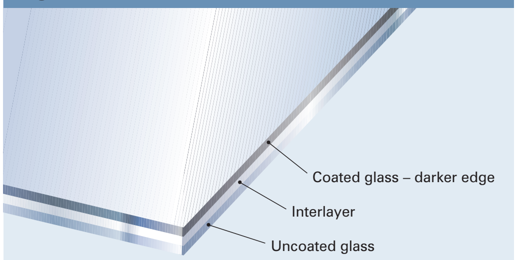


Figure 1.5b: Reflective Laminated Glass



How to tell the difference between glazing surfaces on reflective laminated glass.

Subject to certain exceptions, tinted PVB interlayered laminated glass (i.e. 6.38mm SS22 green laminated) has the reflective coating on surface position (3). The effect of the tinted PVB interlayer is to dampen the reflectivity and allow a building to exhibit a specific colour. This makes identification of 'outside' and 'inside' surfaces easier. However, with clear PVB interlayered laminated glass it may be difficult to determine the coated surface (i.e. 6.38mm TS21 clear laminated). The coated surface can usually be identified by the darker of the two glass edges (identification may be difficult after edge work e.g. flat grinding).

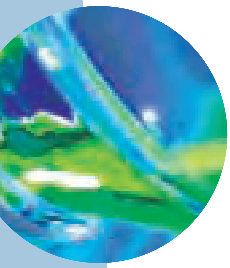
1.6 Glass Staining and Cleaning

Staining

Glass is generally resistant to chemical attack and other degradation. It is inert to most acids, except hydrofluoric and phosphoric.

Typical glass problems on buildings would be:

- Alkalis leaching from concrete, mortar, plaster and gravel onto glass can cause staining and etching
- Hard water, high in calcium concentrates, which are allowed to continually run on the glass
- Deterioration of labels and protective films when left on the glass for prolonged periods
- Pitting of the glass, mainly due to weld splatter (in the form of black specs on the glass), improper sandblasting on site or wind blown debris



- Abrasions to the glass surface by using harsh, powder based cleaning products
- Scratches or spalling caused by the improper removal of plaster, paint, varnish or mortar splash
- A white staining effect which occurs when condensation repeatedly forms and dries on the glass, which in turn can cause surface decomposition
- Iridescence or the oil-stain image is a direct result of the wet-dry action of condensation or water on, or between the glass(es)

The only practical remedy for glass that is badly damaged by scratches, weld splatter, sandblasting, etching and even damaged edges is full replacement.

Cleaning

For cleaning purposes use a soft, clean grit-free cloth and water with a mild detergent. Thoroughly wash off any detergent residue with clean water. Do not under any circumstances use any form of abrasive cleaner as this may cause damage to the glass. Do not allow any metal or hard parts of squeegees or other cleaning equipment to contact the glass surface. Metal scrapers should not be used. Special care should be taken when cleaning coated reflective surfaces. For stubborn stains contact the G.James Technical Advisory Service on 1800 452 637.

1.7 Care and Storage

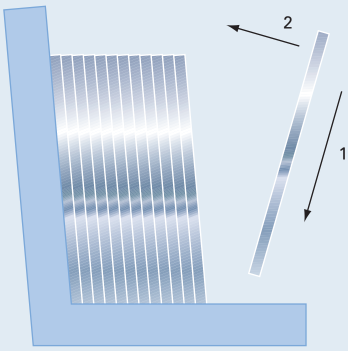
Glass quality can be maintained and risk of damage minimised by following some simple guidelines in storing and handling. Storage areas should be clean and dry with a good circulation of cool dry air, particularly after periods of high humidity to avoid wet-dry staining. Interleaving material should be used at all times, if possible with 'lucite' or 'colacryl', which contains adipic acid which acts as a stain inhibitor.

Store glass on even surfaces in areas not subject to heavy traffic or overhead debris. Where glass has been received in a wet condition, it should be unpacked, dried and re-stacked with separators that allow airflow between the panels.

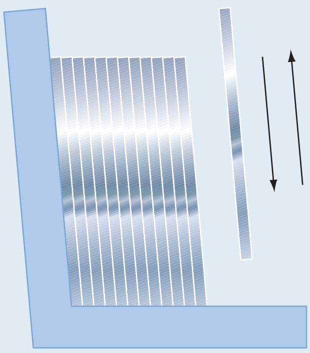
Glass should always be stacked at an incline of 4 degrees from the vertical. Thick glass, tinted glass, insulated glass (IG) units and reflective glass should be stored out of direct sunlight to avoid any risk of thermal breakage. IG units must not be rotated or 'cartwheeled' over their corners.

Always use clean dry suction cups and do not use glass with severely vented or damaged edges.

Figure 1.7a: Handling and Storage

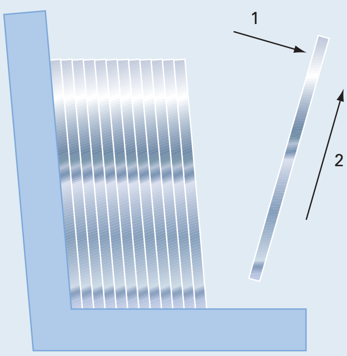


Correct stacking



Incorrect stacking

⚠ Risks scratching



Correct removal

1.8 Glass Processing

G.James offers a wide variety of processing options with a comprehensive range of glass processing equipment, including five state-of-the-art Computer Numeric Control (CNC) machines. This equipment is capable of automatically probing and accurately processing edges, holes, cut-outs and shapes – the complexity of which would be impossible by hand. Discuss your special needs with our Technical Advisory Service on 1800 452 637.

Edgework

Clean Cut (C.C.)

- Edges are as cut with no further processing (15, 19 and 25mm may require processing)
- Edges are sharp

Rough Arris (R.A.)

- This edge is produced by a rough stone, wet belt or split-arris diamond wheel which leaves a white arrised edge. This is the typical edgework for toughened glass

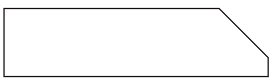
Smooth Arris (S.A.)

- This edge is produced by a wet stone or belt machine producing a smooth arris leaving the edge as cut. The result is a higher quality edge compared to a rough arris

Flat Grind (F.G.)/Flat Smooth (F.S.)

- This edge is produced on a straight line rectilinear machine with the polishing wheels retracted. It leaves a diamond smooth unpolished finish to the edge and arrises, and is the normal finish for silicone butt glazing

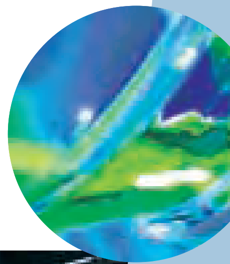
Mitre



- Rectilinear machines produce ground edges suitable for use in angled butt glazing
- Polished mitre edges are also available
- Mitres ranging from 22.5˚ to 89.5˚ are possible

Ordering mitred glass

- The nominated mitre is the angle of the glass edge remaining. To achieve a typical 135˚ angled butt-joint, a nominated mitre of 67.5˚ is therefore required
- Always give long point measurements
- Supply a drawing for out-of-square panels



One of G.James' Intermac CNC processing machines

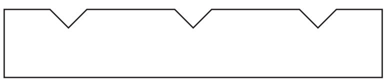
Flat Polish (F.P.)

- This is the standard edge produced by a straight line rectilinear machine and produces a fine polish to the edge and arrises. This edge is suitable for all furniture glass or wherever glass edges are exposed

Round and Polish (R&P)

- Using special purpose machinery, this edge is ground to a bullnose shape and then polished

Brilliant Cut



- This process cuts and polishes linear V shapes into the surface of the glass. It provides a classic elegant finish for decorative purposes

