

Ultrason®

Injection molding



Ultrason® in the web: www.ultrason.de

 **BASF**
The Chemical Company

Ultrason® E, S, P

The Ultrason® resins are amorphous thermoplastics derived from polyethersulfone (PESU), polysulfone (PSU) and polyphenylsulfone (PPSU) and offer very high resistance to heat. Their wide spectrum of beneficial properties allows them to be molded into high-quality engineering parts and high-load mass-produced articles. They can be processed by almost all the techniques adopted for thermoplastics. Ultrason® can be successfully used for applications in which other plastics, e.g. polyamide, polycarbonate, polyoxymethylene and polyalkylene terephthalates, fail to meet the requirements. By virtue of their extraordinary versatility, Ultrason® resins can substitute thermosets, metals and ceramics.

Injection molding of Ultrason®

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Injection molding of Ultrason®

Overview

The same basic rules apply to the injection molding of the high performance plastics Ultrason® S (PSU), Ultrason® P (PPSU) and Ultrason® E (PESU) as to other engineering thermoplastics. The most important difference is the significantly higher processing temperature. Ultrason® requires melt temperatures of 330 to 390°C and mold surface temperatures of up to 190°C. In addition to suitable machinery and molds these high temperatures also demand careful handling. Some advantages, but also some challenges and possible problems are:

Advantages:

- Low shrinkage, no after-shrinkage
- No flashing
- No untypical corrosion or wear resistance problems
- Part quality is mostly more important than cycle time
- Good thermal stability
- No significant influence of residence time on mechanical properties

Challenges:

- Higher melt temperature
- Higher mold temperature
- High injection pressure due to high melt viscosity
- High demolding forces due to good adhesion with metal

Possible problems:

- Risk of stress cracking due to amorphous character (holding pressure profile, sufficient mold temperature!)
- Silver streaks due to humidity, gate system, feeding air (high shear)

Pretreatment

The presence of even tiny amounts of residual moisture during processing can adversely affect the quality of Ultrason® parts, for example causing silver streaks on the molding surface and foaming of the melt. Problems also arise during plastification of the material.

The predrying of Ultrason® should be carried out for three to four hours at 130 to 150°C in dry-air or vacuum dryers to give maximum moisture contents of 0.02 to 0.05%. Circulating air dryers are unsuitable. For best results moisture levels of below 0.02% are preferable. Because of the excellent hydrolysis resistance the material drying is only necessary to achieve a perfect surface quality. Higher humidity typically has no influence on mechanical properties like impact behavior.

Ultrason® granules can absorb moisture very quickly. For this reason the dried material should be fed directly to the injection molding machine.

Machinery

Plastification unit

Ultrason® can be processed using three-zone screws which are commonly used with other engineering thermoplastics. Effective screw lengths of 18 to 22D and pitches of 0.8 to 1.0D have proven successful. It is advisable to use shallow-flighted screws.

Open nozzles are preferred over shut-off nozzles since their design allows better flow. If shut-off nozzles are used, the best design in terms of flow should be used. In contrast to other thermoplastics it has proven successful when processing Ultrason® to increase the play between the shut-off needle and the guide hole to form a 0.05 to 0.06 mm gap. Despite of thermal expansion this should guarantee a sufficient clearance even at high temperatures.

Because of the high melt viscosity of amorphous thermoplastics there is no need for very narrow tolerances in parts of the machinery and the mold.

Particular attention should also be paid to the choice of materials for screws, screw tips, barrels, nozzles, and screw couplings. If there is any uncertainty regarding the thermal stability of machine parts, the machine manufacturer should be consulted. Generally modern machines are already designed for processing temperatures of up to approximately 400°C. In order to allow the processing temperatures of HT (high-temperature) thermoplastics to be achieved reliably heating bands of sufficient heating power are necessary. Barrel temperatures of up to about 400°C cannot always be achieved by means of standard heating bands. Therefore, it is recommended that ceramic heating bands with a specific heating power of about 5 to 8 W/cm² are used. Otherwise long heating time would lead to higher risk of material degradation during every machine start-up.

Injection mold

Like the plastification unit the injection mold must also be suitable for relatively high temperatures. Besides the purely mechanical design and choice of suitable materials the main considerations here are optimum design of the cooling channels and their seals and connections by means of heat- and pressure-resistant hoses.

