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1. Product identification

Spectar sheet is the brand name for extruded Polyethyleneterephthalate Glycol (PETG) copolyester sheet from Quinn Plastics.

The *Spectar* sheet programme offers solutions to both indoor and outdoor applications.

As a result of the extrusion process, Quinn Plastics can offer, in addition to clear and opal versions, a variety of colours and designs to suit a wide range of design requirements.

2. Characteristics

Spectar sheet has good optical properties and a brilliant surface.

The *Spectar* range of sheets are easy to fabricate, to vacuum form, and show an exceptional low temperature performance.

Important benefits of *Spectar* sheet are its very good chemical resistance and very high impact properties.

Spectar sheet meets all current food contact legislation and can be used in contact with unwrapped food. Our UV Grade is not intended for food contact and is therefore not covered by this warranty.

Spectar sheet also combines the following excellent properties:

- Easy to vacuum form, need no predrying
- Exceptional low temperature performance
- Low water absorption
- Easy to recycle
- Very high impact properties

3. Applications

- Bus shelters
- Poster glazing
- Machine guards
- Medical appliance packaging
- Displays & signs for external use
- Refrigerators and cold storeroom equipment
- Bicycle safety helmets
- Food containers
- Lenticular lenses / Graphic Arts
- Lighting controllers for hazardous areas

4. Fabrication and finishing techniques

Spectar sheet is easy to handle.

Milling, drilling, tapping, sawing, shearing and punching, die cutting, laser cutting, routing, forming and cold or hot bending do not offer any problems to the *Spectar* sheet range.

More detailed information on these items can be found in the 'USER GUIDE', further in this brochure.

5. Statements

5.1. Food approval statement

Spectar sheet can be used in contact with food (not UV version).

Therefore, in applications where covers for food or fittings for shops etc. are needed, *Spectar* sheet can offer a perfect solution.

Spectar sheet is extruded Polyethyleneterephthalate Glycol (PETG) which is manufactured from a copolyester made from dimethyl terephthalate, ethylene glycol (EG) and 1,4-cyclohexane dimethanol (CHDM).

This copolyester (PETG) complies with the compositional requirements of:

- The US Food and Drug Administration regulation 21.CFR 177.1315 (April 1, 1995) and
- The EC directives 90/128/EEC (February 23,1990) and 92/39/EEC (May 14,1992) and 93/9/EEC (15 March, 1993) and
- The German BGA Recommendation XVII, Polyterephthalicacididolester (Stand: 15.1.1993) for plastics used in food contact applications

The monomers used in the manufacture of PETG copolyester are all in Section A, List of Authorized Monomers and other starting substances, of the European Union Directive 90/128/EEC. There are specific migration limits for terephthalic acid (7.5 mg/kg of food) and ethylene glycol plus diethylene glycol (30 mg/kg) under the EC Directive.

It is the responsibility of the end user to satisfy himself that the product is fit for purpose and meets the approved migrational standards for his application.

5.2. Statement on flame retardancy

Spectar sheet has been tested in accordance with the following internationally recognised standards for fire safety performance:

BS476:part 7:1987

UL 94

NF F 16-101/102

DIN 4102

IEC 695 (glow wire test)

IEC 112/ASTM d3638

Full details of the results and a copy of the relevant approval certificate can be obtained from Quinn Plastics sales departments or your Quinn Plastics sales manager.

5.3. Statement on 10-year guarantee for UV version

Spectar UV sheet is especially suitable for outdoor use.

