GE
Plastics

Let imagination flow

GE Plastics Solutions
for Fluid Handling and HVAC

GE imagination at work

Contents

1. Introduction

Air Operated Double Diaphragm pump made with LNP Stat-Kon* MC-1003 HS and Stat-Kon FP VC-1003 resin*

1.1 GE Plastics – a leading-edge supplier

Few industries pose a greater challenge to materials than fluid engineering. GE Plastics is a pioneer in metal to plastics conversion in the industry for over 20 years, and can help meet this challenge with advanced material and design capabilities that reach beyond single one-for-one metal replacements.

With a unique portfolio of high performance engineering resin and world-class application development support facilities, GE Plastics is firmly focused on helping customers to achieve their goals of enhanced system efficiency and competitive edge.

1.2 Reshaping the future, today

Engineering plastics have revolutionized the design and manufacture of a wide range of fluid engineering products. For applications that are subject to elevated temperatures, elevated pressure and that require hydrolytic stability, a wide variety of engineering thermoplastics is available from GE Plastics and offers good performance for such parts.

Noryl* PPO* resin, Ultem* resin and the LNP Compounds are prime examples of GE Plastics' portfolio of materials for the fluid engineering industry. Successfuly used in a broad spectrum of applications, ranging from pumps, water meters and boiler components, to hot water heaters, filtration and pipe systems, this family of materials can offer cost-out opportunities and outstanding long-term performance in demanding operating environment.

Whether it is desalination or water recycling plants, smart taps or green roofs, GE Plastics is helping customers around the world to address the design challenges of tomorrow, today.

- Noryl resin for excellent hydrolytic stability
- Noryl GTX* resin for remarkable heat and chemical resistance**
- Cycolac* ABS* resin for excellent processability and gloss
- Lexan* SLX resin, providing superior UV resistance when compared to standard UV stabilized polycarbonate grades
- LNP glass fiber and carbon fiber reinforced and internally lubricated compounds for tailor-made performance
- Ultem PEI resin for unparalleled mechanical performance
- Visual*fx** resin for cost-effective aesthetic differentiation
- LNP Staramide* resin for high strength and processability

GE Plastics materials continue to evolve to help ensure that customers receive outstanding performance combined with unique design and productivity benefits.

- System cost-out
- Hydrolytic stability
- Fatigue and creep resistance
- Drinking water approval
- High heat resistance
- Resistance to chemicals** and contaminants
- Corrosion resistance

1.3 Designing with confidence

GE Plastics' materials consistently meet, and often exceed, increasingly stringent industry standards. Many of our materials are routinely tested in the company's laboratories as part of dedicated development programs. In many cases, when our resins are in contact with potable water, the company strives to list materials according to national standards, including WRAS, KTW, ACS and NSF. Although not mandatory, this reinforces confidence and reliability.

1.4 Innovation from a single source

As a business unit of General Electric Company, GE Plastics benefits from global cross-business resources and expertise. Ongoing materials development is progressed in step with process technology and manufacturing techniques to ensure that the company continues to be a leading-edge supplier.

Recent material innovations include:

- Noryl GFN1520V resin, a 20% glass fiber reinforced PPO/PS blend
- Noryl GFN1630V resin, a 30% glass fiber reinforced PPO/PS blend
- Lexan SLX 2432T resin, a polycarbonate copolymer offering outstanding weatherability

GE Plastics houses one of the most advanced global application development facilities in the industry, encompassing:

- Advanced design and engineering
- Dedicated computer aided design services
- Materials characterization and testing facilities
- Fully equipped processing laboratories

1.5 Fluid Engineering Center of Excellence

GE Plastics has established an application development center, which is dedicated exclusively to customers in the fluid engineering industry. This unique facility helps support world-wide application development needs, assisting customers in all phases of their design process.

By testing long-term polymer performance in accordance with the relevant industry standards, the Center's scientists and technologists are helping customers to develop new and innovative applications. This is complemented by ongoing research into new processing technologies and assembly techniques to help meet the special requirements of fluid engineering applications.

Areas of specific attention include:

- The effect of small amounts of chlorine in water, combined with oxygen
- Hot water resistance
- Creep and fatigue testing
- Wear and erosion resistance
- Vibration and laser welding

Global Fluid Center of excellence, located in Bergen op Zoom, The Netherlands

2. Applications

2.1 Pumps and pump components

*Noryl PPX*630 resin used in a boiler component, produced by Giannoni France*

From in-line distribution applications such as water meters and heat exchangers, to end-line applications such as water taps and mixers, GE Plastics' wide range of engineering thermoplastics can help customers meet both functional criteria and regulatory standards for their fluid handling applications. That is why more and more leading manufacturers are making them their materials of choice.

In components such as pump housings, covers, brackets and impellers, GE Plastics' resins are helping to enhance system cost effi ciency and helping to minimize maintenance. Material selection depends on specific operating conditions.

Noryl resin can deliver excellent hydrolytic stability to applications where parts are exposed constantly to water. Glass fiber-reinforced Noryl GFN1630V, GFN1520V, GFN2 and GFN3 resin and LNP Verton* MFX polypropylene composites can provide tailor-made dimensional stability to help meet the burst pressure and long-term creep and fatigue requirements of parts such as housings and impellers. Where higher chemical resistance is required, Noryl GTX PPO/PA66 blends and LNP Staramide PA resin can be considered, dependent upon the nature of the chemicals.

Fujian Yin Jia Electromechanical of China has been using Noryl GFN2 resin for several years in the manufacture of the pump housing, closed impeller, impeller guide and water outlet on its JET100 B Series self priming pumps. In addition to enhancing the system's cost efficiency, Noryl GNF2 resin helps Fujian Yin Jia Electromechanical deliver durable parts with reliable high performance under pressure and at elevated operating temperatures.

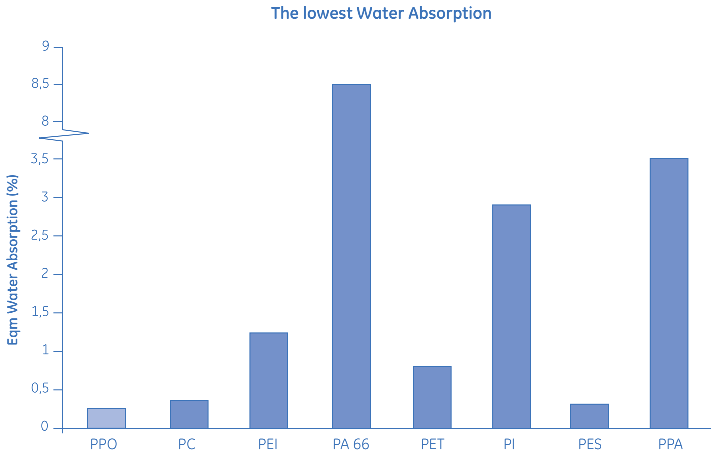


Figure 1
% water absorption at saturation
Noryl resin shows a very low water absorption compared to many other resins. This contributes to the excellent dimensional stability of Noryl resin in watery or humid conditions.

Magnum Logix pump system from GE made with Noryl resin components

Noryl GFN1630V resin is the material of choice for this electric pump body. Designed and manufactured by Six Team of Italy, this self-priming pump has to meet critical requirements for long-term safety and reliability in extreme operating conditions.

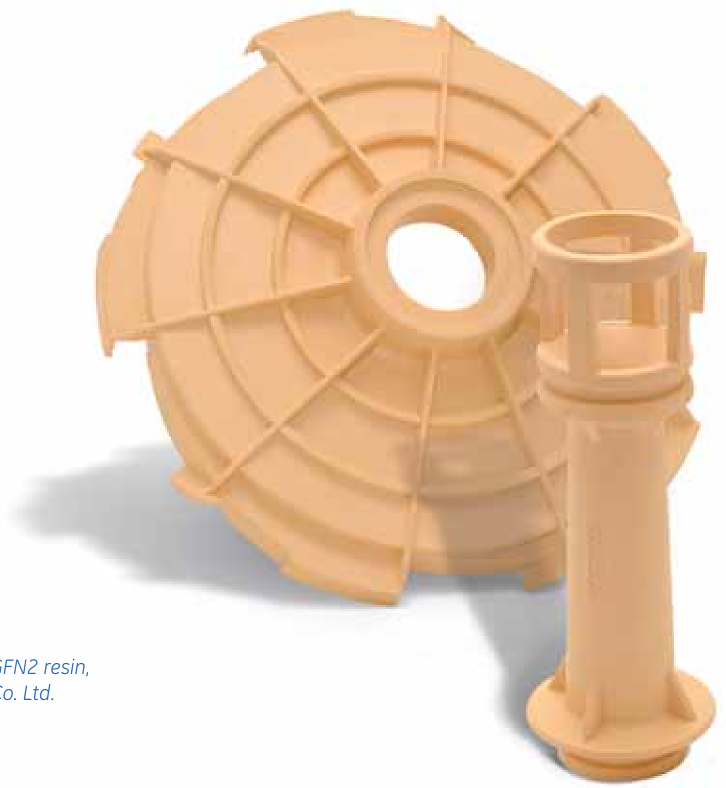
By utilizing Noryl resin, Six Team of Italy was able to create a pump that has potable water contact approval and is practical in fixed installations. This self-priming pump has a suction depth of up to 8.5 meters, and may work continuously over 24 hours due to the high fatigue resistance and hydroliytic stability of Noryl GFN1630V resin.

The application development specialists at GE Plastics worked closely with the design engineers at Six Team throughout the innovation process: from assisting Six Team with material selection through predictive engineering analysis and mold design.

LNP Verton composites can provide exceptional mechanical performance. For highly demanding applications such as submersible pump housings, these remarkably lightweight materials combine rigidity with outstanding strength and resistance to impact failures. Theycan provide dimensionally stability during use, even as the motor generates high heat, and resist water absorption, corrosion and scaling.

Component	GE Plastics resin	Typical Performance Benefits
Pump Housings, Covers, Brackets, Impellers, Diffusers,	Noryl GFN1520V, GFN1630V*, Noryl GTX 830, Ultem 2300, LNP Verton resin	Heat resistance, Hydrolytic stability, Dimensional stability, Mechanical strength at elevated temperature, tensile, knit-line and burst strength
Vane Housings, Rotor Vanes, Propellers	LNP Verton, LNP Thermocomp*, LNP Lubricomp	Wear resistance, Heat resistance, Chemical resistance**, Hydrolytic stability, Dimensional stability, Mechanical strength at elevated temperature
Rotary Pump Lobes, Gears	LNP Thermocomp, LNP Lubricomp	Low coefficient of friction, Noise reduction, Wear resistance, Heat resistance, Chemical resistance**, Hydrolytic stability, Dimensional stability, Mechanical strength at elevated temperature
Bearings, seals	LNP Lubricomp	Chemical resistance**, High temperature performance, Wear resistance, Low coefficient of friction

Table 1



Internal pump components made with Noryl GFN2 resin, produced by Fujian YinJia Electromechanical Co. Ltd.

2.2 Water meters

For many water meter manufacturers around the world, Noryl resin is replacing expensive raw materials such as brass. Compliant with many of the water industry's stringent regulations, Noryl resin delivers tight tolerances and innovative, cost-effective design opportunities for components that need to meet lead- and corrosion free requirements. These include housings, sealing plates and wheels in both residential and industrial water meters.

Kaden-Vodomery, the biggest water meter manufacturer in the Czech Republic, turned to Noryl 731 resin for the sophisticated carrier plates and measurement impeller on this meter. The resin met the manufacturer's key requirements for engineering precision and dimensional stability following long-term exposure to extensive humidity and hot water temperatures of up to 90°C. In addition, these parts can withstand exposure to possible contaminants in the water and sediment deposits.

In applications in which chemical resistance is a key requirement, Noryl GTX resin can provide long-lasting high performance. In this outdoor water meter housing, which is designed by Badger, Noryl GTX resin helps the part to withstand repeated exposure to a wide range of environments, including lawn chemicals and ground water. Furthermore, the resin exhibits excellent mechanical properties, even when exposed to UV rays, and consistent hydrolytic stability and dimensional stability compared with nylon parts.

In water meter covers, Lexan SLX resin can produce highly cost-effective, durable parts. In addition to polycarbonate's characteristic optical clarity, high temperature resistance and impact strength, this unique material offers exceptional UV resistance. This helps to retain a very high level of both optical and mechanical properties over the lifetime of the part.

Component	GE Plastics resins	Performance Benefits
Housing, sealing plate, wheel, rotor	Noryl resin Noryl GTX resin	Dimensional stability (tight tolerance), Impact resistance, Hydrolytic stability, Fatigue resistance, Weatherability
Clear cover	Lexan SLX resin	Transparency, Impact resistance, weatherability
Piston, gears	LNP Lubricomp	Chemical resistance**, High temperature performance, Wear resistance, Low coefficient of friction

Table 2

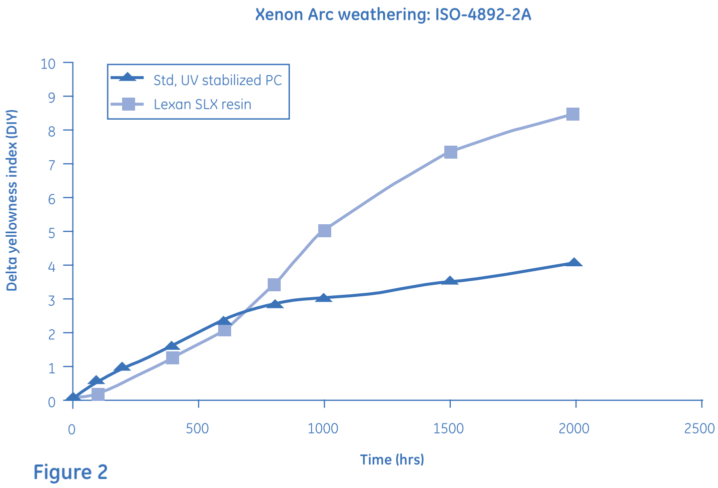


Figure 2
UV comparison Lexan SLX resin versus standard UV stabilized polycarbonate

Even after a service for 4 years or more, components may have different looks, yet have hardly changed dimensions.

