

DuPont™ Zenite®

liquid crystal polymer resin

Moulding guide



The miracles of science™

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1 General information

1.1 Foreword

ZENITE® is the registered trademark for DuPont's thermotropic liquid crystal polymer (LCP) resins. These wholly aromatic polyester resins contain glass fibres and/or other fillers and are specially formulated for high temperature applications. These materials are easily melt processed and offer high productivity manufacturing of high performance parts in a wide range of applications in the automotive, electrical/electronic, industrial and appliance markets.

In this brochure, general handling and injection moulding processing techniques are discussed.

1.2 Description

ZENITE® 6000, 7000 and 7700 series LCP resins offer unique combinations of toughness, stiffness, dimensional stability and creep resistance – even at very high temperatures. Each of these series is characterised in terms of melting point and therefore end-use temperature. In the molten state, the LCP's rod-like molecules are to some extent aligned. With high processing shear stresses, i.e. fast fill speeds, the molecular alignment is further enhanced. This, in turn, contributes to anisotropic properties – including superior physical properties over a wide temperature range, low thermal expansion and low mould shrinkage – especially in the parallel to flow direction.

Although ZENITE® resins are moulded at high melt temperatures, they allow much shorter cycle time versus other technical semi-crystalline or amorphous polymers. These opposing characteristics can be explained by the particular low specific heat of fusion (enthalpy) of these polymers, as shown in Table 1.

Table 1: Melting enthalpy of engineering polymers

Polymer family	Melting enthalpy [kJ/kg]
POM	140-180
PA	50-80
PBT	25-60
ZENITE® LCP	0,5-4

Table 2: Main grades

6130L	30% glass reinforced, good toughness, HDT 264°C
6130LX	30% glass reinforced, improved toughness, HDT 274°C
6140L	40% glass reinforced, high stiffness, HDT 272°C
6244L	20% glass and 20% mineral reinforced, low-warpage, HDT 273°C
6330	30% mineral, high elongation at break, excellent toughness, low warpage, smooth surface aspect, HDT 239°C
7130	30% glass reinforced, good toughness, HDT 289°C
7145L	45% glass reinforced, high stiffness, HDT 303°C

The main grades are displayed in Table 2. More information about ZENITE® products and properties are available in the “ZENITE® product guide and properties” or from datasheets at the following web address: <http://plastics.dupont.com>

Safety precautions

Whilst processing ZENITE® resins is ordinarily a safe operation, consideration should be given to the following:

- A. Since ZENITE® resins are moulded at high melt temperatures, the molten resin can inflict severe burns. Furthermore, above the melting point, moisture and/or gases may generate pressure in the cylinder which, if suddenly released, can cause the molten polymer to be violently ejected from the nozzle.

To minimise the risk of an accident, the instructions given in this manual should be followed carefully. Potential hazards must be anticipated and either eliminated or guarded against by following established procedures which including the use of proper protective equipment and clothing.

Be particularly alert during purging and whenever the resin is held in the machine at higher than usual temperatures or for longer than usual periods of time, i.e. longer than 15 minutes – as in a cycle interruption. Pay particular attention to the section on moulding interruptions 3.1.2.4. When purging, ensure that the screw forward speed is slow and that a purge shield is in place. Reduce the injection pressure and “jog” the screw forward button a few times to minimise the possibility that trapped gas in the cylinder will cause “splattering” of the resin as it exits from the nozzle of the machine.

Put the purged resin immediately into a metal container filled with cold water to limit the development of any smell and/or gassing.

If resin decomposition is suspected at any time, a purge shield should be positioned, the carriage (nozzle) retracted from the mould, and the screw rotated to empty the barrel. After the screw starts to rotate, the feed throat should be closed and then a suitable

purge compound introduced. The best purging is accomplished by using a high glass-reinforced PET such as RYNITE® 545 or 555, followed by a low melt index (<1,0) high-density polyethylene (HDPE). Do not use a flame-retardant grade of PET which could seriously degrade at these temperatures. Also, do not use higher melt index polyethylenes because they will not have enough viscosity at these temperatures to be an effective purge. The temperature can then be gradually lowered and the machine then shut down; see “Purging” in Section 3.1.2. Start-Up and Shut-Down Procedures for further details.

In the event that molten polymer does contact the skin, cool the affected area immediately with cold water or an ice pack and get medical attention for thermal burn. Do not attempt to peel the polymer from the skin.

Caution: do not heat PE above its flashpoint of approx. 340°C ! Danger of self-ignition !

- B. Since ZENITE® resins are dried at high temperature, contact with hot hoppers, ovens or air hose lines could result in severe burns. Insulation of these components will reduce this possibility and increase dryer efficiency.
- C. Small amounts of gases and particulate matter (i.e. low molecular weight modifiers) may be released during the moulding, purging or drying of ZENITE®. We recommend that adequate local exhaust ventilation be provided during the processing of ZENITE®. A ventilation rate of 5 m³ of air per minute per kg of resin processed per hour will keep the concentration of dust particles (and gases) below 5 mg/m³ for nuisance dusts whilst processing the material at the maximum recommended times and temperatures. For more details, refer to the DuPont publication “Proper use of Local Exhaust Ventilation During Hot Processing of Plastics”. A copy of this brochure is available from your DuPont representative or can be downloaded from following site: <http://plastics.dupont.com>
- D. ZENITE®, like all thermoplastic polymers, can form gaseous decomposition products during long hold-up times at the maximum recommended melt temperatures.
- E. When performing any regrinding operation, besides using equipment complying with current safety legislation, the installation should provide appropriate protection against noise and dust. Screens, filters and ventilation in good operating condition should be used. Operating personnel should wear adequate

personal protective equipment including gloves and a face shield.

- F. Prior to mechanical cleaning of any barrel that contains ZENITE® resins, the machine should be thoroughly purged with polyethylene.
- G. If ZENITE® resin is accidentally purged over the heater bands, it should be removed and not allow to degrade.
- H. Adequate local exhaust ventilation must be provided during the burnout of any equipment that contains ZENITE® resin, e.g. nozzles, etc.
- I. Granules of ZENITE® present a slipping hazard if spilled on the floor. They are cube shaped and have a low coefficient of friction. They should be swept up immediately.
- J. For any further information please refer to the “Material Safety Data Sheets”.

1.3 Material safety data sheets

Material Safety Data Sheets (MSDS) are supplied with the initial order of ZENITE® and on the next order after a MSDS is revised. They are also available on the Internet at msds.dupont.com. If you need assistance with one of our Material Safety Data Sheets (MSDS) please contact the DuPont Corporate Information Center at: +1-800-441-7515 (U.S.)
+1-800-387-2122 (Canada)
+1-302-774-1000 (outside the U.S.)

1.4 Handling and preparation of materials

1.4.1 Packaging

The precautions for handling ZENITE® resins are generally the same as those for similar glass-reinforced hygroscopic materials, e.g. polyesters and polycarbonates. ZENITE® resins are packaged in moisture-proofed bags, but the moisture content of the resins in this special moisture-proof bag will be higher than the maximum allowed moisture level for moulding. Broken or part bags should be well closed and properly sealed in order to prevent excessive moisture pick-up over time.

1.4.2 Storage

ZENITE® resins should be stored dry and storage should allow a “first in/ first out” inventory policy. Even though the bags are protected against moisture by a special lamination, some moisture pickup may well occur over time.

1.5 Environment and disposal of waste

In following the guidelines of this manual, the amount of processing waste and reject parts generated will be minimised. However, during the production of moulded

parts, a certain amount of non-reusable waste will still be generated. This waste should be disposed of properly.

DuPont recommends as the preferred option incineration with energy recovery. The incinerator has to be equipped with a state of the art scrubber in order to clean the flue gases before release to the atmosphere.

ZENITE® LCP is not soluble in water and has practically no additives which can be extracted by water. Therefore

ZENITE® LCP represents no known risk to human health or the environment when land filled.

For any disposal local regulations have to be observed which can vary significantly from locality to locality.

LCP is included as 'Solid Plastic Waste' in the 'green list' of the European Regulation EEC 259/93, Annex II. Thus, ZENITE® LCP is not restricted for inter European transport of waste destined for recovery.

2 Drying principles

2.1 Effects of moisture

The presence of excess moisture in the granules prior to moulding can cause degradation of the polymer through hydrolysis. The impact properties as shown in Fig. 1 show the effect of moisture and hold-up time (HUT) during processing. Therefore proper drying of granules prior to moulding is a key requirement to produce optimum quality parts.

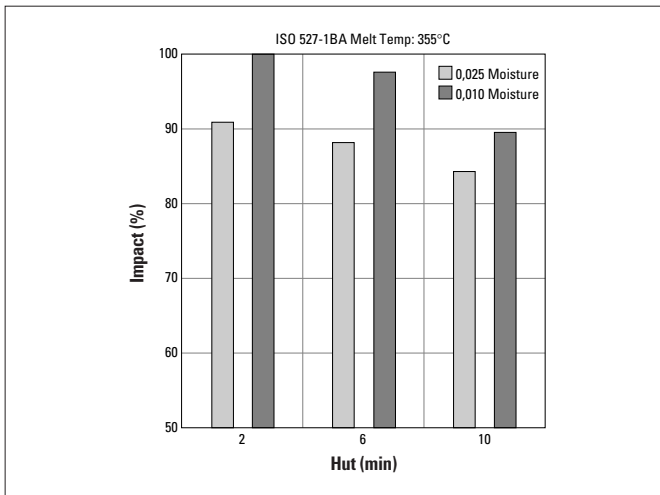


Fig. 1: Granule moisture content versus impact properties for ZENITE® 6130L at three hold-up times.

2.2 Moisture absorption

ZENITE® granules pick-up moisture fairly quickly under standard atmospheric conditions (Fig. 2). Therefore keep properly dried resin in closed containers and always put the cover on the hopper. Never put more resin into the hopper than which will be consumed in less than 30 minutes. Though ZENITE® LCP resins do not absorb high amounts of moisture (see Fig. 3, one year immersion of ZENITE® 6130 in water at 23°C).

