DU PONT®

Hytrel®
polyester elastomer

Rheology and Handling

Hytrel polyester elastomers are true thermoplastic polymers that are processed using conventional thermoplastic techniques. They are semicrystalline materials characterized by relatively sharp melting points, temperature-sensitive viscosities, and, except for some low hardness grades, rapid crystallization.

This bulletin reviews the melt characteristics of the various types of Hytrel and the effects of melt temperature and shear rate on the shear viscosity, and compares the melt rheology of Hytrel with that of various other thermoplastic polymers. In addition, the effects of moisture are reviewed, and suggested drying procedures are given along with recommendations on the use of regrind.

Melting Characteristics

Melting characteristics of Hytrel thermoplastic elastomer as determined by differential scanning calorimetry using ASTM Method D1238 are shown in **Table 1**. The melt temperature at the die should always be equal to or greater than the temperature at which the polymer is completely melted.

Table 1
Thermal Properties of Hytrel

Type of Hytrel	Melting Temperature (Peak of Endotherm), °C (°F)	Melt Complete (Extrapolated End Point), °C (°F)	Crystallization Temperature (Peak of Exotherm), °C (°F)
High Productivity			
G3548W	156 (313)	180 (356)	107 (225)
G4074	170 (338)	190 (374)	120 (248)
G4078W	170 (338)	190 (374)	120 (248)
G4774, G4778	208 (406)	225 (437)	170 (338)
G5544	215 (419)	230 (446)	173 (343)
High Performance			
4056	150 (302)	170 (338)	70 (158)
4069	193 (379)	210 (410)	112 (234)
4556	193 (379)	220 (428)	115 (239)
5526	203 (397)	220 (428)	147 (297)
5556	203 (397)	220 (428)	145 (293)
6356	211 (412)	230 (446)	155 (311)
7246	218 (424)	232 (450)	162 (324)
8238	223 (433)	235 (455)	170 (338)
Specialty			
3078	170 (338)	200 (392)	78 (172)
5555HS	203 (397)	216 (421)	166 (330)
HTR4275BK	196 (385)	213 (415)	173 (343)
HTR5612BK	196 (385)	213 (415)	173 (343)
HTR6108	168 (334)	193 (379)	66 (151)
HTR8068	169 (336)	185 (365)	140 (284)
HTR8139LV	192 (378)	202 (396)	—
HTR8171	150 (302)	188 (370)	—
HTR8206	200 (392)	223 (433)	—

Melt Rheology

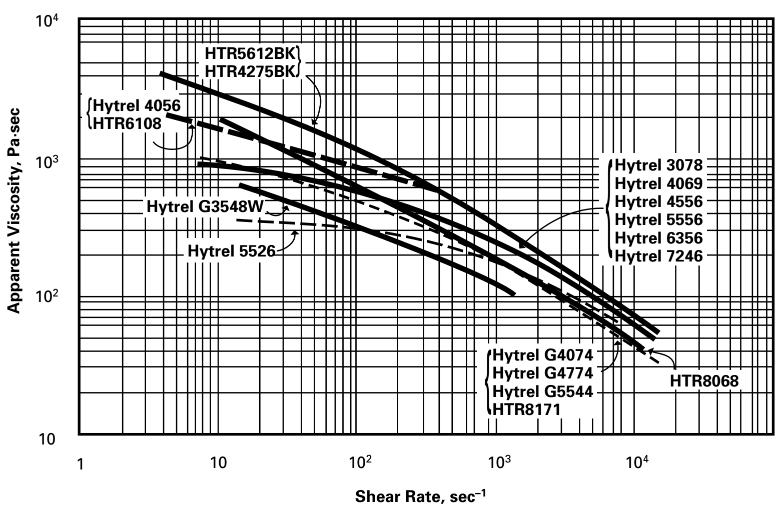
The effect of shear rate on viscosity at typical processing temperatures for the basic types of Hytrel is shown in **Figure 1**. The viscosity versus shear rate curves for polymers of Hytrel are relatively flat, especially at low shear rates. Viscosity does not decrease with increasing shear rate as much as for some other polymers. This means that the resistance to flow of polymers of Hytrel with increases in screw or ram speed may be somewhat greater than experienced with some other polymers. This can result in higher torque or injection-pressure requirements.