Water meter housing with LNP Lubricomp ZML-4334 compound components

2.3 Boilers

Boilers have been made traditionally using many assembled metal parts. The growing use of engineering plastics is allowing manufacturers to produce boilers with reduced system costs and higher operating efficiency.

2.3.1 Heat exchangers

With its excellent balance of heat resistance, resistance to condensates and fumes, mechanical performance and dimensional stability, Noryl PPX630 resin is an excellent candidate resin for parts such as condensing heat exchangers. Typically, glass filled-polyamide resin exhibits the required heat resistance, but lack the chemical resistance, (which is needed as the condensate in the boiler is very acidic - pH2-3), whereas glass fiber-reinforced polypropylene resin shows good resistance to acidic condensates, but offers insufficient heat resistance. This is illustrated in Figure 3.

Giannoni France, a leading manufacturer of wall-hung boiler components, chose Noryl PPX 630 resin for the housing that contains the stainless steel coils in this high-tech condensing heat exchanger. In addition to outstanding chemical resistance, heat resistance (110°C continuous, 130°C peak) and dimensional stability, Noryl PPX resin delivered an important cost-out solution through part integration and fast assembly on a fully automated line.

The combination of easy part consolidation and Noryl PPX resin's inherent light weight offers manufacturers the possibility to reduce boiler dimensions by up 30% and total weight by up to 15%. This can provide easier handling, installation and reduced maintenance costs.

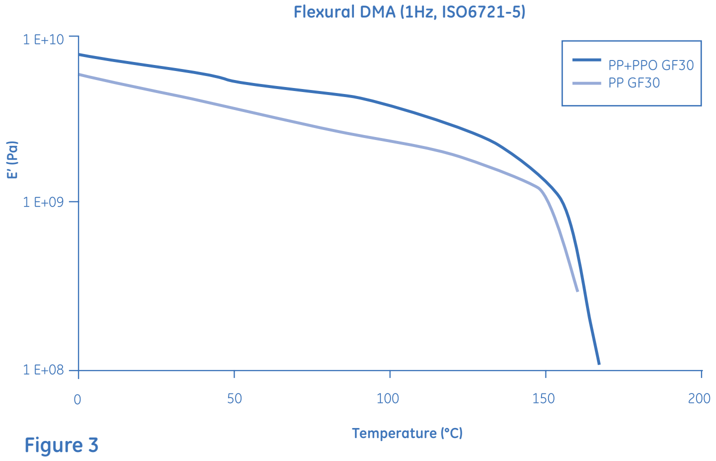


Figure 3
DMA measurements indicate that Noryl PPX630 has a higher stiffness than 30% glass fiber reinforced PP resin (PPGF30) over a wide range of temperatures

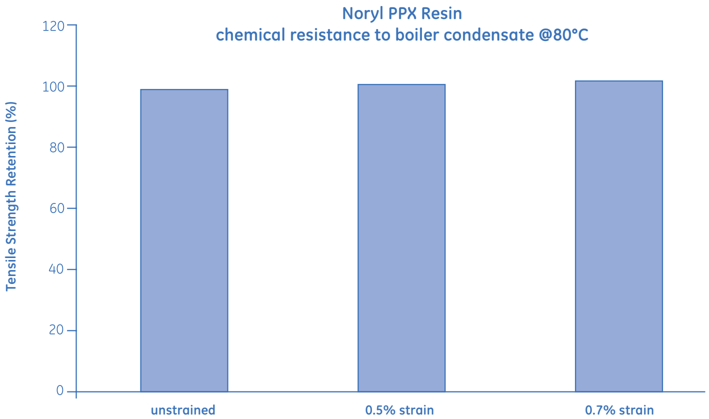


Figure 4
Chemical resistance Noryl PPX630 resin after 7 days exposure to a boiler condensate at 80°C

Figure 5
Concept study of a wall hung domestic gas boiler in wich components in engineering thermoplastics have replaced metal parts

2.3.2 Manifolds

GE Plastics, working in close collaboration with specialist manufacturers, has developed an exciting design concept for manifolds, which can deliver both simplified assembly and low maintenance. As shown below (fig. 6), a substantial part of the copper piping connecting the various water flows has been replaced by a compact manifold with a high level of part integration. This highly intricate part could be cost-effectively molded with Noryl resin or LNP Staramide resin, which can both offer excellent processability and high strength in the end part.

2.3.3 Covers

An innovative design concept for a boiler cover illustrates the broad styling opportunities that are offered by engineering thermoplastics. With large part molding experience, GE Plastics has demonstrated how bosses, ribs and holes can be cost-effectively integrated into a single lightweight molded part, which requires no after-treatment. Covers can be molded in a wide choice of colors using materials such as Cycolac ABS and Geloy* ASA resin, or with distinctive special effects using Visual*fx* resin.

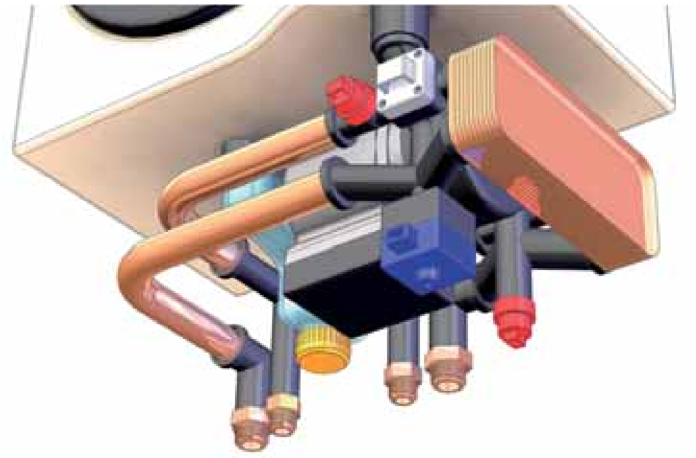


Figure 6
Manifold concepts utilizing engineering materials to its best

2.4 Heating system components

Typically used in a wide variety of fluid engineering and HVAC applications, the use of 35% glass fiber-reinforced LNP Staramide resin can deliver performance, cost savings and design freedom.

In addition to its excellent surface finish, LNP Staramide resin offers a combination of excellent hydrolytic stability, mechanical performance and consistent knit line strength and weld line strength in case parts are welded together. The resin's consistent processability facilitates long flow lengths, and a high level of part integration delivers fast, cost-effective assembly.

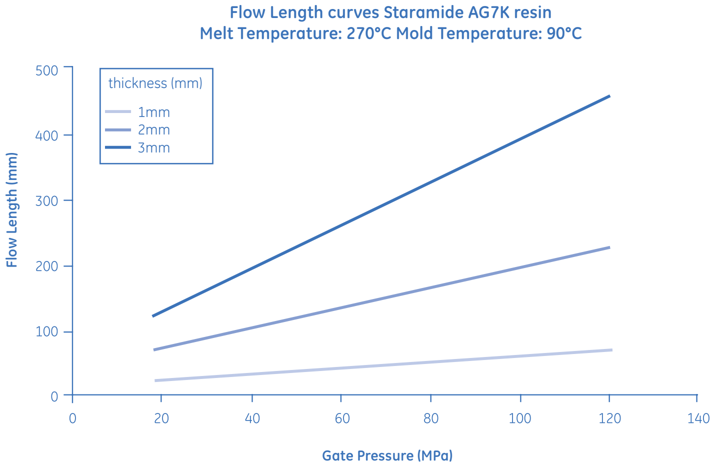


Figure 7
Flow length chart of LNP Staramide AG7K, 35% glass fiber reinforced PA6.6 resin. These flow lengths have been calculated for a center gated disc using flow simulation software.

2.5 Sanitary faucets and shower components

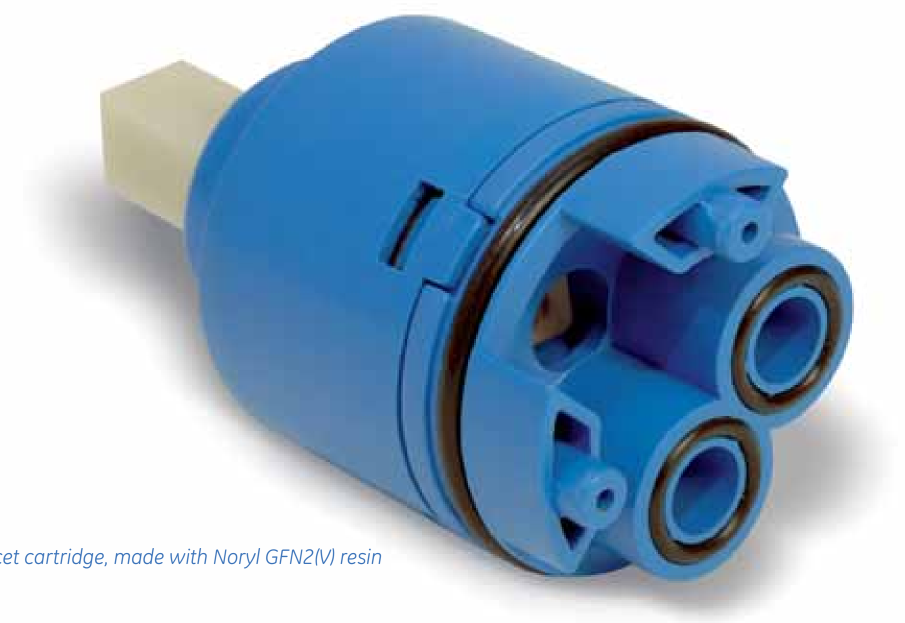
Across a broad range of sanitary faucets and shower components, Noryl resin, Ultem resin and LNP compounds can offer innovative material solutions that are low in cost and high in performance. Compared with traditional metal assemblies, these solutions can offer both raw material and logistics cost savings. In addition, these corrosion-free materials help reduce the problems of mineral build-up and can eliminate corrosion that interfere with the operation of metal parts and fittings. Typical parts include spray water channel inlets, thermostatic control valve housings, hot water mixing channels and shower head inlets.

In faucet cartridge components, Noryl resin offers outstanding hydrolytic stability, high strength and high temperature resistance.

With its excellent dimensional stability, high temperature resistance and design flexibility, LNP Thermocomp compound is the chosen material for this innovative regulated water cartridge, which is designed and manufactured by Sedal of France. Traditionally made of brass, the cartridges can be cost-effectively molded with no secondary operations, and easily fixed to the tap with different mounting possibilities.

Component	GE Plastics resins	Typical Performance Benefits
Faucets, cartridges	Noryl resin, Ultem resin	Dimensional stability (tight tolerance), hydrolytic stability
Shower heads	LNP Lubricomp	Hydrolytic stability, Wear resistance
Sleeves	Noryl resin	Dimensional stability, burst strength, hydrolytic stability
Valves	LNP Lubricomp	Chemical resistance**, wear resistance, low coefficient of friction

Table 3



Faucet cartridge, made with Noryl GFN2(V) resin

2.6 Water softeners

Noryl resin successfully replaced steel in a range of components used in water softeners. This resin is typically selected because, unlike traditional materials such as glass-filled polypropylene, testing demonstrated that it exhibits good property retention and dimensional stability at high temperatures.

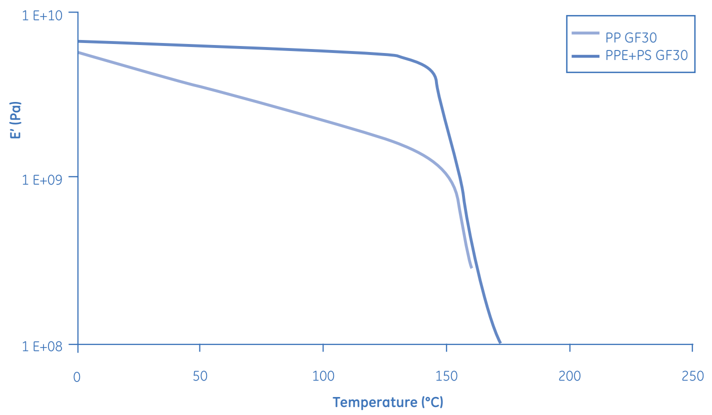


Figure 8
DMA provides an indication for resin stiffness as function of temperature. Noryl resin versus a 30% glass-filled polypropylene resin (PPGF30) retains a constant stiffness over a broad range of temperatures.

2.7 Water filtration

As potable water supply becomes increasingly critical in the face of rapidly rising demand, it is of paramount importance that reliable water treatment systems are put into place as quickly and cost-effectively as possible. Whether the water is for drinking, irrigation or industry, GE Plastics is focused on providing high performance polymers that assist customers save development time, total system cost and deliver long term end use performance.

Noryl resin's proven creep resistance and performance after extended exposure to water may make them an excellent material candidate to replace stainless steel and cast iron in reverse osmosis components including vessel heads, tubing, fittings and valve housings.

