CYROLITE®
ADVANCED MEDICAL ACRYLICS

TECHNICAL INFORMATION

Extrusion & Thermoforming

CYROLITE® and XT® POLYMER
PMMA-based copolymers

Röhm, is a worldwide manufacturer of PMMA molding compounds. Roehm America LLC offers a range of high-performance polymers and compounds for various medical device and packaging applications.

CYROLITE® and XT® POLYMER compounds are both transparent, impact modified, BPA free PMMA-based copolymers. They both have distinctive characteristics that make them particularly successful in the medical device and packaging markets. CYROLITE® and XT® POLYMER PMMA-based copolymers are widely used for thermoforming and extrusion due to their ease of processing and excellent physical properties. Thermoformed parts of these materials are used in medical packaging for EtO and Gamma sterilization, where these considerations may be important.

CYROLITE® and XT® POLYMER compounds offer many advantages

- Optical Transparency
- Toughness and Strength
- Good Low Temperature Impact Resistance
- BPA and DEHP Free
- Chemical Resistance
- Compatibility with PVC Tubing
- CYROLITE® Can be Ethylene Oxide, Gamma, or E-beam Sterilized
- XT POLYMER Can be Ethylene Oxide Sterilized
- Ease of Sealing by Ultrasonic, Laser, Thermal, or Solvent Bonding
- Excellent Deep Draw Characteristics
- Doesn’t Require a Silicone Coating to de-nest
- Reuse of Regrind Material

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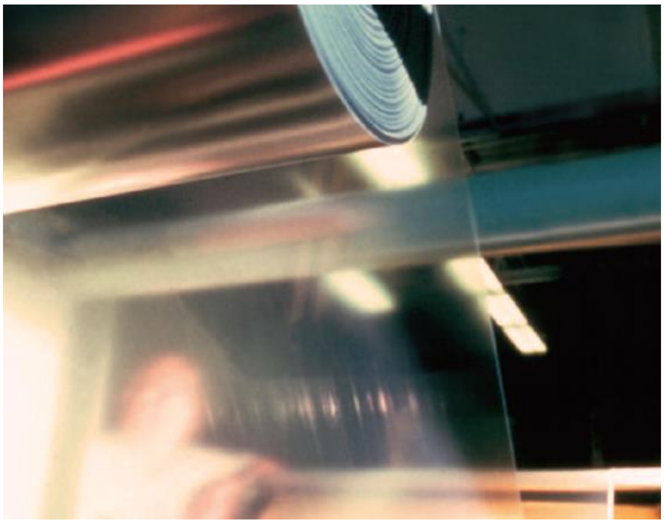
Their ease of processing, ready use of regrind and similar shrinkages allows the use of thermoforming molds and extrusion dies designed for high impact polystyrene, ABS and polycarbonate.

CYROLITE® and XT® POLYMER compounds are most often used in transparent form but can be easily pigmented or dyed to create translucent or opaque items. They can be converted into film and sheet in thicknesses from below 0.002” up to 0.250”.

CYROLITE® and XT® POLYMER compounds can be easily thermoformed using common commercial methods.

They’ve been formed successfully by vacuum forming, air pressure forming and mechanical pressure forming. Processing cycles are fast, draw down is uniform and both deep and shallow drawn objects are readily made with these materials.



1. Housekeeping

When used in opaque colors, and especially in natural or other transparent colors, it is important to avoid contamination of CYROLITE® and XT® POLYMER compounds with other plastics. The extrusion behavior of the melt and the optical and mechanical properties of the finished extrudate can be seriously compromised if such contamination is present. Table 1, below demonstrates the results obtained in a laboratory study showing the effects. Note that in 25 mil film, only 0.6% styrene will increase the haze value to 60%.

Effect of Polystyrene Contamination on Optical Properties of CYROLITE® and XT® polymer compounds

Table 1

Film Thickness (inches)	**Styrene** (%)	**Haze*** (%)	**Transmission*** (%)
.025	0	4	89
.025	0.2	7	86
.025	0.4	37	85
.025	0.6	60	84
.013	1.0	59	86
.013	2.0	78	82

*(ASTM D-1003)

2. Drying

Because of their large acrylic component, CYROLITE® and XT® POLYMER compounds absorb moisture from the atmosphere. It is essential that the moisture level in the pellets (or regrind) fed to the extruder be at 0.03% or less. To achieve this level of moisture it is usually necessary to pre-dry the material using an efficient desiccant type dryer. The desiccated air of the dryer should have a dew point of – 20°F or lower. A residence time in the dryer of about 3 hours at 175°F is typical. The plastic in the dryer should move in a plug flow fashion so that all material spends essentially the same length of time being dried. Failure to dry adequately can result in a slight reduction in transparency and surface gloss in the marginal case, to severe surface streaks and/or bubbles in the extreme case.

