Modified PPE-PS
Americas
Noryl* resin is based on a modified PPO technology developed by SABIC Innovative Plastics. Noryl resin is an extremely versatile material - a miscible blend of PPO resin and polystyrene - and the basic properties may be modified to achieve a variety of characteristics.
Noryl® modified PPO resin PPE-PS

**Characteristics**

Typical characteristics include excellent dimensional stability, low mold shrinkage, low water absorption and very low creep behavior at elevated temperatures. These properties combined with an outstanding hydrolytic stability in hot and cold water, make Noryl resin an excellent potential candidate for fluid engineering, environmental and potable water applications.

An outstanding feature of Noryl resin is its retention of tensile and flexural strength, even at elevated temperatures. The gradual reduction in modulus as temperature is increased, is a key advantage of this material. As a result, parts made or molded from Noryl resin may be used with predictable performance over a wide temperature range.

Another important advantage of Noryl resin is its predictably low creep behavior, even at elevated temperatures.

The family of Noryl resin offers impact strength, which is typically unaffected by humidity and only slightly affected by temperature and wall thickness. Even at lower temperatures, they retain a high percentage of their impact strength.

Noryl resin exhibits excellent electrical properties, which remain stable over a wide range of temperature, humidity and frequency variations. This stability, together with a fine-tuned balance of thermal and impact properties, makes Noryl resin an excellent potential candidate for demanding electrical and electronic applications, including electrical insulators.

All flame retardant Noryl resin is designed with non-brominated and non-chlorinated flame retardant systems. The heat, flammability and electrical properties, which comply with key agency standards, may make Noryl resin an excellent potential candidate material for computer and business machine housings and structural components, electrical and electronic applications.
Reprocessability
Noryl resin may have a high retention of properties when processed multiple times, under recommended processing conditions, and without contamination. This not only applies to its mechanical and thermal properties, but also to its flammability. However, attention to the recommended UL guidelines remains essential.

Chemical and environmental resistance
Noryl resin is specially noted for its outstanding hydrolytic stability. Its low water absorption rate - both at room temperature and at elevated temperatures contributes to the retention of properties and dimensional stability in the presence of water, high humidity and even steam environments.

In addition, Noryl resin is virtually unaffected by most aqueous solutions, detergents, acids and bases. It should be noted that Noryl resin would soften when brought into contact with many halogenated and aromatic hydrocarbons. Where an application requires exposure to or immersion in this type of environment, prototypes and suitably stressed samples should be tested under actual operating conditions.
Noryl® resins are found in a broad range of high performance applications.

Fluid Engineering / HVAC

(Heat ventilation air conditioning)
Hydrolytic stability is essential for all materials used in the transportation of fluids. Noryl® resin has the lowest water absorption rate of any currently known engineering plastic. This contributes to the retention of properties and dimensional stability in a high humidity environment or in direct contact with water. It is for this reason that Noryl resin is still being used after more than 25 years by major manufacturers of fluid engineering equipment in applications such as pumps, impellers, manifold blocks and water meters.

Typical properties include
• Hydrolytic stability
• Dimensional stability
• Low creep behavior at elevated temperatures
• Outdoor weatherability (Great retention of properties)
• Potable water compliance (NSF standard 61, KTW, WRAS, ACS, restrictions apply)
• Resistant to most aqueous solutions, detergents, acids and bases

Solar heating systems
Noryl modified PPE resin products have helped optimize the efficiency of innovative solar heating systems. Noryl resin is used for the profiles and water collection cups, while black Noryl multi-wall sheet is an excellent material of choice for the absorber panel. In addition to being a highly efficient absorbent of the sun’s heat energy, the material combines excellent heat resistance with outstanding hydrolytic stability for continuous contact with hot water.

Packaging
Noryl resin is commonly used as an additive to polystyrene for vacuum formed disposable containers for convenience foods, which are to be microwaved. The addition of Noryl resin may improve heat performance and mechanical properties. Furthermore, wall thickness may be reduced for faster processing and all-round cost efficiency.

Typical properties include
• High heat
• Low temperature Impact performance
• Retention of rigidity at elevated temperatures
• Food contact compliance (FDA 21 CFR 177.2460, restrictions apply)
• Stiffness at elevated temperatures up to 120°C
• Melt strength
• Recyclable
**Cable management**

Tailor-made extrusion grades of Noryl® resin combine excellent physical properties with superb processability. Depending on the grade, different requirements with regard to ball pressure temperature can be fulfilled.

**Typical properties include**
- Meet the requirements for use in non-brominated and non-chlorinated (VDE/DIN 472, part 815) parts
- Low toxicity (GEI 20.37.2)
- Low smoke (ASTM E662 / EN 50268-1-2)
- Low corrosivity
- High heat
- Low weight
- Good impact resistance over a wide range of temperatures
- Good electrical properties
- Recyclable

Developed specifically to meet stringent industry requirements for low corrosion and low smoke, Noryl low smoke resin is positioned to help offer a unique balance of cost efficiency and performance. In addition to the characteristic properties of Noryl resin, it offers very good performance in the event of fire with low smoke behavior in accordance with ASTM E662.

**Electrical**

**Telecommunications**

Noryl resin may be used in the electrical industry due to its excellent dimensional stability, low creep behavior at elevated temperatures, and low water absorption. All flame retardant Noryl resin meets the requirements for use in non-brominated and non-chlorinated (VDE/DIN 472, part 815) parts.