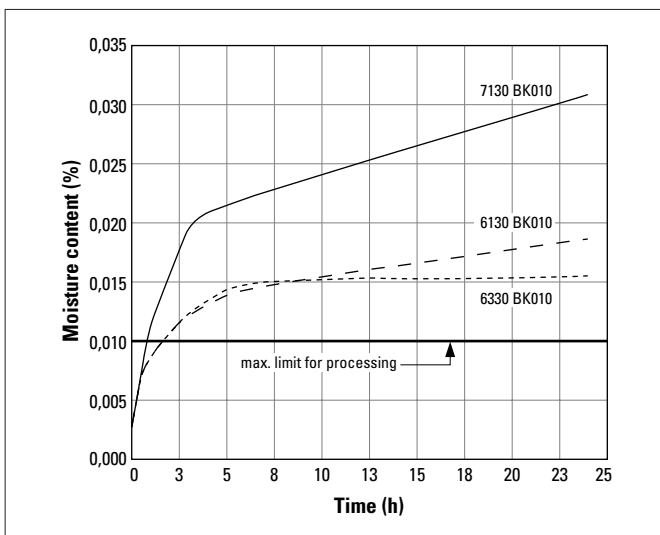


Fig. 2: Moisture absorption of ZENITE® granules at 23°C, 50% RH.

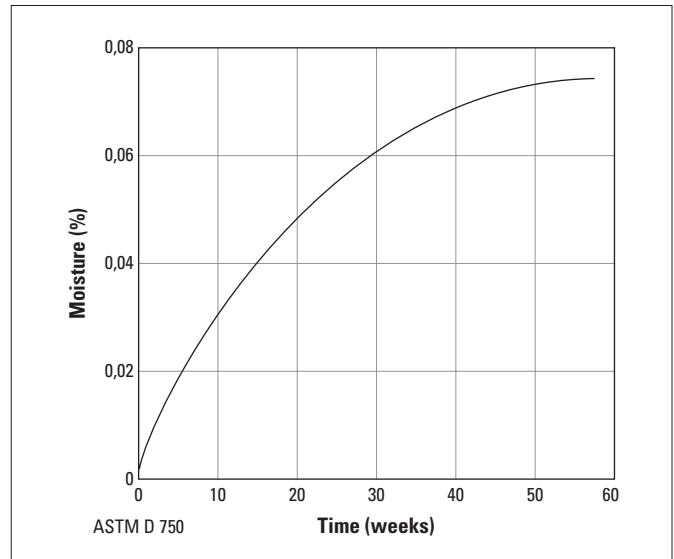


Fig. 3: Water absorption of a moulded part in ZENITE® 6130 immersed in water at 23°C.

2.3 Drying conditions

Moisture levels less than 0,010% prior to processing are recommended for optimum properties. The virgin resin is supplied somewhat above this level in a moisture-resistant package. Therefore, any resin (virgin or regrind) must be dried before processing to avoid any chance of hydrolytic degradation. If degradation should occur because of excessive moisture, there will be no evidence (such as splay) on the surface of the parts. Fig. 2 shows moisture pickup of granules in a standardised atmosphere. Fig. 4 shows drying data for standard grades. Table 3 summarises the recommendations for resin from the bag and for resin or regrind of unknown moisture history.

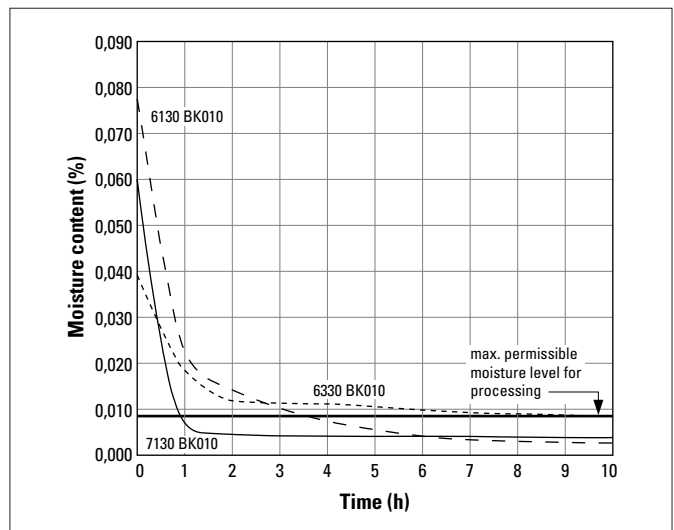


Fig. 4: Drying curve at 160°C, dewpoint -35°C.

Table 3: Recommended drying times in a dehumidifying (or desiccant) dryer

Drying temperature	120° C	140° C	160° C
<i>Resin from the bag</i>			
Glass reinforced resins, i.e. 6130, 6140, 7130, 7145, 6244, etc.	4 h	3 h	2 h
Mineral reinforced resins, i.e. 6330, 77340, etc.	8 h	6 h	4 h
<i>Resin of unknown moisture, regrind, etc.</i>			
Glass reinforced resins, i.e. 6130, 6140, 7130, 7145, 6244, etc.	8 h	6 h	4 h
Mineral reinforced resins, i.e. 6330, 77340, etc.	10 h	8 h	6 h

Comment:

Drying time is valid for continuous drying process. In case of a batch drying process, please add the time it takes to heat the resin to the respective drying temperature. If this time is unknown, add 2 h.

2.4 Drying equipment

a. Desiccant dryers

Pre-drying with desiccant dryers is the most reliable and economical drying method. Monitoring and controlling of desiccant dryers takes place by determination of the dew point. The dew point indicates directly the proportion of water in the air. Values of -30°C and below for the dew point give efficient drying. Drying with desiccant dryers is independent of atmospheric influences. Adequate maintenance (i.e. regular filter cleaning) is important to ensure maximum airflow and to avoid filters becoming blocked.

b. Circulating air oven

The efficiency of drying in a circulating air oven depends on atmospheric conditions at the time. High humidity of the air reduces the level of drying. Therefore it is difficult to achieve a consistent drying result and this equipment is not recommended

c. Vacuum dryers

Vacuum dryers are for economical reasons normally used only in laboratories. Under vacuum, heat energy is transferred almost exclusively by radiation. This results in a long heating time. The recommended drying time is therefore 50% longer than the recommended drying time in Table 3.

d. Degassing

The use of degassing units on injection moulding machines is, with the current state of the art, not a fully equivalent alternative to proper drying. The main reason for this is the hydrolytic degradation of the ZENITE® LCP polymer melt that occurs before it reaches the vent port.

e. Conveying systems

For the sake of a consistent granule moisture content prior to moulding, it is recommended that dry air is used in the conveying system. The dried resin should not be exposed in the hopper to atmosphere for longer than 30 minutes.

3 Moulding

3.1 Process

3.1.1 Injection unit

ZENITE® LCP resins can be moulded in all standard screw injection moulding machines. General-purpose screws are usually adequate. ZENITE® LCP resins, like all other glass-reinforced resins, may cause wear in certain areas of the barrel, screw and mould. When moulding large quantities of ZENITE® LCP resins, the abrasion resistance of standard nitrided equipment may not be satisfactory. In these cases, you may consider the suggestions in following chapters.

Further requirements for optimum and consistent part quality are high-temperature ceramic heater bands, PID control on all zones (including the nozzle) and a L/D ratio of minimum 20/1. For some machines, there is a single controller for both the nozzle and the head cap heater bands on the front of the barrel. For very difficult to mould parts, this may cause problems with inconsistent temperature control since one thermocouple then controls two zones which ramp up and down in temperature at different rates as the controller switches off and on.

Regular maintenance of the injection unit help to eliminate screw retraction problems and inconsistent cushion read-outs. Critical dimensions to be checked are:

- Inner diameter of cylinder, especially in the metering zone.
- Screw diameter (i.e. flight wear).
- Floating check ring diameter.

3.1.1.1 Screw

The general-purpose gradual compression screws that are installed in most moulding machines are usually suitable for moulding ZENITE® LCP resins. Successful moulding has been accomplished with screw compression ratios ranging from 2,0/1 to 3,5/1. For uniform melt homogeneity, a minimum length/diameter ratio of 20/1 is recommended.

LCP resins, in general, have extremely low viscosity and are moulded at high melt temperatures. This may result in screw retraction inconsistency in the case of excessive screw and barrel wear or too high residual back-pressure of the moulding machine. Even with programmed zero back-pressure, the real residual back-pressure caused by mechanical friction and the piston seal of the hydraulic cylinder may exceed 4 MPa on the resin. Under specific circumstances (screw, cylinder wear, resin viscosity) the pumping effect of the rotating

screw may not be sufficient to push back the screw with the molten material. Some newer moulding machines are able to compensate for this excessive residual back-pressure by allowing negative input values for back-pressure. In all other cases it will be necessary to work either on injection unit maintenance or to use a specific screw-design that improves the pumping effect by using a shorter flight pitch. It must be taken into account that such 3-zone screws with optimised pumping effect will have lower throughput and may thus require longer screw retraction time.

An optimised screw for ZENITE® LCP would be designed following these rules

L/D ratio: minimum 20/1

Compression ratio: minimum 2,4/1

Feeding zone length: minimum 50%, preferably 60%

Metering zone length: approx. 20%, not greater

Metering zone depth: 1,8–2,2 mm

Feeding zone depth (according to compression ratio): 4,2–6,0 mm

Pitch: $0,9 \times$ screw diameter

Total clearance on diameter

(between barrel and screw land): max 0,3 mm

Very small (<18 mm) and large screws (>50 mm) may require a wider interpretation.

As screw design experience is changing over time, please consult a DuPont technical representative to get further advice.

Since DuPont cannot anticipate all variations in end-use conditions DuPont makes no warranties and assumes no liability in connection with any use of this information.

3.1.1.2 Back flow valve

The back flow valve or check ring shown in Fig. 5 prevents melt from flowing backwards during injection. It is possible that this unit is not properly designed to eliminate hold-up of resin and flow restrictions. Malfunctioning that allows resin backflow during injection is also common and is caused by poor design or maintenance. A leaking non-return valve will add to screw retraction time, which can increase cycle time, and it will also cause poor control of filling and part dimensional tolerances.