If extruded sheet is to be thermoformed at a later time, then provision should be made to prevent the reabsorption of moisture by the sheet. If excessive moisture is present, some bubbling may occur when the sheet is heated for thermoforming. The normal absorption of moisture will not affect the properties or performance of sheet or a previously formed part. In some pigmented formulations of CYROLITE® and XT® POLYMER compounds, longer drying periods maybe required to drive off moisture that is held more tenaciously by the pigmented particles.

The use of a vented extruder provides a supplement to, but not a substitute for, the desiccant dryer. Other possible causes of surface streaks include damaged die lips, contamination between or on the lips, improper die temperature and undispersed colorant.

3. Regrind

CYROLITE® and XT® POLYMER compounds can be used up to 100% in regrind however, 25% or less regrind content is recommended. The grinder blades used for generating regrind must be sharp, having a clearance not exceeding 0.007" and screen opening size of 1/4" to minimize fines formation.

As with all thermoplastics, excessive fines will sit in the barrel and transfer heat more readily compared to a pellet during reprocessing causing discoloration due to a longer heat history. These fines can be removed by mechanical means using #12 stainless steel screens to reduce the possibility of discoloration or char.

4. Coloring

CYROLITE® and XT® POLYMER compounds, naturally clear, can be pigmented in any color, transparent, translucent or opaque. Many colors are offered by Roehm for extrusion applications.

Extruder Design and Operating Conditions

For optimum gloss and transparency of the finished extrudate consistent with melt control, the stock temperature of CYROLITE® and XT® polymer compounds should be about 480°F for flat sheet. Profile exit temperatures should be in the range of 430°F. Within limits, the higher the stock temperature the better the gloss and transparency of the final sheet or profile. Extrusion conditions should be such that excessively high localized temperatures and long residence times are avoided. Such a combination of temperature and time tends to cause an increase in melt viscosity. This leads to a gel-like "skin" on the extrudate and results in decreased gloss and transparency. In an extreme case, the color of the plastic is adversely affected and a build-up of gelled material occurs within the die and around the lips.

The general characteristics of a suitable screw are a moderately long, constant depth feed zone with a gradual transition to a long metering section. The ratio of the feed depth to the meter depth should be in the range of 2.8/1 to 3.8/1. The screw length/ diameter ratio must be at least 30/1.

Table 2 lists some examples of screw geometries, barrel and die temperature profiles for different diameter machines. The goal, as with any plastic, is to achieve efficient conveyance of pellets, consistent melting without over-heating, and smooth, surge-free delivery of a thermally homogeneous melt to the die.

Typical screw geometries and machine settings
for CYROLITE® and XT® POLYMER compounds sheet extrusion
(two stage screw with L/D of 30/1 assumed)

Table 2

Screw Diameter	3 1/2 inch	4 1/2 inch	6 inch
Turns of Feed – Constant Depth	4 at 0.500	4 at 0.625	7 at 0.635
Turns of Transition – Constant Taper	3	3	3
Turns of Meter Pump – Constant Depth	6 at 0.165	5 at 0.180	4 at 0.190
Turns of Decompression – Constant Taper	1	1	1
Turns of Vent Zone – Constant Depth	4 at 0.650	4 at 0.750	3 at 0.750
Turns of Recompression – Constant Taper	2.5	2.5	2
Turns of 2nd Meter Pump – Constant Depth	5 at 0.300	5 at 0.325	5 at 0.335
Feed Zone °F	350 – 400	340 – 400	280 – 320
Rear °F	380 – 420	380 – 415	320 – 360
Rear Center °F	380 – 425	380 – 425	360 – 420
Center °F	390 – 430	380 – 425	400 – 440
Front Center °F	420 – 470	420 – 460	420 – 460
Front °F	430 – 475	420 – 460	420 – 460
Adapter °F	450 – 470	450 – 470	460
Die End Plates °F	450 – 470	450 – 470	470
Die Left and Right °F	440 – 470	445 – 460	460
Die Center °F	440 – 470	445 – 460	460
Approximate Output (lb/hr)	400 – 550	800 – 1000	1300 – 1800
Drive Horsepower (hp)	75 – 100	125 – 175	200 – 300

The typical figures given in Table 2 are for a 30/1 L/D two stage screw. CYROLITE® and XT® POLYMER ompounds may also be successfully processed on 24/1 L/D machines, with single stage screws, or with sealed vents using two stage screws.

