



Plastics Data File – PP

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1. Introduction

In the words of Alan Griffiths 'Polypropylene is the new mild steel' and PP has a huge market penetration in a wide range of markets and is used in a huge variety of applications.

The good mechanical characteristics and the low cost make it a first material choice for many applications and PP has grown in some cases by displacing other polymers.

PP has a very low surface energy and this makes it difficult to bond, join or coat due to the difficulty of 'wetting' the surface.

PP is a crystalline polymer and the crystal formation after processing can lead to significant dimensional changes for some time after ejection from the mould.

The ability to orient the polymer chains in PP gives rise to the integral hinge effect used to such good effect by product designers.

PP was made possible by the development of stereo-specific catalysts by Zeigler and Natta that allowed precise positioning of the molecules along the polymer chain. PP was the first of the stereoregular plastics and the resulting crystallinity produces a stiff polymer chain and exceptional properties.

Homopolymers: The choice of catalyst allows the production of isotactic, syndiotactic or atactic varieties of homopolymer PP and all have varying properties. It is therefore difficult to characterise PP by one set of statements regarding the properties.

Random Copolymers: These are a type of where the basic structure of the polymer chain has been modified by the incorporation of a different polymer molecule. Ethylene is the most commonly used molecule and this is inserted randomly along the polymer backbone at about 1-7% concentration. The random copolymers give increased clarity and impact strength.

See Section 11 for further details on random co-polymer PP.

See Section 12 for further details on controlled rheology grades of PP.

2. Typical applications

Vehicles and mechanical engineering: Battery cases, air duct casings, parcel shelves, fan wheels, dashboards, gas pedals, sunroofs, cooling water containers, air filters, heater housings, headlamp housings.

Electrical engineering: Housings for electrical components, electric kettles, cable drums, plugs, lawnmower housings, egg poachers, mixers.

Medicine: Sterilisable hospital ware, disposable syringes, infusion bottles, tablet tubes, test tubes, metering units.

Packaging: Storage and transport containers, bottle crates, buckets, margarine tubs, desserts, bottle closures, packaging film, bottles.

Others: Adhesive strips, transparent wrappings, index cards, loose-leaf folders, plant tubs, garden furniture, chair shells, ink cartridges, suitcases, vacuum flasks, cases with hinges.

Articles using integral moulded hinges are almost always PP.

3. Physical and mechanical properties

General

PP is a semi-rigid, translucent polymer with good toughness and weather resistance properties. It has low water absorption and is easily moulded as low cost. Polypropylene is a largely non-polar, partially crystalline thermoplastic with a crystallinity of 60 to 70%. PP has a density of 0.90 to 0.91 g/cm³ which is amongst the lowest densities for all plastics. PP does not absorb moisture.

The glass transition temperature of PP homopolymers is about 0°C. The material is viscous above this temperature. The glass transition temperature of the elastomer component of block copolymers containing elastomers is -50°C. This gives a higher impact strength at 0 to 40°C. The creep strength

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of PP falls very sharply at high temperatures. The strength in one direction can be increased many times over by stretching. This is due to orientation of the macromolecules under a tensile stress.

The homopolymer is translucent, and the transparency can be improved still further by stretching. Block copolymers give dull to opaque moulded parts but this is improved on contact with liquids and the level of containers filled with liquid can be seen from the outside.

Mechanical properties

| Property | Approximate Value |
|----------------------------------|--------------------------------|
| Tensile Strength | 30 - 55 MN/m ² |
| Tensile Modulus | 1 - 2 GN/m ² |
| Elongation at Break | >500 % |
| Flexural Strength | <50 MN/m ² |
| Notched Impact Strength | >20 kJ/m ² |
| Specific Heat | 1.70 - 2.15 kJ/kg/°C |
| Glass Transition Temperature | -10°C |
| Heat Deflection Temperature | <100°C |
| Coefficient of Thermal Expansion | 10 - 15 x 10 ⁻⁵ /°C |
| Long Term Service Temperature | 80°C |
| Specific Gravity | 0.91 - 0.93 |
| Mould Shrinkage | 0.01 - 0.025 m/m |
| Water Absorption | <0.1 % (50% rh) |
| Transparency | Opaque |

4. Thermal, electrical and optical properties

Thermal properties

The melting point of homopolymers is 155 to 160°C and that of block copolymers is 160 to 165°C. If the PP parts are not subjected to mechanical stresses, the service temperature limit is 110°C. Over short periods without any external load, a temperature of 140°C is permissible.

