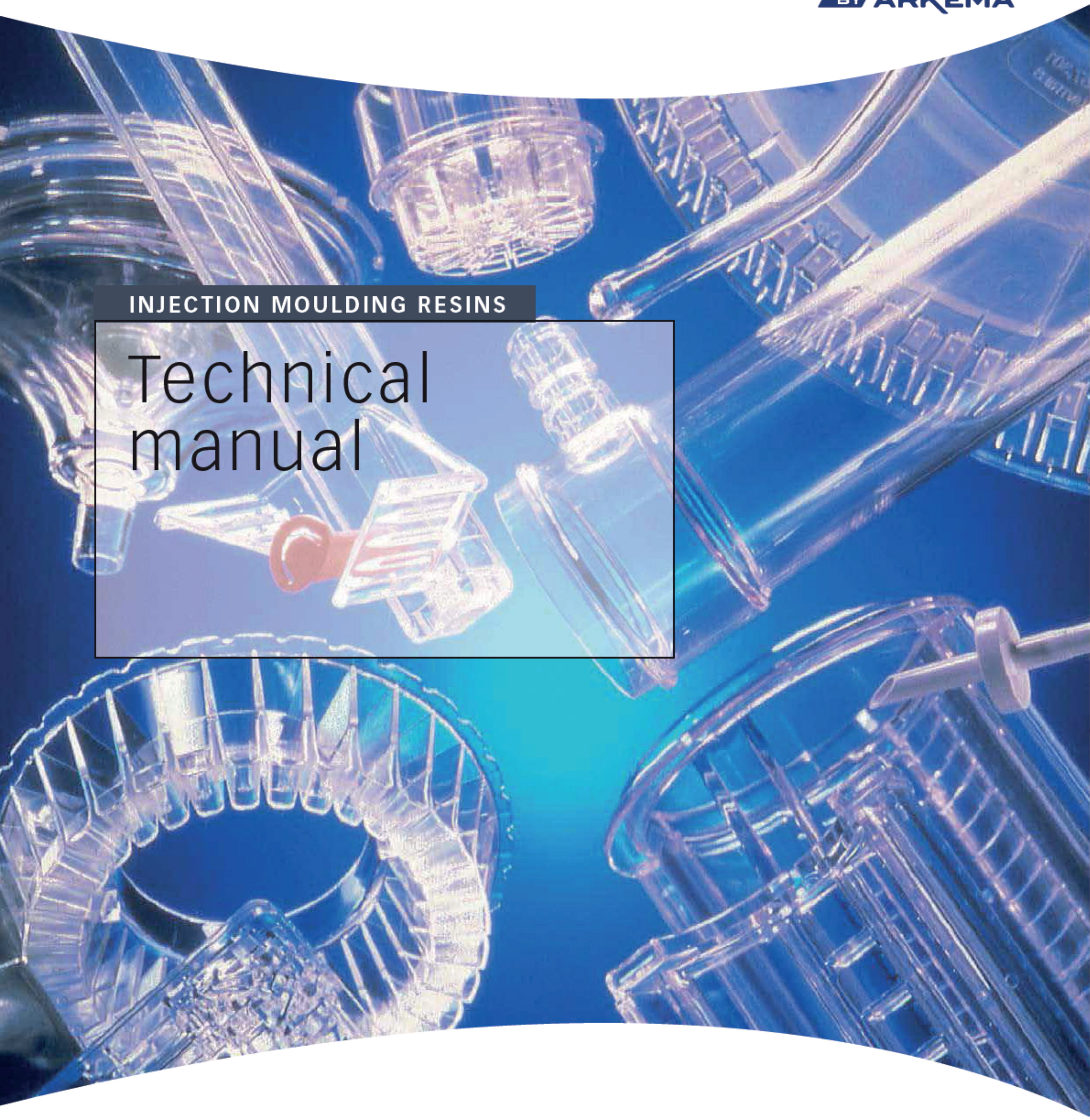
INJECTION MOULDING RESINS

Technical manual



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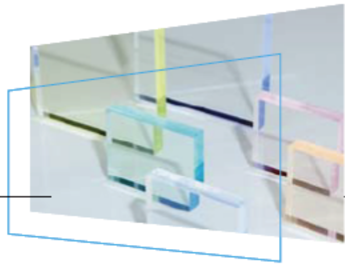
Introduction



ALTUGLAS®

Altuglas® is the registered trade name for Altuglas International products made of polymethyl-methacrylate (PMMA) in the form of granules for injection moulding and extrusion.

GENERAL CHARACTERISTICS OF ALTUGLAS®

Altuglas® resins offer high thermal stability, excellent transparency and a hard surface which protects their brilliance and impacts high resistance to abrasion.

Most Altuglas® products are rated HB according the UL94 standard. Among the many desirable properties of Altuglas® acrylic resins, two are pre-eminent:

Unsurpassed durability indoors and outdoors
Superlative optical properties and clarity

Most applications of Altuglas® acrylic resin take advantage of one or both of these outstanding properties. For example, Altuglas® resin is the material of choice for moulding signal light lenses for automotive, aircraft and marine applications because of its superb optical quality as a light transmitting medium and its proven ability to endure many years of continuous outdoor exposure with little or no change colour or appearance.

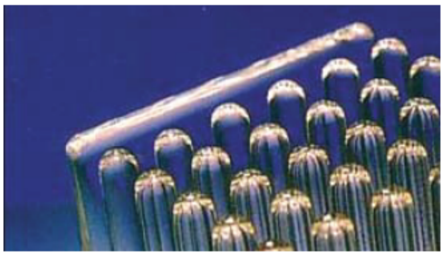
Other applications which demand the ultimate in weather resistance provided by Altuglas® resin are outdoor lighting lenses and shields and moulded letters or extruded sheets for internally illuminated signs.

In addition to unsurpassed resistance to sunlight, Altuglas® acrylic resin is unaffected by long-term exposure to fluorescent light, and it is the material most commonly specified by lighting engineers and architects for lighting applications. Colourless Altuglas® acrylic lighting fixture lenses are widely available either as injection moulded parts or extrusion with prismatic patterns: also diffusers are extruded from white translucent Altuglas® resin. Fluorescent fixtures with Altuglas® acrylic lenses can be operated continuously for many years without significant yellowing or measurable effect on the physical properties. Parts moulded of Altuglas® moulding resins are strong, light in weight and dimensionally stable.

Altuglas® acrylic resin has excellent resistance to many chemical agents including solutions of inorganic acids, alkalis and aliphatic hydrocarbons. Altuglas® acrylic resin is virtually unaffected by a wide range of commercial products including many detergent solutions and cleaners, beverages and foodstuffs. It is not recommended for use with chlorinated and aromatic hydrocarbons, esters or ketones. The chemical resistance of Altuglas® is summarized in table 5.

Altuglas® acrylic resin is a rigid plastic with good strength properties. Although the resistance of Altuglas® resin to sudden impact is lower than that of some plastics, it is several times greater than that of glass. If your design requires even greater impact strength ask us about the family of Altuglas® impact - modified acrylic resins.

Properties like excellent clarity, good chemical resistance and high rigidity, as well as the availability of UV transmitting resins, enable Altuglas® acrylic moulding resins to be used through out the medical industry.



THE RANGE

Altuglas® moulding resins are available in a complete range of transparent, translucent and opaque colours as well as in colourless form.

- Two series of injection moulding and extrusion grades
- A wide range of grades offering high impact strength combined with normal or easy flow.
- Formulations which guarantee the best possible mould release.
- Special formulations to filter or transmit UV
- Special formulations capable of being gamma sterilized

Introduction

- Special grades for food industry applications
- Colours which meet AAMVA requirements.

Parts moulded of Altuglas® moulding resins may be decorated easily by any of variety of methods including painting, silk screening, hot stamping, vacuum metallization, selective chrome plating and laser.

APPLICATIONS

Altuglas® resins are used in many sector's for example:

Transport and automotive industry:
Lights, deflectors, instrument panels, number plates, reflectors, traffic lights, marine lights, etc.

Building and construction industry:
Extruded panels for building, glazing, protection and greenhouses, or co-extruded over ABS and PVC panels for caravans, window frames etc.

Lighting:
Light filters, globes, diffusers, etc.

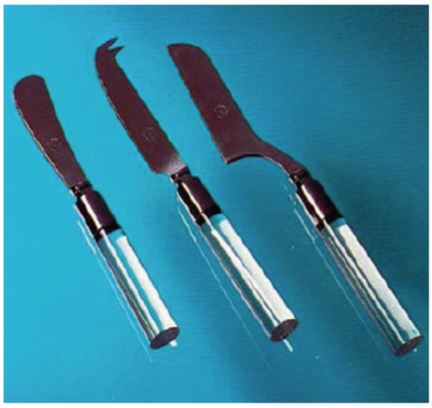
Household appliances and domestic equipment:
Dishes, salad bowls, glasses, bathroom fittings, etc.

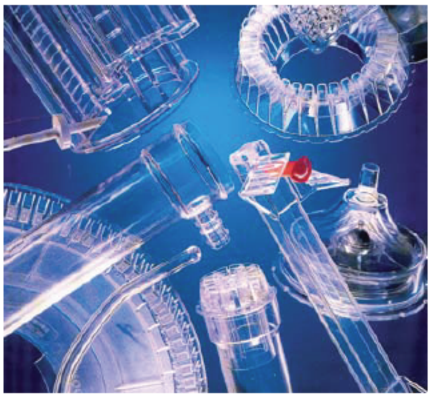
Medical:
In vitro diagnostics, e.g. blood cuvettes

Electronics:
Cellular phone lenses

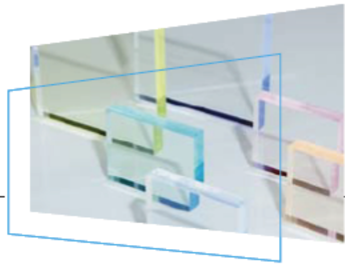
To this list may be added many special applications such as lenses, shoe heels, furniture, display cases, jewellery, etc.

This manual contains a summary of the physical, chemical and weathering properties of the Altuglas® V series, standard grades, and the Altuglas® High Impact grade moulding resins, as well as listing of the wide variety of applications that each of the grades is best suited for. The latter part of the manual provides details on mould design and for handling, processing (including troubleshooting) and post moulding operations.





Product features



PRODUCT FEATURES

Altuglas® acrylic resins are differentiated by two primary characteristics: processability and heat resistance. Individual grades have been formulated with varying trade-offs on these characteristics to provide the best property balance for specific application needs. All Altuglas® acrylic resins possess the following features:

UNSURPASSED OPTICAL CLARITY
PROVEN OUTDOOR WEATHERABILITY
HIGH TENSILE STRENGTH AND STIFFNESS
EXCELLENT SURFACE HARDNESS

PROCESSABILITY

The processing characteristics of a material are a function of its formulation and the processing conditions employed. Melt flow rate is a measurement of a materials flow characteristics under a set of standardized test conditions and is often used as a comparative measurement of material viscosity. Refer to the spiral flow data on page 8 for a more thorough comparison of flow characteristics under varying temperature, shear and thickness conditions.

HEAT RESISTANCE

The heat resistance of Altuglas® acrylic resin varies by grade and is a function of part stress. Generally, heat resistance is gained at the expense of processability. Vicat softening point is a thermal property used to estimate the ability of a material to perform at elevated temperatures. Values shown in fig.2a/b provide an indication of the effect of part stress on heat resistance. Actual service temperature will depend on the level of stress moulded - in and applied within the part. Maximum service temperature is obtained through good design and low stress moulding conditions.

WEATHERABILITY

Altuglas® acrylic resins remain virtually unchanged after long term outdoor exposure.

