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THE EFFECT OF TEMPERATURE AND OTHER FACTORS ON PLASTICS AND ELASTOMERS

Third Edition

Laurence W. McKeen

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Preface

This book is an update to one of the first of a series of PDL books covering the properties of plastic and elastomer materials. The last edition was published in 2008. A lot has changed in the field since 2008. There has been a huge turnover in ownership of the plastic producing companies. There has been a lot of consolidation, which of course means discontinued products.

Plastics of similar polymer types are grouped into nine chapters. Each of these chapters is split into sections covering a specific type of plastic polymer. Included is a brief explanation of the chemistry of the polymers used in the plastics of that section.

Chapter 1 has been updated to provide background to polymer chemistry and plastic formulations. It is an introductory chapter that summarizes the chemistry of making polymers, the formulation of plastics, testing and test methods, and plastic selection.

Most plastic products and parts are expected to be used in environments other than room temperature and standard humidity conditions. Chapters 2–10 are a data bank that serves as an evaluation of plastics as they are exposed to varying operating conditions at different temperatures, humidity, and other factors. In these chapters, several new plastic types have been added along with newly available data. Over 1200 uniform graphs for more than 60 generic families of plastics are contained in these chapters. The following types of graphs may be included.

A. Properties as functions of temperature:
1. Flexural modulus/strength
2. Tensile modulus/strength
3. Shear modulus/strength
4. Impact strength
5. Hardness
6. Torsional modulus
7. Coefficient of thermal expansion
8. Dielectric constant
9. Dissipation factor
10. Water absorption
11. Specific volume/heat
12. Pressure–volume–temperature plots

B. Stress vs. strain curves at various temperatures:
1. Strain rates
2. Humidity levels

C. Mechanical properties as a function of:
1. Strain rate
2. Humidity level

D. Electrical properties as a function of:
1. Humidity level
2. Frequency

E. Also included:
1. Properties vs. thickness
2. Dimensions vs. moisture
3. Properties vs. glass content and other formulation factors

Chapter 11 contains extensive mechanical and electrical data in tabular form. These tables contain data on several thousand plastics. Similarly, Chapter 12 contains thermal data on several thousand plastics.

Data from the previous editions have only been removed if those products were discontinued, and many products were. Product names and manufacturers have been updated.

Laurence W. McKeen
2014

1 Introduction to Plastics, Polymers, and Their Properties

The most basic components of plastic and elastomer materials are polymers. The word polymer is derived from the Greek term for "many parts." Polymers are large molecules comprised of many repeat units called monomers that have been chemically bonded into long chains. Since World War II, the chemical industry has developed a large quantity of synthetic polymers to satisfy the material needs for a diverse range of products, including paints, coatings, fibers, films, elastomers, and structural plastics. Literally thousands of materials can be called "plastics," although the term today is typically reserved for polymeric materials, excluding fibers, which can be molded or formed into solid or semisolid objects. As of the beginning of 2014, IDES The Plastics Web® (http://www.ides.com) listed over 85,900 different grades of plastic from over 900 suppliers.

1.1 Polymer/Plastic Chemistry

This section provides a basic understanding of polymers and plastics from a chemistry point of view.

1.1.1 Polymerization

Polymerization is the process of chemically bonding monomer building blocks to form large molecules. Commercial polymer molecules are usually thousands of repeat units long. Polymerization can proceed by one of several methods. The two most common methods are called addition polymerization and condensation polymerization.

1.1.1.1 Addition Polymerization

In *addition polymerization* (sometimes called *chain-growth polymerization*), a chain reaction adds new monomer units to the growing polymer molecule one at a time through double or triple bonds in the monomer. The polymerization process takes place in three distinct steps:

1. *Chain initiation*—Usually by means of an initiator which starts the polymerization process. The reactive initiation molecule can be a radical (free radical polymerization), cation (cationic polymerization), anion (anionic polymerization), and/or organometallic complex (coordination polymerization).
2. *Chain propagation*—A monomer adds onto the chain and each new monomer unit creates an active site for the next attachment. The net result is shown in Figure 1.1.
3. *Chain termination*—The radical, cation, or anion is "neutralized," stopping the chain propagation.

Many of the plastics discussed in later chapters of this book are formed in this manner. Some of the plastics made by addition polymerization include polyethylene (PE), polyvinyl chloride (PVC), acrylics, polystyrene (PS), and polyoxymethylene (acetal).

1.1.1.2 Condensation Polymerization

The other common method is *condensation polymerization* (also called *step-growth polymerization*), in which the reaction between monomer units and the growing polymer chain end group releases a small molecule, often water, as shown in Figure 1.2. The monomers in this case have two reactive groups. This reversible reaction will reach equilibrium and halt unless this small molecular by-product is removed. Polyesters and polyamides are among the plastics made by this process.

Understanding the polymerization process used to make a particular plastic gives insight into the nature of the plastic. For example, plastics made via condensation polymerization, in which water is released, can degrade when exposed to water at high temperature. Polyesters such as polyethylene terephthalate (PET)

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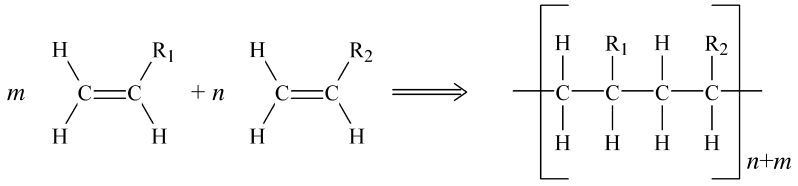


Figure 1.1 Addition polymerization.

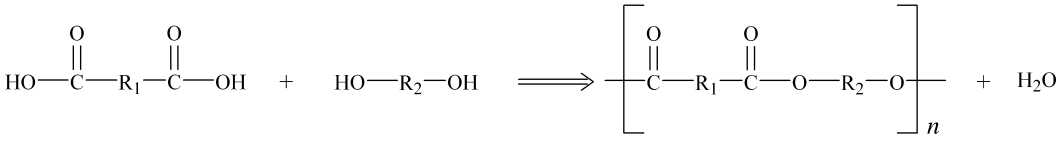


Figure 1.2 Condensation polymerization.

can degrade by a process called hydrolysis when exposed to acidic, basic, or even some neutral environments, severing the polymer chains. The polymer's properties are degraded as a result.

1.1.2 Copolymers

A copolymer is a polymer formed when two (or more) different types of monomers are linked in the same polymer chain, as opposed to a homopolymer where only one monomer is used. If exactly three monomers are used, it is called a terpolymer.

Monomers are only occasionally symmetric; the molecular arrangement is the same regardless of which end of the monomer molecule you are looking at. The arrangement of the monomers in a copolymer can be head-to-tail, head-to-head, or tail-to-tail. Since a copolymer consists of at least two types of repeating units, copolymers can be classified based on how these units are arranged along the chain. These classifications include:

- Alternating copolymer
- Random copolymer (statistical copolymer)
- Block copolymer
- Graft copolymer

In the following examples, A and B are different monomers that do not have to be present in a one-to-one ratio. When the two monomers are arranged in an alternating fashion, the polymer is called an alternating copolymer:

—A—B—A—B—A—B—A—B—A—B—A—B—A—B—A—B—A—B—

Alternating copolymer

In a random copolymer, the two monomers may link in any order:

—A —A—B—A—B—B—A—B—A—A—B—B—B—A—B—A—A—

Random copolymer

In a block copolymer, all monomers of one type are grouped together and all monomers of the other type are grouped together. A block copolymer can be thought of as two homopolymers joined together at the ends:

—A—A—A—A—A—A—A—A—A—B—B—B—B—B—B—B—B—B—

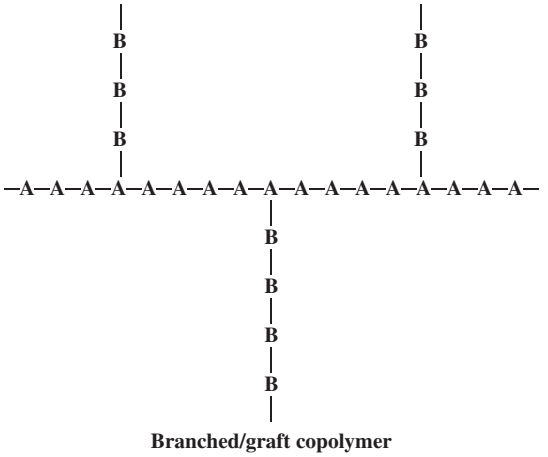
Block copolymer

A polymer that consists of large grouped blocks of each of the monomers is also considered as a block copolymer:

—A—A—A—A—A—A—B—B—B— B—B—B—A—A—A—A—A—

Block copolymer

When chains of a polymer made of monomer B are grafted onto a polymer chain of monomer A we have a graft copolymer:



Branched/graft copolymer

High-impact polystyrene (HIPS) is a graft copolymer. It is a PS backbone with chains of polybutadiene grafted onto the backbone. PS gives the material strength, but the rubbery polybutadiene chains give resilience to make it less brittle.

1.1.3 Linear, Branched, and Cross-linked Polymers

Some polymers are linear—a long chain of connected monomers. PE, PVC, Nylon 66, and polymethyl methacrylate (PMMA) are some linear commercial examples found in this book. Branched polymers can be visualized as a linear polymer with side chains of the same polymer attached to the main chain. While the branches may in turn be branched, they do not connect to another polymer chain. The ends of the branches are not connected to anything. Special types of branched polymers include star polymers, comb polymers, brush polymers, dendronized polymers [1], ladders, and dendrimers. A cross-linked polymer, sometimes called a network polymer, is one in which different chains are connected. Essentially the branches are connected to different polymer chains on the ends. These three polymer structures are shown in Figure 1.3.

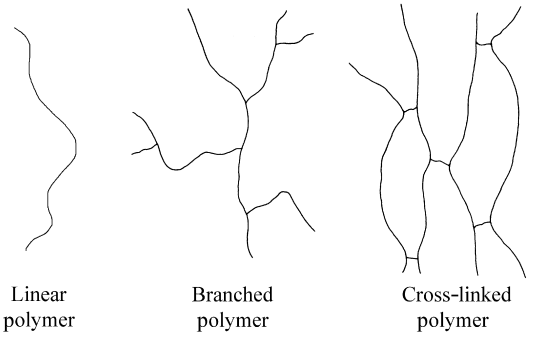


Figure 1.3 Linear, branched, and cross-linked polymers.

1.1.4 Polarity

A molecule is two or more atoms joined by a covalent bond. Basically the positively charged atom nuclei share the negatively charged electrons. However, if the atoms are different they may not share the electrons equally. The electrons will be denser around one of the atoms. This makes that end more negatively charged than the other end and that creates a negative pole and a positive pole (a *dipole*), and such a bond is said to be a *polar bond* and the molecule is polar and has a *dipole moment*. A measure of how much an atom attracts electrons is *electronegativity*. The electronegativity of common atoms in polymers follows:

$$F > O > Cl \text{ and } N > Br > C \text{ and } H$$

The polarity of a molecule affects the attraction between molecular chains, which affects the structure of the polymer and the attraction of polar molecules, so one would expect polarity to affect solubility which affects permeability.

How does one predict molecular polarity? When there are no polar bonds in a molecule, there is no permanent charge difference between one part of the molecule and another, so the molecule is nonpolar. For example, the Cl_2 molecule has no polar bonds because the electron charge is identical on both atoms. It is therefore a nonpolar molecule. The C—C and C—H bonds in hydrocarbon molecules, such as ethane, C_2H_6, are not significantly polar, so hydrocarbons are nonpolar molecular substances and hydrocarbon polymers such as PE or polypropylene (PP) are also nonpolar.

A molecule can possess polar bonds and still be nonpolar, however. If the polar bonds are evenly (or symmetrically) distributed, the bond dipoles cancel and do not create a molecular dipole. For example, the three bonds in a molecule of CCl_4 are significantly polar, but they are symmetrically arranged around the central carbon atom. No side of the molecule has more negative or positive charge than another side, and so the molecule is nonpolar. Dipole moments in some small molecules are given in Table 1.1.

Generally polar polymers are more permeable to water than nonpolar polymers. Figure 1.4 shows a qualitative ranking of some polymer polarities.

1.1.5 Unsaturation

Up to this point in the discussion of polymer chemistry, the atom to atom structure has not been discussed. The covalent bonds between atoms in a polymer can be single, double, triple bonds, or even rings. The presence of bonds higher than single bonds generally makes the polymer molecule stiffer and reduces freedom of rotation along the

Table 1.1 Dipole Moments in Some Small Molecules

Molecule	Dipole Moment	Molecule	Dipole Moment	Molecule	Dipole Moment
H_2	0	HF	1.75	CH_4	0.0
O_2	0	H_2O	1.84	CH_3Cl	1.86
N_2	0	NH_3	1.46	CCl_4	0
Cl_2	0	NF_3	0.24	CO_2	0
Br_2	0	BF_3	0		

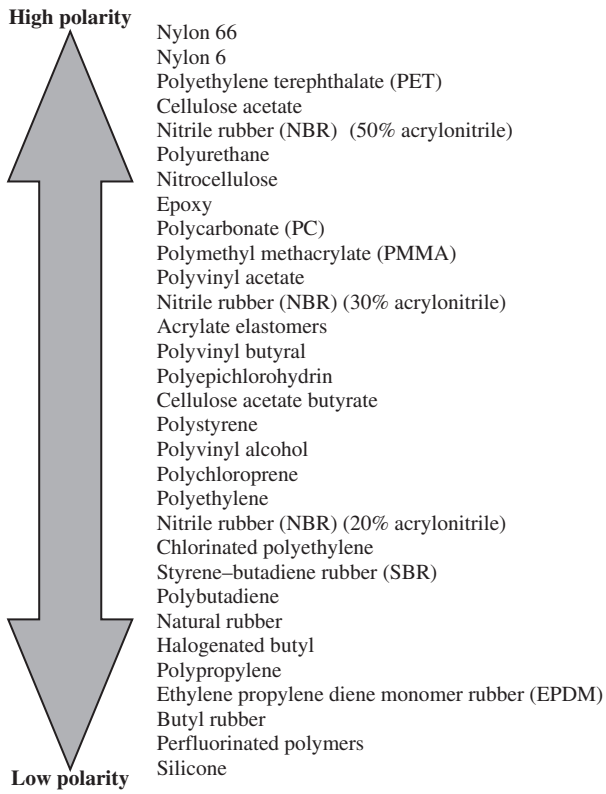


Figure 1.4 Qualitative ranking of polymer polarities.

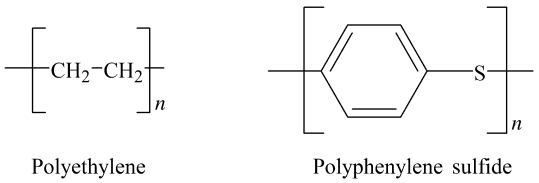


Figure 1.5 Example polymer structures.

polymer chain, and that can affect its properties. It is easier to discuss molecules first and then extend that discussion to polymers. Saturated molecules only contain single bonds with no rings.

Often when talking about molecular unsaturation, the *degree of unsaturation* (DoU) is noted. The formula to calculate DoU, if the molecular formula is given, is

$$\text{DoU} = \frac{2C + 2 + N - X - H}{2} \tag{1.1}$$

where

C, number of carbons

N, number of nitrogens

X, number of halogens (F, Cl, Br, I)

H, number of hydrogens

Oxygen and sulfur are not included in the formula because saturation is unaffected by these elements.

Examples:

$$\text{Ethylene: } C_2H_4 \quad \text{DoU} = \frac{2C + 2 + N - X - H}{2} = \frac{2 \times 2 + 2 + 0 - 0 - 4}{2} = 1 \tag{1.2}$$

$$\text{Benzene: } C_6H_6 \quad \text{DoU} = \frac{2C + 2 + N - X - H}{2} = \frac{2 \times 6 + 2 + 0 - 0 - 6}{2} = 4 \tag{1.3}$$

When polymers are used, the formula shown is often the repeating unit as shown in Figure 1.5. This will often have two bonds that are shown to which the repeating unit is supposed to attach. If applying a DoU formula to the repeating unit, one would remove the "+2" in the formula.

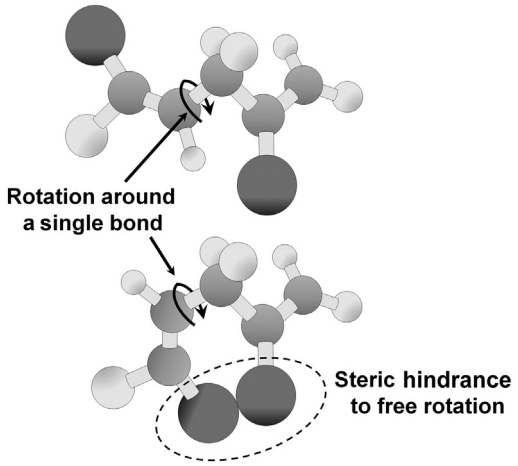


Figure 1.6 Steric hindrance shown with a ball-and-stick molecular model.

Examples:

Polyethylene: $-(CH_2-CH_2)_n-$

$$\text{DoU} = \frac{2C+N-X-H}{2} = \frac{2\times 2+0-0-4}{2} = 0 \tag{1.4}$$

Polyphenylsulfone: $-(C_6H_4-S)_n-$

$$\text{DoU} = \frac{2C+N-X-H}{2} = \frac{2\times 6+0-0-4}{2} = 4 \tag{1.5}$$

1.1.6 Steric Hindrance

As described earlier in this chapter, polymers are long chains of atoms linked together. They may be flexible and bendable. To explain this, one may visual them as ball-and-stick model. In chemistry, the ball-and-stick model is a molecular model of a chemical substance which aims to display both the three-dimensional position of the atoms and the bonds between them. The atoms are typically represented by spheres, connected by rods which represent the bonds. Double and triple bonds are usually represented by two or three curved rods, respectively. The chemical element of each atom is often indicated by the sphere's color and size. The top of Figure 1.6 shows a drawing of a ball-and-stick model of a molecule. Figure 1.6 also indicates that there is free rotation around the single bonds. If there was a double or triple bond, there would not be any rotation possible around those bonds.

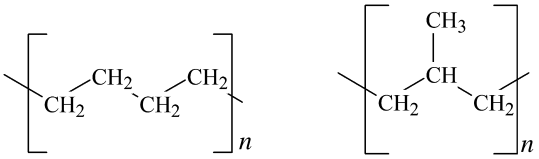


Figure 1.7 Structural isomers.

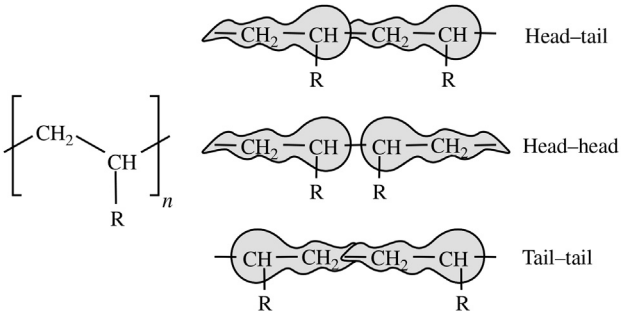


Figure 1.8 Head-to-tail isomers [8].

Similarly, ring structures, while they might flex a little bit, inhibit rotation. In some cases, such as shown in the bottom of Figure 1.6, large atoms or bulky side groups might bump into each other as the molecule rotates around single bonds. This is called *sterically hindered* or *steric hindrance*. Hindered or inhibited rotation stiffens the polymer molecule and dramatically affects its physical properties.

1.1.7 Isomers

Isomers (from Greek isomerès; isos = "equal," méros = "part") are compounds with the same molecular formula but a different arrangement of the atoms in space. There are many kinds of isomers and the properties can differ widely or almost not at all.

1.1.7.1 Structural Isomers

Structural isomers have the atoms arranged in a completely different order as shown in Figure 1.7. Here both polymer repeating groups have the same formula, $-C_4H_8-$, but the atoms are arranged differently. The properties of structural isomers may be very different from each other.

Often the repeating group in a polymer is exactly the same formula, but the repeating group is flipped over as shown in Figure 1.8. If one views the

repeating group as having a head and a tail then the different ways to connect neighboring repeating units are head–tail, head–head, and tail–tail.

1.1.7.2 Geometric Isomers

When there is a carbon–carbon double bond in a molecule, there might also be two ways to arrange the groups attached to the double bonds. This is best seen in side-by-side structures as shown in Figure 1.9.

These are called *geometric isomers* that owe their existence to hindered rotation about double bonds. If the substituents are on the same side of the double bond then the isomer is referred to as *cis*- (Latin: on this side). If the substituents are on the opposite side of the double bond then it is referred to as *trans*- (Latin: across).

1.1.7.3 Stereoisomers—Atactic, Isotactic, and Syndiotactic

Stereoisomerism occurs when two or more molecules have identical molecular formula and the same structural formula (i.e., the atoms are arranged in the same order). However, they differ in their 2D or 3D spatial arrangements of their bonds—which mean different spatial arrangement of the atoms—even though they are bonded in the same order. This may best be understood by example.

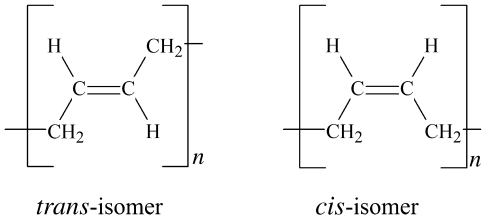


Figure 1.9 *cis*- and *trans*-isomers.

PPs all have the same simplified structural polymer formula of polypropene as shown in Figure 1.10.

However, there are subtle differences in the ways to draw this structure. Figure 1.11 shows a longer structure of polypropene and also some three-dimensional structure. This structure shows how some bonds (the dotted lines) are behind the plane of the paper and others stick out of the paper (the ones on the ends of the little triangular wedges). In this structure, some of the methyl ($-CH_3$) groups are above the paper plane and others are behind the paper plane. This is called *atactic* polypropene.

Atactic polypropene has at random about 50% of hydrogen/methyl groups in front of/behind the C–C–C chain viewing plane. This form of polypropene is amorphous (noncrystalline, discussed in Section 1.1.9.3) and has an irregular structure due to the random arrangement of the methyl groups attached to the main carbon–carbon chain. It tends to be softer and more flexible than the other forms (described below) and is used for roofing materials, sealants, and other weatherproof coatings.

Isotactic polypropene has all of the methyl groups in front of the C–C–C chain viewing plane and all of the Hs behind as shown in Figure 1.12. This stereoregular structure maximizes the molecule–molecule contact and so increases the intermolecular forces compared to the atactic form. This regular structure is much stronger (than the atactic form above) and is used in sheet and film form for packaging and carpet fibers.

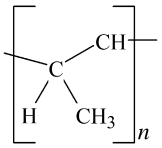


Figure 1.10 The structure of polypropene.

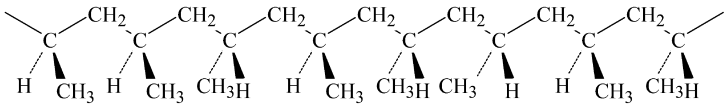


Figure 1.11 The structure of atactic polypropene.

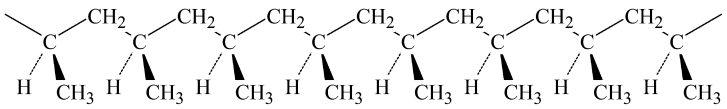


Figure 1.12 The structure of isotactic polypropene.

Syndiotactic polypropene has a regular alternation of 50% of hydrogen/methyl groups in front of/behind the —C—C—C—chain viewing plane as shown in Figure 1.13. Its properties are similar to isotactic polypropene rather than the atactic form, i.e., the regular polymer structure produces stronger intermolecular forces and a more crystalline form than the atactic polypropene.

1.1.8 Inter- and Intramolecular Attractions in Polymers

The attractive forces between different polymer chains or segments within polymer chains play a large part in determining a polymer's properties. As mentioned in Section 1.1.4, atoms can have polarity or dipole moments. Since negative charges are attracted to the opposite positive charges and repelled by like charges, it is possible to generate attractions that lead to certain structures.

1.1.8.1 Hydrogen Bonding

One of the strongest dipole interactions is the attraction of some oxygen atoms to hydrogen atoms even though they are covalently bonded to other atoms. This is called hydrogen bonding and a schematic of it is shown in Figure 1.14. The N—H bond provides a dipole when the hydrogen has a slightly positive charge and the nitrogen has a slight negative charge. The carbonyl group, C═O, likewise is a dipole, where the oxygen has the slight negative charge and the carbon is slightly positive. When polymer chains line up these *hydrogen bonds* are formed (indicated by the wide gray bars in the figure), bonds that are far weaker than the covalent bonds but bonds of significant strength nonetheless.

Other side groups on the chain polymer can lend the polymer to hydrogen bonding between its own chains. These stronger forces typically result in higher tensile strength and higher crystalline melting points. Polyesters have dipole—dipole bonding between the oxygen atoms in C═O groups and the hydrogen atoms in H—C groups. Dipole bonding is not as strong as hydrogen bonding.

1.1.8.2 Van der Waals Forces

Many polymers, such as PE, have no permanent dipole. However, attractive forces between PE chains arise from weak forces called van der Waals forces. Van der Waals forces are much weaker than chemical bonds, and random thermal motion around room temperature can usually overcome or disrupt them.

Molecules can be thought of as being surrounded by a cloud of negative electrons. But the electrons are mobile, and at any one instant they might find

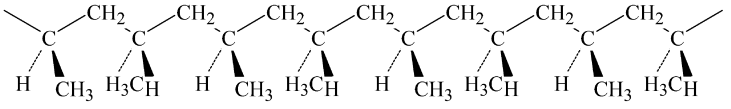


Figure 1.13 The structure of syndiotactic polypropene.

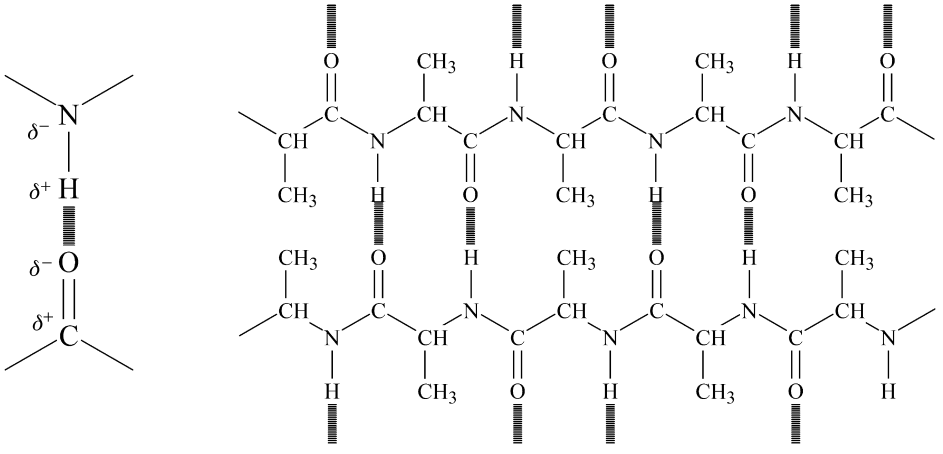


Figure 1.14 Schematic of hydrogen bonding in a pair of polymer chains.

themselves toward one end of the molecule, making that end slightly negative (δ^-). The opposite end of the molecule will be momentarily short of electrons and so becomes δ^+. Basically, temporary fluctuating dipoles are present in all molecules and the forces due to these dipoles are the basis for van der Waals attraction. Van der Waals forces are quite weak; however, PE can have a lower melting temperature compared to other polymers that have hydrogen bonding.

1.1.8.3 Chain Entanglement

Polymer molecules are long chains, which can become entangled with one another, much like a bowl of spaghetti. Along with intermolecular forces, chain entanglement is an important factor contributing to the physical properties of polymers. The difficulty in untangling their chains makes polymers and the plastic made from them strong and resilient.

1.1.9 General Classifications

Besides the chemical structures of the polymers in the plastics, there are several other characterizations that are important, including molecular weight, thermoplastics vs. thermosets, and crystallinity.

1.1.9.1 Molecular Weight

A polymer's molecular weight is the sum of the atomic weights of the individual atoms that comprise a molecule. It indicates the *average* length of the bulk resin's polymer chains. All polymer molecules of a particular grade do not have the exact same molecular weight. There is a range or distribution of molecular weights. There are two important but different ways to calculate molecular weight. The most important one is called the number average molecular weight, M_n. For all "i" molecules in a sample, the number average molecular weight is calculated using Equation 1.6:

$$M_n = \frac{\sum_i N_i M_i}{\sum_i N_i} \tag{1.6}$$

where

i is the number of polymer molecules

N_i is the number of molecules that have the molecular weight M_i.

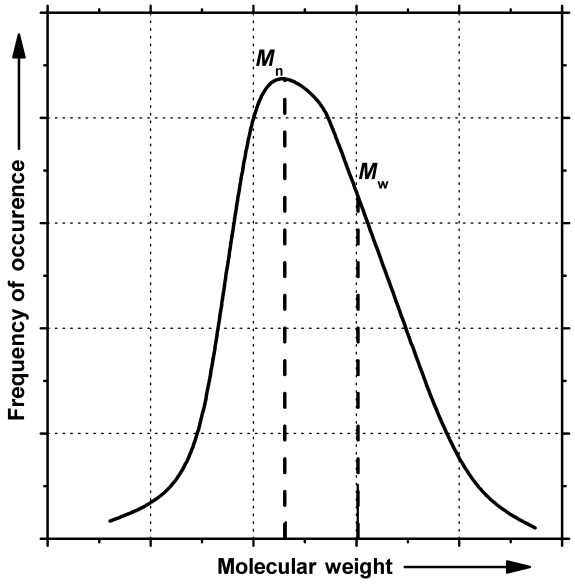


Figure 1.15 Hypothetical molecular weight distribution plot showing number and weight average molecular weights.

The weight average molecular weight is a different calculation as in Equation 1.7:

$$M_w = \frac{\sum_i N_i M_i^2}{\sum_i N_i M_i} \tag{1.7}$$

Figure 1.15 shows a molecular weight distribution chart with the two different molecular weight measures noted on it. The ratio M_w/M_n is called the *molar mass dispersity index* [2] (often called *polydispersity index* (PDI)) [3]. If all the polymer chains are exactly the same, then the number average and weight average molecular weights are exactly the same and the PDI is "1." The larger the molar mass dispersity index the wider the molecular weight distribution. The molecular weight range can affect many properties of plastic materials.

Another common means of expressing the length of a polymer chain is the *degree of polymerization*, which quantifies the average number of monomers incorporated into the polymer chain. The average molecular weight can be determined by several means, but this subject is beyond the scope of this book. Low molecular weight PE chains have backbones as small as 1000 carbon atoms long. Ultrahigh molecular weight (UHMW) PE chains

can have 500,000 carbon atoms along their length. Many plastics are available in a variety of chain lengths or different molecular weight grades. These resins can also be classified indirectly by a viscosity value rather than molecular weight. Within a resin family, such as polycarbonate (PC), higher molecular weight grades have higher melt viscosities (see Chapter 3). For example, in the viscosity test for PC, the melt flow rate ranges from approximately 4 g/10 min for the highest molecular weight, standard grades to more than 60 g/10 min for the lowest molecular weight, high flow, specialty grades.

Selecting the correct molecular weight for your injection molding application generally involves a balance between filling ease and material performance. If your application has thin walled sections, a lower molecular weight/lower viscosity grade offers better flow. For normal wall thicknesses, these resins also offer faster mold cycle times and fewer molded-in stresses. The stiffer flowing, high molecular weight resins offer the ultimate material performance, being tougher and more resistant to chemical and environmental attacks.

The molecular weight of the polymers that are used in engineering plastics affects many of the plastics' properties. While it is not always known exactly what the molecular weights are, as mentioned above higher flowing plastics of a given series of products generally are lower molecular weight polymers.

1.1.9.2 Thermosets vs. Thermoplastics

A plastic or elastomer falls into one of two broad categories depending on its response to heat: thermoplastics or thermosets. Thermoplastics soften and melt when heated and harden when cooled. Because of this behavior, these resins can be injection molded, extruded, or formed via other molding techniques. This behavior also allows production scrap runners and trimmings to be reground and reused. Thermoplastics can often be recycled.

Unlike thermoplastics, thermosets react chemically to form cross-links, as described earlier, which limit chain movement. This network of polymer chains tends to degrade, rather than soften, when exposed to excessive heat. Until recently, thermosets could not be remelted and reused after initial curing. Recent advances in recycling have provided new methods for remelting and reusing thermoset materials.

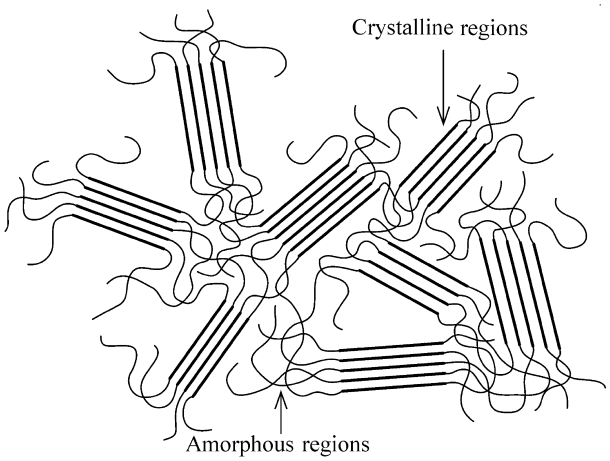


Figure 1.16 Many plastics have crystalline and amorphous regions.

1.1.9.3 Crystalline vs. Amorphous

Thermoplastics are further classified by their crystallinity or the degree of order within the polymer's overall structure. As a crystalline resin cools from the melt, polymer chains fold or align into highly ordered crystalline structures as shown in Figure 1.16.

Some plastics can be completely amorphous or crystalline. Often a plastic's specification will report what percent of it is crystalline as a percent (e.g., 73% crystallinity). Generally, polymer chains with bulky side groups cannot form crystalline regions. The degree of crystallinity depends upon both the polymer and the processing technique. Some polymers such as PE crystallize quickly and reach high levels of crystallinity. Others, such as PET polyester, require slow cooling to crystallize. If cooled quickly, PET polyester remains amorphous in the final product.

Crystalline and amorphous plastics have several characteristic differences. Amorphous polymers do not have a sharp melting point, but do have what is called the glass transition temperature (T_g). The glass transition temperature is discussed in more detail later in this chapter. The glass transition temperature is the temperature at which a polymer changes from hard and brittle to soft and pliable. The force to generate flow in amorphous materials diminishes slowly as the temperature rises above the glass transition temperature. In crystalline resins, the force requirements diminish quickly as the material is heated above its crystalline melt temperature. Because of these easier flow characteristics, crystalline resins

have an advantage in filling thin walled sections of a mold. Crystalline resins generally have superior chemical resistance, greater stability at elevated temperatures, and better creep resistance. Amorphous plastics typically have better impact strength, less mold shrinkage, and less final part warping than crystalline materials. Higher crystallinity usually leads to lower permeation rates. End-use requirements usually dictate whether an amorphous or crystalline resin is preferred.

1.2 Plastic Compositions

Plastics are usually formulated products, meaning that they are not always neat polymers. They may be blends of polymers and they may have many additives used to tailor performance properties.

Polymers can often be blended. Occasionally, blended polymers have properties that exceed those of either of the constituents. For instance, blends of PC resin and PET polyester, originally created to improve the chemical resistance of PC, actually have fatigue resistance and low temperature impact resistance superior to either of the individual polymers.

Sometimes a material is needed that has some of the properties of one polymer and some of the properties of another. Instead of going back into the laboratory and trying to synthesize a brand new polymer with all the properties wanted, two polymers can be melted together to form a blend, which will hopefully have some properties of both.

Two polymers that do actually mix well are PS and polyphenylene oxide (PPO). Two other examples of polymer pairs that will blend are:

- PET with polybutylene terephthalate
- PMMA with poly(vinylidene fluoride) (PVDF)

Phase-separated mixtures are obtained when one tries to mix most polymers. But strangely enough, the phase-separated materials often turn out to be rather useful. They are called immiscible blends.

PS and polybutadiene are immiscible. When PS is mixed with a small amount of polybutadiene, the two polymers do not blend. The polybutadiene separates from the PS into little spherical blobs. If this mixture is viewed under a high-power microscope, something that looks like the picture in Figure 1.17 would be seen.

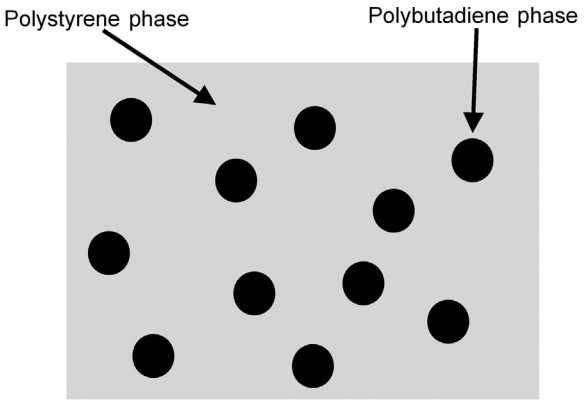


Figure 1.17 Immiscible blend of PS and polybutadiene.

Multiphase polymer blends are of major economic importance in the polymer industry. The most common examples involve the impact modification of a thermoplastic by the microdispersion of a rubber into a brittle polymer matrix. Most commercial blends consist of two polymers combined with small amounts of a third, compatibilizing polymer, typically a block or graft copolymer.

Multiphase polymer blends can be easier to process than a single polymer with similar properties. The possible blends from a given set of polymers offer many more physical properties than do the individual polymers. This approach has shown some success but becomes cumbersome when more than a few components are involved.

Blending two or more polymers offers yet another method of tailoring resins to a specific application. Because blends are only physical mixtures, the resulting polymer usually has physical and mechanical properties that lie somewhere between the values of its constituent materials. For instance, an automotive bumper made from a blend of PC resin and thermoplastic polyurethane elastomer gains rigidity from the PC resin and retains most of the flexibility and paintability of the polyurethane elastomer. For business machine housings, a blend of PC and ABS (acrylonitrile−butadiene−styrene copolymer) resins offers the enhanced performance of PC flame retardance and ultraviolet (UV) stability at a lower cost.

Additional information on the subject of polymer blends is available in the literature [3−5].

The properties of neat polymers are often not ideal for production or the end use. When this is the case, materials are added to the polymer to improve the performance shortfall. The additives

can improve the processing and performance of the plastic. For whatever reason the additive is used, it can affect the permeation, diffusion, and solubility properties.

Additives encompass a wide range of substances that aid processing or add value to the final product [6,7]. Found in virtually all plastics, most additives are incorporated into a resin family by the supplier as part of a proprietary package. For example, you can choose standard PC resin grades with additives for improved internal mold release, UV stabilization, and flame retardance, or nylon grades with additives to improve impact performance.

Additives often determine the success or failure of a resin or system in a particular application. Many common additives are discussed in the following sections. Except for reinforcement fillers, most additives are added in very small amounts.

1.2.1 Fillers, Reinforcement, Composites

Reinforcing fillers can be added in large amounts. Some plastics may contain as much as 60% reinforcing fillers. Often, fibrous materials, such as glass or carbon fibers, are added to resins to create reinforced grades with enhanced properties. For example, adding 30% short glass fibers by weight to Nylon 6 improves creep resistance and increases stiffness by 300%. These glass-reinforced plastics usually suffer some loss of impact strength and ultimate elongation and are more prone to warping because of the relatively large difference in mold shrinkage between the flow and cross flow directions.

Plastics with nonfibrous fillers, such as glass spheres or mineral powders, generally exhibit higher stiffness characteristics than unfilled resins, but not as high as fiber-reinforced grades. Resins with particulate fillers are less likely to warp and show a decrease in mold shrinkage. Particulate fillers typically reduce shrinkage by a percentage roughly equal to the volume percentage of filler in the polymer, an advantage in tight tolerance molding.

Often reinforced plastics are called *composites*. Often, the plastic material containing the reinforcement is referred to as the matrix. One can envision a number of ways how different reinforcing materials might be arranged in a composite. Many of these arrangements are shown in Figure 1.18.

Particulates, in the form of pigments, to impart color may be added. On occasion particulate, called extender, is added to reduce the amount of relatively expensive polymer used which reduces overall cost.

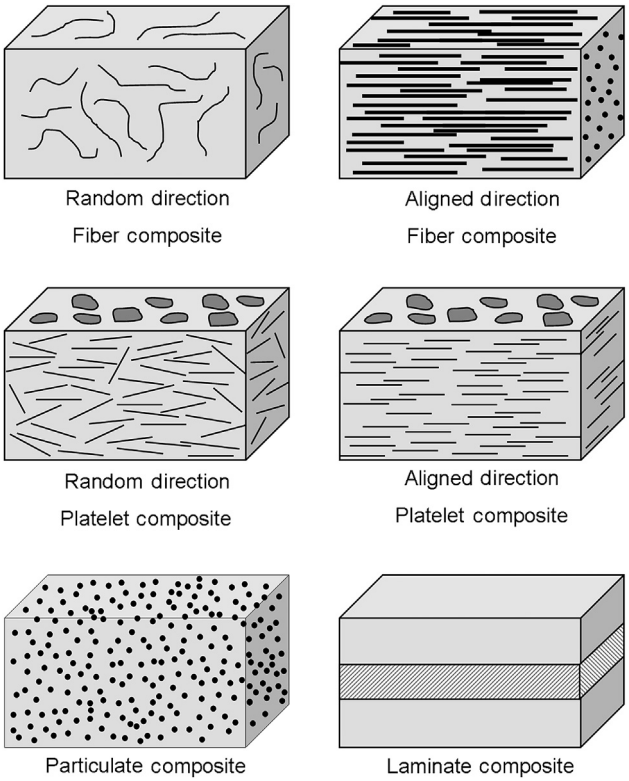


Figure 1.18 Several types of composite materials.

Platelet additives may impart color and luster, metallic appearance, or a pearlescent effect and also can strongly affect permeation properties. Most of these additives have little or no permeation through them, so when a film contains particulate additives, the permeating molecule must follow a path around the particulate additive as shown in Figure 1.19. This is often called a *tortuous path effect*.

1.2.2 Combustion Modifiers, Fire, Flame Retardants, and Smoke Suppressants

Combustion modifiers are added to polymers to help retard the resulting parts from burning. Generally required for electrical and medical housing applications, combustion modifiers and their amounts vary with the inherent flammability of the base polymer. Polymers designed for these applications often are rated using an Underwriters Laboratories (UL) rating system. Use these ratings

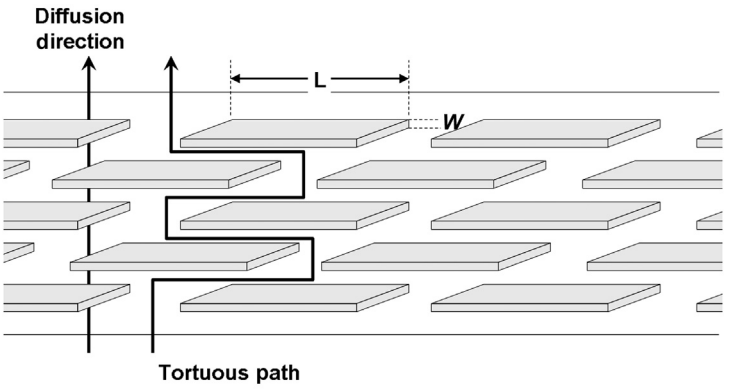


Figure 1.19 Tortuous path of permeant molecule through a platelet particulate-containing film.

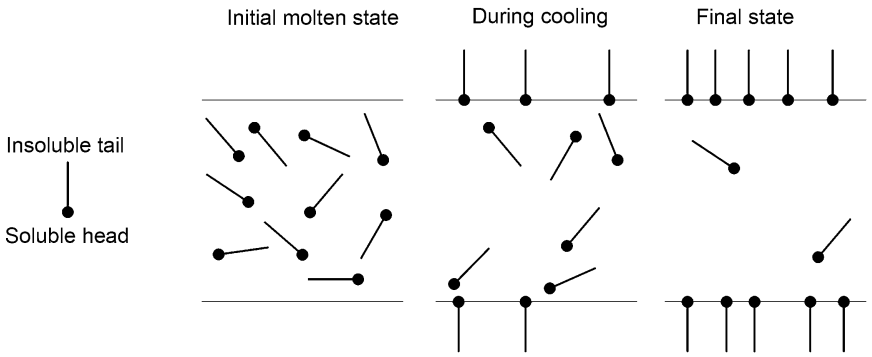


Figure 1.20 Mode of action of a typical migrating slip additive.

for comparison purposes only, as they may not accurately represent the hazard present under actual fire conditions.

1.2.3 Release Agents

External release agents are lubricants, liquids, or powders, which coat a mold cavity to facilitate part removal. Internal release agents can accomplish the same purpose. The identity of the release agent is rarely disclosed, but frequently they are fine fluoropolymer powders called micropowders, silicone resins, or waxes.

1.2.4 Slip Additives/Internal Lubricants

When plastics (particularly films) slide over each other, there is a resistance that is quantified in terms of the coefficient of friction (COF). Films with a high COF tend to stick together instead of sliding over one another. Sticking makes the handling, use, and conversion of films difficult. To overcome sticking, slip agents are added.

Slip additives can be divided into migrating and nonmigrating types. Migrating slip additives are the most common class and they are used above their solubility limit in the polymer. These types of additives are molecules that have two distinct parts, typically pictured as a head and tail as shown in Figure 1.8. One part of the molecule, usually the head, is designed to be soluble in the polymer (particularly when it is molten during processing) making up the plastic. The other part, the tail, is insoluble. As the plastic cools and solidifies from its molten state, these molecules migrate to the surface where the insoluble end "sticks up" reducing the COF. This process is shown in Figure 1.20. These additives are typically fatty acid amides.

There are migrating slip additives that are not of this two part structure. One additive is perfluoropolyether (PFPE) synthetic oil marketed by DuPont under the trademark Fluoroguard®, which is an internal lubricant that imparts improved wear and

low friction properties. Silicone fluids, such as those made by Dow Corning, can also act as a boundary lubricant. Both of these materials may migrate to the surface of the plastic over time.

Some common nonmigrating slip additives include:

- PTFE (polytetrafluoroethylene) in micropowder form imparts the lowest COF of any internal lubricant. Manufacturers and suppliers are many and include DuPont Zonyl®, and 3M Dyneon™.
- Molybdenum disulfide, commonly called "moly," is a solid lubricant often used in bearing applications.
- Graphite is a solid lubricant used like molybdenum disulfide.

1.2.5 Antiblock Additives

Blocking is a surface effect between adjacent film layers that stick to one another. Blocking is quantified by the force needed to separate two film layers under controlled conditions. Two situations where blocking is an issue are the opening of blown film tubes after extrusion and film layer separation after packing and storage. Antiblock additives are used to overcome these issues.

Antiblock additives can be divided into two classes: inorganic and organic. Chemically inert, inorganic antiblock additives migrate to the film surface and partially stick out of the surface to create a microroughness of the film surface. Figure 1.21 illustrates this principle.

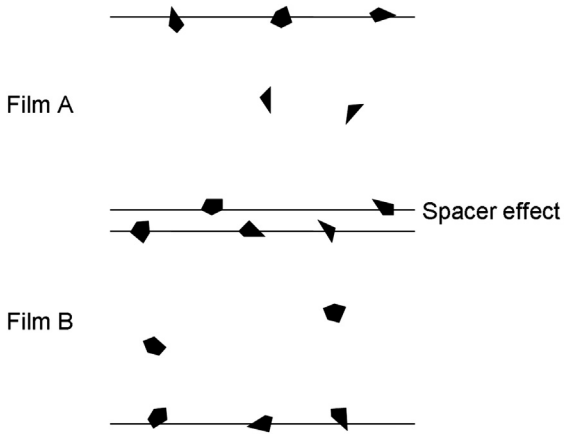


Figure 1.21 Antiblock additives maintain film separation.

The detailed mechanism of how organic antiblock additives work is not yet understood. It is thought that a barrier layer is formed on the plastic film surface, thus inhibiting the two adjacent plastic film layers' adhesion. Their usage is limited. Organic antiblock additives were partially discussed above and will not be further mentioned here.

1.2.6 Catalysts

Catalysts, substances that initiate or change the rate of a chemical reaction, do not undergo a permanent change in composition or become part of the molecular structure of the final product. Occasionally used to describe a setting agent, hardener, curing agent, promoter, etc., they are added in minute quantities, typically <1%.

1.2.7 Impact Modifiers and Tougheners

Many plastics do not have sufficient impact resistance for the use for which they are intended. Rather than changing to a different type of plastic, they can be impact modified in order to fulfill the performance in use requirements. Addition of modifiers called impact modifiers or tougheners can significantly improve impact resistance. These are one of the most important additives. There are many suppliers and chemical types of these modifiers.

General-purpose impact modification is a very low level of impact modification. It improves room temperature impact strength but does not take into account any requirements for low temperature (below 0°C) impact strength. For most of these types of applications, only low levels of impact modifier will be required (<10%).

Low temperature impact strength is required for applications that require a certain level of low temperature flexibility and resistance to break. This is for example the case for many applications in the appliance area. For this purpose, modifier levels between 5 and 15% of mostly reactive modifiers will be necessary. Reactive modifiers can bond chemically to the base polymer.

Super-tough impact strength may be required for applications that should not lead to a failure of the part even if hit at low temperatures (−30 to −40°C) under high speed. This requirement can only be fulfilled with high levels (20−25%) of reactive impact modifier with a low glass transition temperature.

1.2.8 UV/Radiation Stabilizers

Sunshine and its UV radiation have a deteriorating effect on many polymers. UV stabilizers play an important role in plastics for external uses by counteracting the effects of the sun. UV stabilizers are used in plastic items such as greenhouse film, outdoor furniture, and automotive plastic parts. The amounts added are very small and generally $<1\%$.

1.2.9 Optical Brighteners

Many polymers have a slight yellowish color. They can be modified to appear whiter and brighter by increasing reflected bluish light (in the range of 400−600 nm). One way to accomplish this is by using an additive that absorbs in the UV range but re-emits the energy at higher wavelength. This effect is called fluorescence and these types of additives are called optical brighteners or fluorescent whitening agents.

1.2.10 Plasticizers

Plasticizers are added to help maintain flexibility in a plastic. Various phthalates are commonly used for this purpose. Since they are small molecules they may extract or leach out of the plastic causing a loss of flexibility with time. Just as deliberately added, small molecules may leach out, small molecules from the environment may be absorbed by the plastic and act like a plasticizer. The absorption of water by nylons (polyamides) is an example. Plasticizers increase the space between the polymers.

1.2.11 Pigments, Extenders, Dyes, and Mica

Pigments are added to give a plastic color, but they may also affect the physical properties. Extenders are usually cheap materials added to reduce the cost of a plastic resin. Dyes are colorants chemically different than pigments. Mica is a special pigment added to impact sparkle or metallic appearance. Titanium dioxide (TiO_2) and carbon black are two important pigments that merit further discussion.

1.2.11.1 Titanium Dioxide

TiO_2 is one of the most important pigments. It is widely used because it efficiently scatters visible light and absorbs UV light, thereby imparting whiteness, brightness, and opacity when incorporated into a plastic. TiO_2 is commercially available in two crystal structures—anatase and rutile. Rutile TiO_2 pigments are preferred because they scatter light more efficiently, are more stable, and are more durable than anatase pigments. Chalk resistance, retention of color (tinted paints) and gloss, and resistance to discoloration by mildew and dirt collection can be influenced by TiO_2 grade selection.

Few, if any, commercial grades of TiO_2 are pure TiO_2. Most have inorganic and, in some cases, organic treatments deposited on the surfaces of the TiO_2 particles by precipitation, mechanical blending, or via other routes. Unlike colored pigments that primarily provide opacity by absorbing visible light, TiO_2 and other white pigments also provide opacity by scattering light.

1.2.11.2 Carbon Black

Carbon black describes a group of industrial carbons created through the partial combustion or the thermal decomposition of hydrocarbons. Carbon black is unique in that it possesses the smallest particle size and highest oil absorption among the commercially available pigments for plastics. These characteristics lead to carbon black's excellent color strength, cost-effectiveness, and UV performance and place it as the most widely used black pigment for thermoplastic applications.

1.2.12 Coupling Agents

The purpose of adding fillers is either to lower the cost of the polymer, make it tougher or stiffer, or make it flame retardant so that it does not burn when it is ignited. Often the addition of the fillers will reduce the elongation at break, the flexibility, and in many cases the toughness of the polymer because they are added at very high levels. One reason for the degradation of properties is that the fillers in most cases are not compatible with the polymers. The addition of coupling agents can improve the compatibility of the filler with the polymer. As a result, the polymer will like the filler more, the filler will adhere better to the polymer matrix, and the properties of the final mixture (e.g., elongation, flexibility) will be enhanced.

1.2.13 Thermal Stabilizers

One of the limiting factors in the use of plastics at high temperatures is their tendency to not only

become softer but also thermally degrade. Thermal degradation can present an upper limit to the service temperature of plastics. Thermal degradation can occur at temperatures much lower than those at which mechanical failure is likely to occur. Plastics can be protected from thermal degradation by incorporating stabilizers into them. Thermal stabilizers are discussed in detail in Chapter 2.

1.2.14 Antistats

Antistatic additives are capable of modifying properties of plastics in such a way that they become antistatic, conductive, and/or improve electromagnetic interference shielding (EMI). Carbon fibers, conductive carbon powders, and other electrically conductive materials are used for this purpose.

When two (organic) substrates rub against each other electrostatic charges can build up. This is known as tribocharging. Electrostatic charges can impact plastic parts in several ways, one of the most annoying being the attraction of dust particles. One way to counter this effect is to use antistats (or antistatic additives). This effect is principally a surface effect, although one potential countermeasure (conductive fillers) converts it into a bulk effect.

Tools that decrease electrostatic charges and hence increase the conductivity of an organic substrate can be classified as follows:

- External antistat (surface effect)
- Conductive filler (bulk and surface effect)
- Internal antistat (surface effect)

An external antistat is applied via a carrier medium to the surface of the plastic part. The same considerations and limitations apply as with non-migrating slip additives. Conductive filler is incorporated into the organic substrates and builds up a conductive network on a molecular level. While both approaches are used in organic substrates, they are not the most common.

An internal antistat is compounded into the organic substrate and migrates to the plastic part surface. The same principle considerations apply as for migrating slip additives (Figure 1.19).

The need to protect sensitive electronic components and computer boards from electrostatic discharge during handling, shipping, and assembly provided the driving force for development of a different class of antistatic packaging materials. These are sophisticated laminates with very thin metalized films.

There are other additives used in plastics, but the ones discussed above are the most common.

1.3 Testing of Plastics

The bulk of this book contains tables and plots of the change of various properties of plastics as a function of temperature, strain, humidity, frequency, etc. The following sections of this chapter will summarize the standard tests. Details on some of the more common test methods are described in following sections.

Standard plastics tests are generally specified primarily by two standard organizations. ASTM International, originally known as the American Society for Testing and Materials (ASTM), is one organization; its standards are the well-known ASTM standards. The second organization is the International Organization for Standardization, abbreviated as ISO, that is also well known. These organizations do not specify just plastics tests, but they both develop technical standards in whatever fields need them. They are both well accepted, but unfortunately they do not always agree exactly. While there is often one-to-one correlation of ASTM and ISO standards, they may differ in procedure and conditions, which may lead to slightly different measures. For example, tensile modulus can be measured by ASTM D638 or ISO 527-1. While reported values are similar, they are rarely exactly the same. These standard tests are listed in Tables 1.2–1.7.

Many plastic families have their own ASTM and ISO guidelines for testing. These guidelines provide standard testing procedures including sample preparation and often define the subclassification of the plastic products. Some of these standards are given in Table 1.8.

1.3.1 Mechanical Property Testing of Plastics

Plastic and polymer mechanical tests include tensile, tear, shear, flexural, impact, and compression tests. These are summarized in the following sections.

Table 1.2 Standard Mechanical Tests

Measurement	ASTM	ISO
Apparent bending modulus	ASTM D747	–
Coefficient of friction	ASTM D1894	–
Compressive modulus	ASTM D695	ISO 604
Compressive strength	ASTM D695	ISO 604
Deformation under load	ASTM D621	–
Flexural creep	ASTM D2990	–
Flexural creep modulus	–	ISO 6602
Flexural modulus	ASTM D790	ISO 178
Flexural strength	ASTM D790	ISO 178
Flexural strength at break	ASTM D790	–
Flexural strength at yield	ASTM D790	–
Nominal tensile strain at break	–	ISO 527-1, -2
Poisson's ratio	ASTM E132	–
Shear modulus	ASTM D732	–
Shear strength	ASTM D732	–
Tensile creep modulus	–	ISO 527-1, -2
Tensile elongation at break	ASTM D638	ISO 527-1, -2
Tensile elongation at yield	ASTM D638	ISO 527-1, -2
Tensile modulus	ASTM D638	ISO 527-1, -2
Tensile strength	ASTM D638	–
Tensile strength at break	ASTM D638	ISO 527-1, -2
Tensile strength at yield	ASTM D638	ISO 527-1, -2
Tensile strength, ultimate	ASTM D638	ISO 527-1, -2

1.3.1.1 Tensile Properties

Tensile testing is performed by elongating a specimen and measuring the load carried by the specimen. This is done using a test machine known as an Instron® Universal Materials Testing Machine. From knowledge of the specimen dimensions, the load and deflection data can be translated into a stress–strain curve. A variety of tensile properties can be extracted from the stress–strain curve. The standard tests are summarized as follows:

- ASTM D638-03 Standard Test Method for Tensile Properties of Plastics
- ISO 527-1:1993 Plastics—Determination of tensile properties—Part 1: General principles
- ISO 527-2:1993 Plastics—Determination of tensile properties—Part 2: Test conditions for moulding and extrusion plastics
- ISO 37 Rubber, vulcanized or thermoplastic—Determination of tensile stress–strain properties
- ASTM D412-98a(2002)e1 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

Figure 1.22 shows a picture of an Instron® Universal Materials Testing Machine and a diagram of the test plaque and details of the test configuration. The instrument can provide a stress vs. strain curve such as that shown in Figure 1.23. Analysis of this curve leads to several useful mechanical measurements.

Table 1.3 Standard Elastomer Tests

Measurement	ASTM	ISO
Compression set	ASTM D395	ISO 37
Elongation at break	ASTM D412	–
Elongation at yield	ASTM D412	–
Elongation set after break	ASTM D412	–
Tear strength	ASTM D624	ISO 34-1
Tear strength, split	ASTM D412	–
Tensile set	ASTM D412	–
Tensile strength at break	ASTM D412	ISO 37
Tensile strength at yield	ASTM D412	ISO 37
Tensile stress at 100%	ASTM D412	ISO 37
Tensile stress at 200%	ASTM D412	ISO 37
Tensile stress at 300%	ASTM D412	ISO 37
Tensile stress at 50%	ASTM D412	–

Table 1.4 Standard Impact Tests

Measurement	ASTM	ISO
Charpy notched impact strength	ASTM D256	ISO 179
Charpy unnotched impact strength	–	ISO 179
Drop impact resistance	ASTM D4226	–
Gardner impact	ASTM D5420 & ASTM D5628	–
Instrumented dart impact	ASTM D3763	–
Multi-axial instrumented impact energy	–	ISO 6603-2 MAII
Multi-axial instrumented impact peak force	–	ISO 6603-2 MAII
Notched Izod impact strength	ASTM D256	ISO 180
Reverse notch Izod impact strength	ASTM D256	–
Tensile impact strength	ASTM D1822	ISO 8256
Unnotched Izod impact strength	ASTM D256	ISO 180

Table 1.5 Standard Hardness Tests

Measurement	ASTM	ISO
Ball indentation hardness	–	ISO 2039-1
Durometer (shore) hardness	ASTM D2240	ISO 868
Rockwell hardness	ASTM D785	ISO 2039-2

Table 1.6 Standard Electrical Tests

Electrical	ASTM	ISO
Dielectric constant	ASTM D150	IEC 60250
Dielectric strength	ASTM D149	IEC 60243-1
Dissipation factor	ASTM D150	IEC 60250
Surface resistivity	ASTM D257	IEC 60093
Volume resistivity	ASTM D257	IEC 60093

Table 1.7 Standard Thermal Tests

Thermal	ASTM	ISO
Brittleness temperature	ASTM D746	ISO 812 & ISO 974
Coefficient of linear thermal expansion (CLTE)	ASTM D696 & ASTM E831	ISO 11359-1, -2
HDT (heat deflection temperature) at 8.0 MPa	–	ISO 75 Method C
HDT at 1.80 MPa	ASTM D648	ISO 75 Method A
HDT at 0.45 MPa	ASTM D648	ISO 75 Method B
Ductile/brittle transition temperature	–	ISO 6603-2 Ductile Brittle
Glass transition temperature	ASTM E1356	–
Melting temperature (DSC)	–	ISO 3146
Specific heat	ASTM C351	–
Thermal conductivity	ASTM C177	ISO 8302
Vicat softening temperature	ASTM D1525	ISO 306
Melt flow rate/melt flow index	ASTM D1238	ISO 1133

The points on the curve of Figure 1.23 are described as follows:

- "A" is the "Proportional Limit" which is the end of the region in which the resin exhibits linear stress–strain behavior
- "B" is the "Elastic Limit" after which the part is permanently deformed when the strain is removed
- "C" is the "Yield Point" after which the material will deform without a further increase in strain
- "D" is the "Ultimate Strength" which is the maximum stress on the curve
- "E" is the "Breakpoint"

Table 1.9 shows how some of the tensile measurements are made from the stress vs. strain curve in Figure 1.23.

Most plastics when tested will show one of four basic types of stress vs. strain behavior. These are shown in Figure 1.24. The slopes of the curves and the actual measures of stress and strain may differ, but as the reader views the multipoint curves in the subsequent chapters of this book, he will recognize these forms. Table 1.10 lists several plastics that fit each of these behavior types.

1.3.1.2 Compressive Properties

Compressive testing is similar to tensile testing except the strain is applied in the opposite direction. This is also done on an Instron® Universal Materials Testing Machine. From knowledge of the specimen dimensions, the load and deflection data can be translated into a stress–strain curve. A variety of compressive properties can be extracted from

Table 1.8 ISO and ASTM Standards for Common Polymer Families

Polymer Family	ISO Standards[a]	ASTM Standards
Acrylonitrile–butadiene–styrene (ABS) resin	DIS 2580-1&2: 2003	D4673-02
Styrene–acrylonitrile (SAN) resin	4894-1&2: 1997	D4203-07
Polystyrene (PS)	1622-1&2: 1994	D4549-03
Polystyrene, impact (PS-I)	2897-1&2: 2003	D4549-03
Polypropylene (PP)	1873-1&2: 1997	D4101-06b D5857-05a
Polyethylene (PE)	1872-1&2: 2007	D4976-06
Polyvinyl chloride, plasticized (PVC-P)	2898-1&2: 1997	D2287-96
Polyvinyl chloride, unplasticized (PVC-U)	1163-1&2: 1995	D1784-06a
Polymethyl methacrylate (PMMA)	8257-1&2: 2001	D788-06
Polycarbonate (PC)	7391-1&2: 2006	D3935-02
Acetals (POM)	9988-1&2: 2006	D6778-06
Polyamides (PA)	1874-1&2: 2006	D4066-01a
Thermoplastic polyester	7792-1&2: 1997	D5927-03
Polyketone (PK)	15526-1&2: 2000	D5990-00
Polyphenylether (PPE, PPO)	15103-1&2: 2000	D4349-96
Thermoplastic polyester elastomer	14910-1&2: 1997	D6835-02
Ethylene–chlorotrifluoroethylene copolymer (ECTFE)		D3275-06
Polyvinylidene fluoride (PVDF)		D3222-05
Polytetrafluoroethylene (PTFE)		D4894-04
Ethylene–tetrafluoroethylene copolymer (ETFE)		D3159-06
Perfluoroalkoxyalkane (PFA)		D3307-06
Tetrafluoroethylene–hexafluoropropylene copolymer (FEP)		D2116-02

[a]*Part 1 of each ISO material standard addresses the "designatory properties" and Part 2 describes specific tests, test specimens, and test conditions.*

the compressive stress–strain curve. The standard test is

- ASTM D695-02a Standard Test Method for Compressive Properties of Rigid Plastics

1.3.1.3 Shear Properties

Measurement of properties under shear conditions is described in the standard:

- ASTM D732-02 Standard Test Method for Shear Strength of Plastics by Punch Tool

The primary measures are shear strength and shear modulus. Shear strength is the maximum load required to completely shear a specimen divided by the sheared area. Shear modulus is the ratio of shear stress to shear strain.

These tests are often done in an Instron® Universal Materials Testing Machine. The sample is typically molded sheet that has been cut into a disk. A diagram of the apparatus used is shown in Figure 1.25.

The test specimen, disk or plaque, is placed in a clamp such that its upper and lower surfaces are securely supported. Specimen thickness should be between 0.127 and 12.7 mm (0.005 and 0.5 in.). A punch-type shear tool with a 25.4 mm (1 in.) diameter is bolted to the specimen through a hole drilled in the center and a load is applied to the

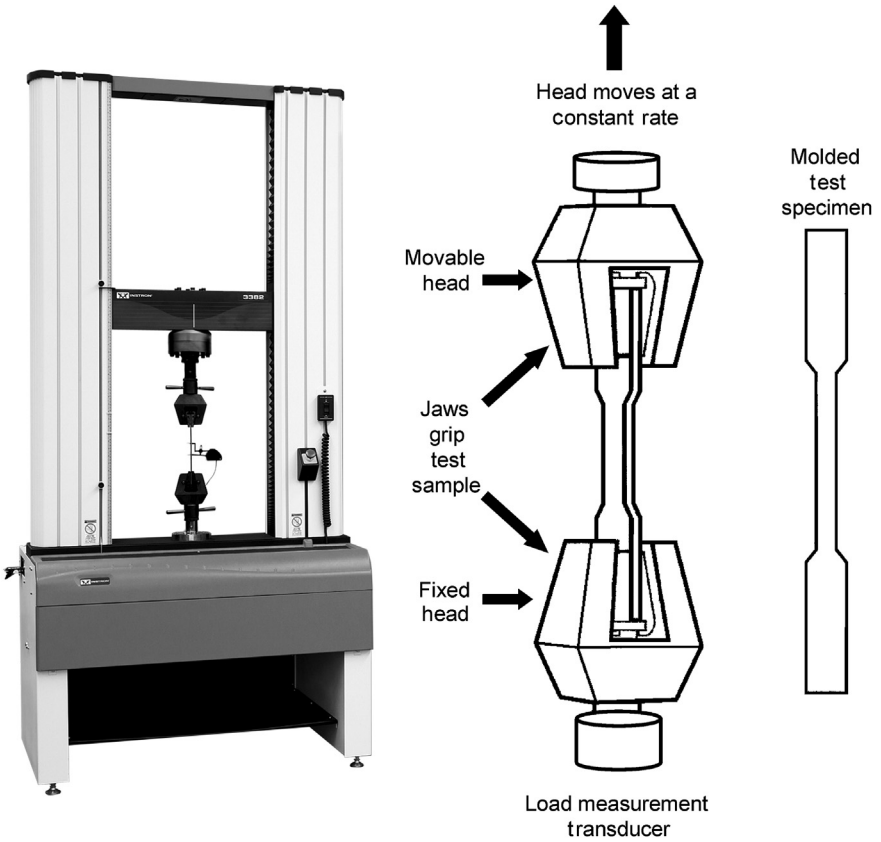


Figure 1.22 Instron® Universal Materials Testing Machine. *(Photo courtesy of Instron® Corporation).*

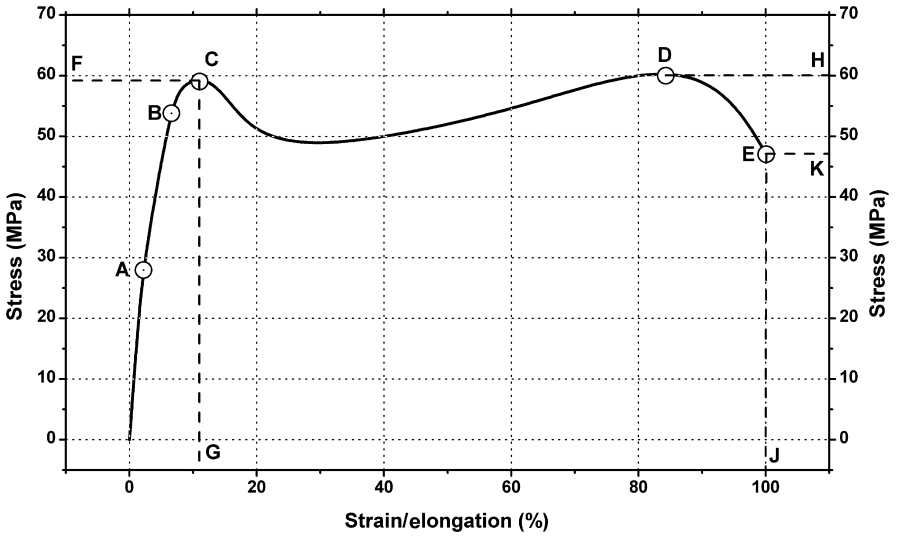


Figure 1.23 Typical stress–strain curve showing some important measurement points.

punch. The shear strength is calculated as the maximum force encountered during the test divided by the area of the sheared edge (circumference of the punched circle multiplied by the specimen thickness, as indicated by the dotted line in Figure 1.25).

Table 1.9 Tensile Properties Determined from a Stress–Strain Curve per ASTM D638

Property	Definition
Tensile elongation at break	Tensile elongation corresponding to the point of rupture, "J" in Figure 1.23
Tensile elongation at yield	Tensile elongation corresponding to the yield (an increase in strain does not result in an increase in stress), "G" in Figure 1.23
Tensile strength at break	Tensile stress corresponding to the point of rupture, "K" in Figure 1.23
Tensile strength at yield	Tensile stress corresponding to the yield point (an increase in strain does not result in an increase in stress), "F" in Figure 1.23
Tensile strength	Tensile stress at a specified elongation
Tensile strength, ultimate	The highest tensile stress a material can support before failing, "H" in Figure 1.23
Tensile modulus	The ratio of tensile stress to tensile strain of a material in the elastic region (from no strain to point "B" in Figure 1.23) of a stress–strain curve. A "Tangent" tensile modulus value is the slope of the elastic region of the stress–strain curve and is also known as Young's modulus, the elastic modulus, or the modulus of elasticity. A "Secant" tensile modulus value is the slope of a line connecting the point of zero strain to a point on the stress–strain curve at a specified strain

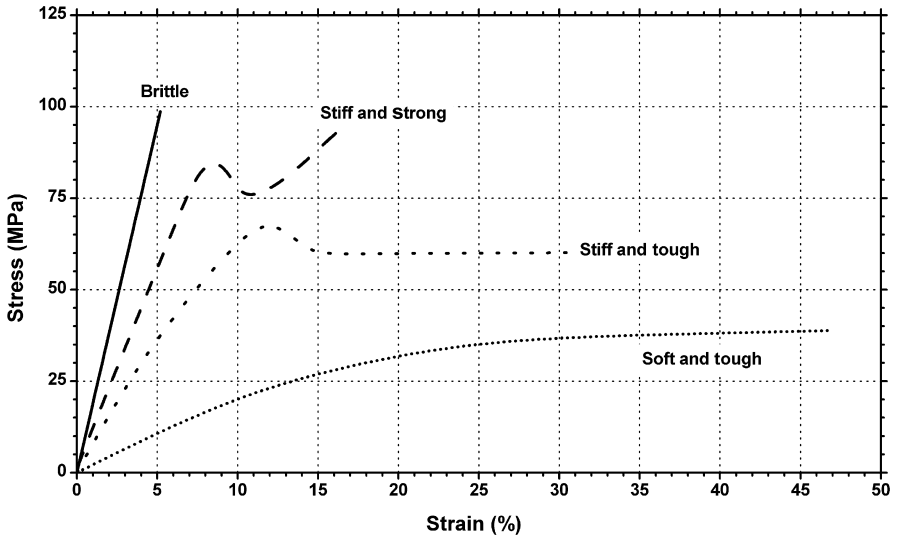


Figure 1.24 The range of stress vs. strain behaviors.

Table 1.10 Examples of Tensile Responses Exhibited by Various Plastics

Behavior	Examples
Brittle	Polystyrene, acrylics, styrene acrylonitrile, highly reinforced material
Stiff and strong	Acrylonitrile–butadiene–styrene, polycarbonate, polyamides, highly filled resin
Stiff and tough	Impact modified polyamides, impact polystyrene
Soft and tough	Elastomers, low density

1.3.1.4 Flexural Properties

The measurement of flexural properties is described in the standards:

- ASTM D790-03 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- ISO 178:2001 Plastics—Determination of flexural properties

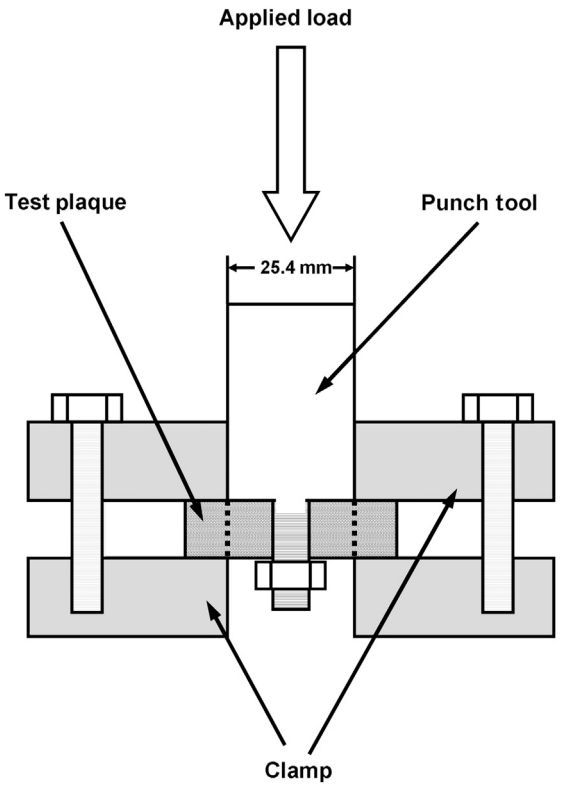


Figure 1.25 Apparatus used for shear property measurements.

A test specimen is held as a simply supported beam and is subjected to three-point bending as shown in Figure 1.26. Typically an Instron® is used. Maximum stress and strain occurs at the underside of the test specimen, directly under the applied force. The preferred test specimen is 80 mm long, 10 mm wide, and 4 mm thick. Other specimens may be used if the length to thickness ratio is equal to 20.

1.3.1.5 Impact Property Testing of Plastics

Table 1.4 listed a number of tests used to measure the impact resistance of plastics. Impact tests allow designers to compare the relative impact resistance. The tests are often used for quality control. However, these tests generally do not translate into explicit design parameters.

While there are many measurements listed, the measurements use test apparatus that fall into two types: based on a pendulum or a falling object. The main differences are sample preparation and measurement units.

Izod Impact Strength and Charpy Impact Strength

The standard tests for Izod impact strength are as follows:

- ISO 180:2000 Plastics—Determination of Izod impact strength
- ASTM D256-06a Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

The standard test for Charpy impact strength is

- ISO 179-1:2000 Plastics—Determination of Charpy impact properties—Part 1: Non-instrumented impact test

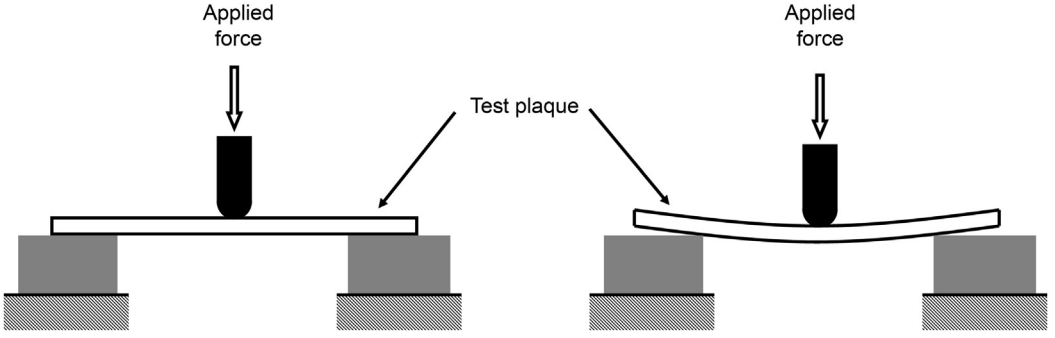


Figure 1.26 Principle used for flexural property measurements.

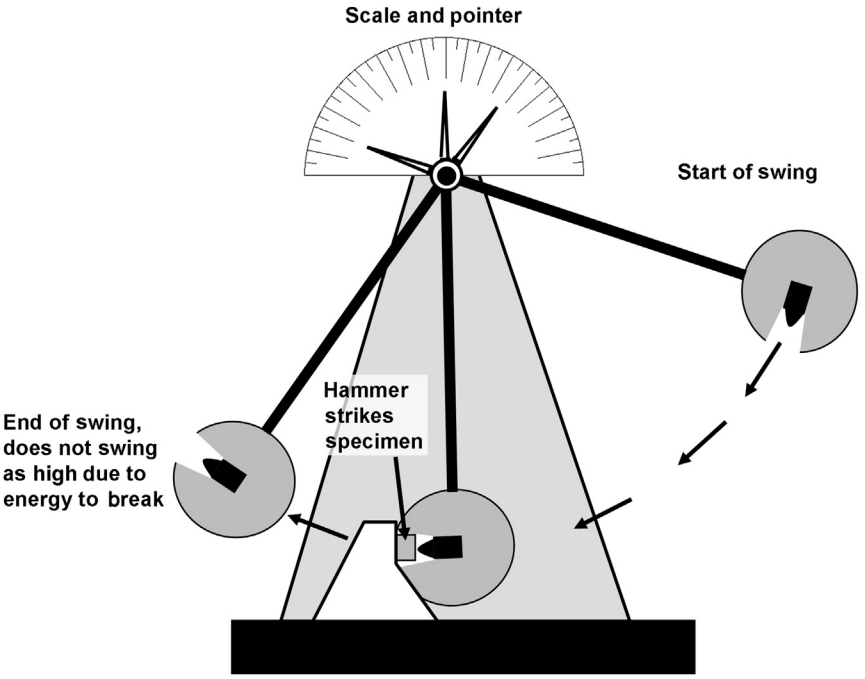


Figure 1.27 Pendulum-type impact strength tester.

Both Izod and Charpy tests are based upon a swinging pendulum, such as that shown in Figure 1.27.

Basically, the pendulum is raised to a measured point, and it is then released. The weighted end of the pendulum gains speed as it swings toward a mounted molded bar of the test plastic. It strikes the bar, breaks it, and the pendulum loses energy while breaking the plastic bar. Therefore it does not swing as high. The energy lost by the pendulum is equated with the energy absorbed by the test specimen during the breaking process.

There are different ways to mount the test specimen, and there are different specimen sizes and preparation methods. The different sample mounting configurations for the Izod and Charpy tests are shown in Figure 1.28. Figure 1.29 shows the details of the notch. The sharpness of the bottom of the notch affects the test result. Table 1.11 shows the different notch radii possible.

The impact resistance is usually reported as energy per unit length or per unit area.

Gardner and Falling Dart Impact Strength

Other impact strength tests that use gravity are the Gardner impact and Falling Dart tests. These are described in the following standards:

- D5420-04 Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)
- D5628-06 Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart (Tup or Falling Mass)
- D3763-06 Standard Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors
- ISO 7765-2:1994 Plastics film and sheeting—Determination of impact resistance by the free-falling Dart method—Part 2: Instrumented puncture test

The Gardner test uses a piece of equipment like that shown in Figure 1.30. A weight is lifted to a given height and it is dropped onto a test plaque. The Falling Dart is based on the same principle, but the weight is free falling rather than guided through a tube as in the Gardner equipment.

1.3.2 Thermal Property Testing of Plastics

- ASTM D746-04 Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

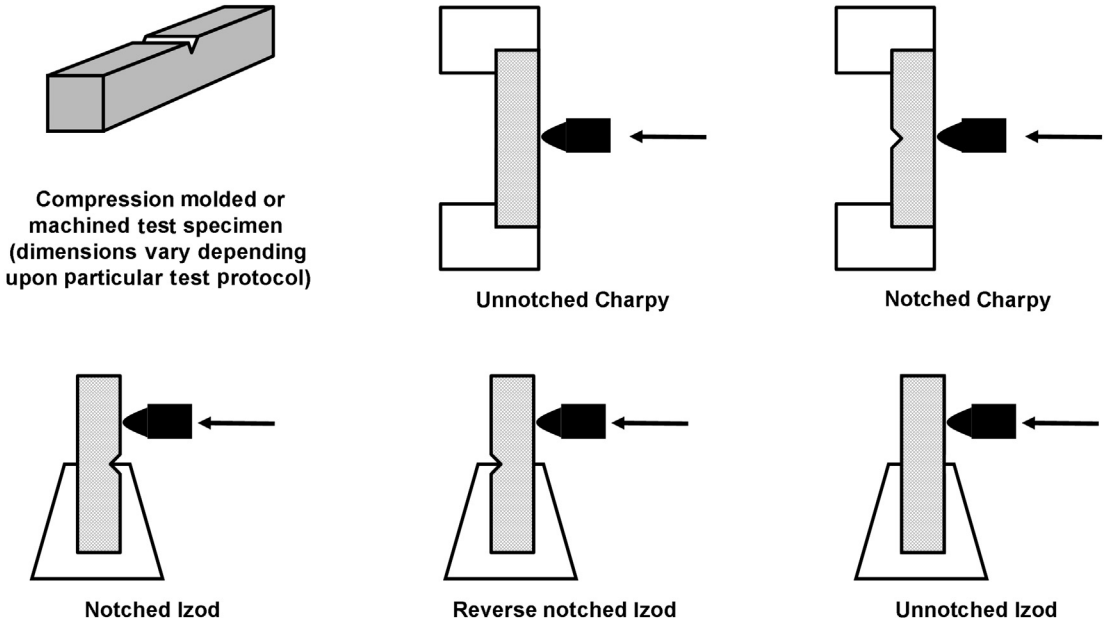


Figure 1.28 Izod and Charpy impact test sample configurations.

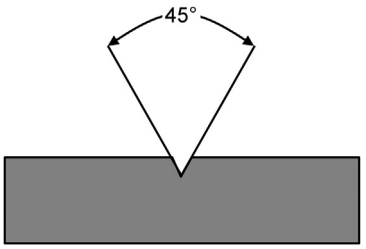


Figure 1.29 Izod and Charpy impact test notch details.

Table 1.11 Izod and Charpy Impact Notch Radius Options

Notch	Izod Notch Radius (mm)	Charpy Notch Radius (mm)
A	0.25	0.25
B	1.00	1.00
C		0.10

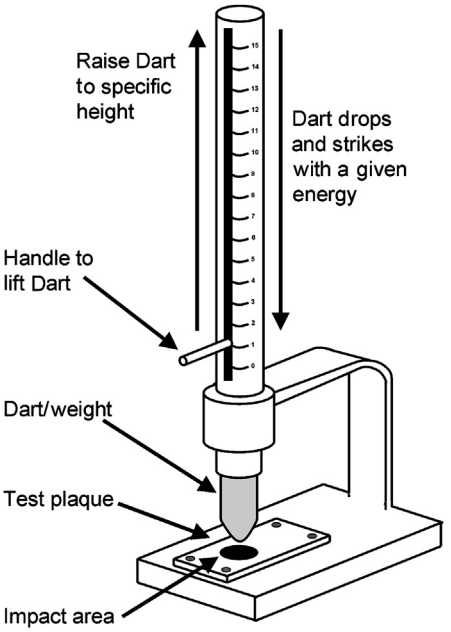


Figure 1.30 Gardner impact test apparatus.

- ISO 812:2006 Rubber, vulcanized or thermoplastic—Determination of low temperature brittleness
- ISO 974:2000 Plastics—Determination of the brittleness temperature by impact
- ASTM D696-03 Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C with a Vitreous Silica Dilatometer
- ASTM E831-06 Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- ISO 11359-1 Plastics—Thermomechanical analysis (TMA)—Part 1: General principles

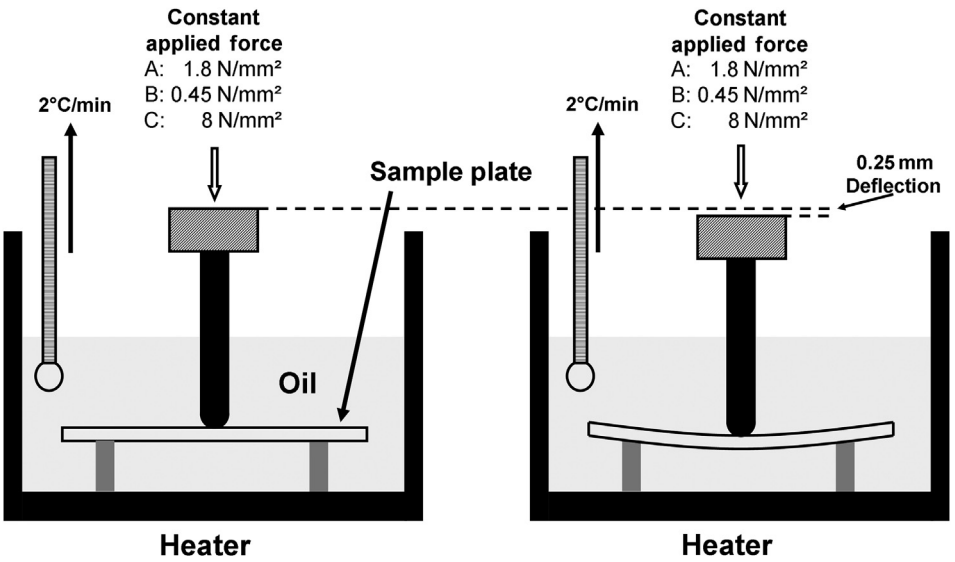


Figure 1.31 Heat deflection temperature (HDT) test apparatus.

- ISO 11359-2 Plastics—Thermomechanical analysis (TMA)—Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature
- ISO 75-1 Plastics—Determination of temperature of deflection under load—Part 1: General test method
- ISO 75-2 Plastics—Determination of temperature of deflection under load—Part 2: Plastics and ebonite
- ISO 75-3 Plastics—Determination of temperature of deflection under load—Part 3: High-strength thermosetting laminates and long fibre-reinforced plastics
- ISO 6603-2 Plastics—Determination of puncture impact behaviour of rigid plastics—Part 2: Instrumented impact testing
- ASTM E1356-03 Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
- ISO 3146:2000 Plastics—Determination of melting behaviour (melting temperature or melting range) of semicrystalline polymers by capillary tube and polarizing-microscope methods
- ASTM C351-92b (1999) Standard Test Method for Mean Specific Heat of Thermal Insulation
- ASTM C177-04 Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
- ISO 8302:1991 Thermal insulation—Determination of steady-state thermal resistance and related properties—Guarded hot plate apparatus
- ASTM D1525-06 Standard Test Method for Vicat Softening Temperature of Plastics
- ISO 306:2004 Plastics—Thermoplastic materials—Determination of Vicat softening temperature (VST)
- ASTM D1238-04c Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
- ISO 1133:2005 Plastics—Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics

1.3.2.1 Heat Deflection Temperature

The heat deflection temperature is a measure of a polymer's resistance to distortion under a given load at elevated temperatures. Other terms for this measurement include deflection temperature under load (DTUL) or heat distortion temperature (HDT).

The test is performed using an apparatus diagrammed in Figure 1.31. A test bar is molded of a specific thickness and width. The test sample is submerged in oil that is gradually heated. The load is

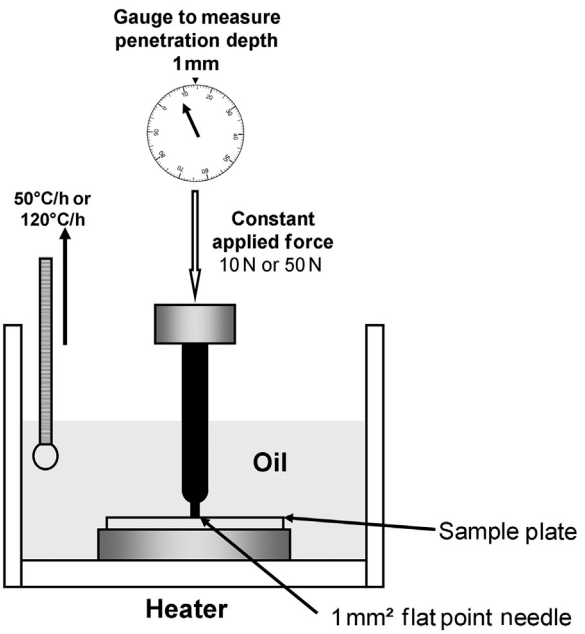


Figure 1.32 Vicat softening temperature test apparatus.

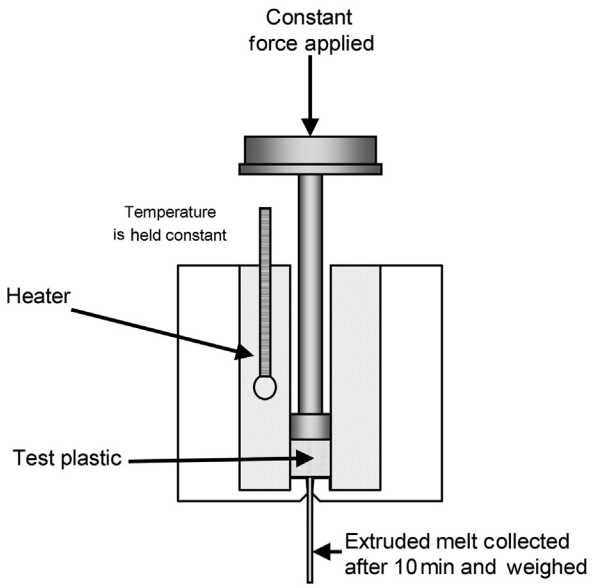


Figure 1.33 Melt flow index test apparatus.

applied to the midpoint of the test bar that is supported near both ends. The temperature at which a bar of material is deformed 0.25 mm is recorded as the HDT.

The ASTM test is ASTM D648 while the analogous ISO test is ISO 75. The test using a 1.8 MPa load is performed under ISO 75 Method A while the test using a 0.46 MPa load is performed under ISO 75 Method B. Less common is the test using an 8 MPa load is performed under ISO 75 Method C.

The HDT value obtained for a specific polymer grade will depend on the base resin and on the presence of reinforcing agents. Deflection temperatures of glass fiber- or carbon fiber-reinforced engineering polymers will often approach the melting point of the base resin.

The HDT test results are a useful measure of relative service temperature for a polymer when used in load-bearing parts. However, the deflection temperature test is a short-term test and should not be used alone for product design. Other factors such as the time of exposure to elevated temperature, the rate of temperature increase, and the part geometry all affect the performance.

1.3.2.2 Vicat Softening Temperature

The Vicat softening temperature is the temperature at which a flat-ended needle penetrates the specimen to a depth of 1 mm under a specific load. The temperature reflects the point of softening to be expected when a material is used in an elevated temperature application.

A test specimen is placed in the testing apparatus such as that diagrammed in Figure 1.32. The penetrating needle rests on its surface. A load of 10 or 50 N is applied to the specimen. The specimen is then lowered into an oil bath at 23°C. The bath is raised at a rate of 50°C/h or 120°C/h until the needle penetrates 1 mm. The temperature at that moment is called the Vicat softening temperature.

The relevant standards are ISO 306 and ASTM D1525. ISO 306 describes two methods, method A with a load of 10 N and method B with a load of 50 N, each with two possible rates of temperature rise, 50°C/h and 120°C/h. This results in ISO values reported as A50, A120, B50, or B120.

1.3.2.3 Melt Flow Index

The melt flow index is a measure of the ease of flow of the melt of a thermoplastic polymer. It is defined as the weight of polymer in grams flowing in 10 min through a die of specific diameter and length by a pressure applied by a given weight at a given temperature. The method is given in ASTM D1238 and ISO 1133. The test equipment is diagrammed in Figure 1.33.

The conditions of the test depend upon the type of the polymer, some of which are shown in Table 1.12. One does not want a temperature so

Table 1.12 Recommended Conditions for Determination of MFR and MVR for Common Materials According to ISO and ASTM Guidelines (e.g., 190/2.16 = 190°C with 2.16 kg weight)

Plastic/Polymer	ASTM Standard Conditions (°C/kg)	ISO Standard Conditions (°C/kg)
Acetals (copolymer and homopolymer)	190/2.16, 190/1.05	190/2.16
Acrylics	230/1.2, 230/3.8	230/3.8
Acrylonitrile–butadiene–styrene (ABS)	200/5.0, 230/3.8, 220/10	220/10
Acrylonitrile/butadiene/styrene/ polycarbonate blends	230/3.8, 250/1.2, 265/3.8, 265/5.0	
Cellulose esters	190/0.325, 190/2.16, 190/21.60, 210/2.16	
Ethylene–chlorotrifluoroethylene copolymer (ECTFE)	271.5/2.16	
Ethylene–tetrafluoroethylene copolymer (ETFE)	297/5.0	
Nylon	275/0.325, 235/1.0, 235/2.16, 235/5.0, 275/5.0	
Perfluoro(ethylene–propylene) copolymer (FEP)	372/2.16	
Perfluoroalkoxyalkane (PFA)	372/5.0	
Polycaprolactone	125/2.16, 80/2.16	
Polychlorotrifluoroethylene (PCTFE)	265/12.5	
Polyethersulfone (PES)	380/2.16, 360/10, 343/2.16	
Polyethylene (PE)	125/0.325, 125/2.16, 250/1.2, 190/0.325, 190/2.16, 190/21.60, 190/10, 310/12.5	190/2.16, 190/21.6, 190/0.325, 190/5
Polycarbonate (PC)	300/1.2	300/1.2
Polypropylene (PP)	230/2.16	230/2.16
Polyphenylsulfone (PPSU)	365/5.0, 380/2.16	
Polystyrene (PS)	200/5.0, 230/1.2, 230/3.8, 190/5.0	200/5
Polysulfone (PSU)	343/2.16, 360/10	
Polyterephthalate	250/2.16, 210/2.16, 285/2.16	
Polyvinyl acetal	150/21.6	
Polyvinylidene fluoride (PVDF)	230/21.6, 230/5.0	
Polyphenylene sulfide (PPS)	315/5.0	
Styrene acrylonitrile (SAN)	220/10, 230/10, 230/3.8	220/10
Styrenic thermoplastic elastomer (TEO)	190/2.16, 200/5.0	
Thermoplastic elastomer–ether–ester	190/2.16, 220/2.16, 230/2.16, 240/2.16, 250/2.16	
Thermoplastic elastomers	230/2.16	
Vinylidene fluoride copolymers	230/21.6, 230/5.0	

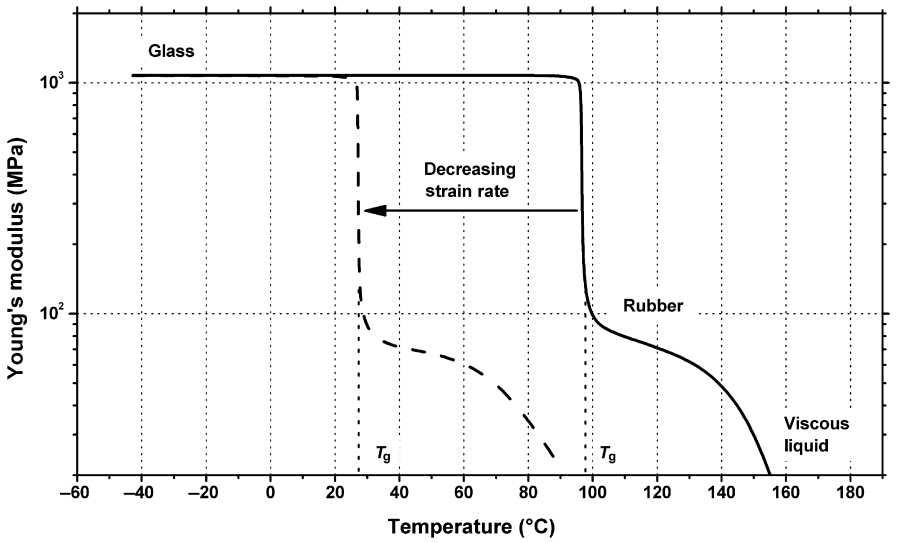


Figure 1.34 T_g estimate from an elastic modulus vs. temperature study.

high that the polymers in the plastic decompose. The melt flow rate is an indirect measure of molecular weight with high melt flow rate corresponding to low molecular weight. Synonyms of melt flow index are melt flow rate and melt index, which are commonly abbreviated as MFI, MFR, and MI.

1.3.2.4 Glass Transition Temperature (T_g)

The glass transition temperature, often called T_g (or "T sub g"), is an important property when considering polymers for a particular end use. The glass transition temperature is the temperature, below which the physical properties of plastics change in a manner similar to those of a glassy or crystalline state, and above which they behave like rubbery materials. A plastic's T_g is the temperature below which molecules have little relative mobility. T_g is usually applicable to wholly or partially amorphous plastics. A plastic's properties can be dramatically different above and below its T_g. The next sections show a number of ways to measure or estimate T_g. These methods will indicate how some of the properties change around T_g. The value of the glass transition temperature depends on the strain rate and cooling or heating rate, so there cannot be an exact value for T_g.

Mechanical Methods of Estimating T_g

It is possible to calculate a value for the glass transition temperature by measuring the elastic (or Young's) modulus of the plastic as a function of the temperature, for example by using a torsion pendulum. Around T_g, there is a large fall in the value of the modulus as shown in Figure 1.34. The frequency of the oscillation is important, since T_g value depends on the time allowed for chain segment rotation. While this approach is not commonly used, as there are better methods, it does demonstrate one way in which a plastic's physical properties change above and below T_g.

A more common mechanical method is *dynamic mechanical thermal analysis* (DMTA). DMTA is also called dynamic mechanical analysis (DMA) or dynamic thermomechanical analysis. An oscillating force is applied to a sample of material and the resulting displacement of the sample is measured. From this the stiffness of the sample can be determined, and the sample modulus can be calculated. A plot of loss modulus as a function of temperature shows a maximum at T_g as shown in Figure 1.35. Figure 1.35 shows a series of blends of high-impact styrene (HIPS) and PPO. As the amount of PPO is increased, T_g increases. The single T_g indicates that these blends are miscible.

Thermal Methods of Estimating T_g

Thermal methods of measuring T_g are based on differential scanning calorimetry, commonly called DSC. In DSC, the thermal properties of a sample are compared against a standard reference material, typically inorganic, which has no transitions, such as a melting point, in the temperature range of

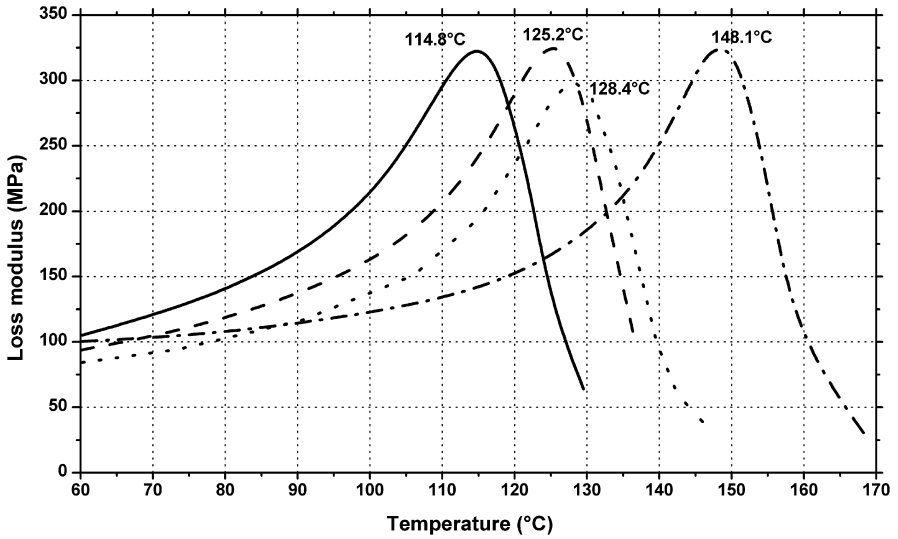


Figure 1.35 T_g estimate from DMTA study.

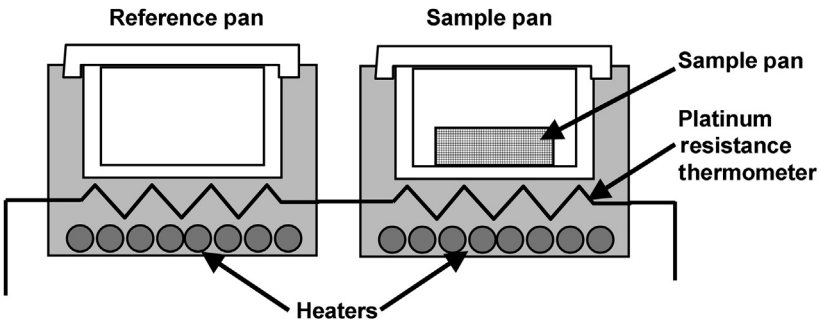


Figure 1.36 Diagram of a DSC sample and reference cell.

interest. A common reference material is powdered alumina. The sample and reference are each contained in a small holder within an adiabatic enclosure as illustrated in Figure 1.36.

The temperature of each holder is monitored by a thermocouple and heat can be supplied electrically to each holder to keep the temperature of the two equal. The difference in the amount of heat required to maintain equal temperature is recorded. A plot is recorded of the difference in energy supplied against the average temperature. As the temperature is slowly increased, thermal transitions may be identified.

The glass transition process is illustrated in Figure 1.37 for a glassy polymer which does not crystallize and is being slowly heated from below T_g.

Here, the drop marked T_g at its midpoint represents the increase in energy supplied to the sample to maintain it at the same temperature as the reference material, due to the relatively rapid increase in the heat capacity of the sample as its temperature is raised through T_g. The addition of heat energy corresponds to this endothermal direction.

The specific heat or specific heat capacity, C_p, can be measured using DSC. It can change dramatically at T_g as shown in Figure 1.38. The value of T_g depends on the heating or cooling rate of the calorimetry experiment.

Volume Methods of Determining T_g

The changes in conformation that occur above T_g require more volume, so plotting a graph of specific volume or thermal expansion coefficient vs. temperature will provide a value for T_g as shown in Figure 1.39.

Electrical Methods of Determining T_g

If a varying electric field is applied to a polymeric material, any polar groups will align with the field. Below T_g, rotation of the

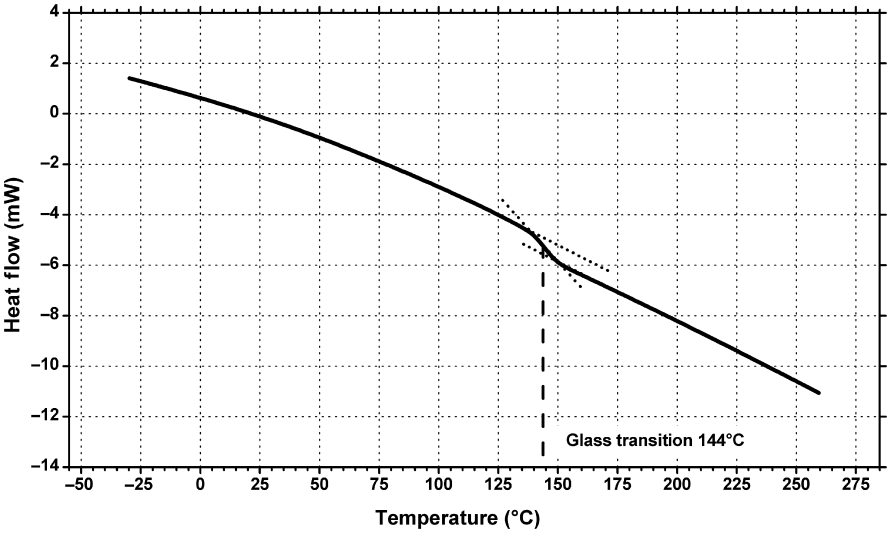


Figure 1.37 Schematic of a DSC showing T_g.

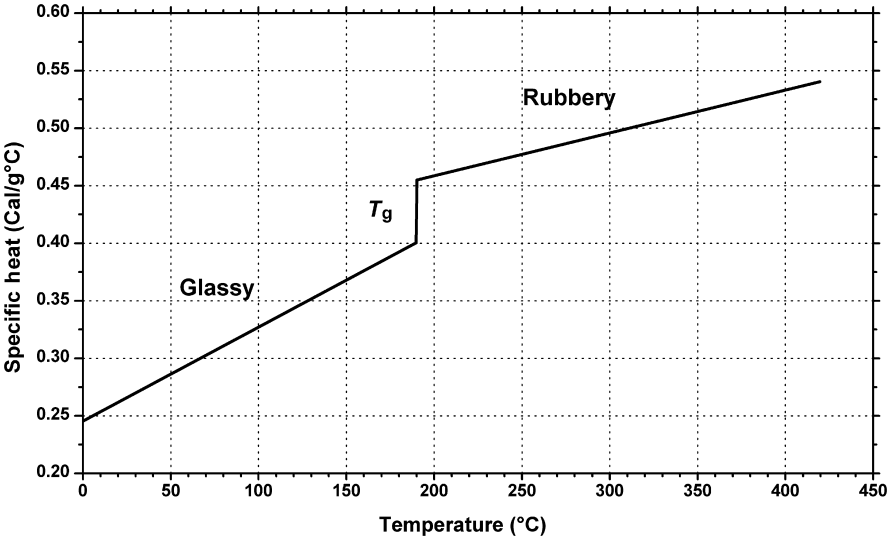


Figure 1.38 T_g estimate from the change in specific heat capacity vs. temperature for a commercial PSU.

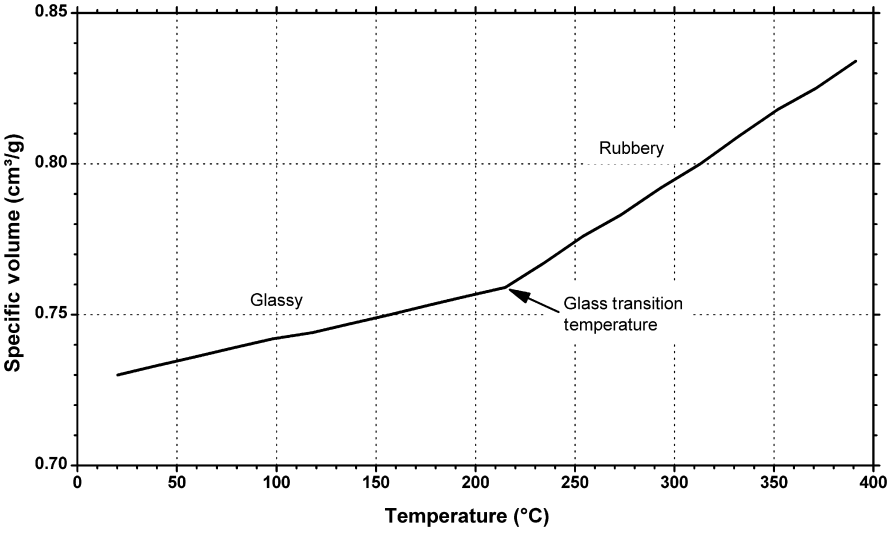


Figure 1.39 T_g estimate from the change in specific volume vs. temperature for a commercial PES.

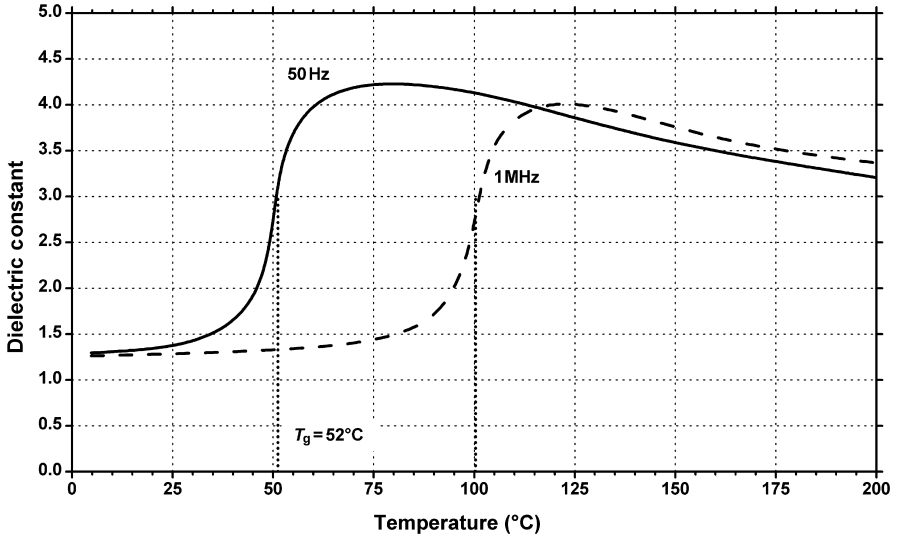


Figure 1.40 T_g estimate from the change in dielectric constant (relative permeability).

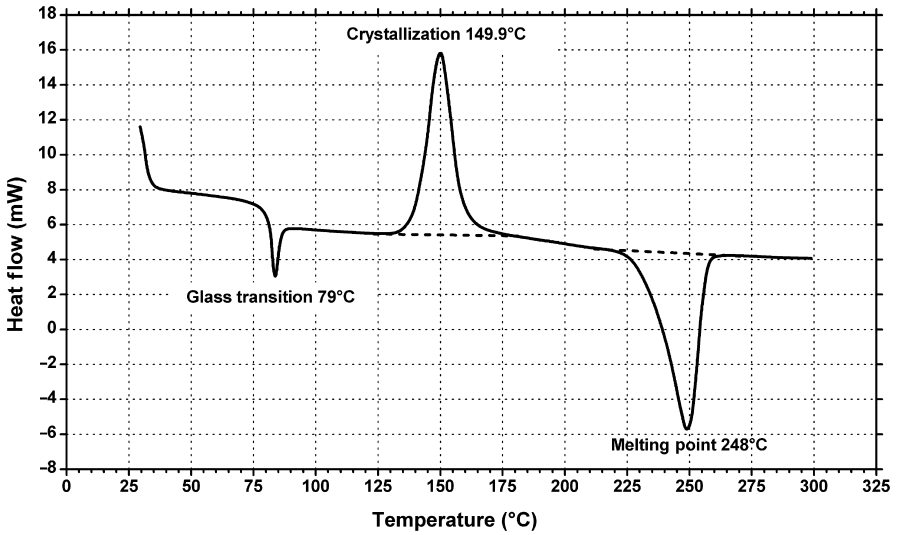


Figure 1.41 Melting point estimation from a DSC of PET.

bonds is not possible, so the permittivity will be low with a big increase around T_g. At higher temperatures, the increased thermal vibrations cause the permittivity to drop again. If the frequency of the field is increased, the polar groups have less time to align, so the glass transition occurs at a higher temperature. This is shown in Figure 1.40.

While there are still more ways to measure glass transition temperature, many methods summarized in this chapter do also indicate how important glass transition temperature is and that it affects many properties.

1.3.2.5 Melting Point (T_m)

A melting process is also illustrated in Figure 1.41 for a PET polymer which is slowly heated through its melting temperature and two other thermal transitions besides.

Again, as the melting temperature is reached, an endothermal peak appears because heat must be preferentially added to the sample to continue this essentially constant temperature process. The peak breadth is primarily related to the size and degree of perfection of the polymer crystals. This DSC also provides additional information, the glass transition temperature and a crystallization temperature

Note that if the process was reversed so that the sample was being cooled from the melt, the plot would be approximately inverted at the melt point and glass transition temperature. This corresponds to an exothermal process.

1.3.2.6 Coefficient of Thermal Expansion

The change in length per unit length of a material per degree of temperature change is called the coefficient of linear thermal expansion (CLTE). The measurement of the CLTE is covered by several ASTM and ISO methods:

- ASTM D696-03 Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics between −30°C and 30°C with a Vitreous Silica Dilatometer
- ASTM E228-06 Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer
- ASTM E831-06 Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- ISO 11359-2:1999 Plastics—Thermomechanical analysis (TMA)—Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature

The CLTE is commonly measured using a silica dilatometer. A plastic specimen is placed inside a silica tube and a silica rod is inserted into the tube. A dial gauge or similar device is attached to the rod. The end of the tube containing the test material is placed in a −30°C constant temperature bath. When the gauge no longer changes, the test specimen has reached a temperature of −30°C. The constant temperature bath is replaced by a 30°C constant temperature bath. After the specimen has reached a temperature of 30°C, the 30°C bath is replaced by the −30°C bath. After the specimen has reached a temperature of −30°C, the specimen is removed and measured at room temperature. ASTM D696 covers temperatures between −30°C and 30°C. The CLTE (α) is calculated using the formula:

$$\alpha = \frac{\Delta L}{L_o \cdot \Delta T}$$

where

ΔL is the change in length of the specimen

L_o is the original length of the specimen

ΔT is the temperature change during the test.

1.4 Principles of Plastic Product Design

Successful product design requires knowledge about the end use and of the materials that can be used. The knowledge requirement may be subdivided into:

1. Requirements of the product, including use environment, exposure conditions, performance needs
2. Knowledge of the behavior of plastic materials
3. Plastic processes and processing
4. Economic constraints

Experience and training is required to relate this knowledge to meeting the product needs. This book is loaded with extensive data on the behavior of plastics as a function of temperature and other factors. But how does one make use of all these data? Some discussion on mechanical and thermal properties relevant to design will help the inexperienced engineer get started.

For successful use a plastic must have appropriate:

1. Rigidity
2. Toughness
3. Resistance to long-term deformation, also called creep (creep is the subject of another work)
4. Recovery from deformation on release of stress
5. Resistance to thermal degradation adversely affecting properties

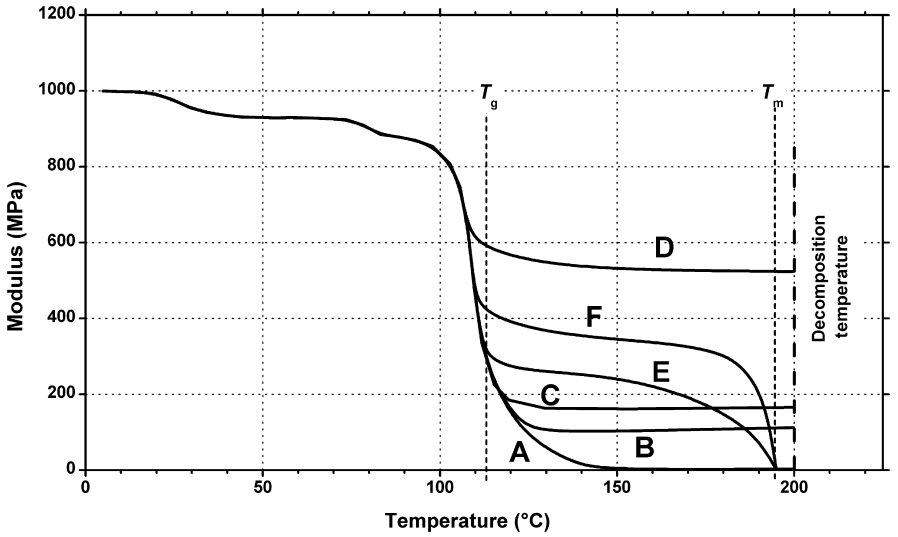


Figure 1.42 Schematic illustration of dependence of the modulus of a polymer on a variety of factors.

These must be not only at room temperature but also over the range of operating conditions likely to be encountered.

Other considerations, depending on intended use and function, include:

1. Elasticity or flexibility
2. Odor and taste
3. Flame/fire resistance
4. Electrical properties
5. Radiation/light resistance and weathering
6. Transparency and color, paintability
7. Moisture absorption
8. Chemical resistance
9. Wear resistance and slip
10. Permeability
11. Dimensional stability

1.4.1 Rigidity of Plastic Materials

The rigidity of a plastic is determined by the ease with which the plastic is deformed under load. Modulus is the measure that corresponds to rigidity in plastics. In amorphous plastics at temperatures well below the glass transition temperature, all load is taken by bond bending and stretching of the polymers making up the plastic. The change in rigidity at T_g in an amorphous polymer is considerable. The modulus may drop more than 3 orders of magnitude. Further heating of a low to moderate uncross-linked plastic past its T_g would rapidly cause a drop of the modulus toward zero. However, in a high molecular weight plastic such as cast polymethyl methacrylate the polymer chain entanglements would enable the material to maintain a significant rubbery modulus up to its decomposition temperature. Similar maintenance of the modulus above zero is achieved when the polymer is cross-linked. The more cross-linking present, the higher the modulus.

Crystallinity can also restrict molecular movement of the polymer chains above T_g, raising the modulus. The higher the crystallinity, the more rigid the polymer. Some polymers tend to melt over a wide temperature range, in which case the modulus may fall over a range of temperatures leading up to the melting point T_m. The above effects are summarized in Figure 1.42.

The points on the curve of Figure 1.42 are described as follows:

A is an amorphous polymer of moderate molecular weight

B is of such a high molecular weight that entanglements inhibit flow

C is lightly cross-linked

D is highly cross-linked

E is some crystallinity

F is higher crystallinity

Plastic materials, in general, are blends of polymers with additives and fillers. All the components may well affect the modulus.

In practice, one is basically concerned with the rigidity of the product and this involves not only the modulus of the material but also the shape and size of the product. From the points of view of weight saving, economics in material, and ease of processing, it is an important aim to keep section thicknesses at a minimum required to achieve performance targets. Since flat or singly curved surfaces have a minimum rigidity, the designer may wish to incorporate domed or other doubly curved surfaces or ribbing into the product in order to increase stiffness. Corrugation can also enhance stiffness, but in this case the enhancement varies with position, being greatest when measured at right angles to the corrugation.

1.4.2 The Assessment of Maximum Service Temperature

The design engineer often must know the maximum temperature for which a polymer can be used in a given application. This depends largely on two independent factors:

1. The thermal stability of the polymer, particularly in air
2. The softening behavior of the polymer

First, consider two polymers, A and B. Polymer A "softens" at 120°C but has long-term thermal stability to 200°C. On the other hand, polymer B softens at 200°C but degrades "at a measurable rate" above 90°C. Consideration of these figures, even allowing for the loose terminology, indicates that material A could not be used much above 90°C for either long or short periods. In the case of polymer B, short-term service might be possible up to about 160−170°C but it could not be used for prolonged periods much above 70−80°C.

1.4.3 Assessment of Thermal Stability

Over the years many attempts have been made to provide some measure of the maximum service temperature which a material will be able to withstand without thermal degradation that would render it unfit for service. Quite clearly any figure will depend on the time the material is likely to be exposed to elevated temperatures. One assessment that is being increasingly quoted is the UL 746B Relative Temperature Index Test of the Underwriters Laboratories. This measure was previously known as the Continuous Use Temperature Rating or Index.

In order to obtain a temperature index rating, a large number of samples are subjected to oven aging at a variety of temperatures for periods of up to a year. During the course of this time, samples are periodically withdrawn from the oven and tested. A plot is then made of the percentage retention in the value of the property measured (compared to its original control value) against time. The time and temperature which gives a 50% reduction in value of the property is noted. Somewhat arbitrarily this is taken as the failure time at that temperature. Using the data from experiments carried out after aging at several temperatures, the logarithm of the "50%" failure time is plotted against 1/K. This type of plot is called an Arrhenius plot. The resulting linear line is then extrapolated to the arbitrary time of 10,000 h. The temperature at which the failure time (as defined above) is 10,000 h is known as the *relative temperature index* (RTI).

An RTI plot for a commercial polyphthalamide is shown in Figure 1.43, which shows four data points. The log of hours of exposure is the *Y*-axis. The *X*-axis is plotted in kelvin (kelvin equals °C + 273.15), which is actually not linear but the inverse.

This long-term thermal performance of a material is usually tested alongside a control material which already has an established RTI and which exhibits a good performance. Such a control is desirable because thermal degradation characteristics are sensitive to variables in the testing program. The control is not shown in Figure 1.43. Since the control material will also be affected by the same unique combination of these factors during the tests, there is a valid basis for comparison of test and control materials.

It is to be expected that the RTI obtained would depend on the property assessed and in UL 746B three properties are assessed:

1. "Mechanical with impact" by measuring tensile impact strength

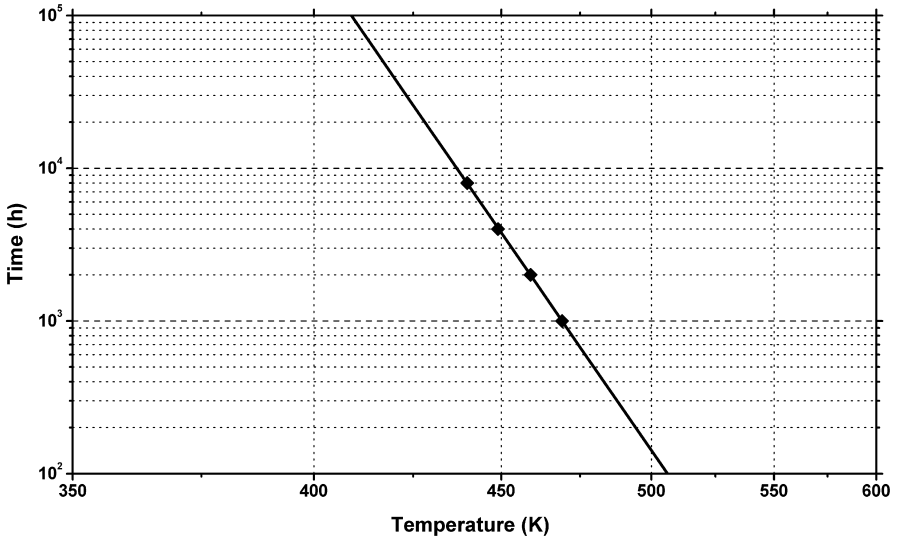


Figure 1.43 An RTI plot for a commercial polyphthalamide.

2. "Mechanical without impact" by measuring tensile strength
3. "Electrical" by measuring dielectric strength

A value for RTI is provided for each of these tests, although in common experience it is found that similar numerical values are obtained.

In addition, RTI may be affected by the thickness of the sample, so this should be given in any RTI specification.

Such a value for RTI will be specific to a particular grade of a polymer, sometimes even to a specific color. The difference between grades of a particular species of polymer can be substantial, depending both on the variation in the inherent stability of a material between differing manufacturing methods and also on the type and amount of additives used. It is possible to obtain from the laboratory a Generic Temperature Index to cover a species of material but this will usually be considerably lower for many of the individual grades within that species.

Some collected values for RTI taken from the literature are given in Table 1.13. (These are given for guidance only and should not be taken to imply official UL ratings.)

Curves A–C of Figure 1.43 show the "softening point" of an amorphous polymer, i.e., the temperature at which the modulus drops catastrophically, is closely associated with T_g. Such softening does not occur in highly cross-linked polymers, as in curve D, unless degradation also takes place.

In the case of crystalline polymers such as curves E and F of Figure 1.43, the situation is more complex. There is some change in modulus around T_g which decreases with increasing crystallinity and a catastrophic change around T_m. Furthermore, there are many polymers that soften progressively between T_g and T_m due to the wide melting range of the crystalline structures, and the value determined for the softening point can depend very considerably on the test method used.

Two particular test methods have become very widely used. They are the Vicat softening point test (VSP test) and the heat deflection temperature under load test (HDT test) (which is also widely known by the earlier name of heat distortion temperature test). These two tests were discussed earlier in Sections 1.3.2.1 and 1.3.2.2.

Whilst the Vicat test usually gives the higher values, the differences are quite modest with many polymers (e.g., those of curves A–C in Figure 1.43). For example, in the case of the PC of bisphenol A the heat distortion temperatures are 135–140°C and 140–146°C for the high and low stress levels, respectively, and the VSP is about 165°C. In the case of an acetal homopolymer, the temperatures are 100°C, 170°C, and 185°C, respectively. With Nylon 66, the two ASTM heat distortion tests give values as different as 75°C and 200°C. A low-density PE may have a Vicat temperature of 90°C but a heat distortion temperature below normal ambient temperatures.

Table 1.13 Some Collected Values for RTI (Unless Otherwise Stated, Data Are for "Mechanical Without Impact" and for Unreinforced Grades)

Polymer	Sample	RTI (°C)
ABS		60–80
Nylons		75
Polyacetal	Homopolymer and copolymer	90
Styrenic polyphenylene oxide	Noryl 731	105
Polycarbonate	Lexan 101	125
	Lexan 3414R (40% glass filled)	130
Polyarylate	Ardel D100	130
Polybutylene terephthalate	Pocan 81305	140
	Pocan 83235 (30% g/f)	140
Polyethylene terephthalate	Petlon 4630 (30% g/f)	150
Polysulfone		160
Polyetherimide	Ultem 1000	170
Polyphthalamide	Amodel A1133HS	180
Polyethersulfone	Victrex 200P	180
Polyphenylene sulfide	Supec G401 (40% g/f)	200
Aromatic polyester	Ekkcel 1-2000	220
Liquid crystal polyester		220
Polyether ether ketone	Victrex PEEK	240

The differences in the assessment of softening point between the tests are clearly largely a matter that the "end point" of the test measures a different modulus. Figure 1.43 shows that with some materials (e.g., curve A) this will not be of great importance but with other types (e.g., curve E or F) the difference could be very large.

Simply, it might be said that the Vicat test gives a measure of the temperature at which a material loses its "form stability" whilst the higher stress level heat distortion temperature (1.82 MPa) test provides a measure of the temperature at which a material loses its load-bearing capacity. The lower stress (0.45 MPa) heat distortion temperature test gives some rather intermediate figures and it is perhaps not surprising that it is today less often quoted than the other two tests.

Some interesting differences are noted between amorphous and crystalline polymers when glass fiber reinforcement is incorporated into the polymer. In Figure 1.44, it will be seen that incorporation of glass fiber has a minimal effect on the heat deflection temperature of amorphous polymers (PS, ABS, PC, and PSU) but a large effect on crystalline polymers. It is particularly interesting, as well as being technically important, that for many crystalline polymers the unfilled polymer has a heat deflection temperature (at 1.82 MPa stress) similar to T_g, whereas the filled polymers have values close to T_m (Table 1.14). Note that incorporation of glass fiber has a much greater effect with crystalline polymers than with amorphous ones.

1.4.4 Toughness

Toughness is complex to define and difficult to understand. Tough thermoplastic resins are usually described as having high elongation to failure or ones that require a large amount of energy to cause failure. If the plastics are reinforced then they need high strength with low elongation. For many applications, the resistance to impact is the most important property of a plastic material. It is also notoriously one of the most difficult to assess.

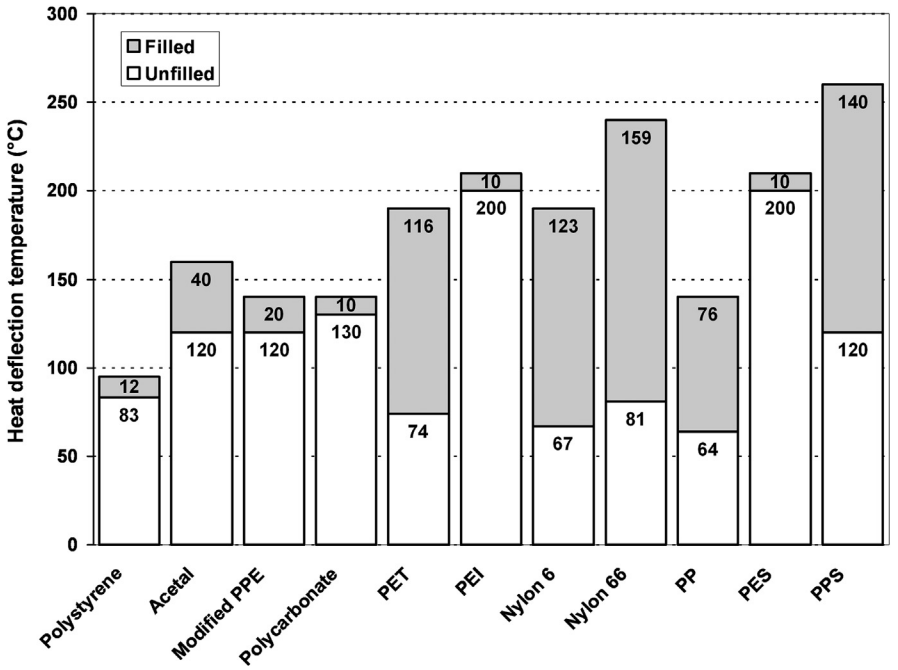


Figure 1.44 Heat deflection temperatures under a load of 1.82 MPa for selected polymers showing the effect of added filler (30% glass fiber).

If a rigid polymer is struck a blow at a temperature well below its glass transition temperature, deformation will be small before break occurs. Nevertheless, because of the high modulus, quite high tensile strengths will be recorded. But the energy required to cause the break will be given by the area under the stress–strain curve and it will not be very large as shown in Figure 1.45A. On the other hand, if an amorphous polymer is struck above T_g, i.e., in the rubbery state, large extensions are possible before fracture occurs and, although the tensile strength will be much lower, the energy to break (the area under the curve in Figure 1.45B) will be much more, so that for many purposes the material will be regarded as tough.

A common material performance need is a rigid plastic with the toughness of rubber. This can be achieved in a number of ways:

1. By the use of a moderately crystalline polymer with T_g well below the expected service temperature (e.g., PE).
2. By blocking copolymerization so that one component of the block copolymer has T_g well below the expected service temperature range (e.g., PP with small blocks of PE or preferably PP with small amorphous blocks of ethylene–propylene copolymer).
3. By blending with semicompatible materials that have T_g well below the expected service temperature range (e.g., HIPS).
4. By the use of a polymer which has effective transitions at or below the expected service temperature range and which is able to respond to stress by extensive deformation (e.g., PCs).
5. By plasticization. This effect reduces T_g and in the case of nylon, which has absorbed small quantities of water, the toughening effect can be quite substantial.

In terms of a stress–strain curve, a brittle material may be considered to be one that breaks without a yield while a tough material yields to give a substantial energy to break. Keep in mind that if a material has not broken after being struck simply because it yielded to an unrecoverable extent the product may still be useless.

Toughness is not simply a function of polymer structure or the mode of stressing. It clearly will also depend on the temperature and the rate of

Table 1.14 Comparison of T_g, T_m, and Various Heat Performance Temperatures of Polymers with and without Glass Fiber Reinforcement (All Values in °C)

Plastic	T_m	T_g	Max service	HDT 0.46	HDT 1.8	Vicat	RTI
PPS unfilled	285	85	190	149	120		
PPS 10% glass fiber	285	85	230	220	210		
PPS 20% glass fiber	285	85	260	260	260		
PPS 30% glass fiber	285	85	250	270	260		190
PPS 40% glass fiber	285	85	240	280	260		200
PPS 50% glass fiber	285	85	260	270	260		
PPS 60% glass fiber	285	85	260		260		
PPS 10% carbon fiber	285	85	250	260	249		
PPS 20% carbon fiber	285	85	260	270	260		
PPS 30% carbon fiber	285	85	260	260	260		
PPS 40% carbon fiber	285	85	260	260	260		
PPS 50% carbon fiber	285	85	260	260	260		
PPS 60% carbon fiber	285	85	260	260	260		
PBT unfilled	225	23–43	70	150	61	160	110
PBT 10% glass fiber	225	23–43	150	190	170	210	100
PBT 20% glass fiber	225	23–43	170	210	180	190	130
PBT 30% glass fiber	225	23–43	190	220	200	190	130
PBT 40% glass fiber	225	23–43	190	220	210		
PBT 50% glass fiber	225	23–43	190	220	210	210	130
ABS unfilled	100	105	86	96	91	100	63
ABS 10% glass fiber	100	105	100	104	100		
ABS 20% glass fiber	100	105	100	110	100	100	110
ABS 30% glass fiber	100	105	110	110	100		
ABS 40% glass fiber	100	105	110	110	110		

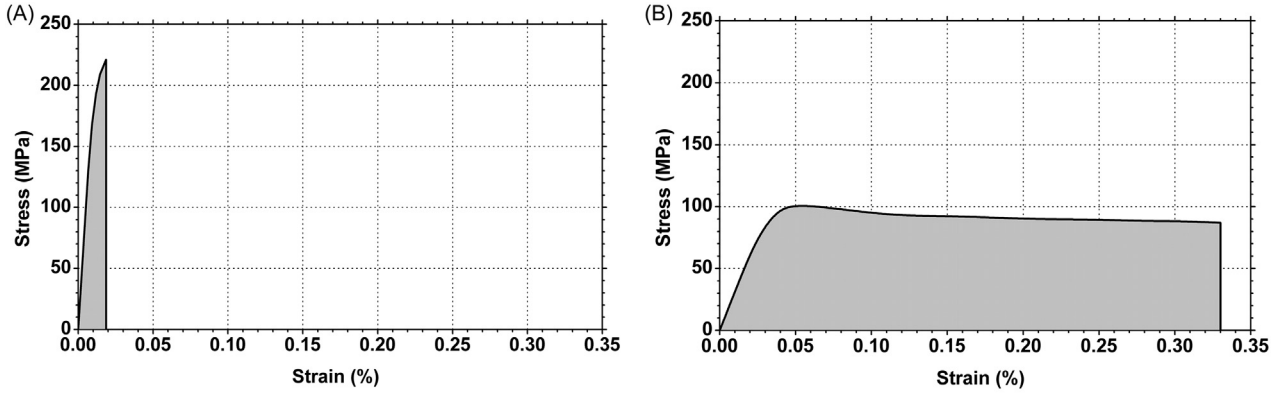


Figure 1.45 Stress vs. strain curves for two plastics: (A) rigid polymer, below T_g has very high tensile strength, but less area under the curve = less energy to break and (B) rigid polymer, above T_g has lower tensile strength, but more area under curve = more energy to break.

striking but more important still it will depend on the product design and method of manufacture.

Stress tends to concentrate at defects such as the presence of notches, sharp angles, holes, voids, particle inclusions, or small inserts. Different polymers vary in their "notch sensitivity" and this is presumably a reflection of how close they are to their tough–brittle transitions. The aim of the designer and processor must be to reduce such stress concentration to a minimum.

1.4.5 The Assessment of Impact Strength

It is probably most useful to consider toughness as a property of a plastics part under some specified conditions of service. It is possible to devise impact tests and to rank a series of plastics materials according to the results obtained. However, it remains almost impossible to use such tests to try to predict whether or not an article made from a specific material will or will not be satisfactory in service.

The factors that will influence service performance are summarized as follows:

1. The effect of additives and impurities
2. Temperature
3. Geometric size and shape
4. Orientation and morphology
5. Surface condition
6. Energy and speed of any impacting blow
7. The shape of the impacting instrument
8. The environment
9. Strains in the article due to external loads

For this reason it is desirable, but not always feasible, to test prototype articles under conditions as close to service conditions as possible.

Impact tests are, however, used to try to compare the impact strength of different materials. Of these tests, four merit specific mention. These are the Izod test, the Charpy test, the falling weight tests, and the tensile impact test.

The most well known impact test is the Izod test. This test is discussed in detail in Section 1.3.1.5. As a result of the stress concentrations around the notch, much lower impact strengths are recorded with notched specimens than with unnotched specimens.

Whilst Izod tests are generally reproducible, it has been found impossible to scale up the results and predict the energy required to break a bar of large cross section from results obtained with a bar of smaller cross section. This has led to some uncertainty in the method of quoting results and the following approaches are used:

1. *Energy to break*. This is quoted usually in joules. The result will only apply to one set of sample dimensions. It is not possible to allow for any change in specimen dimensions.
2. *Energy to break per unit width of sample*. In notched specimens this is taken as the energy to break per unit width of notch. In this case the results are quoted in units such as joules per millimeter of notch. The values obtained depend on the notch width. For example, it has been found that on reducing the notch width from ½″ to ⅛″ the impact strength of a PC increased by a factor of 5.4.
3. *The energy to break per fractured area*. This will be the cross-sectional area of the sample less than the area of the notch (as projected on the cross section). The units used in this method are most commonly kJ/m^2.

A related alternative to the Izod test is the Charpy test, preferred in ISO standards, in which a sample supported (not gripped) at each end is subject to an impact in the center. According to the test a notch may be present in the center of the sample on the face opposite to that subjected to impact.

Because of the diversity of the sources of data for this book, the Izod and Charpy data frequently referred to are expressed in a variety of units according to the test method used and little attempt has been made to convert the data to a common unit except to convert to metric units.

The presence of notches, sharp angles, voids, particle inclusions, and small inserts tends to concentrate stress on impact. One way of studying the sensitivity of a polymer or polymer compound to stress concentration is to carry out a series of tests with different notch angles or notch tip radii. Materials vary enormously in their notch sensitivity, as is shown in Figure 1.46. Materials, such as unplasticized PVC, nylon, polyacetals, and PCs (not shown in the diagram), are very sensitive to

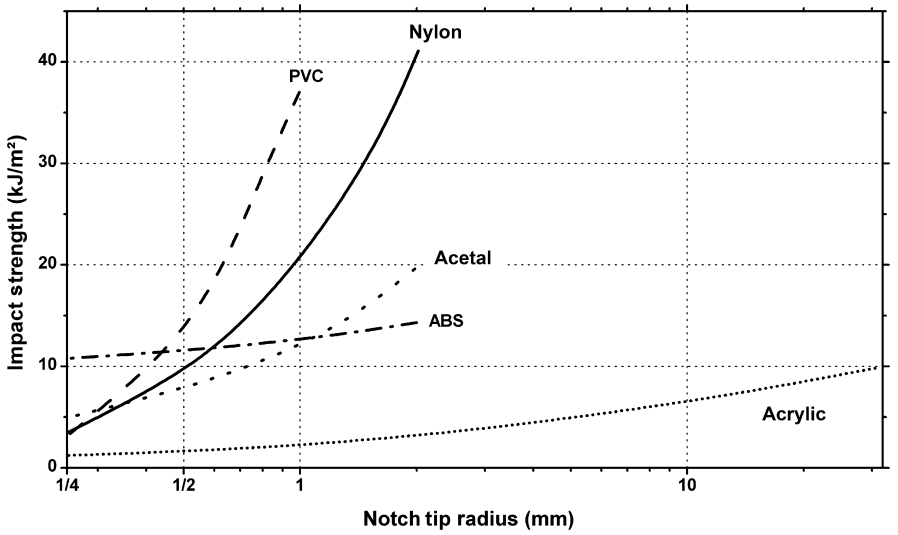


Figure 1.46 Impact strength vs. notch radius for various plastics.

sharp notches. ABS, although good at high stress concentrations, does not perform so well relative to PVC, nylon, and polyacetal at the blunter notch radii.

Other impact tests widely used are the falling weight tests, in which a weight is allowed to fall onto a supported flat or domed surface, and the tensile impact tests in which a sample is subjected to a sudden shock in tension. Whilst the last named test provides results more amenable to theoretical study, plastic products are not commonly subjected to this type of impact and producer data are limited.

1.4.6 Time-Dependent Behavior

Plastics are affected by stress, impact, temperature, and environmental conditions and these are all time dependent. Long-term behavior is the subject of another book in this series and is not discussed further here.

1.4.7 Selection Guides

Selection and evaluation of materials can be very complex. The following series of questions is based on material from San Diego Plastics website. It shows the wide variety of considerations one must take when selecting a plastic material for an application.

It may be necessary to ask some or all of the following questions to define the performance needs of a plastic material for a particular application.

1. What load will the plastic part have to carry?
   a. Will it carry high loads?
   b. What will the highest load be?
   c. What is the maximum stress in the part?
   d. What kind of stress is it (tensile, flexural, torsional, etc.)?
   e. How long will the load be applied?
   f. What is the projected life of the part?

   Thermosets often perform well under high continuous loads. Reinforced thermoplastics, such as thermoplastic polyester, may also perform satisfactorily.

2. Will the part have to withstand impact?
   a. Will the part be subjected to impact?
   b. Which impact test/data most nearly duplicates the impact occurring in this application?

   Reinforced plastics such as glass-reinforced thermosets like epoxy, melamine, or phenolic generally have good impact strength. PC and UHMW PE also exhibit excellent impact resistance.

3. Will the part see cyclic loading (fatigue)?
   a. Will the part be subjected to a variable load?
   b. Is the load alternating compressive/tensile?
   c. What will the stress levels be?
   d. What is the thickness of the part being flexed?
   e. How much will the part be deflected?

Fatigue is the subject of another book in this series and is not discussed in this book. However, materials like acetal and nylon are generally good candidates for cyclic loading.

4. What temperatures will the part see and for how long?
   a. What is the maximum temperature the material will see in use?
   b. What is the minimum temperature the material will see in use?
   c. How long will the material be at these temperatures?
   d. Will the material have to withstand impact at the low temperature?

5. Will the material be exposed to chemicals or moisture?
   a. Will the material be exposed to normal relative humidity?
   b. Will the material be submerged in water? If so, at what temperature?
   c. Will the material be exposed to steam?
   d. Will the material be autoclaved?
   e. Will the material be painted?
   f. Will the material be submerged or wiped with solvents or other chemicals? If so, which ones?
   g. Will the material be exposed to chemical or solvent vapors? If so, which ones and at what temperature?
   h. Will the material be exposed to other materials that can outgas or leach detrimental materials, such as plasticizers?

   Fluoroplastics, crystalline and thermoset materials generally exhibit good chemical resistance. Chemical resistance is the subject of other books and databases in this series.

6. Will the material be used in an electrical application?
   a. What voltages will the part be exposed to?
   b. Alternating (AC) or direct (DC) current?
   c. If AC, what frequencies?
   d. Where will the voltage be applied (opposite side of the material, on one surface of the material, etc.).

   Enough carbon reinforcement can make a plastic conductive. Temperature can also dramatically affect electrical properties.

7. Will the material be used as a bearing or need to resist wear?
   a. Will the material be expected to perform as a bearing?
   b. If so, what will the load, shaft diameter, shaft material, shaft finish, and rpm be?
   c. What wear or abrasion conditions will the material see?
   d. Will a lubricant be used?

   Materials with friction reducers added, such as PTFE, molybdenum disulfide, or graphite, generally exhibit less wear in rubbing applications. Tribology is the subject of another book in this series.

8. Does the part have to retain its dimensional shape?
   a. What kind of dimensional stability is required?

   An application requiring a very high level of dimensional stability may not be suitable for plastic materials. Remember that plastic materials generally expand and contract more with changes in temperature than do metals. They may also expand and contract different amounts in different directions (flow and cross flow).

   The most stable plastics are reinforced with glass, minerals, etc.

9. Will the material have to stretch or bend a lot?
   a. Are rubber-like properties needed?
   b. Does the material have to stretch?

   A flexible material, such as flexible vinyls, urethanes, rubber, or a TEO, may be used.

10. Will the part have to meet any regulatory requirements?
    a. Is a UL listed material required? If so, which rating?
    b. Is a UL yellow card required?
    c. Is a low smoke generating material required (FAA)?
    d. Is an FDA approved material required?
    e. Does the material have any taste or odor?

    Make sure the supplier has approval from the desired agency and not just its own lab. Obtain written proof of approval.

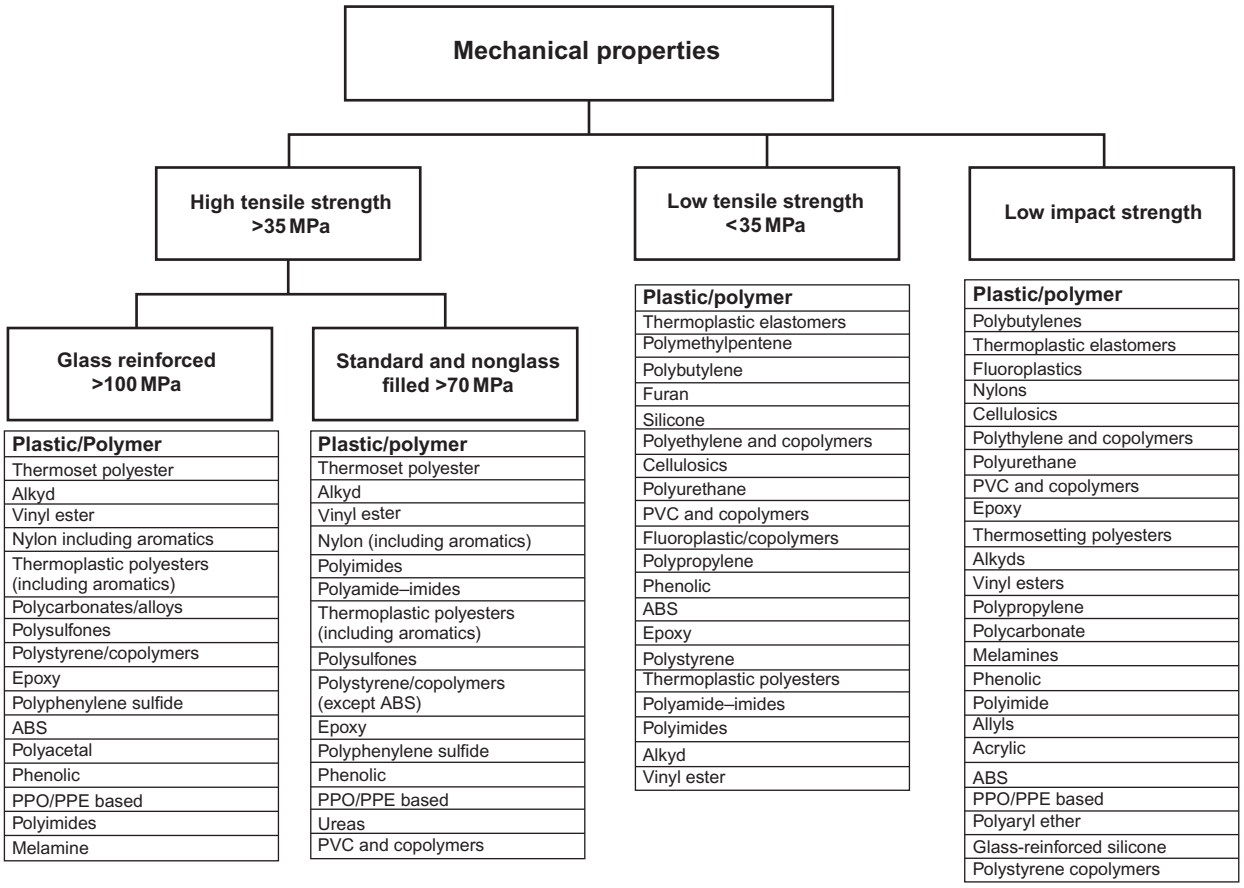


Figure 1.47 Selection guide based on mechanical properties.

11. Does the material or film have to prevent certain gases or liquids from passing through?
    a. Does the material have to be impermeable to gases and/or liquids? If so, which ones? Permeability is the subject of another book in this series.

    This is important for packaging foods and some medical applications.

12. Will the part be exposed to any radiation?
    a. Will the material be exposed to radiation? If so, how much and how long?

    This requirement could occur for military, utility (atomic power plants), or medical applications. The effects of radiation and sterilization methods are the subject of another book in this series.

13. Does the material have to have a special color and/or appearance?
    a. What color material is desired?
    b. Does it have to match anything else?
    c. Is a textured surface needed?

14. Does the part have any optical requirements?
    a. Does the material need to be transparent?
    b. Does the material need to transmit any particular wavelengths? If so, which ones?

    Acrylics, PCs, and amorphous polymers (such as amorphous nylon) in general have excellent optical properties.

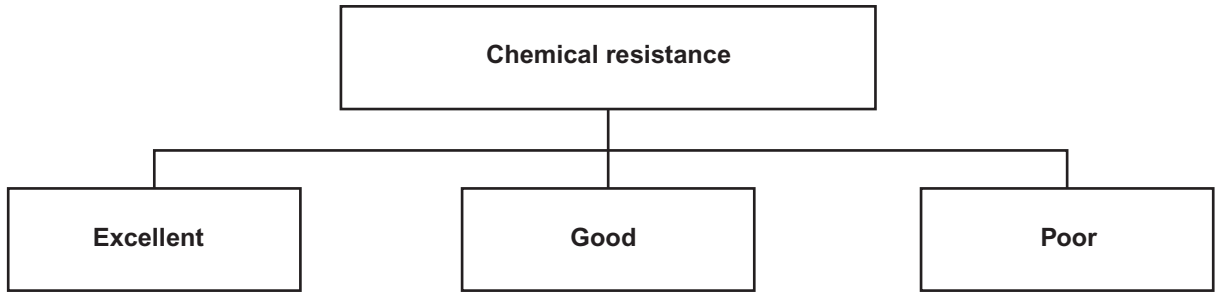
15. Will the part be used outdoors?

    Acrylics have excellent weatherability. UV-stabilized compounds are often used. The effects of UV light and weather are the subject of another book in this series.

16. Can the material give off any volatiles?

    This is often referred to as outgassing and usually occurs at elevated temperatures.

The remainder of this section contains several general selection guides in graphical form (Figures 1.47–1.51). There are plastics in these guides that are not discussed in this book. These are generally thermosets.

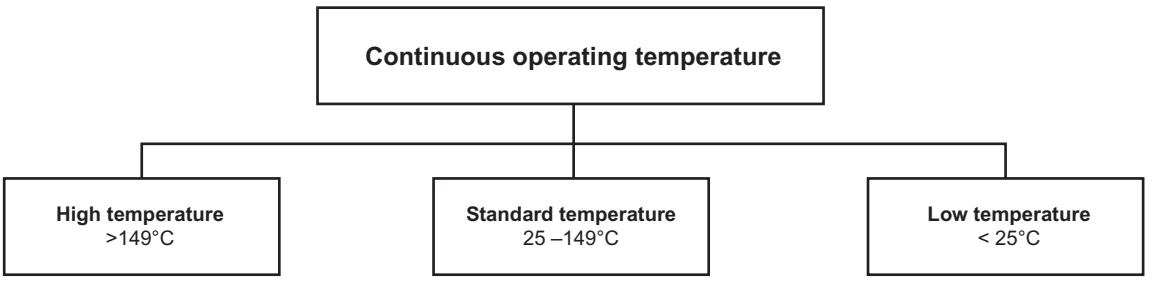


Plastic/polymer
Fluoroplastics
Polyimides
Polyolefins
Acetals
Polyphenylene sulfide
Allyls
Epoxies
Ionomers
Polyamide–imide

Plastic/polymer
Polyesters
Silicones
Phenolics
Polysulfones
Nylons
Vinyls
Polyurethanes
Acrylics
Alkyds
Styrene acrylonitrile
Aminoplastics
Polyaryl ethers
Polyaryl sulfones

Plastic/polymer
Styrenics
Cellulosics
Polycarbonate

Figure 1.48 Selection guide based on chemical resistance.



Plastic/polymer	°C
Polyimides	260–427
Silicones	204–316
Fluoroplastics	149–288
Polyamide–imide	271–285
Epoxy	79–260
Polyphenylene sulfide	260
Allyls	149–232
Phenolics	100–232
Polyethersulfones	204
Polysulfones	171–204
Melamines	149–204
Thermoset polyester	66–204
Ureas	93–177
Acrylate rubber	204
Fluorosilicones	204
Nylons	107–177
Thermoplastic polyester	154–160
Polyarylether	121–160
Polymethylpentene	121–160
Polycarbonate	82–154
Alkyds	121–149
Chlorinated polyethylene	149

Plastic/polymer	°C
PPO/PPE based	77–127
Polypropylene	96–121
Polyurethane	88–121
Vinyls	66–110
Polybutylene	107
Acetals	91–104
ABS and SAN	71–104
Polystyrene	52–96
ABS/Polycarbonate alloy	88–93
Acrylics	60–93
Cellulosics	49–93
Polyethylene and copolymers	49–82

Plastic/polymer	°C
Chlorinated polyethylene	–51
Polyurethane	–65
Fluorosilicone	–68
Silicone	–118
Fluoroplastics	–184

Figure 1.49 Selection guide based on continuous operating temperature.

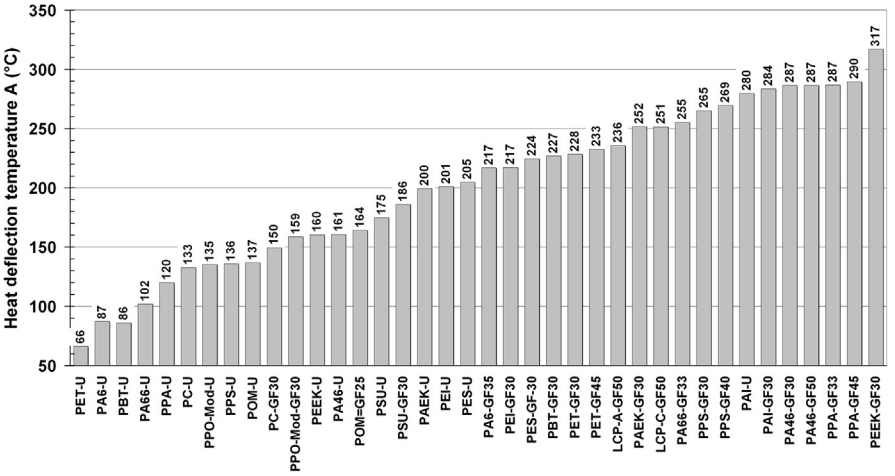


Figure 1.50 Heat deflection data on generic family of plastics.

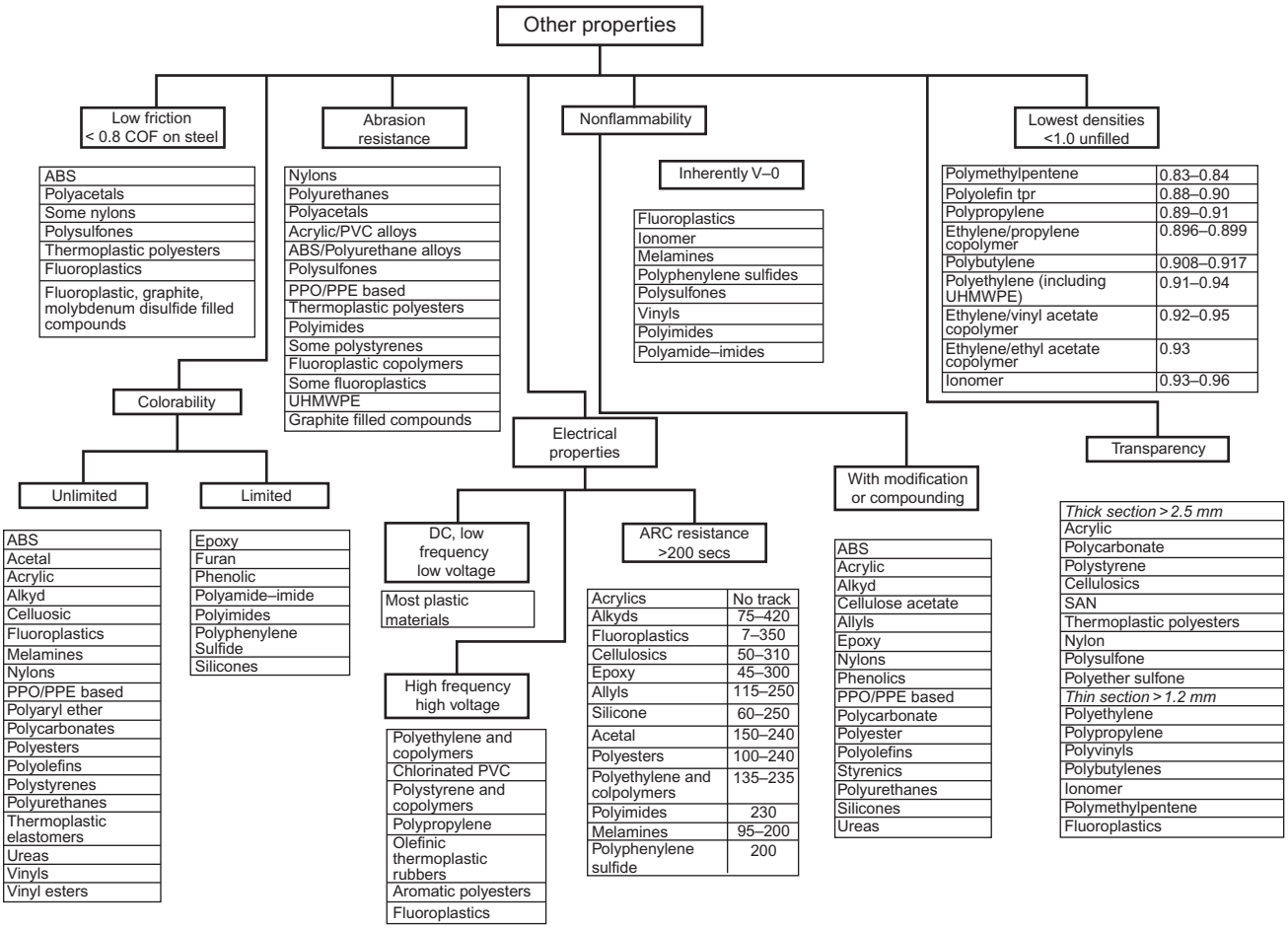


Figure 1.51 Selection guide based on other properties.

1.5 Summary

The rest of this book consists of property data on many plastics and elastomers. Chapters 2–10 contain multipoint data in the form of plots. The plastics are grouped by the basic chemical structures of the plastics. Each of these chapters contains a short introduction that describes the basic chemical structures of the plastics in that chapter. The figures that follow contain the multipoint data. They are grouped by the type of data. Generally stress vs. strain curves start the chapter, followed by various modulus measurements, strength measures, other physical properties, and electrical properties. These properties are measured by the appropriate ISO or ASTM standards.

Chapter 11 contains mechanical and electrical data on hundreds of plastics in tabular form. These data are described in the standard ISO 10350-1:1998, which is titled: *Plastics—Acquisition and Presentation of Comparable Single-point Data—Part 1: Moulding Materials*. This standard ISO 10350 identifies specific test procedures for the acquisition and presentation of comparable data for many basic properties of plastics. The properties included are often in manufacturers' technical data sheets. All the data are defined by ISO standards rather than ASTM standards. Part 1 applies to unreinforced and reinforced thermoplastic and thermosetting materials. While similar ASTM standard-based data may be available, these tables do not include those data.

Chapter 12 contains thermal data in tabular form similar to that of Chapter 11.

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[8] This is a file from the Wikimedia Commons which is a freely licensed media file repository.

2 Styrenic Plastics

This chapter on styrenic plastics covers a broad class of polymeric materials of which an important part is styrene. Styrene, also known as vinyl benzene, is an organic compound with the chemical formula $C_6H_5CH{=}CH_2$. Its structure is shown in Figure 2.1.

It is used as a monomer to make plastics such as polystyrene (PS), acrylonitrile butadiene styrene (ABS), styrene acrylonitrile (SAN), and other polymers discussed in this chapter.

2.1 Acrylonitrile Butadiene Styrene (ABS)

ABS is a common thermoplastic used to make light, rigid, molded products such as pipe, automotive body parts, wheel covers, enclosures, and protective head gear. It is also used in 3D printing technology.

SAN copolymers have been available since the 1940s and while its increased toughness over styrene made it suitable for many applications, its limitations led to the introduction of a rubber, butadiene, as a third monomer and hence was born the range of materials popularly referred to as ABS plastics. These became available in the 1950s and the availability of these copolymers and ease of processing has led ABS to become one of the most popular of the engineering polymers.

ABS is a polymer made by copolymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions of the ingredients can range from 15 to 35% acrylonitrile, 5−30% butadiene, and 40−60% styrene. It can be found as a graft copolymer, in which SAN polymer is formed in a polymerization system in the presence of polybutadiene rubber latex; the final product is a complex mixture consisting of SAN copolymer, a graft polymer of SAN and polybutadiene, and some unchanged polybutadiene rubber. This is shown in Figure 2.2.

The nitrile (−C≡N) groups from neighboring chains, being polar (see Section 1.1.4), attract each other and hold the chains together, making ABS stronger than pure PS.

The styrene gives the plastic a shiny, impervious surface. The butadiene, a rubbery substance, provides resilience even at low temperatures.

There are, therefore, many variables to the process besides the different positions of the starting materials, so this technique is capable of producing polymers with a much wider range of properties [1].

ABS can also be made by blending. The technique involves mechanical blending by mixing a butadiene−acrylonitrile rubber with SAN resins, the process being carried out under such conditions that the two polymers undergo some grafting. This technique is rather limited and has been largely superseded by the chemical process.

The advantage of ABS is that it combines the strength and rigidity of the acrylonitrile and styrene polymers with the toughness of the polybutadiene rubber. The most remarkable mechanical properties of ABS are resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance. For example, the impact resistance can be improved by increasing the proportions of polybutadiene in relation to styrene and acrylonitrile, although this causes changes in other properties. Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads. Even though ABS plastics are used largely for mechanical purposes, they also have good electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperatures [2]. The final properties will be influenced to some extent by the conditions under which the material is processed to the final product; for example, molding at a high temperature improves the gloss and heat resistance of the product whereas the highest impact resistance and strength are obtained by molding at low temperature.

ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
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oils, but they swell when exposed to glacial acetic acid, carbon tetrachloride, and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids. They are soluble in esters, ketones, and ethylene dichloride. The aging characteristics of the polymers are largely influenced by the polybutadiene content, and it is normal to include antioxidants in the composition.

Grades available: There are at least 1700 ABS available. Grades have been developed specifically to meet the requirements of major customers. ABS is readily modified both by the addition of additives and by variation of the ratio of the three monomers: acrylonitrile, butadiene and styrene; hence grades available include high and medium impact, high heat resistance, and electroplatable. Fiber reinforcement can be incorporated to increase stiffness and dimensional stability. ABS is readily blended or alloyed with other polymers, further increasing the range of properties available. Fire retardancy may be obtained either by the inclusion of fire retardant additives or by blending with polyvinyl chloride. The natural ABS is an opaque ivory color and is readily colored with pigments or dyes. Transparent grades are also available.

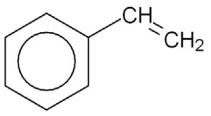

Figure 2.1 Chemical structure of styrene.

Manufacturers and trade names: SABIC Innovative Polymers Cycolac™, INEOS Lustran® and Novodur®, Perrite Ronfalin®, Styron Magnum™, and BASF AG Terluran®.

Applications and uses: medical devices, cosmetics, housewares, automobiles, business equipment, cabinets and casings, baths, shower trays, pipes, boat hulls and vehicle components, and 3D printing.

Data for ABS plastics are found in Figures 2.3–2.37.

2.2 Methyl Methacrylate–Acrylonitrile–Butadiene–Styrene (MABS) Polymer

MABS is similar to ABS except for the addition of an additional monomer, usually methyl methacrylate. MABS is an amorphous, clear, transparent material with thermal and mechanical properties like ABS. The transparency is achieved by matching the refractive indices of the matrix resin (the transparent acrylate–acrylonitrile–styrene polymer) with the polybutadiene rubber impact modifier. MABS has the highest impact resistance of all the styrenic plastics. Sometimes called transparent

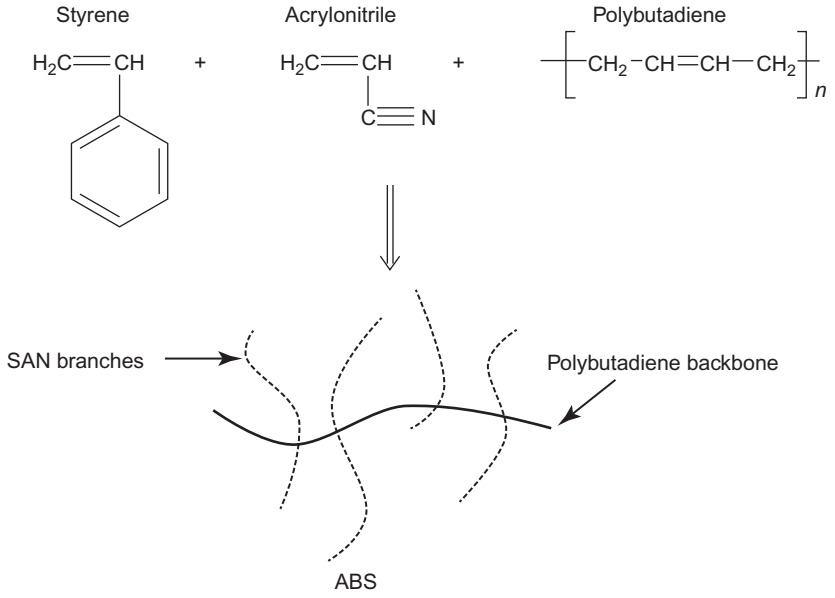

Figure 2.2 Polymerization of ABS.

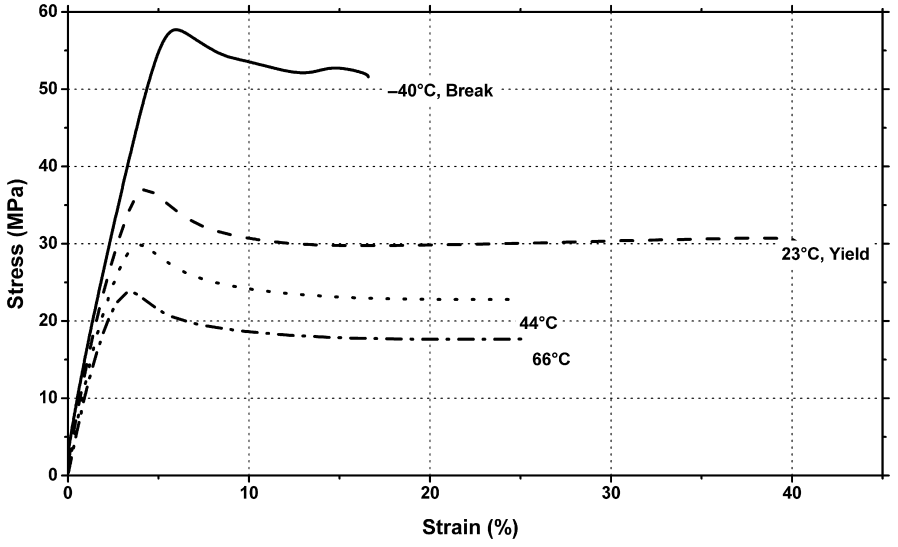

Figure 2.3 Tensile stress vs. strain for SABIC Innovative Plastics Cycolac™ EX39—highest impact extrusion ABS resin for sheet and blow molding applications.

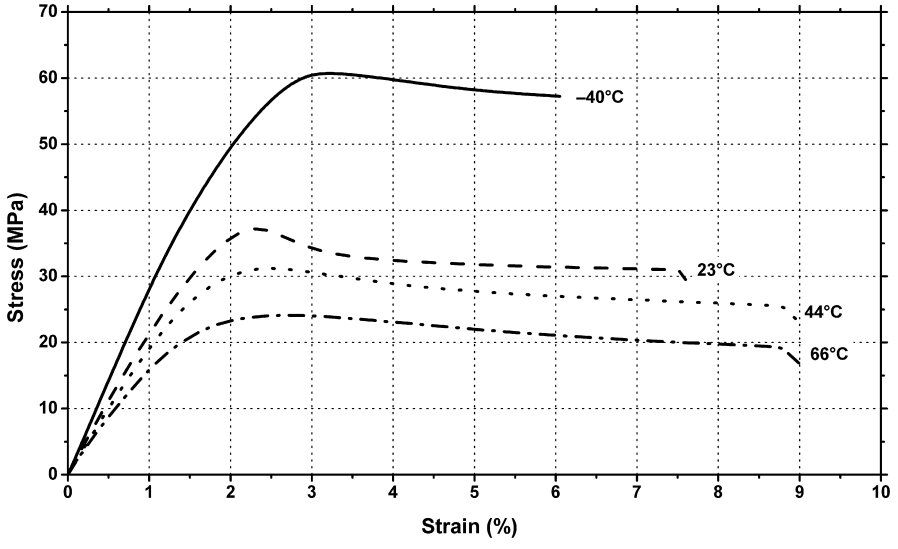

Figure 2.4 Tensile stress vs. strain for SABIC Innovative Plastics Cycolac™ KJB—medium impact, wide processing range ABS resin.

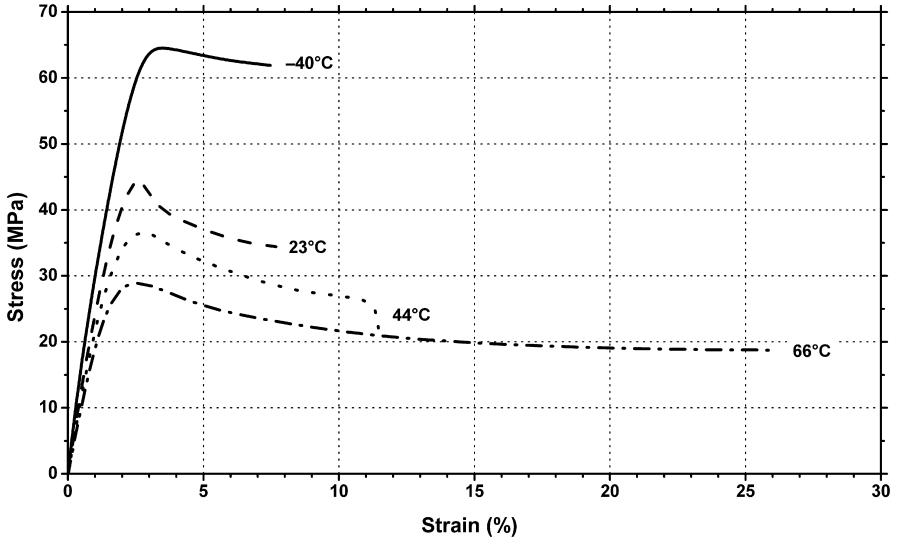

Figure 2.5 Tensile stress vs. strain for SABIC Innovative Plastics Cycolac™ MGABS01—high impact, high gloss, good flow injection molding ABS resin.

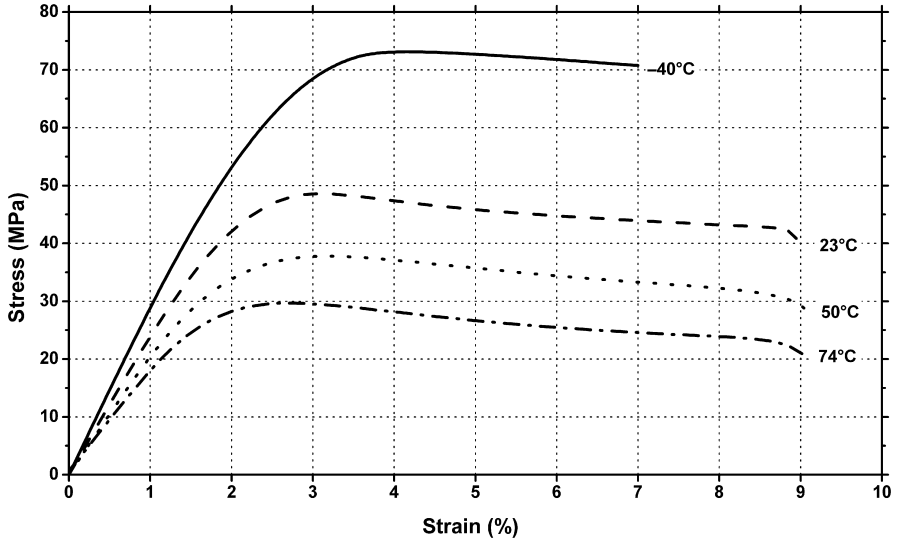

Figure 2.6 Tensile stress vs. strain for SABIC Innovative Plastics Cycolac™ Z48—high heat resistance, medium impact, good strength ABS resin for automotive use.

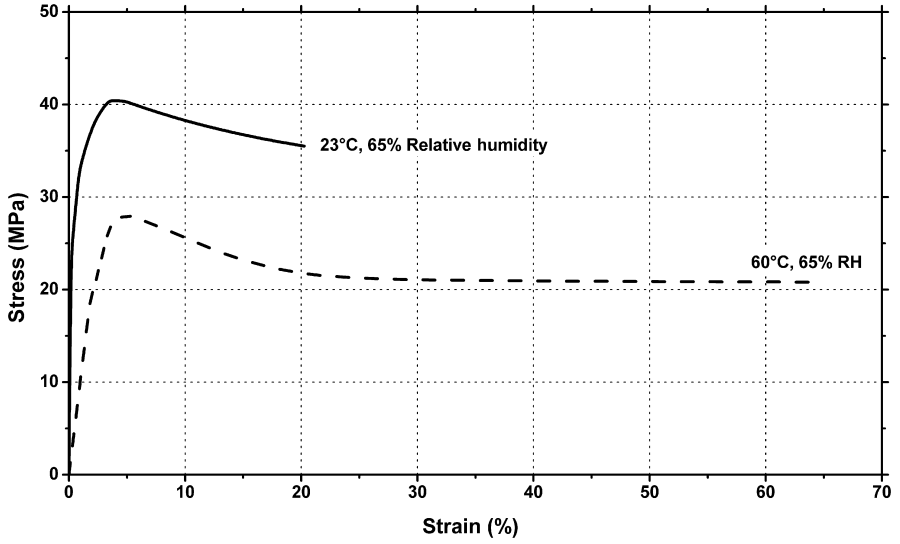

Figure 2.7 Tensile stress vs. strain for Toray Plastics Toyolac™ 100—general purpose, high impact strength ABS resin.

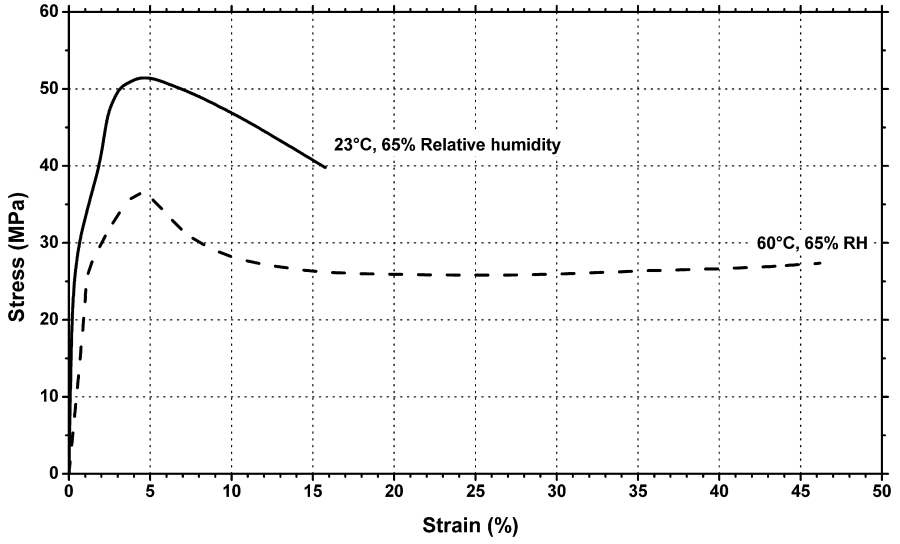

Figure 2.8 Tensile stress vs. strain for Toray Plastics Toyolac™ 500—general purpose, high rigidity ABS resin.

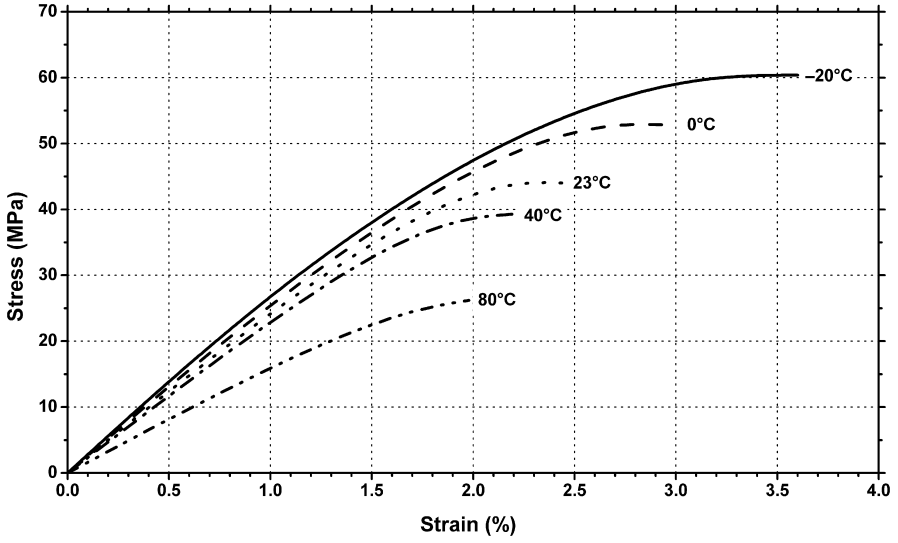

Figure 2.9 Tensile stress vs. strain for Styrolution Novodur® P2H-AT—standard impact, easy flow, high gloss, antistatic ABS resin.

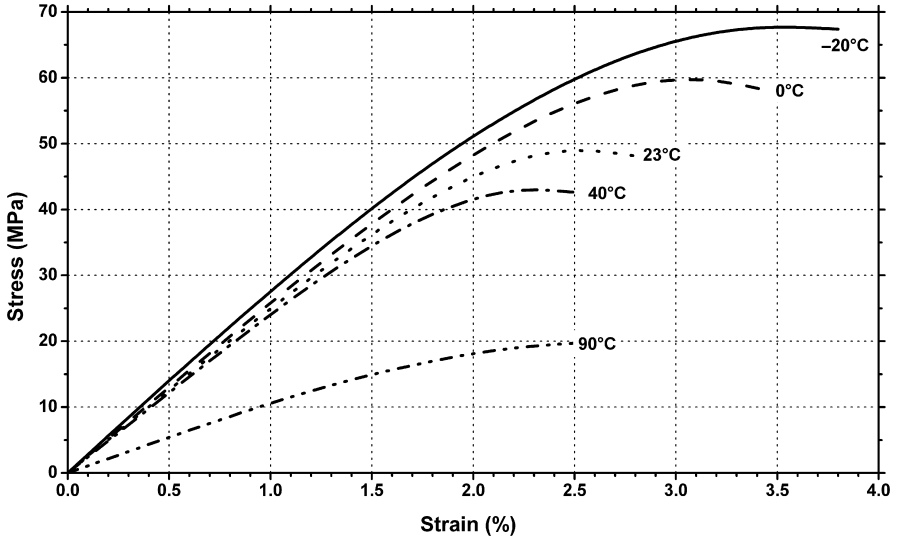

Figure 2.10 Tensile stress vs. strain for Styrolution Novodur® P3H-AT—improved chemical resistance, high gloss, antistatic ABS resin.

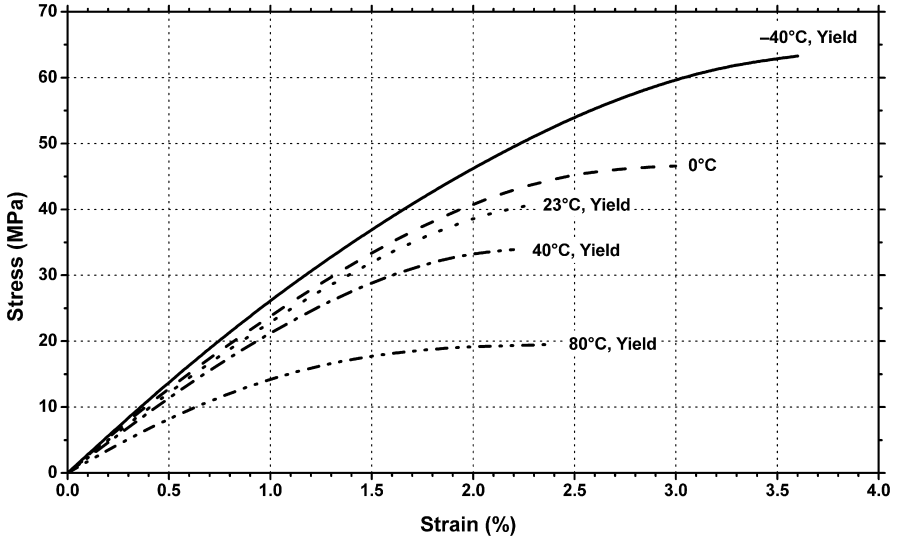

Figure 2.11 Tensile stress vs. strain for BASF Terluran® GP-22—general purpose ABS resin.

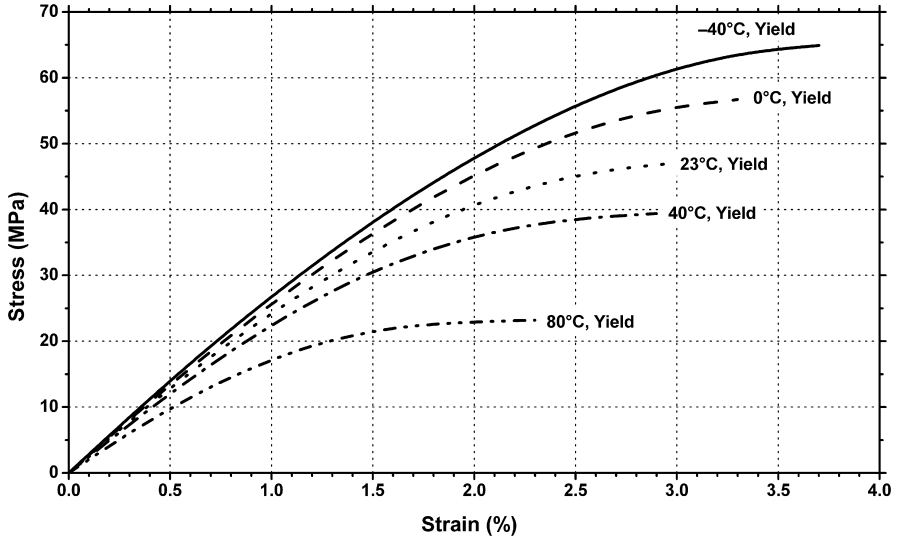

Figure 2.12 Tensile stress vs. strain for BASF Terluran® HH-106—high heat, high impact ABS resin.

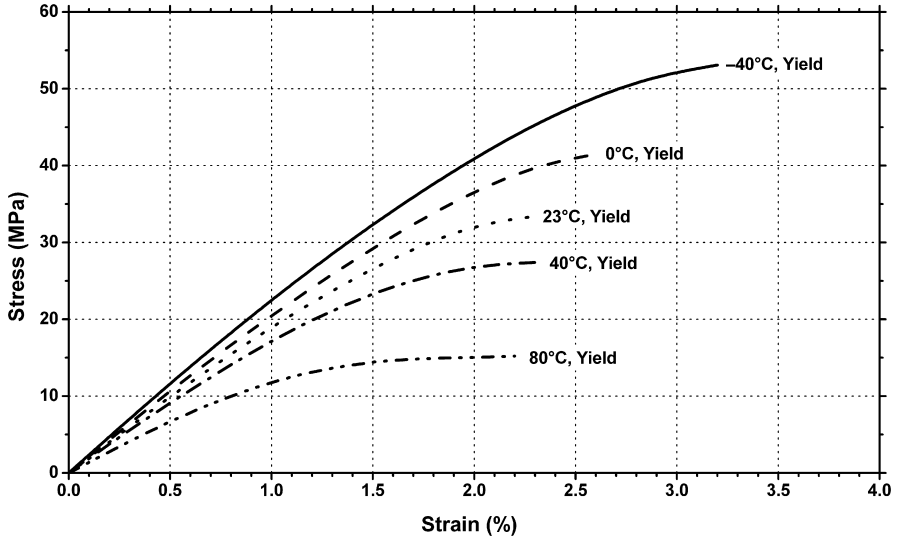

Figure 2.13 Tensile stress vs. strain for BASF Terluran® HI-10—high impact ABS resin.

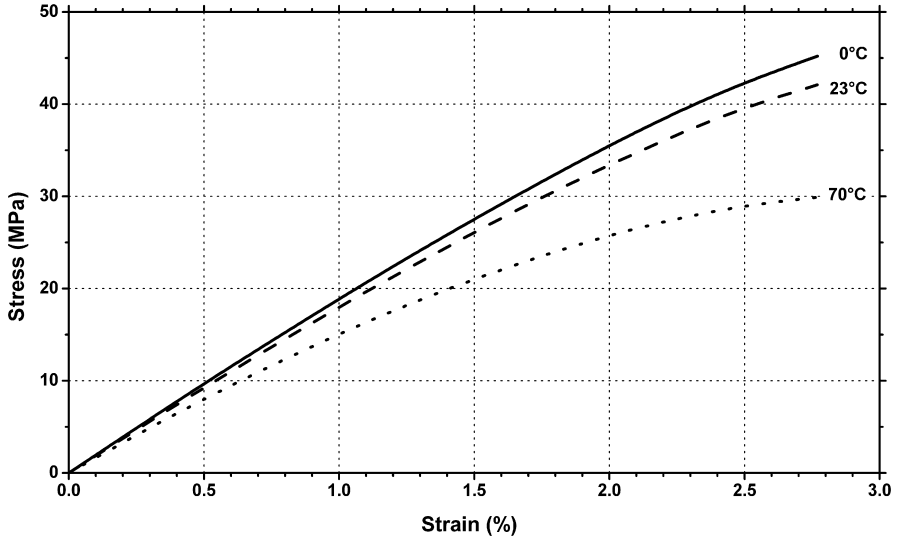

Figure 2.14 Tensile stress vs. strain for Styron Magnum™ 1040—high impact automotive ABS resin.

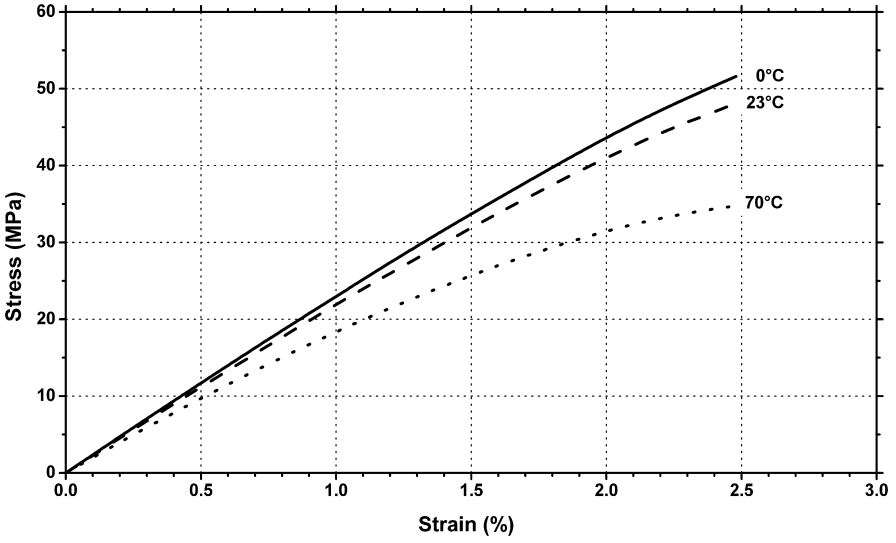

Figure 2.15 Tensile stress vs. strain for Styron Magnum™ 2620—healthcare ABS resin.

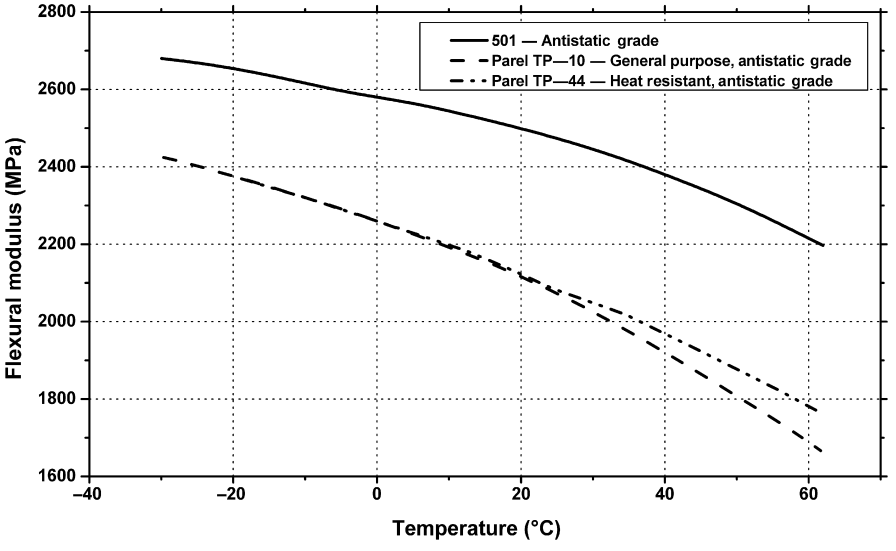

Figure 2.16 Flexural modulus vs. temperature for Toray Plastics Toyolac™ antistatic ABS resins.

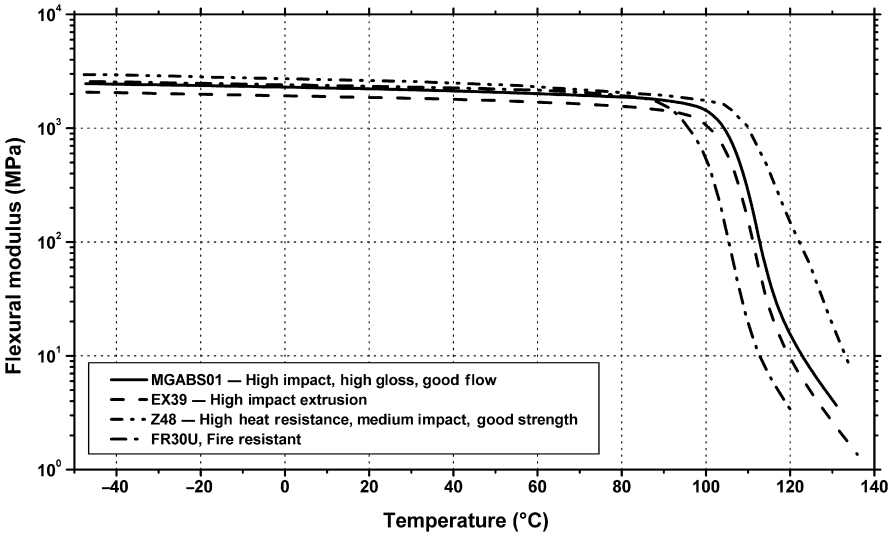

Figure 2.17 Flexural modulus vs. temperature for SABIC Innovative Plastics Cycolac™ ABS resins.

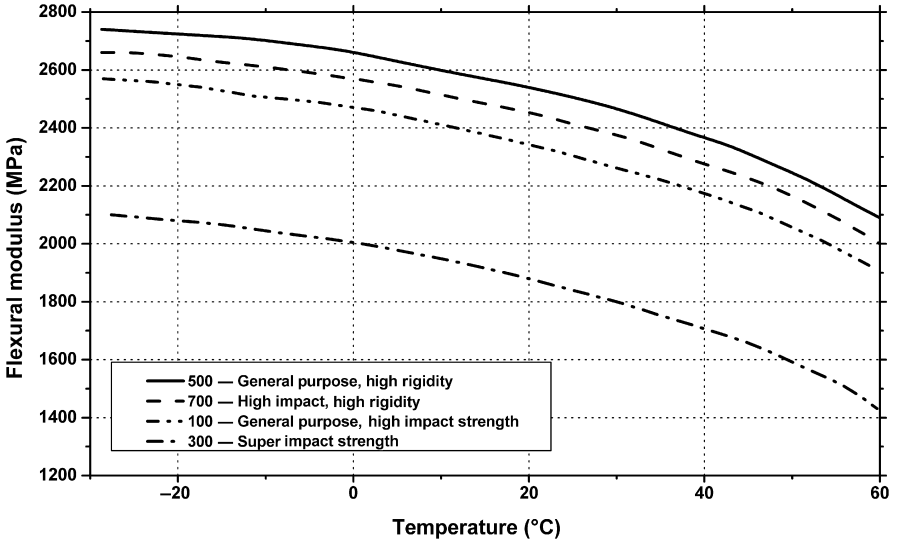

Figure 2.18 Flexural modulus vs. temperature for Toray Plastics Toyolac™ ABS resins.

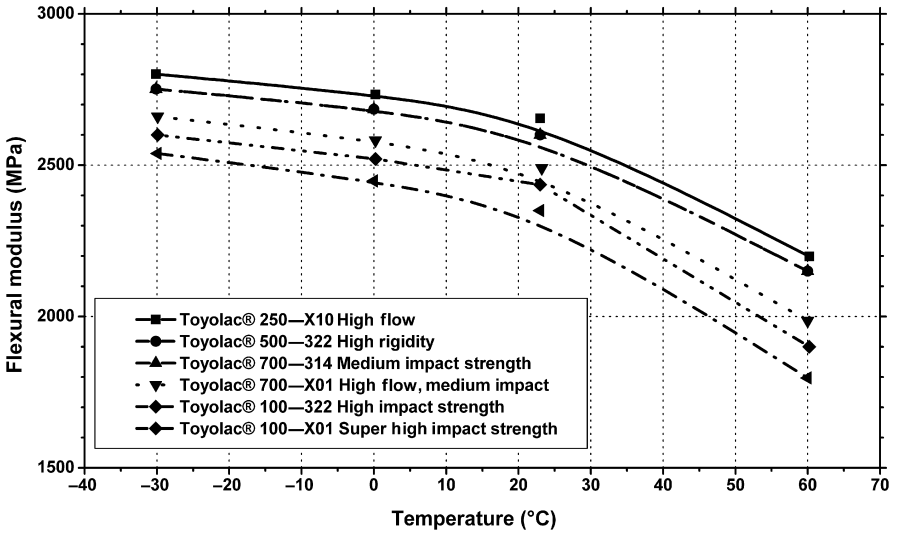

Figure 2.19 Temperature dependence of flexural modulus of Toray Plastics Toyolac™ GP grades [3].

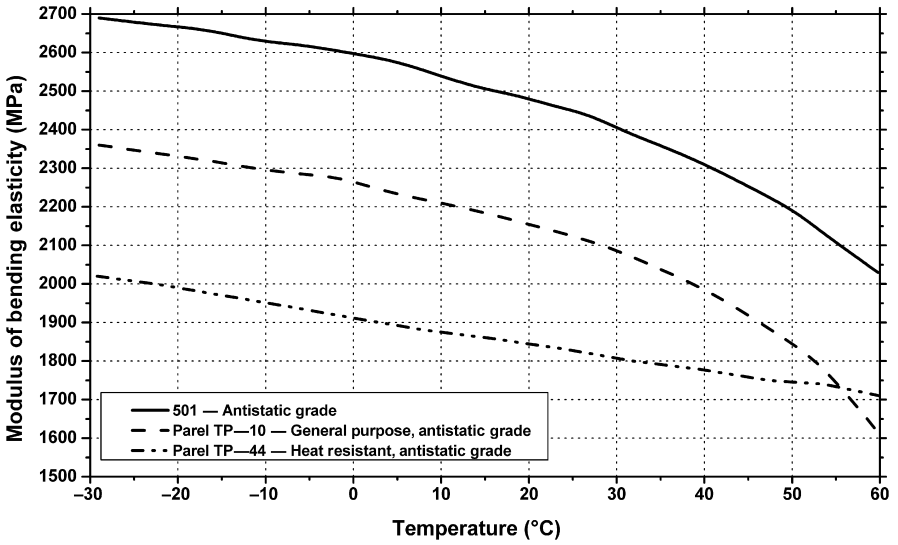

Figure 2.20 Modulus of bending elasticity vs. temperature for Toray Plastics Toyolac™ ABS resins.

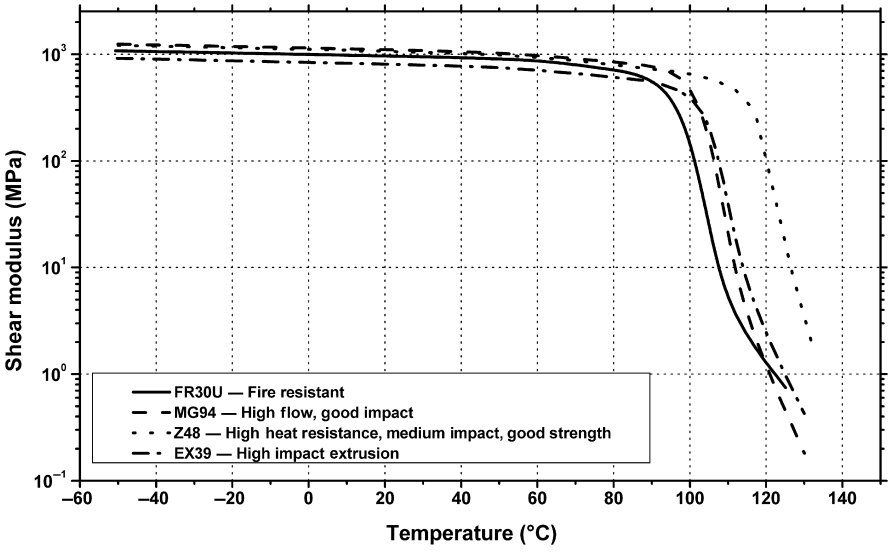

Figure 2.21 Shear modulus vs. temperature for SABIC Innovative Plastics Cycolac™ ABS resins.

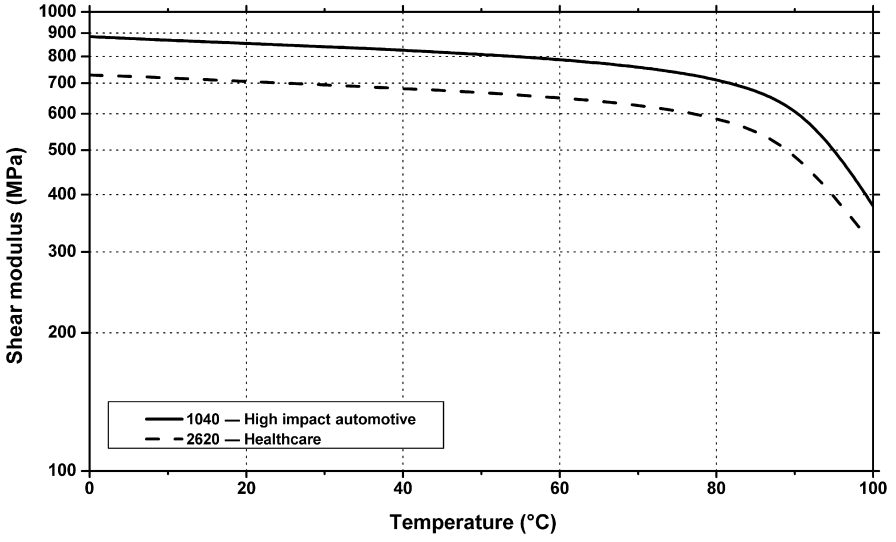

Figure 2.22 Shear modulus vs. temperature for Styron Magnum™ ABS resins.

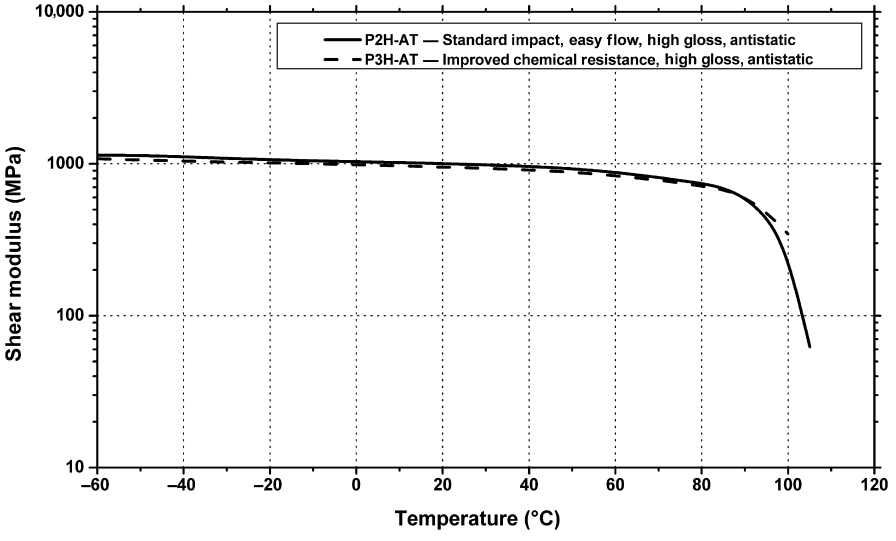

Figure 2.23 Shear modulus vs. temperature for Styrolution Novodur® ABS resins.

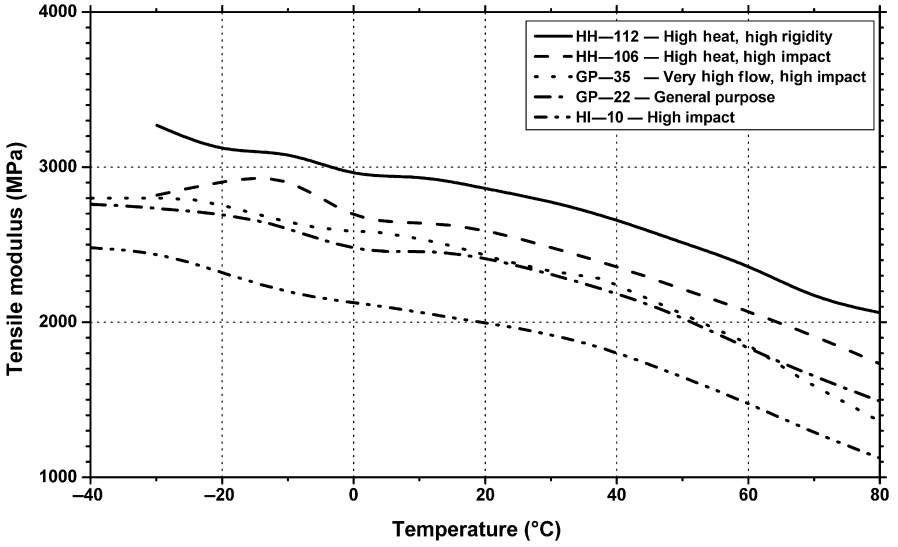

Figure 2.24 Tensile modulus vs. temperature for BASF Terluran® ABS resins.

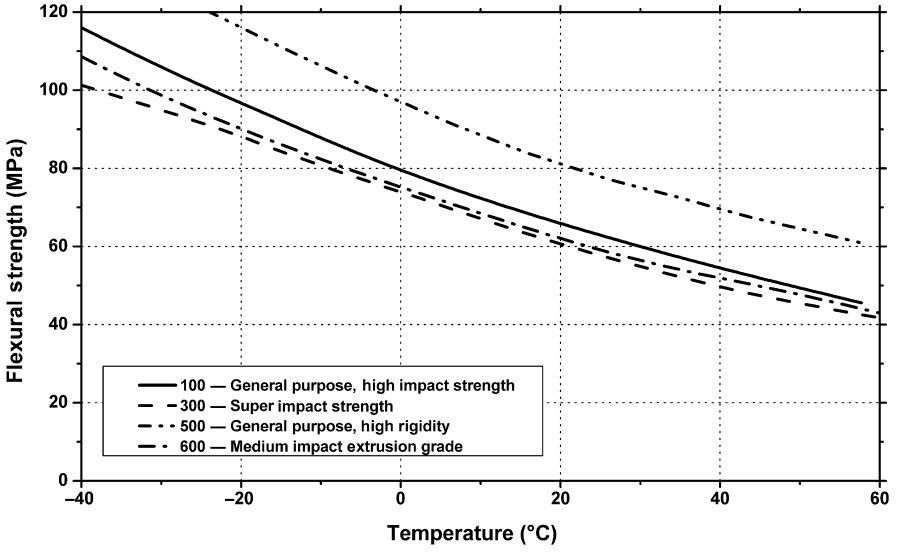

Figure 2.25 Flexural strength vs. temperature for Toray Plastics Toyolac™ ABS resins.

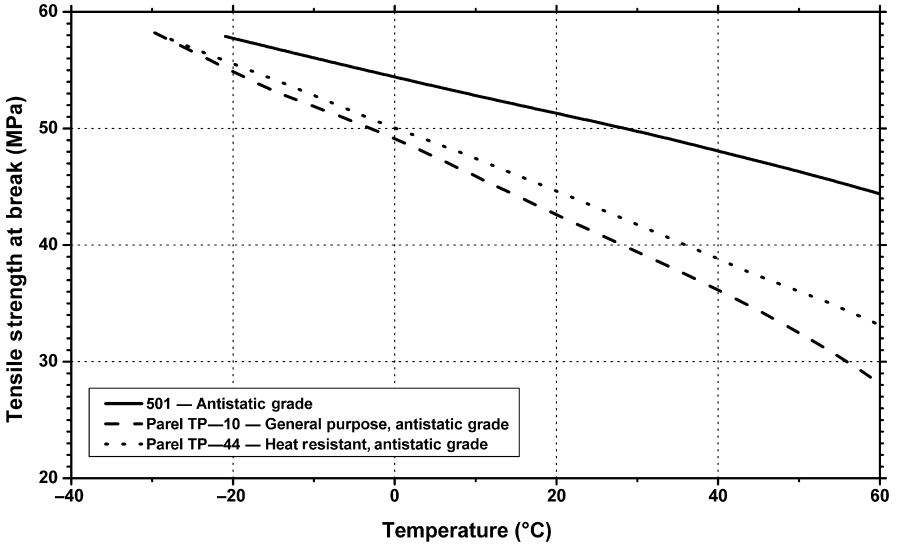

Figure 2.26 Tensile strength at break vs. temperature for Toray Plastics Toyolac™ antistatic ABS resins.

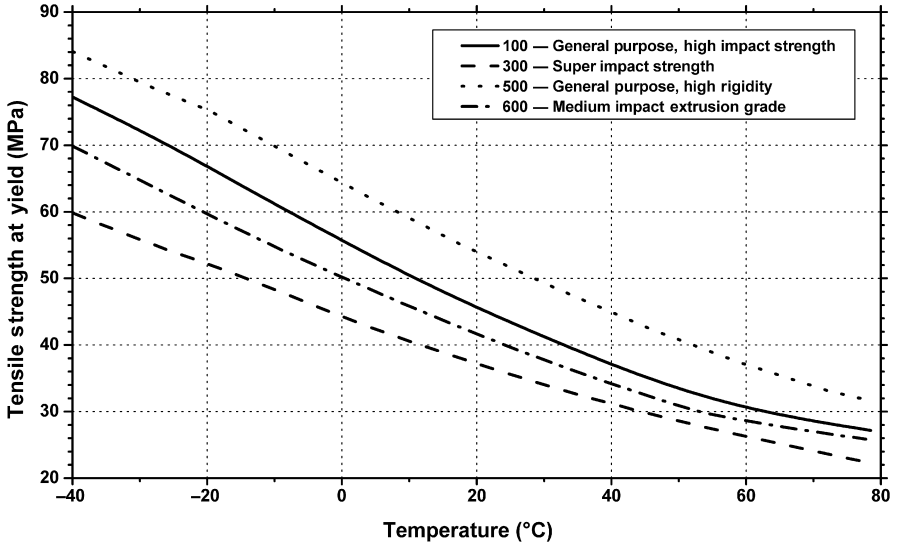

Figure 2.27 Tensile strength vs. temperature for Toray Plastics Toyolac™ ABS resins.

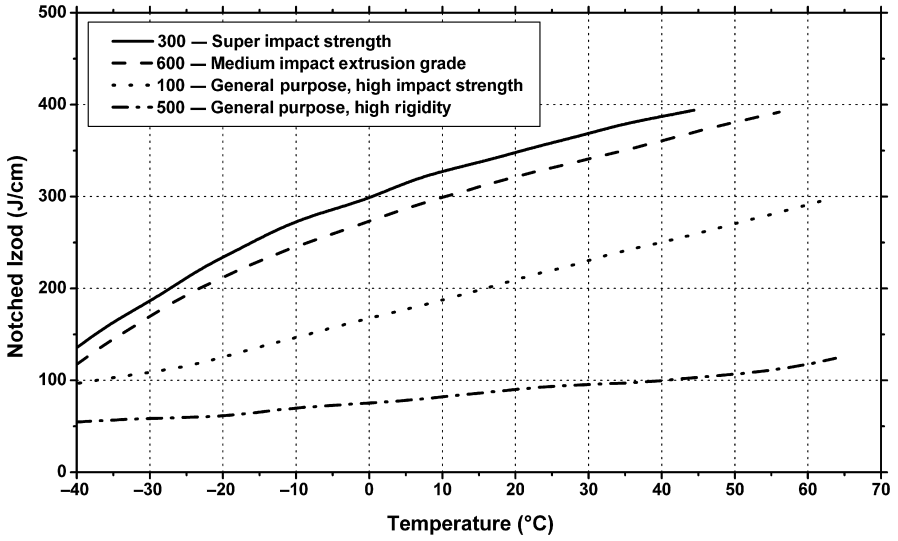

Figure 2.28 Izod impact strength vs. temperature for Toray Plastics Toyolac™ ABS resins.

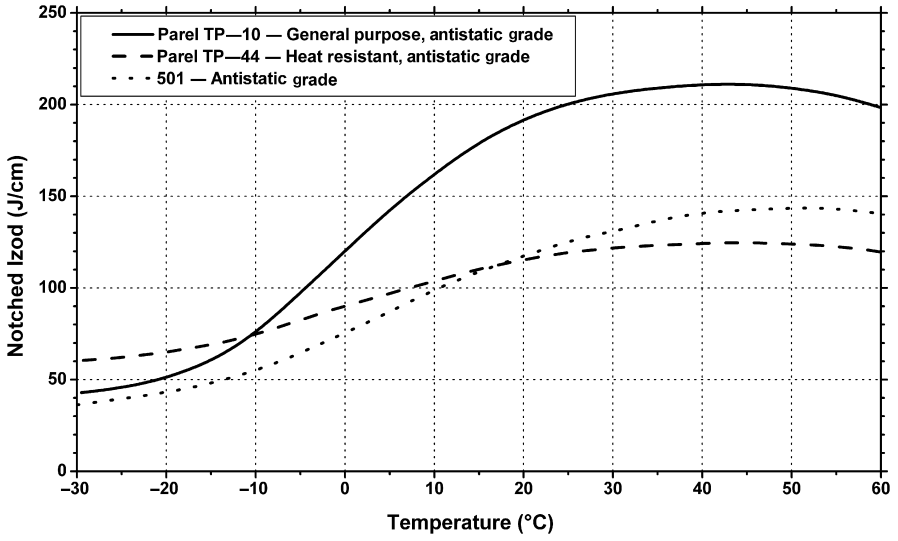

Figure 2.29 Izod impact strength vs. temperature for Toray Plastics Toyolac™ antistatic ABS resins.

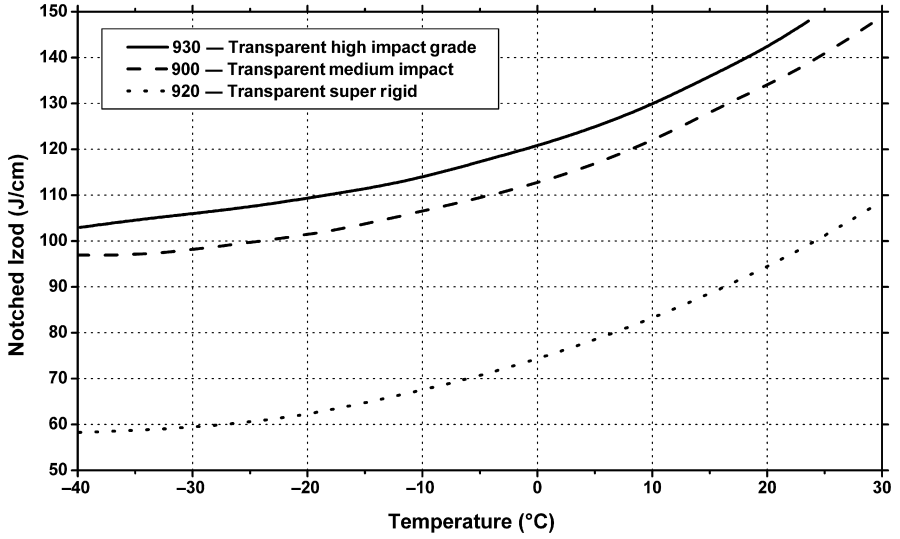

Figure 2.30 Izod impact strength vs. temperature for Toray Plastics Toyolac™ transparent ABS resins.

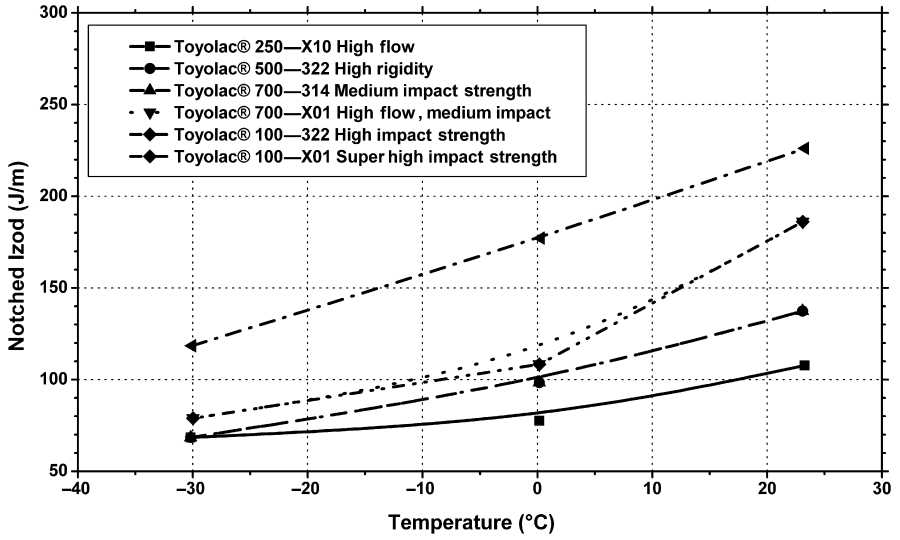

Figure 2.31 Temperature dependence of Izod impact strength of Toray Plastics Toyolac™ GP grades [3].

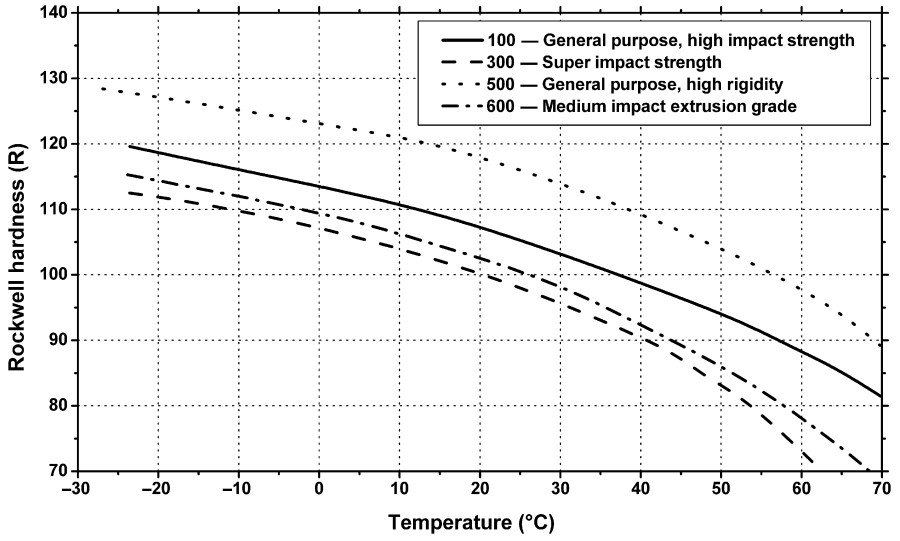

Figure 2.32 Rockwell hardness vs. temperature for Toray Plastics Toyolac™ ABS resins.

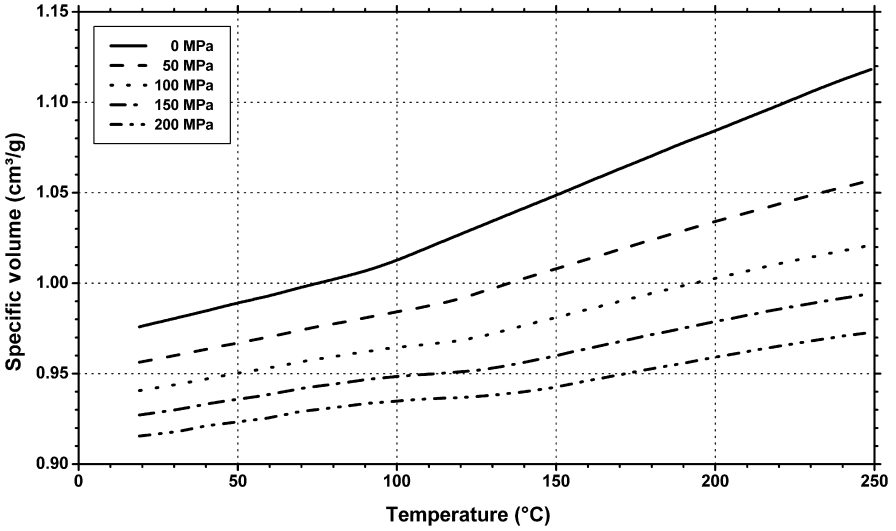

Figure 2.33 Specific volume as a function of temperature and pressure (PVT) for SABIC Innovative Plastics Cycolac™ Z48—high heat resistance, medium impact, good strength ABS resin for automotive use.

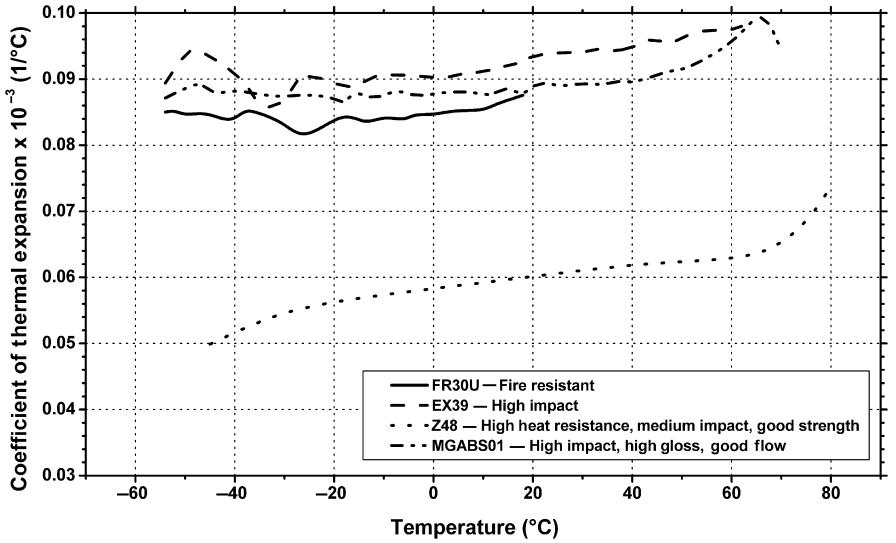

Figure 2.34 Coefficient of thermal expansion vs. temperature for SABIC Innovative Plastics Cycolac™ ABS resins.

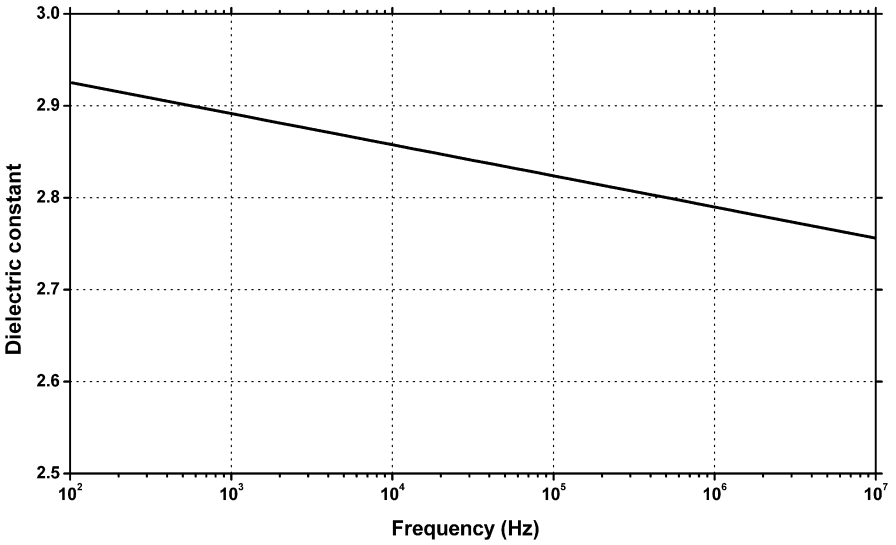

Figure 2.35 Dielectric constant vs. frequency for Styron Magnum™ ABS resin.

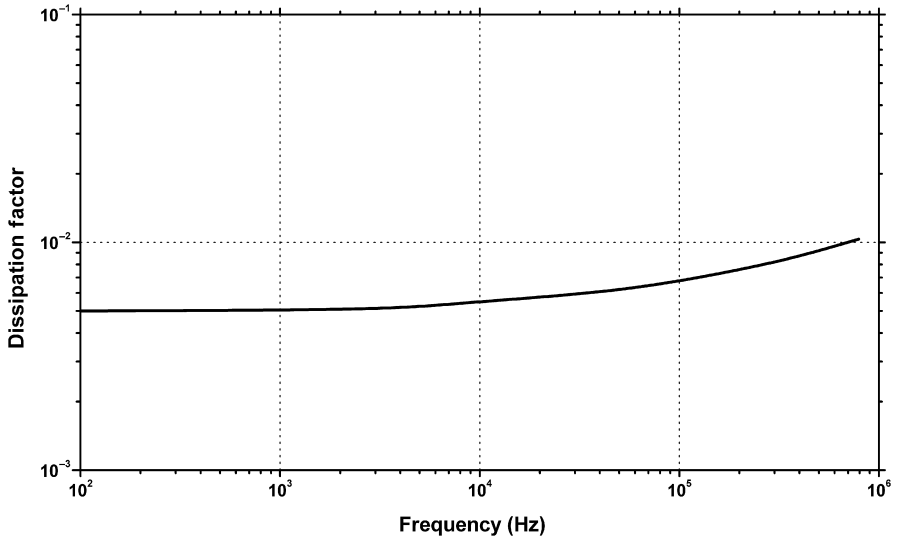

Figure 2.36 Dissipation factor vs. frequency for Styron Magnum™ ABS resin.

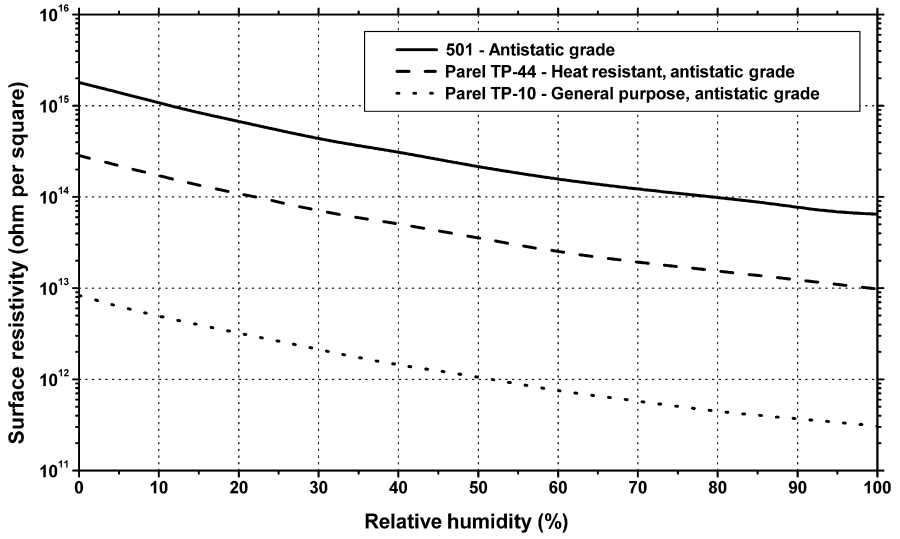

Figure 2.37 Surface resistivity vs. relative humidity for Toray Plastics Toyolac™ antistatic ABS resins.

ABS, MABS is often used as a modifier in other plastics.

Key properties of MABS are as follows:

- Excellent transparency
- High impact strength
- Good mechanical strength and rigidity
- High heat resistance
- Good resistance to chemicals and stress cracking
- Good processability

Manufacturers and trade names: Styrolution Terlux®, Samsung Stare®.

Applications and uses: these include laminates for skis and snowboards, aquarium accessories, hobby model construction, musical instruments such as recorders, fashion accessories such as watches, writing and typing equipment, mobile phones, transparent covers for PCs and copiers, and cosmetics packaging.

Data for MABS plastics are found in Figures 2.38–2.40.

2.3 Acrylonitrile Styrene Acrylate (ASA)

ASA is the acronym for acrylate rubber modified SAN copolymer. ASA is a terpolymer that can be produced by either a reaction process or by a graft process. ASA is usually made by introducing a

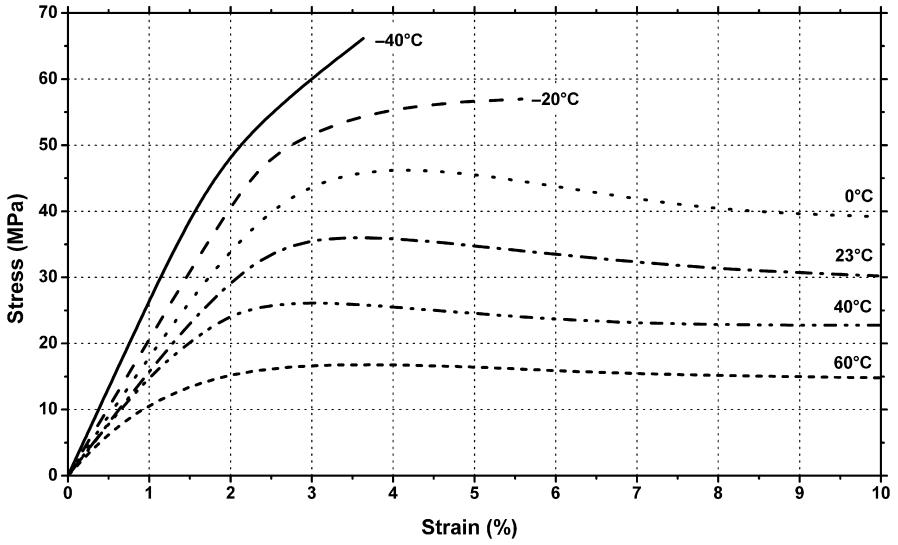

Figure 2.38 Stress–strain curves (ISO 527 tensile test on Styrolution Terlux® 2812 TR MABS resin as a function of temperature; tests terminated at 10% strain) [4].

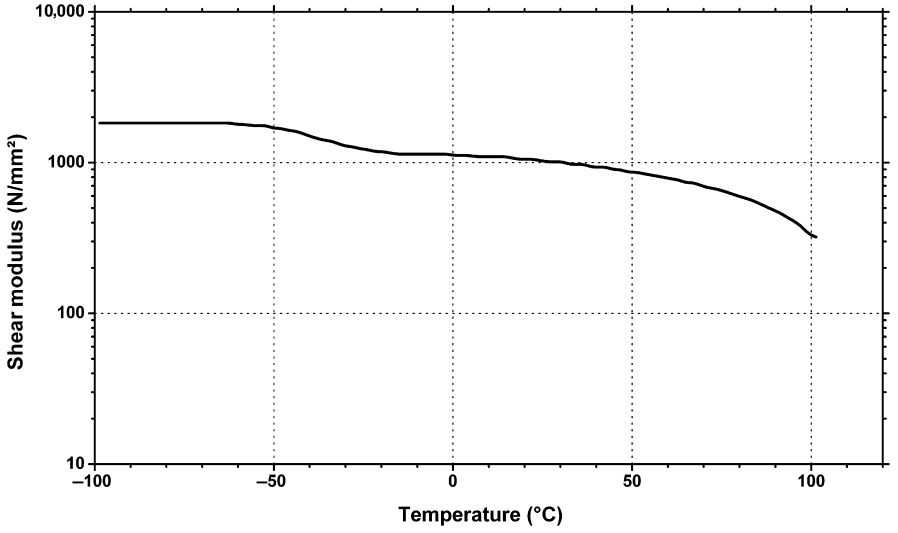

Figure 2.39 Shear modulus vs. temperature (DIN 53 455 torsion pendulum test) for Styrolution Terlux® 2802 TR MABS resin [4].

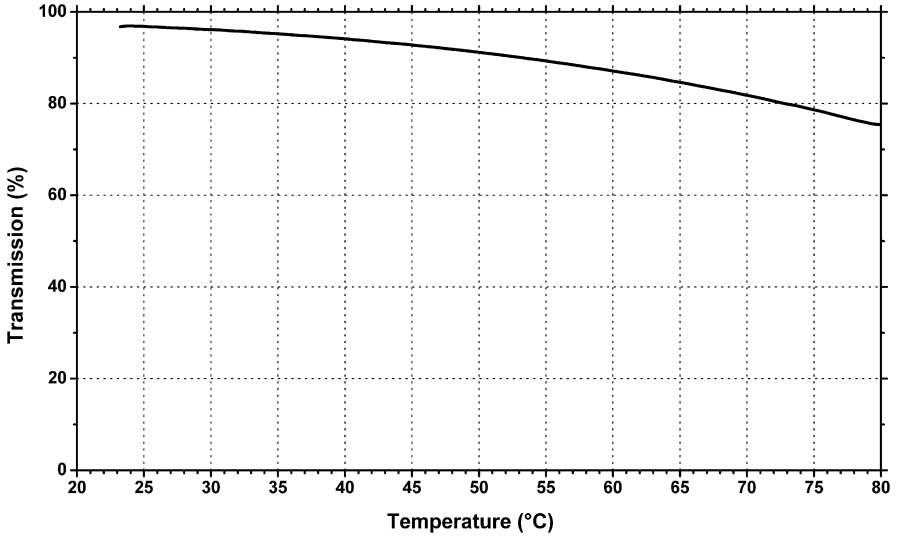

Figure 2.40 Light transmission of Styrolution Terlux® 2802 TR MABS resin as a function of temperature (white light, thickness of specimen 2 mm) [4].

grafted acrylic ester elastomer during the copolymerization of styrene and acrylonitrile, known as SAN. SAN is described later in this chapter. The finely divided elastomer powder is uniformly distributed and grafted to the SAN molecular chains. The outstanding weatherability of ASA is due to the acrylic ester elastomer. ASA polymers are amorphous plastics, which have mechanical properties similar to those of the ABS resins described in Section 2.1. However, the ASA properties are far less affected by outdoor weathering.

ASA resins are available in natural, off-white, and a broad range of standard and custom-matched colors. ASA resins can be compounded with other polymers to make alloys and compounds that benefit from ASA's weather resistance.

Manufacturers and trade names: Styrolution Luran® S.

Applications and uses: automotive components, electrical equipment subjected to high temperatures, parabolic reflectors, solar energy systems, movement sensors, surfboards, golf cars, lawn and garden equipment, sporting goods, automotive exterior parts, safety helmets, and building materials.

Data for ASA plastics are found in Figures 2.41–2.50.

2.4 Polystyrene (PS)

PS is the simplest plastic based on styrene. Its structure is shown in Figure 2.51.

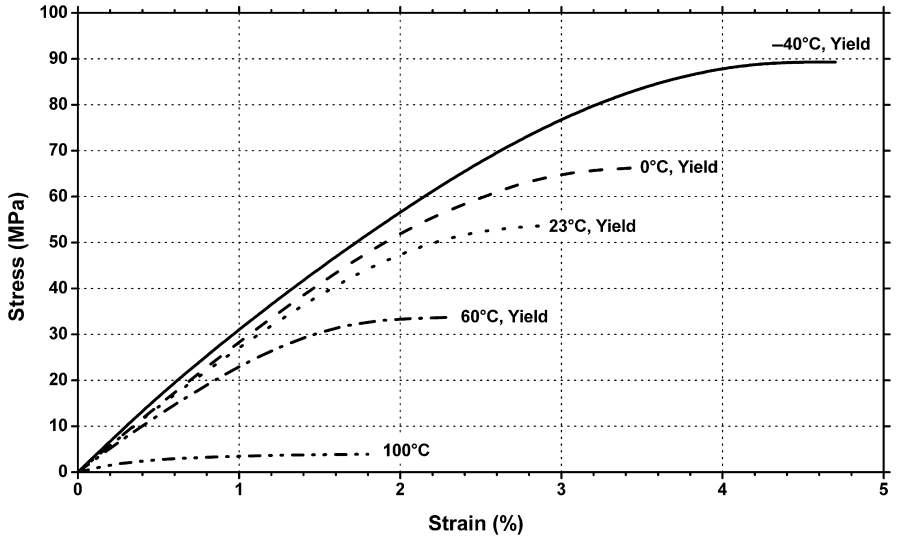

Figure 2.41 Tensile stress vs. strain for Styrolution Luran® S 757 R—general purpose molding grade ASA resin.

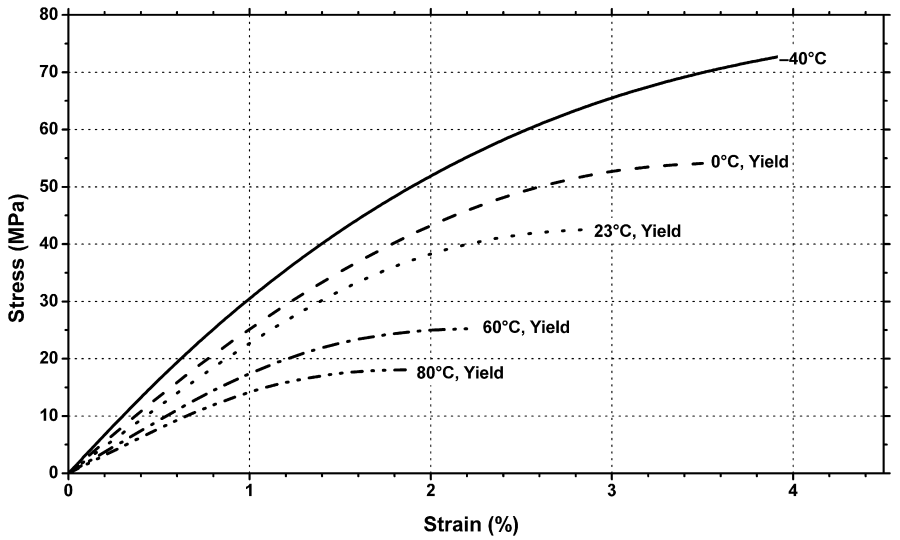

Figure 2.42 Tensile stress vs. strain for Styrolution Luran® S 757 S—tough and strong ASA resin.

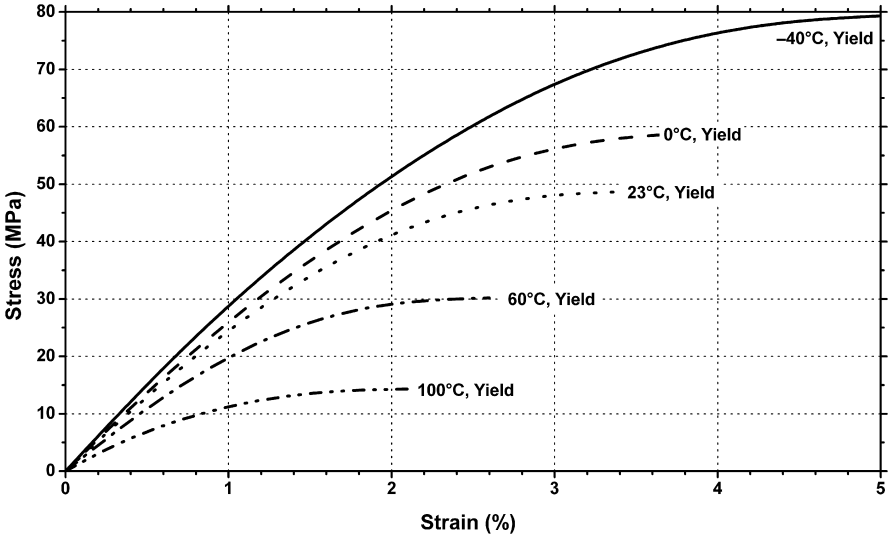

Figure 2.43 Tensile stress vs. strain for Styrolution Luran® S 778 T—tough and heat resistant ASA resin [5].

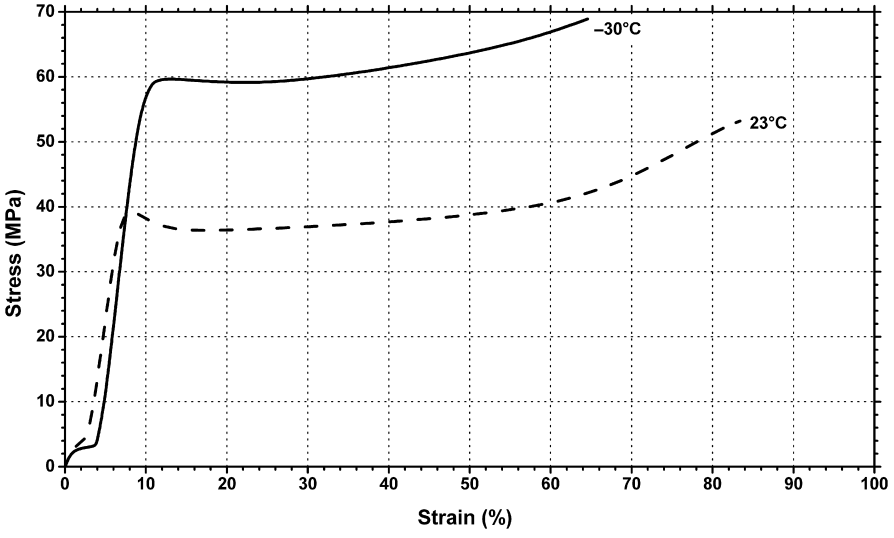

Figure 2.44 Stress vs. strain in compression for SABIC Innovative Plastics Geloy® CR7520—high impact automotive ASA resin.

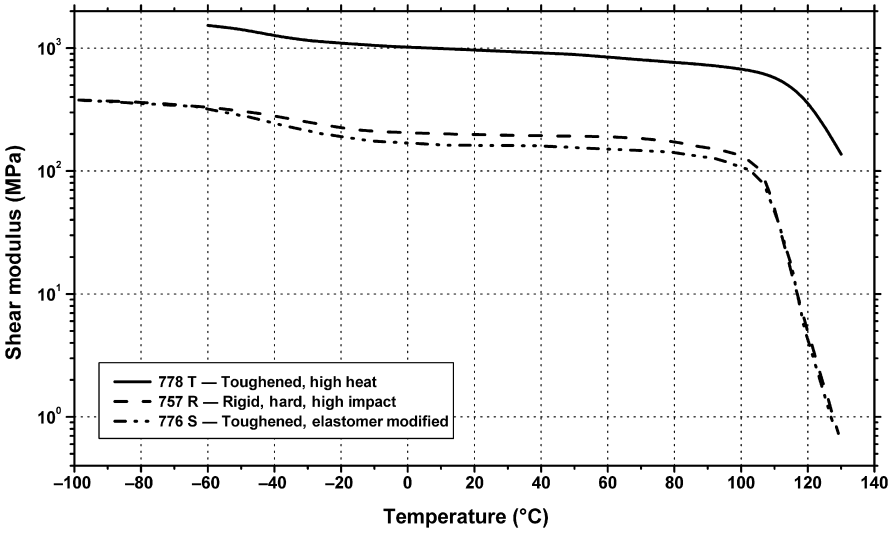

Figure 2.45 Shear modulus vs. temperature for Styrolution Luran® ASA resins.

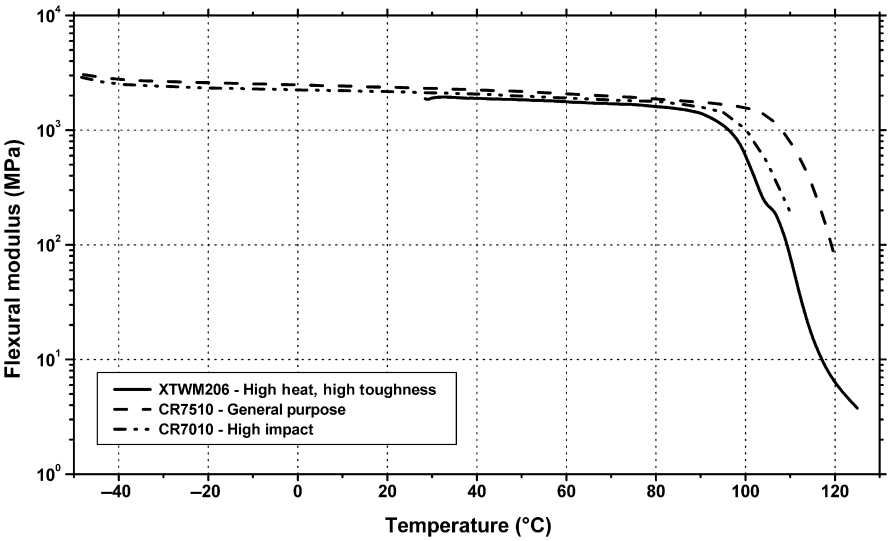

Figure 2.46 Flexural modulus vs. temperature for SABIC Innovative Plastics Geloy® ASA resins.

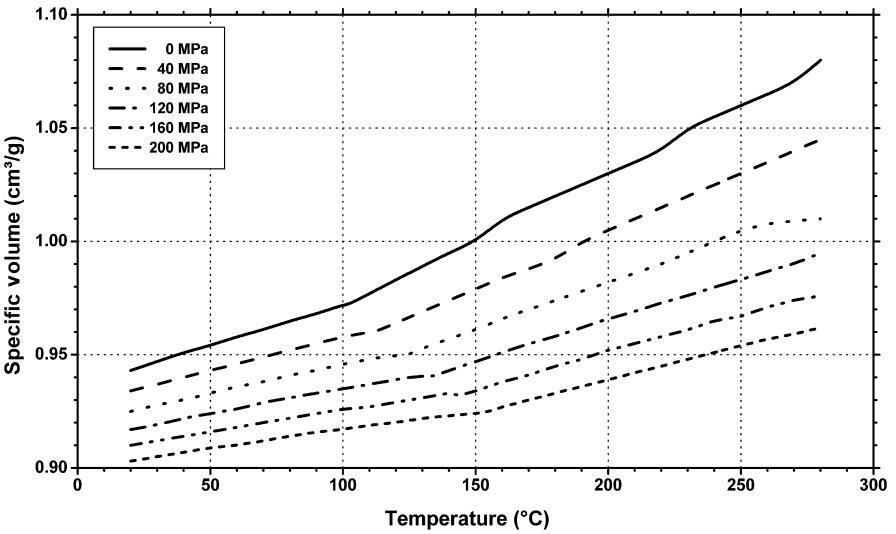

Figure 2.47 Specific volume as a function of temperature and pressure (PVT) for Styrolution Luran® S 757 R—general purpose molding grade ASA resin.

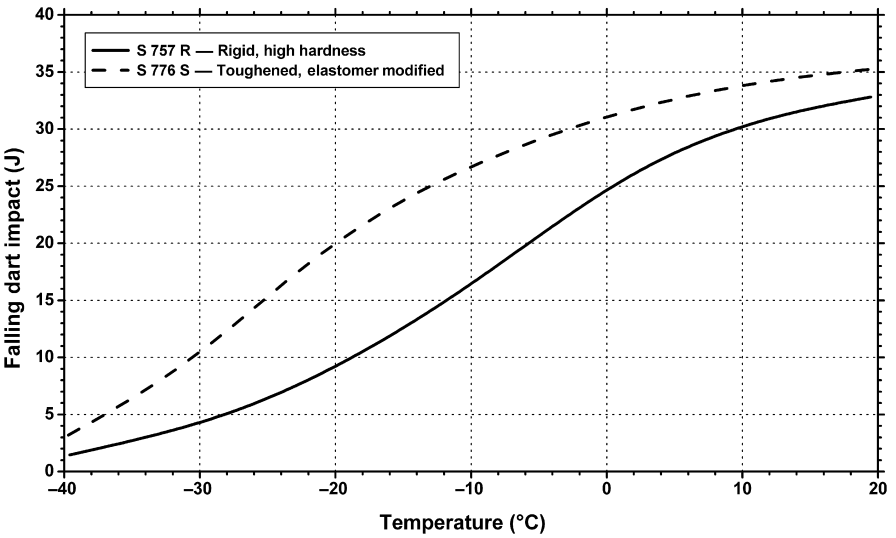

Figure 2.48 Falling dart impact vs. temperature for Styrolution Luran® ASA resins.

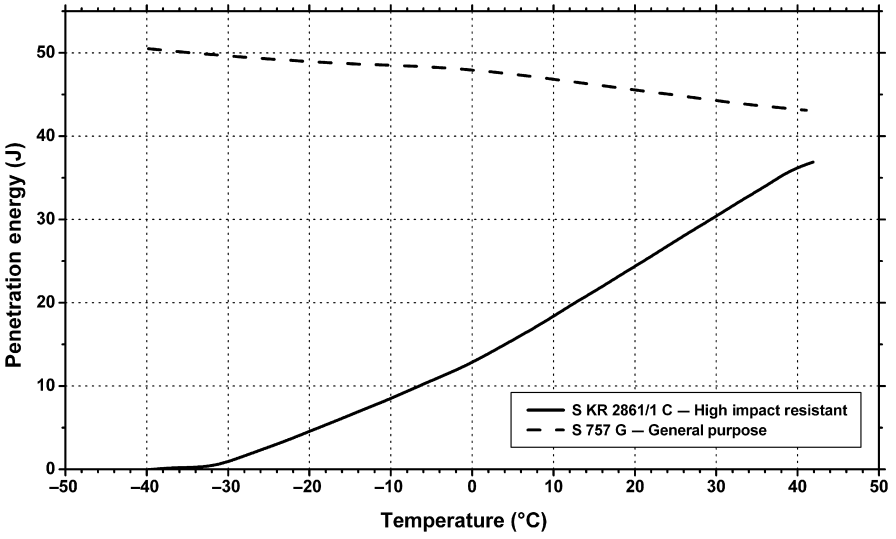

Figure 2.49 Penetration energy vs. temperature for Styrolution Luran® ASA resins [5].

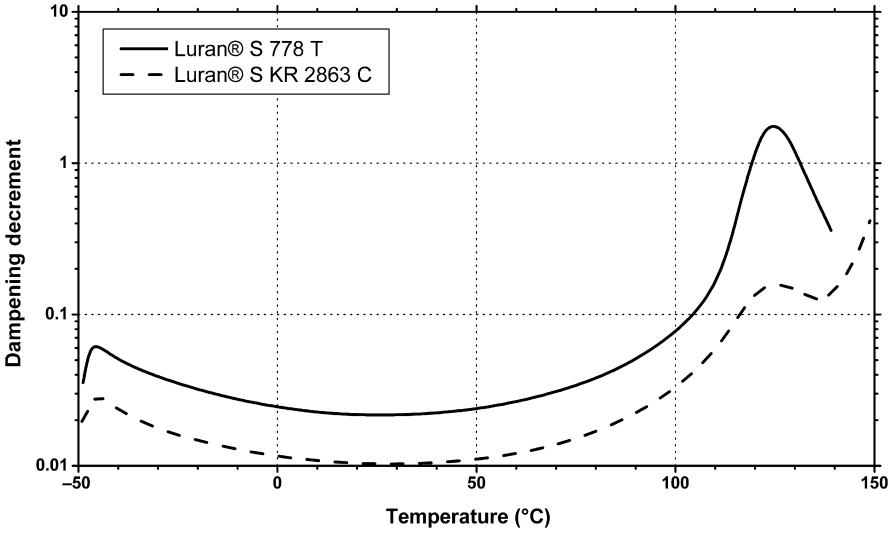

Figure 2.50 Mechanical damping vs. temperature for Styrolution Luran® S 778 T and Luran® S KR 2863 C (ISO 537 torsion pendulum test) [5].

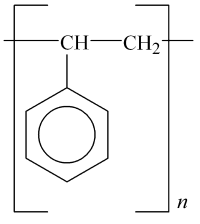

Figure 2.51 Chemical structure of PS.

Pure solid PS is a colorless, hard plastic with limited flexibility. PS can be transparent or can be made in various colors. It is economical and is used for producing plastic model assembly kits, plastic cutlery, CD "jewel" cases, and many other objects where a fairly rigid, economical plastic is desired.

PS's most common use, however, is as expanded PS (EPS). EPS is produced from a mixture of about 5–10% gaseous blowing agent (most commonly pentane or carbon dioxide) and 90–95% PS by weight. The solid plastic beads are expanded into foam through the use of heat (usually steam). The heating is carried out in a large vessel holding 200–2000 liters. An agitator is used to keep the beads from fusing together. The expanded beads are lighter than unexpanded beads so they are forced to the top of the vessel and removed. This expansion process lowers the density of the beads to 3% of their original value and yields a smooth-skinned, closed cell structure. Next, the preexpanded beads are usually "aged" for at least 24 h in mesh storage silos. This allows air to diffuse into

the beads, cooling them and making them harder. These expanded beads are excellent for detailed molding. Extruded PS (XPS), which is different from EPS, is commonly known by the trade name Styrofoam™. All these foams are not of interest in this book.

The three general forms of PS are as follows:

- General purpose (PS or GPPS)
- High impact (HIPS)
- Syndiotactic (SPS or sPS)

One of the most important plastics is HIPS. This is a styrene matrix that is imbedded with an impact modifier, which is basically a rubber-like polymer such as polybutadiene. This is shown in Figure 2.52.

Manufacturers and trade names: BASF Polystyrene and Polystyrol, Dow Chemical Trycite™, Styron Styron™.

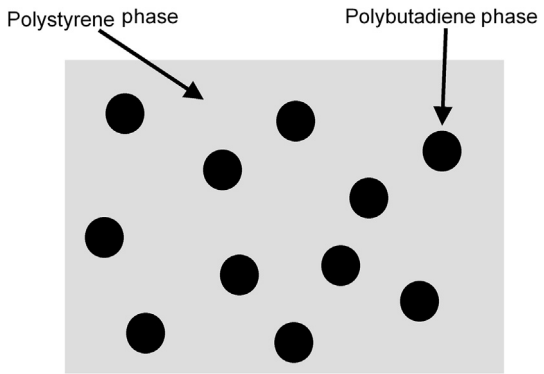

Figure 2.52 The structure of HIPS.

Applications and uses:

General purpose: yogurt, cream, butter, meat trays, egg cartons, fruit and vegetable trays, as well as cakes, croissants, and cookies. Medical and packaging/disposables, bakery packaging, and large and small appliances, particularly where clarity is required.

High impact: refrigeration accessories, small appliances, electric lawn and garden equipment, toys, and remote controls.

Data for PS plastics are found in Figures 2.53–2.69.

2.5 Styrene Acrylonitrile (SAN)

Styrene and acrylonitrile monomers can be copolymerized to form a random, amorphous copolymer that has good weatherability, stress crack resistance, and barrier properties. The copolymer is called styrene acrylonitrile or SAN. The SAN copolymer generally contains 70–80% styrene and 20–30% acrylonitrile. It is a simple random copolymer. This monomer combination provides higher strength, rigidity, and chemical resistance than PS, but it is not quite as clear as crystal PS and its appearance tends to yellow more quickly. The general structure is shown in Figure 2.70.

SAN is used for household goods and tableware, in cosmetics packaging, sanitary and toiletry articles as well as for writing materials and office supplies.

Manufacturers and trade names: Styrolution Luran®, Styron Tyril™ resins.

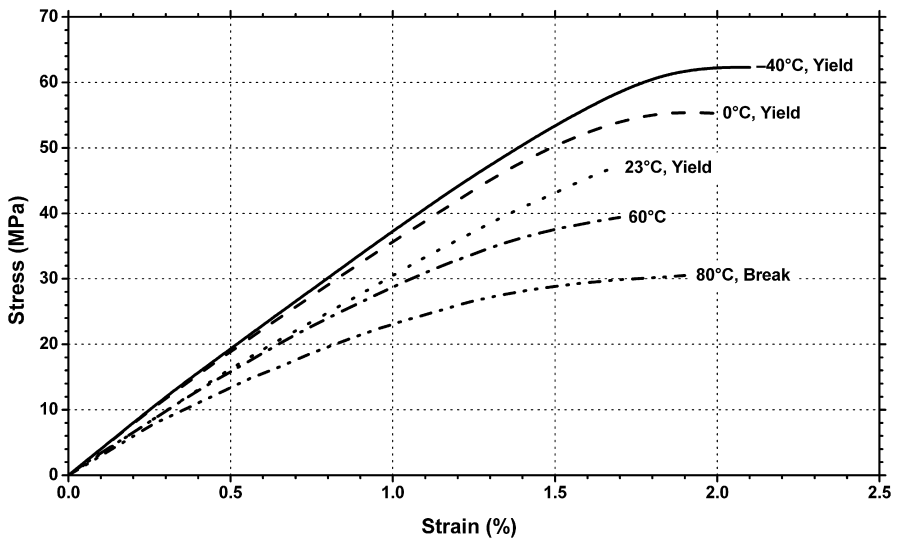

Figure 2.53 Stress vs. strain at various temperatures for BASF Polystyrene 158 K—general purpose, heat resistant PS resin.

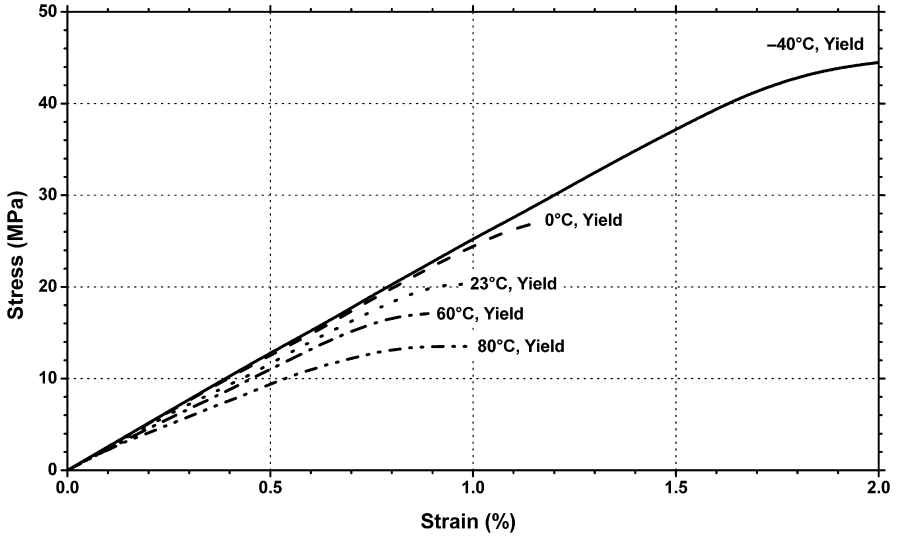

Figure 2.54 Stress vs. strain at various temperatures for BASF Polystyrene 454 C—impact resistant PS resin.

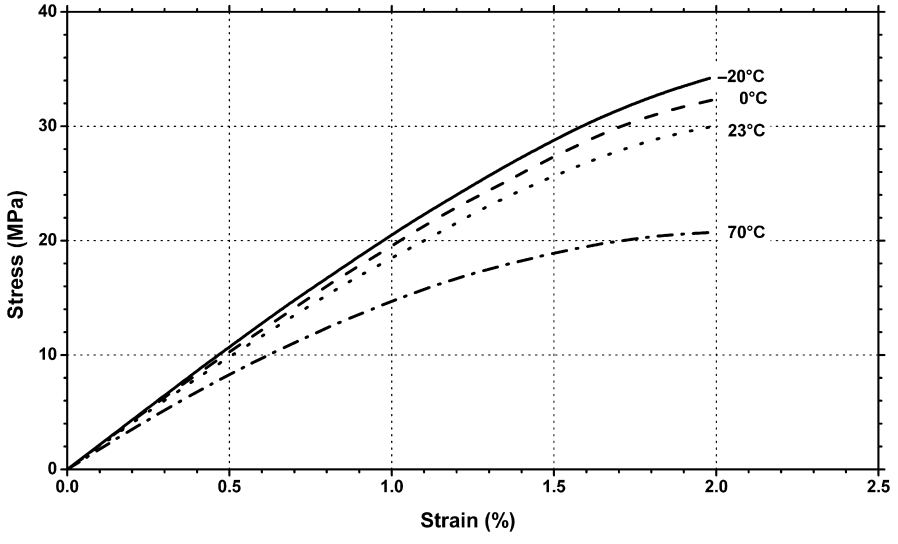

Figure 2.55 Stress vs. strain at various temperatures for Styron Styron™ 457—high impact PS resin.

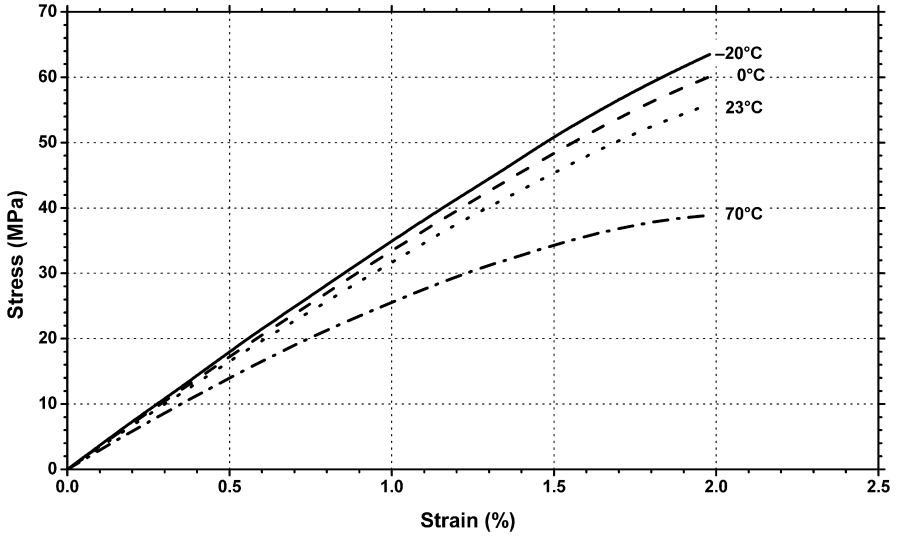

Figure 2.56 Stress vs. strain at various temperatures for Styron Styron™ 648—general purpose PS resin.

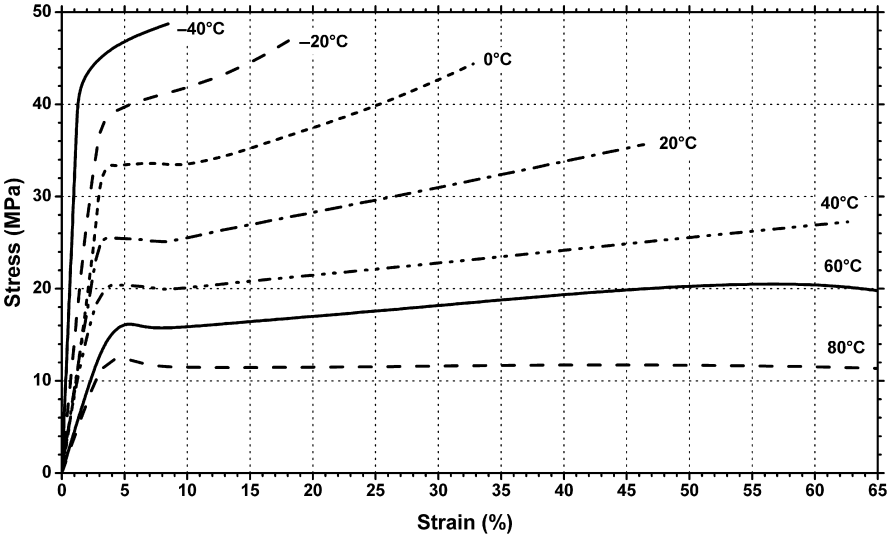

Figure 2.57 Stress–strain curves of high impact BASF Polystyrene resin at various test temperatures [6].

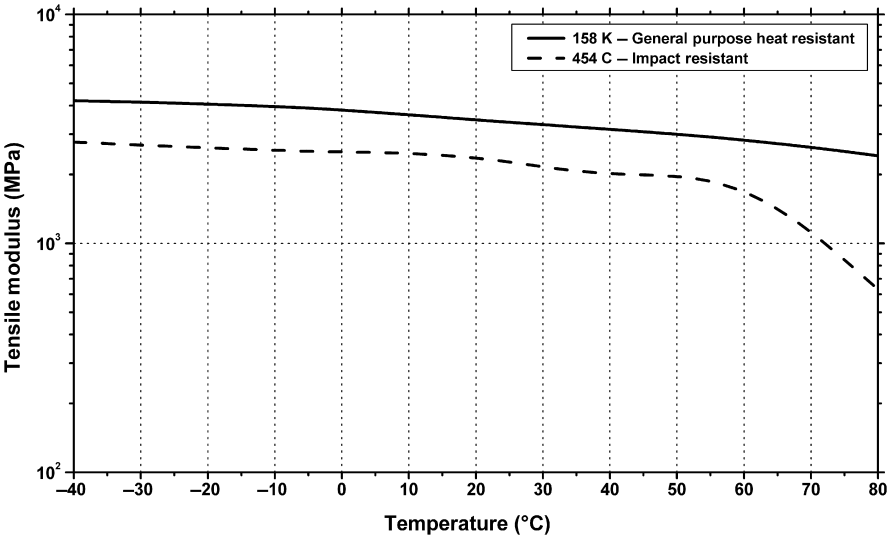

Figure 2.58 Tensile modulus vs. temperature for two BASF Polystyrene resins.

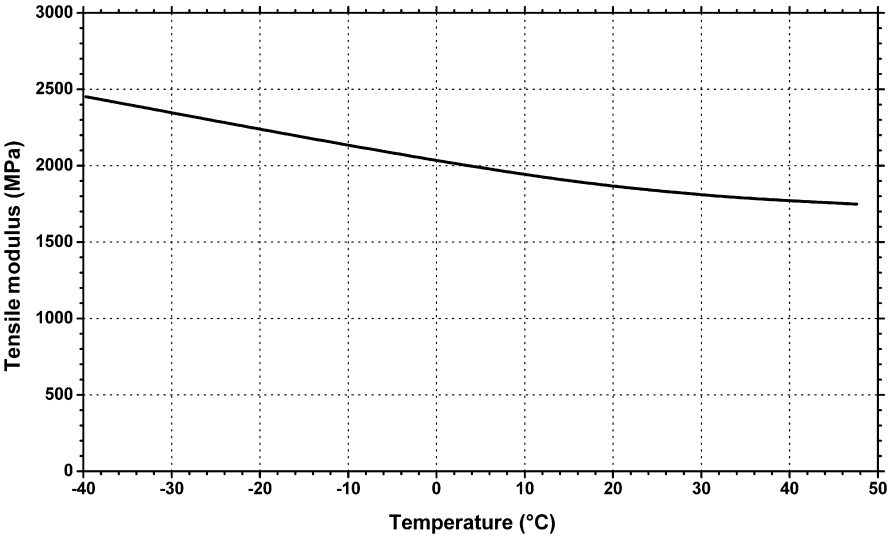

Figure 2.59 Tensile modulus vs. temperature for Styron Styron™ 6075—ignition resistant PS resin.

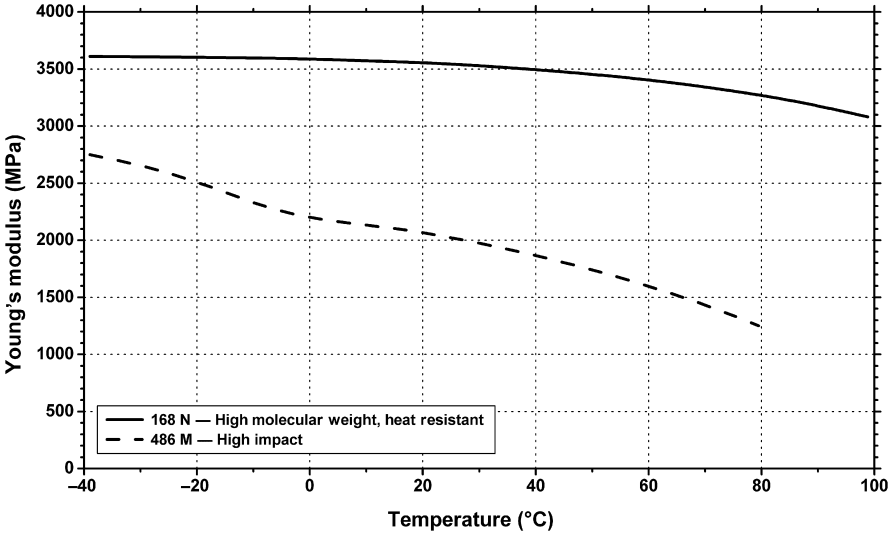

Figure 2.60 Young's modulus vs. temperature for two BASF Polystyrene resins [6].

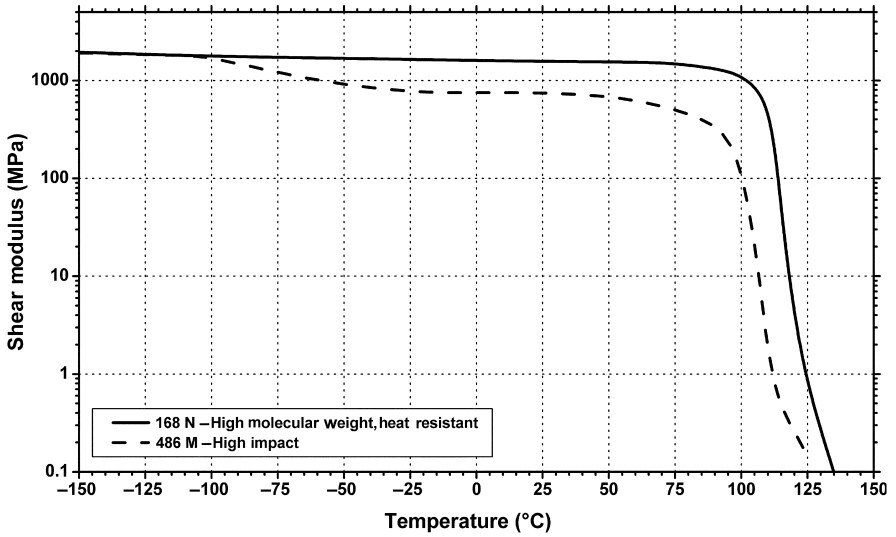

Figure 2.61 Shear modulus vs. temperature for two BASF Polystyrene resins [6].

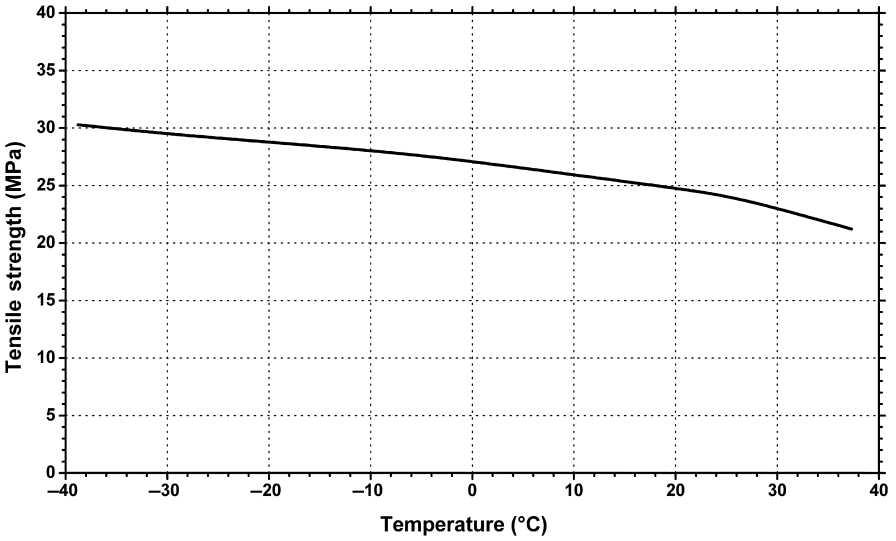

Figure 2.62 Tensile strength vs. temperature for Styron Styron™ 6075—ignition resistant PS resin.

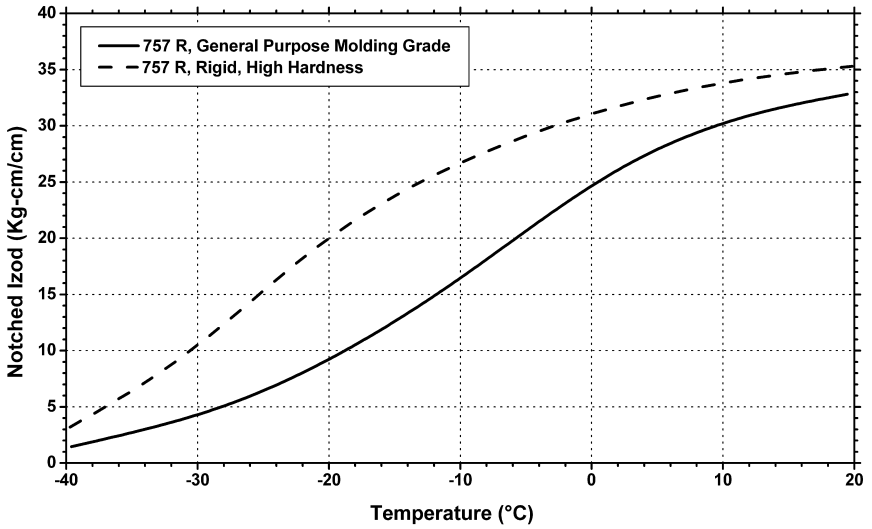

Figure 2.63 Notched Izod impact vs. temperature for Luran 757 – ignition resistant PS resin.

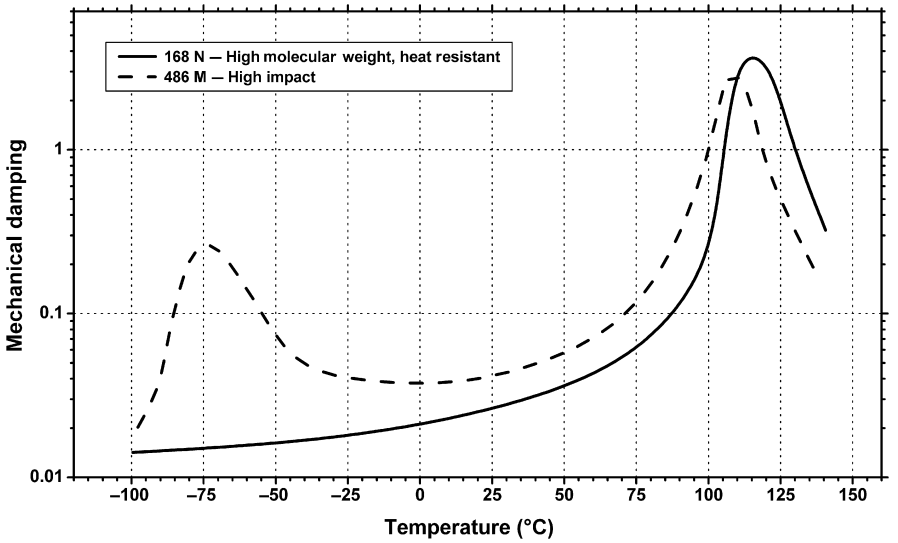

Figure 2.64 Mechanical damping vs. temperature for two BASF Polystyrene resins [6].

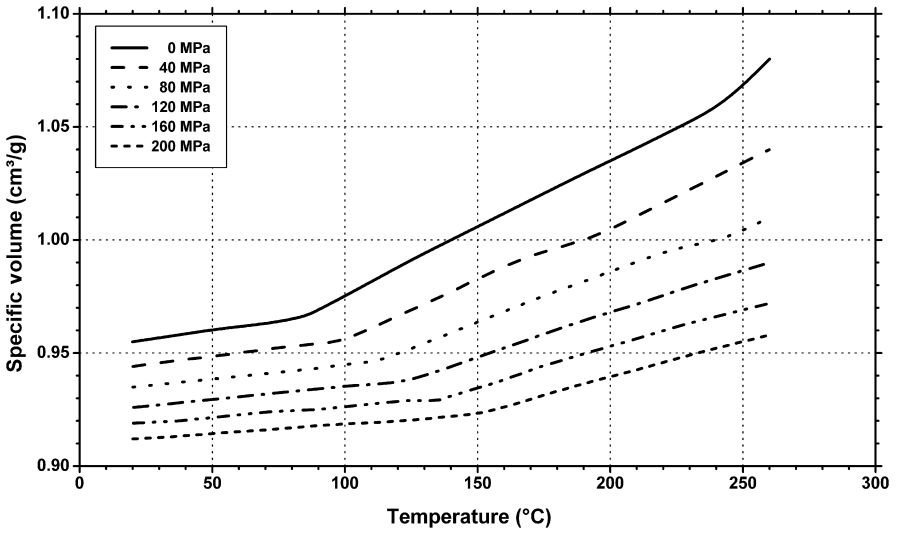

Figure 2.65 Specific volume as a function of temperature and pressure (PVT diagram) for BASF Polystyrene 454 C—impact resistant PS resin.

