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PERSPEX
south africa

Glazing

ACRYLIC SHEET GLAZING MANUAL

CONTENTS

1. INTRODUCTION

‘‘Perspex’® acrylic sheet has for many years been associated with many novel design concepts. Its low density, high tensile strength, good clarity and excellent weatherability have made ‘Perspex’® acrylic sheet a natural choice as a widely used glazing product, allowing natural lighting and ventilation.

The use of acrylic is in many countries subject to control under local regulations. Therefore it is advisable to consult your local regulations at the earliest possible point in the design stage.

2. SAFETY

‘Perspex’® acrylic sheet is a hard material and sharp edges or chips can cause damage to skin or eyes. Also ‘Perspex’® is flammable material and it is important to ensure that any heating ovens are fitted with thermal cutouts in case of over heating. These cutouts should be set at 200C. You are also advised to read the guidance notes on health and safety.

3. PRODUCT RANGE

3.1 STANDARD PRODUCTS

Three different types of acrylic are offered for glazing applications. Extruded Acrylic Sheet MI grade is suitable for general glazing applications. It is available in standard sheet sizes of up to 1850 mm x 9 mm, a range of thicknesses of up to 6 mm, and in a variety of clear, opal and transparent tinted colours. Extruded acrylic is not recommended for areas of high temperatures, high pollution or chemically aggressive environments. Extruded acrylic is also not recommended for barrel vaults over enclosed swimming pools, as in a stressed state, it has insufficient resistance to chlorine emitted from the pool, and environmental stress crazing tends to develop.

‘Perspex’® Cast Acrylic Sheet

This grade is most suitable for use in glazing applications:

1. Where fire regulations or requirements are a consideration

2. In areas of very high temperature; high pollution, or chemically aggressive environments, where the increased environmental craze resistance of cast acrylic is needed over standard extruded sheet.

It is also available in a wide variety of colours and thicknesses in sheet up to 3200 mm x 1930 mm.

Patterned Sheet

A “ripple” effect in 4 mm thicknesses available in 1880 mm x 1270 mm sheet size to special order only.

3.2 GRADES FOR SPECIAL APPLICATIONS

'Perspex'® I M Impact Modified Cast Acrylic Sheet
A grade of 'Perspex'® acrylic sheet developed to give a product with somewhat reduced weatherability, but with greater impact and vandalism resistance. It is available in sheet thicknesses of up to 5 mm and sheet sizes of up to 3200 mm x 1930 mm.

High UV Absorbing Grades
'Perspex'® VE has been formulated to absorb very high levels of UV light to prevent degradation of artifacts placed behind the material. As a result, this special product has been used primarily in museums, to minimize the harmful effect to UV light.

'Perspex'® VA clear has been developed for applications requiring a high resistance to both UV light and high levels of humidity. These two properties make it particularly useful in both tropical areas and in dessert conditions.

Infra-red Light Absorbing Grades
'Perspex'®: certain tints, such as U5040 and U90, give absorption on infrared light and thereby reduce solar heat gain within glazed areas.

'Perspex'® Opals 040, 050 and 068: All of these opals will also give protection against solar heat gain, but note that Opal 030 does not.

Infra-red Transmitting Grades
Most grades of 'Perspex'® will transmit in the infra-red range except those listed above and a few others with restricted transmission.

However there is one colour: 'Perspex'® Cast Black 962 that has a special property in that it will only transmit infra-red light and hence has wide uses in the security industry.

Photographic Applications
Several of the tints and Opal 040 are suitable for applications within the photographic industry.

Another application for which 'Perspex'® is used, is as filters for lighting during photography. Further advice is available on request.

'Perspex'® Opal 040 is the best opal for light boxes for viewing photographic transparencies and x-rays.

Laser Light Protection
Amber 300 might be suitable for some laser light protection screens, for more information please contact the Technical Service section. The wavelength of the laser is needed to determine the most suitable grade of 'Perspex'® for the job.

4. PHYSICAL PROPERTIES OF 'PERSPEX'®

4.1 PHYSICAL TEST DATA

Table 1 compares the physical properties of cast, extruded and impact modified cast 'Perspex'® acrylic sheet.

Table 1: Physical performance parameters of 'Perspex'® sheet

	TEST METHOD	UNIT	EXTRUDED ACRYLIC	'PERSPEX'® CAST	'PERSPEX'® IM CAST
Tensile strength	ISO R 527	Mpa	71	80	62
Tensile modulus	ISO R 527	Mpa	2310	3200	3370
Flexural strength	ISO 178	Mpa	111	116	105
Flexural modulus	ISO 178	Mpa	3030	3210	2960
Charpy impact (unnotched)	ISO 179/2D	KJ/m_2	11	12	22
Falling ball impact	ICI	mm	-	300	3200
Vicat softening point	BS 2782	°C	106	114	112
Rockwell hardness	ISO 2039/2	-	M101	M102	M98.5
Light transmission	ASTM D1003	%	92	92	92
Water absorption	ISO 62	%	0.2	0.2	0.4
Density	ISO 1183	g/cm_3	1.186	1.189	1.175

The above properties are the results of tests on representative samples and do not constitute a specification.

There are a number of reasons why 'Perspex'® acrylic sheet is chosen over other materials for glazing applications

These are listed below:
1. UV Stability. Clear 'Perspex'® cast acrylic sheet will not show any noticeable colour change in excess of 10 years. Also no significant deterioration in the physical performance of 'Perspex'® will be observed over that time.

2. Rigidity – 'Perspex'® acrylic sheet is one of the stiffest of all plastic glazing products, thereby reducing the chance of any in-service distortion of the product.

3. Impact performance – acrylic polymers have about five times the impact performance of glass. Independent testing has shown cast 'Perspex'® to be a safety glazing product when tested to BS 62006.

4. High Continuous Service temperature – products produced from 'Perspex'® cast acrylic sheet will have a maximum constant service temperature of approximately 80oC.

5. Scratch resistance – acrylic polymers have the hardest surface finish of all the traditional glazing plastics.

4.2 TEMPERATURE PERFORMANCE RANGE

'Perspex'® can be successfully used over a very wide temperature range (-40oC / +80oC). Indeed at the low temperature limit the impact performance of 'Perspex'® is better that at room temperature.

Care however must be taken during the installation of 'Perspex'®, if a wide inservice temperature is required, to ensure suitable expansion/contraction allowance have been made.

An expansion allowance of 5 mm per metre length is recommended for use with 'Perspex'® in an in-service temperature range of 50ºc. If greater temperature ranges are anticipated, greater allowances should be made.

NB: the above allowance also includes a factor for any increase in dimension due to water absorption.

4.3 FLAMMABILITY AND FIRE PERFORMANCE

'Perspex'® sheet is tested throughout Europe to many different national fire tests (see Table 2) and is found to be ideally suited in a variety of applications. It is however the installer's responsibility to ensure that the design and construction of the structure fully complies with all relevant codes and standards.

Table 2: Details of the main regulatory fire tests to which cast 'Perspex'® and extruded acrylic have been tested

COUNTRY	PRODUCT TYPE	TEST	RESULT/CLASS
Germany	Cast	DIN 4102	B2
Germany	Extruded	DIN 4102	B2
Holland	Cast	NEN 3883	Class 3 surface spread of flame Class 4 contribution to flashover
France	Cast	NFP 92-307	M4 without drips
France	Extruded	NFP 92-307	M4 with drips
Great Britain	Cast	BS 476 PART 7	3 >/=3 mm thickness
Great Britain	Cast	BS 476 PART 7	4 </=2 mm thickness
Great Britain	Extruded	BS 476 PART 7	4 all thicknesses

As a product, 'Perspex'® cast acrylic sheet burns at a rate equivalent of many hard woods but with low evolution of smoke. Encapsulating the edges of 'Perspex' acrylic sheets into glazing profiles greatly reduces the ease with which 'Perspex' can be ignited

4.4 SOUND INSULATION

'Perspex'® being a rigid plastic works primarily as a noise insulator rather a noise absorber. It does not resonate as much as glass, and correctly constructed double glazing units using 'Perspex' can give sound reduction indices of over 30db (Table 3).

Table 3: Sound reduction index

GLAZING ARRAY	SOUND REDUCTION INDEX (db)
1 X 3 MM 'Perspex'®	26
1 x 6 mm 'Perspex'®	32
1 x 8 mm 'Perspex'®	34
1 x 12 mm 'Perspex'®	35

To maximize the efficiency of double glazing with 'Perspex'® it is important to minimize sound leakage within the glazing profile.

4.5 THERMAL INSULATION AND HEAT TRANSFER

'Perspex'® acrylic sheet has a lower heat loss figure than the equivalent thickness of glass, since both its transfer coefficient (U value) and its thermal conductivity (K-value) are lower (Table 4 and 5).