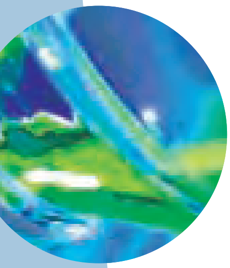
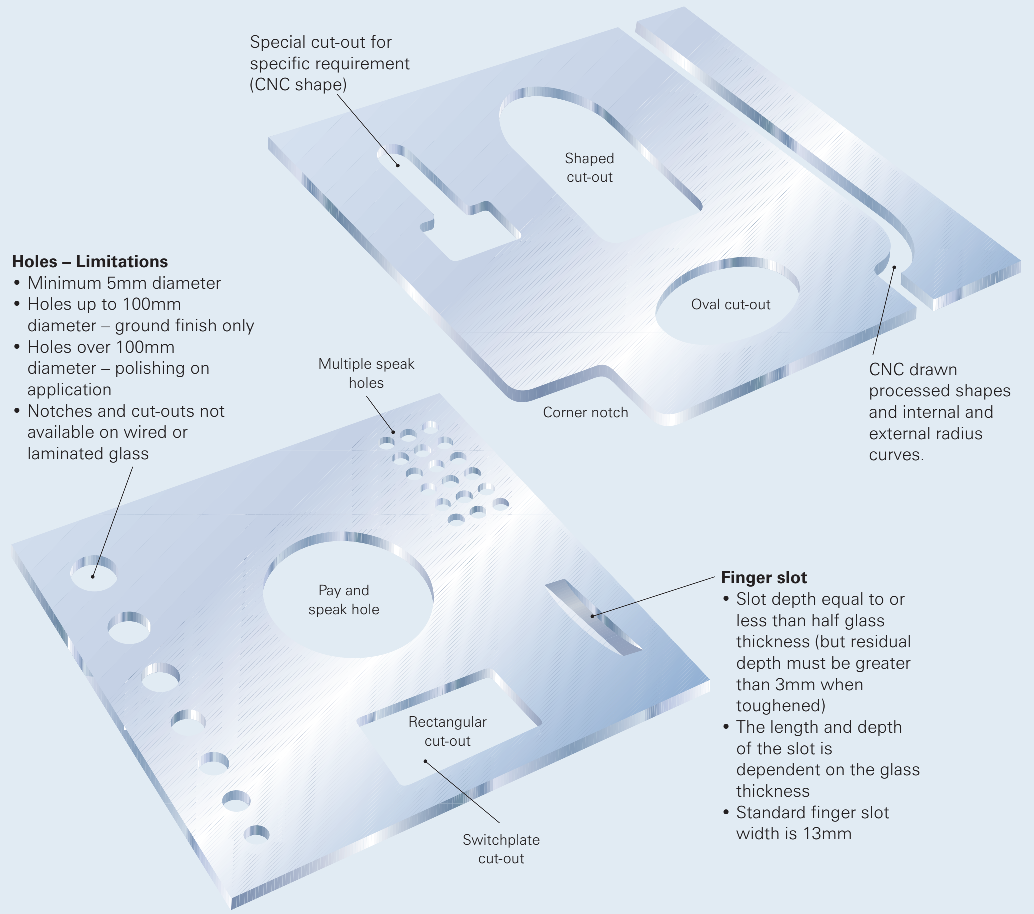
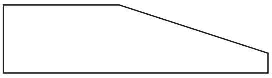


Figure 1.8a: Special Processing



Bevelling



With straight line and shaped bevelling machines, a beautiful and decorative touch can be added to mirrors, table tops and glass panels in doors. The bevel width is dependent upon glass thickness, and the required residual edge.

All bevelled glass has a clean cut edge as a standard finish, flat polishing is an optional extra.

NB: For toughened glass a 4mm minimum residual edge is mandatory. Bevelling limitations may apply.

Polished and Bevelled Cut-off Corners

- Minimum 200mm cut-off corners on 10mm/12mm glass, up to a maximum size of 2000mm x 1200mm
- Minimum 100mm cut-off corners on 10mm/12mm glass, up to a maximum size of 1500mm x 1000mm

Straight Line Bevelling

- Minimum size 100mm x 100mm
- Maximum size of 3200mm x 1500mm, up to maximum weight of 250kg. Consult our Technical Advisory Service for larger sizes

Table 1.8a: Straight Line Bevels

Thickness	Max. Bevel Width
4mm	25mm
5mm	30mm
6mm-19mm	35mm

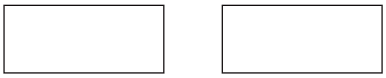
Shaped Bevelling

- Minimum 350mm diameter
- Minimum internal radius 70mm
- Maximum diameter 2100mm

Table 1.8b: Shaped Bevels

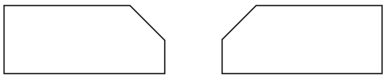
Thickness	Max. Bevel Width
4mm	20mm
5mm	30mm
6mm-19mm	35mm

Holes



- Holes can be drilled in all thicknesses of glass. For hole limitations see Figure 1.8a

Countersunk Hole



- Holes can be countersunk in toughened glass before toughening to accommodate mechanical fixings

Hole Sizes

The available holes are:
5mm, 6mm, 6.5mm, 7mm, 8mm, 9mm,10mm, 11mm, 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. (Other hole sizes are available on request.)
Finger pull/thimble hole size = 21mm.

Cut-outs, Notches and Special Processing

See Figure 1.8a. For your specific requirements contact the G.James Technical Advisory Service on 1800 452 637.

Irregular Shapes

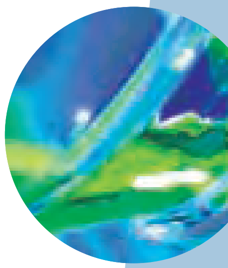
Defined as irregular shapes are:

- Shaped pieces of glass
- Glass cut to templates
- Circles or ovals
- Rakes with more than two corners not at right angles (90°)
- Glass that requires a diagram because it cannot be expressed as a size on paper
- Squares and rectangles with notches

Not recognised as irregular shapes are:

- Squares and rectangles with radius or cut-off corners (charged as corners)

See Figure 1.8b for examples of irregular shapes.

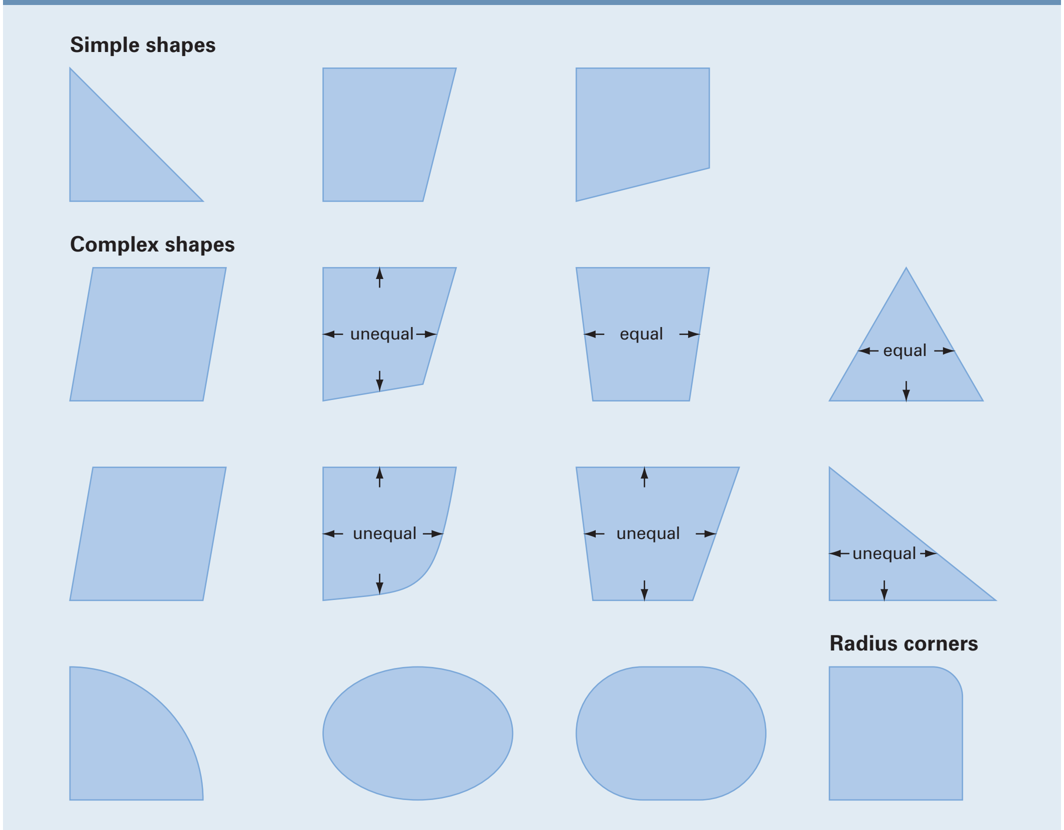


Templates

In many instances templates provided on plywood or proper architectural drawings are requested. Detailed information required is as follows:

- Glass sizes
- Holes
- Edgework
- Cut-outs
- Stamp position (if applicable)

Figure 1.8b: Examples of Irregular Shapes



Ordinary float glass

Laminated safety glass

Toughened safety glass

Wired safety glass

1.9 Breakage Characteristics

Ordinary Float Glass

The familiar jagged edge pattern with lethal slivers of glass which, depending on the force of impact, either fly out or remain precariously intact. Often the removal of shattered pieces is difficult and dangerous.

Laminated Safety Glass

In the event of breakage, a web-like pattern is formed as a result of the bond between the glass and the vinyl interlayer. With a tendency to remain within the frame under impact, the severity of physical injury is significantly reduced. Broken laminated safety window glass will remain intact as a barrier against the weather while visibility is partially retained. Grade A laminated safety glass should be used anywhere there is a risk of human impact.