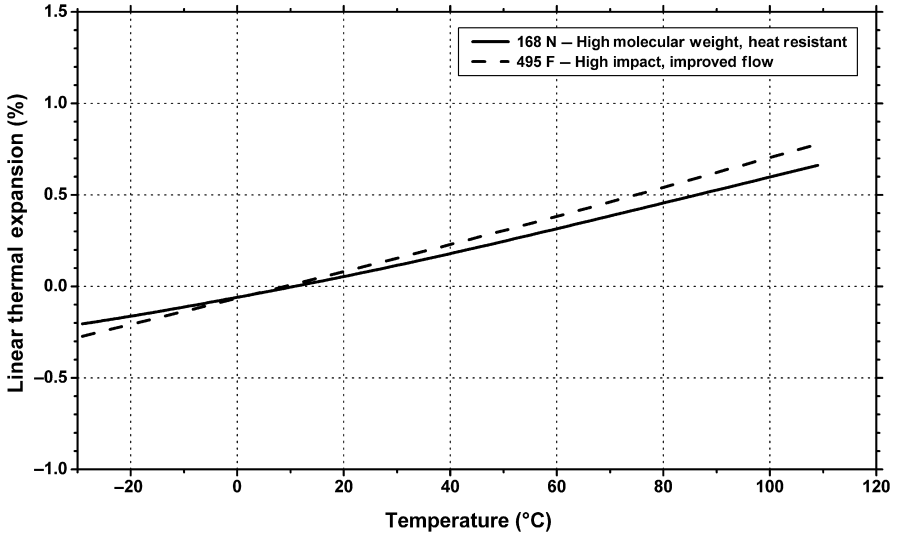

Figure 2.66 Linear thermal expansion vs. temperature for two BASF Polystyrene resins [6].

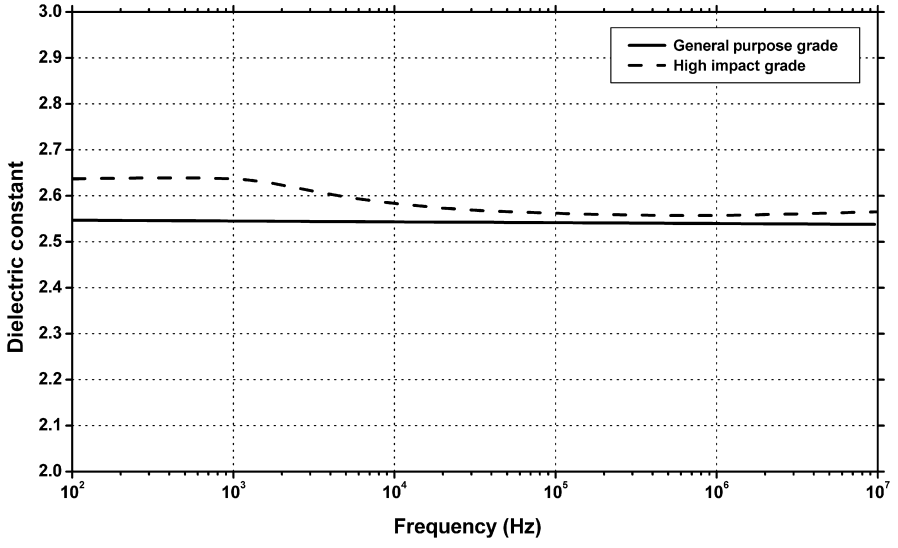

Figure 2.67 Dielectric constant vs. frequency for two Styron Styron™ PS resins.

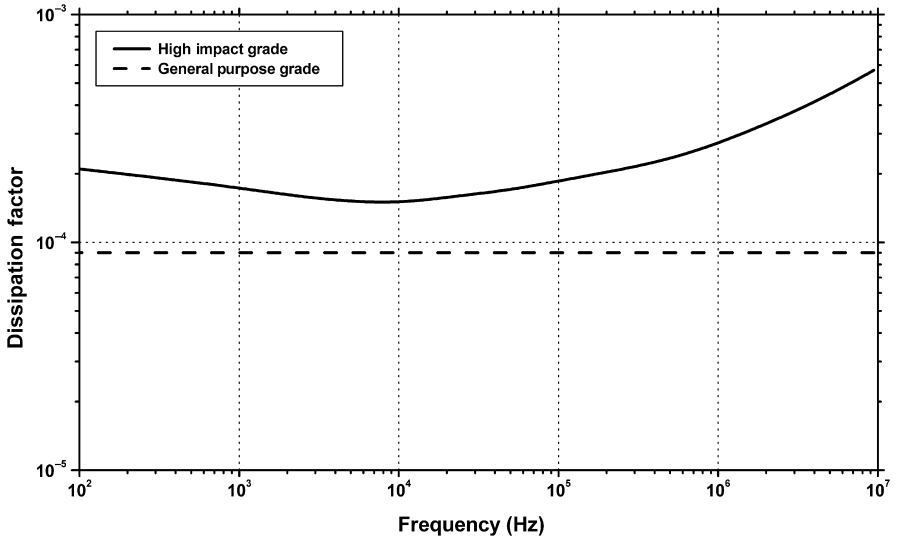

Figure 2.68 Dissipation factor vs. frequency for two Styron Styron™ PS resins.

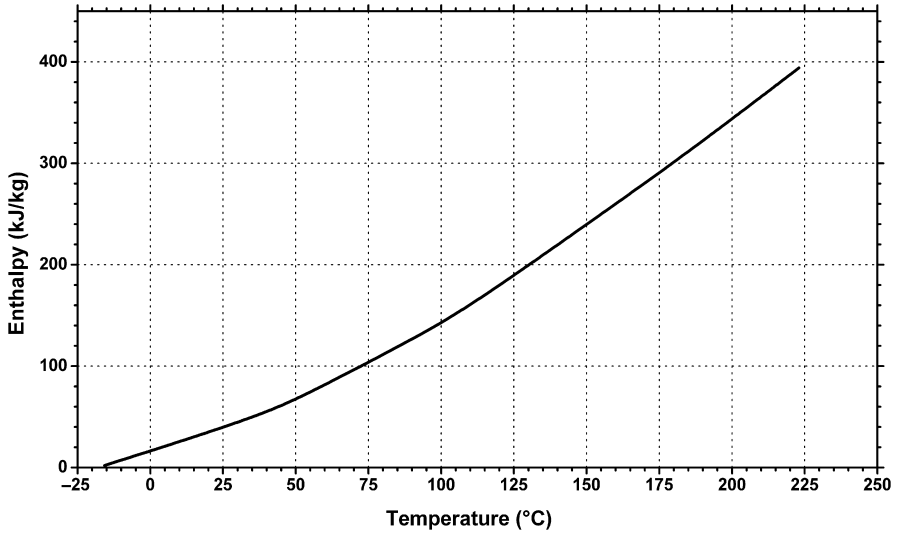

Figure 2.69 Enthalpy (heat content) vs. temperature for Styron Styron™ PS resin.

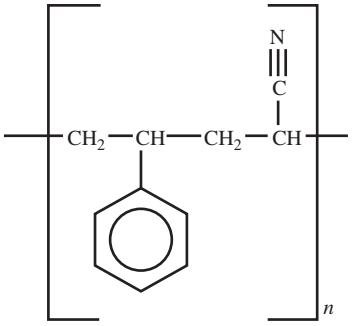

Figure 2.70 Chemical structure of SAN.

Applications and uses: mixing bowls, electric mixers, refrigerator inserts, tableware, vacuum flask casings, food storage containers, toiletries, cosmetics packaging, writing implements, and industrial batteries.

Data for PS plastics are found in Figures 2.71–2.84.

2.6 Styrenic Butadiene Block Copolymers (SBC)

SBC is a commercially important thermoplastic elastomer. The polymer is made of three separate polymeric blocks (see Section 1.1.2 for an explanation of block copolymers). At one end is a hard PS block, in the middle a long polybutadiene (or other elastomeric) block, followed by a second hard block of PS. These blocks are immiscible, so they form discrete domains of PS within a polybutadiene matrix. The separate domains are chemically connected. This is shown in Figure 2.85, and one might notice that this looks a lot like HIPS, except that the continuous phase and hard discrete phase are switched in SBC and the domains are connected. One additional property of interest is that some SBCs blend well with general purpose PS, allowing customization of properties.

SBCs are crystal clear, combining high transparency with impact strength. They are often blended or mixed with PS.

Manufacturers and trade names: Chevron Phillips K-Resin®, Styrolution Styrolux®, Kraton Polymers Kraton™.

Applications and uses: clear disposable drinking cups, lids, plates, deli containers, high impact blow-molded bottles, candy twist wrap, shrink sleeves and overwrap, medical devices, medical trays, blister packaging, appliances, refrigerator crisper trays, flashlight lenses, overcaps, displays, clothes hangers, toys.

Data for SBC are found in Figures 2.86–2.90.

2.7 Styrene Maleic Anhydride (SMA)

Copolymerization of styrene with maleic anhydride creates a copolymer called SMA. This reaction is shown in Figure 2.91. SMA has a higher glass transition temperature than PS and is chemically reactive with certain functional groups. Thus, SMA polymers are often used in blends or composites where interaction or reaction of the maleic anhydride causes desirable interfacial effects.

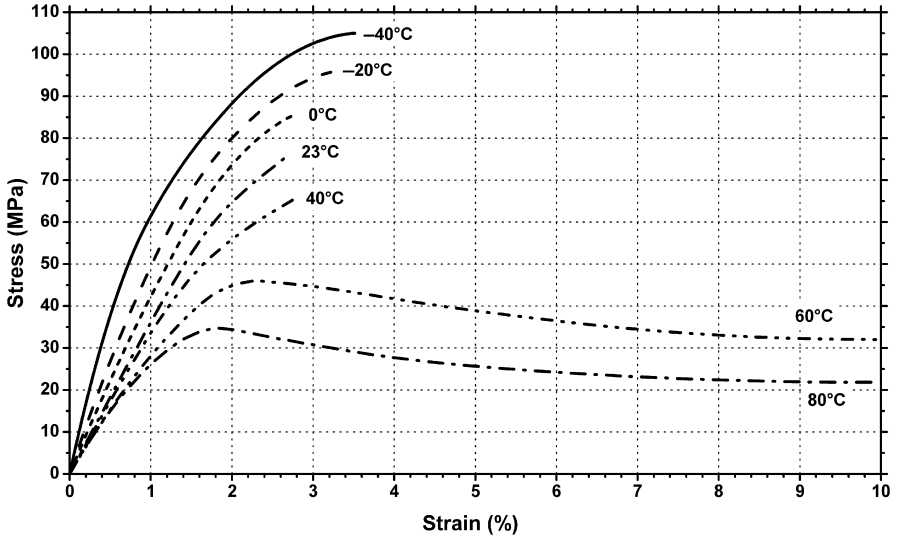

Figure 2.71 Tensile stress vs. strain for Styrolution Luran® 368 R—general purpose SAN resin (test discontinued at 10% elongation) [7].

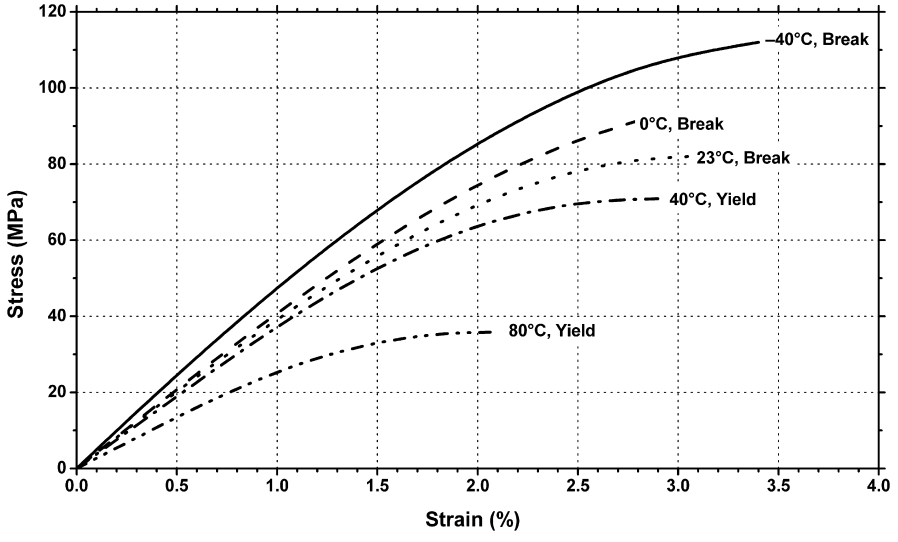

Figure 2.72 Tensile stress vs. strain for Styrolution Luran® 378P—easy flow, chemical resistant grade SAN resin.

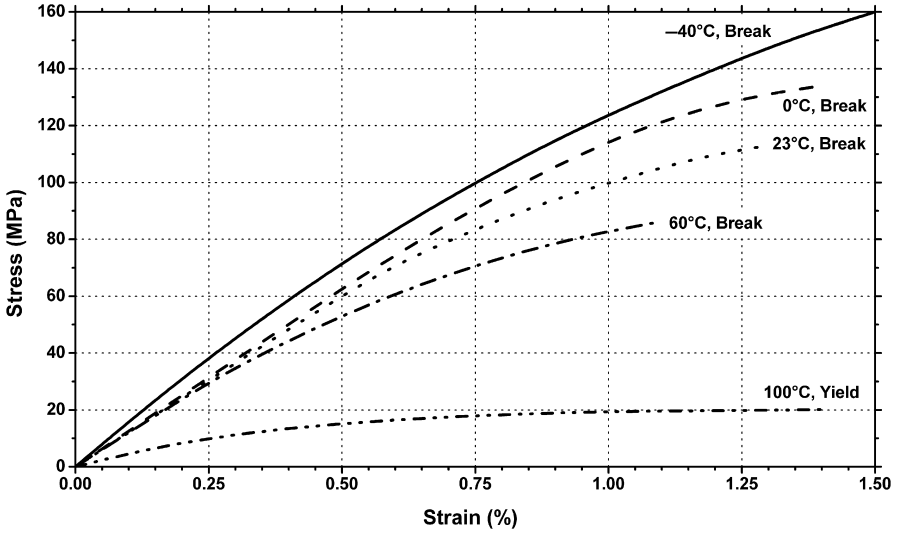

Figure 2.73 Tensile stress vs. strain for Styrolution Luran® 378P G7—glass reinforced grade SAN resin.

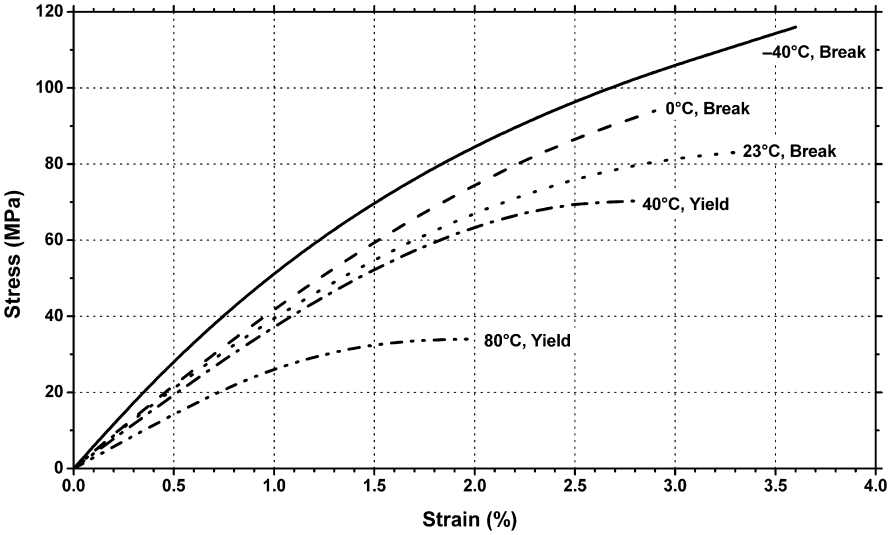

Figure 2.74 Tensile stress vs. strain for Styrolution Luran® 388S—high mechanical strength, chemical resistant grade SAN resin.

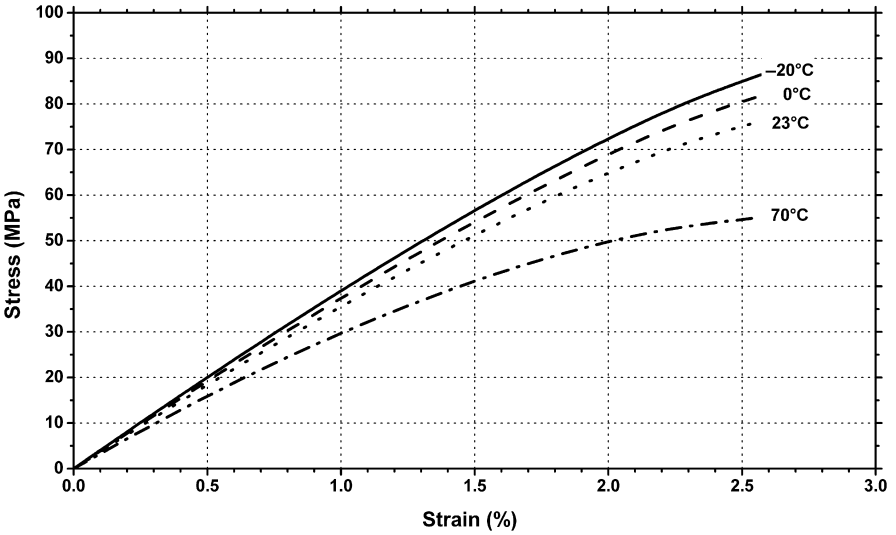

Figure 2.75 Tensile stress vs. strain for Styron Tyril™ 790—general purpose grade SAN resin.

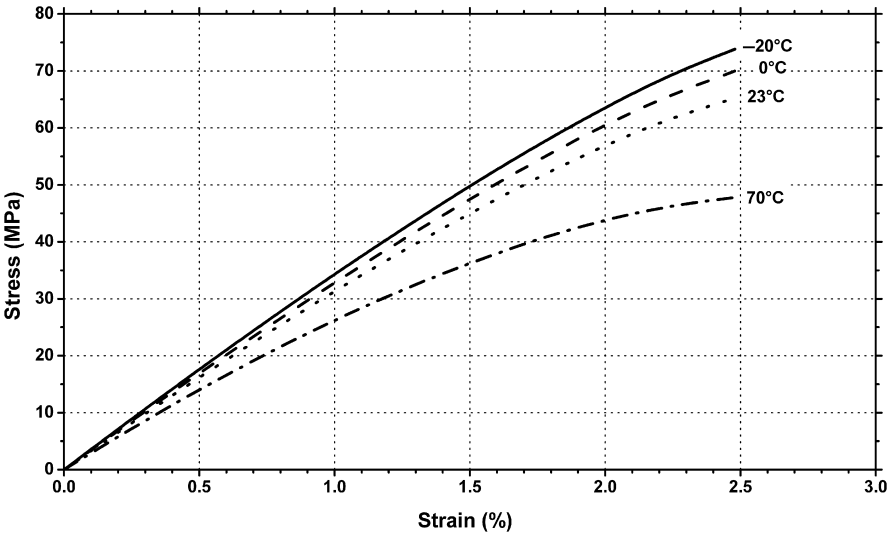

Figure 2.76 Tensile stress vs. strain for Styron Tyril™ 905—general purpose grade SAN resin.

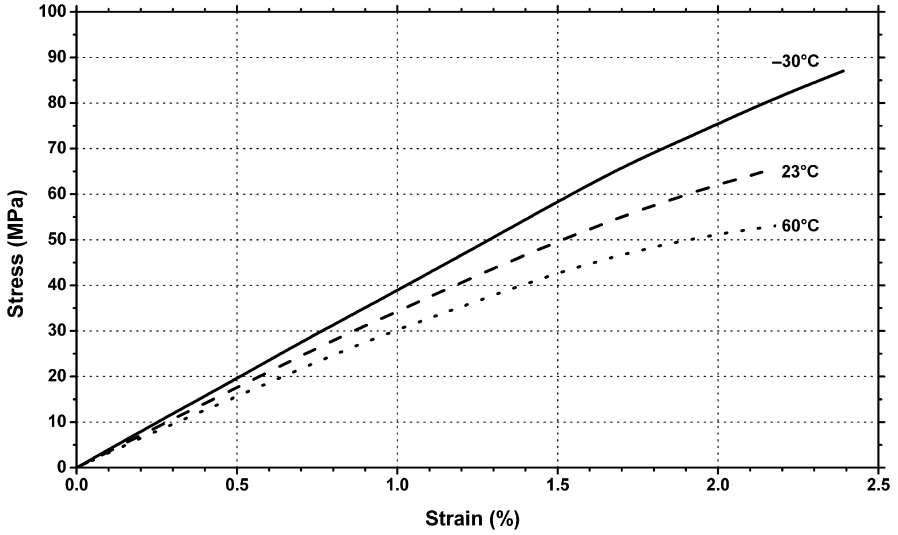

Figure 2.77 Tensile stress vs. strain for Polimeri Europa Kostil® B 265—general purpose SAN resin.

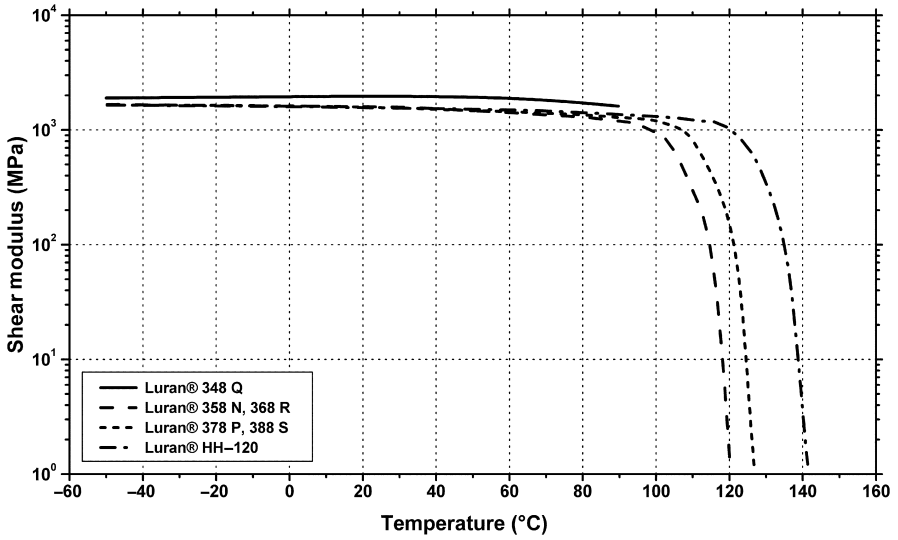

Figure 2.78 Shear modulus vs. temperature for Styrolution Luran® SAN resins [7].

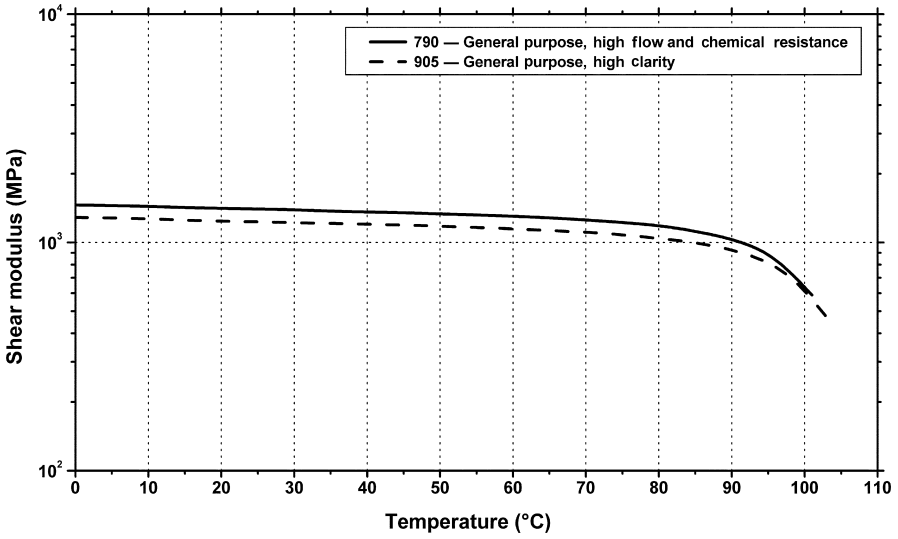

Figure 2.79 Shear modulus vs. temperature for Styron Tyril™ SAN resins.

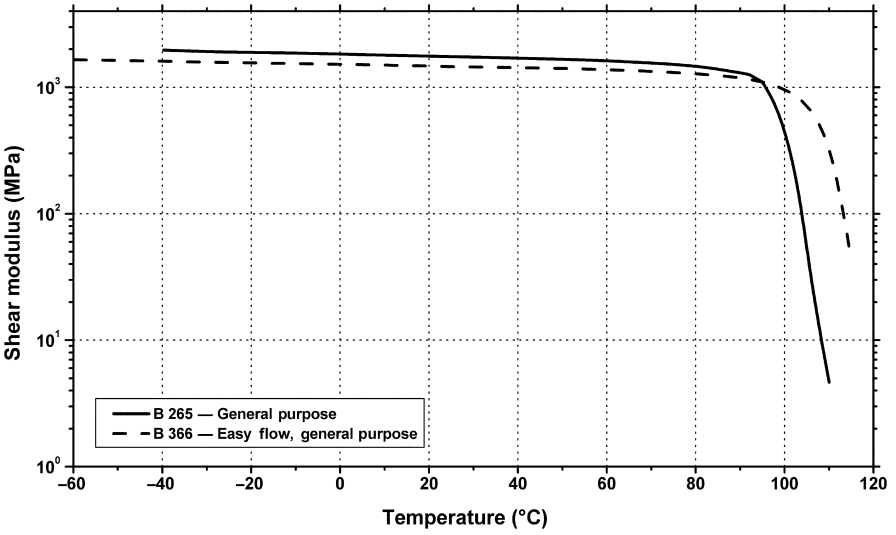

Figure 2.80 Shear modulus vs. temperature for Polimeri Europa Kostil® SAN resins.

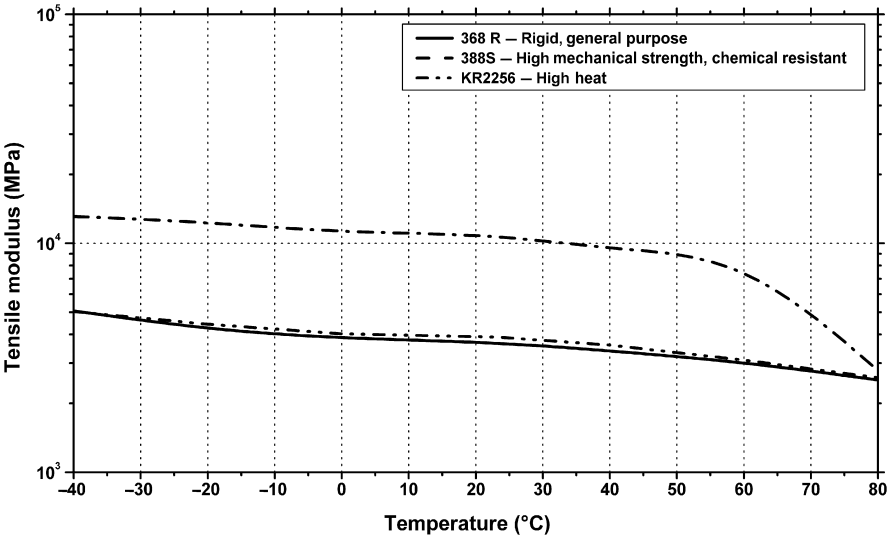

Figure 2.81 Tensile modulus vs. temperature for Styrolution Luran® SAN resins.

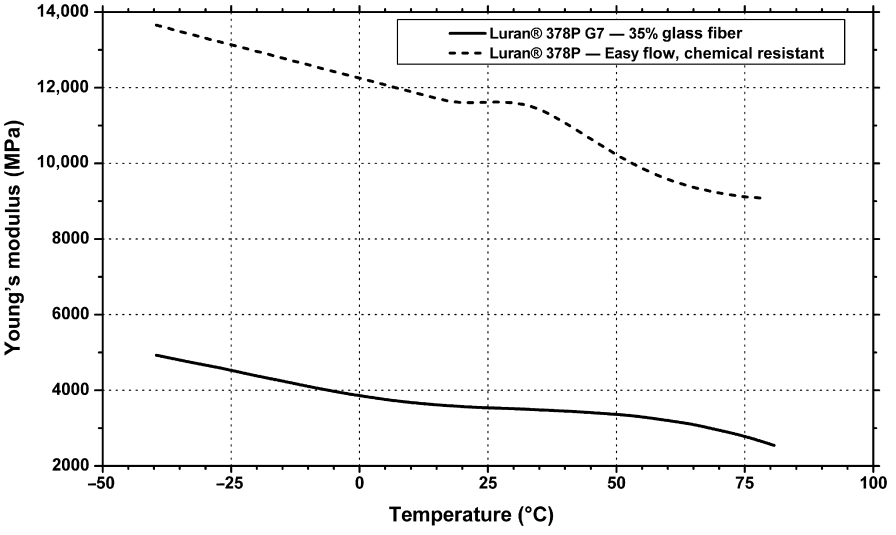

Figure 2.82 Young's modulus of Styrolution Luran® 378 P G7 and Luran® 378 P as a function of temperature (measured in accordance with ISO 527) [7].

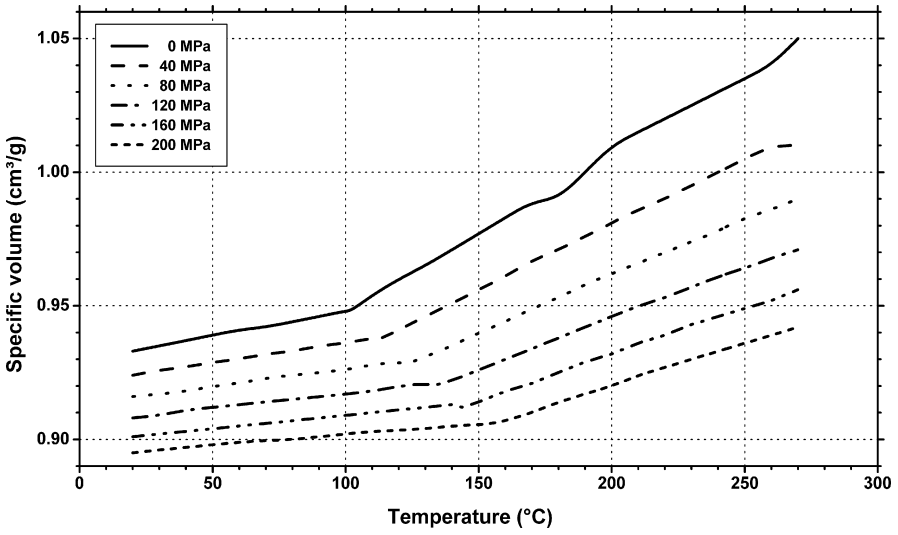

Figure 2.83 Specific volume as a function of temperature and pressure (PVT) for Styrolution Luran® 368 R—general purpose SAN resin.

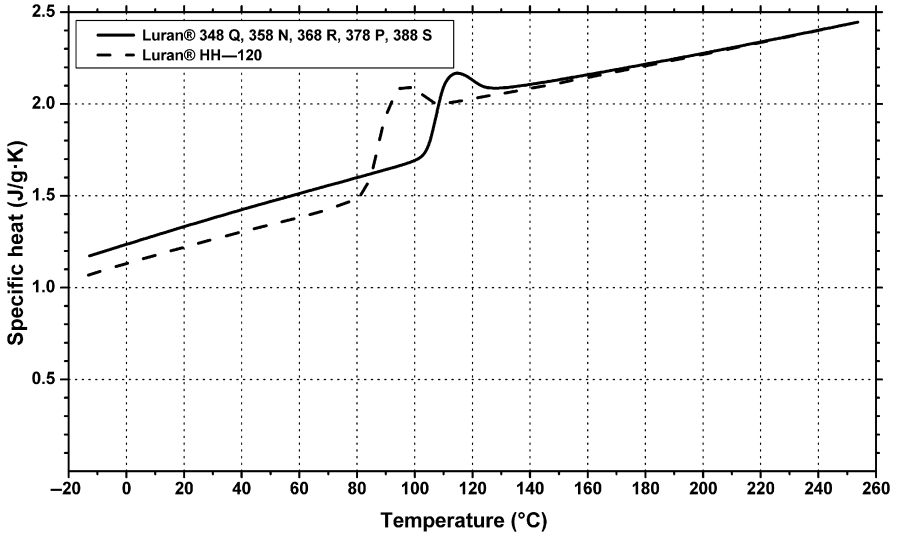

Figure 2.84 Specific heat of various Styrolution Luran® grades as a function of temperature (measured by the differential scanning calorimetry (DSC) method; rate of heating 20 K/min) [7].

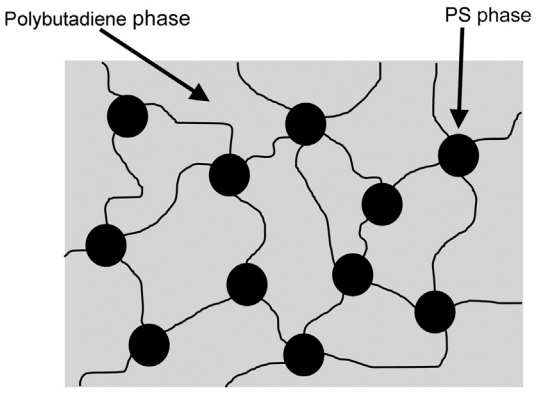

Figure 2.85 The "microscopic" structure of SBCs.

The anhydride reaction with primary amines is particularly potent.

Properties of SMA include:

- Outstanding structural properties and dimensional stability
- Proven heat and long-term thermal aging resistance
- Exceptional urethane-foam adhesion
- Processing ease for injection molding and extrusion applications
- Ease of recycling

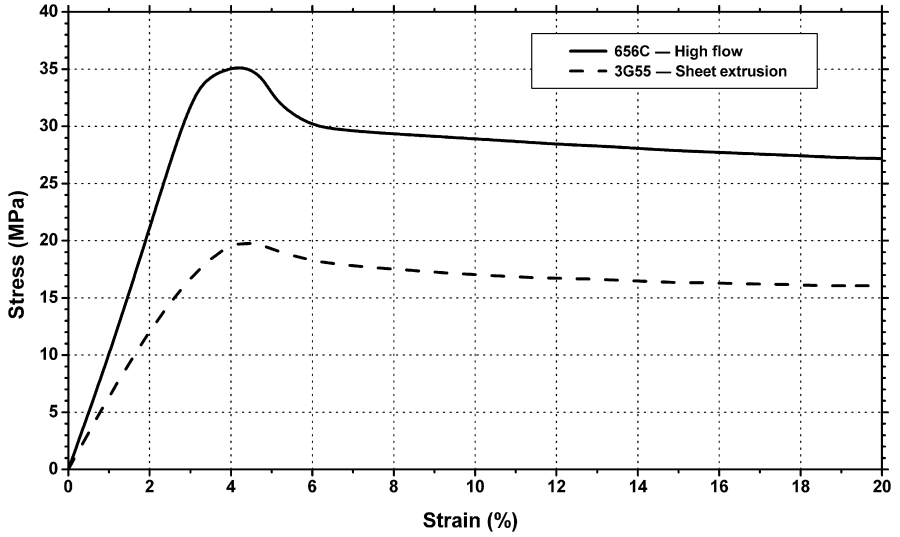

Figure 2.86 Stress vs. strain at 23°C for Styrolution Styrolux® SBC resins [6].

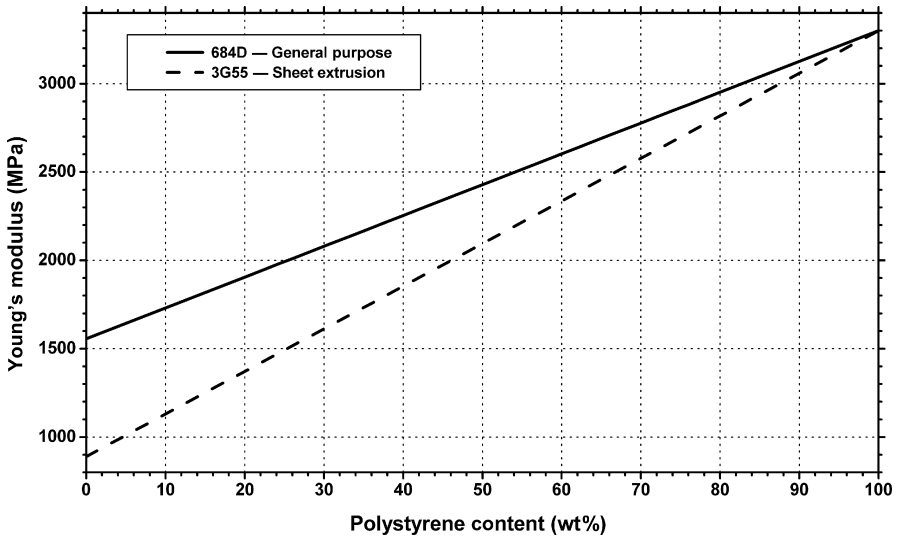

Figure 2.87 Young's modulus vs. PS content for Styrolution Styrolux® SBC resins [6].

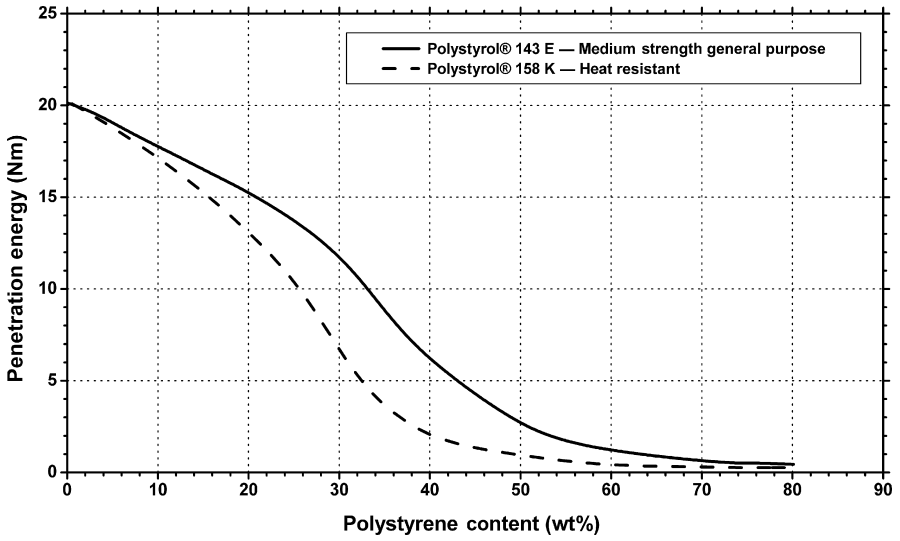

Figure 2.88 Penetration energy (ISO 6603-2) vs. PS content for Styrolution Styrolux® 684D blended with different polystyrene resins [6].

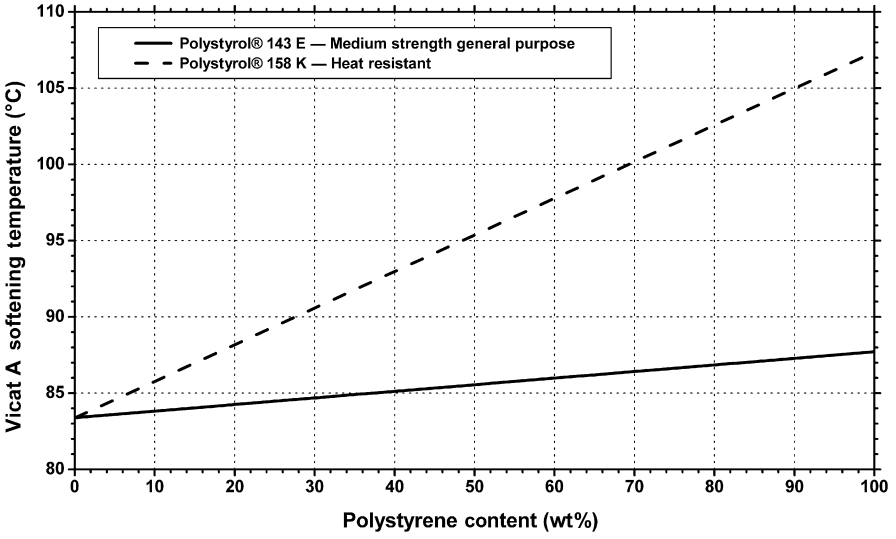

Figure 2.89 Vicat softening temperature vs. PS content for Styrolution Styrolux® 684D blended with different polystyrene resins [6].

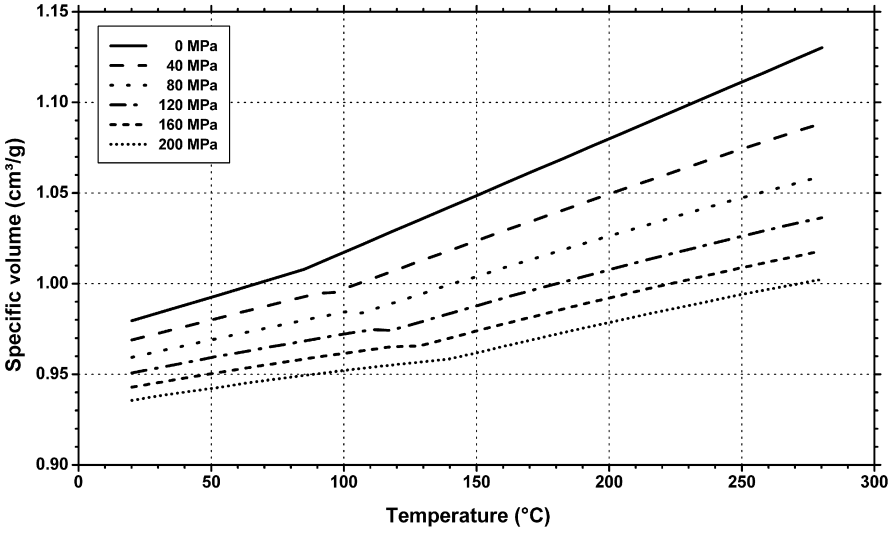

Figure 2.90 Specific volume as a function of temperature and pressure (PVT diagram) for Styrolution Styrolux® 656C—high flow SBC resin.

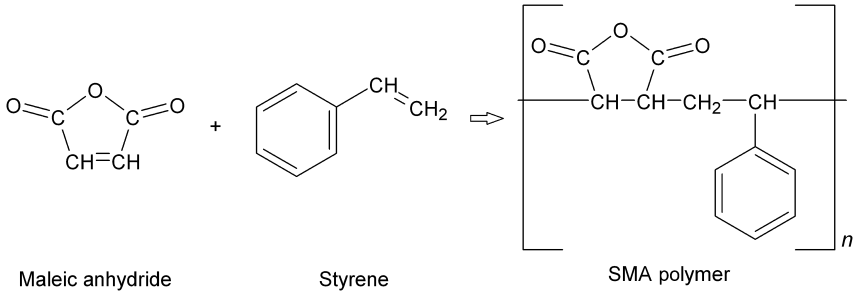

Figure 2.91 The production of SMA.

- Outstanding thin-wall capability
- Consistent property performance: −40°F (−40°C) to 185°F (85°C)
- Excellent chemical resistance to most stamping or screw oils
- Low creep—fastener torque remains high over the life of the part
- High modulus
- Responds well to joining technologies, such as chemical bonding, ultrasonic welding, vibration welding, and heat staking
- Excellent processability—flows easily in the mold, does not require drying, and achieves short cycle times with fewer drops than competitive materials

Manufacturers and trade names: SABIC Innovative Plastics Prevex®, Nova Chemicals Dylark® (discontinued), Bayer Cadon®, INEOS Lustran®.

Applications and uses: automotive applications, such as soft IPs, structural consoles, roof-mounted LCD video supports, interior trim and audio components.

Data for SMA plastics are found in Figures 2.92–2.101.

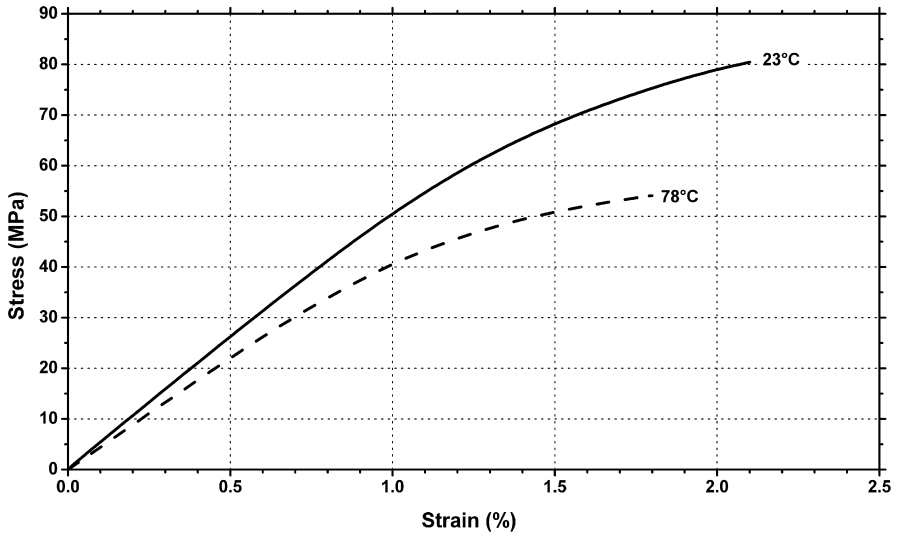

Figure 2.92 Tensile stress vs. strain for SABIC Innovative Plastics Prevex® IP-16 SMA resin.

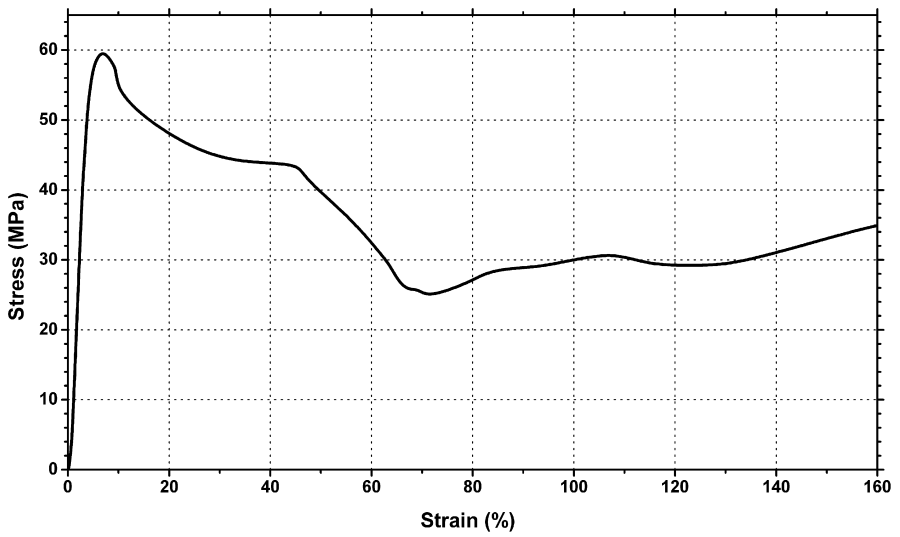

Figure 2.93 Tensile stress vs. strain in compression for SABIC Innovative Plastics Prevex® IP-16 SMA resin.

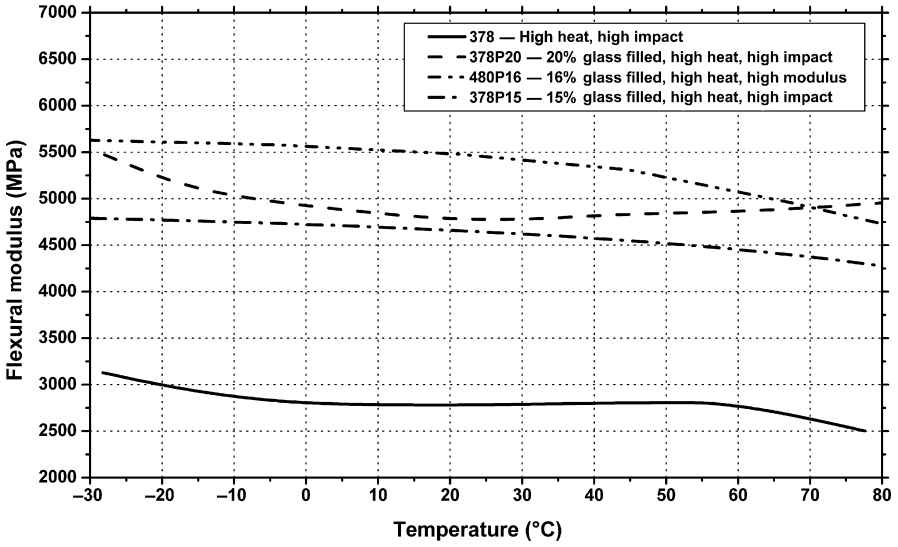

Figure 2.94 Flexural modulus vs. temperature for Nova Chemicals Dylark® SMA resins.

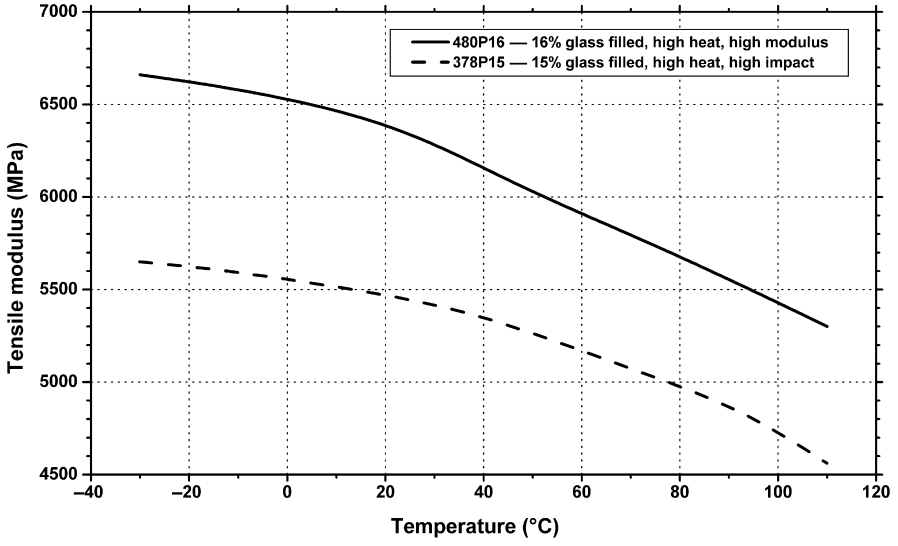

Figure 2.95 Tensile modulus vs. temperature for Nova Chemicals Dylark® SMA resins.

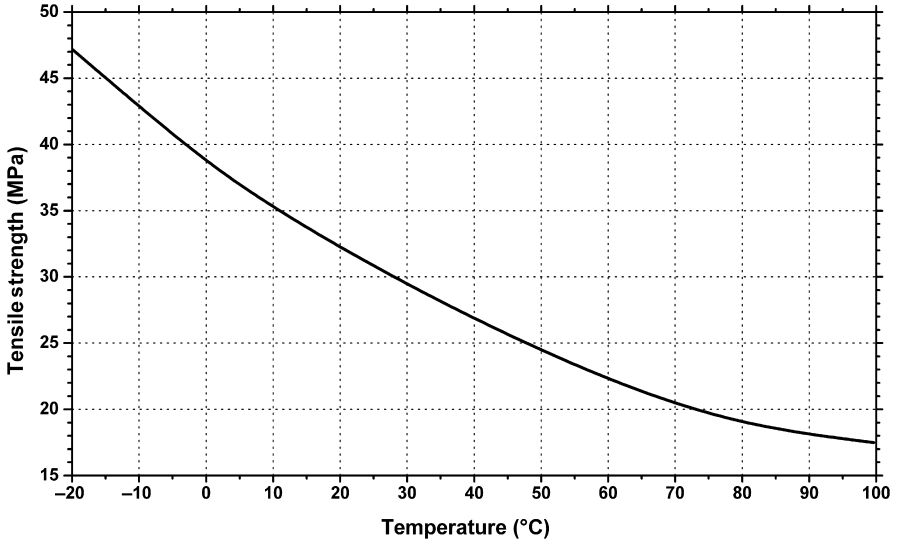

Figure 2.96 Tensile strength vs. temperature for Bayer Cadon® SMA resin.

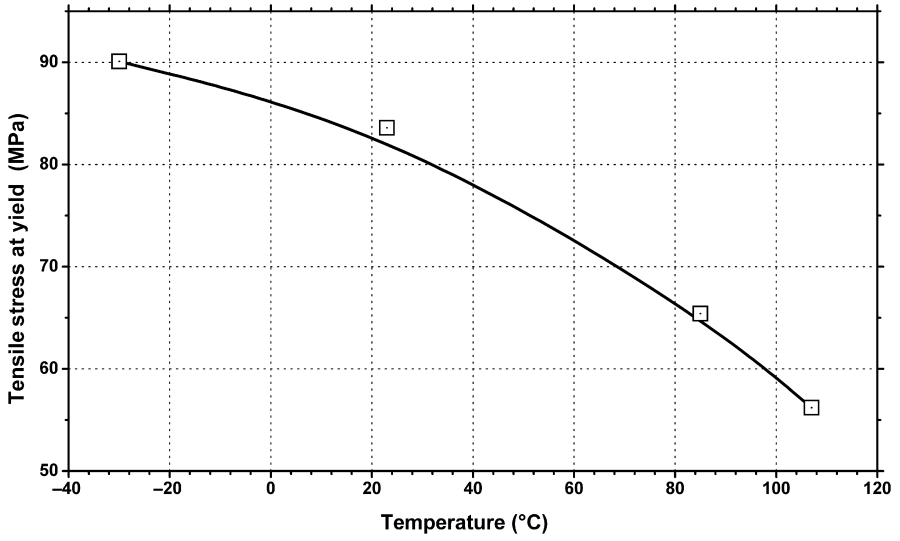

Figure 2.97 Tensile strength at yield vs. temperature for INEOS Lustran® 2316 16% glass fiber reinforced SMA resin.

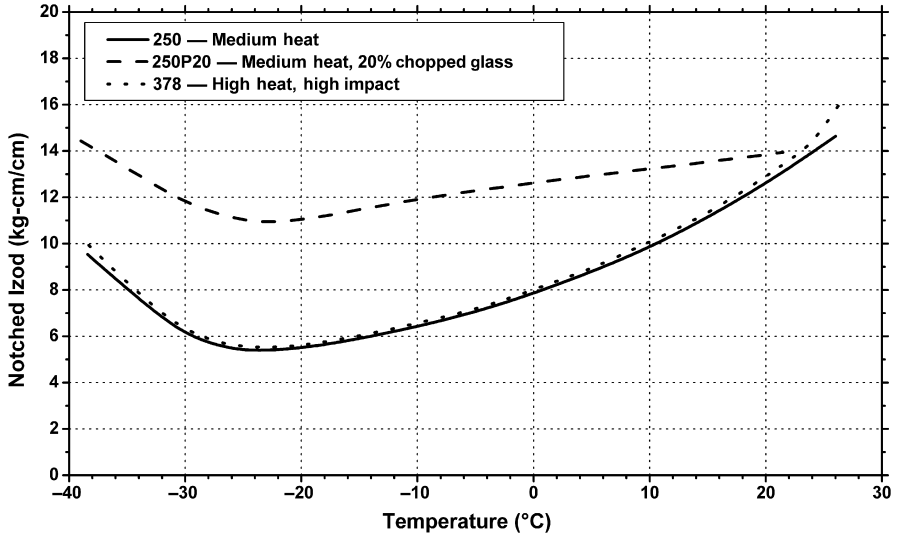

Figure 2.98 Notched Izod impact strength vs. temperature for Nova Chemicals Dylark® SMA resins.

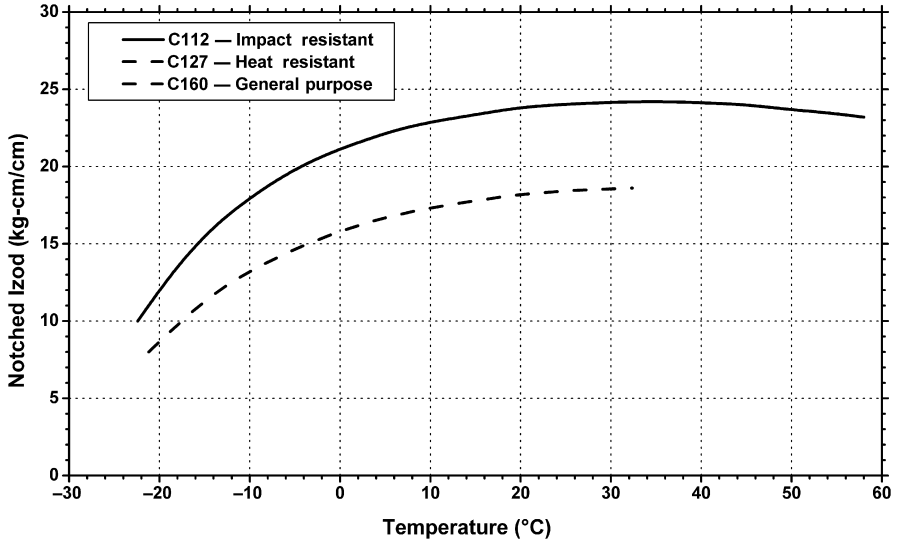

Figure 2.99 Notched Izod impact strength vs. temperature for Bayer Cadon® SMA resins.

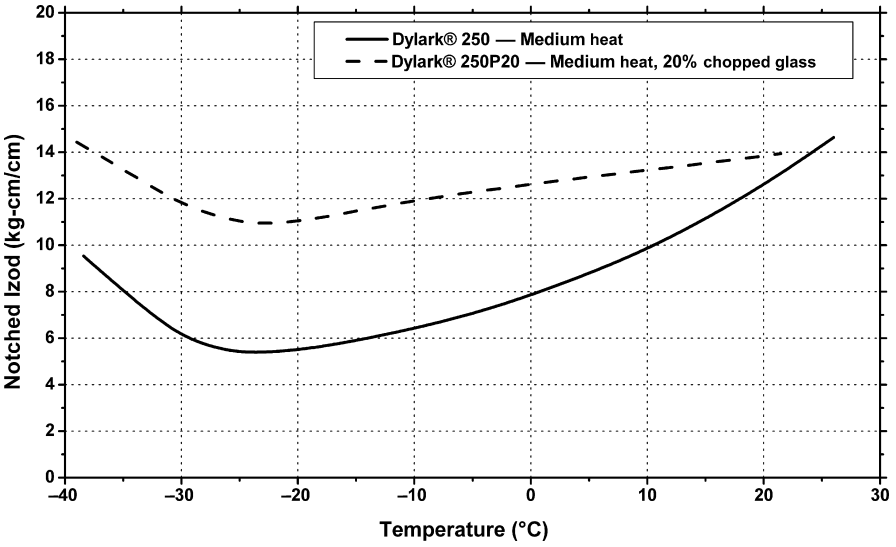

Figure 2.100 Notched Izod impact strength vs. temperature for Nova Chemicals Dylark® SMA resins.

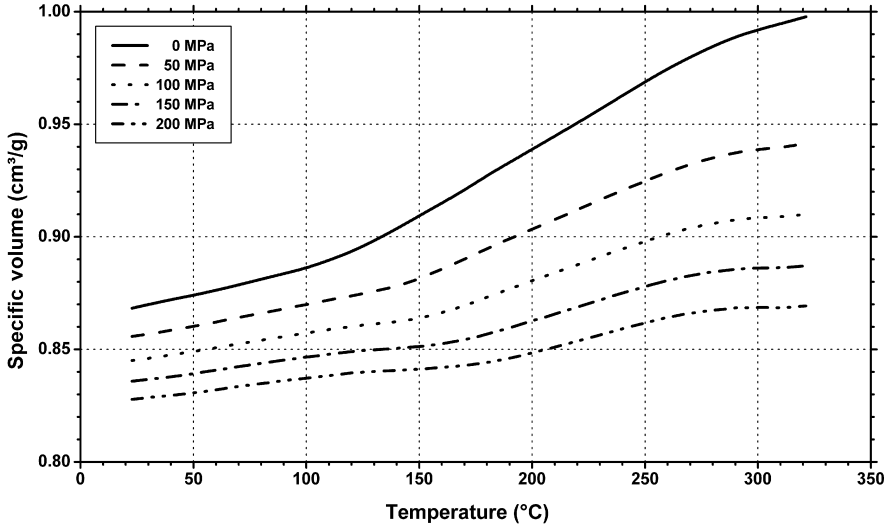

Figure 2.101 Specific volume as a function of temperature and pressure (PVT) for SABIC Innovative Plastics Prevex® IP-16 SMA resin.

2.8 Styrenic Blends and Alloys

While the number of styrenic blends might seem limitless, compatibility and morphology limit blend types. Styrenic blends are many but most are limited to only a couple types. The most important blend is ABS and polycarbonate (PC). Next in importance is ABS and polyamide (or nylon, PA). PS and polyethylene are often used in expandable foams. PS and polyphenylene ether (PPE or PPO) are commercially important blends, which are covered in later chapters. The other classes of the styrenic blends are not major product lines but can be very important in some applications.

Manufacturers and trade names: Bayer MaterialScience Bayblend®, SABIC Innovative Plastics Cycoloy®, Styrolution Terblend®, LANXESS Triax®.

Applications and uses: automotive applications including center consoles, ventilation nozzles, gearshifts, airbag covers, radio covers, glove boxes; sporting equipment including skis, ski bindings, snowboards, roller-bladers protective gear; tools including compass saws, power drills, planers, lawn mowers; electrical equipment housings such as computers or cellular phones.

Data for styrenic blend plastics are found in Figures 2.102–2.121.

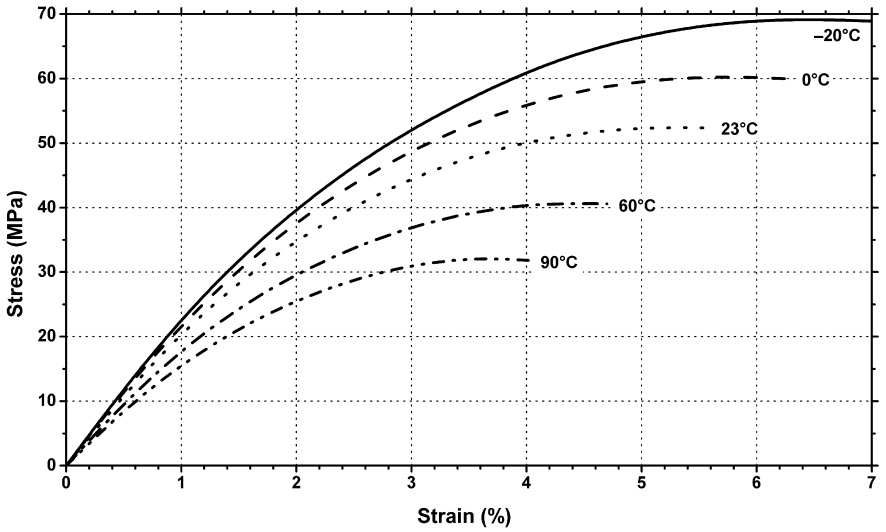

Figure 2.102 Stress vs. strain at various temperatures for Bayer MaterialScience Bayblend® T85—general purpose injection molding grade ABS/PC resin.

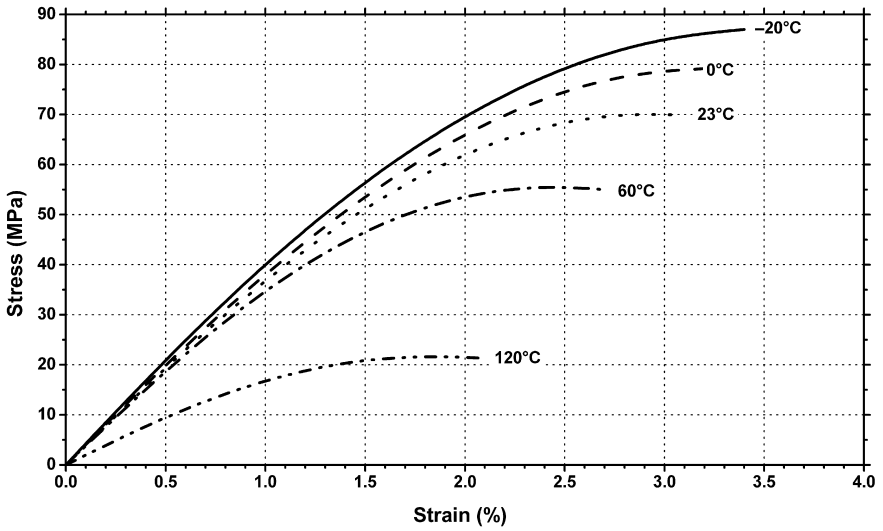

Figure 2.103 Stress vs. strain at various temperatures for Bayer MaterialScience Bayblend® T88-2N—10% glass fiber filled ABS/PC resin.

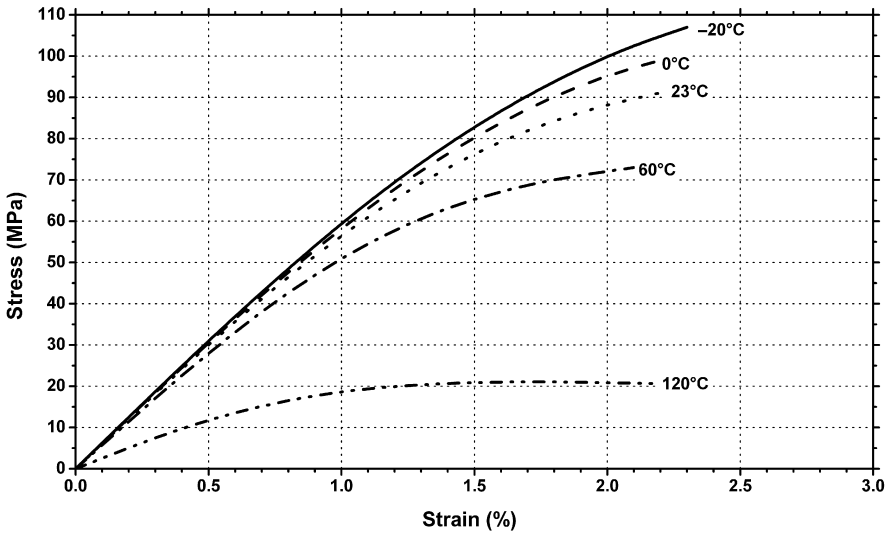

Figure 2.104 Stress vs. strain at various temperatures for Bayer MaterialScience Bayblend® T88-4N—20% glass fiber filled ABS/PC resin.

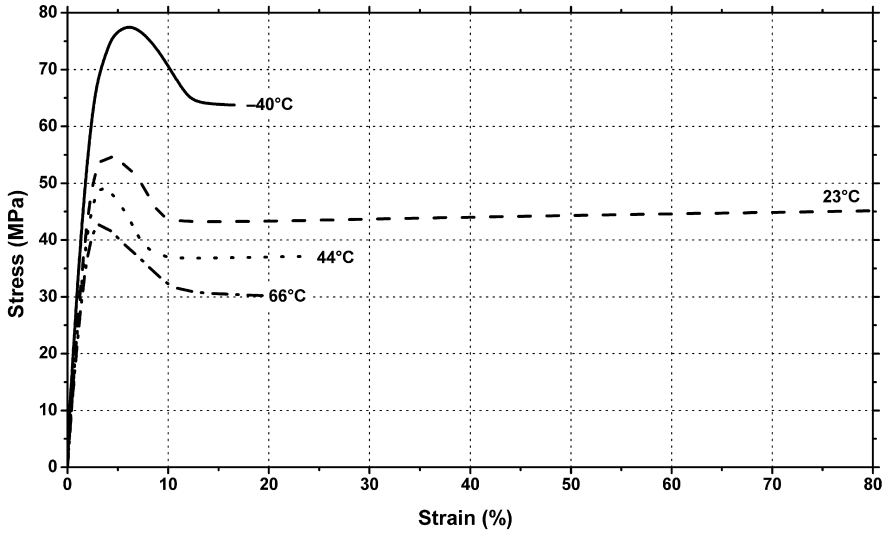

Figure 2.105 Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy® C1000HF—general purpose, high flow ABS/PC resin.

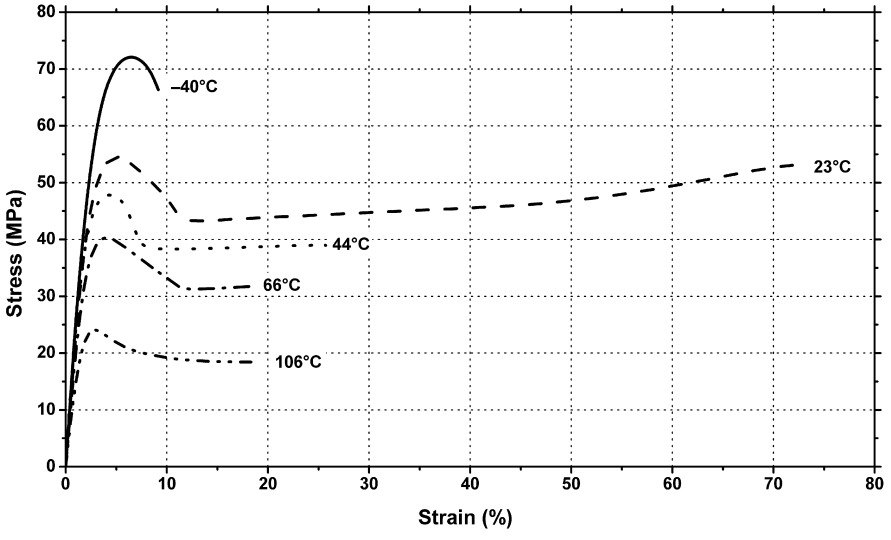

Figure 2.106 Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy® C1200HF—general purpose, high heat, high flow ABS/PC resin.

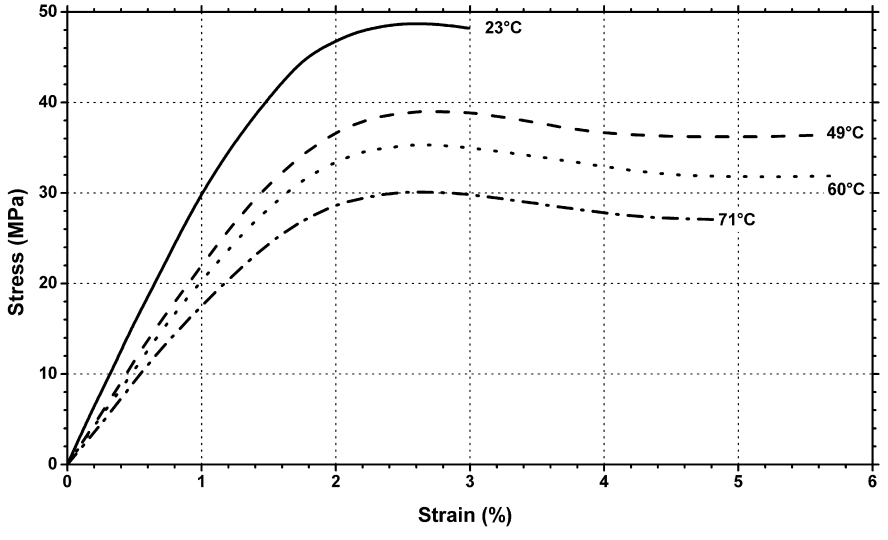

Figure 2.107 Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy® EHA—platable, high heat ABS/PC resin (plated for test).

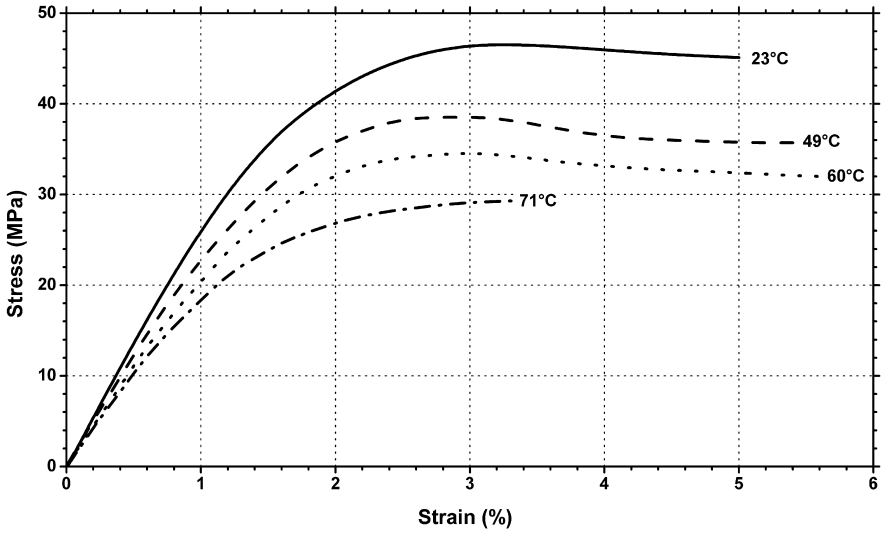

Figure 2.108 Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy® EHA—platable, high heat ABS/PC resin (unplated for test).

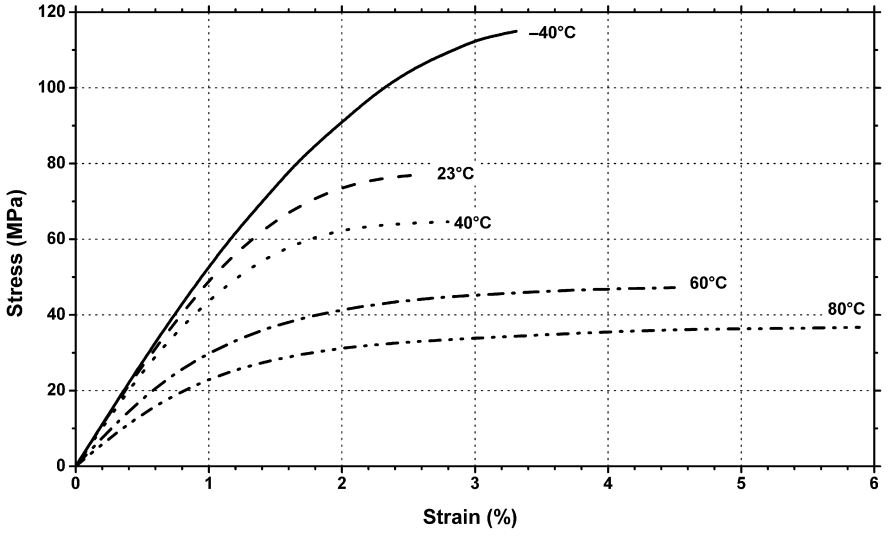

Figure 2.109 Stress vs. strain at various temperatures for Styrolution Terblend® N NG04—20% glass fiber ABS/PA resin.

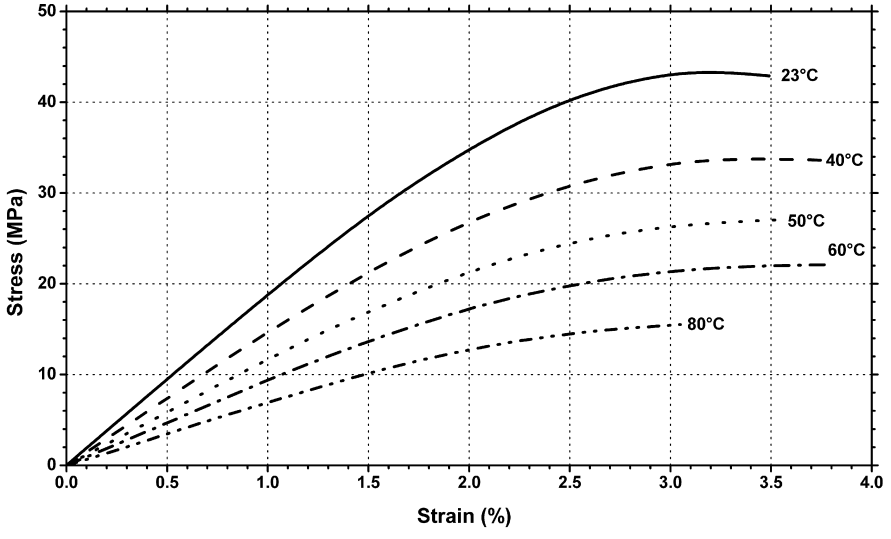

Figure 2.110 Stress vs. strain at various temperatures for LANXESS Triax® 1120—standard injection molding grade ABS/PA resin.

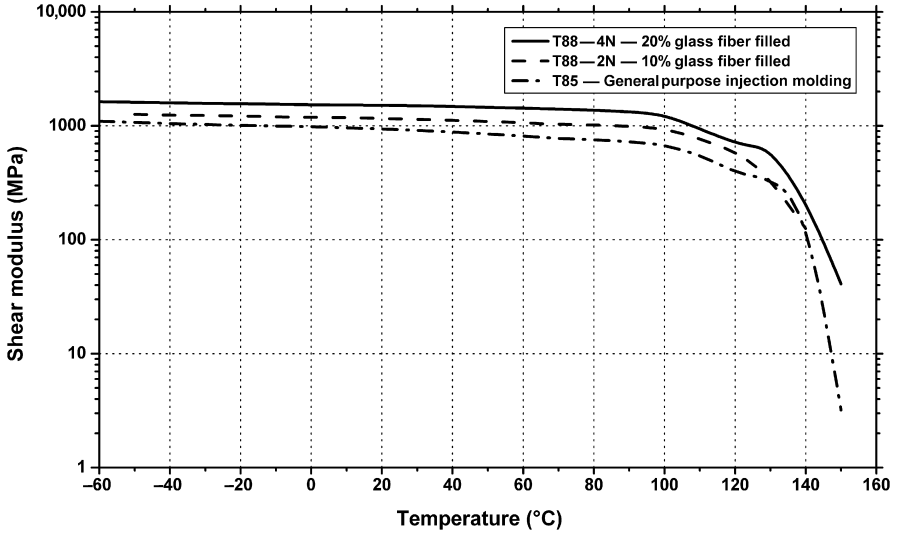

Figure 2.111 Shear modulus vs. temperature for several Bayer MaterialScience Bayblend® ABS/PC resins.

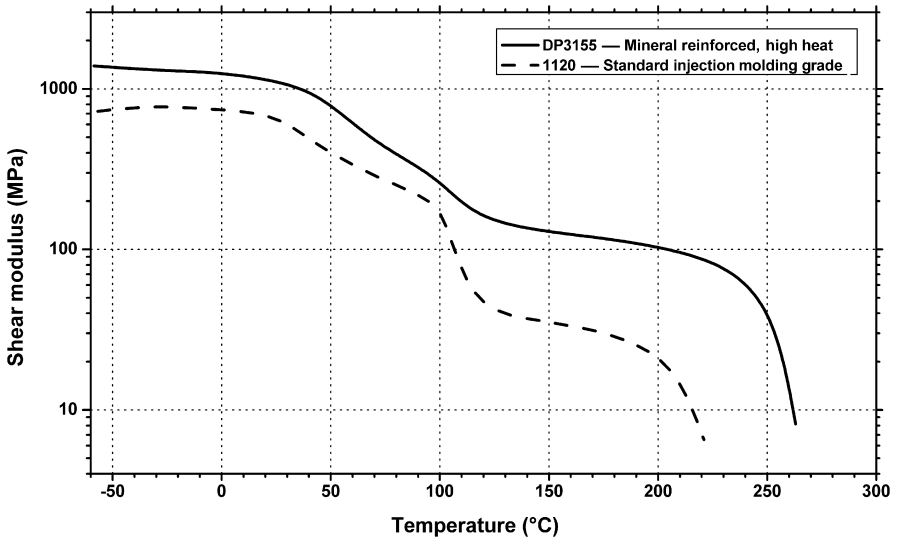

Figure 2.112 Shear modulus vs. temperature for two LANXESS Triax® ABS/PA resins.

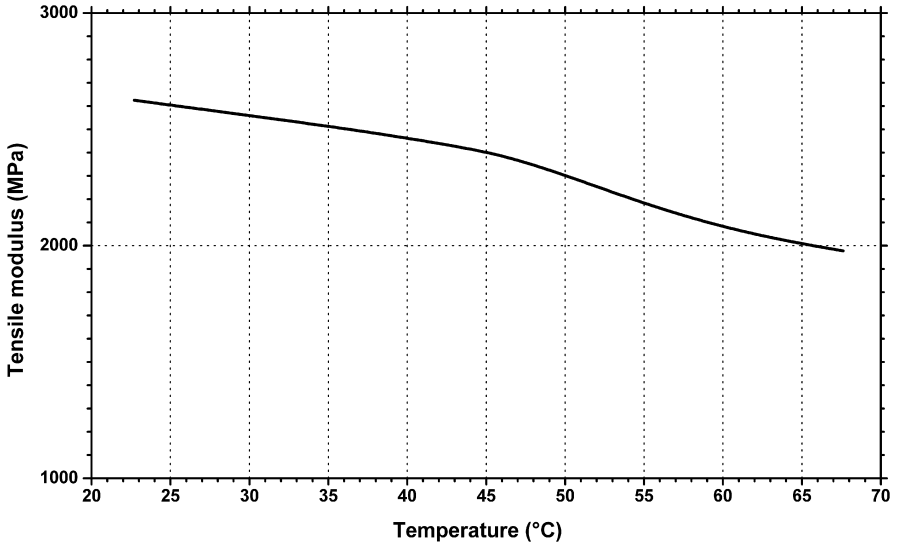

Figure 2.113 Tensile modulus vs. temperature for SABIC Innovative Plastics Cycoloy® EHA—platable, high heat ABS/PC resin.

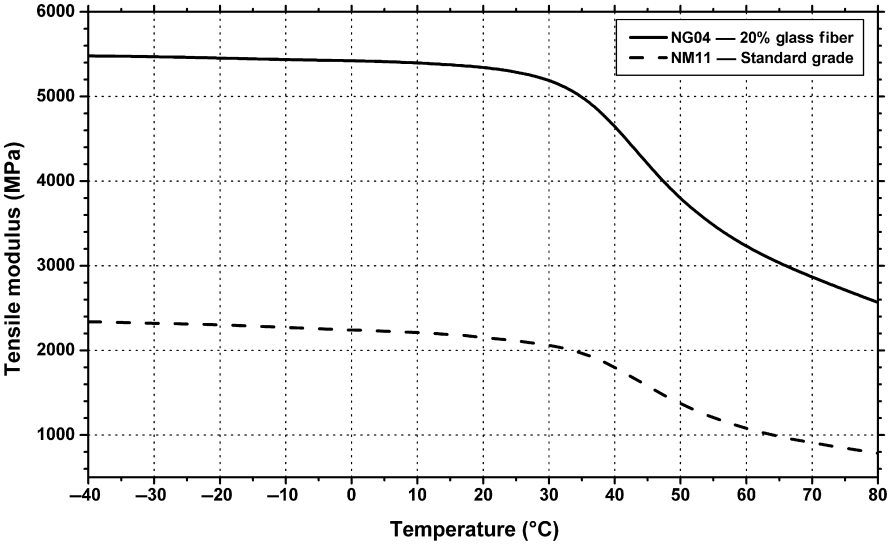

Figure 2.114 Tensile modulus vs. temperature for Styrolution Terblend® ABS/PA resins.

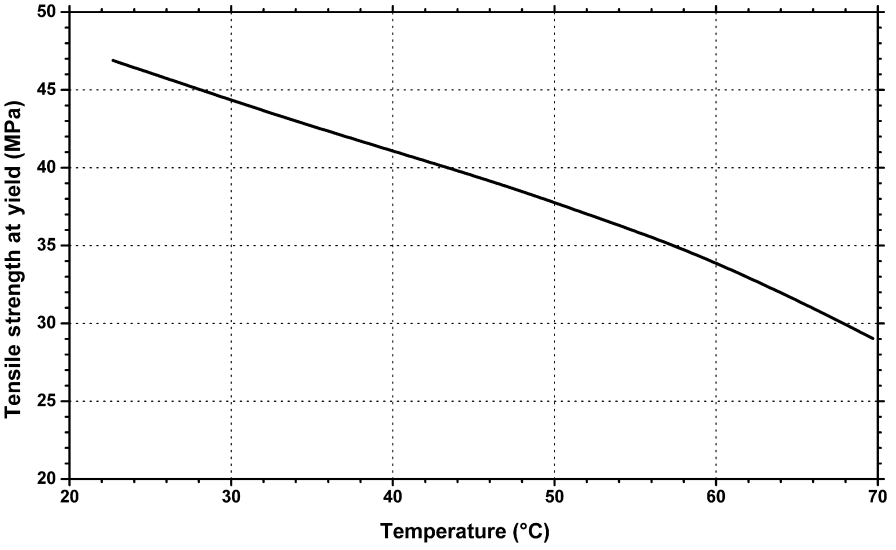

Figure 2.115 Tensile strength at yield vs. temperature for SABIC Innovative Plastics Cycoloy® EHA—platable, high heat ABS/PC resin.

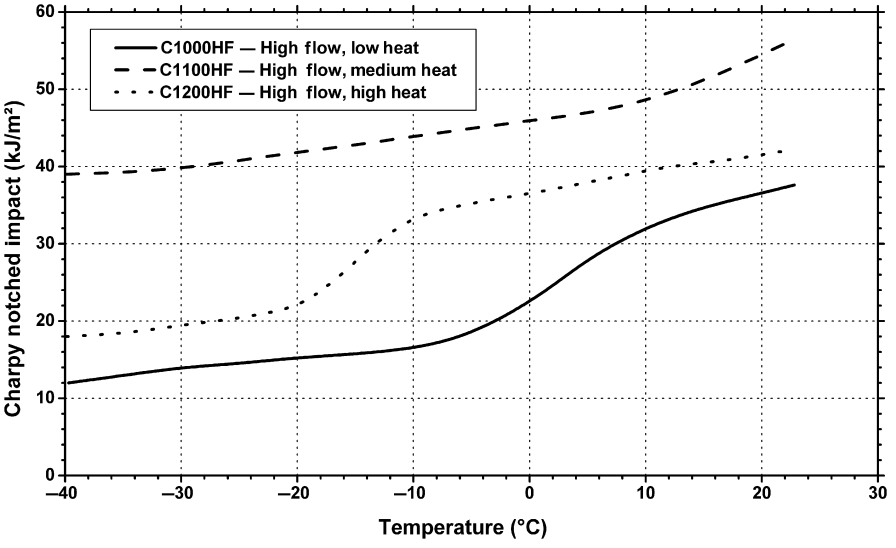

Figure 2.116 Charpy impact strength vs. temperature for SABIC Innovative Plastics Cycoloy® ABS/PC resins.

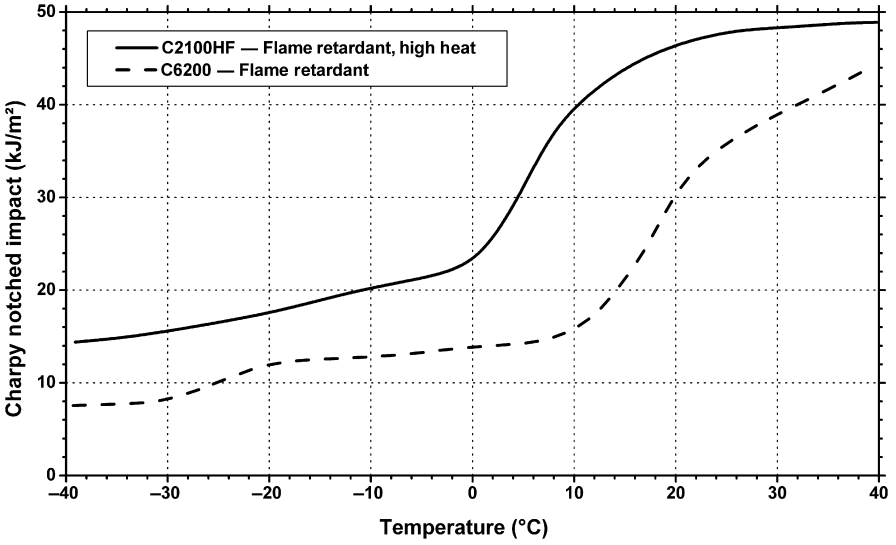

Figure 2.117 Charpy impact strength vs. temperature for SABIC Innovative Plastics Cycoloy® ABS/PC resins.

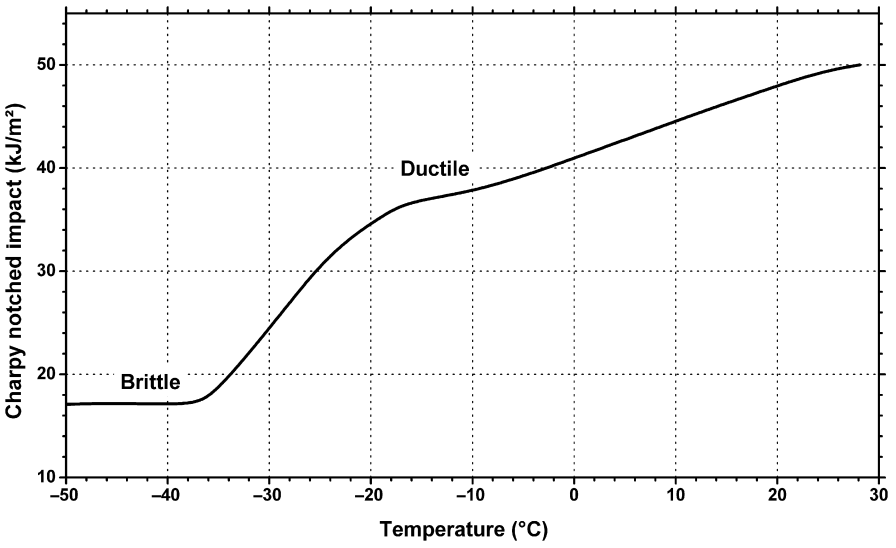

Figure 2.118 Notched Izod impact strength vs. temperature for SABIC Innovative Plastics Cycoloy® C1100HF—general purpose, medium heat ABS/PC resin.

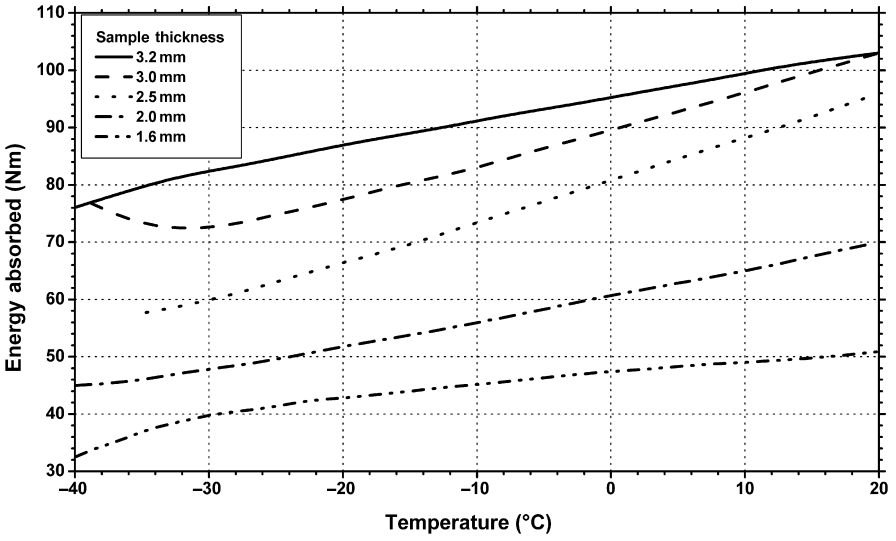

Figure 2.119 Puncture impact test (ISO 6603-2) vs. temperature for SABIC Innovative Plastics Cycoloy® C1200HF—general purpose, high heat ABS/PC resin.

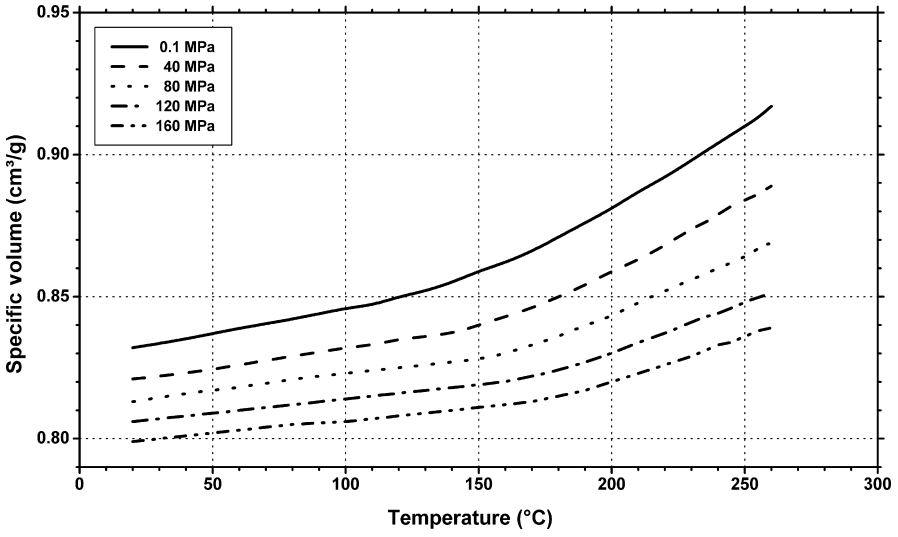

Figure 2.120 Pressure–volume–temperature (PVT) for Bayer MaterialScience Bayblend® T88-2N—10% glass fiber filled ABS/PC resin.

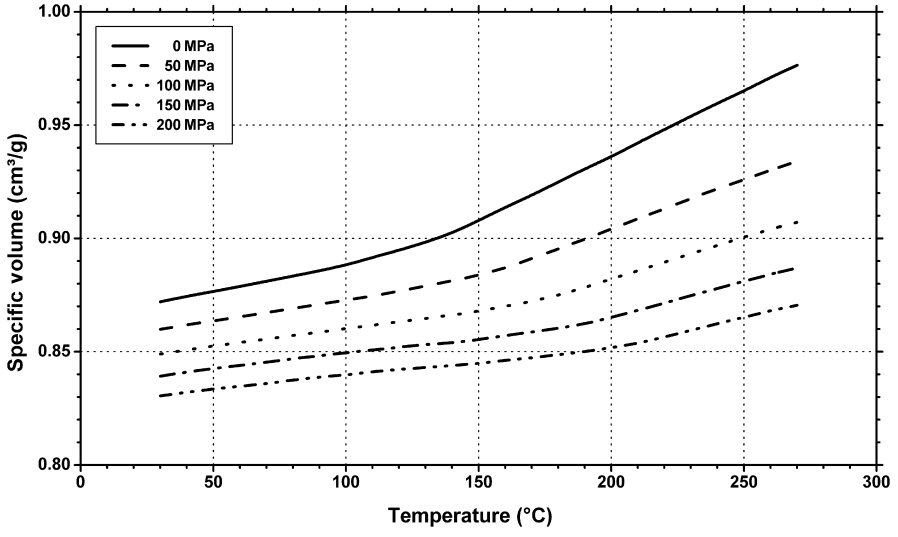

Figure 2.121 Pressure–volume–temperature (PVT) for SABIC Innovative Plastics Cycoloy® C1200HF—general purpose, high heat ABS/PC resin.

References

[1] Brighton CA, Pritchard G, Skinner GA. Styrene polymers: technology and environmental aspects. London: Applied Science Publishers; 1979. pp. 70, 72.

[2] Harper CA. Handbook of plastic and elastomers. New York, NY: McGraw-Hill; 1975. pp. 1–3,1–62, 2–42, 3–1.

[3] ABS Resin "TOYOLAC" Technical Guide. Toray Plastics; 2010.

[4] Terlux® methyl methacrylate–acrylonitrile–butadiene–styrene polymer (MABS) applications properties processing. BASF; 2003.

[5] Luran® S. BASF; 2010.

[6] Polystyrene and Styrolux® general purpose polystyrene (GPPS) high impact polystyrene (HIPS) styrene/butadiene-block copolymer (S/B/S). BASF; 2011.

[7] Luran® (SAN) styrene/acrylonitrile copolymer. BASF; 2011.

3 Polyether Plastics

This chapter covers polymers in which the most important linking group is the ether moiety, which is —O—. Included in this chapter are the acetals also called polyoxymethylene (POM) or polyacetal. Acetals come in two types, homopolymer and copolymer. The third plastic type included in this chapter is polyphenylene ether (PPE) also referred to as polyphenylene oxide (PPO).

3.1 Acetals—Polyoxymethylene (POM or Acetal Homopolymer)

Acetal polymers, also known as POM or polyacetal, are formaldehyde-based thermoplastics that have been commercially available since the 1960s. Polyformaldehyde is thermally unstable. It decomposes on heating to yield formaldehyde gas. Two methods of stabilizing polyformaldehyde for use as an engineering polymer were developed and introduced by DuPont, in 1959, and Celanese in 1962.

DuPont's method for making polyacetal yields a homopolymer through the condensation reaction of polyformaldehyde and acetic acid (or acetic anhydride). The acetic acid puts acetate groups (CH_3COO—) on the ends of the polymer as shown in Figure 3.1, which provide thermal protection against decomposition to formaldehyde.

Further stabilization of acetal polymers also includes the addition of antioxidants and acid scavengers. Polyacetals are subject to oxidative and acidic degradation, which leads to molecular weight decline. Once the chain of the homopolymer is ruptured by such an attack, the exposed polyformaldehyde ends may decompose to formaldehyde and acetic acid.

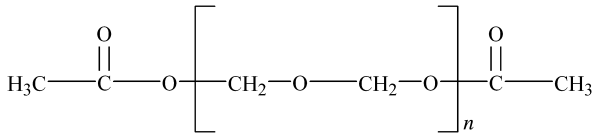

Figure 3.1 Chemical structure of acetal homopolymer.

Manufacturers and trade names: DuPont Delrin®, Asahi Kasei Corporation Tenac™.

Applications and uses: metal and glass replacement in many automotive, industrial equipment, consumer goods, appliances, electrical, and office automation.

Tables 3.1–3.5 describe the compositions and designed purpose for the DuPont Delrin® acetal homopolymers resins discussed in the rest of this section. The data for acetal homopolymer are found in Tables 3.6–3.15 and Figures 3.2–3.24.

3.2 Polyoxymethylene Copolymer (POM-Co or Acetal Copolymer)

The Celanese route for the production of polyacetal yields a more stable copolymer product via the reaction of trioxane, a cyclic trimer of formaldehyde, and a cyclic ether, such as ethylene oxide or 1,3 dioxolane. The structures of these monomers are shown in Figure 3.25. The polymer structure is represented in Figure 3.26.

The improved thermal and chemical stability of the copolymer vs. the homopolymer is a result of randomly distributed oxyethylene groups, which is circled in Figure 3.26. All polyacetals are subject to oxidative and acidic degradation, which leads to molecular weight decline. Deterioration in the copolymer ceases, however, when one of the randomly distributed oxyethylene linkages is reached. These groups offer stability to oxidative, thermal, acidic, and alkaline attack. The raw copolymer is hydrolyzed to an oxyethylene end cap to provide thermally stable polyacetal copolymer.

The copolymer is also more stable than the homopolymer in an alkaline environment. Its oxyethylene end cap is stable in the presence of strong bases. The acetate end cap of the homopolymer, however, is readily hydrolyzed in the presence of alkalis, causing significant polymer degradation.

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
DOI: http://dx.doi.org/10.1016/B978-0-323-31016-1.00003-9
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Table 3.1 Compositions of General Purpose DuPont Delrin® Acetal Resins [1]

Delrin® Grade	Process	Characteristics	Typical Applications
100	Injection molding, extrusion	High-viscosity resin, best combination of stiffness and toughness, very good creep resistance	High-performance engineering parts, e.g., gears, seat belt restraint systems, fasteners, conveyors
100P	Injection molding, extrusion	Same as Delrin® 100, best molding thermal stability for deposit-free molding in demanding processing conditions	Same as Delrin® 100
111P	Injection molding, extrusion	Same as Delrin® 100P, but modified for enhanced crystallization and more precise molding	Same as Delrin® 100, plus fuel system components
500	Injection molding	Medium viscosity resin. Optimum combination of flow and physical properties	General mechanical parts, automotive fuel systems, snap-fits, fasteners, and gears
500P	Injection molding	Same as Delrin® 500, best molding thermal stability for deposit-free molding in demanding processing conditions	Same as Delrin® 500
511P	Injection molding	Same as Delrin® 500P, but modified for enhanced crystallization, and more precise molding	Same as Delrin® 500, plus fuel system components
900	Injection molding	Low-viscosity resin	Multicavity molds and parts with thin sections difficult to fill
900P	Injection molding	Low viscosity, fast molding, best molding thermal stability for deposit-free molding in demanding processing conditions	Same as Delrin® 900
911P	Injection molding	Same as Delrin® 900P, but modified for enhanced crystallization and more precise molding	Same as Delrin® 900, plus fuel system components
1700P	Injection molding	Very low viscosity, fast molding resin, best molding thermal stability for deposit-free molding in demanding situations	Parts with complex shapes, thin walls, long flow paths, or multicavity tools

Table 3.2 Compositions of Toughened DuPont Delrin® Acetal Resins [1]

Delrin® Grade	Process	Characteristics	Typical Applications
100ST	Injection molding, extrusion	Super tough, high-viscosity resin, outstanding resistance against repetitive impact, even at very low temperature	Fasteners and lock systems
500MT	Injection molding	Moderately toughened resin, with higher level of toughener than Delrin® 500T; improved thermal stability in processing	Fasteners and gears
500T	Injection molding	Toughened medium viscosity resin, optimizing flow properties and impact performance	Fasteners and gears

Table 3.3 Compositions of Low Friction and Wear DuPont Delrin® Acetal Resins [1]

Delrin® Grade	Process	Characteristics	Typical Applications
500AL	Injection molding	Advanced lubricant system, very good low-friction and low-wear properties	Gears, drive trains, and sliding devices
500CL	Injection molding	Chemically lubricated Delrin® 500, very good low-friction and low-wear properties	Gears, drive trains, and sliding devices
100AF	Injection molding, extrusion	Delrin® 100 with 20% Teflon® PTFE fibers, outstanding friction and wear properties	Specialty friction and wear applications, conveyor systems
500AF	Injection molding	Delrin® 500 with 20% Teflon® PTFE fibers, outstanding friction and wear properties	Specialty friction and wear applications, conveyor systems
520MP	Injection molding	Delrin® 500P with 20% Teflon® PTFE micropowder, with low-wear and low-friction properties	Specialty friction and wear applications
510MP	Injection molding	Delrin® 500P with 10% Teflon® PTFE micropowder, with low-wear and low-friction properties	Specialty friction and wear applications
500TL	Injection molding	Delrin® 500 with 1.5% Teflon® powder, low-friction and low-wear properties	Specialty friction and wear applications, conveyor systems
900SP	Injection molding	Delrin® 900P with special polymer additive for low wear/low friction against itself and other plastics	Gears, drive trains, and sliding devices
100KM	Injection molding	Delrin® 100P modified with Kevlar® aramid resin for abrasive wear reduction	Specialty friction and wear applications

Table 3.4 Compositions of Higher Stiffness DuPont Delrin® Acetal Resins [1]

Delrin® Grade	Process	Characteristics	Typical Applications
570NC	Injection molding	20% glass-filled medium-viscosity resin	General engineering parts for high stiffness
577BK	Injection molding	Delrin® 570 with carbon black for improved weathering	General engineering parts
510GR	Injection molding	10% glass-reinforced resin	Parts requiring high stiffness and strength
525GR	Injection molding	25% glass-reinforced resin	Parts requiring very high stiffness and strength

Table 3.5 Compositions of UV Stabilized and Specialty DuPont Delrin® Acetal Resins [1]

Delrin® Grade	Process	Characteristics	Typical Applications
UV Stabilized Grades			
127UV	Injection molding	Delrin® 100P with UV stabilizer system	Automotive interior parts with maximum UV performance requirements, ski bindings, and seat belt restraint parts
527UV	Injection molding	Delrin® 500P with UV stabilizer system	Automotive interior parts with maximum UV performance requirements, interior trim, and seat belt restraint parts
927UV	Injection molding	Delrin® 900P with UV stabilizer system	Automotive interior parts and loudspeaker grilles
1727UV	Injection molding	Delrin® 1700P with UV stabilizer system	Automotive interior parts and loudspeaker grilles
Extrusion Grades			
Delrin® II 150E	Extrusion	High-viscosity extrusion resin	Extruded rods and slabs for machining, tubes and sheets
Delrin® II 150SA	Extrusion	High-viscosity extrusion resin	Extruded rods and slabs for machining, tubes and sheets
Delrin® II 550SA	Extrusion	Medium-viscosity extrusion resin	Extruded rods and slabs for machining, tubes and sheets
Concentrates			
500SC	Injection molding	20% silicone concentrate in Delrin® for let-down to 1% or 2% silicone	Conveyors, moving parts, and gears

The homopolymer is more crystalline than the copolymer. The homopolymer provides better mechanical properties, except for elongation. The oxyethylene groups of the copolymer provide improved long-term chemical and environmental stability. The copolymer's chemical stability results in better retention of mechanical properties over an extended product life.

Acetal polymers have been particularly successful in replacing cast and stamped metal parts due to their toughness, abrasion resistance, and ability to withstand prolonged stresses with minimal creep. Polyacetals are inherently self-lubricating. Their lubricity allows the incorporation of polyacetal in a variety of metal-to-polymer and polymer-to-polymer interface applications such as bearings, gears, and switch plungers. These properties have permitted the material to meet a wide range of market requirements.

The properties of acetal can be summarized as follows:

- Excellent wear resistance
- Very good strength, stiffness
- Good heat resistance
- Excellent chemical resistance
- Opaque
- Moderate to high price
- Somewhat restricted processing

Manufacturers and trade names: Asahi Kasei Corporation Tenac C™, Celanese Celcon®, Celanese Hostaform®, Mitsubishi Engineering-Plastics Iupital®.

Applications and uses: metal and glass replacement in many automotive (door handles/locks, seat belt buckles, fuel/fuel sending systems, gas tank

Table 3.6 Tensile Elongation at Break (%) of DuPont Delrin® Acetal Resins at Various Temperatures [2]

Temperature (°C)	100	500	900	1700	150SA, 150E	550SA	107	507	570	577	500CL	100AF	500AF	500TL	100ST	500T
−55	38	15	10	–	38	15	38	15	3	3	13	15	10	9	–	–
23	75	40	25	17	75	40	75	40	12	12	40	22	15	13	>200	60
70	230	220	180	–	230	220	230	220	50	50	190	50	40	110	>250	>250
100	>250	>250	>250	>250	>250	>250	>250	>250	>250	>250	>250	>250	160	>250	>250	>250
121	>250	>250	>250	>250	>250	>250	>250	>250	>250	>250	>250	>250	190	>250	>250	>250

Note: 5.1 mm/min per ASTM D638 and ISO R527.

Table 3.7 Tensile Strength (MPa) of DuPont Delrin® Acetal Resins at Various Temperatures [2]

Temperature (°C)	100	500	900	1700	150SA, 150E	550SA	107	507	570	577	500CL	100AF	500AF	500TL	100ST	500T
−55	101	101	101	88	101	101	101	101	88	88	96	75	74	101	65	100
23	69	69	69	68	69	69	69	69	59	59	66	52	48	69	45	58
70	48	48	48	40	48	48	48	48	40	40	46	37	32	46	32	43
100	36	36	36	27	36	36	36	36	28	28	30	28	23	36	23	34
121	26	26	26	21	26	26	26	26	21	21	23	21	19	26	18	24

Note: 5.1 mm/min per ASTM D638 and ISO R527.

Table 3.8 Flexural Modulus (MPa) of DuPont Delrin® Acetal Resins at Various Temperatures [2]

Temperature (°C)	100	500	900	1700	150SA, 150E	550SA	107	507	570	577	500CL	100AF	500AF	500TL	100ST	500T
−55	3650	3900	4130	4500	3650	3900	3650	3900	6400	6400	3800	3600	3700	–	3250	3650
23	2900	2950	2960	3000	2900	2950	2900	2950	5000	5000	2750	2350	2400	3000	1250	2400
70	1550	1600	1650	1400	1550	1600	1550	1600	3800	3800	1500	1300	1400	1600	700	1250
100	900	900	950	900	900	900	900	900	2050	2050	900	750	800	1000	350	700
121	600	600	600	700	600	600	600	600	1850	1850	550	550	600	650	200	400

Note: 1.3 mm/min (0.05 in/min) per ASTM D790 and ISO 178.

Table 3.9 Mechanical Properties at Various Temperatures of DuPont P Type (Enhanced Thermal Stability) Delrin® Acetal Resins [2]

Temperature (°C)	100P	500P	900P	1700P
Tensile Stress at Yield (MPa) per ASTM D638 and ISO R527				
−40	93	86	97	88
23	70	68	67	72
100	26	28	30	28
Elongation at Yield (%) per ASTM D638 and ISO R527				
−40	21	13	9	8
23	23	15	11	8
100	10	9	9	8
Tensile Strength (MPa) per ASTM D638 and ISO R527				
−40	95	86	97	90
23	68	68	69	70
100	31	31	31	31
Elongation at Break (%) per ASTM D638 and ISO R527				
−40	40	20	12	10
23	70	35	20	10
100	>250	>250	>250	>150
Tensile Modulus (MPa) per ASTM D638 and ISO R527				
−40	3310	3450	3930	3620
23	2900	3250	3480	3470
100	760	700	930	930
Flexural Modulus (MPa) (1.3 mm/min) per ASTM D790 and ISO 17				
−40	3310	3930	4000	4140
23	2900	3100	3240	3380
100	760	830	830	970

Table 3.10 Mechanical Properties at Various Temperatures of General Purpose Grades of DuPont Delrin® POM [2]

	Toughest			Medium Flow			High Flow			Ultra Flow
Property/Temperature (°C)	**D100[a]**	**D100P**	**D111P**	**D500**	**D500P**	**D511P**	**D900**	**D900P**	**D911P**	**D1700P**
Tensile Stress at Yield in MPa (5 mm/min) ASTM D638										
−40	–	NY	NY	–	93	98	–	94	97	98
23	69	67	72	69	68	72	69	69	73	71
70	45	44	49	49	45	50	48	47	–	48
100	36	29	33	–	28	32	–	33	34	28
Tensile Strength in MPa (5 mm/min) ASTM D638										
−40	–	91	96	–	93	99	–	94	97	–
23	69	66	69	69	68	72	69	69	73	71
70	–	–	–	–	–	–	48	47	–	48
100	–	–	–	–	–	–	–	–	–	–
Elongation at Yield in % (5 mm/min) ASTM D638										
−40	–	NY	NY	–	13	11	–	9	9	8
23	25	23	21	14	15	11	11	11	10	8
70	13	13	11	10	12	9	10	10	–	9
100	9	11	9	–	9	8	–	9	8	8
Elongation at Break in % (5 mm/min) ASTM D638										
−40	–	40	50	–	22	20	–	18	17	10
23	75	80	73	45	40	33	30	25	20	15
70	>100	>100	>100	>100	>100	>100	>100	>100	–	28
100	>100	>100	>100	>100	>100	>100	>100	>100	>100	–
Tensile Modulus in MPa (5 mm/min) ASTM D638										
−40	–	3310	–	–	4030	4100	–	3930	–	3620
23	3120	2940	3000	3300	3250	3380	3410	3480	3300	3560
70	1370	1360	1660	1680	1470	1760	1700	1590	–	1780
100	–	760	–	–	1020	1150	–	930	–	930
Flexural Modulus in MPa (1.3 mm/min) ASTM D790										
−40	3410	3430	3500	3770	3700	3900	3900	3800	3970	3900
23	2890	2790	2970	3110	3100	3300	3240	3240	3380	3380
70	1400	1280	1440	1450	1380	1540	1500	1380	1600	1500
100	900	780	870	930	900	1080	950	900	980	900

[a] *The "D" in front of the product number is optional, i.e., D100 = 100.*

NY, no yield.

Table 3.11 Mechanical Properties at Various Temperatures of Specialty Grades of DuPont Delrin® POM [1]

	Extrusion Grades		UV Stabilized		Glass Filled Glass Reinforced			Chemically Lubricated with Teflon® PTFE Fibers and Filler	
Property/Temperature (°C)	**D150E, SA**	**D550SA**	**D127UV**	**D527UV**	**D570**	**D577**	**D525GR**	**D500AL**	**D500CL**
Tensile Stress at Yield in MPa (5 mm/min) ASTM D638									
−40	–	–	97	96	81	–	NY	87	84
23	69	69	67	67	58	57	NY	66	65
70	–	–	49	40	–	–	113	–	–
100	–	–	34	33	28	–	89	28	27
Tensile Strength in MPa (5 mm/min) ASTM D638									
−40	–	–	–	–	82	–	210	87	84
23	–	–	–	–	58	58	151	66	65
70	–	–	–	–	–	–	113	–	–
100	–	–	–	–	28	–	89	–	–
Elongation at Yield in % (5 mm/min) ASTM D638									
−40	–	–	31	16	3	–	NY	14	9
23	20	–	26	13	5	5	NY	10	14
70	–	–	–	–	–	–	4	–	–
100	–	–	11	9	6	–	5	8	11
Elongation at Break in % (5 mm/min) ASTM D638									
−40	–	–	40	–	–	–	3	18	12
23	84	40	75	45	12	10	3.2	30	40
70	–	–	–	–	–	–	5	–	–
100	–	–	>100	>100	–	–	6	–	–
Tensile Modulus in MPa (5 mm/min) ASTM D638									
−40	–	–	–	–	7340	–	–	–	–
23	3100	3100	2910	3230	5920	5700	9000	3170	3250
70	–	–	–	–	–	–	–	–	–
100	–	–	–	–	2280	–	–	–	–
Flexural Modulus in MPa (1.3 mm/min) ASTM D790									
−40	–	–	3710	4000	5450	–	8720	3660	4260
23	2900	2950	2800	3050	5000	4800	8000	2970	3000
70	–	–	1270	1320	–	–	5200	1440	–
100	–	–	840	850	1650	–	4500	830	830

NY, no yield.

Table 3.12 Mechanical Properties at Various Temperatures of More Specialty Grades of DuPont Delrin® POM [1]

Property/Temperature (°C)	Chemically Lubricated with Teflon® PTFE Fibers and Filler					Impact Modified		
	D100AF	D500AF	D520MP	D510MP	D500TL	D100ST	D500MT	D500T
Tensile Stress at Yield in MPa (5 mm/min) ASTM D638								
−40	NY	NY	76	86	92	69	70	85
23	NY	NY	54	61	67	45[a]	44[a]	53[a]
70	–	–	–	–	–	–	28	36
100	23	23	26	27	28	19	22	29
Tensile Strength in MPa (5 mm/min) ASTM D638								
−40	–	65	71	79	92	69	71	85
23	53	50	54	61	67	45	44	53
70	–	–	–	–	–	–	–	–
100	–	–	–	–	–	–	–	–
Elongation at Yield in % (5 mm/min) ASTM D638								
−40	NY	NY	7	8	–	47	15	11
23	NY	NY	12	10	12	35	21	15
70	–	–	–	–	–	–	19	14
100	8	7	8	9	–	28	13	12
Elongation at Break in % (5 mm/min) ASTM D638								
−40	–	9	12	11	–	94	50	30
23	19	11	14	13	25	>150	80	75
70	–	–	–	–	–	>100	>100	>100
100	>100	>100	–	–	–	>100	>100	>100
Tensile Modulus in MPa (5 mm/min) ASTM D638								
−40	–	–	–	–	–	2370	2650	3290
23	2750	2910	3130	3030	3100	1300	1800	2400
70	–	–	–	–	–	–	1000	1300
100	–	–	–	–	–	460	–	–
Flexural Modulus in MPa (1.3 mm/min) ASTM D790								
−40	–	3440	3780	3760	3780	1960	2100	2960
23	2510	2710	3100	3160	3080	1130	1400	2250
70	–	–	1340	–	–	–	600	800
100	–	730	1010	970	1010	240	340	500

[a] *Impact modified grades are tested at 50 mm/min, all others at 5 mm/min.*

NY, no yield.

Table 3.13 Mechanical Properties at Various Temperatures of General Purpose Grades of DuPont Delrin® POM ISO Data [1]

Property/Temperature (°C)	Toughest			Medium Flow			High Flow			Ultra Flow
	D100	D100P	D111P	D500	D500P	D511P	D900	D900P	D911P	D1700P
Yield Stress in MPa (5 mm/min) per ISO 11403										
−40	99	94	100	98	97	100	100	99	100	99
0	80	77	80	80	78	82	78	81	83	82
23	68	66	70	68	67	72	69	70	71	70
60	56	56	57	56	55	56	55	55	58	–
80	40	37	41	40	38	42	39	41	42	41
100	30	29	31	32	28	34	31	30	34	31
120	23	21	25	23	22	24	24	23	23	24
Yield Strain in % (5 mm/min) per ISO 11403										
−40	21	–	22	15	17	10	13	7.8	7.6	7.6
0	–	39	28	14	15	11	14	9.5	8.8	8
23	23	24	20	14	14	10	13	9	9.5	8
60	19	19	16	14	14	10	13	9	–	–
80	12	13	12	10	11	9.3	9.2	9	9.2	8
100	12	10	9.9	9	10	7.8	8.9	9	7.2	8
120	11	12	9	9	9.7	8.8	8.3	8.9	8	8
Tensile Modulus in MPa (1 mm/min) per ISO 11403										
−40	4030	4040	4200	4150	4300	4300	4320	4420	4300	4600
0	2940	–	3320	3250	3500	–	–	3640	3750	3570
23	3100	3000	3200	3200	3200	3400	3400	3200	3400	3400
60	1700	1600	1920	1900	1900	2000	–	–	2000	2000
80	1400	–	1420	1440	1410	1700	1600	1700	1610	1800
100	1060	870	1120	1090	910	–	1090	1120	1430	1600
120	600	540	790	640	690	770	580	630	720	670

Table 3.14 Mechanical Properties at Various Temperatures of Specialty Grades of DuPont Delrin® POM ISO Data [1]

Property/ Temperature (°C)	UV Stabilized				Low Wear/Low Friction				
	D127UV	D527UV	D927UV	D1727UV	D500AF	D520MP	D500TL	D500CL	D500AL
Yield Stress in MPa (5 mm/min) per ISO 11403									
−40	97	99			69	74	98	98	92
0	79	78			NY	58	77	80	74
23	66	68			NY	51	68	66	64
60	–	50			–	38	–	–	–
80	37	38			29	31	38	39	36
100	29	30			22	23	31	30	29
120	22	22			16	18	24	22	22
Yield Strain in % (5 mm/min) per ISO 11403									
−40	–	10			–	10	13	17	7
0	–	12			NY	14	13	19	9
23	30	12			NY	12	12	13	10
60	–	11			–	–	–	–	–
80	14	10			10	8.6	9.2	11	10
100	13	10			9.3	7.8	8.1	10	8.5
120	13	10			8.5	6.8	8.1	10	7.5
Tensile Modulus in MPa (1 mm/min) per ISO 11403									
−40	3700	3700			4000	3300	4100	4000	3800
0	3300	3200			–	3000	3500	3500	3300
23	3000	3200	–	3600	2900	2800	3300	3100	3100
60	–	1630			–	1800	–	–	–
80	1300	1270			1700	1100	1560	1350	1440
100	930	1200			1020	820	1120	1140	1320
120	530	750	590	8000	730	540	8000		

NY, no yield.

Table 3.15 Mechanical Properties at Various Temperatures of More Specialty Grades of DuPont Delrin® POM ISO Data [1]

	Impact Modified			Glass Grades		
Property/Temperature (°C)	**D100ST**	**D500MT**	**D500T**	**D570**	**D510GR**	**D525GR**
Yield Stress in MPa (5 mm/min) per ISO 11403						
−40	69	74	83	71	NY	NY
0	–	54	63	62	NY	NY
23	38	43	52	55	95[a]	138[a]
60	32	–	44	–	–	–
80	20	24	29	33	62	95
100	13	18	23	24	54	83
120	12	17	22	18	41	63
Yield Strain in % (5 mm/min) per ISO 11403						
−40	33	24	31	–	NY	NY
0	–	44	32	9	NY	NY
23	33	21	16	9	NY	NY
60	24	24	–	–	4.8	2.4
80	23	23	13	8	4.8	4.4
100	23	23	14	8	4.8	4.3
120	19	19	13	8	5.7	6.1
Tensile Modulus in MPa (1 mm/min) per ISO 11403						
−40	2200	2350	3540	6000	5700	9900
0	1370	1800	2900	–	–	–
23	1400	1800	2500	6000	5500	9500
60	600	–	1300	–	3270	6750
80	430	690	770	2600	3450	5560
100	290	610	530	1850	2950	5270
120	100	240	440	1080	1470	3660

[a]*Tested at 5 mm/min.*
NY, no yield.

caps, windshield wiper components, window hardware, control cables), industrial equipment (gears, bearings, conveyor links, cams, bushings, valve bodies, hose connectors, pistons, pulleys, casters, rollers), consumer goods (zippers, cosmetic applicators/containers, aerosol valves, pens, phone housing, keys and parts), appliances (food processor blades, dishwasher soap dispensers, spray nozzles and rollers, food containers, functional gears in washers and dryers, kettles, mixer bowls, washing machine/dryer parts, electrical and office automation).

The data for acetal copolymer are found in Figures 3.27–3.83.

3.3 Modified Polyphenylene Ether/Polyphenylene Oxides (PPE or PPO)

PPE plastics are also referred to as PPO. The structure of the polymer is shown in Figure 3.84.

The PPE materials are always blended or alloyed with other plastics, so they are called modified PPE

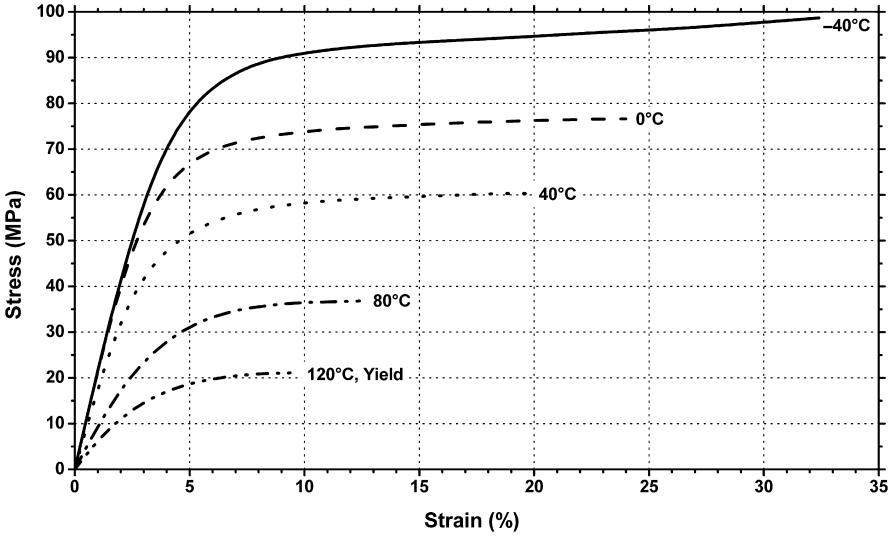

Figure 3.2 Stress vs. strain for DuPont Engineering Polymers Delrin® 100P NC010—general purpose, high viscosity with improved processing acetal resin.

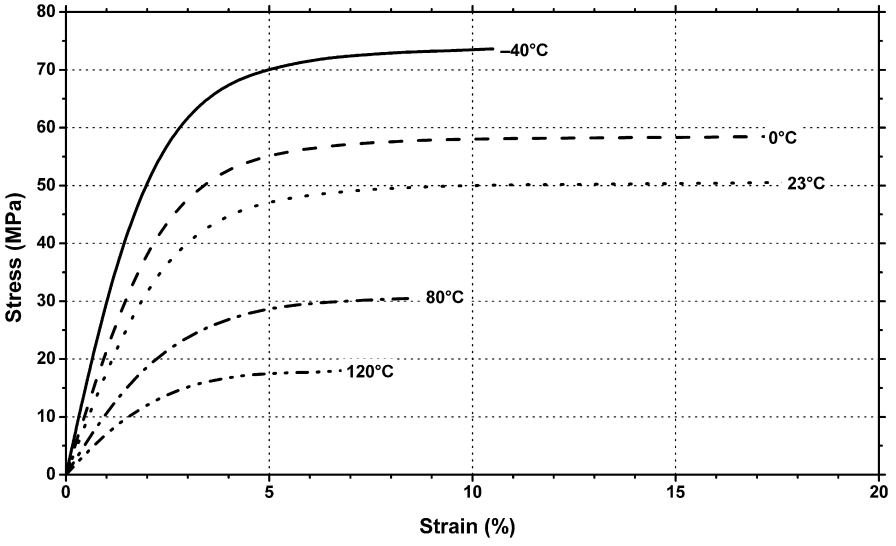

Figure 3.3 Stress vs. strain for DuPont Engineering Polymers Delrin® 500MP NC010—general purpose, medium viscosity, containing Teflon® PTFE micropowder acetal resin.

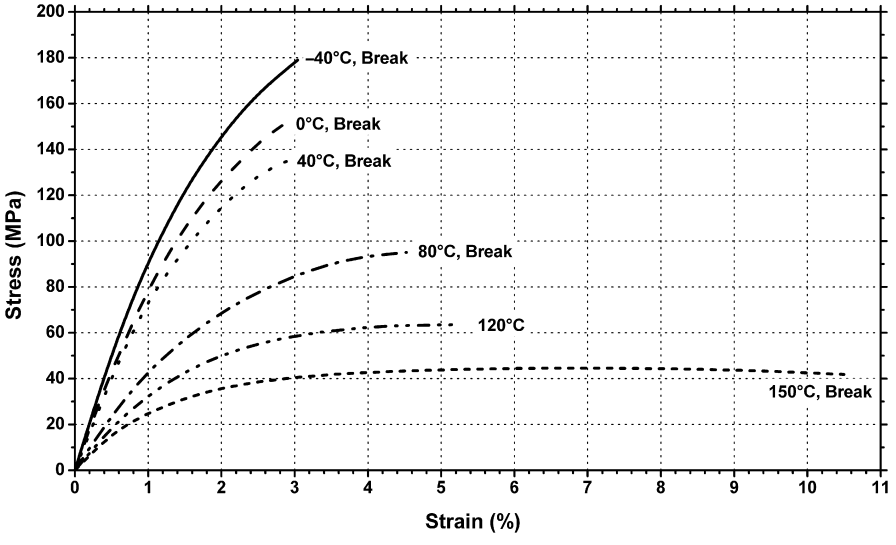

Figure 3.4 Stress vs. strain for DuPont Engineering Polymers Delrin® 525GR NC000—25% glass fiber reinforced acetal resin.

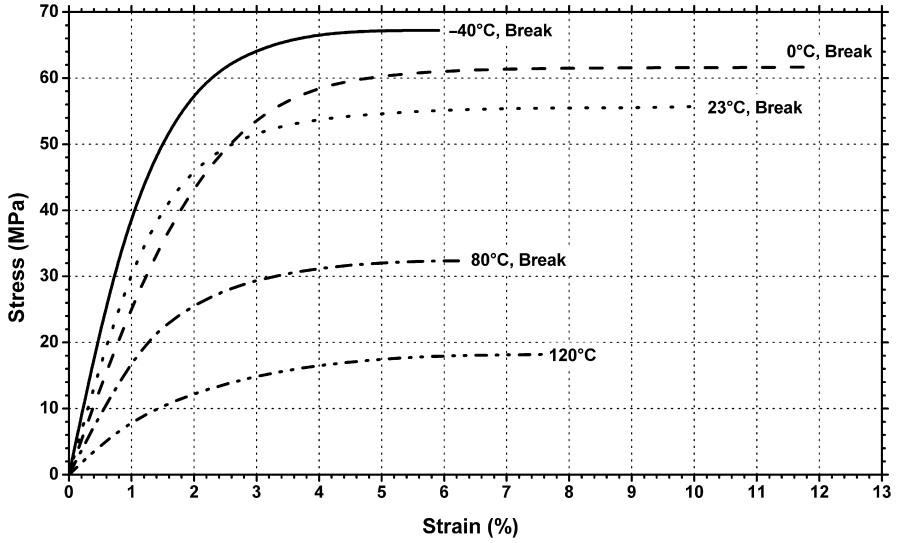

Figure 3.5 Stress vs. strain for DuPont Engineering Polymers Delrin® 570—medium viscosity, 20% glass fiber reinforced, high stiffness acetal resin.

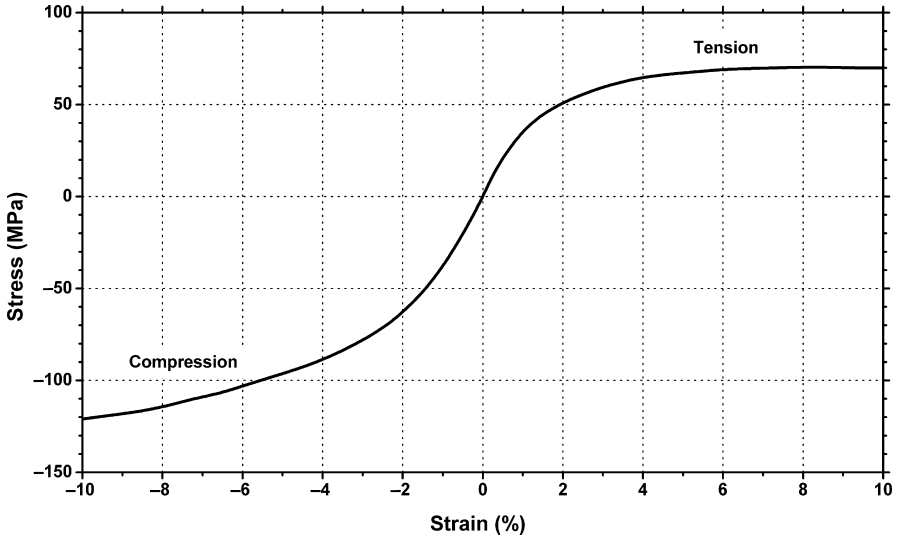

Figure 3.6 Stress vs. strain in tension and compression for DuPont Engineering Polymers Delrin® acetal resin at 23°C [2].

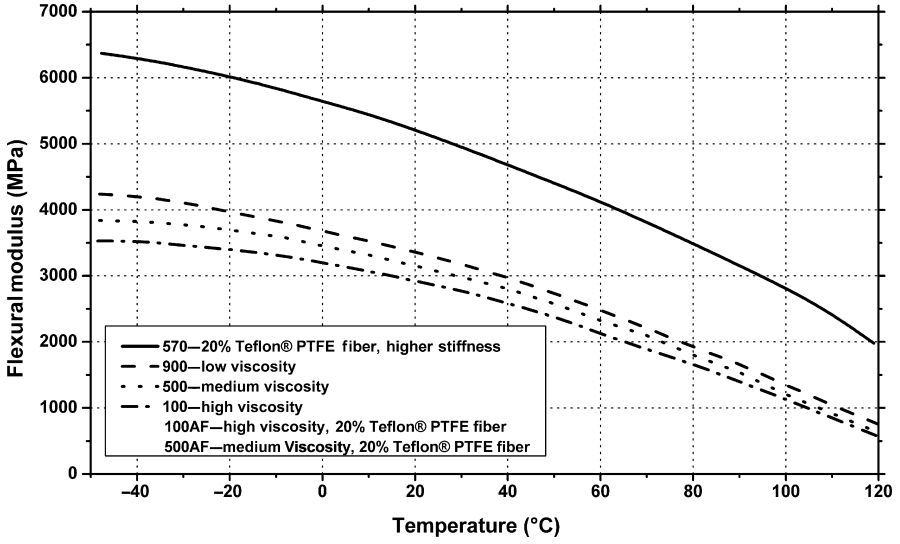

Figure 3.7 Flexural modulus vs. temperature for various DuPont Engineering Polymers Delrin® acetal resins [2].

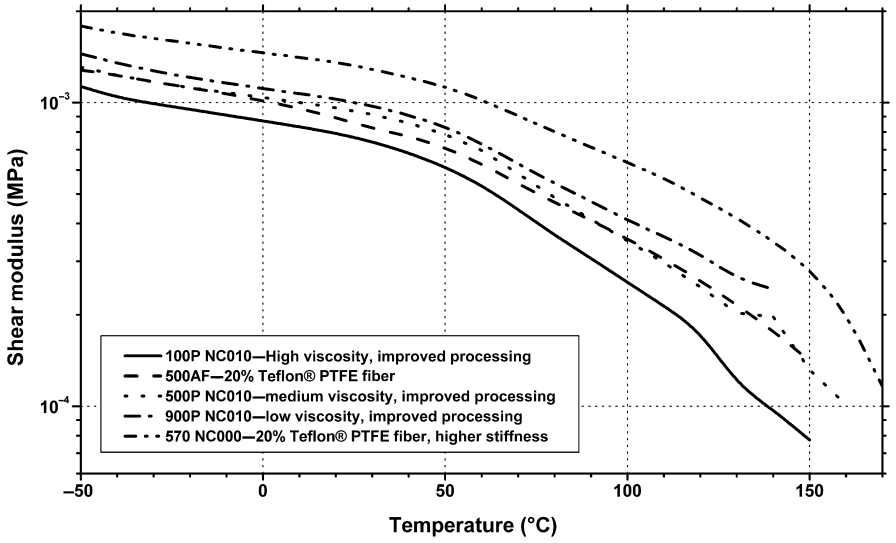

Figure 3.8 Shear modulus vs. temperature for DuPont Engineering Polymers Delrin® 100, 500, 900 acetal resins.

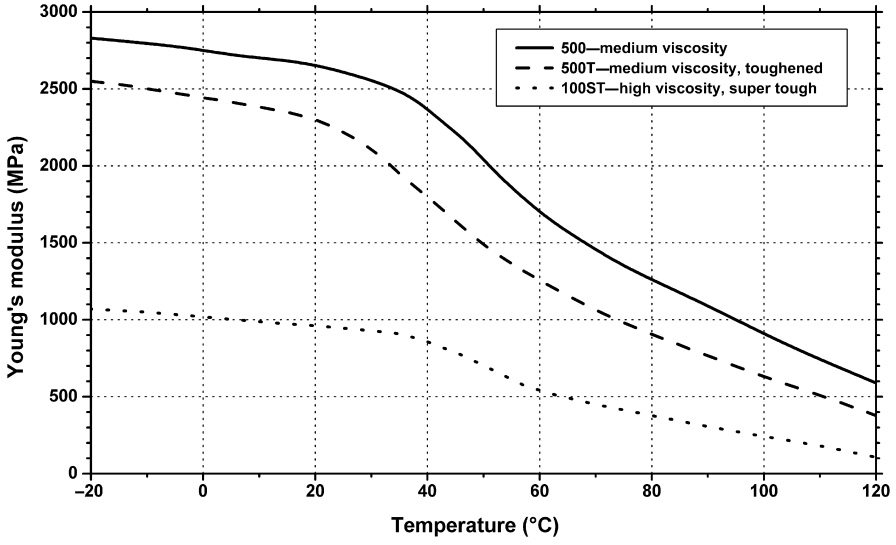

Figure 3.9 Young's modulus vs. temperature for DuPont Engineering Polymers Delrin® 100, 500T, 100ST acetal resins (at 5 mm/min).

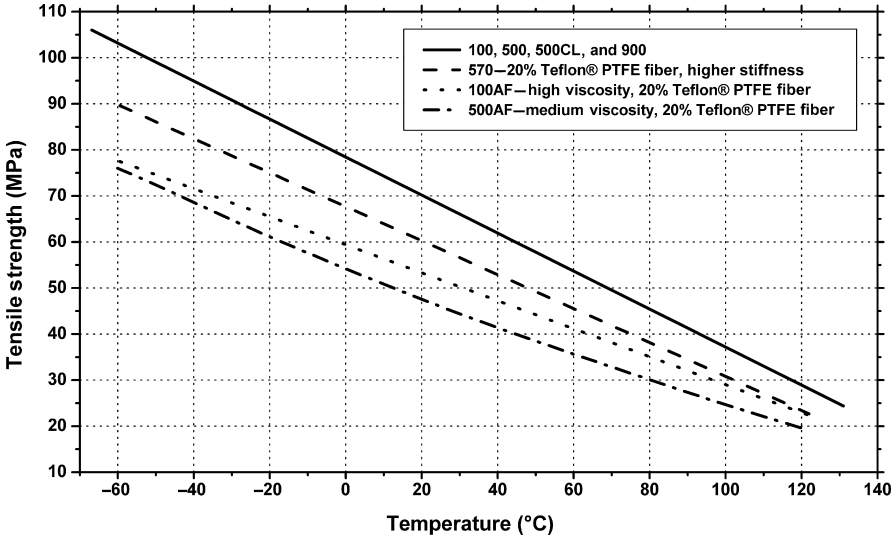

Figure 3.10 Tensile strength vs. temperature for DuPont Engineering Polymers Delrin® acetal resins (at 5.1 mm/min crosshead speed).

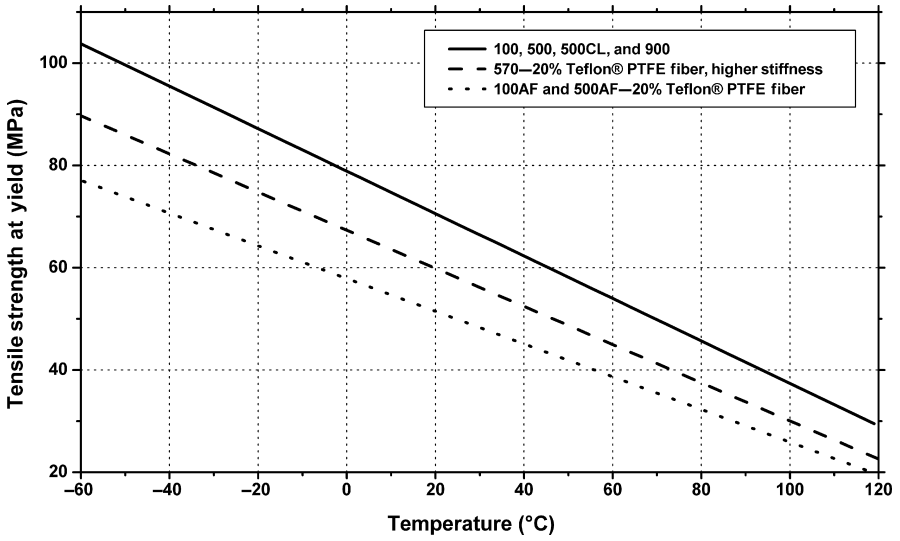

Figure 3.11 Tensile yield strength vs. temperature for DuPont Engineering Polymers Delrin® acetal resins (at 5.1 mm/min crosshead speed) [2].

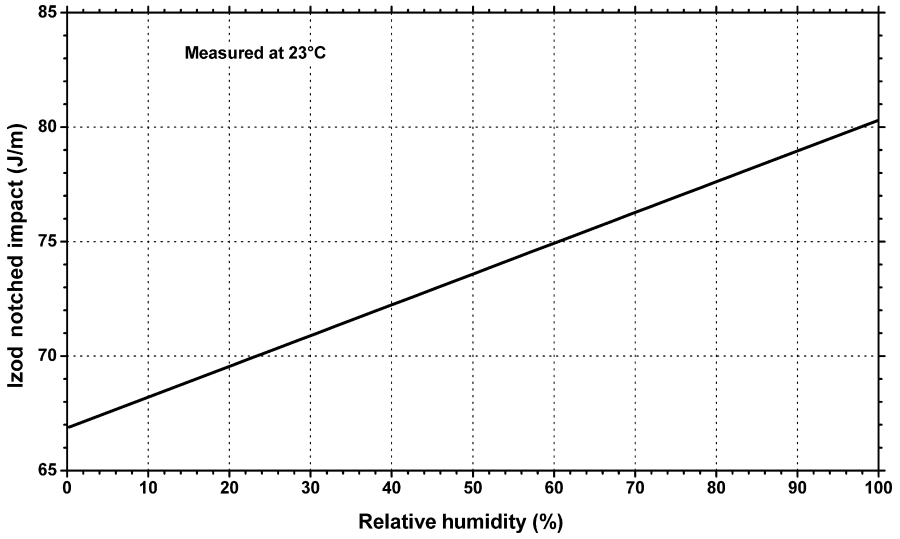

Figure 3.12 Notched Izod impact strength vs. humidity for DuPont Engineering Polymers Delrin® 500—medium viscosity acetal resin at 23°C [2].

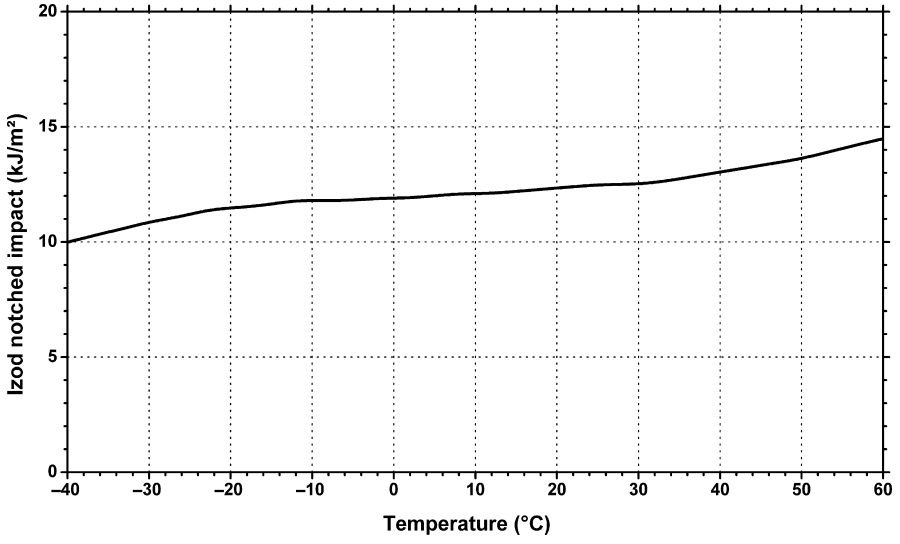

Figure 3.13 Notched Izod impact strength vs. temperature for DuPont Engineering Polymers Delrin® 100—high viscosity, general purpose acetal resin.

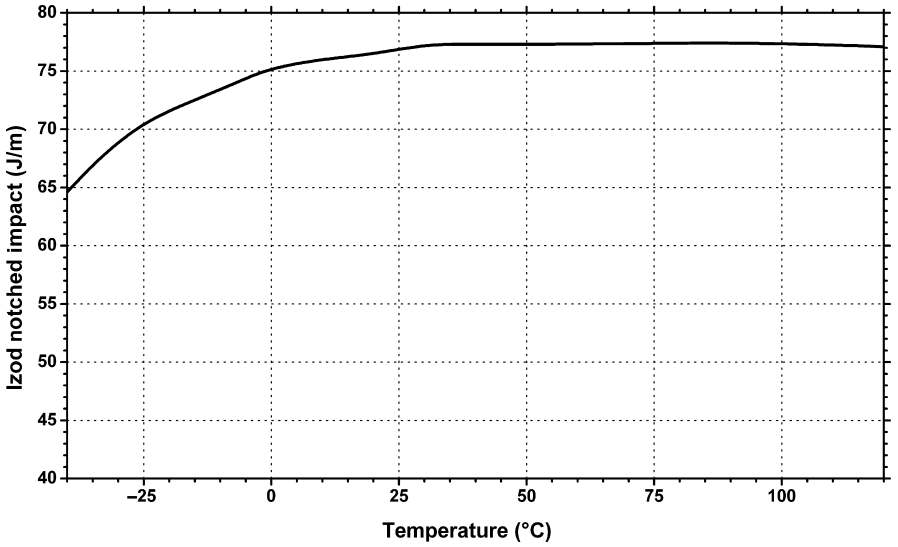

Figure 3.14 Notched Izod impact strength vs. temperature for DuPont Engineering Polymers Delrin® 500—medium viscosity acetal resin [2].

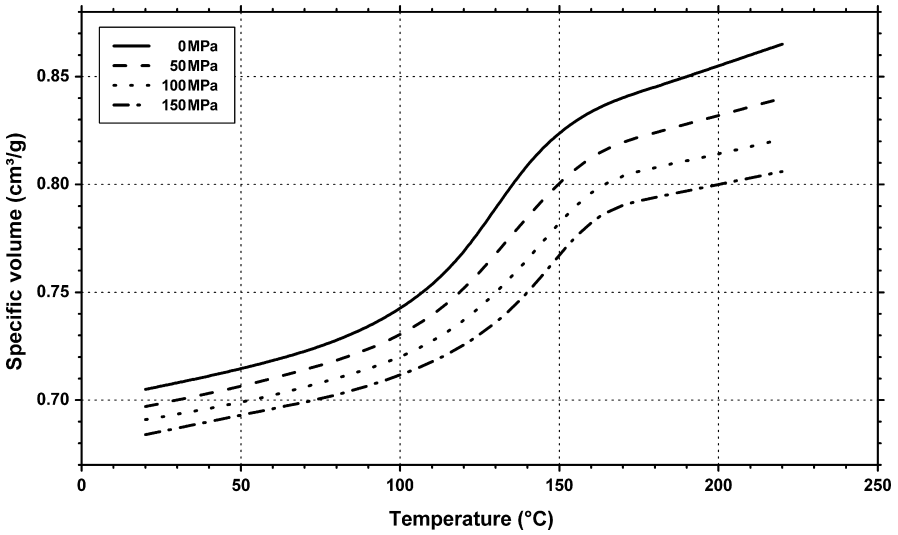

Figure 3.15 Specific volume as a function of temperature and pressure (PVT) for DuPont Engineering Polymers Delrin® 107 NC010—high viscosity, UV stabilized acetal resin.

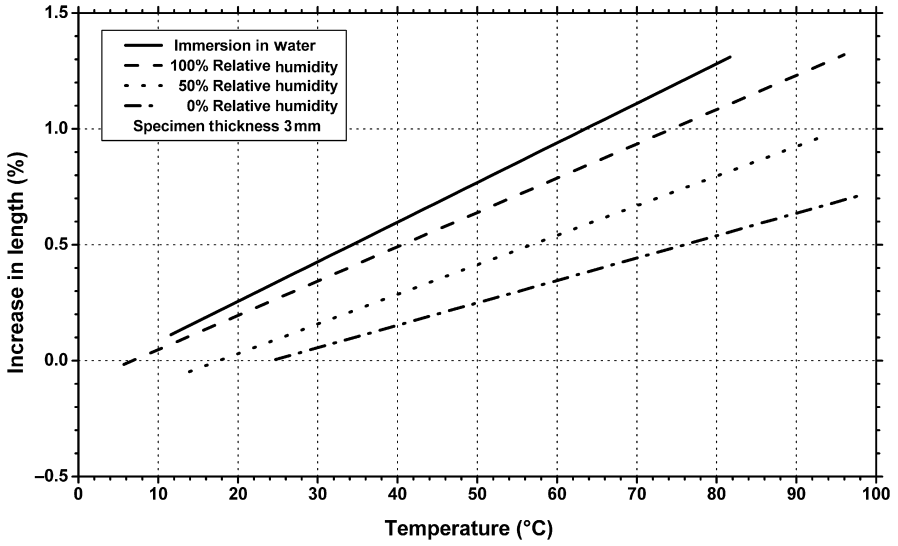

Figure 3.16 Change in length vs. temperature and humidity for DuPont Engineering Polymers Delrin® 100 and 500 acetal resins [2].

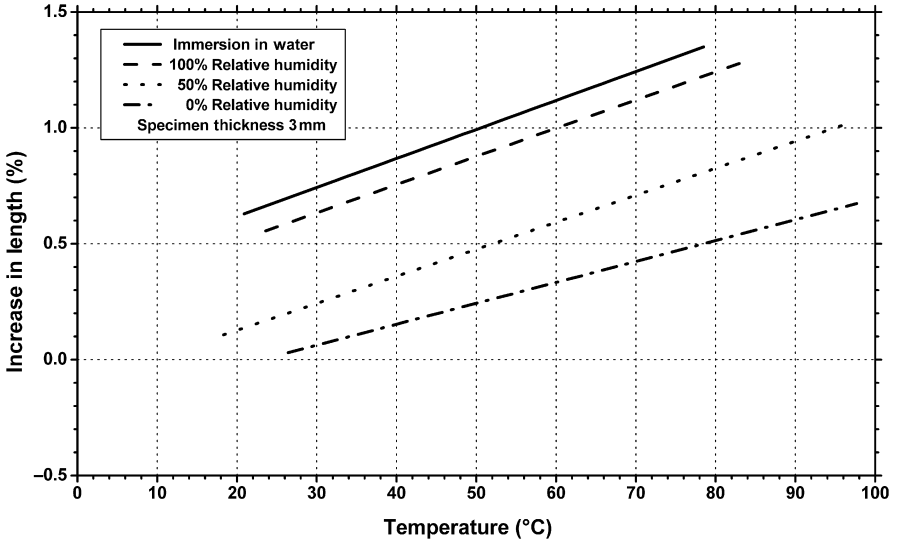

Figure 3.17 Change in length vs. temperature and humidity for DuPont Engineering Polymers Delrin® 100P, 500P, and 900P acetal resins.

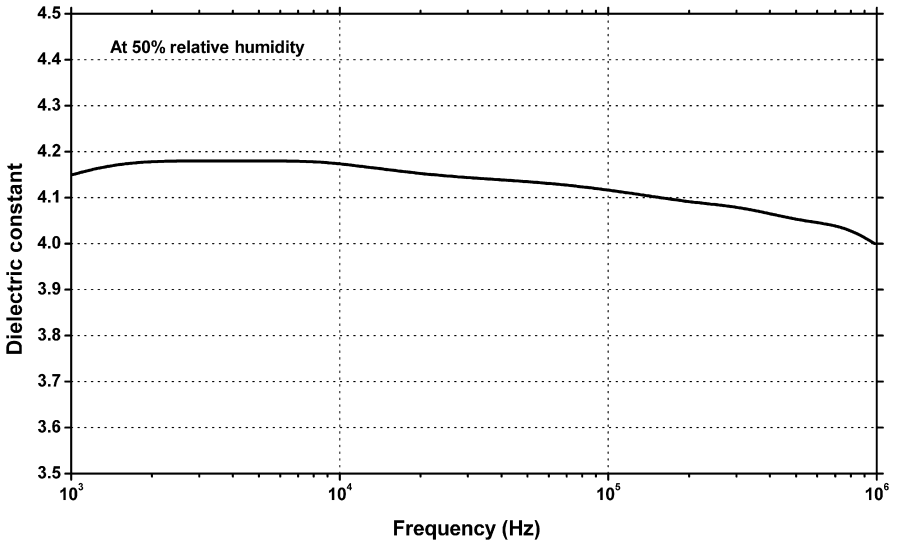

Figure 3.18 Dielectric constant vs. frequency at 50% relative humidity after immersion in water at 23°C for DuPont Engineering Polymers Delrin® 500P—medium viscosity with improved processing acetal resin.

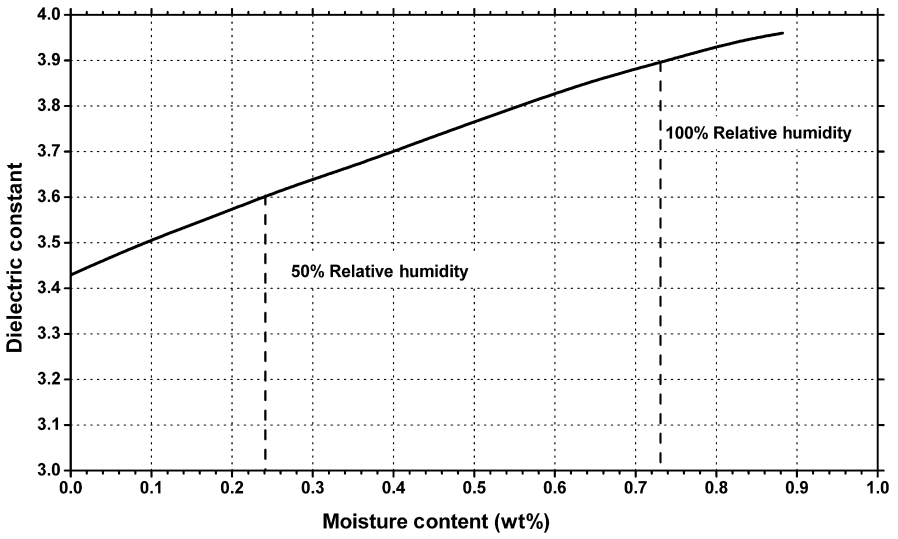

Figure 3.19 Dielectric constant vs. moisture content at 23°C for DuPont Engineering Polymers Delrin® 500 NC010—medium viscosity acetal resin [2].

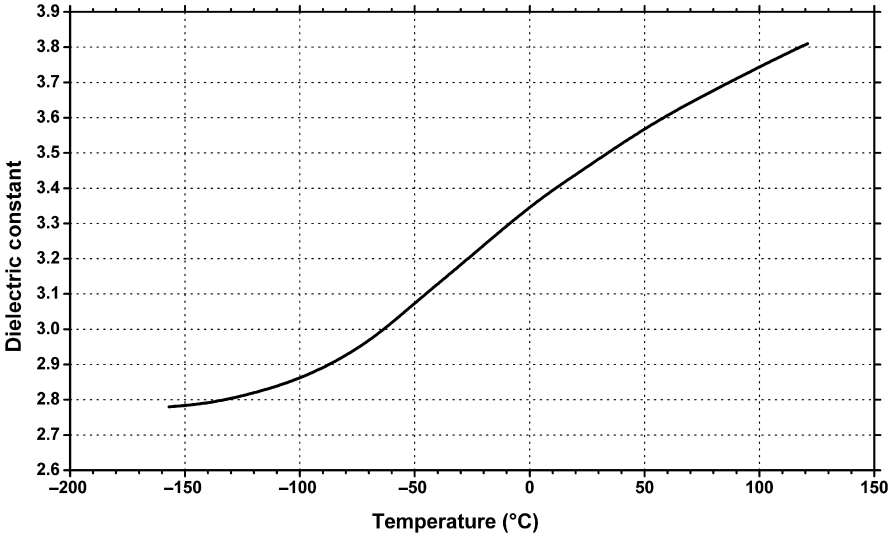

Figure 3.20 Dielectric constant vs. temperature for Delrin® 100 and 500 NC010 acetal resins [2].

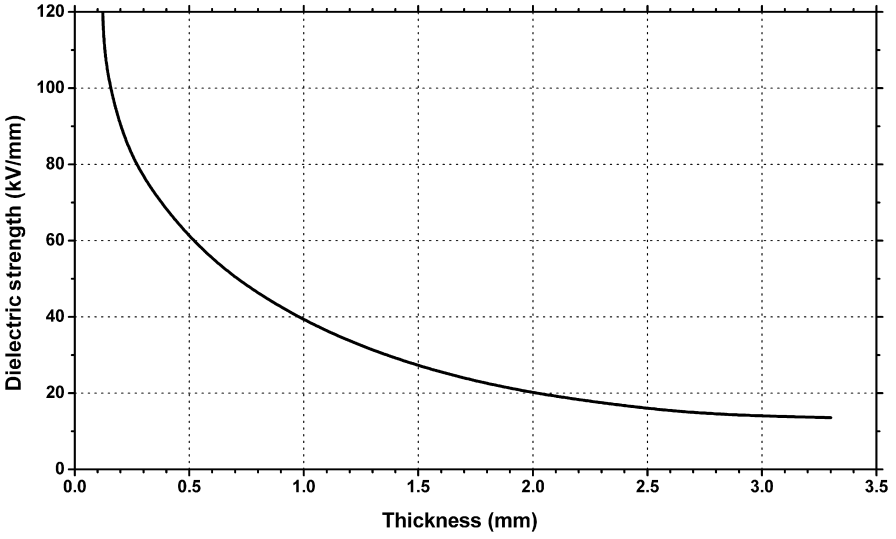

Figure 3.21 Dielectric strength vs. thickness at 23°C for DuPont Engineering Polymers Delrin® 500 NC010—medium viscosity acetal resin [2].

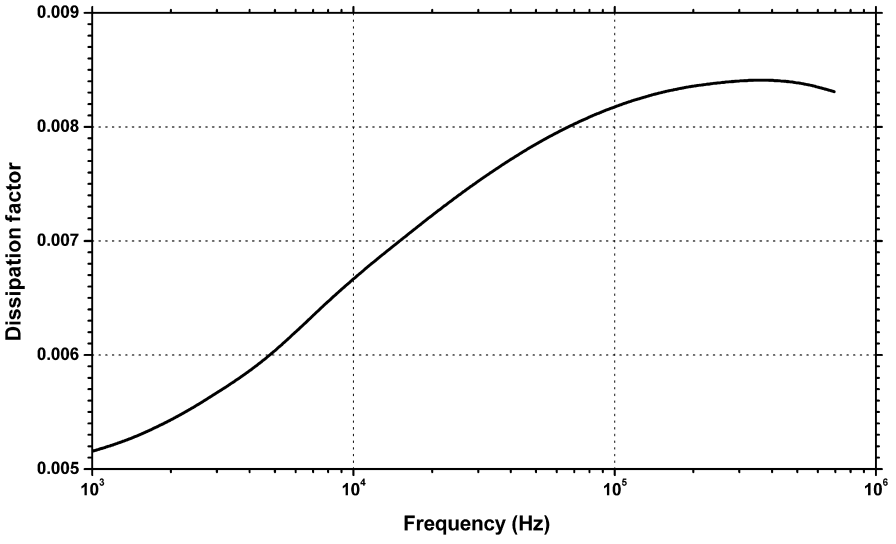

Figure 3.22 Dissipation factor vs. frequency at 50% relative humidity at 23°C for DuPont Engineering Polymers Delrin® 500—medium viscosity acetal resin [2].

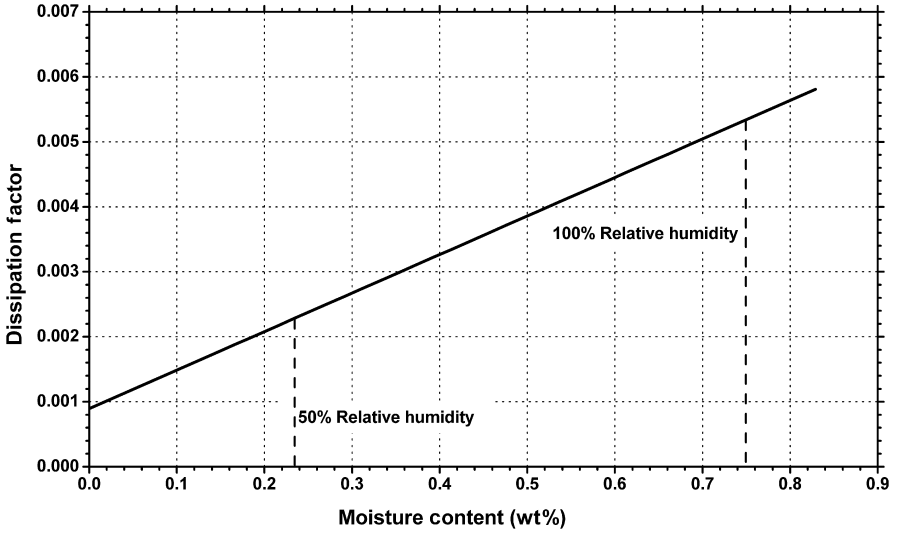

Figure 3.23 Dissipation factor vs. moisture content at 23°C for DuPont Engineering Polymers Delrin® 500 NC010 acetal resin [2].

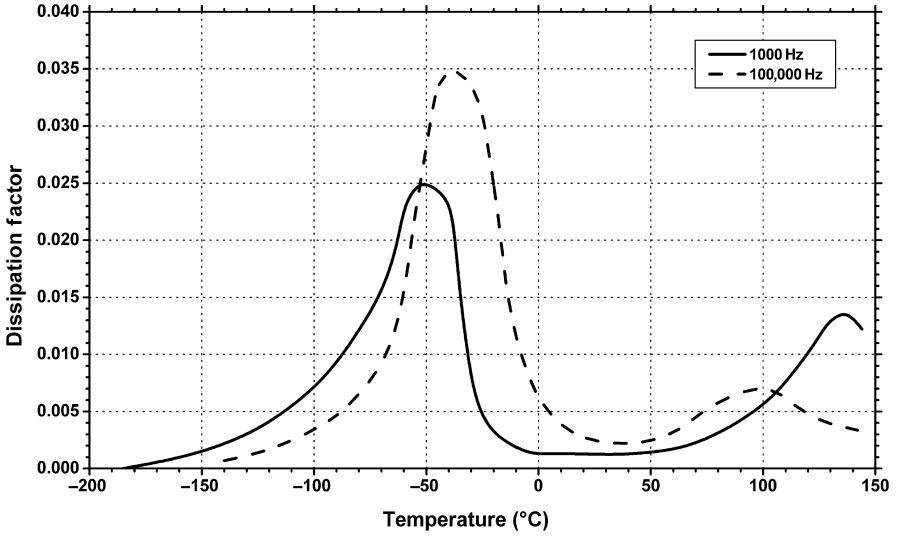

Figure 3.24 Dissipation factor vs. temperature for DuPont Engineering Polymers Delrin® 500 NC010—medium viscosity acetal resin [2].

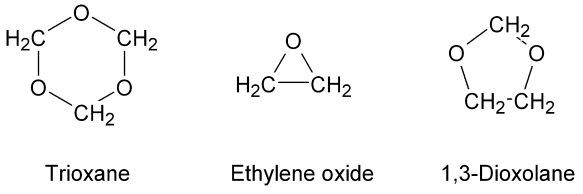

Figure 3.25 Chemical structure of POM copolymer monomers.

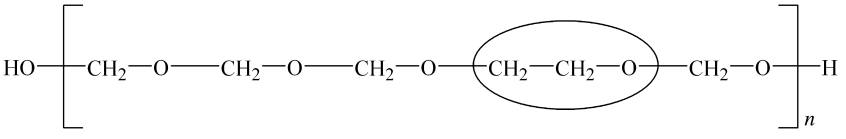

Figure 3.26 Chemical structure of acetal copolymer.

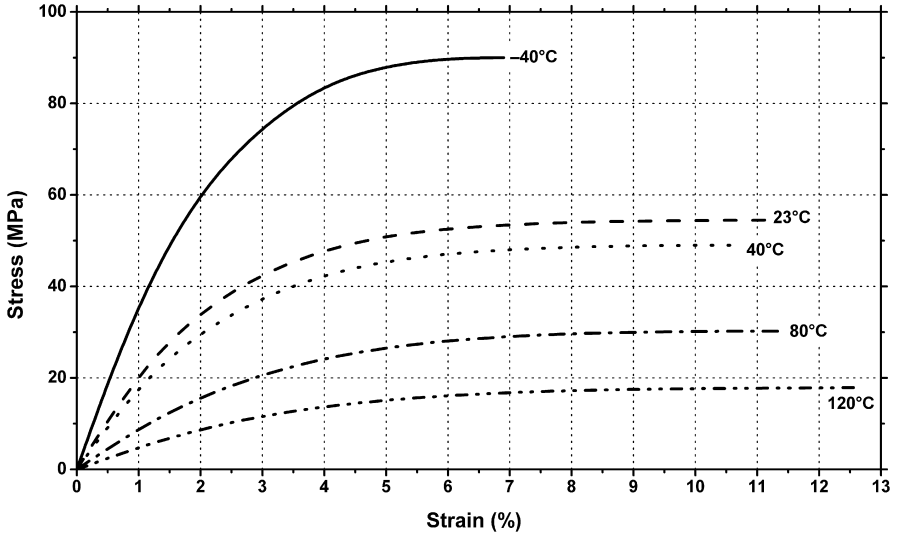

Figure 3.27 Stress vs. strain for Celanese Celcon® M25—high molecular weight, high toughness, high impact acetal copolymer resin.

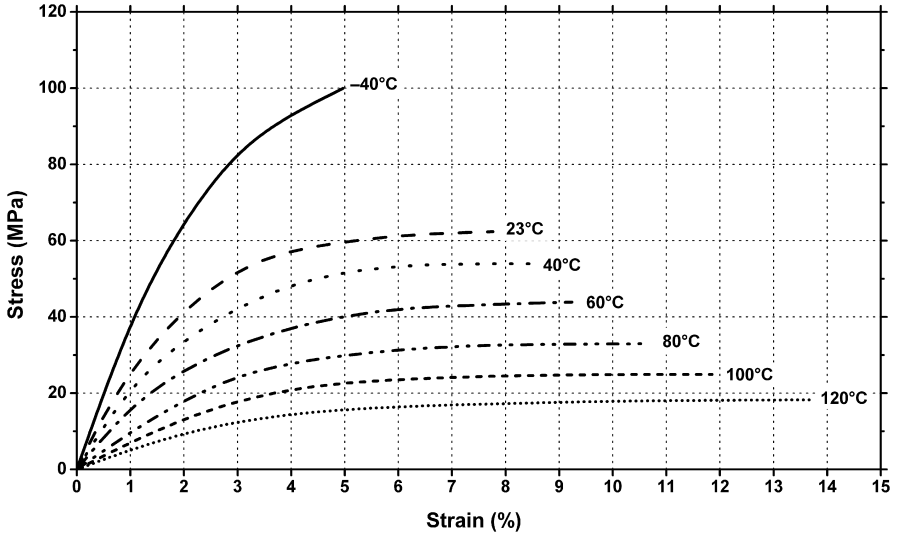

Figure 3.28 Stress vs. strain for Celanese Celcon® M90—medium viscosity, general purpose acetal copolymer resin [3].

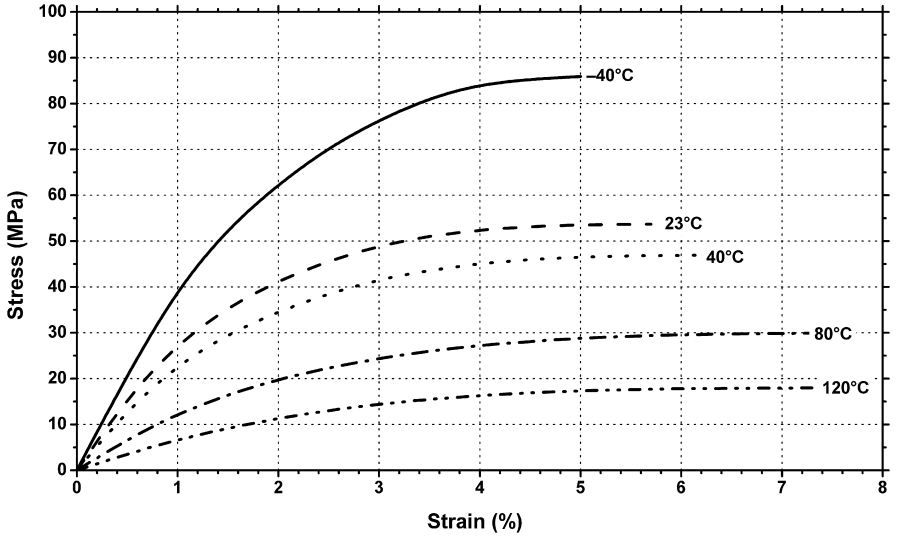

Figure 3.29 Stress vs. strain for Celanese Celcon® M270—low molecular weight, high flow acetal copolymer resin.

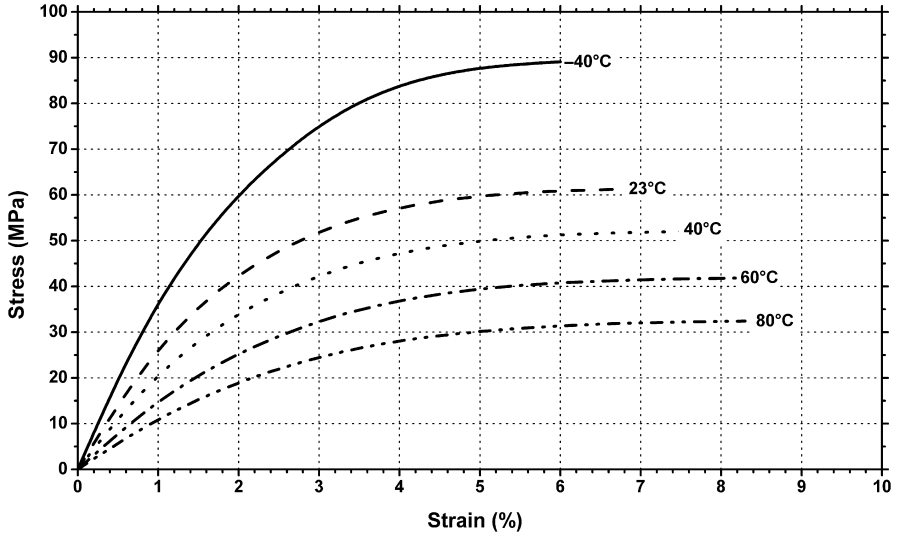

Figure 3.30 Stress vs. strain for Celanese Hostaform® C 9021—general purpose grade acetal copolymer resin.

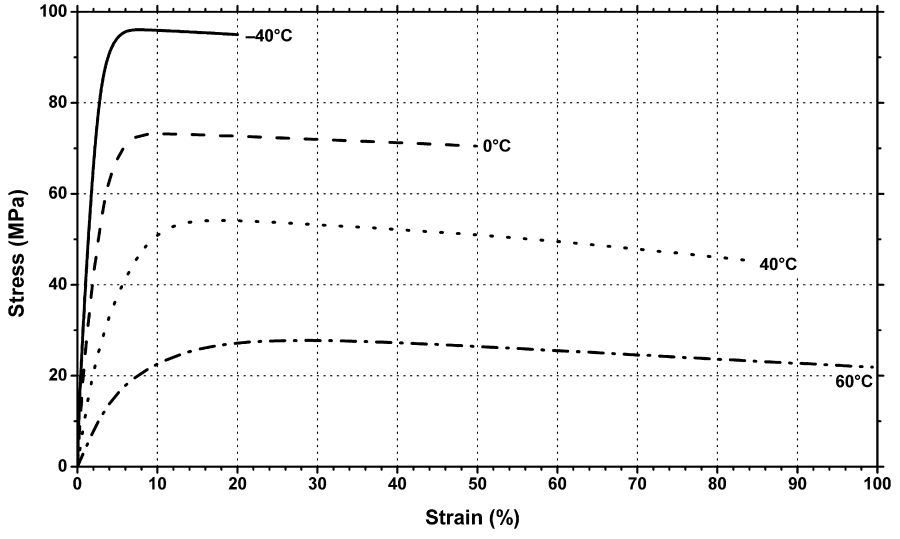

Figure 3.31 Stress vs. strain for Mitsubishi Engineering-Plastics Iupital® F20-02—medium viscosity, general purpose acetal copolymer resin.

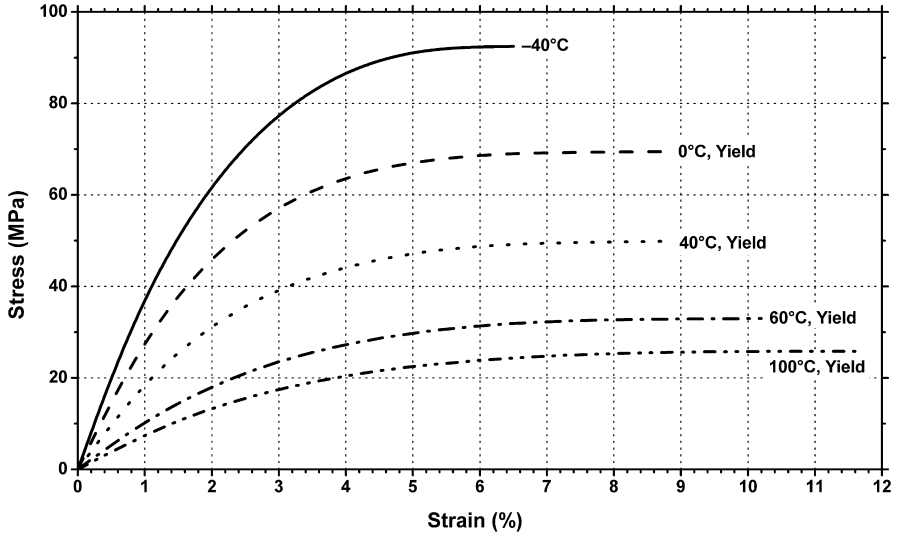

Figure 3.32 Stress vs. strain for BASF Ultraform® H 2320 006—high molecular weight injection molding grade acetal copolymer resin.

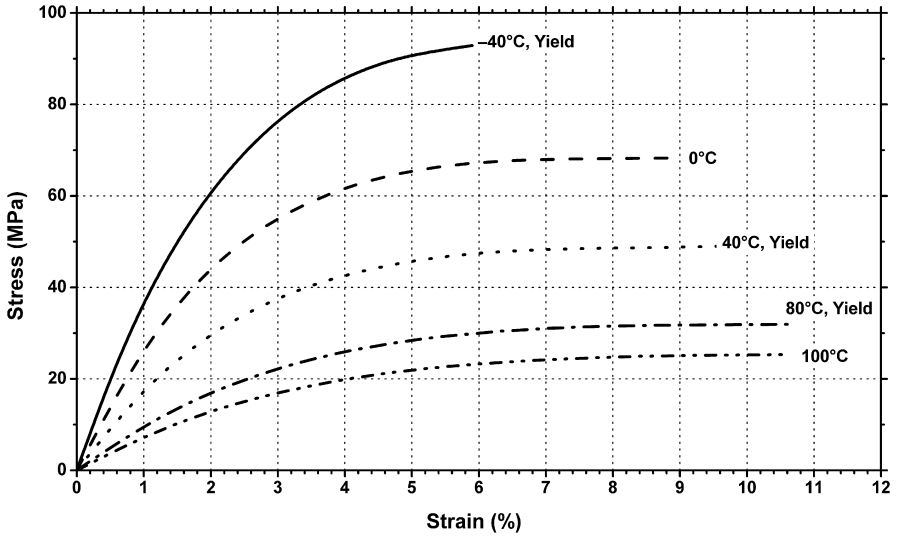

Figure 3.33 Stress vs. strain for BASF Ultraform® H 4320—high molecular weight, extrusion grade acetal copolymer resin.

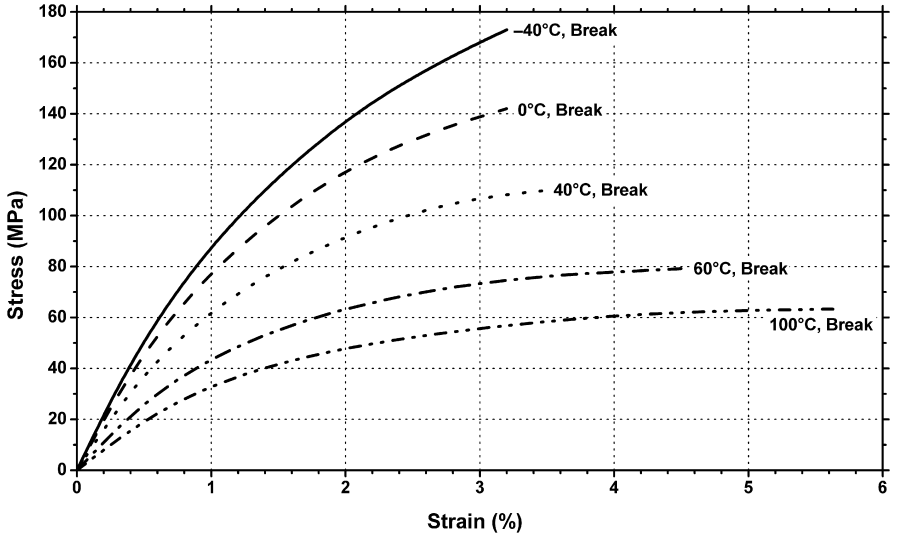

Figure 3.34 Stress vs. strain for BASF Ultraform® N 2200 G53—25% glass fiber reinforced, injection molding with enhanced stiffness and toughness acetal copolymer resin.

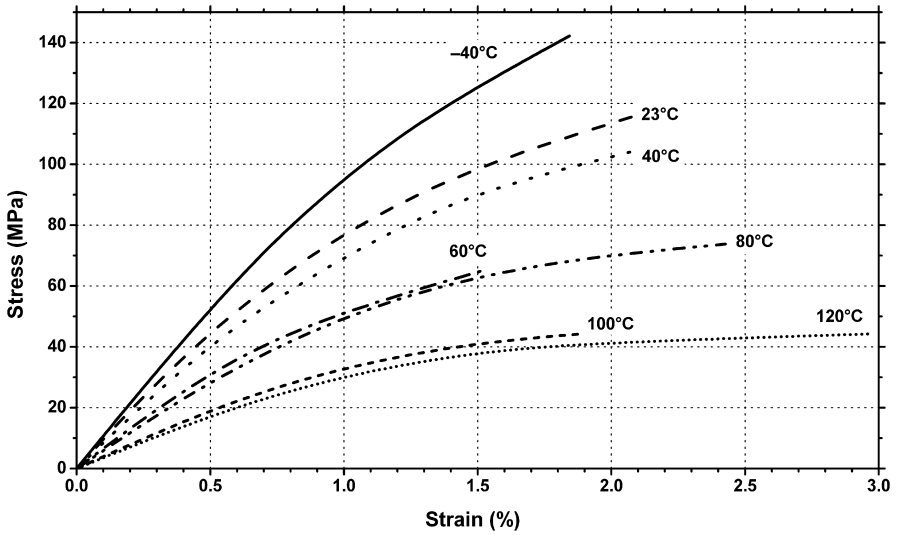

Figure 3.35 Stress vs. strain plot for 25% glass-reinforced grade of Celanese Celcon® acetal copolymer (ISO 527) [3].

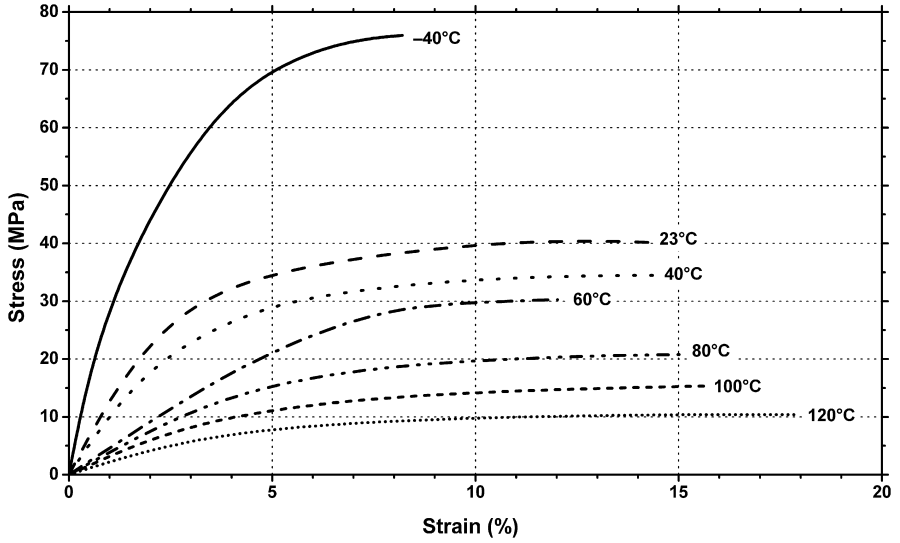

Figure 3.36 Stress vs. strain plot for toughened grade of Celanese Celcon® acetal copolymer (ISO 527) [3].

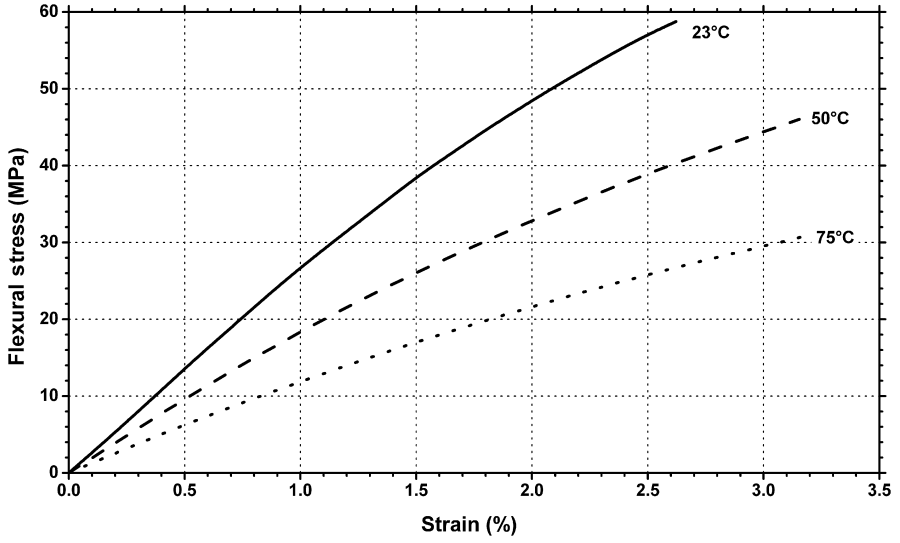

Figure 3.37 Flexural stress vs. strain at various temperatures for Mitsubishi Engineering-Plastics Iupital® acetal copolymer resin [4].

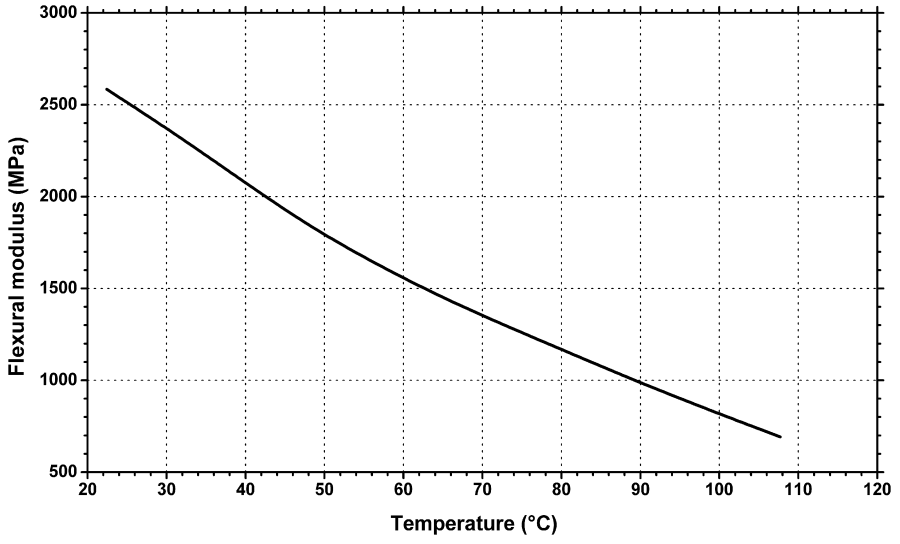

Figure 3.38 Flexural modulus vs. temperature for Celanese Celcon® M25/M90/M270 acetal copolymer resins.

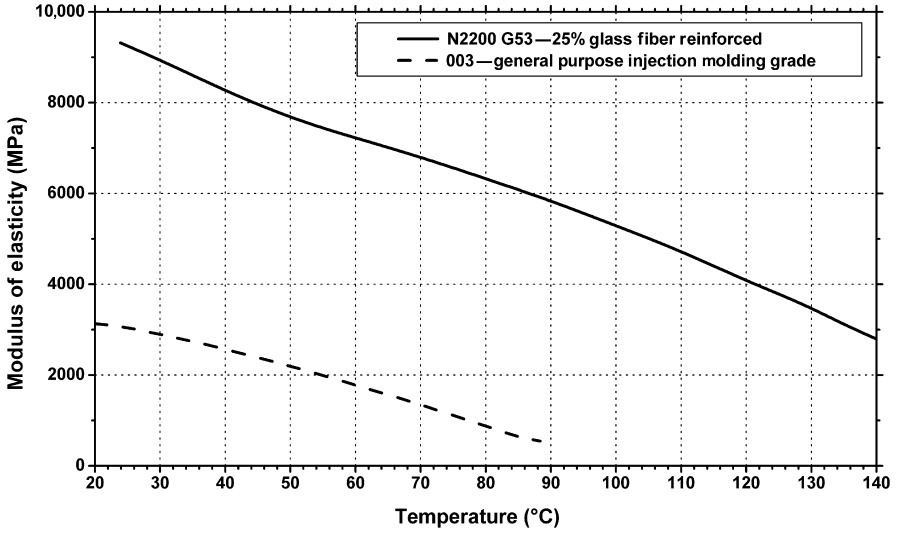

Figure 3.39 Modulus of elasticity vs. temperature for BASF Ultraform® acetal copolymer resins.

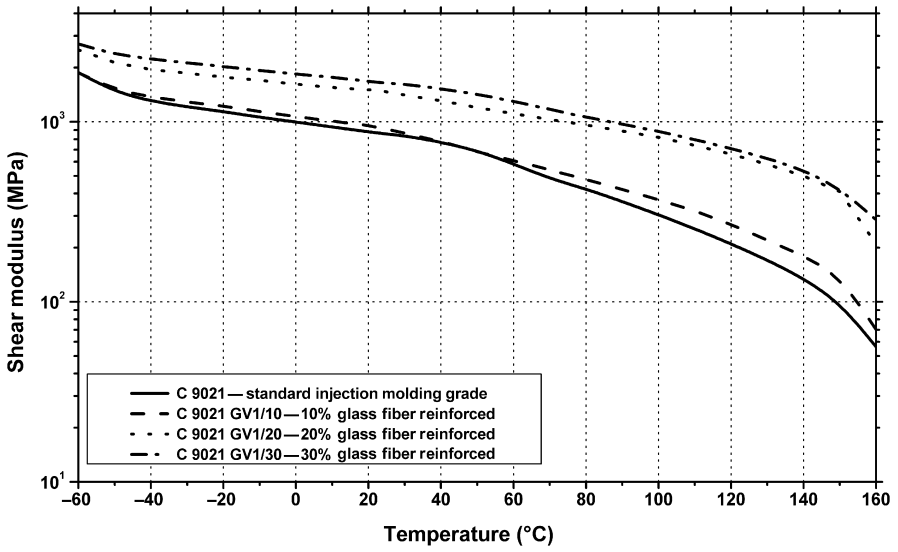

Figure 3.40 Shear modulus vs. temperature for Celanese Hostaform® acetal copolymer resins with different amounts of glass fiber reinforcement.

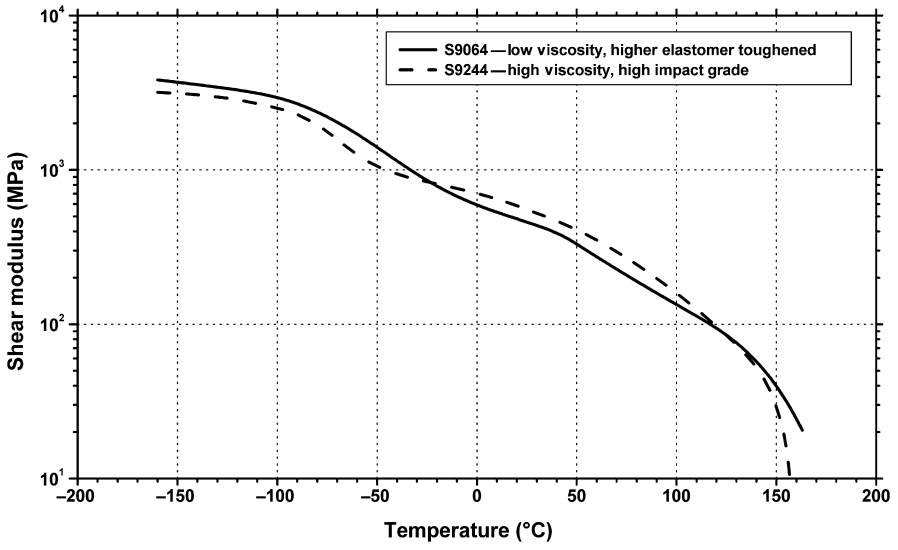

Figure 3.41 Shear modulus vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

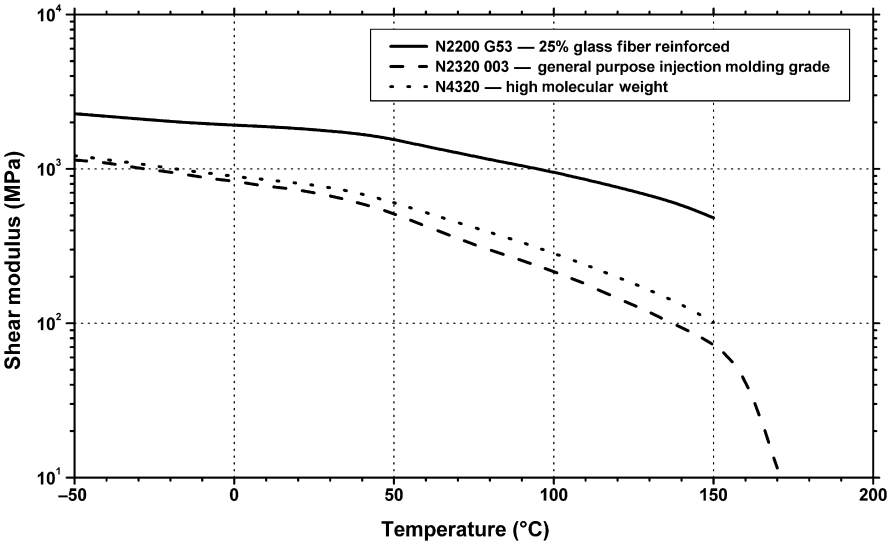

Figure 3.42 Shear modulus vs. temperature for several BASF Ultraform® acetal copolymer resins.

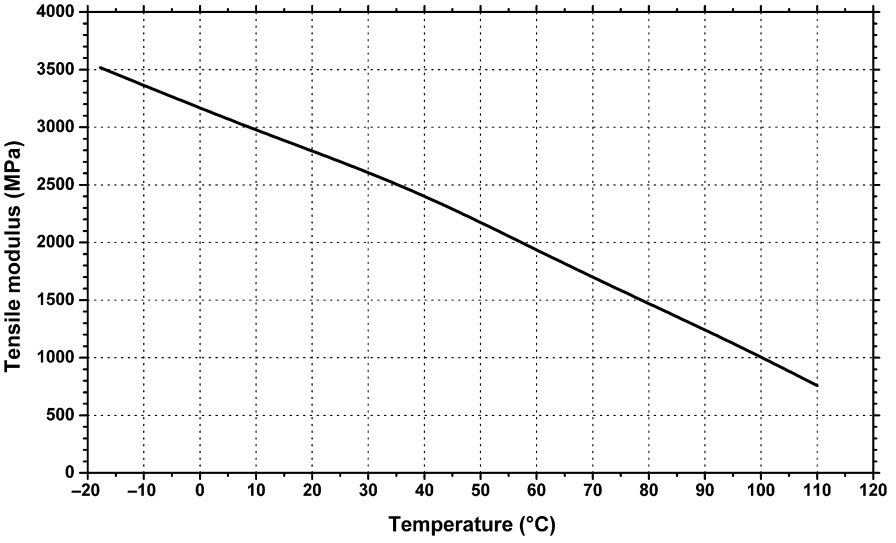

Figure 3.43 Tensile modulus vs. temperature for Celanese Celcon® M25/M90/M270 acetal copolymer resins.

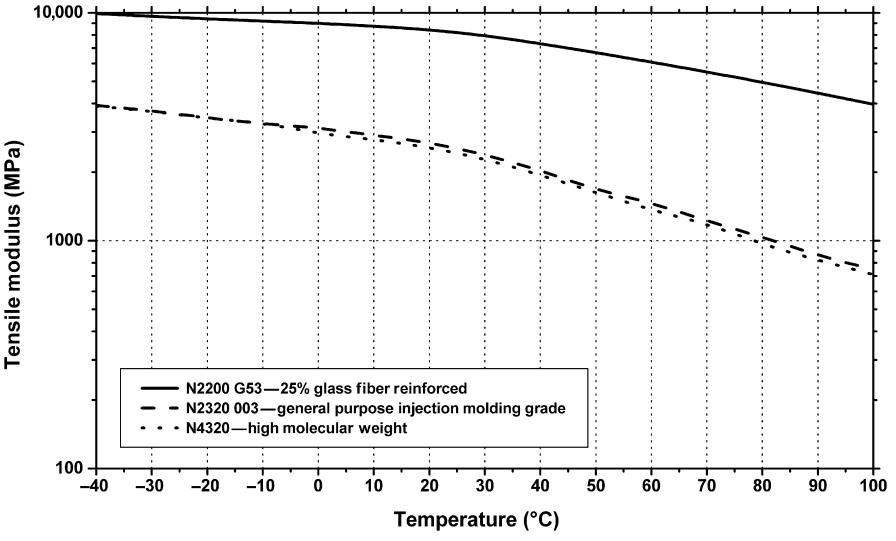

Figure 3.44 Tensile modulus vs. temperature for BASF Ultraform® acetal copolymer resins.

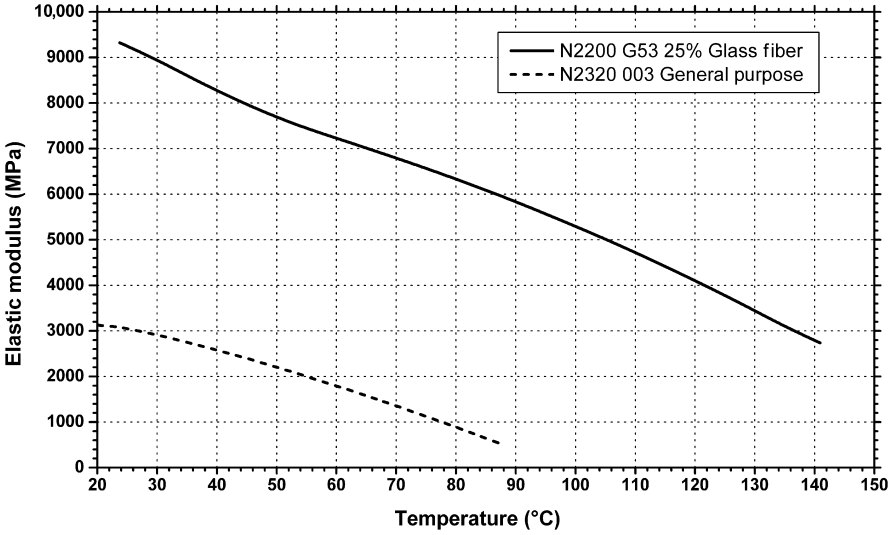

Figure 3.45 Modulus of elasticity of unreinforced and reinforced BASF Ultraform® measured in accordance with ISO 527 as a function of temperature [6].

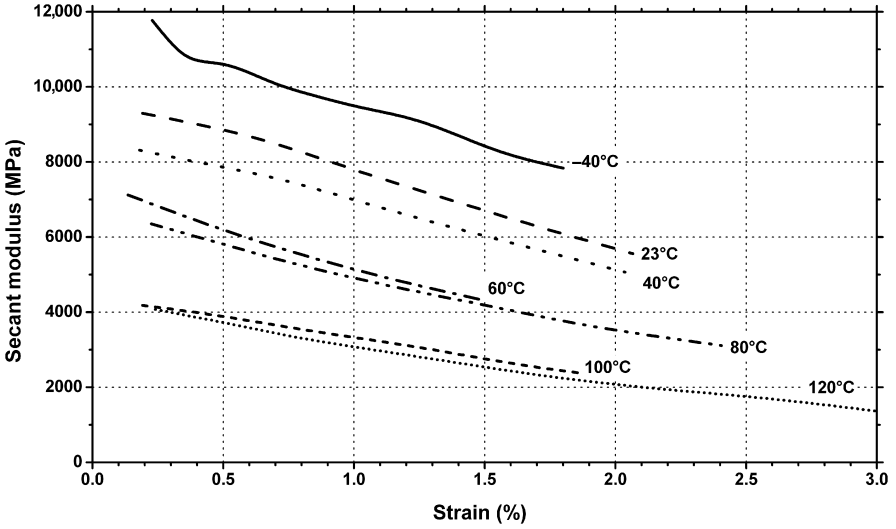

Figure 3.46 Secant modulus vs. strain plot for 25% glass-reinforced grade of Celanese Celcon® acetal copolymer [3].

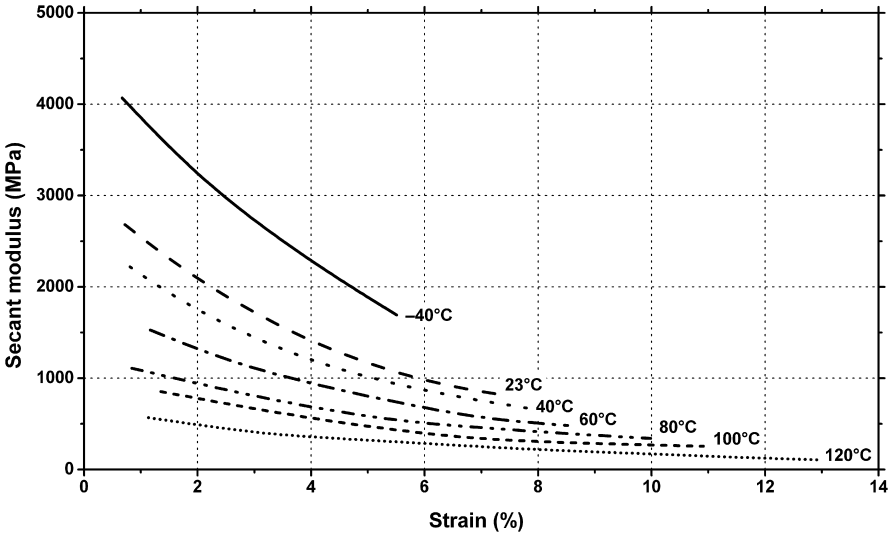

Figure 3.47 Secant modulus vs. strain for unfilled 9.0 melt flow grade of Celanese Celcon® acetal copolymer [3].

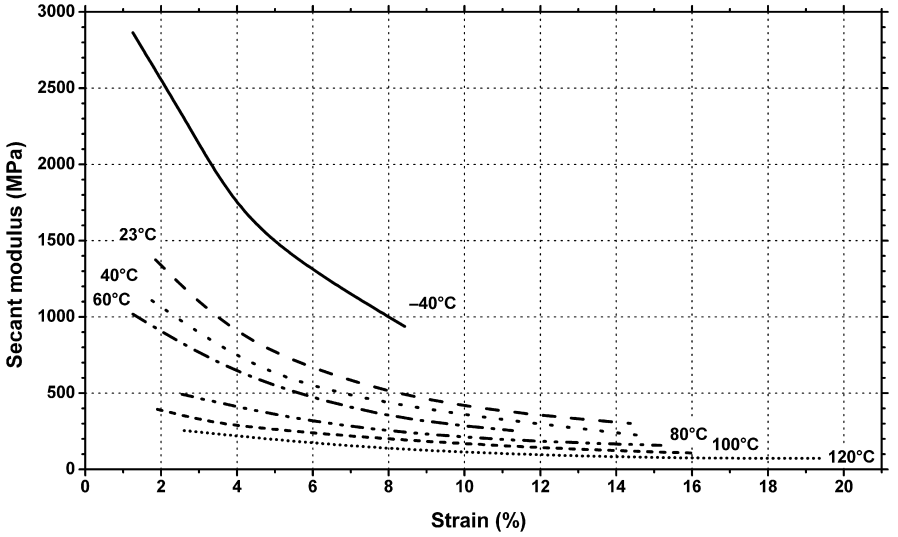

Figure 3.48 Secant modulus vs. strain plot for toughened grade of Celanese Celcon® acetal copolymer [3].

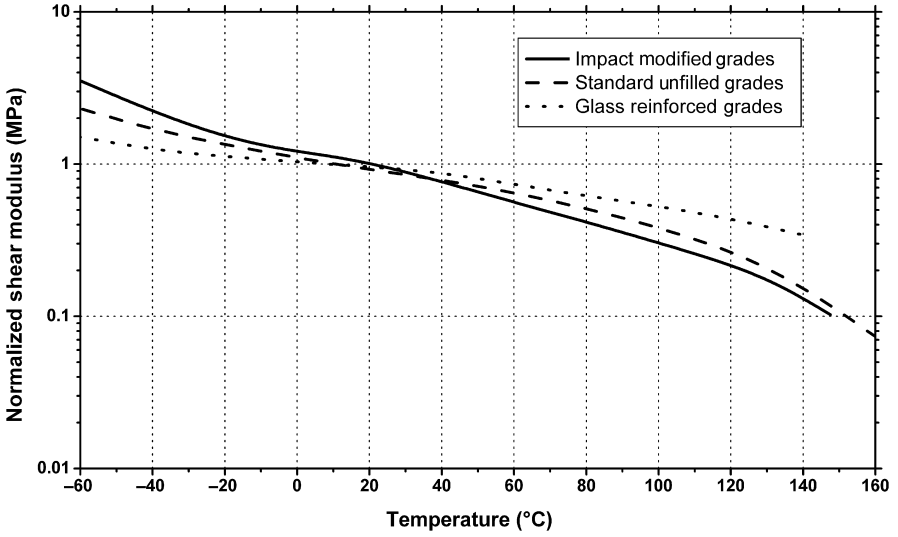

Figure 3.49 Typical normalized Celanese Celcon® acetal copolymer DMA plot [3].

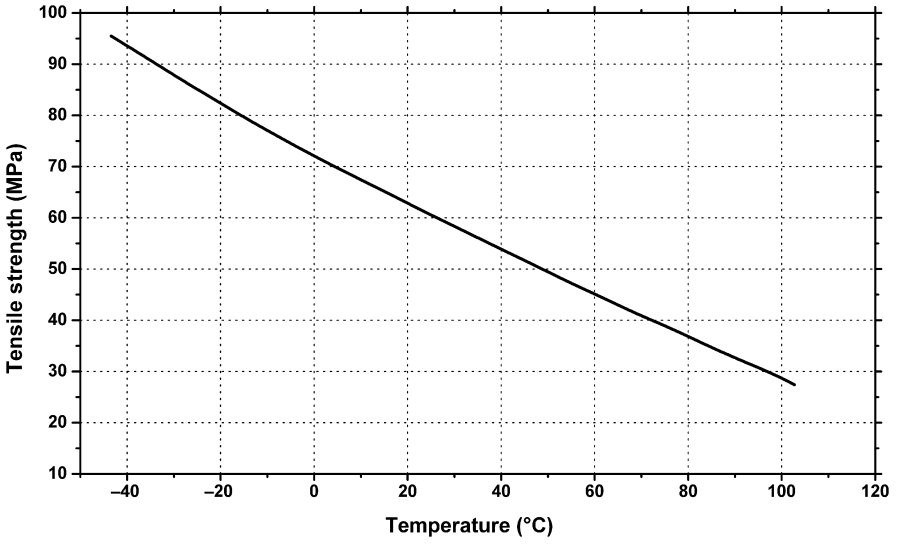

Figure 3.50 Tensile strength vs. temperature for Mitsubishi Engineering-Plastics Iupital® acetal copolymer resin [4].

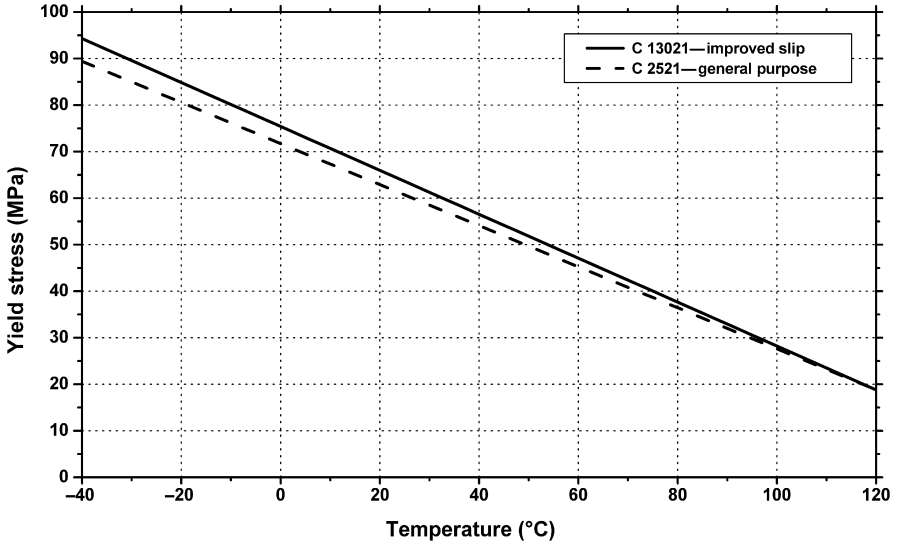

Figure 3.51 Yield stress vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

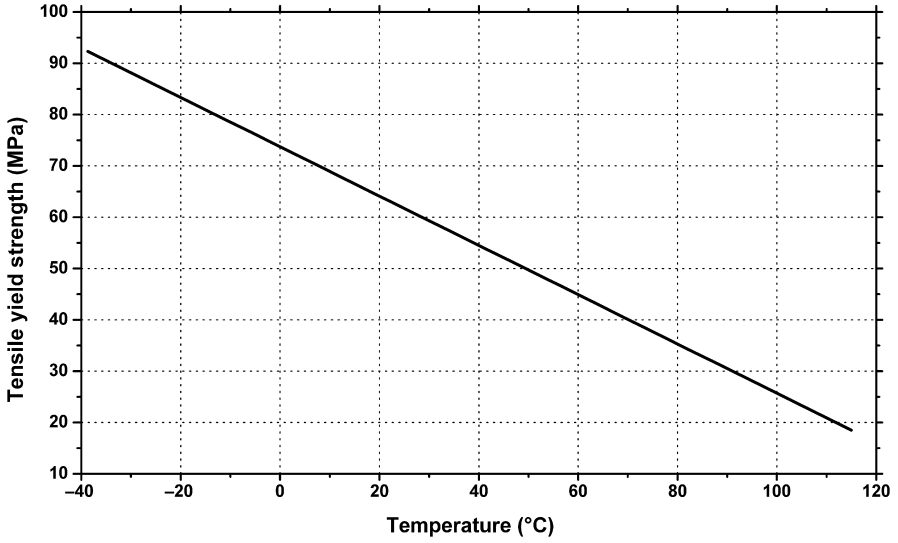

Figure 3.52 Tensile yield strength vs. temperature for Celanese Celcon® M90—medium viscosity, general purpose acetal copolymer resin.

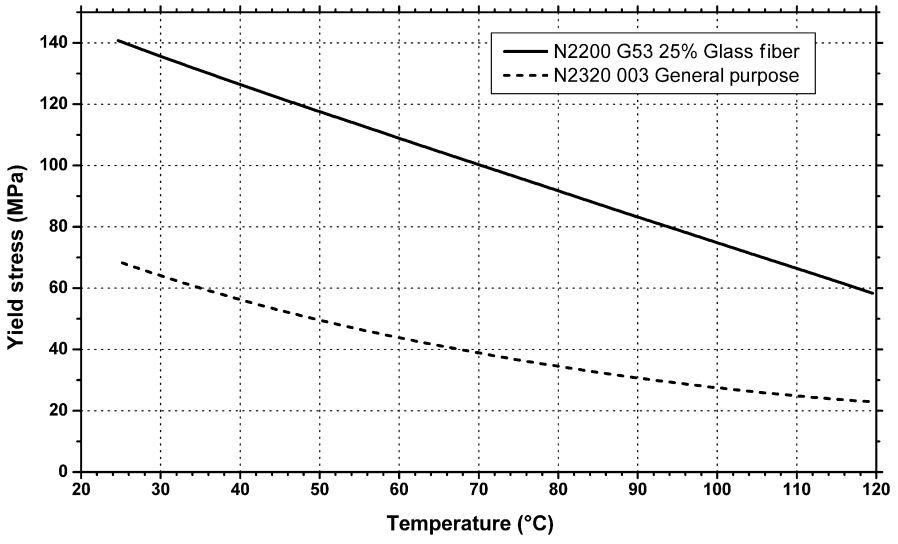

Figure 3.53 Yield stress or tensile strength of unreinforced and reinforced Ultraform® measured in accordance with ISO 527 as a function of temperature.

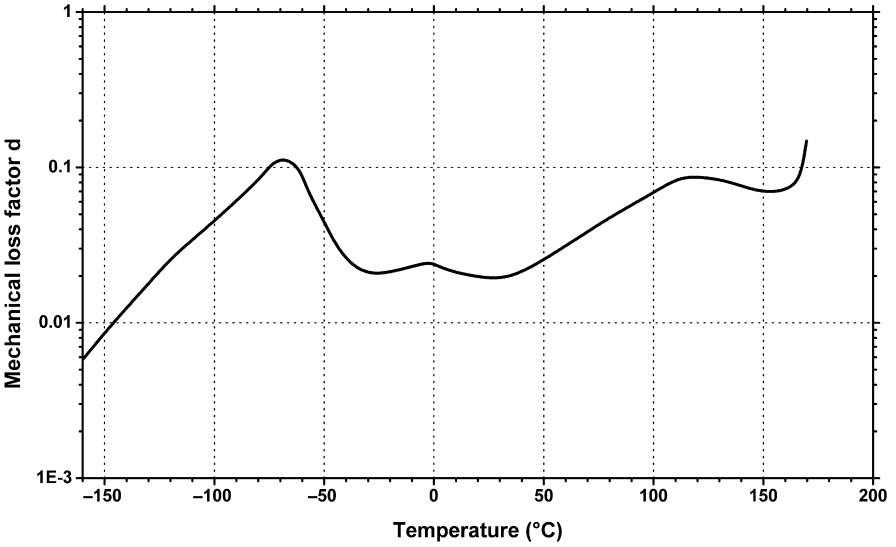

Figure 3.54 Mechanical loss factor d of Celanese Hostaform® C 9021 as a function of temperature; torsional oscillation test DIN 53 445 [5].

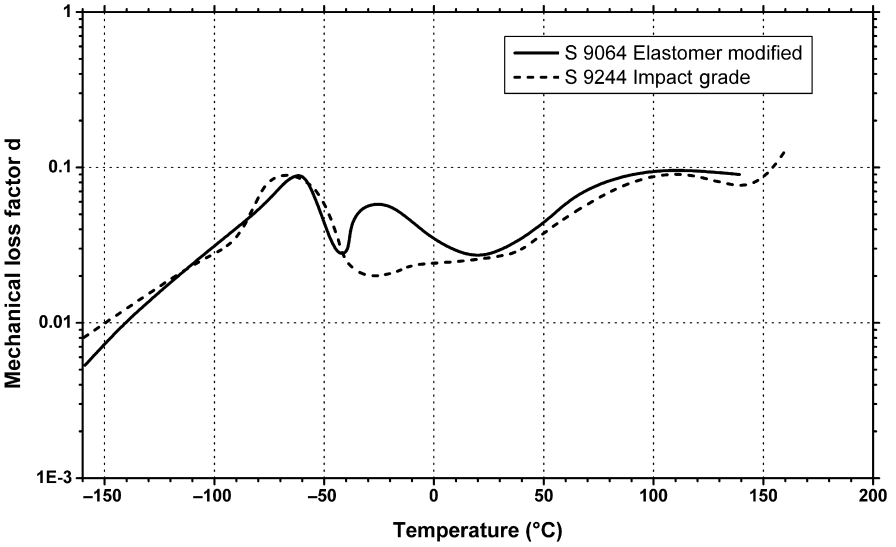

Figure 3.55 Mechanical loss factor d of Celanese Hostaform® S 9064 and S 9244 as a function of temperature; torsional oscillation test DIN 53 445 [5].

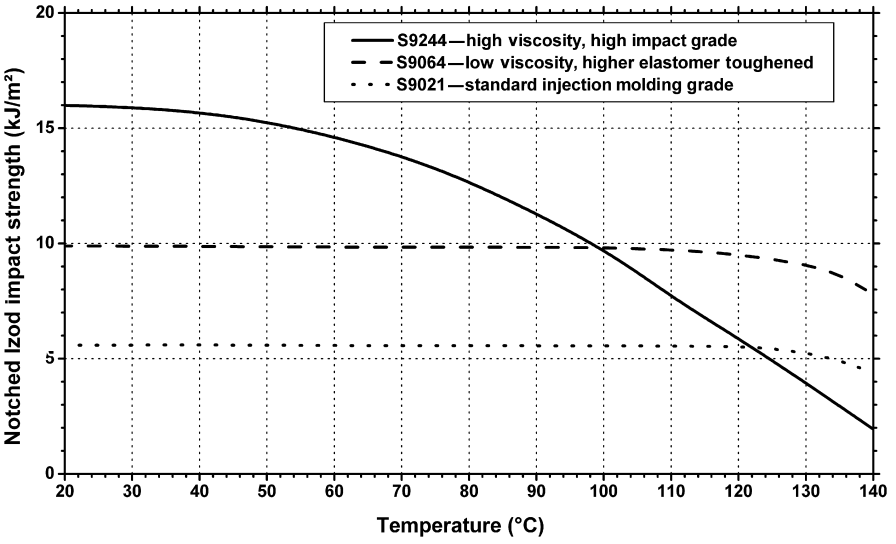

Figure 3.56 Izod notched impact strength vs. temperature for Celanese Hostaform® acetal copolymer resins after 1000 h storage in air at temperature [5].

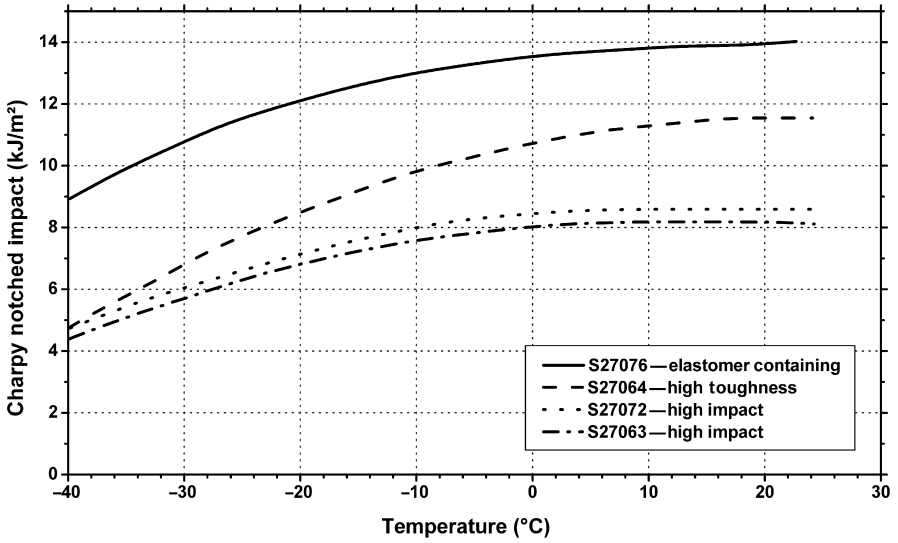

Figure 3.57 Charpy notched impact strength vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

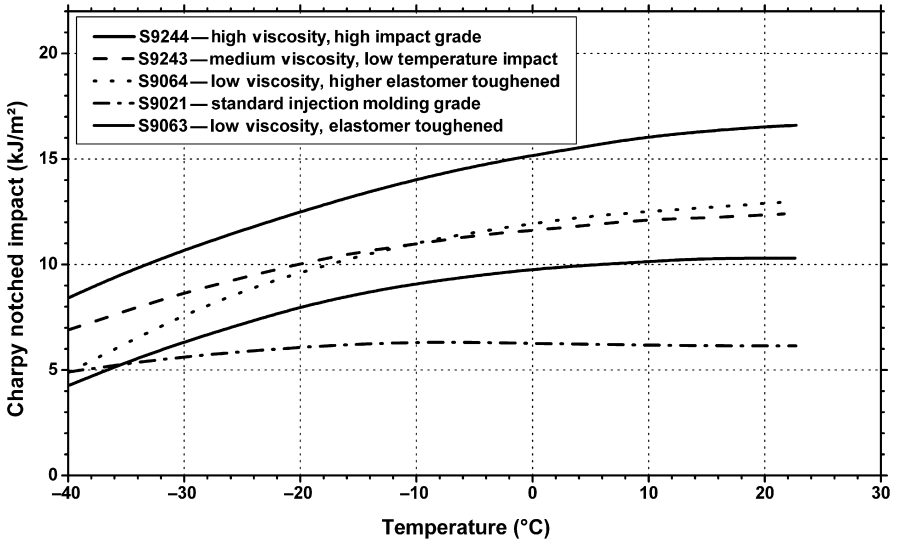

Figure 3.58 Charpy notched impact strength vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

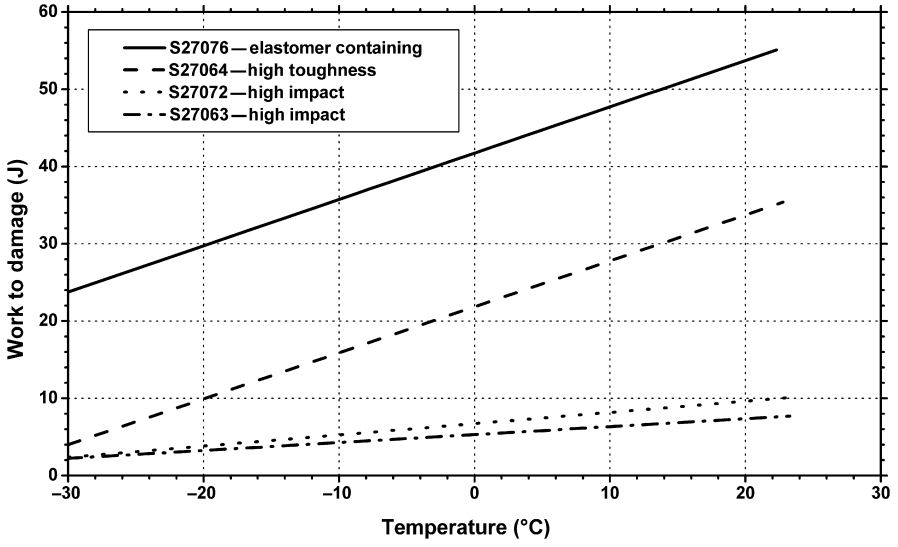

Figure 3.59 Work to damage (penetration test ISO 6603-2) vs. temperature for Celanese Hostaform® acetal copolymer resins.

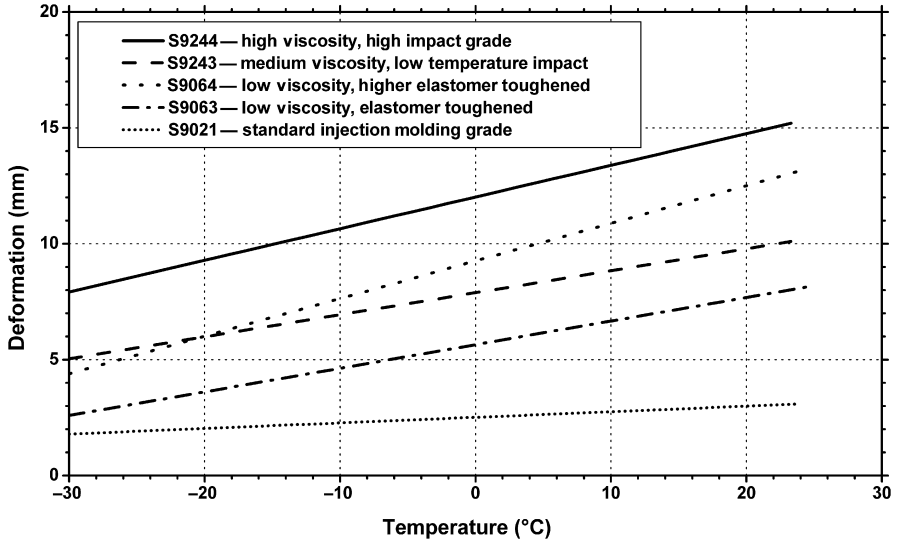

Figure 3.60 Deformation (penetration test ISO 6603-2) vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

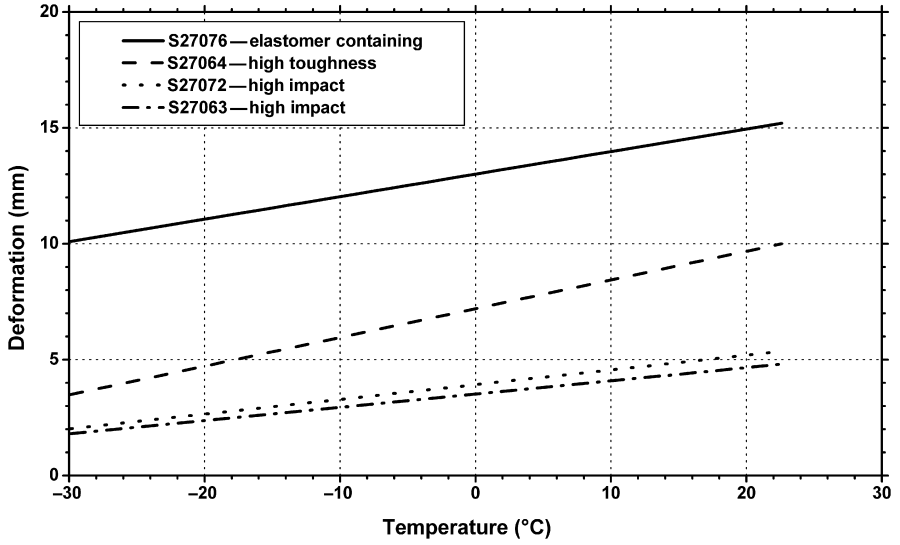

Figure 3.61 Deformation (penetration test ISO 6603-2) vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

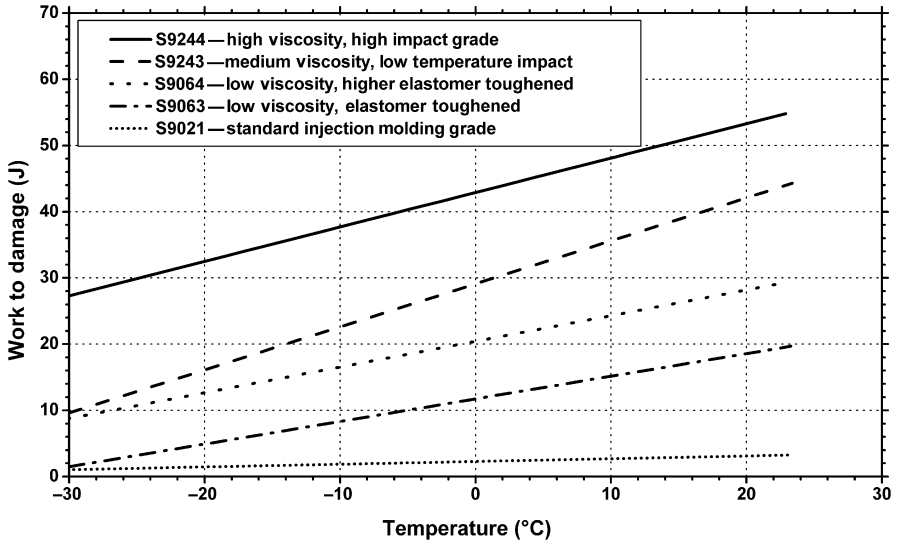

Figure 3.62 Work to damage (penetration test ISO 6603-2) vs. temperature for Celanese Hostaform® acetal copolymer resins [5].

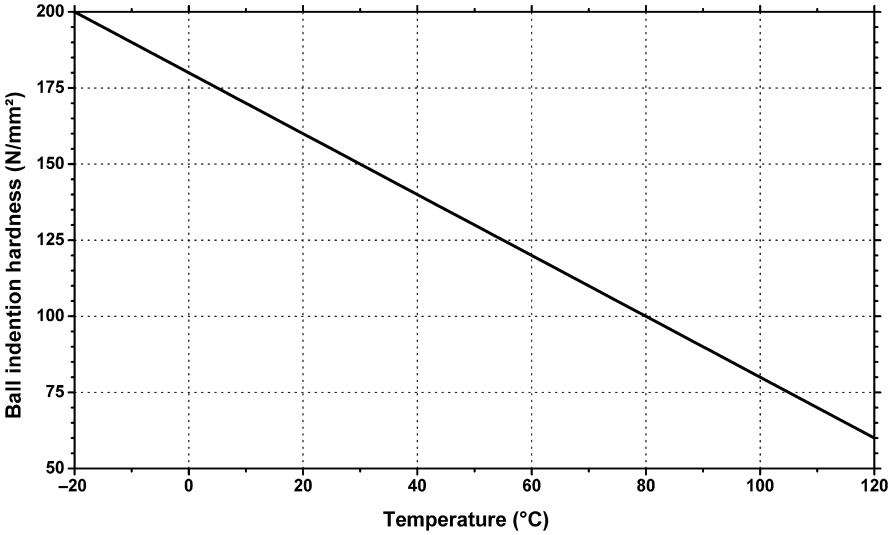

Figure 3.63 Ball indentation hardness vs. temperature for Celanese Hostaform® C 9021 general purpose acetal copolymer resin (ISO 2039, Part 1) [5].

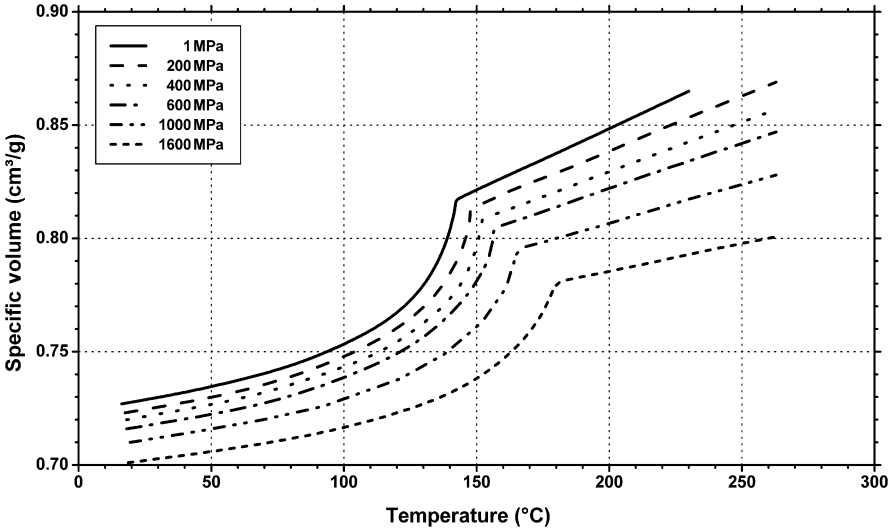

Figure 3.64 Specific volume as a function of temperature and pressure (PVT) for Celanese Hostaform® C 9021 general purpose grade acetal copolymer resin.

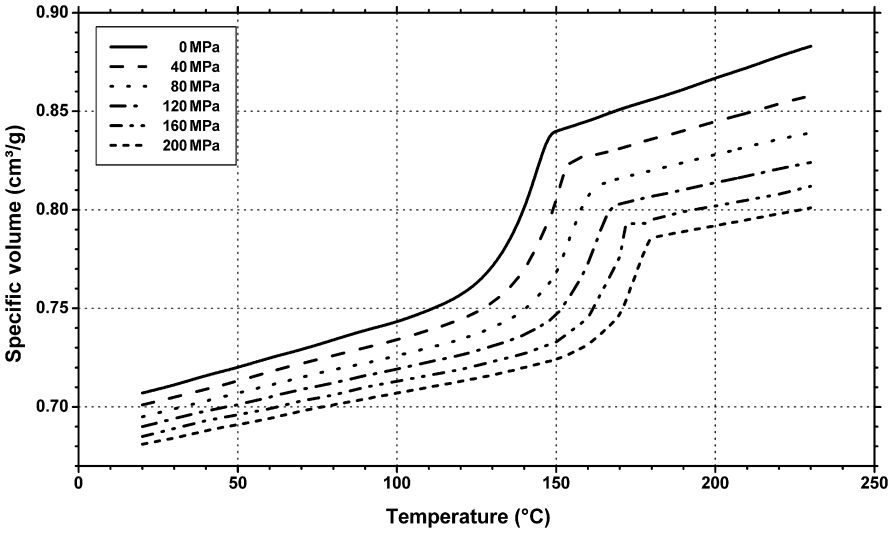

Figure 3.65 Specific volume as a function of temperature and pressure (PVT) for BASF Ultraform® H 2320 006—high molecular weight injection molding grade acetal copolymer resin.

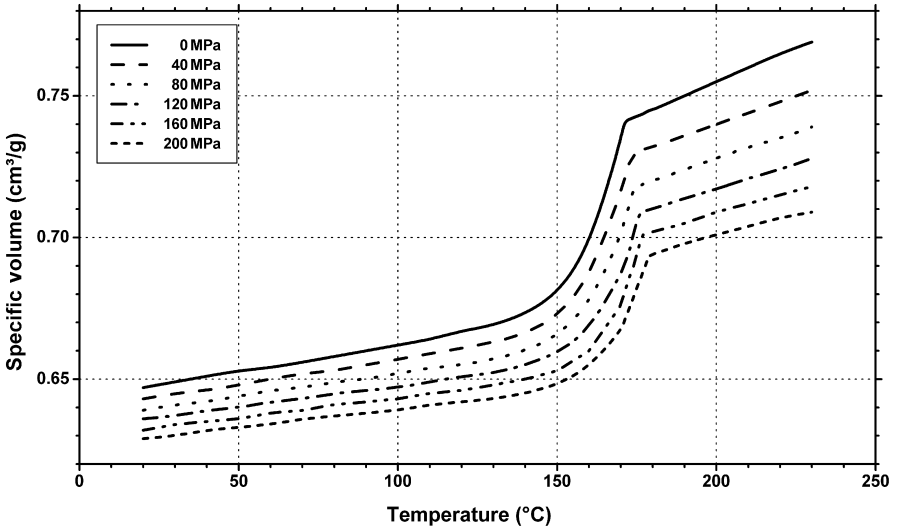

Figure 3.66 Specific volume as a function of temperature and pressure (PVT) for BASF Ultraform® N 2200 G53—25% glass fiber reinforced, injection molding with enhanced stiffness and toughness acetal copolymer resin.

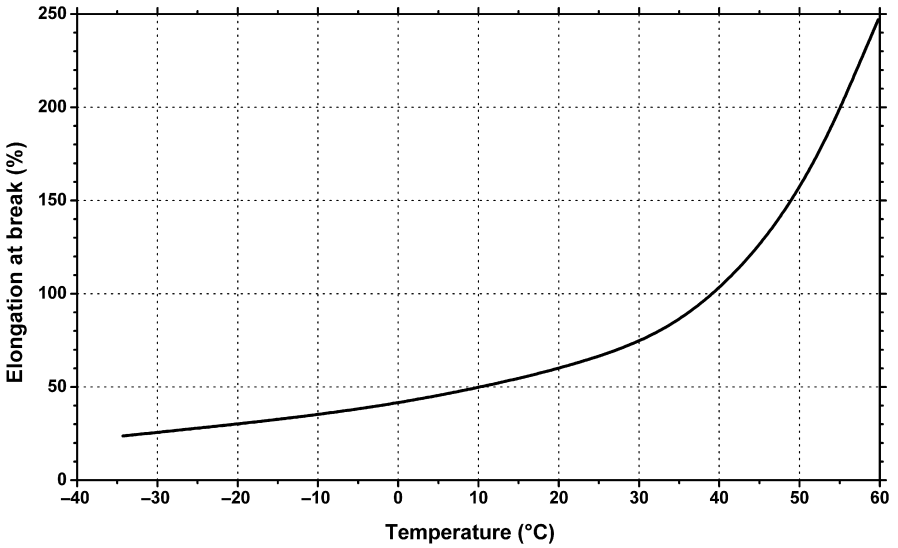

Figure 3.67 Elongation at break vs. temperature for Celanese Celcon® M90—general purpose acetal copolymer resin.

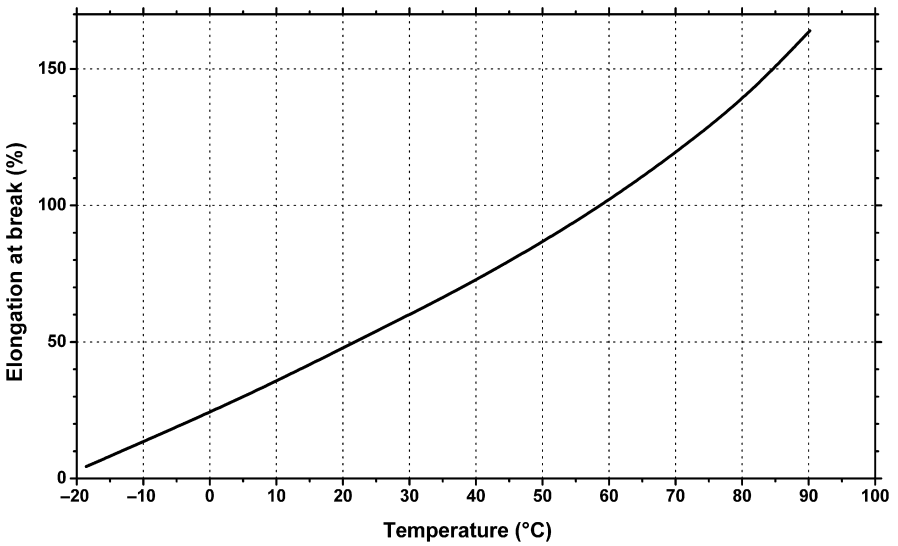

Figure 3.68 Elongation at break vs. temperature for Celanese Hostaform® C 2521—standard for sheet and tube acetal copolymer resin [5].

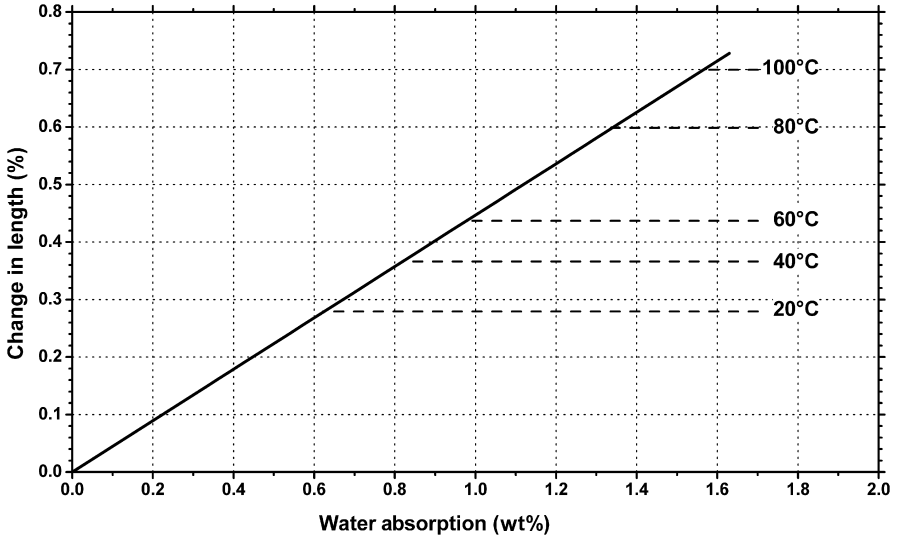

Figure 3.69 Change in length vs. water absorption for Celanese Hostaform® C 9021—general purpose acetal copolymer resin.

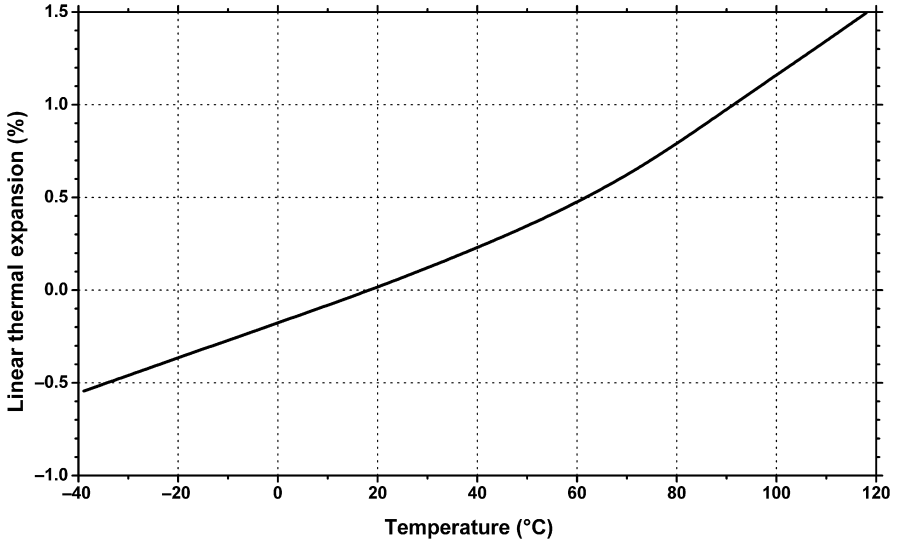

Figure 3.70 Linear thermal expansion vs. temperature for Celanese Celcon® M90—general purpose acetal copolymer resin.

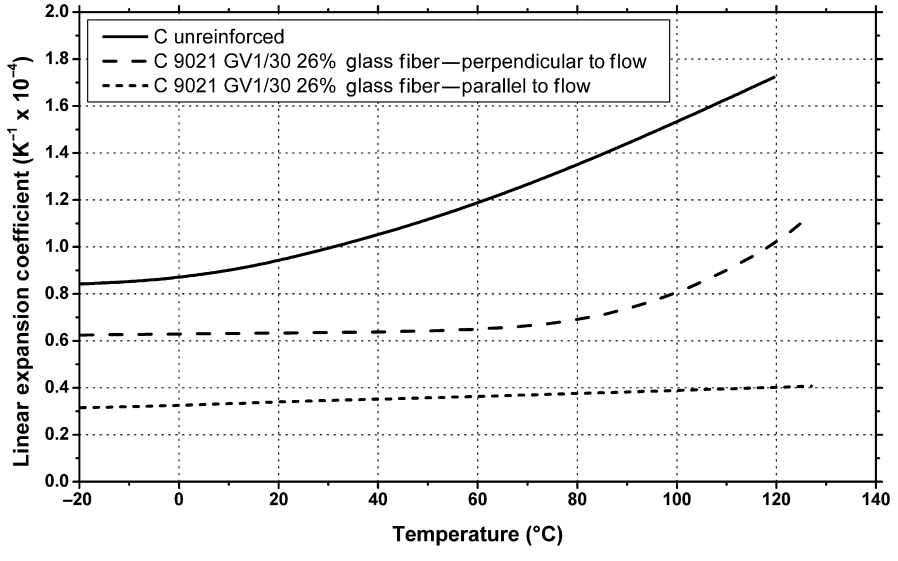

Figure 3.71 Linear expansion coefficient of reinforced and unreinforced Hostaform® C acetal copolymer resins [5].

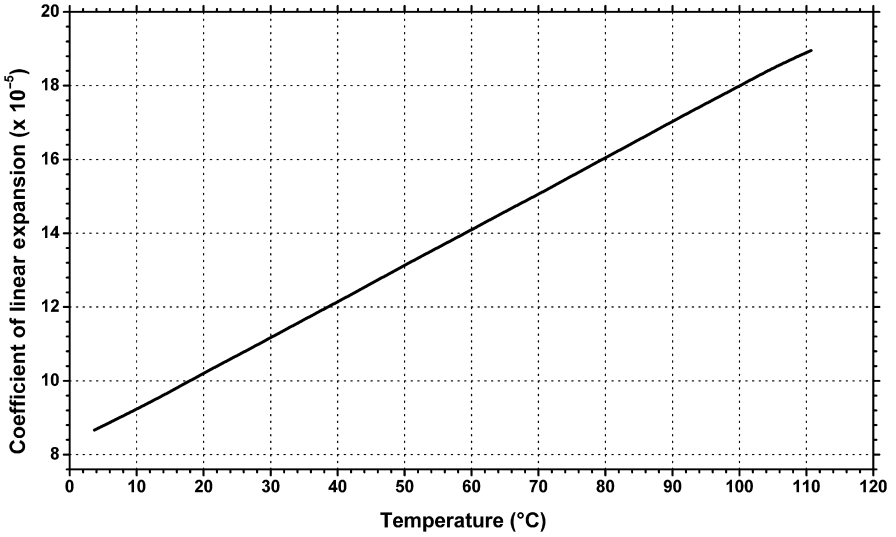

Figure 3.72 Linear expansion coefficient vs. temperature of Mitsubishi Engineering-Plastics Iupital® acetal copolymer resin [4].

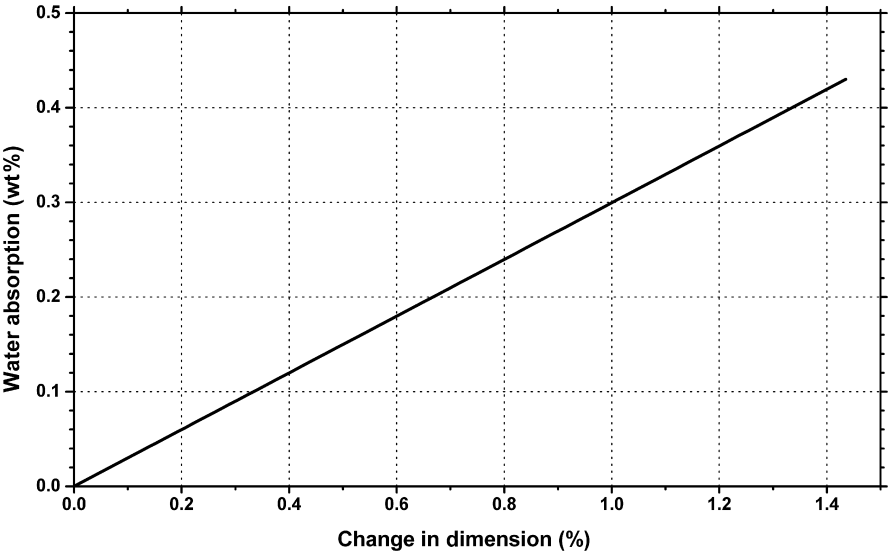

Figure 3.73 Water absorption vs. change of dimension for Mitsubishi Engineering-Plastics Iupital® F20-02—medium viscosity, general purpose acetal copolymer resin.

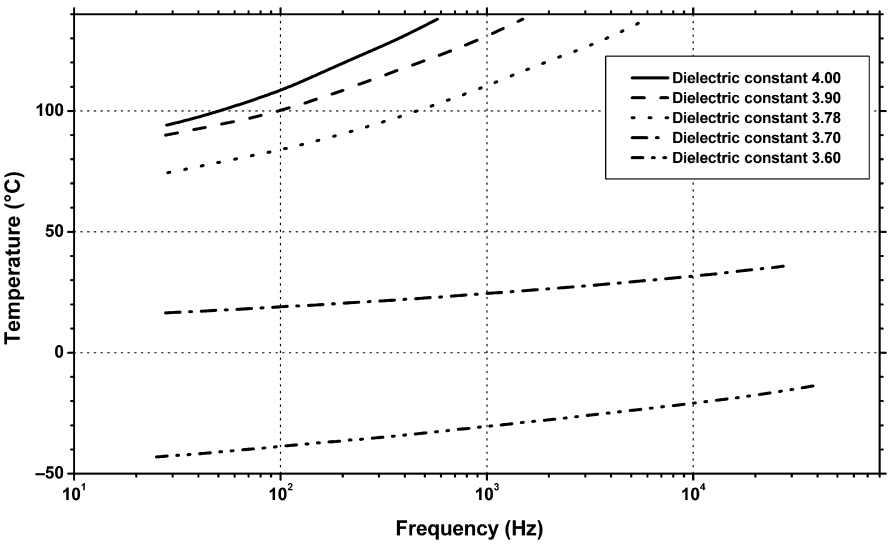

Figure 3.74 Dielectric constant variation with temperature and frequency for Celanese Celcon® M25/M90/M270 acetal copolymer resins.

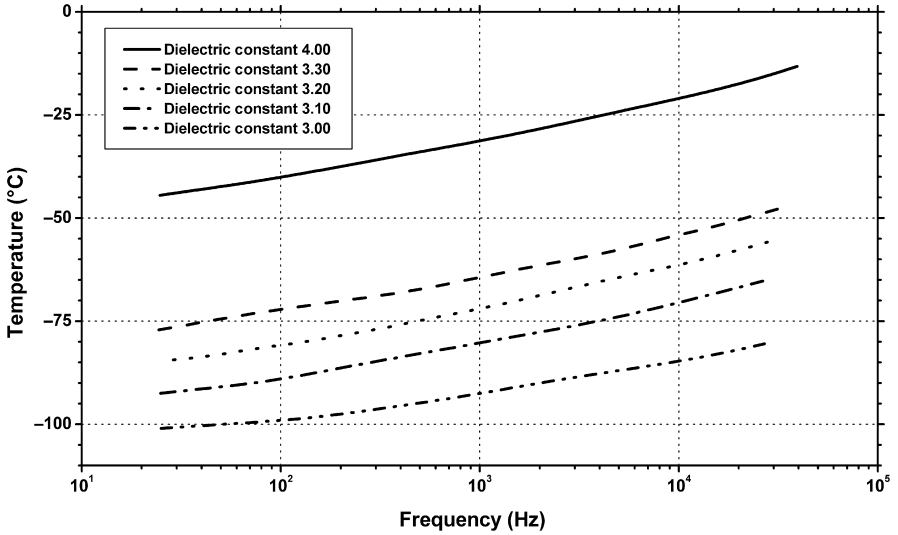

Figure 3.75 Dielectric constant variation with temperature and frequency for Celanese Celcon® M25/M90/M270 acetal copolymer resins.

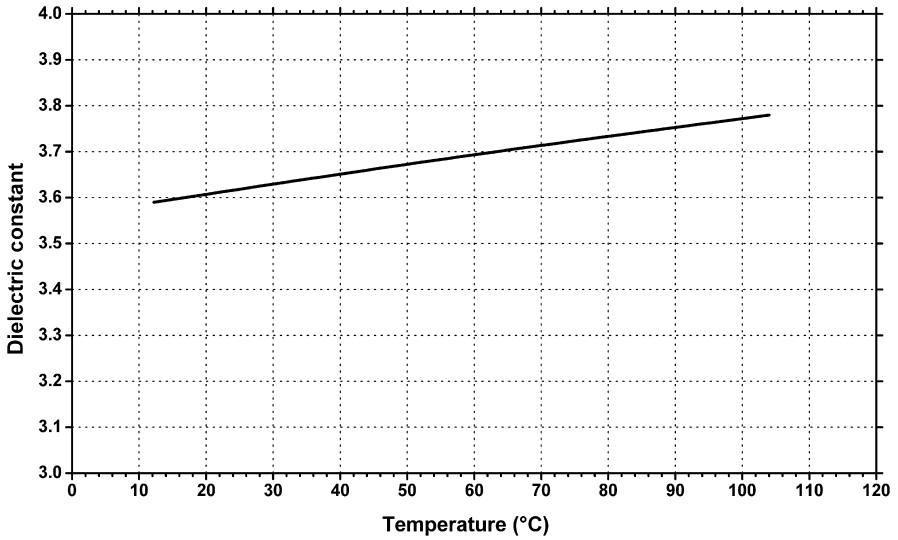

Figure 3.76 Dielectric constant vs. temperature for Mitsubishi Engineering-Plastics Iupital® F20-02—medium viscosity, general purpose acetal copolymer resin.

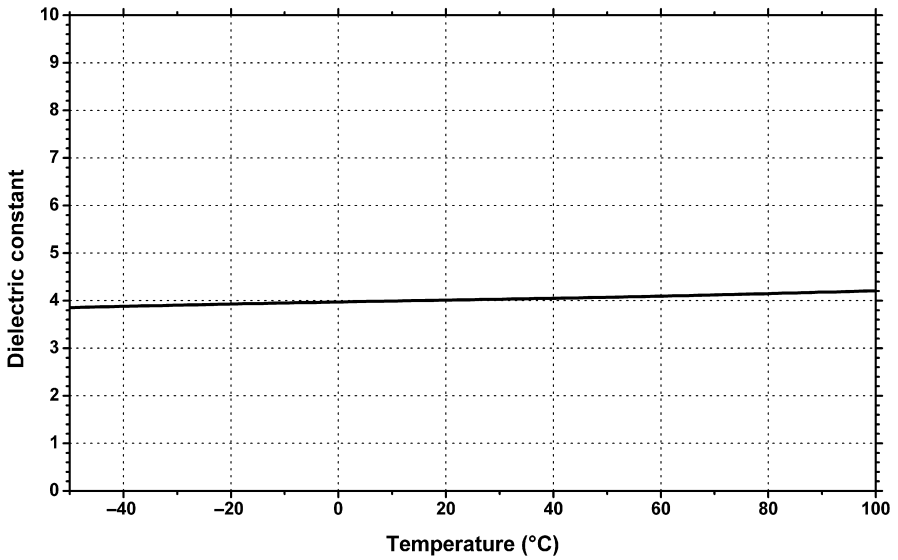

Figure 3.77 Effect of temperature on the relative permittivity (dielectric constant) of Celanese Hostaform® POM-Co (measured at 10^5 Hz) [5].

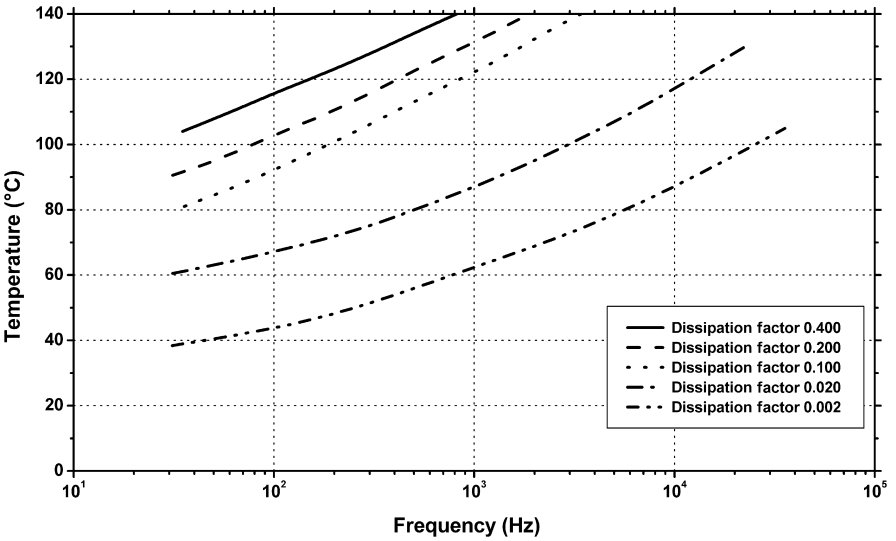

Figure 3.78 Dissipation factor variation with temperature and frequency for Celanese Celcon® M25/M90/M270 acetal copolymer resins.

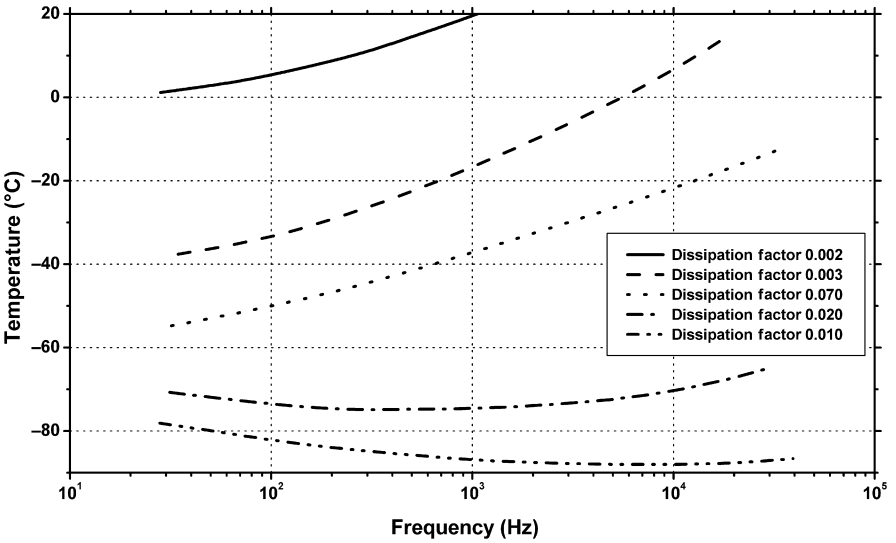

Figure 3.79 Dissipation factor variation with temperature and frequency for Celanese Celcon® M25/M90/M270 acetal copolymer resins.

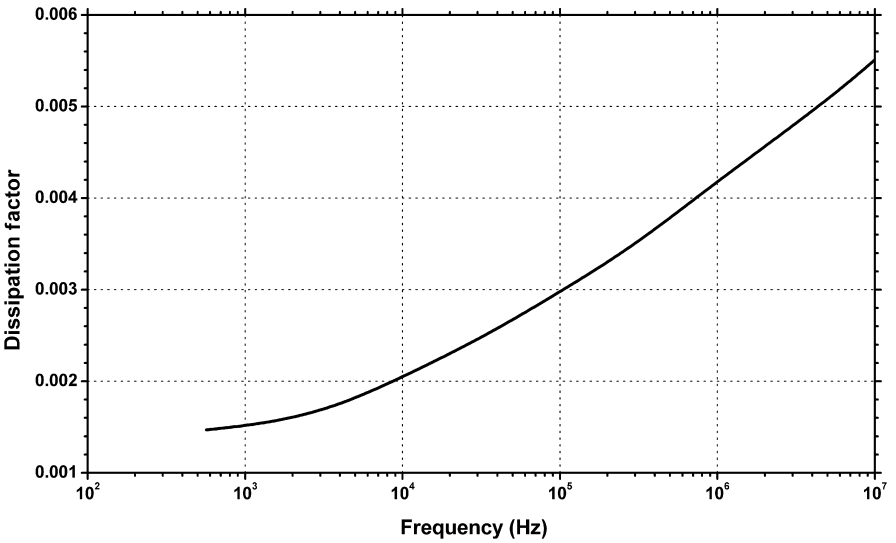

Figure 3.80 Dissipation factor vs. frequency at 25°C for Celanese Hostaform® acetal copolymer resin.

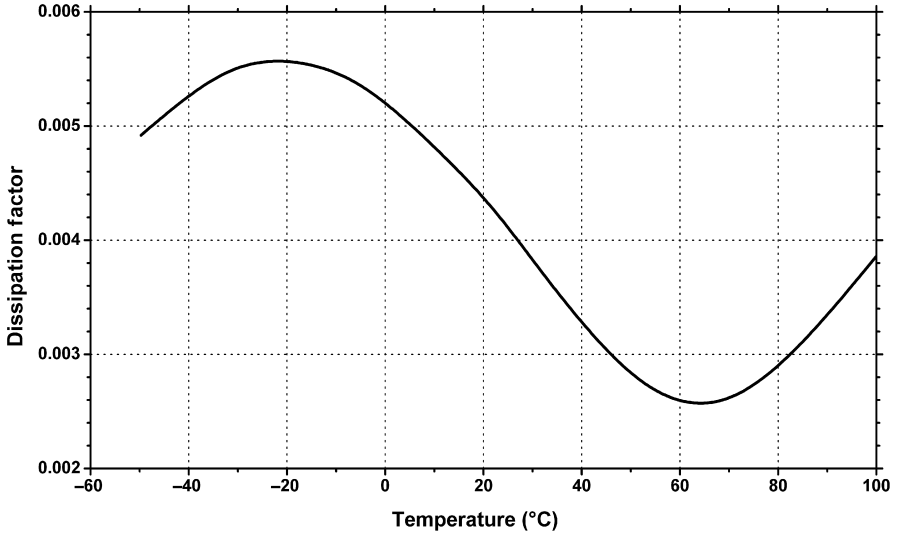

Figure 3.81 Dissipation factor vs. temperature at 10^5 Hz for Celanese Hostaform® acetal copolymer resin [5].

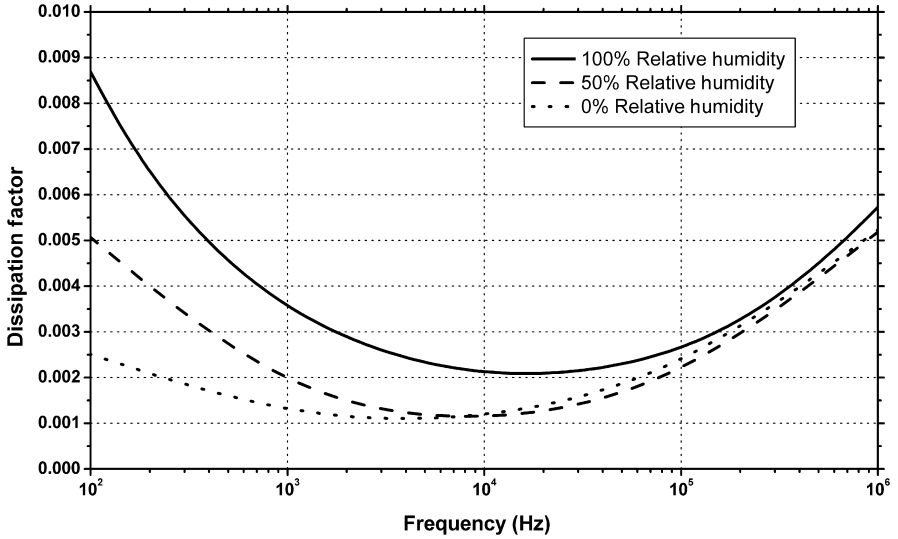

Figure 3.82 Dissipation factor vs. frequency at 23°C for unfilled Celanese Celcon® acetal copolymer resin [3].

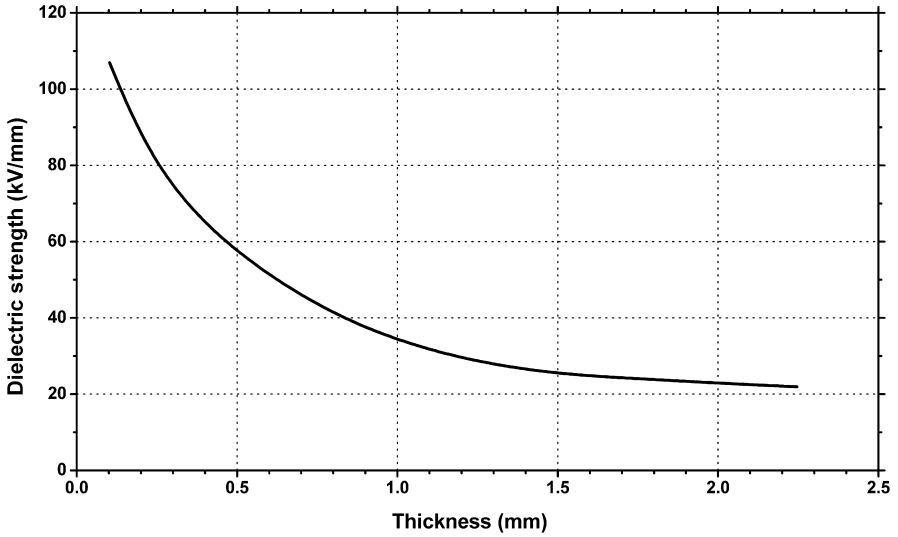

Figure 3.83 Dielectric strength at 23°C vs. thickness for Celanese Celcon® M25/M90/M270 acetal copolymer resins [3].

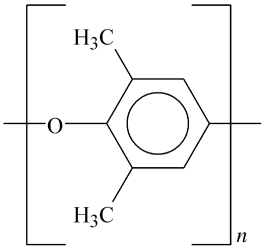

Figure 3.84 Chemical structure of PPE or PPO.

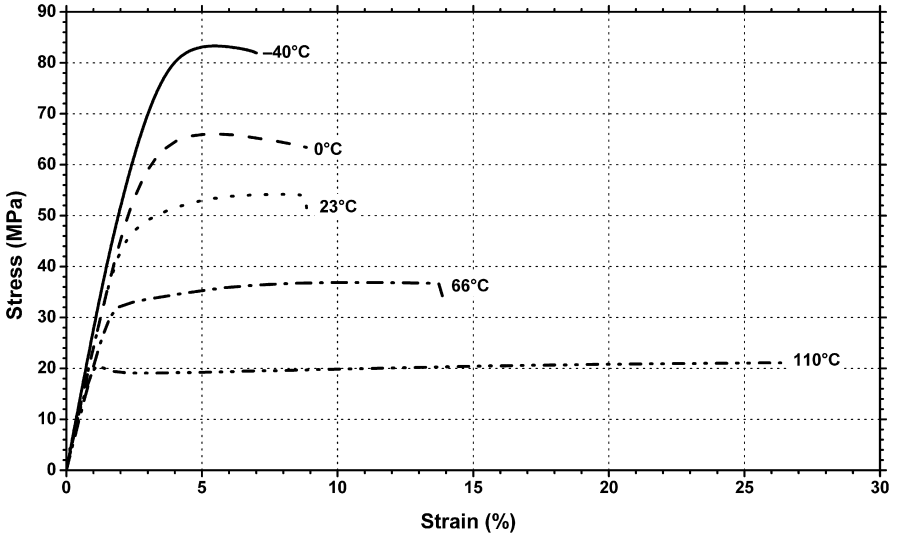

Figure 3.85 Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl® 731—general purpose, UL94 HB rated, polypropylene ether, and PS blend resin.

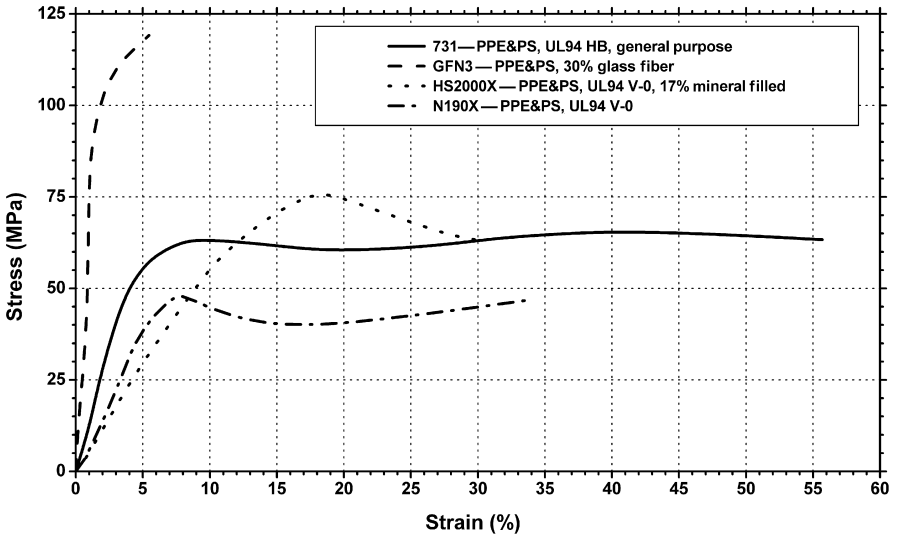

Figure 3.86 Stress vs. strain at 23°C for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

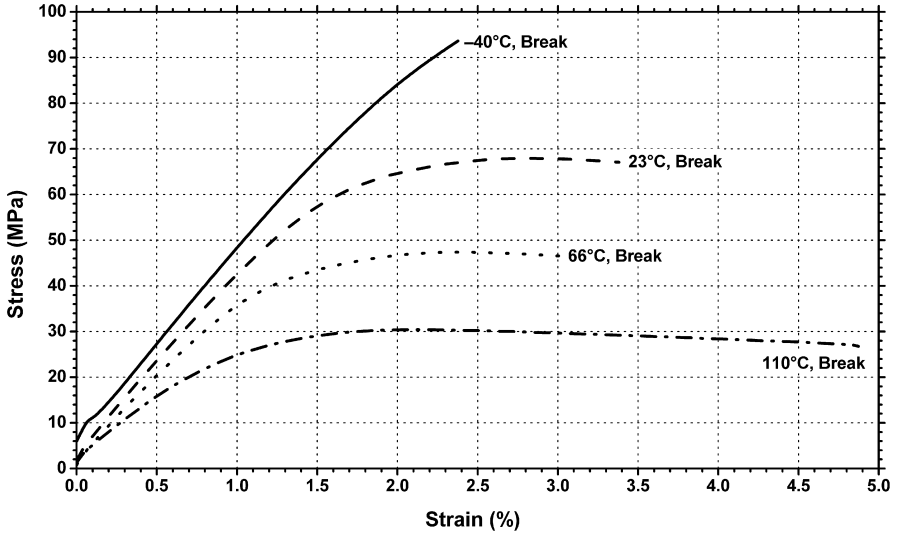

Figure 3.87 Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl® GFN1—10% glass fiber reinforced, polypropylene ether, and PS blend resin.

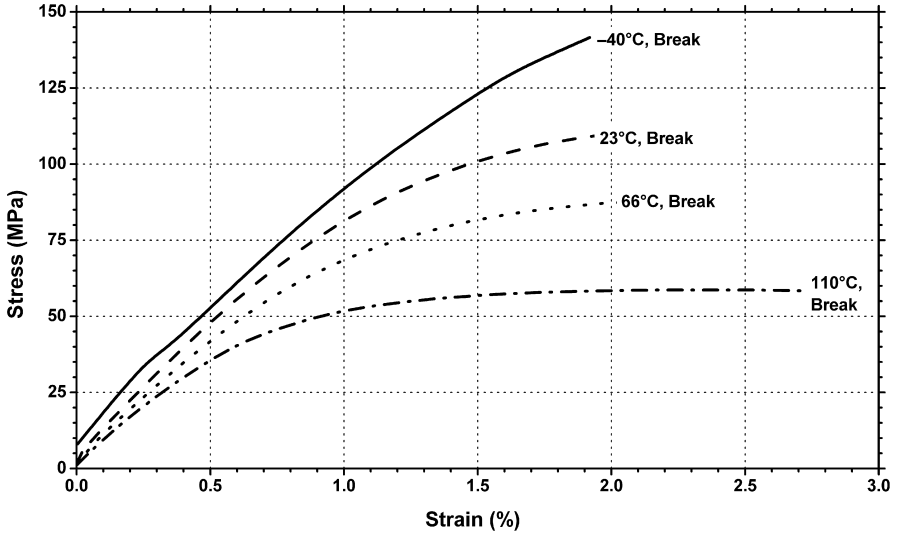

Figure 3.88 Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl® GFN3—30% glass fiber reinforced, polypropylene ether, and PS blend resin.

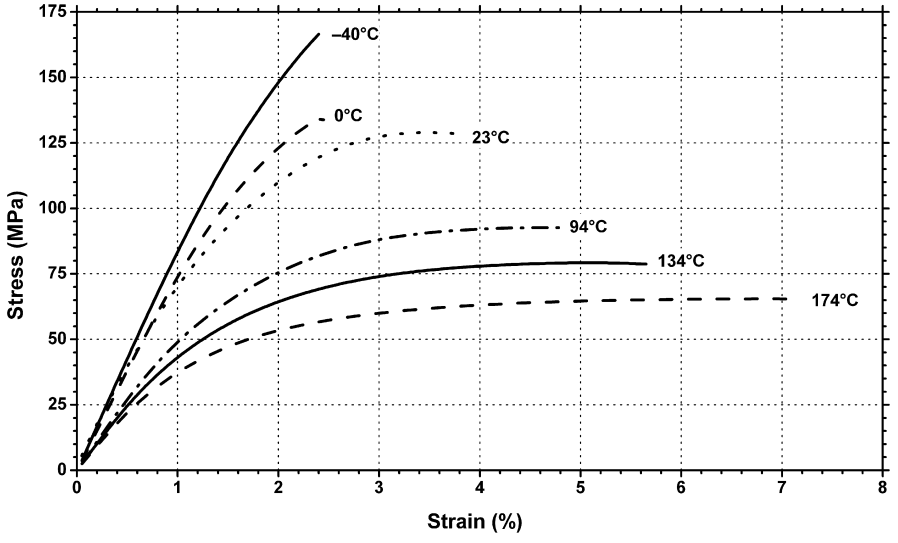

Figure 3.89 Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl GTX® GTX830—30% glass fiber reinforced, polypropylene ether, PS, and polyamide blend resin.

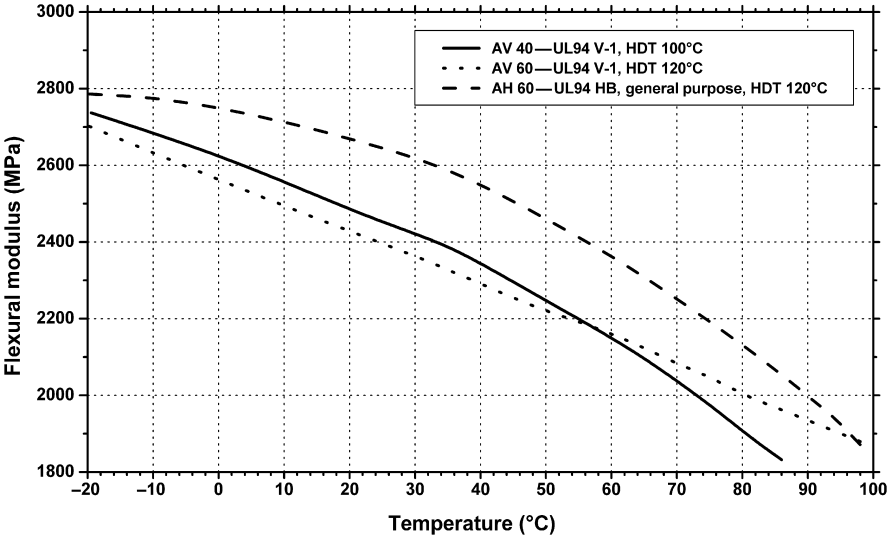

Figure 3.90 Flexural modulus vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

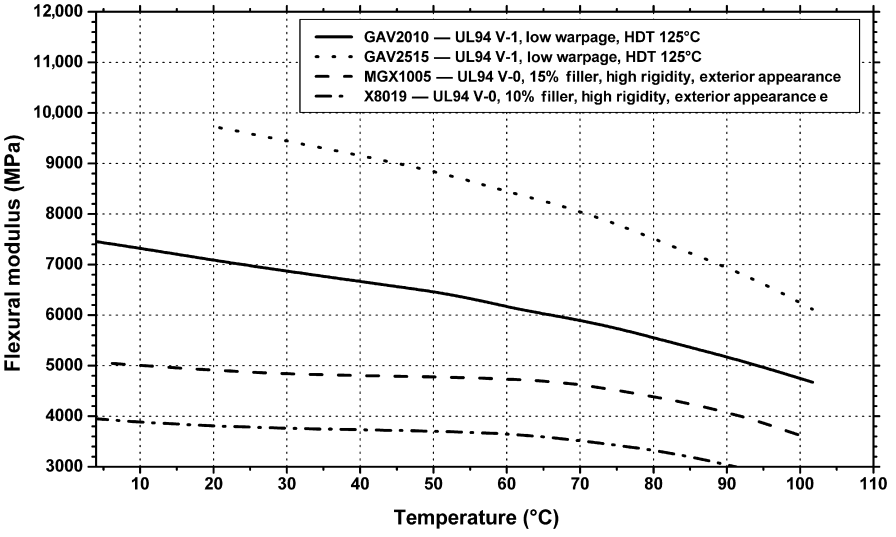

Figure 3.91 Flexural modulus vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

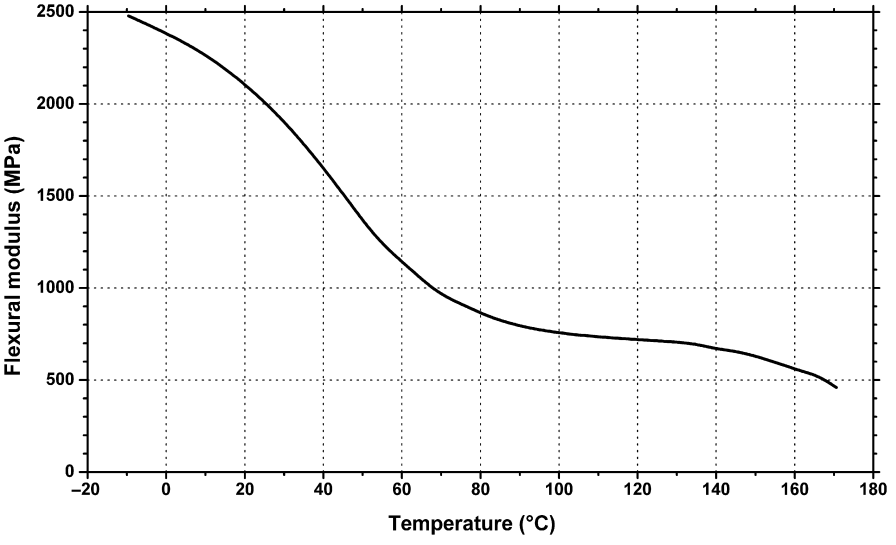

Figure 3.92 Flexural modulus vs. temperature for Mitsubishi Engineering-Plastics Iupiace® NX-9000—heat and chemical resistant, SAE grade polypropylene ether, and nylon 6 blend resin.