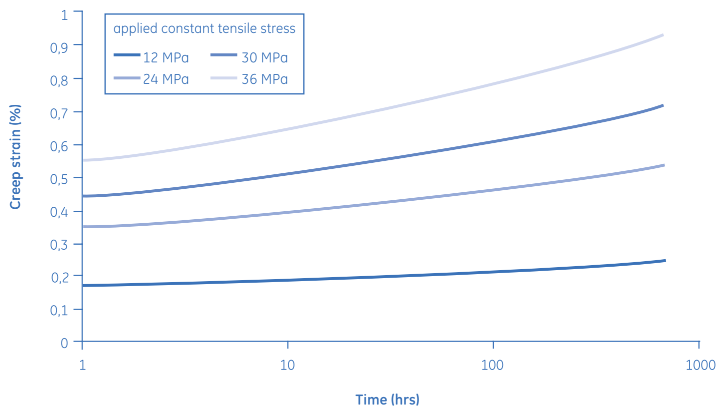


Figure 9
Noryl PPO+PS resin shows very low deformation when exposed to a constant stress (tensile creep) at elevated temperature

Hot water control valve made with Ultem 2300 resin

2.8 Pipes, fittings and valves

Water distribution and industrial piping systems demand materials that can withstand extreme environments and deliver a long life-span. Cycolac ABS resin is a well-established material in this area, providing reliable piping for various industries around the world. They combine toughness and durability, maintaining their high performance over a wide range of temperatures and pressures. Furthermore, they provide good extrudability and quick on-site jointing.

Swiss manufacturer Georg Fischer, a world leader in water distribution and industrial piping technology, has selected Cycolac X399 resin as the material of choice for this pre-insulated pipe system. Used in a wide variety of cooling and refrigeration installations around the world, the system relies on the resin's consistent low temperature resistance and good resistance to pressure. The resin's unique combination of durability and good extrudability has helped the company to deliver cost-effective pipe systems, which can withstand an extreme environment over a long life-span.

For thermostatic valves, GE Plastics offers a range of materials to meet specific performance needs. For example, GE Osmonics, part of GE Water Technologies, has developed an innovative all-plastic control valve using Noryl GFN2 resin. This strong, lightweight material delivers exceptional dimensional and hydrolytic stability, which helped enable the valve to set new standards in performance and serviceability.

Designed by American manufacturer Mueller Company, this breakthrough water service valve is molded using Noryl GTX830 resin. The first engineering thermoplastic material to replace brass in this type of application, Noryl GTX resin helps the molded part meet critical requirements for burst and thread strength, fatigue and chemical resistance. This material that can meet ther requirements for lead-free components can also deliver lower overall system costs as installation time and secondary operations are reduced.

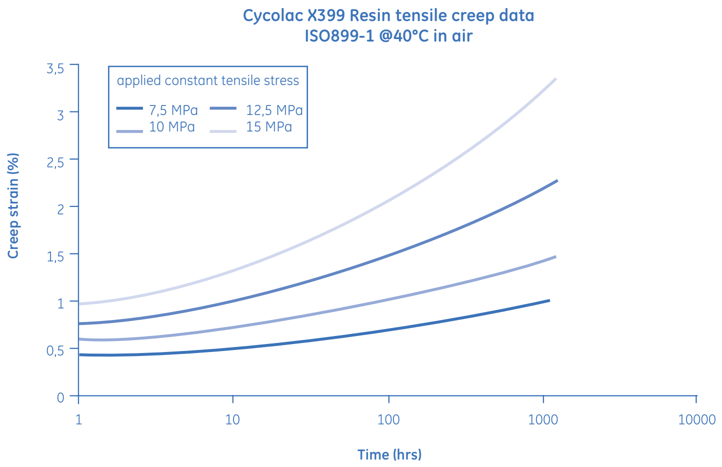


Figure 10
Cycolac ABS resin shows low deformation when exposed to a constant stress (tensile creep)

Georg Fischer chose Cycolac X399 ABS resin to help it provide highly reliable piping products for various markets around the globe

2.9 Solar panels

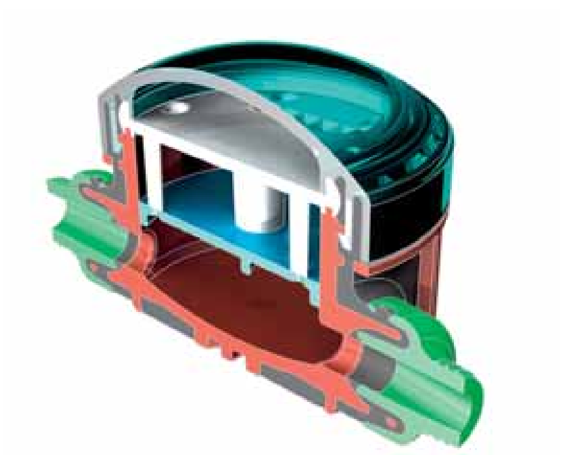
As concern about global warming increases world-wide, solar power, with its versatility and convenience, provides an important low-cost, renewable energy source for the future. The success of solar systems is dependent on their efficiency, reliability, ease of installation and cost-efficiency.

Solarnor, a Norwegian manufacturer of integrated solar heating systems, has developed a solar panel system working with application development engineers at GE Plastics. Using Noryl EN150SP resin, these innovative extruded panels collect and retain as much heat as possible for domestic heating and hot water.

The unique design of the thermal system exposes the Noryl resin panels to continuous contact with water at varying temperatures, depending on the season and the time of day. Noryl resin's excellent balance of hydrolytic stability and temperature resistance helps to ensure that the panels retain their shape, rigidity and aesthetics over time.

Unlike traditional panels which use copper or aluminum, these lightweight, attractive panels are easy to transport and integrate into roofs or facades.

3 The Customer Innovation Process



Water meter concepts by GE Plastics: patent pending

3.1 Introduction

As can be seen in this Chapter, GE Plastics has much to offer: from concept generation through the many development stages to industrialization, the company supports its customers in their development process.

- Initial concept to meet specific industry criteria
- Design assistance using dedicated engineering design services
- Material selection assistance to meet performance criteria and industry standards
- Advanced predictive engineering
- CAD/CAE analysis
- Processing evaluation in state-of-the-art laboratories
- Secondary operations evaluation
- Prototyping

With this unique level of technical support, GE Plastics is helping customers around the world to be at the cutting edge of design. From submersible pump housings to condensing heat exchangers, from reverse osmosis components to state-of-the-art solar panels, GE Plastics is willing and able to help customers develop their next generation fluid handling applications.

When this process concerns metal to plastics conversion, GE Plastics can assist using a structured approach, which starts with design evaluation and leads to enhanced system efficiency through part integration, elimination of secondary operations, weight reduction and ease of assembly.

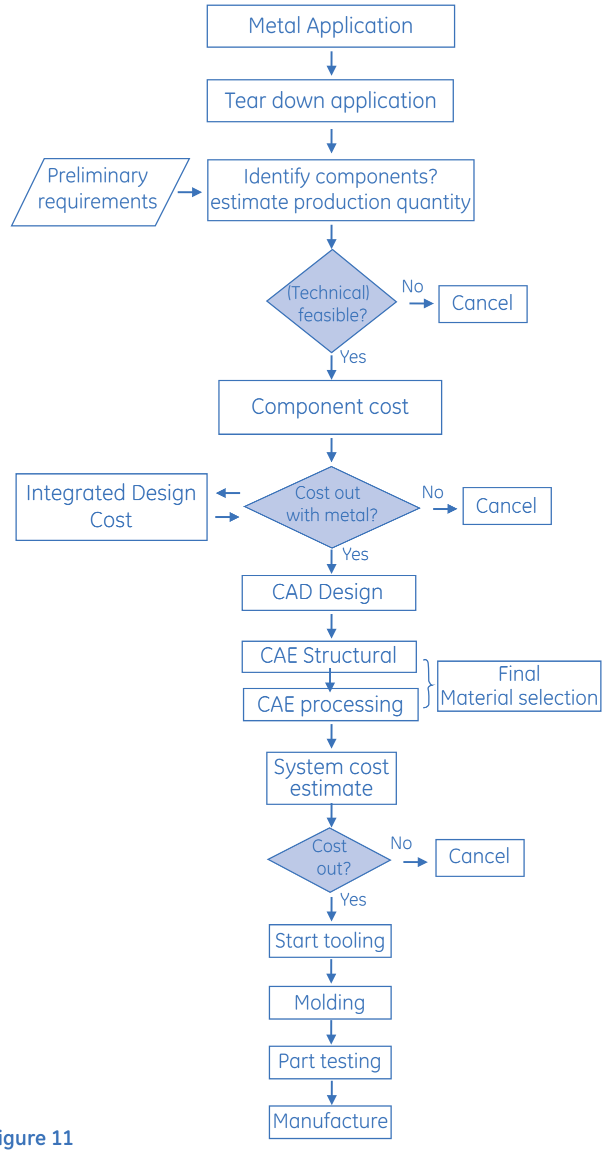


Figure 11
Steps to follow when translating a metal part to plastics

3.2 End-use requirements

Fluid engineering components have to perform in critical environments. In addition to satisfying the many formal requirements and test protocols, the design engineer must have a thorough understanding of the functional design factors relating to manufacture and assembly, as well as the environmental and physical capabilities of the material.

This is a critical phase in the design process, which can be helped by considering a number of different performance requirements, including those listed below:

- Where appropriate, the part needs to be made strong enough to withstand short-term loads, such as an internal pressure peak.
- Exposure to constant stress may cause a part to slowly creep and change dimensions. The part may fail ultimately after very long exposure to constant stress as a result of "creep rupture".
- When a part is exposed to fluctuating pressure, care must be taken to avoid designing with notches, sharp corners and/or knit lines to help prevent fatigue damage and cracking.
- A constant temperature may result in a constant internal load in the system when the thermal expansion of one component differs from the thermal expansion of the component against which it is mounted, such as thermoplastics on steel.
- A fluctuating temperature may also cause fluctuating loads because of differences in thermal expansion. This may happen even within a component if a temperature difference exists within that component. In this case, splitting the part may be a better option.
- If a material is sensitive to its chemical environment, (including the effect of hot water), then the failure mechanisms may accelerate, a phenomenon known as "environmental stress cracking". Chemical compatibility during both assembly and use is therefore essential.
- Abrasion between moving parts or erosion caused by abrasive particles in the fluid can cause wear. Wear can be caused also by surface fatigue if surface stress exceeds the endurance limit of the material.
- If the part design requires openings, these will usually cause knit lines during injection molding which could cause a weak spot in the material. It is important to minimize the effect of these knit lines during design, engineering and manufacture.

In addition to complying with all of the relevant standards and regulations that apply to fluid engineering applications, it is critical that the supplier of the end part undertakes finished part testing to ensure that it meets all of the end-use performance requirements that were defined during the engineering phase.

3.3 Concept generation

GE Plastics works closely with its customers to help them develop fluid engineering concepts that are based on a thorough understanding of the industry, the engineering materials and the manufacturing processes.

Based on this knowledge, these initial concepts can be converted successfully into real parts, which are focused on meeting specific industry needs, satisfying stringent industry standards, optimizing manufacturing costs and cutting time to market.

3.4 Material selection

GE Plastics makes available a wealth of material data to support customers in their application development, once the preliminary design has been established. Customers are invited to visit the company's website at geplastics.com for an excellent introduction to the wide range of materials. However, because of the complicated environment of many fluid engineering environments, customers are recommended to contact their local GE Plastics representative before using these data for application development.
Based on their microscopic structure, engineering polymers can be grouped into two types: amorphous and semi-crystalline resins. This distinction is particularly useful in fluid engineering applications because it has a fundamental effect on the behavior of the material in use.

GE Plastics can assist customers in identifying a material for the specified end-use requirements. Finished part performance should always be evaluated on the actual part under actual service conditions. The end-user bears the full responsibility for determining suitability of any GE resin selected for its application.

3.4.1 Amorphous materials

Amorphous materials such as GE Plastics' Noryl resin, Ultem resin and Cycolac resin, are based on amorphous polymer matrices like PPO+PS, PEI or ABS. These thermoplastic materials have a gradual transition between the melt and solid phase, which is characterized by the glass transition temperature (Tg).

One consequence of the "glassy" solid state below Tg is the relative good creep behavior of these polymers. In other words, they will deform relatively less under a constant load. Furthermore, the shrinkage of the material when cooling down will be lower, resulting in more accurate parts and less thermal expansion.

3.4.2 Semi-crystalline materials

Semi-crystalline polymers such as GE Plastics' Noryl GTX resin and LNP Staramide resin are based on a semi-crystalline polymer matrix like polyamide (PA). These materials form crystals with a distinct melting point, which gives them mechanical integrity below the melting temperature (Tm). Semi-crystalline materials also show a glass transition temperature usually at or below operating temperature. This results in a more ductile or rubbery type of behavior in these materials between Tg and Tm. Compared with amorphous materials, semi-crystalline resins will typically perform better in fatigue situations, but will creep more when subjected to a constant load. In addition, mold shrinkage and thermal expansion will be greater compared to amorphous materials.

Figure 12
Schematic picture of the molecular structures of amorphous (left) and semi-crystalline (right) resins

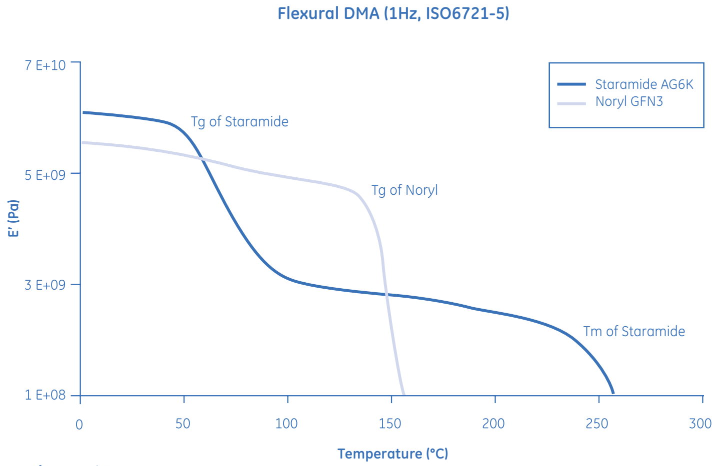


Figure 13
DMA measurements show the different change in stiffness as funtion of temperature of an amorphous (Noryl GFN3) resin compared to a semi-crystalline (LNP Staramide AG6K) resin

3.4.3 Reinforced materials

Reinforcements like glass fibers are often used to improve the dimensional and mechanical stability of resins. Apart from the more traditional glass fibers, GE Plastics offers a wide choice of special reinforcements ranging from carbon fibers to various lubricated systems in the LNP Lubricomp product line for parts that are exposed to abrasion or erosion.

