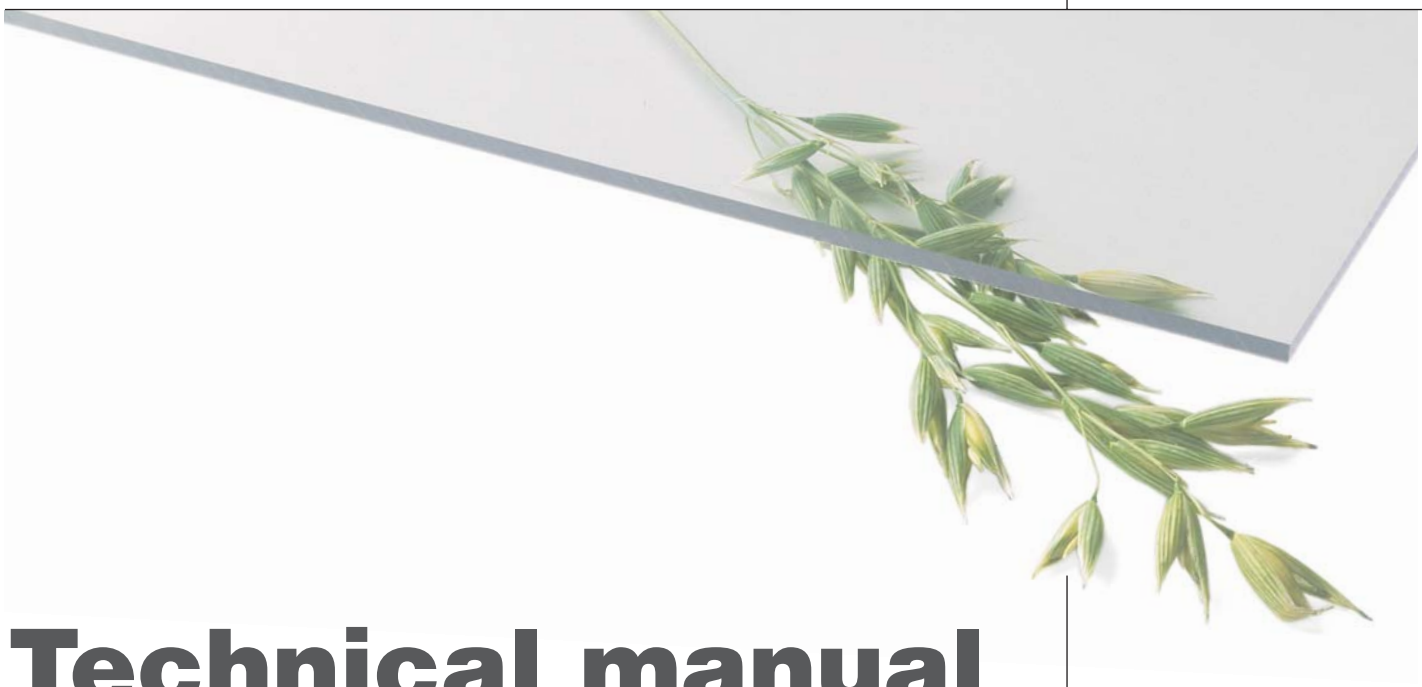


# Technical manual for Polycarbonate

## from Arla Plast AB

**ARLA PLAST AB**
Box 33
590 30 Borensberg
Sweden
Tel +46 (0)141 20 38 00
Fax +46 (0)141 414 30
info@arlaplast.se
www.arlaplast.se

ARLA PLAST AB SWEDEN

# Technical Manual for polycarbonate


**All information herein described is valid for MAKROCLEAR®, MAKROLIFE® and SAPHIR™ unless stated otherwise.**

## Contents of this Manual :



Last update : 03-03-2003

# Chemical resistance

SAPHIR™ is a Polycarbonate sheet with a hard coat of silicon. The coating gives a high protection against abrasion and also an improved chemical resistance compared to standard polycarbonate. For short term contact (droplets, accidental fumes ...) its surface is resistant to most chemicals. For longer exposure or exposure to liquids please refer to the chemical compatibility of MAKROCLEAR®.
MAKROCLEAR® and MAKROLIFE® will have identical chemical compatibility.

MAKROCLEAR®shows a good resistance to a number of chemicals. The overall chemical resistance is however dependent upon the following parameters :

- -temperature (resistance decreases with higher temperatures)
- -stress level (best resistance is with flat sheet, clamped in a frame)
- -chemical concentration (mostly in water, from some ppm to pure)
- -exposure time (from fumes over drips to continuous contact)

Following information is meant as a guideline. As to the above influences, it is recommended to perform own testing according to the final application. Do not hesitate to contact us in case of questions regarding the chemical compatibility of MAKROCLEAR® .
In case you want Arla Plast AB to perform compatibility testing, the product and its MSDS, together with indications on above parameters are required.

In general, MAKROCLEAR® shows a good chemical resistance for various chemicals such as dilute solution of acids, salts and aliphatic hydrocarbons, but it is significantly affected by aromatic hydrocarbons and ketones.

The various materials were tested according to our standard chemical resistance test procedure. Polycarbonate strips are exposed to the chemicals during a certain period at induced stress levels and temperatures, to check the suitability of MAKROCLEAR® for use with the tested chemicals.

Test results are based on visual observations and physical testing of the bars before and after the exposure to the chemical.

The data published in this report are correct to the best of our knowledge.

If there is any question of the validity of the data, actual testing before using is recommended.

Following are some general guidelines on the chemical resistance of MAKROCLEAR® sheet.

Acids:

MAKROCLEAR® in general has a good resistance against diluted inorganic and organic acids. With acids in concentrated form care must be taken.

Bases:

MAKROCLEAR® will be chemically attacked ranging from partial to complete destruction of the polycarbonate by long-term contact with alkali and alkaline salts. Though MAKROCLEAR®, s hydraulic stability is limited; it is successfully used in continuous contact with water up to 50°C and can also be used for applications where regular sterilisation up to 120°C is required.

Salt solutions:

MAKROCLEAR® has a good resistance at room temperature to solutions of neutral and acid salts.

Alcohols and Glycols:

In general compatibility with MAKROCLEAR® is good when using alcohols, except for methanol; however, high temperatures in combination with high stress levels should be avoided.

Ethers:

Most ethers can be used with MAKROCLEAR® in stressless condition for short contact, e.g. dip treatment.

Aromatic, Halogenated, Per chlorinated Hydrocarbons:

MAKROCLEAR® will be affected by most of these chemicals. It is readily dissolved by certain halogenated solvents, such as Methylene chloride, 1.2 dichloroethane are the most common choice for solvent cementing and casting. Plasticization and crystallisation can result from contact with aromatic and per chlorinated hydrocarbons.

Aliphatic Hydrocarbons:

MAKROCLEAR® shows good compatibility with many aliphatic hydrocarbons.

Esters:

Most Esters will affect MAKROCLEAR® resulting in plasticization and crystallisation.

Ketones:

Depending on the ketone type these chemicals will dissolve and degrade MAKROCLEAR® even with short time contacts.

Oil and greases:

Mineral oils without aromatic and naphtenic components are harmless to MAKROCLEAR®. However, some mineral oils and greases may contain additives and dopes which can attack MAKROCLEAR®.

Many synthetic oils and greases do attack MAKROCLEAR®.

Silicone oils do not attack MAKROCLEAR® in most cases. However with these lubricants also some exceptions have been found.

# Fabricating



Back to contents

## 1 General

Top

### General guidelines

MAKROCLEAR® sheet can be worked with most tools used for machining wood or metal. Tool speeds should be such that the sheet does not melt from frictional heat. In general, the highest speed at which overheating of the tool or plastic does not occur will give the best results. Allow for sufficient clearance so that only the cutting edge contacts the material.

It is important to keep cutting tools sharp at all times. Hard, wear-resistant tools with greater cutting clearances than those used for cutting metal are suggested. High-speed or carbon-tipped tools are efficient for long runs and provide accuracy and uniformity of finish.

Since plastics are poor heat conductors, the heat generated by machining operations must be absorbed by the tool or carried away by coolant. Note however that MAKROCLEAR® is not compatible with most coolants and cutting oils, therefore we suggest a jet of compressed air directed on the cutting edge aiding the cooling of the tool and removal of chips.
Plain water without additives or soapy water is sometimes used for cooling unless the trim scrap is to be reused.

MAKROCLEAR® sheet is provided with polyethylene masking on both sides to avoid damage to the polished surfaces during transport and processing. The protective masking should be left on the sheet during machining and subsequent installation. However, remove the masking immediately after installation. Failure to do so could make removal at a later stage extremely difficult: exposure to sunlight, surface erosion, humidity and temperature changes will degrade and embrittle the polyethylene masking.