Fire behaviour

PP can be ignited by flames and burns with a weak flame with burning drips.

Electrical properties

PP has a very good electrical insulation capacity and parts easily become electrostatically charged and attract dust.

Optical properties

Moulded parts produced from natural homopolymer are translucent. The transparency can be improved still further by stretching below the crystallisation temperature. The refractive index is 1.50.

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5. Chemical resistance properties

General

PP has very good chemical resistance. It is stable to aqueous solutions of salts, acids and alkalis. Polypropylene is resistant to alcohol, solvents up to 60°C and detergent solutions. Aromatic and halogenated hydrocarbons and, at high temperatures, fats, oils and waxes, cause PP to swell.

A detailed chemical resistance chart is given in Section 13.

Resistance to weathering

PP has adequate stability to radiation within the region of visible light. UV light causes embrittlement and surface damage. This oxidation process is accelerated by high temperatures. Weathering resistance can be improved by the addition of carbon black but this reduces the resistance to thermal ageing.

Resistance to stress cracking

The resistance to stress cracking is good.

6. Advantages and limitations

| Advantages | Limitations |
|---|---|
| 1. Chemical resistance similar to that of polyethylenes (i.e., resistant to most inorganic acids, alkalis, and salts) but without susceptibility to environmental stress cracking when in contact with alcohols, esters, detergents, or polar hydrocarbons. | 1. More expensive than polyethylene. |
| 2. Very good fatigue resistance; possesses integral-hinge property. | 2. Embrittles below -17°C. |
| 3. Excellent dielectric properties. | 3. Upper service temperature 90-120°C, depending on grade and anti-oxidant content (upper limit applies to filled grades, lower limit to flame-retardant grades). |
| 4. More rigid than polyethylenes and because of high melting point retains mechanical properties at elevated temperatures. | 4. Heat-ageing stability is adversely affected by contact with metals. |
| 5. Mechanical and electrical properties unaffected by submersion in water. | 5. Attacked by highly oxidising acids, such as fuming sulphuric, liquid and gaseous halogens; swell rapidly in chlorinated solvents and aromatics. |
| 6. Low density. | 6. 2 % carbon black needed to prevent degradation by UV light. |
| 7. Non-toxic grades available for use with foodstuffs; can be steam sterilized. | 7. Colour purity adversely affected by reinforcing materials. |
| 8. Filled grades available with improved stiffness, these are comparable to unfilled nylon but of lower price. | 8. Not readily thermoformed because of low melt strength and hence requires close control of processing parameters. |

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| | |
|--|---|
| 9. Can be joined by hot-gas, hot-tool, induction, or friction welding. | 9. Joined more easily to other materials, for example wood and aluminium, than to itself. |
| 10. Available as pipe, sheet, rod and injection mouldings. | 10. Post moulding dimensional changes due to crystallinity effects. |

7. Processing

Injection moulding

PP has a wide processing range. The material temperatures are between 180 and 300°C. The mould temperature can be between 20 and 60°C and the higher the mould temperatures then the better the surface gloss. A high injection pressure 1200 – 1800 bar is generally needed and to avoid sink marks a hold time of approximately 50% of the injection time is needed. A high injection speed is also recommended.

Up to 100% regrind can be used.

Extrusion

The extrusion temperature is between 240 and 270°C and it is best to use a short compression screw with an L/D ratio of 20 to 25.

Blow moulding

Hollow bodies with a volume up to 5 litres and above can be blow moulded. The material temperature should be between 190 and 220°C and the mould temperature should be between 20 and 40°C.

Process selector

| Processing Method | Applicable |
|-------------------------|--|
| Injection Moulding | Yes The crystalline nature of PP means that post moulded articles are not always dimensionally stable until full crystallisation has taken place. This can take up to 24 hours and involve significant movement in the article. |
| Extrusion | Yes PP extrusion needs a low flow rate formula to give adequate melt strength. PP is also used to produce monolayer and co-extruded blown film. |
| Extrusion Blow Moulding | Yes |
| Rotational Moulding | No |
| Thermoforming | Yes |
| Casting | Yes |
| Bending and joining | Yes Difficult to join unless pre-treated. |

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8. Finishing

Machining

High cutting speeds and a slow rate of travel should be chosen in order to achieve clean surfaces. Knurling, grinding, filing and polishing are less suitable.

