SPECTAR
copolyester

Fabricating and Forming Sheet Made With *Spectar* Copolyester

EASTMAN

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Note: Conversion of metric/U.S. customary values may have been rounded off and therefore may not be exact.

General Health and Safety Precautions

Safety

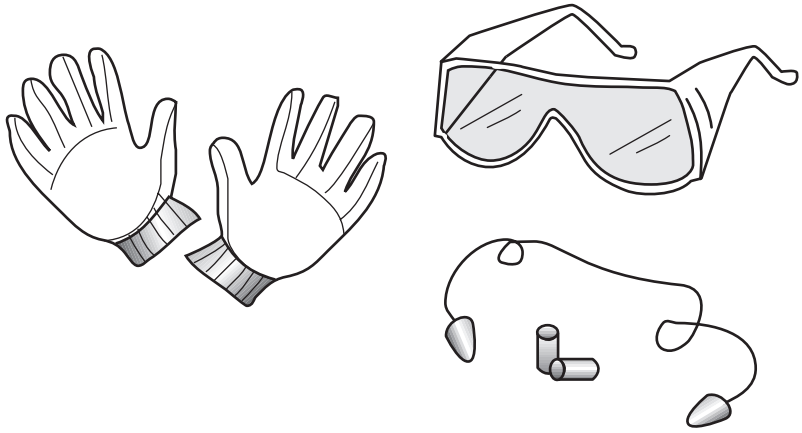
Always exercise good, safe shop practices when fabricating or forming sheet made with *Spectar* copolyester and other plastic materials. Heat generated during sawing, machining, finishing, and thermoforming operations can burn unprotected skin. Flying particles and contact with chemicals and vapors are also areas of concern. Be sure to adhere strictly to all instructions in Material Safety Data Sheets (MSDS) provided by equipment and material suppliers. In addition, keep tools sharp and in good working order for safe operation and high-quality work.

Ventilation

It is always good shop practice to work in a well-ventilated area, particularly when solvent bonding or cementing. Provide localized exhaust venting in the work area.

Protective Equipment

Always use appropriate safety equipment (goggles, gloves, hearing protection, etc.) when handling plastic sheet and operating shop equipment.



FDA Compliance

Sheet made with *Spectar* copolyester can lawfully be used for articles used in contact with certain foods, including coffee, candy, nuts, etc.[1]

[1] *FDA regulation 21 CFR 177.1315 (b) (1)*

Do's and Don'ts of General Health and Safety

Do

- Wear goggles, hearing protection, gloves, and protective clothing as appropriate.
- Keep tools sharp and equipment in good repair.

Don't

- Work in areas with inadequate ventilation.
- Proceed without first reviewing appropriate Material Safety Data Sheets.

Storage and Handling

Sheet Stock

Heavy-gauge plastic sheet is generally shipped in corrugated cases, on pallets, or as continuous rolls. Store large sheet flat with masking intact. Sheet stored on edge in storage racks should have a supported, slightly angled backboard (A-frame) to prevent sheet from warping. Be sure storage areas are clean, dry, cool, and well ventilated. When possible, rotate inventories on a first-in/first-out basis.

Masking

Sheet made with *Spectar* copolyester is protected with a mask of polyethylene film. Whenever possible, leave the masking intact during fabrication. Use older stock first. Also, avoid any unsupported overhang of the sheet.

Remove any adhesive residue on the sheet with a clean, soft cloth dampened with a 50:50 mixture of isopropyl alcohol and water. If the sheet has a static charge after removing the masking, wipe the sheet with a clean cloth slightly dampened with water to help remove the charge.

Handling Formed Parts

Formed parts will continue to cool after they are removed from the mold. To prevent deformation, it is important, especially with large parts, to provide proper support during cooling. Also, avoid any unsupported overhang of the flat sheet or formed parts. To prevent dishing (becoming concave), support parts along their edges, facedown, until completely cooled. Do not nest-stack formed parts.

Do's and Don'ts of Storage and Handling

Do

- Wear gloves when handling large sheets to prevent cuts.
- Keep masking in place for as long as possible.
- Keep table tops clean to avoid scratching the sheet.
- Store sheets flat, as delivered, to prevent warpage. If vertical storage is necessary, it is best to store the sheet and formed parts at a slight angle with full support underneath.
- Support large, formed panels by their edges, facedown, while cooling.
- Store material indoors in a dry, cool, well-ventilated area.
- Use first-in/first-out (FIFO) method to rotate inventory.

Don't

- Use a knife or scraper to remove masking.
- Reuse plastic masking.
- Store plastic sheet near radiators or steam pipes or in direct sunlight.

Cleaning

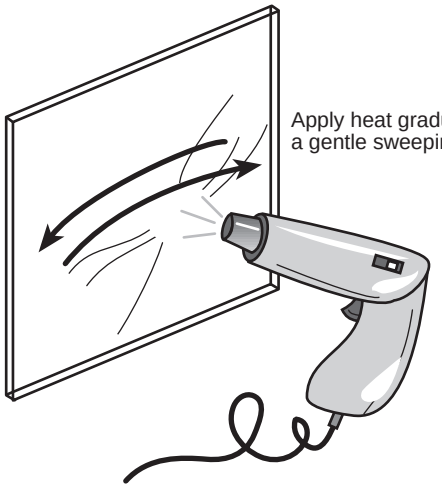
Dust and Dirt

Remove dust and dirt from sheet made with *Spectar* copolyester with a soft cloth and a solution of mild soap or liquid detergent in water. A 50:50 solution of isopropyl alcohol and water also works well. Remove grease and residue from tape or paper masking with naphtha followed by a water wash. Always use a soft, damp cloth and blot dry. Rubbing with a dry cloth can scratch the material and create a static charge. Never use scrapers or squeegees on sheet made with *Spectar* copolyester. Also avoid scouring compounds, gasoline, benzene, acetone, carbon tetrachloride, deicing fluids, lacquer thinner, or other strong solvents. Additional cleaning instructions are included on page 28.

Don't: Use a squeegee.
Use strong solvents.
Rub with a dry cloth.

Removing Scratches

Unlike acrylic, sheet made with *Spectar* copolyester can be polished using a simple heat gun such as found in retail stores. This is covered in more detail on pages 31–33. Apply heat gradually using a gentle sweeping motion. Avoid overheating; this may cause warpage.



Apply heat gradually using a gentle sweeping motion.

Light surface scratches can easily be removed from sheet made with *Spectar* copolyester by applying heat from a handheld torch (typically butane or oxygen/hydrogen) or an electric heat gun. To remove shallow scratches it is best to apply the heat evenly with several passes lengthwise over the scratch. To avoid overheating or damaging the sheet, care should be taken to not focus the heat in a constant position. A suitable distance between the heat source and the sheet along with rapid movement of the heat source over the scratched area are important factors in this technique. Though this technique works for light surface scratches, deep scratches or gouges in the material's surface are not suitable for repair by this method.