## 2 Sawing

Top

### Circular saw

The table saw is the most used type for sawing flat sheet. Sawing thinner gauges (below 2 mm) may display a cracked edge due to vibration of the sheet. This can mostly be solved by sawing stacks of ±16 mm using a thicker sheet or strip (3 mm) beneath as a support (use either MAKROCLEAR®, MDF PVC foam or material of similar rigidity). When sawing thin gauge sheet, decrease saw speed, feed rate and pitch. Keep the gap between blade and table as small as possible. Carbide-tipped circular saws with alternate bevel are preferred.

Ensure that the table is free of particles that may damage the masking and scratch the MAKROCLEAR® sheet. For sawing single sheet thinner than 2 mm, shearing is preferred to sawing.

### Band saw

Band saws are used to cut out formed parts and irregular shapes. For a series of the same shape, a supporting calliper can be useful in preventing chipping.
Thicker gauges are best sawn with a bigger tooth size.
To achieve a smooth edge, circular saws and routers are preferable to a band saw.

| | band saw | circular saw |
|---|---|---|
| clearance angle | 20 - 40° | 10 - 30° |
| rake angle | 0 - 5° | 5 - 15° |
| tooth angle | - | 15 ° |
| Cutting speed (m/min.) | 600 - 1000 | 1000 - 3000 |
| tooth distance (mm) t (larger for thicker sheet) | 1.5 - 3.5 | 2 – 10 |

### Trouble shooting

Chipping: Increase blade tooth size and saw speed, decrease feed rate.

Gumming: Decrease blade tooth size and saw speed, increase feed rate.

Cracks or notches: As for chipping, check clamping.

In all cases, inspect blade sharpness, check blade fence alignment and if needed use air to cool blade. Change of sound or vibration during sawing, is an indication that sharpness and/or alignment might have changed.

## 3 Routing

Top

Routing is especially recommended for trimming workpieces. Always use routers of at least 750 Watts, and a speed of 18 000 to 25 000 rpm is preferred. Bits should be straight fluted preferably two-fluted, carbide-tipped, or high-speed steel, with a diameter of 4 to 12 mm. Always feed counter rotation-wise up to 1.5 m/min, and cool with compressed air only.

Manufacturers of routers:
Geiss Thermofoming, Max Mayer , Pacer Systems Limited

## 4 Shearing, punching & die cutting

Top

Shearing and Punching
Shearing will produce linear straight-edged cuts, while punching and blanking can produce a variety of shapes. These fabrication methods can be used on MAKROCLEAR® sheet up to 3 mm. For thicker sheet, routing is preferable to above mentioned techniques.
It is important to adjust the blade clearance in relationship to the bed knife. A clearance of approx. 0,025 mm is desirable to avoid a rough edge cut. Cracking and chipping can be reduced by heating the sheet to max 45°C; however, some allowance for hole shrinking due to cooling may be necessary. Stack shearing of MAKROCLEAR® sheet is not recommended, but when done use clamping bar covered with industrial felt, and allow a peel cut of 0.5 mm for better quality.

Die Cutting
This is a technique frequently applied to paper. MAKROCLEAR® can be die cut up to 3 mm, with steel rule dies (A ribbon of steel bent to any desired contour and mounted in or around a block of wood). Blades of 0,8-1 mm thickness work well. The steel rule must be sharpened or replaced fairly often.

As for punching, allowance for shrinkage of the holes is necessary (up to 5%) if a thermal treatment follows the machining of the sheet. The tendency towards shrinkage decreases with increasing thickness and hole diameter. Symmetric double bevelled blades (15 & 30°) are recommended. For thicknesses above 1,5 mm asymmetric blades should be used. To obtain straight edges, one side bevelled blades under 30° must be used.

Keep the back-up pad, made out of polyamide (PA) or high density polyethylene (HDPE), in good shape and ensure a perfect alignment of the die and the pad to obtain appropriate cuts.
Adequate power in the die press is needed to achieve the desired cut.

The die press tonnage can be calculated using following formula:

$$F(\text{Tons}) = \sigma \times t \times P / 10\,000$$

$\sigma$ = Shear strength = 33 (MPa)
t = thickness in mm
P = Perimeter of cut in mm

Manufacturers of shearing, punching & die cutting machines:
Sandt AG, Polar Mohr

## 5 Drilling

Top

Drills designed for plastics are recommended, but standard twist drills for metal will do the job as long as they have not been used on metals before, though they require slower speeds and feed rates to produce a clean hole. For deep holes, in the edges of thicker gauge sheet for example, cool with compressed air and frequently back out the drill to free chips and prevent melting of them. Never use cutting oils. Like other transparent plastics, MAKROCLEAR® is a notch-sensitive material and cutting threads develop stress points that can create stress crazing or cracking.
For large holes, commercially available clock cutters can be used. Always keep a distance from the edge, minimum 1,5 times the diameter of the hole. Be sure drilled holes are smooth with no evidence of cracks or roughness, to avoid breakage when fastening.

It is recommended not to use countersunk screws/bolts with MAKROCLEAR® sheet. (see mechanical fastening)

| | |
|---|---|
| clearance angle | 5 - 15° |
| rake angle | 0 - 5° |
| top angle | 110 - 130° |
| helix angle | 30° |
| cutting speed | 15 - 60 m/min. |
| feed | 0,1 – 0,3 mm/rev |

## 6 Tapping

Top

Be aware that tapping will create notches in the part, which might decrease local impact resistance and stress resistance.

Conventional 4-flute taps can be used for cutting internal threads in plastic sheet when a close fit is required. Such taps, however, have a tendency to generate considerable heat during the tapping operation. A high-speed, 2-flute tap will offer longer life and greater tapping speed than a conventional tap, and provide clearance for chip discharge. In order to obtain uniform thread, flutes should be ground so that both edges cut simultaneously. Cutting edges should be 85° from the centreline, giving a rake of minus 5° on the front face of the lands so that the tap will not bind in the hole when it is backed out. It is desirable to have some relief on the sides of threads.

## 7 Milling

Top

Standard high-speed milling cutters for metal achieve best results, provided they are sharp (not been used on metal before) when applied on.
Typical parameters are 500 rpm and feed of 0,25 mm/rev.

## 8 Laser cutting

Top

Lasers can be used to cut MAKROCLEAR®, giving undiscoloured edges up to 1.5 mm thickness. Thicker gauges will show a light brown to dark brown burnt edge; the result of the cut depends on the installation and its parameters. Preliminary cutting-tests are recommended. Laser power and travel speed must be optimised to minimise 'whitening' of the MAKROCLEAR® sheet while cutting. Fumes coming off during cutting might smell unpleasant and therefore it is recommended to use appropriate exhaust systems, preferably with active carbon filtering.

Do not to induce stress into freshly laser cut sheet (e.g. cold forming), as breakage might occur. Therefore it is recommended to anneal the sheet (max 50 °C) or stock it for some time (min 1 week) prior to the brake forming
A 2 mm MAKROCLEAR® sheet absorbs about 50 % of the capacity of a $CO_2$ laser.
Excimer-Lasers also perform very well with MAKROCLEAR®, but only a few types are available for industrial use.
Nd-YAG lasers are not effective, because of the transparency of MAKROCLEAR® for wavelengths in the visible range, unless wavelength doubling is used.

# Forming



All techniques mentioned in this chapter are applicable to all Arla plast AB polycarbonate sheet grades, with exception of SAPHIR™, which can be used for flat glazing only. Its hard and scratch resistant surface does not allow for any forming techniques.

Back to contents

## 1 Cold forming

Top

### Cold curving

MAKROCLEAR® can be cold curved with a minimum radius of 175 times the gauge thickness for outdoor applications, and 125 times the thickness for indoor applications. When smaller radii are needed thermoforming is the solution.

## Cold bending & Brake forming

Brake forming can be done on standard sheet metal brakes, but preferably on table folding machines, especially for thicker sheet.
When brake forming MAKROCLEAR® sheet over 6 mm, stress levels are too high and failure can occur. The maximum angle which can be formed depends on the sheet thickness, and is limited by the internal stresses due to the forming. Preferably, the forming should be done parallel to the extrusion direction. Note that a number of properties including chemical resistance and impact resistance will decrease due to the increased internal tensions. Annealing can reduce these residual stress levels (see below).
Due to relaxation immediately following the bending, an overbend of approximately 25° is required. If possible, allow the sheet to relax for a few days after bending before assembling it.
In general, hot line bending is preferable to brake forming.

