PROCESSING GUIDELINES

ISOPLAST®

ENGINEERING TPU RESINS

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These guidelines present information that is common to all forms of processing for ISOPLAST® Engineering Thermoplastic Polyurethane resins, followed by sections specifically for injection molding, extrusion, and blow molding.

The single most important consideration in processing ISOPLAST resins is DRYING! If ISOPLAST resins are not dried correctly before processing, they will not perform as expected during processing or in the finished parts.

IF YOU DON'T DRY IT…DON'T TRY IT!

PLASTIC DRYING FUNDAMENTALS

Physical nature of water in plastics

Many plastic resins need to be dried before they are processed. A moisture content that is too high in molding or extruding can cause appearance defects such as splay and bubbles on the surface of the finished parts. In addition to creating an unacceptable part appearance, water may react with the polymer during processing, reducing the molecular weight and changing the physical performance of the final part.

Polyamide, polycarbonate, and polyester are examples of resins which require careful drying prior to processing in order to avoid unwanted polymer degradation. Thorough drying is a critical requirement for ISOPLAST resins as well. The resin may suffer a reduction in molecular weight as a result of processing at a moisture content above the indicated maximum. ISOPLAST resins can provide the excellent balance of performance properties for which they are designed, if they are processed at moisture levels below 0.02 wt% and optimally below 0.01 wt%. Masterbatch or regrind added to virgin resin must also meet the same moisture specification (i.e., they must be dried in the same way as virgin ISOPLAST resins).

Water can collect on the surface of a pellet (adsorption) and/or diffuse into a pellet (absorption). Absorbed water in particular can have a significant negative effect on part performance when the resin is inadequately dried. The more hygroscopic materials absorb moisture at faster rates and retain it easily, so it is critical to follow the proper guidelines for drying ISOPLAST resins.

Process of drying

The effective drying of a resin involves two distinct processes:

- The diffusion of moisture from within the pellet to the pellet surface
- The removal of water from the pellet surface

The diffusion of moisture to the polymer surface is facilitated by elevating the temperature of the pellet. This ensures sufficient mobility to transport the water to the pellet surface where it is removed by a continuous air flow that is sufficiently dry (low dew point). This creates an adequate and steady driving force from the pellet to the air. The rate of diffusion, and to a lesser extent the amount of water absorbed, determine the residence time required in the dryer to remove the absorbed moisture.

DRYING

ISOPLAST resins are thermoplastic polyurethane polymers and are hygroscopic. Because polyurethane polymers absorb moisture, and react with it at processing temperatures, it is very important to remove the moisture prior to processing.

Molecular weight reduction and an associated loss of physical properties are some examples of what can happen if ISOPLAST engineering thermoplastic polyurethane resins are not dried properly prior to processing.

We cannot emphasize enough the importance of properly drying ISOPLAST resins.

ISOPLAST resins that are put into drying hoppers directly from the sealed shipping containers should typically dry in four to six hours hours under optimal drying conditions (see dryer requirements). If the seals on the containers have been broken, or if the resin or regrind has been exposed to the atmosphere for any reason, the necessary drying time will be 10 to 12 hours. A moisture level at or below 200 ppm is necessary for successful processing.

Once dry, keeping the resin dry is critical. The ambient air dew point will have a great effect on how fast ISOPLAST resins pick up moisture when exposed to the environment. During the summer, when ambient temperatures and humidity are both high, ISOPLAST resins that have been properly dried can pick up enough moisture to begin to cause splay (bubbles and streaking) in as little as 15 minutes!

Regrind can be used with ISOPLAST resins at levels up to 25 percent if care is taken to avoid contamination and moisture pickup. Additionally, parts that are rejected because they were originally processed when wet cannot be reground and reprocessed. Once the molecular weight of the resin has been degraded by processing in the presence of moisture, it should be disposed of in an appropriate manner according to the MSD sheet. If regrind is not used immediately at the press, it will have to be redried according to the same guidelines as exposed virgin resin.

The dew point of the air used to dry ISOPLAST resins must be at or below -40°C (-40°F). If the dryer regenerates based on time rather than dew point, you must be sure that the dew point does not rise above -40°C (-40°F) before the dehumidifying/desiccant beds switch for regeneration. If the dew point does rise above -30°C (-20°F), the dryer will add moisture to the resin.

DRYING (cont.)

Dryer requirements

Not every dryer is capable of reducing the moisture level in ISOPLAST resins to an acceptable level. In general, dehumidifying/desiccant dryers are suitable for drying ISOPLAST resins, provided they can produce:

- an air flow minimum of 2.5 m 3/ hr/kg (40 ft3/hr/lb) of material
- a drying temperature between 85°C (185°F) and 138°C (280°F) dependant on the ISOPLAST resin
- a continuous dry air flow with a dew point of -40°C (-40°F) which corresponds to 0.008 weight percent moisture in the dehumidified air

In addition, the hopper must be designed to ensure plug flow so that all pellets have a similar residence time.