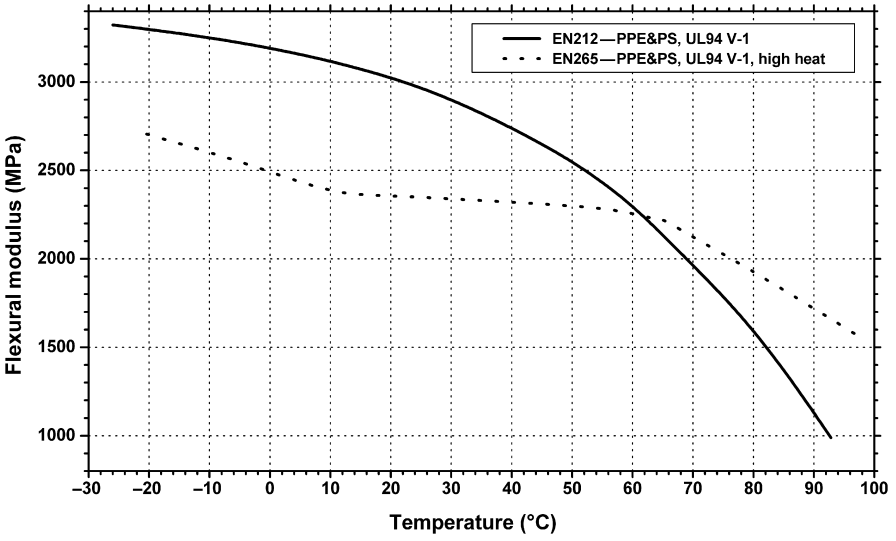

Figure 3.93 Flexural modulus vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

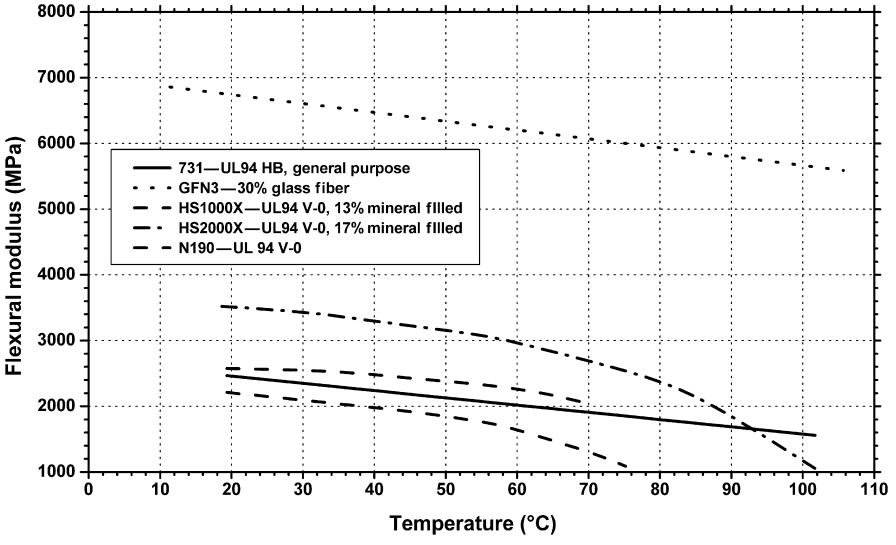

Figure 3.94 Flexural modulus vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

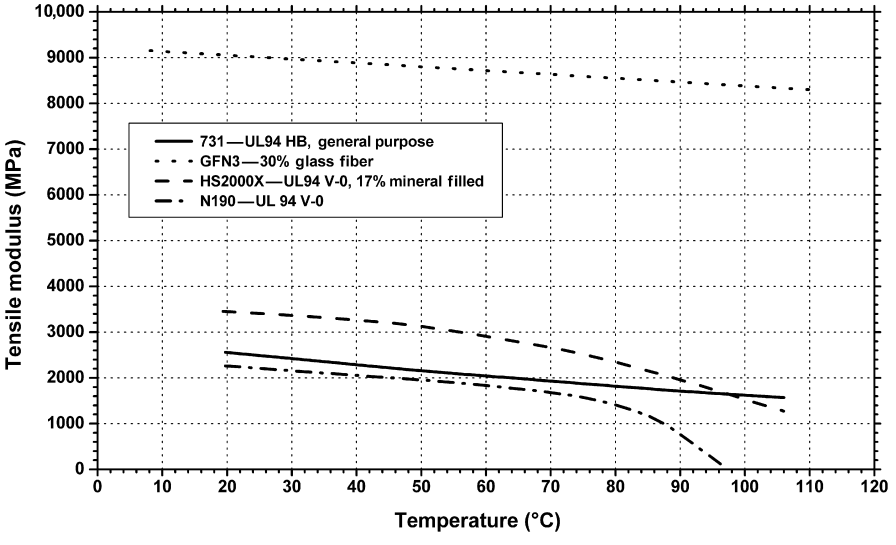

Figure 3.95 Tensile modulus vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

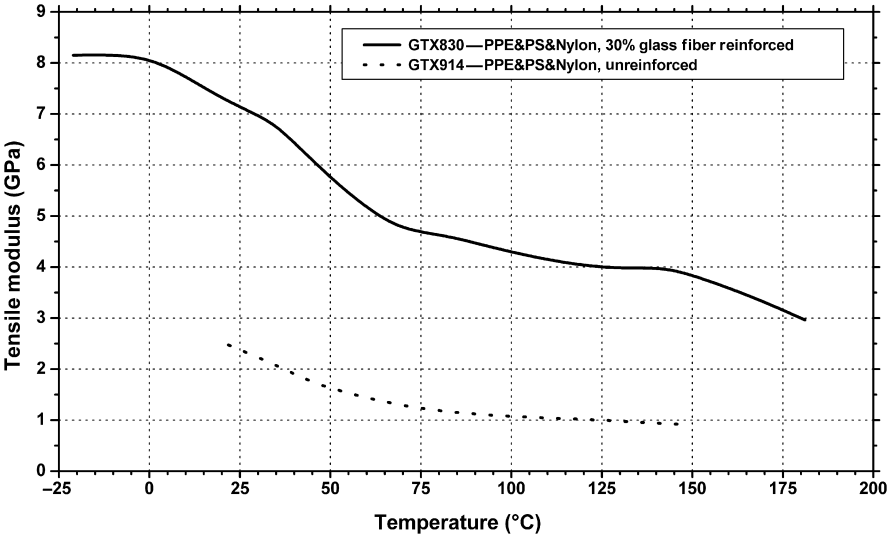

Figure 3.96 Tensile modulus vs. temperature for SABIC Innovative Plastics Noryl GTX® polypropylene ether, PS, and polyamide blend resins.

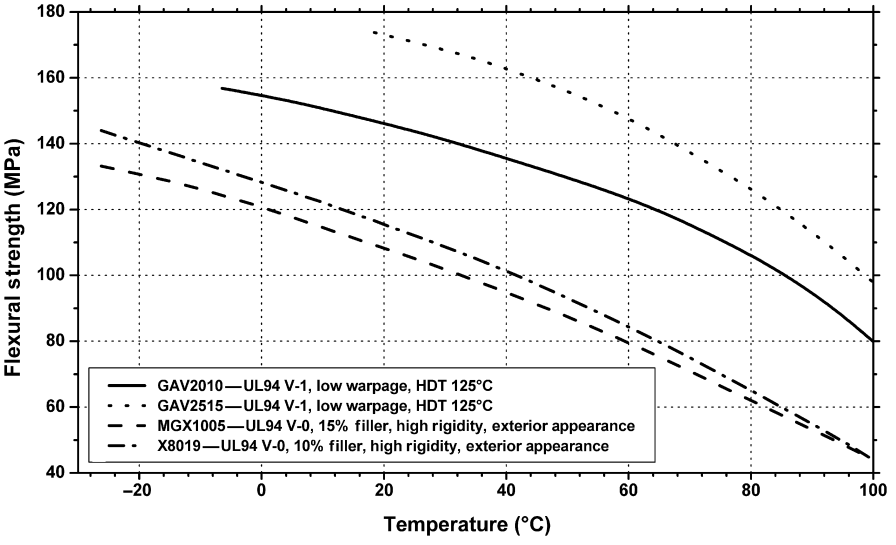

Figure 3.97 Flexural strength vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

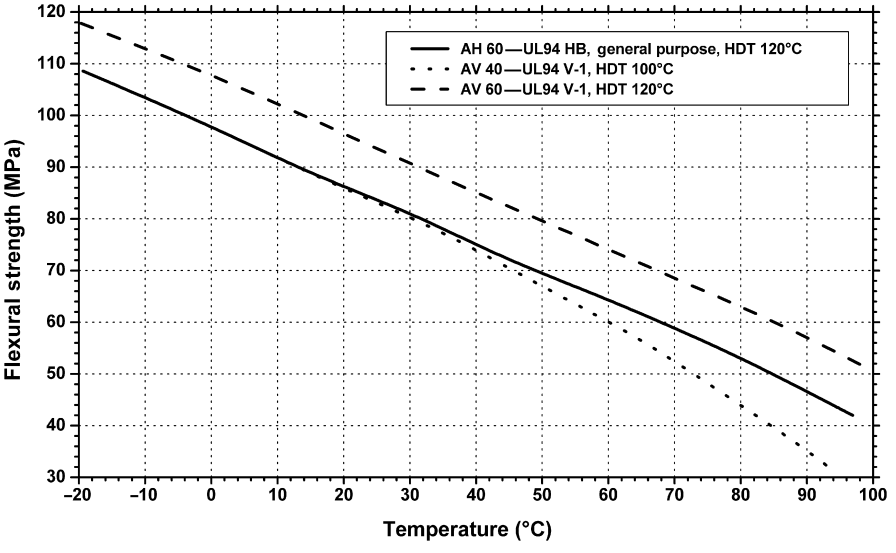

Figure 3.98 Flexural strength vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

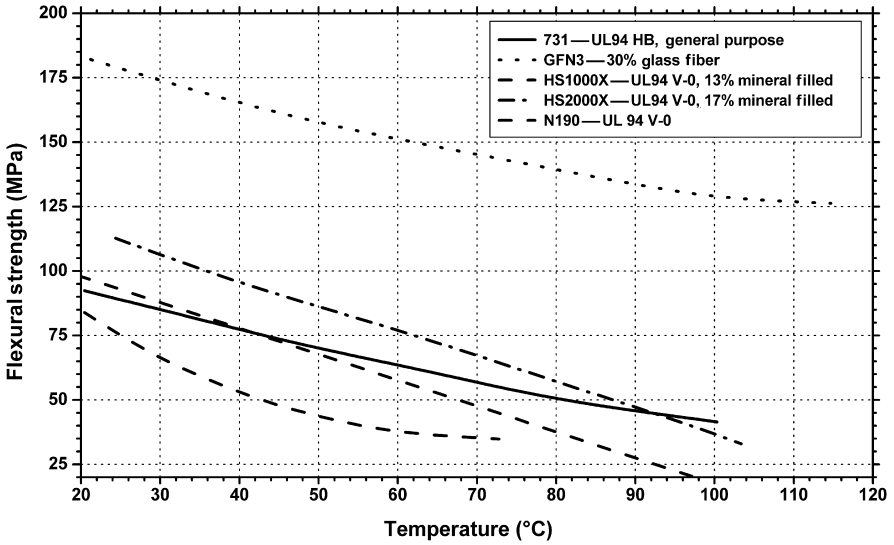

Figure 3.99 Flexural strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

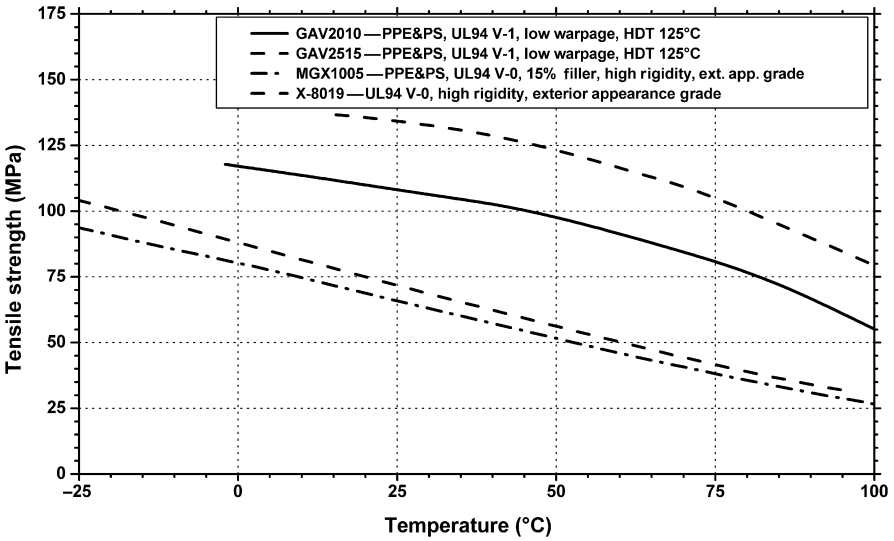

Figure 3.100 Tensile strength vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

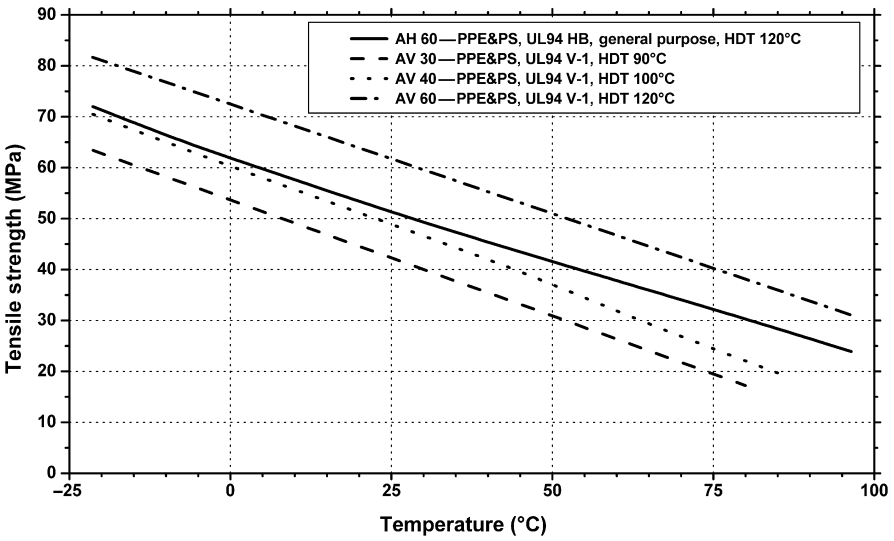

Figure 3.101 Tensile strength vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

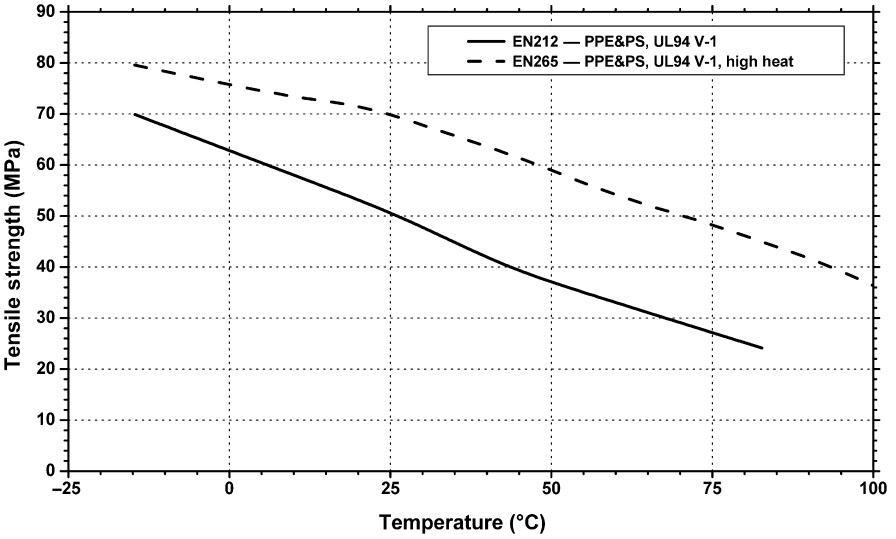

Figure 3.102 Tensile strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

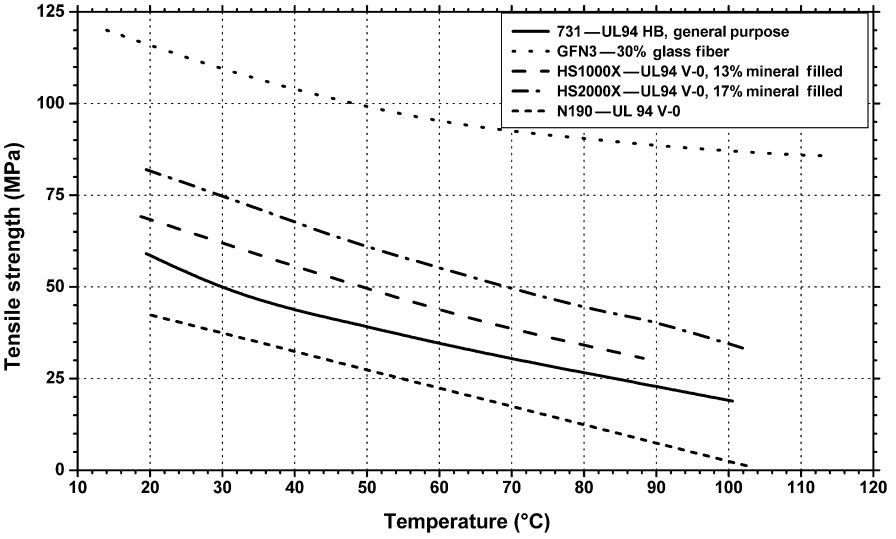

Figure 3.103 Tensile strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

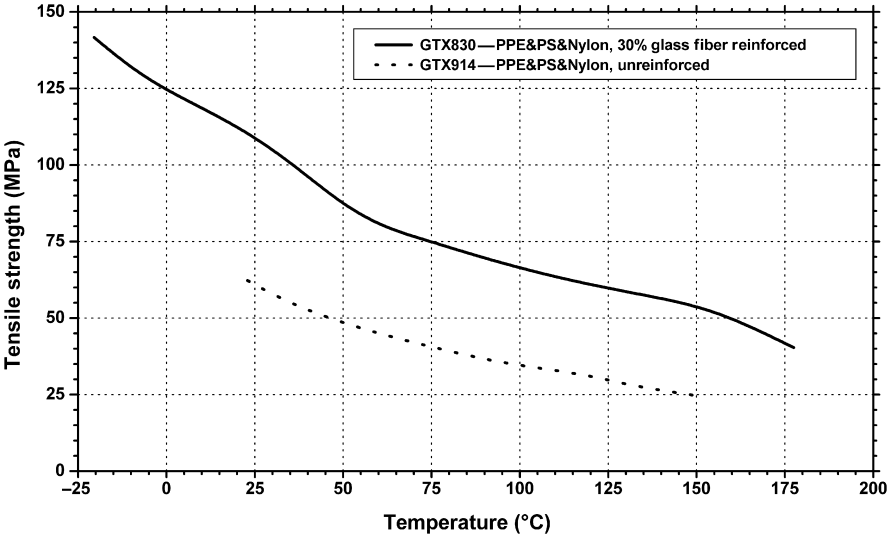

Figure 3.104 Tensile strength vs. temperature for SABIC Innovative Plastics Noryl GTX® polypropylene ether, PS, and polyamide blend resins.

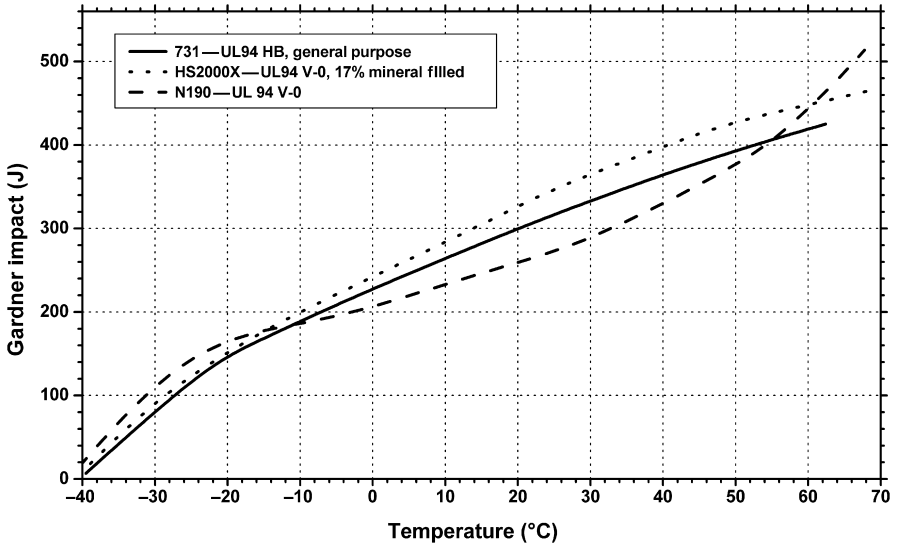

Figure 3.105 Gardner impact strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

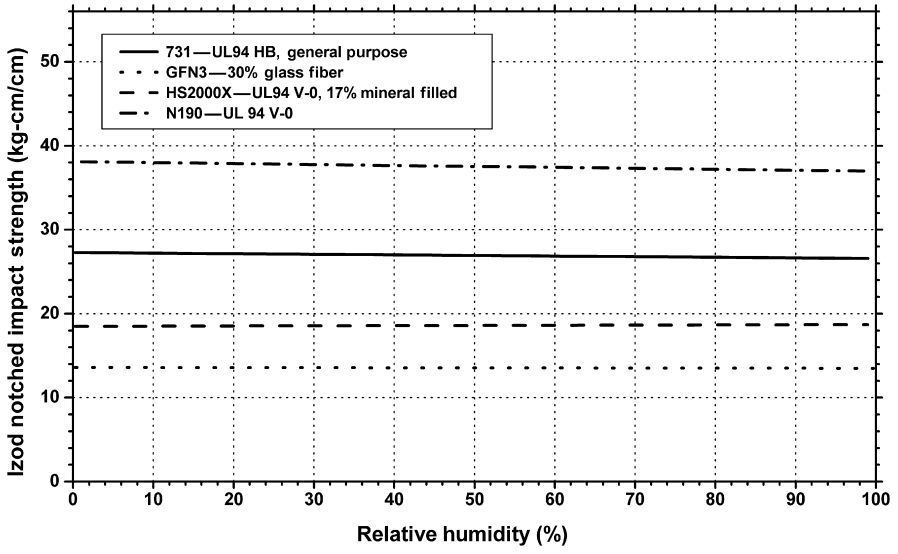

Figure 3.106 Izod impact strength vs. relative humidity for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

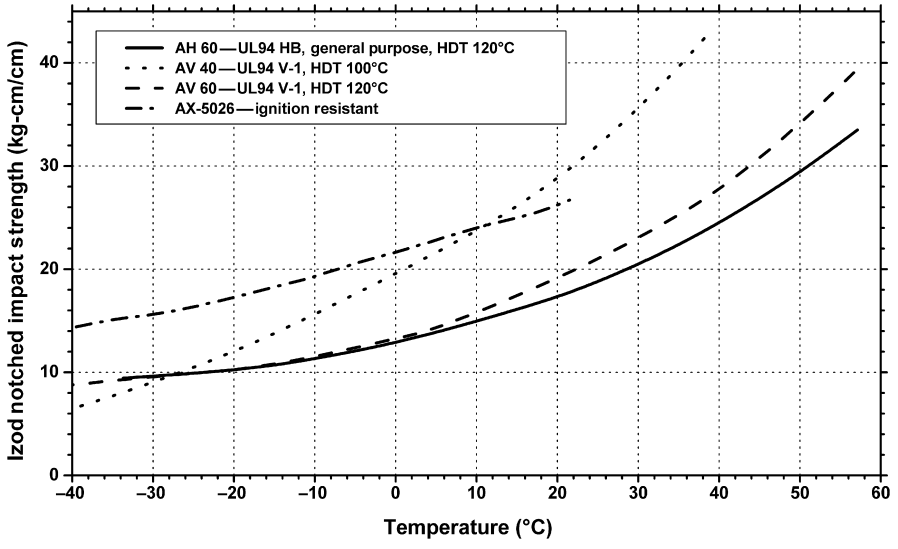

Figure 3.107 Izod impact strength vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

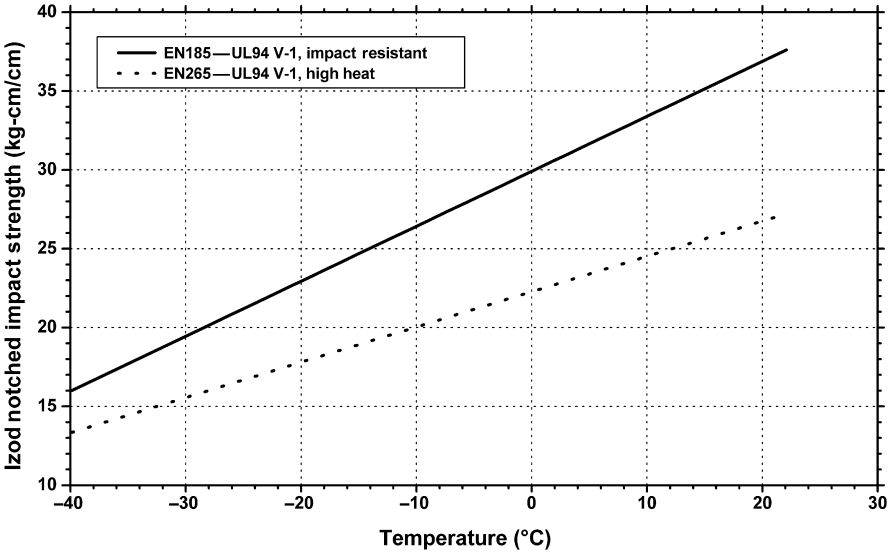

Figure 3.108 Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

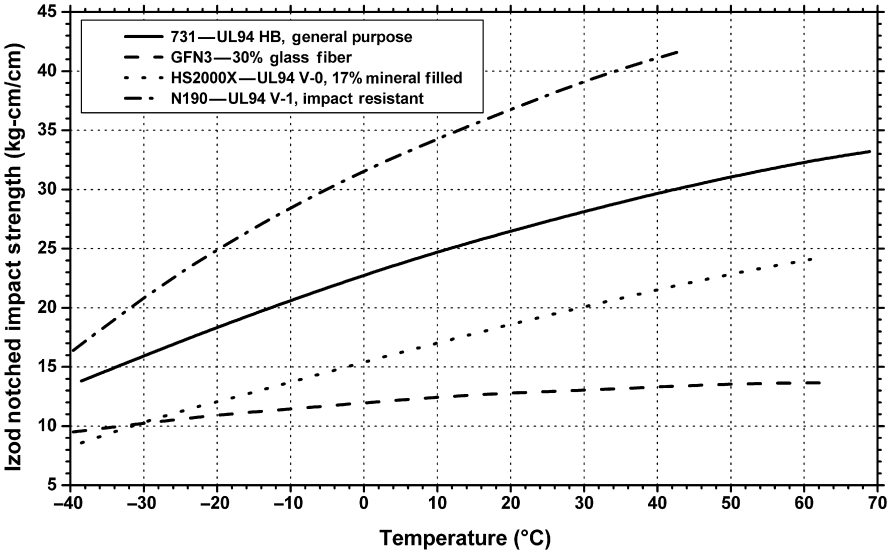

Figure 3.109 Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins.

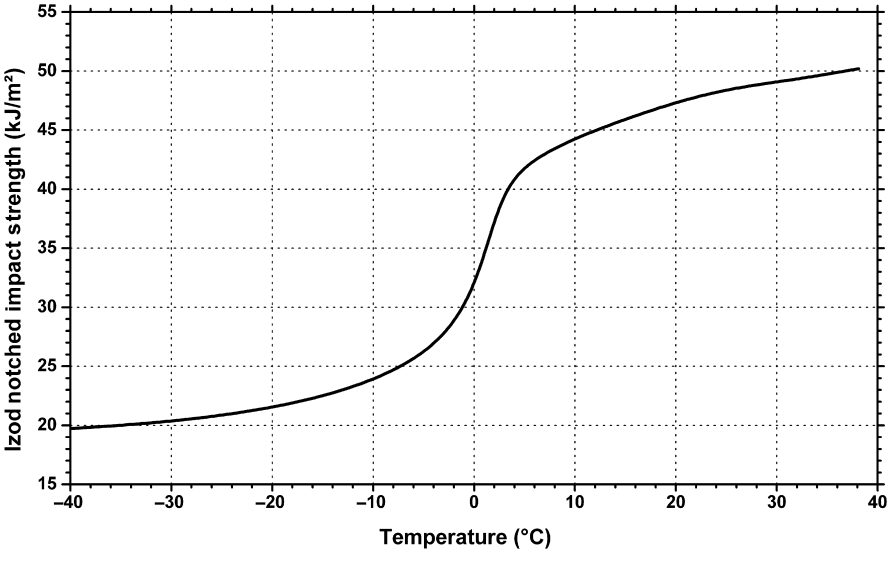

Figure 3.110 Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl GTX® GTX964—unreinforced, impact modified polypropylene ether, PS, and polyamide blend resin.

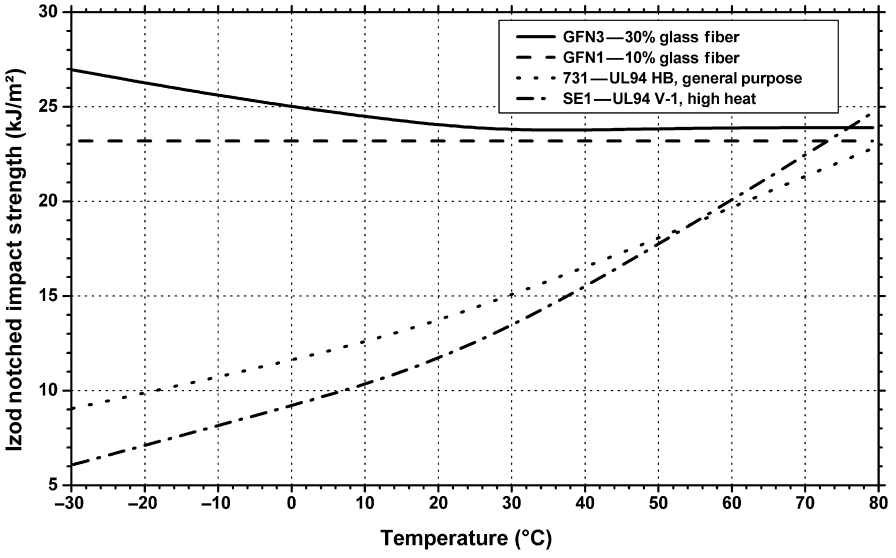

Figure 3.111 Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resins [7].

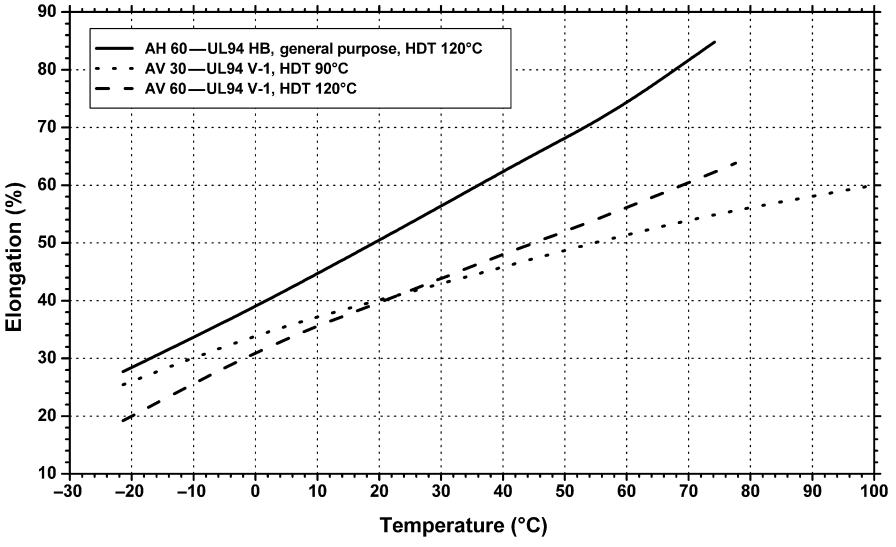

Figure 3.112 Elongation vs. temperature for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

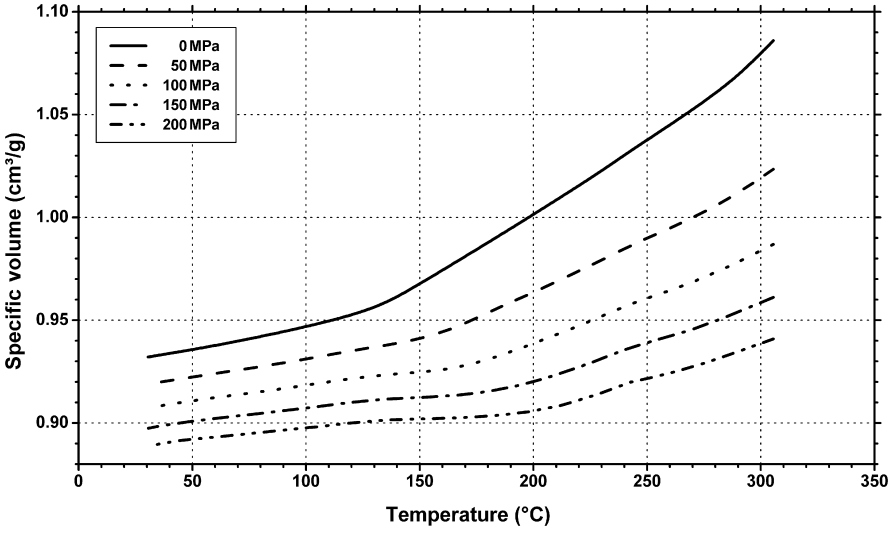

Figure 3.113 Pressure-specific volume–temperature (PVT) for SABIC Innovative Plastics Noryl® 731—general purpose, UL94 HB rated, polypropylene ether and PS blend resin.

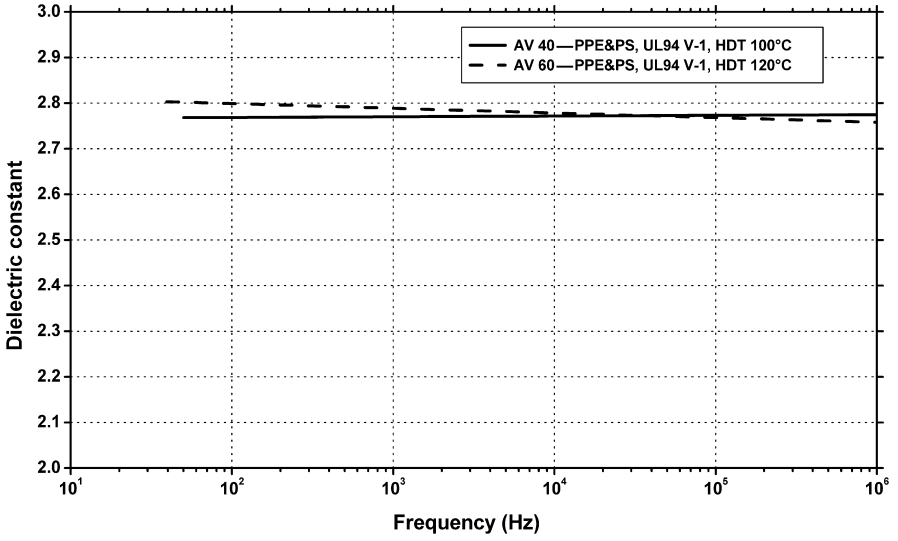

Figure 3.114 Dielectric constant vs. frequency for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

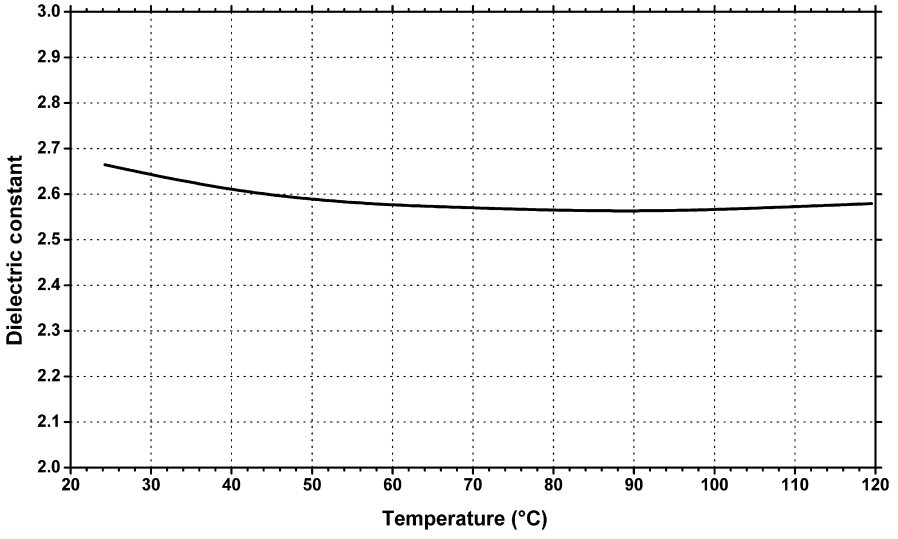

Figure 3.115 Dielectric constant vs. temperature for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resin.

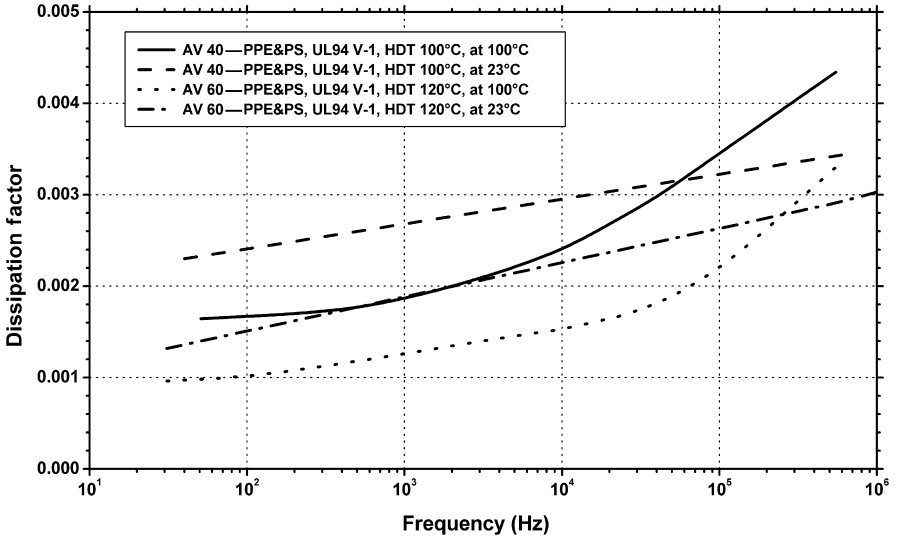

Figure 3.116 Dissipation factor vs. frequency and temperature for Mitsubishi Engineering-Plastics Iupiace® AV 40—UL94 V-1 rated, heat deflection temperature (HDT) 100°C polypropylene ether, and PS blend resin.

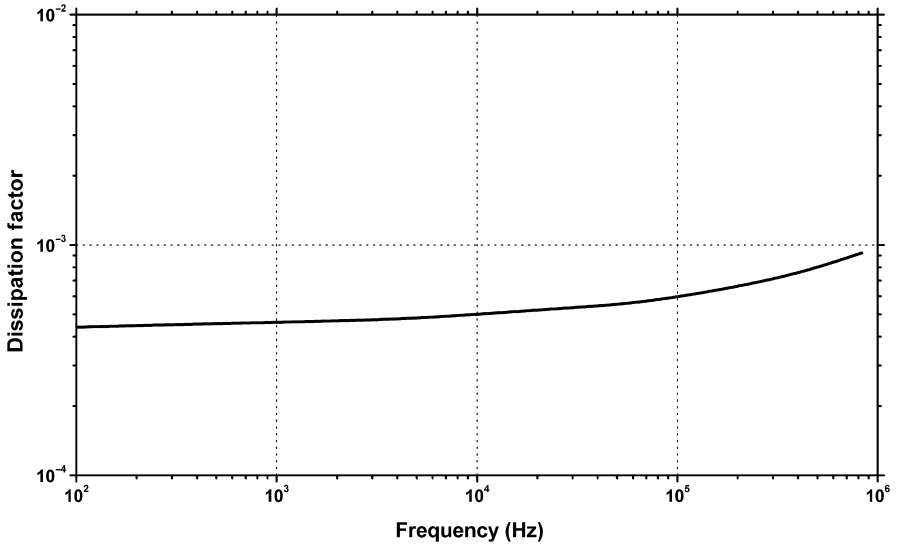

Figure 3.117 Dissipation factor vs. frequency for SABIC Innovative Plastics Noryl® polypropylene ether and PS blend resin.

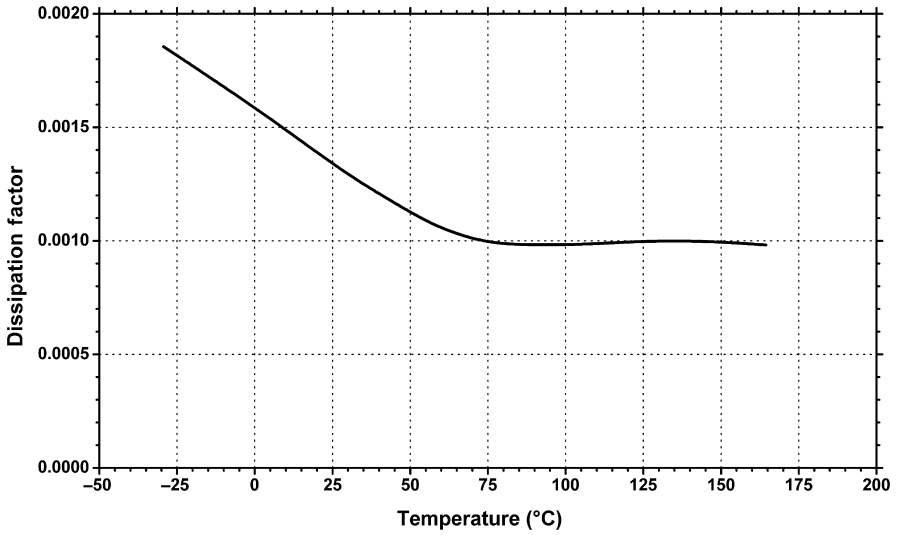

Figure 3.118 Dissipation factor vs. temperature at 60 Hz for Mitsubishi Engineering-Plastics Iupiace® AV 60—UL94 V-1 rated, HDT 120°C polypropylene ether, and PS blend resin.

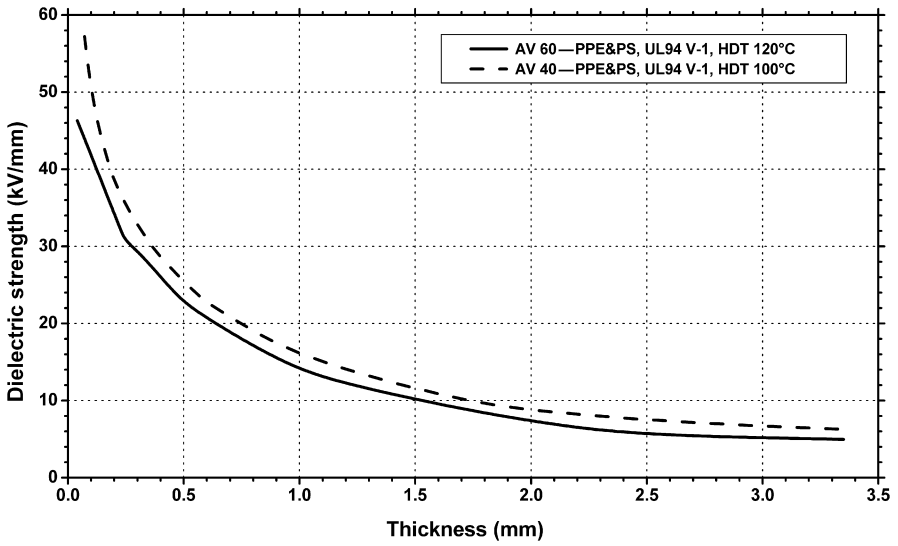

Figure 3.119 Dielectric strength vs. thickness for Mitsubishi Engineering-Plastics Iupiace® polypropylene ether and PS blend resins.

or PPO. PPE is compatible with polystyrene (PS) and is usually blended with high-impact PS over a wide range of ratios. Because both PPE and PS plastics are hydrophobic, the alloys have very low water absorption rates and high dimensional stability. They exhibit excellent dielectric properties over a wide range of frequencies and temperatures. PPE/PS alloys are supplied in flame-retardant, filled and reinforced, and structural foam molding grades. PPE can also be alloyed with polyamide (nylon) plastics to provide increased resistance to organic chemicals and better high-temperature performance.

Manufacturers and trade names: SABIC Innovative Plastics Noryl®, Mitsubishi Engineering-Plastics Iupiace®.

Applications and uses: automotive electrical applications, water pump impellers, HVAC equipment, solar heating systems, packaging, and circuit breakers.

Data for PPE plastics are found in Figures 3.85−3.119.

References

[1] Delrin® acetal resin, Delrin® P performance acetal resin, Delrin® "ELEVEN Series" acetal resin Product and Properties Guide. DuPont; 2000.
[2] Delrin® acetal resin, Design Guide-Module III. DuPont; 1997.
[3] Designing with Celcon® acetal copolymer. Celanese; 2007.
[4] Physicality. Mitsubishi Engineering-Plastics Corporation; 2010.
[5] Hostaform® acetal copolymer (POM). Celanese; 2006.
[6] Ultraform® (POM) Product Brochure. BASF; 2011.
[7] Noryl® resins modified PPE-PS. SABIC Innovative Plastics; 2006.

4 Polyesters

Polyesters are formed by a condensation reaction that is very similar to the reaction used to make polyamide or nylons. A diacid and dialcohol are reacted to form the polyester with the elimination of water as shown in Figure 4.1.

While the actual commercial route to making the polyesters might be different, the end result is the same polymeric structure. The diacid is usually aromatic. Polyester resins can be formulated to be brittle and hard, tough and resilient, or soft and flexible. In combination with reinforcements such as glass fibers, they offer outstanding strength, a high strength-to-weight ratio, chemical resistance, and other excellent mechanical properties. The three dominating materials in this plastics family are PC, polyethylene terephthalate (PET), and polybutylene terephthalate (PBT). The thermoplastic polyesters are similar in properties to Nylon 6 and Nylon 66 but have lower water absorption and higher dimensional stability than the nylons.

4.1 Polycarbonate (PC)

Theoretically, PC is formed from the reaction of bisphenol A and carbonic acid. The structures of these two monomers are given in Figure 4.2.

Commercially, different routes are used, but the PC polymer of the structure shown in Figure 4.3 is the result.

PC performance properties include:

- Very high impact resistance and is virtually unbreakable and remains tough at low temperatures
- "Clear as glass" clarity
- High heat resistance
- Dimensional stability
- Resistant to ultraviolet light, allowing exterior use
- Flame-retardant properties

Other bisphenols are often used in place of bisphenol A. Isophorone bisphenol is common and its structure is shown in Figure 4.4. Copolymer PCs are also common where blends of different bisphenols are used. These are often block copolymers. The T_g of the co-PCs can be adjusted by changing bisphenol monomers and their ratios.

PC sheet and injection molded parts may have a variety of coatings, including a range of hardcoats that enhance weathering, scratch, and abrasion resistance.

Manufacturers and trade names: Bayer MaterialScience Makrolon®, Styron Calibre™, Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex®, SABIC Innovative Plastics Lexan®.

Applications and uses: Glazing, safety shields, lenses, casings and housings, light fittings, kitchenware (microwaveable), medical apparatus (sterilizable), and CDs (the discs).

Data for PC plastics are found in Figures 4.5–4.27.

4.2 Polybutylene Terephthalate (PBT)

PBT is a semicrystalline, white or off-white polyester similar in both composition and properties to PET. It has somewhat lower strength and stiffness than PET, is a little softer but has higher impact strength and similar chemical resistance. As it crystallizes more rapidly than PET, it tends to be preferred for industrial scale molding. Its structure is shown in Figure 4.28.

PBT performance properties include:

- High mechanical properties
- High thermal properties
- Good electrical properties
- Dimensional stability
- Excellent chemical resistance
- Flame retardancy

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
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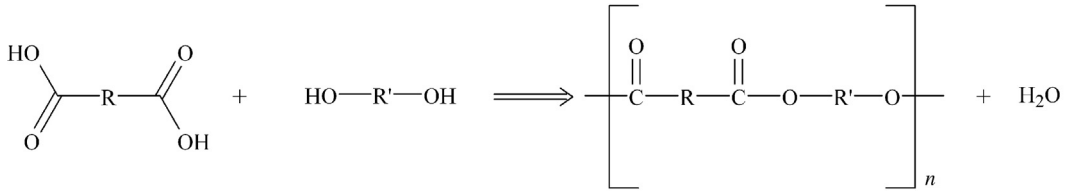
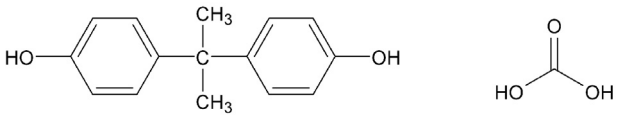


Figure 4.1 Condensation reaction that forms typical polyester.



Dialcohol
bisphenol A
2,2-bis(4-hydroxyphenyl) propane

Diacid
carbonic acid

Figure 4.2 Chemical structures of monomers used to make PC polyester.

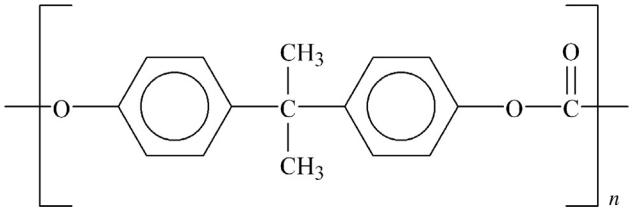


Figure 4.3 Chemical structure of PC polyester.

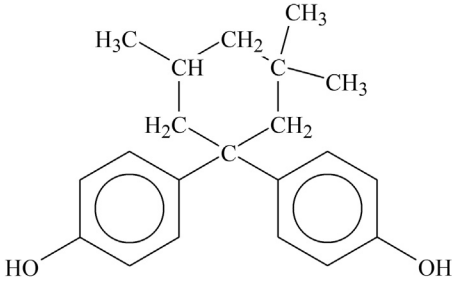


Figure 4.4 Chemical structure of isophorone bisphenol (trimethyl cyclohexyl bisphenol).

Manufacturers and trade names: BASF Ultradur®, DuPont Crastin®, PolyOne Burgadur™, SABIC Innovative Plastics Enduran®, Celanese Celanex®, Evonik Vestodur®.

Applications and uses: packaging, automotive, electrical, and consumer markets.

Data for PBT plastics are found in Figures 4.29–4.81.

4.3 Polyethylene Terephthalate (PET)

PET is the most common thermoplastic polyester and is often called just "polyester." This often causes confusion with the other polyesters in this chapter. PET exists both as an amorphous (transparent) and as a semicrystalline (opaque and white) thermoplastic material. The semicrystalline PET has good strength, ductility, stiffness, and hardness. The amorphous PET has better ductility but less stiffness and hardness. It absorbs very little water. Its structure is shown in Figure 4.82.

Manufacturers and trade names: DuPont Rynite®, DuPont Teijin Films™ Mylar® and Melinex®, Mitsubishi Polyester Film Hostaphan®, Celanese Impet®.

Applications and uses: bottles for soft drinks and water, food trays for oven use, roasting bags, audio/video tapes, and mechanical components.

Data for PET plastics are found in Figures 4.83–4.105.

4.4 Liquid Crystalline Polymer (LCP)

LCPs are a relatively unique class of partially crystalline aromatic polyesters based on 4-hydroxybenzoic acid and related monomers shown in Figure 4.106. Liquid crystal polymers are capable of forming regions of highly ordered structure while in the liquid phase. However, the degree of order is somewhat less than that of a regular solid crystal. Typically LCPs have outstanding mechanical properties at high temperatures, excellent chemical resistance, inherent flame retardancy,

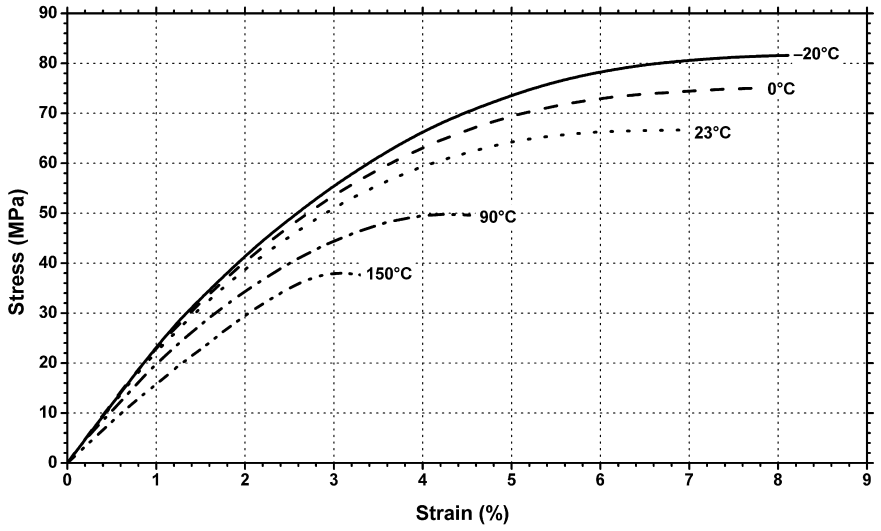


Figure 4.5 Stress vs. strain at various temperatures for Bayer MaterialScience Apec® 1600—high heat PC resin.

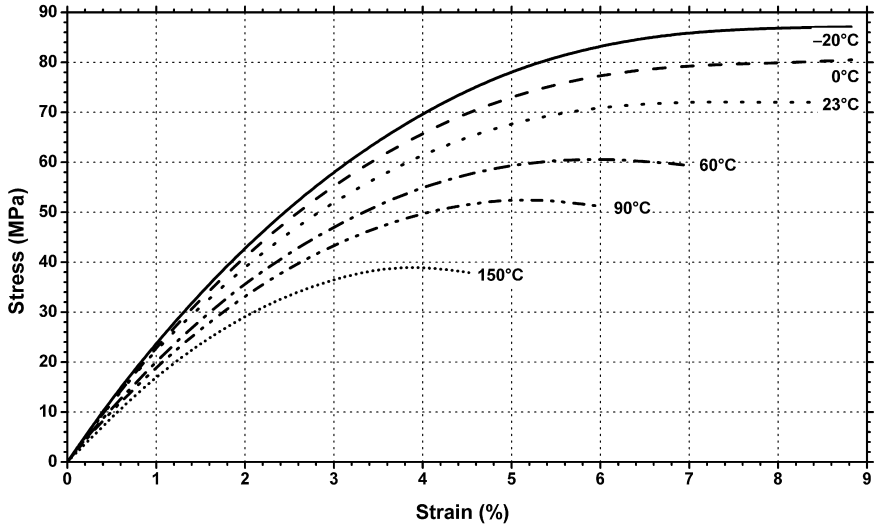


Figure 4.6 Stress vs. strain at various temperatures for Bayer MaterialScience Apec® 1700—higher heat PC resin.

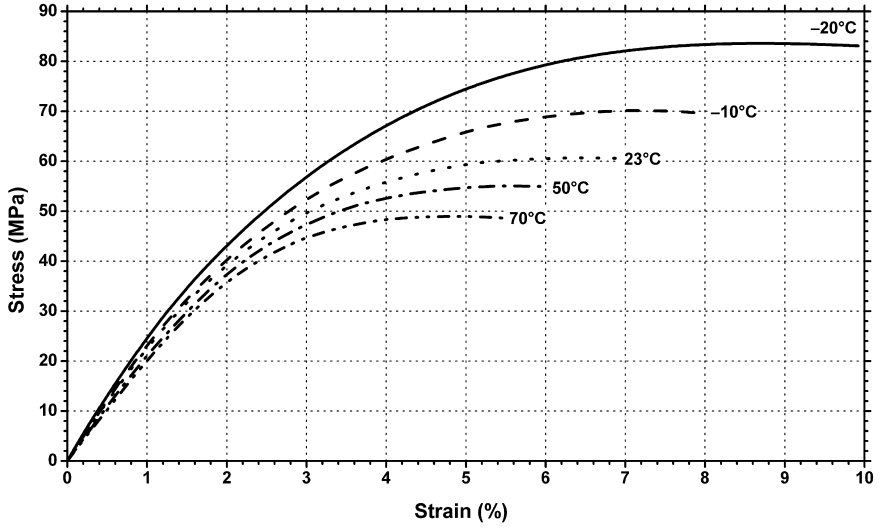


Figure 4.7 Stress vs. strain at various temperatures for LG-Dow Calibre™ 300-10—general purpose 10 MFR PC resin.

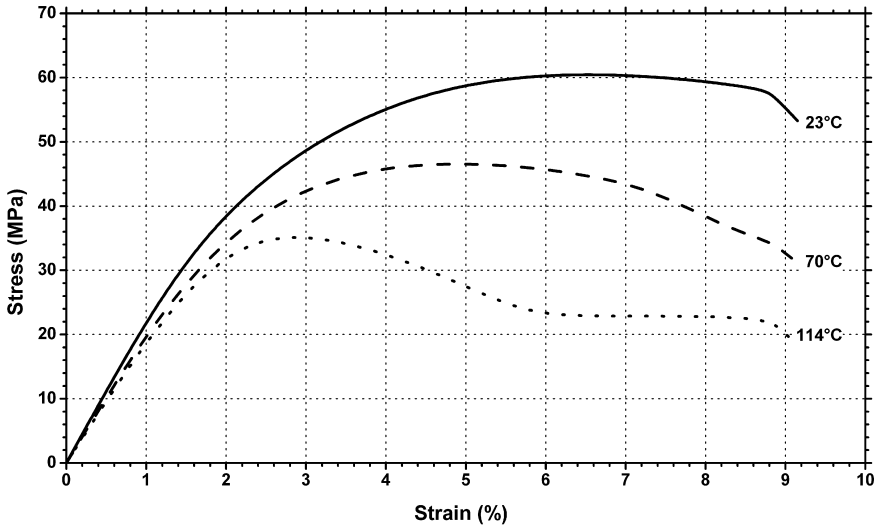


Figure 4.8 Stress vs. strain at various temperatures for SABIC Innovative Plastics Lexan® 101—general purpose PC resin.

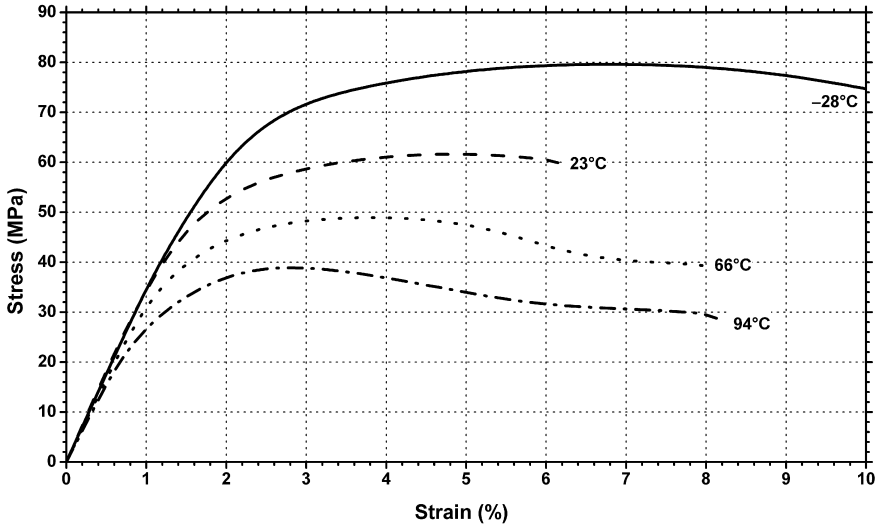


Figure 4.9 Stress vs. strain at various temperatures for SABIC Innovative Plastics Lexan® 500R—10% glass fiber reinforced PC resin.

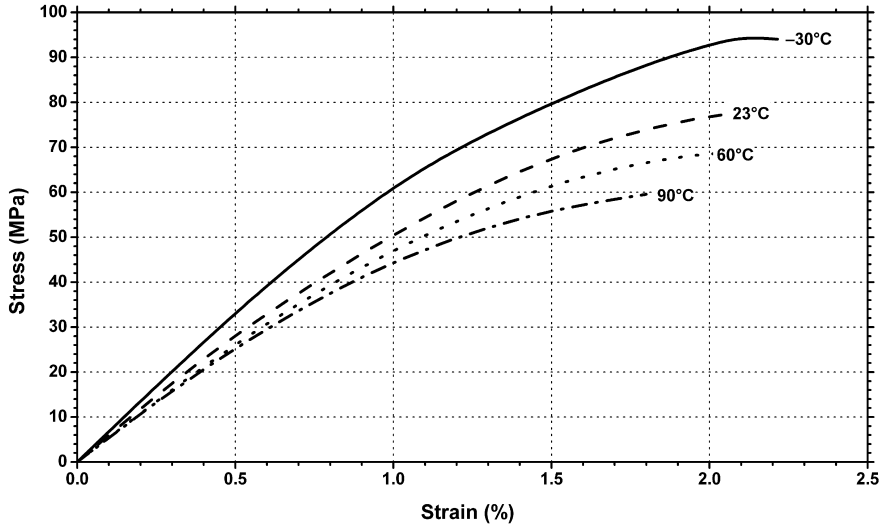


Figure 4.10 Stress vs. strain at various temperatures for SABIC Innovative Plastics Lexan® 3412R—high viscosity, 20% glass reinforced PC resin [1].

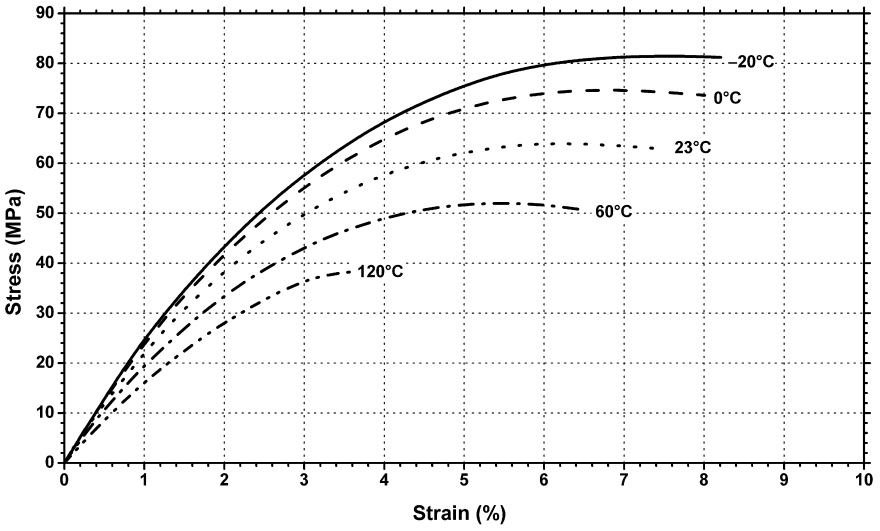


Figure 4.11 Stress vs. strain at various temperatures for Bayer MaterialScience Makrolon® 2205—general purpose, low viscosity PC resin.

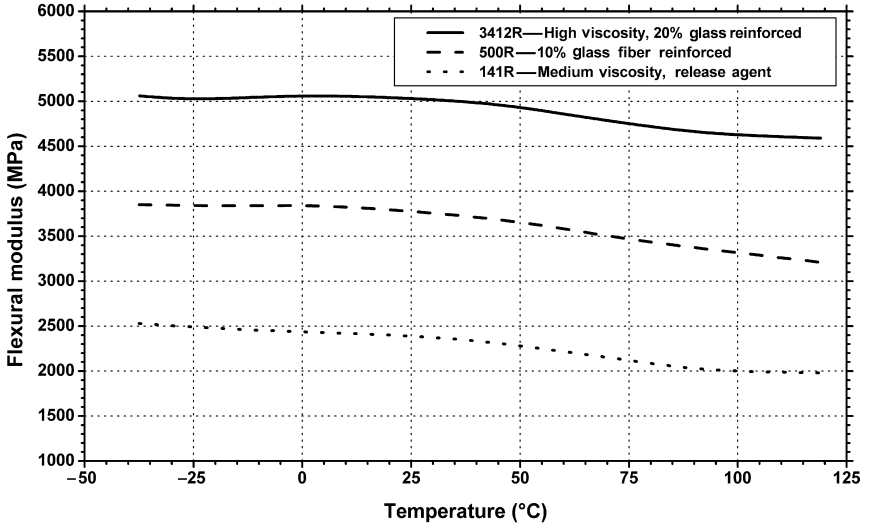


Figure 4.12 Flexural modulus vs. temperature for SABIC Innovative Plastics Lexan® PC resins [1].

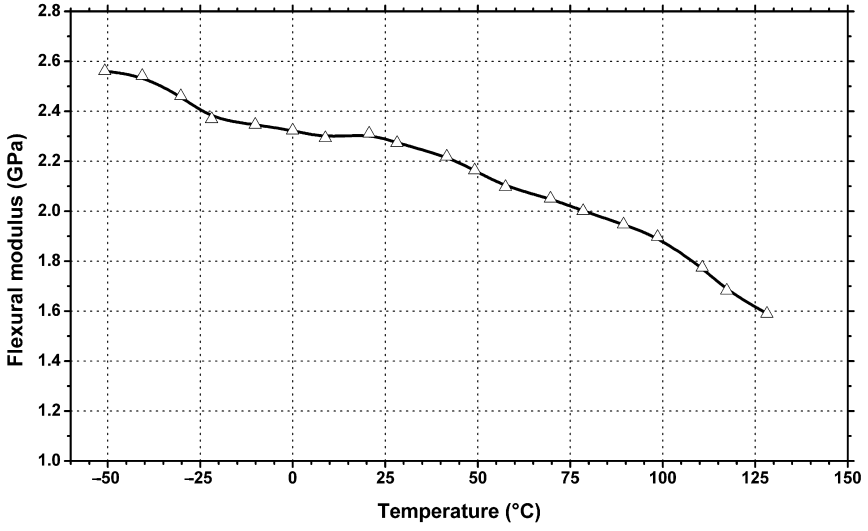


Figure 4.13 Flexural modulus vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

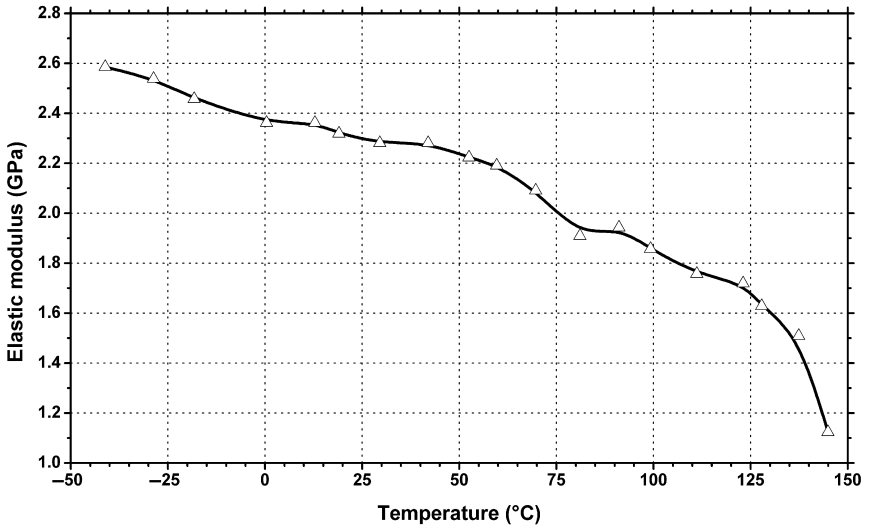


Figure 4.14 Elastic modulus vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

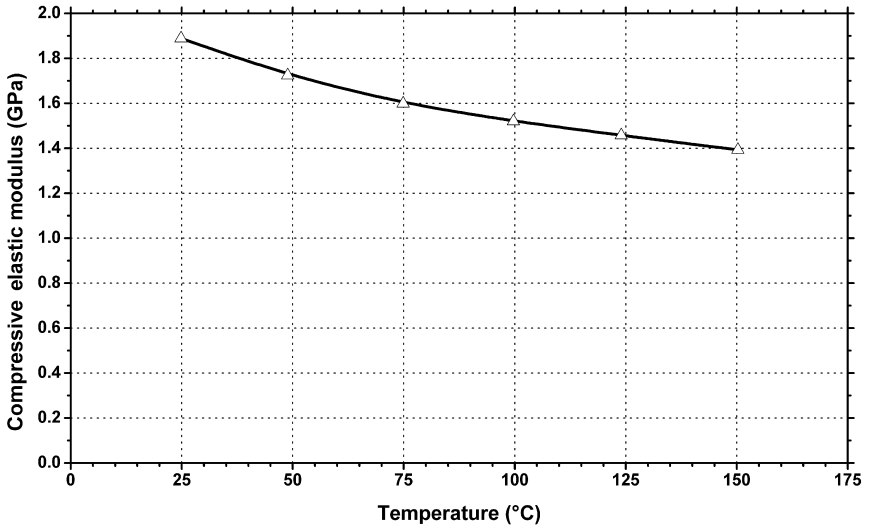


Figure 4.15 Compressive modulus of elasticity vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

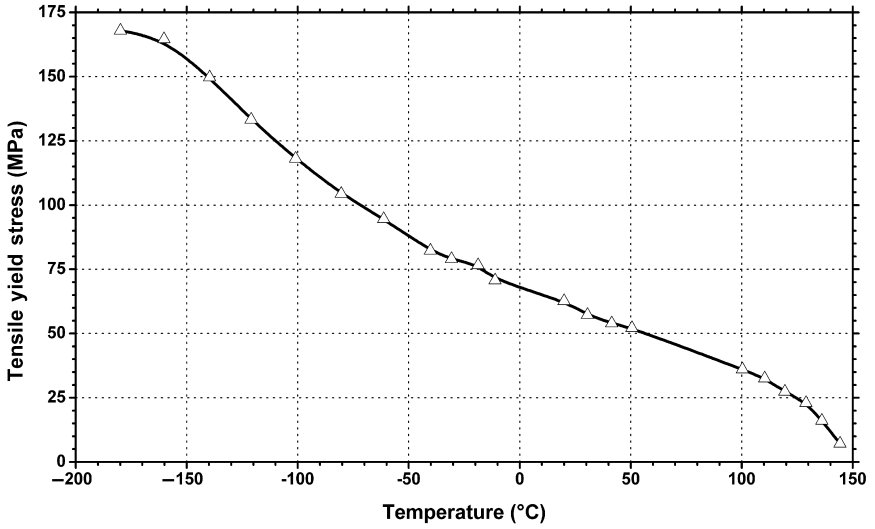


Figure 4.16 Tensile yield stress vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

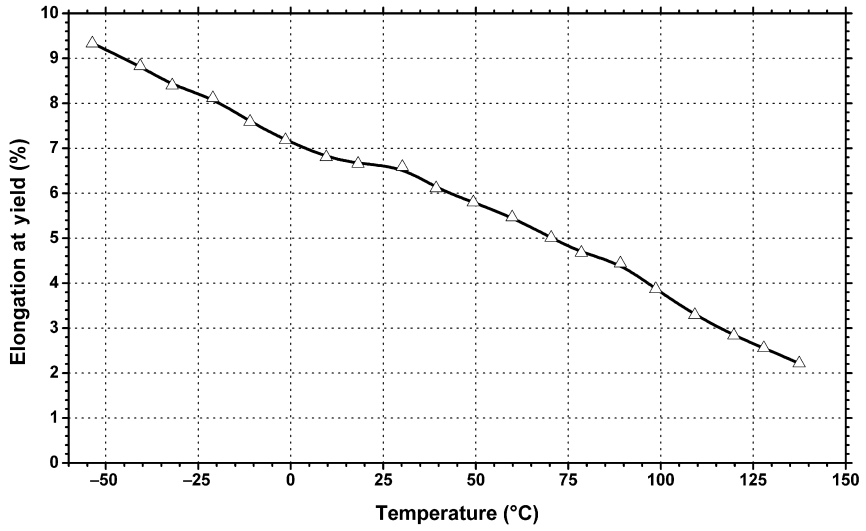


Figure 4.17 Elongation at yield vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

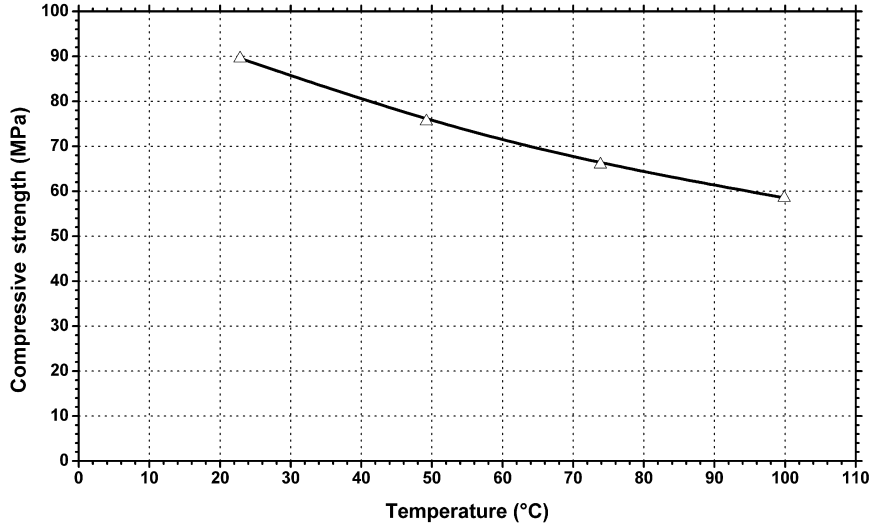


Figure 4.18 Compressive strength vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

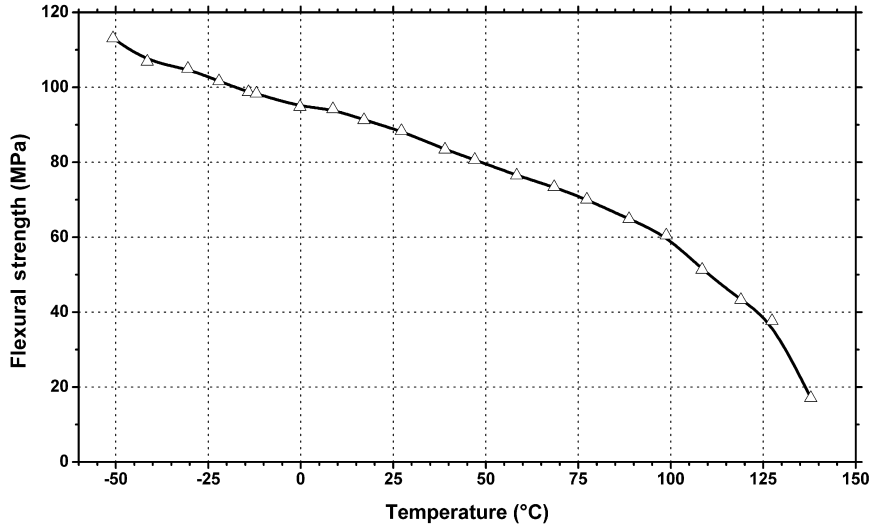


Figure 4.19 Flexural strength vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].

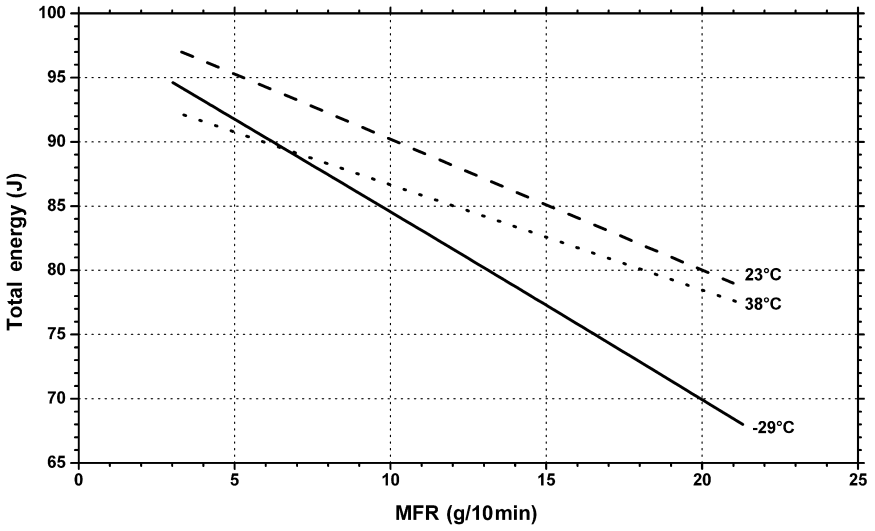


Figure 4.20 Instrumented dart impact vs. melt flow rate (MFR) for LG-Dow PC Calibre™ 300-10—general purpose 10 MFR PC resin.

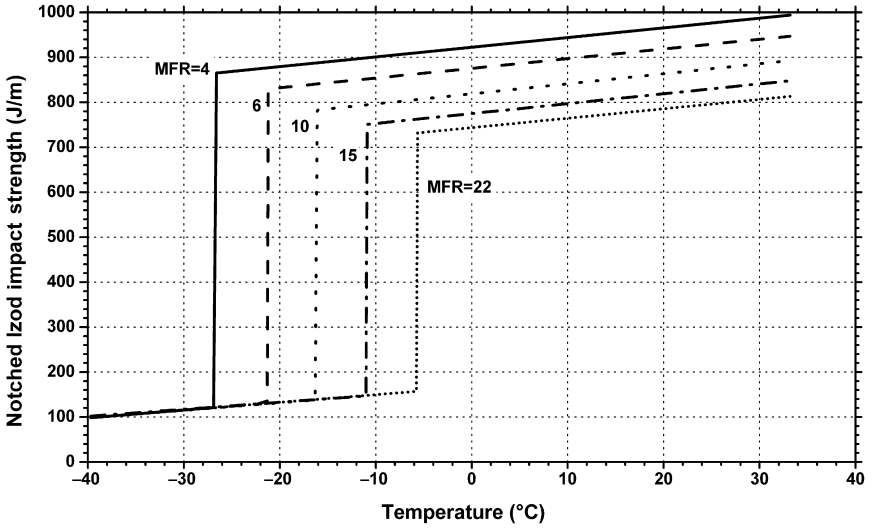


Figure 4.21 Notched Izod impact strength vs. temperature and MFR for LG-Dow PC Calibre™ 300 general purpose PC resins.

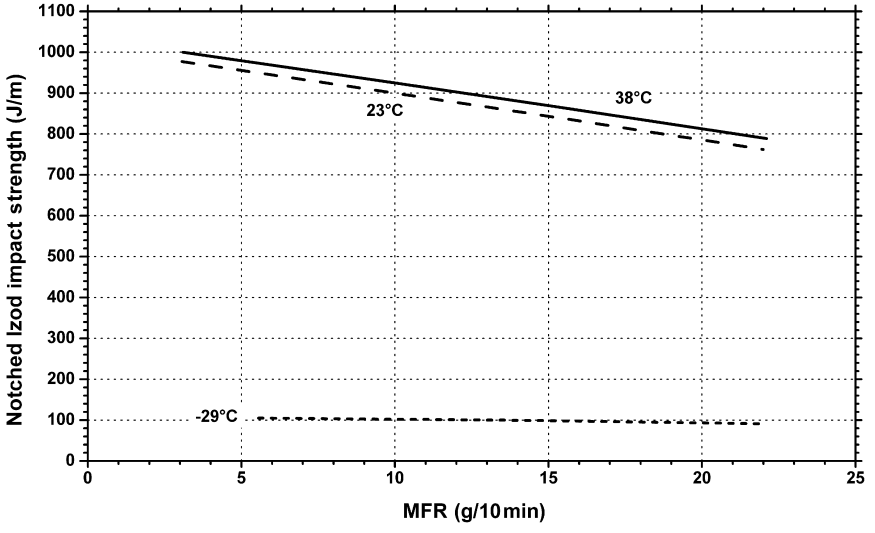


Figure 4.22 Notched Izod impact strength vs. MFR and temperature for LG-Dow PC Calibre™ 300 general purpose PC resin.

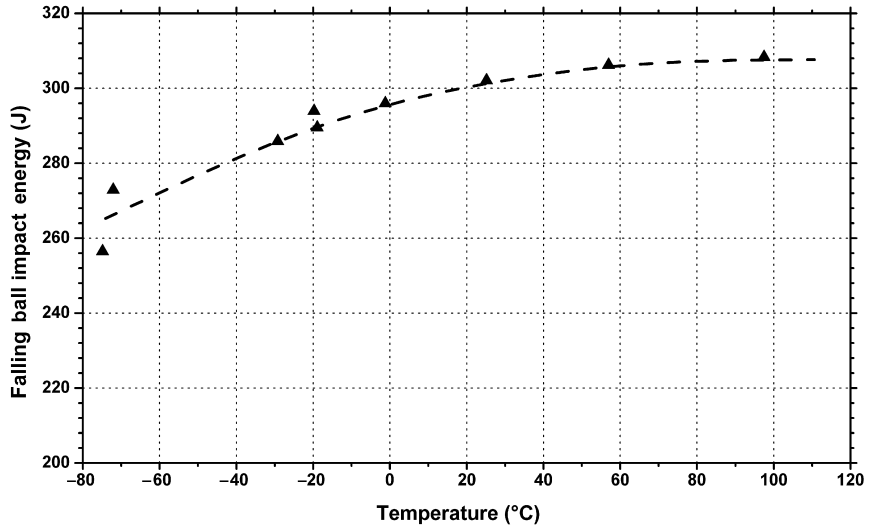


Figure 4.23 Falling ball impact energy vs. temperature for Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC [2].
Note: circular disk with a thickness of 2 mm.

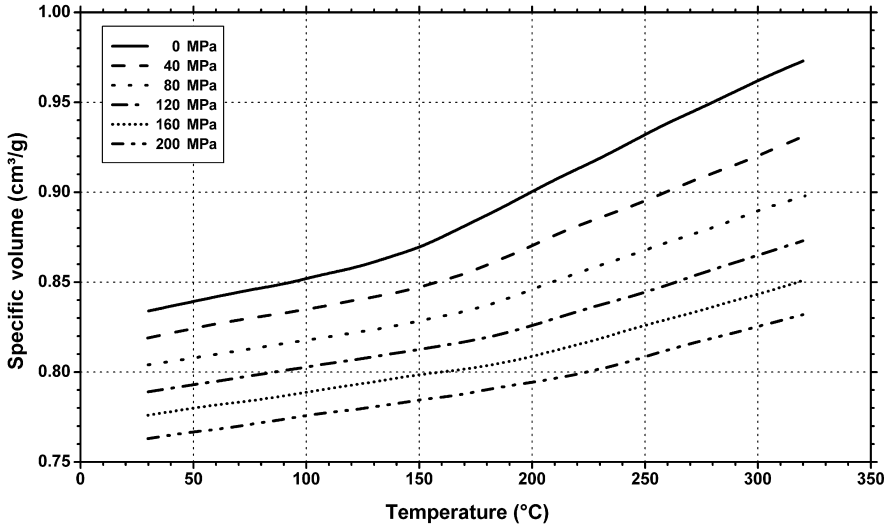


Figure 4.24 Pressure-specific volume–temperature (PVT) for Bayer MaterialScience Makrolon® 2205—general purpose, low viscosity PC resin.

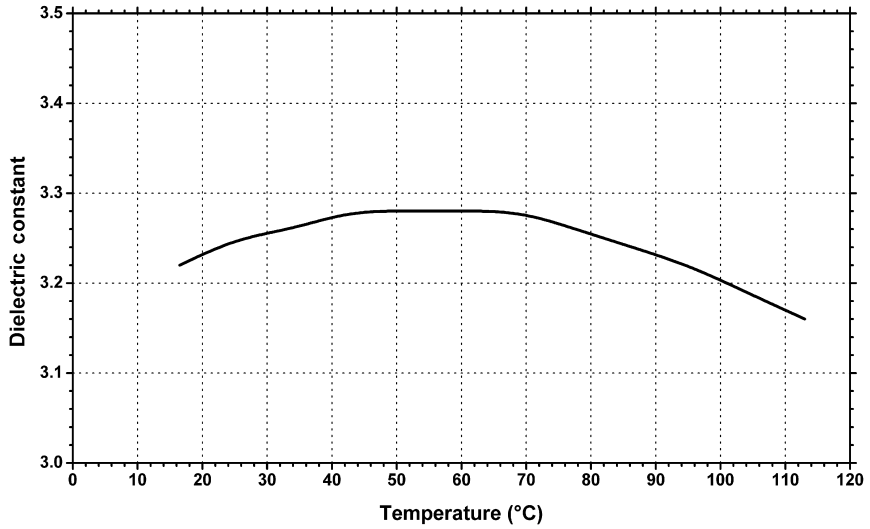


Figure 4.25 Dielectric constant vs. temperature for SABIC Innovative Plastics Lexan® PC resins [1].

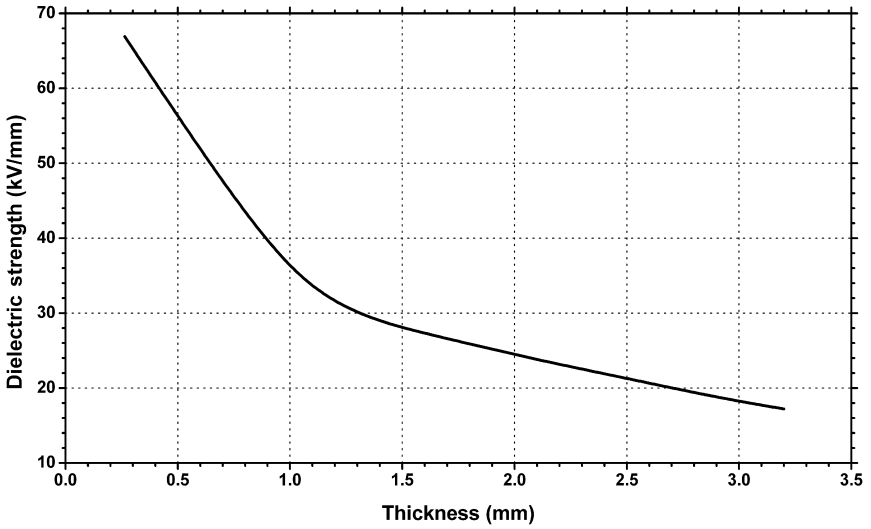


Figure 4.26 Dielectric strength vs. thickness for SABIC Innovative Plastics Lexan® PC resins [1].

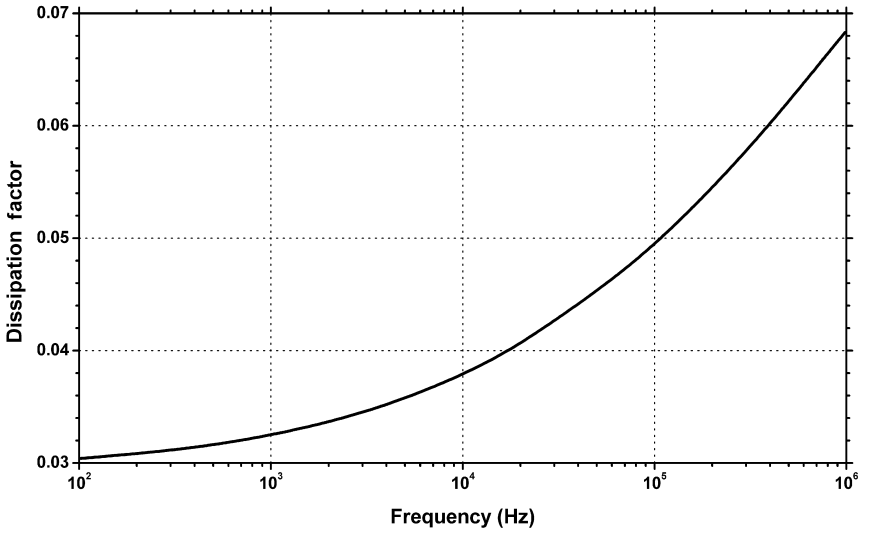


Figure 4.27 Dissipation factor vs. frequency for SABIC Innovative Plastics Lexan® PC resins [1].

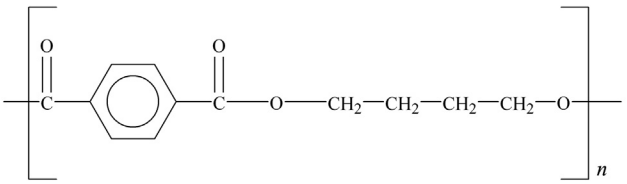


Figure 4.28 Chemical structure of PBT polyester.

and good weatherability. Liquid crystal polymers come in a variety of forms from sinterable high temperature to injection moldable compounds.

LCPs are exceptionally inert. They resist stress cracking in the presence of most chemicals at elevated temperatures, including aromatic or halogenated hydrocarbons, strong acids, bases, ketones, and other aggressive industrial substances. Hydrolytic stability in boiling water is excellent. Environments that deteriorate these polymers are high temperature steam, concentrated sulfuric acid, and boiling caustic materials.

As an example, the structure of Celanese Vectra® A950 LCP is shown in Figure 4.107.

Manufacturers and trade names: Eastman Thermx®, DuPont Engineering Polymers Zenite®, Celanese Vectran™ and Vectra®, Solvay Advanced Polymers Xydar®, Sumitomo Sumikasuper®, Toray Siveras®.

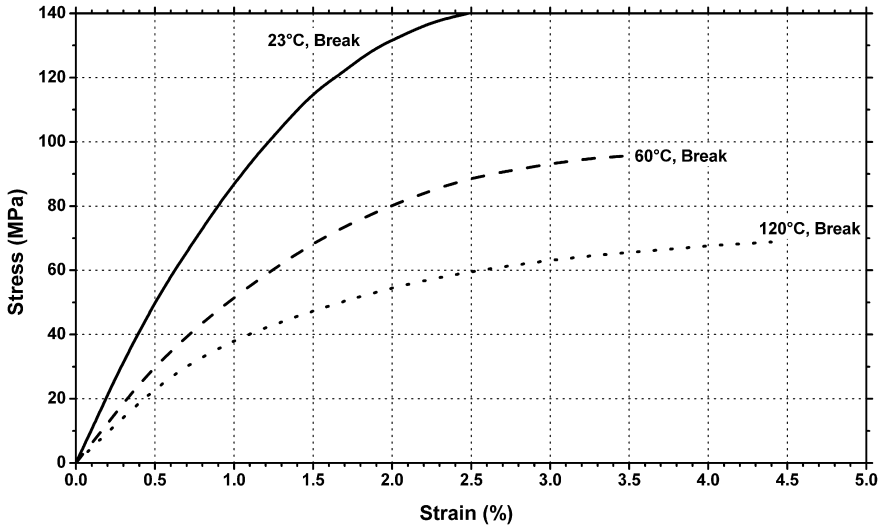


Figure 4.29 Stress vs. strain at various temperatures for Celanese Celanex® 2300 GV/30—general purpose, 30% glass fiber reinforced PBT resin [3].

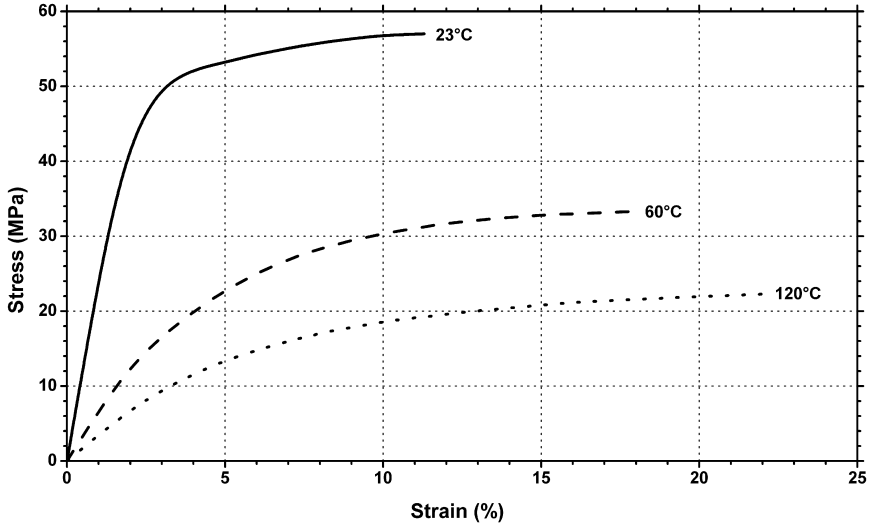


Figure 4.30 Stress vs. strain at various temperatures for Celanese Celanex® 2500—general purpose, nucleated, easy flow PBT resin [3].

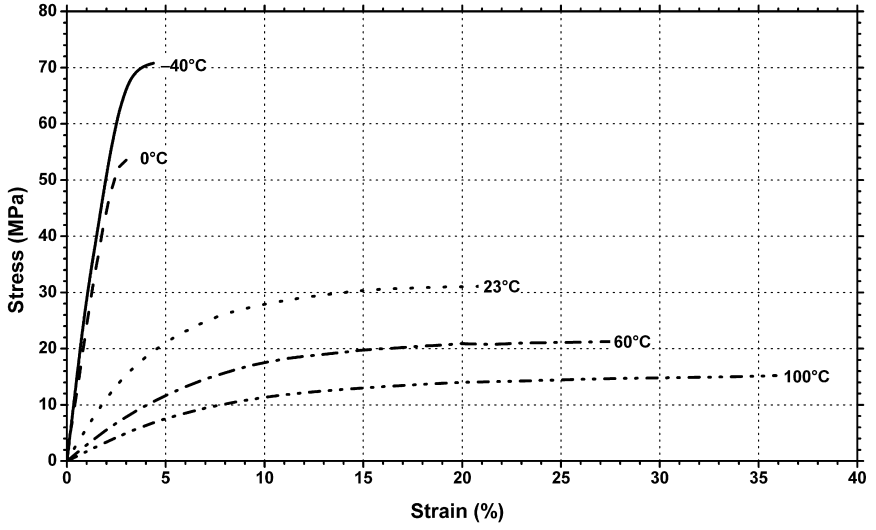


Figure 4.31 Stress vs. strain at various temperatures for DuPont Crastin® S600F10 NC010—medium viscosity, lubricated PBT resin [4].

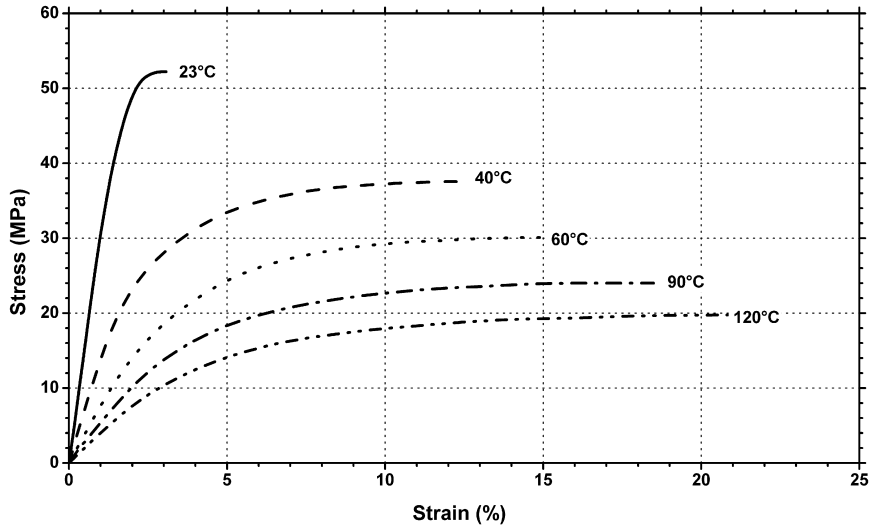


Figure 4.32 Stress vs. strain at various temperatures for DuPont Crastin® SO653 NC010—20% glass bead filled, lubricated PBT resin [4].

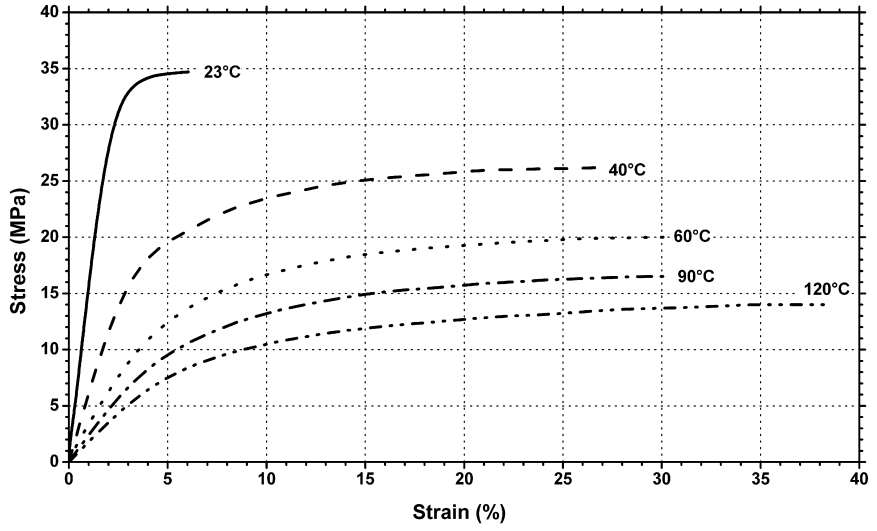


Figure 4.33 Stress vs. strain at various temperatures for DuPont Crastin® ST820 NC010—super tough, lubricated PBT resin [4].

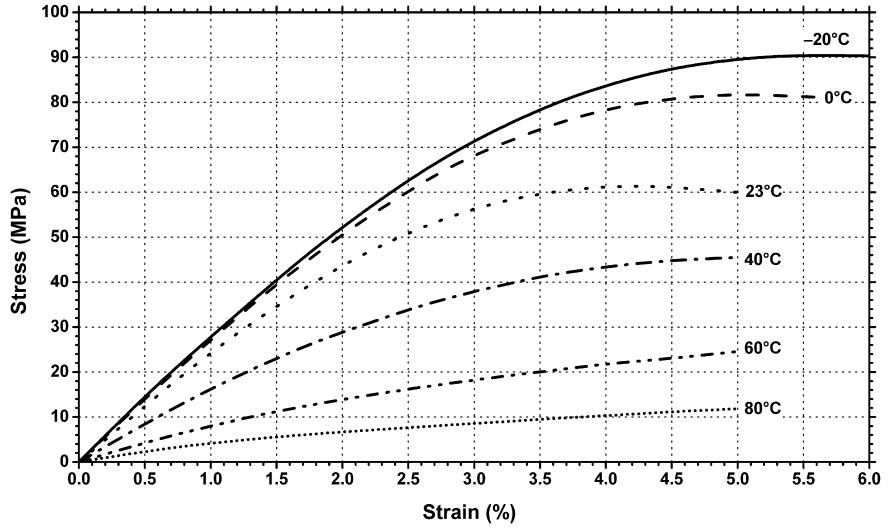


Figure 4.34 Stress vs. strain at various temperatures for LANXESS Pocan® B1505—high viscosity, nucleated, heat stabilized PBT resin.

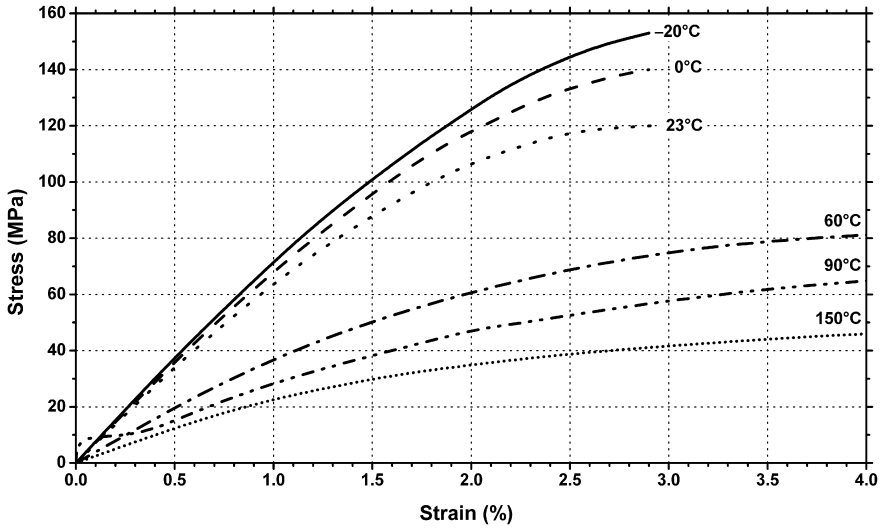


Figure 4.35 Stress vs. strain at various temperatures for LANXESS Pocan® B3225—20% glass fiber reinforced PBT resin.

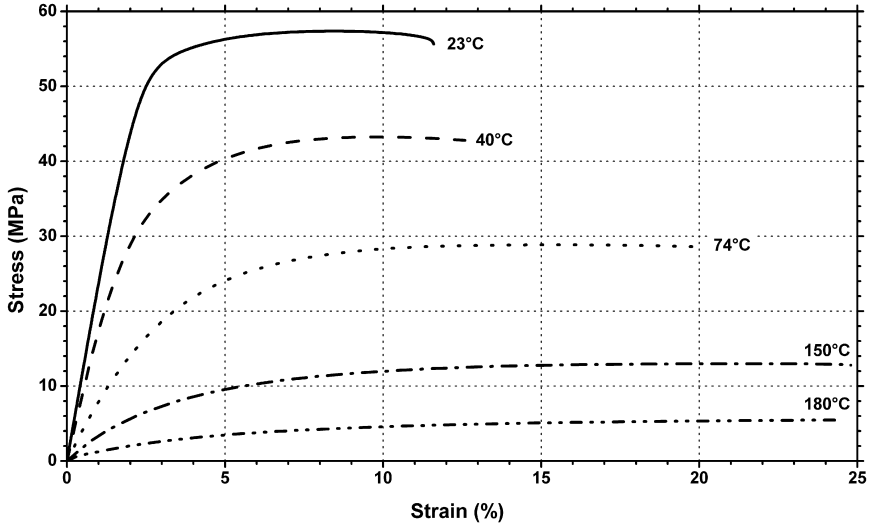


Figure 4.36 Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® 310-SEO—unreinforced, UL94 V-0 rated PBT resin.

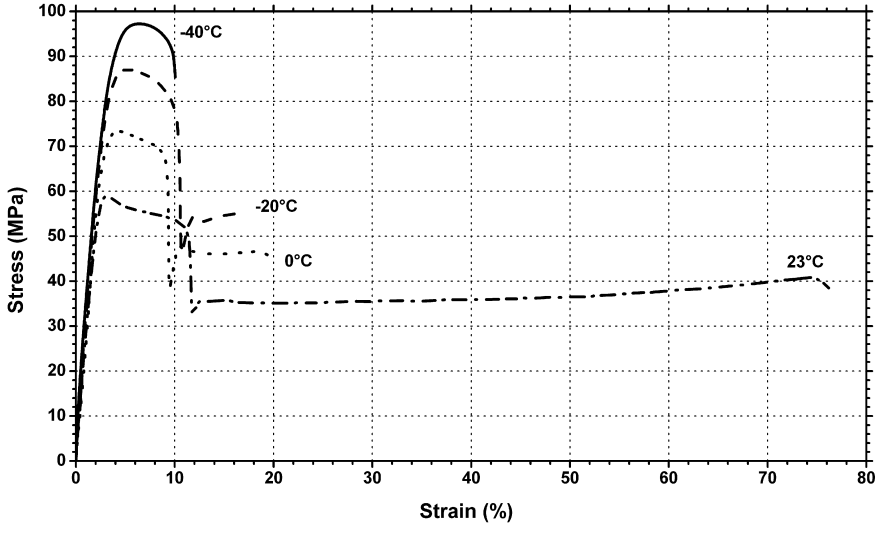


Figure 4.37 Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® 325—unreinforced, improved processing PBT resin.

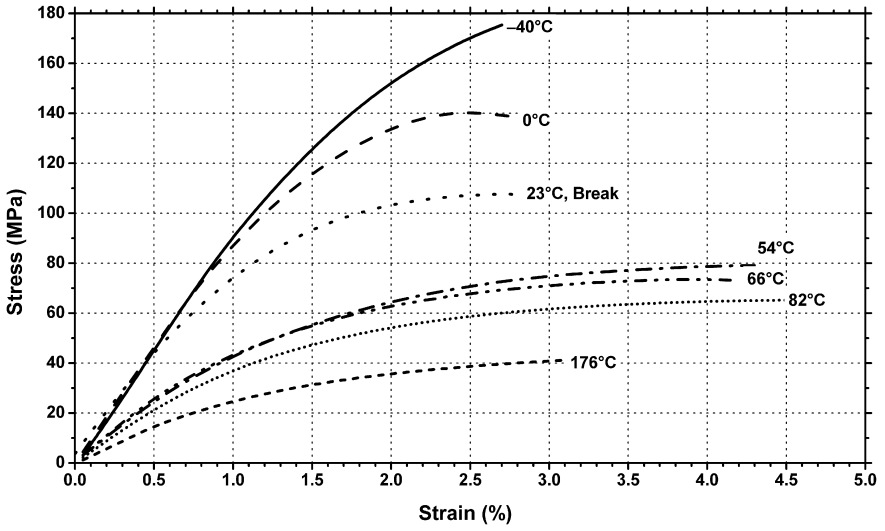


Figure 4.38 Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® 420—30% glass fiber reinforced, high heat PBT resin.

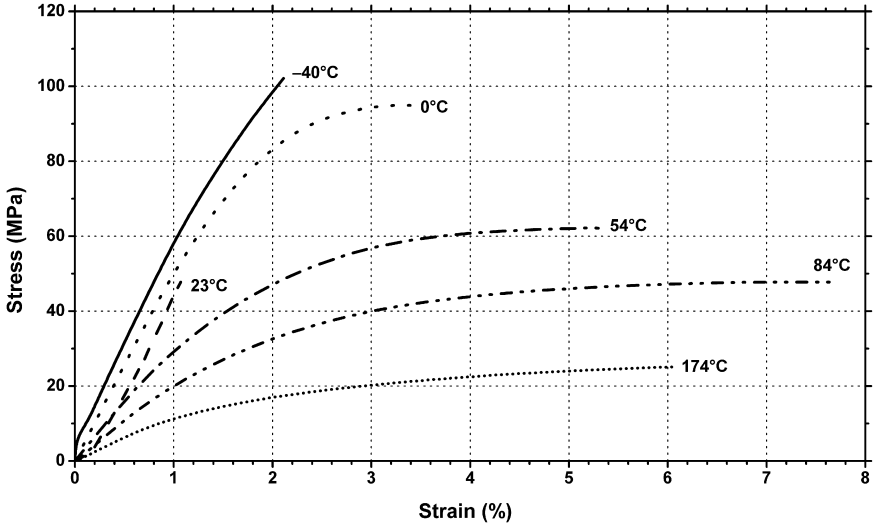


Figure 4.39 Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® DR-51—15% glass fiber reinforced PBT resin.

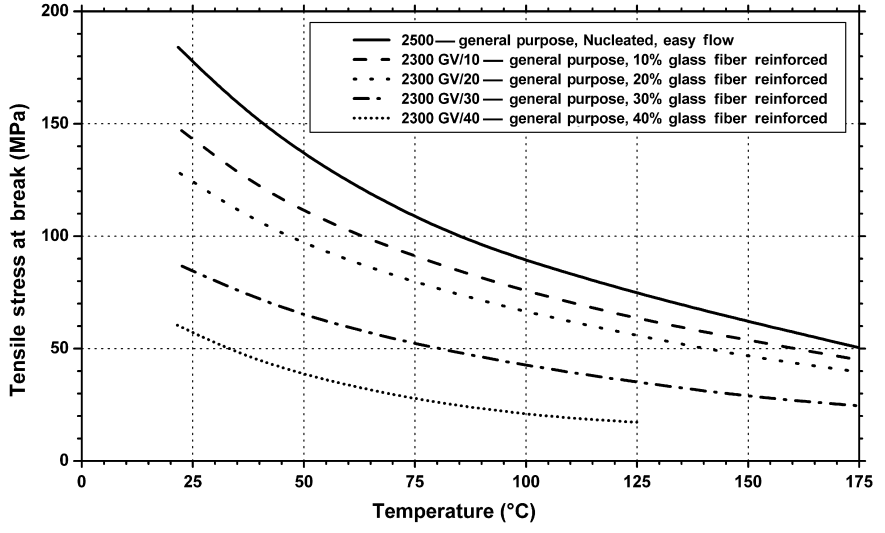


Figure 4.40 Tensile stress at break vs. temperature for Celanese Celanex® general purpose PBT resins [3].

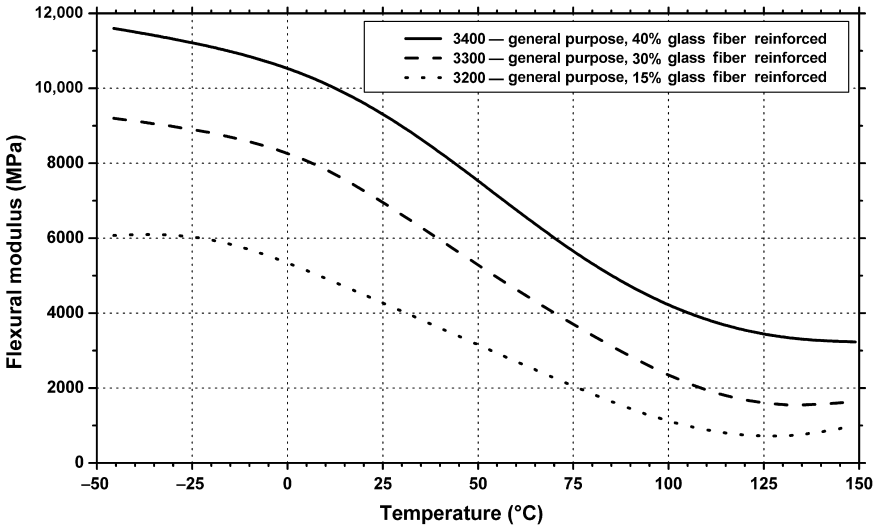


Figure 4.41 Flexural modulus vs. temperature for Celanese Celanex® general purpose glass fiber reinforced PBT resins [3].

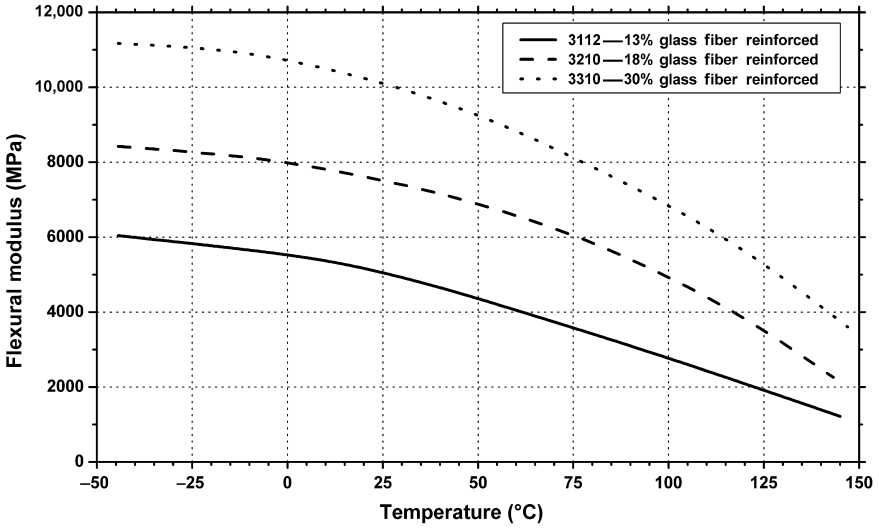


Figure 4.42 Flexural modulus vs. temperature for Celanese Celanex® flame retardant, glass fiber reinforced PBT resins.

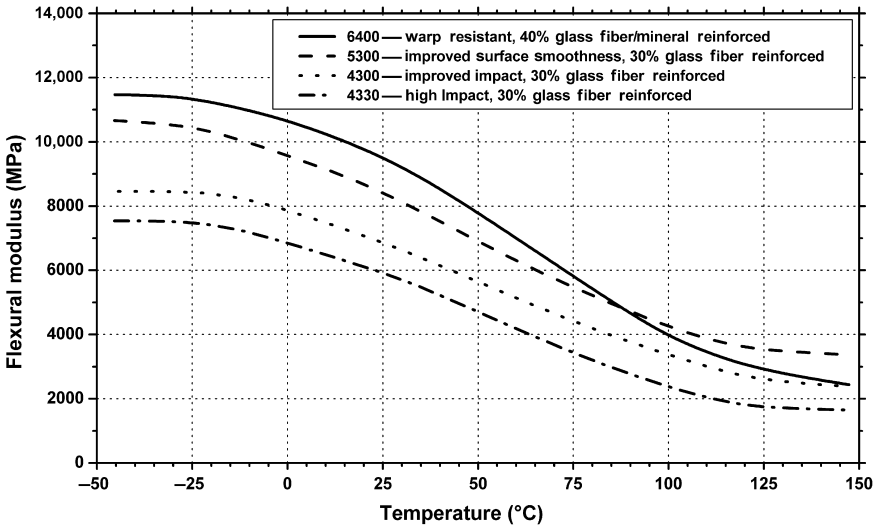


Figure 4.43 Flexural modulus vs. temperature for Celanese Celanex® high impact, glass fiber reinforced PBT resins.

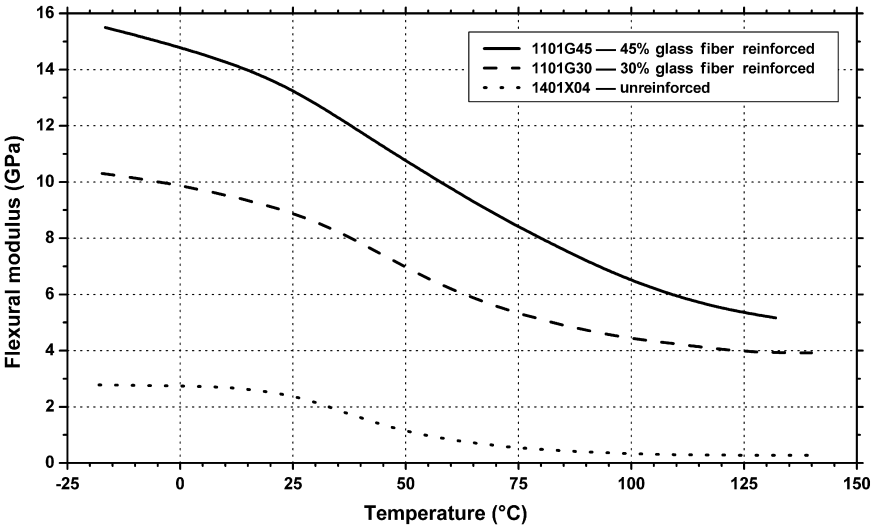


Figure 4.44 Flexural modulus vs. temperature for Toray Toraycon® PBT resins.

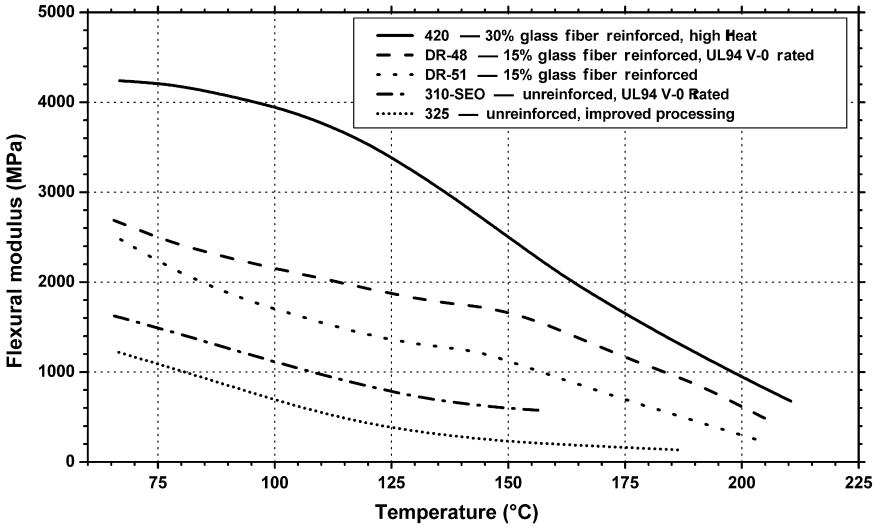


Figure 4.45 Flexural modulus vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

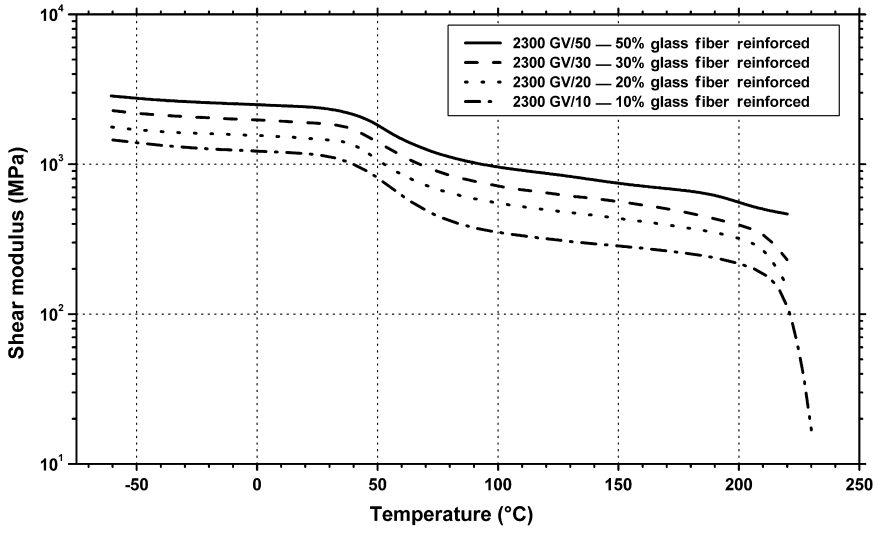


Figure 4.46 Shear modulus vs. temperature for Celanese Celanex® 2300 series, general purpose, glass fiber reinforced PBT resins.

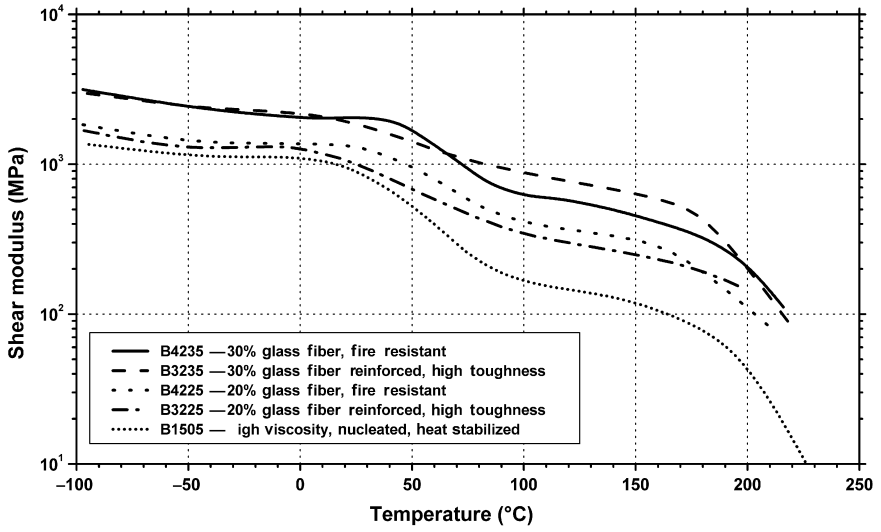


Figure 4.47 Shear modulus vs. temperature for LANXESS Pocan® reinforced PBT resins.

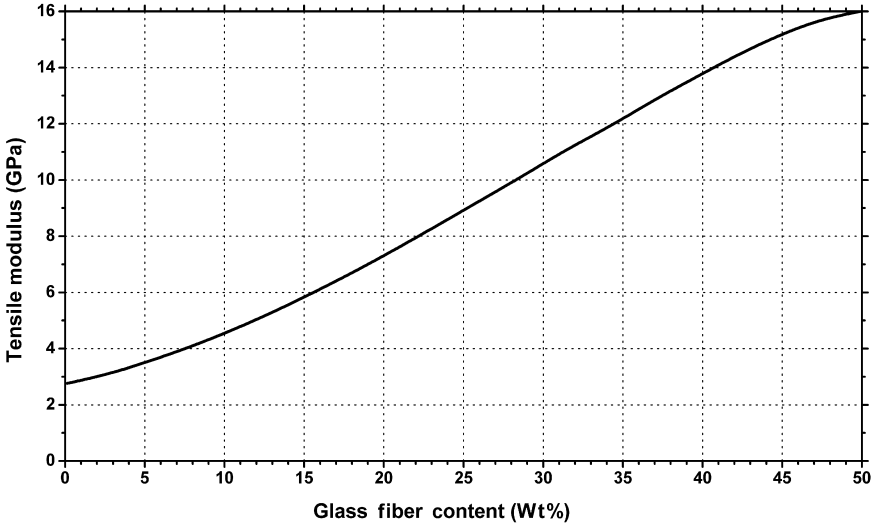


Figure 4.48 Tensile modulus vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

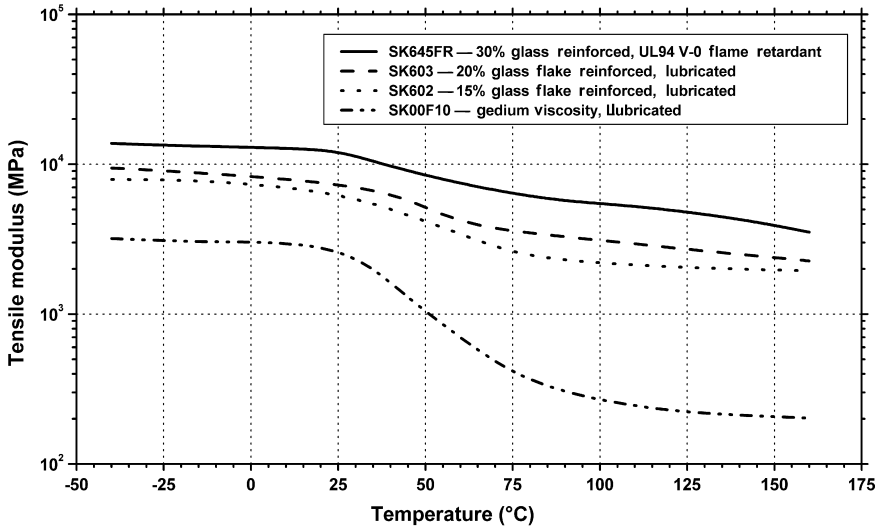


Figure 4.49 Tensile modulus vs. temperature for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

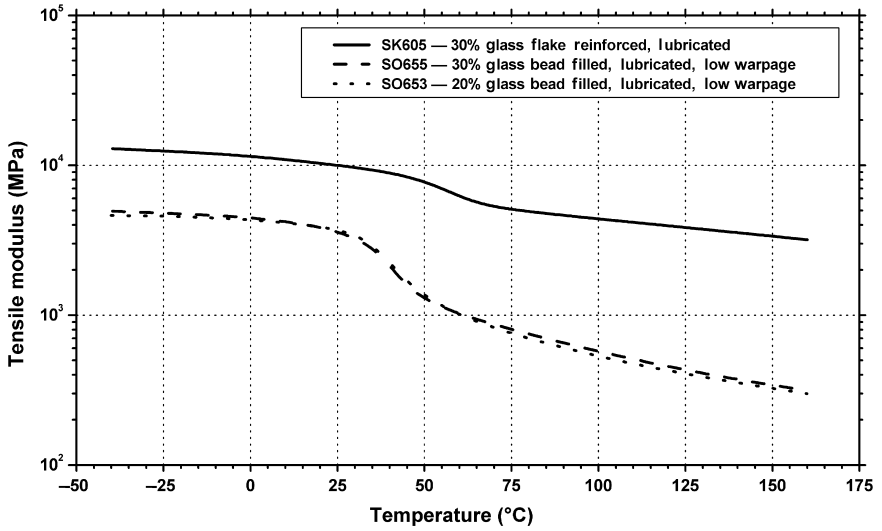


Figure 4.50 Tensile modulus vs. temperature for DuPont Crastin® glass reinforced PBT resins [4].

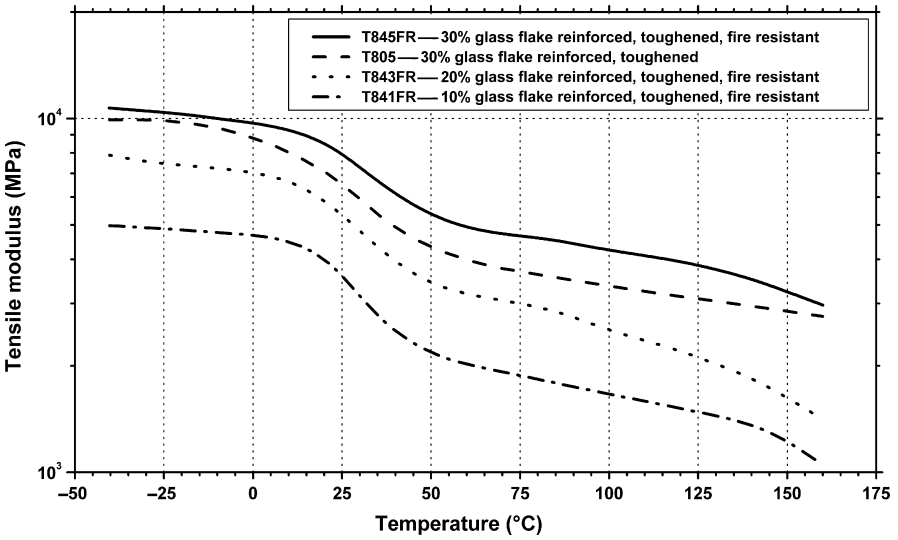


Figure 4.51 Tensile modulus vs. temperature for DuPont Crastin® high impact/toughened PBT resins [4].

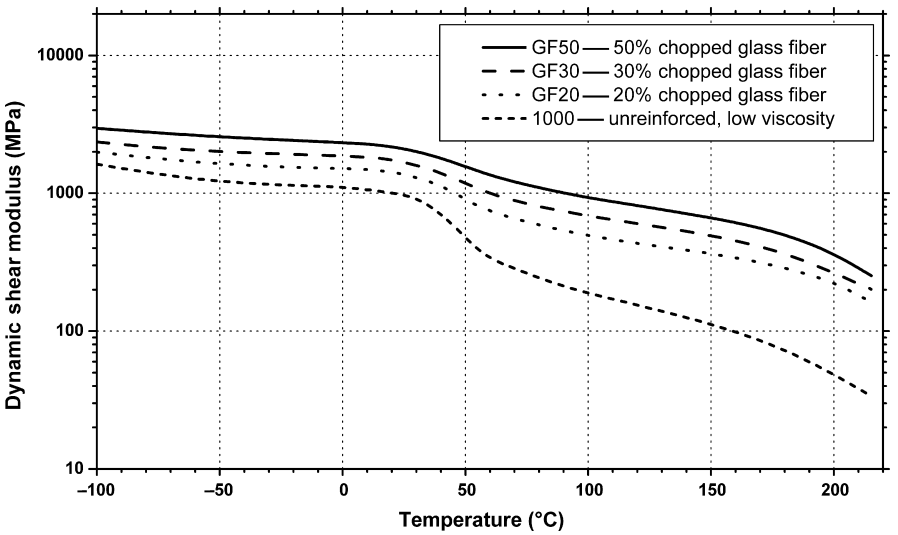


Figure 4.52 Dynamic shear modulus as a function of temperature of Evonik Vestodur® PBT plastics according to ISO 6721 [5].

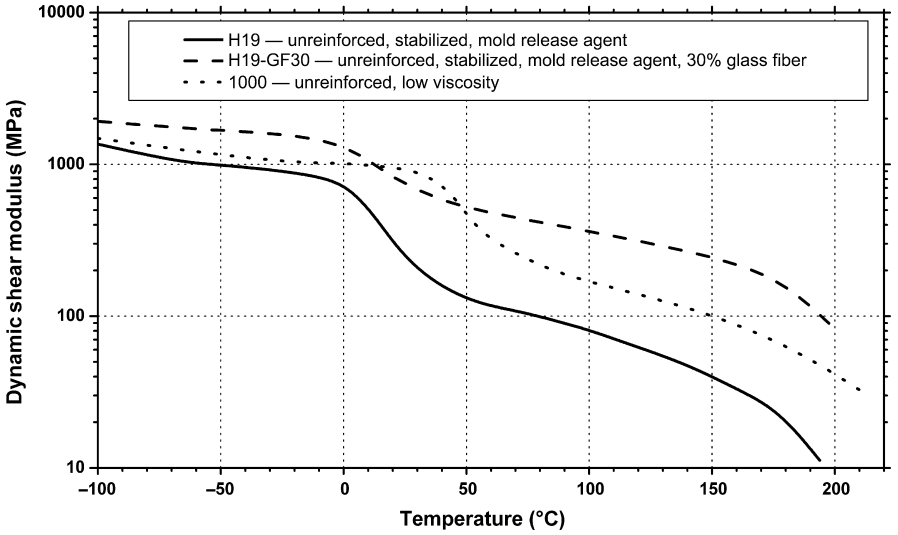


Figure 4.53 Dynamic shear modulus as a function of temperature of Evonik Vestodur® PBT plastics according to ISO 6721 [5].

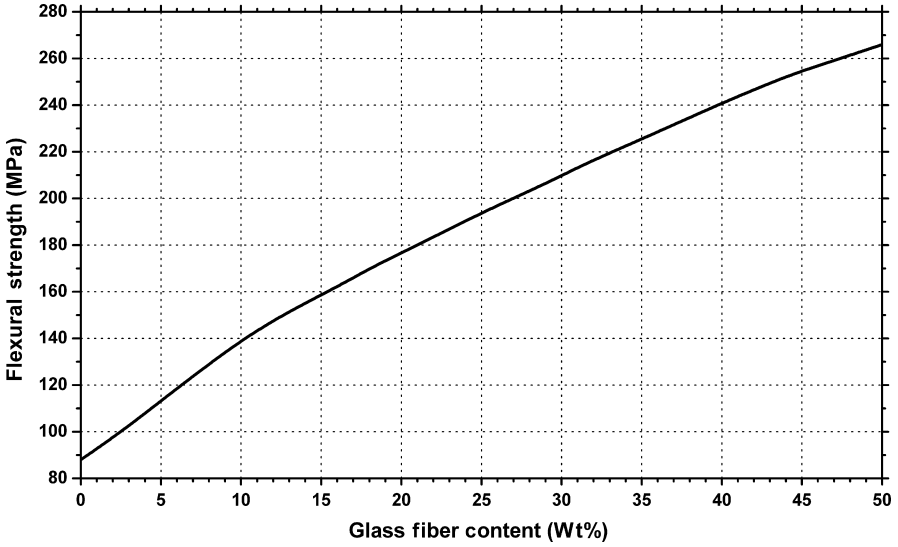


Figure 4.54 Flexural strength vs. glass fiber content for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

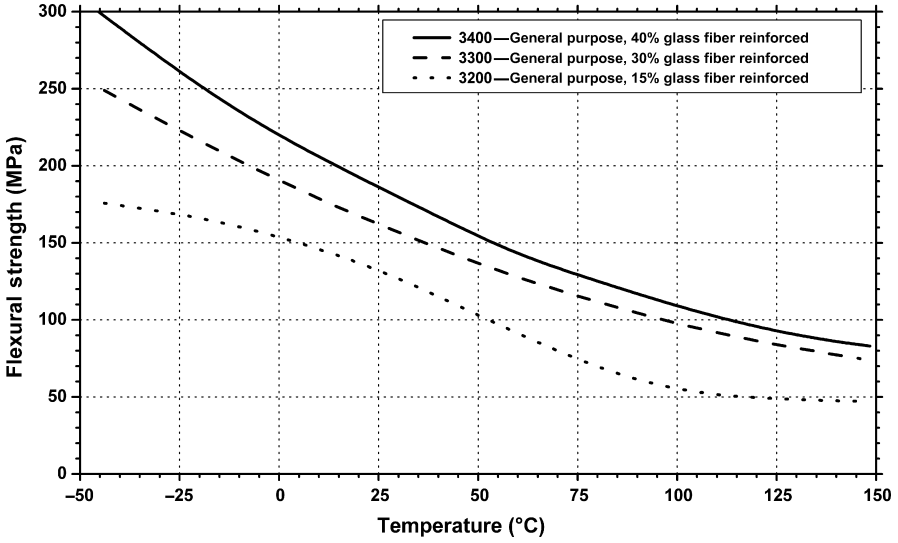


Figure 4.55 Flexural strength vs. temperature for Celanese Celanex® general purpose, glass fiber reinforced PBT resins.

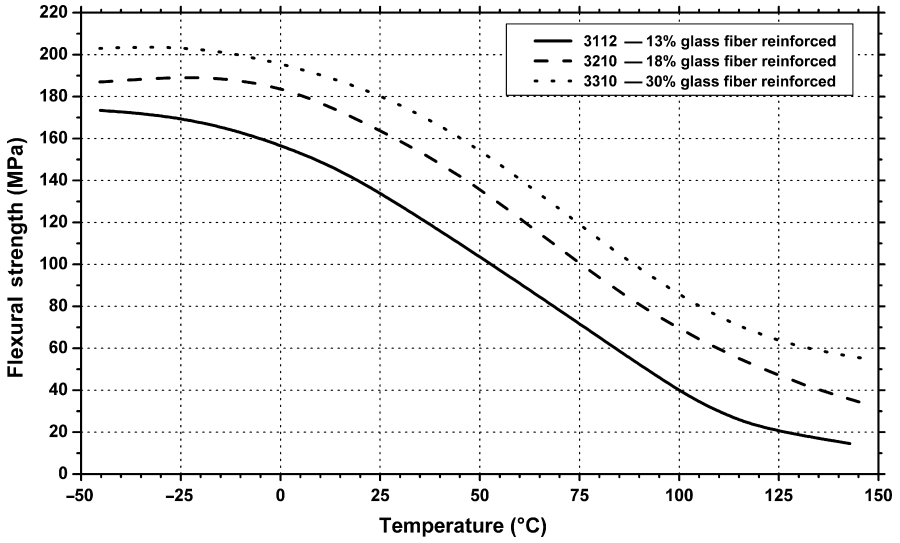


Figure 4.56 Flexural strength vs. temperature for Celanese Celanex® flame retardant, glass fiber reinforced PBT resins.

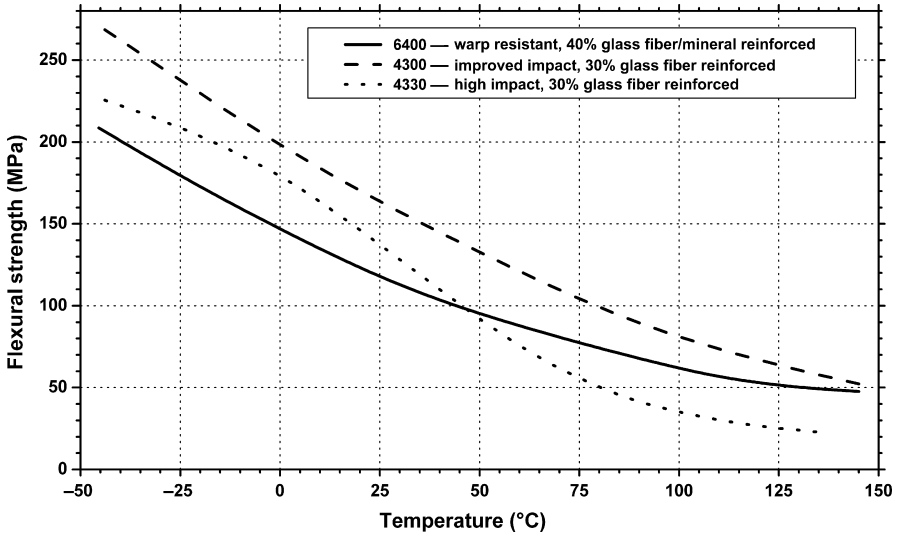


Figure 4.57 Flexural strength vs. temperature for Celanese Celanex® high impact, glass fiber reinforced PBT resins.

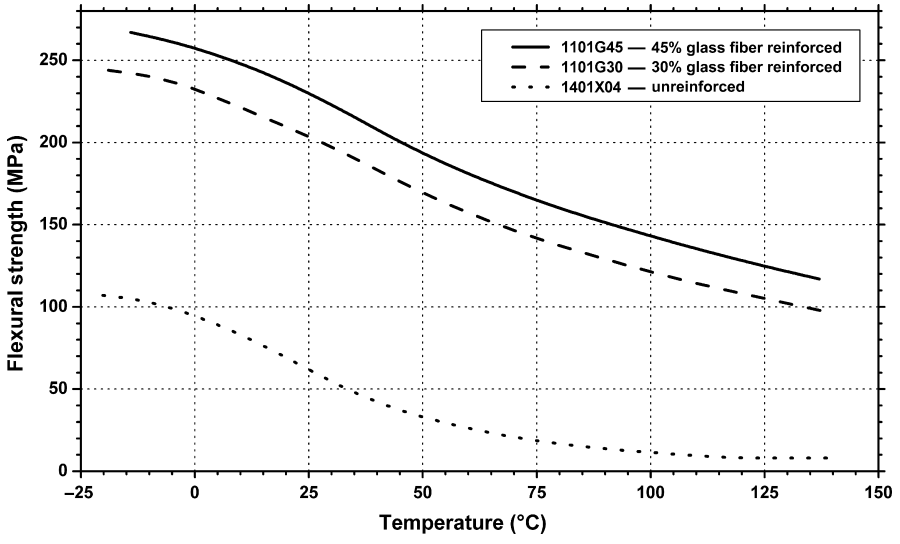


Figure 4.58 Flexural strength vs. temperature for Toray Toraycon® PBT resins.

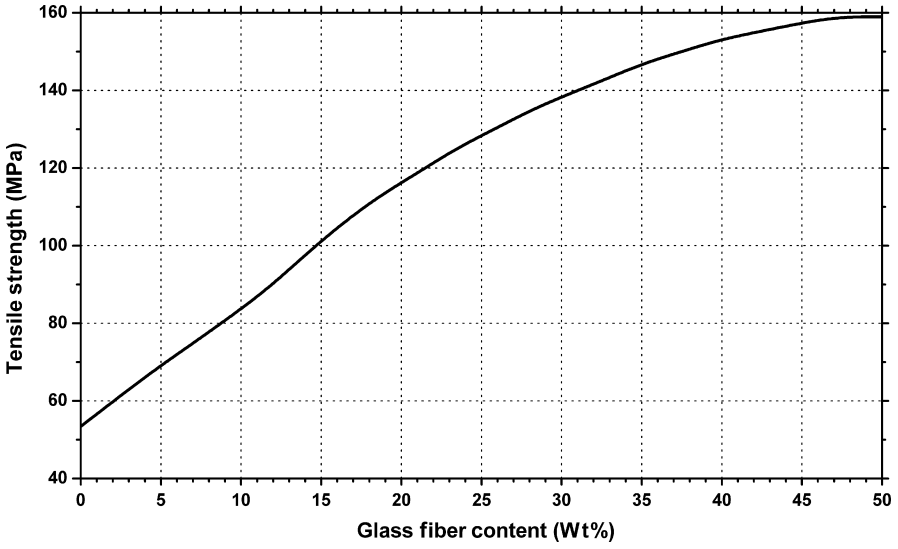


Figure 4.59 Tensile strength vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

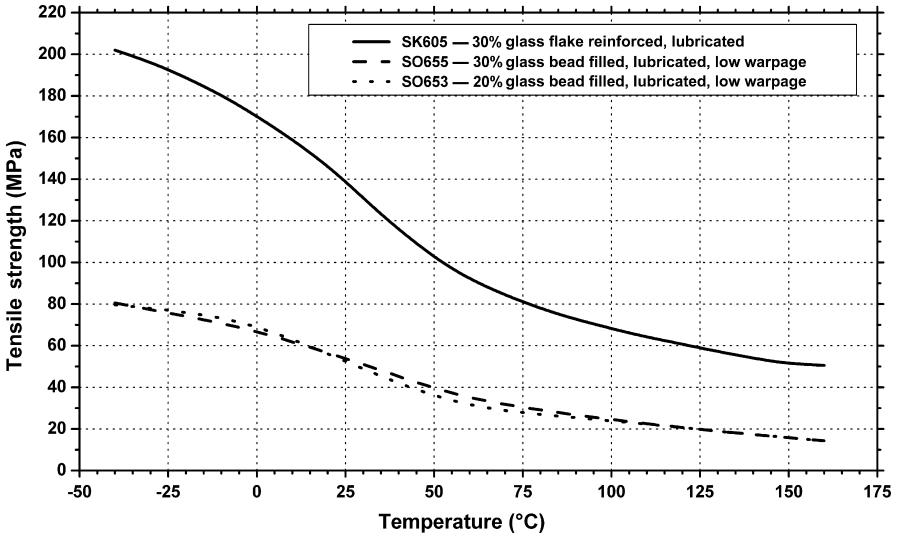


Figure 4.60 Tensile strength vs. temperature for DuPont Crastin® glass reinforced PBT resins [4].

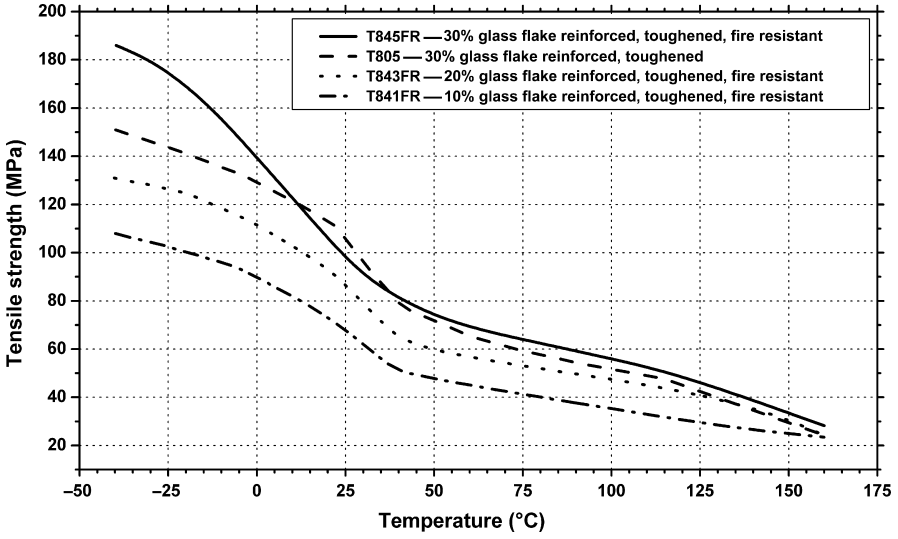


Figure 4.61 Tensile strength vs. temperature for DuPont Crastin® high impact/toughened PBT resins [4].

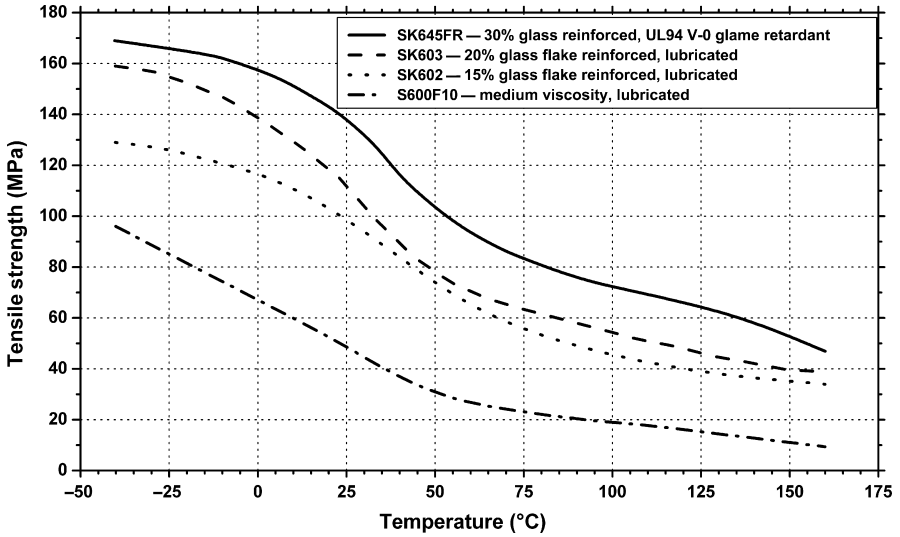


Figure 4.62 Tensile strength vs. temperature for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

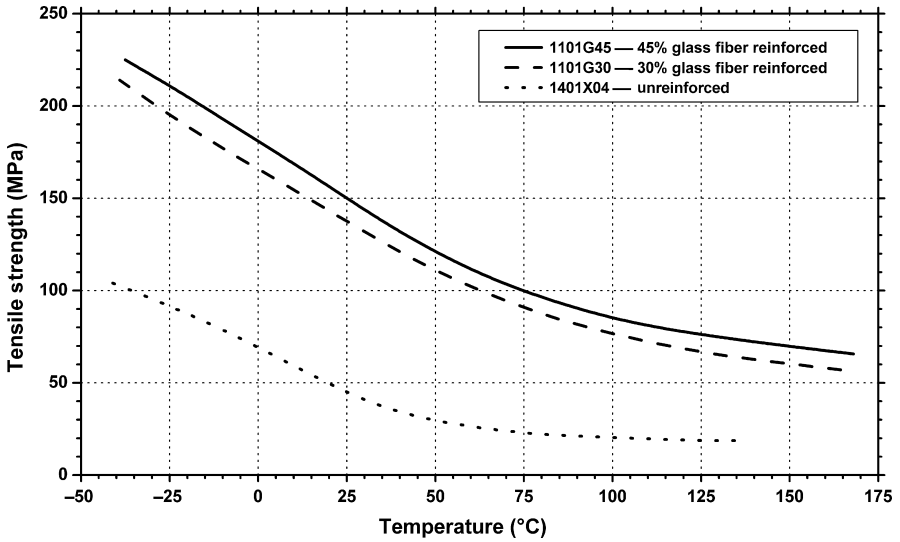


Figure 4.63 Tensile strength vs. temperature for Toray Toraycon® PBT resins.

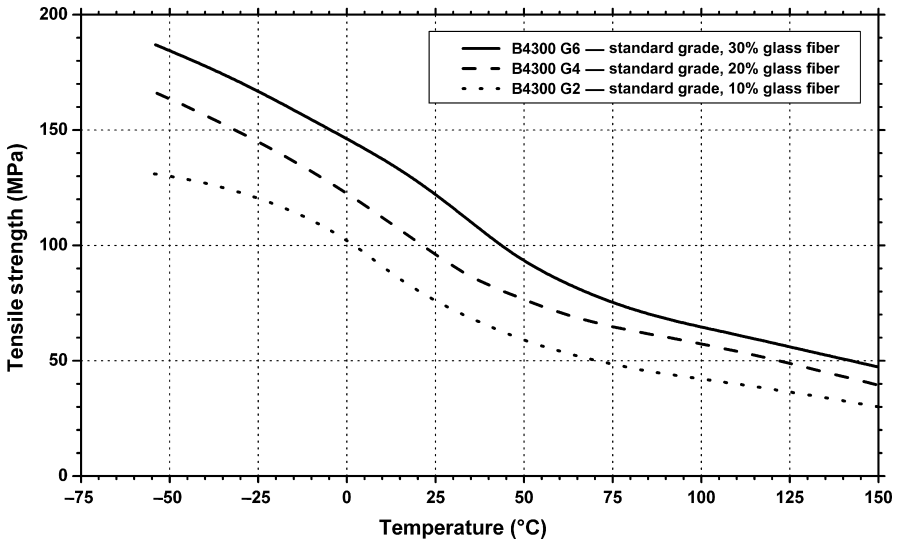


Figure 4.64 Tensile strength vs. temperature for BASF Ultradur® standard grade, fiber glass reinforced PBT resins.

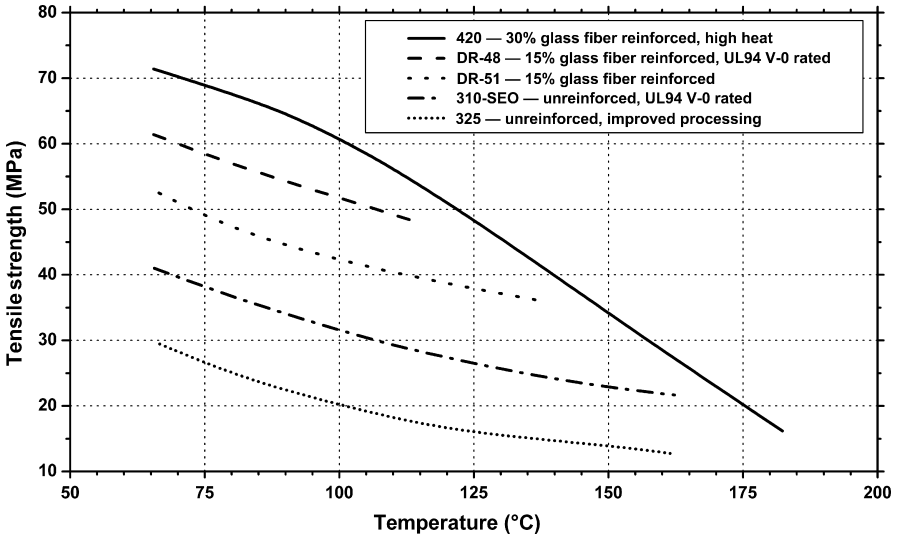


Figure 4.65 Tensile strength vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

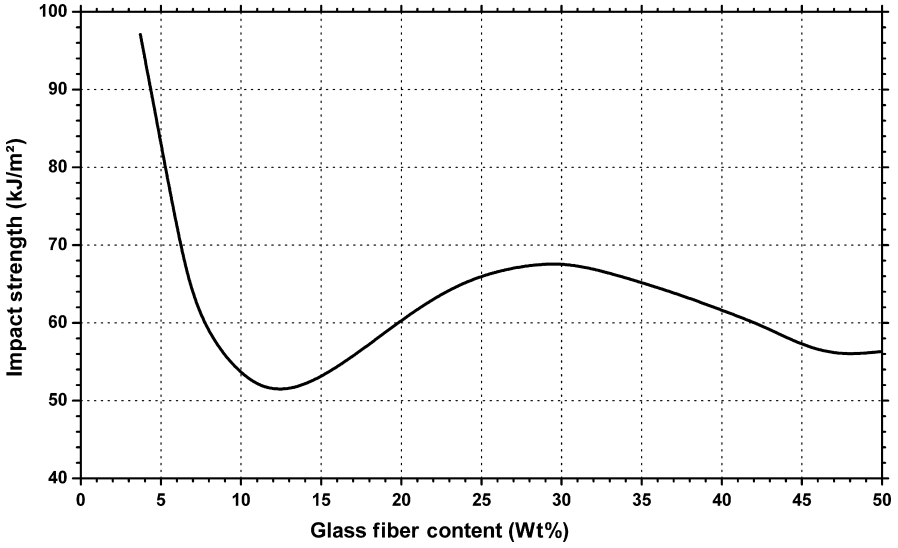


Figure 4.66 Impact strength vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

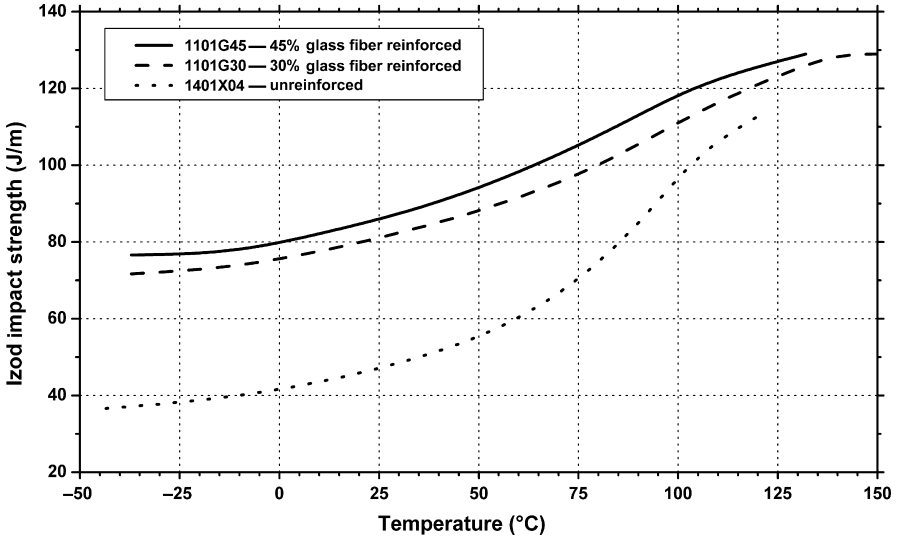


Figure 4.67 Izod impact strength vs. temperature for Toray Toraycon® PBT resins.

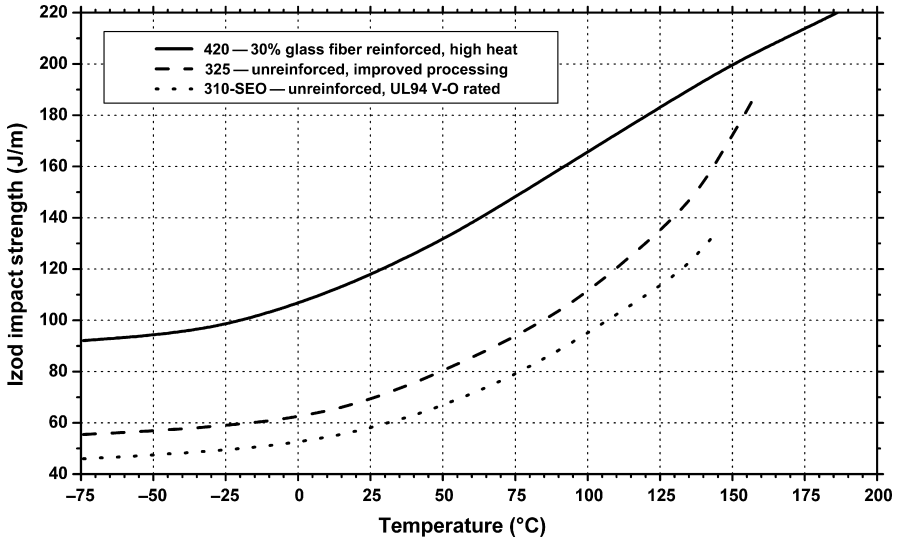


Figure 4.68 Izod impact strength vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

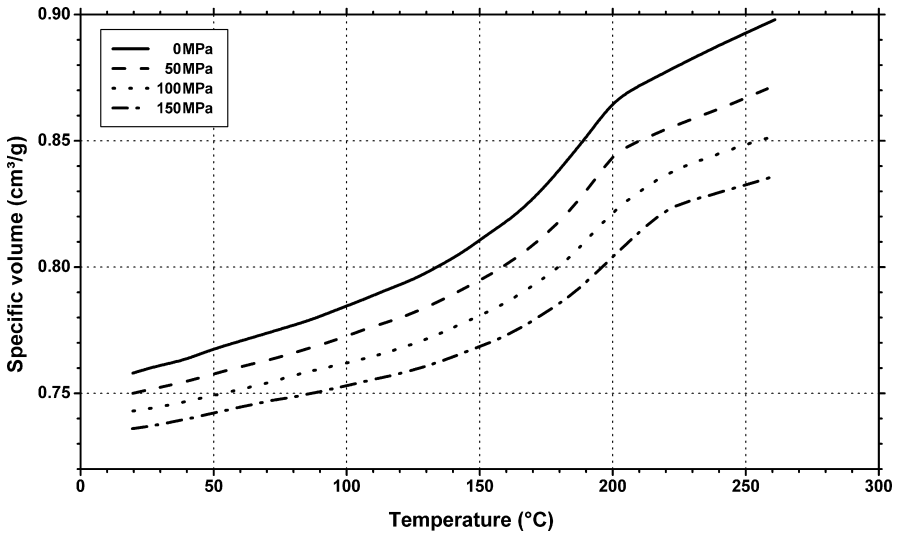


Figure 4.69 PVT for DuPont Crastin® S600LF NC010—PTFE lubricated PBT resin [4].

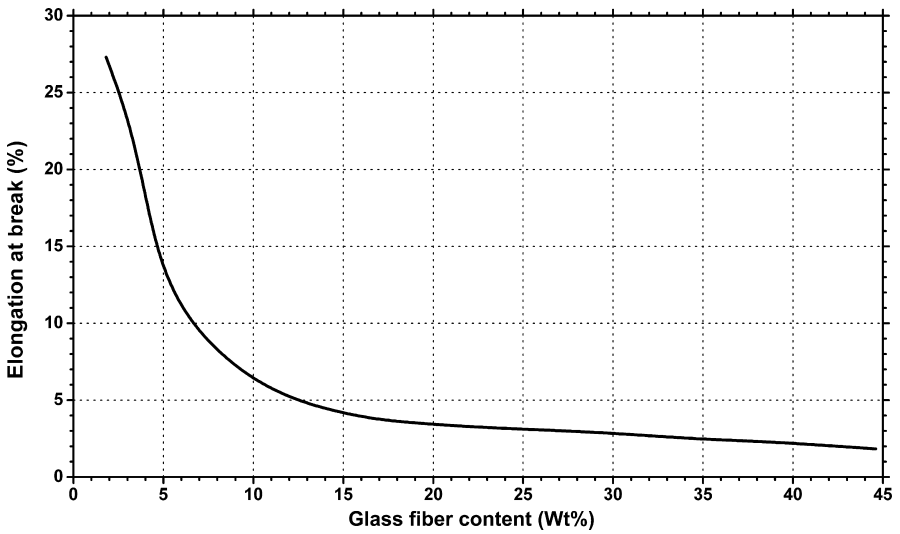


Figure 4.70 Elongation at break vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

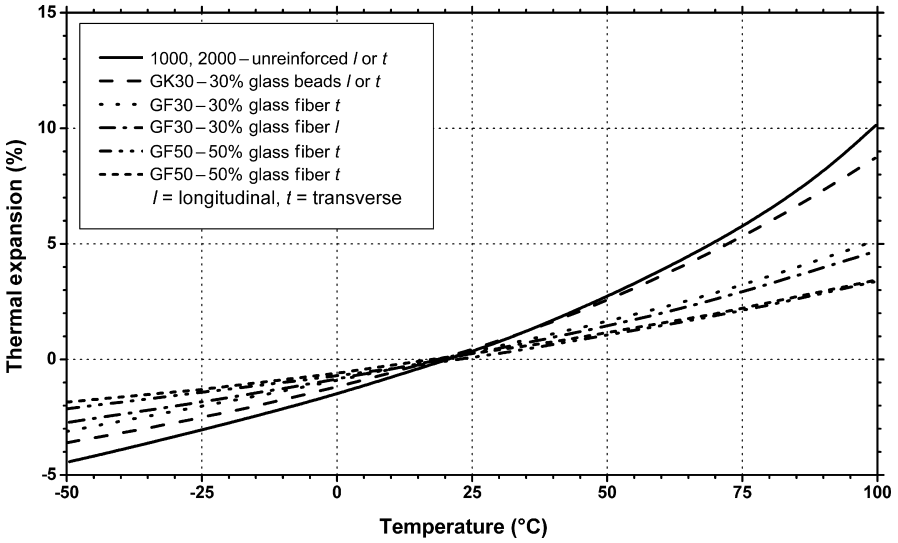


Figure 4.71 Thermal expansion vs. temperature for Evonik Vestodur® PBT plastics according to ISO 11359 [5]. *Note: pretreatment: 20 h at 120°C, heating rate: 2 K/min.*

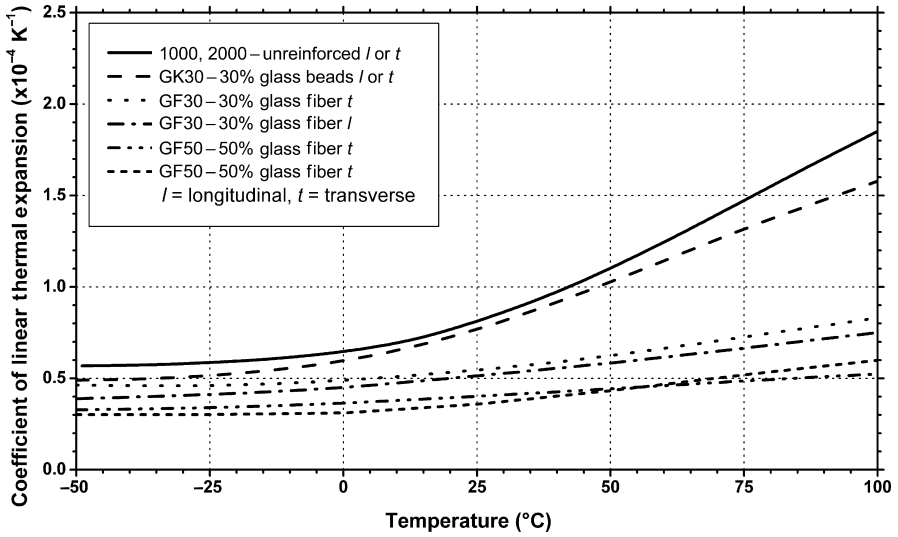


Figure 4.72 Linear thermal expansion coefficient vs. temperature for Evonik Vestodur® PBT plastics according to ISO 11359 [5].

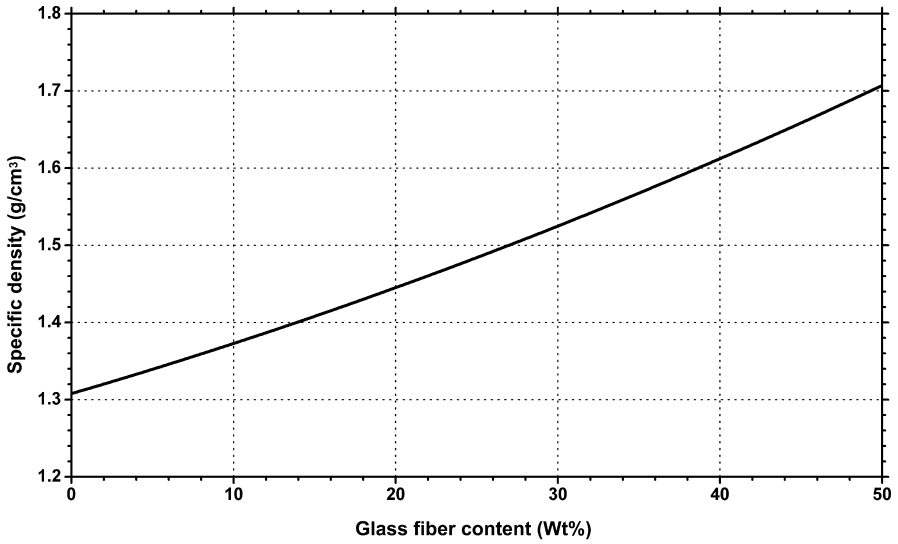


Figure 4.73 Specific density vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins [4].

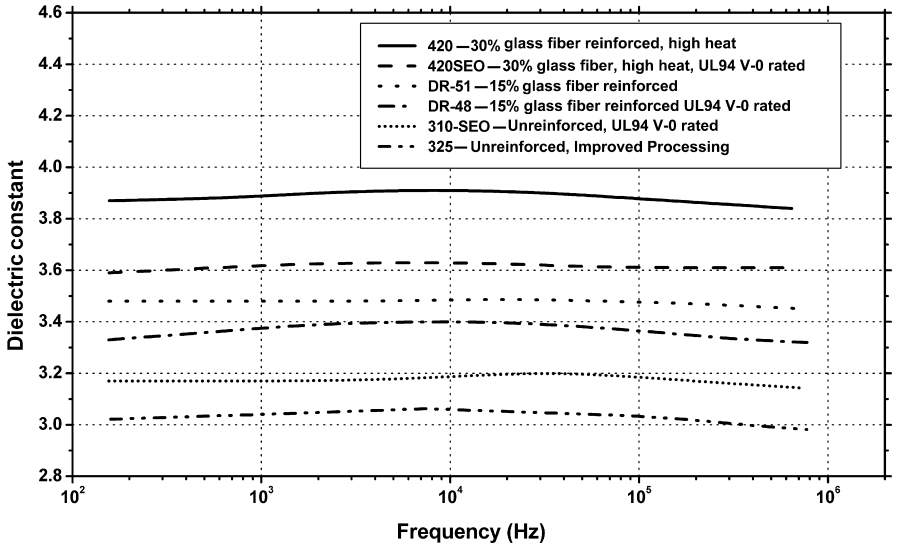


Figure 4.74 Dielectric constant vs. frequency at 23°C for SABIC Innovative Plastics Valox® PBT resins.

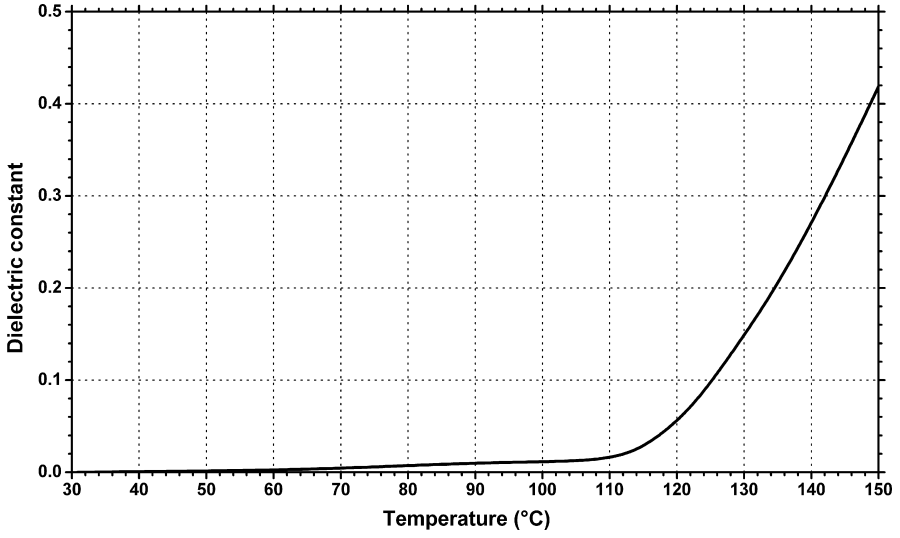


Figure 4.75 Dielectric constant vs. temperature for Toray Toraycon® PBT resins.

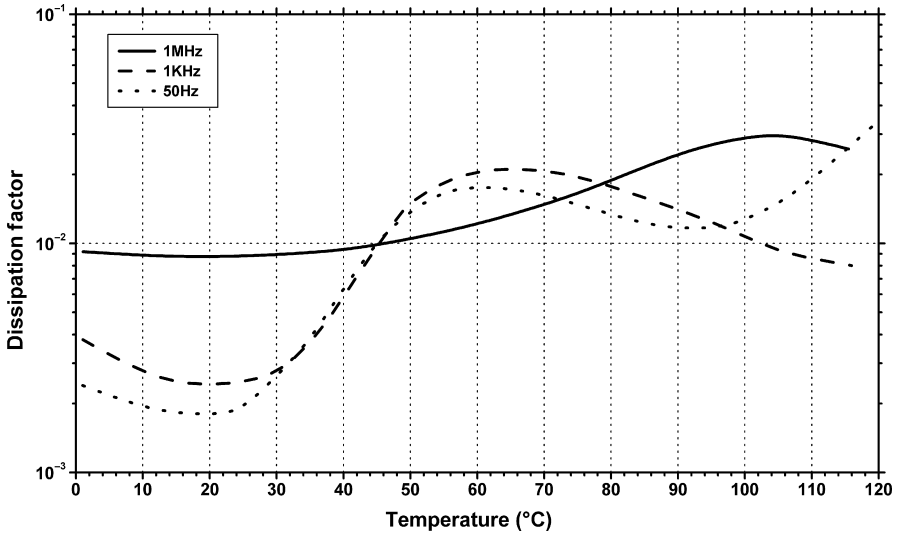


Figure 4.76 Dissipation factor vs. temperature and frequency for LANXESS Pocan® B3235—30% glass fiber reinforced, high toughness PBT resin.

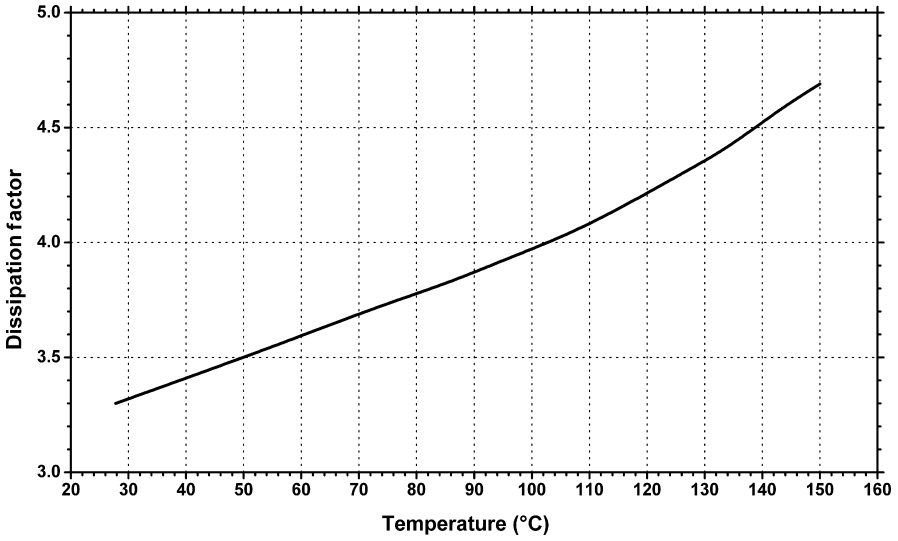


Figure 4.77 Dissipation factor vs. temperature for Toray Toraycon® PBT resin.

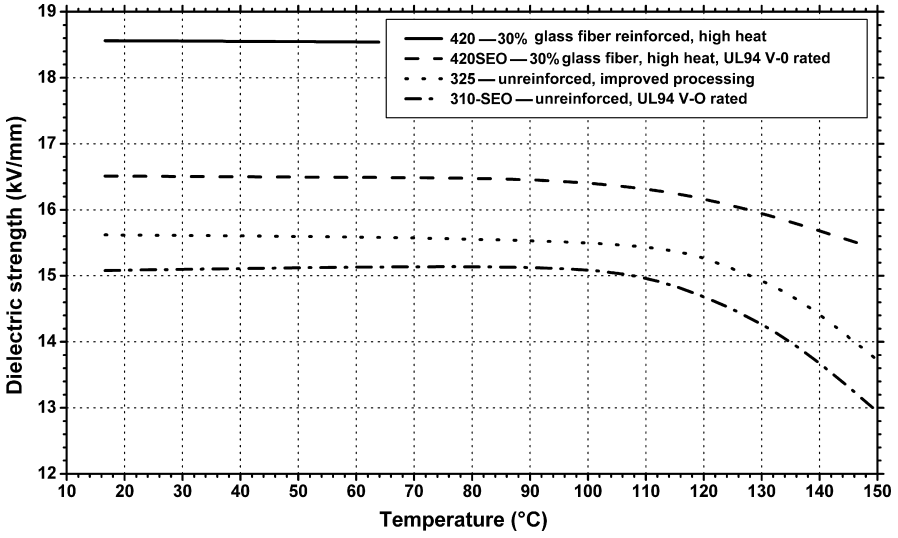


Figure 4.78 Dielectric strength vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

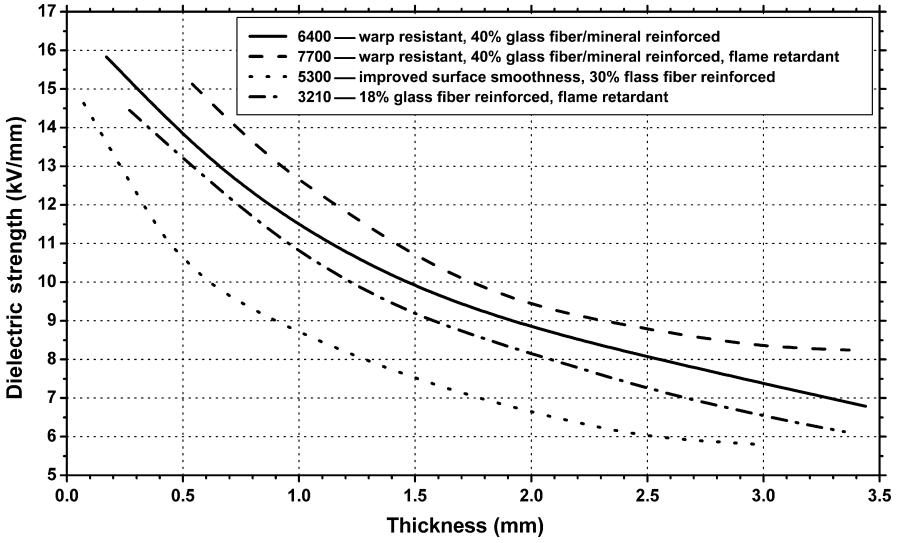


Figure 4.79 Dielectric strength vs. thickness for Celanese Celanex® PBT resins.

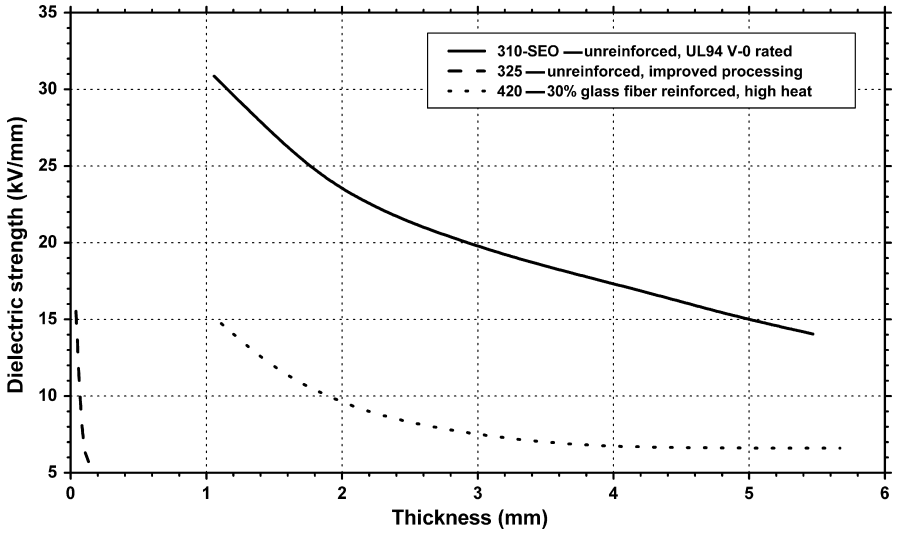


Figure 4.80 Dielectric strength vs. thickness for SABIC Innovative Plastics Valox® PBT resins.

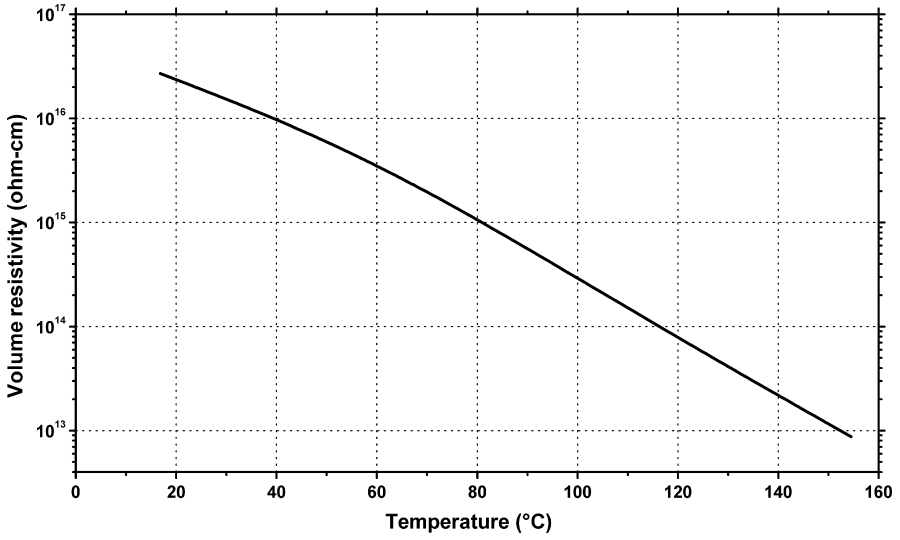


Figure 4.81 Volume resistivity vs. temperature for SABIC Innovative Plastics Valox® 420SEO—30% glass fiber, high heat, UL94 V-0 rated PBT resin.

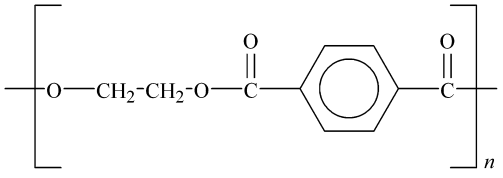


Figure 4.82 Chemical structure of PET polyester.

Applications and uses: electrical and electronic parts (connectors, sockets, chip carriers), mechanical parts, food containers, automotive underhood parts, and chemical processing, household cookware for conventional and microwave ovens.

Data for LCP plastics are found in Figures 4.108–4.131.

4.5 Polycyclohexylene–Dimethylene Terephthalate (PCT)

PCT is a high temperature polyester that possesses the chemical resistance, processability, and dimensional stability of polyesters PET and PBT. However, the aliphatic cyclic ring shown in Figure 4.132 imparts added heat resistance. This puts it between the common polyesters and

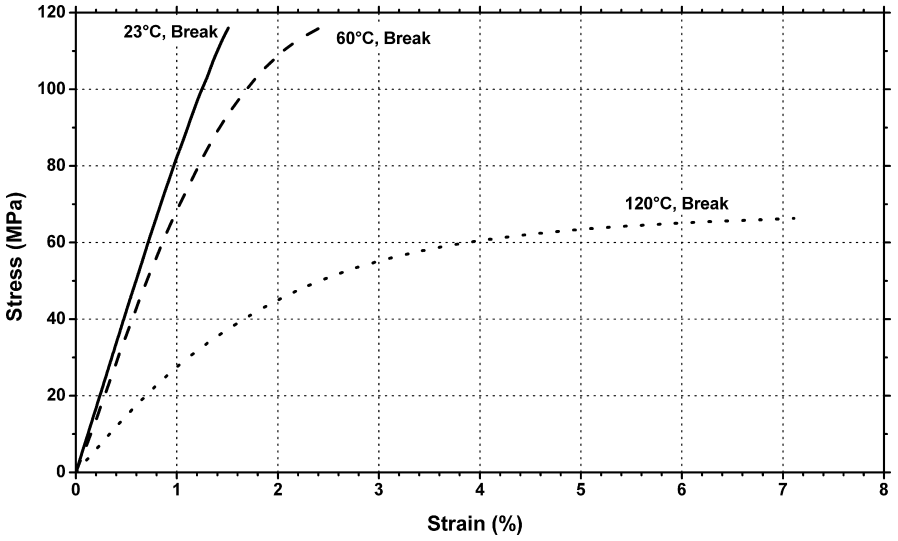


Figure 4.83 Stress vs. strain at various temperatures for Celanese Impet® 2700 GV1/20—20% glass fiber reinforced PET resin.

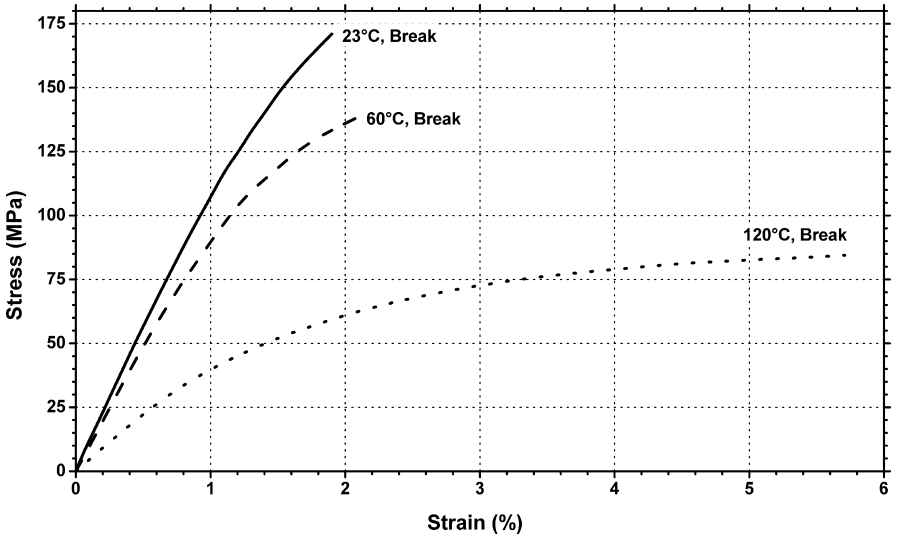


Figure 4.84 Stress vs. strain at various temperatures for Celanese Impet® 2700 GV1/30—30% glass fiber reinforced PET resin.

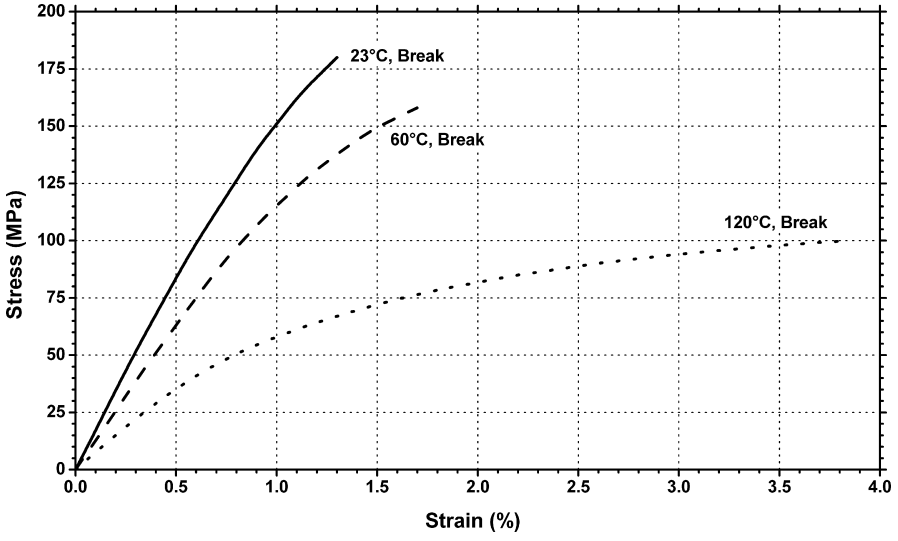


Figure 4.85 Stress vs. strain at various temperatures for Celanese Impet® 2700 GV1/45—45% glass fiber reinforced PET resin.

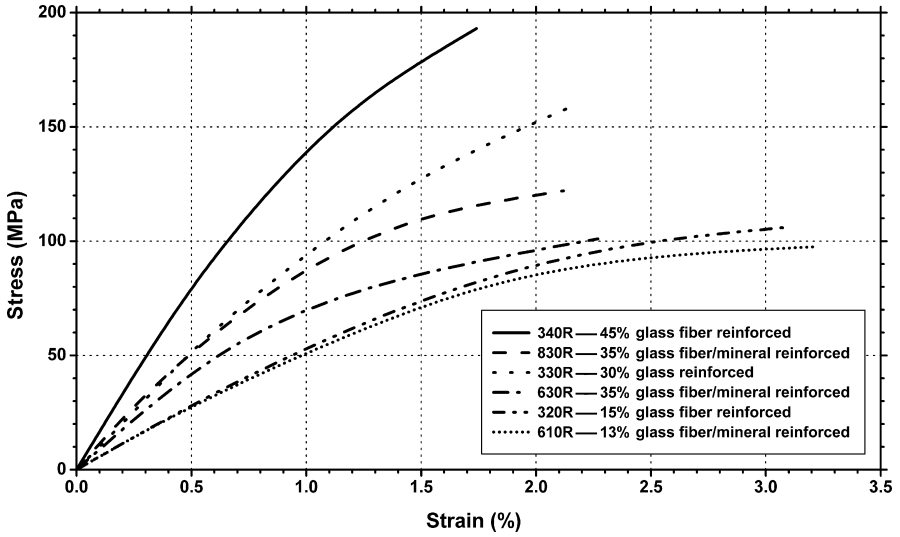


Figure 4.86 Stress vs. strain at 23°C for several Celanese Impet® reinforced PET resins.

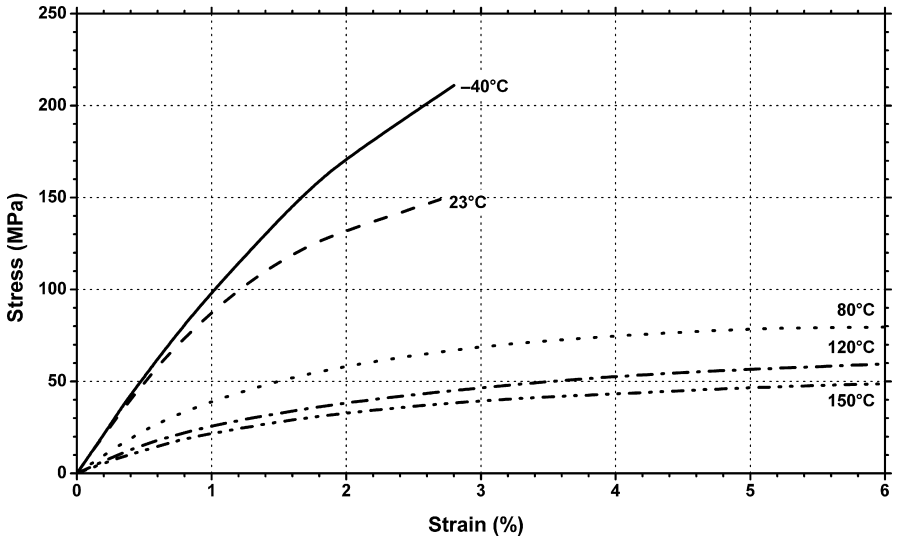


Figure 4.87 Stress vs. strain at various temperatures for BASF Petra® 130—30% glass fiber reinforced recycled PET resin [6].

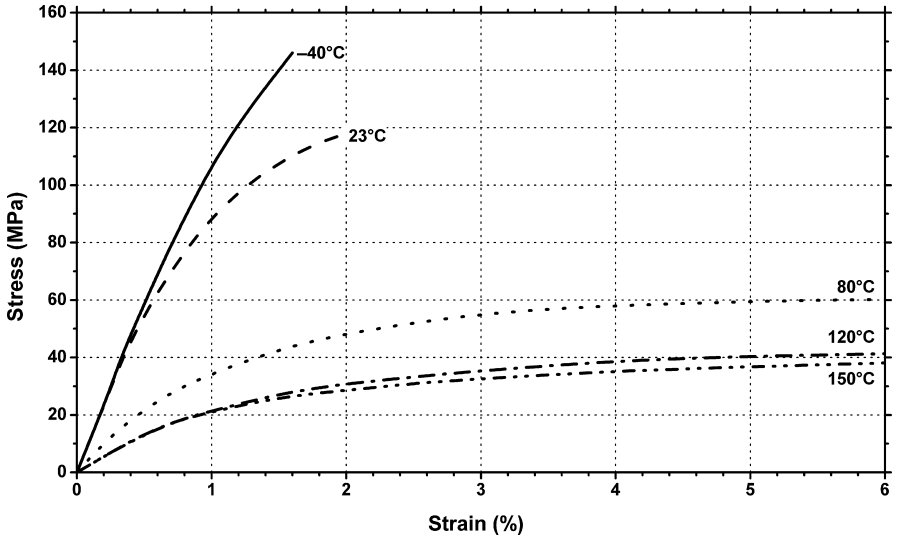


Figure 4.88 Stress vs. strain at various temperatures for BASF Petra® 230 BK-112—35% mineral/glass fiber reinforced, black, injection molding, recycled PET resin [6].

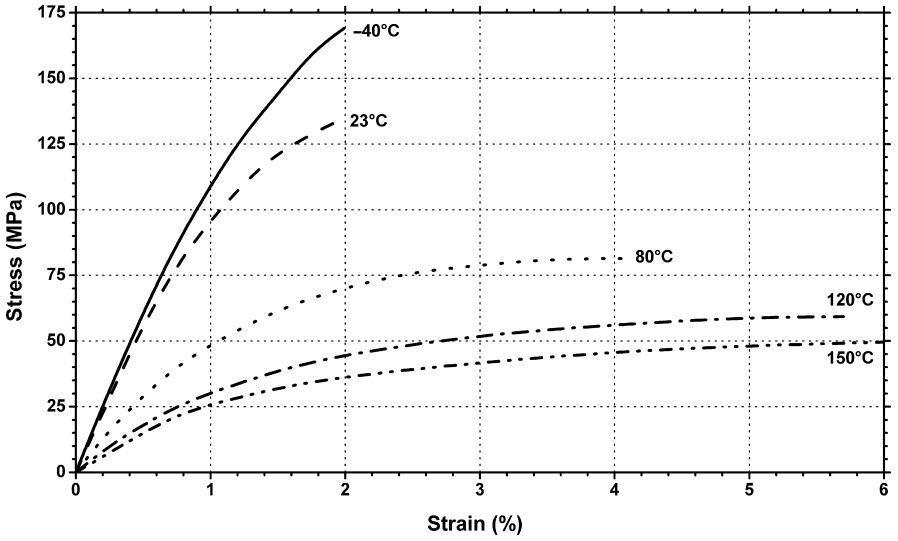


Figure 4.89 Stress vs. strain at various temperatures for BASF Petra® 330 FR BK-112—30% glass reinforced, flame retardant, black, injection molding, UL94 V-0 rated, recycled PET resin [6].

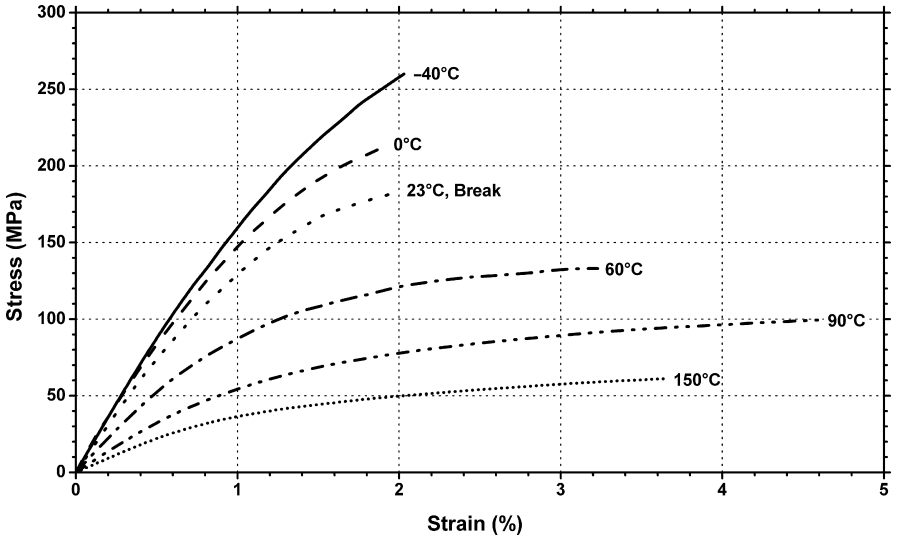


Figure 4.90 Stress vs. strain at various temperatures for DuPont Rynite® 545—general purpose, 45% glass fiber reinforced PET resin [7].

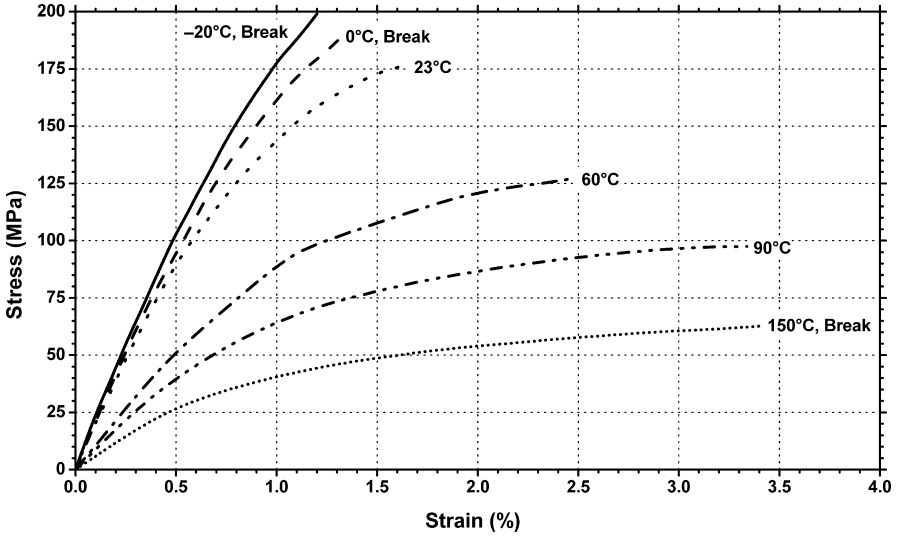


Figure 4.91 Stress vs. strain at various temperatures for DuPont Rynite® 555—general purpose, 55% glass fiber reinforced PET resin [7].

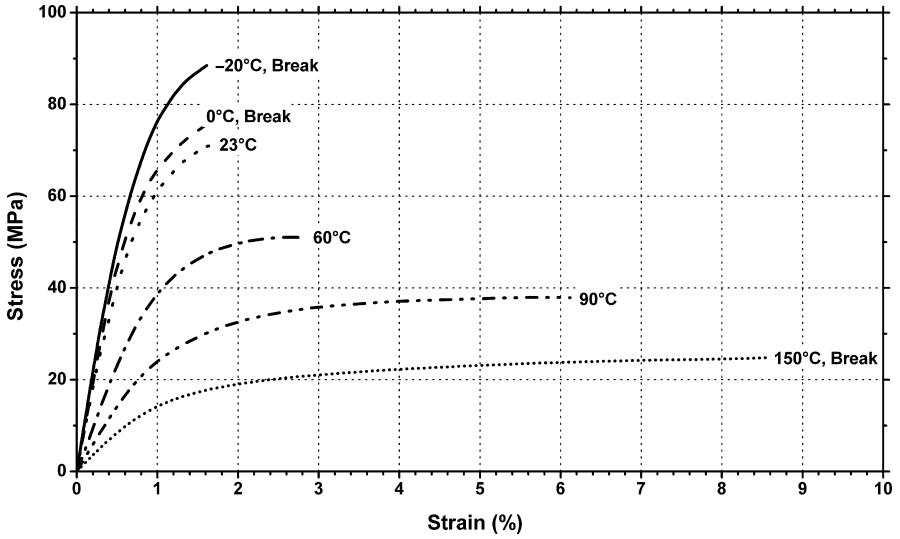


Figure 4.92 Stress vs. strain at various temperatures for DuPont Rynite® 935—low warp, 35% mica/glass reinforced PET resin [7].

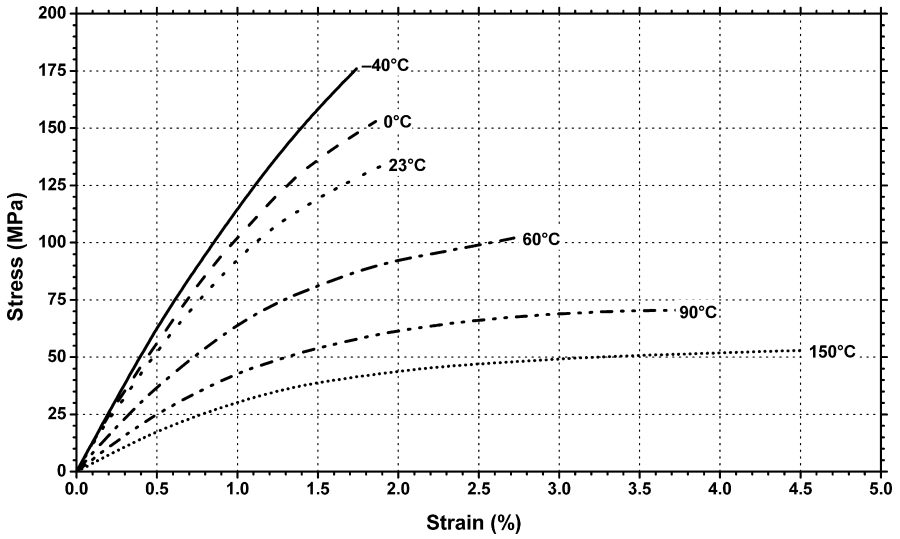


Figure 4.93 Stress vs. strain at various temperatures for DuPont Rynite® FR530L—flame retardant, 30% glass reinforced, higher heat, lubricated PET resin [7].

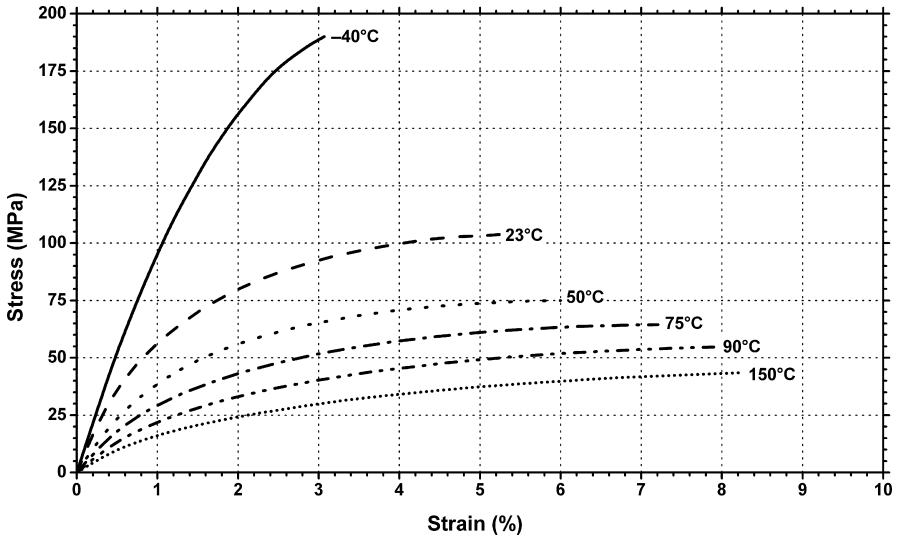


Figure 4.94 Stress vs. strain at various temperatures for DuPont Rynite® SST35—super tough, 35% glass reinforced PET resin [7].

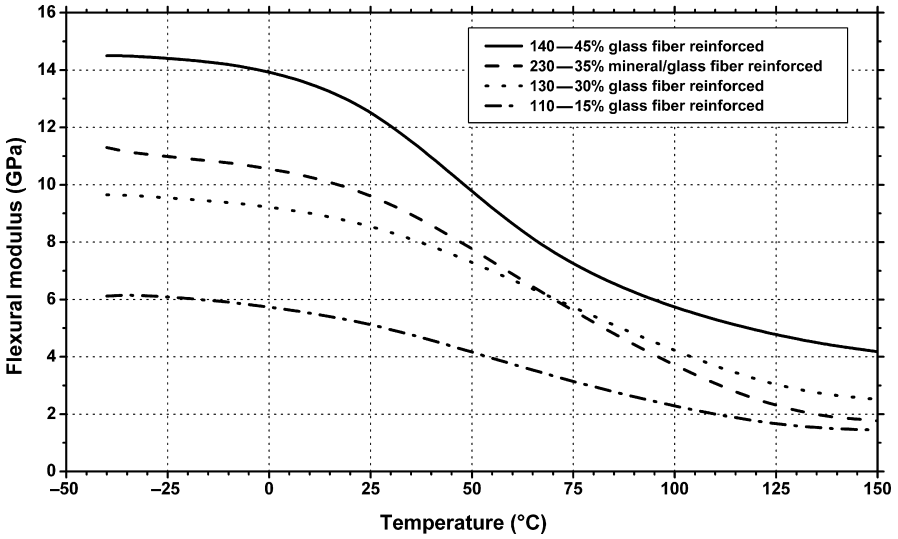


Figure 4.95 Flexural modulus vs. temperature for BASF Petra® reinforced recycled PET resins [6].

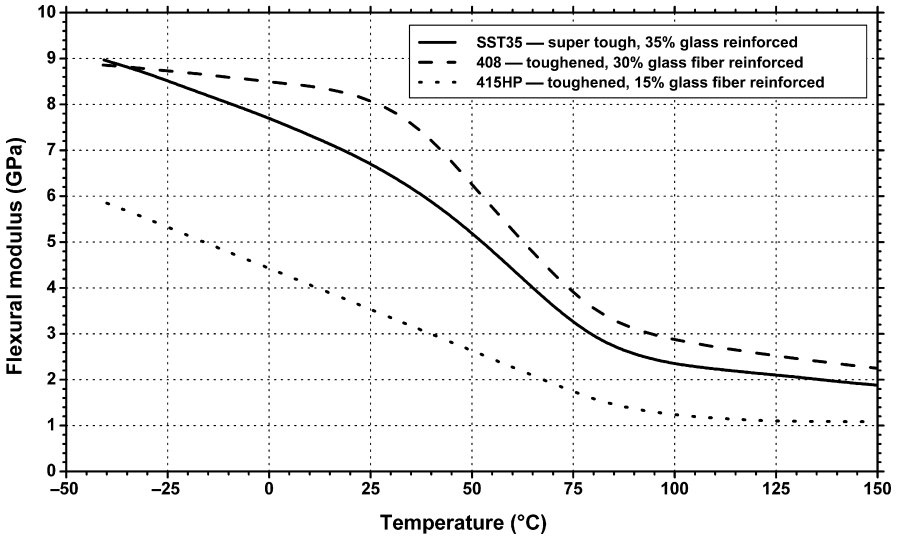


Figure 4.96 Flexural modulus vs. temperature for DuPont Rynite® toughened, reinforced PET resins [7].

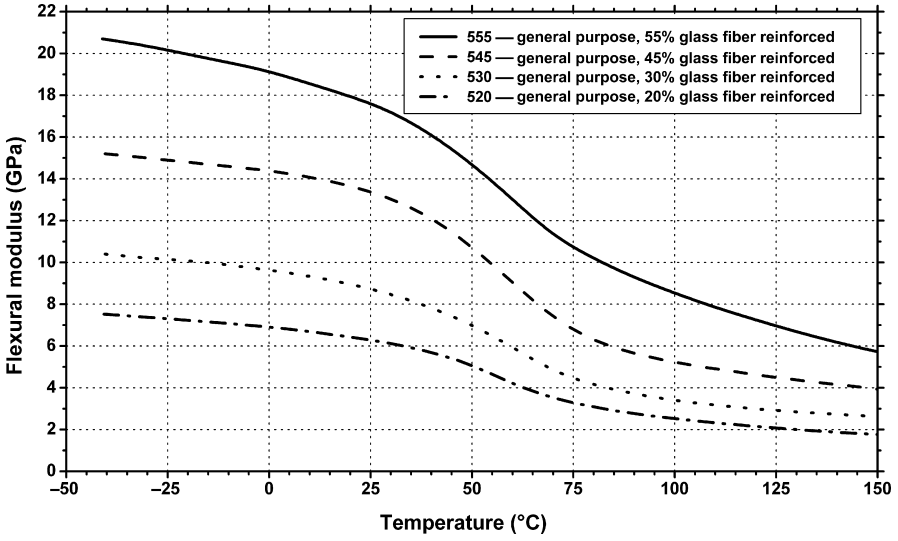


Figure 4.97 Flexural modulus vs. temperature for DuPont Rynite® 500 series of toughened, reinforced PET resins [7].

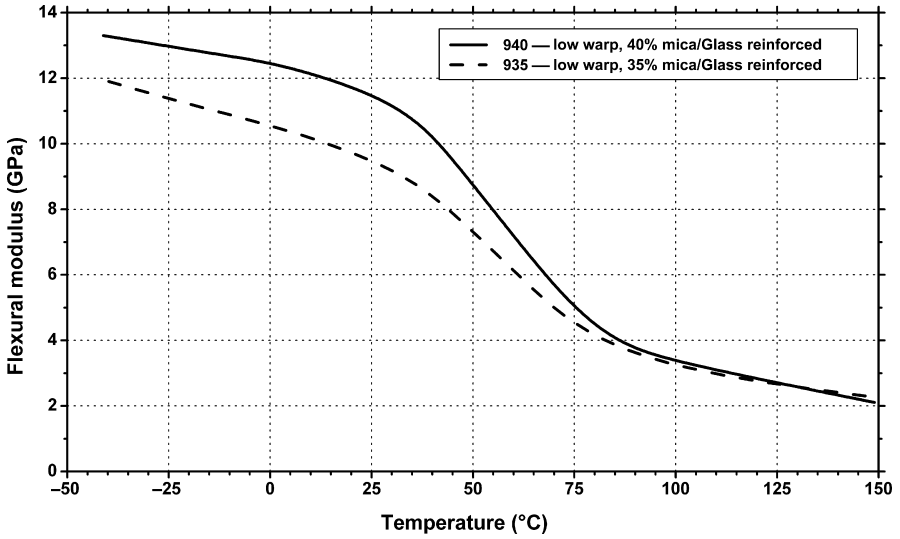


Figure 4.98 Flexural modulus vs. temperature for DuPont Rynite® 900 series of low warp PET resins [7].

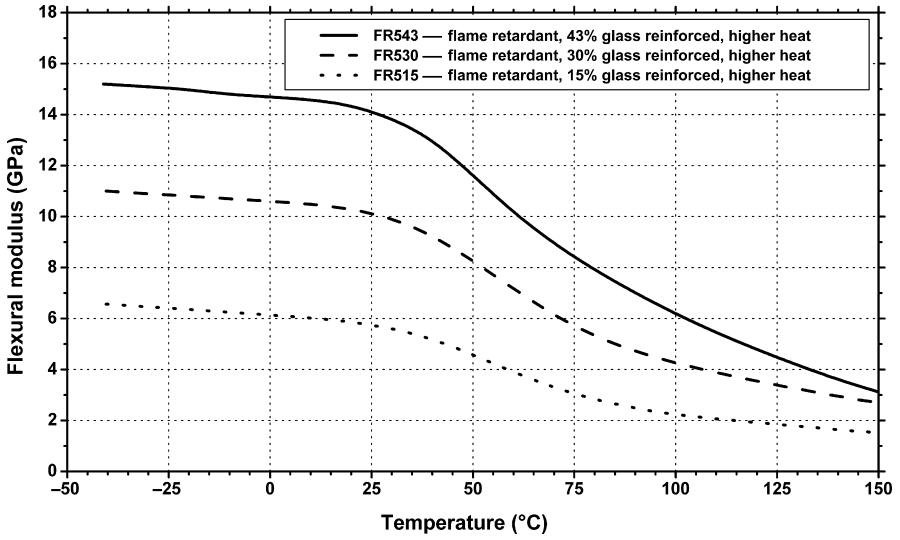


Figure 4.99 Flexural modulus vs. temperature for DuPont Rynite® FR500 series of flame retardant PET resins [7].

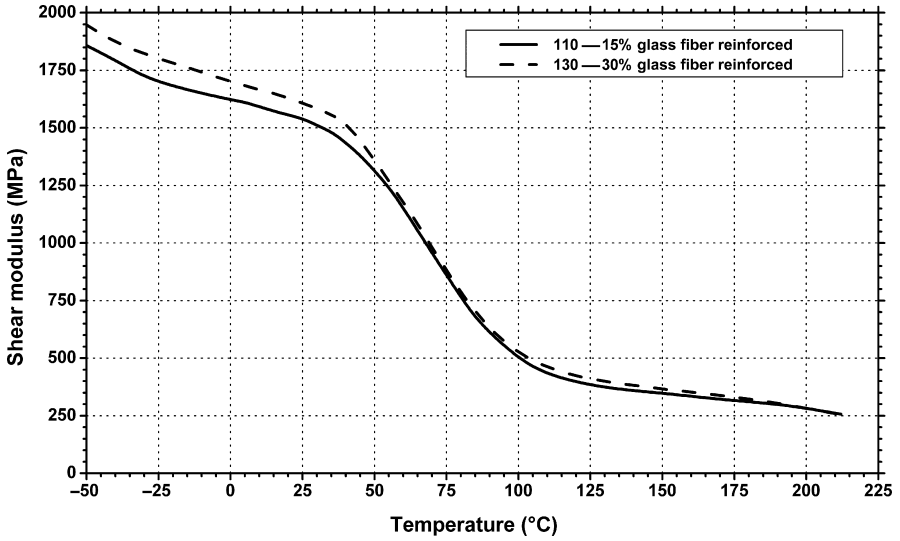


Figure 4.100 Flexural modulus vs. temperature for DuPont Rynite® FR900 series of flame retardant, low warp PET resins [7].

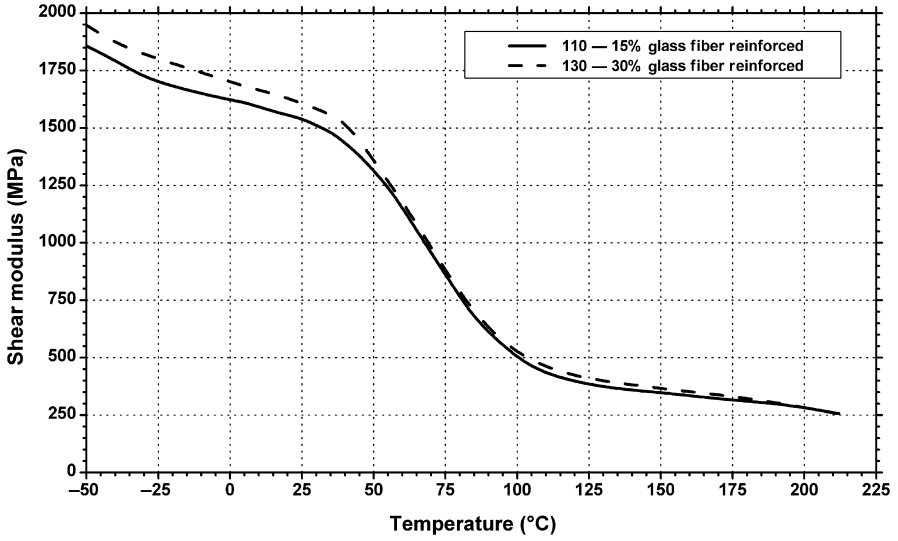


Figure 4.101 Shear modulus vs. temperature for BASF Petra® reinforced recycled PET resins.

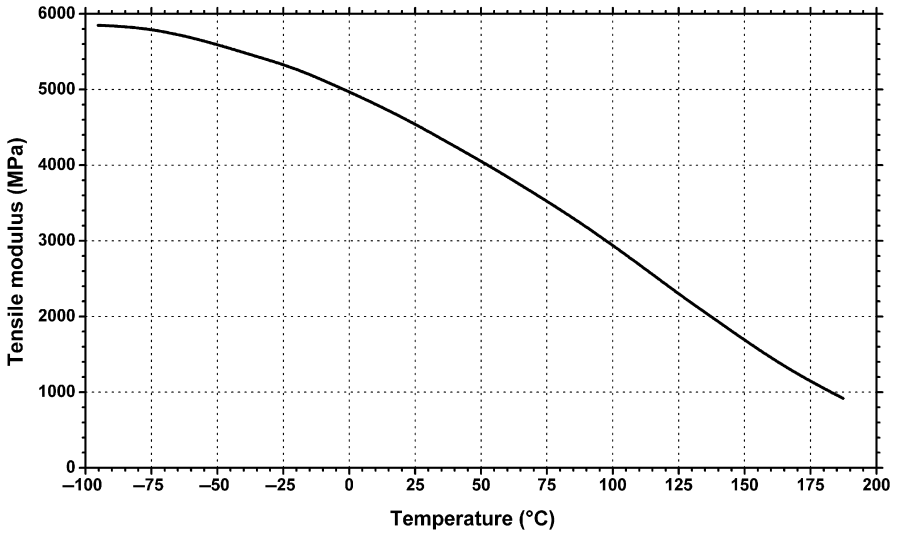


Figure 4.102 Tensile modulus vs. temperature of Mitsubishi Polyester Film Hostaphan® PET film [8].

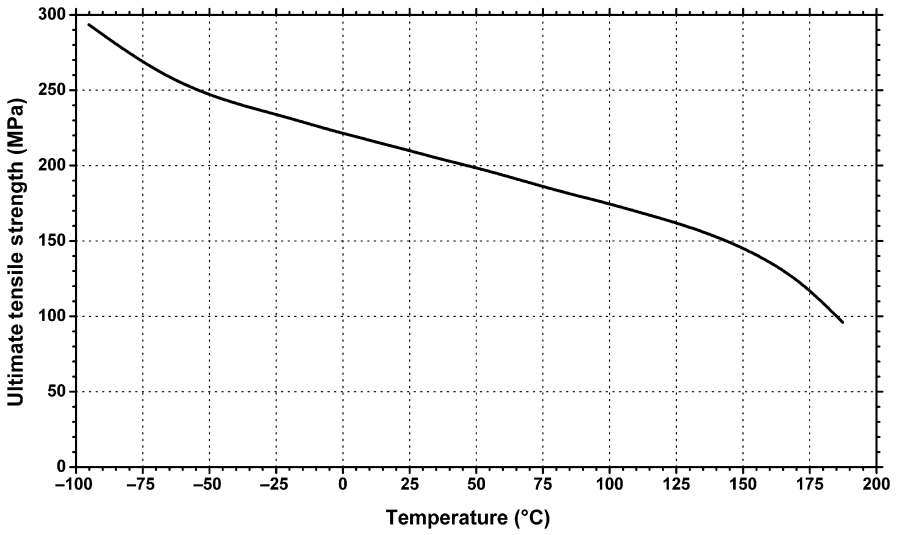


Figure 4.103 Ultimate tensile strength vs. temperature of Mitsubishi Polyester Film Hostaphan® PET film [8].

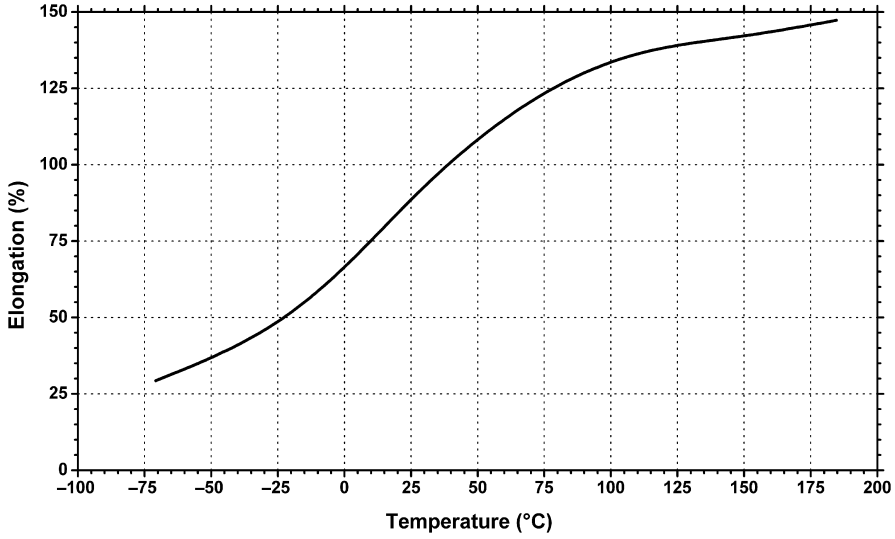


Figure 4.104 Elongation vs. temperature for Mitsubishi Polyester Film Hostaphan® PET film [8].

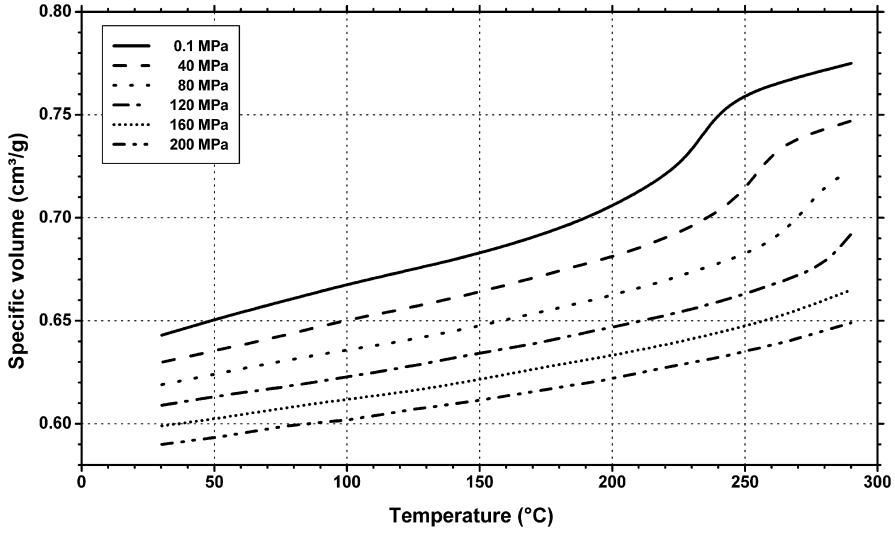


Figure 4.105 PVT for DSM Engineering Plastics Arnite® AV2 372—35% glass fiber reinforced PET resin.

the LCP polyesters described in the previous section.

This material has found use in automotive, electrical, and housewares applications.

Manufacturers and trade names: Celanese Thermx®.

Applications and uses: rigid medical, blister packaging, laundry bags, and hospital bed pads.

Data for PCT plastics are found in Figures 4.133–4.139.

4.6 Polyethylene Naphthalate (PEN) and Polybutylene Naphthalate (PBN)

PEN is similar to PET but has better temperature resistance. The CAS number for PEN is 25853-85-4. The structure of this polyester is shown in Figure 4.140.

Manufacturers and trade names: DuPont™ Teijin Films TEONEX®, Eastman Eastar®, BP.

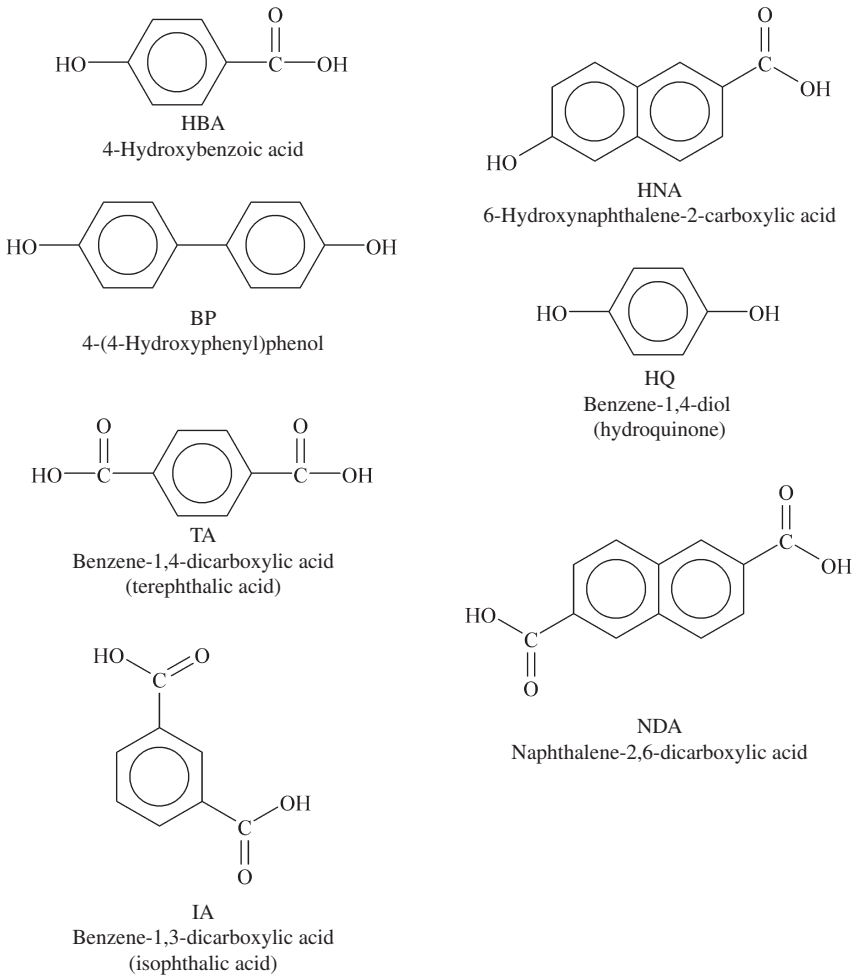


Figure 4.106 Chemical structures of monomers used to make LCP polyesters.

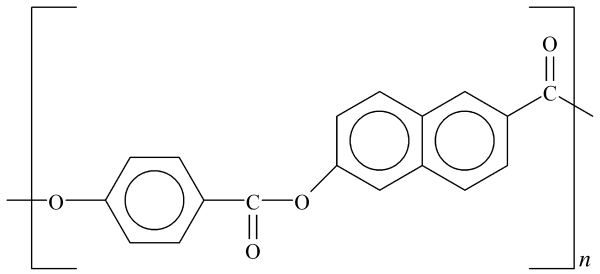


Figure 4.107 Chemical structure of Celanese Vectra® A950 LCP.

Applications and uses: electrical, industrial, general purpose, high-value-added applications in labels, laminates, circuitry, and release.

Data for PEN/PBN plastics are found in Figures 4.141 and 4.142.

4.7 Polyester Blends and Alloys

There are numerous polyester blends and alloys. Often the different polyesters are blended.

Manufacturers and trade names: Ticona Vandar®, SABIC Innovative Plastics Xenoy®, DuPont Crastin®, BASF Ultradur®.

Applications and uses: telephone line splice cases, switches, connectors, housings, improved impact brake and fuel line clips, wheel covers, headlamp bezels and covers, panels, power distribution boxes, cold temperature air bag doors, automotive safety systems, wheel covers, impact fascias, improved impact appliance lids, power tools, panels, and housings.

Data for polyester blends and alloys plastics are found in Figures 4.143–4.158.

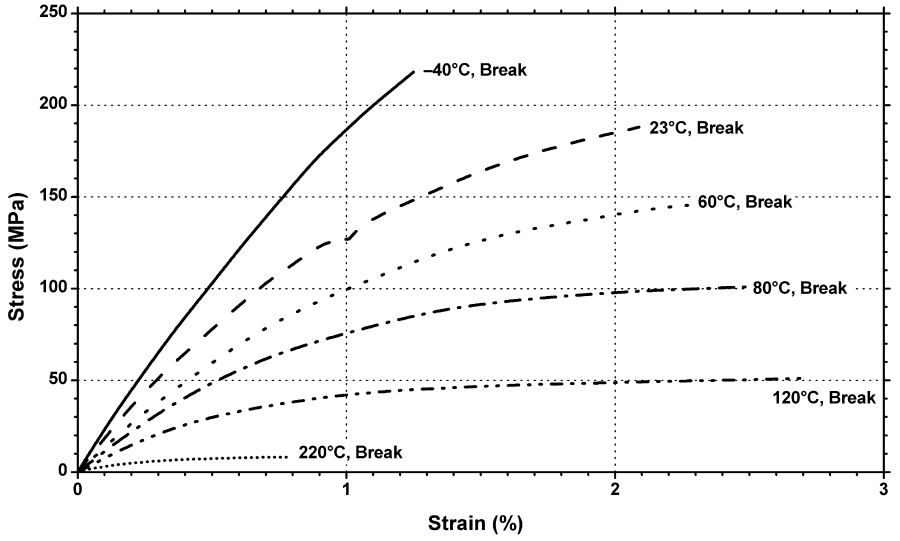


Figure 4.108 Stress vs. strain at various temperatures for Celanese Vectra® A130—30% glass fiber reinforced, standard grade LCP.

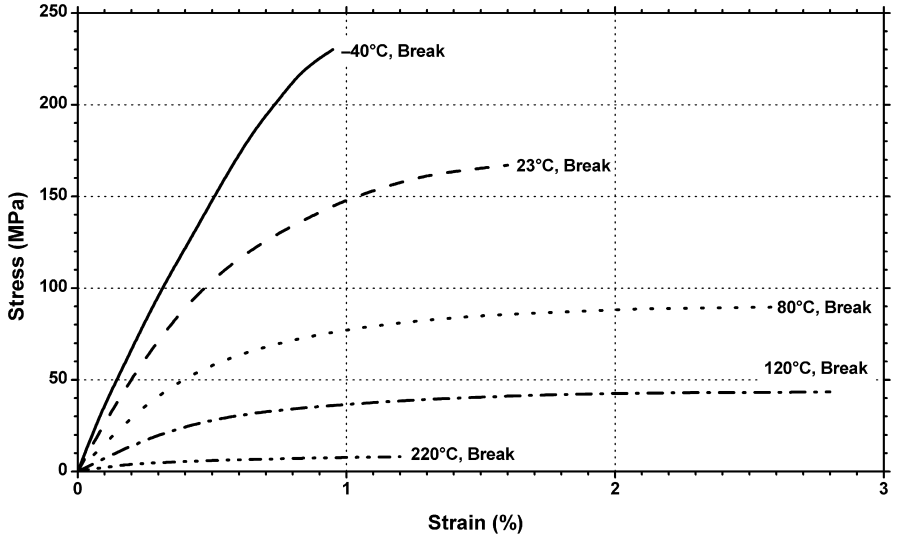


Figure 4.109 Stress vs. strain at various temperatures for Celanese Vectra® A230—30% carbon fiber reinforced, high stiffness LCP.

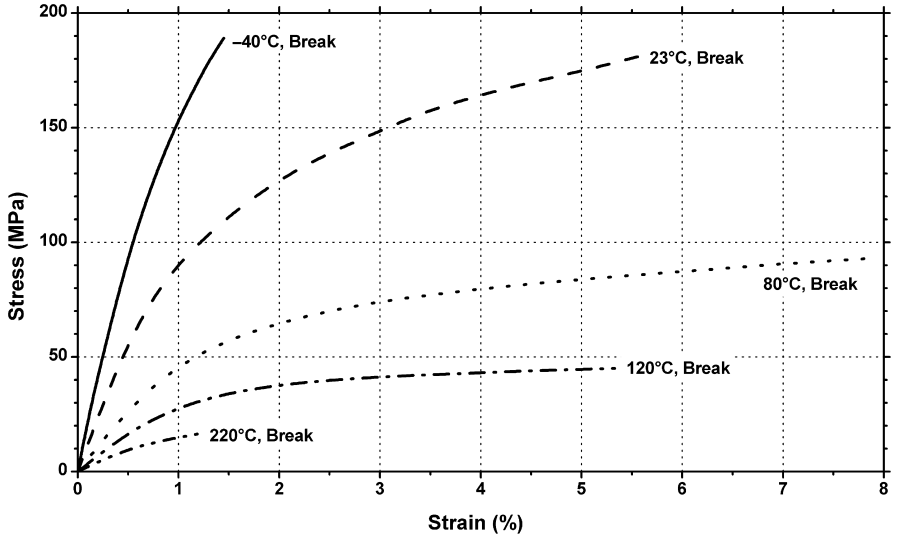


Figure 4.110 Stress vs. strain at various temperatures for Celanese Vectra® A530—30% mineral reinforced, standard grade LCP.

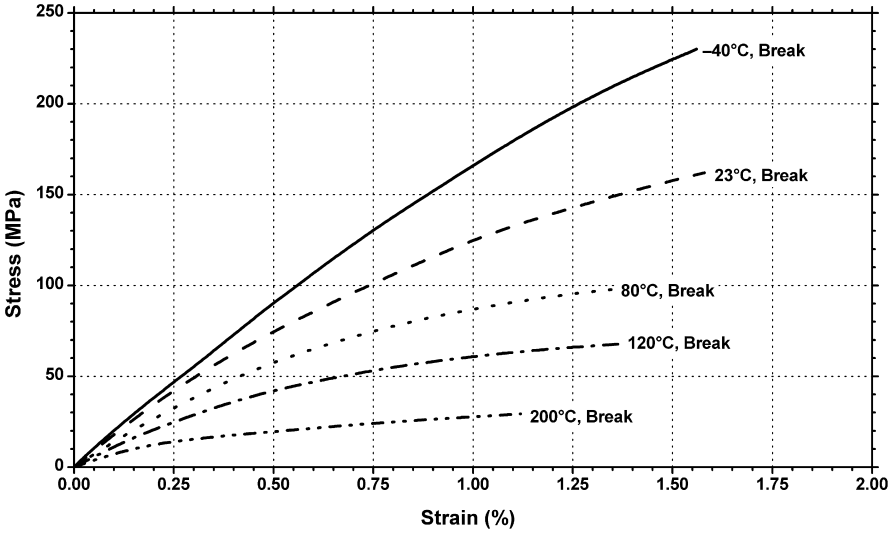


Figure 4.111 Stress vs. strain at various temperatures for Celanese Vectra® E130i—30% glass fiber reinforced, easy flow, high temperature LCP [9].

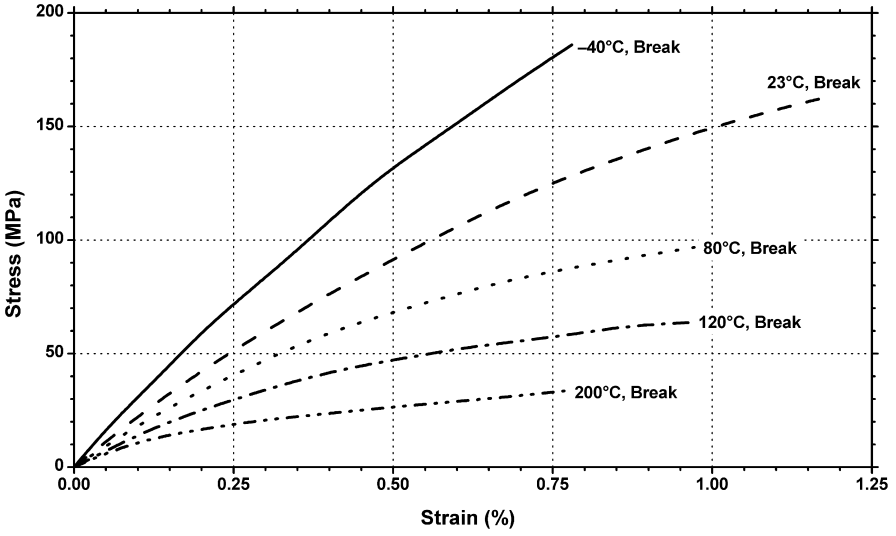


Figure 4.112 Stress vs. strain at various temperatures for Celanese Vectra® H140—40% glass fiber reinforced, highest temperature LCP.

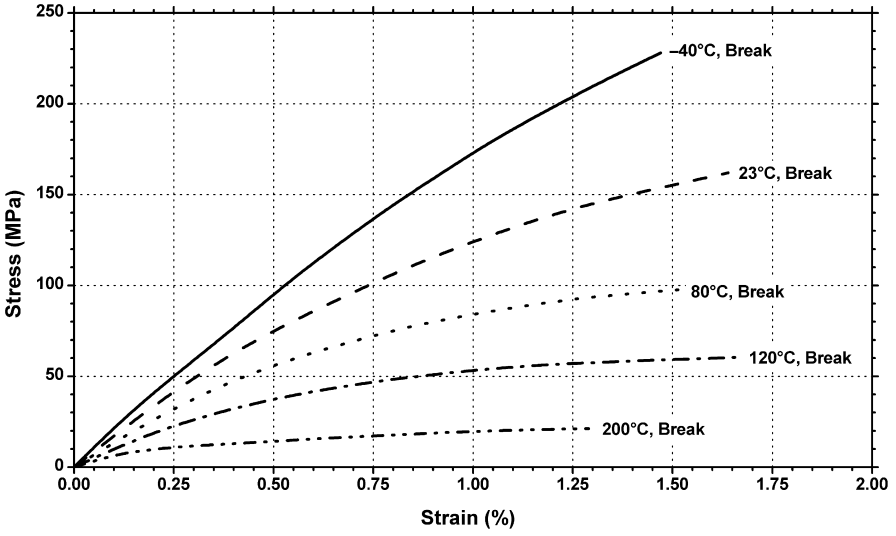


Figure 4.113 Stress vs. strain at various temperatures for Celanese Vectra® L130—30% glass fiber reinforced, high flow LCP.

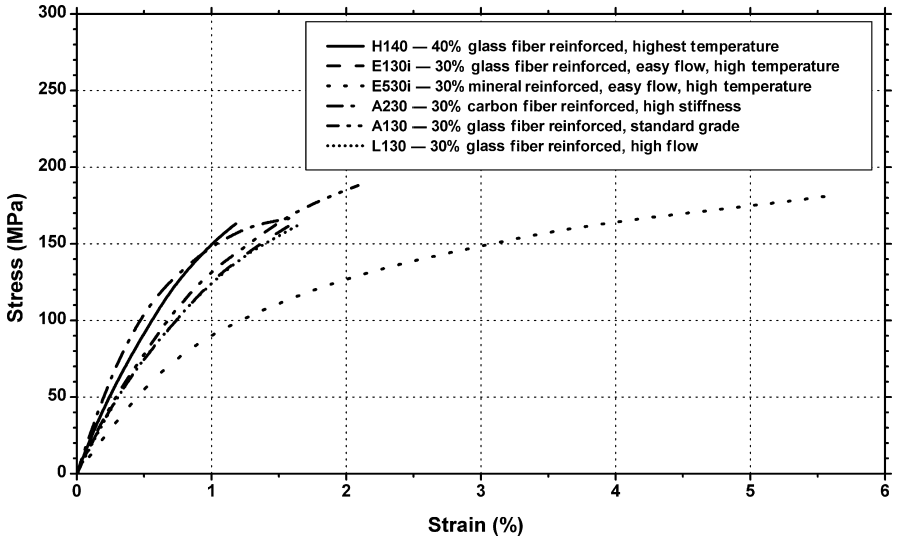


Figure 4.114 Stress vs. strain at 23°C for several Celanese Vectra® L130—30% glass fiber reinforced, high flow LCPs.

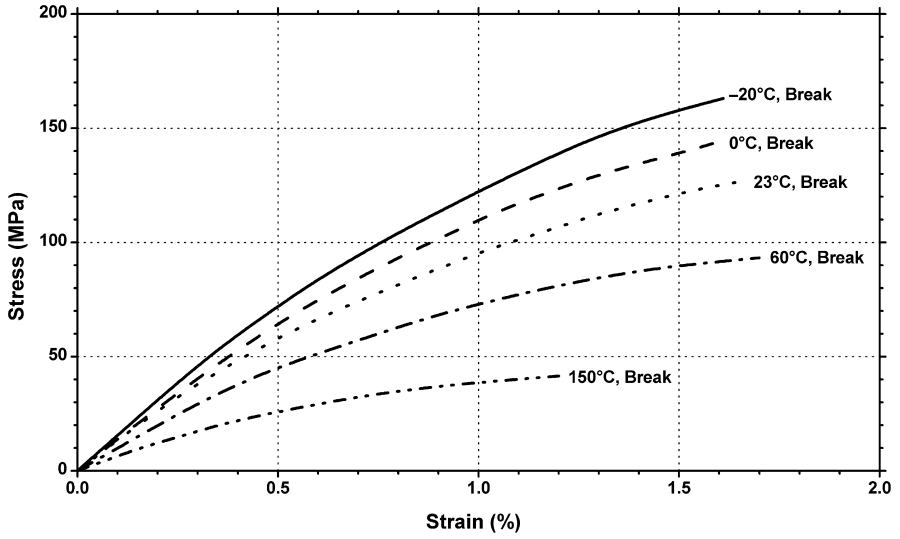


Figure 4.115 Stress vs. strain at various temperatures for DuPont Zenite® 6130L BK010—30% glass reinforced, lubricated LCP.

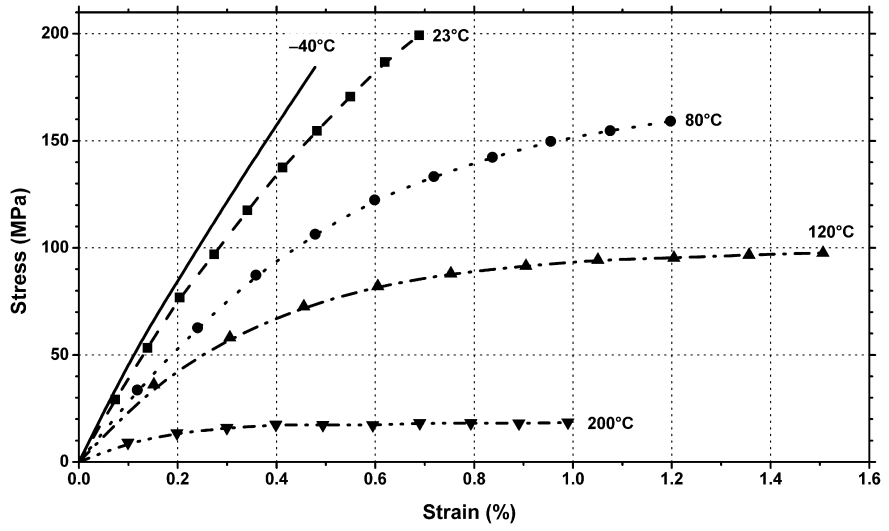


Figure 4.116 Influence of temperature on tensile stress–strain behavior of Celanese Vectra® B230 LCP [9].

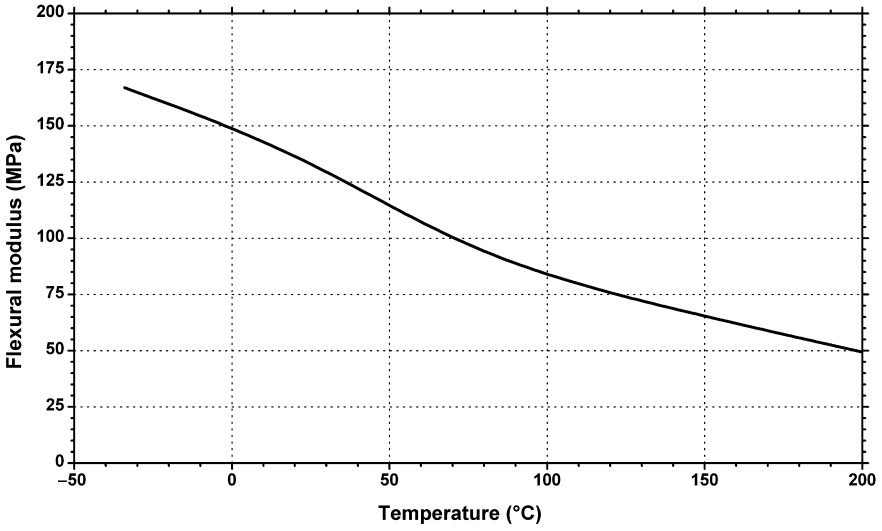


Figure 4.117 Flexural modulus vs. temperature for Toray Siveras® L204G35—35% glass fiber reinforced, standard grade LCP.

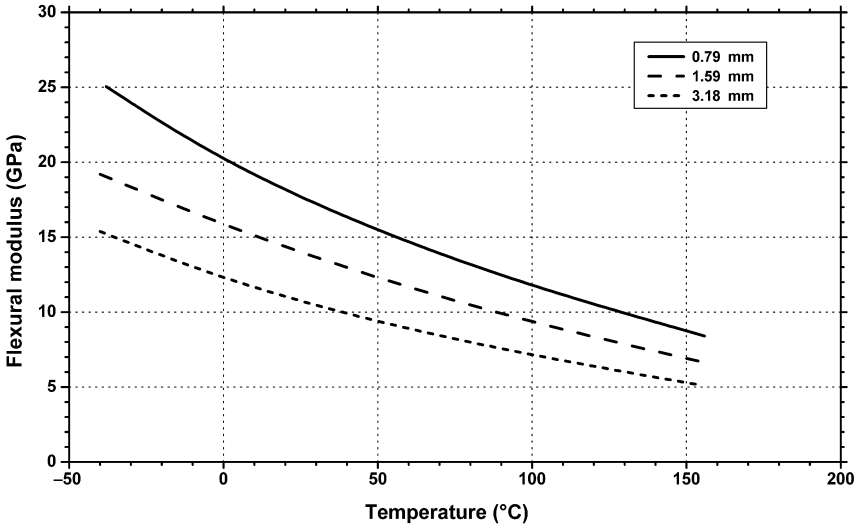


Figure 4.118 Flexural modulus vs. temperature for DuPont Zenite® LCP 6130 [10].

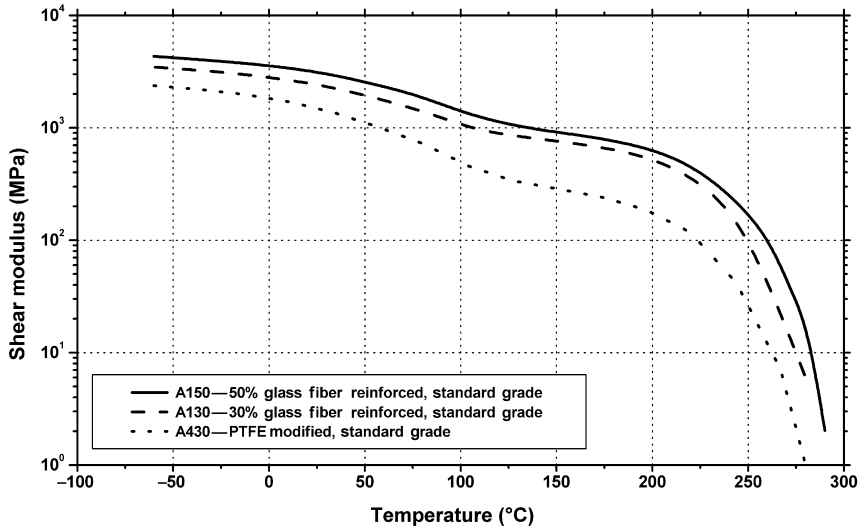


Figure 4.119 Shear modulus vs. temperature for various Celanese Vectra® LCPs.

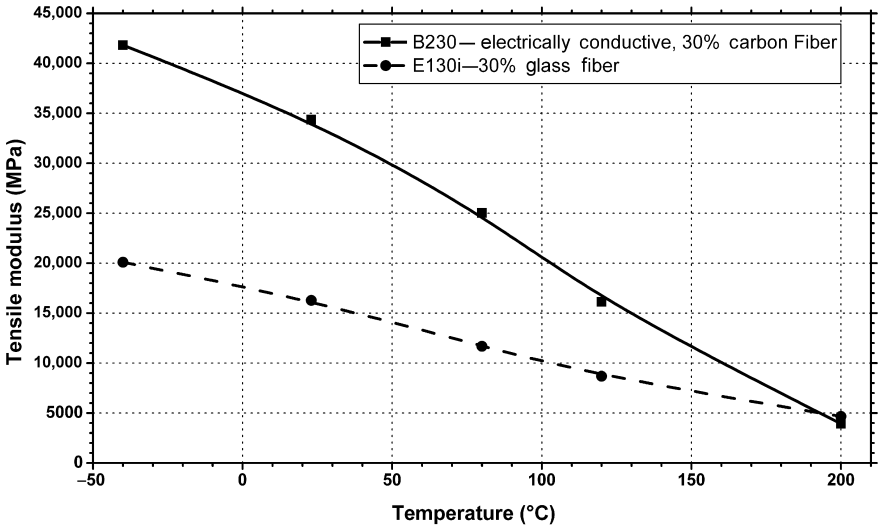


Figure 4.120 Tensile modulus vs. temperature for Celanese Vectra® LCP [9].

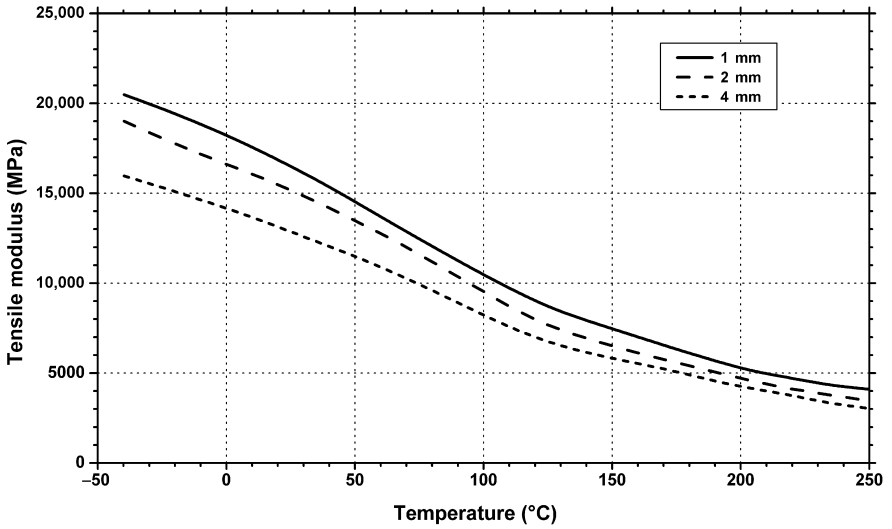


Figure 4.121 Tensile modulus vs. temperature for DuPont Zenite® LCP 6130 [11].

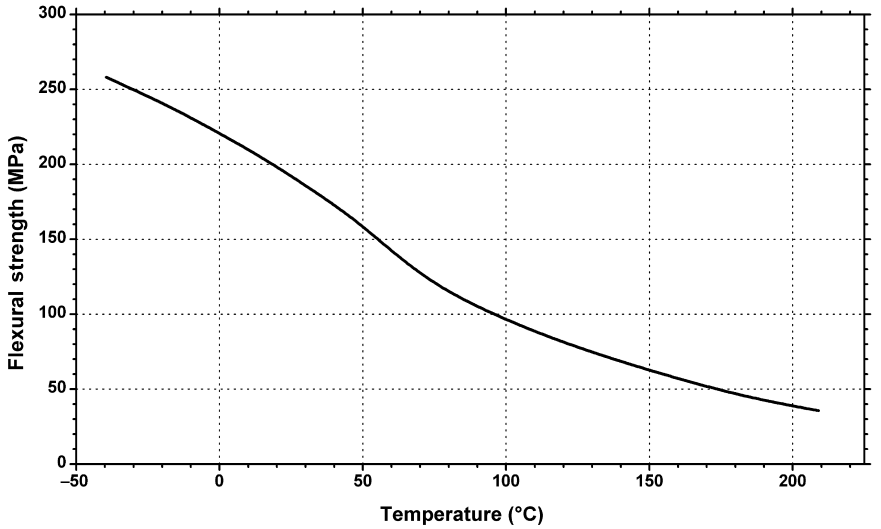


Figure 4.122 Flexural strength vs. temperature for Toray Siveras® L204G35—35% glass fiber reinforced, standard grade LCP.

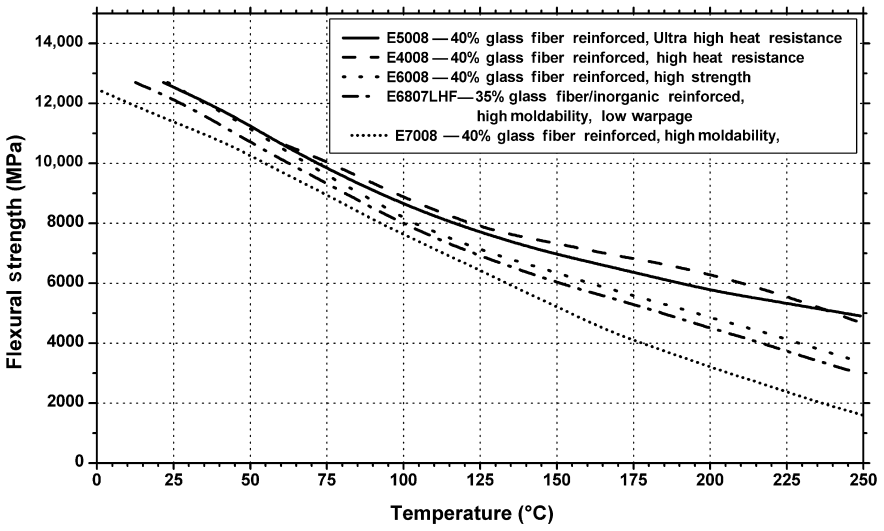


Figure 4.123 Flexural strength vs. temperature for various Sumitomo Chemical Sumikasuper® LCPs.

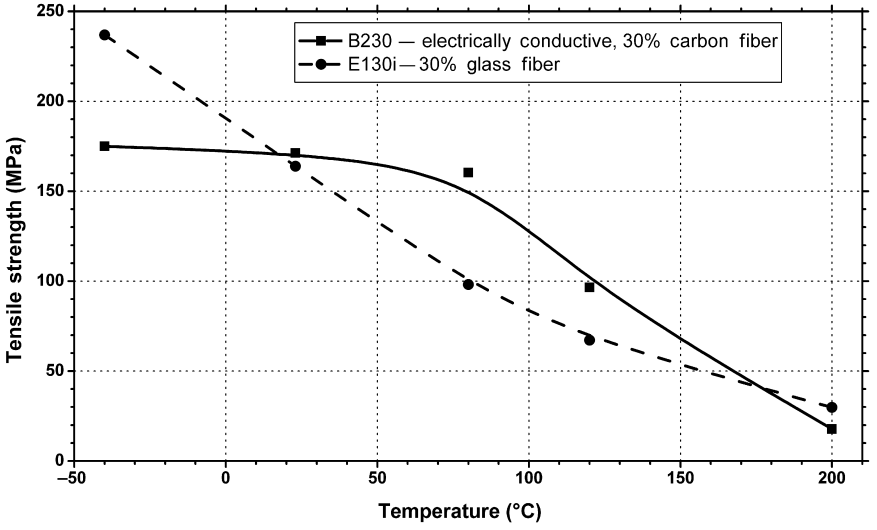


Figure 4.124 Tensile strength vs. temperature for Celanese Vectra® LCP [9].

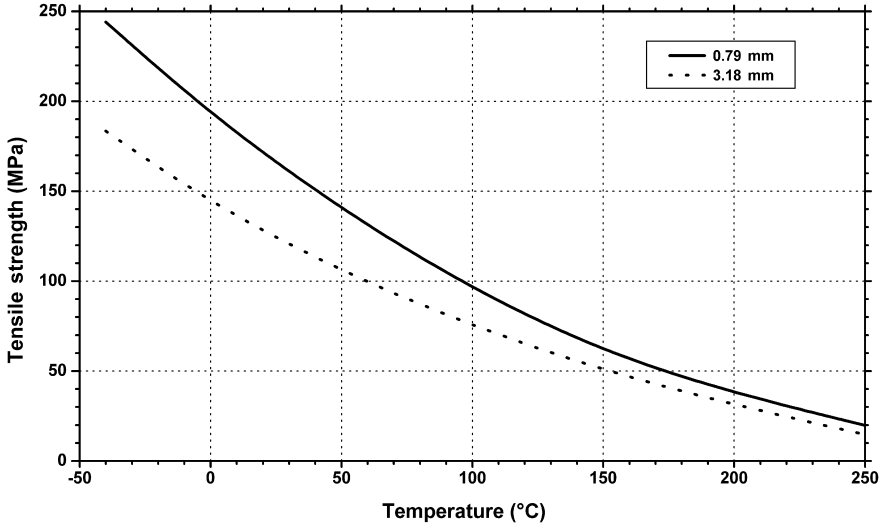


Figure 4.125 Tensile strength vs. temperature for DuPont Zenite® LCP 6130 [10].

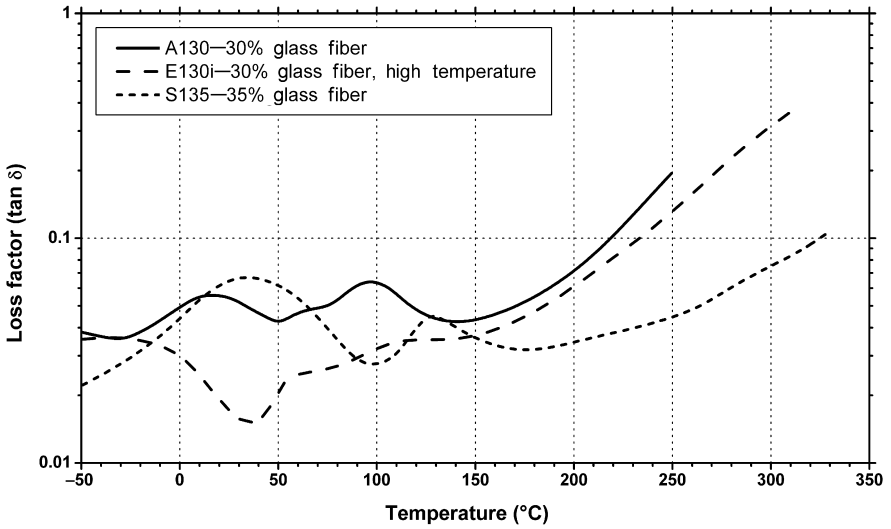


Figure 4.126 Dampening factors vs. temperature by dynamic mechanical analysis of Celanese Vectra® LCPs [9].

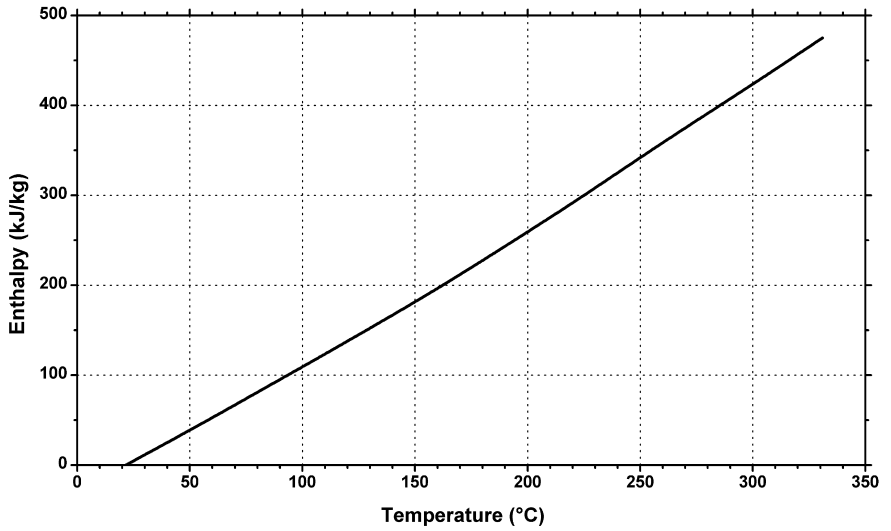


Figure 4.127 Enthalpy vs. temperature for Celanese Vectra® A130—30% glass fiber reinforced, standard grade LCP [9].

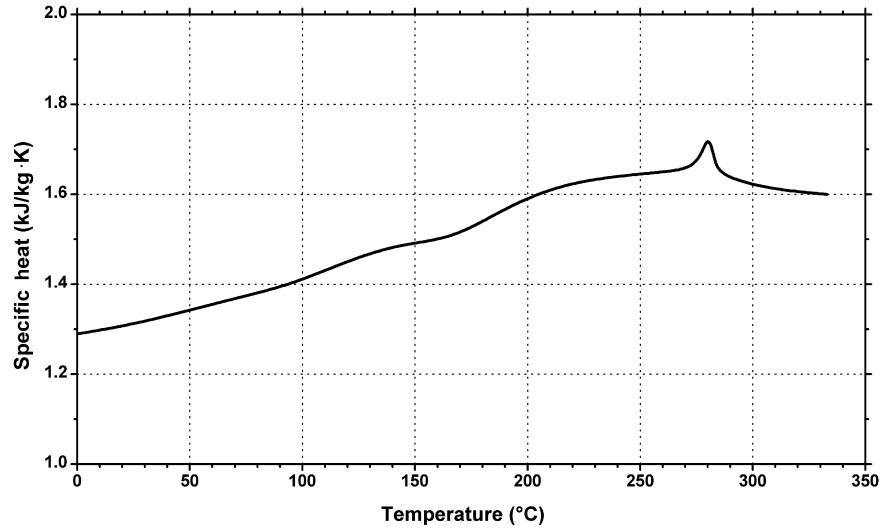


Figure 4.128 Specific heat vs. temperature for Celanese Vectra® A130—30% glass fiber reinforced, standard grade LCP [9].

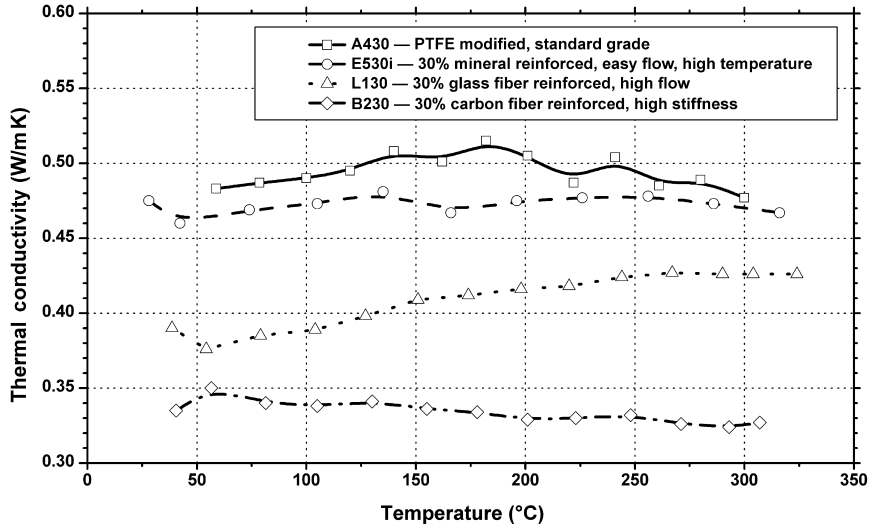


Figure 4.129 Thermal conductivity vs. temperature for various Celanese Vectra® LCPs [9].

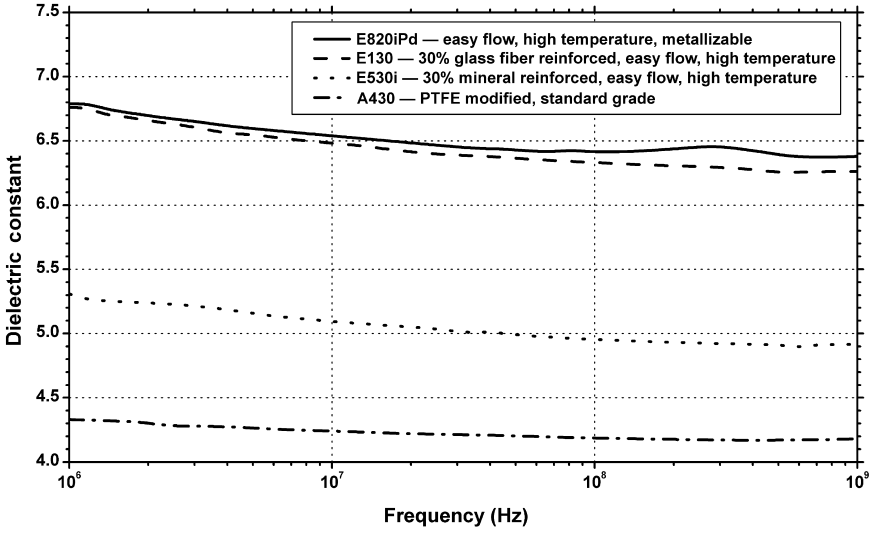


Figure 4.130 Dielectric constant vs. frequency at 23°C for various Celanese Vectra® LCPs.

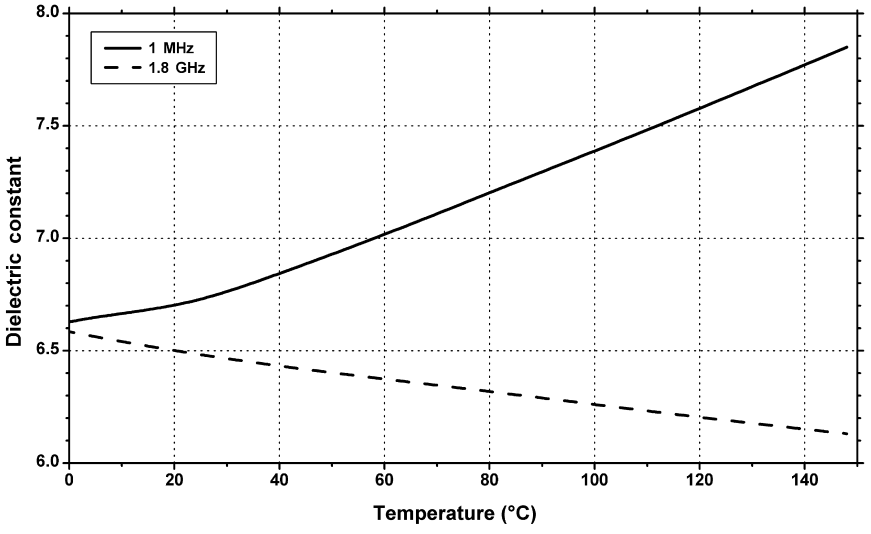


Figure 4.131 Dielectric constant vs. temperature for Celanese Vectra® E820iPd—easy flow, high temperature, metallizable LCP [9].

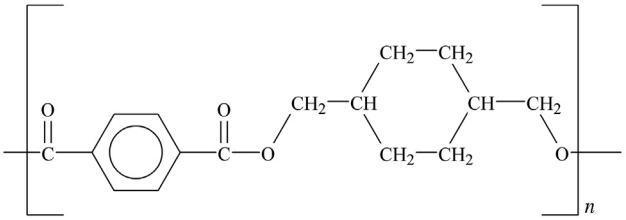


Figure 4.132 Chemical structure of polybutylene PCT polyester.

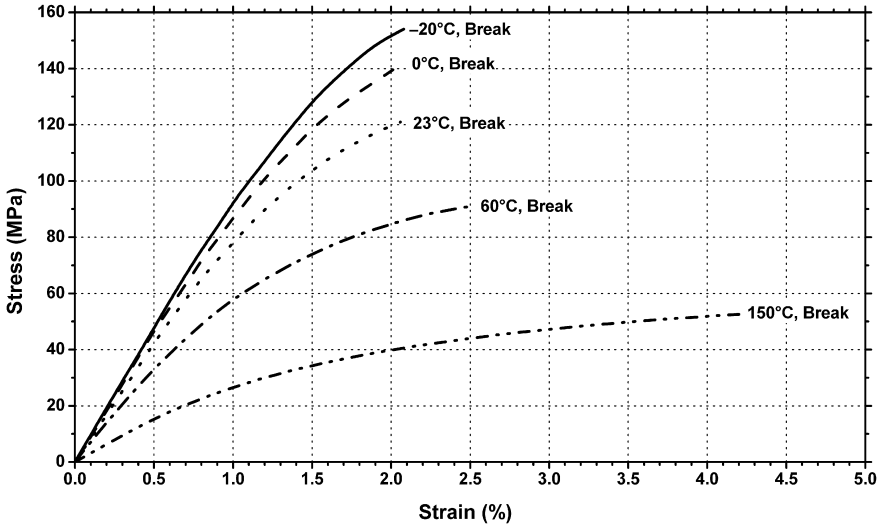


Figure 4.133 Stress vs. strain at various temperatures for Celanese Thermx® CG033—20% glass reinforced, general purpose PCT resin.

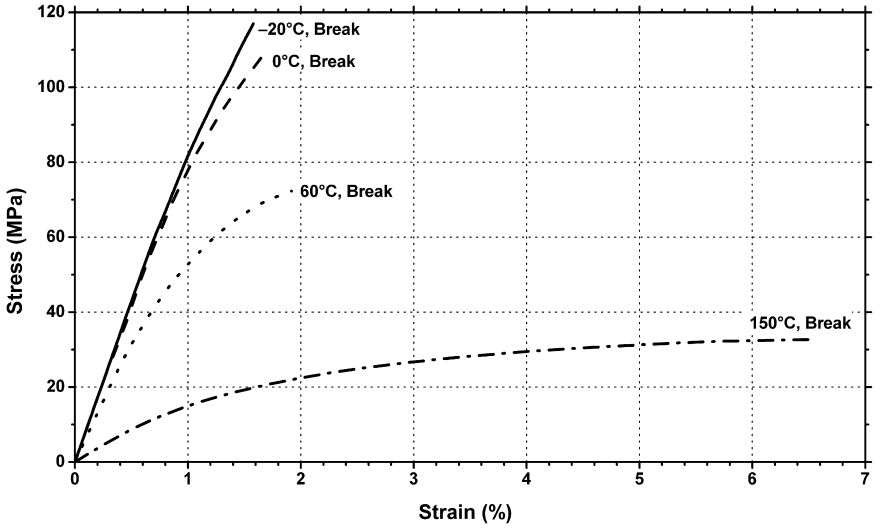


Figure 4.134 Stress vs. strain at various temperatures for Celanese Thermx® CG923—20% glass reinforced, flame retardant PCT resin.

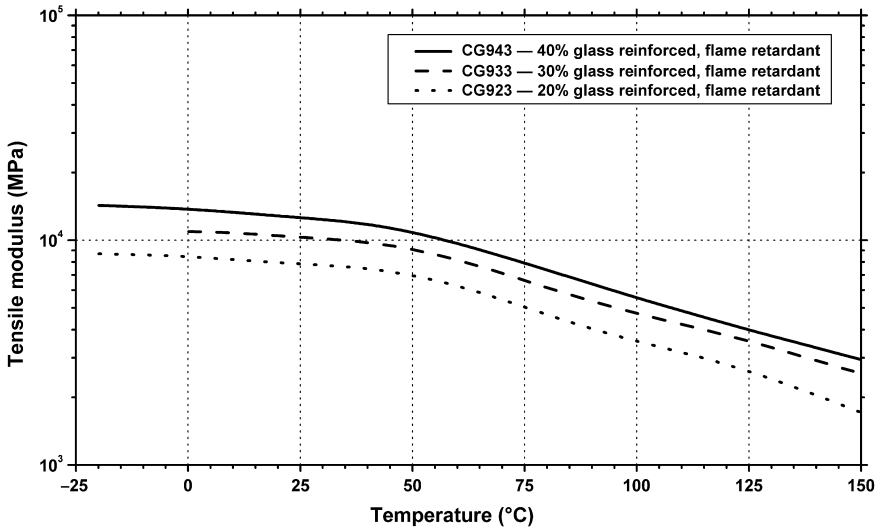


Figure 4.135 Tensile modulus vs. temperature for Celanese Thermx® glass reinforced, flame retardant PCT resins.

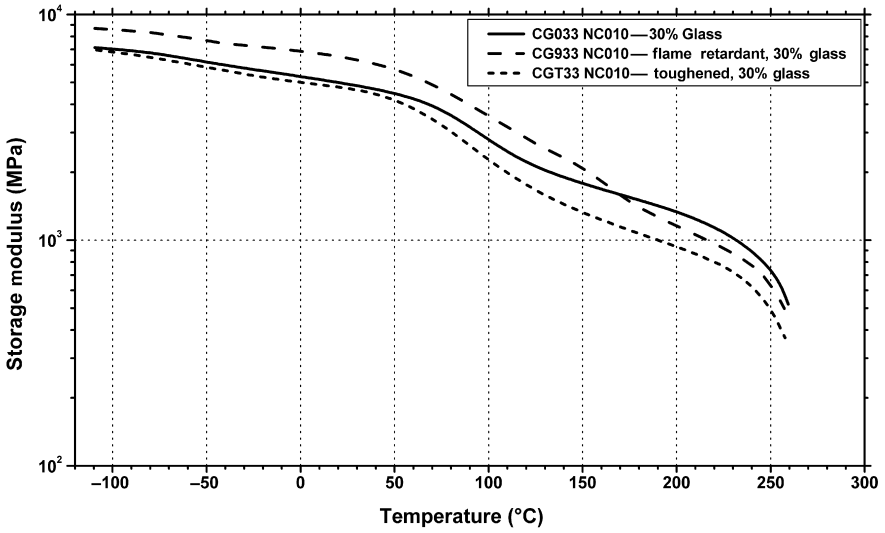


Figure 4.136 Storage modulus vs. temperature (DMA curves) for Celanese Thermx® PCT resins [12].

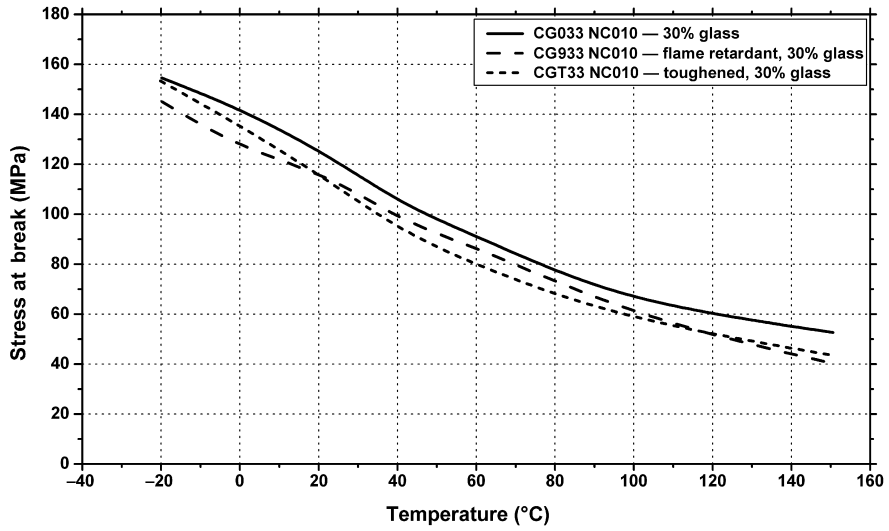


Figure 4.137 Stress at break vs. temperature (ISO 527) for Celanese Thermx® PCT resins [12].

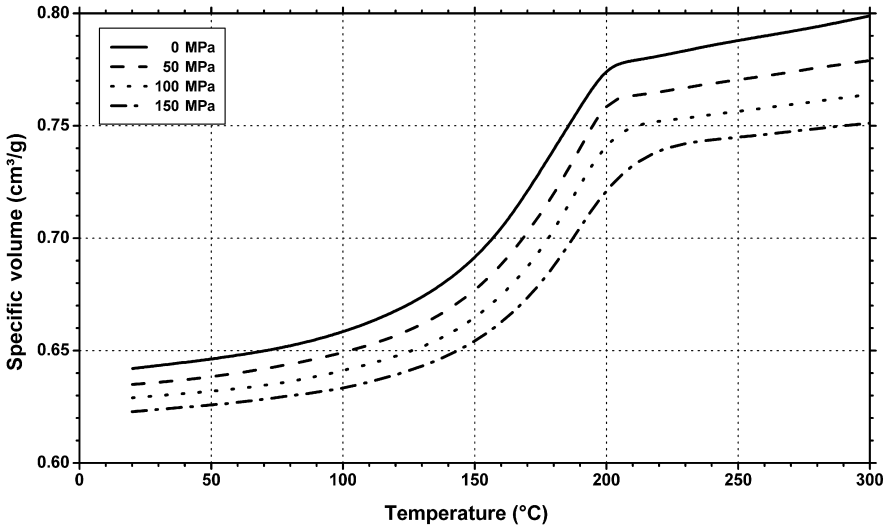


Figure 4.138 PVT for Celanese Thermx® CG923—20% glass reinforced, flame retardant PCT resin.

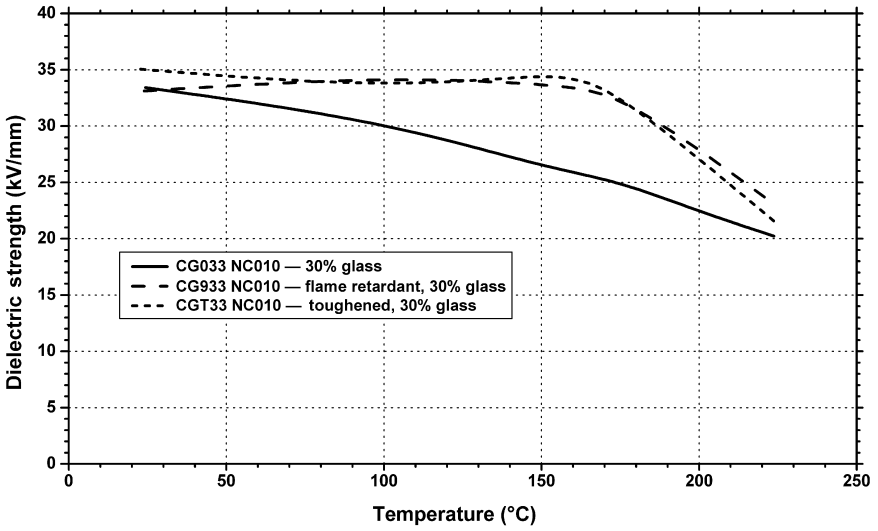


Figure 4.139 Dielectric strength vs. temperature for Celanese Thermx® PCT resins (IEC60243-1 1.6 mm) [12].