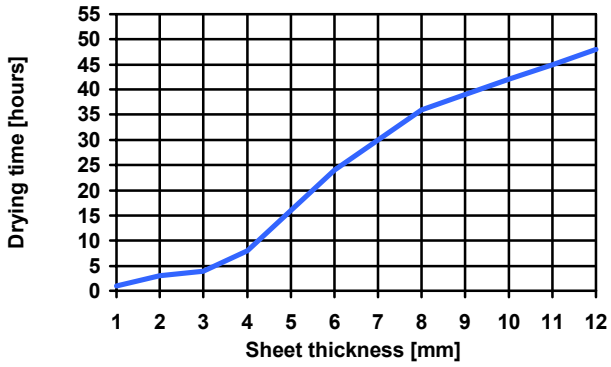
Manufacturers of cold bending & brake forming presses :
R Clarke & Company Ltd, Haubold Technik, Jürgen Schönwolff, Reichel GmbH,

## 2 Thermoforming

Top

## Pre-drying

In spite of the very low moisture absorption which contributes to the good dimensional stability of MAKROCLEAR® sheet, thorough pre-drying of sheet stock is essential for all thermoforming techniques in which the sheet temperature will rise above 160°C. Failure to do so will probably result in moisture blisters.
The recommended procedure is to use an air circulating oven set at 120-125°C. After removal of the protective masking the sheet should be suspended, put upright or laid flat on racks in the oven. Make sure that the sheets are arranged 20-30 mm apart so that the air can circulate freely between them.
Note that it is also possible to pre-dry with the masking on. In that case it is recommended that temperature should not exceed 90°C in order to avoid sticking problems. In that case drying temperature is much longer.



Pre-dried sheet should, if possible, be left in the oven until immediately before forming to save heating power and heating time on the thermoforming machine. The minimum drying time depends not only on the sheet thickness, but mainly on the moist content. A simple test can be done to obtain optimum drying time: place a part of the dried sheet into an oven at 180°C for 10 minutes. If bubbles appear, the sheet is not fully dried, and process needs to be maintained. As soon as no bubbles appear no more, optimum drying time is set.

Fully dried sheets taken out of the oven and cooled down to room-temperature may be used within a period of 1 hour up to a maximum of 10 hours (depending on the relative humidity and temperature of the work-shop) without the necessity of pre-drying them again.
When preparing a blank for a thermoformed MAKROCLEAR® part, remember that the sheet shrinks the first time it is heated above the glass transition temperature of about 148°C. Shrinkage up to a maximum of 10% (for thin sheet) can be expected, unless the sheet is clamped in a frame.
Before starting the heating and thermoforming operation, the MAKROCLEAR® sheet should be cleaned by means of an anti-static cleaning agent or an ionised air gun. This is necessary to avoid marks on, or even imbedding of dirt or dust particles in, the final article.

Take care while heating the sheet. Heating too fast will result in heat accumulating at the sheet surface and degrade it. The most appropriate heaters are infra red heaters. Contact heating and high-frequency heating are not suitable. Halogen heaters are only suitable for coloured sheet.

## Hot line bending

The Hot Line Bending equipment is a simple IR- or electrical resistance heater, bending-calliper coated with fabric and a clamping device.
It is preferred to remove the masking, as forming occurs at 150-160 °C, but in order to keep the finished part protected, remove the masking locally but avoid cutting the sheet surface. In some cases the masking can stay on the sheet during the entire process. Perform a preliminary test to find out the correct heating time. For sheet up to 2 mm pre-drying might not be needed. However, if bubbles occur on the edges, place some insulating material against the edges.
If inner angles are smaller than 45° the masking should be removed on the inner side. Whenever possible, form with the unprinted masking on the outside.
The heating time depends on the power of the IR heaters. With one side heating, it takes about 2 min to make a 3 mm sheet weak enough to bend. Thicker sheet need to be heated from both sides. If not available, turn periodically during the heating cycle. Always bend the sheet with the last heated side forming the outside radius.

When MAKROCLEAR® softens, remove from heating source, bend, place into calliper and clamp.
Cool slowly to prevent distortion. Keep the part close to the heating device to make it cool down evenly and reduce tensions. Once the part is at about 145 °C, it can be placed in a fixing device and cool down in the air.

Manufacturers of hot line bending machines:
R Clarke & Company Ltd, EFC, Shannon BV

## Drape forming

Uni-axial or slightly curved 3D bent parts can be achieved by drape forming. The mould, preferably pre-heated to 80-100°C - can be made out of wood or aluminium covered with felt. Slight pressure (with soft gloves or cloth, e.g. linen) is sufficient to drape the MAKROCLEAR® sheet over a positive mould. An alternative method is to place the flat sheet on the mould, foreseen with a load to push the sheet in place when getting soft. Then place mould and sheet in an oven.

Remove standard masking before putting into an IR oven to be heated. Preferably the sheet should be clamped in a frame or hung, as placing it on a bed might mark the sheet. The sheet temperature should be about 170°C to achieve easy forming. Place sheet on the mould immediately after heating; therefore minimise distance between mould and oven. Cool in surrounding air, but take care for drafts which could cause distortion of, and stress in the finished parts.

In most cases it is not needed to pre-dry the sheet for the drape forming process. Note that, as the sheet is not framed during the process, it will shrink during the heating process (for thin sheet up to 10% in extrusion direction)

## Vacuum forming

Because of its good flow properties, MAKROCLEAR® sheet, allows you to make complex finished parts. Draw ratios of 3:1 can be achieved.
Standard available vacuum forming machines, preferably with a sandwich heating system can be used to form MAKROCLEAR® sheet.
MAKROCLEAR® requires a minimum vacuum of 500 mm Hg (0,66 atm = 0,066 MPa), but higher vacuum is preferred.

Moulds

For long production runs and/or when optical quality is required, use temperature controlled (120 - 130°C) aluminium or steel tools. For prototypes or limited production work, tools made of plaster, hardwood, reinforced epoxy or polyester resins may be used.
Allow for moulding shrinkage of 0.8 to 1%.
For good evacuation of air, it is important to make an optimum number of holes in the right locations. To avoid marks on the final moulding, these vent holes should not have diameters larger than 0.5 - 0.8 mm. Back drilling with larger drills is suggested to speed up air evacuation.
Depending on series to be produced and the required finish of the parts, one can use different mould materials. Be aware that the mould material affects both cooling time and finish of the formed parts.
Design moulds with such roundings (minimum equal to sheet thickness) that the MAKROCLEAR® can slip over without risk for thinning and webbing. A good release of the moulding can be obtained by providing a draft angle of 4 - 6°. For a good evacuation of air, it is important to make an optimum number of holes in the right places. Inadequately placed holes might cause optical defects on the formed parts. This may occur especially on parts with large flat surfaces.

Negative and positive mouldings

Negative moulds result in finished parts with a thin bottom and thick walls, whilst positive moulds result in parts with a thick bottom and thin walls. Depending on the application, either a positive or a negative mould should be built. For better external finish use negative moulds which show more detail.

Understand that MAKROCLEAR® reproduces every detail, badly finished moulds included. This can be reduced by either refinishing the mould or by reducing the mould temperature and/or the sheet surface temperature.

Heating
Remove standard protection masking prior to thermoforming, and blow off the sheet with ionised pressurised air.
When clamped on 2 sides only (e.g. in automatic feeders) be informed that the free side might shrink (see drape forming). Therefore 4 side clamping is preferred. If a heating profile is available, it is recommended to adjust it as such that when pre-blown, the sheet forms the same shape as the mould. That way the best thickness spread is obtained. It is also recommended that the systems used to support and clamp the edges of the sheet should also be heated, to avoid significant heat losses during heating as well as uneven cooling which could result in internal stresses or edge warping.
To improve the thickness gradient the sheet can be blown or mechanically pre-formed by means of a plug.

MAKROCLEAR® sheet requires between 175 and 210°C to form most structures.
It is recommended to supply minimum 30 kW/m² as heating power, but if present power is not sufficient, it might help to insulate the process with heat-reflecting material. One side heating is not recommended for sheets of 3 mm and above. To prevent surface degradation, avoid fast heating. The sheet can only absorb part of the IR radiation and accumulation of heat will damage the sheet and embrittle the formed part.

Cooling the formed part
Cool with compressed air; possibly with water mist (avoid droplets as they might cause marking). Let the part stiffen sufficiently and take it from the mould. MAKROCLEAR® sheet cools rapidly, and because of this it requires rapid forming. At the same time, however, its high heat deflection temperature under load enables short cooling cycles to be achieved. The mouldings can be removed from the mould with little risk of deformation as soon as they have cooled down to about 135°C. Mould shrinkage of MAKROCLEAR® is about 0,8%. Using positive moulds, this might cause removal problems. Take care to remove before the part shrinks on the mould. Do not cool too fast, because the generated stresses may result in cracking.
If necessary, annealing can be done.

Manufacturers of vacuum forming machines:
Adolf Illig Maschinenbau GmbH & Co KG, Brown Machinery LLC, Formech Ltd, Jürgen Schönwolff, Maschinenfabrik Georg Geiss, Meaf Machines BV, Meico srl – T.S.T., Kiefel GmbH, Reichel GmbH, Shelley Thermoformers International Ltd.

## Free forming
These techniques are utilized in forming dome shapes. Free blown billow forming uses air pressure while free drawing uses a vacuum.