Figure 1a: MFR Altuglas® standard grades

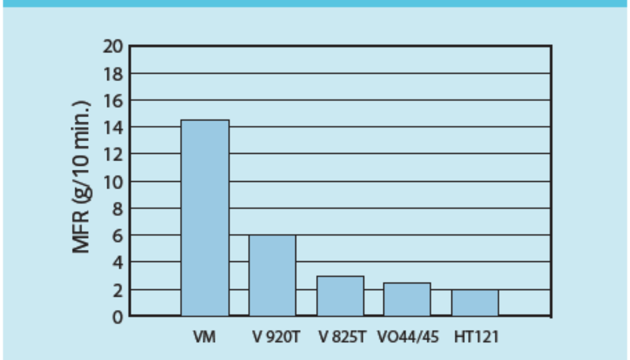


Figure 1b: MFR Altuglas® high impact grades

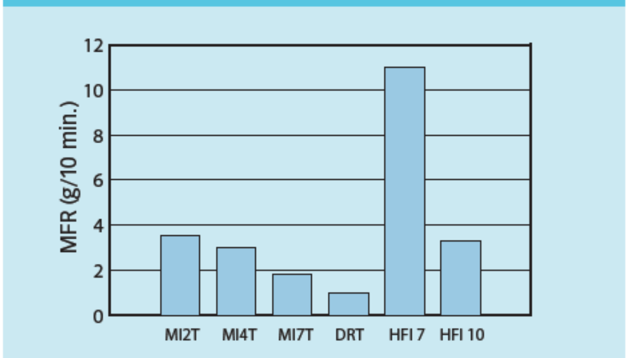


Figure 2a: Thermal properties Altuglas® standard grades

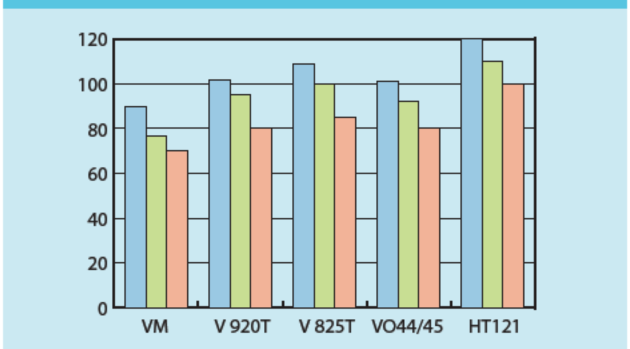
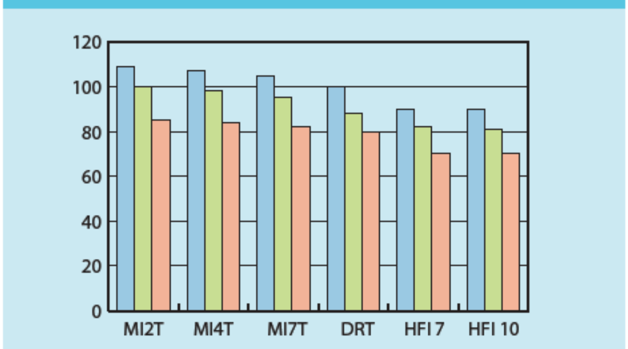


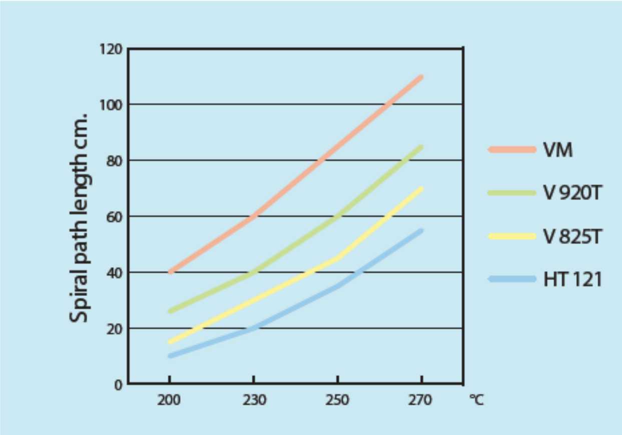
Figure 2b: Thermal properties Altuglas® high impact grades

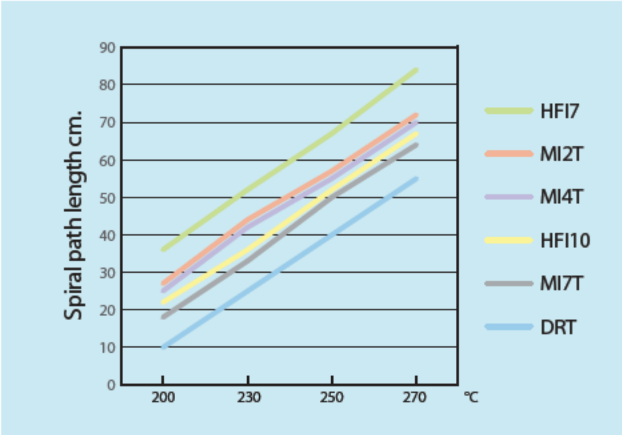


KEY: VICAT 50N HDT 1.82MPa MAX USE TEMPERATURE

Product features

FLOWABILITY VS. TEMPERATURE

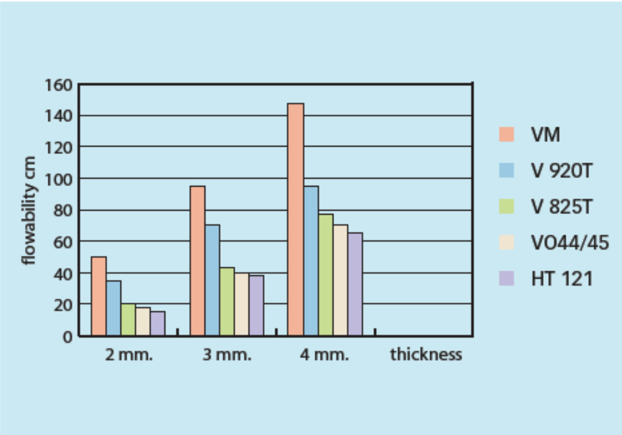


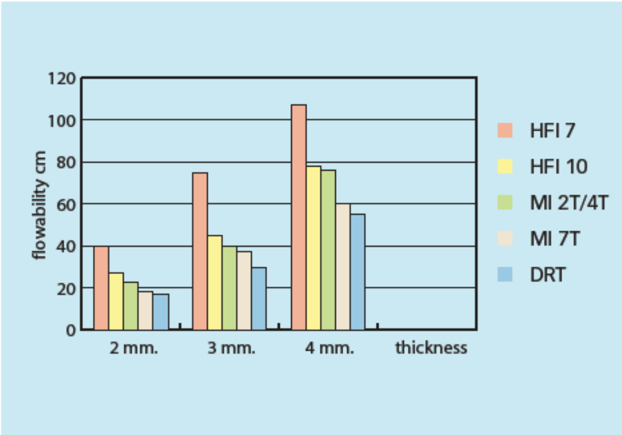


Injection molding operative conditions:

melt temperature: see table - mould temperature: 75° C - pressure: 1800 bar injection speed 40 mm/ sec
cushion 5 mm - mould: Archimedes spiral

FLOWABILITY VS. THICKNESS

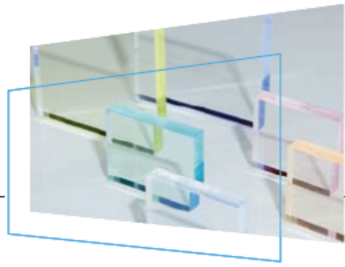




Injection moulding operative conditions:

melt temperature: 240° C - mould temperature: 75° C -pressure: 1800 bar - injection speed 40 mm/ sec
cushion 5 mm - mould: Archimedes flat spiral - spiral wide 40 mm - Gate dimension 10 mm x 2-3-4 mm.

Equipment & mould design



THE KEY TO QUALITY

Altuglas® granules can be used on any conventional injection moulding machine. Due to their outstanding combination of properties and very wide processing range moulded Altuglas® parts are used for a multitude of applications. The properties of injection moulded components depend heavily on the conditions under which the material is processed. The shape of the mould also has a certain, though less significant, effect on the final properties of the moulded part.

The interaction between various parameters as shown below. This handbook give general recommendations on the use of the material and mould design.

For any further information, do not hesitate to consult our commercial and technical service.

EQUIPMENT CONSIDERATIONS

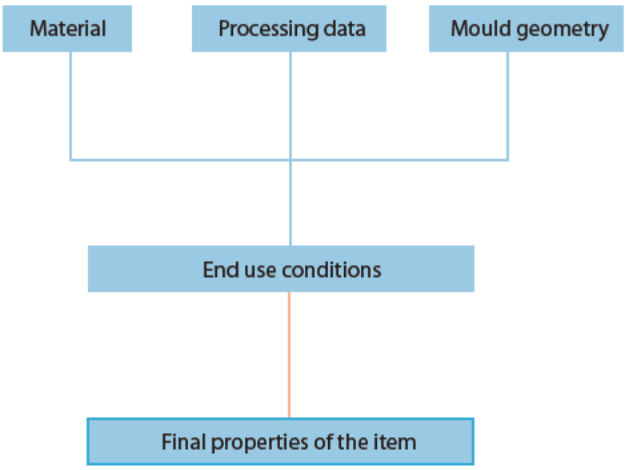
Clamp tonnage recommendation

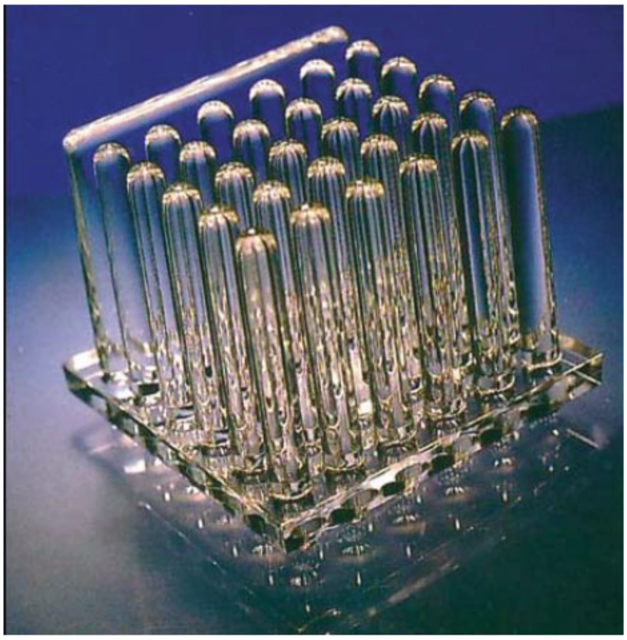
Altuglas® experience has shown that for every cm2 of projected surface area of the item there should be 0.3 / 0.4 tons of clamp on the moulding machine being used. The projected area of the item may be defined as the item area seen by the plastic entering.

Less clamp tonnage will tend to produce flashed parts. More tonnage will not hurt and may be necessary for thin – walled items (< 2 mm) or other difficult to fill items where high injection pressures are used.

As with other thermoplastic polymers it is necessary to take into consideration a correct shot size of the machine versus item weight, generally the value employed is 50 –70% to have a good compromise of clamping force, item weight and residence time of the molten into cylinder.

Interaction of major parameters which affect quality





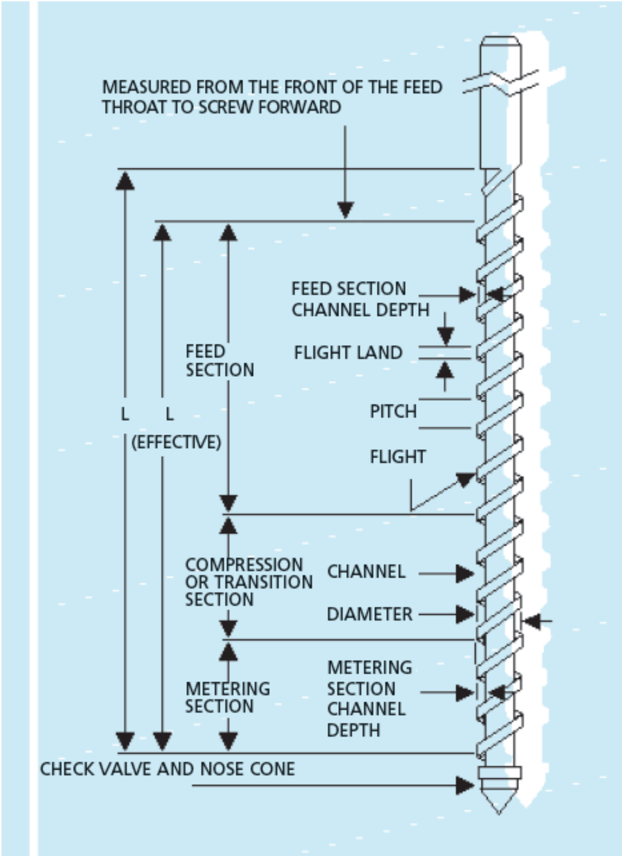
Equipment & mould design

SCREW DESIGN

Altuglas® can be moulded satisfactorily in reciprocating screw moulding machines for nearly all applications using general purpose screws for thermoplastics.
The screw has three basic parts: the tip, the non-return valve and helical screw. The function of the non-return valve is to prevent the plastic from flowing backward when the screw is used to inject the material into the mould. The recommended non-return valve for acrylics is the ring type.

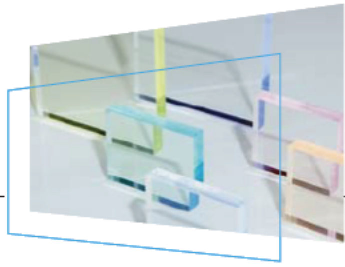
Typical screw nomenclature is shown below for a non vented barrel, the feed sections length is considerably longer than that of the transition and metering sections. For most machines up to 450 tons in size the manufacture's so called general purpose screw is suitable for acrylics. These screw typically have a L/D ratio of 18-24 to 1 with compression ratio of 2.3 to 3.0 and a square pitch helix angle of 17.6°.

Suggested screws design for various size machines are listed in the following table, for large machines, in addition to using a square pitch screw with proper compression ratio, the number of turns into the transition zone need to be fewer than used for other thermoplastic to facilitate the melting of the acrylic.
When comparing various screws, be sure that the Length/Diameter ratio of the different screws are based on the same definition of the length. Compression ratio is the ratio of the volume of first turn past feeding zone / volume of the last turn at the end output.