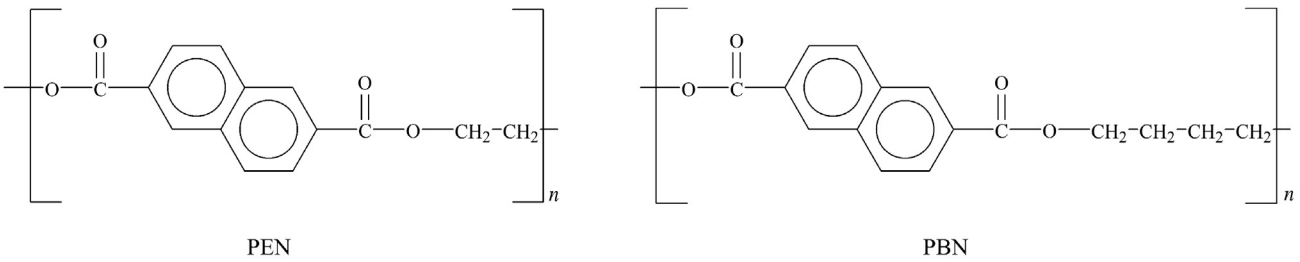


Figure 4.140 Structures of PEN and PBN.

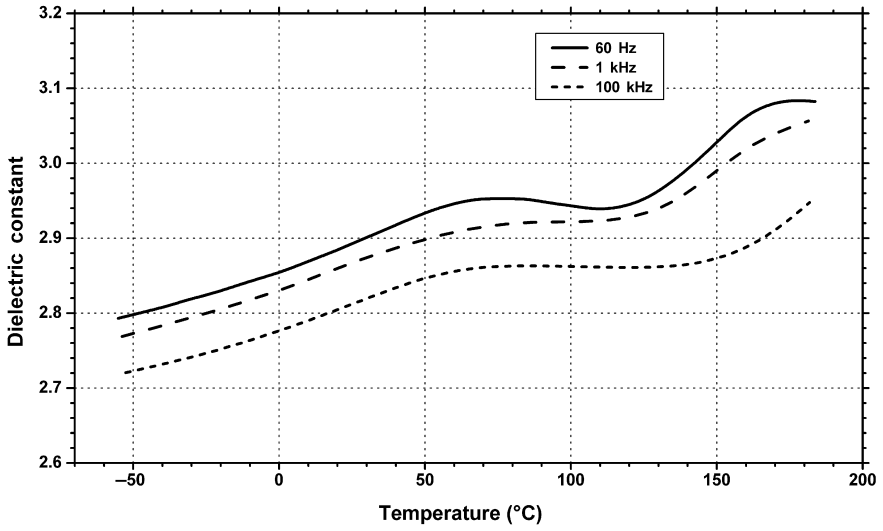


Figure 4.141 Dielectric constants of PEN as a function of temperature at different frequencies [13].

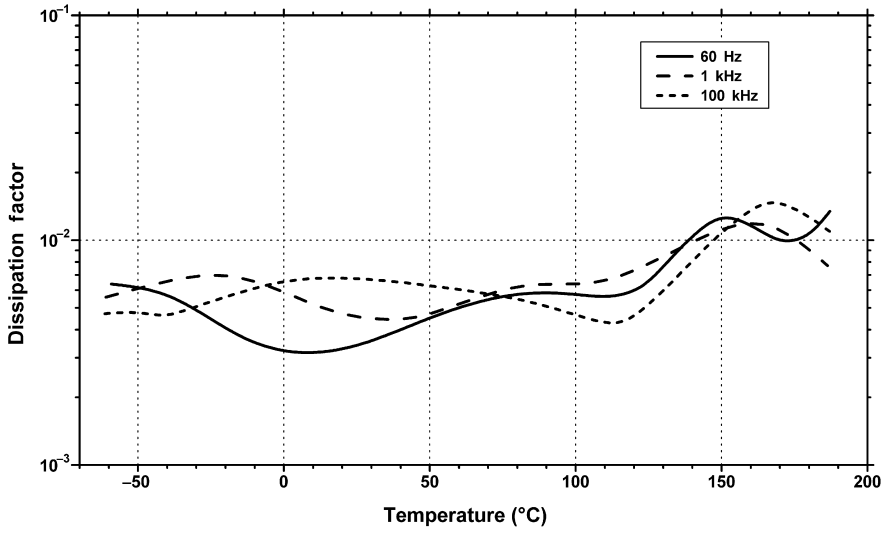


Figure 4.142 Dissipation factors of PEN as a function of temperature at different frequencies [13].

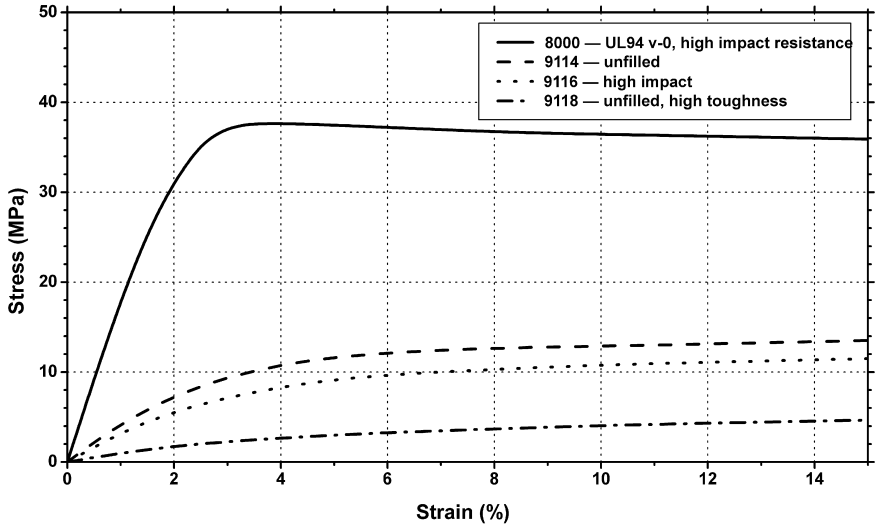


Figure 4.143 Stress vs. strain at 23°C for Ticona Vandar® polyester alloy/blend resins (alloy type unspecified) [14].

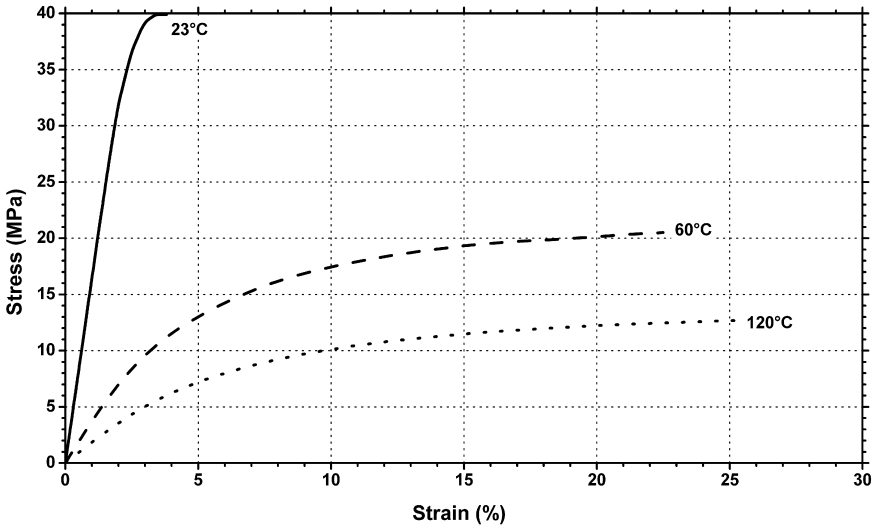


Figure 4.144 Stress vs. strain at various temperatures for Ticona Vandar® 2100—unreinforced (alloy type unspecified) polyester alloy/blend resin [14].

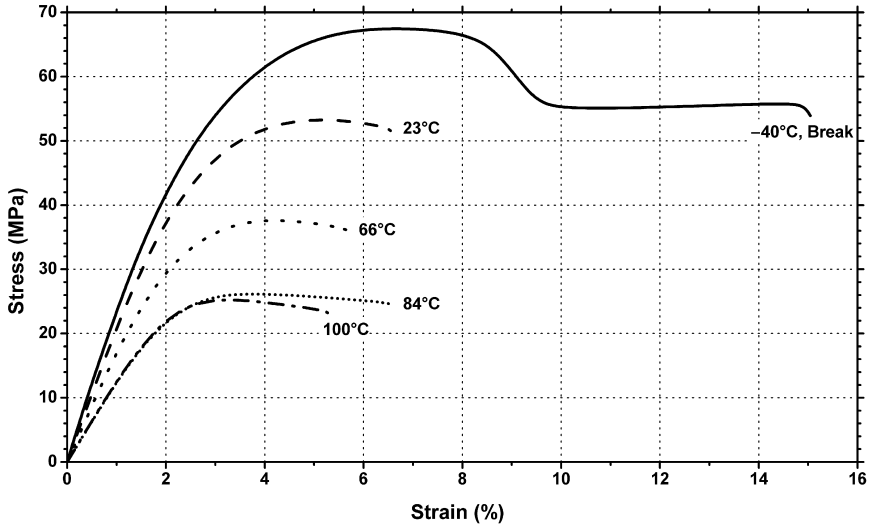


Figure 4.145 Stress vs. strain at various temperatures for SABIC Innovative Plastics Xenoy® 2230—PET/PC alloy polyester alloy/blend resin.

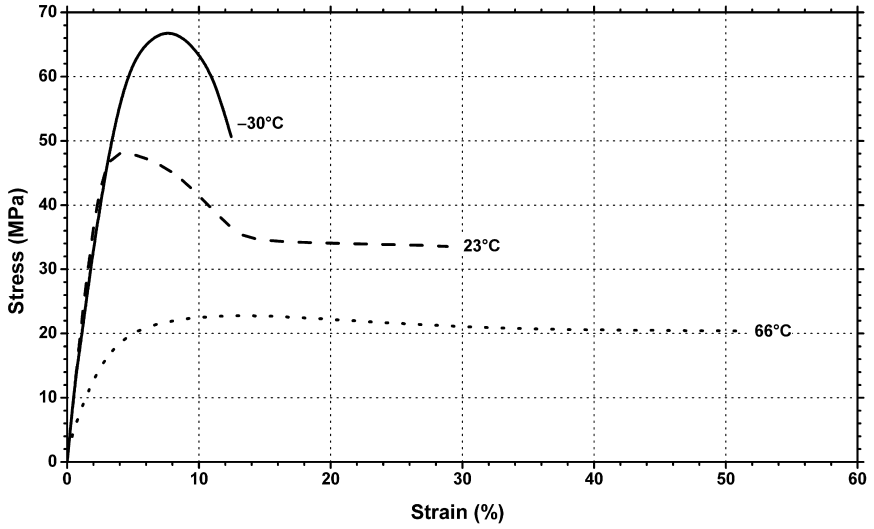


Figure 4.146 Stress vs. strain at various temperatures for SABIC Innovative Plastics Xenoy® 6127—PBT/PC alloy, unreinforced polyester alloy/blend resin.

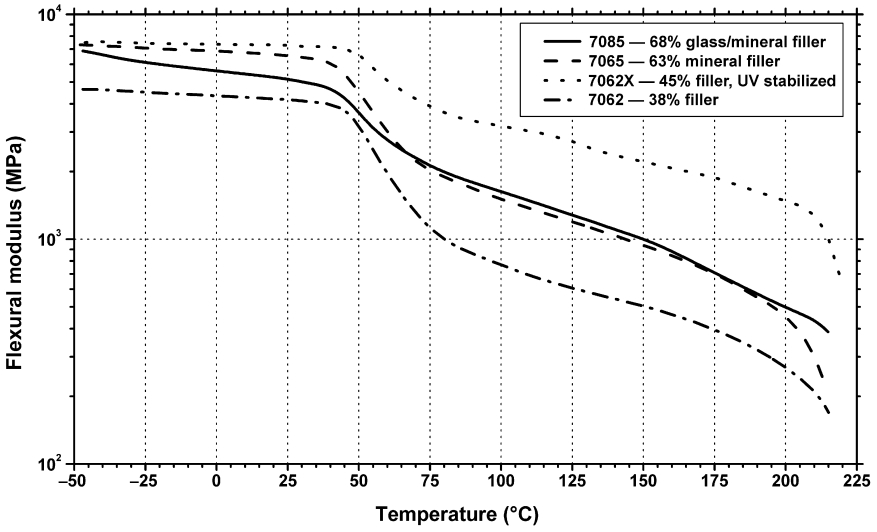


Figure 4.147 Flexural modulus vs. temperature for SABIC Innovative Plastics Enduran® PBT/PET blend polyester alloy/blend resins.

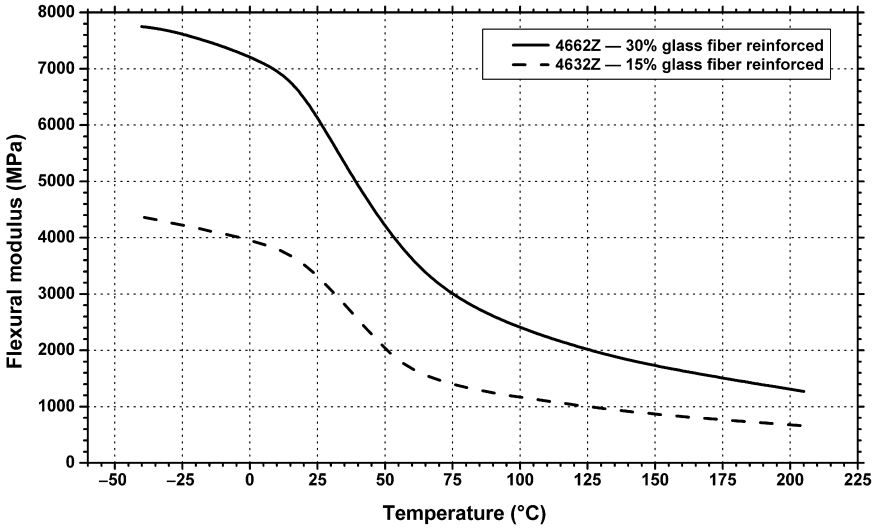


Figure 4.148 Flexural modulus vs. temperature for Ticona Vandar® high stiffness polyester alloy/blend resins [14].

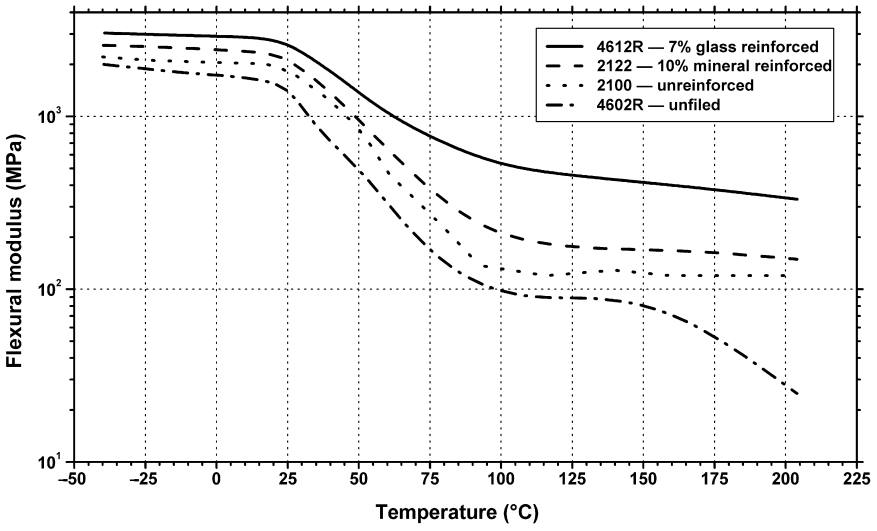


Figure 4.149 Flexural modulus vs. temperature for Ticona Vandar® low stiffness polyester alloy/blend resins [14].

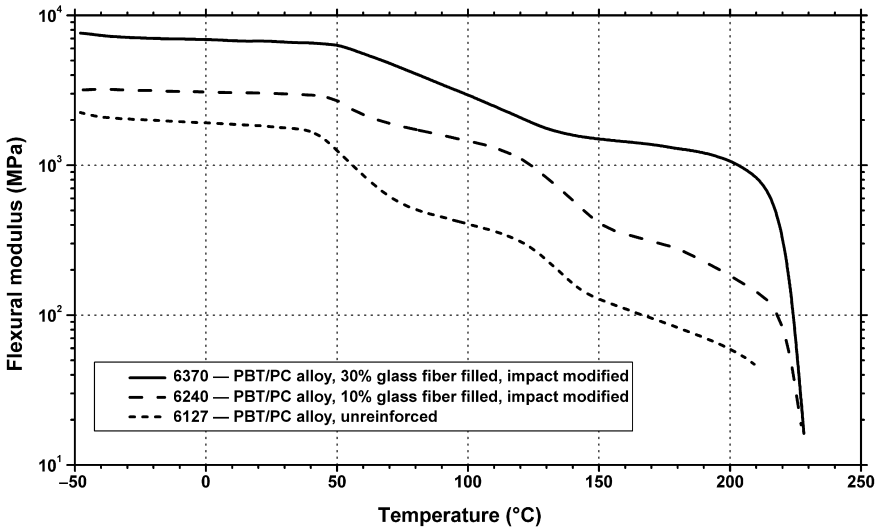


Figure 4.150 Flexural modulus vs. temperature for SABIC Innovative Plastics Xenoy® PBT/PC alloy polyester alloy/blend resins.

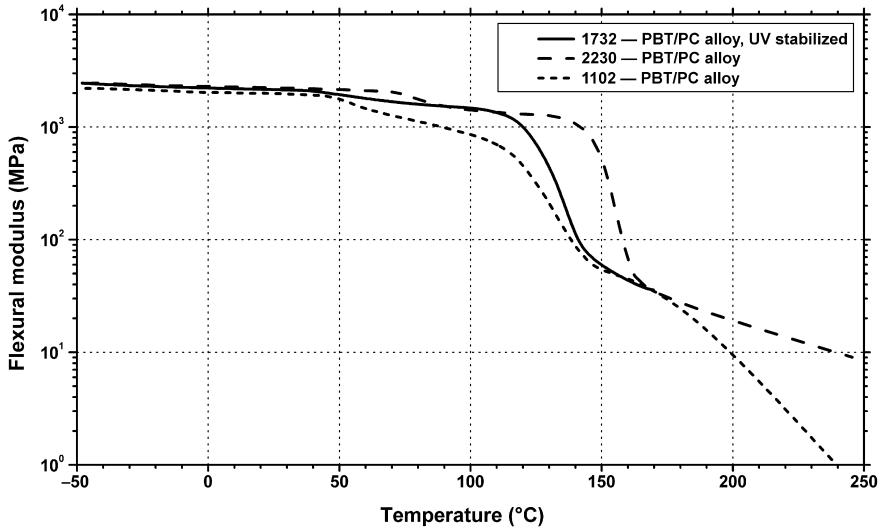


Figure 4.151 Flexural modulus vs. temperature for SABIC Innovative Plastics Xenoy® polyester alloy/blend resins.

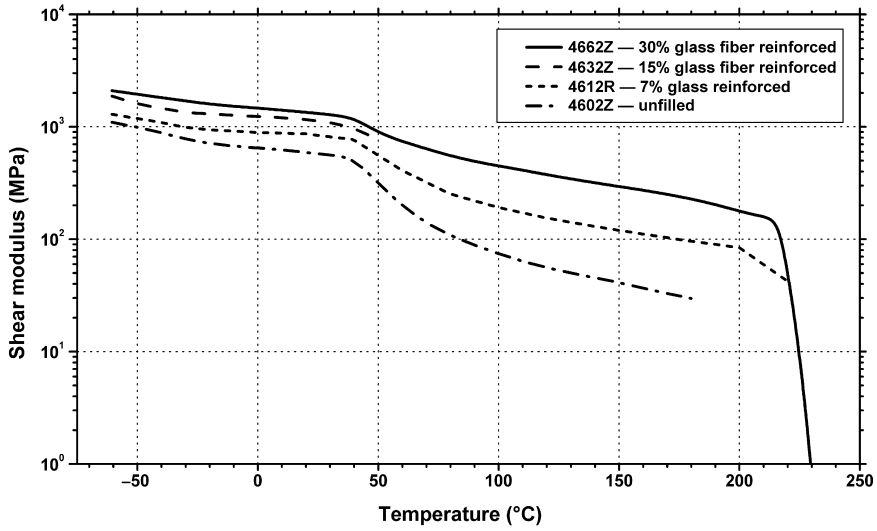


Figure 4.152 Shear modulus vs. temperature for Ticona Vandar® polyester alloy/blend resins [14].

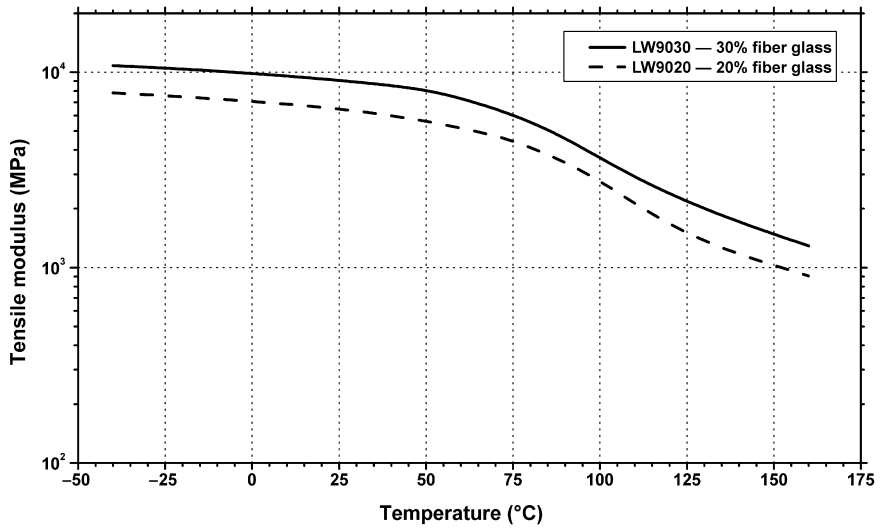


Figure 4.153 Tensile modulus vs. temperature for DuPont Crastin® PBT/ASA polyester alloy/blend resins.

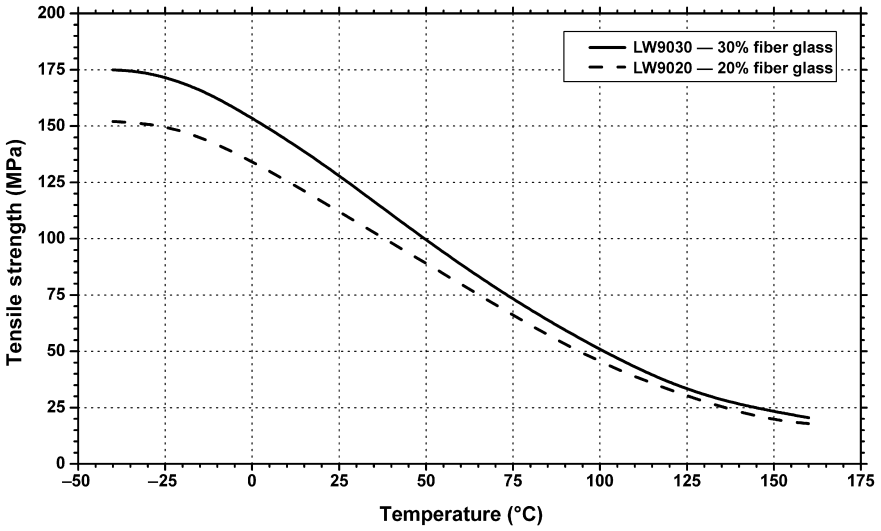


Figure 4.154 Tensile strength vs. temperature for DuPont Crastin® PBT/ASA polyester alloy/blend resins.

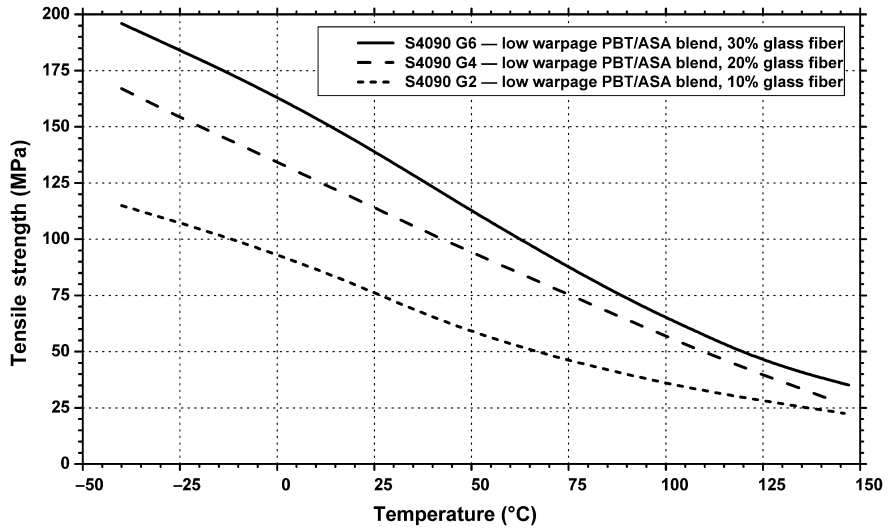


Figure 4.155 Tensile strength vs. temperature for BASF Ultradur® S4090—low warpage PBT/ASA blend polyester alloy/blend resins.

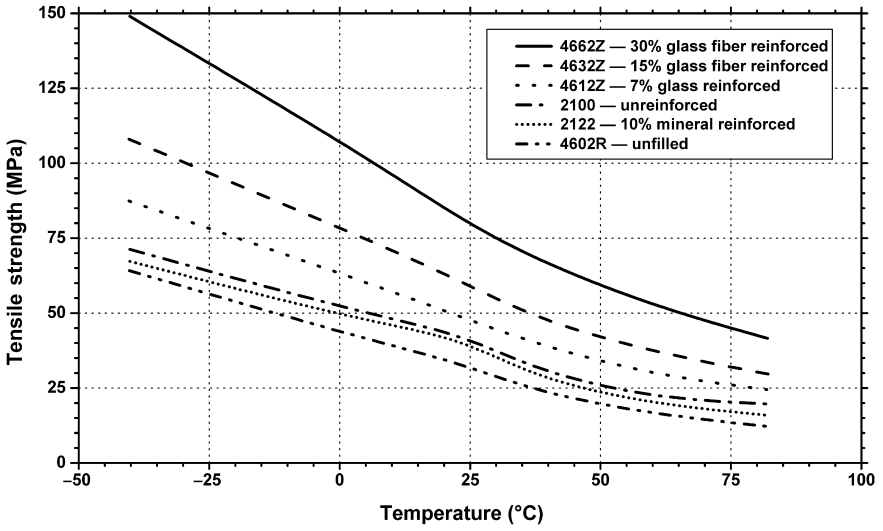


Figure 4.156 Tensile strength vs. temperature for Ticona Vandar® polyester alloy/blend resins [14].

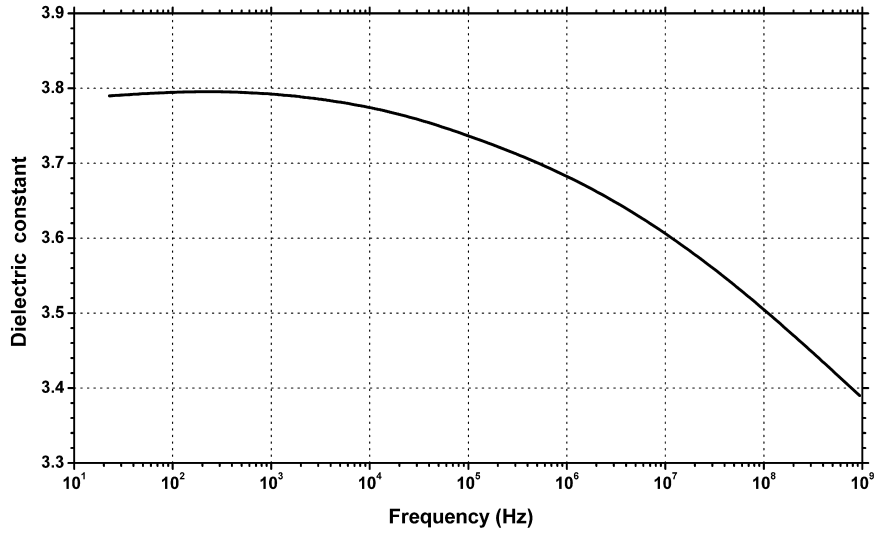


Figure 4.157 Dielectric constant vs. frequency at 23°C for BASF Ultradur® S4090 G4—low warpage PBT/ASA blend, 20% glass fiber polyester alloy/blend resin.

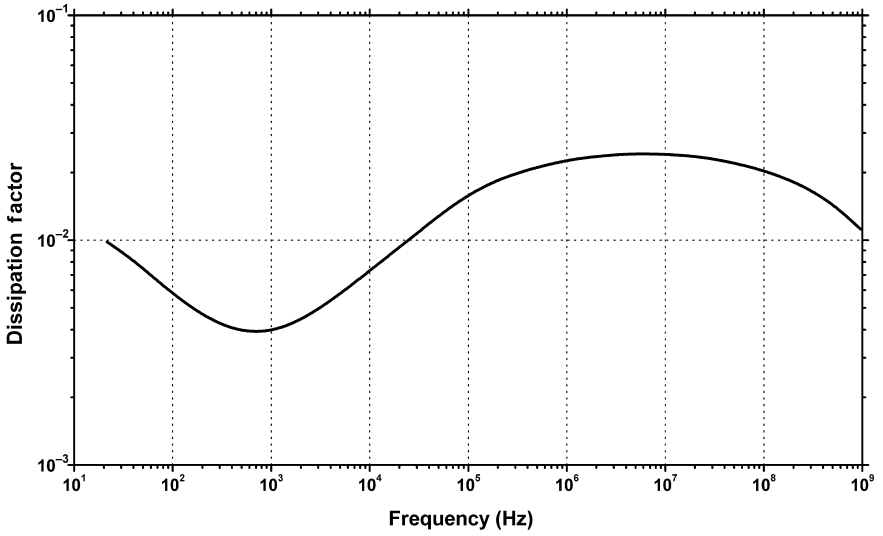


Figure 4.158 Dissipation factor vs. frequency at 23°C for BASF Ultradur® S4090 G4—low warpage PBT/ASA blend, 20% glass fiber polyester alloy/blend resin.

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5 Polyimides

This chapter covers a series of plastics of which the imide group is an important part of the molecule. The imide group is formed by a condensation reaction of an aromatic anhydride group with an aromatic amine as shown in Figure 5.1.

This group is very much thermally stable. Aliphatic imides are possible, but the thermal stability is reduced, and thermal stability is one of the main reasons to use an imide type of polymer.

5.1 Polyimide (PI)

PIs are high-temperature engineering polymers originally developed by the DuPont Company. PIs exhibit an exceptional combination of thermal stability (>500°C), mechanical toughness, and chemical resistance. They have excellent dielectric properties and an inherently low coefficient of thermal expansion. They are formed from diamines and dianhydrides such as the two shown in Figure 5.2.

Many other diamines and several other dianhydrides may be chosen to tailor the final properties of a polymer whose structure is like that shown in Figure 5.3.

DuPont makes a PI called "*thermoplastic polyimide*." The structure of this polymer is shown in Figure 5.4 and might be called a polyetherimide.

The data for polyimides is split into two parts, one for typical PIs (like Figure 5.3) and the other for thermoplastic polyimides (like Figure 5.4)

Manufacturers and trade names: DuPont Kapton®, Vespel®, Ube Industries Upilex®-S, Upitol®.

Applications and uses: aerospace, flexible printed circuits, automotive, heaters, bar code labels, pressure-sensitive tape, electrical insulation, and safety.

5.1.1 Standard PIs

Data for standard PI polymers are contained in Figures 5.5–5.32.

5.1.2 Thermoplastic PIs

Data for thermoplastic PI polymers are contained in Table 5.1 and Figures 5.33–5.46.

5.2 Polyamide–Imide (PAI)

PAIs are thermoplastic amorphous polymers that have useful properties:

- Exceptional chemical resistance
- Outstanding mechanical strength
- Excellent thermal stability
- Performs from cryogenic up to 260°C
- Excellent electrical properties

The monomers used to make PAI resin are shown in Figure 5.47.

When these monomers are reacted, carbon dioxide, rather than water, is generated. The closer the monomer ratio is to 1:1, the higher the molecular weight of the polymer shown in Figure 5.48. Other monomer combinations are shown in Tables 5.2 and 5.3.

Manufacturers and trade names: Solvay Advanced Polymers Torlon®.

Applications and uses: electrical connectors, switches and relays, thrust washers, spline liners, valve seats, bushings, bearings, wear rings, cams, and other applications requiring strength at high temperature and resistance to wear.

Data for PAI polymers are contained in Tables 5.4–5.8 and Figures 5.49–5.57.

Composition details of Solvay Torlon® PAIs used in Tables 5.4–5.8 and Figures 5.49–5.57:

- Torlon® 4203L: 3% titanium dioxide, 0.5% fluorocarbon
- Torlon® 4301: 12% graphite powder, 3% fluorocarbon

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
DOI: http://dx.doi.org/10.1016/B978-0-323-31016-1.00005-2
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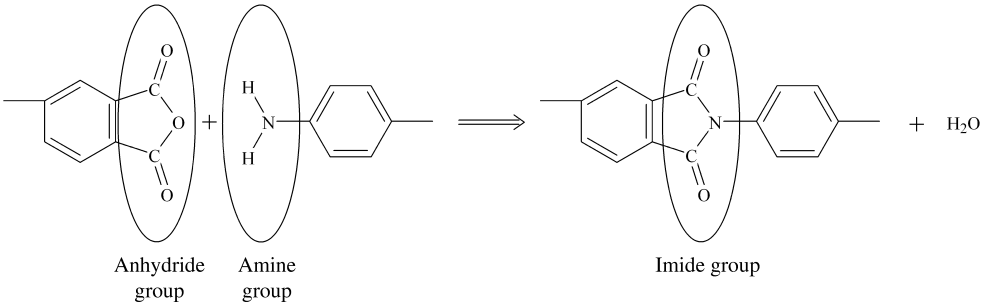


Figure 5.1 Reaction of amine with anhydride to form an imide.

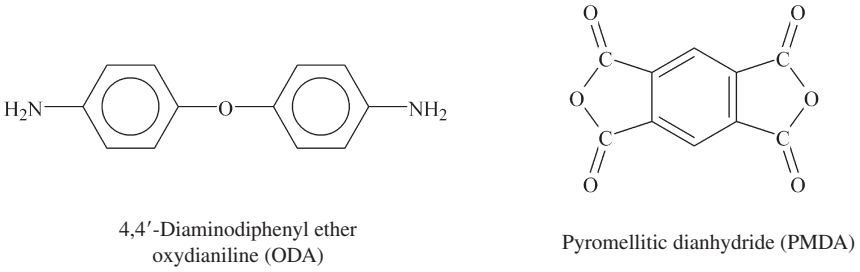


Figure 5.2 Chemical structures of monomers used to make PIs.

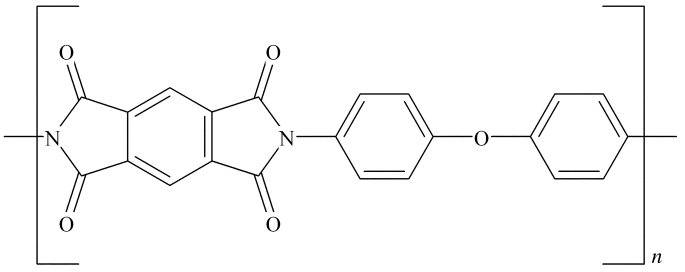


Figure 5.3 Chemical structure of a typical PI.

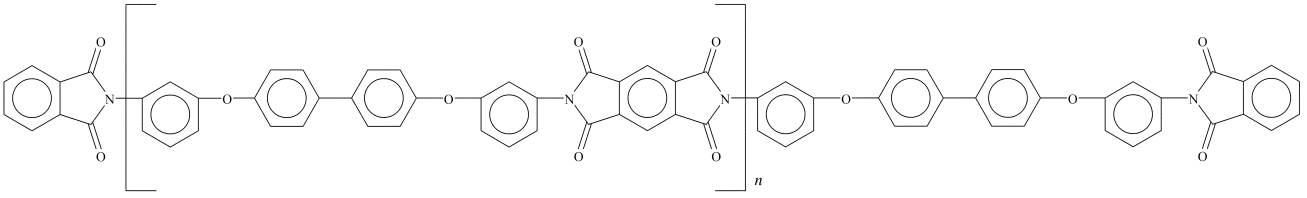


Figure 5.4 Chemical structure of the thermoplastic PI DuPont Vespel® TP-8000 series [1].

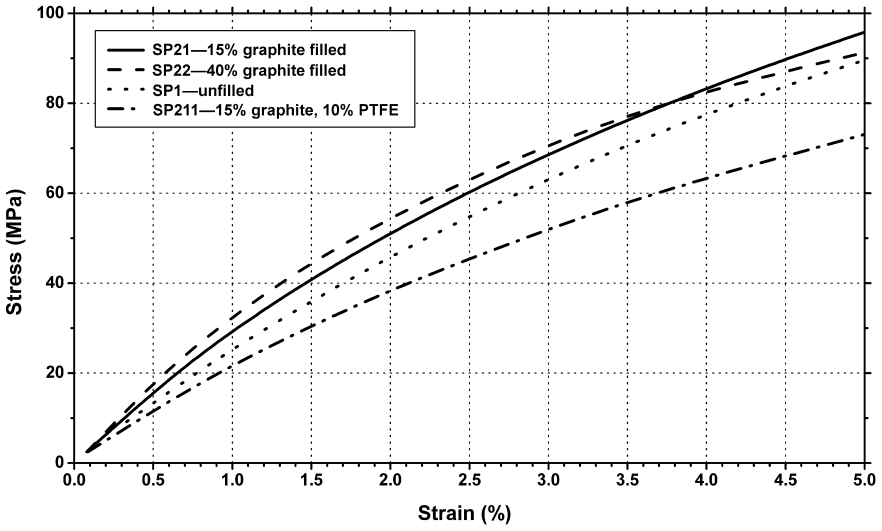


Figure 5.5 Stress vs. strain at 23°C in compression for DuPont Vespel® machined PI [2].

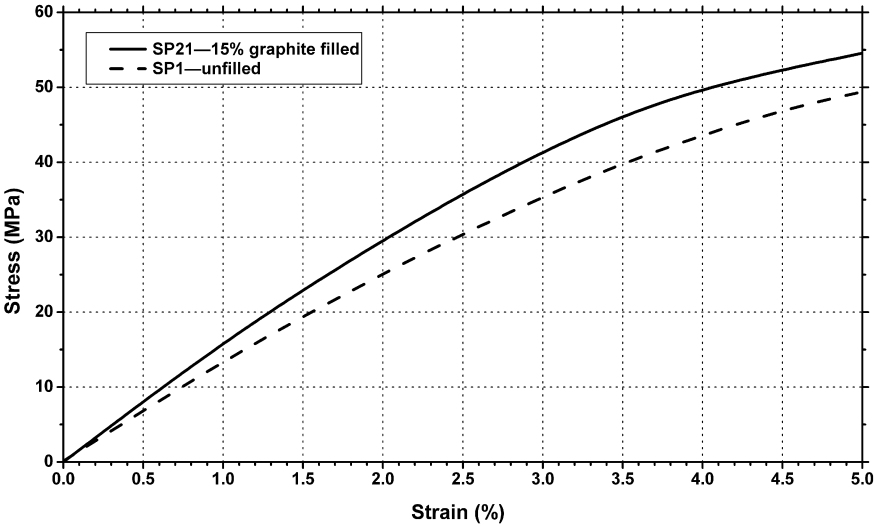


Figure 5.6 Stress vs. strain at 300°C in compression for DuPont Vespel® machined PI [2].

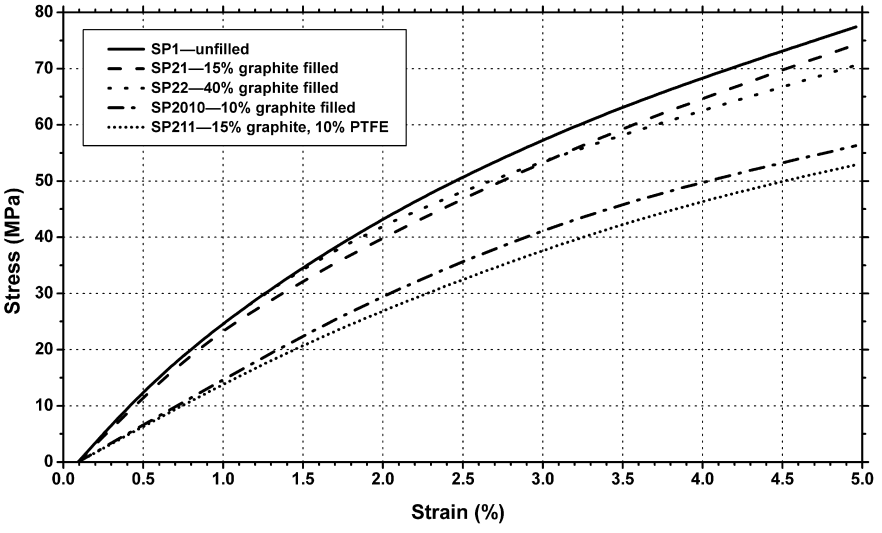


Figure 5.7 Stress vs. strain at 23°C in compression parallel to forming for DuPont Vespel® direct-formed PI [2].

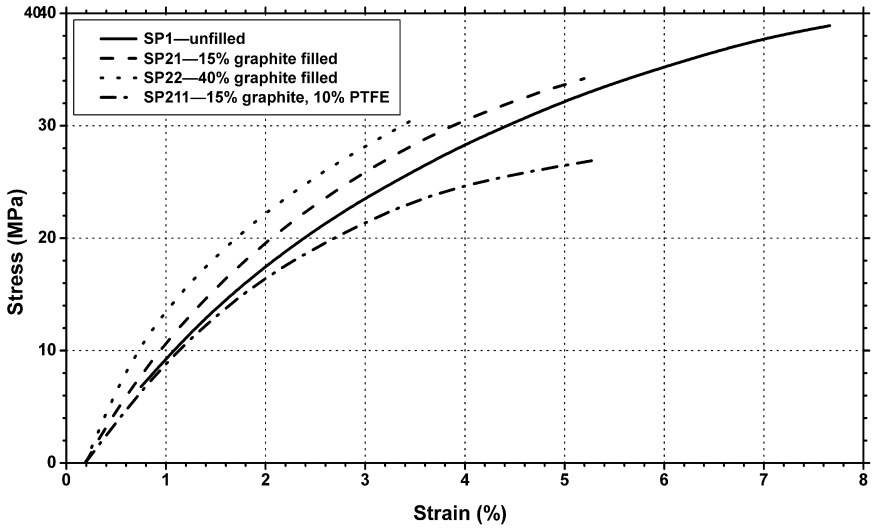


Figure 5.8 Stress vs. strain at 260°C in tension parallel to forming for DuPont Vespel® direct-formed PI [2].

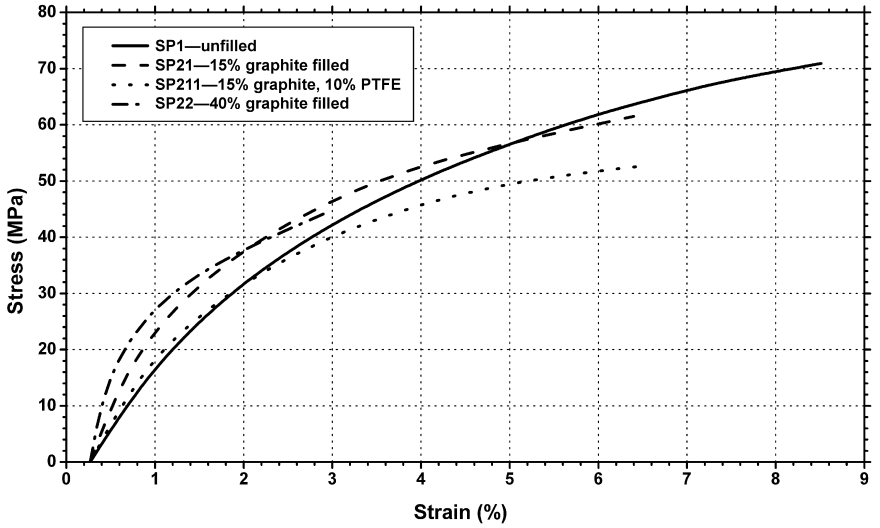


Figure 5.9 Stress vs. strain at 23°C in tension perpendicular to forming for DuPont Vespel® direct-formed PI [2].

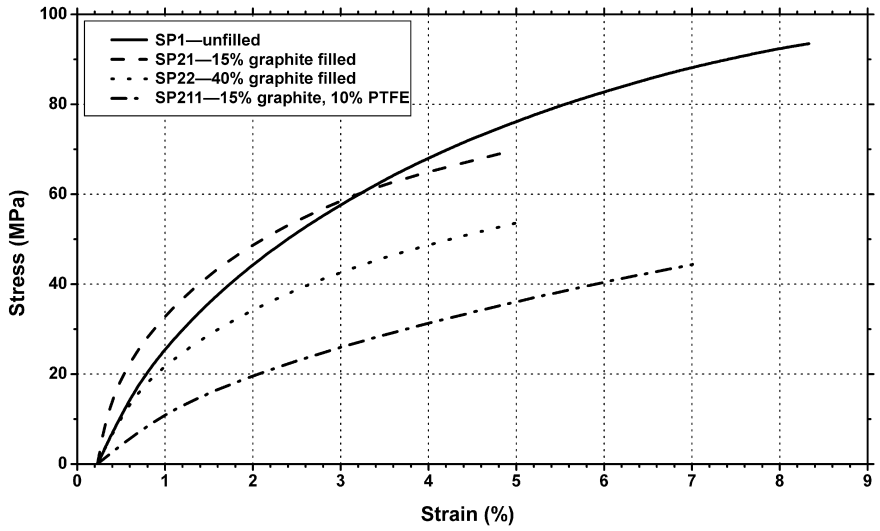


Figure 5.10 Stress vs. strain at 23°C in tension perpendicular to forming for DuPont Vespel® machined PI [2].

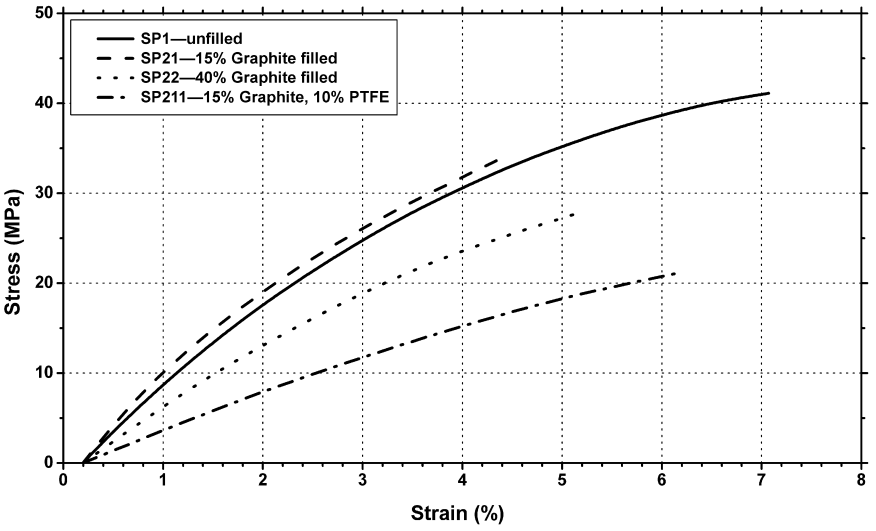


Figure 5.11 Stress vs. strain at 260°C in tension for DuPont Vespel® machined PI [2].

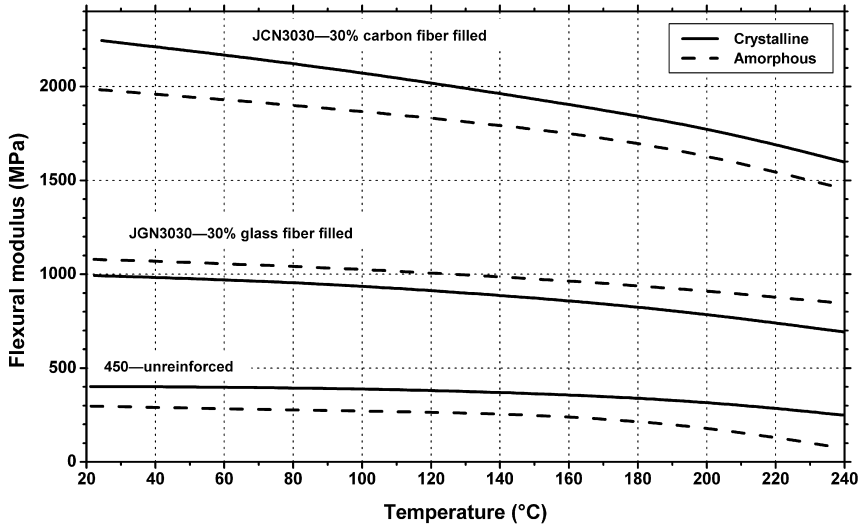


Figure 5.12 Flexural modulus vs. temperature for Mitsui Chemicals Aurum® PI resins.

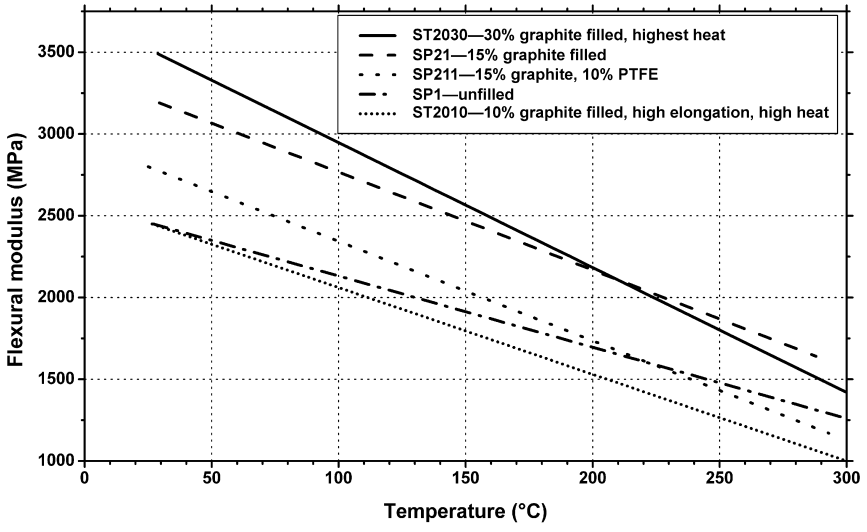


Figure 5.13 Flexural modulus vs. temperature for DuPont Vespel® direct-formed PI [2].

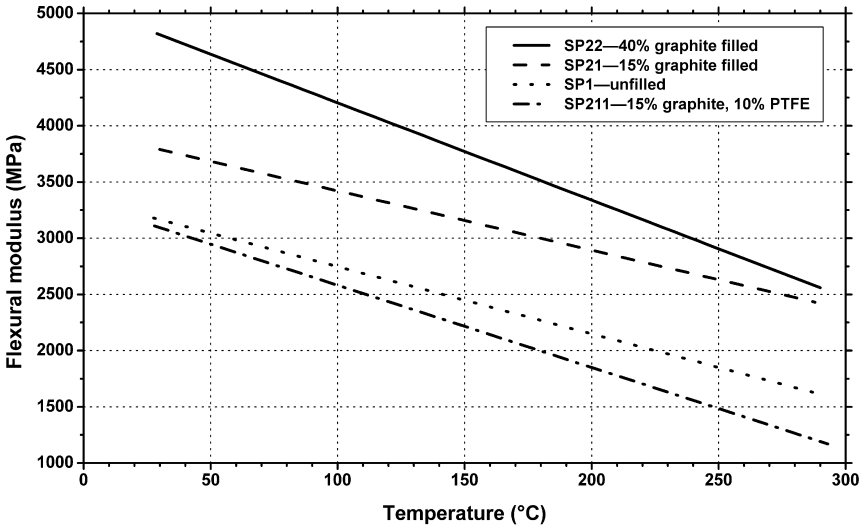


Figure 5.14 Flexural modulus vs. temperature for DuPont Vespel® machined PI [2].

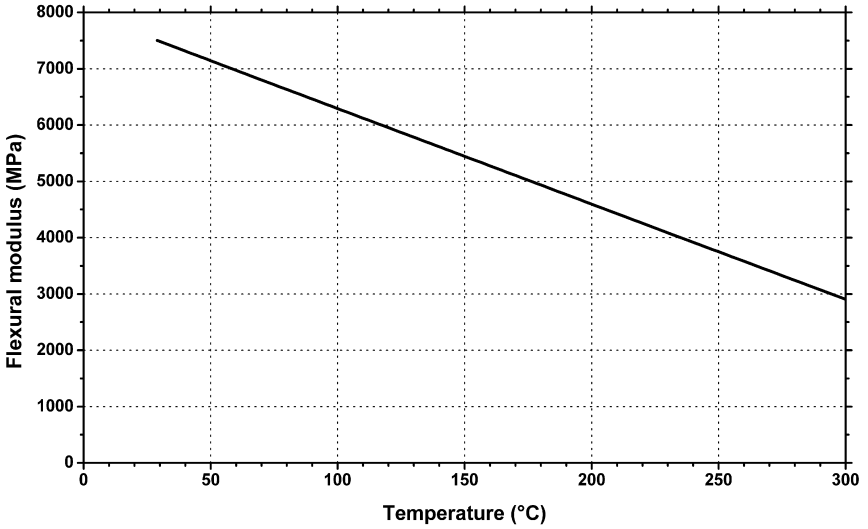


Figure 5.15 Flexural modulus vs. temperature for Ube Industries Upitol® SA 101 PI.

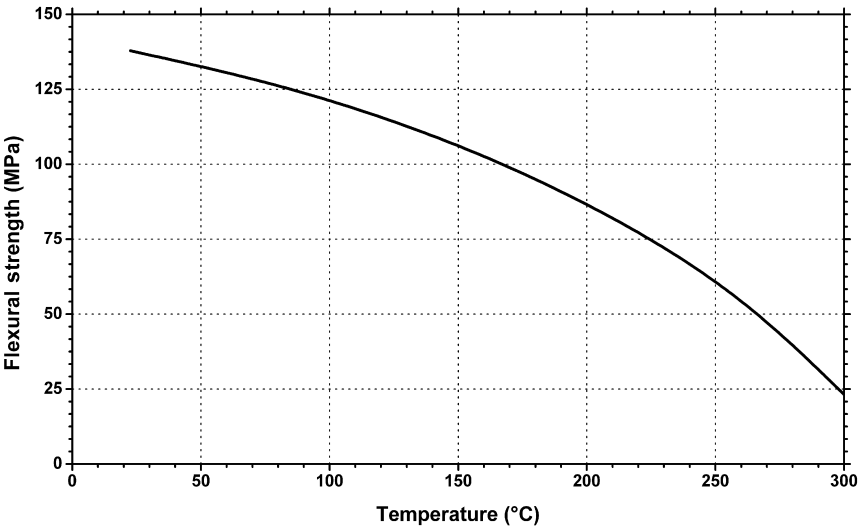


Figure 5.16 Flexural strength vs. temperature for Ube Industries Upitol® SA 101 PI.

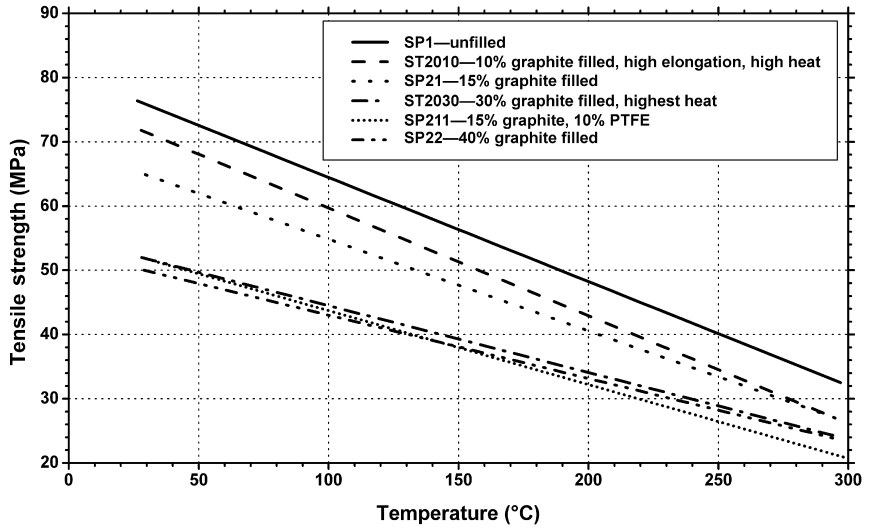


Figure 5.17 Tensile strength vs. temperature for DuPont Vespel® direct-formed PI [2].

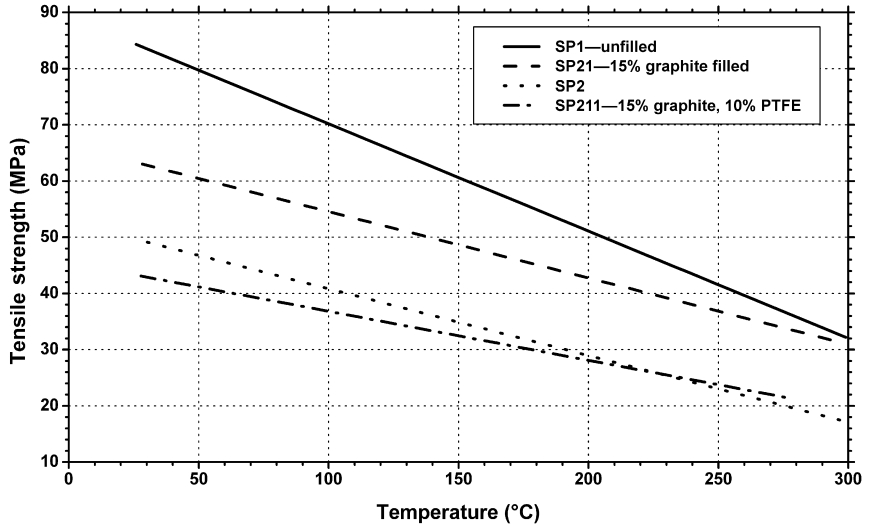


Figure 5.18 Tensile strength vs. temperature for DuPont Vespel® machined PI [2].

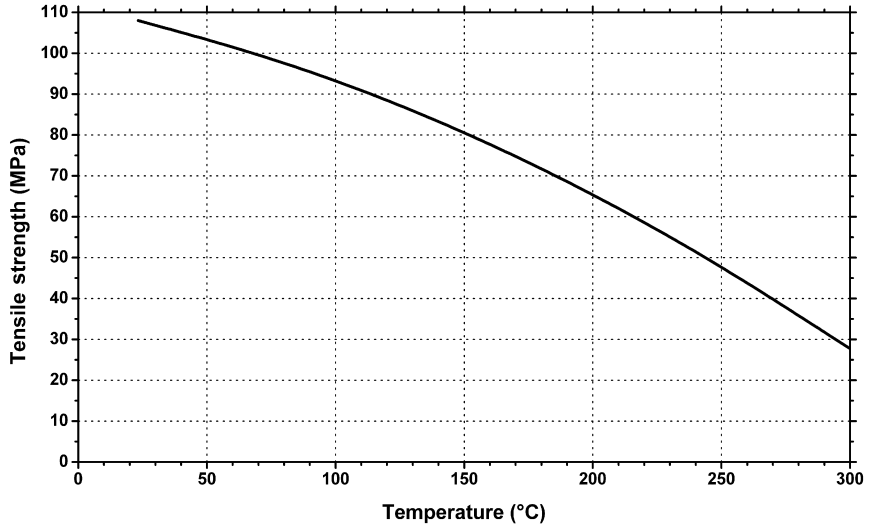


Figure 5.19 Tensile strength vs. temperature for Ube Industries Upitol® SA 101 PI.

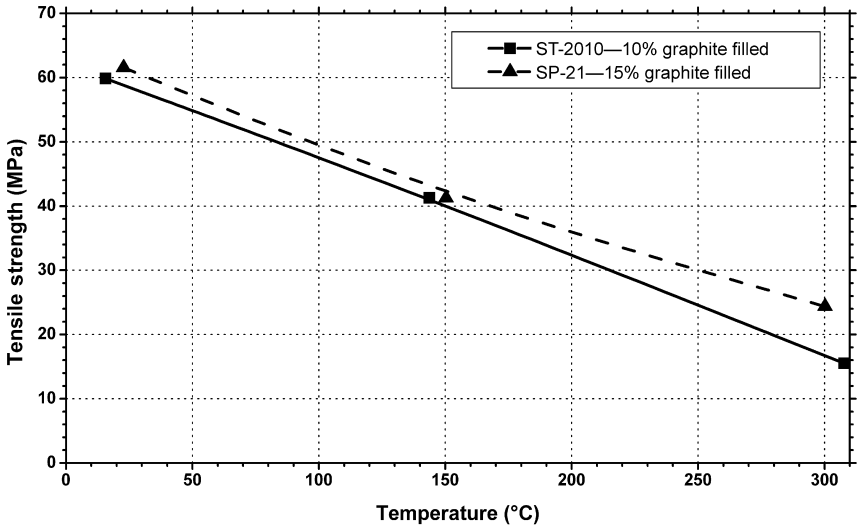


Figure 5.20 Tensile strength vs. temperature for DuPont Vespel® SP-21 and ST-2010 PI resins [3].

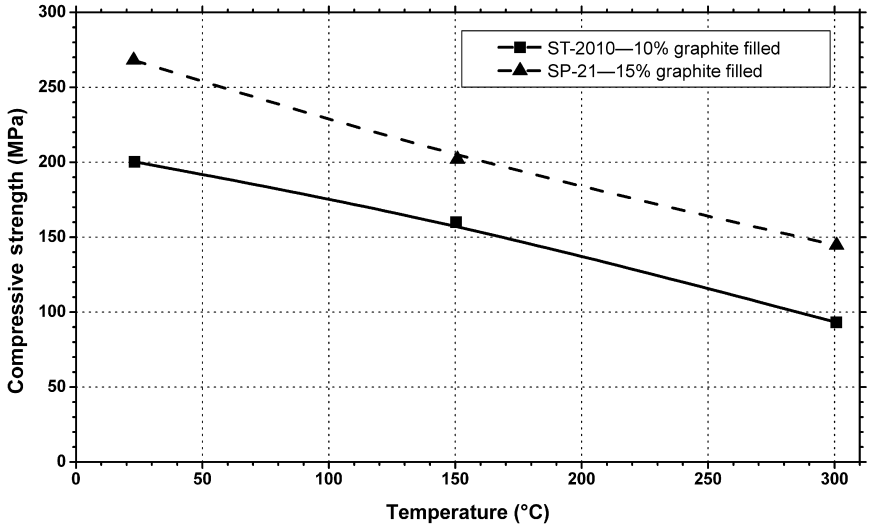


Figure 5.21 Compressive strength vs. temperature for DuPont Vespel® SP-21 and ST-2010 PI resins [3].

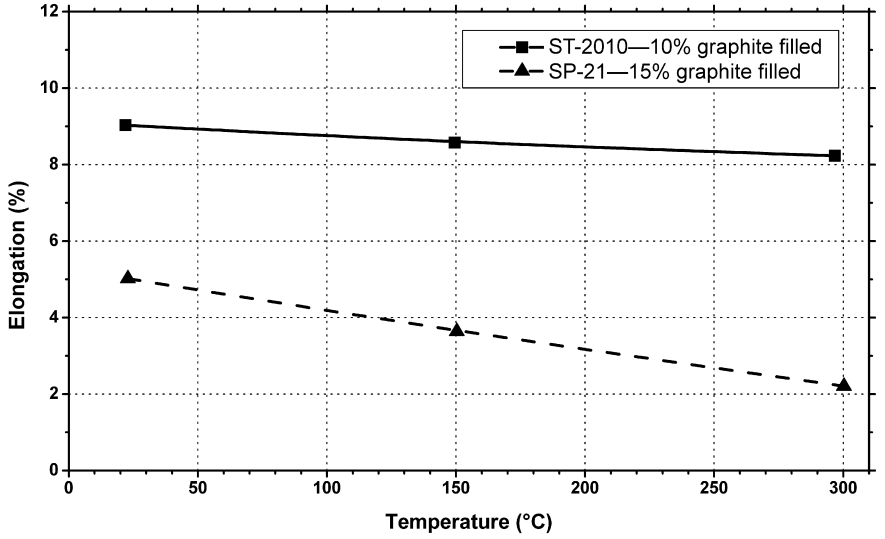


Figure 5.22 Elongation vs. temperature for DuPont Vespel® SP-21 and ST-2010 PI resins [3].

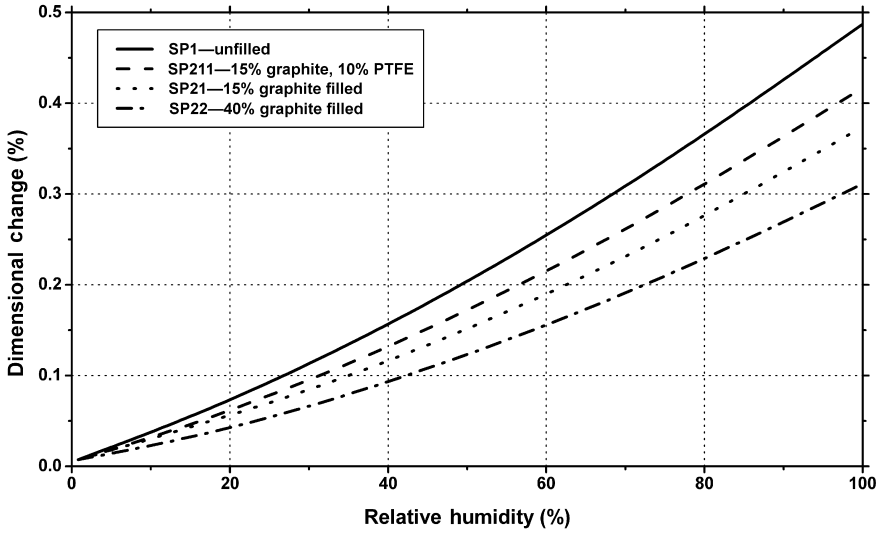


Figure 5.23 Dimension change vs. relative humidity at 23°C for DuPont Vespel® direct-formed PI [2].

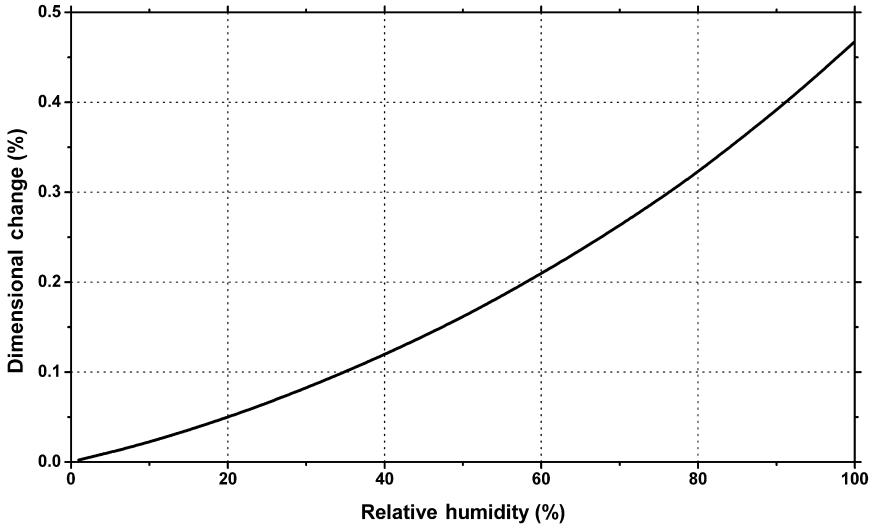


Figure 5.24 Dimension change vs. relative humidity at 23°C for DuPont Vespel® machined PI [2].

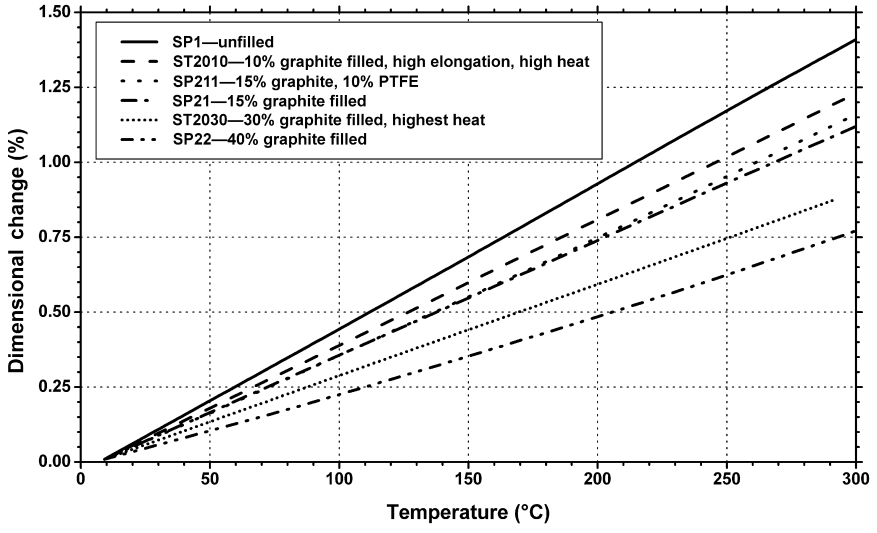


Figure 5.25 Dimension change vs. temperature perpendicular to forming for DuPont Vespel® direct-formed PI [2].

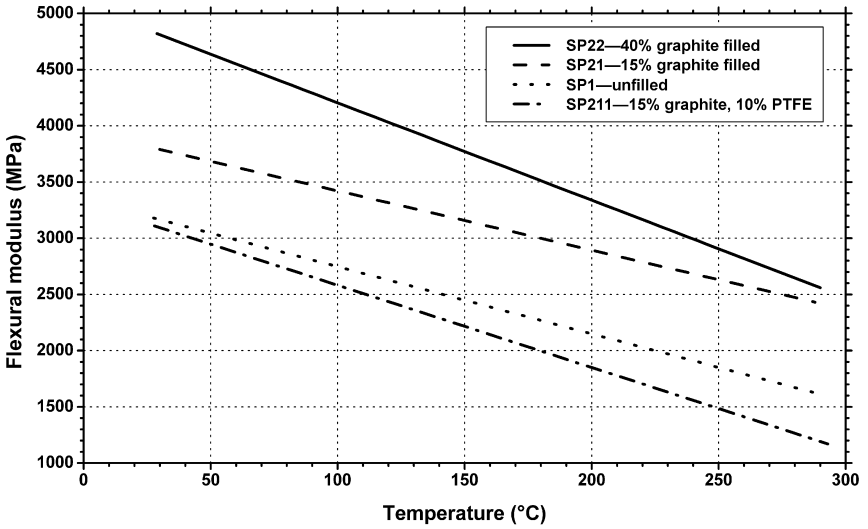


Figure 5.26 Dimension change vs. temperature for DuPont Vespel® machined PI [2].

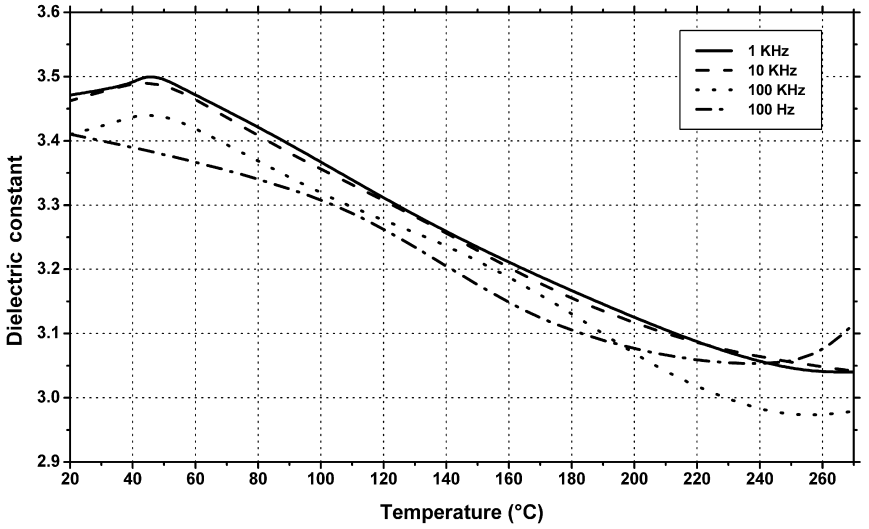


Figure 5.27 Dielectric constant vs. temperature for DuPont Vespel® SP1 PI [2].

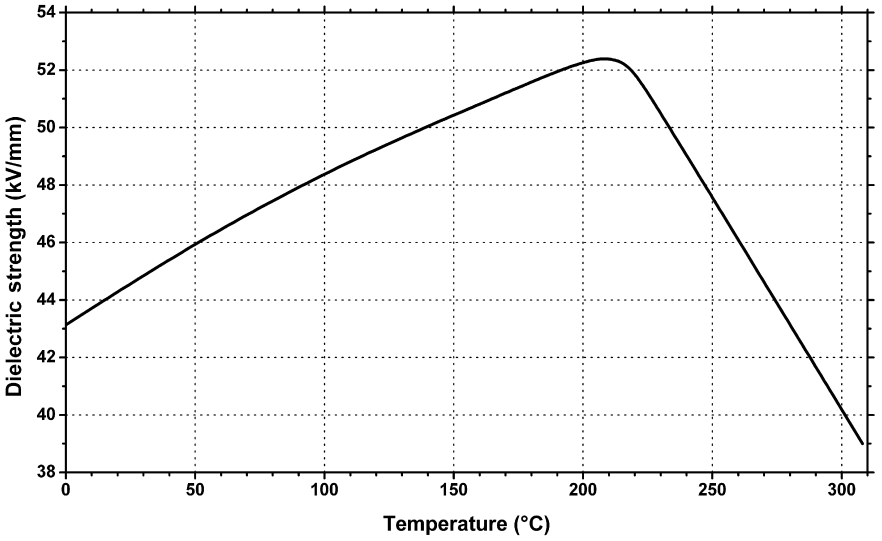


Figure 5.28 Dielectric strength vs. temperature for DuPont Vespel® SP1 PI [2].

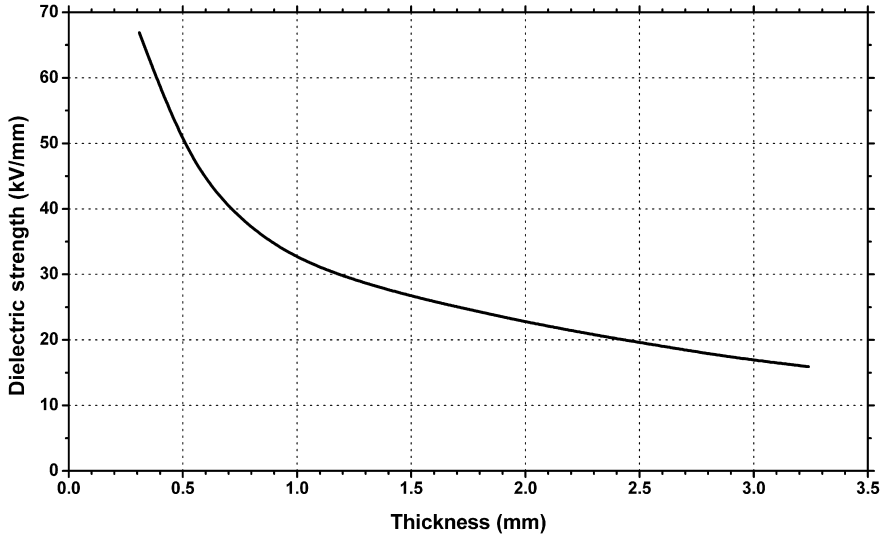


Figure 5.29 Dielectric strength vs. thickness for DuPont Vespel® SP1 PI [2].

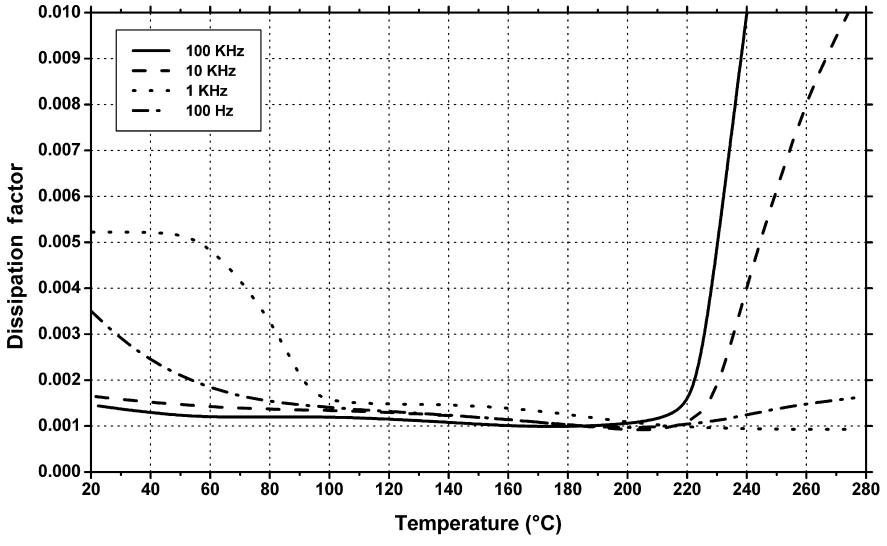


Figure 5.30 Dissipation factor vs. temperature and frequency for DuPont Vespel® SP1 PI [2].

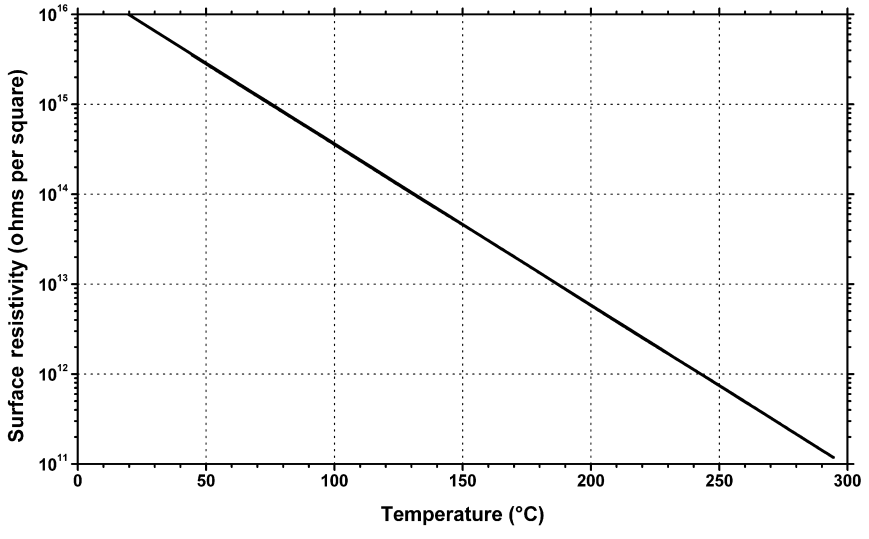


Figure 5.31 Surface resistivity vs. temperature for DuPont Vespel® SP1 PI [2].

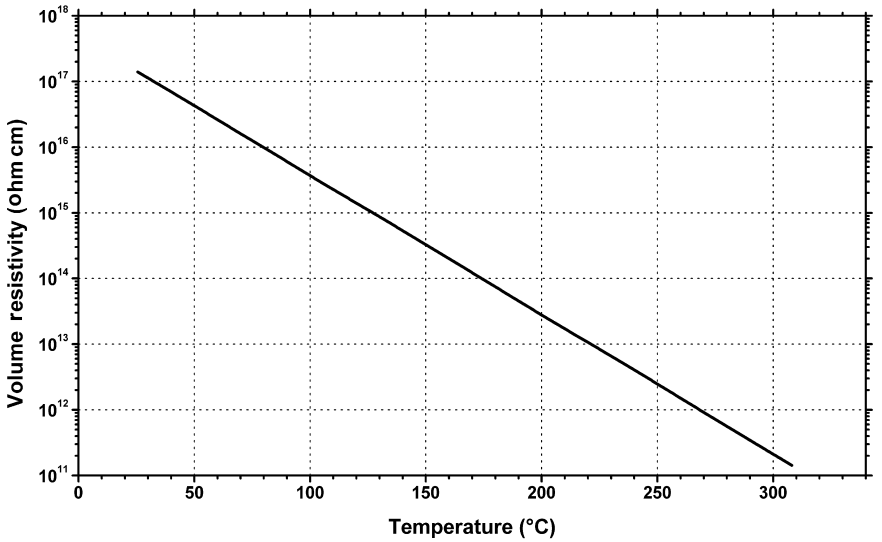


Figure 5.32 Volume resistivity vs. temperature for DuPont Vespel® SP1 PI [2].

- Torlon® 5030: 30% glass fiber, 1% fluorocarbon
- Torlon® 7130: 30% carbon fiber
- Torlon® 4275: PTFE and graphite
- Torlon® 4630: PTFE and graphite
- Torlon® 4435: PTFE and graphite
- Torlon® 4645: PTFE and carbon fiber

5.3 Polyetherimide (PEI)

PEI is an amorphous engineering thermoplastic. Thermoplastic PEIs provide the strength, heat resistance, and flame retardancy of traditional PIs with the ease of simple melt processing seen in standard injection-molding resins like polycarbonate and ABS.

The key performance features of PEI resins include:

- Excellent dimensional stability at high temperatures under load
- Smooth as-molded surfaces
- Transparency, though slightly yellow
- Good optical properties
- Very high strength and modulus
- High continuous-use temperature
- Inherent ignition resistance without the use of additives
- Good electrical properties with low ion content

There are several different polymers that are offered in various PEI plastics. Their structures are shown in Figures 5.58–5.62 with references to one of the product lines that utilize that molecule.

The acid dianhydride used to make most of the PEIs is 4,4′-bisphenol A dianhydride (BPADA), the structure of which is shown in Figure 5.63.

Some of the other monomers used in these PEIs are shown in Figure 5.64.

Manufacturers and trade names: SABIC Innovative Plastics Ultem®, DuPont Aurum®.

Applications and uses: surgical probes, pharmaceutical process equipment manifolds, high-frequency insulators used in microwave communications equipment, clamps used to connect printed circuit boards to video display units used in airplanes, tanks, and ships.

Data for PEI polymers are contained in Figures 5.65–5.83.

Table 5.1 Mechanical Properties at Various Temperatures of DuPont Vespel® TP-8000 Series PI Compounds [1]

Properties/ Temperature (°C)	TP-8054 Unfilled	TP-8395 PTFE and Graphite	TP-8212 30% Glass	TP-8130 30% Carbon Fiber	TP-8311 10% Carbon Fiber	TP-8549 30% Carbon Fiber	TP-8792 15% Carbon Fiber, 15% PTFE
Tensile Strength (MPa)							
−40	106	86	158	223	243	257	194
23	85	68	147	203	174	208	181
100	50	48	98	160	144	154	155
150	48	38	96	132	127	138	126
Tensile Elongation (%)							
−40	13		92	1	1	1	2
23	92	14	2	1	2	1	2
100	102	7	1	1	2	1	2
150	94	8	1	1	2	1	1
Tensile Modulus (MPa)							
−40	1520	1470	10,200	26,100	28,300	27,000	14,400
23	1120	1210	10,200	22,500	11,200	24,300	16,600
100	742	1040	6500	21,900	10,700	22,800	15,400
150	621	804	6000	21,000	13,300	19,100	14,900
Flexural Strength (MPa)							
0	–	–	–	353	273	380	294
23	137	117	241	336	258	358	278
150	88	–	172	227	191	212	198
Flexural Modulus (MPa)							
0	–	–	–	20,670	9853	21,690	13,504
23	2942	2598	9646	21,042	10,349	21,648	14,104
150	2549	–	8268	19,664	9584	19,113	13,270
Compressive Strength (MPa)							
0	–	–	–	309	229	305	203
23	256	233	331	310	219	306	205
150	154	144	220	220	149	191	145
Compressive Modulus (MPa)							
0	–	–	–	410	348	426	403
23	197	197	391	445	413	417	387
150	166	182	365	434	365	388	389

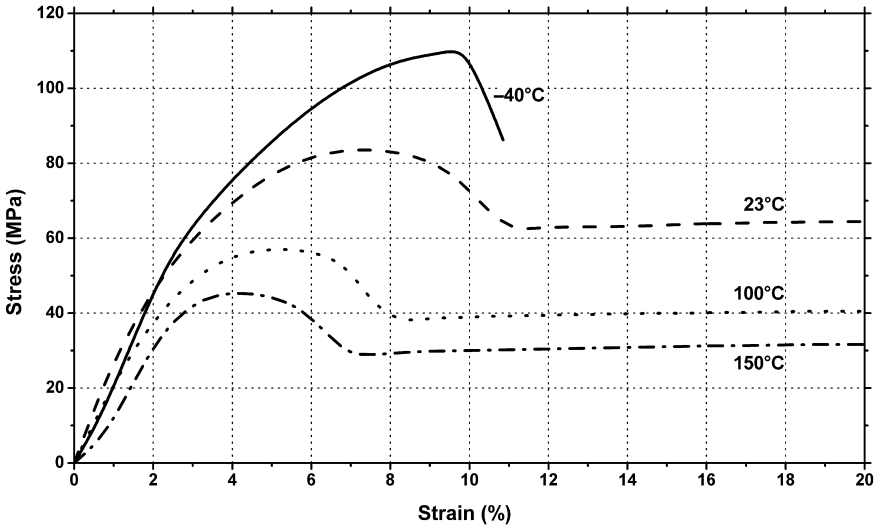


Figure 5.33 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8054 unfilled thermoplastic PI [1].

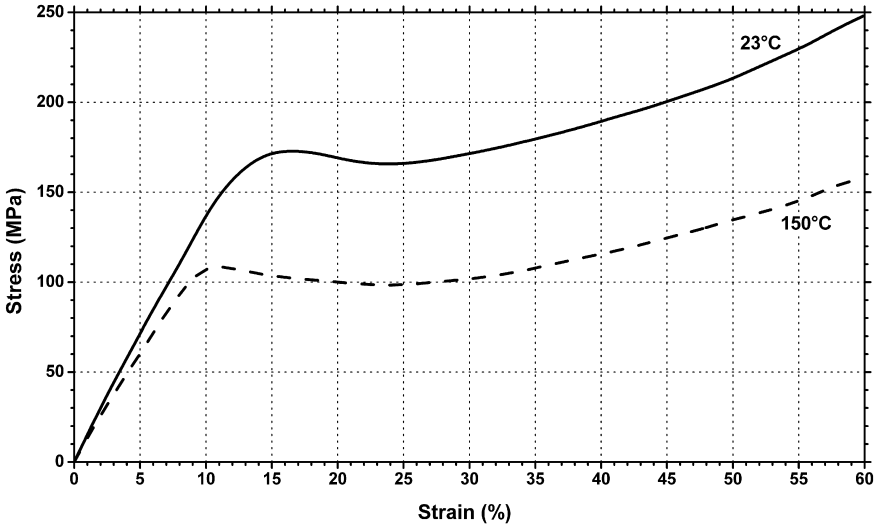


Figure 5.34 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8054 unfilled thermoplastic PI [1].

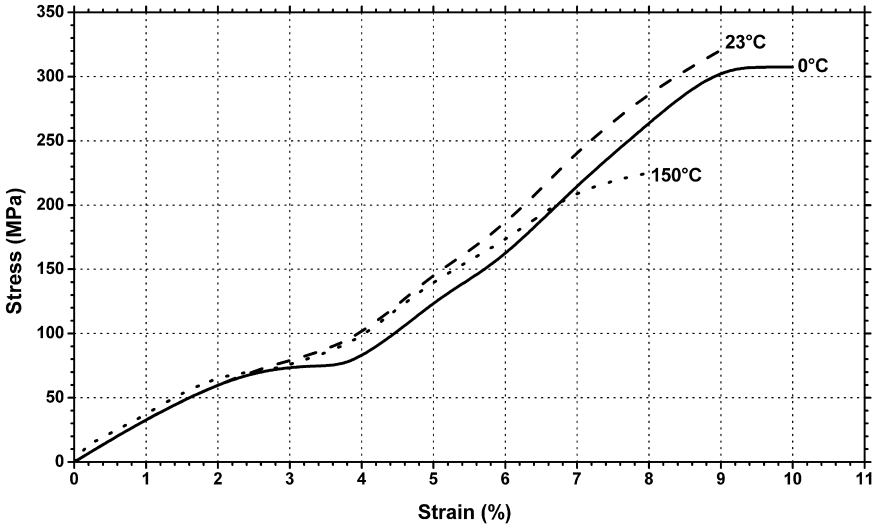


Figure 5.35 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8130 containing 30% carbon fiber thermoplastic PI [1].

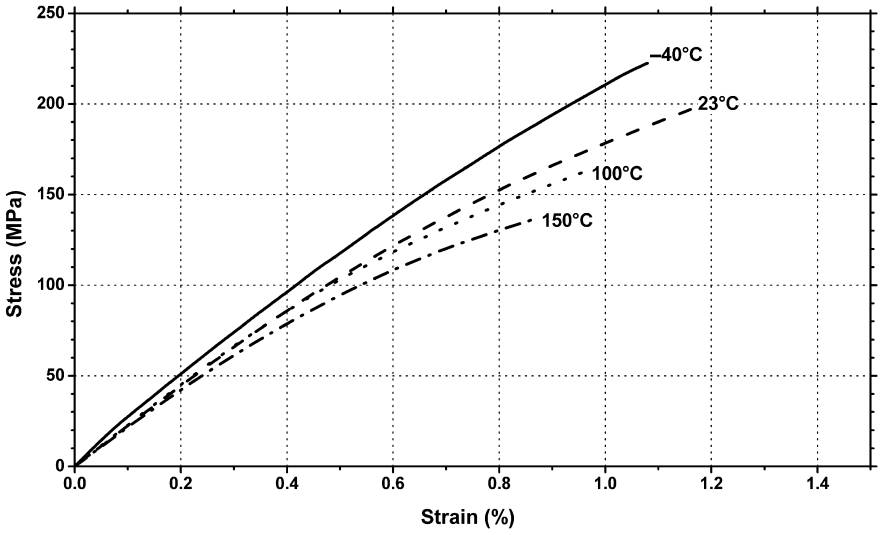


Figure 5.36 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8130 containing 30% carbon fiber thermoplastic PI [1].

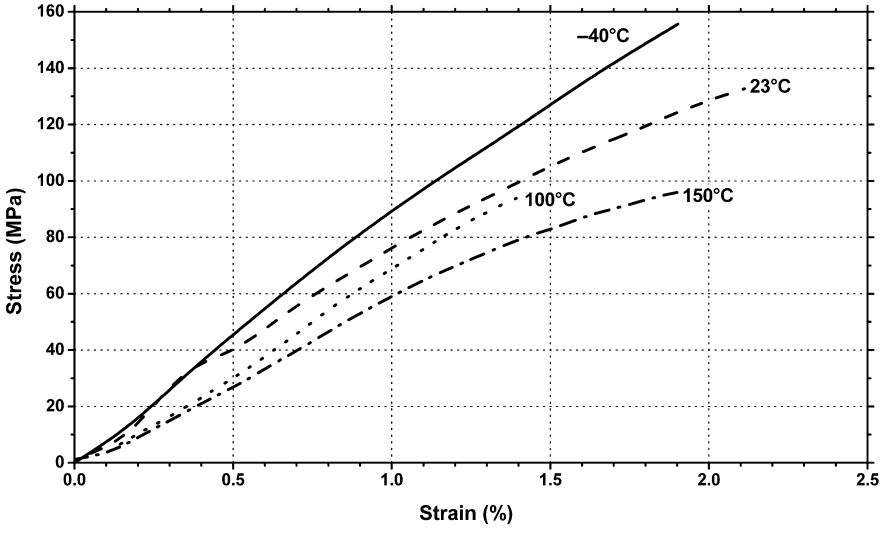


Figure 5.37 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8212 with 30% glass thermoplastic PI [1].

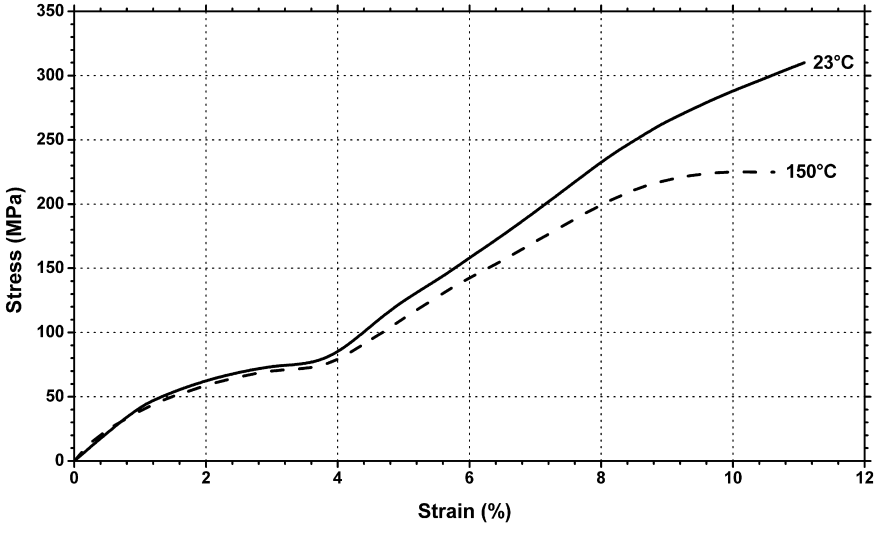


Figure 5.38 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8212 with 30% glass thermoplastic PI [1].

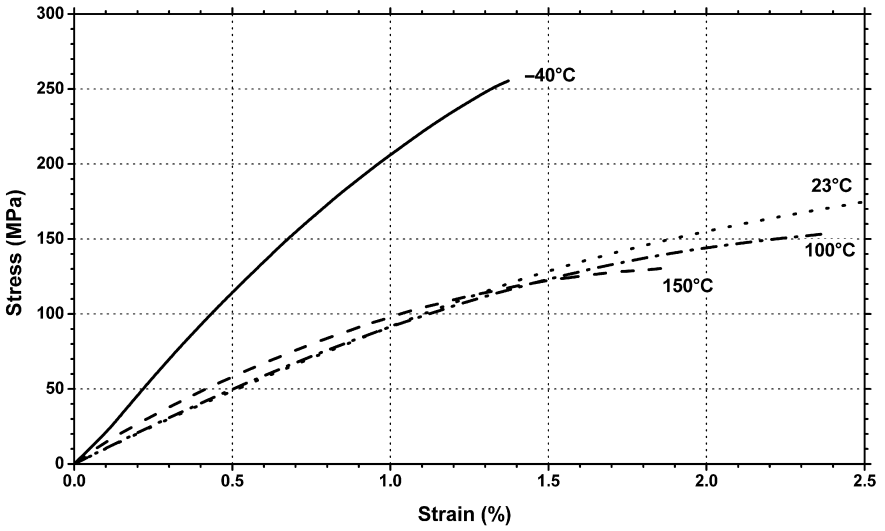


Figure 5.39 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8311 with 10% carbon fiber thermoplastic PI [1].

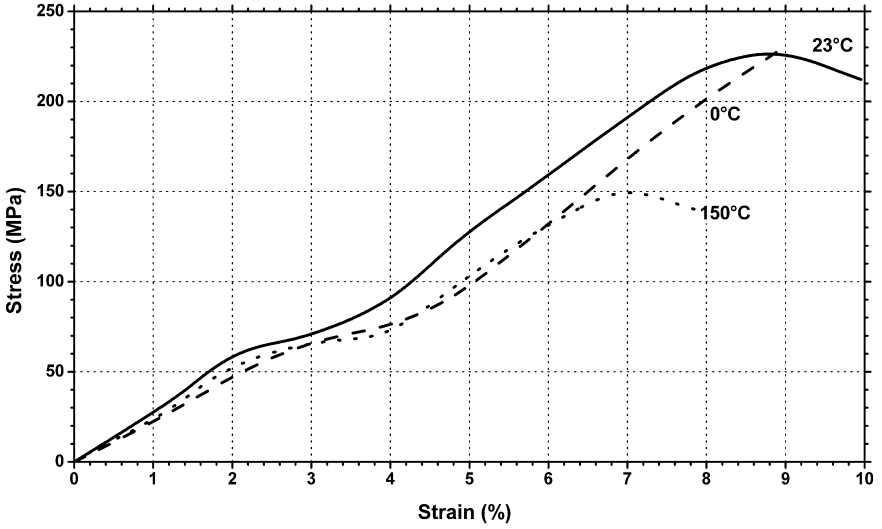


Figure 5.40 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8311 with 10% carbon fiber thermoplastic PI [1].

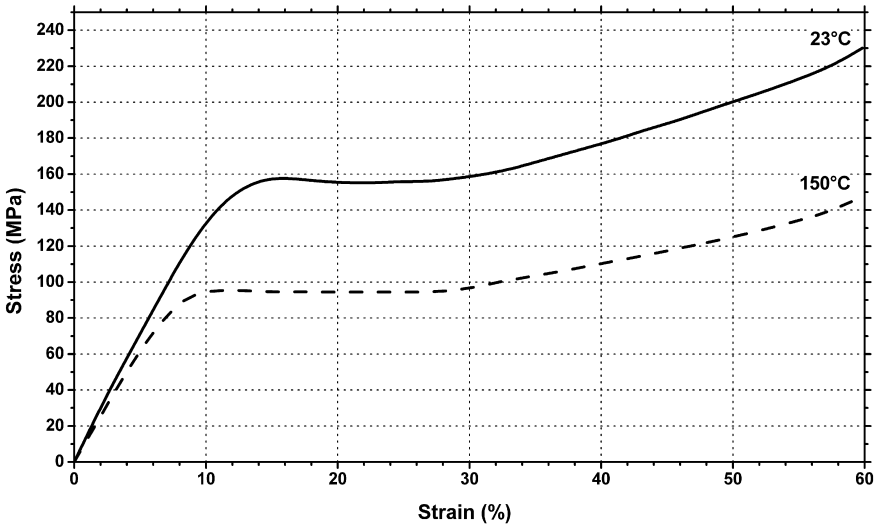


Figure 5.41 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8395 with PTFE and graphite thermoplastic PI [1].

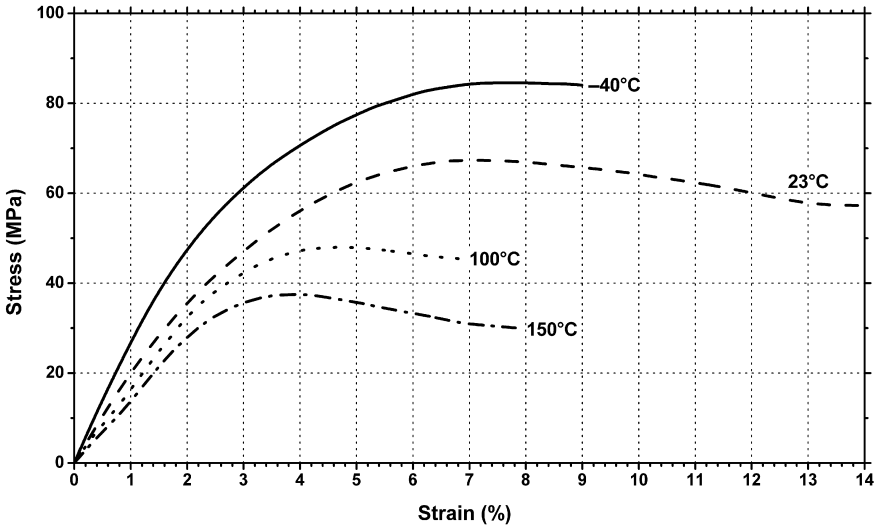


Figure 5.42 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8395 with PTFE and graphite thermoplastic PI [1].

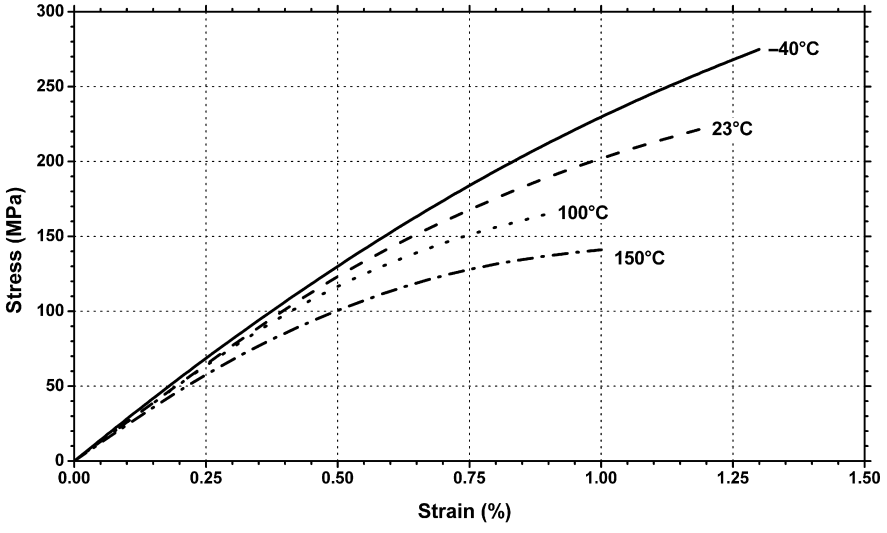


Figure 5.43 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8549 with 30% carbon fiber thermoplastic PI [1].

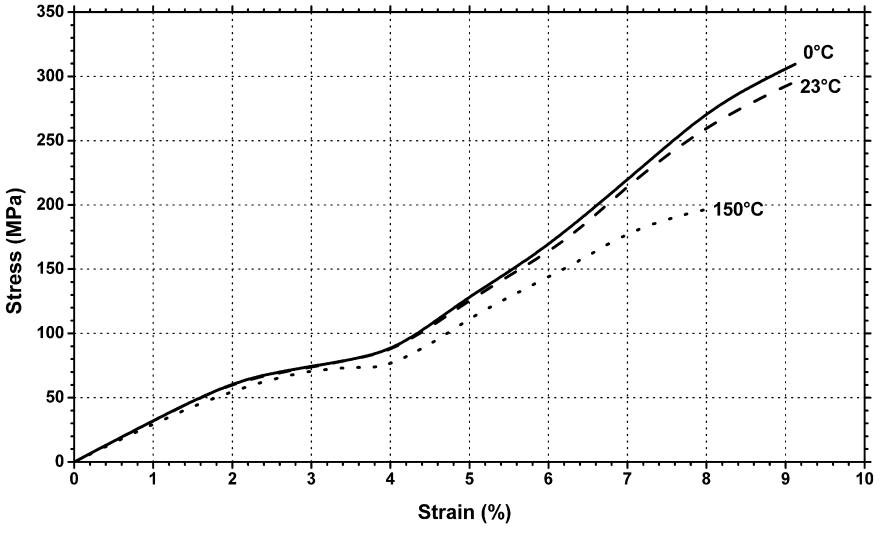


Figure 5.44 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8549 with 30% carbon fiber thermoplastic PI [1].

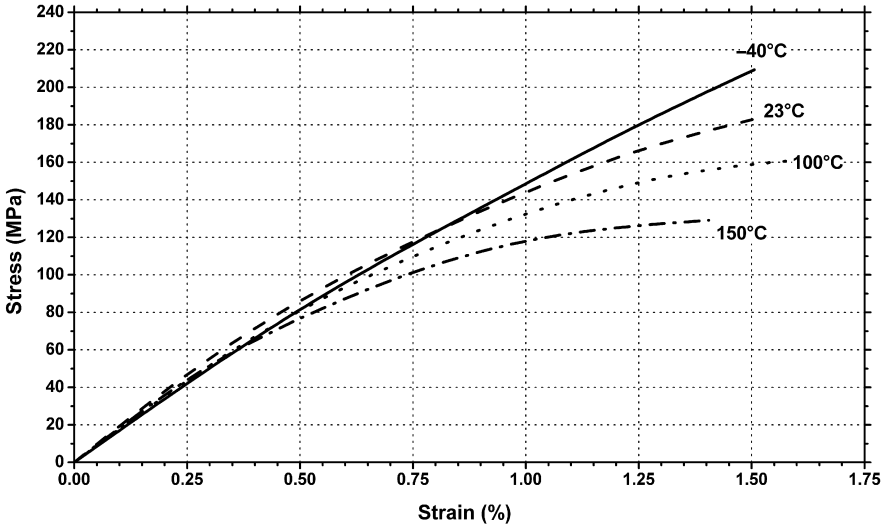


Figure 5.45 Stress vs. strain in tension at various temperatures for DuPont Vespel® TP-8792 with 15% carbon fiber and 15% PTFE thermoplastic PI [1].

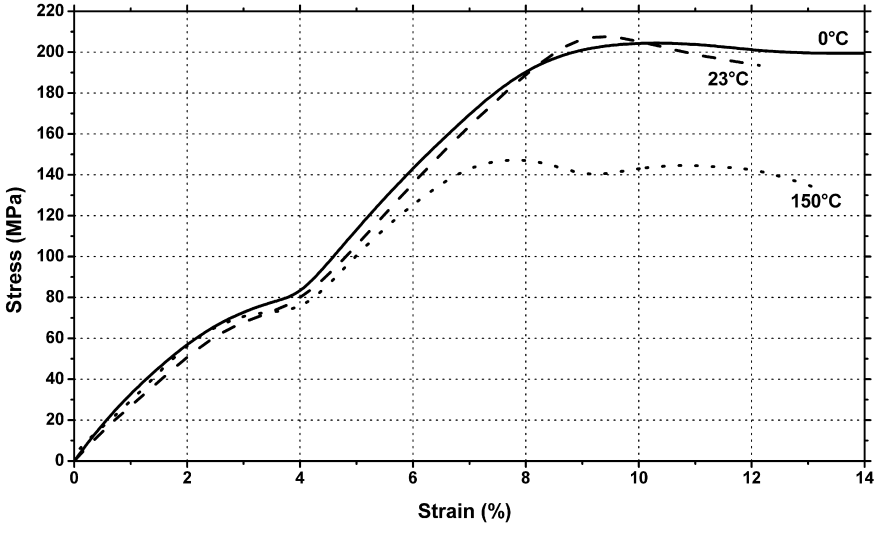
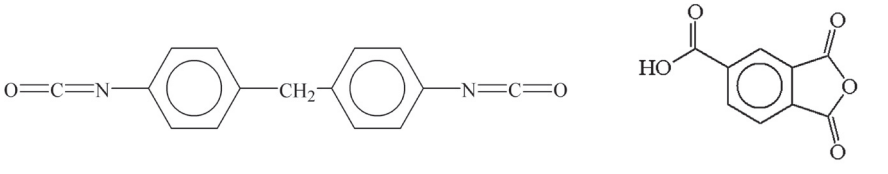


Figure 5.46 Stress vs. strain in compression at various temperatures for DuPont Vespel® TP-8792 with 15% carbon fiber and 15% PTFE thermoplastic PI [1].



4,4′-Diphenyl methane diisocyanate (MDI) Trimellitic anhydride (TMA)

Figure 5.47 Chemical structures of monomers used to make PAIs.

Table 5.2 The Polymer Units of Various Amide–Imide Polymers (Refer to Figure 5.48 for Polymer Structure)

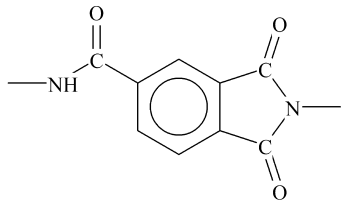
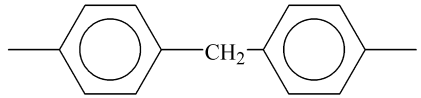
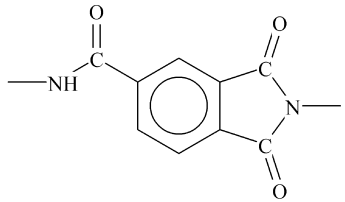
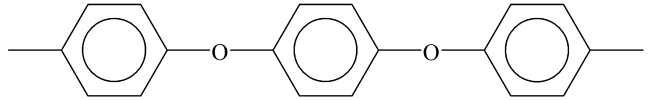
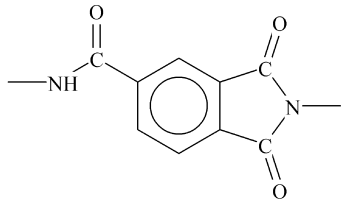
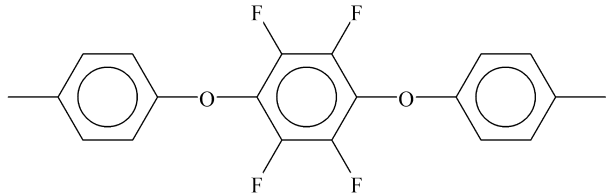
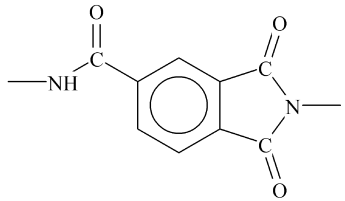
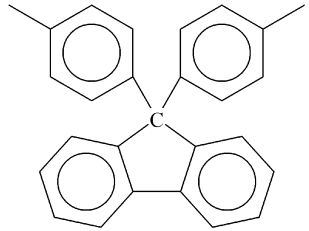
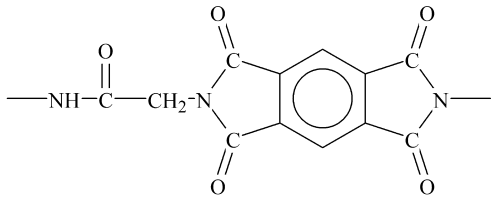
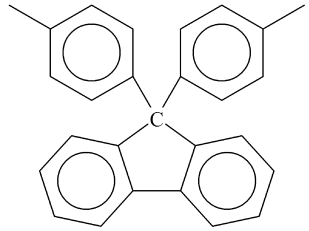
PAI Code	R1 from Acid Anhydride	R2 from Diisocyanate
PAI(TMI/DPA)		
PAI(TMI/HEA)		
PAI(TMI/TFA)		
PAI(TMI/CDA)		
PAI(PMI/CDA)		

Table 5.3 The Polymer Units of More Amide–Imide Polymers (Refer to Figure 5.48 for Polymer Structure) [4]

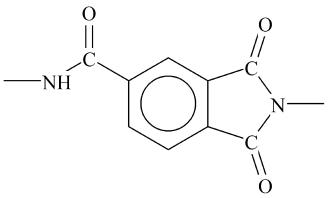
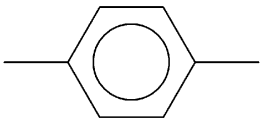
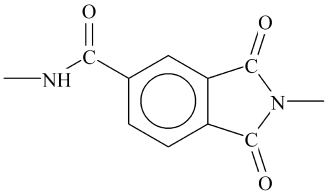
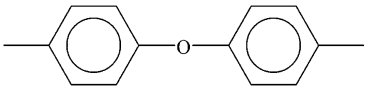
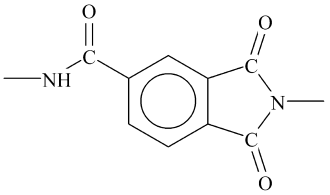
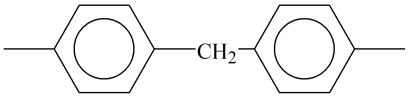
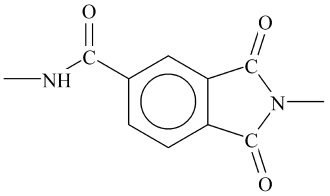
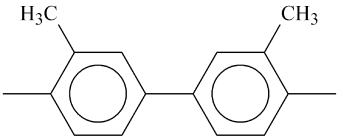
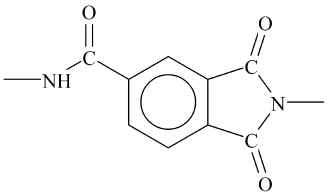
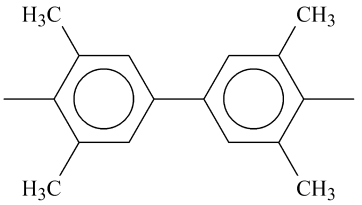
PAI Code	R1 from Acid Anhydride	R2 from Diisocyanate
PAP		
PAO		
PAM		
PAD		
PAT		

Table 5.4 Compressive Properties for Solvay Advanced Polymers Torlon® PAI Resins at Various Temperatures per ASTM D695 [5]

Property/Temperature (°C)	Grade					
	4203L	4601	4630	4645	5030	7130
Compressive Strength (MPa)						
23	172	165	96	124	214	234
100	131	124	83	124	165	186
150	103	103	76	110	138	158
200	83	83	62	90	110	124
Compressive Modulus (MPa)						
23	3163	3114	4706	5236	4892	6139
100	2191	2122	2026	3645	3273	3803
150	2136	2067	2115	3149	3087	3790
200	2067	2046	2019	3383	3121	3645

Table 5.5 Tensile Properties for Solvay Advanced Polymers Torlon® PAI Resins at Various Temperatures per ASTM D1708 [5]

Property/Temperature (°C)	Grade					
	4203L	4301	4275	4435	5030	7130
Tensile Strength (MPa)						
23	192	164	131	110	205	203
135	117	113	116	90	160	158
232	66	73	56	52	113	108
Tensile Elongation at Break (%)						
23	15	7	7	6	7	6
135	21	20	15	4	15	14
232	22	17	17	3	12	11
Tensile Modulus (GPa)						
23	4.5	6.8	8.8	14.5	14.6	16.5

Table 5.6 Flexural Modulus (in GPa) at Various Temperatures of Solvay Advanced Polymers Torlon® PAI Resins [5]

Temperature (°C)	Torlon® Grade							
	High Strength Grades			Wear Resistant Grades				
	4203L	5030	7130	4301	4275	4435	4630	4645
−196	7.9	14.1	24.6	9.6				
23	5.0	11.7	19.9	6.9	7.3	14.8	6.8	12.4
135	3.9	10.7	15.6	5.5	5.6	11.2		
232	3.6	9.9	13.1	4.5	5.1	10.3		

Note: ASTM Test Method D790.

Table 5.7 Flexural Strength (in MPa) at Various Temperatures of Solvay Advanced Polymers Torlon® PAI Resins [5]

	Torlon® Grade							
	High Strength Grades			Wear Resistant Grades				
Temperature (°C)	4203L	5030	7130	4301	4275	4435	4630	4645
−196	282	374	310		200			
23	244	338	355	219	212	152	131	154
135	174	251	263	165	157	129		
232	120	184	177	113	111	91		

Note: ASTM Test Method D790.

Table 5.8 Specific Heat at Various Temperatures of Solvay Advanced Polymers Torlon® PAI Resins [5]

	Specific Heat (cal/gm°C)			
	Grade			
Temperature (°C)	4203L	4301	5030	7130
25	0.242	0.240	0.229	0.230
100	0.298	0.298	0.276	0.285
200	0.362	0.359	0.327	0.346
250	0.394	0.385	0.353	0.375

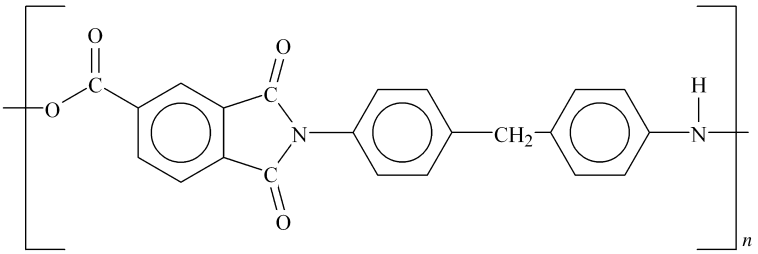


Figure 5.48 Chemical structure of a typical PAI.

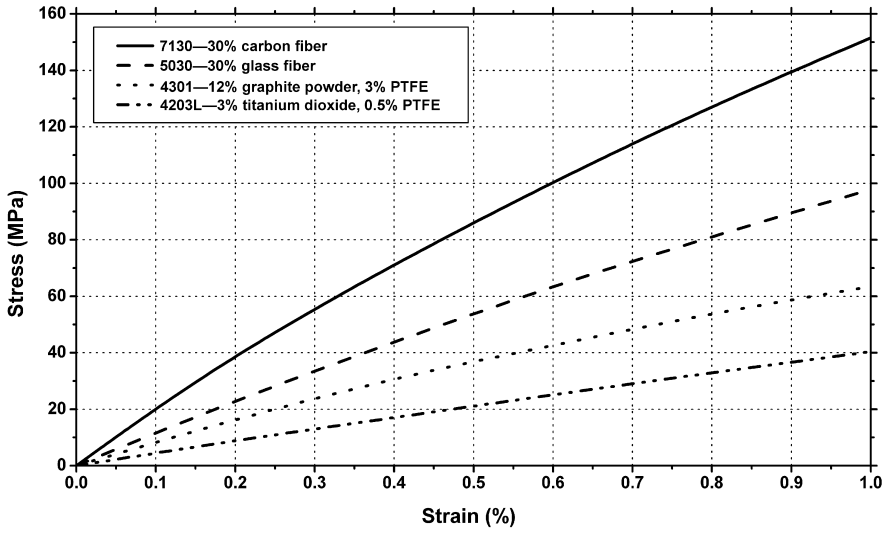


Figure 5.49 Stress vs. strain detail in tension at 23°C tested on ASTM D638 type 1 specimens for Solvay Advanced Polymers Torlon® PAI resins [5].

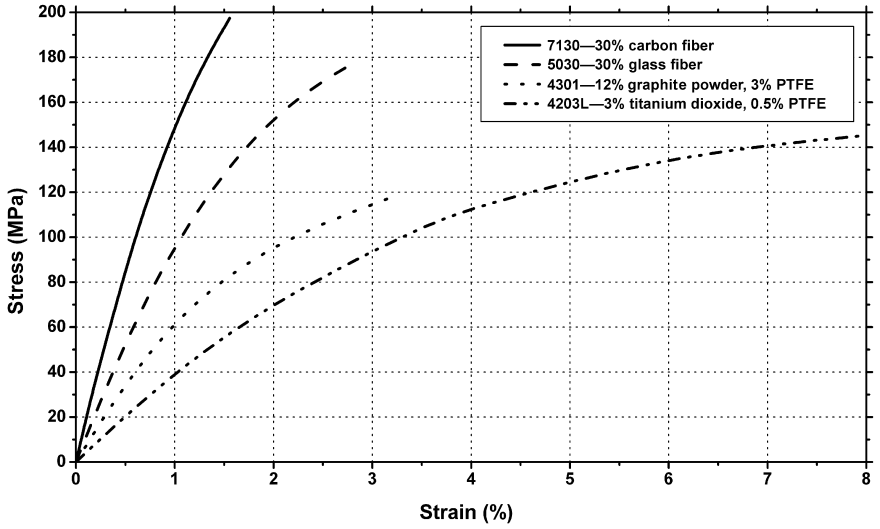


Figure 5.50 Stress vs. strain in tension at 23°C tested on ASTM D638 type 1 specimens for Solvay Advanced Polymers Torlon® PAI resins [5].

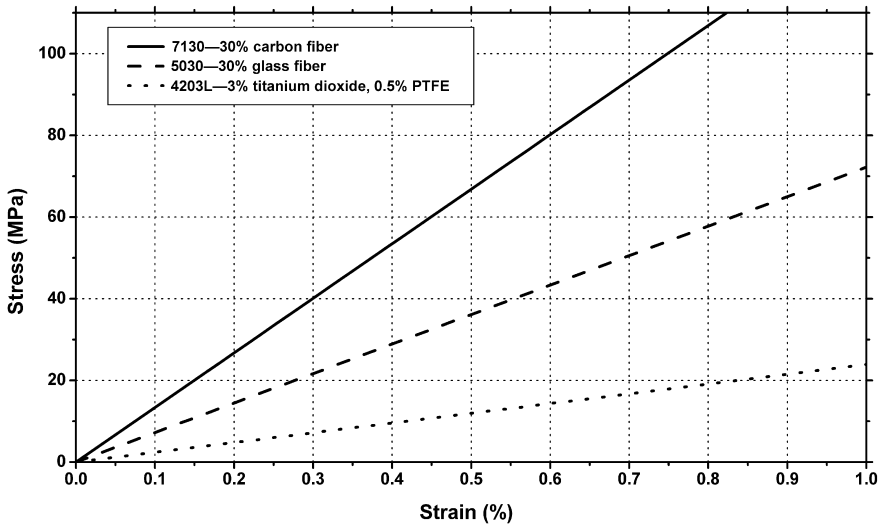


Figure 5.51 Stress vs. strain in tension for various Solvay Advanced Polymers Torlon® PAI resins at 135°C.

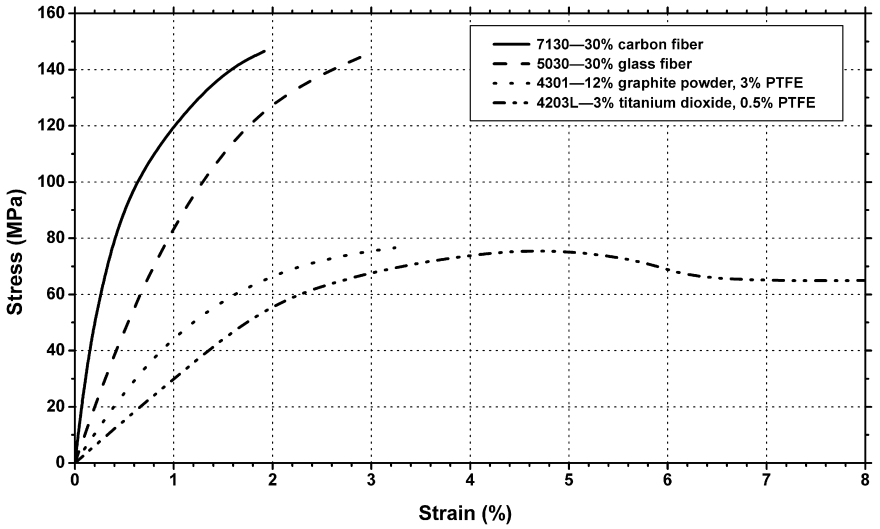


Figure 5.52 Stress vs. strain in tension for various Solvay Advanced Polymers Torlon® PAI resins at 200°C [5].

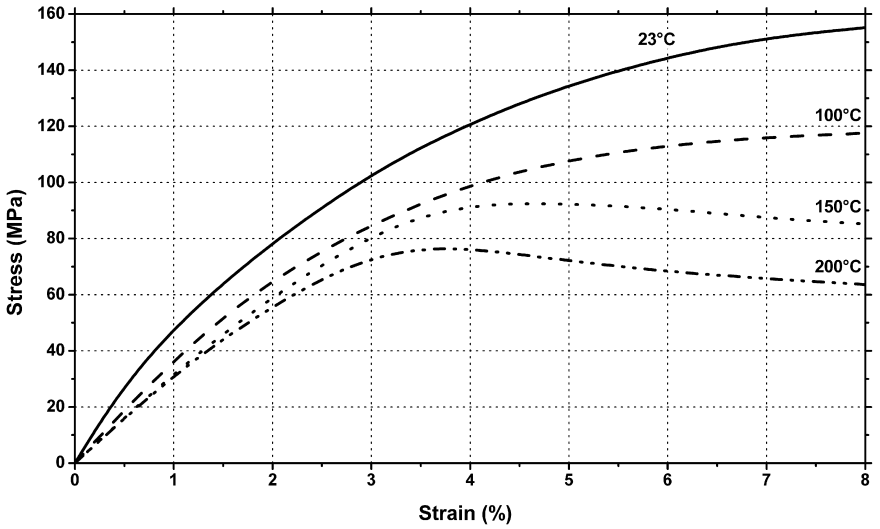


Figure 5.53 Stress vs. strain in tension for Solvay Advanced Polymers Torlon® 4203LF PAI at various temperatures [5].

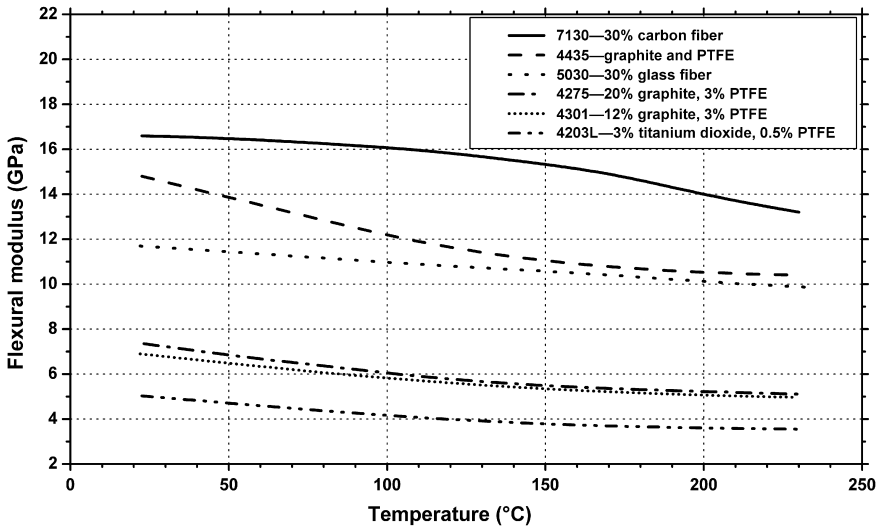


Figure 5.54 Flexural modulus vs. temperature for Solvay Advanced Polymers Torlon® PAI resins [5].

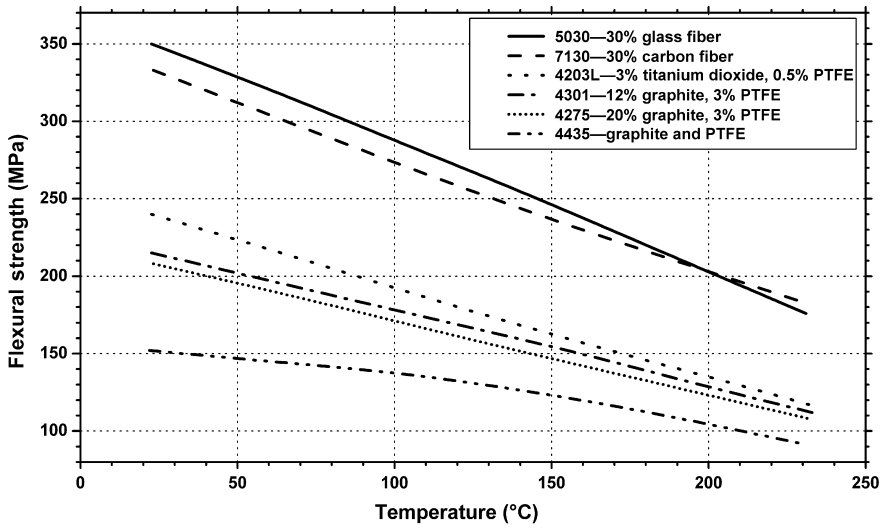


Figure 5.55 Flexural strength vs. temperature for Solvay Advanced Polymers Torlon® PAI resins [5].

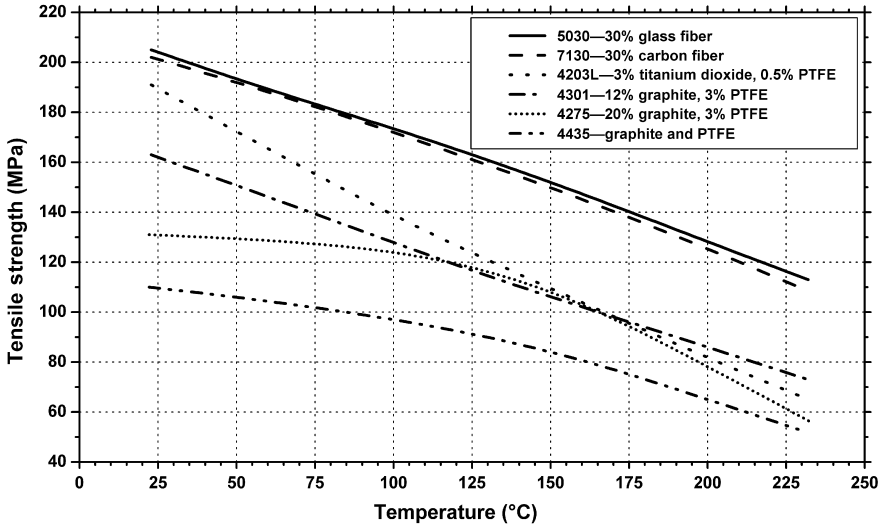


Figure 5.56 Tensile strength vs. temperature for Solvay Advanced Polymers Torlon® PAI resins [5].

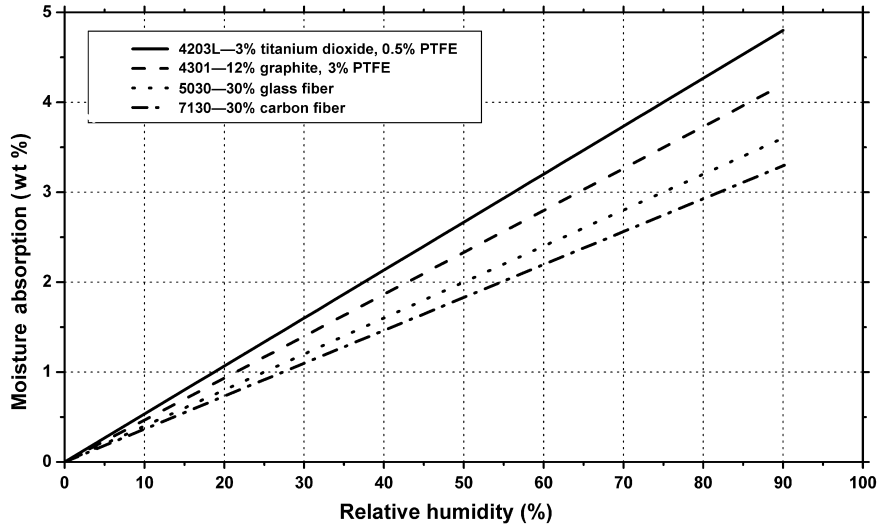


Figure 5.57 Moisture absorption vs. relative humidity for Solvay Advanced Polymers Torlon® PAI resins [5].

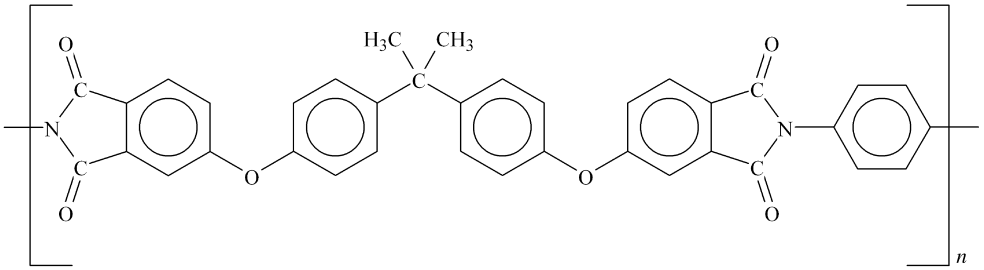


Figure 5.58 Chemical structure of BPADA-PPD PEI (SABIC Innovative Plastics Ultem® 5000 series).

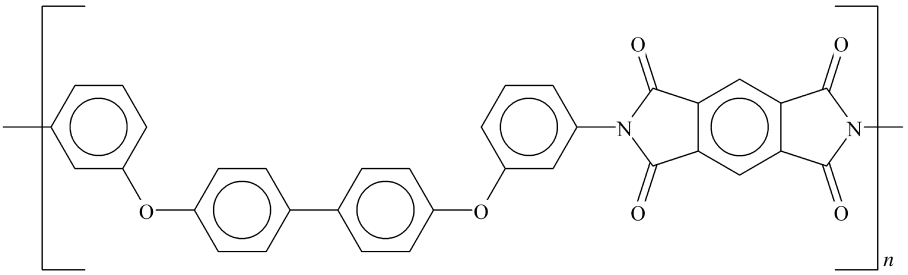


Figure 5.59 Chemical structure of biphenol diamine PMDA PEI (DuPont Aurum®).

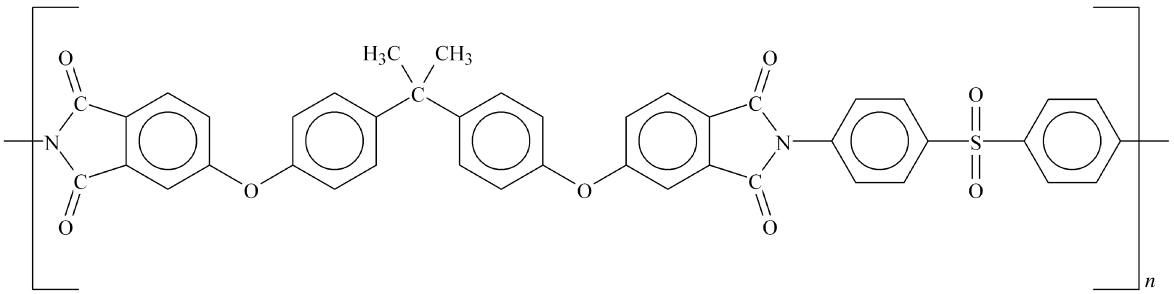


Figure 5.60 Chemical structure of BPADA-DDS PEI sulfone (SABIC Innovative Plastics Ultem® XH6050).

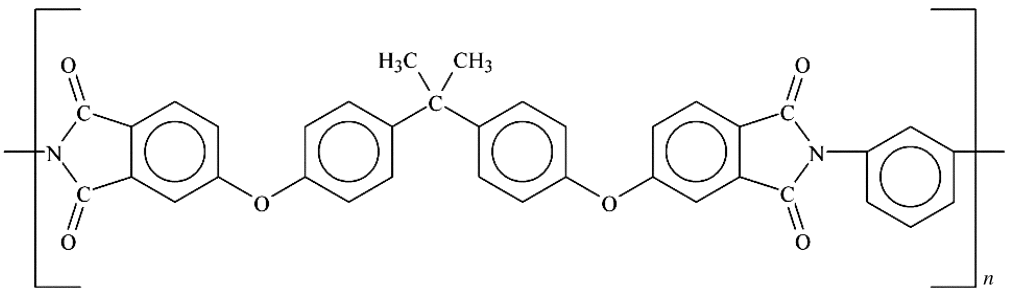


Figure 5.61 Chemical structure of BPADA-MPD PEI (SABIC Innovative Plastics Ultem® 1000 series).

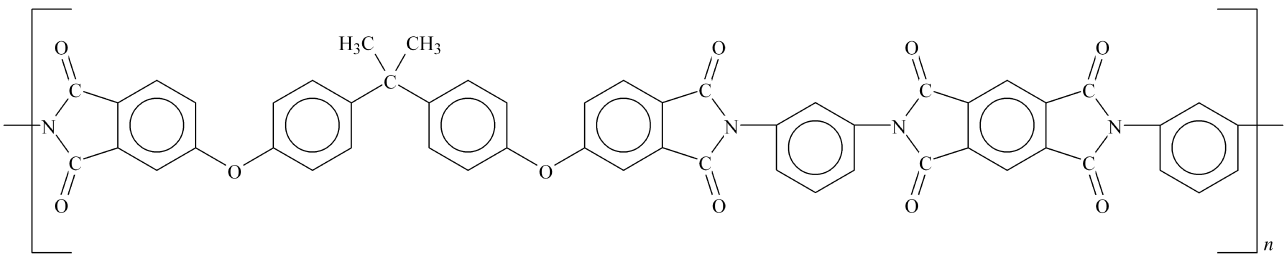


Figure 5.62 Chemical structure of BPADA-PMDA-MPD co-PEI (SABIC Innovative Plastics Ultem® 6000 series).

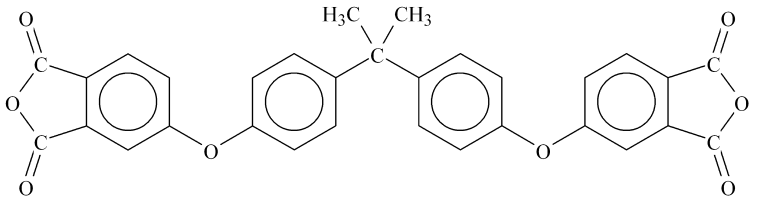
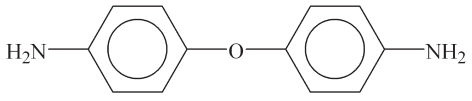
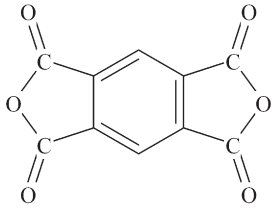


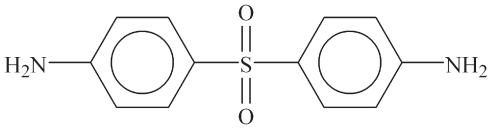
Figure 5.63 Chemical structure of BPADA monomer.



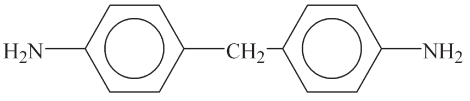
Oxydianiline
(ODA)



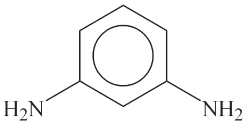
Pyromellitic dianhydride (PMDA)



Diamino diphenyl sulfone
(DDS)

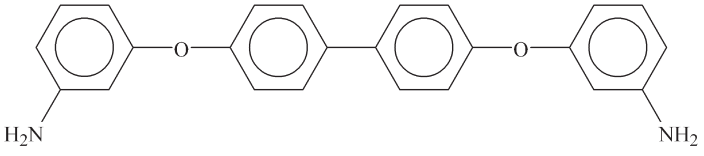


Methylene dianiline
(MDA)



m-Phenylene diamine
(MPD)

p-Phenylene diamine
(PDA)



Biphenol diamine
(BP diamine)

Figure 5.64 Chemical structures of some other monomers used to make PEIs.

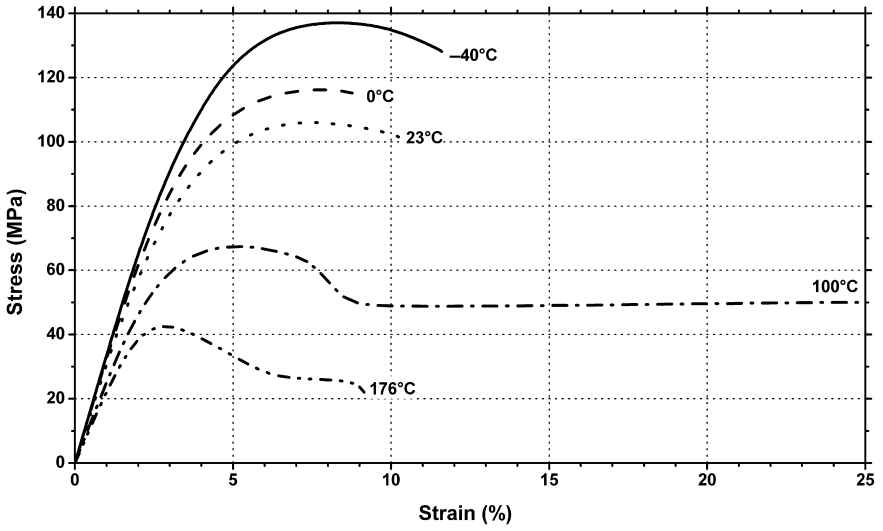


Figure 5.65 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

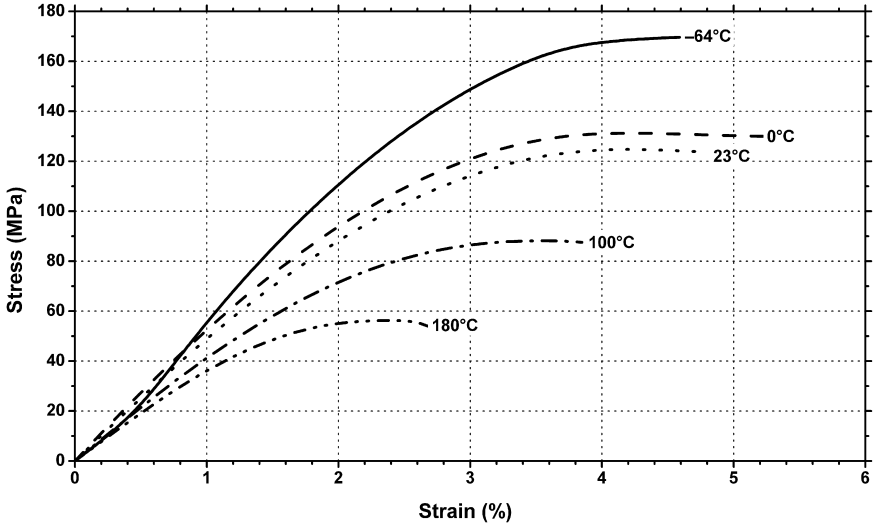


Figure 5.66 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 2100—10% glass reinforced PEI resin.

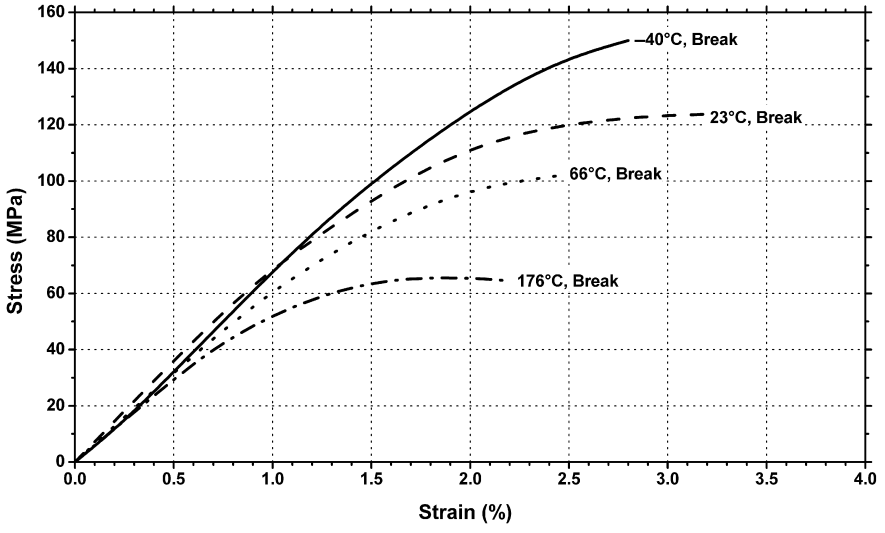


Figure 5.67 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 2200—20% glass reinforced PEI resin.

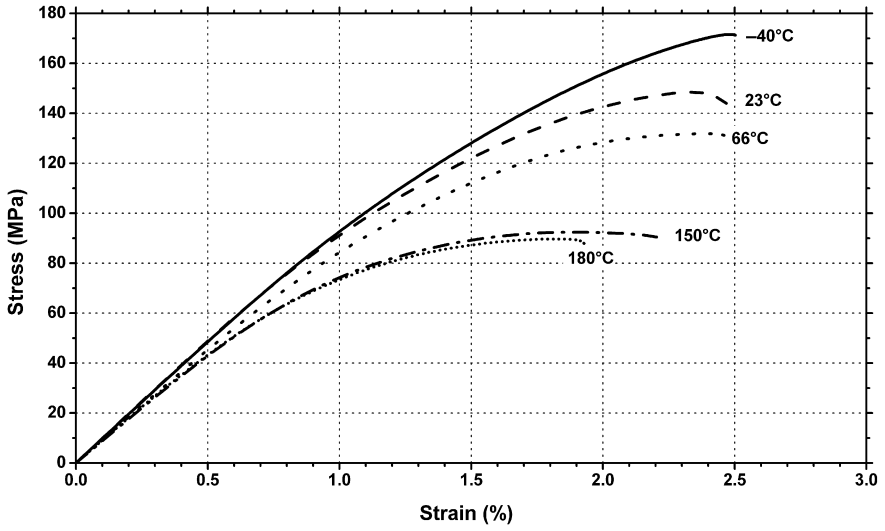


Figure 5.68 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 2300—30% glass reinforced PEI resin.

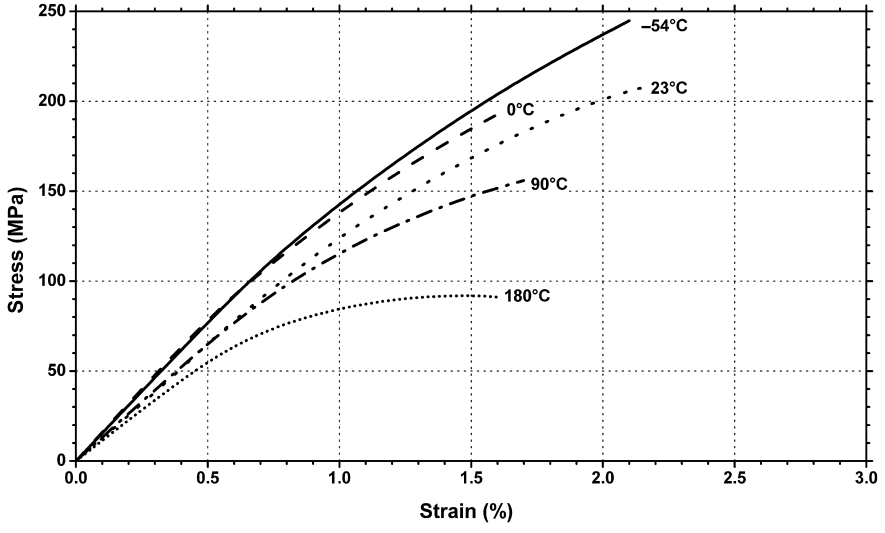


Figure 5.69 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 2400—40% glass reinforced PEI resin.

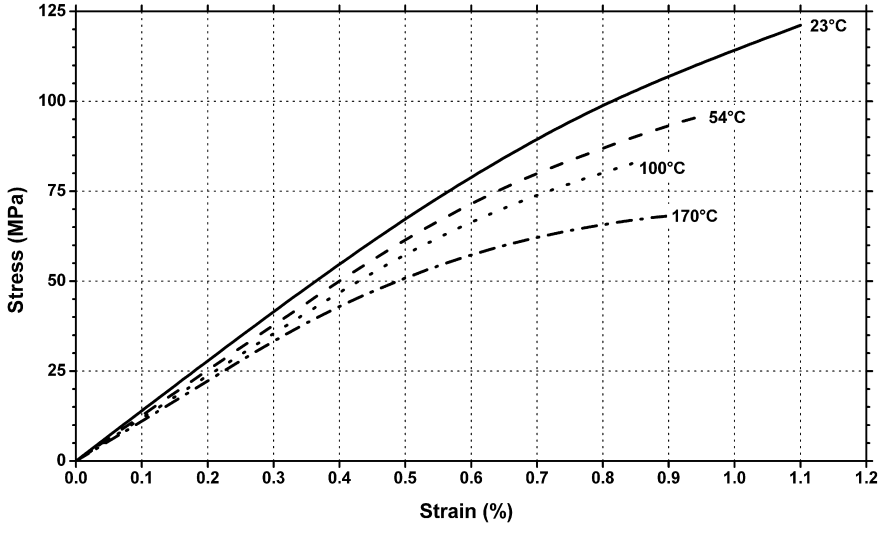


Figure 5.70 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 3452—45% glass/mineral reinforced PEI resin.

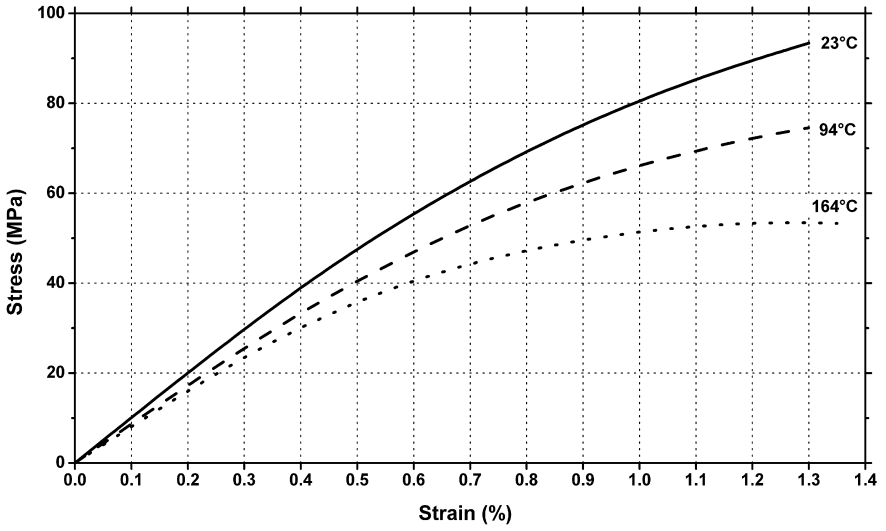


Figure 5.71 Stress vs. strain at various temperatures for SABIC Innovative Plastics Ultem® 4000—wear resistant, 25% glass, 15% PTFE PEI resin.

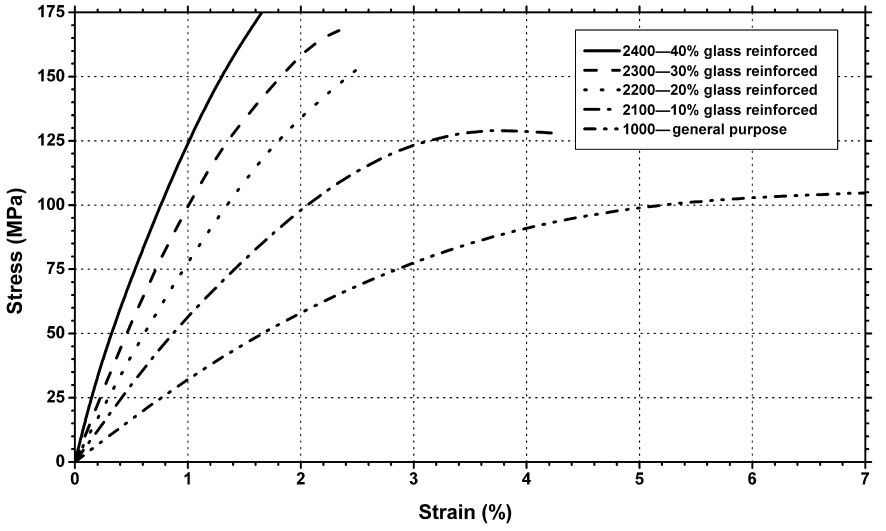


Figure 5.72 Stress vs. strain at 23°C for several SABIC Innovative Plastics Ultem® PEI resins.

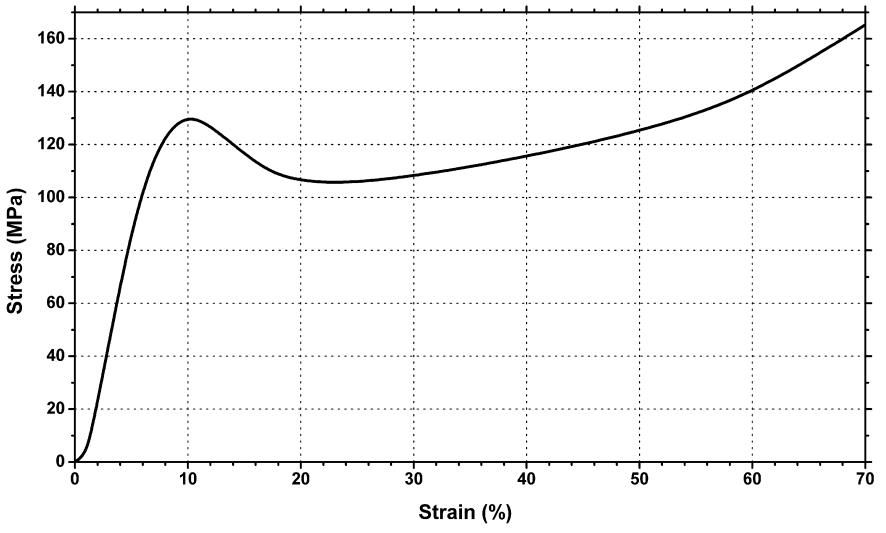


Figure 5.73 Stress vs. strain in compression for SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

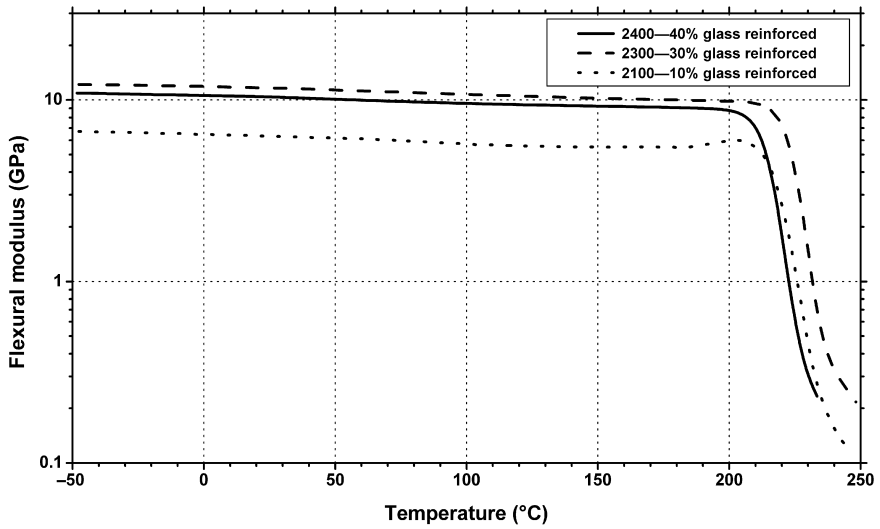


Figure 5.74 Flexural modulus vs. temperature for several SABIC Innovative Plastics Ultem® glass reinforced PEI resins.

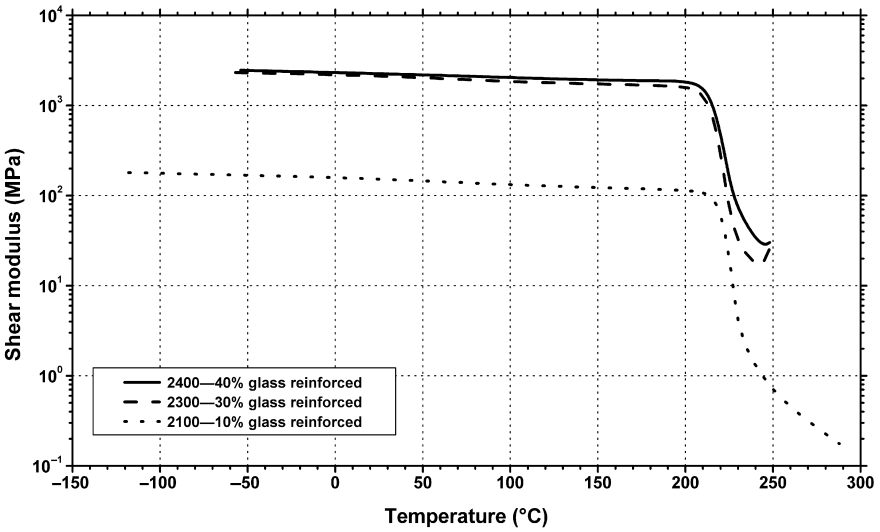


Figure 5.75 Shear modulus vs. temperature for several SABIC Innovative Plastics Ultem® glass reinforced PEI resins.

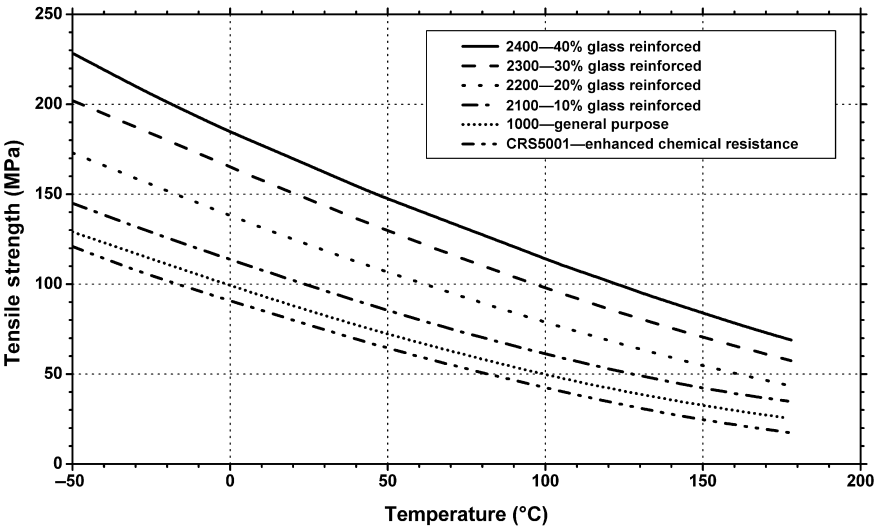


Figure 5.76 Tensile strength vs. temperature for several SABIC Innovative Plastics Ultem® PEI resins [6].

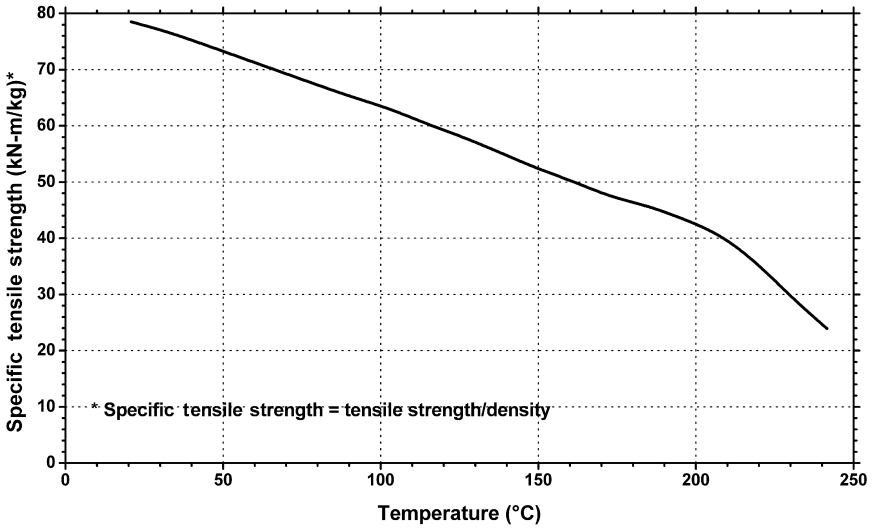


Figure 5.77 Specific strength at elevated temperatures for Extem® XH resin vs. cast aluminum [7].

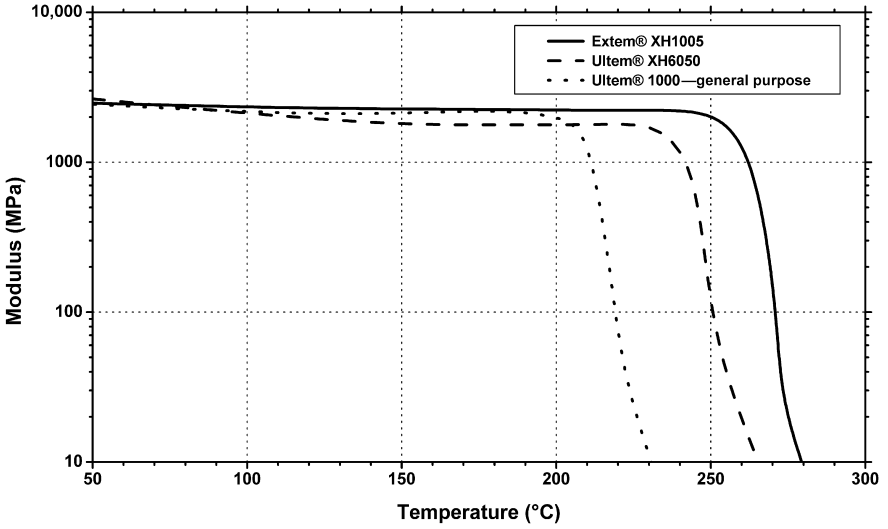


Figure 5.78 Storage modulus of unfilled Extem® XH resin vs. other unfilled polymers as a function of temperature by DMA [7].

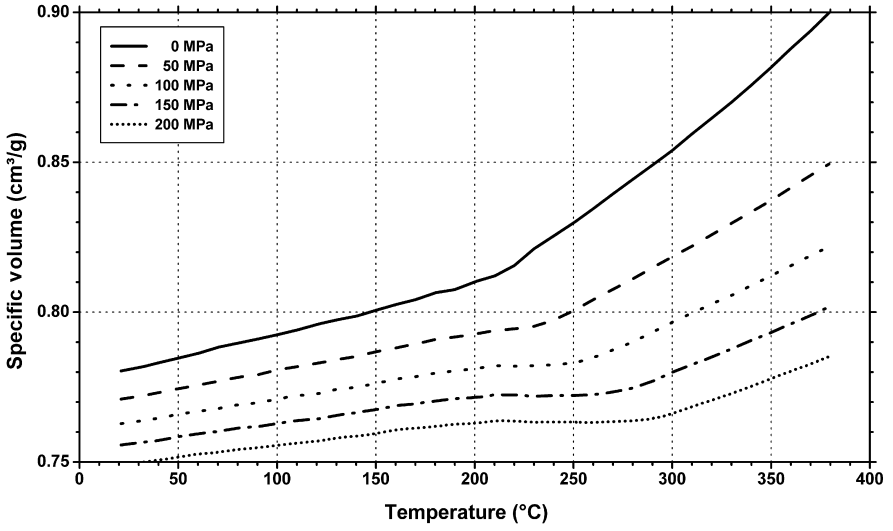


Figure 5.79 Pressure-specific volume–temperature (PVT) for SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

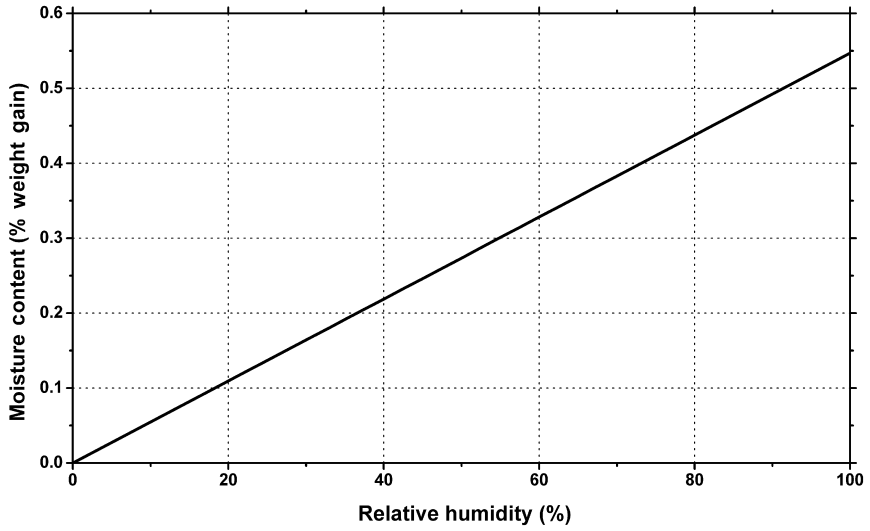


Figure 5.80 Moisture absorption vs. relative humidity for SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

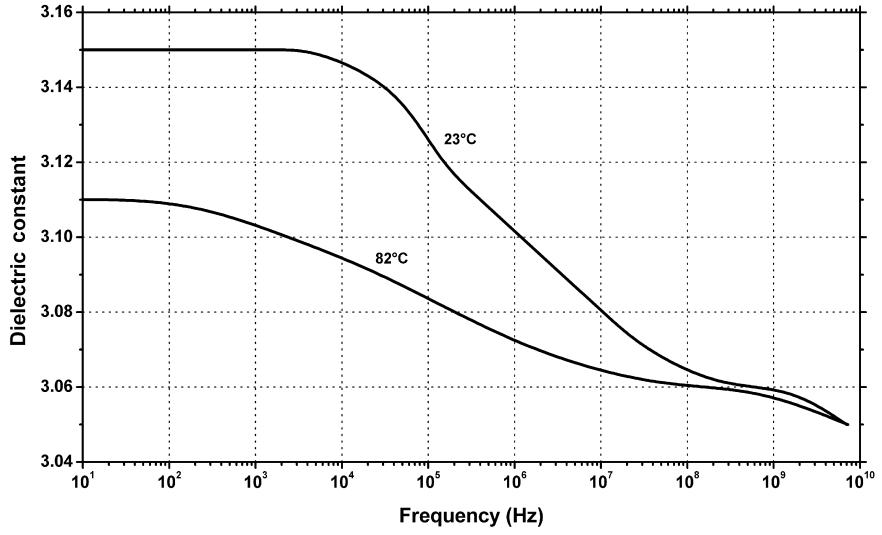


Figure 5.81 Dielectric constant vs. frequency and temperature for SABIC Innovative Plastics Ultem® PEI resin [6].

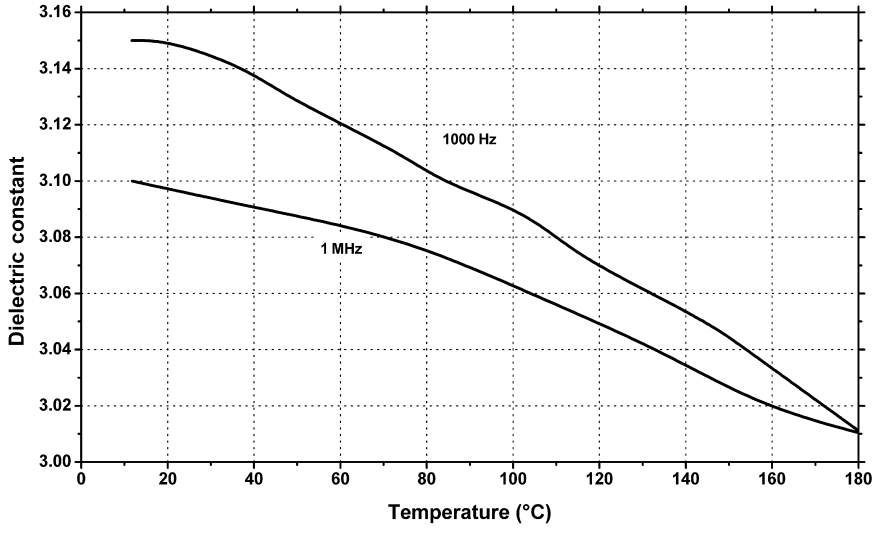


Figure 5.82 Dielectric constant vs. temperature and frequency for SABIC Innovative Plastics Ultem® PEI resin [6].

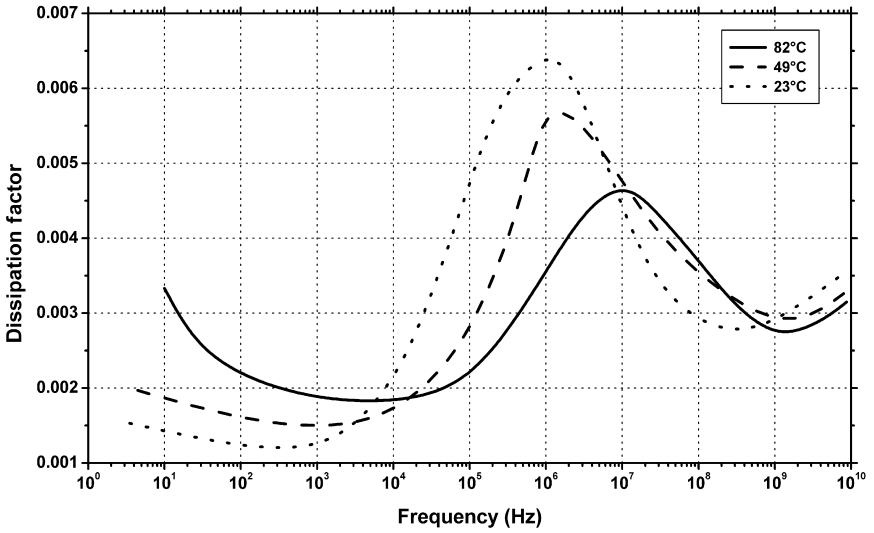


Figure 5.83 Dissipation factor vs. temperature and frequency for SABIC Innovative Plastics Ultem® PEI resin [6].

References

[1] DuPont™ Vespel® TP-8000 series design handbook. DuPont; 2007.

[2] Properties of DuPont VESPEL® parts. DuPont; 1997.

[3] Introducing the new generation in high-temperature components—technical information. DuPont; 2000.

[4] Cao X, Lu F. Structure/permeability relationships of polyamide−imides. J Appl Polym Sci 1994;54:1965−70.

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[7] Extem® resins products, markets and processing guide extreme performance made easy. SABIC Innovative Plastics; 2008.

6 Polyamides (Nylons)

High molecular weight polyamides are commonly known as nylon. Polyamides are crystalline polymers typically produced by the condensation of a diacid and a diamine. There are several types and each type is often described by a number, such as Nylon 66 or Polyamide 66 (PA66). The numeric suffixes refer to the number of carbon atoms present in the molecular structures of the amine and acid respectively (or a single suffix if the amine and acid groups are part of the same molecule).

The polyamide plastic materials discussed in this book and the monomers used to make them are given in Table 6.1.

The general reaction is shown in Figure 6.1.

The $-COOH$ acid group reacts with the $-NH_2$ amine group to form an amide. A molecule of water is given off as the nylon polymer is formed. The properties of the polymer are determined by the R and R′ groups in the monomers. In Nylon 66, $R' = 6C$ and $R = 4C$ alkanes, but one also has to include the two carboxyl carbons in the diacid to get the number it donates to the chain.

The structures of these diamine monomers are shown in Figure 6.2, the diacid monomers are shown in Figure 6.3. Figure 6.4 shows the amino-acid monomers. These structures only show the functional groups, the CH_2 connecting groups are implied at the bond intersections.

All polyamides tend to absorb moisture which can affect the properties. Properties are often reported as DAM (dry as molded) or conditioned (usually at equilibrium in 50% relative humidity (RH) at 23°C). The absorbed water tends to act like a plasticizer and can have a significant effect on the plastics properties.

Table 6.1 Monomers Used to Make Specific Polyamides/Nylons

Polyamide/ Nylon Type	Monomers Used to Make
Nylon 6	Caprolactam
Nylon 11	Aminoundecanoic acid
Nylon 12	Aminolauric acid
Nylon 66	1,6-Hexamethylene diamine and adipic acid
Nylon 610	1,6-Hexamethylene diamine and sebacic acid
Nylon 612	1,6-Hexamethylene diamine and 1,12-dodecanedioic acid
Nylon 666	Copolymer based on Nylon 6 and Nylon 66
Nylon 46	1,4-Diaminobutane and adipic acid
Nylon amorphous	Trimethyl hexamethylene diamine and TPA
PPA	Any diamine and IPA and/or TPA

6.1 Nylon 6 (PA6)

Nylon 6 begins as pure caprolactam, which is a ring structured molecule. This is unique in that the ring is opened and the molecule polymerizes with itself. Since caprolactam has six carbon atoms, the nylon that is produced is called Nylon 6, which is nearly the same as Nylon 66 described in Section 6.5. The structure of Nylon 6 is shown in Figure 6.5 with the repeating unit in the brackets.

Some of the Nylon 6 characteristics are as follows:

- Outstanding balance of mechanical properties
- Outstanding toughness in equilibrium moisture content
- Outstanding chemical resistance and oil resistance
- Outstanding wear and abrasion resistance
- Almost all grades are self-extinguishing. The flame-resistant grades are rated UL 94VO

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
DOI: http://dx.doi.org/10.1016/B978-0-323-31016-1.00006-4
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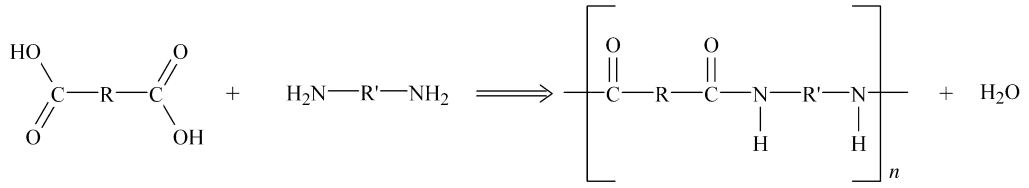

Figure 6.1 Generalized polyamide reaction.

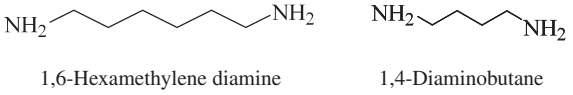

Figure 6.2 Chemical structures of diamines used to make polyamides.

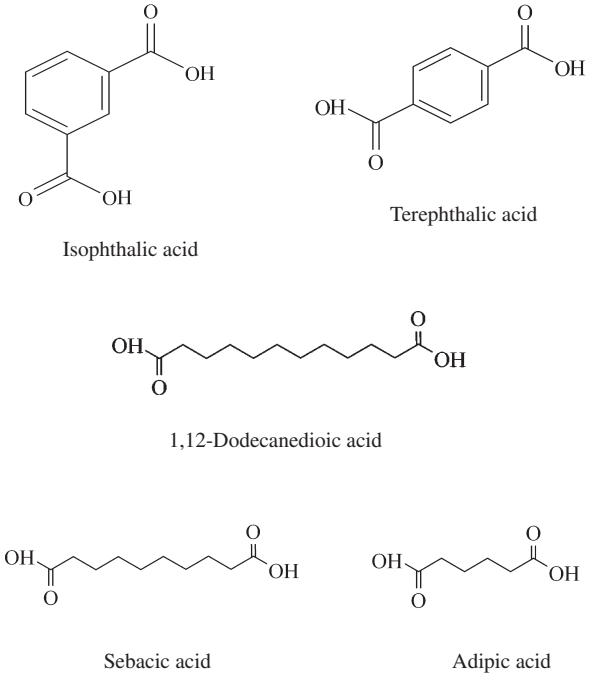

Figure 6.3 Chemical structures of diacids used to make polyamides.

- Outstanding long-term heat resistance (at a long-term continuous maximum temperature ranging between 80°C and 150°C)
- Grades reinforced with glass fiber and other materials offer superior elastic modulus and strength

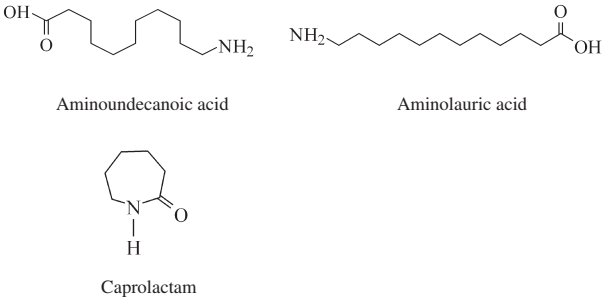

Figure 6.4 Chemical structures of aminoacids used to make polyamides.

- Offers low gasoline permeability and outstanding gas barrier properties
- Highest rate of water absorption and highest equilibrium water content (8% or more)
- Excellent surface finish even when reinforced
- Poor chemical resistance to strong acids and bases

Manufacturers and trade names: BASF Ultramid® B, Honeywell Capran® and Aegis®, EMS Grivory Grilon® B, UBE Industries, SABIC Innovative Plastics LNP Thermocomp™.

Applications and uses: gears, fittings, and bearings, in automotive industry for under-the-hood parts, power tools housings, as thread in bristles for toothbrushes, surgical sutures, and strings for acoustic and classical musical instruments, gun frames, such as those used by Glock.

Data for polyamide 6 plastics are found in Figures 6.6–6.35.

6.2 Nylon 11 (PA11)

Nylon 11 has only one monomer, aminoundecanoic acid. It has the necessary amine group on one end, and the acid group on the other. It polymerizes

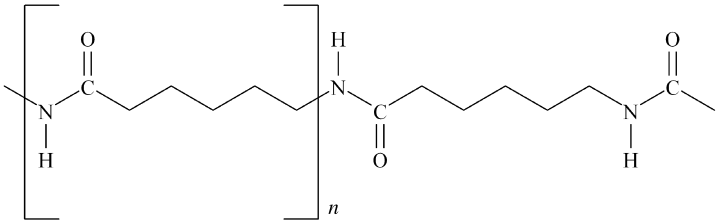

Figure 6.5 Chemical structure of Nylon 6.

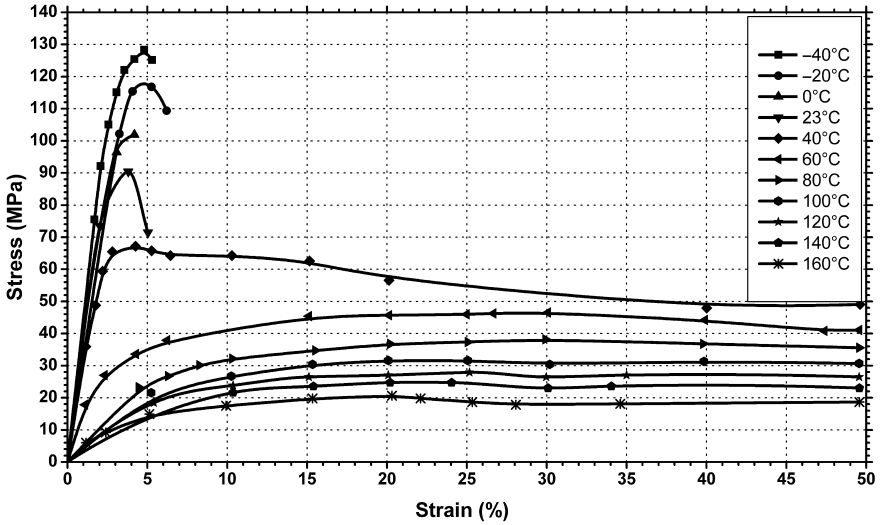

Figure 6.6 Stress vs. strain for dry EMS Grivory Grilon® BS/2 impact modified PA6 resin [1].

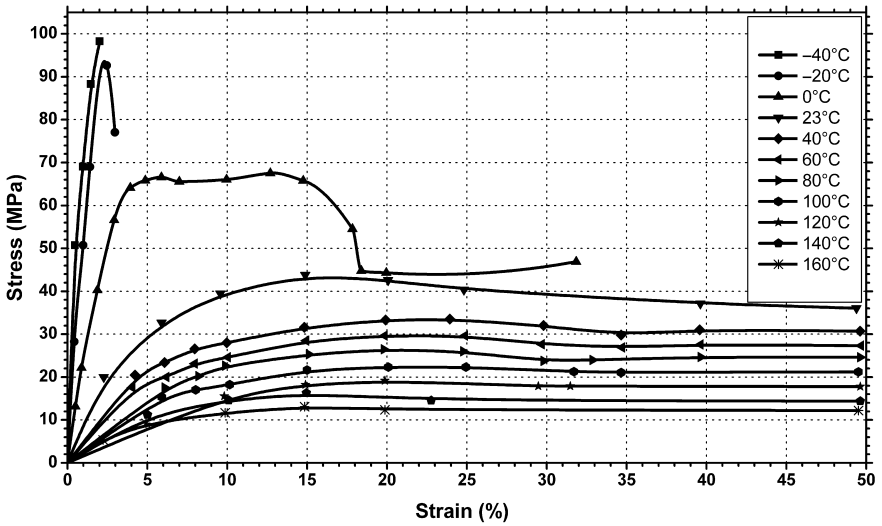

Figure 6.7 Stress vs. strain for conditioned EMS Grivory Grilon® BS/2 impact modified PA6 resin [1].

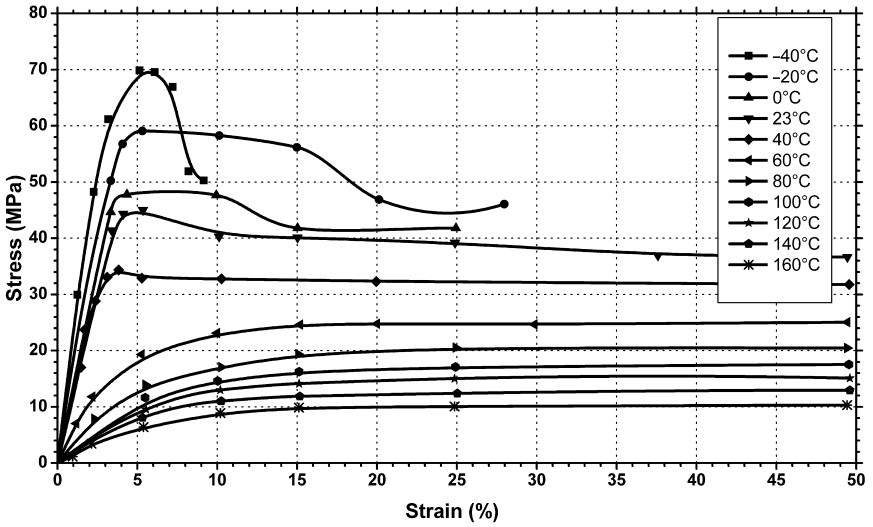

Figure 6.8 Stress vs. strain for dry EMS Grivory Grilon® BZ 3 high impact modified PA6 resin [1].

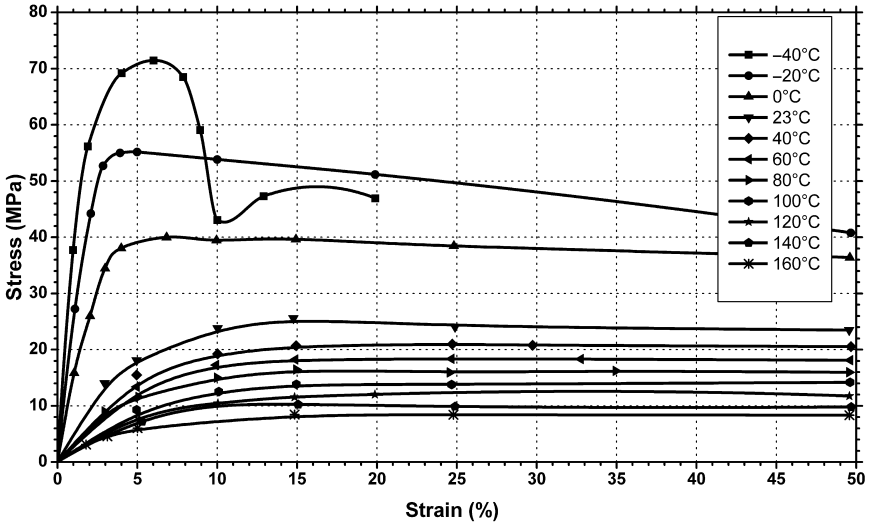

Figure 6.9 Stress vs. strain for conditioned EMS Grivory Grilon® BZ 3 high impact modified PA6 resin [1].

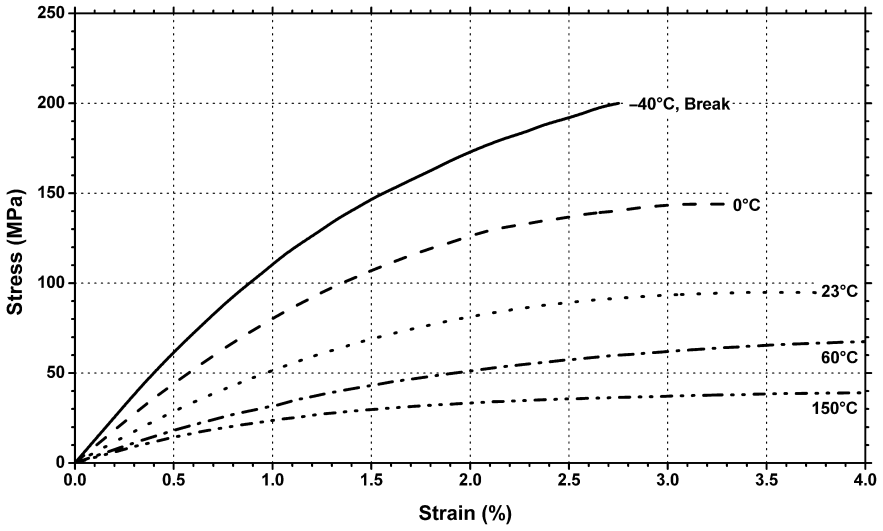

Figure 6.10 Stress vs. strain at various temperatures for BASF Ultramid® B3EG5—stabilized, 25% glass fiber reinforced Nylon 6 resin (conditioned at 50% RH).

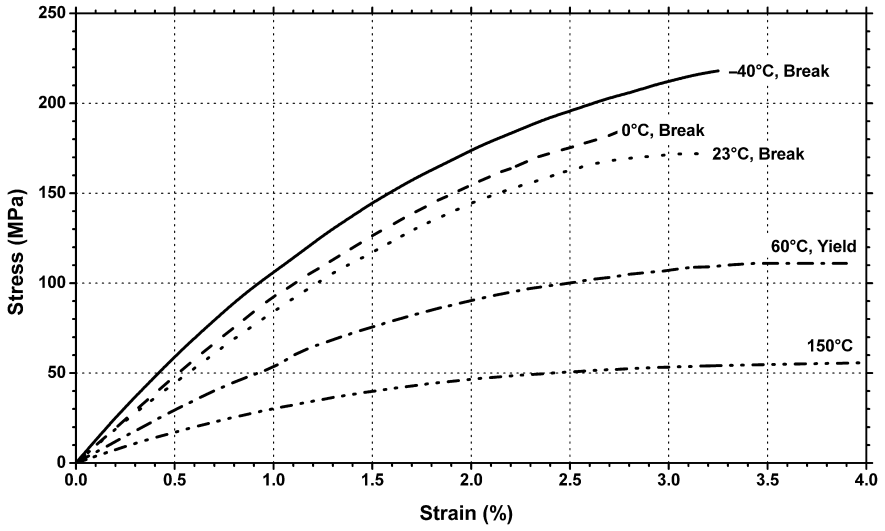

Figure 6.11 Stress vs. strain at various temperatures for BASF Ultramid® B3EG5—stabilized, 25% glass fiber reinforced Nylon 6 resin (DAM).

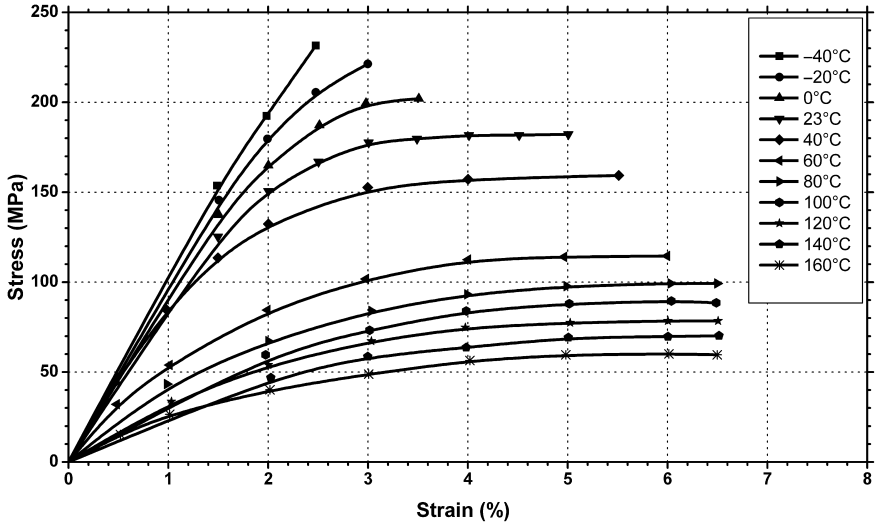

Figure 6.12 Stress vs. strain for dry EMS Grivory Grilon® BG-30 S 30% glass fiber, smooth PA6 resin [1].

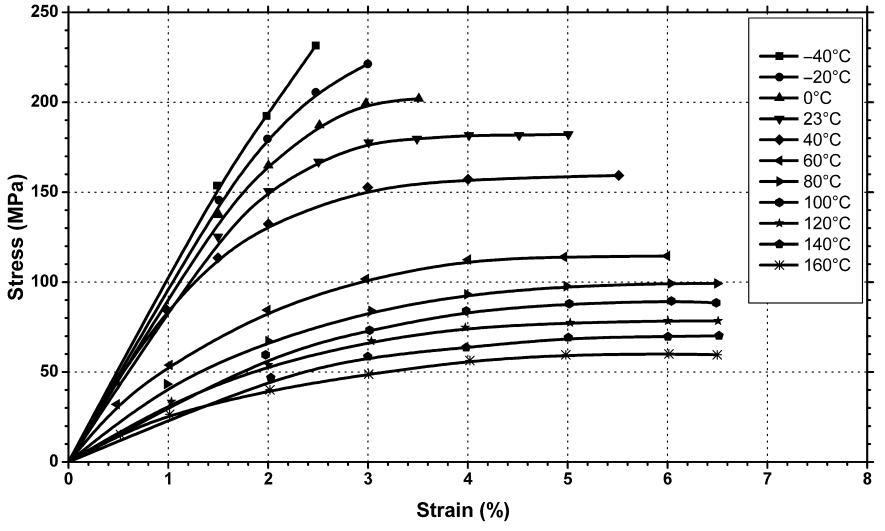

Figure 6.13 Stress vs. strain for conditioned EMS Grivory Grilon® BG-30 S 30% glass fiber, smooth PA6 resin [1].

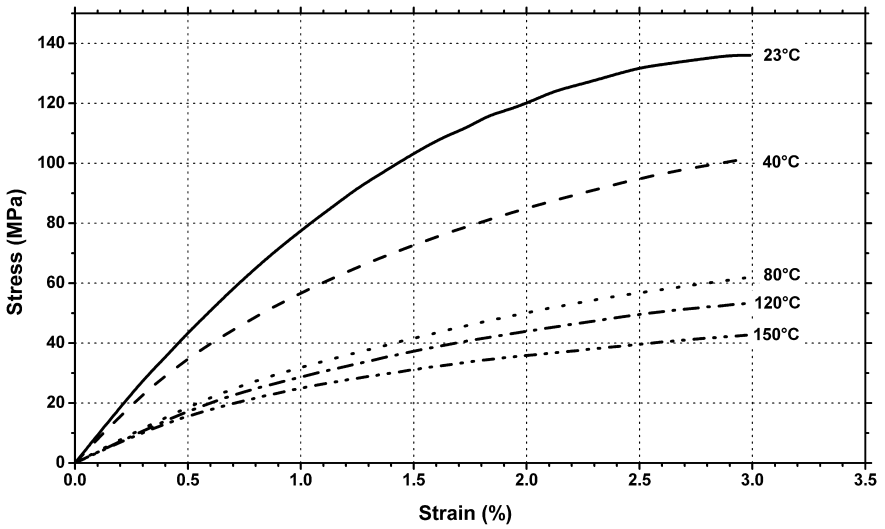

Figure 6.14 Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp™ PF006—30% glass fiber reinforced Nylon 6 resin (DAM).

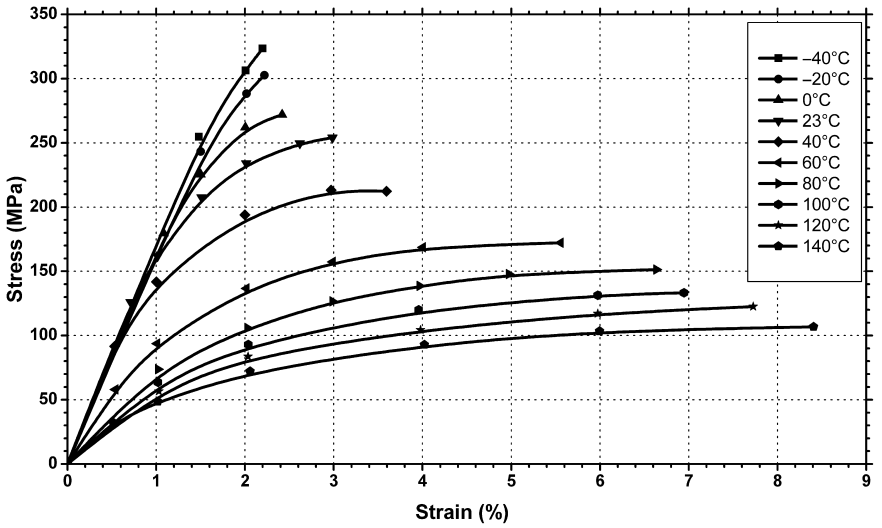

Figure 6.15 Stress vs. strain for dry EMS Grivory Grilon® BG-50 H 50% glass fiber, heat stabilized PA6 resin [1].

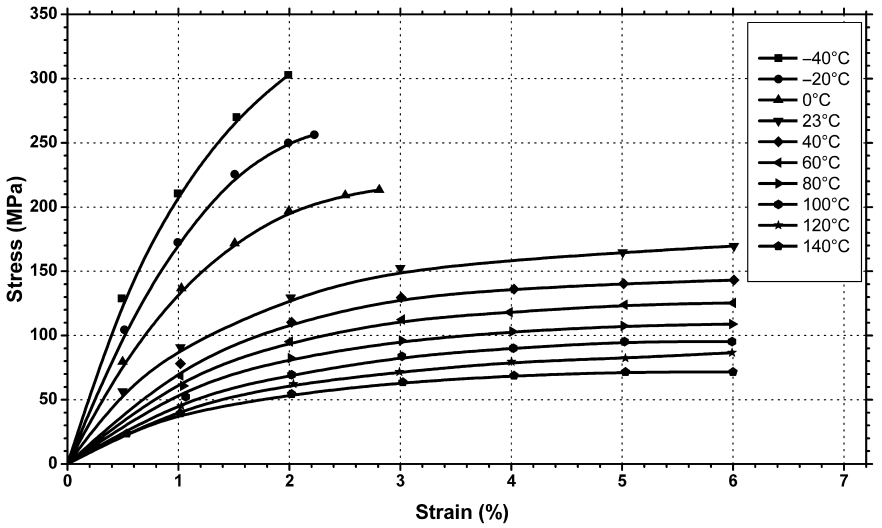

Figure 6.16 Stress vs. strain for conditioned EMS Grivory Grilon® BG-50 H 50% glass fiber, heat stabilized PA6 resin [1].

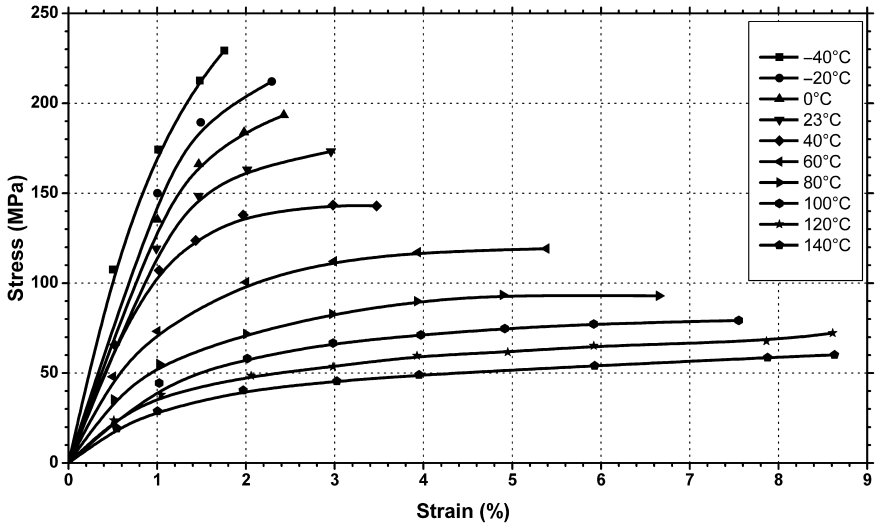

Figure 6.17 Stress vs. strain for dry EMS Grivory Grilon® BG-50 HM 50% glass fiber (adhesion modified) PA6 resin [1].

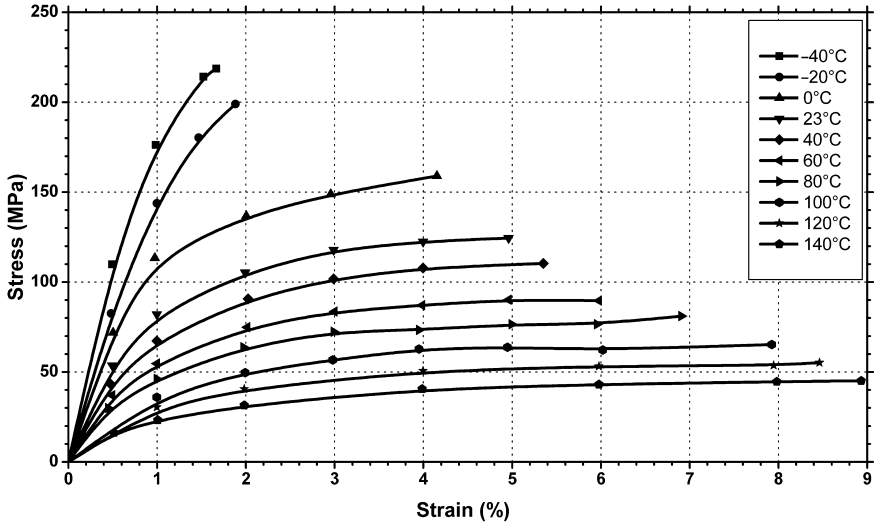

Figure 6.18 Stress vs. strain for conditioned EMS Grivory Grilon® BG-50 HM 50% glass fiber (adhesion modified) PA6 resin [1].

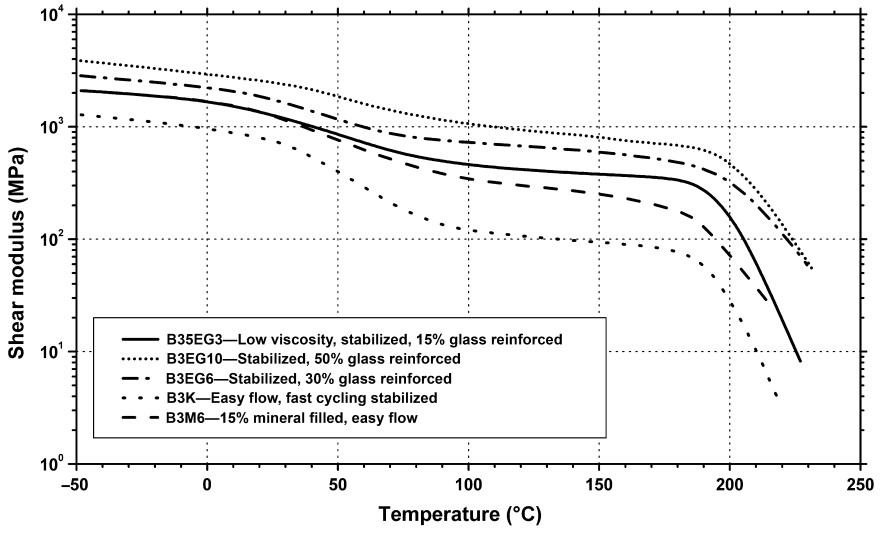

Figure 6.19 Shear modulus vs. temperature for several BASF Ultramid® Nylon 6 resins.

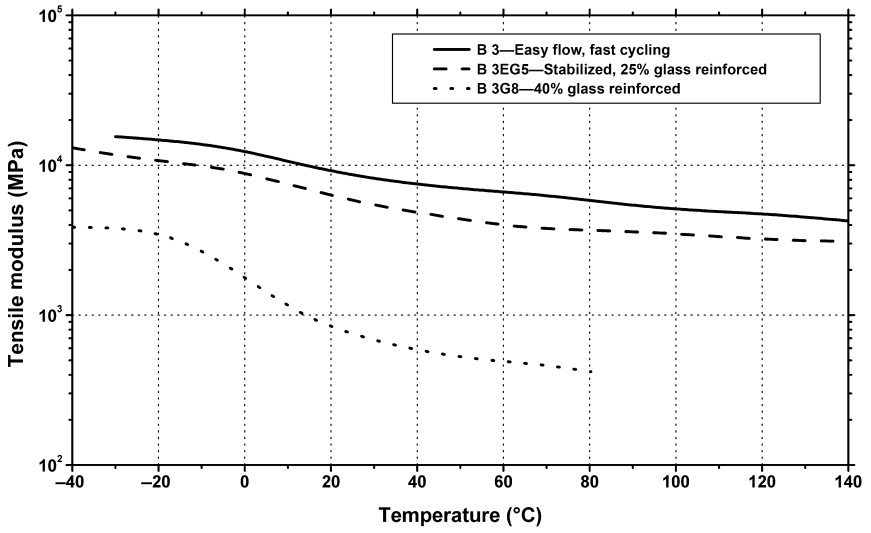

Figure 6.20 Tensile modulus vs. temperature for BASF Nylon 6 resins (conditioned at 50% RH).

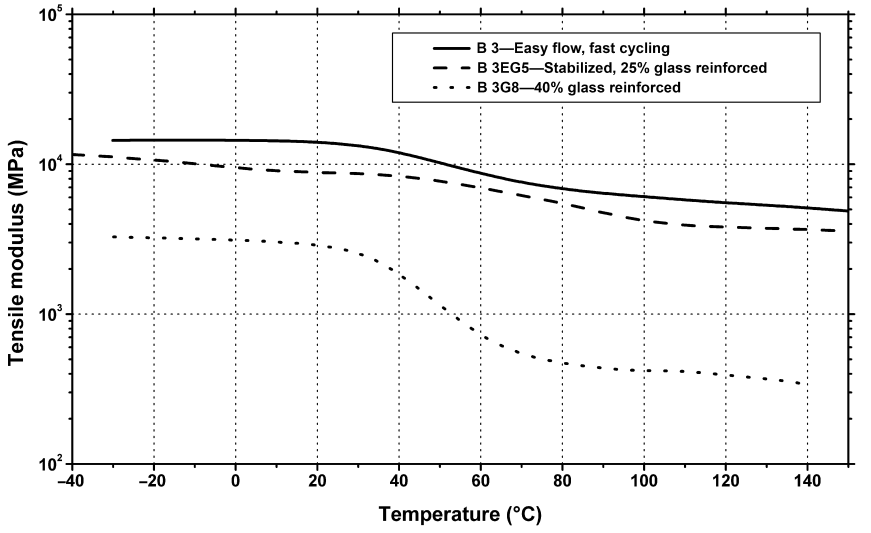

Figure 6.21 Tensile modulus vs. temperature for BASF Nylon 6 resins (DAM).

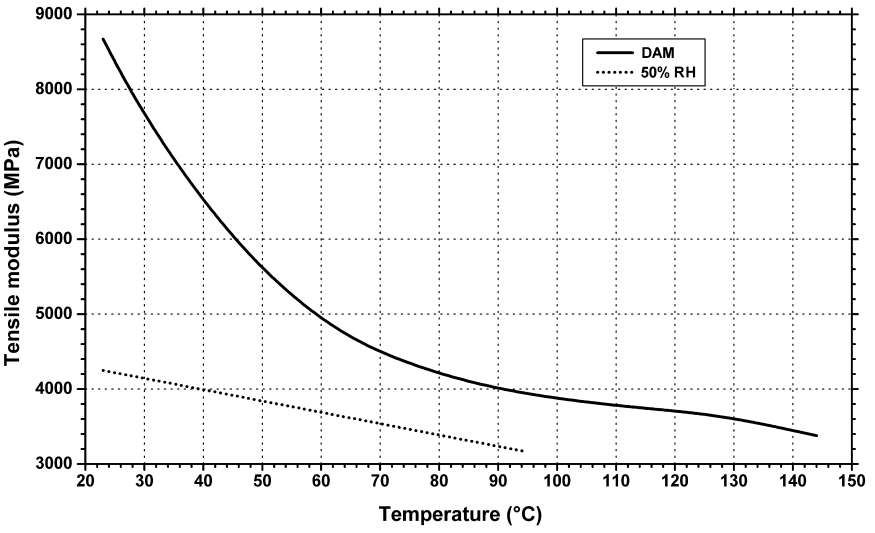

Figure 6.22 Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ PF006—30% glass fiber reinforced Nylon 6 resin.

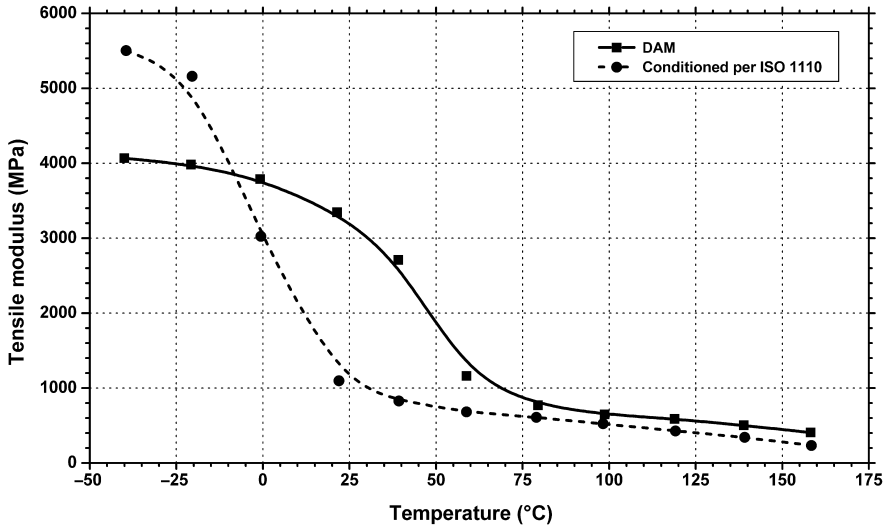

Figure 6.23 Tensile modulus vs. temperature, dry and conditioned, for EMS Grivory Grilon® BS/2 impact modified PA6 resin [1].

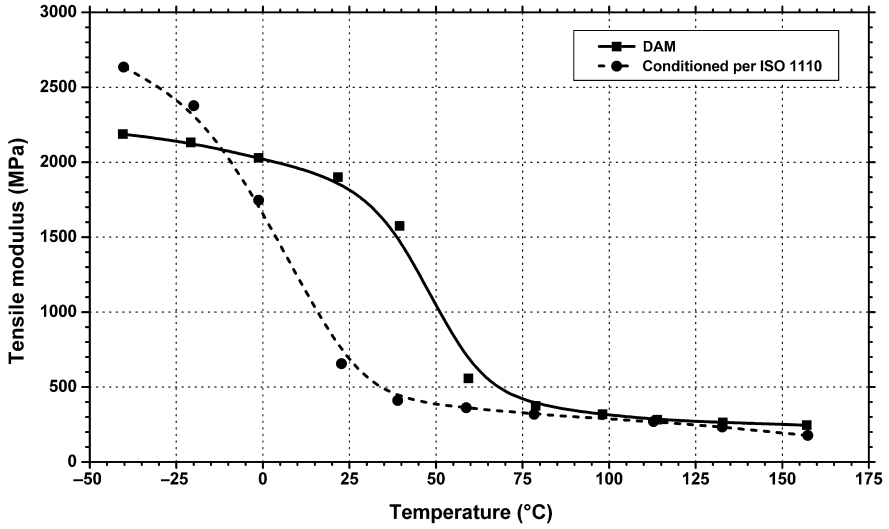

Figure 6.24 Tensile modulus vs. temperature, dry and conditioned, for EMS Grivory Grilon® BZ 3 high impact modified PA6 resin [1].

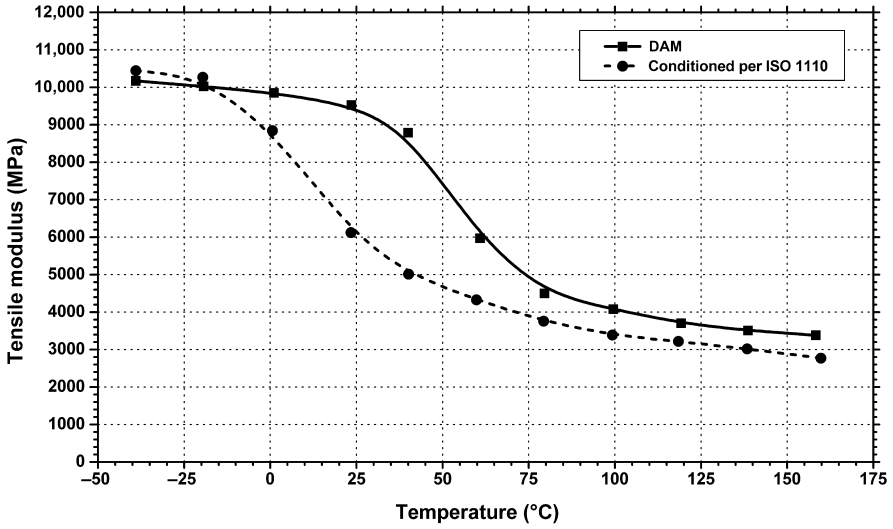

Figure 6.25 Tensile modulus vs. temperature, dry and conditioned, for EMS Grivory Grilon® BG-30 S 30% glass fiber, smooth PA6 resin [1].

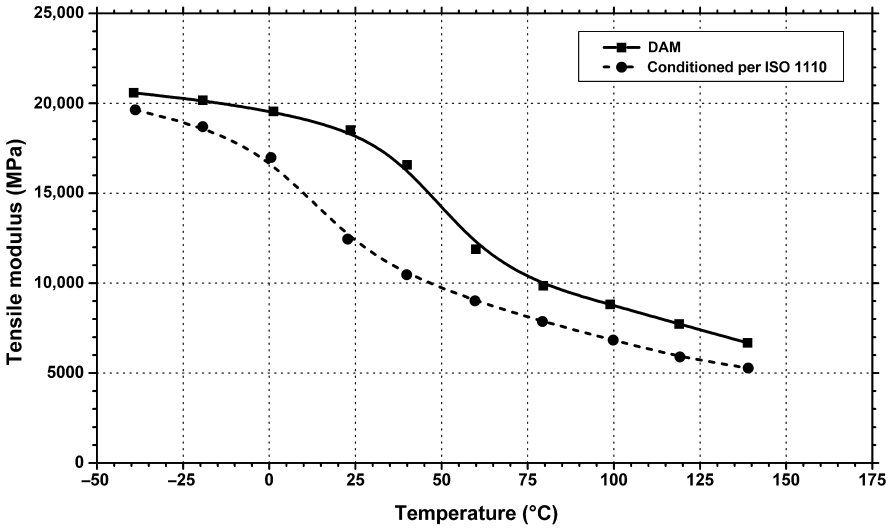

Figure 6.26 Tensile modulus vs. temperature, dry and conditioned, for EMS Grivory Grilon® BG-50 H 50% glass fiber, heat stabilized PA6 resin [1].

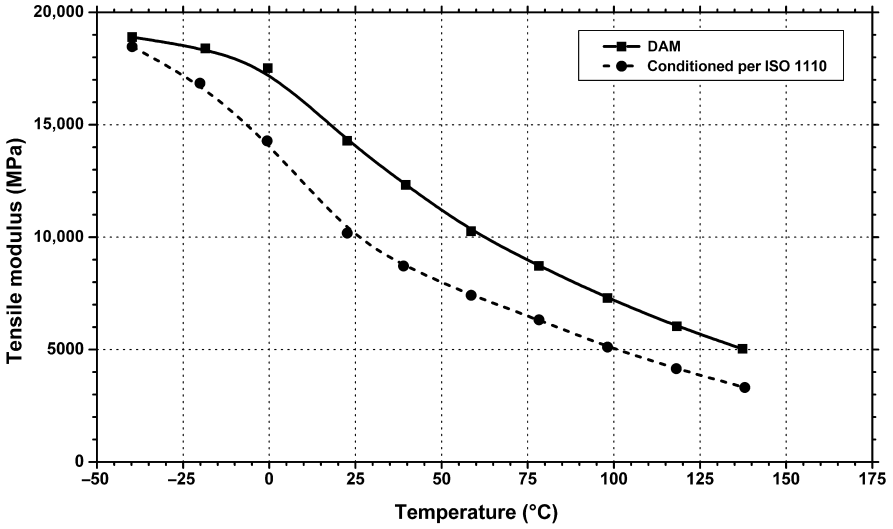

Figure 6.27 Tensile modulus vs. temperature, dry and conditioned, for EMS Grivory Grilon® BG-50 HM 50% glass fiber (adhesion modified) PA6 resin [1].

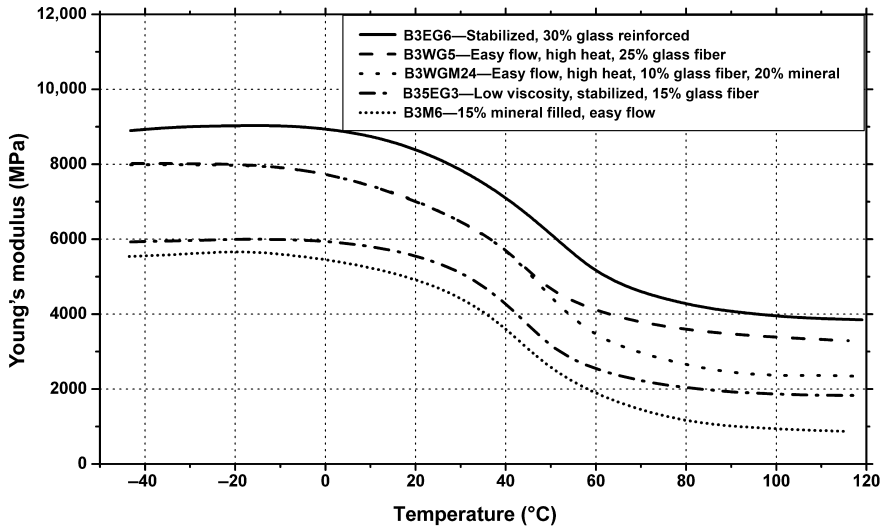

Figure 6.28 Young's modulus vs. temperature for BASF Ultramid® reinforced Nylon 6 resins.

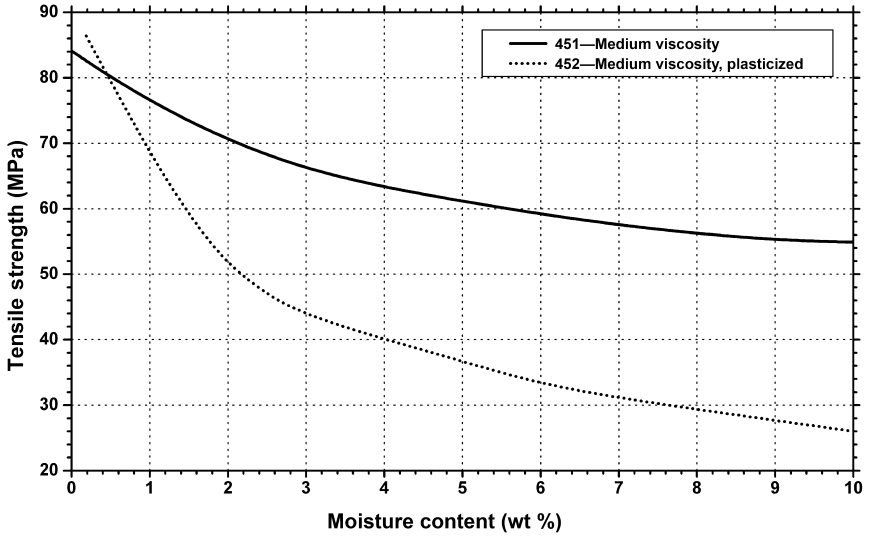

Figure 6.29 Tensile strength vs. moisture content for Polymeric Resources Corporation Nylene® Nylon 6 resins.

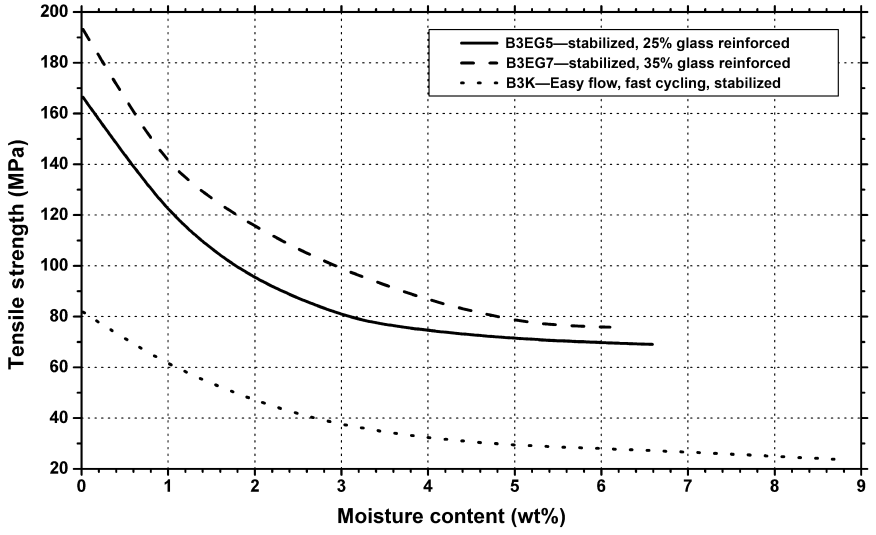

Figure 6.30 Tensile strength vs. moisture content for several BASF Ultramid® Nylon 6 resins.

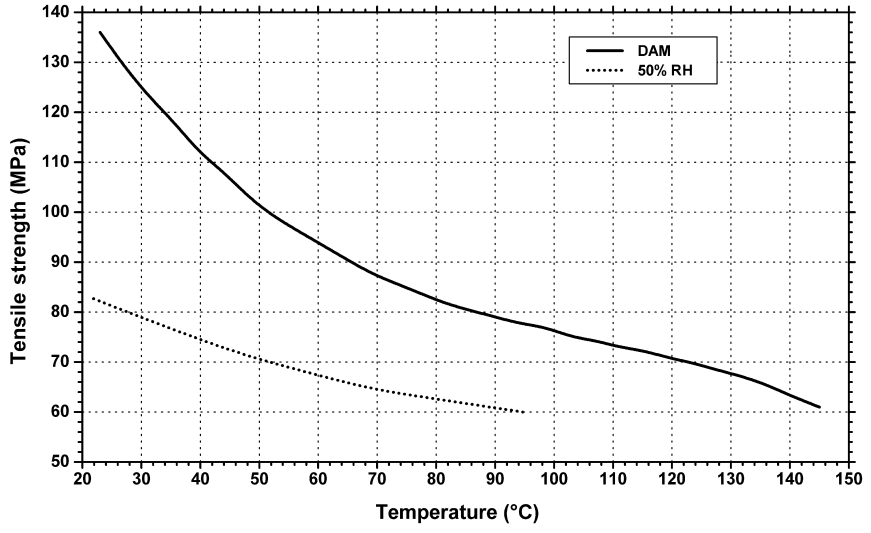

Figure 6.31 Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ PF006—30% glass fiber reinforced Nylon 6 resin.

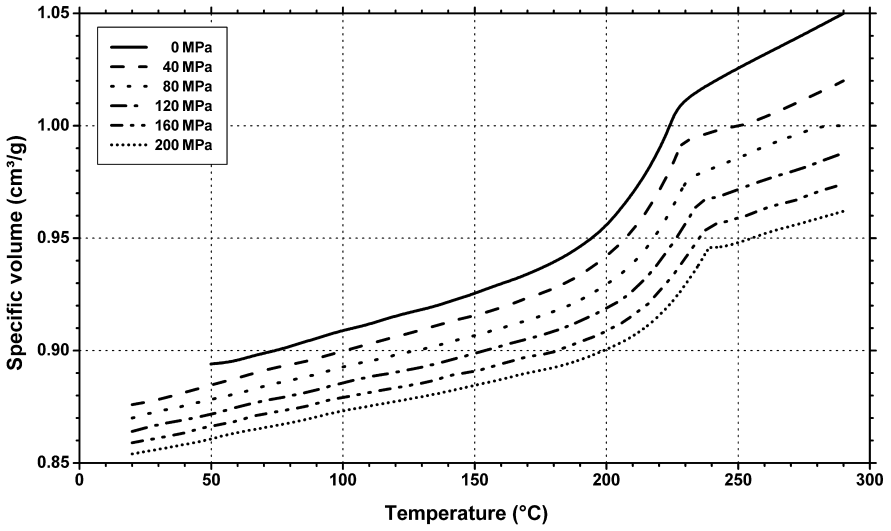

Figure 6.32 Pressure–specific volume–temperature (PVT) for BASF Ultramid® B3K easy flow, fast cycling Nylon 6 resin.

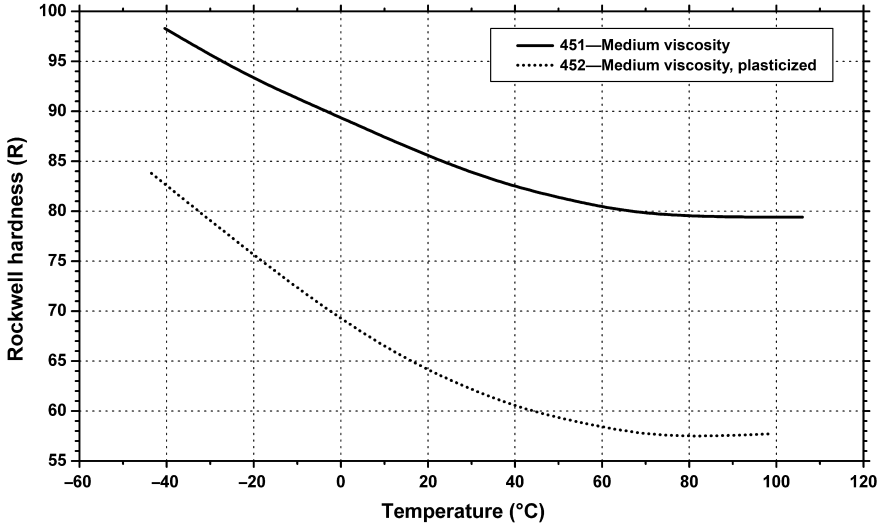

Figure 6.33 Rockwell hardness vs. temperature for Polymeric Resources Corporation Nylene® Nylon 6 resins.

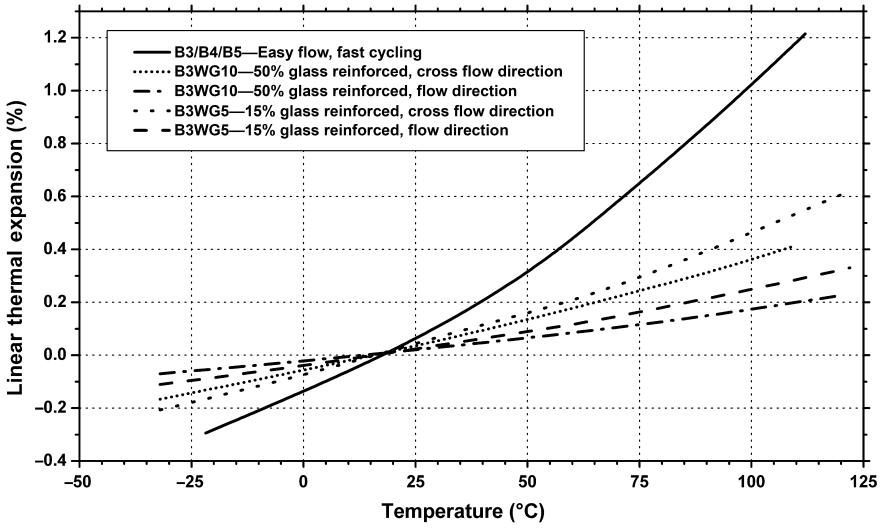

Figure 6.34 Linear thermal expansion vs. temperature for several BASF Ultramid® Nylon 6 resins.

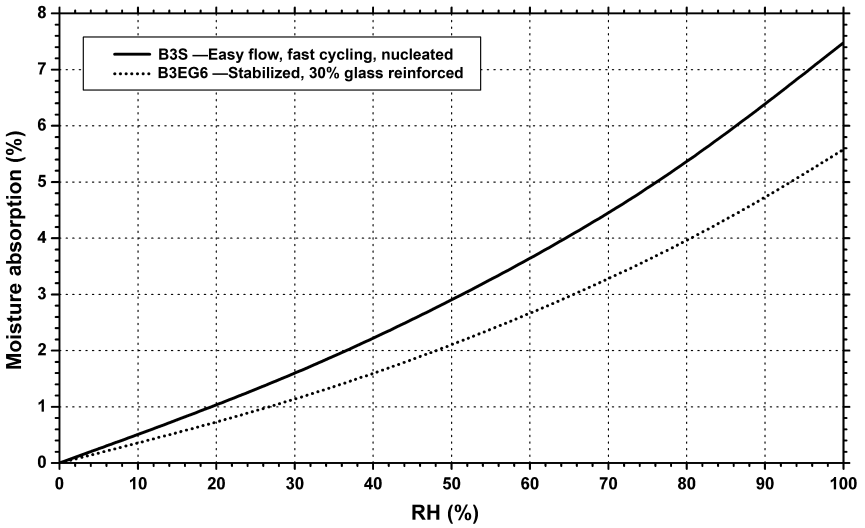

Figure 6.35 Water absorption vs. RH for two BASF Ultramid® Nylon 6 resins.

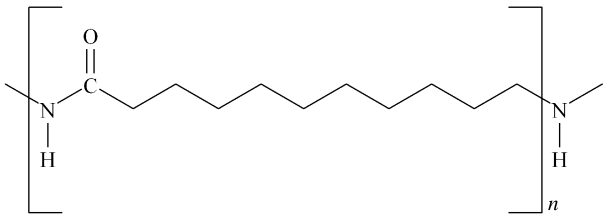

Figure 6.36 Chemical structure of Nylon 11.

with itself to produce the polyamide containing 11 carbons between the nitrogens of the amide groups. Its structure is shown in Figure 6.36.

Rilsan® PA11 is produced from a "green" raw material—castor beans.

Some of the Nylon 11 characteristics are as follows:

- Low water absorption for a nylon (c. 2.5% at saturation)
- Reasonable UV resistance
- Higher strength
- Ability to accept high loading of fillers
- Better heat resistance than Nylon 12
- More expensive than Nylon 6 or Nylon 66
- Relatively low impact strength

Manufacturers and trade names: Arkema Rilsan® B, Suzhou Hipro Polymers Hiprolon®, SABIC Innovative Plastics LNP Thermocomp™.

Applications and uses: automotive fuel lines, fluid transfer lines (brake, clutch, cooling), quick connectors, fittings, fasteners and clips, friction parts, pneumatic hoses, air lines, hydraulic hoses, oil and gas umbilical hoses, racket eyelets and bumpers, badminton shuttlecocks, ski top layers, shoes soles, and mechanical parts (footwear, rackets, ski industry).

Data for polyamide 11 plastics are found in Figures 6.37–6.52.

6.3 Nylon 12 (PA12)

Nylon 12 has only one monomer, aminolauric acid. It has the necessary amine group on one end, and the acid group on the other. It polymerizes with itself to produce the polyamide containing 12 carbons between the two nitrogen atoms of the two amide groups. Its structure is shown in Figure 6.53.

The properties of semicrystalline polyamides are determined by the concentration of amide groups in the macromolecules. Polyamide 12 has the lowest amide group concentration of all commercially available polyamides thereby substantially promoting its characteristics, given as follows:

- Lowest moisture absorption (~2%): Parts show largest dimensional stability under conditions of changing humidity

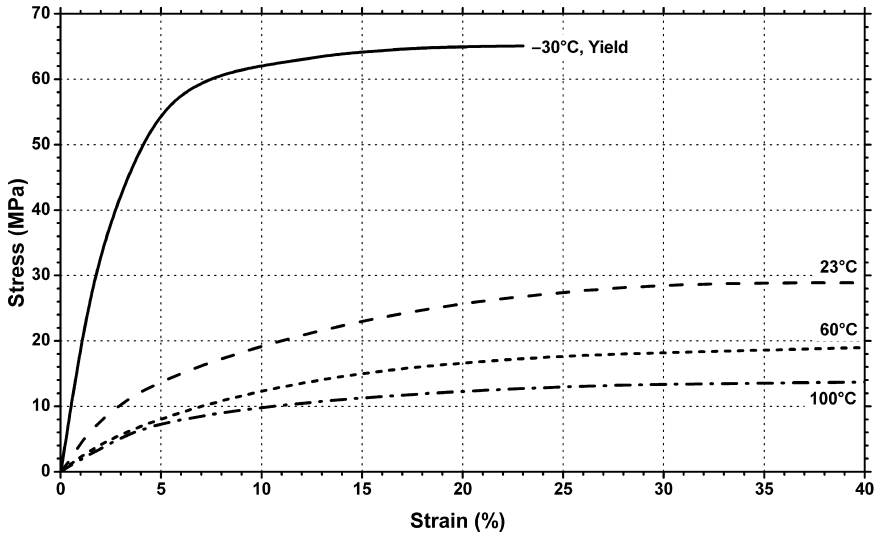

Figure 6.37 Stress vs. strain at various temperatures for Arkema Rilsan® BMN P20—medium flexibility grade Nylon 11 resin (conditioned at 50% RH).

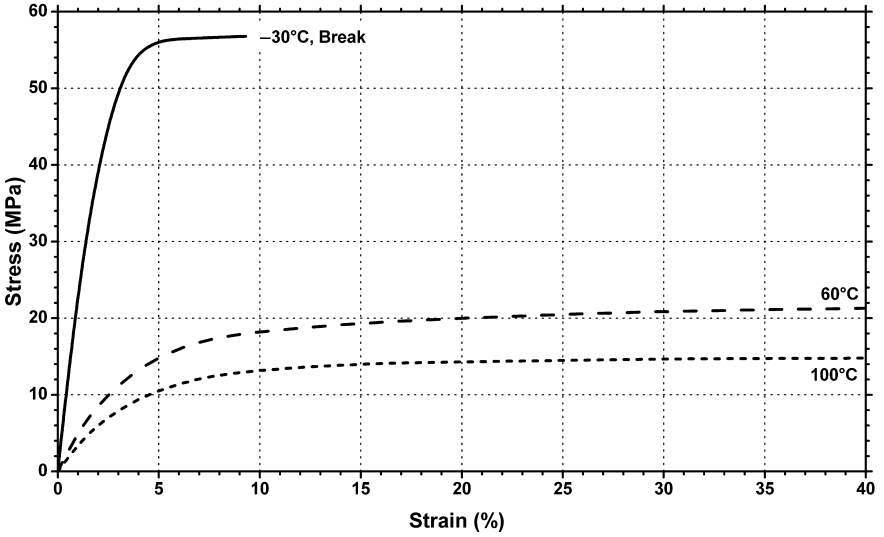

Figure 6.38 Stress vs. strain at various temperatures for Arkema Rilsan® BUM 30 O—rigid grade, 30% glass bead reinforced Nylon 11 resin.

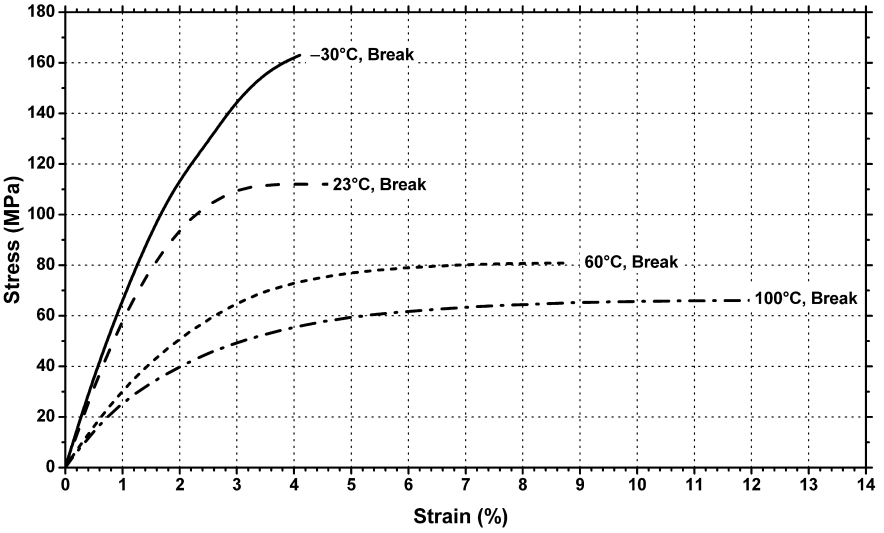

Figure 6.39 Stress vs. strain at various temperatures for Arkema Rilsan® BZM 23 G9—rigid grade, 23% glass and 9% graphite reinforced Nylon 11 resin.

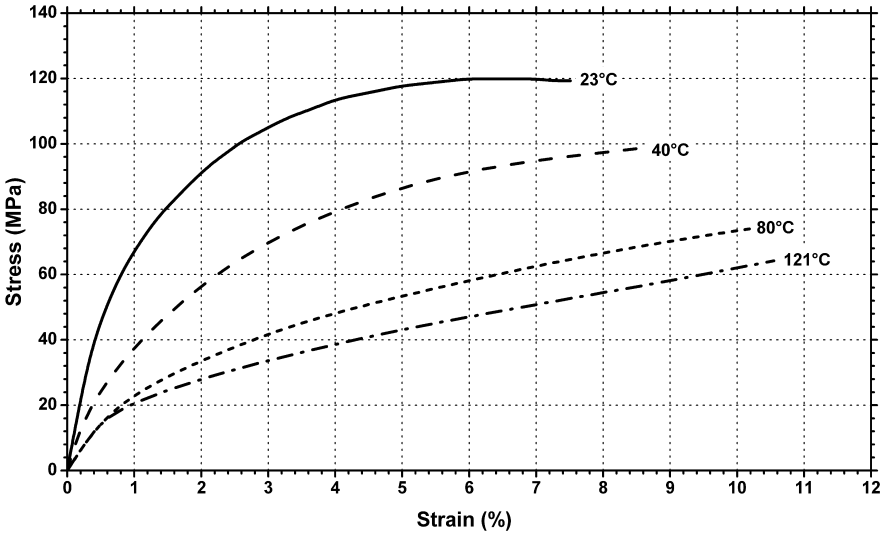

Figure 6.40 Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp™ HX05073—30% glass filled Nylon 11 resin.

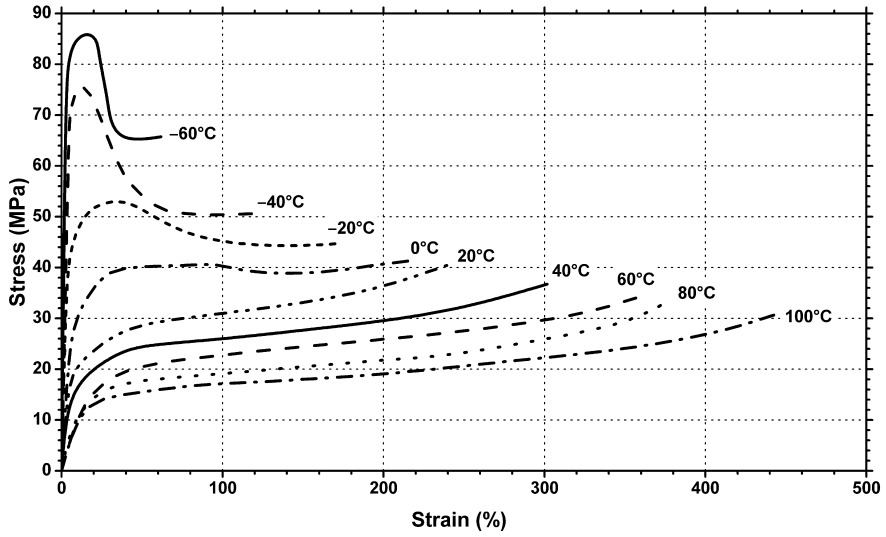

Figure 6.41 Stress vs. strain curve at various temperatures for Arkema Rilsan® BESNO P40 TL [2].

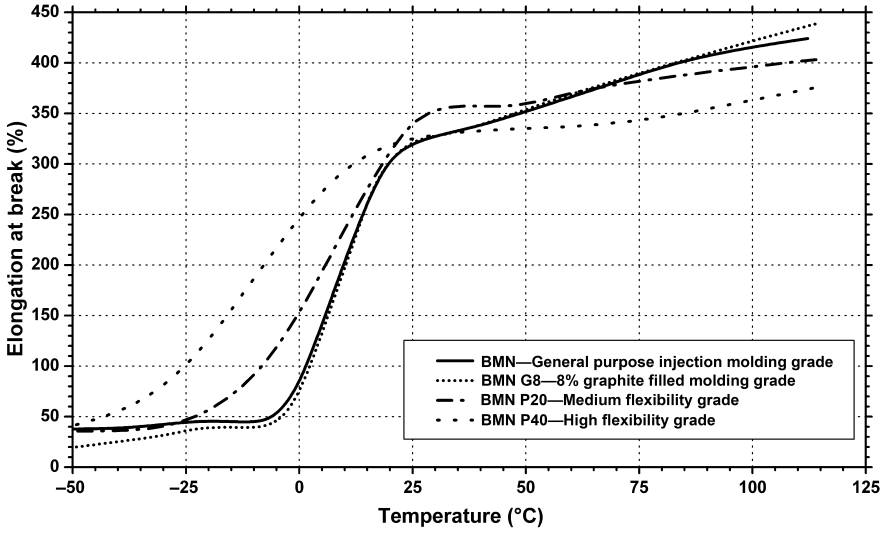

Figure 6.42 Elongation at break vs. temperature for several Arkema Rilsan® BMN Nylon 11 resins.

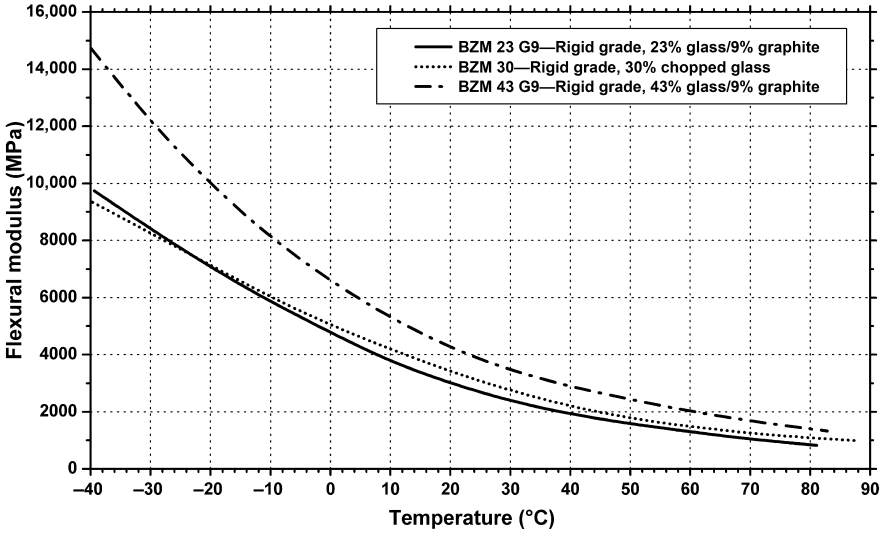

Figure 6.43 Flexural modulus vs. temperature for several Arkema Rilsan® BMZ Nylon 11 resins.

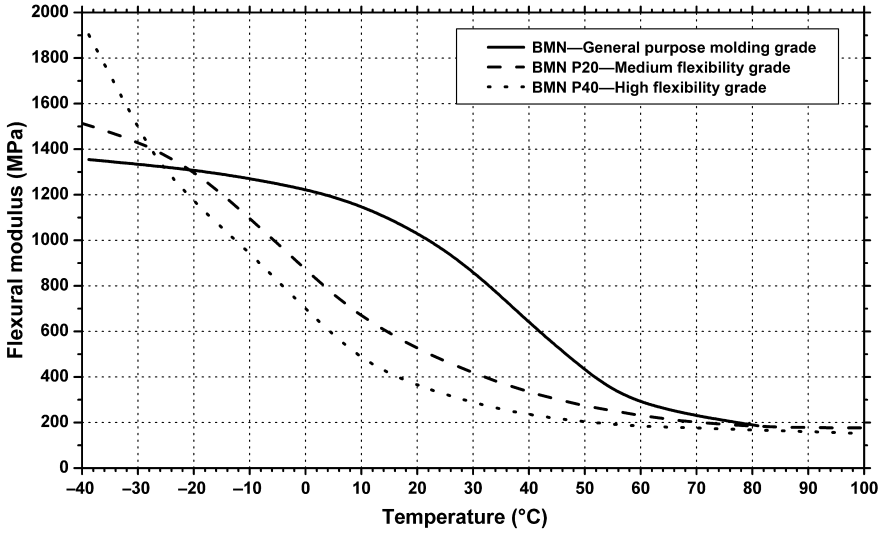

Figure 6.44 Flexural modulus vs. temperature for several Arkema Rilsan® BMN Nylon 11 resins.

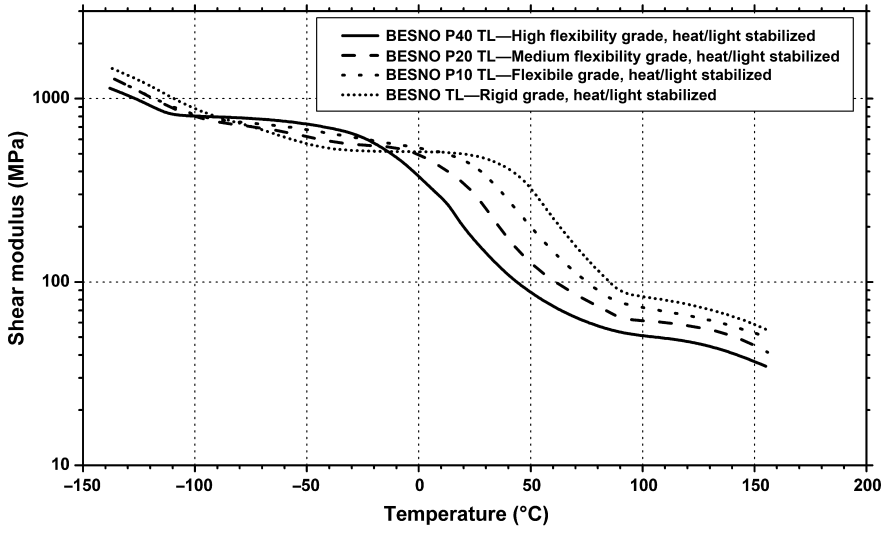

Figure 6.45 Shear modulus vs. temperature for several Arkema Rilsan® BESNO Nylon 11 resins [2].

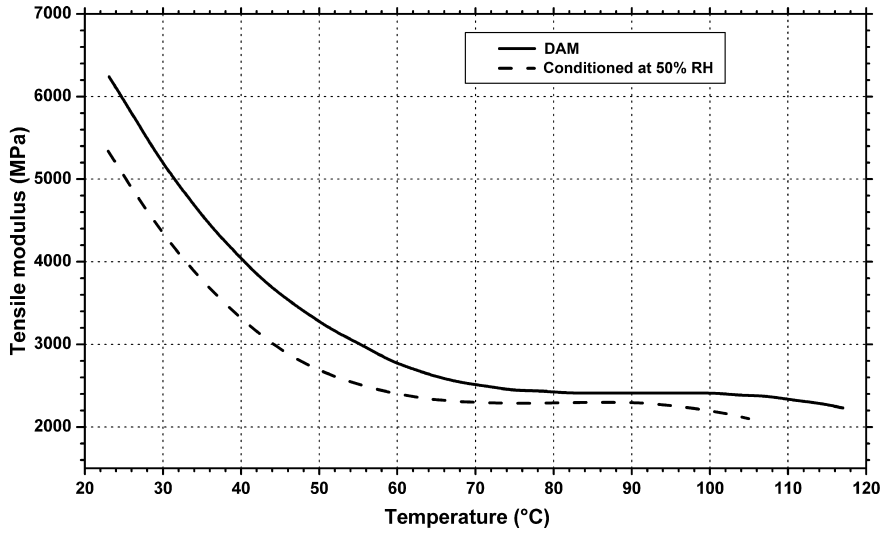

Figure 6.46 Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ HX05073—30% glass filled Nylon 11 resin.

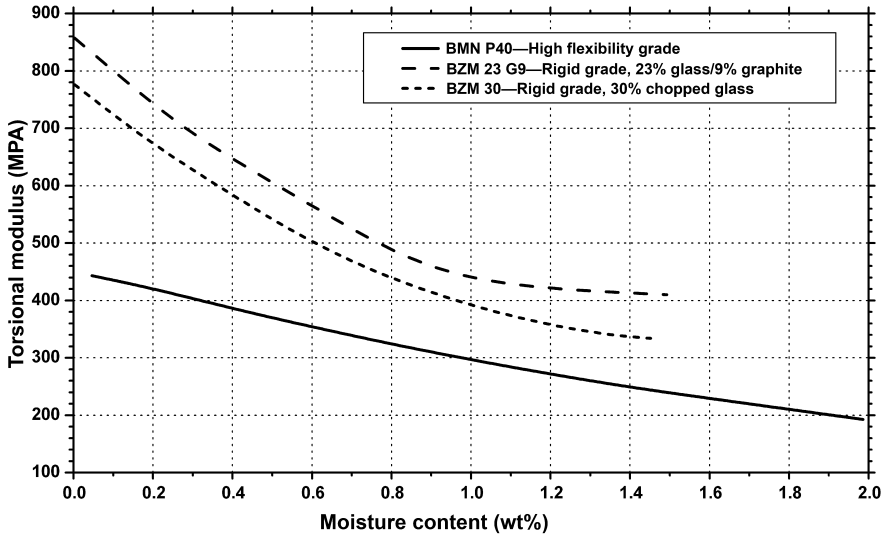

Figure 6.47 Torsional modulus vs. moisture content for several Arkema Rilsan® Nylon 11 resins.

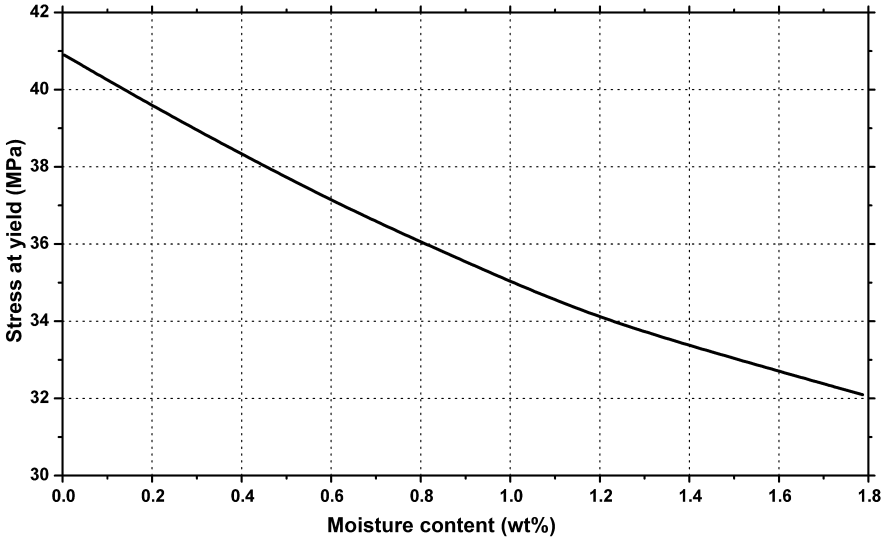

Figure 6.48 Stress at yield vs. moisture content for Arkema Rilsan® BMN Nylon 11 resin.

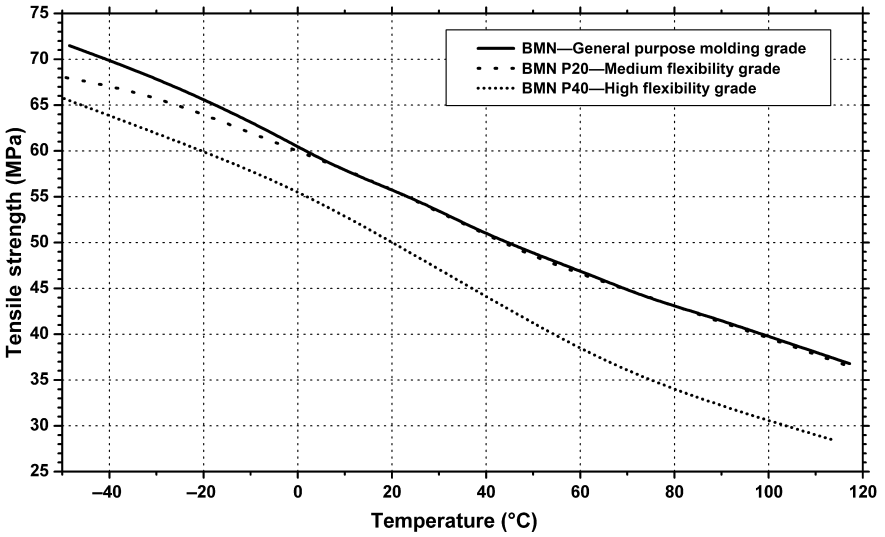

Figure 6.49 Tensile strength vs. temperature for several Arkema Rilsan® BMN Nylon 11 resins.

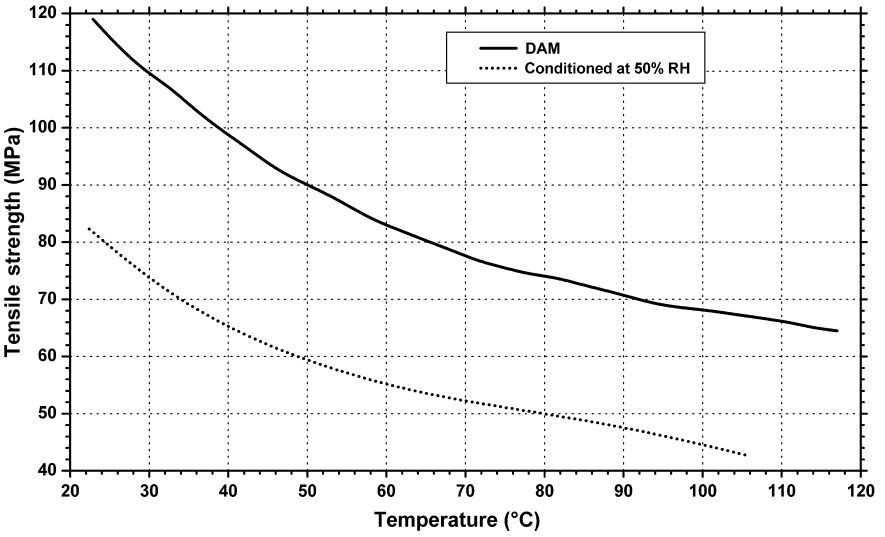

Figure 6.50 Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ HX05073—30% glass filled Nylon 11 resin.

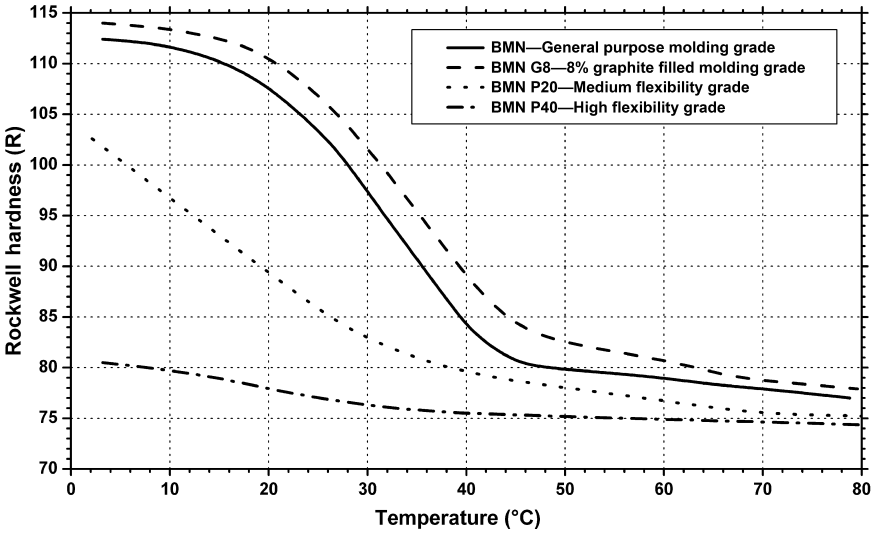

Figure 6.51 Rockwell hardness vs. temperature for several Arkema Rilsan® BMN Nylon 11 resins.

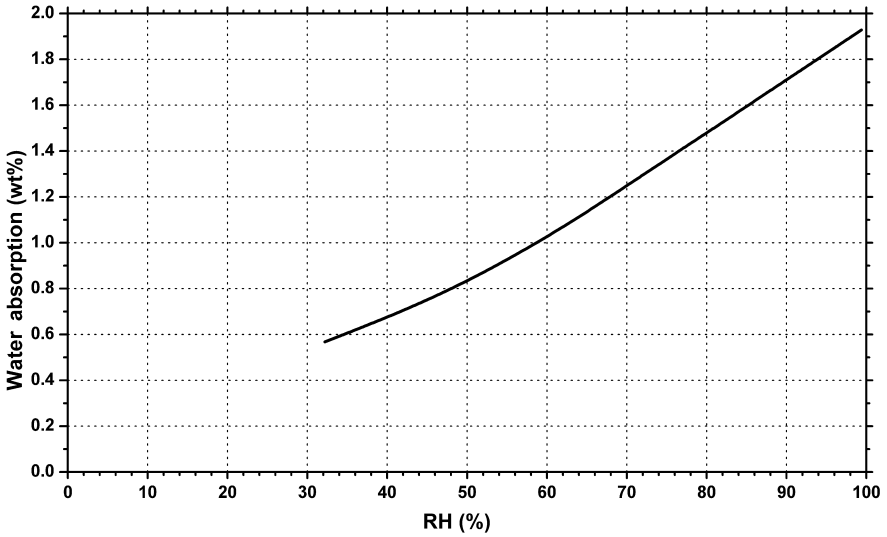

Figure 6.52 Equilibrium water absorption vs. RH for Arkema Rilsan® BMN Nylon 11 resin.

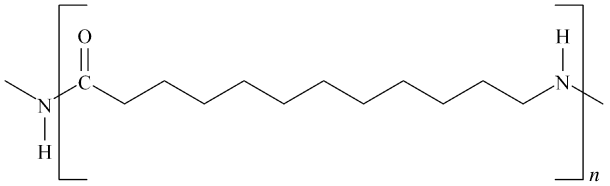

Figure 6.53 Chemical structure of Nylon 12.

- Exceptional impact and notched impact strength, even at temperatures well below the freezing point
- Good to excellent resistance against greases, oils, fuels, hydraulic fluids, various solvents, salt solutions, and other chemicals
- Exceptional resistance to stress cracking, including metal parts encapsulated by injection molding or embedded
- Excellent abrasion resistance
- Low coefficient of sliding friction
- Noise and vibration damping properties
- Good fatigue resistance under high frequency cyclical loading condition
- High processability
- Expensive
- Lowest strength and heat resistance of any polyamide unmodified generic

Manufacturers and trade names: Arkema Rilsan® A, EMS-Grivory Grilamid®, Exopack Dartek®, Evonik Industries Vestamid®.

Applications and uses: many uses in the fields of automotive, electric and electronic, packaging, leisure, sport and mechanical engineering.

Data for polyamide 12 plastics are found in Figures 6.54–6.63.

6.4 Nylon 46 (PA46)

The structure of Nylon 46 is shown in Figure 6.64.

Some of the Nylon 46 characteristics are as follows:

- Higher heat distortion temperature than Nylon 6 or Nylon 66
- Higher crystallinity than Nylon 6 or Nylon 66
- Better chemical resistance, particularly to acidic salts
- Similar moisture absorption to Nylon 66, but dimensional increase is less
- High processing temperature
- Highest mechanical properties at high temperatures
- Excellent resistance to wear and low friction
- Outstanding flow for easy processing

Manufacturers and trade names: DSM Stanyl®, DuPont Zytel®.

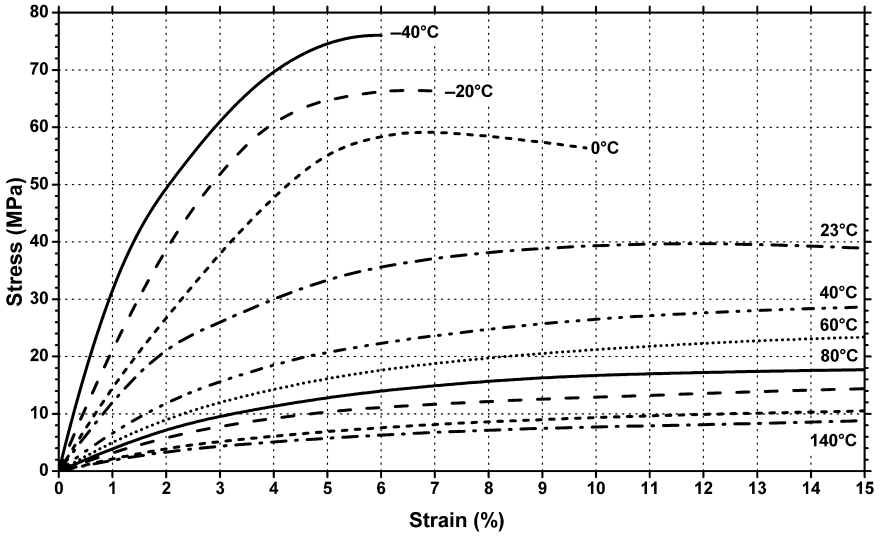

Figure 6.54 Stress vs. strain at various temperatures for conditioned EMS-Grivory Grilamid® L 20 G—medium viscosity, lubricated Nylon 11 resin [3].

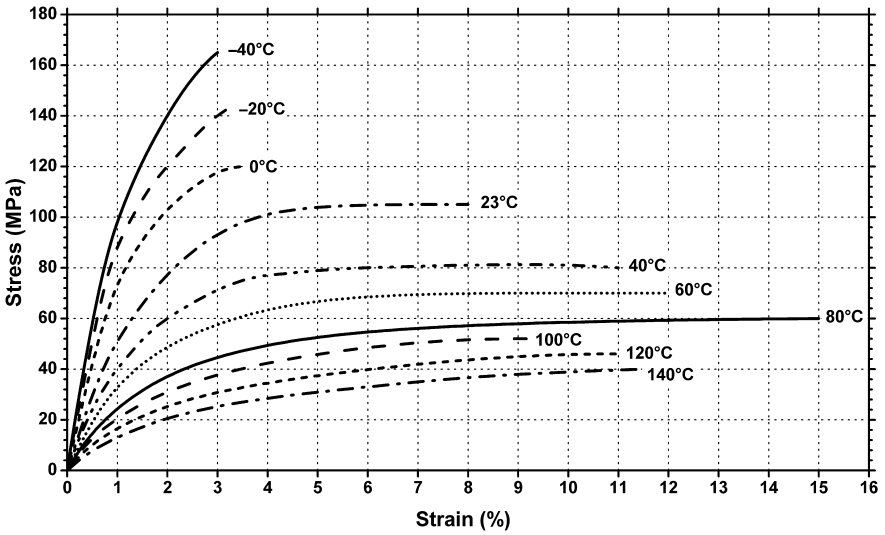

Figure 6.55 Stress vs. strain at various temperatures for conditioned EMS-Grivory Grilamid® LV-3H—30% glass fiber, heat stabilized Nylon 11 resin [3].

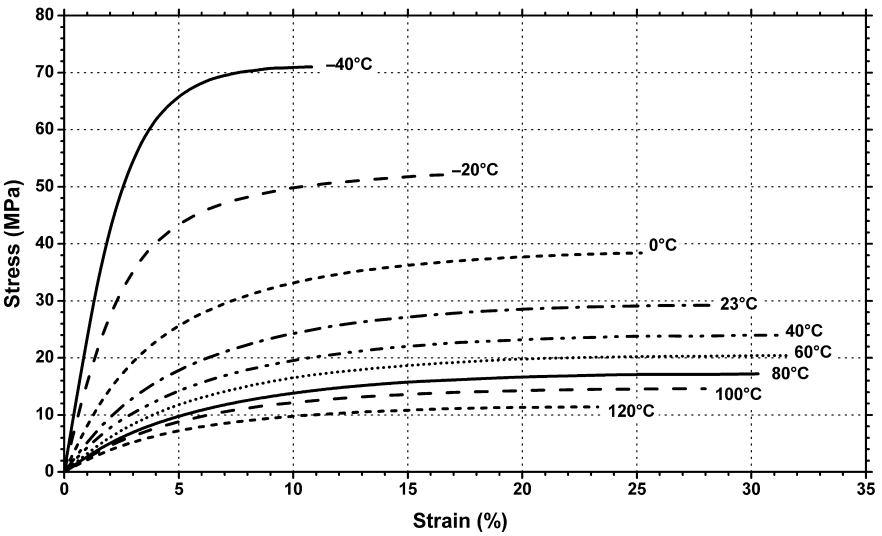

Figure 6.56 Stress vs. strain at various temperatures for Evonik Industries Vestamid® L1723 sw (DAM)—low viscosity, plasticized, heat stabilized Nylon 12 resin.

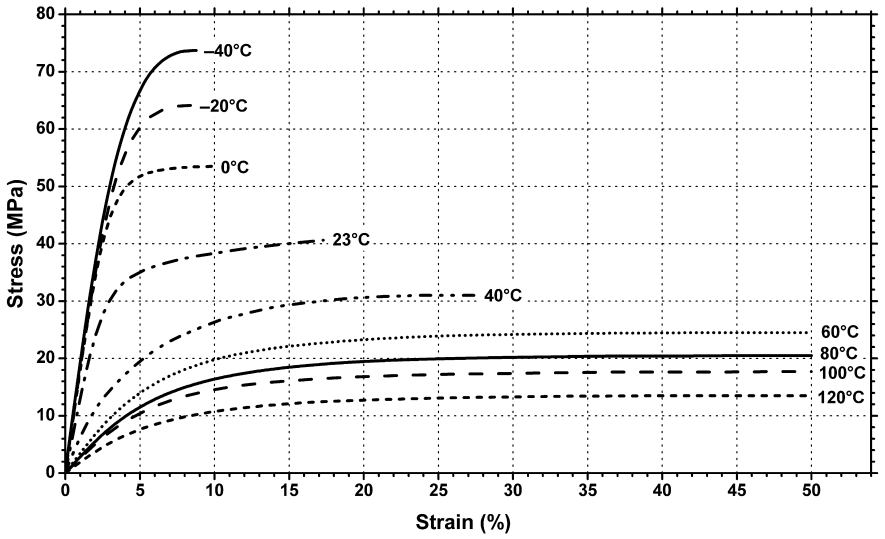

Figure 6.57 Stress vs. strain at various temperatures for Evonik Industries Vestamid® L2141 sw (DAM)—high viscosity, high heat Nylon 12 resin.

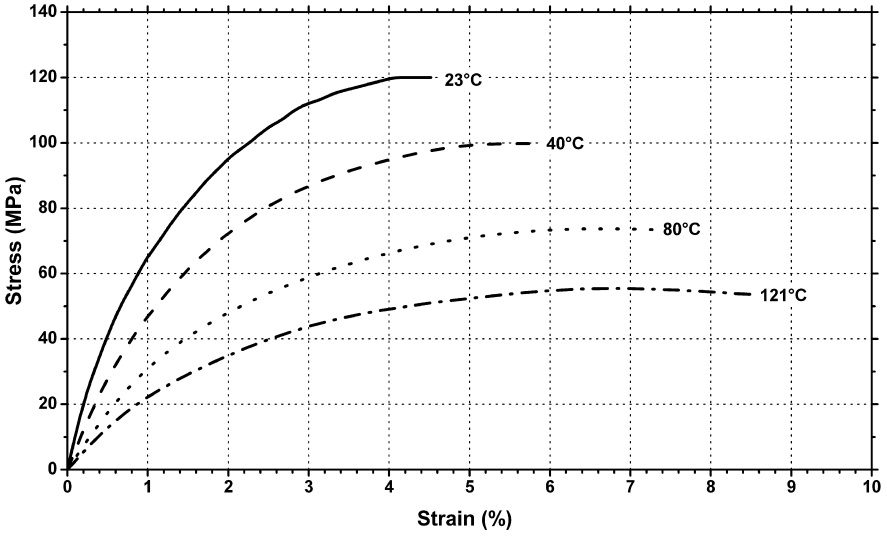

Figure 6.58 Stress vs. strain at various temperatures for SABIC Innovative Plastics Thermocomp™ SF006 (DAM)—30% glass filled Nylon 12 resin.

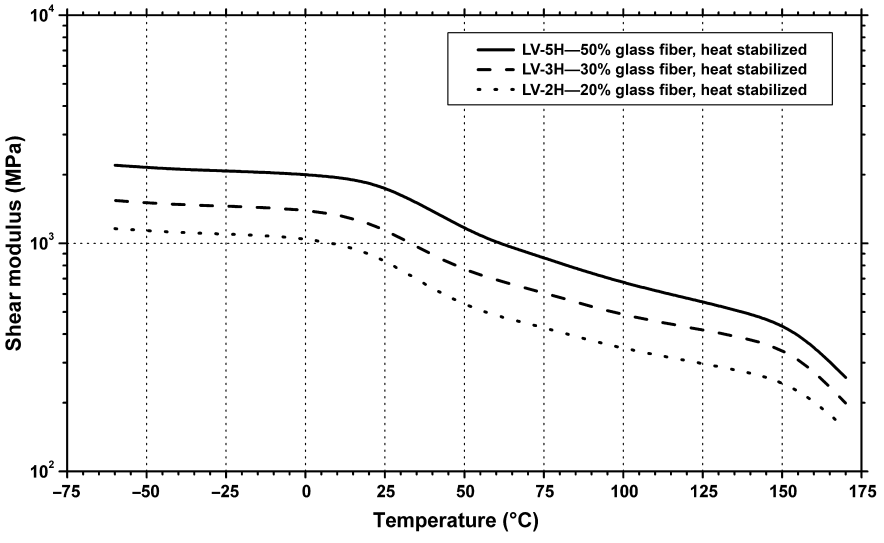

Figure 6.59 Shear modulus vs. temperature for several EMS-Grivory Grilamid® LV Nylon 12 resins.

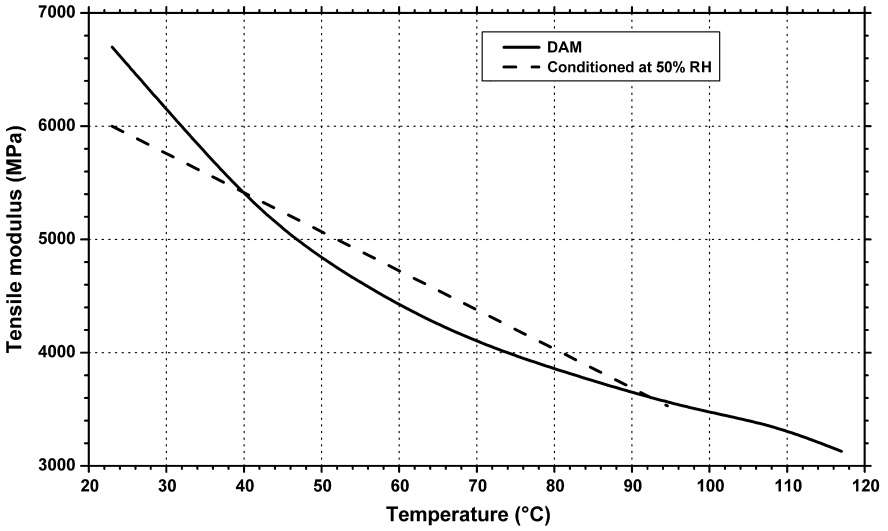

Figure 6.60 Tensile modulus vs. temperature for SABIC Innovative Plastics Thermocomp™ SF006—30% glass filled Nylon 12 resin.

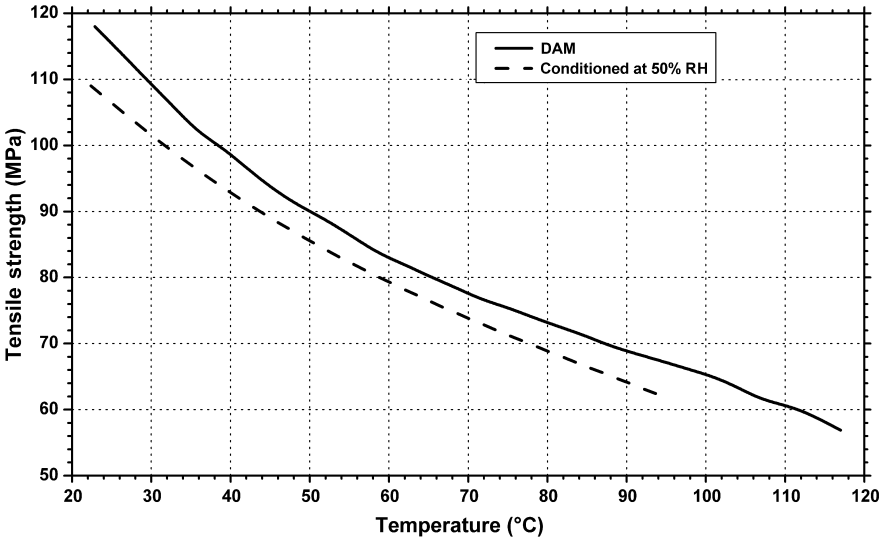

Figure 6.61 Tensile strength vs. temperature for SABIC Innovative Plastics Thermocomp™ SF006—30% glass filled Nylon 12 resin.

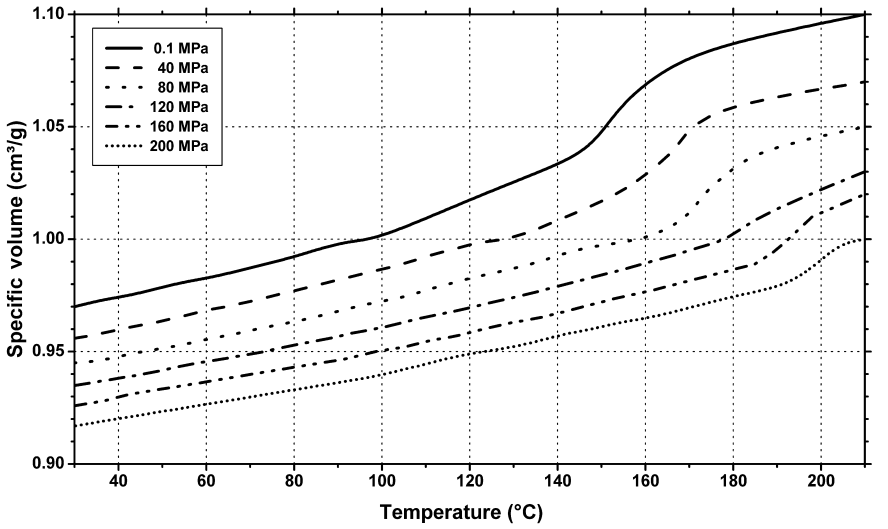

Figure 6.62 PVT for Evonik Industries Vestamid® L1723 sw (DAM)—low viscosity, plasticized, heat stabilized Nylon 12 resin.

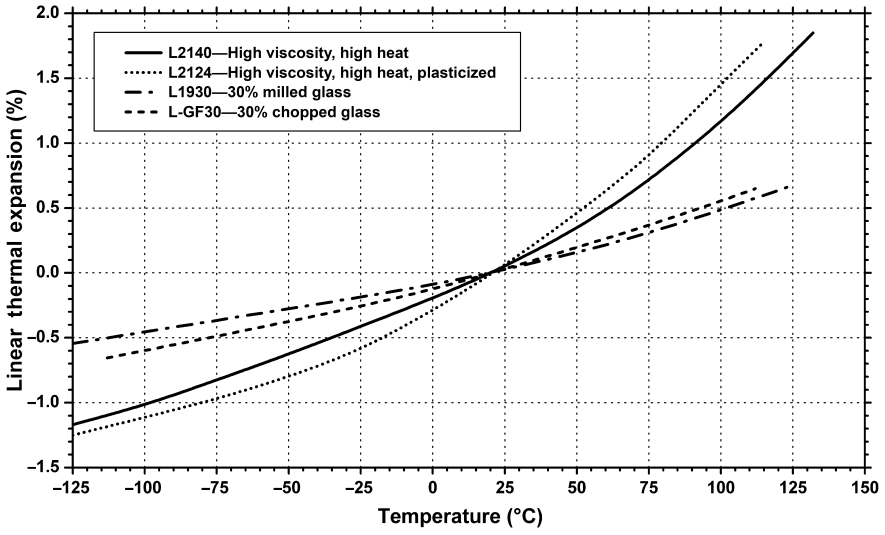

Figure 6.63 Thermal expansion vs. temperature for several Evonik Industries Vestamid® Nylon 12 resins [4].

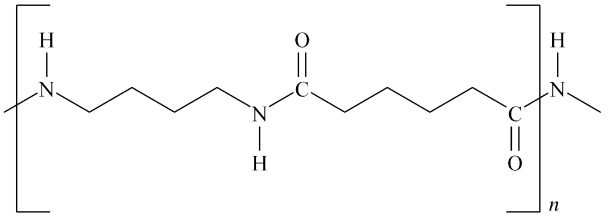

Figure 6.64 Chemical structure of Nylon 46.