Reinforcements improve certain physical properties, such as strenght and modulus, but can reduce a material's processability. The injection molding process causes fibers to align in the direction of the melt flow in the mold. In many fluid engineering applications, the primary stress will be perpendicular to this fiber alignment direction, as a result of which the reinforcement will be significantly less effective. Processing of these materials can be further affected if the design includes knit lines, which should be avoided wherever possible.

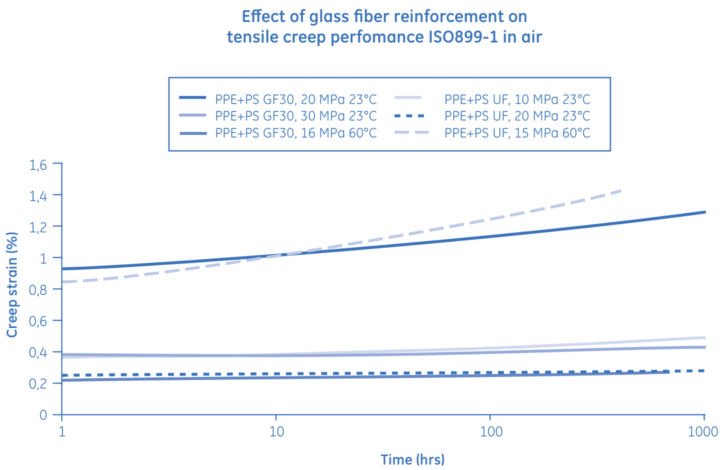


Figure 14
The effect of glass fibers on the creep modulus of PPO+PS

3.5 Design for strength

GE Plastics' customers can benefit from full state-of-the-art computer-aided engineering design facilities. The computer programs are tailored to plastics engineering and can provide valuable savings in both time and cost in the product development process.

In the design development of fluid engineering products, it is important that stresses do not exceed recommended design limits to avoid part failure. These limits are dependent on factors like material, temperature, loading and environment (chemical and water). GE Plastics provides customers with access to a broad range of data from the Engineering Design Database, which shows the influence of these factors on its materials.

As with all engineering materials, it is impossible to control all aspects of production and use. For this reason, conservative estimates and risk dependent safety factors should be applied when appropriate.

Design calculations and limitations

In design calculations for parts loaded with an internal pressure, it is recommended to use curved shapes like a pressure vessel to limit stresses in the part. Circular sections are most suited to minimizing stresses: the smaller the diameter, the lower the stresses will be.

Handbook equations for thick and thin pipes can help also in predicting stress levels. In cases where the design is particularly complex, a structural CAE analysis is recommended to ensure that stresses stay within acceptable limits. GE Plastics' Fluid Engineering Center can help customers to carry out this type of analysis using highly specific engineering data.

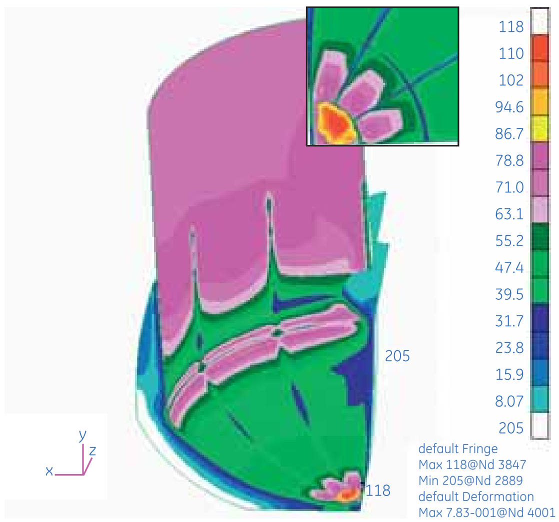


Figure 15
Example of a burst pressure stress analysis on a water meter

Increasing part stiffness

Part stiffness should be increased where needed, typically in areas where rotational displacements are high, or, in other words, where bending loads are high. In most cases, it is better to add ribs or change the curvature of the part rather than add thickness because the latter can have an effect on cost, weight and processability.

Ribs offer structural advantages but they can result in warpage and appearance problems. The following general guidelines may help achieve a successful rib design:

- **Shape and thickness**
  Processing and tooling determine certain requirements for the shape and thickness of the ribs. As a rule of thumb, the ribs should be approximately 60% of the thickness of the base.
- **Height**
  Ribs should be positioned at a height of no more than three times the base thickness.
- **Radius at base**
  This should be a minimum of 0.5mm.
- **Intersection of ribs**
  This causes local increased thickness (cooling time). Design features can be used to reduce this effect.
- **Draft angle**
  This should be at least 1°.
- **Orientation**
  For a part under bending, the ribs should be positioned perpendicular to the bending moment. For parts under torsion, ribs increase stiffness most efficiently if they are placed diagonally.

3.5.1 Stress-Strain data

The tensile stress-strain curve can help estimate maximum allowable stress for short-term loads. Due to their visco-elastic nature, thermoplastic materials may demonstrate different behavior with changes in the rate of loading. This means that at low rates of deformation, the polymer will tend to become weaker as yield stress decreases.

3.5.2 Creep data

Many fluid engineering components are subjected to continuous internal pressure. Creep curves represent the behavior of a material when exposed to this condition, typically at elevated temperatures in air. They give an indication of the time that it takes for the material to deform, dependent upon the applied stress, temperature and duration. A creep modulus curve, based on the same test data, will plot more clearly the rate at which stiffness decreases under constant stress.

Creep is a stiffness property and, as such, has no value for determining the time when creep rupture will occur. However, at certain stress levels, temperatures and duration of loading, strain increases more rapidly, which indicates that creep rupture is imminent. Such conditions should be avoided.

Ribs

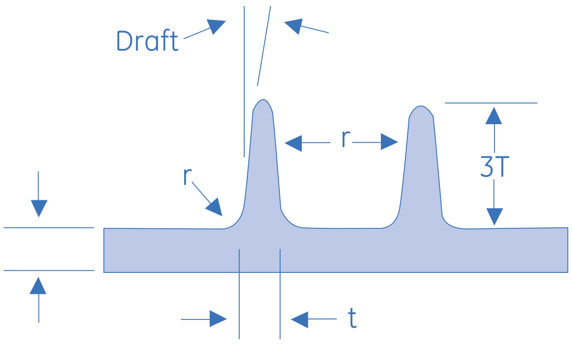


Figure 16
Optimal rib design

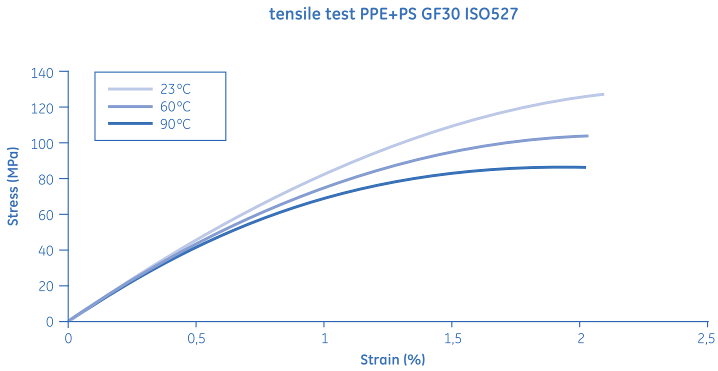


Figure 17
The effect of temperature on the initial stiffness and strength of Noryl GFN1630V, measured with a tensile test according ISO527

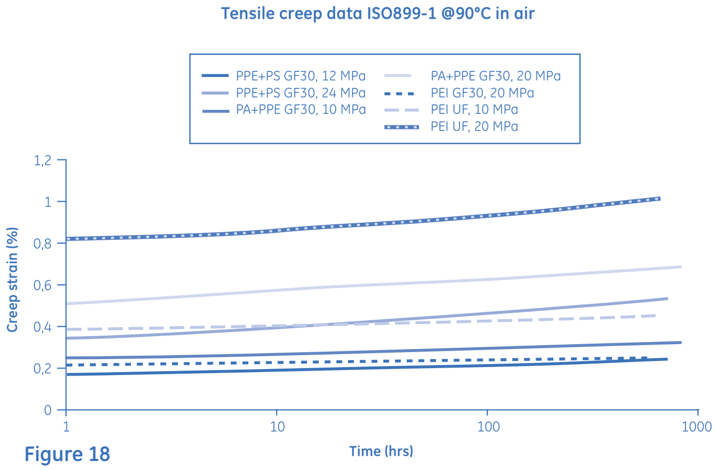


Figure 18
Tensile creep: deformation strain resulting from exposure to a constant stress

Creep data are generated using injection molded tensile bars. In the case of fiber reinforced materials, the creep performance in cross-flow direction can deviate significantly from the datasheet properties.

Water may have an influence on both the load bearing capability and the creep behavior of the material when the part is subjected to long loading times at elevated temperatures.

3.5.3 Fatigue resistance

Fatigue is the process of subjecting parts to cyclic loading, which may culminate in cracks or complete fracture. Wöhler curves are used to plot the amount of cycles until fatigue failure for a given maximum applied stress. It should be emphasized that the actual fatigue life of a part is strongly dependent on geometry, stress frequency, environment and processing conditions. For this reason, fatigue data should be used only for a first comparison between materials and not to calculate service life.

3.5.4 Effects of various factors on strength

A variety of different factors can have a major influence on the strength of a material in use.

3.5.4.1 Processing

There is a distinct relationship between processing and final performance of the part, especially with glass-reinforced materials. The orientation of the fibers will have a significant effect on the material's properties. The performance of glass-reinforced materials is measured mostly in the orientation direction using injection molded tensile bars. For glass fiber reinforced thermoplastics, stiffness and strength in the cross direction may be significantly lower than the values in the orientation direction.

Knit lines should be avoided as they can cause a localized decrease in strength, especially in the case of reinforced materials. It is important therefore that knit lines are located in areas that are not subjected to maximum stress levels.

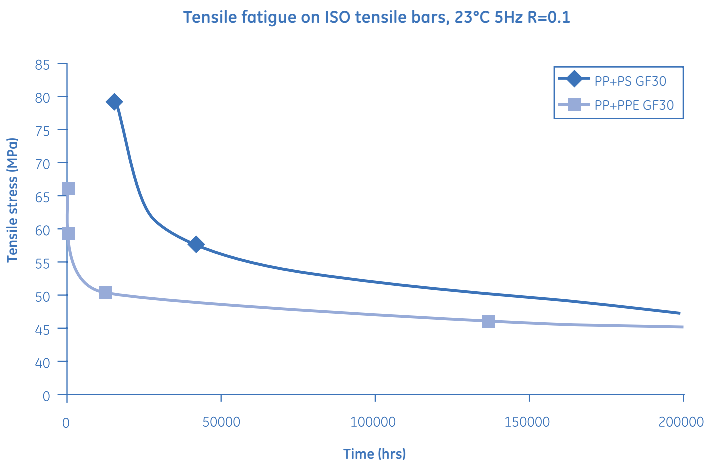


Figure 19
Tensile fatigue data (Wöhlercurves) enable a first comparison of materials in fluctuating stress conditions

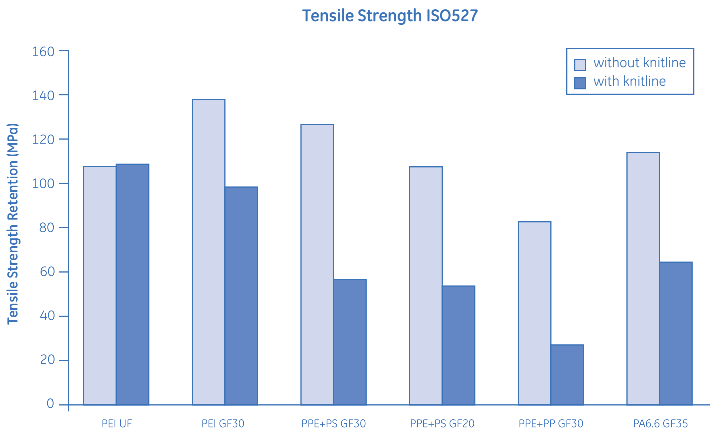


Figure 20
Effect of knit line on the tensile strength of several materials.
Note the knitline in these double side gated tensile bars is a very severe case. Knitlines in applications can be made stronger with improved design and molding.

3.5.4.2 Temperature

High temperatures will usually increase the ductility of a material, but reduce strength and creep resistance.

A first indication of temperature resistance is given by the DMA charts, which plot stiffness as a function of temperature. This DMA chart also shows that amorphous resins will have more stable mechanical properties over a wide range of temperatures, whereas semi-crystalline resins are more influenced by temperature in their operating temperature range.

It should be noted that DMA data are representative for lightly loaded conditions and do not include any long-term effect of the environment on material properties. For that purpose it is necessary to refer to engineering properties like creep or fatigue resistance.

