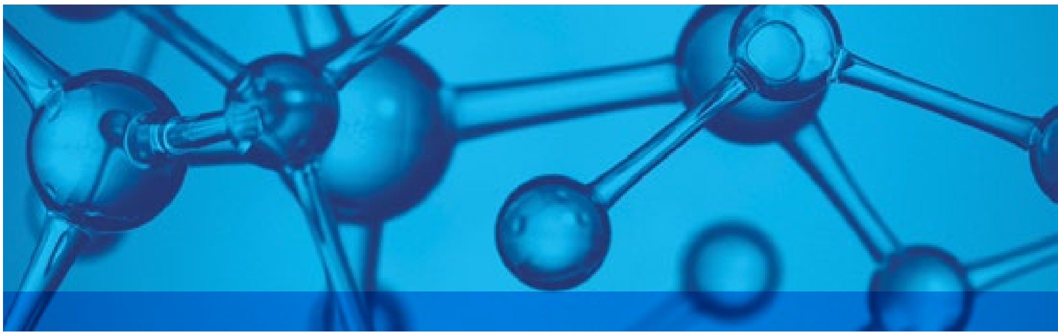

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Rotational Molding Processing Guide

Halar® ECTFE

Halar® ECTFE (ethylene chlorotrifluoroethylene) is a melt-processable fluoropolymer that is manufactured by Solvay Specialty Polymers at its ISO-certified plant in Orange, Texas (USA). This high-performance fluoropolymer retains its physical characteristics from cryogenic to 150 °C (302 °F). It is a tough material with excellent impact strength, good abrasion resistance and electrical properties. Halar® ECTFE is a non-flammable polymer meeting requirements of UL 94 V-0 vertical flame test. It does not ignite or propagate flame in atmospheres containing less than 52 % oxygen. On removal of flame, it extinguishes immediately.

Halar® ECTFE resists attack by strong acids and bases, oxidants, organic acids and bases, alcohols, aliphatic hydrocarbons, halogens, and salts at remarkably high temperatures. The material has very low permeability to hydrogen, oxygen, water, chlorine, hydrogen chloride and hydrogen sulfide. For some gases, the permeation rate of Halar® ECTFE is lowest among all fluoropolymers.

Halar® ECTFE is widely used in corrosion protection applications (linings, piping and other self-supporting construction) in the chemical processing, pharmaceutical, energy production, and semiconductor industries. It is also recommended for high purity fluid systems, particularly where the process surface must be smooth, pure (low extractables), and chemically resistant.

Halar® ECTFE Product Forms

- Powder for electrostatic coating
- Powder for fluidized bed
- Powder for rotational molding
- Pellets for extrusion, injection, compression, and transfer molding for pipe, valves, fittings, and heat exchangers. Molded components can be machined on standard metal working machines.

This document focuses on rotational molding processing and is intended to help manufacturers become familiar with processing Halar® 6012F powder designed specifically for use in rotational molding and linings.

Table 1: Typical properties of Halar® 6012F powder

Property	Units	Halar® 6012F	Test Method
Melting point	°C (°F)	220 – 227 (428 – 441)	ASTM D3275
Specific gravity		1.68	ASTM D3275
Melt flow index (2.16 kg, 275 °C)	g/10min	6 – 9	ASTM D3275
Average particle size	microns	300 – 500	ASTM D1921

Rotomolding and Rotolining

Rotomolding with Halar® 6012F is accomplished by charging a pre-weighed amount of resin into a hollow mold, placing the mold into a heated oven, and then rotating the mold about the x-axis and y-axis while the mold and the resin are heated.

When the interior metal surface becomes heated above the material's melting point, the resin melts on contact with the metal. Rotomolding can produce very uniform parts by carefully controlling rotation and heating conditions. Following the heating step, the mold is then cooled by ambient air or water spray and the part is removed.