Do's and Don'ts of Cleaning

Do

- Use a heat gun to remove minor scratches or abrasions from sheet made with *Spectar* copolyester.
- Use warm water, mild detergent, and a soft cloth or a 50:50 solution of isopropyl alcohol and water.
- Use plenty of water to prevent scratching.
- Blot dry with slightly damp, soft cloth or chamois.

Don't

- Use scouring compounds or solvents such as acetone, gasoline, benzene, carbon tetrachloride, or lacquer thinner to clean the sheet.
- Use hand polishing or power buffing to remove scratches.
- Use abrasives or highly alkaline cleaners.
- Use a cloth of synthetic fiber such as rayon or polyester as this may scratch the sheet.
- Use scrapers or squeegees as they may scratch the sheet.

Sawing and Routing

General Recommendations

If possible, leave the original masking on the sheet during cutting operations. In addition, cover working surfaces with a soft, clean cloth to prevent scratching.

Use sharp, clean blades, holding the sheet securely in place. Bring the blade to full speed before starting the cut and use compressed air to cool the blade and remove chips.

Wear proper safety equipment including safety glasses, gloves, and protective clothing as required by local regulations.

Saw and Cutter Types

Most saws commonly used for wood or metal should satisfactorily cut sheet made with *Spectar* copolyester. These include circular saws, band saws, saber saws, jigsaws, hacksaws, or handsaws. However, circular saws and band saws usually produce smoother, cleaner, faster cuts. Routing is also a common technique.

For the highest quality cut, use a triple-chip style carbide-tipped blade commonly used for plastics. Several sheets made with *Spectar* copolyester can be stacked and cut together *but only if the stack is held securely to prevent movement from sheet to sheet. Otherwise, chipping and irregular cuts may result*. Use a slow and consistent feed rate.

Blade Characteristics

Circular Saws

- Number of teeth—2 to 4 teeth per 25 mm (per in.).
- Blade thickness— 2.5 mm (3⁄32 in.) for single sheets in thicknesses of 1 to 10 mm (0.040 to 0.375 in.) ; 3 mm (⅛ in.) blade should be used for cutting thicker sheet.
- Blade tooth rake angle—5 to 10 degrees.
- Depth of cut—for best results, allow the blade to protrude through the piece by no more than 3 mm (⅛ in.) This will minimize the chance of creating a chipped edge.
- For circular saws, the following blade speeds are recommended:

Blade Diameter, mm (in.)	Blade Speed, rpm
100 (3.5-4) Trimming Saw use Wood Combination Blade	10,000
180 (7¼)	5,000
200 (8)	4,300
250 (10)	3,400
300 (12)	2,900
350 (14)	2,500

Band Saws

- Number of teeth—8 to 14 teeth per 25 mm (per in.) for general cutting; 18 to 24 per 25 mm (per in.) for a smoother, cleaner edge.
- Blade width—for intricate cuts and tighter turns, 6 to 10 mm (¼ to ⅜ in.) is suggested. For straight cuts, larger turns, 12 to 25 mm (½ to 1 in.) is suggested.
- Blade speed—approximately 760 m (2,500 ft) per minute.

Saber Saws and Jigsaws

Always hold your work securely in place. This is especially important when using a saber saw or jigsaw. Excessive vibration can cause cracking and/or possible injury.

- A blade with 6 to 10 teeth per 25 mm (per in.) works well with the orbital action setting at zero.
- A scroll-type blade with 12 to 20 teeth per 25 mm (per in.) can be used to achieve a good edge finish on intricate cuts.

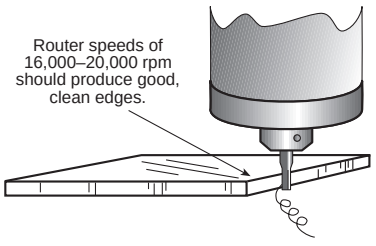
Handsaws and Hacksaws

Although not commonly used on plastic sheeting, handsaws and hacksaws can work satisfactorily if used carefully and with little pressure. Use sharp blades that range from 6 to 18 teeth per 25 mm (per in.), depending on the desired finish. As always, securely support the sheet to avoid flexing.

Routers

Routing with sharp, two-flute, straight cutters produces very smooth edges. Also spiral-cut router bits have been found to work successfully depending on the application. It is especially useful for trimming the edges of flat or formed parts, or parts too large or irregular in shape to cut with a band saw. Portable, overarm, and small table routers work equally well.

- Use router speeds of 16,000 to 25,000 rpm to produce good, clean edges.
- Feed the sheet into the router slowly to avoid excessive frictional heating, shattering, or chipping.
- Use a suitable jig to support the sheet during routing.
- Use compressed air to cool the bit and to aid in chip removal.



Troubleshooting Guide for Cutting Sheet Made With *Spectar* Copolyester

Problem	Possible Cause	Possible Solution
Rough or chipped edges	High feed rate	Reduce feed rate.
	Sheet vibration	Secure sheet firmly.
	Blade protrusion	Limit to maximum of 3 mm (⅛ in.).
	Broken teeth	Replace blade.
	Blade too coarse	Use more teeth/in. (mm).
Cracking	Blade and fence not parallel	Realign blade and fence.
	Sheet vibration	Secure sheet firmly.
	Feed rate too high	Reduce feed rate.
Surface scratching	No masking	If possible, leave masking intact.
	Dirty work surface	Clean work surface.
	Jigs/fixtures are nicked, burred	File, sand, or polish to remove burrs.
Blade gums up	Dull blade	Sharpen or replace blade.
	Inconsistent feed rate	Use steady, even feed rate.
	Feed rate too slow	Increase feed rate.
	Improper blade	Use blade specified.
Dust buildup	Dull blade	Sharpen or replace blade.
	Clogged blade	Clean or replace blade.
	Static charge on sheet	Wipe with damp cloth.
	Masking removed	Leave masking in place.

Do's and Don'ts of Sawing and Routing

Do

- Practice on pieces of scrap before cutting parts.
- Use recommended saw blades.
- Use slow, consistent feed rate.
- Hold sheet firmly while cutting to minimize vibration.
- Use compressed air to minimize heat buildup, especially for sheet more than 5 mm (0.195 in.) thick.
- Use just enough clamp pressure to prevent vibration.
- Feed against the rotation of the blade or tool.

Don't

- Cut plastic sheet without wearing proper safety equipment.
- Cut plastic sheet with a dull blade or cutter.
- Reverse the natural curve of the material when cutting sheet from roll stock. This overstresses the sheet and can cause fractures.
- Apply excessive clamping pressure.
- Use a blade with side-set teeth.
- Scribe-break sheet made with *Spectar* copolyester.
- Remove safety guards from equipment.

