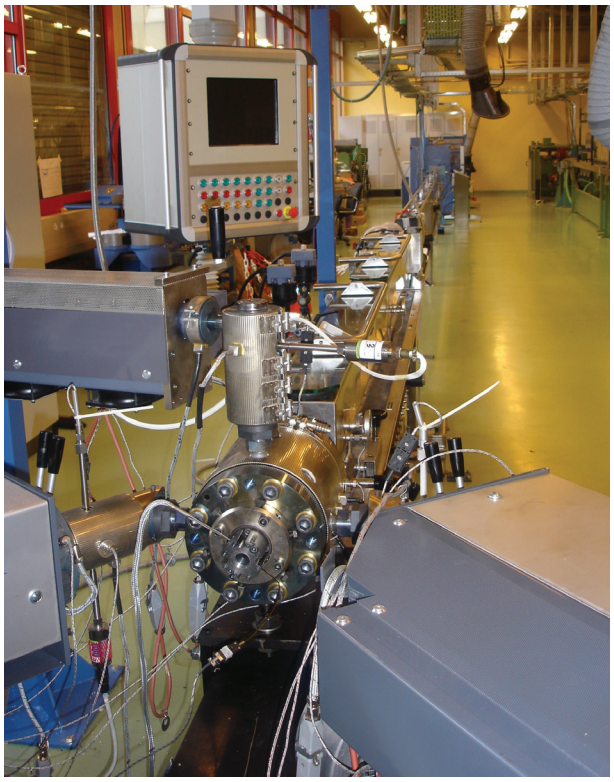
DUPONT™ HYTREL®

All In One Extrusion Processing Manual

Thermoplastic Polyester Elastomer



MULTILAYER TUBING EXTRUSION LINE

HIGH PERFORMANCE & FLEXIBILITY

DuPont™ Hytrel® is the DuPont registered trademark for its family of high performance engineering thermoplastic elastomers. It combines many of the most desirable characteristics of high performance elastomers and flexible plastics.

It offers exceptional toughness and resilience; high resistance to creep, impact and flex fatigue; flexibility at low temperature and good retention of properties at elevated temperatures. In addition, it resists deterioration when used with many industrial chemicals, oils and solvents.

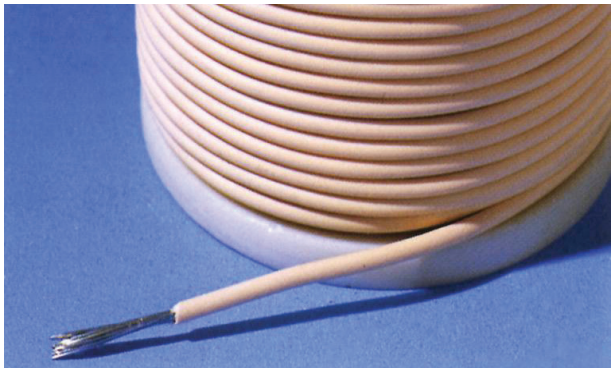
According to ISO 1043, Hytrel® is identified as TPC-ET (thermoplastic polyester elastomer). It is a block copolymer, consisting of a hard (crystalline) segment of polybutylene terephthalate and a soft (amorphous) segment based on long-chain glycols. Properties are determined by the ratio of hard to soft segments and by the composition of the segments. Hytrel® grades do not contain plasticizer to enhance flexibility. The range of available hardnesses is from 30 to 80 Shore D for Hytrel®.

CUSTOMIZED PRODUCT RANGE

The grades of Hytrel® are grouped into four categories, by performance:

1. Standard grades "G" exhibit versatile processing characteristics, have the best balance of cost/performance and are suitable for many extrusion applications.
2. High-Performance grades provide an extra margin of mechanical properties for more demanding applications.
3. Specialty grades "HTR" and "BM" provide special properties or processing characteristics for particular applications.
4. Concentrate additives contain relatively high concentrations of specific property-enhancing additives for blending with other grades of Hytrel® *(see table page 3)*. Hytrel® engineering thermoplastic elastomers for extrusion are supplied as cylindrical pellets (approximately 3 mm in diameter by 3 mm in length), having a bulk density of about 700 kg/m^3.