**Enclosures / circuit breakers**

Noryl resin is commonly used for electrical boxes, meter base, circuit box cover and smoke detectors. Noryl resin offers high impact resistance combined with great dimensional stability, good tracking resistance and excellent electrical properties.

Noryl resin is an excellent electrical insulator as it exhibits excellent electrical properties that remain stable over a wide range of temperature, humidity and frequency variations. This stability, together with a fine-tuned balance of thermal and impact properties, may make Noryl resin an excellent candidate for demanding electrical and electronic applications.

**Key strengths of flame retardant Noryl resin include**
- Dielectric strength
- Heat resistance
- RTI (Relative Thermal Index) 95°C-120°C
- Drop impact
- Dimensional stability
- Non-brominated and non-chlorinated flame retardancy (VDE/DIN 472, part 815)
2. Applications

Uninterrupted power supply (UPS) batteries

Flame retardant Noryl® resin may be used for UPS batteries that require flame retardancy, chemical resistance and ease of molding. For applications, which have high aesthetic requirements, Noryl resin may offer a high quality surface finish, and is self-colored or paintable.

Chassis and indoor enclosures

Glass and glass/mineral reinforced grades of Noryl resin are an excellent material choice for Chassis and Indoor Enclosures as they provide tailored properties which typically include: good isotropic behavior for excellent dimensional stability and surface appearance, very high stiffness, high temperature resistance, low shrinkage, non-brominated and non-chlorinated flame retardancy (VDE/DIN 472, part 815).

Fiber optic connectors

Glass-reinforced Noryl resin is a potentially excellent candidate for the optical fiber connector market, where it has the potential to meet key design specifications including dimensional stability, tight tolerances and a low, uniform coefficient of thermal expansion.

Connectors

In telecommunications connectors, there is an excellent fit for non-brominated and non-chlorinated flame retardant Noryl resin, specifically in large dimension connectors in less aggressive environments.

Business machines

Noryl resin is commonly used in office automation equipment including business machine chassis, frames and housings, computer components, printers and copiers. The material meets the stringent requirements of Blue Angel RAL-UZ 78 due to its non-brominated and non-chlorinated flame retardancy (VDE/DIN 472, part 815), that helps minimize corrosion and toxicity in the event of a fire.
Audio/video

TV back plates
Noryl® resin is an excellent potential candidate for TV back plates as it offers:
- Non-brominated and non-chlorinated flame retardancy, in line with IEC 65
- Recyclability
- Good flow
- Fast cycle times
- Good surface appearance unpainted

TV components
With the design flexibility offered by a range of both reinforced and unreinforced grades, Noryl resin is an established material for a variety of TV components including deflection yokes, fly back transformers and bobbins.
In these applications, key properties include:
- Excellent electrical properties
- RTI (Relative Thermal Index) 95°C-120°C
- Non-brominated and non-chlorinated flame retardancy
- Dimensional stability
- Wide processing window
- High flow grades for thin-walled parts

Automotive
Noryl resin is successfully employed in a range of automotive applications where weight savings, system cost reductions and quality are of critical importance.

The material is highly versatile, performing over a wide temperature range with excellent heat performance and stability. Noryl resin flow characteristics allow thinner wall molding, helps reduce material usage and final part weight.

Exceptional rigidity reduces the need for reinforcement, taking these advantages still further. Where higher degrees of stiffness are required, Noryl resin is also available in glass-reinforced grades.

Instrument panels
Noryl resins are excellent candidates for instrument panels. SABIC Innovative Plastics is committed to focusing its efforts on product innovation to help its customers achieve a good balance of performance versus cost.

The specific advantages of this proven technology include:
- Excellent impact performance over a wide temperature range
- Wide processing window, allowing thin wall molding
- Excellent dimensional stability and low creep behavior
- Low density
- Good paint/foam/foil adhesion without pre-treatment
- Precision molding for part consistency
- Recyclability

For instrument panel sub-assemblies, SABIC Innovative Plastics has developed tailor-made grades to satisfy specific requirements. These include, for example, a grade with anti-squeak properties and, specifically for air vents, another that can be painted without pre-treatment with water-based, soft feel paints.

Vent grilles
For a complex part such as the cowl vent grille, Noryl resin is excellent potential candidates due to its good flow. This important property is complemented by the resin’s excellent dimensional stability over a wide temperature range.
SABIC Innovative Plastics’ Noryl* modified PPE resin is extremely versatile.

3.1 General properties
Noryl* modified PPE resin is an extremely versatile amorphous engineering thermoplastic whose key characteristics include:
- High heat resistance
- Non-brominated and non-chlorinated flame retardancy (VDE/DIN472, part 815)
- Excellent dimensional stability
- Low mold shrinkage
- Very low water absorption
- Low creep at elevated temperatures
- Outstanding insulation properties: dielectric strength, dissipation factor

Physical properties of plastic are dependent on the expected temperature and stress levels. Once this dependency is understood, and the end-use environment has been defined for an application, standard engineering calculations can be used to predict part performance.¹

While there are many factors to be considered in product design with Noryl resin, the material’s gradual drop-off in modulus with increasing temperature is a key advantage.