The sheet is heated until a sag is formed. An optical switch and/or a micro-switch are coupled with the pressure (vacuum).The initial pressure (vacuum) is high (2,8 MPa or more) and is lowered towards the end of the forming cycle. The pressure (vacuum) is held until the sheet temperature reaches 135°C and the forming is able to be removed. Here will be no mark-off as no moulds are used, but dirt or oil in compressed air may cause marks on the sheet.

### Plug-assist vacuum forming

Corner or periphery thinning of box-shaped articles can be prevented by use of a plug-assist to mechanically stretch and pull additional plastic material into the female cavity. The plug should be 10 to 20 % smaller than the mould and should be heated to ca 170-180°C. Once the plug has forced the hot sheet into the mould cavity, air is drawn from the mould to form the part.

### Other methods

Other thermofoming methods are combinations of above mentioned ones. Plug-assist vacuum forming and plug-assist pressure allow deep drawing and permit shorter cooling cycles and good wall thickness control. Both processes require close temperature control and are more complex than straight vacuum forming. High pressure forming (HPF) and Twin sheet forming (TSF) are two advanced methods which for small to average series can compete with injection moulding and blow moulding.

High Pressure Forming

Using a negative mould, the atmospheric air pressure that spreads the softened sheet over the mould, is increased by pressurised air up to 1 $N/mm^2$ (10 $Kgf/cm^2$).

Twin Sheet Forming

Two heated sheets are brought between two negative moulds. Air pressure in between those sheet is applied while the circumference of the sheet is clamped. An alternative technique forms the upper and lower part seperatly, and both parts are brought together, the circumference is reheated to obtain fusion of both parts. This technique creates hollow shapes, to obtain light parts with high structural stiffness.

## 3 Annealing

Top

Whenever possible, use the optimum processing conditions to minimise the creation of internal stresses.
Parts with too high internal stress levels should be annealed to avoid failure in service. This can be done by heating the parts evenly in an air circulating oven up to 120 - 130°C, at which temperature they should be kept for 1 hour for every 3 mm of the part thickness. Then the part should be cooled slowly to room temperature, preferably in the oven with the doors closed.

## 3 Trouble shooting

Top

| Problem | Possible cause | Solution | Hot line bending | Drape forming | Vacuum forming | Free forming |
|---|---|---|---|---|---|---|
| Crazed or weak parts | sheet too hot | reduce heating | | | x | x |
| | mould too cold | increase mould temperature | | | x | |
| | part removed too late | shorten cooling cycle | | | x | |
| | vacuum rate too fast | restrict vacuum | | | x | |
| | sharp edges | round corners | | | x | |
| | sheet surface too small | use bigger sheet | | | x | |
| Webbing | uneven heating | check for hot spots or shade spots | | | x | |
| | mould spacing too small | min. spacing = 2 x depth | | | x | |
| | vacuum rate too fast | restrict vacuum | | | x | |
| | sheet surface too big | clamp-mould spacing < 50 mm | | | x | |
| Reduced or incomplete details | too small vacuum | check for leaks | | | x | |
| | | add vacuum holes | | | x | |
| | sheet temperature too low | increase heating | | | x | |
| Part sticks on to mould | mould too hot | reduce mould temperature | | | x | |
| | part removed too late | remove earlier | | | x | |
| | draft angle too small | draft angle should be> 6° | | | x | |
| Mark-off | mould surface too smooth | Sand surfaces | | | x | |
| | sheet temperature too high | reduce heating time | x | x | | |
| | edges: masking came off | cut sheet with unprinted masking up | | x | | |
| | vacuum holes at the wrong place | redesign vacuum holes | | | x | |
| Surface defects | vacuum holes at the wrong place | redesign vacuum holes | | | x | |
| | dust on mould or sheet | clean with compressed air | | x | x | |
| Unequal parts | mould/clamp too cold | increase pre-heating | | | x | |
| | uneven heating/cooling | check for drafts, check heater | x | | | |
| | part removed too late | remove part sooner | | | x | |
| Brittle parts | overheated parts | decrease heating power | x | x | x | x |
| Cracks or breakage | stresses too high | heat slower on wider area | x | | | |
| Bubbles in the sheet | too much heat | reduce heating | x | | x | x |
| | moisture | pre-dry | x | x | x | x |

# Bonding & Fastening



Back to contents

## 1 Solvent bonding

Top

**Use extreme caution when working with solvents: they may be toxic or contain carcinogens. Adequate ventilation is essential. Obtain Safety Data Sheets from the solvent manufacturer.**

This technique is not applicable on SAPHIR™ because of its enhanced chemical resistance. Routing off the hard coating is an alternative, but local swelling due to solvent attack might alter the properties of the coating.

Furthermore it is not recommended to use solvent bonding for bonding two different substrates; adhesive bonding is more appropriate here.

Also note that the use of solvents might decrease properties of the substrates.

Solvent bonding has been used for years to make displays from acrylic sheet, but can also be used to construct three-dimensional shapes with MAKROCLEAR® sheet.
To bond small pieces, one can use a hypodermic needle and making sure that the solvent flows throughout the area to be cemented.
Edge dipping is another method used to assemble two flat parts under a 90° angle. The edge of the sheet which is to be bonded is dipped in the solvent until it becomes soft. Then it is put on the flat sheet under slight pressure. The jointed articles can be safely placed on a table to dry after the solvent has been applied. Special care should be taken that no air bubbles are left after curing. Both methods depend on smooth edge preparation, pressure and curing.

To eliminate the solvent presence, maintain the article under pressure at 80-90°C for six hours. If the article is to be exposed to higher temperatures or to boiling water for short periods of time, the parts must be kept at 120°C for five hours.

| Suitable solvents | Boiling point |
|---|---|
| Methylene dichloride | 40,5 °C |
| Acetone | 56,5 °C |
| Chloroform | 61,1 °C |
| Tetrahydrofuran (THF) | 66,1°C |
| Trichloroethylene | 87,0°C |
| Cyclohexanone | 155,0°C |

When using solvents it is advisable that the work area be climate controlled with low humidity to minimise joint 'whitening'. If this is not possible, the addition of 10 % glacial (> 99.8%) acetic acid (boiling point 116.5 °C) to the solvent or use of a slower curing cement-type bond is suggested. Solvents with a low boiling point may cause whitening or insufficient softening of the treated surface which results in improper joints.
To prevent early evaporation, use mixtures of the above mentioned solvents or dissolve MAKROCLEAR® chips (e.g. saw dust) or granules in one of them to increase boiling point.

When using a solvent in which 8% of MAKROCLEAR® chips have been dissolved, the curing time is longer, allowing you to adjust the position of the two parts to be bonded, and preventing them from whitening.

To obtain above mentioned solvents contact local chemist or drugstore, or check for specialty chemicals suppliers like www.brenntag.com

## 2 Adhesive bonding

Top

### When working with adhesives, the usual safety and health precautions should be taken and eventual special instructions from the adhesive manufacturer should be observed.

This technique is not applicable on SAPHIR™ because of its enhanced chemical resistance. Routing off the hard coating is an alternative, but local swelling due to solvent attack might alter the properties of the coating.

Also note that the use of solvents might decrease properties of the substrates.

Adhesive bonding is interesting for gap-filling bondings, which is not possible with the solvent bonding technique. Also, adhesive bondings mostly are more flexible than solvent bondings. A lot of commercial adhesives have proven their effectiveness for bonding MAKROCLEAR® (to MAKROCLEAR® or other materials).

In general, one need only consider the first five types of adhesive listed below, as these are suitable for virtually all types of engineering assembly work and, unlike most of the others, they do not generally need sophisticated equipment.

Essentially there are 12 basic adhesive types which cover nearly all requirements.

1-Anaerobics: Often known as ‘sealants’ or ‘locking compounds’. Mainly acrylic based, they will normally set in the presence of metal and absence of air (atmospheric oxygen). They are generally used to lock or seal and retain all manner of turned or threaded parts and are often used to seal flanges.

2-Cyanoacrylates: also based on acrylic resins. Unlike anaerobics, they require surface moisture as the vital catalyst in hardening. Generally, they harden in seconds. Often used for bonding small parts and rubber.

3-Epoxies: based on an epoxy resin which is mixed with a hardener. This allows great variety in formulation; their strength is often employed in bonding larger components. Single part epoxies (ESP) - resin and hardener are pre-mixed so they give high performance without mixing by the user.

4-Toughened variants: toughened adhesives incorporate low molecular weight rubbers that build in exceptional resistance to peel and impact forces. Most adhesive types (Acrylic-based, epoxy and epoxy single part (ESP)) can be toughened in this way. ‘Toughening’ reinforces the best features of these adhesives with the unique shock absorption and strength of the rubber matrix.

5-UV Adhesives: These cure under exposure to UV light (some types even to visible light). Due to their extremely fast cure speeds they can be easily incorporated into high speed production lines.