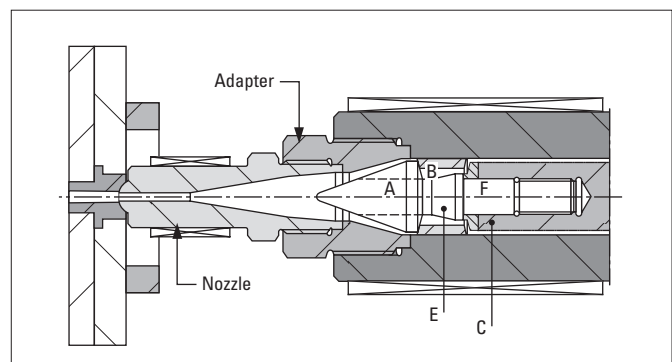


Fig. 5: Design of adaptor and back flow valve.

The non-return valve must meet the following requirements:

- No hold-up spots.
- No flow restrictions.
- Good seal.
- Control of wear.

These requirements are provided for in the back flow valve shown in Fig. 5.

The slots or flutes (A) in the screw tip are generously sized, and the space (B) between the check ring and tip is sufficient for resin flow.

The seating of the fixed ring is cylindrical (not conical) where it joins both the end of the screw (C) and the screw tip (E) in order to allow accurate matching of these diameters to avoid hold-up areas.

The screw tip thread has a cylindrical section (F) ahead of the thread that fits closely into a matching counter-bore for support and alignment of the screw tip and fixed ring. The screw tip and check ring seat should be harder (about HRC 62) than the floating ring (HRC 55), because it is less expensive to replace the floating ring when wear occurs.

Wear resistant steel is suggested for the tip. Good matching of cylindrical diameters is essential to avoid hold-up spots.

3.1.1.3 Corrosion/Abrasion

ZENITE® LCP resins, like other glass- or mineral-reinforced resins, can cause wear in certain areas of the barrel, screw and mould. When moulding large quantities of these resins, certain precautions should be taken to minimise wear effects in the equipment and moulds. To improve the injection unit when processing glass-reinforced resins such as ZENITE®, hard surfacing alloys and /or wear resistant steels should be used for barrels, screws and back flow valves.

Tests on bimetallic and specially treated injection units (barrel, screw and back flow valve) show a significant lifetime improvement versus standard nitrided equipment. In order to minimise screw wear, special abrasion and corrosion resistant steels (i.e. powdermetallurgic steels) and treatments are available.

Please contact your machine and screw manufacturer for further details and recommendations. Specific corrosion resistance treatments of the injection unit is normally not required for moulding ZENITE®.

3.1.1.4 Nozzles

Open nozzles

Conventional free-flow type nozzles (see Fig. 6) can be used, especially with small orifice diameters (i.e. <2,5 mm). For larger diameters, surface finish requirements, minimising cold slug formation or if drooling is a problem, the use of a reverse taper bore nozzle (see Fig. 7) is highly recommended. The reverse taper length should be approx. 8-10 times the diameter of the thicker end.

The nozzle temperature must be independently and precisely controlled. The heater band must cover the full length of the nozzle. The thermocouple should be placed as far forward as practical for correct temperature control of the nozzle. High wattage ceramic heater bands should be used to maintain temperatures up to 380°C. Although not recommended, positive shut-off nozzles may be used when proper temperature control is provided. Again, streamlining is important and the risk of hold-up spots could be a concern.

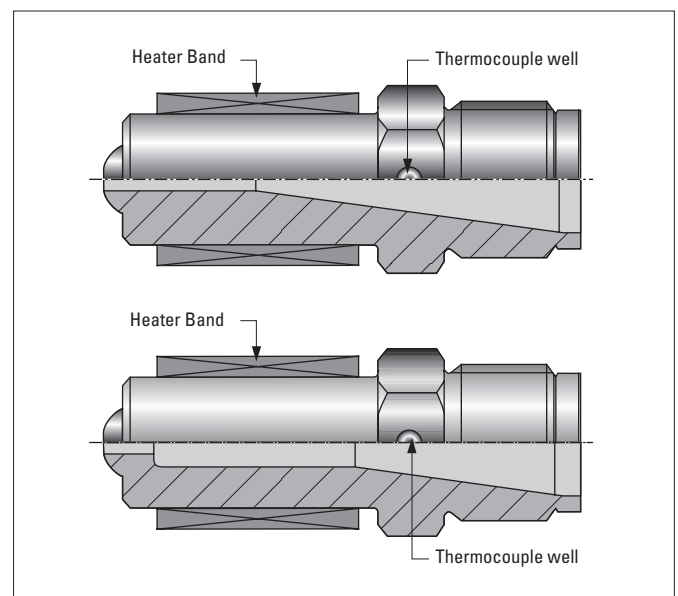


Fig. 6: Free flow nozzles.

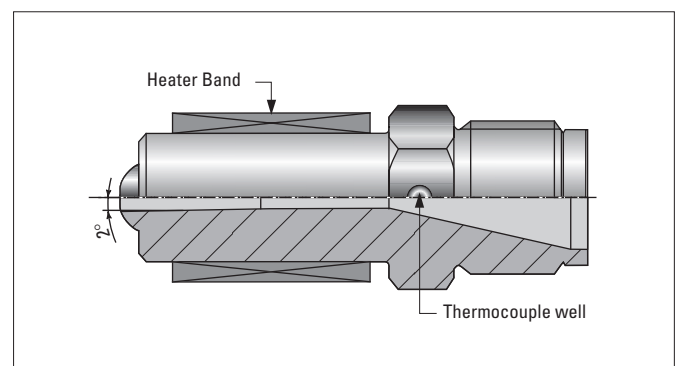


Fig. 7: Reverse taper nozzle for ZENITE®.

Shut-off nozzles

Generally the use of shut-off nozzles should be avoided, as most shut-off nozzle systems would struggle to work satisfactorily at temperatures above 350°C. Specifically designed needle-shut-off systems with special surface treatment of the melt channel, together with specifically well designed temperature balance may be beneficial in terms of surface aspect when moulding large, esthetical parts in mineral reinforced ZENITE® grades, or when screw retraction needs to be extended into the mould opening phase, which may lead to a reduction in cycle time.

3.1.1.5 Accumulator for thin wall applications

ZENITE® grades generally require fast injection speed. Many LCP applications are small and thin-walled, requiring a machine capable of injecting within the 0.2-0.5 seconds range. Machines equipped with an accumulator may help to increase injection speed resulting in increased flow lengths, especially in applications with very thin walls. For those machines without accumulators, it may be possible to achieve fast injections speeds by only using moulds where the shot size is less than one screw diameter.

3.1.2 Start-up and shutdown procedures

3.1.2.1 Purging

Purging is essential before and after moulding ZENITE® LCP resins because many plastics (including other lower melting point LCPs) degrade at ZENITE® LCP melt processing temperatures. Therefore, contamination with other resins (including other LCP resins) may cause moulding difficulties or resin decomposition. Refer to Chapter 1.2. "Safety Precautions" for advice on proper handling of the purged resin. The best purging is accomplished by first using a high glass-reinforced PET such as RYNITE® 545 or 555, followed by a low melt index (<1,0), high-density polyethylene (HDPE). Do not use a flame-retardant grade of PET which would seriously degrade at these temperatures. Also, do not use a higher melt index polyethylene which will not have enough viscosity at these high temperatures to be an efficient purge.

Note: When the cylinder temperatures are above 290°C, the polyethylene must be continually purged because resin decomposition and ignition of the vapours may occur.



CAUTION: do not heat PE above its flashpoint of approx. 340°C! (There is a danger of self-ignition!)

Polystyrene should not be used to purge as it will decompose at ZENITE® processing temperatures. The following purge procedures are recommended:

From other resins to ZENITE® LCP resins:

1. Retract the injection unit, close the hopper throat and increase the back pressure so that the screw is held in the forward position.
2. Run the screw at high rpm and pump out at its melt temperature as much of the other resin as possible. Introduce the low melt index polyethylene purging material and feed until the extrudate comes out cleanly.
3. Empty the cylinder of polyethylene purge, raise temperature settings and proceed as outlined in the following Start-Up section 3.1.2.2.

From ZENITE® LCP resins to other resins:

1. Retract the injection unit and increase the back pressure so that the screw is held in the forward position.
2. Run the screw at high rpm and pump out at its melt temperature as much of the ZENITE® LCP resin as possible. Lower the temperature settings to 300°C and at the same time feed RYNITE® 545 or 555 until no further traces of ZENITE® LCP resins appear. Pump out as much of the RYNITE® resin as possible.
3. Lower the cylinder temperature settings to 290°C and feed the low melt index, polyethylene purging material until the extrudate comes out cleanly. Empty the cylinder of the polyethylene and proceed to start-up conditions for other resins or shut down.

3.1.2.2 Start-up

The cylinder and screw should be cleaned prior to start-up by using the method described under "Purging".

The recommended start-up procedure is:

1. Set the cylinder temperatures 30°C and the nozzle temperature 10°C below the minimum processing temperature for the grade of ZENITE® to be moulded. Allow the heat to "soak in" for at least 20 min. Raise the cylinder temperatures to the desired operating temperatures. (Use Table 4 Typical ZENITE® cylinder temperatures as a guide.)
2. Check to make sure that the nozzle is at the set temperature and that it is open and contains no frozen material.
3. Jog the screw. If the screw will not rotate, allow a longer heat "soak in" time.
4. When the screw begins to rotate, open the hopper feed slot briefly and then close it. As the material is being pumped forward by the screw, check the load

on the screw motor. If it is excessive, increase cylinder temperatures.

