Forming

Cold bending

Unlike in the case of thermoforming, cold bended PLAZCRYL - PLAZCAST will not keep its form unless installed into a frame.
The sheet must be with perfect edges to avoid breakage during bending.
Drilling PLAZCRYL - PLAZCAST before bending must be done with extra care. Cracks and melting must be avoided and annealing is highly recommended.
The length between the two edges of the bend should not exceed the minimum length, as per the formula below, to avoid high permanent stress, which would eventually cause small cracks or even breaks in the sheet.

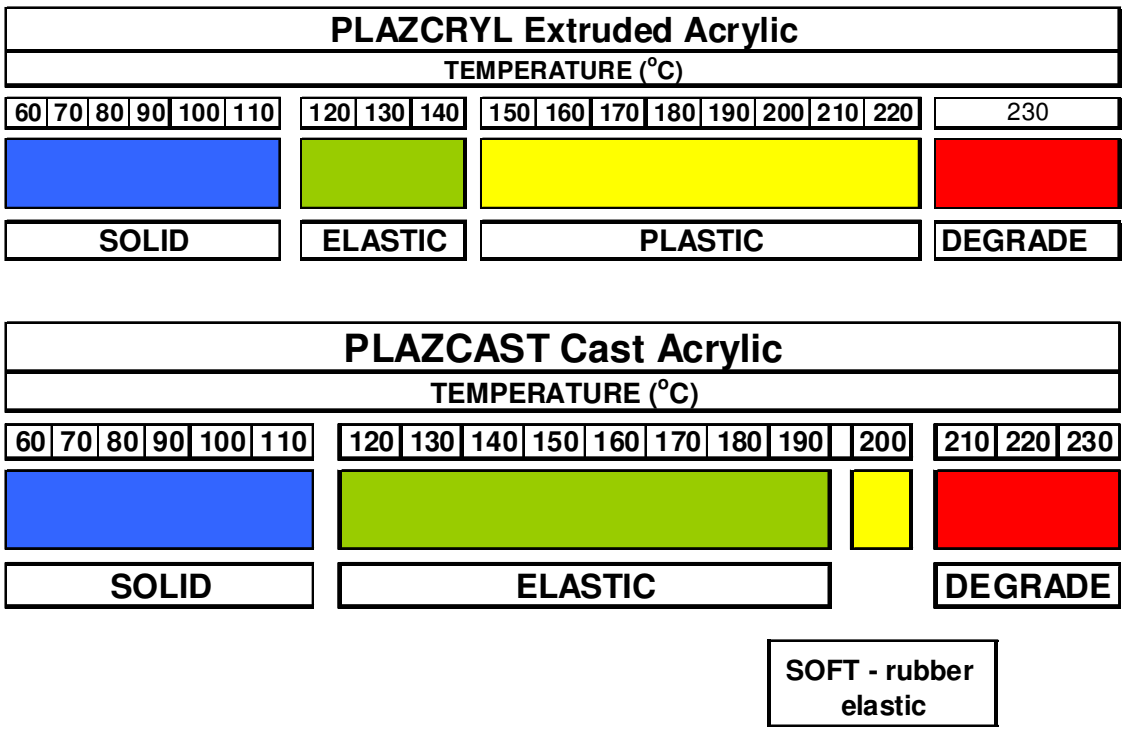
Minimum bend radius of **300 times** the thickness of the sheet.

For 2 mm sheets minimum radius is 600 mm
For 3 mm sheets minimum radius is 900 mm
For 4mm sheets minimum radius is 1200 mm
For 5 mm sheets minimum radius is 1500 mm
For 6 mm sheets minimum radius is 3600 mm

Cold bended sheets are at stress and special attention must be paid not to install them in environments with chemical that affect acrylics in unstressed stage. The combination of high stress and chemical attack will cause cracks and total deterioration of the sheets. That includes cracks and cloudiness.