1. Quinn Plastics warrants that clear and opal *Spectar* UV sheet is protected on both surfaces from the adverse effects of UV-radiation and, when exposed to moderate North European climates, will not show a significant change in yellowness index and mechanical properties, as described below, for a period of 10 years from the date of sales by Quinn Plastics.
2. This warranty applies exclusively to clear and opal *Spectar* UV sheet used correctly as flat sheets which are installed, handled and maintained according to Quinn Plastics recommendations and instructions. The purchaser is presumed to be informed of said recommendations and instructions. If this is not the case he can obtain said documents through the sales representative or authorised distributor.
3. No warranty will be available for sheets that have been scratched, abraded, cracked or exposed to corrosive materials or environments, nor for sheet that has notches (resulting for instance from sawing) or if the protective layer of the sheet has been damaged in any manner whatsoever. Furthermore, this warranty does not apply to product that has been exposed to extremes of temperature for prolonged periods of time.
4. In the event of a claim against this warranty, the sheet and the original sales receipt must be returned to Quinn Plastics via the sales representative or original authorised distributor.
5. The extent of yellowing will be determined on samples of the sheet in question according to the Yellowness Index Test ASTM D1925 (1977). Multiple samples will be taken from the sheet and cut into sizes suitable for testing; the samples will be cleaned prior to testing. A *Spectar* UV sheet showing a change in yellowness index of an average less than 10 Delta units compared to its original value, as defined by Quinn Plastics on the date of manufacturing, will not be subject to any claim.
6. The mechanical properties are defined by the flexural modulus (DIN 53452), the tensile strength (DIN 53455) and Charpy Impact (unnotched ISO 179 at 23°C). Multiple samples will be taken and a sheet showing a change of less than 10% in the flexural modulus and the tensile strength compared to its original value, as defined by Quinn Plastics on the date of manufacturing, will not be subject to any claim. For the impact test multiple samples will be taken and only those sheets not achieving an average of NB (no break), as defined in ISO 179, will be subject to any claim. The section on Charpy impact applies only to flat sheets, not to patterned sheets.
7. In the event of a claim against this warranty proving justified, Quinn Plastics will provide a replacement for the material at issue without any other liability for any other additional indemnification whatsoever:
Up to 5 years time from the purchase date, Quinn Plastics will replace 100% material.
Between 5-7 years time from the purchase date, Quinn Plastics will replace 60% material.
Between 8-10 years time from the purchase date, Quinn Plastics will replace 30% material.
If replacement material cannot be provided within a reasonable period of time, Quinn Plastics may choose to refund the original cost of the material without any other liability for any additional indemnification whatsoever. This warranty does not, for instance, cover (re)installation expenses or any other incidental costs which may result from a breakage.
8. There are no express or implied, written or oral warranties and or representations by Quinn Plastics including warranties and representations of merchantability or fitness of purpose, except as set forth herein.

5.4. Safety data statement

This statement indicates all safety rules, to be taken into account when using *Spectar* sheet.

■ **Composition/information on ingredients**

- Chemical nature: Polyethyleneterephthalate Glycol sheet
- Hazardous ingredients: none known

■ **Possible hazards**

- None

■ **First aid measures**

If inhaled:

- On inhalation of decomposition products: keep patient calm, remove to fresh air and request medical help (if required)
- On skin contact: areas affected by molten material should be quickly placed under cold running water
- On contact with eyes: wash affected eyes for at least 15 minutes under running water with eyelids held open. Get medical attention if symptoms persist
- On ingestion: no special measures necessary

Note to physician:

- On inhalation of decomposition products: treat according to symptoms (decontamination, vital functions), no known specific antidote.

■ **Fire fighting measures**

- Suitable extinguishing media: water, dry extinguishing media
- Unsuitable extinguishing media for safety reasons: none
- The following can be given off in a fire: carbon dioxide (CO₂) and steam. In addition small quantities of the following substances can be formed: carbon monoxide, monomers, other degradation products
- Special protective equipment: in case of fire, wear a self contained breathing apparatus
Further information: dispose of fire debris and contaminated extinguishing water in accordance with local regulations

■ **Accidental release measures**

- Methods for cleaning up: sweep / shovel up

■ **Handling and storage**

Handling:

- Gaseous products of degradation can be given off if the product is greatly overheated: monomers, other degradation products
- Avoid inhalation of vapour
- Processing machines must be fitted with local exhaust ventilation

Protection against fire and explosion:

- No special measures necessary

Storage:

- Keep in a dry place

■ **Exposure controls and personal protection**

- Personal protective equipment:
- Normal handling: eye protection
- Thermal processing: gloves, eye and / or a face protection

■ **Physical and chemical properties**

- Form: solid sheet
- Colour: clear, opal, coloured or translucent

Change in physical state:

- Softening point: > 70°C DIN 53460
- Ignition temperature: > 400°C ASTM E659
- Density: 1.27 g/cm³ DIN 53479
- Fire promoting properties: none
- Solubility in water: insoluble
- Solubility in other solvents: soluble in aromatic solvents

■ **Stability and reactivity**

- Conditions to avoid: to avoid thermal decomposition, do not overheat
- Starts to decompose at temperatures > 270°C
- Possible thermal degradation products: monomers, other degradation products

■ **Toxicological information**

Effects of exposure:

- Inhalation: low hazards for usual industrial handling or commercial handling by trained personnel
- Eyes: same as above
- Skin: molten material may cause thermal burns
- Ingestion: expected to be a low ingestion hazard

■ **Ecological information**

- Extremely low water solubility. Low volatility.
- No environmental hazards known

■ **Disposal considerations**

- Product: must be disposed of or incinerated in accordance with local regulations

■ **Transport information**

- Not classified as hazardous under transport regulations

■ **Regulatory information**

- Labelling according to EC Directives: not subject to labelling

■ **Other information**

- The information contained herein is based on the present state of our knowledge and does not therefore guarantee certain properties.
- Recipients of our product must take responsibility for observing existing laws and regulations.