Rotational molding techniques using Halar® ECTFE are also used to fabricate linings for equipment used in chemical processing as well as product transfer and storage. Unlike conventional rotomolding where the molded piece is removed from the mold, rotolining uses the piece of equipment to be lined as the mold. The resin is then rotomolded inside the equipment to form an integral, pin-hole free liner. Even flange faces can be lined in this manner by employing appropriately designed and insulated end caps.

Rotational molding outperforms sheet lining

- Seamless construction
- Smooth interior surface
- Perfect conformation of the liner to the vessel wall
- Greater wall thickness flexibility
- Improved performance under vacuum
- Significantly lower cost at modest production volumes

A primer suited for Halar® ECTFE can be used to increase adhesion to the part. In many cases, standard rather than custom castings can be employed in the rotolining process.

The outstanding balance of properties exhibited by Halar® ECTFE makes it an ideal candidate for a variety of rotomolding and rotolining applications.

Typical Applications

- Drum and carboy liners
- Chemical storage vessels and vessel liners
- Tanks for pickling, etching, plating and waste treating
- Lined pipe and pipe fittings
- Lined valves, pumps and flow meters
- Sight gauges
- Aircraft and aerospace components

Processing Halar® ECTFE

Processing steps are the same for rotomolding and rotolining except for the surface treatment. For rotomolding, a mold release is used to aid in part removal, while a mold release is not used with rotolining since an adherent coating is desired. A primer suited for Halar® ECTFE can be used to improve adhesion.

Process for Rotomolding

1. Prepare surface, then spray or coat mold surface with a release coating.
2. Install vent in the mold to permit air release during the heating step.
3. Charge mold with pre-weighed amount of Halar® ECTFE.
4. Close mold and install on oven spindle of rotomolding machine.
5. Process part through heating and cooling steps to fuse resin into a complete part.
6. After cooling, disassemble mold and remove completed part.

Process for Rotolining

1. Prepare surface by degreasing to remove oils and residues, and then grit blast to remove rust and scale and to roughen surface. Once prepared, the surface should only be handled with clean gloves or tongs to prevent contamination of the surface.
2. Install vent in the mold to permit air release during the heating step.
3. Charge mold with pre-weighed amount of Halar® ECTFE.
4. Close mold and install on oven spindle of rotomolding machine.
5. Process part through heating and cooling steps to fuse resin into complete part. Liners made from Halar® 6012F are semi-transparent and may relect the color of the substrate.

Temperature and Cycle Time

Oven air temperatures ranging between 250 °C – 302 °C (482 °F – 576 °F) have been successfully employed in rotomolding Halar® ECTFE. Temperatures ranging from 250 °C – 288 °C (482 °F – 550 °F) are recommended. The best results can be obtained when the Peak Internal Air Temperature (PIAT) is between 255 °C – 275 °C (491 °F – 527 °F).

Due to excessive heat loss, some rotomolding equipment requires higher air temperatures. Additionally, higher initial temperatures can be utilized when the two-step heating cycle is used.

For simple parts, a single-stage heating cycle is generally sufficient to produce satisfactory parts. Larger or more complex parts may benefit from a two-stage heating program in order to incorporate the higher temperatures needed to initiate the melt flow process, while allowing adequate time for the proper film to build.

Figure 1: Heating cycles

One-stage heating cycle

Temperature 1 (~250 – 290 °C) → Cooling

Two-stage heating cycle

Temperature 1 (~280 – 320 °C) → Temperature 2 (~240 – 270 °C) → Cooling

Table 2: Typical processing conditions[1]