Each ISOPLAST resin has a specific drying temperature range and the drying temperature must be controlled very carefully. The resin itself must be at the temperature indicated. A substantial amount of heat can be lost between the dryer control unit and the dryer hopper. Additionally, if the dryer hopper is not insulated, more heat will be lost, especially along the outer shell. Therefore, the hopper must be insulated and the thermocouple that measures the dry air temperature should be located at the inlet to the drying hopper.

When drying, it is important to keep the air returning to the dehumidifying/desiccant unit below 55°C (130°F). If the air returning from the dryer hopper to the dehumidifying/desiccant unit is above 55°C (130°F), the unit cannot remove the moisture from the air. Drying becomes progressively less efficient the hotter the return air is above 55°C (130°F).

With return air above 65°C (150°F), there will be no drying at all. Most dryer manufacturers can supply an after-cooler for their drying units that will cool the return air below the 55°C (130°F) maximum allowable temperature. As the required drying temperature increases, the need for an after-cooler also increases.

Once dry, it is critical to retain low resin moisture levels during processing. This can be accomplished by mounting the dryer hopper directly on the in feed of the processing equipment. Alternatively, a small shot hopper can be used fed by a closed loop, dry-air conveying system from the large dryer hopper.

Managing residual moisture content

It is prudent to test the dryness of the resin with an air shot. Wet resin will give an air shot that is foamy and will "pop" as it is extruded from the nozzle. It will also cause significant nozzle or die drool.

In addition to checking the quality of the melt (must be free of bubbles), the residual moisture content of the pellets can be measured by a variety of moisture analyzers. Please contact your preferred equipment provider for further information.

DRYER TECHNOLOGY

Principle of dehumidifying/desiccant dryers

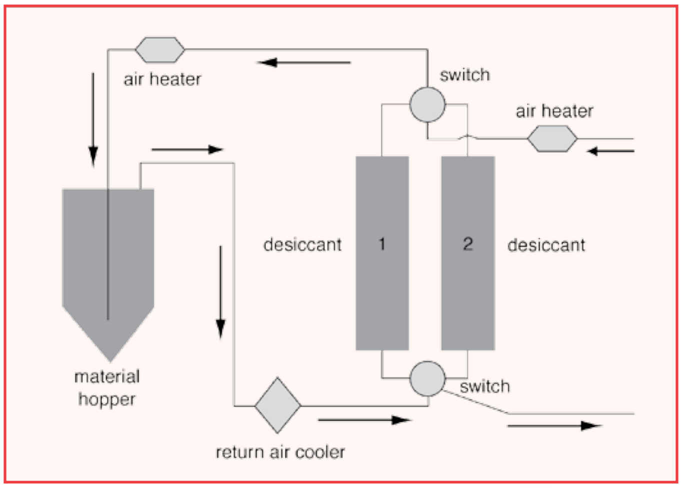
The principle of a dehumidifying/desiccant bed dryer is the closed loop circulation of heated 'dry' air over thermoplastic granules. This releases moisture into the passing air. 'Wet' air subsequently passes through a dehumidifying/desiccant bed containing a molecular sieve material. This material is able to absorb the moisture from the circulating air, thus making it 'dry' again (see Figure 1).

After frequent circulation, the dehumidifying/desiccant bed becomes saturated with moisture and is no longer able to reduce the moisture in the passing air. To dry the material further, the saturated dehumidifying/desiccant bed first needs to release its absorbed moisture. This process of drying a dehumidifying/desiccant bed is called regeneration.

Regeneration

The process of drying a moisture saturated dehumidifying/desiccant bed is achieved by passing heated ambient air over the bed. The higher temperature (>200°C [>392°F]) makes the bed release the absorbed moisture. When the bed is sufficiently dry, it is cooled down and can be switched back into the closed loop when the alternate bed becomes saturated with moisture.

Figure 1 – Schematic diagram of a 2 dehumidifying/desiccant bed dryer.



DRYER TECHNOLOGY (cont.)

Single/multiple dehumidifying/desiccant bed dryers

If the dryer has only one dehumidifying/desiccant bed, the material will not dry during the regenerating of the moisture saturated bed. To overcome this time loss, multiple dehumidifying/ desiccant bed dryers were developed. While the saturated dehumidifying/desiccant bed is regenerating, another 'dry' dehumidifying/desiccant bed is switched into the closed loop and is able to continue drying the material.

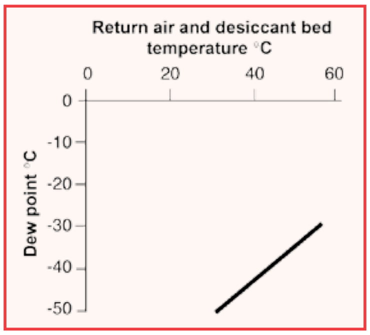
To dry ISOPLAST resins sufficiently, multiple dehumidifying/desiccant bed dryers are preferred because a continuous flow of dry air with sufficiently low dew point is required. Single dehumidifying/desiccant beds tend to give a larger fluctuation in moisture content in the air. This is not ideal for drying ISOPLAST resins.

