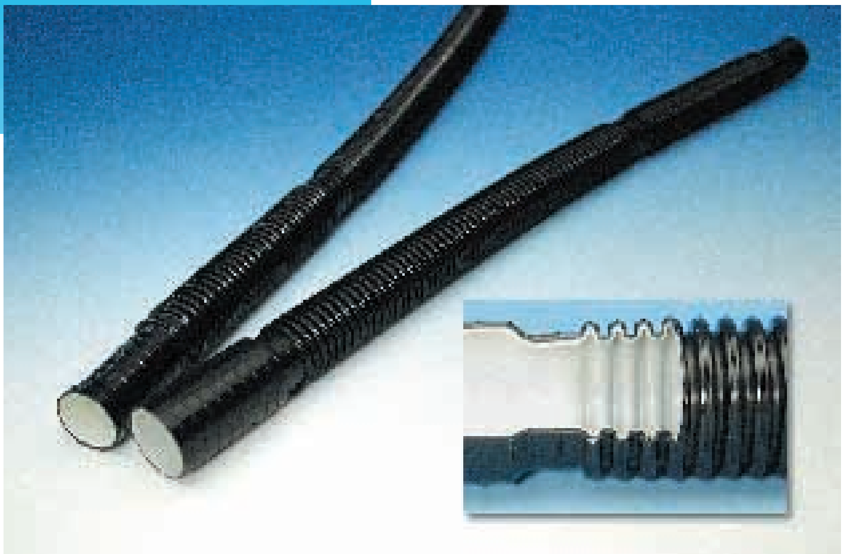
DuPont™ ETPV

engineering thermoplastic vulcanizates

Extrusion guide



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engineering thermoplastic vulcanizates

The thermoplastic rubber that resists oil and heat

Product description

DuPont™ ETPV engineering thermoplastic vulcanizates significantly reduce costs for high performance rubber parts. They have properties similar to high performance rubbers but are processed on standard thermoplastic equipment.

DuPont™ ETPV consists of a high performance cross-linked elastomer dispersed in a high performance thermoplastic elastomer. The recycling code for DuPont™ ETPV according to ISO 11469 is >AEM + TPC-ET<.

Benefits of DuPont™ ETPV:

- Significant cost savings compared with cross-linked rubber
- Excellent oil and heat resistance
- Fast cycle times save costs
- Design flexibility allows integration of functions
- Recyclable

Product line description

DuPont™ ETPV is available in different degrees of hardness ranging from 60 to 90 shore A.

Standard grades

- 60A01L NC010 60 shore A, lubricated, natural color
- 80A01 NC010 80 shore A, natural color
- 90A01 NC010 90 shore A, natural color

Heat stabilized grades

- 60A01HSL BK001 60 shore A, lubricated, heat stabilized, black
- 90A01HS BK001 90 shore A, heat stabilized, black

Grades in natural color may be pigmented black using carbon black concentrate HYTREL® 40CB. If alternative colors are required, please contact your DuPont representative for more information.

Handling and processing guidelines

All safety practices normally followed in the handling and processing of thermoplastic polymers should be followed for DuPont™ ETPV. The polymer is not hazardous under normal shipping and storage conditions. During processing, particularly if recommended temperatures and hold-up times are exceeded to any great degree, DuPont™ ETPV may degrade and decompose, and gaseous by-products may evolve. Potential hazards from these gaseous decomposition products include "blow-back" through the hopper, fire and exposure to toxic vapors. As with all thermoplastics, thermal burns from contact with molten polymer are a potential hazard. Before processing DuPont™ ETPV observe the recommended guidelines. Compounding ingredients or additives may present hazards in handling and use. Before proceeding with any compounding or processing work, consult and follow the directions and handling guidelines from suppliers of all ingredients, as listed on the packaging label. Before processing DuPont™ ETPV, reference should be made to the document "Handling and Processing Guidelines for DuPont™ ETPV", which can be found on the plastics.dupont.com website. Ensure adequate ventilation and wear protective clothing when handling and processing DuPont™ ETPV.

Thermal and rheological properties

All DuPont™ ETPV grades have a melting point of 205°C, and their flow and draw-down behavior differs from that of conventional thermoplastic materials because they contain a high level of cross-linked elastomer. Apparent melt viscosity at a range of temperatures for DuPont™ ETPV 60A01L, 80A01 and 90A01 is shown in Fig. 1 to 3.