Toughened Safety Glass

Should toughened glass break, it shatters into small, relatively harmless particles compared with the sharp splinters resulting from the breakage of ordinary glass. Grade A toughened safety glass should be used where the possibility of human impact exists or in any situation requiring strength, safety or resistance to temperature fluctuations.

Wired Safety Glass

When wired glass is broken, the glass tends to remain attached to the wire enabling the panel to remain intact and in place. Safety applications are limited to Grade B safety glass applications.

Heat Strengthened Glass

Heat strengthened glass is about twice as strong as ordinary float glass and is used generally as a protection against thermal breakage. The breakage of heat strengthened glass is such that it fragments into large, non-jagged pieces which tend to remain in place within the frame. Heat strengthened glass is not considered a safety glass and therefore cannot be used where human impact requirements apply.

1.10 Solar Spectrum

The sun radiates solar energy or sunlight by electromagnetic waves over a range of wavelengths known as the Solar Spectrum (290 – 2500 nanometres, where 1 nanometre = 1/1,000,000,000 of a metre).

The solar spectrum is divided into three bands, these are:

Ultra-violet light (UV)	290nm – 380nm
Visible light	380nm – 780nm
Infra-red	780nm – 2500nm

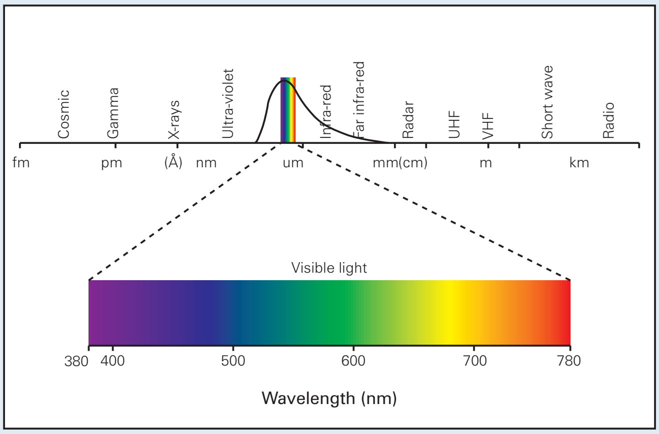
The energy distribution within the solar spectrum is approximately 2% UV, 47% visible and 51% infra-red. Only the visible light band is seen by the human eye.

It is important to understand that the shorter the wavelength (i.e. the lower the nanometres), the higher is the energy associated with the radiation. This is highlighted by the fact that it is the shorter wavelength, high energy UV light which causes humans to sunburn, fabrics to fade and plastics to deteriorate. While the longer wavelength, low energy radiation produced by the visible light and infra-red bands are less damaging.

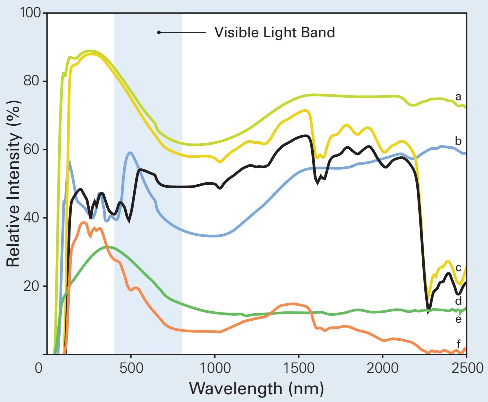
RAT Equation

When the combined UV, visible light and infra-red (solar energy) strikes glass it is reflected (R), absorbed (A) and transmitted (T) in different proportions, depending on the type of glass involved. This gives us the RAT Equation which accounts for 100% of solar energy. For example, 3mm clear float glass Reflects 8% of solar energy, Absorbs 9% and Transmits (directly) 83% (See Figure 1.10b).

Graph 1.10a: Electromagnetic Spectrum



Graph 1.10b: UV Transmission



Spectrum of representative glass products showing UV transmission

- a - 6mm Clear
- b - 6mm Grey
- c - 6.38mm Clear Laminate
- d - 6.38mm Grey Laminate
- e - Solarplus TS30 on 6mm Clear
- f - Optilight HL229 Laminate

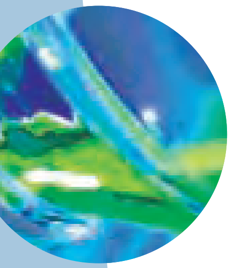
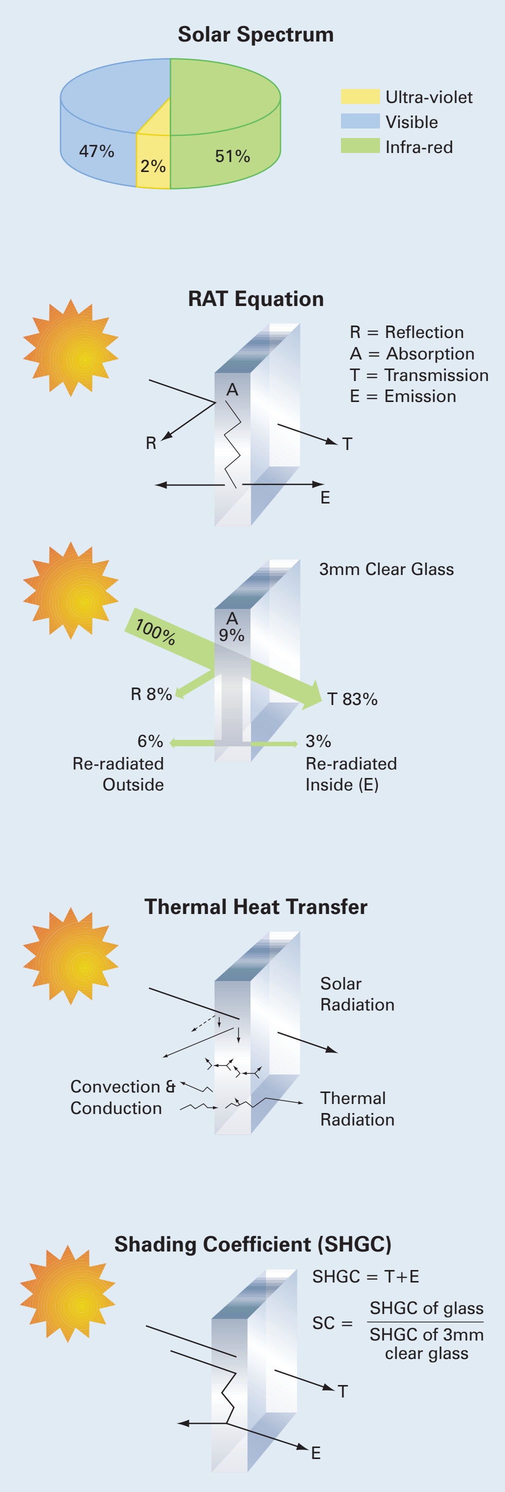


Figure 1.10b



G.James
Technical Advisory Service

Phone: 1800 GJAMES (452637)

National Toll Free Number

Thermal Heat Transfer

Heat is transferred either by convection (upward warm air currents), conduction (passing from one object to another) or radiation (where heat passes through space to an object where it is reflected, absorbed or transmitted). The absorbed portion of the energy is subsequently dissipated by re-radiation (or emission) to both the outside and inside, in varying proportions, dependent on the type of glass and external weather conditions.

Solar Control

As visible light and infra-red account for 98% of solar energy, they are extremely important considerations when selecting the glass. Solar control glasses are either body tinted and/or coated or surface modified to absorb or reflect the sun's energy and reduce the solar heat gain transmitted through the glass. (See Graph 1.10b)

Performance Terms

Visible Light Transmittance: Expressed as the percentage of visible light (380 - 780nm's) that is transmitted through a glass type.

Visible Light Reflectance: The percentage of visible light (380 - 780nm's) that is reflected from the glass surface(s).

Solar Energy Transmittance: The percentage of ultra-violet, visible and infra-red energy (290 - 2500nm's) that is directly transmitted through a glass type.

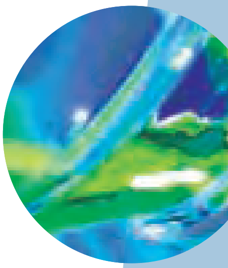
Solar Energy Reflectance: The percentage of solar energy that is reflected from the glass surface(s).

Solar Heat Gain Coefficient (SHGC) or Total Solar Energy Transmittance: The proportion of directly transmitted and absorbed solar energy that enters into the building's interior. The lower the number is, the better the glass is able to exclude solar radiation.

U-value (expressed in W/m²K): The measure of air-to-air heat transfer (either loss or gain) due to thermal conductance and the difference between indoor and outdoor temperatures. The lower the number is, the better the insulating qualities of the glass.