Thermoforming

Thermal behavior is one of main differences between extruded and cast acrylics. This is related to the molecular number/weight of the acrylic polymer.
Extruded acrylic is produced with low molecular weight what make it able to be processed by extrusion.
Cast acrylic is produced at as unique unit and by in situ polymerization at the mold it takes its form. This process makes an acrylic with large number of molecules at the polymer chain.



Thermoforming involves three stages:

1. Heating –softening PLAZCRYL - PLAZCAST until its plastic/soft phase
2. Forming – forcing PLAZCRYL - PLAZCAST into the desired form.
3. Cooling – restoring PLAZCRYL - PLAZCAST its initial rigidity.

The protective film can be left in position during heating and forming, however the easy removal type is recommended for producers, who remove the film before thermoforming PLAZCRYL - PLAZCAST.

The working area must be sealed from drafts. Wind will badly influence the results.

Safety note

PLAZCRYL - PLAZCAST sheets are combustible, and so before heating, the necessary fire precautions must be considered, based on regional regulations and good judgment, taking into accounts the burning behavior of acrylic.

When heating PLAZCRYL - PLAZCAST horizontally, extra care should be taken to prevent sagging on the heater causing damage and a possible risk of fire.

PLAZCRYL - PLAZCAST surface temperature must not exceed 200^{0}C, as this might cause flammable decomposition gasses to occur.

When heated to the maximum recommended temperature (190°-200°C), high pressure must be applied to PLAZCAST to cause deformation, and the pressure must be applied gradually, avoiding large changes in pressure. Abrupt pressure changes can lead to cracks.
PLAZCRYL can be thermoformed more easily where there are numerous details and sharp change.
PLAZCRYL SUPER Hi Impact sheets can be more easily thermoformed with better accuracy of shapes.

Pre-drying

PLAZCRYL - PLAZCAST can be thermoformed without pre-drying, however, if improperly stored, PLAZCRYL - PLAZCAST sheets can absorb moisture, which will seriously affect their thermoforming performance. Unlike other materials, moisture in PLAZCRYL - PLAZCAST during thermoforming doesn't rein degradation of the material.
The appearance of superficial bubbles is a sign that sheet has over heated and start to decompose.
The appearance of small bubbles in the sheet, after the heating process, is a sign that too much moisture was absorbed in PLAZCRYL - PLAZCAST and therefore the rest of the sheets must be pre-dried.
Pre-drying is done by heating PLAZCRYL - PLAZCAST, after removing the protective film, between 70^{o}C to 80^{o}C in a ventilated oven for a period of 1 to 2 hours per mm of thickness.

Heating

If PLAZCRYL - PLAZCAST is formed before it is fully soft, stress is generated and mechanical failure will occur. On the other hand, too much energy will melt the material, making it impossible to work with, or might even cause surface blisters.
Care should be taken to ensure that PLAZCRYL - PLAZCAST is uniformly heated. If not heated uniformly dispersion of the material while forming will also not be uniform i.e. the formed part will not have a uniform wall thickness distribution.

Hot-air circulation oven

This technique is characterized by the uniformity of heating and by its mass production capabilities. Temperature is accurately controlled and more than one sheet, in different stages of heating, can be in the oven, therefore it is the obvious choice of high volume producers.

Infra red heating

The main advantage of this heating method is its portability. Inline machines (All three stages of the thermoforming are done on the same machine) require a heating head, which can be moved freely when the heating process is done, making room for the forming and cooling process.

Although heating time is very short, the possibility to heat only one sheet at a time makes this method cost efficient only for low volume / high versatility production.

PLAZCRYL - PLAZCAST of 5 mm thickness and above must be heated by a double-sided heating device.

Heating conditions

The following factors should be taken into consideration when determining the temperature and time of the heating process:

1. The sort of heating source (Infra red or hot air circulation).
2. The distance between the sheet and the heating source.
3. The uniformity of the heating (On all three dimensions of the sheet).
4. The distance between the heating and the forming devices.
5. The material thickness.
6. The depth and complexity of the required shape.