Surface treatment

PUR or acrylic-based one or two component paints should be used for painting. If a small-scale printing operation is required, hot stamping is used. A new process is printing under hot conditions, where the ink is applied to the untreated surface and then fixed at high temperature. For the best results in high vacuum metallising, the surfaces should be pre-treated electronically. Good results can be obtained using primers and a base coat.

Welding

Hot gas, heated tool, friction and vibration welding are suitable for welding PP. Ultrasonic welding can be carried out only in the near-field. HF welding is not possible because of the low dissipation factor.

Bonding

As the high resistance to solvents prevents partial dissolution of the surface of the moulded part, only impact adhesives can be used. In order to improve adhesion, the surface must be pre-treated, e.g., by a flame treatment, application of primers, by corona discharge and by immersion in a bath of chromosulphuric acid.

9. Health and safety

PP is odourless and tasteless and is physiologically safe, apart from those grades with certain stabiliser types, e.g., copper and UV radiation. PP will, however, pick up aromas from materials and can transmit these to the contents of packaging.

10. Other Information

Identification

Material is flammable. It drips and continues to burn once alight.

The flame is bright with a blue core and there is an odour of burning paraffin similar to that of a candle which has just been snuffed out.

The smell of PP when it is being processed is easily recognisable.

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11. PP – random copolymers

Polypropylene random copolymers are a type of polypropylene in which the basic structure of the polymer chain has been modified by the incorporation of a different monomer molecule. Ethylene is the most common comonomer used. This causes changes to the physical properties of the PP. In comparison with PP homopolymers, random copolymers exhibit improved optical properties (increased clarity and decreased haze), improved impact resistance, increased flexibility, and a decreased melting point, which also results in a lower heat-sealing temperature. At the same time, they exhibit essentially the same chemical resistance, water vapour barrier properties, and organoleptic properties (low taste and odour contribution) as PP homopolymer.

Random copolymer PPs were developed to combine improved clarity and impact strength, and are used in blow moulding, injection moulding, and film and sheet extrusion applications. They are used in food packaging, medical packaging, and consumer products.

Chemistry

Random copolymer PP typically contains between 1 and 7 wt.-% of ethylene molecules and 99 to 93 wt.-% propylene molecules. The ethylene molecules are inserted randomly between the propylene molecules in the polymer chain. In such random or statistical co-polymers, the majority (usually 75%) of the ethylene is incorporated as single molecular insertions termed X3 groups (these have three consecutive ethylene [CH₂] molecules in sequence in the polymer chain). These also can be viewed as one ethylene molecule inserted between two propylene molecules.

About 25% of the ethylene is incorporated in multiple molecular insertions. These are called X5 because there are five methylene groups in sequence (two ethylenes inserted together between two propylenes). It is difficult to distinguish between X5 and higher groups (X7, X9, etc.). Because of this, the content of multiple ethylene insertions for X5 and higher groups is usually reported as >X3%. The randomness ratio (X3/X5) also can be determined. A large percentage of >X3 groups will significantly decrease the crystallinity of the resulting copolymer. This has important effects on the final properties of the random copolymer. Very high levels of ethylene in the copolymer have similar effects on the crystallinity of the polymer, as do high levels of atactic PP.

Random PP differs from homopolymer because the ethylene molecules randomly inserted into the polymer backbone hinder the crystal-type arrangement of the polymer molecules. This reduction in copolymer crystallinity is responsible for the modification of physical properties: random copolymers have reduced stiffness, higher impact resistance, and much better clarity than homopolymer PP. Ethylene copolymers also have lower melting temperatures which give them advantages in some applications.

Random copolymers also have higher levels of extractable materials and atactic PP, and polymer chains with much higher levels of ethylene (to 15wt.-%). These higher extractable levels occur to one degree or another with all commercial copolymer materials (depending on the polymerization process), and can cause problems in meeting FDA food contact regulations for some applications.