6-Hot melts: a refined form of the earliest adhesive — hot wax. They are used for assembling small, lightly loaded parts for use in less severe environments. However, they are too viscous for use on small parts.

7-Phenolics: one of the earliest types of structural adhesive. Their use often involves specialised equipment and complex procedures. Nevertheless, they perform well in severe environments,

8-Plastisols: based on PVC dispersions. They cure only at elevated temperatures, and are generally used only on large scale work or where there is access to a heat source, intended for another purpose.

9-Polyurethanes: like epoxies, they offer variety in formulation. However, polyurethanes are difficult to handle and usually require specialised mixing equipment generally used for bad bearing applications in dry conditions — as they are prone to moisture attack. Transparent types suit well for polycarbonate.

10-Rubber adhesives: based on a rubber solution, where the solvent evaporates to effect bonding. Not suitable for loaded joints or harsh environments.

11-Tapes: adequate for bonding small components but cannot support heavy loads. Some will withstand quite harsh environments.

12-Silicones: At present, silicones in combination with polycarbonate sheet is mainly used in glazing and building. Such silicones should be of a neutral type. Also for SAPHIR®, adhesion will be sufficient for building applications.

Material to be bonded: Adhesives can bond virtually every material in common engineering use. Nevertheless, it's sensible to avoid materials troubled by weak or loose surface layers, stress cracking, solvent attack and water migration. Where there is no substitute for untreated aluminium, cadmium, magnesium zinc, Flexible PVC, unprepared glass, polyacetals, polyethylene, polypropylene and PTFE, performance may be improved by appropriate techniques.

Adhesives on polyurethane or acrylic (toughened) basis give mainly good results. Take into account that stresses in the sheet or parts in combination with solvents or adhesives may cause cracking. Cut and finish the surfaces to be bonded carefully.

Two component polyurethane adhesives, which exist in a clear transparent grade or transparent UV curables, are the best transparent types. Fast curing cyanoacrylics seem transparent, but often cause whitening.

Note that there is no universal glue. Applicable glue type depends on the application: substrates to be bonded, temperature, humidity, UV resistance, fixed load – shocks or vibrations, bonding speed, bonding surface...

Also keep in mind that rigid, hard adhesives might cause part breakage due to crack propagation.

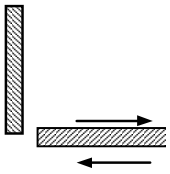
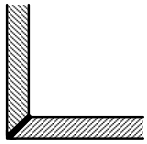
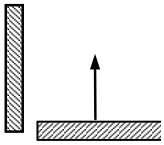
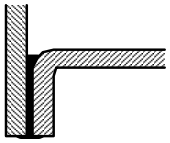
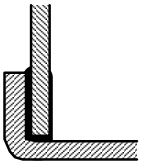
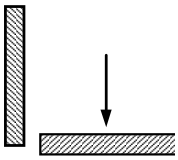
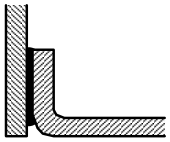
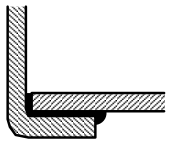
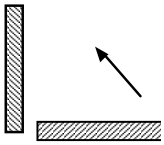
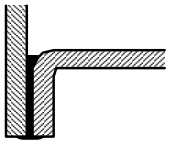
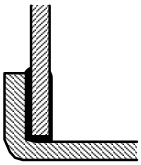
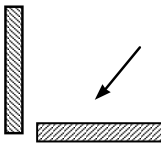
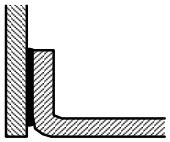
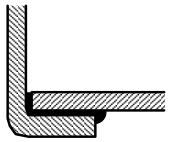
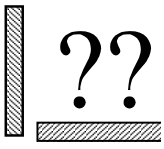
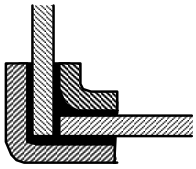
Manufacturers of adhesives:
Agomet Klebstoffe GmbH, Bostik Findley B.V., Engineering Chemicals BV, Kömmerling Chemische Fabrik KG, Loctite Corporation, Lord Corporation (Europe) Ltd., Meco GmbH, National Starch & Chemical NV , Bison International bv, Permabond, Rectavit NV, Ruderer GmbH, UHU GmbH, Vantico

## 3 Recommended bonding designs

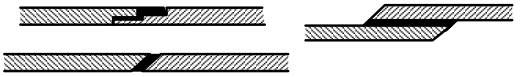
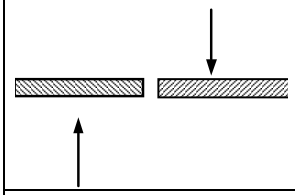
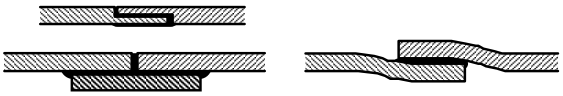
Top

Joint design, often overlooked, should be such that the bonding area carries the load equally, with the major stresses in tension or shear thereby minimising cleavage and peel stresses. The lap joint is the most frequently encountered joint type when working with relatively thin gauge materials.

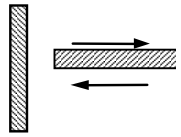
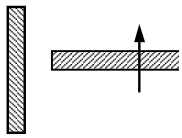
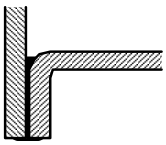
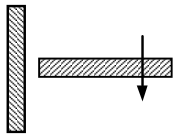
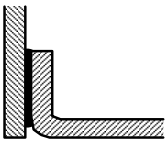
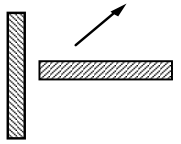
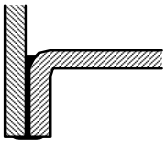
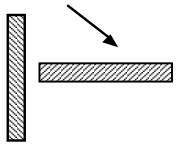
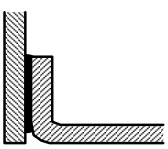
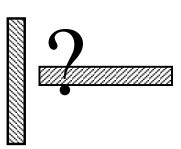
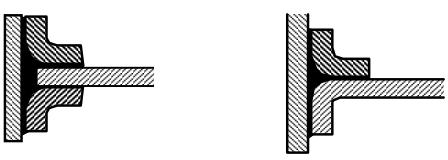
*Angular connection*

| Direction of forces | Recommended construction |
|---|---|
|  |  |
|  |   |
|  |   |
|  |   |
|  |   |
|  |  |

*Flat connection*

| Direction of forces | Recommended construction |
|---|---|
|  |  |
|  |  |
|  |  |

*T-shape connection*

| Direction of forces | Recommended construction |
|---|---|
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Top

## 4 Tape bonding

Double sided self adhesive tapes, transparent and mostly on an acrylic basis, can be used to make quick fastenings. These tapes are elastic and stick to different materials. They can be quite useful in bonding thin sheet materials to other plastics, glass or metals.
Use following procedure to make proper bondings:
- Bend along the part for more than tape width.
- Clean this zone with a 50% Isopropyl alcohol - water solution.
- Pressing with wooden roller evacuates trapped air and improves strength.

Manufacturers of bonding tapes:
3M Company, MACtac Europe S.A., Scapa Tapes

Top

## 5 Mechanical fastening

Due to its high impact resistance, all types of mechanical fastening can be applied, depending on thickness of the MAKROCLEAR® sheet
Up to 1,5 mm, it can be nailed, stapled or riveted. These kinds of fastening are not recommended for industrial applications.
The best way to fasten MAKROCLEAR® is to use screws with a cylindrical head. Never use screws with chamfered (conical) heads. They cause stress cracking. Drill holes 0,5 mm larger than the screw. The distance between the centre of the hole and the outer edge of the sheet should be at least 2 times the diameter of the hole, with a minimum of 6 mm. The screws should be tightened to a point which still allows the sheet to move under fluctuating temperatures. Screws of plastic can always be used. When using metal screws or bolts, use washers preferably plastic washers (nylon) . Metal thumbscrews can be used without washers, as tensions are limited.

Use galvanised types only.
Never use glue to tighten bolts.
No more than 2 extra twists after turning firm by hand.

Mechanical fastening will produce a stronger part than solvent bonded parts and allows for easier disassembly and cleaning.

Special care has to be taken to allow for dilatational movement in case of temperature changes during construction or application. For MAKROCLEAR® count for 3,5 mm per meter. Solutions are a.o. sleeve holes, flexible fastenings, clamping in gasket system (dry systems or plasticiser free neutral types), …

Ultrasonic insertion of internally threaded metal bushes can also present a suitable method of fixing MAKROCLEAR® articles or for attaching metal parts such as hinges, metal standard profiles, etc. to MAKROCLEAR® sheet. Window machine guards can also be clamped in EPDM rubber profiles, avoiding stress concentrations and maximising the impact strength of the machine guard.