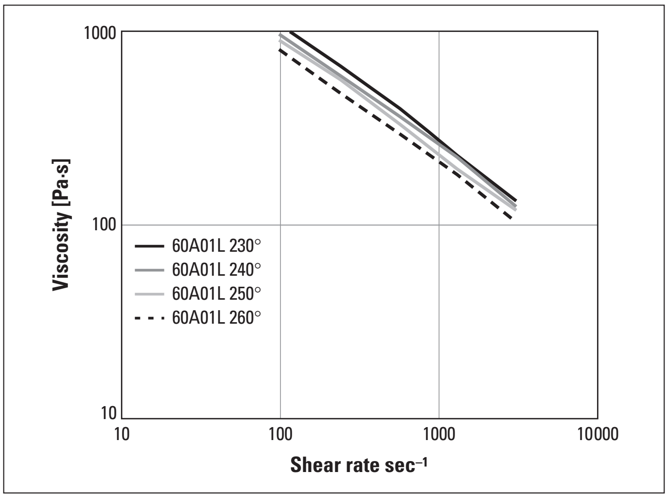


Fig. 1 **Apparent melt viscosity versus shear rate for DuPont™ ETPV 60A01L.**

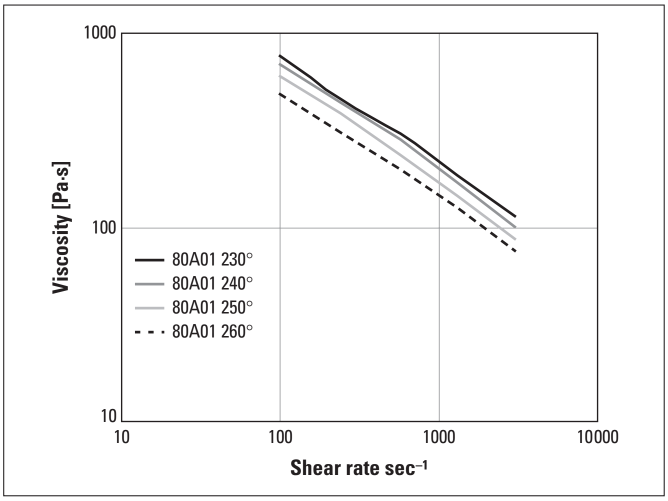


Fig. 2 **Apparent melt viscosity versus shear rate for DuPont™ ETPV 80A01.**

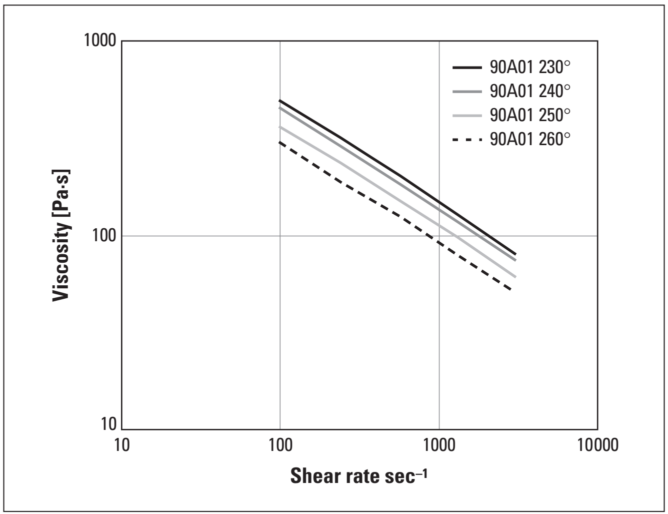


Fig. 3 **Apparent melt viscosity versus shear rate for DuPont™ ETPV 90A01.**

Processing equipment

General design of extruder

Experience has shown that the best results with DuPont™ ETPV are obtained with a single screw extruder design. Twin screw extruders tend to generate excessive shear, and are not recommended. Vented machines are not necessary since there are no significant volatiles present in DuPont™ ETPV. The use of melt/gear pumps may be possible, although we have no direct experience of melt/gear pumps with DuPont™ ETPV at this time. The emphasis should be on the uniformity and quality of the melt produced. A constant delivery of homogeneous melt of uniform temperature, with the ability to maintain the desired melt temperature over a range of screw speeds, should be the objective for good extrusion.

The extruder drive should provide good speed control and adjustment over a wide speed range. The drive should have automatic current limitation in order to prevent screw breakage as a result of excessive torque.

Safety devices

As well as automatic current limitation in the extruder drive, the extruder should be equipped with the following protective devices in order to prevent personal injury or damage to the extruder:

- A pressure transducer installed in the flow channel immediately after the screw and before the breaker plate/screen pack. The pressure indicator should have an alarm setting for high pressure and ideally also a cutout setting designed to stop the extruder screw before any damage can occur.
- As a further safety option, a high-pressure rupture disc should be installed in the same area as the pressure transducer, designed to rupture at a pressure above the alarm/cut-out settings on the pressure indicator.
- An ammeter, installed to show the drive motor current, can be a useful indicator to help monitor startup and running torque on the screw. Abnormally high motor current normally means insufficient temperature in parts of the extruder, and low or fluctuating current may indicate feeding problems or even wrong screw design for the material.