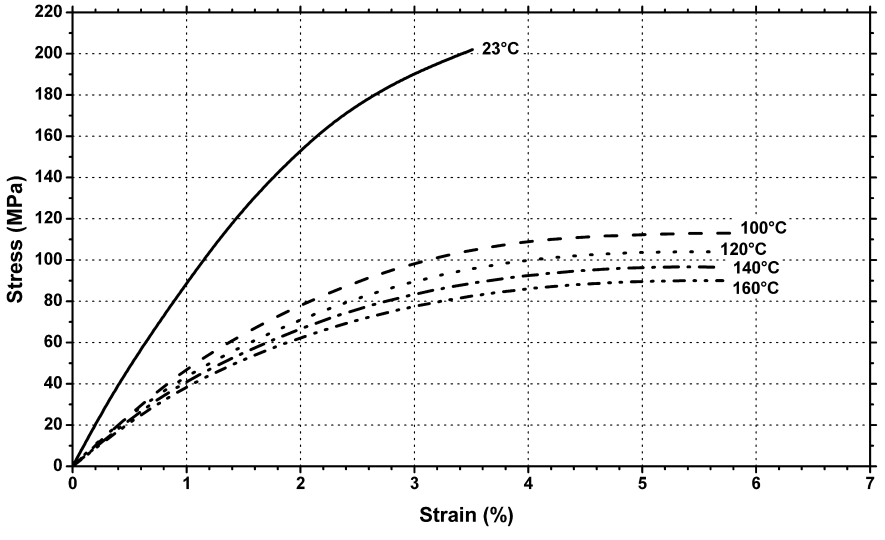

Figure 6.65 Stress vs. strain at various temperatures for DSM Engineering Plastics Stanyl® TE200F6—30% glass fiber reinforced, heat stabilized Nylon 46 resin.

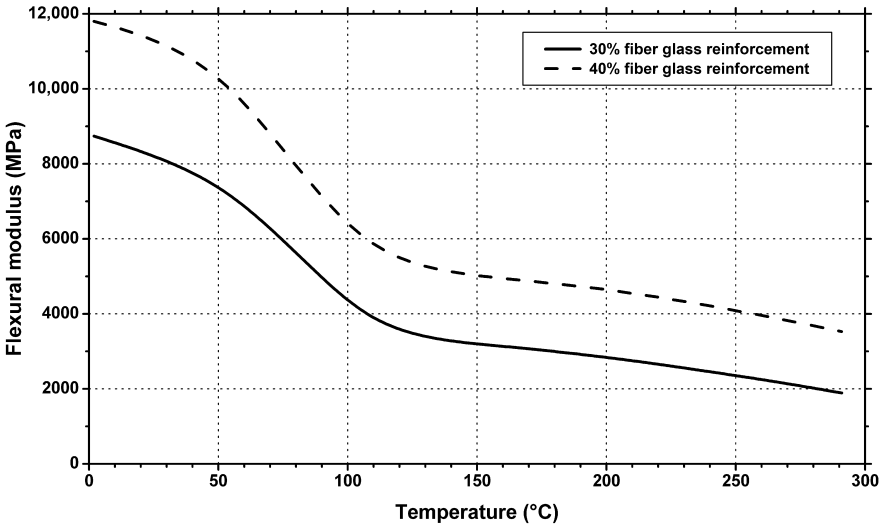

Figure 6.66 Flexural modulus vs. temperature for DSM Engineering Plastics Stanyl® Nylon 46 resins [5].

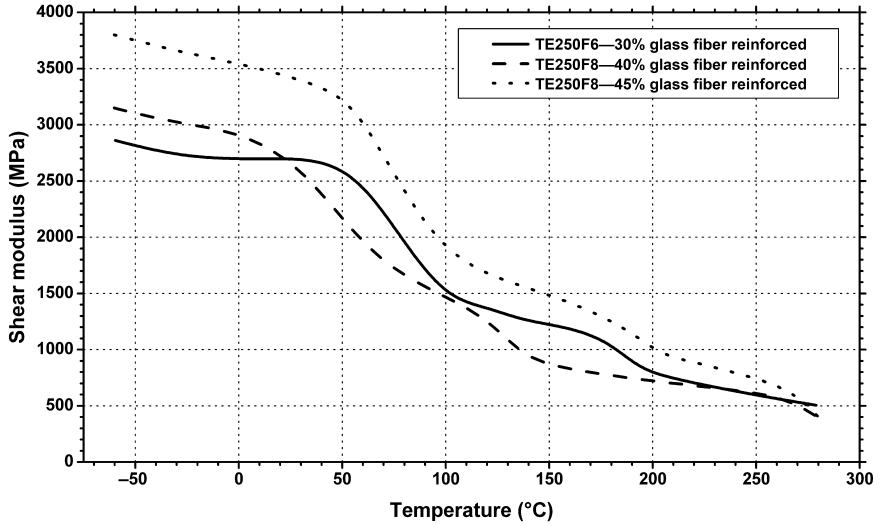

Figure 6.67 Shear modulus vs. temperature for DSM Engineering Plastics Stanyl® TE250 Series—fiber glass filled, heat stabilized, fire retardant Nylon 46 resins [5].

Uses and applications: automotive: powertrain components, charge air coolers, EPS and ETC gears, motor sensors, auto connectors, chain tensioners; E&E: connectors, microswitches, bobbins, memory modules, motor components, specialty films and fibers, consumer appliances.

Data for polyamide 46 plastics are found in Figures 6.65–6.68.

6.5 Nylon 66 (PA66)

The structure of Nylon 66 is shown in Figure 6.69. The CAS number is 32131-17-2.

Some of the Nylon 66 characteristics are as follows:

- Outstanding balance of mechanical properties
- Outstanding toughness in equilibrium moisture content
- Outstanding chemical resistance and oil resistance
- Outstanding wear and abrasion resistance
- Almost all grades are self-extinguishing. The flame-resistant grades are rated UL 94V0
- Outstanding long-term heat resistance (at a long-term continuous maximum temperature ranging between 80°C and 150°C)
- Grades reinforced with glass fiber and other materials offer superior elastic modulus and strength

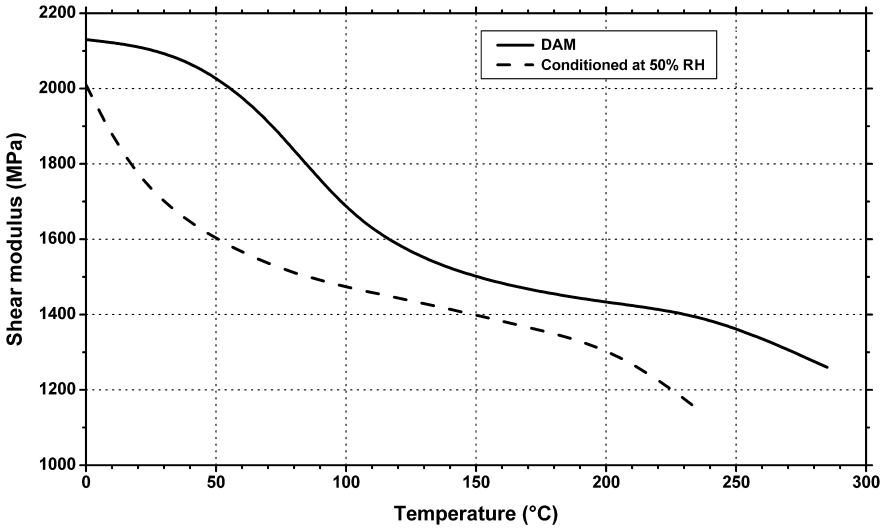

Figure 6.68 Shear modulus vs. temperature and humidity for DSM Engineering Plastics Stanyl® Nylon 46 resins [5].

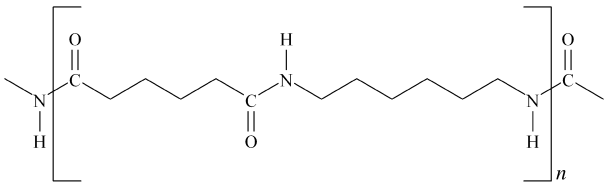

Figure 6.69 Chemical structure of Nylon 66.

- Offers low gasoline permeability and outstanding gas barrier properties
- High water absorption
- Poor chemical resistance to strong acids and bases

Manufacturers and trade names: EMS-Grivory Grilon® A, DuPont Zytel®, BASF Ultramid® A.

Uses and applications: airbags, tires, cords, conveyor belts, hoses, bearings, gears.

Data for polyamide 66 plastics are found in Figures 6.70–6.158.

6.6 Nylon 610 (PA610)

The structure of Nylon 610 is shown in Figure 6.159.

Some of the Nylon 610 characteristics are as follows:

- Outstanding suppleness and impact strength at low temperature
- Relatively low hygroscopic properties
- Outstanding flex fatigue properties

Manufacturers and trade names: SABIC Innovative Plastics LNP Thermocomp™, Toray Resin Company Amilan®, DuPont Zytel®, BASF Ultramid® S.

Uses and applications: bristles and brushes.

Data for polyamide 610 plastics are found in Figures 6.160–6.168.

6.7 Nylon 612 (PA612)

The structure of Nylon 612 is shown in Figure 6.169.

Some of the Nylon 612 characteristics are as follows:

- High impact strength
- Very good resistance to greases, oils, fuels, hydraulic fluids, water, alkalis, and saline
- Very good stress cracking resistance, even when subjected to chemical attack and when used to cover metal parts
- Low coefficients of sliding friction and high abrasion resistance, even when running dry
- Heat deflection temperature (melting point nearly 40°C higher than Nylon 12)
- Tensile and flexural strength

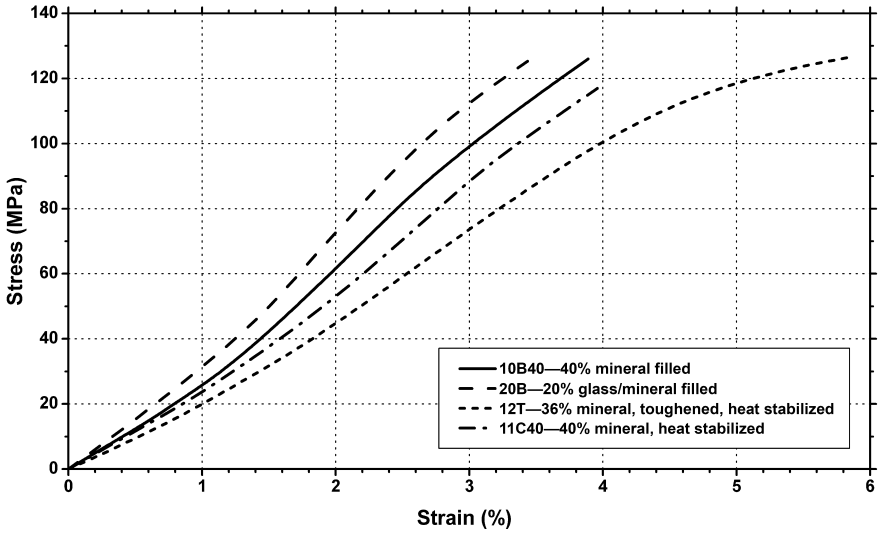

Figure 6.70 Stress vs. strain in compression at 23°C for several DuPont Minlon® mineral reinforced Nylon 66 resins [6].

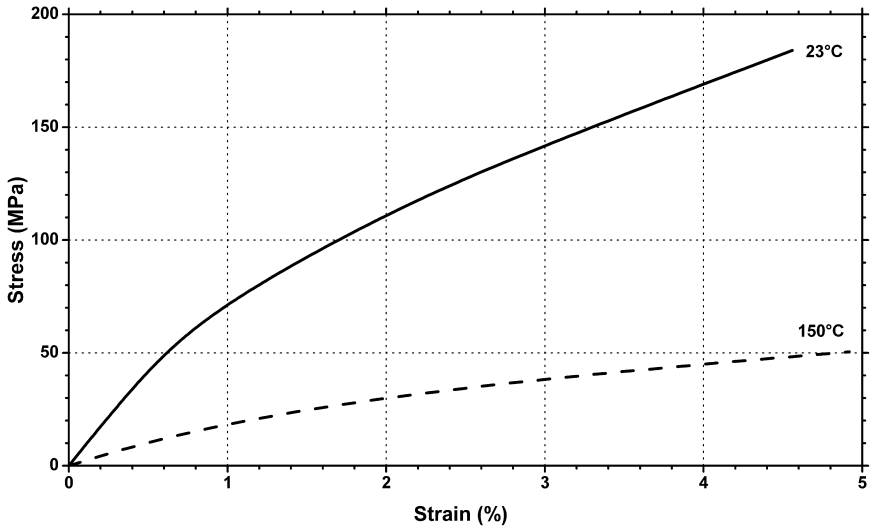

Figure 6.71 Stress vs. strain in compression at various temperatures for DuPont Zytel® 70G-33L—33% glass reinforced, lubricated Nylon 66 resin [6].

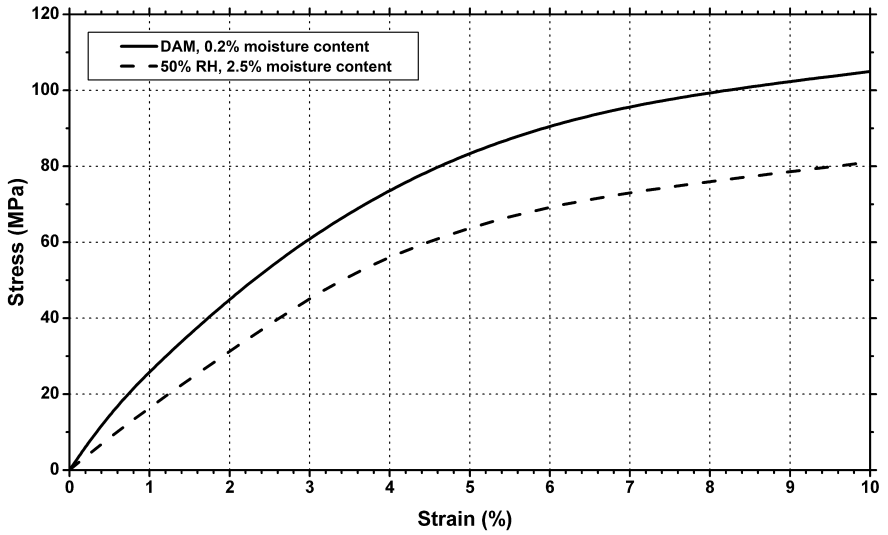

Figure 6.72 Stress vs. strain in compression at 23°C for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

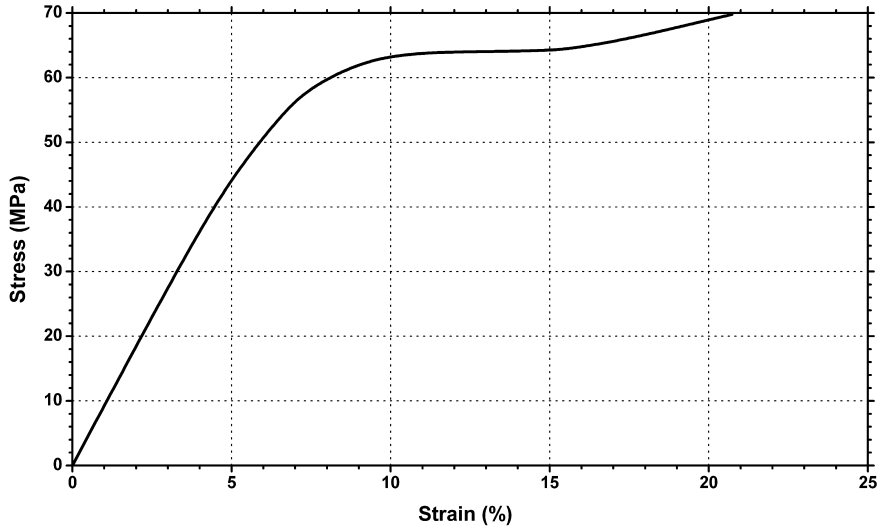

Figure 6.73 Stress vs. strain in compression at 23°C for DuPont Zytel® ST-801—super tough Nylon 66 resin [6].

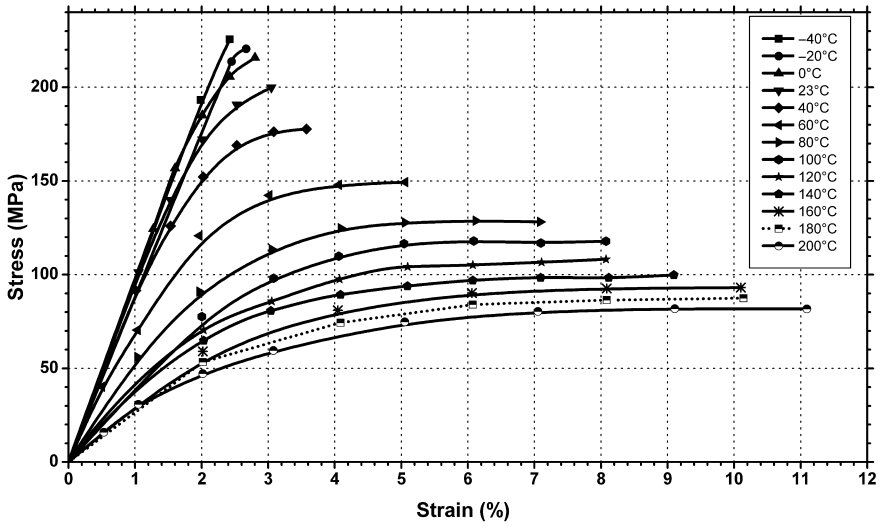

Figure 6.74 Stress vs. strain at various temperatures for EMS-Grivory Grilon® AG-30—30% glass fiber reinforced Nylon 66 resin (dry) [7].

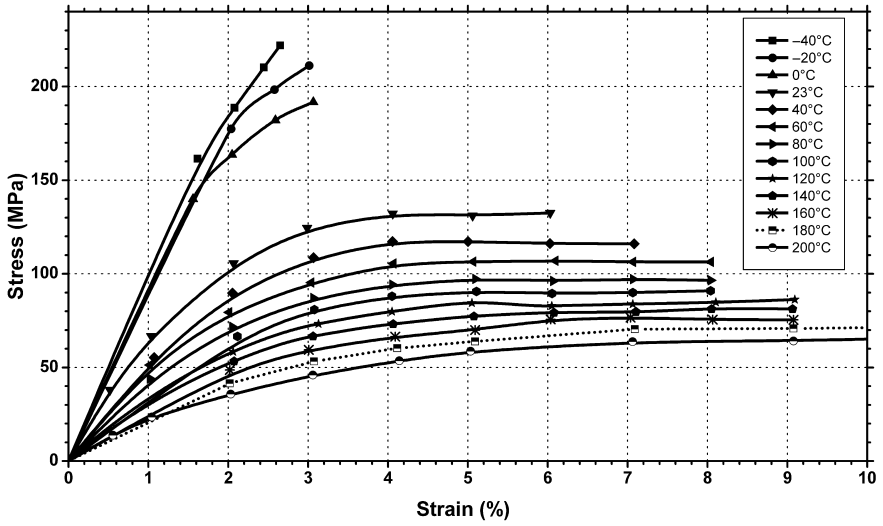

Figure 6.75 Stress vs. strain at various temperatures for EMS-Grivory Grilon® AG-30—30% glass fiber reinforced Nylon 66 resin (conditioned at 50% RH) [7].

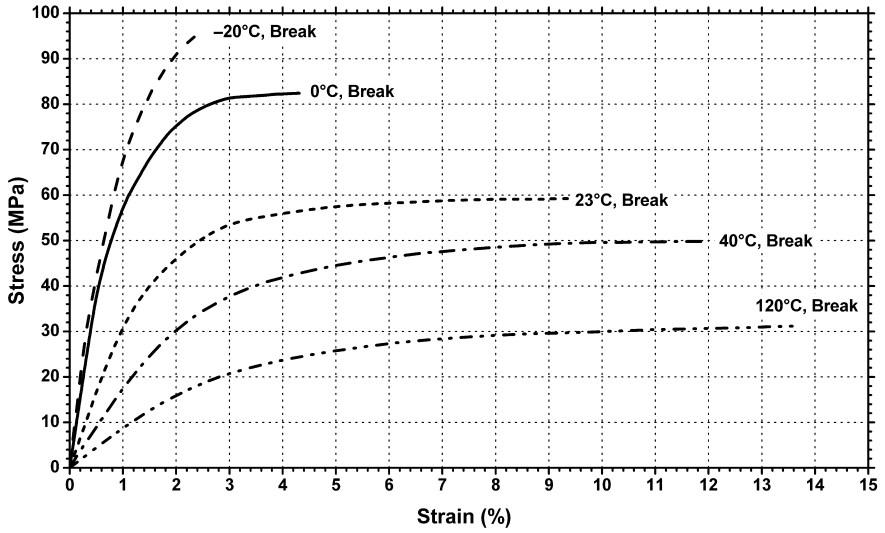

Figure 6.76 Stress vs. strain at various temperatures for DuPont Minlon® 10B140 NC010—40% mineral reinforced Nylon 66 resin (conditioned at 50% RH) [6].

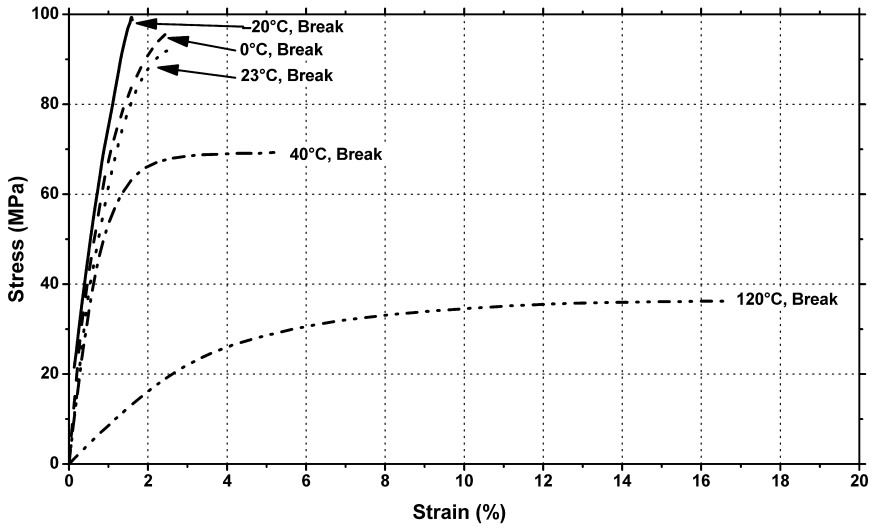

Figure 6.77 Stress vs. strain at various temperatures for DuPont Minlon® 10B140 NC010—40% mineral reinforced Nylon 66 resin (DAM) [6].

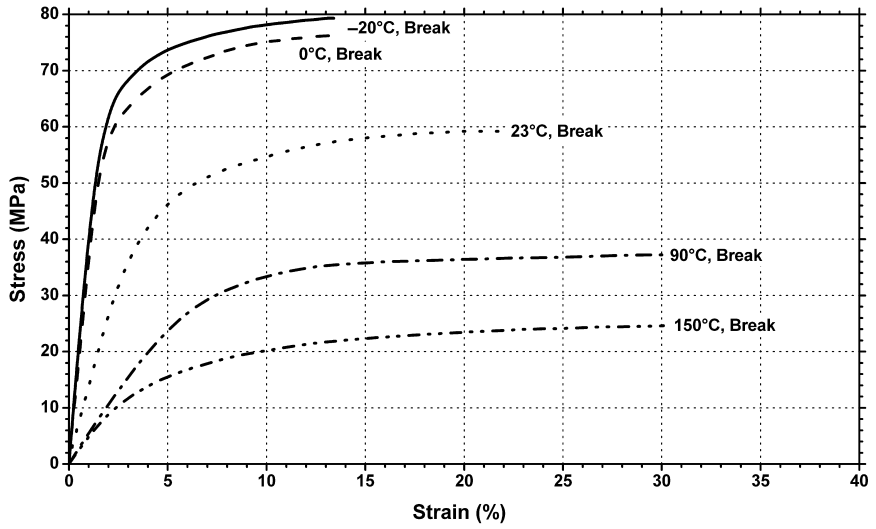

Figure 6.78 Stress vs. strain at various temperatures for DuPont Minlon® 11C140 NC010—40% mineral reinforced Nylon 66 resin (conditioned at 50% RH) [6].

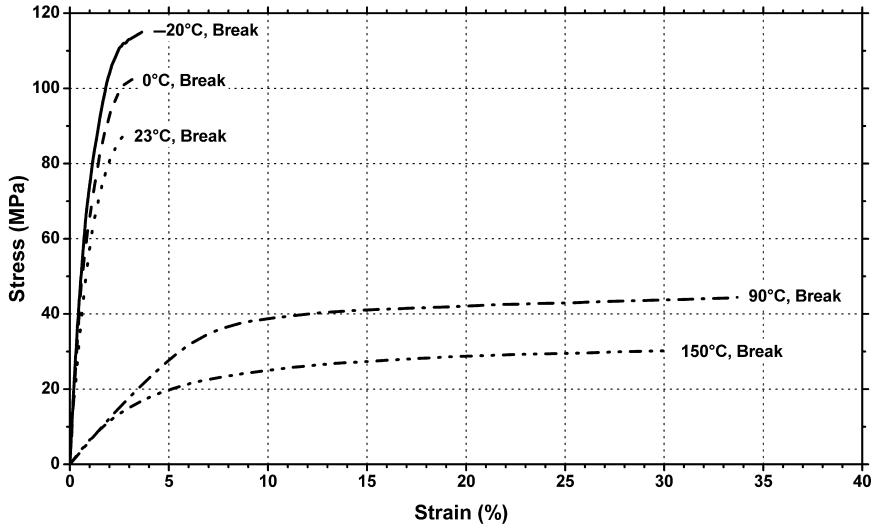

Figure 6.79 Stress vs. strain at various temperatures for DuPont Minlon® 11C140 NC010—high impact, 40% mineral reinforced Nylon 66 resin (DAM) [6].

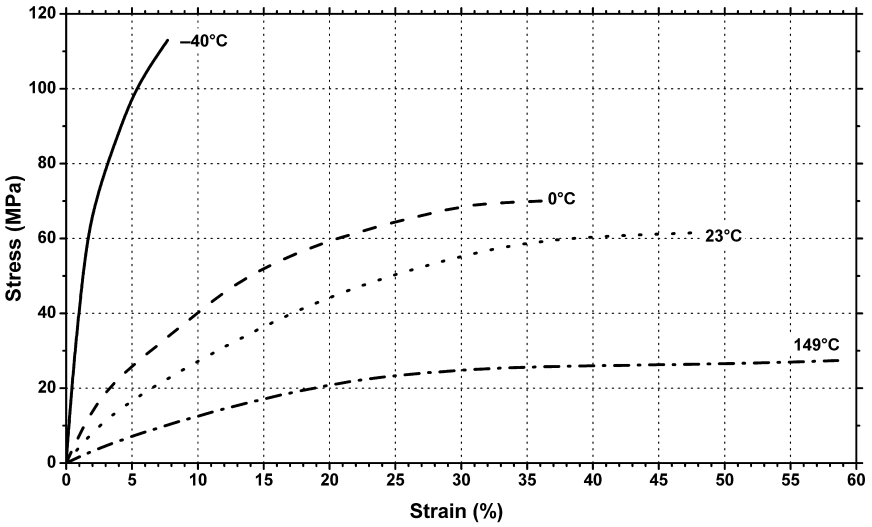

Figure 6.80 Stress vs. strain at various temperatures for DuPont Minlon® 12T—super high impact, 40% mineral reinforced Nylon 66 resin (conditioned at 50% RH) [6].

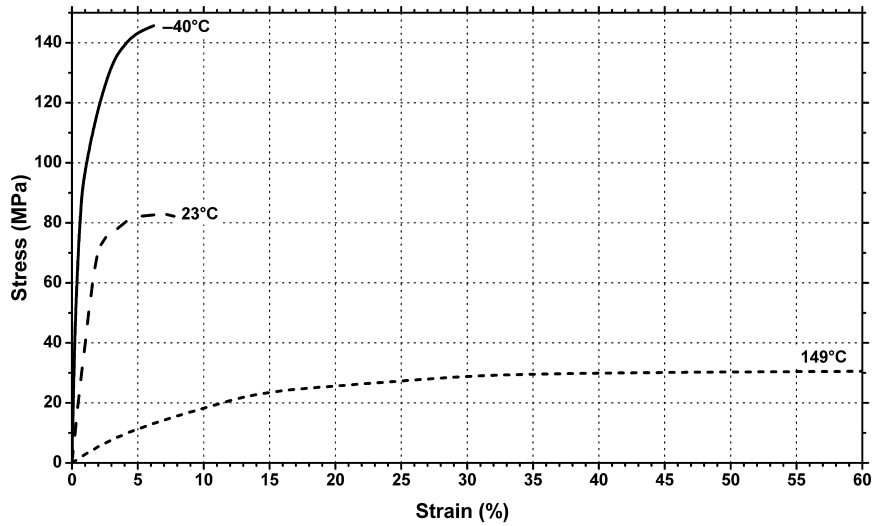

Figure 6.81 Stress vs. strain at various temperatures for DuPont Minlon® 12T—super high impact, 40% mineral reinforced Nylon 66 resin (DAM) [6].

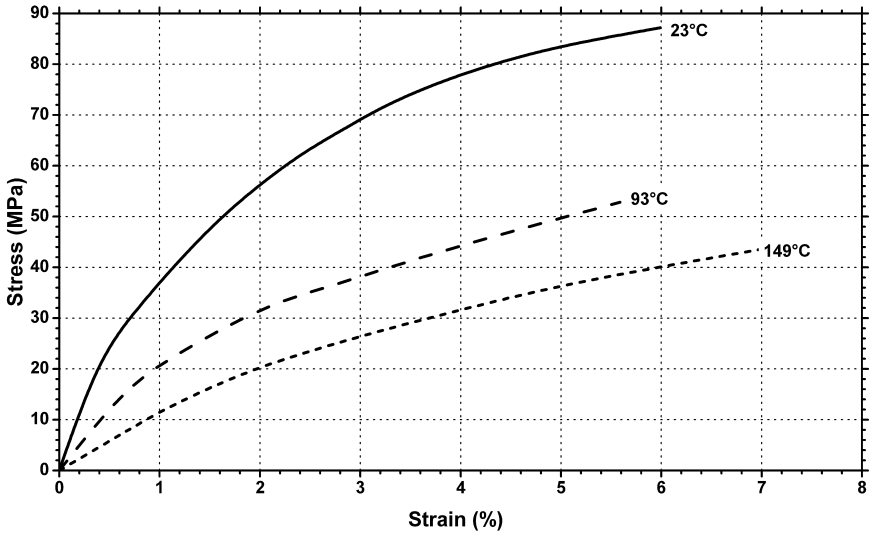

Figure 6.82 Stress vs. strain at various temperatures for DuPont Minlon® 20B—40% glass/mineral reinforced Nylon 66 resin (conditioned at 50% RH) [6].

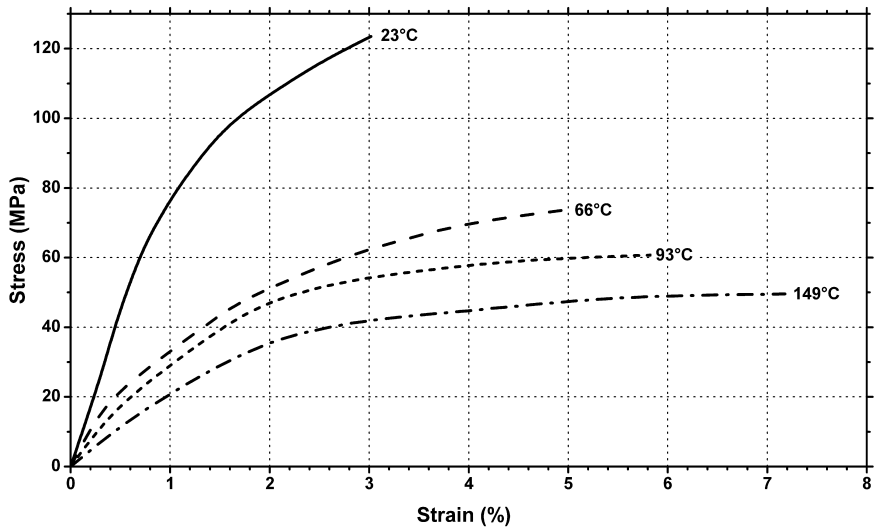

Figure 6.83 Stress vs. strain at various temperatures for DuPont Minlon® 20B—40% glass/mineral reinforced Nylon 66 resin (DAM) [6].

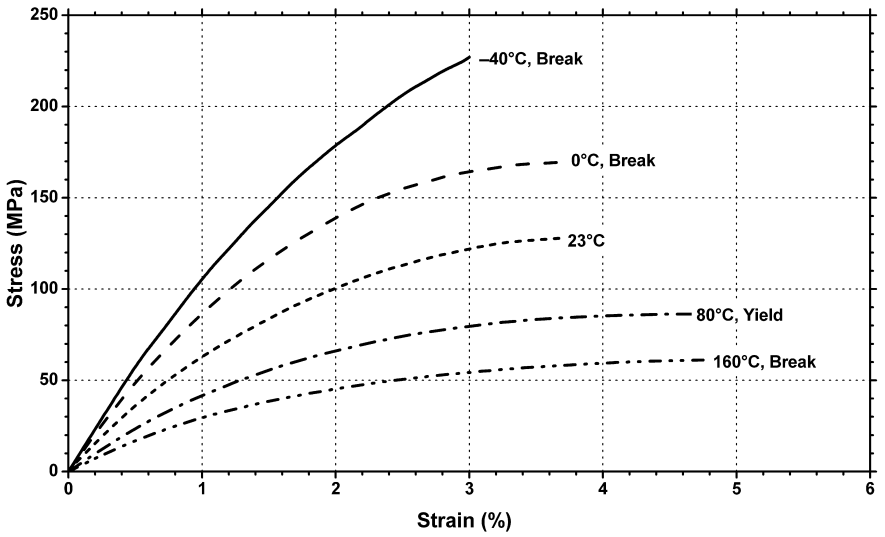

Figure 6.84 Stress vs. strain at various temperatures for BASF Ultramid® A3EG6—high stiffness, 30% glass fiber filled Nylon 66 resin (conditioned at 50% RH) [8].

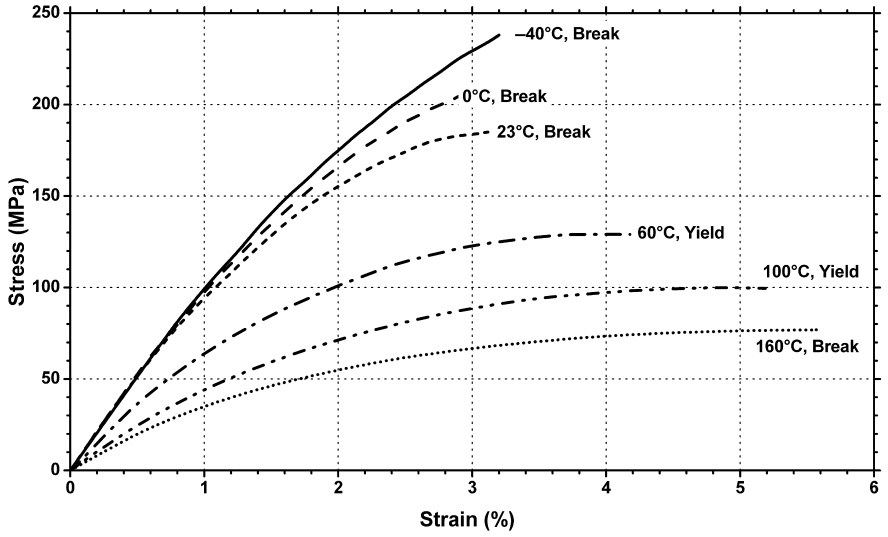

Figure 6.85 Stress vs. strain at various temperatures for BASF Ultramid® A3EG6—high stiffness, 30% glass fiber filled Nylon 66 resin (DAM) [8].

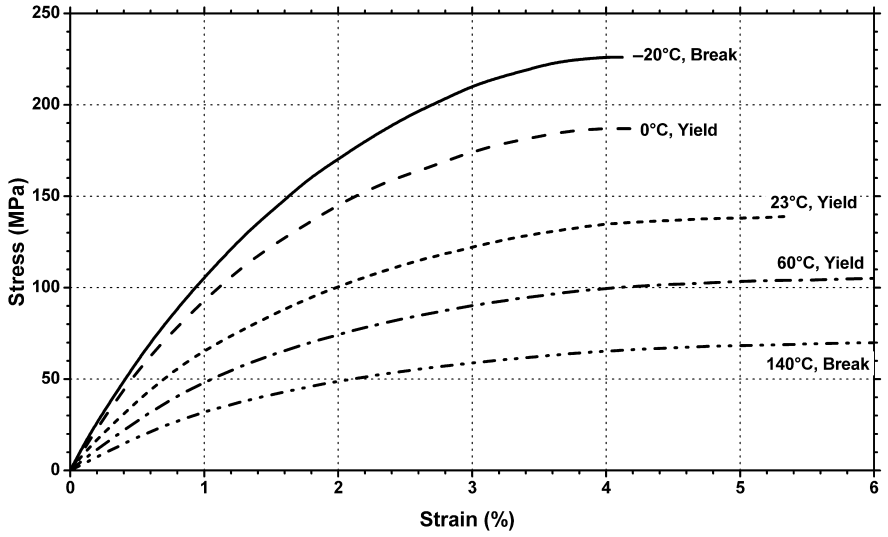

Figure 6.86 Stress vs. strain at various temperatures for BASF Ultramid® A3WG7—heat resistant, 35% glass fiber filled Nylon 66 resin (conditioned at 50% RH) [8].

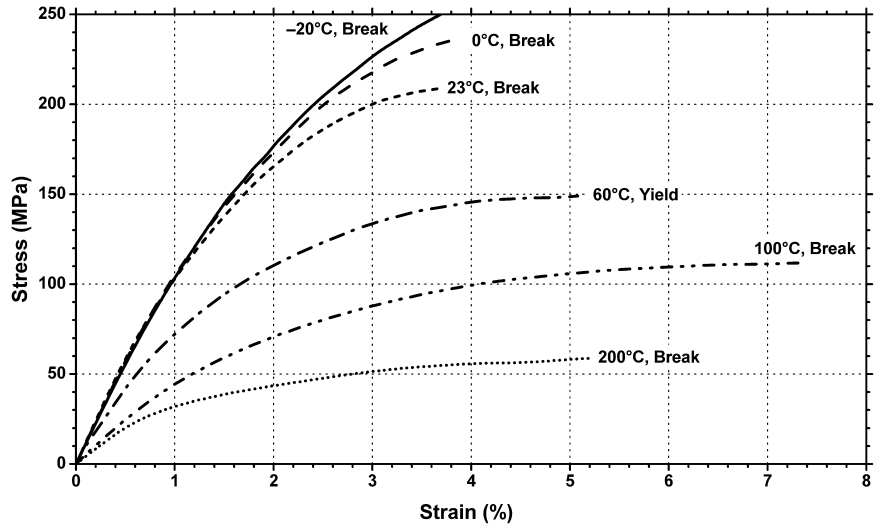

Figure 6.87 Stress vs. strain at various temperatures for BASF Ultramid® A3WG7—heat resistant, 35% glass fiber filled Nylon 66 resin (DAM) [8].

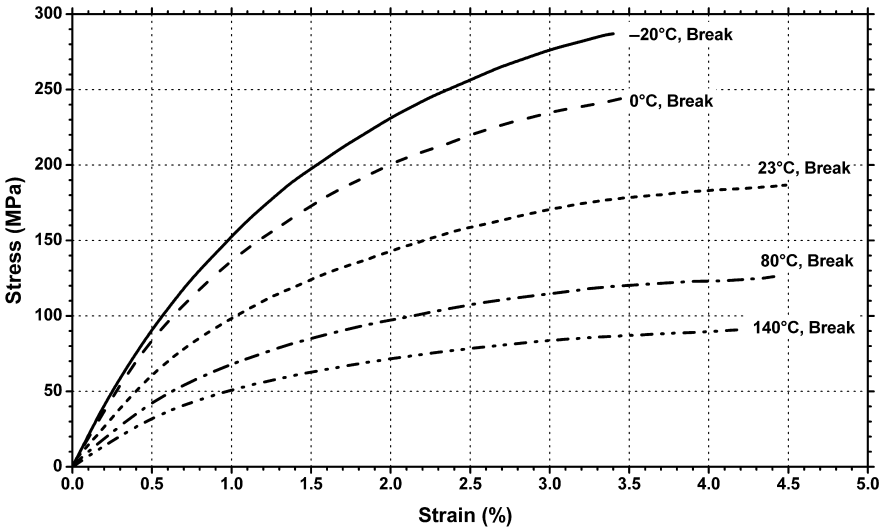

Figure 6.88 Stress vs. strain at various temperatures for BASF Ultramid® A3EG10—rigid, 50% glass fiber filled Nylon 66 resin (conditioned at 50% RH) [8].

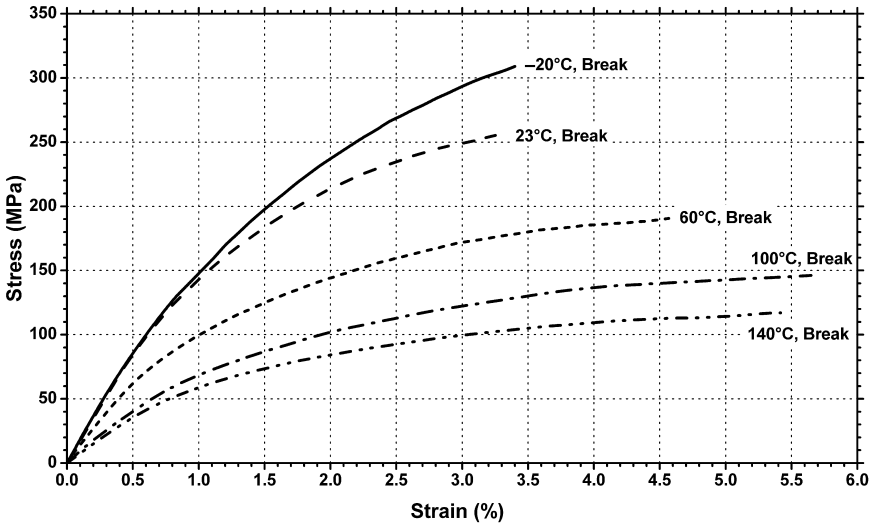

Figure 6.89 Stress vs. strain at various temperatures for BASF Ultramid® A3EG10—rigid, 50% glass fiber filled Nylon 66 resin (DAM) [8].

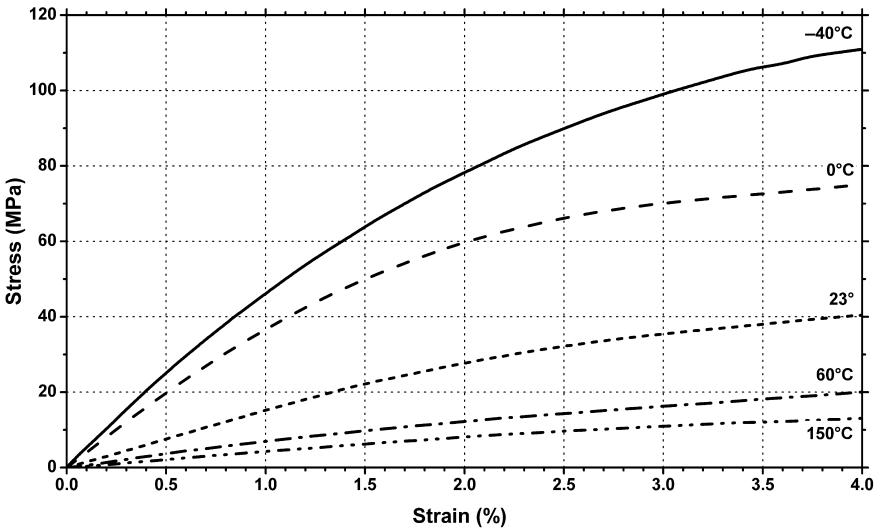

Figure 6.90 Stress vs. strain at various temperatures for BASF Ultramid® A3K—easy flowing, injection molding Nylon 66 resin (conditioned at 50% RH) [8].

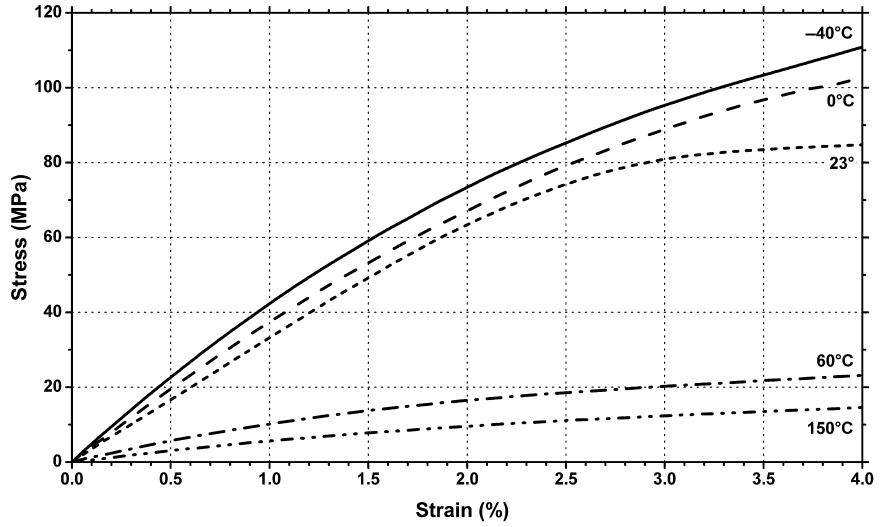

Figure 6.91 Stress vs. strain at various temperatures for BASF Ultramid® A3K—easy flowing, injection molding Nylon 66 resin (DAM) [8].

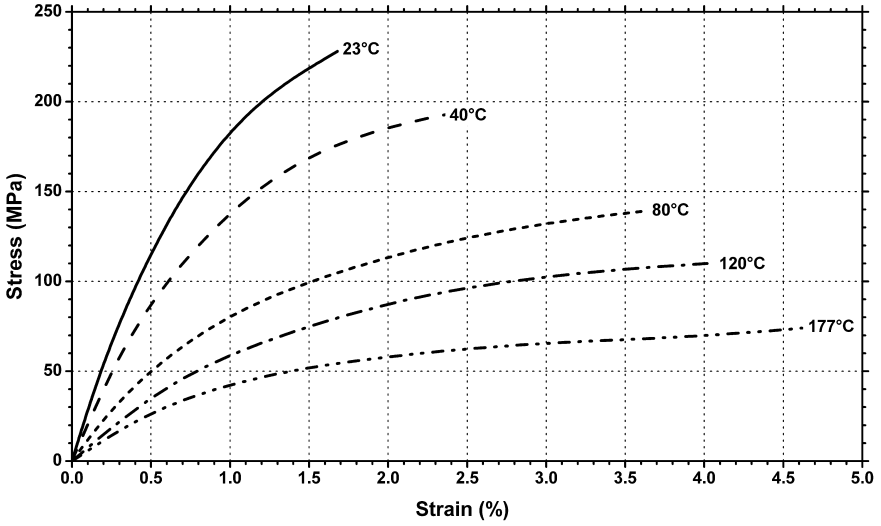

Figure 6.92 Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp™ RC006—electrically conductive, 30% carbon fiber filled Nylon 66 resin (DAM).

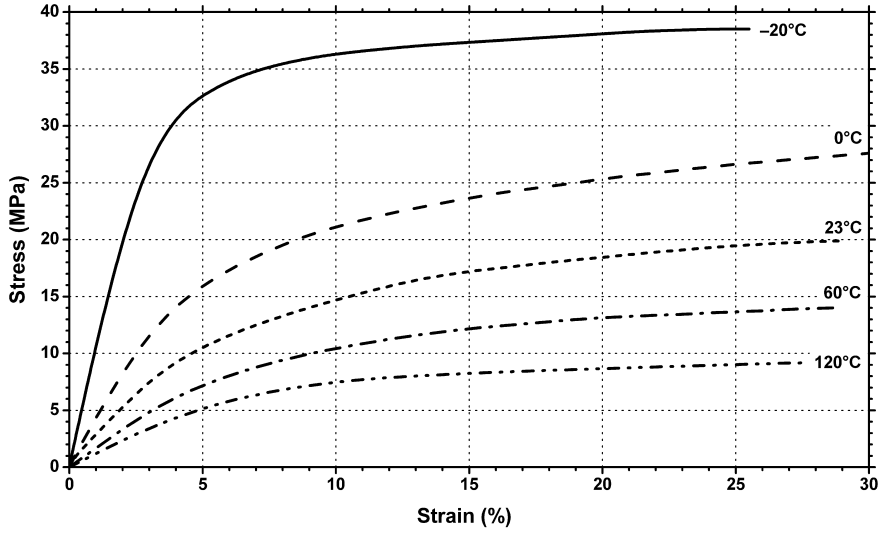

Figure 6.93 Stress vs. strain at various temperatures for DuPont Zytel® ST811 HS NC010—super tough Nylon 66 resin (conditioned at 50% RH) [6].

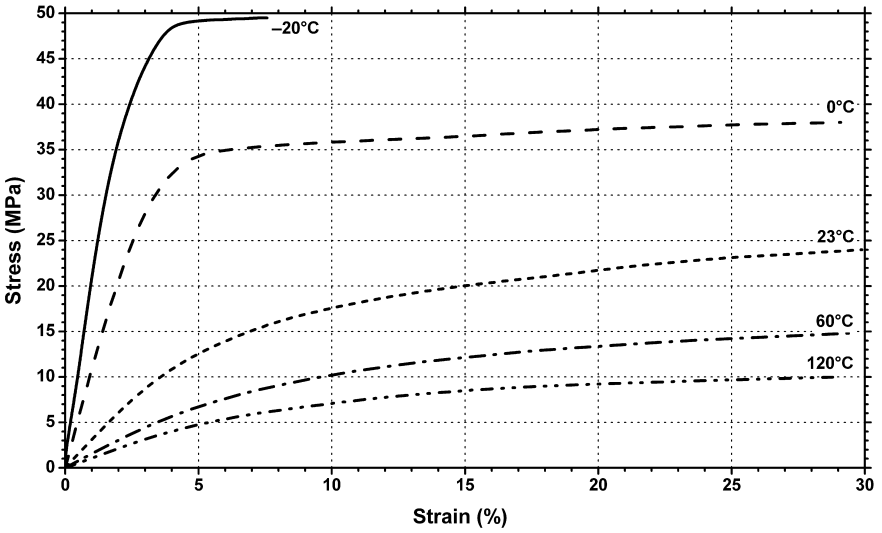

Figure 6.94 Stress vs. strain at various temperatures for DuPont Zytel® ST811 HS NC010—super tough Nylon 66 resin (DAM) [6].

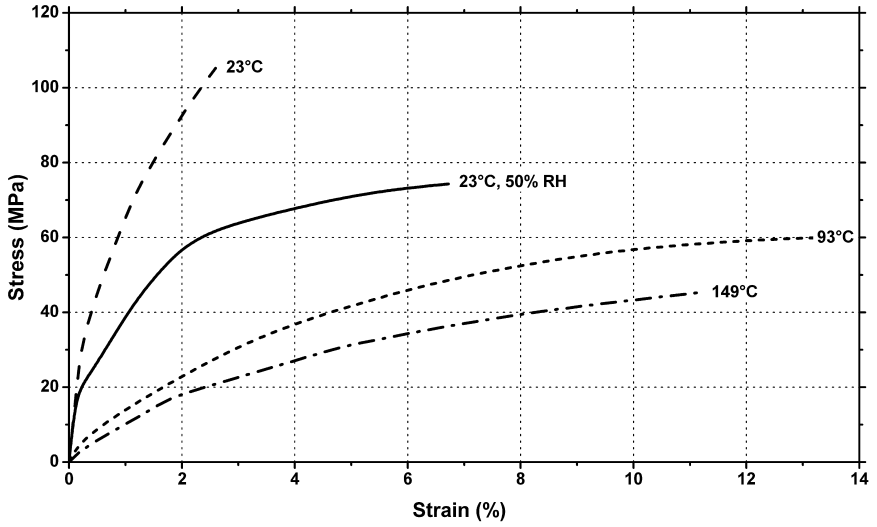

Figure 6.95 Stress vs. strain at various temperatures for DuPont Zytel® 70G-13L—13% chopped glass filled, lubricated Nylon 66 resin [6].

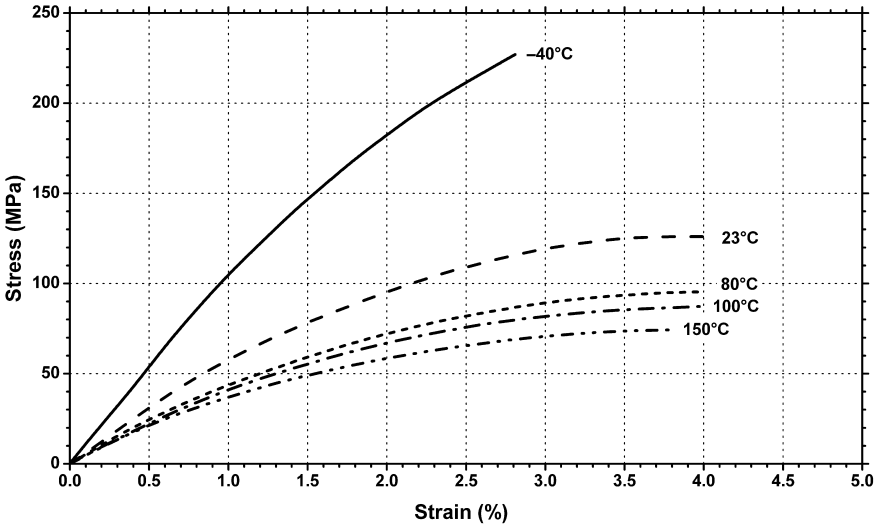

Figure 6.96 Stress vs. strain at various temperatures for DuPont Zytel® 70G-33L NC010—33% chopped glass filled, lubricated Nylon 66 resin (conditioned at 50% RH) [6].

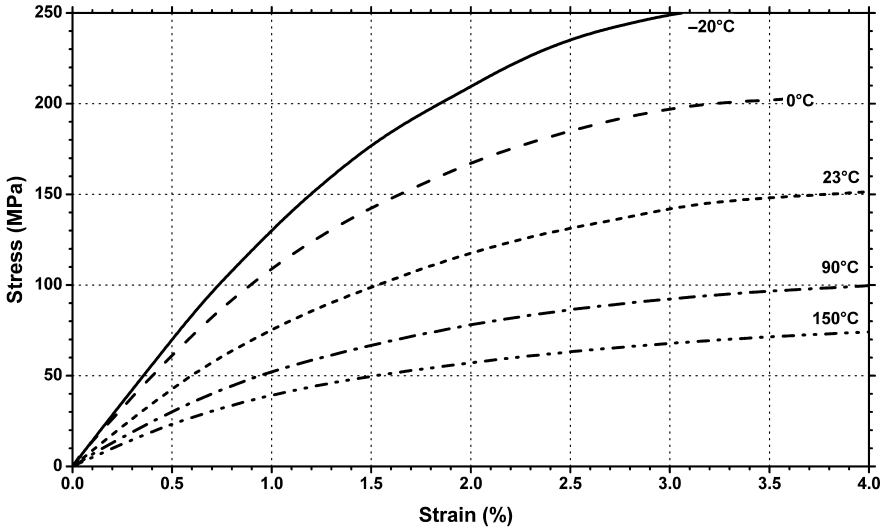

Figure 6.97 Stress vs. strain at various temperatures for DuPont Zytel® 70G-43L NC010—43% chopped glass filled, lubricated Nylon 66 resin (conditioned at 50% RH) [6].

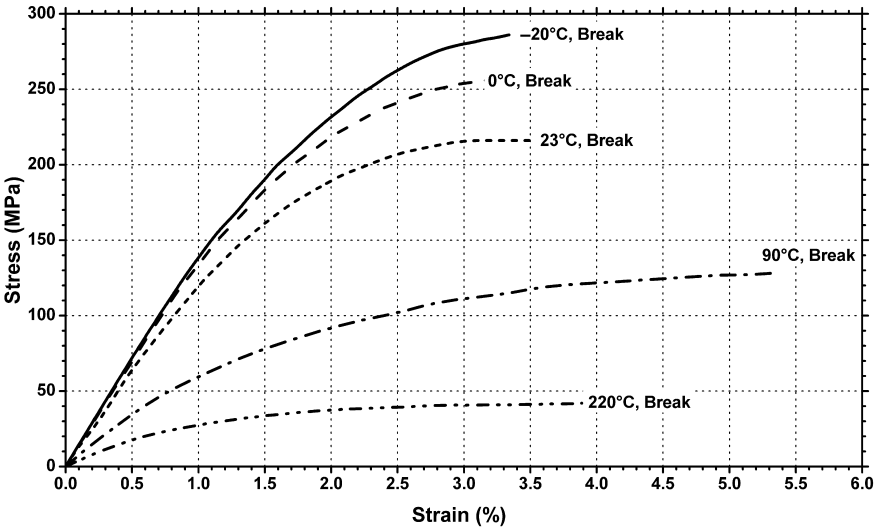

Figure 6.98 Stress vs. strain at various temperatures for DuPont Zytel® 70G-43L NC010—43% chopped glass filled, lubricated Nylon 66 resin (DAM) [6].

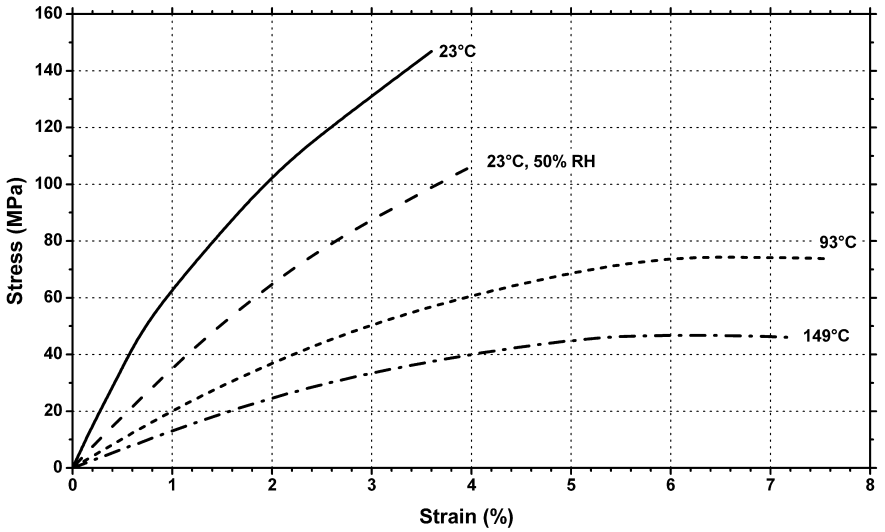

Figure 6.99 Stress vs. strain at various temperatures for DuPont Zytel® 71G-33L—toughened, 33% chopped glass filled, lubricated Nylon 66 resin [6].

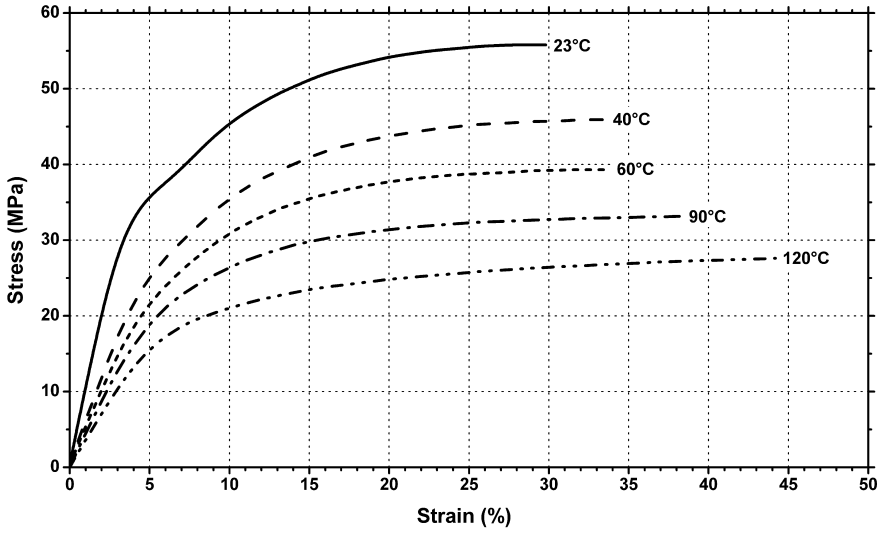

Figure 6.100 Stress vs. strain at various temperatures for DuPont Zytel® 101L NC010—lubricated, general purpose Nylon 66 resin (conditioned at 50% RH) [6].

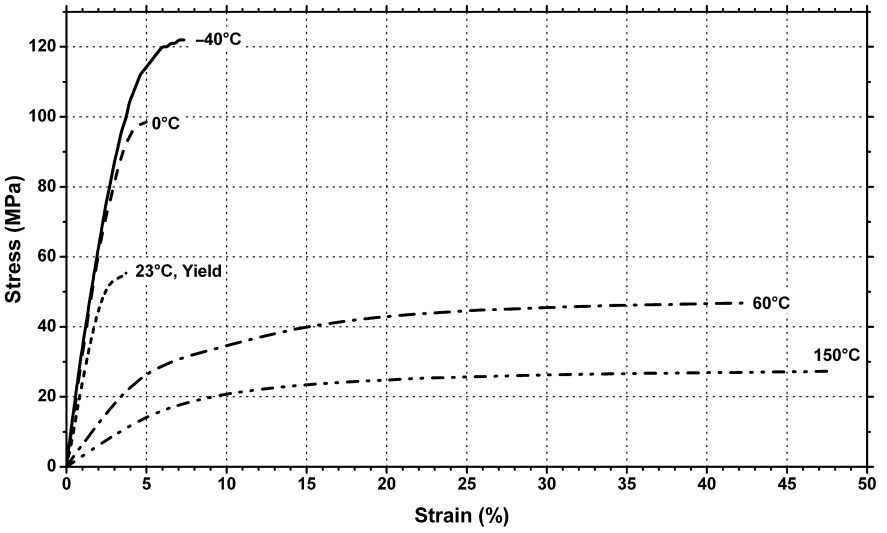

Figure 6.101 Stress vs. strain at various temperatures for DuPont Zytel® 101L NC010—lubricated, general purpose Nylon 66 resin (DAM) [6].

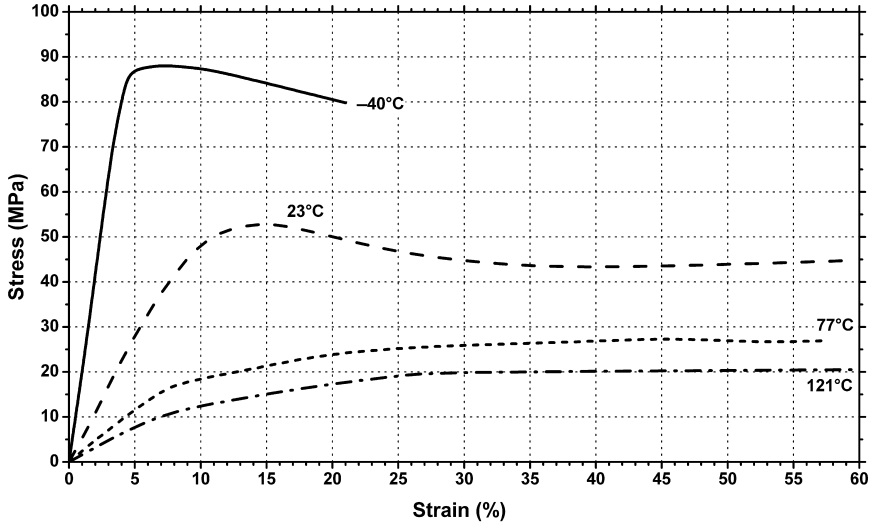

Figure 6.102 Stress vs. strain at various temperatures for DuPont Zytel® 408—toughened Nylon 66 resin (conditioned at 50% RH) [6].

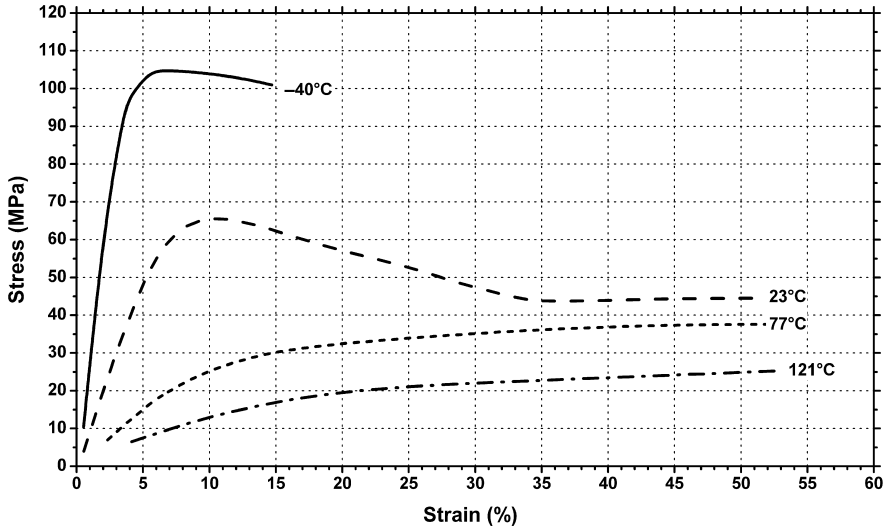

Figure 6.103 Stress vs. strain at various temperatures for DuPont Zytel® 408—toughened Nylon 66 resin (DAM) [6].

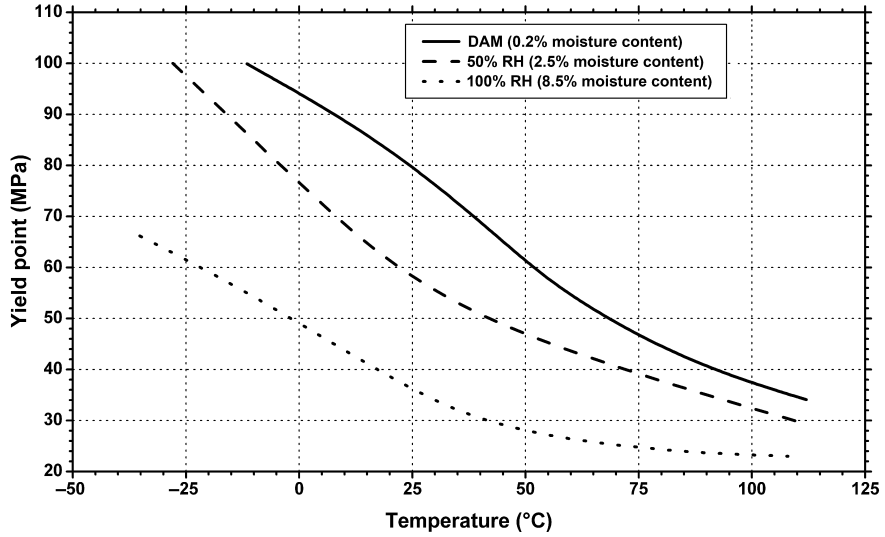

Figure 6.104 Yield point vs. temperature and moisture content for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

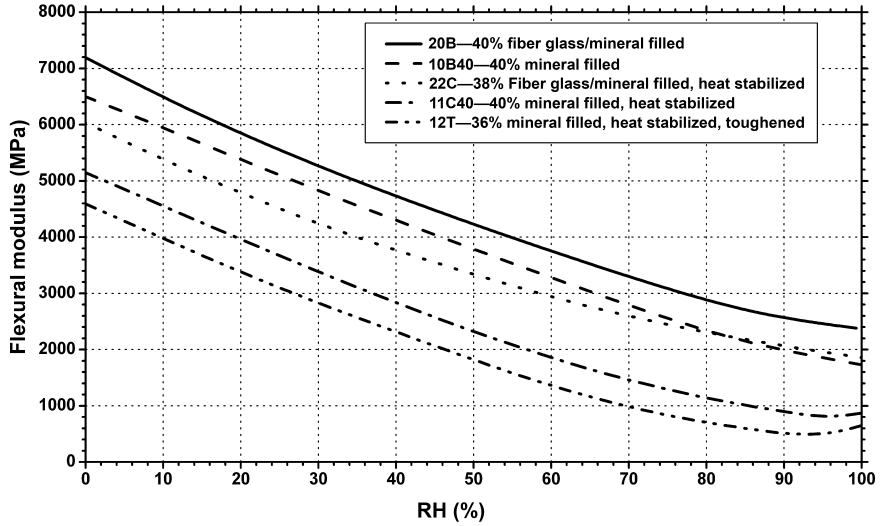

Figure 6.105 Flexural modulus vs. RH at 23°C for several DuPont Minlon® mineral filled Nylon 66 resins [6].

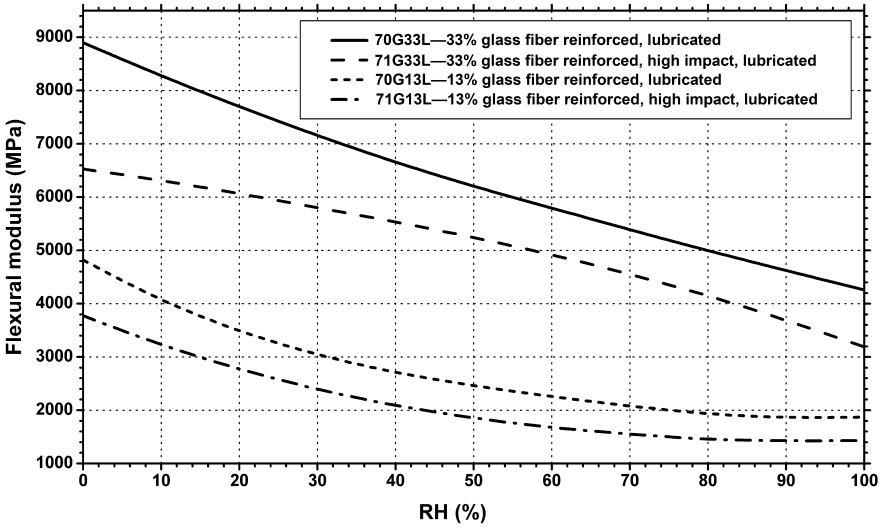

Figure 6.106 Flexural modulus vs. RH at 23°C for several DuPont Zytel® glass filled Nylon 66 resins [6].

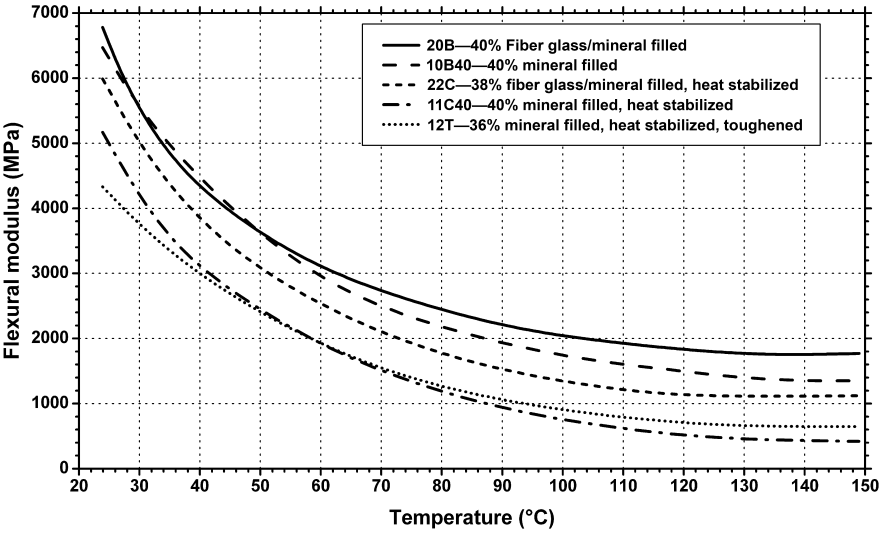

Figure 6.107 Flexural modulus vs. temperature for DuPont Minlon® mineral filled Nylon 66 resins [6].

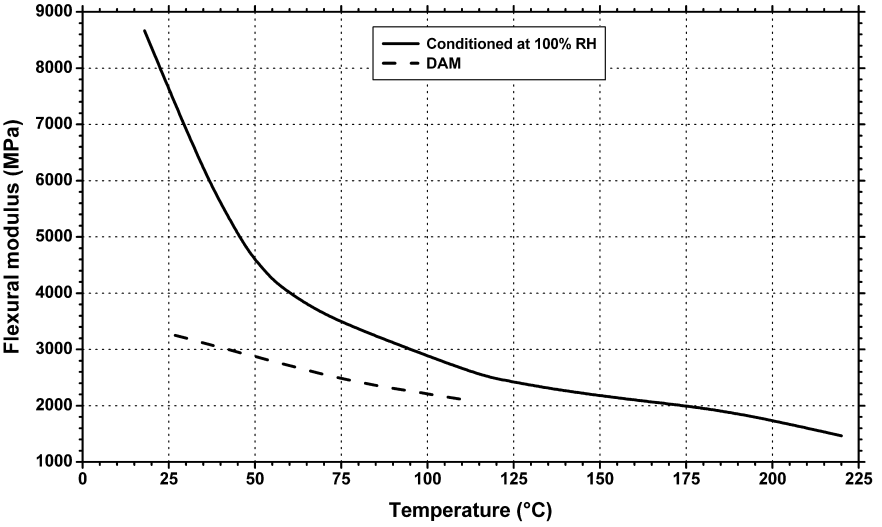

Figure 6.108 Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® 71G-33L—toughened, 33% chopped glass filled, lubricated Nylon 66 resin [6].

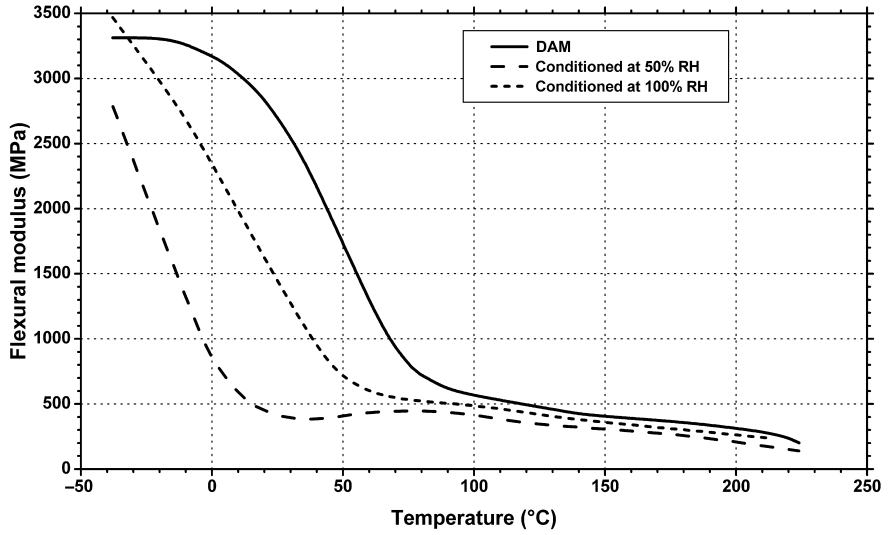

Figure 6.109 Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

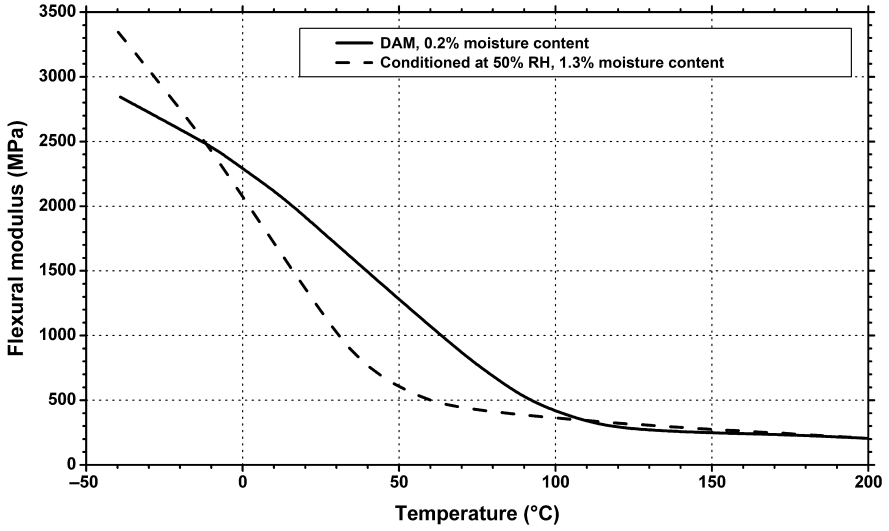

Figure 6.110 Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® 408—toughened Nylon 66 resin [6].

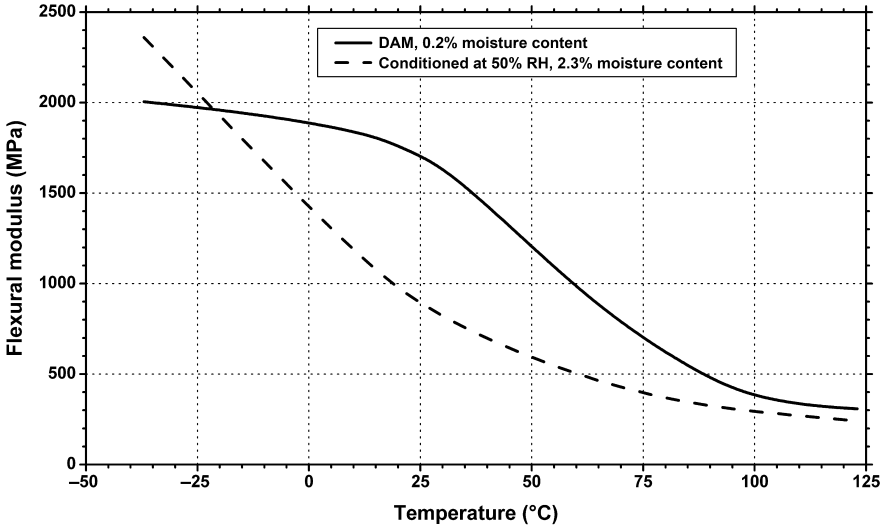

Figure 6.111 Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® ST-801—super tough Nylon 66 resin [6].

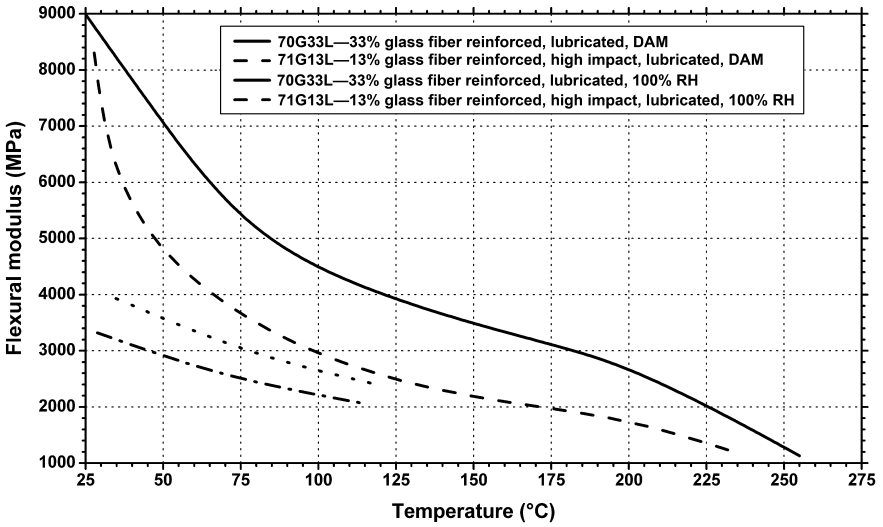

Figure 6.112 Flexural modulus vs. temperature and RH for several DuPont Zytel® Nylon 66 resins [6].

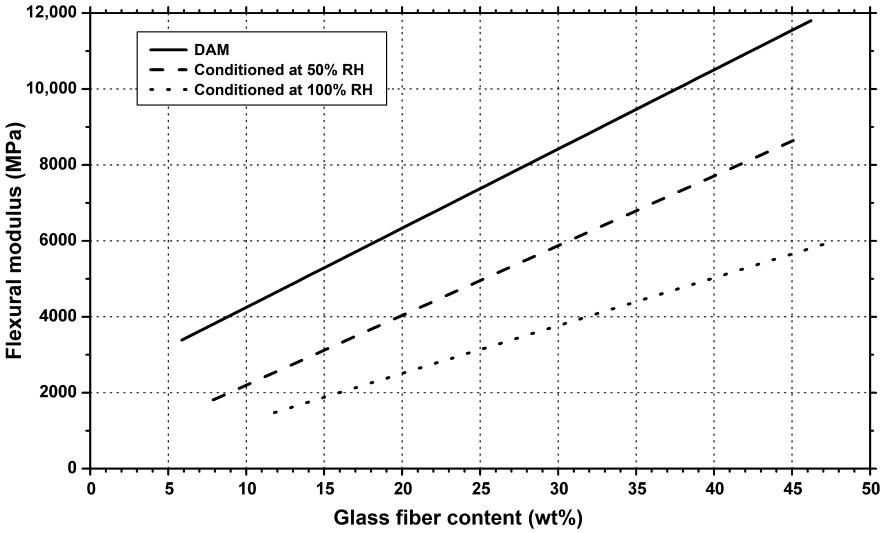

Figure 6.113 Flexural modulus vs. fiber glass content at 23°C for several DuPont Zytel® 70G series Nylon 66 resins [6].

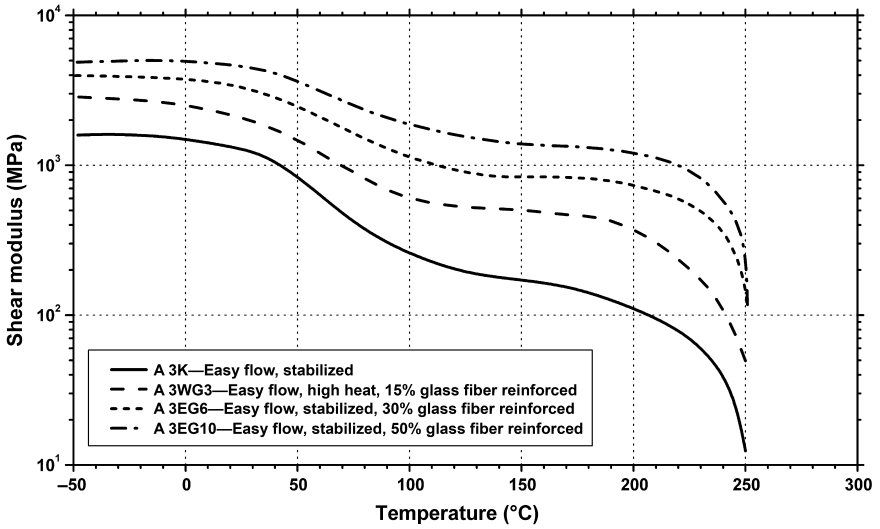

Figure 6.114 Shear modulus vs. temperature for several BASF Ultramid® Nylon 66 resins [8].

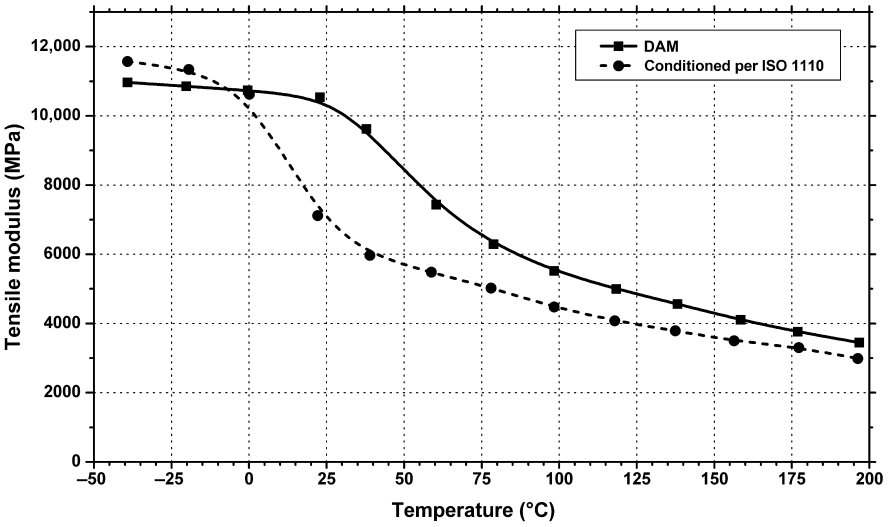

Figure 6.115 Tensile modulus vs. temperature for EMS-Grivory Grilon® AG-30—30% glass fiber reinforced Nylon 66 resin (conditioned at 50% RH) [7].

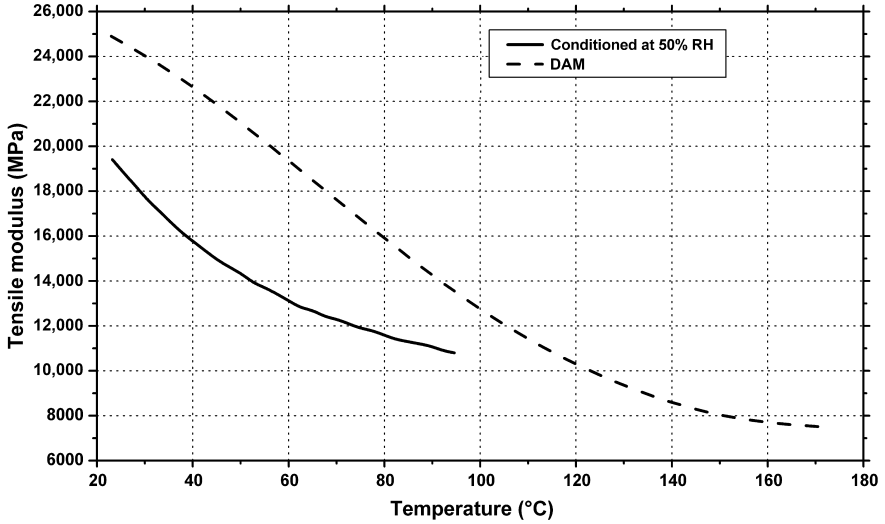

Figure 6.116 Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ RC006—electrically Conductive, 30% Carbon Fiber Filled Nylon 66 resin.

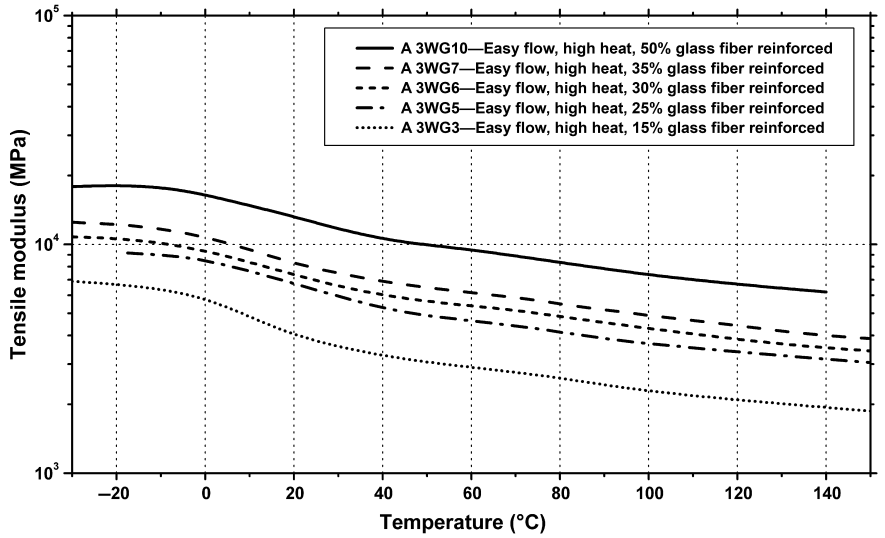

Figure 6.117 Tensile modulus vs. temperature for several BASF Ultramid® Nylon 66 resins (conditioned at 50% RH) [8].

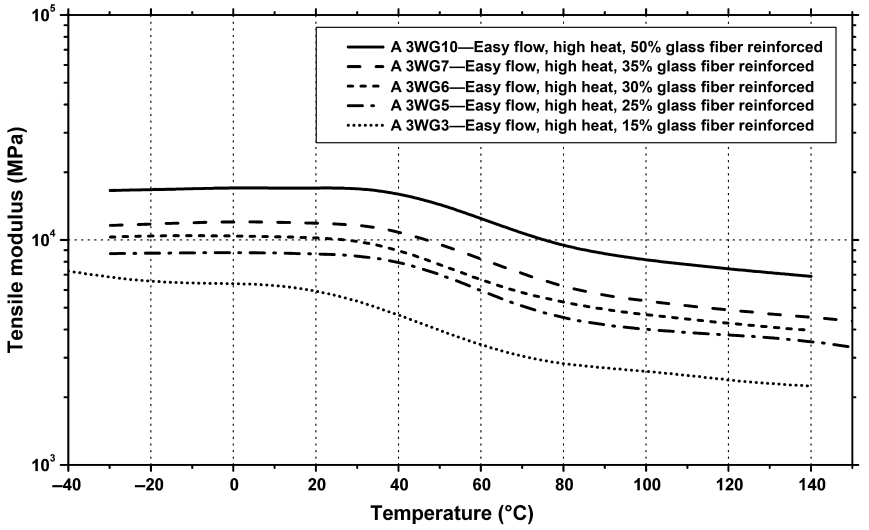

Figure 6.118 Tensile modulus vs. temperature for several BASF Ultramid® Nylon 66 resins (DAM) [8].

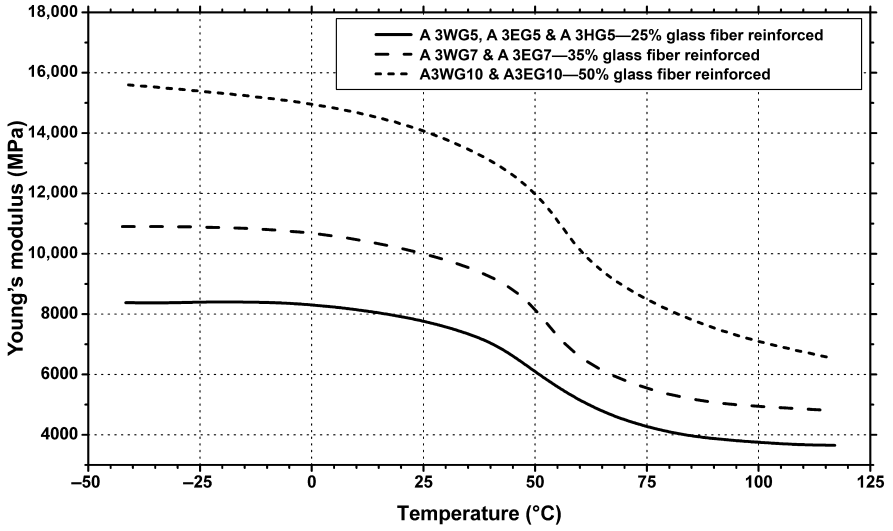

Figure 6.119 Young's modulus vs. temperature for several BASF Ultramid® Nylon 66 resins (DAM) [8].

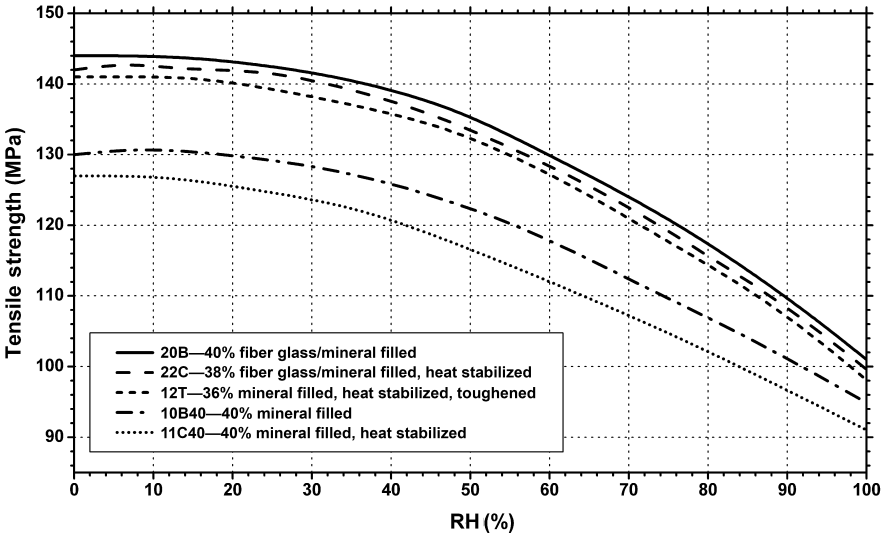

Figure 6.120 Tensile strength vs. humidity at −40°C for several DuPont Minlon® Nylon 66 resins [6].

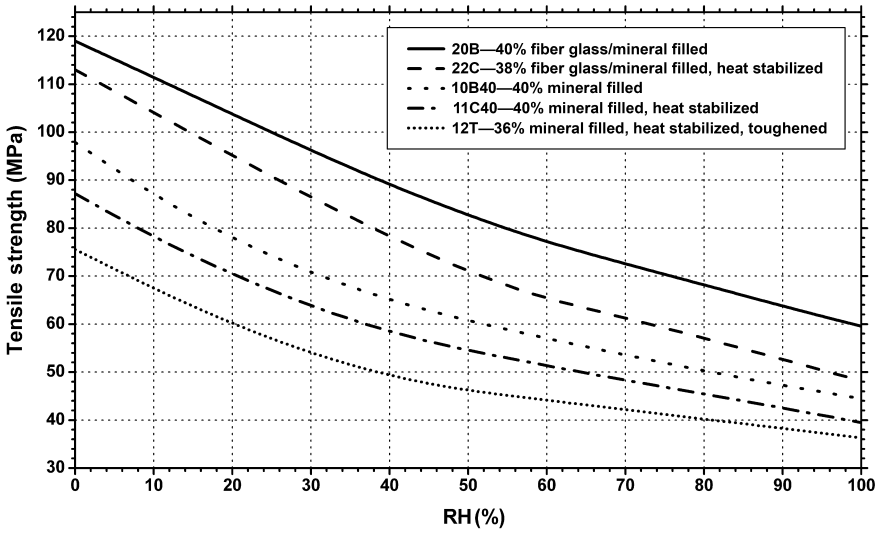

Figure 6.121 Tensile strength vs. humidity at 23°C for several DuPont Minlon® Nylon 66 resins [6].

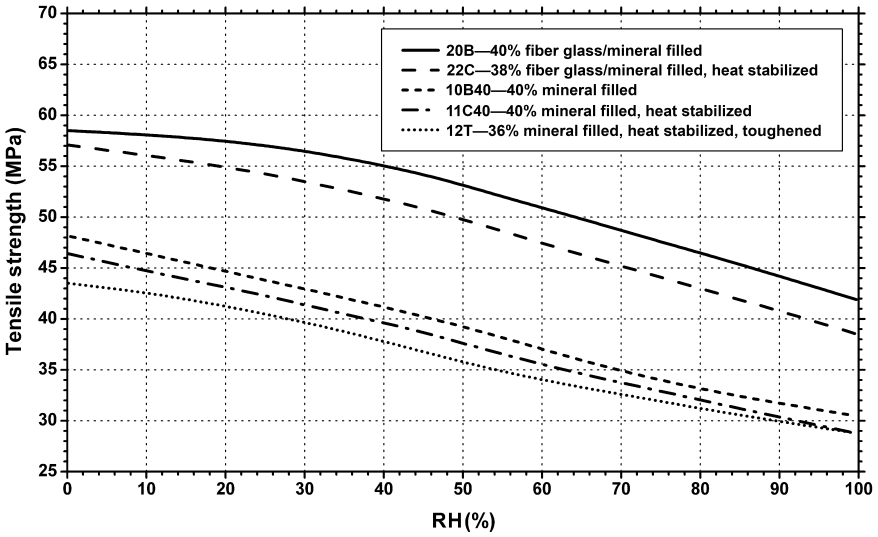

Figure 6.122 Tensile strength vs. humidity at 93°C for several DuPont Minlon® Nylon 66 resins [6].

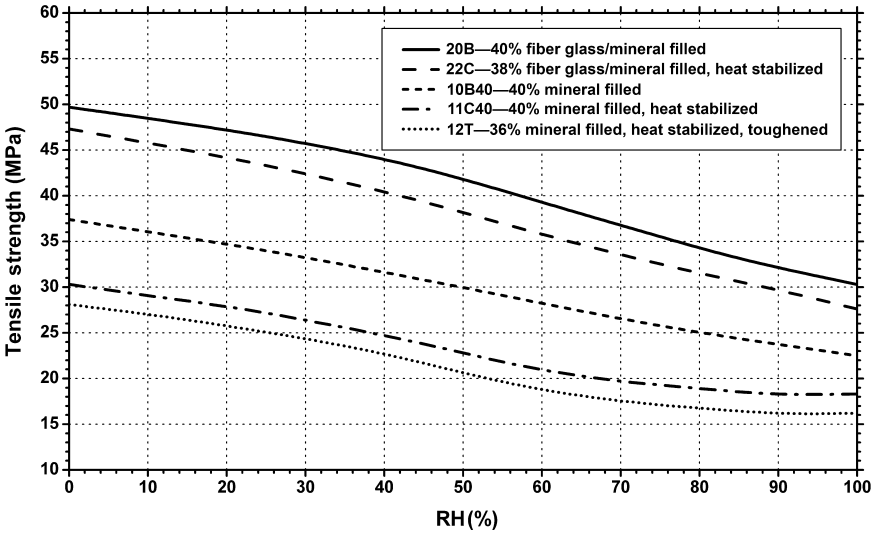

Figure 6.123 Tensile strength vs. humidity at 149°C for several DuPont Minlon® Nylon 66 resins [6].

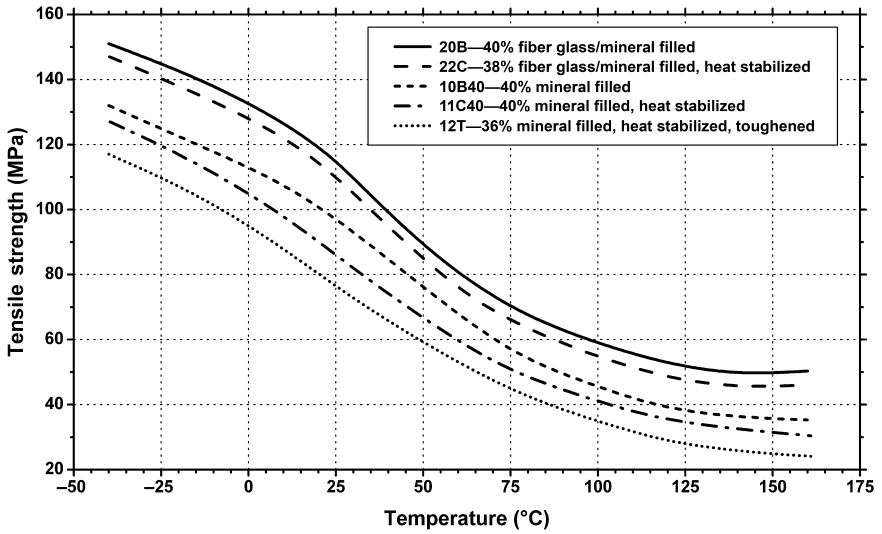

Figure 6.124 Tensile strength vs. temperature for several DuPont Minlon® Nylon 66 resins [6].

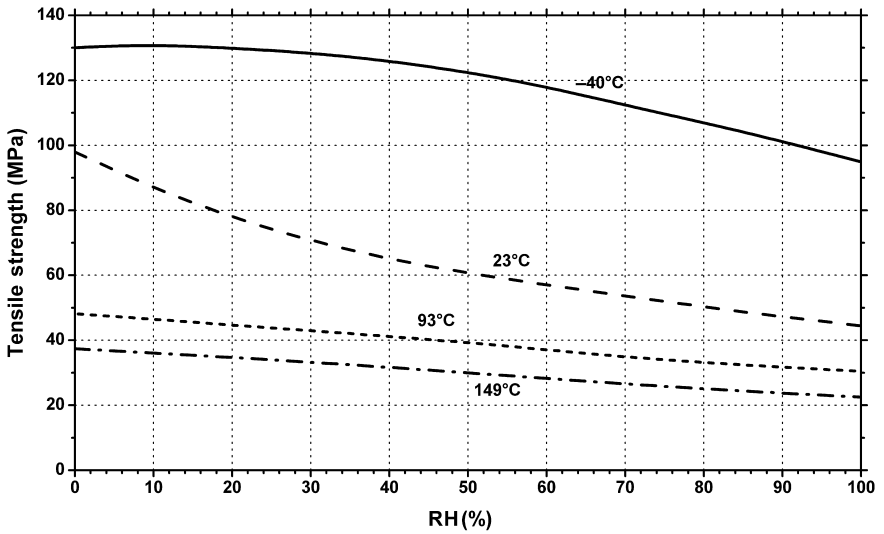

Figure 6.125 Tensile strength vs. humidity at various temperatures for DuPont Minlon® 10B40—40% mineral filled, stiffened Nylon 66 resin [6].

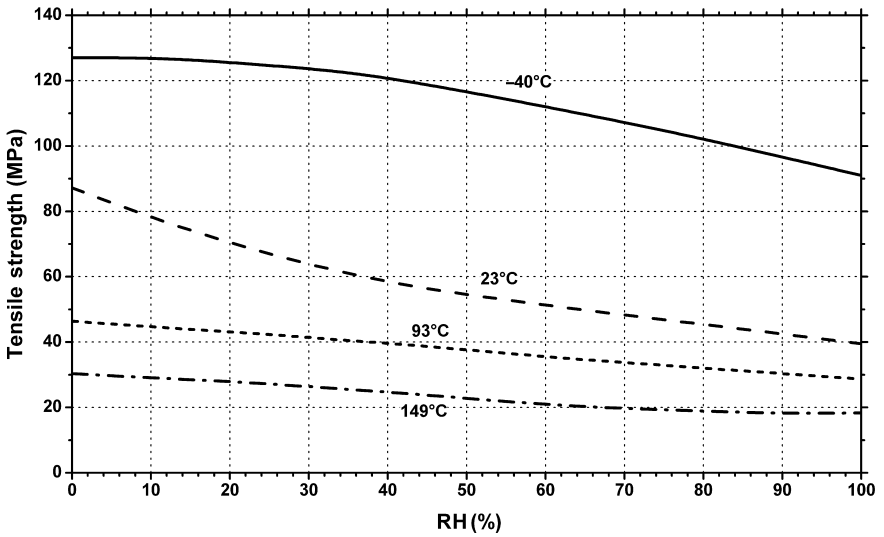

Figure 6.126 Tensile strength vs. humidity at various Temperatures for DuPont Minlon® 11C40—40% mineral filled, high impact Nylon 66 Resin [6].

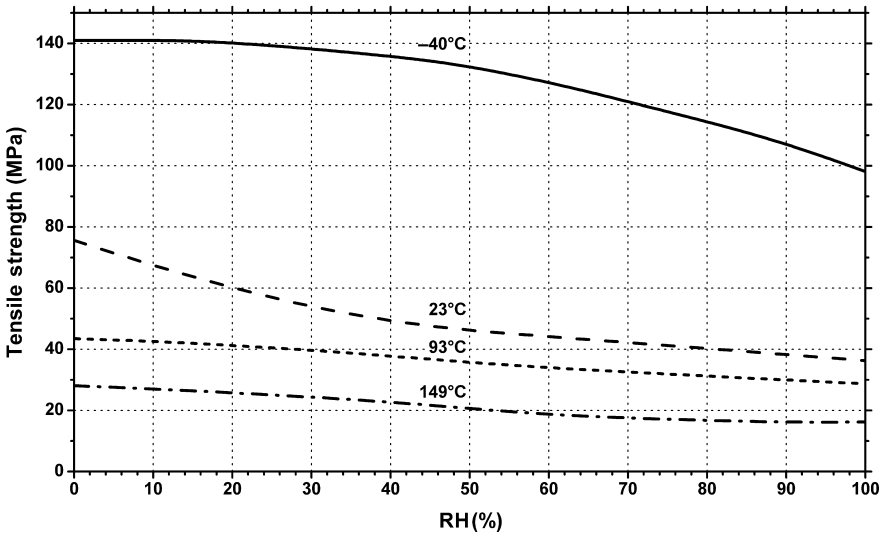

Figure 6.127 Tensile strength vs. humidity at various temperatures for DuPont Minlon® 12T—40% mineral filled, super impact Nylon 66 resin [6].

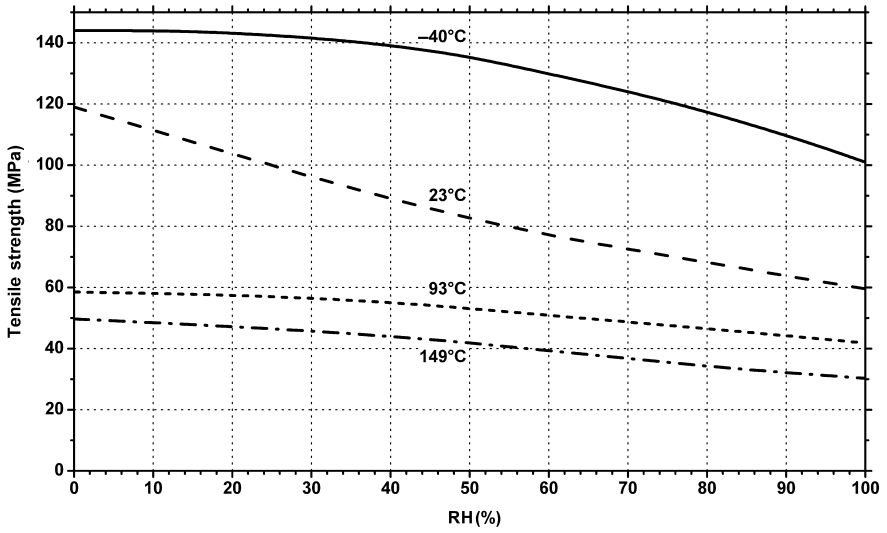

Figure 6.128 Tensile strength vs. humidity at various temperatures for DuPont Minlon® 20B—40% glass fiber/mineral filled, stiffened, strength high Nylon 66 resin [6].

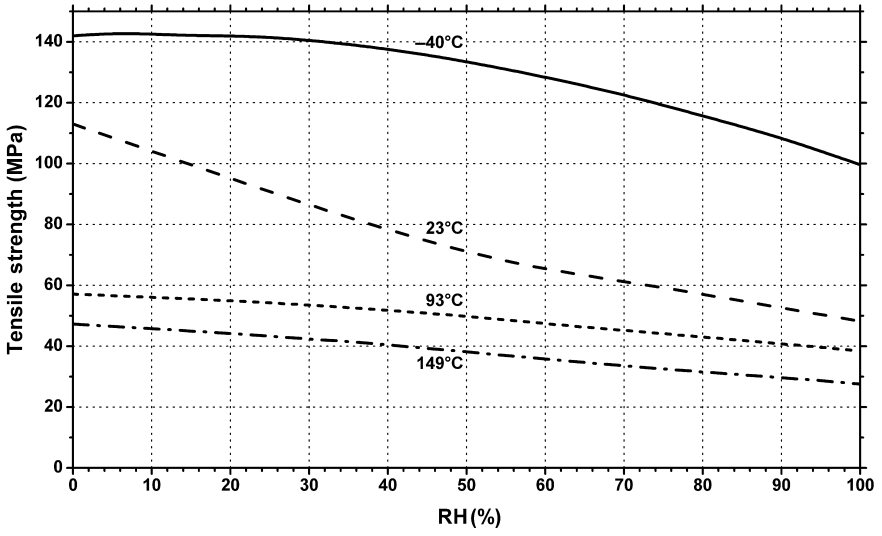

Figure 6.129 Tensile strength vs. humidity at various temperatures for DuPont Minlon® 22C—40% glass fiber/mineral filled, low warpage high Nylon 66 resin [6].

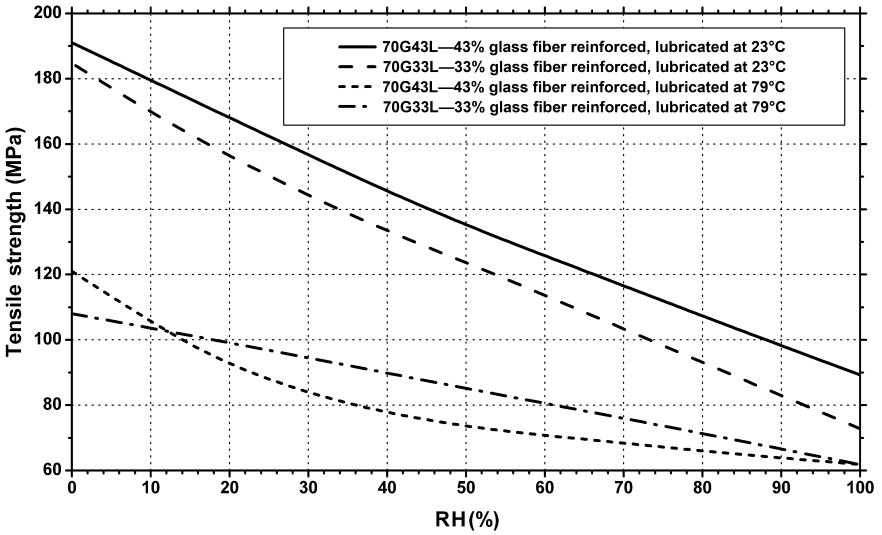

Figure 6.130 Tensile strength vs. humidity at two temperatures for two DuPont Zytel® glass fiber filled Nylon 66 resins [6].

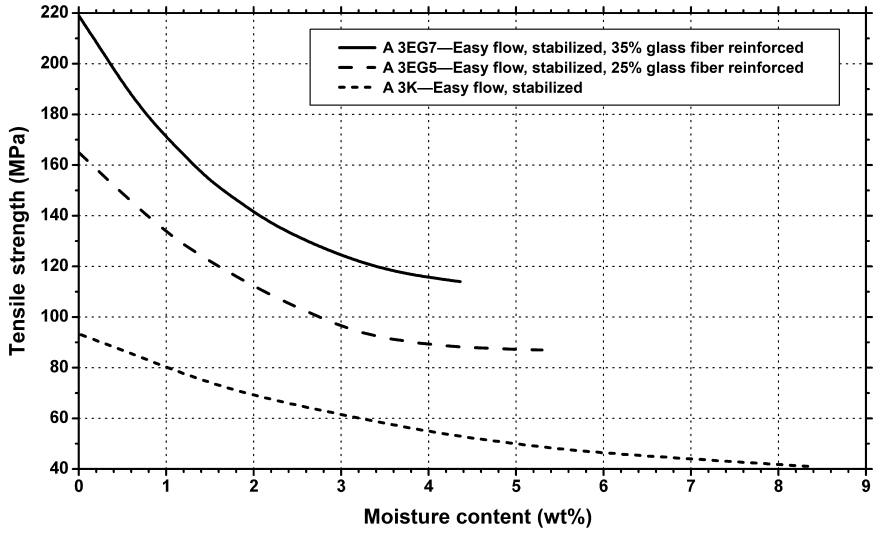

Figure 6.131 Tensile strength vs. moisture content for several BASF Ultramid® Nylon 66 resins [8].

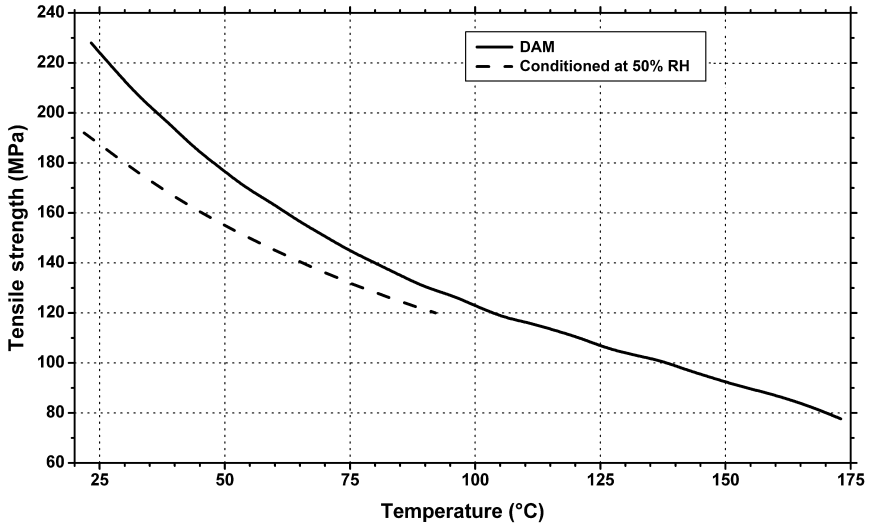

Figure 6.132 Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ RC006—electrically conductive, 30% carbon fiber filled Nylon 66 resin.

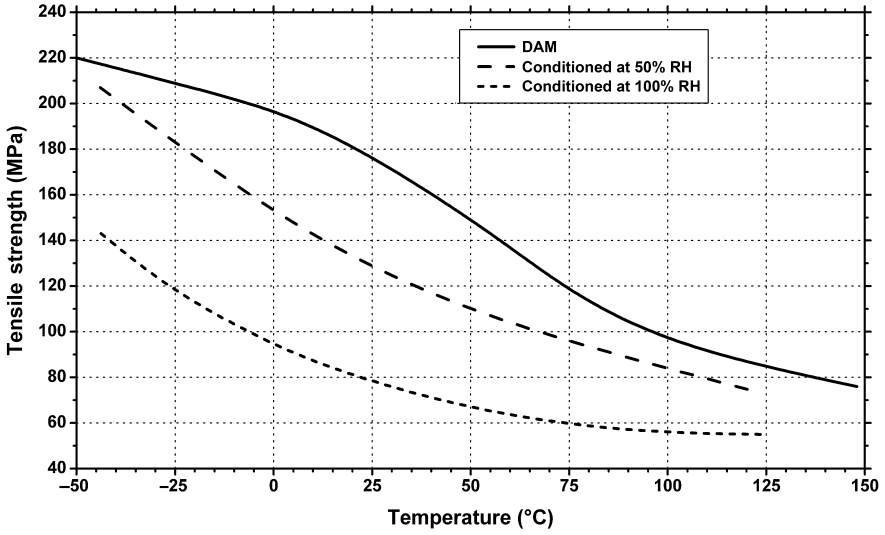

Figure 6.133 Tensile strength vs. temperature and moisture content for DuPont Zytel® 70G-33L—33% glass filled, lubricated Nylon 66 resin [6].

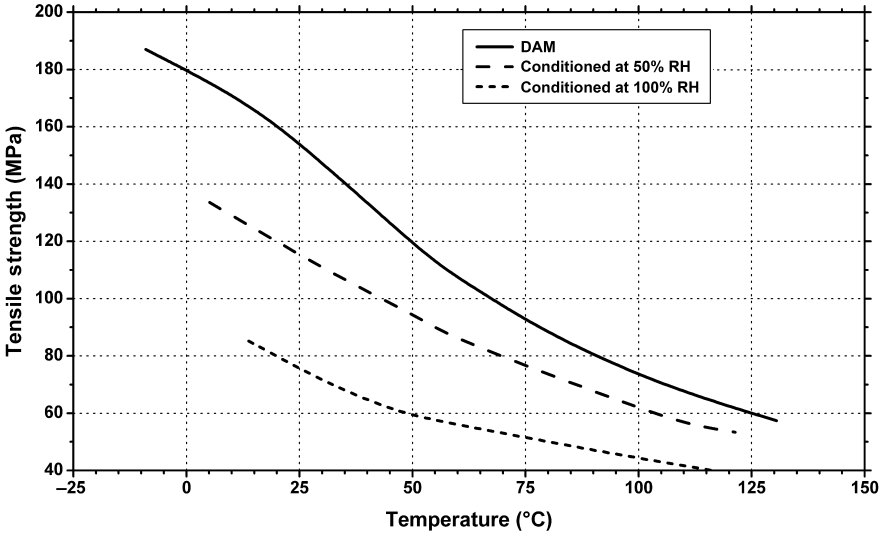

Figure 6.134 Tensile strength vs. temperature and moisture content for DuPont Zytel® 71G-33L—33% glass filled, toughened lubricated Nylon 66 resin [6].

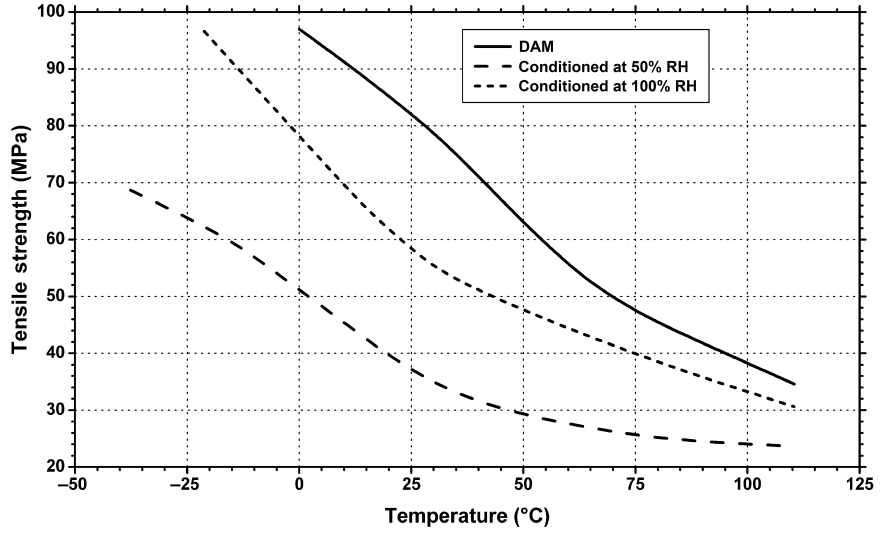

Figure 6.135 Tensile strength vs. temperature and moisture content for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

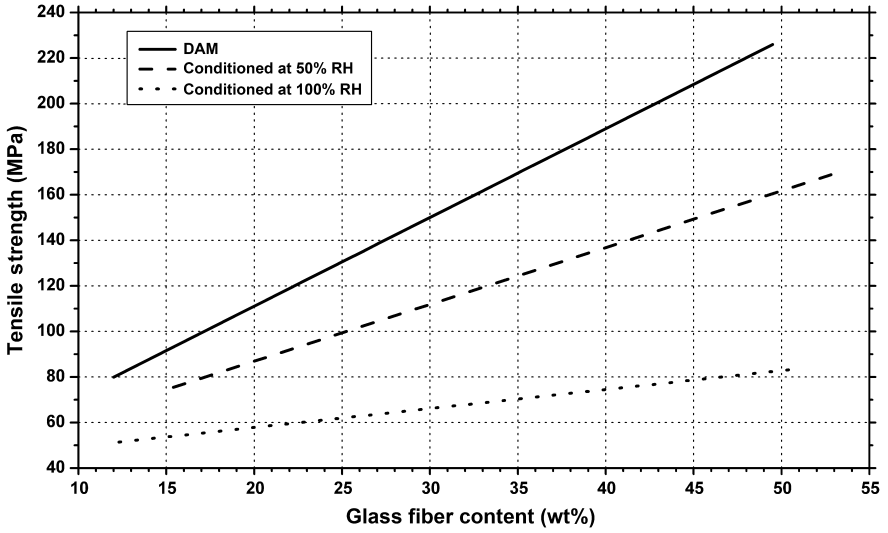

Figure 6.136 Tensile strength vs. fiber glass content for DuPont Zytel® 70G series Nylon 66 resins [6].

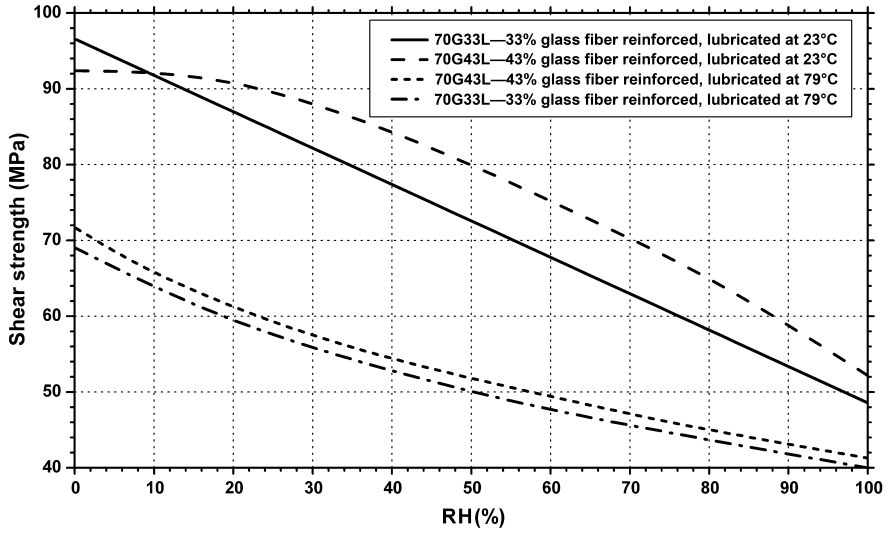

Figure 6.137 Shear strength vs. humidity at two temperatures for two DuPont Zytel® Nylon 66 resins [6].

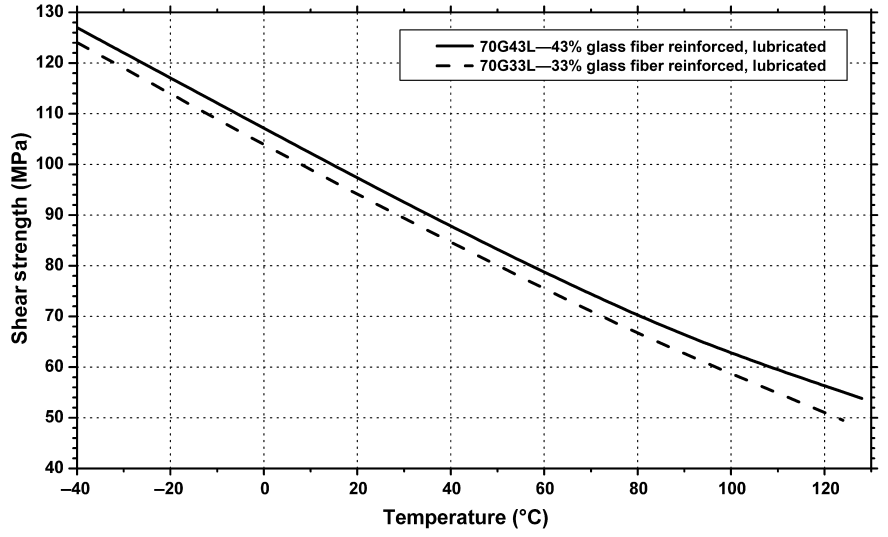

Figure 6.138 Shear strength vs. temperature for two DuPont Zytel® Nylon 66 resins (DAM) [6].

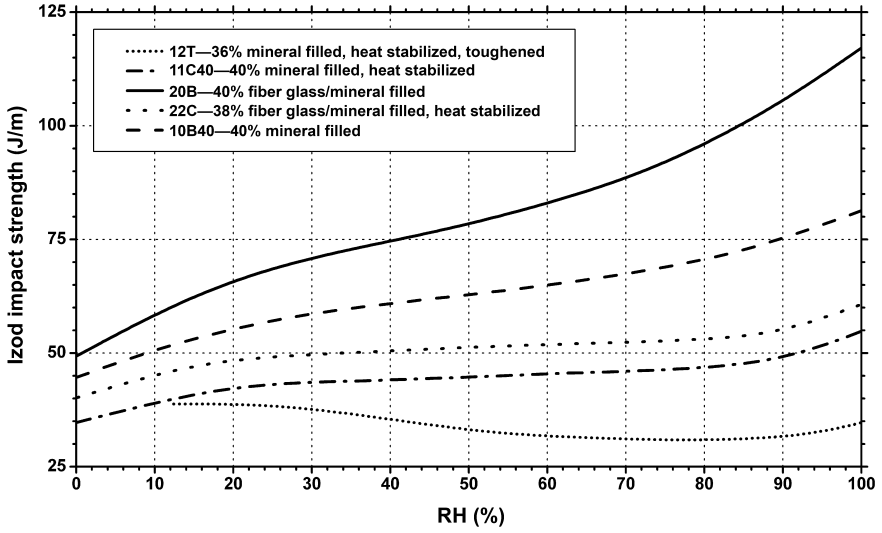

Figure 6.139 Izod impact strength vs. humidity at −40°C for several DuPont Minlon® Nylon 66 resins [6].

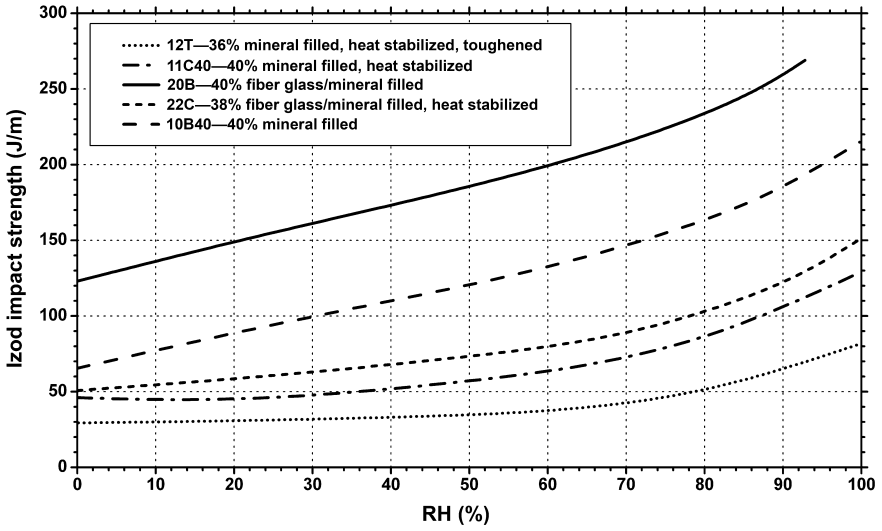

Figure 6.140 Izod impact strength vs. humidity at 23°C for several DuPont Minlon® Nylon 66 resins [6].

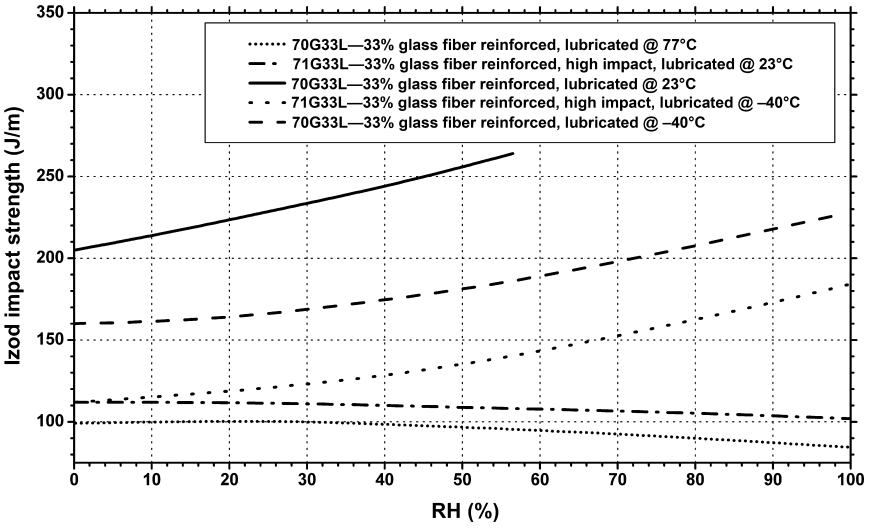

Figure 6.141 Izod impact strength vs. humidity and temperature for two DuPont Zytel® glass filled Nylon 66 resins [6].

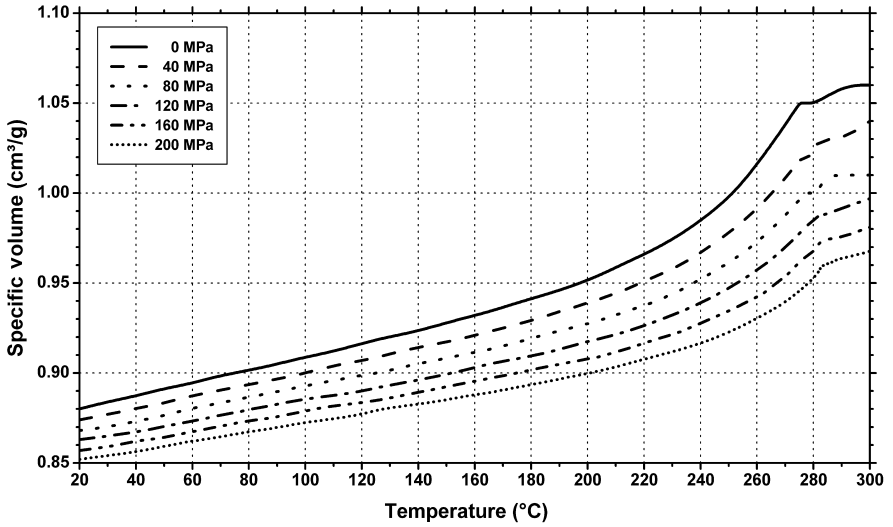

Figure 6.142 PVT for BASF Ultramid® A3K—high flow, fast cycling, high impact Nylon 66 resin [8].

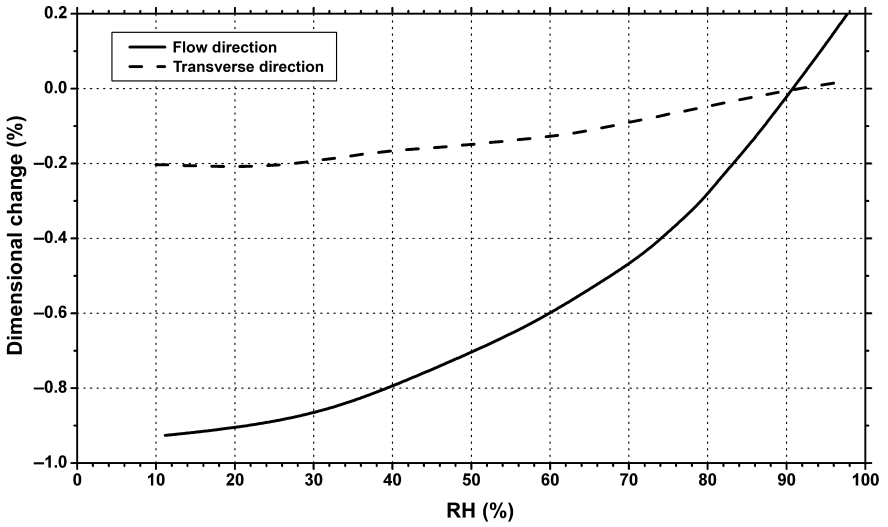

Figure 6.143 Dimensional change vs. humidity for DuPont Zytel® 70G-33L—33% glass filled, lubricated Nylon 66 resin [6].

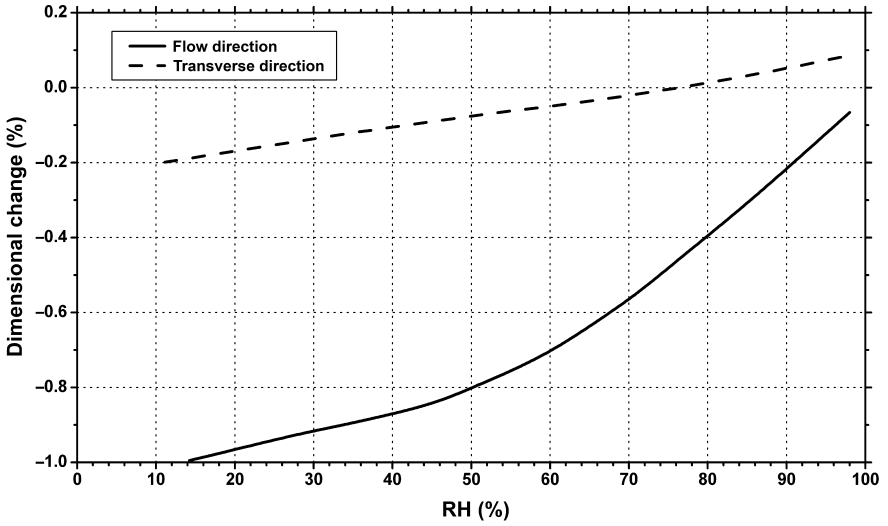

Figure 6.144 Dimensional change vs. humidity for DuPont Zytel® 71G-33L—33% glass filled, lubricated, toughened Nylon 66 resin [6].

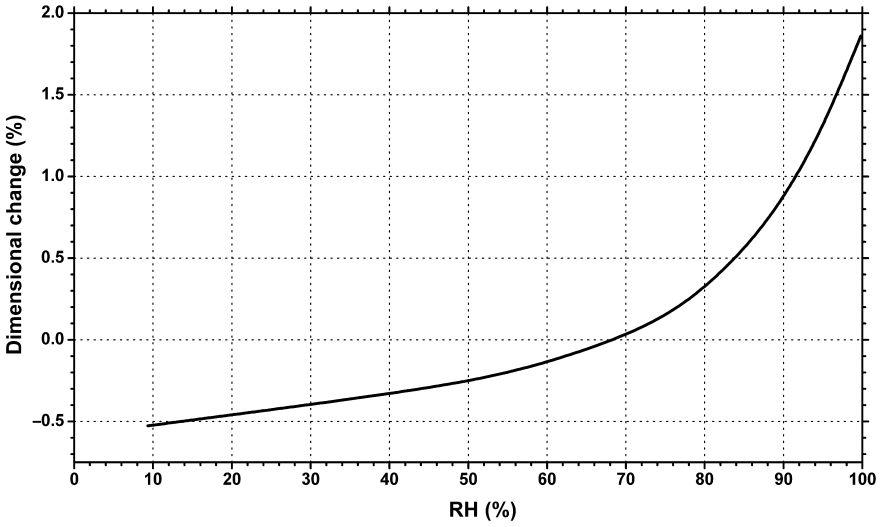

Figure 6.145 Dimensional change vs. humidity for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

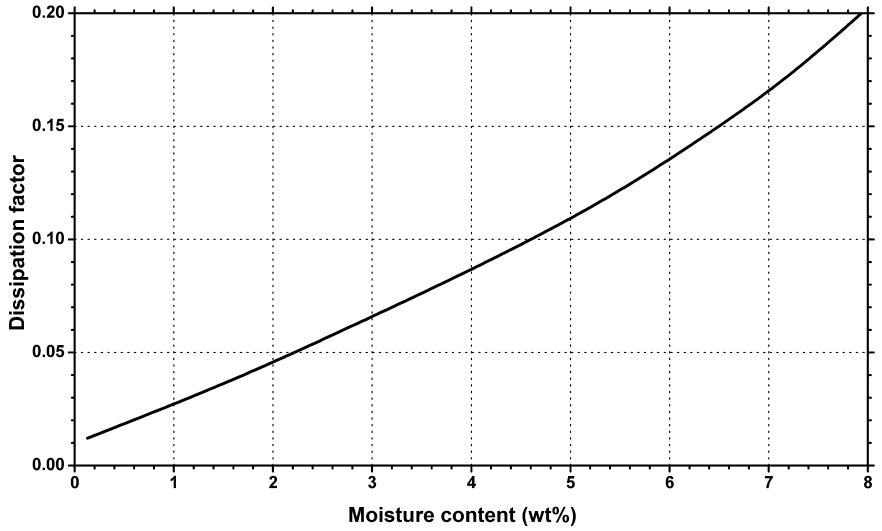

Figure 6.146 Dimensional change vs. moisture content for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

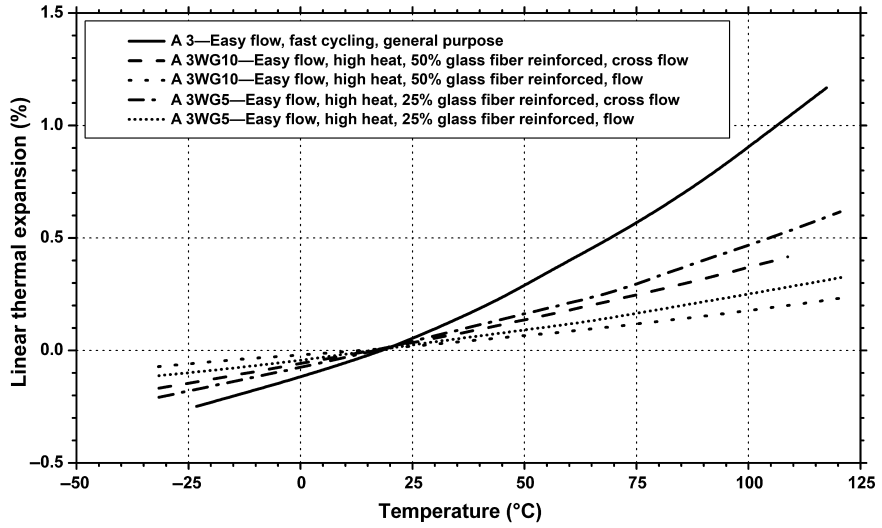

Figure 6.147 Linear thermal expansion vs. temperature for BASF Ultramid® Nylon 66 resins [8].

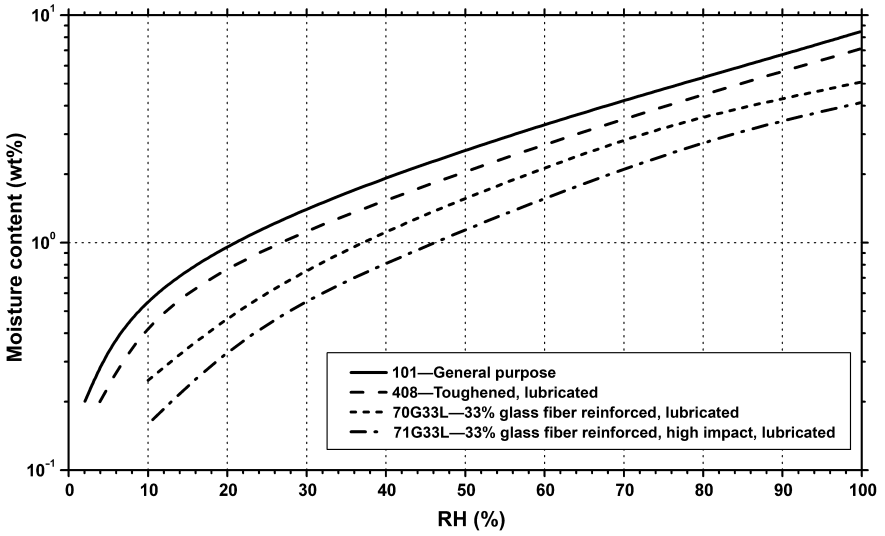

Figure 6.148 Moisture content vs. RH for DuPont Zytel® Nylon 66 resins [6].

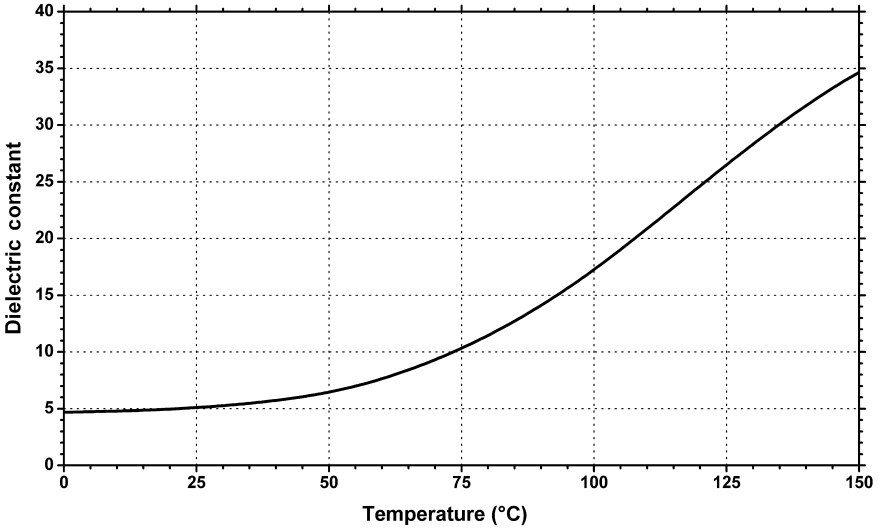

Figure 6.149 Dielectric constant vs. temperature at 100 Hz for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

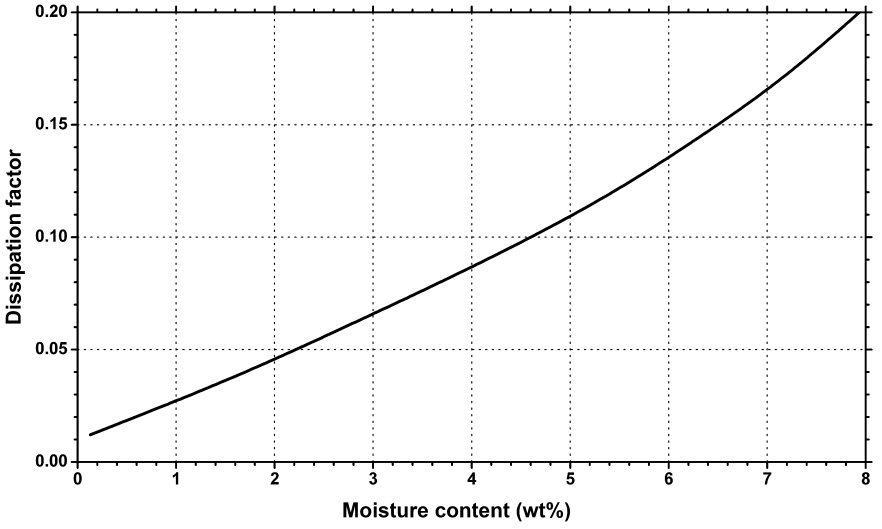

Figure 6.150 Dissipation factor vs. moisture content at 100 Hz and 23°C for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

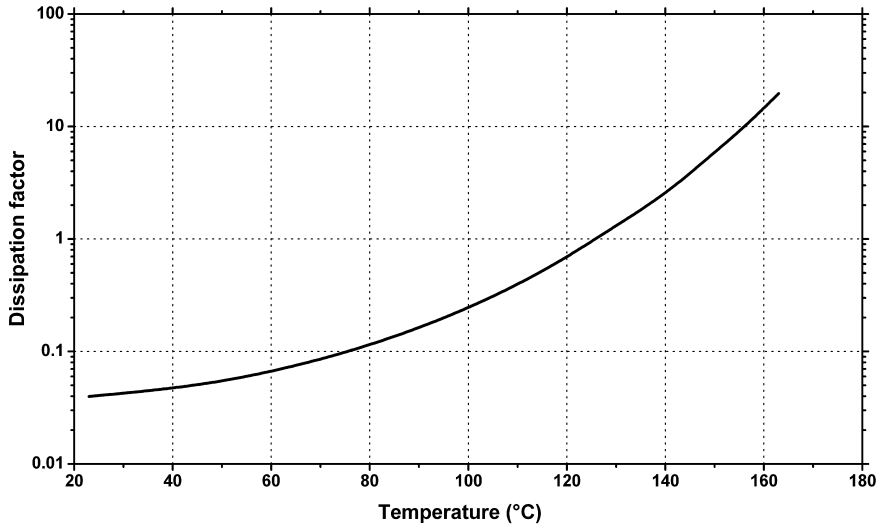

Figure 6.151 Dissipation factor vs. temperature at 100 Hz for DuPont Zytel® 101—general purpose Nylon 66 resins [6].

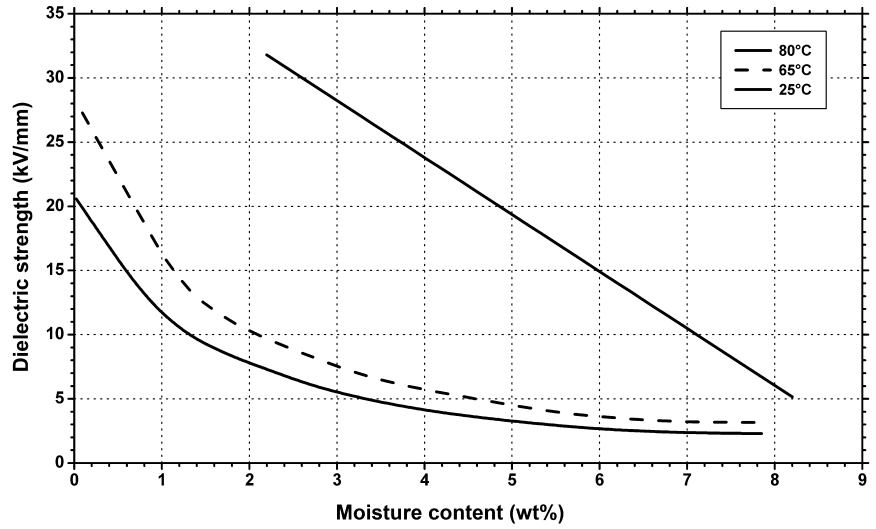

Figure 6.152 Dielectric strength vs. moisture content and temperature for BASF Ultramid® A3EG6—30% glass fiber, heat stabilized Nylon 66 resin [8].

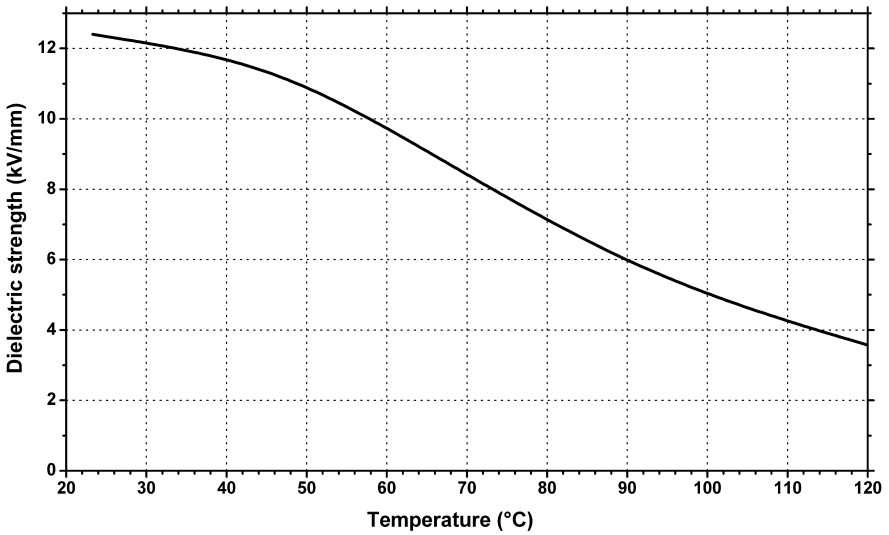

Figure 6.153 Dielectric strength vs. temperature for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

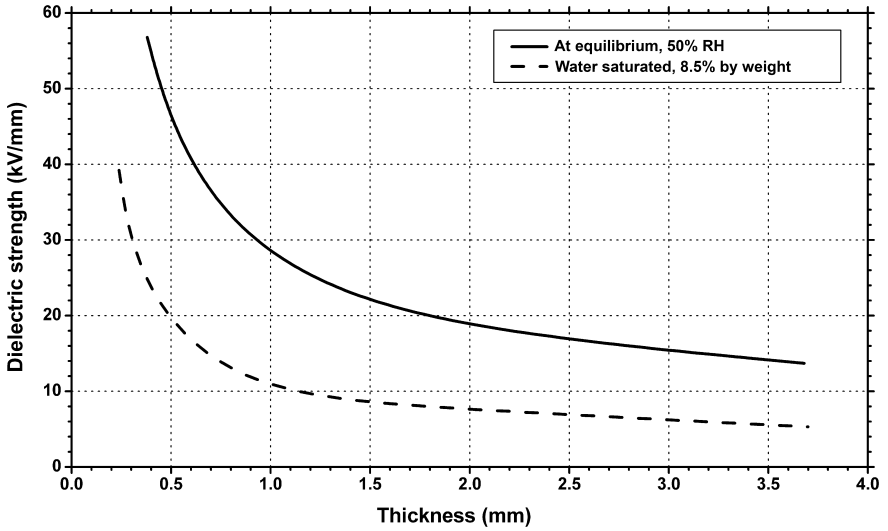

Figure 6.154 Dielectric strength vs. thickness for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

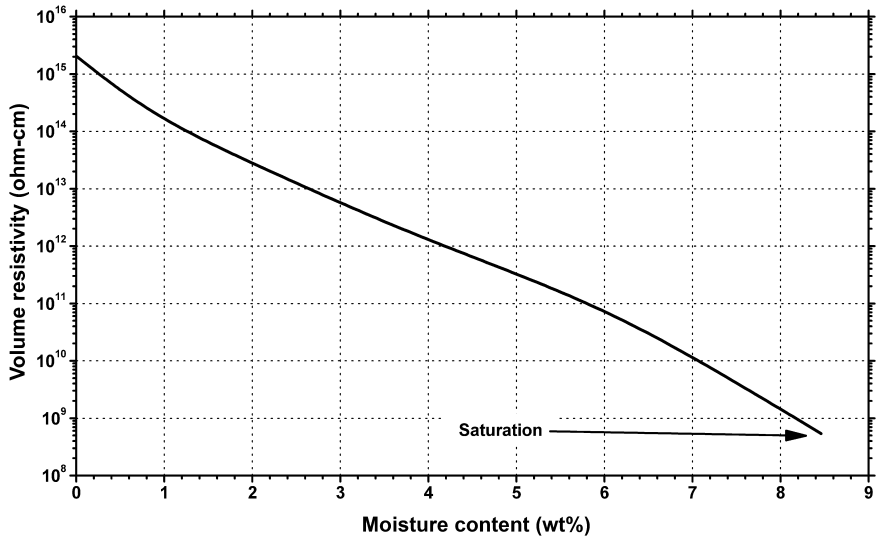

Figure 6.155 Volume resistivity vs. moisture content for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

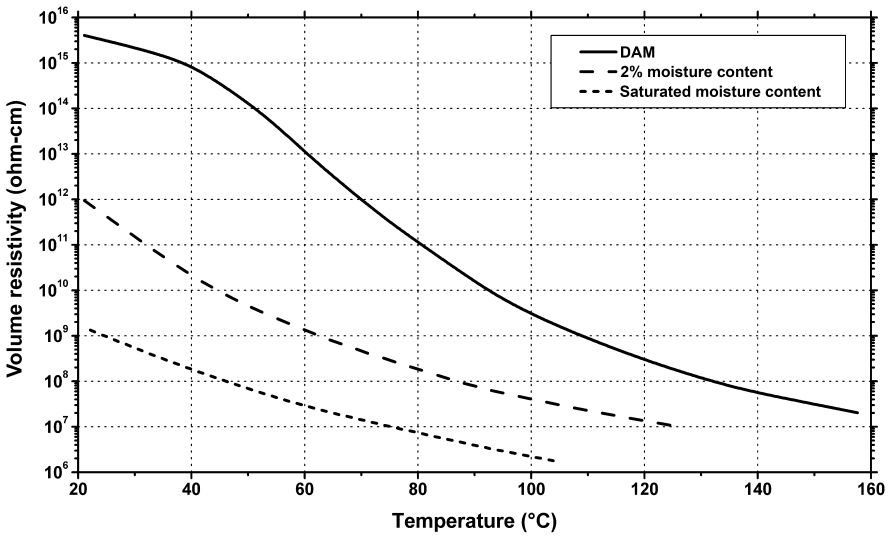

Figure 6.156 Volume resistivity vs. temperature and various moisture levels for BASF Ultramid® A3EG6—high stiffness, 30% glass fiber filled Nylon 66 resin [8].

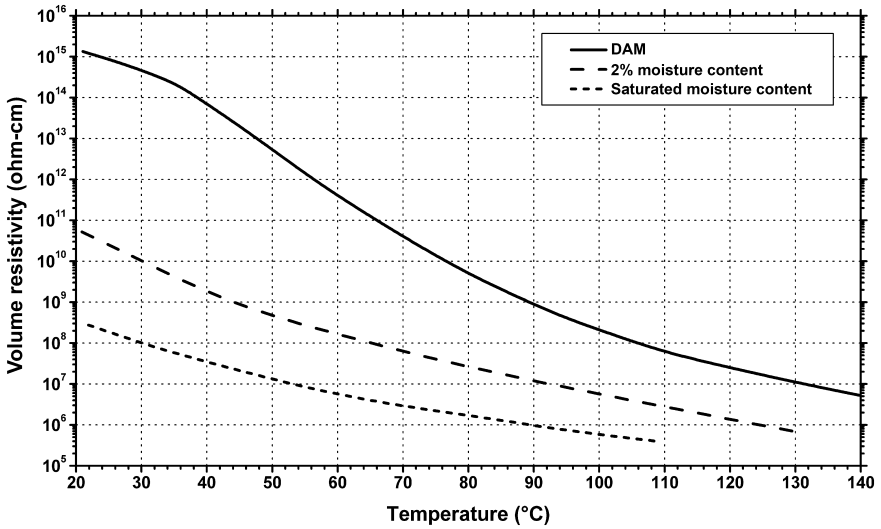

Figure 6.157 Volume resistivity vs. temperature and various moisture levels for BASF Ultramid® A3XG6—30% glass fiber filled Nylon 66 resin [8].

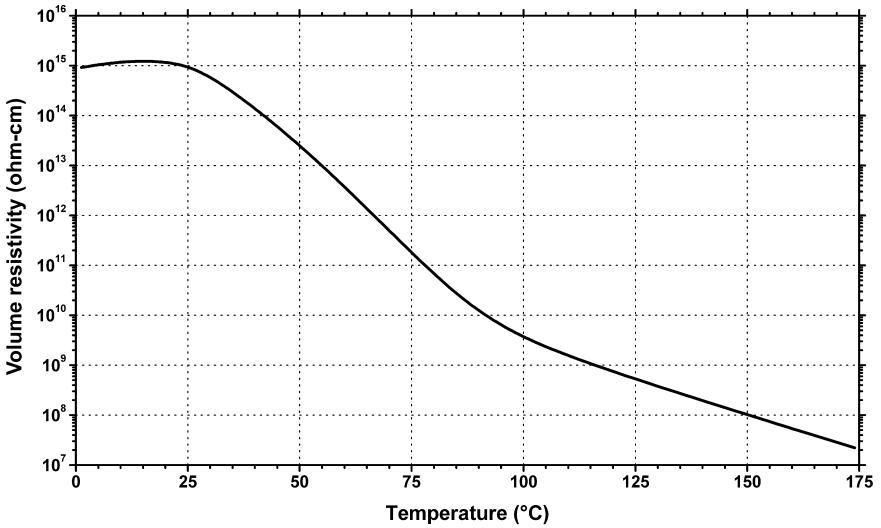

Figure 6.158 Volume resistivity vs. temperature (DAM) for DuPont Zytel® 101—general purpose Nylon 66 resin [6].

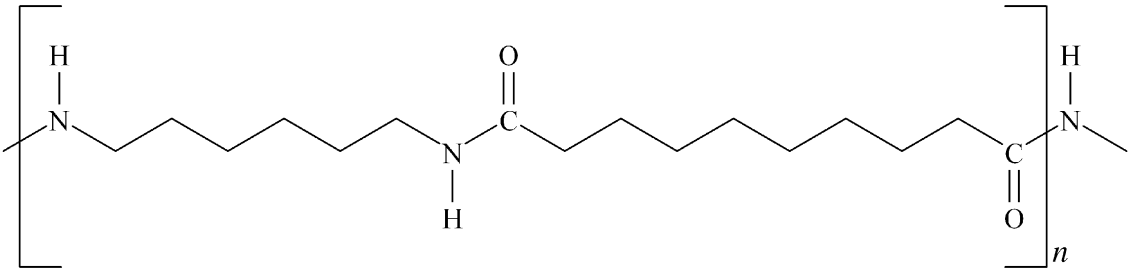

Figure 6.159 Chemical structure of Nylon 610.

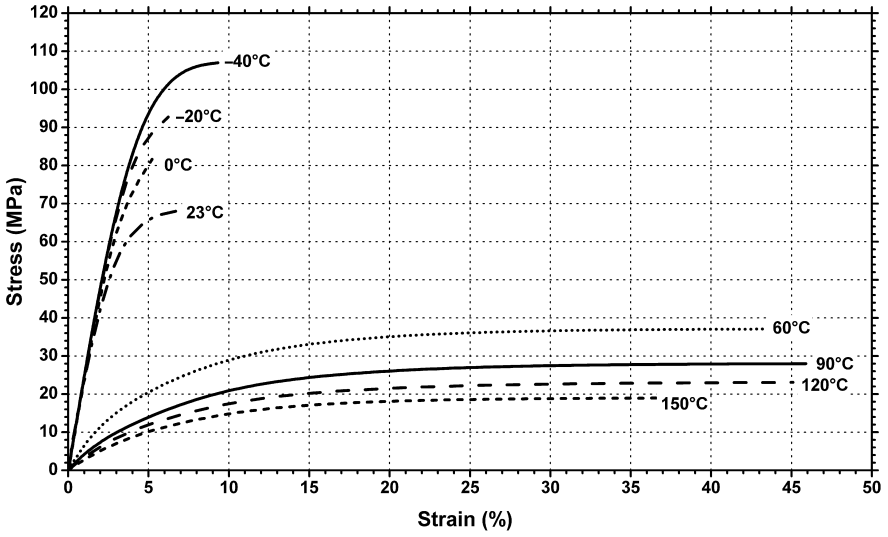

Figure 6.160 Stress vs. strain at various temperatures for DuPont Zytel® RS3061HSL BK039A Nylon 610 resin (DAM).

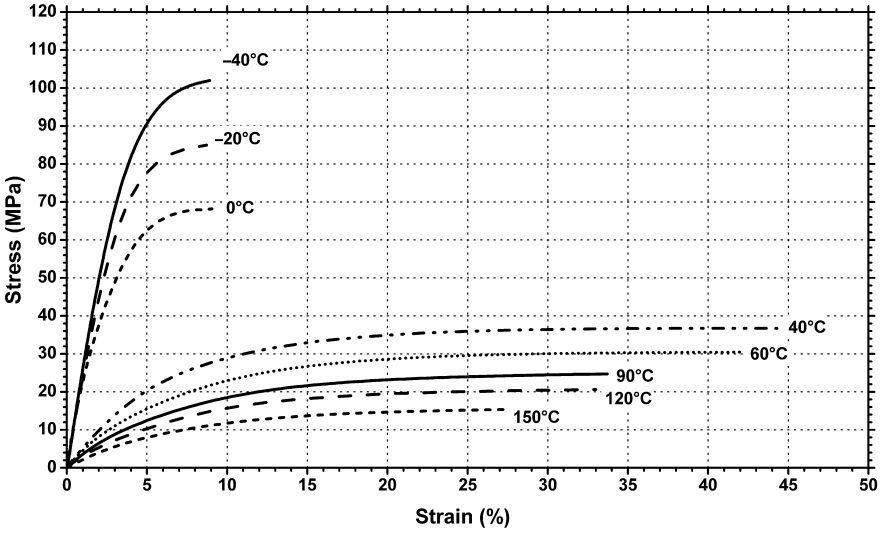

Figure 6.161 Stress vs. strain at various temperatures for DuPont Zytel® RS3061HSL BK039A Nylon 610 resin (conditioned).

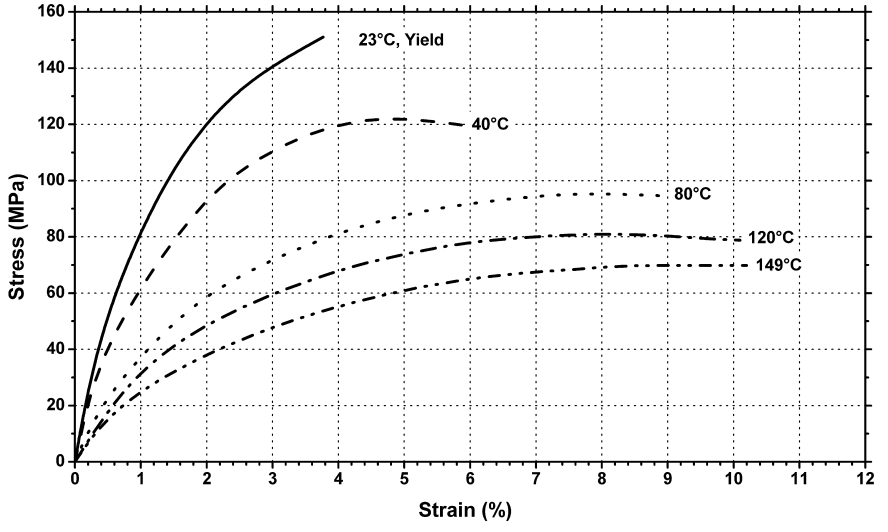

Figure 6.162 Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp™ QF006—30% glass fiber reinforced Nylon 610 resin (DAM).

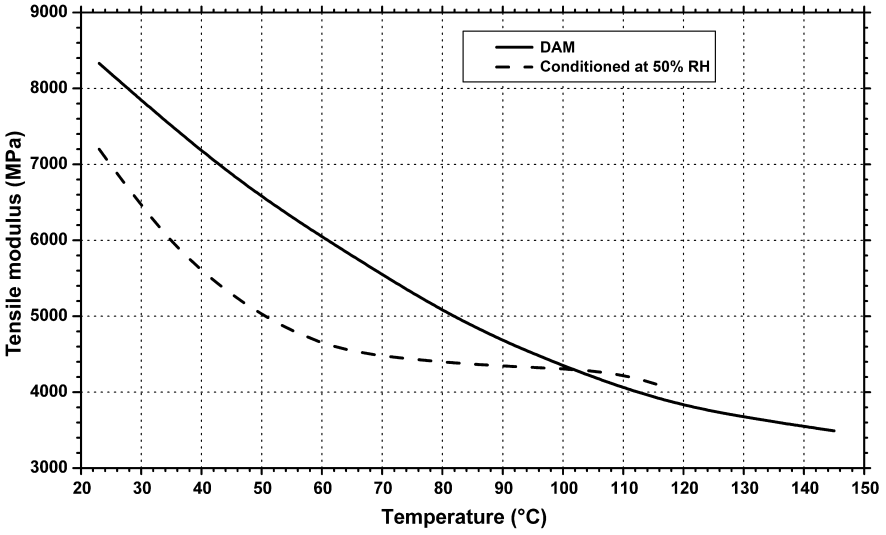

Figure 6.163 Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ QF006—30% glass fiber reinforced Nylon 610 resin (DAM).

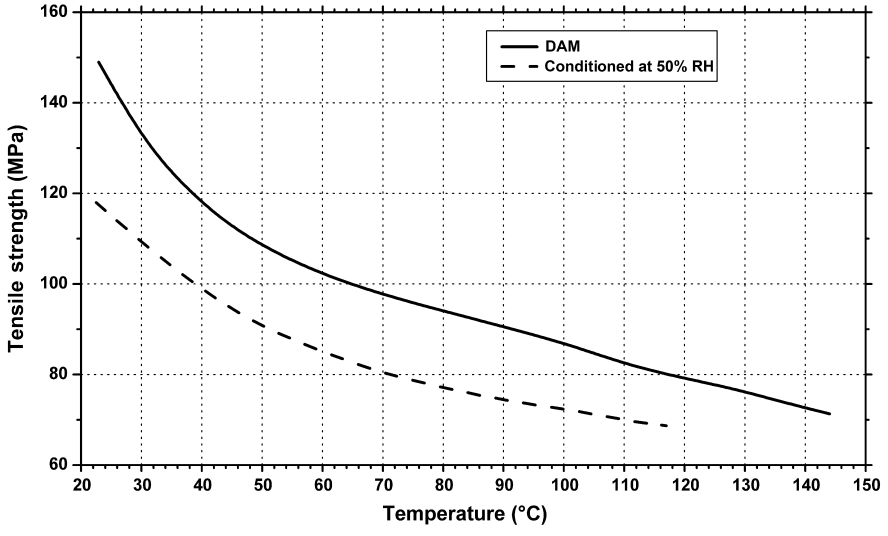

Figure 6.164 Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ QF006—30% glass fiber reinforced Nylon 610 resin (DAM).

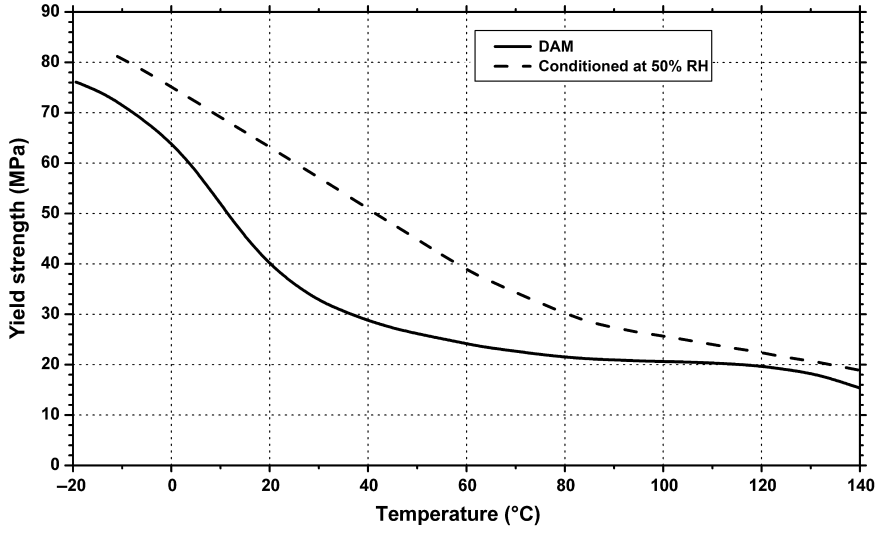

Figure 6.165 Tensile yield strength vs. temperature for Toray Resin Company Amilan® CM2001—25% crystallinity, standard grade Nylon 610 resin.

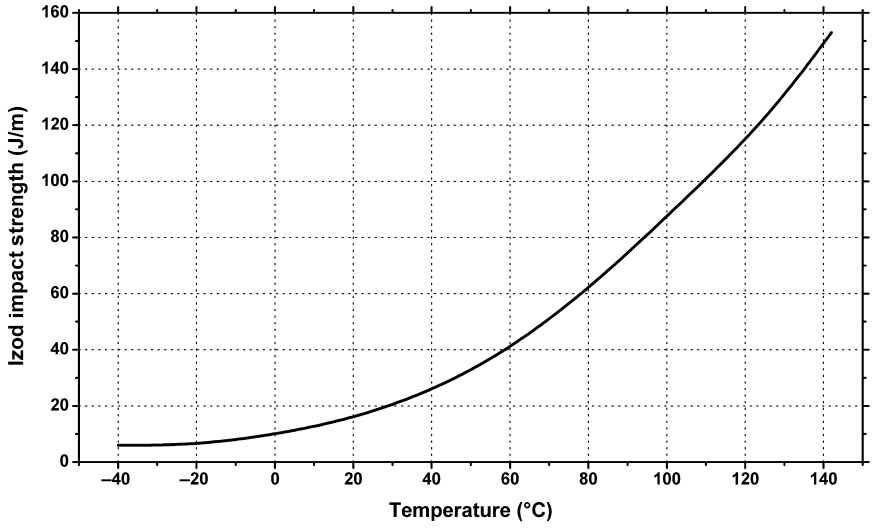

Figure 6.166 Izod impact strength vs. temperature for Toray Resin Company Amilan® CM2001—25% crystallinity, standard grade Nylon 610 resin.

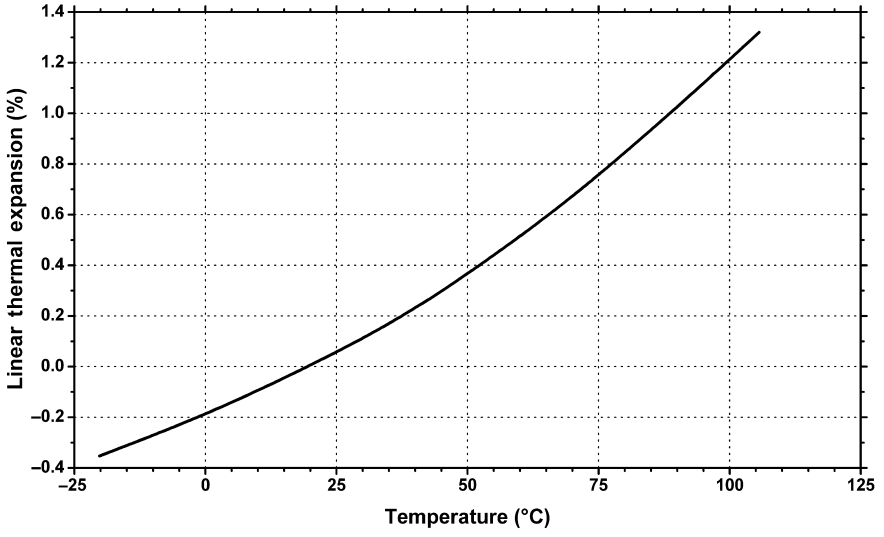

Figure 6.167 Linear thermal expansion vs. temperature for BASF Ultramid® S3 and S4 Nylon 610 resins.

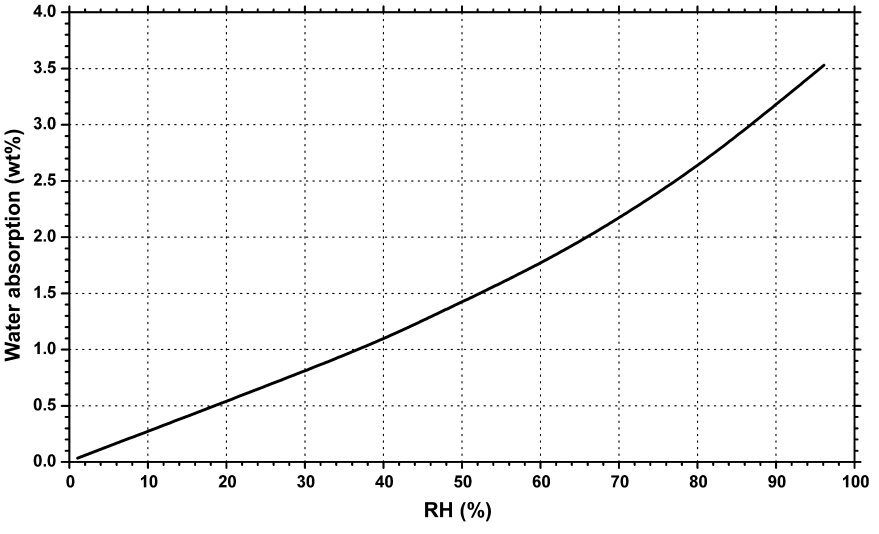

Figure 6.168 Water absorption vs. RH for BASF Ultramid® S3 and S4 Nylon 610 resins.

- Outstanding recovery at high wet strength

Manufacturers and trade names: EMS-Grivory Grilon® CF and CR, Ube Industries, DuPont Zytel®, Evonik Industries Vestamid® D.

Uses and applications: multilayer food packaging, boil in bag, automotive fuel components.

Data for polyamide 612 plastics are found in Figures 6.170–6.198.

6.8 Nylon 6/66 (PA666)

Polyamide 666 or 6/66 is the designation given to copolyamides made from PA 6 and PA 66 building blocks. A precise structure cannot be drawn.

Manufacturers and trade names: Honeywell Aegis®, UBE Industries, BASF Ultramid®, EMS-Grivory Grilon® TS.

Uses and applications: packaging, monofilament fishing line, tubes for central lubrication systems, fuel and oil pipes, pneumatic and hydraulic control lines, and Bowden cables.

Data for polyamide 666 plastics are found in Figures 6.199–6.216.

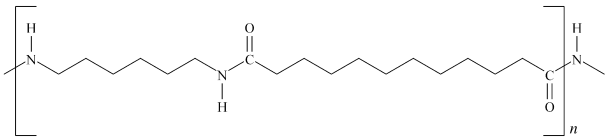

Figure 6.169 Chemical structure of Nylon 610.

6.9 Nylon 1010 (PA1010)

The structure of Nylon 1010 is shown in Figure 6.217. PA1010 is 100% renewably sourced. The monomers, 1,10-decamethylene diamine and 1,10-decanedioic acid (sebacic acid), used in PA1010 are both derived from castor bean oil. PA1010 offers the typical properties of flexible polyamide with additional benefits such as superior high temperature resistance and lower permeability to fuel and gases.

Some of the Nylon 1010 characteristics are as follows:

- High mechanical strength
- Good UV and chemical resistance
- Low water absorption so that the mechanical properties are scarcely affected by changes in atmospheric humidity
- For use at high temperatures
- High translucency; good transparency with thin walls

Manufacturers and trade names: DuPont Zytel®, Evonik Industries Vestamid® Terra DS.

Uses and applications: automotive fuel and powertrain systems, fuel lines, hydraulic hoses, transmission oil cooler hoses, servo brakes vacuum tubes, clutch tubes, and filaments.

Data for polyamide 1010 plastics are found in Figures 6.218–6.219.

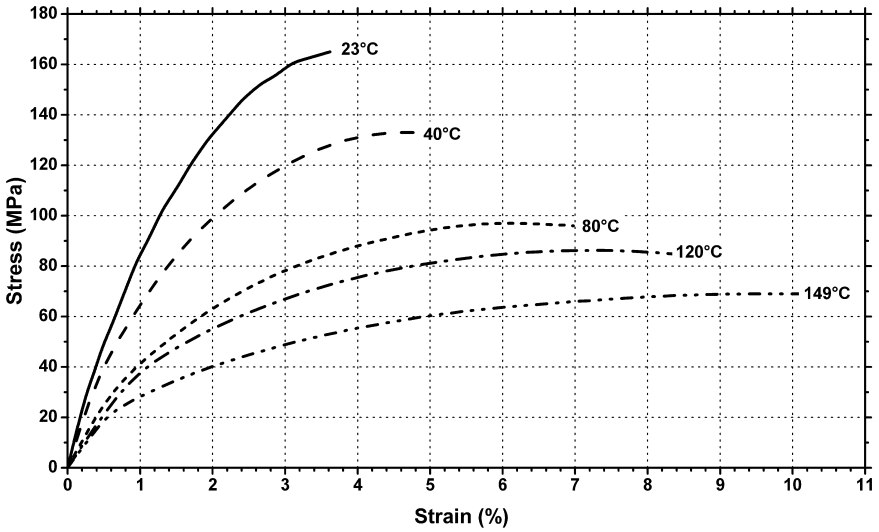

Figure 6.170 Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp™ IF006—30% glass fiber reinforced Nylon 612 resin (DAM).

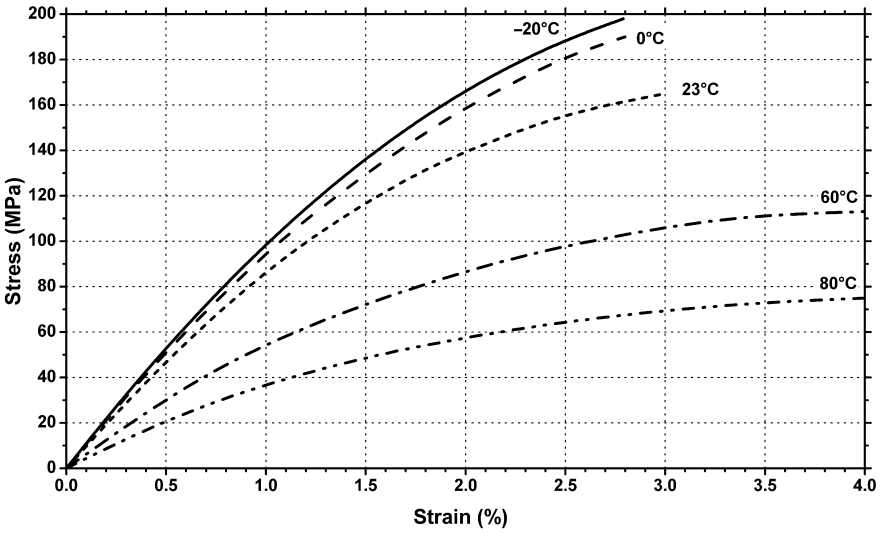

Figure 6.171 Stress vs. strain for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin (DAM).

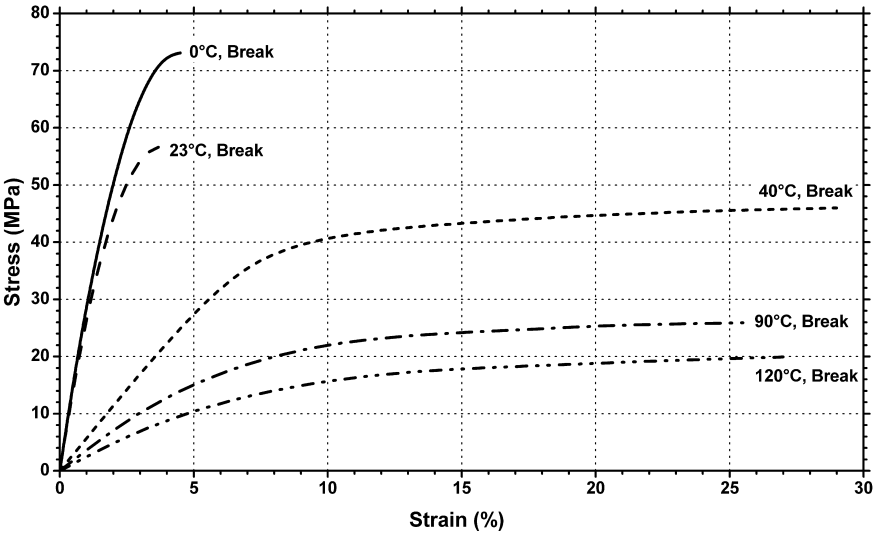

Figure 6.172 Stress vs. strain at various temperatures for DuPont Zytel® 158 NC010—general purpose, lubricated Nylon 612 resin (DAM).

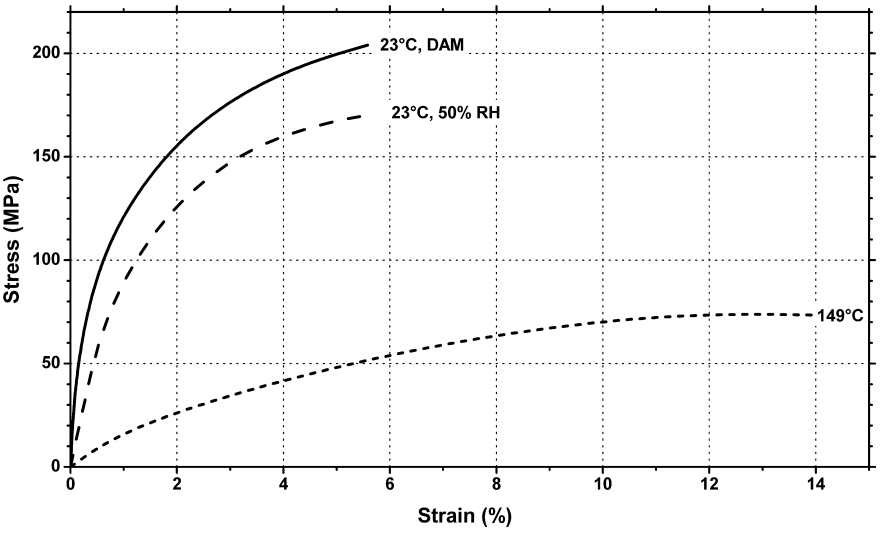

Figure 6.173 Stress vs. strain for DuPont Zytel® 77G43L—general purpose, lubricated, 43% short glass fiber reinforced Nylon 612 resin.

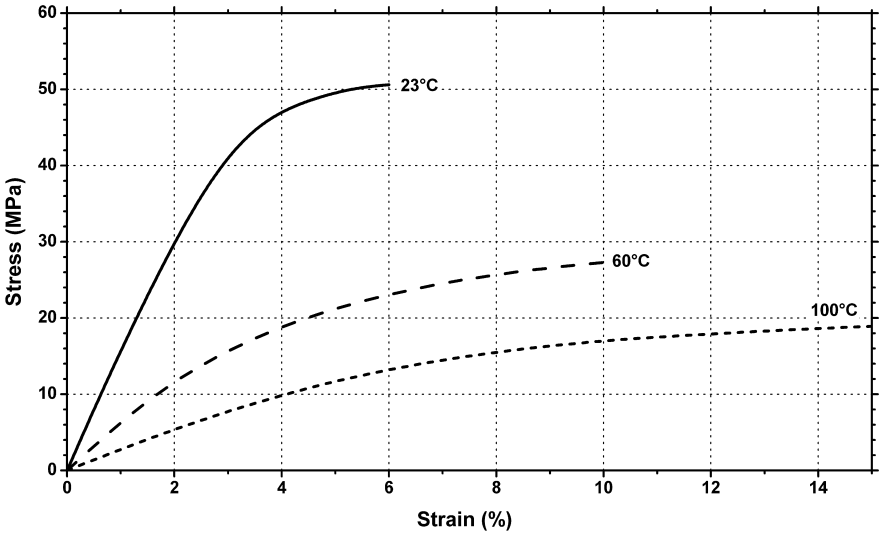

Figure 6.174 Stress vs. strain at various temperatures for Evonik Industries Vestamid® D16 low viscosity Nylon 612 resin [9].

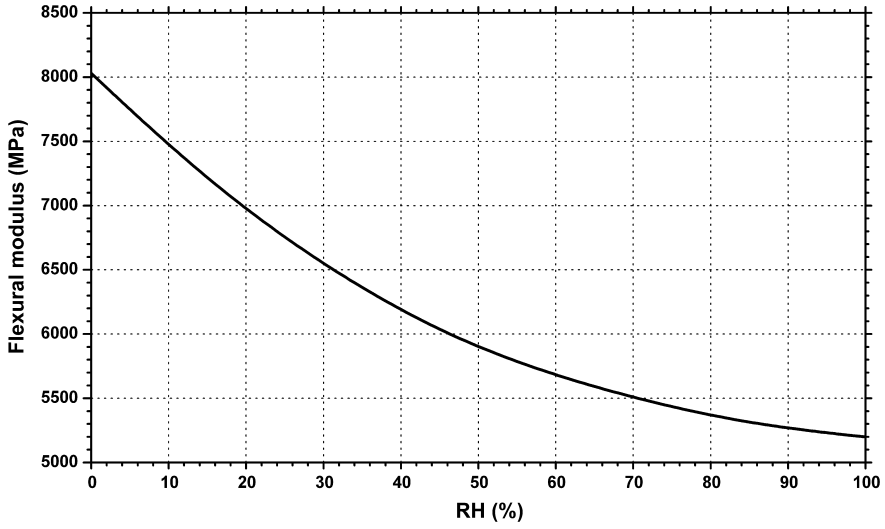

Figure 6.175 Flexural modulus vs. humidity for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin.

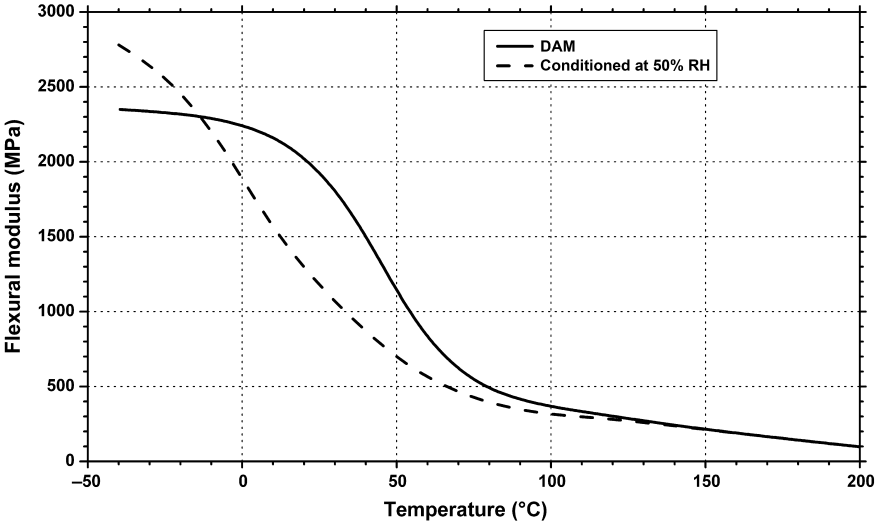

Figure 6.176 Flexural modulus vs. temperature and moisture content for DuPont Zytel® 158L—general purpose, lubricated Nylon 612 resin.

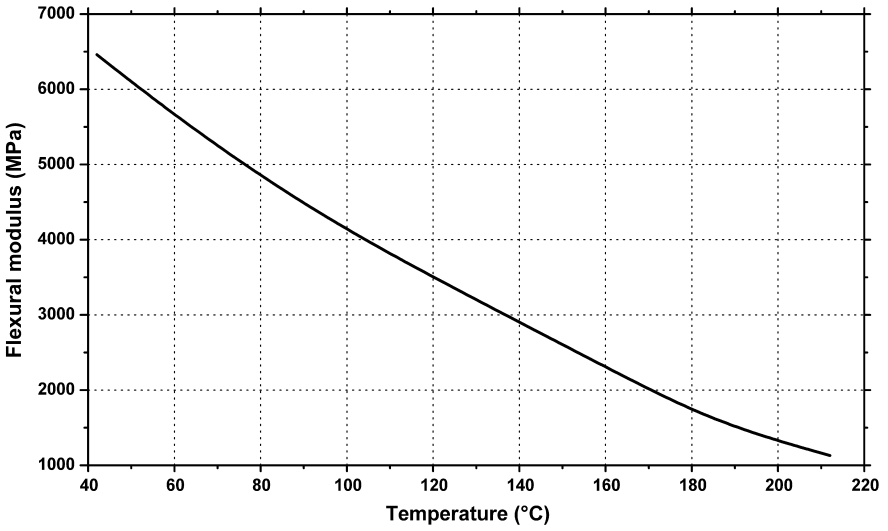

Figure 6.177 Flexural modulus vs. temperature for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin.

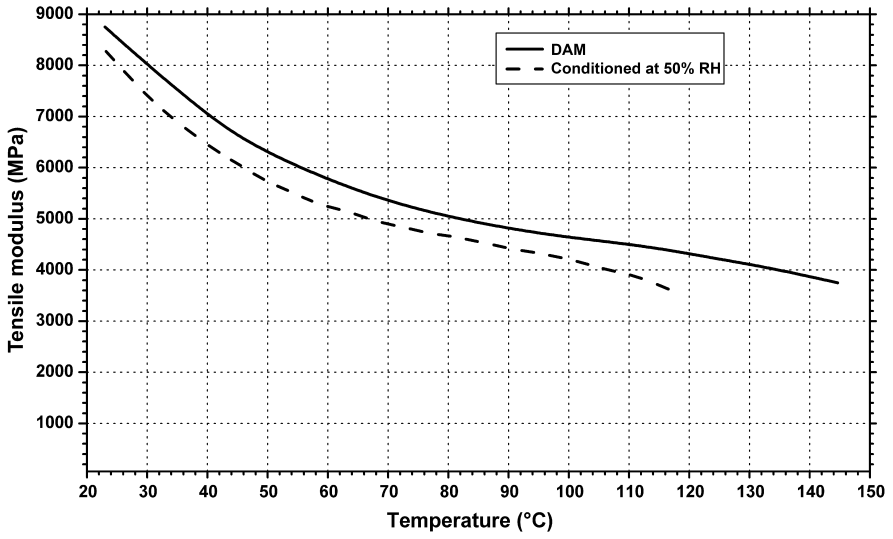

Figure 6.178 Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ IF006—33% glass filled Nylon 612 resin.

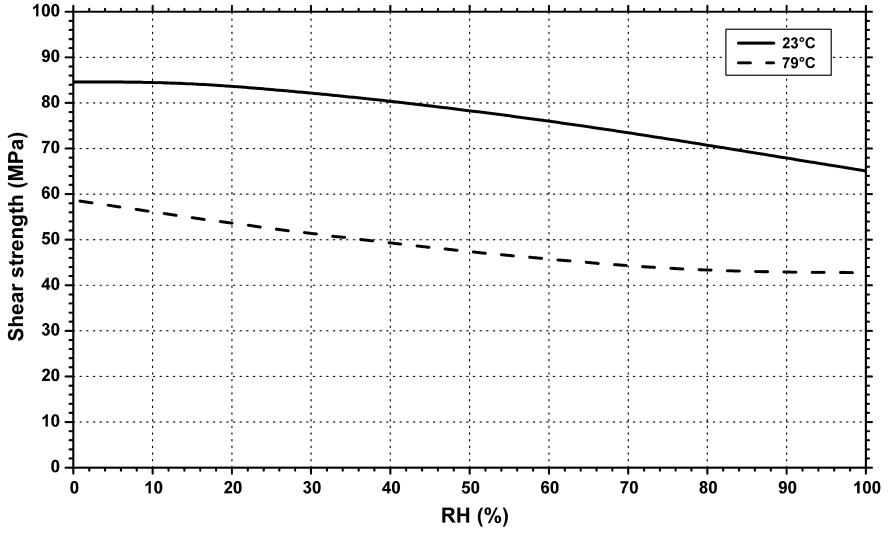

Figure 6.179 Shear strength vs. RH for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin.

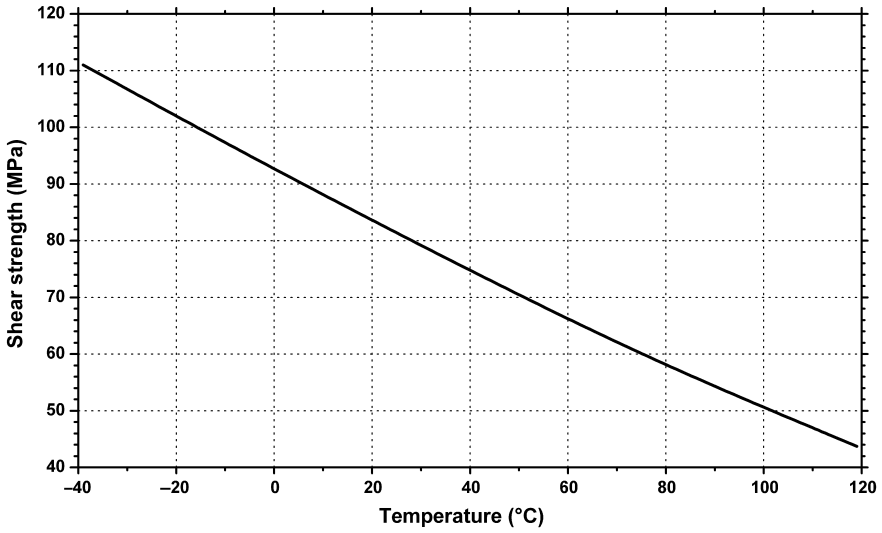

Figure 6.180 Shear strength vs. temperature for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin.

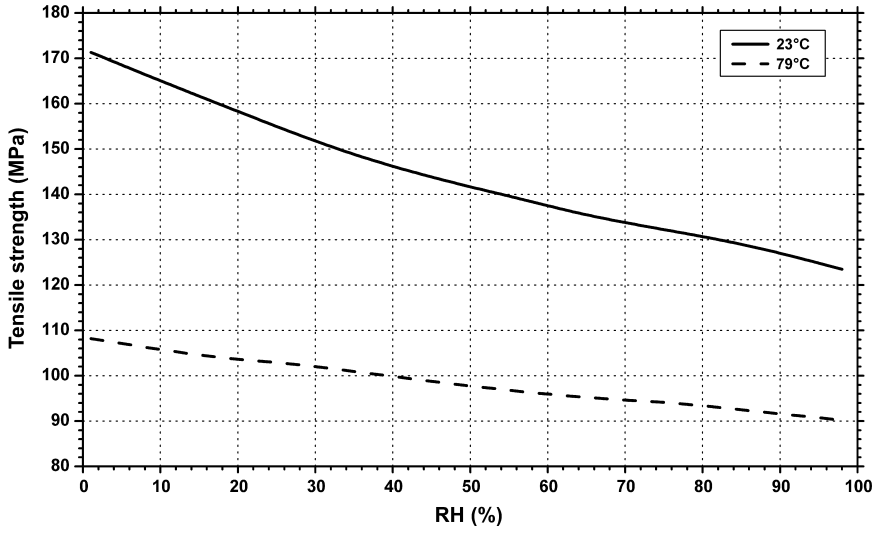

Figure 6.181 Tensile strength vs. RH for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin.

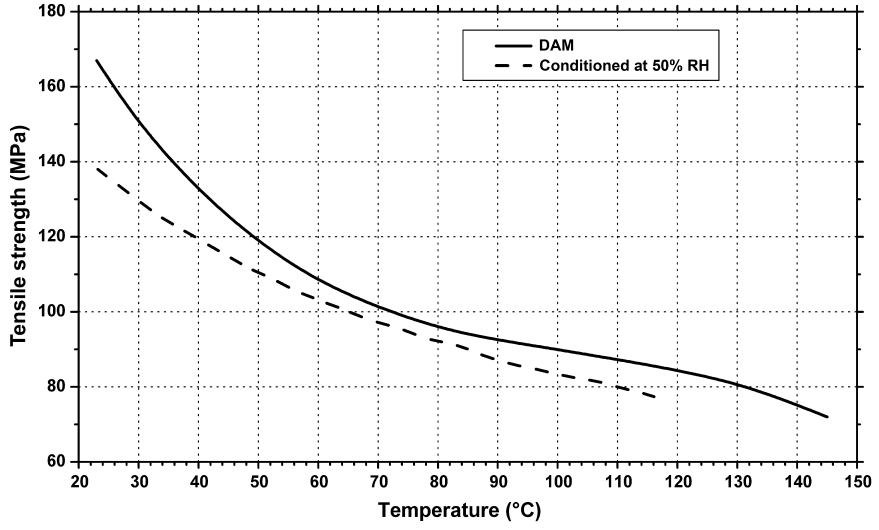

Figure 6.182 Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ IF006, 33% glass filled Nylon 612 resin.

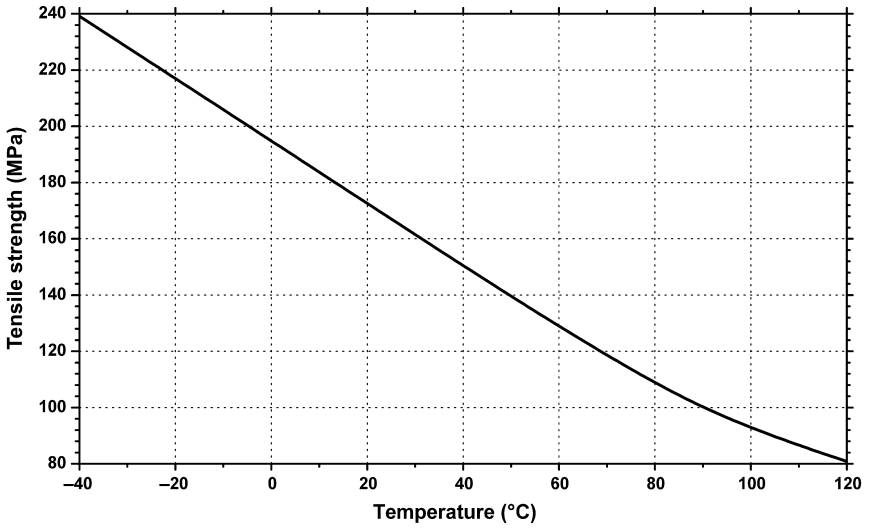

Figure 6.183 Tensile strength vs. temperature for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced Nylon 612 resin.

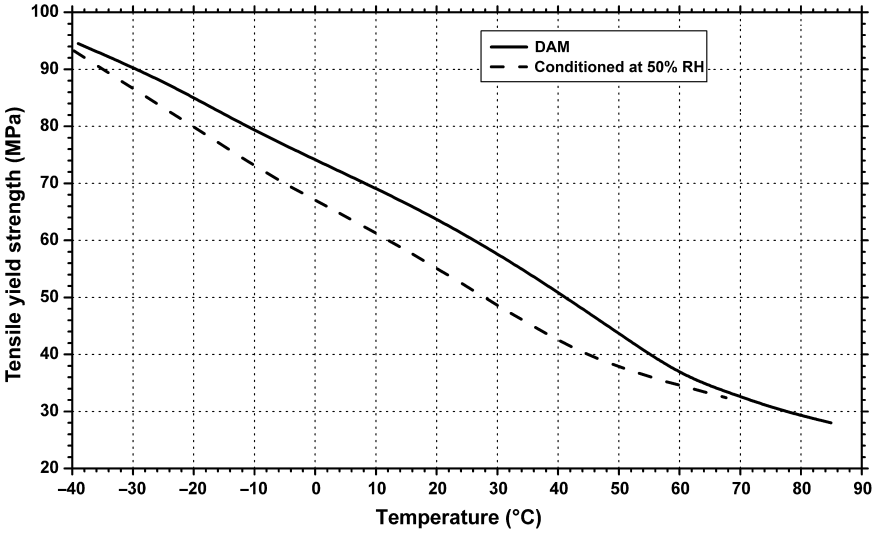

Figure 6.184 Tensile yield strength vs. temperature for DuPont Zytel® 158 NC010—general purpose, lubricated Nylon 612 resin.

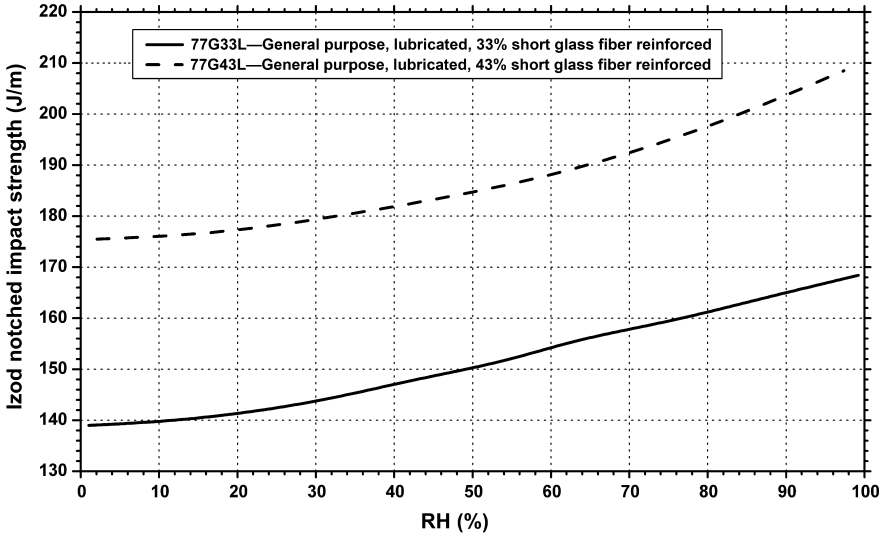

Figure 6.185 Izod notched impact strength vs. RH at 23°C for two DuPont Zytel® Nylon 612 resins.

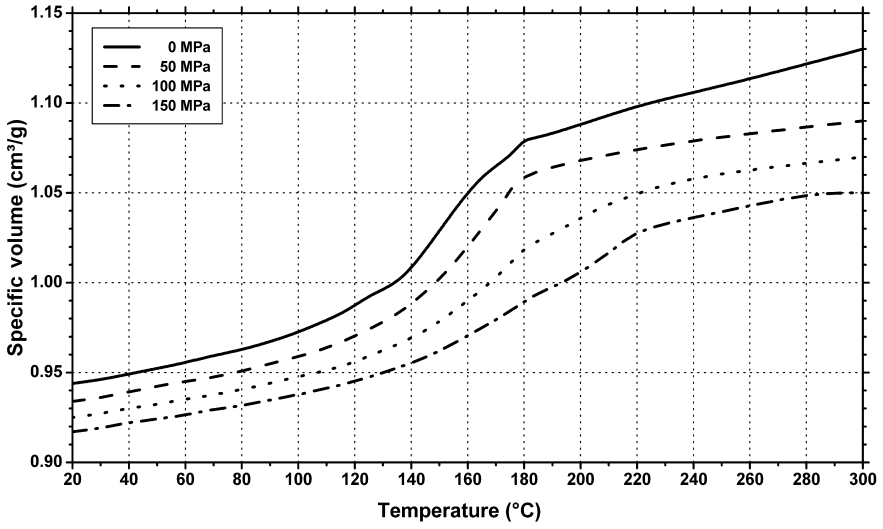

Figure 6.186 PVT of DuPont Zytel® 158 NC010—general purpose, lubricated Nylon 612 resin.

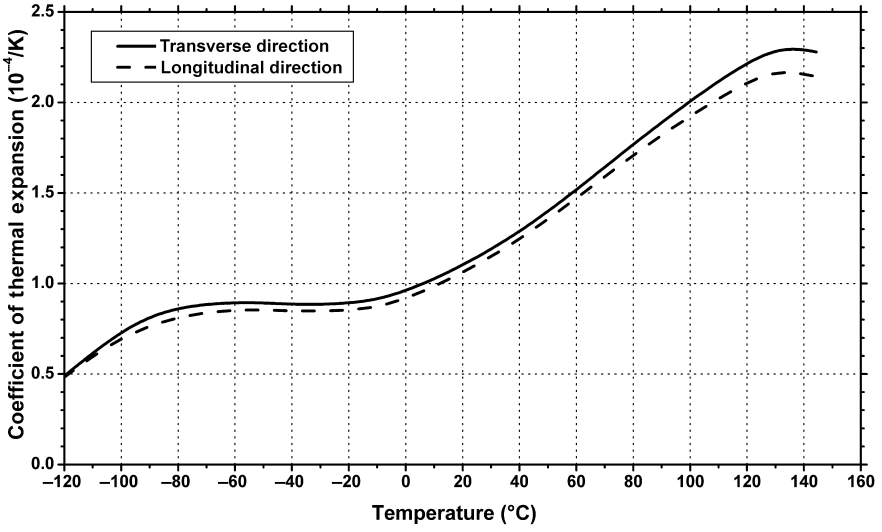

Figure 6.187 Coefficient of thermal expansion vs. temperature according to ISO 11359 for Evonik Industries Vestamid® DX9300—low viscosity, heat stabilized, with improved release properties Nylon 612 resin [9].

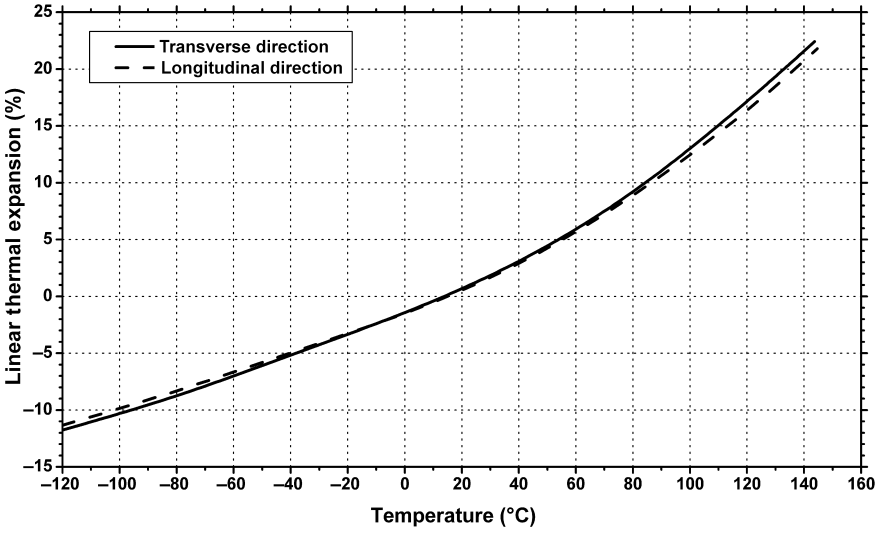

Figure 6.188 Thermal expansion vs. temperature according to ISO 11359 for Evonik Industries Vestamid® DX9300—low viscosity, heat stabilized, with improved release properties Nylon 612 resin [9].

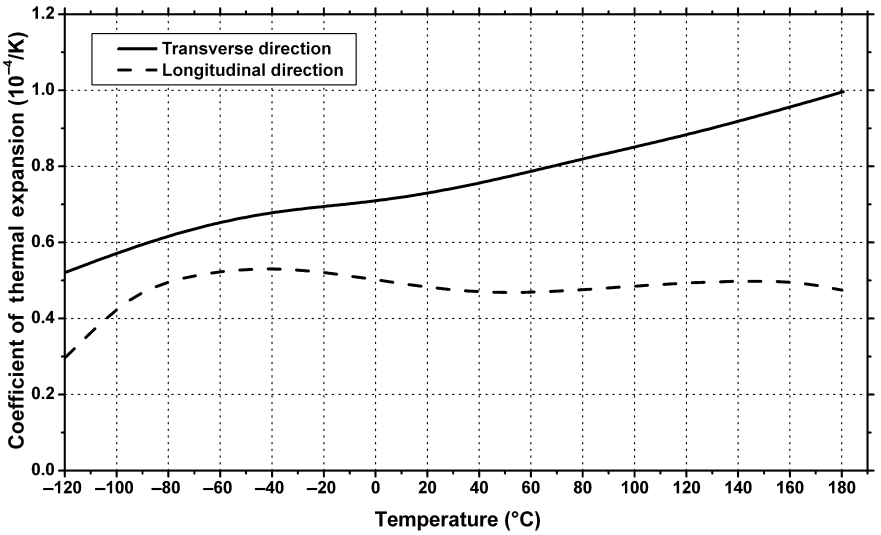

Figure 6.189 Coefficient of thermal expansion vs. temperature according to ISO 11359 for Evonik Industries Vestamid® DX9321 (impact-resistant, 20% glass fiber reinforced, heat stabilized) and X7099 (20% glass fiber reinforced, heat stabilized) Nylon 612 resin [9].

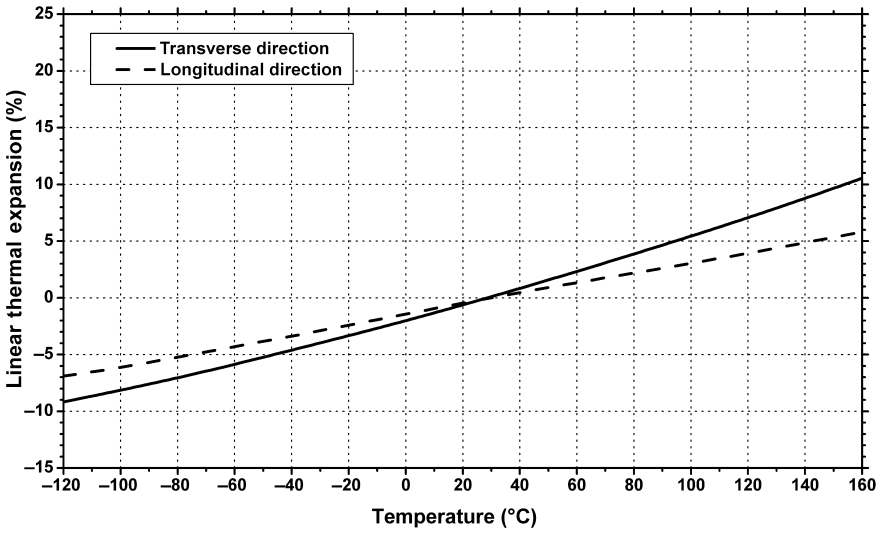

Figure 6.190 Thermal expansion vs. temperature according to ISO 11359 for Evonik Industries Vestamid® DX9321 (impact-resistant, 20% glass fiber reinforced, heat stabilized) and X7099 (20% glass fiber reinforced, heat stabilized) Nylon 612 resin [9].

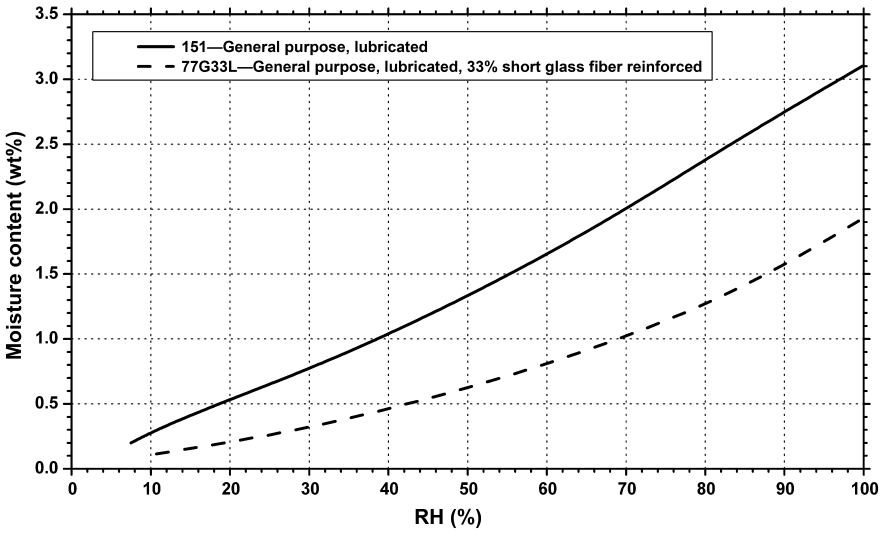

Figure 6.191 Equilibrium moisture content vs. RH for two DuPont Zytel® Nylon 612 resins.

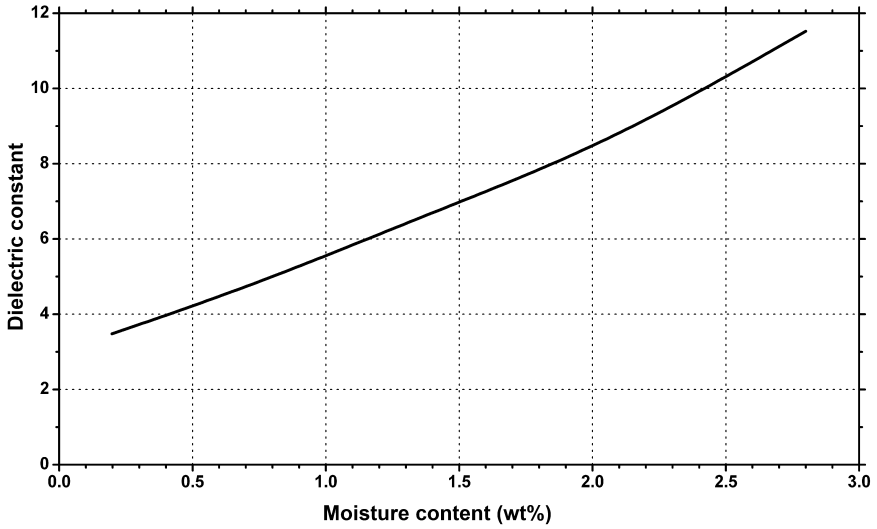

Figure 6.192 Dielectric constant vs. moisture content for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

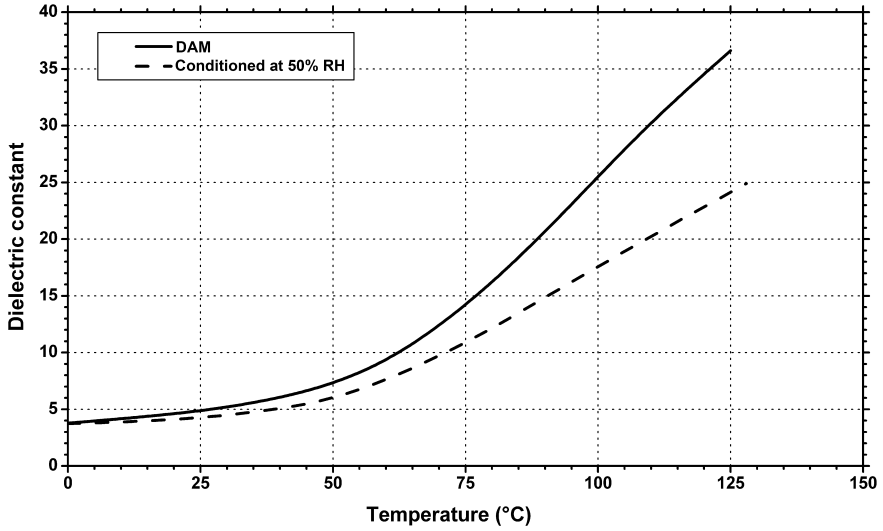

Figure 6.193 Dielectric constant vs. temperature for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

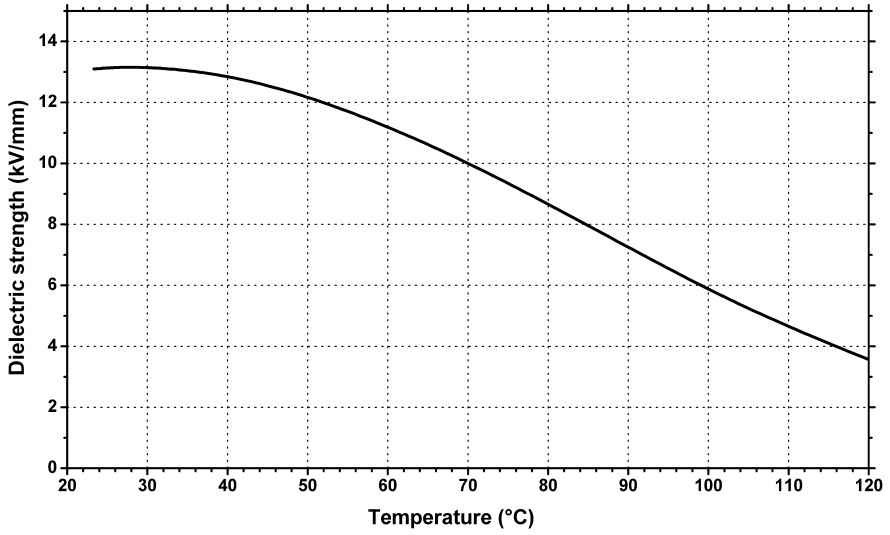

Figure 6.194 Dielectric strength vs. temperature for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

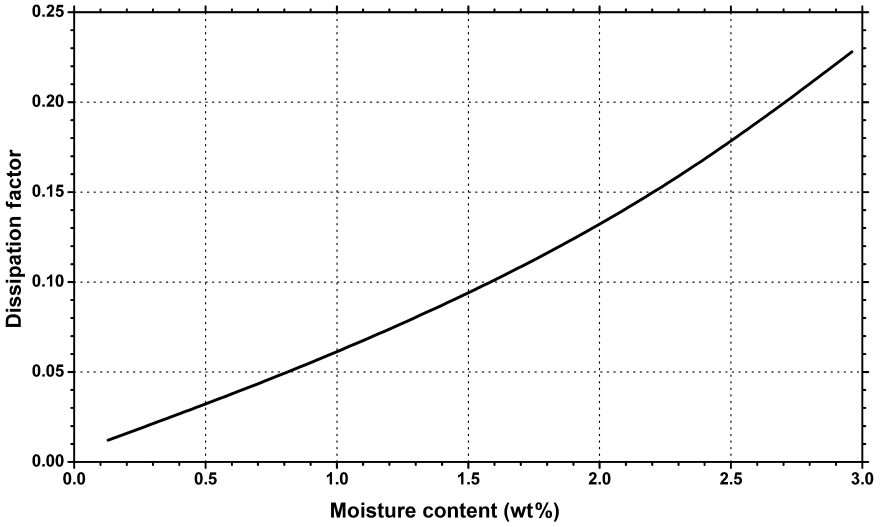

Figure 6.195 Dissipation factor vs. moisture content at 100 Hz for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

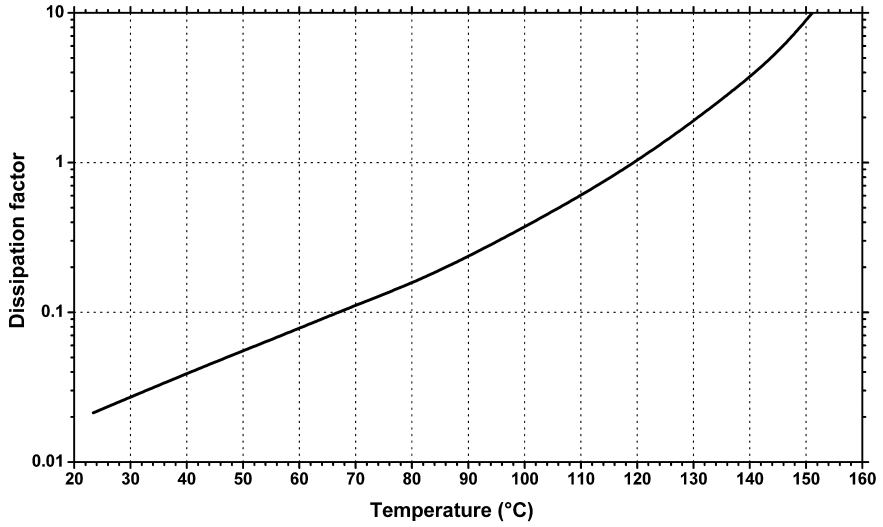

Figure 6.196 Dissipation factor vs. temperature at 100 Hz for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

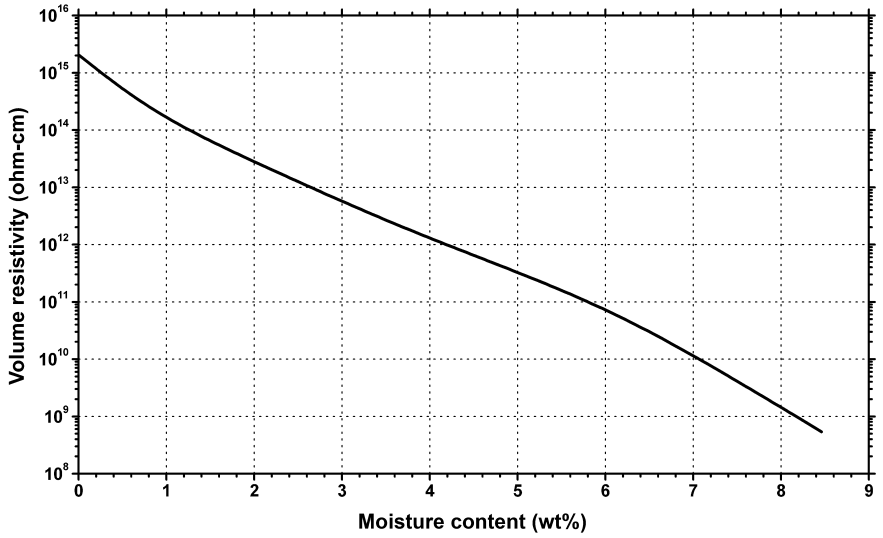

Figure 6.197 Volume resistivity vs. moisture content for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

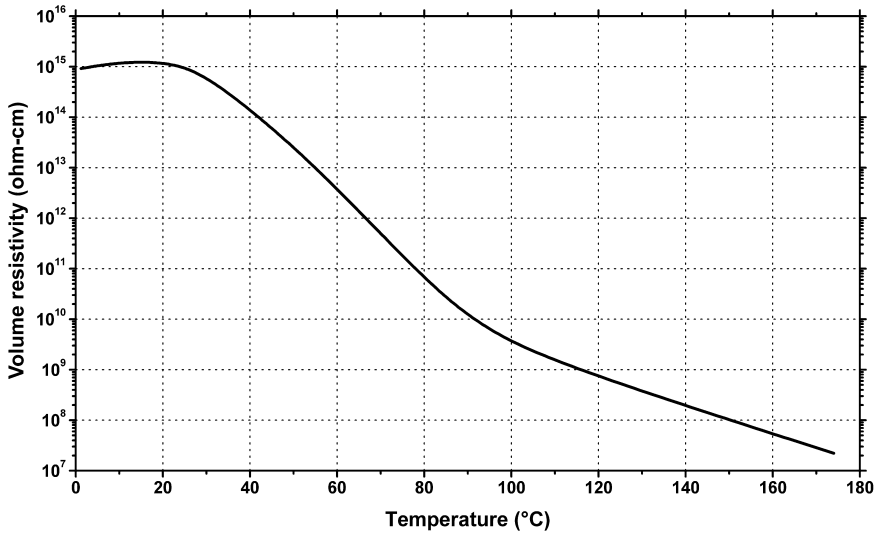

Figure 6.198 Volume resistivity vs. temperature for DuPont Zytel® 151L—general purpose, lubricated Nylon 612 resin.

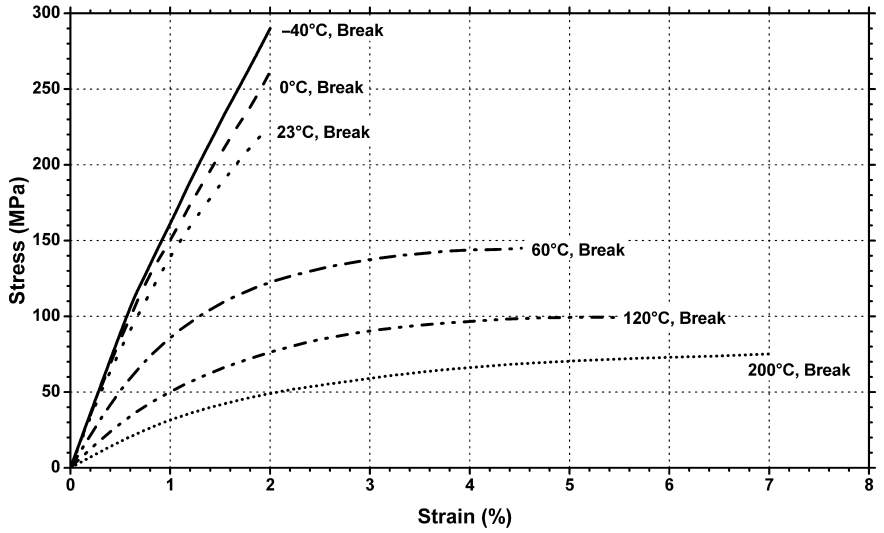

Figure 6.199 Stress vs. strain at various temperatures for EMS-Grivory Grivory® HT2V-5H—(PA 6T/66) 50% glass fiber, heat stabilized Nylon 6/66 resin (conditioned at 50% RH).

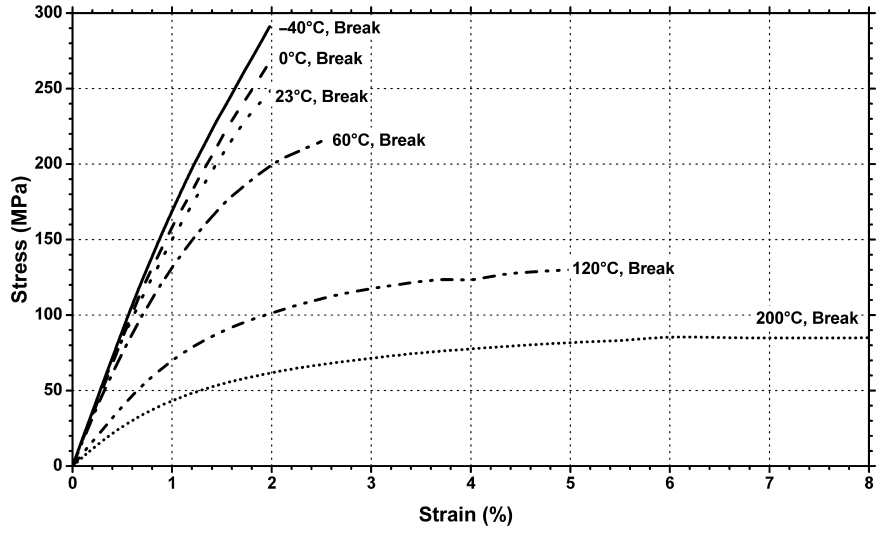

Figure 6.200 Stress vs. strain at various temperatures for EMS-Grivory Grivory® HT2V-5H—(PA 6T/66) 50% glass fiber, heat stabilized Nylon 6/66 resin (DAM).

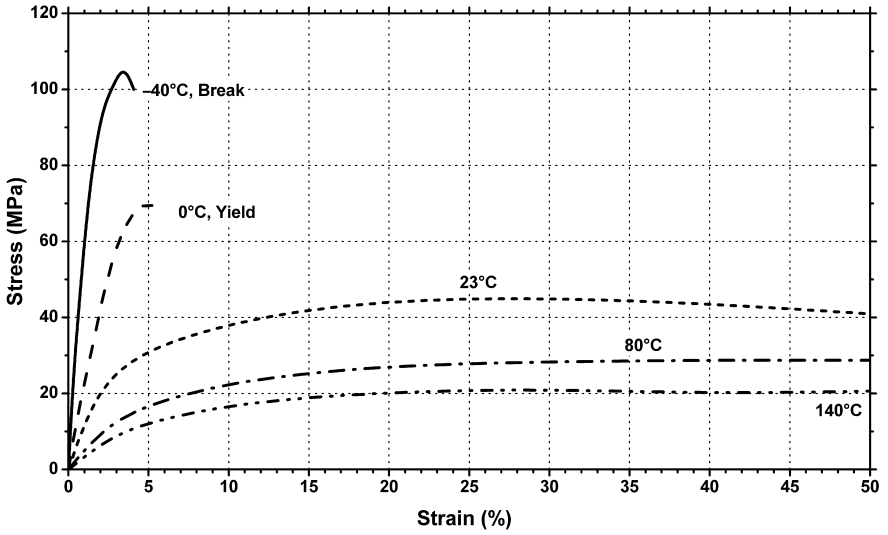

Figure 6.201 Stress vs. strain at various temperatures for EMS-Grivory Grilon® TS V0—heat stabilized, flame retardant Nylon 6/66 resin (conditioned at 50% RH).

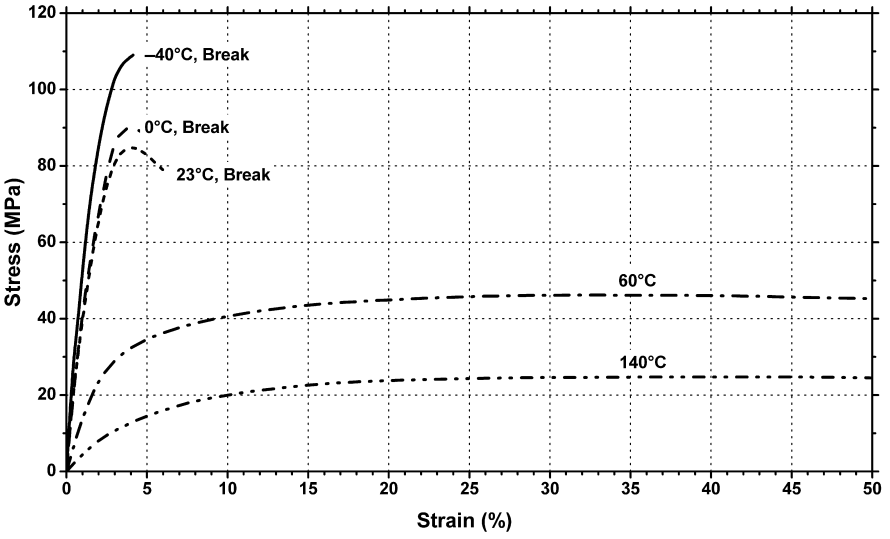

Figure 6.202 Stress vs. strain at various temperatures for EMS-Grivory Grilon® TS V0—heat stabilized, flame retardant Nylon 6/66 resin (DAM).

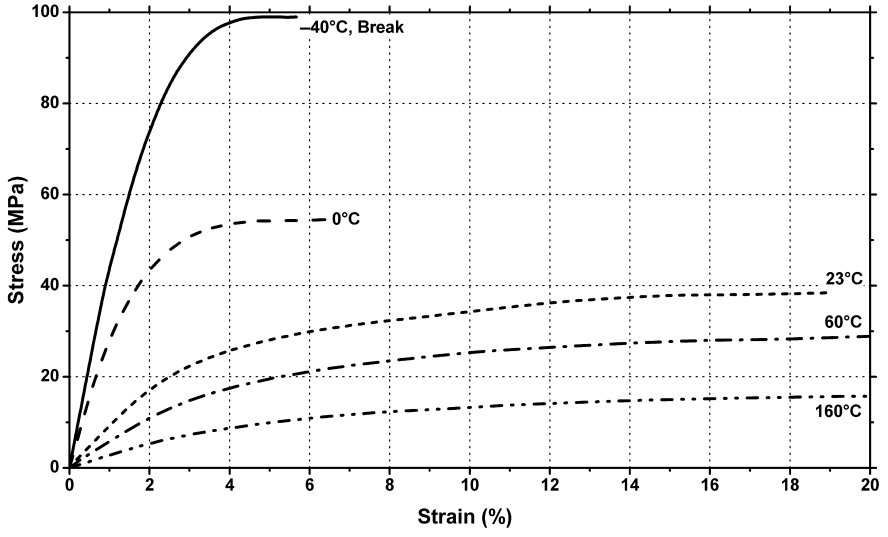

Figure 6.203 Stress vs. strain at various temperatures for BASF Ultramid® C3U—general purpose injection molding grade with improved flame retardant Nylon 6/66 resin (conditioned at 50% RH).

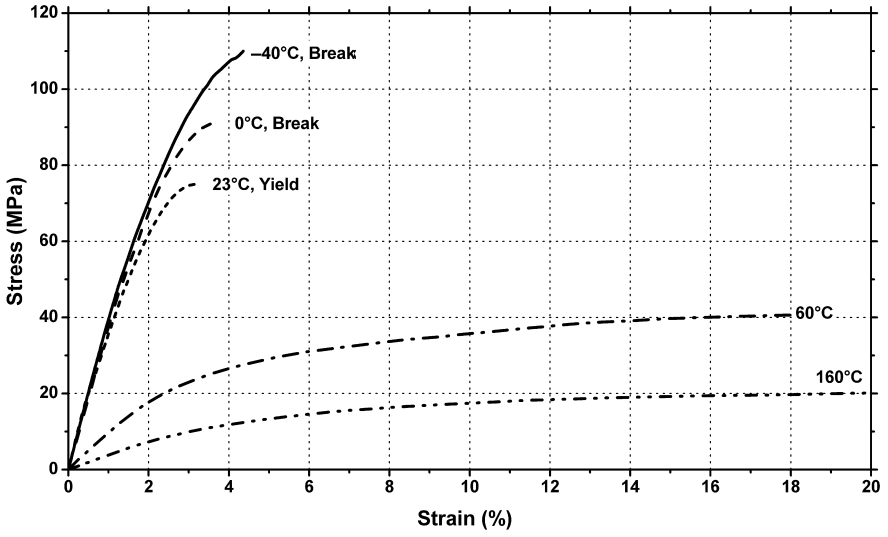

Figure 6.204 Stress vs. strain at various temperatures for BASF Ultramid® C3U—general purpose injection molding grade with improved flame retardant Nylon 6/66 resin (DAM).

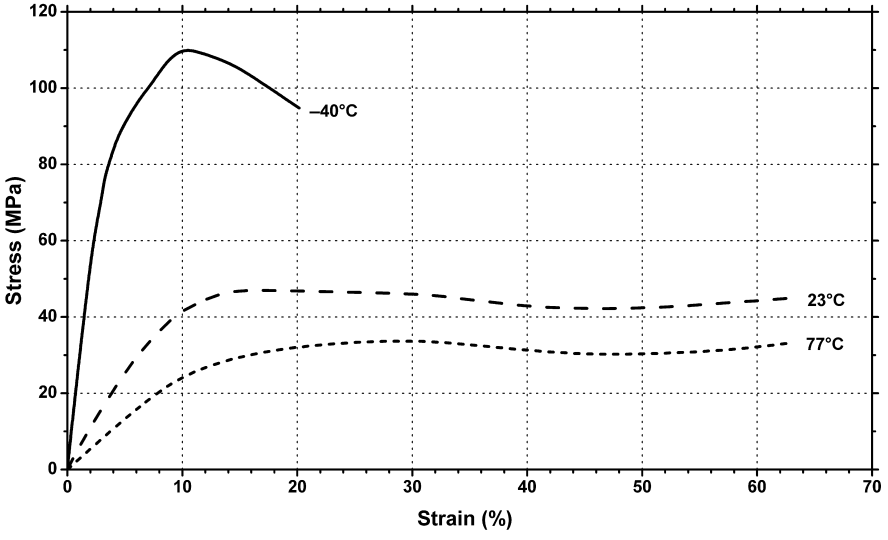

Figure 6.205 Stress vs. strain at various temperatures for DuPont Zytel® 109L—nucleated, lubricated Nylon 6/66 resin (conditioned at 50% RH).

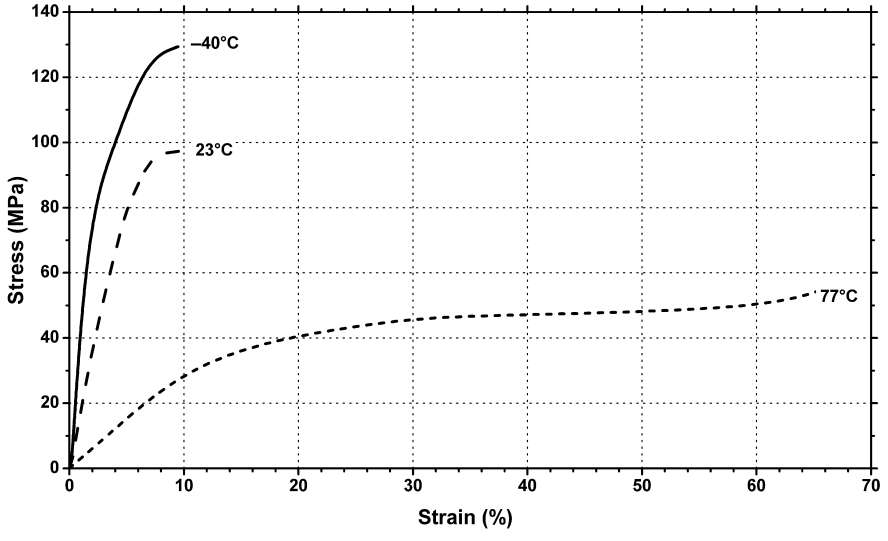

Figure 6.206 Stress vs. strain at various temperatures for DuPont Zytel® 109L—nucleated, lubricated Nylon 6/66 resin (DAM).

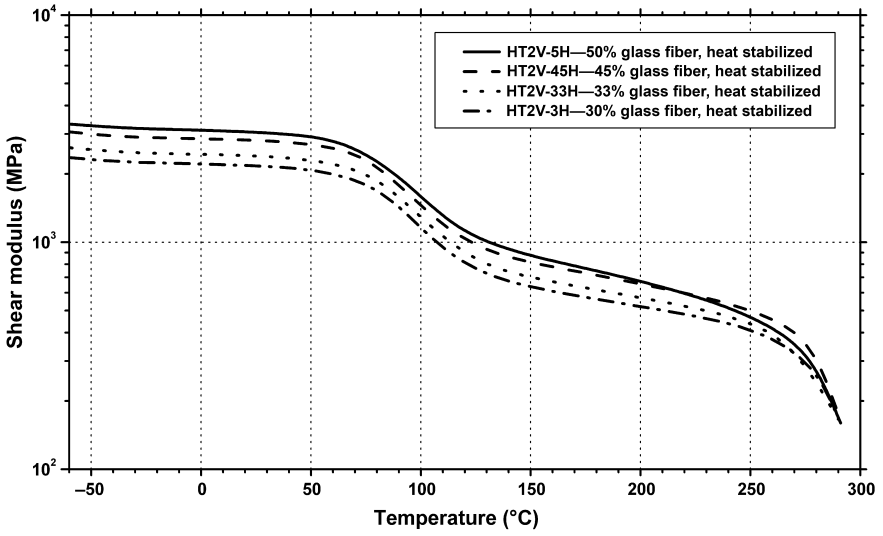

Figure 6.207 Shear modulus vs. temperature for EMS-Grivory Grivory® HT2V series of Nylon 6/66 resins.

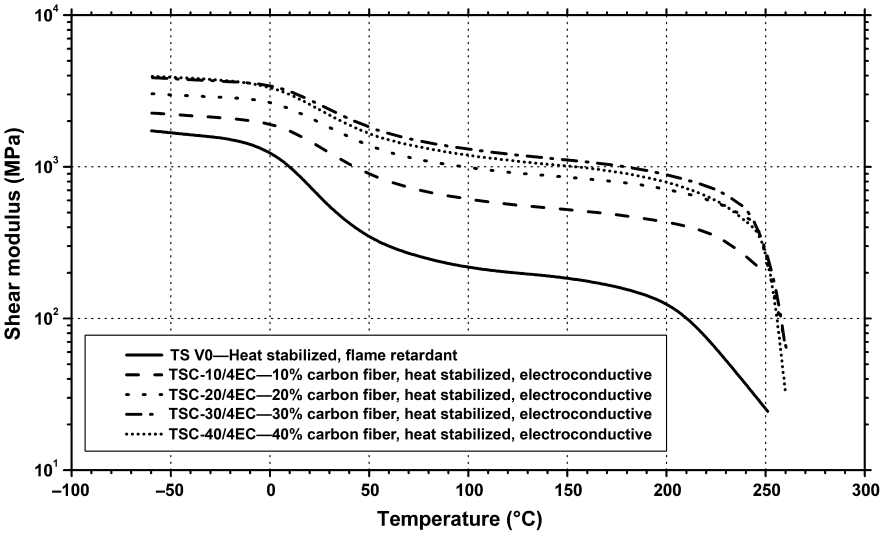

Figure 6.208 Shear modulus vs. temperature for EMS-Grivory Grilon® TS series of Nylon 6/66 resins (conditioned at 50% RH).

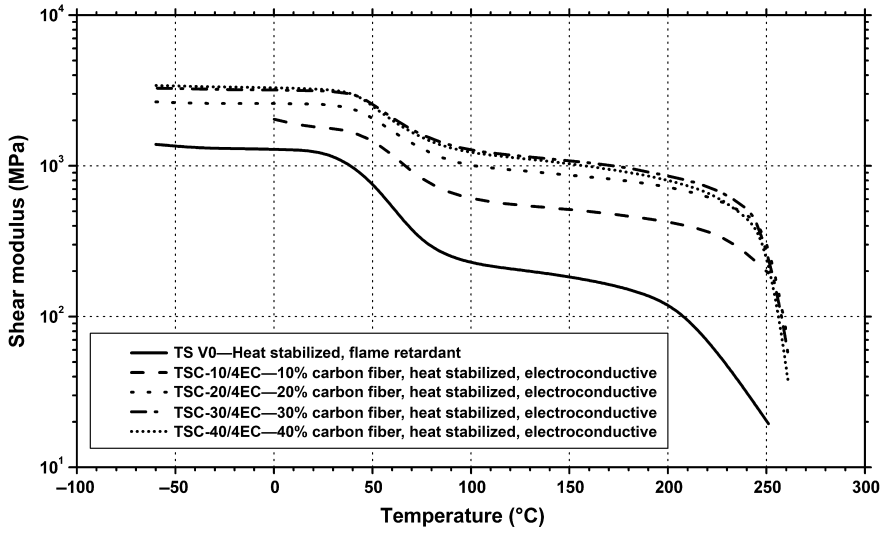

Figure 6.209 Shear modulus vs. temperature for EMS-Grivory Grilon® TS series of Nylon 6/66 resins (DAM).

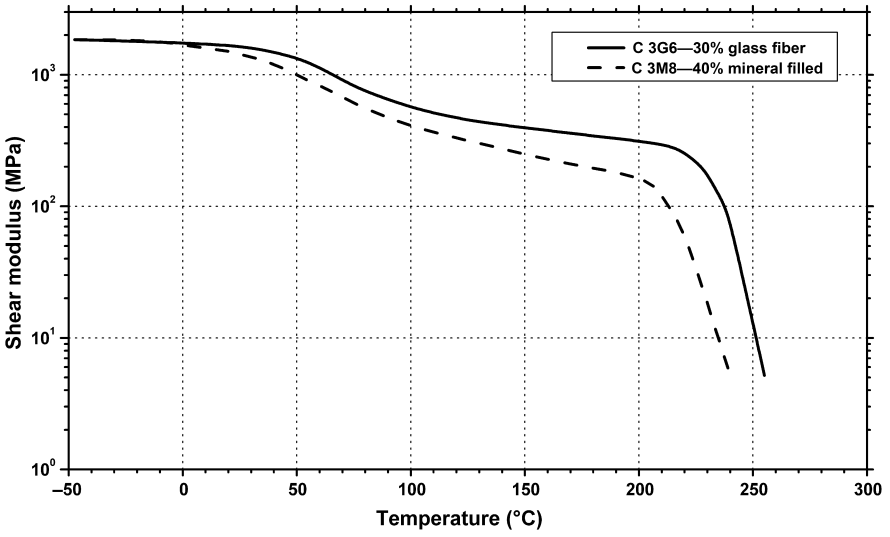

Figure 6.210 Shear modulus vs. temperature for BASF Ultramid® Nylon 6/66 resins.

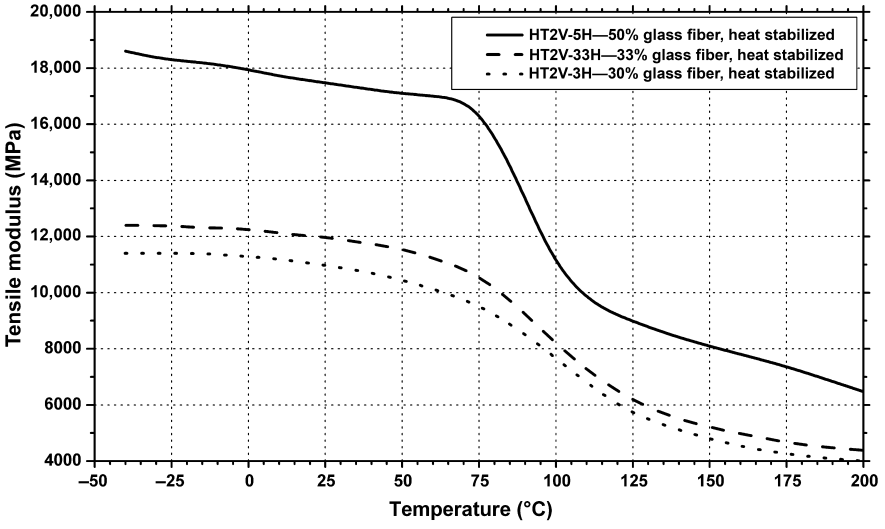

Figure 6.211 Tensile modulus vs. temperature for EMS-Grivory Grivory® HT2V series Nylon 6/66 resins.

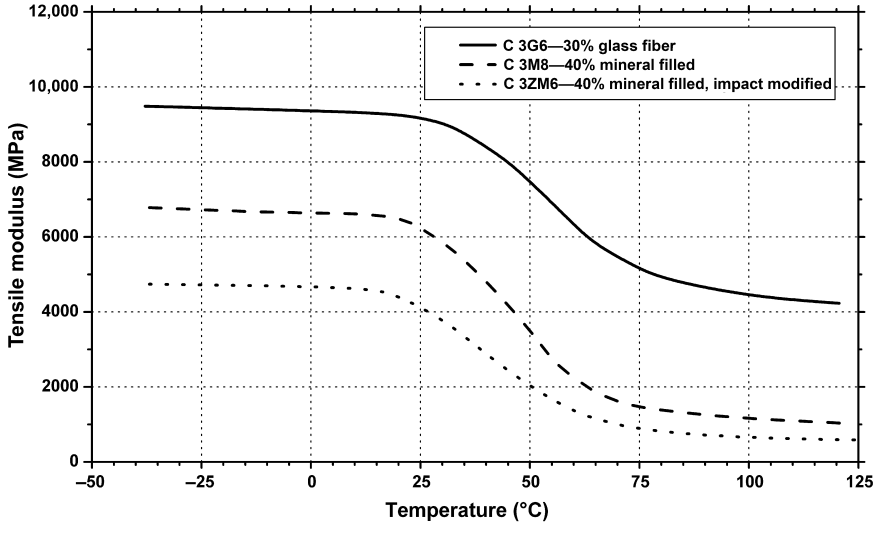

Figure 6.212 Tensile modulus vs. temperature for BASF Ultramid® Nylon 6/66 resins.

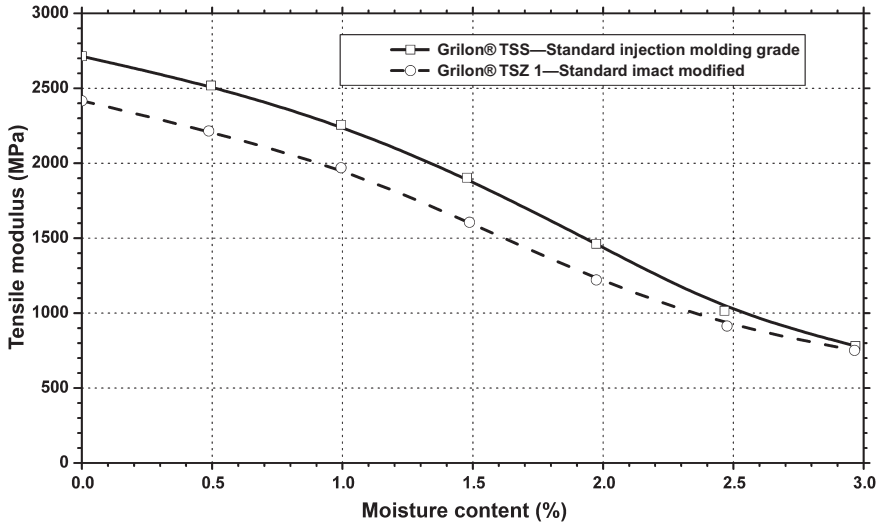

Figure 6.213 Tensile E-modulus vs. moisture content for EMS-Grivory Grilon® TSS, Grilon® TSZ 1 PA666 resins [7].

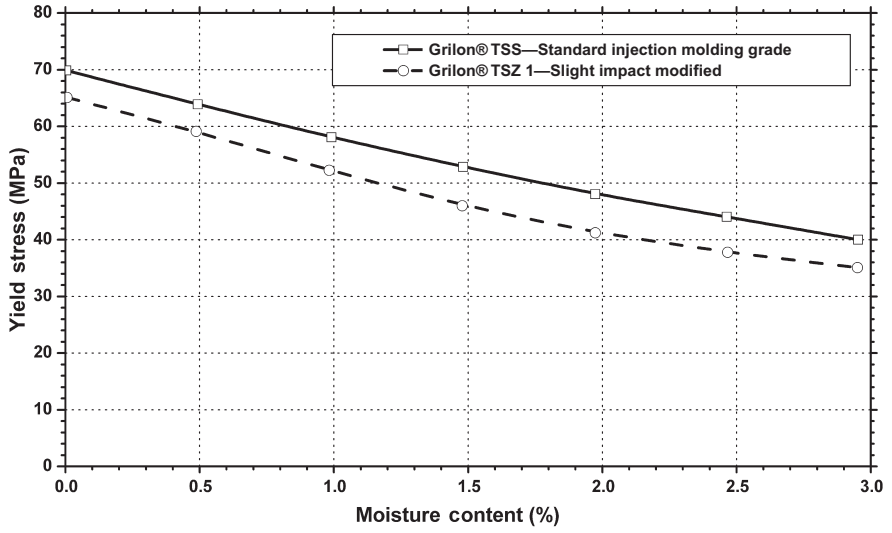

Figure 6.214 Yield stress vs. moisture content for EMS-Grivory Grilon® TSS, Grilon® TSZ 1 PA666 resins [7].

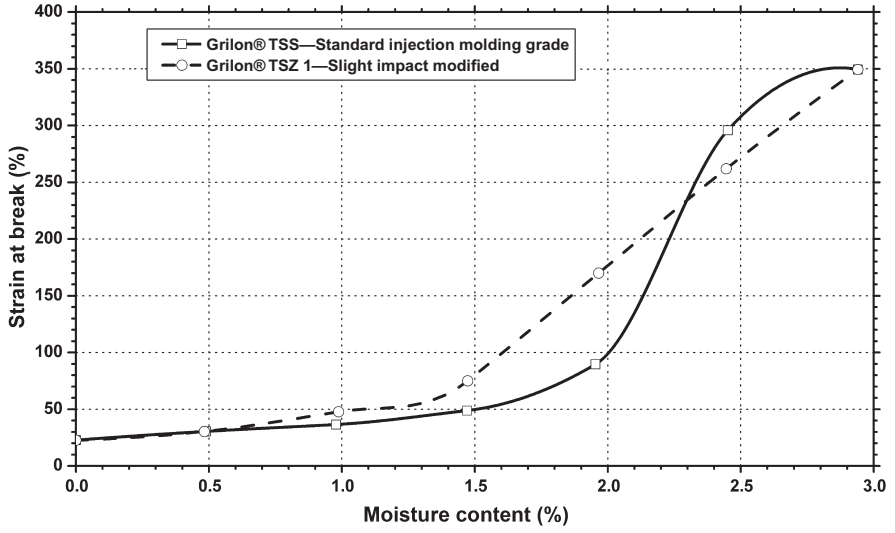

Figure 6.215 Strain at break vs. moisture content for EMS-Grivory Grilon® TSS, Grilon® TSZ 1 PA666 resins [7].

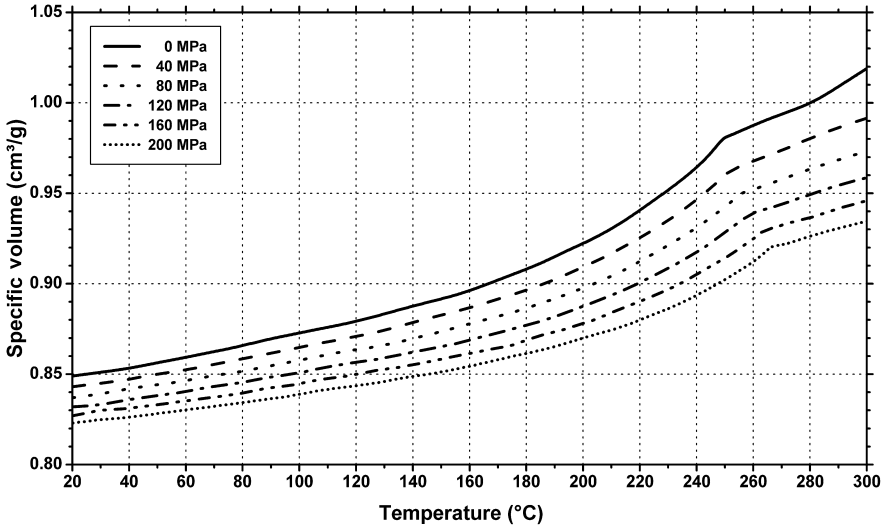

Figure 6.216 PVT for BASF Ultramid® C3U-C 3U—general purpose, injection molding, improved flame retardant Nylon 6/66 resin.

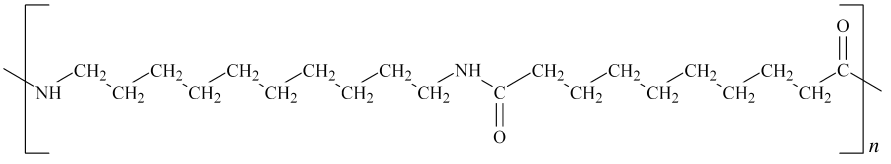

Figure 6.217 Chemical structure of Nylon 1010.

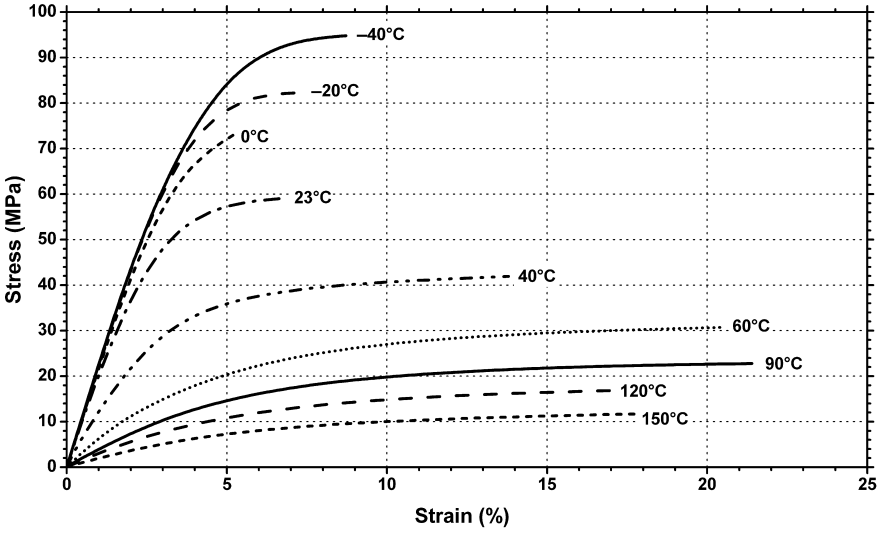

Figure 6.218 Stress vs. strain at various temperatures for DuPont Zytel® RS LC1000 BK395 Nylon 1010 resin (DAM).

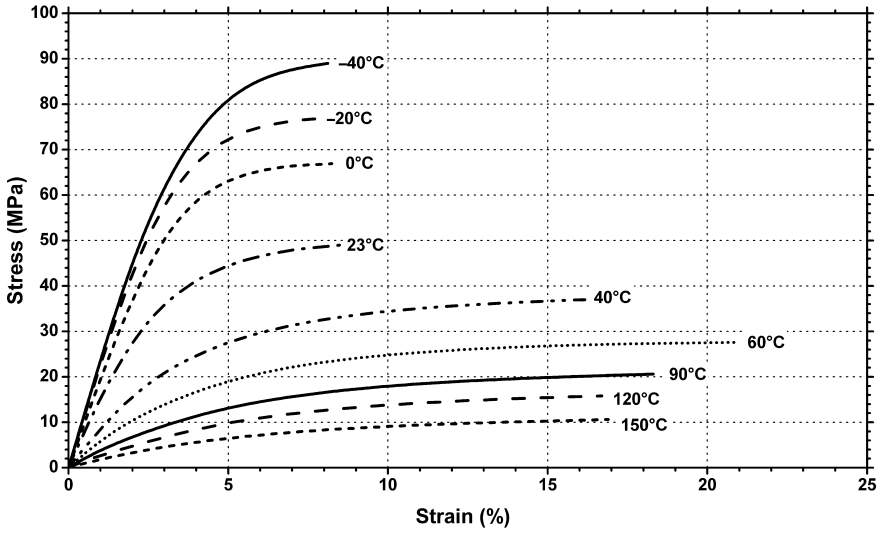

Figure 6.219 Stress vs. strain at various temperatures for DuPont Zytel® RS LC1000 BK395 Nylon 1010 resin (conditioned).

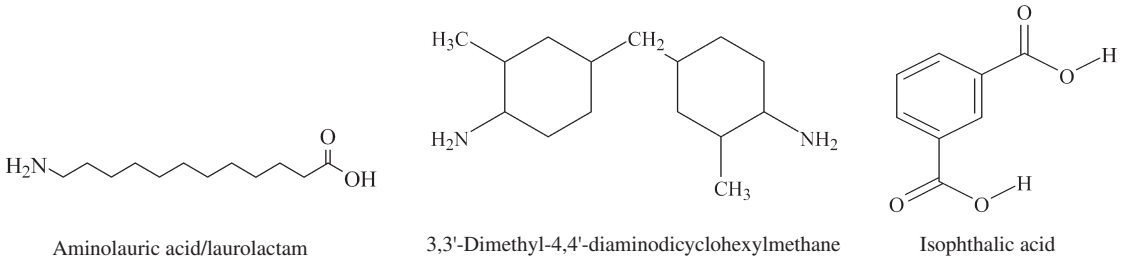

Figure 6.220 Monomers used to make Grilamid® TR55 amorphous polyamide.

6.10 Nylon Amorphous

Polyamide copolymers are usually designed to make amorphous materials which give no crystallinity to the polymer structure. One such amorphous polyamide is Grilamid® TR55 and is a polymer made from the three monomers shown in Figure 6.220.

Some of the amorphous nylon characteristics are as follows:

- Crystal-clear, high optical transparency
- High mechanical stability
- High heat deflection temperature
- High impact strength
- Good chemical resistance compared to other plastics
- Good electrical properties
- Low mold shrinkage

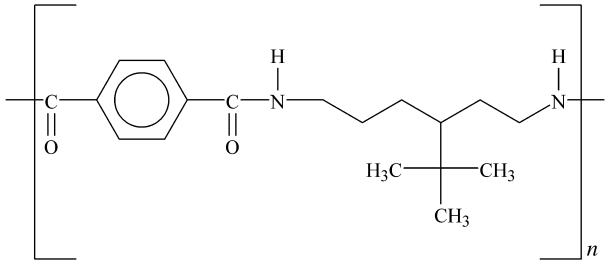

Figure 6.221 Chemical structure of amorphous nylon.

One such amorphous nylon is shown in Figure 6.221.

The tertiary butyl group attached to the amine molecule is bulky and disrupts this molecule's ability to crystallize. This particular amorphous nylon is sometimes designated as Nylon 6-3-T. Amorphous polymers can have properties that differ significantly from crystalline types, one of which is optical transparency.

Blending even low percentages (20%) of DuPont Selar® PA with Nylon 6, Nylon 66, and nylon copolymers will result in a product that behaves like an amorphous polymer. These blends retain all of the advantages of the Selar® PA resin with some of the mechanical property advantages of semicrystalline nylon.

Manufacturers and trade names: DuPont Selar® PA; EMS-Grivory Grivory® G16, Grivory G21, Grilamid® TR; Evonik Industries Trogamid® T.

Applications and uses: used as a monolayer or as a component of multilayer flexible packaging film for meat and cheese, as well as rigid packaging; multilayer or monolayer are used in transparent hollow vessels (bottles), packaging films, deep-drawn plates.

Data for amorphous polyamides/copolyamides are shown in Figures 6.222–6.238.

6.11 Polyarylamide (PAA)

A partially aromatic high performance polyamide is PAA. The primary commercial polymer, PAMXD6, is formed by the reaction of *m*-xylylenediamine and adipic acid giving the structure shown in Figure 6.239. It is a semicrystalline polymer.

- Very high rigidity
- High strength
- Very low creep

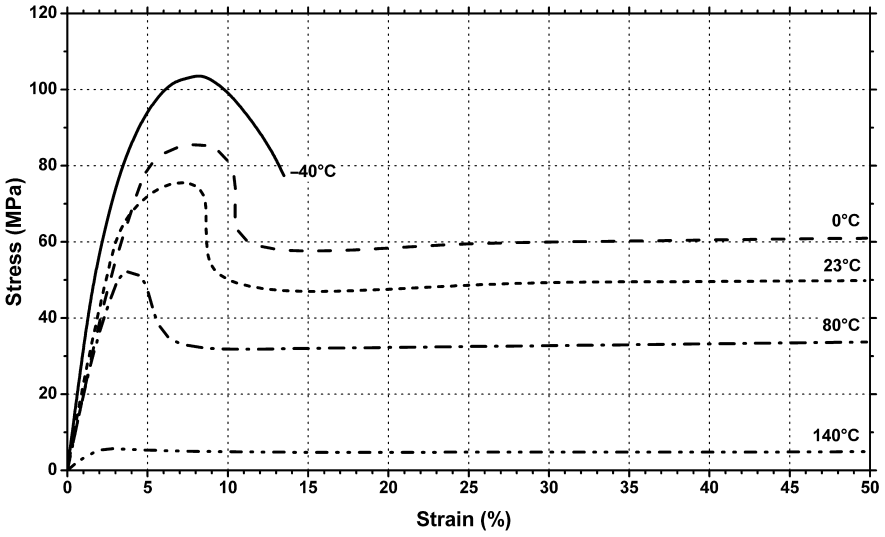

Figure 6.222 Stress vs. strain at various temperatures for EMS-Grivory Grilamid® TR55—standard grade amorphous nylon (conditioned at 50% RH) [10].

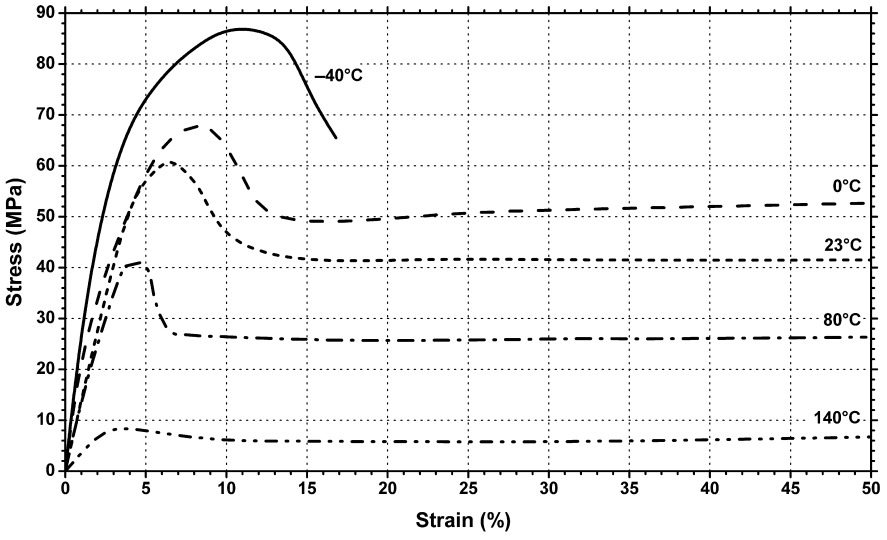

Figure 6.223 Stress vs. strain at various temperatures for EMS-Grivory Grilamid® TR90—high strength amorphous nylon (conditioned at 50% RH) [10].

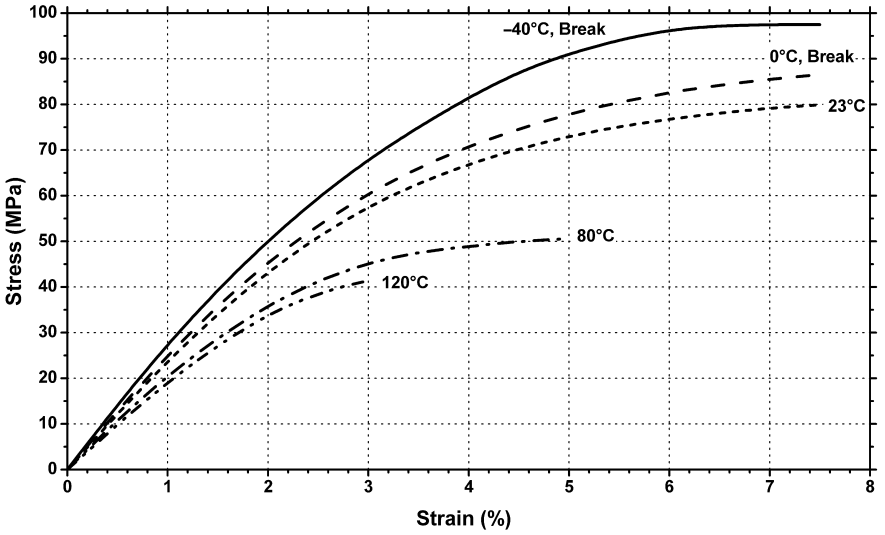

Figure 6.224 Stress vs. strain at various temperatures for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

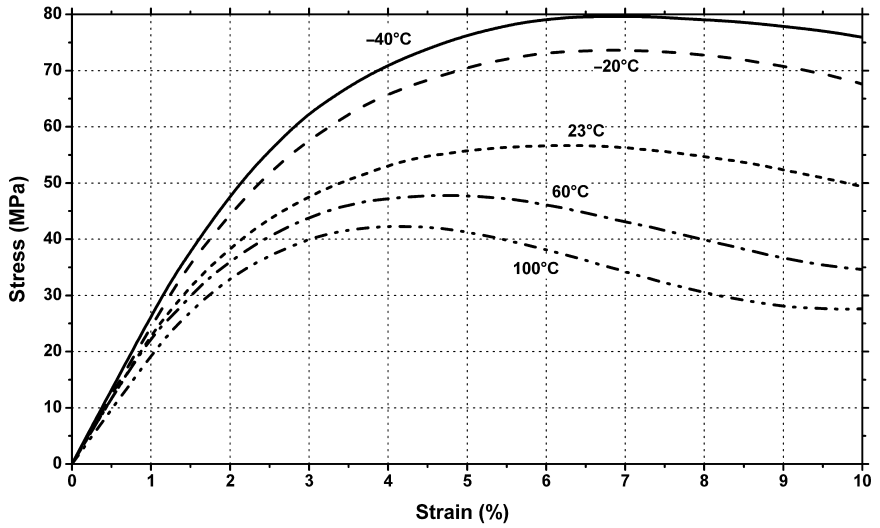

Figure 6.225 Stress vs. strain at yield at various temperatures for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

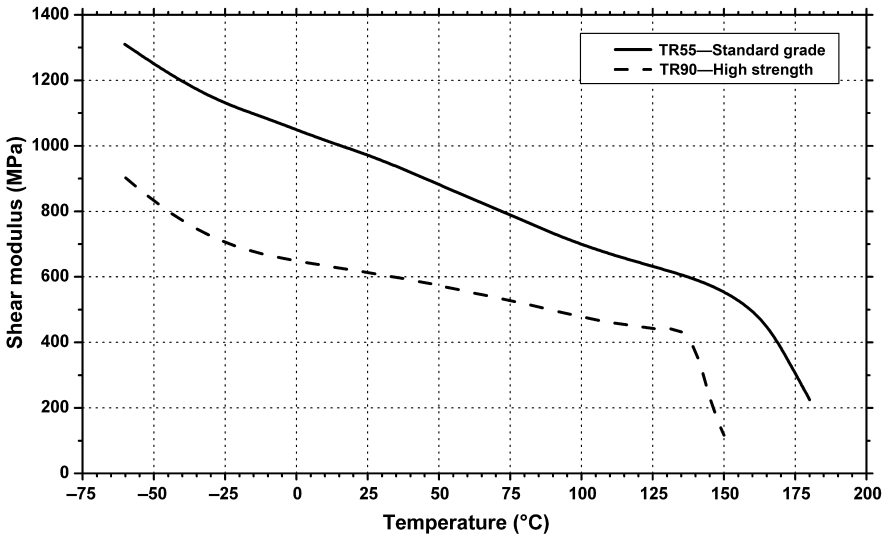

Figure 6.226 Shear modulus vs. temperature for two EMS-Grivory Grilamid® amorphous nylons.

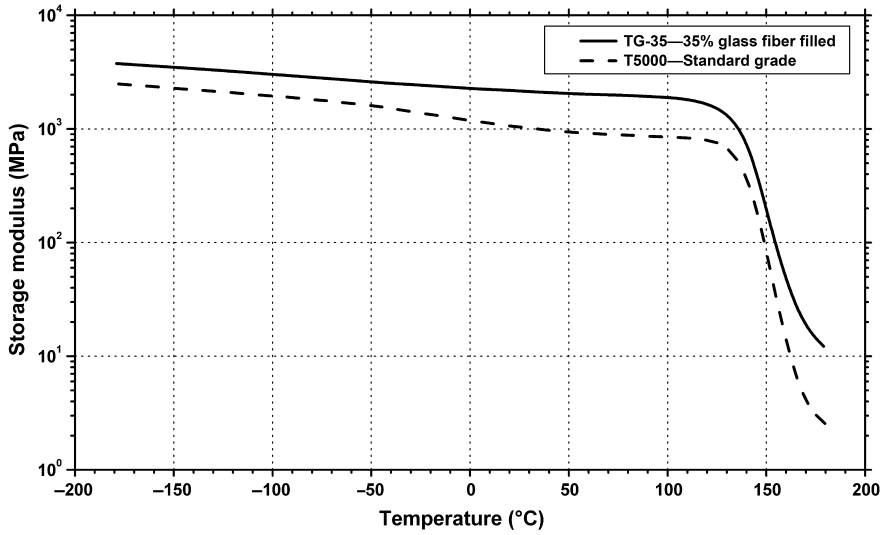

Figure 6.227 Storage modulus vs. temperature for two Evonik Industries Trogamid® amorphous nylons [11].

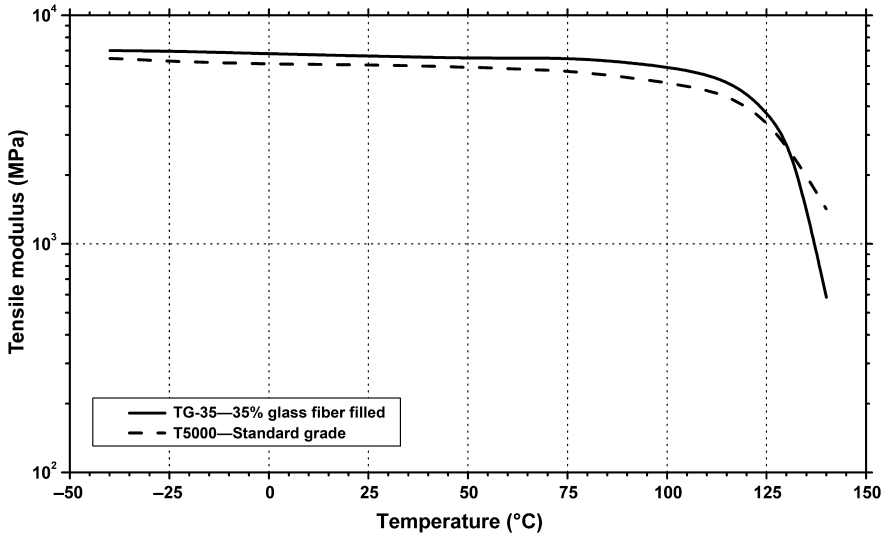

Figure 6.228 Tensile modulus vs. temperature for two Evonik Industries Trogamid® amorphous nylons.

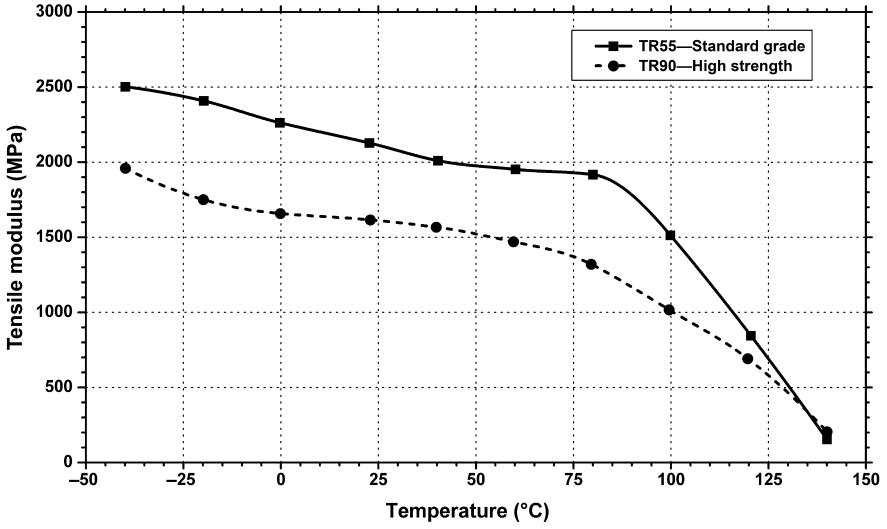

Figure 6.229 Tensile modulus vs. temperature for EMS-Grivory Grilamid® amorphous nylons [10].