¹ Data shown in this brochure is measured on test bars. To determine actual performance the final part must be tested before end use.

3.2 Mechanical properties

3.2.1 Stiffness
The stiffness of a part is defined as the relationship between the load and the deflection of a part. The most important material property for stiffness is the stress/strain curve. In general, the Young’s modulus, which is determined from the stress/strain curve, is one of the better parameters to be used when comparing the stiffness of materials, as can be seen in figure 1.

As for all thermoplastics, the stress/strain curve is heavily dependent on temperature. It is important therefore to calculate part stiffness using the temperature at which the load is applied, figure 2 shows the flexural modulus of Noryl resin as a function of temperature.
3.2.2 Strength
An outstanding feature of Noryl® resin is its retention of tensile and flexural strength, even at elevated temperatures. As already stated, the gradual reduction in modulus as temperature is increased, is a key advantage of this material. Figure 3 clearly indicates that, with attention to recommended design practices, parts molded from Noryl resin can be used with predictable performance over a wide temperature range.

The strength of a part is defined as the maximum load that can be applied to a part without causing part failure under given conditions. In order to be able to determine the strength of a part, failure has to be defined first.

The right definition of failure depends on the application and how much deformation is allowed.

Material strength is a stress/strain related property that is inherent in the material. The tensile test provides the most useful information for engineering design. Figure 4 shows the stress/strain curves of unreinforced Noryl resin at different temperatures; figure 5 shows glass reinforced Noryl resin, while figure 6 illustrates that, at higher strain rates, there is an increase in both strength and modulus.

3.2.3 Behavior over time
Two phenomena should be considered: static time dependent phenomena, such as creep, are caused by the single long-term loading of an application; whereas dynamic time dependent phenomena such as fatigue, on the other hand, are produced by the cyclic loading of an application. Both behaviors are heavily influenced by the operating environment and component design.
3. Properties and design

Creep behavior
An important advantage of Noryl® resin is its predictably low creep behavior, even at elevated temperatures, as shown in figure 7. This is due to the material’s inherent high heat resistance, and is particularly true for glass-reinforced grades of Noryl resin. Creep is defined as the increasing rate of deformation of a geometrical shape when subjected to a constant long-term load. The creep rate for any material is dependent on temperature, load and time. Creep behavior is initially examined using plots of strain as a function of time, over a range of loads at a given temperature, as shown in figure 8. Measurements may be taken in the tensile, flexural or compression mode.

Fatigue endurance
Structural components subjected to vibration, components subjected to repeated impacts, reciprocating mechanical components, plastic snap-fit latches and molded-in plastic hinges are all examples where fatigue can play an important role. Cyclic loading can result in mechanical deterioration and fracture propagation through the material leading to ultimate part failure, often at a stress level considerably below the yield point of the material.

Fatigue tests are usually conducted under flexural conditions, though tensile and torsion testing is also possible. A specimen of material is repeatedly subjected to a constant deformation at a constant frequency, and the number of cycles to failure is recorded. The stress level can be predicted using standard and dynamic structural engineering equations. The test data are usually presented as a plot of log stress versus log cycles; this is commonly referred to as an S-N curve. Figures 9 and 10 show the S-N curves of standard unified grades of Noryl resin and a 30% glass-reinforced grade. S-N curves obtained under laboratory conditions may be regarded as ideal. However, practical conditions usually necessitate the use of a modified fatigue limit, as other factors may affect performance, including most notably the type of loading, the size of the component and the loading frequency.

However, fatigue testing can only provide an indication as to a given material’s relative ability to survive fatigue. It is therefore essential that tests be performed on actual molded components, under actual end use operating conditions.

3.2.4 Impact strength
The family of Noryl resin offers excellent impact strength that is virtually unaffected by humidity and only slightly affected by temperature (see figure 11) and wall thickness. A key advantage of these materials is that, even at lower temperatures, they retain a high percentage of their impact strength.

Figure 7 - Creep performance of Noryl 731 resin as a function of time at 10 MPa stress and different temperatures

Figure 8 - Creep performance of Noryl 731 resin as a function of time at room temperature and at different stress level

Figure 9 - Fatigue performance of Noryl 731 resin with a frequency of 5 Hz at room temperature

Figure 10 - Fatigue performance of Noryl GFN3 resin with a frequency of 5 Hz at room temperature
Impact strength can be described as the ability of a material to withstand an impulsive loading. There are several factors that determine the ability of a plastic part to absorb impact energy.

In addition to the type of material, these factors include:
- Wall thickness
- Geometric shape and size
- Material flow
- Operating temperature and environment
- Rate of loading
- Stress state induced by loading

3.3 Electrical properties
Noryl resin generally exhibits excellent electrical properties that remain stable over a wide range of temperature, humidity and frequency variations. This stability, together with a fine-tuned balance of thermal and impact properties, makes Noryl resin a potentially excellent candidate for demanding electrical and electronic applications.

Noryl resin is an excellent electrical insulator. Noryl resin’s dielectric strength values vary between 16 and 18 KV/mm at 3.2 mm. The Noryl resin values for the relative permittivity and the dissipation factor are the lowest, compared to other polymers (figures 12 and 13).