Shading Coefficient (SC): The ratio of total solar radiation through a particular glass type,

1.0 GETTING TO KNOW GLASS



relative to the total solar radiation through 3mm clear float glass. The lower the number, the better the glass performs in reducing heat gain. (See Figure 1.10b)

Luminous Efficacy (or Coolness Factor): The ratio of visible light transmittance to the shading coefficient. This ratio is helpful in selecting glass in terms of those which transmit more light than heat. A glass with a luminous efficacy of 1 or greater is considered thermally efficient.

1.11 Thermal Breakage

Cause of Thermal Stress

Thermal stress is caused when the central area of the glass is heated (naturally or artificially) and expands, while the glass edges remain cool resisting expansion. (See Figure 1.11a)

Thermal breakage is a result of an excessive build-up of thermal stress in annealed glass. The amount of thermal stress depends upon the temperature difference between the hottest and coldest areas of the glass and also on the distribution of the temperature gradient across the glass.

Glass which has cracked as a result of thermal stress can be easily identified by the break pattern which is unique to a thermal fracture. The crack in the glass is initially at 90° to the edge and glass face for approximately 2cm-5cm and then branches out into one or more directions. The number of branches or secondary cracks is dependent on the amount of stress in the glass. (See Figure 1.11b)

Factors affecting Thermal Stress

Any factors that encourage an increase in the ‘hot centre/cold edge’ conditions tend to increase the thermal stress. These include:

Climate: The intensity of solar radiation on the glass which is determined by the geographical location of the building, the orientation of the building and the outside day and night temperatures.

Glass Types: Certain types of body tinted glass and coated glasses, inherently have a higher risk of thermal breakage due to their higher energy absorption. Similarly IG units or double-glazing are at greater risk as the outer glass is usually at a higher temperature due to the reduced heat transfer across the air space. (See Table 1.11a)

Figure 1.11a: Effects of Thermal Stress

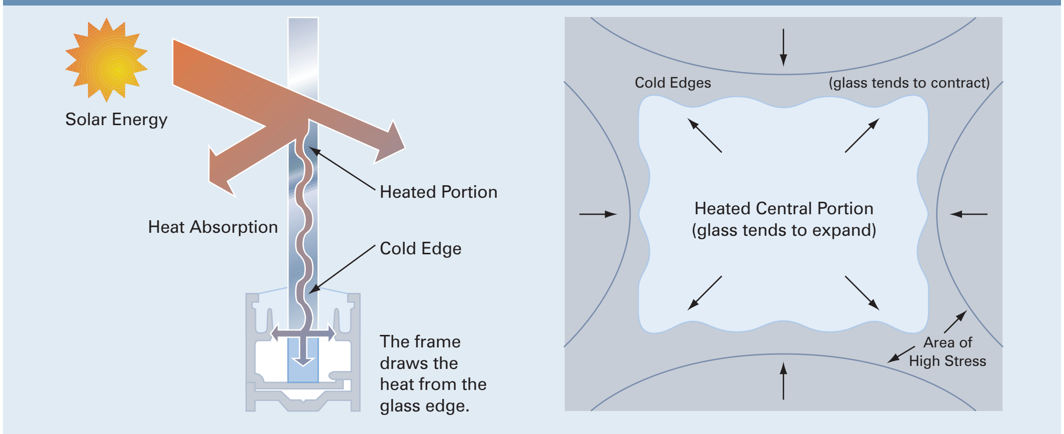
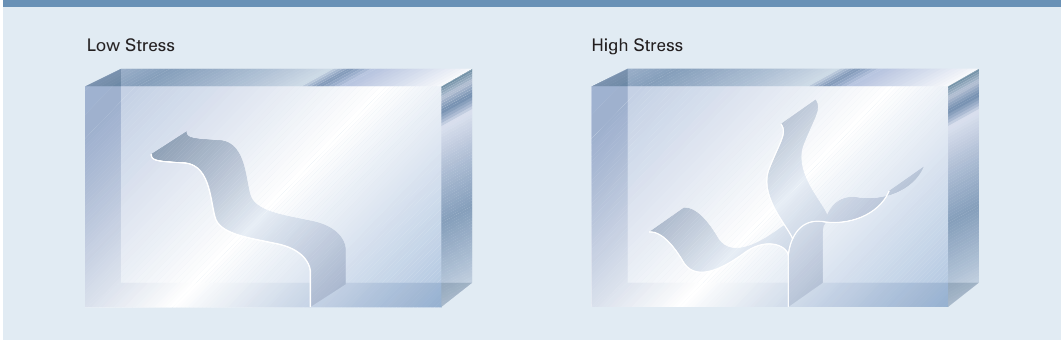
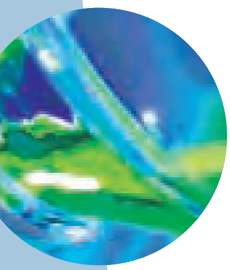


Figure 1.11b: Examples of Thermal Breakage





Edge Condition: The breaking stress of the glass is directly related to the position and size of any flaws in the edges. Good clean cut edges are considered the strongest edge for monolithic glass. With laminated glass good edges can be difficult to achieve, therefore flat ground edges are recommended on all high performance laminated products. (See Figure 1.11c)

Size and Thickness: The risk of thermal breakage increases as the size and thickness of the glass increases.

Glazing System: The thermal properties of the glazing system are an important consideration including:

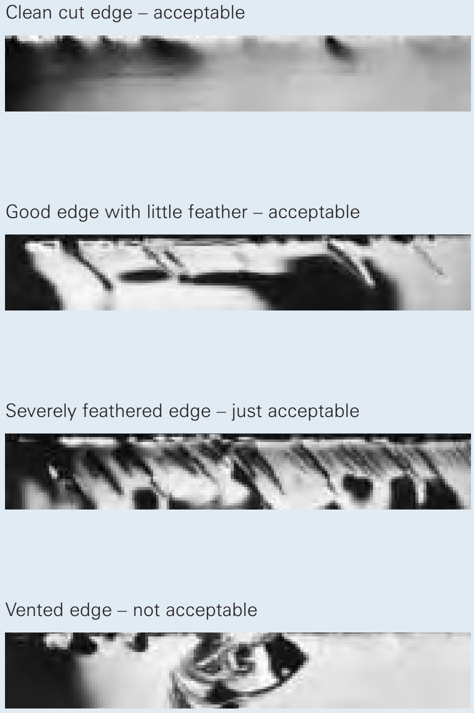
- Framing materials (aluminium, steel, timber, and PVC)
- Colour of framing materials (light or dark)
- Type of glazing (fully captive, 2-sided captive or 4-sided structural)

External Shading: Thermal stress will be increased if the glass is partially shaded by balconies, canopies, sun shades or deep mullions, transoms and columns.

Internal Shading: Internal blinds or curtains can reflect heat back into the glass increasing thermal stress. To reduce the risk of thermal breakage it is recommended that the confined space between the internal shading device and the glazing be ventilated. This can be achieved by allowing a minimum 38mm clearance to the top and bottom or side and bottom of the shading device and creating a minimum 50mm clearance between the glazing and shading device.

Internal Cooling/Heating Sources: Direct air streams from air conditioners, heaters, computers etc. onto the glass surface may increase the risk of thermal breakage. (See Figure 1.11e)

Figure 1.11c: Glass Edge Condition



Backup Material: Materials used behind glass in spandrel or suspended ceiling applications reduce the heat loss of the glass, therefore raising the glass temperature, increasing the thermal stress and the risk of thermal breakage. The colour of the backup material is important, as a light coloured surface will reflect heat back towards the glass while a dark coloured surface will absorb heat.

Where thermal breakage is a concern, heat strengthened glass should be specified as it has higher compressive stresses which resist thermal breakage. If in doubt, a thermal safety assessment should be conducted to determine if heat strengthened glass is required (See Appendix One for a Thermal Safety Assessment Request form).

Table 1.11a: Risk of Thermal Breakage

Glass Type	Solar Absorption %	Risk of Thermal Breakage
Clear	18	Low
Tinted	30 - 40	Medium
Supertints	45 - 65	Medium - High
Reflective coating on clear	60 - 70	High
Reflective coating on tinted	80 - 85	Very High

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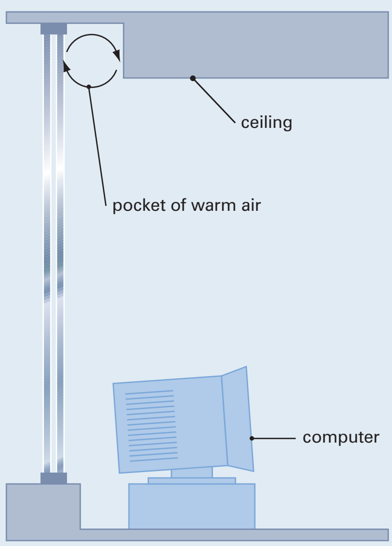
Figure 1.11d: Factors affecting Thermal Safety

Figure 1.11e: Air Pockets



Avoid pockets of warm air

1.12 Fade Control

It is well recognised that carpets, curtains and furnishings exposed to direct sunlight for continual periods of time will experience the effects of fading and yellowing. While the solution is usually to close off the room with curtains and blinds, this darkens the room and shuts out any view of, or relationship with the outside. However by selecting an appropriate glass type, it is possible to allow natural light to enter a room yet significantly reduce the rate at which fading occurs. Before we consider glass in this respect, the process of fading should firstly be explained.

