DuPont™ ETPV

ENGINEERING THERMOPLASTIC VULCANIZATES
INJECTION MOLDING GUIDE

The miracles of science™

Table of contents

Front cover:
Ignition coil boot made out of
DuPont™ ETPV 60A01HSL BK001

Engineering Thermoplastic Vulcanizates

The thermoplastic rubber that resists oil and heat

Product description

DuPont™ ETPV engineering thermoplastic vulcanizate significantly reduces costs for high performance rubber parts. It has properties similar to high performance rubbers and is 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:

- Cost savings versus cross-linked rubber
- Excellent oil and heat resistance
- Fast cycle times
- Design flexibility allows integration of functions
- Recyclability

Product line description

DuPont™ ETPV is available in different degrees of hardness ranging from 60 to 95 shore A (ASTM D2241).

Standard grades

• 60A01L NC010	60 shore A, lubricated, natural color
• 70A01 NC010	70 shore A, 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
• 95A02HS BK001	95 shore A, heat stabilized, black

Concentrates

• MB80L NC	Lubrication, natural color, add up to 20%
• MB80L BK	Lubrication, black, add up to 20%
• Hytrel® 40CB	Black, add ~2%
• Hytrel® 30HS	Heat stabilizer MB, add ~5%

If alternative colors are required, please contact your DuPont™ representative for advice.

DuPont™ ETPV 70A01 NC010 is an extrusion grade and is therefore not included in the following guide.

Handling and processing precautions

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 holdup times are exceeded to any great degree, DuPont™ ETPV may degrade and decompose, with evolution of gaseous products. 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 precautions recommended. Compounding ingredients or additives may present hazards in handling and use. Before proceeding with any compounding or processing work, consult and follow label directions and handling precautions from suppliers of all ingredients. Before processing DuPont™ ETPV, reference should be made to the bulletin "Handling and Processing Precautions for DuPont™ ETPV", which is available on our website www.plastics.dupont.com. Ensure adequate ventilation and wear protective clothing when handling and processing DuPont™ ETPV.

Thermal and rheological properties

All DuPont™ ETPV grades, exept the 95A02HS BK001, have a melting point of 205° C, and their flow behavior differs from that of conventional thermoplastic materials because they contain a high level of a cross–linked elastomer. DuPont™ ETPV 95A02HS BK001 has a melting point of 216° C. Apparent melt viscosity at different temperatures for DuPont™ ETPV 60A01L, 80A01 and 90A01 is shown in Figures 1 to 3.