Manufacture

Ethylene/propylene random copolymers are produced by the simultaneous polymerisation of propylene and ethylene molecules in the same reactors used to produce homopolymer PP. Ethylene molecules are smaller than propylene molecules, and react faster (they are about ten times more reactive). This makes the catalyst less stereospecific but more active, which results in an increased production of atactic PP. To reduce such atactic production, the temperatures at which the reaction is carried out are reduced. This lowers the activity of the catalyst and so reduces the eventual atactic content, resulting in the production of a copolymer product with a better balance of properties.

Random copolymers with high levels of ethylene (>3%) are more difficult to handle in production. Polymerizing high ethylene copolymers in hexane diluent is more difficult because of the solubility in hexane of the secondary by-products of the reaction (atactic PP and copolymer with very high ethylene content). This also is true in bulk polymerization with liquid propylene, although the solubilities are lower. Thus, the hexane diluent process produces a large amount of by-product that must be separated in a hexane recycle stage, adding to the overall manufacturing cost. It does, however, result in cleaner polymer with lower levels of extractable components.

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In a bulk process, these residues tend to stay in the polymer and cause handling problems with flake materials. Also, the final copolymer product tends to have higher residual extractable components. Secondary washing steps that use organic solvents can remove a large part of these residues, but this also serves to increase the overall cost of manufacturing the copolymers. Generally, random copolymer flakes are stickier because of these high level of by-product materials, and this problem becomes critical when ethylene levels are greater than 3.5 wt.-%.

Increased handling problems and lower reactor temperatures lead to lower production rates for random copolymers. Also, random copolymers usually are produced in much shorter runs. These factors contribute to the overall higher production cost for random copolymers compared to homopolymers, especially for the higher ethylene types.

Reduction of the copolymer's melting point is directly related to ethylene content. Thus, melting point values as low as 60°C. have been reported with copolymers with 7 wt.-% ethylene. The X₃ content has a greater effect on the copolymer melting point than the content of X₅ and higher sequences. It also depends on the catalyst itself and its ability to incorporate ethylene as X₃ sequences instead of as X₅ sequences.

Properties

Physical properties: Generally, random co-polymers are more flexible and less stiff than homopolymer PP. They have moderately better impact strength at temperatures down to 0°C, and they have limited utility down to -25°C. The molecular weight of the material has a greater effect on the stiffness for homopolymers than it does for copolymers.

Chemical resistance: Random copolymers are highly resistant to attack by such chemicals as acids, alkali's, alcohols, low-boiling hydrocarbon solvents, and many inorganic chemicals. At room temperature, PP copolymers are essentially insoluble in most organic solvents. Also, they are not susceptible to environmental stress cracking failures when exposed to soaps, soap solutions, wetting agents, and alcohols, as are many other polymers. Contact with some chemicals-particularly liquid hydrocarbons, chlorinated organic compounds, and strong oxidizing acids-can cause surface crazing or swelling. Generally, non-polar compounds are absorbed more easily by PP than are polar chemicals.

Barrier properties: Both homopolymer and copolymer PP have very low water vapour permeability. Resistance to permeation by gases is fair to moderate. These can be improved through orientation. Stretch-blow moulded PP bottles improve the moisture vapour resistance and the O₂ permeability.

Electrical properties: Generally, PP has excellent electrical properties-including high dielectric strength, low dielectric constant, and low dissipation factor. However, homopolymers are the usual choice for electrical applications.

Applications

Random copolymer PP is mainly used in film, blow moulding, and injection moulding applications where high clarity is a requirement. Because of their lower sealing initiation temperatures, higher-ethylene copolymers find wide use as special sealing layers in co-extruded film structures.

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12. PP – controlled rheology grades

Introduction

Controlled rheology (CR) grades of polypropylene extend and improve the characteristics of PP. In order to maximise the benefits obtainable with these products a knowledge of the process and basic properties of the materials is very useful. This review gives some background information to allow understanding of these factors.

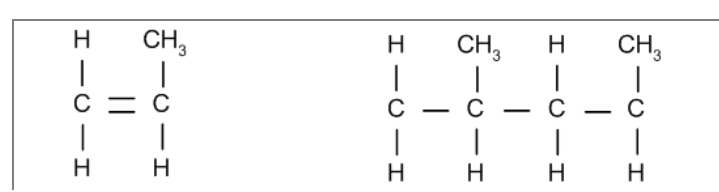
Basic concepts

Controlled rheology PP is produced by degrading normal PP to give a product with a high melt flow index (MFI), lower molecular weight (MW), narrower molecular weight distribution (MWD) and hence easier and more consistent flow.

