Acrylic Advisor

Technical reference guide for CYROLITE®, XT® polymer, CYREX® and Vu-Stat™ acrylic polymers

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Table of Contents

Introduction

Evonik Cyro LLC, a part of the Performance Polymers Business Unit of Evonik, is a worldwide manufacturer of PMMA molding compounds. Evonik 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, acrylic-based multipolymer compounds. CYROLITE® and XT® polymers are unique materials in that they do not have direct counterparts. They both have distinctive characteristics that make them particularly successful in the medical device and packaging markets. XT® polymer has successful applications that range from refrigerator pans to paper dispenser cabinets and fishing tackle boxes. XT® polymers offer exceptional chemical resistance which includes resistance to plasticizers found in flexible PVC and other plastics. CYROLITE® and XT® polymers are extruded and coextruded into fast food packages such as salads and soft serve ice cream cups.

CYROLITE® compounds are resistant to both alcohol and lipids and are recommended for applications requiring gamma radiation sterilization.

CYREX® acrylic-polycarbonate alloy has an izod impact strength higher than polycarbonate yet maintains the ease of processing associated with acrylic materials.

Vu-Stat™ is a transparent, electro-static dissipative acrylic multipolymer compound with outstanding ESD properties mainly for molding medical applications.

Evonik Cyro offers the following product lines for the medical and packaging markets:

- CYROLITE® G-20
- CYROLITE® G-20 HIFLO®
- CYROLITE® GS-90
- CYROLITE® CG-97
- CYROLITE® Med 2
- CYROLITE® MD™
- XT® polymer 250
- XT® polymer 375
- XT® polymer X800RG
- CYREX® acrylic-polycarbonate alloy
- Vu-Stat™ Y-20 static dissipative acrylic compound

CYROLITE®

Developed specifically for the medical industry, CYROLITE® is an acrylic-based multipolymer compound terpolymer with an added impact modifier. CYROLITE® grades differ in melt flow, color change after gamma exposure, and in lipid and alcohol resistance. All grades meet the requirements of USP class VI, ISO 10993 and are BPA free. All grades of CYROLITE® compounds are suitable for applications where gamma, electron beam (E-beam) or Eto sterilization is required. They exhibit no loss in mechanical properties. CYROLITE® GS-90 compound is the most gamma and E-beam stable grade of CYROLITE® compounds as it experiences almost no yellowing due to irradiation. They are:

- transparent
- resistant to alcohol and lipids
- high heat deflection temperature
- resistant to plasticizers found in PVC tubing
- outstanding impact strength
- gamma and EtO stable
- suitable for ethylene oxide sterilization
- resistant to plasticizers in PVC tubing

CYROLITE®

Typical Applications

- Luer locks
- Dialyzer housings
- Protection caps and covers
- Blood / plasma separators
- Collection and specimen vessels
- Connectors and injection ports
- Catheter accessories
- Chest drainage units
- Valve assemblies
- Meter housings
- Flow controls
- IV and lab filter housings
- Drip chambers
- Yankauers
- Inhalation mouthpieces and spacers

Description of Grades

All grades of CYROLITE® acrylic-based multipolymer compounds are suitable for applications where gamma or electron beam sterilization is required. The CYROLITE® compounds listed vary according to molecular weight and impact modifier loading. CYROLITE® GS-90 is the most gamma and E-beam stable grade as it experiences almost no yellowing due to irradiation.

CYROLITE®

CYROLITE® G-20
CYROLITE® G20-HIFLO®
CYROLITE® Med 2

Parts made from these grades initially shift color upon irradiation. The color returns to near normal after four to five weeks.

CYROLITE® GS-90
CYROLITE® CG-97

These grades are designed specifically for gamma and E-beam sterilized products and may exhibit a very slight color change to a pleasing permanent blue-green tint after irradiation. Medical parts may, therefore, be immediately sent to market after sterilization. CYROLITE® CG-97 offers high lipid resistance.

CYROLITE® Med 2 is both alcohol and lipid resistant.

CYROLITE® MD™ acrylic polymers are available in two grades, CYROLITE® MD™ H12 and CYROLITE® MD™ L40, that vary according to processing conditions. They are well suited for diagnostic applications. Both CYROLITE® MD™ grades are non-hemolytic, non-cytotoxic, non-pyrogenic, non-sensitizing, and non-mutagenic.

Performance formulations offer:

- Exceptional ultra-violet light transmittance
- Excellent optical clarity
- Maximum flow characteristics
- Good dimensional stability
- Regulatory compliance for quality control
- Total cost-of-use advantage over glass