## 6 Welding

Top

While mechanical fastening and solvent bonding are the most often recommended methods of joining MAKROCLEAR®, another alternative is welding. However, from an aesthetic point of view, welding is not the preferred assembly technique. Therefore it is mainly used to assemble opaque sheet products.

Ultrasonic welding and spin welding have both proven to be appropriate. High frequency welding is not suited. Contact manufacturers of ultrasonic welding equipment for recommendations on section and joint design.

Manufacturers of ultrasonic welding equipment:
Branson Ultrasonics Corp, Pfaff AG,

Also possible is hot air welding, using a welding rod made of PC or if not available locally, also a strip cut from a 3 or 4 mm MAKROCLEAR® sheet will work well. In both cases both the rod and the substrate should be pre-dried in order to avoid bubble formation. Typical parameters are: airflow at 350 - 400°C, measured at 5 mm from the nose and min. 100 mm/min feed in order to avoid material decomposition. Maximum welding zone is 300 mm to avoid severe shrinkage and excessive internal tensions with risk for breakage.

This technique is not suitable for SAPHIR™.

Manufacturers of hot air welding equipment:
Pfaff AG

# Finishing



Back to contents

## 1 Sanding

Top

The sheet edges can be sanded using both wet and dry systems. Dry sanding can result in gumming as frictional heat build-up is created. Wet sanding gives a smooth finish. In both cases, further finishing in order to restore the gloss will be necessary. In case of abrasive belts with synthetic resin bonding are used (for dry and wet sanding), a belt speed of 20 - 30 m/s and a low contact pressure are recommended

Example: start with 80-grit paper and end with 400 or 600-grit.

## 2 Polishing

Top

Polishing is a time consuming activity and should only be applied for smaller series and parts made out of thick gauge sheet. The edges can be polished by different techniques. Keep in mind the specific colour of MAKROCLEAR®: a glass clear edge will rarely be achieved.

### Mechanical polishing

After sanding, surfaces of MAKROCLEAR® sheet can be polished in order to obtain a better surface finish. Burnish wheels of cloth or fleece and felt polishing bands, together with a suitable polishing wax, give good results. Keep surface temperature low, in order to a later appearance of fine cracks.

Suppliers of mechanical polishing tools :
3M, EFC (US)

### Diamond polishing

MAKROCLEAR® sheet can be diamond polished resulting in an excellent surface quality that does not need further treatment. No pre-grinding step is required, as per step up to 0.5 mm can be removed.

Suppliers of Diamond polishing tools:
Shannon B.V., EFC (US)

## Flame polishing

Use a standard propane - or butane torch or a hot nitrogen welder. It is very important to control the distance between the sheet and the heat source. Without proper control, surface whitening or material flow of the MAKROCLEAR® might occur.
Instead of a torch, an electrical hot air device can be used. Typically 400-550 °C for 5 seconds moving at 100 mm can be used to remove scratches.

As with Acrylics, flame polishing MAKROCLEAR® sheet can cause long-term edge cracking. However, with continued practice and by using proper techniques, excellent results can be achieved.

## Solvent polishing

The appearance of saw-cut edges can be improved by first sanding them. For smoother, glossy edges, consider solvent polishing with Methylene dichloride. To prevent humidity blush after drying, add a small amount of a slow-drying component such as diacetone alcohol.

**Use extreme caution when working with solvents. Adequate ventilation is essential. Follow precautions in the Safety Data Sheets from the solvent manufacturer.**

# 3 Decorating

Top

Flat sheets can be screen printed, tampon printed, hot stamped or decorated with self adhesive films (thin cast films are preferred as they limit bubble formation, and are less subject to out gassing). Vacuum formed parts can be tampon printed or hot stamped.

The decoration of SAPHIR™ sheet is extremely difficult due to the chemical resistant properties of its surface.

Other common techniques are (spray) painting, laser marking and sand blasting.

## Hot stamping

MAKROCLEAR® sheet or formed parts made out of MAKROCLEAR® are easily decorated by hot stamping. Decoration can be done on single pieces (vertical stamping or roll-on stamping) up to continuous pieces. Special types can be thermoformed.

Typical conditions are:
Die temperature: 190 °C
Pressure: 0.4 N/mm$^2$
Dwell time: 2-3 seconds

Hot stamping foil / tools manufacturers:
Leonhard Kurz GmbH & Co, John T Marshall Ltd

## Screen printing

MAKROCLEAR® sheet can be printed with conventional printing equipment. In general, printing inks which are compatible with polycarbonate work well. Since the ink does not penetrate MAKROCLEAR® as it does with paper or fabric, it is subject to abrasion. This problem can be minimised by reverse printing or by applying a clear top lacquer over the printing.
All standard MAKROCLEAR® sheets have a static (glue free) polyethylene masking which is easy to remove. To avoid the so-called ghosting effect with metallic paints, it is recommended to print on the side with the non-printed masking. It is very important to ensure the sheet is clean and free from dust and dirt prior to screening. Use ionized air to remove dust.

In case of questions, please consult your ink supplier.

Following printing ink manufacturers have experience with our sheet:
Apollo colours Ltd ,Coates Screen Inks GmbH, Coates Screen inks Ltd, Diegel GmbH, Marabuwerke GmbH & Co, Pröll KG, Ruco Druckfarben, Sericol International, Unico NV,

# Cleaning

MAKROCLEAR® sheet may be cleaned by using a clean soft sponge and washing with lukewarm water containing a mild soap or a slightly acidic, neutral or slightly alkaline detergent. Then rinse thoroughly with clean water and dry with chamois leather or a moist sponge. A subsequent anti-static treatment is recommended.

Fresh paint splashes, grease, smeared glazing compounds, etc. can be removed before drying by rubbing lightly with isopropyl alcohol on a soft cloth followed by a thorough wash and rinse as described above. Rust stains can be removed with a 10% oxalic acid solution.
Do not use abrasive or highly alkaline cleaners, acetone, benzene, leaded gasoline or carbon tetrachloride on MAKROCLEAR® sheet. Never scrape with razor-blades or other sharp instruments.
Minor scratches can be removed or made less noticeable by polishing with hot air. (*see polishing*)

Having good electrical insulating properties, MAKROCLEAR® sheet is subject to electric static charge and dust attraction. Treatment with an anti-static agent keeps the sheet free from static charge and dust over prolonged periods.
There are some commercially available products which act simultaneously as cleaning agent and anti-static agent.
Before commencing certain operations on MAKROCLEAR® sheet such as painting, screen printing or thermoforming, it is recommended that dust particles be blown off first, using an ionised air gun. Dusting with a regular air gun or a cloth only moves the particles rather than removing them.

The protective coating of the SAPHIR™ sheet makes it more tolerant towards chemical attacks. Stains from ink, paint and marks from graffiti can be removed with products designed for this purpose (ask the supplier for the right graffiti remover). Always be careful not to scratch the surface of the sheet, and – in cas it is not compatible with polycarbonate – to avoid contact with non-coated areas.

Suitable cleaning solvents for MAKROCLEAR® at room temperature are water, white spirit, hexane, heptane, Ethyl alcohol, Butyl alcohol, isopropylic alcohol (also known as IPA or Isopropanol)

As far as cleaning in dish washing machines or rinsing devices is concerned, in order to remove bits of food and the remains of meals, care should be taken that the concentration recommended by the manufacturers, mostly 0,1-0,5%, of the normally strongly alkaline pre rinsing solution, is not exceeded and that the temperature will not rise above 60°C, better still 55°C. The rinsing cycle which follows, when usually weakly acidic or neutral active substances are contained in the water, can be carried out as usual at 80-85°C on account of the very short contact time (less than two minutes).

It is important when cleaning animal breeding cages made of Makroclear® that the litter is carefully removed. If an alkaline cleaning material is used, this must be rinsed off completely, as the following conventional sterilisation will otherwise leave dull marks on the surface.

In order to avoid scale deposits the water used in cleaning equipment should be demineralised. If in spite of this lime has formed on the surface of the product it is advisable to remove this, e.g., with dilute acetic acid.

# Material Safety Data Sheet

Back to contents

## 1. Chemical product and company identification

Product name: MAKROCLEAR® and MAKROLIFE®
Product description: Polycarbonate bisphenol A, extruded sheet.

Manufacturer/Supplier: Arla Plast AB
Box 33
590 30 Borensberg
Tel. +46-141-20 38 00
Fax. +46-141-414 30
Email : info@arlaplast.se

## 2. Composition/information on ingredients

Polycarbonate. This product consists primarily of high molecular weight polymers which are not expected to be hazardous.

## 3. Hazards identification

Hazard warning not required.

## 4. First aid measures

Skin: Not applicable

Eyes: Remove contact lenses. Flush well with copious quantities of water or normal saline for at least 15 minutes. Seek medical attention, if irritation persists.