Drilling

Drills and Bits

Sheet made with *Spectar* copolyester can be readily drilled using a standard drill press or handheld drill with sharp, clean drill bits. Drill bits designed for use with plastic are recommended. Bits designed for use with polycarbonate have been found to work well with sheet made with *Spectar* copolyester. Standard drill bits can, on occasion, be used but may have to be ground to reduce the depth or angle of cut. As with any plastic sheet product, it is important to keep vibration to a minimum to prevent chipping or cracking. Hold the work securely in place when drilling but avoid excessive clamping pressure.

Drilling Procedure

Optimum bit speed, feed rate, and applied pressure will depend on hole size and sheet thickness. Drill speeds up to 1,750 rpm are best for smaller holes, while speeds as low as 350 rpm can work for larger holes. Use water or compressed air to minimize heat buildup when drilling sheets thicker than 4.8 mm (0.187 in.), stacked sheets, or very large holes.

When drilling holes that will penetrate the second surface, back up the piece with wood to cushion the drill bit as it passes through the sheet. Move the drill bit in and out to remove plastic shards.

Do's and Don'ts of Drilling

Do

- Use sharp drill bits designed for plastic.
- Use just enough clamping pressure to prevent vibration.
- Use a load spreader to distribute clamp pressure evenly.
- Use compressed air to prevent overheating, especially if sheet is more than 4.8 mm (0.187 in.) thick.

Don't

- Apply excessive clamping pressure.
- Use a dull drill bit.
- Use power tools without proper protection.

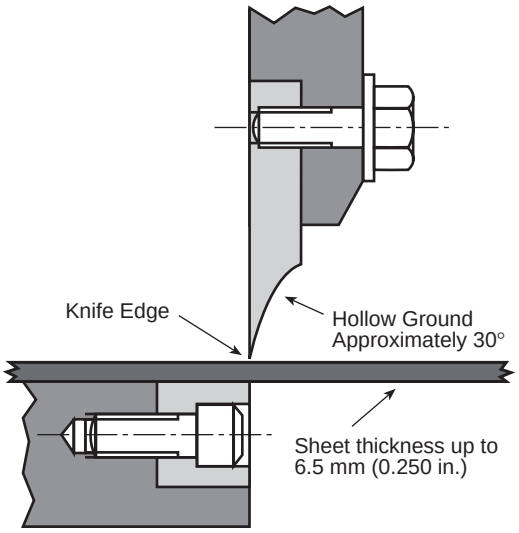
Shearing, Punching, and Die-Cutting

General Recommendations

Sheet made with *Spectar* copolyester is a tough but ductile material and is readily sheared, punched, and die-cut when proper tools and techniques are used. A shear cut yields a straight edge, while punches and dies can be used to produce holes of almost any desired shape.

Shearing

A power shear can be used to cut sheet in thicknesses up to 6.5 mm (0.250 in.). For thicker sheet, sawing is recommended. To achieve smooth cuts, maintain a blade-to-bed knife clearance of approximately 0.025 mm (0.001 in.). The following diagram shows a typical shearing assembly.



Shear Strength

The following table shows shear strength requirements for cutting various thicknesses of sheet made with *Spectar* copolyester.

Shear Strength Requirements
(ASTM D732, Shear Strength Determination Method)

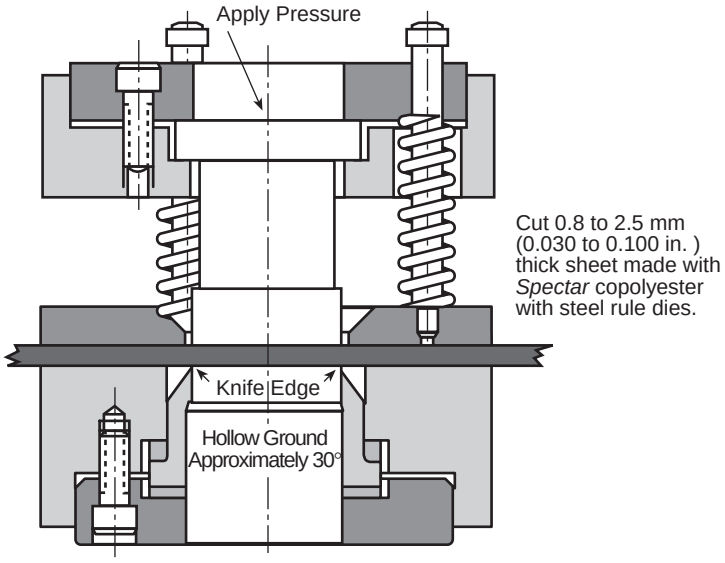
Thickness, mm (in.)	Sheet Shear Strength, MPa (psi)
2 (0.080)	57.6 (8,354)
3 (0.118)	56.5 (8,195)
6 (0.236)	46.1 (6,686)

Punching

When a particularly sharp or smooth cut is not required, a punch can be used. Hand-operated punches are useful for small holes, but larger holes may require a power-operated punch. Heating the sheet to approximately 38°C (100°F) will minimize the possibility of cracking or chipping; however, allow for hole shrinkage due to cooling. We recommend sawing, drilling, and routing instead of punching sheet thicker than 2.5 mm (0.100 in.).

Die-Cutting

Cut 0.8 to 2.5 mm (0.030 to 0.100 in.) thick sheet made with *Spectar* copolyester with steel rule dies. These are usually 12.5 mm (½ in.) deep and are mounted in a properly shaped slot cut into a wooden block (see the following diagram). While relatively inexpensive, steel rule dies must be sharpened or replaced fairly often to remain effective.



Die Press Capacity

A die press must have adequate power to achieve the desired cut. Use the shear strengths shown on page 12 with the following formula to calculate the required press capacity.

$$F = \frac{S \times P \times T}{C}$$

where:

F = Required press capacity in tons
S = Sheet shear strength in MPa (psi)
P = Perimeter of cut in mm (inches)
T = Thickness of sheet in mm (inches)
C = 8,896 N/ton (2,000 lb/ton)

Example:

A 3mm (0.118 in.) thick sheet made with *Spectar* copolyester requires a shear strength of 56.5 MPa (8,195 psi). The press tonnage required to die-cut a sheet measuring 381 mm (15 in.) square is calculated in the following equation. The perimeter measurement is calculated by multiplying 0.381 (15 in.) × 4 because the shape is square.