CYROLITE®
acrylic-based multipolymer compounds

Physical Properties

Property	ASTM Method	G-20	G-20 HIFLO
OPTICAL			
Light Transmission, %	D-1003	89	89
Haze, %	D-1003	5.0	6.0
Refractive Index	D-542	1.515	1.515
UV Transmittance 340 nm, %	–	–	–
RHEOLOGICAL			
Avg Melt Flow, g/10 min @ 230°C & 5.0 kg	D-1238	2.6	10
MECHANICAL			
Tensile Strength, psi (MPa)	D-638	6,800 (46.9)	7,000 (48.3)
Tensile Modulus, x10^6 psi (GPa)	D-638	0.32 (2.2)	0.37 (2.6)
Tensile Elongation @ Yield, %	D-638	4.0	3.6
Tensile Elongation @ Break, %	D-638	9.5	9.5
Flexural Strength, psi (MPa)	D-790	10,500 (72.4)	9,400 (64.8)
Flexural Modulus, x10^6 psi (GPa)	D-790	0.34 (2.3)	0.31 (2.1)
Notched Izod, ft-lb/in (J/m) on 1/4" (6.35mm) bar @ 23°C	D-256	1.9 (101)	1.9 (101)
@ 0°C	D-256	1.1 (59)	1.1 (59)
Compressive Strength, psi (MPa)	D-695	11,500 (79.3)	11,500 (79.3)
Rockwell Hardness, M scale	D-785	39	27
PHYSICAL			
DTL, °F (°C) @ 264 psi, annealed	D-648	186 (86)	186 (86)
Vicat Softening Point, °F (°C)	D-1525	214 (101)	214 (101)
Specific Gravity	D-792	1.11	1.11
Water Absorption, %	D-570	0.30	0.30
Mold Shrinkage, in/in, mm/mm	D-551	0.004 – 0.007	0.004 – 0.007
Coefficient of Linear Expansion in/in/°F, 32 – 212°F (mm/mm °C, 0 – 100°C)	D-696	0.0000514 (0.0000925)	0.0000514 (0.0000925)
Flammability		UL 94 HB	UL 94 HB

GS-90	CG-97	Med 2	MD H12	MD L40
89	87	85	92	92
3.0	5.0	7.0	<1	<1
1.515	1.515	1.515	1.49	1.49
–	–	–	min 87.7	min 87.7
6.5	1.8	2.1	7.0 @3.8 kg	26.0 @3.8 kg
6,300 (43.4)	5,270 (36.3)	5,320 (36.7)	9,500 (65.5)	8,800 (60.7)
0.32 (2.2)	0.27 (1.9)	0.25 (1.7)	0.47 (3.2)	0.47 (3.2)
3.6	3.8	3.9	4 - 6	2 - 4
6.7	13.9	22	4 - 6	2 - 4
10,800 (74.5)	9,800 (67.6)	8,590 (59.2)	17,000 (117.2)	14,200 (97.9)
0.33 (2.3)	0.27 (1.8)	0.24 (1.6)	0.49 (3.4]	0.44 (3.0)
2.0 (107) 0.8 (43)	2.3 (122) –	2.2 (117) –	0.36 (19) –	0.36 (19) –
8,190 (56.5)	6,200 (42.8)	–	17,000 (117.2)	13,700 (94.5)
30	35	33	94	84
163 (73)	158 (70)	163 (73)	201 (95)	165 (74)
210 (99)	194 (90)	201 (94)	221 (105)	180 (82)
1.11	1.08	1.08	1.19	1.19
0.30	0.35	0.38	.030	0.30
0.004 – 0.006	0.005 – 0.007	0.005 – 0.007	0.004 – 0.006	0.003 – 0.006
0.00004 (0.000072)	0.000053 (0.000095)	0.000048 (0.00086)	0.00004 (0.000072)	0.00004 (0.000072)
UL 94 HB	UL 94 HB	UL 94 HB	UL 94 HB	UL 94 HB

CYROLITE®
acrylic-based multipolymer compounds

Processing Conditions – Injection Molding

CYROLITE®	G-20	G-20 HIFLO	GS-90
Drying Temperature, °F (3 – 4 hours)	175	175	160
Feed Section Temperature, °F	380 – 435	360 – 435	375 – 425
Center Section Temperature, °F	400 – 460	380 – 460	410 – 450
Front Temperature, °F	400 – 475	380 – 460	410 – 450
Nozzle Temperature, °F	400 – 475	380 – 460	410 – 450
Melt Temperature, °F	400 – 475	380 – 460	410 – 450
Mold Temperature, °F	120 – 180	120 – 180	90 – 150
Injection Pressure, psi	10,000 – 20,000	6,000 – 15,000	6,000 – 15,000
Clamp Pressure, Psi	2.5 tons/in² of projected area for flow length/wall thickness <100/1 5 tons/in² of projected area for flow length/wall thickness >100/1		
Screw Speed, rpm 2:1 compression ratio 3.5:1 compression ratio	 20 – 100 20 – 70	 20 – 100 20 – 70	 75 – 150 60 – 130
Ram Speed, in/sec small gates large gates	 0.5 – 1.5 1 – 4	 0.5 – 1.5 1 – 4	 0.5 – 1.5 1 – 4
Back Pressure, psi	0 – 100	0 – 100	0 – 100

CG-97	Med 2	MD H12	MD L40
160	160	170	160
410 – 450	425 – 450	430 – 480	410 – 470
430 – 480	450 – 480	430 – 480	410 – 470
430 – 480	450 – 480	430 – 480	410 – 470
430 – 480	450 – 480	430 – 480	410 – 470
420 – 480	450 – 480	430 – 480	410 – 470
90 – 150	90 – 180	90 – 175	90 – 160
6,000 – 15,000	6,000 – 15,000	6,000 – 15,000	6,000 – 15,000
75 – 150 60 – 130	75 – 150 60 – 130	75 – 150 60 – 130	75 – 150 60 – 130
0.5 – 1.5 1 – 4	0.5 – 1.5 1 – 4	0.5 – 1.5 1 – 4	0.5 – 1.5 1 – 4
0 – 100	0 – 100	25 – 100	25 – 100