Normal Diameter mm turns	Feed Section Depth, mm	Length, turns	Transition Length, turns	Metering Section Depth, mm	Length,
40	7	11	4	2.6	5
50	7.5	11	4	2.8	5
70	8	11.5	3.5	3	5
90	10	11.5	3.5	3.5	5
150	13	12	3	5	5
170	16	12	3	6	5

Equipment & mould design



MOULD DESIGN INTRODUCTION

For best results and maximum melt fluidity during mould filling designers need to take the following considerations into account: The design of sprues and runners to transfer the melt from the nozzle to the mould cavity should aim at retention of required melt temperature and consistent pressure. Techniques involve adequate sprue diameter, the need to minimize their length, either as an inherent design feature or by providing extended nozzle and externally heated sprue bushings.

A runner shaped approximating as close as possible to being round is preferred. The design may also incorporate restrictions for melt pressure correction and the raising of temperatures.

Alternatively, melt heat may be controlled by heated runners with the attendant advantages of reduced scraps.

Appropriate shape of the gate transition points from runner to mould cavity will vary according to the characteristics of mould shapes.

Finally it is important that the correct mould temperature is controlled by sufficient coring and venting of the mould.

FEED AND RUNNER SYSTEM

The feed system for a multicavity mould generally includes a sprue, a primary runner, two or more secondary runners and an injection gate to feed each cavity.

SPRUES

In a typical two cavity, two-plate mould, melt is injected through the nozzle, sprue and runner into cavities. When the mould is opened the sprue pulls out of the sprue bush, parting at the hot nozzle where the material is still fluid. For Altuglas® the optimum sprue bush diameter at the nozzle is 7 mm for most moulds when used with a 6 mm orifice free-flow nozzle. Moulding a deep part with a long sprue bush may require long cycles to permit the sprue and sprue puller to harden enough to hold together when the mould is opened. Long cycles may be avoided by using an extended nozzle that penetrates the mould and seats on a short sprue bush approximately 12 to 25 mm. The minimum diameter of such short sprue bushes may be as little as 6 mm. Extended nozzles and short sprue bushes will reduce cycle time, increase pressure in the mould and result in less scraps.

The size of sprue will vary with the thickness and shape of the moulded part.

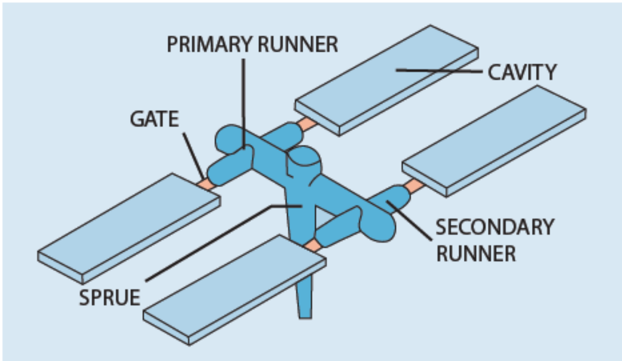
As a general rule, the sprue bush diameter will exceed that of the machine nozzle

Machine nozzle diameter ....4.0 mm to 7.5 mm

Sprue bush diameter ....4.4 mm to 8.5 mm

Part thickness ....2-4 mm 4-6 mm

Sprue bushes should be tapered at an angle between 5-7° to allow for easy extraction of unwanted solidifying material.



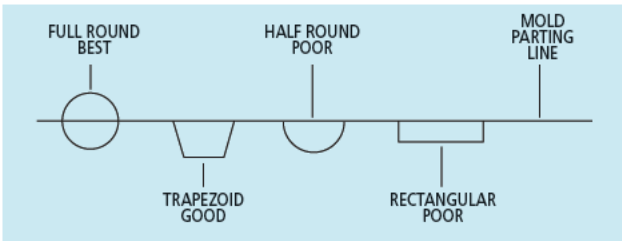
RUNNERS

Runners distribute the molten material from the sprue to the cavities. They should cause minimum cooling and resistance to flow. To do this, the runner should combine maximum cross section with a minimum surface area and should be as short as possible.

A full round runner meets these requirement better than any other shape but is more difficult to machine because both sides of the mould must be cut individually and then the half round in each section must mate when the mould is closed.

The trapezoidal runner is the next best since it approaches the full round in one side of the mould.

Half round or shallow rectangular runners are not desirable because of their high surface to volume ratio and restricted flow area.



Equipment & mould design

GATES

Experience has shown that full round runner of the following diameter gives good performance:

– Runner less than 125 mm long: ....6 mm diameter

– Runners more than 125 mm,
but less 200 mm long: ....7.5 - 8.0 mm diameter

– Runner more than 200 mm: ....9 -10 mm diameter

It is important to avoid sharp bends or sudden changes in direction and also to use as short a path as possible.

This will ensure greater flexibility in filling the cavity and produces parts with a good visual finish and high performances.

Runner dimensions depend of the shape and number of the cavities.

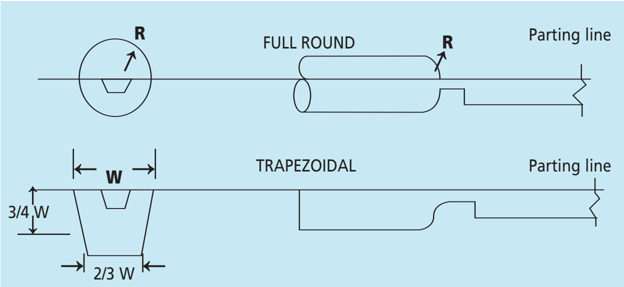
In general the primary runner should be 3.5 to 5 mm in diameter for parts 2 to 4 mm thick.

For thicker parts the primary runner diameter should be 7 to 15 mm.

The diameter of secondary runner is 1-2 mm less than that of the primary runner

GATES

Gates size, shape and placement affect the flow pattern of the material entering the mould and may influence the temperature, fill time and overall part quality. In parts of variable cross section the gate should be located in the thickest section to minimize fill problems. Parts are usually weakest in the region near the gate, therefore, an unstressed area should be considered for the location of the gate. Gate transition from full round and trapezoidal runner is shown in the following figure.

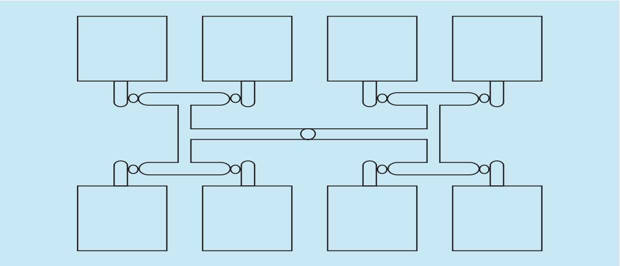


The round runner terminates in a spherical shape which traps cool material at the outside while passing hot material at the center of the runner.
Runners of trapezoidal or other shapes cut into the cavity because of the symmetrical transition shape.
A streamlined transition section minimizes this tendency.

GATES - RUNNERS LAYOUT

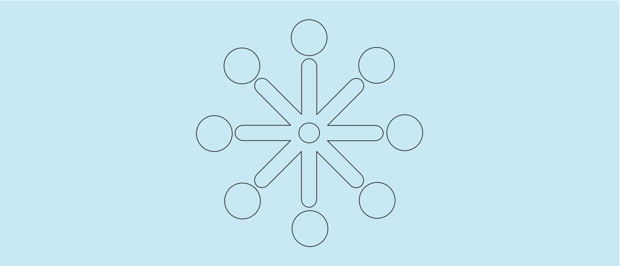
For best results, all cavities must fill uniformly, continuously and simultaneously.

The balanced H runner uses the same runner length from the sprue to each cavity and contains the same number of equivalent turns and identical gates to help ensure uniform moulding conditions in each cavity.



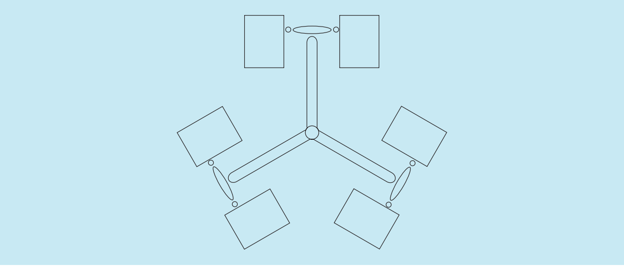
The balanced runner system requires slightly more material for each shot than an unbalanced runner system but this is off set by improved yields of good parts. This system can be used to fill 4 – 8 – 16 – 32 cavities only.

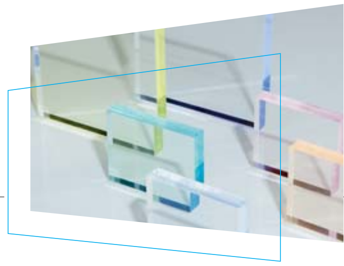
Should a different number of cavities be desired the spoke runner system can be used to provide a balanced layout.

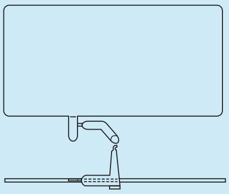
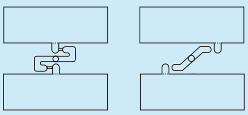
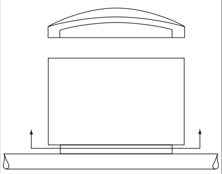
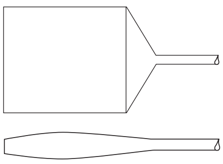
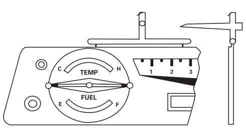
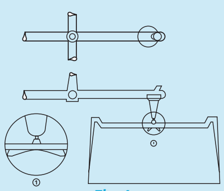


As with the balanced H runner layout the spoke runner layout uses the same runner length from the sprue to each cavity.

A modified spoke gate layout can be used to meet specific mould design.

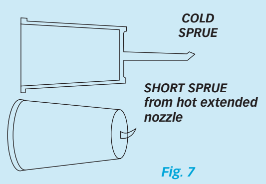
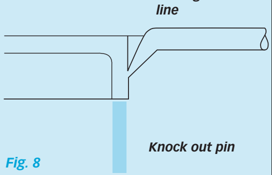
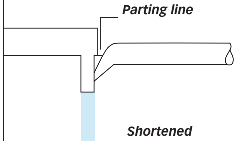
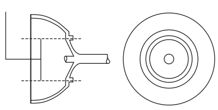
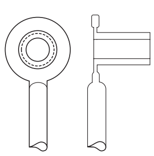
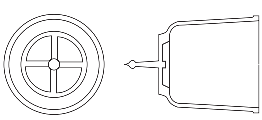




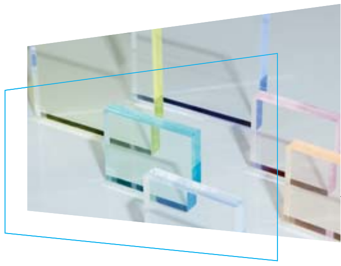
TYPE OF GATE	SPECIFICATIONS	APPLICATIONS/REMARKS
Single cavity - TAB gate  *Fig. 1* *Multi-cavity - TAB gate*  *Fig. 2*	Minimum tab size: 6.5 mm Wide by three-quarters of the item thickness Gate depth: 80 % of tab thickness Land length max: 1.6 mm.	Recommended for relatively flat thin parts
Thick section - EDGE gate  *Fig. 3*	For thick parts: gate thickness may be the same as or greater than the runner thickness. For thin parts: a runner restriction may be necessary	Suitable for thick as well as thin parts. Permits keeping melt under pressure longer during cooling.
Thick section - FAN gate  *Fig. 4*	Smooth transition from runner to part. Gate should be at least 80 % of part thickness.	For thin dials with an uninterrupted straight edge.
FLASH gate for flat dials  *Fig. 5*	Gate should be 0.8 to 1.6 mm thick, no more than one-quarter the length of the part. Maximum land length is 1.6 mm.	For thin dials with an uninterrupted straight edge.
CENTRE gate - three plate mould  *Fig. 6*	Maximum diameter is 2.0 mm. Maximum land length is 1.6 mm.	Recommended for deep circular parts such as bowls, cup.

Equipment & mould design

GATES

TYPE OF GATE	SPECIFICATIONS	APPLICATIONS/REMARKS
SPRUE gate  Fig. 7	COLD SPRUE: diameter 9 mm for a long sprue. SPRUE-SHORT: from 13 to 25 mm long diameter 5 mm. SPRUE-HOT: Diameter: 2.5 mm.	Use when it is possible to run the sprue directly into the mould (leaves de-gating scar). Hot sprue bushing eliminates all but a very small de-gating scar.
SUBMARINE gate  Fig. 8	Gate 0.8 - 2.0 mm.	Part de-gate automatically when the mould opens.
SUBMARINE - plug gate  Fig. 9	Plug diameter approximately. Equal to the wall thick of the part. Diameter of approx. 3 mm is adequate (knockout pin cut-off). Gate: 0.8 mm to 2 mm. Note: larger plugs will cause sinks while.	Part de-gate automatically when the mould opens, leaving the plug to be removed from the part.
DIAPHRAGM gate  Fig. 10	Diaphragm thickness may vary from 3.0 to 5.0 mm.	For cylindrical shapes or parts requiring a large cut-out.
RING gate  Fig. 11	3.0 to 5.0 mm diameter ring with short land of 0.8 to 1.6 mm thickness.	For hollow cylindrical parts such as tubes, pen barrels, etc.
SPOKE gafe  Fig. 12	Gate dimensions can vary from very large to pin-point depending on whether the material flows directly into an open area or impinges on the mould.	Same application as diaphragm gate: produces less scrap.