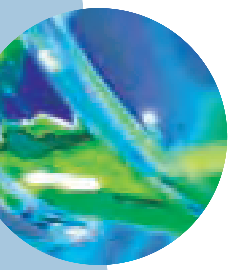


Table 1.12a: Damaged Weighted Transmission

Glass Type	Tdw
3mm Clear Float	0.72
6mm Clear Float	0.65
6.38mm Clear Laminate	0.34
6.38mm Green Laminate	0.26
6mm Solarplus TS30 on Clear	0.15
6.38mm Solarplus SL22 Laminate	0.12
6.38mm Optilight HL229 Laminate	0.12

NB: Solarplus (refer to Section 6.2)/Optilight (refer to Section 3.5)

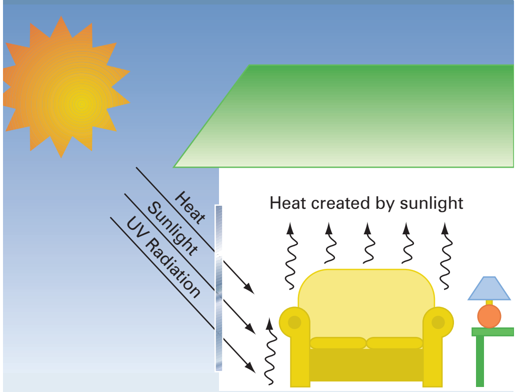
Research has confirmed that one of the major causes of fading is solar radiation (or sunlight), which comprises of three specific energy bands: ultra-violet radiation (UV), visible light and infra-red radiation. Pollutants, moisture and oxygen are, to a lesser extent, other contributing factors.

As solar radiation enters the room, it is absorbed by the exposed fabric causing the temperature to rise. This continual heating of the fabric by the visible light and infra-red radiation, and the more damaging effects of the UV rays, combine to deteriorate and break-down the dye and fabric structure of the furnishings, eventually leading to the discolouration that is associated with fading.

From a glass perspective, the objective is therefore to select a product that has high absorption or reflection of UV, visible light and infra-red radiation. In the instance of reducing the damaging effects of UV radiation, it is important to know the clear polyvinyl butyral interlayer in laminated glass effectively absorbs up to 99% of the UV. By incorporating a reflective or tinted solar control glass into a laminated product will reduce both the amount of visible light and total solar energy that passes through the glass.

In order to compare the relative fading reduction offered by different glass types and configurations, a measurement called the Damage Weighted Transmittance (Tdw) is employed. This measure is 'weighted' to include the fact that fading damage decreases as the energy wavelength increases. In addition, clear 3mm float is designated as the benchmark against which the fading reduction qualities of all other glass types are measured. For this purpose 3mm float has a Tdw of 0.72, while complete exposure is stated as 1.0Tdw. Consequently the lower the Tdw of a glass, the better the fade reduction.

Figure 1.12a: Fading your Furnishings



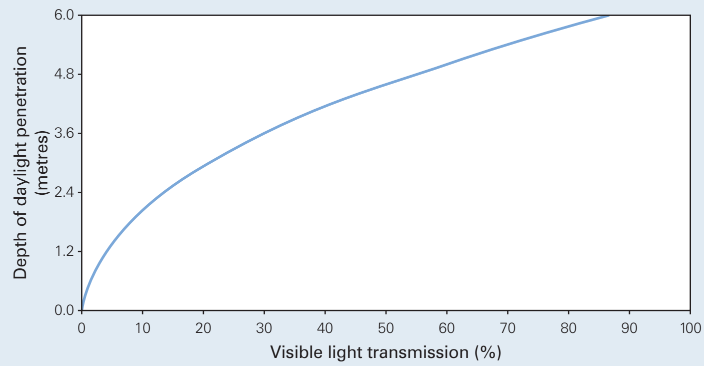
How sun fades your furnishings

Fading is caused by a combination of UV radiation, sunlight and heat.

UV radiation is the greatest contributing factor to fading and its effect is increased by heat.

The right glass can eliminate up to 99% of UV radiation and significantly cut sunlight and heat.

Graph 1.13a: Glass Transmission



1.0 GETTING TO KNOW GLASS

1.13 Daylighting and Colour Perception

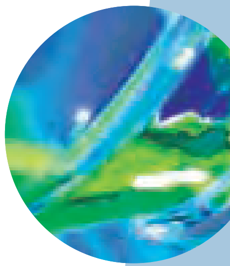
Daylighting

As building occupants we have traditionally required daylight to work, enhance the appearance of interiors and save energy by reducing the need for artificial lighting. The more daylight, the higher the amount of solar energy and heat that enters the interior hence cooling costs become a major concern. The question here then is to ascertain what transmittance is required to achieve a specific penetration of daylight, or given a transmittance %, what depth of daylight can be expected.

As an indicator, the relationship between the depth of daylight and the visible light transmittance (VLT) of glass has been mapped (See Graph 1.13a). For a reference point, it has been determined that 6mm clear float with a VLT of 87%, can supply adequate daylight to a depth of approximately six metres. Because of the clarity of clear float, six metres has therefore been nominated as the maximum depth possible and hence the curve peaks at 87% transmission.

If we consider 6mm grey tinted float with a VLT of 43%, approximately one-half that of 6mm clear, the curve reveals a daylight depth of 4.50 metres. As the curve is non-linear, it should be noted that a one-half reduction in VLT does not translate to a one-half reduction in daylight depth. In essence there is no correlation between the percentage decrease in VLT (when compared to 6mm clear float) and the daylight depth.

NB: Refer to Section 15 for the visible transmittance properties for various glass types.



Colour Perception

Transmitted colour is produced from either tints in the body of glass, tinted interlayer (laminated glass) and/or applied coatings. Studies have shown that the psychological considerations of the brain and eye influence the way we perceive colour. Where the view out is exclusively through a tinted glass (with no reference to normal daylight), the human eye adapts to, and compensates for the colour of the light received through the glass. For example, snow will still look white through grey glass. However if an adjacent window is glazed with clear glass or open, the snow will appear purple/blue (when viewed through the grey glass) as the eye attempts to balance the white of daylight and the colour of the tint. In summary, the view outside will appear normal through tinted or coated glass unless there is a reference to natural, white light.

1.14 Sound Insulation

Sound is created when a source or object produces vibrations. The vibrations result in small changes in the surrounding air pressure producing spherical, three dimensional sound waves. If they were visible, these vibrations would resemble a series of concentric circles that spread out in all directions from the point source, similar to when a stone is dropped

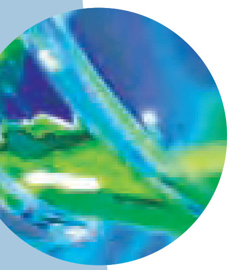
Table1.14a: Perceived Loudness

Change in sound pressure level (dB)	±3	±5	±10
Apparent loudness change	Just perceptible	Clearly noticeable	Twice (or half) as loud

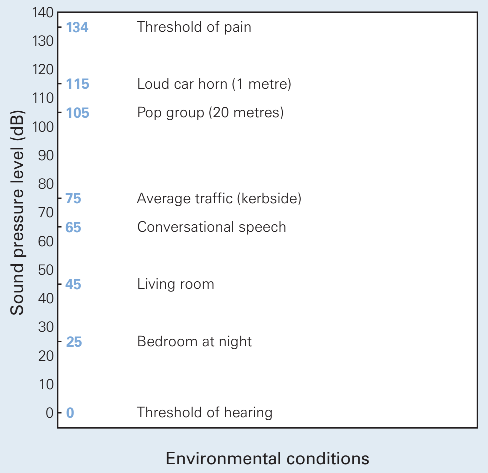
Table1.14b: Recommended Design Sound Levels

Environment	Satisfactory	Maximum
Classrooms	35 dB(A)	40 dB(A)
Conference rooms	30 dB(A)	35 dB(A)
Hotel/motel sleeping areas	30 dB(A)	35 dB(A)
Residential		
Recreation areas	30 dB(A)	40 dB(A)
Sleeping areas	30 dB(A)	35 dB(A)
Work areas	35 dB(A)	40 dB(A)

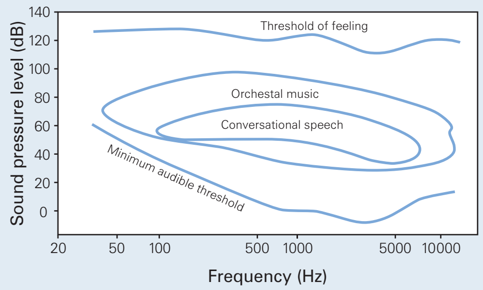
NB: (A) refers to a weighted measure which has been included to correlate subjective results with measured results.