HEATING TEMPERATURES (^{o}C)		
	PLAZCRYL Extruded sheet	PLAZCAST Cast sheet
Minimum	140	130
Maximum	180	200
Recommended	155 - 175	165 -190

HEATING TIME seconds/mm thickness		
	PLAZCRYL Extruded sheet	PLAZCAST Cast sheet
CIRCULATION OVEN	130 to 180	180 to 240
ONE PANEL INFRARED	33 - 40	40 to 50
TWO PANELS INFRARED	15 to 25	25 to 35

The best way to know if PLAZCRYL - PLAZCAST is heated to the right point and is ready to be formed, would be for a skilled worker to look at it and feel it with protected hands. It takes much practice to acquire proficiency in this process.

Shrinkage

They are main differences in response to heating cast or extruded sheets.

During the extrusion process, as opposed to the cast process, the acrylic is formed and cooled while it is stretched. PLAZCRYL has a memory and when heated, it will shrink, especially in the extrusion direction, trying to get back to its relaxed form before extrusion.

The table below details the shrinking percentage of two PLAZCRYL - sheets:

1. PLAZCRYL standard – produced according to the shrinkage definitions of ISO standards.
2. PLAZCRYL for sky domes – produced upon special request, for use in thermoforming.

This characteristic of PLAZCRYL should be taken into account when planning the dimensions of the sheet.

	PMMA XT Sheets – Standard		*PMMA XT Sheets – Sky Domes*	
Thickness in mm	*Shrinkage M.D*	*Shrinkage* T.D*	*Shrinkage M.D*	*Shrinkage* T.D*
1.80 – 2.30	6% – 7%	0.5%	3% – 4%	0.5%
2.30 – 3.50	5% – 6%	0.5%	2% – 3%	0.5%
3.50 – 4.00	3% –4%	0.5%	1% – 2%	0.5%
4.00 – 6.00	2% – 3%	0.5%	0% - 1%	0.5%
6.00 ++	2%	0.5%	0% - 1%	0.5%
Hot air circulation oven	Temp: 160c Time: 60 minute (70 minutes for 5.0++ mm)		Temp: 170c Time: 4 minute	

M.D – Machine direction

T.D – Transverse direction

These differences in shrinkage mean PLAZCRYL sheets must be clamped to a frame during the heating stage, to avoid distortion of their flat surfaces.

PLAZCAST shrinks the same at all directions (isotropic behavior), it shrinks by a maximum of 2 %. This is due the internal stress accumulated at the cast process when the monomers becomes a polymer increasing its density by 20%

HEATING UNIFORMITY

PLAZCAST can be heated with temperatures gradients of 10°C to 15°C within a given sheet, without any effect on the final quality.
PLAZCRYL must be heated very uniformly: exceeding 5°C non uniformity may lead to considerable internal stress.

Forming

While in its viscosity phase, PLAZCRYL - PLAZCAST can be formed into almost any shape, by different methods and equipment.
Home made machines as well as sophisticated commercial machines can be used depending on the demands of the product (complexity, quality and volume).

Line bending

Double side heating machines with cooling strips are available, if a very accurate bend and high quality surface near the bend is needed, but for most common line bending very simple equipment will give excellent results.
Ceramic and quartz tubes or even metal rod heaters equipped with a thermo regulator and installed with parallel support on both sides are most commonly used. The supports should keep PLAZCRYL - PLAZCAST at least 0.5 cm away from the heater.
First, remove PE. Film from the bend line facing the heater, then laid PLAZCRYL - PLAZCAST, on the supports, with the bend line above the strip heater. PLAZCRYL - PLAZCAST is sufficiently heated when it slightly resists bending. Remove the sheet from the heater, place it in a fixture with the desired angle, clamp it and leave it to cool naturally.
Please note the following points:

1. Avoid direct contact of PLAZCRYL - PLAZCAST with the hot strip heater.
2. Sheets of more than 5 mm thickness should be heated from both sides. If the two sides are not heated simultaneously, heat the outer side of the bend last.
3. Make a V shape cut, on the inner side of the bend, prior to the heating, if PLAZCRYL - PLAZCAST is to be acutely bent.
4. A bend line longer than 1000 mm might bow across the bend. This can be avoided if PLAZCRYL - PLAZCAST is bended perpendicularly to the machine direction.
5. The greater the diameter of the rod heater and the more the rod heater is distant from PLAZCRYL - PLAZCAST, the wider the heating zone will be enabling formation of a bend with a larger radius

6. The width of the zone should be:

Bending PLAZCRYL - PLAZCAST up to 90° - 3 times the thickness.