3.4 Flammability

3.4.1 Flame resistance
The most widely accepted flammability performance standards for plastics are UL94 ratings, which identify a material’s ability to extinguish a flame once ignited.²

Noryl resin has broad UL94 recognition across a wide range of applications. These include, most notably, business machines, power distribution and electrical enclosures. All flame retardant Noryl resin meets the requirements for non-brominated and non-chlorinated parts in applications according to VDE/DIN 472, part 815.

² These ratings are not intended to reflect hazards presented by this or any other materials under actual fire conditions

3.4.2 Combustion characteristics
A key factor in determining the relative safety of a polymer is its smoke generation under actual fire conditions. Noryl resin has been specifically developed to meet the most stringent industry requirements for performance and cost efficiency. It exhibits low smoke behavior in accordance with ASTM E662 and low toxicity in accordance with GEI 20.37.2.
3.5 Environmental resistance

3.5.1 Chemical resistance
Noryl® resin is virtually unaffected by many detergents, acids and bases. However, exposure to many halogenated and aromatic hydrocarbons should be avoided as these will soften or dissolve the material. In applications requiring exposure or immersion in this type of environment, finished part performance should always be evaluated on the actual part under actual service conditions.

3 In all cases, testing of the application under working conditions is strongly recommended. The actual performance and interpretation of the results of end-use testing are the end producer’s responsibility.

3.5.2 Hydrolytic stability
Noryl resin is particularly noted for its outstanding hydrolytic stability. Both at room temperature and at elevated temperatures, it exhibits a water absorption rate, which is amongst the lowest of any engineering thermoplastic. Its low water absorption rate contributes to the retention of properties and dimensional stability in the presence of water, high humidity and even steam environments.

3.5.3 Agency recognition
Noryl resin has been widely tested, and complies with a number of agency regulations and specifications. It is SABIC Innovative Plastics’ policy to only market materials that meet the stringent requirements laid down by the EU, national bodies and the Food and Drug Administration (FDA) of the USA. The most important examples are found in food contact, potable water contact, medical, pharmaceutical and toy applications.

A range of Noryl resin grades is available offering potable water contact approval. These materials are produced under stringent manufacturing conditions and contain specific approved pigments and additives.

3.6 Processability
For molding or extrusion processes, the material’s flow properties are critical. These are measured based on melt flow length and melt temperature. The flow lengths of SABIC Innovative Plastics’ materials are given as calculated disk flow lengths, where the injection pressure is plotted against the radial flow length. Determination of the calculated disk flow length is important when trying to predict whether or not a part can be filled.

The melt flow length of a material is a function of viscosity, shear properties and thermal properties. Common viscosity tests include melt viscosity, MV, and melt volume rate (MVR) measurements.

In general, for a simple comparison or quality assurance check, the MVR is measured. However, as materials show significantly different MV curves, more accurate comparisons for design calculations should be made according to the MV curves rather than on the MVR. MV tests are carried out over a large range of shear rates, figure 14.

The broad Noryl resin family offers a wide range of melt viscosities. In general, the grades with a lower heat resistance, or a low transition temperature (Tg), exhibit lower melt viscosity compared to the higher heat resistant grades.
3.7 Mold shrinkage

Amorphous materials such as Noryl® resin may exhibit lower shrinkage than semi-crystalline ones. Furthermore, the levels of shrinkage in flow and cross-flow direction are closer for amorphous materials. It is easier, therefore, to produce precise parts with amorphous unreinforced materials than with semi-crystalline resin or with reinforced resin. The use of fillers, in particular those such as glass fibers which have an aspect ratio >1, can cause anisotropic effects on material behavior. This can be explained by the orientation of these fillers during the molding process that hinders shrinkage in one direction and may lead to distortion.

Mold shrinkage refers to the shrinkage that a molded part undergoes when it is removed from a mold and cooled at room temperature. The shrinkage of a component is a time/temperature related process, with most of the shrinkage occurring directly after part ejection. As the part cools down to room temperature, final mold shrinkage will be reached.

Expressed as an average percentage, mold shrinkage can vary considerably depending on the mold geometry, the processing conditions and the type of resin. The three critical processing stages that govern shrinkage behavior are the cooling phase, the packing or holding phase and orientation. In general, the higher the holding pressure and the longer it is effective, the smaller the shrinkage. The influence of the material is usually expressed by the pressure-volume-temperature (PVT) relationship, as shown in figures 15 and 16.
Noryl® resin amorphous polymer blend may be successfully processed on most standard molding machines.

4.1 Pre-drying
Noryl resin has one of the lowest moisture absorption rates of all engineering thermoplastics. However, if it is not removed prior to processing, the residual moisture will cause surface defects like splay marks and may lead to degradation of the flame retardant system. Due to the wide variety of products in the Noryl resin portfolio, only broad processing guidelines can be given here.

The suggested drying temperature range for Noryl resin is 150 °F to 240 °F (65 °C to 115 °C). Using a dehumidifying dryer, the target moisture level of <0.02% is normally achieved after between 2 to 4 hours, depending on the moisture level of the incoming material and the type of dryer. Consistent drying parameters should result in improved productivity by increasing part-to-part consistency and producing tougher parts.

When using oven dryers, the resin should be spread in trays to a depth of approximately one inch (0.25mm).

When using automatic systems, hot air should always be used to transport the pre-dried material to the hopper to avoid moisture pick-up. It is also advised to keep the hopper lid closed and to limit the material in the hopper to the amount that is required for 10 minutes of production.