Machines with longer screws, 30/1 L/D extruders, provide higher outputs, improved stability and ease of web control.

High quality barrel and die temperature controllers are desirable to minimize fluctuations in machine temperatures. Heater zones with cast-in channels for water cooling of the barrel are also desirable. Screws bored for water or oil cooling are useful in certain critical situations. The bore is normally plugged so that cooling extends only into the midpoint of the first transition section of the screw. In this way the melting of the plastic can be fine tuned if necessary. Robust, streamlined sheeting dies with flexible restrictor bars and lips give excellent results. Precise temperature control with minimal hunting is desirable for maintaining uniform transverse and longitudinal gauge. Die lip opening is normally set at the desired gauge or several percent higher. Significant drawdown to thin film thickness is possible if the stock temperature is high enough to prevent undesirably high (20%) orientation/shrinkage.

Screen packs may be desirable for the usual reasons, especially when regrinds are used. A screen pack consisting of 20-40-60, 20-40-80 or even higher mesh screens can be used.

Start-up and Purging

Start-up is achieved by having the extruder barrel and die preheated to operating temperatures. Gradually increase the screw speed to the desired level while being sure to avoid excessive motor load current and pressure levels. CYROLITE® and XT® POLYMER compounds melt is rather viscous, so that normally a short period of purging will suffice to remove any CYROLITE® and XT® POLYMER compounds which was in the machine at start-up. If the material in the extruder has been there for long periods or at excessive temperatures, a longer purge may be needed. It may also be necessary to manually clean the screw, barrel or die in order to achieve optimum quality sheet. When shutting down, be sure to run as much material out of the machine as possible and turn all heaters off.

Styrene Contamination

Keep CYROLITE® and XT® POLYMER compounds clean as you would other transparent materials. Contamination by impact styrene is a prevalent problem. An extremely low percentage of styrene will greatly increase haze. See Table 1 which summarizes a laboratory study showing this effect. For example, in 25 mil film only 0.6% styrene will increase haze to 60%.

Orientation

Orientation can affect the use and life expectancy of an extruded end product. High orientation can cause manufacturing and finishing problems of the extrudate. It is preferable to keep the orientation below 25%. See measuring orientation on page 12.

Thickness Variations

Present thickness monitoring systems provide excellent gauge control. Film or sheet thickness should be closely controlled in both the machine direction and transversely across the web. Extruder surging might cause a difficult-to-detect cyclic gauge length variation, causing forming problems. Most commercial processors constantly monitor their production in both areas to provide quality sheet.

Die Lip Buildup

In rare cases, a die lip “buildup” has been seen in the extrusion of CYROLITE® and XT® POLYMER compounds. Analysis shows the buildup to be gelled or cross-linked material. These polymers, both natural and to a greater extent colored, develop a tendency to form gels when held at high temperatures. The rate of gel formation and the hardness of the gel are increased as the high-temperature exposure time lengthens. When the material is under shearing stresses, gelling is reduced. Thus, in extrusion, competing mechanisms are operative – heat and residence time promote gel formation while shearing action opposes gel formation.

Streamlined dies will eliminate a degradation problem or make it insignificant. Properly streamlining the die surface and adaptor promotes minimal drag on the material so that the polymer boundary layer is not spending excessive time in the machine.

Haul-off Equipment

An excellent surface finish– smooth and glossy – requires the use of high quality polishing rolls. These rolls should be microfinished, chrome rolls, hardened to Rockwell C50-60. They should be equipped with accurate and independent temperature and speed controls which are coupled to rubber pull rolls for best results.

The temperature of the rolls in a three roll stack should be determined by trial, in order to give the best appearing flat sheet. The maximum roll temperature is normally limited by sticking of the plastic to the roll.

The larger the roll diameters the better, since polishing effectiveness and heat transfer are improved.