0. Bending PLAZCRYL - PLAZCAST more than 90° - 5 times the thickness.

7. Avoid contact of the heated PLAZCRYL - PLAZCAST with hard rough surfaces. Felt, Flannel or Aluminum can be used to coat the surface of the fixture, to help prevent stamping.

8. Anneal the bent part before exposure to solvents or excessive temperature changes.

Drape forming

This method of forming is restricted to two dimensional or very simple three dimensional shapes, which require no stretching for formation.

Heat PLAZCRYL - PLAZCAST properly between 140°C and 150°C and without delay drape it over the mold. In drape forming it is crucial that PLAZCRYL - PLAZCAST is placed on the mold at the right temperature. If not hot enough, PLAZCRYL - PLAZCAST will not obtain its shape but if too hot, it will curl and twist.

PLAZCRYL - PLAZCAST will often obtain its form by the force of its own weight but in some cases the help of some forcing is needed.

The hot edges of PLAZCRYL - PLAZCAST tend to curl and therefore clamping or heavy covering should force the edges to the mold.

Free blown forming

High optical quality and limited bubble like part shapes are the characteristics of this method.

Requiring low cost equipment and short production cycles, this method is the most cost efficient for sky dome production.

The free blowing equipment is composed of a plywood board attached to a compressed air source with a pressure control device.

Heat PLAZCRYL - PLAZCAST, frame it tightly to the board and gradually increase the air pressure to the desired point. Let PLAZCRYL - PLAZCAST cool and dismantle it after regaining its rigidity.

9. The air pressure controls the height of the dome.

10. The shape of the dome can be altered by an imprint and by using a different frame shape.

11. The top part of the dome will be much thinner than the part close to the base.

12. Since vacuum is restricted to 1 atmosphere, the use of vacuum free forming will limit the height of the dome.

13. Commonly used air pressure is 3 to 4.5 At.

14. Disperse the incoming air, using a protective plate felt or cotton wool. Cold air jet, directed onto the hot PLAZCRYL - PLAZCAST will cause rapid local cooling and as a result high tense and non-uniform expansion of the sheet.

15. Forming big domes is better preformed when blowing with hot air.

Molds

Used in different forming methods and for production of different products, molds can be made of a variety of materials such as hard wood, aluminum, steel, Gypsum, reinforced polyester or epoxy resins.

Land finishing of molds, made of other materials metal, should produce a surface, which will resist wear and will prevent distortion by moisture.

Aluminum made mold with temperature control will achieve best results, for large quantity production.

Faults in the finished mold will leave imprints on the molded part.

When making a mold, the shrinking properties of PLAZCRYL - PLAZCAST, must be taken into account. Allow for shrinkage, to make sure that the finished part is not smaller than required. (Shrinkage of PLAZCRYL - PLAZCAST after thermoforming is 3 to 6% in length or 1 to 2% in width).

Mold clearance angle, must be a 3^0-6^0 for convex parts and 0.5^0- 1^0 for concave parts (PLAZCRYL - PLAZCAST tends to shrink on convex parts and away from concave parts).

When molding PLAZCRYL - PLAZCAST the mold temperature range is 60-80^{0}C. Heated mold will result better part shaping and will help with gradual cooling.

Press forming

Restricted to forming only shallow parts with low quality surface (especially on the inside corners) this method is mainly used in the sign industry.

The heated PLAZCRYL - PLAZCAST is clamped over the cavity, and then pressured into it, up to a fixed depth, by the plug. Pressing can be done by a manual drill press, air cylinder or pneumatic cylinder.

The Plug and Cavity must match in a way that enough space will be left for the sheet.

