IşıkPlastik

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Policam

Acrylic Sheet Fabrication Guide

1. PRODUCT IDENTIFICATION

Policam™ is the brand name of industrial extruded sheets manufactured by Işık Plastik A.Ş. This Fabrication Guide is published to explain and to offer solutions regarding fabrication details of PMMA Acrylic Sheets for indoor and outdoor applications. You can contact with Işık Plastik for more information if needed.

2. GENERAL HEALTH AND SAFETY PRECAUTIONS

All safety instructions must be followed by qualified operators for all applications of Policam™ Acrylic extruded sheets including thermoforming and fabricating processes.

Operators must take into consideration that heat for thermoforming, machining, finishing, annealing etc. of acrylic sheet may release of gases and vapor which contain methyl methacrylate (MMA) monomer.

Also, bonding and cementing of acrylic sheets with solvent and polymerization adhesives introduces other vapors related to the formulation of the adhesives.

But under recommended techniques at recommended temperatures, with adequate ventilation there should be no harmful results may occur.

All fabrication process should be done in well ventilated workplaces, workshops or plants. For ventilating standards please refer to The American Conference of Governmental Industrial Hygienists (ACGIH), Air Contaminant Standards.

All fabrication and forming techniques has special conditions which should be cared. So please follow the further instructions about safety precautions in every section of this manual.

3. APPLICATIONS

You can find some specific application areas of Policam™ Acrylic Sheets.

Advertising and Visual Communications	Interiors and Household Goods
Corporate identity	Appliance parts and control panel fascia
Display POS/POP and Advertising	Furniture
Museum casings	Gift and tableware
Exhibit and trade show displays	Kitchen sinks
Recognition awards	Lighting
Signage	Paints
	Worktops and surfaces
Architectural and Construction	**Automotive and Transport**
Aquaria/structural panels	Accessories
Cladding	Interior and exterior trim
Door canopies and balustrades	Caravan windows
Door and window profiles	Acrylic Ship Windows
Lighting	Coatings
Windows for Swimming Pools	Light covers
Public Aquarium Windows	Storage
Partitioning	Windshields
Transparent Barriers	
Skylights	
Flood Windows	
Solid surfaces	
Sound barriers	

4. STORING AND HANDLING

The originally packed Policam™ Acrylic Sheets should be stored under suitable conditions. Sheets must be avoided direct sunlight exposure and also variations of weather and temperature. With wide range variation of temperature and humidity may causes distortion of the flat sheets even when stored flat and stacked.

Policam™ Acrylic Sheet comes with polyethylene (PE) film on its surface to keep itself clean and also protect against dirt, dust, mechanical load and scratches. It is highly recommend removing protective PE film just before the final process

Please follow instructions below regarding storing and handling:

- Policam™ Acrylic Sheets should never be stored outdoors.
- Do not store Policam™ Acrylic Sheets in direct sunlight.
- Do not be stored near radiators, steam pipes or other heat sources.
- Do not stored near spray painting booths or expose it to other solvent vapors.
- Storage areas should be well ventilated. Air should circulate freely and should be relatively moist and cool.
- Policam™ Acrylic Sheet should be stored vertically or in special racks where the sheet can lean at an angle of approximately 10°. These angled racks should have plywood panels, which give full support to the material.

4. CLEANING

After you remove the protective polyethylene (PE) film from the surface of the sheet, it may induce electrostatic charge. This charge may cause to collect airborne dust or some particles on the surface. It is recommended to remove PE film with antistatic treatment such as blowing by ionized compressed air or cleaning by hand with a cloth wetted with suitable antistatic agents.

To clean Policam™ Acrylic Sheet, you should use unaggressive materials and solvents. You can use warm water and a weak alkaline, non-abrasive cleaning agent. Also you can wash with mild soap or detergent and lukewarm water. You can dry and wipe by a clean damp cloth or chamois.

For removing grease, oil or tar you may use a good grade of hexane, aliphatic naphtha, or kerosene. Also you can use aromatic -free benzene or petroleum ether.

You can use;

- mild &neutral soap and household detergents,
- common vinegar,
- diluted acids such as citric acid, hydrochloric acid, sulphuric acid.

Do not use;

- window cleaning fluids,
- scouring compounds,
- leaded or ethyl gasoline,
- benzene,
- acetone,
- carbon tetrachloride,
- fire extinguisher or de-icing fluid,
- lacquer thinners,
- other strong solvents.

5. CHEMICAL RESISTANCE

You can find tables regarding chemical resistance of acrylic below. There are three kind of resistance degree as Resistant (chemicals which can be used), Limited Resistance (should be used carefully), Not Resistant.

Resistant (Chemicals which can be used):
*Water
*Dilute acid
Hydrochloric acid(30%),sulfuric acid(30%), nitric acid(30%), etc.
* alkali(aqueous solution)
Sodium hydroxide (45%),etc
*Aqueous solution of inorganic salts
Sodium Chloride, etc.
*Aqueous solution of surface-active agents
*Milk, Soy sause, Worcester sause, Vineger,
Beer, Sake

Limited resistance (Chemicals requiring careful handling):
*Aliphatic hydrocarbon
*Alcohol
Methanol, Ethanol, Ethylene glycol, Glycerin, etc
* Oil, Grease
Gasoline, Engine oil, Kerosene,Wax remover, Rape-seed oil , Batter, etc
*Surface-active agents
Shampoo(undiluted) , Kitchen cleaning agents(undiluted), etc
*Others
Hair dressing agents,Insecticide, etc.

Not resistant (Chemicals which must not be used):
*Aromatic hydrocarbons
Benzene, Toluene, Xylene, etc.
*Ketones
Acetone, Methyl ethyl ketone, etc.
*Ethers
Diethyl ether, Tetrahydrofuran, etc.
*Halogenated hydrocarbon
Chloroform, Carbon tetrachloride, etc
*Esters
Ethyl acetate, Butyl acetate, etc.
*Aldehydes,Amides
Form aldehyude,Dimethil aldehyde, etc.
*Organic acid
Formic acid, Acetic acid, etc.
*Strong concentrated acids
Hydrochloric acid(35%), sulfuric acid(70%), nitric acid(70%), etc.

You can find an enlarged chemical resistance table at specific temperature degrees below. E - 30 days of constant exposure with no damage. Plastic may even tolerate chemical for years. G - Little or no damage after 30 days of constant exposure to the reagent. F - Some effect after 7 days of constant exposure to the reagent. Solvents may cause softening, and swelling. N - Not recommended for continuous use. Immediate damage may occur such as severe crazing, cracking, or permeation losses. Please feel free to ask Işık Plastik for further information regarding a chemical substance's effect on acrylic sheets.

CHEMICAL	@68°F/20°C	@122 °F/50°C	CHEMICAL	@68°F/20°C	@122 °F/50°C
Acetaldehyde	G	F	Formic Acid, 98%-100%	N	N
Acetamide (saturated)	E	E	Freon, TF	G	F
Acetic Acid 5%	E	G	Fuel Oil	G	F
Acetic Acid 50%	N	N	Gasoline	G	F
Acetic Acid, Glacial	N	N	Acetic Acid, Glacial	N	N
Acetic Anhydride	N	N	Glycerine	E	E
Acetone	N	N	Gluteraldehyde	G	F
Acetonitrile	N	N	n-Heptane	E	E
Acrylonitrile	N	N	Hexane	E	E
Adipic Acid	G	F	Hydrochloric Acid, 15%	E	E
Alanine	E	G	Hydrochloric Acid, 20%	E	E
Allyl Alcohol	N	N	Hydrochloric Acid, 35%	E	G
Aluminum Hydroxide	G	F	Hydrochloric Acid, 45%	F	F
Aluminum Salts	E	E	Hydrochloric Acid, 48%	N	N
Amino Acids	E	G	Hydrogen Peroxide, 3%	E	E
Ammonia	G	F	Hydrogen Peroxide, 30%	E	E
Ammonium Acetate, saturated	E	E	Hydrogen Peroxide, 90%	N	N
Ammonium Glycolate	E	E	Hydrazine	N	N
Ammonium Hydroxide, 50%	E	G	Iodine Crystals	N	N
Ammonium Hydroxide, 5%	E	E	Isobutyl Alcohol	F	F
Ammonium Oxalate	E	G	Isopropyl Acetate	N	N
Ammonium Salts	E	E	Isopropyl Alcohol	F	N
n-Amyl Acetate	N	N	Isopropyl Benzene	N	N
Amyl Chloride	E	E	Isopropyl Ether	F	N
Aniline	N	N	Jet Fuel	G	F
Aqua regia	F	N	Kerosene	G	G
Benzaldehyde	F	N	Lactic Acid, 35%	E	E
Benzene	N	N	Lactic Acid, 85%	E	E
Benzoic Acid, saturated	E	G	Lacquer Thinner	N	N
Benzyl Acetate	N	N	Mercury	E	E
Benzyl Alcohol	N	N	Methoxyethyl Oleate	E	E
Bromine	N	N	Methyl Alcohol	F	N
Bromobenzene	N	N	Methyl Ethyl Ketone	N	N
Bromoform	N	N	Methyl Isobutyl Ketone	N	N
Butadiene	G	G	Methyl Propyl Ketone	N	N
n-Butyl Acetate	N	N	Methylene Chloride	N	N
n-Butyl Alcohol	F	N	Mineral Oil	E	E
i-Butyl Alcohol	F	N	2-Methoxyethanol	F	N
t-Butyl Alcohol	F	N	Methyl-t-Butyl Ether	G	F
Butyric Acid	N	N	Methyl Acetate	N	N
Butyl Chloride	N	N	Mineral Spirits	F	N
Calcium Hydroxide, Conc.	G	G	Nitric Acid, 1-10%	E	E
Calcium Hypochlorite, saturated	G	F	Nitric Acid 50%	G	F
Cellosolve Acetate	G	F	Nitric Acid 70%	F	N
Carbazole	N	N	Nitrobenzene	N	N
Carbon Disulfide	F	N	Nitromethane	N	N
Carbon Tetrachloride	N	N	n-Octane	E	E
Cedarwood Oil	F	N	Orange Oil	E	E
Chlorine, 10% in Air	E	E	Oxalic Acid	E	E
Chlorine, 10% (Moist)	E	G	Ozone	E	E
Chloroacetic Acid	N	N	Perchloric Acid	N	N
p-Chloroacetophenone	N	N	Perchloroethylene	F	N
Chlorobenzene	N	N	Phenol, Crystals	N	N
Chloroform	N	N	Phenol, Liquid	N	N
Chromic Acid, 10%	E	E	Phosphoric Acid, 85%	F	N
Chromic Acid, 50%	F	N	Phosphoric Acid, 1-5%	E	E
Cinnamon oil	N	N	Picric Acid	N	N
Citric Acid, 10%	E	E	Pine Oil	E	G
Cresol	N	N	Potassium Hydroxide, 1%	E	E
Cyclohexane	N	N	Potassium Hydroxide, Conc.	E	G
Cyclohexanone	N	N	Propane Gas	E	E
Cyclopentane	G	F	Propionic Acid	N	N

CHEMICAL	@68°F/20°C	@122 °F/50°C	CHEMICAL	@68°F/20°C	@122 °F/50°C
Decalin	F	N	Propylene Glycol	E	E
n-decane	F	N	Propylene Oxide	N	N
o-Dichlorobenzene	N	N	Resorcinol, saturated	N	N
p-Dichlorobenzene	N	N	Resorcinol, 5%	G	F
Diethyl Benzene	N	N	Salicylaldehyde	G	F
Diethyl Ether	F	N	Salicylic Acid, Powder	F	F
Diethyl Ketone	N	N	Salicylic Acid, saturated	F	F
Malonate	F	F	Salt Solutions, Metallic	E	E
Diethylene Glycol	E	E	Silicone Oil	E	E
Diethylene Glycol Ethyl Ether	E	G	Silver Acetate	E	E
Dimethyl Formamide	N	N	Silver Nitrate	E	E
Sulfoxide	N	N	Sodium Acetate, Saturated	E	E
1, 4-dioxane	N	N	Sodium Chloride	E	E
Dipropylene Glycol	E	E	Sodium Hydroxide, 1%	E	E
Diethylamine	G	G	Sodium Hydroxide, 50% to Sat	E	E
Diacetone alcohol	N	N	Sodium Hypochlorite, 15%	E	E
1, 2-dichloroethane	N	N	Stearic Acid Crystals	E	E
2, 4-dichlorophenol	N	N	Sulfur Dioxide, Wet or Dry	N	N
Dimethyl acetamide	E	E	Sulfur salts	G	G
Dioxane	N	N	Sulfuric Acid, 1-6%	E	E
Dibutyl phthalate	F	N	Sulfuric Acid, 20%	E	E
Dioctyl phthalate	F	N	Sulfuric Acid, 60%	G	G
Ethanol	F	N	Sulfuric Acid, 98%	N	N
Ether	F	N	Sulfuric Acid, 98%	N	N
Ethyl Acetate	N	N	Tartaric Acid	E	E
Ethyl Alcohol (Absolute)	G	F	Tetrahydrofuran	N	N
Ethyl Alcohol, 40%	E	E	Thionyl Chloride	N	N
Ethyl Benzene	N	N	Toluene	N	N
Ethyl Benzoate	N	N	Tributyl Citrate	F	N
Ethyl Butyrate	N	N	Trichloroethane	N	N
Ethyl Chloride liquid	N	N	Trichloroethylene	N	N
Ethyl Cyanoacetate	N	N	Triethylene Glycol	E	E
Ethyl Lactate	F	N	Tripropylene Glycol	E	E
Ethylene Chloride	N	N	Trichloroacetic Acid	N	N
Ethylene Glycol	E	E	1,2,4 Trichlorobenzene	N	N
Ethylene Glycol Methyl Ether	E	G	2,2,4 Trimethylpentane	G	F
Ethylene Oxide	E	G	Tris buffer	E	E
Fatty Acids	E	E	Turpentine	F	N
Fluorides	N	N	Undecyl Alcohol	N	N
Fluorine	N	N	Urea	E	E
Formaldehyde, 10%	E	E	Vinylidene Chloride	N	N
Formaldehyde, 40%	E	G	Xylene	N	N
Formic Acid, 35%	E	E	Zinc Stearate	E	E
Formic Acid, 50%	G	G			

6. DRYING

Like most other plastics, Acrylic sheets absorb moisture during storage. Before processing at the high temperatures, it is highly recommend pre-drying treatment to avoid bubbles and surface defects. The recommended conditions for pre-drying of sheets with high moisture are 24 hours at 80 °C in an oven with air circulation.