The build up of a bank of plastic in the nip of the rolls should be avoided since

this leads to excessive orientation in the sheet. Such orientation can cause brittleness in the cross-machine direction and difficulties if the sheet is to be thermoformed.

Slitting of sheet made from CYROLITE® and XT® POLYMER compounds can be done using razor type knives or rotating wheel knives. The razor knife is more likely to cause a slightly raised lip at the edge of the sheet. Since CYROLITE® and XT® POLYMER compounds are tough impact plastics, the use of heavy duty grinders is recommended for recovering trim and scrap sheet for re-extrusion.

Thermoforming

Equipment

Equipment ranges from inexpensive single-station prototype or sample machines to massive units producing industrial components up to 10 x 30 feet. Small manual operation machines provide for economical short run production.Automatically operated high production equipment can produce thousands of parts per hour.

Equipment can be selected through an economic feasibility study. High volume production requires the use of automatic, continuous operation equipment. Modern food packaging uses form, fill and in-line seal equipment. Knowledge of material properties and shelf-life studies must be considered to achieve optimum results and a commercially acceptable package. Although equipment decisions can be difficult, there are many good forming machines with many processing options available.

CYROLITE® and XT® POLYMER compounds will form satisfactorily on most types of forming equipment. A working knowledge of these materials is necessary for proper machine operation.

High heating temperatures may affect product gloss and clarity. Multi-station heating will correct this condition. Product orientation from forming can affect product performance

Filmstock storage is important. Thin film, tightly wound, is usually no problem if stored properly and kept clean. Since heavy-gauge sheet picks up moisture, polyethylene-wrap should be used to prevent moisture pick-up. Rolls should be stored on end as supplied by the processor.

Roll stock yield is critical in cost analysis. Table 4 gives the approximate area yield for CYROLITE® and XT® POLYMER compounds with a specific gravity value of 1.1.

Roll Stock – Approximate Area Yield for CYROLITE® and XT® polymer compounds (1.1 Specific Gravity)

Table 3

Gauge	Square inches per pound
.001	25,200
.0075	3,360
.010	2,520
.015	1,680
.020	1,260

Mold Design Data

Shrinkage

.004 - .008 inch/inch

Venting

#65 to #75 drill 0.035” to 0.020” back drill at least 1/8” diameter or larger to within 1/4” of surface. Use insert venting whenever possible for best results.

Draft Angle

2 – 3° Female Mold

5 – 7° Male Mold

Mold Finish

All radii, undercuts, and vertical draws should be polished. Flats should have an SPE #5 finish to prevent air entrapment.

Cooling

Design molds for uniform cooling. Uneven cooling distribution may cause shrinkage strains within the part. When forming, mold temperature should be slightly below material distortion temperature (160°F - 180°F).

Processing Guidelines

Film Orientation/shrinkage: A sheet or film’s degree of orientational strain can affect its forming characteristics. Allowable orientation varies depending on thermoforming technique and end product. It is preferable to keep the orientation/shrinkage below 25%. Low orientation is needed for preprinted forming since a distorted sheet distorts the printed product. Low and uniform orientation is also needed for forming processes using contact heat. Uneven orientation causes a sheet to ripple during the heating cycle, leading to uneven surface contact. This leads to non-uniform heat distribution and causes mottled spots or webbing in the end products.

See “Measuring Orientation” on page 12.

Mold Design

The variety of forming equipment also provides wide contrast in thermoforming mold design. You should consider many factors for proper mold design. For example:

1. Determine if the mold is for production or prototype
2. Should it be male or female?
3. What material should be used? Should it be cast or machined?
4. What should be considered concerning mold shrinkage, finish and cooling design?
5. Does the part require trimming?
6. Does it have a mating component, as with a container and lid?

Mold Construction

Molds may be either male (raised) or female (recessed). Female molds are preferred, with plug assist if necessary, for CYROLITE® and XT® POLYMER compounds. A female mold will provide a thicker flange area, sharp definition on the outside area, and easy ejection. A male mold is usually cheaper to construct and provides for a deeper draw. Disadvantages include a tendency to web, form a weak flange area, and provide an extremely difficult release.

Thermoforming Characteristics – Semi-Automatic

CYROLITE® and XT® polymer compounds have been processed on most types of commercial thermoformers with excellent results.

