NORYL™ RESIN

INJECTION MOLDING GUIDE

CHEMISTRY THAT MATTERS™

SABIC

Founded in 1976, SABIC is the first public, global multinational enterprise headquartered in the Middle East. Our products range from bulk commodity chemicals to highly engineered plastics for demanding applications. We are a leading producer of polyethylene, polypropylene, glycols, methanol and fertilizers and a global leader in the production of polyolefins.

SABIC's offerings include Chemicals, Polymers, Specialties, Agri-Nutrients and Metals. In Saudi Arabia, the Netherlands, Spain, the USA, India, China and Japan, our dedicated Technology & Innovation centers research ways to meet our customers' needs with excellence.

INNOVATING FOR CUSTOMER SUCCESS

We believe that SABIC customers deserve the full benefit of every advantage our enterprise can offer. After all, our success is defined by our customers' success. And with more than 80 years of experience pioneering advanced engineering thermoplastics, SABIC is positioned to help create new opportunities for growth and breakthrough applications.

We offer expertise and experience to our customers in a variety of ways:

- Material solutions to help drive innovation and market leadership.
- Design, logistics and processing expertise to spark new ideas and better efficiencies.
- Unwavering commitment to build long-term relationships with ingenuity, trust and continuous improvement.

It's what we strive for and work to deliver... a mutual benefit. Excellence and nothing less.

CONTENTS

1.0

ABOUT NORYL™ RESINS

The NORYL™ resin family is built on SABIC's proprietary polyphenylene ether (PPE) technology. NORYL resins for injection molding exhibit a broad range of outstanding properties for applications in water management, automotive, electrical, solar, energy storage, building & construction, appliances and many other industries.

The intention of this guide is to provide general information and recommendations for molders and designer to consider when injection molding using NORYL resins.

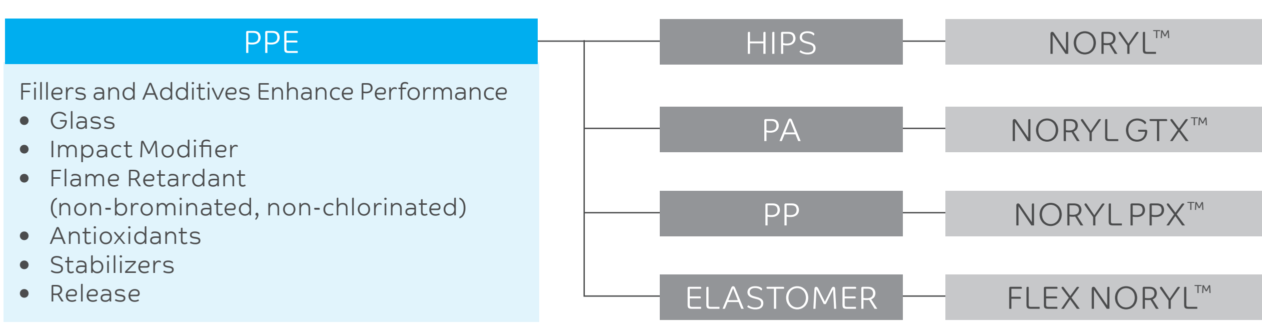
NORYL resin, which is compounded with high impact polystyrene (HIPS), exhibits amorphous characteristics.

Semi-crystalline members of the NORYL family include:

- NORYL GTX resin, which is compounded with polyamide
- NORYL PPX resin, which is compounded with polypropylene

NORYL GTX and NORYL PPX resins leverage the flow and chemical resistance characteristics of semi-crystalline materials, while adding the good dimensional stability, low moisture absorption and low creep tendency of the amorphous PPE technology.

Whenever a recommendation is specifically important to either the amorphous or semi-crystalline nature of the resin, it is referred to. General recommendations are valid for the entire NORYL resin product family.