Sheets should be dried with protective film but in this case, sheets should not touch any place, it will be better if the sheets keep suspended in the oven

The maximum cooling speed after drying has to be less than 15°C per hour to avoid repeated induction of moisture or internal stress due to cooling down too fast after drying.

Policam™ Acrylic Sheets need not be pre-dried before thermoforming process unless if they keep stored under suitable conditions and protective polyethylene (PE) film is undamaged.

6. JOINING POLICAM™ ACRYLIC

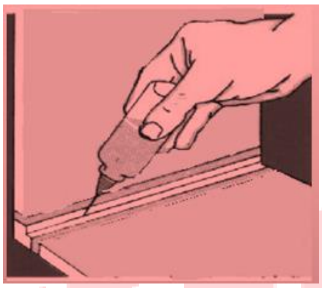
Policam™ Acrylic Sheets can be joined by several techniques. Most common techniques are bonding, welding (clench), using clamps and screws (temporarily) as mechanical joining. The joining method practically depends on requirements but bonding is the most widely used method. You can find some explanations and hints about these techniques below.

6.1. Bonding

In this section, you can find explanations of chemical bonding treatments. Please know that, surfaces of acrylic sheet must be cleaned with warm water includes washing-up liquid if necessary and dry with a dustless fabric before bonding. Additionally, in order to avoid stress-cracking, sheets should be tempered to release or reduce inner stress.

Policam™ Acrylic Sheets can be bonded by solvent-based, mixed solvent-based and polymerization adhesives.

The solvent-based adhesives may be used as supplied or may be thickened with acrylic sheet chips. Adhesives that contain solvents or catalysts that are not compatible with Policam™ Acrylic Sheets should not be used. Otherwise crazing can occur on the sheet. These kinds of adhesives are suitable for small and plane bonding surfaces. After the treatment, the solvents escape from the adhesive by evaporation and diffusion into the material. After drying, the joint is solid.



The bonding strength of solvent-based adhesives is lower than polymerization adhesives and should be waiting for curing approximately 24 hours after treatment. Also solvent-based treatment is usually adequate for outdoor use.

Solvent-based adhesives containing dichloromethane (DCM or methylene chloride) which are generally for commercial use are easily obtainable; also there are some new generation solvent-based adhesives without dichloromethane in the market.

Capillary Cementing Method is also offers a simple technique for jointing and fixing of the components but proper techniques must be practiced to avoid problems such as crazing and poor joint strength. Solvent-based adhesive is applied by a syringe, eyedropper or an applicator onto the bonding surface. This method works by the ability of low-viscosity solvent type cement to flow thorough the joint area by capillary action. After a few seconds later from the treatment, the joint should be firmly pressed together to set the joint. Three hour cure time is usually enough for fabrication and 24-48 hours for maximum bonding strength.

The *mixed solvent-based* adhesives are produced with adding acrylic polymers to solvent-based adhesives and their most common usage is a filling material for small craters. The curing time is much longer than conventional solvent-based adhesives.

The *polymerization adhesives* are applied by adding a proper catalyst to polymethyl methacrylate/methyl methacrylate (PMMA/MMA) and those kinds of adhesives are consisting of one or several components and they cure on exposure to UV light. They are useful and more suitable for large and uneven bonding applications. The gap-filling capacity and bonding provide very strong and weather resistant joining. The curing time is approximately 45 minutes at room temperature and shortens with higher temperatures.

Please take in consideration these instructions:

- The adhesive must be mixed as prescribed by the adhesive supplier also adhesive must be applied bubble-free. You should keep the catalyst ratio under %7.
- Use a bowl or a cup which is made with glass or PE for preparing the adhesive, otherwise there could be a chemical reaction between adhesive and cup material or the mix can be contaminated.
- You should shake the mixture for approximately 2 minutes and you should ensure the adequate blending for the application. You can wait for 10 minutes if there are bubbles in the mixture.

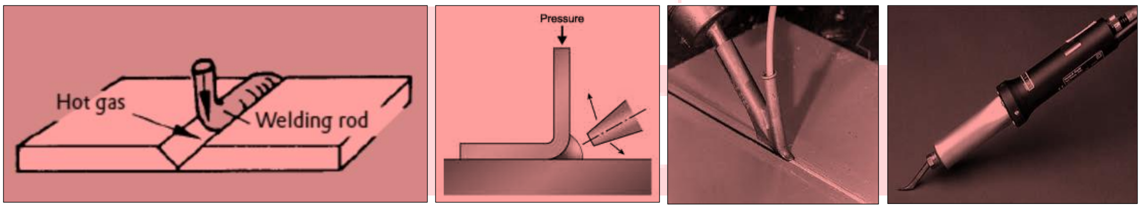
6.2. Welding (Thermal Joining)

Welding is also common technique for joining applications and Policam™ Acrylic Sheets can be welded easily. When heated, acrylic creates a narrow range of rubber-like elasticity before they become soft and formable over a wide temperature range, as required for welding. This technique is preferable if high joining strength, impermeability and sealing needed. But a disadvantage of welding should take in consideration. Possible tensile stress in the weld zone when the cool down from high temperatures to local temperature, has to be relieved by annealing. The stress level can be reduced by heating the parts just before the welding operation. You can find some notes about several welding techniques.

6.2.1. Hot Gas Welding

Hot gas welding is a fabrication process for thermoplastic materials and also for acrylic. The process uses a stream of heated gas, usually air, to heat and melt both the thermoplastic substrate material and the thermoplastic welding rod.

Gas-welding temperature should be between 280 - 350°C. Welding pressure with 3 mm rod is about 20 Newton, welding speed should be 200-250 mm/min, try to keep the distance from the welding gun and joint 10 to 20 mm and about 20-25 l/min air will be enough.



Application Figures and Hot Gas Welding Gun

6.2.2. Extrusion Welding

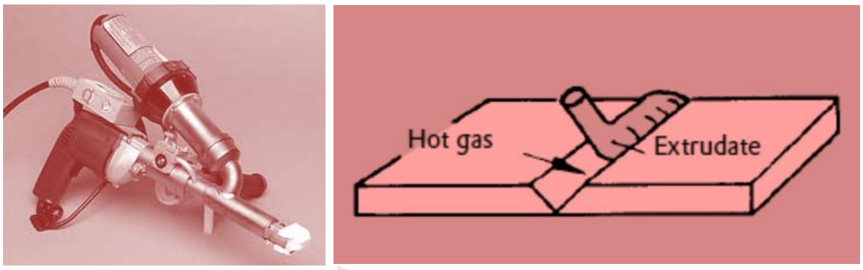
Extrusion welding allows the application of bigger welds in a single weld pass. It is the preferred technique for joining material over 6 mm thick. Welding rod is drawn into a miniature hand held plastic extruder, plasticized, and forced out of the extruder against the parts being joined, which are softened with a jet of hot air to allow bonding to take place. Extrusion welding is used where it is necessary to produce large volume, homogeneous seams in a single pass, unlike hot gas welding where it would be necessary to produce a seam using multiple runs.

Extrusion welders are available in a variety of sizes, from compact units with an integral air supply, weighing a mere 2.8 kg, through to large 13kg machines used for welding lining material in landfill applications.

Extrusion welders are designed to ensure that certain parameters are accurately defined to maximize weld quality, these being:

- Temperature of the welding material - extrudate
- Mass flow rate of the welding material
- Temperature of the hot gas for substrate pre-heat
- Quantity of hot gas

The welding speed that can be achieved is dependent on the flow rate of the extrudate, the material thickness, the cross sectional area of the seam and the size and design.



The Application and Extrusion Welder

6.2.3. Hot Plate Welding

Hot plate welding is beneficial to manufacturers seeking to join thermoplastic parts where both high-strength and hermetic seals are required, or where parts have complex geometries, such as irregular shape, or curved or internal walls The process of hot plate welding uses a heated platen to melt the joining surfaces of the two halves of a thermoplastic part. The part halves are brought into contact with a precisely heated platen for a predetermined period. After the plastic interfaces have melted, the parts are brought together to form a molecular, permanent, and often hermetic bond. A properly designed joint welded under precise process control often equals or exceeds the strength of any other part area.

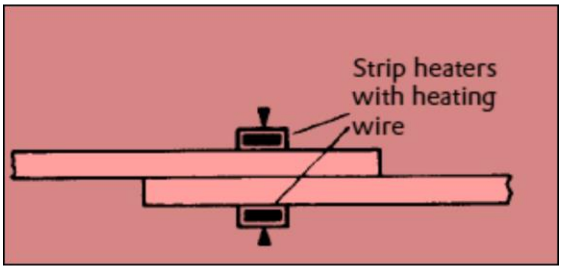
Advantages of hot plate welding include precise control of the melt temperature, excellent weld strength, ability to weld large, complex parts, and ease of attaining hermetic seals.

1. Parts are loaded in their nests.
2. The heated platen moves forward between the parts.
3. The parts contact the heated platen. The plastic begins to melt.
4. After the parts' joint interfaces are plasticized, the nests move back allowing the heated platen to retract.
5. The parts are pressed together so that a molecular bond forms.
6. The nests move apart and the finished assembly is unloaded.

6.2.4. Thermal Impulse Welding

In the case of thermal impulse welding, the welding heat is created in a thin metallic heater band by means of electrical impulses. The heater band is made from a special alloy and can come in the form either of a straight heater band with a welding width of 3 to 45 mm, or as a contoured heater band as required. The welding temperature for this process can be precision regulated. Owing to the low mass of the heater band, it can be heated (to 20 to 200°C in approx. 0.5 seconds) and cooled quickly. The option of further cooling under pressure ensures that the quality of the seam is very high.

Characteristics:

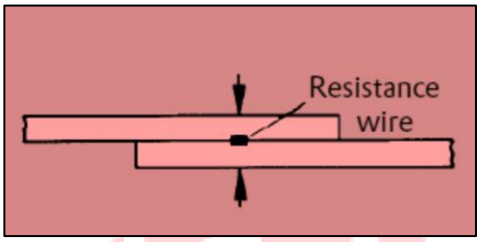


- Excellent seam appearance thanks to cooling under pressure
- Wide range of application options
- Easy to use
- Low investment costs
- Low energy requirement

6.2.5. Resistance Welding

Resistance welding is a welding technology widely used in manufacturing industry. The weld is made by conducting a strong current through the metal combination to heat up and finally melt the acrylic at localized point(s) predetermined by the design of the electrodes and/or the work pieces to be welded. A force is always applied before, during and after the application of current to confine the contact area at the weld interfaces and, in some applications, to forge the work pieces.

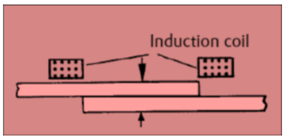
A resistance wire inserted in the weld zone is heated electrically or inductively. Wire remains in the welded material.



6.2.6. Induction Welding

Induction welding is a form of welding that uses electromagnetic induction to heat the work piece. The welding apparatus contains an induction coil that is energized with a radio-frequency electric current. This generates a high-frequency electromagnetic field that acts on either an electrically conductive piece. The welding system consists of a generator of electrical energy that powers a high frequency induction coil. The coil is designed to generate high-frequency electromagnetic field (EMF) (hence the name High Frequency Induction Welding).Acrylic can be induction-welded by implanting them with metallic or ferromagnetic compounds, called subsectors, that absorb the electromagnetic energy from the induction coil, become hot, and lose their heat to the surrounding material by thermal conduction. Acrylic can also be induction welded by embedding the plastic with electrically conductive fibers like metals or carbon fiber. Induced eddy currents resistively heat the embedded fibers which lose their heat to the surrounding plastic by conduction.