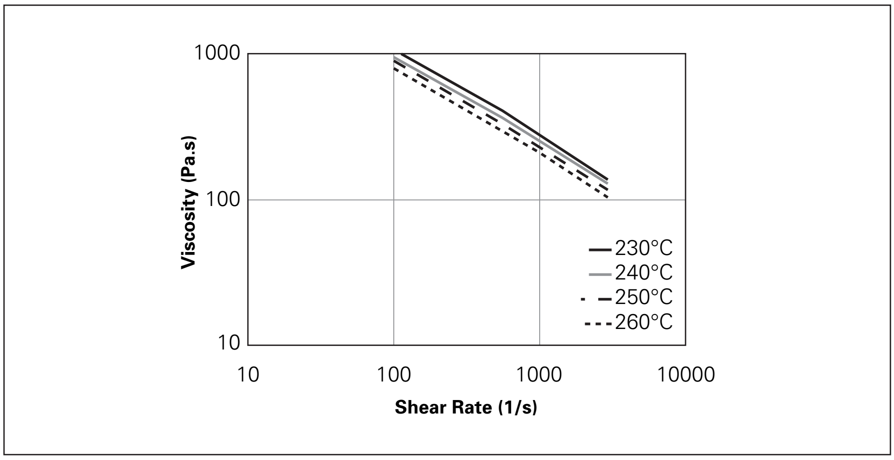

Fig. 1 **Apparent melt viscosity versus shear rate for DuPont™ ETPV 60A01L.**

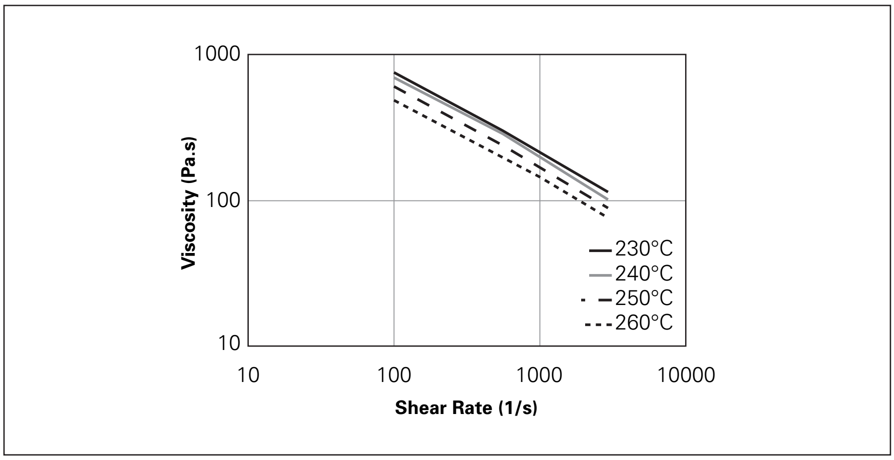

Fig. 2 **Apparent melt viscosity versus shear rate for DuPont™ ETPV 80A01.**

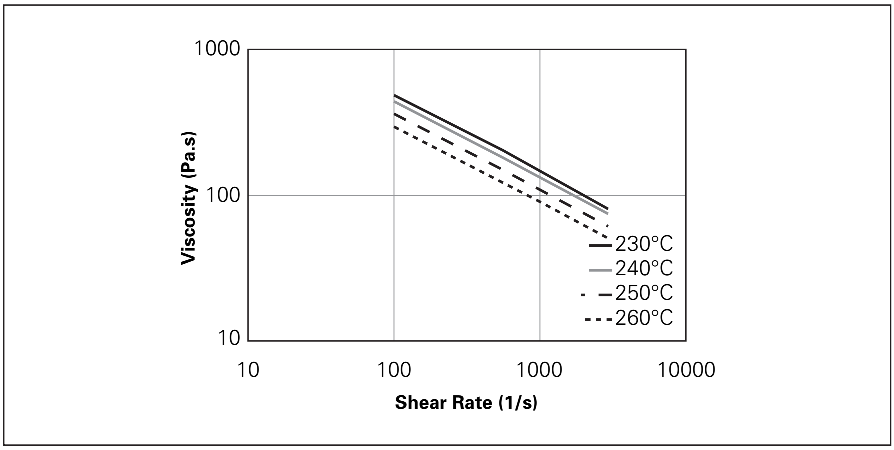

Fig. 3 **Apparent melt viscosity versus shear rate for DuPont™ ETPV 90A01.**

Processing equipment

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.

Nozzle Design

Standard open nozzles as shown in Figure 4 are recommended for processing DuPont™ ETPV. Shut-off nozzles are not required because DuPont™ ETPV does not drool at normal operating temperatures. Because the polymer melt is generally more viscous than conventional semi-crystalline thermoplastics, nozzle diameter (and runner system) should be dimensioned somewhat larger. Material passages must be smooth, and streamlined, with no hold-up spots.