Materials of construction

DuPont™ ETPV in the molten state is non-corrosive to metals. Screws should have hardened (nitrided) surfaces but need not be made from corrosion-resistant alloys.

Material hopper and feed throat

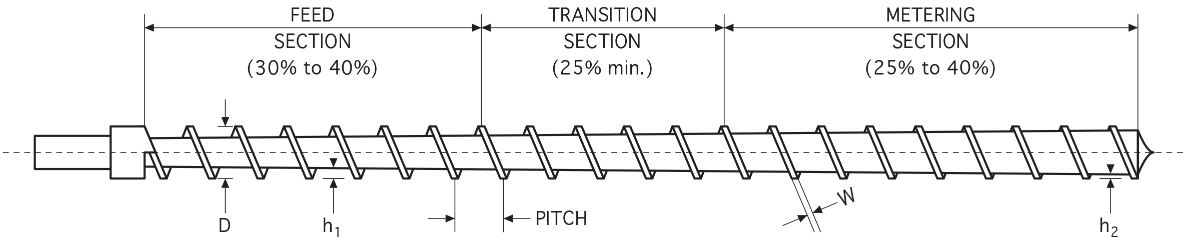
Overhead or tangential-type feed throats, as normally provided on single screw extruders, work well with DuPont™ ETPV. Water cooling of the throat is essential to prevent excessive heating of the resin as it enters the screw, which could result in “bridging” of the material at this point, and also to serve as protection for the drive bearings.

Extruder barrel

Extruder barrels, which are suitable for use with common thermoplastics such as nylon, PVC or polyolefins are usually suitable for DuPont™ ETPV. Length-to-diameter ratios of at least 20:1, and preferably 24:1 or higher, provide the best melt quality for good extrusion. Small clearances between the screw flights and the barrel wall are important to prevent backflow of molten resin and possible surging in extruder output. It is suggested that a clearance of 0.08 to 0.10 mm is maintained for extruders up to 50 mm screw diameter, or 0.10 to 0.16 mm for larger extruders. These clearances should be checked from time to time, and refurbishment of the screw or barrel carried out when necessary. It is recommended that the barrel is equipped with at least four heat control zones (three for small extruders) and the temperature of each zone controlled by a separate thermocouple and proportional control instrument. Efficient cooling should also be provided by air blowers or water, and independently controlled for each zone.

Screw design

The most important element of an extruder is the screw. Its design can mean the difference between successful or troublesome processing of any thermoplastic. For most DuPont™ ETPV extrusion purposes, advantageous results can be obtained with simple 3-zone screws having approximately equal length feed, transition (compression) and metering sections. The length-to-diameter (L/D) ratio should be a minimum of 20:1 and ideally 24:1 or higher for good uniformity of the extrudate. Compression ratios should be between 2.5:1 and 3.5:1 as determined by the depth of feed zone channel divided by the depth of metering zone channel (“apparent compression ratio”). The depth of the channel in both feed and metering sections is important. If the feed channel is too deep and not sufficiently long, particu-



Typical dimensions*

Diameter (D) (mm)	Pitch (P) (mm)	Channel depth of feed section (h_1) (mm)	Channel depth of metering section (h_2) (mm)	Land width (W) (mm)
30	30	6.5	2	3.5
40	40	7	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	5	15

* For guidance only

Fig. 4 **Gradual transition screw.**

larly with large diameter screws, it can cause poor feeding and irregular output. If the metering channel is too deep it can result in non-uniform temperature distribution through the melt. Meanwhile a metering channel that is too shallow can result in overheating of the melt due to excessive shear. The screw should have a rounded or conical tip to avoid "dead spots" in front of the screw where degradation of polymer could occur.

A typical screw of the 3-zone, gradual transition type suitable for processing DuPont™ ETPV is shown in Fig. 4. For further details of screw design for DuPont™ ETPV, please contact your DuPont representative for more information.