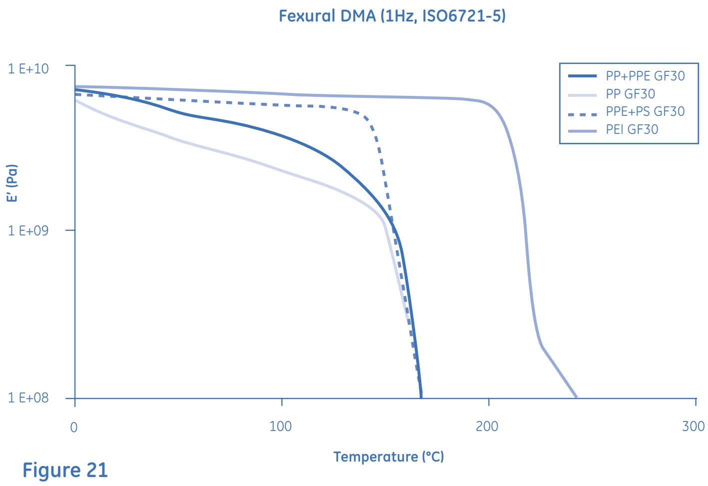


Figure 21
DMA provides an indication for resin stiffness as function of temperature

3.5.4.3 Chemical resistance

Chemical resistance is a key material property in fluid engineering products, as many of them are exposed to highly aggressive operating environments.

The chemical resistance of engineering thermoplastics is dependent on time, temperature, stress and concentration of the chemical. Chemical incompatibility may result in loss of polymer properties and ultimate part failure.

It is important to establish which chemicals the part will be exposed to both during assembly, such as cutting oils and soldering chemicals, and during use, such as cleaning agents and corrosion inhibitors.

GE Plastics has a chemical resistance testing database which can be shared with customers. However, please keep in mind that these test are typically short-term tests (7 days or less) and the results should only be used as a guide for identifying candidate materials. If chemical compatibility is a key requirement for an application, the customer should ensure that chemical exposure is integrated into its end-use test protocol.

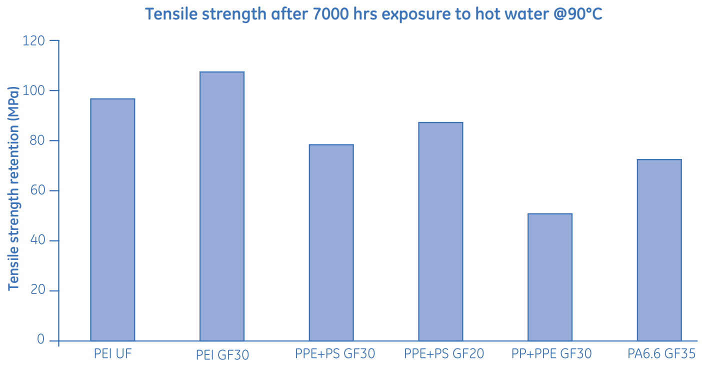


Figure 22
Comparison of the resistance of various resins against hot water.

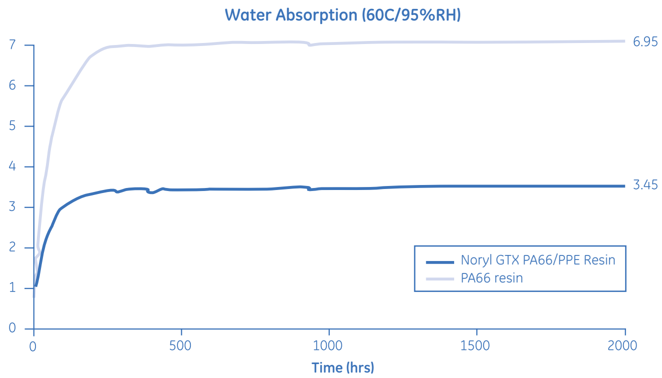


Figure 23
Typical Water Absorption behavior at 60°C of Noryl GTX PPO/PA resin in comparison with unreinforced PA66 resin.

3.5.4.4 Moisture and hot water

Moisture can significantly affect the strength of engineering thermoplastics. Noryl resin absorbs only very small amounts of water and consequently can maintain its mechanical and dimensional properties in a humid environment.

Polyamides, on the other hand, absorb relatively large amounts of moisture in humid conditions, which changes in part dimensions. Furthermore, the absorbed water molecules will significantly change the mechanical behavior of the material.

Many fluid engineering parts are in contact with hot water, which can affect material strength. At GE Plastics' Fluid Engineering Center of Excellence, extensive testing has been carried out in which tensile bars molded in various materials are stored in hot water basins, with and without load. As a sample of this research, Figures 24-28 show the burst strength of cylinders molded in GE Plastics' resins, calculated using the strength of tensile bars with knit line after 7000 hours of water of 90°C.

3.5.4.5 Wear and erosion

The wear resistance of an engineering thermoplastic is dependent on the environmental conditions of the end-use application. Wear phenomena are difficult to characterize and design for. However, GE Plastics offers customers a range of LNP lubricated compounds that are designed to meet a broad range of wear requirements.

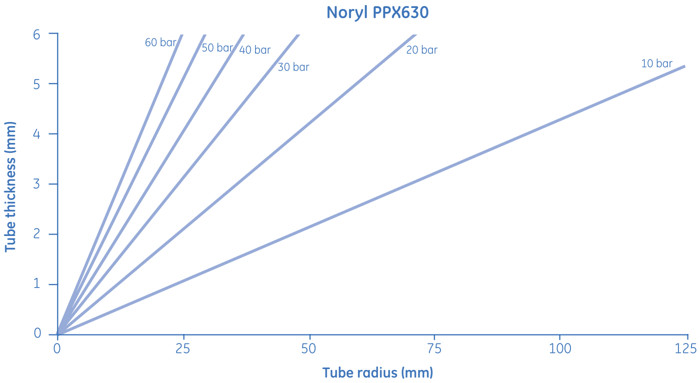


Figure 24
Indication of the pressure resistance of cylinders made of Noryl PPX 630 resin after 7000 hrs exposure to hot water of 90°C

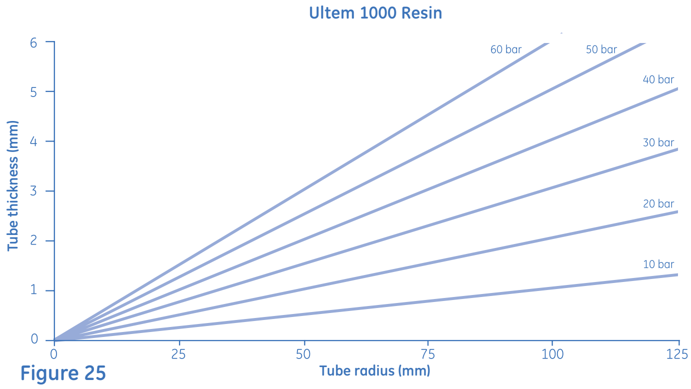


Figure 25
Indication of the pressure resistance of cylinders made of Ultem 1000 resin after 7000 hrs exposure to hot water of 90°C

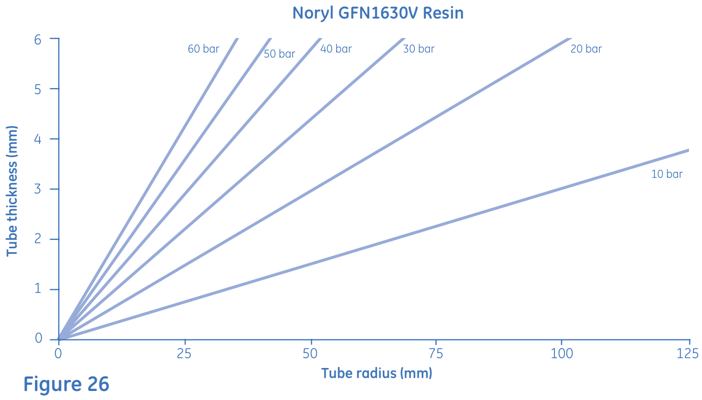


Figure 26
Indication of the pressure resistance of cylinders made of Noryl GFN1630V resin after 7000 hrs exposure to hot water of 90°C

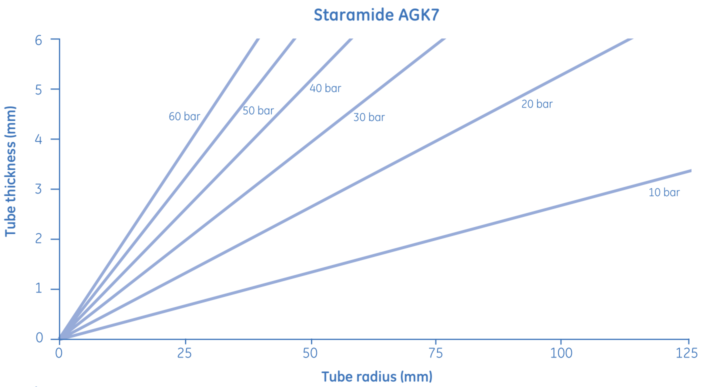


Figure 27
Indication of the pressure resistance of cylinders made of LNP Staramide AG7K resin after 7000 hrs exposure to hot water of 90°C

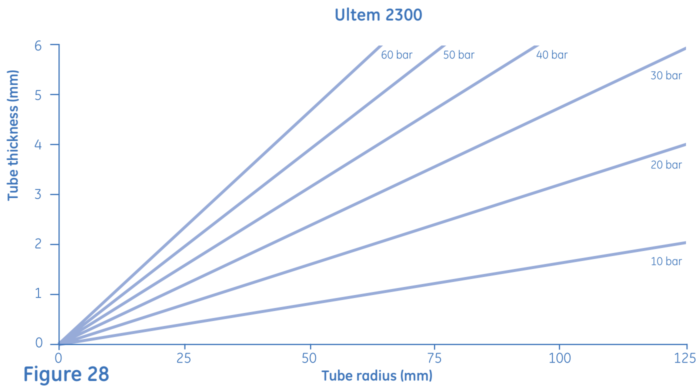


Figure 28
Indication of the pressure resistance of cylinders made of Ultem 2300 resin after 7000 hrs exposure to hot water of 90°C

3.6 Design for moldability

The injection molding process offers many advantages, compared to more traditional manufactring processes. Most notably it allows the manufacture of highly complex parts with cost-effective molded-in features. The end-performance of an injection molded part, however, depends also on the complexity of the mold.

In general, simple shapes do not present material flow problems to the experienced tool-maker and molder. However, larger components of complex geometry can present difficulties, which can affect processing and part performance. These difficulties include the positioning and number of gates, runner dimensions and location of knit lines.

In the design of parts containing tubes or undercuts in different directions, for example, there are limits to the level of function integration that is possible in one mold. With state-of-the-art CAD/CAE systems, GE Plastics offers customers data on many aspects of mold design to help them achieve optimum processability. For example, these computer systems simulate flow, warpage, mold cooling and molded-in stresses.

3.6.1 Nominal wall thickness

Wall thickness should be tailored to the allowable stress level for the specific material grade and the expected lifetime over a given temperature range. Wall thickness should be as constant as possible, with thick spots avoided. Thick areas will shrink more and generate high local shrinkage and hence molded-in stress.

3.6.2 Knit lines

Knit lines are areas where two melt fronts come together and bond during the filling of a part. In addition to causing possible surface defects, they can reduce part strength and increase levels of molded-in stress. Especially in the case of LNP Verton long fiber reinforced materials, knit lines should be avoided where possible as they can affect processability.

GE Plastics recommends that design engineers consider the following:

- Locate knit lines in structurally and/or aesthetically non-critical areas
- Position the lines close to the gating point with preferably a large cross section
- Use diaphragm or ring gates for cylindrical parts where possible to eliminate the lines
- Create a thicker section connected to the gating point, changing the flow in such a way that the knit line is stronger
- Consider strengthening a section with a knit line with another part such as a housing or a ring or nut placed around the part
- Consider assembling the part using a suitable welding technology such as vibration or laser welding.

3.6.3 Gating

In general, large sprue gates or tab gates are recommended as they permit high speed and low shear rates. This is important particularly for LNP Verton long fiber reinforced materials where a generous gate must be used to avoid fiber breakdown. In the case of Noryl resin, shear rates should stay ideally under 25000 sec-1.

For medium-sized parts, the typical sprue size is 4-6 mm, and the gate diameter is a minimum 60% of the maximum thickness of the component wall. Wall thickness should not increase going away from the gate, which is preferably placed on the thickest section. This will help to ensure effective packing pressure at all locations.
A single, centrally-located gate is the ideal configuration as it can provide an equal flow length in all directions and even pressure distribution at fill.

3.6.4 Hot runners

Open, externally-heated nozzles and manifolds are usualloy recommended. The size of the channels and nozzles should be adapted to the material flow rate, to accommodate low pressure losses in the hot runner system. When using LNP Verton resin, the sprue bushings and corner radii should be large enough to prevent fiber breakage. GE Plastics can help by carrying out a mold flow study to help evaluate the gating system and the part.

3.6.5 Venting

Good venting at the location of all knit lines is necessary to get the best possible knit line strength. As above, a mold flow study will accurately locate the knit line and air trap locations.

3.6.6 Cooling

The mold should be designed with adequate cooling circuits, to ensure a constant cavity surface temperature.

3.6.7 Processing variables

Processing conditions like mold and melt temperature and residence time are of major importance to the quality of the final part. GE Plastics has state-of-the-art processing laboratories, equipped with all types of molding equipment, to help evaluate these processing variables.

3.7 Design for assembly

When parts have to be assembled, there is a variety of different techniques that can be employed, depending on the function of the assembly. GE Plastics has a wide expertise in this area and can advise customers on the different possibilities to consider.

3.7.1 Welding

Hot-plate, vibration and ultrasonic welding are the most commonly-used techniques for welding engineering thermoplastics. A widely-used welding technique in fluid engineering applications is vibration welding.