	Units	Pipe 5 cm ID x 15 cm (2 in. ID x 6 in.)	Pipe 5 cm ID x 15 cm (2 in. ID x 6 in.)	P-Trap Mold 5 cm ID (2 in. ID)	Tee 5 cm ID (2 in. ID)
Process		Rotomolding	Rotomolding	Rotomolding	Rotolining
Mold				Aluminum	Cast Iron
Charge weight	grams	150	150	400	300
Bake Cycle		1-stage heating	2-stage heating	2-stage heating	2-stage heating
One-stage heating					
Oven temperature	°C (°F)	250 – 280 (482 – 536)	280 – 290 (536 – 554)	310 – 320 (590 – 608)	300 – 320 (572 – 608)
Residence time	minutes	50 – 70	10 – 20	10 – 20	10 – 20
Two-stage heating					
Oven temperature	°C (°F)		260 – 270 (500 – 518)	250 – 270 (482 – 518)	250 – 270 (482 – 518)
Residence time	minutes		50 – 80	50 – 60	20 – 40
Rotation ratio		5 : 1	5 : 1	5 : 1	2 : 1
Cooling time	minutes	20	20	20	20
Average wall thickness	mm (in.)	3.6 (0.14)	3.6 (0.14)	2.54 (0.10)	2.79 (0.11)

[1] *Conditions developed on clamshell equipment*

Cycle time must be determined experimentally for each part. It is recommended that the cycle times be approached from the short side and increased until complete flow-out is achieved.

Because optimum processing temperature can change from one rotomolding oven to another, the best operating temperature is generally determined experimentally for each oven used. Cooling the mold is not overly critical and is typically done by fan cooling, which may be followed by water quenching.

Molds

Aluminum and stainless steel molds are satisfactory for rotomolding with Halar® ECTFE. Surface finish is critical since the resin will accurately duplicate the mold surface. Stainless steel molds require approximately 15 % more flow-out time than aluminum molds. A thick metal mold can take longer to heat but it provides the advantage of excellent heat uniformity with no hot spots. Generous radii are recommended to produce a uniform wall thickness and a smooth interior surface.

Mold Venting

Venting the mold is necessary since the enclosed air volume expands significantly during heating. Failure to vent adequately can create bubbles in molded parts and can distort thin-sheet metal molds. Lack of venting can also cause flash formation as the expanding air forces powder through mating surfaces. Additional clamping force is necessary if adequate venting is not provided.

Venting is most commonly accomplished by the insertion of a PTFE tube into the center cavity of the mold or part. The tube contains a plug of glass or steel wool to prevent the loose powder from pouring out during the start of the rotomolding process. The plug also prevents moisture from getting into the object or mold during the cooling step, which can cause distortion due to non-uniform cooling.

Mold Release

Satisfactory part removal can be accomplished by using a dry PTFE release agent

Rotomolding Part Design

Rotomolding provides a lot of flexibility in the size and complexity of fabricated parts. As long as the mold configuration allows uniform contact between the material and the mold surface, the mold shape can be reproduced. Rotolining with Halar® ECTFE has been demonstrated over a range of 0.038 – 0.953 cm (0.015 – 0.375 in.) with wall thickness controlled to ± 5 %.

When rotomolding with Halar® ECTFE, little or no draft angle is necessary since the part shrinks due to both thermal and crystallization effects. Halar® 6012F exhibits shrinkage in the range of 1 – 2 %. The broad range is indicated since part design, mold design, and cooling conditions have an effect on measured shrinkage.

Uniformity of Linings and Parts

The factors affecting both lining and part uniformity are:

- Uniform metal thickness
- Part geometry
- Rotation conditions

Metal thickness has an important effect on the rate of polymer fusion. Thin spots and areas of high thermal conductivity will transmit heat more rapidly, resulting in more material buildup in these areas.

Molds made from more than one alloy can cause problems due to the different rate of heat conductivity of the alloys. When rotolining heavy parts such as valve, pump, or pipe components, consideration must be given to the end caps used to complete the closure of the part.

Thin sheet metal caps on a heavy metal casting will heat up rapidly causing the Halar resin to preferentially coat the thin metal caps. This can be prevented by using heavy metal caps of the same thickness as the part body, or, preferably, by using insulating materials that can take both the heating and cooling cycles involved.