For large pellet size (regrind) or glass reinforced materials, the residence time should be increased to 4 to 6 hours. To avoid excessive heat history, it is suggested that the material be dried no longer than 8 hours. Excessive drying may result in loss of physical properties, color shift, loss of processability, or a combination of the three.

4.2 Equipment
When determining the size of equipment to be used for molding a particular part molded from Noryl resin, total shot weight and total projected area are the two basic factors to be considered. Optimum results are generally obtained when the total shot weight (all cavities plus runners and sprues) is equal to 30 to 80% of the machine capacity. Very small shots in a large barrel machine may create unnecessarily long resin residence times, which may lead to resin degradation. If it is necessary to mold at the high end of the temperature range, reduced residence time is usually required to reduce the possibility of material heat degradation. Therefore, for higher temperature molding requirements, it is suggested that the minimum shot size be greater than 60% of the machine capacity.

Once the total projected area of the complete shot (all cavity and runner areas subjected to injection pressure) has been determined, 3 to 5 tons of clamp force should be provided for each square inch of projected area to reduce flashing of the part. Glass reinforced resin may require slightly higher clamp force (estimate one ton per square inch more). Wall thickness, flow length and molding conditions will determine the actual tonnage required.

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

When specific screw selection is not possible, general-purpose screws with length to diameter ratios from 16:1 through 24:1 and compression ratios from 1.5:1 to 3.0:1 have been used successfully.

Machinery nozzles must be generous as well as all the runners and gating. Hot runners can be used, but internally heated torpedo systems are not suggested as they cause excessive shear.

In general, good tool venting is suggested for all Noryl resin.
4.3 Processing conditions

Melt temperature
The temperature of the barrel heating zone closest to the hopper should be set between 70 °F to 80 °F (20°C to 27°C) below the specified grade’s suggested melt temperature. The barrel temperature profile should increase progressively up to the melt temperature, while the nozzle setting should be somewhat lower. The actual melt temperature must always be measured. Material residence time in the barrel should always be as short as possible, preferably not exceeding 4-5 minutes.

Mold temperature
The best aesthetics and mechanical properties will be achieved when tool temperatures of 150 °F to 200 °F (65°C to 95°C) are used. For low heat, flame retardant grades of Noryl resin, a tool surface temperature of 150°F to 170°F (65°C to 80°C) is required. Homogeneous tool temperature should be reached by adequate cooling channel layout.

Back pressure
A back pressure of 50 to 100 psi (0.3 to 0.6 MPa) is suggested to promote a homogeneous melt and help maintain consistent shot size. Higher back pressures used to improve melt mixing result in higher melt temperatures. When molding reinforced grades, low back pressure will help reduce glass fiber damage during plastification.

Screw speed
Screw speeds (RPM) should be adjusted to permit screw rotation during the entire cooling cycle without delaying the overall cycle. Low screw speeds can help reduce glass fiber damage during plastification when molding reinforced grades. Suggested screw speed is dependent on screw diameter. It is recommended keeping the circumferential speed below 0.25 m/s.

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

A moderate to fast injection speed is required to obtain proper tool filling. Excessive speed will increase shear, which may lead to material degradation. A very slow injection speed, on the other hand, may cause splay marks due to possible degradation gases having more time to migrate to the surface.

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

Screw cushion
The use of small cushions (1/8 inch or 5 mm suggested) reduces material residence time in the barrel and allows for machine variations. Without a cushion it is not possible for the hold pressure to have an effect.

4.4 Purging of the barrel
Noryl* resin does not ordinarily tend to adhere to metal. Nevertheless, thorough purging of the barrel is suggested when a production run ends or a material change is necessary. PS or PMMA are good purging materials for Noryl resin. However, when carbonized material is present in the barrel, special purging agents can be used following manufacturer instructions. It is important to have proper ventilation during the purging procedures.

4.5 Recycling
Properly molded Noryl resin may be reground, dried and remolded repeatedly. If the application permits the use of regrind, reground sprues, runners, and non-degraded parts may be added to the virgin pellets up to a level of 25%. Grinder screen sizes should be at least 5/16 to 3/8 inches (7.9 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 the same size as virgin pellets, and therefore water diffusion will be different. Regrind utilization may produce a slight change in color and impact properties. Great care should be taken, therefore, in applications where impact performance and/or agency compliance are required.

Actual regrind usage should be determined for each individual application. For applications requiring UL recognition, the maximum allowable regrind content is 25%.
Although most Noryl* resin parts are molded as finished components, the design and ultimate use of certain parts may require machining, assembly or finishing operations. Noryl resin makes a wide variety of secondary operations available to the design engineer.

5.1 Welding
Welding is a commonly used permanent assembly technique for engineering thermoplastics. Parts molded from Noryl resin may be welded using different processes. Selecting the right process depends on the size, shape and function of the part.

**Hot plate welding**
Allows excellent weld strengths to be achieved. However, sticking of the material to the hot plate may occur. Heating by radiation hot plate can solve this problem but requires more accurate part dimensions and process control.