CYROLITE® acrylic-based multipolymer compounds and XT® polymer

Recommended drying conditions

Condition	
Drying Temperature, °F (3 – 4 hours)	180

Processing Conditions – Extrusion

Screw Diameter	3 ½ inch
Turns of Feed – Constant Depth	4 at 0.500
Turns of Transition – Constant Taper	3
Turns of Meter Pump – Constant	6 at 0.165
Turns of Decompression – Constant Taper	1
Turns of Vent Zone – Constant Depth	4 at 0.650
Turns of Recompression – Constant Taper	2.5
Turns of 2nd Meter Pump – Constant Taper	5 at 0.300
Feed Zone, °F	350 – 400
Rear, °F	380 – 420
Rear Center, °F	380 – 425
Center, °F	390 – 430
Front Center, °F	420 – 470
Front, °F	430 – 475
Gate, °F	450 – 470
Adapter, °F	450 – 470
Die End Plates, °F	450 – 470
Die Left and Right, °F	440 – 470
Die Center, °F	440 – 470

Typical screw geometries and machine settings for sheet extrusion (two stage screw with L/D of 24/1 assumed)

4 ½ inch	6 inch
4 at 0.625	7 at 0.635
3	3
5 at 0.180	4 at 0.190
1	1
4 at 0.750	3 at 0.750
2.5	2.0
5 at 0.325	5 at 0.335
340 – 400	280 – 320
380 – 415	320 – 360
380 – 425	360 – 420
380 – 425	400 – 440
420 – 460	420 – 460
420 – 460	420 – 460
450 – 470	460
450 – 470	460
450 – 470	470
445 – 460	460
445 – 460	460

XT® polymer acrylic-based multipolymer compounds

XT® polymer is an acrylic-based multipolymer compound terpolymer with an added impact modifier. It has been used in rigid medical packaging for over 30 years. It's one of the most cost effective thermoplastics for rigid sterilizable packaging. There are three different grades of XT® polymer varying in molecular weight.

XT® polymer is an outstanding material choice with:

- good heat distortion temperatures
- outstanding crush strength
- clarity
- rigidity
- chemical resistance
- suitable for ethylene oxide sterilization

Typical Applications

- Medical packaging competing with PETG
- Paper and soap dispenser housings
- Appliance housings
- Vacuum canisters
- Food packaging

XT® polymer acrylic-based multipolymer compounds

Description of Grades

XT® polymer 250

Low levels of impact modifier and a higher molecular weight. Consequently, it has low melt flow rates, lower impact strength, and higher strength properties.

XT® polymer 375

Highest impact modifier loading, hence the highest impact strength and the lowest melt flow rate.

XT® polymer X800RG (non medical)

Very high impact modifier content and a low molecular weight giving it a high melt flow rate and a high impact resistance.

XT® polymer acrylic-based multipolymer compounds

Physical Properties – XT® polymer

Property	ASTM Method	250
OPTICAL		
Light Transmission, %	D-1003	90
Haze, %	D-1003	2.5
Refractive Index	D-542	1.515
RHEOLOGICAL		
Avg Melt Flow, g/10 min @ 230°C & 5.0 kg	D-1238	4.2
MECHANICAL		
Tensile Strength, psi (MPa)	D-638	8,000 (55.2)
Tensile Modulus, $x10^6$ psi (GPa)	D-638	0.43 (3.0)
Tensile Elongation @ Yield, %	D-638	4
Tensile Elongation @ Break, %	D-638	15
Flexural Strength, psi (MPa)	D-790	13,000 (89.6)
Flexural Modulus, $x10^6$ psi (GPa)	D-790	0.40 (2.8)
Notched Izod, ft-lb/in (J/m) on 1/4" (6.35mm) bar @ 23°C @ 0°C	 D-256 D-256	 1.2 (64.0) 0.9 (48)
Compressive Strength, psi (MPa)	D-695	11,500 (79.3)
Rockwell Hardness, M scale	D-785	56
PHYSICAL		
DTL, °F (°C) @ 264 psi, annealed	D-648	189 (87)
Vicat Softening Point, °F (°C)	D-1525	214 (101)
Specific Gravity	D-792	1.11
Water Absorption, % max	D-570	0.30
Mold Shrinkage, in/in, mm/mm	D-551	0.004 – 0.007
Coefficient of Linear Expansion in/in/°F, 32 – 212°F (mm/mm °C, 0-100°C)	D-696	0.00004 (0.000072)
Flammability		UL 94 HB

375	X800RG
86	86
2.5	5.0
1.515	1.515
2.6	11
7,000 (48.3)	6,300 (43.4)
0.37 (2.6)	0.43 (3.0)
4	4
28	28
11,000 (75.8)	9,700 (66.9)
0.35 (2.4)	0.32 (2.2)
2.0 (107.0) 1.6 (85)	1.9 (101.0) 1.2 (64)
9,500 (65.5)	11,500 (79.3)
45	22
186 (86)	186 (86)
217 (103)	201 (94)
1.11	1.11
0.30	0.30
0.004 – 0.007	0.004 – 0.007
0.00005 (0.00009)	0.000048 (0.000086)
UL 94 HB	UL 94 HB