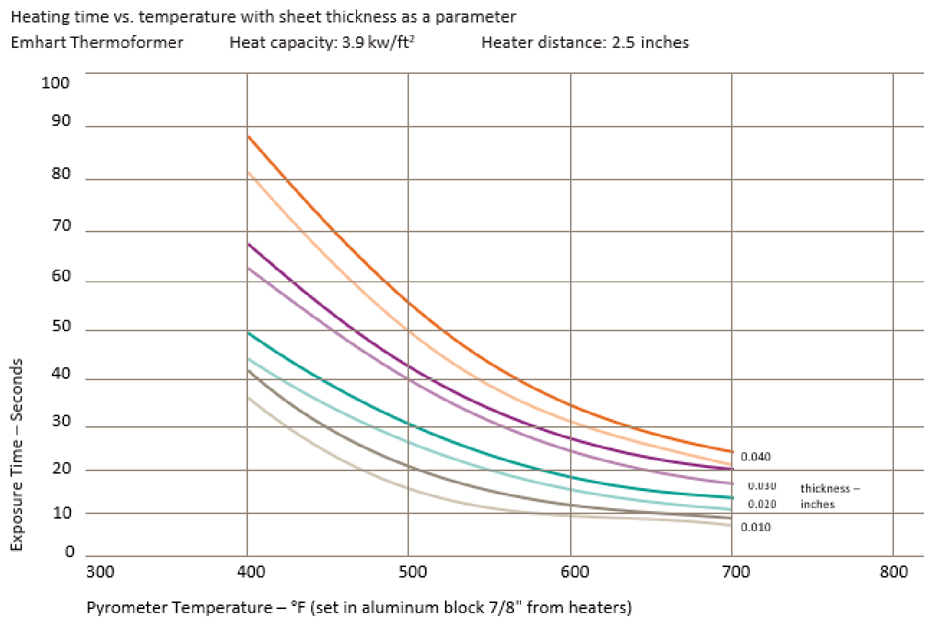
Appearance of parts made of these materials depends on tooling design and time/temperature relationships.

Excellent clarity can be achieved on shallow-draw parts with large radii. As the part becomes more intricate, heating time should be increased for improved detail. Clarity can diminish unless heating time is increased and temperature is reduced.

Figure 1 below demonstrates forming conditions developed on an Emhart thermoformer for 10 through 40 mil sheet using top half molds with 3:1,5:1, and 7:1 area ratios. The results showed the 3:1 area containers had excellent clarity; the 5:1 containers excellent to good; and the 7:1 container good to fair. Sheet surface temperature was 350°F for a 500°F/24 sec. draw.

Thermoforming of CYROLITE® and XT® polymer compounds

Figure 1



To begin an evaluation, choose a time/temperature thickness relationship from the graph on previous page. In general, wait five to ten seconds after sheet recovery before draping CYROLITE® and XT® POLYMER compounds. Since machine operating conditions vary, the following processing guidelines should assist in establishing a proper machine cycle.

Heat

Adjust heat control settings to provide a sheet temperature range of 320°F – 350°F (depending on polymer). For high speed forming, higher temperatures up to 400°F may be best. Excessive heat, however, can cause surface degradation. To achieve best clarity, use low, uniform heat and extend residence time.

Plug Assist

Most forming equipment with moderate draw ratios use an aluminum plug assist to pre-stretch the material. For best results, heat the plug to 270°F - 300°F. You can change plug assist designs to modify container side wall distribution. Control wall thickness by the plug assist timing within the cycle.

Vacuum
Vacuum control circuit design can affect machine forming characteris- tics. Locate valves near the work function. Eliminate excessive piping and hoses. Evaluate the flow rate of control valves to prevent flow restrictions.

Pressure
The higher the pressure, the better the definition. Pressure should always be above the manufac- turer's recommendation. On rare occasions, purging within the air line can cause forming problems. Correct this by adding an accumulator tank within the forming unit.

Mold Temperature
Design molds for uniform thermal conductivity. An operating temperature slightly below the material's heat distortion tempera- ture is best (160 - 180°F). Uneven mold temperature may result in excessive stress.

Form, Fill & Seal Equipment
Heating capacity is important when developing form, fill and seal capabilities for CYROLITE® and XT® POLYMER compounds. Some machines overheat the center of the plastic, causing an uneven sheet temperature. Use shielding to even out heat distribution.