Design and material selection

The relatively high operating temperatures must be taken into account in the mechanical design of molds. HT thermoplastics can always be processed using the steels customary for the construction of molds for other engineering thermoplastics. High-alloyed hot-worked steels (Table 1), which are also suitable for extended use at temperatures of about 200°C, and melt temperatures of above 400°C, have proven successful. Fits and guides must be matched to the increased operating temperatures. This is particularly true for combinations of materials of different coefficients of thermal expansion. The metal treatment temperature has to be 50 Kelvin above the afterwards maximum use temperature.

Temperature control

Like other engineering thermoplastics the production of high-quality moldings in reproducible quality requires optimum temperature control of the injection molds. Suitable temperature-control media for achieving mold temperatures from 140°C to about 190°C are both water and oil. The use of water as temperature-control medium is possible to about 200°C with appropriately designed temperature-control equipment. Electrical temperature control may also be possible under certain circumstances.



Bezel for head lamp

Steels for unreinforced grades	1.2343	X38CrMoV51
	1.2344	X40CrMoV5
Steels for reinforced grades with protection against wear	1.2378	X220CrVMo122
	1.2379	X150CrVMo121
	1.3344	S6-5-2
Steels additional corrosion resistance	1.2083	X42Cr13 13% Cr

Table 1: High-alloyed hot-worked steels for mold and/or plastification unit

Molding geometry and gate design

The molding design rules are basically the same as those applicable to other thermoplastics. In the case of Ultrason® moldings particular attention should be paid to adequate drafts, transition radii (≥ 0.4 mm), and large-area ejector systems. The draft should be at least 1 to 2° for smooth surfaces. For structured surfaces approximately an additional 1.5° should be provided per 0.02 mm of structure depth. For grades that are optimized for demolding smaller drafts can be possible.

The design rules applicable to other thermoplastics also apply to the design and dimensions of the gating systems. The draft of sprues (half cone angle) should be at least 1.0 to 1.5° . In order to make demolding of the sprue easier the sprue bushing should be well polished. It should be ensured that the transition radius between the sprue and molding is sufficient ($R = 1.0$ to 2.0 mm).



Fog lamp reflector

In pin gates the gate diameter is generally between about 1.5 and 3.0 mm. In tunnel gates the gate diameter should be as small as possible but not less than 0.8 mm. Smaller gates of about 0.4 to 0.8 mm may be possible for small parts and microparts. However, the lowest permissible gate diameter must be checked in each individual case. When designing tunnel gating systems the limited toughness in the just-injected state must be noted.

Ultrason® can also be processed using hot runner systems. Particular attention should be paid to adequate insulation between the hot runner and the remaining mold. Especially for small gate diameters freezing of the nozzle can occur. Furthermore, dead spots and large pressure losses, caused by excessively narrow runner cross sections, must be avoided under all circumstances.



Headlight bezel

Injection-molding parameters

Barrel temperatures

The material temperatures shown in Table 2 have proven successful for the processing of Ultrason®. Especially for the combination of high melt temperature and long residence time a rising temperature profile from the feed zone to the nozzle is recommended. The barrel temperature in the first barrel heating zone (feed zone) should be between 320 and 360 °C. For shorter residence times of the melt in the barrel a horizontal temperature profile may also be appropriate. The hopper region should be maintained at about 60 to 90 °C. Figure 1 shows illustrative temperature profiles for Ultrason®. In order to prevent melt escaping from open nozzles it may be helpful to lower the nozzle temperature by about 5 to 10 °C relative to the final barrel heating zones or to operate with screw retraction. However, it is to be taken into account that a screw reversal that is too big can lead to entrapped air and therefore to streaks.

Back pressure

It is recommended to use back pressure during plastification, since a low back pressure improves the melting behavior and metering accuracy. In general, a back pressure of up to 50 bar is adequate (depending on the machine, this corresponds to a hydraulic pressure of about 3 to 5 bar).