Equipment & mould design



HOT RUNNERS SYSTEM

Acrylic polymers are also injected through heated runners, particularly for mass production such as in the automotive, household appliance, lighting industries, etc.

The main advantages of this technique is:
The polymer in the feed runners is not wasted and shrinkage is minimized.

The flow paths are shorter, the filling process is easier to control and the pressure drops, the volume of polymer injected and the cycle times are all reduced.

However, the technique can also have some disadvantages:
• Changing of the colour takes longer and is more difficult.

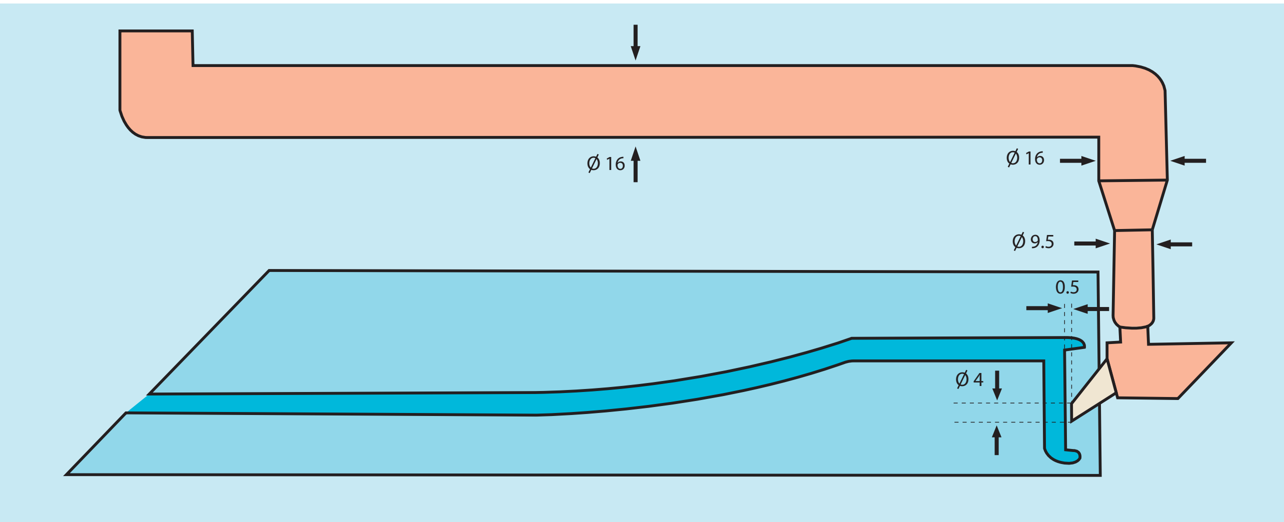
• It requires greater care and skill in handling the tooling.

• Problems frequently found on mould release include: Streaks resulting from the decomposition of the polymer due to the high shear stresses generated in narrow sections of the feed system linked to the system geometry and material parameters (temperature and injection speed).

• Weld lines which occur if the molten polymer is not homogeneous or if the temperature is too low.

When the finish and appearance are of particular importance, a torpedo, with no supporting bracing, must be mounted directly on the block to prevent seams forming.

For intensive production, it is recommended to use external heating but not a torpedo heater system. Although this type of injection system leaves larger marks on the part, it minimises the pressure drop during moulding. To manufacture large parts with side gates use hot runner diameters greater than 12.5 mm.



Equipment & mould design

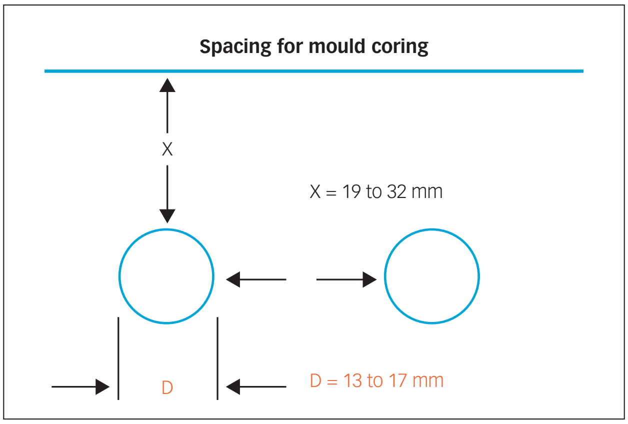
THE CAVITY

Introduction

When calculating the cavity dimension it is important to allow for polymer shrinkage during moulding.

The position and shape of the cooling channels depend on the part being moulded and must always ensure complete filling. Mould's are cored for the circulation of a liquid usually oil, to provide adequate control of cavity temperature. Good mould temperature control is important for uniform cooling of the part and it helps minimize stresses and shorten the moulding cycle. Good mould temperature control is achieved if the mould surface returns to the same temperature at the beginning of each cycle and the temperature differentials across the cavity surface served by cooling are at the minimum.

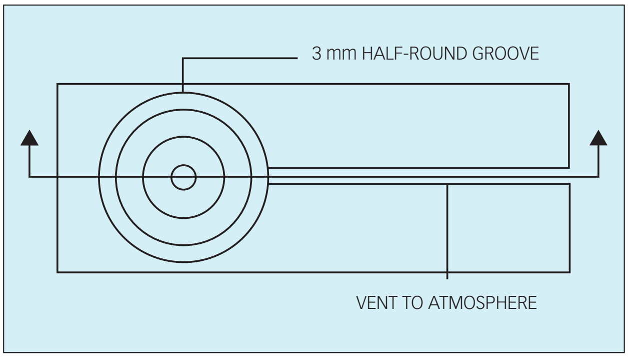
Generally cooling should be located as following figure.

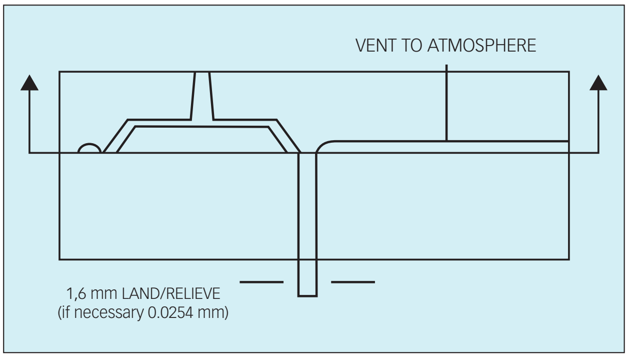


Venting

As the mould fills, the hot plastic displaces the air in the cavities. Many moulds have adequate clearance around the knock out pins and at the parting line to serve as a vent.

However, if voids or burned areas are encountered in the part, adequate clearance for venting must be provided.

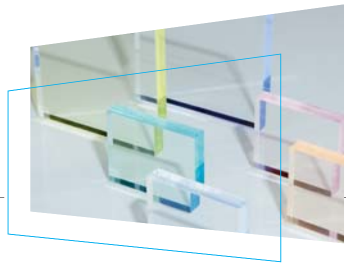




The continuous venting technique ensures adequate venting and since it is incorporated into the initial design of the mould; continuous venting may cut the time required to put the mould into production.

To obtain continuous venting a groove is cut into the mould around the inserts as shown. This permits air to pass quickly out of the mould through the short lands and large groove's. Another method of venting is to cut vents up to 0.075 mm deep and 9.5 mm wide in a sunburst pattern around the mould; however this approach provides a more localized type of venting. Additional clearance may be provided around the knock out pins to provide localized venting in the cavity.

Equipment & mould design



THE CAVITY

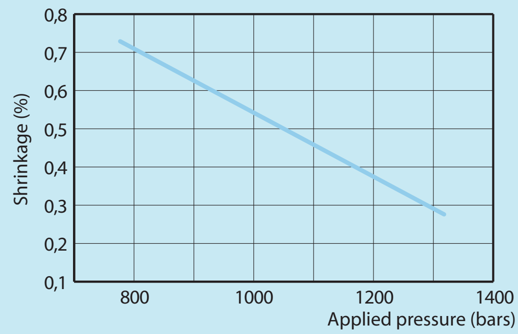
Polishing

To obtain optimum clarity and lustre parts moulded with Altuglas®, the mould should be ground to eliminate all tool marks and polished to a high lustre.
Draw polishing in the direction of ejection of the parts. This will minimize any tendency for the parts to stick in the mould.

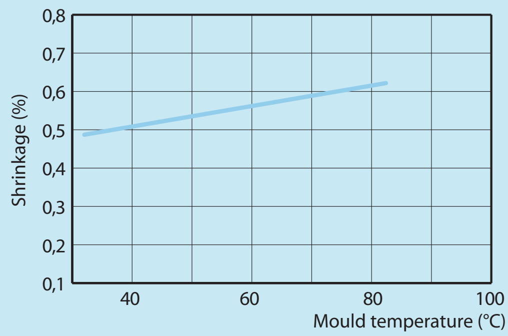
Mould shrinkage

Cold-mould to cold piece shrinkage is the difference between the dimensions of the moulded part and the corresponding dimension of the mould cavity, booth measured at ambient temperature. For Altuglas® range the moulding shrinkage according ASTM D 995 is located into range 0.2 – 0.6 %. The magnitude of the mould shrinkage varies appreciably with the part shape, mould design, direction of flow and moulding conditions. The typical mould shrinkage for Altuglas® is approx. 0.004 mm per mm but under extreme conditions it may go as high as 0.007 mm. The next tables show the changes in operating that will increase or decease mould shrinkage. Mould shrinkage generally increases as the part thickness is increased.

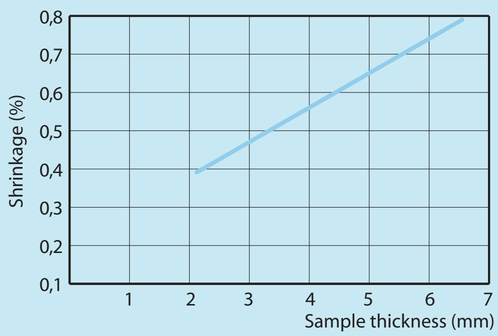
Shrinkage vs applied pressure



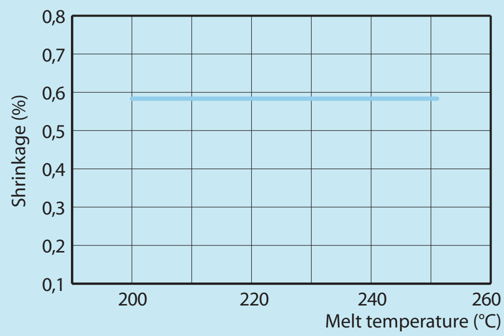
Shrinkage vs mould temperature



Shrinkage vs thickness



Shrinkage vs melt temperature

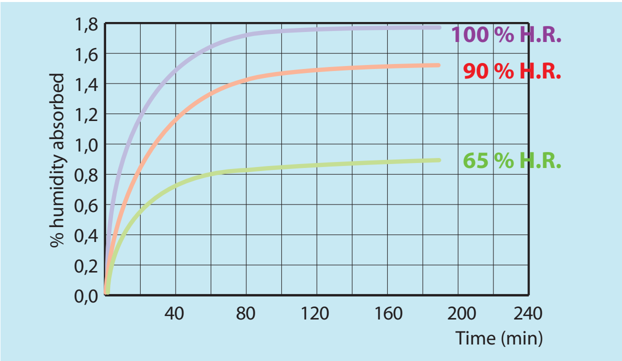


Mould shrinkage

In designing moulds for parts requiring extreme dimension accuracy, a sample cavity should be built and tested before industrial production. Parts should be moulded in the sample cavity using the same formulation and moulding conditions that will be used in production.

Moulded parts will reach temperature equilibrium several hours after moulding and can be measured to determine shrinkage.

Moulded parts will undergo further dimensional changes as they absorb the moisture from the atmosphere and they may take more than 30 days to reach equilibrium at a given relative humidity conditions on line with humidity absorption for granules.



To eliminate the need or waiting for humidity, the parts may be cooled to service temperature in a dedicated atmosphere and a correction factor added to the part size based on the humidity conditions the parts will encounter in service.

The next table shows the correction factors for various relative humidity.

Relatively Humidity to which parts will be exposed in service at 23°C	Correction factor to be added to parts measured after cooling to 23°C in a dry atmosphere
40 %	0.001 mm per mm
65 %	0.002 mm per mm
80 %	0.003 mm per mm

Plastic consideration item / mould project

Particular attention should be paid to the geometrical configuration of the item at the initial design stage.

Careful consideration will directly influence the properties of plastic in the moulding. The aim to promote designs with the expected mechanical and thermal performances which are the results of respect for processing constraints.

Some of the most common geometric considerations for Altuglas® resins are given below.