5.5. Statement on thermal insulation

Spectar sheet used in glazing applications results in considerable energy cost savings by preventing excessive heat loss in winter and blocking heat entry in the summer. The heat loss factor, normally referred to as the K-value, of *Spectar* sheet is significantly lower than for glass at the same thickness. Some examples of the heat insulation performance of *Spectar* sheet in single and double glazing systems are given below and compared with glass.

Advantages of Spectar sheet to glass

- **At the same thickness:**
 - Improvement of the K-value
 - Resistance to breakage
 - Weight saving

Single glazing:

- Improvement K-value:

glass 5 mm:	K-value = 5.74 W/m ² °C
Spectar sheet 5 mm:	K-value = 5.13 W/m ² °C
Δ = 0.61 W/m ² °C = 10.6%	
- Weight saving:

glass 5 mm:	12.5 kg/m ²
Spectar sheet 5 mm:	6.35 kg/m ²
Δ = 6.15 kg = 49.2%	

Double glazing:

- Improvement K-value:

2 x glass 4 mm with air gap 5 mm:	K-value = 3.57 W/m ² °C
2 x Spectar sheet 4 mm with air gap 5 mm:	K-value = 3.23 W/m ² °C
Δ = 0.34 W/m ² °C = 9.5%	
- Weight saving:

2 x glass 4 mm:	20 kg/m ²
2 x Spectar sheet 4 mm:	10.16 kg/m ²
Δ = 9.84 kg/m ² = 49.2%	

- **At the same K-value:**
 - Weight saving
 - Volume saving

Single glazing:

- glass 10 mm:
 K-value = 5.60 W/m²°C |- Spectar sheet 2 mm:
 K-value = 5.56 W/m²°C |- Weight saving:

glass 10 mm:	25.0 kg/m ²
Spectar sheet 2 mm:	2.54 kg/m ²
Δ = 22.46 kg/m ² = 89.8%	
- Volume saving:

Δ = 8 mm	
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Double glazing:

- 2 x glass 5 mm with 15 mm air:
 K-value = 3.05 W/m²°C |- 2 x Spectar sheet 3 mm with 10 mm air:
 K-value = 3.04 W/m²°C |- Weight saving:

glass 2 x 5 mm:	25.0 kg/m ²
Spectar sheet 2 x 3 mm:	7.62 kg/m ²
Δ = 17.38 kg/m ² = 69.5%	
- Volume saving:

glass 2 x 5 + 15:	25 mm
Spectar sheet 2 x 3 + 10:	16 mm
Δ = 9 mm	

K-values for customer specific glazing systems can be provided upon request. For more information contact your local Quinn Plastics sales office.

6. Technical information

6.1. Technical data sheet

■ GENERAL

Property	Method	Units	Spectar sheet + Spectar UV sheet
Density	D1505	g/cm ³	1.27
Rockwell Hardness	D-785	R scale	105

■ OPTICAL

Property	Method	Units	Spectar sheet + Spectar UV sheet
Light Transmission	5036	%	88
Refractive Index	53491		1.57
Haze	D1003	%	<1

■ MECHANICAL

Property	Method	Units	Spectar sheet + Spectar UV sheet
Flexural Modulus	53452	MPa	2075
Flexural Strength	53452	MPa	70
Tensile Modulus	53455	MPa	2200
Tensile Strength	53455	MPa	50
Elongation	53455	%	54

■ THERMAL

Property	Method	Units	Spectar sheet + Spectar UV sheet
Vicat Temp. (B)	53460	°C	82
Heat Deflection Temp. (A/B)	53461	°C	72/68
Specific Heat Capacity	D-2766	J/gK	1.1
Coefficient of linear thermal expansion	53752	K ⁻¹ x10 ⁻⁵	6.8
Thermal conductivity	52612	W/mK	0.20
Degradation temperature		°C	>280
Max. service temperature		°C	70
Sheet forming temp. range		°C	120-160

■ IMPACT STRENGTHS

Property	Method	Units	Spectar sheet + Spectar UV sheet
Izod (notched)	ISO 180	kJ/m ²	11.5
Charpy (notched)	53453	kJ/m ²	10
Charpy (unnotched)	53453	kJ/m ²	NB

■ ELECTRICAL

Property	Method	Units	Spectar sheet + Spectar UV sheet
Dielectric constant 100 HZ	IEC 250		2.6
Volume Resistivity	D257	Ω.cm	≥10 ¹⁵
Surface Resistivity	D257	Ω	≥10 ¹⁶
Dielectric strength	D149	kV/mm	16
Dissipation Factor (50 HZ)	IEC 250		0.01