XT® polymer acrylic-based multipolymer compounds

Processing Conditions – XT® polymer

Condition	250
Drying Temperature, °F (3 – 4 hours)	180
Melt Temperature, °F	400 – 475
Mold Temperature, °F	90 – 140
Injection Pressure, psi	10,000-20,000
Clamp Pressure	2.5 tons/in^2 of projected area for flow length/wall thickness <100/1 5 tons/in^2 of projected area for flow length/wall thickness >100/1
Screw Speed, rpm 2:1 compression ratio 3.5:1 compression ratio	 20 – 100 20 – 70
Ram Speed, in/sec small gates large gates	 0.5-1.5 1 – 4
Back Pressure, psi	0-100

375	X800RG
180	180
400 – 475	425 – 475
90 – 175	80 – 150
10,000-20,000	10,000-20,000
20 – 100 20 – 70	20 – 100 20 – 70
0.5-1.5 1 – 4	0.5-1.5 1 – 4
0-100	0-100

CYREX® acrylic-polycarbonate alloys

CYREX®, an opaque acrylic-polycarbonate alloy, is a unique marriage between acrylic and polycarbonate where the final product exceeds the sum of the two components that make up the product. The most notable property advantage of CYREX® alloy over either of its components is in notched izod impact strength. It is an ideal material for applications which require excellent toughness CYREX® alloy offers:

- excellent impact strength
- lower processing temperatures than polycarbonate for reduced cycle times
- good heat resistance
- good chemical resistance
- gamma resistance
- ease of processing

Applications

- Phone and electronic device housings
- Appliances
- Toys
- Furniture
- Automotive components
- Medical devices
- Molded applications
- Extruded/thermoformed sheet applications

CYREX® acrylic-polycarbonate alloys

Description of Grades

CYREX® 200-8000
CYREX® 200-8005

Medical grades with excellent resistance to alcohol and lipids, good heat resistance so it can be ethylene oxide sterilized, and it is both gamma and E-beam resistant.

CYREX® 953

ideal for both thin wall applications and cold temperature applications.

Typical Applications include:

- Luer fittings
- Spikes
- Protection caps and covers
- Adapters
- Fittings
- Valve assemblies
- Sharp needle dispenser receptacles

CYREX® acrylic-polycarbonate alloys

Physical Properties – CYREX® alloys

Property	ASTM Method	200-8000
OPTICAL		
Light Transmission, % d = 3.2 mm %	D-1003	Opaque
RHEOLOGICAL		
Avg Melt Flow, g/10 min @ 230°C & 3.8 kg	D-1238	3.9
MECHANICAL		
Tensile Strength, psi (MPa)	D-638	8,850 (61.0)
Tensile Modulus, x10^6 psi (GPa)	D-638	0.35 (2.4)
Tensile Elongation @ Yield, %	D-638	4.7
Tensile Elongation @ Break, %	D-638	58
Flexural Strength, psi (MPa)	D-790	12,500 (86.2)
Flexural Modulus, x10^6 psi (GPa)	D-790	0.35 (2.4)
Notched Izod, ft-lb/in (J/m) on 1/8" bar (3.2 mm) @ 23°C @ 0°C	D-256 D-256	30.0 (1600) 4.0 (213)
Rockwell Hardness, M scale	D-785	46
PHYSICAL		
DTL, °F (°C) @ 264 psi, annealed	D-648	214 (101)
Vicat Softening Point, °F (°C)	D-1525	277 (136)
Specific Gravity	D-792	1.15
Water Absorption, %	D-570	0.26
Mold Shrinkage, in/in, mm/mm	D-551	0.004-0.008
Coefficient of Linear Thermal Expansion in/in/°F, 32-212°F (mm/mm °C, 0-100°C)	D-696	0.000052 (0.0000936)
Flammability		UL 94 HB
Product Description		Medical grade

200-8005	953
Opaque	Opaque
3.5	1.9
8,000 (55.2)	7,860 (54.2)
0.32 (2.2)	0.30 (2.1)
4.3	4.2
57	88
11,300 (78.9)	12,500 (86.2)
0.32 (2.2)	0.30 (2.1)
26.0 (1387) –	26.1 (1392) 17.1 (913)
49	44
214 (101)	217 (103)
286 (141)	275 (135)
1.15	1.15
0.26	0.26
0.004-0.008	0.004-0.008
0.000052 (0.0000936)	0.000052 (0.0000936)
UL 94 HB	UL 94 HB
Medical grade	Low-temperature impact grade

CYREX® acrylic-polycarbonate alloys

Processing Conditions – Injection Molding

Condition	Suggested	Starting Point
Drying Temperature, °F (3 – 4 hours)	180	180
Feed Section Temperature, °F	390 – 445	410
Center Section Temperature, °F	445 – 485	450
Front Section Temperature, °F	460 – 510	480
Nozzle Temperature, °F	460 – 510	480
Melt Temperature, °F	460 – 510	480
Mold Temperature, °F	150 – 210	180
Injection Pressure, psi	8,000 – 18,000	10,000
Clamp Pressure 2.5 tons/in² of projected area for flow length/wall thickness < 100/1 5 tons/in² for projected area for flow length/wall thickness > 100/1		
Screw Speed, rpm 2:1 compression ratio 3.5:1 compression ratio	 75 – 150 60 – 130	 100 80
Ram Speed, in/sec small gates large gates	 0.5 – 1.5 1 – 4	 1 2
Back Pressure, psi	50 – 300	100