Equipment & mould design

PLASTIC CONSIDERATION ITEM / MOULD PROJECT

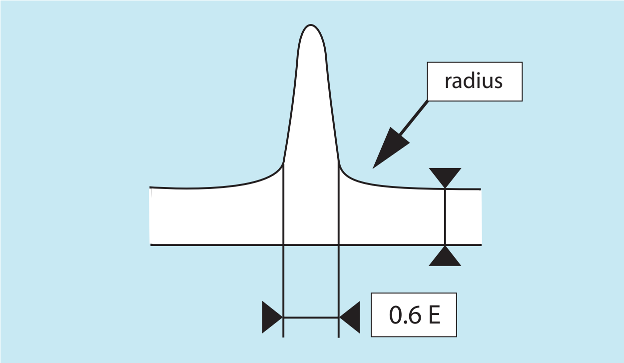
Wall thickness

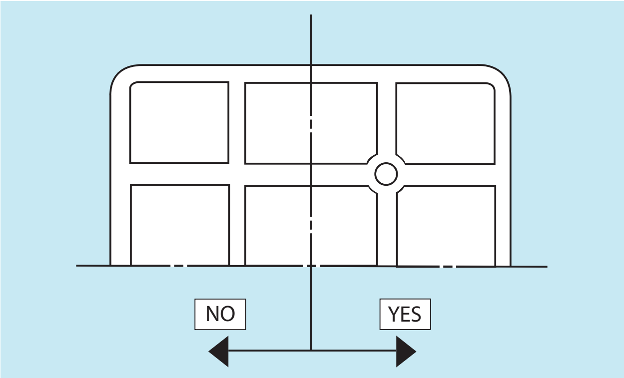
While the wall thickness of Altuglas® moulded parts is a function of load under service conditions, the need for evenness is an essential consideration. Major or abrupt variations in thickness may lead to material deformation and sink marks resulting from differential rate of mould shrinkage. Whenever variations in wall thickness are unavoidable, these should be gradual, and the injection gate position so designed as to enable the melt to flow from thinner section.

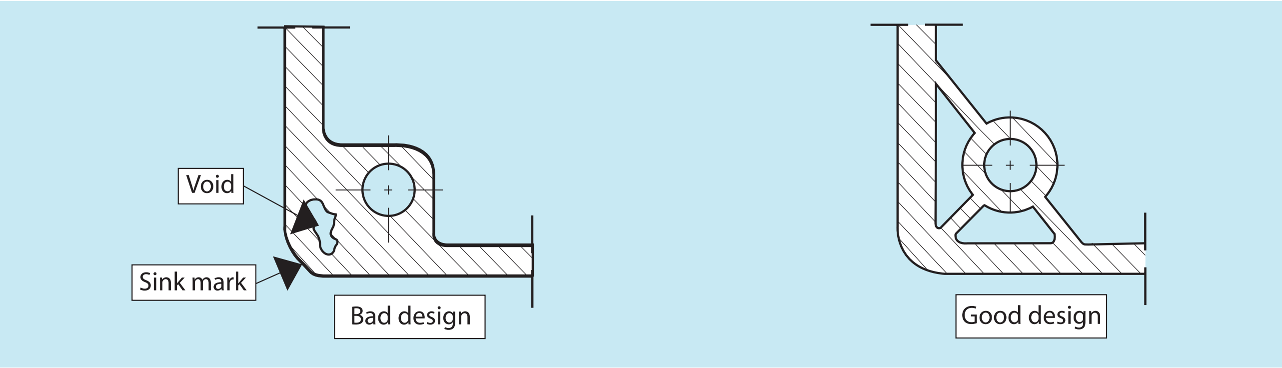
Corners

Corners should be rounded, sharp internal angles should be avoided because of the potential high stress concentration which may be generated.
The radius/wall thickness ratio should be no less than 0.6 to keep internal stress levels within acceptable limits.

In practice a 1.0 to 1.5 mm radius gives good results.







Injection moulding process

Introduction

The moulding process conditions vary as function of the type of part being produced.
The machine and mould characteristics and in particular the type of Altuglas® used. The general guidelines can used on the use of Altuglas® given below must be adapted to each specific case.

An injection moulding cycle comprises several phases:

- mould closing
- injection of molten polymer
- polymer solidification in the mould
- mould opening and item ejection

1 MOULD	closed	locked	open
2 INJECTION UNIT	forward	held closed	retracted
3 SCREW	stroke	compacting	filling by rotation
4 PRESSURE	increasing	maximum	residual filling
5 POLYMER	cooling		part-ejection

Handling of the Altuglas® granules

The excellent clarity of Altuglas® can be jeopardized with poor material handling.
We seal our resins in heavy gauge, moisture resistant, PE lined drums or carton boxes.
When loading hoppers, the container lid should be wiped clean to avoid contamination.

The container should be kept covered during the run to keep dust and dirt from contaminating the contents of the container.

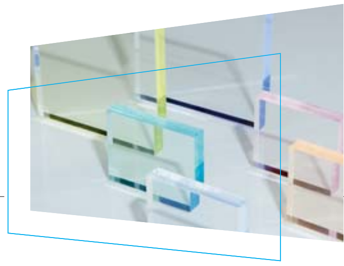
Container should be resealed when not in use. Hopper, loaders must be disassembled and cleaned before loading for anything polymer other than acrylic. Similarly, the machine hopper should be vacuumed and wiped down before use.

A small amount of transparent polymers as PS or SAN or PC can contaminate a entire hopper load.

Drying ovens must be also checked to avoid contamination from blowing fines and stray resins.

Considering the high hardness of the acrylic granules the material used for hopper, tubes for pneumatic transport and generally for all parts in contact with granules, must be iron steel in order to avoid contamination by friction.

Injection moulding process



PRE DRYING OF ALTUGLAS® GRANULES

Pre drying is at first look a simple process.
It is in practice the source of operational errors. The main reason being that the degree of moisture in the granule before it is dried and the humidity level finally reached are usually unknown.

This problem can be solved, even without moisture testing equipment, by defining the following parameters:

- ambient air humidity
- drying temperature
- drying time

PMMA granules must be subjected to very accurate treatment to avoid contamination caused by dust and other polluting agents. Contamination during drying operation is mainly due to polymers tendency to attract electrostatic charges resulting from friction and to the granules abrading action on a surface. The material used in the construction of pre drying system must be selected carefully. Soft or easily alterable material is must be avoided. The recommended material is iron steel.

During drying in forced ventilation dryers the air must be purified and filtered to avoid the deposition of any impurities on the polymer.

Since Altuglas® granules have a medium level hygroscopic behaviour, moisture is absorbed within the granules as well as on the surface. The moisture content of an air exposed granules increase constantly until it reaches an equilibrium which depends on the level of the relative humidity on the air.

Using a standard drying system for granules the operating conditions are not fully controlled because the ambient conditions are variable. Hence it is normal to see that using the same parameters for drying we see varying results during different production runs.

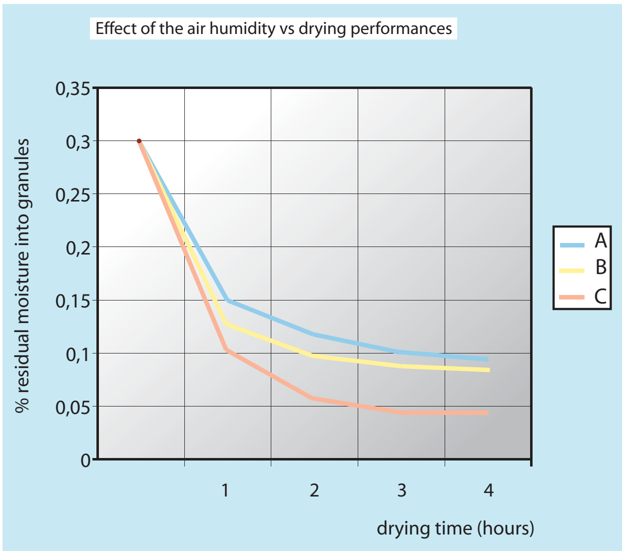
In order to solve this it is recommended to use a system which controls the dew – point of the air (temperature at which the absolute humidity begin to condense). This is not an absolute value but must be related to a precise temperature.

Lower dew point = greater drying speed and lower level of residual moisture into granules. Recommended dew point for PMMA is - 40 or 50 °C

Pre drying efficiency in various operative conditions

ALTUGLAS® GRADES	TEMPERATURE °C	TIME HOURS
VM—VML	65 - 70	2 - 4
V 920T	70 - 75	2 - 4
V825T	80 - 85	2 - 4
HT 121	90 - 100	2 - 4
MI 2 T	80 - 85	2 - 4
MI 4 T	80 - 85	2 - 4
MI 7 T	75 - 80	2 - 4
DRT	75 - 80	2 - 4
HF I7	70 - 75	2 - 4
HFI 10	70 - 75	2 - 4

Pre drying efficiency in various operative conditions



A = AIR AT 70% U.R.   B = AIR AT 50% U.R.   C = AIR DEW POINT - 40 °C

Injection moulding process

To check that the Altuglas® has been effectively dried, visually check the molten mass before starting production: foam or gas bubble in the molten plastic indicates excessive moisture.

Good residual moisture

Moisture to high

Level of residual moisture in the granules vs. processability

TECHNOLOGY	QUALITY OF PART	RESIDUAL MOISTURE LEVEL
Injection moulding with venting	Critical level for processability	0.15 / 0.20 %
Injection moulding	Level for normal item (i.e standard level of acceptability)	0.10 %
Injection moulding	Level to obtain good items (i.e aesthetics - big surface)	0.07 %
Injection moulding	Level to obtain very good items (i.e. high thickness)	0.05%
Injection moulding	Level to obtain excellent item (i.e.optical properties restricted value)	0.03 %

Injection moulding process

MOULDING TEMPERATURES

The moulding temperatures depend on the Altuglas® resin used. Typical barrel, mould and melt temperatures are listed in the tables below.

High processing temperature causes surface effects, bubbles and reduction in the properties of the item. High temperatures cause greater shrinkage and can lead to sink marks especially in thick parts.

Lower temperatures around the hopper, improve the feed.

To avoid overheating, the barrel nozzle temperature should be kept slightly higher than that of the surrounding area. When operating with slow cycles and particularly long nozzles keep the temperatures slightly higher.

The temperature profile of the barrel is not generally the real temperature of the molten polymer. Other factors affect the temperature of the material: the ratio between part weight and the machine shot capacity, the screw speed during screw return and injection speed.

Altuglas® grades	Rear °C	Centre °C	Front °C	Nozzle °C	Mold °C	Melt °C
VM	170-190	175-195	185-200	180-195	50-60	200
V920T	195-215	205-225	210-230	210-220	70-80	230
V825T	205-225	215-235	225-245	220-240	75-85	240
HT 121	210-230	220-235	230-245	230-240	80-90	240

Altuglas® grades	Rear °C	Centre °C	Front °C	Nozzle °C	Mold °C	Melt °C
MI2T	205-225	215-235	225-245	220-240	75-85	240
MI4T	200-220	210-230	225-235	220-230	75-85	235
MI7T	210-225	215-225	220-230	225-235	70-80	235
DRT	215-230	225-235	235-245	230-240	70-80	245
HFI7	190-210	215-225	220-230	215-225	60-70	225
HFI10	200-215	225-235	230-240	225-235	60-70	235

Injection moulding process

In the injection moulding process the residence time of the material in the barrel and its thermal profile are the parameters used in order to have the real temperature or melt temperature.

The residence time evaluation is a very important parameter to determine the values of the profile temperatures of the barrel to obtain a correct melt temperature for each Altuglas® grade. In fact in some case it is necessary to change the barrel capacity in order to avoid degradation problems.

Using the data concerning barrel capacity and density's of the molten polymer resins it is possible to obtain accurate data about the real injection capacity.

Polymer	PS	PC	SAN	PMMA
Density molten gr/cm²	0.91	0.97	0.88	0.95

Real injection capacity: screw volume x density

$$\textbf{\textit{residence time}} = \frac{\textbf{Injection capacity x 2}}{\textbf{Item weigh}} \times \frac{\textbf{total cycle}}{\textbf{60}}$$

Where injection capacity/item weight: gr Total cycle: sec.

The value of residence time in injection moulding of Altuglas® granules has a very important rule in order to obtain item at maximum quality level. Using for example Altuglas® V 825T at 240 °C (usual melt temperature) we have the following limit: residence time < 1 minute incomplete plasticization. Residence time > 7 or 8 minutes overheating or degradation of the polymer.

- To evaluate correctly the melt temperature we use the following guideline:
  take the value when the injection moulding machine. works in production conditions for 10-20 moulded items.
- purge the barrel and evaluate the melt temperature by thermometer introducing the sensor into core of the molten material. If the sensor is placed in the nozzle, usually the melt temperature will be higher of 5-10 °C than real value because friction during injection.

MOULD TEMPERATURE

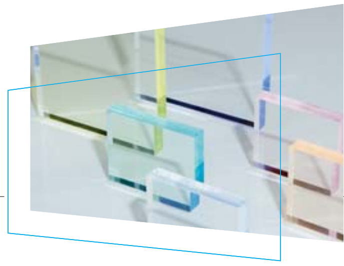
The mould temperature is extremely important since it affects overall properties of the item (both aesthetic and physical).