Table 4: Heat transfer coefficient (U value) of glass and 'Perspex'® window system

	AIR GAP BETWEEN GLAZING PANELS	HEAT LOSS (U VALUE) GLASS	$W/m^2{}_oC$ 'PERSPEX'®
3 mm thick single pane	-	5.6	5.2
5 mm thick single pane	-	5.5	4.9
Double glazing each panel 3 mm thick	3	4.0	3.6
	6	3.5	3.2
	12	3.1	2.9
	16	3.0	2.8
	20	2.9	2.7

Double glazed units in 'Perspex'® should not be hermetically sealed because the acrylic is permeable to moisture and sealing of the glazing units may lead to water droplets forming long term on the inside of the glazing. It is possible on unsealed units that water droplets may form temporarily but they should clear quickly provided that a small air circulation hole is drilled top and bottom of the exterior panel/

Table 5: Thermal conductivity coefficient (K-value of glass and 'Perspex'®)

UNITS	GLASS	'PERSPEX'
W m/m$_2$ ^{o}C	1.15	0.189

4.6 WEATHERABILITY

Most grades of 'Perspex'® acrylic sheet exhibit excellent weathering characteristics and resistance to UV light. No significant loss in the physical performance of cast 'Perspex'® should be exhibited after 10 years outdoor exposure. The life expectancy of 'Perspex'® in roofing applications is of the order of 20 years in a well maintained building, provided the original design and construction are to the design parameters listed in technical note published by Perspex SA.

Cast 'Perspex'® in particular has been used extensively for roof-lights and barrel vaults in hot climates (temperate and tropical) and in areas of high pollution. Providing the correct grade for the application and area is used the weatherability of the 'Perspex'® should be more than adequate.

4.7 LIGHT TRANSMISSION

Clear 'Perspex'® transmits 92% of visible light and even after 10 years of weathering it will transmit 85% of visible light. Of all the clear sheet materials available, acrylic sheet has by far the most superior light transmission performance.

Table 6 Optical properties of 'Perspex'® and extruded acrylic

MATERIAL	VISIBLE (380nm–780nm)		SOLAR (350 nm – 2100nm)					SHADING COEFFICIENT	ULTRA-VIOLET ELIMINATION
	A	B	1	2	3	4	5		
	LIGHT TRANSMISSION %	LIGHT REFLECTION %	TOTAL ELLIMINATION %	DIRECT REFLECTION %	ABSORBTION %	DIRECT TRANSMISSION %	TOTAL TRANSMISSION %		
'Perspex'® Clear 000	93	8	11	8	4	88	89	1.0	62
'Perspex'® Bronze 5040	10	5	62	5	78	18	39	0.44	89
'Perspex'® Bronze U95	55	6	32	6	35	59	68	0.78	95
'Perspex'® Opal 028	20	79	75	66	12	22	25	0.29	100
'Perspex'® Opal 030	66	15	27	13	20	67	73	0.83	81
'Perspex'® Opal 050	27	42	59	31	38	31	41	0.47	99
'Perspex'® Opal 040	38	39	55	40	20	40	45	0.40	100
'Perspex'® Neutral U 90	38	5	29	7	30	63	71	0.82	79
'Perspex'® U 97	41	6	27	7	28	66	73	0.84	69
Extruded Acrylic Clear 000	92	8	10	8	3	89	90	1.0	10
Extruded Acrylic Bronze 504	7	5	64	5	82	13	34	0.40	100
Extruded Acrylic Bronze 505	23	5	52	5	64	31	48	0.55	98
Extruded Acrylic Bronze 506	47	5	38	6	44	50	63	0.72	96
Extruded acrylic Opal 050	35	53	57	39	25	36	43	0.49	99
UHI (impact Modified) Extruded Acrylic Clear 000	89	78	12	8	6	86	88	1.0	99

5. ROOF GLAZING

5.1 INTRODUCTION

Modern architectural trends have led to many buildings using natural sunlight to produce a light airy atmosphere within the building. This is often achieved by the use of large areas of transparent roofing and 'Perspex'® acrylic sheeting has been at the forefront of this development. The physical attributes of 'Perspex'® which make it ideal for this are:

1. Lightweight – 'Perspex'® has only one half the density of glass allowing major savings in roof support structure to be made.

2. flexibility – 'Perspex'® like other plastics products is more flexible than glass, allowing the production of curved barrel vaults by cold bending rather than the expensive techniques required to bend glass.

3. Weatherability – 'Perspex'® has outstanding external performance which other non-acrylic materials cannot meet.

4. Colour Range – Few products offer the wide range of colours and tints offered by 'Perspex'® cast acrylic sheet. This allows the production of exactly the right ambiance within a glazed area. The solar control grades of 'Perspex'® acrylic sheet cam also be an advantage in controlling heat gain in a glazed building.

5.2 DESIGN CONSIDERATION

Minimum Cold-Bending Radii

"Perspex'® and extruded acrylic can be readily cold bent to allow the installation of continuous roof lighting. A minimum cold bend radius of 200 times the thickness is possible with 'Perspex'®, and 300 times for the extruded grades.

Table 7: Minimum cold bending radii for 'Perspex'®

SHEET THICKNESS (mm)	3	4	5	6
Cast 'Perspex'®	600	800	1000	1200
Extruded Acrylic	750	1200	1500	1800

If these minimum bend radii are exceeded there is a great risk of the 'Perspex'®, and especially extruded acrylic, surface crazing in service. In tropical or sunny climates we would recommend the minimum cold bend ratio for 'Perspex'® to be 300 times the sheet thickness.

Rebate Depths and Allowances

Rebate Allowance – 'Perspex'®, in common with most glazing plastics, has a high coefficient of thermal expansion (7 x 10-5 m/m per K) in comparison to traditional building material (e.g. glass, wood and aluminium). Therefore care needs to be taken to ensure that in any roofing application the 'Perspex' is free to expand or contract and cannot become thermally over stressed. Perspex SA recommends that an expansion allowance of 5 mm/m be made on all sides of each pane in the installation to allow expansion to occur, thereby minimizing thermal stress build up in the sheet.

Rebate Depth - 'Perspex'® is a more flexible material than glass and therefore requires the use of larger rebate overlap. Perspex SA recommends the use of an overlap of 15 mm for sheets up to 750 mm wide and 20 mm for sheets of greater width.

Table 8:
Recommended sheet thickness of 'Perspex'® for barrel vaults (barrel height is ½ barrel span)

BARREL SPAN (mm)	PROFILE SUPPORT WIDTH	
	1000 mm	2000 mm
800	3mm	4mm
1100	4mm	5mm
1400	5mm	5mm
1700	6mm	6mm
2000	6mm	8mm

Table 9:
Recommended sheet thickness of 'Perspex'® for barrel vaults (barrel height ¼ span)

BARREL SPAN (mm)	PROFILE SUPPORT WIDTH	
	1000 mm	2000 mm
800	4mm	5mm
1100	4mm	5mm
1400	5mm	6mm
1700	6mm	8mm
2000	6mm	8mm

Table 10:
Recommended sheet thickness of 'Perspex'® for barrel vaults (barrel height is 1/8 barrel span)

BARREL SPAN (mm)	PROFILE SUPPORT WIDTH	
	1000 mm	2000 mm
800	4mm	6mm
1100	5mm	6mm
1400	6mm	8mm
1700	6mm	6mm
2000	8mm	10mm

NB:
1) The difference between these thicknesses recommendations (Tables 8 – 10) and those in (Table 11) are the result of the major improvement in product stiffness caused by the curving of the roof structure.

2) The above calculations have been on an assumed wind load of 1000 N/m2.

3) When impact modified grades are used, the above thicknesses should be increased to the next size.

The above tables are to serve as guidelines for general use.

Pitched Roofs
Table 11 gives recommended sheet thickness for 'Perspex'® acrylic sheet in a variety of flat pitched roof sizes. They have been calculated to give a maximum loading of 750 N/m2.

Table 11: Recommended thickness for flat roofs

ROOF SPAN (mm)	GLAZING PROFILES SPACING		
	800 mm	**1000 mm**	**1200 mm**
800	5 mm	6 mm	6 mm
1400	6 mm	8 mm	8 mm
2000	6 mm	8 mm	10 mm

Roof Lights
'Perspex'® acrylic sheet is readily formed by a variety of forming techniques into most types of roof lights used in South Africa. Unlike some products, no evidence exists (to Perspex SA's knowledge) to show that any roof lights manufactured from 'Perspex'® acrylic sheet using recommended procedures and grades, has demoulded or discoloured in service due to the effects of solar radiation.

6. VERTICAL WINDOW GLAZING

6.1 SAFETY GLAZING STANDARDS

Perspex'® cast acrylic sheet has been tested to the ANSIZ.97 and BS 6206 plastic safety glazing standards. Testing to BS 6206 1981 has led to 3 and 5 mm cast 'Perspex' being classified as Class B and 8 mm cast 'Perspex' as Class A safety glazing. 'Perspex' also conforms to the requirements in BS 626:1982 Code of Practice for Glazing for Buildings.

6.2 IMPACT PERFORMANCE

Although many methods exist to demonstrate the impact performance of a glazing product perhaps the most realistic to in-life requirements is a falling ball test.

Table 12 gives some typical results demonstrating the resistance of glazing materials to a 3,6 kg steel falling from varying heights into horizontal sheets.