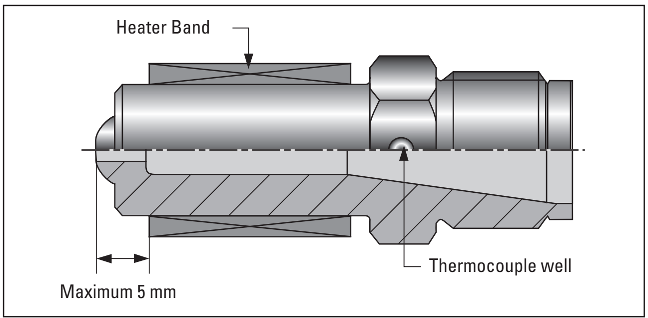

Fig. 4 **Open nozzle.**

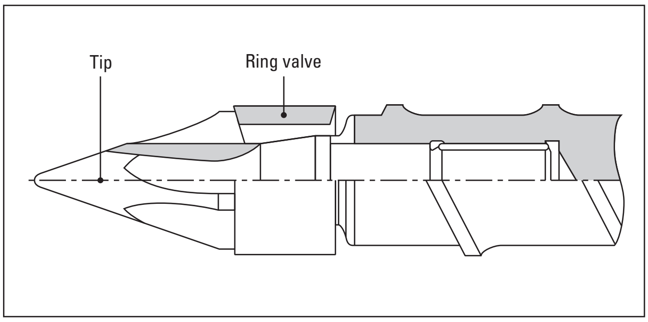

Fig. 5 **Back flow valve.**

Screw design

General purpose, gradual transition screws with compression ratios between 2.0:1 and 3.5:1 and an L/D ratio of >20 are usually suitable for molding DuPont™ ETPV. The metering zone should be relatively deep, i.e. 2.5 mm for a 40 mm screw. Screws with a short compression zone (two flights) and long metering zones (six flights) with very shallow flights should be avoided. They tend to overheat the melt at high screw speeds. Screws equipped with full back flow valve may be used as shown in Figure 5. Flow passages must be carefully streamlined to eliminate melt stagnation and potential degradation.

Processing conditions

Drying

Although DuPont™ ETPV is supplied in moisture–proof packaging, we strongly recommend that the polymer is dried, according to recommendations in Table 1, to a moisture content of 0.08% or less before it is injection molded. DuPont™ ETPV is hygroscopic and 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 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. The desiccant dryer should have a set dew point of at least –30°C. Excessive drying (longer than 3 hours) might result in sticking of pellets which may lead to feeding problems.

Table 1 Recommended drying conditions for DuPont™ ETPV

Dryer type	Desiccant
Time	2–3 h
Temperature	80°C (175°F)

At temperatures substantially above the melting point, excess water causes hydrolytic degradation of the polymer. Such degradation does not appear as visual defects, but results in poor physical properties, brittleness and poor in-service performances particularly at low temperatures. 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. For longer shutdowns, it is recommended that the barrel be purged, ideally using a low melting point Hytrel® grade, 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 molded parts made from DuPont™ ETPV.

Melt temperature and thermal stability

The melt temperature should be taken directly from the molten polymer (using a needle pyrometer) and should be checked periodically during production. Typical melt temperatures for DuPont™ ETPV are given in Table 2. When handled properly (i.e. acceptable moisture content), DuPont™ ETPV has outstanding thermal stability, minimizing problems such as formation of black specs or reduction in viscosity with increased hold up time in the injection unit.

Table 2 Recommended melt temperatures for DuPont™ ETPV

Grade	Melt Temp. °C / °F
60A01L	255 (250–260) / (480–500)
80A01	250 (245–255) / (473–491)
90A01	250 (245–255) / (473–491)
95A02HS	255 (250–260) / (480-500)

Cylinder temperature profile

To minimize sticking of pellets on the screw and when higher than recommended melt temperatures are used a rising cylinder temperature profile (lower rear temperature) is normally preferred.

Screw speed

The tangential screw speed suggested to process DuPont™ ETPV is around 0.2 m/s (i.e. 100 rpm for a 40 mm screw – this can be calculated using the equation below). High screw speed could overheat the material, so it should be set in a way that the melt temperature remains stable and within the suggested limits.

$$\text{Maximum screw rotation} = \frac{0.2\ \text{m/s} \times 60{,}000}{\text{Screw diameter (mm)} \times 3.14}$$

Back pressure

Generally low backpressure is needed for plastification and a backpressure of 1 to 2 MPa (150 to 300 psi, or 15 to 30 psi hydraulic pressure for a 10:1 intensification screw) is recommended.

Mold temperature

The mold temperature depends on part thickness, shape, and product grade. Minimum recommended mold temperatures are given in Table 3. Higher mold temperatures are recommend for improved flow. For 2 K injection molding the mold temperature of the hard compound should be used

Table 3 Recommended mold temperatures for DuPont™ ETPV

Grade	Little sticking °C / °F	Dimensional stability °C / °F
60A01L	30 / 86	50 / 122
80A01	30 / 86	50 / 122
90A01	30 / 86	50 / 122
95A02HS	30 / 86	50 / 122

Low mold Temperatures like 30°C help de-mold the material easier, 50°C will give a better dimensional stability.

Injection speed

High injection speed can cause high shear and possible surface delamination, especially at the gate. For this reason, a low or medium injection speed is recommended, such as 15–50 mm/s (0.6–2.0 in/s).

Injection pressure / hold pressure

Injection pressure should be set to a minimum required to fill the mold cavity in order to avoid excessive shear. A decreasing hold pressure profile should be used, for example 60 MPa down to 30 MPa (8700 psi down to 4300 psi).