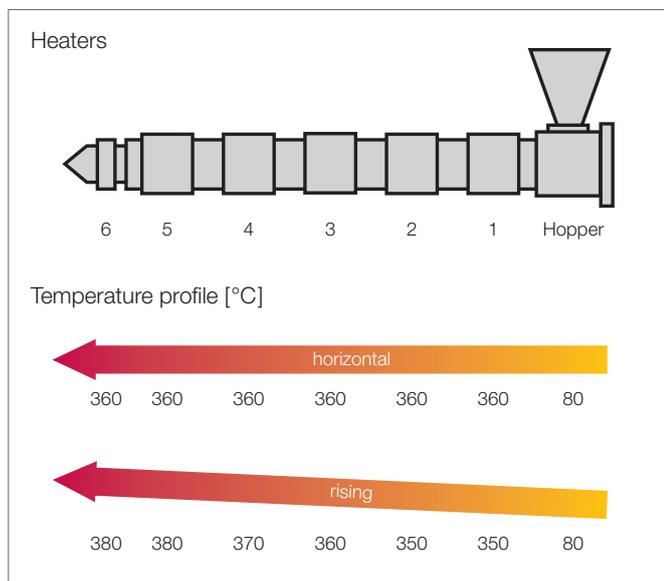


Fig. 1: Barrel temperature profile, examples for Ultrason®

Product	Melt temperature [°C]	Mold-surface temperature [°C]
Ultrason® S unreinforced	330 - 390	120 - 160
Ultrason® S reinforced	350 - 390	130 - 180
Ultrason® E unreinforced	340 - 390	140 - 180
Ultrason® E reinforced	350 - 390	150 - 190
Ultrason® P unreinforced	350 - 390	140 - 180

Table 2: Recommended temperatures for the injection molding of Ultrason®

Screw speed

Screw peripheral speeds of about 0.1 to 0.3 m/s (6 to 18 m/min) have been found to be successful for the processing of Ultrason® (Fig. 2).

Mold surface temperature

In order to obtain optimum properties of the molded part the mold surface temperatures shown in Table 2 should be observed. Inadequate mold temperatures can lead to increased internal stresses, impairment of the surface quality, and increased sensitivity to stress cracking. Excessively high mold temperatures generally cause demolding problems. For molds with sliders or other movable parts temperature control is even more critical. Before production starts a uniform temperature across the whole mold has to be reached and the clearance of the movable parts has to be checked.

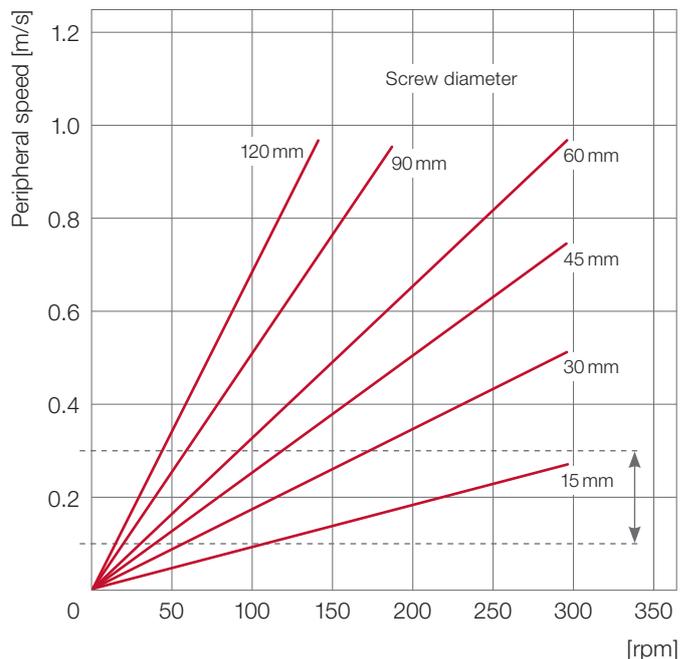


Fig. 2: Typical screw speeds for Ultrason®

Ultrason® type	T _{melt} [°C]	T _{mold} [°C]	Spiral length [mm]			
			Thickness 1 mm	Thickness 1.5 mm	Thickness 2 mm	Thickness 2.5 mm
S 2010	370	160	90	195	280	380
S 3010	370	160	73	165	230	315
	390	160	95	180	250	370
S 6010	370	160	69	120	155	230
	390	160	77	150	180	270
S 2010 G6	370	160	75	105	150	300
E 1010	370	160	125	200	290	420
	390	160	131	260	375	520
E 2010	370	160	77	160	230	320
	390	160	97	195	290	410
E 3010	370	160	70	110	165	210
	390	160	73	130	200	270
E 2010 G6	370	180	58	135	160	230
	390	180	72	145	210	300
P 3010	370	160	55	95	125	165
	390	160	67	120	160	270

Table 3: Flow behavior of Ultrason® in the flow spiral

Injection speed

The required injection speed is also determined by the geometry of the molding and by the gating system. Generally speaking, rapid injection rates are advantageous for achieving good surface qualities.