RETRACTABLE CABLE FOR TRUCKS



HYTREL® FOR WIRE AND CABLE APPLICATIONS

IMPORTANT CHECK-LIST before processing

- Use Hytrel® resin from sealed, undamaged containers.
- Dry Hytrel® before extrusion and check the moisture content. It has to be less than 0.10%, the suggested value is 0.06%.
- A clean extruder is preferred. Using polyethylene is generally not recommended because of the difficulty to eliminate all traces of PE.
- If concentrates or pigments are added, they should be dried.
- Barrier screw profile is indicated for the processing of Hytrel®. Double flight design provides better homogeneity for high speed extrusion. Standard screw could be used to process Hytrel®, the best results are observed when compression ratio of the screw is 3, L/D is 25 or higher.
- When needed, stainless steel screen pack unit of 80-mesh could be used for Hytrel®.
- For tubing by vacuum calibration, a Draw-Down Ratio (DDR) in the range of 1.5 to 3.5 and a Draw Ratio Balance (DRB) close to 1 (0.95 to 1.05 is acceptable) are optimum.
- Follow the suggested temperature profiles. As a general point the process melt temperature of Hytrel® should be 15 to 30°C (25-55°F) above the nominal melting point. Thermal degradation can occur with excessive time and temperature.
- Local Exhaust Ventilation should be used - refer to page 6.

ADDING CONCENTRATES AND PIGMENTS

The properties of Hytrel® can be modified by adding pigments or concentrates during the processing to reach outstanding efficiency and optimal performance for a specific application.

List of concentrates and additives			
	Shore D	**Melting point**	**Properties**
Hytrel® 40CB	40	150 °C / *300 °F*	Carbon black concentrate
Hytrel® 60LW	63	211 °C / *410 °F*	Improve wear and friction properties
Hytrel® 21UV	40	150 °C / *300 °F*	Ultraviolet light stabilizer
Hytrel® 30HS			Heat stabilizer
Hytrel® 52FR	55	203 °C / *400 °F*	Flame retardant concentrate

DRYING PARAMETERS AND VISCOSITY OF DUPONT™ HYTREL®

Grades		Drying		Max moisture level	Melt viscosity at rate 1000 s^{-1}	Melt flow rate
Name	Shore D	Temperature	Time (h)	%	Pa.s	cm^3 / 10 min
DuPont™ Hytrel®						
3078	30	80 °C *175 °F*	2-3	0.06	270 (190°C)	5 (190°C)[1]
HTR8351	30		2-3	0.06	180 (190°C)	2 (190°C)[1]
G3548L	35		2-3	0.06	130 (190°C)	10 (190°C)[1]
4056	40		2-3	0.06	320 (190°C)	5(190°C)[1]
G4074, G4078W	40		2-3	0.06	210 (190°C)	5 (190°C)[1]
HTR8068	44		2-3	0.06	240 (195°C)	3.6 (190°C)[1]
4068, 4069	40	100 °C *210 °F*	2-3	0.06	240 (220°C)	9 (220°C)[1]
4556	45					8 (220°C)[1]
HTR8206	45	110 °C *230 °F*	2-3	0.06	110 (230°C)	14 (220°C)[1]
HTX 8532	45		2-3	0.06	325 (230°C)	0.7 (220°C)[1]
HTR5612	54		2-3	0.06	380 (230°C)	2.9 (230°C)[1]
HTR8667	46		2-3	0.06	340 (240°C)	0.9 (220°C)[1]
HTR8441	55		2-3	0.06	370 (235°C)	9.6 (240°C)[2]
G4774, G4778	47	100 °C *210 °F*	2-3	0.06	140 (230°C)	11 (230°C)[1]
HTR8636	40		2-3	0.06	480 (230°C)	6.5 (230°C)[2]
5555HS	55		2-3	0.06	210 (215°C)	8.5 (220°C)[1]
5556	55		2-3	0.06	190 (220°C)	7 (220°C)[1]
5586	55		2-3	0.06	330 (220°C)	4.9 (220°C)[1]
HTR4275	55		2-3	0.06	370 (230°C)	0.5 (230°C)[1]
G5544	55		2-3	0.06	190 (230°C)	10 (230°C)[1]
G5564	55		2-3	0.06	270 (230°C)	5 (230°C)[1]
HTR8539	72	110 °C *230 °F*	2-3	0.06	540 (250°C)	7 (250°C)[2]
HTR6108	61	100 °C *210 °F*	2-3	0.06	190 (195°C)	5 (190°C)[1]
6356	63	100 °C *210 °F*	2-3	0.06	270 (230°C)	7 (230°C)[1]
HTR8163 HVBK	65		2-3	0.06	290 (235°C)	5 (230°C)[1]
HTR8241	65		2-3	0.06	290 (240°C)	4.5 (230°C)[1]
HTR8303FR	65		2-3	0.06	720 (245°C)	4 (250°C)[2]
HTR8620	65	110 °C *230 °F*	2-3	0.06	360 (230°C)	4 (230°C)[1]
7246	72		2-3	0.06	250 (240°C)	12 (240°C)[1]
8238	82		2-3	0.06	290 (240°C)	11.5(240°C)[1]