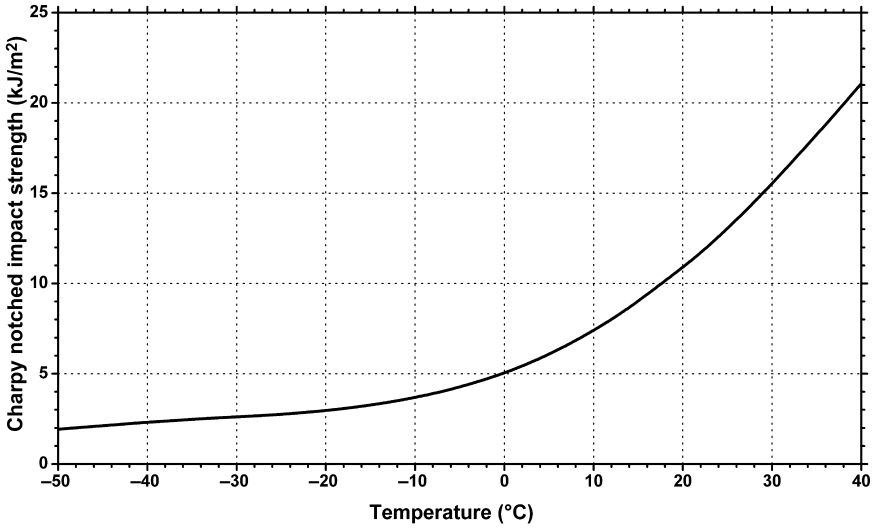

Figure 6.230 Charpy notched impact strength vs. temperature for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

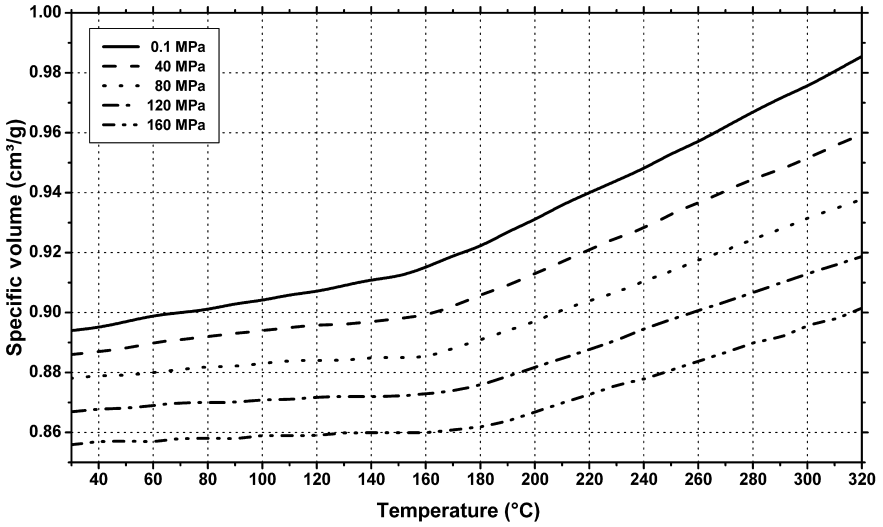

Figure 6.231 PVT for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

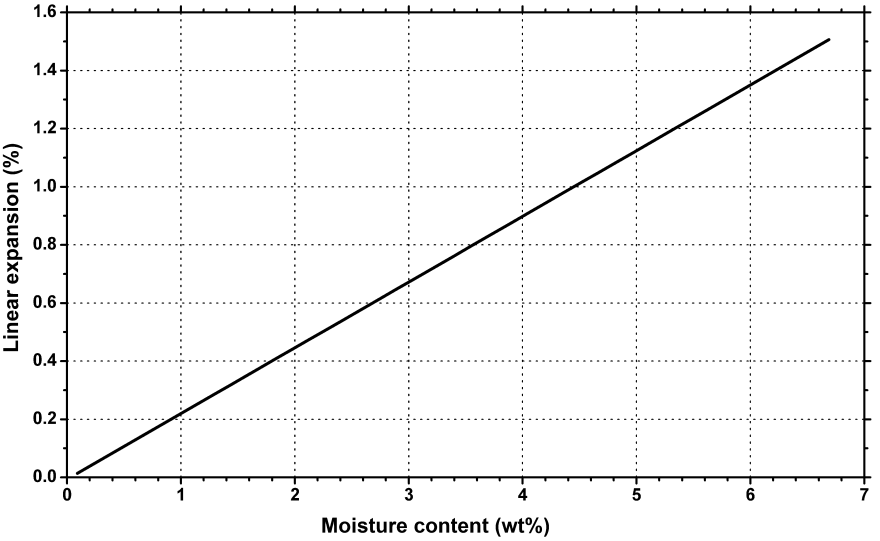

Figure 6.232 Linear expansion vs. moisture content for Evonik Industries Trogamid® amorphous nylon [11].

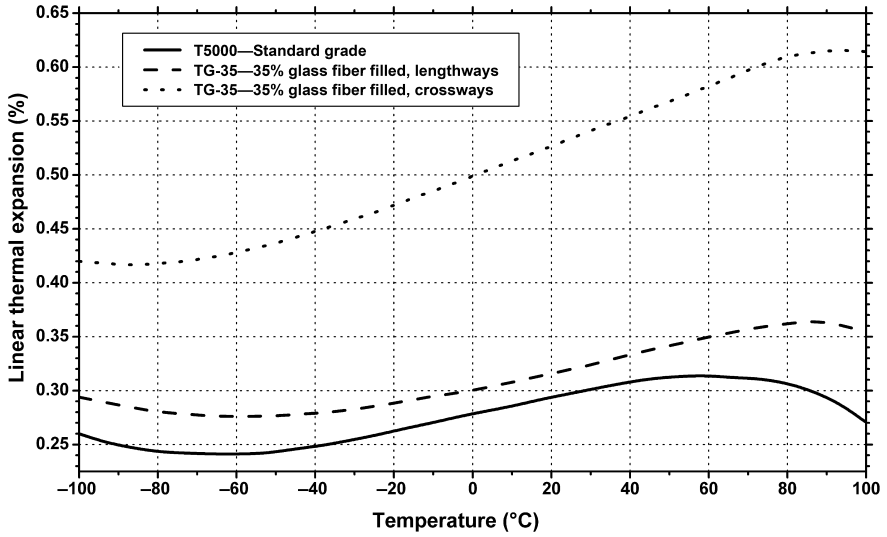

Figure 6.233 Linear thermal expansion vs. temperature for Evonik Industries Trogamid® amorphous nylons [11].

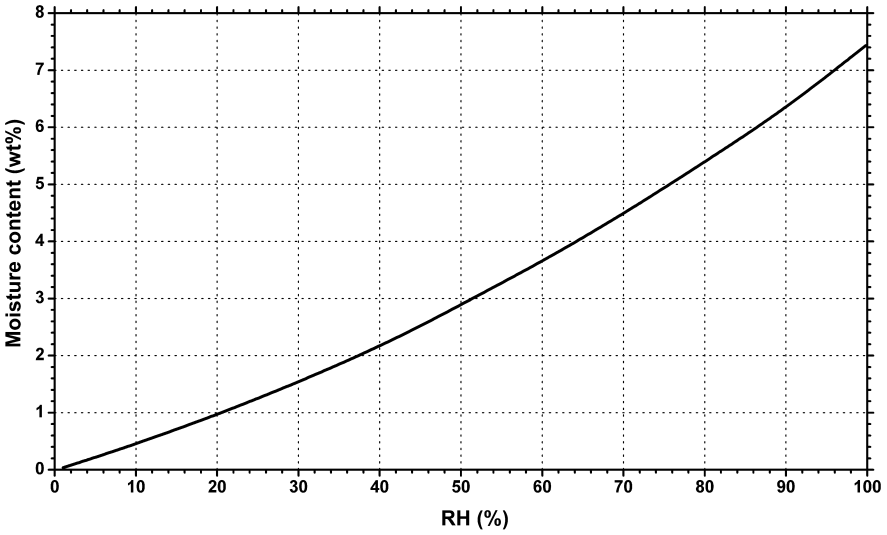

Figure 6.234 Moisture content vs. RH for Evonik Industries Trogamid® amorphous nylon [11].

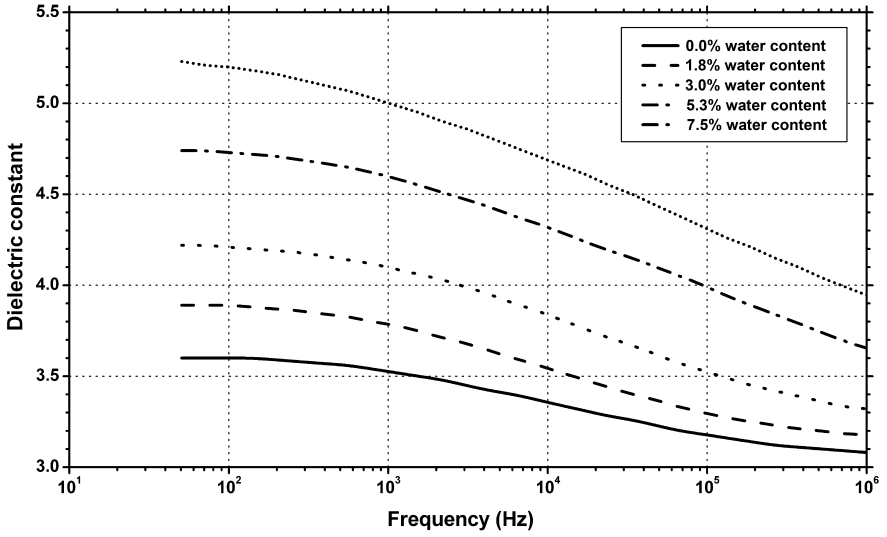

Figure 6.235 Dielectric constant vs. frequency and water content for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

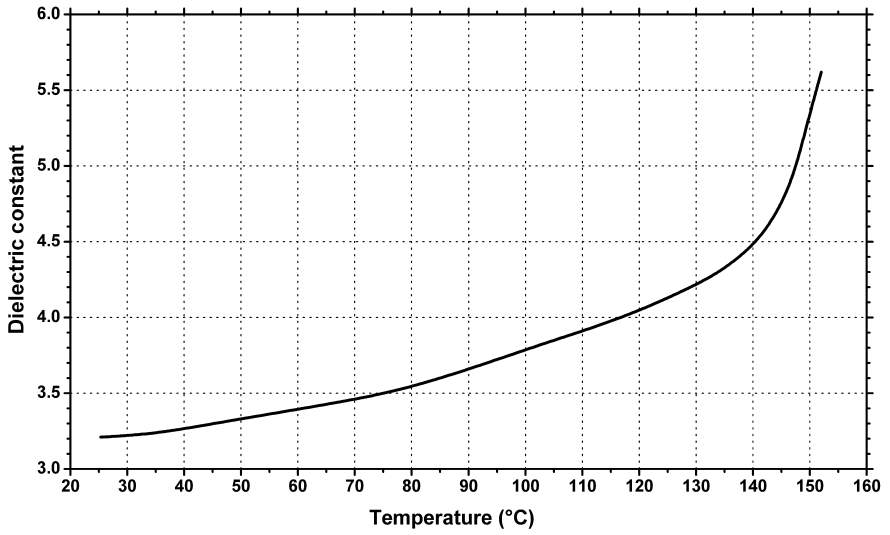

Figure 6.236 Dielectric constant vs. temperature for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

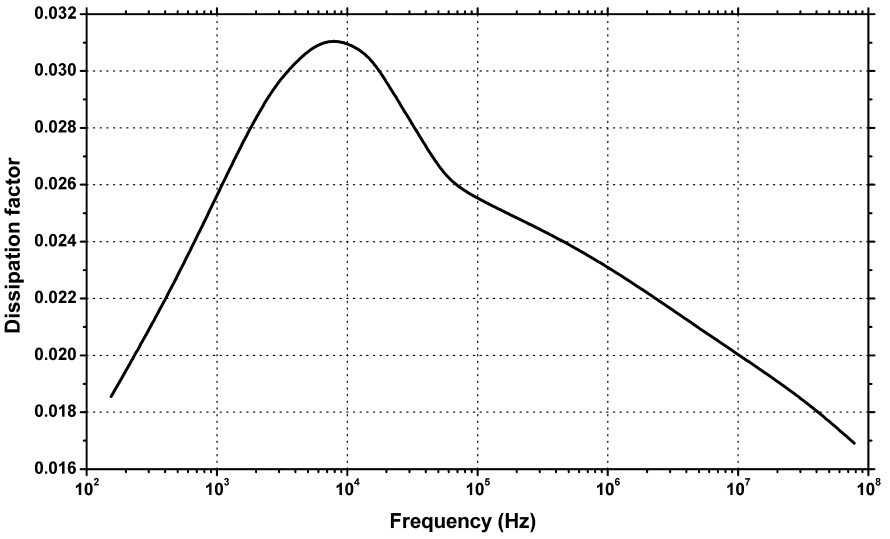

Figure 6.237 Dissipation factor vs. frequency for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

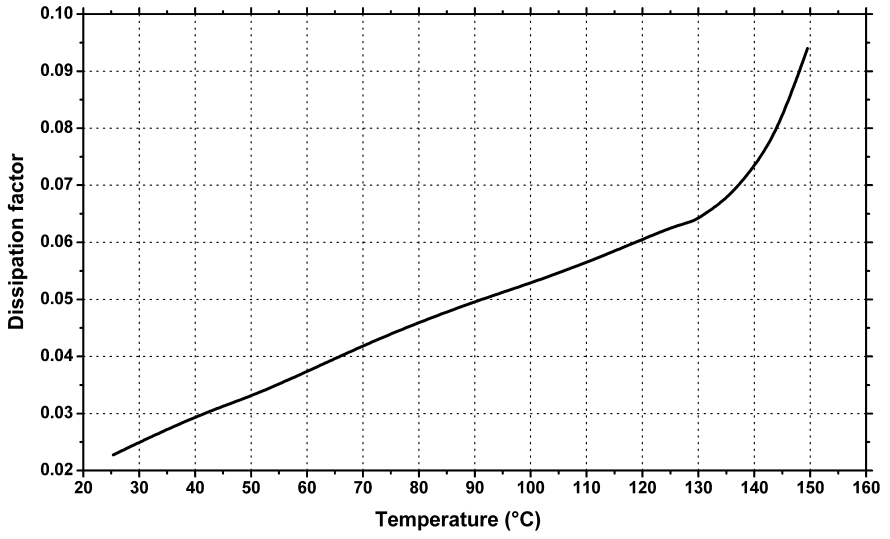

Figure 6.238 Dissipation factor vs. temperature for Evonik Industries Trogamid® T5000—standard grade amorphous nylon [11].

- Excellent surface finish even for a reinforced product even with high glass fiber content
- Ease of processing
- Good dimensional stability
- Slow rate of water absorption

Manufacturers and trade names: Solvay Advanced Polymers Ixef®, Mitsubishi Gas Chemical Co. Nylon-MXD6, Nanocor Imperm®.

Applications and uses: automotive fuel systems, packaging.

Data for PAA plastics are found in Figures 6.240–6.258.

6.12 Polyphthalamide (PPA)

As a member of the nylon family, it is a semi-crystalline material composed from a diacid and a diamine. However, the diacid portion contains at least 55% terephthalic acid (TPA) or isophthalic acid (IPA). TPA and IPA are aromatic components which serve to raise the melting point and glass transition temperature, and generally improve chemical resistance vs. standard aliphatic nylon polymers. The structure of the polymer depends on the ratio of the diacid ingredients and the diamine used and varies from grade to grade. The polymer usually consists of mixtures of blocks of two or more different segments, four of which are shown in Figure 6.259.

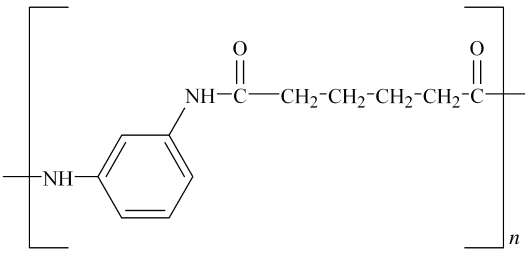

Figure 6.239 Chemical structure of PAMXD6 PAA.

Some of the PPA characteristics are as follows:

- Very high heat resistance
- Good chemical resistance
- Relatively low moisture absorption
- High strength or physical properties over a broad temperature range
- Not inherently flame retardant
- Requires good drying equipment
- High processing temperatures

Manufacturers and trade names: Solvay Advanced Polymers Amodel®, EMS-Grivory Grivory® HT, DuPont Zytel® HTN.

Applications and uses: automotive fuel systems.

Data for PPA plastics are found in Figures 6.260–6.299.

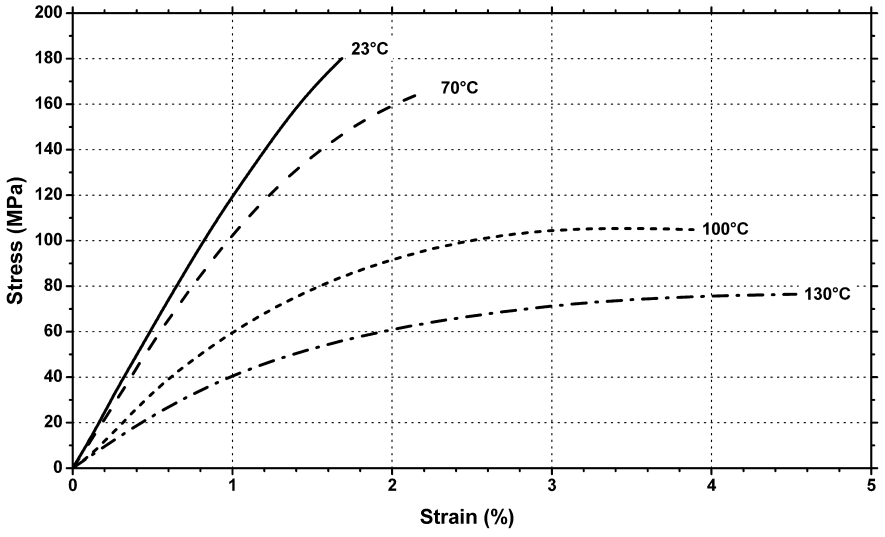

Figure 6.240 Stress vs. strain at various temperatures for Solvay Ixef® 1002—30% glass fiber reinforced PAA resin (DAM).

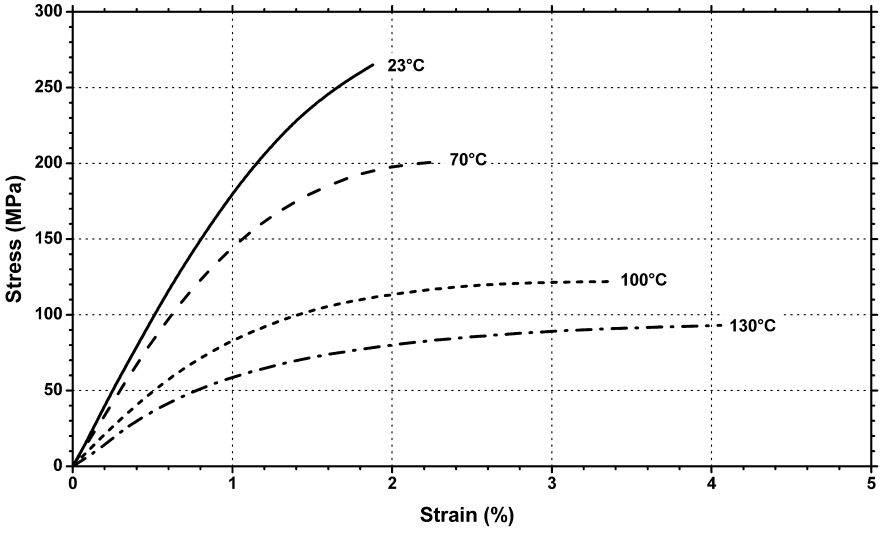

Figure 6.241 Stress vs. strain at various temperatures for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin (DAM).

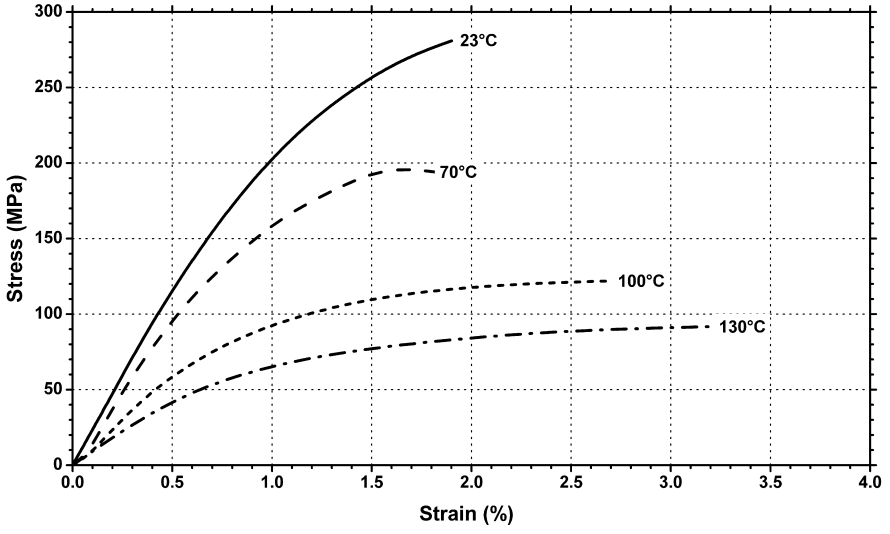

Figure 6.242 Stress vs. strain at various temperatures for Solvay Ixef® 1032—60% glass fiber reinforced PAA resin (DAM).

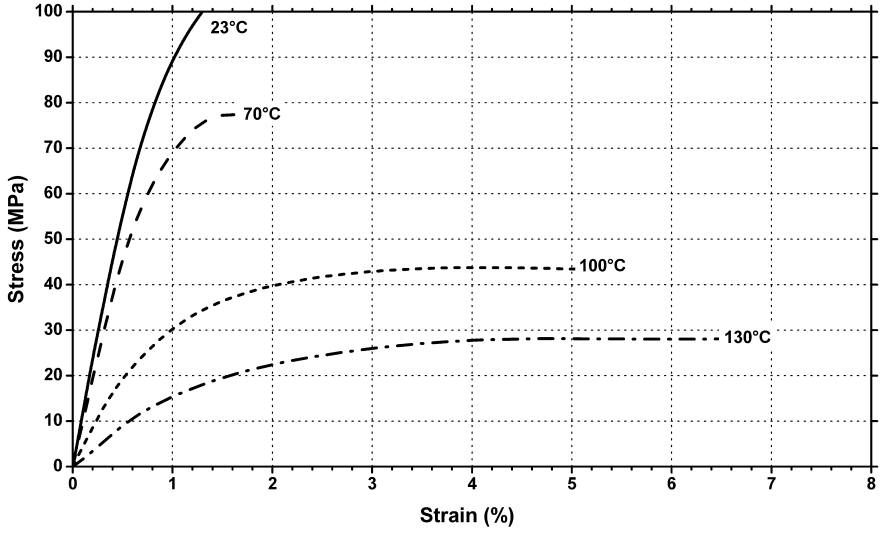

Figure 6.243 Stress vs. strain at various temperatures for Solvay Ixef® 2057—45% mineral reinforced PAA resin (DAM).

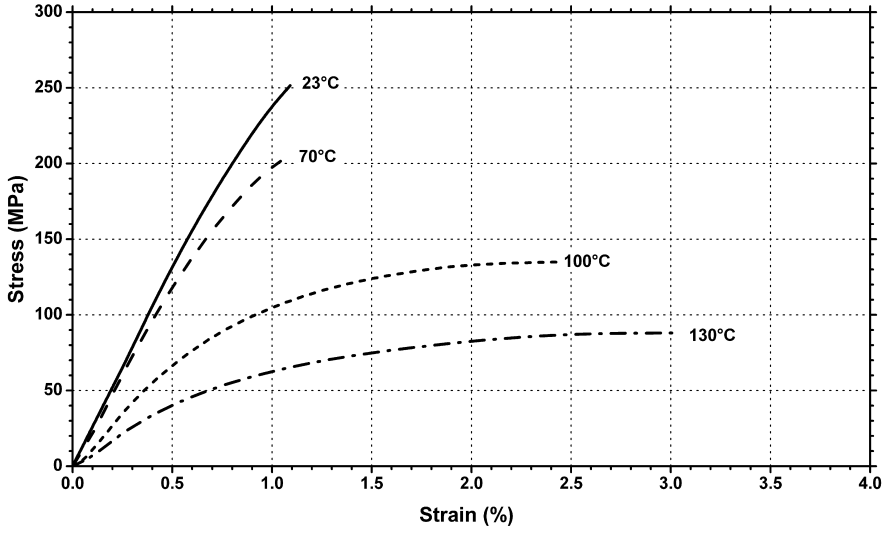

Figure 6.244 Stress vs. strain at various temperatures for Solvay Ixef® 3006—30% carbon fiber reinforced PAA resin (DAM).

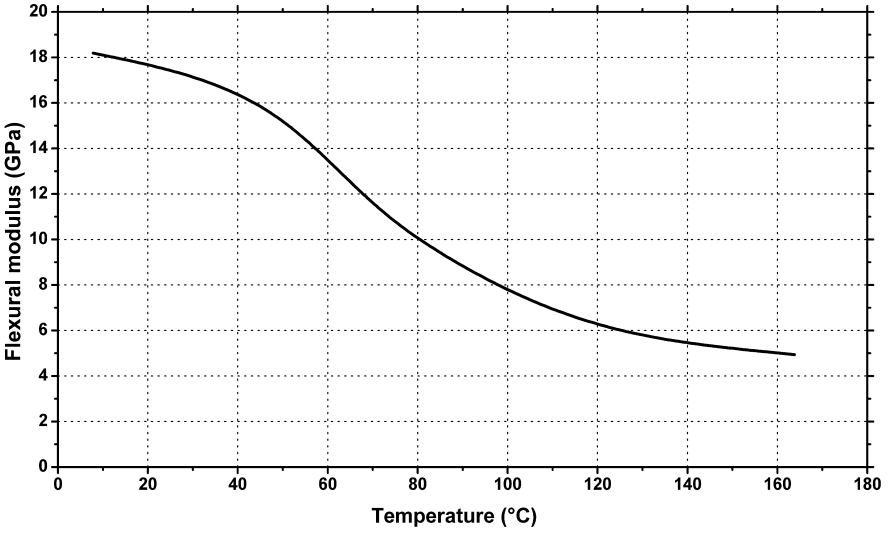

Figure 6.245 Flexural modulus vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

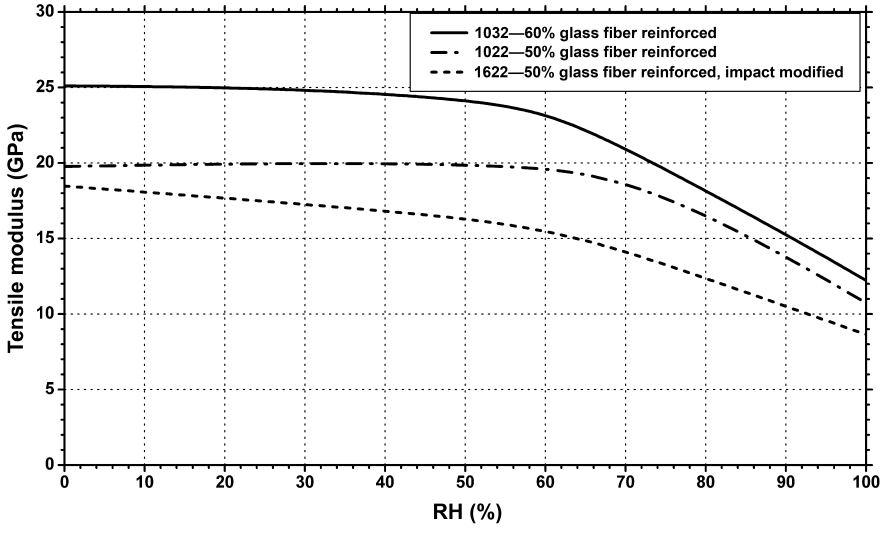

Figure 6.246 Tensile modulus vs. RH at 23°C for Solvay Ixef® reinforced PAA resins [12].

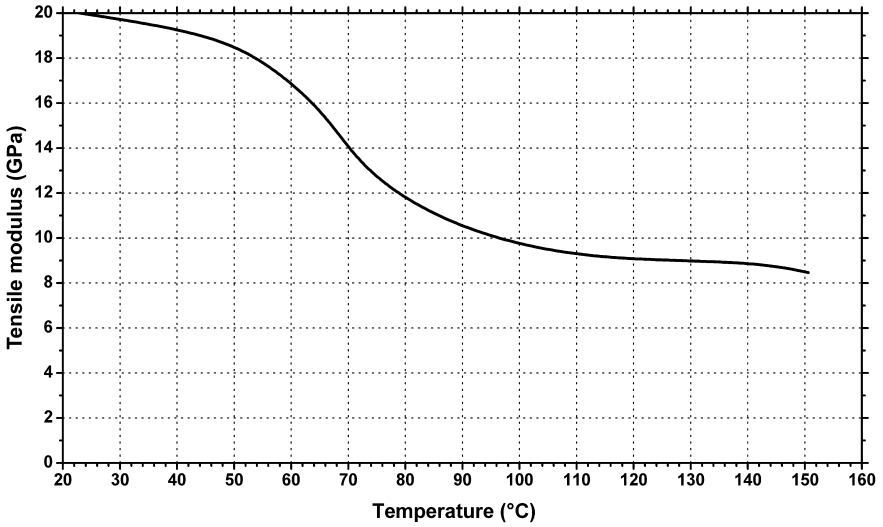

Figure 6.247 Tensile modulus vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

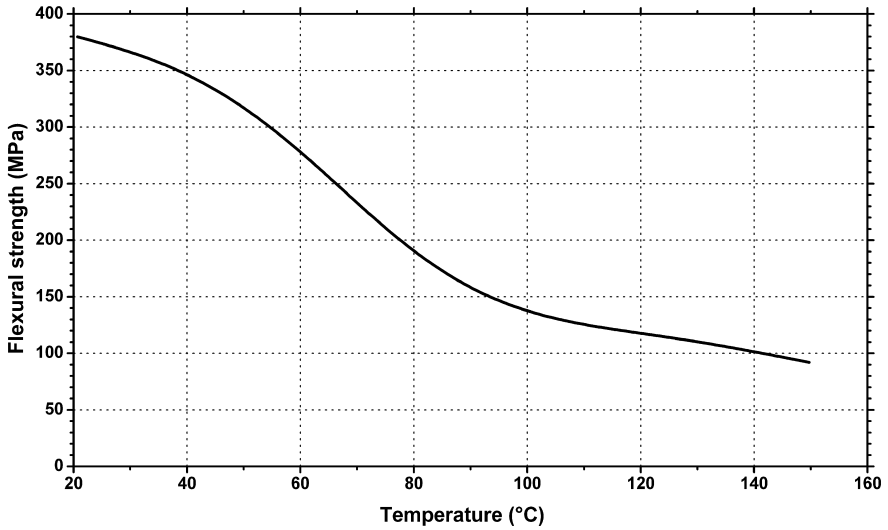

Figure 6.248 Flexural strength vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

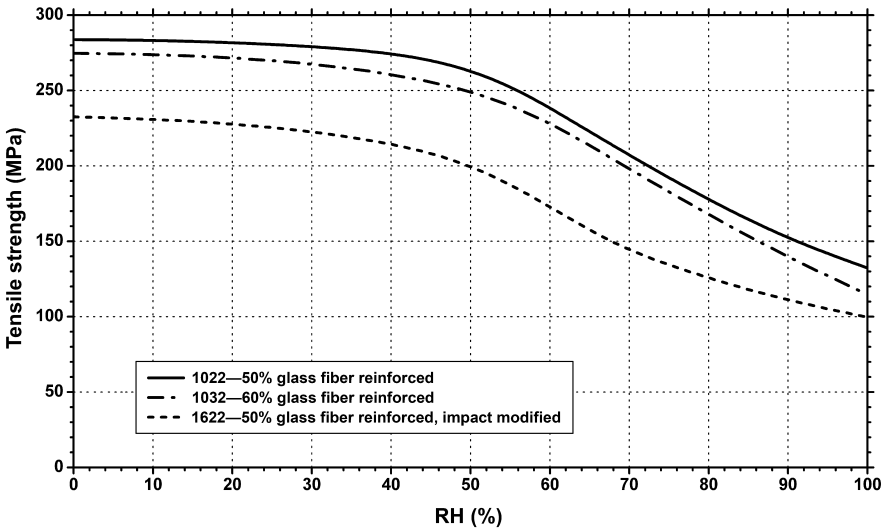

Figure 6.249 Tensile strength vs. RH at 23°C for Solvay Ixef® reinforced PAA resins [12].

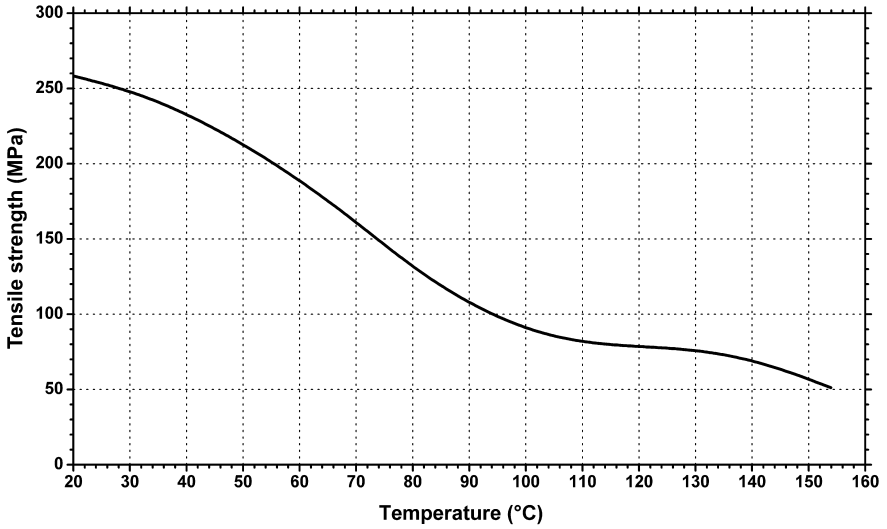

Figure 6.250 Tensile strength vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

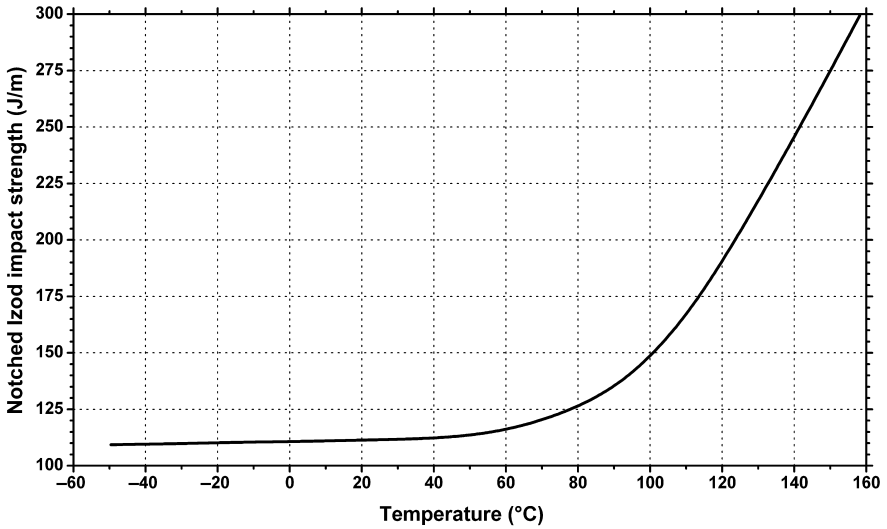

Figure 6.251 Notched Izod strength vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

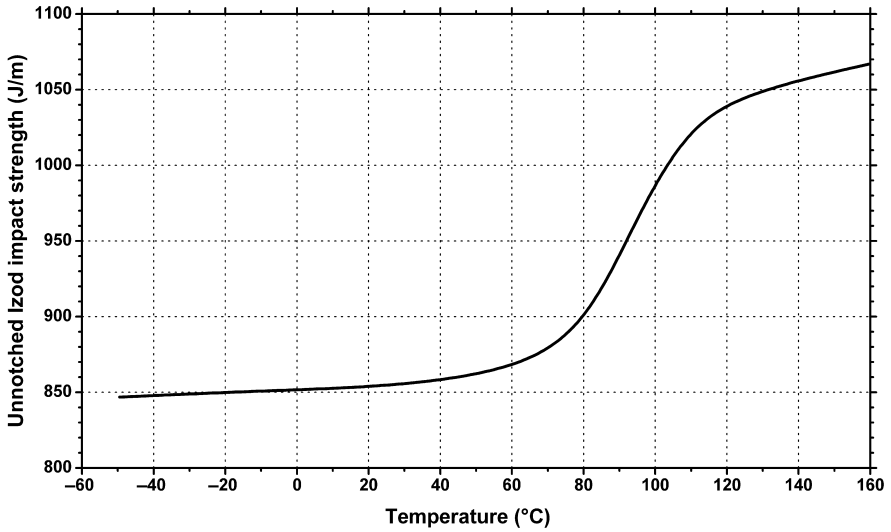

Figure 6.252 Unnotched Izod strength vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

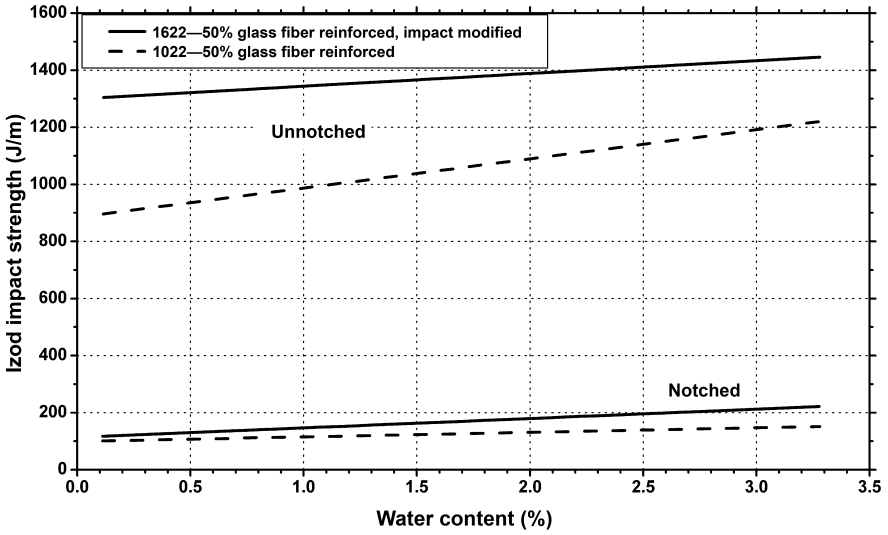

Figure 6.253 Izod strength vs. water content for Solvay Ixef® PAA resins [12].

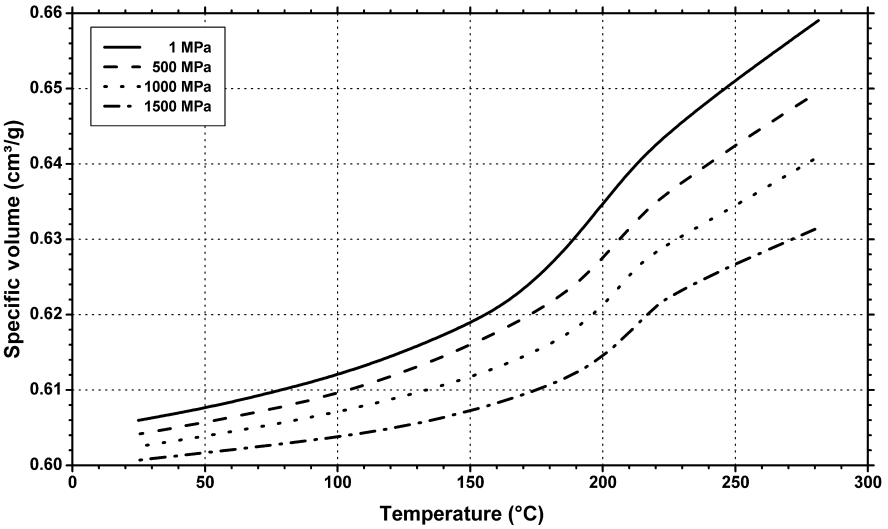

Figure 6.254 PVT for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

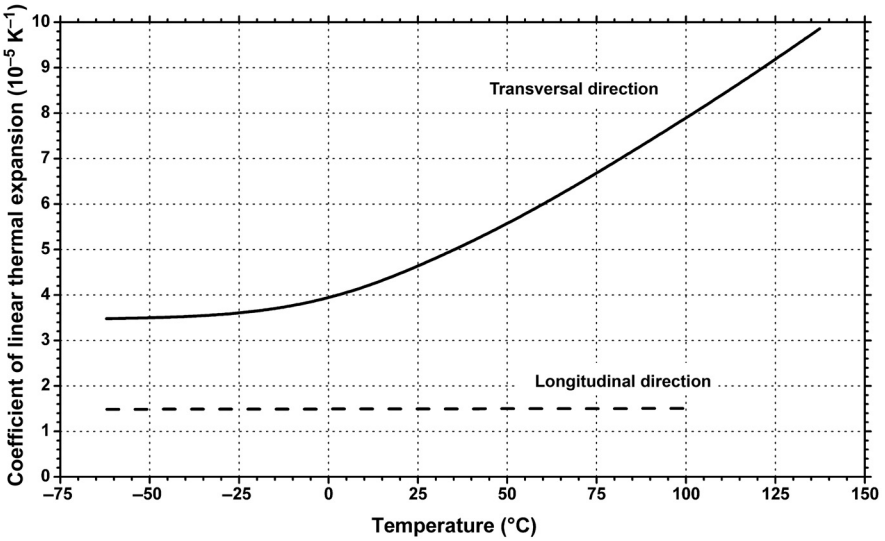

Figure 6.255 Coefficient of linear thermal expansion (COLTE) vs. temperature for Solvay Ixef® 1022—50% glass fiber reinforced PAA resin [12].

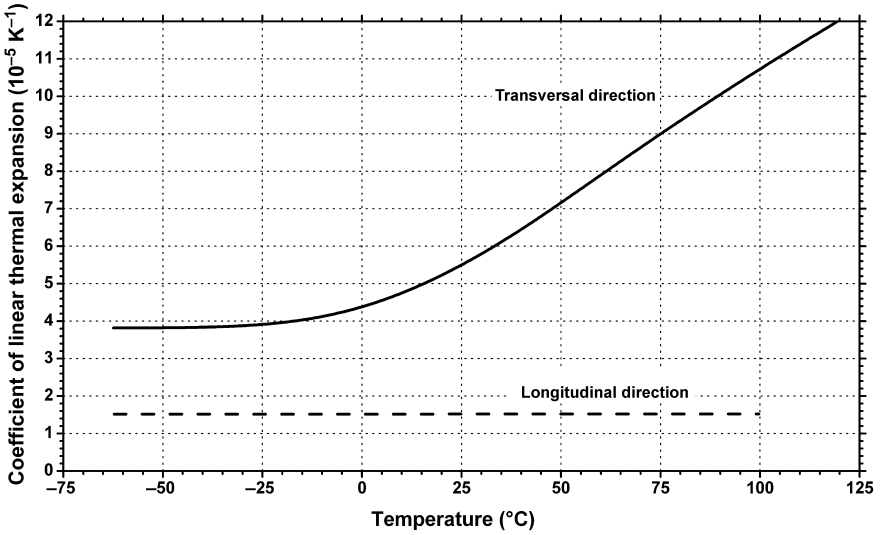

Figure 6.256 COLTE vs. temperature for Solvay Ixef® 1622—50% glass fiber reinforced, impact modified PAA resin [12].

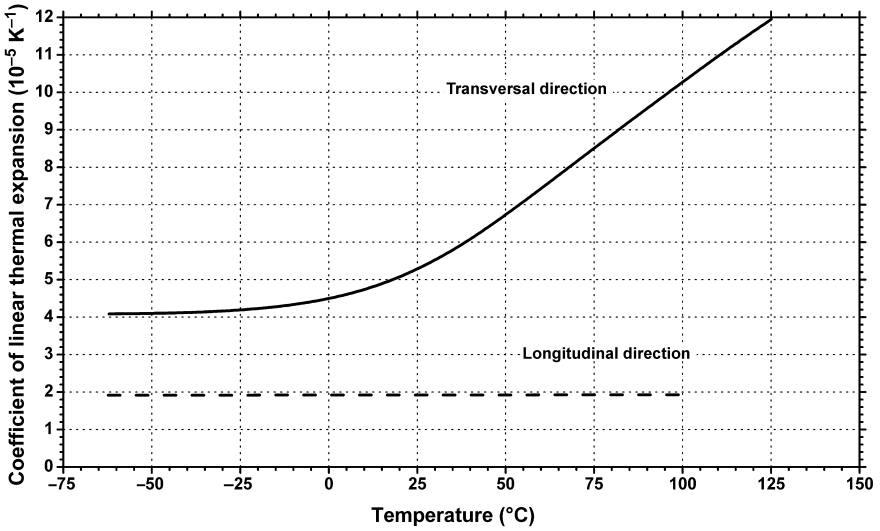

Figure 6.257 COLTE vs. temperature for Solvay Ixef® 2011—42% mineral reinforced PAA resin [12].

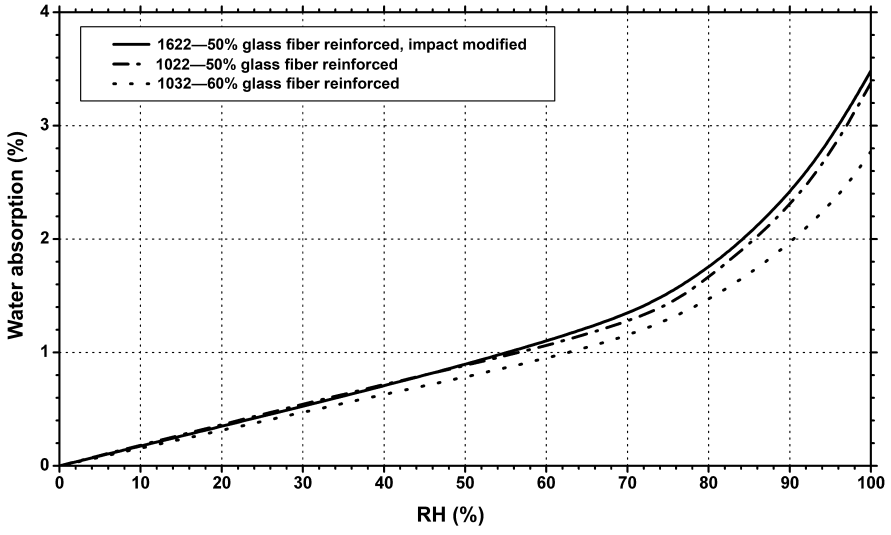

Figure 6.258 Water absorption vs. RH for Solvay Ixef® PAA resins [12].

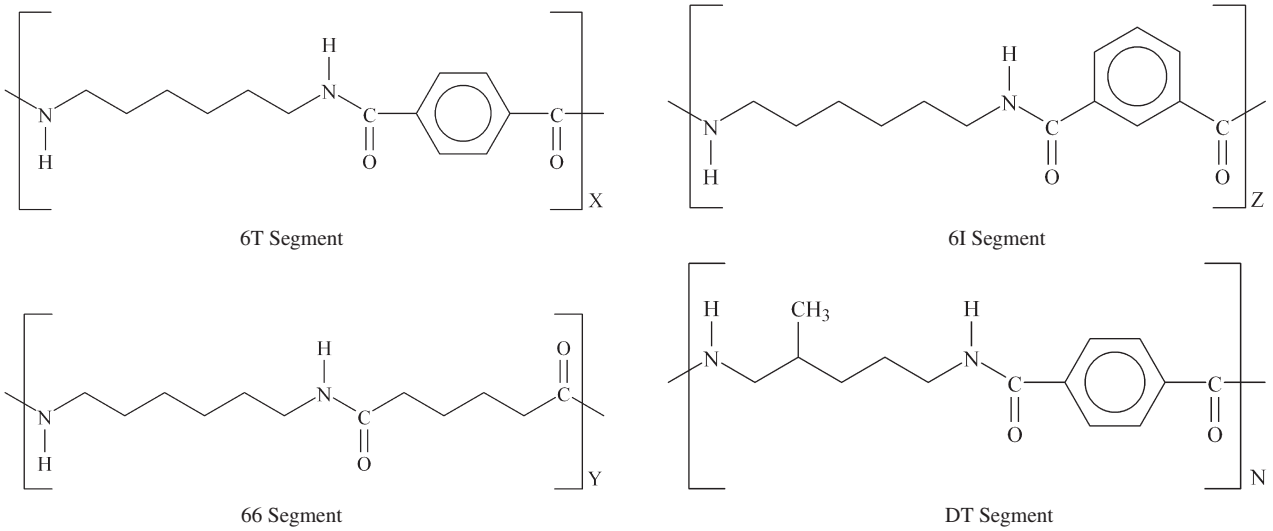

Figure 6.259 Chemical structures of blocks used to make PPAs.

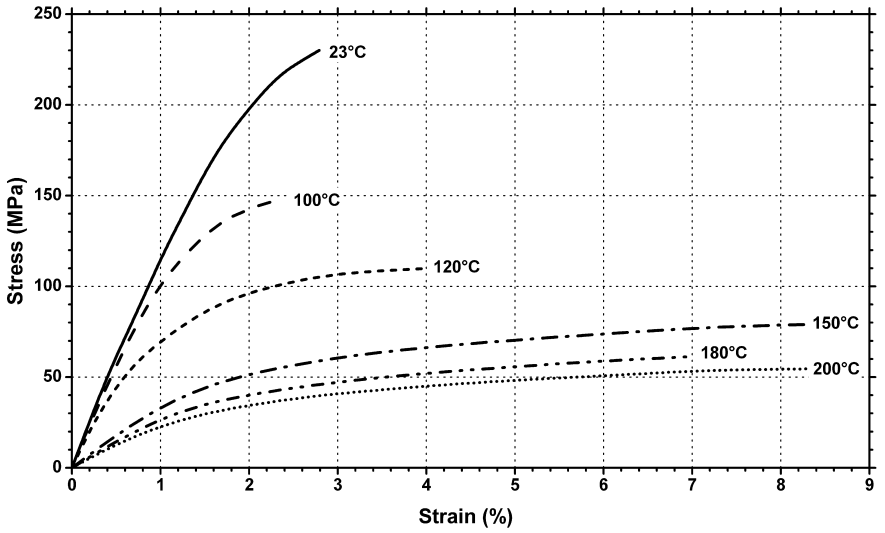

Figure 6.260 Stress vs. strain at various temperatures for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin (DAM).

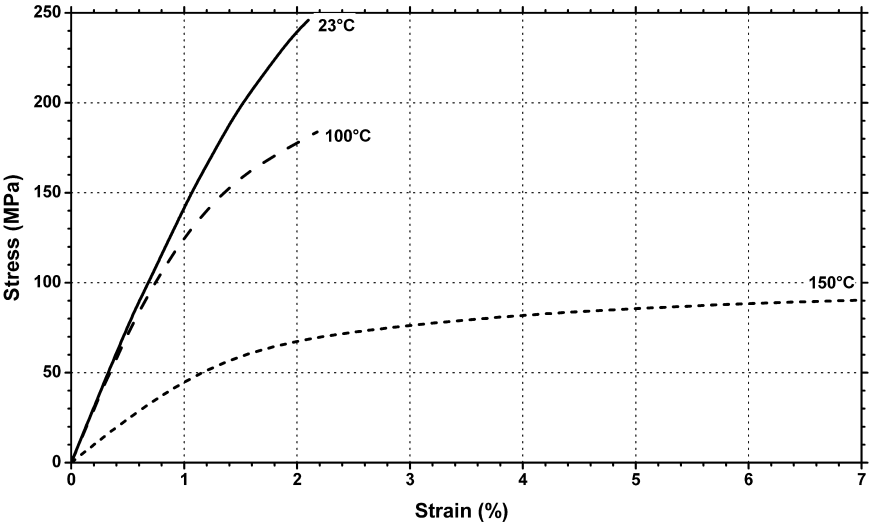

Figure 6.261 Stress vs. strain at various temperatures for Solvay Amodel® A-1145 HS—45% glass reinforced, heat stabilized PPA resin (DAM).

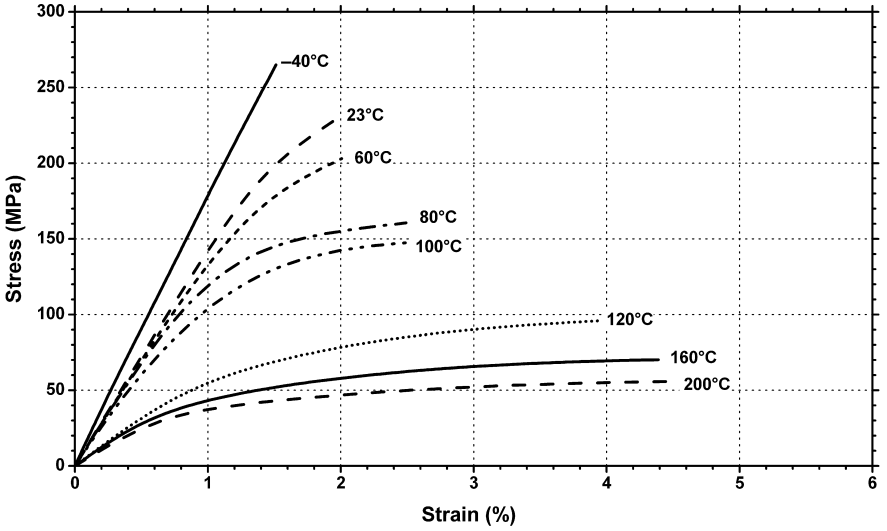

Figure 6.262 Tensile stress vs. strain at various temperatures for EMS-Grivory® HTV-5H1—DAM heat stabilized 50% glass fiber PA6T/6I based PPA resin [13].

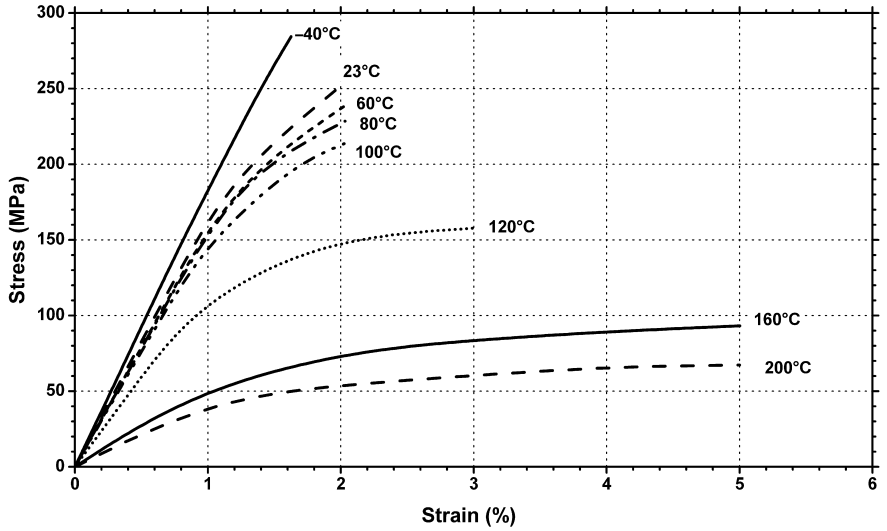

Figure 6.263 Tensile stress vs. strain at various temperatures for EMS-Grivory® HTV-5H1—conditioned heat stabilized 50% glass fiber PA6T/6I based PPA resin [13].

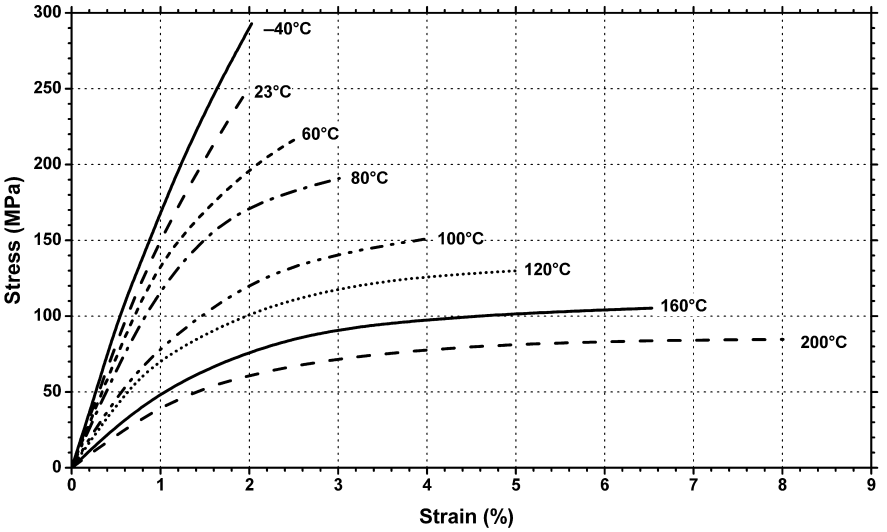

Figure 6.264 Tensile stress vs. strain at various temperatures for EMS-Grivory® HT2V-5H—DAM heat stabilized 50% glass fiber PA6T/66 based PPA resin [13].

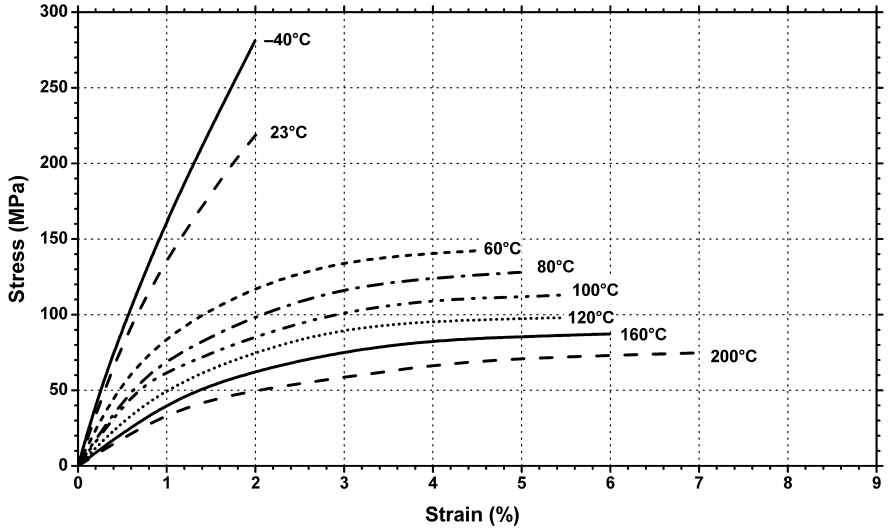

Figure 6.265 Tensile stress vs. strain at various temperatures for EMS-Grivory® HT2V-5H—conditioned heat stabilized 50% glass fiber PA6T/66 based PPA resin [13].

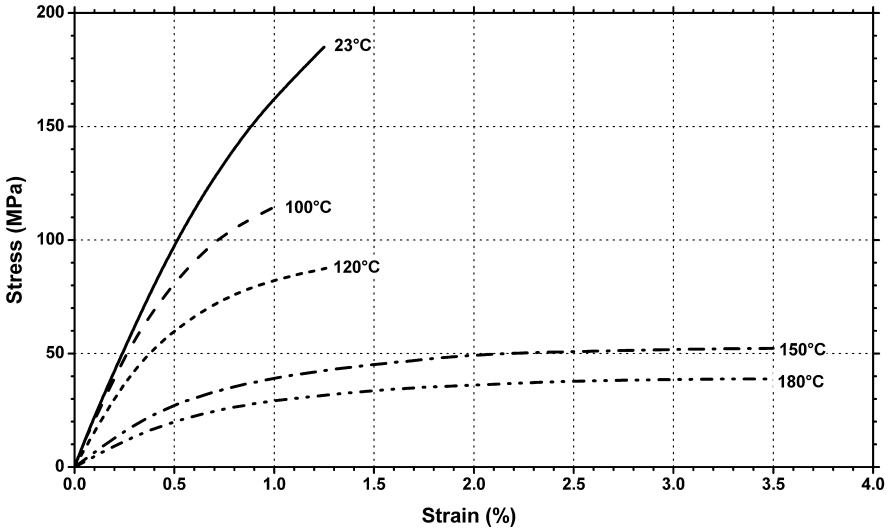

Figure 6.266 Stress vs. strain at various temperatures for Solvay Amodel® AS-1566 HS—65% glass/mineral reinforced, heat stabilized PPA resin (DAM).

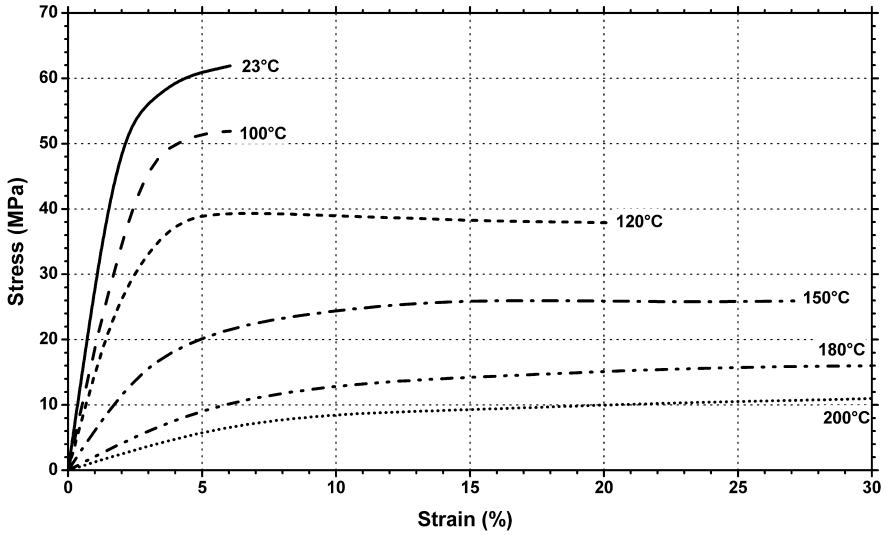

Figure 6.267 Stress vs. strain at various temperatures for Solvay Amodel® AT-5001—high impact PPA resin (DAM).

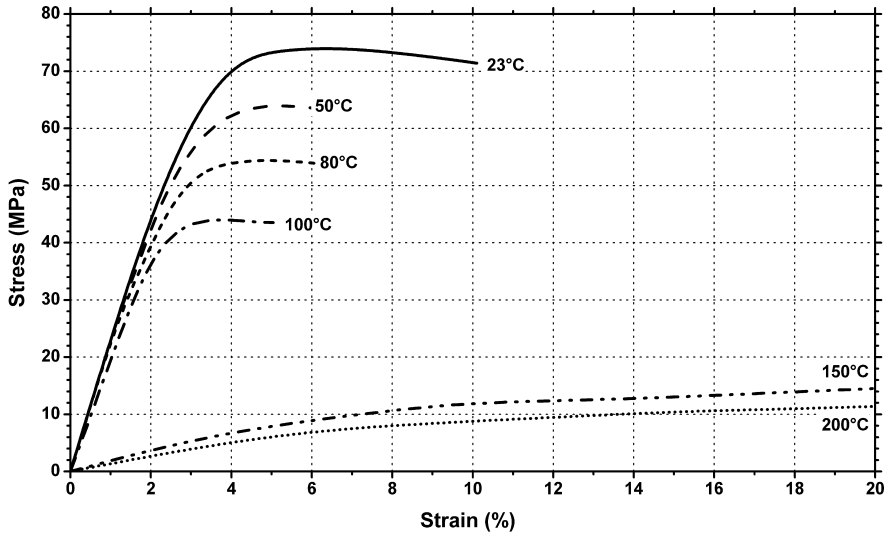

Figure 6.268 Stress vs. strain at various temperatures for Solvay Amodel® ET-1001 HS—impact modified, heat stabilized PPA resin (DAM).

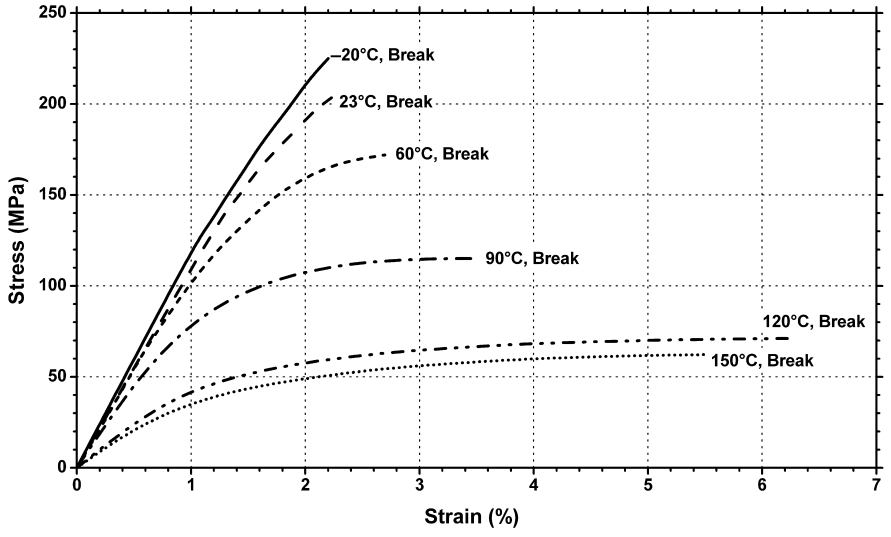

Figure 6.269 Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G35HSL—35% glass reinforced, heat stabilized, lubricated PPA resin (DAM).

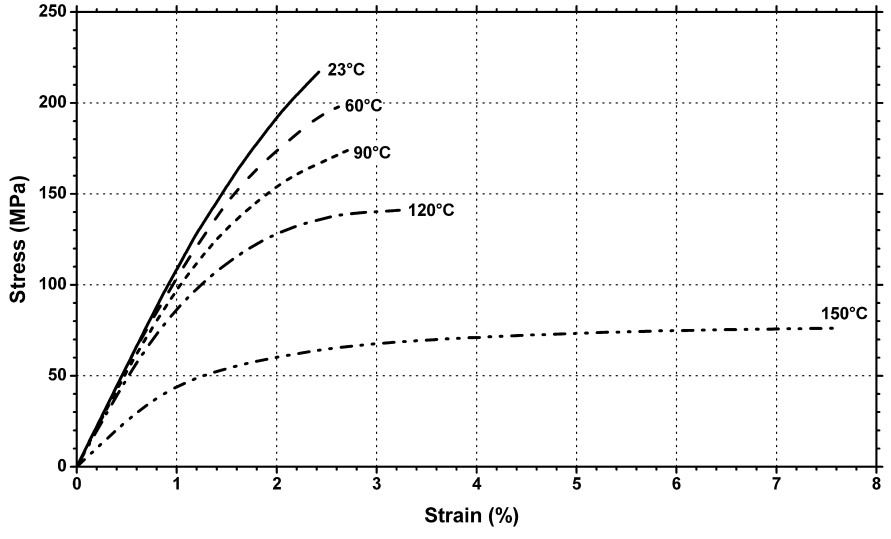

Figure 6.270 Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G35HSL—35% glass reinforced, heat stabilized, lubricated PPA resin (conditioned at 50% RH).

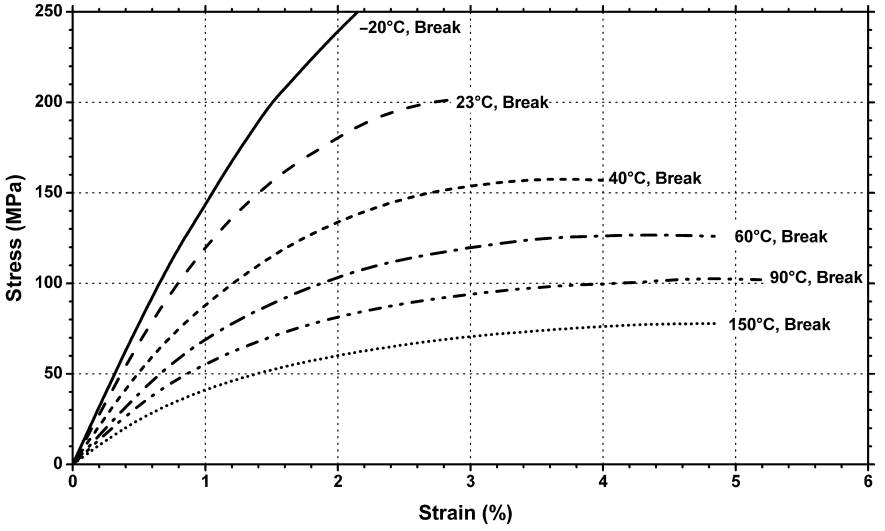

Figure 6.271 Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G45HSL—45% glass reinforced, heat stabilized, lubricated PPA resin (DAM).

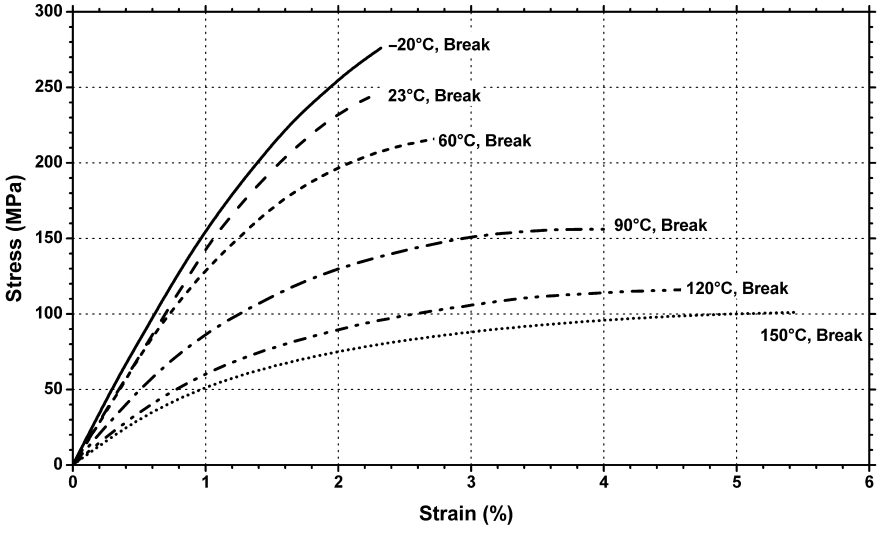

Figure 6.272 Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G45HSL—45% glass reinforced, heat stabilized, lubricated PPA resin (conditioned at 50% RH).

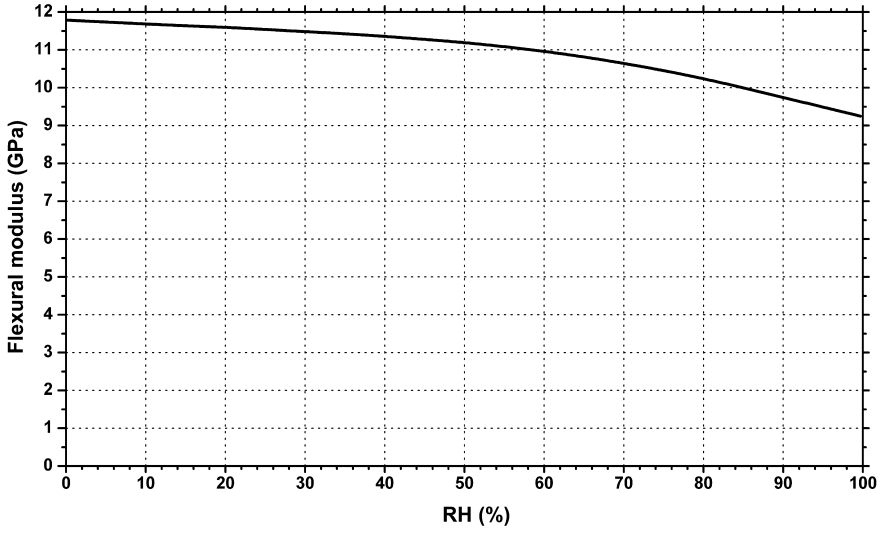

Figure 6.273 Flexural modulus vs. RH for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin [14].

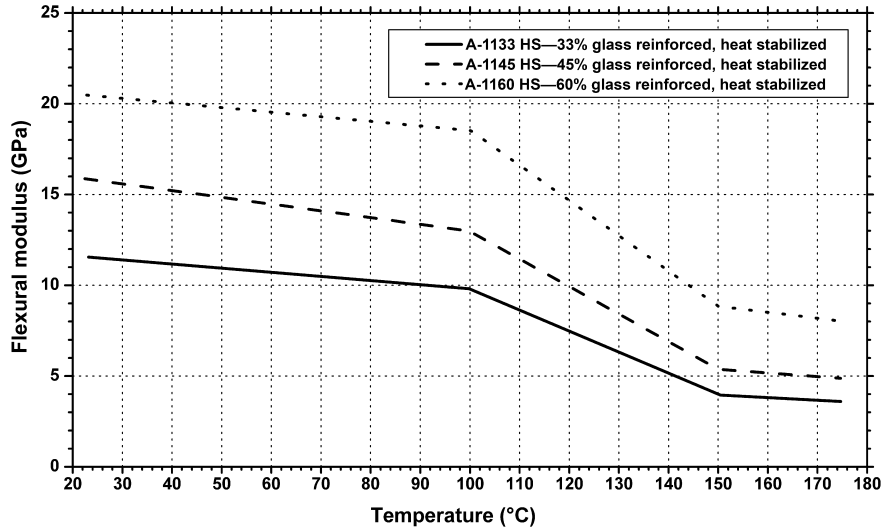

Figure 6.274 Flexural modulus vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

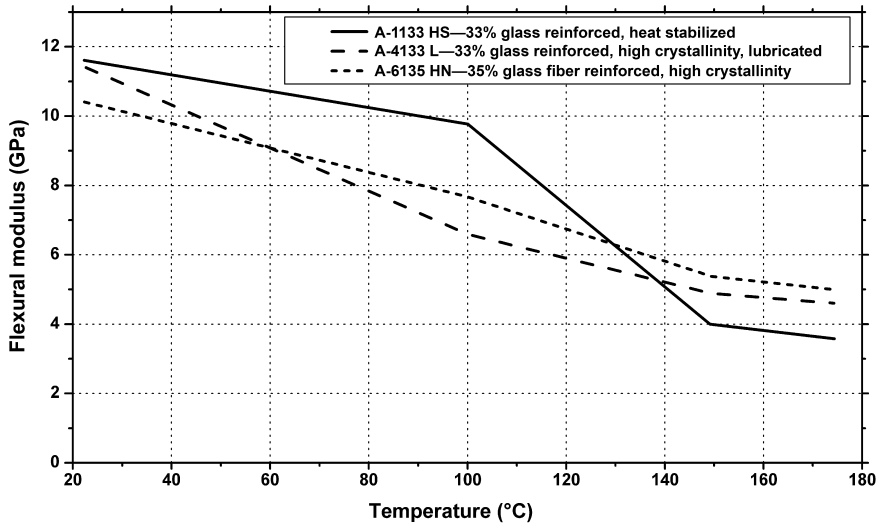

Figure 6.275 Flexural modulus vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins [14].

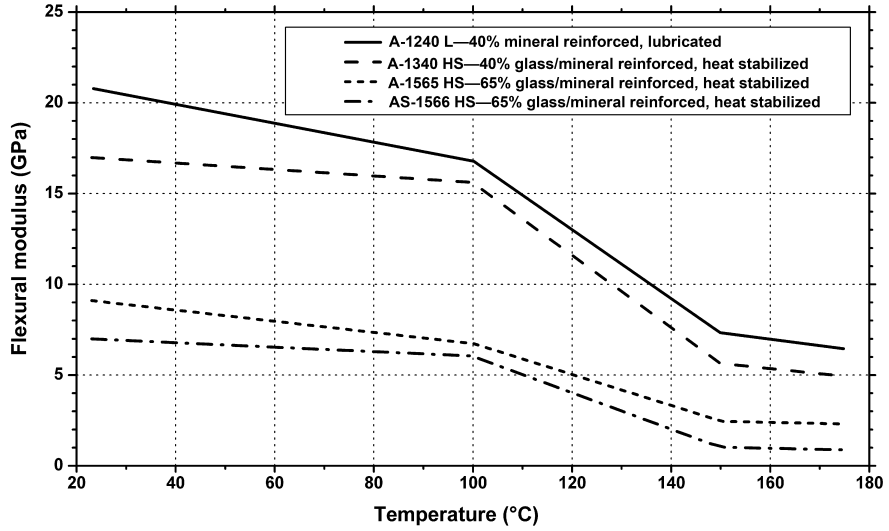

Figure 6.276 Flexural modulus vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins [14].

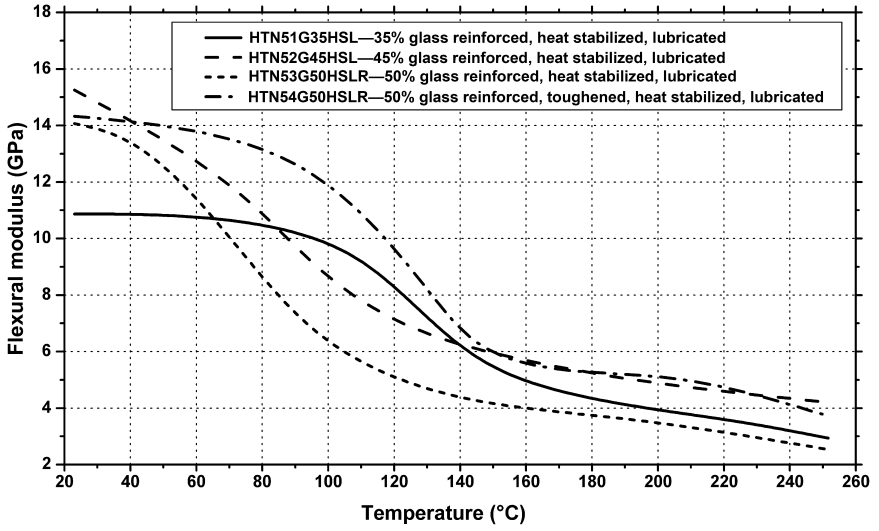

Figure 6.277 Flexural modulus vs. temperature for DuPont Engineering Plastics Zytel® glass fiber reinforced, heat stabilized PPA resins [15].

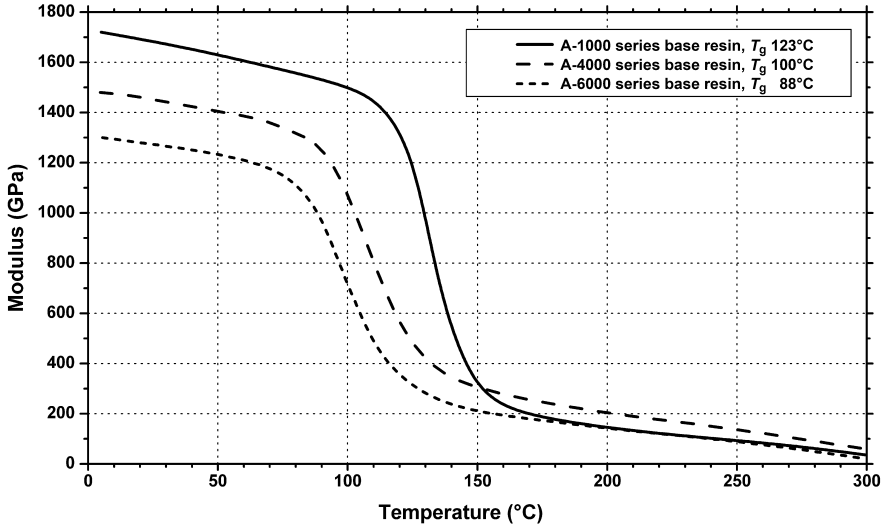

Figure 6.278 Modulus vs. temperature for Solvay Amodel® unreinforced base PPA resins [14].

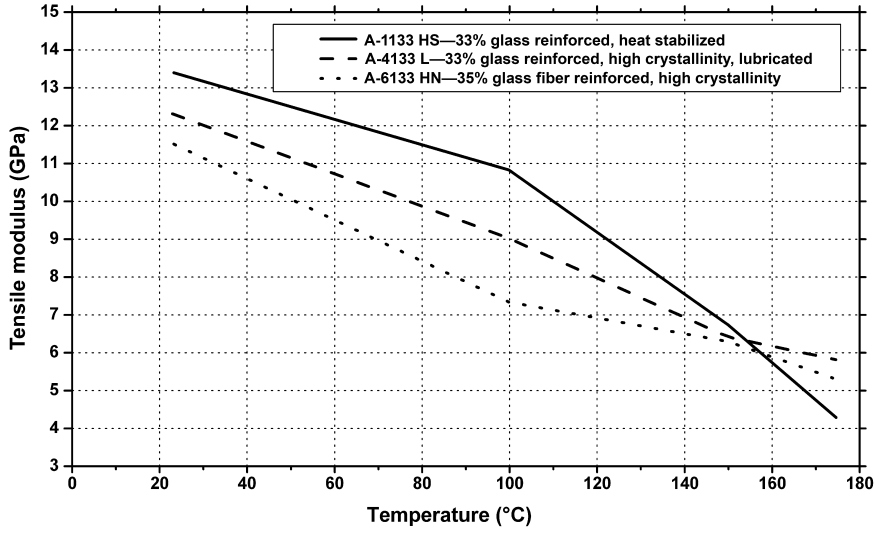

Figure 6.279 Tensile modulus vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins [14].

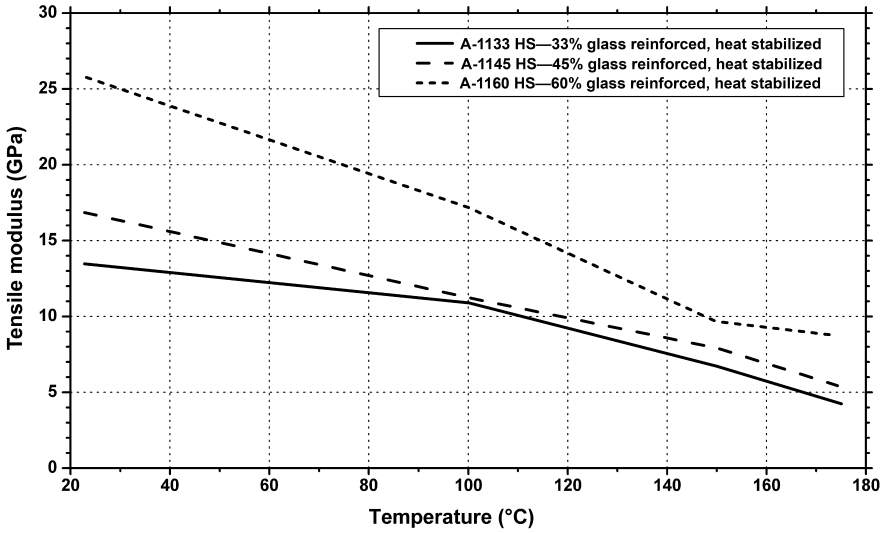

Figure 6.280 Tensile modulus vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

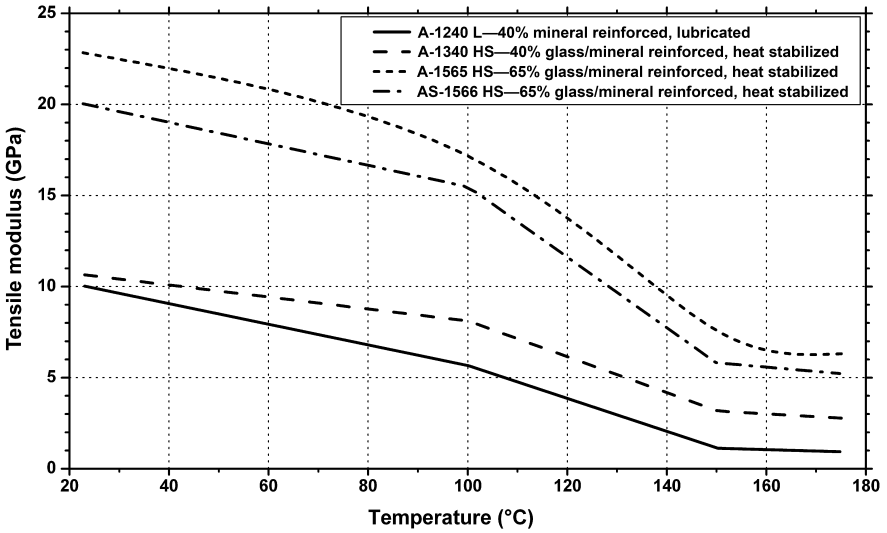

Figure 6.281 Tensile modulus vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins [14].

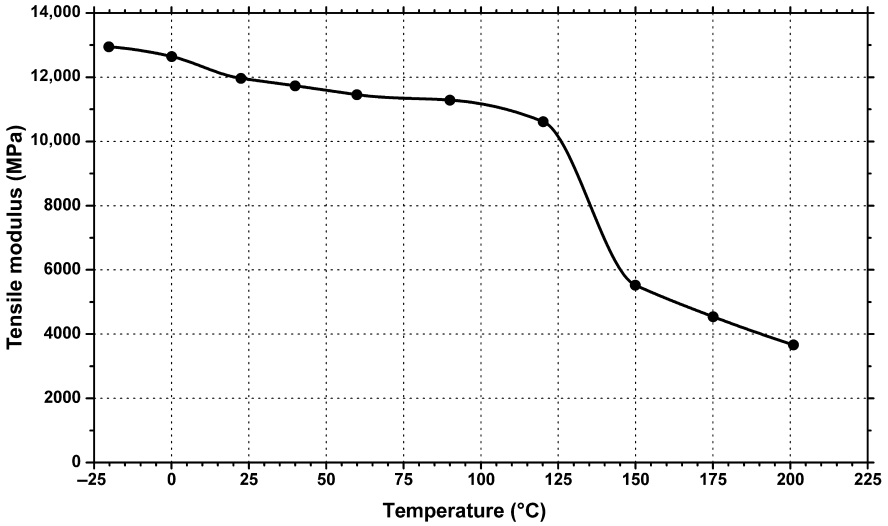

Figure 6.282 Tensile modulus vs. temperature for DuPont Zytel® HTN51G35HSL NC010—35% glass reinforced PPA resins [16].

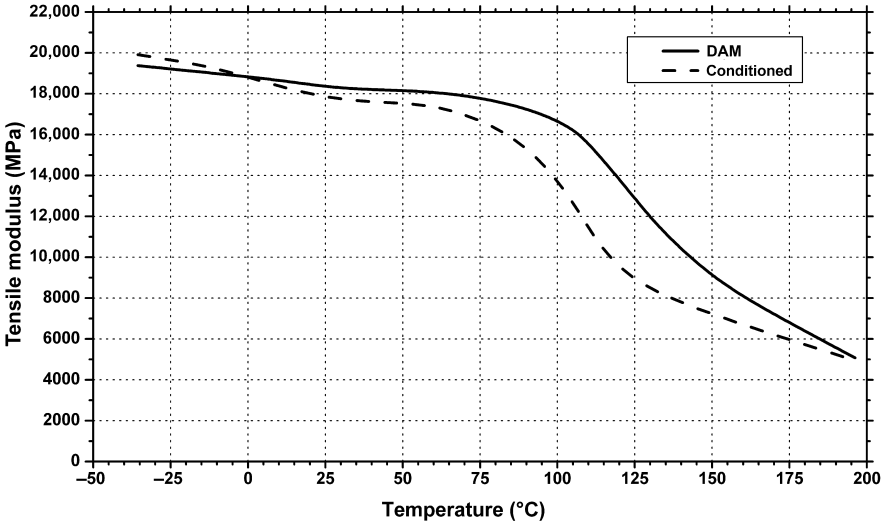

Figure 6.283 Tensile E-modulus vs. temperature for EMS-Grivory® HTV-5H1—dry and conditioned heat stabilized 50% glass fiber PA6T/6I based PPA resin [13].

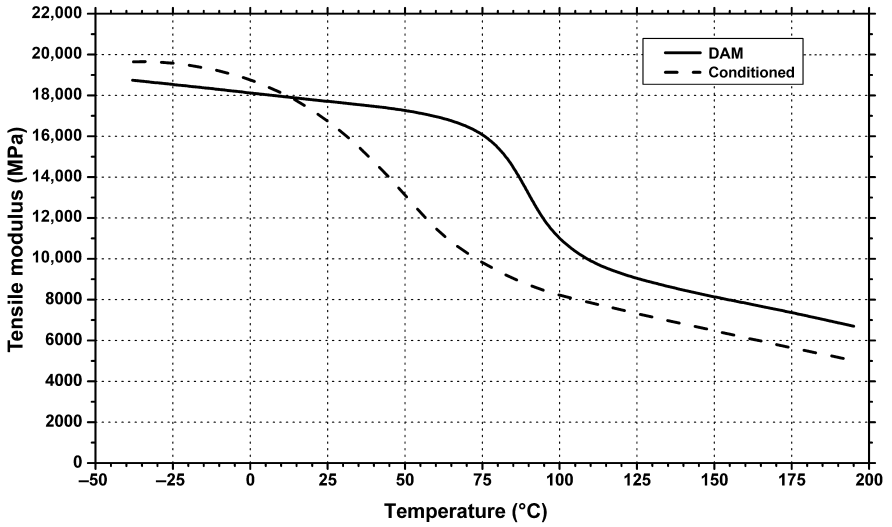

Figure 6.284 Tensile E-modulus vs. temperature for EMS-Grivory® HT2V-5H—dry and conditioned heat stabilized 50% glass fiber PA6T/66 based PPA resin [13].

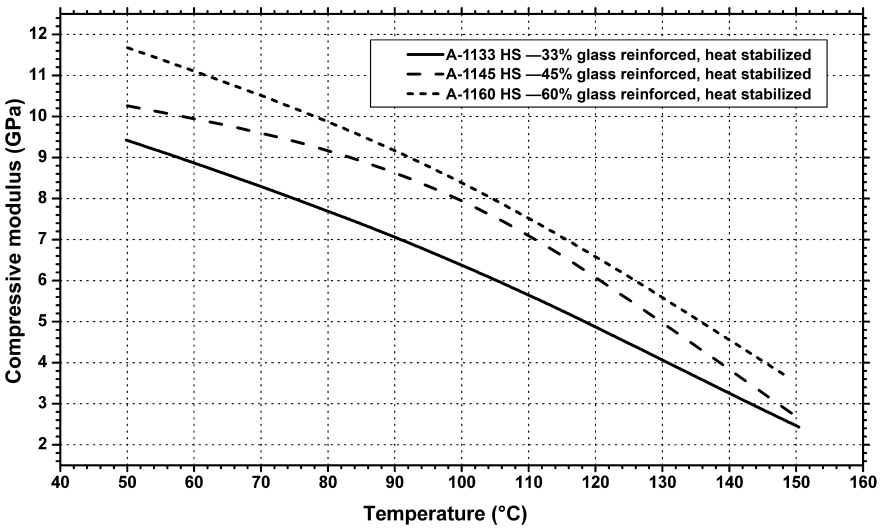

Figure 6.285 Compressive modulus vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

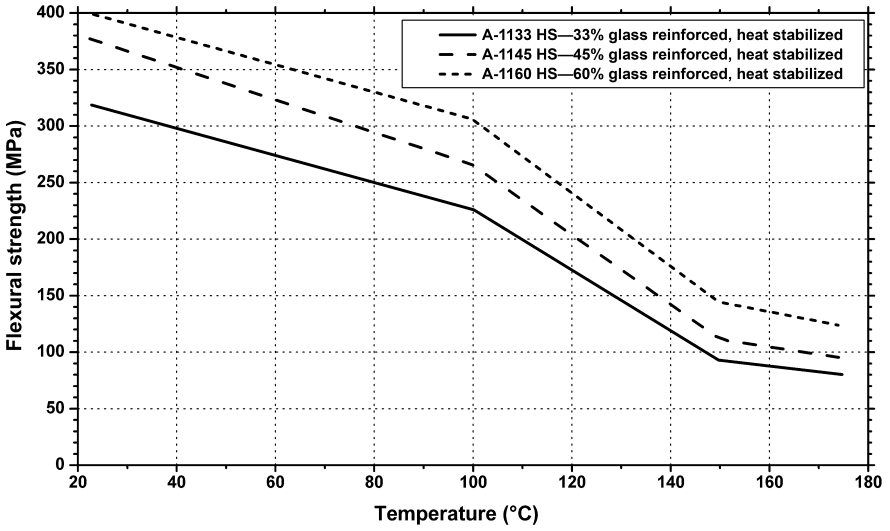

Figure 6.286 Flexural strength vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

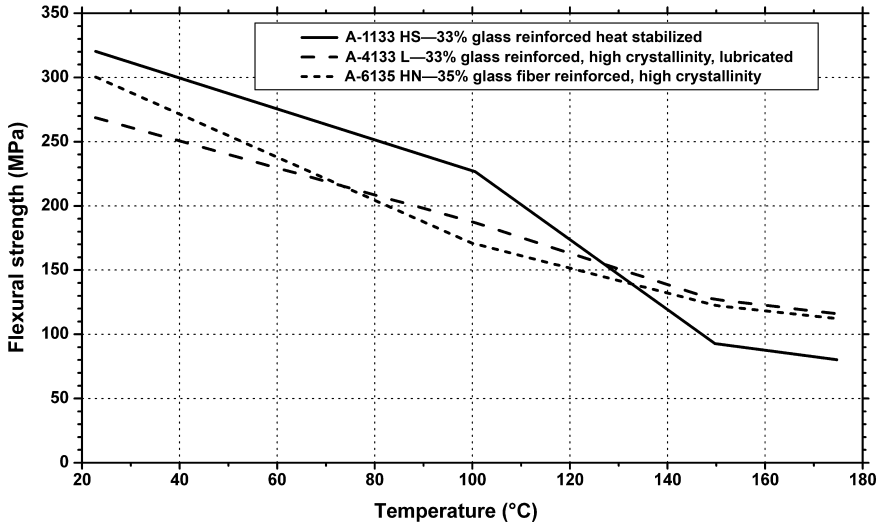

Figure 6.287 Flexural strength vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins [14].

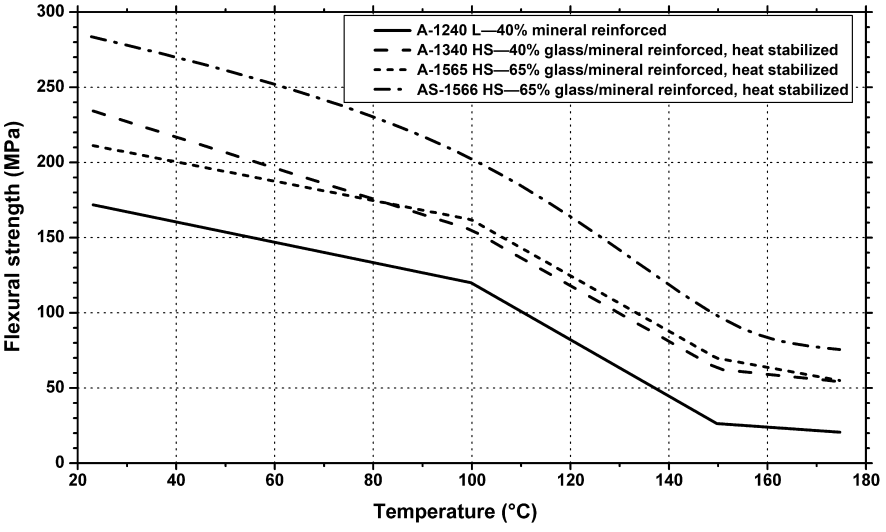

Figure 6.288 Flexural strength vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins [14].

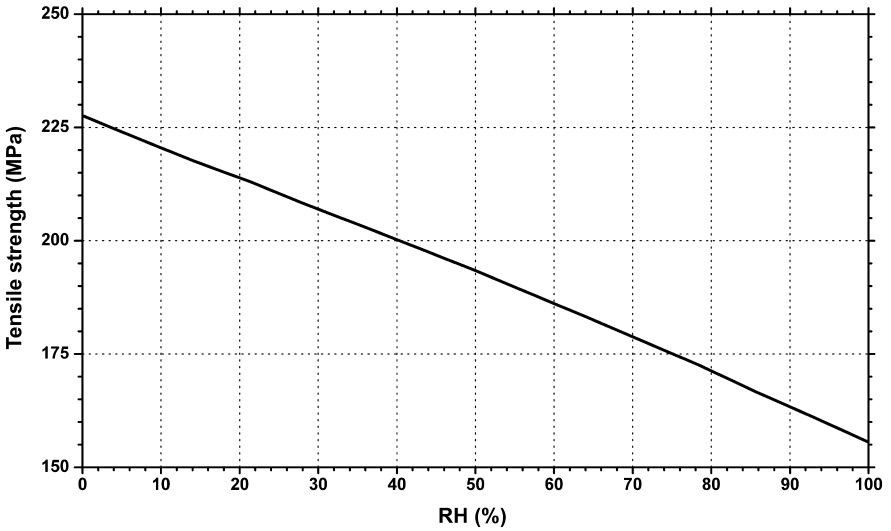

Figure 6.289 Tensile strength vs. RH for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin [14].

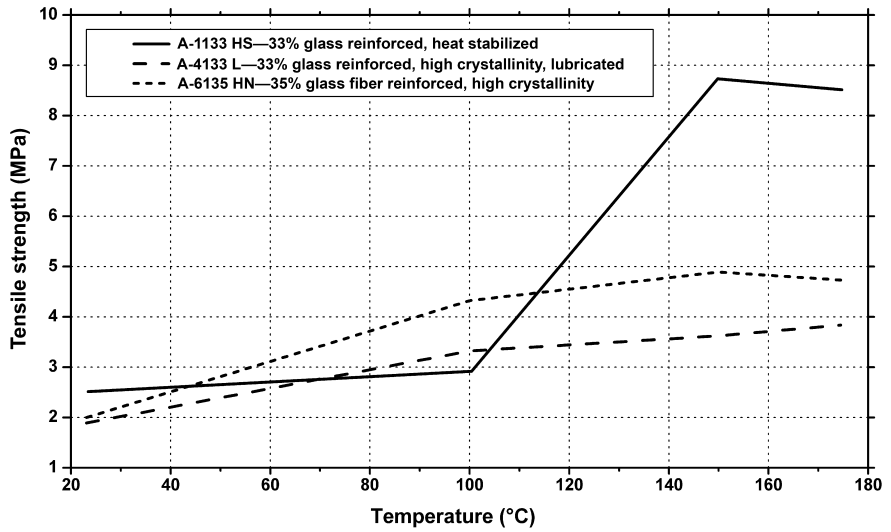

Figure 6.290 Tensile strength vs. temperature for Solvay Amodel®—glass fiber reinforced PPA resins [14].

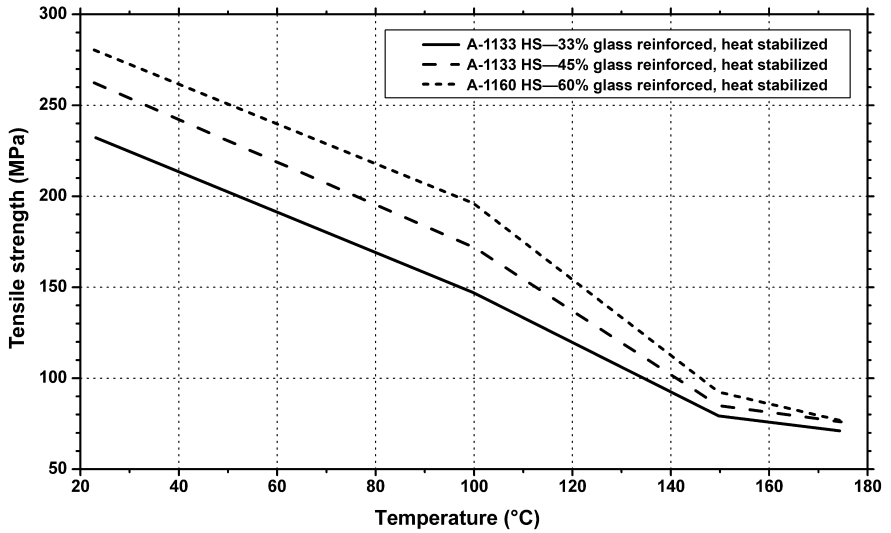

Figure 6.291 Tensile strength vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

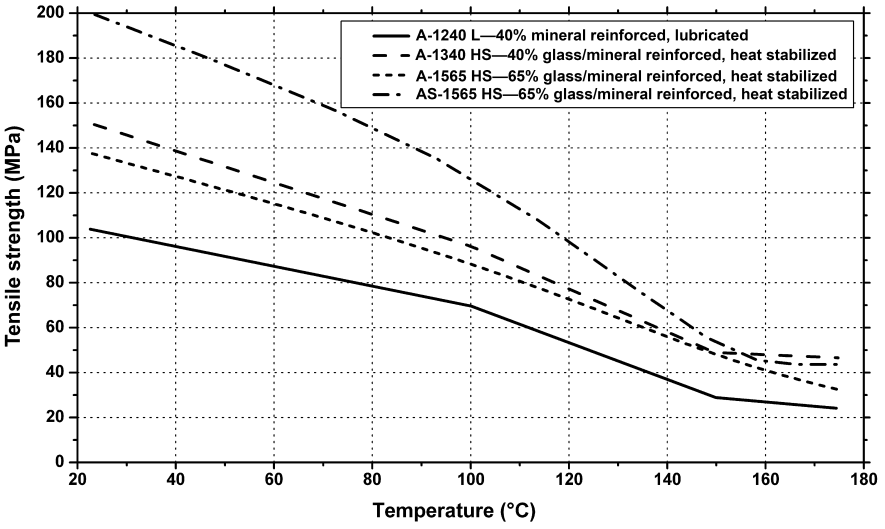

Figure 6.292 Tensile strength vs. temperature for Solvay Amodel®—glass and mineral reinforced, heat stabilized PPA resins [14].

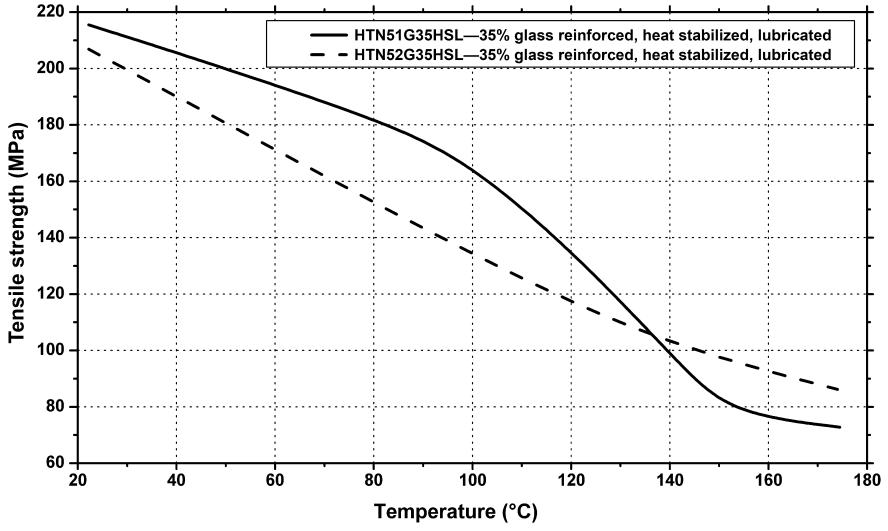

Figure 6.293 Tensile strength vs. temperature for DuPont Engineering Plastics Zytel®—glass fiber reinforced, heat stabilized PPA resins [15].

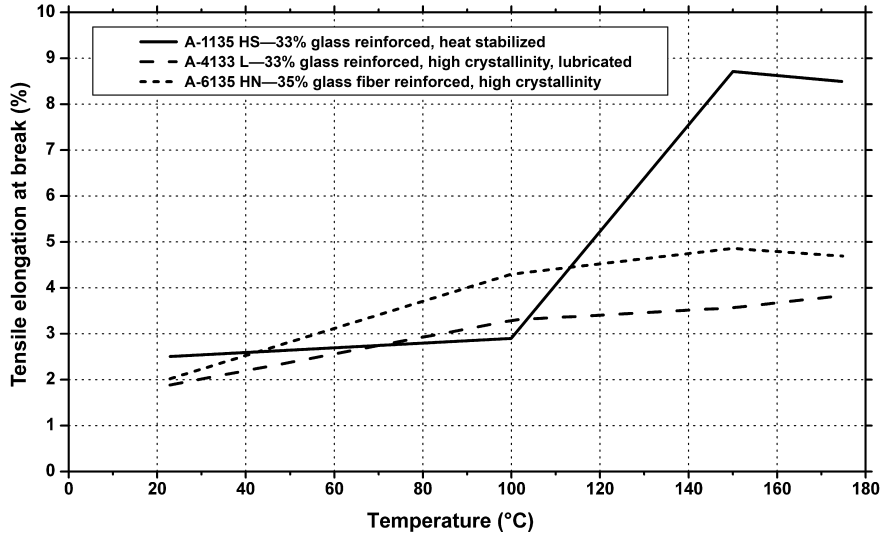

Figure 6.294 Tensile elongation at break vs. temperature for Solvay Amodel®—glass fiber reinforced PPA resins [14].

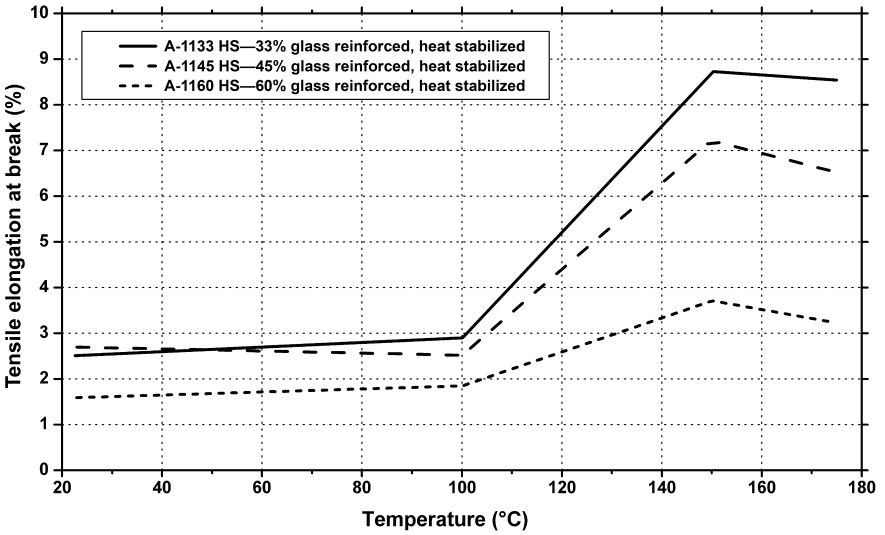

Figure 6.295 Tensile elongation at break vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

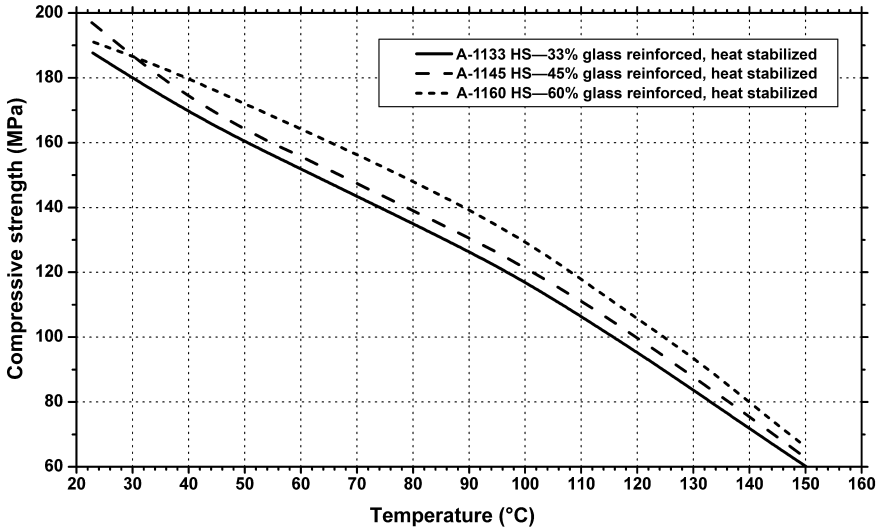

Figure 6.296 Compressive strength vs. temperature for Solvay Amodel® A-1000 series glass fiber reinforced, heat stabilized PPA resins [14].

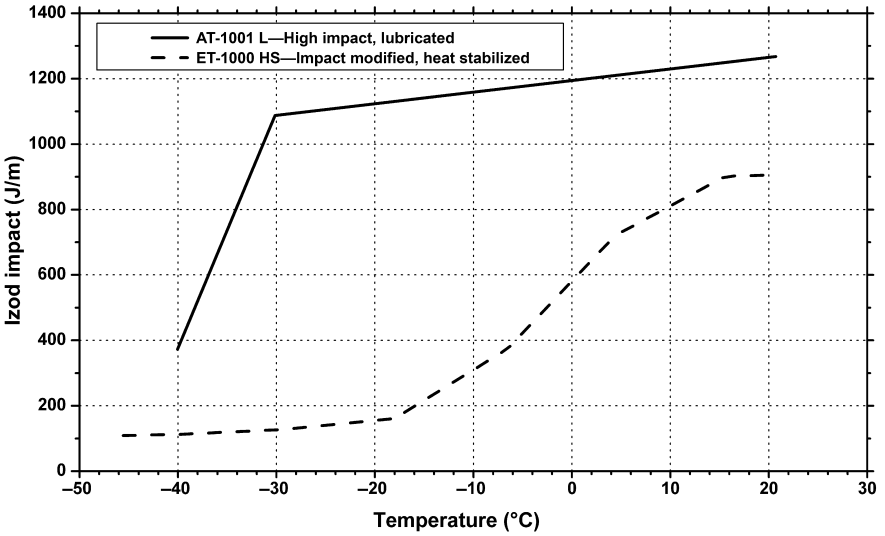

Figure 6.297 Izod impact strength vs. temperature for Solvay Amodel® PPA resins [14].

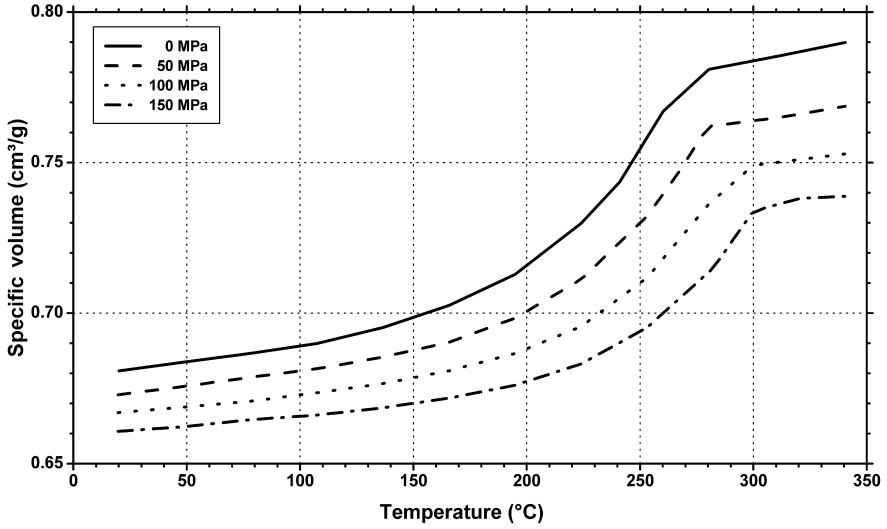

Figure 6.298 PVT for DuPont Engineering Plastics Zytel® HTN51G35HSL—35% glass reinforced, heat stabilized, lubricated PPA resins.

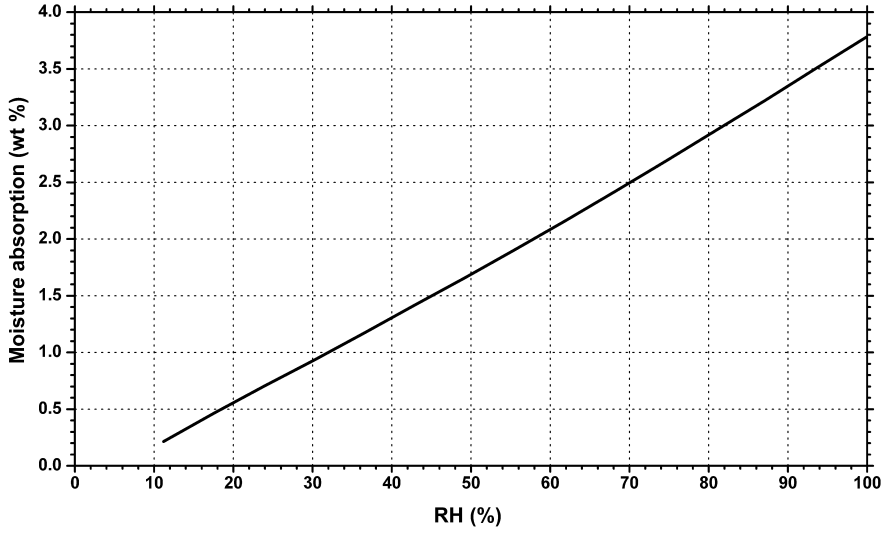

Figure 6.299 Moisture absorption vs. RH for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin [14].

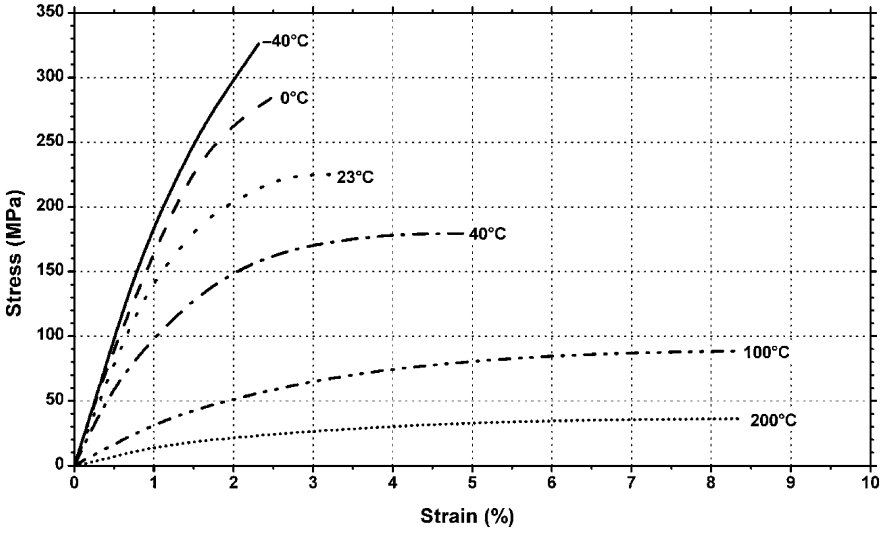

Figure 6.300 Stress vs. strain at various temperatures for EMS-Grivory Grivory® GC-4H—PA66/PPA alloy, 40% carbon fiber reinforced polyamide blend resin (conditioned).

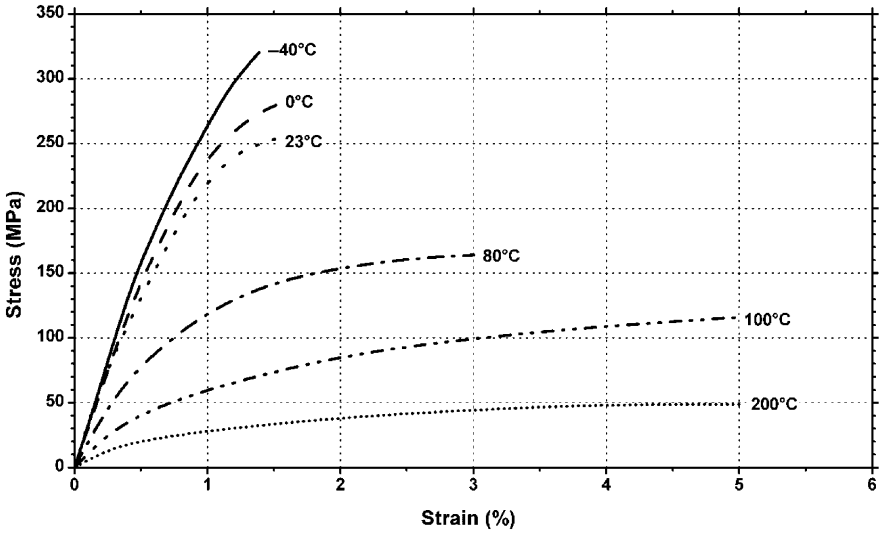

Figure 6.301 Stress vs. strain at various temperatures for EMS-Grivory Grivory® GC-4H—PA66/PPA alloy, 40% carbon fiber reinforced polyamide blend resin (DAM).

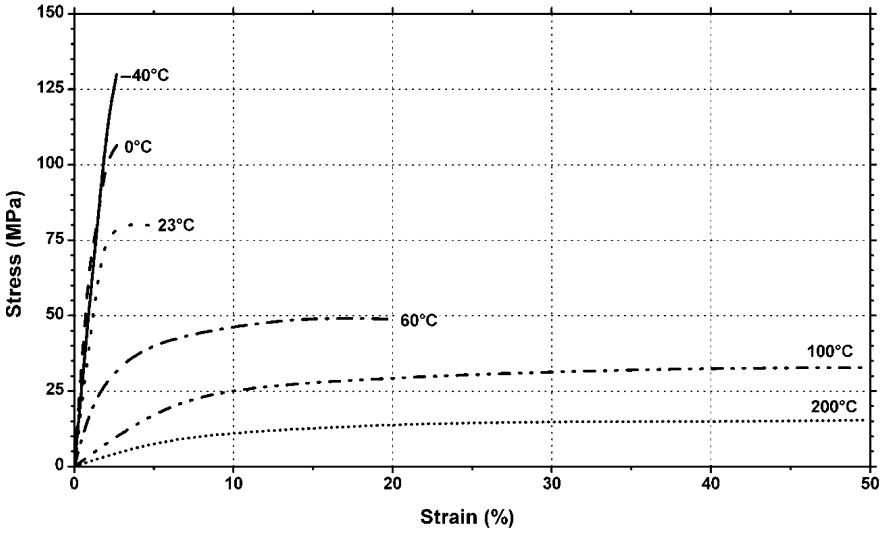

Figure 6.302 Stress vs. strain at various temperatures for EMS-Grivory Grivory® GM-4H—PA66/PPA alloy, 40% mineral reinforced polyamide blend resin (conditioned).

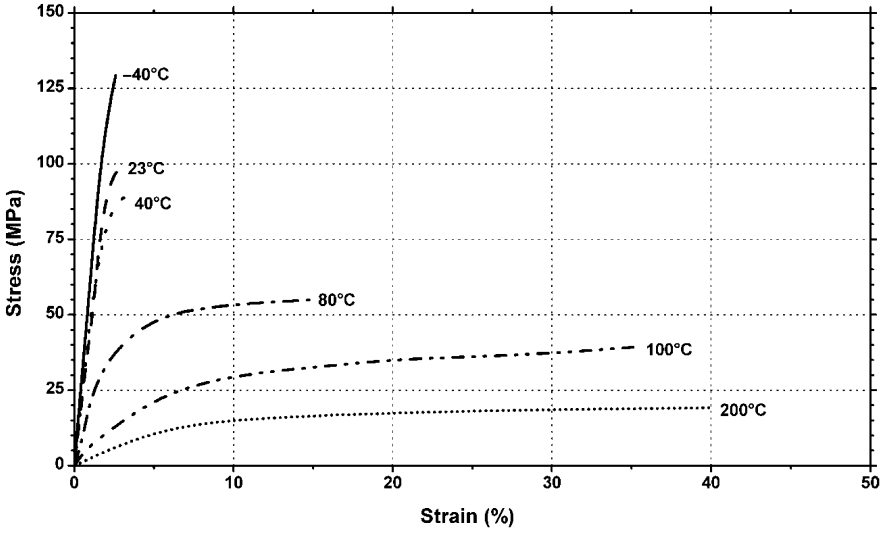

Figure 6.303 Stress vs. strain at various temperatures for EMS-Grivory Grivory® GM-4H—PA66/PPA alloy, 40% mineral reinforced polyamide blend resin (DAM).

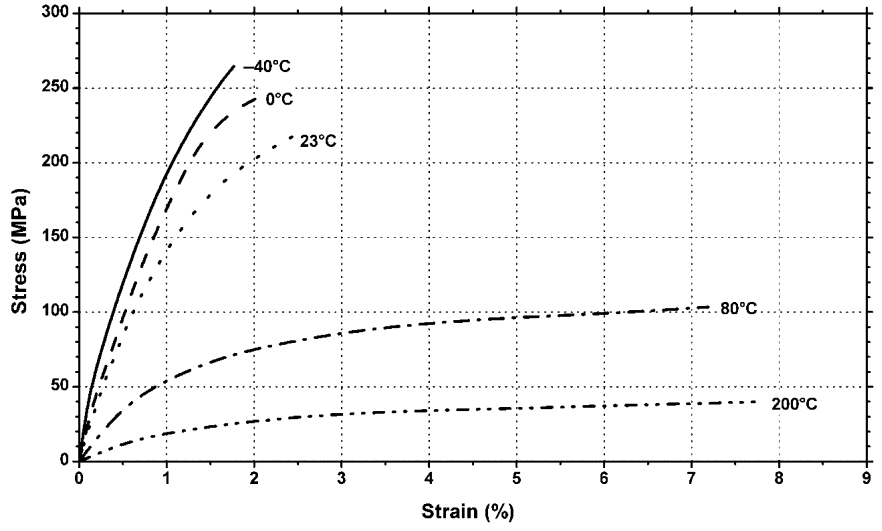

Figure 6.304 Stress vs. strain at various temperatures for EMS-Grivory Grivory® GV-5H—PA66/PPA alloy, 50% glass fiber reinforced polyamide blend resin (conditioned).

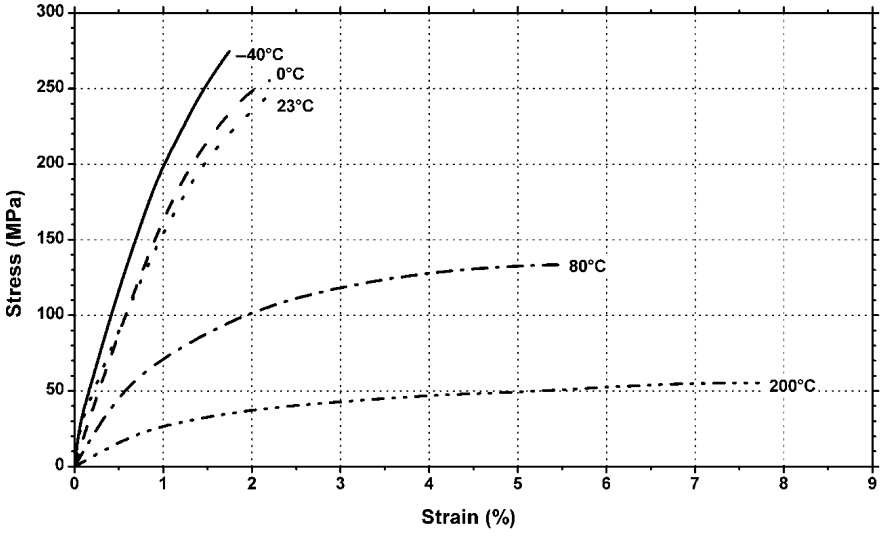

Figure 6.305 Stress vs. strain at various temperatures for EMS-Grivory Grivory® GV-5H—PA66/PPA alloy, 50% glass fiber reinforced polyamide blend resin (DAM).

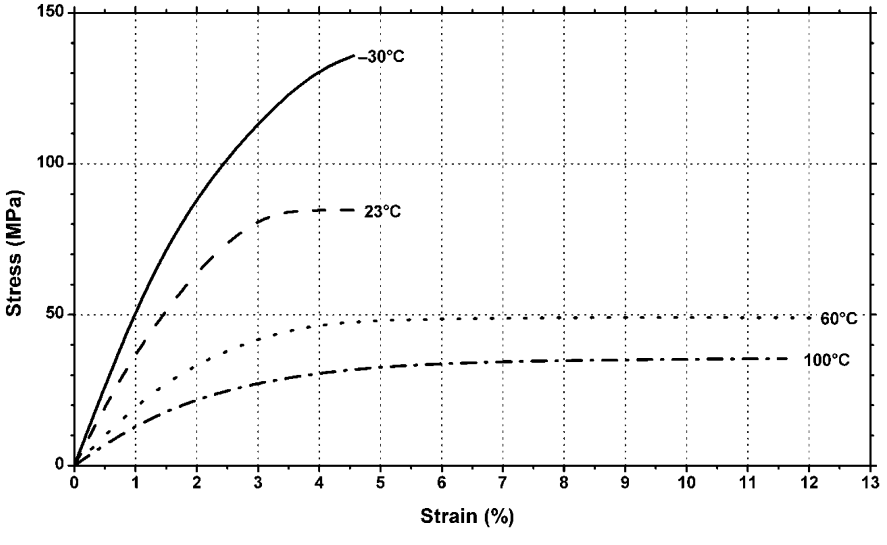

Figure 6.306 Stress vs. strain at various temperatures for Arkema Orgalloy® RS 6010—PA6 alloy, 10% glass fiber reinforced polyamide blend resin (DAM).

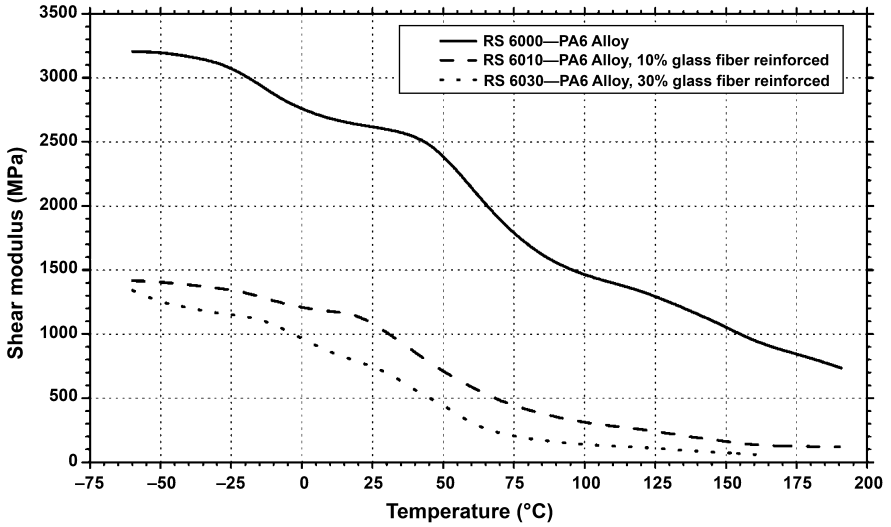

Figure 6.307 Shear modulus vs. temperature for Arkema Orgalloy® polyamide blend resins (DAM).

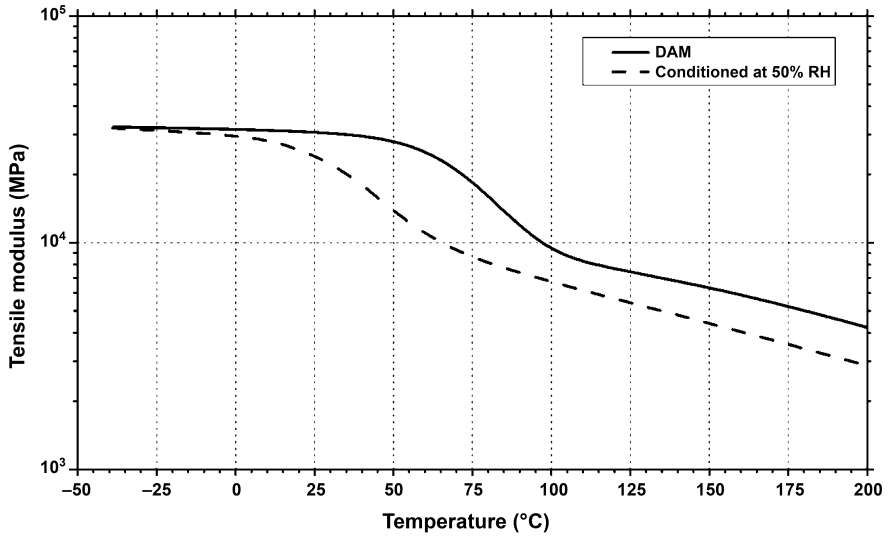

Figure 6.308 Tensile modulus vs. temperature for EMS-Grivory Grivory® GC-4H—PA66/PPA alloy, 40% carbon fiber reinforced polyamide blend resin.

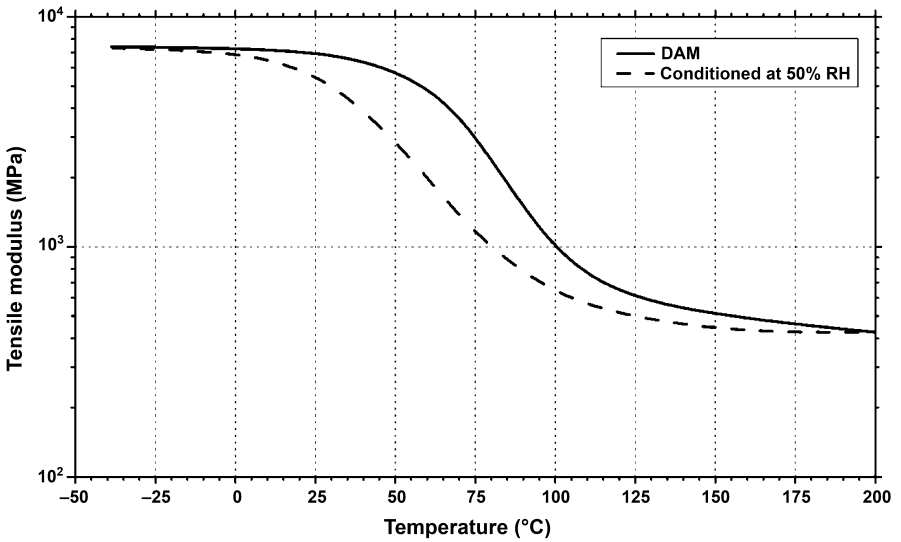

Figure 6.309 Tensile modulus vs. temperature for EMS-Grivory Grivory® GM-4H—PA66/PPA alloy, 40% mineral reinforced polyamide blend resin.

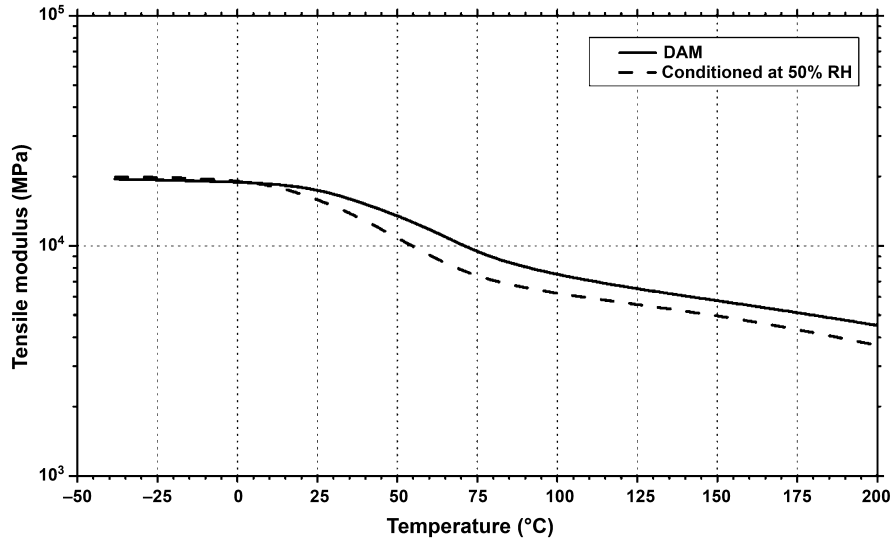

Figure 6.310 Tensile modulus vs. temperature for EMS-Grivory Grivory® GV-5H—PA66/PPA alloy, 50% glass fiber reinforced polyamide blend resin.

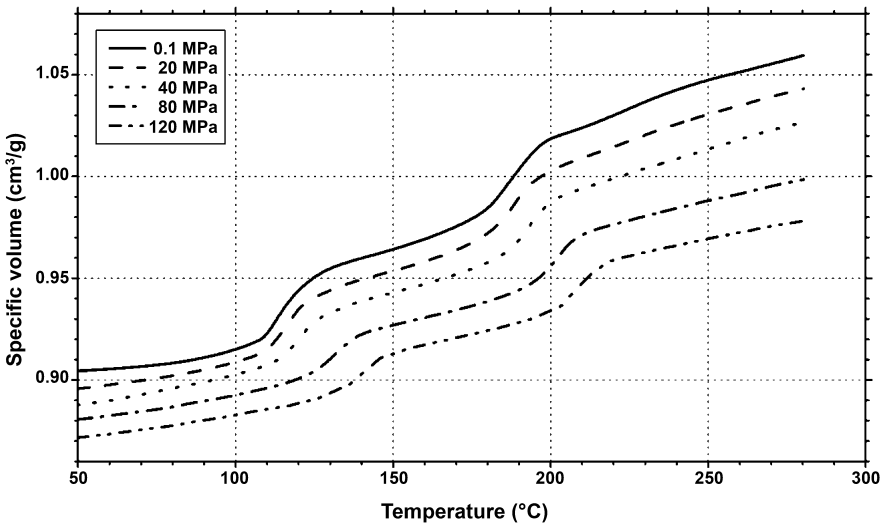

Figure 6.311 PVT for Arkema Orgalloy® RS 6010—PA6 alloy, 10% glass fiber reinforced polyamide blend resin.

6.13 Polyamide Blends and Alloys

Polyamides are often blended together and with other thermoplastics for property and cost balance.

Manufacturers and trade names: EMS-Grivory Grivory®, Arkema Orgalloy®

Data for polyamide blends and alloys are found in Figures 6.300–6.311.

References

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7 Polyolefins and Acrylics

In organic chemistry, an alkene, also called an olefin, is a chemical compound containing at least one carbon-to-carbon double bond. The simplest alkenes, with only one double bond and no other functional groups, form a homologous series of hydrocarbons with the general formula C_nH_{2n}. The two simplest alkenes of this series are ethylene and propylene. When these are polymerized, they form polyethylene (PE) and polypropylene (PP), which are two types of the plastics discussed in this chapter. A slightly more complex alkene is 4-methylpentene-1, the basis of polymethylpentene, known under the trade name of TPX™. If one of the hydrogens on the ethylene molecule is changed to chlorine, the molecule is called vinyl chloride, the basis of polyvinyl chloride, commonly called PVC. Acrylic polymers are also polymerized through the carbon−carbon double bond. Methyl methacrylate is the monomer used to make polymethyl methacrylate (PMMA).

The structures of these monomers are shown in Figure 7.1 with polymer structures shown in Figure 7.2.

7.1 Polyethylene (PE)

PE can be made in a number of ways. The way it is produced can affect its physical properties. It can also have very small amounts of comonomers, which will alter its structure and properties.

The basic types or classifications of PE, according the ASTM D1248-12 Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable, are:

- Ultra low density polyethylene (ULDPE)—Polymers with densities ranging from 0.890 to 0.905 g/cm^3, contain comonomer
- Very low density polyethylene (VLDPE)—Polymers with densities ranging from 0.905 to 0.915 g/cm^3, contain comonomer
- Linear low density polyethylene (LLDPE)—Polymers with densities ranging from 0.915 to 0.935 g/cm^3, contain comonomer (often a copolymer with butane (C4), hexane (C6), or octane (C8), when made with a metallocene catalyst designated as mLLDPE)
- Low density polyethylene (LDPE)—Polymers with densities ranging from about 0.915 to 0.935 g/cm^3
- Medium-density polyethylene (MDPE)—Polymers with densities ranging from 0.926 to 0.940 g/cm^3, may or may not contain comonomer
- High density polyethylene (HDPE)—Polymers with densities ranging from 0.940 to 0.970 g/cm^3, may or may not contain comonomer.

Additionally ultra high molecular weight polyethylene (UHMWPE) typically has a molecular weight 10 times that of HDPE.

Figure 7.3 shows the differences graphically. The differences in the branches in terms of number and length affect the density and melting points of some types.

Branching affects the crystallinity. A diagram of a representation of the crystal structure of PE is shown in Figure 7.3. One can imagine how branching in the polymer chain can disrupt the crystalline regions. The crystalline regions are the highly ordered areas in the shaded rectangles of Figure 7.4. A high degree of branching would reduce the size of the crystalline regions, which leads to lower crystallinity.

Manufacturers and trade names: Dow Chemical Dowlex®; Exopack Sclairfilm®; DuPont Tyvek®; LyondellBasell Alathon®, Petrothene®; ExxonMobil Paxon™, Pax-Plus™, Exceed™; Chevron Philips Marlex®; NOVA Chemicals Sclair®.

Uses and applications: packaging including films, bottles, water pipes, hip and knee replacements, toys.

Data for PE plastics are shown in Figures 7.5−7.23.

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
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7.2 Polypropylene (PP)

The three main types of PP generally available are:

1. *Homopolymers* are made in a single reactor with propylene and catalyst. It is the stiffest of the three propylene types and has the highest tensile strength at yield. In the natural state (no colorant added) it is translucent and has excellent see through or contact clarity with liquids. In comparison to the other two types it has less impact resistance, especially below 0°C.
2. *Random copolymers* (homophasic copolymers) are made in a single reactor with a small amount of ethylene (<5%) added which disrupts the crystallinity of the polymer allowing this type to be the clearest. It is also the most flexible with the lowest tensile strength of the three. It has better room temperature impact than homopolymer but shares the same relatively poor impact resistance at low temperatures.
3. *Impact copolymers* (heterophasic copolymers), also known as block copolymers, are made in a two reactor system where the homopolymer matrix is made in the first reactor and then transferred to the second reactor where ethylene and propylene are polymerized to create ethylene propylene rubber (EPR) in the form of microscopic nodules dispersed in the homopolymer matrix phase. These nodules impart impact resistance both at ambient and cold temperatures to the compound. This type has intermediate stiffness and tensile strength and is quite cloudy. In general, the more ethylene monomer added, the greater the impact resistance with correspondingly lower stiffness and tensile strength.

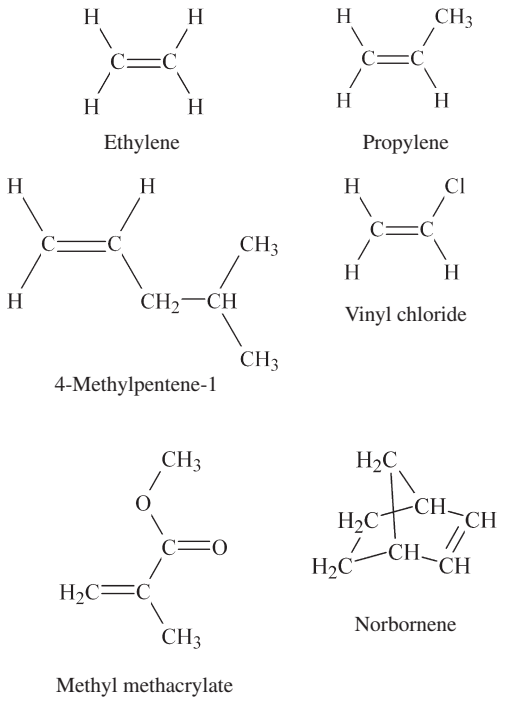

Figure 7.1 Chemical structures of monomers used to make polyolefins.

Oriented and multilayered films of PP are also common.

Manufacturers and trade names: INEOS polypropylene; LyondellBasell Adflex™; Mophen; ExxonMobil Bicor™, OPPalyte™; Dow Chemical; Flint Hill Resources.

Uses and applications: plastic hinges, RF capacitors, food containers, plastic pails, car batteries, wastebaskets, pharmacy prescription bottles, cooler containers, dishes and pitchers, carpets, rugs and mats, ropes.

Data for PP plastics are shown in Figures 7.24–7.40.

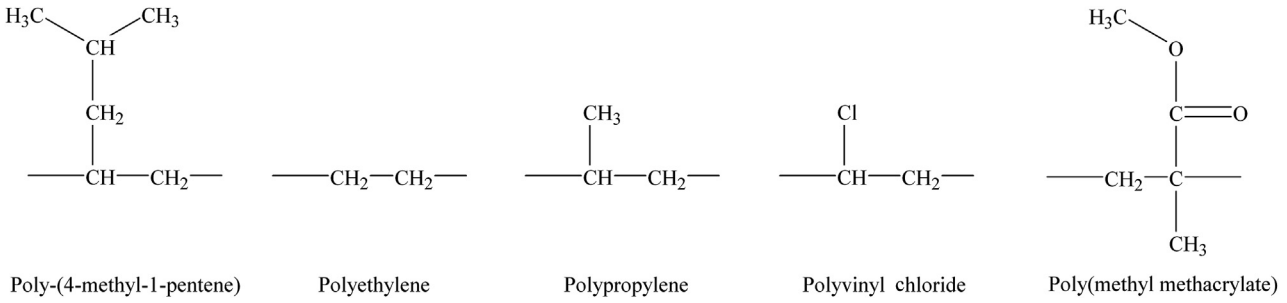

Figure 7.2 Structures of polyolefin polymers.

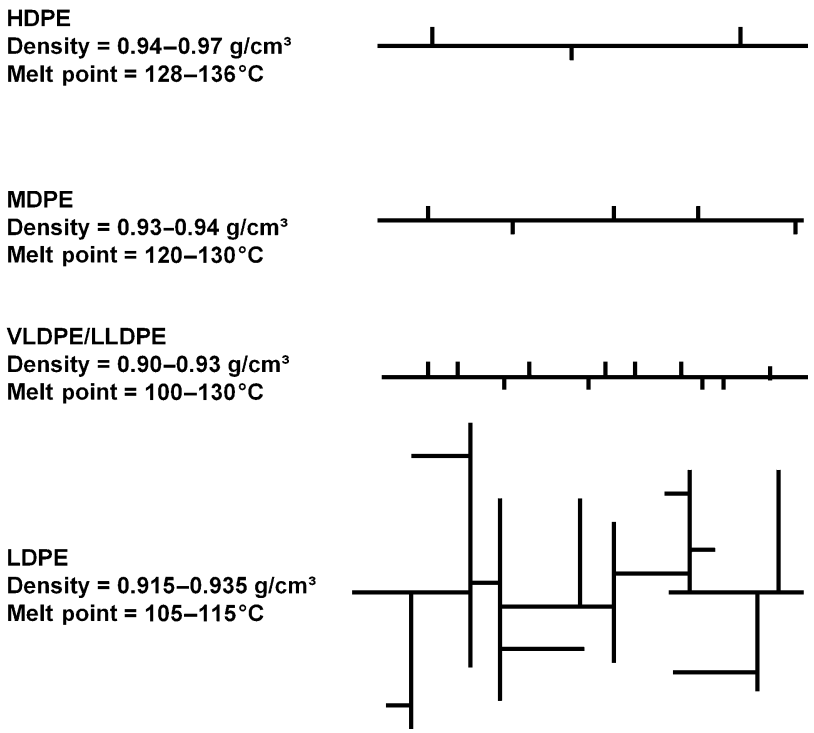

Figure 7.3 Graphical depictions of PE types.

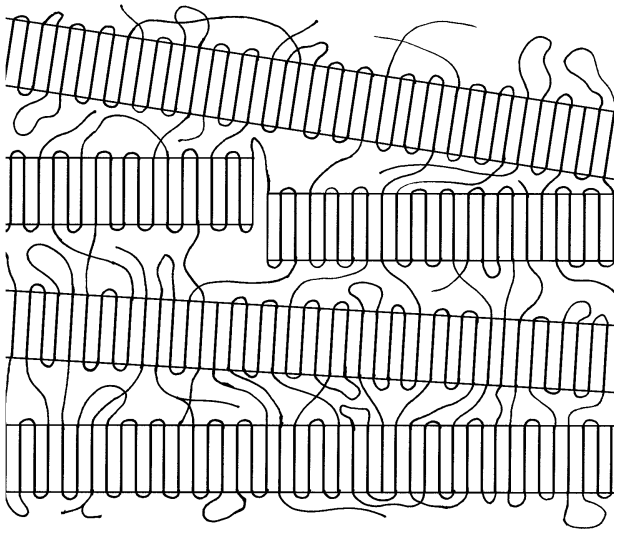

Figure 7.4 Graphical diagram of PE crystal structure.

7.3 Polymethylpentene (PMP)

4-Methylpentene-1 based polyolefin is a lightweight, functional polymer that displays a unique combination of physical properties and characteristics due to its distinctive molecular structure, which includes a bulky side chain as shown in Figure 7.41. Its CAS number is 89-25-8.

PMP is a crystalline polyolefin. PMP possesses many characteristics inherent in traditional polyolefins, such as excellent electrical insulating properties and strong hydrolysis resistance. Moreover:

- PMP has high heat resistance with a melting point of 220−240°C.
- PMP has excellent transparency; its transmittance of visible light is more than 90%. PMP has an especially high transmittance of ultraviolet light (300−400 nm).
- PMP has excellent chemical and oil resistance.
- PMP has good heat aging and steam (boiling water) resistance.
- PMP has low density, the lightest of all common plastics, so it is useful for weight alleviation.
- PMP has high electric insulation and a low dielectric constant.
- Since the surface tension of PMP is 24 dyne/cm, it has excellent nonstick character.

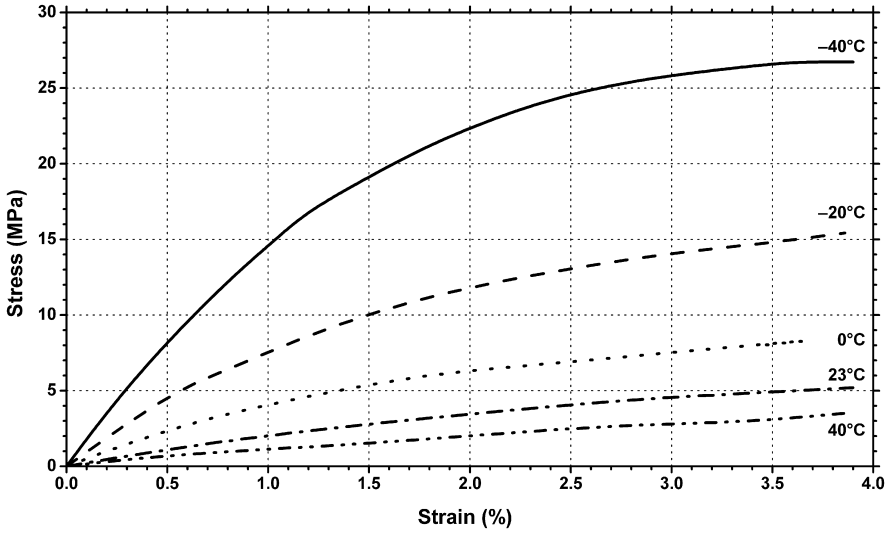

Figure 7.5 Stress vs. strain at various temperatures for Basell Polyolefins Lupolen® 1810H—low density (0.918 g/cm^3), MFR 1.5 g/10 min PE resin.

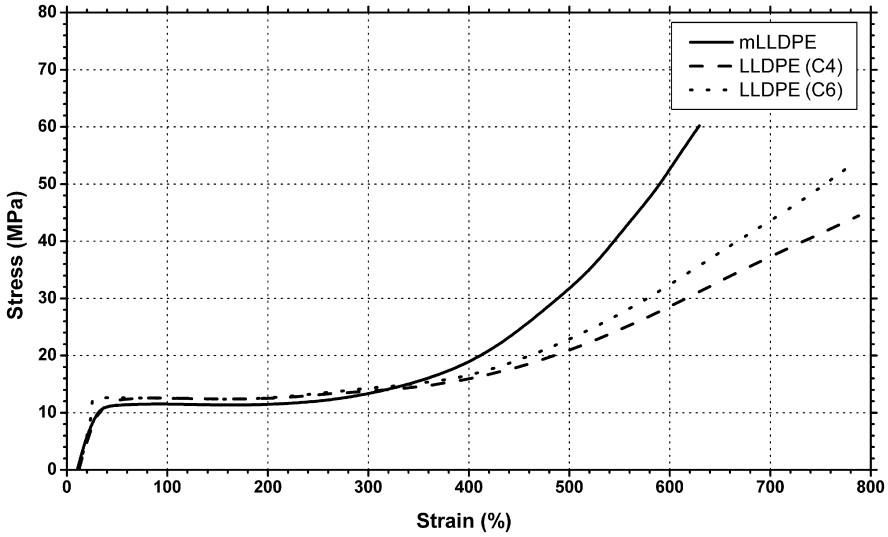

Figure 7.6 Tensile stress vs. strain for various LLDPEs.

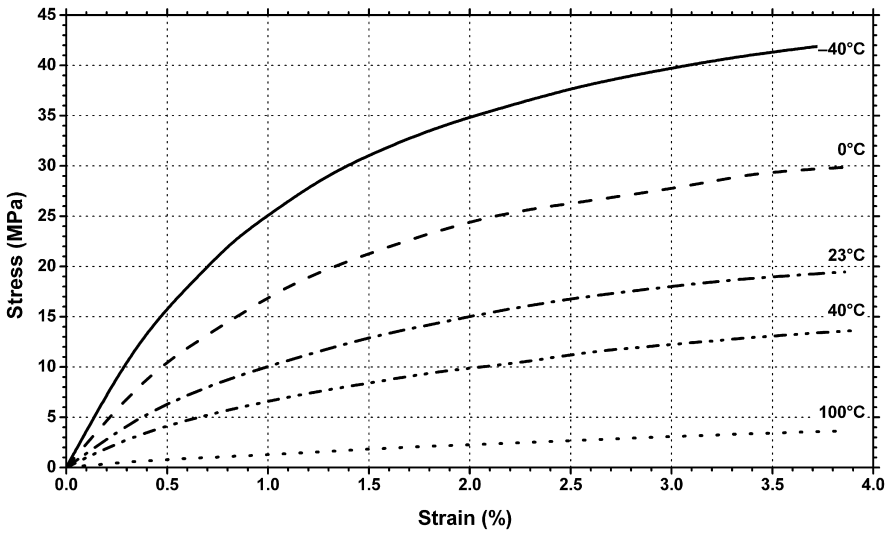

Figure 7.7 Stress vs. strain at various temperatures for Basell Polyolefins Lupolen® 5031L—high density (0.950 g/cm^3), MFR 6.5 g/10 min, stabilized PE resin.

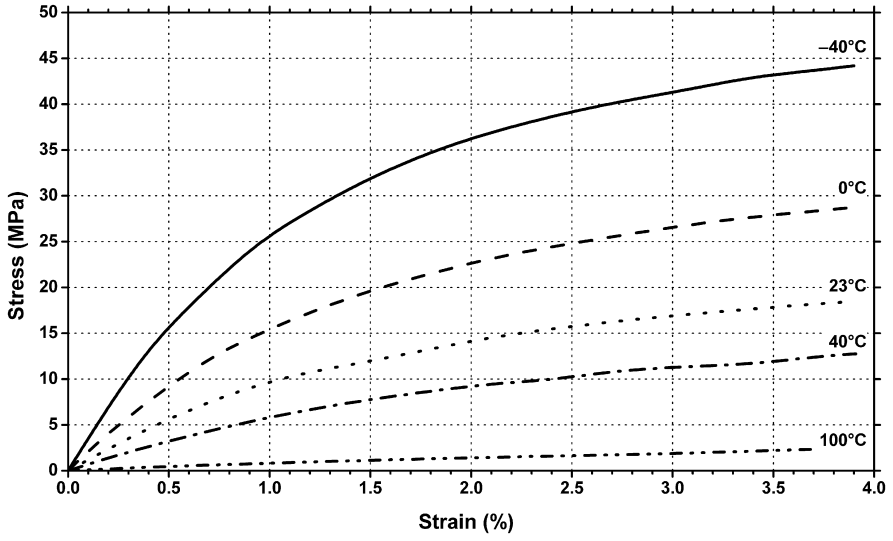

Figure 7.8 Stress vs. strain at various temperatures for Basell Polyolefins Lupolen® 5041H—high density (0.950 g/cm^3), MFR 1.5 g/10 min, stabilized PE resin.

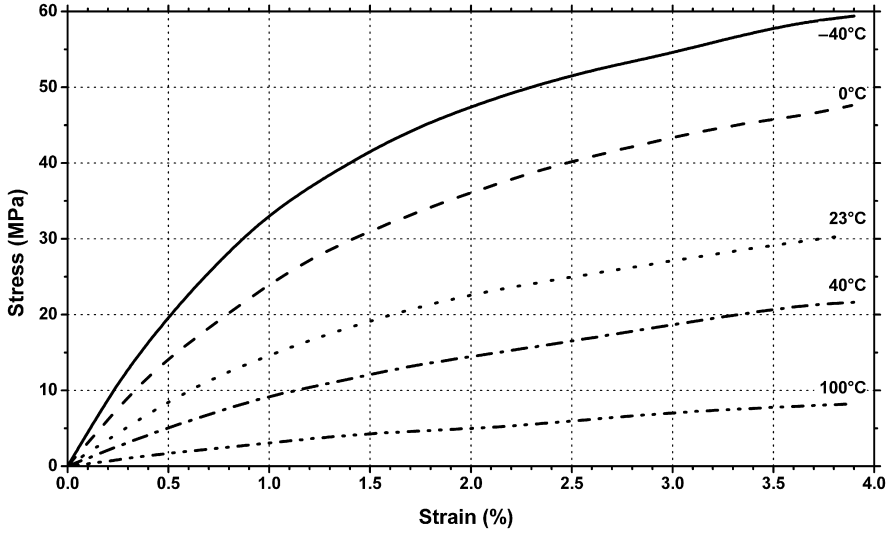

Figure 7.9 Stress vs. strain at various temperatures for Basell Polyolefins Lupolen® 5261Z—high density (0.952 g/cm^3), MFR 2 g/10 min, stabilized PE resin.

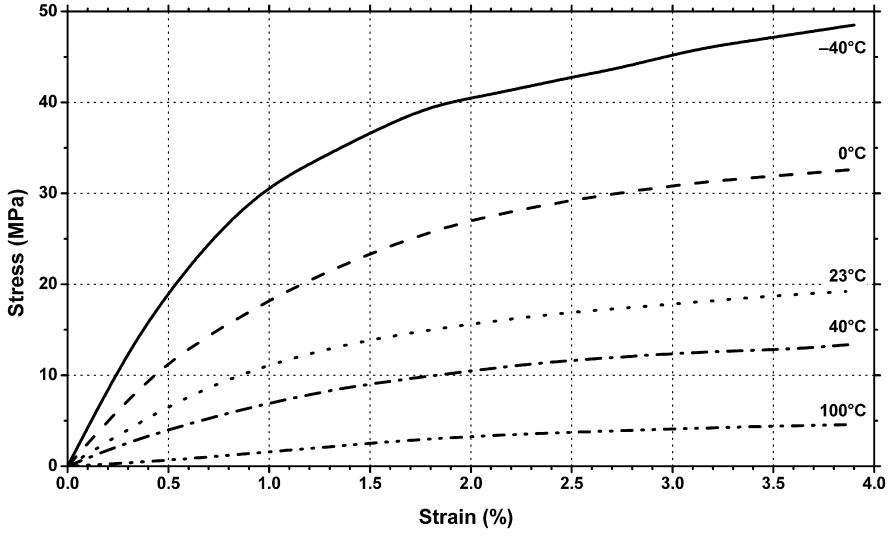

Figure 7.10 Stress vs. strain at various temperatures for Basell Polyolefins Lupolen® 6031M—high density (0.960 g/cm^3), MFR 8 g/10 min, stabilized PE resin.

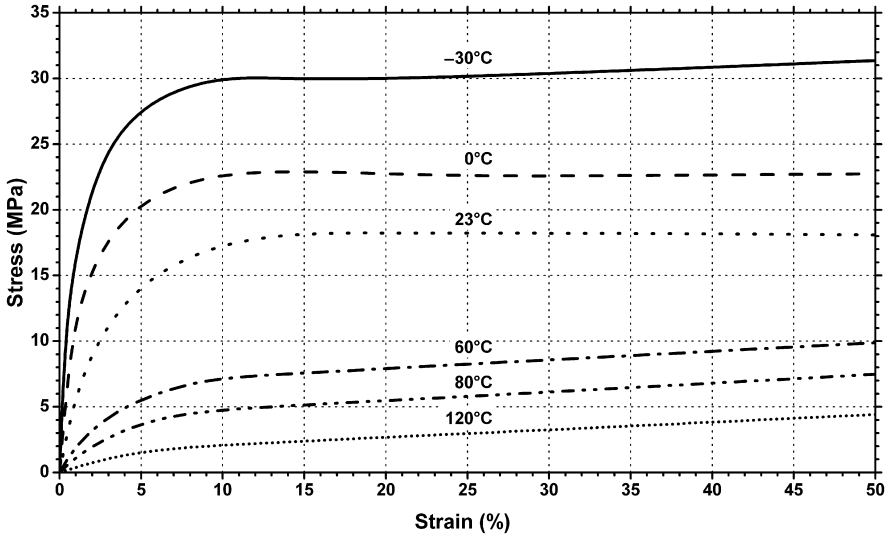

Figure 7.11 Stress–strain curves for Celanese GUR® 4120 UHMWPE measured at different temperatures [1].

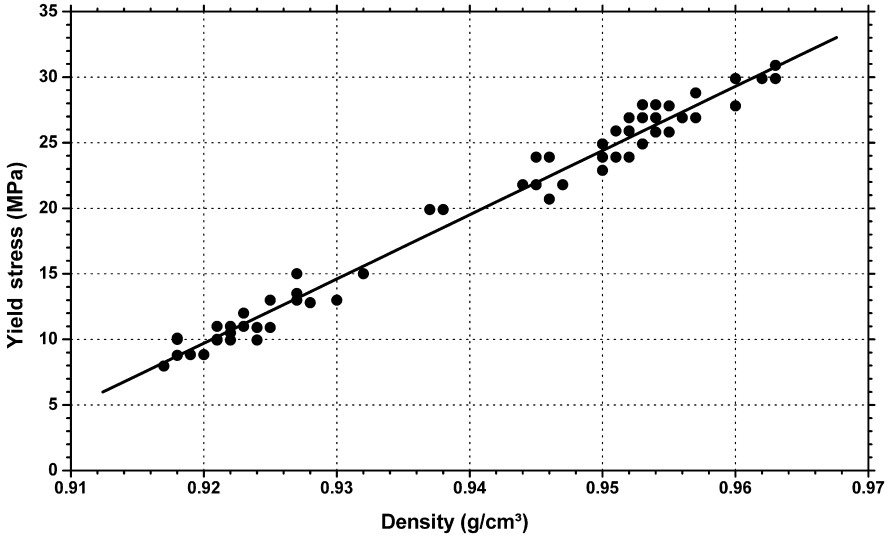

Figure 7.12 Yield stress vs. density for Basell Polyolefins PE resins [2].

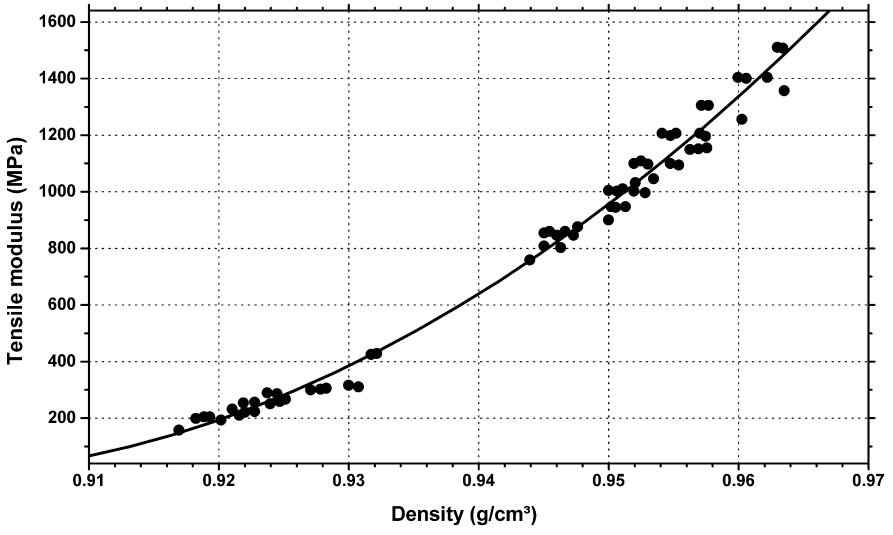

Figure 7.13 Tensile modulus vs. density for Basell Polyolefins PE resins [2].

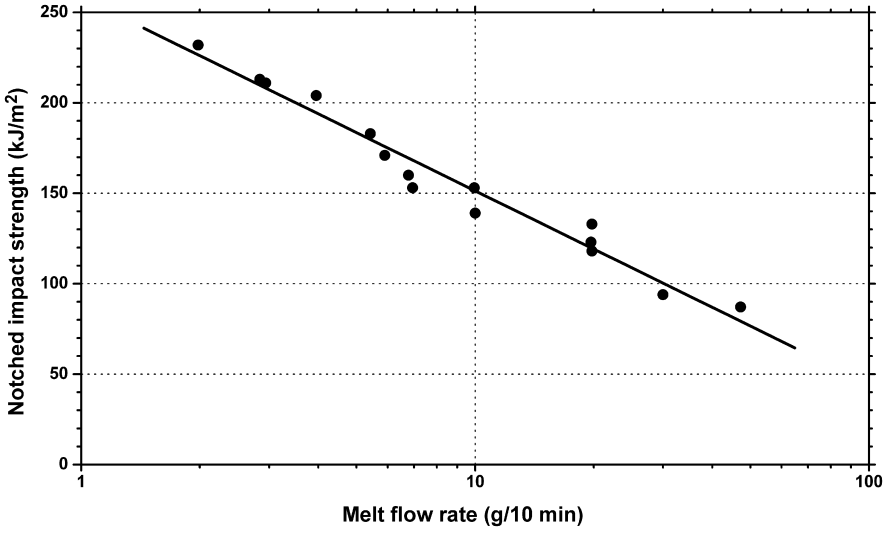

Figure 7.14 Notched tensile impact strength vs. melt flow rate (MFR) for Basell Polyolefins PE resins [2].

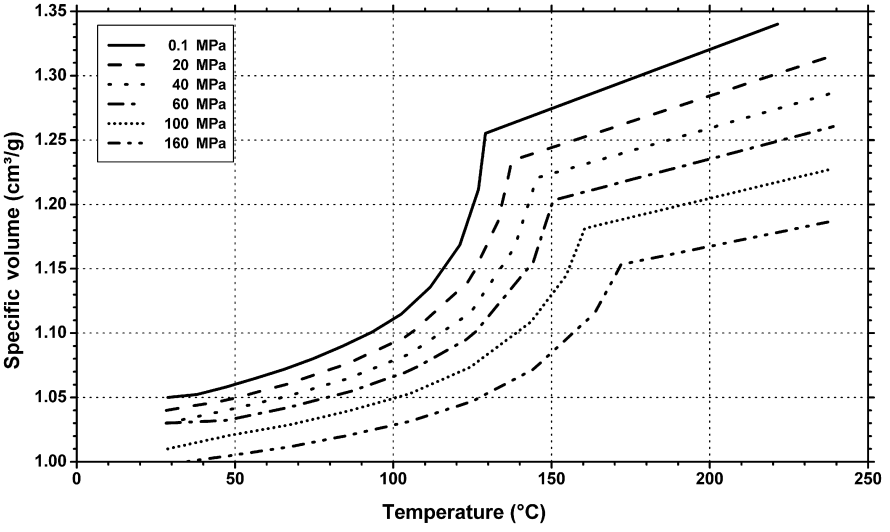

Figure 7.15 Specific volume vs. temperature and pressure (PVT) for Basell Polyolefins PE resins [2].

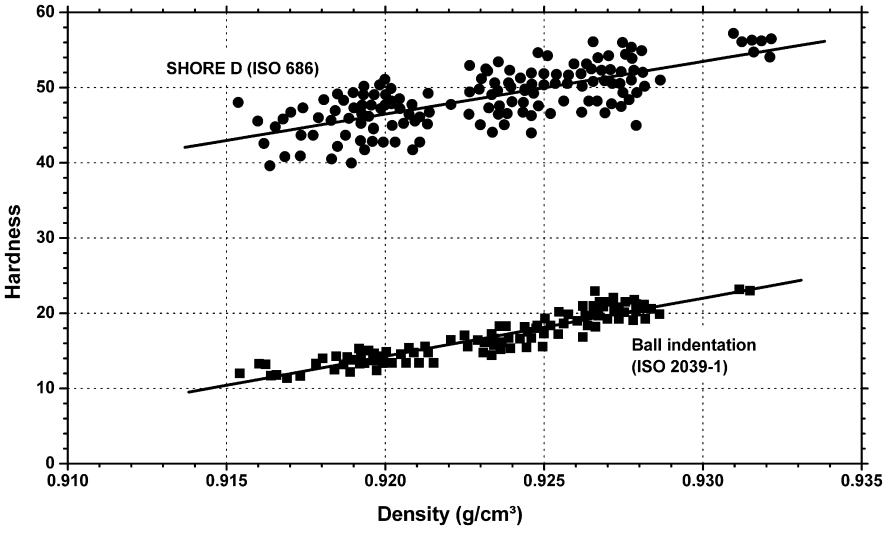

Figure 7.16 Hardness vs. density for Basell Polyolefins PE resins [2].

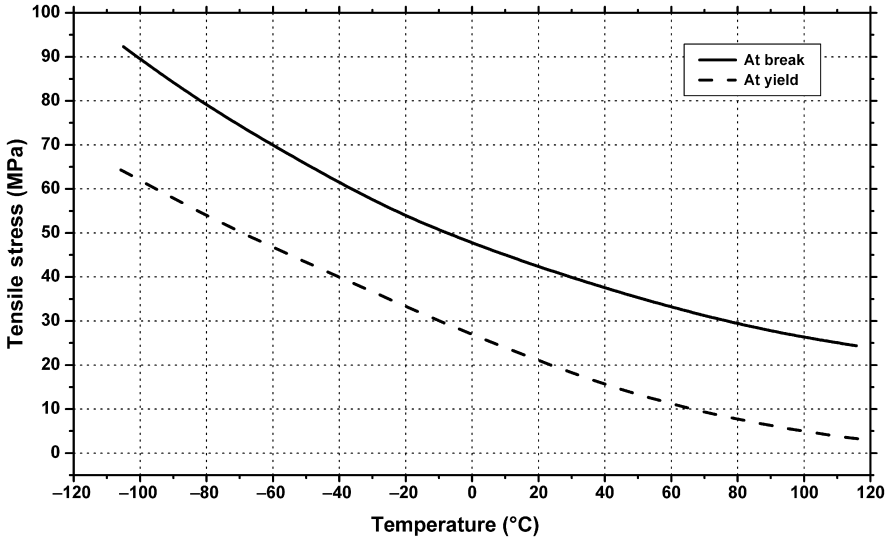

Figure 7.17 Tensile strength vs. temperature for Ticona ultra high molecular weight PE resin [1].

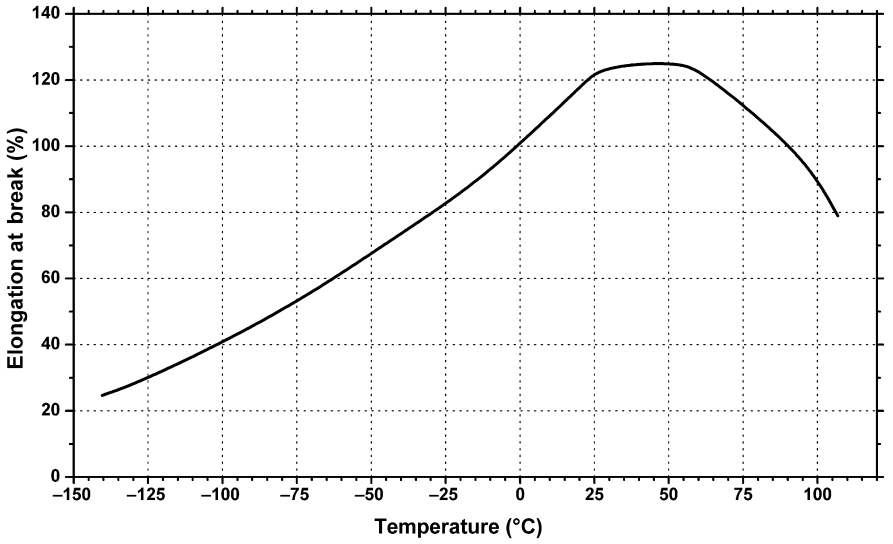

Figure 7.18 Elongation at break vs. temperature for Ticona ultra high molecular weight PE resin [1].

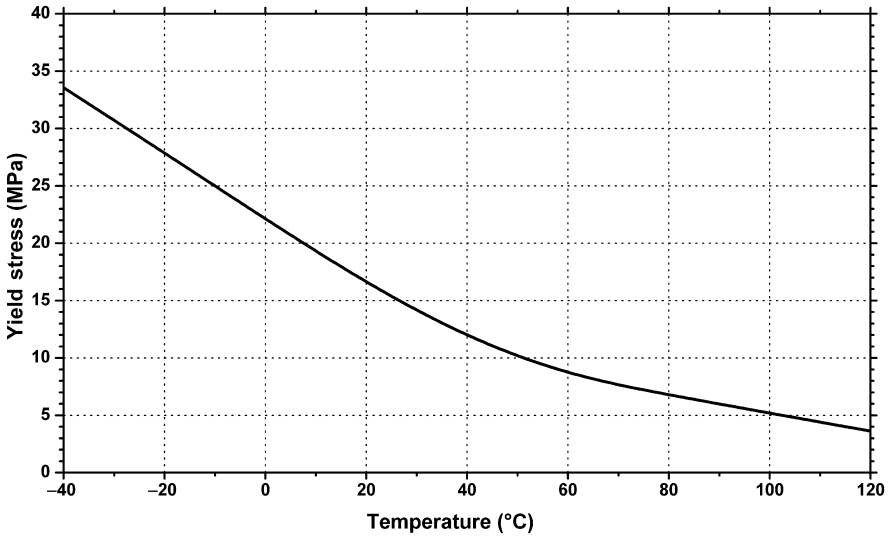

Figure 7.19 Yield stress vs. temperature for Ticona GUR® 4120—high bulk density, corrosion stabilized ultra high molecular weight PE resin [1].

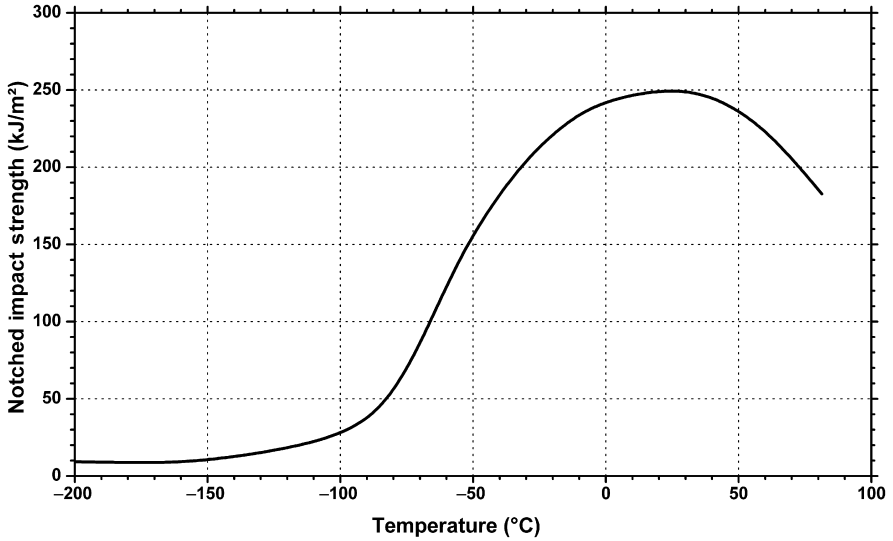

Figure 7.20 Notched Charpy impact strength vs. temperature for Ticona GUR® 4120—high bulk density, corrosion stabilized ultra high molecular weight PE resin [1].

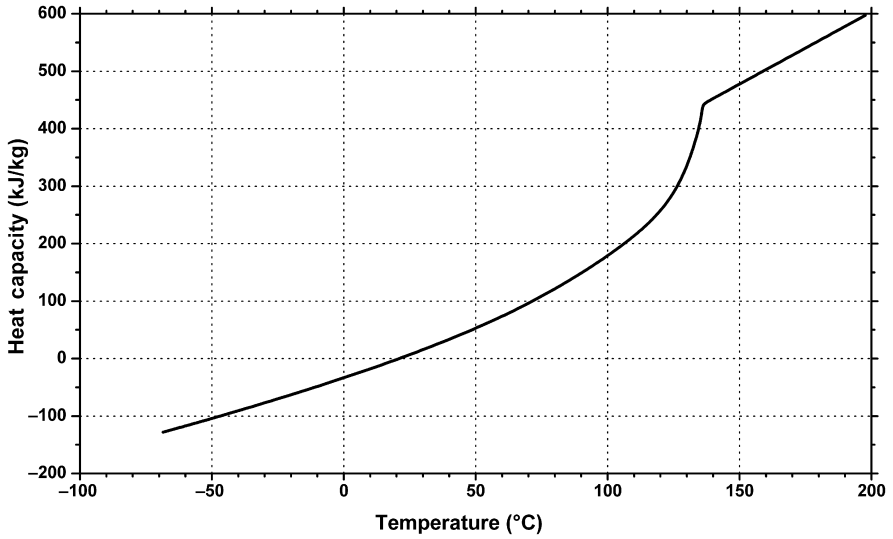

Figure 7.21 Heat capacity (enthalpy) vs. temperature for Ticona GUR® ultra high molecular weight PE resin [1].

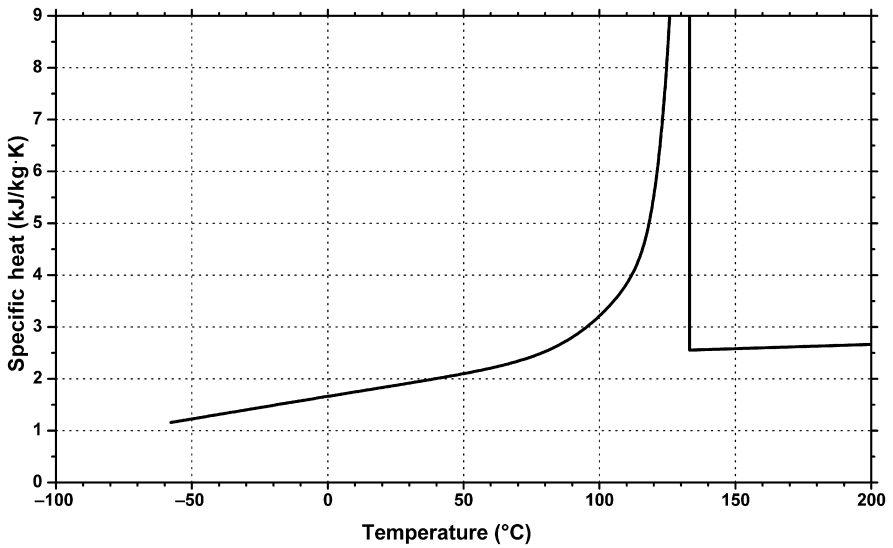

Figure 7.22 Specific heat vs. temperature for Ticona GUR® ultra high molecular weight PE resin [1].

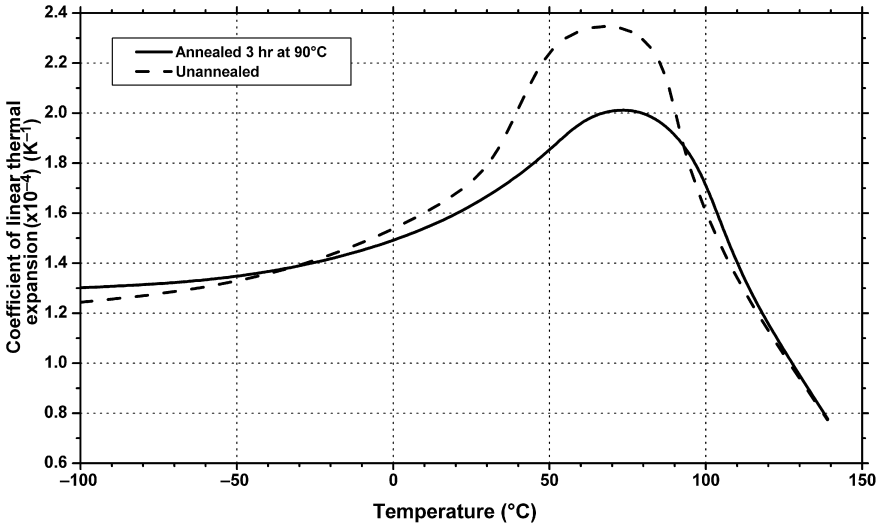

Figure 7.23 Coefficient of linear thermal expansion vs. temperature for Ticona GUR® 4120—high bulk density, corrosion stabilized ultra high molecular weight PE resin [1].

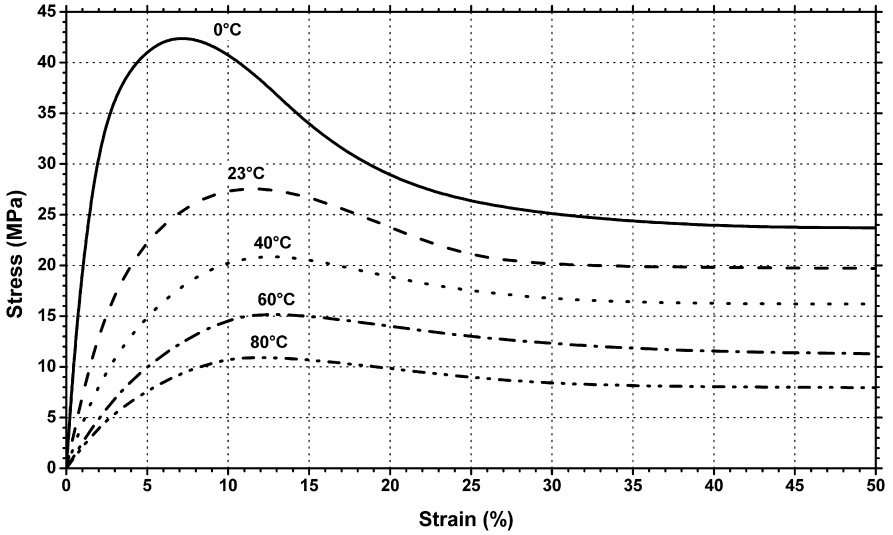

Figure 7.24 Stress vs. strain at various temperatures for Basell Polyolefins Hostalen® H1022—easy flow, high impact PP resin [3].

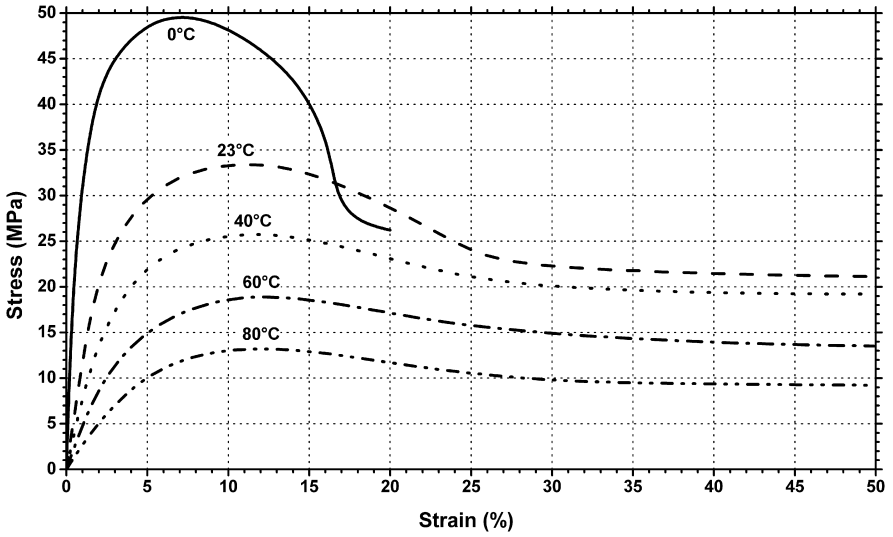

Figure 7.25 Stress vs. strain at various temperatures for Basell Polyolefins Hostalen® H2250—easy flow, high heat PP resin [3].

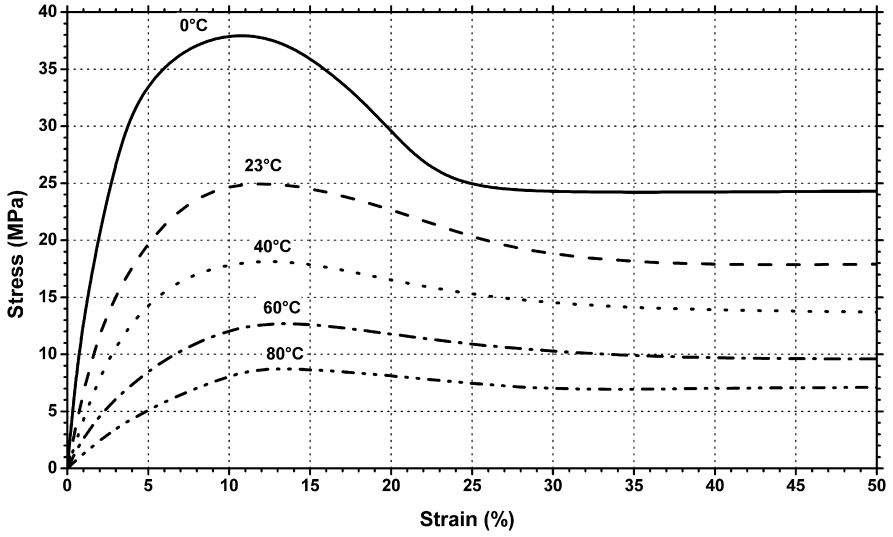

Figure 7.26 Stress vs. strain at various temperatures for Basell Polyolefins Hostalen® H5216—easy flow, random copolymer PP resin [3].

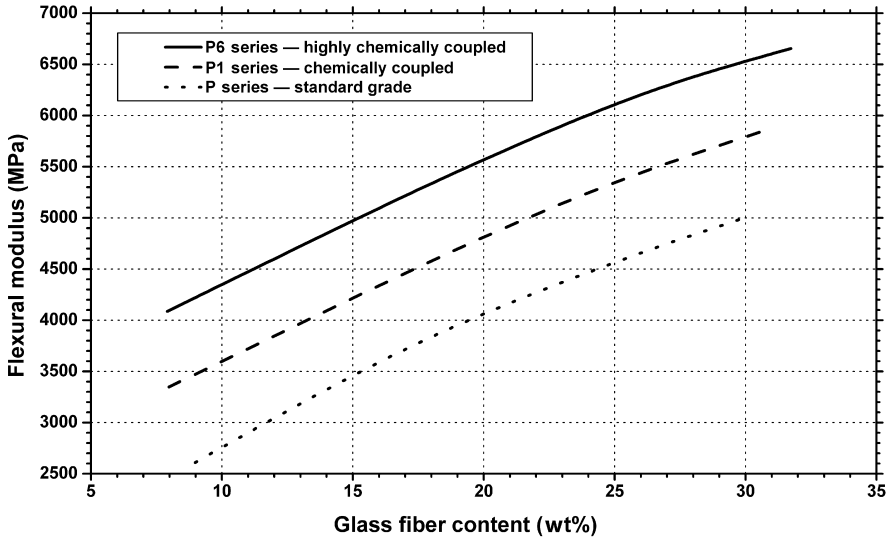

Figure 7.27 Flexural modulus at 23°C vs. glass fiber content for Asahi Kasei Thermylene® PP resins.

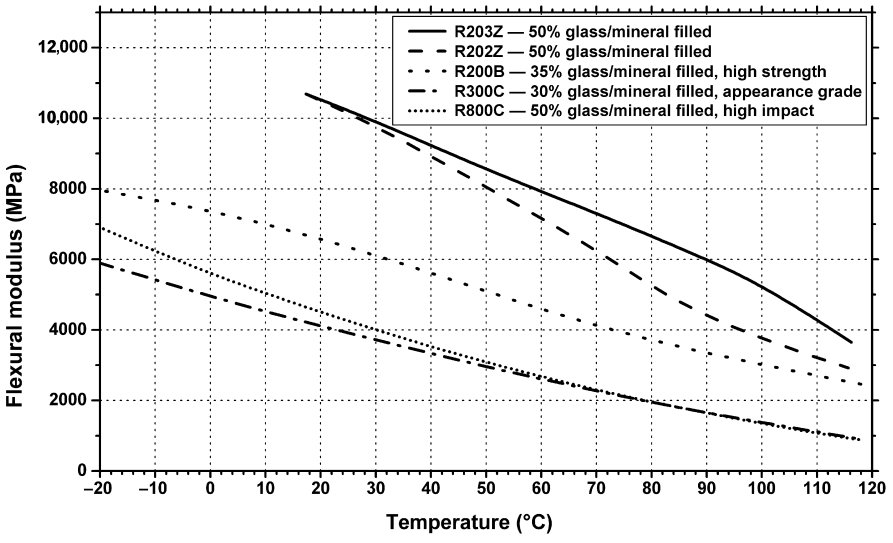

Figure 7.28 Flexural modulus vs. temperature for Chisso America Olehard® glass and mineral-filled PP resins.

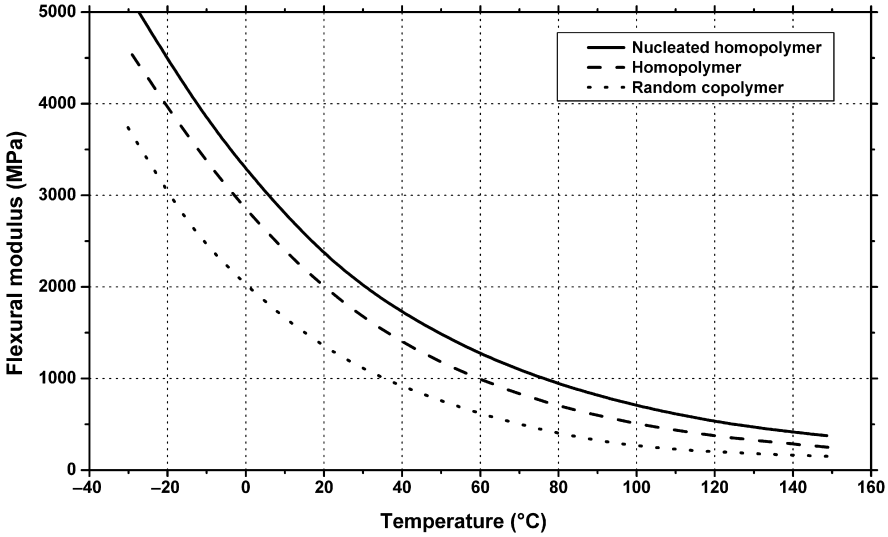

Figure 7.29 Flexural modulus vs. temperature for Chevron Phillips Chemical Marlex® PP resins.

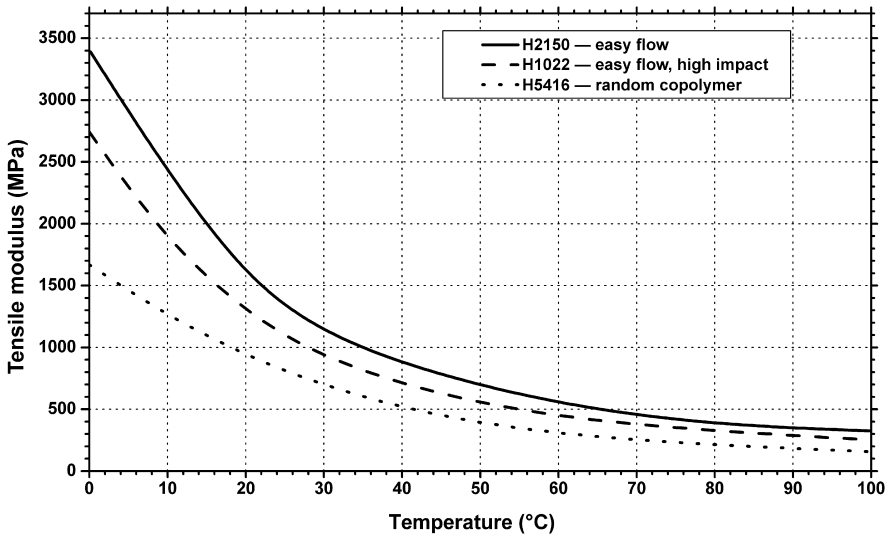

Figure 7.30 Tensile modulus vs. temperature for Basell Polyolefins Hostalen® PP resins [3].

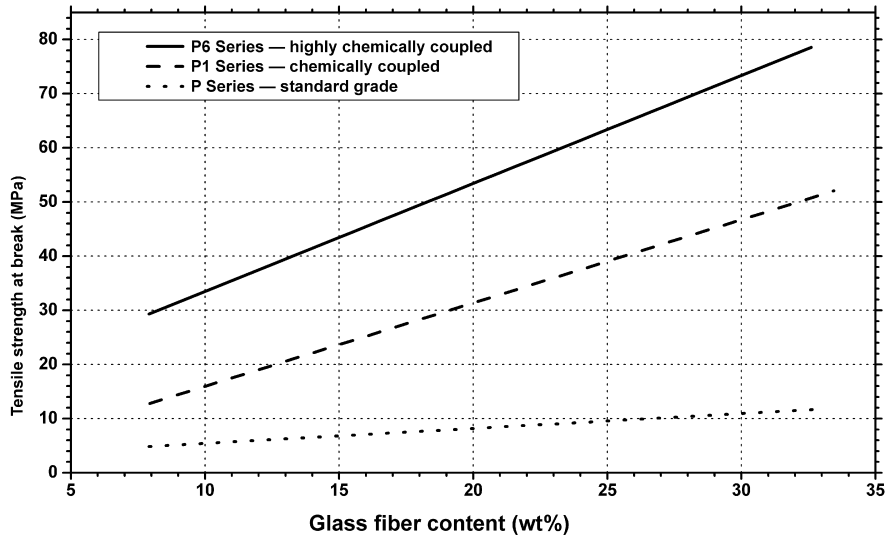

Figure 7.31 Tensile strength at break vs. glass fiber content at 23°C for Asahi Kasei Thermylene® PP resins.

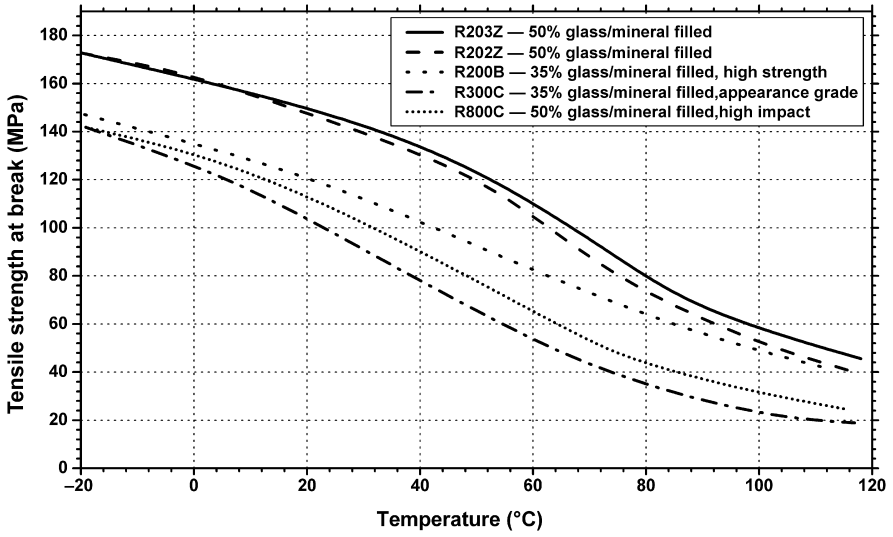

Figure 7.32 Tensile strength at break vs. temperature for Chisso America Olehard® glass and mineral-filled PP resins.

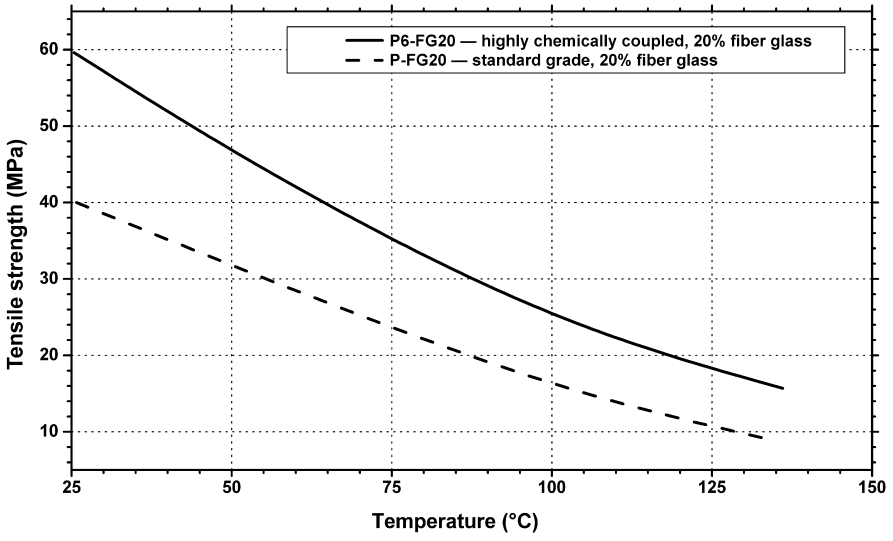

Figure 7.33 Tensile strength vs. temperature for Asahi Kasei Thermylene® PP resins.

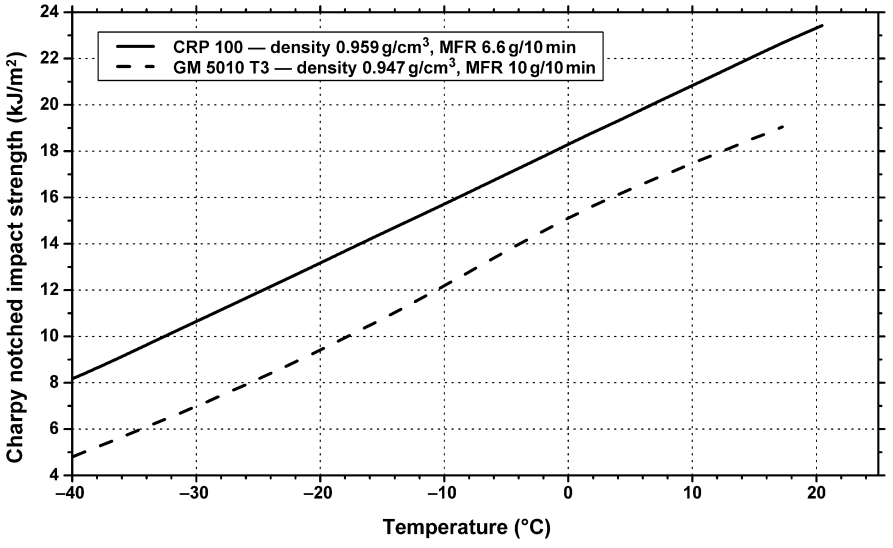

Figure 7.34 Notched Charpy impact strength vs. temperature for Basell Polyolefins Hostalen® PP resins [3].

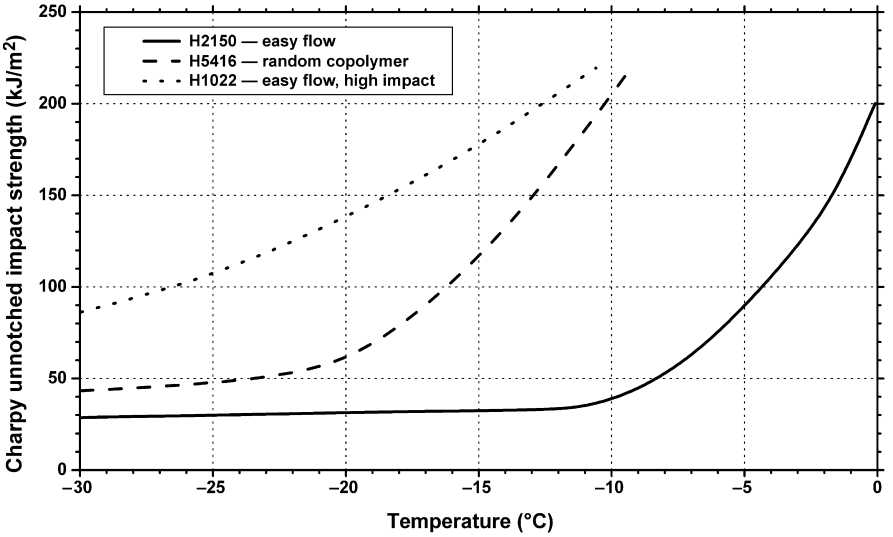

Figure 7.35 Notched Charpy impact strength vs. temperature for Basell Polyolefins Hostalen® PP resins [3].

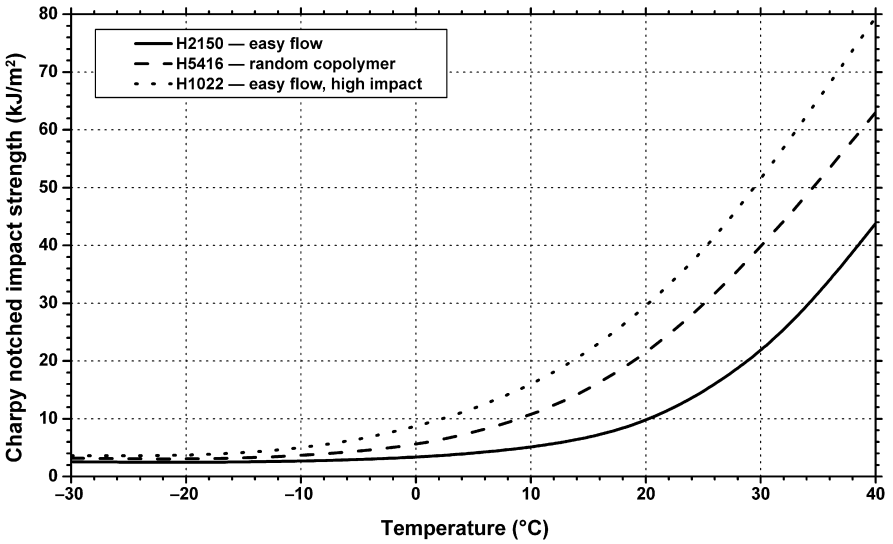

Figure 7.36 Notched Charpy impact strength vs. temperature for Basell Polyolefins Hostalen® PP resins [3].

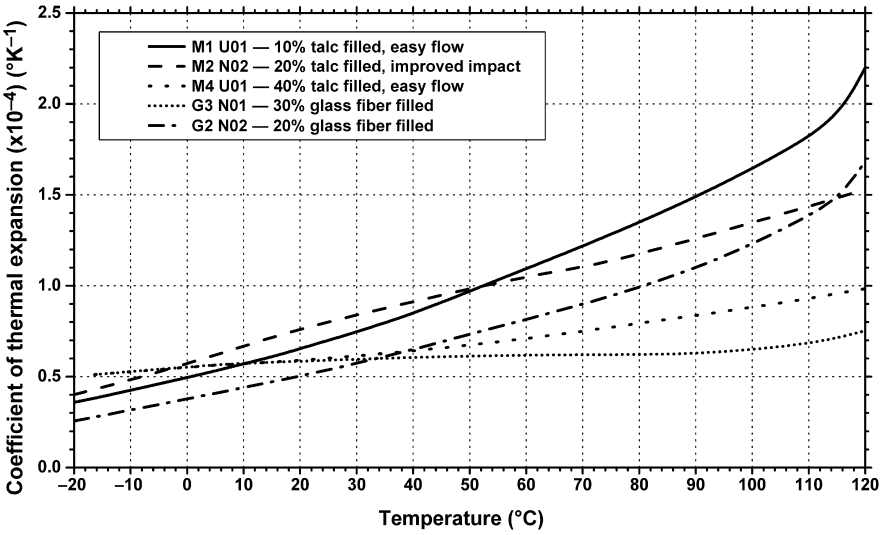

Figure 7.37 Coefficient of thermal expansion (in flow direction) vs. temperature for Basell Polyolefins Hostalen® PP resins.

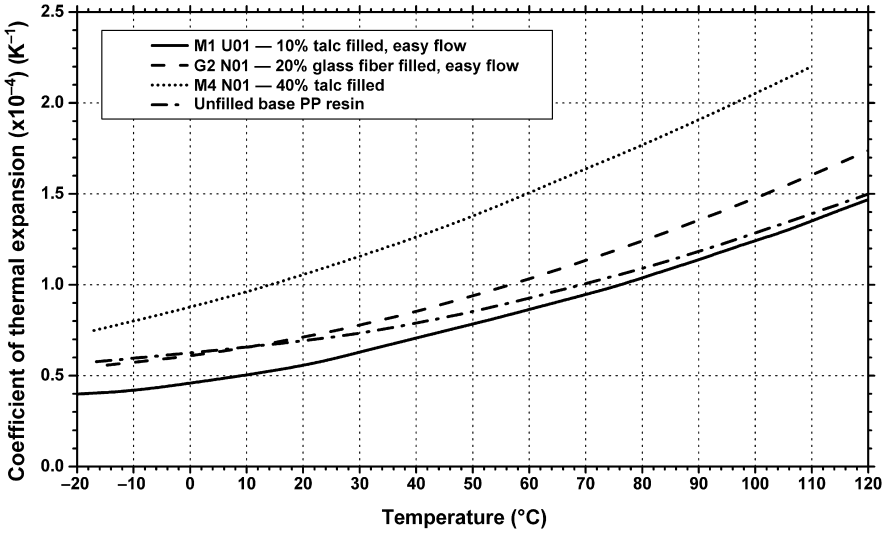

Figure 7.38 Coefficient of thermal expansion (in flow direction) vs. temperature for Basell Polyolefins Hostalen® PP resins.

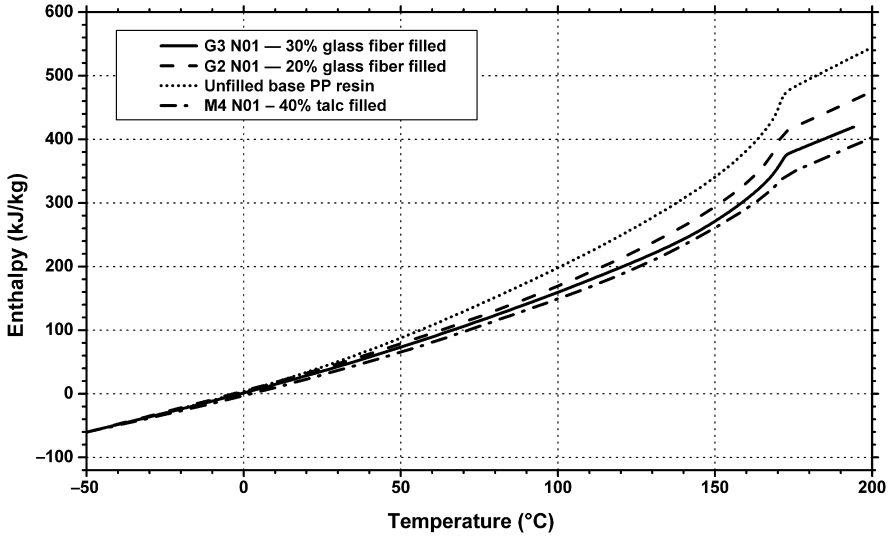

Figure 7.39 Enthalpy vs. temperature for Basell Polyolefins Hostalen® PP resins.

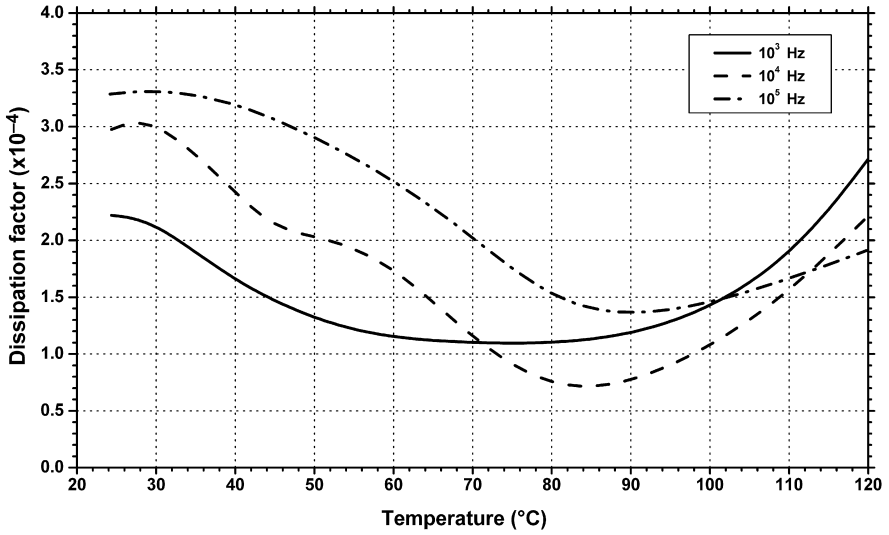

Figure 7.40 Dissipation factor vs. temperature and frequency for Basell Polyolefins Hostalen® PPN 1060 F PP resin.

Manufacturers and trade names: Mitsui Chemicals TPX™, Opulent™, Honeywell PMP; Chevron Philips Crystalor—discontinued.

Applications and uses: films, particularly release films, chemical tubing, cosmetic caps, and tubes.

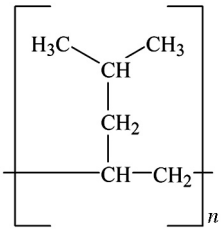

Figure 7.41 Structure of PMP.

Data for PMP plastics are shown in Figures 7.42–7.51.

7.4 Rigid Polyvinyl Chloride (PVC)

PVC is a flexible or rigid material that is chemically nonreactive. Rigid PVC is easily machined, heat formed, welded, and even solvent cemented. PVC can also be machined using standard metal working tools and finished to close tolerances and finishes without great difficulty. PVC resins are normally mixed with other additives such as impact modifiers and stabilizers, providing hundreds of PVC-based materials with a variety of engineering properties.

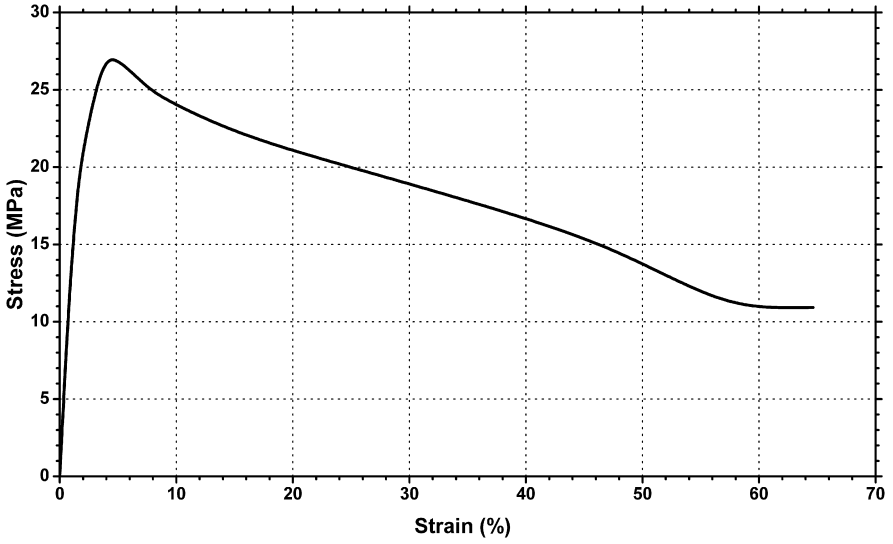

Figure 7.42 Stress vs. strain at room temperature for Ensinger Tecafine PMP [4].

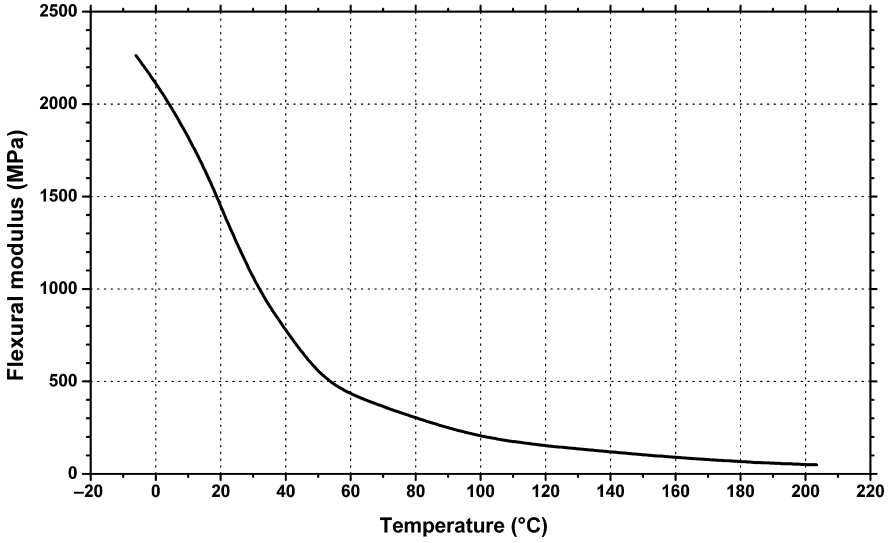

Figure 7.43 Flexural modulus vs. temperature for Mitsui Chemicals TPX™ RT18—general-purpose, unfilled PMP resin.

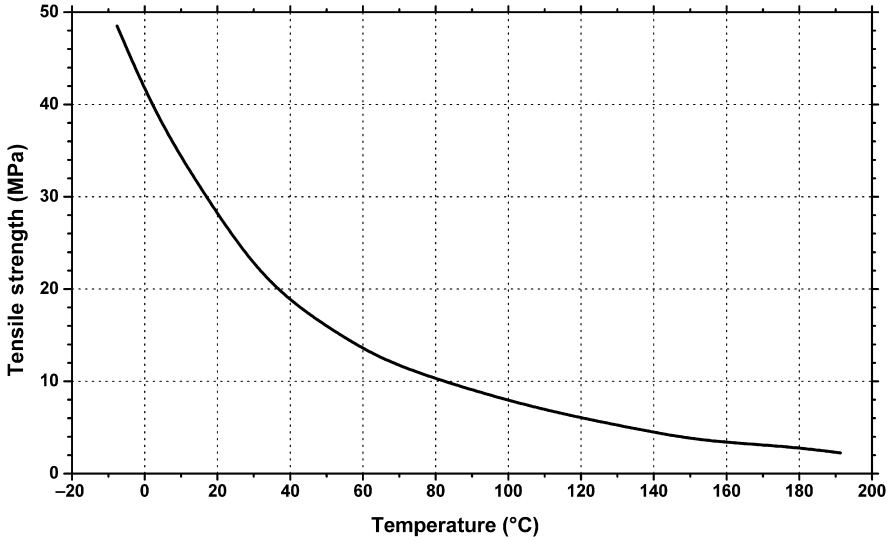

Figure 7.44 Tensile strength vs. temperature for Mitsui Chemicals TPX™ RT18—general-purpose, unfilled PMP resin [5].

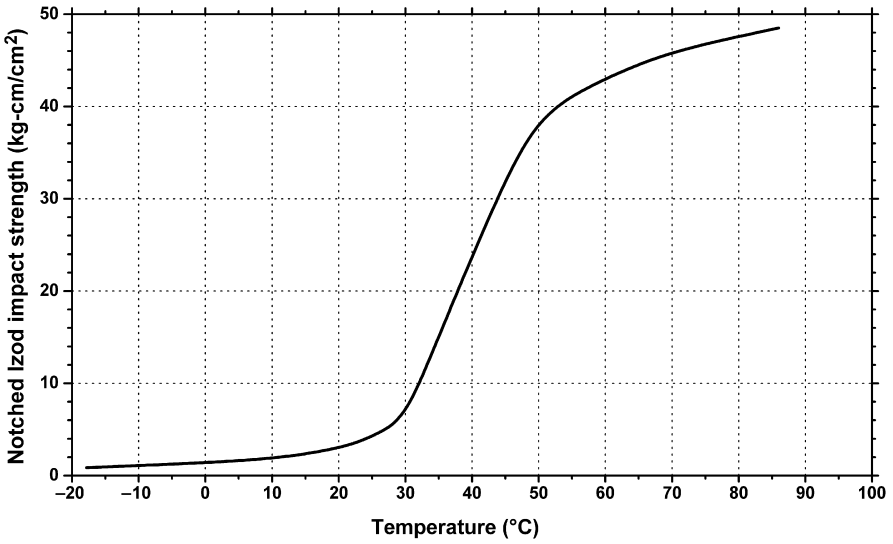

Figure 7.45 Notched Izod impact strength vs. temperature for Mitsui Chemicals TPX™ RT18—general-purpose, unfilled PMP resin.

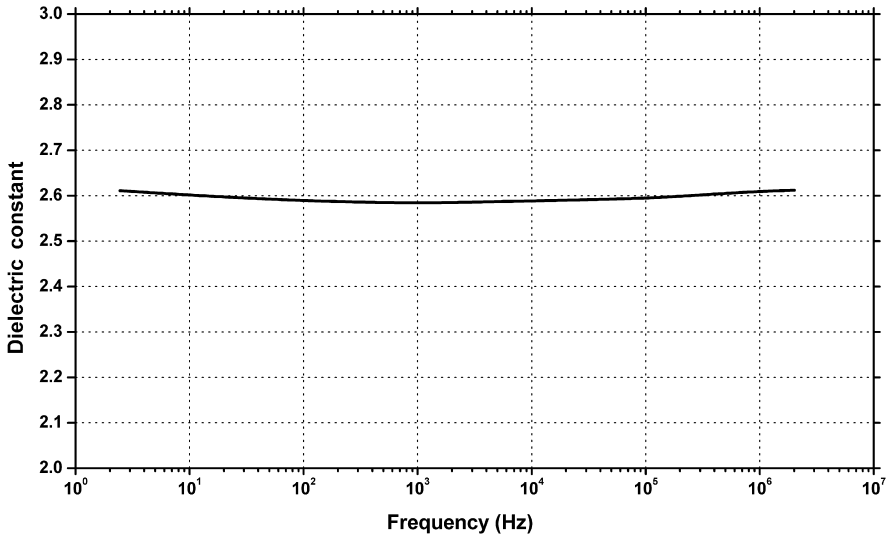

Figure 7.46 Dielectric constant vs. frequency at 20°C for Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

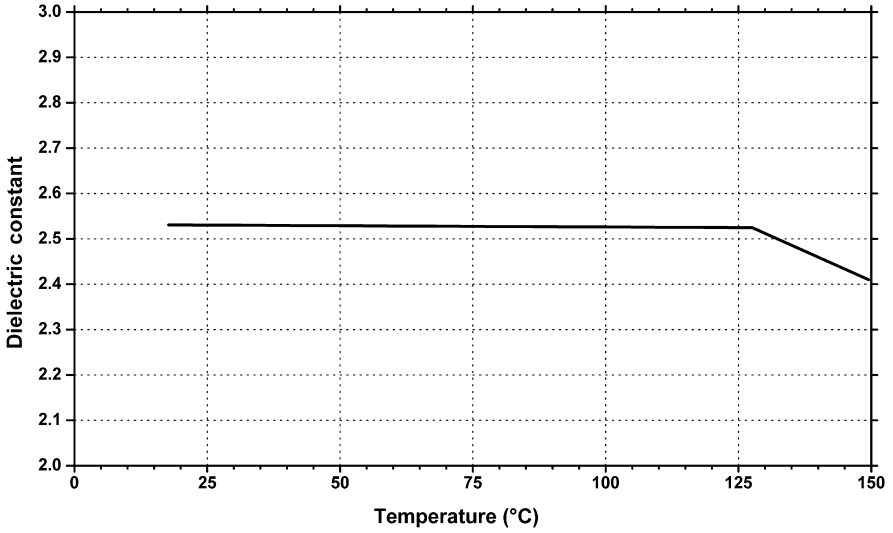

Figure 7.47 Dielectric constant at 1 MHz vs. temperature for Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

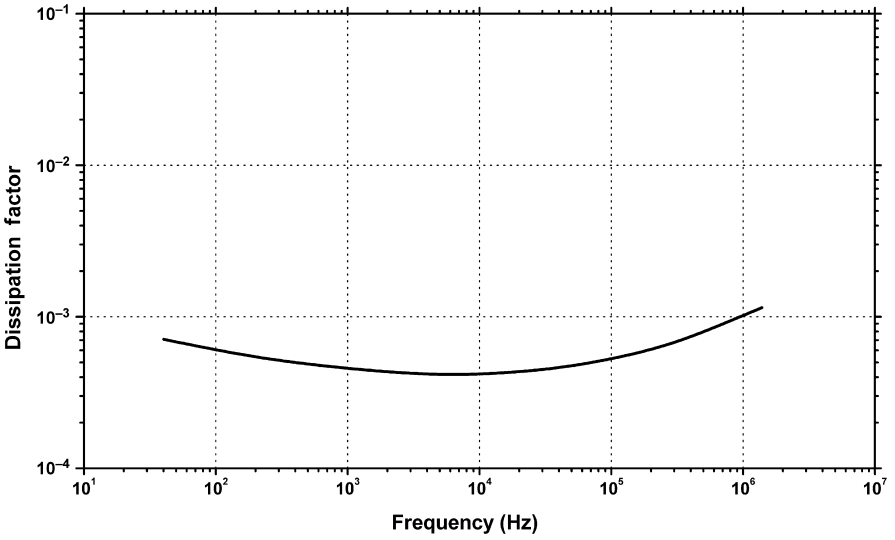

Figure 7.48 Dissipation factor vs. frequency at 20°C for Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

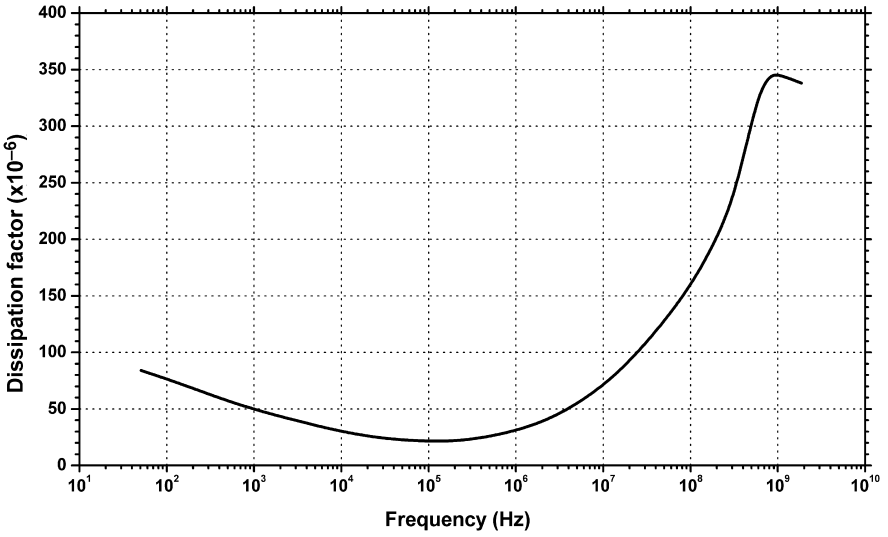

Figure 7.49 Dissipation factor vs. frequency for Mitsui Chemicals TPX™ RT18—general-purpose, unfilled PMP resin.

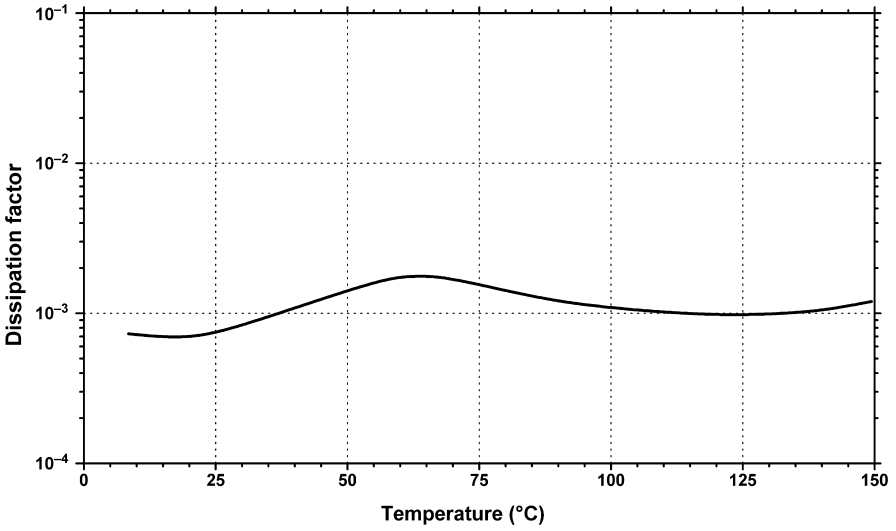

Figure 7.50 Dissipation factor vs. temperature at 1 MHz for Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

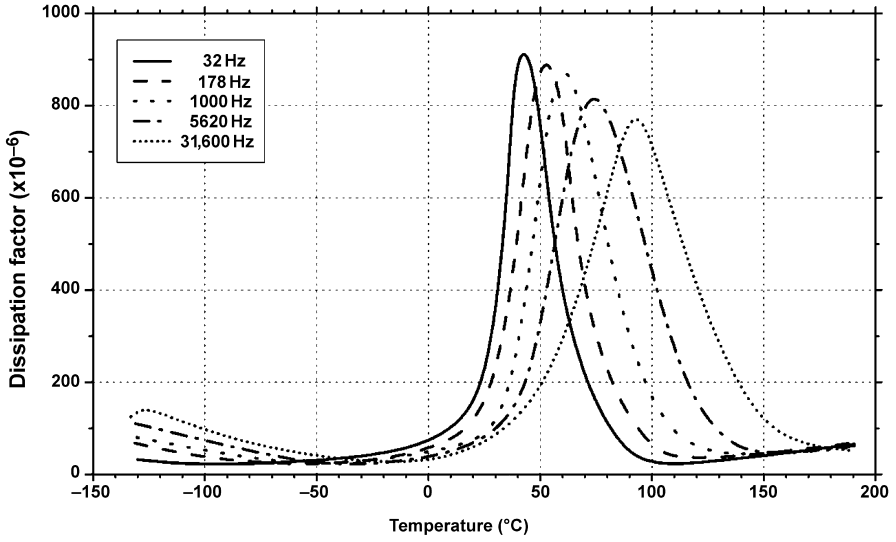

Figure 7.51 Dissipation factor vs. temperature and frequency for Mitsui Chemicals TPX™ RT18—general-purpose, unfilled PMP resin.

There are three broad classifications for rigid PVC compounds: Type II, chlorinated polyvinyl chloride (CPVC), and Type I. Type II differs from Type I due to greater impact values, but lower chemical resistance. CPVC has greater high temperature resistance. These materials are considered "unplasticized," because they are less flexible than the plasticized formulations. PVC has a broad range of applications from high volume construction related products to simple electric wire insulation and coatings. CAS numbers are 9002-86-2, 8063-94-3, 51248-43-2, and 93050-82-9.

Manufacturing and trade names: PolyOne Geon™, Fiberloc™; VPI LLC Mirrex®.

Applications and uses: Building siding, fence, and packaging are major markets for PVC. Rigid grades are blown into bottles and made into sheets for thermoforming boxes and blister packs. Flexible PVC compounds are used in food packaging applications because of their strength, transparency, processability, and low raw material cost. PVC film can be used in marine/boat windows, recreational vehicle windows, tents and awning windows, industrial curtains/enclosures, spray booths, rack covers, weld screens and partitions, clean rooms, golf cart covers, binder covers, tags and sign holders, menus, apparel and clothing, packaging, bags.

Data for PVC plastics are shown in Figures 7.52–7.59.

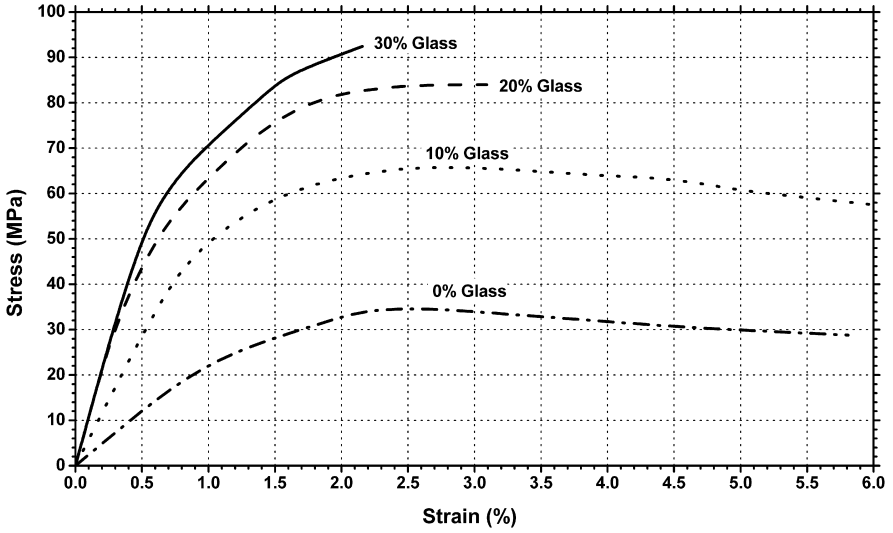

Figure 7.52 Stress vs. strain at 23°C for PolyOne Fiberloc™ rigid PVC resins with different amounts of glass fiber reinforcement.

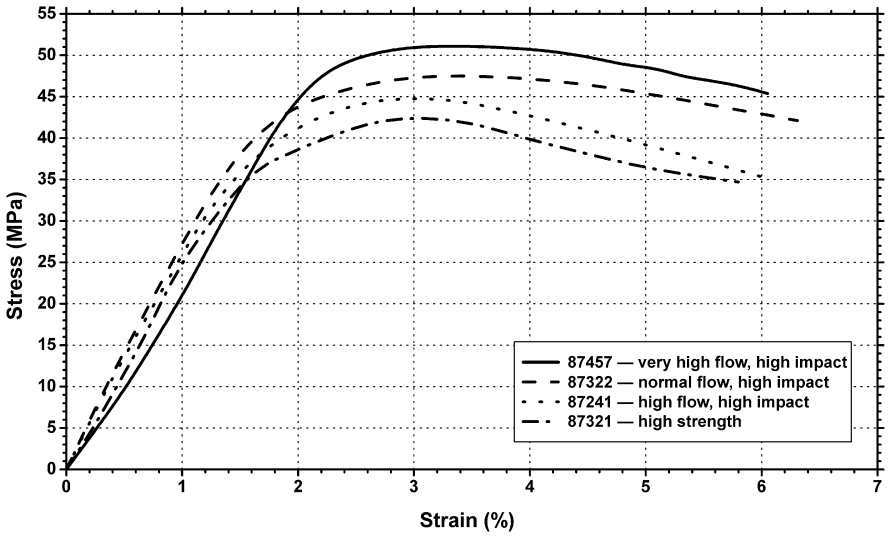

Figure 7.53 Stress vs. strain at 23°C for various PolyOne Geon™ rigid PVC resins.

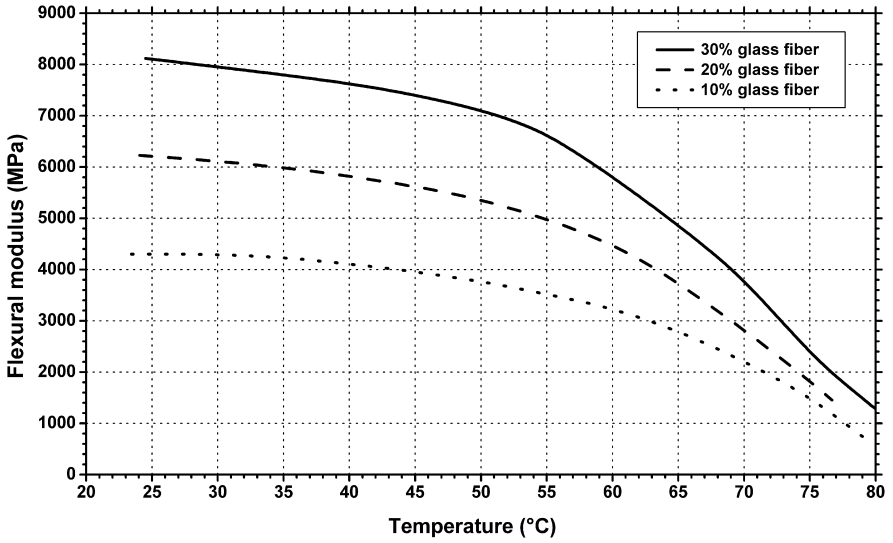

Figure 7.54 Flexural modulus vs. temperature for PolyOne Fiberloc™ rigid PVC resins with different amounts of glass fiber reinforcement.

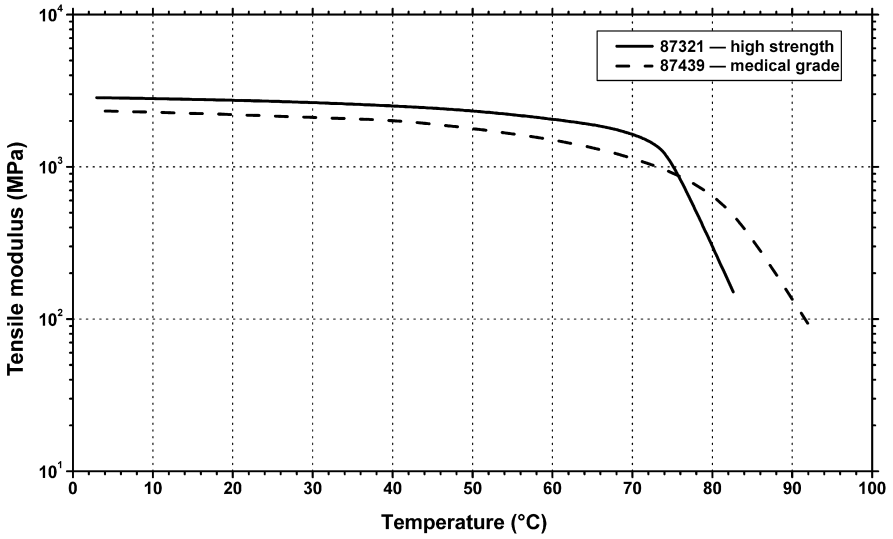

Figure 7.55 Tensile modulus vs. temperature for two PolyOne Geon™ rigid PVC resins.

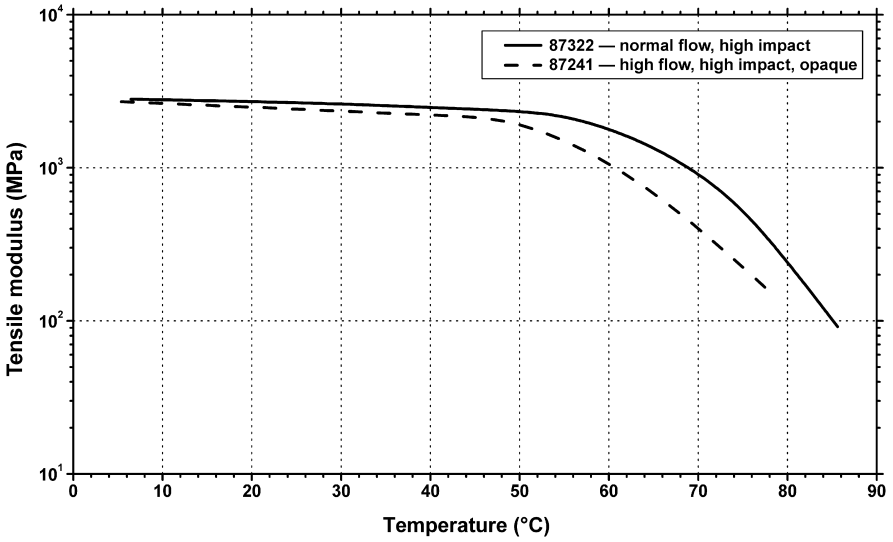

Figure 7.56 Tensile modulus vs. temperature for two PolyOne Geon™ rigid PVC resins.

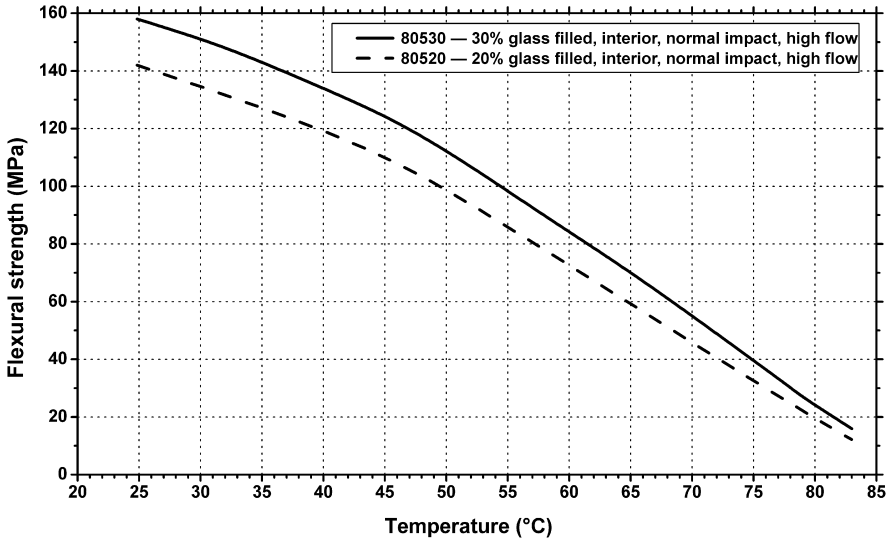

Figure 7.57 Flexural strength vs. temperature for PolyOne Fiberloc™ rigid PVC resins with different amounts of glass fiber reinforcement.

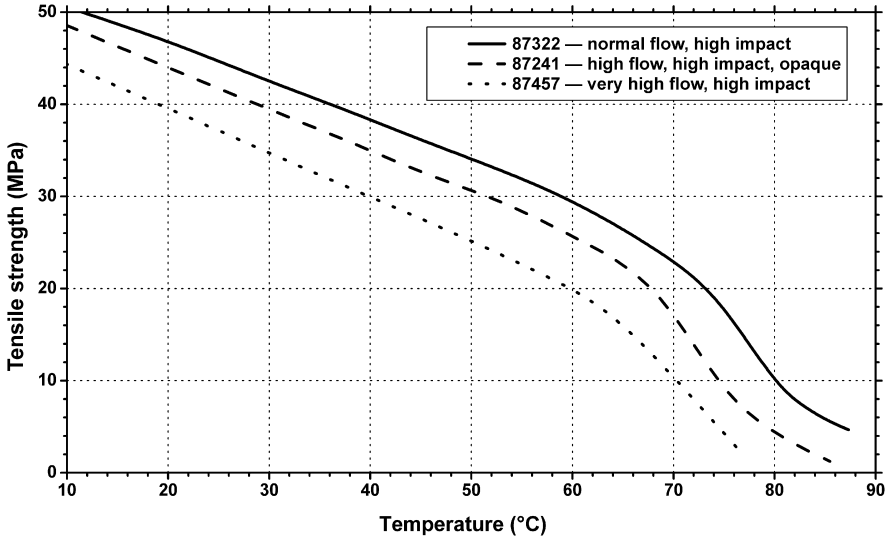

Figure 7.58 Tensile strength vs. temperature for PolyOne Geon™ rigid PVC resins.

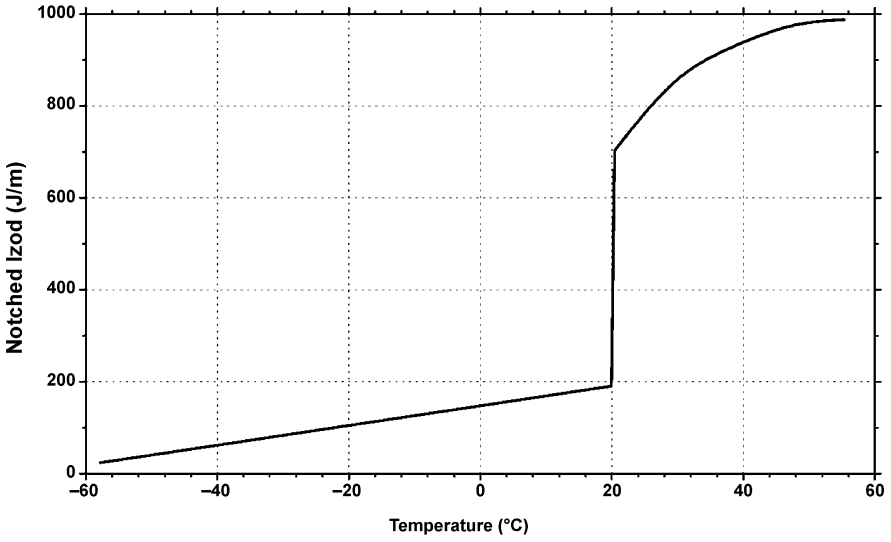

Figure 7.59 Notched Izod strength vs. temperature for PolyOne Geon™ 87241—high flow, high impact, opaque rigid PVC resin.

7.5 Cyclic Olefin Copolymer (COC)

Cyclic olefin copolymer (COC) is an amorphous polyolefin made by reaction of ethylene and norbornene in varying ratios. Its structure is shown in Figure 7.60. The properties can be customized by changing the ratio of the monomers found in the polymer. Being amorphous it is transparent. Other performance benefits include:

- Low density
- Extremely low water absorption
- Excellent water vapor barrier properties
- High rigidity, strength, and hardness

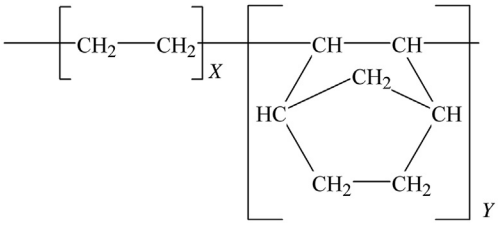

Figure 7.60 Chemical structure of COCs.

- Variable heat deflection temperature up to 170°C
- Very good resistance to acids and alkalis

COC is often blended with other polyolefins.

Manufacturers and trade names: Topas Advanced Polymers Topas®.

Applications and uses: Transparent moldings such as lenses, sensors, primary packaging of pharmaceuticals, medical devices, and diagnostic disposables.

Data for COC plastics are shown in Figures 7.61–7.67.

7.6 Polyacrylics

While a large number of acrylic polymers are manufactured, PMMA is by far the most common. The structure of PMMA is shown in Figure 7.68. Nearly everyone has heard of Plexiglas®. PMMA has two very distinct properties that set the products apart from others. First it is optically clear and colorless. It has a light transmission of 92%. The 4% reflection loss at each surface is unavoidable. Second its surface is extremely hard. They are also highly weather resistant. PMMA has a CAS number of 9011-14-7.

Acrylic resins are available as homopolymer (primarily PMMA), copolymer, and terpolymer.

Manufacturers and trade names: Lucite International Lucite® Diakon® and Perspex®; Evonik Industries Plexiglas®, Acrylite®, Europlex®, and Rohaglas®; Arkema Oroglas®; Rowland Technologies, Inc. SolaTuf®; Mitsubishi Rayon Co., Ltd. Shinkolite®; Altuglas International Plexiglas®; Novacor.

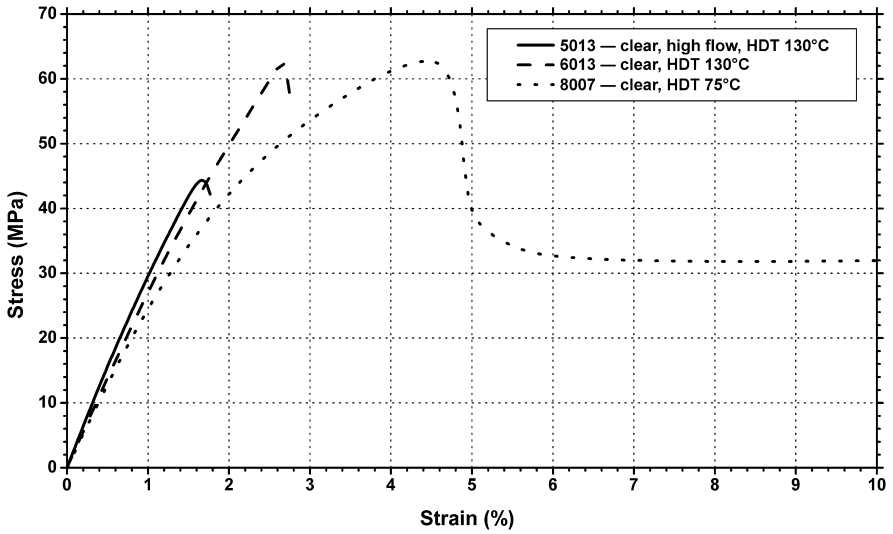

Figure 7.61 Stress vs. strain at 23°C for several Topas Advanced Polymers Topas® COC resins [6].

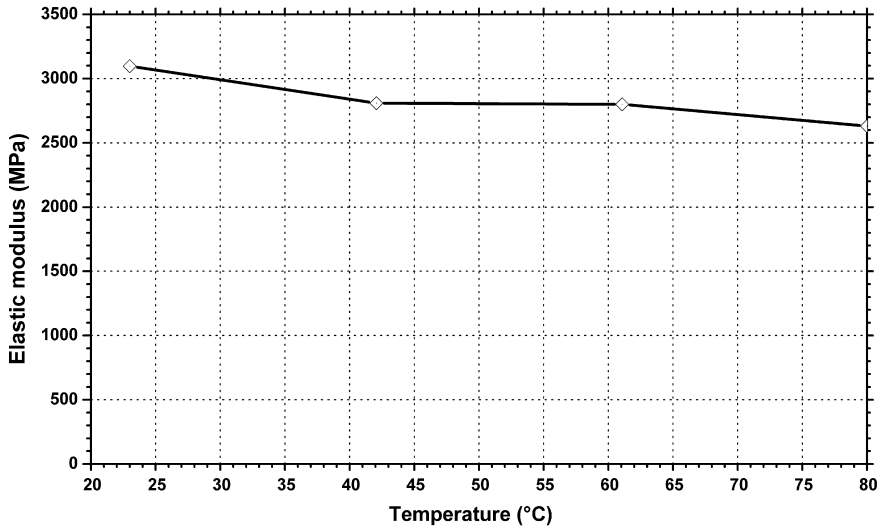

Figure 7.62 Elastic modulus vs. temperature for Topas Advanced Polymers Topas® 5013, 6013, 6015, and 6017 COC resins [6].

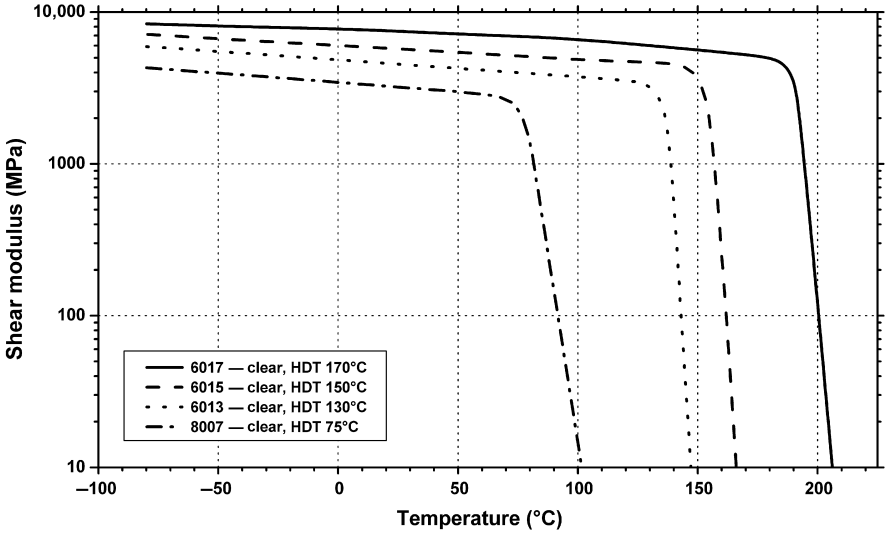

Figure 7.63 Shear modulus vs. temperature for Topas Advanced Polymers Topas® COC resins [6].

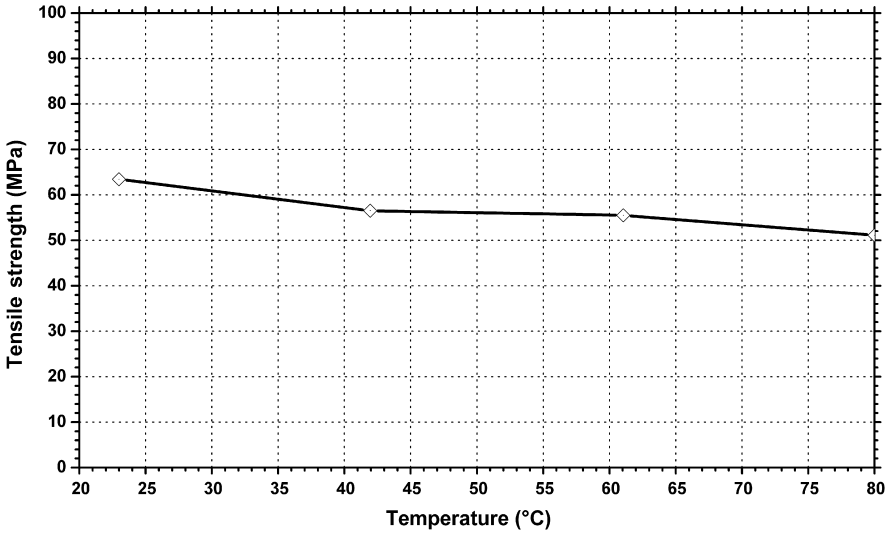

Figure 7.64 Tensile strength vs. temperature for Topas Advanced Polymers Topas® 5013, 6013, 6015, and 6017 COC resins [6].

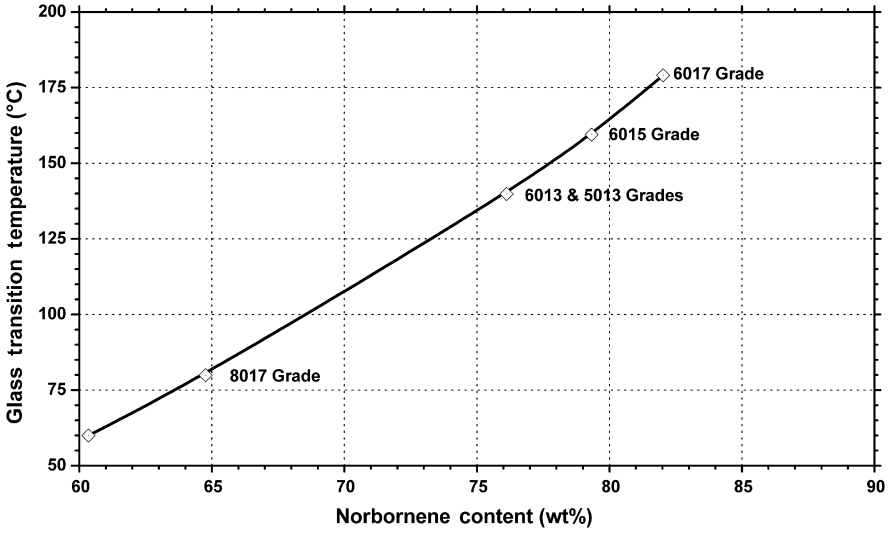

Figure 7.65 Glass transition temperature vs. norbornene content for Topas Advanced Polymers Topas® COC resins [6].

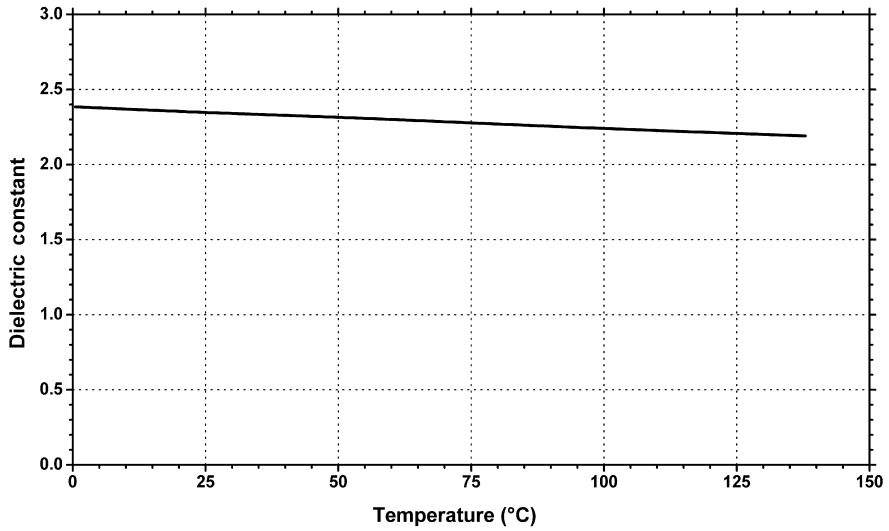

Figure 7.66 Dielectric content vs. temperature for Topas Advanced Polymers Topas® 6015—clear, HDT 150°C COC resin.

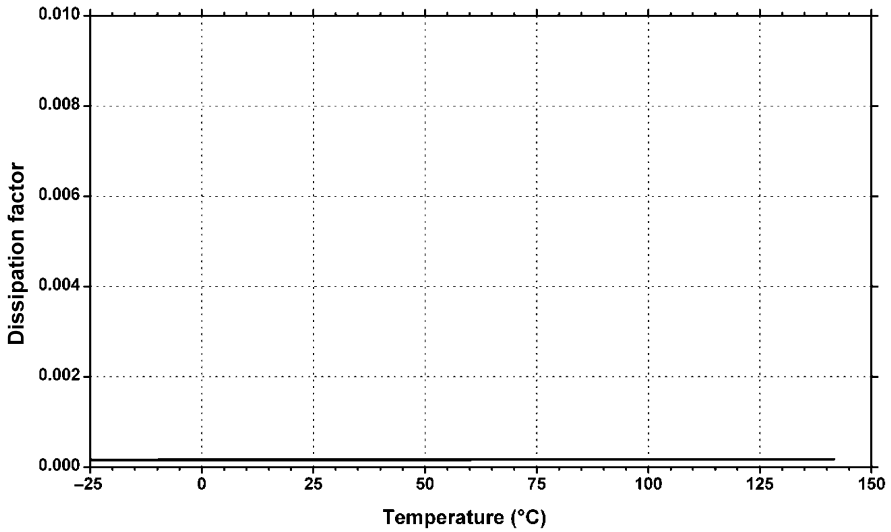

Figure 7.67 Dissipation factor vs. temperature for Topas Advanced Polymers Topas® 6015—clear, HDT 150°C COC resin [6].

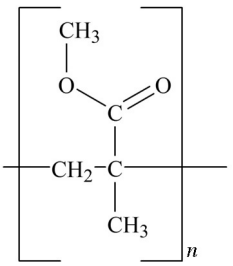

Figure 7.68 Structure of PMMA.

Applications and uses: optical parts, display items, tube and profile extrusion, automotive rear lights and dashboard lenses, extruded sheet, copying equipment and lighting diffusers, UV protective films for exterior laminates.

Data for acrylic plastics are shown in Figures 7.69–7.82.

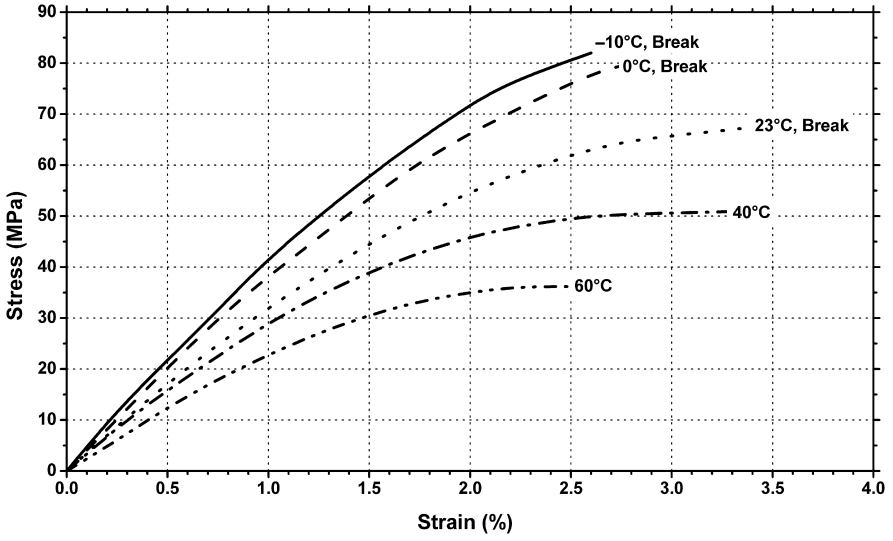

Figure 7.69 Stress vs. strain at various temperatures for Evonik Industries Plexiglas® 6N—standard grade acrylic resin.

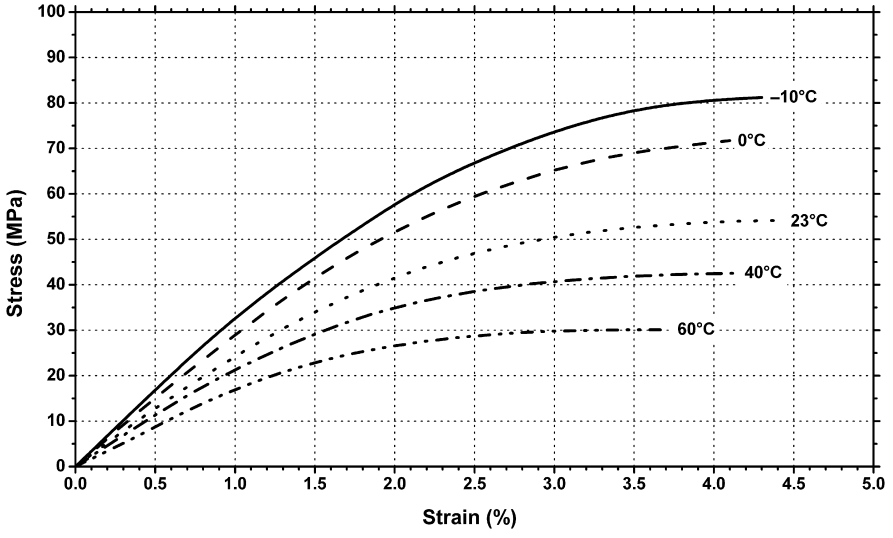

Figure 7.70 Stress vs. strain at various temperatures for Evonik Industries Plexiglas® zk20—high impact grade acrylic resin.

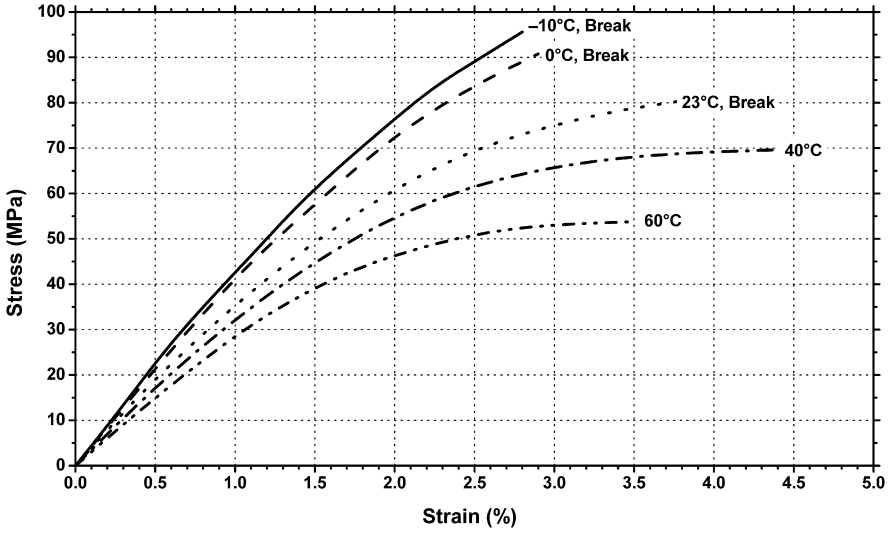

Figure 7.71 Stress vs. strain at various temperatures for Evonik Industries Plexiglas® hw55—heat resistant grade acrylic resin.

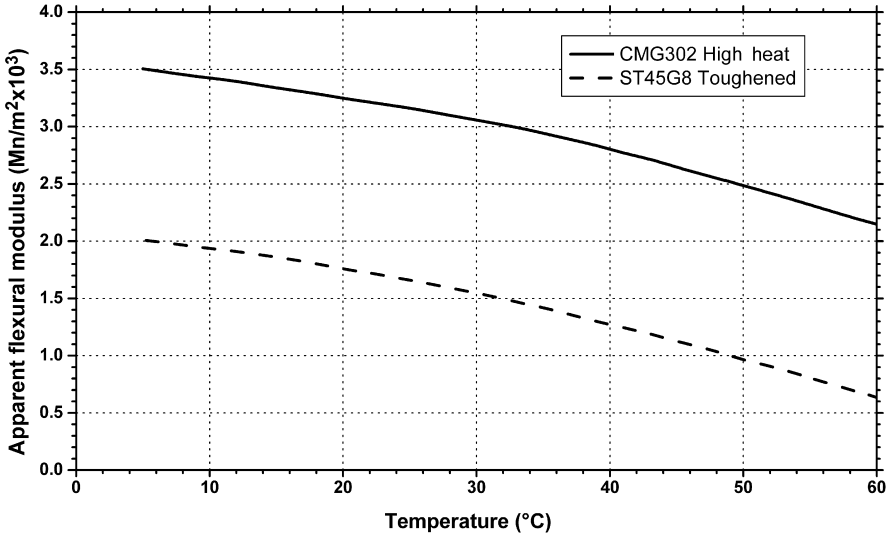

Figure 7.72 100-s apparent flexural modulus vs. temperature for Lucite International Diakon® acrylic resins [7].

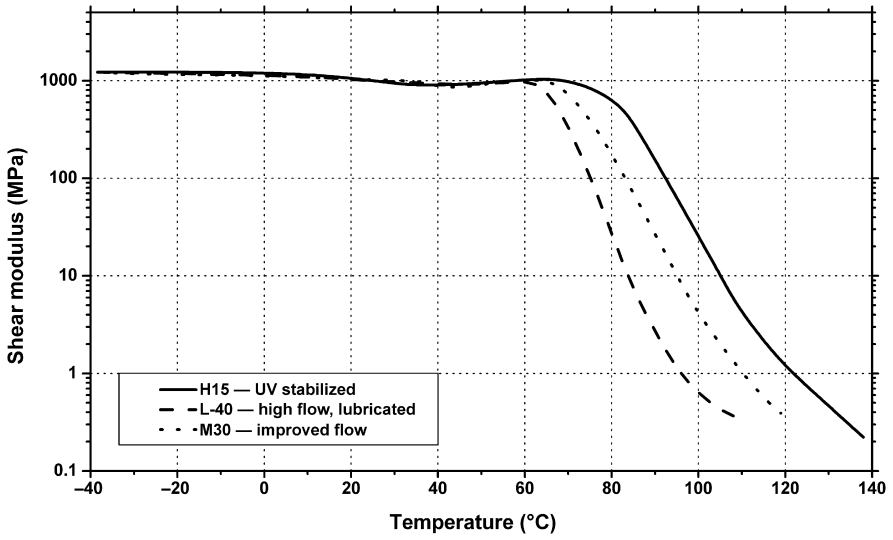

Figure 7.73 Shear modulus vs. temperature for Cyro Industries Acrylite® acrylic resins.

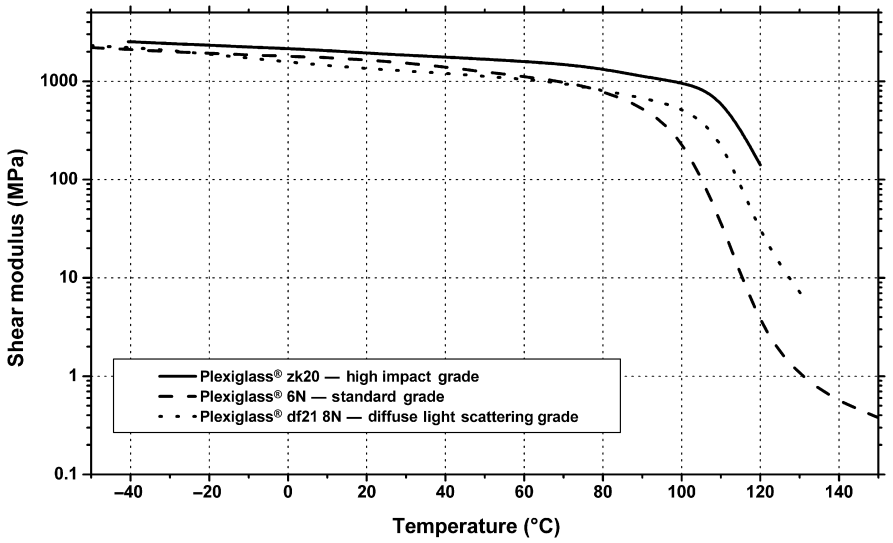

Figure 7.74 Shear modulus vs. temperature for Evonik Industries Plexiglas® acrylic resins.

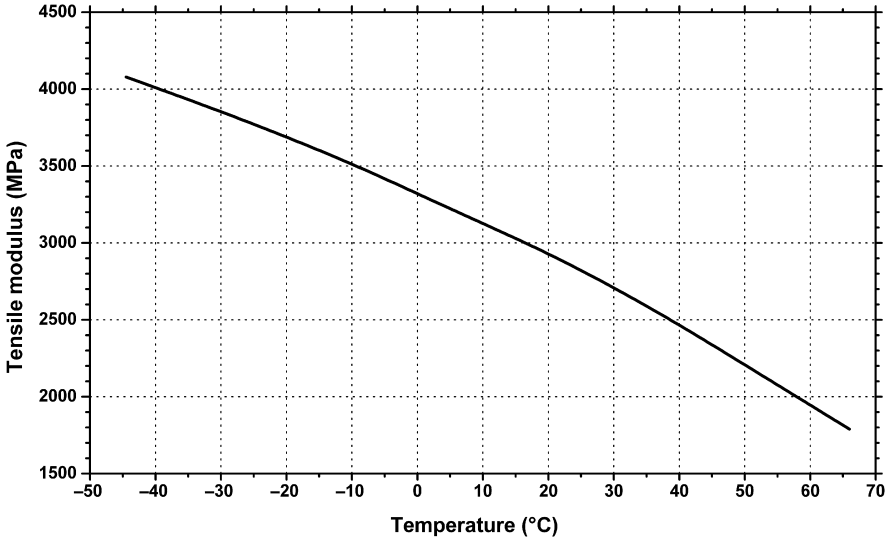

Figure 7.75 Tensile modulus vs. temperature for general-purpose acrylic resin.

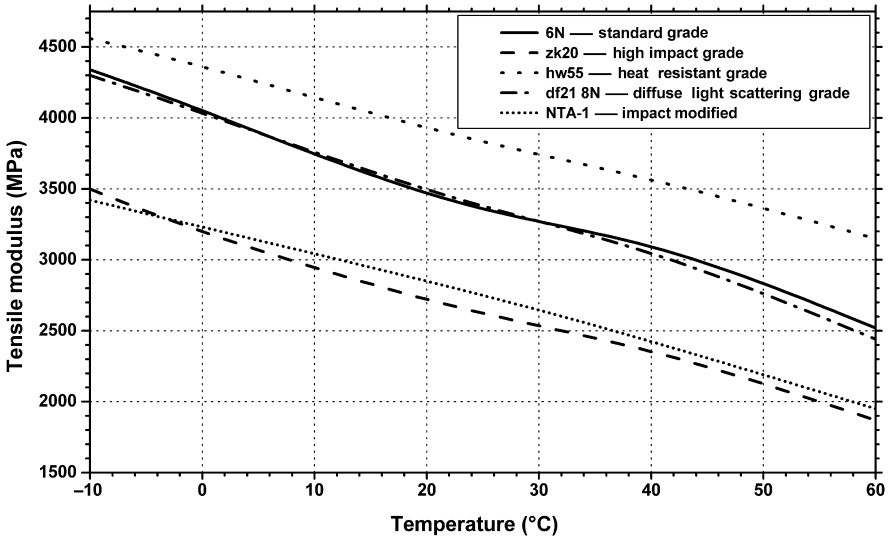

Figure 7.76 Tensile modulus vs. temperature for Evonik Industries Plexiglas® acrylic resins.

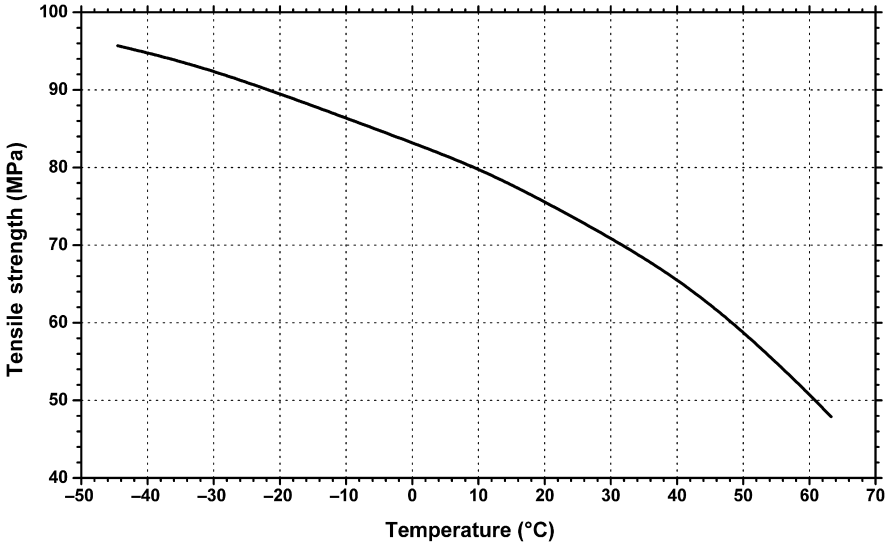

Figure 7.77 Tensile strength vs. temperature for general-purpose acrylic resin.

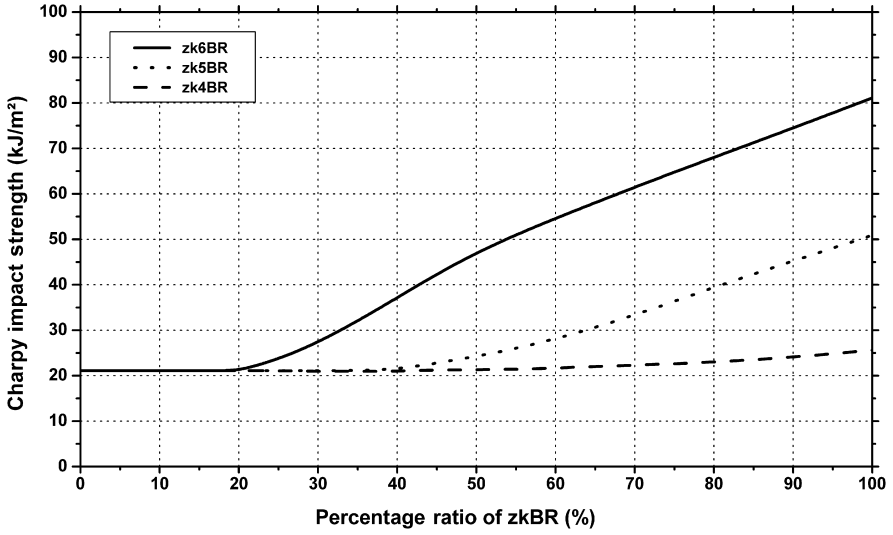

Figure 7.78 Charpy impact strength of Evonik Industries Plexiglas® 7N—general-purpose extrusion grade acrylic resin vs. percentage of Plexiglas® zkBR additives.

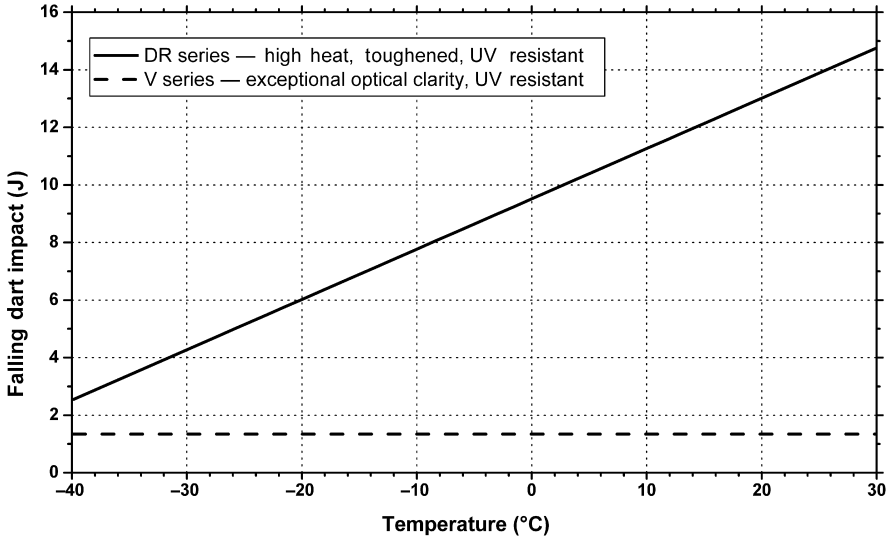

Figure 7.79 Impact strength vs. temperature for Evonik Industries Plexiglas® acrylic resins [8]. *Note*: sample size: 152 mm × 152 mm × 3.2 mm.

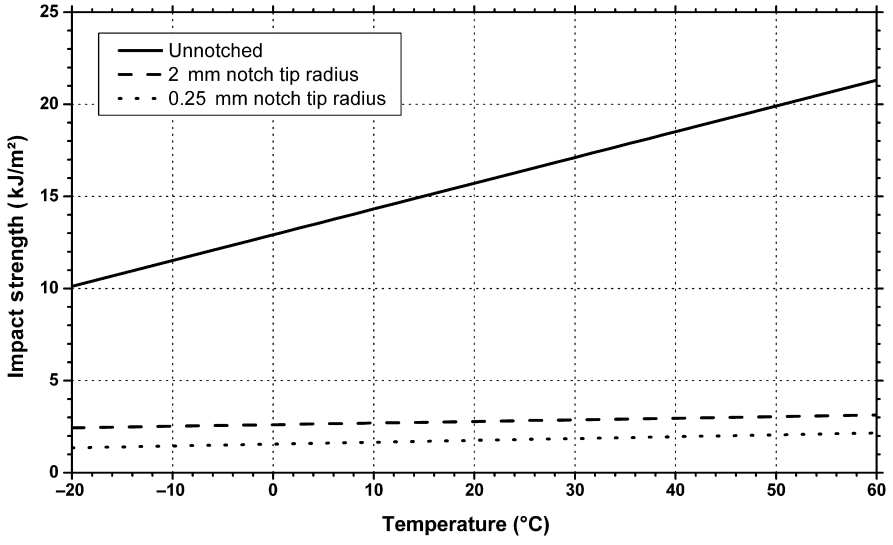

Figure 7.80 Charpy impact strength vs. temperature for Lucite International Diakon® CMG302 general-purpose high heat acrylic resin [7].

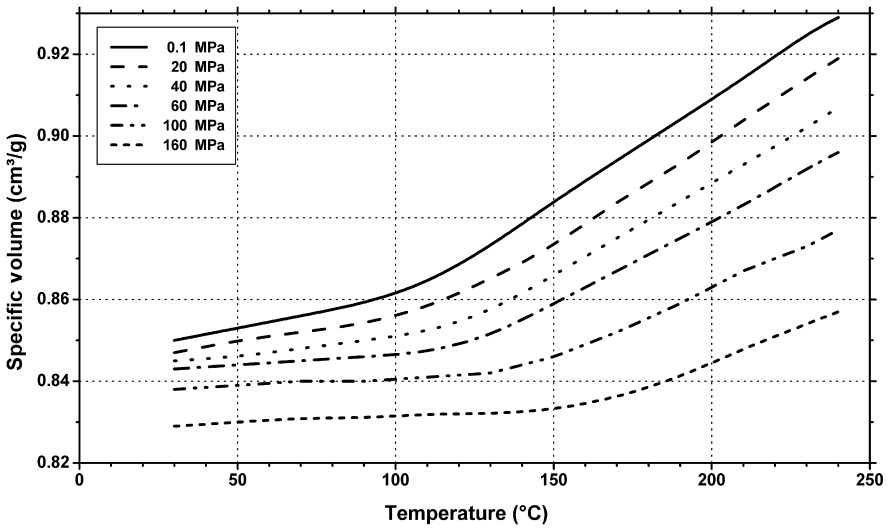

Figure 7.81 Specific volume as a function of temperature and pressure (PVT) for Evonik Industries Plexiglas® 7N—general-purpose extrusion grade acrylic resin.

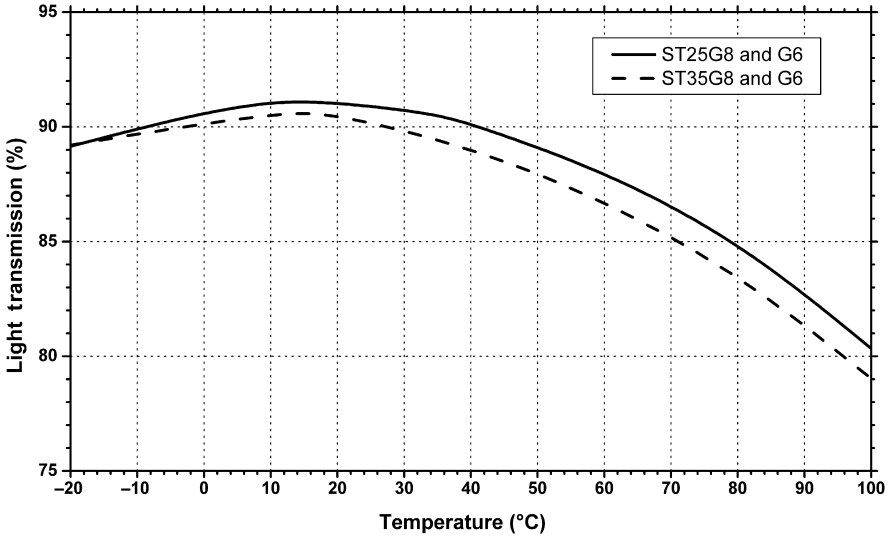

Figure 7.82 Light transmission vs. temperature for Lucite® Diakon® ST grades toughened acrylic polymers [7].