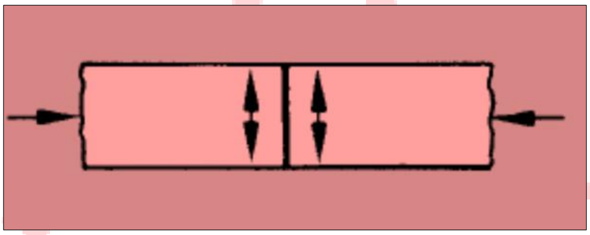
Advantages of Induction Welding



- Energy saving
- No physical contact and less maintenance.
- Minimizes the time of heating. Therefore it reduces oxidation and decrease production time.
- Easier cleaning processes afterwards
- Reduces the heat affected area
- Reduced risk causing a more pleasant work environment than conventional methods.
- Possibility to automate welding processes which leads to an easier implementing and repetitive process.

6.2.7. Friction Welding

In friction welding, the two parts to be assembled are rubbed together at a lower frequency (typically 100–300 Hz) and higher amplitude (typically 1 to 2 mm (0.039 to 0.079 in)) than ultrasonic welding. The friction caused by the motion combined with the clamping pressure between the two parts creates the heat which begins to melt the contact areas between the two parts. At this point, the plasticized materials begin to form layers that intertwine with one another, which therefore results in a strong weld. At the completion of the vibration motion, the parts remain held together until the weld joint cools and the melted plastic re-solidifies. The friction movement can be linear or orbital, and the joint design of the two parts has to allow this movement.

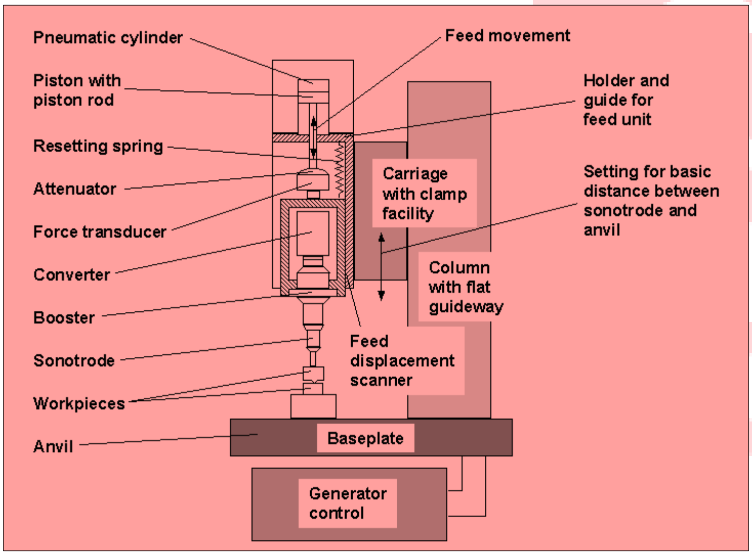


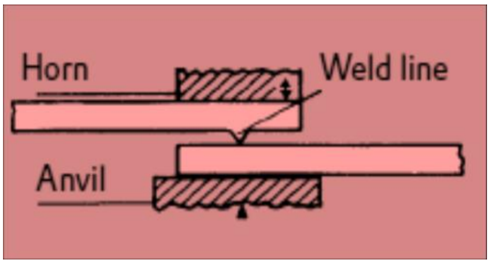
Heating of the weld zones by friction and pressure at the same time.

6.2.8. Ultrasonic Welding

In ultrasonic welding, high frequency (15 kHz to 40 kHz) low amplitude vibration is used to create heat by way of friction between the materials to be joined. The interface of the two parts is specially designed to concentrate the energy for the maximum weld strength. Ultrasonic can be used on almost all plastic material. It is the fastest heat sealing technology available.

Ultrasonic plastic welding is the joining or reforming of thermoplastics through the use of heat generated from high-frequency mechanical motion. It is accomplished by converting high-frequency electrical energy into high-frequency mechanical motion. That mechanical motion, along with applied force, creates frictional heat at the plastic components' mating surfaces (joint area) so the plastic material will melt and form a molecular bond between the parts.





6.3. Mechanical Joining

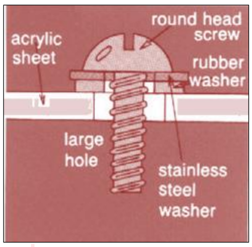
Mechanical techniques are also common ways for acrylic parts or acrylic and some different materials with using screws, bolts, union nuts etc.

Acrylic thermal expansion and tolerances at high temperatures should definitely take in consideration for mechanical applications. You can find summarized instructions about Screw Union and Clamping.

6.3.1. Screw Unions

When it comes to screw union applications of Policam™ Acrylic Sheet, it should be remembered that temperature differences affect internal stress level of the sheets and drilling must be applied carefully.

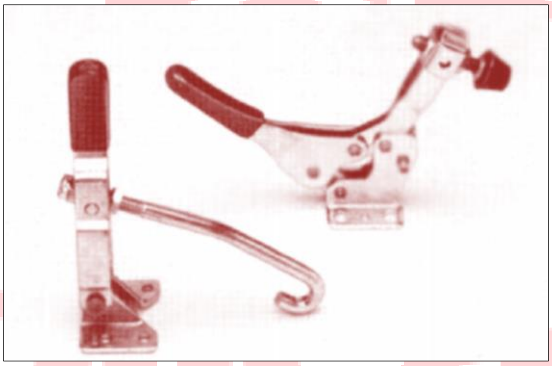
When installing sheets, great care must be taken for stress-free in order to avoid undue tendency to buckling and bending. Bore diameters must be a bit larger than screw sizes. The screws should not be over-tightened, and any applied forces should be distributed evenly across the plastics parts.



You can find further technical details in the section of "8.Drilling" in this fabrication manual.

6.3.2. Clamping

Clamping is the best technique for Policam™ Acrylic Sheet installations because it lets to release stress and distributes the applied forces over the largest possible area and makes adequate allowance for expansion. The elastic seals should be selected with a view to avoiding stress cracks. Moreover, the clamping pressure should not be higher than necessary, as this might cause pronounced friction between the plastic and the seal, thereby preventing the former from sliding and the latter from flexing.



6.4. Comparison of Joining Techniques

You can find a comparison table for joining techniques below. “A” stands for “Preferred”, “B” stands for “Recommended (conditions permitting)” and C stands for “Not Recommended”.

Joint Requirement	Welding (Thermal)	Mechanic	Bonding (Chemical)
High Strength	A	B	B
Leak Proof	A	C	A
Repeat Assembly	C	B	C
Recyclability	A	B	B
Dissimilar Materials	B	A	A
Contamination Free	A	B	C
Chemical Resistance	A	B	A
Fast Cycle Time	A	A	C
Low Capital Cost	C	A	B

6.5. Thermal Expansion of Acrylic and Dimensional Change with Moisture

Policam™ Acrylic Sheet will expand and contract with changes in temperature and humidity. Different temperature and/or humidity conditions on the inner and outer surfaces of Policam™ sheet may cause it to bow slightly in the direction of the higher temperature and/or humidity. However, this type of bowing is reversible. The sheet will return to its original flat state when the temperature and humidity differentials become zero.

Like nearly all materials Policam™ acrylic sheet, is subject to linear change at variable temperatures. Plastics show higher linear change than metals, and this must be taken into account when mounting Policam™ acrylic sheets into frames.

- Policam™ Acrylic Sheet shows a coefficient of linear thermal expansion of 0.065 mm/m°C. (Test Method ISO 11359-2)

When mounting Policam™ Acrylic Sheets, attention must be paid to the elongation clearance in order to avoid damage during material usage.

Material	Coefficient of Thermal Expansion K 10^{-6} mm/m°C
Aluminum	23,5
Steel	5,5
Glass	18,8
Acrylic	65-70
Acrylic Impact	70-100
PC	70

Also the content of moisture can effect an additional dimensional change up to 0.5%. Great attention must be paid when mounting of Policam™ Acrylic Sheets especially at places where has high moisture level such as winter garden, swimming pool glazing, greenhouse etc. Additionally the difference of moisture, between inside and outside surface of the sheet can cause curvature of the mounted sheet. This curvature can be avoided by choosing an applicable higher thickness of sheet, in order to get inherent stability.

7. MACHINING POLICAM™ ACRYLIC SHEETS

7.1 Safety Comes First

All machining applications should be done under proper conditions and each manufacturer's recommendations for safe use of these products. Policam™ Acrylic Sheets can be worked with most tools used for metals. Both cutting speed and forward feed should be such that the material doesn't melt. The lowest possible heat development during cutting operations will avoid the need for material lubrication.

Sharp cutting tooling with cutting clearances suitable for Policam™ Acrylic Sheets are prerequisite. Moreover, tool cooling, which should exclusively be done by water or acrylic compatible cooling emulsions, may eliminate heat. Cooling reduces local heating of the surface in process and the resultant post-processing strains and stresses. You can find some instructions of machining techniques of acrylic below.

<u>Drilling Machine Safety;</u>

Drilling machines are one of the most dangerous hand operated pieces of equipment in the shop area. Following safety procedures during drilling operations will help eliminate accidents, loss of time, and materials. Listed below are safety procedures common to most types of drilling machines found in the machine shop.

- *You should use some cooling liquid which is normally used for milling.*
- *Duct tape is good to give the drill more grips on the surface and to prevent scratches.*
- *The drill needs a decent speed to cut through the acrylic.*
- *You can use some wood plates or something else which is rigid and put it underneath while drilling make sure the acrylic is held in place nicely.*
- *You can use a stand for your drilling machine to make straight drill holes and to prevent cracking.*
- *Don't drill one hole for too long otherwise it will also produce much heat on low speeds.*
- *Don't use too much force pressing the drill on the surface, let the drill do the work.*
- *When your hole is drilled, don't turn off the machine before your drill is out of the drilled hole and be sure to use so force to hold the acrylic down near the area where you drill the hole while pulling the drill out.*

<u>General Drilling precautions;</u>

- Do not support the workplaces by hand. Use a holding device to prevent the work piece from being released from the operator's hand.
- Never make any adjustments while the machine is operating.
- Never clean away chips with your hand. Use a brush.
- Keep all loose clothing away from turning tools.
- Make sure that the cutting tools are running straight before starting the operation.
- Never place tools or equipment on the drilling tables.
- Keep all guards in place while operating.
- Ease up on the feed as the drill breaks through the work to avoid damaged tools or workplaces.
- Remove all chuck keys and wrenches before operating.
- Always wear eye protection while operating any drilling machines.

<u>Laser Cutting Machine Safety;</u>

Laser cutting devices are versatile tools that can be used to cut or drill wood, plastics, and metals. These devices are economical, efficient and can easily be automated.CO2 lasers are particularly well suited for laser cutting acrylic, for instance for the production of illuminated or neon advertising displays, signs, POS/POP displays, etc. When laser cutting acrylic, the result depends on various components – first and foremost the material itself, but also the CO2 laser used, and the performance of the laser cutting machine.

Typically, these Lasers are classified by the American National Standards Institute (ANSI) as Class 1 Lasers. Class 1 Lasers emit low levels of energy that are not hazardous to the eyes or skin. However, enclosed within these devices are often Class 3B or 4 Lasers which are capable of emitting high levels of energy which are hazardous to the eyes and skin. Therefore, the beams generated by these devices are safe when operated according to manufacturer's instructions.

These devices can also be hazardous when used to cut or drill certain materials. As the beam strikes these materials, they may produce Laser-generated Air Contaminants (LGAC). These LGACs may be gaseous or particulate and can, under certain conditions, pose health risks to those exposed to them. The LGAC generated depends on the type of material being cut or drilled.

To control the hazards associated with cutting or drilling certain materials, ventilation systems must be used to reduce or eliminate personnel exposures and to safely exhaust these by products.

<u>Water Jet Cutting Machine Safety;</u>

Water jet cutting is not quite as precise as laser cutting, with a minimum cut size slit of .02". Because of the high level of force used, thin, small, parts do not fare well and must be handled carefully. Although thermal stress is not an issue and burring doesn't occur in the cut, the surface of the material will appear sand-blasted as a result of the added abrasive to the water-jet, and goggles should be worn to protect the eyes and face. The water jet cutting process is quite noisy, and requires a significant amount of clean up—large amounts of waste occur as a result of the mixed water and abrasive.

Jet cutting is one of the safer cutting technologies, but you still need to take precautions to minimize the chances of or ill effects of an injury:

- Do not put your hands in the tank while the jet is operating.
- Wear safety glasses to keep abrasive particles out of your eyes.
- Use hearing protection when the jet is not submerged during cutting.
- Use ozone or hot tub chemicals to minimize bacteria in the tank.
- Carry a medical alert card to show to any doctor treating a water jet-related injury.
- Do not walk on material support slats.
- Do not build your own high-pressure parts, unless you are an expert in high-pressure design.
- Load and unload materials with a proper lifting device to avoid cutting yourself on sharp slats.
- Keep guards on and covers closed.