**Friction welding**
Can be applied to both unreinforced and glass-reinforced grades of Noryl resin, using either the vibration, orbital or rotation method. Low weld pressures (<0.5 MPa) favor high bond strength. Specific glass-reinforced, high flow automotive grades give reduced weld strength. However, with suitable weld design good results can be obtained. Proper weld design for instrument panels include so-called flash traps to contain the flash generated during welding.
**Ultrasonic welding**

Noryl® resin has been successfully ultrasonically welded in numerous applications. The use of energy director or shear joints is always recommended.

The following dimensions for the energy director apply. Frequency ranges should be 20-40 kHz, the amplitude can be 20-40 m. The sonotrode should be positioned exactly above the weld line to avoid dampening and mechanical losses. Part size to weld should not exceed 200 mm when using 20 kHz equipment.

**Laser welding Noryl resin**

Laser welding offers an interesting possibility to generate welds that are gas tight in a clean and efficient way without flash. 3-D contours can be welded with this technology.

Special grades in Noryl resin (TN series) have been developed that are laser transparent and can be used in combination with laser welding. While pigmentation, fillers and morphology of the blend have an influence on IR transparency and laser weldability, it is recommended to test each grade and new application for suitability to laser welding.

**5.2 Adhesives**

Parts molded from Noryl resin may be bonded to other plastics, glass, aluminum, brass, steel, wood and other materials. A wide variety of adhesives can be used, sometimes with the addition of a suitable primer (see table 1). In addition, parts molded from Noryl resin may be solvent bonded to other parts made from Noryl resin. Recommended solvents include chlorinated hydrocarbons and, for specific non-flame retarded grades only, toluene.

**Cleaning parts**

In order to avoid part failure, thorough cleaning of parts molded from Noryl resin before bonding is essential. All oil, grease, paint, mold releases, rust oxides, etc., must be removed by washing with solvents, which are compatible with Noryl resin. These solvents include isopropyl alcohol, heptane or a light solution of non-alkaline detergents. Bond strength is further improved by sanding, sand blasting, or vapor blasting the bonding surfaces.

<table>
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<td>0.5-0.6</td>
</tr>
<tr>
<td>a</td>
<td>60-90°</td>
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**Table 1 - Compatibility of adhesives with Noryl resin**

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<th></th>
<th>Epoxy</th>
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<th>PUR 2K</th>
<th>PUR Hot Melt Reactive</th>
<th>MS polymer</th>
<th>Silicone 1K</th>
<th>Silicone 2K</th>
<th>Acrylic 2K</th>
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</table>
5. Secondary operations

5.3 Mechanical assembly
Mechanical assembly techniques are widely used with parts molded from Noryl® resin. To achieve optimum results, mechanical fasteners should be kept free from oil and grease. Depending on the type of fastener, a permanent stress or deformation is applied locally. Clamp forces should be controlled or distributed over a large surface area. This is in order to decrease local stresses in the part after assembly and to minimize the risk of loosening the fasteners through creep and relaxation. Notches in the design as well as notches resulting from mechanical fasteners should also be avoided.

Suggested assembly techniques
- Thread-forming screws rather than thread cutting screws are recommended. Screws with a maximum flank angle of 30° are preferred for minimal radial stresses.

The following design of boss is recommended

![Diagram of boss design](image)

Depth = Thread engagement
Hole ø = Inner ø

Noryl resin

<table>
<thead>
<tr>
<th>Hole ø</th>
<th>Outer ø</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85d</td>
<td>2.5d</td>
<td>2.2d</td>
</tr>
</tbody>
</table>

Other options for design are
- Use screw designed for plastic
- Avoid triangular or square holes
- Ratio stripping/driving torque maximal (>>2)
- Use stress relief on top of boss
- Max. installation speed 600 r.p.m. to avoid melting of material

5.4 Painting
A wide variety of colors and textures can be applied to Noryl resin using commercially available organic paints and conventional application processes. Painting is an economical means of enhancing aesthetics and providing color uniformity.

Pre-treatment
- Hand washing the part with cleaning agents based on alcohol or aliphatic hydrocarbons; or
- Power washing the part with cleaning agents based on detergents dissolved in water. These detergents can be acidic by nature (pH 3-4), neutral or alkaline (pH 8-9).

Paint selection
Paint selection is determined by the desired decorative effect, specific functional needs and the application technique to be applied. A variety of conventional and waterborne paints may be successfully applied to Noryl resin. Generic types include
- Acrylic
- Epoxy
- Polyester
- Polyurethane

Paint solvents
It is important that solvent formulations are carefully considered when selecting a paint for use with amorphous resin. The solvent, while ensuring the keying in of the paint to the substrate, poses the threat of solvent attack. However, compared to other amorphous resin, it should be noted that Noryl resin may offer superior stress cracking resistance and are less critical in this respect.

The occurrence of stress cracking is a result of solvent action on the one hand and stress to the part on the other. The level of stress to the part should be ideally below 5 MPa.

Ideally, this is achieved through optimal part and tool design and proper molding procedures. In general, if stress levels are above 10 MPa, painting will become critical.

In case of doubt, parts molded from Noryl resin should be tested through exposure to Tri n-butylphosphate at different temperatures (please refer to your local technical field support for detailed information).

4 General Information on Secondary operations such as welding, mechanical assembly and bonding of engineering thermoplastics can be found in the following SABIC Plastics brochures
- Assembly guide
- Design guide
Special coatings

- Coatings can be used to help minimize color degradation that is common to most resin when exposed to UV or fluorescent light.
- Conductive coatings offer shielding against radio frequency interference (RFI) or electromagnetic interference (EMI).
- Coatings are used to provide a color match when parts are assembled with painted parts in other materials.