Return air cooling

Dehumidifying/desiccant beds have a better moisture absorption capacity when they remain at a low temperature because more moisture condenses at a lower temperature (see Figure 2).

Therefore, a return air cooler is sometimes placed between the material hopper and the dehumidifying/desiccant bed to reduce the temperature of the hot returning air. The presence of a return air cooler is recommended for drying ISOPLAST resins.

Figure 2 – An illustration of the dependency of the dry air dew point on the return air and dehumidifying/desiccant bed temperature.

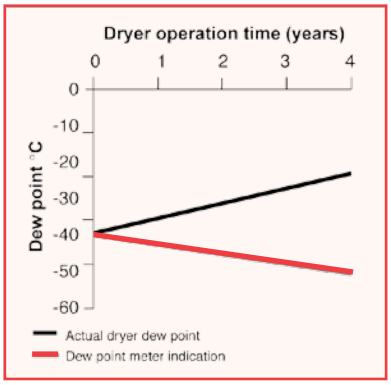


Dew point meters and calibration

The specification of a dryer will give an indication of the lowest possible dew point it can reach when in its optimum state. If the dew point is approximately -40°C (-40°F), the dryer will most likely be able to dry ISOPLAST resins.

The accuracy of a dew point measurement goes down with time rather rapidly. Dew point meters need calibration frequently, especially when used continuously. Deviations are counter to what actually happens (i.e., the measured dew point readings appear to become lower with time). In reality, as the desiccant gets older, its efficiency decreases and the true dew point rises (see Figure 3).

Figure 3 – An example of the discrepancy between the actual dew point of the dryer and the 'measured' dew point over time.



To ensure accuracy from your permanently connected dew point meter, disconnect it from the dryer, and expose the sensor to the ambient air. This prevents the sensor from drying out, which causes inaccuracy. Refer to manufacturer recommendations.

The efficiency of a dehumidifying/desiccant bed

If the dryer has been in use continuously for more than three years, or an equivalent period intermittently, some degradation of the molecularsieve in the dehumidifying/desiccant beds may have taken place. The dryer may no longer be able to reach the initial specified dew point. The best way of establishing whether there has been a serious deterioration of the moisture absorption capacity of the dehumidifying/desiccant beds, is to calibrate the dryer on a regular basis with an external calibrated dew point meter.

Location of the dew point meter is important. An internal or external dew point meter should measure samples from the air inlet to the drying hopper; in order to provide the best indication of equipment performance. A dew point meter will help detect any malfunction of the drying system prior to processing.

All drying systems should be "predried." By running the system one full cycle prior to loading, the system will come to the necessary operating temperature. This will ensure the dew point in the drying hopper is -40°C (-40°F) before the ISOPLAST engineering thermoplastic polyurethane resins are placed in the hopper.

Options

ISOPLAST resins have also been dried in vacuum ovens and in microwave dryers. The drying temperature table still applies, as do the drying times. ISOPLAST resins will not dry in dryers that use ambient air, whether it is heated or not.

SCREW DESIGN

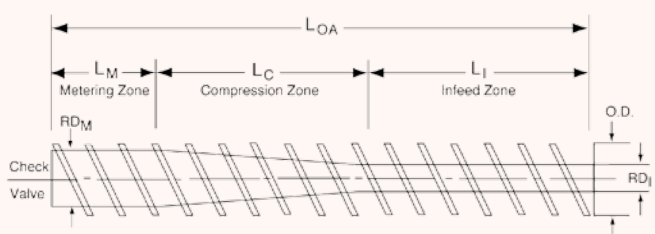
Nearly all types of processing equipment for thermoplastics use some form of a plasticating screw device. Extrusion, injection molding, and blow molding equipment all use plasticizing screws. The design of the screw is very important to the satisfactory performance of the processing equipment.

A properly designed screw will melt the resin and yield a uniform melt temperature in the proper temperature range, without over shearing the resin and causing it to degrade. Every resin family has different requirements for the screws that can be used to process it.

ISOPLAST resins require a screw with a moderate compression ratio (between 2.0:1 and 2.5:1) and a low "compression rate." Compression rate is defined as the difference between the in feed zone flight depth and the metering zone flight depth divided by the number of flight turns in the compression zone. The compression rate should be between 0.5 to 1.25 mm/turn (0.02 to 0.05 in/ turn) for processing ISOPLAST resins. The drawing below helps explain how the "compression rate" is calculated. This definition only applies to a so called "general purpose" screw. This is a screw with a single flight throughout its length and a relatively long compression zone. The transition or compression zone should be about 7 flights for a screw with a 20:1 L/D (length to diameter ratio). Higher compression rates will cause too much shear heating and melt temperature will be uncontrollable at reasonable production rates (see Figure 4).