Ingestion/inhalation: are not expected and therefore, no first aid procedures are required.

Specific case : Contact during thermoforming:
In case of skin contact with molten material, cool rapidly with water. Seek medical attention. Do not attempt to remove material from skin without medical assistance. Do not use solvent for removal. In case of irritation from inhalation of fumes, leave contaminated area and breathe fresh air. If coughing, difficult breathing or any other symptoms develop, seek medical attention, even if symptoms develop at a later time.
In case of skin contact with fume condensate, wash thoroughly with soap and water. If irritation develops, seek medical attention.
Burns should be taken care of as thermal burns; material will come off as healing occurs. Therefore immediate removal from skin is not necessary.

## 5. Fire fighting measures

Fire fighting: wear approved protective clothing and self-contained breathing apparatus.

Extinguishing media: Water spray and foam. Water is the preferred extinguishing medium.$CO_2$ and dry chemicals are not generally recommended because of their lack of cooling capacity which may permit re-ignition.

Hazardous combustion products: carbon monoxide, carbon dioxide and hydrocarbon fragments. Formation of traces of aliphatic and aromatic hydrocarbons, aldehydes, acids, phenol and phenol-derivatives may occur.

Condition of flammability: Requires a continuous flame source to ignite.
Explosion data impact sensitivity: Not applicable.
Static discharge: Not sensitive to static discharge.

**6. Accidental release measures**

General: Sweep up material and place in proper container for disposal or recovery.

**7. Handling and storage**

Handling: Ensure adequate ventilation or exhaust ventilation in the working area in case of fabricating. Dust must be removed by effective exhaust ventilation. Wear suitable gloves.

Storage: Inert material under normal storing conditions. No special precautions required.

**8. Exposure controls/ Personal protection**

Engineering controls: When heated up to high temperatures, virtually all thermoplastics emit fumes. The exact composition and concentration of these fumes depend on the resin formulation, heating temperature and heating time. Provide for good ventilation and local exhaust.

Personal protection:
Eye/face: Wear safety glasses with side shields or chemical goggles.

Skin: Avoid prolonged or repeated contact with skin. When thermoforming the product, wear long pants, long sleeves, well insulated gloves and face shield when applicable. Gloves should be worn when handling hot material.

Respiratory: Good industrial hygiene practice requires adequate general ventilation of the workplace. When dust and powder either from handling or from secondary operations, such as grinding, sanding or sawing are not adequately controlled, use respirator approved for protection from dust. When processing fumes are not adequately controlled, use respirator approved for protection from organic vapours and acid gases.

**9. Physical and chemical properties**

Physical state: Solid.(sheet form)

| | |
|---|---|
| Colour: | Colourless or colour dependent on colouring |
| Odour: | slight. |
| Boiling point: | Not applicable. |
| Density: approx. | 1,2 g/cm$^3$ at 20°C. |
| Evaporation rate: | Not applicable. |
| Explosive limits: | Not applicable |
| Flash point: | FIT > 450°C.(combustible solid) |
| Self Ignition temperature: | SIT > 450°C. |
| Melting range: | 220-230°C |
| pH: | Not applicable. |
| Vapour density (air=1): | Not applicable. |
| Vapour pressure (mmHg): | Negligible. |
| % Volatiles: | Negligible. |
| Water solubility: | Insoluble. |

**10. Stability and reactivity**

| | |
|---|---|
| Stability: | Stable. |
| Reactivity: | Inert. |
| Conditions to avoid: | Do not exceed melting temperature. |
| Hazardous reactions: | No hazardous reactions observed. |

**11. Toxicological information**

| | |
|---|---|
| Oral: | LD50 (rat) > 5000g/kg estimated |
| Inhalation: | LC50 not available. |
| Dermal: | LD50 not available. |

**12. Ecological information**

General: Not expected to present any significant ecological problems: no aquatic, germination or seeding effect.

Water pollution class (WGK): 0 -not generally hazardous to water.

WGK = Classification in accordance with the German Water Resources Act.

**13. Disposal information**

Waste disposal: This product is not regarded as hazardous waste. Dispose in accordance with local regulations. May be incinerated under controlled conditions.

**14. Transportation information**

General: This product is not subject to transport regulations.

**15. Regulatory information**

No labelling is required in accordance with the EEC directives.

In connection with dusts formed in consequence of mechanical treatment, e.g. grinding, the appropriate regulations/limits values for fine dusts must be observed.

MAK -values (fine dust): 6 mg/$m^3$.
OES – value : not established

During heating of this product the threshold limit values for chlorobenzene and phenol should be observed. Chlorobenzene and phenol are substances which come under TRGS 900 (technical regulation for dangerous substances).

MAK-value (chlorobenzene) : 10 ppm (46 mg/$m^3$)
MAK-value (phenol): 5 ppm (19 mg/$m^3$)

**16. Other**

This publication provides information and guidelines for safe handling and secondary fabrication of MAKROLIFE®, SAPHIR™ and Makrolife® and is based on currently available experience and knowledge.
The data does not signify any warranty with regard to the product's properties.

MAKROCLEAR® and MAKROLIFE® are registered trade marks and SAPHIR™ is a trade mark of Arla Plast AB.

# Material Properties

Back to contents

| Property | Unit | Value | Standard |
|---|---|---|---|
| **Physical Properties** | | | |
| Density | $g/cm^3$ | 1.2 | ISO 1183 |
| Light transmission (Light source D65, thickness 1 mm) | % | 88 | ASTM D1003 |
| Refractive index | | 1.586 | ISO 489 |
| Moisture absorption 24 hours, 23°C, 50%RH | % | 0.15 | ISO 62 |
| **Mechanical Properties** | | | |
| Tensile strength at yield | $N/mm^2$ | 63 | ISO 527 |
| Elongation at yield (at break) | % | 6(110) | ISO 527 |
| Modulus of elasticity | $N/mm^2$ | 2300 | ISO 527 |
| Charpy unnotched impact strength<br>+23°C<br>-40°C | $kJ/m^2$ | <br>NB<br>NB | ISO 179/2D |
| Izod notched impact strength +23°C<br>-30°C | $kJ/m^2$ | 65<br>10 | ISO 180/1A |
| Rockwell hardness | | M70 | ISO 2039-2 |
| **Thermal Properties** | | | |
| Linear coefficient of thermal expansion (23-40°C) | $10^{-6}$x $K^{-1}$ | 70 | ASTM D696 |
| Heat deflection temperature,<br>HDT A (1,80 $N/mm^2$)<br>HDT B(0,45 $N/mm^2$) | °C | <br>132<br>142 | ISO 75 |
| Thermal conductivity λ | W/m K | 0,21 | DIN 52612 |
| **Fire Properties** | | | |
| Fire classification according to UL94 | Class | HB | UL 94 |
| National fire standards | | | See below(°) |
| Oxygen Index | % | 26 | ASTMD2863-77 |
| **Electrical Properties** | | | |
| Volume resistivity, dry | Ω x cm | $10^{16}$ | IEC 93 |
| Surface resistivity, dry | Ω | $10^{15}$ | IEC 93 |
| Dielectric strength, dry (1 mm) | kV/mm | 30 | IEC 243 |
| Dielectric constant, dry 1MHz | | 2,9 | IEC 250 |
| Dissipation factor (tan δ), dry 1 MHz | | 0,01 | IEC 250 |

(°) A list of products that have been tested to national fire standards and their respective classification is presented at www.arlaplast.se. For latest information contact our technical support.

# Useful Addresses

Back to contents

3M Europe
Hermeslaan 7
B-1831 Diegem
Tel.: ++32-2-722 45 00
Fax: ++32-2-722 45 11
innovation@mmm.com
www.3m.com

Adolf Illig Maschinenbau GmbH & Co KG
Robert Boschstrasse 10
D-74081 Heilbronn
Tel. ++49-7131-50 50
Fax ++49-7131-50 53 03
info@illig.de
http://www.illig.de

Apollo colours Ltd
127 Nathan way
West Thamesmead business park
UK-SE28 0AB London
Tel ++44-20-88 54 00 17
Fax ++44-20-83 16 69 56
London@apollocolours.co.uk
http://www.apollocolours.co.uk

Bostik Findley B.V.
Postbus 303
NL-5201 AH 's-Hertogenbosch
De Voerman 8
NL-5215 MH 's-Hertogenbosch
Tel. ++31-73-624 42 44
Fax. ++31-73-624 43 44
info@bostikfindley.nl
www.bostikfindley.nl

Branson ultrasonics
Applied Technologies Group
41 Eagle Rd.
Danbury, CT 06813-1961
Tel : ++1-203-796 04 00
Fax : ++1-203-796 98 38
info@bransonultrasonics.com
www.branson-plasticsjoin.com