<u>Cutting Safety;</u>

Cutting acrylic sheets may cause localized heating, resulting in the release of methyl methacrylate (MMA) monomer vapor, and may also generate some polymer dust. Any dust produced by the cutting of acrylic sheets is considered "nuisance" dust. The OSHA PEL/TWA (The permissible exposure limit PEL or OSHA PEL is a legal limit in the United States for exposure of an employee to a chemical substance or physical agent such as loud noise. Permissible exposure limits are established by the Occupational Safety and Health Administration OSHA. Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health Act in 1970) for nuisance dusts is 15 mg/m3 total dust, and 5 mg/m3 respirable dust. (For chemicals, the chemical regulation is usually expressed in parts per million ppm, or sometimes in milligrams per cubic meter mg/m3 TWA is the average exposure over a specified period of time, usually a nominal eight hours. This means that, for limited periods, a worker may be exposed to concentration excursions higher than the PEL, so long as the TWA is not exceeded and any applicable excursion limit is not exceeded. The ACGIH (Association Advancing Occupational and Environmental Health) TLV/TWA for particles (insoluble or poorly soluble) not otherwise specified is 10 mg/m3 inhalable particulate and 3 mg/m3 respirable particulate. Worker exposure to dust can be controlled with adequate ventilation, vacuum dust removal at the point of generation, or the use of suitable protective breathing devices.

- ✓ Protective PE film should be kept intact during fabrication to protect the surfaces and provide lubrication. Acrylic sheet is a combustible thermoplastic material. Fire precautions, as are appropriate for comparable forms of wood and paper products, should be observed.

7.2. Cutting

The hardness value of Policam™ Acrylic Sheet is 92 Rockwell according to the test method ISO 2039-2 in M-Scale and this value is between the wood and steel, thus enables to use cutting machines and tools which are useful for wood, steel and light alloys. For instance acrylic can easily cuttable with saw.

Practitioner of sawing can cut Policam™ Acrylic Sheet with several techniques like sawing or routing with power equipment, or by using a laser cutter. Sawing and routing with power equipment suits both straight and curved cuts on any sheet thickness. Laser cutting is suited for both straight and curved cuts, and the maximum sheet thickness is dependent on the power (i.e., wattage) of the laser. Scribing and breaking can be useful just for thinner acrylic sheets for thickness 0,6 mm and less.

7.2.1. Sawing

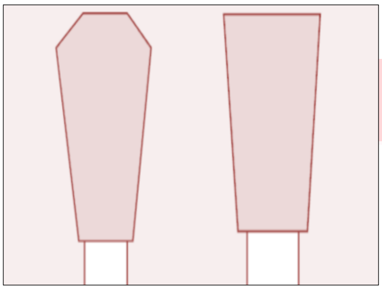
Policam™ Acrylic Sheet can be cut easily by using Circular Blade Saws, Band Saws, Jigsaws, Routers and Hole Saws, Veneer Saws, Saber Saws. When using circular saws, blades with tungsten carbide-tipped cutting edges have proven effective. At very high cutting speeds and cut-off frequency respectively, the saw blade should be cooled by compressed air, water spray or using an adequate cooling emulsion. It is very important to employ an efficient saw dust extraction system to remove saw dust and chips generated by the saw blade. Band saws are frequently used to trim the moldings. The cut edge remains quite rough due to the slightly “crossed” saw teeth. Jigsaws can cut out recess clearances. The cut edge often turns out to be rough. Only saw blades should be used which are suitable for acrylic treatment. When working with jigsaws, the shoe of the jigsaw must be tightly pressed to the surface of the sheet and a high cutting speed should be selected. The rotary stroke should be switched off, especially when using thin sheets. The sheets must be adequately fixed to avoid saw chattering or vibrating.

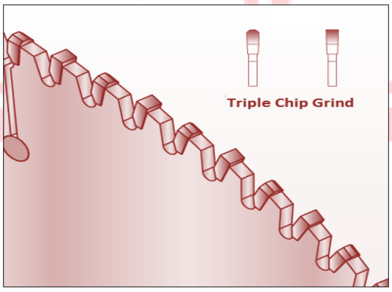
7.2.2. Circular Blade Saws

Several kinds of circular blade saws are suitable for cutting acrylic sheet. Table saws vary in size from small, light-duty models to large, heavy-production models. Here the saw stays in position while the sheet moves through the cut. Use circular saws for cutting acrylic sheet to close dimensions. You can use some special fixtures to hold the work steady for a suitable cutting and to provide safety. Radial saws and swing saws move while the work is held stationary. In general, use these saws to make angle cuts and cross cuts in narrow pieces of acrylic sheet. Panel saws fall into two categories. The first has the saw blade and motor mounted above the material to be cut. The work sits on the table against a fence and the saw feeds through the work. The second type has the saw blade and motor mounted below the material to be cut. This type comes with a combination saw guard and hold-down bar. The blade extends through the table high enough to cut through the material. For safety, the saw blade must generally be retracted before the saw guard and hold-down bar can be released. Panel saws come with either horizontal or vertical tables. The vertical saws take up less floor space. With vertical panel saws you may place acrylic sheet on the saw more easily and remember that you are less likely to scratch unmasked acrylic sheets. Circular saws should have motors with sufficient power.

The saw blades should have carbide-tipped teeth of the triple-chip grind. With triple-chip-grind teeth, alternate teeth start and finish the cut. The slight chamfering of the square tooth corners minimizes chipping. Carbide tipped blades give cuts of superior quality, cut faster, and requires fewer blade changes because of dulling.

For best results with acrylic sheet produced by melt calendaring, use circular saw blades with the largest diameter possible. The blades should have 60 carbide tipped teeth with a triple-chip tooth design.



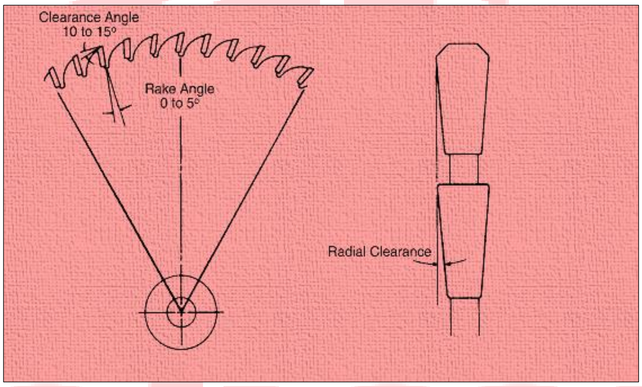


Advantages of Triple Chip Grind

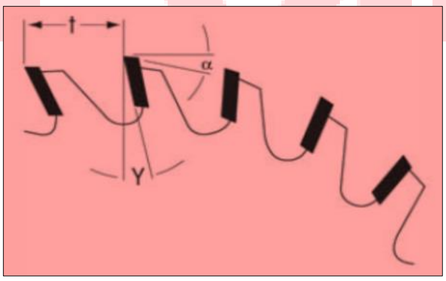
- Balanced cutting force
- Best wear resistance
- Good chip flow
- Typically used for cutting metal, aluminum, plastic, and solid surface materials

Triple Chip Grind Figures & Advantages

Triple Chip Grind – TCG is a versatile tooth shape but the primary purpose is for cutting hard materials, like aluminum, laminate flooring, hardwoods and “solid surface”. It incorporates flat top raker teeth with what look like a flat top teeth with the corners ground off at an angle. Without using sharp points like ATB (Alternating Top Bevel) or ATAF (Alternating Top Alternating Face) blades, a TCG blade will last much longer and handle the high impact of cutting hard stock. Manufacturers combine this shape with different hook/rake angles to specialize blades, from negative hook angles on non-ferrous blades to very aggressive hooks on rip blades.



- The teeth should have a positive rake angle of 0° to 5° and should be of uniform height and shape.



Circular saw machining	
Clearance angle α	15-20o
Rake angle γ	0-5o
Cutting speed	3000 m/min.
Circular pitch t	10-20 mm

- To obtain the optimum cut from carbide-tipped blades, the saw and stabilizer discs must fit the arbor closely with a clearance of about 0.001 inch/0.03 mm, and must run true.
- Loose bearings, bent arbors, or misaligned or burred stabilizers will vibrate, resulting in poor quality cuts and shortened blade life.
- For maximum service life, use the carbide-tipped blades only for acrylic sheet.
- To minimize blade wobble, which can generate heat and possibly melt the sheet, you may use a single- or double-mounted, precision-ground, hardened-steel stiffener with a diameter 4 inches/100 mm less than the saw blade. Also, a blade with radial/side tooth clearance minimizes heat generation.
- You can find a table below which contains the specifics on the recommended carbide-tipped circular saw blades. Where the quantity of the acrylic sheet to be cut does not warrant the purchase of carbide-tipped blades, use high-speed steel blades designed to cut acrylic sheet.

Material Thickness		Type	Diameter		No. of	Rake	Plate Thickness		Kerf Width	
inch	mm	Saw	inch	mm	Teeth	Angle	inch	mm	inch	mm
0,030"-0,080"	0,76-2,0	Table (Hand Feed)	8	203	80	0°	0,095	2,4	0,075	1,9
			10	254	80	0°	0,095	2,4	0,080	2,0
			12	305	80	0°	0,095	2,4	0,085	2,2
0,100"-0,177"	2,5-4,5	Table (Hand Feed)	8	203	80	5°-10°	0,072	1,8	0,100	2,5
			10	254	80	5°-10°	0,072	1,8	0,100	2,5
			12	305	80	5°-10°	0,090	2,3	0,125	3,2
			14	356	80	5°-10°	0,105	2,7	0,145	3,7
0,236"-0,944"	6 to 15 mm	Table (Hand Feed)	8	203	60	5°-10°	0,090	2,3	0,125	3,2
			10	254	60	5°-10°	0,090	2,3	0,125	3,2
			12	305	60	5°-10°	0,090	2,3	0,125	3,2
			14	356	60	5°-10°	0,105	2,7	0,145	3,7

- When cutting 0.150"/3.8 mm or thinner sheet, you should choose a hollow ground blade. Teeth of uneven height will cause chipping of the sheet and will place undue cutting strains on a few teeth, causing the saw blade to crack. These saw blades should be machine filed or ground. For cutting very small quantities of acrylic sheet, you can choose standard hollow ground, fine-tooth blades or ply tooth blades such as those used for cross cutting wood. The recommended high-speed steel circular saw blade table for cutting various thicknesses of acrylic sheet as below.

Thickness to be Cut	*Blade Thickness*	*Teeth per Inch*	*Type of Blade*
030"-.080"	1/16"-3/32"	8-14	Hollow Ground
.098"-.150"	3/32"-3/8"	6-8	Hollow Ground
.177"-.354"	3/32"-1/8"	5-6	Spring Set or Hollow Ground
472"-.708"	1/8"	3-4	Spring Set or Swaged
944"-2.000"	1/8"-5/32"	3-3-1/2	Spring Set or Swaged

7.2.2.1. Cutting Operation with Circular Blade Saws

- Circular blade saw operation to minimize both chipping and overheating tendencies, make sure that circular saw blades protrude about 1/2 inch more than the thickness of the acrylic sheet.
-
- Firmly hold the work against the fence, which must be parallel to the saw blade. You can cut several sheets of acrylic sheet at one time by stacking them. But use a suitably designed holding fixture when cutting sheet stacks to close tolerances.
-
- When cutting unmasked acrylic sheets, take care to avoid scratching the sheet surfaces. Cover working surfaces with some soft material such as medium-density felt and keep the surface free of dirt and chips. Remove sawdust and chips remaining on the sheet surface after cutting by blowing with compressed air. You can wipe the surface with a damp cloth to remove sawdust that clings to the material because of static electricity. The damp cloth will also dissipate the static charge.
-
- When cutting acrylic sheet with a table saw, use a cutting board for stacked/ clamped material or for making cuts not parallel to another edge (angle cut). The acrylic sheet lies stationary on the board while the board moves across the saw table.
-
- When cutting stacked acrylic sheet to final dimensions with a panel saw, use hold-down clamps when feasible. The clamps will also help reduce chipping. The manual feed rate should be uniform at a rate of 3 to 4 inches per second. Allow the saw to cut freely while maintaining the rated speed of the motor.
-
- While coolants are not required for most sawing operations, a fine spray mist directed against the saw blade can produce exceptionally smooth cuts in thick sheet. Use a spray of detergent in water or 10 percent soluble oil in water. The oil must be compatible with acrylic.
- To assure a smooth, chip-free edge on either single or stacked cutting of sheets, set the saw blade at a height only slightly greater than the thickness of the material being cut. You can eliminate or reduce gumming or

welding of the sheets during stack cutting by applying compressed air or an approved liquid coolant to the saw blade and material.