Table 12: Impact resistance of glazing products

TEST METHOD	PANE SIZE 610 x 457 mm		PANE SIZE 1219 x 914 mm	
	THICKNESS mm	DROP HEIGHT FOR BREAKAGE mm	THICKNESS mm	DROP HEIGHT FOR BREAKAGE mm
'Perspex'® Cast	3.00	300		
'Perspex'® Cast	5.00	800		
'Perspex'® Cast	6.00	1100	6.00	1600
Toughened Glass	6.35	1520	9.50	1520
Georgian Wire Glass	6.35	380	6.35	380
Plate Glass	6.35	250	9.50	510

6.3 RECOMMENDED WINDOW THICKNESSES

The required sheet thickness is dictated by two considerations. One is the desired impact strength which is indicated in Table 12, the other is the wind loading which the window has to sustain; this is considered as a function of pane size in Figure 1. These should be considered in turn and the minimum thickness which fulfils both requirements should be used.

At the recommended thickness, the sheet will deflect under wind load and it is therefore important to use the appropriate depth of rebate, as shown in **Table 13**, to ensure that the sheet remains fixed in the frame.

Figure 1: The recommended thickness of 'Perspex'® for various wind loads when designing for square windows, with all edges fully supported.

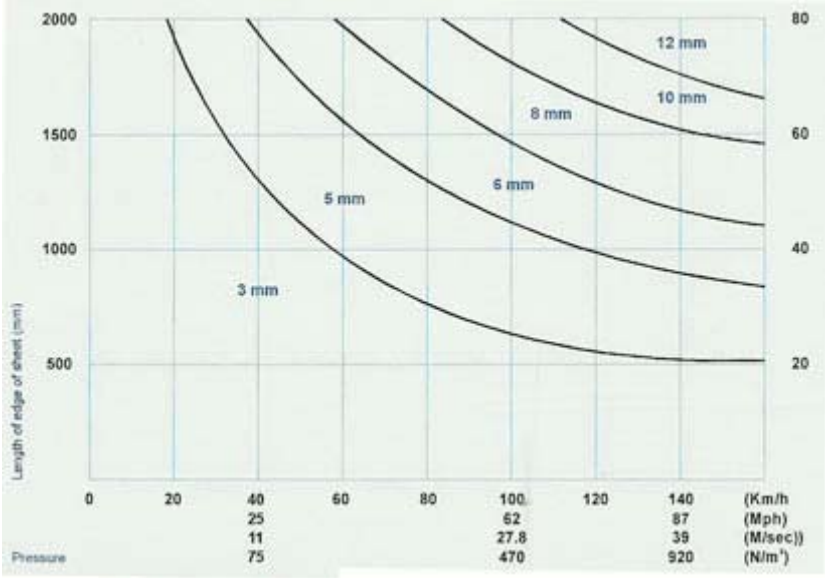


Figure 2: The recommended thickness of 'Perspex'® for various wind loads when designing for rectangular windows, with all edges fully supported.

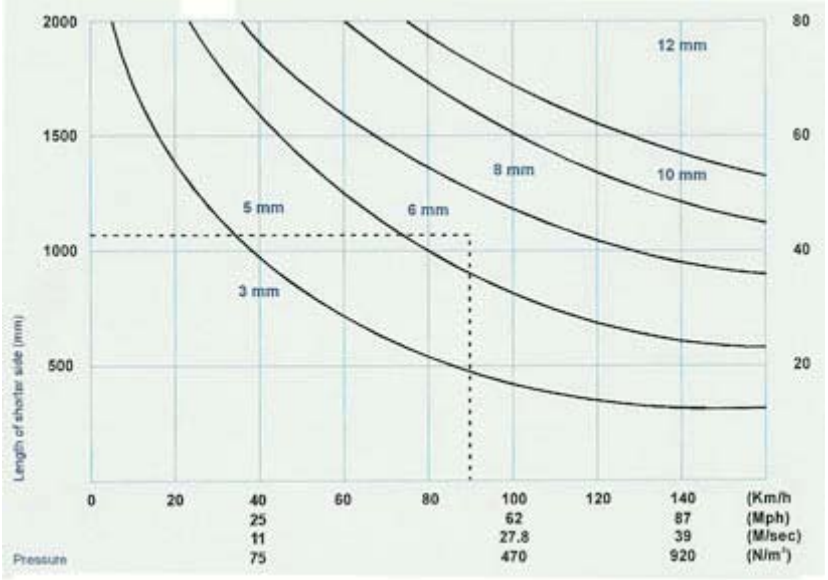


Figure 3 shows a typical profile assembling and Table 13 the recommended rebate depth for various panel sizes, based on installation at 20ºc.

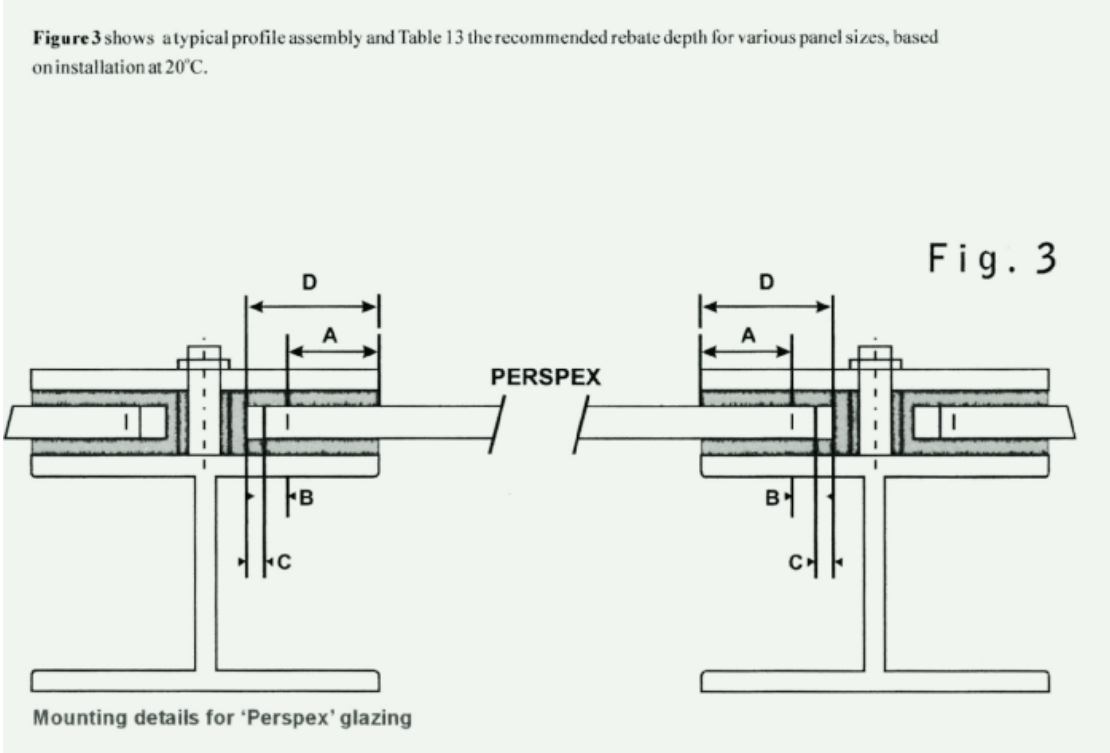


Table 13: The recommended rebate depth for glazed 'Perspex'® panels in frames.

NOMINAL PANEL SIZE	MINIMUM REBATE DEPTH A	CONTRACTION ALLOWANCE B	EXPANSION ALLOWANCE C	TOTAL REBATE D
1000 mm	30mm	5 mm	5 mm	40 mm
2000 mm	35 mm	10 mm	10 mm	55 mm
3000 mm	40 mm	15 mm	15 mm	70 mm

6.4 MOUNTING DETAILS

The preferred method of mounting 'Perspex' glazing is between metal frames. Aluminium profiles or glazing bars are generally acceptable.

As a general rule, 'Perspex'® should be fixed in the frames with rubber profile sections as is the normal glazing practice. If preferred, flexible mastics may be used and polysulphide sealants have been found to be suitable for this purpose. Silicone sealants can also be used but, as stated earlier, it is very important to use rubber profiles or sealants which are known to be compatible with acrylic sheet.

In the event of any doubt the manufacturer's advice should be sought first. When installing glazing in any frame system, two critical observations need to be taken into account:

1) Thermal expansions clearance

2) Rebate depth

Thermal expansion clearance

'Perspex'® has a high thermal expansion coefficient compared to traditional glazing materials and allowance within the frames must be in both directions for thermal expansion and contraction. Failure to observe this rule can lead to stresses and the sheet which can cause distortions in the panel and crazing at the edges of the sheet in time.

An allowance of 5 mm per metre run length should be allowed in both dimensions during installation. This figure has been found from long experience to be sufficient for all locations and climates.

Rebate depth

It follows from the above that the rebate depth must be sufficient to allow for the expansion clearance and also the thermal contraction that can take place in winter. Rebate depth must also be sufficient to prevent sheet from being deflected out of the frame in gale force winds.

Figure 3 shows a typical profile assembly and Table 13 the recommended rebate depth for various panel sizes, based on installation at 20ºC.

7. SECURITY SCREENING

Clear 'Perspex' acrylic block of the correct thickness will stop projectiles from revolvers, pistols and shot guns without chips or splinters being thrown from the rear face.