■ Chemical resistance at 20°C

Acetone	-	Glycols	+
Acids (weak solution)	+	Glycerine	+
Alcohols		Hexane	+
Ethyl	+	Methylenechloride	-
Isopropyl	+	Methylethylketone	-
Methyl	+	Mineral Oil	+
Ammonia (weak solution)	+	Paraffin	+
Benzene	-	Toluene	-
Carbon tetrachloride	-	Sodium Chloride (aq)	+
Chloroform	-	Sodium Hydroxide (aq)	+
Ethyl Acetate	-		

- = Attacked

+ = Not attacked

6.2. Product range Spectar sheet

Spectar sheet is protected on both sides with a PE-film.

■ Thickness Range

From 0.8mm up to 15mm

Standard thickness: 0,8-1-1,5-2-3-4-5-6-8 and 10 mm (12 and 15 mm available to special order)

■ Widths cut - on - line

Min 1250 mm from 0,8 mm up to 6 mm (8-10-12 and 15 mm available to special order)

Max 2050 mm from 2 mm up to 10 mm (12 and 15 mm available to special order)

■ Length cut - on - line

Min 1000 mm

Max 2050 mm from 0,8 mm up to 6 mm

Max 3050 mm for thicknesses 2 mm or more ('OVER' lengths available to special order)

■ Thickness tolerances

< 1,524 mm ± 10%

1,524 mm - 3,05 mm ± 6%

> 3,05 mm ± 4%

■ Cut - on - line tolerances

More than 1000 mm -0 + 3‰ (3 mm per 1000 mm)

Less than 1000 mm ± 1.5 mm

■ Cut - to - size tolerances

± 1.00 mm

■ Minimum production runs for

Special thickness 2.000 kg

Special pattern 5.000 kg

Special colour 5.000 kg

Other thicknesses, sizes and tolerances on request.

7. User guide

7.1. Introduction

The manufacture of plastic articles from *Spectar* sheet normally involves secondary fabrication operations, including sawing, drilling, bending, decorating, and assembling. This guide covers the properties and characteristics of *Spectar* sheet that need to be taken into account if secondary operations are to be performed successfully.

7.2. Fabricating

7.2.1. Machining guidelines

Spectar sheet can be worked with most tools used for machining wood or metal. Tool speeds should be such that the sheet does not melt from frictional heat. In general, the highest speed at which overheating of the tool or plastic does not occur will give the best results.

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

Since plastics are poor heat conductors, the heat generated by machining operations must be absorbed by the tool or carried away by coolant. A jet of air directed on the cutting edge aids in cooling the tool and in removing chips.

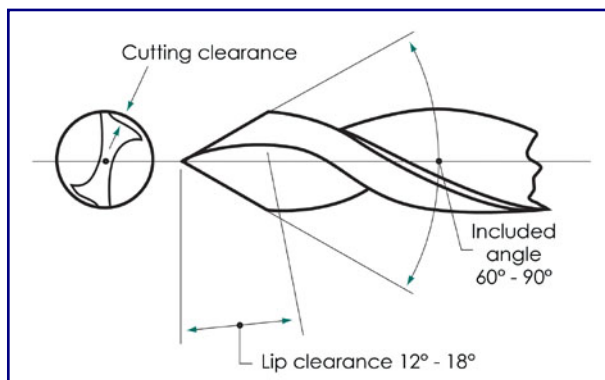
Plain water or soapy water is sometimes used for cooling unless the trim scrap is to be reused.

7.2.2. Milling

Sheet manufactured from *Spectar* sheet can be machined with standard high-speed milling cutters for metal, provided they have sharp edges and adequate clearance at the heel.

7.2.3. Drilling

Figure 1
Suggested drill-point design for drilling plastic sheet



Drills designed especially for plastics are available, and their use is suggested. Standard twist drills for wood or metal can be used; however they require slower speeds and feed rates to produce a clean hole. Twist drills for plastics should have 2 flutes, a point with an included angle of 60° to 90°, and a lip clearance of 12° to 18°, as shown in Figure 1.

Wide, highly polished flutes are desirable since they expel the chips with low friction and thus tend to avoid overheating and consequent gumming. Drills should be backed out often to free chips, especially when drilling deep holes. Peripheral speeds of twist drills for plastics

ordinarily range from 30 to 61 m per minute. The rate of drill feed into the plastic sheet generally varies from 0.25 to 0.63 mm per revolution.

NOTE:

When drilling, be sure to hold or clamp the part securely to prevent it from cracking or slipping and presenting a safety hazard to the operator.