The effect of temperature change on polymer melt viscosity for shear rates of 100 and 1000 sec^{-1} are shown in **Figures 2** and **3**, respectively. A significant change in melt viscosity can be effected by a nominal change in melt temperature. Therefore, injection molding processing temperatures are often increased to reduce viscosity and facilitate mold filling. Conversely, in extrusion the melt temperature can be decreased to provide greater melt strength for dimensional stability of the extrudate.

The effect of injection pressure on melt flow of Hytrel through long narrow channels is shown in **Figures 4** and **5**. Increases in flow can also be attained by increasing melt or mold temperatures. Because of the rapid crystallization rate and viscosity/shear rate characteristics of Hytrel, relatively high pressures or high melt temperatures are required to fill long shallow cavities, especially below 1.6 mm (1/16 in) cavity depth.

The melt viscosity characteristics of Hytrel enable these polymers to be used in a wide range of processing techniques, from low shear operations (such as rotational molding) to medium and high shear operations (such as extrusion and injection molding). Very high viscosity grades, HTR5612BK and HTR4275BK are designed primarily for blow molding and extrusion. **Figure 6** compares the melt viscosity versus temperature relationships for polymers of Hytrel with various other thermoplastic polymers.

Figure 1. Melt Viscosity at Processing Temperature



Type	Processing Temperature, °C (°F)
Hytrel G3548W	190 (374)
Hytrel G4074	200 (392)
Hytrel G4774	230 (446)
Hytrel G5544	230 (446)
Hytrel 3078	190 (374)
Hytrel 4056	190 (374)
Hytrel 4069	230 (446)
Hytrel 4556	230 (446)
Hytrel 5526	230 (446)
Hytrel 5556	230 (446)
Hytrel 6356	230 (446)
Hytrel 7246	240 (464)
HTR4275BK	230 (446)
HTR5612BK	230 (446)
HTR6108	190 (374)
HTR8068	190 (374)
HTR8171	190 (374)

Figure 2. Shear Melt Viscosity versus Temperature at a Shear Rate of 100 sec^{-1}

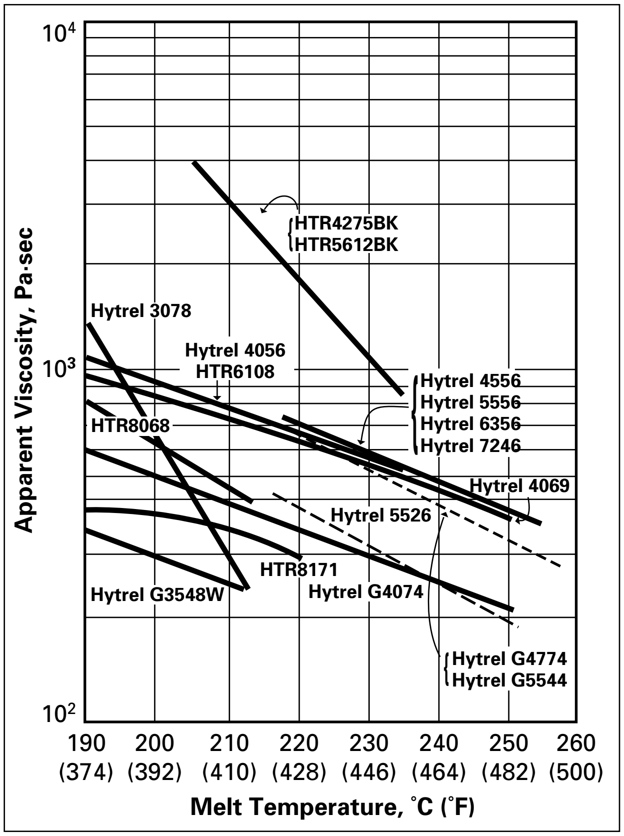


Figure 3. Shear Melt Viscosity versus Temperature at a Shear Rate of 1000 sec^{-1}