Hold pressure time

The recommended hold pressure time (HPT) is the time for the molten polymer to become fully crystallized in the mold cavity. As the crystallization (solidification) leads to a large volume drop, additional molten material has to be pushed into the cavity throughout the HPT. In general, 4 s/mm should be used, at least for parts with up to 4mm thickness. The hold pressure time has a strong influence on shrinkage, i.e. a longer hold pressure time results in less shrinkage. On the other hand, the gate design (i.e. fan gates) and a long hold pressure time have a strong influence on delamination effects near the gate. For the right gate design, see Fig.12 of this guide.

Mold shrinkage

The shrinkage of DuPont™ ETPV depends on different factors such as:

- Product grade of DuPont™ ETPV
- Molding conditions (e.g. injection pressure, screw forward time, and mold temperature)
- Part geometry and thickness

The data we provide in Table 4 below has been measured on test standard ISO specimens (60 × 60 × 2 mm), molded at recommended conditions. The shape of this ISO specimen results in an extreme orientation in flow of the polymer melt.

Table 4 Typical ISO shrinkage* of DuPont™ ETPV

Grade	Cross Flow (%)	In Flow (%)
60A01L	1.7	5.0
60A01HSL	1.6	3.5
80A01	1.6	2.3
90A01	1.6	1.9
90A01HS	1.6	1.7

*Mold Temperature: 50°C

When molding parts with different geometry, less shrinkage has been observed. A round part, 82 mm diameter and 1.3 mm wall thickness gated with a diaphragm gate in the center of the part has a shrinkage as shown in Table 5.

Table 5 Shrinkage of DuPont™ ETPV in round shape

Grade	Total shrinkage 24 h after molding (%)	Total shrinkage after annealing at 150°C for 2 hours (%)
60A01L	2.2	4.2
90A01	1.0	2.2

Annealing DuPont™ ETPV for 1 hour at 150°C results in a post shrinkage that needs to be taken into account if the part is operating later at elevated temperatures and has to be in a certain tolerance range. The dimensional changes are assumed to be stable after annealing the parts for 1 hour at 150°C. Apart from the dimensional stability at elevated temperatures, annealing DuPont™ ETPV is only necessary to improve the compression set of the material.

If the application does not require high compression set or a small tolerance range at elevated temperatures, annealing is not necessary!

Table 6 Total ISO shrinkage (post shrinkage) of DuPont™ ETPV after annealing 1 hour at 150°C

Grade	Cross Flow (%)	In Flow (%)
60A01L	0.9	14.4
60A01HSL	0.7	10.3
80A01	1.5	5.7
90A01	1.8	4.1
90A01HS	2.0	3.3

Annealing reduces molded in stresses. As the specimen for testing the shrinkage is highly oriented in flow, the highest molded in stress will be in this direction, therefore the specimen gets shorter. As the part has still the same volume the dimensional change in flow must be compensated and therefore the part gets a little wider and most probably thicker.

Flow length

To generate flow length data for DuPont™ ETPV, a snake flow tool with a cavity width of 5 mm and a spiral flow tool with a cavity width of 8 mm were used. Four thicknesses of 0.5, 1.0, 2.0 and 3.0 mm were tested, using gates, which had the same thickness as the selected cavity. The flow length for the thickness of 0.5 mm was measured using the snake flow tool and the flow length of 1, 2 and 3 mm were measured using the spiral flow tool. This could result in a slightly different filling behavior. The molding parameters used were in line with those recommended in this guide. The test settings are shown in Table 7. A 1250 KN molding machine was used with a 40 mm screw and no accumulator. There was no hold pressure applied in order to see the flow behavior of the material during the dynamic phase of the injection molding process. The mold temperature was modified between 30° and 50°C to check the influence of the mold temperature on the flow length. For the tests done with a tool temperature of 30°C, an injection speed of 50 mm/s was used. The tests done with a tool temperature of 50°C were performed with an injection speed of 20 mm/s. Results are shown in Figures 6 to 8.

Table 7 Test settings

Melt temperature	246°C
Injection speed	20 mm/s (mold 50°C)
	50 mm/s (mold 30°C)
Cooling time	25 s
Screw retraction	145 RPM

Figures 6 to 8 all show a similar trend. Increasing the mold temperature significantly improves the flow length. This effect is most obvious when using a large part thickness. In many cases, increasing the mold temperature by 20°C improves the flow length by more than double, even at a lower injection speed. For small part thicknesses, i.e. 0.5 mm, the injection speed determines the flow length and the mold temperature has only a minor effect. A mold temperature of approximately 50°C is therefore recommended for the best filling result.