SI Units

$$F = \frac{(56.5 \text{ MPa})\ (3 \text{ mm})\ (1{,}524 \text{ mm})}{8{,}896 \text{ N/ton}} = 29 \text{ ton}$$

U.S. Customary Units

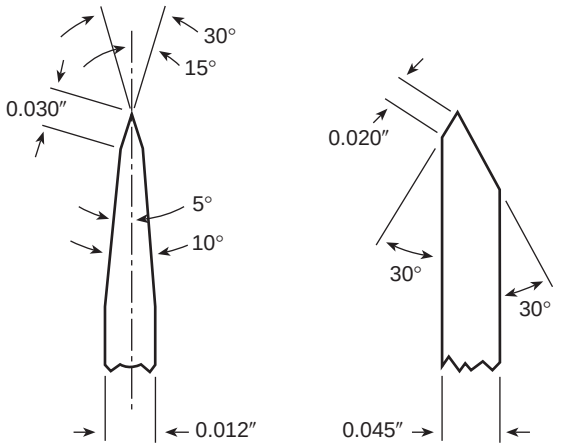
$$F = \frac{(8{,}195 \text{ psi})\ (60 \text{ in.})\ (0.118 \text{ in.})}{2{,}000 \text{ lb/ton}} = 29 \text{ ton}$$

NOTE: The actual cutting force required to cut through a thicker sheet increases with added sheet thickness. Shear strength (psi) is calculated by dividing the cutting force by the sheared area.

However, as sheet thickness increases, the sheared area (sheet thickness × cut length/perimeter) over which the cutting force is distributed increases at a greater rate than the magnitude of the required cutting force, thus causing the shear strength values to decrease with increasing thickness.

Die Design

Designs for 2 steel-rule cutting edges that work equally well with sheets up to 2.5 mm (0.100 in.) thick are shown below. Steel hardness should be 45 to 55 Rockwell C, depending on the degree of bending required in fabrication.



Die-Cutting Procedure

Adjust the press to make a complete cut in a single stroke without damaging the die. Shim the die as necessary to ensure that all areas cut uniformly through the plastic sheet. To ensure that the entire die is level and true:

- Tape kraft or carbon paper, 150 to 200 micron (0.006 to 0.008 in.) thick, to the plate.
- Lower die to mark an imprint of the cutting pattern.
- Shim low rule areas.
- Make a test cut.
- Alternate cutting/shimming until a full, uniform cut is obtained.
- Position test parts consistently.
- Keep cutting dies as sharp as possible.

To prevent contact between the die and the press bed, use a steel cutting plate 0.5 to 3 mm (0.020 to 0.118 in.) thick with a Rockwell C hardness of 30 to 35.

Do's and Don'ts of Shearing, Punching, and Die-Cutting

Do

- Heat sheet to 38°C (100°F) before punching.
- Ensure entire die is level and true before cutting.
- Shim areas as necessary to ensure uniform cut.
- Use carbon paper imprint to set die properly.

Don't

- Shear sheet thicker than 6.5 mm (0.250 in.).
- Use a dull die.
- Use steel cutting plate harder than 30 to 35 Rockwell C.
- Use power equipment without proper safeguards.

Bonding and Fastening

Bonding Methods

Solvent-bonding is generally preferred when the components to be joined are made from sheet made with *Spectar* copolyester. However, when joining dissimilar materials or considerations such as part size, bond flexibility, or bond appearance prevail, adhesives or mechanical fastening may be needed. Recommended adhesives include cyanoacrylates, two-part acrylics, two-part polyurethanes, and two-part epoxies.

Adhesive-Bonding

When joining dissimilar materials, solvent bonds are rarely strong and durable, so the use of adhesives is often recommended for this purpose. The adhesive selected must be compatible with each material involved.

If the materials being joined expand and contract at different rates, a flexible bond may be required. Take this into account when selecting the adhesive formulation. If expansion and contraction are a major concern, consider the use of mechanical fastening.

Adhesive Characteristics

A variety of adhesives are available for joining dissimilar plastic materials. As a result, it is difficult to make general observations. Unlike solvents, which evaporate, an adhesive layer remains a functional part of the finished assembly. Hence, the performance and appearance of the finished part may depend primarily on the characteristics of the adhesive layer.

For example, the selection of a brittle adhesive or one that contains aggressive chemicals may lower the impact strength of sheet made with *Spectar* copolyester. Several characteristics to consider when selecting an adhesive are:

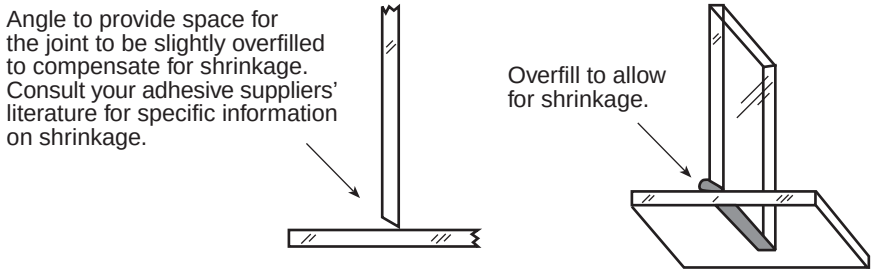
- Chemical compatibility with the parts being joined.
- Aesthetics of the finished joint.
- Expansion/contraction with temperature changes.
- Brittleness/rigidity/flexibility.
- Weatherability, if required.
- Durability/service life.
- Adhesive strength (adhesion to the plastic).
- Cohesive strength (resistance to internal tearing).
- End-use requirements.
- Suitability for food contact.

Adhesive-Bonding Procedure

Joined surfaces must fit well without forcing and have no visible gaps. The surfaces to be bonded should be smooth but not polished. Sand the surfaces to be joined with a 120 grit or finer paper. Diamond-wheel polishers, jointer/planers, or other mechanical devices can produce excellent results. However, soft polishing wheels or flame-polishing are not recommended as these can round the edges, causing gaps and improper fit.

Adhesive Shrinkage

Some adhesives with a volatile component may shrink while curing. To compensate for this, cut the joint on an angle, providing space for the joint to be slightly overfilled to compensate for shrinkage. Consult your adhesive suppliers' literature for specific information on shrinkage.