The high degree of clarity and gloss of 'Perspex'® make it particularly attractive for prestige buildings and other public premises. The abrasion resistance of 'Perspex'® is lower than that of glass and is equivalent to that of aluminium. However the excellent surface finish of 'Perspex'® is maintained by cleaning with warm soapy water and clean cloths and if it should become scratched it can be refurbished. Proprietary window cleaning materials should NOT be used.

8. NOISE SCREENING

Noise pollution is an ever increasing problem. The two main sources of noise pollution are either motorized vehicles or industrial equipment.

Cast ‘Perspex’® has been used in the general area of noise insulation for in excess of 25 years. Its initial use was in areas such as enclosures for food canning lines where the following attributes of ‘Perspex’® were found to be major selling points.

1) Good Chemical Resistance – Many aggressive chemicals are used in cleaning procedures for food handling equipment.

2) Good Impact Resistance against accidental damage in-service.

3) Good resistance to scratching.

4) Lightweight and easy to install.

5) Excellent clarity.

In most applications the optimum relative performance of noise reductions (in the region of 2000 Hz) against cost was produced by the use of 13 mm ‘Perspex’®. Due to its thickness, it is easy to produce attractive self standing structures free from meat; support structures.

Actual in-service noise reduction values achieved from thick ‘Perspex’® sheets are difficult to predict because of the effects of noise leakage. However, independent testing has shown that noise reduction levels is excess of 30 db can be achieved using ‘Perspex’.

9. FLOORING

Many entertainment buildings (e.g. dance halls and restaurants either interior or exterior) use the light transmitting property of 'Perspex'® to provide design features e.g. a dance floor.

'Perspex' sheets and blocks are used because of their resistance to breakages, weathering and scratching.

The prime requirement of these floors is that they must feel rigid to walk across. Care should he taken to ensure the floor design meets all local building codes. Table 14 gives recommendations for 'Perspex'® sheet thicknesses against panel size assuming a loading requirement of 5000N/m2 (509 kg/m2).

Table 14: Guideline thicknesses of 'Perspex'® required for different areas.

PANEL SIZE mm	Minimum sheet thickness	To restrict deflection to 25% of sheet thickness
300 x 300	8 mm	12 mm
750 x 750	15 mm	20 mm
1000 x 1000	20 mm	30 mm
1500 x 1500	25 mm	30 mm
2000 x 2000	30 mm	35 mm

The surface hardness of 'Perspex'® is usually acceptable for floors and if required the surface gloss can be refurbished by polishing.

The 'Perspex'® floor should be protected against damage arising from contact with metal or wooden support structures. This can be achieved by the use of acrylic compatible glazing rubbers.

The above thicknesses are only guidelines.

10. VEHICLE GLAZING

10.1 INTRODUCTION

Since its first application in the second world war as the glazing material for Spitfire canopies, 'Perspex'® acrylic sheet has been used extensively in vehicular glazing both as a true glazing material and as an accessory to improve driver comfort. Today, 'Perspex' can be found as a glazing material thousands of feet up in the air and hundreds of feet under the sea.

In traditional glazing areas, 'Perspex'® is the natural choice of many designers, who require the following attributes:-

- UV stability
- Rigidity
- Impact performance
- Scratch resistance
- High continuous service temperature
- Refurbishability; ease of fabrication

'Perspex'® cast acrylic sheet is easily fabricated into 3-dimensional shapes by the use of conventional thermoforming techniques. Coupled with the ease of edge polishing acrylic, this allows the cost-effective production of automotive accessories.

'Perspex'® is unsuitable for use as windscreens, except motorcycle windscreens.

'Perspex'® has since its introduction been used as an aircraft glazing product. This is a specialised and highly technical area outside the scope of this document.

10.2 AUTOMOTIVE GLAZING
Legal Aspects Controlling the Use of Plastic Automotive Glazing

The use of plastic safety glazing in many applications is controlled by national legislation requiring approved materials which must meet certain physical performance standards. Dependent upon the country, these glazing standards can also control approvals for some automotive accessories.

The approval systems for automotive safety glazing vary widely from country to country in specific detail but in general depend upon a mixture of finished product and raw material testing.

The most widely accepted of the approval systems are the American ANZIZ.26 and the German ABG. 'Perspex'® cast acrylic sheet has regularly been tested to both standards and complies with their requirements for plastic safety glazing materials.

Most approval systems consider the following performance areas to be the prime requirements of a plastic safety glazing material;

Impact performance:

3) Simulated "head form" impact testing to ensure that in an automotive crash people cannot be ejected from vehicles.

4) General impact resistance to ensure the performance and life expectancy of the glazing material against chipping.

Weatherability:
1) Resistance against ultra-violet radiation and general weather conditions.

2) Resistance to atmospheric humidity especially in areas required for driver visibility and optical performance.

Chemical resistance:
1) Good craze resistance against the effects of standard chemicals used in cars (e.g. automotive oils, wiper fluids and petrol).

Flammability:
1) Only plastics with a slow burning rate (<40 mm/min) can be approved to minimise the risk of fire as a result of a crash.

Abrasion resistance:
1) Optical clarity and freedom from optical distortions are a pre-requisite for driver safety. Therefore, in areas required for driver vision, abrasion resistance is one of the requirements for plastic materials

10.3 APPLICATION AREAS
The main automotive uses of 'Perspex'® are in are as such as:

1) Motorcycle wind deflectors

2) Motor car rain deflectors

3) Solar control glazing accessories

4) Car number plates

5) Aero dynamic spoilers

6) Lorry visors

7) Caravan side windows

Examples of 'Perspex'® being used in all these applications except car number plates can be found across Europe. Car number plates are manufactured from many different products and plastic number plates are only legally allowed in some European Countries. In Britain the performance of car number plates is regulated by British Standards BS AU145.

The ease of fabrication and availability of colour are the main reasons why 'Perspex 'is used in these applications.

Very rarely, other than in various types of caravans or tractors will plastics be found as the primary glazing material.

In most countries the use of plastic windscreens on fast moving vehicles is normally banned by legislation. The abrasion resistance of plastics is insufficient to allow long term use of a plastic window that could affect the driver's viewing visibility.

10.4 BOAT GLAZING
Most boat glazing is subjected to extended periods of UV exposure and seawater attack there by requiring the correct use and production of windows to ensure their long service.

Greatest care is required in the choice of fixing methods for the window with particular regard to the following points.

'Perspex'® has a high thermal expansion coefficient and also will absorb water Because of these two properties, it expands and contracts more than traditional glazing materials. An allowance of 6 mm per metre of edge length should be allowed to accommodate expansion I contraction. Similarly if a window is to be screwed to a boat structure, over size holes must be drilled in the 'Perspex'®, 50% larger in diameter than the screw shank.

Pressure from the screw loads should be distributed by the use of washers suitably sealed with sealant. Fixing screws or bolts should be tightened very lightly and if possible the use of self locking nuts is advisable. NB Do not use counter sunk screws.

Sheet thickness
IS0 standards are being prepared by largely combining existing American and French standards. 'Perspex'® should be used in accordance with those standards, which lay down thickness recommendations for acrylic windows. It should be noted that on ocean going yachts, heavy seas will lead to high pressures being exerted on the glazing structure.

Moulding techniques
It is recommended that all 'Perspex'® sheets are annealed (at 80oC for 1 – 2 hrs depending on thickness) as the last step in the production process. This simple step reduces the stresses within a fabricated window and thereby maximises the service life of the window.

The preferred method for producing curved boat glazing panels is by thermoforming. This is essential if the boat windows are likely to be exposed to wave motion. 'Perspex'® is a relatively flexible product and therefore some glazing panels might be produced by cold bonding and subsequent fixing in place. Such techniques are not recommended for 'Perspex' unless the window will not be exposed to any external pressure or solvents and the radius of curvature is very big.

Due to its high impact resistance and cold flex properties; polycarbonate is the normal preferred glazing material for ocean going boats; however it does suffer from a shorter life span owing to limited UV and weathering resistance. Consult local regulations.

11. BALCONY GUARDING

11.1 INTRODUCTION

'Perspex'® cast acrylic sheet has been used a balcony guard in fill panel for in excess of 20 years. The colour, impact resistance and weatherability of ‘Perspex'® are the main attributes that make it an ideal choice for designers of balcony guard infill panels. Independent testing has shown that when tested to ANSIZ.97 after 7 years outdoor exposure the impact resistance of 'Perspex' ® was unaltered.

11.2 TECHNICAL REQUIREMENTS

Sheet thickness requirement for balcony guards are dominated by three main considerations (ie panel width, impact strength and panel flexibility). 'Perspex'® meets the impact requirements of a plastic safety glazing product for the UK, American and French regulations in 6 – 8 mm sheet. The flexibility needs are met by ensuring that when under load the panel distorts by less than 1% of the support distance. The most common panel sizes require the use of 8 mm sheet, however large panels may require thicker sheet.

11.3 FIXING DETAILS

Lucite recommends that infill panels from 'Perspex'® should be supported on all four edges to provide sufficient panel rigidity at a minimum sheet thickness. In order to reduce the possibility of the infill panel being sprung from its frame, the rebate depth should be at least 20mm. lf only two edge support is possible, then the thickness of the 'Perspex'® sheet should be increased because of the lower flexural strength of the fixing system. Also minimum rebate depths should be increased to 35 mm to prevent "spring out" occurring.