Barrier and mixing screws have been used successfully, but due to the large number of potential designs, no specific details can be recommended. Please refer to your technical service and development representative for assistance. In general, barrier and mixing screws should be "low shear" or "gentle" in nature. In some cases, screws designed for rigid PVC have worked well for ISOPLAST resins.

Figure 4 – Injection Molding Machine Screw Configuration.



Screw Length Overall = L_{OA} = Screw Outside Diameter = O.D. = ________

L/D = L_{OA} / O.D. ________ = (L/D should be 20:1 or greater)

Infeed Zone Root Diameter = RD_I = ________

Metering Zone Root Diameter = RD_M = ________

Compression Ratio = $\frac{O.D.-RD_I}{O.D.-RD_M}$ = ________

(Compression Ratio should be between 2:1 and 2.5:1)

Compression Rate = $\frac{[O.D.-RD_I]-[O.D.-RD_M]}{L_C \text{ Turns}}$

INJECTION MOLDING

Drying is the most important consideration when processing ISOPLAST resins. Please review the section on drying for important details.

In general, ISOPLAST resins mold best at low melt temperatures, low injection pressures, and very low injection speeds. The suggested melt temperature and injection pressures are for parts that are relatively simple and have typical wall thicknesses. More complex parts or those with thinner walls will require higher melt temperatures and injection pressures.

Injection pressures (hydraulic) often run in the range of 40-70 bar (600-1,000 psi), with injection speeds in the range of 13-40 mm/sec (0.5-1.6 in/sec). Packing, or second stage pressures usually run in the 35-55 bar (500-800 psi) range. Higher pressures and speeds may be needed in more complex parts. Running an injection speed that is too fast will result in brittle parts and splay caused by high shear. This can result in the "melt fracture" of the parts. Melt fracture usually shows up as a series of weld lines in a chevron pattern, but can take other forms known as "flow lines."

Reciprocating screw type injection molding machines are recommended for molding ISOPLAST resins. Plunger or ram type machines are not recommended.

Do not leave the barrel and screw full of ISOPLAST resins during prolonged shut downs. Always shut off the in feed throat and empty the screw before leaving the machine idle for more than 15 minutes, especially at processing temperatures. In the case of the long glass fiber filled resins, never leave the barrel full during a shut down. The resin can evaporate, leaving the barrel full of glass fiber only. This would require pulling the screw to clean it.

Purging can be done with polystyrene (GPPS or HIPS), SAN, or ABS. We do not recommend polyolefins, as they are not compatible with ISOPLAST resins. They will take a very long time to purge out. Do not use cellulosic or polyamide resins to purge ISOPLAST resins. ISOPLAST resins will react with these, resulting in a cross-linked material that is no longer thermoplastic (i.e., you will have to pull the screw to clean it).

Besides the specific screw design recommendations given above, we suggest that injection molding machines for processing ISOPLAST resins should have an L/D ratio (length of screw to diameter of screw) of at least 20:1. The check valve selection is also very important. Ring check valves are preferred over ball type valves. In addition, the check valve should have streamlined flow channels but should not be too open. ISOPLAST melt can be pumped out of the screw more quickly than it can be replaced. This situation can cause a vacuum void in the screw, stopping the screw from returning (retracting) until the void is filled. This will cause gassing in the next shot. If the screw is not returning smoothly and consistently, a more restrictive check valve may be needed.

INJECTION MOLDING (cont.)

Barrel capacity should be no more than six times the shot size (shot size should not be less than 15 percent nor greater than 85 percent of barrel capacity). If the shot size is too large for the machine, the melt temperature will not be uniform. If the shot size is too small for the machine, ISOPLAST resins are more likely to degrade. Degradation will start to show up as a yellow color shift and move to splay and gassing in more extreme cases.

Injection molding machine clamping capability should allow for 0.3 to 0.7 metric tones/square centimeter (2 to 5 tons/square inch) of clamping force based on the projected area of the part to be molded. General purpose nozzles are recommended, rather than nylon type. The orifice in the nozzle tip should be as big a diameter as possible, based on the sprue diameter. Variac temperature control is not recommended. A thermocouple and temperature controller should be used on the nozzle and tip. ISOPLAST resins tend to freeze off easily at the nozzle tip, therefore, good temperature control is necessary. It may also be necessary to insulate the nozzle tip from the sprue bushing. Cardboard can be used to do this. Sprue break, or pulling the nozzle tip away from the mold after the screw has returned (recovered) can allow the nozzle temperature to recover between shots.

Gate sizes should be at least equivalent to a 2.5 mm (0.10 in) diameter round gate, except in the case of very small components. Larger gates are usually better. Submarine gates can be used in some cases with 'neat' resins, but with long glass fiber resins, high shear rates through the gate may result in splay and fiber length reduction. Additionally, early gate freeze off can cause sinks.