This is a broad statement and may confuse more than explain. The basic concepts of molecular weight, molecular weight distribution and MFI are explained below.

Molecular weight (MW)

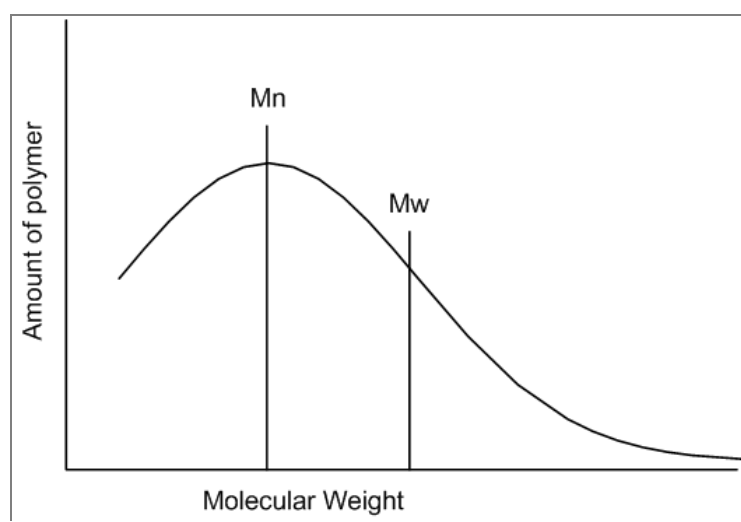
A polymer (poly = many) is made up of many repeated units of a monomer (mono = one). For polypropylene the repeat unit is the propylene monomer. This can be illustrated as below:



The length of the polymer chain is specified by the number of repeat units in the chain. This is called the 'degree of polymerisation' (DP). The molecular weight of the polymer is defined by:

MW = Degree of polymerisation x molecular weight of repeat unit.

All processes used in polymer production lead to chains of varying lengths and hence varying molecular weights. The distribution of molecular weights for a typical polymer is shown below.



This shows that it is difficult to describe the molecular weight by use of a single number and any number quoted will always be an average of some type. Two averages are generally used. These are:

Number-average molecular weight (Mn). This is generally measured by methods such as vapour pressure lowering or other colligative property measurements. Essentially the techniques involve counting the number of molecules in a known mass of material. Mn normally lies near the peak of the weight distribution curve, i.e., the most probable molecular weight.

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Weight-average molecular weight (Mw). This is generally measured by light scattering or other methods and tends to emphasise the contribution of heavier or longer molecules. The value for Mw is equal to or higher than that of Mn.

The two values are shown in Figure 1 and the ratio Mw/Mn is used as a measure of the breadth of the molecular weight distribution. Values of Mw/Mn, range from 1.5 to 50. In general, a narrow distribution gives more regular and repeatable production characteristics.

For commercial polypropylenes the molecular weights are approximately:

Mn = 38,000 - 60,000

Mw = 220,000 - 700,000

Mw/Mn = 5.6 - 11.9

Melt Flow Index (MFI)

In injection moulding the heated and softened material is forced into a mould and the way in which the material flows is very important. The most commonly used test or indicator for flow characteristic is the Melt Flow Index (MFI) or Melt Flow Rate (MFR).

The test involves heating a polymer to a specified temperature in a piston and then loading the piston with a specified weight. The piston extrudes the polymer through a hole and the amount of material extruded in a given time (usually 10 minutes) is the MFI value. The test suffers from some disadvantages in that the shear rate is very low and varies throughout the test. Processing at much higher shear rates can lead to a great reduction in apparent viscosity. It is thus possible for two materials to have identical MFI values but process differently. MFI is to be regarded as an indicator test only.

When dealing with MFI results it is essential that the temperature and piston load used are noted. Common conditions used are:

- 230°C/2.16 kg – Used for granules and general-purpose materials.
- 190°C/10 kg – Used for powders where the increased load is required to avoid air bubbles and give good packing.

The results of each condition are not equivalent and for the same material in different forms, e.g., granule copolymer and powder copolymer the results can vary by up to a factor of 10.

The conditions of test must be noted otherwise the results are useless.