2.0

NORYL™ RESINS INJECTION MOLDING RECOMMENDATIONS

Material Handling and Preparation - Drying

All NORYL™ resins require thorough drying prior to injection molding to assure maximum properties in the molded part. Always check the datasheet to determine the exact recommended drying temperature and drying time.

MATERIAL	DRYING TEMPERATURE [°C]	DRYING TIME [HRS]	MOISTURE CONTENT
NORYL	100 – 120	2 – 4	< 0.02%
NORYL GTX	100 – 120	2 – 3	0.02% - 0.05%
NORYL PPX	65 – 75	2 – 4	< 0.02%

- A machine-mounted, dehumidifying hopper dryer equipped with a closed-loop circulating air system is preferred. When bulk drying, ensure the resin remains dry via positive flow of dry air through the conveying system.
- The hopper dryer should be equipped with a diffuser cone to ensure proper distribution of air flow and to allow "plug flow" of material through the hopper.
- Batch drying can be accomplished with air circulating, desiccant tray dryers with trays filled to a depth of no more than 25mm. Material dried in this manner should be placed in a sealed hopper and residence time should be kept to a minimum.

Special care must be taken when drying NORYL GTX™ resin. If the material is too wet (>0.05%) or too dry (<0.02%), it will cause splay.

It is highly recommended to closely monitor the moisture content during production and to carefully size the dryer to the job, based upon the kg/h usage and drying time needed.

The recommended drying temperature for all NORYL GTX grades is 110°C. During a production standstill, the dryer temperature should be dropped to between 70°C to 80°C.

The temperature of the cooling ring around the hopper zone should be between 40°C and 60°C when processing NORYL GTX. To avoid condensation at the intake of the machine, in some cases it is better to work without cooling.

Signs of poor drying

- Swelling purge
- Drooling nozzle
- Increased or variable flow rate
- Voids in thin part areas
- Splay on flow fronts of part
- Splay on filled parts
- Brittle parts

Machine Preparation

Prior to introducing NORYL resins, the molding machine barrel should be thoroughly cleaned either by purging or mechanically cleaning the cylinder with brass wool.

If the screw is removed, clean it and check carefully for nicks, cracks, or excessive wear. The check ring should also be inspected for any abnormalities.

To check for cleanliness without removing the screw, purge with an unfilled, amorphous resin such as polystyrene and look for foreign particles or discoloration in the air shot.

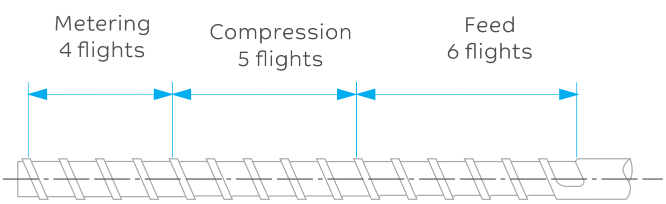
Any evidence of contamination in the first several molded parts may indicate that the cleaning procedure should be repeated.

Mold Release Agents

The application of external mold release agents to tool surfaces should be kept to a minimum. Initially, part sticking can be corrected by making adjustments to pressure, temperature or cycle time. In addition, draft angles, mold surface finish, and the ejector pin area may require attention. Intermittent part sticking can often be overcome by moderate application of a mold release spray. Since some mold release sprays may have a detrimental effect on the properties and surface appearance of NORYL resins, compatibility testing is necessary prior to their use. In some cases, formulation adjustments are possible, permitting internal release agents to be added to the resin during compounding. Internal releases will reduce the tendency for part sticking.

Barrel Selection and Screw Design Considerations

Conventional materials of construction for compatible screws and barrels are acceptable for processing NORYL resins. The use of bimetallic barrels is suggested for better abrasion and corrosion resistance.