- Clamp the stack if possible. To prevent rubbing, make sure that the saw arbor runs true and the blade plate is flat. Some fabricators with special cutting problems have found it helpful to purchase a circular saw blade with additional clearance behind the teeth — so called “no melt” blades. With these blades you can increase the feed rate up to six inches/second, and increase the height of blade above the plastic sheet short of developing chipping of the sheet. You can find a suitable saw speeds according to blade diameter table and solution table for burning and chipping :

Blade Diameter		*Saw*
mm	*inch*	*Rpm*
150	6"	6400
200	8"	5000
250	10"	4000
300	12"	3000
350	14"	2800
400	16"	2400

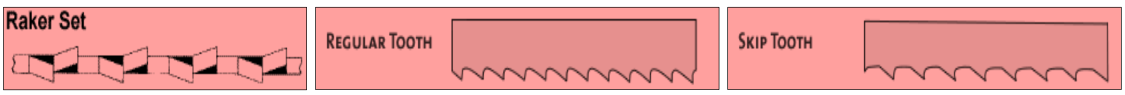
Chipping	*Burning*
Slow Feed Rate	Increase Feed Rate
Decrease Blade Penetration	Increase Blade Penetration
Support Material Continuously	Ensure Fence is Parallel to Blade
Provide Hold Down	Use Blade Stiffener
Increase Tooth Rake Angle	Decrease Tooth Rake Angle
Ensure Teeth Are of Uniform Height	Ensure Blade Has Been Properly Sharpened
	Use Blade With Greater Side Clearance

7.2.3. Band Saws

You can use band saws for cutting curves in flat sheets or when formed parts are rough trimmed. You can also use these saws for making straight cuts in thick pieces of acrylic sheet. For production work, large saws with a 30- to 36-inch (750 to 915 mm) throat perform best, although smaller band saws are satisfactory for small work. The blade should run at a speed of 2.300 to 7.500 feet per minute.

Please note that as a general rule, as the thickness of the acrylic sheet increases, the number of teeth per inch on the blade should decrease. See the table for recommendations.

Thickness to be Cut		*Blade Width*	*No. Teeth Per Inch*	*Tooth Style*
Up to .118"	*Up to 3 mm*	*3/8"*	*18*	*Regular (Raker Set)*
0.118" to 0.472"	*3 to 12 mm*	*1/2"*	*10 to 14*	*Regular (Raker Set)*
.472" to 2"	*12 to 25 mm*	*3/4"*	*6*	*Skip or Buttress*



- Metal cutting blades and, in particular, bimetallic blades, stay sharp longer than blades designed for cutting wood.
- Blade thickness and width, along with the number and type of teeth, depend on the size of the band saw, the thickness of the sheet, and the minimum radius to be cut. Use band saw blades of 0.250 inch to 0.375 inch (6,3 mm to 9,5 mm) width for cutting curves; use blades of 0.50 inch to 0.75 inch (12,5 to 19 mm) width for straight ripping or cutting large-radius curves.
- The diameter of the band saw wheels will determine the maximum thickness of the blade. Blade thickness increases as the diameter of the wheels increases. Special band saw blades, called “skip tooth” or “buttress” blades, have been developed for soft materials such as plastics. These blades are with 2, 3, 4 or 6 teeth per inch. These blades should be used when cutting thicknesses greater than 0.472 inch. These blades are hardened and will retain their sharpness for long periods when used only for cutting acrylic sheet. Variable pitch blades work well in reducing chipping when cutting sheet 0.472 inch thick or less.

7.2.3.1. Cutting Operations with Band Saws

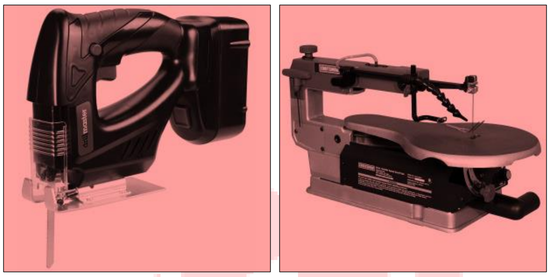
- Adjust the tension on the saw blade just enough to prevent slipping on the wheels, but not enough to stretch the blade and cause misalignment.
- Set the guide rolls or blocks so they just miss the teeth but support the rest of the blade width. Set them so you can stop their rotation with pressure from the thumb and forefinger when turning the saw by hand.
- Adjust the back-up roll so that it does not turn when the saw is idling, but make sure it provides support while the saw is cutting.
- When cutting formed sections, you may find it necessary to raise the upper guide. In this case, use extra care to ensure proper alignment. For added safety, set the upper guide as low as possible (within 1/2 inch of the acrylic sheet).
- The action of the saw carries sawdust from the sheet onto the wheels. The dust builds up on the wheels and may cause the blade to run off track. To avoid this, you must remove this accumulation of dust. Stiff bristle brushes can be placed so that they touch the tires and clean them as they revolve. The brushes should be held with a light spring tension so that they will make contact, yet not cause excessive wear on the tires.
- You can make internal cuts by drilling a hole through the acrylic sheet and cutting and welding the blade inside the hole.
- Once the internal cut is completed, the blade must be recut, removed from the hole, and re-welded. This technique may be useful for special jobs but is too time-consuming for production use.
- When cutting unmasked acrylic sheet on a band saw, take special care to prevent scratching. Keep the saw table clean and free of nicks or burrs. Place brown paper or cardboard on the table under the unmasked sheet. You can use tape or rubber cement to hold the paper and the acrylic sheet together to ensure that both will move through the saw together.
- When trimming flanges on formed parts, the flange will slide on the saw table so any scratching will not be objectionable for most applications.
- The band saw blades should be edge-hardened and designed for cutting metal. The teeth should be raker set or broach-style, 10 to 14 to the inch. Speeds can range between 2,300 and 5,000 feet per minute.
- In general, the thicker the stack of material, the slower the blade speeds to avoid overheating. Blade speed and material feed and thickness should be such that each saw tooth cuts a clean chip.

Band saw machining	
Clearance angle α	30-40°
Rake angle γ	0-8°
Cutting speed	1000-3000 m/min.
Circular pitch t	3-8 mm

7.2.4. Jigsaws and Scroll Saws

Jigsaws can be used to cut acrylic when you need something other than a straight cut. If a jigsaw is all you have and you need to keep costs down, the right blade and a bit of preparation can produce good results. To reduce the work of cleaning up the cut, use the finest blade that you can find. Blades with reduced depth will work best due to less friction and less resistance when turning the blade. You'll have to experiment with cutting speed to see what works best. Too much pressure can cause excessive chipping. Going too slow may cause the acrylic to melt. If the acrylic melts when cutting, use light lubricating oil. Have someone apply the oil to the blade as you're making the cut. Don't use aerosol dispensed oil. The propellant may be flammable and may be ignited by the jigsaw motor.

Scroll saws can cut sharp radii and closed holes in thin pieces of acrylic sheet, but are less suitable for cutting thick sections or multiple sheets. Because of their short stroke, scroll saw blades do not clear the chips and tend to gum up. When this happens, the plastic softens and welds around the blade. When you use a scroll saw, lightly feed the work without forcing it. Clear the teeth often. As soon as the blade stops cutting cleanly, back it out, remove the chips, and cool the sheet. Welding of the plastic behind the blade may be reduced by using two blades mounted side by side, or by using an air blast to remove chips and cool the acrylic sheet. You can also use a coolant. Masking material should always be left intact to provide lubrication and protect the sheet.



Jigsaw and Scroll Saw

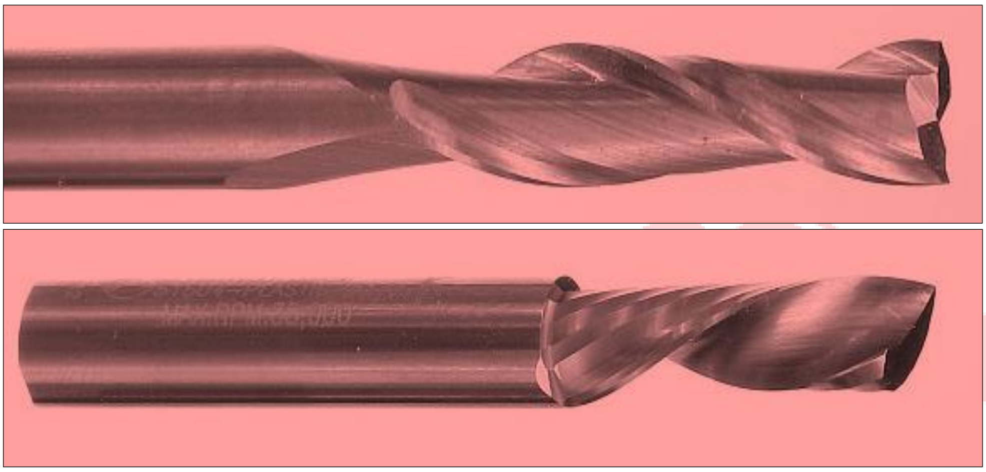
Jig saws or scroll saws should be used only for inside cuts and for intricate letters. The blade should contain some set for clearance. Use a fast, steady feed rate. Because the stroke is short, the blade heats up quickly, and tend to soften and fuse the plastic. Most jig saws have a small blower nozzle attached to the blade guide. This stream of air will help to cool the blade and keep the plastic from gumming. You may also use a cooling fluid like oil or water.

7.2.5. Routers

Routers are one of the most versatile pieces of equipment available to trim acrylic sheets. Bit selection is important, and tools specifically designed to rout acrylic are commercially available. Use a down- ward spiral router bit to prevent masking from fraying. Routers produce a high quality machined edge, ready for finishing, provided the following formulas are followed:

Chip Load = Feed Rate/(RPM X number of cutting edges)
Feed Rate = RPM X number of cutting edges X chip load
Speed (RPM) = Feed Rate/(number of cutting edges X chip load)

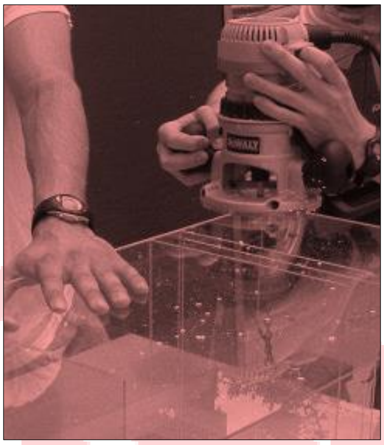
When cutting acrylic with a router, it's generally better if you rough-cut the material and use the router to trim the remaining material. You can use the router or any other saw for the rough-cut. If you are cutting through a large panel and want a fine finish on the cut, you need to support both pieces of the panel. If you don't support both pieces, the piece that falls away as the cut it finished could cause the corner of either piece to chip. This is a minor problem for rough cuts but for cuts where you don't want to do any finishing of the cut edge, it's important.



Figures of solid carbide spiral bits. First one is a standard spiral bit (on top).

Second one is slow spiral bit. Two kinds of bits works great with acrylic but the slow spiral produces cuts that are a bit cleaner.

Hand routers are best used for low volume work. With a bearing-mounted, flush trim bit, the router can trim around a clamped template.



Pin, table and vacuum routers (hand routers mounted under a table) are more convenient to rout around intricately shaped templates

Circle routers can cut round parts by securing the acrylic sheet to a turntable, then rotating the sheet around the stationary router.

Computer Numerically Controlled (CNC) routers are used for high volume, intricate, precise acrylic parts. The part is designed on a CAD/CAM system and geometry is programmed directly into the CNC machine. Many of the variables; feed rate, RPM, bit diameter, depth of cut are adjustable for optimum cutting performance.

7.2.6. Veneer Saws

Veneer saws are small circular saws mounted on arbors and powered by high speed electric or air motors. The saw blades have considerable set and come in 3 and 4-inch diameters. They should be driven at 10,000 to 15,000 rpm to give a surface speed of 8,000 to 15,000 feet per minute. Portable veneer saws are most often used to trim large formed parts of acrylic sheet held in trimming fixtures.

Adjust the height of the saw to the proper distance above the table and move the work past the revolving blade. These saws are not easily guarded and must be used with great care. Do not use carbide-tipped blades unless designated for high-speed operations.

7.2.7. Sabre Saws

This method is useful for cutting involving a frequent change of direction. The blade should have a raker set design. You should provide adequate support for the sheet since the vibration caused by the reciprocating action of the saw blade may chip or crack it. A straight board clamped to the sheet near the cutting line may be used as a saw guide and will assist in reducing vibration. Adjust chisel-type sabre saws so that the cutting chisel stroke is about 3/16 inch greater than the thickness of the work to be cut. The stroke of the chisel should clear the upper surface of the sheet by about 1/16 inch and penetrate into the corrugated fiberboard approximately 1/8 inch, driving the plastic chips into the board. Blow compressed air onto the blade to remove chips and to cool the blade.

7.2.8. Hole Saws

A hole saw (also styled hole saw), also known as a hole cutter, is a saw blade of annular (ring) shape, whose annular kerf creates a hole in the work piece without having to cut up the core material. It is used in a drill. Hole saws typically have a pilot drill bit at their center to keep the saw teeth from walking. The fact that a hole saw creates the hole without needing to cut up the core often makes it preferable to twist drills or spade drills for relatively large holes (especially those larger than 25 millimeters (1.0 inch)). The same hole can be made faster and using less power. For optimum results, cut the sheet halfway through, turn it over, and make the finishing cut from the other side. When cutting sheet greater than 0,6 millimeters thick, use a /water lubricant and coolant. A finishing operation may be needed.

The main advantage over conventional drill bits is the hole saw's efficiency, because very little of the total material being removed is actually cut, which ultimately reduces the overall power requirement. Another advantage over drill bits is the wider size capability. For example, a 100 millimeters (3.9 inches) hole would require a huge twist drill or spade drill, unable to be properly driven by a pistol-grip drill or bench top drill press; but it can be cut with a hole saw with relative ease.