5. Open the feed slide and increase back pressure to hold the screw in the forward position. Extrude melt and adjust operating conditions (screw rotation speed and estimated delay time) until the melt shows no indication of unmelted particles or degradation. A good melt will be smooth in appearance. If the melt is foamy, degradation is occurring. Once the melt looks smooth, release the back pressure.
6. Take several air shots with the stroke size and cycle time anticipated for the moulding operation. Then try to check the melt temperature with a handheld pyrometer. Since ZENITE® LCP resins melt quickly and set up equally as fast, more than one melt temperature measurement may be needed to obtain an accurate melt temperature. Make any necessary adjustments in the cylinder temperatures to achieve the recommended melt temperature.
7. Start moulding on cycle at low injection fill pressure (except where short shots will interfere with part ejection) and then adjust operating conditions to produce quality parts.
8. Recheck the melt temperature

3.1.2.3 Shutdown

1. Retract the injection unit, close the hopper throat and increase the back pressure so that the screw is held in the forward position.
2. Run the screw at high rpm and pump out at its melt temperature as much of the ZENITE® LCP resin as possible. Lower the temperature settings to 300°C and at the same time feed RYNITE® 545 or 555 until no further traces of ZENITE® LCP resins appear. Pump out as much of the RYNITE® resin as possible.
3. Lower the cylinder temperature settings to below 290°C and feed the low melt index, polyethylene purging material until the extrudate comes out cleanly. Empty the cylinder of the polyethylene and shut down, once the barrel temperatures are below 290°C.

3.1.2.4 Interruptions

Due to the excellent thermal stability of ZENITE® LCP resins, minor cycle delays up to 10 minutes can usually be tolerated without purging and loss of material. Although it is good practice to purge the cylinder once prior to start-up and to eliminate the first moulded parts until the process has reached its thermal balance again. If the delay is expected to be longer than 10 minutes (or reaches 10 minutes), empty the resin from the cylinder as some degradation will occur. No purge compound is

necessary at this time. The cylinder temperatures should be lowered to 250-300°C. Upon resumption of the run, raise the temperatures and reintroduce the ZENITE® LCP resin per the startup procedures.

For anticipated delays greater than a few hours, the resin must be purged sequentially with RYNITE® 545 or 555 polyester resin, followed by a low melt index polyethylene as described in the procedure for purging from ZENITE® LCP resins to other resins.

3.2 Parameters

3.2.1 Melt and cylinder temperature

As with all resins, achieving and controlling the desired melt temperature is essential for successful moulding. The melt temperature achieved is a result of cylinder and screw design, heater design, screw back pressure, screw rotation rate (rpm), shot size and overall cycle time. Table 4 provides “typical” cylinder settings. N.B. these can vary widely depending on the particular moulding machine used.

Taking into account the short cycle time when moulding ZENITE®, the typical injection stroke would be in the range of 15-30% of the machine’s maximum stroke. This allows standard machines to reach the appropriate volume flows with relatively short injection times.

Table 4: Typical ZENITE® cylinder temperature settings

ZENITE® resin series	Typical cylinder temperatures			Preferred melt temp. range °C
	Rear °C	Center °C	Front °C	
6xxx series	340	345	355	350-360
7xxx series	350	355	365	360-370
77xxx series	355	360	370	365-375

Fig. 8 suggests adjustments to the cylinder temperature settings based on hold up time (HUT) and injection stroke.

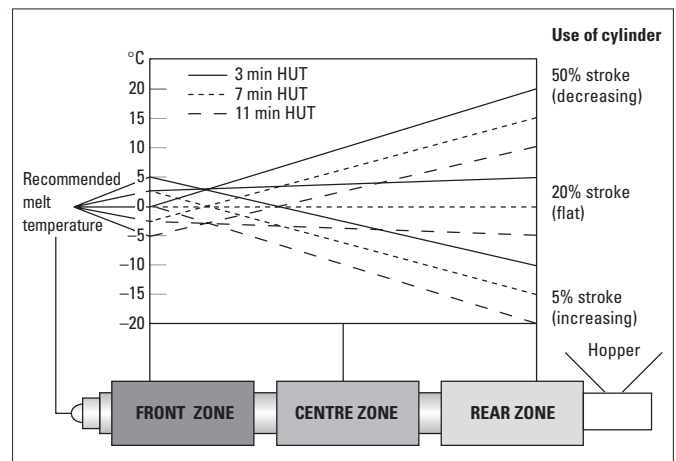


Fig. 8: Zone temperature adjustment versus HUT and stroke.

Because it is not possible to accurately predict the combined effect of all the variables, the actual melt temperature should be measured after the machine operation has reached equilibrium. This is best done by taking air shots into an insulated container and measuring with a fast-response (needle probe) pyrometer. In order to properly measure the melt temperature, three or more air shots may be required. In general, settings are normally slightly lower than desired melt temperature due to heat provided by the screw working with the resin.

ZENITE® LCP resins exhibit excellent melt stability.

These resins have broad melting points versus other engineering plastics. The minimum melt processing temperature is above the bottom limit of the broad melting point range as seen in Fig. 9 and Fig. 10 and listed in Table 4.

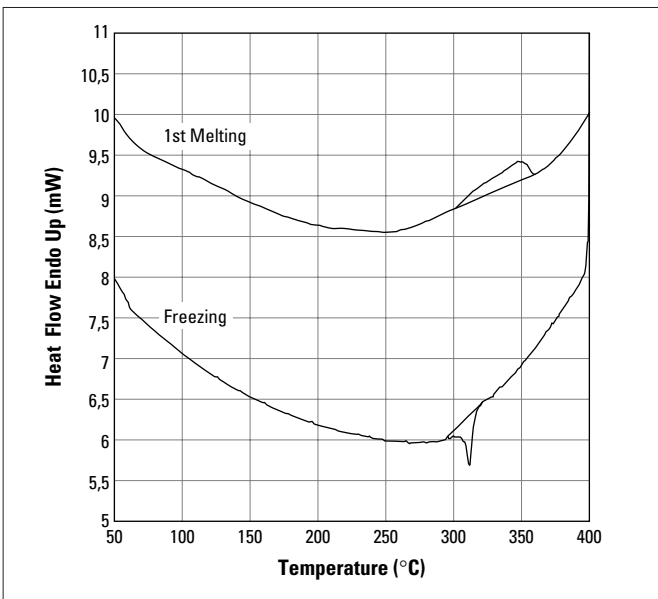


Fig. 9: DSC of ZENITE® 7130L WT010.

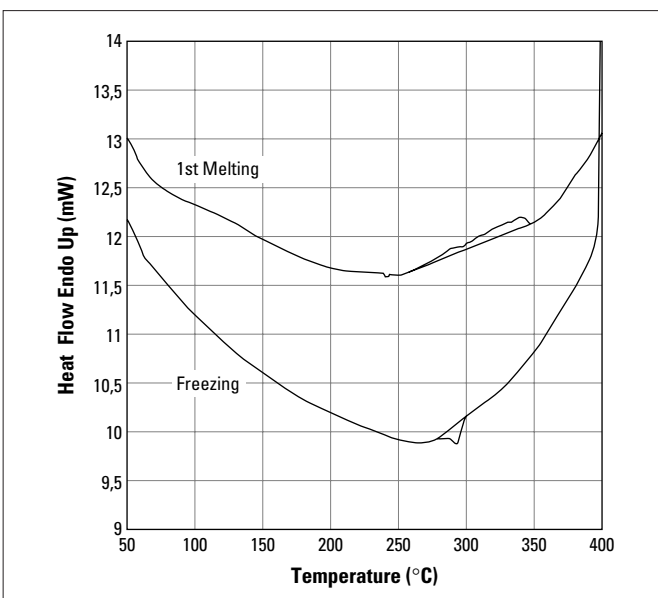


Fig. 10: DSC of ZENITE® 6130L WT010.

Although the resins can physically be moulded below the minimum temperature given in the preferred melt temperature ranges, poor physical properties – especially brittle parts – could result. Therefore, the resins should not be moulded below the minimum melt temperature values listed in Table 4.

ZENITE® resins give optimum part quality at the recommended melt temperature and at short hold-up times (HUT < 6 min). It should therefore be standard practice to optimise cycle time and to choose the appropriate cylinder size when selecting machines to mould ZENITE®.

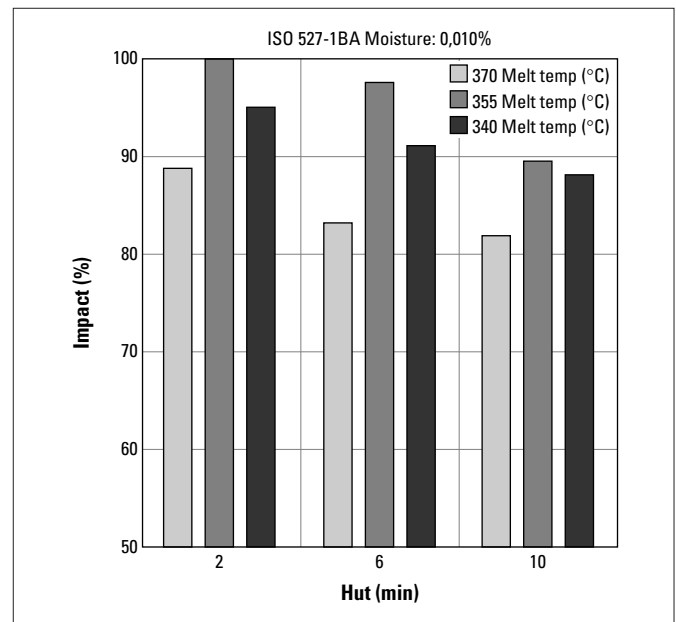


Fig. 11: Effect of melt temperature and HUT on impact properties of ZENITE® 6130L.

3.2.2 Cavity temperature

ZENITE® resins mould well over a wide range of mould temperatures. Mould surface temperatures from 40°C to 150°C have been used. The most common range is 65-110°C.

High temperatures should be used for thin, hard-to-fill parts. (Good safety practices require using high-temperature rated hoses with swaged fittings for hot water or hot oil heaters.) Lower temperatures are recommended with complex parts experiencing sticking problems.

Since mould surface temperature is a product of many variables (not just the cooling fluid), it must be measured after start-up (when the process has stabilised, normally after about 10 shots) and after any major process change.

Unlike many other materials, the effect of mould temperature on shrinkage and post-moulding shrinkage is quite small. The effect on transverse flow and thickness is not measurable. On highly aligned flow parts, there is a measurable effect in the flow direction as the molecu-

lar alignment is further ordered at higher mould temperatures or when annealed at very high temperatures. In each case, this alignment results in part growth once out of the cavity, such that the part can eventually be larger than the cavity dimension.