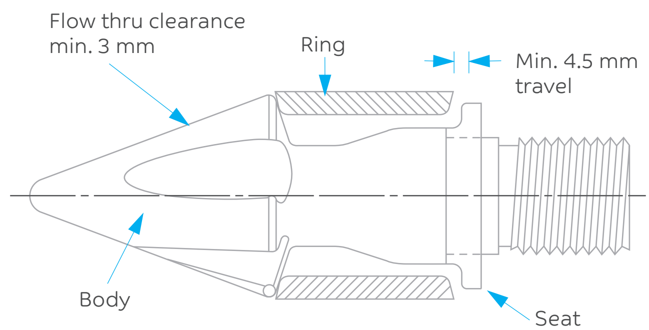
Compression ratio 2-3:1

Depending on screw diameter, a compression ratio of about 2:1 to 2.5:1 with a length to diameter ratio of 20:1 is preferred. A short feed zone (6 flights) and a long compression zone (11 flights) with a gradual constant taper leading to a short metering zone (4 flights) are also suggested. The compression should be accomplished over a gradual and constant taper since sharp transitions can result in excessive shear and material degradation.

When specific screw selection is not possible, general purpose screws with length to diameter ratios from 16:1 through 24:1 and compression from 1.5:1 to 3:1 have been used successfully.

Vented barrels are not suggested for processing NORYL resins.

The non-return valve should be of the sliding check ring type (See Figure below). Flow-through clearances of at least 80% of the cross-section of the flow area in the metering zone of the screw are necessary. The check ring travel should be at least 4.5mm for small diameter screws (60mm diameter or less). Larger screws may require longer travel to provide the necessary flow-through area.



Ball check type screw tips are not suggested because they can cause degradation of the resin due to excessive shear and dead spots.

Molding Conditions

As a general guideline, the standard grades of NORYL resins are molded at different temperatures – the lower temperatures for the low viscosity resins and the highest temperatures for the high viscosity grades. Increasing melt temperatures reduces viscosity and increases resin flow, thus providing for longer flow for thin-wall sections and producing lower residual stress.

Mold temperatures are important in determining final part finish and molded-in stress levels. Cold molds are more difficult to fill, necessitating high injection pressure and melt temperature and are not recommended when processing NORYL resins.

Heated molds generally produce a part with better finish and lower molded in-stress.
The fastest fill speed possible provides longer flow, fills thinner wall sections and helps to create a better surface finish. Slower fill is suggested for sprue-gated and edge-gated parts to prevent gate blush, splay and jetting. In thick wall parts (>4mm), slow fill helps reduce sinks and voids. For Typical processing parameters, see tables on page 14.

Melt Temperature

Suggested melt temperatures for NORYL™ resin are listed on page 14. Like the majority of thermoplastic molding materials, NORYL resins are sensitive to prolonged exposure to heat. Long residence times and excessive melt temperatures should be avoided. It is not recommended to exceed 8 minutes residence time.

A relatively small increase in screw speed (RPM) can result in a dramatic increase in melt temperature with no change in controller set point. It is suggested that melt temperatures be measured using hand-held pyrometers. These measurements should be taken on the thermoplastic melts after the machine is on cycle.

When processing near, or at, the upper limit of the melt range, the shot weight should approach 70% to 80% of the cylinder capacity of the machine. If the cylinder temperature exceeds the upper limit of the suggested melt range, thermal degradation of the resin and loss of physical properties may result.

NORYL resin, like other engineered thermoplastics, should not be left at elevated temperatures for prolonged periods of time without occasional purging.

Mold Temperature

The usual range for processing unreinforced NORYL grades is from 65 to 100°C. Operating molds in this temperature range can also be used to maximize flow, improve knitline strength and optimize surface finish.

NORYL GTX resin should always be molded in temperature-controlled molds. Optimal tool temperatures for NORYL GTX resins are between 120°C and 140°C, with a recommended mold surface temperature of 120°C.