CYROLITE® and XT® POLYMER compounds have been sealed by the following methods: ultrasonic welding, spin welding, thermal sealing, adhesive and solvent bonding.

CYROLITE® and XT® POLYMER compounds can be ultrasonically weldedwelded or solvent bonded to ABS, HIPS and PVC and bonded to self adhesiveself-adhesive Tyvek® and Tyvek type films. Compatibility with various materials will depend on the sealing method chosen for each application.

Be careful about plug design for medium or deep draw items. Both aluminum and Teflon® coating have been used successfully. For aluminum, use plug heating to 270 - 290°F for accurate control.

Tyvek® and Teflon® are registered trademarks of DuPont.

High Speed Thermoforming

Excellent results can be achieved in high speed thermoforming. On the next page there are two examples.

1. *A sixteen-ounce spin-welded container of 0.070" sheet made of XT® POLYMER 375 PMMA-based copolymer.*

Tooling: Four cavities, side by side, consisting of two base and two threaded top cavities. The thread area is ejected by mechanical drive, with an air motor spinning the threads off by rotation.

Operating Conditions: 10 Cycle Heat Residence Time.

The user then assembled containers under all conditions into spin- welded jars without difficulty.

Example 1 – processing settings

Heat	Cycle	Stock Temp	Plug
740°F	6 sec	350°F	270°F
800°F	5 sec	350°F	270°F
900°F	4 sec	350°F	270°F

2. *Fourteen-ounce wide-mouth container of 0.070" sheet made of XT® POLYMER 375 PMMA-based copolymercompound.*

Tooling: Single cavity. Air-actuated, spring-loaded, three section cam thread ejection.

Operating Conditions: 6 Cycle Heat Residence Time

The user obtained the best clarity at the 600°F heat setting. Using 10-12 cycles of heating would improve clarity. Long resident heat times are desired for CYROLITE® and XT® POLYMER compounds processing.

Example 2 – processing settings

Heat	Cycle	Stock Temp	Plug
600°F	16 sec	350°F	280°F
800°F	12 sec	350°F	280°F
1000°F	8 sec	350°F	280°F

Trimming

Several systems for trimming are used in thermoforming. The most desirable, but also most expensive, is matched metal dies. These dies may be best since they produce a cut essentially free of fines and slivers.

Several concepts of trimming are used with the matched metal die systems. Some machines trim at the forming station, others trim at a secondary station and extremely high speed units use a secondary trimming machine for a post-trimming operation.

The heat, form and trim system at the same station has the advantage of excellent orientation control for pre-printed items. Usually the pressure box limits sheet travel, control- ling shifting from sheet orientation. The system also has the disadvantage of part ejection as the part is supported by web fingers for removal.

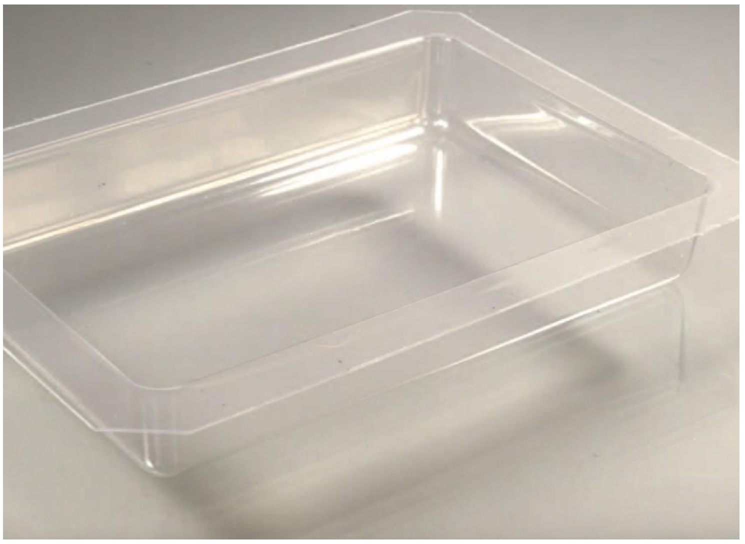
Secondary trim stations have the advantage of finished part control. Parts may be cut upward or downward, depending on tool design. Parts are also usually stacked automatically for inspection, post forming operations and packing.

The third system for highest volumes, trims single or double rows per cycle, but cycles several multiples faster than the basic former. Thus, you can use a large forming area. By multiple trimming, you can achieve substantial savings because of lower trim die costs.