3.2.3 Injection phase

Injection fill rate is a key variable in the moulding of ZENITE® LCP resins. Fig. 12 shows the significant effect melt temperature has on melt viscosity. Likewise, Fig. 13 depicts the high sensitivity of these resins to shear rate. Therefore, in order to capitalise on their low viscosity and high flow capabilities, very high fill rates need to be used over almost 100% of the stroke. Fill (or ram-in-motion) times of 0,3-0,8 s are very common in small parts such as electronic connectors and bobbins.

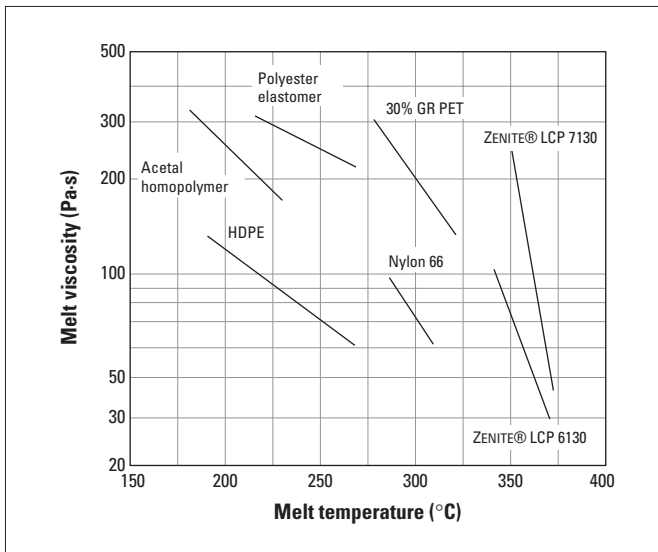


Fig. 12: Melt viscosity versus melt temperature at 1000 s^{-1} shear rate.

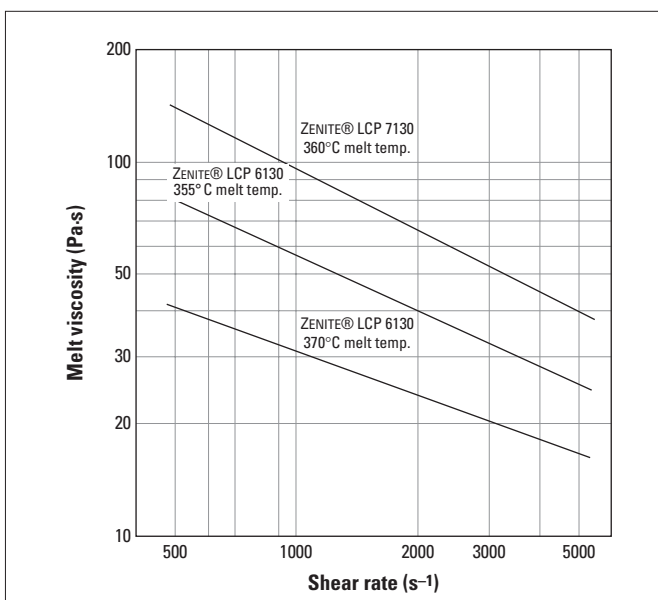


Fig. 13: Melt viscosity versus shear rate.

Fast injection rates also contribute to the material's anisotropic properties, including high physical properties, low thermal expansion and low mould shrinkage in the flow direction.

When the fill rate is reduced, the viscosity is significantly increased such that the polymer's flow can quickly stop and set up. Fast injection implies a high shear rate, which contributes to maintaining the melt front temperature above its freezing point. This assumes adequate venting to allow efficient gas evacuation. For details refer to chapter 4.6.

The injection fill pressure during the dynamic mould filling phase is a function of:

- the programmed injection speed;
- material viscosity at its melt temperature;
- material set-up rate;
- cavity flow resistance (geometry, wall thickness, flow length).

The resulting injection fill pressure may be much lower than hold pressure, e.g. for thick parts and short flow length, or even much higher than hold pressure, e.g. for thin parts and long flow length.

3.2.4 Hold pressure phase

The complexity of the part and its effect on ease of ejection will determine the optimum hold pressure. For complex parts, it is recommended to start with low (e.g. 15 MPa) hold pressure and then increase it in small increments. Because these resins set up very quickly, the gates will quickly freeze and pack time is quite short versus other thermoplastic resins. Most thin-walled parts are typically moulded with a hold pressure time in a range of 0,1-0,8 s at a constant specific hold pressure in a range of 20-60 MPa. Thicker parts (>1,5 mm) may require a hold pressure time of about 1 s per mm wall thickness. Due to the low shrinkage of ZENITE® LCP resins, it is possible to overpack and stick parts, especially in the area of ribs, domes and the sprue. Therefore, hold pressures and times should be increased carefully.

3.2.5 Screw retraction phase

Screw decompression

Screw decompression (or suck-back) should be a minimum and only used when necessary. Nozzle drooling can be reduced by correctly drying the resin, proper nozzle temperature setting (with good temperature control) and if necessary, using a reverse taper nozzle.

Screw rotation speed

In order to balance glass fibre breakage and optimum melt homogeneity, the screw speed should be medium. The following formula allows a rough approximation of the optimal screw speed:

$$RPM = \frac{4000}{D}$$

with D = screw Diameter in mm.

When facing screw retraction inconsistencies, the RPM may need to be increased.

Back pressure

Typically ZENITE® LCP resins are moulded with little or no back-pressure. Where small silver streaks are observed on the part surface, the back pressure should be raised gradually to get rid of the air, which can go right through the cylinder with the molten polymer.

Some new moulding machine types allow for compensation of excessive residual back-pressure by permitting the input of negative values for back-pressure. This may help in cases where screw retraction is inconsistent. Please refer to chapter 3.1.1.1. for further details.

4 Mould

4.1 Mould temperature control

ZENITE® LCP processing can be carried out with mould temperatures in the range of 40-150°C. Generally, a mould temperature of approximately 90°C is sufficient to obtain good quality parts. Moulds containing elements that are difficult to cool (pins, cores) may be set to lower temperatures to increase the heat-flow from these respective elements to the mould base. High mould temperatures may improve slightly the surface finish of the part.

4.2 Abrasion resistance

ZENITE® LCP resins are not corrosive to moulds, unless there is insufficient venting. This can lead to trapped gas due to the high injection fill rates of the resin causing damage. However, glass, mineral and other fillers may be abrasive and tool steels for cavities, cores, runner systems and sprue bushings should be selected and hardened as with other filled engineering polymer resins. Also, as a result of the fast injection rates used in processing ZENITE® LCP resins, gates are subject to considerable heat build-up and loss of hardness.

In practice, only very local abrasion problems have been sporadically observed, mainly in areas where the melt does not meet the condition of laminar flow, i.e. jetting, opposite hot-runner gates, or too small gates for a large fill volume. In these cases the wear must be managed and some of the suggestions in this chapter may lead to significant improvements.

4.2.1 Steel selection

Typical tool steels as used in high-precision and high-performance injection moulding tools for glass-reinforced engineering polymers are suitable for ZENITE® LCP. Some cold work steels, such as 1.2162 (HRC up to 54) and the austenitic 1.2379 (HRC up to 58) are being used, though they bear the risk of softening, when their temperature limit is reached. High quality hot work steels, such as 1.2343 and 1.2344 (HRC up to 56) are commonly being used in the mould manufacturing of small component applications. A further option with improved abrasion resistance are powdermetallurgic (PM) steels. They allow HRC to reach up to 68, whilst still maintaining an acceptable ductility.

Please consult your toolmaker to make the right choice of steel for an appropriate balance of hardness, wear resistance, ductility, heat conductivity, dimensional stability and tooling capability.

4.2.2 coatings

Both physical vapour deposit (PVD) and chemical vapour deposit (CVD) may lead to improved wear resistance and easy ejection, thus they increase intervals between mould maintenance. They may potentially reduce cycle time. Both technologies require the right steel selection and compatible hardening and annealing processes, otherwise, they do not improve the performance of the steel used.

PVD coatings are applied at temperatures between 280 and 500°C. Their typical thickness is between 2 and 6 µm. Technically it is not feasible to add PVD into holes or into sharp corners. A very common multi-purpose PVD coating is TiN, which has a yellow colour and therefore gives visual verification of tool abrasion. It increases surface hardness significantly and reduces the ejection force in most cases by approximately 50%.

CVD coatings are applied prior to the hardening and annealing of the tool steel. They are applied in similar thickness to PVD coatings, but they also coat holes, inner diameters and corners. Therefore they are suitable for sprues, machine nozzles and specific tool elements.

PVD and CVD coatings are not recommended in order to significantly reduce gate wear or “jetting” wear. In these cases consideration should be given to inserting specific inserts as described in chapter 4.2.3.

For further recommendations, please consult your mould maker and respective companies specialising in high-performance coatings.

4.2.3 Inserts

In local areas of severe abrasion (jetting, gates, walls opposite hot runner nozzles etc.) it may be advisable to manage the wear with replaceable inserts. These can be made of high quality tool steel, PM steels, sinter metal or hard metal, depending on the geometry, required ductility and lifetime expectations.

For specific recommendations and solution suggestions, please consult your toolmaker.

4.3 Stiffness

ZENITE® LCP requires fast injection fill speeds. In thin wall applications the specific injection fill pressure may even exceed 100 MPa. Therefore a stiff mould construction will make an important contribution to:

- flash free moulding;
- increased lifetime of the mould;
- more robust processing window (e.g. allows faster injection speed).

Recommendations for increasing mould stiffness:

- use thick bolster plates and back plates;
- use large spacer blocks;
- use a very stable frame when using many inserts or large hot runner systems;
- use support blocks in the ejector box between the rear back plate and bolster plate.