Bolt fixing at the edge of a 'Perspex'® sheet should NOT be used as the primary support method without the use of load spreading devices, because of problems associated with stress build-up and crazing in service.

Similarly the panel must be fitted on the inside of a support post to ensure that any impact loads bear against metal supports and not fixing bolts. All bolt holes must be drilled oversize and contain Neoprene washers. Also a good quality Neoprene gasket should be used between 'Perspex'® and any metal.

12. ACRYLIC COMPATIBLE PRODUCTS

Only sealants and rubber profiles which are compatible with acrylic sheet should be used. Failure to do so may lead to premature failure and crazing of 'Perspex'®. Chemicals which have previously been shown to cause crazing of 'Perspex'® include silicone sealants containing glacial acetic acid, many methyl ethyl ketone (MEK) based sealant primers, plasticised pvc profiles and peroxide cured EPDM rubber. Advice on suitable glazing rubbers and sealants should always be sought from your supplier.

It is very important that ONLY acrylic compatible products be used for heavily tinted grades of acrylic. These grades can absorb very high levels of infra-red solar radiation giving sheet surface temperature in excess of 70°C despite air temperatures of no more than 30oC. Under these conditions failure of 'Perspex'® sheeting in contact with non-acrylic products may become a problem.

If 'Perspex'® has to be painted or exposed to vapours from paint or varnish in a confined space then it is very important that forced extraction is used to reduce the chances of the acrylic crazing. Also any paint splashes should be wiped off immediately.

Only screen printing inks that are acrylic based compatible with 'Perspex' ®acrylic sheet should he used. Other types of inks can cause crazing, if not immediately then in the long term; if any solvent is trapped the degree of adhesion can also be impaired.

When installing 'Perspex'® glazing panels it is essential to ensure that all ancillary products and materials used in contact with the sheet are fully compatible with acrylic. Failure to observe this may result in per in permanent damage to the 'Perspex'® glazing. For example, rubber sealing strips and profiles should be made from butyl rubber or polysulphide rubber. Certain EPDM rubbers can be used as alternatives, as can compatible silicone sealants, but in all cases it is important to seek the advice of the product supplier before use. Plasticised PVC sealing strips should not be used under any circumstances as these are known to cause stress crazing of acrylic sheets.

13. BUILDING REQUIREMENTS

Acceptable building practices vary from country to country and therefore it is outside the scope of this document to comment upon the requirements of a specific country. Architects should contact their local building regulatory authority at an early stage of design to ensure acceptability of design and products.

14. ACRYLIC FABRICATION

Full details concerning the fabrication of cast and extruded ‘Perspex’® are given the relevant workshop manuals and therefore this document will only highlight the most important features of acrylic fabrication

14.1 CUTTING

Most types of wood or metal working saws are suitable for cutting 'Perspex'® provided suitable blades are used. In general cutting speeds and blade types suitable for cutting soft metals (e.g. brass or aluminium) should be used. 'Perspex'® breaks in a brittle manner, and therefore standard wood-working blades should not be used to cut 'Perspex'®.

14.2 DRILLING

Twist drills are recommended for all normal drill working in 'Perspex'® (spring loaded centre punches are NOT recommended for use with acrylic sheet because of the risk of cracking or crazing 'Perspex'®). Due to the notch sensitivity of acrylic, if it is necessary to fix 'Perspex'® using screws or bolts, any holes must be elongated and oversize and also a load spreading bar or washers must be used.

DO NOT USE COUNTER SUNK SCREWS.

Solvents
Organic solvents are capable of causing a toxic hazard; therefore it is important that the precautions advised by manufacturers should be followed.

3. 'TENSOL'® 7
3.1 PHYSICAL PROPERTIES

DESCRIPTION: A two component glue consisting of 7A adhesive and 7B catalyst.

PROPERTIES: Viscosity: 130 – 150 seconds @ 25 ºC by Darwin Cup.

STORAGE: Should be stored in closed containers in a cool, dark room.

HAZARDS: It is flammable and its vapours are toxic. Flash point is 11, 5 ºC

3.2 MIXING RATIO OF THE COMPONENTS

Component A 96%

Component B 4%

3.3 SPECIFICATION

APPLICATIONS: In the natural form (colourless) as 'Perspex'® bonding adhesive for indoor and outdoor use.

APPEARANCE: Component A is a clear syrup, which may also be pigmented, free from visible impurities. Component B is a colourless to straw coloured solution.

SETTING TIME: The cement will set and harden after one hour of its application. After setting, the cement may take on a pale straw colour appearance and may deepen if exposed to sunlight.

VISCOSITY: Between 130 - 150 @ 25°C by Darwin Cup.

PACKAGING: Component A - 500gm amber glass bottles. Component B – 30gm plastic bottles. 12 x 500gm Component A and 12 x 30gm. Component B make up a carton of 'Tensol'® 7.

LABELING: Labels give information on product, handling and hazards.

SHE: The solvents used in manufacturing 'Tensol'® 7 are volatile and inflammable. It should be used in well ventilated areas and contact with skin or eyes should be avoided. In case of fire, smoke given off may be toxic - Carbon dioxide (C02) or dry powder fire extinguisher should be use

4. 'TENSOL'® 7A
4.1 PHYSICAL PROPERTIES

APPEARANCE: a clear colourless mobile syrup free from visible impurities and sediment or coloured for Bath Repair Kits.

DESCRIPTION: A solution of PMMA dissolved in monomer containing an initiator, stabiliser/antioxidant and UV absorber

STORAGE: Should be stored in closed containers in a cool, dark room.

HAZARDS: It is flammable and its vapours are toxic. Flash point is 11, 5 ºC.

4.2 SPECIFICATIONS
APPLICATIONS: 96% of component A is used in conjunction with the 4% of the catalyst (Component B) to form a 'Tensol'® cement.

APPEARANCE: The material is a homogeneous, colourless, viscous liquid free from visible impurities, foreign and suspended matter and sediment

VISCOSITY: At room temperature; 30s - 40s (falling ball test)

PACKAGING: 500g amber glass bottles

LABELING: Labels give information on product, handling and hazards.

SHE: The solvents used in manufacturing 'Tensol'® are volatile and inflammable. It should be used in well ventilated areas and contact with skin or eyes should be avoided. In case of fire, smoke given off may be toxic - Carbon dioxide (C02) or dry powder fire extinguisher should be used

5. 'TENSOL'® 7B
5.1 PHYSICAL PROPERTIES
DESCRIPTION: A clear, colourless to a pale straw coloured liquid.

STORAGE: As it is unstabilised, it should be stored in closed containers in a cool, dark room.

HAZARDS: It is flammable and because of its organic peroxide content, dangerous.

5.2 SPECIFICATION

APPLICATIONS: 4% of this component B is used as a catalyst with Component A to make a 'Tensol'® glue cement.

APPEARANCE: The material is a clear, colourless, to a straw coloured liquid free from visible impurities, foreign and suspended matter.

PACKAGING: 30g plastic bottles.

LABELING: Labels give information on product, handling and hazards.

SHE: The solvents used in manufacturing 'Tensol'® are volatile and inflammable. It should be used in well ventilated areas and contact with skin or eyes should be avoided. In case of fire, smoke given off may be toxic - Carbon dioxide (CO_2) or dry powder fire extinguisher should be used.

6. 'TENSOL'® 12
6.1 PHYSICAL PROPERTIES

APPEARANCE: Clear, colourless mobile syrup free of visible impurities/sediment, packed in 200gm, 500gm, or 5Kg tins

DESCRIPTION: A solution of polymer in solvents.

STORAGE: Should be stored in closed containers in a cool, dark room.

HAZARDS: Its vapours are toxic. Should be kept away from naked flames and direct heat

6.2 SPECIFICATION
APPLICATIONS: For bonding 'Perspex'® to 'Perspex'®, for indoor and outdoor use.

SETTING TIME: A joint may be handled after 3 hours of application of the glue.

VISCOSITY: +/- 40 seconds at 25°C (falling ball test).

LABELING: Labels give information on product, handling and hazards.

SHE: The solvents used in manufacturing 'Tensol'® are volatile and inflammable. It should be used in well ventilated areas and contact with skin or eyes should be avoided. In case of fire, smoke given off may be toxic - Carbon dioxide (CO_2) or dry powder fire extinguisher should be used.

7. 'TENSOL'® 30 & 17
7.1 PHYSICAL PROPERTIES

APPEARANCE: Clear, colourless liquid free of suspended solids and foreign matter.

DESCRIPTION: A solution that is applicable for the glueing of extruded acrylic sheet only; for indoor and outdoor use.

STORAGE: As it is unstabilised, it should be stored in closed containers in a cool, dark room.

HAZARDS: Vapours of dichloromethane/nitromethane are toxic. Material should be kept away from naked flames and direct heat.

7.2 SPECIFICATION
APPLICATIONS: For bonding of extruded acrylic sheet only.

SETTING TIME: 1 hour after application of the glue.

PACKAGING: 200gm or 500g tins.

LABELING: Labels give information on product, handling and hazards.

SHE: The solvents used in manufacturing Tensol are volatile and inflammable. It should be used in well ventilated areas and contact with skin or eyes should be avoided. In case of fire, smoke given off may be toxic - Carbon dioxide (CO_2) or dry powder fire extinguisher should be used.