We recommend for Altuglas® grades the mould temperature is perfectly controlled. The effects on the item of incorrect mould temperatures are:

- low mould temperature: cavity filling problem, orientation and residual stress in the item and bad surface (i.e. orange skin, flow lines). Reason for the use of the low temperature is a reduction in total cycle time. However the final result is a decrease of production efficiency due to higher reject levels of the items.
- high mould temperature: good filling of the cavity, better physical properties of the items and longer cooling time before ejection of the item. Hence increasing of total cycle time. Reason for the use high temperature is to increase performance of the item photometry capacity, thermal and chemical resistance.

(see page 21 for mould temperature values)

Injection moulding process



PRESSURE AND INJECTION SPEED

Injection pressure

The operating pressure depends on the pressure drop which occurs when cavity is filled.

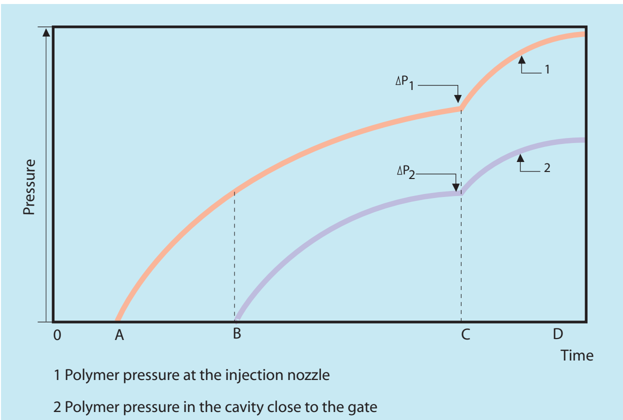
The pressure drop itself depends on the flow properties of the material as melt temperature viscosity and flow rate) and the geometry of the flow path (width, height, length).

As a guide pressures vary from 500 bars for thick parts to 1500 bars for thin parts with long filling paths.

Holding pressure and cushion

To obtain good results i.e. a top-class visual finish. It is important to maintain a residual pressure after filling the cavity. This pressure compensates for shrinkage during cooling and holds the molten polymer against the mould faces. The finish is consequently better. The pressure and length of time it is applied is critical to avoid over packing of the cold polymer which will cause excessive stress in the areas around the gate. The dimension of secondary runners and the gate must be carefully selected to guarantee that the holding pressure is effective. For the pressure to have a real effect on the item, ensure there is an extra cushion of polymer available after injection.

Variation in pressure versus time



Back pressure during filling

A moderate back pressure can be applied during screw return to achieve suitable compacting of the polymer. The back pressure is generally between 5 and 10 % of the machine capacity. It eliminates air bubbles which can lead to visual defects. However, an excessive back pressure can lead to high stress in the material and degradation of the polymer.

Injection speed

The injection speed depends on the thickness of the part being moulded; use low speeds for very thick parts and higher speeds for thinner parts.

Excessively high injection speed causes considerable shear and therefore overheating or air entrapment and burnt parts. Low speeds can lead to both weld lines and flow marks.

Screw speed

The screw speed must be selected to ensure a constant feed and avoid overheating due to friction. The screw speed used is generally 40 - 80 rpm.

A – B is the time required to fill the sprue secondary runners and the gate. Δ P1 is the drop in pressure due to release of the polymer. The molten polymer then completely fills the cavity during time B-C causing a pressure drop Δ P2.

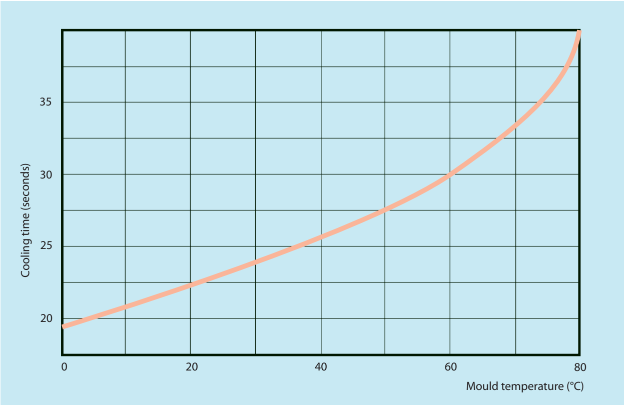
Compression (C-D) and compacting begin at the end of this phase, when the plastic has reached the inner face of the cavity.

The holding pressure is maintained for a certain period after which this pressure is released. The material contracts as it cools.

The pressure on the mould decreases. However a residual pressure may exist when the mould is opened.

CYCLE TIMES

Cycle times depend on the part thickness and the resin selected. The next figure shows the typical cycle time vs. mould temperature using Altuglas® V 825T at 235 °C melt and 3.0 mm thickness.



Generally the cycle times increases with:

High melt temperature or high mould temperature or high thickness.

In industrial production practice the choice of cycle times are a compromise of moulding cost and expected quality of the moulded items.

MATERIAL HANDLING

The excellent colour, clarity of Altuglas® acrylic resins can be jeopardized with poor material handling.
We package our resins in heavy gauge, moisture resistant polyethylene lined cartons.

The liner should be slit with a knife: tearing the liner may cause contamination with polyethylene particles. When loading hoppers, the container lid should be wiped clean to avoid contamination. The container should be kept covered during the run to keep dust and dirt from contaminating the contents of the container. The container should be resealed when not in use. Hopper loaders must be assembled and cleaned before loading if previously used for anything other than PMMA. Similarly, the machine hoppers should be vacuumed and wiped down before use.

A small amount of polystyrene or other transparent plastic such as PC or SAN can contaminate an entire hopper load.

PS contamination 2 %

PMMA Good item

Drying ovens must also be checked to avoid contamination from blowing fines and stray resins. Moulded cluster lenses and edge lighted parts require the most extreme care in material handling to avoid visible contamination.

The recommended material for hopper drying container and generally for the PMMA granules pneumatic transport is iron steel to have good cleaning operations and to avoid contamination due to friction of the granules vs. soft materials (i.e PVC or PE tubes)

REGRIND

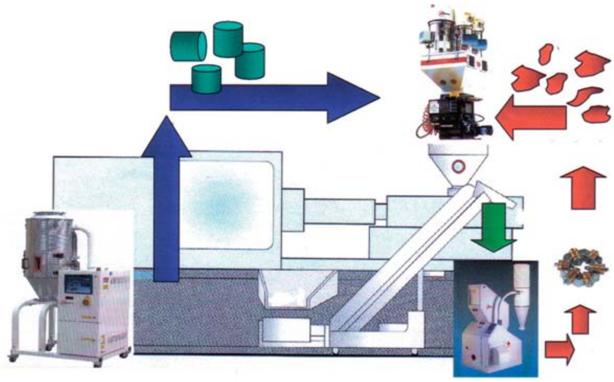
When regrind is used, the level should be kept to 10 to 20 % of virgin material. The use of regrind does not harm physical properties, but may affect colour and appearance due to increased risk of contamination during handling. Regrind should not be allowed to accumulate since it will readily pick up moisture and be very difficult to dry correctly.

(regrind)

For a critical moulding, it may be necessary to remove the fines in the regrind to prevent white spots or streaks in the moulded items.

The figure shows an example of plant for continuous regrind use.

Gravimetric scale blender are installed to avoid problems of virgin granules and regrind shapes.



PURGING

Changing from one grade of Altuglas® resin to another is readily done by emptying the barrel, resetting the heats for the new grade and running the machine like an extruder to clean the screw. A good purging procedure is to empty the cylinder of all previous material and to clean the hopper and feed throat. Start the cleaning with clean acrylic regrind using cylinder temperatures of 230 – 260 °C

Colour changes can be handled in a similar manner but may take slightly longer to clear the last traces of previous material.

When switching from another polymer it is frequently more economical to pull the screw and thoroughly clean all the equipment.

An alternate procedure involves sustained flushing with virgin or regrind Altuglas® resins until the air shots are clear of contamination. In this case it is better to use Altuglas® having low fluidity e.g. an extrusion grade (Altuglas® V 044 –V 046)

SHUTDOWN PROCEDURE

For a short hold period (one hour or less):

1. STOP RESIN FEED
2. RETRACT CARRIAGE
3. LOWER BARREL HEAT (150°C)
4. RUN SCREW TO EMPTY CYLINDER
5. LEAVE SCREW IN FORWARD POSITION WITH CARRIAGE BACK

For an extended shutdown, follow the above procedure, except all heaters can be turned off when the barrel is empty.

Moulding defects

MOULDING DEFECTS

Altuglas® is a polymer relatively viscous compared to other polymers. In addition because it is transparent any moulding defects caused by the process or mould finish are particularly visible.

The chapter looks at the main types of defects and practical ways of resolving them. As has already been started, the injection moulding process must be satisfy several main criteria:

- Correctly sized injection sprues runners and gates.
- Moulding condition which facilitate the flow of material into the cavity without generating high stresses.

Satisfying these criteria guarantees greater flexibility during the second part of the cycle (compacting and cooling) and consequently improves the appearance and the physical and mechanical properties of the part.

If defects do occur, it is always advisable to re-evaluate the moulding conditions before changing the mould geometry.

INSUFFICIENT FILLING

This fault is generally due to:

Inadequate flow of polymer into the cavity

improve the flow of polymer by increasing its temperature, the injection pressure and or holding pressure, injection speed and mould temperature.

Excessively narrow runners, gates or sprues

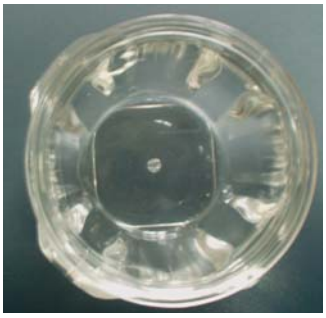
if changing moulding condition is ineffective, i.e. if a part is still incomplete or has defects such burns or bubbles, increase the size of the sprue, runners and gates. It is always advisable, when designing the mould, to ensure that the runner and sprue are as short and wide possible, while remaining compatible with production requirements.

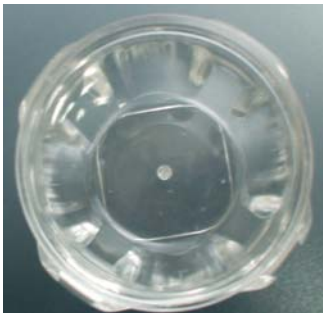
SURFACE IRREGULARITIES

These are generally caused by inadequate packing of the polymer or an excessive shrinkage.

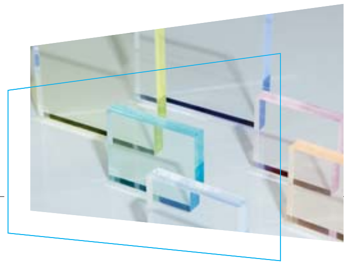
In the first case, increase the mould and polymer temperature and the injection and filling pressures to achieve a better flow of molten polymer. If necessary also improve the geometry of the injection runner/ sprue. In the second case, achieve finer control over shrinkage by varying the temperatures of the mould and polymer during injection.

If necessary "stop" shrinkage by quenching the part in water at 40-50 °C.





Moulding defects



WELD LINES

On flat surfaces

These occur where two streams of polymer meet under non-optimum conditions

- increase the mould and melt temperature
- increase the filling speed and pressure
- modify the injection runners and gate to improve the flow of molten polymer
- provide vents in the cavity

Close to reliefs

The phenomenon is then caused by incorrect flow caused by protrusion or patterns included in the shape of the cavity. Two streams meet behind the protrusion and the defect may be more or less visible.

- increase the mould temperature
- reduce the polymer temperature and increase injection pressure
- reduce the injection speed
- round any sharp edges on the protrusion, letters or pattern
- reposition the gates.

BROKEN PARTS

During mould release.

The fault generally lies in the shape of the mould or incorrect behaviour during release

- modify the mould, for example by reducing undercuts, improving the finish in the cavity and ensuring ejectors apply a uniform force.
- reduce the injection pressure and the time for which it is applied and/or reduce the holding pressure.
- reduce the mould cooling rate

After mould release

Caused by high internal stress, refer to the chapter on stresses and orientation

BUBBLES INSIDE THE PART

Transparent bubbles

These generally occur in very thick parts and are caused by high shrinkage in the mould.

Modifications include the following:

- increase the mould temperature
- reduce the polymer temperature
- lengthen the injection cycle
- increase the holding pressure or time
- reduce the injection speed

Transparent bubbles with white stains

These are caused by partial depolymerization

- reduce the melt temperature and any factors which can affect polymer stability, for example injection speed and pressure
- reduce the residence time of the molten polymer into cylinder.

Moulding defects

AIR BUBBLE ON THE EDGES OF PARTS

These are generally caused by introduction of air during filling or by localized shrinkage:

- reduce the injection speed
- reduce the polymer temperature
- facilitate the flow of air in the areas affected
- review the arrangement of the vents.

OPAQUE AREAS AND/OR STAINS

These are caused by "cold polymer", generally close to the gate or at point where the cross section changes suddenly. It is important to ensure that there are no oil or water leaks into the cavity from the mould cooling system. Change the working conditions to ensure uniform polymer temperature and flow into the cavity:

- increase the polymer and mould temperature
- increase the nozzle temperature
- improve the geometry and finish (polishing) of the runners and gates. If necessary, provide a cold slug well at the cavity gate to retain the cold polymer.