Vu-Stat™ Y-20 static dissipative acrylic multipolymer compound

Vu-Stat™ has inherent electrostatic dissipative (ESD) properties and an excellent balance of mechanical, thermal and flow properties. Developed specifically for molding medical applications that are sensitive to static discharge, Vu-Stat™ Y-20 compound retains permanent static dissipative properties even after several washings. These transparent compounds can be processed in all types of molding equipment. Vu-Stat™ offers:

- transparency
- durability
- reliability
- permanent ESD protection

Applications

- Inhalation therapy systems
- brachytherapy applications

Vu-Stat™ Y-20 – Electro-static dissipative properties

Electrical @ (73 °F) 20 °C/20% RH		
Volume Resistivity, ohm-cm	D257-78	3.8×10^{10}
Surface Resistance, ohms/sq	D257	1.4×10^{10}
Static Decay, sec	FTM 101C (Method 406.1)	0.01

Physical Properties – Vu-Stat™ Y-20 static dissipative acrylic multipolymer compound

Property	ASTM Method	Vu-Stat™ Y20
OPTICAL		
Light Transmission, %	D-1003	85
Haze, %	D-1003	7.0
Yellowness Index	D-542	-0.3
RHEOLOGICAL		
Avg Melt Flow, g/10 min @ 230°C & 5.0 kg	D-1238	9.0
MECHANICAL		
Tensile Strength, psi (MPa)	D-638	5,700 (39.3)
Tensile Modulus, x10^6 psi (GPa)	D-638	0.31 (2.1)
Tensile Elongation @ Yield, %	D-638	3
Tensile Elongation @ Break, %	D-638	18
Flexural Strength, psi (MPa)	D-790	8,300 (57.2)
Flexural Modulus, x10^6 psi (GPa)	D-790	0.24 (1.7)
Notched Izod, ft-lb/in (J/m) on 1/4" (6.35mm) bar		
@ 23°C	D-256	1.3 (68.2)
@ 0°C	D-256	0.5 (26.2)
Rockwell Hardness, L Scale	D-785	54
PHYSICAL		
DTL, °F (°C) @ 264 psi, annealed	D-648	194 (90)
Vicat Softening Point, °F (°C)	D-1525	217 (103)
Specific Gravity	D-792	1.13
Water Absorption, % max	D-570	0.30
Mold Shrinkage, in/in, mm/mm	D-551	0.004 – 0.007
Coefficient of Linear Expansion in/in/°F, 32 – 212°F (mm/mm °C, 0-100°C)	D-696	0.000053 (0.000095)

Processing Conditions – Injection Molding

Condition	Suggested
Drying Temperature, °F (3 – 4 hours)	180
Feed Section Temperature, °F	380 – 435
Center Section Temperature, °F	400 – 460
Front Section Temperature, °F	400 – 475
Nozzle Temperature, °F	400 – 475
Melt Temperature, °F	400 – 475
Mold Temperature, °F	90 – 140
Injection Pressure, psi	10,000 – 20,000
Clamp Pressure, Psi 2.5 tons/in² of projected area for flow length/wall thickness < 100/1 5 tons/in² for projected area for flow length/wall thickness > 100/1	
Screw Speed, rpm 2:1 compression ratio 3.5:1 compression ratio	 20 – 100 20 – 70
Ram Speed, in/sec small gates large gates	 0.5 – 1.5 1 – 4
Back Pressure, psi	0 – 100

Material Considerations

Material Selection

- Selecting the right acrylic-based polymer for a particular application is an extremely important part of the design process.
- The first step is to clearly define the application and the end-use performance requirements for the molded part.
- Performance requirements include: weather resistance, heat resistance, toughness, and chemical resistance.
- Match the end-use performance requirements with the properties/attributes of potential materials. A grade with the highest strength and dimensional stability under heat will result in the most durable parts, although it may be more difficult to mold.

Drying

Acrylic-based polymers are slightly hygroscopic and therefore require pre-drying in vacuum or a desiccant type dryer where the effluent air has a dew point of -20°F or lower. Moisture levels must be below 0.06% for injection molding and below 0.03% for extrusion. Problems with reduced transparency, increased haze, the appearance of surface streaks, and bubbling throughout the part can all arise due to insufficient drying. The following table lists recommended drying conditions for each material.

Recommended drying conditions

Material	Temperature	Time
CYROLITE®		
G20-100	175°F	3 - 4 hours
G20-HIFLO	175°F	3 - 4 hours
GS-90	160°F	3 - 4 hours
CG-97	160°F	3 - 4 hours
Med 2	160°F	3 - 4 hours
MD L40	160°F	3 - 4 hours
MD H12	170°F	3 - 4 hours
XT® polymer		
250	180°F	3 hours
375	180°F	3 hours
X800RG	180°F	3 hours
CYREX®		
200	180°F	3 - 4 hours
953	180°F	3 - 4 hours
Vu-Stat™		
Y20	180°F	3 - 4 hours

Regrind

- Evonik's materials can all be reground and reprocessed without adversely affecting physical properties.
- The primary effect from using reground material is a shift in color.
- Use 25% regrind to 75% virgin material to minimize significant color change.
- Avoid contamination and remove all fines in the regrind process.
- Regrind may require additional drying due to the increased surface to volume ratio.