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[1] GUR® ultra high molecular weight polyethylene (PE-UHMW). Ticona; 2010.
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8 Thermoplastic Elastomers

An elastomer is a polymer with the property of "elasticity," generally having a notably low Young's modulus and high yield strain compared with other materials [1]. The term is often used interchangeably with the term rubber. Elastomers are amorphous polymers existing above their glass transition temperature, so that considerable segmental motion is possible; so it is expected that they would also be very permeable. At ambient temperatures rubbers are thus relatively soft and deformable. Their primary uses are for seals, adhesives, and molded flexible parts. Elastomers may be thermosets (requiring vulcanization, a form of cross-linking) or thermoplastic, called thermoplastic elastomers (TPEs).

TPEs have two big advantages over the conventional thermoset (vulcanized) elastomers, which are ease and speed of processing. Other advantages of TPEs are recyclability of scrap, lower energy costs for processing, and the availability of standard, uniform grades (not generally available in thermosets).

TPEs are molded or extruded on standard plastics-processing equipment in considerably shorter cycle times than those required for compression or transfer molding of conventional rubbers. They are made by copolymerizing two or more monomers, using either block or graft polymerization techniques. One of the monomers provides the hard, or crystalline, polymer segment that functions as a thermally stable component; the other monomer develops the soft or amorphous segment, which contributes the elastomeric or rubbery characteristic.

Physical and chemical properties can be controlled by varying the ratio of the monomers and the length of the hard and soft segments. Block techniques create long-chain molecules that have various or alternating hard and soft segments. Graft polymerization methods involve attaching one polymer chain to another as a branch. The properties that are affected by each phase can be generalized:

"Hard Phase"—plastic properties:

- Processing temperatures
- Continuous use temperature
- Tensile strength
- Tear strength
- Chemical and fluid resistance
- Adhesion to inks, adhesives, and over-molding substrates

"Soft Phase"—elastomeric properties:

- Lower service temperature limits
- Hardness
- Flexibility
- Compression set and tensile set

8.1 Thermoplastic Polyurethane Elastomers (TPUs)

Urethanes are a reaction product of a diisocyanate and long- and short-chain polyether, polyester, or caprolactone glycols [2]. The polyols and the short-chain diols react with the diisocyanates to form linear polyurethane molecules. This combination of diisocyanate and short-chain diol produces the rigid or hard segment. The polyols form the flexible or soft segment of the final molecule. Figure 8.1 shows the molecular structure in schematic form.

There are three main chemical classes of TPUs: polyester, polyether, and a smaller class known as polycaprolactone [3].

1. *Polyester TPUs* are compatible with PVC and other polar plastics. Offering value in the form of enhanced properties, they are unaffected by oils and chemicals, provide excellent abrasion resistance, offer a good balance of physical properties, and are perfect for use in polyblends.
2. *Polyether TPUs* are slightly lower in specific gravity than polyester and polycaprolactone grades. They offer low temperature flexibility and good abrasion and tear resilience. They are also durable against microbial attack and

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provide excellent hydrolysis resistance—making them suitable for applications where water is a consideration.

3. *Polycaprolactone TPUs* have the inherent toughness and resistance of polyester-based TPUs combined with low temperature performance and a relatively high resistance to hydrolysis. They are an ideal raw material for hydraulic and pneumatic seals.

TPUs can also be subdivided into aromatic and aliphatic varieties:

- *Aromatic TPUs* based on isocyanates like 4,4′-methylenediphenyl diisocyanate (MDI) are workhorse products and can be used in applications that require flexibility, strength, and toughness.
- *Aliphatic TPUs* based on isocyanates like methyldicyclohexyl diisocyanate (H12 MDI), 1,6-hexamethylene diisocyanate (HDI) and isophorone diisocyanate (IPDI) are light stable and offer excellent optical clarity. They are commonly employed in automotive interior and exterior applications and as laminating films to bond glass and polycarbonate together in the glazing industry. They are also used in projects where attributes like optical clarity, adhesion, and surface protection are required.

The properties of the resin depend on the nature of the raw materials, the reaction conditions, and the ratio of the starting raw materials. The polyols used have a significant influence on certain properties of the thermoplastic polyurethane. Polyether and polyester polyols are both used to produce many products.

The polyester-based TPUs have the following characteristic features:

- Good oil/solvent resistance
- Good UV resistance
- Abrasion resistance
- Good heat resistance
- Mechanical properties

The polyether-based TPUs have the following characteristic features:

- Fungus resistance
- Low temperature flexibility
- Excellent hydrolytic stability
- Acid/base resistance

In addition to the basic components described above, most resin formulations contain additives to facilitate production and processability. Other additives can also be included such as:

- Demolding agents
- Flame retardants

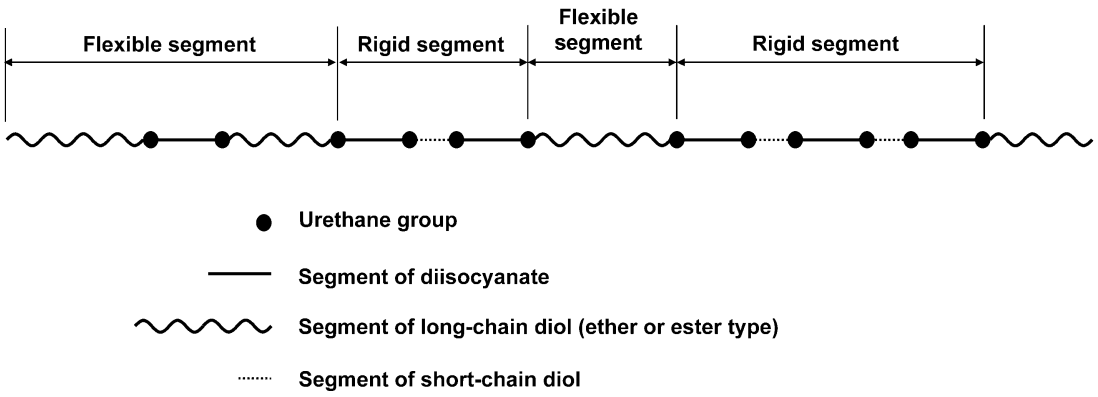

Figure 8.1 Molecular structure of a TPU.

- Heat/UV stabilizers
- Plasticizers

The polyether types are slightly more expensive and have better hydrolytic stability and low temperature flexibility than the polyester types.

Manufacturers and trade names: Lubrizol Advanced Materials Estane® TPU, Bayer MaterialScience Texin® and Desmopan®, BASF Elastollan®, Huntsman IROGRAN®, AVALON®, KRYSTALGRAN®, and IROSTIC®.

Applications and uses: medical thin walled, flexible tubing, catheters, connectors, luers and stopcocks, films and fabric coatings, component housings, soft touch grips, dental parts, automotive battery cables, ski goggles, ski boot shells, snowboard surfaces, and sports shoe soles.

Data for TPU elastomers are found in Figures 8.2–8.25.

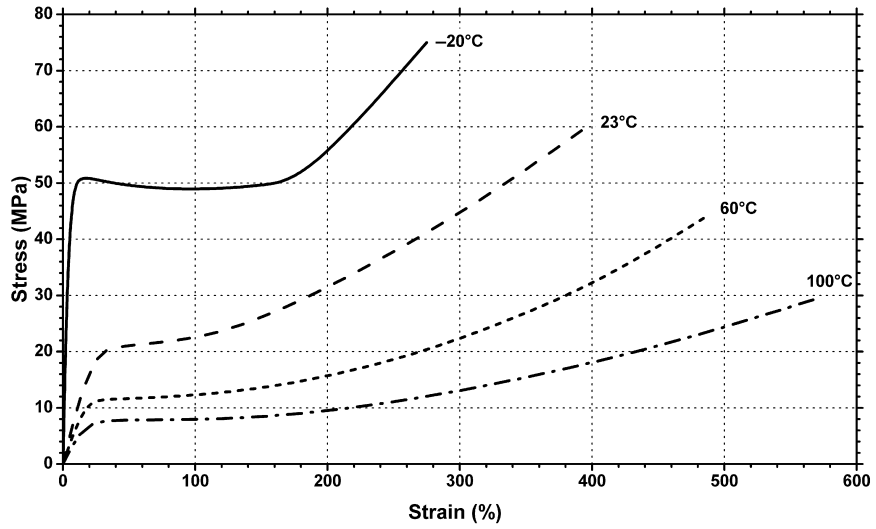

Figure 8.2 Stress vs. strain at various temperatures for BASF Elastollan® 1164 D—polyether resin, Shore hardness 64D TPU resin [4].

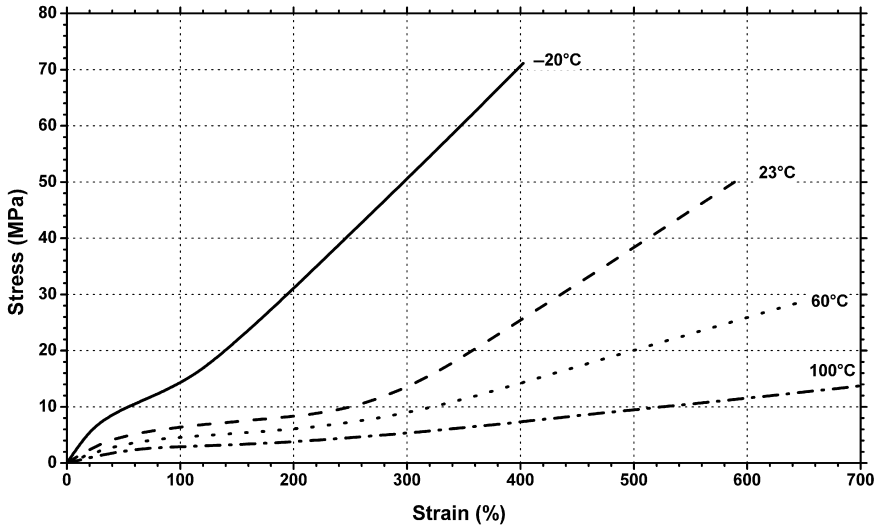

Figure 8.3 Stress vs. strain at various temperatures for BASF Elastollan® 1185 A—polyether resin, Shore hardness 85A TPU resin [4].

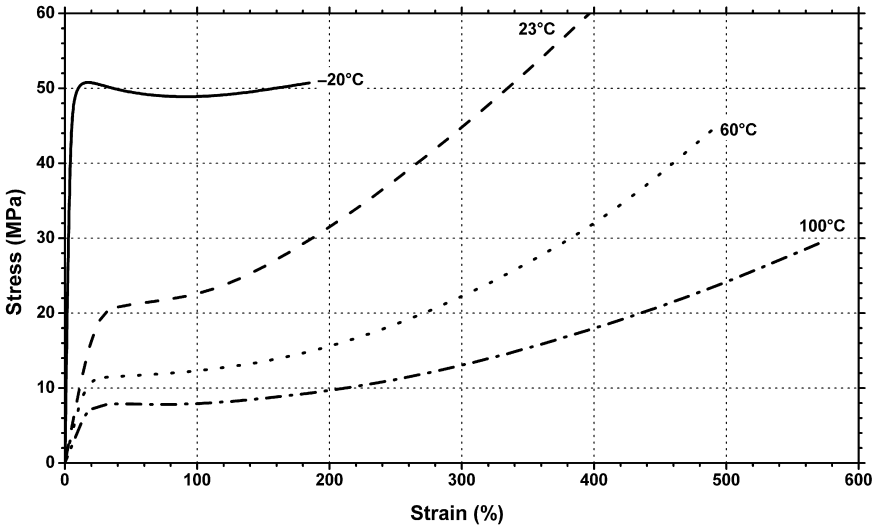

Figure 8.4 Stress vs. strain at various temperatures for BASF Elastollan® C 64 D—polyester resin, high crystallinity, Shore hardness 64D TPU resin [4].

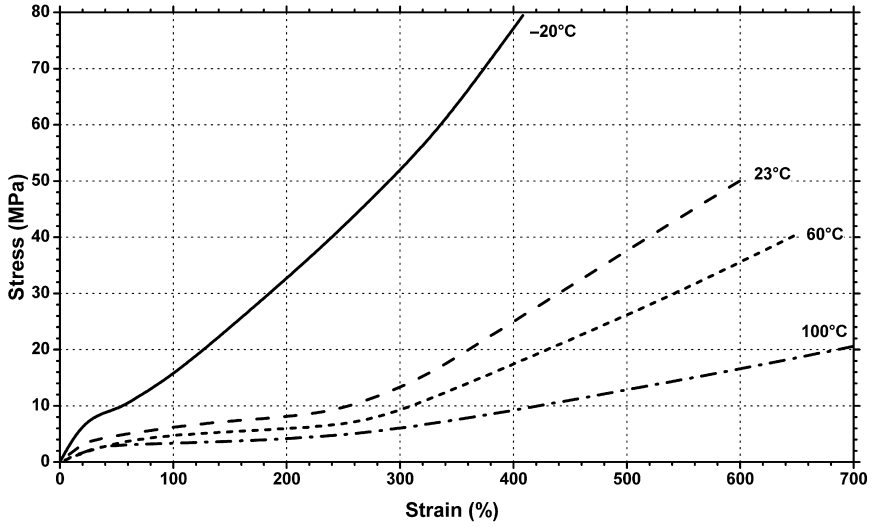

Figure 8.5 Stress vs. strain at various temperatures for BASF Elastollan® C 85 A—polyester resin, high crystallinity, Shore hardness 85A TPU resin [4].

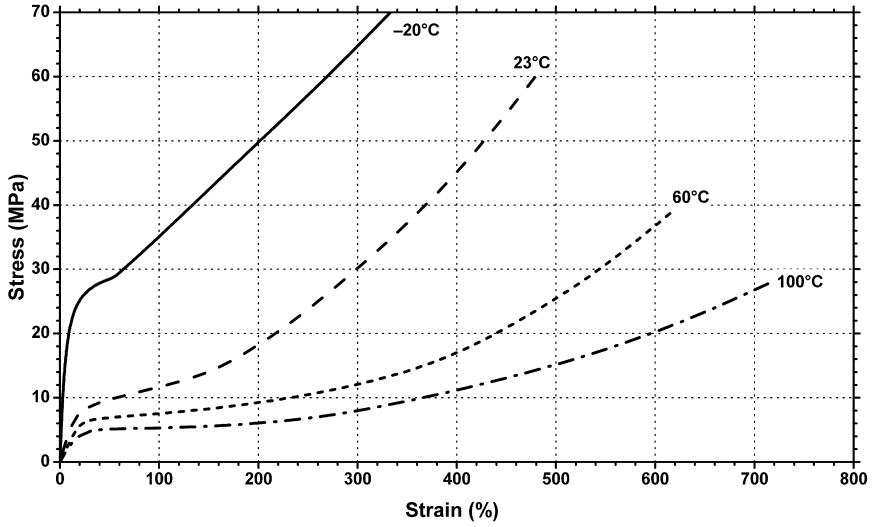

Figure 8.6 Stress vs. strain at various temperatures for BASF Elastollan® C 95 A—polyester resin, high crystallinity, Shore hardness 95A TPU resin [4].

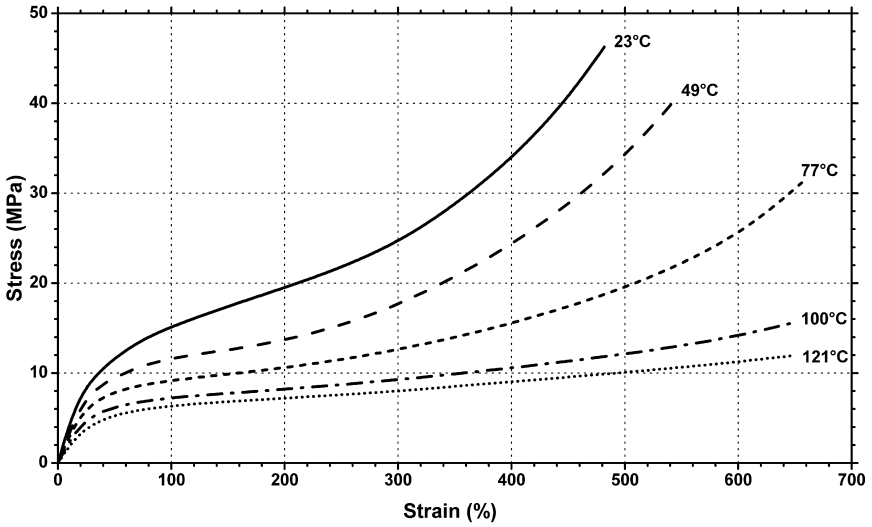

Figure 8.7 Stress vs. strain at various high temperatures for Bayer Desmopan® 453—polyester resin, Shore hardness 53D TPU resin [5].

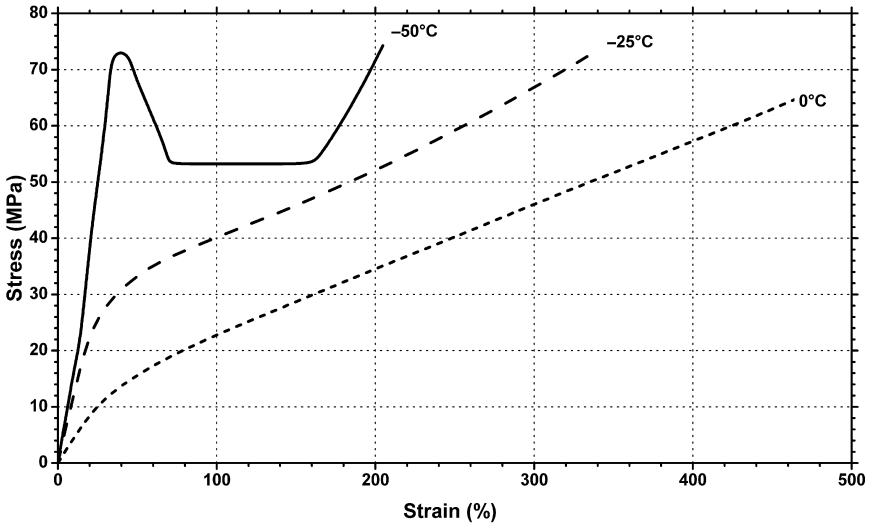

Figure 8.8 Stress vs. strain at various low temperatures for Bayer Desmopan® 453—polyester resin, Shore hardness 53D TPU resin.

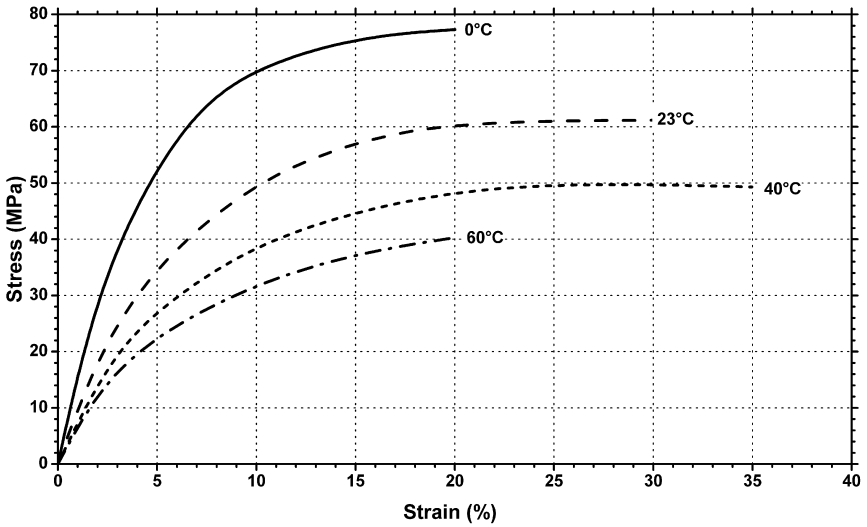

Figure 8.9 Stress vs. strain at various temperatures for BASF Elastollan® R 1000—20% glass fiber, Shore hardness 60D TPU resin [4].

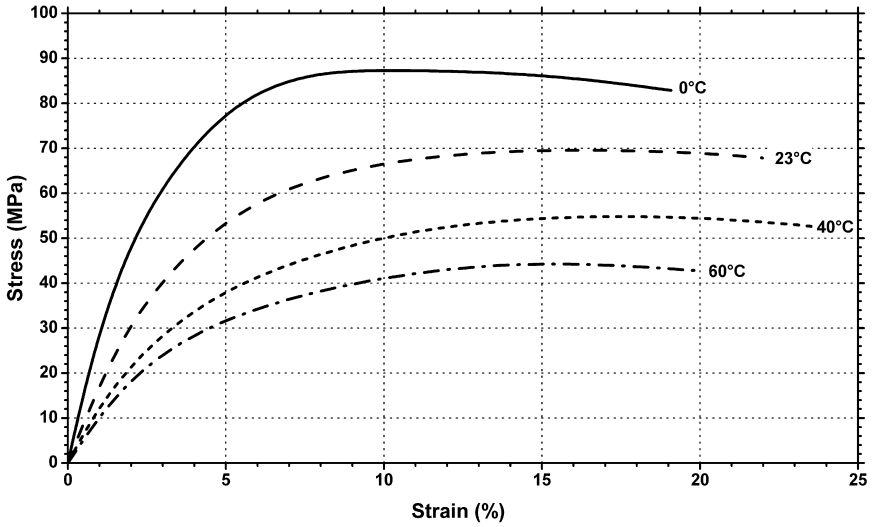

Figure 8.10 Stress vs. strain at various temperatures for BASF Elastollan® R 2000—20% glass fiber, Shore hardness 67D TPU resin [4].

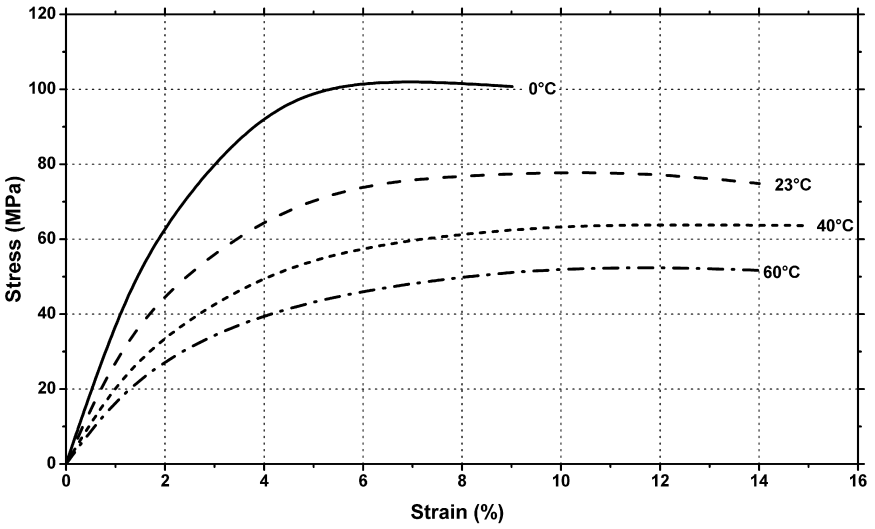

Figure 8.11 Stress vs. strain at various temperatures for BASF Elastollan® R 3000—20% glass fiber, Shore hardness 73D TPU resin [4].

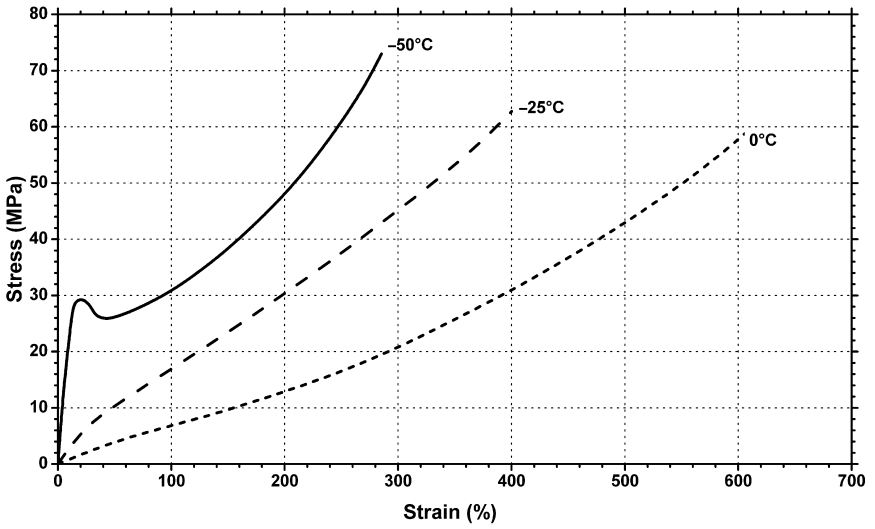

Figure 8.12 Stress vs. strain at various low temperatures for Bayer Texin® 285—polyester resin, Shore hardness 85A TPU resin [5].

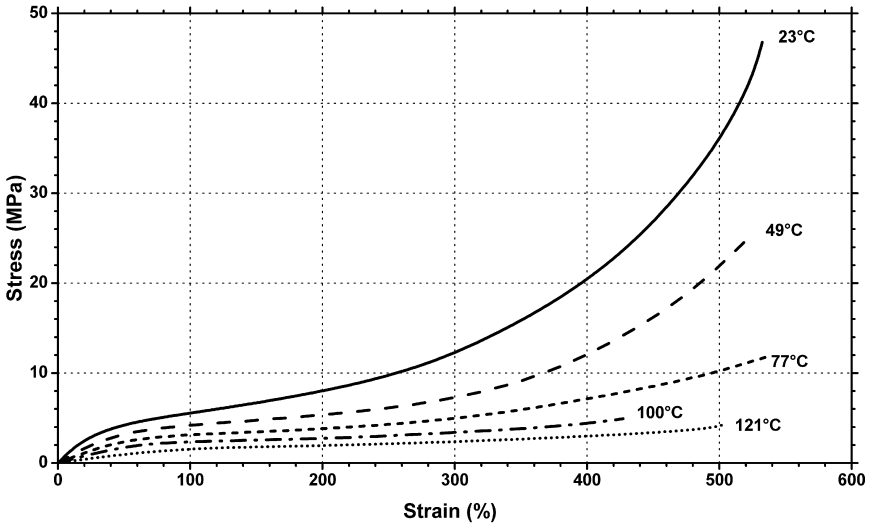

Figure 8.13 Stress vs. strain at various high temperatures for Bayer Texin® 285—polyester resin, Shore hardness 85A TPU resin [5].

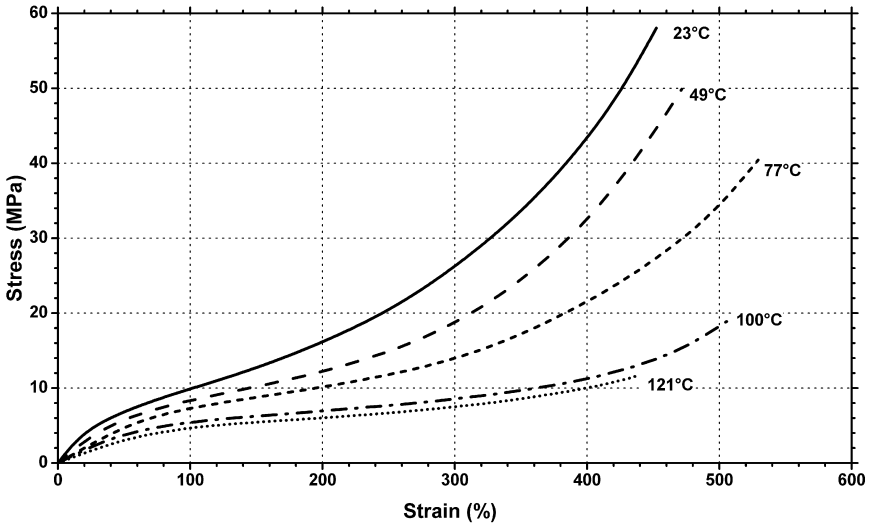

Figure 8.14 Stress vs. strain at various high temperatures for Bayer Texin® 390—polyester resin, Shore hardness 88A TPU resin [5].

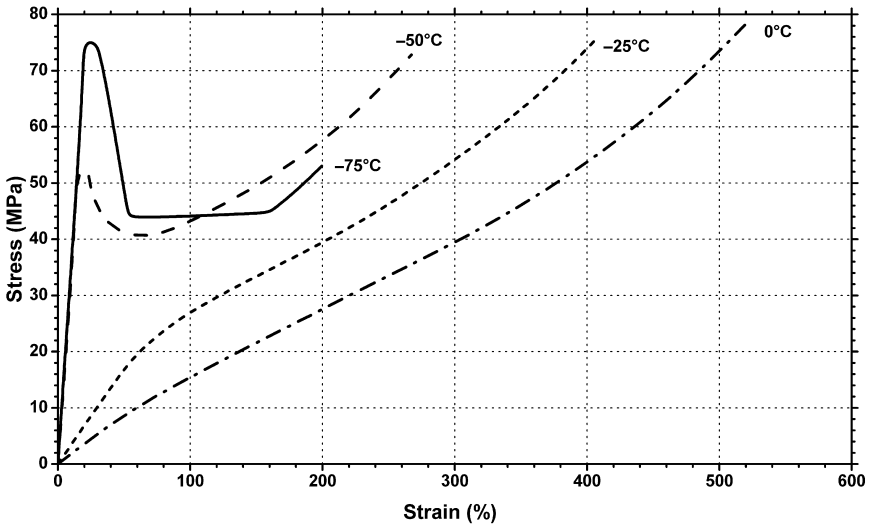

Figure 8.15 Stress vs. strain at various low temperatures for Bayer Texin® 390—polyester resin, Shore hardness 88A TPU resin [5].

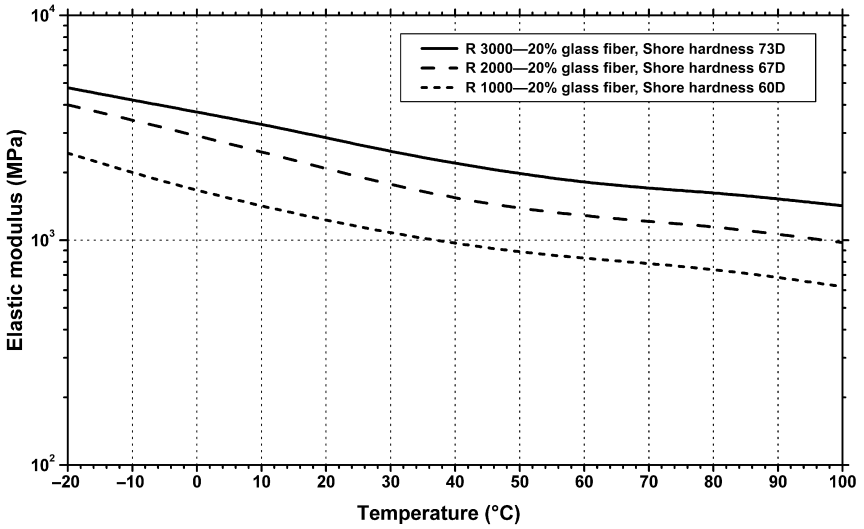

Figure 8.16 Elastic modulus vs. temperature for BASF Elastollan® R glass fiber filled TPU resins [4].

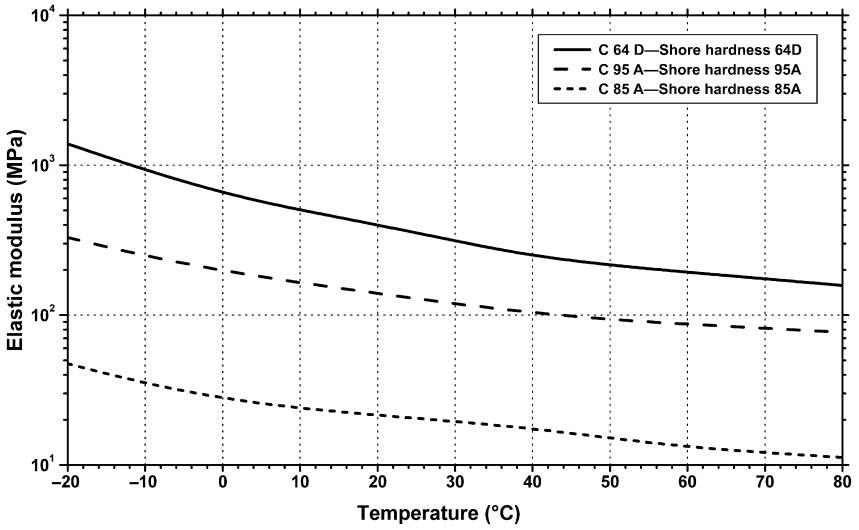

Figure 8.17 Elastic modulus vs. temperature for BASF Elastollan® polyester TPU resins [4].

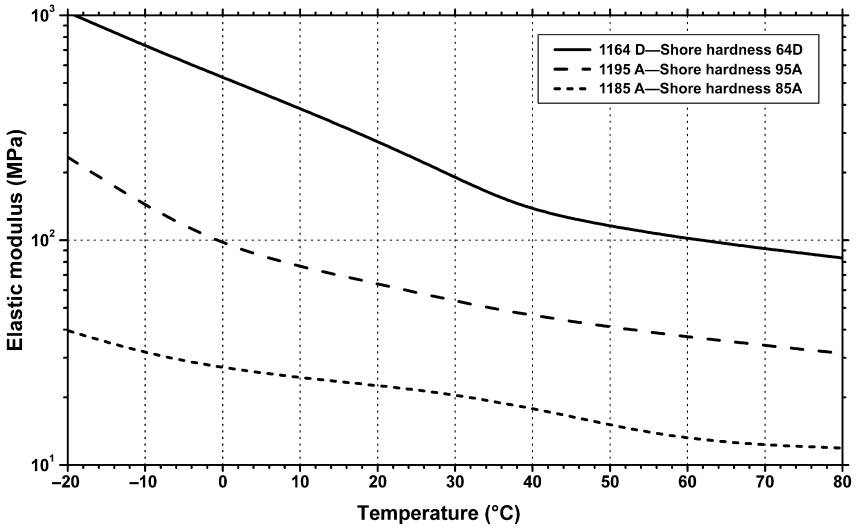

Figure 8.18 Elastic modulus vs. temperature for BASF Elastollan® polyether TPU resins [4].

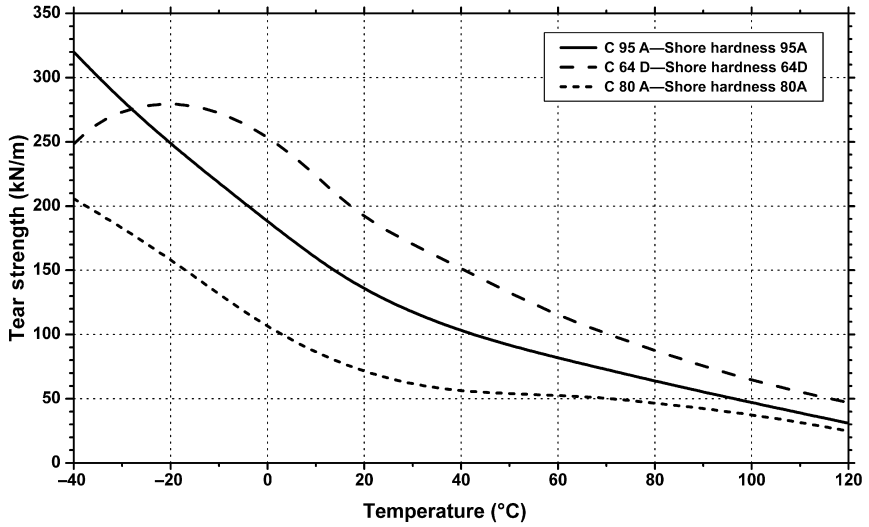

Figure 8.19 Tear strength vs. temperature for BASF Elastollan® polyester TPU resins [4].

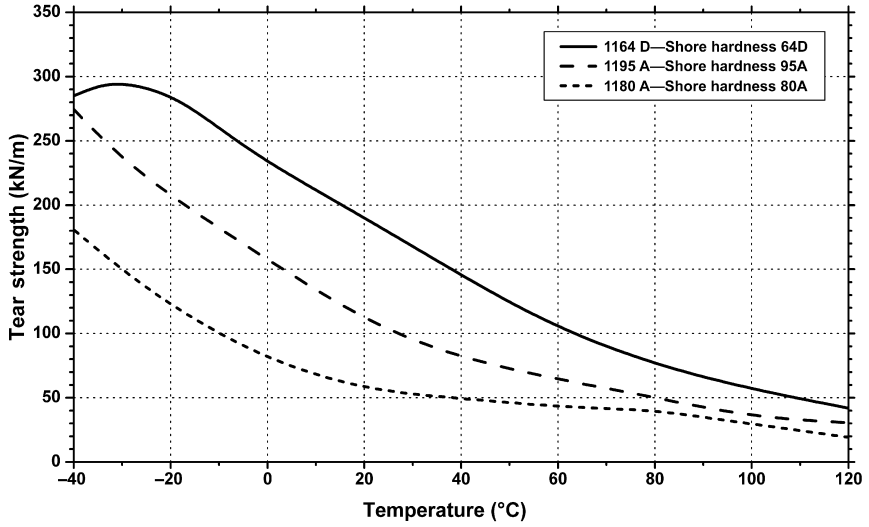

Figure 8.20 Tear strength vs. temperature for BASF Elastollan® polyether TPU resins [4].

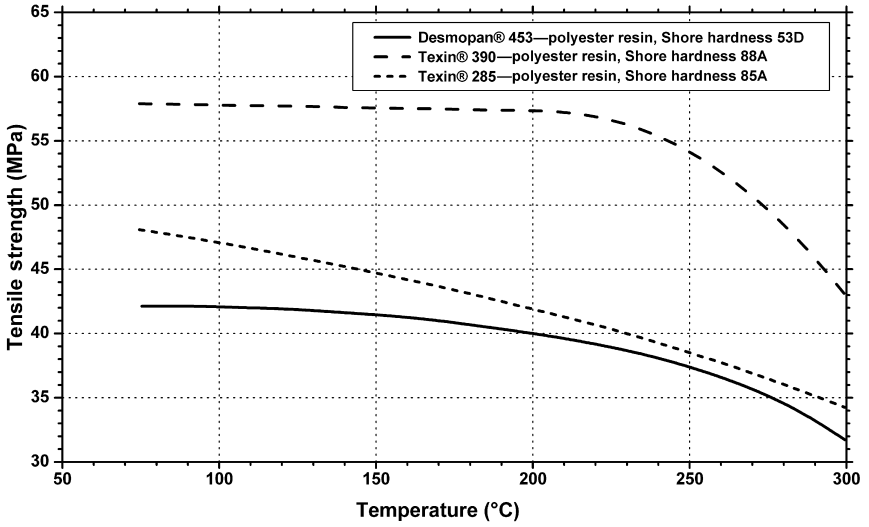

Figure 8.21 Tensile strength vs. temperature for Bayer TPU resins.

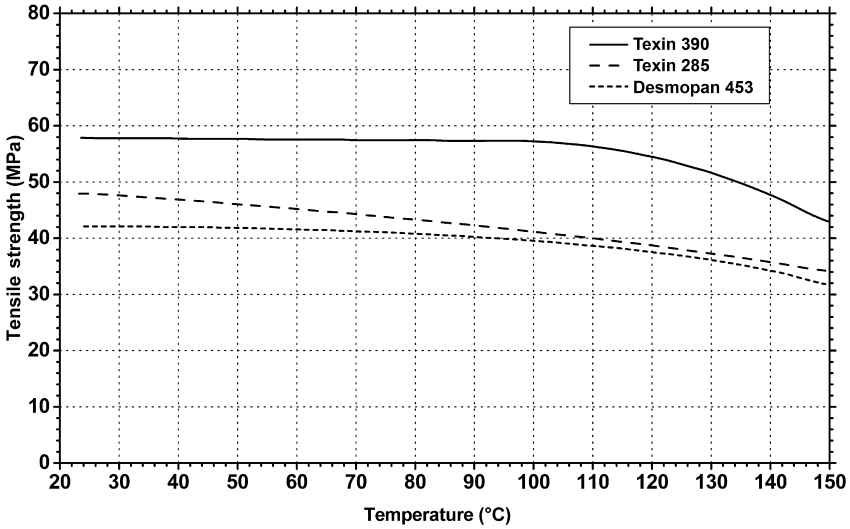

Figure 8.22 Tensile strength vs. temperature (different temperature range) for Bayer TPU resins [5].

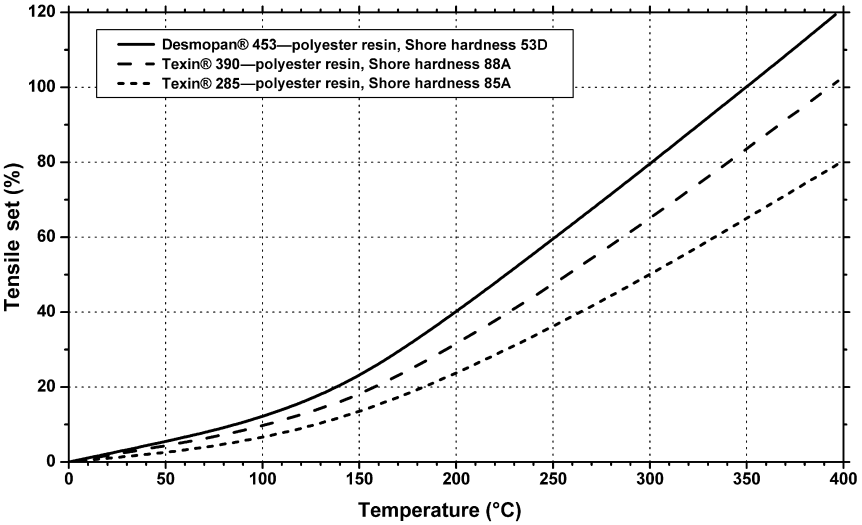

Figure 8.23 Tensile set vs. temperature for Bayer TPU resins [5].

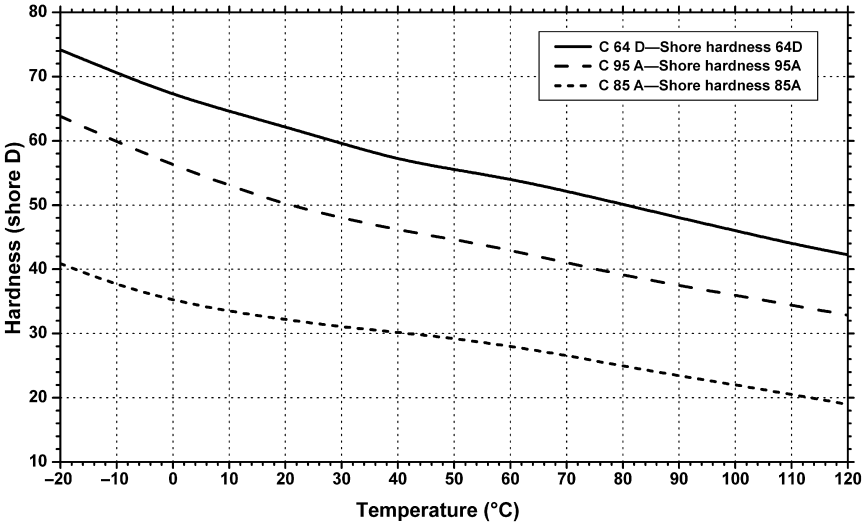

Figure 8.24 Hardness vs. temperature for BASF Elastollan® polyester TPU resins [4].

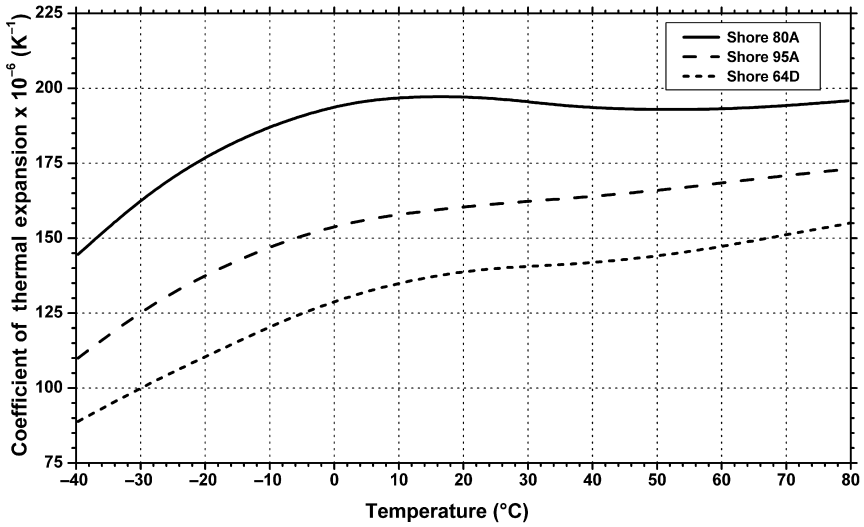

Figure 8.25 Coefficient of linear thermal expansion vs. temperature for BASF Elastollan® TPU resins [4].

8.2 Olefinic Thermoplastic Elastomers (TPO)

TPO materials are defined as compounds (mixtures) of various polyolefin polymers, semicrystalline thermoplastics, and amorphous elastomers. Most TPOs are composed of polypropylene and a copolymer of ethylene and propylene called ethylene–propylene rubber (EPR) [2]. A common rubber of this type is called ethylene propylene diene monomer rubber (EPDM), which has a small amount of a third monomer, a diene (two carbon–carbon double bonds in it). The diene monomer leaves a small amount of unsaturation in the polymer chain that can be used for sulfur cross-linking. Like most TPEs, TPO products are composed of hard and soft segments. TPO compounds include fillers, reinforcements, lubricants, heat stabilizers, antioxidants, UV stabilizers, colorants, and processing aids. They are characterized by high impact strength, low density, and good chemical resistance; they are used when durability and reliability are primary concerns.

Manufacturers and trade names: ExxonMobil Santoprene®, LyondellBasell Advanced Polyolefins Dexflex®.

Applications and uses: roofing and automotive exterior parts, capping distilled water, dairy products, fruit juices, sports drinks, beer, wine and food, cosmetics, toiletries and pharmaceutical packaging, sterilized closures, seals, and liners.

Data for TPOs are found in Figures 8.26–8.39.

8.3 Thermoplastic Copolyester Elastomers (TPE-Es or COPEs)

TPE-Es or COPEs are block copolymers [2]. The chemical structure of one such elastomer is shown in Figure 8.40.

These TPEs are generally tougher over a broader temperature range than the urethanes described in Section 8.1. Also, they are easier and more forgiving in processing.

- Excellent abrasion resistance
- High tensile, compressive, and tear strength
- Good flexibility over a wide range of temperatures
- Good hydrolytic stability
- Resistance to solvents and fungus attack
- Selection of a wide range of hardness

In these polyester TPEs, the hard polyester segments can crystallize, giving the polymer some of the attributes of semicrystalline thermoplastics, most particularly better solvent resistance than ordinary rubbers, and also better heat resistance. Above the melting temperature of the crystalline regions, these TPEs can have low viscosity and can be molded easily in thin sections and complex structures. Properties of thermoplastic polyester elastomers can be fine-tuned over a range by altering the ratio of hard to soft segments.

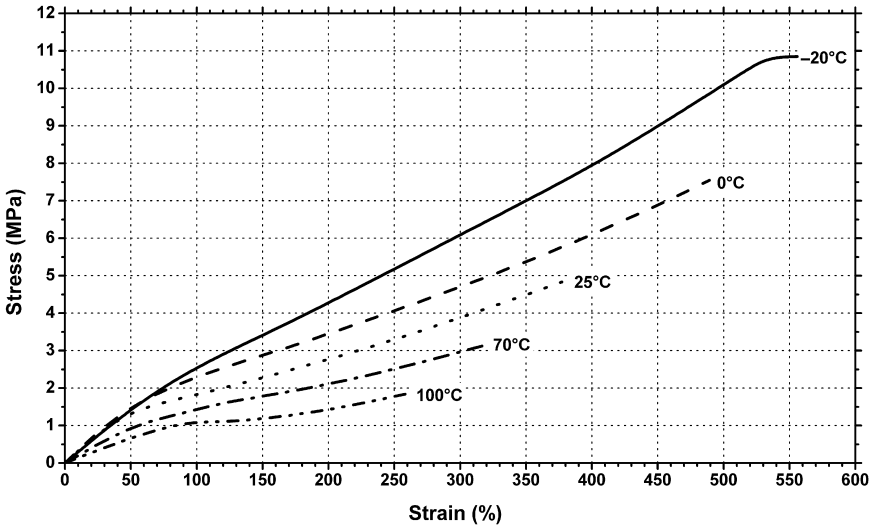

Figure 8.26 Tensile stress vs. strain for ExxonMobil Santoprene® 55 Shore A grades of TPO elastomers (per ASTM D 412) [6].

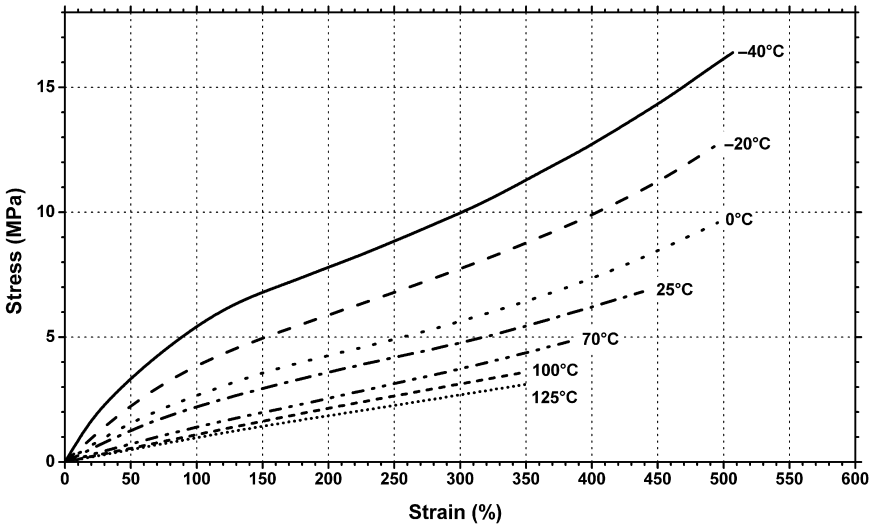

Figure 8.27 Tensile stress vs. strain for ExxonMobil Santoprene® 64 Shore A grades of TPO elastomers (per ASTM D 412) [6].

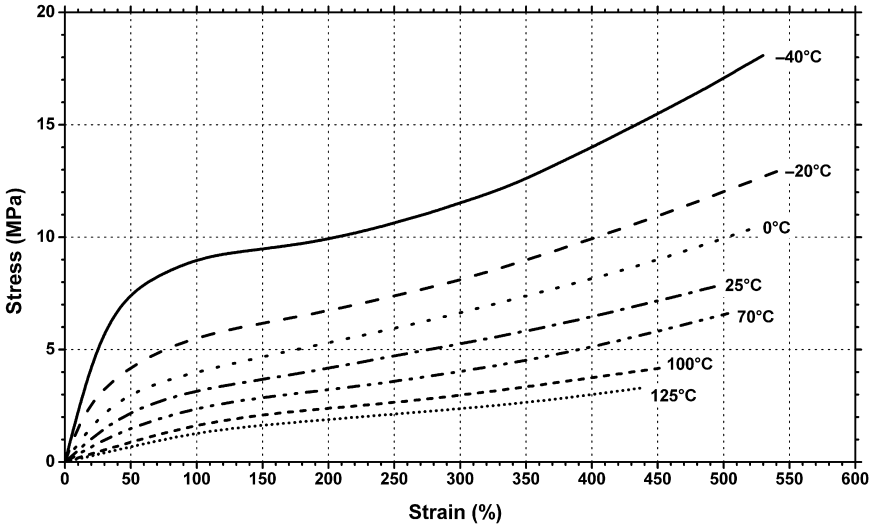

Figure 8.28 Tensile stress vs. strain for ExxonMobil Santoprene® 73 Shore A grades of TPO elastomers (per ASTM D 412) [6].

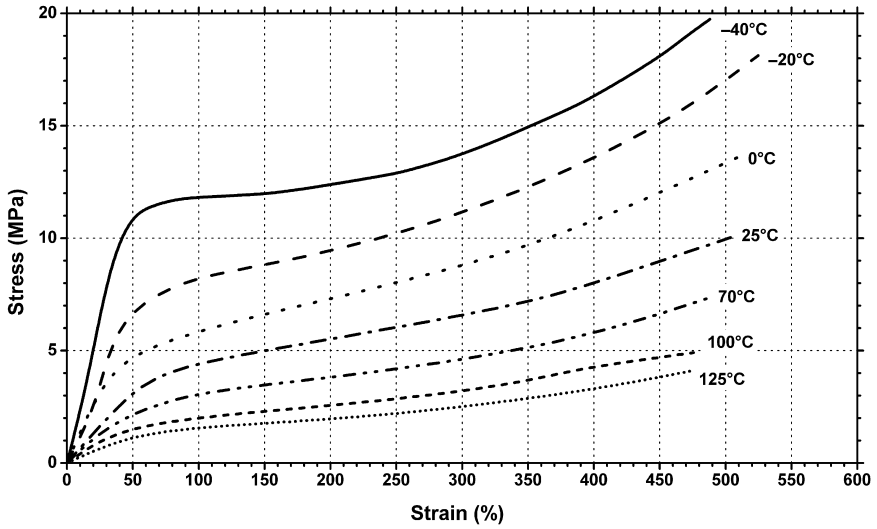

Figure 8.29 Tensile stress vs. strain for ExxonMobil Santoprene® 80 Shore A grades of TPO elastomers (per ASTM D 412) [6].

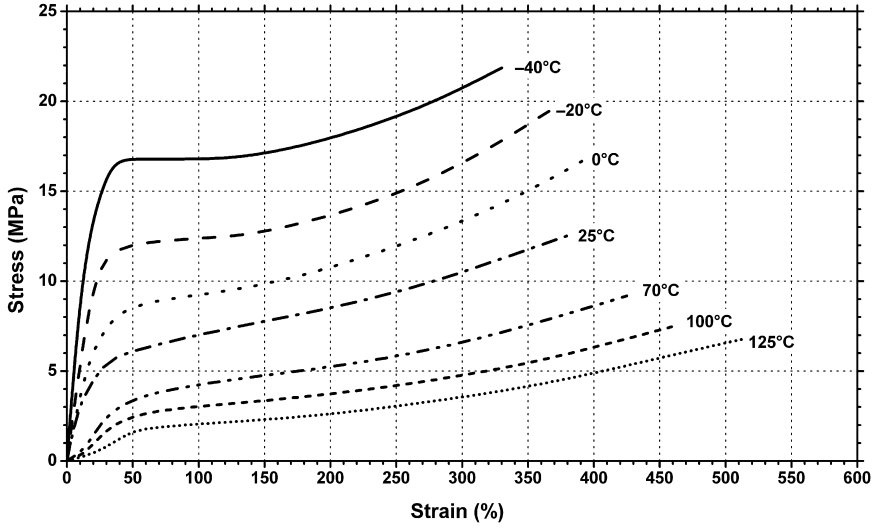

Figure 8.30 Tensile stress vs. strain for ExxonMobil Santoprene® 87 Shore A grades of TPO elastomers (per ASTM D 412) [6].

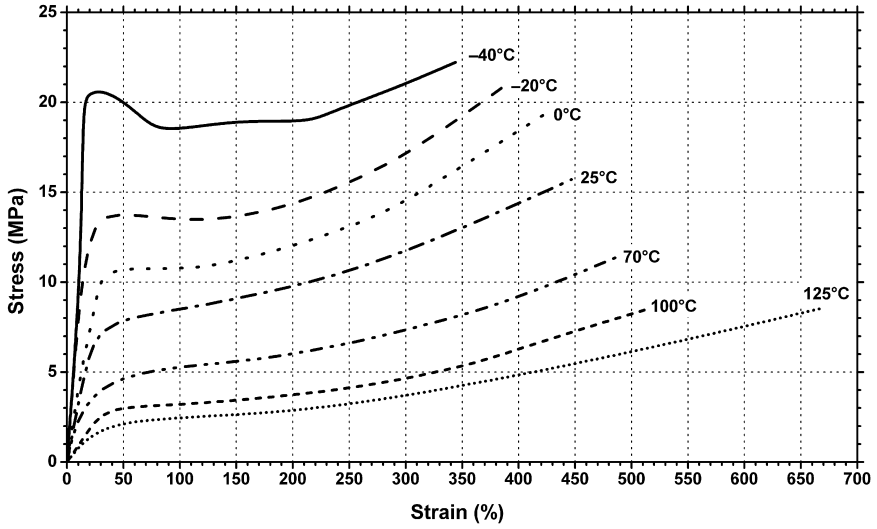

Figure 8.31 Tensile stress vs. strain for ExxonMobil Santoprene® 40 Shore D grades of TPO elastomers (per ASTM D 412) [6].

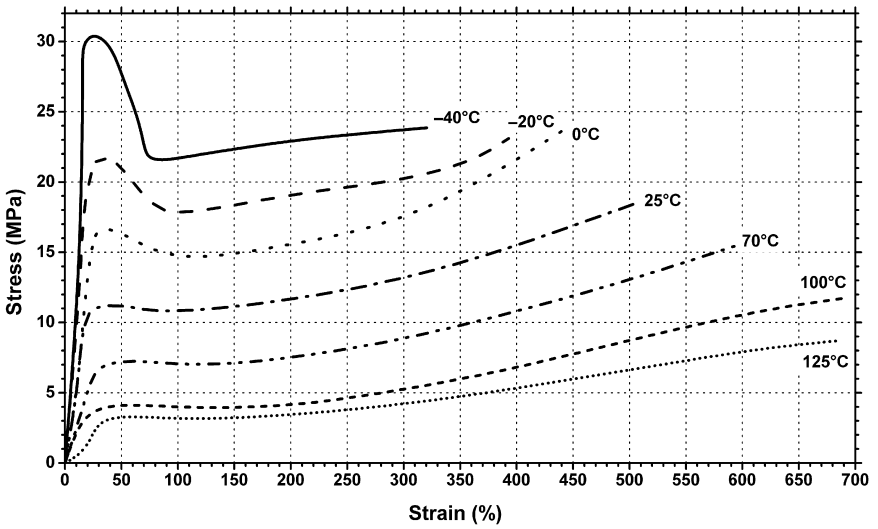

Figure 8.32 Tensile stress vs. strain for ExxonMobil Santoprene® 50 Shore D grades of TPO elastomers (per ASTM D 412) [6].

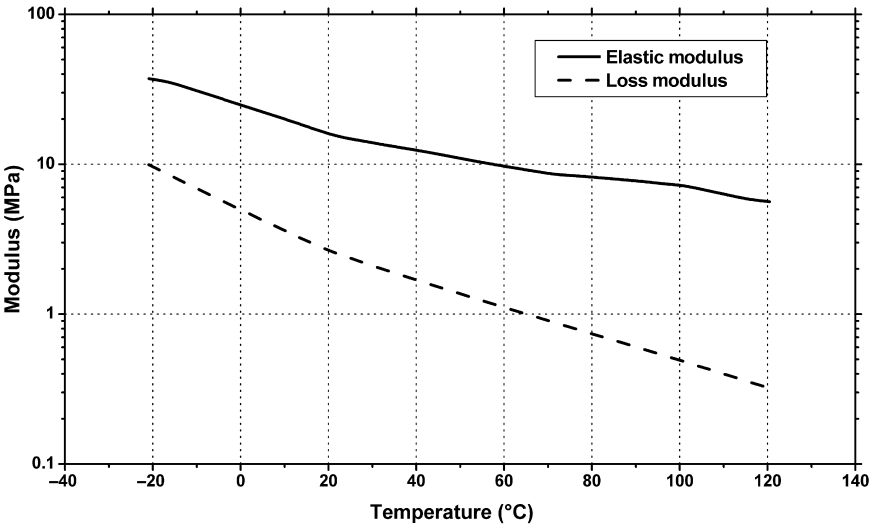

Figure 8.33 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 55 Shore A grades of TPO elastomers (per ASTM D 412) [6].

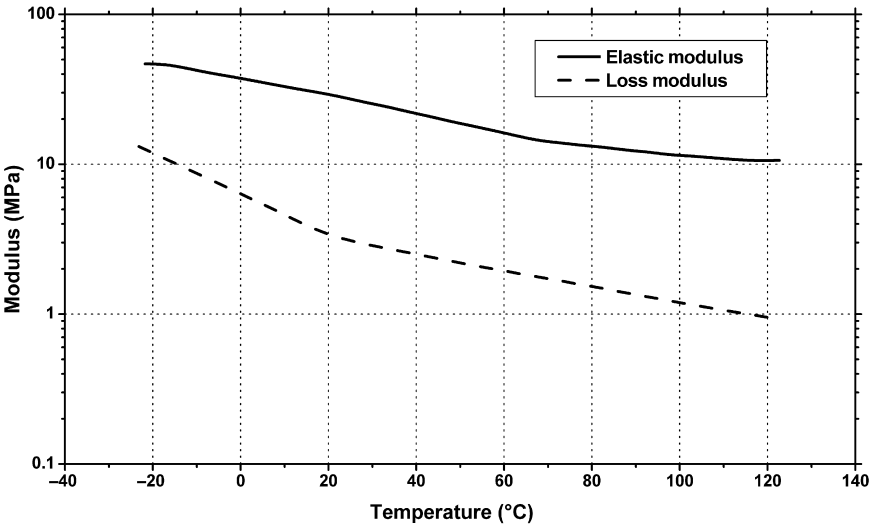

Figure 8.34 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 64 Shore A grades of TPO elastomers (per ASTM D 412) [6].

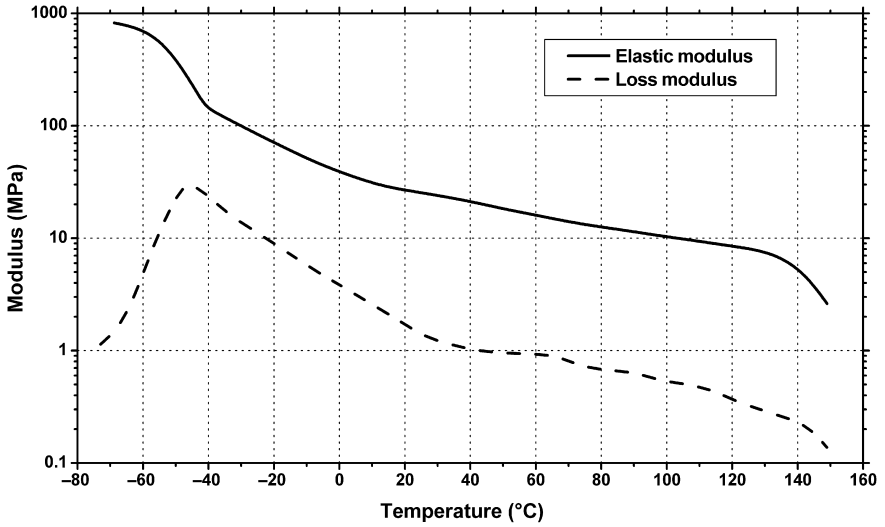

Figure 8.35 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 73 Shore A grades of TPO elastomers (per ASTM D 412) [6].

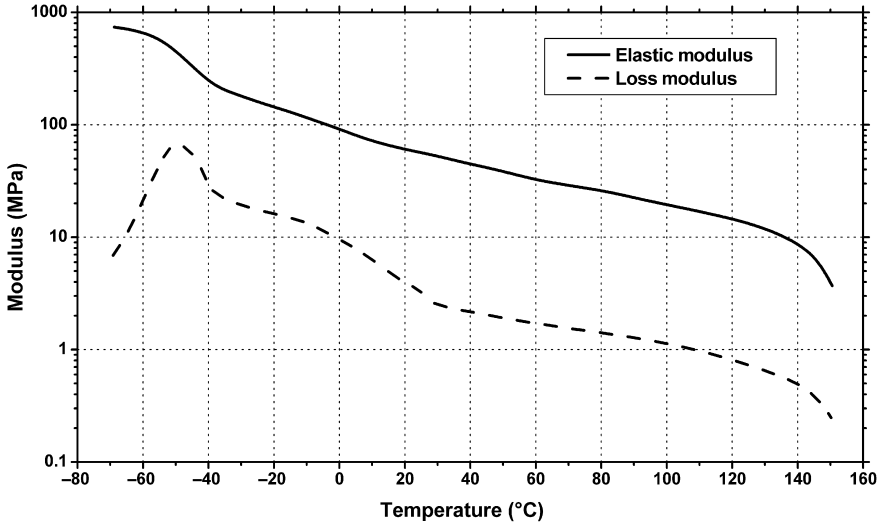

Figure 8.36 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 80 Shore A grades of TPO elastomers (per ASTM D 412) [6].

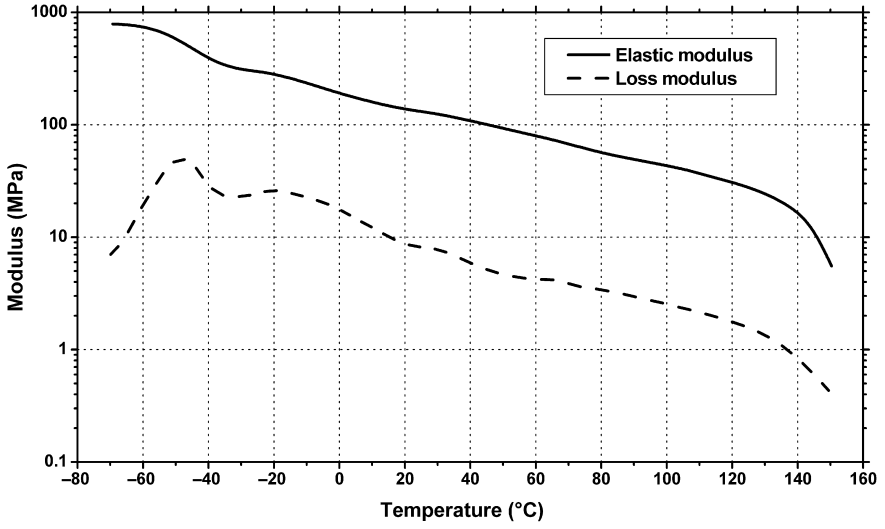

Figure 8.37 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 87 Shore A grades of TPO elastomers (per ASTM D 412) [6].

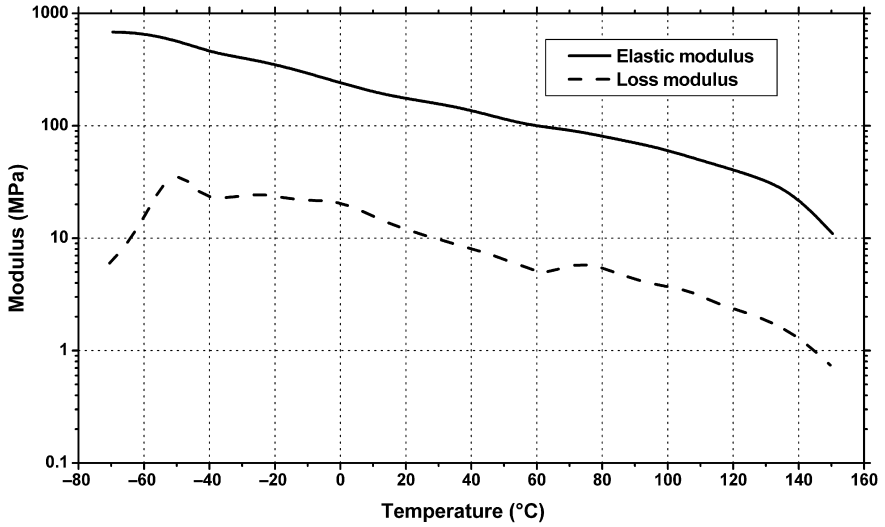

Figure 8.38 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 40 Shore D grades of TPO elastomers (per ASTM D 412) [6].

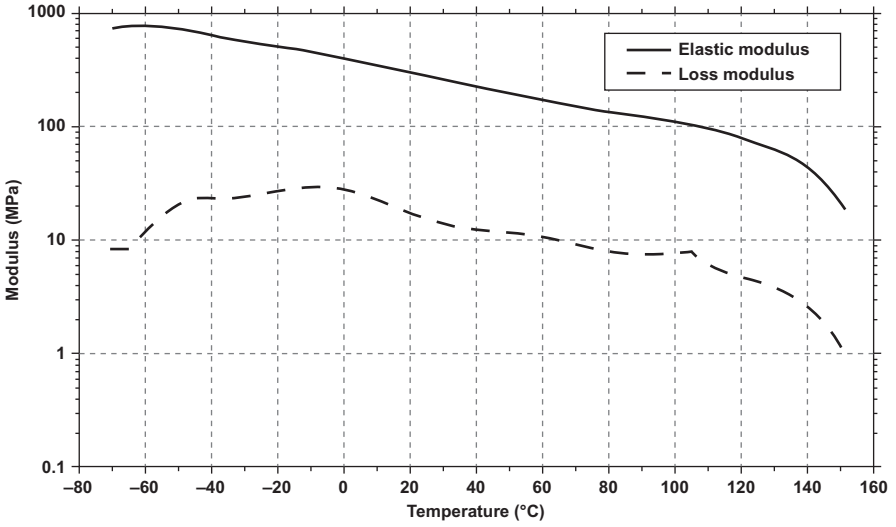

Figure 8.39 Elastic and loss modulus vs. temperature for ExxonMobil Santoprene® 50 Shore D grades of TPO elastomers (per ASTM D 412) [6].

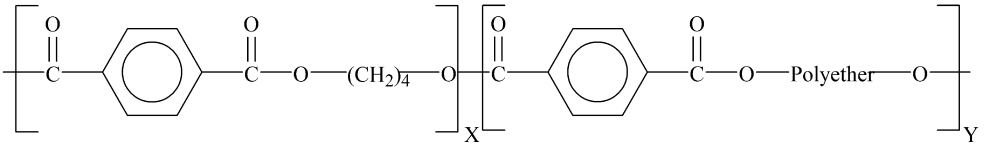

Figure 8.40 Molecular structure of Ticona Riteflex® TPE-Es.

In DuPont Hytrel® polyester TPEs, the resin is a block copolymer. The hard phase is polybutylene terephthalate (PBT). The soft segments are long-chain polyether glycols.

Manufacturers and trade names: Ticona Riteflex®, DuPont Hytrel®, Eastman Ecdel®, DSM Engineering Plastics Arnitel®.

Applications and uses: seals, belts, bushings, pump diaphragms, gears, protective boots, hose and tubing, springs, and impact-absorbing devices, sporting goods, footwear, wire and cable.

Data for thermoplastic polyester elastomers are found in Figures 8.41–8.64.

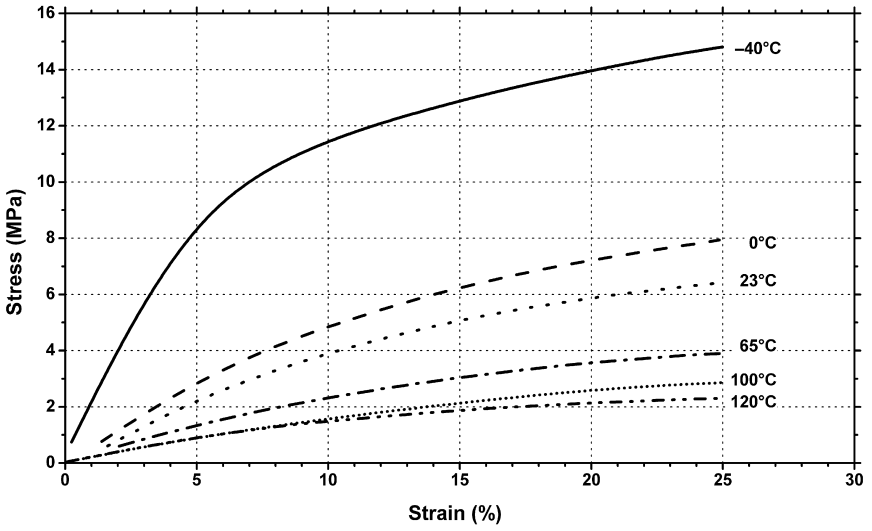

Figure 8.41 Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® G4075—general purpose, low modulus, Shore D40 thermoplastic polyester elastomer resin [7].

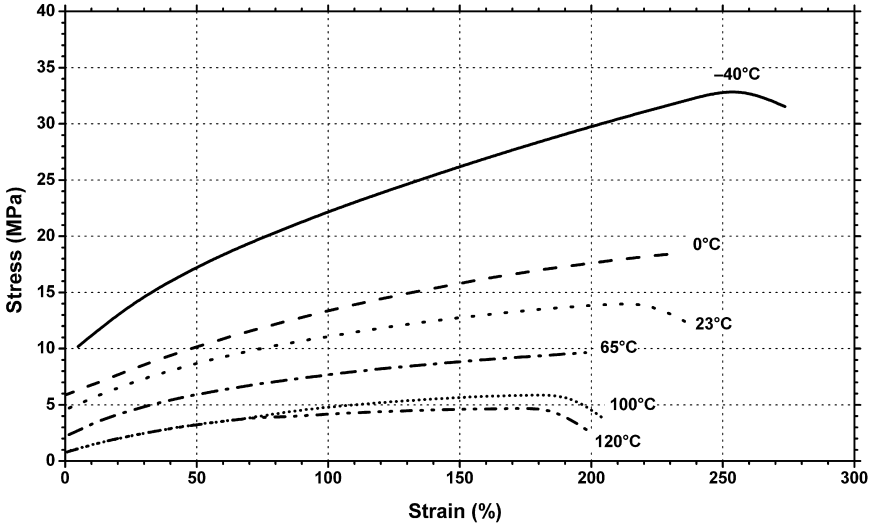

Figure 8.42 Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® G4075—general purpose, low modulus, Shore D40 thermoplastic polyester elastomer resin [7].

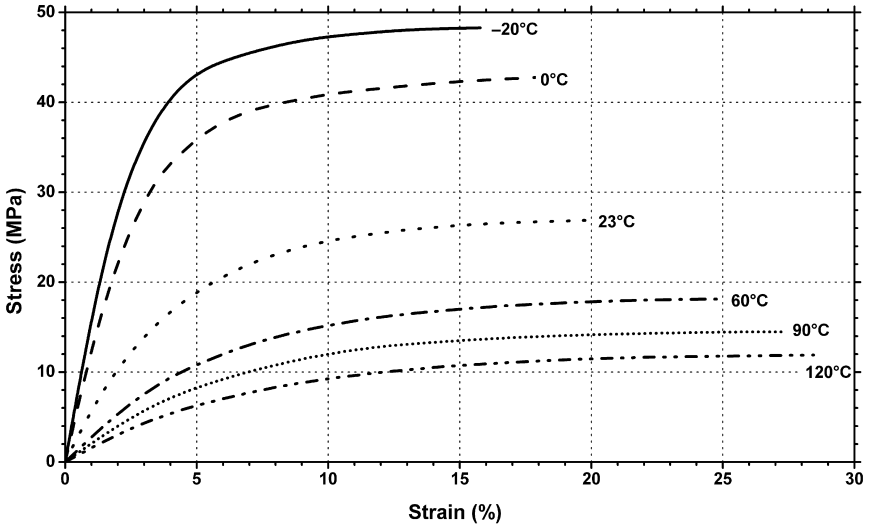

Figure 8.43 Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 7246—high performance, high modulus, Shore D72 thermoplastic polyester elastomer resin [7].

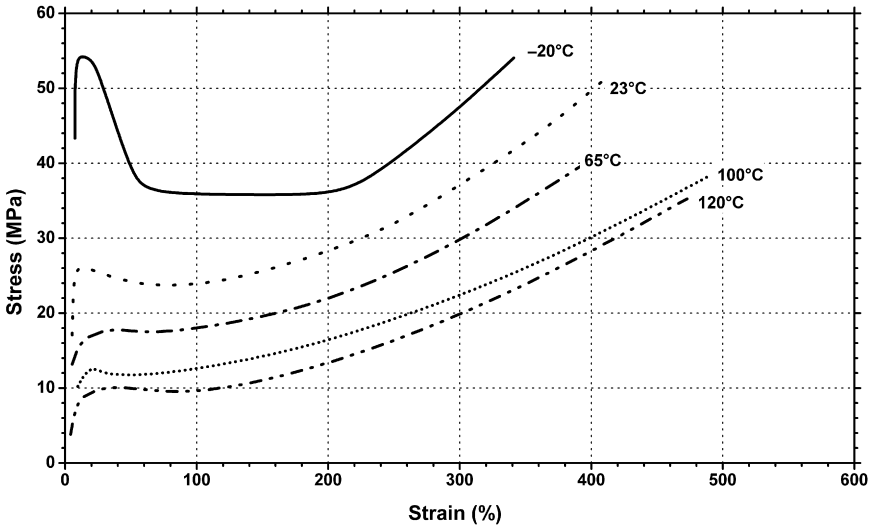

Figure 8.44 Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 7246—high performance, high modulus, Shore D72 thermoplastic polyester elastomer resin [7].

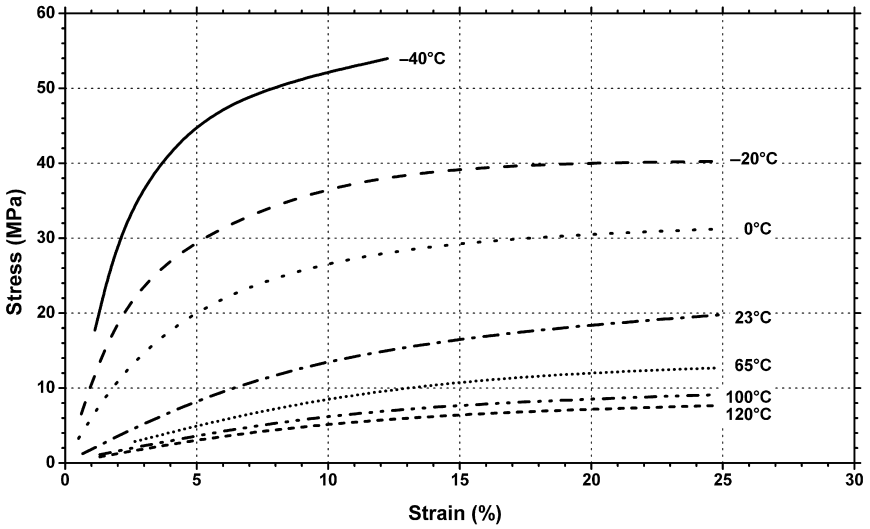

Figure 8.45 Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 6356—high performance, medium-high modulus, Shore D63 thermoplastic polyester elastomer resin [7].

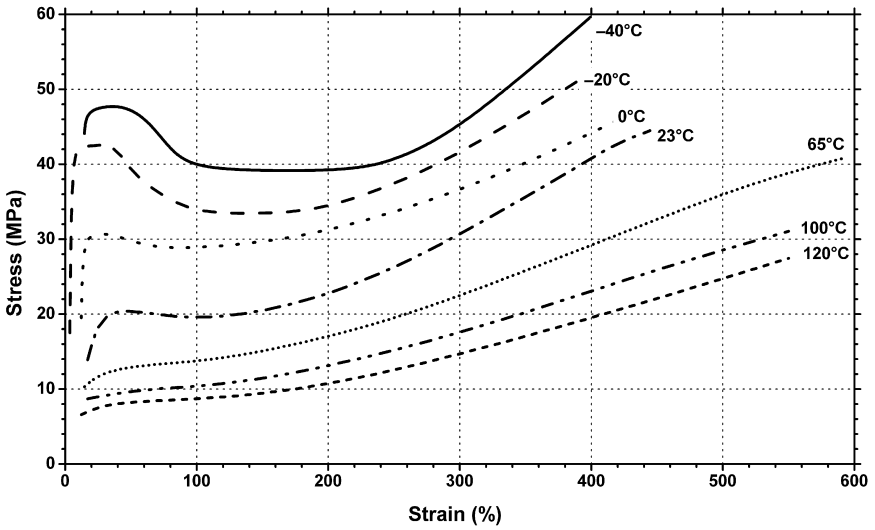

Figure 8.46 Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 6356—high performance, medium-high modulus, Shore D63 thermoplastic polyester elastomer resin [7].

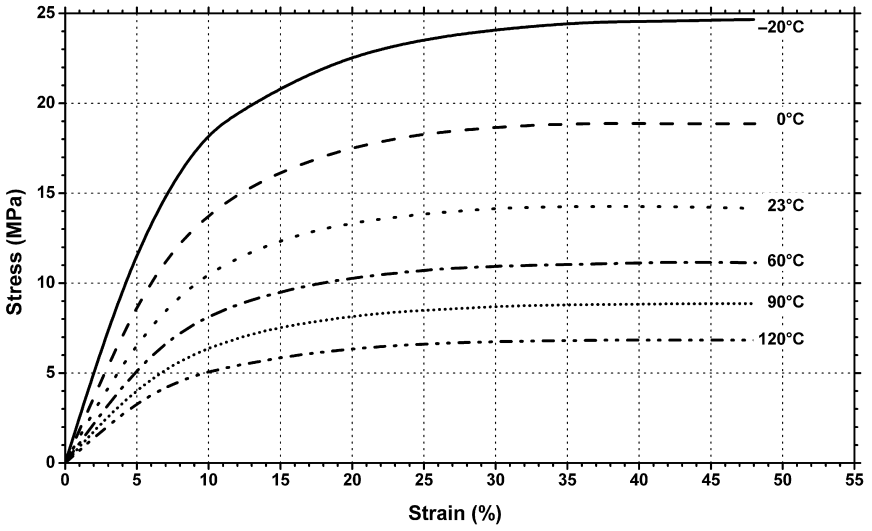

Figure 8.47 Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 5556—high performance, medium-high modulus, Shore D55 thermoplastic polyester elastomer resin [7].

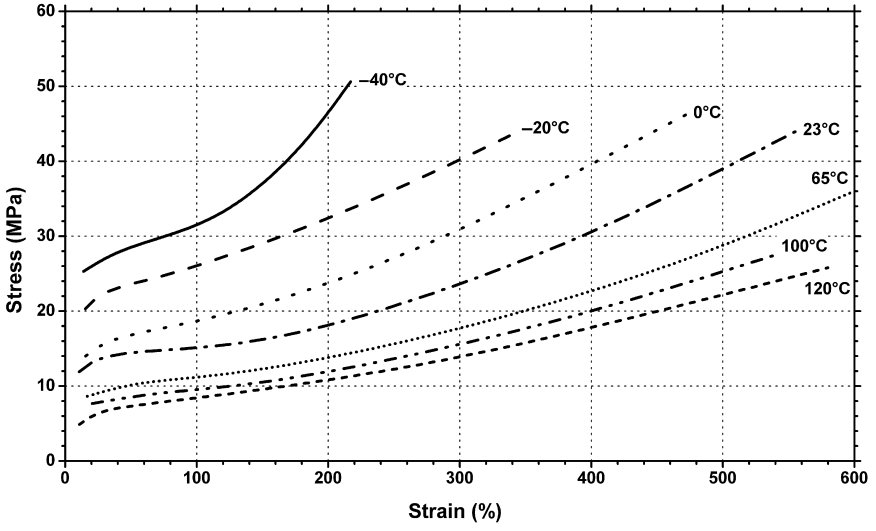

Figure 8.48 Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 5556—high performance, medium-high modulus, Shore D55 thermoplastic polyester elastomer resin [7].

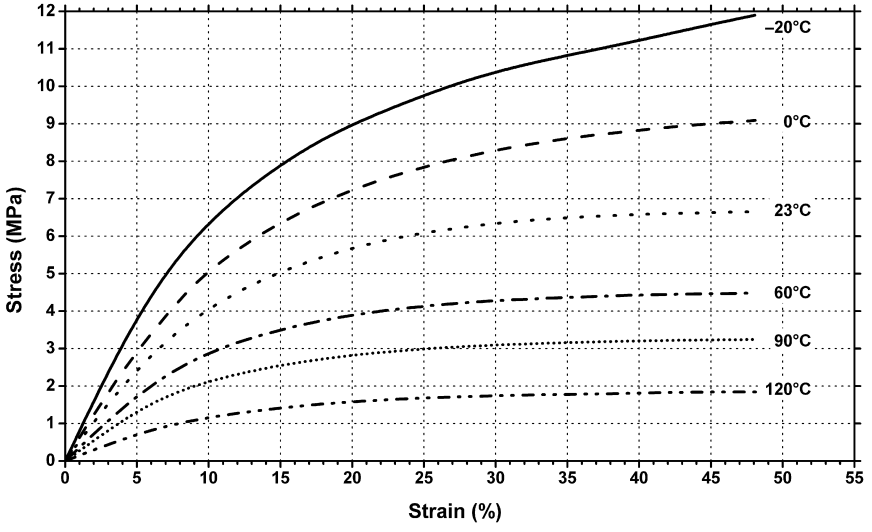

Figure 8.49 Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 4056—high performance, low modulus, Shore D40 thermoplastic polyester elastomer resin [7].

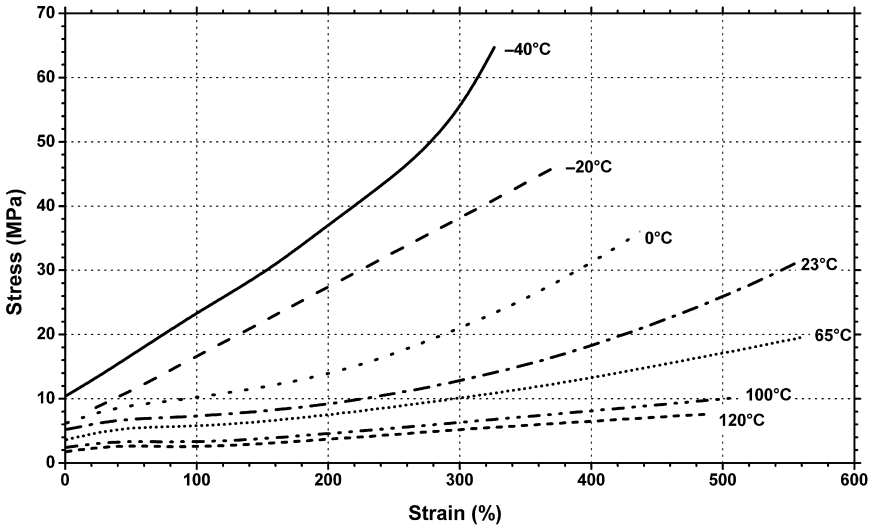

Figure 8.50 Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 4056—high performance, low modulus, Shore D40 thermoplastic polyester elastomer resin [7].

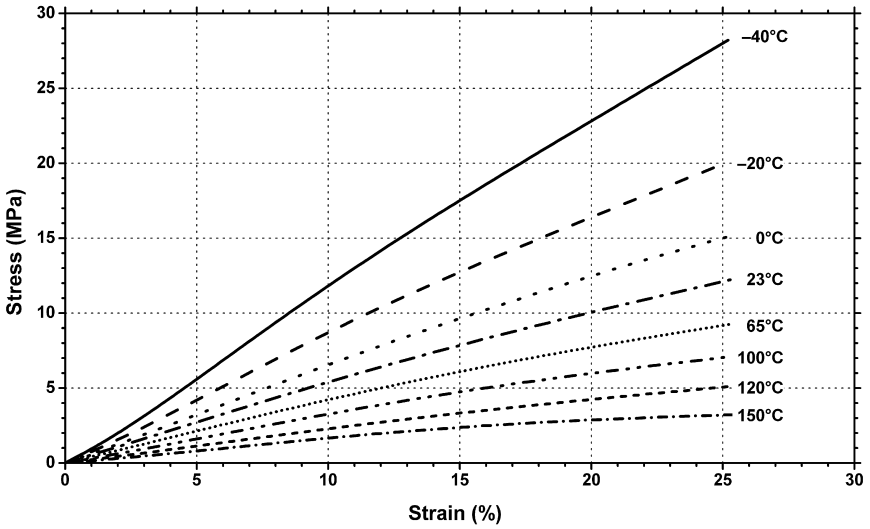

Figure 8.51 Stress vs. strain at various temperatures in compression for DuPont Hytrel® G4075—general purpose, low modulus, Shore D40 thermoplastic polyester elastomer resin [7].

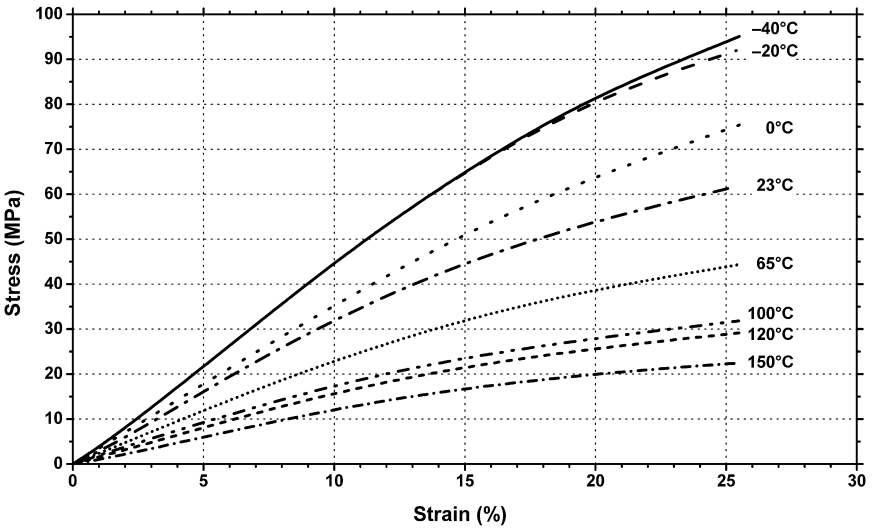

Figure 8.52 Stress vs. strain at various temperatures in compression for DuPont Hytrel® 7246—high performance, high modulus, Shore D72 thermoplastic polyester elastomer resin [7].

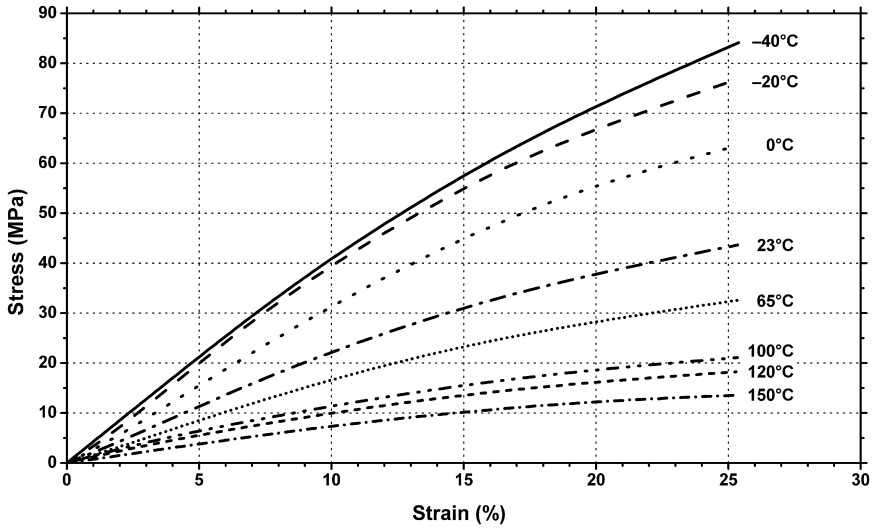

Figure 8.53 Stress vs. strain at various temperatures in compression for DuPont Hytrel® 6356—high performance, medium-high modulus, Shore D63 thermoplastic polyester elastomer resin [7].

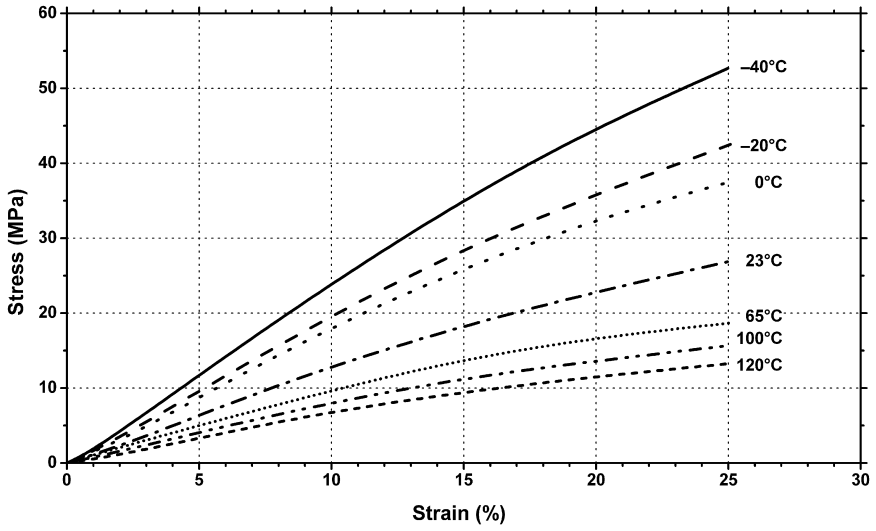

Figure 8.54 Stress vs. strain at various temperatures in compression for DuPont Hytrel® 5556—high performance, medium-high modulus, Shore D55 thermoplastic polyester elastomer resin [7].

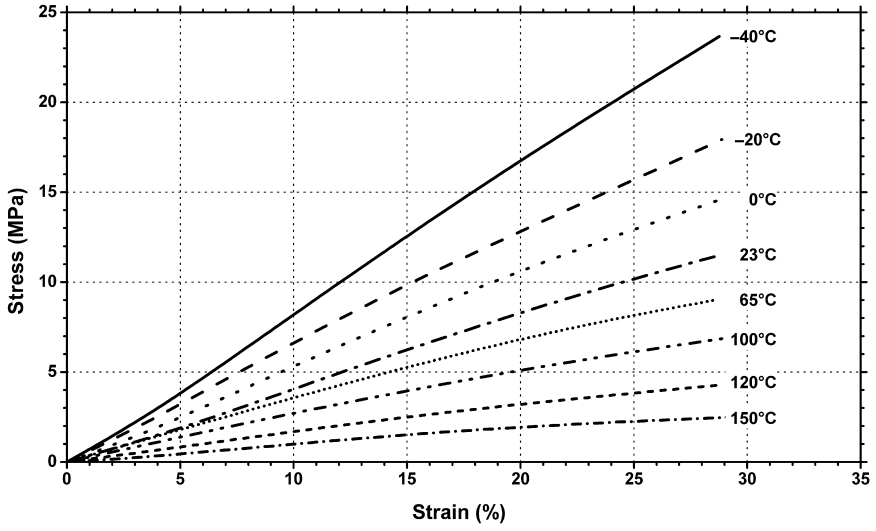

Figure 8.55 Stress vs. strain at various temperatures in compression for DuPont Hytrel® 4056—high performance, low modulus, Shore D40 thermoplastic polyester elastomer resin [7].

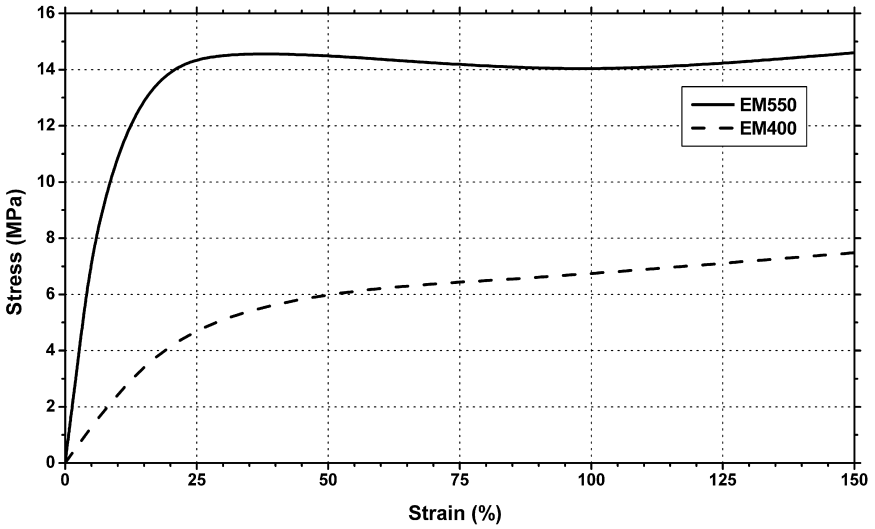

Figure 8.56 Typical stress vs. strain curves for DSM Arnitel® EM400 and Arnitel® EM550 TPE thermoplastic polyester elastomer resins [8].

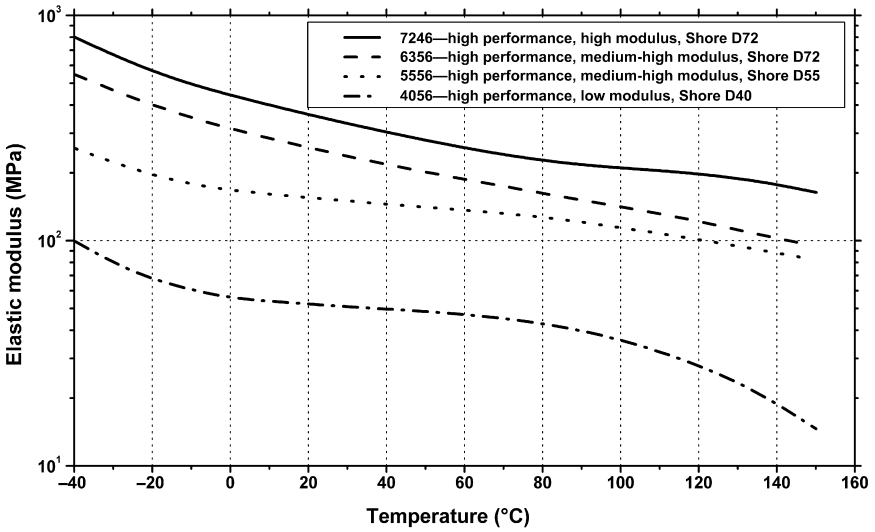

Figure 8.57 Elastic modulus in compression vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

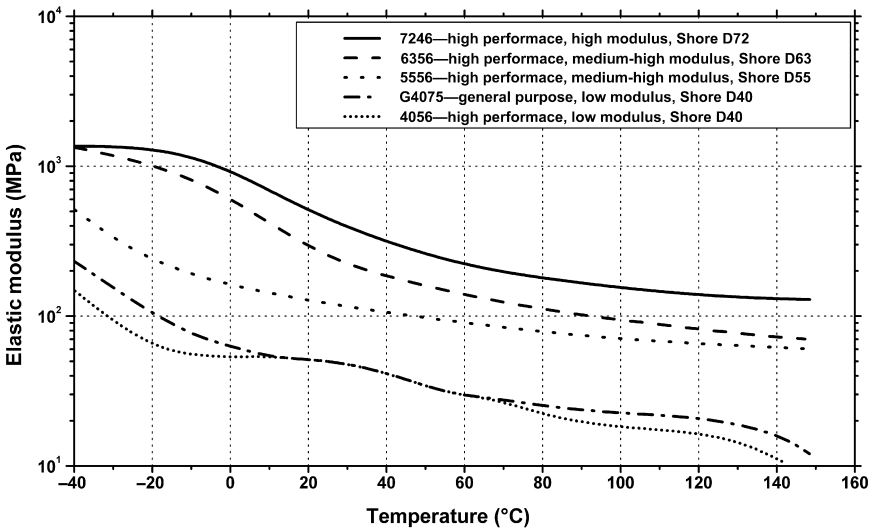

Figure 8.58 Elastic modulus vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

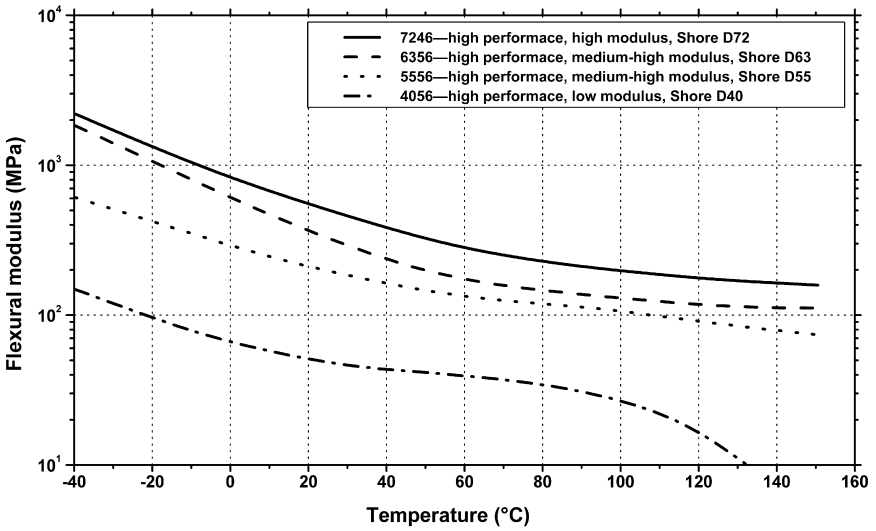

Figure 8.59 Flexural modulus vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

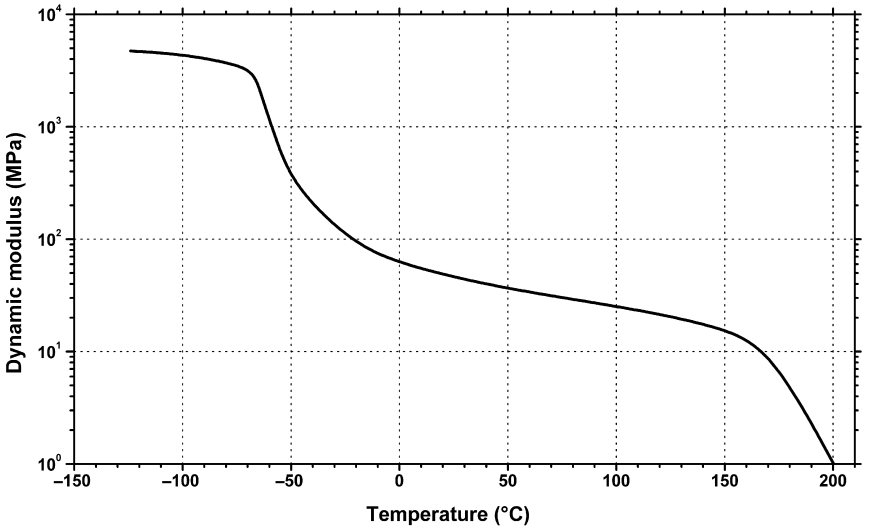

Figure 8.60 Dynamic modulus vs. temperature for DSM Arnitel® PL 380 TPE [8].

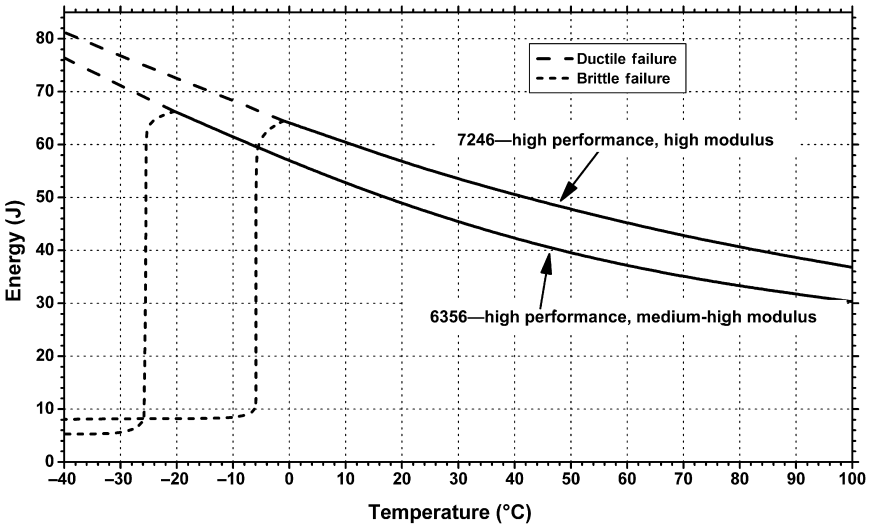

Figure 8.61 Dropped weight impact failure energy vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

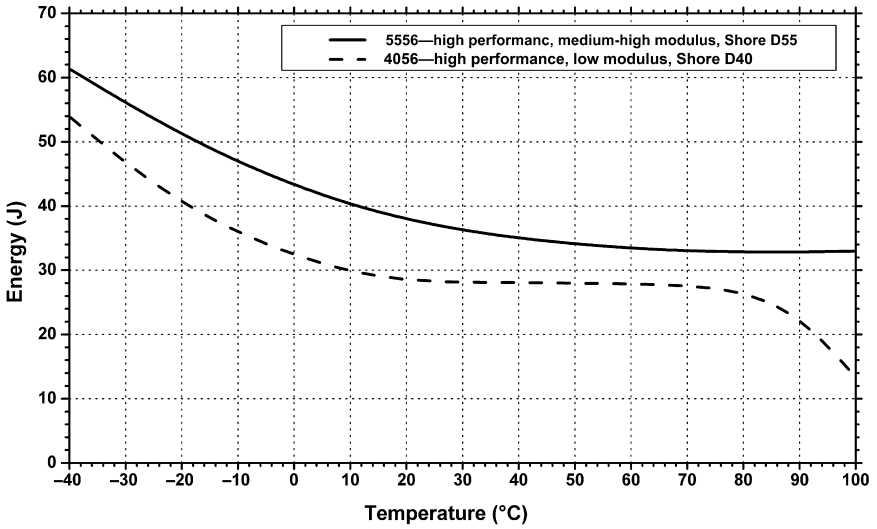

Figure 8.62 Dropped weight impact failure energy vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

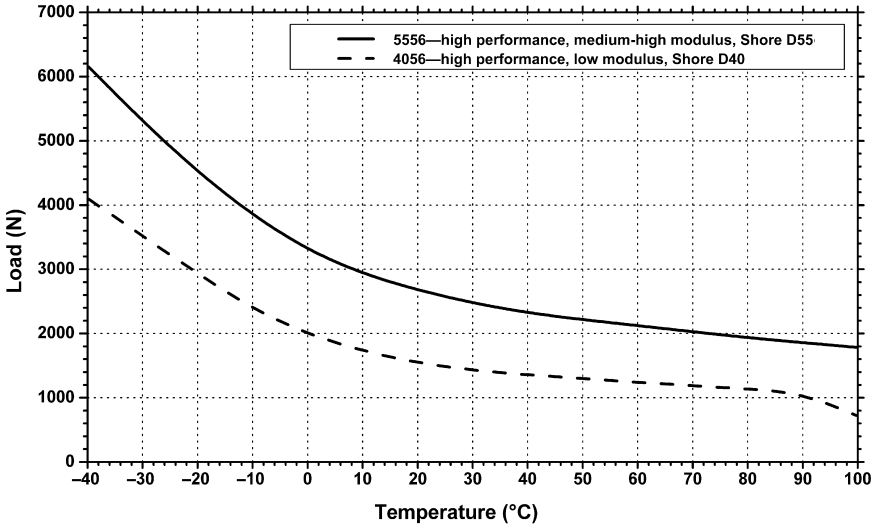

Figure 8.63 Dropped weight impact failure load vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

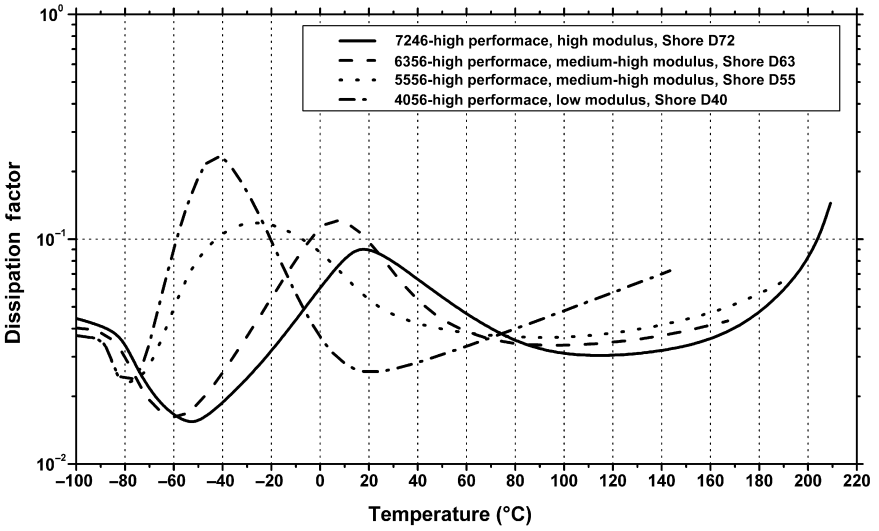

Figure 8.64 Dissipation factor vs. temperature for DuPont Hytrel® thermoplastic polyester elastomer resins [7].

8.4 TPEs—Polyether Block Amide (PEBA)

PEBAs are plasticizer-free TPEs. The soft segment is the polyether and the hard segment is the polyamide (nylon). They are easy to process by injection molding and profile or film extrusion. Often they can be easily melt-blended with other polymers, and many compounders will provide custom products by doing this. Their chemistry allows them to achieve a wide range of physical and mechanical properties by varying the monomeric block types and ratios.

- Light weight
- Great flexibility (extensive range)
- Resiliency
- Very good dynamic properties
- High strength
- Outstanding impact resistance properties at low temperature
- Easy processing
- Good resistance to most chemicals

Manufacturers and trade names: Arkema Pebax®, Evonik Vestamid® E.

Applications and uses: noiseless gears and functional elements of sports shoes, as well as for high-performance extrusion components like paint spray hoses, vacuum brake booster lines.

Data for PEBA elastomers are found in Figure 8.65–8.73.

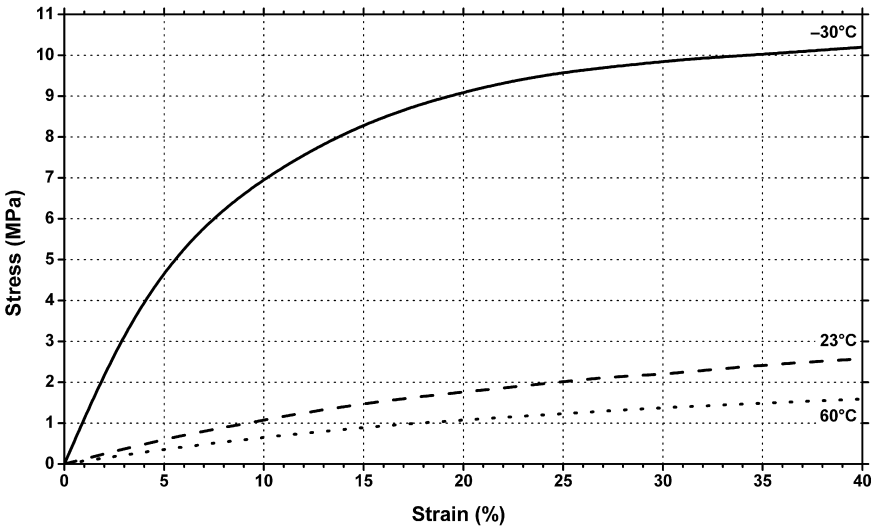

Figure 8.65 Stress vs. strain at various temperatures for Arkema Pebax® 2533 SN 01—Shore hardness 25 TPEs—PEBA resin.

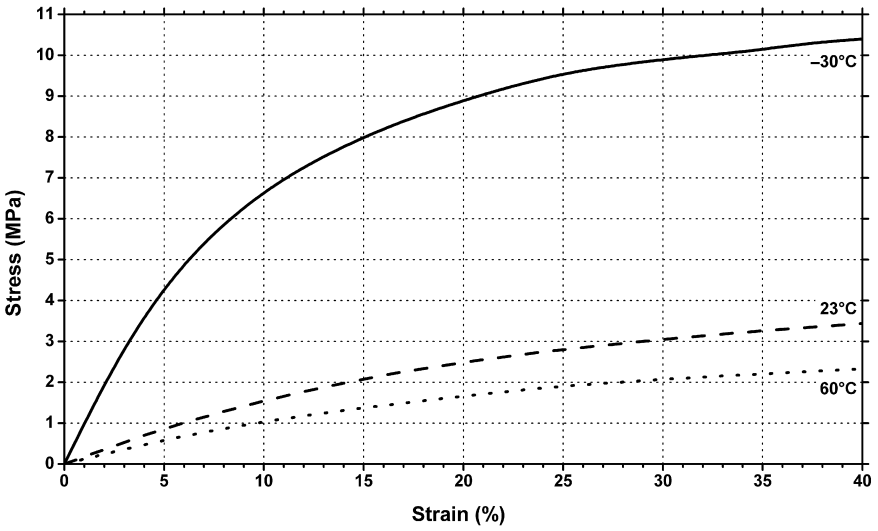

Figure 8.66 Stress vs. strain at various temperatures for Arkema Pebax® 3533 SN 01—Shore hardness 35 TPEs—PEBA resin.

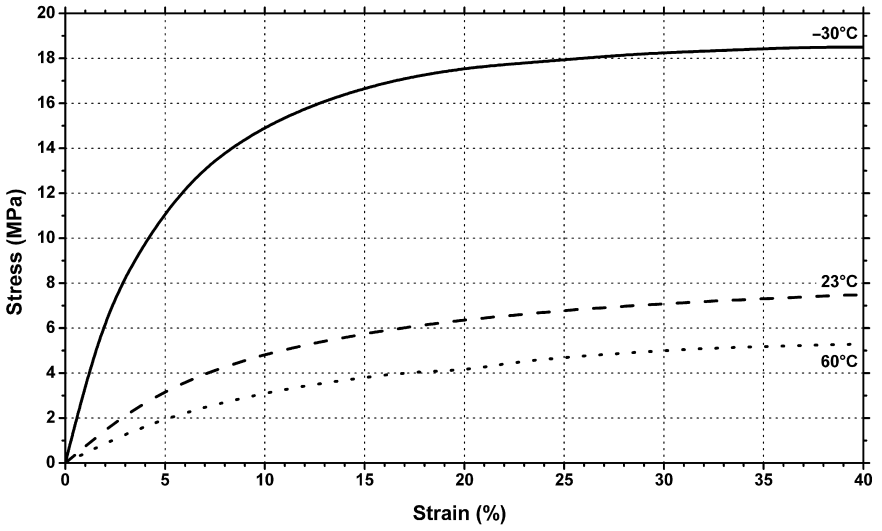

Figure 8.67 Stress vs. strain at various temperatures for Arkema Pebax® 4033 SN 01—Shore hardness 40 TPEs—PEBA resin.

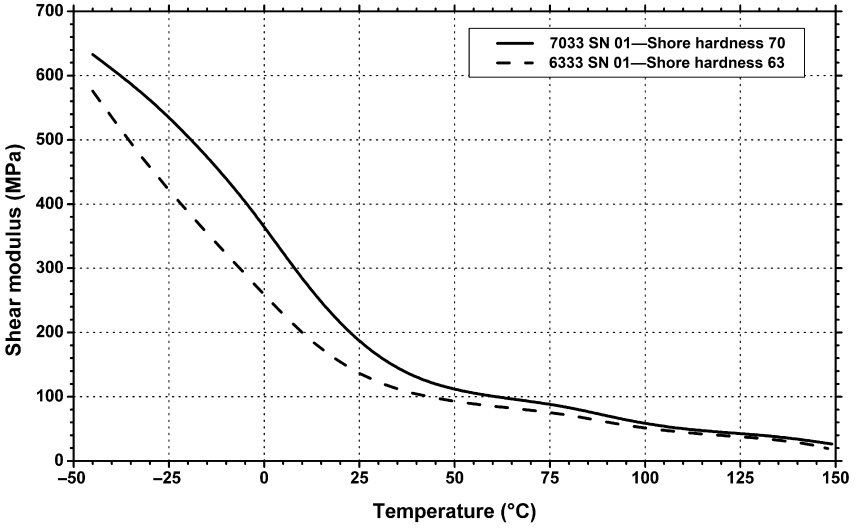

Figure 8.68 Shear modulus vs. temperature for Arkema Pebax® TPEs—PEBA resins.

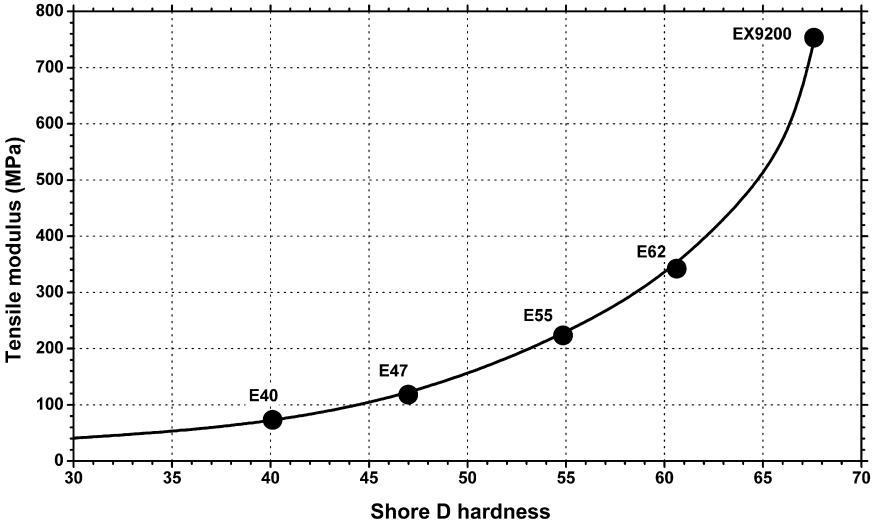

Figure 8.69 Relationship between tensile modulus and Shore hardness of Evonik Corporation Vestamid® PEBA resins [9].

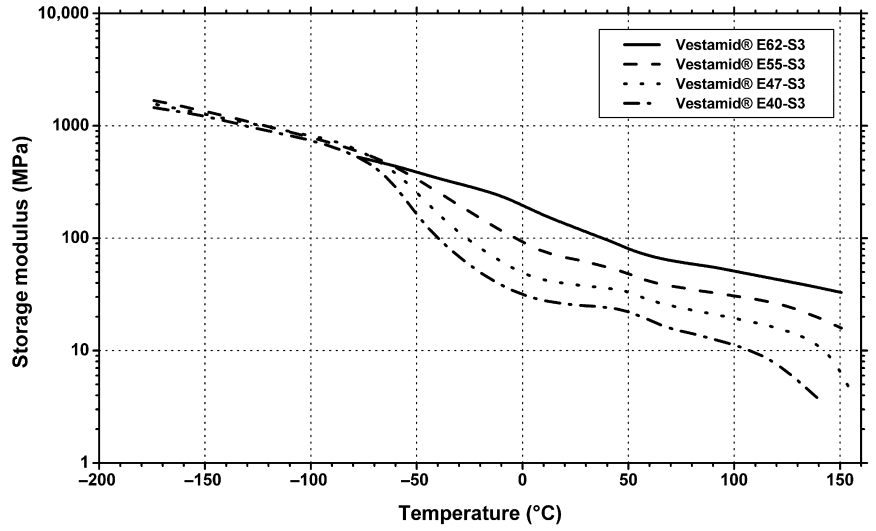

Figure 8.70 Temperature dependence of the dynamic shear modulus of Evonik Corporation Vestamid® PEBA resins determined with torsional vibration analyses according to ISO 6721-2 [9].

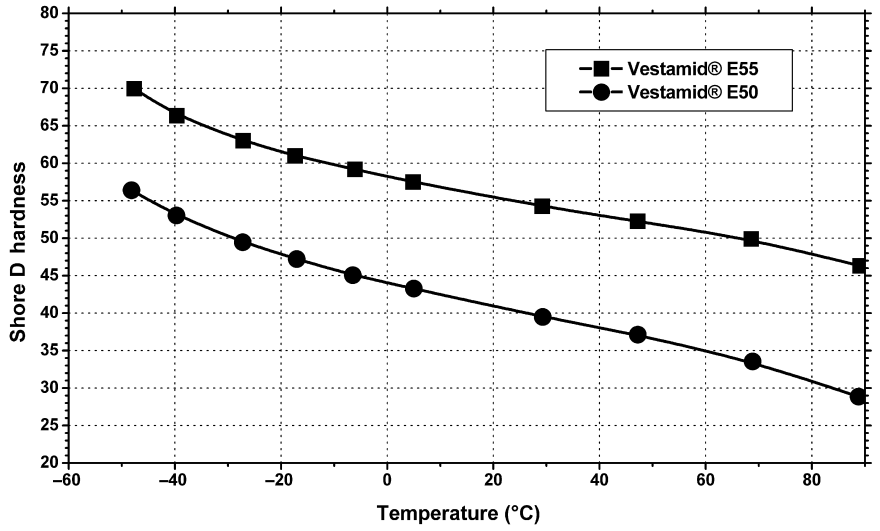

Figure 8.71 Temperature dependence of Shore hardness using Evonik Corporation Vestamid® E 40 and Vestamid® E55 PEBA resins [9].

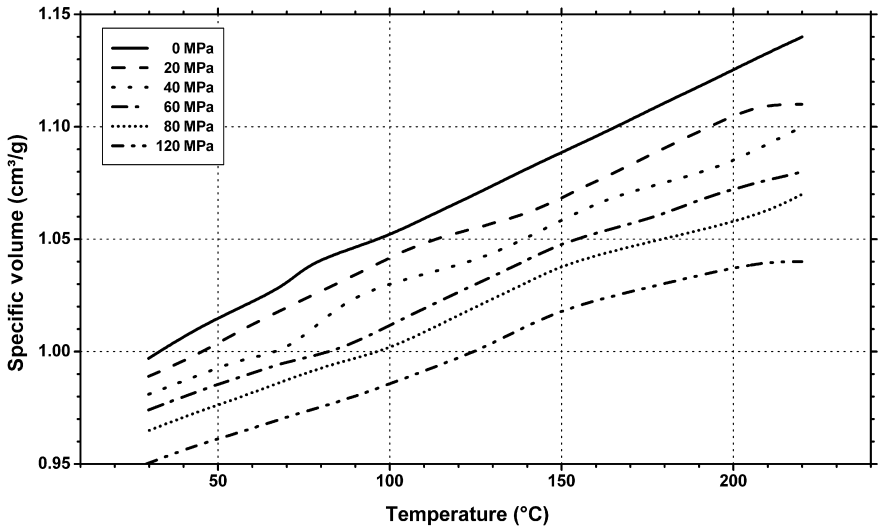

Figure 8.72 Specific volume vs. temperature for Arkema Pebax® 3533 SN 01—Shore hardness 35 TPEs—PEBA resin.

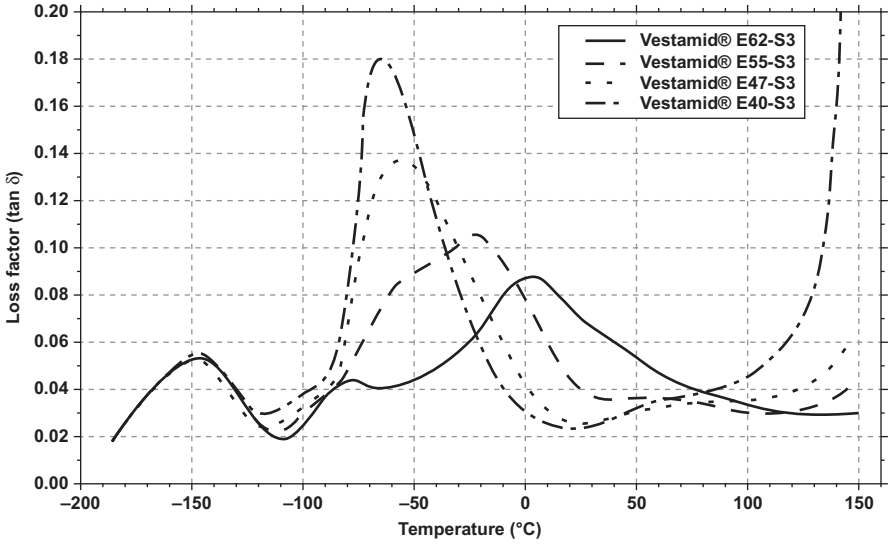

Figure 8.73 Temperature dependence of the loss factor tan δ of Evonik Corporation Vestamid® PEBA resins determined with torsional vibration analyses according to ISO 6721-2 [9].

References

[1] McKeen LW. The effect of temperature and other factors on plastics, Plastics Design Library. Waltham, MA: William Andrew; 2008.
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[3] A guide to thermoplastic polyurethanes (TPU). Huntsman Chemical; 2010.
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9 Fluoropolymers

The following sections will briefly explain the structures and properties of the various fluoropolymers. It is important to keep in mind there are variations of most of these polymers. The most common variation is the molecular weight, which will affect the melting point somewhat, and the viscosity of the polymer above its melting point, properties that are very important in determining processing conditions and use.

Traditionally, a fluoropolymer or fluoroplastic is defined as a polymer consisting of carbon (C) and fluorine (F). Sometimes these are referred to as perfluoropolymers to distinguish them from partially fluorinated polymers, fluoroelastomers, and other polymers that contain fluorine in their chemical structure. For example, fluorosilicone and fluoroacrylate polymers are not referred to as fluoropolymers. The monomers used to make the various fluoropolymers are shown in Figure 9.1.

Details of each of the fluoropolymers are in the following sections. The melting points are compared in Table 9.1.

9.1 Polytetrafluoroethylene (PTFE)

Polytetrafluoroethylene (PTFE) polymer is an example of a linear fluoropolymer. Its structure in simplistic form is shown in Figure 9.2. The CAS number for PTFE is 9002-84-0.

Formed by the polymerization of tetrafluoroethylene (TFE), the ($-CF_2-CF_2-$) groups repeat many thousands of times. The fundamental properties of fluoropolymers evolve from the atomic structure of fluorine and carbon and their covalent bonding in specific chemical structures. The backbone is formed of carbon−carbon bonds and the pendant groups are carbon−fluorine bonds. Both are extremely strong bonds. The basic properties of PTFE stem from these two very strong chemical bonds. The size of the fluorine atom allows the formation of a uniform and continuous covering around the carbon−carbon bonds and protects them from chemical attack, thus imparting chemical resistance and stability to the molecule. PTFE is rated for use up to 260°C. PTFE does not dissolve in any known solvent. The fluorine sheath is also responsible for the low surface energy (18 dynes/cm) and low coefficient of friction (0.05−0.8, static) of PTFE. Another attribute of the uniform fluorine sheath is the electrical inertness (or nonpolarity) of the PTFE molecule. Electrical fields impart only slight polarization in this molecule, so volume and surface resistivity are high.

The PTFE molecule is simple and is quite ordered. This is shown in the three-dimensional models of Figures 9.3 and 9.4. PTFE can align itself with other molecules or other portions of the same molecule. Disordered regions are called *amorphous* regions. This is important because polymers with high crystallinity require more energy to melt. In other words they have higher melting points. When this happens it forms what is called a crystalline region. Crystalline polymers have a substantial fraction of their mass in the form of parallel, closely packed molecules. High molecular weight PTFE resins have high crystallinity and therefore high melting points, typically as high as 320−342°C (608−648°F). The crystallinity of as-polymerized PTFE is typically 92−98%. Further, the viscosity in the molten state (called melt creep viscosity) is so high that high molecular weight PTFE particles do not flow even at temperatures above its melting point. They sinter much like powdered metals; they stick to each other at the contact points and combine into larger particles.

PTFE is called a *homopolymer*, a polymer made from a single monomer. Recently, many PTFE manufacturers have added minute amounts of other monomers to their PTFE polymerizations to produce alternate grades of PTFE designed for specific applications. Fluoropolymer manufacturers continue to call these grades modified homopolymer at below 1% by weight of comonomer. DuPont grades of this type are called Teflon® NXT resins. Dyneon™ TFM™ modified PTFE incorporates less than 1% of a comonomer perfluoropropyl vinyl ether (PPVE). Daikin's modified grade is Polyflon™ M-111.

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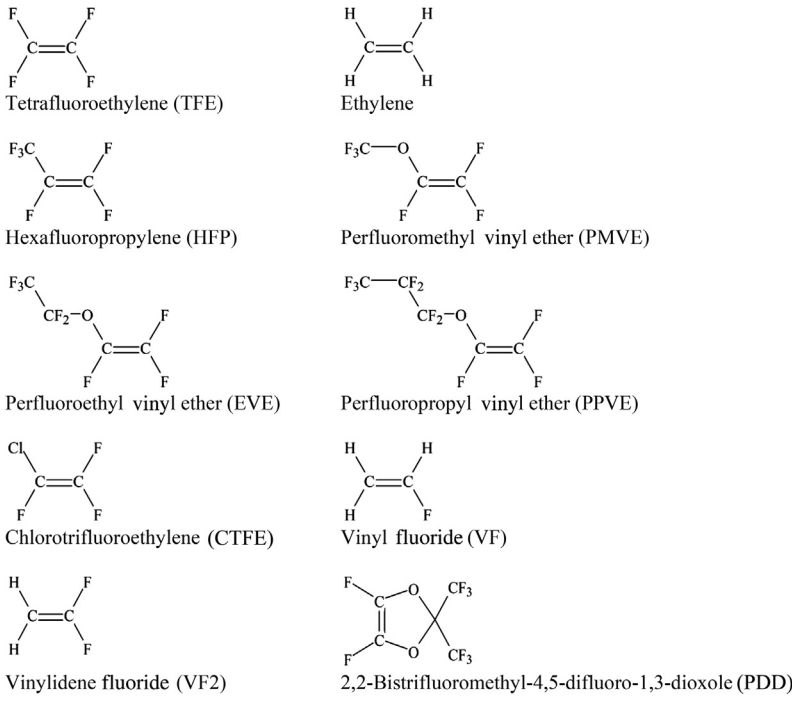

Figure 9.1 Structures of monomers used to make fluoropolymers.

Table 9.1 Melting Point Ranges of Various Fluoroplastics

Fluoroplastic	Melting Point (°C)
PTFE	320–340
ECTFE	240
ETFE	255–280
FEP	260–270
Perfluoroalkoxy (PFA)	302–310
Perfluoroalkoxy (MFA)	280–290
PCTFE	210–212
PVDF	155–170

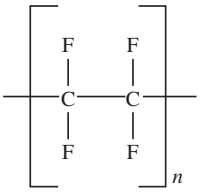

Figure 9.2 Chemical structure of PTFE.

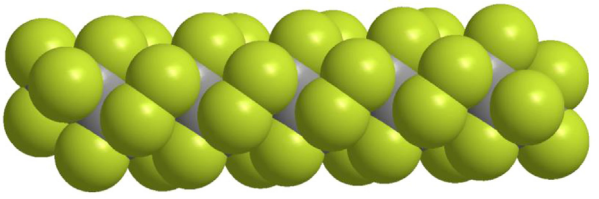

Figure 9.3 Three-dimensional representation of PTFE.

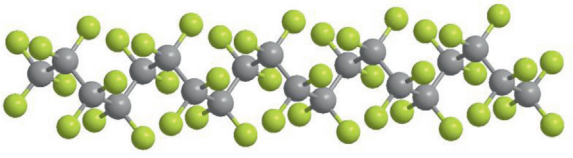

Figure 9.4 Ball and stick three-dimensional representation of PTFE.

These modified granular PTFE materials retain the exceptional chemical, thermal, antistick, and low-friction properties of conventional PTFE resin, but offer some improvements:

- Weldability
- Improved permeation resistance

- Less creep
- Smoother, less porous surfaces
- Better high-voltage insulation

The copolymers described in the next sections contain significantly more of the non-TFE monomers.

Manufacturers and trade names: DuPont Teflon® PTFE, Dyneon PTFE, Daikin Polyflon™, Asahi Glass Fluon®, and many others.

Applications and uses: pipe liners, fittings, valves, pumps, and other components used for transferring aggressive, ultrapure fluids.

Data for PTFE plastics are found in Figures 9.5–9.17.

9.2 Ethylene Chlorotrifluoroethylene (ECTFE)

Ethylene chlorotrifluoroethylene copolymer, also called polyethylene chlorotrifluoroethylene or ECTFE, is a copolymer of ethylene and chlorotrifluoroethylene. Its CAS number is 25101-45-5. Figure 9.18 shows the molecular structure of ECTFE:

This simplified structure shows the ratio of the monomers being 1:1 and strictly alternating, which is the desirable proportion. Commonly known by the trade name, Halar®, ECTFE is an expensive, melt-processible, semicrystalline, whitish semi-opaque thermoplastic with good chemical resistance

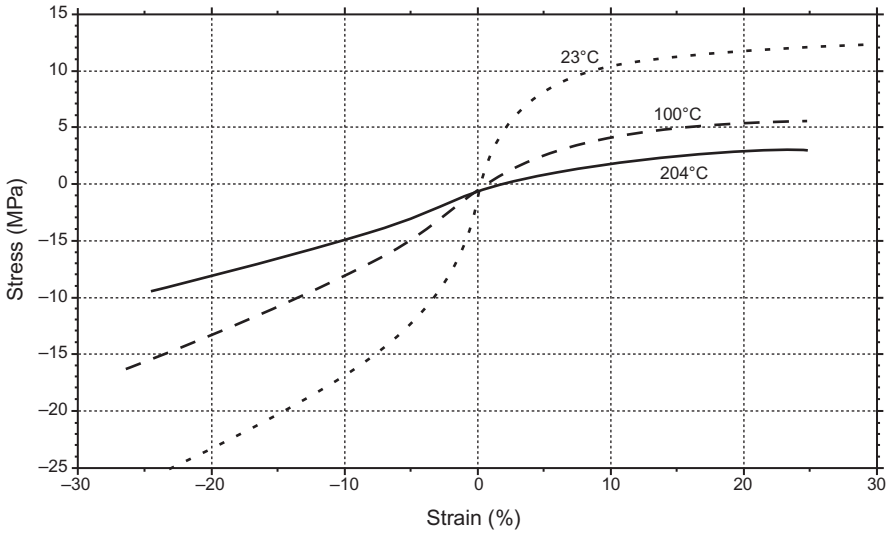

Figure 9.5 Stress vs. strain in tension and compression for DuPont general purpose Teflon® PTFE resin [1].

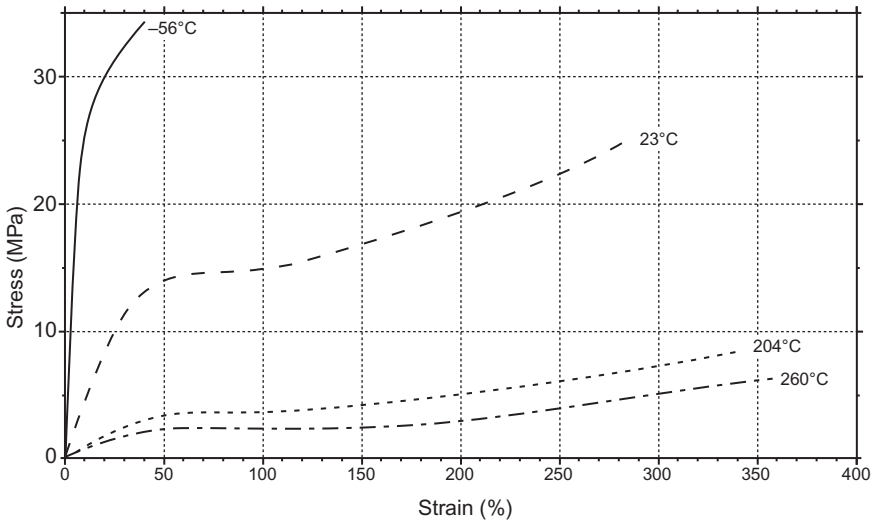

Figure 9.6 Stress vs. strain at high strain rate for DuPont general purpose Teflon® PTFE resin [1].

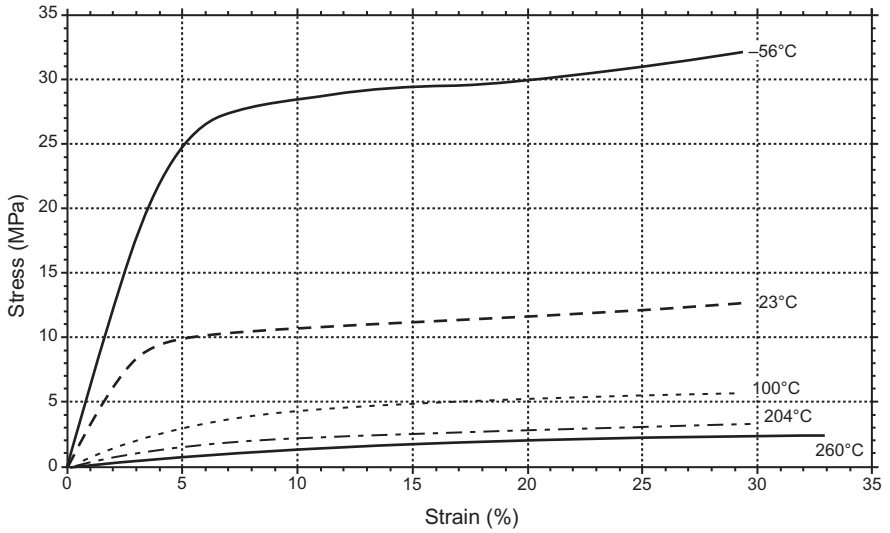

Figure 9.7 Stress vs. strain at low strain rate for DuPont general purpose Teflon® PTFE resin [1].

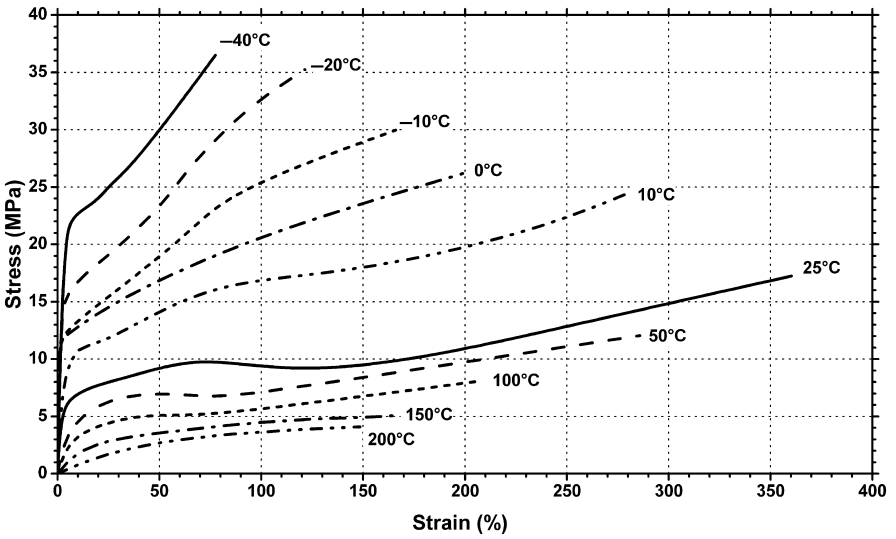

Figure 9.8 Effect of temperature upon tensile stress–strain curves for Asahi Glass Fluon® PTFE [2].

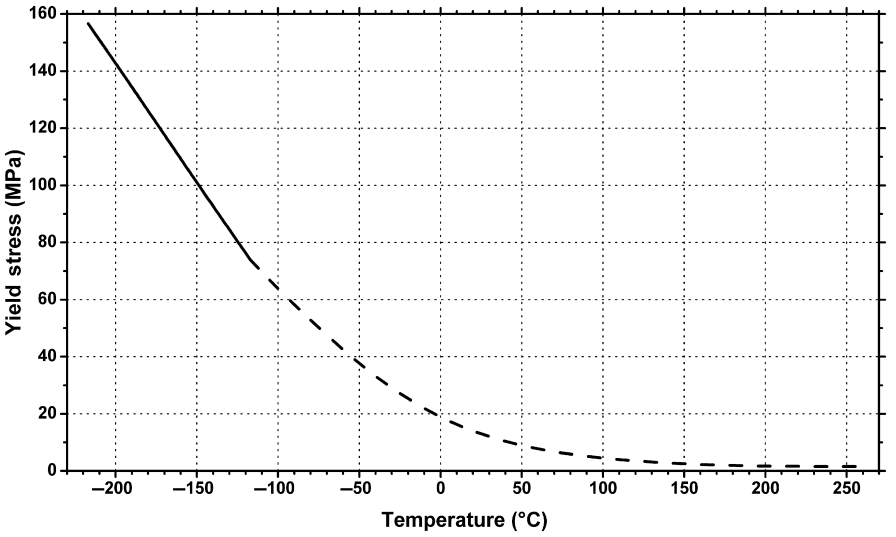

Figure 9.9 Effect of temperature upon tensile yield stress of Asahi Glass Fluon® PTFE [2].

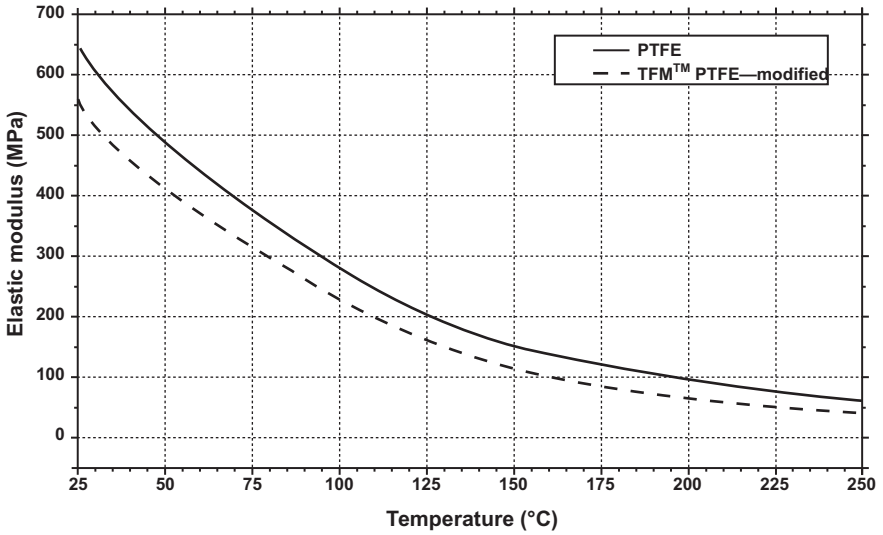

Figure 9.10 Young's modulus vs. temperature for 3M Dyneon™ PTFE resins [3].

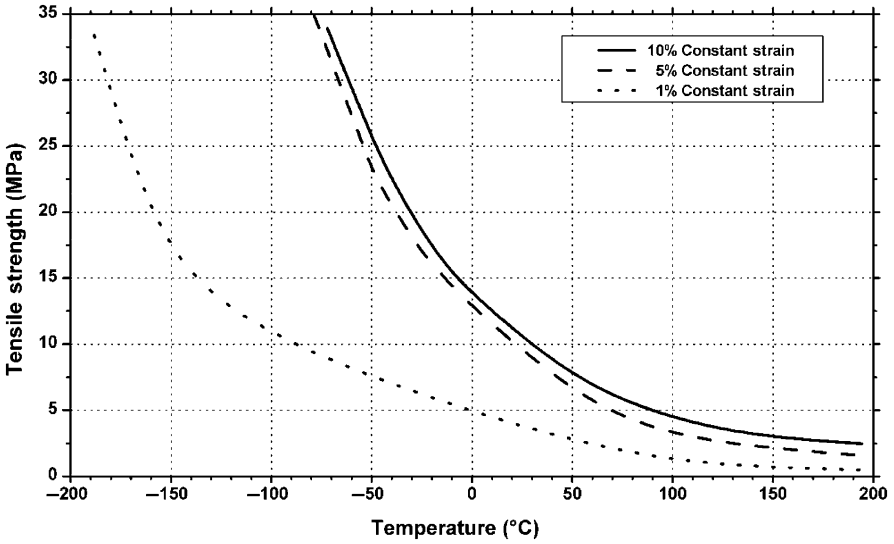

Figure 9.11 Tensile strength vs. temperature for DuPont general purpose Teflon® PTFE resin.

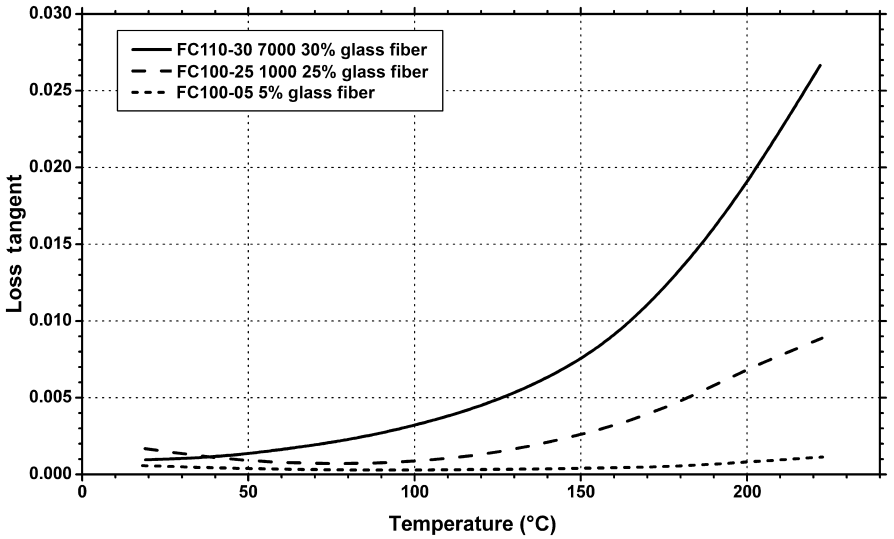

Figure 9.12 Loss tangent vs. temperature at 1 kHz for glass-filled Asahi Glass Fluon® PTFE [2].

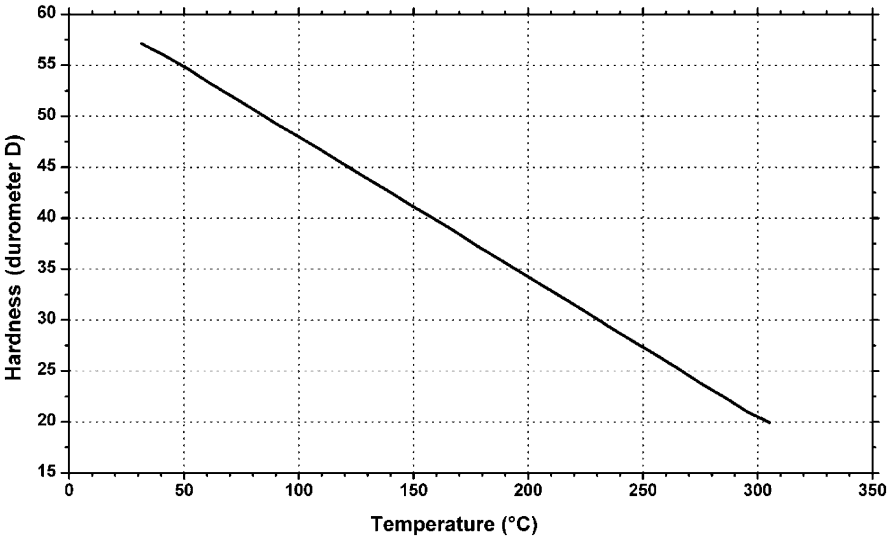

Figure 9.13 Hardness vs. temperature for DuPont general purpose Teflon® PTFE resin.

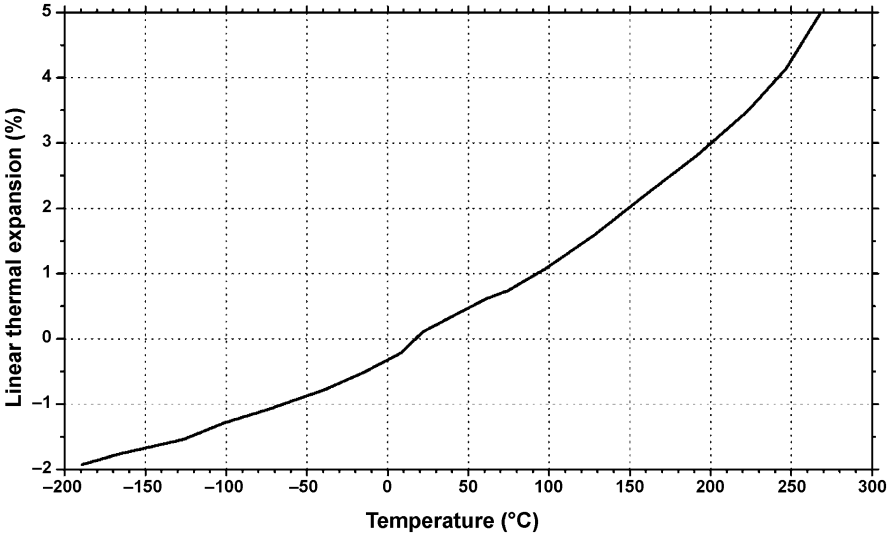

Figure 9.14 Linear thermal expansion vs. temperature for DuPont general purpose Teflon® PTFE resin [1].

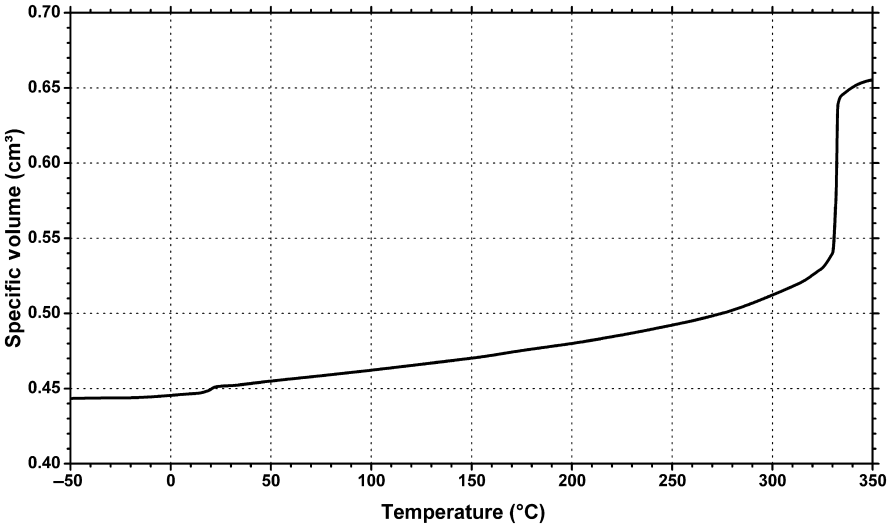

Figure 9.15 Variation of specific volume with temperature of Asahi Glass Fluon® PTFE [2].

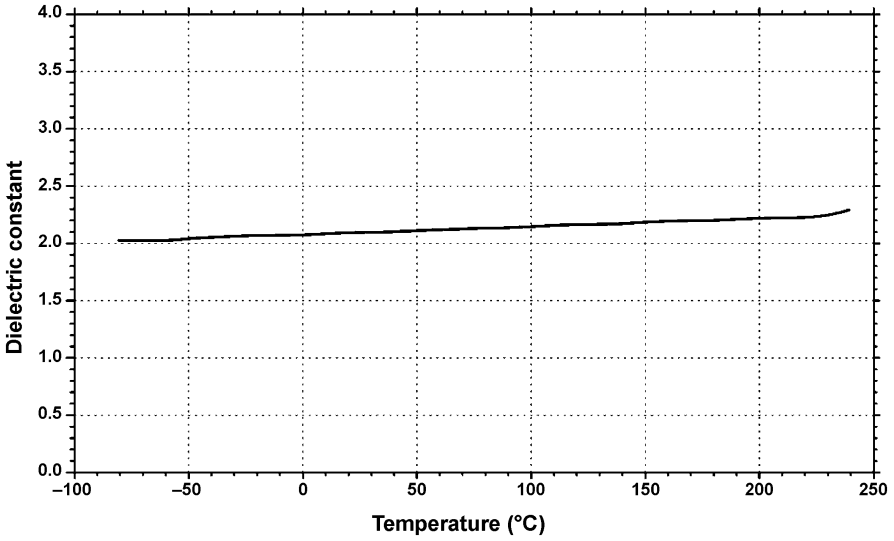

Figure 9.16 Dielectric constant vs. temperature for DuPont general purpose Teflon® PTFE resin.

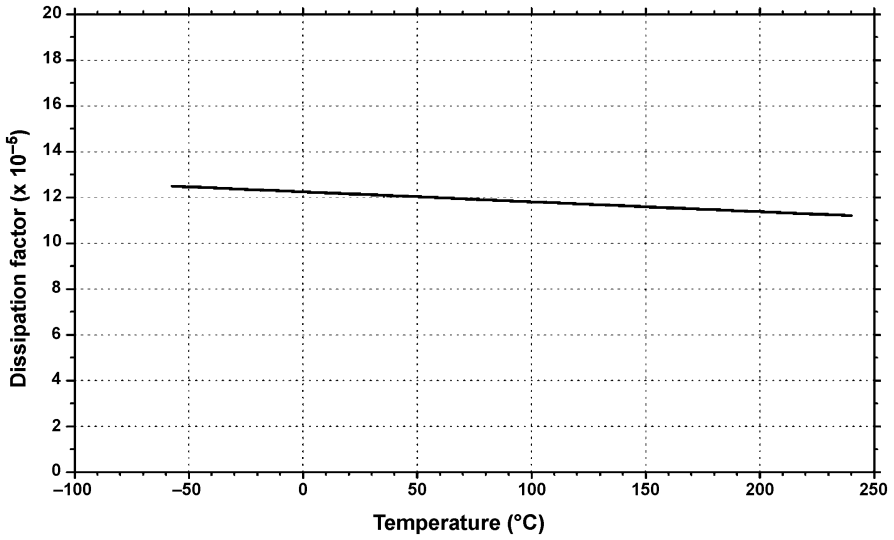

Figure 9.17 Dissipation factor vs. temperature for DuPont general purpose Teflon® PTFE resin.

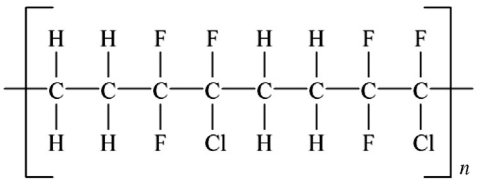

Figure 9.18 Chemical structure of ECTFE.

and barrier properties. It also has good tensile and creep properties and good high-frequency electrical characteristics.

Processing methods include extrusion, compression molding, rotomolding, blow molding, and liquid and powder coating.

Manufacturers and trade names: Solvay Solexis Halar®.

Applications and uses: chemically resistant linings and coatings, valve and pump components, hoods, tank and filter house linings, nonwoven filtration fibers, barrier films and release/vacuum bagging films. It is used in food processing particularly involving acidic food and fruit juice processing.

Data for ECTFE plastics are found in Figures 9.19–9.29.

9.3 Ethylene Tetrafluoroethylene (ETFE)

ETFE is a copolymer of ethylene and TFE. The basic molecular structure of ETFE is shown in Figure 9.30.

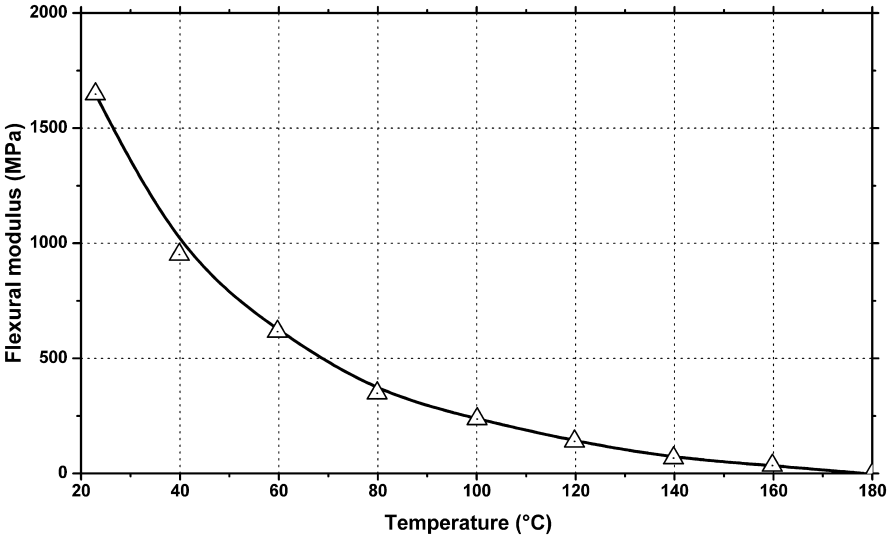

Figure 9.19 Flexural modulus vs. temperature for Solvay Solexis Halar® ECTFE resin [4].

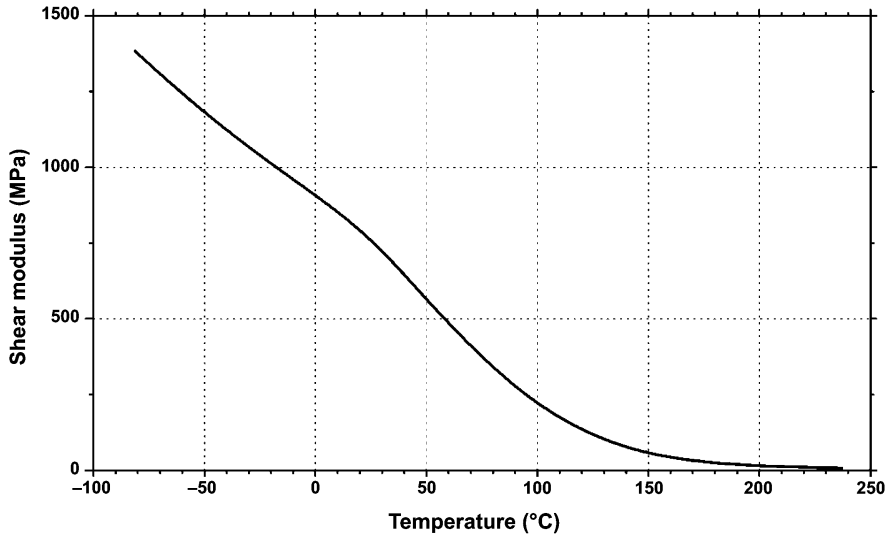

Figure 9.20 Shear modulus vs. temperature for Solvay Solexis Halar® ECTFE resin.

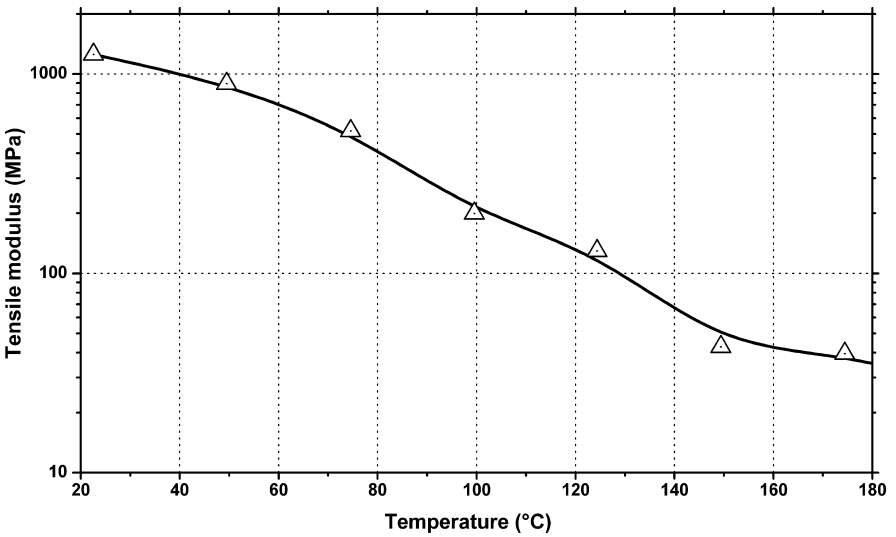

Figure 9.21 Tensile modulus vs. temperature for Solvay Solexis Halar® ECTFE resin [4].

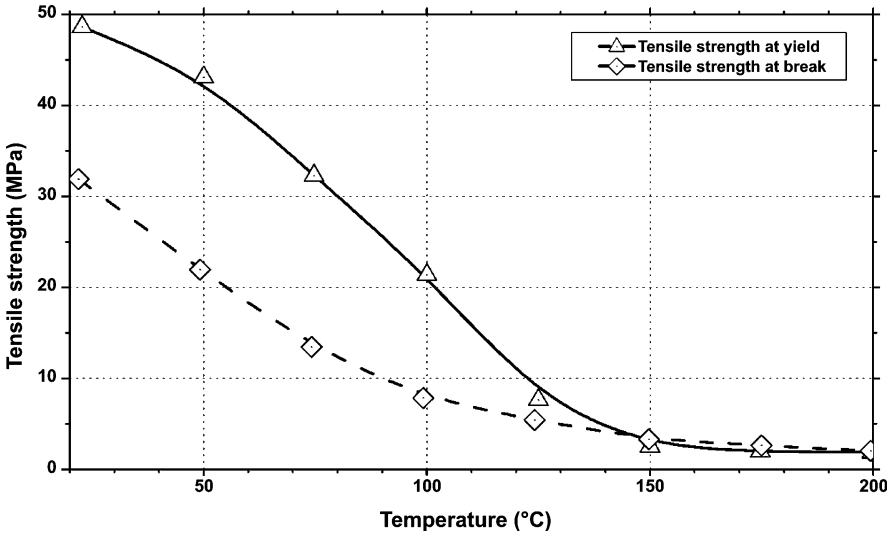

Figure 9.22 Tensile strength vs. temperature for Solvay Solexis Halar® ECTFE resin [4].

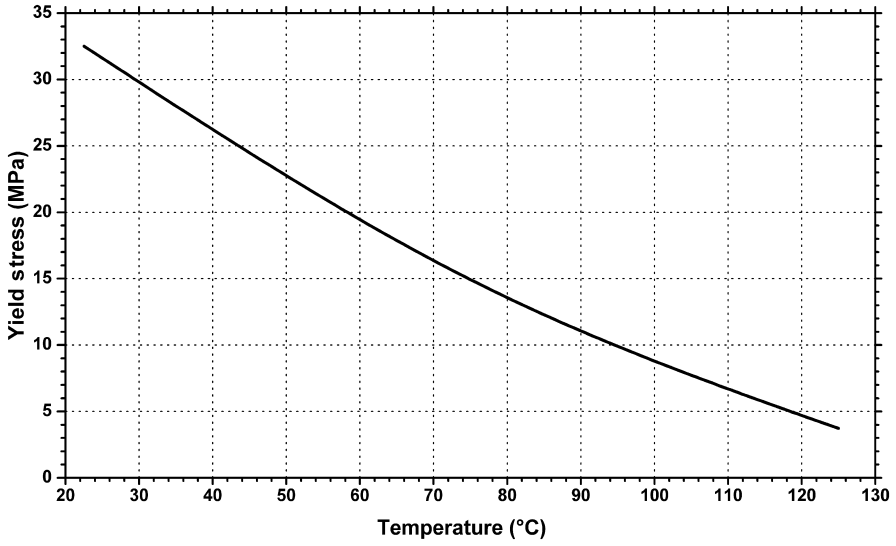

Figure 9.23 Yield stress vs. temperature for Solvay Solexis Halar® ECTFE resin [5].

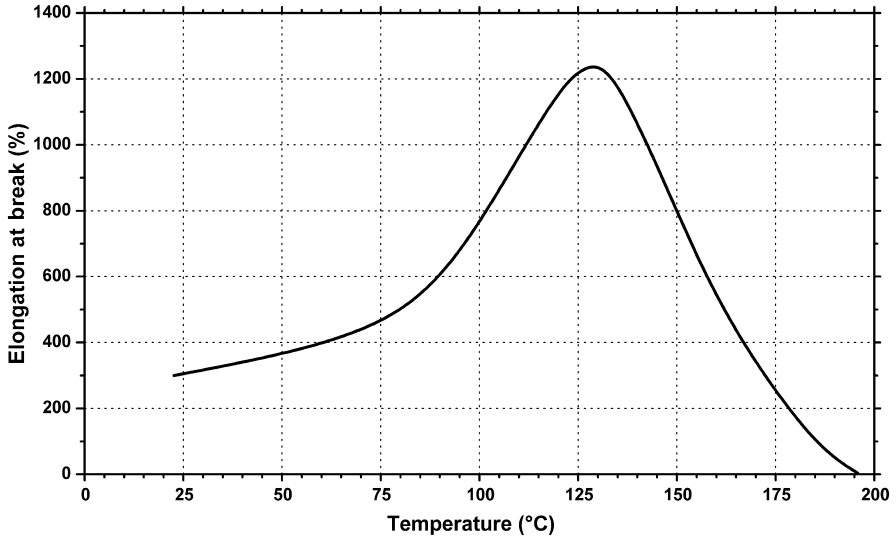

Figure 9.24 Elongation at break vs. temperature for Solvay Solexis Halar® ECTFE resin [5].

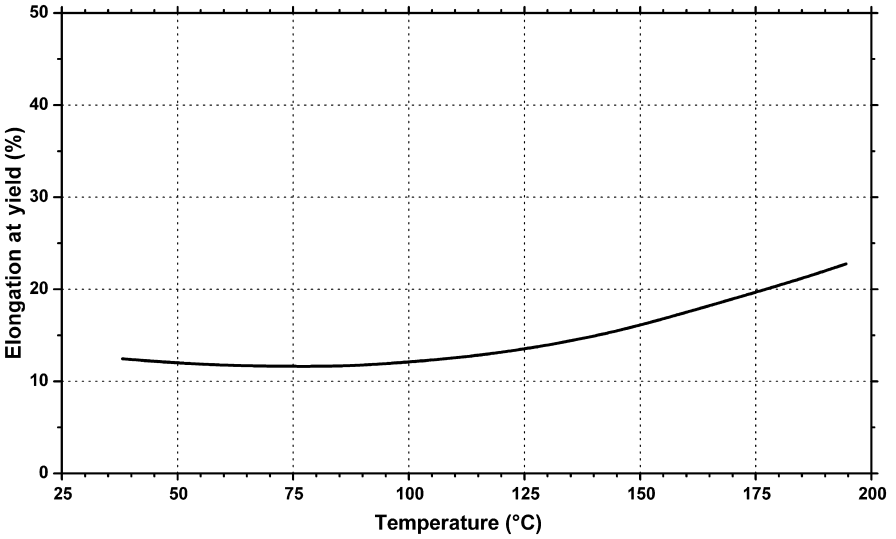

Figure 9.25 Elongation at yield vs. temperature for Solvay Solexis Halar® ECTFE resin [5].

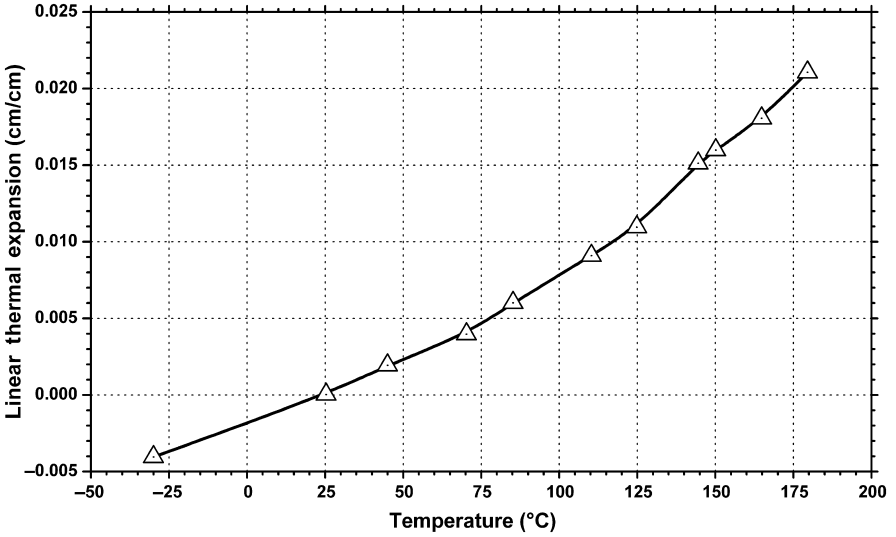

Figure 9.26 Linear thermal expansion vs. temperature for Solvay Solexis Halar® ECTFE resin [4].

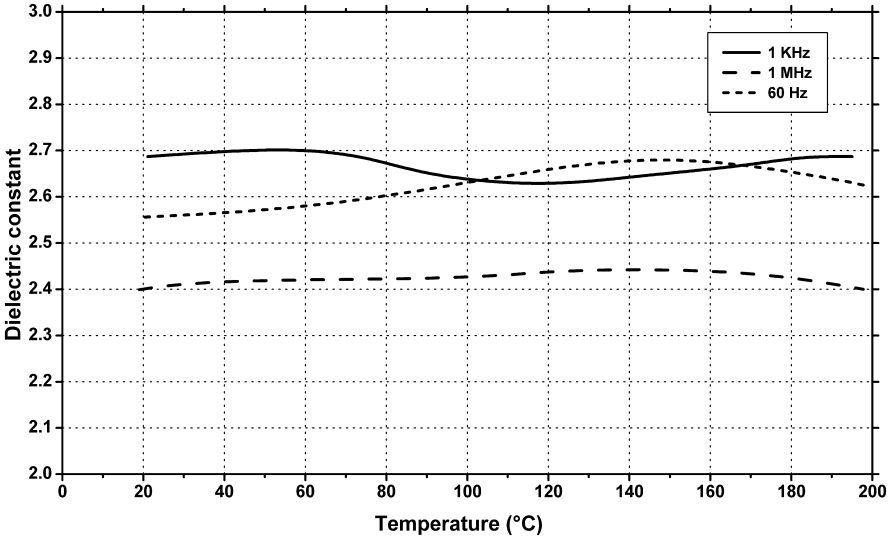

Figure 9.27 Dielectric constant vs. temperature at various frequencies for Solvay Solexis Halar® ECTFE resin [5].

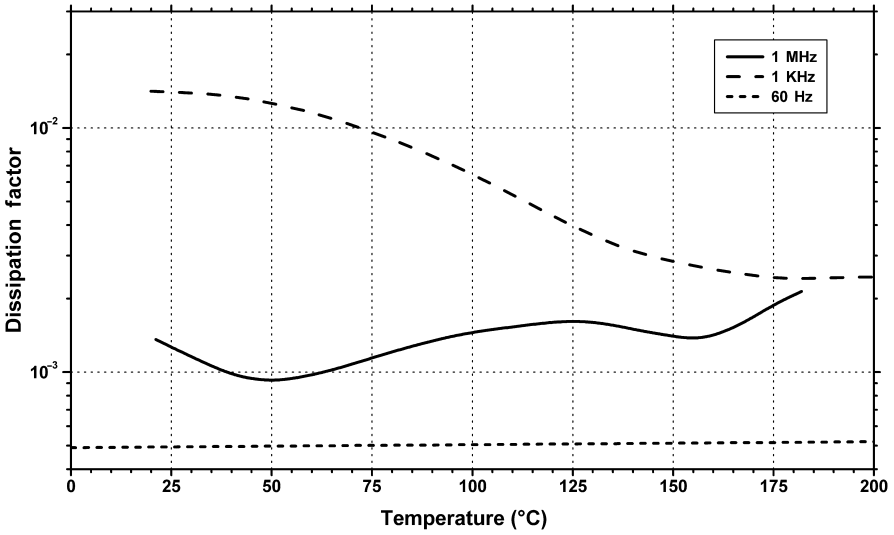

Figure 9.28 Dissipation factor vs. temperature at various frequencies for Solvay Solexis Halar® ECTFE resin [5].

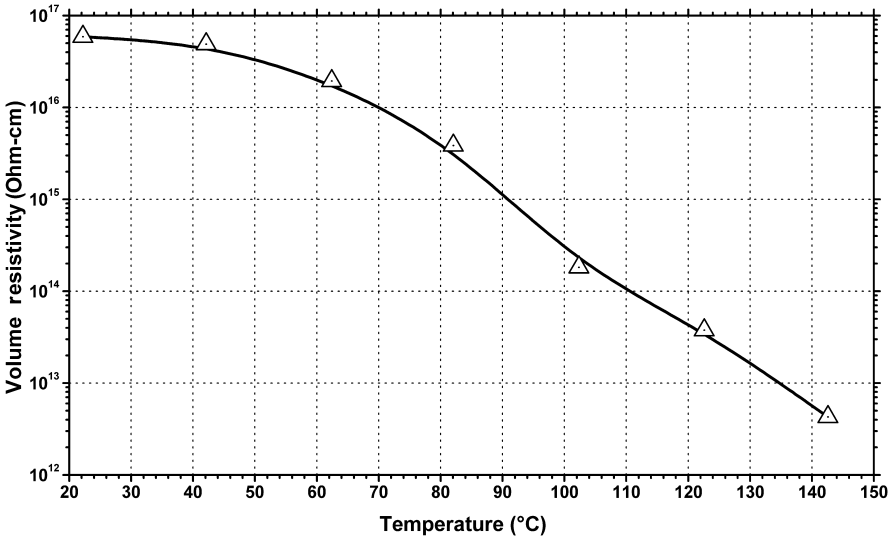

Figure 9.29 Volume resistivity vs. temperature for Solvay Solexis Halar® ECTFE resin [4].

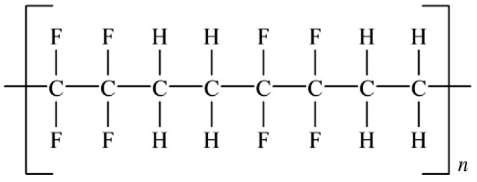

Figure 9.30 Chemical structure of ETFE.

It is sometimes called polyethylene tetrafluoroethylene. The depicted structure in Figure 9.38 shows alternating units of TFE and ethylene. While this can be readily made, many grades of ETFE vary the ratio of the two monomers slightly to optimize properties for specific end uses. Its CAS number is 25038-71-5.

ETFE is a fluoroplastic with excellent electrical and chemical properties. It also has excellent mechanical properties. ETFE is especially suited for uses requiring high mechanical strength, chemical, thermal, and/or electrical properties. The mechanical properties of ETFE are superior to those of PTFE and FEP. ETFE has:

- Excellent resistance to extremes of temperature, ETFE has a working temperature range of −200°C to 150°C
- Excellent chemical resistance
- Good mechanical strength with excellent tensile strength and elongation and has superior physical properties compared to most fluoropolymers

- Low smoke and flame characteristics, ETFE is rated 94V-0 by the Underwriters Laboratories Inc. It is odorless and nontoxic
- Outstanding resistance to weather and aging
- Excellent dielectric properties
- Nonstick characteristics

Manufacturers and trade names: DuPont Tefzel®, Asahi Glass Fluon®, 3M Dyneon™, SABIC Innovative Plastics.

Uses and applications: electrical and fiber optic wiring, stadium roofing, liner in pipes, tanks, and vessels.

Data for ETFE plastics are found in Table 9.2; Figures 9.31–9.56.

Table 9.2 describes the Asahi Glass Grades of ETFE found in the figures of this section.

9.4 Fluorinated Ethylene Propylene (FEP)

If one of the fluorine atoms on TFE is replaced with a trifluoromethyl group ($-CF_3$), then the new monomer is called hexafluoropropylene (HFP). Polymerization of monomers HFP and TFE yields a fluoropolymer, fluorinated ethylene propylene, called FEP. The number of HFP groups is typically 13% by weight or less and its structure is shown in Figure 9.57. The CAS number for FEP is 25067-11-2.

The effect of using HFP is to put a "bump" along the polymer chain as shown in the three-dimensional models shown in Figures 9.58 and 9.59. This bump disrupts the crystallization of the FEP, which has a typical as-polymerized crystallinity of 70% vs. 92–98% for PTFE. It also lowers its melting point. The reduction of the melting point

Table 9.2 Grades of Asahi Glass Fluon® ETFE [6]

Grade	Melt Flow Rate[a]	Melt Index[b]	Characteristics	Molding Methods
C-55AP	3.9–6.5	1–2	Standard	Extrusion
C-88AP	9.0–12.0	3–4	Standard	Extrusion, injection
C-55AXP	3.9–6.5	1–2	Stress–crack resistant	Extrusion
C-88AXP	9.0–12.0	3–4	Stress–crack resistant	Extrusion, injection
C-88AXMP	27–43	10–16	High fluidity	Extrusion, injection

[a]*Melt flow rate per ASTM D3159 at 297°C, 5 kgf.*
[b]*Melt index per ASTM D1238 at 300°C, 2.16 kgf.*

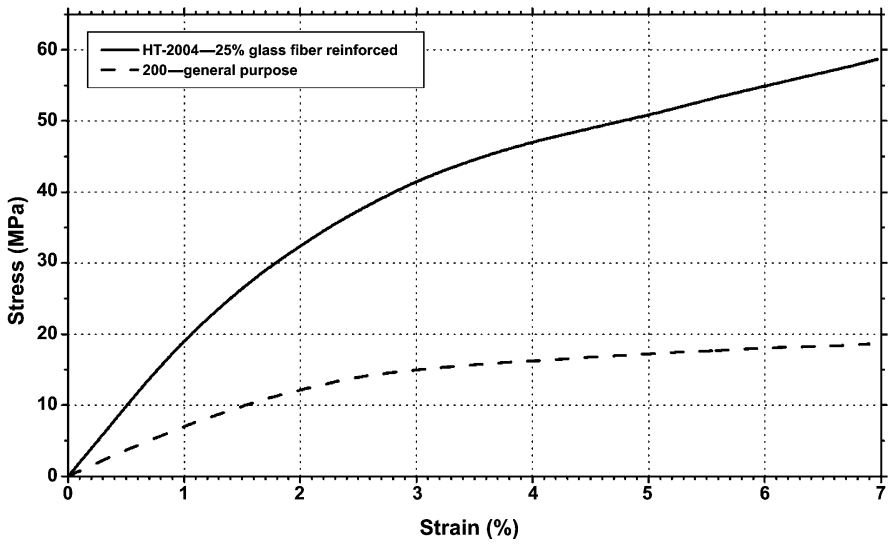

Figure 9.31 Stress vs. strain in compression at 23°C for DuPont Tefzel® ETFE resins [7].

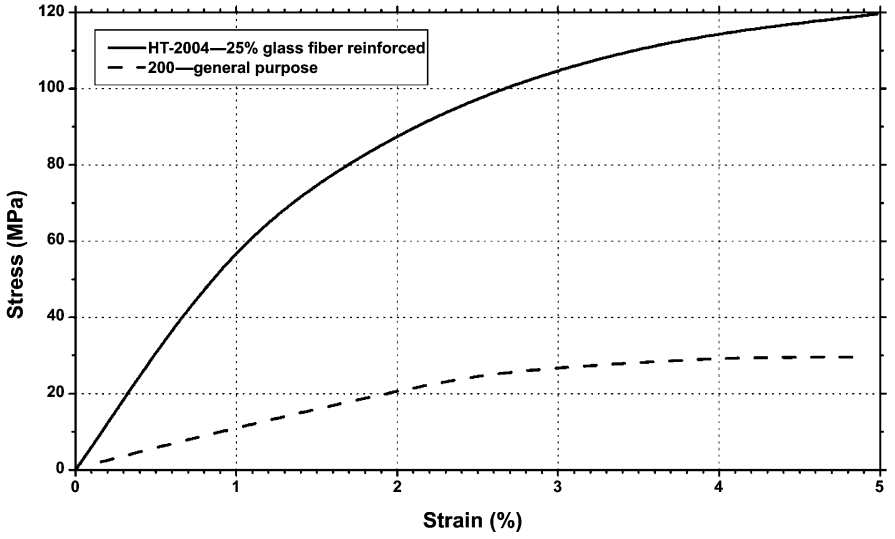

Figure 9.32 Stress vs. strain in flexure at 23°C for DuPont Tefzel® ETFE resins [7].

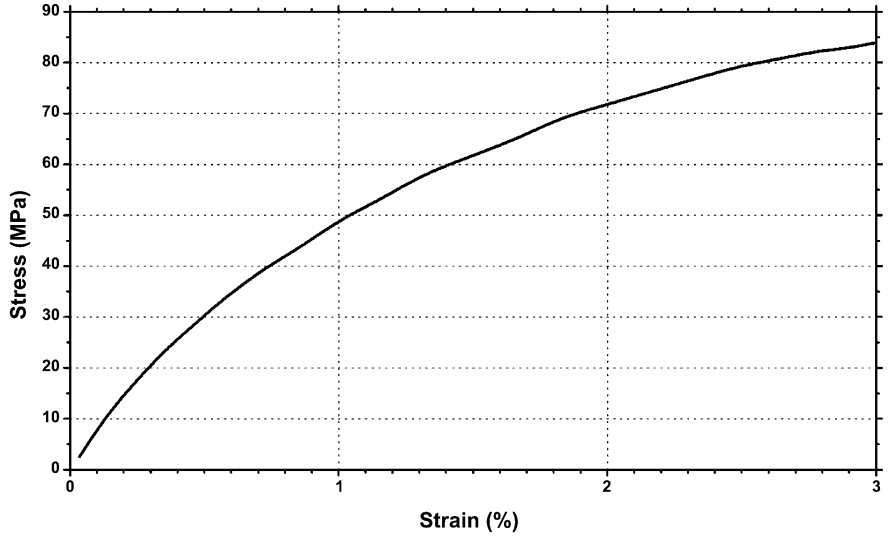

Figure 9.33 Tensile stress vs. strain and temperature for SABIC Innovative Plastics LNP Thermocomp™ C2004 electrically conductive carbon fiber filled ETFE resin.

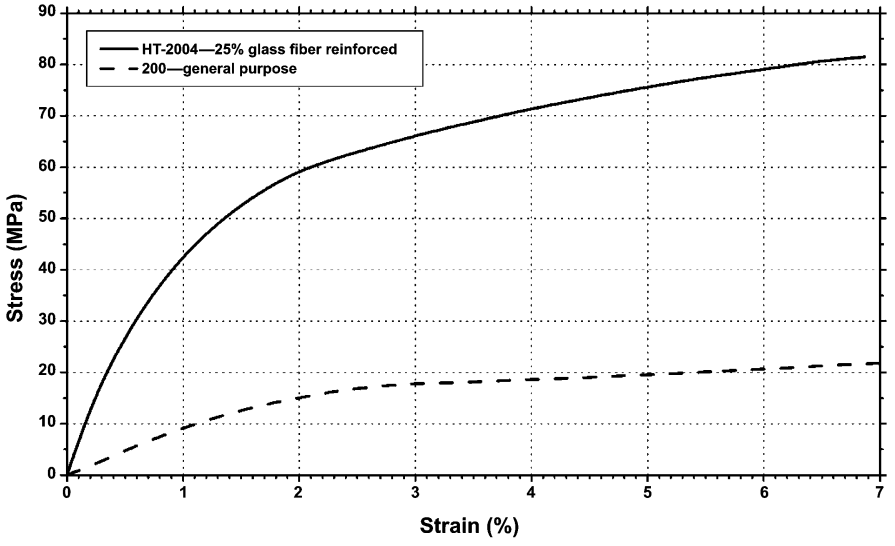

Figure 9.34 Tensile stress vs. strain at 23°C for DuPont Tefzel® ETFE resins [7].

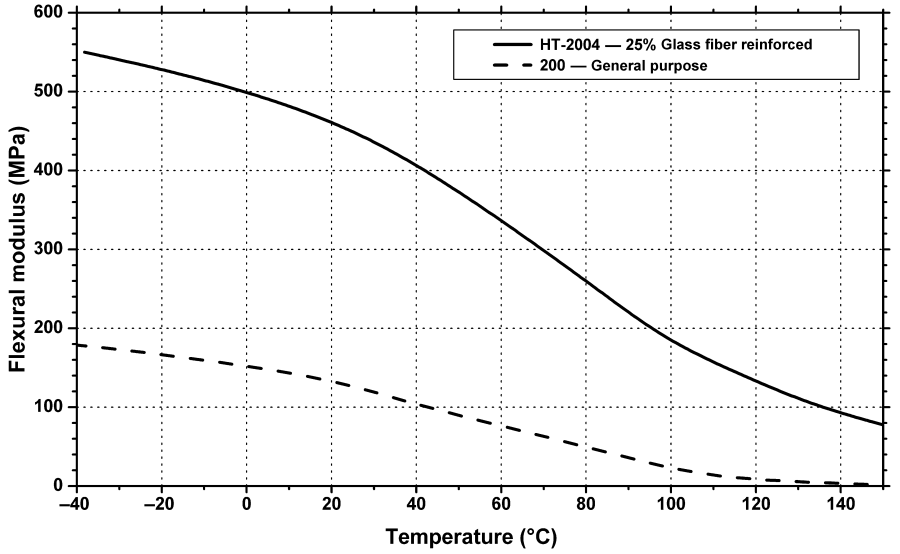

Figure 9.35 Flexural modulus vs. temperature for DuPont Tefzel® ETFE resins [7].

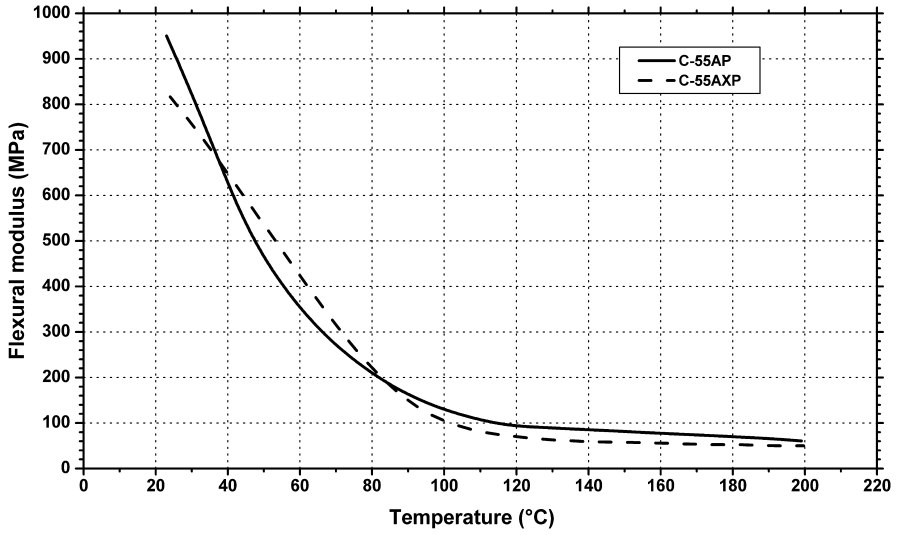

Figure 9.36 Flexural modulus vs. temperature for Asahi Glass Fluon® C-55 series ETFE resins [6].

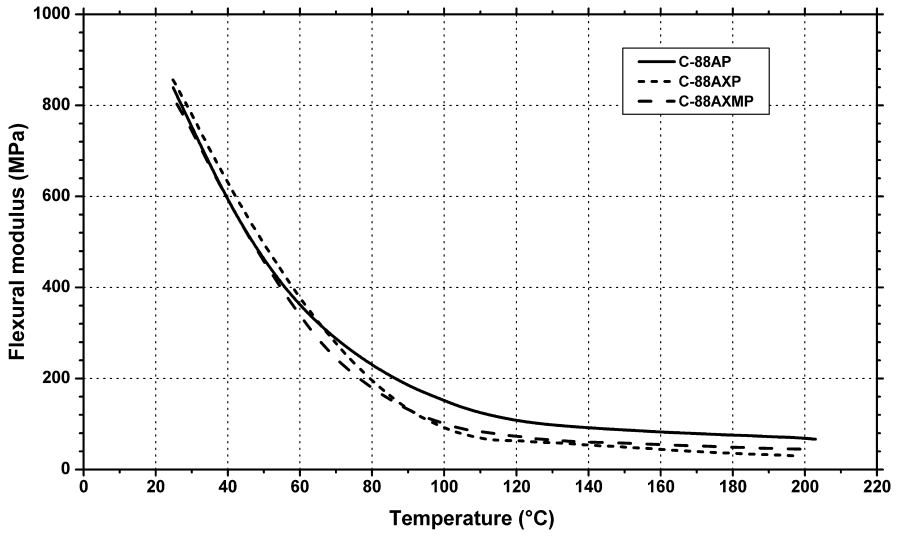

Figure 9.37 Flexural modulus vs. temperature for Asahi Glass Fluon® C-88 series ETFE resins [6].

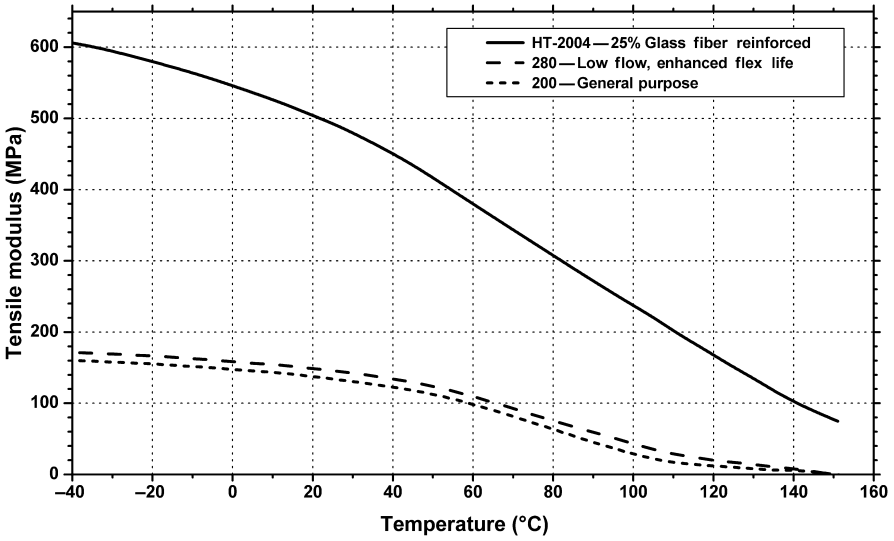

Figure 9.38 Tensile modulus vs. temperature for DuPont Tefzel® ETFE resins [7].

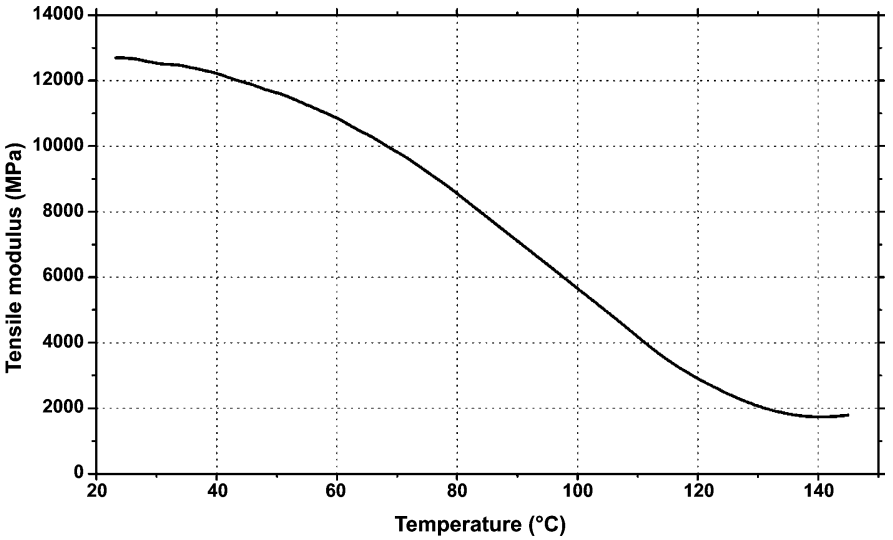

Figure 9.39 Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ FP-EC-1004 electrically conductive carbon fiber filled ETFE resin.

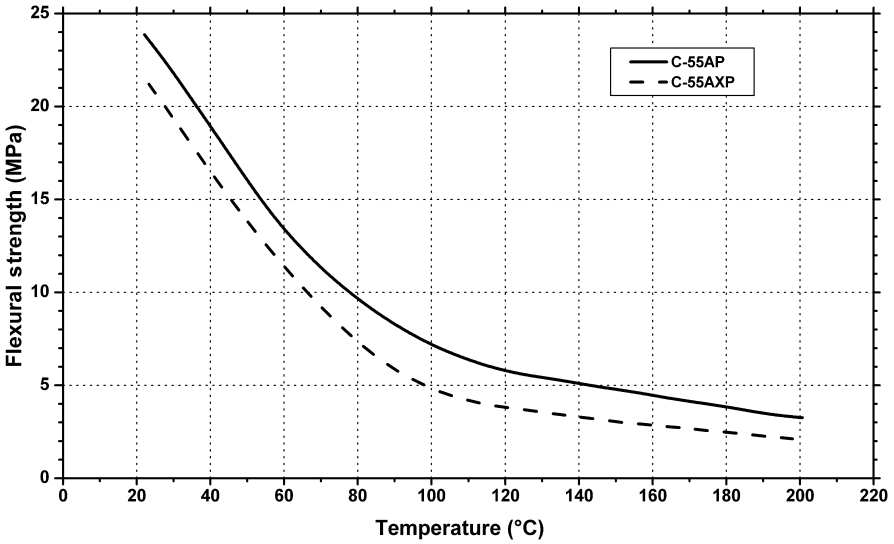

Figure 9.40 Flexural strength vs. temperature for Asahi Glass Fluon® C-55 series ETFE resins [6].

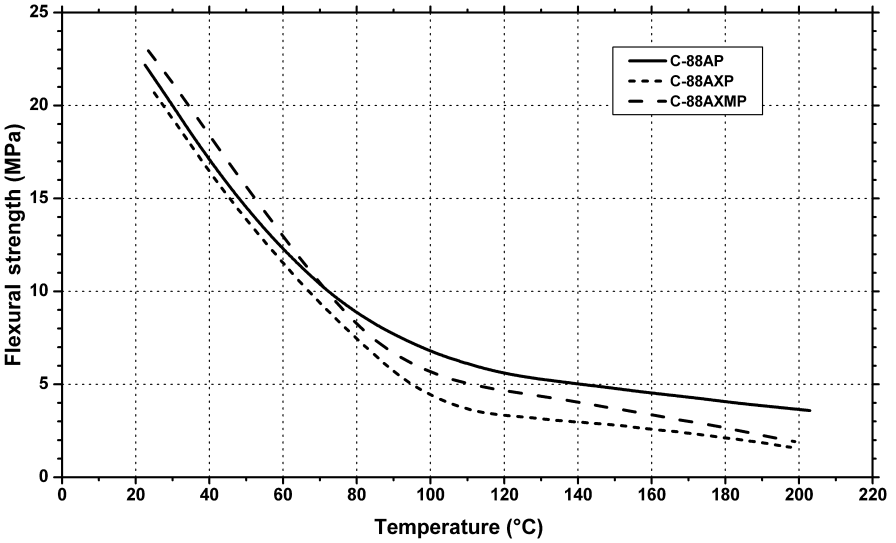

Figure 9.41 Flexural strength vs. temperature for Asahi Glass Fluon® C-88 series ETFE resins [6].

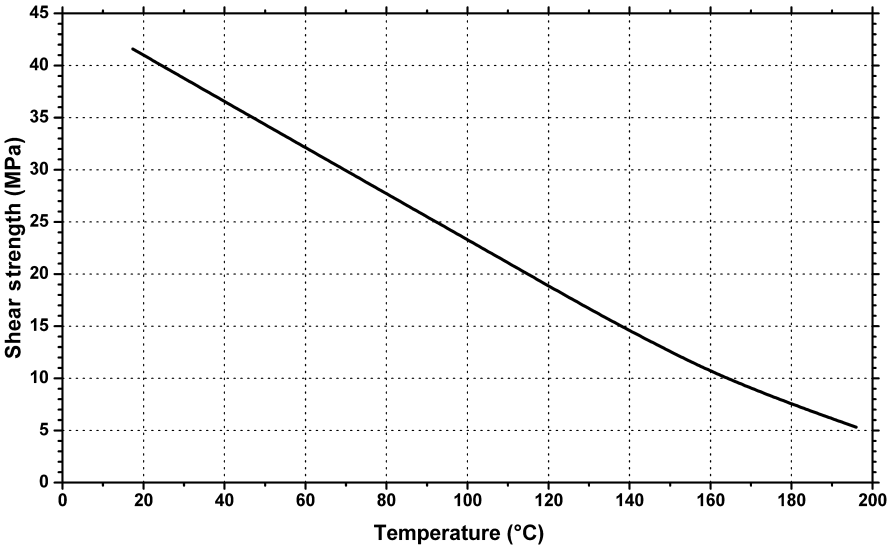

Figure 9.42 Shear strength vs. temperature for DuPont general purpose Tefzel® 200 ETFE resin [7].

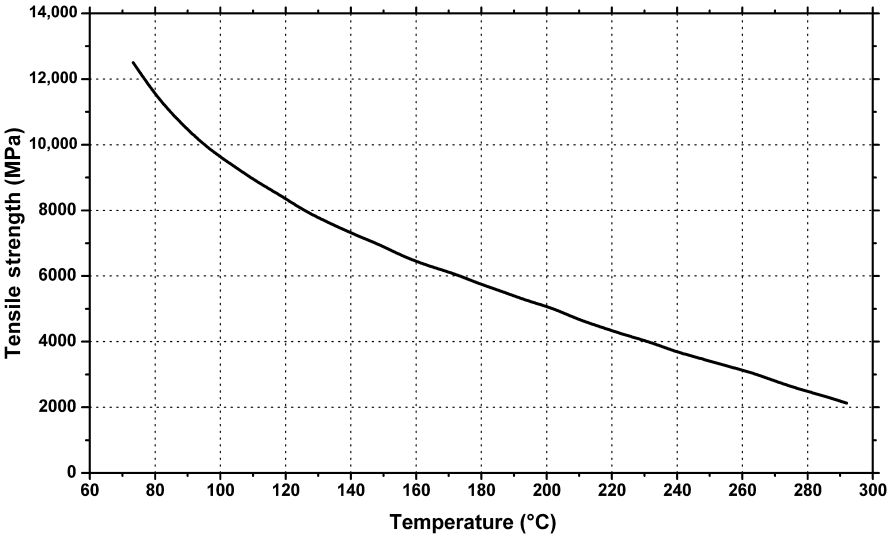

Figure 9.43 Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp™ FP-EC-1004 electrically conductive carbon fiber filled ETFE resin.

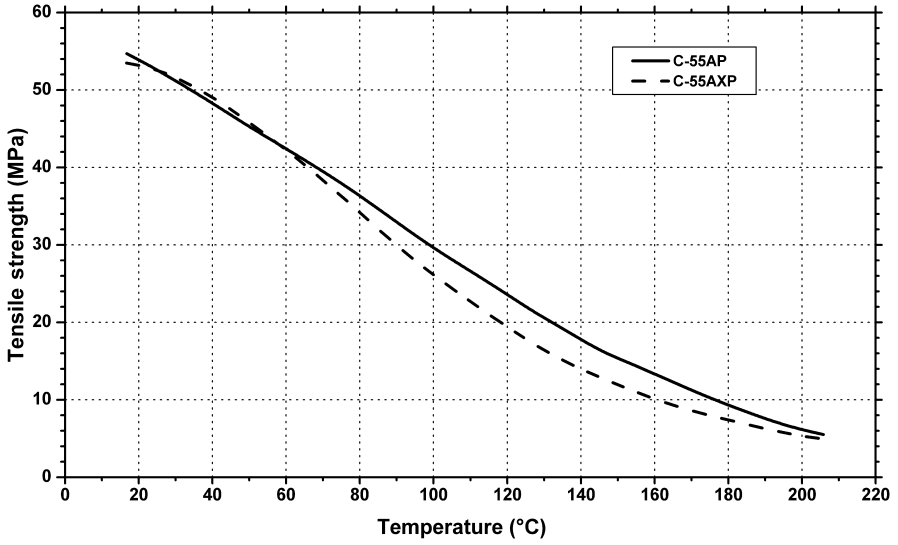

Figure 9.44 Tensile strength vs. temperature for Asahi Glass Fluon® C-55 series ETFE resins [6].

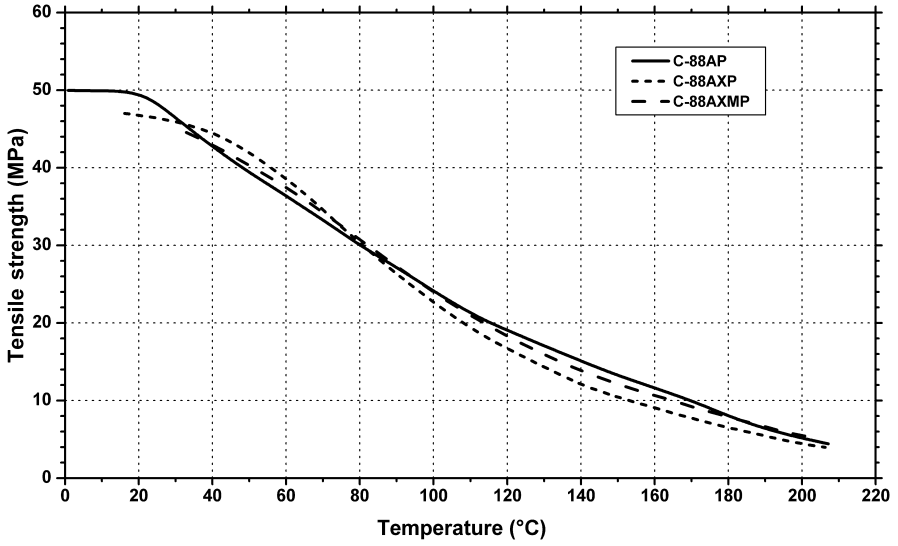

Figure 9.45 Tensile strength vs. temperature for Asahi Glass Fluon® C-88 series ETFE resins [6].

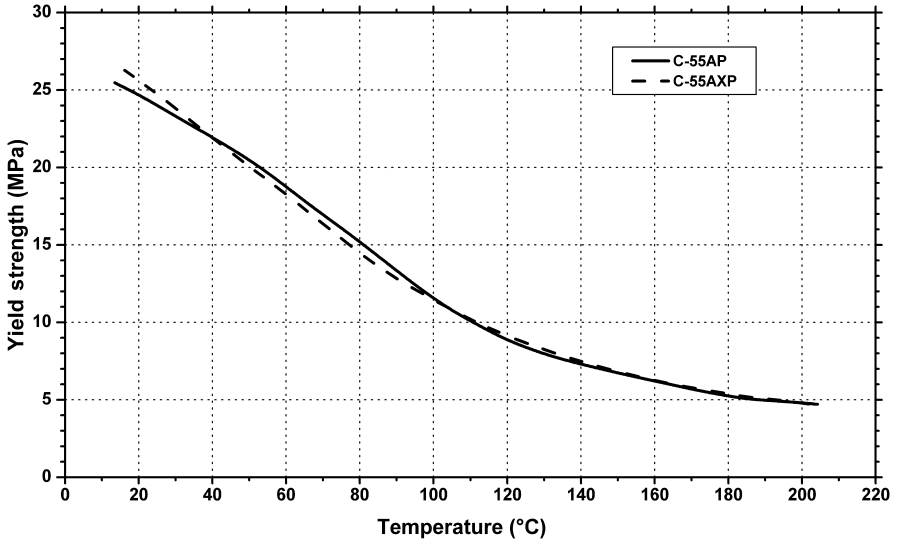

Figure 9.46 Yield strength vs. temperature for Asahi Glass Fluon® C-55 series ETFE resins [6].

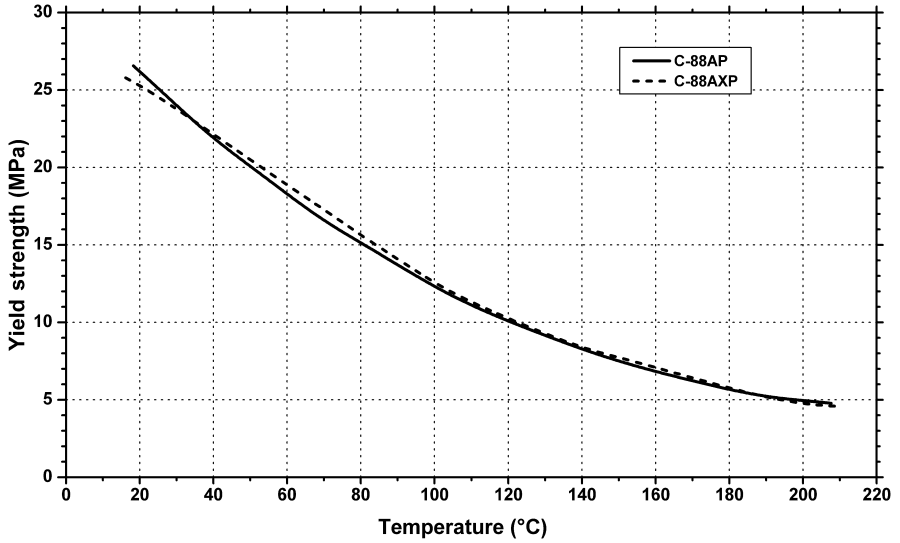

Figure 9.47 Yield strength vs. temperature for Asahi Glass Fluon® C-88 series ETFE resins [6].

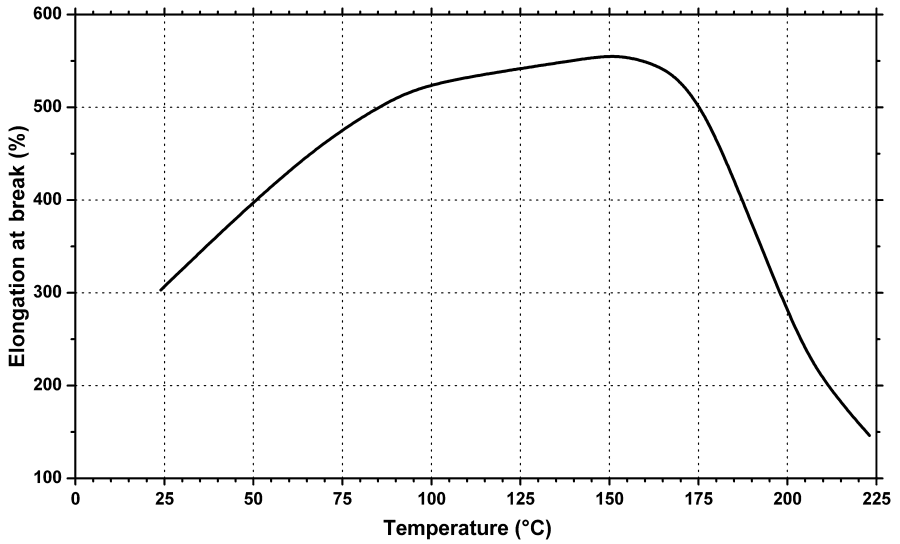

Figure 9.48 Elongation at break vs. temperature for DuPont general purpose Tefzel® 200 ETFE resin [7].

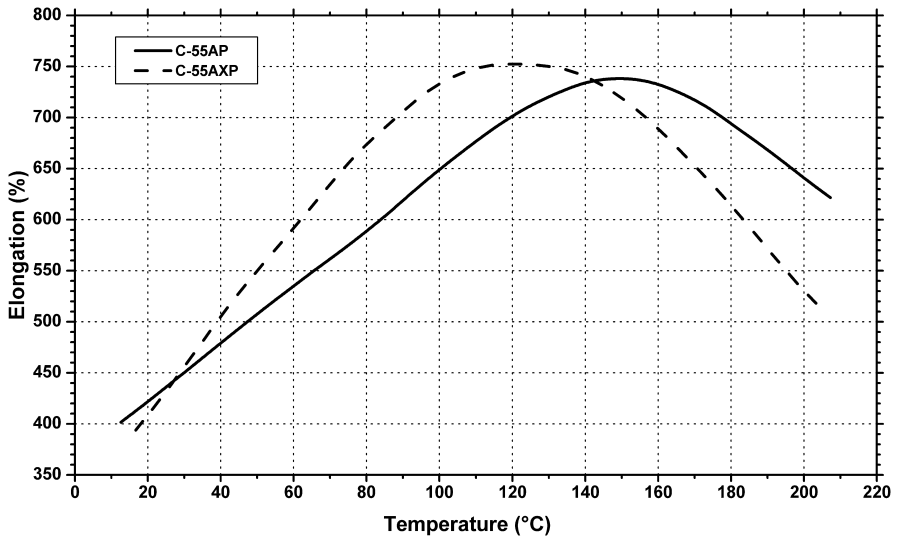

Figure 9.49 Elongation vs. temperature for Asahi Glass Fluon® C-55 series ETFE resins [6].

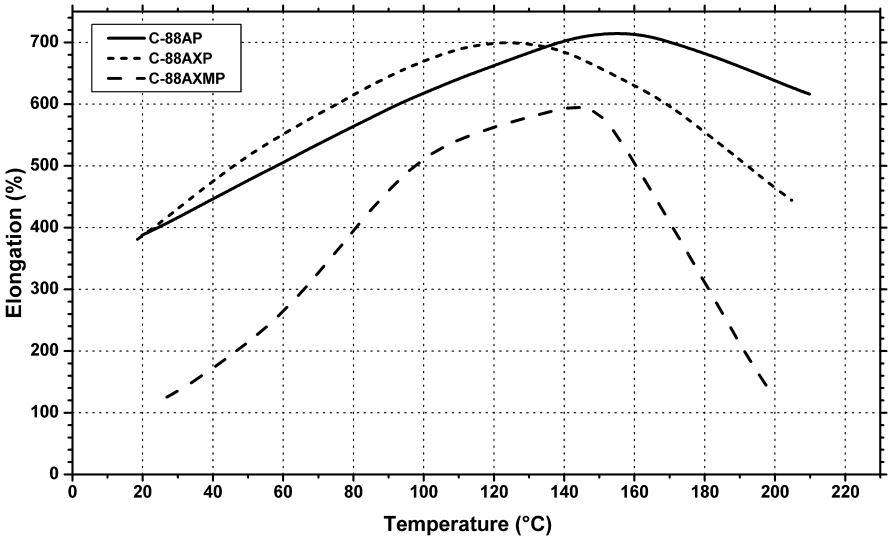

Figure 9.50 Elongation vs. temperature for Asahi Glass Fluon® C-88 series ETFE resins [6].

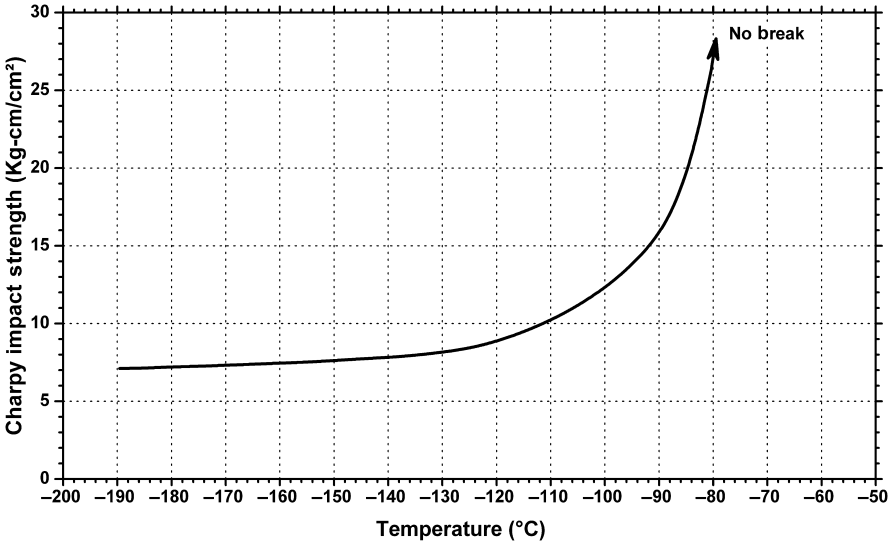

Figure 9.51 Charpy impact strength vs. temperature for Asahi Glass Fluon® ETFE [6].

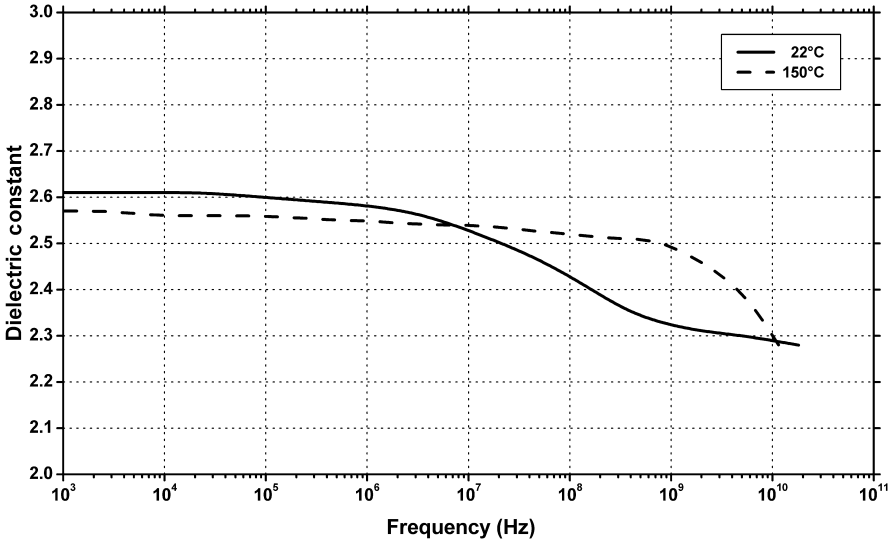

Figure 9.52 Dielectric constant vs. frequency for DuPont general purpose Tefzel® 200 ETFE resin [7].

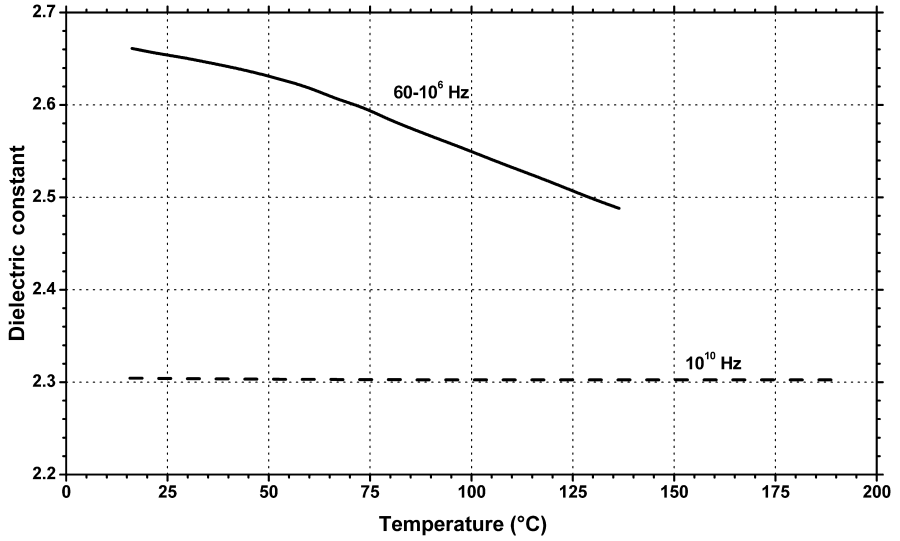

Figure 9.53 Dielectric constant vs. temperature for Asahi Glass Fluon® ETFE.

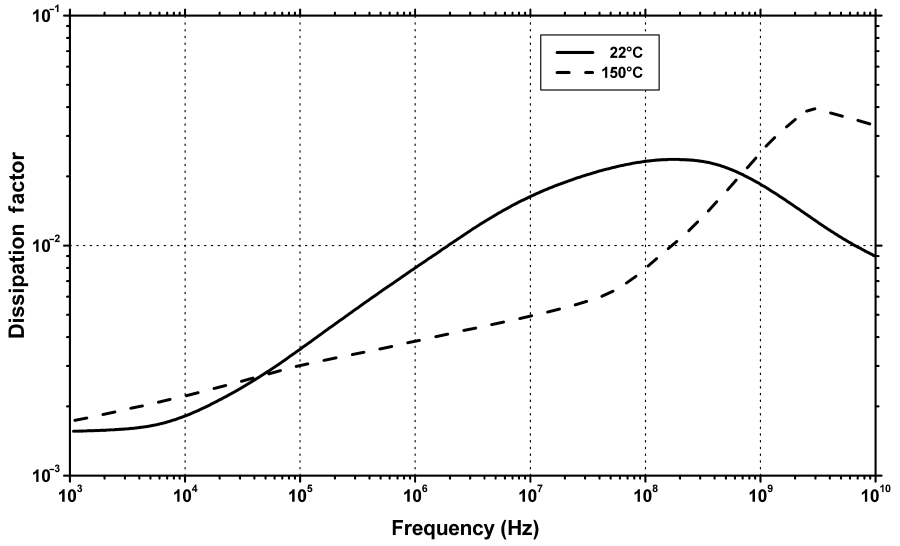

Figure 9.54 Dissipation factor vs. frequency for DuPont general purpose Tefzel® 200 ETFE resin [7].

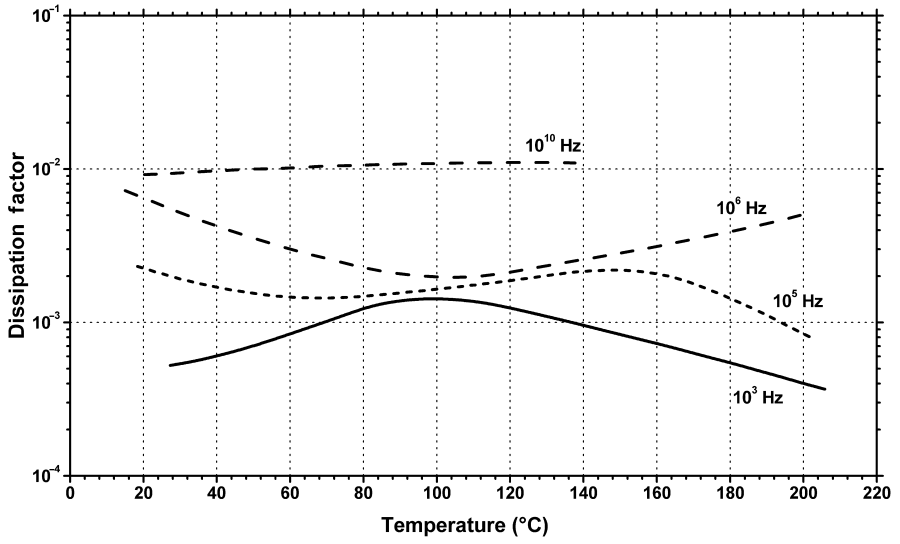

Figure 9.55 Dissipation factor vs. temperature for Asahi Glass Fluon® ETFE [6].

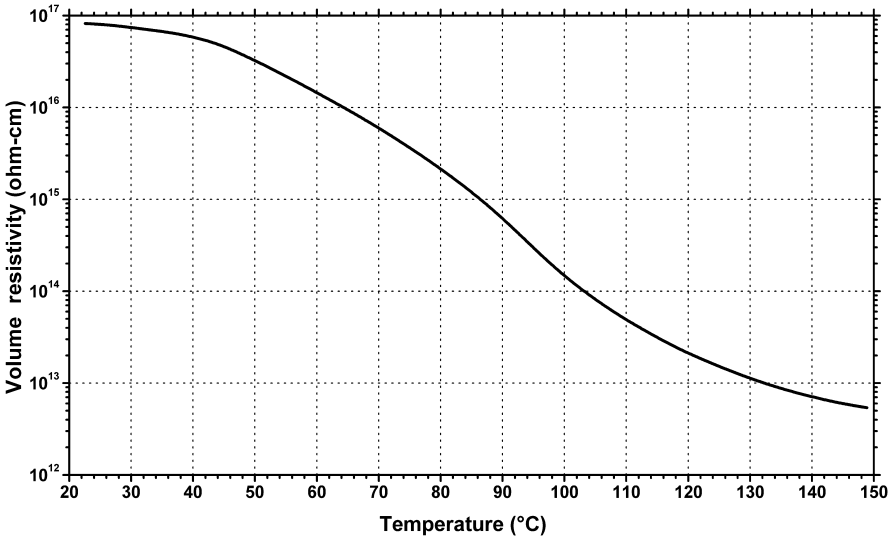

Figure 9.56 Volume resistivity vs. temperature for Asahi Glass Fluon® ETFE [6].

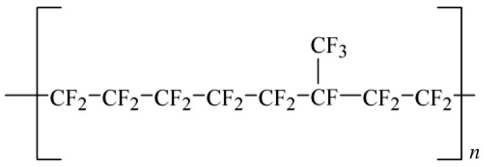

Figure 9.57 Chemical structure of FEP.

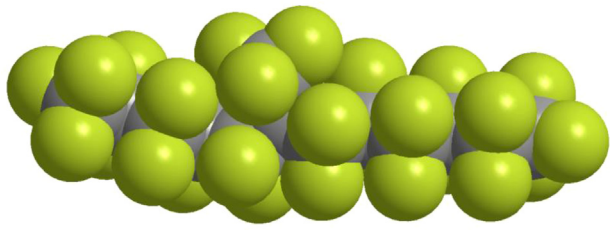

Figure 9.58 Three-dimensional representation of FEP.

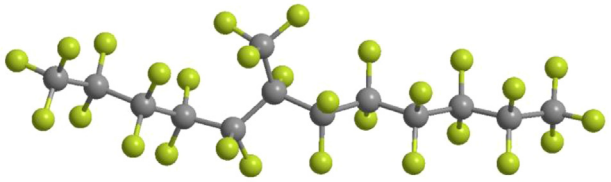

Figure 9.59 Ball and stick three-dimensional representation of FEP.

depends on the amount of trifluoromethyl groups added and secondarily on the molecular weight. Most FEP resins melt around 274°C (525°F), although lower melting points are possible with high HFP content. Even high molecular weight FEP will melt and flow. The high chemical resistance, low surface energy, and good electrical insulation properties of PTFE are retained.

Manufacturers and trade names: DuPont Teflon® FEP, Dyneon™ THV FEP, Daikin Neoflon™.

Applications and uses: applications requiring excellent chemical resistance, superior electrical properties, and high service temperatures. Release films, tubing, cable insulation, and jacketing.

Data for FEP plastics are found in Figures 9.60–9.81.

9.5 Perfluoroalkyl Vinyl Ether (PFA/MFA)

Making a more dramatic change in the side group than that done in making FEP, chemists put a perfluoroalkoxy (PFA) group on the polymer chain. This group is signified as $-O-R_f$, where R_f can be any number of totally fluorinated carbons. The most common comonomer is perfluoropropyl ($-O-CF_2-CF_2-CF_3$). However, other comonomers are shown in Table 9.3.

The polymers based on PPVE are called PFA and the perfluoroalkyl vinyl ether group is typically added at 3.5% or less. When the comonomer is PMVE the polymer is called MFA. A structure of PFA is shown in Figure 9.82. The CAS number of PFA using PPVE as comonomer is 26655-00-5.

The large side group as shown in Figures 9.83 and 9.84 reduces the crystallinity drastically. The melting point is generally between 305°C and 310°C (581–590°F) depending on the molecular weight.

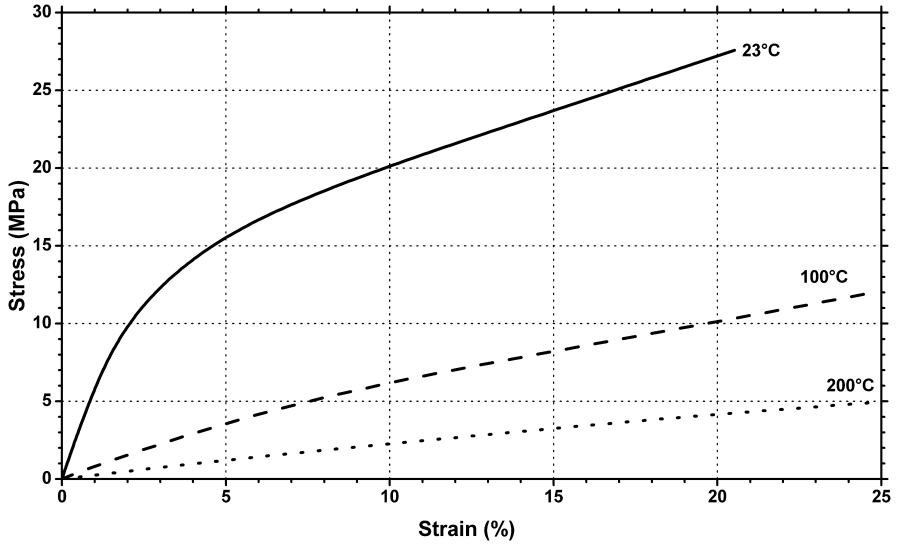

Figure 9.60 Tensile stress vs. strain in compression at various temperatures for DuPont general purpose FEP resin [8].

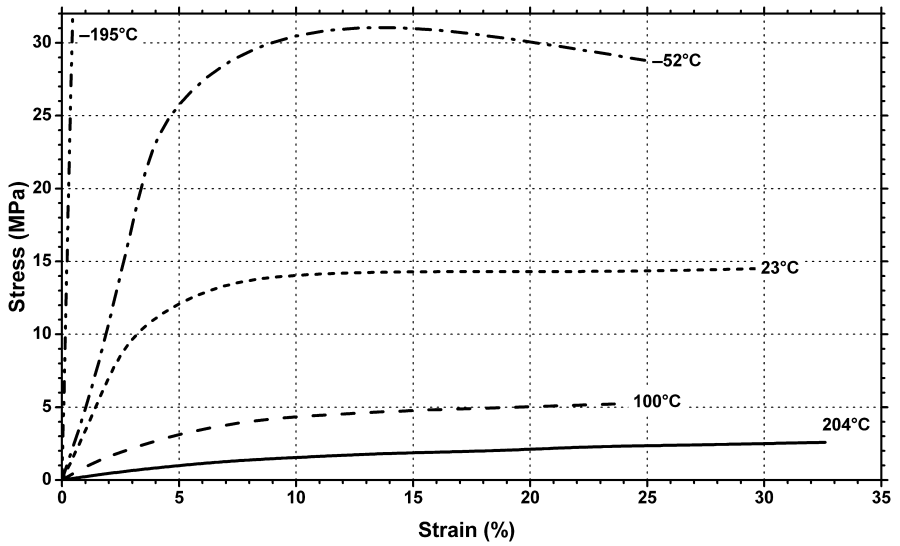

Figure 9.61 Tensile stress vs. strain at various temperatures for DuPont general purpose FEP resin [8].

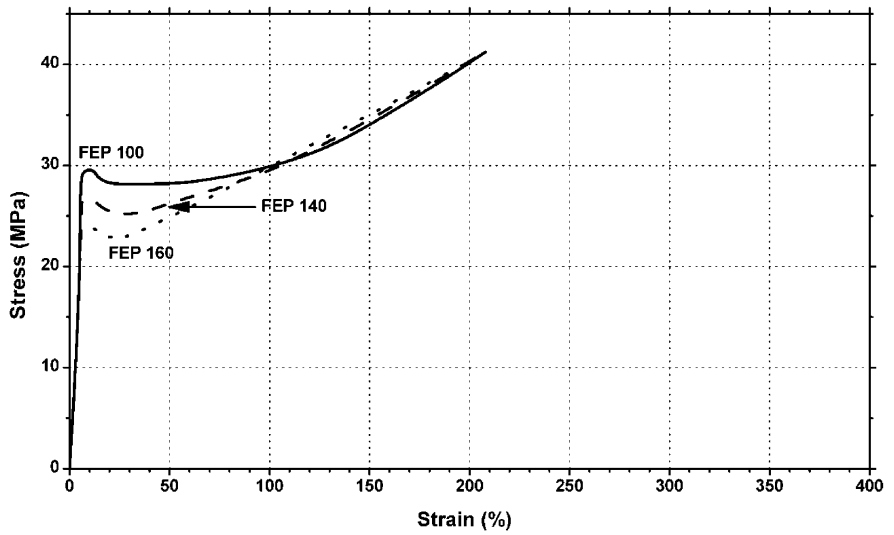

Figure 9.62 Tensile stress vs. strain at −52°C for DuPont FEP resins [8].

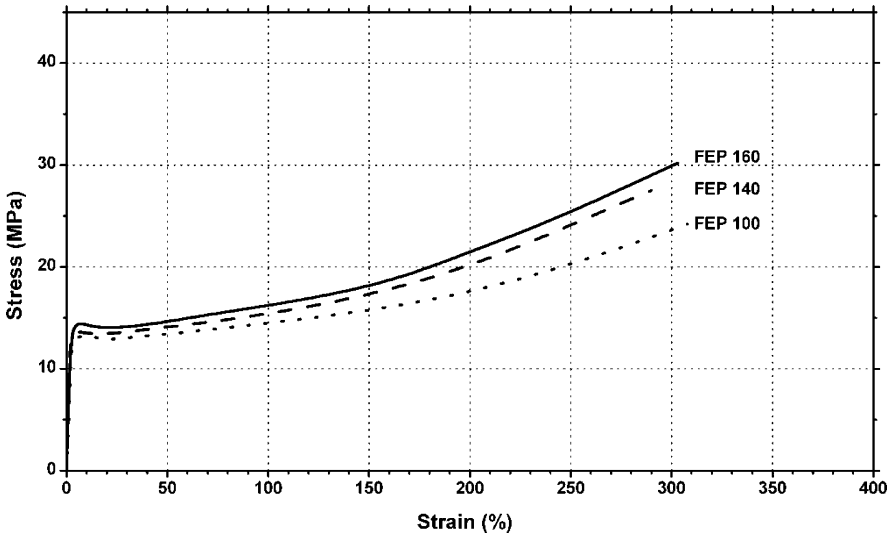

Figure 9.63 Tensile stress vs. strain at 23°C for DuPont FEP resins [8].

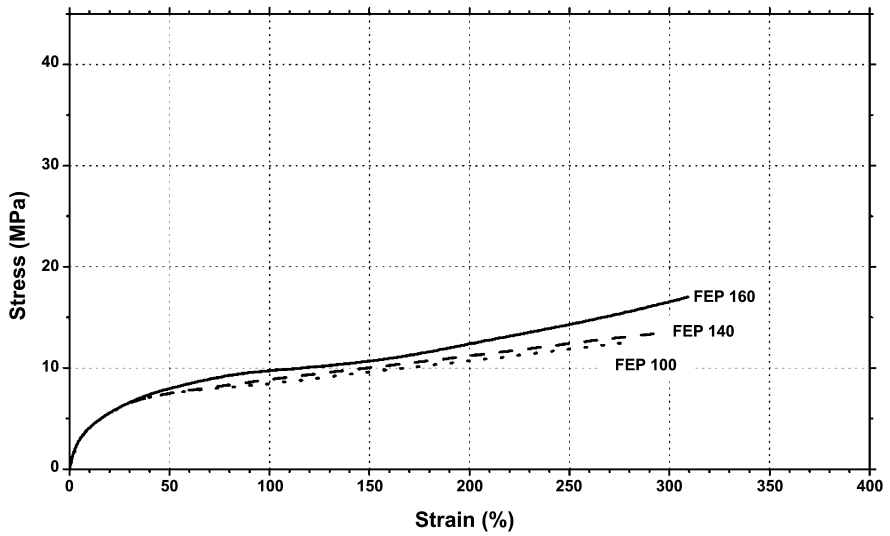

Figure 9.64 Tensile stress vs. strain at 100°C for DuPont FEP resins [8].

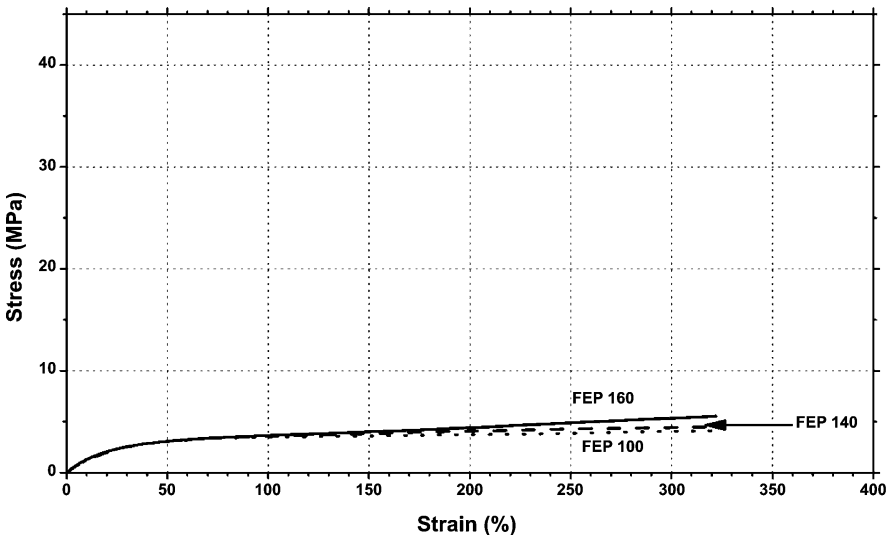

Figure 9.65 Tensile stress vs. strain at 200°C for DuPont FEP resins [8].

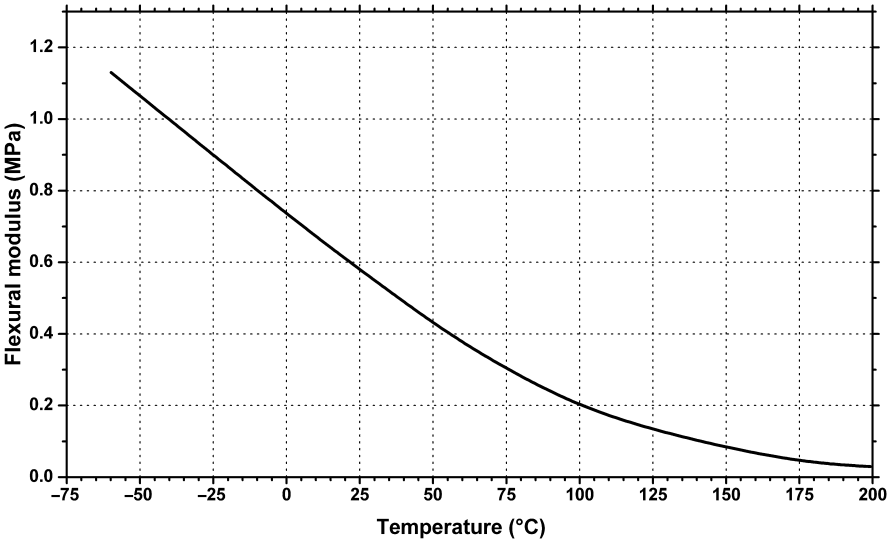

Figure 9.66 Flexural modulus vs. temperature for DuPont FEP resins [8].

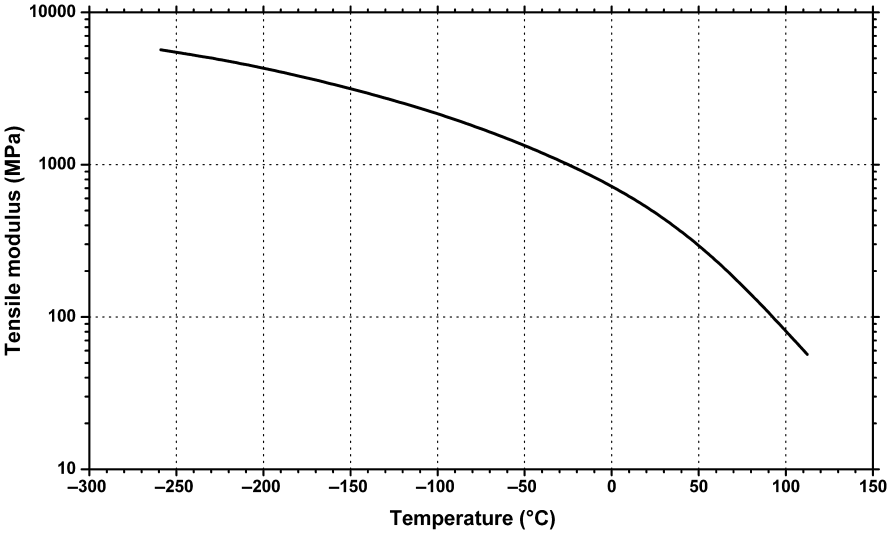

Figure 9.67 Tensile modulus vs. temperature for Daikin Neoflon™ FEP [9].

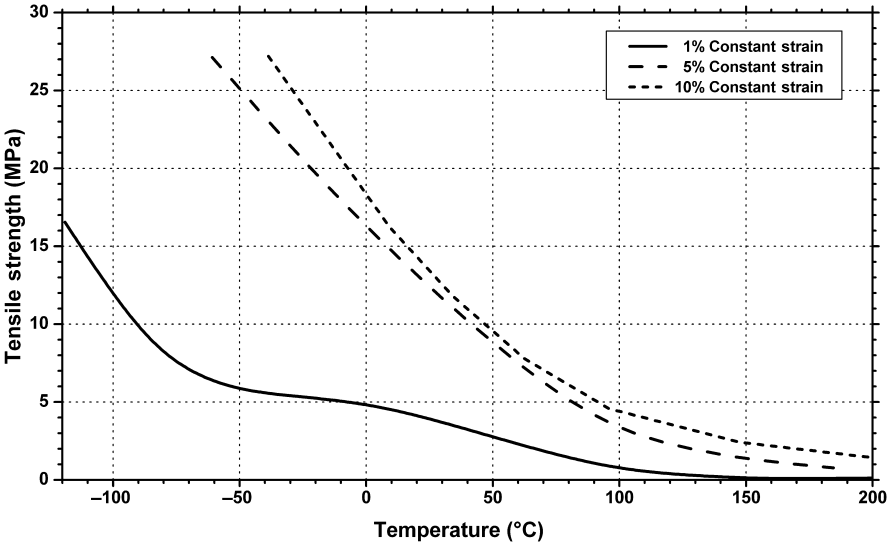

Figure 9.68 Tensile strength vs. temperature and various strain levels for DuPont general purpose FEP resin.

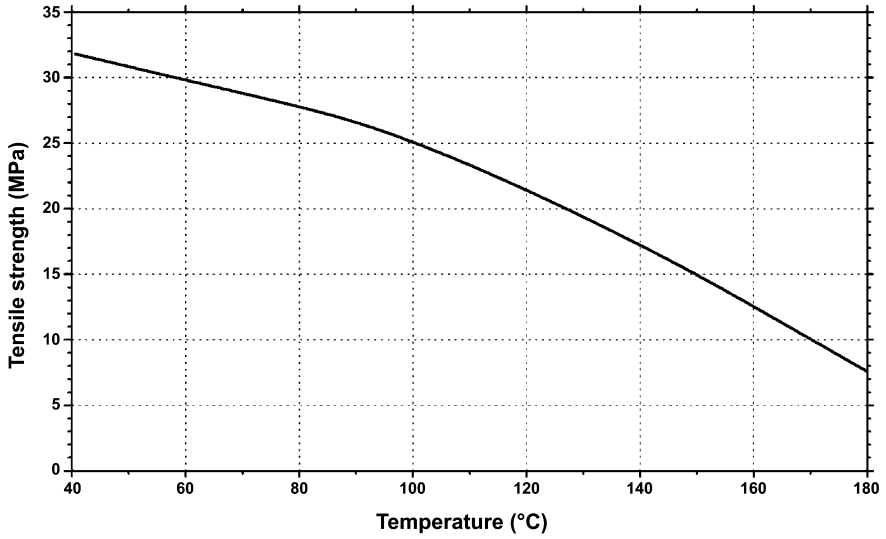

Figure 9.69 Tensile strength vs. temperature for SABIC Innovative Plastics LNP FEP resin with 20% glass fiber.

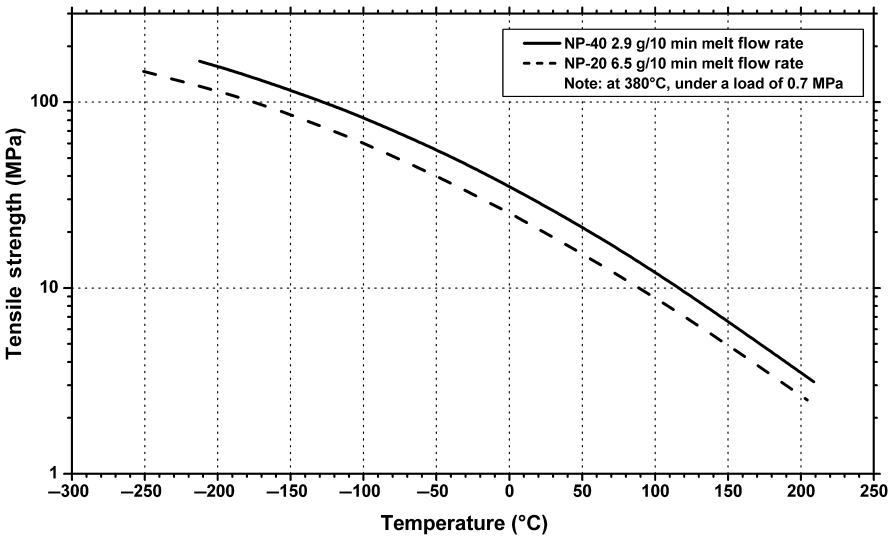

Figure 9.70 Tensile strength vs. temperature for Daikin Neoflon™ FEP [9].

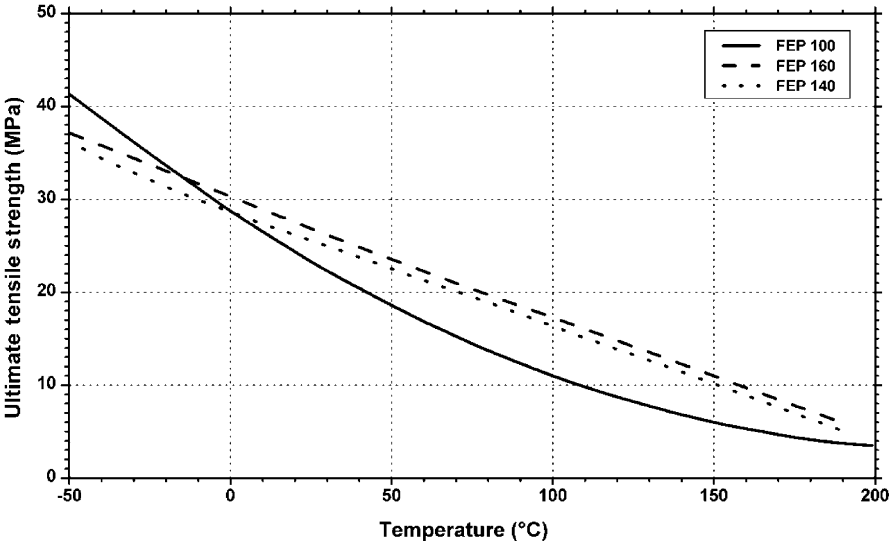

Figure 9.71 Ultimate tensile strength vs. temperature for DuPont FEP resins [8].

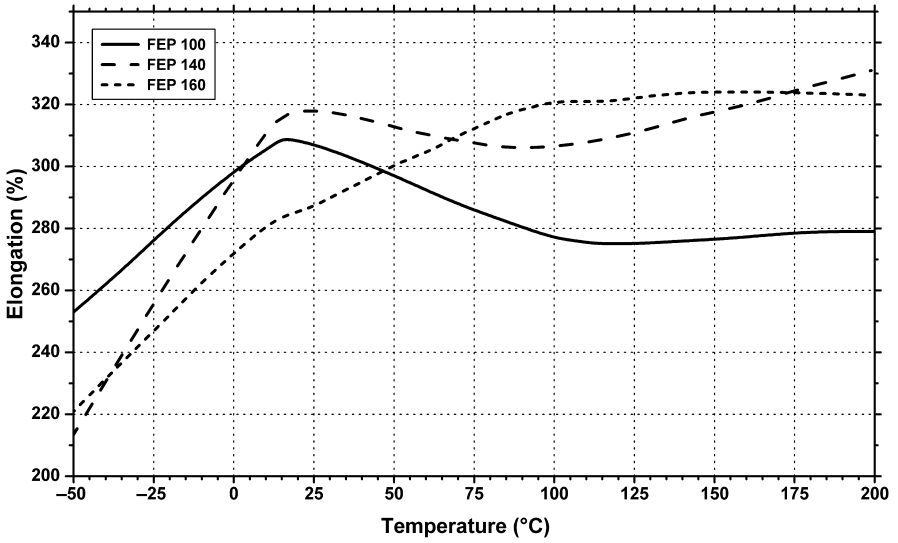

Figure 9.72 Ultimate elongation vs. temperature for DuPont FEP resins [8].

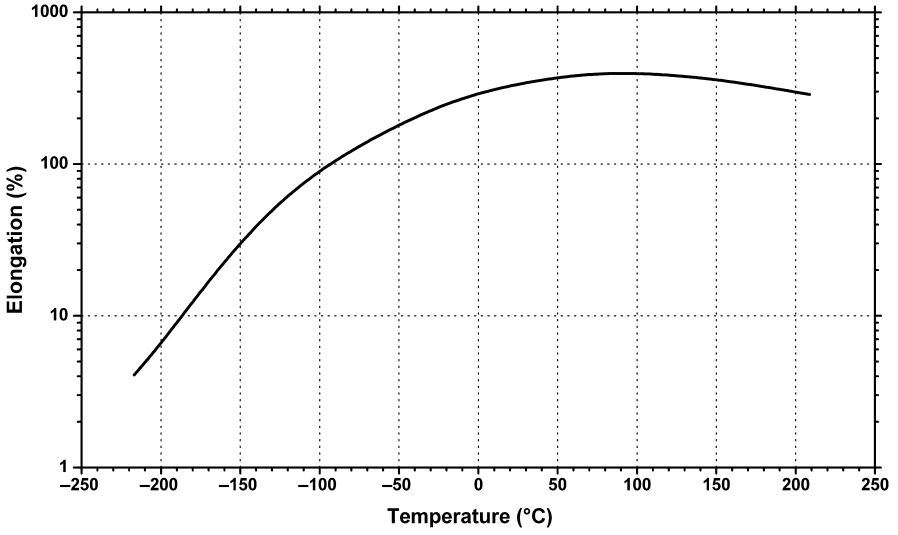

Figure 9.73 Elongation vs. temperature for Daikin Neoflon™ FEP [9].

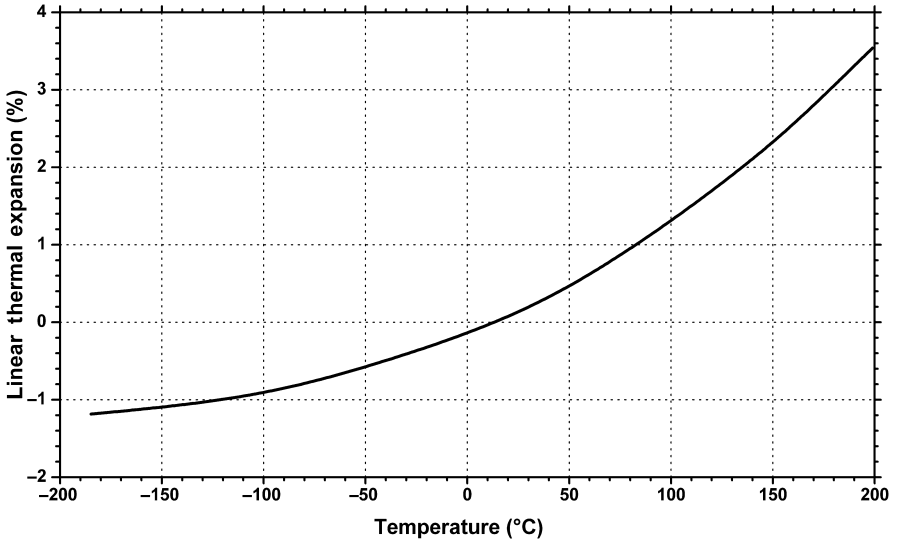

Figure 9.74 Linear thermal expansion vs. temperature for DuPont general purpose FEP resin.

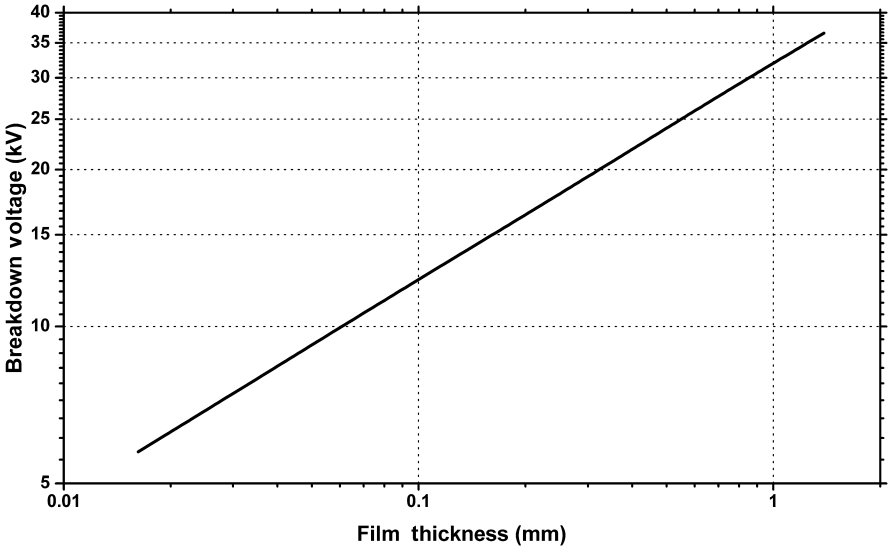

Figure 9.75 Breakdown voltage vs. film thickness for Daikin Neoflon™ FEP [9].

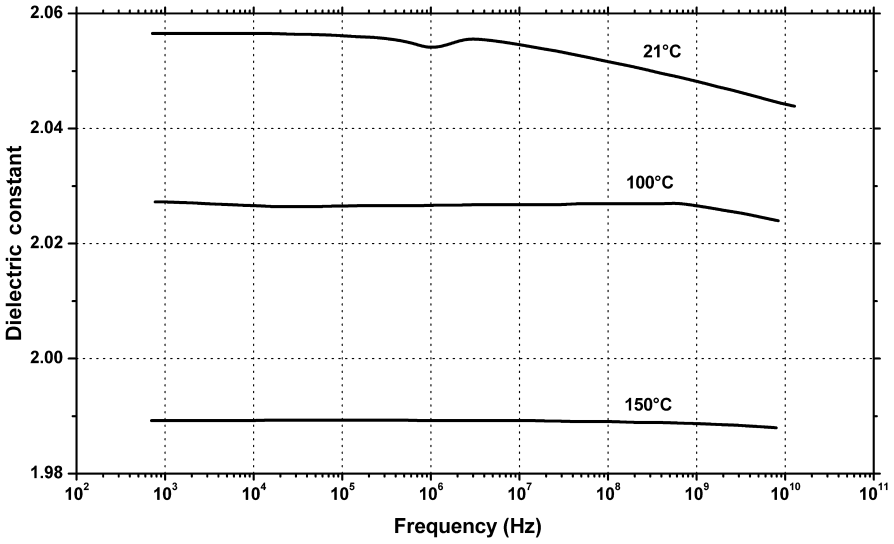

Figure 9.76 Dielectric constant—elevated temperature, Teflon® FEP 100 fluoropolymer resin [8].

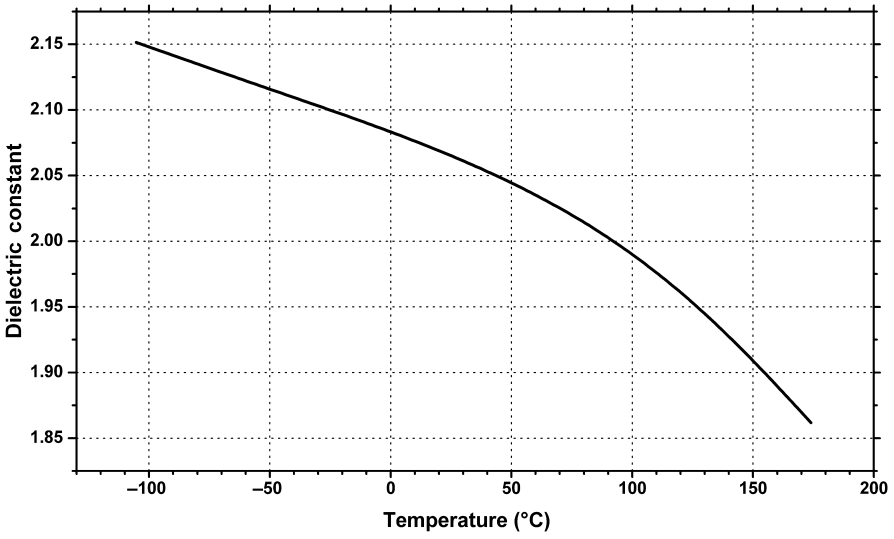

Figure 9.77 Dielectric constant vs. temperature for Daikin Neoflon™ FEP [9].

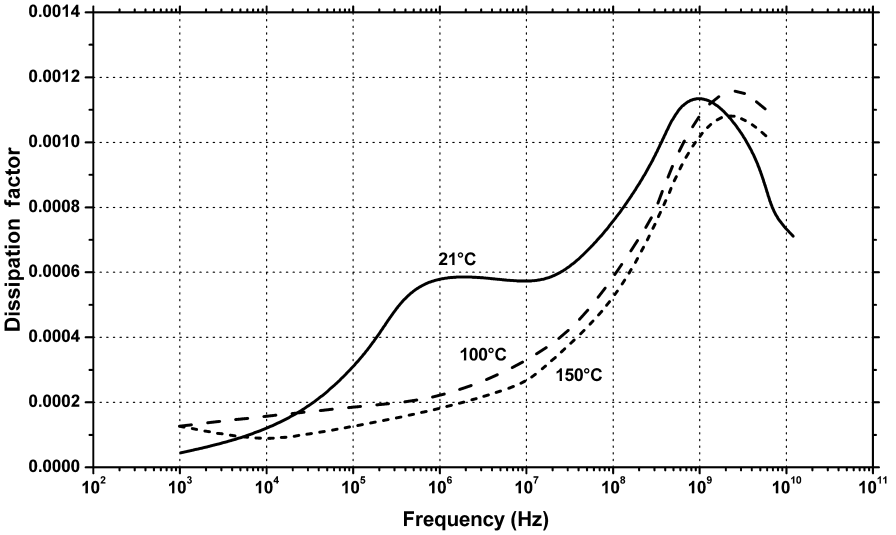

Figure 9.78 Dissipation factor vs. frequency at various temperatures for DuPont general purpose Teflon® FEP 100 resin [8].

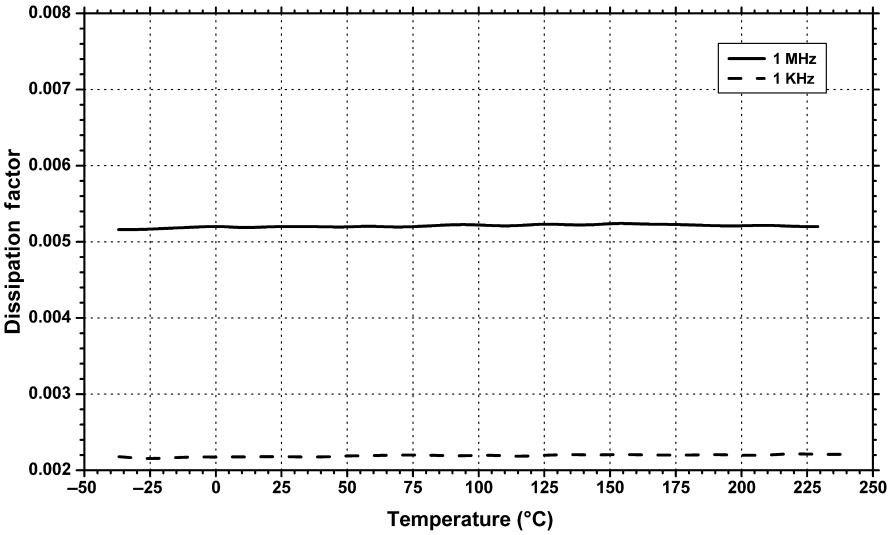

Figure 9.79 Dissipation factor vs. temperature for DuPont general purpose FEP resin [8].

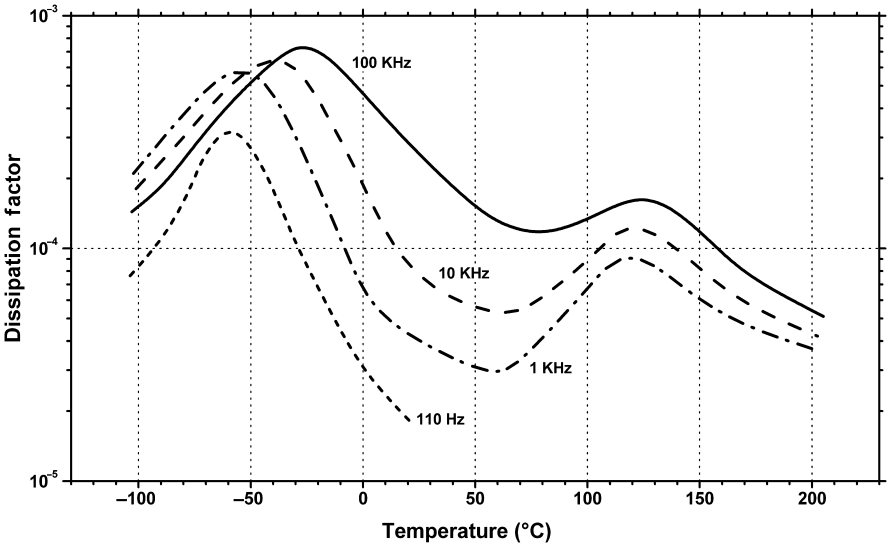

Figure 9.80 Dissipation factor vs. temperature for Daikin Neoflon™ FEP [9].

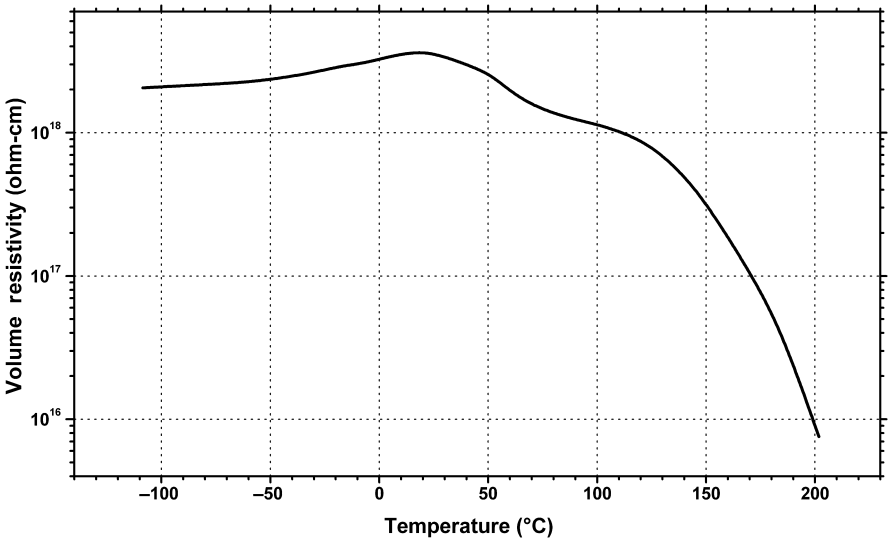

Figure 9.81 Volume resistivity vs. temperature for Daikin Neoflon™ FEP [9].

Table 9.3 PFA Comonomers

Comonomer	Structure
Perfluoromethyl vinyl ether (PMVE)	$CF_2{=}CF{-}O{-}CF_3$
Perfluoroethyl vinyl ether (EVE)	$CF_2{=}CF{-}O{-}CF_2{-}CF_3$
Perfluoropropyl vinyl ether (PPVE)	$CF_2{=}CF{-}O{-}CF_2{-}CF_2{-}CF_3$

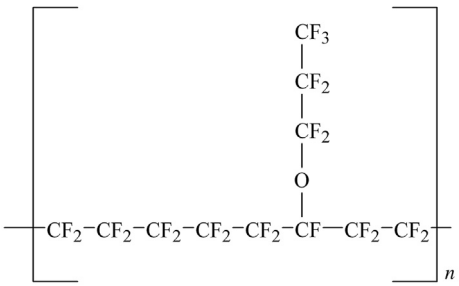

Figure 9.82 Chemical structure of PFA.

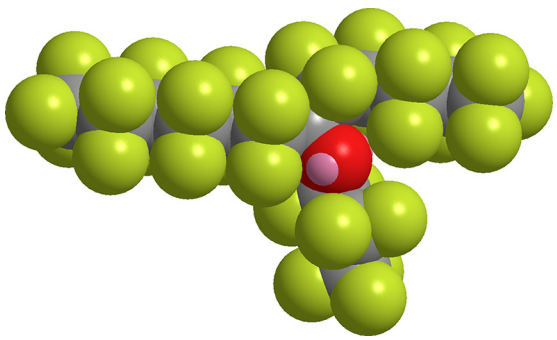

Figure 9.83 Three-dimensional representation of PFA.

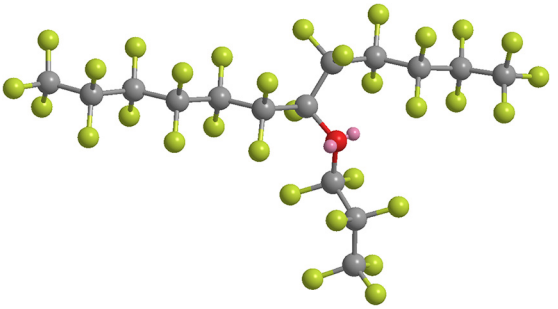

Figure 9.84 Ball and stick three-dimensional representation of PFA.

The melt viscosity is also dramatically dependent on the molecular weight. Since PFA is still perfluorinated as with FEP the high chemical resistance, low surface energy, and good electrical insulation properties are retained.

Solvay Solexis Hyflon® MFA and PFA are semi-crystalline fully fluorinated melt-processible fluoropolymers. Hyflon® PFA belongs to the class of PFA having a lower melting point than standard PFA grades.

Manufacturers and trade names: DuPont Teflon®; Solvay Solexis Hyflon®; Dyneon™ (a 3M company); Daikin Industries Neoflon™ PFA.

Applications and uses: lined and coated processing equipment, vessels and housings, high purity chemical storage.

The data for PFA and MFA are separated into two sections.

9.5.1 PFA

Data for PFA plastics are found in Figures 9.85–9.104.

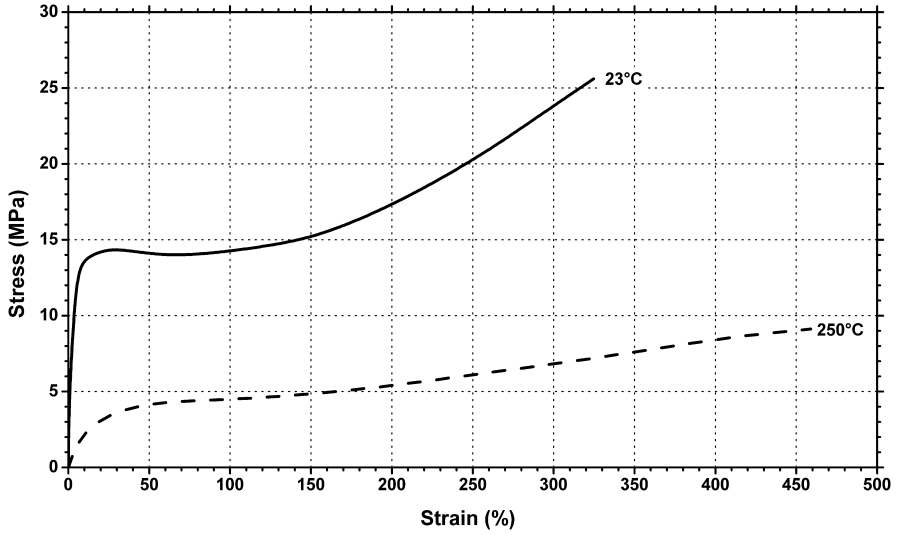

Figure 9.85 Stress vs. strain at two temperatures for Solvay Solexis Hyflon® PFA resin [10].

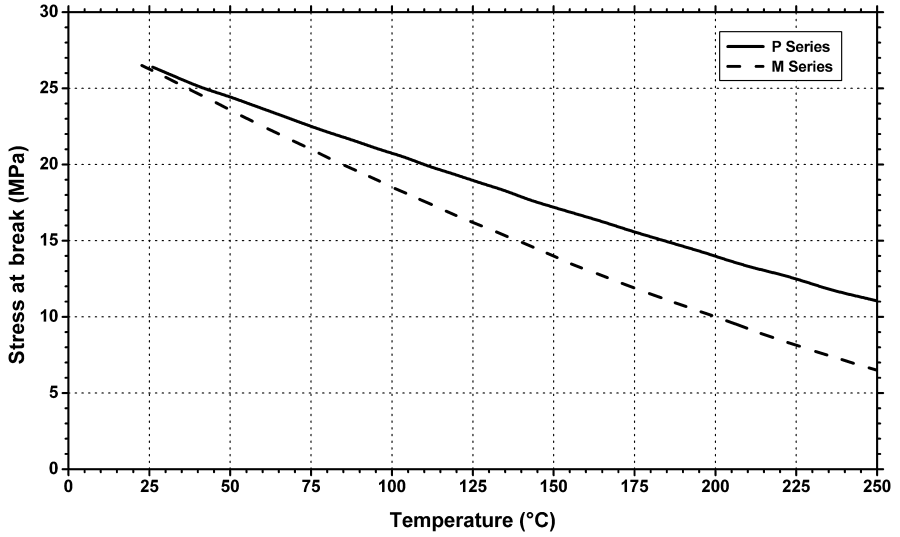

Figure 9.86 Stress at break vs. temperature for Solvay Solexis Hyflon® PFA resins [10].

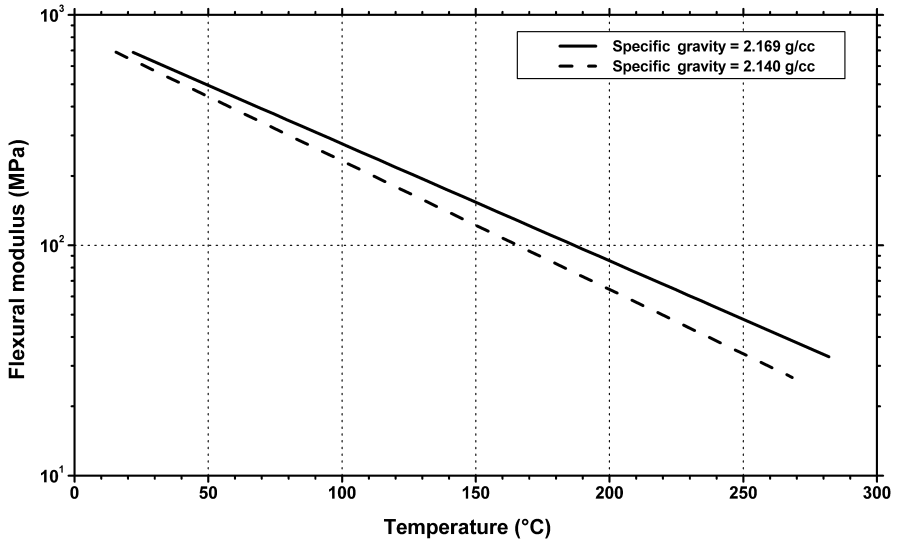

Figure 9.87 Flexural modulus vs. temperature for DuPont Teflon® PFA 340 and 350 grade resins.

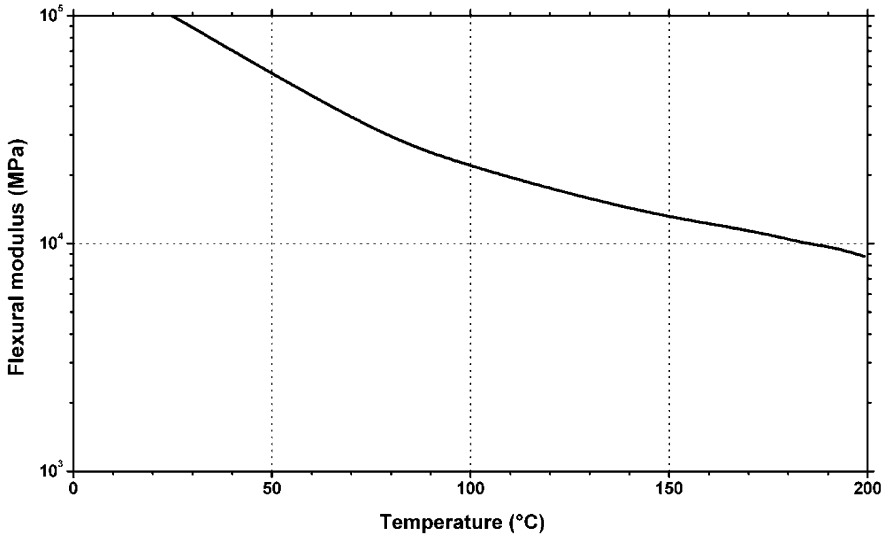

Figure 9.88 Flexural modulus vs. temperature for DuPont Teflon® PFA HP plus resins.

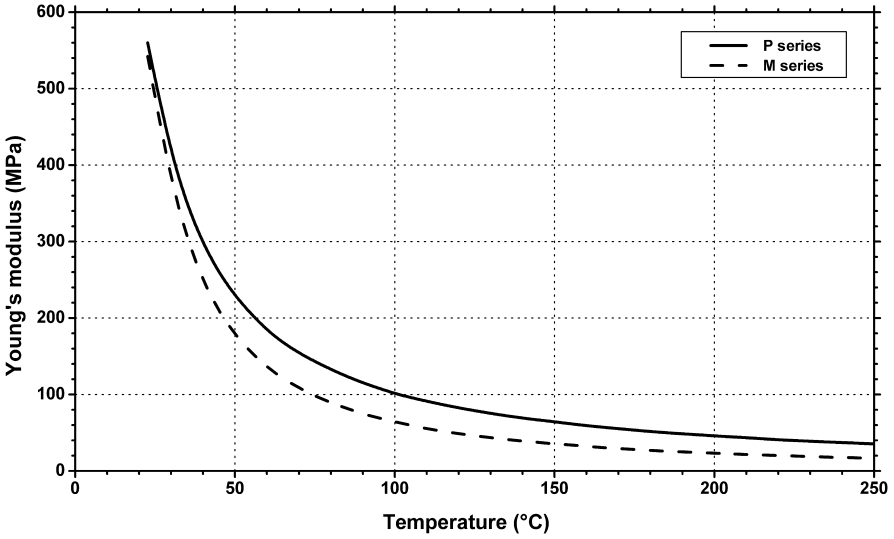

Figure 9.89 Young's modulus vs. temperature for Solvay Solexis Hyflon® PFA resins [10].

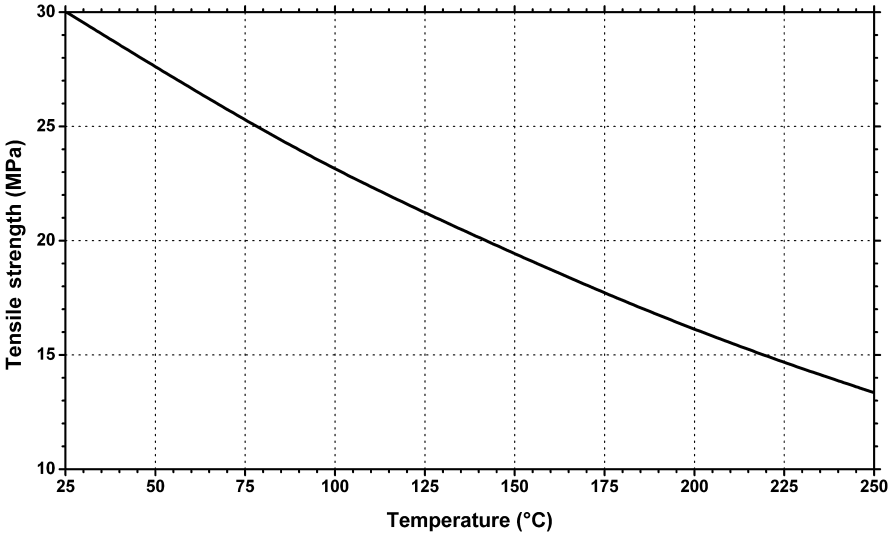

Figure 9.90 Tensile strength vs. temperature for DuPont Teflon® PFA 340 and 350 grade resins.

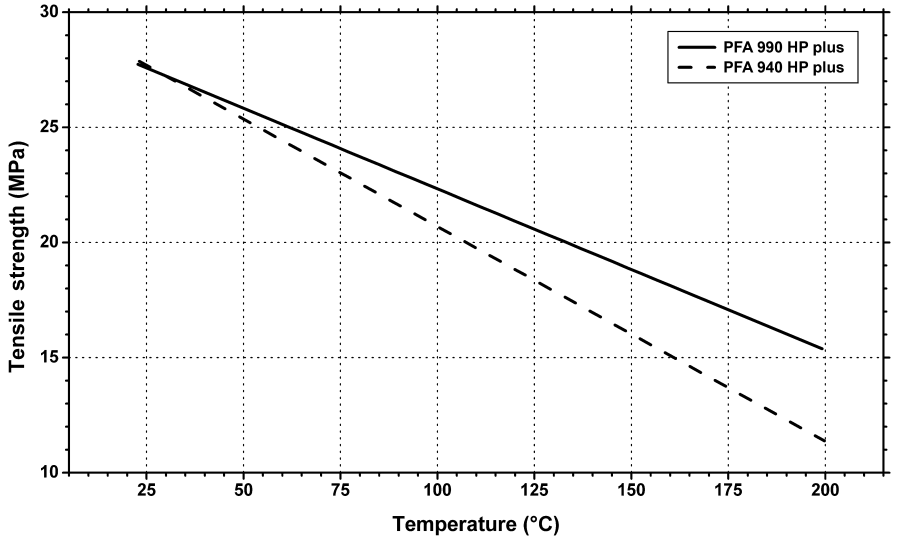

Figure 9.91 Tensile strength vs. temperature for DuPont Teflon® PFA HP plus resins.