7.2.4. Tapping

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

7.2.5. Sawing

Any of the following saw types, commonly used for wood or metal, should be satisfactory for cutting Spectar sheet; circular saws, band saws, sabre saws, jigsaws, hacksaws, or handsaws. However, some saw designs are better suited than others for sawing plastics because they produce smoother or faster cuts.

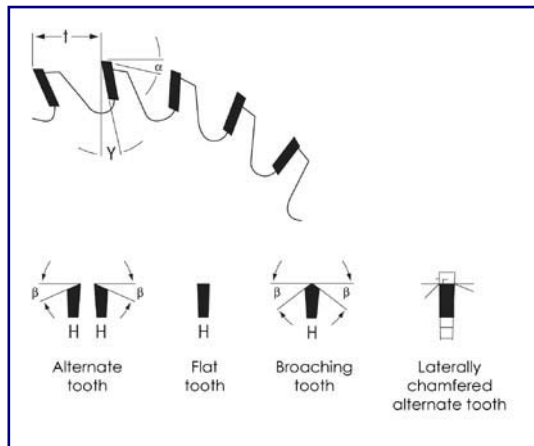


Figure 2
Example of Sawblades

Blade design plays an important part in successful sawing of plastics. A skip-tooth band saw blade is preferred because the wide gullet provides ample space for the plastic chips to be carried out of the kerf (the cut made by the saw).

For best results, the teeth should have zero rake and some set. For a curved cut, the blade should be narrower and have more set than for a straight cut. The blade should be kept sharp to prevent melting or chipping of the plastic, and the blade guide should be placed very near the cut to minimise vibration. Several different types of blades have been evaluated for each type of saw, and the following suggestions are made, based on the smoothness and general cut appearance.

The saw blades listed in Table 1 are commercially available.

NOTE:

Be sure to hold or clamp the part securely while sawing to prevent chattering, which can cause cracking.

Table 1
Sawing recommendations

Settings	Band saw	Circular saw
Tooth distance	sheet thickness below 3 mm, 1 to 2 mm	8 to 12 mm
	sheet thickness 3 to 12 mm, 2 to 3 mm	8 to 12 mm
Clearance angle α	30 to 40°	15°
Rake angle ψ	15°	10°
Tooth angle β	-	15°
Cutting speed	1200 - 1700 m/min	2500 - 4000 m/min
Feed speed	-	3-6 m/min

7.2.6. Shearing and punching

Shearing and punching are suitable methods for cutting *Spectar* sheet up to 2.5 mm thick. A shear will produce a straight-edged cut whereas a punch can produce holes of almost any desired shape. For thicker sheet, sawing is preferable. It is important to maintain a blade-to-bed knife clearance of approx. 0.025 mm. Punches may be used when a fairly rough edge is satisfactory. Hand-operated punches are useful for small holes; however, power operated punches are normally used for holes larger than approx. 6 x 50 mm. Cracking and chipping can be reduced by heating the sheet to approx 38°C; however, some allowance for hole shrinking due to cooling may be necessary. Sawing, drilling and routing are preferable to punching when thicknesses are greater than approx 2.5 mm.

7.2.7. Die cutting

Spectar sheet can be cut satisfactorily with steel rule dies, which are ribbons of steel that may vary from 0.8 to 2.5 mm in thickness by 12.7 mm wide and are sharpened on one edge. They are generally mounted in slots cut into wood blocks and are relatively inexpensive. The steel rule must be sharpened or replaced fairly often.

**Table 2
Shear strength**

Sheet Thickness (mm)	Shear Strength (MPa)
2	57.6
3	56.5
6	46.1

Table 2 reflects the shear strengths, as determined in accordance with ASTM D732, required to cut various thicknesses of sheet extruded from *Spectar* sheet.

A die press must have adequate power to achieve the desired cut. The shear strengths of *Spectar* sheet shown in Table 2 can be used with the following formula to calculate the required die press tonnage.

$$F \text{ (tons)} = \frac{\text{Shear strength (MPa)} \times \text{perimeter of cut (mm)} \times \text{thickn. (mm)}}{8896 \text{ N/ton}}$$

7.2.8. Laser cutting

Spectar sheet can be cut by laser beam in thicknesses up to 4.7 mm. A laser may be used to make intricate holes and complex patterns, or it can be controlled to merely etch the plastic. Holes and cuts produced by a laser have a slight taper; the cuts are clean and precise, with finished appearance. Tolerances can be controlled more closely with a laser than with conventional machining operations. Laser power and travel speed must be optimised to minimise ‘whitening’ of the *Spectar* sheet while cutting.