Do's and Don'ts of Adhesive Bonding

Do

- Use an adhesive system to bond sheet made with *Spectar* copolyester to other materials such as acrylic or polycarbonate:
  - For bonding sheet made with *Spectar* copolyester to itself, use *Weld-On* 58, *Weld-On* 55, *Weld-On* 42, *Scotch-Weld* DP-100, *Durabond* 105CL, *Light Cure* 3104, *Light Cure* 3105, *Ultra Light-Weld* 3072, or *Plastic Welder* II.[1]
  - For bonding sheet made with *Spectar* copolyester to sheet of acrylic, use *Weld-On* 42, *Durabond* 105CL, *Light Cure* 3104, *Light Cure* 3105, *Ultra Light-Weld* 3094, *Ultra Light-Weld* 3072, or *Plastic Welder* II.[1]
  - For bonding sheet made with *Spectar* copolyester to sheet of polycarbonate, use *Weld-On* 58, *Weld-On* 55, *Durabond* 105CL, *Light Cure* 3104, *Light Cure* 3105, *Ultra Light-Weld* 3094, *Ultra Light-Weld* 3072, or *Plastic Welder* II.[1]

[1]Weld-On *is a trademark of IPS Corporation;* Scotch-Weld *is a trademark of 3M;* Durabond *and* Light Cure *are trademarks of Loctite;* Ultra Light-Weld *is a trademark of Dymax; and* Plastic Welder *is a trademark of Devcon.*

- Use the following procedure:
  - Start with a flat surface.
  - Prepare the sheet properly:
    - Remove all foreign particles.
    - Wipe surface with a 50:50 mixture of isopropyl alcohol and water.
    - Allow surfaces to dry thoroughly before bonding.
    - Sanding with fine-grit sandpaper to lightly roughen the surfaces to be bonded may improve bond strength.
  - Apply the two-component system to one surface.
  - Place the two surfaces in desired bonded position.
  - Fill joints completely with adhesive so that no voids remain.
  - Use a jig or fixture to securely hold parts being bonded together while curing.
  - Follow manufacturer's recommendations for proper pressure and time needed for the adhesive to cure.

Don't

- Work in poorly ventilated areas.

Mechanical Fastening

Because of its outstanding toughness, sheet made with *Spectar* copolyester adapts to mechanical fastening more readily than some other materials. This method is useful when assembling or installing large or heavy parts or when a suitable solvent or adhesive system is not available.

Use screws designed specifically for plastics. If bolting parts together, allow for thermal expansion and contraction by drilling oversized holes. Use of washers is suggested when bolting for better load distribution.

Use metal inserts if frequent assembly/reassembly is involved. Inserts are not recommended where thermal expansion and contraction may occur.

Do's and Don'ts of Mechanical Fastening

Do

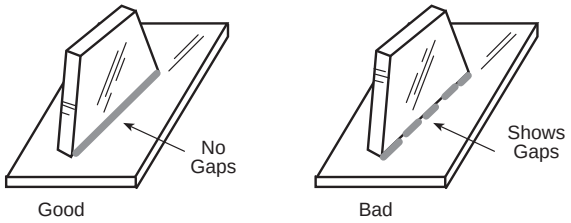
- Use screws designed specifically for plastic.
- Drill holes slightly oversized to allow for thermal expansion and contraction.
- Ensure drilled holes have smooth edges.
- Use washers for better load distribution. The use of flexible washers is preferred.

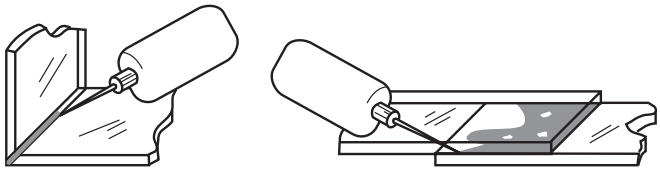
Don't

- Overtighten fasteners.
- Use self-tapping screws to hang large panels.

Solvent-Bonding

The excellent chemical resistance of sheet made with *Spectar* copolyester allows its use in certain applications where other plastic materials might be unsuitable. This feature must be taken into account when choosing a solvent for an optimum bond. Use of a proper solvent, good technique, and cure time should result in a clear, haze-free, joint that is strong and durable. Whether using the capillary action technique commonly employed for smaller parts and bonds of fairly short length or some other method, the parts must fit together well without forcing—***leaving no visible gaps.***





- Use needle-type applicator.
- Apply solvent evenly along entire length.

- Apply from inside for corner joints.
- Apply from both sides for lap joints.

Solvent Selection

There are several options for bonding sheet made with *Spectar* copolyester to itself. These include commercial products as well as custom blends of MEK and methylene chloride. You may also consult the sheet extruder or your distributor for additional solvent agents suitable for use with sheet made with *Spectar* copolyester.

MEK, a fast-acting solvent, gives quicker set-up with more likelihood of freeze-off (setting up before the joint is filled). Methylene chloride, on the other hand, is a slower solvent and offers more work time with less potential for freeze-off. In some locations, a 50:50 mix of methylene chloride and MEK is used as a starting point to formulate custom solvent blends. A small amount of acetic acid can be added when bonding in humid environments.

Some water-thin formulas designed for bonding acrylics can also be used to bond sheet made with *Spectar* copolyester to itself if they are used with care. *Weld-on* 3 and *Weld-on* 4, available from IPS Corporation, are two such formulas. Hazing may, however, occasionally be a problem.

Do not use thick cements intended for use with other plastics; they are generally incompatible with sheet made with *Spectar* copolyester.

Troubleshooting Guide for Solvent Bonding Sheet Made With *Spectar* Copolyester

Problem	Possible Cause	Possible Solution
Solvent freeze-off	Use of improper solvent	Switch to a system designed for sheet made with *Spectar* copolyester.
	Solvent too active	Dilute mixture with a slower solvent.
	Application technique	Reevaluate technique.
Hazy/cloudy joints	Use of too much solvent	Use less solvent.
	Poor part fit	Improve part fit.
	Solvent pooling	Check leveling of part to reduce pooling.
	Old solvent mixture	Add fresh solvent.
Weak joints	Use of improper solvent	Switch to a system designed for *Spectar* sheet.
	Application technique	Reevaluate technique.
	Poor part preparation	Prepare part properly.
Voids appear as part cures	Use of too much solvent	Use less solvent.
	Poor part fit	Reshape parts to improve fit.
	Solvent pooling	Check leveling of parts as solvent is applied.
	Part shifts during set-up	Increase clamping pressure and/or use a jig to hold the parts in place while the bond sets up.
	Overly rough surface	Lightly sand surface.

Do's and Don'ts of Solvent Bonding

Do

- Use the appropriate solvent for bonding sheet made with *Spectar* copolyester to itself:
  - Use solvents such as methyl ethyl ketone, methylene chloride, tetrahydrofuran, *Weld-On* 3, *Weld-On* 4, or *RHW-29*.[1]
- Use the following procedure:
  - Start with a flat surface.
  - Be sure that surfaces to be bonded are smooth and mate well.
  - Prepare the sheet properly:
    - Remove all foreign particles.
    - Wipe surface with a 50:50 mixture of isopropyl alcohol and water.
    - Allow surfaces to dry thoroughly before bonding.
  - Press surfaces to be bonded together.
  - Apply solvent to edge of joint with a hollow needle. Solvent will wick into joint by capillary action.
  - Hold joints in a horizontal position to prevent solvent from pooling at one end.
  - Use minimum amount of solvent needed to wet surfaces to be bonded.
  - Use a jig or fixture to securely hold parts being bonded together while curing.

Don't

- Use solvents to bond sheet made with *Spectar* copolyester to other materials such as acrylic or polycarbonate.
- Work in poorly ventilated areas.
- Flood the joint as this can cause hazing.
- Leave gaps where solvent can pool.