1. Nominal Value - Test conditions: 2.16 kg load, temperature shown in parenthesis
2. Nominal Value - Test conditions: 10.0 kg load, temperature shown in parenthesis
conversion from (°C) to (°F) -> (°F) = (°C)*1.8+32
IMPORTANT: Before any development with the above listed grades, please check the availability of the material with your DuPont representative.

TEMPERATURE PROFILES FOR DUPONT™ HYTREL® PROCESSING

Grades	Typical temperature settings (°C / °F)						
Name	Nominal melting point	Rear	Center rear	Center front	Front	Head and Die	Melt Temp
DuPont™ Hytrel®							
3078	177 / *351*	165-185 *330-370*	180-185 *360-370*	185-195 *370-390*	190-205 *380-405*	190-205 *380-405*	190-205 *380-405*
HTR8351	156 / *313*	145–165 *290-330*	160–165 *320-330*	165–175 *330-345*	170-185 *340-365*	170-185 *340-365*	170-185 *340-365*
G3548L	154 / *309*						
4056	150 / *302*	140–160 285-320	155–160 310-320	160–170 320-340	165–180 330-355	165–180 330-355	165–180 330-355
G4074, G4078W	170 / *338*	160–180 *320-355*	175–180 *345-355*	180–190 *355-380*	185–200 *370-390*	185–200 *370-390*	185–200 *370-390*
HTR8068	170 / *338*						
4068, 4069	193 / *379*	185-205 *365-400*	200-205 *390-400*	205-215 *400-420*	210-225 *410-435*	210-225 *410-435*	210-225 *410-435*
4556							
HTR8206	200 / *392*	190-210 *375-410*	205-210 *400-410*	210-220 *410-430*	215-230 *420-445*	215-230 *420-445*	215-230 *420-445*
HTX 8532	200 / *392*						
HTR5612	200 / *392*						
HTR8667	208 / *406*	200-220 *390-425*	215-220 *420-430*	220-230 *430-445*	225-240 *435-465*	225-240 *435-465*	225-240 *435-465*
HTR8441	210 / *410*						
G4774, G4778	208 / *406*						
HTR8636	207 / *405*	195–215 *385-420*	210–215 *410-420*	215–225 *420-435*	220–235 *420-440*	220–235 *420-440*	220–235 *420-440*
5555HS	203 / *397*						
5556	203 / *397*						
5586	203 / *397*						
HTR4275	190 / *374*	180-200 *355-390*	195-200 *380-390*	200-210 *390-410*	205-220 *400-430*	205-220 *400-430*	205-220 *400-430*
G5544	214 / *417*	205-225 *401-435*	220-225 *425-435*	225-235 *435-455*	230-245 *445-475*	230-245 *445-475*	230-245 *445-475*
G5564	215 / *419*						
HTR8539	217 / *423*						
HTR6108	162 / *324*	150-170 *305-340*	165-170 *330-340*	170-180 *340-360*	175-190 *350-380*	175-190 *350-380*	175-190 *350-380*
6356	210 / *410*	200-220 *395-430*	215-220 *420-430*	220-230 *430-450*	225-240 *440-465*	225-240 *440-465*	225-240 *440-465*
HTR8163 HVBK	211 / *412*						
HTR8241	212 / *414*						
HTR8620	210 / *410*						
HTR8303FR	222 / *432*	210-230 *415-450*	225-230 *440-450*	230-240 *450-470*	235-250 *460-485*	235-250 *460-485*	235-250 *460-485*
7246	218 / *424*						
8238	221 / *430*						