Vibration welding can handle reasonably-sized parts up to 600mm, produce hermetic seals and weld internal and external walls simultaneously. This technique, which is also called friction welding, uses the heat generated by rubbing the components together for some seconds under pressure, (0.5-5 MPa), in a linear movement with a frequency of 100-400 Hz, and an amplitude of 2.0-0.5 mm.

The knit line has to lie in a single plane parallel to the direction of movement, which can be a disadvantage. Because the movement under pressure produces considerable friction forces, it is important to have component nesting without play. To ensure sufficient stiffness and direct support of the weld surface, a common solution is a flange with a weld rib on it.

Figure 29 presents the vibration weld strength values of glass-reinforced grades of GE Plastics materials that are typically used in fluid engineering applications. The results are generated in a T-joint configuration, and the welding parameters are: pressure 3 bars, time 3 seconds and amplitude 1.3 mm (Noryl resin @ 1 mm).

The formation of hermetic seals is of particular importance in fluid engineering components. When the mating of the parts is not exact as a result of warpage, this can cause a variation in weld pressure and, consequently, a less than optimum welding process. For this reason, the use of amorphous resins may be favored over crystalline materials.

Laser welding is a fairly new welding technology, which offers some advantages over vibration welding, mainly in the area of weld strength, flash formation during welding and quality control of the seal. A diode of Nd-YAG laser is used to generate heat at the interface of a laser light-transparent and a laser light-absorbing material. This produces a highly localized welding joint.

Figure 29 compares the weld strength that is achieved using vibration and laser welding.

3.7.2 Screws

When a part needs to be disassembled only a few times during its life, screws are usually a reliable alternative to inserts. By using screws, only one fixing element is applied, which means that for the same amount of strength, less space is required and costs are typically lower.

The characteristics of a good screw for thermoplastics are a 30° flank angle to minimize stress, a maximum thread pitch of 8° for vibration resistance, and a small core diameter to enable maximum flank coverage.

Thread-cutting screws are usually recommended for use in materials with a low elongation at break, such as highly filled plastics. Because the thread is cut into the plastic, the tension between plastic and thread flank will be relatively low.

Thread-forming screws, on the other hand, push aside the plastic, which results in permanent deformation as well as stress between screw and plastic. This type of screw is not recommended in fluid engineering applications using glass-reinforced materials.

The use of screws is more critical in amorphous materials than in semi-crystalline, because of notch sensitivity. This means that, when using amorphous materials, boss designs require a larger inner and outer diameter than with semi-crystalline materials.

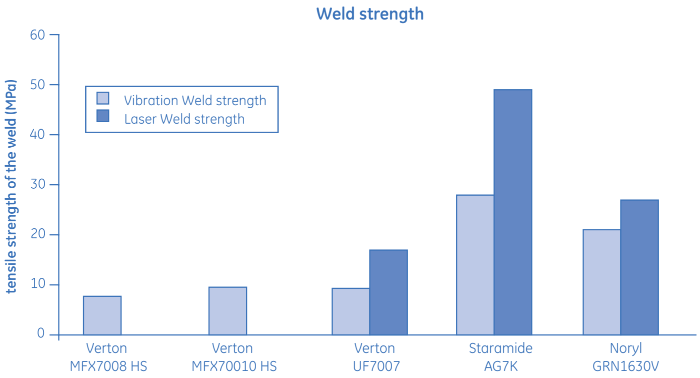


Figure 29
Tensile strength of vibration and laser welded joints

The top of the boss is a highly vulnerable part, which is why it is recommended that designers consider creating a lead-in counter-bore or stress relief, which is equal to the screw's outer diameter. A typical boss design and recommended design parameters are shown below.

GE Plastics' resins	Hole	Outer	Depth
Noryl/Lexan resin	0.85*d	2.50*d	2.2*d
Ultem/Xenoy resin	0.85*d	2.50*d	2.2*d
Cycoloy resin	0.85*d	2.20*d	2.0*d
Cycolac resin	0.80*d	2.00*d	2.0*d
Noryl GTX resin	0.80*d	2.00*d	2.0*d
Valox resin	0.75*d	1.85*d	1.7*d
Valox GF resin	0.80*d	1.80*d	1.7*d
LNP Staramide GF resin	0.80*d	2.00*d	1.8*d
LNP Verton MFX resin	0.80*d	2.00*d	2.0*d

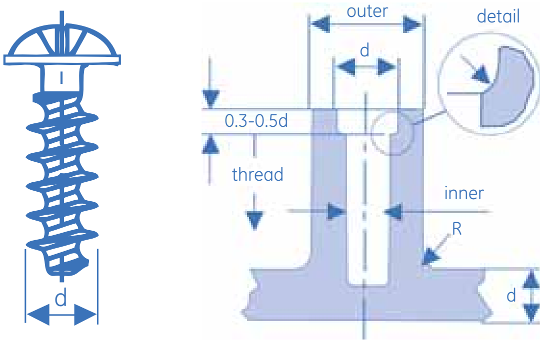
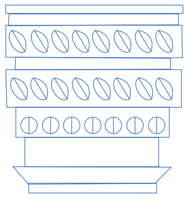


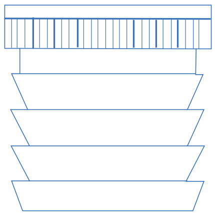
Figure 30
Recommended boss design parameters

3.7.3 Inserts

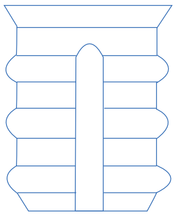
Inserts should be considered when an application requires repeated assembly and disassembly, or the available engagement length is insufficient. Figure 31 shows a sample of insert designs that are available. Each design has advantages and disadvantages and many of these styles can be used for more than one application. For instance, an insert that is specified for use as an ultrasonic insert might work just as well in a thermal application.



a) Knurl inserts provide a general holding improvement with limited pull-out and strip-out possibilities



b) Apposed herringbone inserts provide excellent strip-out possibilities with limited pull-out and jack-out capabilities



c) Undercuts provide excellent jack-out and pull-out opportunities with limited strip-out capability

Figure 31


RENISHAW
PUSH

4 Agency approvals

It is GE Plastics' policy to only market materials, which meet the stringent regulations that are laid down by the EU and the FDA.

Furthermore, as there is currently no global agency governing potable water contact, GE Plastics lists its materials at the national bodies in Germany (KTW), France (ACS) and the UK (WRAS). At the time of writing, it is expected that by 2009 a central European Acceptance Scheme will have come into effect to regulate all potable water applications across Europe.

For potable water products that are used in the USA and in some cases in the Pacific region, an NSF listing may be needed. A wide variety of GE Plastics' materials manufactured for the USA market has these listings, as shown in Table 4. In 2007, GE Plastics Europe will be making additional materials available with NSF approval.

All grades with potable water approval are shown in Table 4 Materials are tested at elevated temperatures for stability in water, and releases of organic or inorganic compounds are measured. Water that has been in contact with the material is tested on odor and flavor to help ensure a high drinking water quality. Certificates detailing test conditions and suitable applications for compliant GE Plastics' materials can be supplied free of charge on demand. It must be emphasized that ALL potable water end products need to be tested by the relevant national body, both for water standard conformity and compliance with the specific end-use. Please check the certificate for the exact details on surface volume ratios and other specific properties.

Material	WRAS (UK)		ACS (FR)		KTW (Ger)				NSF61 (USA)	
	Temp	Valid till	Temp	Valid till	Temp	Valid till	W270	Vail till	Temp	Facility
Cycolac X399 - 36500F	85 °C	Jun-08								
Cycolac MG37EPN-NA1000[1]									Cold	pittsfield
Cycolac MG38N-NA1000[1]									Cold	pittsfield
Cycolac MG47N-NA1000[1]									Cold	pittsfield
Noryl 731-701S									Cold & Hot	selkirk
Noryl 731-780S									Cold & Hot	selkirk
Noryl 731-802S									Cold & Hot	selkirk
Noryl 731-873S									Cold & Hot	selkirk
Noryl 731-GY5229F									Cold & Hot	selkirk
Noryl 731S-701	85 °C	Oct-08	All[+]	Mar-09	85 °C	Jan-09	W270	Dec-08		
Noryl 731S-801	85 °C	Jan-09			85 °C	Jan-09	W270	Dec-08		
Noryl 731S-845	85 °C	Jan-09								
Noryl 731S-90419	85 °C	Mar-08								
Noryl 731S-90560	85 °C	Mar-08								
Noryl 731S-9487	85 °C	Jan-09								
Noryl 731S-960	85 °C	Jan-09					W270	Dec-08		
Noryl ENG265-2338S									Cold & Hot	selkirk
Noryl ENG265-701S									Cold & Hot	selkirk
Noryl ENG265-780S									Cold & Hot	selkirk
Noryl ENG265-7982S									Cold & Hot	selkirk
Noryl ENG265-8746S									Cold & Hot	selkirk
Noryl GFN1520V-73701	85 °C	Oct-08	All[+]	Feb-09	85 °C	Feb-08	W270	Apr-09	Cold & Hot	BoZ
Noryl GFN1520V-801	85 °C	Apr-08	All[+]	Oct-11	85 °C	Feb-09	W270	May-10	Cold & Hot	BoZ
Noryl GFN1520V-960	85 °C	Nov-10	All[+]	Oct-11	85 °C	Feb-09			Cold & Hot	BoZ
Noryl GFN1630V-73701	85 °C	Jan-10	All[+]	Mar-09	85 °C	Aug-10	W270	Dec-08	Cold & Hot	BoZ
Noryl GFN1630V-801	85 °C	Apr-08	All[+]	Oct-11	85 °C	May-08	W270	Jun-09	Cold & Hot	BoZ
Noryl GFN1630V-960	85 °C	Nov-10			85 °C	Feb-09			Cold & Hot	BoZ
Noryl GFN1-701S									Cold & Hot	selkirk
Noryl GFN1740V-73701									Cold & Hot	BoZ
Noryl GFN1-780S									Cold & Hot	selkirk
Noryl GFN1-80106S									Cold & Hot	selkirk
Noryl GFN1V-73701	85 °C	Jan-09			85 °C	Jul-09				
Noryl GFN2-701S									Cold & Hot	selkirk
Noryl GFN2-780S									Cold & Hot	selkirk
Noryl GFN2-801S									Cold & Hot	selkirk
Noryl GFN2V-73701	85 °C	Jan-09			85 °C	Jan-09				
Noryl GFN2V-801	85 °C	Jan-07			cold	Feb-07				
Noryl GFN2V-960	85 °C	Jan-07			85 °C	Feb-07	W270	Dec-08		
Noryl GFN2V-RD2A020	60 °C	Jan-09								
Noryl GFN3-701S									Cold & Hot	selkirk
Noryl GFN3-780S									Cold & Hot	selkirk
Noryl GFN3-7982S									Cold & Hot	selkirk
Noryl GFN3-801S									Cold & Hot	selkirk
Noryl GFN3-873S									Cold & Hot	selkirk
Noryl GFN3V-73701	85 °C	Oct-07	All[+]	Oct-11			W270	Dec-08		
Noryl GTX 820-70782									Cold & Hot	selkirk
Noryl GTX 830-70782									Cold & Hot	selkirk
Noryl GTX830-BK1A183N									Cold & Hot	selkirk
Noryl N110S-701	85 °C	Jan-09								
Noryl PN275F-708S									Cold & Hot	selkirk