4.4 Runner system

4.4.1 Layout

In designing the feed system, the first point to be considered is the wall thickness (t) of the moulded part (see diagram). Nowhere should the diameter of the runner be less than the wall thickness of the injection moulding. Starting out from the gate, the runner diameter at each branch point can be slightly increased (see Fig. 14) so that an almost constant shear rate is maintained. To prevent the inevitable cold slug reaching the moulding from the injection nozzle, the sprue should always be extended so that the cold slug can be trapped. This extension should have roughly the same diameter as the sprue to ensure that the cold slug really is retained. When moulding liquid crystalline polymers, the maximum gate thickness should be 50% of the wall thickness of the moulded part. Depending on the part weight and wall thickness, gate thickness down to 20% of the wall thickness or 0,15 mm have given good parts. It is good practice to start first with a relatively small gate, and then to open it up to match the requirement of the process and part. Gate length is especially crucial. This should be <1 mm to prevent premature solidification of the gate.

4.4.2 Tunnel gates

Proper demoulding of tunnel gates requires a certain flexibility of the solidified polymer in the runner.

Fig. 15 shows critical details that need attention in order

to allow positive functioning of tunnel gates. Basically the runner prior to the gate should be flexible (thinner is better). The dive angle of the tunnel gate is differentiated versus other engineering polymers in a way that it is much steeper in order to minimise deformation of the tunnel gate during ejection.

4.5 Hot runner

When injection moulding liquid crystalline polymers using runnerless technology, the choice of the correct hot runner system determines the functioning of the mould and moulded part quality. When using any hot runner the temperature must be controlled much more precisely than with any other polymer. The type of hot runner system used, and its installation, will have a great effect on the properties of the finished parts.

The key to success is to effectively thermally isolate the hot runner and nozzles from the cavity and mould platens, as this is the most efficient way to get optimum thermal balance and to minimise power requirement in use. The more power a hot runner requires, the higher are local differences in temperature. Nozzles should be designed so that naturally balanced runners can be used. This is the only way of ensuring uniform pressure losses, equal filling times and the same melt residence time for all the mould cavities. Generally, and specifically in the case of small shot weights, indirect gating is preferable to direct gating. Material throughput per nozzle increases, so that the heat applied to the moulding material is more easily manageable. Gates for hot runner nozzles can be large and the gate on the moulded part remains small through conventional cold runner gating. A cold slug trap must in any case be incorporated facing the hot runner nozzle. This is the only way of preventing cold material getting into the moulded part from the hot runner nozzle.

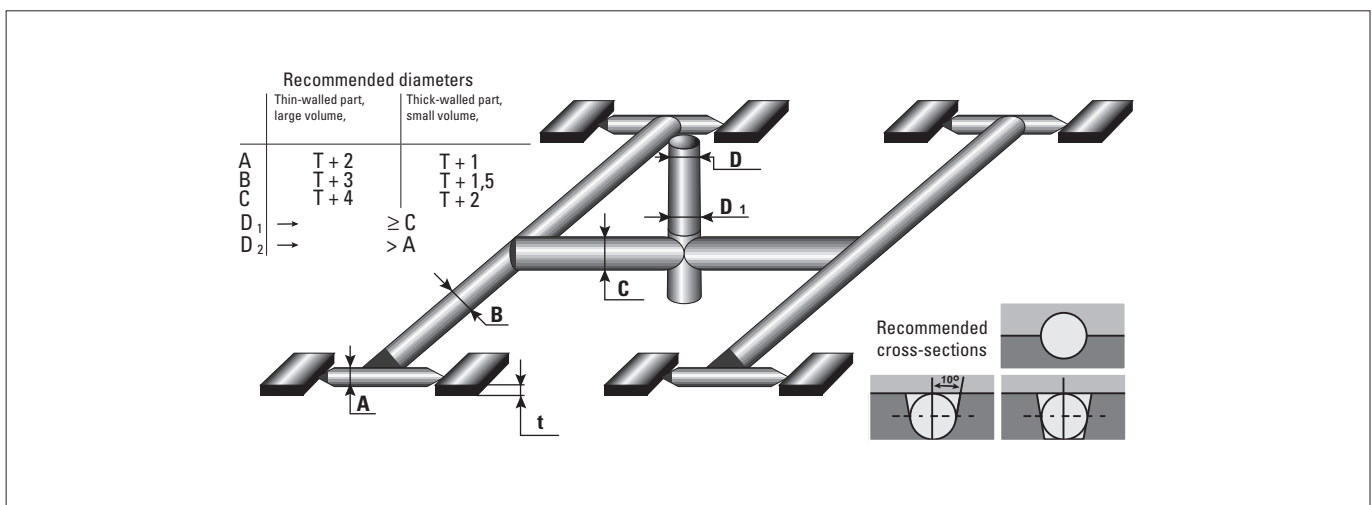


Fig. 14: Design of a multiple runner.

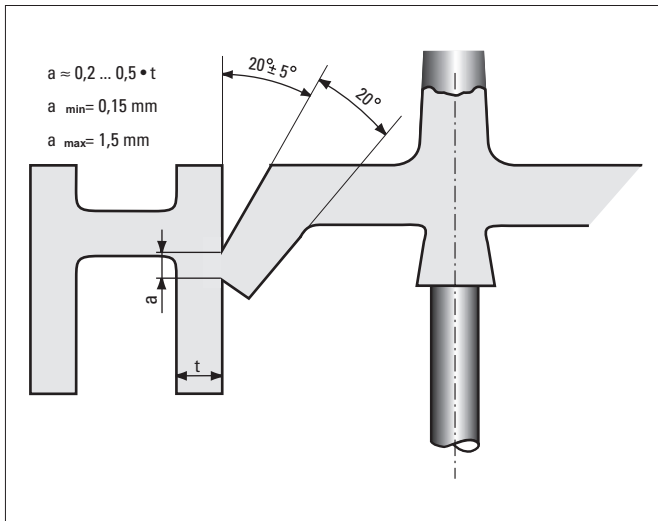


Fig. 15: Typical tunnel gate suitable for moulding LCP.

Due to the relatively high melt temperatures of ZENITE® LCP, DuPont does not encourage the use of hot runner systems for aesthetic parts, safety related parts, use of coloured material, or parts made out of resins requiring melt temperatures $>370^{\circ}\text{C}$.

Specific attention is required to control abrasive wear in all areas where laminar flow is questionable, specifically torpedo tips, gates and the wall opposite the gate (jetting). It is good practice to use exchangeable high performance wear resistant steel inserts in these areas.

When engineering a mould with hot runner technology, it is an absolute must to consult the hot runner supplier early in the tool design phase to tailor the system to the needs of LCP processing, such as

- natural balancing;
- wear management;
- perfect thermal balance;
- optimised thermal insulation;
- perfect streamlining;
- no hold up spots;
- self-adaptable PID control;
- maximum hold-up time 10 minutes (cylinder plus hot runner);
- easy cleaning;
- indirect gating preferred;
- cold slug trap;
- enough power at the nozzle tip to melt frozen tips within 1 minute.

4.6 Venting

The high filling speed used when moulding ZENITE® LCP, together with the continuously increasing mould mak-



Safety advice:

Always retract the nozzle before doing anything inside an open hotrunner mould and wear appropriate protective equipment, i.e. safety glasses and protective gloves.



ing precision means spending specific attention to the venting of the mould.

Inadequate mould venting can cause the following problems:

- Poor weld line strength.
- Discolouration (burning).
- Erosion and/or corrosion of the mould.
- Dimensional variation on the moulded part.
- Short shots.

Both cavities and runners should be vented at the parting line or at the ejector as recommended on Fig. 16. The vent land should be preferably short (i.e. 0.7 – 1,0 mm) to minimise airflow restriction. The depth of the secondary vent should be above 0,8 mm, dependant upon cavity volume and vent channel length.

4.7 Draft angles

Mould surfaces that are perpendicular to the parting line should have draft to allow easy part ejection. These include ribs, bosses and sides. A taper (draft angle) of 0,5 to 1° per side is usually satisfactory with ZENITE® LCP.

However, an additional 0,5-1,5° may be required for complex parts, parts with deep drafts, or for tools that do not have polished surfaces.

4.8 Sharp corners

Good part design and correct mould finishing involves radiusing sharp corners wherever possible.

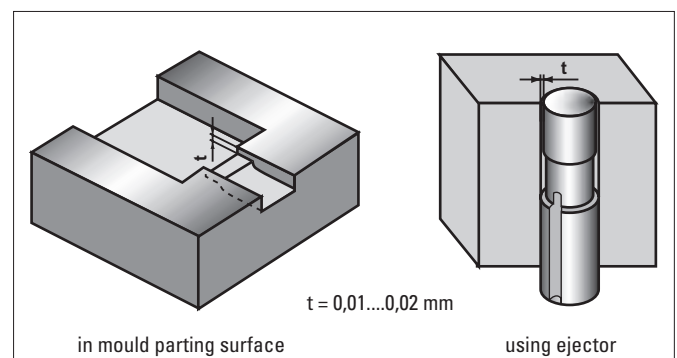


Fig. 16: Typical vent designs.

5 Material behaviour

5.1 Chemical structure

ZENITE® LCP resins are polymerised through a complex multi-step polycondensation process from two or more aromatic monomers combined in different ratios.

Details of the polymerization chemistry are beyond the scope of this brochure. For recycling and identification purposes, parts should be labelled generically such as <LCP>, <LCP-GF30> for 30% glass-filled LCP or <LCP-M30> for 30% mineral filled LCP.

5.2 Flow length

ZENITE® LCP resins have excellent flow properties, see Fig. 17 to 21. Parts with long flow paths and narrow wall thickness are easily moulded. These good flow properties also help in the exact reproduction of mould details.

Flow length data are generated on moulds with a “spiral” or “snake” flow pattern. Data from one study can vary a lot compared to some from other studies, as flow length is highly dependent on:

- moulding parameters (fill pressure, fill speed, melt temperature, moisture, hold up time);
- mould layout (channel width, gate design);
- type of moulding machine (valve response time, ability to avoid hydraulic pressure peaks at v/p switch point).