Some disadvantages include:

- The portable drill used must be capable of producing considerable torque at low speed
- They tend to bind if choked with dust, or if allowed to wander away from the central axis of the planned hole
- The kick-back from a powerful drill may be severe under some conditions, and long side-handles should be used, preferably with two operators for very large holes.
- The core plug often binds inside the hole saw, and often must be pried out after each hole is cut. Sometimes the prying is quite difficult.

Sometimes the core plug will twist apart mid-cut, creating a condition where the core inside the hole saw spins on the yet-uncut portion of the core still in the work piece. This tends to stop the cutting action of the saw, and if the work piece is wood or plastic, the friction will start to singe it, creating a burning smell and heating up the hole saw. The twisted-off core must then be pried out of the hole saw before the cutting can continue.

7.2.9. Laser Cutting

Policam™ Acrylic Sheet can be successfully laser cut and laser engraved. Typically CO2 lasers are employed in sizes ranging from 25 watts to 400 watts per laser head. The primary benefit of using a higher powered laser is to increase cutting speed. Additionally, larger lasers often come equipped with an air or gas assist and a vacuum table. Both of these options help to remove vapors generated during the cutting operation leading to improved results.

When cutting acrylic, it is necessary to remove both sides of the original masking. The original masking paper is coated with paraffin wax and will not absorb water. Wax and paper are highly prone to produce a flame, which easily escalates into a fire.

When cutting through thick acrylic, 1/4" or greater, it is necessary to re-mask both sides with paper transfer tape and dampen the masking on both sides of the acrylic with water from a spray bottle. Re-masking and water will act as a heat sink and pull the laser heat away from the cutting area. When dampening, do not leave puddles of water on the surface to be cut as they will reduce the cutting depth significantly.

Acrylic should not be cut directly on the engraving table as trapped heat and smoke may cause damage and pitting to the acrylic part and machine. The down-draft honey-comb table should be used. If a down-draft table is not available, the acrylic must be elevated off of the table 1/2" before focusing the laser.

For best results when combining engraving (etching) and cutting on the same piece, first engrave lightly and unmasked, then mask with transfer tape, dampen, elevate, re-focus, and cut as a second step.

Remove smoke residue from parts with a plastic polish compound using a cleaner and polisher.

Recommended Starting Point Settings:

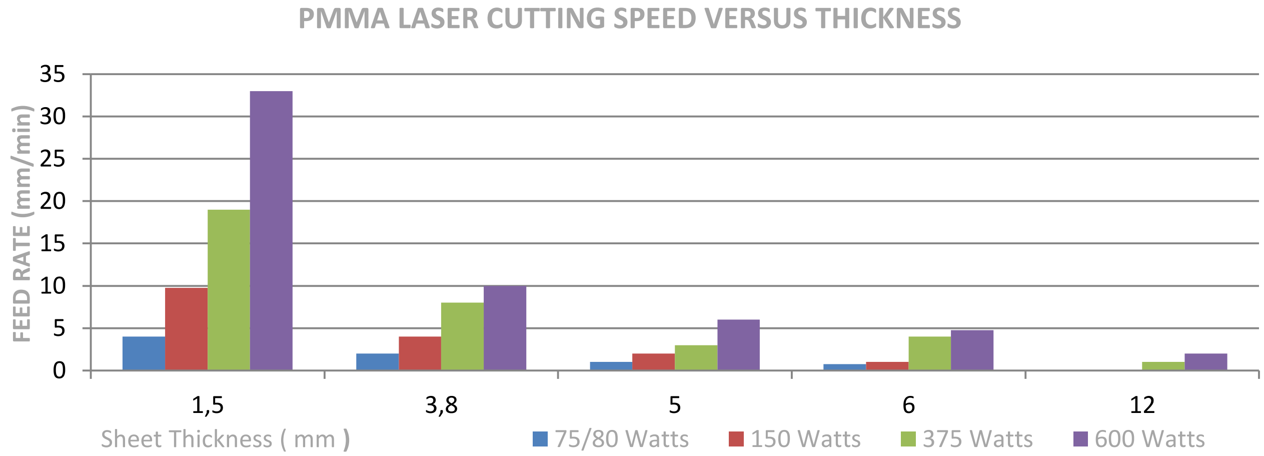
Laser Wattage	Power	Speed	PPI/Frequnecy	Depth per Pass
60 Versa	100	2	1000	0.25"
120 Universal	100	6	1000	0.25"
150 Universal	100	10	1000	0.25"

Some adjustments may be necessary to the above settings; make a test cut first. Use the printer driver settings' rule-of-thumb recommendations when cutting material that is thinner than 1/4". When cutting material that is thicker than 1/4", multiple passes are necessary. After the first pass, refocus the laser slightly into the depth of the material and cut the same geometry again. Be sure to keep the air assist cone of the laser focus carriage above the material.

Watch out below steps during laser cutting operations;

- Make sure to use the vacuum table. You will need lots of air flow. Use sheets of paper to cover most of the table and concentrate the air flow to around the acrylic piece. You want to ensure the acrylic will cool off properly.
- Make sure to adjust the air nozzle to have high air flow. As the laser is cutting, the air flow will clear the kerf of debris, fumes, and helps to cool the surrounding acrylic. If the surrounding acrylic gets too hot, the material could catch fire and burn down your machine
- Elevate the acrylic above the vacuum table. Use some other acrylic to create a space gap under the acrylic. As the laser hits the aluminum honeycomb, it will flash back up at the acrylic. The reflected flash may be close enough to the acrylic to burn spurs onto the acrylic. The flash-back leaves marks on the bottom edge of the laser cut acrylic. Elevating the acrylic will remove the flashback effect.

- Follow below configuration to take better results.



- Be sure that Policam™ Acrylic Sheet is completely dry.

<u>Acrylic engraving techniques:</u>

- Most acrylic is reverse engraved on the back side of the item. This produces a "look through effect" from the front of the surface. We recommend removing the two protective cover from the acrylic before engraving. Leave the bottom protective layer on so that it remains intact to prevent scratching while handling the acrylic.
- Remember to reverse or mirror your artwork prior to starting an engraving project on acrylic. This will be important because you are engraving on the backside of the material.
- Engrave the acrylic at a high speed and low power. A small amount of power is all it takes to mark acrylic and if you set your power level too high, you run the risk of distorting the acrylic when engraving.
- When engraving acrylic, set the focus so the acrylic is slightly further from the lens than normal. Lowering the focus by approximately 1/16 inch (1.6 mm) will soften the engraving so that each individual raster line blends better with the lines above and below producing a smoother, more pleasing look.
- There are a large number of acrylic products that are painted on one side to add color to the clear acrylic piece. You can engrave directly through the paint into the acrylic for a very nice presentation effect. Leave the speed the same as if you are engraving clear acrylic and increase the power about 10% to engrave through the paint. Applying too much power to the paint will melt it and cause distortion.
- Cutting acrylic is usually best achieved with relatively slow speed and higher power. This combination allows the laser beam to melt the edges of the acrylic and produce an almost flame-polished edge.
- Acrylics generally require only a single pass to cut, but thicker acrylics may need two passes. As with engraving, it is sometimes necessary to mask and dampen the acrylic before cutting. Acrylic is very flammable – you should never leave your laser unattended when vector cutting any material.

There are many factors for laser cutting that will play a role in your ability to get the best possible edge; both in the material as well as the laser cutting machine itself. For example, the brand of acrylic and the type of acrylic can great impact the job. Other factors of variance include laser parameters: power, frequency, and speed; and laser process setup: table setup, focus, gas, exhaust, and material preparation.

It's true that laser cutting acrylic can be very profitable if you achieve a "flame polished edge". There are several best practices and tips-of-the-trade for processing acrylic on laser cutting machines, one important factor is the power and velocity of your laser machine.

It is important to factor in the physics of the laser cutting machine, specifically the power and velocity of motion system during cutting. Sometimes it is better to slow the laser down and lower the power to not overpower the material. The less vibration the motion system makes the better the cut.

The performance of motion system in the change of direction is also critical. This would include the lasers ability interprets curves, as well as how smoothly the laser's motion system can change direction. A very "clunky" motion system will show up as waviness in the acrylic in and around changes of direction.

Also consider how the laser's printer driver sends a curve to the laser. Reducing the nodes in the original file and will help smooth out the curves.

Printer Driver Settings

Power Setting:

- Higher burns deeper. Too much power sacrifices detail. Has no effect on running time.
- Lower burns shallower. Too little power sacrifices detail. Has no effect on running time.

Speed Setting:

- Higher saves time. Burns shallower and reduces detail.
- Lower increases time. Burns deeper but too deep may reduce detail.

PPI Setting:

- Higher increases the burning or melting effect. Produces finer detail if speed is not too fast. PPI setting has no effect on running time and very little effect on depth.
- Lower decreases the burning or melting effect. Reduces image detail if set too low. PPI setting has no effect on running time and very little effect on depth. Very low settings are used to perforate the material.

Rule of Thumb

- Doubling the power doubles the depth and halving the power halves the depth.
- Halving the speed doubles the depth and doubling the speed halves the depth.

7.2.10. Water Jet Cutting

Unlike laser cutters, water jet cutters use pressurized water to cut material. To increase cutting ability, abrasives such as garnets and aluminum oxide are often added. The overall process mimics erosion in nature, just at a much higher speed and concentration: a high-pressure pump drives the water through rigid hoses, resulting in a forceful water jet—a typical water jet can output between 4 to 7 kilowatts. Unlike a laser cutter, where the laser source is located inside the machine, the work area and pump are often separate.

Water jets can cut virtually any material including combination materials—with combination materials, however, water jets pose the threat of delamination. They can sometimes handle 3D material cutting, and exhibit limited ability with sandwich structures and cavities. Cutting materials with limited access is possible, but difficult.

Water jets usually perform cutting, ablation, and structuring, specifically with materials like acrylic, stone, ceramics, and thick metals. The possible cutting speed depends on both thicknesses of the material to be cut and desired cutting quality. The cut edges look "sand-blasted" as a result of water jet cutting. No thermal stresses occur in the material when using water jet cutting technique. The water used for cutting contains abrasive additives. The optimum cutting speed is between 1500 - 2000 mm/min and a material thickness of 4 mm. Also a feed rate of 400 - 800 mm/min and a material thickness of 10 mm is going to produce good results.

7.2.11. Troubleshooting For Cutting Operations

Problem	Cause	Solution
Chipping	Sheet vibration	On table saws, hold stacked sheet firmly while feeding. If gang cutting, hold sheets tightly together by clamping or taping them together. On panel saws, ensure sheet is fully supported underneath and that the sheet is being firmly held down across the entire cut.
	Chipping at bottom of cut: the clearance of the blade above the material is too large	Reduce clearance
	Chipping at top of cut: the clearance of the blade above the material is too small	Increase clearance
	Feed rate too fast	Decrease feed rate
	Incorrect blade style	Use carbide tipped, triple chip design, saw blade
	Incorrect blade size or number of teeth	Use recommended blade size and tooth selection
	Rake angle too high	Rake should be 0° to + 5°
	Excessive width of throat plate gap	Replace throat plate
	Blade vibration or wobble	Clean collar and measure blade run out. Employ a blade stiffener. Replace blade with stiffer, higher quality blade.
	Defective teeth (broken or out of alignment)	Replace blade
	Sheet feed rate of blade is too low	Increase RPM or blade size
	Misalignment of blade or fence	Verify that saw blade and fence are properly aligned
Melting	Blade clearance too small	Adjust clearance
	Feed rate too slow	Increase feed rate
	Incorrect blade style	Use carbide tipped, triple chip design, saw blade
	Insufficient clearance behind cutting edge of blade teeth (top clearance)	Clearance behind cutting edge of blade teeth (top clearance) should be 10° to 15°
	Insufficient radial clearance of blade teeth (kerf to blade plate clearance)	Use a blade with increased radial clearance on the teeth
	Dull blade	Replace blade
	Incorrect blade size or number of teeth	Use recommended blade size and tooth selection
	Sheet feed rate of blade too high	Reduce RPM or blade size
	Misalignment of blade or fence	Verify that saw blade and fence are properly aligned

7.3. Annealing

After cutting and fabrication techniques, internal stresses occur. To reduce the possibility of crazing, bending, thermoforming, screen printing, cementing, machining, buffing, flame polishing and other fabrication operations annealing is recommended. The process reduces internal stresses in the sheet which can cause crazing when the acrylic comes in contact with solvents such as glass cleaners and some paints. Stress due to water absorption can also cause crazing. Annealing reduces to a minimum the likelihood that crazing or large scale cracking will occur. Annealing can increase bond strength by more than 50%.

You can use commercially available, forced-air circulation ovens designed for the annealing. Good forced air circulation ensures uniform temperatures essential to the annealing process. The oven's air velocity should be between 45-75 meters (150-250 feet) per minute and should be controllable to within +/- 6°C (+/-10°F) to avoid uneven or excessive heating.