MFI thus gives an indication of the viscosity of a polymer melt. A high MFI indicates that the polymer will be very liquid and flow very easily at a given temperature. A lower MFI material will not flow as easily and will require more effort to fill a given mould.

The relationship between MFI and MW is such that low MW materials give high MFI values and vice versa.

For injection moulding it is usual to choose the highest MFI material that will provide sufficient strength in order to obtain maximum output.

Production of High MFI PP

High MFI PP can be produced by two basic methods. These are:

1. Polymerisation control - This involves changing the polymerisation conditions to control the molecular weight of the final product. This method may lead to a high value of M_w/M_n , i.e., a broad MW distribution. Production by this method should be cheaper as it is a one-step method but the volume of the batch may affect this. MFI values achievable by this method range from 4 to 1500, the upper value being used for high-rate fibre production to give very soft fibres for non-woven fabric production.
2. Post-Treatment - This involves taking PP from the reactor and subjecting it to a variety of treatments to break the main chain and reduce the MW. This is a degradation treatment and can be achieved by:
 - Thermal mechanical treatment
 - Gamma radiation

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- Oxidation
- Addition of organic peroxides

Peroxide addition is most widely used and these are added prior to extrusion and pelletising. When a peroxide and a PP polymer mixture is heated the peroxide will produce free radicals that react with the PP molecules. The peroxide attacks randomly but statistically the longest molecules are most susceptible to attack. This results in a narrow MW distribution and increased MFI.

The anti-oxidant system used in CR grades must be very carefully chosen. Anti-oxidants are added to PP in order to retard the degradation of the polymer under the effects of heat and sunlight. For CR grades the system must first allow controlled degradation during production and later protect the polymer from further degradation due to heat and sunlight. At the same time the system must be suitable for food contact and satisfy the relevant legislation.

Properties of CR grades

Homopolymer PP

The influence of MW (and MFI) on the bulk properties of PP is often the reverse of that found with other polymers. The main reason for this is that crystal formation is more difficult at high MW and this affects the properties via degree of crystallisation rather than simply through MW.

In common with most polymers a decrease in MW (increase in MFI) gives a decrease in melt viscosity, i.e., easier flow. The effect of MFI on impact strength is such that impact strength is at a minimum for an MFI of approximately 11 and increases if MFI is increased or decreased. Other property changes are summarised below:

Increase in MFI (e.g., 11 => 25) gives:

- increase in tensile strength.
- increase in thermal stability.
- increase in stiffness.
- increase in hardness.
- increase in softening point.
- increase in impact strength.
- decrease in warpage.

In addition, CR grades show considerably fewer gels than conventional polymers.

Copolymer PP

The conventional method of producing a block copolymer, i.e., adding 4-15% ethylene to the polypropylene gives much improved impact strength and considerably lowers the brittle point such that it is well below normal service temperatures, i.e., -15 to -20°C. This greatly improves the service performance of copolymer PP relative to homopolymer PP.

With CR grades of copolymer, the MW is not only reduced by chain cleavage but the ethylene containing block of the copolymer also experiences chain growth. This can lead to a very small decrease in impact strength but the improved flow properties more than counteract this.

Processing of CR grades

Due to the decreased melt viscosity of CR grades the application of these materials is mainly in the following areas:

1. Thin-walled packaging.
2. Straight sided and thin-walled boxes.
3. Products requiring a long flow path.

CR grades show several processing advantages over conventional grades. The most significant of these are:

1. The decreased viscosity means less injection pressure is required for mould filling.
2. Lower melt temperatures are required to achieve the same viscosity, i.e., approximately 30°C lower mass temperature.
3. Cycle times can generally be reduced by 10-15%.
4. Lower temperatures mean that warpage on demoulding is reduced.

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5. Pigment/colour mixing may be improved due to decreased viscosity and better flow at a given temperature.
6. The narrower MWD should show minimal differences parallel to and across the flow direction.
7. The decreased injection pressure may allow a machine with a lower clamping force to be used.

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13. Detailed chemical resistance

Important Note:

Whilst we try to ensure that this table is as accurate as possible, we cannot guarantee that the data contained in the tables is accurate for all blends and grades. In all cases the supplier of the material should be contacted to determine the exact chemical resistance of the material.