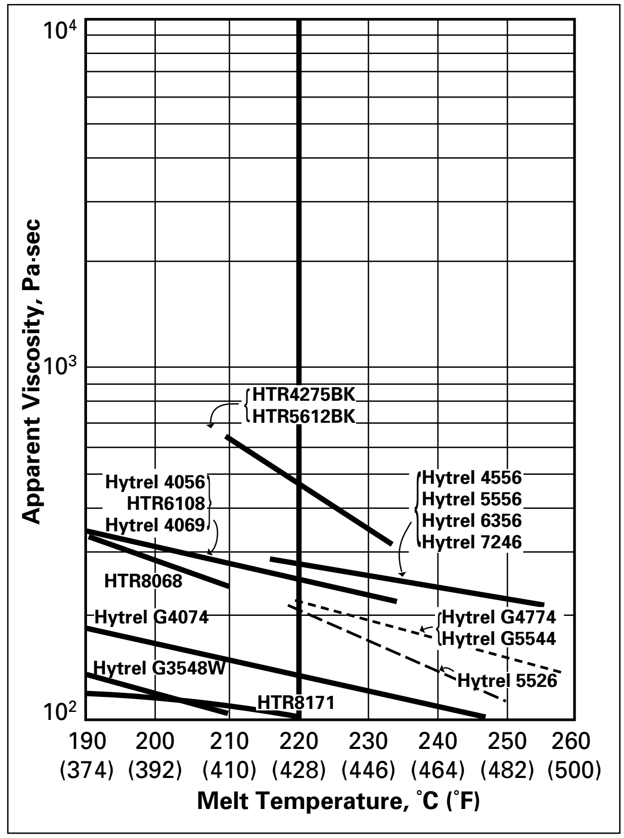


Figure 4. Snake Flow at Processing Temperature

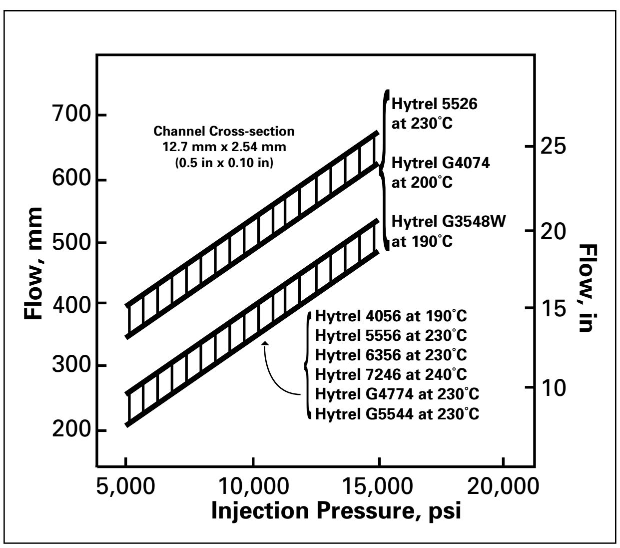


Figure 5. Snake Flow at Processing Temperature

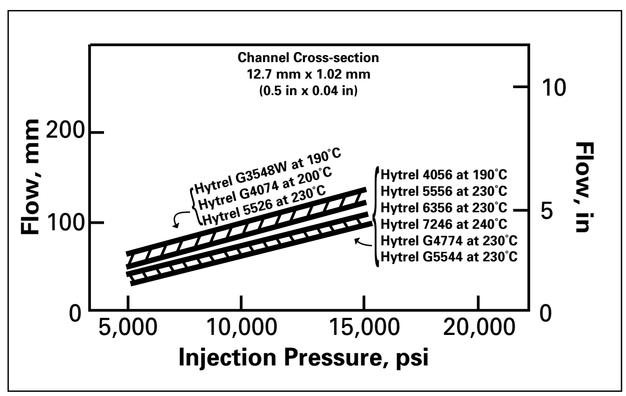
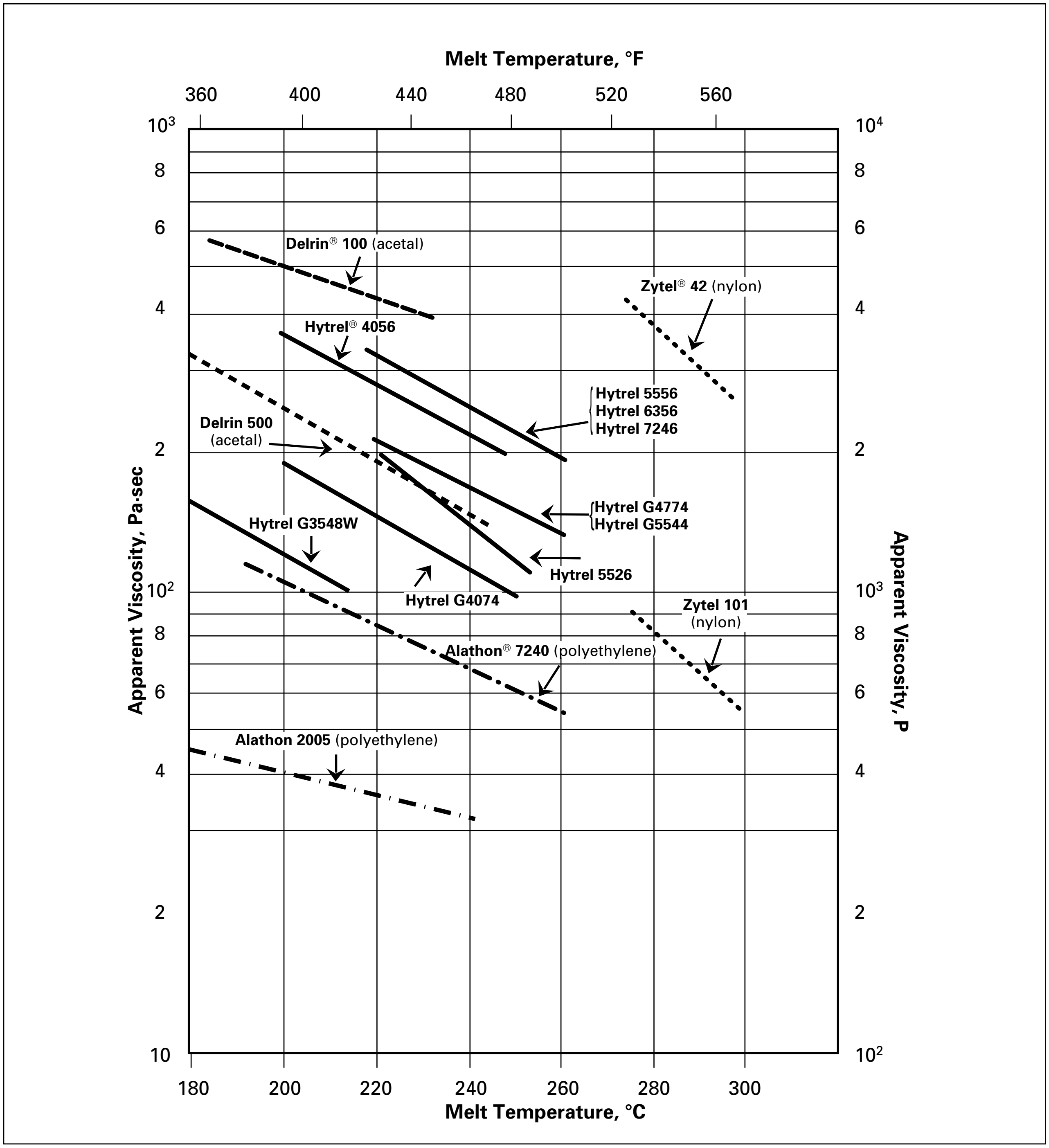


Figure 6. Apparent Melt Viscosity versus Temperature at a Shear Rate of 1000 sec⁻¹



Handling Precautions

All safety practices normally followed in the handling and processing of thermoplastic polymers should be followed for Hytrel polyester elastomer. The polymer is not hazardous under normal shipping and storage conditions. During processing, particularly if recommended temperatures and holdup times are exceeded to any great degree, Hytrel may degrade and decompose with evolution of gaseous products. Potential hazards from these gaseous decomposition products include “blowback” through the hopper, fire, and exposure to toxic vapors (principally tetrahydrofuran). As with all thermoplastics, thermal burns from contact with molten polymer are a potential hazard. Before processing Hytrel, read bulletin “Handling and Processing Precautions for Hytrel,” and observe the precautions recommended therein.

Compounding ingredients or additives may present hazards during handling and use. Before proceeding with any compounding or processing work, consult and follow label directions and handling precautions from suppliers of all ingredients, as per MSD sheets.

For specific processing recommendations, please refer to the following publications:

Bulletin	Title
HYT-201	Handling & Processing Precautions for Hytrel
H-33430	Hytrel Injection Molding Guide
HYT-403 (R2)	Extrusion of Hytrel
HYT-409 (R1)	Melt Casting
HYT-451 (R1)	Rotational Molding of Hytrel Polyester Elastomers
HYT-452 (R1)	Blown Film of Hytrel Polyester Elastomers

Drying

Hytrel polyester elastomer must be dried prior to processing. It is critical to ensure that the resin is dry during processing to make quality parts that would give good service performance.