Painting Noryl* resin for automotive interiors

Noryl resin is used in various interior automotive applications, both painted and unpainted. Noryl resin applications can be painted with standard coatings for aesthetic and color match purposes and also ‘soft-feel’ coatings. The paint systems can be both solvent-based and water-based. For solvent-based coatings, numerous single layer systems have been developed. ‘Soft-feel’ coatings normally require a primer for good adhesion.

Water-based painting of parts molded from Noryl resin is possible but not as common; ‘soft-feel’ water-borne painting of Noryl resin needs a primer that can be water-borne as well. Single waterborne coatings are also available but these are acrylic-based with a high styrene content, which results in a rather poor mechanical and thermal performance for automotive applications.

To improve water-borne paintability, a special automotive grade has been developed that can be painted with a single layer of an automotive grade of coating and with water-borne ‘soft-feel’ paints.

5.5 Metalization

Properties usually associated with metals such as reflectivity, abrasion resistance, electrical conductivity and decorative surfaces can be added to plastics through metalization. Three of the more commonly applied metalization techniques are discussed here.

Vacuum metalization

Vacuum metalization through Physical Vapor Deposition involves the depositing of an evaporated metal, mostly aluminum, on a substrate. To achieve evaporation, the pure metal is heated in a deep vacuum. To ensure a good result when using this method with Noryl resin, a glow discharge pre-treatment is highly recommended.

After vacuum metalization, the aluminum must be protected against environmental influences. This is because of the ultra-thin layer thickness combined with the reactive nature of aluminum to humidity.

Typically, this protection is provided through the application of a Plasil/Glipoxan top layer, (a silicone-based monomer layer which is applied in the vacuum), or a clear coat top layer.

In general, unreinforced Noryl resin does not require a basecoat or lacquer primer layer before metalization because of the good surface quality of parts molded from Noryl resin after molding. However, in certain cases, application of a basecoat is recommended to enhance reflectivity, in particular where glass-reinforced materials made from Noryl resin has been specified.

In most cases a surface activation pre-treatment is required

- Glow discharge takes place in a vacuum vessel in the presence of a low-pressure gas such as air. This method gives an increased surface energy and micro porosity to the parts molded from Noryl resin.
- Cleaning with a cloth or solvents is not recommended because of the sensitivity to scratches that can be seen after metalization. The best method is to keep the moldings clean and to metallize the parts as soon as possible after molding, or to store them in clean containers.

Plating

This can be done by two methods. The first method, electroless plating, is executed without the addition of current to the galvanic process. Electroless plating can be further divided into non-selective (double-sided) and selective (single-sided) plating.

- For non-selective or all-over electroless plating, a pre-etch is generally required with Noryl resin.
- Selective electroless plating starts with the masking of those areas of the part, which must remain metal-free.

A catalyst or precursor is then applied to seed the exposed surface to initiate the deposition of metal after immersion in the metal salt solution.

- If only EMI shielding is required, an electroless copper layer of 1-2 um is applied with a finish of electroless nickel.

* General information on Secondary operations like painting and metalization of engineering Thermoplastics can be found in the following Brochures of SABIC Innovative Plastics
  - Painting guide
  - Metalization guide
In the second method, electroplating current is used to effect an electrolytic deposition of metals derived from a dissolved metal salt on top of the conductive electroless deposited metals. Most frequently used metals include chrome, nickel or gold.

**Hot foil stamping**
In this dry metalization technique, the metal foil is impressed on the plastic surface with a heated die or rubber roll. Standard foils are available for use with parts molded from Noryl® resin, but it is recommended to test each grade and new application for compatibility and melting point.

**5.6 Laser marking**
The laser marking of thermoplastics is a complex process. The differing demands of applications, together with a diverse range of materials, pigments and additives, as well as the equipment itself, provide a large number of variables. Through its advanced research and development program, SABIC Innovative Plastics has gained valuable insight into the thermal, optical, mechanical and chemical processes, which take place during laser marking. An important result of this has been the development of Noryl resin grades using proprietary combinations of pigments and additives.

**5.7 Foaming**
For automotive instrument panel carriers, SABIC Innovative Plastics has developed special grades of Noryl resin featuring excellent foam adhesion properties. These materials include glass-reinforced and unreinforced grades.
Noryl* resins
Americas
Noryl® resins product family

- Injection molding
  - Unreinforced
    - Non-flame retardant
    - Flame retardant
  - Reinforced
    - Non-flame retardant
    - Flame retardant
- Extrusion & blow molding
  - Non-flame retardant
  - Flame retardant
- Structural foam molding
## Noryl® resins, injection molding

**Unreinforced, general purpose**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Heat</th>
<th>FDA/NSF 61</th>
<th>Translucent</th>
<th>Chemical resistance</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNA055</td>
<td>Noryl® grade. Sterilization trays, ISO 10993 compliant (restrictions apply)</td>
<td>Translucent</td>
<td>Translucent</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td></td>
</tr>
<tr>
<td>PX1390</td>
<td>HB/0.7 mm. Electrical performance, lighting brackets.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td></td>
</tr>
<tr>
<td>T31</td>
<td>HB/1.5 mm. RTI 105/105/105, C1/3. Hydrolytic stability. FDA compliant and NSF Std 61 listed (restrictions apply).</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td></td>
</tr>
<tr>
<td>TN240</td>
<td>HB/1.5 mm. Translucent. 83.1% Light transmission. Scratch resistance.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td>Chemical resistance to acids/cleaners, sensors, connectors, speaker grilles.</td>
<td></td>
</tr>
</tbody>
</table>

**Grade flammability:** UL94 at indicated mm thickness.
- **RTI:** UL 746B listing in °C. Electrical, Mechanical w/impact. Mechanical w/o impac.
- **CTI:** UL 746A PLC Code.