Temperature control selection effects oven performance. Controllers monitoring oven temperature and maintaining constant voltage into the heating elements are considered to work best. Percentage timer controls, which regulate the percent of time heaters are on, can be used, but may not provide uniform heat. Proportional time controls with step switches to vary heat output may also produce uneven temperatures.

To anneal acrylic sheet, heat it to 80°C (180°F) and cool slowly. Heat the sheet one hour per millimeter of thickness – for thin sheet, at least two hours total.

Cooling times are generally shorter than heating times. For sheet thickness above 8mm, cooling time in hours should equal thickness in millimeters divided by four. Cool slowly to avoid thermal stresses – the thicker the part, the slower the cooling rate.

Remove the items when oven temperature falls below 60°C (140°F). Removing a part too soon can offset annealing's positive effects.

While annealing acrylic sheet parts, support them to avoid stress. Lack of support may inhibit relaxation or cause warpage. Be sure parts are clean and dry before annealing. It is recommended to keep protective PE film during annealing.

If the only fabrication you have done is surface machining and you do not need to anneal cemented joints, heating time can be reduced. This reflects the fact that machining forms stresses only at and slightly below the surface – the entire sheet thickness needn't be annealed. Heat at least two hours; cool the same amount of time. If holes have been drilled entirely through the sheet, position the part so heated air flows through the holes.

If you are annealing following cementing, allow the part to sit at least six hours to avoid bubble formation resulting from rapid solvent evaporation in the joint. You can see the table below about sheet thickness vs. heating and cooling time.

Thickness		Heating Time	Cooling Time	Cooling Rate	
(in.)	(mm)	(hours)	(hours)	(°C/h)	(°F/h)
.080	2	2	2	-2	28
.098	2,5	2,5	2	-2	28
.118	3	3	2	-2	28
.125	3,2	3,2	2	-2	28
.177	4,5	4,5	2	-2	28
.187	4,7	4,7	2	-2	28
.220	5,6	5,6	2	-2	28
.236	6	6	2	-2	28
.375	9,5	9,5	2,5	-6	22

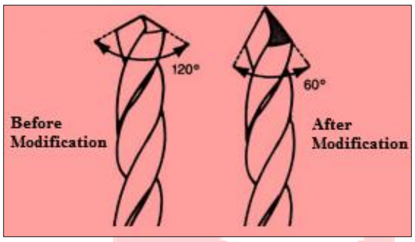
7.4. Drilling

Policam™ Acrylic Sheets can be drilled using commercially available power driven equipment, such as portable drills, drill presses, lathes, or automatic multiple-spindle drilling units. For drilling operations you should choose the correct tool and equipment because the first step in working with acrylics is to obtain the proper tools.

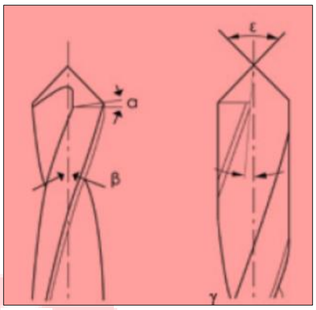
Some standard or conventional high speed drill bits do not work well with acrylic. Metal working, high-speed twist drill bits can be used with minor bit modification. These drill bits are made to bite into metal when pushed. If used as is, metal working drill bits will chip acrylic sheet as well as cause other damage. Drill bits manufactured specifically for plastics work best when drilling acrylic sheet.

Drill Bits are generally made of HSS (High Speed Steel), HSS with carbide tips, solid carbide or cobalt. You can use these kinds of bits but you should make a modification. Follow the steps below to make the modification.

- Generally metal drilling bits have 120° tip angle. If you use these bits they will chip and cause other damage to the plastic. If you want to have a better drilling on acrylic and some other plastic sheets you should grind the tip angle from 120° to 60-90°.



- Second step is about rake angle. You should grind the cutting edge to 0 - 4° rake angle. This aims to scrape acrylic sheet.
- Finally, you should grind away the surface behind the cutting edge to clearance angles of 12 - 15°.



Tip angle ε	60-90°
Clearance angle α	3 – 8°
Twist angle β	12 – 15°
Rake angle γ	0 – 4°

7.4.1. Drilling Operation

Please remember to follow the safety recommendations of equipment manufacturer when working with acrylic sheets.

You should make the sheet stable by using clamps or holding firmly on the worktable before the drilling operation.

Backup the piece being drilled with acrylic sheet or plywood to prevent chipping or blowout of the bottom surface. This allows the drill bit to continue into solid material as it penetrates the bottom surface. Allow the bit to enter the material using a slow feed rate. Slowing the feed rate as the bit exits the bottom surface prevents chipping.

You can use water as a cutting fluid, it acts like a coolant and reduces the heat, helps to create smoother hole walls especially drilling acrylic sheet stack 6mm (1/4") thick or greater. However water may seem like a good choice and it is but not plain water. Water will cause tools to corrode, especially if you're drilling on a drill press with a bare steel table. Water and baking soda, will not cause corrosion. Baking soda is a rust inhibitor. This keeps the acrylic cool, the baking soda adds a bit of lubrication and cleanup is easy. For a lubricant, you can also use several things. Oil is likely the obvious choice and any light oil like 3-in-1 oil or even WD-40 will work but they're a bit messy.

Suggested drill speeds: You can use the table below for drill speeds guideline on equipment that allows variation of the rotational speeds.

Drill Diameter		Speed (RPM)
1/8"	3 mm	3500
3/16"	4,5 mm	2500
1/4"	6,0 mm	1800
3/8"	9,5 mm	1200
1/2"	12,7 mm	900
5/8"	16,0 mm	700
1"	25,4 mm	450

- Please remember that, table provides a proper starting point but optimum speed is also depend on the feed rate depth of the hole being produced and also the finish requirements. You should know that the drill speed should be lowered if melting or whitening is occurring and raised if chipping is occurring.

- Shallow holes are less prone to melting due to easy chip removal and may permit higher speeds.

- Deep holes are more likely to experience melting. For deep holes use a coolant and consider peck drilling, drilling the hole in steps and removing the bit periodically to clean chips.

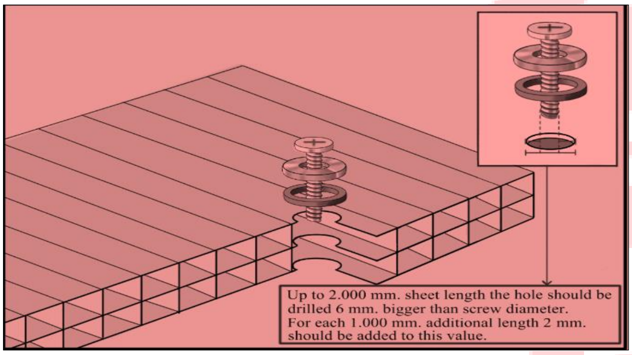
In higher volume or automated operations, a continuous air stream directed at the drill bit can provide cooling and enhance chip removal, thereby reducing melting.

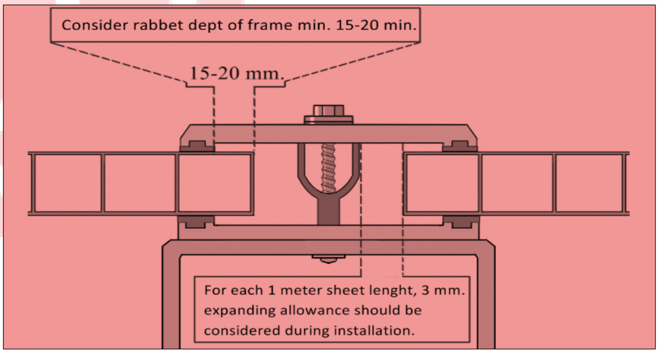
7.4.2. Troubleshooting for Drilling Operations

Problem	Cause	Solution
Chipping	Feed rate too fast	Reduce feed rate
	Bit rake angle too large	Rake angle should be 0-4°
	Sheet vibration	Clamp sheet tightly using solid backing
	Drill bit wobble	Replace bit or chuck
Melting	Feed rate too slow	Increase feed rate
	RPM too high	Reduce RPM
	Heavy chip load	Clear chip buildup periodically. Increase bit twist angle.
	Insufficient coolant	Increase coolant supply
	Clearance angle too small	Regrind drill bit to a 12-15°clearance angle
Irregular Hole	Drill bit is not true	Regrind drill bit
	Bent drill bit	Replace bit
	Worn chuck	Replace chuck
	Worn spindle	Replace spindle or spindle bearings

Screw Unions: Up to 2000 mm Policam™ Acrylic Sheets length the hole should be drilled 6 mm bigger than screw diameter. For each 1000 mm additional length 2 mm should be added to this value. The screws should only be tightened to a position that enables the Policam™ Acrylic Sheets to expand or shrink freely when exposed to temperature stress.

Consider rabbet depth of frame min. 15-20 mm. For each 1 meter Policam™ Acrylic Sheets length, 3 mm expansion allowances should be considered during installation.





7.5. Milling

You can use milling machines which can achieve cutting speeds up to 4500 m/min kind of universal, spindle moulding, profile etc. for milling Policam™ Acrylic Sheets. Small tool diameters require the application of one or two-edged milling cutters. They offer perfect removal of chips, high cutting speed and an excellent milling pattern. When using one-edged milling cutters, tighten carefully the clamping chuck to avoid marks on the sheet.

7.5.1. Milling Cutter

Milling enables clean and shiny finishes for complex shapes. The most preferred milling cutter bits are flat, cylindrical, two or more cutting edged, carbide mono block structured ones. High Speed Steel (HSS) tools give an average quality and finishing. Generally the suitable speed is between 10.000 and 30.000 rpm regarding tool diameter and the number of cutting edges. You can use this technique for flat cutting, engraving and edge finishing.

7.5.2. Material Removing with Milling

You should use vertical moveable, fixed spindle or parallel milling cutters for material removing. Solid carbide or High Speed Steel (HSS) tools are preferable. The speed should be between 1.500 and 25.000 rpm and also coolant is required.

You can have shiny finishes with using diamond tools for **cutting edges.**

8. ACRYLIC SHEET EDGE AND SURFACE FINISHING

The amount of finishing required to produce a smooth, transparent edge is dependent on the quality of the machined edge. A sharp and properly designed cutting tool will reduce the amount of finishing work needed. Finishing is also reduced when a spray coolant is used with the cutting tool to prevent excessive heat build-up.

Finish	Method
High Luster	Polishing
Satin	Sanding
Medium High Luster	Flame Polishing (for edges)
Matte to Medium Luster	Edge Finishing Machines

8.1 Polishing

Depending on the quality of the cut and the desired end use, the edge may need to be polished. To make things easy, use a rubber or foam block and waterproof sandpaper. With a foam sanding block, start with rough paper (~180 grit). Sand until the edge is uniform and relatively smooth. Then change to finer and finer paper until you get a satin finish with 600 grit paper (180, 360 and 600 grit will work fine). When you get to 360 grit paper, start wet-sanding.

Polishing Edges:

You can have a very good finished edge by polishing. Milled edge can be polished without prior sanding. But you should sand the saw-cut edge, with shaper, router or edge-finishing machine. Another option is to be hand scraped before it can be polished. For edge polishing is you can use 8" to 14" (200-300mm) diameter polishing heads.

Edge finish quality depends on the selection of the polishing compounds. The use of a medium cutting compound will give a fairly good finish in one operation. For a high luster finish, it is best to first use a fast cutting compound to remove all sanding marks, and then a high luster compound for the final buffing operation.

Be careful to avoid excessive heat buildup when buffing edges. Too much heat can induce stress into the sheet and eventually cause crazing. To reduce the amount of stress to a minimum, if possible, anneal the part after all fabrication steps are complete (including polishing).

Polishing Surfaces:

If the scratches or machining marks are not too deep, the surface can be polished without prior sanding. Wheels used for surface polishing can be 6" to 12" (150-300mm) in diameter, built up to a width of 1.5" to 2" (38-51mm). The wheels should be made of soft, bleached muslin for the initial polishing operation and of soft flannel for the final finishing.

For the first buffing operation use a medium-coarse polishing compound or a fine compound depending on the depth of the scratches.

When polishing the surface of the sheet, the piece must be kept in motion at all times. Do not use excessive pressure, as softening from over-heating can result.

Polished acrylic components are a very popular option for engineers when considering the design of optical devices. Acrylic is known for its excellent light transmittance, clarity and lack of color. Unfortunately, acrylic does not polish to an optical finish as easily as other materials such as polycarbonate or others. Interior surfaces such as tapped holes are difficult to achieve high clarity.

Acrylic polishing can give the best clarity and light transmittance of all the clear plastics. In both the extruded and cast form, acrylic is readily polished. Depending on configuration of the component, any of the four polishing techniques may be used; **vapor polishing, buffing, flame polishing and direct machine polishing**.

Vapor polishing utilizes a solvent vapor to flow the surface of the acrylic plastic. This method is good for internal features however its effect on acrylic is to produce more of a translucent finish. Typically, the better the machined finish, the better the end result with vapor polishing. Part cleanliness is critical.