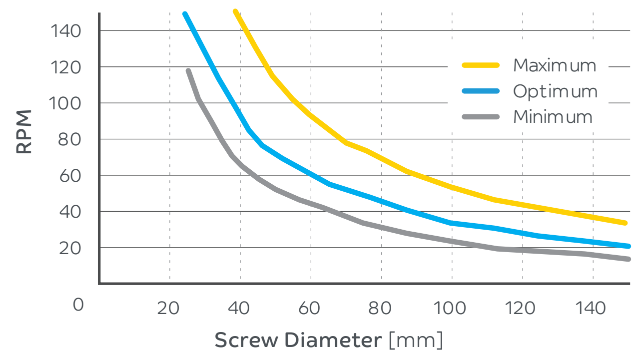
Full advantage of the rapid crystallization of NORYL GTX resin can be realized by the effective location of uniform cooling channels in the mold inserts and cores to achieve an even tool surface temperature.

For semi-crystalline materials such as NORYL GTX™ and NORYL PPX™ resins, high mold temperatures will produce higher degrees of in-mold crystallization. This, in turn, will result in high shrinkage values. Mold temperatures that are too low, on the other hand, may result in crystallization after molding, with the risk of warpage during secondary operations.

Screw Circumferential Speed and Screw Diameter

Screw circumferential speeds (RPM) should be adjusted to permit screw rotation during the entire cooling cycle without delaying the overall cycle (Figure right) but must not result in a screw surface speed of more than 0.5m/s. Low screw circumferential speeds will reduce glass fiber damage during plastification when molding reinforced grades.

Material degradation can occur at too high screw speeds due to excessive shear heating.



Graph 1: screw circumferential speeds suggestion for NORYL resins

SCREW DIAMETER [MM]														
RPM	18	25	30	35	40	45	50	60	70	80	90	100	110	120
20	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.13
40	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.25
60	0.06	0.08	0.09	0.11	0.13	0.14	0.16	0.19	0.22	0.25	0.28	0.31	0.35	0.38
80	0.08	0.10	0.13	0.15	0.17	0.19	0.21	0.25	0.29	0.34	0.38	0.42	0.46	0.50
100	0.09	0.13	0.16	0.18	0.21	0.24	0.26	0.31	0.37	0.42	0.47	0.52	0.58	0.63
120	0.11	0.16	0.19	0.22	0.25	0.28	0.31	0.38	0.44	0.50	0.57	0.63	0.69	0.75
140	0.13	0.18	0.22	0.26	0.29	0.33	0.37	0.44	0.51	0.59	0.66	0.73	0.81	0.88

Table 1: Calculating the screw circumferential speed [m/s] based on RPM and screw diameter

Back Pressure

A back pressure of 0.3 to 0.7 MPa is suggested to insure a homogeneous melt and to maintain consistent shot size.

Higher back pressure used to improve melt mixing results in higher melt temperatures. When molding reinforced grades, low back pressure will reduce glass fiber damage during plastification.

Shot Size

The shot size should dictate the size of the machine used. It is suggested that the optimum shot be 40% to 60% of the machine's capacity. However, shots which are 20% to 75% of machine capacity have been successfully molded when temperatures were precisely maintained and all processing conditions were very closely controlled.

Injection Speed

When selecting injection speed, careful consideration must be given to adequate mold venting, resin melt temperature and injection pressure along with the potential for jetting.

The fastest fill speed possible provides longer flow, fills thinner wall sections and creates a better surface finish. In thick parts, slow fill helps to reduce voids. Thin-wall sections below 1.5mm always require fast injection speeds in order to fill the cavity and produce high knitline strength. The fill rate of thick sections may be reduced to aid packing when filling through restricted gates.

Programmed injection is suggested for parts with small gates (pin gates and subgates). A slow injection rate can be used at the start to reduce shear, jetting and burning of the material.

Following maximum shear rates for NORYL resins are recommendations and based on experience and observations from different applications:

MATERIAL	MAXIMUM RECOMMENDED SHEAR RATE
NORYL	40.000/s
NORYL FExxxxPW series	20.000/s
NORYL GTX	40.000/s
NORYL PPX	40.000/s

Table 2: Maximum Recommended Shear Rate

In practice, higher shear rates have been observed without influence on mechanical or flame retardance performance.