ISOPLAST resins normally do not exhibit excessive sink. If the gate is large enough to allow fully packing the part before it freezes off, there will be little or no sinking or internal voids in the parts.

Programmable injection velocity can be a big help in molding ISOPLAST resins. In cases where gate blush is a problem, it can often be solved by slowing down the injection velocity until the flow front has just passed the gate and then subsequently speeding it up to more normal rates. Sometimes minor splay and weld line problems can be controlled by changing the injection velocity, either up or down. Different molds will require different solutions.

The melt should have the consistency of honey, with few to no bubbles. There should also be no nozzle drooling. Under no circumstances should the melt temperature exceed 270°C (518°F) and preferably not above 260°C (500°F).

These are recommendations for average set ups with screws that meet the screw specifications listed above. The temperature profiles may need to be adjusted for any given machine/mold set up.

Some general guidelines are discussed below to help guide changes that might be needed to compensate for a screw that is not optimal for ISOPLAST resins.

To keep shear history to a minimum, run the screw at as low a speed as is possible while still allowing it to recover in the required cycle time. Back pressure can be used at levels up to about 14 bar (200 psi). Back pressure can help with color mixing, melt temperature uniformity, and in controlling minor splay problems. Long glass fiber reinforced ISOPLAST resins require some back pressure, otherwise the screw will retract without plasticizing the pellets. This will yield short shots and/or unmelted pellets in the melt. However, as a general rule, back pressure should be kept as low as possible.

Vented barrels are not recommended for the ISOPLAST resins because it is difficult to keep the ISOPLAST resins from foaming out of the vent. Vented barrels are NOT a substitute for drying ISOPLAST resins. By the time the melt reaches the vent, damage to the molecular weight has already occurred.

It is a good practice to use "position transfer", or changing from first stage injection pressure to second stage injection pressure by screw position rather than time. This ensures that the injection stroke does not bottom out and over fill the cavity before packing or the second stage takes place. To determine the proper position for switch over, short shoot the mold using only the first stage, filling pressure, and no second stage packing. Gradually change the switch over position until the cavity is 95 – 99% full on first stage, this will be the proper switch over position.

Over packing the cavity on first stage pressure can cause clear Isoplast resins to become brittle. To determine whether brittleness was caused by over packing or by moisture, anneal the parts for 2 – 4 hours at the appropriate temperatures shown in Table 1. If they were over packed, the parts will become ductile after annealing. If the material was process wet, the parts will remain brittle.

Table 1 – Recommended Annealing Temperatures for ISOPLAST Resins (Anneal for 2-4 Hours in Hot Air Oven)

ISOPLAST RESIN	TEMPERATURE °C	RANGE °F
101	81-89	178-192
202EZ	124-135	255-275
301	101-109	214-225
302EZ	124-135	255-275
101LGF40 & 60	81-89	178-192
202LGF40	124-135	255-275
2510	81-89	178-192
2530	81-89	178-192
2531	101-109	214-225
2540	81-89	178-192

INJECTION MOLDING (cont.)

With the long glass fiber filled resins, early position transfer will cause an artificial weld line. The interrupted flow will result in an area in the part that is low in glass fiber, creating a weak spot. Position transfer is still a good idea, but make sure the part is 95 percent full before this takes place. Generally, with long glass fiber filled resins, faster filling will give stronger weld lines and better surface finish, but excessive speed will cause jetting into the cavity and may contribute to brittleness.

ISOPLAST resins are sensitive to mold temperature. If the mold is too cold, there will be low molecular weight on the surface of the finished part. If the mold is too hot, cycle time will be too long. Do not run the mold temperatures higher than the annealing temperatures shown previously in Table 1. If parts of the mold surface, such as small core pins, are not cooled well, they will heat up and the ISOPLAST resin may begin to stick to the mold surface. Uniform mold temperature is very important.

Cooling time will run between 10-40 seconds for parts with wall thicknesses of 1.3-3.2 m (0.051-0.126 in). Thicker parts will require longer cooling times. The long glass fiber filled ISOPLAST composites must be cooled until a rigid skin has formed on the outside of the part. If these composites are removed from the mold too quickly, they will "post mold blow" (i.e., they will puff up and warp as the hot plastic allows the long glass fibers to try to straighten out). The only cure is more cooling, with either more time, a colder mold, or both.

ISOPLAST resins will exactly reproduce the mold surface. If you need a glossy surface, the mold will have to be finished to at least an ISO 1302 N-1 (SPE #2) finish. Matte finishes are reproduced from mold surfaces very well.

Generally, ISOPLAST resins release easily from molds. If necessary for a specific part, standard mold release agents may be used (including silicone mold release), providing the parts are not intended for subsequent painting, plating, or printing. Stearate based mold release agents should NOT be used with ISOPLAST resins under any circumstances. This will drastically reduce part performance.