7.2.9. Routing

Routers with sharp two-flute straight cutters produce very smooth edges. They are useful for trimming the edges of flat or formed parts, particularly when the part is too large or irregular in shape for a band saw. Portable, overarm, and under-the-table routers work equally well. The plastic sheet should be fed to the router slowly to avoid excessive frictional heating and shattering. The router or plastic sheet, whichever is moving, must be guided with a suitable jig. Compressed air can be used during the routing operation to cool the bit and aid in chip removal.

Diameter of the router	4 - 6 mm
Feed speed	ca. 1.5 m/min
Rpm	18 - 24 000

Table 3
Routing recommendations

7.3. Forming

7.3.1. Hot bending

Spectar sheet can be bent to a small radius by preheating an area on both sides with an electric strip heater and then quickly bending the sheet along the heated line. Thicker gauges (above 3 mm) may need to be turned periodically during the heating cycle. The side of the sheet that is to form the inside angle should be heated first and the outer side last. When the optimum sheet temperature is reached (slightly over 105°C) and a slight resistance to bending is noticeable, the part can be readily formed. If bending is performed too cold, stresses will be created that will result in a brittle part; however, overheating can cause bubbles in the bend area.

Strip heaters are available from CP Clarke, Ammanford, South Wales and from Shannon B.V., Voorschoten (The Netherlands).

7.3.2. Cold bending

Brake forming and cold bending can be used to produce simple shapes from *Spectar* sheet; the permissible degree of bending is dependent on both sheet thickness and rate of deflection. Cold bending of gauges over 2.5 mm is likely to result in high stress levels.

7.3.3. Thermoforming

There are a number of different thermoforming techniques that can be used to form *Spectar* sheet, once heated, into the shape of a mould by mechanical, air pressure, or vacuum forces. Both male (plug) and female (cavity) moulds are used. Tooling can range from low cost plaster moulds to expensive water cooled steel moulds, but cast aluminium is more commonly used. Other materials including wood, gypsum, and epoxy can also be used. Forming processes to be discussed include straight vacuum, drape, matched mould, pressure-bubble plug-assist, plug-assist pressure, vacuum snap-back, pressure-bubble vacuum snap-back, trapped-sheet contact-pressure, free, and mechanical.

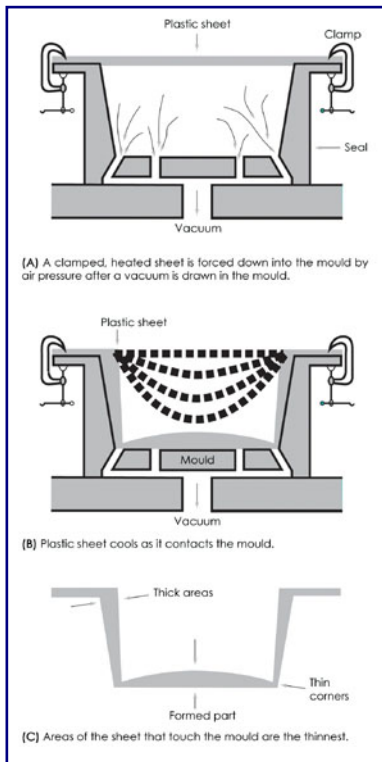
Spectar sheet does not need to be pre-dried prior to thermoforming.

7.3.4. Straight vacuum forming

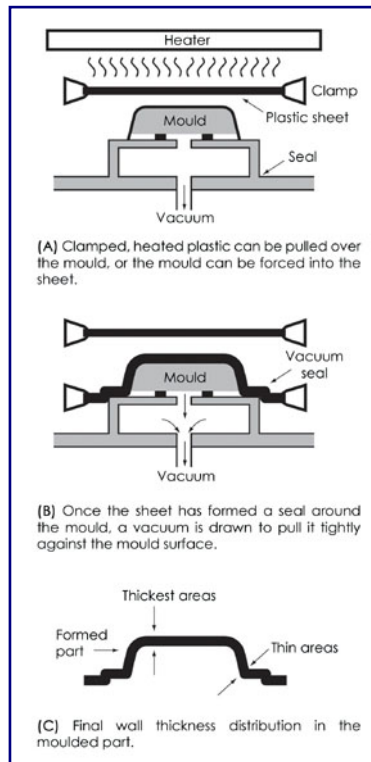
Vacuum forming is the most versatile and widely used forming process. The equipment costs less and is simpler to operate than most pressure or mechanical techniques. In straight vacuum forming, *Spectar* sheet is clamped in a frame and heated. When the hot sheet is in an elastic state, it is placed over the female mould cavity. The air is then removed from the cavity by vacuum, and atmospheric pressure then forces the hot sheet against the contours of the mould. When the *Spectar* sheet has cooled sufficiently, the formed part can be removed. Thinning at the upper edges of the part usually occurs with relatively deep moulds. Thinning is caused by the hot sheet being drawn to the centre of the mould first. Sheeting at the edges of the mould must stretch the most and thus becomes the thinnest portion of the formed item. Straight vacuum forming is normally limited to simple, shallow designs. See figure 3