Material Considerations *– continued*

Purging

- In most cases the acrylic polymers in un-dried state is a sufficient purging compound.
- Commercial compounds such as ASA Clean, Dyna-Purge, and Ultimax are recommended.
- Acrylic-based polymers will discolor if left in the barrel too long (5 - 10 minutes).
- Material that is exposed to high temperatures for long periods of time (i.e. 1 hour) will decompose and develop a skin on the screw barrel and nozzle.
- Decomposition will not cause any permanent machine damage and can be removed by purging with un-dried PMMA or ground cast acrylic sheet.
- Prolonged interruptions, or when temperatures are unusually high (above 500°F), may lead to a yellowing of material in the cylinder. If yellowing occurs, purging may be required.

Material Handling

- Molding of high quality transparent parts requires high quality handling processes to prevent contamination from external sources.
- The high surface hardness of acrylic-based polymers also means that it is abrasive in conveying systems.
- Stainless steel must be used for curved conveying lines and should be used for fixed straight conveying lines.
- Polyurethane hoses can be used for short, flexible hose runs.
- PVC should never be used as it softens and feeds particles of PVC into the conveying stream as it is abraded.
- Separators should be used to remove fines that are generated during the conveying process.

The Injection Mold

Basic Design

- The mold plates should be thick enough to prevent mold deformation that can occur from high melt pressures in the cavity.
- Slide molds can be used because the relatively viscous melt scarcely penetrates the gap between the sliding members.
- Acrylic-based polymers require 2.5 tons/in^2 (352 kg/cm^2) of projected area for flow length/wall thickness (L/t) <100/1 and 5 tons/in^2 (703 kg/cm^2) for L/t >100.
- Undercuts are not recommended.
- The mold cavity should have a smooth and nonporous surface, especially important when using crystal clear polymers.
- Chrome plating is preferred for a high gloss finish and to protect against penetration of lubricants into the mold surface.
- Molds for long runs should be case hardened and highly polished.
- To maintain reasonable residence time and minimize shear degradation, the shot size should range from 40 to 60% of the barrel capacity.
- If the cylinder is too large, difficulties in processing may occur because of long residence time or because of excessive stress on the machine drive.
- The choice of using a single-cavity versus a multi-cavity mold is dependent upon the capacity of the machine and the overall production economics.

Wall Thickness

- As a general rule, it is best to work with walls that are not excessively thin, 0.039 inches (1.0 mm).
- Thin wall parts are more difficult to process and often deform at temperature much lower than expected due to increased molecular orientation.
- In order to adequately fill a thin wall part, a lower molecular weight compound with a higher melt flow rate should be used.
- Evonik offers grades of materials that are better suited for thin wall applications.

The Injection Mold *– continued*

Mold Temperature

- The mold temperature has a significant influence on both the processing and properties of acrylic-based polymers.
- A mold temperature control device is recommended.
- A cold mold is more difficult to fill and can lead to high cooling stresses, warping, strong orientation, and sink marks.
- A cold mold will also lead to a hazy surface appearance of parts molded from impact-modified materials.

Venting

- Acrylic-based polymers tend to generate gases during processing requiring the mold to be vented.
- Venting serves two main purposes:
  1. Allows for displacement of the air in the mold so that the polymer can fill the mold.
  2 Releases gases from the process resulting in a quality part free of dullness and poor finish.
- Use 0.0015" (0.0038mm) deep vents relieved to 0.005" (0.127mm) for a length of 0.25 inches (6.4mm)
- For complex molds, vacuum venting should be considered.

Shrinkage

- Acrylic and acrylic-based parts will shrink upon cooling.
- The amount of shrinkage is dependent upon the grade of acrylic-based polymer, the processing conditions at which the part was processed, and the size and thickness of the part.
- Evonik’s acrylic-based polymers have a relatively low and predictable shrinkage in the range of 0.003 in/in to 0.008 in/in, depending on the particular product.
- Mold design and process conditions should be taken into consideration when estimating the shrinkage.

Sprue

- The cone sprue is the simplest form of sprue.
- It connects the nozzle of the injection cylinder directly to the mold.
- It must allow good filling of the mold cavity with a low pressure drop.

- The sprue should be as short as possible with a smooth surface as flow resistance increases with sprue length.
- If the sprue is not seated directly on the mold, a cold slug well should be used opposite the sprue.
- The cold well will collect the cooler compound that emerges first from the nozzle.

Runners

- The best cross-section for a runner is full-round.
- Oval and rectangular cross-sections are not recommended.
- The runners should be kept as short as possible to facilitate complete and uniform filling.