Brown Machinery LLC
330 N. Ross Street
Beaverton
USA-48612 MI
Tel 001-989-435 77 41
Fax 001-989-435 28 21
102557.2203@compuserve.com
www.brown-machine.com

Coates Screen Inks GmbH
Wiederholdplatz 1
D-90459 Nürnberg
Tel. ++49-911-64 220
Fax. ++49-911-64 222 00
info@coates.de
http://www.coates.com

Coates Screen inks Ltd
Cray avenue
St. Mary Cray
Orpington
UK-BR5 3TT Kent
Tel 0044-1689-89 96 66
Fax 0044-1689-87 82 62
Coates.screen@coates.com
www.coates.com

C.R Clarke & Company Ltd
Betws Industrial Park
Soundry Rd
UK-SA18 2LS Carmarthenshire
Tel. ++44/1269 590 530
Fax ++44/1269 590 540
sales@crclarke.co.uk
http://www.crclarke.co.uk

Diegel GmbH
Ernst-Diegel-Straße 1
D-36 291 Alsfeld
Tel. ++49-6631 78 50
Fax. ++49-6631 78 585
info@diegel.de
http://www.diegel.de

Dymax Europe GmbH
Trakehner Strasse 3
D-60441 Frankfurt am Main
Tel:++49-6971-65 20 58
Fax:++49-6971-65 38 30
dymaxinfo@dymax.de
www.dymax.com

Edge Finisher Company
16 Stony Hill Road,
USA-06801 Bethel CT
Tel: 001-800-625-5863
Fax: 203-796-7924
info@edgefinisher.com
www.edgefinisher.com

Engineering Chemicals BV
Van Andelstraat 7
NL-4650 AB Steenbergen
Tel. ++31-1675-669 84
Fax ++31-1675-611 18
e-chem@e-chem.nl
www.e-chem.nl

Formech Ltd.
Unit 4
Thrales end farm/lane
Harpenden
UK-AL5 3NS Hertfordshire
Tel ++44-1582-46 97 97
Fax ++44-1582-46 96 46
sales@formech.com
www.formech.com

Geiss Thermofoming
Industriestrasse 2
D-96 143 Sesslach
Tel.++49-95-69 92 21 0
Fax.++49-95-69 92 21 20
mail@geiss-ttt.com
www.geiss-ttt.com

Haubold Technik
Industriestraße 8
D-69 509 Mörlenbach
Tel. ++49-6209-88 19
Fax ++49-6209-53 53
Haubold-tgw@t-online.de
www.haubold-technik.de

Henkel Loctite Corporation
Adresses : see website
Email : see website
www.loctite-europe.com

John T Marshall Ltd
Canonbury Works
Dove Road, Essex Road
UK-N1 3LY London
Tel. ++44-20-7226 7957
Fax ++44-20-7704 9885
sales@johntmarshall.co.uk
www.johntmarshall.co.uk

Jürgen Schönwolff
Reparaturtechnik, Apparatebau
Solterbergstraße 30
D-32602 Vlotho
Tel. ++49-5228-549
Fax ++49-5228-74 56
info@schoenwolff.de
www.schoenwolff.de

Kiefel GmbH
Industriestraße 17-19
D-83 395 Freilassing
Tel. ++49-8654-78 0
Fax ++49-8654-78 490
w.eglseer@kiefel.de
www.kiefel.de

Kömmerling Chemische Fabrik KG
Adresses : see website
Email : see website
www.kömmerling.de

Leonhard Kurz GmbH & Co
Schwabacher Straße 482
D-90 709 Fürth/Bay
Tel. ++49-911-714 10
Fax. ++49-911-714 13 57
sales@kurz.de
www.kurz.de

Lord Corporation (Europe) Ltd.
Chemical Products Division
Stretford Motorway Estate
Barton Dock Road, Stretford
UK-M32 0ZH Manchester
Tel. ++44-161-8658048
Fax ++44-161-8650096
infoadhesives@lord.com
www.lordadhesives.com

MACtac Europe S.A.
Boulevard Kennedy
B-7060 Soignies
Tel. ++32-67-34 62 11
Fax ++32-67-33 05 74
mactac.europe@bemis.com
www.mactac-europe.com

Max Mayer
Maschinenbau GmbH - Werk I
Postfach 80 13
Flurstraße 34
D-89 218 Neu-Ulm
Tel. ++49/730 88 130
Fax. ++49/730 88 133 10
centrale@maka.com
www.maka.com

Marabuwerke GmbH & Co
Aspergestraße 4
D-71 730 Tamm
Tel. ++49-7141 6910
Fax. ++49-7141 691147
info@marabu.de
www.marabu.de

Meaf Machines BV
Industrieweg 10
Postbus 98
NL-4401 LB Yerseke
Tel. ++31/113 57 14 95
Fax ++31/113 57 12 56
office@meaf.nl
www.meaf.nl/sitemap

Meco GmbH
Radolfzellerstraße 56
D-78473 Allensbach
Tel. ++49-7533-16 11
Fax ++49-7533-44 35
service@meco-online.de
www.meco-online.de

Meico srl – T.S.T.
Via della Giardina 8
I-20052 Monza (MI)
Tel. ++39/39 27061
Fax ++39/39 2706235
sales@meico.it
www.meico.it

National Starch & Chemical
Adresses : see website
Email : see website
www.nationalstarch.com

Pacer Systems Limited
Gauntley Street
UK-NG7 5HF Nottingham
Tel. ++44-1159-88 77 770
Fax ++44-1159-88 77 88
Support@pacersystems.co.uk
www.pacersystems.co.uk

Bison international
Dr. A.F. Philipsstraat 9
NL-4462 EW Goes
Tel. ++31-113-24 82 48
Fax ++31-113-23 20 77
info@bison.boltongroup.nl
www.bison.net

Permabond
Woodside Road, Eastleigh
UK-SO50 4EX Hants
Tel. ++44-2380-629 628
Fax ++44-2380-629 629
helpline.asia@permabond.com
www.permabond.com

Pfaff AG
Postfach 3020
Königstraße 154
D-67 653 Kaiserslautern
Tel. ++49-631 2000
Fax ++49-631 17202
info@pfaff-industrial.com
www.pfaff-industrial.com

Polar-Mohr
Maschinenvertriebsgesellschaft GmbH&Co.KG
Hattersheimer Straße 25
D-65719 Hofheim
Tel: +49-6192-204-0
Fax: +49-6192-22193
polar@polar-mohr.com
www.polar-mohr.de

Pröll KG
Treuchtlinger Straße 29
D-91 781 Weißenburg i. Bay.
Tel. ++49-91419060
Fax. ++49-914190649
wug@proell.de
www.proell.de

Rectavit NV
Anton Catriestraat 39
B-9031 Drongen
Tel. ++32-92-26 89 41
Fax ++32-92-27 52 49
info@rectavit.be
www.rectavit.be

Reichel GmbH
Mühle 1
D-55 270 Bubenheim
Tel. ++49/6130 92030
Fax ++49/6130 920322
info@reibu.de
www.reibu.de

Ruco Druckfarben
Lorsbacher straße 28
D-65 817 Eppstein
Tel. ++49-6198 30 40
Fax. ++49-6198 32 288
info@ruco-inks.com
www.ruco.de

Ruderer
Harthauser Strasse 2
D-85604 Zorneding
Tel ++49-8106-24 210
Fax ++49-8106-298 96
info@ruderer.de
www.ruderer.de

Sandt AG
Lemberger Straße 82
D-66 932 Pirmasens
Tel. ++49-6331-71 30
Fax ++49-6331-71 31 43
www.schoen-sandt.de

Scapa Tapes Europe
Holland Street
Denton
UK-M34 3GH Manchester
Tel. ++44-1613-36 44 33
Fax ++44-1613-35 01 04
www.scapa.com

Sericol International
Pysons Road
Broadstairs
UK-CT10 2LE Kent
Tel. ++44/1843 866668
Fax ++44/1843 872122
sales@sericol.co.uk
www.sericol.co.uk

Shannon BV
Turfschipper 11-13
NL-2292 JC Wateringen
Tel. ++31/174 225 240
Fax ++31/174 225 249
info@shannon.nl
www.shannon.nl

Shelley Thermoformers International Ltd.
Stonehill
Stukeley Meadows Industrial Estate
UK-PE29 6DR Huntingdon, Cambridgeshire
Tel. ++44-1480-45 36 51
Fax ++44-1480-521 13
mbarson@cannon-shelley.co.uk
www.cannon.com

UHU GmbH & Co. KG
Herrmannstrasse 7
D-77815 Bühl/Baden
Tel.: ++49-7223-28 40
info@uhu.de
www.uhu.de

Unico NV
Essenestraat 20
B-1740 Ternat
Tel. ++32-2-582 16 90
Fax ++32-2-582 52 40
labo@unico.be
www.unico.be

Vantico
Adresses : see website
Email : see website
www.adhesives.vantico.com