7.3.5. Drape forming

Drape forming is similar to straight vacuum forming except that after the *Spectar* sheet is framed and heated, it is mechanically stretched, and a pressure differential is then applied to form the sheet over a male mould. In this case, however, the sheet touching the mould is close to its original thickness. It is possible to drape-form items with a depth-to-diameter ratio of approx. 4 to 1; however, the technique is more complex than straight vacuum forming. Male moulds are easier to build and generally cost less than female moulds; however, male moulds are more easily damaged. Drape forming can also be used with gravitational force alone. For multi-cavity forming, female moulds are preferred because they do not require as much spacing as male moulds. See figure 4



**Figure 3
Straight Vacuum Forming**



**Figure 4
Drape Forming**

7.3.6. Matched-mould forming

Matched-mould forming is similar to compression moulding in that heated *Spectar* sheet is trapped between male and female dies made of wood, plaster, epoxy or some other material. Although they cost more, water-cooled matched moulds produce more accurate parts with close tolerances.

7.3.7. Pressure-bubble plug-assist vacuum forming

The pressure-bubble plug-assist vacuum forming technique can be used when *Spectar* sheet is to be formed into deep articles that must have good thickness uniformity. The sheet is placed in a frame and heated, and controlled air pressure is used to create a bubble. When the bubble has been stretched to a predetermined height, the male plug-assist (normally heated) is lowered to force the stretched sheet into the cavity. Plug speed and shape can be varied for improved material distribution; however, the plug is made as large as possible so that the plastic material is stretched close to the shape of the finished product. The plug should penetrate 75 to 85% of the mould cavity depth. Air pressure is then applied from the plug side while a vacuum assist is being drawn on the cavity. The female mould must be vented to allow the escape of trapped air.

7.3.8. Plug-assist pressure forming

Plug-assist pressure forming is similar to plug-assist vacuum forming in that a plug forces the hot *Spectar* sheet into a female cavity. Air pressure applied from the plug then forces the plastic sheet against the walls of the mould. Plug design and plug speed can be varied to optimise material distribution.

7.3.9. Plug-assist vacuum forming

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

Plug-assist vacuum forming and plug-assist pressure forming (see previous section) allow deep drawing and permit shorter cooling cycles and good wall thickness control. Both processes require close temperature control and are more complex than straight vacuum forming.

7.3.10. Free forming

In free forming, air pressures of about 2.76 MPa can be used to blow a hot *Spectar* sheet through the silhouette of a female mould. Air pressure causes the sheet to form a smooth bubble-shaped article such as used in skylight panels or window well covers. Since only air touches each side of the pad, there will be no mark-off unless a stop is used to form a special contour in the bubble.

See Figure 5

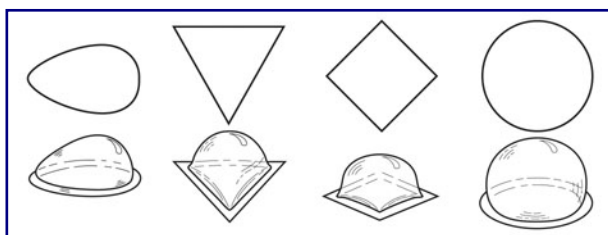


Figure 5
Examples of free-form shapes that can be obtained with openings

7.4. Assembly

Spectar sheet can be fabricated into a variety of shapes and articles with solvent, cement (a polymer dissolved in a solvent), or adhesive bonds. In general, when the surfaces to be joined are irregular, a cement is preferred over a solvent.

Solvents and cements are not the best choice when bonding *Spectar* sheet to other thermoplastics. Adhesives, including cyanoacrylates, two-part acrylics and hot melts, are more effective when bonding *Spectar* sheet to dissimilar plastics and can be used to bond *Spectar* sheet to itself.

7.4.1. Assembly guidelines

The following guidelines should be observed when bonding *Spectar* sheet:

- The sheet edges must be clean and free from contamination.
- The surfaces must be smooth and accurately aligned.
- A solvent or cement must be sufficiently active to soften the mating surfaces for some flow to occur when pressure is applied.
- When using solvents in *Spectar* sheet assembly, it is advisable that the work area be climate controlled with low humidity to minimise joint 'whitening'. If this is not possible, the addition of 10% glacial acetic acid to the solvent or use of a slower curing cement-type bond is suggested.
- Fixture pressure must be maintained to prevent movement of the joint until it is solid.
- Good ventilation is required when working with solvents. Exposure levels must be controlled according to OSHA guidelines.