Injection Pressure

The actual injection pressure will depend on variables such as melt temperatures, mold temperature, part geometry, wall thickness, flow length and other mold equipment considerations. Generally, the lowest pressures which provide the desired properties, appearance and molding cycle are preferred.

Holding Pressure

Holding pressures from 60% to 80% of the injection pressure are adequate for normal requirements.

For NORYL resin, it is suggested to apply a decreasing holding pressure profile so as not to overpack the part and create in-molded stress.

Holding pressure should be applied after the part is volumetrically filled.

Cushion

The use of a small cushion reduces material residence time in the barrel and allows for machine variations. In general, the cushion should be big enough to effectively apply holding pressure.

Clamping Force

Once the total projected area of the complete shot (all cavity and runner areas are subjected to injection pressure) has been determined, 0.5 to 1.5 tons of clamping force should be provided for each cm^2 to avoid flashing of the part. Glass-reinforced resins may require slightly higher clamping force (estimate one ton per cm^2 of additional clamping force).

Wall thickness, flow length and molding conditions will determine the actual tonnage required.
To determine an initial injection molding setting, it is recommended to set up a higher clamping force rather than too low a clamping force in order to prevent tool damage.

Regrind

The reinforcing effect of glass or carbon fibers decreases with repeated processing because of fiber breakdown. Also, thermal degradation will cause a decrease in mechanical properties, particularly impact strength. Where molded components need to meet specific demands for tensile or impact strength, the use of regrind is not recommended until thorough testing is conducted. Fiber breakdown and thermal degradation can also effect the dimensions of molded parts. Care should be taken with the addition of regrind for use in applications where tight dimensional tolerances must be met. Should the use of regrind be possible, always use a set ratio of regrind and virgin material.

A maximum of 20% regrind should not be exceeded if retaining physical properties is important.

Grinder screen sizes should be 8 to 9.5 mm. If a smaller size is used, too many fines could be generated, creating molding problems such as streaking and burning.

It is important to keep the ground parts clean and to avoid contamination from other materials. Drying time should be increased since regrind will not be same size as virgin pellets and therefore moisture diffusion will be different. Regrind utilization may have an effect on color.

Actual regrind usage should be determined for each individual application, especially in cases when the application needs to meet strict regulatory or testing standards such as potable water certification or UL testing.

Down Time

When it becomes necessary to stop molding, the following steps are suggested:

- Maintain cylinder temperature for interruptions up to 15 minutes
- Decrease cylinder temperature by 50°C for periods from 15 minutes to 2 hours
- Reduce further to 180°C for interruptions from 2 to 12 hours
- Purge out the barrel and shut off the heat for periods longer than 12 hours

Purging

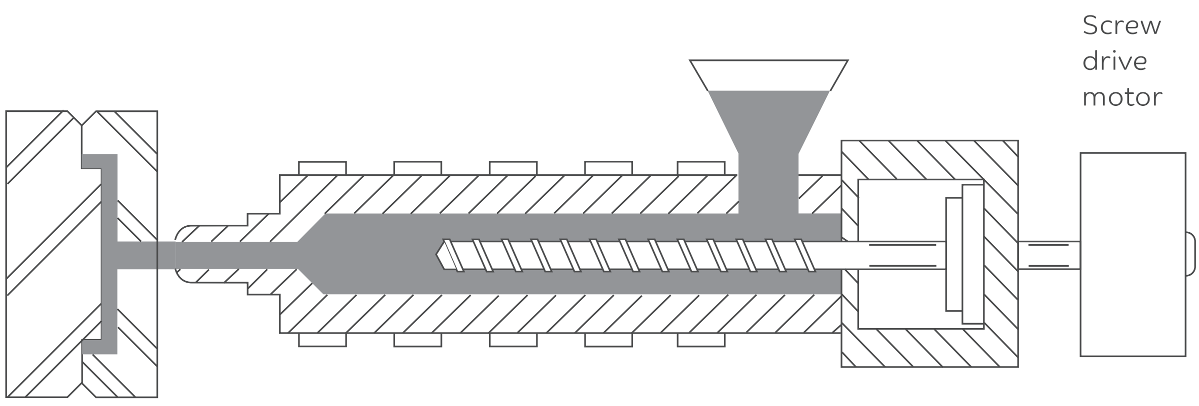
Polystyrene and reground cast acrylic are effective purging materials for NORYL™ resin. Purging should be done within the melt temperature range for the particular grade of resin. It is important to have proper ventilation during the purging procedures.