Gating

- All types of gating designs have been used successfully with Evonik's line of acrylic-based products.
- If the gate is too small it will restrict the filling speed which in turn prevents adequate filling of the mold.
- When using a restricted gate, the diameter should not be less than 0.036 inch (0.9 mm) for articles of average weight and 0.028 inch (0.7 mm) for smaller articles with a uniform wall thickness.
- The tab gate is used in situations where the weak area around a restricted gate must be avoided. The wall of the tab should not be thicker than the wall of the part to avoid excessive cooling time.
- The fan gate is used for flat, thin moldings such as scales, covers, or rulers where one does not wish to inject on the large, flat faces.
- The umbrella gate is recommended for tubular articles.
- Submarine gating allows the molding to be automatically separated from the runner upon removal from the mold.
- Center gating was one of the first types of gates used in injection molding and is considered to be one of the best. It provides a balanced fill for the molded part which reduces stress and minimizes weld lines. Center gating requires adequate cooling around the gate area for hot runner molds.
- The position of the gate is important as it affects the strength properties of the molded part.
- The gate should be located in a position of minimum mechanical stress as the gate has a notch effect and can induce failure.

Extrusion

There are many steps to follow in extrusion to ensure high quality product.

1. A clean dryer, conveying line, hopper, screw, barrel, and die.
2. Maintain the proper melt temperature.
3. Use microfinished, chromed, hardened polishing rolls.
4. Dry the material adequately.

A clean screw, barrel and die will help minimize contamination problems.

It is very important to avoid contamination with other plastics as the extrusion behavior of the melt and the optical and mechanical properties of the finished extrudate can be seriously jeopardized.

When the die temperatures are too high, a build up will form on the die lips.

- A die lip buildup can cause lines to form on the extrudate in the machine direction. On the other hand, if the die lip is too cool, the surface will be dull. Die lip edges must be very sharp to eliminate build up.
- High quality polishing rolls are necessary to produce an excellent surface finish that is smooth and glossy.
- We recommend using microfinished, chromed, and hardened rolls to Rockwell C 50-60.
- The rolls should be equipped with accurate and independent temperature and speed controls, coupled to rubber pull rolls.
- Drying of the material is critical in extrusion. A moisture level at or below 0.03% is recommended to ensure quality parts will be produced. Failure to adequately dry the material can result in a slight reduction in transparency and surface gloss, to severe surface streaks and/or bubbles.
- When using regrind, it is important to separate fines from the regrind. Failure to do this will result in black specks as the fines degrade and form char in the barrel which will slough off into the melt stream during processing.

Coextrusion

- Multi-manifold/multichannel dies produce the best, easily controlled, consistent multilayer sheet structure.
- CYROLITE® grades may be used as an outer/shell cap approximately 0.003 inch (0.076 mm) thick.
- XT® polymers may be considered for their environmental stress craze resistance.
- The rheology (shear-viscosity) of the polymers used in the coextruded structure must be similar and determines individual grades.
- Contact Evonik's Technical Service for testing of considered polymers. A layer of regrind containing a blend of CYROLITE® and XT® polymers, styrene, impact styrene and polymers made from related monomers may be incorporated into the structure.

Outdoor Use

CYROLITE® and XT® polymers are not recommended for outdoor use in applications where sensitivity to ultraviolet light and color stability are important.

Finishing and Post Treatment Options

Separation of the Sprue

- It is best to remove the sprue immediately after removal from the mold.
- Thin gates are cut with scissors, heated diagonal cutting pliers, or are broken off.
- Tab gates are usually removed with a small circular saw.
- Sprues are removed with cutters. The short, residual stump may be faced on a milling machine.
- Umbrella-type gates and annular gates are usually trimmed off.

Annealing

- Annealing minimizes the effects of internal stresses caused by the molding process.
- Annealing is recommended to avoid stress crazing if the molding may contact solvents or if the part will be solvent bonded or painted.
- The optimum annealing temperature is approximately 5°C below the distortion temperature under load (DTL).
- The annealing time is dictated by the thickness of the part.
- A rough guideline is one hour of heating per millimeter of material thickness and most importantly, one hour of cooling per millimeter of material thickness.
- The cooling time and rate are very important to the annealing process. If the molded parts are cooled too quickly, stresses may actually increase.

Antistatic Treatment

- The attraction of dust can be reduced by surface treatment with ionized air or liquid antistatic agents.
- Moldings can be immersed in this liquid immediately after removal from the mold.

Finishing and Post Treatment Options – *continued*

Ethyl Acetate Test for CYROLITE® MD™ grades

- The ethyl acetate test aids in identifying internal stresses.
- The molding is immersed in ethyl acetate for two to three minutes. It is subsequently dried and examined for cracks and crazing.
- A properly molded part or annealed part will not craze, or craze very little, and will, as a matter of experience, meet all practical requirements.
- Evonik's Technical Center can be contacted for a complete procedure.

Bonding

There are a number of methods for bonding Evonik's line of acrylic-based products.

- Solvent bonding uses a solvent to soften the bonding area to the point where molecular entanglement between the two surfaces will occur.
- When the solvent dissipates, the entanglement is frozen in place.

The bond strength is often as strong as the parent material.

- Common solvents used for acrylic-based polymers are methylene chloride, toluene, tetrahydrofuran, cellusolve, and methyl ethyl ketone.

Adhesive bonding differs from solvent bonding in that the adhesive itself forms the bond.

- Here, the bond is only as strong as the adhesive can adhere to the plastic substrate.

Two-part epoxies, 100% solids UV curable, and cyanoacrylate adhesives are often used for acrylics.

It is important to minimize molded-in stresses when any type of bonding will be performed on a part.

- This can be achieved by following recommended processing conditions and/or annealing the part prior to bonding.
- The Tech Brief entitled "Solvent and Adhesive Bonding" gives further recommendations for this process.