conversion from (°C) to (°F) -> (°F) = (°C)*1.8+32

IMPORTANT: Before any development with the above listed grades, please check the availability of the material with your DuPont representative.

Typical practices for DuPont™ Hytrel® Extrusion

SAFETY PRECAUTIONS

Thermal degradation can occur with excessive time and temperature causing the evolution of toxic vapors. However, under normal operating conditions, the risk of decomposition of these resins is minimal. It is necessary to refer to the Safety Datasheet (SDS) before handling and using the material, and to wear appropriate personal protection as needed. Local Exhaust Ventilation should be used to capture and remove fumes at places where volatiles may be generated (e.g. during drying, processing, shaping, assembly) and especially at the die head. Please refer to our brochure *Proper use of Local Exhaust Ventilation during processing of plastics*.

DRYING

Hytrel® granules are supplied in moisture resistant packaging, typically at a moisture content of less than 0.10%. When exposed to air, the granules pick up moisture; the suggested limit for processing can be reached in less than 30 min. This may result in a decrease of quality e.g. bubbles in the extrudate, drop in viscosity, reduction of the melt strength or mechanical properties. Drying time and temperature will depend on the grade of resin, the initial moisture level in the material and the type of drier or oven used. Therefore, general guidelines given in the table can be adapted taking care that the polymer does not suffer from degradation. The recommended dew point of the dryer is between -35°C and -40°C to guarantee efficient drying of the polymer. Drier exhausts should not be discharged into the workplace air.

TEMPERATURE SETTINGS

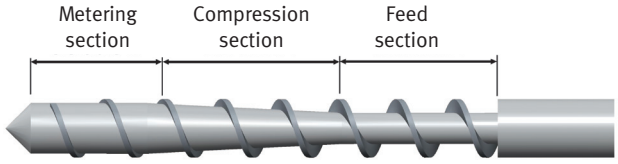
Typically, the melt temperature of Hytrel® resins during extrusion should be 15-30°C (25-55°F) above the nominal melting point, with the extruder running at normal operating speed.

Occasionally it may be necessary to use temperature settings that differ from these guidelines. For example, it might be necessary to increase the die temperature 25-45°C (45-80°F) above the desired melt temperature to improve surface finish and reduce shear orientation through small die openings.

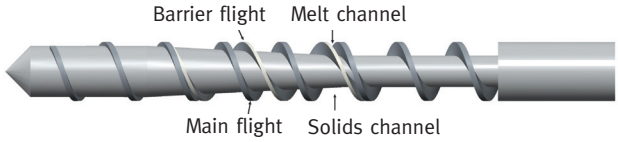
SCREW

A barrier screw profile is usually recommended to process Hytrel® because double flight design provides better melt homogeneity for high speed extrusion. However, simple 3-zone standard screws having typical dimensions given in the table below and with equal length for feed, transition (compression) and metering zones are also appropriate. The best results are observed when the compression ratio of the screw is 3 and L/D is 25 or higher.