R = Resistant, LR = Limited Resistance, NR = Not Recommended, ND = No Data

| Chemical | Resistance | | |
|--------------------------|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Acetaldehyde | R | ND | NR |
| Acetic acid (10%) | R | R | ND |
| Acetic acid (glac./anh.) | R | R | NR |
| Acetic anhydride | R | R | NR |
| Aceto-acetic ester | R | R | R |
| Acetone | R | R | ND |
| Other ketones | R | NR | NR |
| Acetonitrile | R | R | ND |
| Acetylene | ND | ND | ND |
| Acetyl salicylic acid | LR | LR | LR |
| Acid fumes | R | R | NR |
| Alcohols | R | R | ND |
| Aliphatic esters | R | NR | NR |
| Alkyl chlorides | NR | NR | NR |
| Alum | R | R | R |
| Aluminium chloride | R | R | R |
| Aluminium sulphate | R | R | R |
| Ammonia, anhydrous | R | R | R |
| Ammonia, aqueous | R | R | R |
| Ammonium chloride | R | R | R |

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| Chemical | Resistance | | |
|----------------------------------|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Amyl acetate | R | NR | NR |
| Aniline | R | R | R |
| Antimony trichloride | R | R | ND |
| Aqua regia | R | NR | NR |
| Aromatic solvents | R | NR | NR |
| Ascorbic acid | ND | ND | ND |
| Beer | R | R | ND |
| Benzaldehyde | R | R | NR |
| Benzene | NR | NR | NR |
| Benzoic acid | R | R | ND |
| Benzoyl peroxide | NR | NR | NR |
| Boric acid | R | R | R |
| Brines, saturated | R | R | ND |
| Bromide (K) solution | R | R | ND |
| Bromine | NR | NR | NR |
| Bromine liquid, tech. | ND | ND | ND |
| Bromine water, saturated aqueous | ND | ND | ND |
| Butyl acetate | R | NR | NR |
| Calcium chloride | R | R | R |
| Carbon disulphide | NR | NR | NR |
| Carbonic acid | R | R | ND |
| Carbon tetrachloride | NR | NR | NR |
| Caustic soda & potash | R | R | R |
| Cellulose paint | NR | NR | NR |
| Chlorates of Na, K, Ba | R | R | ND |
| Chlorine, dry | NR | NR | NR |

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| Chemical | Resistance | | |
|---------------------------|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Chlorine, wet | NR | NR | NR |
| Chlorides of Na, K, Ba | R | R | R |
| Chloroacetic acid | R | R | ND |
| Chlorobenzene | NR | NR | NR |
| Chloroform | NR | NR | NR |
| Chlorosulphonic acid | NR | NR | NR |
| Chromic acid (80%) | R | ND | ND |
| Citric acid | R | R | ND |
| Copper salts (most) | R | R | ND |
| Cresylic acids (50%) | ND | ND | ND |
| Cyclohexane | NR | NR | NR |
| Detergents, synthetic | R | R | R |
| Emulsifiers, concentrated | R | R | ND |
| Esters | R | NR | NR |
| Ether | NR | NR | NR |
| Fatty acids (>C6) | R | R | ND |
| Ferric chloride | R | R | R |
| Ferrous sulphate | R | R | R |
| Fluorinated refrigerants | NR | NR | NR |
| Fluorine, dry | NR | NR | NR |
| Fluorine, wet | NR | NR | NR |
| Fluorosilic acid | R | R | ND |
| Formaldehyde (40%) | R | R | ND |
| Formic acid | R | ND | ND |
| Fruit juices | R | R | ND |
| Gelatine | R | R | ND |

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| Chemical | Resistance | | |
|------------------------------|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Glycerine | R | R | R |
| Glycols | R | R | ND |
| Glycol, ethylene | R | R | R |
| Glycolic acid | R | R | R |
| Hexamethylene diamine | NR | NR | NR |
| Hexamine | ND | ND | ND |
| Hydrazine | R | ND | ND |
| Hydrobromic acid (50%) | R | R | R |
| Hydrochloric acid (10%) | R | R | R |
| Hydrochloric acid (conc.) | R | R | NR |
| Hydrocyanic acid | R | R | ND |
| Hydrofluoric acid (40%) | R | ND | ND |
| Hydrofluoric acid (75%) | R | ND | NR |
| Hydrogen peroxide (30%) | NR | NR | NR |
| Hydrogen peroxide (30 - 90%) | NR | NR | NR |
| Hydrogen sulphide | R | R | ND |
| Hypochlorites | R | R | R |
| Hypochlorites (Na 12-14%) | R | R | R |
| Iso-butyl-acetate | R | NR | NR |
| Lactic acid (90%) | R | R | ND |
| Lead acetate | R | R | ND |
| Lead perchlorate | NR | NR | NR |
| Lime (CaO) | R | R | R |
| Maleic acid | R | R | R |
| Manganate, potassium (K) | R | R | ND |
| Meat juices | R | R | ND |