Screens and breaker plate

A breaker plate of streamlined design, e.g. counter-bored on both sides, is usually clamped between the end of the extruder barrel and the head. It acts to convert the material from the screw to a linear flow and also develops some back-pressure on the screw. Screen packs normally sit on the front of the breaker plate and are used for two purposes: to remove any impurities or unmelted material from the melt stream, and to ensure sufficient back-pressure at the end of the screw to help create a homogeneous melt and constant output pressure. However, high back-pressure can lead to the generation of excess heat through shear, so according to the actual performance of the machine it may be necessary to use very coarse screens (80 mesh or less) or to run without one at all. If screens are used, they need to be replaced regularly to avoid excessive pressure drops developing across the screen pack, and consequent loss of flow. If fine mesh screens are used, this replacement may be necessary every 12 to 24 hours of running, or whenever an extended shutdown occurs.

Good external heating is essential in the breaker plate/clamp area of the extruder. Sufficient heating capacity should be provided in order to rapidly raise the temperature in this region during start-up to the normal processing setting. This will ensure that any residual polymer is thoroughly melted. Because the breaker plate (head clamp) area is usually such that a large amount of heat is lost to the surrounding air, the heater design in this zone is critical.

Adapter, head and die

Both the adapter and the head must be of a streamlined design. Flow channels should not contain sudden changes in cross section, surface interruptions (caused for example by mis-matched assembly joints or damage), or other effects, which might cause "dead spots". Such small areas of flow stagnation can give rise to localised polymer degradation and subsequent release of particles of degraded resin into the melt stream. Similar problems can occur if flow velocity is reduced due to large cross sections in some flow channels. Adequately sized heaters must be provided for the adapter since it is generally a heavy piece of metal. It is especially important to control the temperature of the adapter and head separately, since they usually differ greatly in size and energy requirements.

The die, where it extends beyond the extruder head, should also have its own thermocouple and temperature controller. Details on head and die designs for specific extrusion processes, such as tubing extrusion, are given in section 6 of the HYTREL® Extrusion manual, which can be found on the DuPont Engineering Polymers website plastics.dupont.com

Instrumentation

The function of an extruder is to pump molten thermoplastic at a constant rate and temperature. Sophisticated instrumentation is a prerequisite for quality production. To gauge extruder performance it is important to determine the pressure and temperature of the melt, as well as to provide adequate methods of control. The requirements for DuPont™ ETPV will be the same as those detailed in the HYTREL® Extrusion Guide, pages 5 and 6.

Processing conditions

Drying

Although DuPont™ ETPV is supplied in moisture-proof packaging, we strongly recommend that the polymer is dried, according to the conditions in Table 1, to a moisture content of 0.05% or less before it is extruded. DuPont™ ETPV is hygroscopic so if left exposed to air, it will absorb moisture. Water absorption of DuPont™ ETPV when exposed to air at 23°C and 50% relative humidity may reach 0.3%. All material, including regrind, exposed to air more than a few minutes should be re-dried before use according to the recommendations in Table 1. It is recommended to use a suitably-sized dehumidifying hopper, or alternatively a small sealed hopper, which is then fed directly and continuously from a separate, dehumidifying drying unit.

Table 1 Recommended drying conditions for DuPont™ ETPV

Dryer type	Desiccant
Time	3 hours, (max. 4 hours)
Temperature	80°C

At temperatures substantially above the melting point, excess water causes hydrolytic degradation of the polymer. Such degradation does not appear in the form of visual defects but results in poor physical properties and poor in-service performance. It can also have a detrimental effect on the process performance of the polymer by reducing its viscosity or, in the worst case, by creating voiding and/or foaming of the melt.

Purging

For short shutdowns of up to 30 minutes' duration there should be no need to purge the barrel, but it may be advantageous to leave the screw turning at around 5 rpm if it is safe and feasable to do so. For longer shutdowns it is recommended that the barrel be purged, ideally using a low melting point grade of HYTREL® such as G3548L, before turning off the heat. Alternatively, low density polyethylene (LDPE) may also be used although when restarting the machine it is essential to ensure that all traces of the LDPE are purged from the extruder before collecting DuPont™ ETPV for use.

Melt temperature

All DuPont™ ETPV grades have relatively flat viscosity versus shear rate curves, especially at the low shear rates, which are typical for extrusion. This means, for example, that high shear screw and die designs will not reduce the melt viscosity of DuPont™ ETPV as much as with some other polymers, but may cause undesirable local temperature increase. It can also be seen from Fig. 1 to 3 that a significant change in melt viscosity can result from a relatively small change in melt temperature. The extrusion melt temperature can therefore be decreased, within limits, to provide greater melt strength for improved stability of the extrudate. It also means that good control of melt temperature is an important factor in the successful extrusion of DuPont™ ETPV resins.

Whereas for injection moulding a melt temperature in the region of 250°C is recommended, for extrusion lower temperatures have been found to give the best melt strength, homogeneity and surface finish. The melt temperature range for extruding DuPont™ ETPV is 215-230°C.