Hold pressure

The hold pressure depends principally on the geometry of the molding and gating system and on the surface quality required. The hold pressure is usually about 500 to 1,000 bar, but pressures both above and below this range are entirely possible. An inadequate hold pressure can result in noticeable sink marks, voids, and impaired surface quality. An excessively high hold pressure usually causes demolding problems and may result in increased internal stresses in the region around the gate. A hold pressure profile is recommended in these cases.

Hold-pressure time

The required hold-pressure time again depends on the geometry of the molding and gating system. The hold pressure should always be maintained only until the sprue has completely solidified. Small pin, tunnel or film gate sprues in particular solidify relatively quickly. In these cases the hold-pressure time is correspondingly shorter.

Cooling time

The cooling time is determined primarily by the maximum wall thickness of the molding or the gating system. Demolding takes place at significantly higher temperatures than for other thermoplastics. In spite of the higher processing temperatures the cooling times do not differ significantly from those of other thermoplastics.

Flow behavior

The flow behavior is characterized by determining the flow length in a spiral mold. The injection pressure of the injection molding machine is uniformly limited here to, for example, 1,000 bar. The flow paths achievable with a thermoplastic are dependent on the processing conditions, the wall thickness, and geometry of the molding, and the gating system in addition to the flowability of the thermoplastic melt. The flow path determined in the spiral mold can therefore only be applied to a limited extent to practical moldings. Table 3 shows the results for Ultrason® for spiral thicknesses of 1.0 to 2.5 mm.

Shrinkage

Typical shrinkage values for different Ultrason® grades are summarized in Table 4. Shrinkage was measured in flow direction and perpendicular to flow on two mm plaques according to ISO294. Unreinforced grades show very small anisotropy while reinforced grades have smaller shrinkage in flow direction due to fiber orientation. Of course, shrinkage depends also on part geometry and processing parameters, e.g. holding pressure.

	Ultrason® type	length [%]	width [%]
unreinforced	E 1010	0.79	0.82
	E 2010	0.82	0.86
	E 3010	0.85	0.90
	S 2010	0.69	0.72
	S 3010	0.70	0.74
	P 3010	0.90	1.00
reinforced	E 2010 G4	0.36	0.61
	E 2010 G6	0.28	0.58
	KR 4113	0.31	0.46
	E 2010 C6	0.15	0.35
	S 2010 G4	0.31	0.52
	S 2010 G6	0.29	0.46

Table 4: Shrinkage for different Ultrason® grades according to ISO 294

unreinforced, uncolored	
Ultrason® E 2010 MR UN	Polyethersulfone with medium viscosity
Ultrason® E 2010 UN Q26	Polyethersulfone with medium viscosity
Ultrason® E 3010 MR UN	Polyethersulfone with higher viscosity
Ultrason® S 3010 MR UN	Polysulfone with medium viscosity
unreinforced, colored	
Ultrason® E 2010 MR black	Polyethersulfone with medium viscosity
Ultrason® E 2010 MR black HM	IR-transparent Polyethersulfone with medium viscosity
Ultrason® E 2010 black Q31	Polyethersulfone with medium viscosity
Ultrason® P 3010 MR black	Polyphenylsulfone – standard grade
Ultrason® P 3010 MR gray	Polyphenylsulfone – standard grade
Ultrason® P 3010 MR white	Polyphenylsulfone – standard grade
reinforced, colored	
Ultrason® E 2010 G4 MR black	Polyethersulfone with 20% glass fibers and medium viscosity

Table 5: Ultrason® products with improved demolding behavior

Typical injection molding problems

Demolding

Due to the good adhesion between Ultrason® and metal problems could occur during the demolding (see also sufficient draft for mold design!). During production start up the use of mold release agent could be necessary. Materials with improved demolding properties are listed in Table 5. The effect of a demolding agent is shown by measurements in a BASF mold in Figure 3.