The end caps themselves can be made from PTFE, or metal. With adequate insulation and the use of a mold release, all of these materials can be utilized. PTFE has the advantage of excellent inherent release characteristics without the use of a mold release.

Geometry of a part is another important consideration in rotomolding and rotolining. Undercuts, sharp transitions and sharp projections should be avoided wherever possible. In many instances, complex parts can be coated or molded when proper processing conditions are established.

Rotation conditions are a critical parameter for uniform molding or lining. With rotomolding and rotolining, it is essential that the resin cascades uniformly over the metal surface as the metal is heating. Rotation ratios of 2 : 1 to 8 : 1 work well with Halar® ECTFE.

Rotomolding Equipment

Halar® ECTFE can be used in variety of commercially available rotomolding machines, including:

- Clamshell machines
- Turret (Carousel) machines
- Shuttle machines
- Swing machines
- Vertical wheel machines

Charge Weight

The charge weight of Halar® ECTFE is based on the surface area of the part and the desired wall thickness. This can be calculated using the following equation:

Halar® ECTFE (kg) = surface area (cm^2) x wall thickness (mm) x 0.000168 kg/cm^2mm

Halar® ECTFE (lb) = surface area (ft^2) x wall thickness (mils) x 0.009lb/ft^2mil

Table 3: Suggested rotation ratio for typical shapes[1]

Ratio	Shapes
8 : 1	Oblongs, horizontally mounted straight tubes
5 : 1	Ducts
4 : 1	Cubes, balls, rectangular boxes, regular 3-D shapes
2 : 1	Rings, tires, flat shapes like picture frames, odd shapes. Any rectangle which shows two or more thin sides when run at 4 : 1
1 : 2	Parts which should run at 2 : 1 but show thin side walls
1 : 3	Flat rectangles (gas tanks, suitcases, tote bin covers)
1 : 4	Tires, curved air ducts, pipe angles, flat rectangles, parts that show thinning at 4 : 1.
1 : 5	Vertically mounted cylinders

(1) The rotational ratio may need an additional adjustment since it depends on the equipment type and the position of the mold.

Table 4: Troubleshooting guide for rotomolding and rotolining Halar® ECTFE

Problem	Cause	Recommended Solution
Thin coating	Insufficient resin charge	Increase resin charge
	Improper rotation ratio	Check positioning and rotation ratio
	Poorly insulated end caps	Increase end cap insulation
	Insufficient heat	Increase temperature or time
Rough surface finish	Thin coating	Increase coating thickness
	Improper flow-out conditions	Increase flow-out time and/or increase oven temperature
Poor adhesion	Failure to use primer in large parts	Use Halar® ECTFE primer
	Improper flow-out conditions	Increase flow-out time and/or increase oven temperature
	Inadequate surface treatment	Degrease part and grit-blast to remove surface contaminants
Poor edge coverage, pull-out on inside corners	Sharp edges	Radius all corners, minimum recommended radius is 6.25 mm (0.25 in.)
	Rapid cooling after flow-out	Quenching or rapid air cooling with a fan is not recommended
Pin holes in the coating	Porous metal evolving gases at flow-out temperature	Degas metal part by baking for several hours at a temperature well above processing temperatures Suggested range is 380 °C – 420 °C (716 °F – 788 °F)
	Inadequate surface treatment	Grit blast to remove surface contaminants
Bubbles in coating, beige to dark brown discoloration	Resin degradation due to improper flow-out conditions	Reduce flow-out temperature and/or reduce flow-out time
Bubbles in coating, no discoloration	Inadequate heating	Increase flow-out time and/or increase oven temperature
Bubbles in coating on metal surface, no discoloration	Inadequate mold release	Change mold release
Ripples in coating, sagging and dripping	Improper cooling procedure (resin is still molten at end of cycle)	Lengthen cooling time

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