Graph 1.14a: Acoustic Spectrum



Graph 1.14b: Acoustic Spectrum



into water. The vibrations travel at a constant speed of 344 metres per second at 20˚C (i.e. the speed of sound) but faster if the temperature is higher. The more the air pressure is disturbed, the louder the sound.

As the distance from the source increases, there is a gradual decrease in the energy associated with the sound waves and the sound decays or attenuates.

All sound waves have a frequency which is measured in Hertz (Hz). A sound wave with a frequency of 800 Hz implies there are 800 vibrations per second generating from the source. The human ear is able to detect frequencies ranging from 20 Hz to 20,000 Hz however it is most sensitive to sound within a range of 500 Hz to 8,000 Hz.

Sound Intensity

Sound intensity is the amount of acoustical energy associated with a sound wave and is directly proportional to the Sound Pressure Level (SPL). For instance, the SPL of a jet plane's engines at 10 metres would be significantly reduced at a distance of 1 kilometre. The resulting sound pressure intensity may be similar to a domestic vacuum cleaner at 3 metres. This example clearly illustrates how the sound pressure intensity relates to the sound power of the source and the distance from the source.

The SPL is measured in Decibels (dB), and employs a non-linear, logarithmic scale to evaluate sound intensity. This logarithmic or compressed scale is such that it cannot be used to compare the loudness of particular sounds in a simple linear fashion. For example an 80 dB sound is not twice as loud as a 40 dB sound. To the contrary, any change in the sound intensity multiplies (or divides) tenfold for every 10 dB increment change. In this instance the noise has 10,000 times more sound power.

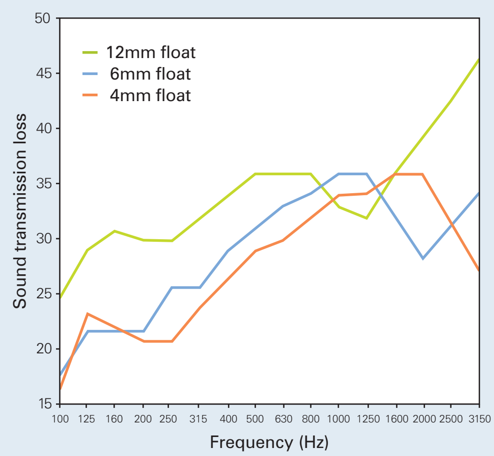
Perceived loudness on the other hand relates to the human ears ability to detect changes in the sound pressure level and doubles every 10 dB change in measured SPL (See Table 1.14a).

Graphs 1.14a & b provide an indication of the various SPL's experienced in our daily lives and the frequency range over which certain sounds occur. Note that as a normal human ear can only detect sound at 0 dB, this is used as a reference point for such acoustic scales - it does not mean there is no sound.

Sound Insulation Measures

As all glass allows the transmission of sound, in varying degrees, it is important to be aware of

Graph 1.14c: Coincidence Dip



Frequency spectra for 4mm, 6mm and 12mm Float Glass showing how the coincidence dip occurs at different frequencies for each glass thickness.

the various rating systems that may be referred to when considering the acoustic performance of glass in the construction industry.

Sound Transmission Loss (STL)

The STL measures (in decibels) the insulation effectiveness of a particular glass as a barrier in reducing exterior noise, i.e. the amount of sound diffused or lost as the noise travels through the glass. The parameters used in determining this figure only considers the frequency range between 125 Hz - 4000 Hz, with the higher the STL (dB), the better the acoustic performance of the glass.

Sound Transmission Class (STC)

STC utilises a single-number rating system to categorise the acoustic reducing qualities of glass when used for interior applications such as partitions, ceilings and walls. While not intended for use in selecting glass for exterior wall applications, STC ratings are often specified for such purposes. G.James can provide a comprehensive range of openable windows and doors, and fixed glass systems that have been STC rated and tested at the National Acoustic Laboratories.

Traffic Noise Reduction (Rtra)

This measure incorporates a weighted factor for typical town and city road traffic noise over a range of frequencies. Combining this factor with the basic sound insulation of the window, provides a more meaningful guide to the actual acoustic performance of a glazed area.

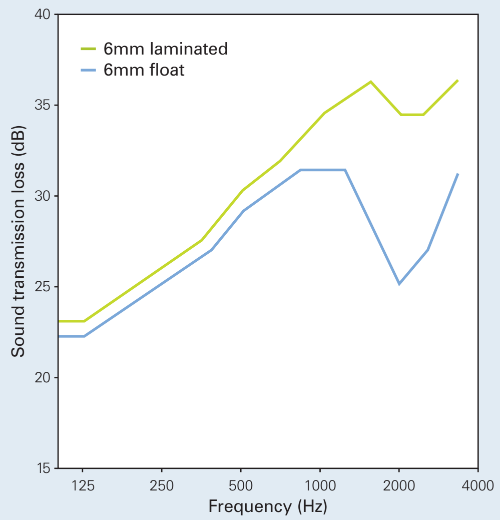
Coincidence Dip

This term refers to the dip or loss in insulating properties of glass which occurs when the glass is vibrating at the same frequency as the sound being transmitted. The frequency at which this occurs is largely dependent on the thickness of the glass (See Graph 1.14c).

Glass Performance

Unwanted sound is considered noise when it intrudes on our daily lives. To minimise this intrusion all aspects of the building construction need to be evaluated, however in this instance we will only analyse the acoustic qualities of glass. The first step in this analysis is to determine the source of the unwanted noise. This is a critical step, as the noise source can vary from low frequency traffic noise to high frequency aircraft noise.

Graph 1.14d: Laminated Glass Insulation



The effect of lamination on the sound insulation of glass. Note the coincidence dip for solid glass is virtually non-existent for laminated glass.

To proceed in this regard, the sound insulation qualities of the various glass configurations are as follows:

Monolithic Glass

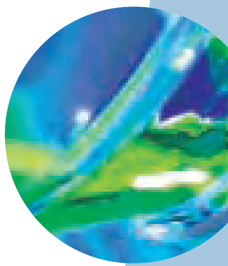
Glass generally follows the Mass Law, i.e. the thicker the glass, the better the sound insulation properties. Graph 1.14c illustrates this principle by portraying 12mm monolithic float as superior to 4mm or 6mm float over the lower frequency range, which is generally associated with unwanted traffic noise.

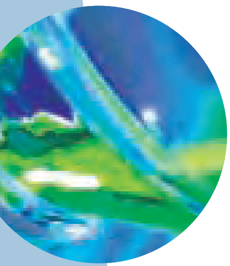
Laminated Glass

The polyvinyl butyral interlayer (0.38mm to 1.52mm) used in laminated glass provides a dampening effect which reduces the loss of insulation at the coincidence frequency. Graph 1.14d shows the coincidence dip for laminated glass is significantly reduced when compared to float glass of equal thickness. Laminated glass also has superior sound insulation qualities in the higher frequency range where the noise from sources such as aircraft are a problem. Increasing the interlayer thickness will only have a marginal effect on improving the sound insulation performance of laminated glass.

Double Glazing

A common misconception is that a standard hermetically sealed double glazed unit with an airspace (up to 12mm) will provide effective sound insulation, this is not the case. For double glazing to be effective an airspace





between 100mm to 200mm would be required. An additional benefit can be obtained by incorporating glasses of different thickness (at least 30% difference) or using laminated glass in one or both of the panels.

Where double glazing is not feasible, the most cost-effective method of reducing sound is achieved by installing a thick monolithic or laminated glass.

Areas around windows

It is important to note that no matter how good the noise insulation qualities of the window are, there should be no gaps or cracks around the window frame. A gap of no more than 1% of the total window area will result in a 10 dB loss in sound insulation.

1.15 Spandrel Design

As curtain wall design became more popular, the question of what glass to use in the spandrel area became more of an issue for architects and designers.

In the spandrel cavity, temperatures can exceed 100˚C along with extreme humidity. It is therefore critical for architects and designers to ensure the building and glazing materials specified in the spandrel design are temperature stable and chemically compatible.

The spandrel glass options are as follows:

Ceramic Painted Glass

Ceramic painted glass offers a well proven, time-tested product available in a comprehensive range of colours. This allows architects either the choice of a relatively similar match to the vision glass or a complete contrast.