Again, parts are stacked automatically for inspection, post forming operations and packing.

Steel rule dies are used when volume does not justify the expense of matched metal dies. Several systems can be used for steel rule dies. They can be used with contact heat, form and trim units; mounted at a secondary station in a progressive forming system; or used as a post-operative function. The machine style or the volume determines the system used.

Small prototype orders are usually finished in a hand press. Other systems that may be used for trimming CYROLITE® and XT® POLYMER compounds include saw cutting, rollers, slitting and hot wires.



Trim Tooling Design

CYROLITE® and XT® POLYMER compounds are moder- ately easy to finish. Be careful about cutter design and maintenance. Keep trim tools clean, very sharp, and tolerances close. These materials trim best when warm.

Matched Metal Dies:

1. Keep tolerance low (.001inch total clearance).
2. Sharpen as required.
3. Concentricity of round items is important.

Steel Rule Dies:

1. Bevel from both sides.
2. Sharpen as required.
3. Heated steel rule dies reduce fines and slivers.

Measuring Orientation/Shrinkage

Many processors have developed a particular techniquetechnique for measuring orientation. The common test method for CYROLITE® and XT® polymer compounds is immersion in a 300°F oil bath. Place 4-inch square test samples on a wire rack with a light wire screen over each piece to prevent curling. Immerse the rack in 300°F oil for ten minutes.

After cooling, measure the percent change in length in both the machine and transverse directions. Since allowable orientation can vary for different forming situations, the amount of orientation should be established between the thermoformer and extruder prior to production.

Define test conditions precisely since problems may arise because of test procedure modifications. Residence time, part size, oil bath temperature and support method can vary. Some processors use an air oven rather than an oil bath.

CYROLITE®
ADVANCED MEDICAL ACRYLICS

Typical Physical Properties

	ASTM Method	XT® POLYMER 250	XT® POLYMER 375	CYROLITE® G-20	CYROLITE® G-20 HIFLO
Optical Properties					
Light Transmission, (%)	D-1003	90	86	89	89
Haze, (%)	D-1003	2.5	2.5	5.0	6.0
Rheological Properties					
Average Melt Flow g/10 min (@ 230°C/5.0 kg)	D-1238	4.2	2.6	2.6	10.0
Mechanical Properties					
Notched Izod, ft. lbs./in. [J/m]on 1/4 in. (6.35mm) bar					
73°F (23°C)	D-256	1.2 [64.0]	2.0 [107.0]	1.9 [101]	1.9 [101]
32°F (0°C)	D-256	0.9 [48]	1.6 [85]	1.1 [59]	1.1 [59]
Tensile Strength, psi [MPa]	D-638	8,000 [55.2]	7,000 [48.3]	6,800 [46.9]	7,000 [48.3]
Tensile Modulus, psi [GPa]	D-638	0.43 [3.0]	0.37 [2.6]	0.32 [2.2]	0.37 [2.6]
Tensile Elongation @ yield, %	D-638	4	4	4.0	3.6
Tensile Elongation @ break, %	D-638			9.5	9.5
Flexural Strength, psi [MPa]	D-790	13,000 [89.6]	11,000 [75.8]	10,500 [89.6]	9,400 [75.8]
Flexural Modulus, psi [GPa]	D-790	0.40 [2.8]	0.35 [2.4]	0.335 [2.3]	0.310 [2.1]
Compressive Strength, psi [MPa]	D-695	11,500 [79.3]	9,500 [65.5]	11,500 [79.3]	11,500 [79.3]
Rockwell Hardness	D-785	M56	M45	M39	M27
Physical Properties					
Deflection Temperature °F [°C]@ 264 psi	D-648	189 [87]	186 [86]	186 [86]	186 [86]
Coefficient of Linear Expansion (in/in/°F) 32-212°F	D-696	0.00004	0.00005	0.0000514	0.0000514
Specific Gravity	D-792	1.11	1.11	1.11	1.11
Mold Shrinkage, in/in	D-551	0.004 - 0.007	0.004 - 0.007	0.004 - 0.007	0.004 - 0.007
Bulk Density, g/cc loose	D-1895	0.65	0.65	0.65	0.65
Vicat Softening Point, °F [°C]	D-1525	214 [101]	217 [103]	214 [101]	214 [101]
Flammability	–	UL94HB	UL94HB	UL94HB	UL94HB