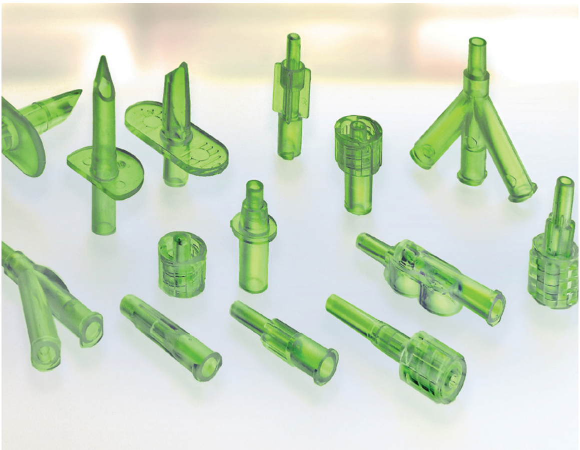
Regulatory Information

CYROLITE® and XT® polymer compounds comply with USP Class VI, ISO 10993 (Tripartite), and FDA food contact regulations as shown. The products comply with RoHS and REACH requirements, WEEE and CONEG regulations and the European Directive 2003/11/EC restriction of pentabromodiphenyl ether, and octabromo-diphenyl ether. CYROLITE® and XT® polymer compounds are free of heavy metals, plasticizers/phthalates, Asbestos, PCB, PCT PCP, chlorofluorocarbons, formaldehyde, isocyanate, polyurethane, natural latex and are BPA free.

Since XT® polymer compounds contain acrylonitrile in their composition, they are not acceptable for beverage containers and are further regulated by 21CFR180.2. This regulation specifies the maximum level of acrylonitrile that may be extracted from a package by a food product. We recommend that each package/application be evaluated against these requirements. Contact Evonik's Technical Center for specific details.

CYROLITE® and XT® polymer compounds may be used as intended in contact with food in full compliance with California Safe Drinking Water and Toxic Enforcement Act of 1986, (Proposition 65) without providing a warning to consumers.

None of these products may be considered for medical implant applications.



Regulatory Requirements

Evonik's products comply with the following Tripartite, USP and FDA regulations

Grade	FDA Food Contact (1, 2)	USP Class VI (2)	ISO 10993 (Tripartite) (3)
CYROLITE® G-20	Yes	Yes (2)	Yes (2)
CYROLITE® G-20 HIFLO®	Yes	Yes (2)	Yes (2)
CYROLITE® GS-90	Yes	Yes (2)	Yes (2)
CYROLITE® CG-97	Yes	Yes (2)	Yes (2)
CYROLITE® Med 2	Yes	Yes (2)	Yes (2)
CYROLITE® MD™ L40	Yes	Yes	Yes
CYROLITE® MD™ H12	Yes	Yes	Yes
Vu-Stat™ Y20	Yes	Yes	Yes
XT® polymer 250	Yes	Yes (2)	Yes (2)
XT® polymer 375	Yes	Yes (2)	Yes (2)
XT® polymer X800 RG	Yes	Yes (2)	Not Tested
CYREX® 200-8000	Yes	Not Tested	Not Tested
CYREX® 200-8005	Yes	Yes	Yes
CYREX® 953	Not Tested	Not Tested	Not Tested

(1) Products meet FDA food contact requirements of 21 CFR 177.1010 or 21 CFR 180.22 under Condition C (no Alcohol) and Condition D @ 8% alcohol.

(2) In clear and 000, 001, 301 and 3128 tints only. Other colors not tested.

(3) Indicated products have been found to be non-hemolytic, non-cytotoxic, non-pyrogenic, non-sensitizing and non-mutagenic when tested following the Tripartite and ISO 10993 Protocols.

None of these products may be considered for medical implant applications.

Additional Information

There are a number of Tech Briefs available upon request from Evonik's Technical Service, including:

Injection Mold Design Start-up and Shut down

Sterilization Methods and Considerations

Solvent and Adhesive Bonding

Cleaning Solutions

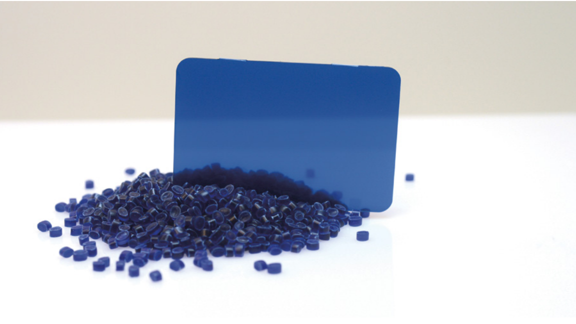
Insert Molding and Assembly of Molded Plastic Parts

Packaging

All CYROLITE® and XT® polymer compounds are supplied as 1/8 inch cylindrical pellets. They are packaged in 300-lb drums, 1,500-lb cartons, or in bulk – via truck or railroad car.

Technical Support

Our TechKnowlogy Center at www.cyrolite.com offers access to frequently asked questions, physical properties, processing conditions, regulatory compliance information, tips for trouble shooting and more. Evonik's Technical Service Center utilizes a broad range of extrusion, thermoforming, injection molding, and testing equipment for product and process evaluations. Our Technical Service Engineers are also available for on-site assistance as needed. For technical information, please call +1 203 514 9366.



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