The process of manufacturing ceramic painted glass involves paint being fused into the glass surface through the heat treatment process. The resulting product is both mechanically and thermally stable, with a colouring that will not fade or peel.

A minimum gap of 50mm should be maintained between the spandrel glass and other building components. In addition, ceramic painted glass should not be used in applications where the painted surface is viewed or where backlighting may occur.

Organic Opacifier

As reflective glass became more popular, it was increasingly difficult to match the spandrel panels to the vision glass. Today reflective glass is being specified for spandrel as well as vision panels providing the facade with an overall uniform appearance.

To mask the vision into the spandrel area, an organic (polyester) opacifier film is bonded to the coated (second) surface of monolithic panels. It is essential the glass in these applications be heat strengthened to withstand thermal stress. Should breakage, either mechanical or thermal occur, the opacifier will tend to hold the glass in place until the panel can be replaced.

G.James does not recommend the use of opacifier on glass which has a visible light transmission greater than 25%, as it highlights any imperfections in the film application. It should also be noted, that panels used in structural glazing applications are to be ordered with the necessary cutback to the opacifer to ensure good adhesion of the silicone to the glass substrate.

Under certain lighting conditions a banding effect may be noticeable between the vision and spandrel glass. If this is unacceptable, insulated glass units should be specified. As with all spandrel glass, a minimum 50mm gap should be maintained between the opacified glass and any backup material.

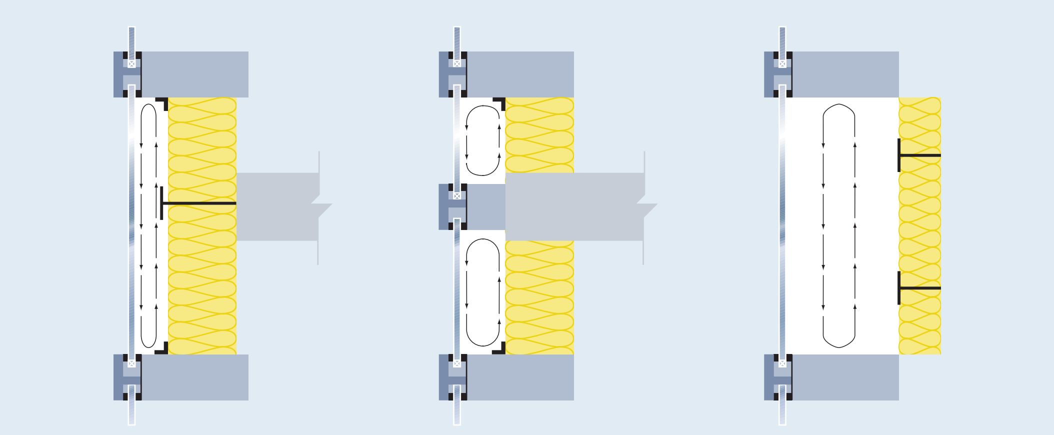
Insulated Glass Units

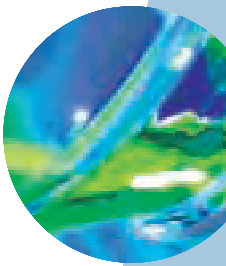
To minimise the banding effect and achieve greater uniformity between the vision and spandrel glass, new glass combinations were required. This saw the development and introduction of IG units into spandrel applications. A unit that incorporates the vision glass as the outer lite and a ceramic painted (dark grey) panel as the inner lite is now considered the ultimate spandrel glass. This spandrel make-up provides an ideal match for vision areas regardless of whether reflective, Low E or tinted glass is installed. Many monumental projects use IG units in the spandrel applications.

Shadow Boxes

Some designers prefer to address the ‘read through’ of reflective, unopacified glass by

Figure 1.15a: Spandrel Design Types





using a simple shadow box design. A situation arises when the temperature and humidity conditions in this cavity become extreme causing out-gassing from the backup materials, depositing a visible film on the glass. Consequently G.James does not recommend the use of shadow boxes with unopacified Solarplus products or transparent glasses.

Glass – The versatile building material (Rialto Hotel, Melbourne)

2.0 Float glass

Crown Towers, Surfers Paradise

2.1 Clear Float

Production of float glass involves the pouring of molten glass from a furnace onto a large, shallow bath of molten tin. The glass floats on the molten tin, spreading out and forming level parallel surfaces, with the thickness controlled by the speed at which the solidifying glass is drawn off the tin bath.

The glass then travels through an annealing lehr where the cooling process continues under controlled conditions and emerges in one long continuous ribbon, where it is then cut to suit customer requirements.

Clear float glass is colourless and transparent thereby providing a high degree of visible light transmittance.

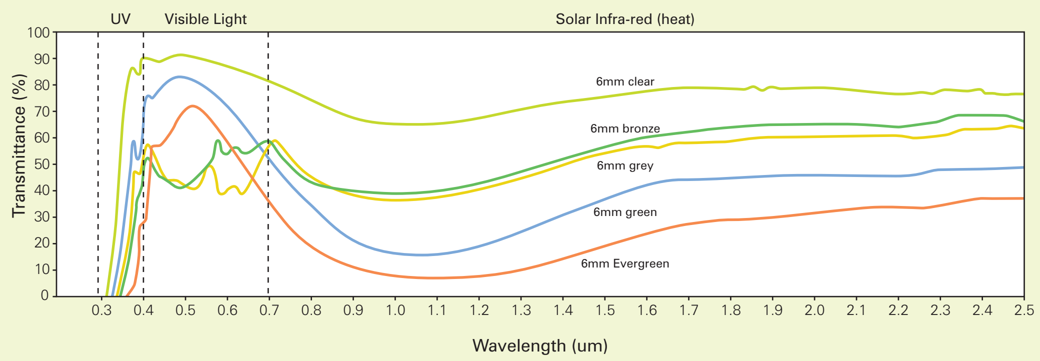
2.2 Tinted Float

Body tinted or heat absorbing glasses are produced on the float process with the addition of small quantities of metal oxides to the normal clear glass mix.

The standard range of colours are Green, Grey, Blue and Bronze. Addition of colour does not affect the basic properties of the glass although visible light reflectance will be slightly lower than clear glass. The colour density will increase with thickness while the visible light transmittance will decrease correspondingly as the thickness increases.

Tinted glasses reduce solar transmittance by absorbing a large proportion of the solar energy, the majority of which is subsequently dissipated to the outside by re-radiation and convection. It is for this reason that extra care needs to be given to edge condition and the fact that heat strengthening may be required, particularly with the thicker glasses, to avoid the risk of thermal breakage.

Graph 2.2a: Transmitted Energy Wavelength



2.3 Supertints

The supertints are a further extension of the family of tinted glass products. Products such as Evergreen/Solargreen, Azurlite and Arctic Blue provide excellent light transmittance while still maintaining effective solar control properties. These products are often termed 'spectrally selective' as they effectively select the visible light band from the solar spectrum (resulting in a higher light transmission) and filter out the UV and infra-red bands when compared to standard tints. In contrast, Supergrey and Optigray have been designed to reduce light transmittance and solar heat gain to achieve desirable shading coefficients.

As supertints have higher absorption properties than standard tinted glass, a thermal safety assessment is recommended to determine if heat treatment is required.

Evergreen: Is one of the supertints specifically designed to provide high light transmittance along with excellent solar control properties. At the same time it reduces glare and UV transmittance. With a 66% light transmittance, this compares to 43% for standard grey, 51% for standard bronze and 78% for standard green. An additional benefit of Evergreen is that it offers approximately 20% better solar performance than body tinted glass with a shading coefficient of 0.58 compared to 0.69 - 0.71 for the standard tints. Its overall solar performance ratio or luminous efficacy is exceptional with a ratio of 1.13 (the higher the figure the better) which compares to standard grey or bronze with 0.62 and 0.72 respectively. Evergreen is an ideal choice for reducing both air-conditioning and lighting costs.

Azurlite: Has a pleasing azure blue appearance, and combines a high light transmittance with an effective, relatively low shading coefficient. At 71% light transmittance, the total solar energy transmitted is only 50% giving a shading coefficient of 0.58 and a luminous efficacy 1.22.

Optigray: Optigray 23 is designed to offer a much lower light transmittance of only 23%. While at the same time, the total heat transmittance is reduced to 41% and achieving an effective shading coefficient of 0.47 and a luminous efficacy of 0.49. The reduction of the light transmittance has the added advantage of cutting reflection down to 5% while simultaneously allowing only 8% ultra-violet transmittance. It is therefore very beneficial in providing protection against fading.

Supergrey: Provides the lowest visible light transmittance (8%) of any body tinted glass. However, it gives exceptional solar control with the lowest shading coefficient (0.39) of any uncoated glass and, in some instances, better than that of certain reflective glasses. In addition it has very low indoor and outdoor reflectance of only 4% and is extremely effective in reducing glare and the need for internal blinds. Its deep grey toned colour enables it to be used in matching spandrel panels with no read through. Further, Supergrey blocks 99% of ultra-violet radiation reducing the degradation of carpets and fabrics.