Plastics Data File – PP

| Chemical | Resistance | | |
|--|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Mercuric chloride | R | R | ND |
| Mercury | R | R | R |
| Methanol | R | R | R |
| Methylene chloride | NR | NR | NR |
| Milk products | R | R | R |
| Moist air | R | R | R |
| Molasses | R | R | ND |
| Monoethanolamine | LR | LR | LR |
| Naptha | R | ND | ND |
| Napthalene | R | R | R |
| Nickel salts | R | R | R |
| Nitrates of Na, K and NH3 | R | R | ND |
| Nitric acid (<25%) | R | R | R |
| Nitric acid (50%) | NR | NR | NR |
| Nitric acid (90%) | NR | NR | NR |
| Nitric acid (fuming) | NR | NR | NR |
| Nitrite (Na) | NR | NR | NR |
| Nitrobenzene | LR | LR | LR |
| Oils, diesel | R | NR | NR |
| Oils, essential | R | R | R |
| Oils, lubricating + aromatic additives | R | NR | NR |
| Oils, mineral | R | NR | NR |
| Oils, vegetable and animal | R | R | NR |
| Oxalic acid | R | R | NR |
| Ozone | ND | ND | ND |
| Paraffin wax | R | R | ND |

Plastics Data File – PP

| Chemical | Resistance | | |
|---------------------------|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Perchloric acid | NR | NR | NR |
| Petroleum spirits | NR | NR | NR |
| Phenol | R | R | ND |
| Phosphoric acid (20%) | R | R | R |
| Phosphoric acid (50%) | R | R | ND |
| Phosphoric acid (95%) | R | R | ND |
| Phosphorous chlorides | R | ND | ND |
| Phosphorous pentoxide | R | R | ND |
| Phthalic acid | R | R | ND |
| Picric acid | R | R | ND |
| Pyridine | R | ND | ND |
| Salicyl aldehyde | ND | ND | ND |
| Sea water | R | R | R |
| Silicic acid | R | R | ND |
| Silicone fluids | R | R | ND |
| Silver nitrate | R | R | ND |
| Sodium carbonate | R | R | ND |
| Sodium peroxide | ND | ND | ND |
| Sodium silicate | R | R | R |
| Sodium sulphide | R | R | R |
| Stannic chloride | R | R | R |
| Starch | R | R | R |
| Sugar, syrups & jams | R | R | ND |
| Sulphamic acid | R | R | ND |
| Sulphates (Na, K, Mg, Ca) | R | R | NR |
| Sulphites | R | R | ND |

Plastics Data File – PP

| Chemical | Resistance | | |
|------------------------|------------|------|-------|
| | 20°C | 60°C | 100°C |
| Sulphonic acids | ND | ND | ND |
| Sulphur | R | R | ND |
| Sulphur dioxide, dry | R | R | NR |
| Sulphur dioxide, wet | R | R | ND |
| Sulphur dioxide (96%) | R | R | ND |
| Sulphur trioxide | ND | ND | ND |
| Sulphuric acid (<50%) | R | R | NR |
| Sulphuric acid (70%) | R | NR | NR |
| Sulphuric acid (95%) | R | NR | NR |
| Sulphuric acid, fuming | NR | NR | NR |
| Sulphur chlorides | ND | ND | ND |
| Tallow | R | R | ND |
| Tannic acid (10%) | R | R | ND |
| Tartaric acid | R | R | ND |
| Trichlorethylene | NR | NR | NR |
| Urea (30%) | R | R | NR |
| Vinegar | R | R | ND |
| Water, distilled. | R | R | R |
| Water, soft | R | R | R |
| Water, hard | R | R | R |
| Wetting agents (<5%) | R | R | R |
| Yeast | R | R | ND |
| Zinc chloride | R | R | ND |