STREAKS

COLOURLESS

These are caused by the presence of different grades of Altuglas® with different viscosities or by inadequate mixing of the molten polymer:

- check that different grades have not accidentally mixed
- reduce the filling speed and the screw speed
- increase the melt temperature
- increase the nozzle temperature
- polish and/or change the size of gates and/or runners to improve the polymer flow.

WHITE/SILVER

These are caused by residual moisture in granules or polymer degradation

- check the product drying conditions
- reduce filling speeds, feed speeds and the moulding cycles to reduce fiction and residence time into cylinder.

BLACK

These are caused by air inclusion during the granules feeding on the screw, due to injection speed the air burn with "diesel effect":

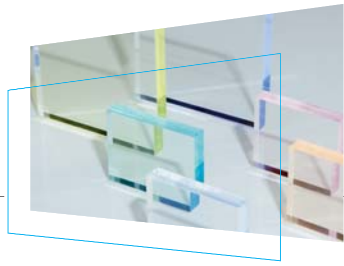
- reduce the screw speed
- increase the back pressure on the feed
- reduce the filling speed

COLOURED

Caused by contamination of the polymer:

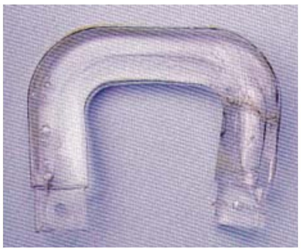
- carefully check potential sources of contamination, such as drying equipment, the hopper and areas which polymer is handled.

Moulding defects



TYPICAL EXAMPLE OF MOULDING DEFECTS

The following photo shows four factor, all inter-related



Black streaks caused by introduction of air into the feed and subsequent carbonization when the polymer is injected into mould.

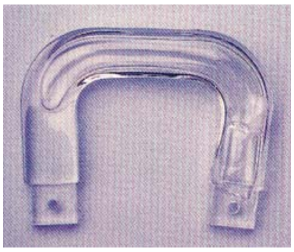
Bubbles caused by very high temperatures in the molten polymer, this itself is caused by high screw speeds which increases the melt temperature by friction.

Shrinkage bubbles in this case, the defect is close to the gate and combined with the large difference between the mould and polymer temperature, this is undoubtedly the main cause of mentioned defects.

Warped part bearing in mind the high temperature of the molten polymer, the deformation of the part is almost certainly caused by allowing insufficient cooling time.

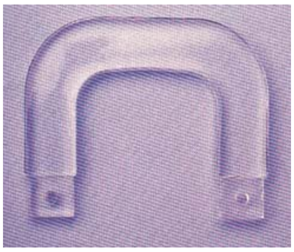
First action to minimize the defects.
Factors which adversely affected the real polymer temperature were finally eliminated: by reducing the cylinder temperature, feed speed to obtain back pressure and injection speed compatibles with PMMA.

The next photo shows that, although the part is still defective, considerable improvement was achieved.



In this case, the polymer temperature and feed and injection speed must be reduced even further. Next photo shows the results.

Black streaks and bubbles have virtually disappeared although a few remain and the part is still not regular. These defects can be corrected by further reduction to the melt temperature, injection speed and increasing mould temperature to minimize shrinkage. Finally it has been necessary to enlarge the runner and gate geometry to improve filling and the processability window.



The visual finish of the part was considerably improved by the above measures. However the result was still not satisfactory because presence of residual stress and orientation.

A large number of production samples were tested by the ethanol test. These test showed up light stress. Consequently the manufacturing conditions (mould temperature and filling pressure) were again slightly modified and the part which fully complied with the specification was obtained. Specification was decoration by silk screening and assembling with metal insert.

Moulding defects

Orientation and stress

The moulding process basically consists of two stages:

1. The pressure drives the molten polymer into the runners and then the cavity
2. Once in the mould, the polymer solidifies and retains the shape of the cavity

These two operations cause cooling and shrinkage stresses respectively

Orientation stress

Viscous flow tends to align the polymer chains parallel to the flow direction. This orientation becomes fixed during cooling in practice, different orientations still exist in the moulded parts depending, obviously, on the conditions applied during the process.

Melt temperature

High temperatures reduce orientation in the polymer since the polymer melt becomes more fluid and the viscous forces, which have a direct effect on the alignment of the molecular chains, are reduced. Higher temperatures also mean longer part cooling times and consequently orientation is partially relieved particularly in the centre of the part.

Injection speed

Effects of this parameter vary depending on the laminar structure of the polymer flow, i.e the thickness of the moulded part. Increasing the speed increases surface orientation. In the centre of the part, however, the degree of orientation is reduced due to reduction in internal forces since higher injection speeds increase the temperature due to friction.

Mould temperature

An high mould temperature means the polymer cools more slowly and encourages stress relaxation.

Injection and holding pressure

High injection pressures increase stress particularly during final compression since the product is already cooling but further molten polymer is introduced, to compensate for shrinkage, until the pressure is in equilibrium. The polymer in the gates and secondary runners hardens and stress increases.

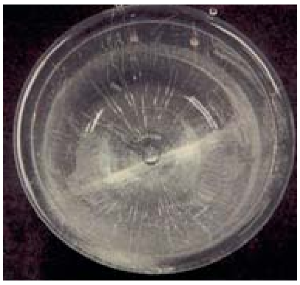
Cooling stress

These stresses are caused by non–uniform cooling of the moulded part. The surface layers of polymer, adjacent to the tool surface, begin to solidify while the inner layers are still hot. Consequently a hard external skin forms with molten polymer in its centre.

Since the specific volume of the material depends on temperature, and therefore rate of cooling, the various layers contract differentially causing residual stress.

These stresses are compressive at the surface and tensile in the centre. As the hot centre cools. It generates tensile stress which remain in the moulded part even when it is completely cold.

The stresses are higher in thick parts and increased by high cooling rates caused by cold moulds.



Moulding defects

Stresses due to post cooling shrinkage

The specific volume of the polymer depends directly on the cavity rate of cooling. An extremely long cooling time would be required to obtain volumetric stability.

Such periods are impractical and therefore the specific volume of an injection moulded part is always greater than theoretical volume at equilibrium.

When stored for long periods, the parts shrink slightly, particularly along the edges.

If not restrained the material tends to return to the equilibrium volume it should have attained the temperature applied at the end of its production cycle. However the stress level remains relatively low.

ASSESSMENT OF STRESS

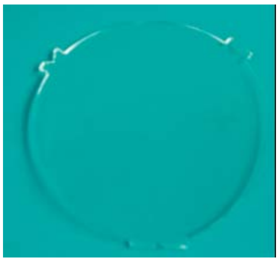
Ethanol will reveal any residual stress.

Strong surface orientation is seen as a white film on the surface of stress concentration area.

Stresses which exceed the critical values give rise to crazing. The test involves immersing the cooled part in 90 % ethanol at 25 °C (± 1 °C) for 15 minutes and then drying it as quickly as possible with compressed air.

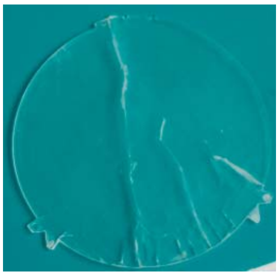
The temperature of the ethanol is important since it determines the rate at which crazing forms.

POSSIBLE RESULTS AFTER ETHANOL TEST

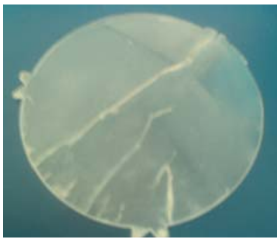


Good quality of the item

Presence of orientation



Presence of high residual stress



Presence of high residual stress and orientation

Moulding defects

ANNEALING MOULDED ITEMS

The injection moulding process normally sets up surface and internal stresses in moulded parts. The purpose of annealing is to redistribute both surface and internal stresses more uniformly and also to reduce their magnitude.

Annealing is simply insurance of optimum quality for a well-moulded part: it cannot overcome the defects of a poor items. Properly annealed parts are more resistant to crazing by solvents which may be present in adhesives, lacquers, paints or cleaning and polishing agents. Annealing produces a substantial improvement in the strength of cemented joint.

No single combination of annealing time and temperature is satisfactory for annealing all items moulded in Altuglas® grades.

An annealing cycle which is good for one part may have no annealing effect whatsoever on another part.

Although annealing is often omitted, it is an important operation and the benefits should be evaluated wherever possible, especially where moulded parts are to be machined or bonded or decorated.

Annealing involves holding the parts at a constant temperature (thermostatic control).

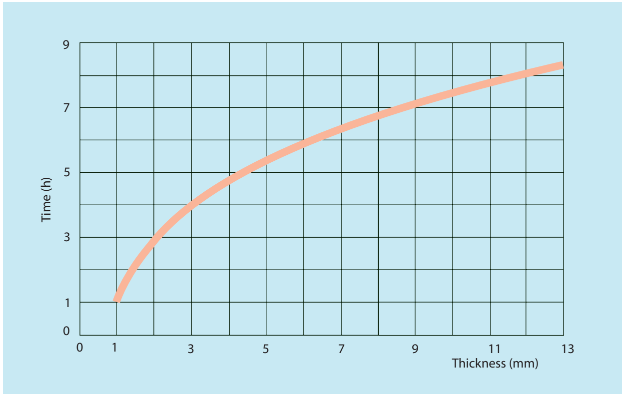
The temperature depends on the type of Altuglas® grade and thickness of the part.

This operation only effect cooling stresses and not orientation stresses.

Items must not be distorted by the annealing temperature and must be cooled gradually to ambient temperature.

Annealing temperature will be more or less 15 to 20 °C lower than the VICAT 360 B 50.

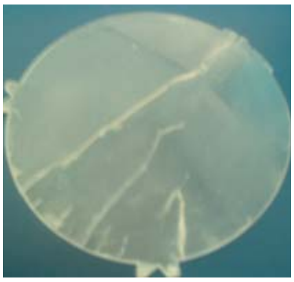
Typically, the cooling rate is 1 to 1.5 °C per minute. Correct annealing will not distort the part. The next table shows the annealing time vs. part thickness.



RESULTS AFTER ANNEALING

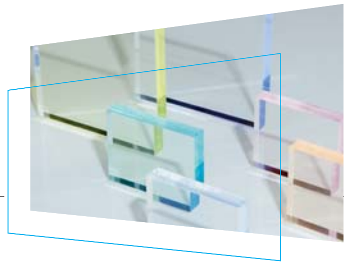

Residual stress present


After annealing and ethanol test


Residual & orientation stress present


Post annealing & ethanol testing: residual stress: NO, orientation stress: YES

Post moulding operations



ALTUGLAS® ASSEMBLY SELECTION

Altuglas® acrylic resins may be bonded to themselves or other polymers through:

1. Thermal bonding (welding)

2. Mechanical assembly

3. Chemical bonding

Each of these techniques has certain advantages which should be fully understood for proper assembly.

Altuglas® acrylic resins are compatible with each of these techniques. This versatility provides designers the freedom to create attractive, functional parts cost effectively.

The stability of Altuglas® acrylic resins provides for long service life assemblies, even under continuous outdoor exposure.

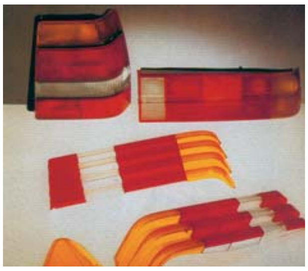
THERMAL BONDING

Welded assemblies result from frictional or conduction heating of the polymers under applied pressure such that a melt bond occurs between the components.

Welding methods are best suited for applications which require high strength, leak proof, attractive or contamination free bonds.

Joint requirement	Thermal	Mechanical	Chemical
High strengh	PREFERRED	RECOMMENDED	RECOMMENDED
Leak proof	PREFERRED	NOT RECOMMENDED	PREFERRED
Repeat assembly	NOT RECOMMENDED	RECOMMENDED	NOT RECOMMENDED
Recycle ability	PREFERRED	RECOMMENDED	RECOMMENDED
Dissimilar marerials	RECOMMENDED	PREFERRED	PREFERRED
Contamination free	PREFERRED	RECOMMENDED	NOT RECOMMENDED
Chemical resistance	PREFERRED	RECOMMENDED	PREFERRED
Fast cycle time	PREFERRED	PREFERRED	NOT RECOMMENDED

PREFERRED | RECOMMENDED (condition permitting) | NOT RECOMMENDED



Common welding techniques include:
ultrasonic, vibration & hot plate.

These techniques are best suited to polymers with similar melt properties.

The broad melting range of Altuglas® acrylic resins make them compatible with a number of common amorphous thermoplastic polymers.

Polymer	Ultrasonic	Vibration	Hot plate
PMMA	Good	Excellent	Excellent
ABS	Good	Excellent	Excellent
ABS/PC	Good	Very good	Very good
PC	Good	Very good	Very good

The following guidelines may be used as a reference point when welding Altuglas® acrylic resins.