8. 'TENSOL'® 2000
8.1 PHYSICAL PROPERTIES

APPEARANCE: A clear yellowish viscous liquid, (which becomes colourless on cure) free from visible impurities and sediment.

DESCRIPTION: A solution of PMMA in MMA monomer, containing a photo sensitive catalyst and U.V. stabilizer.

STORAGE: Store in a cool dark room.

HAZARDS: It is flammable and its vapours are toxic. Flash point is 11,5°C.

8.2 SPECIFICATION
APPLICATIONS: Single component adhesive for acrylic sheet, applied as is, and polymerised by specified light in the 400 nm band.

APPEARANCE: The material shall be homogeneous, yellowish, clear viscous liquid, free from visible impurities, foreign and suspended matter and sediment.

VISCOSITY: 150 sec +/-15 sec at 25°C using the "Darwin Cup".

REACTIVITY:
a) On exposure to the specified light, a 10 gm pool of 'Tensol'® 2000, on a polythene lid carrier, will photo bleach within approximately 8 mins and be substantially polymerised to handleability within 15 to 20 mins, with no residual tackiness, at an ambient of 20 – 25°C.

b) A lap joint made with 3 or 4 mm thick clear cast acrylic sheet and 'Tensol'® 2000 when exposed to the specified light shall photo bleach within 8 mins and cure to a strong tack free, handleable state, within 15 to 20 mins, at an ambient of 20-25°C. No boiling of the Tensol shall take place in either of the above tests.

PACKAGING: 500 gm tinplate screw top containers.

LABELING: Labels give information on product, handling and hazards.

SHE: The solvents used in manufacturing 'Tensol'® are volatile and inflammable. It should be used in well ventilated areas and contact with skin or eyes should be avoided. In case of fire, smoke given off may be toxic - Carbon dioxide (CO_2) or dry powder fire extinguisher should be used.

SPECIFIED LIGHT: This shall be a 125 watt miniflood fitting, using an OSRAM HQL (MBF-U) 125 watt lamp. The lamp shall be switched on not less than 5 mins prior to the test, in order to reach its full light intensity. The sample shall be placed immediately below the glass cover of the light fitting.

Cement should be used in a ventilated room and, as the vapour is heavier than air, fume extraction from the periphery of the work bench as well as from the floor level is important. Care should be taken to avoid contact with the skin and eyes.

9. PREPARATION OF CONTACT SURFACES

To ensure a good surface-to-surface bond, 'Perspex'® components should be degreased if necessary, using petroleum ether or white spirit, then thoroughly washed in clean hot water. Antistatic agents should not be used prior to cementing operations. The best bond strength is obtained if gloss surfaces have been lightly sanded or wiped with a cloth moistened with chloroform or ethylene dichloride.

9.1 STRESS-RELIEF

A fully satisfactory joint is only obtained if a stress-relief operation is carried out both before and after the cementing operation. The purpose of stress-relief before cementing is twofold. Firstly, it removes local stresses which may be present in as-cast 'Perspex'® or which may have been caused by prior machining or shaping, and secondly, it dries the material. Both these factors, but particularly the relief of stresses, contribute towards reducing the risk of subsequent crazing of the 'Perspex' around the cemented joint. The drying of the material makes it less likely that haze will develop. Annealing after cementing removes as much solvent as possible and relieves stresses set up by the polymerization process and by the clamping attachments. If possible, this final annealing operation should be carried out with the cemented parts assembled together to form the complete article, including any retaining metal frame, bolts, and so on. For successful stress relief an oven with good temperature control is required, and the best results are obtained when the temperature at any point within the heating enclosure does not vary by more than +/- 2°C. This requirement is most easily achieved with air circulation ovens.

9.2 MASKING

Solvent attack on the 'Perspex'® surface is an essential feature of bonding with 'Tensol'® cements and it is necessary to mask areas around the joint from such attack.

Commonly used methods of masking are:
(1) Self-adhesive tapes, low-tack adhesive being preferred.
(2) Aluminium foil fixed to the 'Perspex'® by means of soft soap.

Regardless of the method of masking, a pointed knife is used to cut through the excess cement before it is completely hard, thus facilitating removal of the masking material.

9.3 APPLICATION TO THE JOINT

It is an essential feature of an acrylic joint that there should be an adequate thickness of cement. For all but solvent joints, the cement film should never be less than 0.125 mm thick. The method of application of cement is mainly dependent upon its viscosity and to a lesser degree upon the type of joint being made. It is important to prevent a skin forming on the cement surface before the joint is complete. The following methods are recommended for the application of the various types of cement:

Dipping: for solvents only:
A pool of solvent is poured on to a glass plate or other flat surface. The machined edge of the 'Perspex'® is then held in the pool of solvent until it is uniformly soft throughout the joint area; this takes about one minute using chloroform. The 'Perspex'® is then removed, excess solvent is shaken off, and the edge is applied to the second 'Perspex'® surface. One end is applied first and the edge is gradually lowered, forcing air out in front of the advancing point of contact. The joint is then lightly clamped while solvent evaporates.
Dispensing: for solvents, 'Tensol'® 12, 17 and 30
After masking with self-adhesive tape, the edges to be cemented are brought together and held in a suitable jig as shown in Figure 1 so that these edges form a V-shape into which solvent or cement is dispensed. A suitable dispenser is a dropper fitted to a polyethylene bottle, such as that in which 'Tensol' 7 component B is supplied. Such a dispenser is shown in use in Figure 2. After being allowed to stand for about 30 seconds the V-shaped gap is firmly closed and the joint lightly clamped. Before the cement is completely hard, a pointed knife is used to cut through the excess, thus facilitating removal of the masking material.

Brushing: for 'Tensol'® 7
Where it is desirable to limit the amount of excess cement round the joint, this cement, which is fairly viscous, may be applied to the 'Perspex'® surfaces with a brush or spatula.

Figure 1: Dispensing

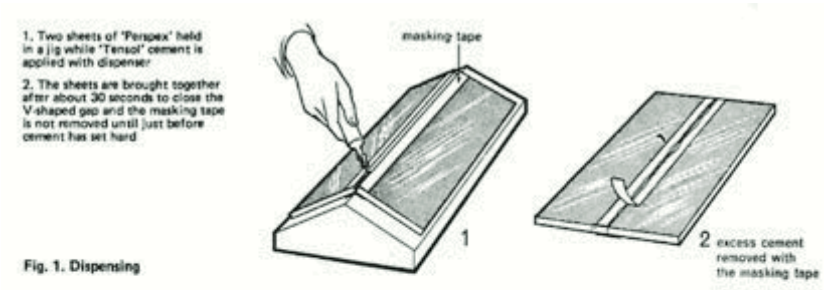


Fig. 1. Dispensing

Eliminating air bubbles
Air bubbles may mar both the strength and appearance of an acrylic joint. They can be avoided if care is taken not to shake the cement before application and by careful application to the joint. Bubbles can also occur because of incomplete wetting of the 'Perspex'® surfaces by the cement, as a result of the presence of grease or dirt, or where a machined 'Perspex'

surface retains small pockets of air. Wiping the surface with chloroform or methyl methacrylate monomer will help to eliminate both these difficulties. Air bubbles should not be confused with contraction voids.

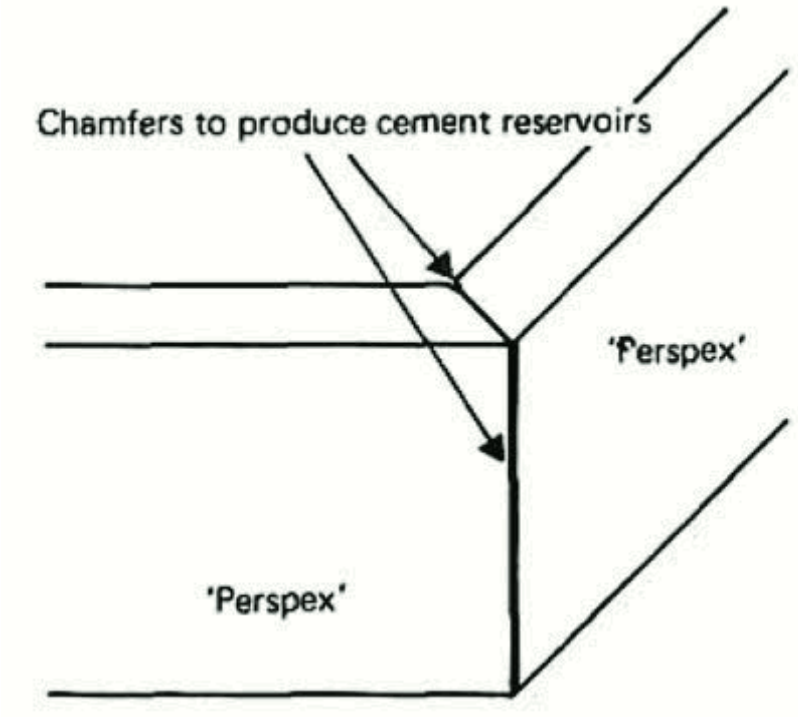
Eliminating contraction voids
Contraction of the cement occurs whether setting is by polymerisation or by evaporation of solvent. Polymerising cements contract much less and are therefore preferable to solvent cements. Contraction marks can be eliminated by the following techniques. Preferably, both should be employed.