NORYL GTX™ resin can be purged using the usual procedures for standard nylon.

NORYL PPX™ resin can be purged using the standard procedures for polypropylene.

3.0

OVERVIEW OF BASIC SETTINGS



	MELT	MOLD	NOZZLE	ZONE 3	ZONE 2	ZONE 1	HOPPER	DRYING CONDITIONS	MOISTURE CONTENT
	ALL VALUES MENTIONED: TEMPERATURE (°C)								
NORYL	280 - 300	100 – 120	280 – 300	280 - 300	270 - 290	250 - 270	60 - 80	2-4 hours at 100-120°C	0.02%
NORYL GTX	280 - 300	80 – 100	270 – 290	280 – 300	270 – 290	260 – 280	60 – 80	2-3 hours at 100-110°C	0.02%
NORYL PPX	260 – 300	40 – 65	260 – 300	255 – 290	250 – 290	245 – 290	60 - 80	2-4 hours at 65 – 75°C	0.02%
NORYL FExxxxPW	290 – 320	80 – 120	290 – 320	300 - 310	280 – 300	270 – 280	60 - 80	2-4 hours at 100-120°C	0.02%

Table 3: General parameters for injection molding NORYL™ resin

For NORYL FExxxxPW series, a medium to low injection speed and tool temperature in combination with a high melt temperature has been observed as an optimal injection setting.

Please contact your SABIC representative for further information on injection molding recommendations.

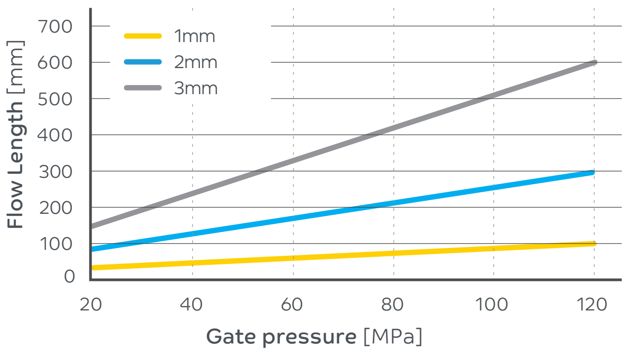
PARAMETER	ADVISED SETTING
Screw length	20 – 26D
Compression ratio	2:1 – 2.5:1
Screw speed	0.1 - 0.3 m/s
Back pressure	30 – 70 bar
Injection speed	Medium to Fast
Cushion	4 – 10 mm
Injection pressure	As low as possible
Hold pressure	60 – 80% of Injection Pressure

Table 4: Recommended settings for molding NORYL™ resin

Flowpath-wall section ratio of selected NORYL™ resins

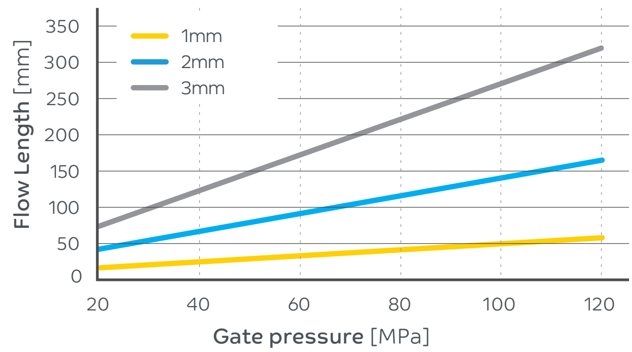
Below are charts showing the anticipated flow length for various grades of NORYL resins, based on melt and mold temperatures and gate pressure settings.