Troubleshooting

Some problems to look for during molding include runaway temperature zones and screws that do not return smoothly and consistently. In the case of runaway temperature zones, turn up the temperature of the zone just before the problem zone. This symptom is an indication that the resin is being over sheared in the runaway zone and needs to be pre-heated more before entering that zone.

It may be necessary to go to a "reverse" temperature profile in some cases to compensate for less than ideal screw geometry. A "reverse" temperature profile is defined as one in which the temperature of the in feed zone is the highest and the zone at the nozzle end is the lowest. This type of profile will help pre-heat the resin before it enters the compression zone of the screw, lowering the viscosity and the power requirement to convey the resin forward.

It is recommended that there be no water cooling on the feed throat of the molding machine. The resin must be pre-heated in the dryer. Cooling the resin down and then heating it again in the screw is counterproductive. Bridging in the feed throat is not normally a problem with ISOPLAST resins, if they have been dried at the recommended conditions.

The problem of screw stall and/or inconsistent screw return usually will accompany a runaway temperature zone, but not always. The problem is that the resin viscosity is too high at some point in the screw, usually entering the compression zone. The solution is to raise the zone temperature just before that spot. One way to locate the spot is by finding the difference between the zone temperature set point and the actual zone temperature. When this difference is more than approximately 10°C (18°F), the set point of the preceding zone should be turned up until the difference disappears.

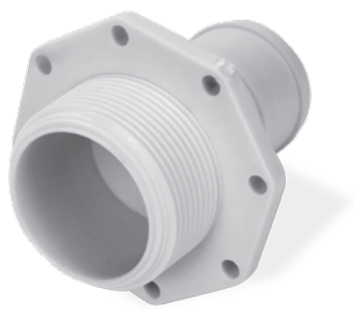
When the screw stalls (turns, but does not retract), melted resin pumps out of the screw faster than the unmelted pellets can be conveyed forward. This creates a void in the screw and the next shot will be gassy. Rather than using temperatures, a second method of correcting this problem is to use a more restrictive check valve. It will need to be streamlined, but the flow path must be more restrictive to reduce the pumping rate of the melted polymer.

If the compression ratio or compression rate of the screw is too great, the problem may not be solvable with temperature zone control. In these cases, a new screw will be needed.

Weld line strength

Weld lines, the hair lines formed by two or more flow fronts coming together, always form behind holes in parts. This often occurs around any obstruction or easy flow channel in the flow path. Weld lines can be strong with ISOPLAST resins. The melt temperature must be kept high until the two flow fronts meet. There can be no gas trapping at the flow fronts. If there are problems, changing the injection speed up or down will usually move the point at which the flow fronts meet, allowing better ventilation.

If the location of the weld line is constantly moving from part to part, it is a good indication that the melt temperature is not uniform from shot to shot. Slow the screw speed down as much as possible and raise the back pressure to help make the melt temperature more uniform. Minor melt temperature changes will cause significant viscosity changes in ISOPLAST resins.



INJECTION MOLDING (cont.)

Tool balancing

ISOPLAST resins are very sensitive to over packing in unbalanced tools. Family molds, molds with dissimilar parts that are molded together, are not normally recommended with ISOPLAST resins. If a family mold is required for any reason, the runner and gate system must be designed for balanced flow and pressure drop. If one part has significantly lower resistance to flow than other parts, it will fill first, causing over packing of that cavity and resulting in brittleness. While that cavity is filling, the gates to the other parts may freeze off creating short shots or sink. Careful balancing of the runners and gates can often remedy this problem.

Regrind

Up to 25 percent of reground ISOPLAST resin can be used. Care must be taken to keep out contamination and to keep the regrind dry. Wet regrind can cause the same problems as wet virgin ISOPLAST resin. It does not matter where the moisture came from, the resulting parts will be brittle with splay and there will be nozzle drool.

Annealing

The recommended annealing temperatures for ISOPLAST resins are shown in Table 2. Parts can be annealed in any air oven that gives uniform heat and can support the part. Heavy parts should be annealed on the lower side of the temperature range for a longer period of time. Small or thin parts that can support themselves may be annealed at a higher temperature for a shorter period of time. There may be some yellowing of the surface, but it will not have an adverse effect on the physical properties of the final parts.

Table 2 – Glass Transition Temperatures (Tg) for ISOPLAST Resins

ISOPLAST RESIN	TEMPERATURE °C	RANGE °F
101	81-89	178-192
202EZ	124-135	255-275
301	101-109	214-225
302EZ	124-135	255-275
101LGF40 & 60	81-89	178-192
202LGF40	124-135	255-275
2510	81-89	178-192
2530	81-89	178-192
2531	101-109	214-225
2540	81-89	178-192

EXTRUSION

The single most important factor in successfully extruding ISOPLAST resins is that they be dry before processing. This also applies to extrusion operations. (See the section on drying for complete details.) Up to 25 percent regrind can be used, but the same drying requirements still apply.