Hytrel is resistant to hydrolysis. It does not react with moisture in the air, but will absorb the moisture if left exposed. Equilibrium moisture levels as determined by ASTM D570 depend on grade (see **Table 2**).

At temperatures substantially above the melting point, excess moisture causes hydrolytic degradation of the polymer. Such degradation results in poor physical properties and brittleness. No visual defects may be apparent but poor in-service performance can occur, particularly at low temperatures.

Generally, no degradation of the polymer or imperfections in the molding or extrusion occur if the moisture content is less than 0.10%, the maximum moisture specification for all grades of Hytrel. When dry polymer is subjected to 50% relative humidity, 0.10% moisture increase occurs in about 2 hr, whereas at 100% relative humidity, it occurs in less than 1 hr (see **Figure 7**). Therefore, pellets so exposed should be redried before use.

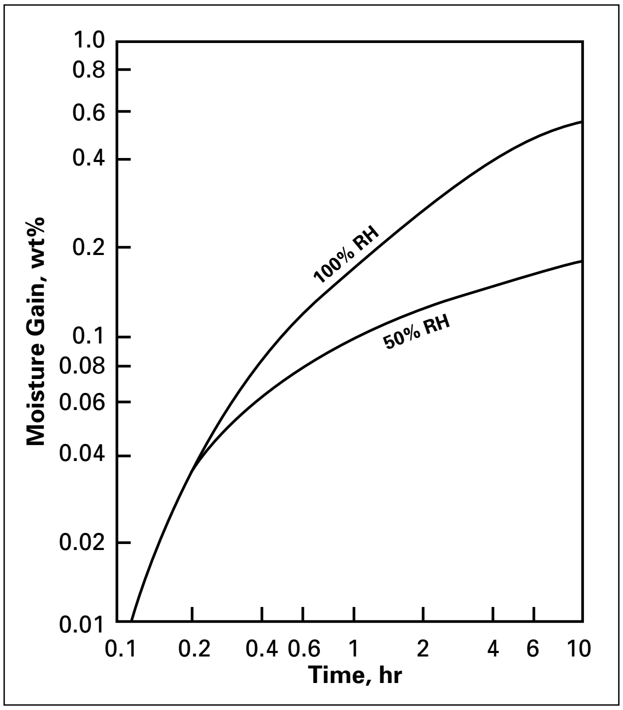
When drying Hytrel, dehumidified air ovens are recommended. Effective drying with such ovens takes place in 2–3 hr at 100°C (212°F) or overnight at 70°C (158°F).* Drying ovens without dehumidifiers may be used but will require 4–6 hr or more, depending on the quantity being dried. Even then, these ovens may not be adequate during periods of high humidity.

* It is critical to ensure that the dehumidifying medium is dry prior to the drying of Hytrel.

Table 2
Equilibrium Moisture Levels of Hytrel

Type of Hytrel	Equilibrium Moisture Level, % after 24 hr
High Productivity	
G3548W	5.0
G4074	2.1
G4078W	3.0
G4774, G4778	2.5
G5544	1.5
High Performance	
4056	0.6
4069	0.7
4556	0.6
5526	0.5
5556	0.5
6356	0.3
7246	0.3
8238	0.3
Specialty	
3078	3.0
5555HS	0.7
HTR4275BK	0.3
HTR5612BK	0.4
HTR6108	0.2
HTR8068	1.9
HTR8139LV	0.7
HTR8171	54
HTR8206	30