2.4 Low Iron

Standard everyday clear glass has an inherent green tinge, which is more apparent when viewing the edge of the glass or in a composite stack of many panels.

The colour is due to the iron content in the sand (silica) whereas the low iron glasses contain approximately one tenth of the iron content of standard clear glass. Products such as Starphire and Diamant are ultraclear glasses that are amazingly white. In monolithic form, these are ideal in decorative and furniture applications while it can be toughened or laminated for use in showcases, shopfronts and toughened glass entries.

Increasingly, architects are looking for a white glass because of its high fidelity colour transmittance and the clarity of the edges make it ideal for atriums or indeed entire facades where solar control is not a factor.

3.0 Laminated safety glass

Clean room, G.James Malaysia

3.1 Introduction

In 1903 French chemist Edward Benedictus accidentally broke a bottle of cellulose acetate in his laboratory. As a result, he discovered that the cellulose, on hardening, held the fragments of glass together. This subsequently led to the use of cellulose as the binding agent in the glass laminating process. A Saint-Gobain patent of the process followed in 1910. Further development by Dupont and Monsanto led to the use of laminated windscreens in cars after the Second World War.

Autoclaving glass, Brisbane

Vinyls have long since replaced the earlier use of celluloid, which tended to turn brown with age and become brittle. Polyvinyl Butyral (PVB) is now the most common interlayer material used around the world for laminating purposes.

3.2 Process

The manufacture of laminated glass commences with the glass being thoroughly washed and dried before passing into an air-conditioned ‘clean room’. Here the humidity and temperature are strictly controlled, with operators wearing special lint-free headgear and clothing, to ensure the atmosphere is free of dust, moisture and debris of any description.

A PVB interlayer, initially translucent in appearance, is sandwiched between the glass(es) which then pass through pressurised rollers and heating ovens. This pre-nip, de-airing process removes air trapped between the glass and the interlayer(s) as well as softening the PVB to give initial adhesion or pre-tacking.

The glass is then autoclaved where it is again heated and subjected to extreme pressure (between 8 and 12 BAR) permanently bonding the glass and the interlayer. It is during this final process that the glass becomes completely transparent.

G.James produce laminated glass covering the full spectrum from basic 2 ply clear laminates, through tinted, reflective to multi-ply, bandit and bullet resistant, and very high impact performance products.

Table 3.2a: Manufacturing Capabilities

	Minimum	Maximum
Thickness	5.38mm	50mm
Size	100mm x 100mm	2440mm x 3660mm

Brisbane Convention Centre

3.3 Benefits

G.James laminated glass is a durable, versatile, high performance glazing material that offers a range of benefits:

Safety

When subjected to accidental human impact, the bond between the glass and interlayer combine to absorb the force of the impact, resisting penetration of the laminate. Should the impact be sufficient to break the glass, the resulting fragments typically remain intact, firmly adhered to the PVB interlayer. This important characteristic significantly reduces the likelihood of serious injury qualifying laminated glass as a Grade A safety glass.

Security

Laminated glass offers greater protection for people and property by providing an effective barrier when under attack. Although the glass will break if hit with a hammer, brick or similar object, the interlayer will resist penetration ensuring any attempt to enter the premises will be slow and noisy. Also, if attacked the glass will tend to remain in the opening, keeping wind and rain out of the building until it can be replaced at a convenient time.

Sound Reduction

In many instances laminated glass is often overlooked as an acoustic glass. For most applications, laminated glass provides an effective, low cost method of reducing the transmission of noise through the glass. This is achieved through the 'viscoelastic' properties of the PVB interlayer which dampens the coincidence dip (See Section 1.14) in the mid to high frequency range (1000 - 2000 Hz). Coincidence impairs the overall acoustic performance of glazing systems, as general environmental noise sources such as traffic and aircraft have significant amounts of sound energy in this frequency range.

Heat and Glare Control

While it is desirable to allow more natural light into our homes and buildings, more light often means more heat entering the interior. Laminated glass with a tinted interlayer, can reduce heat gain by absorbing this radiated heat while simultaneously cutting down the amount of glare that occurs with high levels of natural light. The underlying benefit is lower costs associated with cooling the interior.

For optimum heat and glare control, G.James' range of Optilight products (See Section 3.5) or laminated glass incorporating a Solarplus reflective coating (See Section 6.2) are recommended.

Laminated glass application

UV Elimination

G.James laminated glass products protect expensive curtains, furnishings and carpets from the damaging effects of short-wave ultra-violet radiation. The PVB interlayer filters the sun eliminating up to 99% of UV rays while allowing the important visible light to pass through.

Low Visible Distortion

Due to the controlled nature of the laminating process, facades glazed with laminated, annealed glass avoid the risk of visible distortions, providing significantly sharper reflections.

NB: These benefits are dependent on the nature of the final processed product.

With glass laminating facilities in Australia and Malaysia, G.James has the capability to manufacture the complete range of architectural glass products to satisfy specific design requirements for colour, thermal and mechanical performance.

3.4 Applications

The many features and possible configurations of laminated glass combine to provide a product that has a wide and varied range of applications:

- Overhead glazing, skylights and rooflights
- Glazed areas surrounding gymnasiums and swimming pools
- Glass balustrading and lift wells
- Showerscreens, mirrors, sliding doors and sidelights
- Shopping centres, offices and banks
- Hospitals, schools and libraries
- Aquariums and zoos
- Jails, embassies and security vehicles
- Blast resistant glazing

3.5 Optilight

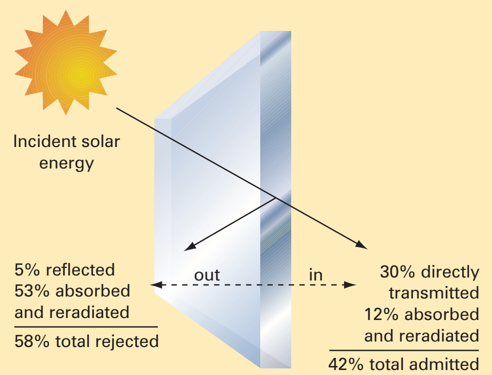
Optilight is G.James' range of spectrally selective, high performance laminated glass products that offer optimum light transmission, reduced solar heat gain/loss and minimum reflectance while maintaining the natural toning of the glass.

By combining readily available raw glass and interlayer, and the latest hard-coating technology, Optilight provides a cost-effective product with proven durability, reliability and serviceability. The neutral coloured coating incorporated within this glass ensures minimal reflection and is therefore ideal in commercial applications where the original clear or tinted appearance of glass is desired.

Capable of being supplied as either a laminated product or incorporated into an IG unit, Optilight products are suitable for vision and overhead glazing applications.

As with all high performance solar control products, a thermal safety assessment is recommended to assess the need for heat processing to avoid thermal fracture of the glass. (See Appendix One for a Thermal Safety Assessment Form.)

Figure 3.5a: Optilight HL719



Solar performance analysis based on 12.76mm Optilight HL719

3.6 Cyclone Resistant Laminate

By incorporating a thicker combination of interlayers, Cyclone Resistant laminate is designed to resist penetration of flying debris and maintain clear vision (dependent on glass configuration) in the event of breakage. Also designed to satisfy the criteria for protection in openings, as defined in the Australian Standards AS 1170.2, this product resembles an ordinary panel of glass when glazed.

It is essential that cyclone resistant glass is held captive in a suitable framing system to prevent the glass from evacuating the building when subjected to severe storm and cyclone conditions.

G.James cyclone resistant, laminated safety glass can be manufactured to incorporate solar control products.

Tests have shown that cyclone resistant glass meets the requirement of resisting penetration from impact of a 4kg, 50mm x 100mm timber plank on end, travelling at 15mtrs/sec. This is equivalent to an impact energy of 450J.

3.7 Anti-bandit Glass

G.James Anti-bandit glass is a laminated product incorporating a 1.52mm PVB interlayer. It is this increased thickness of interlayer which foils attacks from such items as bricks, hammers and axes.

It is essential that anti-bandit glass is held captive in a suitable framing system to prevent the glass evacuating the building when subjected to an attack.

3.8 Characteristics

Edge Delamination

Delamination to the edge of laminated glass is an inherent characteristic of this product. More noticeable where the glass edges are exposed, delamination is the result of a breakdown in the bond between the polyvinyl butyral interlayer and the glass. The extent of the breakdown will depend on the glazing application and location but generally will not extend any further than 10mm in from the glass edge. It should be noted delamination is not detrimental to the strength or performance of the glass. If delamination is a concern, it is recommended that the glass be glazed fully captive in a frame.

Lloyds of London