The following screw configuration is suggested when extruding ISOPLAST resins. A length to diameter ratio (L/D) of at least 24:1 is recommended. Compression ratios should be between 2.0:1 and 3.0:1. Below 2.0:1 there will be air entrainment. Above 3.0:1 the melt temperature will not be controllable. Check with your technical service and development representative for complete details on the best ratio.

If the resin is exposed to too much shear, the melt temperature will be higher than desired. This will result in very low melt strength and may also result in foaming, die build up, surface splay, and discoloration of the extrudate.

If the screw cannot be changed to a low shear profile, pre-heating the resin will usually help. Also, do not use cooling water on the feed throat. Instead, run the dryer at the upper limit of the recommended drying temperature range, being careful not to cake the material and starve feed the extruder. Slowing down the screw rpm may also help.

Screws designed for rigid PVC have performed well with ISOPLAST resins in some cases.

The resin should be below its glass transition temperature before it is exposed to water. See Table 2 for the glass transition temperatures of ISOPLAST resins. ISOPLAST resins can react with water at elevated temperatures (above glass transition temperature) and will lower the molecular weight of the resin and the physical properties of the resulting product.

It is best to try to reduce the melt temperature as much as possible at the die. Too high a melt temperature will result in die build up and low melt strength.

BLOW MOLDING

ISOPLAST resins can be blow molded. Injection, continuous extrusion, and accumulator head blow molding techniques have been used. Currently, only relatively light parisons can be extruded because of the tendency towards low melt strength and a narrow processing window. Parts up to 1.5 kg (3.3 lbs) have been successfully blow molded to date. Check with your technical service and development representative for more details.

COLORING

Unfilled ISOPLAST resins are not normally supplied pre-colored (factory colored). Long glass filled resins can be supplied in black or natural only. We encourage all customers that need colored final parts to use natural plus color concentrate (in-house coloring).

Please check with your Lubrizol Sales or TS&D contact for details of suitable masterbatches and where they can be obtained.

HANDLING CONSIDERATIONS

Material Safety Data (MSD) sheets for ISOPLAST* engineering thermoplastic polyurethane resins are available from Lubrizol, a business group of Lubrizol Advanced Materials, Inc. and its subsidiaries. MSD sheets are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations, such as OSHA (U.S.A.), MAK (Germany), or WHMIS (Canada). MSD sheets are updated regularly, therefore, please request and review the most current MSD sheet before handling or using any product.

The following comments are general and apply only to ISOPLAST engineering thermoplastic polyurethane resins as supplied.

Various additives and processing aids used in fabrication and other materials used in finishing steps have their own safe use profile and must be investigated separately.

Hazards and Handling Precautions

This resin contains glass fibers as a reinforcing component.

ISOPLAST engineering thermoplastic polyurethane resins have a very low degree of toxicity and under normal conditions of use should pose no unusual problems from ingestion, eye, or skin contact. However, caution is advised when handling, storing, using, or disposing of these resins and good housekeeping and controlling of dusts are necessary for safe handling of product. Workers should be protected from the possibility of contact with molten resin during fabrication.

Handling and fabrication of plastic resins can result in the generation of vapors and dusts including small particles of glass fibers. Dusts resulting from sawing, filing, and sanding of plastic parts in post-molding operations may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator.

Pellets or beads may present a slipping hazard. Slight itching and irritation may result from skin contact. Repeated exposure to particles generated by grinding glass fiber-reinforced materials may result in implantation of particles in the skin.

Good general ventilation of the polymer processing area is recommended.

Processing may release fumes which may include polymer fragments and other decomposition products. Fumes can be irritating. At temperatures exceeding melt temperature, polymer fragments can occur. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation may be necessary for some operations.

Use safety glasses. If there is a potential for exposure to particles which could cause mechanical injury to the eye, wear chemical goggles. If vapor exposure causes eye discomfort, use a full-face respirator. No other precautions other than clean body-covering clothing should be needed for handling ISOPLAST engineering thermoplastic polyurethane resins. Use gloves with insulation for thermal protection, when needed.

Combustibility

ISOPLAST engineering thermoplastic polyurethane resins will burn and, once ignited, may burn rapidly under the right conditions of heat and oxygen supply. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Dense black smoke is produced when product burns. Toxic fumes are released in fire situations.

Fire fighters should wear positive-pressure, self contained breathing apparatus and full protective equipment. Water or water fog are the preferred extinguishing media. Foam, alcohol resistant foam, carbon dioxide, or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred options include sending to a licensed recycler, reclaimer, incinerator, or other thermal destruction device. For used or contaminated material, the disposal options remain the same although additional evaluation is required (see, for example, in the U.S.A., 40 CFR, Part 261, "Identification and Listing of Hazardous Waste"). All disposal methods must be in compliance with Federal, State/Provincial, and local laws and regulations.

As a service to its customers, Lubrizol can provide lists of companies which recycle, reprocess, or manage chemicals or plastics, and companies that manage used drums. Contact the nearest Lubrizol Customer Service Center for further details.