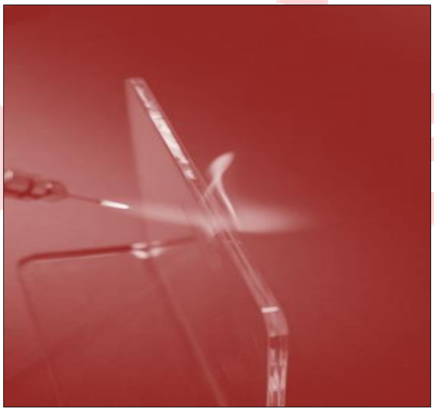
Buffing of acrylic produces a good finish. Buffing is mostly used on exterior surfaces in larger components. Buffing utilizes a spinning cotton wheel with cutting compound. Being a mechanical process, the wheel leaves microscopic scratches and can leave a haze or uneven clarity on acrylic.

Flame polishing utilizes a hot flame to flow a surface. Much like spray painting, finish quality depends on the operator's skill level. Done properly, flame polishing can produce some of the clearest finishes.

Direct machine plastic polishing utilizes specialty tooling to produce polished finishes directly from a machine tool. This method, while the most technical, can produce complicated surface profiles with near flawless finishes.

Acrylic polishing requires special skill since acrylic is a stress sensitive material and is fairly brittle. It can surface stress crack or craze due to poor machining or stresses setup from polishing. For the most stable, stress-free component, always specify an annealing cycle after machining, otherwise stress cracking will occur in service.

Flame polishing is frequently used in acrylic plastic fabrication because of its high speed when compared to abrasive methods. In this application, a torch burning hydrogen and oxygen is typically used; one reason being that the flame chemistry is unlikely to contaminate the plastic.



Flame polishing can be applied with an oxygen & hydrogen torch for welding. You should keep the torch at least 60-70 mm away from the edge of the work piece. Bluish and invisible flame is preferable. It will be better to allow cooling of the part if the first pass failed. You should aware of sudden heat loading to the surface due to inducing stress.

Hold the torch stable with a constant inclined angle and apply only one direction from right to left or vice versa at one time. We recommend a practice trial for the technician, thus will help to estimate proper speed and angle for the real application. Also we highly recommend annealing after flame polishing application to decrease the amount of stress and reduce or prevent the chance of crazing over time.

8.2 Sanding

All methods of sanding will result in the removal of machining marks, and produce a matte finish. The choice of hand, palm, random orbit, disc, belt, or drum sanding, depends on the quantity, size and shape of the acrylic sheet. Like sanding wood, work from coarse to fine paper. Use light pressure, and keep the part or sander moving to avoid heat buildup. After sanding, the edge is ready for buffing or flame polishing.

Sanding Surfaces:

Sanding is not advisable unless the surface scratch and imperfection is too deep. You can test the surface with your fingernail by rubbing over the surface. If it can be felt, then sanding is required. It is recommended that wet sanding be used. The application of water makes it possible to produce a smoother finish because fine-grit sandpaper can be used. Without water, the same fine-grit paper would fill up and over-heat the acrylic. Use light pressure, and keep the part or sander moving to avoid heat buildup. First try using 600-grit sandpaper wrapped around a rubber-padded sanding block. Sand over the scratch using increasingly larger areas. If this does not help remove the scratch, use 400-grit. The sanding should be done in directions mutually 30° apart to produce a diamond pattern. Be sure to use plenty of water and rinse the sandpaper frequently to keep it from clogging. After sanding, you should polish the surface for getting a higher finish.

Sanding Edges:

You will need 2 types of 'wet or dry' sandpaper: one with a grit of 320 – 360, the other with a grit of 180. Grit measures how coarse sandpaper is; the higher the number the finer the sandpaper. Start off with the 180 coarse sandpaper and wet sand the edges. Rinse your sandpaper as needed to stop it clogging up. As the edges level and smooth move onto the sandpaper with the grit of 320 – 360 to give a more polished finish. You could also finish off with the fine 600 sandpaper. For highly polished, shiny edges there are products you can use. If you are considering using a wax or paste be sure to use one that is suitable for acrylic.

8.3 Buffing

For getting a glossy look instead of matte appearance, you can apply buffing operation to the sheet. For the best edge result, perform an initial wet sanding or scraping operation. This removes saw cut marks. Portable heads usually consist of buffing wheels that are chucked into a standard drill. Loose stitched, bleached muslin wheels work best and will result in a high luster edge. Preferably, use stationary machines with polishing wheels dedicated to buffing acrylic. Wheels 8-14" diameter, 2-3" wide, of bleached muslin with bias strips, run cooler than ones fully stitched. With light pressure, keep the acrylic sheets moving across the wheel to prevent excess heat buildup.

9. ACRYLIC PAINTING

You can use acrylic based paints and silk screening inks on Policam™ Acrylic extruded sheet surface for painting applications. You should follow paint manufactures guidelines for thinners, viscosity, methods, and volumes for optimum results.

You should remove dirt from the surface. You can read cleaning section at page 6. Also if there is static electricity issue, you can use an air gun for neutralization of the sheet surface. Leave the protective masking in place or use a peelable spray mask, to protect the sheet from overspray. Please take account for designing issues to avoid potential breakage that acrylic sheet painting reduces impact resistance. You can use a liquid maskant if there are areas which are not to be painted.

9.1 Spray Painting

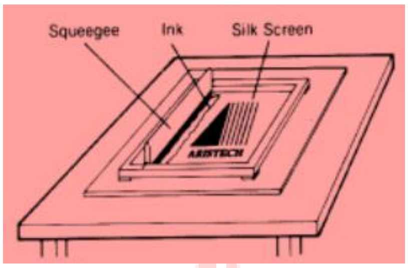
You can use an atomizing spray gun system for acrylic painting. The most suitable system is HVLP Spray Guns. HVLP is a conventional spray gun using a compressor to supply the air, but the spray gun itself requires a lower pressure (LP). A higher volume (HV) of air is used to aerosolize and propel the paint at lower air pressure. The result is a higher proportion of paint reaching the target surface with reduced overspray, materials consumption, and air pollution. A regulator is often required so that the air pressure from a conventional compressor can be lowered for the HVLP spray gun. Alternatively a turbine unit (commonly containing a vacuum cleaner derived motor) can be used to propel the air without the need for an airline running to the compressor.

HVLP, or High-Volume/Low Pressure, uses a high volume of air (typically between 15-26 CFM) delivered at low pressure (10 PSI or less at the air cap) to atomize paint into a soft, low-velocity pattern of particles. In most cases, less than 10 psi is needed in order to atomize. Proper setup utilizes no more fluid and air pressure than is needed to produce the required quality and a flow rate that will meet production requirements. As a result, far less material is lost in overspray, bounce-back and blowback than with conventional air spray. This is why HVLP delivers a dramatically higher transfer efficiency (the amount of solids applied as a percent of solids sprayed) than spray systems using a higher atomizing pressure. The HVLP spray gun resembles a standard spray gun in shape and operation. Models that use high inlet pressure (20- 80 psi) and convert to low pressure internally within the spray gun are called HVLP conversion guns. Some HVLP models, particularly those using turbines to generate air, bleed air continuously to minimize back-pressure against the air flow of the turbine. The air cap design is similar to that of a standard spray gun, with a variety of air jets directing the atomizing air into the fluid stream, atomizing it as it leaves the tip. HVLP is growing in popularity and new environmental regulations are requiring it for many applications. HVLP can be used with any low-to-medium solids materials that can be atomized by the gun.

9.2 Silk Screening-Screen Printing

As an economical option, screen printing is a suitable way for decorating acrylic sheets. The ability to print on acrylic, offers screen printers several lucrative opportunities, including P.O.P graphics and flat faced and thermoformed signage.

For high-volume jobs, screen printing with either solvent or UV curable inks is an economical solution. In selecting an ink system, ask your screen print supply distributor for a recommendation. The ink manufacturers' technical bulletins will give you printing specifications. The type of mesh, squeegee, stencil and thinners are a few of the variables that will determine the amount of ink deposited on the sheet, which affect the appearance of the sign, when it is illuminated. In selecting the best ink for the job, you should consider using a UV thermoforming ink. These inks adhere to a wider range of acrylic sheets than general purpose inks and provide the flexibility required for secondary operations, such as cutting, bending and thermoforming.



Basic Silk Screening Setup

Thermoforming inks typically cure in two steps. The initial UV curing hardens surface of the ink. The ink fully cures in the second step, when it is subjected to the high heat of the thermoforming process, which can range between 150-190°C. Prior to thermoforming, these inks are very soft. For this reason, handle the acrylic sheets carefully to prevent scratching.

A silk screen technique is often used when multicolor decorations or designs are required. This technique uses stencils made from silk. Those stencils are made by coating the screens in the areas not to be painted with a glue filler or other nonporous material. The screening paint or lacquer is then forced through the open meshes of the screen onto the surface of the plastic by rolling a rubber squeegee over the screen with straight, back-and-forth strokes. The edges of the squeegee must be kept free of dried deposits of paint or lacquer to obtain the best results. A separate screen is used for each color with the mesh of each screen determined by the viscosity of the screening paint and by the desired density of the decoration. Screen patterns are usually handmade by an artist. Paints, lacquers, and inks formulated for silk screening acrylic plastics are available with instructions from the various paint companies. The silk screening technique finds wide use in the sign industry. Many signs of the same design can be rapidly decorated by this method. Silk screening equipment consists of three basic parts; a baseboard, a hinge bar and a printing frame. For high-volume work, high-speed automatic silk screening machines are commercially available. The cost of decorating an article in its flat form is usually much less than the cost of decorating it after forming.

In some cases, a general purpose ink may provide adequate results, when the job requires either bending or forming. The risk of adhesion failure, when using these inks, is much higher. For this reason, you should carefully monitor the performance of the ink during production. In selecting a screen printing ink, the printer must weigh the risk of failure against higher material cost.

9.3 Paint Removal

Commercial paint strippers of unknown composition should not be used for removing paint from the surfaces of acrylic sheet because they can cause crazing, particularly of highly stressed areas. Cyclohexanone can be applied by wiping with a cloth (do not immerse) to remove the paint just for a very short time contact. Solvesso 100 an aromatic fluid of ExxonMobil Chemical (or equivalent) can be used similarly, or in an immersion process. Immersion time should be limited to not more than ten minutes, followed by wiping to remove the degraded film. It is advisable to anneal the part after stripping to remove solvent residue and to eliminate the possibility of crazing upon repainting. Soaking in a 15% solution of caustic soda or trisodium phosphate followed by thorough water rinsing can be used to remove non-acrylic paints or freshly-applied acrylic paints. These chemicals attack human skin and protective gloves should be worn when handling them. Paint may also be removed from sheet by sand blasting with a fine grit. This method is more expensive than using solvents and leaves a frosted surface which can produce a grey tone when repainted with white paint.

10. FORMING

One of the most important properties of the Policam™ Acrylic Sheets is formability. The main forming technique is thermoforming. Also there are some other methods to give a shape for extruded acrylic sheets. In this section you can find fundamentals of some techniques for forming applications.

10.1 Preparation

Cutting and Shrinkage: When Policam™ Acrylic Sheet heated over the softening temperature, it undergo a one-time shrinkage between the ratio of %0,2-0,6 through the extrusion direction. These dimensional changes should take into the account when sheets intended for forming are pre-cut to size.

Shrinkage does not occur when the sheets are processed in vacuum forming machines, but rather only when unclamped blanks are heated, such as in the oven. It is recommended a preliminary test if you have doubt.

Protective Film: Policam™ Acrylic Sheet comes with polyethylene (PE) film on its surface to keep itself clean and also protect against dirt, dust, mechanical load and scratches. Normally we recommend that the protective film should remain on the sheet until the finished article is ready for use. If it has to be removed before an application such as thermoforming or bonding, please hold the sheet firmly down at one edge and peel off the film with one time quick movement of the hand through the opposite corner of the sheet.

If the sheets stored outside or exposed to the weather for a time (regarding the climate conditions) protective polyethylene film will become brittle and couldn’t be removed from the sheet surface easily. After that protective film can lead some surface defects. It is recommended to remove the protective film less than 5 weeks if it is stored outside or exposed to the weather.

After you remove the protective polyethylene (PE) film from the surface of the sheet, it may induce electrostatic charge. This charge may cause to collect airborne dust or some particles on the surface. It is recommended to remove PE film with antistatic treatment such as blowing by ionized compressed air or cleaning by hand with a cloth wetted with suitable antistatic agents.

Storage and Pre-Drying: Generally plastics absorb more or less moisture depending on the conditions of storage or weather conditions of the location. Moisture absorption of acrylic may cause surface defects such as bubbles or marks during thermoforming applications. It is highly recommended a pre-drying application with an air-flow oven under the temperature of softening point of acrylic. For Policam™ Acrylic Sheet we recommend 24 hours at 80°C (176°F). In most cases this conditions ensure to remove moisture content of the sheet. But you can prefer longer time if sheet has high moisture inside.

It is recommended to strip off the protective film before the pre-drying application so the drying air able to circulate between the sheets. Acrylic sheets are tending to gain moisture even after pre-drying. In an effective and economic way of process, it will be a better approach making forming just after pre-drying. Pre-drying is not required for line bending.