Straight vacuum (pressure) forming

This is a very simple method with fairly good results. The quality of the surface is good and the wall thickness, for shallow drawn parts, is quite even.

Both female and male molds can be used.

The heated PLAZCRYL - PLAZCAST is clamped over the mold. The air, trapped between PLAZCRYL - PLAZCAST and the mold, is then sucked through vacuum forcing the sheet to form against the mold.
When using air pressure instead of vacuum it is essential to make vent holes in the mold to enable evacuation of the trapped air to form its final shape.
Since vacuum is restricted to 1 bar, straight vacuum is limited to shallow, simple parts forming. Using high pressure, up to 5 bar (75 PSI) the straight forming method can be used for more complex parts.

Reverse blow forming

This method is quite similar to the straight pressure forming method and the same machinery can be used.
Although the only difference between the two methods is the order of events with this method the uniformity of the wall thickness will be much better.
The heated PLAZCRYL - PLAZCAST is clamped over a pressure box. Air pressure is used, to blow PLAZCRYL - PLAZCAST to a bubble. The plug is then lowered into the bubble, forming the desired shape.

Plug-assist forming

This is a more demanding process. Better control of forming rate and temperature are required, and only experienced workers will be able to achieve the needed results.
Plug-assist is used for forming deep drawn parts that require a better wall thickness uniformity.
The heated PLAZCRYL - PLAZCAST is clamped over the cavity and the plug is then lowered to stretch the sheet. When the plug is in its final course, applied vacuum, from the cavity, or pressure, from the plug, force PLAZCRYL - PLAZCAST against the cavity to form its final shape.
For even better wall thickness uniformity, vacuum is first used, to create a maximal bubble, and only then the plug is lowered. When the plug is in its final course, pressure, from the plug, force PLAZCRYL - PLAZCAST against the cavity to form its final shape.
The plug will be 80% - 90% of the volume of the cavity.
The shape of the plug will influence the distribution of wall thickness.
The plug should be heated or at least made of low thermal conductivity material to prevent mark-off.

Snap-Back forming

With this method complex shapes can be formed but depth is restricted.

The heated PLAZCRYL - PLAZCAST sheet is clamped over a vacuum box. Vacuum is used, to draw the PLAZCRYL - PLAZCAST sheet into the box forming a bubble, slightly bigger than the plug. The plug is lowered and when in place the vacuum is released, causing the sheet to snap back onto the plug and form its shape.
The process must be done fast enough to ensure that PLAZCRYL - PLAZCAST is sufficiently hot to perform the snap back.
Forming complex shapes by this method requires the use of applied vacuum, from the plug, or pressure, from the box, to help PLAZCRYL - PLAZCAST gain its final shape from the plug.

Quality of molded parts

Results	Possible causes
Cracks or broken areas	Sheet is too hot or too cold. Drawing is done too quickly, especially with PAZCAST. The mould is too cold, or has angles that are too sharp. The air jet is too forceful or poorly diffused.
Optical problems	Defects in the surface of the mould. Contact between the sheet and mould at high temperature, before forming, especially for PLAZCRYL. Heating above 190°C for PLAZCAST and 170°C for PLAZCRYL. Mould is to hot. Jet of air not evenly distributed.

Cooling

After the shaping, PLAZCRYL - PLAZCAST must be left on the mold, with the applied pressure to cool.
Remove PLAZCRYL - PLAZCAST when at 60^0C - 70^0C. If too hot PLAZCRYL - might not retain it's shape, but if left for too long, PLAZCRYL - PLAZCAST might cool and shrink too much on the mold, causing excessive stress and making it hard to release.
Slow uniform cooling is essential to prevent stress. Avoid drafts and when working in a cold environment cover PLAZCRYL - PLAZCAST with felt or flannel. Covering is also very important, for cooling not only the surface, of thick wall final parts.
A heated mold helps with the gradual cooling process.
Parts formed from PLAZCRYL must be annealed to relieve internal stress before any solvents, paints, printing inks or adhesive films are applied.