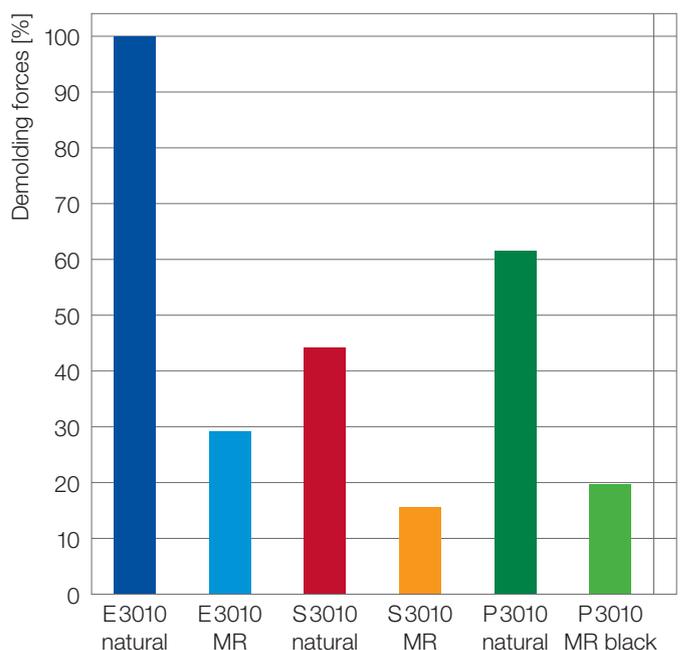


Fig. 3: Demolding behavior of Ultrason®, BASF test mold E9.3

Silver streaks

Typical reasons for silver streaks are:

Humidity

- Drying, humidity level <0.02 to 0.05 %

Cold slug

- Check geometry of sprue and the temperature at hot runner or plastification tip

Feeding air

- Screw design (flight depth, length of feeding zone, barrier flight ...)
- Plastification parameters (e.g. back pressure)
- Reduction of decompression
- Use of needle valve nozzle

Shear

- Reduce injection speed

Entrapped air due to overflow of ribs

- Part design, gate position, mold venting, avoid sharp edges or sudden wall thickness changes

Black specks/residence time

During normal production residence time in the range of 5 to 10 minutes will be no problem also for high melt temperature. At lower melt temperatures even longer residence times are possible. The main problem resulting from long residence time and/or high melt temperature is the discoloration of the product (more yellowish for transparent materials or brownish color for glass fiber reinforced materials). The mechanical properties will be influenced only upon exposure to excessively long residence time. The main cause of black specks are areas in the cylinder or hot runner with low or no flow velocity (“dead spots”). This leads to areas of isolated degradation of the material. This problem could also occur as a result of long interruptions with too long heat-up or cool-down periods (Fig. 4).

Haze

When Ultrason® is impurified with foreign polymer, either during handling (e.g. in the dryer, in the feed pipes) or by small remains in the plasticizing unit, the moldings can become hazy. This also applies to the mixture of the different Ultrason® polymers with each other.