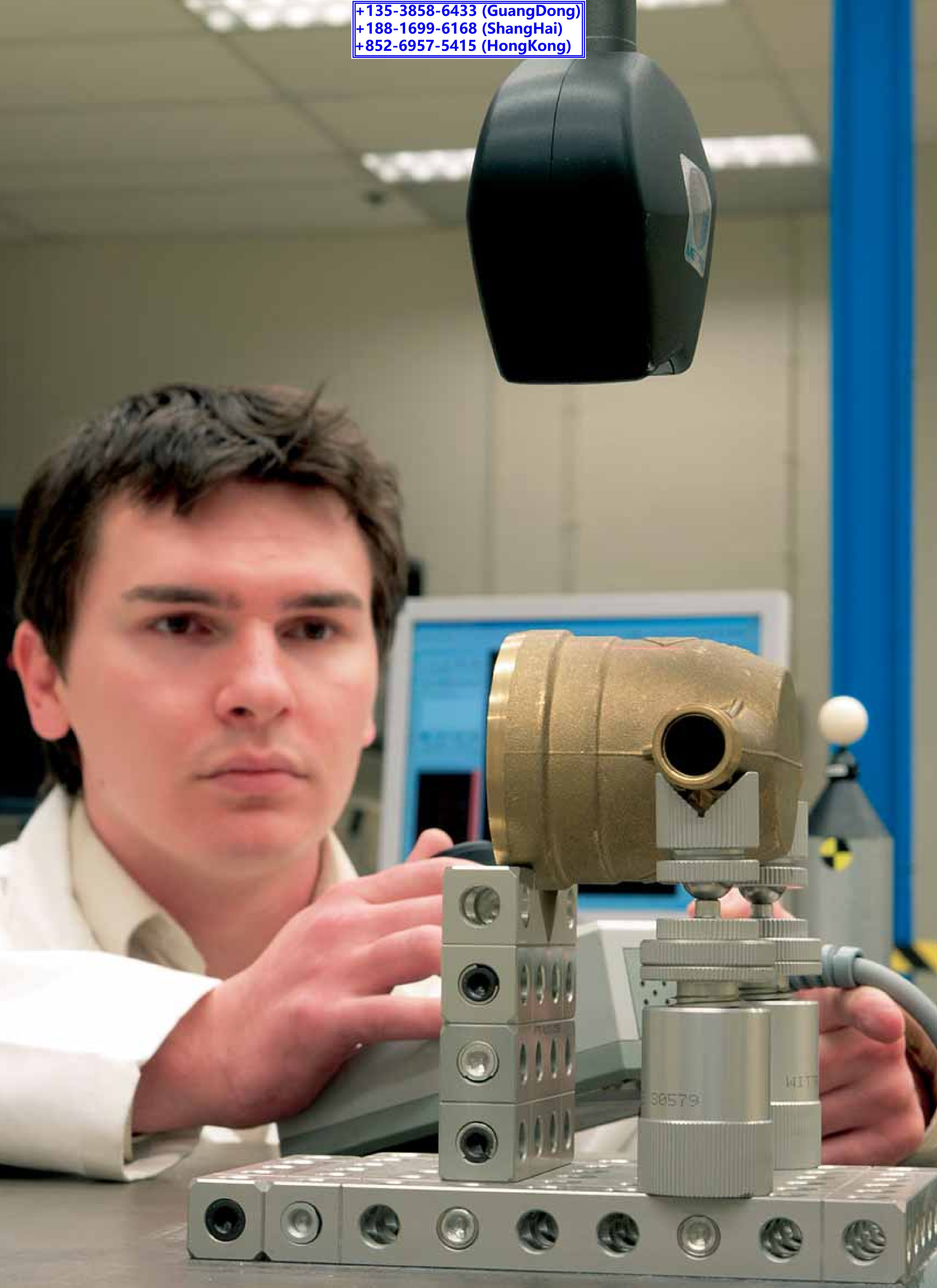
Table 4

Material	WRAS (UK)		ACS (FR)		KTW (Ger)				NSF61 (USA)	
Noryl PPX630-111S									Cold & Hot	selkirk
Noryl PPX630-BK1005F									Cold & Hot	selkirk
Noryl PPX640-111S									Cold & Hot	selkirk
Noryl PPX640-BK1005F			All+	Mar-09	cold	Feb-09			Cold & Hot	selkirk
Noryl PPX7115-111N									Cold & Hot	selkirk
Noryl PPX7115-780N									Cold & Hot	selkirk
Noryl PX 1040-701S									Cold & Hot	selkirk
Noryl PX 1436-701S									Cold & Hot	selkirk
Noryl PX 1543-701S									Cold & Hot	selkirk
Noryl PX 1543-780S									Cold & Hot	selkirk
Noryl PX 1543-80106S									Cold & Hot	selkirk
Noryl PX 4608-701S									Cold & Hot	selkirk
Noryl PX 4608-780S									Cold & Hot	selkirk
Noryl RFN20-701S									Cold & Hot	selkirk
Noryl RFN20-780S									Cold & Hot	selkirk
Noryl RFN30-701S									Cold & Hot	selkirk
Noryl RFN30-780S									Cold & Hot	selkirk
Lubricomp CL-4020-BK81475					85 °C	May-11				
Lubricomp CL-4360 S Nat	25 °C	Nov-09								
Lubricomp CL-4360S-NT8			All+	Oct-11	85 °C	May-11				
Lubricomp HAL-4023 Black	25 °C	Apr-11								
Lubricomp OFL-4036 Black			All+	Oct-11	85 °C	Sep-11				
Lubricomp RCL-4036 Nat	85 °C	Nov-07								
Staramide AG-10K BK1066					cold	May-11				
Staramide AG7K Black					cold	Mar-09				
Staramide AG7K Grey					cold	Mar-09				
Staramide AG7KNat					cold	Mar-09				
Thermocomp GF-1004 Black BK8-067			All+	Oct-11	85 °C	May-11				
Thermocomp GF-1006 EM Nat	85 °C	Sep-07								
Thermocomp JF-1006 Nat	85 °C	Aug-10								
Thermocomp MB-1006 HS S Black	85 °C	Jul-07								
Thermocomp MFX-1004 HS CuS Black	85 °C	Sep-08								
Thermocomp OF-1008 Black			All+	Oct-11	85 °C	Jul-11				
Thermocomp UF-1008 A NAT-0-20 - Black					85 °C	May-11				
Verton MFX-700-10 HS Black	85 °C	Sep-08								
Verton MFX-700-10 HS UV Nat	85 °C	Sep-08								
Verton MFX-7008 HS Black	85 °C	Sep-08								
Verton MFX-7008 HS UV Nat	85 °C	Sep-08								
Ultem 1000 - 1000	85 °C	Oct-07	All+	Apr-09						
Ultem 2100 - 1000	85 °C	Oct-07	All+	Apr-09						
Ultem 2200 - 1000	85 °C	Oct-07								
Ultem 2300 - 1000	85 °C	Oct-07								
Ultem 2400 - 1000	85 °C	Oct-07								

Table 4 continued

+ ACS does not issue a certification on a temperature

[1] GE Bergen op Zoom, NL
[2] GE Ottawa, Il USA
[3] GE Selkirk, NY USA


30579

5 The portfolio of fluid engineering materials

Where most suppliers focus on a single class or family of materials, GE Plastics offers a wide spectrum of basic resin chemistries. Each of these polymer families continues to evolve and spawn advanced copolymers, alloys and composites. This ongoing commitment to material development ensures that the company continues to offer one of the broadest, most versatile ranges of engineering thermoplastics that is on the market today.

The materials that are described in this product guide represent a small part of the GE Plastics' portfolio. However, they reach into virtually every sector of the fluid engineering industry and can help designers to tailor part, function and performance to meet their precise application needs.

Noryl PPO resin

Based on proprietary modified PPO technology, the extremely versatile Noryl resin portfolio offers customers a wealth of material solutions to meet specific application requirements. With their best-in-class hydrolytic stability and excellent high heat resistance, they are engineered to perform in both hot and cold water handling applications.

An amorphous blend of PPO resin and PS, Noryl resin is characterized by excellent dimensional stability, low mold shrinkage, low water absorption and excellent creep resistance.

With one of the lowest specific gravities in GE Plastics' engineering portfolio, Noryl resin provides designers with opportunities to create lower weight, cost-efficient parts. Furthermore, the structural performance of Noryl resin can assist with easy part consolidation and assembly. Less parts and reduced secondary operationshelp to achieve higher yields, improved quality and lower costs.

Noryl GTX resin

Noryl GTX resin is a modified PPO alloy that combines the high heat resistance, stiffness, and dimensional stability of amorphous PPO resins with the inherent chemical resistance and excellent flow of semi-crystalline polyamide (PA).

Excellent tensile strength and chemical resistance are the key properties of this material. Compared with straight PA, it also offers lower water absorption, lower specific weight and higher inherent strength and rigidity, with less glass reinforcement.

Suitable for many applications requiring cold water contact, the two grades for fluid engineering applications are Noryl GTX820 resin and Noryl GTX830 resin.

Noryl PPX resin

Noryl PPX alloy combines the flow properties and chemical resistance** of polypropylene (PP) with the high temperature performance, surface hardness and rigidity of polyphenylene oxide (PPO). Filled Noryl PPX resin grades offer high elongation, high stiffness and long-term heat resistance.

Noryl PPX 630 resin has excellent dimensional stability, where precise assembly is required, especially in contact with hot water. It also offers outstanding heat resistance at a continuous temperature of 110°C and at a peak of 130°C.

Tests indicate that Noryl PPX resin has a higher resistance to acidic fumes and liquids, compared to thermoplastics such as polyamide and Noryl PPO resin.

Product	Glass %	NSF 61+	HDT	Flex. Modulus	Specific Gravity
731	No	Y	127°C	2650 MPa	1.06
GFN1520V	20%	Y	135°C	5000 MPa	1.25
GFN2	20%	Y	138°C	6500 MPa	1.20
GFN3	30%	Y	138°C	7170	1.33
GFN1630V	30%	Y	140°C	7200 MPa	1.33

Noryl resin Features	Typical Application Benefits
Hydrolytic Stability	Retention of properties after long water exposure
Tensile Strength	Performance under pressure
Low Water Absorption	Superior dimensional stability
Chemical Resistance	Suitable for several end-use environments
Modulus at High Temperatures	Enhanced processability with shorter cooling times

Table 5
Typical Noryl resin grades used in water handling applications

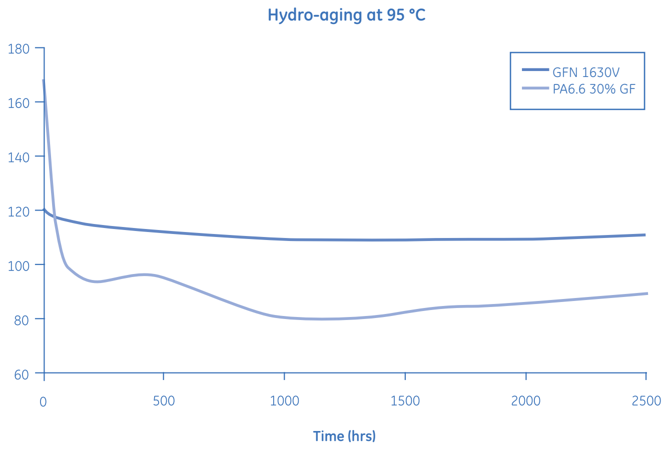


Figure 32
Strength retention of Noryl resin versus polyamide 6.6 after exposure to hot water

LNP compounds

Founded on a portfolio of over 30 base resins, and a wide range of reinforcements, fillers and additives, the LNP family of specialty engineering thermoplastics and composites offers customers a unique range of products, each with a balance of key properties to meet specific industry needs.

LNP Lubricomp, LNP Verton and LNP Thermocomp compounds, and customer engineered products such as 35% glass fiber reinforced LNP Staramide AG7K PA6,6 resin, provide the fluid engineering industry with virtually unlimited material solutions.

LNP Lubricomp resin was developed for the manufacture of parts requiring low wear and low friction, like gears, bearings and guides. Compared with metals, these materials offer greater design freedom, reduced weight, corrosion resistance and elimination of external lubricants. LNP Lubricomp compounds offer inherent lubrication through the addition of PTFE, silicone, aramid fiber or graphite. While PTFE and/or silicone internal lubricants are the most commonly used in lubricated compounds, graphite powders deliver low friction wear performance in fluid handling applications.

LNP Thermocomp glass and carbon fiber reinforced products can offer dimensional accuracy, thermal resistance, chemical resistance and/or structural mechanical performance.

LNP Verton long fiber thermoplastic composites provide superior mechanical properties compared with short fiber reinforced products. Remarkably lightweight, these materials deliver a unique combination of strength, exceptional stiffness and impact resistance. These properties, combined with the resin's processability, corrosion resistance and inherent design freedom, provide designers with excellent cost-out opportunities in metal replacement applications.

Typical applications include

- Valve bodies and brackets
- Compressor housings, brackets and plates
- Pump housings, volutes, covers, cases, couplings and caps

In applications such as specific pump housings, couplings or pump impellers in which electrical conductivity is required, LNP Stat-Kon MC1003 HS is an excellent candidate material. LNP Stat-Kon electrically active compounds offer protection from electro-static discharge (ESD) and are available in a full range of base resins. In hazardous fluid handling applications where fre or explosions are a risk, LNP Stat-Kon compounds can be tailor made to deliver the right level of electrical conductivity needed for self-grounding perfornamce,

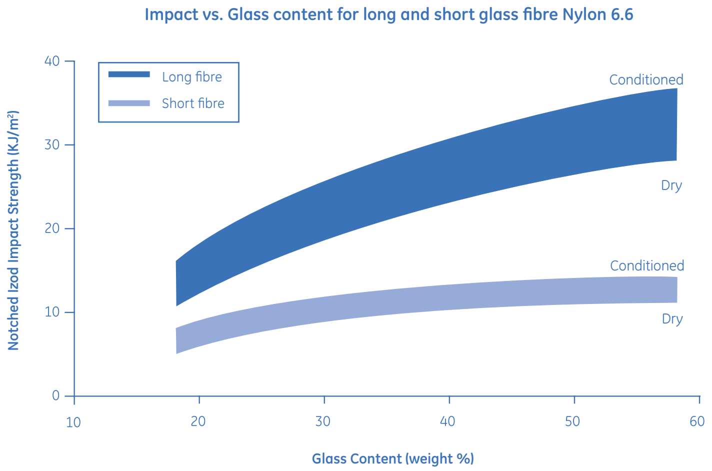


Figure 33
Impact performance comparison of LNP's short and long glass fiber reinfor-ced PA6.6

TYPICAL PROPERTIES	UNIT	STANDARD	LNP Lubricomp			LNP Thermocomp		LNP Verton	
			BML-4334	CL-4360	ZML-4334	JF-1006 EM	OF1008	RF-700-10 EM HS	UF-700-10
Physical									
Specific gravity	g/cm³	ISO 1183	1,31	1,22	1,33	1,6	1,65	1,58	1,63
Mechanical									
Tensile strength	MPa	ISO 527	56	35	50	145	170	256	245
Tensile elongation	%	ISO 527	13	1,5	2,1	1,9	1,5	1,9	1,5
Flexural strength	MPa	ISO 178	86	65	88	209	240	370	356
Flexural modulus	MPa	ISO 178	7750	7000	6000	9700	13000	15550	17700
Izod impact	kJ/m²	ISO 180/1A	13			8	8	45	38
Thermal									
HDT 1.82 Mpa	°C	ISO 75/Af	102	80	132	213	260	253	276
Tribological									
Wear factor	-	LNP SOP	196	-	102	-	-	-	-
Coefficient of Friction (Dynamic)	-	LNP SOP	0,39	-	0,36	-	-	-	-

Table 6
Typical Properties of LNP compounds for Fluid Handling and HVAC

Ultem PEI resin

Ultem polyetherimide (PEI) resin is a high performance amorphous engineering thermoplastic resin that offers an outstanding balance of properties. These include:

- Excellent long-term heat resistance. Various unfilled grades have an RTI listing of 170°C and several filled grades 180°C, according to UL746B. Although this test method is applied to electrical applications, it demonstrates the material's long-term thermal capability.
- Excellent short-term heat resistance. For example, Ultem 1000 resin has a glass transition temperature (Tg) of 217°C and an HDT/Ae of 190°C, and Xtreme heat resistant Ultem XH6050 resin has a Tg of 247°C.
- Outstanding dimensional stability over a wide temperature range. Highly filled Ultem resin has a CTE that matches, or is close to, that of metal (see table 7).
- Good resistance to a broad range of chemicals**
- Excellent resistance to UV light

Glass fiber- and glass fiber/mineral-filled grades further enhance the properties of the material. Blends with polycarbonate resins offer improved cost efficiency and modified PEI grades offer increased chemical resistance and/ or higher heat performance.