[1]RHW-29 *is a product of AAM Manufacturing.* Weld-On *is a trademark of IPS Corporation.*

Plastic Welding

Technology has been developed that allows plastic sheet fabricators to obtain clear, strong bonds by welding with a rod of sheet made with *Spectar* copolyester material. The technology can be used to bond sheet made with *Spectar* copolyester to itself or to other plastic sheet materials.

Like metal welding, particularly wire-feed welding, plastic extrusion welding produces a strong, uniform bond on plastic sheet or other plastic applications.

There are many advantages of plastic welding that can be easily realized when working with sheet made with *Spectar* copolyester. Advantages include:

- No messy or environmentally unsafe glues or solvents.
- Clear, yet tough bonds.
- Quick fabrication—no drying time required.
- Water tight, long-lasting joints.
- Diverse fastening method for a variety of applications.
- Better, stronger designs.
- With welding rod produced from FDA-approved sheet made with *Spectar* copolyester, the bonds are safe for food contact.

Forming

Forming Methods

The term forming refers to any process used to transform a flat plastic sheet into a shaped article. The process may be carried out at room temperature (cold bending) or using heat (thermoforming). In either case, *sheet made with* Spectar *copolyester is uniquely suited to a variety of forming operations, offering a combination of features unmatched by acrylic or polycarbonate*. The sheet can be formed without pre-drying, forms at lower temperatures, heats and cools rapidly, releases easily from the mold, and processes with impressive consistency. Deep draws and intricate part definition are routine using simple vacuum pressure.

Drying

Unlike some sheet products, sheet made with Spectar *copolyester can be thermoformed without pre-drying*. This translates into major labor, energy, and capital savings.

Heater Design

Sheet made with *Spectar* copolyester may be heated using single- or double-sided radiant heat or convection ovens. While single-side heating is common, it can heat the sheet unevenly. *Generally speaking, this factor is less critical when forming* Spectar *sheet because it has a wider forming temperature window than acrylic or polycarbonate*. For more critical applications such as distortion screen-printing, complex shapes, or very deep draws, use double-sided radiant heat with zone control if possible.

Forming Temperature

Sheet made with *Spectar* copolyester will form at lower temperatures and over a wider range of temperatures than acrylic or polycarbonate. Typical oven temperatures of 200° to 260°C (400° to 500°F) produce corresponding sheet temperatures of 135° to 155°C (275° to 310°F). In general, temperatures on the high end of the range will allow the sheet to draw more deeply and reproduce more intricate mold detail. However, too much heat can result in excessive sag, which may lead to webbing or bridging when a vacuum is applied. Monitor sheet temperatures with an infrared thermometer or observe the degree of sag. If the sheet has been stored for long periods under conditions of high humidity, select a forming temperature on the lower end of the range. Take care to avoid air drafts in the forming area, especially if the process is heat critical (as in distortion screen-printing). Use air curtains or other barriers if necessary.

A general guide to forming temperature follows:

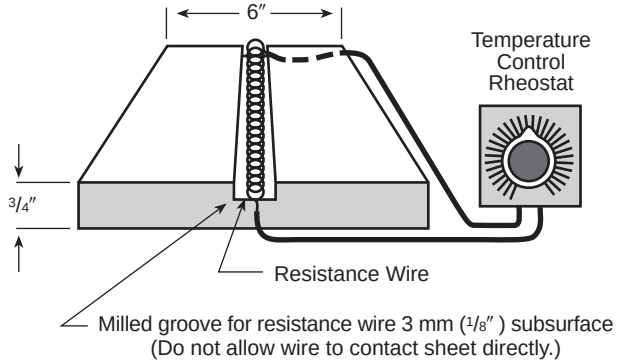
Factor	Temperature Range
Deep draws	Higher end
Moderate draws	Lower end
Large parts	Lower end
High moisture	Lower end
Complex detail	Higher end

Thermoforming

Sheet made with *Spectar* copolyester forms at substantially lower temperatures than required for acrylic or polycarbonate. It also lends itself to deeper draws and more complex shapes. The most common thermoforming techniques include line-bending, free-forming, and vacuum-forming.

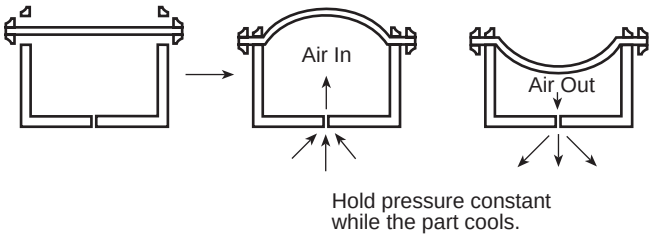
Line-Bending

To line bend, heat the sheet on one side to 100° to 120°C (212° to 250°F) along a straight line. Bend to the desired angle and hold in place until the part has cooled and the new shape is set. A jig is useful for holding the part in place during cooling, although it may be possible to hold the part in the desired position by hand.



Free-Forming

Use free-forming to produce domes, bubbles, and other symmetrical shapes. Heat the sheet, then seal against the opening of a pressure box and apply air pressure to force the sheet into the desired shape. Hold pressure constant while the part cools. The shape of the opening and the quantity of air forced into the box determine the shape. Achieving some shapes may be as simple as allowing the sheet to sag in the oven, without pressure, to a desired depth, at which point the part is removed to cool. In either case, the formed part exhibits an excellent finish because the heated sheet never makes contact with a mold surface. Another option involves using a vacuum box that gives similar results.



Vacuum-Forming

There is a limited variety of shapes that can be produced with line-bending and free-forming. There is, however, virtually no limit to the variety of shapes that can be achieved through vacuum-forming. In this process, heat the sheet and then position over a male or female mold. Evacuate the air between the sheet and the mold surface. This will cause the heated sheet to assume the contours of the mold surface. Hold the vacuum while the part cools, then release the vacuum and remove the part from the mold. Positive pressure, or a combination of positive and negative pressure, can be used.

Cold-Bending

Cold-bending can be used to produce simple shapes from sheet made with *Spectar* copolyester. When brake-forming, the maximum amount of bend will depend on sheet thickness and rate of deflection. Cold-bending sheet more than 2.5 mm (0.100 in.) thick will likely cause high stress levels, which may lead to part failure. When cold-bending use the general recommendation of radius equals 100 × thickness of sheet.

Molds

Mold Materials

Commonly used mold materials include wood, vacuum board (medium density fiber board), pressure laminates (for flat surfaces), plasters, aluminum-filled epoxies, automobile body putties, fiberglass, and aluminum. Molds made from wood or vacuum board are inexpensive and easy to fabricate into the desired shape with common woodworking tools. Limitations of wooden molds include durability, slower part cooling, and less control over surface texture.