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Extrusion – Troubleshooting Guide

Defect	Probable Cause	Solution
Screw Rubbing on Barrel	Not enough clearance	Check dimensions of screw and barrel.
	Misaligned barrel	Bore scope barrel and realign.
	Bent screw	Check T.I.R. and straighten screw.
	Screw shank off center	Clean shank and thrust bearing. Reinstall screw.
	Worn out thrust bearing	Replace bearing.
	Gross contamination causing wedge against barrel	Check screens for metal. Use magnets in hopper.
Contamination in Product	Resin, additives	Contact supplier. Use finer screens.
	Open gaylords	Use a gaylord cover.
	Dirty transfer system	Inspect/clean/replace: dirty pick-up hoses, conveying lines, storage bins, etc.
	Air filters	Correct mesh size. Replace dirty/broken filters.
	Dirty extruder	Purge extruder. Brush screw. Clean die tooling.
	Broken screenpack	Monitor psi. Replace screens.
Loss of Output	Resin bridging in feed throat	Use feed throat cooling. Check heat transfer on inlet/outlet pipes. Reduce temperature on first barrel zone. Remove screw and clean off fused resin.
	Restriction in hopper	Clear restriction. Open slide gate fully.
	Drive belts slipping	Adjust pulleys.
	Burned out heater	Replace heater.
Rough or Wavy Extrudate (Poor Surface)	Poor melt quality	Raise barrel temps. Use screw cooling. Use finer screens. Reduce screw speed. Preheat resin. New screw design.
	Poor flow in die	Raise die temperature. Increase die gap.
	Cooling imperfection	Use shield to prevent splashing. Wipe air bubbles off in cooling trough. Use deaerated water.
	Wire vibration	Reduce vibration.

Extrusion – Troubleshooting Guide Continued…

Defect	Probable Cause	Solution
Lumps in Extrudate	Contamination Overheated resin	Refer to "Contamination in Product" section above. Reduce melt temperature. Cool head and die. Shutdown and cleanup.
	Moisture buildup release	Check resin for moisture. Use hopper dryer.
Streaks in Extrudate	Scratches in die	Polish tooling.
	Build-up in die	Check for moisture. (see above) Check for scorch and overheating. (see above) Clean die.
Diameter Variations	Extruder surging	Increase temperature of middle and rear zones. Use screw cooling. Check screw cooling for temperature cycling. New screw design.
	Screw speed fluctuating	Repair drive controls.
	Line Seed fluctuating	Repair line speed controls.
	Core size variations	Measure core diameter and correct.
Out of Roundness	Die and guider not centered	Adjust tooling.
	Sagging before freezing	Reduce melt temperature. Move cooling trough closer to die. Reduce wire preheat.
	Extrudate deforming on capstan or puller	Use more cooling. Lower line speed. Decrease contact pressure of pulling device.
High Head Pressure	Clogged screen	Put in fresh screens.
	Unmelted/cold resin	Raise barrel temps. Use screw cooling. New screw design.
	Restrictive flow path in head/die	Use coarser screens. Use larger die, shorter land lengths. Move guider tip back.

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Thermoforming – Troubleshooting Guide

Defect	Probable Cause	Solution
Bridging or Webbing	Sheet too hot	Reduce temperature or heating time.
	Improper mold design	Redesign or use assists.
	Assist too slow	Increase speed.
	Vacuum rate too fast	Use smaller vacuum holes.
Bubbles	Sheet too hot	Reduce temperature and increase heating time.
Color Blotches	Orientation causing uneven heating	Increase air holding pressure for uniform contact.
Parts Lack Detail	Sheet too cold	Increase heating time.
	Insufficient vacuum	Increase number and/or size of vacuum holes. Check for leaks in vacuum system.
Postforming Distortion	Part removed from mold; too hot	Increase cooling time; add cooling to mold.
Poor Clarity	Overheating	Decrease heat. Increase cycle.
Poor Part Release	Insufficient draft	Change draft angle.
	Undercuts too deep	Use female mold. Use split mold.
	Poor mold surface	Improve mold surface.
Wall Thickness Variation	Non uniform heating or uneven sheet temperature	Change heat profile. Check heaters.
	Orientation in sheet	Change roll.
	Uneven roll gauge	Change roll.
	Improper plug temperature	Change plug temperature profile.

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