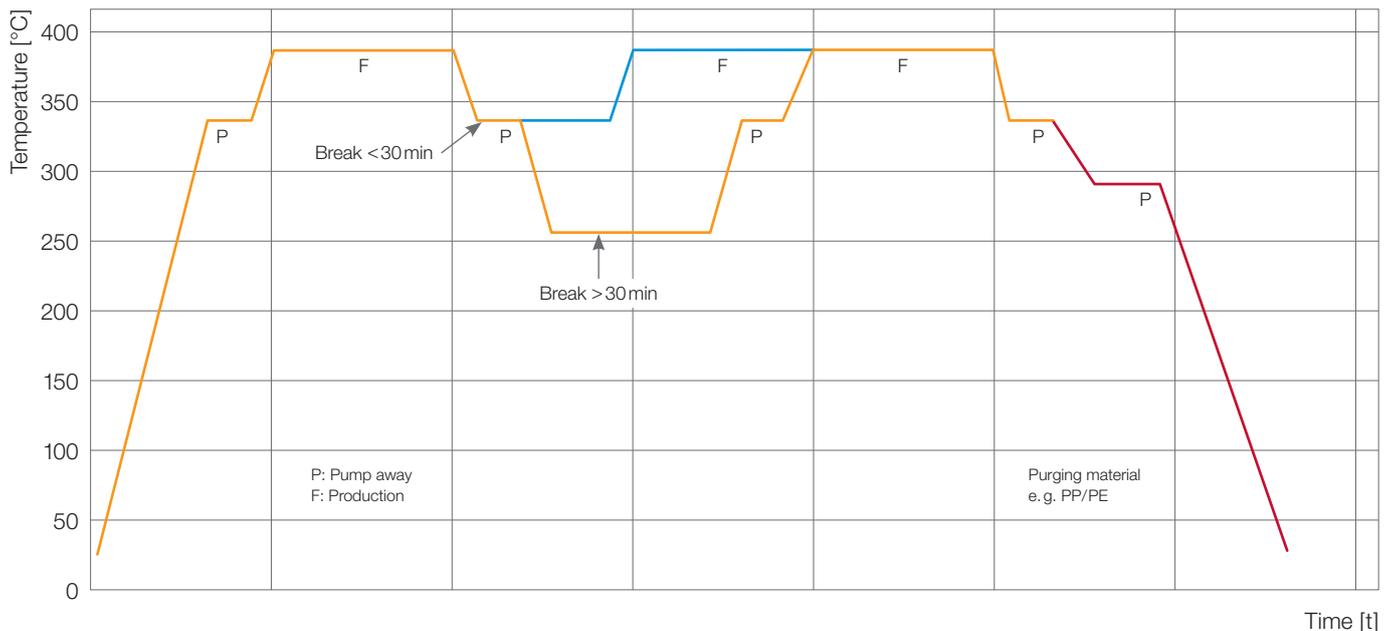


Fig. 4: Ultrason® processing: temperatures during interruption or break

For 250°C the material could stay for several hours inside the cylinder. For high processing temperatures the material inside the cylinder should be pumped away every 10 minutes.

Machine start-up, interruption and shut-down

It has been found that heating to the required processing temperatures is best carried out in two steps. First the barrel temperatures are initially set at the lower processing temperature range for the particular thermoplastic (about 330 to 350°C). As soon as these temperatures have reached a steady state the material in the barrel is pumped out. In a second step, the barrel temperatures are then adjusted to the required processing temperature.

Before shutting down or lowering the temperature it is again advisable first to set the barrel temperatures to the lower processing temperature range for the particular thermoplastic and to pump out the material in the barrel once this temperature has been reached. The barrel should always be emptied and the screw should be pulled back approx. 10mm from the front position. This will prevent the screw tip from breakage during the next start-up. The heating can then be turned down or switched off completely.

Relatively short breaks lasting from about 10 to 20 minutes are generally not a problem at the usual processing temperatures. At temperatures in the upper processing range for the thermoplastic (> about 380°C) interruptions lasting more than about 5 minutes should be avoided. If necessary, material in the barrel should be pumped out at regular intervals. During extended interruptions the barrel temperatures should be lowered to about 250°C or the heating should be switched off completely (Fig. 4). Pumping out is generally advisable after breaks.

Purging and cleaning

The high processing temperatures of high-temperature thermoplastics mean that purging or cleaning of the plastification units is not straightforward. For Ultrason® this process is carried out in two steps. First the barrel temperatures are reduced to about 330 to 350°C. Only when this temperature has been reached a suitable purging material can be feeded into the barrel (Fig. 4). By continuous purging the barrel temperatures can be lowered very quickly to the normal processing temperatures for the purging material. The main purging materials that have been found to be successful are high-molecular-weight PE or PP granules and polycarbonate. It is vital to ensure that the temperatures in the feed zone are not too high, otherwise feed problems caused by “bridging” of the purging material can occur.

Extreme care must be taken during purging because the temperatures are high for the purging material. Excessive overheating of the purging material entails the risk of self-ignition of the purged material. Discharging into a water bath or the use of an extractor fan is recommended.

The use of purging materials only simplifies dismantling and subsequent mechanical cleaning of the plastification unit. However, it is usually impossible to remove all material residues by purging. Therefore, mechanical treatment is essential for final cleaning. The mechanical removal of thick, cooled material should be avoided as well as burning off at superheated temperatures, since this can result in damage to the metal surface and screw distortion, especially for nitrated units.