Environment

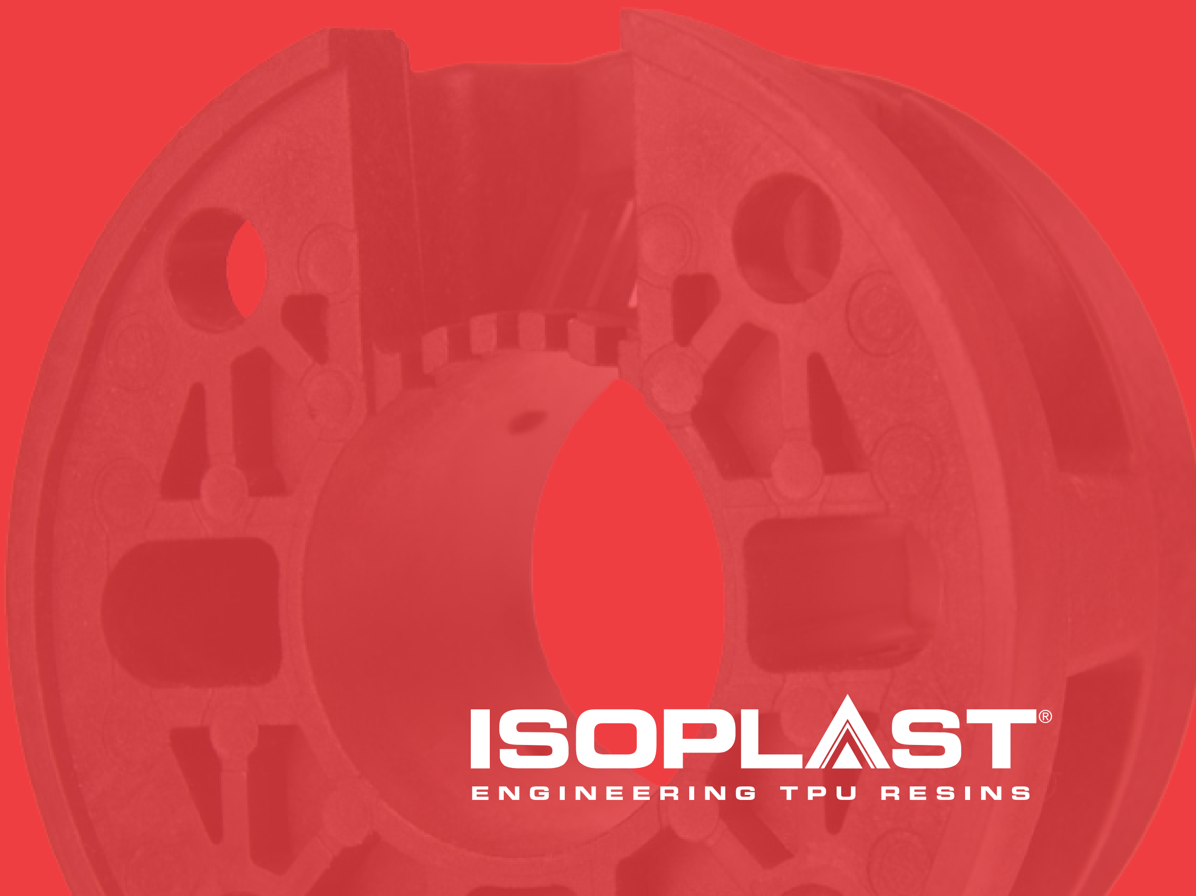
Generally speaking, in the environment lost pellets are not a problem except under unusual circumstances — when they enter the marine environment. They are inert and benign in terms of their physical environmental impact, but if ingested by waterfowl or aquatic life, they may mechanically cause adverse effects. Spills should be minimized and they should be cleaned up when they happen. Plastics should not be discarded into the ocean or any other body of water.

Product Stewardship

Lubrizol Advanced Materials, Inc. has a fundamental concern for all who make, distribute, and use its products, and for the environment in which we live. This concern is the basis of our Product Stewardship philosophy, by which we assess the health and environmental information on our products and then take appropriate steps to protect employee and public health and the environment. Our Product Stewardship program rests with every individual involved with Lubrizol products from initial concept and research to the manufacture, sale, distribution, and disposal of each product.

Customer Notice

Lubrizol encourages its customers and potential users of Lubrizol products to review their applications for such products from the standpoint of human health and environmental quality. To help ensure that Lubrizol products are not used in ways for which they were not intended or tested, Lubrizol personnel will assist customers in dealing with ecological and product safety considerations. Your Lubrizol sales representative can arrange the proper contacts. Lubrizol literature, including Material Safety Data sheets, should be consulted prior to the use of Lubrizol products. These are available from the nearest Lubrizol Customer Service Center.



ISOPLAST®

ENGINEERING TPU RESINS

PROCESSING GUIDELINES

Lubrizol

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