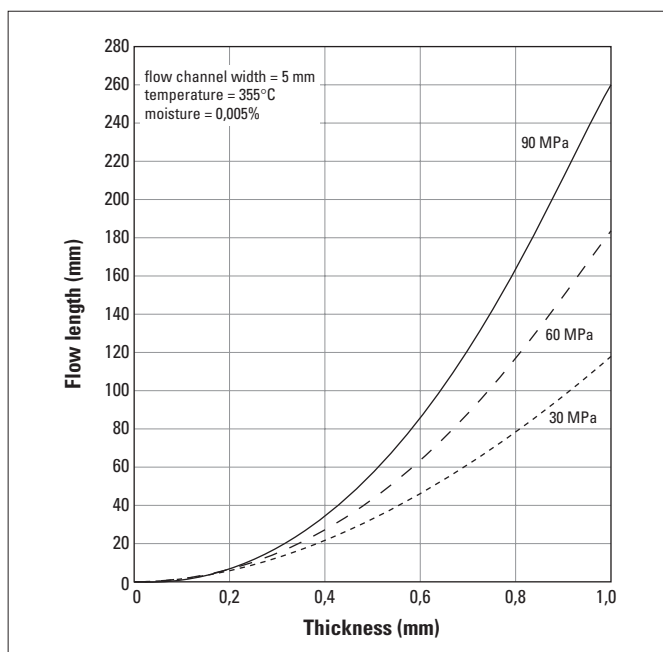


Fig. 17: Flow of ZENITE® 6130 WT010.

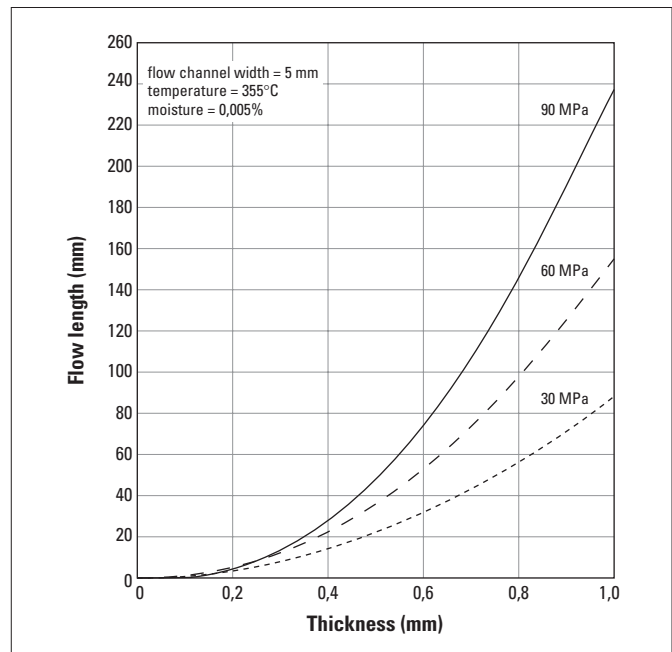


Fig. 18: Flow of ZENITE® 6140L WT010.

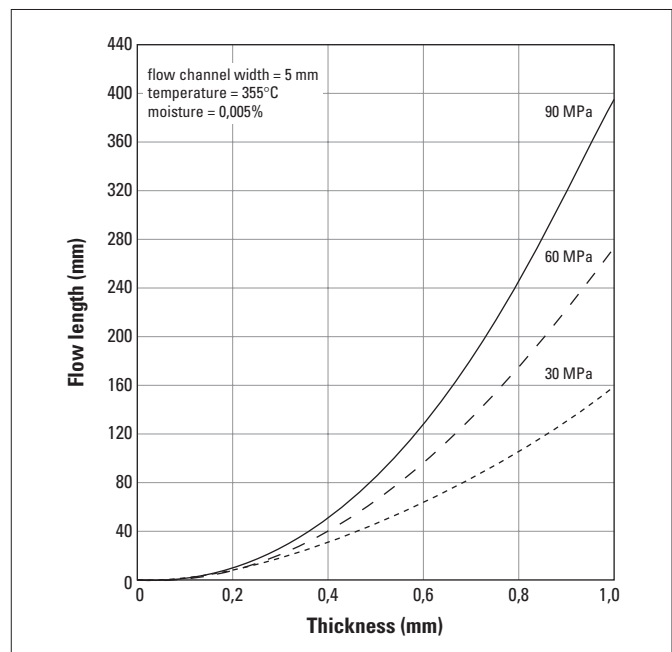


Fig. 19: Flow of ZENITE® 6330 NC010.

5.3 Shrinkage

The mould shrinkage of ZENITE® LCP resins is highly dependent upon the orientation of the molecules and fillers, part thickness, part design, and processing conditions. Values for shrinkage listed in Tables 5 and 6 are intended as a guide, using a typical mould temperature of 80° C, for estimating out-of-mould dimensions as a function of part thickness. Negative shrinkage (i.e. part growth) can occur in the parallel direction in thin wall sections. This means the part dimensions can be larger than the cavity dimensions.

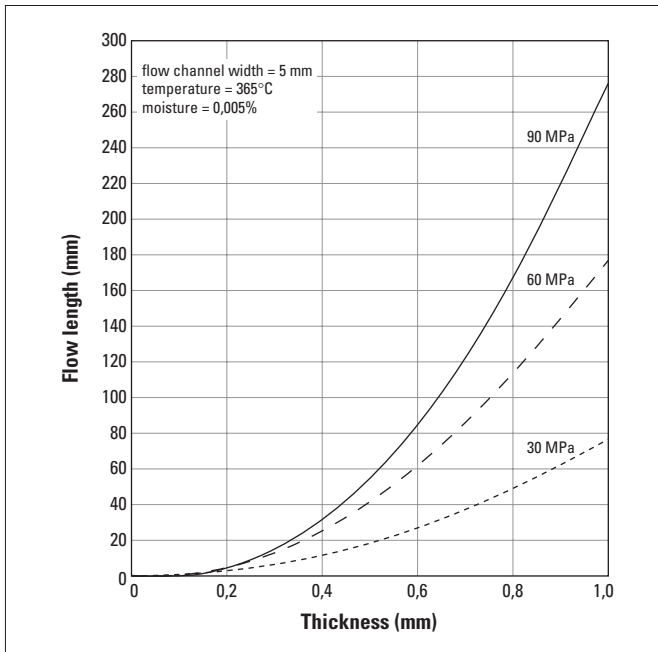


Fig. 20: Flow of ZENITE® 7130 WT010.

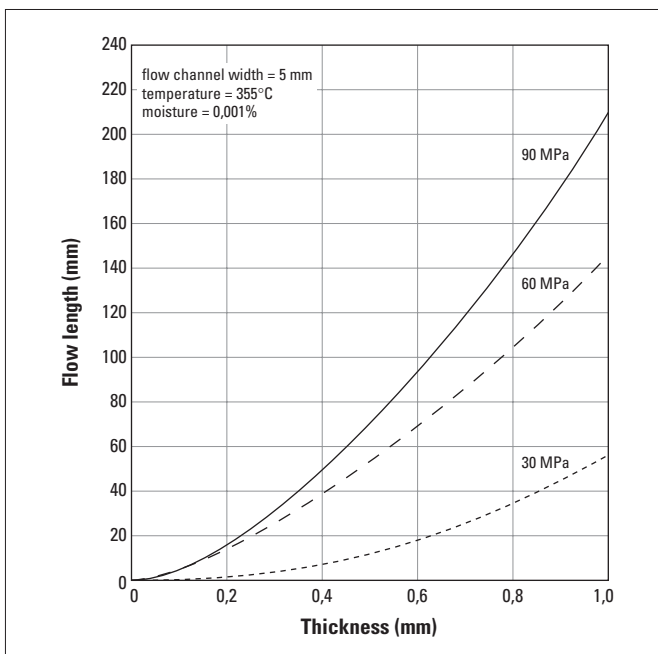


Fig. 21: Flow of ZENITE® 7145 WT010.

For ZENITE® LCP, shrinkage is considerably influenced by the direction in which the polymer rod-like molecules and the fillers are oriented. As a result, there is a difference in shrinkage parallel to and at right angles (normal) to the direction of flow, and this makes accurate prediction of the shrinkage very difficult. Depending on the orientation, which is determined by the way in which the mould fills, shrinkage can also occur between the parallel and normal shrinkage shown in Tables 5 and 6. In extreme cases, the difference in shrinkage may be

greater than shown. This depends on the position of the gate, the respective fill pattern and the shear history of the melt. The effects of shear, divergent and convergent flow patterns may be such that layers close to the wall may have completely different orientation than those in the centre section of the part.

For complex precision parts, prototype moulds should be used to obtain more accurate dimensional data. The prototype mould (or cavity) must mimic production intent, especially with regard to gate position.

5.4 Post-shrinkage

Post-shrinkage can be defined as the dimensional change (in %) of a moulded part measured at $23 \pm 2^\circ\text{C}$ after annealing for a specific period at a specific temperature.

Tables 5 and 6 contain shrinkage values before and after annealing (= moulding shrinkage + post-shrinkage) for different annealing conditions

5.5 Viscosity retention

Properly dried ZENITE® resins have exceptionally good melt stability over the recommended melt temperature range and hold up times of up to 10 minutes. When running capillary rheometer studies on granules and moulded parts, it is not unusual to find viscosity drops of up to 40%. These are mainly caused by the breakage of glass fibres and other fillers during injection moulding. Therefore capillary viscosity measurements cannot isolate the effect of polymer degradation to verify moulded part quality, although viscosity drops of more than 50% may be cause for concern.

Due to the extremely good chemical resistance of ZENITE® resins, solution viscosity measurements are impractical and not feasible.

5.6 Flow and weldlines

LCP resins have limited butt weldline strength and acceptable to good running weldline, also referred to as flowline strength. Typical values for weldline strength are shown in Table 7. A butt weldline is defined as one where two melt fronts meet and stop (normally perpendicular to the flow) and a running weldline is defined as one where the flow separates and then joins together (e.g. flowing around a pin or small shut-out).

Weldlines normally achieve approx. 15-20% of the original material's tensile strength for standard grades. Flowlines normally achieve up to 90% of the materials cross-flow properties, see Fig. 22. This explains the observation of excellent properties of ZENITE® resins in multi-pin connector applications.