7.4.2. Bonding techniques: solvents, cements and adhesives

Small articles with flat surfaces can be joined by placing the pieces together and applying the appropriate bonding agent (solvent, cement, or adhesive). Care should be taken to ensure that the joints are uniformly coated; a solvent can be effectively applied with a needle applicator. The assembly should be clamped into position until the bond is set. When larger articles are to be solvent bonded, it is best to immerse the joining surfaces in a solvent bath until the material is softened and then clamp them into position until the bond has set. A constant level of solvent immersion should be maintained in a shallow pan with a support pad, screens, and other means to ensure part-to-part uniformity.

List of several solvents, cements, and adhesives that provide strong bonds with good clarity when used in PETG sheeting fabrication operations.

Material	Bond Type
Methyl Ethyl Ketone (MEK)	Solvent
Cyclohexanone	Solvent
Perchloroethylene	Solvent
Methylene Chloride	Solvent
Tetrahydrofuran (THF)	Solvent
Trichloroethylene	Solvent
Super Glue Cyanoacrylate	Adhesive

7.4.3. Mechanical fastening

Spectar sheet can be fabricated with mechanical fasteners into attractive joints. Self-threading screws are used if the fastener is not to be removed very often: when frequent disassembly is required, threaded metal inserts are preferred. Screws and rivets provide permanent assembly. Standard nuts, bolts, and machine screws are used in many instances: in addition, special screws and rivets specifically designed for use with plastics are available. Springs, clips, and nuts are low cost, rapid, mechanical fasteners. Hinges, knobs, catches, and dowels are some other devices used in mechanical assemblies.

7.5. Finishing

7.5.1. Sanding

Spectar sheet is best sanded wet to avoid the frictional heat build-up that is characteristic of dry sanding techniques. If water coolants are used, the abrasive lasts longer and the cutting action increased. Progressively finer abrasives should be used: for example, rough sanding with 80-grit silicon-carbide would be followed by finer sanding with 280-grit silicon-carbide, wet or dry. The final sanding may be with 400 or 600-grit sandpaper. After the sanding is finished and the abrasives removed, additional finishing operations may be required.

7.5.2. Joining

A standard woodworking jointer-planer will produce an accurately aligned and good quality finished edge on *Spectar* sheet. Carbide or high speed blades, which have a longer life, will provide a uniform finish as well.

7.5.3. Filing

When many thermoplastics, including *Spectar* sheet, are filed, a light powder that tends to clog some files is produced. Therefore, aluminium Type A, shear-tooth, or other files that have coarse, single-cut teeth with an angle of 45° are preferred.

7.5.4. Polishing techniques

■ Mechanical polishing

After grinding, surfaces of *Spectar* sheet can be polished in order to obtain a high surface finish. Burnishing wheels of cloth or fleece and felt polishing bands, together with a suitable polishing wax, give good results. Experience has shown that material surface temperatures should not be allowed to increase too much, as these can be responsible for a later appearance of fine cracks.

■ Diamond polishing

Spectar sheet can be diamond polished resulting in an excellent surface quality that does not need further treatment. No pre-grinding step is required prior to the polishing step with a diamond tool.

■ Flame polishing

Spectar sheet can be flame-polished using a standard propane torch or a Hot Nitrogen Welder. Both techniques require accurate control of the distance between the sheet and the heat source, otherwise surface whitening or excessive material flow will occur. A heat gun can be used to remove scratches from *Spectar* sheet. A gun with a temperature range of about 400° to 540°C, should be held about 100 mm from the scratch for approx. 5 seconds. The time may vary according to the severity of the scratch. **It is important to keep the flame moving and not to dwell on one spot.**

■ Solvent polishing

The appearance of saw-cut edges can be improved by first sanding and then solvent polishing with MEK or methylene dichloride. It may be necessary to add a slow drying component such as diacetone alcohol to prevent humidity blush after drying. Complete removal of all surface scratches and edge sand marks is not likely with solvent polishing since *Spectar* sheet has good chemical resistance.

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.

7.5.5. Printing

Spectar sheet can be printed with conventional equipment; however, the ink does not penetrate a plastic as it does with paper and cloth and is therefore subject to damage by abrasion. This can be minimised by applying a light coat of clear lacquer over the printing.

There are a number of different methods used when printing on plastics including letterpress, letterflex, dry offset, offset lithography, rotogravure, stencilling, and silk screen process.

Since each application may require a different type of ink, it is suggested that an ink manufacturer be consulted for recommendations. In general, inks that are used on oriented PET film have been found to perform satisfactorily on *Spectar* sheet.