Standard screw

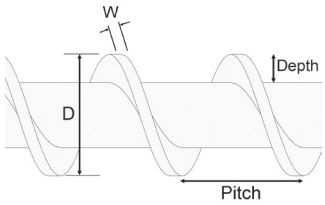


Barrier screw



SCREW DIMENSIONS

D (mm)	*Pitch (mm)*	*Feed channel depth (mm)*	*Metering channel depth (mm)*	*Flight width W (mm)*
30	30	5.5	2	4
40	40	6	2.2	4
50	50	8	2.5	5
60	60	10	3	6
80	80	11	3.5	8
90	90	11	3.5	9
120	120	13	4	11
150	150	15	4.6	15



SCREEN PACK

Stainless steel screen pack units of 80-mesh are generally used for Hytrel®. Occasionally, it may be necessary to use finer mesh screens (e.g. supported 120 or 150-mesh) to increase back pressure.

TUBING EXTRUSION: SPECIFIC PARAMETERS

To extrude successfully a tube of a given resin and diameter, the dimensions of the extruder die and pin should be calculated considering the following formulas.

Draw-Down Ratio (DDR) is defined here as the ratio of the cross-sectional area of the extrudate at the extrusion die-face, to the cross sectional area of the finished tube.

$$DDR = \frac{(D_d^2 - D_m^2)}{(D_t^2 - D_b^2)}$$

Draw Down Ratio

The Draw Ratio Balance (DRB) for all DuPont grades should be around 1, meaning that the inside surface of the molten tube is drawn the same amount as the outside surface.

$$DRB = \frac{(D_d / D_t)}{(D_m / D_b)}$$

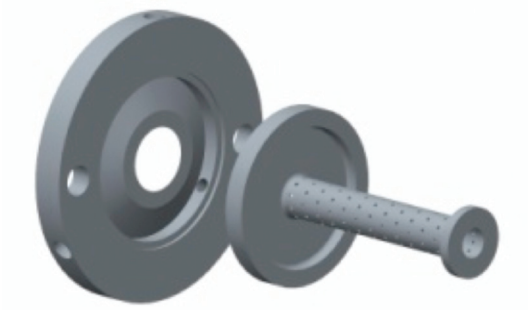
Draw Ratio Balance

Calibration for tubing

D_t (mm) (OD)	D_b (mm) (ID)	D_d (mm)	D_m (mm)	DDR	DRB
8	6	11.3 to 17.9	8.5 to 13.4	1.5 to 5	0.95 to 1.05
10	8	14.2 to 22.4	11.3 to 17.8		
12	10	17 to 26.8	14.2 to 22.3		
16	13	22.6 to 35.8	18.4 to 29		
23	20	32.5 to 51.4	28.3 to 44.7		
30	26	42.4 to 67.1	36.8 to 58.1		
44	39	62.2 to 98.4	55.2 to 87.2		

SIZING DIE FOR TUBING EXTRUSION

It is recommended that a tubular sleeve sizing die made from brass is used, with holes allowing the surrounding vacuum to act on the extruded tube. The diameter of the holes is advised to be around 1 mm and the distance between each hole around 5 mm. The diameter of the die should be between 3 and 15% oversized to compensate for shrinkage of the tube. An annular water ring device is recommended at the entrance to the die, to allow a fine water flow that provides lubrication between the extruded polymer and the metal surface of the sizing die.



ANNULAR WATER RING & TUBULAR SIZING DIE WITH HOLES

SHUT-DOWN AND PURGING REMARKS

No action is required for brief interruptions of up to 30 minutes. For anything more than 30 minutes it is suggested that the temperature in the barrel is reduced to 120°C. If the extruder is to be shut down for longer periods, it is recommended to purge a small amount of a low melting point Hytrel® grade (such as 4056) through the extruder before emptying the barrel and turning off the heaters.

REGROUND MATERIAL

Using regrind is not recommended for extrusion applications.