Table 5: Effect of part thickness on mould shrinkage and total shrinkage

Grade	Thickness [mm]	Mould shrinkage [%]		Total shrinkage [%] after annealing	
		Parallel	Normal	Parallel	Normal
ZENITE® 6130L BK010	0,5	-0,05	0,75	-0,05	1,55
	0,8	-0,10	0,70	-0,20	1,60
	1,6	-0,05	0,75	-0,15	1,30
ZENITE® 6130L WT010	0,5	-0,05	0,70	-0,15	1,50
	0,8	-0,05	0,90	-0,15	1,60
	1,6	0,00	0,80	-0,10	1,35
ZENITE® 6140L BK010	0,5	0,00	0,60	0,05	0,75
	0,8	0,00	0,60	0,00	1,25
	1,6	0,05	0,60	0,00	1,00
ZENITE® 6140L WT010	0,5	0,00	0,60	0,00	-
	0,8	0,00	0,65	0,00	1,25
	1,6	0,05	0,65	-0,05	1,30
ZENITE® 6244L BK010	0,5	0,00	0,40	0,15	0,75
	0,8	0,00	0,35	0,00	0,85
	1,6	0,05	0,45	0,05	0,80
ZENITE® 6330 NC010	0,5	0,00	0,80	-0,20	1,05
	1,6	-0,15	0,40	-0,30	0,70
ZENITE® 6330 BK010	0,5	0,00	0,50	-0,25	1,05
	0,8	-0,05	0,35	-0,30	0,80
	1,6	-0,05	0,40	-0,20	0,70
ZENITE® 6434L NC010	0,5	-0,05	0,45	-0,10	0,90
	0,8	-0,15	0,80	-0,30	1,50
	1,6	0,00	0,65	-0,15	1,05
ZENITE® 7130L WT010	0,5	0,05	0,65	-0,10	0,90
	0,8	-0,05	0,85	-0,10	1,60
	1,6	-0,05	0,75	-0,10	1,25
ZENITE® 7145L BK010	0,5	0,00	0,45	0,00	0,65
	0,8	-0,05	0,60	-0,05	1,05
	1,6	0,00	0,60	-0,05	1,05
ZENITE® 7145L WT010	0,8	0,10	0,62	0,15	1,05
	1,6	0,00	0,75	0,00	1,20
ZENITE® 7223 WT050	0,5	0,00	0,60	-0,20	1,10
	1,6	0,00	0,55	-0,20	1,00

Plate dimension : 40 × 50 mm, equidistant film gate technology, mould temperature: 80°C; hold pressure: 50 MPa, annealing: 1 h/250°C.

Table 6: ISO-shrinkage

Grade	Mould shrinkage [%]		Total shrinkage [%] after annealing	
	Parallel	Normal	Parallel	Normal
ZENITE® 6130 WT010	0,15	0,90	0,05	1,25
ZENITE® 6140L WT010	0,15	0,75	0,10	0,95
ZENITE® 6330 NC010	0,00	0,65	-0,15	0,90
ZENITE® 7130 WT010	0,10	0,90	0,05	1,10
ZENITE® 7145L WT010	0,15	0,85	0,15	1,00

Plate 2 × 60 × 60 mm, mould temperature: 80°C; hold pressure: 40 MPa; annealing: 3 h/250°C.

Unless there is a defect in moulding (e.g. insufficient venting) it is almost impossible to improve weldline strength by modifying moulding parameters (see Fig. 23). An appropriate grade selection may help to overcome potential problems. Standard grades like ZENITE® 7145L have been optimised for weldline strength. Further improved speciality grades may be available on request.

Table 7: Weldline strength for ZENITE® grades, 2-gated bar 180 × 27 × 2 mm

	Weldline strength (MPa)
6130 WT010	12,1
6330 NC010	11,2
7130 WT010	14,4
6140L BK010	13,2
7145L WT010	21,1
7755 BK010	19,2
7223 WT050	18,3

Part design and gate position are important factors for successful moulding of ZENITE®. Gate position directly influences weldline position. It is therefore good practice to move any weldlines outside highly stressed areas. Very thin walls (<0,5 mm) may have a positive effect on weldline strength.

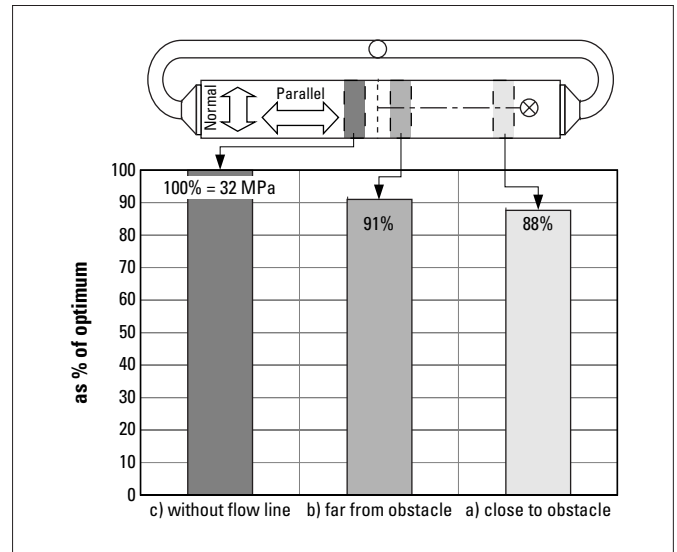


Fig. 22: Flowline strength of ZENITE® 6130 WT010 on 2-gated bar 180 × 27 × 2 mm.

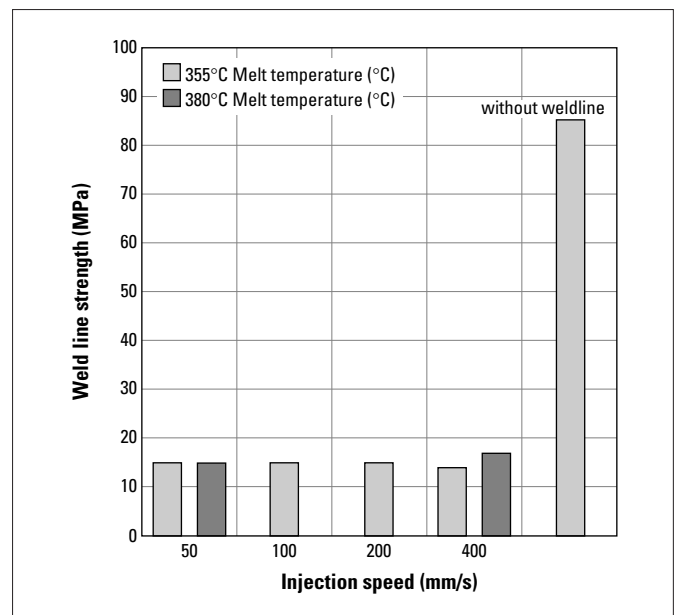


Fig. 23: Weldline strength versus injection speed and melt temperature for ZENITE® 6130 WT010 on bar 180 × 27 × 2 mm.

6 Auxiliary operations

6.1 Regrind

ZENITE® LCP resins have excellent thermal stability when using recommended moulding conditions. This results in a remarkable retention of properties when using regrind. Studies with ZENITE® 6130 using 25, 50, and 100% regrind have been run for a total of 6-8 passes (virgin resin plus 5-7 regrind). Table 8 exhibits the excellent retention (>90%) of its physical properties. In addition, measurements of shrinkage on 127 × 12,7 × 1,6 mm bars showed only a 0,03% shrinkage increase in the flow direction and an unmeasurable change in the transverse direction after five passes versus the virgin resin pass.

The considerations around determining a maximum regrind percentage are many, e.g. UL and automotive requirements, product design requirements, drying, fines, feeding consistency and regrind quality. We have demonstrated that good property retention is possible at 100% regrind levels. The UL yellow card listing for 6130 and other grades allows up to 50% regrind. However, customer testing around the specific end-use requirements is the most important tool for final selection of maximum regrind percentage.

Conventional slow rotor plastic granulators are used for granulating ZENITE® LCP parts. The blades should be uninterrupted, straight, sharp and set for close clearance and the screen size should be as large as practical for feeding the particular machine. However, due to the fibrous nature of all LCPs, a high degree of fines (up to 10%) and ragged cut can occur. Ideally the cut of the regrind should be close to 2,5 × 2,5 × 2,5 mm. To optimise the cut, sprues and runners should be fed to the grinder immediately out of the mould whilst still hot. Fines should be further separated by a post-screening operation. Another option is to re-pelletise the regrind through an extruder. This of course adds an additional heat history to the resin, and the UL listing may not be valid anymore.

Table 8: ZENITE® 6130 regrind study

	Method ASTM	Regrind level, %	Retention, % (6th pass)	Retention, % (8th pass)
Tensile strength, 23°C	D638	100	96	96
		50	98	
		25	97	
Elongation at break, 23°C	D638	100	100	95
		50	100	
		25	90	
Tensile modulus, 23°C	D638	100	100	100
		50	100	
		25	100	
Flexural strength, 23°C	D790	100	92	
Flexural modulus, 23°C	D790	100	94	
Heat deflect. temper. at 1,8 MPa	D648	100	99	
Izod impact, 23°C	D256	50	100	100
		25	100	

Caution: Do not mix other LCP resin regrind with ZENITE® LCP resin regrind. Severe degradation of other LCP resins can occur when moulded at ZENITE® LCP resin melt temperatures.

Please refer to Underwriters Laboratories at <http://data.ul.com/iqlink/> to find out the maximum allowed regrind levels for ZENITE® grades.

6.2 Colouring

Due to the high processing temperatures of ZENITE® LCP grades, the use of standard masterbatches, liquid colorants or dry pigments is not recommended. DuPont has developed a few ZENITE® LCP based masterbatches with temperature resistant pigments which have proved to work well. It must always be born in mind that the colour may change in use over time at high temperatures, that the colours are pastel-like and that colours cannot be guaranteed to be repeatedly matched. Therefore they are used mainly for part identification and seldom for aesthetic parts.

Please contact your DuPont representative for more information about colours.

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