When molding commercial parts, the melt temperature may be increased, the injection fill pressure may be raised above 90 MPa and an accumulator may be used to increase injection fill speed. Therefore, it may be assumed that the flow values in Figures 6 to 8 are easily achieved when molding actual parts. However, it should be taken into account, that spiral flow cavities have optimum venting (open end), and flow restrictions may be encountered in tools with insufficient venting.

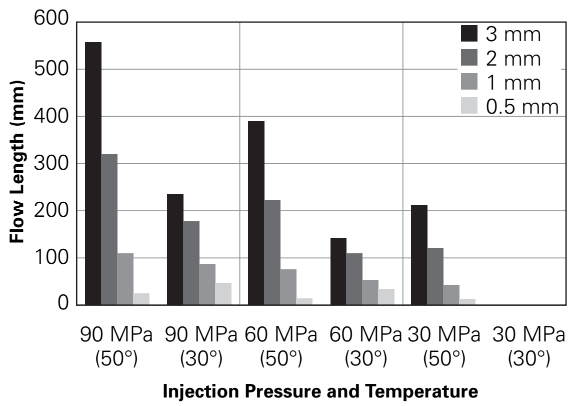

Fig. 6 **Comparison of flow lengths of DuPont™ ETPV 60A01L NC010 at 50°C and 30°C.**

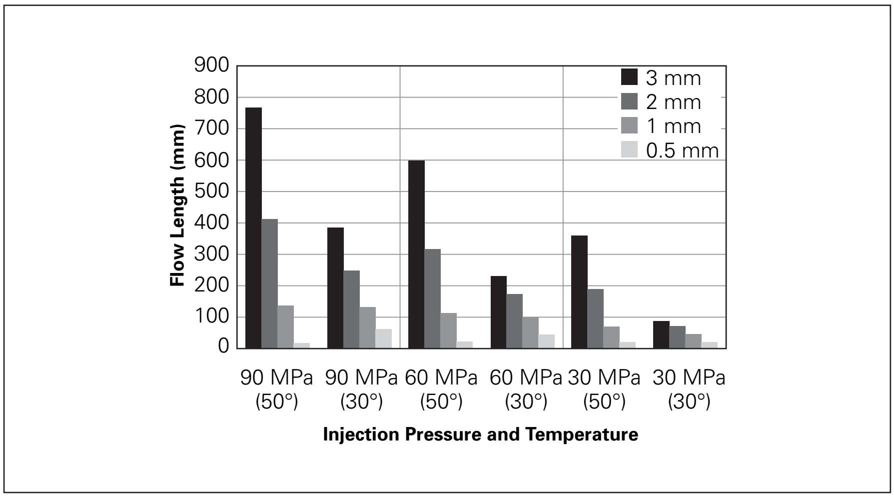

Fig. 7 **Comparison of flow lengths of DuPont™ ETPV 80A01 NC010 at 50°C and 30°C.**

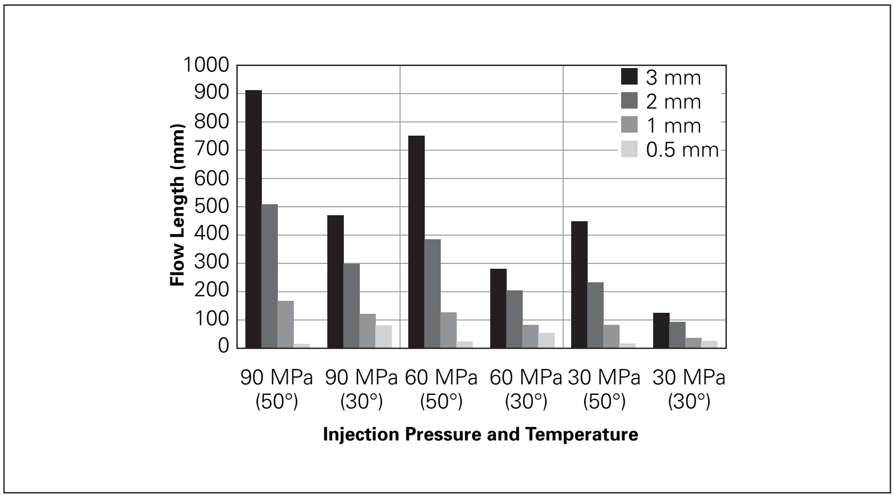

Fig. 8 **Comparison of flow lengths of DuPont™ ETPV 90A01 NC010 at 50°C and 30°C.**