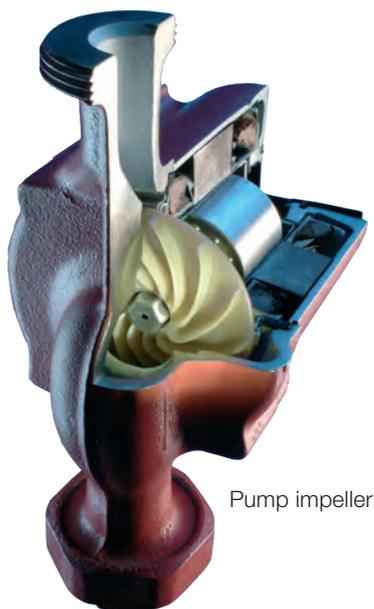


Microwave dishes

Recycling

Reground scrap from sprues or reject parts can be recycled in Ultrason® to a limited extent (in a ratio of up to about 20%) as long as it is clean and has not been thermally damaged during prior processing. The addition of regrind may impair the feed, flow, and demolding behavior. As far as the mechanical properties are concerned a reduction in the impact strength in particular is possible. In fiber-reinforced products a shortening of the fiber length and consequently a change in the mechanical properties (for example a drop in strength) can be expected for each processing operation.

Ultrason® regrind can take up moisture quickly. It is therefore advisable to dry the material before further processing. Furthermore, it is imperative to remove fine dust particles from the regrind.



Pump impeller

Safety precautions during processing

In view of the high temperatures involved in processing Ultrason®, great care must be exercised – even more than for other thermoplastics – in handling the machinery, molds, moldings, and residual melts. The machine manufacturer must be consulted if any doubts exist on the thermal capacity of the machinery and installation. If the normal precautions are observed and the upper temperature limit, i. e. 390°C, is not exceeded, no vapors that are injurious to health are released while Ultrason® is being processed. Like all other thermoplastics it decomposes on exposure to excessive heat, for instance if the melt temperature is too high, if the residence time in the plasticizing unit is too long, or if residues in the plasticizing unit are burned off and gaseous decomposition products are given off. The place of work must be well ventilated, preferably by means of an exhaust system installed above the barrel unit. Irrespective of this all precautions relating to accident prevention must be strictly observed. Under no circumstances may the plasticizing unit be dismantled after a breakdown while it is still hot.

Any product that has decomposed during injection molding must be removed from the barrel by injecting it into the atmosphere and simultaneously reducing the barrel temperature.

Noxious odors that might be caused can be reduced by rapidly cooling the degraded material, e. g. in a water bath. If the degraded material is not pumped off, gas pressure may build up in the barrel, particularly if nozzle shutoff devices are used. This pressure may be released violently in the area of the nozzle or the hopper and explosions can therefore be expected in the course of pumping. The figures laid down for the maximum allowable dust concentrations* must be observed in further processing.

*In Germany, the MAK-Wert-Richtlinien.



Latches for circuit breakers



Oil control piston



Chip carrier

Nomenclature

Structure

The nomenclature adopted for the products consists of an alphanumeric code, the key to which is given below. An appended "P" signifies that the product concerned is a specialty intended for the preparation of solutions.

1st digit (letter):

type of polymer

E = Polyethersulfone (PESU)

S = Polysulfone (PSU)

P = Polyphenylensulfone (PPSU)

2nd digit (number):

viscosity class

1 ... = low viscosity

6 ... = high viscosity

6th digit (letter):

reinforcements

G = glass fibers

C = carbon fibers

7th digit (number):

proportion of additives

2 = mass fraction of 10%

4 = mass fraction of 20%

6 = mass fraction of 30%

Example

E	2	0	1	0	G	6
1 st digit	2 nd digit	3 rd digit	4 th digit	5 th digit	6 th digit	7 th digit

e. g. Ultrason® E 2010 G6

E = Polyethersulfon (PESU)

2 = of medium viscosity (standard injection-molding grade)

G6 = 30% by weight of glass fibers

For your notes

Selected Product Literature for Ultrason®:

- Ultrason® E, S, P – Product Brochure
- Ultrason® E, S, P – Product Range
- Ultrason® – Resistance to Chemicals
- Ultrason® – Products for the Automotive Industry
- Ultrason® – Special Products
- Ultrason® – A Versatile Material for the Production of Tailor-made Membranes

Note

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed. (July 2013)

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e. g. www.plasticsportal.eu/ultrason

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