D_t = External diameter of tube
D_b = Internal tube bore or diameter
D_d = Internal diameter of extrusion die
D_m = External diameter of pin (mandrel)

MAIN APPLICATIONS

Grades Name	Hose, liners, pipes	Profile	Monofilament	Tubing	Sheeting/cast film	Blown film	Films, coated films	Wire and cable	Coating, jacketing	Corrugate	Optical cable	Stock shape	Mandrels
DuPont™ Hytrel®													
3078				•	•		•						
HTR8351											•		
G3548L					•		•	•					
4056	•	•	•					•		•			
G4074, G4078W	•	•		•	•		•	•					•
HTR8068		•			•		•		•				
4068, 4069 4556	•			•	•			•		•			
HTR8206				•		•	•						
HTX 8532	•			•			•						
HTR5612	•				•	•	•					•	
HTR8667	•			•	•	•	•					•	
HTR8441	•				•	•	•					•	
G4774, G4778	•	•		•			•	•					•
HTR8636	•	•		•	•		•	•	•				
5555HS	•			•				•					
5556	•	•	•	•	•			•		•	•		•
5586	•	•		•		•		•		•		•	
HTR4275	•	•		•	•	•				•			
G5544	•	•	•	•	•		•	•					•
G5564	•			•									•
HTR8539		•			•		•		•				
HTR6108	•			•	•		•						
6356	•		•	•	•		•	•		•			•
HTR8163 HVBK	•			•				•		•			
HTR8241	•												•
HTR8620	•				•								
HTR8303FR								•					
7246	•		•	•	•		•	•		•	•	•	
8238	•		•	•	•		•	•		•	•	•	

IMPORTANT: Before any development with the above listed grades, please check the availability of the material with your DuPont representative.

TROUBLESHOOTING GUIDE FOR EXTRUSION OF DUPONT™ HYTREL®

PROBLEMS	PROBABLE CAUSES & SUGGESTED SOLUTIONS
Unmelted or frozen particles in extrudate	▪ Barrel temperature setting too low, heater capacity too low. Recommended: 4 to 7 W/cm^2 ▪ Granules are not melting properly in screw: change temp. profile (e.g. raising rear, reducing front temperature) ▪ Compression ratio of screw too low: may be adjusted by increasing back pressure with screen pack ▪ Change screw to recommended design ▪ Inadequate screen pack: increase screen pack density ▪ Cold spots in extruder: check operation of heaters, controllers and thermocouples
Diameter variations along the extruded length	▪ Temperature cycling: check operation of controllers including setting of proportional band ▪ Variations in take-off speed: check resin drying conditions ▪ Excessive drag on sizing die: check design, reduce vacuum
Out of roundness - poor concentricity or deformed extrudate	▪ Extrudate sags before entering water bath or sizing die: reduce temperature of melt, check moisture ▪ Reduce pressure applied by haul-off, increase cooling capacity so that the tube is cold before it reaches haul-off
Surging	▪ Irregular feeding: change temperature profile, check feed throat cooling, barrel or screw wear ▪ Inadequate melt back pressure: check mesh screen pack and screw design ▪ Temperature variations: check temperature controllers, thermocouples and heater, power ▪ Slippage in haul-off or speed variations
Deformed/Folded/ Warped extrudate	▪ Adjust die centering, check DDR and DRB
Blisters/Bubbles (on surface)	▪ Resin contains volatile substances: pre-heat or dry material, reduce temperatures ▪ Check for stagnation (dead spots) in extruder or die, check operation of heaters, controllers, thermocouples ▪ Check moisture in resin
Surface roughness	▪ Die temperature too low, contamination, build-up (deposits) on die face, degradation, resin moisture ▪ Die imperfections, burrs: check surface finish of die and pin ▪ Melt fracture ("sharkskin"): reduce shear in die by reducing extrusion rate ▪ Increase die and melt temperature, increase die opening & DDR
Internal "ripples" on surface of tubing	▪ Excessive water turbulence in cooling bath ▪ Vibrations in equipment ▪ Stick-slip: reduce vacuum on sizing die, sandblast inner surface of sizing die
Pinholes, lumps tears, splits or cone breaks	▪ Contamination, excessively high DDR ▪ Temperature of extrudate too low: raise melt and / or die temperature ▪ Poor dispersion of fillers or pigments ▪ Degraded resin released from head: ensure head design is streamlined with no hold up spot

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