---

### Graph

**Heat Performance**
- **TYS:** psi
- **HDT,F:** °C
- **All grades are non-halogen flame retardant**
  - V0
  - V1
  - V2
### Noryl* resins, injection molding

#### Unreinforced. flame retardant

<table>
<thead>
<tr>
<th>Material</th>
<th>Heat Resistance</th>
<th>Flame Retardancy</th>
<th>Electrical Performance</th>
<th>Mechanical Performance</th>
<th>CTI</th>
<th>Other Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>N300X</td>
<td>V0 (1.5 mm, RTI 165/165/165, CTI 3)</td>
<td>UL94 at indicated mm thickness.</td>
<td>Electrical, Mechanical</td>
<td>RTI: UL 746B listing in °C. Electrical, Mechanical w/impact. Mechanical w/o impact.</td>
<td>CTI: UL 746A PLC Code.</td>
<td>Noryl* resins, injection molding</td>
</tr>
</tbody>
</table>
### Noryl* resins, injection molding

**Unreinforced, flame retardant**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Glass/Mineral Content</th>
<th>Flammability</th>
<th>RTI</th>
<th>CTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE1GFN3</td>
<td>30% glass filled, V1/1.47 mm, SG 1.31.</td>
<td>UL94 at indicated mm thickness.</td>
<td>UL 746B listing in ºC. Electrical, Mechanical w/impact. Mechanical w/o impact.</td>
<td>UL 746A PLC Code.</td>
</tr>
<tr>
<td>SE1GFN2</td>
<td>20% glass filled, V1/1.5 mm, 5VA/2.5 mm, SG 1.12.</td>
<td>Electrical meter housings, bobbins, RTI 110/105/110. CTI 1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE1GFN1</td>
<td>10% glass filled, V1/1.47 mm, SG 1.16.</td>
<td>Electrical meter bases, bobbins, RTI 110/105/110. CTI 2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE1GFN7</td>
<td>5% glass filled, V1/1.47 mm, SG 1.16.</td>
<td>Electrical meter bases, bobbins, RTI 110/105/110. CTI 2.</td>
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<td></td>
</tr>
<tr>
<td>SE1GFN10</td>
<td>3% glass filled, V1/1.47 mm, SG 1.16.</td>
<td>Electrical meter bases, bobbins, RTI 110/105/110. CTI 2.</td>
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</tr>
<tr>
<td>SE1GFN30</td>
<td>1% glass filled, V1/1.47 mm, SG 1.16.</td>
<td>Electrical meter bases, bobbins, RTI 110/105/110. CTI 2.</td>
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<td></td>
</tr>
<tr>
<td>HS2000X</td>
<td>17% mineral filled, V0/1.5 mm, 5VA/2.0 mm, SG 1.24.</td>
<td>Electrical ceiling box, smoke detector covers, RTI 100/85/100. CTI 2. UL 746C/f1.</td>
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<td></td>
</tr>
<tr>
<td>HS1000X</td>
<td>13% mineral filled, V0/1.0 mm, 5VA/2.5 mm, SG 1.23.</td>
<td>Thermostat components, RTI at 1.5 mm 100/85/100. CTI 2. UL 746C/f1.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Noryl resins, extrusion / blow molding

**Unreinforced, general purpose**

<table>
<thead>
<tr>
<th>Application</th>
<th>Resin Code</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDA/Translucent</td>
<td>PKN4752</td>
<td>Translucent, hydrolytic stability. FDA compliant (restrictions apply). SG 1.08.</td>
</tr>
<tr>
<td>FDA</td>
<td>PKN4775</td>
<td>Food packaging. ESCR performance. FDA compliant (restrictions apply). SG 1.06.</td>
</tr>
<tr>
<td></td>
<td>PKN4765</td>
<td>Food packaging. Thin sheet. FDA compliant (restrictions apply). SG 1.06.</td>
</tr>
<tr>
<td>NSF 61</td>
<td>ENG265</td>
<td>Resistance stability. NSF Std 61 listed (restrictions apply). SG 1.08.</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>BNN003G</td>
<td>Chemical and impact resistance. Automotive spoilers. SG 1.06.</td>
</tr>
</tbody>
</table>
Noryl resins, extrusion / blow molding

Unreinforced. Flame retardant

<table>
<thead>
<tr>
<th>Grade flammability: UL94 at indicated mm thickness.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTI: UL 7468 listing in °C. Electrical, Mechanical w/impact. Mechanical w/o impac.</td>
</tr>
<tr>
<td>CTE: UL 746A PLC Code.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Noryl resins, structural foam molding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unreinforced. general purpose</td>
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</tbody>
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</tbody>
</table>
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