Flow Length Curves: NORYL™ NH6020 Resin



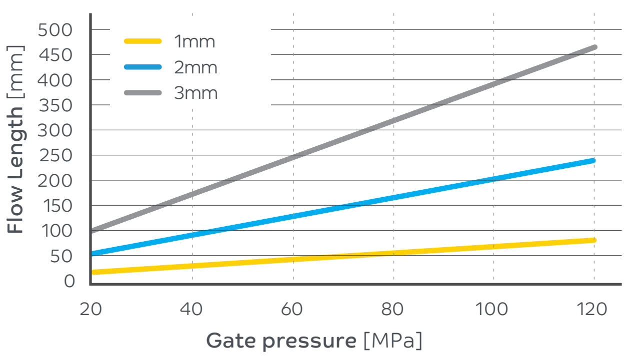
Graph 2a: Flow length curves NORYL™ NH6020 resin T(melt) = 310°C, T(mold) = 115°C

Flow Length Curves: NORYL™ V0150B Resin



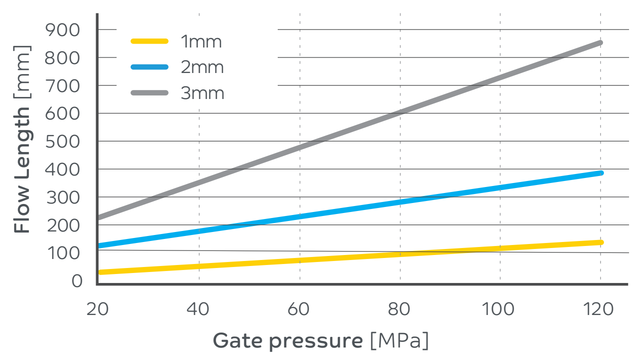
Graph 2b: Flow length curves NORYL™ V0150B resin T(melt) = 300°C, T(mold) = 85°C

Flow Length Curves: NORYL™ FE1630PW Resin



Graph 2c: Flow length curves NORYL™ FE1630PW resin T(melt) = 290°C, T(mold) = 100°C

Flow Length Curves: NORYL GTX™ 985 Resin



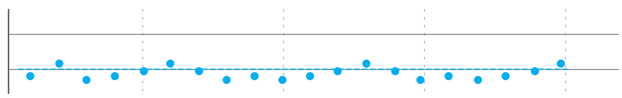
Graph 2d: Flow length curves NORYL GTX™ 985 resin T(melt) = 310°C, T(mold) = 110°C

Record Injection Molding Parameters

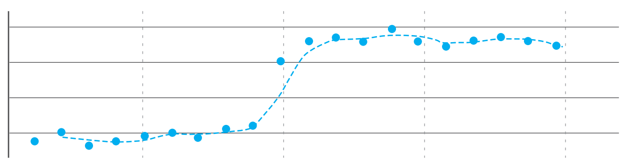
Continuous recording of injection molding parameters is always suggested and can help to determine root causes of quality issues.

When encountering quality issues during injection molding it is recommended to carefully evaluate the type of issue and then create a detailed issue resolution plan. It is important to not change more than one injection molding parameter a time, otherwise it will not be possible to isolate the effect on the process.

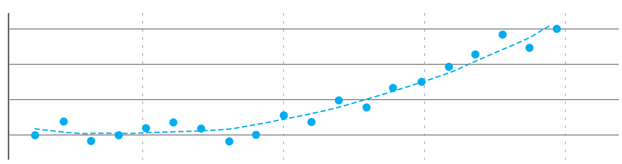
Usually there are two types of failures:
- Periodical
- Change of trend



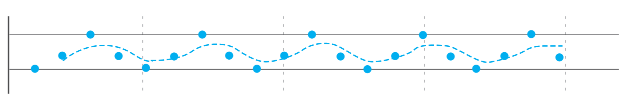
Normal Fluctuation



Volatile Change



Change of Trend



Regular Oscillation

Periodic Changes

Sources for periodic changes can be a result of the temperature changes into the hot runner system (if the frequency is within several minutes) or can be found within the material feeding (if the frequency is within several hours).