Mold Design

Formed sheet made with Spectar *copolyester typically has very good release characteristics.* For most male molds, a minimum draft angle of 5 to 7 degrees ensures easy part removal. Large-scale production runs may justify the production of a prototype mold to determine optimum draft angles, shrinkage, and other mold design features. *Parts formed from sheet made with* Spectar *copolyester will typically shrink about 0.5%, which is less than generally experienced with polycarbonate or acrylic.* Sharp edges and corners on molds should be avoided. A corner radius of at least 4.5mm (3⁄16 in.) is required.

Thickness Control

The wall thickness of vacuum-formed parts varies with thinner areas occurring at the points of deepest draw or greatest stretch. For example, if a pan configuration is drawn into a female mold, the thinner areas will occur at the corners, or face, of the formed part. Material distribution can be optimized through mold design, the use of plug assist, or billowing, depending on the specific design of the part.

Mold Finish

Formed sheet made with *Spectar* copolyester provides an excellent reproduction of the mold surface. For this reason, vacuum holes should be no more than 0.4 mm (0.015 in.) in diameter. Keep the mold surface clean during the forming operation (even dust marks can be picked up in the surface of the formed part). A smooth, clean mold surface produces a smooth, clean formed part. On the other hand, using unique mold finishes offers a wide range of customized design possibilities.

Part Removal

Reduce the possibility of warping by allowing formed parts to cool to 50°C (120°F) or lower before removing them from the mold. They will continue to cool after removal, so proper support is required to prevent deformation. This is especially true for large, heavy parts. To prevent dishing (concave shape), large parts should be supported along their edges, facedown, until completely cooled. Do not nest formed parts since this can cause blocking and scratching. Large parts should be fully supported when being transported to prevent excessive flexing.

Predecorated Sheet

Since it forms at lower temperatures, sheet made with *Spectar* copolyester may be used with less concern about overheating preapplied inks or vinyl films. In some cases, parts have been formed with the decorated surface in contact with the mold with no adverse effects. The compatability of Spectar with vinyl can allow thicker guage sheet to be used than with polycarbonate without the fear of damaging the vinyl.

Troubleshooting Guide for Thermoforming Sheet Made With *Spectar* Copolyester

Problem	Possible Cause	Possible Solution
Webbing or bridging	Sheet too hot	Decrease heating time or temperature.
	Complex shape	Use female mold and/or prestretch sheet with plug or pressure assist.
Bubbles in formed sheet	Sheet too hot	Reduce forming temperature.
Surface defects on part	Oversized vacuum holes	Use smaller holes.
	Rough mold surface	Sand/polish mold.
		Use aluminum mold.
	Dirty mold	Clean mold.
Release difficulties	Insufficient draft	Increase draft angle or use female mold.
Poor material distribution	Forming technique	Try plug, bubble, or vacuum assist.
	Uneven heat	Adjust heat zones.
Uneven sag	Uneven heat	Adjust heat zones.
Poor detail	Vacuum released too soon	Hold vacuum longer.
	Vacuum applied too slowly	Apply vacuum sooner.
	Sheet too cold	Increase heating time or temperature.
Warped parts	Insufficient cooling	Allow parts to cool longer in mold.

Do's and Don'ts of Forming

Do

- Keep molds and sheet very clean. Remove dust with a damp cloth or blow it off with pressurized air.
- Provide a 5 to 7 degree draft on male molds for easy release.
- Leave masking in place when possible.
- Form sheet made with *Spectar* copolyester at lower temperatures than those used for acrylic and polycarbonate.
- Ensure the unprotected side of the sheet is in the proper position in the final part orientation if UV-protected sheet is being used.
- Allow parts to cool sufficiently before removal from mold.
- Allow generous radii on internal corners (≥ initial sheet thickness).

Don't

- Predry sheet made with *Spectar* copolyester.
- Heat sheet made with *Spectar* copolyester as hot as recommended for competitive materials.
- Lay larger formed parts faceup while cooling.
- Nest formed parts during storage.
- Use vacuum holes larger than 0.4 mm (0.015 in.) in diameter.

Decorating

General

There are many ink products and processes used for decorating plastic sheet. The objective of this section is to illustrate that sheet made with *Spectar* copolyester can be decorated with existing inks, vinyl film, and decorating methods. Specific ink references are not included because of the numerous options available. If you have questions or need additional information, please contact Eastman at one of our offices listed on the back cover of this publication.

This sheet's high gloss and optical clarity, along with low thermoforming temperatures, allow a variety of decorating techniques that include painting, printing, and hot stamping.

Cleaning the Sheet

Before sheet decoration, remove any dust, dirt, or static buildup. Use a clean, soft cloth dampened with a 50:50 solution of isopropyl alcohol and water. Test commercial cleaning to ensure there is no adverse effect on the sheet. The use of commercial cleaners should be in strict compliance with the manufacturer's instructions. Additional information on cleaners is found on page 5.

Spray-Painting

Conventional spray-painting techniques are often used to decorate large panels. There are commercial spray paints available for sheet made with *Spectar* copolyester. When selecting paint, carefully consider fitness-for-use requirements such as dry film adhesion and impact strength retention. Obtain more detailed information about these characteristics from the paint supplier.

Dry Film Adhesion

Sheet made with *Spectar* copolyester generally exhibits excellent chemical resistance compared with other plastic sheet materials. As a result, some solvent-based paints designed for use with polycarbonate or acrylic *may not* be sufficiently active to provide good adhesion to sheet made with *Spectar* copolyester. Generally, a paint that produces a flexible, tough dry film, such as some polyurethanes, has better adhesion than one yielding a rigid, brittle film. Contact your paint supplier for details.

Impact Strength

The excellent impact strength of sheet made with *Spectar* copolyester accounts for its use in a host of demanding applications. Select an ink, a paint, or a coating material that will not compromise this important feature using a system that provides a tough film if on-site abuse is a factor. It is important that such fitness-for-use requirements be clearly communicated to the paint supplier.

Spray-Masking

Conventional spray-masking materials work well with sheet made with *Spectar* copolyester. Compared with acrylic or polycarbonate, it may be easier to cut away the masking since parts formed from sheet made with *Spectar* copolyester usually exhibit crisper forming detail to guide the knife.

When cutting the masking, use a sharp knife and minimum pressure to avoid cutting into the plastic sheet, as this may notch the sheet, reducing its impact resistance.

Printing

Many printing processes can be used with sheet made with *Spectar* copolyester. The process depends largely on the configuration, production volume, and fitness-for-use requirements of the finished part. Specially formulated inks are available to meet the specific requirements for a given end use. Consult your ink supplier to determine the best choice of inks and application techniques.

Screen-printing produces clean, sharp images, intricate detail, and true color reproduction, allowing it to be used on a variety of sizes with low set-up costs. It is useful for decorating flat sheet or formed parts in moderate to high production volumes. sheet made with *Spectar* copolyester particularly lends itself to distortion screen-printing because of its excellent registration and even material distribution during thermoforming.