1) The surfaces being joined must be held together throughout the setting process. The clamping should therefore be arranged so that pressure is maintained irrespective of contraction, and the contraction movement is allowed to take place. When making a joint, the two surfaces should be brought together gently to avoid forcing too much cement out of the joint. Clamping should be light and even; not exceeding about 18 gf/cm2 pressure.
Heavy pressure does not merely cause loss of cement but can result in crazing of the 'Perspex'® where it is highly stressed. Either spring13 loading or gravity-loading is to be recommended because this permits pressure to be maintained during the period the cement is setting and contracting. It should be noted that spring-loaded clothes pegs exert
localized high pressure and should only be used as clamps in conjunction with packing strips to spread the applied load.

2) Small cement 'reservoirs' should be provided at the edges of the joints to prevent air from being drawn into the joint as contraction takes place. Small chamfers, such as can be produced with a scraper, on the joint edges are usually adequate.

See **Figure 2**.

Figure 2: Mitre jointing



10. MAKING SPECIFIC JOINTS

10.1 LAMINATING

This operation is only satisfactorily carried out using cements of low viscosity such as 'Tensol'® 7. The essential point is to avoid trapping air bubbles between the two laminate. In small-area lamination this is achieved by pouring a small pool of cement on to the centre of one lamina, allowing air bubbles formed in the pouring to come to the surface and burst, and then lowering the second lamina slowly so that contact is first made at a single point. This forces the cement out sideways without occluding any air. For large-area lamination it is more convenient to pour a strip of cement along one edge and to lower the top sheet so that contact is first made along the whole edge and then a wave of cement forced across the lamination. This procedure is particularly successful when the upper sheet is thin enough to be flexible.

If air bubbles are trapped in a large-area lamination it may be possible to ease them to the edges before the cement sets by moving small weights about the surface of the laminate. This will result in cement being forced from the edges and a liberal quantity of cement must be used in order to allow for this.

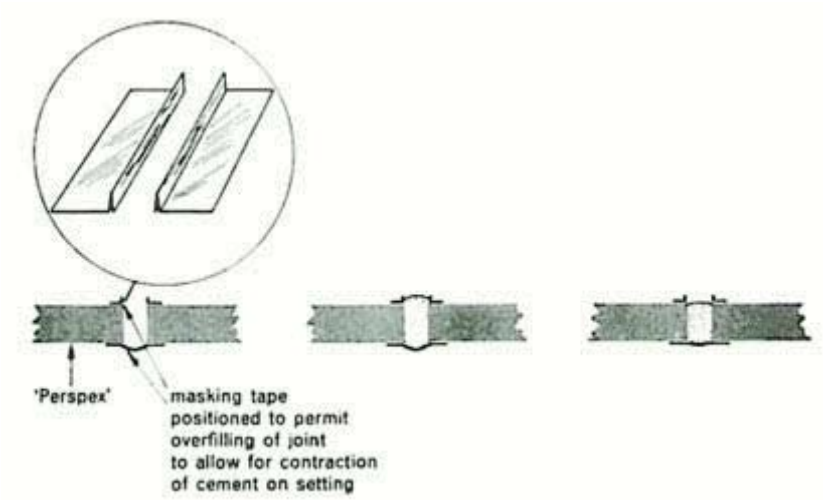
As a rough guide to quantities, approximately 1 kg/m2 should be used for small areas, but a higher proportion of cement is likely to be required for areas of several square feet. The lower sheet is best protected by masking near the edges with selfadhesive tape and by carrying out the whole operation on a sheet of polyethylene film, to which the cement does not adhere.

10.2 BUTT JOINTING

Machined or sawn edges of 'Perspex'® may be cemented together forming a bun joint. Some degree of roughness is desirable but too much prevents the cement wetting the 'Perspex'® completely. The adjacent areas are masked and the joint area is coated with cement. The two edges are then joined and held together until the cement sets.

If the edges to be joined form part of a larger assembly, or if they are irregularly machined so that large spaces need to be filled, the gap should be taped-over at the lower surface and the upper edges protected adjacent to the joint, as shown in Figure 3. The tape may usefully be built up above the surface of the 'Perspex'® to provide a reservoir of cement to allow for contraction of the cement on setting. Cement is then poured into the gap from a beaker or injected with a hypodermic syringe. The gap width needs to be large, of course, in order to admit cement. For example for 25 mm sheet, a gap of about 3 mm has been found necessary. Heavy sheets to be butt jointed in this way should be mounted so that they are free to follow the cement contraction; this may involve resting the work on rollers. With thick joints a subsequent machining operation is usually necessary if the appearance of the finished work is of great importance.

Figure 3: Butt Jointing



10.3 ANGLE (OR T-) JOINTING

The essential requirement in this operation is to ensure that sufficient cement is retained in the joint during the setting period. If a cement of low viscosity is being used, the edge to be in contact with the flat surface should be chamfered, as shown in **Figure 4** to provide an approximately 5° angle, and the cement then applied with a syringe. Because leverage may easily be applied to this type of joint, it is advisable to cement a 'Perspex'® fillet in position as shown. As an alternative, angle joints can be prepared as illustrated in **Figure 5**, using wire packing (withdrawn after application of the cement) to promote capillary attraction and ensure a sufficiently thick layer of cement.

Figure 4: Angle jointing using a cement of low viscosity

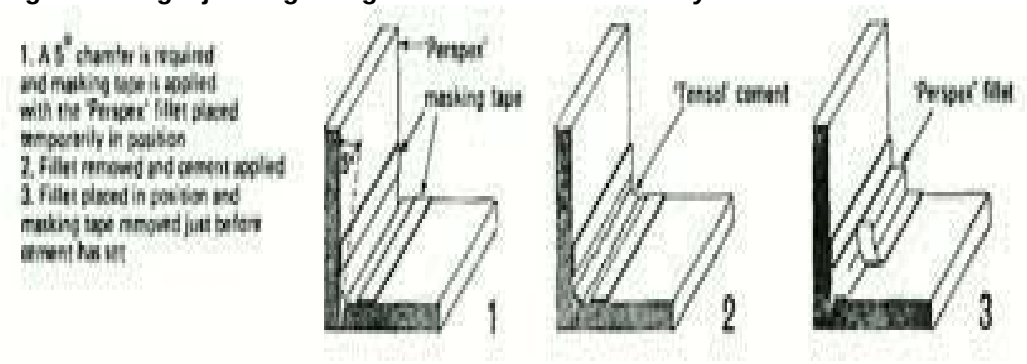


Figure 5: Angle jointing using a low viscosity cement with wire packing to promote capillary attraction and ensure a sufficiently thick cement layer.

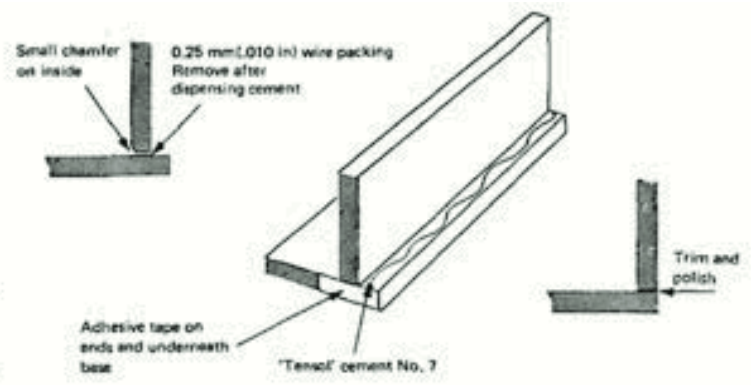


Fig. 9. Angle jointing using a low viscosity cement with wire packing to promote capillary attraction and ensure a sufficiently thick cement layer

10.4 COLOURING

'Tensol'® 7 is the only cement which can be satisfactorily coloured. It may be coloured by the use either of artists' oil colour or of pigments and dyes. Oil colours have the advantage that the colouring matter which they contain is already in a completely dispersed form, so that it is easy to disperse in the cement. On the other hand, it may not always be possible to produce exact matches to the 'Perspex'® colours by this method because the range available in oil colours is limited. If pigments are used, it is almost always possible to obtain a good colour match, but it is necessary to wet-out pigments with a minimum quantity of monomer or dibutyl phthalate prior to addition to the cement.

10.5 CARE OF EQUIPMENT

Benches may be protected from cement by polyethylene film, to which 'Tensol'® cements do not adhere. Cement may be removed from benches, containers or brushes by using solvents such as chloroform, trichorethylene, ethylene dichloride or acetone. Surplus cement should be poured out of the mixing vessel before it sets hard. It is most easily removed from open-top glass or ceramic containers by adding hot water and allowing to stand, whereupon the skin of cement will be loosened and may be removed in one piece.