The actual melt temperature should be confirmed using a hand-held needle pyrometer inserted into the melt while the extruder is running at the typical production screw speed. Experience has shown that there is often a difference between the actual melt temperature measured this way and the temperature recorded by thermocouple probes fitted through the wall of the barrel, head or die.

A typical temperature profile could be:

Barrel →				Head	Die
210	220	225	230	230	225°C

Draw-down

Most extrusion processes require that the melt be drawn down after it leaves the die. In the case of DuPont™ ETPV the amount of draw down that can be tolerated will depend on the grade and the processing conditions.

The draw down ratio is calculated by comparing the cross sectional area of the die to the cross sectional area of the extrusion. For a tube this is calculated by the formula:

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

Where DDR = Draw-down ratio

D_d = Internal diameter of extrusion die

D_m = External diameter of mandrel or torpedo

D_t = External diameter of tube

D_b = Internal tube bore or diameter

Based on experience gained so far with DuPont™ ETPV, the following draw-down ratios are suggested:

DuPont™ ETPV 60A01L

- most suited to free extrusion processes in which there is very little or no draw-down at all, i.e. a draw-down ratio of 1.0:1 to 1.2:1.

DuPont™ ETPV 80A01

- greater care is required and draw-down should be minimized as far as possible, i.e. a draw-down ratio of 1.5:1 to 2.0:1.

DuPont™ ETPV 90A01

- can be extruded by most conventional processes and will comfortably tolerate a draw-down ratio of up to 3.0:1 or more.

Tube extrusion

To produce tubes from DuPont™ ETPV grades using standard vacuum sizing techniques, a tubular sleeve sizing die should be used similar to the one shown in Fig. 5. For a detailed design drawing please contact your DuPont representative. Any surface of the die, which is in contact with the melt should be roughened by grit blasting. Suitable lubrication must be provided between the extruded polymer and the surface of the calibrator. Usually this is provided by a fine water flow through small holes or slits at the front of the tubular die, or through an annular water ring device at the entrance to the die. In all vacuum-sizing operations there should be provision for fine adjustment of the vacuum in order to accurately control and maintain the external diameter of the extruded tube. In the case of DuPont™ ETPV, because the melt is relatively soft and flexible, a good quality surface and good concentricity can be achieved using very little vacuum. When starting up the process it is therefore advisable to gradually increase the vacuum until the desired size, finish and concentricity is achieved.

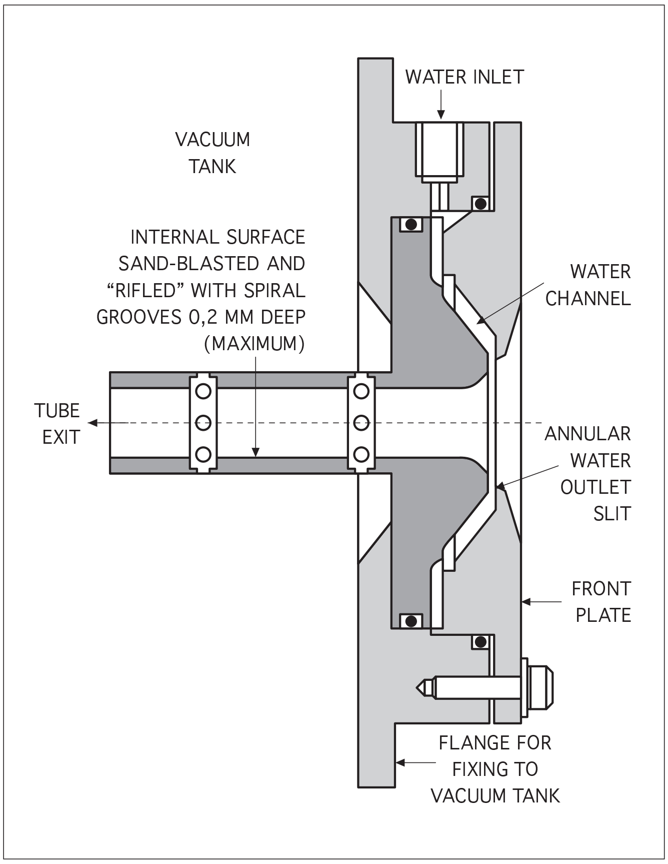


Fig. 5 **Tubular sizing die.**

Co-extrusion

Only a limited amount of co-extrusion process work has so far been completed, but DuPont™ ETPV can be extruded directly with HYTREL® TEEE without the need for an adhesive. It is likely that DuPont™ ETPV may also bond directly to CRASTIN® PBT and RYNITE® PET but this has yet to be thoroughly tested.

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