Figure 7. Moisture Absorption at Ambient Temperature—Hytrel 5556



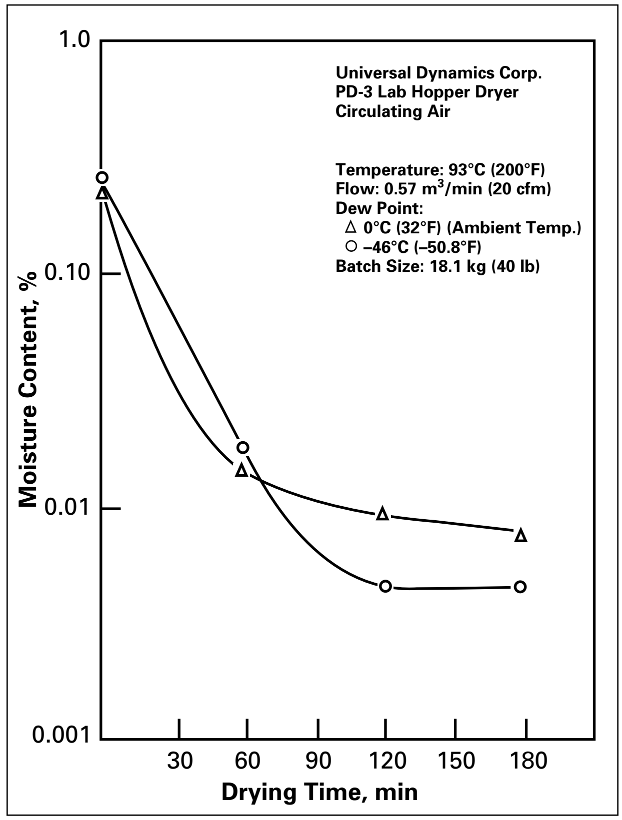
Regrind

The unusually good melt stability and completely thermoplastic nature of Hytrel allow use of scrap moldings and extrusions. Hytrel can be reground and blended with virgin polymer at a level up to 50%. Keep the heat history of the regrind as low as practical to maintain the high quality of the polymer. If a higher level of rework is used, exercise care to ensure that it is not degraded and is free from foreign matter. To prevent any contamination the grinder should be thoroughly cleaned in the beginning.

Melt flow rate checks are a practical way to monitor quality of regrind on representative samples. Recommendations for usage levels of regrind based on melt flow rate are shown in **Table 3**.

Melt flow rate, in effect, measures restricted flow of molten polymer and thus inversely relates to viscosity. A range of typical values for various grades of Hytrel are given in **Table 4**. The higher the index, the lower the viscosity, and, therefore, the molecular weight—thus it is an indication of polymer degradation. As an example from **Table 3**, up to 50% of the feedstock of Hytrel 4056 can be reground provided that the regrind has a melt index of 8 g/10 min or less. Other grades of Hytrel will follow similar patterns.

Figure 8. Drying with Dehumidified Air—Hytrel 4056



Chop scrap into chips approximately the same size as the original pellets. Use a scrap grinder with well adjusted, sharp knives shaped for polyethylene cutting to produce clean, sharp regrind. Size reduction is accomplished by cutting, not by fracture or impact.

Dry all regrind and blend well with virgin polymer to ensure uniform quality.

Table 3
Recommended Usage Levels for Regrind of Hytrel

Type of Hytrel	Melt Flow Rate Spec. Range, g/10 min*	Max. Regrind Usage, %	Max. Allowable Melt Flow Rate of Regrind, g/10 min
4056	4.1–6.5 at 190°C (374°F)	25 50	10 8
5526	14–21 at 220°C (428°F)	25 50	31 25
5556	5–9 at 220°C (428°F)	25 50	15 11
6356	7–10.5 at 230°C (446°F)	25 50	14 11
7246	10.5–15 at 240°C (464°F)	25 50	21 17
5555HS	7–10 at 220°C (428°F)	25 50	15 12

*ASTM Method D1238, 2.16 kg load

Table 4
Typical Melt Flow Rate Values of Hytrel

Type of Hytrel	Melt Flow Rate, g/10 min, 2.16 kg load	Test Temperature, °C (°F)
High Productivity		
G3548W	10	190 (374)
G4074	5.2	190 (374)
G4078W	5.4	190 (374)
G4774, G4778	12	230 (446)
G5544	12.5	230 (446)
High Performance		
4056	5.3	190 (374)
4069	8.5	220 (428)
4556	12	230 (446)
5526	18	220 (428)
5556	7	220 (428)
6356	8.5	230 (446)
7246	12.5	240 (464)
8238		
Specialty		
3078	5	190 (374)
5555HS	0.5	220 (428)
HTR4275BK	1.8	230 (446)
HTR5612BK	3	230 (446)
HTR6108	5.2	190 (374)
HTR8068	4.6	190 (374)
HTR8139LV	3.3	230 (446)
HTR8171	9	190 (374)
HTR8206	12	230 (446)

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