Typical grades used in the fluid industry include Ultem 1000, Ultem 1010, Ultem 2300, and Ultem 2312 resin.

With its exceptional strength and modulus, excellent knit line and weld line strength and resistance to high dynamic stresses, Ultem resin can be used in thin wall designs, even when superior strength and stiffness are required.

A comparison of the tensile modulus and strength of unfilled Ultem resin is given in Figure 35

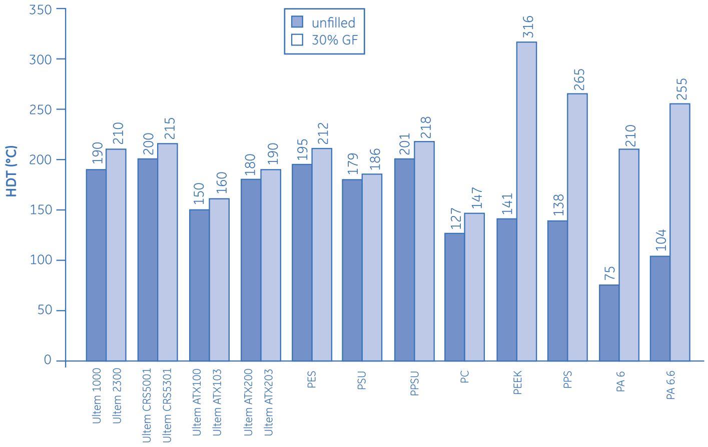


Figure 34
Heat resistance of several resins measured according HDT 1.82 MPa

Material	CTE Flow Direction ppm/°C	CTE Cross Flow Direction ppm/°C
Ultem 1000 resin	50	50
Ultem XH6050 resin	50	50
Ultem 2100 resin	26	60
Ultem 2300 resin	20	60
Ultem 2312 resin	23	27
Ultem 2400 resin	15	45
Ultem 3452 resin	17	34
Noryl GF1630C	25	70
Polysulfone (PSU)	56	56
Polysulfone 10% GF	36	
Polyphenylene sulphone (PPSU)	56	56
Polycarbonate (PC)	75	75
Aluminium	20-24**	
Brass	16-18**	
Steel	12-15**	
Zinc	27**	

** many different alloys exist within a metal group wich can influence results

Table 7

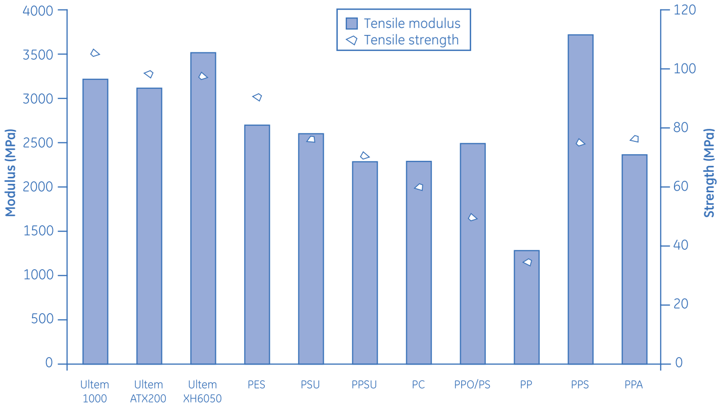


Figure 35
Tensile modulus (TM) and tensile strength (TS) of several unreinforced resins

Cycolac ABS resin

Cycolac ABS resin can be found in a range of fluid engineering applications, including heating, air conditioning and meter housings, thermostat valves, and drain, waste and vent piping systems. The material's key properties in these applications include:

- Consistently good processability
- Excellent surface quality and gloss
- Broad range of colors and effects
- High strength and fatigue resistance
- Good thermal properties over a wide temperature range
- Glass-reinforced grades for enhanced dimensional stability and thermal resistance

Cycolac resin extrusion grades are characterized by high melt strength, high gloss, good stiffness, toughness and good vacuum forming properties. They are widely used for pipe, profile and sheet extrusion, where they provide good impact performance at low temperatures. In high pressure water pipes, these grades offer typically:

- Good thermal properties, with all grades passing the ball pressure test at 75°C
- Good low temperature ductility
- Very good hydrolytic stability at temperatures up to 90°C
- Good chemical resistance**
- Agency compliance for potable water applications

Cycolac ABS resin grades typically used in fluid engineering applications

General Purpose
GPM5500S - enclosures
S701S - high flow for enclosures
S702 - high impact for hose couplings and covers
S705 - chrome plating

Glass-Filled
CRT3370

Flame Retardant
S157 – UL94 V0 @ 1.5 mm
VW300 – UL94 V0 @ 1.5 mm, for enhanced indoor UV stability
FR15U - UL94 V0 @ 1.5 mm

Extrusion
S849 - High impact extrusion grade
X399 - High Impact grade for high pressure piping

Visual*fx* resin
FXS610SK – distinctive special effects

USA Grades
MG47N – general purpose
MG38P – pipe fittings
MG37EP - chrome plating
MG37EPN - chrome plating, potable water compliant
EX39P - extrusion

Lexan PC resin

Lexan polycarbonate resin is an amorphous engineering thermoplastic, which is characterized by high levels of mechanical, electrical, optical and thermal properties. The Lexan resin portfolio provides broad design versatility through its wide range of viscosities and especially product options. These options include flame retardancy conforming to various environmental regulations, optical quality and compliance with stringent FDA and USP requirements.

Typical applications include meter housings and covers, impellers, filter housings, shower components and solar panels.

Key material properties include:

- High impact strength
- Inherent "water clear" transparency
- Product purity, consistency and durability
- High heat resistance – RTI up to 125°C
- Dimensional stability at elevated temperatures
- Transparent, translucent and opaque colors
- Flame retardancy
- UV stability
- Compatibility with injection molding, extrusion and blow molding processes

Tailor-made UV-stable Lexan resin extrusion grades offer consistent ease of processing, excellent surface finish and transparency and outstanding impact performance.

Lexan resin fluid engineering grades include:

- Lexan resin 100 series: Unreinforced, non-flame retardant
- Lexan resin 900 series: Flame retardant
- Lexan 500R, 3412R resin, 3414 resin: Glass fiber reinforced
- Lexan ML3324 resin and Lexan resin ML3021A Extrusion
- Lexan EXL resin series: Enhanced toughness
- Lexan SLX 2000 resin series: Outstanding weatherability

Lexan SLX resin is a new material development, which is based on polyester carbonate technology. This unique copolymer delivers up to four times the weathering performance of UV-stabilized polycarbonates.

Lexan EXL resin is a new generation of super tough polycarbonate siloxane copolymer based grades offering exceptional impact performance, low temperature ductility and resistance to heat and humidity aging, when compared to conventional polycarbonates.

Cycoloy* PC/ABS resin

Cycoloy resin is an amorphous PC/ABS blend, which combines the excellent processability of ABS and the excellent mechanical and electrical properties and heat resistance of polycarbonate. These materials are commonly used for pump and water filter housings, components and covers.

Traditional grades include unreinforced Cycoloy C1000, C1100HF and C1200 resin, and flame retardant Cycoloy C2950 and C3650 grades. Recent material developments include grades with significantly improved stability after prolonged exposure to heat and humidity. These include Cycoloy CY9640, CY9650 and flame retardant C6600 resin. Under extreme test conditions, (1,000 hrs at 90°C and 95% relative humidity), Cycoloy CY9640 and CY9650 grades retain 100% strength and show a >90% retention in polycarbonate molecular weight.

Key material properties include:

- Broad temperature performance
- Wide range of colors and special effects (Visual*fx*)
- Excellent UV stability
- Chlorine- and bromine-free flame retardancy
- Chrome platable
- Excellent processability

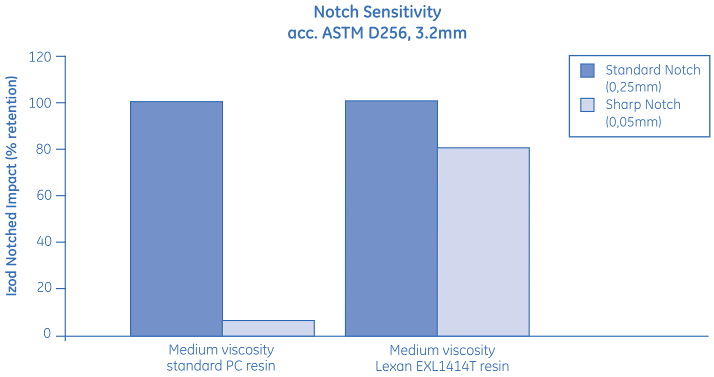


Figure 36
effect of resin viscosity on notch sensitivity

Global Fluid Center of excellence, located in Bergen op Zoom, The Netherlands

Overview application grades

Pump housing

Noryl GFN1630V resin
Noryl GFN1520V resin

Noryl GTX830 resin

LNP Verton RF70010
LNP Verton RF70012EM
LNP Verton MFX70018

LNP Lubricomp OFL4036
LNP Thermocomp OF1008
LNP Stat-Kon MC1003 HS
LNP Stat-Kon FP VC1003

Impellers, diffusor

Noryl GFN1630V resin
Noryl GFN1520V resin
Noryl 731S resin

Ultem 1000 resin
Ultem 2300 resin

LNP Verton MFX8036
LNP Verton MFX7008

LNP Lubricomp ZFL4034
LNP Lubricomp RFL4036
LNP Lubricomp BFL4334

Gears

LNP Lubricomp CL4360S
LNP Lubricomp ZML4334
LNP Lubricomp OCL4036
LNP Lubricomp ZFL4326

Electr. connectors

Noryl GFN1630V resin
Noryl V0150B resin
Noryl SE1GFN1 resin
Noryl SE1GFN2 resin

Valox 4920 resin
Valox 4631 resin
Valox 420(SE0) resin
Valox DR51 resin
Valox 508 resin
Valox 325 resin

Lexan EXL9330 resin
Lexan 121R resin

Water meters

Housing, disc:
Noryl GFN1630V resin
Noryl 731S resin
Noryl GTX830 resin
Cycolac CRT3370 resin
Cycolac GPM5500S resin
Lexan 164R resin
LNP Lubricomp ZML4334
LNP Thermocomp MFX1006

Pressure plate:
Noryl GTX830 resin
Noryl GFN1630V resin

Pistons:
LNP Lubricomp BFL4016LE

Reading device:
Lexan SLX2432T resin

Sanitary

Cartridges:
LNP Thermocomp PES
Noryl GFN1630V resin

Faucets:
Noryl 731S resin
Noryl GFN1630V resin

Showers:
Cycolac S705 resin
Cycolac MG37EP(N) resin
Xylex X8300
Xylex X7300 resin
Lexan EXL 1443T resin
LNP Lubricomp GFL4314

Water purification/ RO

Noryl GFN1630V resin

Boiler cladding

Noryl GTX830 resin

Noryl GFN1630V resin
Cycolac GPM5500S resin
Cycolac S701S resin
Cycolac FXS610SK resin

Sprinklers

Noryl GTX810 resin
Noryl GTX820 resin
Noryl GFN1520V resin

Water Manifold

Noryl GTX830 resin
Noryl GFN1630V resin

Condensate Housing

Noryl PPX630 resin
Noryl PPX640 resin

Pipes & fittings

Cycolac X399 resin
Cycolac S848 resin
Cycolac S849 resin
Cycolac MG38P resin
Cycolac EX39P resin

Solar Thermo panels

Insulation panel:
Lexan ML3324 resin
Lexan ML3021 resin
Lexan SLX1431T resin

Absorber panel
Noryl EN150SP resin

Electrical heaters

Heater:
LNP Staramide AG7K
Noryl GFN1630V resin

Body:
Cycolac S157 resin
Cycolac VW300 resin
Cycolac FR15U resin
Cycolac S701S resin
Cycolac GPM5500S resin

Exhaust pipe

Noryl PPX630 resin
Ultem 1000 resin

Americas:
GE
Plastics
One Plastics Avenue
Pittsfield, MA 01201
USA
Tel: 1 413 448 5800
Fax: 1 413 448 5573

Europe:
GE
Plastics
Plasticslaan 1
NL - 4612 PX Bergen op Zoom
The Netherlands
Tel: +31 164 292911
Fax: +31 164 292940

Pacific:
GE
Plastics
1266 Nanjing Road (W)
16th Floor, Plaza 66
200040 Shanghai
China
Tel: +86 21 3222 4500
Fax: +86 21 6289 8998

email: gelit@ge.com
geplastics.com

* Trademarks of General Electric Company.
** Chemical resistance is dependant on chemical used, resin type, exposure time, temperature and other phenomena.

GE imagination at work

PLA-2676-REV2-1106