Technology Parameters	Ultrasonic	Vibration	Hot plate
Amplitude	40 - 70μ	0.8 - 1.8 mm	NA
Pressure	2 - 4 bar	14 - 35 bar	NA
Temperature	NA	NA	300 °C
Melt depth	NA	NA	0.75 - 1 mm
Seal depth	NA	NA	0.25 - 0.5 mm

Post moulding operations

MECHANICAL ASSEMBLY

Mechanical methods include techniques such a screw fastening, riveting or snap-fits which employ a fastener or physical means of part assembly. These techniques are used for applications requiring non-destructive disassembly or rapid assembly with low capital investment.

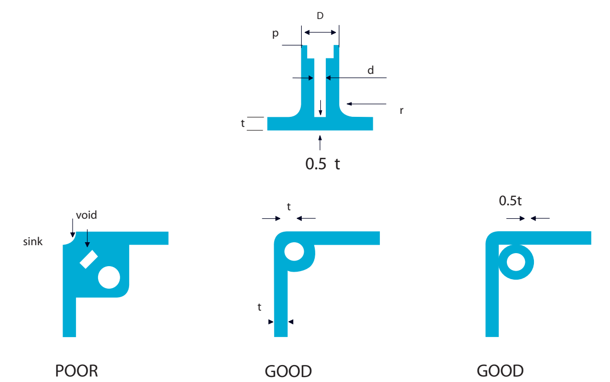
Unlike other fastening methods, these techniques are readily using for joining all materials, including metals.

Altuglas® acrylic resins may be joined with themselves or other materials providing appropriate design considerations have been taken.

BOSSES

Accumulation of material, not only in the walls, but at the joints and corners should be avoided by coring out.

Good practice in the design process will help in the minimizing of the risk of sink marks, voids.



Snap-fits assemblies must be designed within the elastic limitations of the material employed. The following formulas may be used to estimate the percent deformation of Altuglas® acrylic resins for a given design.

For CANTILEVER : e = d/ (0.67x l^2/h)

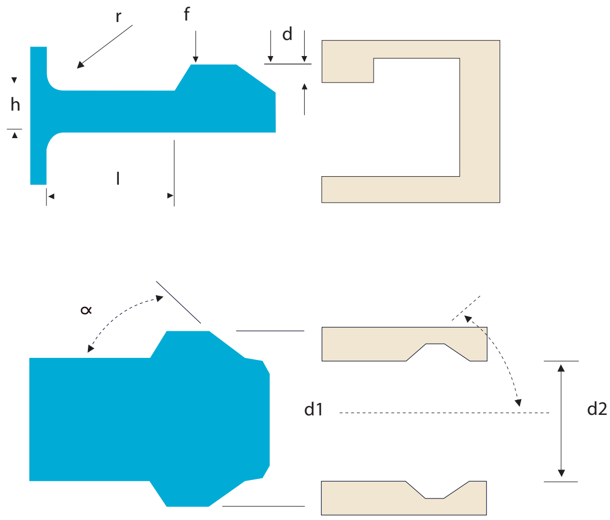
For BUSH FIT : e = (d1- d2) / D1x 100?

↓ angle range for a dismountable system = 40 - 50°

↓ angle range for a non dismountable system = ⊇ 50°

↑ angle should be between 20 - 30°

SNAPS - FITS



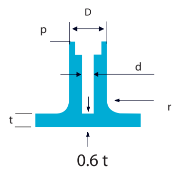
Bush fit type

Permissible deformation:

Altuglas® grades V series .... 2 %
Altuglas® grade MI7T .... 3 – 4 %
Altuglas® grade DRT V .... 4 – 5 %

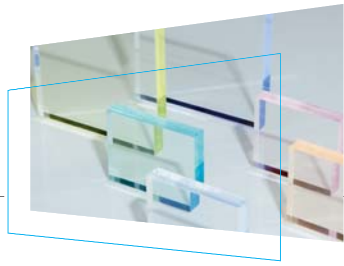
Applications such as car instruments clusters and lenses require mechanical attachment of the Altuglas® part to the component parts having boss areas for attachment. Studies on recommended screw for these applications have been performed.

Some general guidelines are offered in the following table.



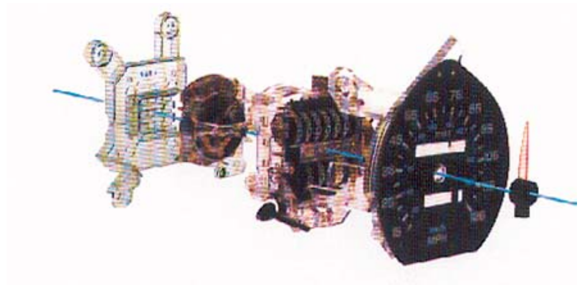
Preferred screw

Post moulding operations



Thread cutting

	Screw attachment V grades to MI7T	Screw attachment DRT
Pilot hole	= /> 0.9 screw OD	= /> 0.85 screw OD
Boss diameter	= /> 2.5 d	= /> 2.0 d
Screw guide	= /> 2.0 mm	= /> 2.0 mm
Base radius	> 0.6 t	> 0.6 t



CHEMICAL METHOD

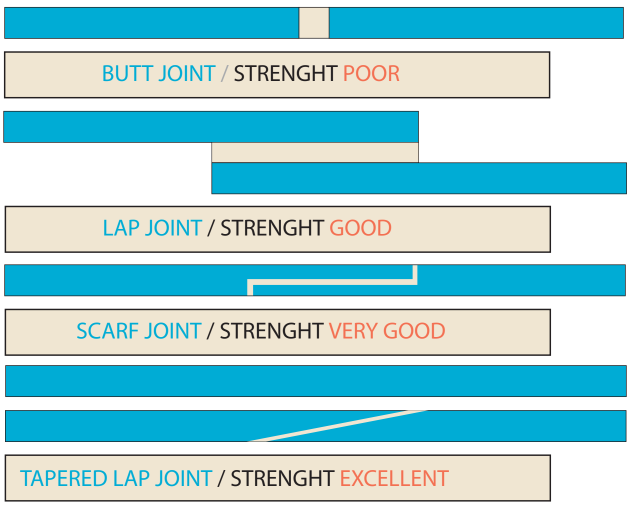
Chemical methods of assembly include the use of adhesives, adhesive tapes or cements. These methods are readily used for attaching awkwardly shaped or fragile materials.

The strength of a chemical bond is dependent on the material, the bonding agent used, the joint design and the orientation of the applied load. Bond strength is maximized when compatible materials are loaded in compression or shear with load evenly distributed over the maximum possible area. Cleavage and peel stresses should be avoided when possible.

Adhesive compatibility

	Epoxy	Polyester	Cyanoacrylates	Nitrile - phenolics
ALTUGLAS®	Recommended	Recommended	Recommended	Recommended
ABS	Recommended	Recommended	Recommended	Recommended
Polycarbonate	Recommended	Recommended	Recommended	NOT Recommended
Polystyrene	Recommended	NOT Recommended	NOT Recommended	NOT Recommended

Adhesives are also frequently used for leak proof assembly of dissimilar materials.



Chemical methods may require a longer time period for bonding as the adhesive or cement cures. Solvent cements may be used in selected cases, usually to bond like materials, to provide a leak proof bond

Post moulding operations

DECORATION

The combination of high surface gloss, superb clarity, good abrasion and weatherability makes Altuglas® an ideally suitable material for the production of decorated components as medallions, metalized bezels, tap handles and signs.

It is essential that all the following advise is followed because decoration can be an expensive operation and the recovery of faulty decorated parts is difficult or impossible.

Preparation

All the decorating processes mentioned in this section involve the surface treatment of moulded parts. It is therefore essential that the parts are produced under clean, dry and grease free conditions.

Moulds must be free from oil contamination especially around ejector pins and stripper plates. Generous tapers should be allowed on all surface in the line of the draw to reduce the need for a mould lubricant. Silicon based mould release agents must be avoided since these cause surface blemishes and loss of adhesion.

When handling components, lint-free cotton gloves should be worn to avoid fingerprints. Antistatic agents in the form of aqueous solutions may be used but care must be taken to ensure that the “film” of antistatic agent is dry before decorating or poor results will be obtained. Although antistatic solutions prevent dust from being attracted to the component, they will not prevent a gravitational deposit of dust.

When parts are to be decorated with more that one colour it is usually necessary to use one or more masks.

In order to obtain a fine definition between colours, the masks have to be made to strict tolerances. Consequently the dimension of the part must be controlled to equally precise limits, and all the principal moulding variables must therefore be controlled accurately to ensure dimensional consistency.

Many of lacquers used for decorating Altuglas® components contain active solvents which will produce surface crazing or cracking if undue levels of stress are present.

It is recommended that all components subjected to a decorating process containing active solvents are annealed before decorating. All machining, polishing, hot foil stamping and ultrasonic assembly operations should be carried out before annealing.

Decorating processes

Either a first (front) or second (back) surface coating technique may be used with Altuglas®. Second surface decoration is more commonly used because the high transparency of Altuglas® makes it possible to achieve a wide variety of attractive effects.

The coating is protected by the Altuglas® against deterioration from weathering and abrasion.

Lacquering and spray painting

These techniques may be used with Altuglas® and are normally associated with 3-dimensional decoration of intricate components where silkscreen printing cannot be used.

The viscosity of the paint is critical and it is advisable to follow the recommendations of the supplier to achieve the best results.

Poor paint adhesion may be traced to excessive mould lubricant, oil from an outside source, water in the line or “humidity blush”.

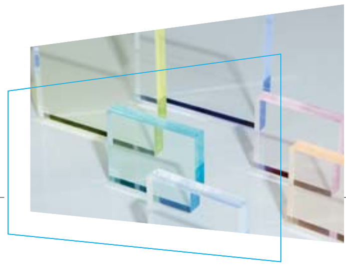
“Humidity blush” is the result of water condensing into the paint from the air during the application process. This may be adjusted using the thinners recommended for high humidity conditions.

Faults commonly associated with paint of incorrect viscosity are “orange peel” and “cobwebbing”. Orange peel is caused by poor levelling of the paint film because the viscosity of the paint is too high. This may be overcome by adjusting the spray gun to give a wetter spray or by using a thinner with a higher boiling (Flash) point.

A cobweb between the spray gun and the object being sprayed is caused by some paints which may string when insufficiently thinned.

This is a normally corrected by reducing the solid content of the paint by the addition of extra thinners.

Post moulding operations



Silkscreen

This a widely practiced technique, mouldings with flat surfaces lend themselves to this process. It is particularly adaptable for multi-colour decorating by successive screening operations with a series of different screens.

Silkscreen printing involves the use of a screen and a sponge which is used to force ink through the design in the screen on to the part being printed.

The screen consists of a taut woven fabric, normally nylon, securely attached to a frame. It is carefully masked with a stencil in a manner that will only allow ink to be pressed through the fabric in areas where the stencil is open.

Hot foil stamping

This process involves the hot blocking of characters onto the surface of a component. An electrically heated metal die of the required design is pressed onto a stamping foil, the coated side of which is in contact with the object to be decorated. The hot die melts the coating, releases the foil backing and bonds it to the object. Thus, engraving and colour filling are achieved in one operation.

Vacuum metallizing

This techniques is used to impart a metallic or mirror like appearance to the moulded parts. The metal used (commonly aluminium) is deposited onto the surface by evaporation under high vacuum using specialized equipment.

Either first or second surface metallizing may be applied to Altuglas®, the latter process is more commonly used.

Vacuum metallized components, in particular those for the car industry, are often required to meet application specifications, most of which include a test for adhesion. The test commonly used is the “adhesive tape” test (e.g. scotch tape) in which the decorated layer is cross–hatched and a length of tape is applied, and then removed. To pass the test, none of the decorated layers should adhere to the tape. Before metallizing, it is advisable to spray the moulding with a base coat. Apart from improving adhesion between the moulding and the metal coating, the base coat also acts as a smoothing coat on those mouldings which do not have a high surface finish. If the moulding is metallized directly and the metallizing then protected with a single layer or back – coat, it is unlikely that the moulding will pass the adhesive test.

Post moulding operations

MACHINING

Machine / tools

The hardness of Altuglas® lies between that of wood and steel or light alloys.

It can be machined (cut, milled, turned and drilled) using either wood or metal machine tools.

Altuglas® has a staff of engineers ready to assist you with Altuglas® acrylic resins machining.

EXAMPLE OF MACHINING

Sprue Cutting by saw

Abrasion sand paper and water

Polishing with felt belt or disc turret fitted with cotton or flanel buffer and polishing agent

ITEM MAINTENANCE

Cleaning in normal conditions to remove: dust use cotton wool cloth with cold water.

In order to have good results for longer time use of the Altuglas® antistatic cleaner is recommended.

In the case of more dirty or fat traces soiling: use a soap detergent in water (10 -20 % by volume).
An alternative is ***Altuglas® cleaner.***

Deposit of fat substances or oil can be eliminated using a cloth, sprinkled with ethyl alcohol, wipe the part for a couple seconds only.

It is possible to eliminate some surface scratches that may happen over time.
The procedure is similar to gate polishing.

For small defects Altuglas® polish should be a speedy solution.

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