Offset lithography, flexography, and **rotogravure** are usually used for large volume runs (sheet- or roll-fed) requiring consistently excellent image quality. However, these methods typically have higher set-up costs and a limited range of suitable part sizes.

Pad-printing does an excellent job when highly detailed artwork is required on an irregular or textured surface. It is well suited to single or multiple color work in low to high production volumes. It generally works well with UV-curable inks and deposits a thinner ink layer than a screen print process. It is useful for low, medium, and high production volumes.

Hot-Stamping

Copy, trademarks, and other design elements may be transferred to flat, smooth surfaces on sheet made with *Spectar* copolyester by hot-stamping. Eastman has found die temperatures of 149° to 204°C (300° to 400°F) and a 1 to 2 second dwell time at 0.62 MPa (90 psi) a good starting place. Additional information on hot-stamping can be obtained from foil manufacturers.

Vinyl Decorating

Benefits of vinyl decorating sheet made with *Spectar* copolyester include uniform color distribution and correct color matches. Also, vinyl can be applied to first and second surfaces prior to forming.

The following procedure will aid in production of a long lasting, thermoformed, vinyl-decorated sheet with excellent color consistency.

- Remove masking and clean sheet to remove static and contamination with equal parts isopropyl alcohol and water.
- Apply vinyl to first or second surface.
  - Dry surface.
  - Apply liquid soap and water solution to surface with a garden sprayer.
- Prepare mold.
  - Ensure edges are smooth.
  - Apply cornstarch or baby powder to mold to aid with mold release.
  - Can be thermoformed after vinyl decoration.
  - Follow vinyl suppliers recommendations for proper drying time between application of vinyl film and thermoforming.
- Thermoform.
- Weed any excess vinyl.

Do's and Don'ts of Decorating

Do

- Use paints formulated for use on sheet made with *Spectar* copolyester sheet.
- Review relevant Material Safety Data Sheets before attempting to use any cleaning agents, inks, or paints.
- Wear adequate protective equipment and clothing.
- Determine fitness-for-use requirements before selecting ink or paint.
- Ensure parts are clean and dry before decorating.

Don't

- Use commercial cleaners without first testing them.
- Decorate plastic parts in any area that is not properly ventilated.
- Use a dull knife or a "heavy" hand when cutting masking as this may score and weaken the formed part.
- Blend different paints or inks together.
- Use antistatic agents prior to decorating.

Finishing

General

Because of its forgiving nature, sheet made with *Spectar* copolyester readily lends itself to standard shop-finishing techniques. Of special note is the removal of surface scratches with a conventional, hand-held heat gun—a feature not generally possible with other sheet products.

Sanding

Wet sanding is generally recommended for edge finishing sheet made with *Spectar* copolyester. This should avoid complications such as overheating that can be experienced with dry sanding. In addition, the abrasive should cut more effectively and last longer when a water coolant is used. Progressively finer abrasives should be used for the sanding process. For example, wet-sanding with 120-grit silicon carbide would be followed by finer sanding with 280-grit silicon carbide, wet or dry. This can be followed by a final sanding with a 400- or 600-grit sandpaper. Any remaining fine surface scratches can be removed with heat- or flame-polishing.

Jointing

A standard woodworking jointer-planer produces an accurately aligned and good quality finished edge on sheet made with *Spectar* copolyester. Carbide or high-speed blades, which have a longer life, provide a uniform finish as well. A cut of 0.4 mm (0.015 in.) or less per pass is suggested since heavier cuts can result in rough edges. For best appearance, use a consistent feed rate.

Ashing

Ashing utilizes a wet abrasive, such as number 00 pumice that is applied to a loose muslin wheel. Surface speeds of 20 to 21 m/sec (65 to 70 ft/sec) are typical since overheating is not normally a problem.

Buffing

A buffing operation involves the use of a grease-filled or wax-filled abrasive bar that is applied to a rotating muslin wheel. Loose buffs are used for irregular shapes or crevices. The most common buffing abrasives are tripoli, rouge, and other fine silica.

As with any dry system, care should be taken to prevent overheating the plastic part.

Edge Polishing

Polishing, sometimes called luster buffing or burnishing, employs wax compounds containing the finest abrasives (such as levigated alumina or whiting). Polishing wheels are generally made of loose flannel or chamois. The wax fills many imperfections and protects the polished surface. If a static charge is generated on the surface during polishing, wiping the sheet with a clean, damp flannel cloth should remove the charge.

Multiple sheets made with *Spectar* copolyester can be finished simultaneously if securely fastened together in a vise or jig before polishing begins. This takes less time and results in a higher-quality finish.

Again, since this is a dry system, avoid overheating.

Heat-Polishing

If a higher finish is required than can be obtained mechanically, the part may be heat-polished using a standard propane torch, a hot-nitrogen welder, or a conventional heat gun. When using a torch or welder, control the distance between the sheet and the heat source with care; otherwise, the part may be damaged.

NOTE: Flame-polishing sheet made with *Spectar* copolyester requires less heat than used with acrylics or polycarbonate.

When using a heat gun, hold the gun about 10 cm (4 in.) from the sheet for no more than 5 seconds. (The time will vary according to the severity of the scratch.) A heat gun is a more forgiving heat source than a flame and is less likely to overheat or otherwise damage the part.

If it meets fitness-for-use requirements, mechanical edge-finishing is preferred. In any case, the best possible mechanical finish should be considered a prerequisite to minimizing the need for heat-polishing.

Solvent-Polishing

Solvent-polishing is another way to improve edge finish. As with heat-polishing, it should be used only when a good mechanical finish fails to yield the desired quality. Solvents often used to polish sheet made with *Spectar* copolyester include methyl ethyl ketone (MEK) and methylene dichloride.

NOTE: When using solvents, proper ventilation of the area is essential. Follow all precautions listed on the Material Safety Data Sheet supplied with the solvent being used.

Filing

When plastics are filed, a light powder is usually produced that can clog the file. Use an aluminum type A, shear-tooth file. Files with coarse, single-cut teeth and a tooth angle of 45 degrees can also be used.

Do's and Don'ts of Finishing

Do

- Use a heat gun or relatively cool flame to remove scratches or abrasions from sheet made with *Spectar* copolyester.
- Use carbide or high-speed blades.
- Wet-sand to avoid excessive heat buildup.
- Use consistent feed rates.
- Use files with coarse, single-cut teeth.

Don't

- Overheat sheet when finishing.
- Engage in any shop operation without wearing proper protective clothing and equipment.
- Employ solvents or heat if mechanical finishing will suffice.
- Work in a poorly ventilated area.
- Expect solvent-polishing to remove all scratches.

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