If the frequency is even longer (i.e. days) it can be a sign for changes of the ambient temperature.

Change of Trend

Root causes of volatile changes can easily be monitored and many times are an interplay of changing material properties in terms of drying, change from Lot A to B, masterbatch change, different ratio of regrind, etc.

A change of trend is usually caused by machine or tool defects. If the heating band of the injection molding machine or a tool temperature controller is not working appropriately, this usually triggers the change of trend.

4.0

INJECTION MOLDING TROUBLESHOOTING GUIDE

ISSUE	CAUSE	REMEDY
Brittleness	Wet material Overheating Molded-in stresses Poor part design Weld-lines	• Review drying procedure • Reduce barrel/nozzle temperature • Increase barrel/nozzle temperature • Eliminate sharp corners • Increase injection pressure • Increase melt temperature
Warped Parts	Part temperature differential Excessive shrinkage Orientation of material Poor part design Ejection problem	• Check mold cooling system • Increase part packing • Change gate location • Add ribs or part thickness to improve stiffness • Check for uniform wall thickness • Increase cooling time • Reduce mold temperature • Increase ejector pin area
Flashing	Inadequate clamp tonnage High injection pressure Misaligned platen Excessive vent depth	• Use a larger machine • Reduce injection pressure • Align platen • Review mold venting
Burn Marks	Air trapped in cavity Barrel or nozzle overheating Shear heat Contamination Hang-up in molding machine	• Improve mold venting • Check heater controls • Reduce injection speed • Purge barrel • Clean hopper dryer • Remove and clean screw
Weak Weld-Lines	Insufficient venting Injection speed or mold temperature too low Incorrect gate location	• Improve cavity venting • Increase injection rate and tool temperature • Relocate gate or add overflow tab
Surface Imperfections (frosty surface or white marks)	Injection speed too low Cold melt/cold mold Wet material	• Increase injection speed • Increase barrel temperature/mold temperature • Review drying procedures
Sinks or Voids	Holding pressure or time too low Insufficient feed Gate freezing off or located improperly	• Increase hold pressure or time • Increase shot size • Check gate dimension and location
Gate Blush	Cold material Melt fracture	• Add cold slug well in runner • Increase melt temperature • Reduce injection speed • Increase gate size • Add radius to gate
Dimensional Inconsistency	Shot to Shot variation Melt temperature variation Inadequate packing	• Maintain adequate cushion • Check for worn check ring • Check heater bands/controllers • Increase hold time • Enlarge gate to prevent premature freeze-off
Sticking Mold	Over packing Mold design	• Reduce injection pressure • Reduce injection speed • Check for undercuts • Inspect ejector system • Increase draft in tool

CONTACT US

Middle East and Africa
SABIC Global Headquarters
PO Box 5101
Riyadh 11422
Saudi Arabia
T +966 (0) 1 225 8000
F +966 (0) 1 225 9000
E info@sabic.com

Americas
2500 CityWest Boulevard
Suite 100
Houston, Texas 77042
USA
T +1 713 430 2301
E productinquiries@sabic.com

Technical Answer Center
T +1 800 845 0600

Europe
Plasticslaan 1
PO Box 117
4600 AC
Bergen op Zoom
The Netherlands
T +31 164 292911
F +31 164 292940

Technical Answer Center
T (0) 0 800 1 238 5060
T2 00 36 1 238 5060
E webinquiries@sabic.com

Asia Pacific
2550 Xiupu Road
Pudong
201319 Shanghai
China
T +86 21 2037 8188
F +86 21 2037 8288