Regrind

All DuPont™ ETPV grades can be reground. To facilitate the regrind process, it helps to cool the polymer before regrinding. One way this can be done is by submerging it in liquid nitrogen. Another way would be to use a regrinder with a cooled cutting chamber. Please contact your local regrind-machinery supplier for more information. DuPont has recently carried out a study on the injection-moldability of reground material. The test was carried out on 5 different regrinds. The first test used 10% regrind. The second used 10% regrind from the first test. The third used 10% regrind from the second test, and so forth. The results, illustrated in Figure 9, indicated an insignificant change in the flow lengths of the different regrinds.

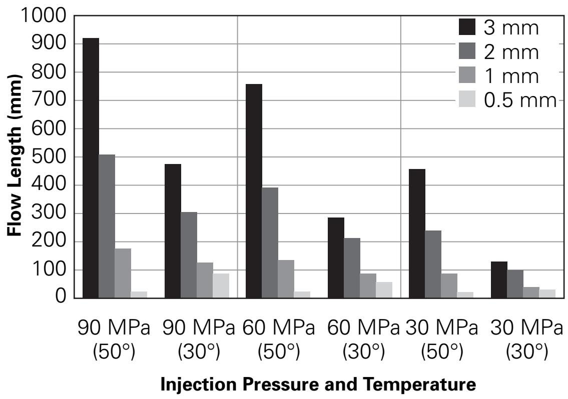

Fig. 9 **The effect of regrind on the flow length of DuPont™ ETPV 90A01 NC010.**

The use of regrind does not have any affect on the shrinkage properties of the material as shown in Table 8.

Table 8 Typical shrinkage of DuPont™ ETPV after the use of 20% regrind

Grade	X Flow (%)	X Flow (%) 20% regrind pass 5	In Flow (%)	In Flow (%) 20% regrind pass 5
60A01L	1.7	1.7	5.0	5.0
60A01HSL	1.6	1.6	3.5	3.6
80A01	1.6	1.6	2.3	2.3
90A01	1.6	1.6	1.9	1.8
90A01HS	1.6	1.6	1.7	1.6

Mold design

The following paragraphs explain some important points that should be considered when designing a mold for parts made of DuPont™ ETPV.

Materials of construction

No special metals are required since DuPont™ ETPV has no corrosive action on the alloys commonly used for injection molds and cavities.

Mold surface finish

Highly polished, plated mold finishes may cause difficulty in ejecting parts. In order to minimize the vacuum effect in the mold and causing the part to stick to the surface of the mold, it is recommend texturing or at least applying a matte (i.e. sandblasted) finish to the cavity. The effect of various surface treatments on the maximum ejection force required is shown in Figure 10. Please contact your DuPont representative for more information on surface coatings.

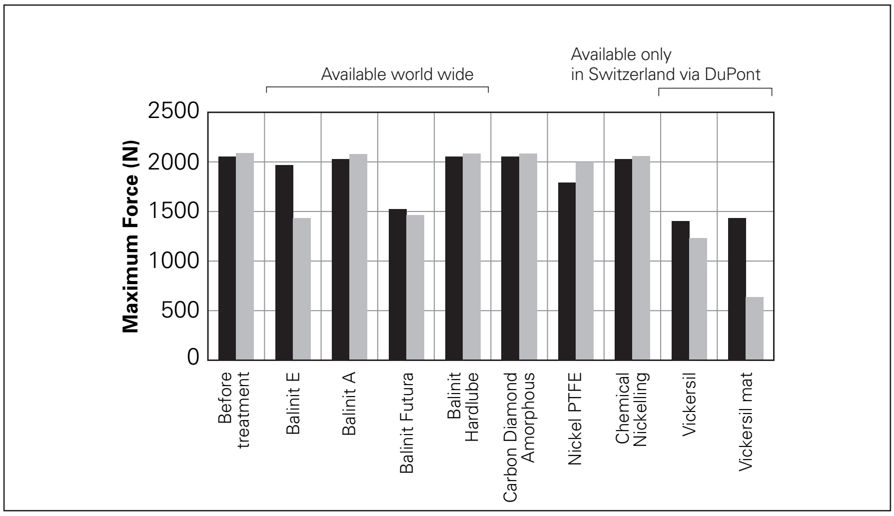

Fig. 10 **Ejection Force of ETPV 60A01 HSL (shown in black) and ETPV 90A01 HS (shown in gray).**

The gate design is the key to success. It strongly influences the properties of the molded part. Therefore please carefully read the following.