11. JOINING 'PERSPEX'® TO OTHER MATERIALS

11.1 CEMENTING

Two problems have to be faced when cementing 'Perspex'® to other materials. The first is that the high order of bond strength obtained with 'Tensol' cements for bonding 'Perspex'® results from a controlled degree of solvent attack on the surfaces by the cement. Such attack obviously will not occur with other plastics, but the degree of attack is seldom within the range which permits a good bond to be formed. If the non-'Perspex'® material is porous, a good bond may be obtained by the penetration of cement into it. The second problem is that of the difference in coefficient of expansion between 'Perspex'® and most non-plastic materials, which can lead to the weakening of an inflexible bond if it is exposed to significant temperature changes. For instance. 'Perspex'® has a coefficient of expansion about 7 times that of steel. The cement film in such cases needs to be of such a type as to remain permanently flexible unless a constant temperature environment is anticipated for the component. These two problems may be overcome by the use of rubber-based adhesives or non-hardening, pressure-sensitive adhesives. Joints formed from these latter materials do not have the outdoor weathering properties of a 'Tensol'® cement joint, and have appreciably lower bond strength. Another method of obtaining a flexible joint between 'Perspex'® and other materials is to use an interlayer of rubber which can be bonded to 'Perspex'® with

‘Tensol’® cement as described in the section immediately following. The rubber may be bonded to other materials using an epoxy resin adhesive.

‘Perspex’® To Glass
The following method using plasticised ‘Tensol’® 7 may be employed to obtain a flexible joint between ‘Perspex’® and glass, but it is suitable for small indoor applications only. The glass is primed with a 5% solution of vinyl trichlorosilane in petroleum ether (boiling range 100/120°C) Dibutyl phthalate is mixed with component A of ‘Tensol’® 7 (in the proportions 1:3 by volume) before addition of component B. The ‘Perspex’® and glass surfaces may then be cemented together as for a ‘Perspex’® to ‘Perspex’® joint.

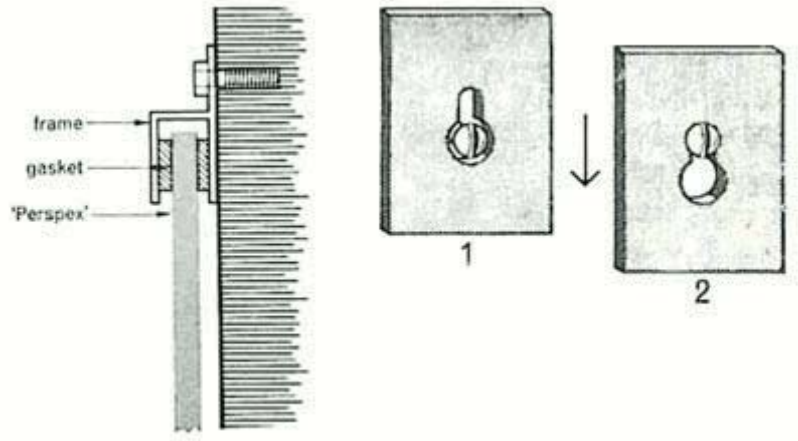
‘Perspex’® To Wood
The technique to be used depends on the nature of the wood. If it has an open grain, into which cement penetrates, 'Tensol'® 7 may be used successfully. With a smooth, close grained wood which will not allow penetration, a rubber-based adhesive will be more successful.

11.2 MECHANICAL FIXING
When attaching 'Perspex'® to other materials by mechanical means, allowance must be made, as in cementing, for differences in expansion coefficients. Some of the methods which are suitable are described below.

Bolting
When it is necessary to fix bolts through 'Perspex'®, the holes should be drilled oversize and the edges radiused and polished, because 'Perspex'® is notch-sensitive, and any minute cracks which originate at the hole could be propagated a large distance across the sheet. A flexible grommet should be inserted in the oversize hole to accommodate the bolt. This method is not recommended for structures loaded beyond 7 kgf/cm2. An expansion allowance of 5mm per metre is recommended for external applications or where large differentials in temperature are likely to be encountered.

Framing
For thick and heavy sheets of ‘Perspex’®, the material may be fixed, as shown in Figure 9, in a suitable channel section frame, usually of metal, which is bolted to the main structure. The edges of the ‘Perspex’® should be smooth and polished, and the sheet is held in position by a flexible gasket of appropriate cross-section, which takes up any expansion.

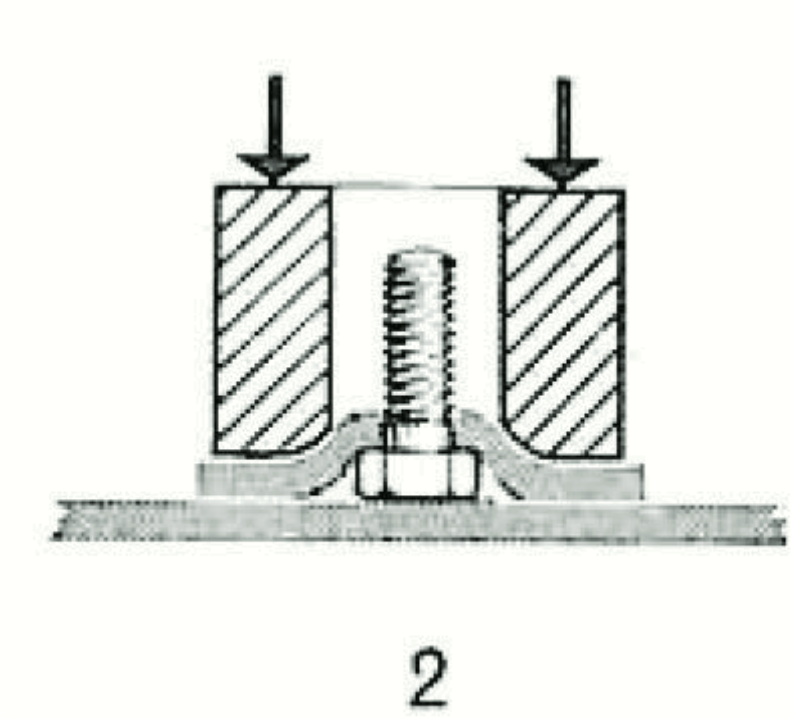
Figure 6: Framing



Keyhole Slotting

Another method of mechanical fixing which is useful for light-weight components, such as flat-backed ‘Perspex’® letters produced by the sign industry, is to cement the back of the component to a ‘Perspex’® block, into which has been routed a keyhole slot, as shown in **Figure 10**, so that the assembly may be slid on to a bolt or screw affixed to the main structure.

Figure 7: Keyhole slotting (far right)

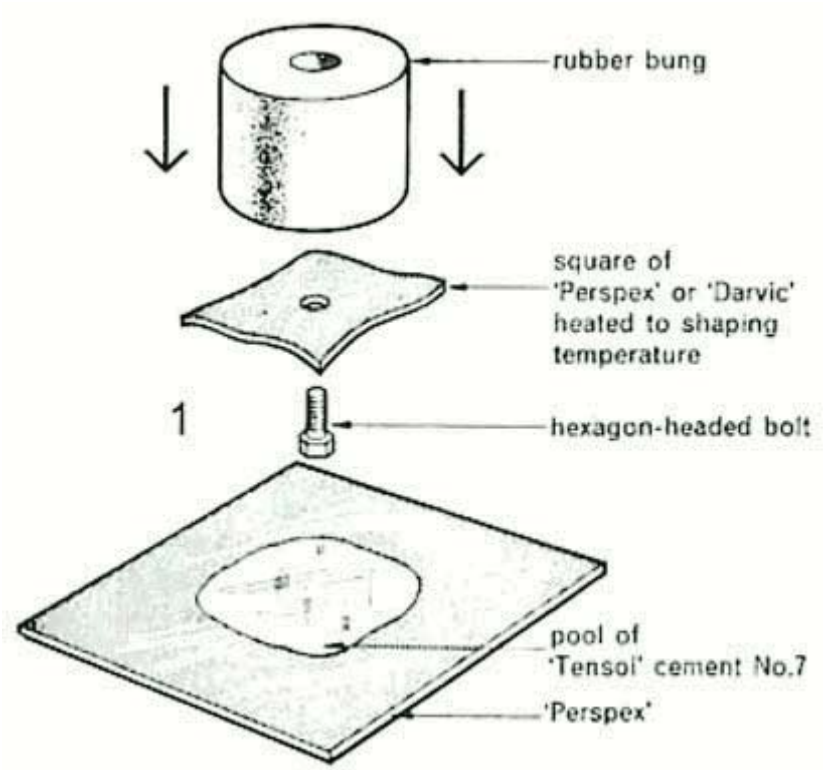


2

Cementing Fixtures To ‘Perspex’®

In some instances it is desirable to attach fixtures such as metal bolts, spring clips, press-studs to one side of a ‘Perspex’® sheet or to a shaped article, without having to drill holes through the ‘Perspex’®. This can be done in the manner indicated in Figure 12. A square piece of 'Perspex'® 3 mm thick and about 38 mm square, is drilled oversize to take a bolt, and is heated to shaping temperature 150 -170°C ‘Tensol’® 7 is applied to the article where it is intended to fix the bolt. When at shaping temperature, the square piece of ‘Perspex’® is removed from the oven and a hexagon-headed bolt pushed through it. This assembly is then applied to the cement so that the bolt-head is sandwiched between the two pieces of ‘Perspex’®. Light pressure is applied with a suitably bored-out rubber bung for about 30 seconds, and the joint may be handled after about one hour.

Figure 8: Cementing fixtures to ‘Perspex’®



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