Gating

Gates must be designed to stay open long enough to adequately pack out the part and to minimize shear that is direct cause of possible delamination. The gate land length must be short (< 1mm) and the thickness should be 60% to 80% of the part thickness. A crystalline gate design is recommended (see Figure 11). The gate should be located at the thickest section of the part.

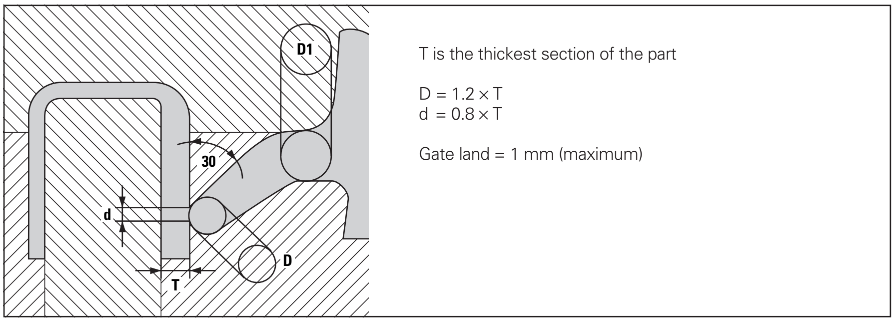

Fig. 11 **Crystalline gate design.**

Runners and sprue

Runners should be streamlined to reduce turbulence. The runner system should be designed to give a balanced layout, a minimum number of runners, a minimum runner length and smooth runner turns. To improve flow and facilitate ejection, the surface of the runners should be smooth, but not polished. The sprue should be short, with a taper angle of 3° to 5° to avoid possible sticking.

Both hot and cold runner molding is possible. For hot runners, sufficient heating capacity and control must be provided to insure that neither freezing nor overheating occurs. This will prevent unnecessary cycle interruptions and possible polymer degradation.

Vents

Sufficient venting is essential for surface and weld line quality. Inadequate venting may result in burnt surface (diesel effect) or weak weld lines. Typical vents should be <0.04 mm in depth and as wide as possible.

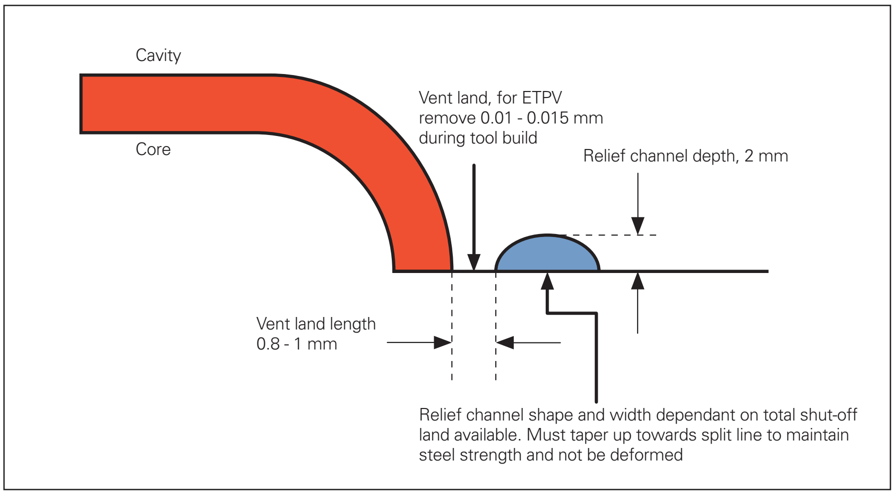

Fig. 12 **Typical split line vent cross-section.**

Part ejection

Ample draft, i.e. 1° to 2° taper per side, can ease part ejection, especially when a core is removed from a deep part or when a part is removed from a deep cavity. If possible, use ejector plaques or rings. When pin ejectors are used, they should have a large surface area and act on the thickest sections of the part. Ejection can also be helped with air. To improve part ejection, it is possible to add up to 20% lubricated masterbatch (please refer to the "Product line description" on page 2).

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