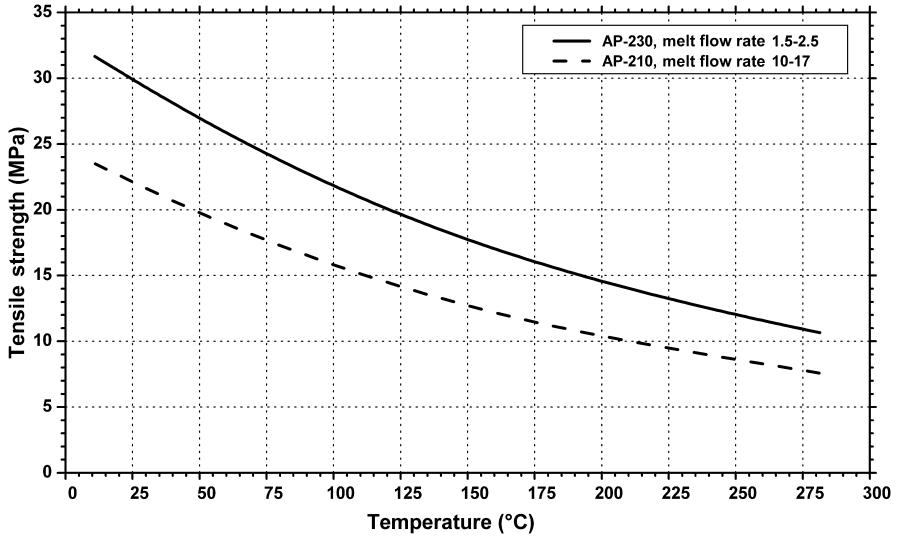

Figure 9.92 Tensile strength vs. temperature for Daikin Industries Neoflon™ PFA [11].

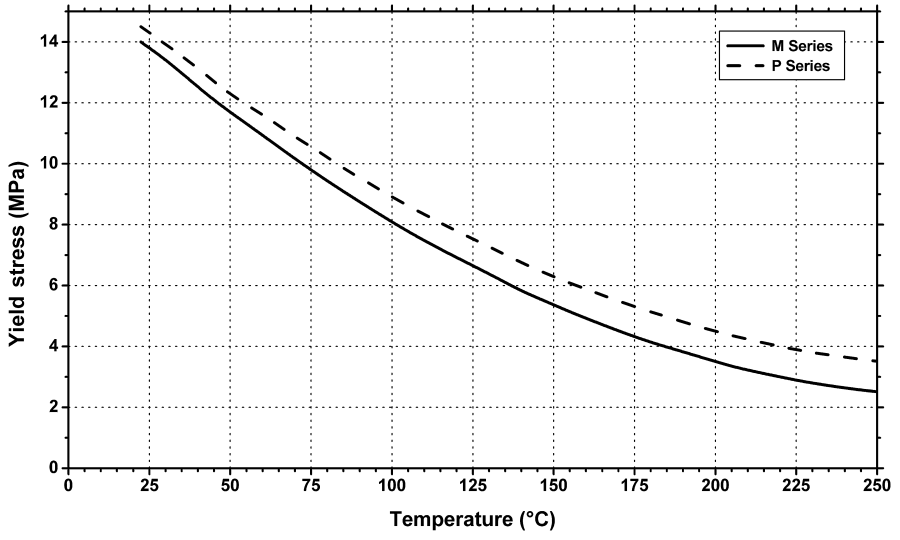

Figure 9.93 Yield stress vs. temperature for Solvay Solexis Hyflon® PFA resins [10].

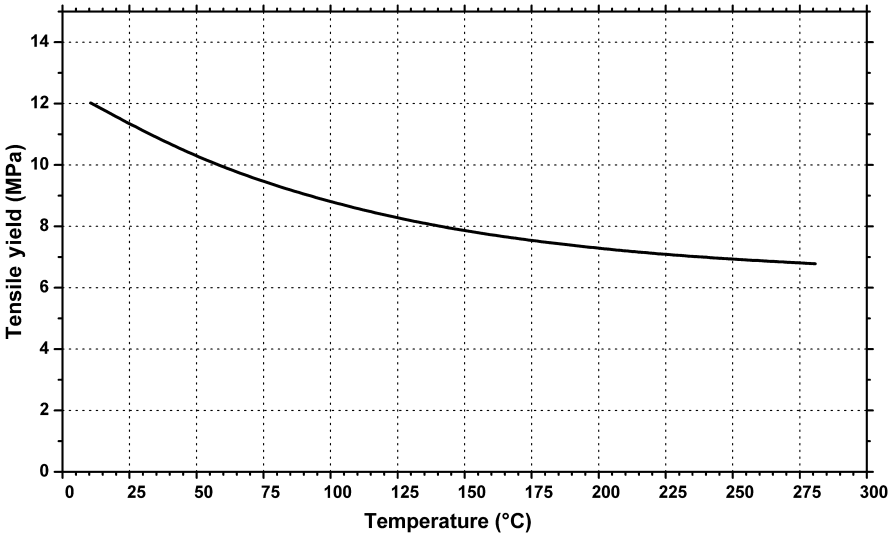

Figure 9.94 Tensile yield vs. temperature for Daikin Industries Neoflon™ PFA [11].

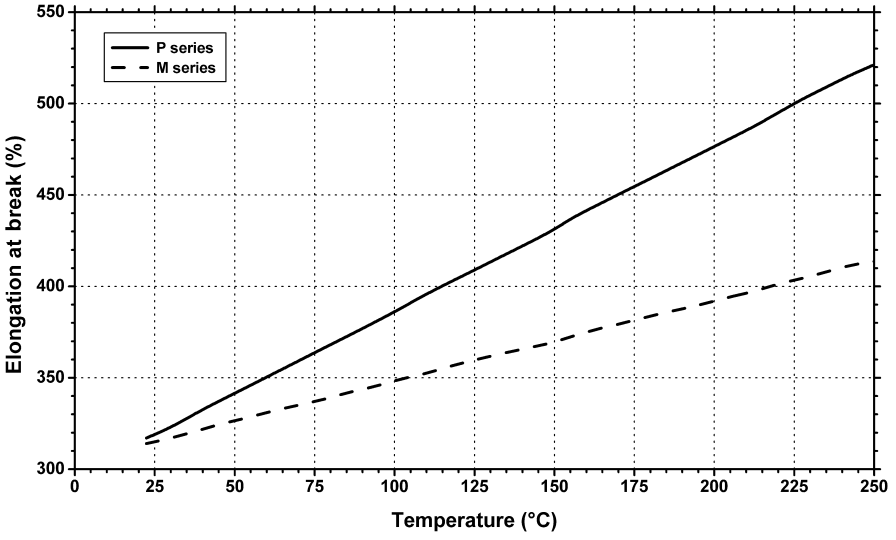

Figure 9.95 Elongation at break vs. temperature for Solvay Solexis Hyflon® PFA resins [10].

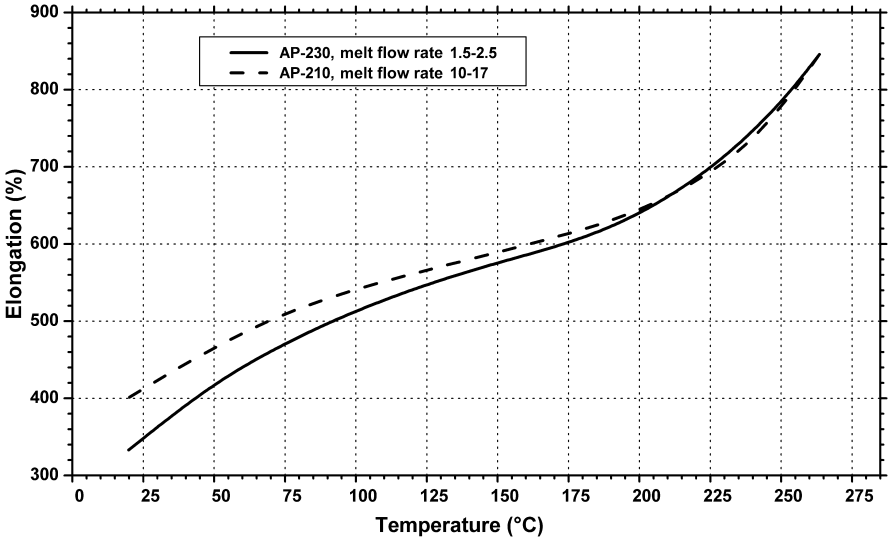

Figure 9.96 Elongation vs. temperature for Daikin Industries Neoflon™ PFA [11].

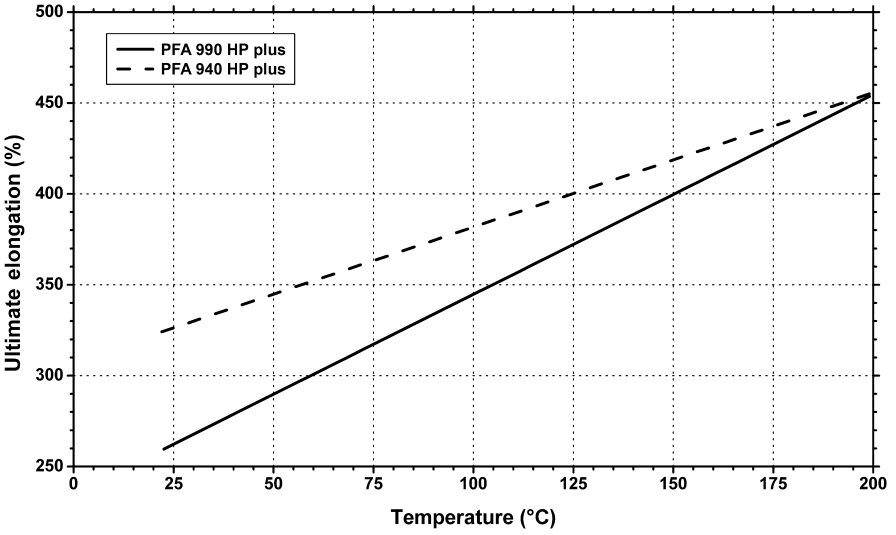

Figure 9.97 Ultimate elongation vs. temperature for DuPont Teflon® PFA HP plus resins.

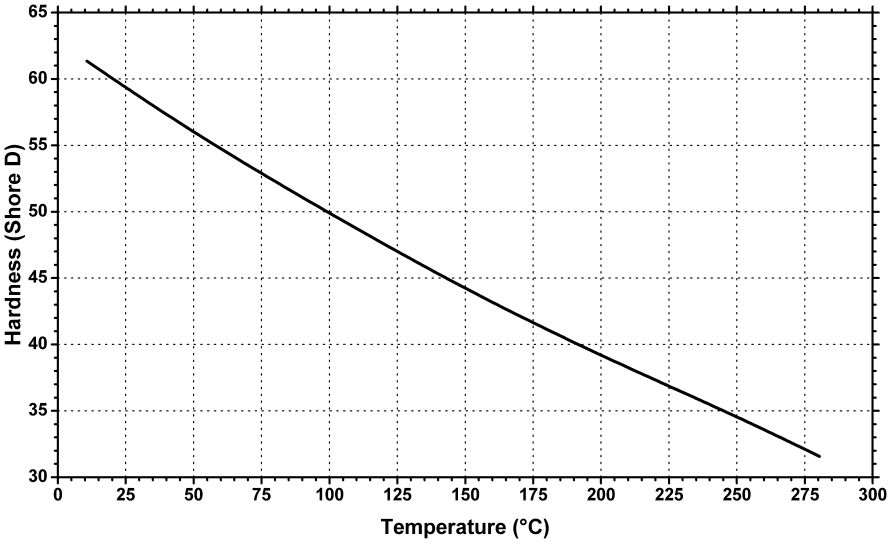

Figure 9.98 Shore D hardness vs. temperature for Daikin Industries Neoflon™ PFA [11].

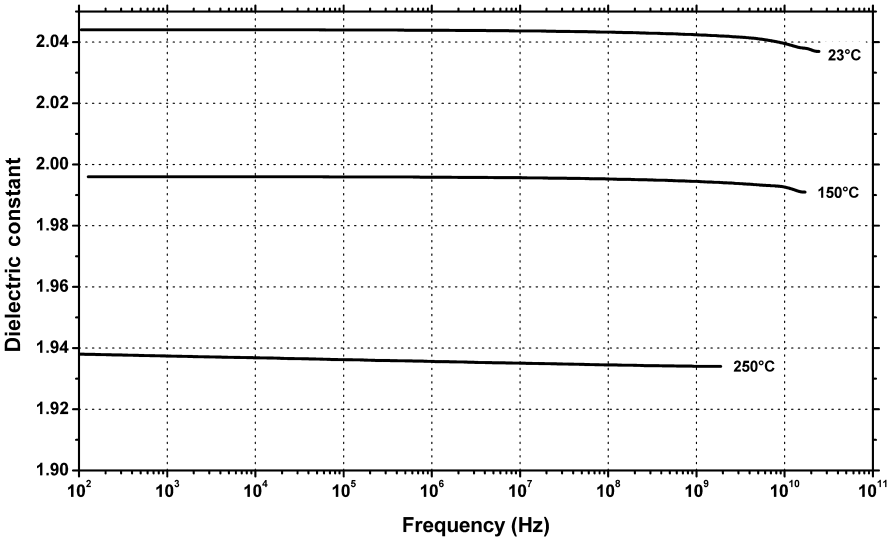

Figure 9.99 Dielectric constant vs. frequency for DuPont Teflon® PFA 340 and 350 grade resins.

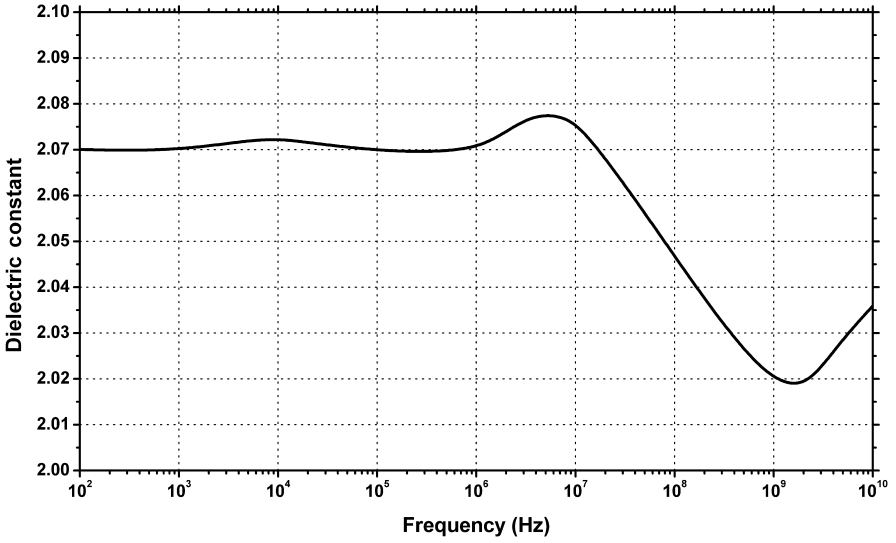

Figure 9.100 Dielectric constant vs. frequency for DuPont Teflon® PFA HP plus resins.

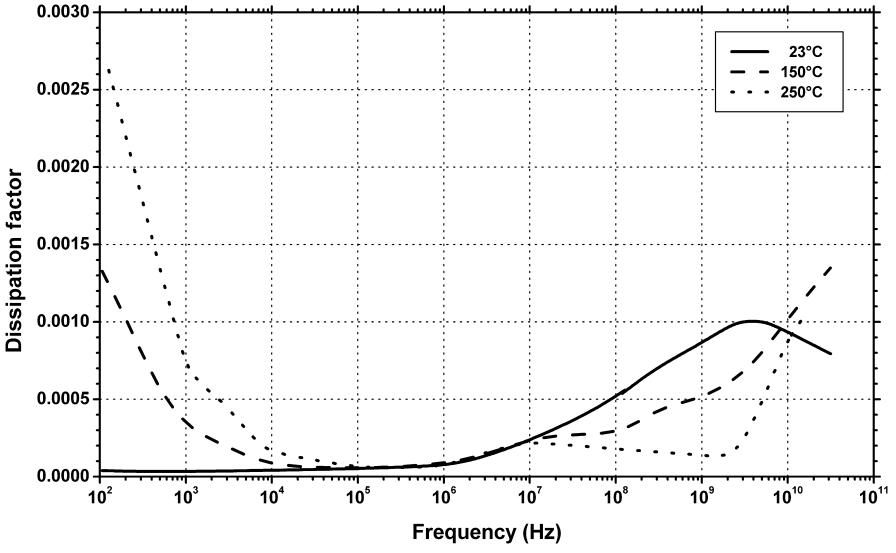

Figure 9.101 Dissipation factor vs. frequency and temperature for DuPont Teflon® PFA 340 and 350 grade resins.

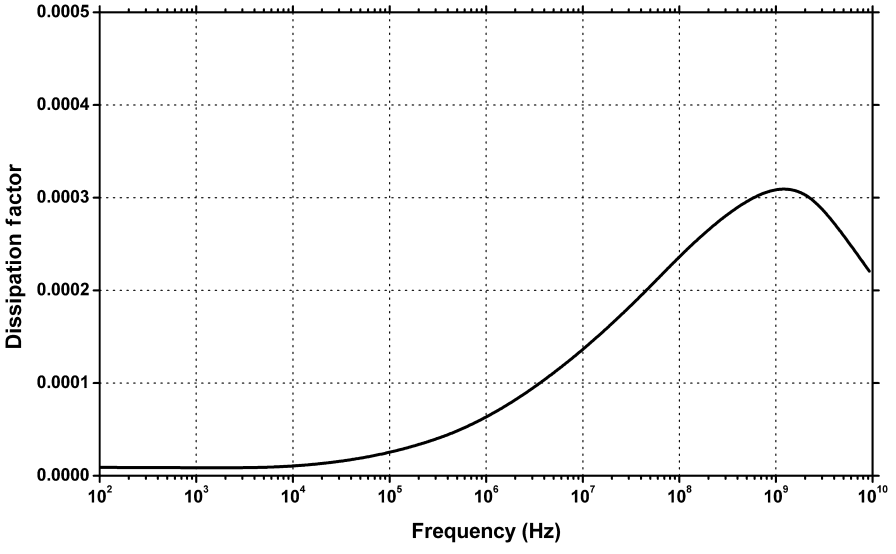

Figure 9.102 Dissipation factor vs. frequency and temperature for DuPont Teflon® PFA HP plus resins.

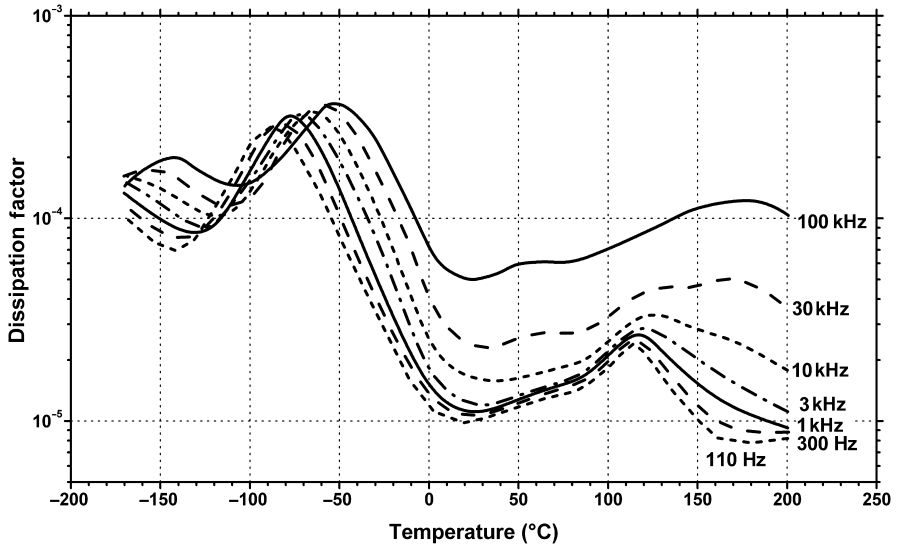

Figure 9.103 Dissipation factor vs. temperature at various frequencies for Daikin Industries Neoflon™ [11].

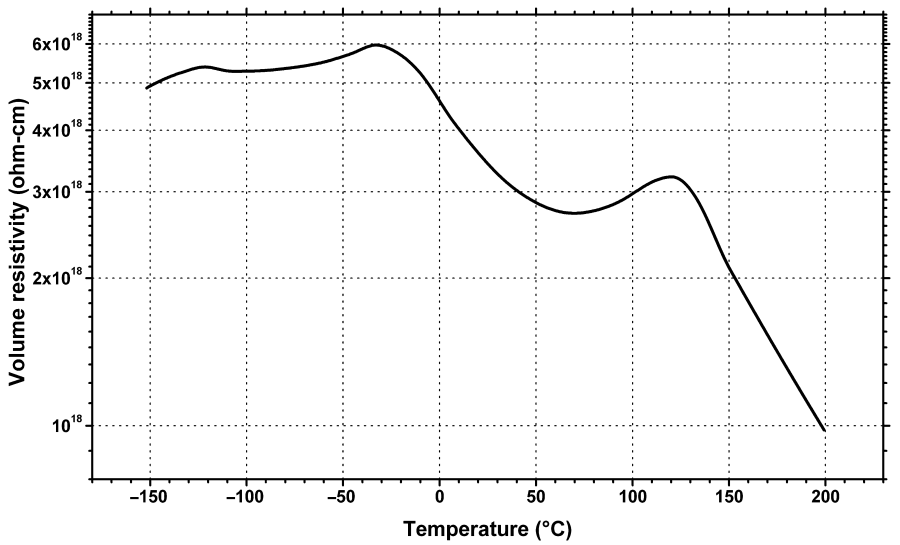

Figure 9.104 Volume resistivity vs. temperature for Daikin Industries Neoflon™ [11].

9.5.2 MFA

Data for MFA plastics are found in Table 9.4 and Figure 9.105.

9.6 Polychlorotrifluoroethylene (PCTFE)

PCTFE is a homopolymer of chlorotrifluoroethylene, characterized by the structure shown in Figure 9.106. The CAS number is 9002-83-9.

The addition of the one chlorine atom contributes to lowering the melt viscosity to permit extrusion and injection molding. It also contributes to the transparency, the exceptional flow, and the rigidity characteristics of the polymer. Fluorine is responsible for its chemical inertness and zero moisture absorption. Therefore, PCTFE has unique properties. Its resistance to cold flow, dimensional stability, rigidity, low gas permeability, and low moisture absorption is superior to any other fluoropolymer. It can be used at low temperatures. Some products contain a small amount of a comonomer.

Manufacturers and trade names: Honeywell Aclar®, Arkema VOLTALEF®, Daikin Industries Neoflon™ CTFE.

Uses and applications: pharmaceutical blister packaging, electroluminescent lamps, liquid crystal display (LCD) panels.

Data for PCTFE plastics are found in Figures 9.107–9.124.

Table 9.4 Solvay Solexis Hyflon® MFA Typical Tensile Properties at Different Temperatures [12]

Property and Test Method	Hyflon® MFA Product and Typical Tensile Properties			
	F1520	F1530	F1540	1041
Young's Modulus (MPa) ASTM D3307 1 mm/min				
23°C	400	450	470	470
150°C	40	40	40	55
200°C	20	20	20	35
First Yield Stress (MPa) ASTM D3307 50 mm/min				
23°C	12.0	12.5	12.5	13.0
150°C	2.5	2.5	3.0	3.5
200°C	2.0	2.0	2.0	2.5
Stress at Break (MPa) ASTM D3307 50 mm/min				
23°C	30	27	24	20
150°C	15.0	13.0	10.5	9.0
200°C	8.0	7.0	6.0	5.5
Elongation at Break (%) ASTM D3307 50 mm/min				
23°C	>300	>300	>300	>275
150°C	>300	>300	>300	>275
200°C	>300	>300	>300	>275

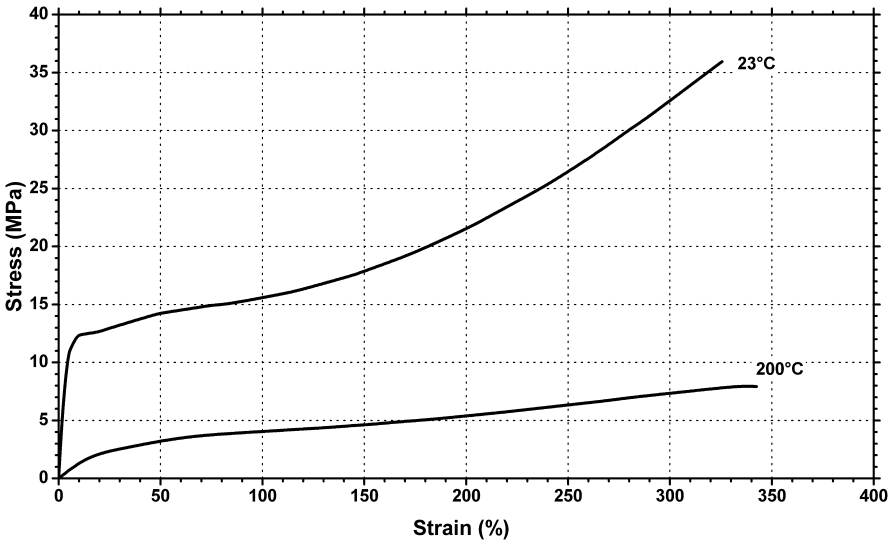

Figure 9.105 Stress vs. strain for typical Solvay Solexis Hyflon® MFA [12].

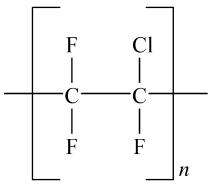

Figure 9.106 Chemical structure of PCTFE.

9.7 Polyvinylidene Fluoride (PVDF)

The polymers made from 1,1-difluoroethene (or vinylidene fluoride) are known as PVDF—polyvinylidene fluoride. They are resistant to oils and fats, water and steam, and gas and odors,

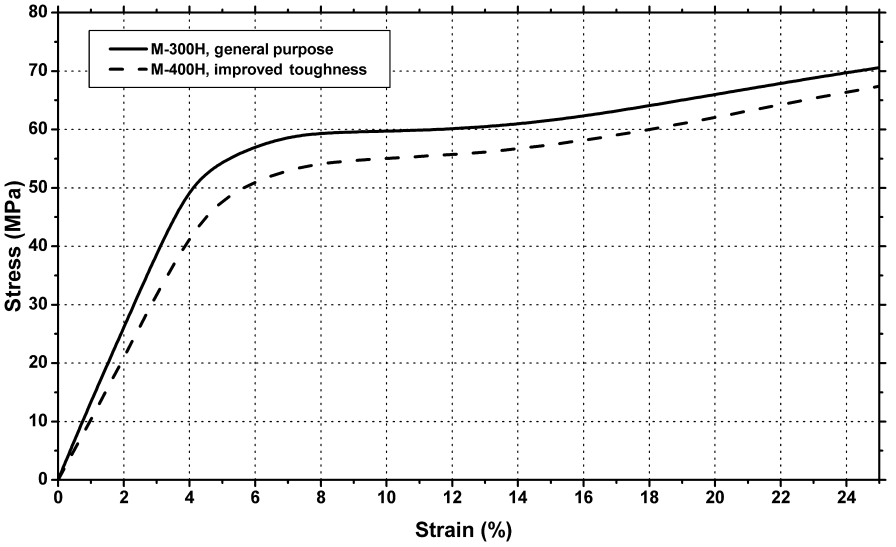

Figure 9.107 Stress vs. strain at 23°C for Daikin Industries Neoflon™ PCTFE resins [13].

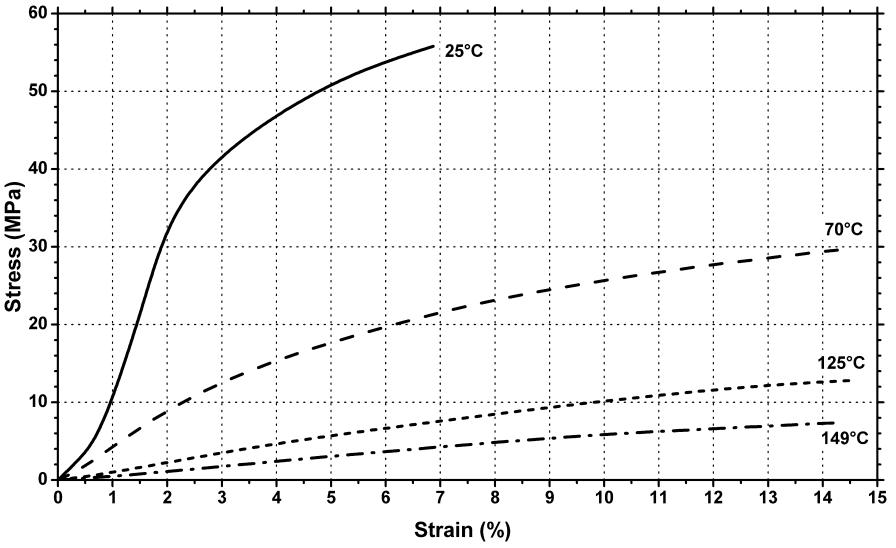

Figure 9.108 Stress vs. strain in compression at various temperatures for Dyneon PCTFE resin.

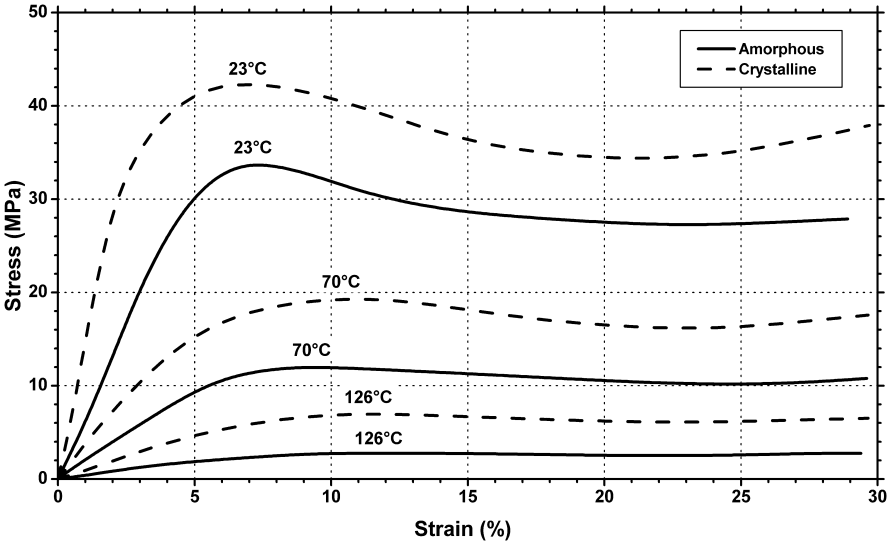

Figure 9.109 Stress vs. strain at various temperatures for Dyneon crystalline and amorphous PCTFE resins.

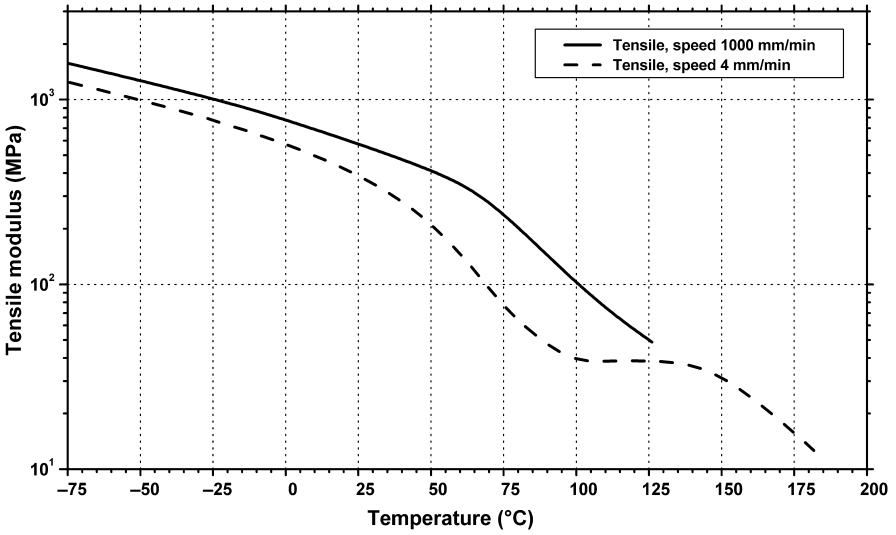

Figure 9.110 Tensile modulus vs. temperature for Daikin Industries Neoflon™ PCTFE resin [13].

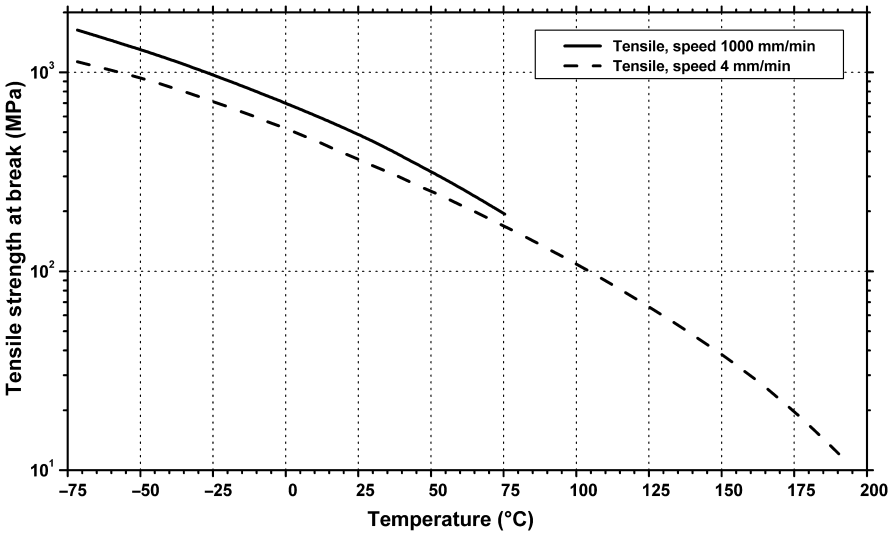

Figure 9.111 Tensile strength at break vs. temperature for Daikin Industries Neoflon™ PCTFE resin [13].

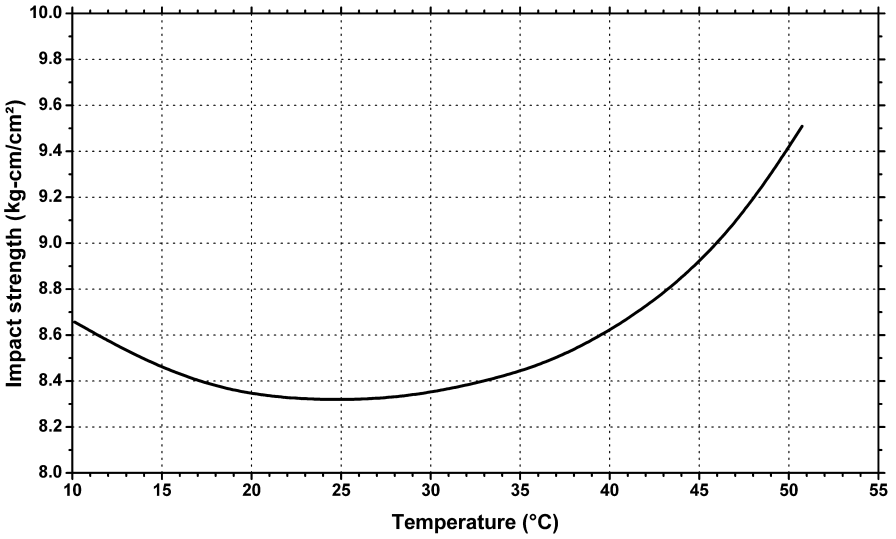

Figure 9.112 Izod impact strength vs. temperature for Daikin Industries Neoflon™ PCTFE resin [14].

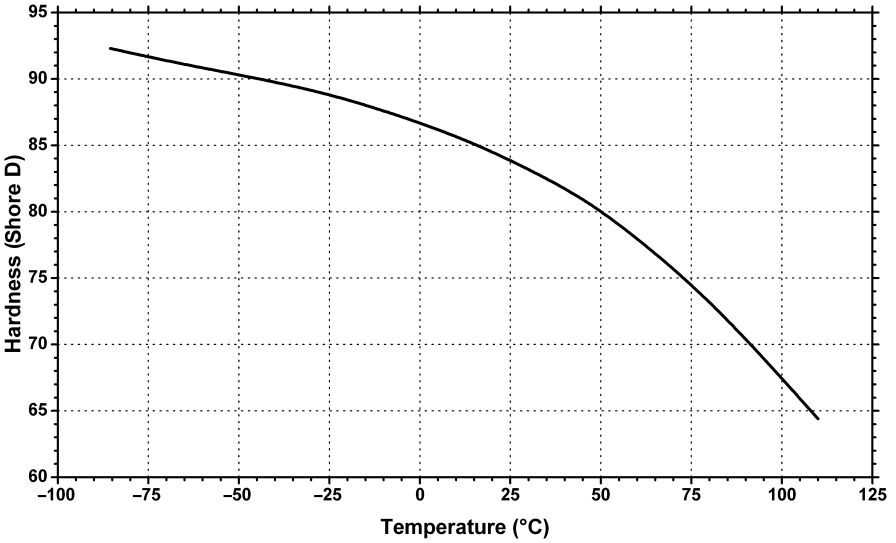

Figure 9.113 Shore D hardness vs. temperature for Daikin Industries Neoflon™ M-300H—general purpose and M-400H—higher molecular weight, increased toughness PCTFE resins [13].

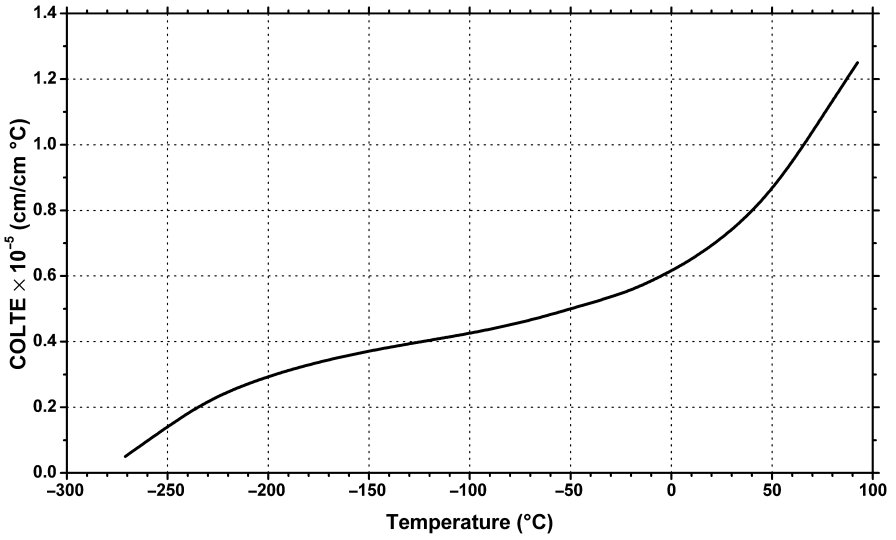

Figure 9.114 Coefficient of linear thermal expansion vs. temperature for Dyneon PCTFE resin.

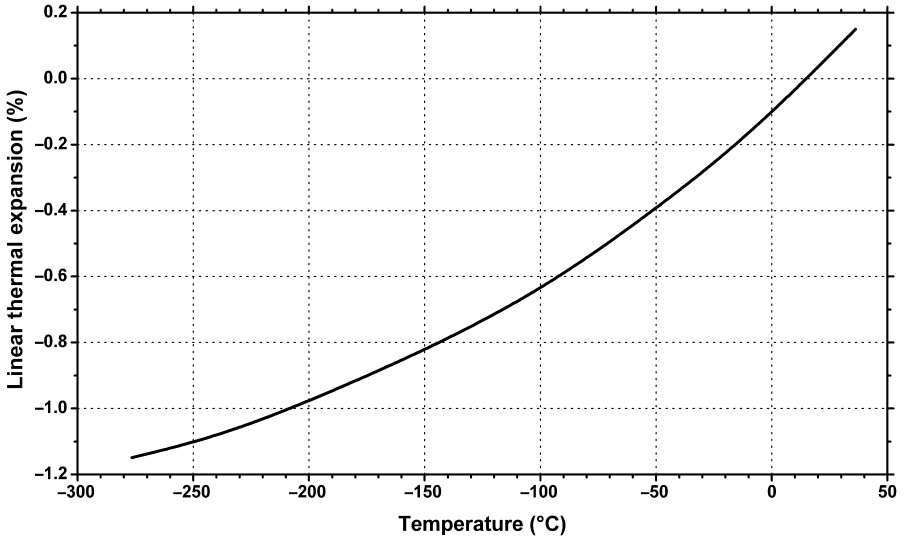

Figure 9.115 Linear thermal expansion vs. temperature for Daikin Industries Neoflon™ PCTFE resin [13].

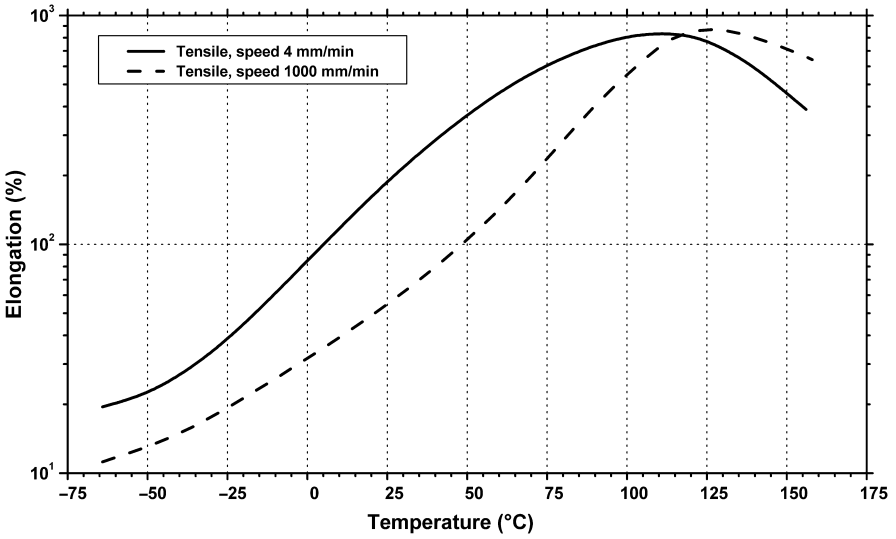

Figure 9.116 Elongation vs. temperature for Daikin Industries Neoflon™ M-300H—general purpose PCTFE resin [13].

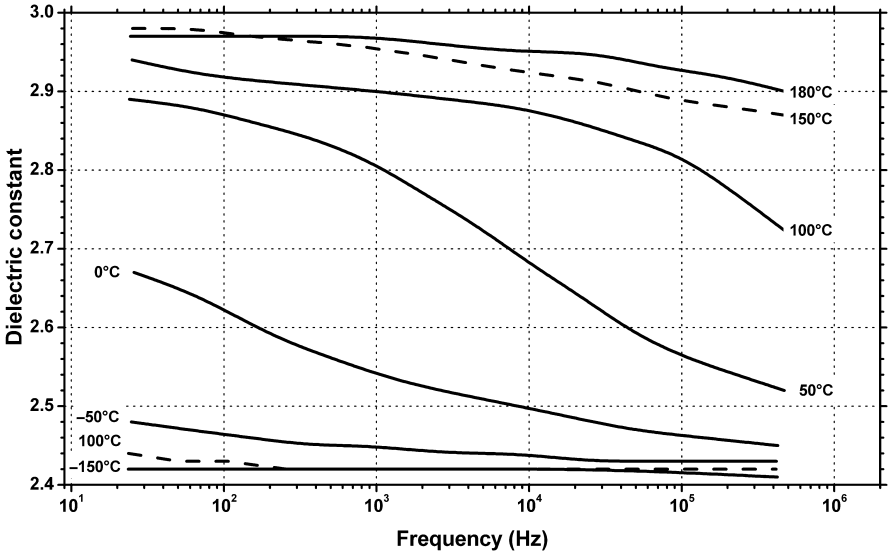

Figure 9.117 Dielectric constant vs. frequency and temperature for Daikin Industries Neoflon™ PCTFE resin [13].

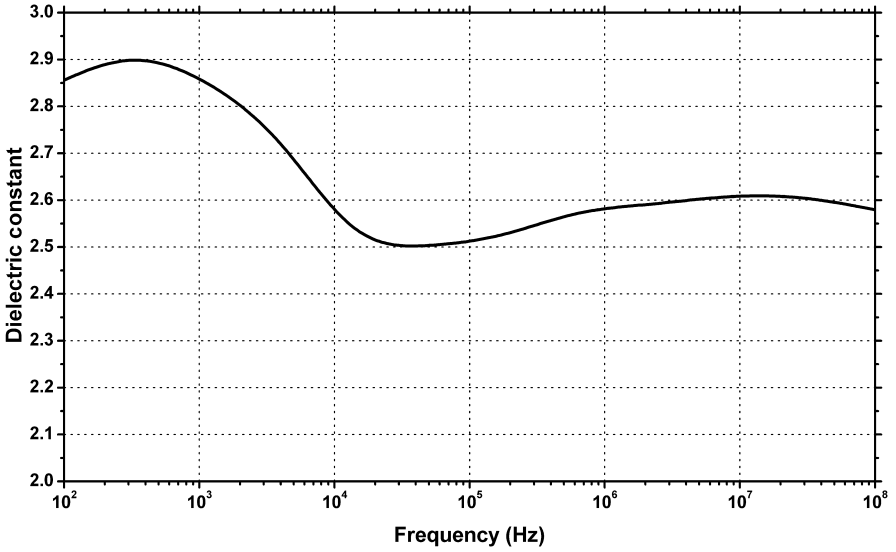

Figure 9.118 Dielectric constant vs. frequency at 25°C for Arkema VOLTALEF® 302 PCTFE resin [15].

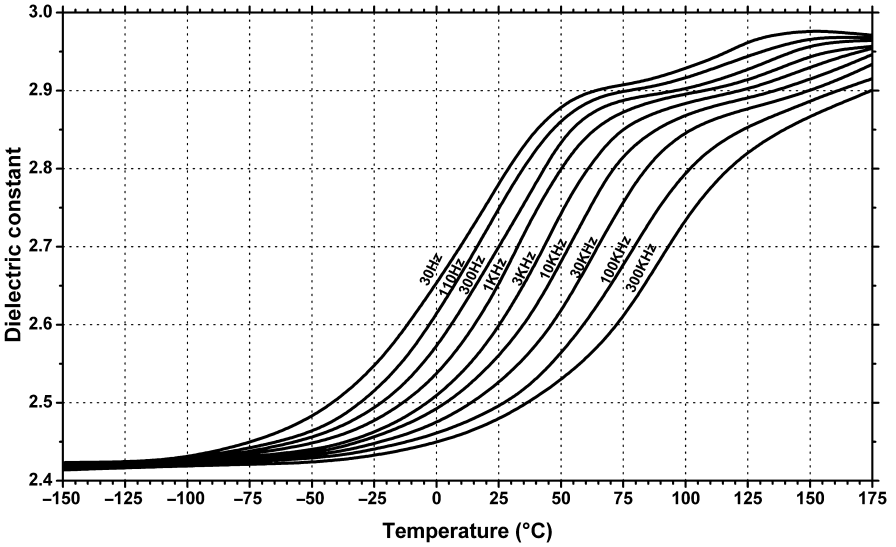

Figure 9.119 Dielectric constant vs. temperature and frequency for Daikin Industries Neoflon™ PCTFE resin [13].

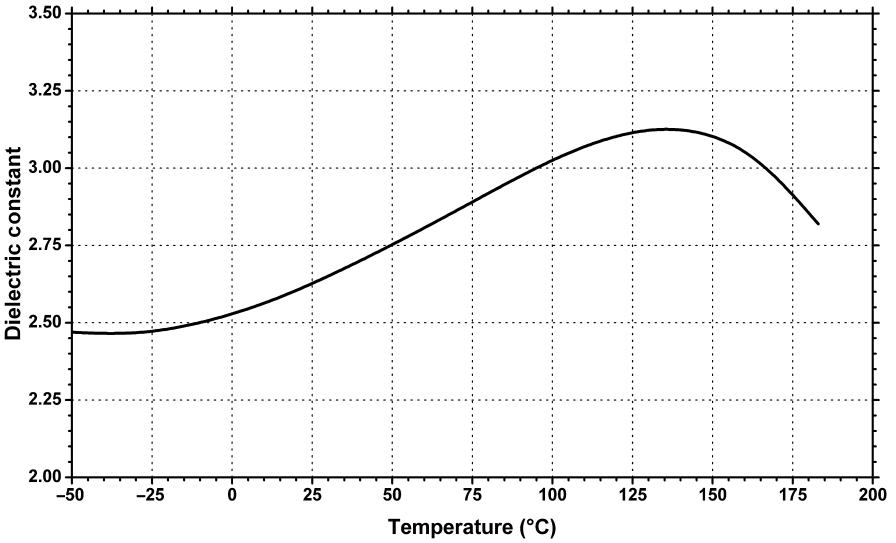

Figure 9.120 Dielectric constant vs. temperature at 25°C for Arkema VOLTALEF® 302 PCTFE resin [15].

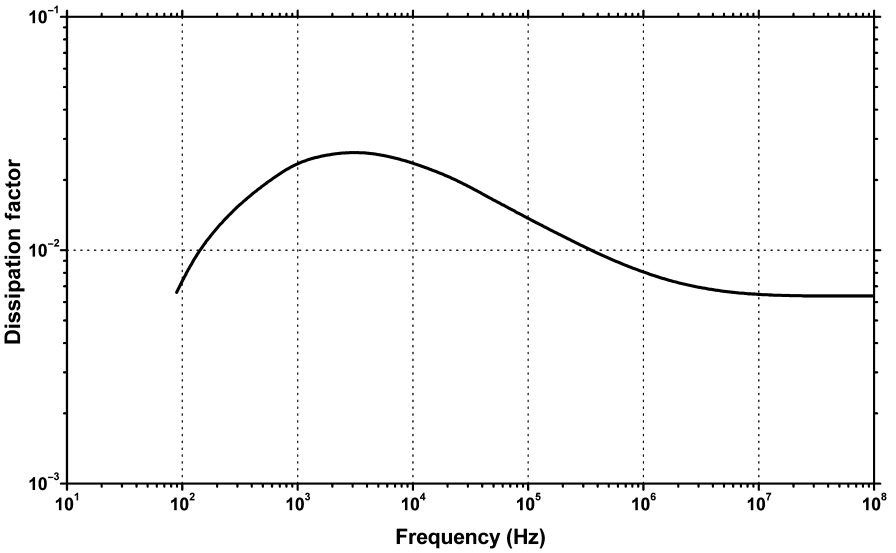

Figure 9.121 Dissipation factor vs. frequency at 25°C for Arkema VOLTALEF® 302 PCTFE resin [15].

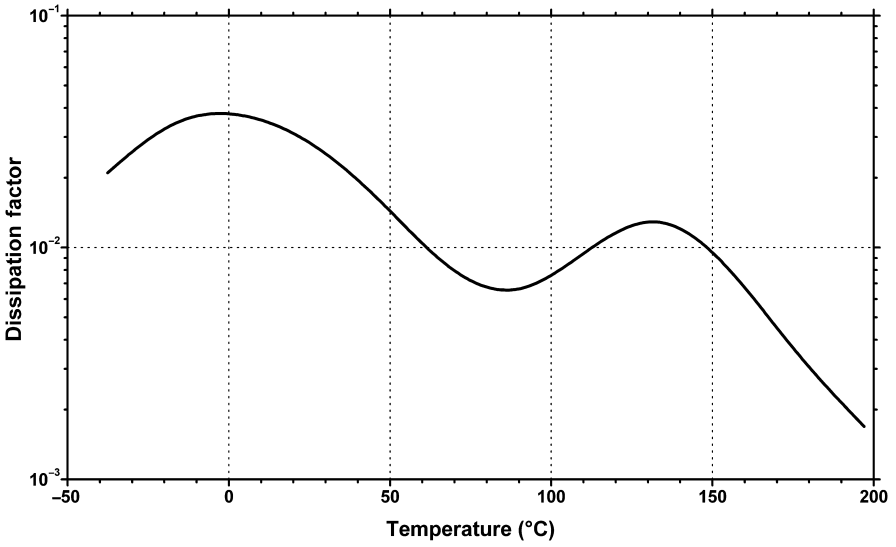

Figure 9.122 Dissipation factor vs. temperature at 60 Hz for Arkema VOLTALEF® 302 PCTFE resin [15].

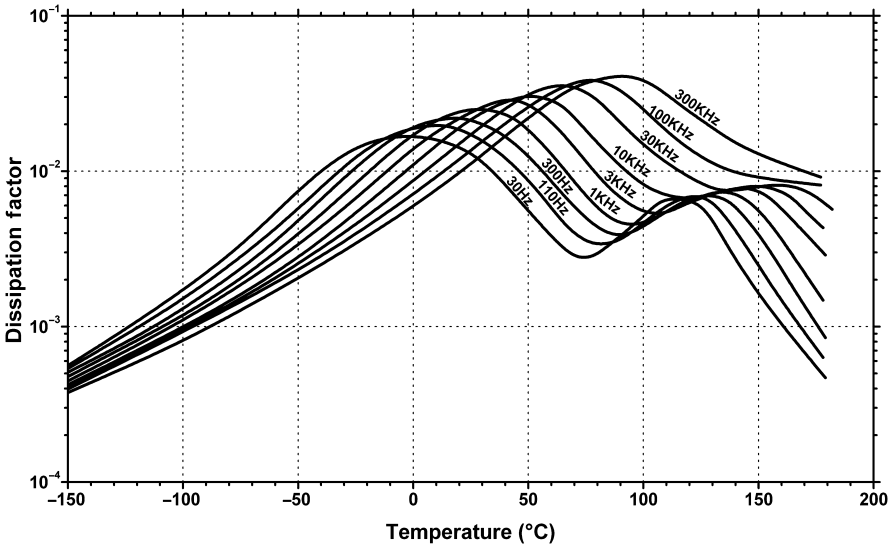

Figure 9.123 Dissipation factor vs. temperature and frequency for Daikin Industries Neoflon™ PCTFE resin [13].

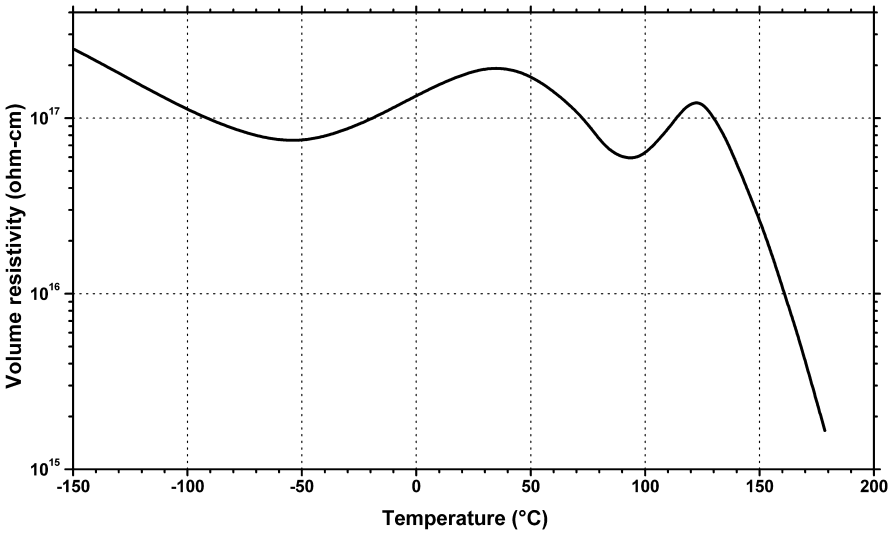

Figure 9.124 Volume resistivity at various temperatures of Daikin Industries Neoflon™ PCTFE resin [13].

making them of particular value for the food industry. PVDF is known for its exceptional chemical stability and excellent resistance to ultraviolet radiation. It is used chiefly in the production and coating of equipment used in aggressive environments, and where high levels of mechanical and thermal resistance are required. It has also been used in architectural applications as a coating on metal siding where it provides exceptional resistance to environmental exposure. The chemical structure of PVDF is shown in Figure 9.125. Its CAS number is 24937-79-9. Some products are copolymers.

The alternating $-CH_2-$and $-CF_2$ groups along the polymer chain provide a unique polarity that influences the polymer's solubility and electric properties. At elevated temperatures PVDF can be dissolved in polar solvents such as organic esters and amines. This selective solubility offers a way to prepare corrosion resistant coatings for chemical process equipment and long-life architectural finishes on building panels.

Key attributes of PVDF include:

- Mechanical strength and toughness
- High abrasion resistance
- High thermal stability
- High dielectric strength
- High purity
- Readily melt processible
- Resistant to most chemicals and solvents
- Resistant to ultraviolet and nuclear radiation
- Resistant to weathering
- Resistant to fungi
- Low permeability to most gases and liquids
- Low flame and smoke characteristics

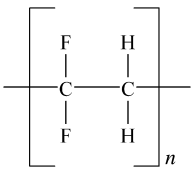

Figure 9.125 Chemical structure of PVDF.

Manufacturers and trade names: Arkema Kynar®, Solvay Solexis Solef® and Hylar®.

Uses and applications: electrical wires, tactile sensor arrays, strain gauges, audio transducers, piezoelectric panels, lithium ion batteries, monofilament fishing line, membranes.

Data for PVDF plastics are found in Figures 9.126–9.152.

9.8 Polyvinyl Fluoride (PVF)

PVF is a homopolymer of vinyl fluoride. The molecular structure of PVF is shown in Figure 9.153.

DuPont™ is the only known manufacturer of this polymer, which they call Tedlar®. The structure is a head-to-tail configuration of the CF monomer; there are no fluorines on adjacent carbons. But in reality vinyl fluoride polymerizes in both head-to-head

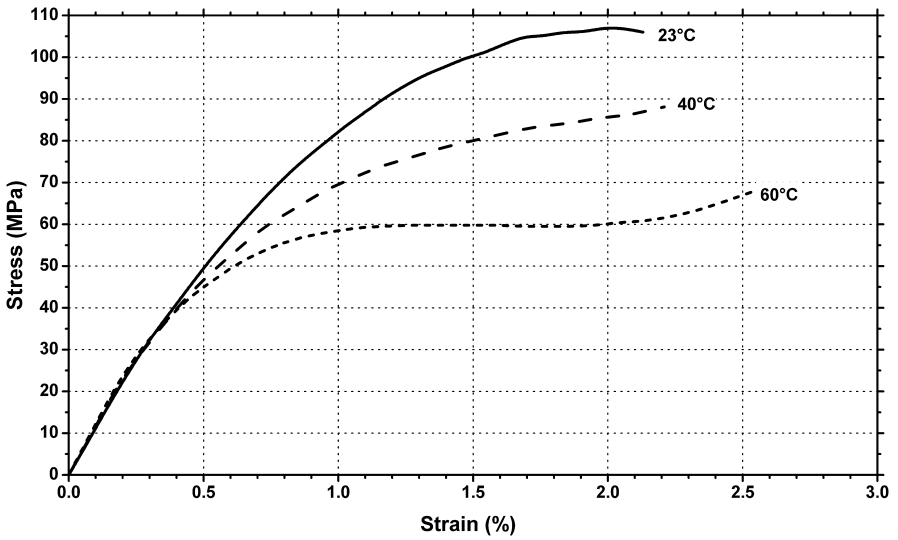

Figure 9.126 Stress vs. strain at various temperatures for SABIC Innovative Plastics Thermocomp™ 5C003—electrically conductive, carbon fiber filled PVDF resin.

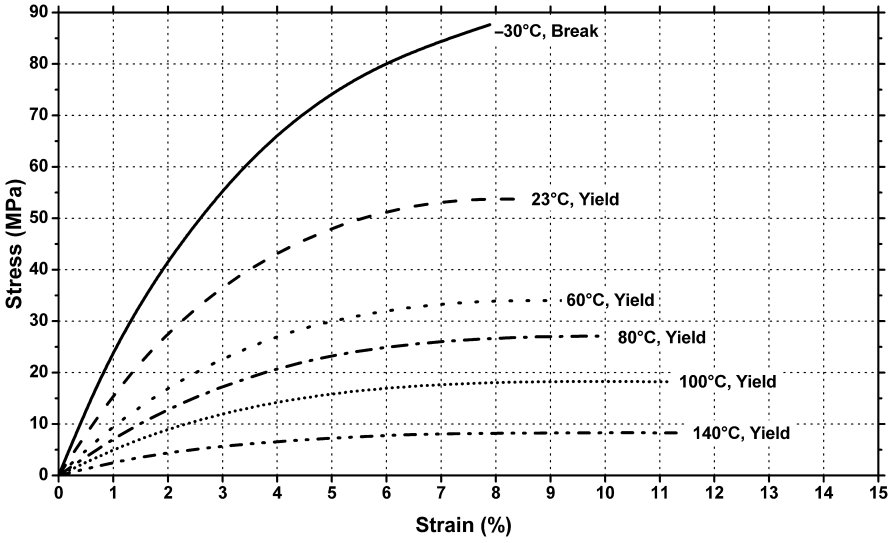

Figure 9.127 Stress vs. strain at various temperatures for Arkema Kynar Flex® 710—homopolymer PVDF resin.

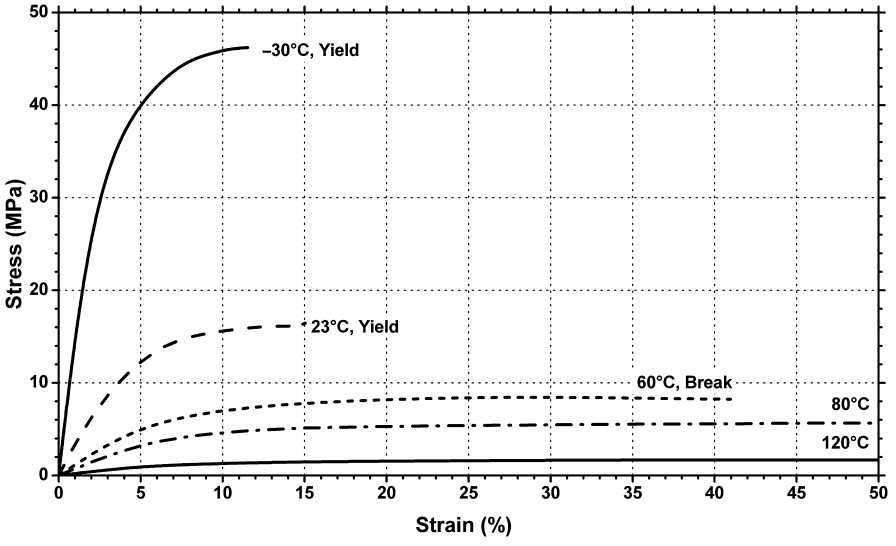

Figure 9.128 Stress vs. strain at various temperatures for Arkema Kynar Flex® 2750—copolymer PVDF resin.

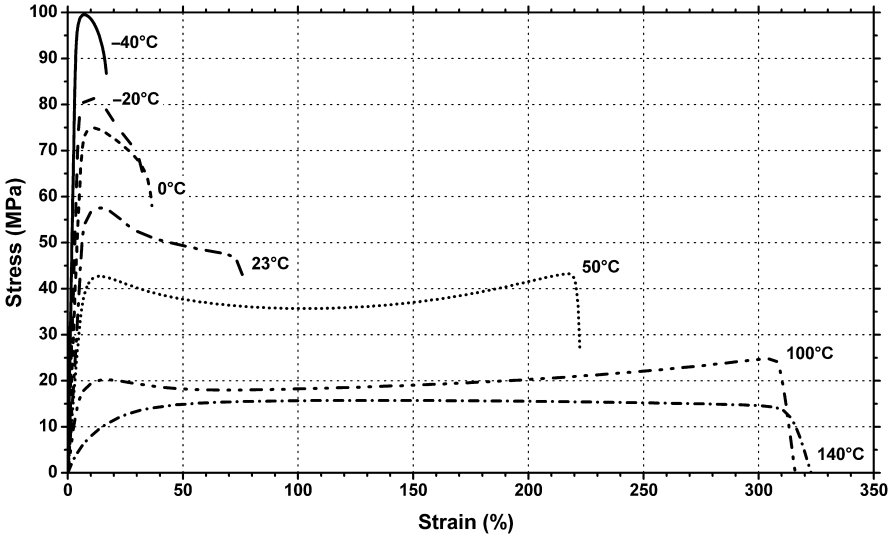

Figure 9.129 Stress vs. strain at various temperatures for Solvay Solexis Solef® 1008—general purpose homopolymer injection molding PVDF resin [16].

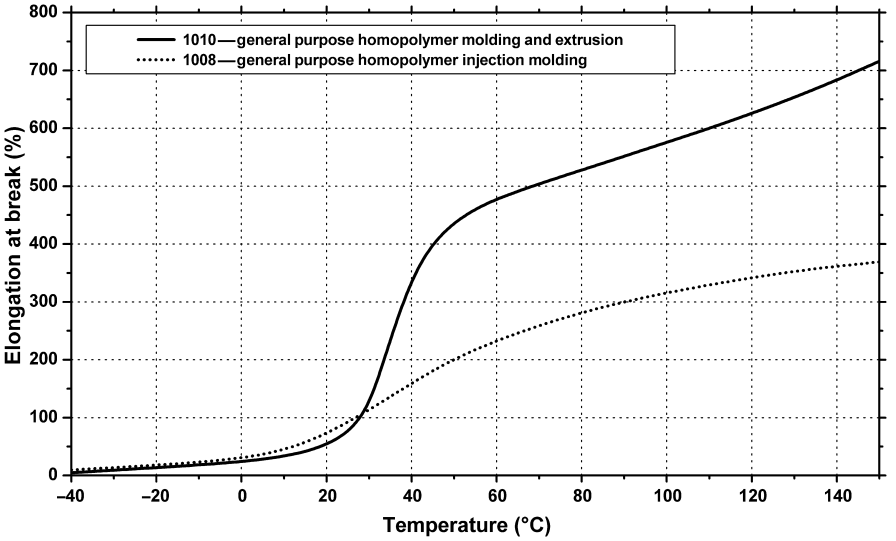

Figure 9.130 Elongation at break vs. temperature for Solvay Solexis Solef® PVDF resins [16].

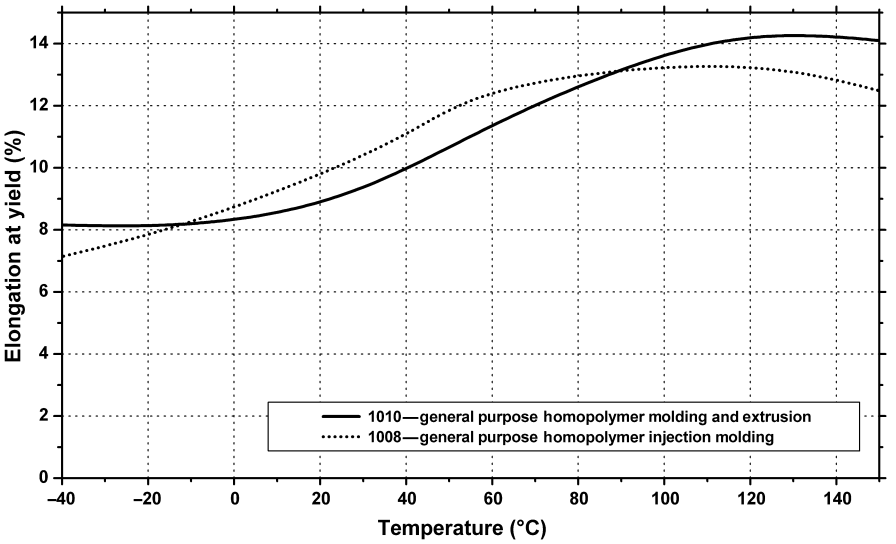

Figure 9.131 Elongation at yield vs. temperature for Solvay Solexis Solef® PVDF resins [16].

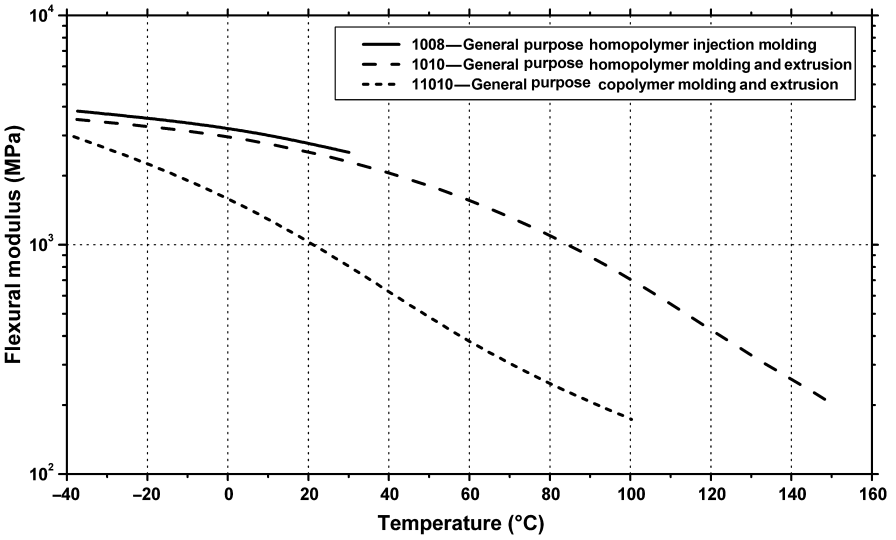

Figure 9.132 Flexural modulus vs. temperature for Solvay Solexis Solef® PVDF resins [16].

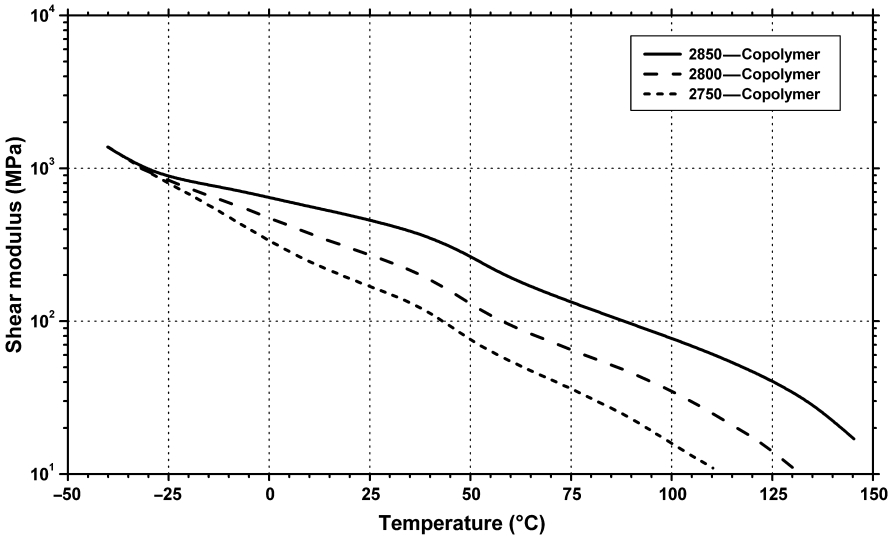

Figure 9.133 Shear modulus vs. temperature for Arkema Kynar Flex® copolymer PVDF resins.

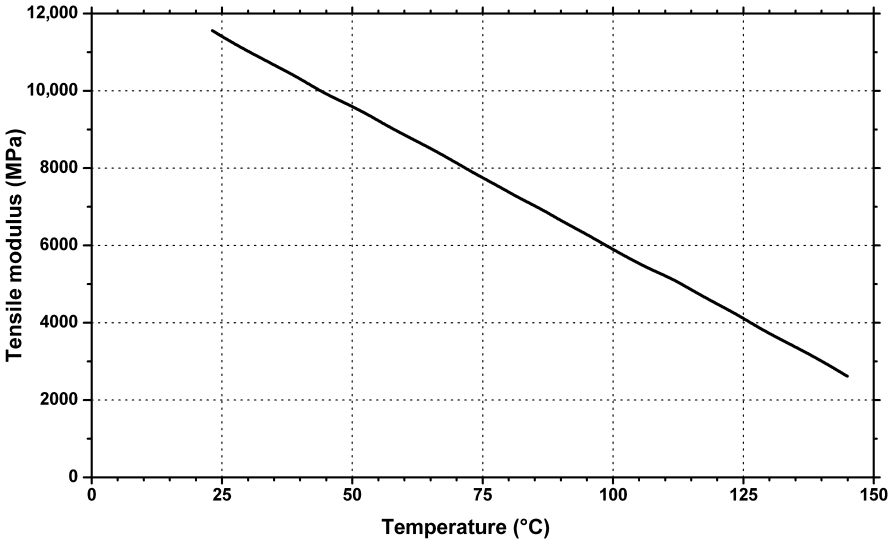

Figure 9.134 Tensile modulus vs. temperature for SABIC Innovative Plastics Thermocomp™ 5C003—electrically conductive, carbon fiber filled PVDF resin.

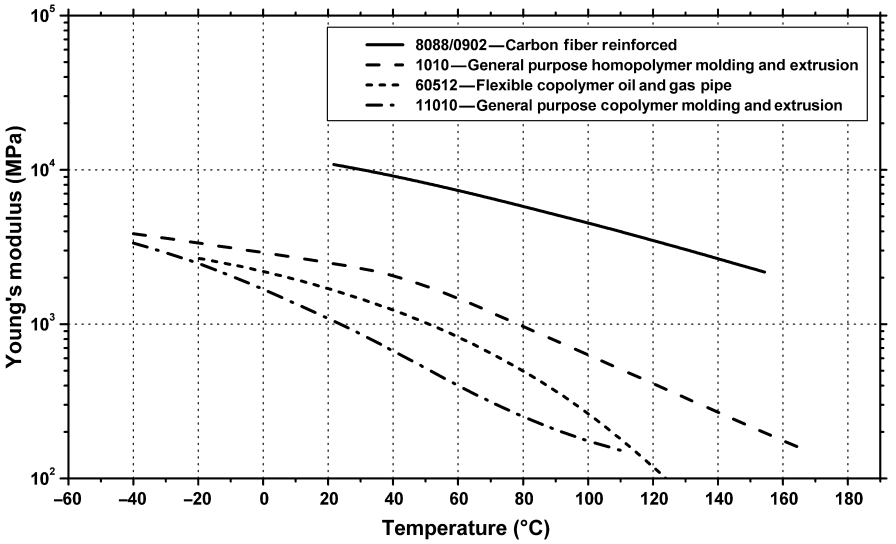

Figure 9.135 Young's modulus vs. temperature for Solvay Solexis Solef® PVDF resins [16].

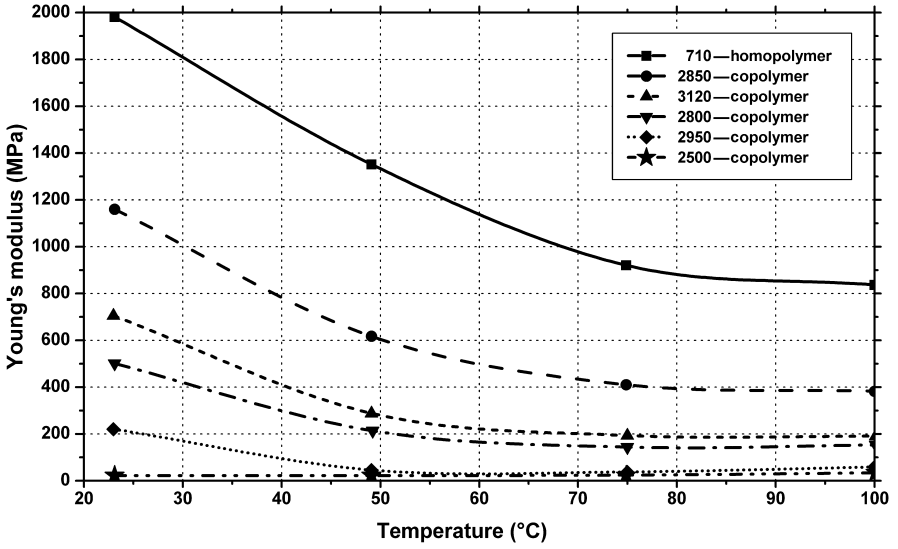

Figure 9.136 Young's modulus vs. temperature for Arkema Kynar Flex®—PVDF resins.

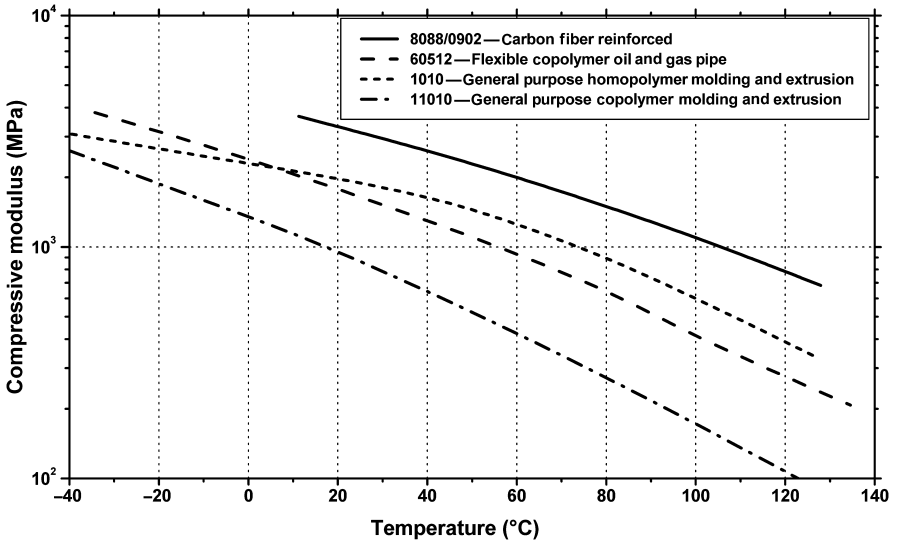

Figure 9.137 Compressive modulus vs. temperature for Solvay Solexis Solef® PVDF resins [16].

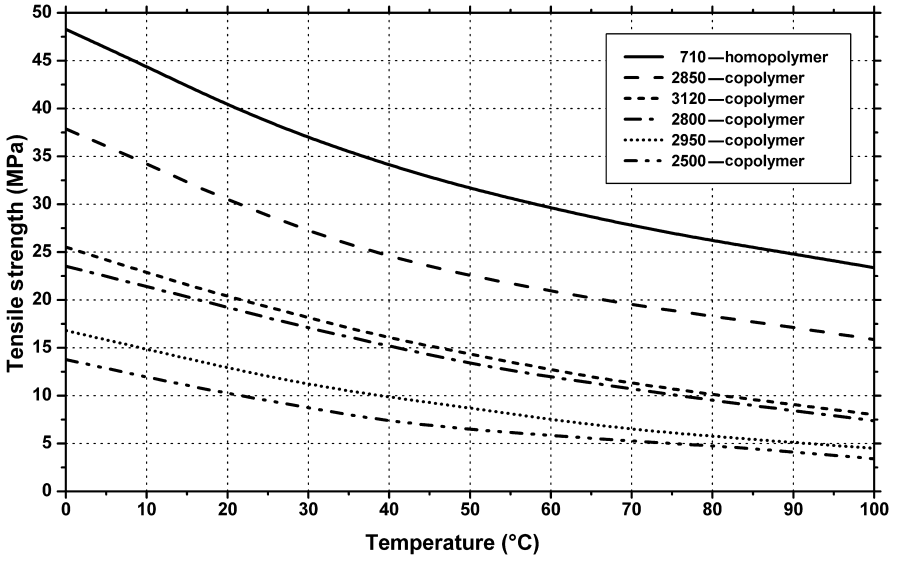

Figure 9.138 Tensile strength vs. temperature for Arkema Kynar Flex®—PVDF resins.

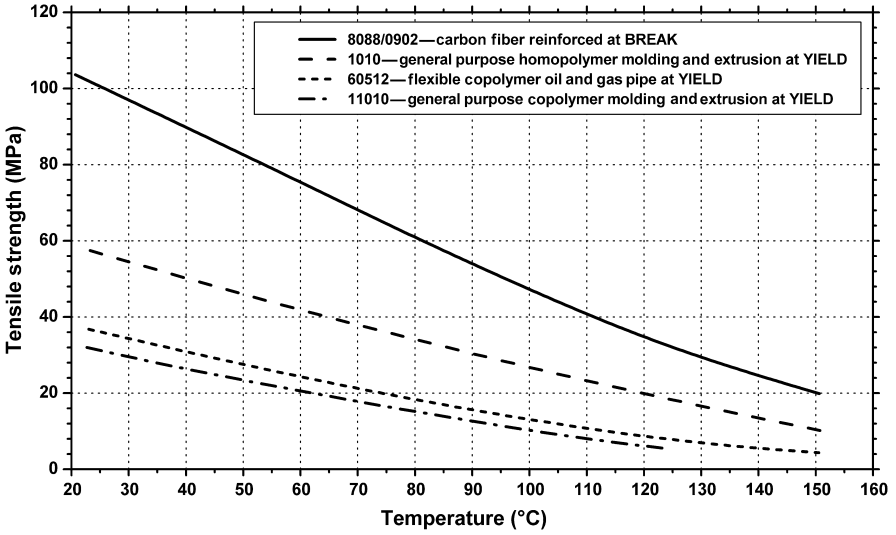

Figure 9.139 Tensile strength vs. temperature for Solvay Solexis Solef® PVDF resins [16].

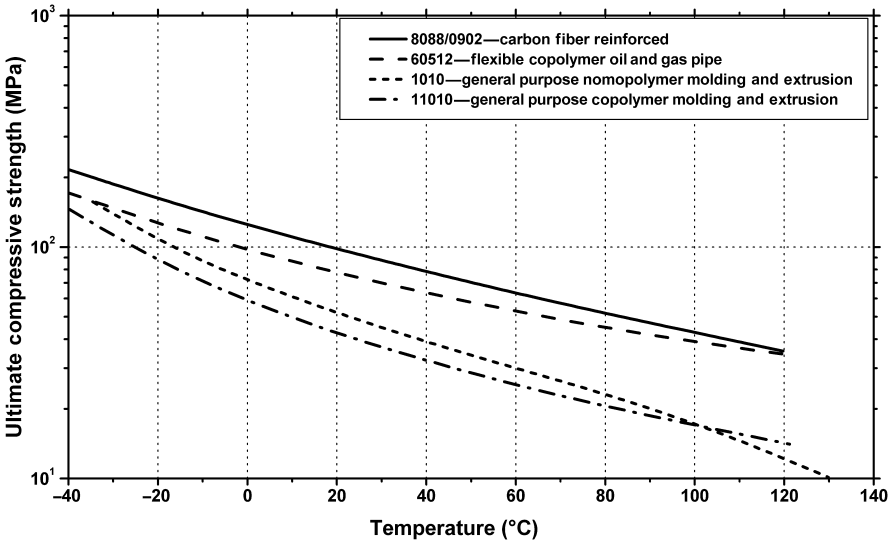

Figure 9.140 Ultimate compressive strength vs. temperature for Solvay Solexis Solef® PVDF resins [16].

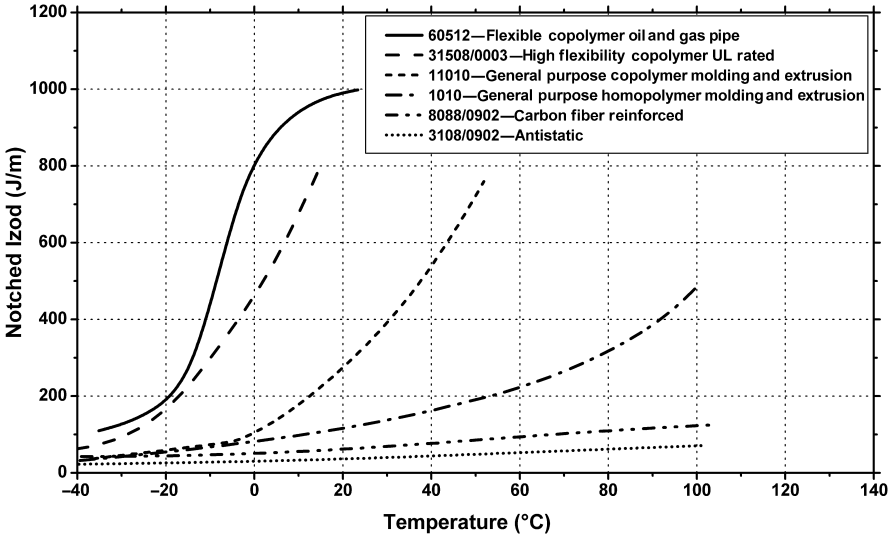

Figure 9.141 Notched Izod impact strength vs. temperature for Solvay Solexis Solef® PVDF resins [16].

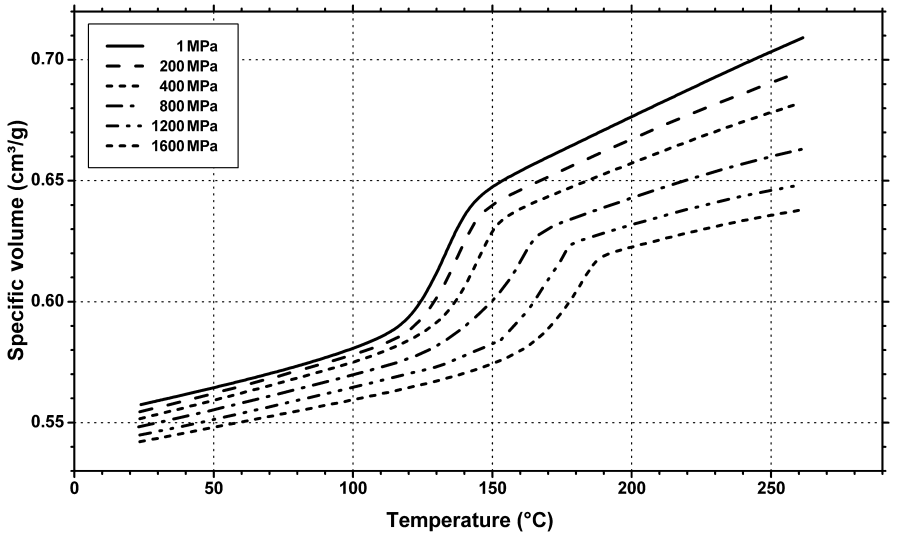

Figure 9.142 Pressure–volume–temperature (PVT) plot for Solvay Solexis Solef® 1008—general purpose homopolymer injection molding PVDF resin [16].

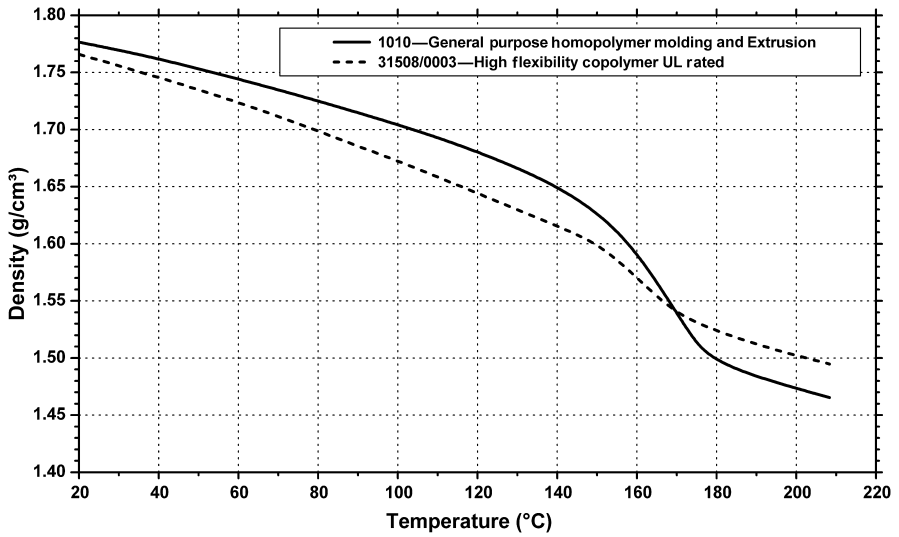

Figure 9.143 Density vs. temperature for Solvay Solexis Solef® PVDF resins [16].

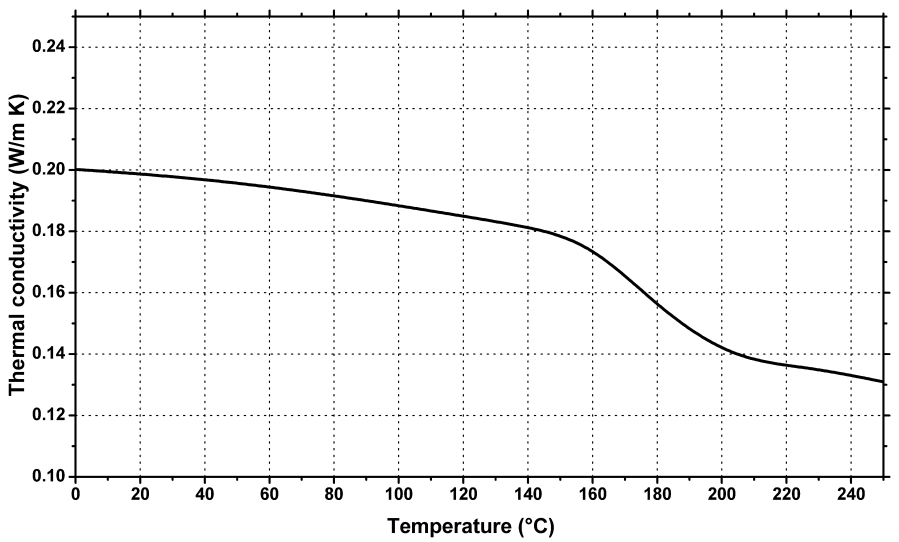

Figure 9.144 Thermal conductivity vs. temperature for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin [16].

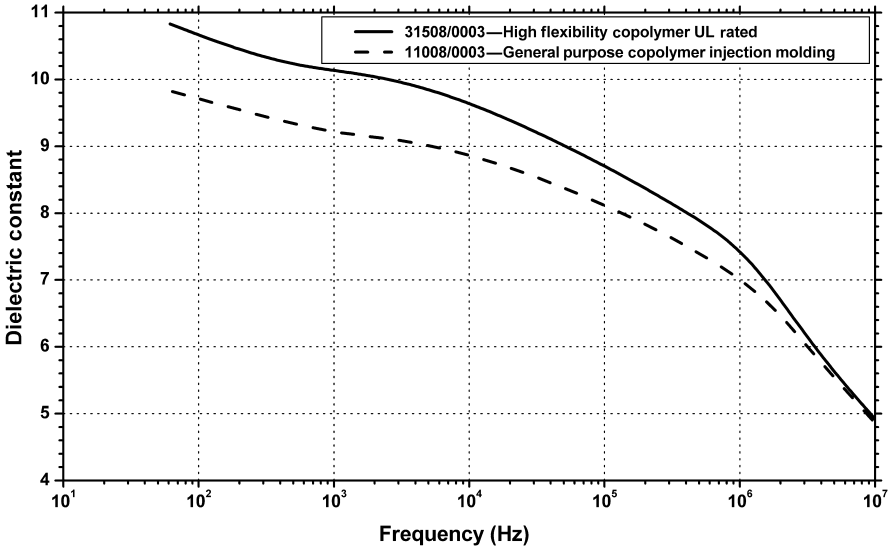

Figure 9.145 Dielectric constant vs. frequency for Solvay Solexis Solef® PVDF resins [16].

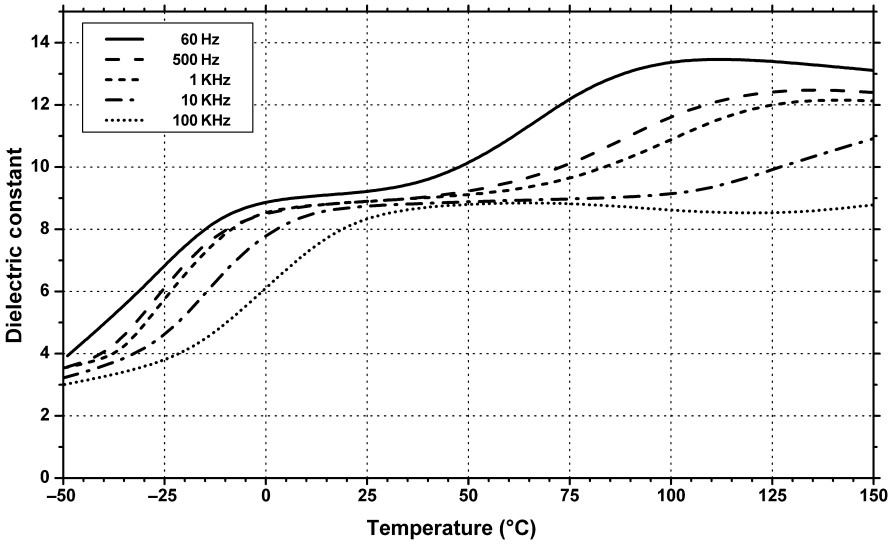

Figure 9.146 Dielectric constant vs. temperature and frequency for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin [16].

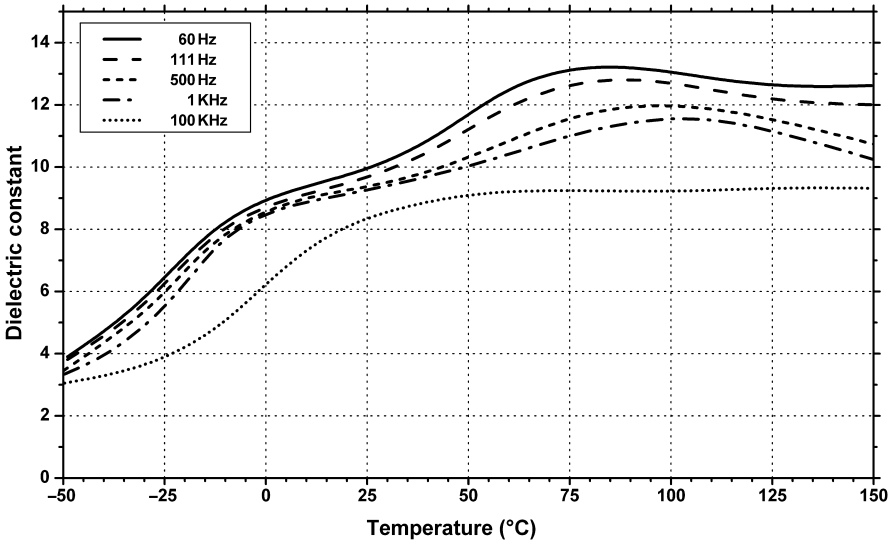

Figure 9.147 Dielectric constant vs. temperature and frequency for Solvay Solexis Solef® 11008—general purpose copolymer injection molding PVDF resin [16].

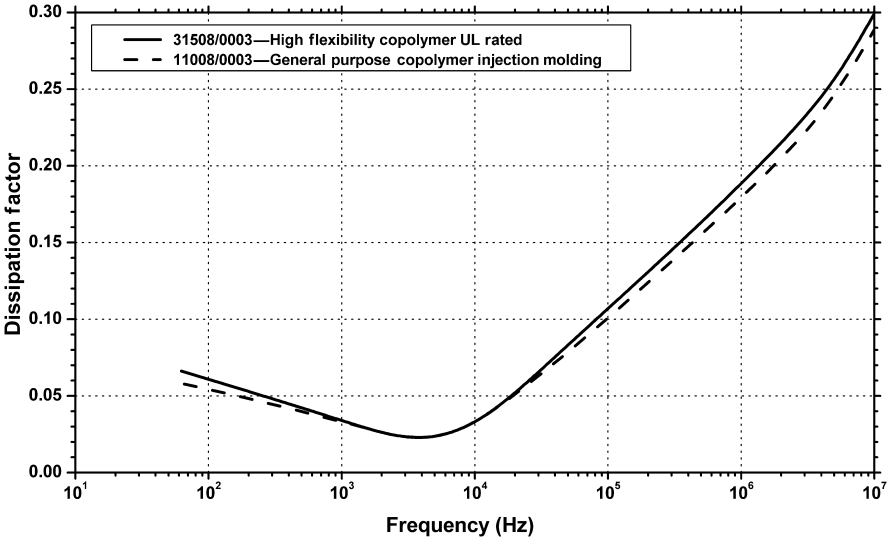

Figure 9.148 Dissipation factor vs. frequency for Solvay Solexis Solef® PVDF resins [16].

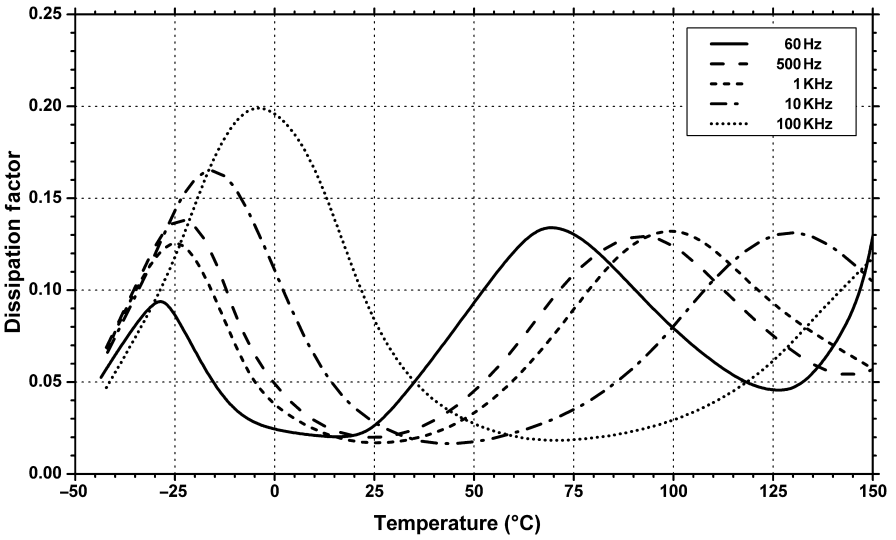

Figure 9.149 Dissipation factor vs. temperature and frequency for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin [16].

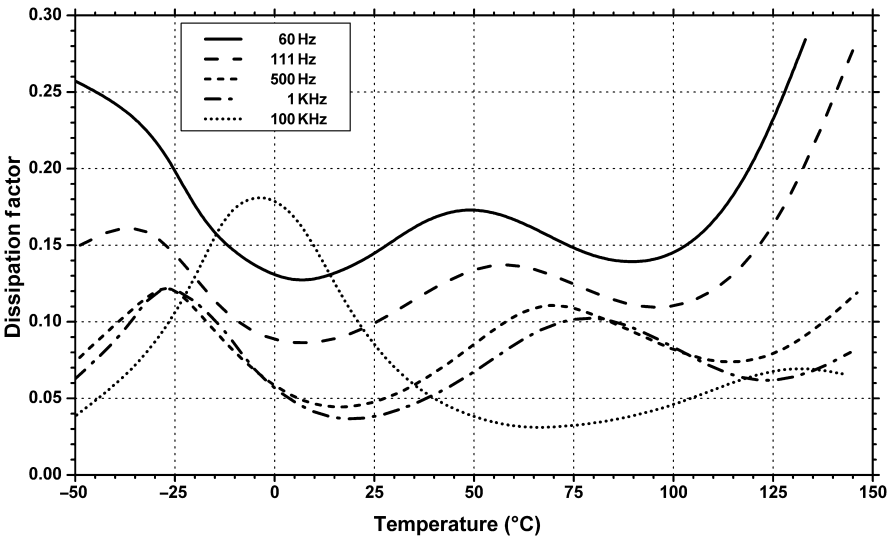

Figure 9.150 Dissipation factor vs. temperature and frequency for Solvay Solexis Solef® 11008—general purpose copolymer injection molding PVDF resin [16].

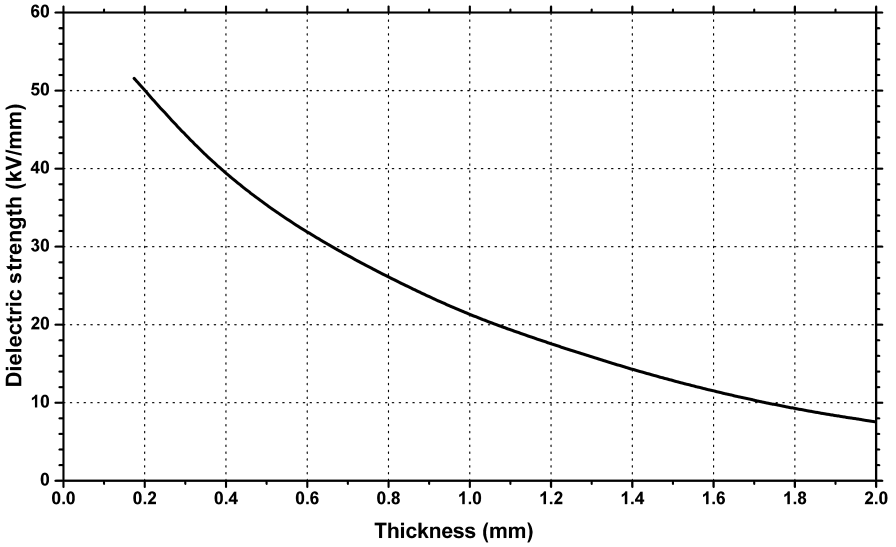

Figure 9.151 Dielectric strength vs. thickness for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin [16].

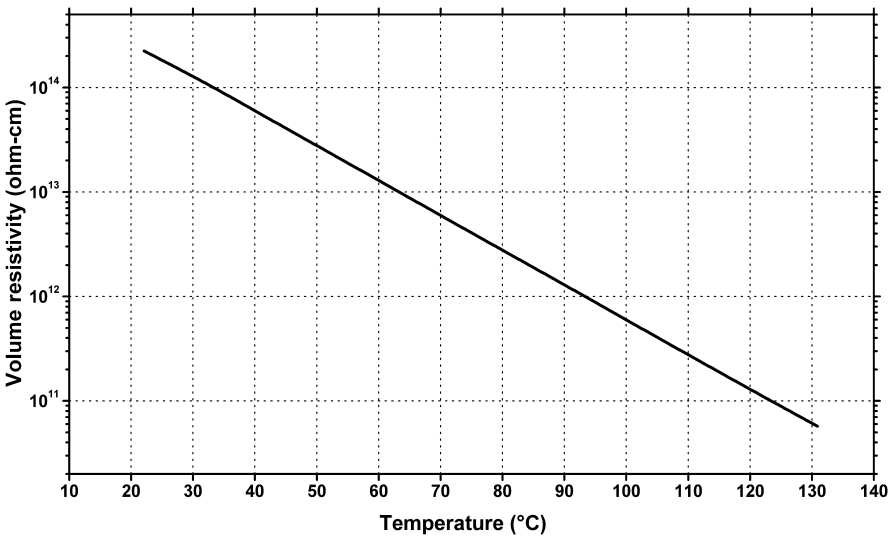

Figure 9.152 Volume resistivity vs. temperature for Solvay Solexis Solef® PVDF resin.

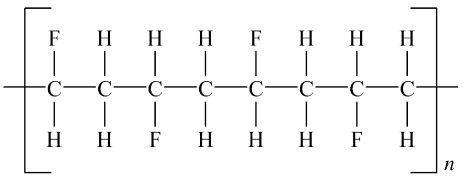

Figure 9.153 Structure of PVF.

and head-to-tail configurations. DuPont's commercial PVF contains 10–12% of head-to-head and tail-to-tail units, also called *inversions* [17]. Its CAS number is 24981-14-4.

PVF has excellent resistance to weathering, staining, and chemical attack (except ketones and esters). It exhibits very slow burning and low permeability to vapor. Its most visible use in on the interiors of the passenger compartments of commercial aircraft.

General description: PVF is available only in film form. DuPont Tedlar® films are available in clear, translucent, or opaque white film and in several surface finishes.

Manufacturers and trade names: DuPont Tedlar®.

Applications and uses: Release: the outstanding mechanical properties, inertness to a variety of chemicals and solvents and antistick properties make Tedlar® an excellent release film for epoxy, phenolic, polyester, and rubber compounds. Building: abrasion resistance and atmospheric agents' properties, together with colors durability, make the use of Tedlar® ideal as surface of panels in building.

Transportation: Tedlar® film is suitable for fiberglass truck bodies (high salts resistance) and for aircraft interiors. Others: production of labels and electrical insulation. Moreover, Tedlar® laminated with other films, like polyester, PVF, etc., becomes an ideal product for the realization of solar cells, decorative panels and road signs.

Data for PVF plastics are found in Figures 9.154–9.169.

Product coding logical for DuPont Tedlar® PVF film products is given in Table 9.5.

9.9 Amorphous Fluoropolymer: Teflon® AF

A perfluorinated polymer made by DuPont called Teflon® AF breaks down the crystallinity completely, hence its designation amorphous fluoropolymer (AF). It is a copolymer made from 2,2-bistrifluoromethyl-4,5-difluoro-1,3-dioxole (PDD) and TFE. The structure of Teflon® AF is shown in Figure 9.170.

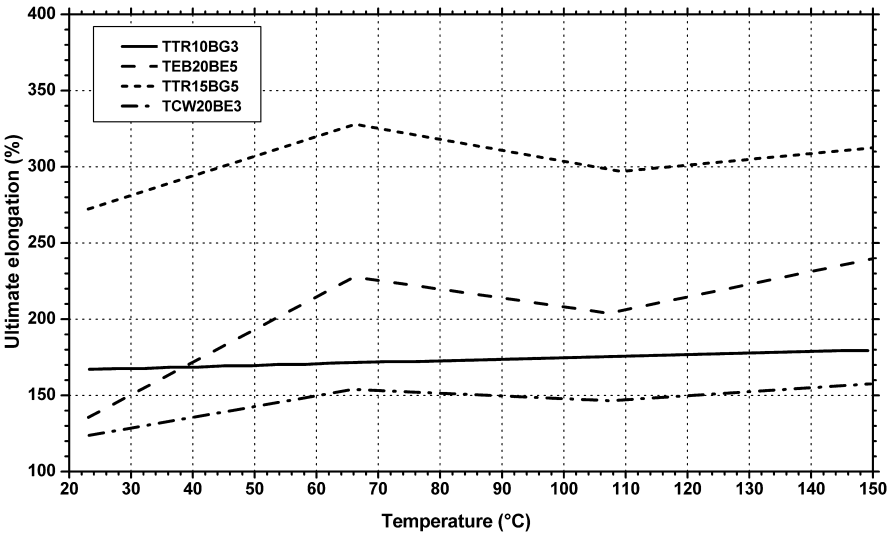

Figure 9.154 Ultimate elongation vs. temperature for several DuPont Tedlar® Type 3 and Type 5 PVF films [18].

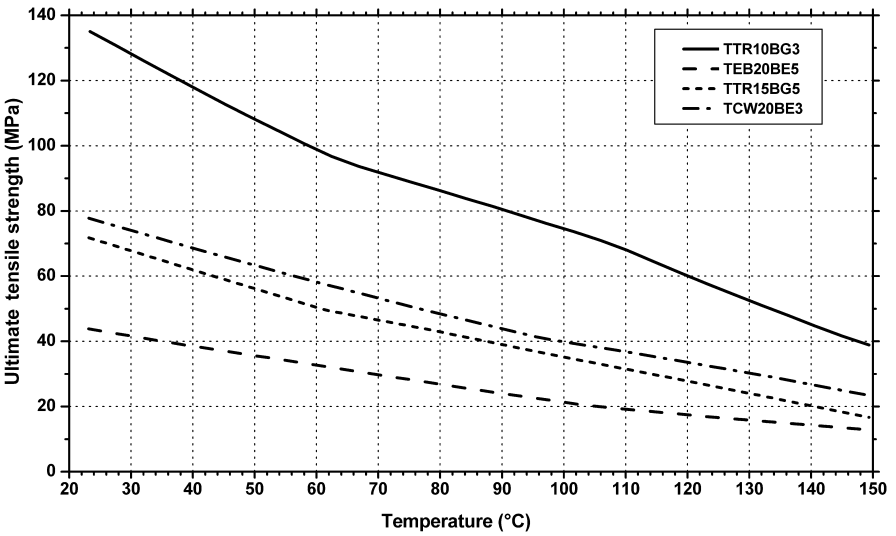

Figure 9.155 Ultimate tensile strength vs. temperature for several DuPont Tedlar® Type 3 and Type 5 PVF films [18].

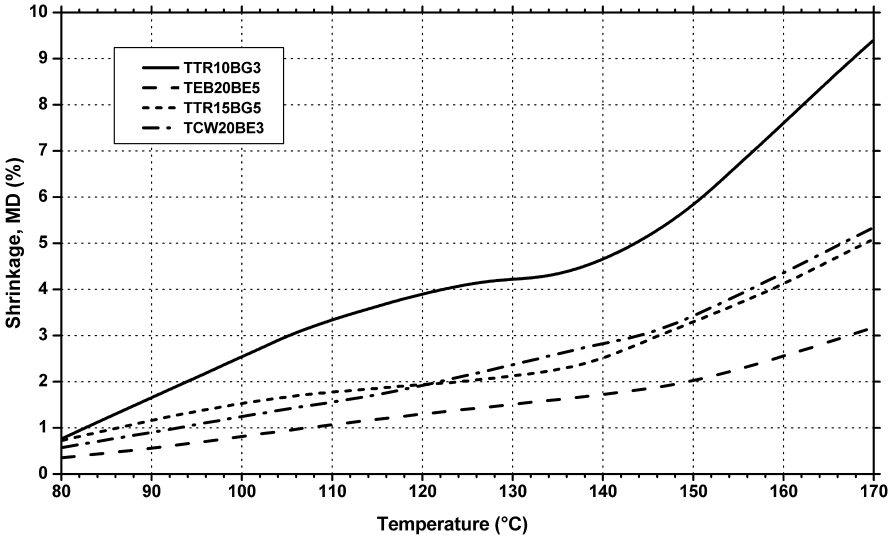

Figure 9.156 Machine direction shrinkage vs. temperature for several DuPont Tedlar® Type 3 and Type 5 PVF films [18].

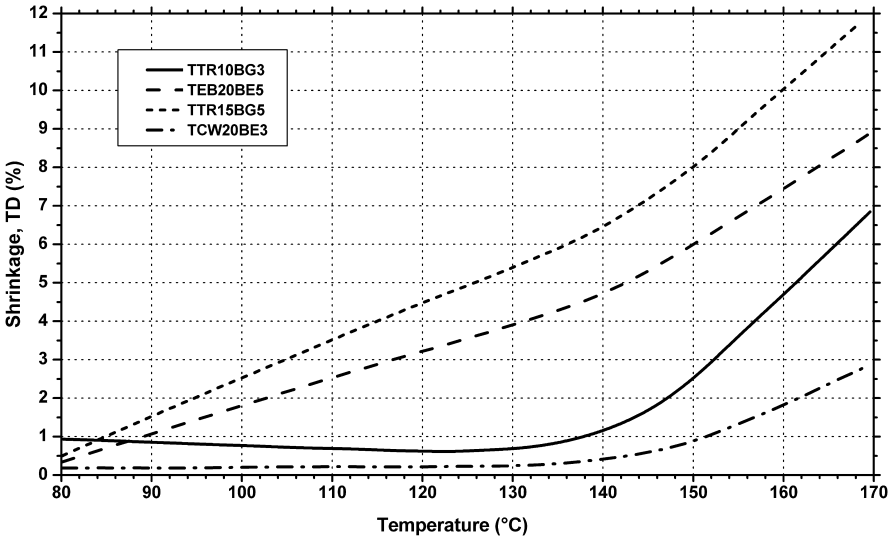

Figure 9.157 Transverse direction shrinkage vs. temperature for several DuPont Tedlar® Type 3 and Type 5 PVF films [18].

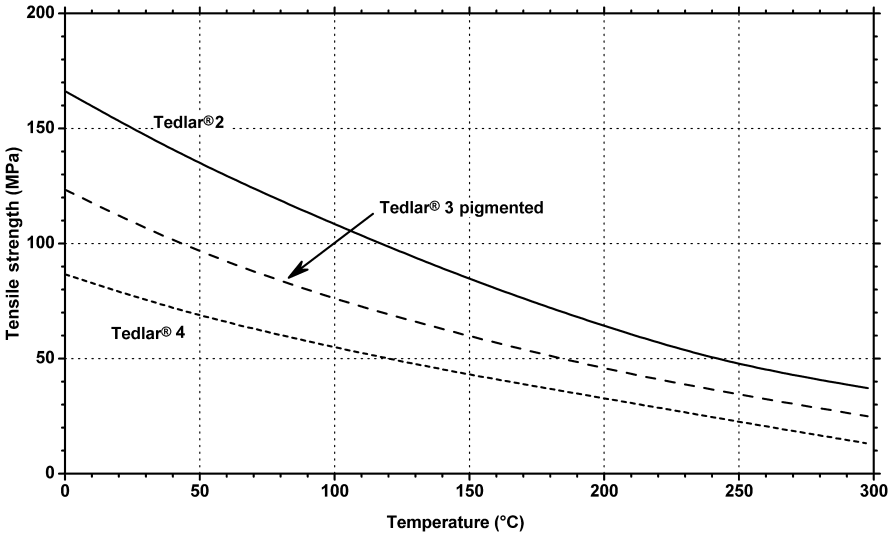

Figure 9.158 Tensile strength vs. temperature for several DuPont Tedlar® PVF films [18].

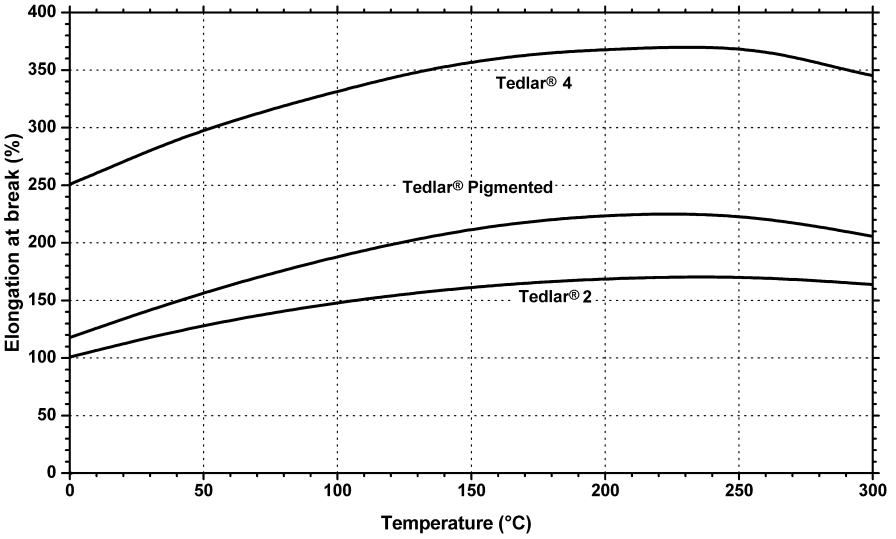

Figure 9.159 Elongation at break vs. temperature for several DuPont Tedlar® PVF films [18].

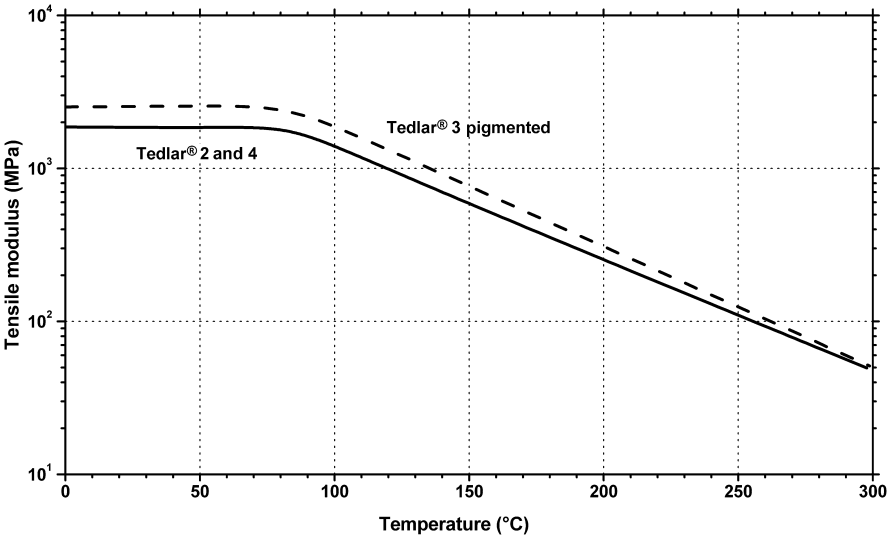

Figure 9.160 Tensile modulus vs. temperature for several DuPont Tedlar® PVF films [18].

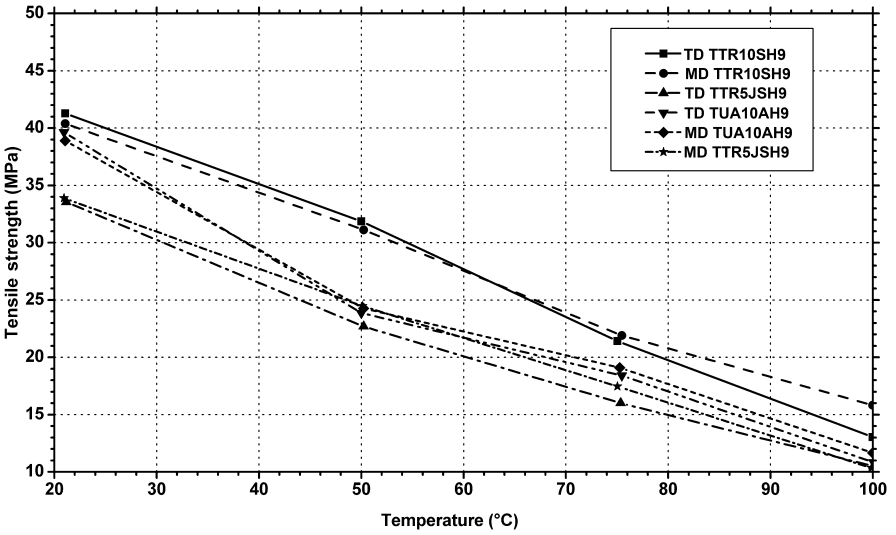

Figure 9.161 Tensile strength vs. temperature for several DuPont Tedlar® SP Clear PVF films [19].

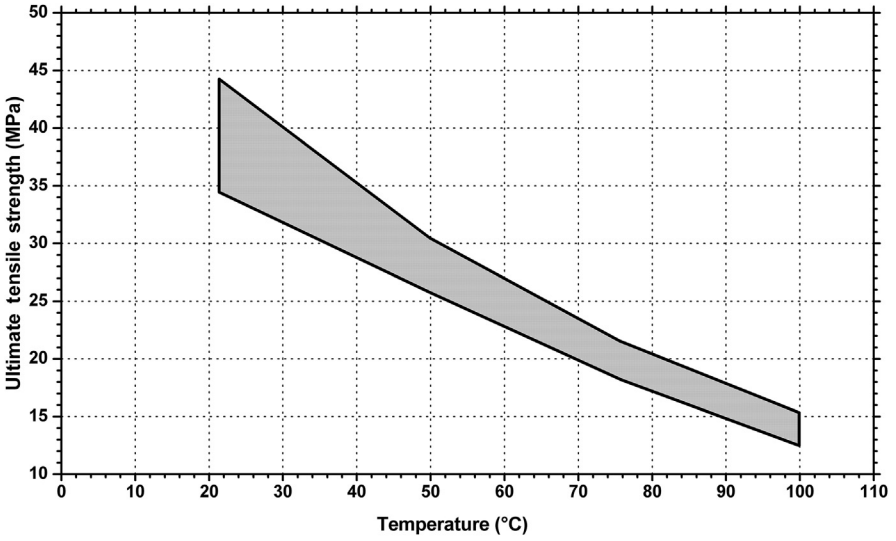

Figure 9.162 Ultimate tensile strength range vs. temperature for DuPont Tedlar® SP colored PVF films [19].

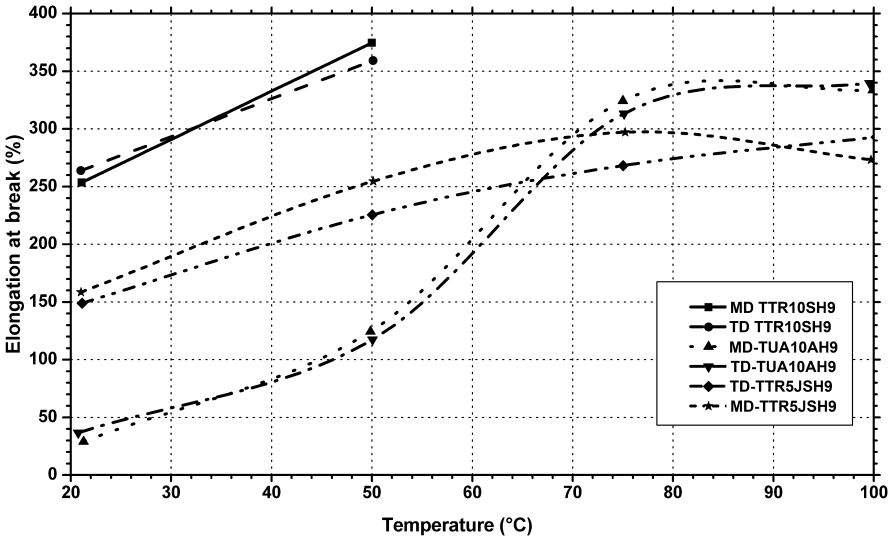

Figure 9.163 Elongation at break vs. temperature for several DuPont Tedlar® SP clear PVF films [19].

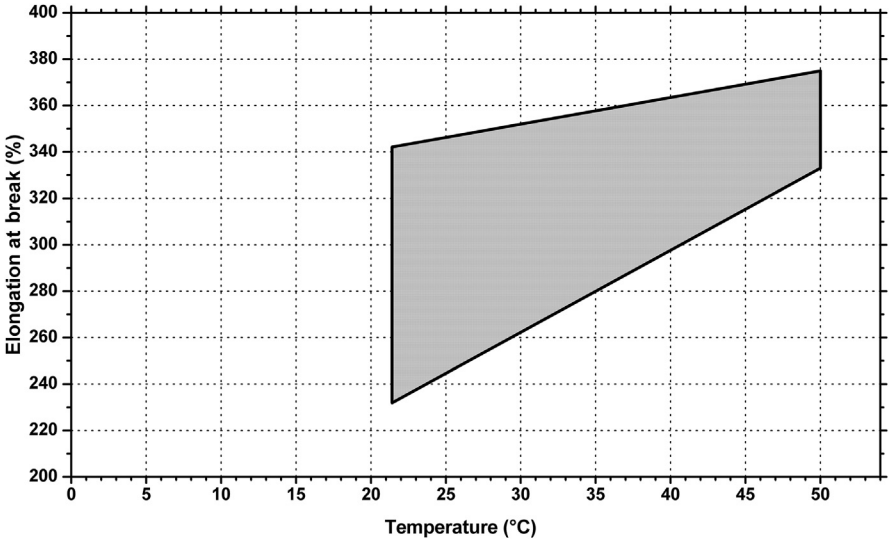

Figure 9.164 Elongation at break range vs. temperature for DuPont Tedlar® SP colored PVF films [19].

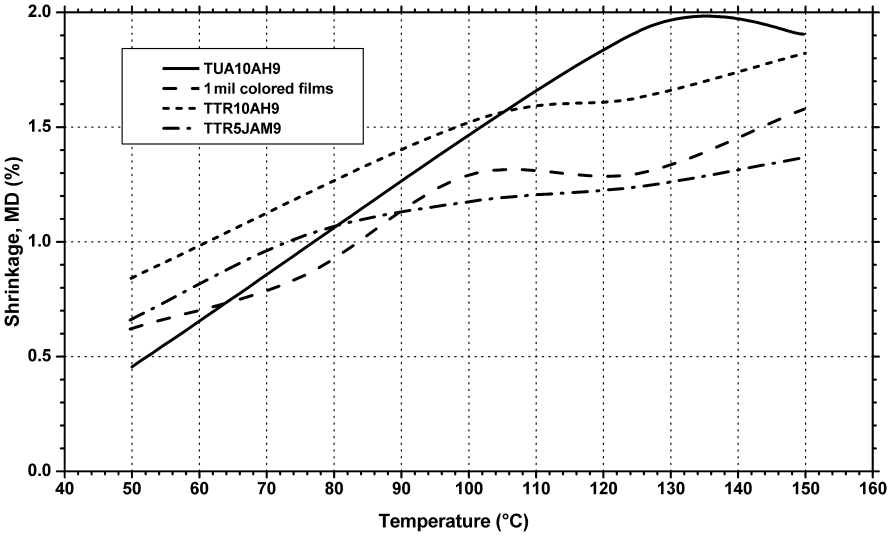

Figure 9.165 Film shrinkage vs. temperature for several DuPont Tedlar® SP PVF films [19].

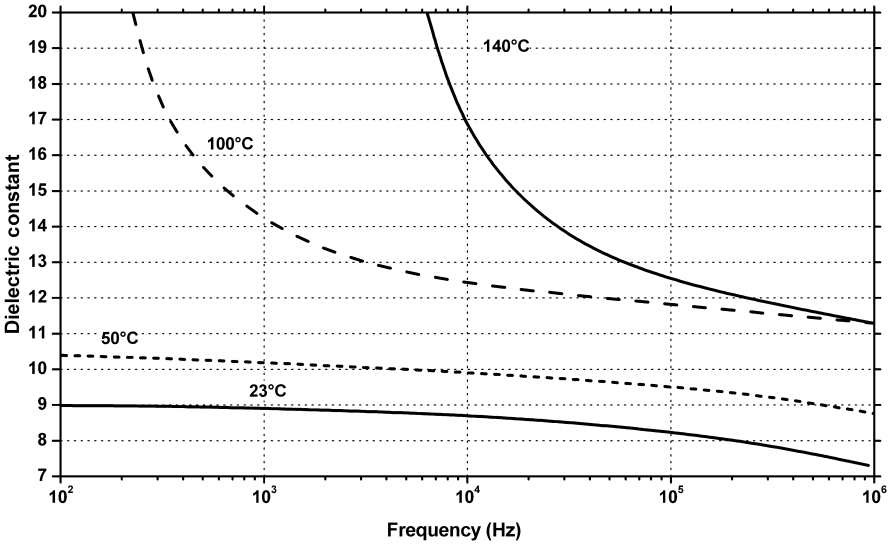

Figure 9.166 Dielectric constant vs. frequency at various temperatures of DuPont Tedlar® TST20BG4 PVF film [20].

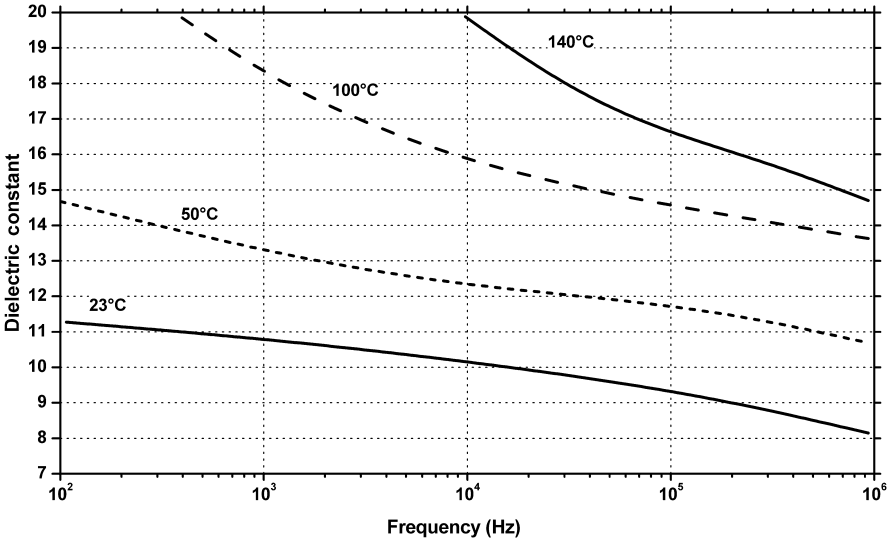

Figure 9.167 Dielectric constant vs. frequency at various temperatures of DuPont Tedlar® TWH20BS3 PVF film [20].

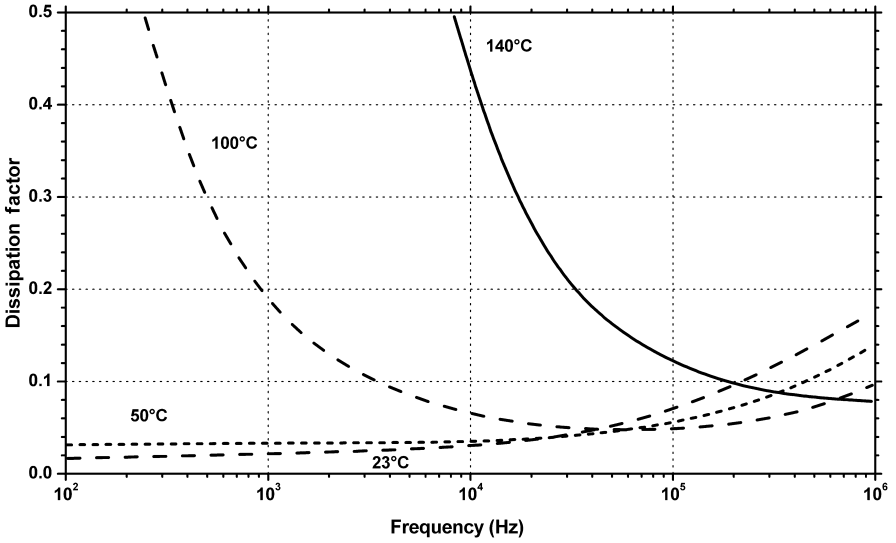

Figure 9.168 Dissipation factor vs. frequency at various temperatures of DuPont Tedlar® TST20BG4 PVF film [20].

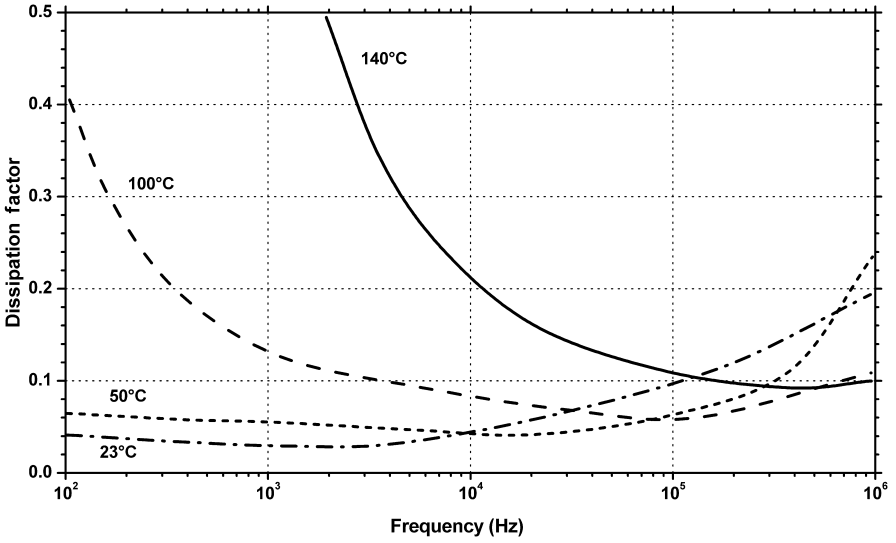

Figure 9.169 Dissipation factor vs. frequency at various temperatures of DuPont Tedlar® TWH20BS3 PVF film [20].

The Teflon® AF family of AFs is similar to Teflon® PTFE and PFA in many of the usual properties but is unique in the following ways. It:

1. Is a true AF
2. Has a somewhat higher coefficient of friction than Teflon® PTFE and PFA
3. Has excellent mechanical and physical properties at end-use temperature up to 300°C (572°F)
4. Has excellent light transmission from ultraviolet (UV) through a good portion of infrared (IR)
5. Has a very low refractive index
6. Has the lowest dielectric constant of any plastic even at gigahertz frequencies
7. Is soluble to a limited extent in selected perfluorinated solvents

Teflon® AF can be designed to have some solubility in selected perfluorinated solvents but remains chemically resistant to all other solvents and process chemicals. The solubility is typically only 3–15% by weight, but this allows solution-cast extremely thin coatings in the submicron thickness range.

Manufacturers and trade names: DuPont Teflon® AF.

Table 9.5 Product Code Decoding for DuPont Tedlar® PVF Film Products Example: TTR10SG3

T	TR	10	S	G	3
Tedlar® Symbol	**Color and/or Optical Properties[a]**	**Thickness**	**Surface Treatment**	**Glass Grade**	**Type**
	FM = Flame modified	10 = 25 μm	S = Nonadherable film	G = Glossy	1 = High shrinkage
	UA/UT = Ultraviolet screening film transparent	15 = 37.5 μm	A = One side adherable	M = Medium gloss	2 = High tensile strength and flexibility
	MR = High temperature release	20 = 50 μm	B = Both sides adherable	L = Low gloss	3 = Medium tensile and elongation values
	PC = Epoxy board release	30 = 75 μm		S = Satin gloss	4 = High elongation, good formability, good heat sealing
	UW = Ultraviolet screening film translucent white	85 = 212 μm		E = Enhanced film for aircraft	5 = Excellent formability for release and lamination of plastics and metal
	ST = Special transparent			H = High gloss	8 and 9 = nonoriented films
	TR = Transparent				
	WH = White				

[a]*There are many color codes.*

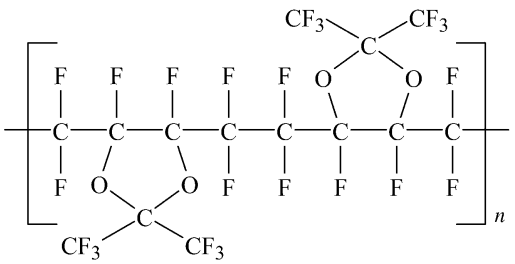

Figure 9.170 Structure of Teflon® AF.

Applications and uses: developmental applications are currently under evaluation for optical fiber cladding, photolithography, and as an electronic dielectric for the next generation of high-speed computer circuits.

Data for Teflon® AF plastics are found in Table 9.6 and in Figures 9.171–9.173.

Table 9.6 Typical Property Data for Teflon® AFs [21]

Property	ASTM Method	Unit	Grade	
			1600	2400
Electrical				
Dielectric constant	D150		1.93	1.90
Dissipation factor	D150		0.0001–0.0002	0.0001–0.0003
Dielectric strength	D149	kV/0.1 mm	2.1	1.9
Optical				
Optical transmission	D1003	%	>95	>95
Refractive index	D542		1.31	1.29
Mechanical				
Yield strength @23°C		MPa	27.4±1.0	26.4±1.9
Yield strength @150°C		MPa	6.7±5.9	
Yield strength @220°C		MPa		8.7±4.0
Tensile strength @23°C	D638	MPa	26.9±1.5	26.4±1.9
Tensile strength @150°C		MPa	7.7± 6.1	
Tensile strength @220°C		MPa		4.2±1.8
Elongation at break @23°C	D638	%	17.1±5.0	7.9±2.3
Elongation at break @150°C		%	89.3±13.1	
Elongation at break @220°C		%		8.4±4.1
Tensile modulus	D638	GPa	1.6	1.5
Flexural modulus @23°C	D790	GPa	1.8±0.1	1.6±0.1
Flexural modulus @150°C		GPa	1.0±0.1	0.7±0.1
Hardness Rockwell @23°C	D785		103	97.5
Hardness durometer@23°C	D1706	Shore D	77	75
Hardness durometer@150°C	D1706	Shore D	70	
Hardness durometer@220°C	D1706	Shore D		65
T_g	D3418	°C	160	240
Specific gravity	D792		1.78	1.67

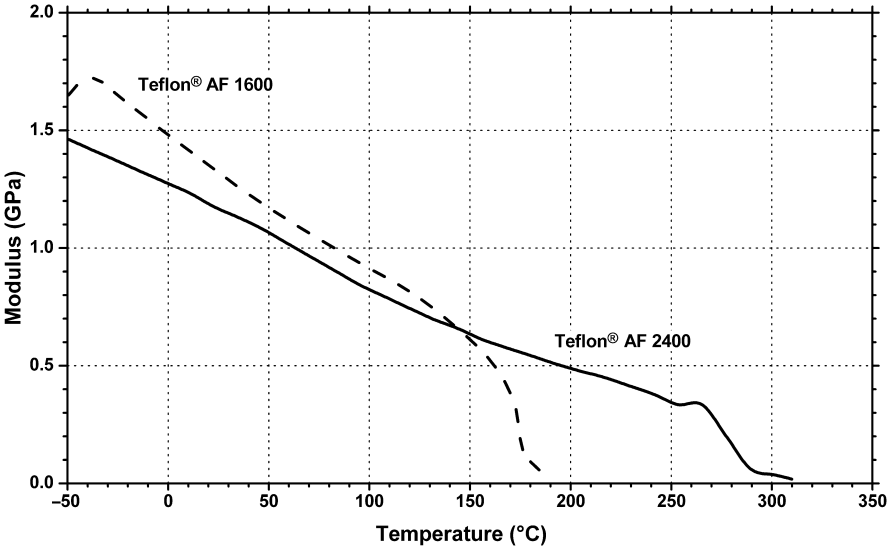

Figure 9.171 Modulus vs. temperature for DuPont Teflon® AF films.

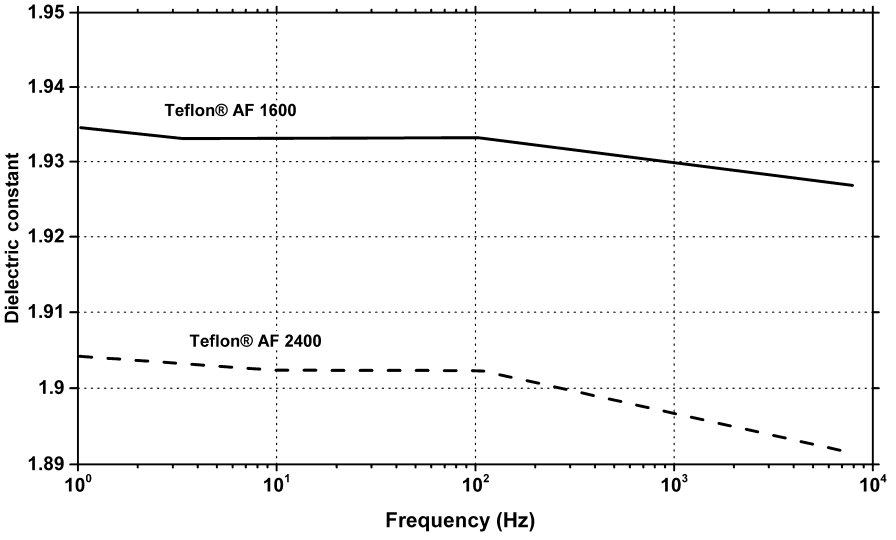

Figure 9.172 Dielectric constant vs. frequency for DuPont Teflon® AF films.

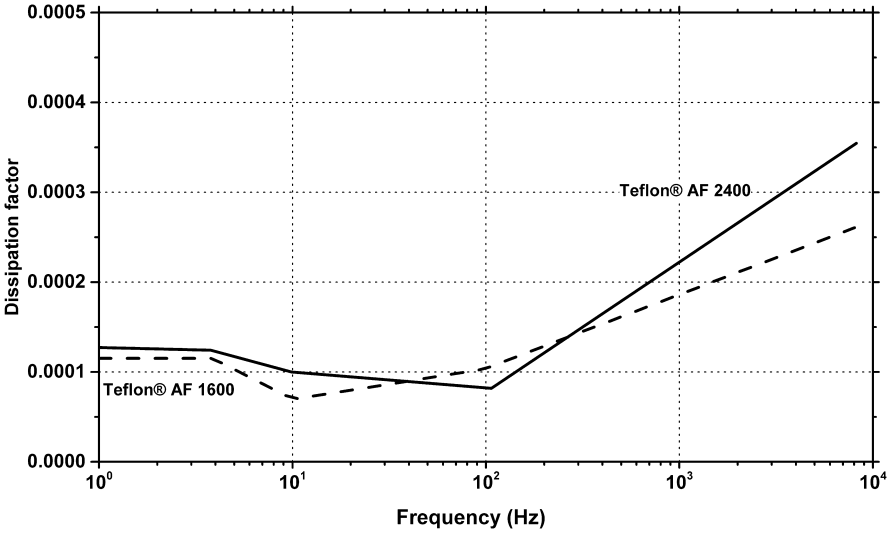

Figure 9.173 Dissipation factor vs. frequency for DuPont Teflon® AF films.

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10 High Temperature Polymers

This chapter contains information and multipoint properties for several high temperature, high-performance plastics. They might be classified or been appropriate to include in another chapter, but they are grouped in this chapter because of their performance levels.

10.1 Polyketones (PAEK)

Polyketones (or chemically accurate polyaryletherketones (PAEK)) are a family of semicrystalline thermoplastics with high temperature stability and high mechanical strength. Some of the commercial plastics that fall within this family include those listed with their structures in Table 10.1.

The good strength of the semicrystalline aromatic polymers is maintained even at high temperatures. In addition, PAEK materials show very good impact strength at low temperatures, high mechanical fatigue strength, a very low tendency to creep as well as good sliding and wear properties. The chemical resistance is also very good. Due to their unusual characteristics, PAEK are used for particularly demanding applications:

- High mechanical strength, even at high temperatures
- Very good impact strength
- Low tendency to creep
- Good chemical resistance
- Good sliding and wear properties
- Low moisture absorption
- Very good dielectric strength, volume resistivity, tracking resistance
- Good radiation resistance
- Poor resistance to weathering

Manufacturers and trade names: *PEEK*: Victrex Victrex® and APTIV®, Greene, Tweed & Co. Arlon®, Solvay Advanced Polymers GATONE™ and KetaSpire®; *PEKK*: Polymics Arylmax® K, Arkema Kepstan®; *PEKEEK*: Victrex Victrex® ST; *PEK*: Victrex Victrex® HT; *PAEK* (unspecified): Solvay Advanced Polymers Avaspire®, Polymics Arylmax® P.

Applications and uses: medical implants, sealing rings, bearings, piston parts, pumps, high pressure liquid chromatography (HPLC) columns, compressor plate valves, and cable insulation.

The various PAEK types are discussed in separate sections.

10.1.1 Polyether Ether Ketones (PEEK)

The data for PEEK-based plastics are given in Tables 10.2–10.5 and shown in Figures 10.1–10.31.

The following Solvay Advanced Polymers products are referred to in this section's figures and tables:

- KetaSpire® KT-820 NT—Low melt flow for extrusion and injection molding
- KetaSpire® KT-880 NT—High melt flow for injection molding
- KetaSpire® KT-820 GF30—Low melt flow, 30% glass fiber
- KetaSpire® KT-880 GF30—High melt flow, 30% glass fiber
- KetaSpire® KT-820 CF30—Low melt flow, 30% carbon fiber
- KetaSpire® KT-880 CF30—High melt flow, 30% carbon fiber
- KetaSpire® KT-820 SL10—Reduced friction coefficient grade
- KetaSpire® KT-820 SL30—Very good wear resistance, dry and lubricated
- KetaSpire® KT-880 FW30—High melt flow, very good wear resistance, dry and lubricated

McKeen: The Effect of Temperature and other Factors on Plastics and Elastomers.
DOI: http://dx.doi.org/10.1016/B978-0-323-31016-1.00010-6
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Table 10.1 The Structures of Several Commercial Polyketone Polymers

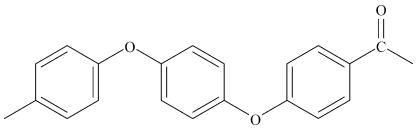
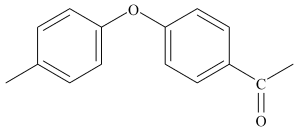
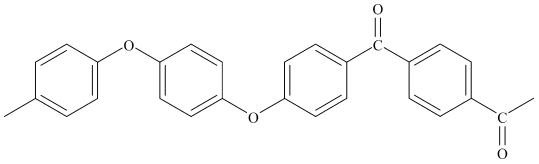
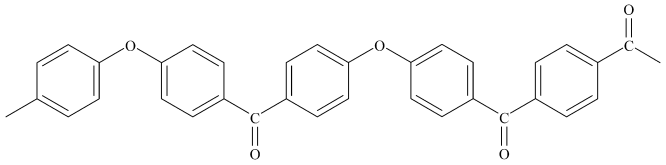
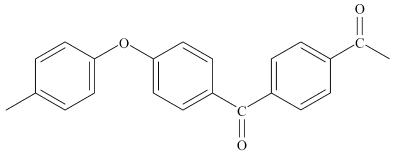
Polymer (Abbreviation)	Approximate T_g/T_m (°C)	Structure
Polyether ether ketone (PEEK)	151/338	
Polyether ketone (PEK)	160/372	
Polyether ether ketone ketone (PEEKK)	160/360	
Polyether ketone ether ketone ketone (PEKEKK)	165/384	
Polyether ketone ketone (PEKK)	156/338	

Table 10.2 Compressive Yield Strength of Solvay KetaSpire® PEEK at Several Temperatures [1]

Grade	23°C	100°C	150°C	200°C
KT-820 NT 123	83.5	63.5	23.8	
KT-820 GF30 BG20	168	120	80.2	36.6
KT-820 CF30	170	124	83.9	44.4
KT-820 SL10	114	76.1	55.0	22.3
KT-820 SL30	112	85.0	61.3	32.0
KT-820 SL45	128	100	71.0	39.1

The following Victrex products are referred to in this section's figures and tables:

- Victrex® 150G—Easy flow grade for injection molding of thin sections and complex parts
- Victrex® 450G—General-purpose grade for injection molding and extrusion
- Victrex® 150GL30—Easy flow, 30% glass fiber reinforced for injection molding
- Victrex® 450GL30—General-purpose, 30% glass fiber-reinforced grade for injection molding and extrusion
- Victrex® 150CA30—Easy flow, 30% carbon fiber reinforced for injection molding
- Victrex® 450CA30—Standard viscosity, 30% carbon fiber-reinforced grade for injection molding

Table 10.3 Tensile Properties at Elevated Temperatures of Select Solvay KetaSpire® PEEK Grades [1]

Temperature (°C)	KetaSpire® KT-820 NT	KetaSpire® KT-880 NT	KetaSpire® KT-820 GF30	KetaSpire® KT-880 GF30	KetaSpire® KT-820 CF30	KetaSpire® KT-880 CF30
Tensile strength at yield (MPa)						
23	103	105				
100	69	70				
150	34	39				
200		20				
Tensile strength at break (MPa)						
23	76	69	175	197	209	234
100	48	46	126	147	152	179
150	43	44	77	95	91	112
200	(26	28	44	58	57	68
Tensile modulus (GPa)						
23	3.8	4.0	10.6	11.4	19.0	24.0
100	3.4	2.5	10.1	10.9	18.1	23.4
150	2.5	1.7	8.1	8.6	13.1	16.4
200		0.4				5.4
Tensile elongation at yield (%)						
23	5.0	5.9				
100	3.0	6.7				
150	12.0	14.0				
200		19.0				
Tensile elongation at break (%)						
23	17.0	19.0	3.2	2.8	2.2	1.6
100	52.0	45.0	3.0	2.7	2.6	1.7
150	120.0[a]	120.0[a]	4.4	3.6	4.2	2.5
200	120.0[a]	120.0[a]	8.6	6.0	9.4	4.4

[a] *120.0 = limit of testing machine.*

- Victrex® 150FC30—Easy flow, 30% carbon/PTFE grade for injection molding
- Victrex® 450FC30—Standard viscosity, 30% carbon/PTFE grade for injection molding and extrusion
- Victrex® 90HMF40—High-performance thermoplastic material, 40% carbon fiber for injection molding, easy flow, color black

10.1.2 Polyether Ketones (PEK)

The data for PEK-based plastics are shown in Figures 10.32–10.34.

10.1.3 Polyether Ketone Ether Ketone Ketones (PEKEKK)

The data for PEKEKK-based plastics are shown in Figures 10.35 and 10.36.

Table 10.4 Tensile Properties at Elevated Temperatures of Wear-Resistant Solvay KetaSpire® PEEK Grades [1]

Temperature (°C)	KetaSpire® KT-820 SL10	KetaSpire® KT-820 SL30	KetaSpire® KT-820 SL45
Tensile strength at yield (MPa)			
23	91		
100	60		
150	33		
200			
Tensile strength at break (MPa)			
23	77	139	173
100	51	104	130
150	43	66	81
200	25	40	47
Tensile modulus (GPa)			
23	2.7	13.4	22.5
100	2.7	12.5	21.4
150	1.9	9.7	15.7
200	0.3		
Tensile elongation at yield (%)			
23	6.4		
100	4.0		
150	18.0		
200			
Tensile elongation at break (%)			
23	27.0	2.0	1.2
100	52.0	2.2	1.2
150	120.0[a]	4.8	2.1
200	120.0[a]	9.0	4.6

[a] *120.0 = limit of testing machine.*

Table 10.5 Flexural Properties vs. Temperature of Select Solvay KetaSpire® PEEK Grades [1]

	Flexural Strength (MPa)		Flexural Modulus (GPa)	
Temperature (°C)	**KT-820 NT**	**KT-820 GF30 BG20**	**KT-820 NT**	**KT-820 GF30 BG20**
23	156	268	3.77	10.0
100	112	210	3.44	9.34
150	56	136	2.35	6.60
200	13	61	0.32	2.26

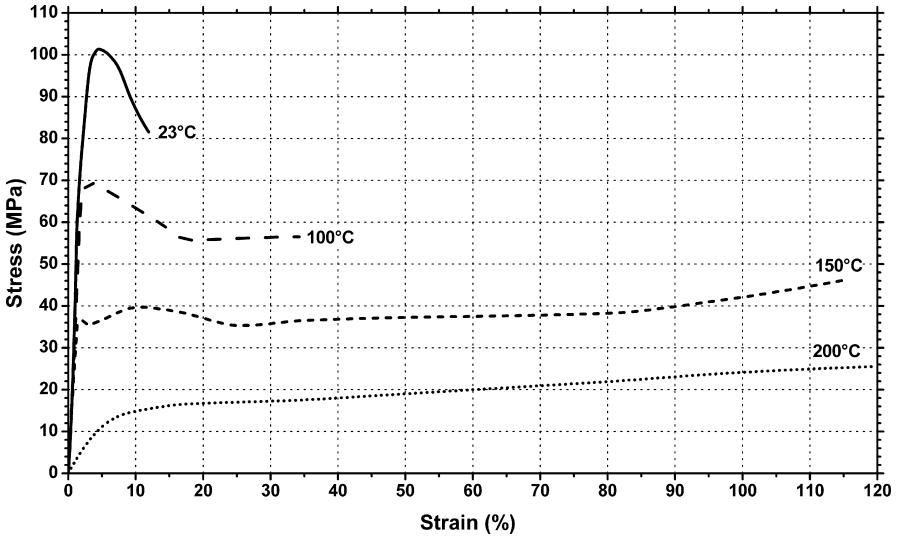


Figure 10.1 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 NT—low melt flow for extrusion and injection molding PEEK resin [1].

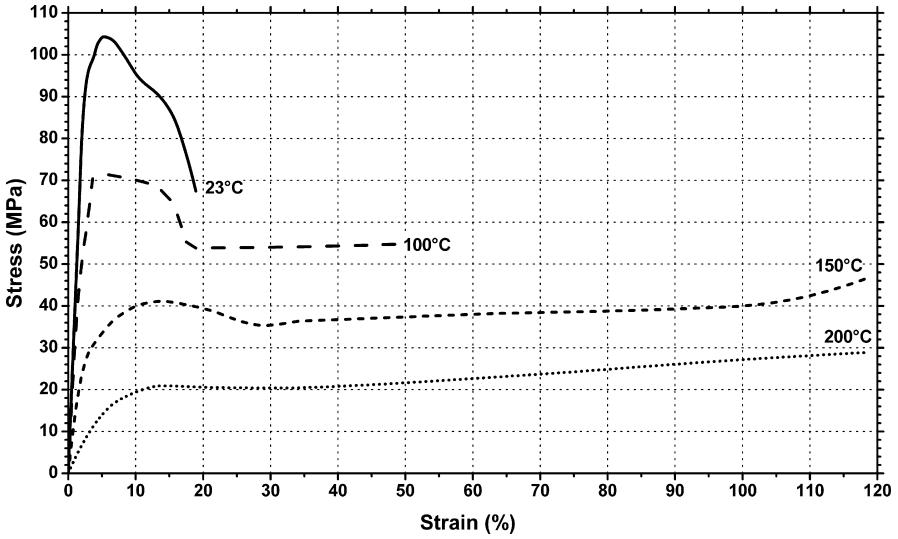


Figure 10.2 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-880 NT—high melt flow for injection molding PEEK resin [1].

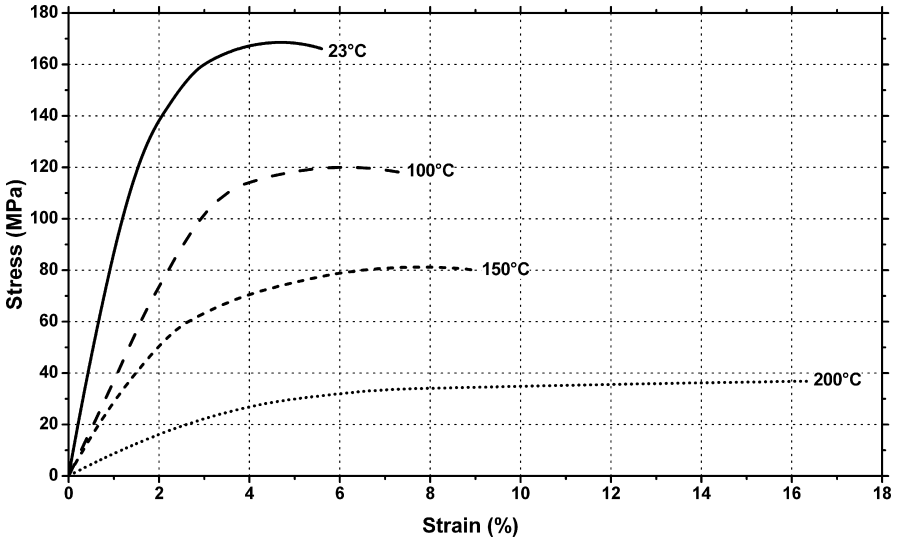


Figure 10.3 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 GF30—low melt flow, 30% glass fiber PEEK resin [1].

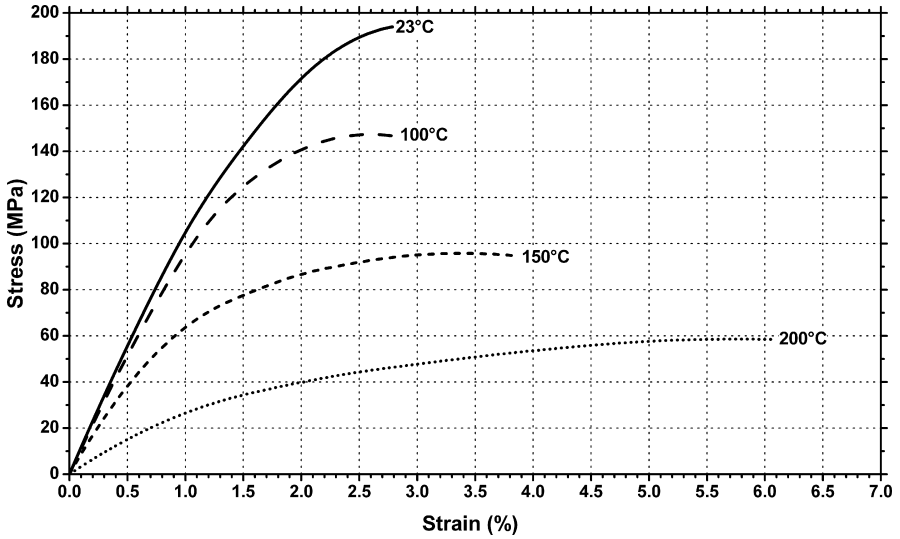


Figure 10.4 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-880 GF30—high melt flow, 30% glass fiber PEEK resin [1].

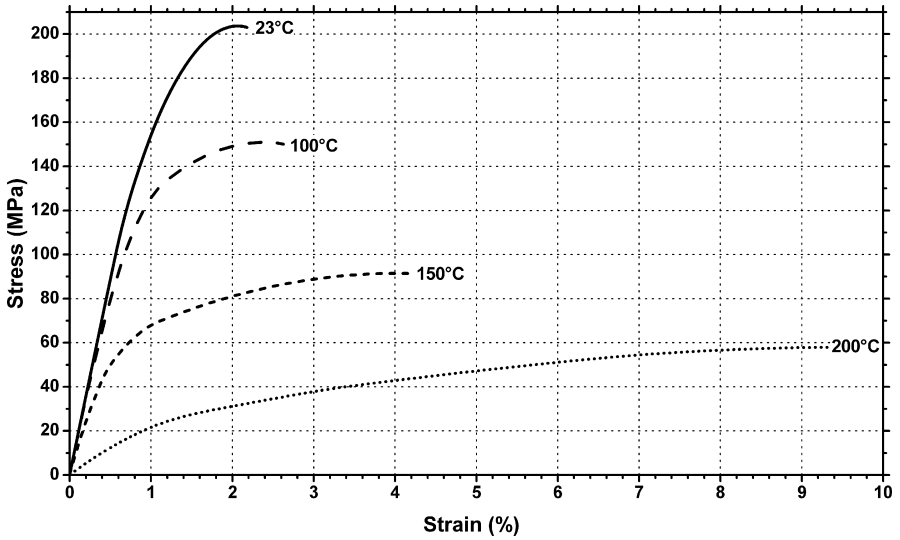


Figure 10.5 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 CF30—low melt flow, 30% carbon fiber PEEK resin [1].

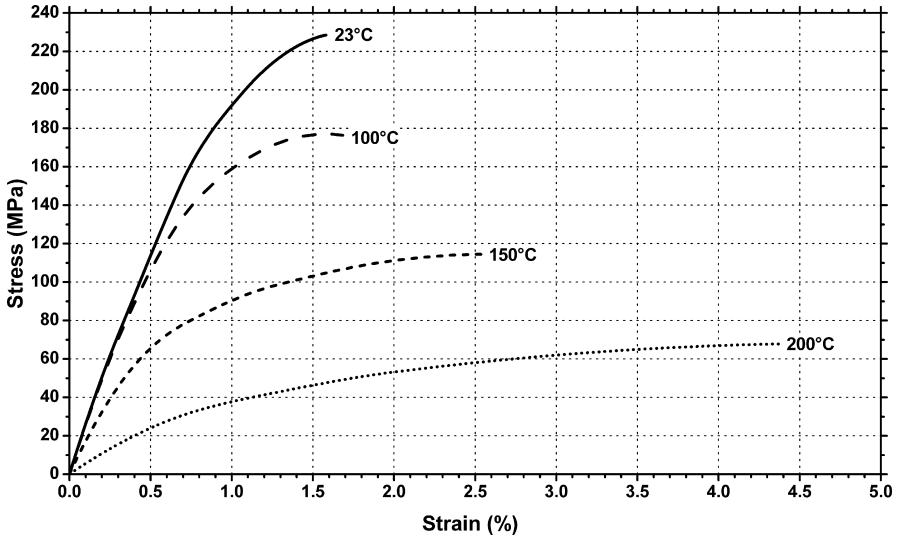


Figure 10.6 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-880 CF30—high melt flow, 30% carbon fiber PEEK resin [1].

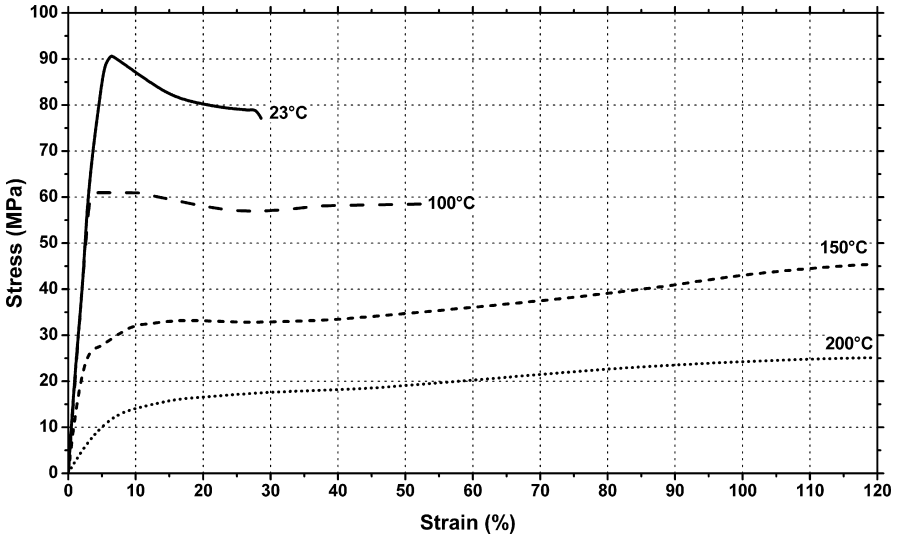


Figure 10.7 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 SL10—reduced friction coefficient grade PEEK resin [1].

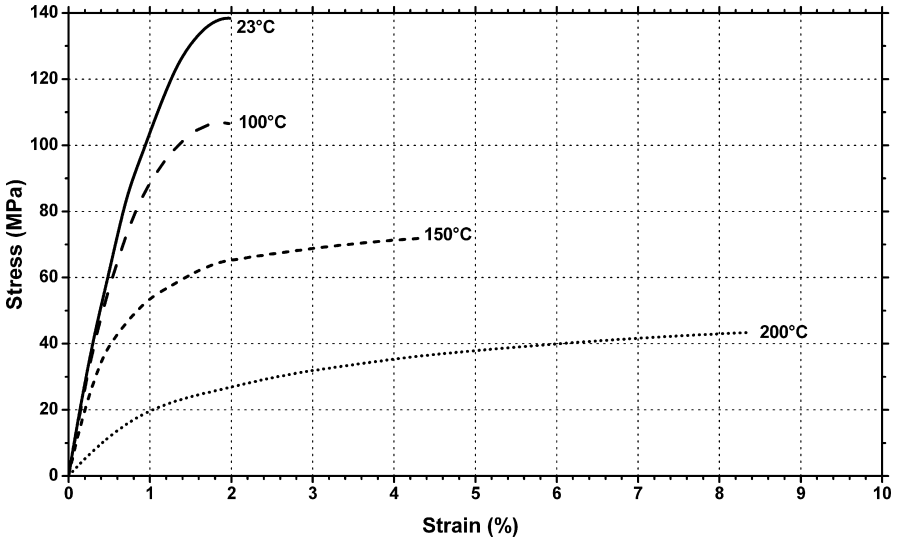


Figure 10.8 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 SL30—very good wear resistance, dry and lubricated PEEK resin [1].

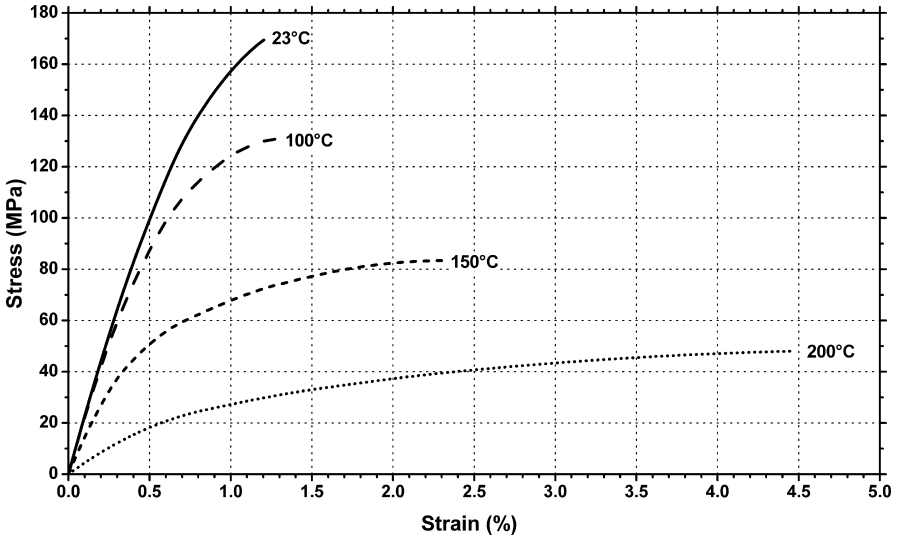


Figure 10.9 Stress vs. strain at various temperatures for Solvay KetaSpire® KT-880 FW30—high melt flow, very good wear resistance, dry and lubricated PEEK resin [1].

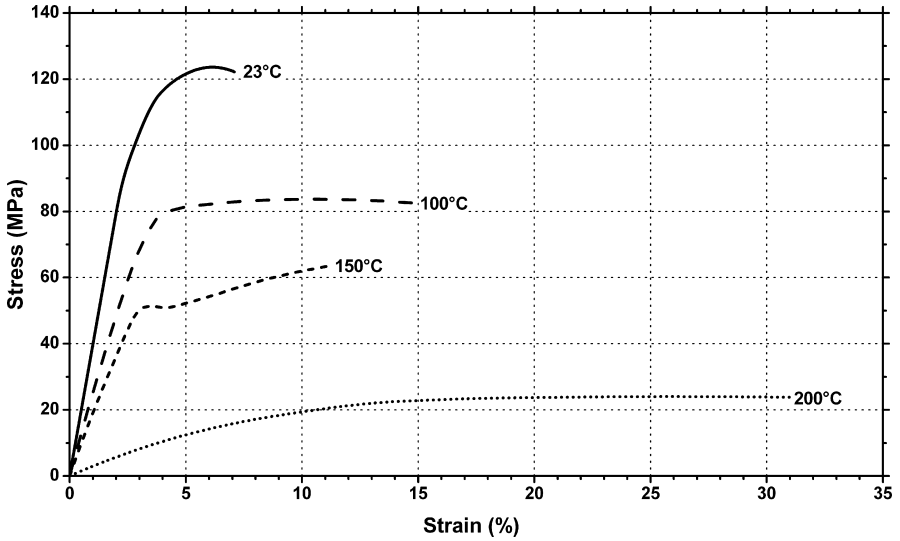


Figure 10.10 Compressive stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 NT [1].

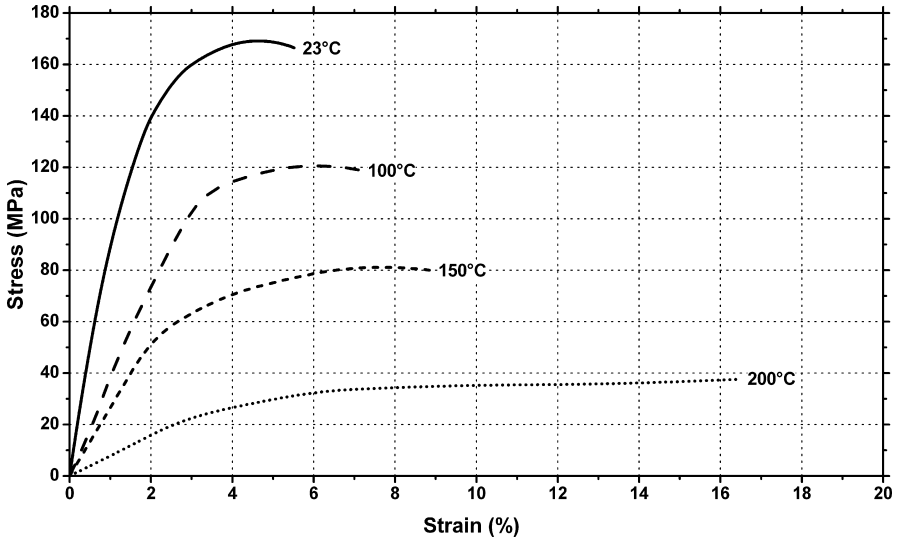


Figure 10.11 Compressive stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 GF30 [1].

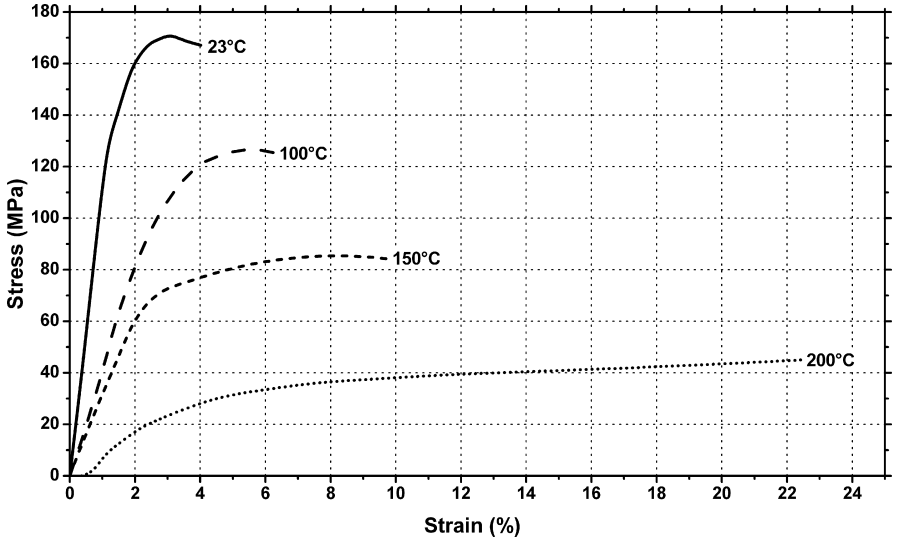


Figure 10.12 Compressive stress vs. strain at various temperatures for Solvay KetaSpire® KT-820 CF30 [1].

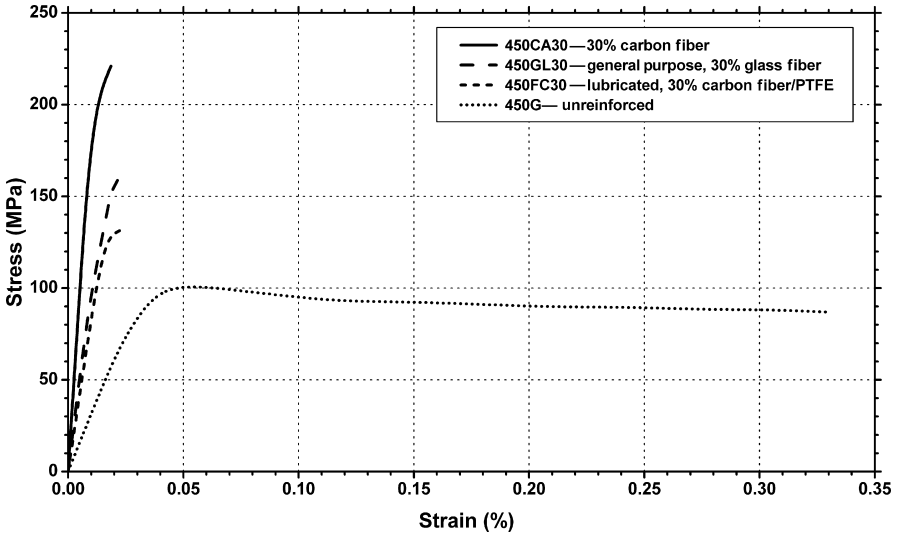


Figure 10.13 Stress vs. strain at 23°C for various Victrex® PEEK resins.

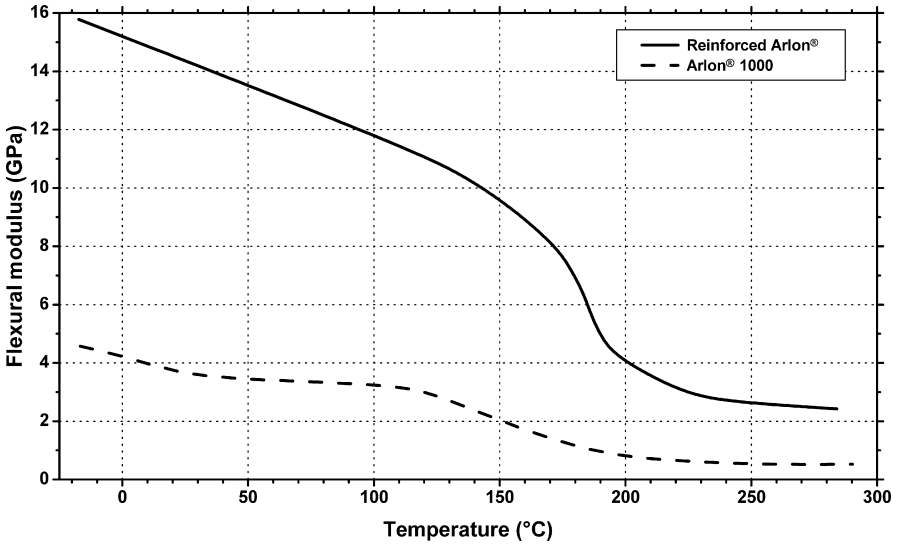


Figure 10.14 Flexural modulus vs. temperature for Greene, Tweed Arlon® PEEK resins.

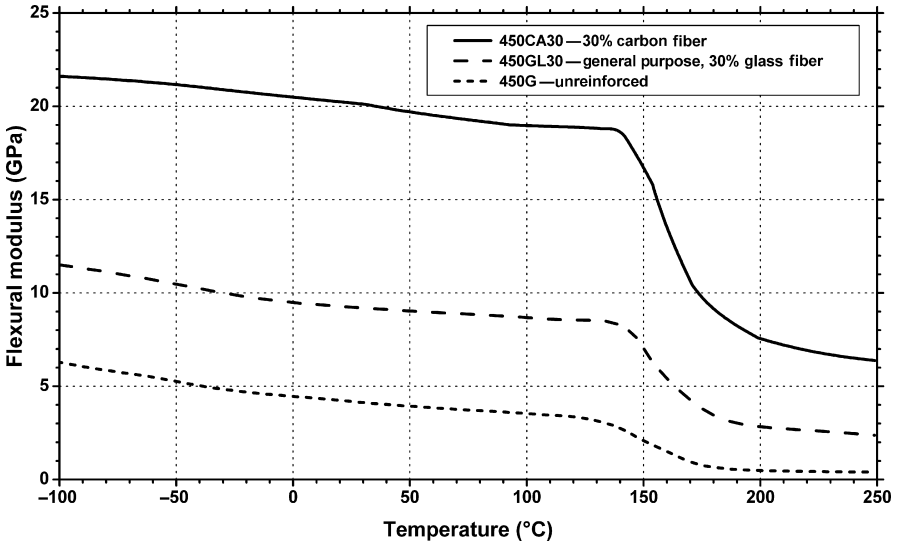


Figure 10.15 Flexural modulus vs. temperature for different fiber-filled Victrex® PEEK resins.

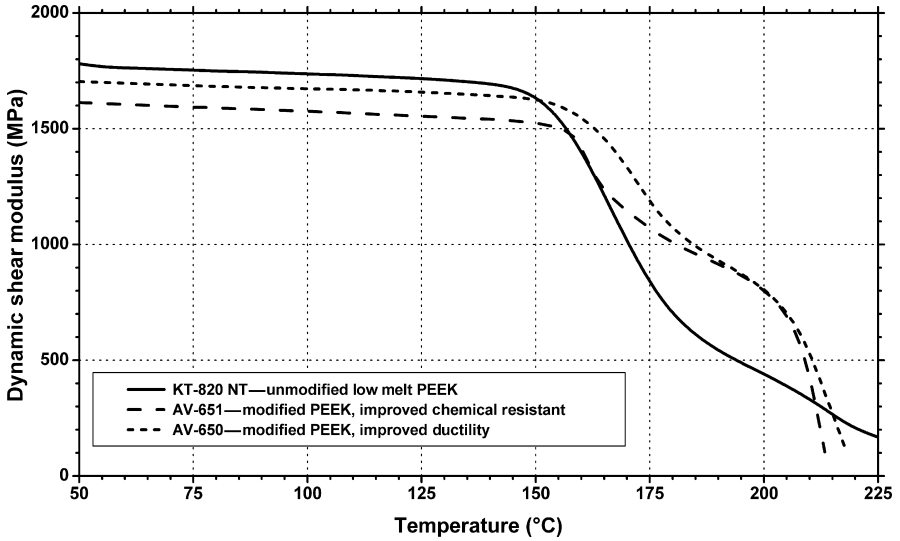


Figure 10.16 Dynamic shear modulus vs. temperature for Solvay KetaSpire® and AviSpire® PEEK resins.

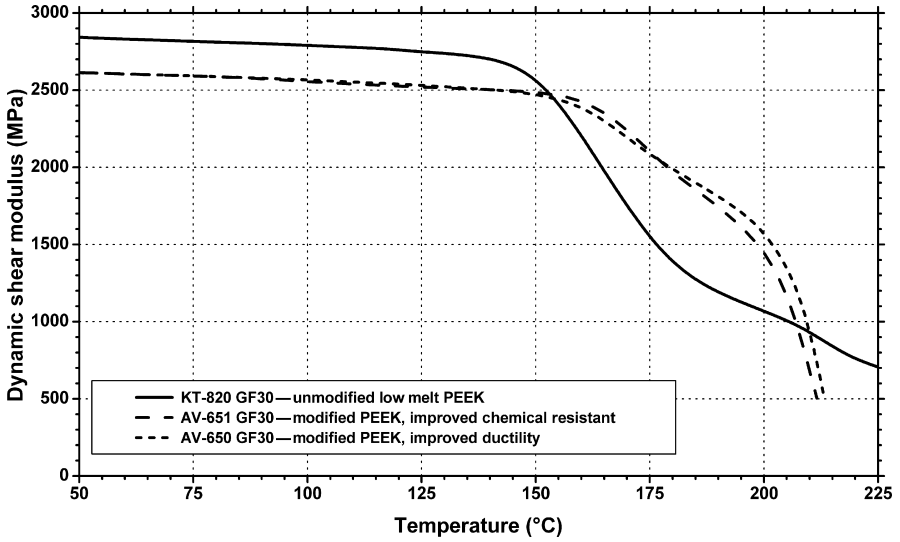


Figure 10.17 Dynamic shear modulus vs. temperature for Solvay KetaSpire® and AviSpire® 30% glass fiber-reinforced PEEK resins.

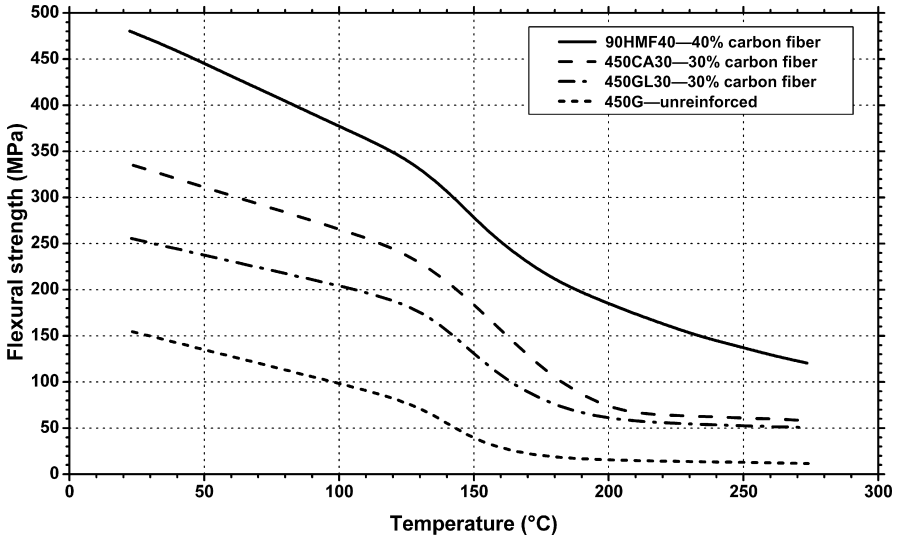


Figure 10.18 Flexural strength vs. temperature for different fiber-filled Victrex® PEEK resins [2].

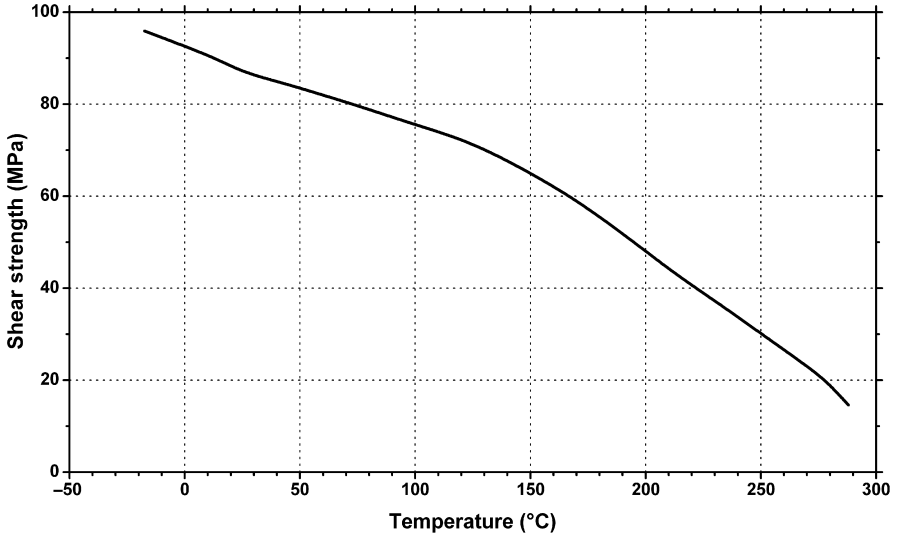


Figure 10.19 Shear strength vs. temperature for Greene, Tweed Arlon® 1000—unreinforced, general-purpose PEEK resin.

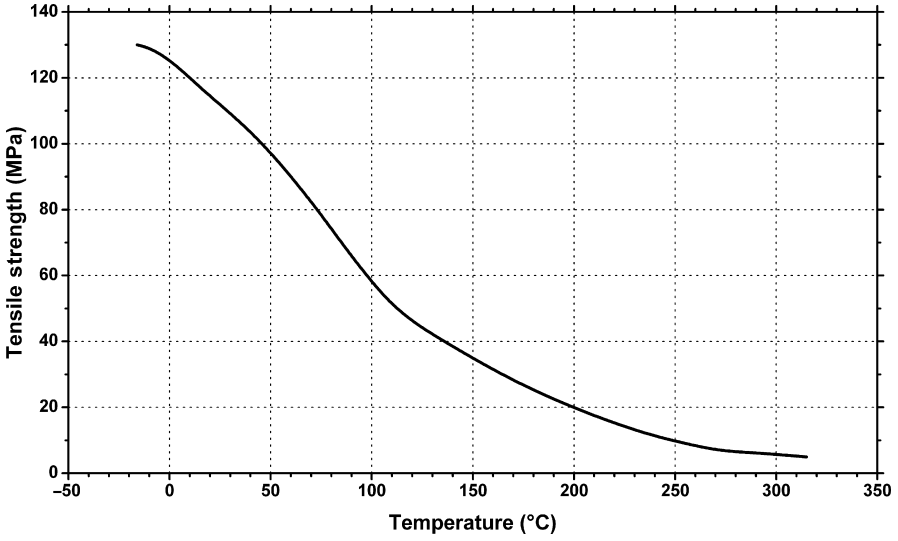


Figure 10.20 Tensile strength vs. temperature for Greene, Tweed Arlon® 1000—unreinforced, general-purpose PEEK resin.

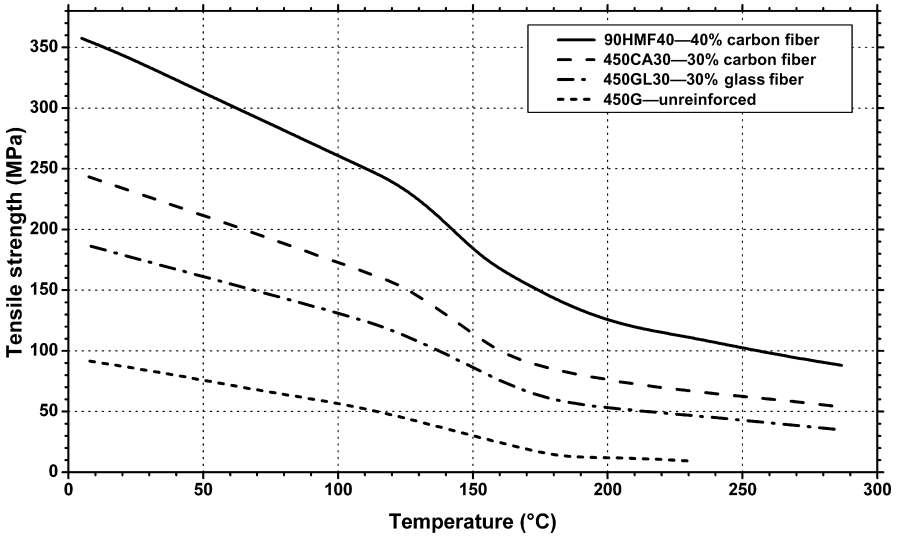


Figure 10.21 Tensile strength vs. temperature for Victrex® PEEK resins [2].

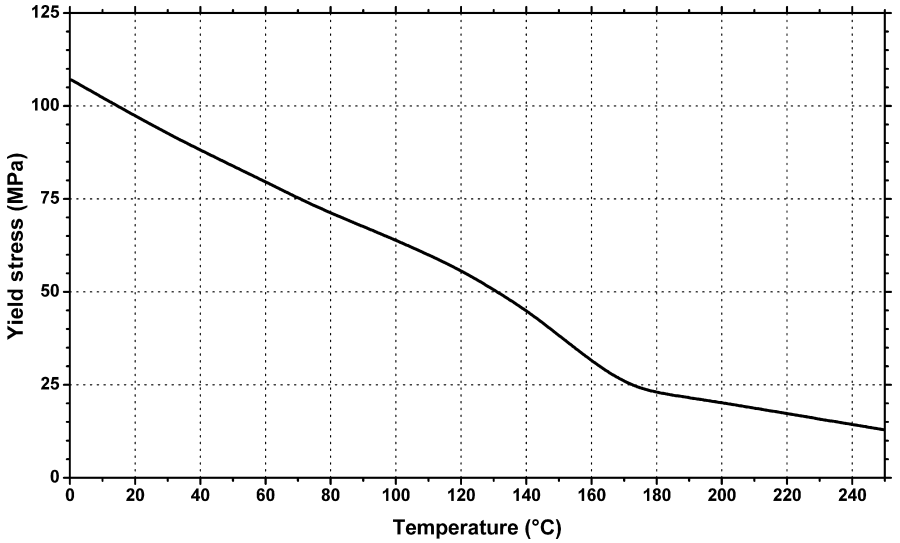


Figure 10.22 Yield stress vs. temperature for Victrex® 450G PEEK resin.

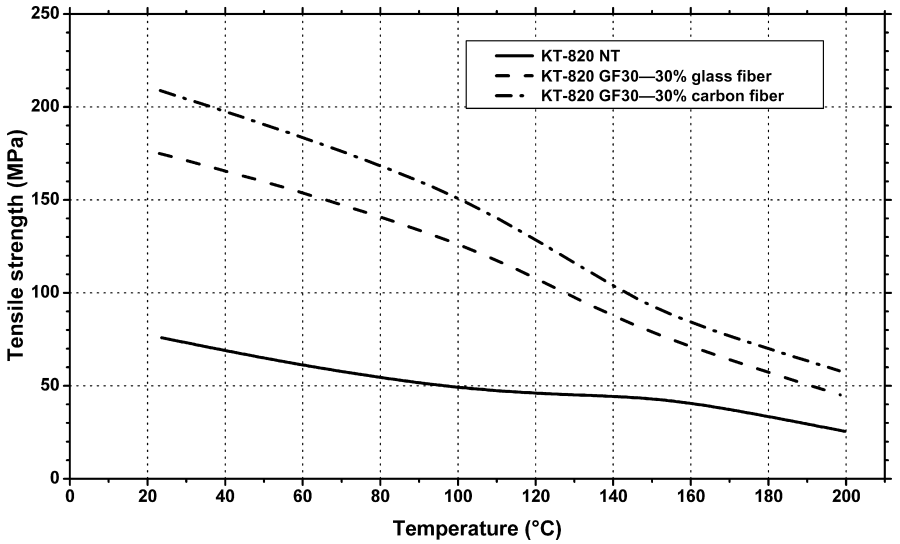


Figure 10.23 Tensile strength vs. temperature for Solvay KetaSpire® KT-820 Series PEEK resins [1].

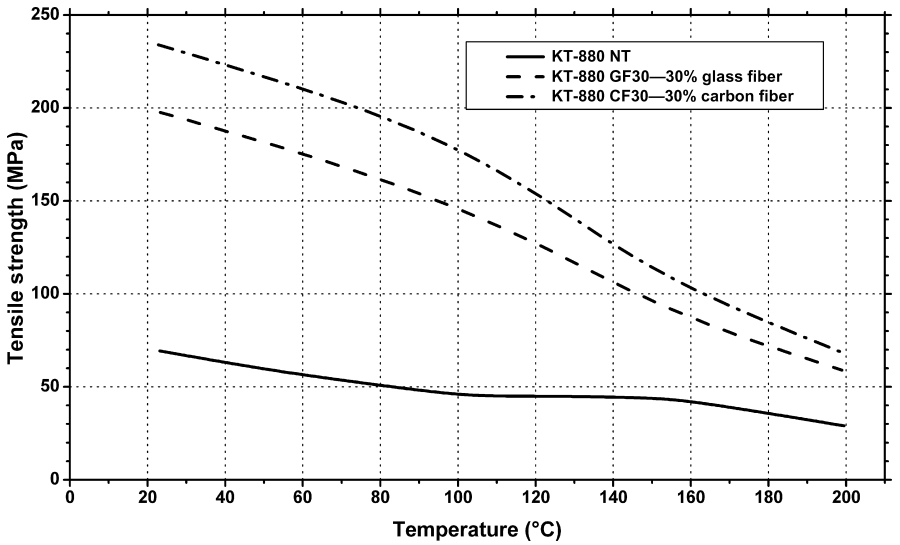


Figure 10.24 Tensile strength vs. temperature for Solvay KetaSpire® KT-880 Series PEEK resins [1].

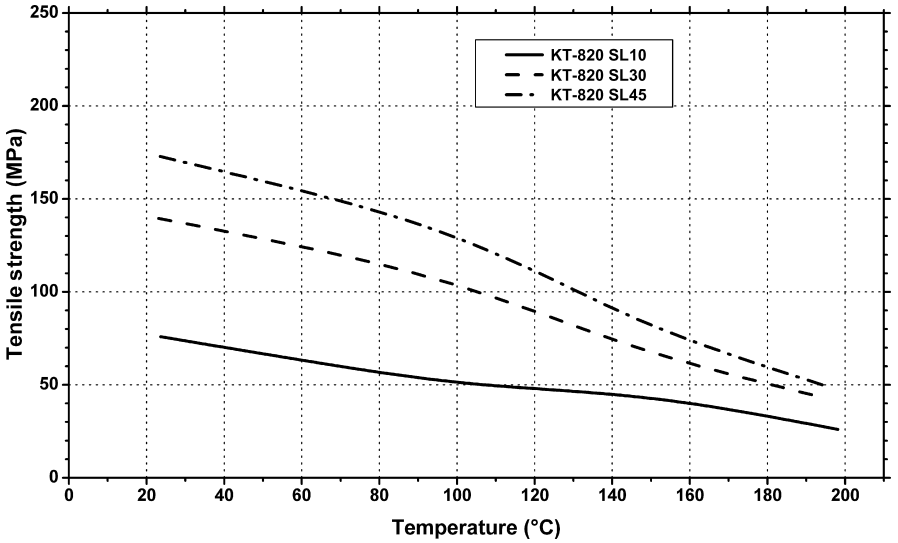


Figure 10.25 Tensile strength vs. temperature for Solvay KetaSpire® KT-820 wear-resistant series PEEK resins [1].

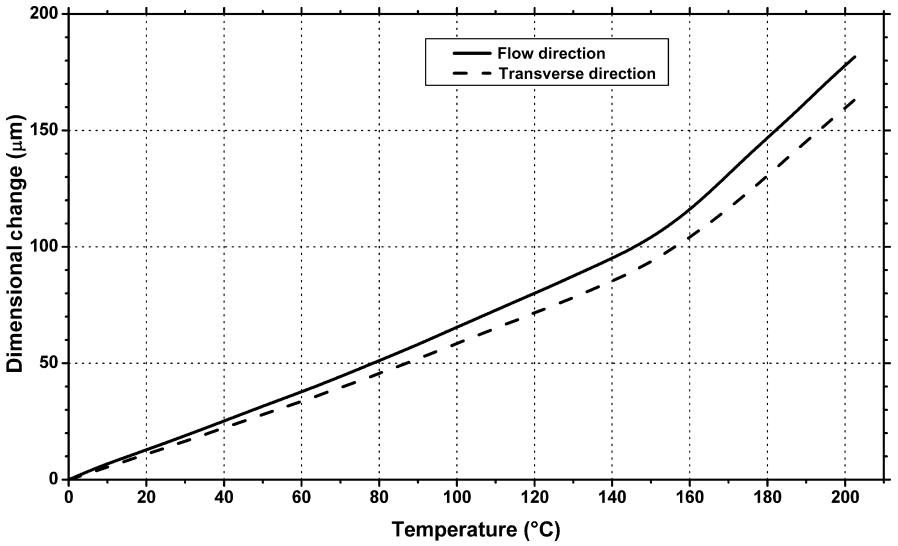


Figure 10.26 Coefficient of linear thermal expansion vs. temperature for Solvay KetaSpire® KT-880 NT PEEK resin [1].

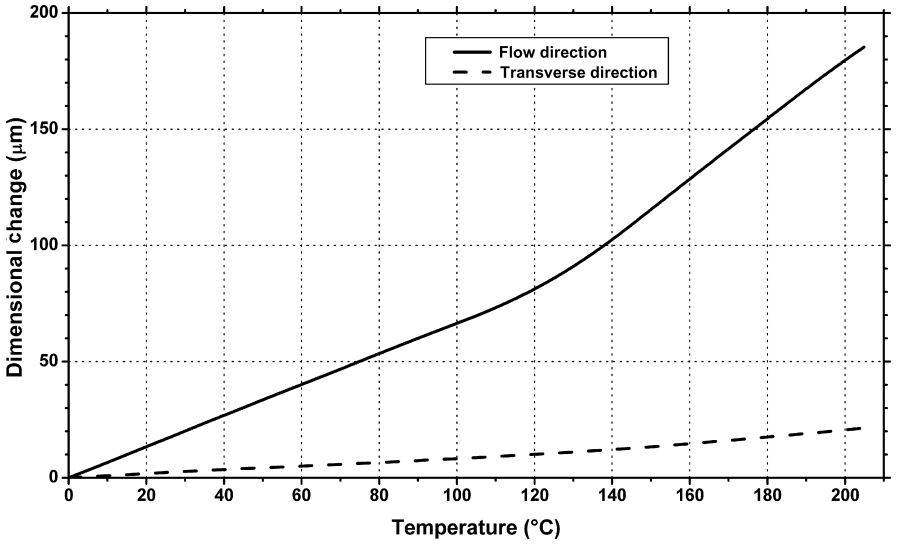


Figure 10.27 Coefficient of linear thermal expansion vs. temperature for Solvay KetaSpire® KT-880 CF30—30% carbon fiber-reinforced PEEK resin [1].

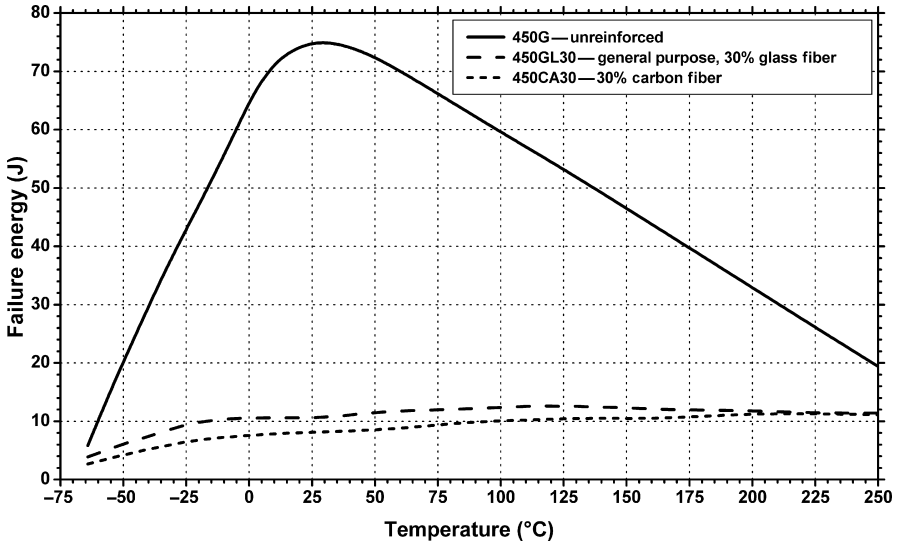


Figure 10.28 Falling weight impact failure energy vs. temperature for Victrex® PEEK resins.

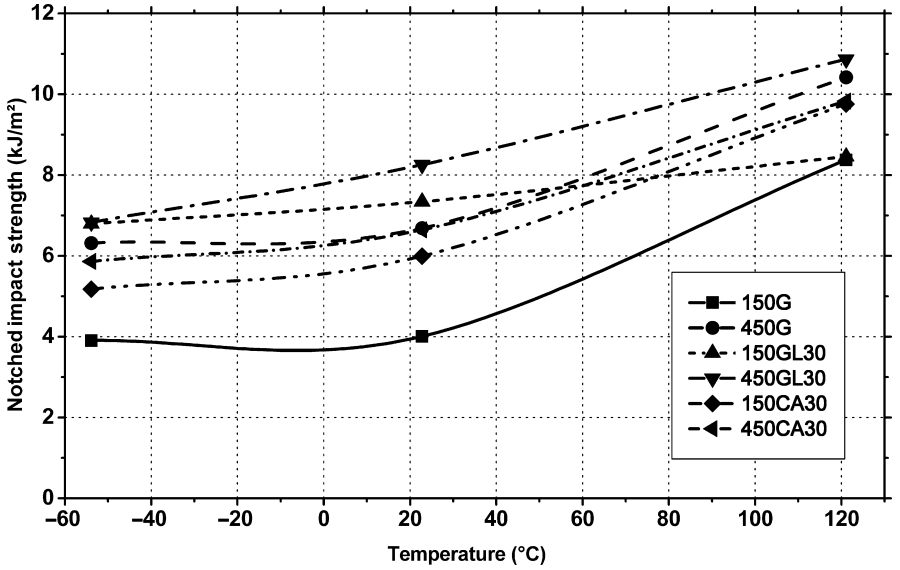


Figure 10.29 Notched Charpy impact strength vs. temperature for Victrex® PEEK resins [2].

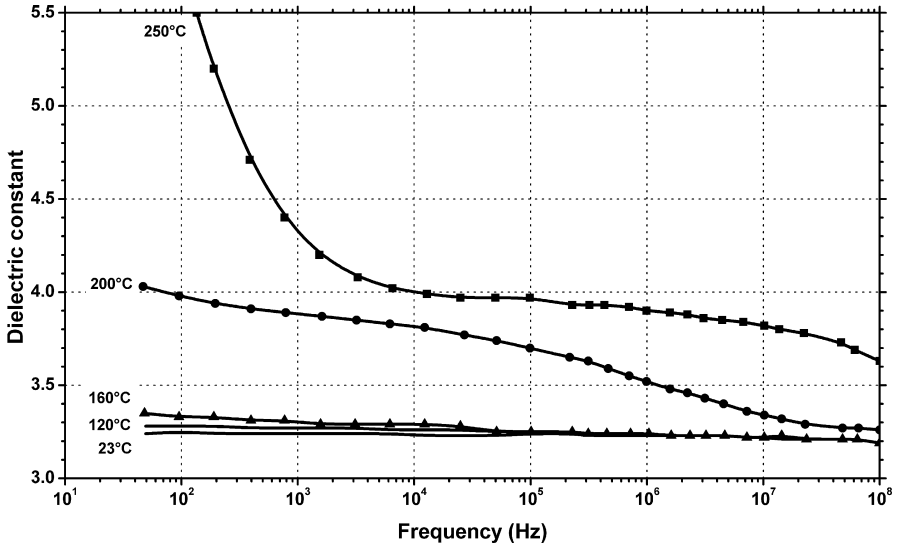


Figure 10.30 Dielectric constant vs. frequency and temperature for Victrex® 450G unreinforced PEEK resin.

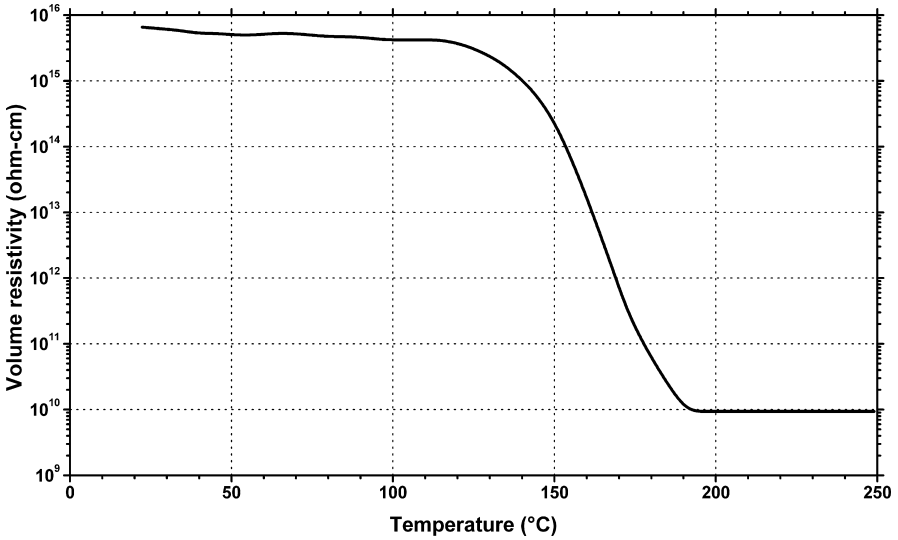


Figure 10.31 Volume resistivity vs. temperature for Victrex® 450G unreinforced PEEK resin.

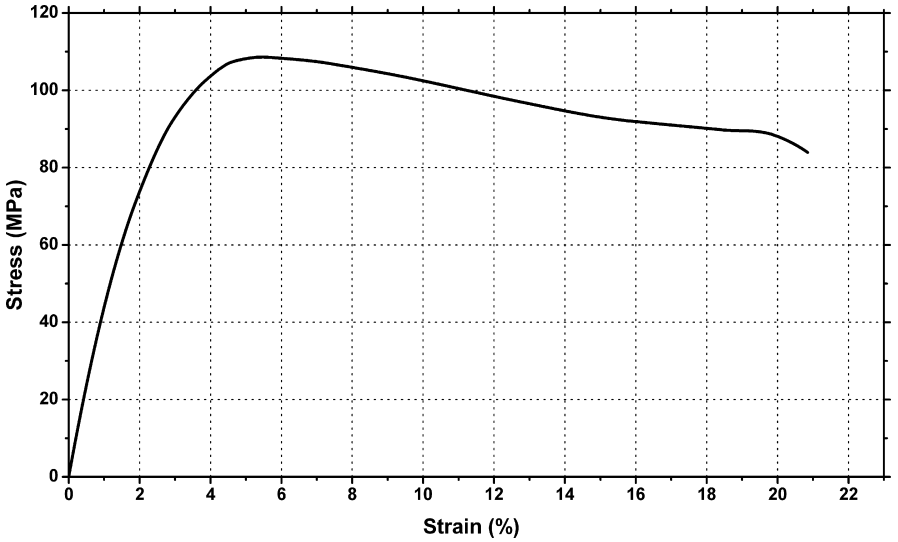


Figure 10.32 Stress vs. strain at room temperature for Victrex® HT G22 PEK resin [2].

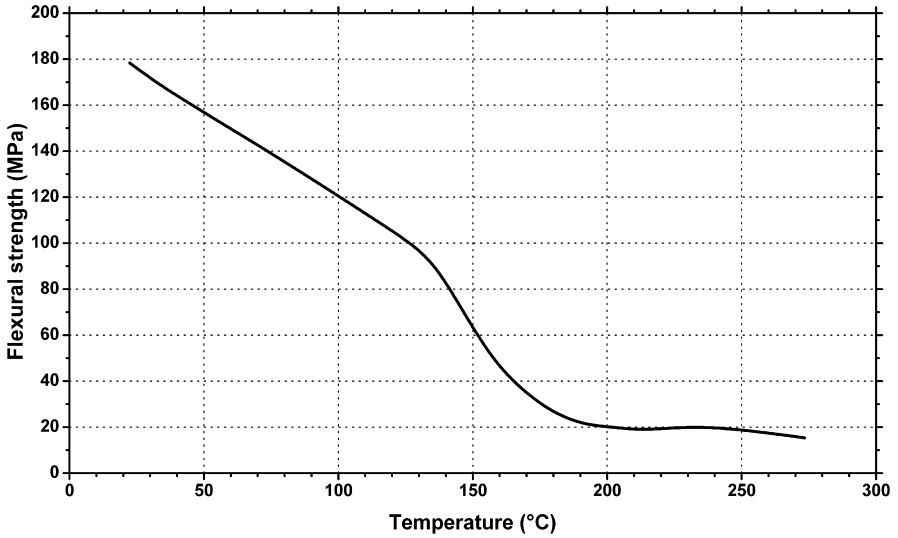


Figure 10.33 Flexural strength vs. temperature for Victrex® HT G22 PEK resin [2].

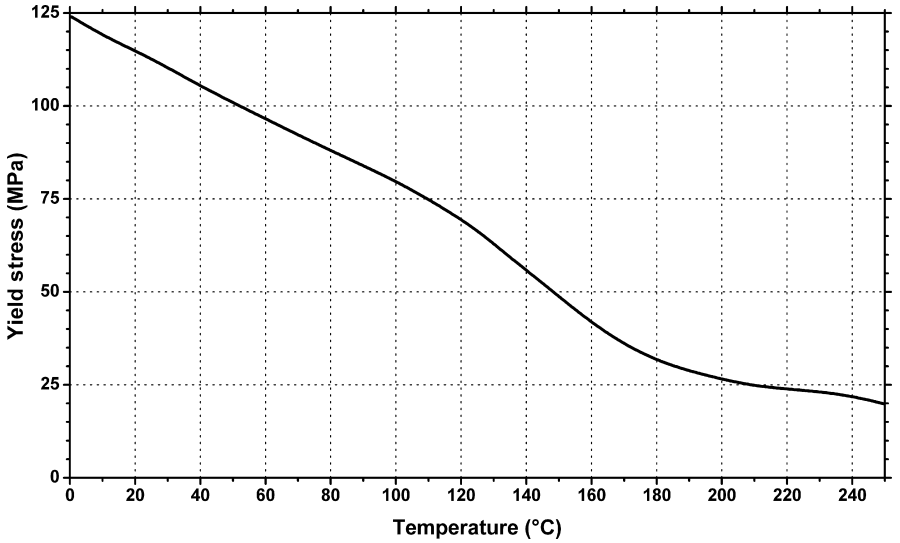


Figure 10.34 Yield stress vs. temperature for Victrex® HT G22 PEK resin [2].

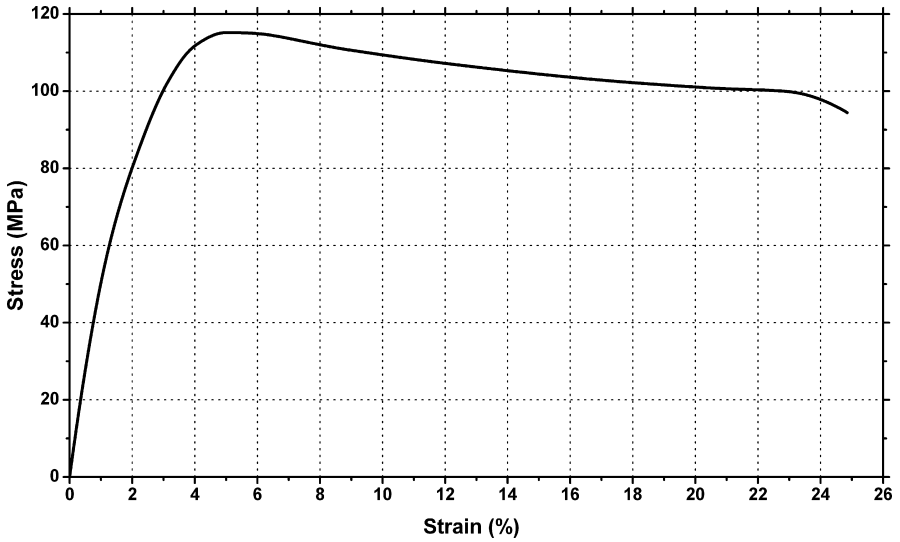


Figure 10.35 Stress vs. strain at room temperature for Victrex® ST G45 PEKEEK resin [2].

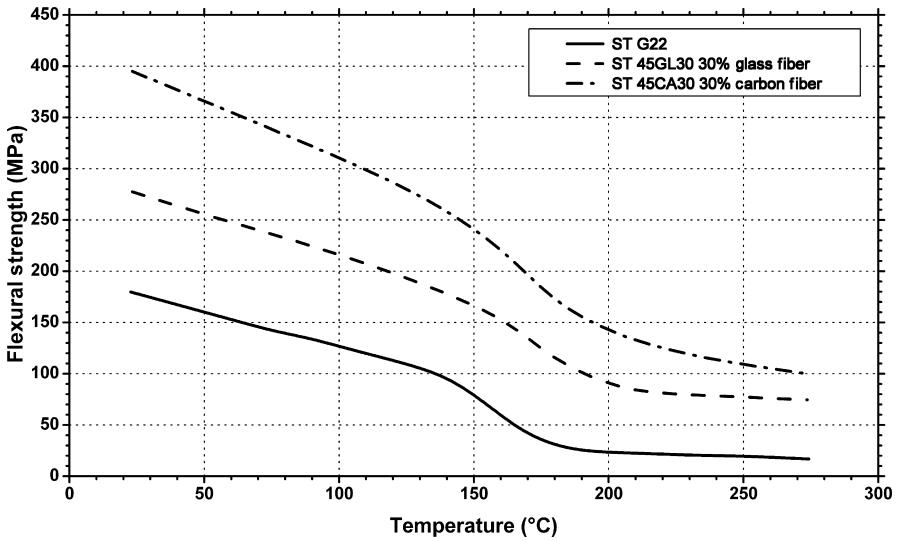


Figure 10.36 Flexural strength vs. temperature for Victrex® ST PEKEEK resin [2].

10.1.4 Polyaryletherketones (PAEK)

The industry classifies some of their products as polyaryletherketones (PAEK) even though PAEK also describes the other polyketone resins. These chemical structures of these resins differ slightly from the other polyketone resins described in this chapter; those structures are generally not disclosed.

The data for PAEK-based plastics are given in Tables 10.6–10.11 and shown in Figures 10.37–10.57.

Solvay Advanced Polymers AvaSpire® products in the following graphs and tables are summarized as follows:

AV-600 Series: Distinctive Performance

Key features:

- Higher stiffness than PEEK from 150°C to 190°C
- Improved ductility and toughness
- Excellent chemical resistance
- UL 94 V0 rating at 0.8 mm
- Excellent esthetics and colorability
- AvaSpire® AV-651—Better ductility and higher heat deflection temperature (HDT) than comparable PEEK, high melt flow for injection molding
- AvaSpire® AV-630—Optimized for ultra-thin film thicknesses down to 5 microns, low melt flow

Table 10.6 Tensile Properties at Elevated Temperature for Unreinforced AvaSpire® PAEK Grades [3]

Temperature (°C)	AvaSpire® AV-621 NT	AvaSpire® AV-651 BG20	AvaSpire® AV-722 BG20	AvaSpire® AV-848 NT
Tensile strength at yield (MPa)				
23	77	88	95	94
100	55	61	58	62
150	25	33	33	
200		14		
Tensile strength at break (MPa)				
23	68	73	85	73
100	59	59	67	49
150	37	40	50	48
200	23	19	26	
Tensile modulus (GPa)				
23	3.0	3.1	4.0	3.1
100	2.6	2.2	2.5	2.9
150	1.6	1.8	1.4	1.4
200	0.6	0.6		1.4
Tensile elongation at yield (%)				
23	6.2	6.4	5.4	7.0
100	4.0	5.0	13	5.8
150	4.0	4.5		5.4
200		14		
Tensile elongation at break (%)				
23	64	93	35	35
100	120[a]	120[a]	91	53
150	120[a]	120[a]	120[a]	70
200	120[a]	120[a]		92

[a] *120 = limit of testing machine*

Table 10.7 Tensile Properties at Elevated Temperature for Glass Fiber-Reinforced AvaSpire® PAEK Grades [3]

Temperature (°C)	AvaSpire® AV-621 GF30	AvaSpire® AV-651 GF30 BG20	AvaSpire® AV-750 GF40	AvaSpire® AV-848 GF30
Tensile strength at break (MPa)				
23	160	148	185	171
100	120	111	132	136
150	82	74	74	101
200	41	35	50	67
Tensile modulus (GPa)				
23	10.4	9.9	15.7	11.3
100	9.9	9.1	13.8	10.7
150	9.1	7.7	7.8	9.3
200	3.1	3.6	5.2	4.4
Tensile elongation at break (%)				
23	2.8	2.7	1.7	2.1
100	2.7	2.4	1.8	1.9
150	3.5	3.1	2.9	2.5
200	9.3	6.7	2.8	5.1

Table 10.8 Tensile Properties at Elevated Temperature for Carbon Fiber-Reinforced AvaSpire® PAEK Grades [3]

Temperature (°C)	AvaSpire® AV-621 CF30	AvaSpire® AV-651 CF30	AvaSpire® AV-722 CF30	AvaSpire® AV-848 CF30
Tensile strength at break (MPa)				
23	194	207	201	204
100	146	155	119	152
150	103	105	76	106
200	45	48	54	63
Tensile modulus (GPa)				
23	21.2	21.9	21.6	22.8
100	20.3	21.4	23.5	21.5
150	19.1	18.7	6.7	17.8
200	6.7	6.7	3.2	7.9
Tensile elongation at break (%)				
23	1.6	1.6	1.7	1.4
100	1.6	1.6	1.8	1.2
150	1.6	1.7	2.9	1.4
200	4.1	3.7	2.8	2.8

Table 10.9 Tensile Properties at Elevated Temperature for Wear-Resistant Solvay Advanced Polymers AvaSpire® PAEK Grades [3]

Temperature (°C)	AvaSpire® AV-722 SL30	AvaSpire® AV-742 SL30	AvaSpire® AV-755 SL45
Tensile strength at break (MPa)			
23	152	149	174
100	105	106	137
150	68	69	79
200	40	46	60
Tensile modulus (GPa)			
23	14.7	13.9	34.5
100	12.7	11.7	18.3
150	7.9	6.9	12.8
200	2.4	2.7	6.5
Tensile elongation at break (%)			
23	2.0	1.8	0.9
100	2.7	2.3	2.5
150	5.2	4.5	3.4
200	7.7	6.4	4.6

Table 10.10 Compressive Yield Strength of AvaSpire® PAEK at Various Temperatures [4]

AvaSpire® Grade	Compressive Yield Strength (MPa)			
	23°C	100°C	150°C	200°C
AV-621 NT	102	77.7	55.7	23.9
AV-621 CF30	150	109	79.7	37.8
AV-722 BG20	114	76.6	48.3	18.7
AV-722 CF30	169	124	73.0	42.5
AV-722 SL30	106	75.8	47.9	26.8
AV-742 SL30	121	91.7	59.0	32.8

- AvaSpire® AV-621—Highest performing unreinforced AvaSpire grade, tough, better ductility, and higher HDT than comparable PEEK, low melt flow for extrusion and injection molding
- AvaSpire® AV-650 GF30—30% Glass fiber, better dimensional stability than AV-621, high melt flow for injection molding
- AvaSpire® AV-651 GF30—30% Glass fiber, better chemical resistance than AV-621, high melt flow for injection molding
- AvaSpire® AV-651 CF30—30% Carbon fiber, high melt flow for injection molding
- AvaSpire® AV-621 GF30—30% Glass fiber, low melt flow for extrusion and injection molding
- AvaSpire® AV-621 CF30—30% Carbon fiber, low melt flow for extrusion and injection molding

AV-700 Series: Lower Cost Alternative

Key features:

- Comparable strength and stiffness to PEEK
- Equal or better chemical resistance than PEEK
- Very good friction and wear properties
- Up to 30% lower cost
- AvaSpire® AV-722—Low melt flow for extrusion and injection molding reinforced grades
- AvaSpire® AV-722 CF30—30% Carbon fiber, low melt flow for extrusion and injection molding
- AvaSpire® AV-750 GF40—40% Glass fiber, high melt flow for injection molding wear-resistant grades

Table 10.11 Elevated Temperature Flexural Properties of AvaSpire® PAEK [5]

Grade	Temperature (°C)			
	23	100	150	200
Flexural strength (MPa)				
AV-621 NT	137	110	72	18
AV-621 GF30 BG20	256	205	150	56
Flexural modulus (GPa)				
AV-621 NT	3.28	2.98	2.63	0.58
AV-621 GF30 BG20	8.96	8.40	7.90	2.44

- AvaSpire® AV-722 SL30—Very good wear resistance, dry and lubricated, low melt flow for extrusion and injection molding
- AvaSpire® AV-742 SL30—Very good wear resistance, dry and lubricated, high melt flow for injection molding
- AvaSpire® AV-755 SL45—Very good wear resistance, lubricated, high load bearing, high melt flow for injection molding

10.1.5 Blends

Polybenzimidazole (PBI) is a unique and highly stable linear heterocyclic polymer that is often

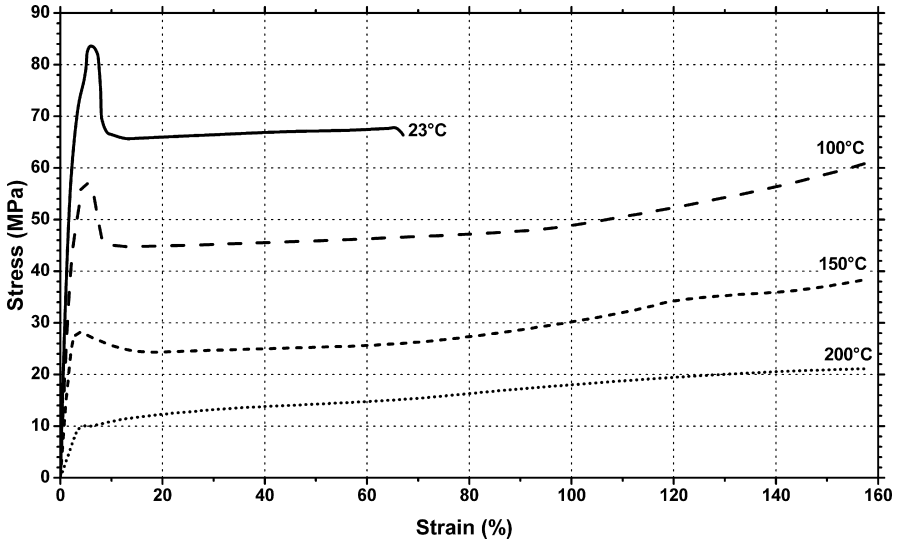


Figure 10.37 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-621 NT unreinforced PAEK [3].

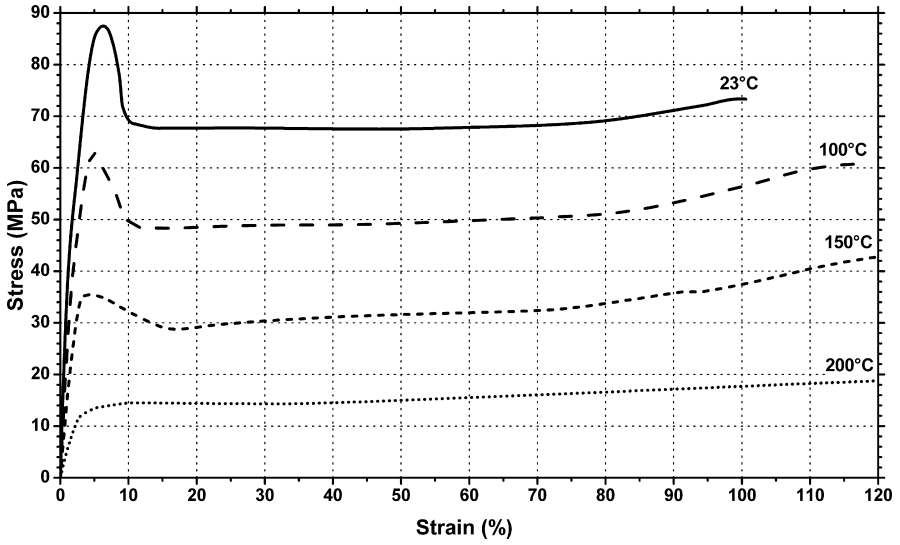


Figure 10.38 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-651 BG15 PAEK [3].

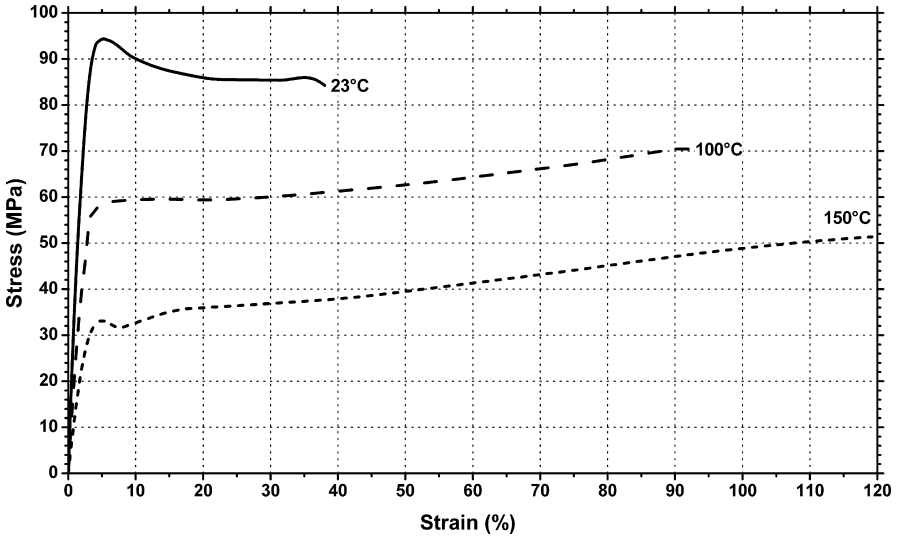


Figure 10.39 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-722 BG20 PAEK [3].

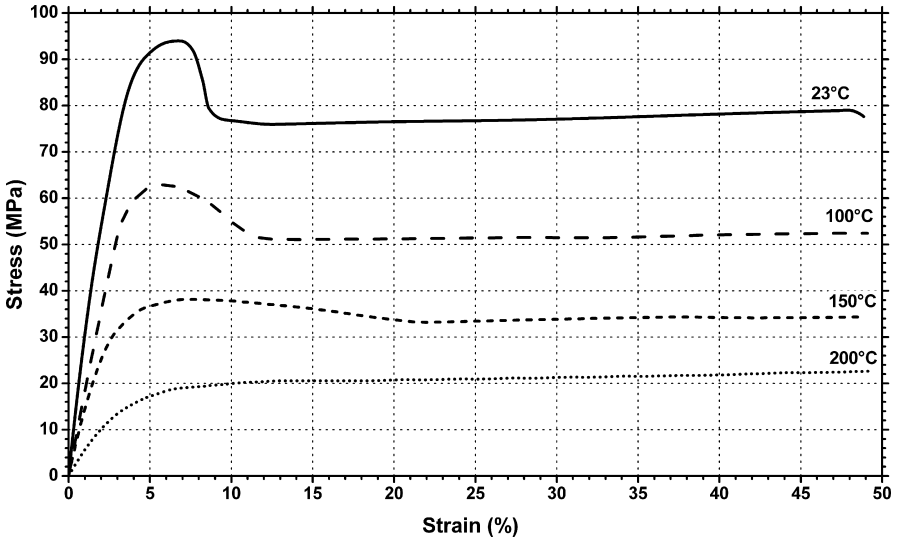


Figure 10.40 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-848 NT PAEK [3].

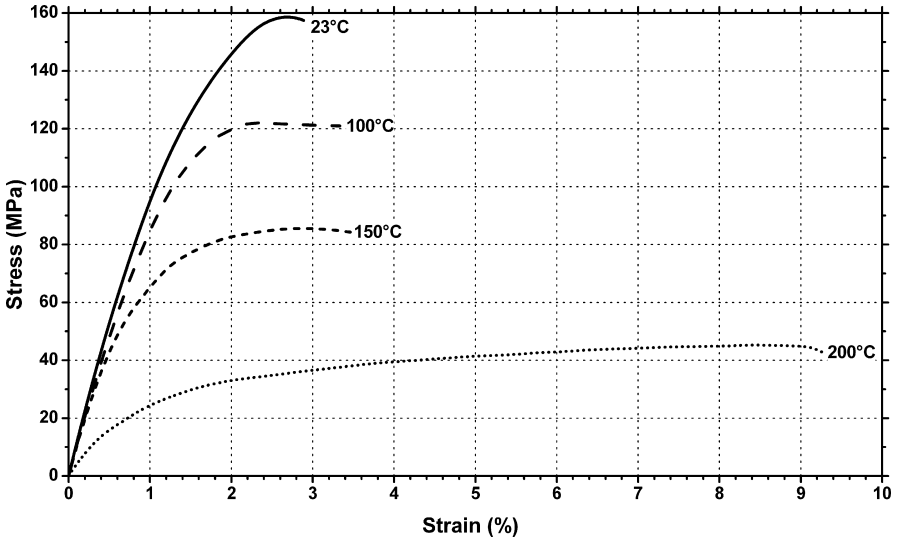


Figure 10.41 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-621 GF30—30% glass fiber PAEK [3].

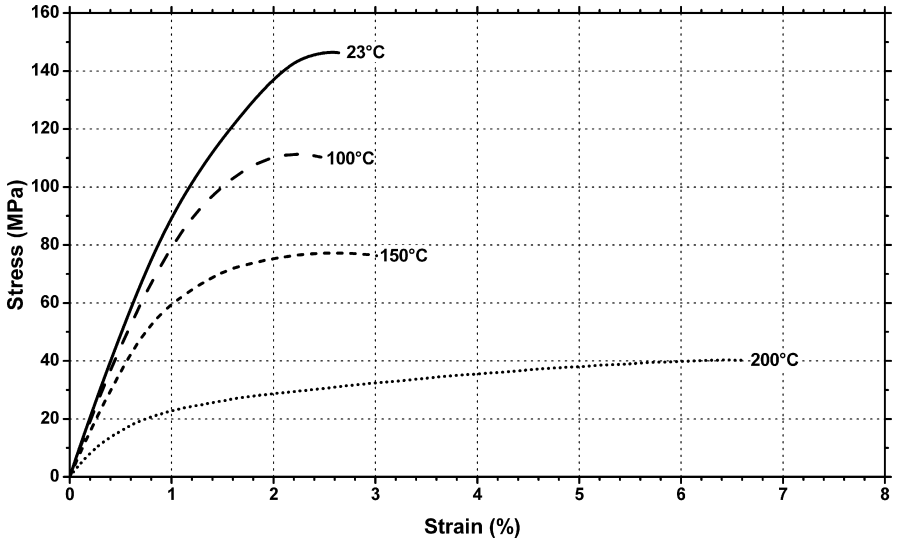


Figure 10.42 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-G51 GF30—30% glass fiber PAEK [3].

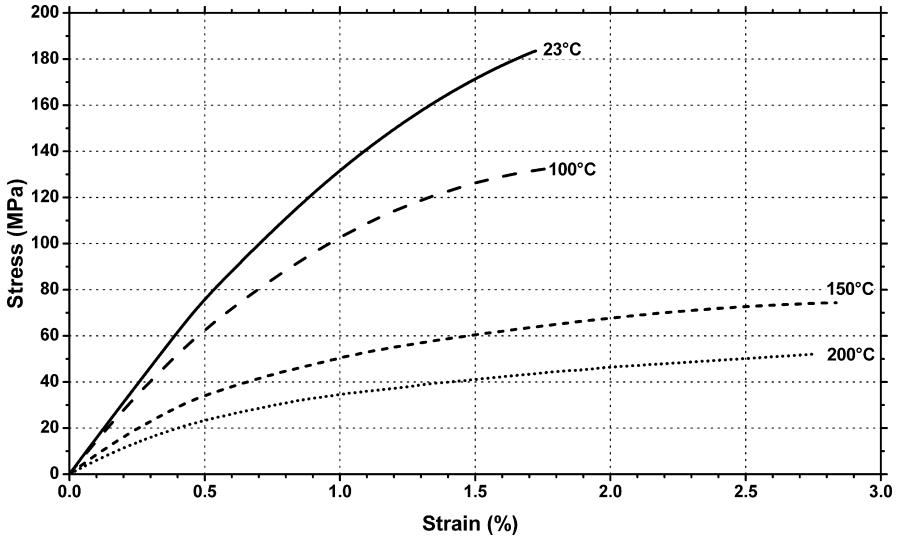


Figure 10.43 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-750 GF40—40% glass fiber PAEK [3].

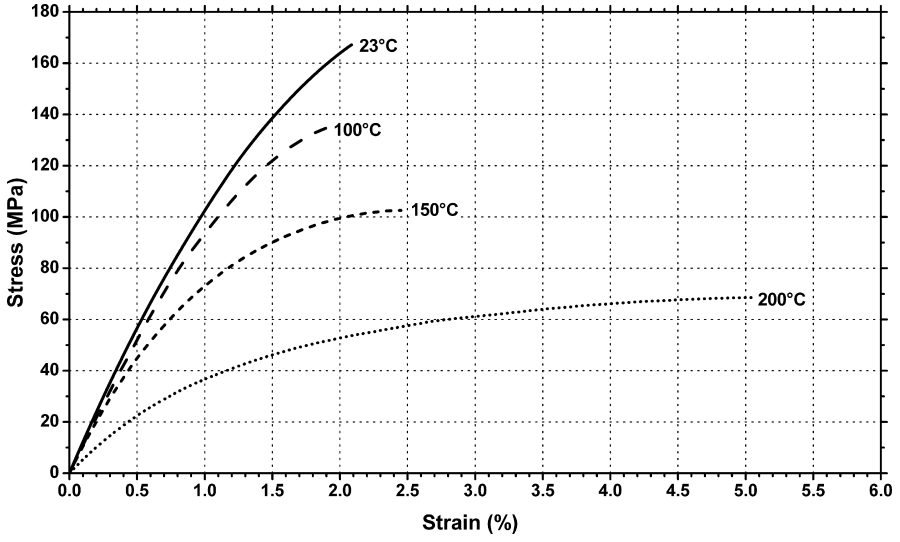


Figure 10.44 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-848 GF30—30% glass fiber PAEK [3].

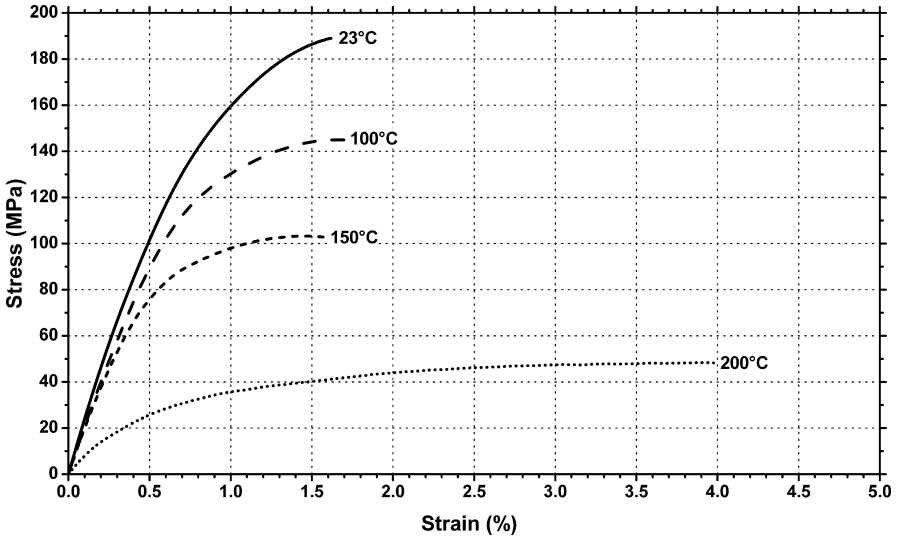


Figure 10.45 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-621 CF30—30% carbon fiber-reinforced PAEK [3].

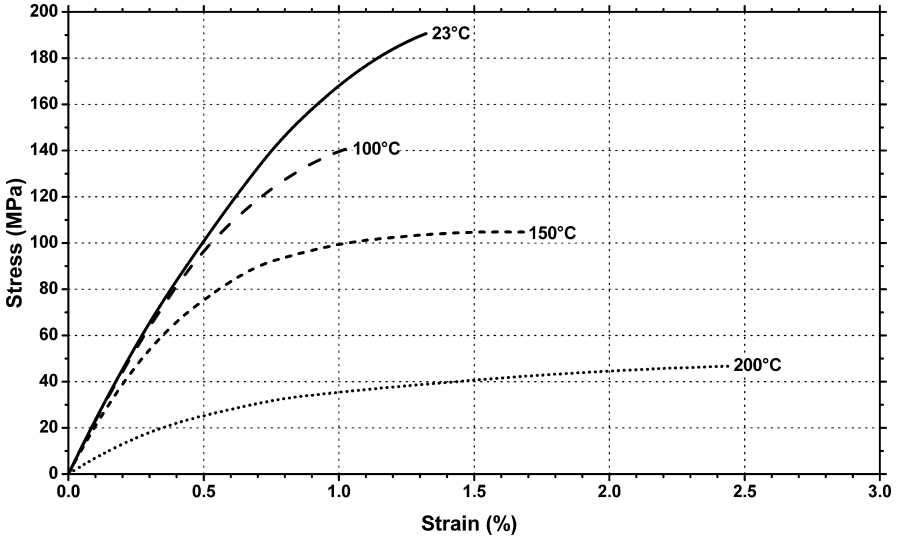


Figure 10.46 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-651 CF30—30% carbon fiber-reinforced PAEK [3].

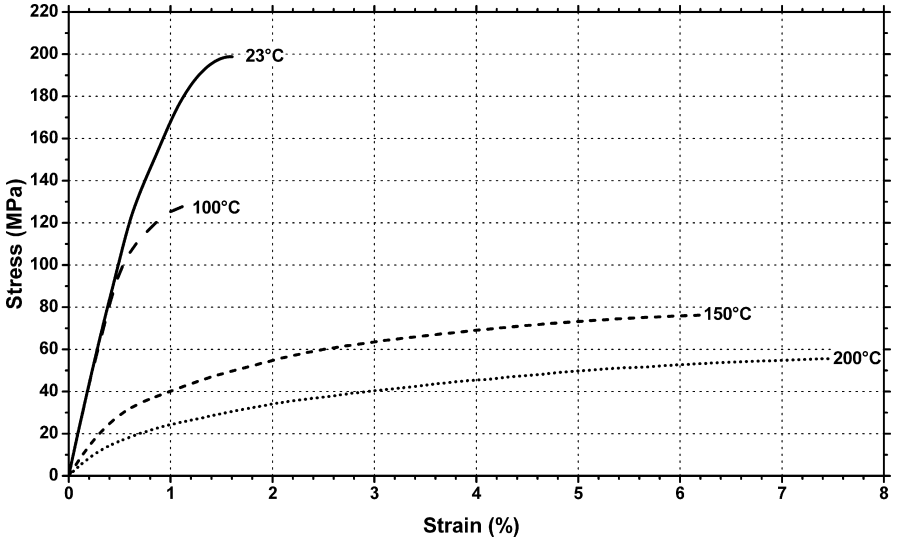


Figure 10.47 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-722 CF30—30% carbon fiber-reinforced PAEK [3].

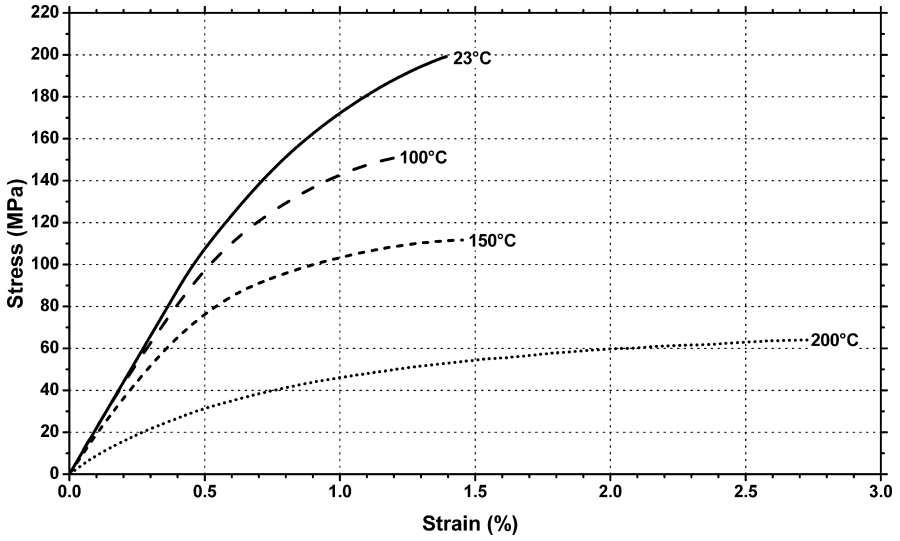


Figure 10.48 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-848 CF30—30% carbon fiber-reinforced PAEK [3].

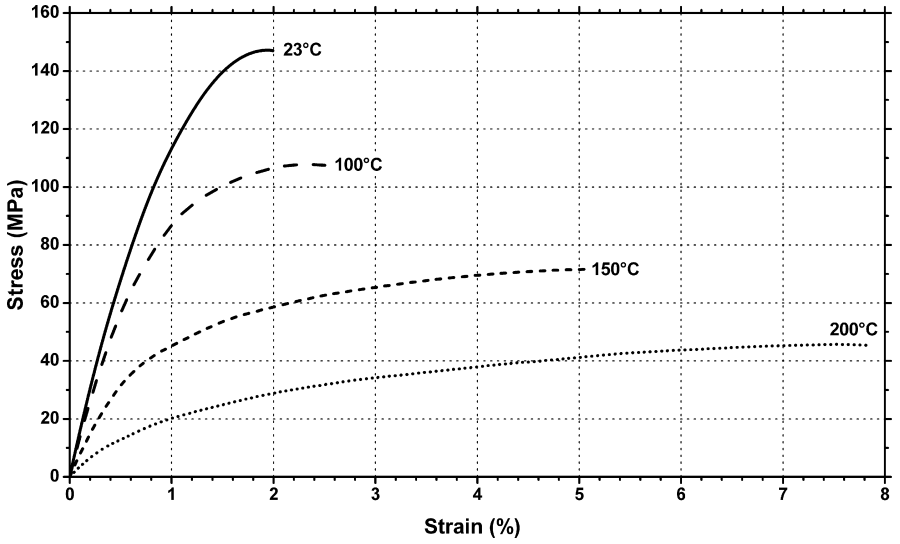


Figure 10.49 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-722 SL30 wear-resistant PAEK with carbon fiber, graphite, and PTFE [3].

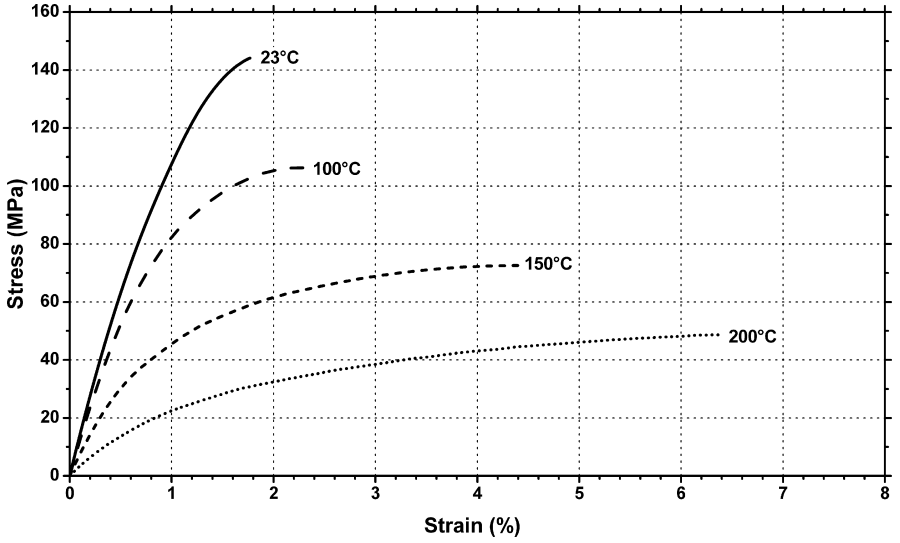


Figure 10.50 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-742 SL30 wear-resistant PAEK with carbon fiber, graphite, and PTFE [3].

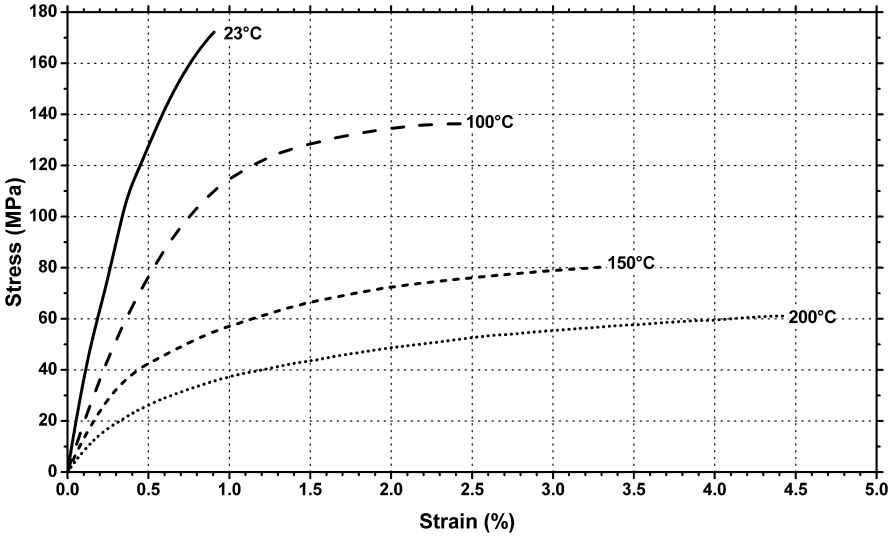


Figure 10.51 Stress vs. strain curves at various temperatures for Solvay Advanced Polymers AvaSpire® AV-755 SL45 wear-resistant PAEK with carbon fiber, graphite, and PTFE [3].

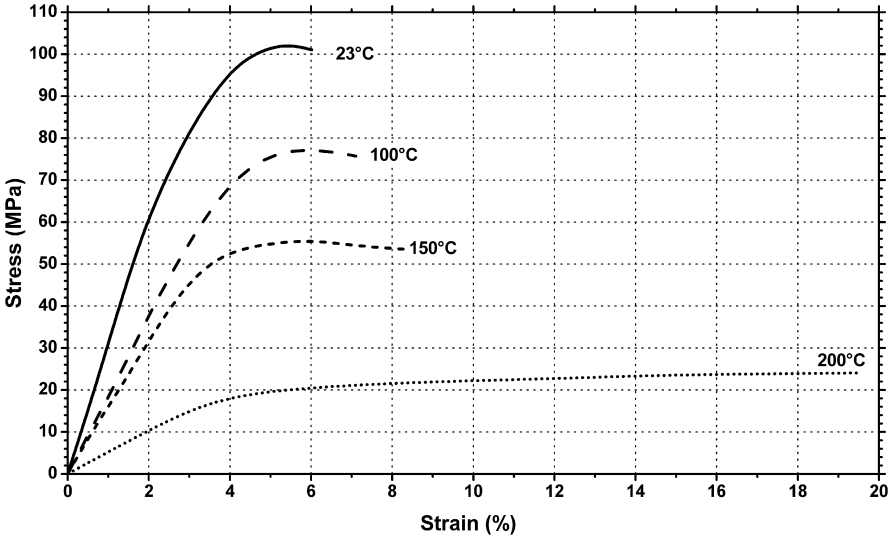


Figure 10.52 Compressive stress vs. strain curves for Solvay Advanced Polymers AvaSpire® AV-621 NT unreinforced PAEK [4].

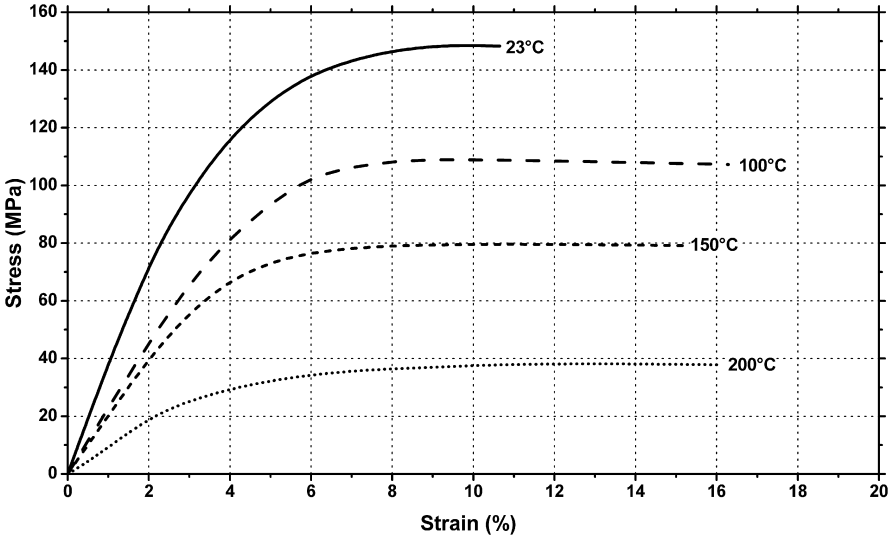


Figure 10.53 Compressive stress vs. strain curves for Solvay Advanced Polymers AvaSpire® AV-621 CF30—30% carbon fiber-reinforced PAEK [4].

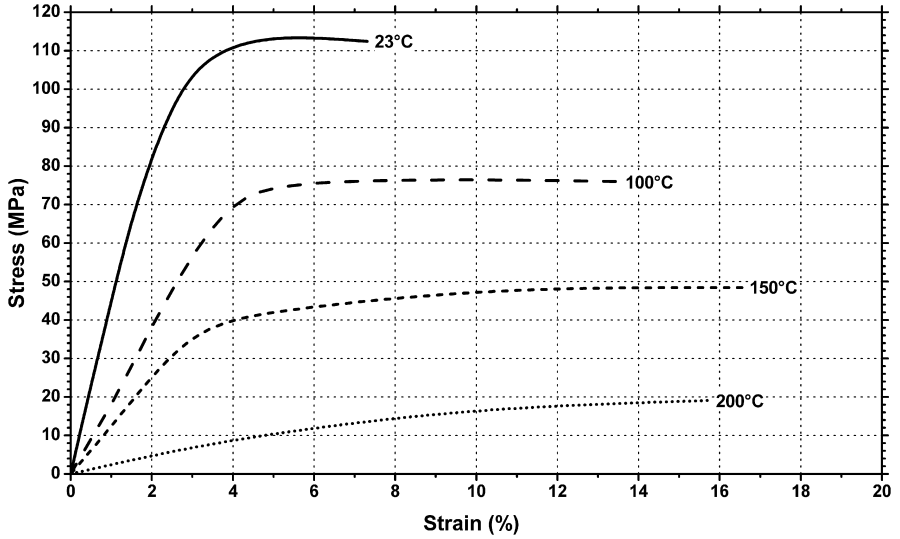


Figure 10.54 Compressive stress vs. strain curves for Solvay Advanced Polymers AvaSpire® AV-722 BG20 low melt unreinforced PAEK [4].

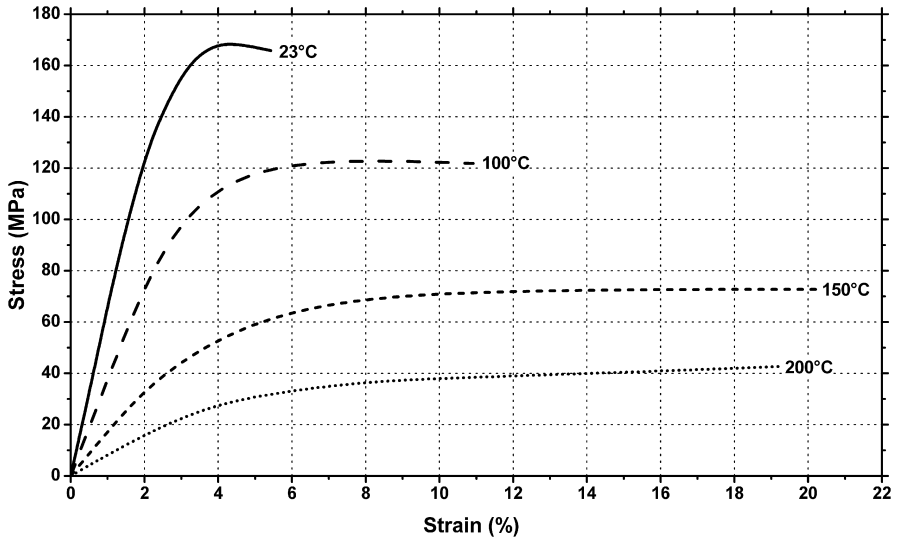


Figure 10.55 Compressive stress vs. strain curves for Solvay Advanced Polymers AvaSpire® AV-722 CF30—30% carbon fiber-reinforced PAEK [4].

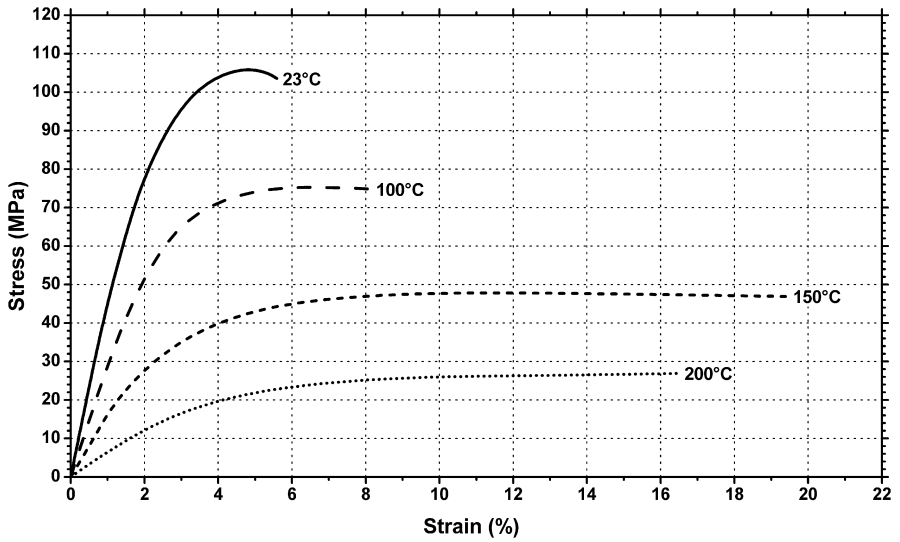


Figure 10.56 Compressive stress vs. strain curves for Solvay Advanced Polymers AvaSpire® AV-722 SL30 wear-resistant PAEK with carbon fiber, graphite, and PTFE [4].

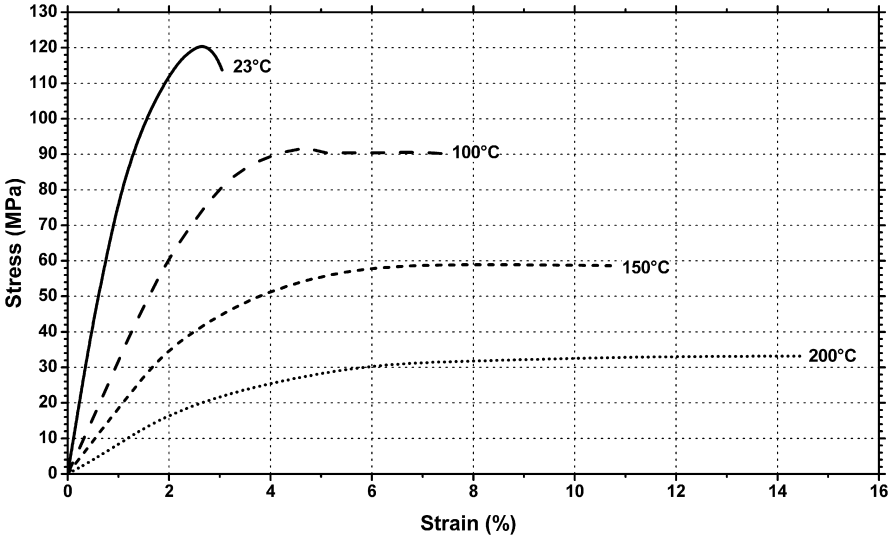


Figure 10.57 Compressive stress vs. strain curves for Solvay Advanced Polymers AvaSpire® AV-742 SL30 wear-resistant PAEK with carbon fiber, graphite, and PTFE [4].

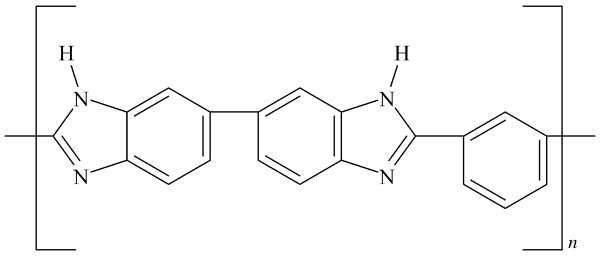


Figure 10.58 Structure of PBI.

blended with other polymers, particularly PEEK. The chemical structure is shown in Figure 10.58. PBI exhibits excellent thermal stability, resistance to chemicals, acid and base hydrolysis, and temperature resistance. PBI can withstand temperatures as high as 430°C, and in short bursts, to 760°C. PBI does not burn and maintains its properties as low as −196°C.

The data for PEEK-based blends are shown in Figures 10.59 and 10.60.

10.2 Polyethersulfone (PES)

PES is an amorphous high temperature engineering thermoplastic. Even though PES has high temperature performance, it can be processed on conventional plastics processing equipment. Its chemical structure is shown in Figure 10.61. PES has an outstanding ability to withstand exposure to elevated temperatures in air and water for prolonged periods.

Because PES is amorphous, mold shrinkage is low and it is suitable for applications requiring close tolerances and little dimensional change over a wide temperature range. Its properties include:

- Excellent thermal resistance—T_g 224°C
- Outstanding mechanical, electrical, flame, and chemical resistance
- Very good hydrolytic and sterilization resistance
- Good optical clarity
- Processed by all conventional techniques

Manufacturers and trade names: BASF Ultrason® E, Sumitomo Chemical Co., Ltd. Sumika Excel® PES, Solvay Advanced Polymers Veradel®, Radel® A.

The data for PES plastics are shown in Figures 10.62–10.87.

10.3 Polyphenylene Sulfide (PPS)

PPS is a semicrystalline material. It offers an excellent balance of properties, including high temperature resistance, chemical resistance, flowability, dimensional stability, and electrical characteristics. PPS must be filled with fibers and fillers to overcome its inherent brittleness. Because of its low viscosity, PPS can be molded with high loadings of fillers and reinforcements. Because of its outstanding flame

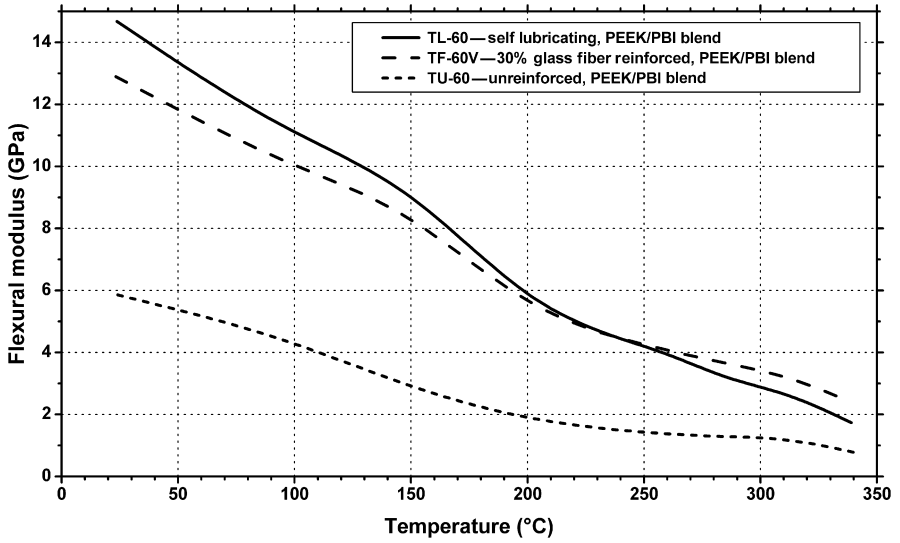


Figure 10.59 Flexural modulus vs. temperature for various Victrex® PEEK resins.

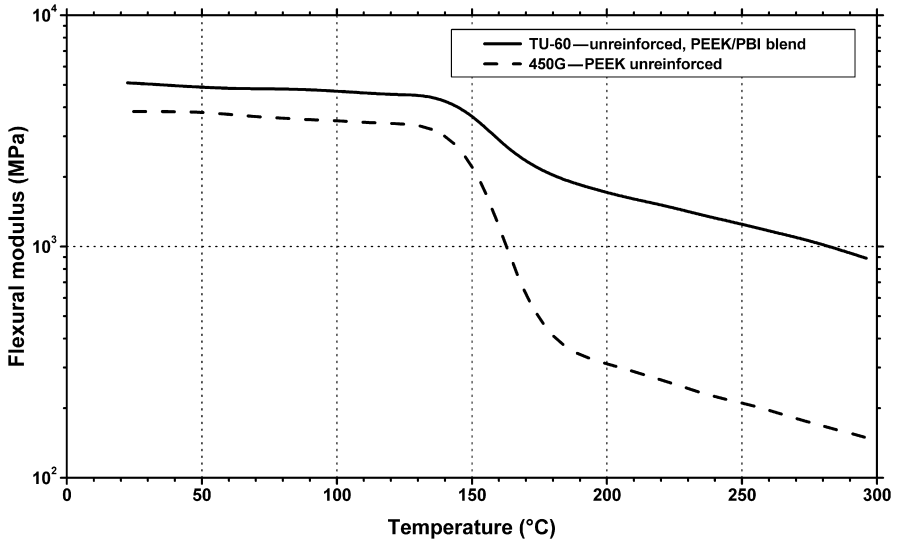


Figure 10.60 Flexural modulus vs. temperature for Victrex® PEEK resins, comparing a PBI/PEEK blend to PEEK resin.

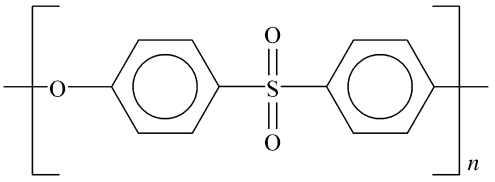


Figure 10.61 The structure of PES.

resistance, PPS is ideal for high temperature electrical applications. It is unaffected by all industrial solvents. The structure of PPS is shown in Figure 10.88. The CAS number is 26125-40-6.

There are several variants to regular PPS that may be talked about by suppliers or may be seen in the literature. They are:

- Regular PPS is of "modest" molecular weight. Materials of this type are often used in coating products.
- Cured PPS is PPS that has been heated to high temperature, above 300°C, in the presence of air or oxygen. The oxygen causes some cross-linking and chain extension called oxidative cross-linking. This results in some thermoset-like properties such as improved thermal stability, dimensional stability, and improved chemical resistance.

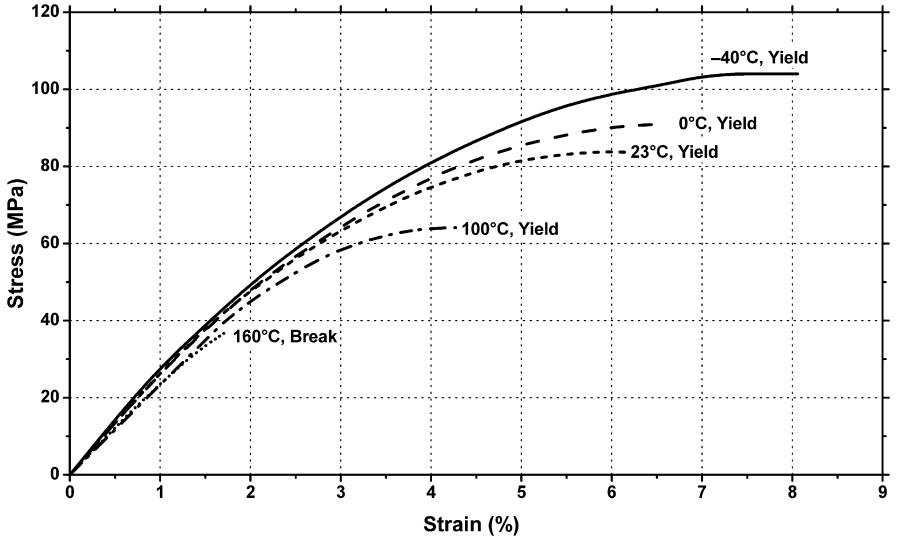


Figure 10.62 Stress vs. strain at several temperatures for BASF Ultrason® E 1010—low viscosity, unreinforced PES resin (conditioned at 50% RH).

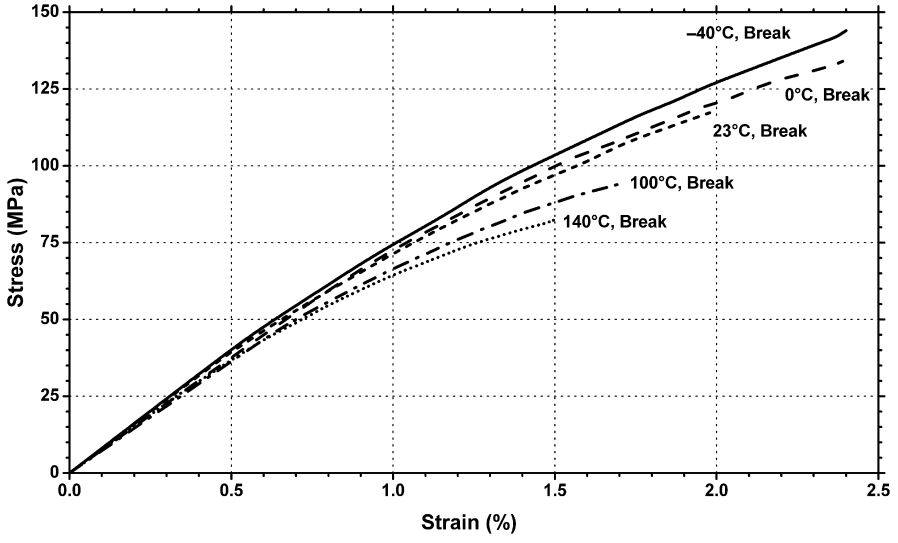


Figure 10.63 Stress vs. strain at several temperatures for BASF Ultrason® E 2010 G4—medium viscosity, 20% glass fiber-reinforced PES resin (conditioned at 50% RH).

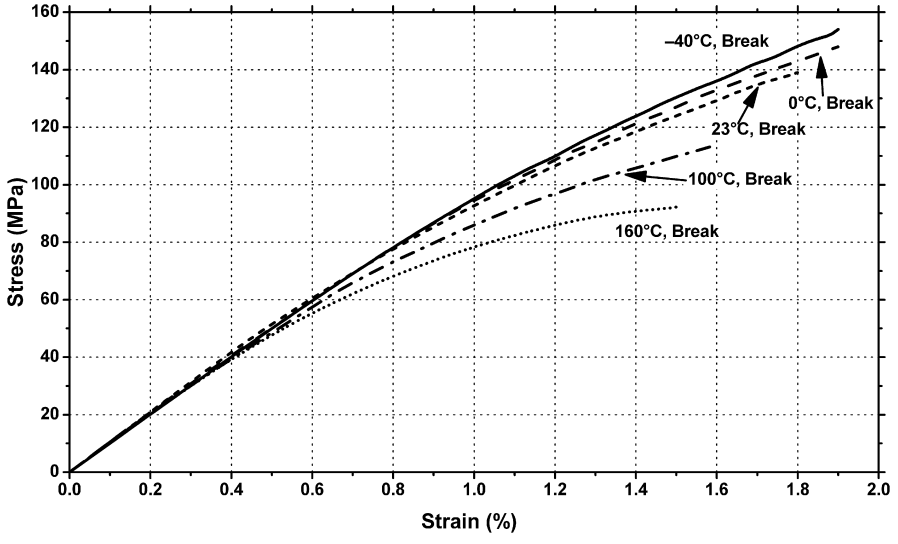


Figure 10.64 Stress vs. strain at several temperatures for BASF Ultrason® E 2010 G6—medium viscosity, 30% glass fiber-reinforced PES resin (conditioned at 50% RH).

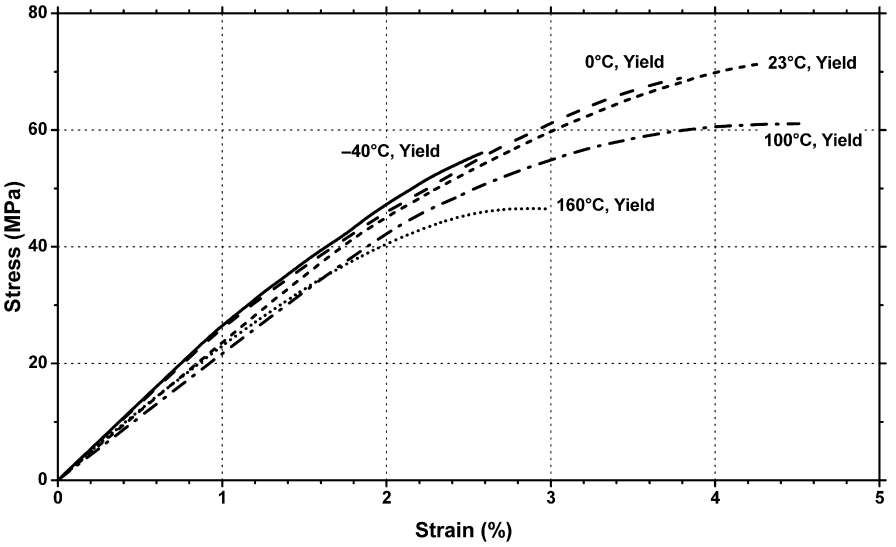


Figure 10.65 Stress vs. strain at several temperatures for BASF Ultrason® E 2010—medium viscosity, unreinforced PES resin (conditioned at 50% RH).

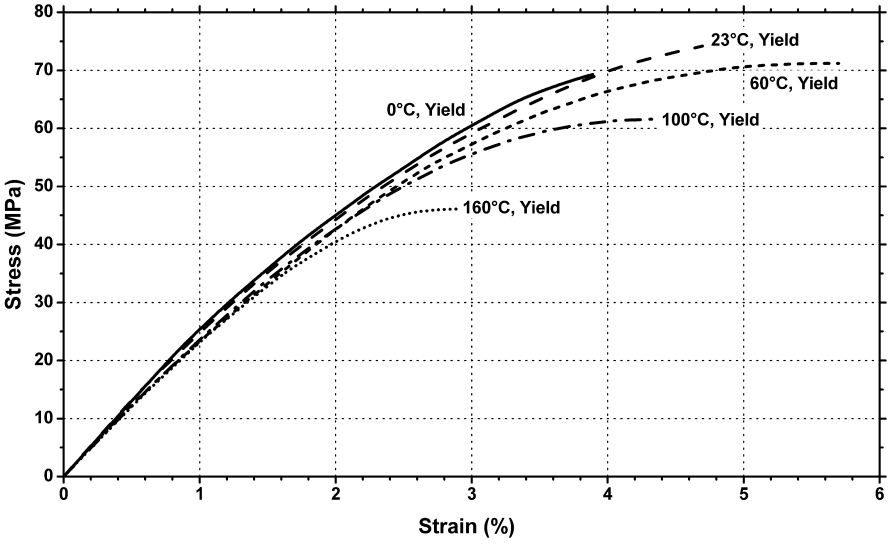


Figure 10.66 Stress vs. strain at several temperatures for BASF Ultrason® E 3010—high viscosity, unreinforced PES resin (conditioned at 50% RH).

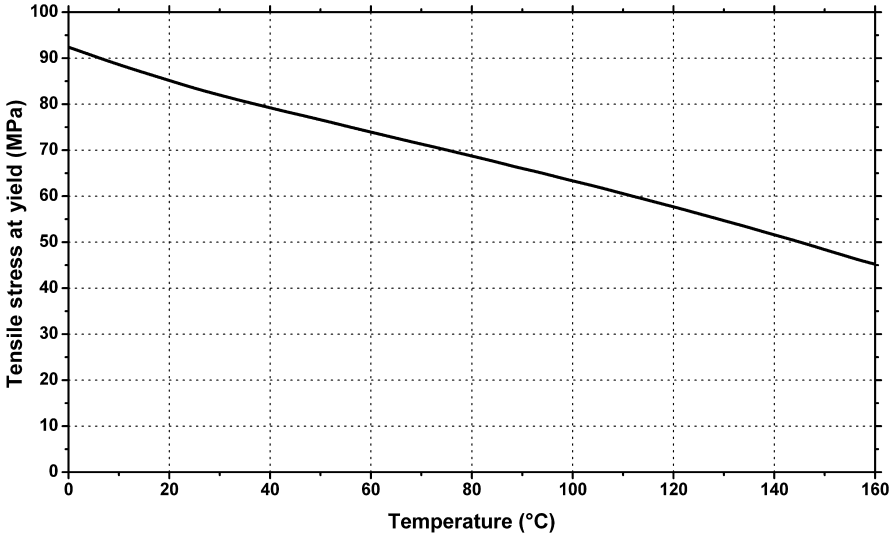


Figure 10.67 Temperature dependence of the tensile stress at yield (dry) of BASF Ultrason® E 3010 PES resin [6].

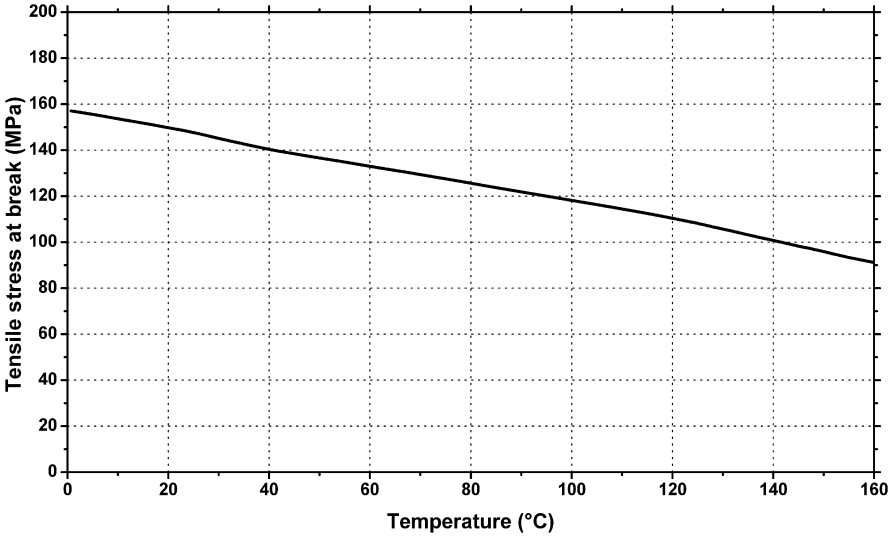


Figure 10.68 Temperature dependence of the tensile stress at break (dry) of BASF Ultrason® E 2010 G6 30% glass fiber PES resin [6].

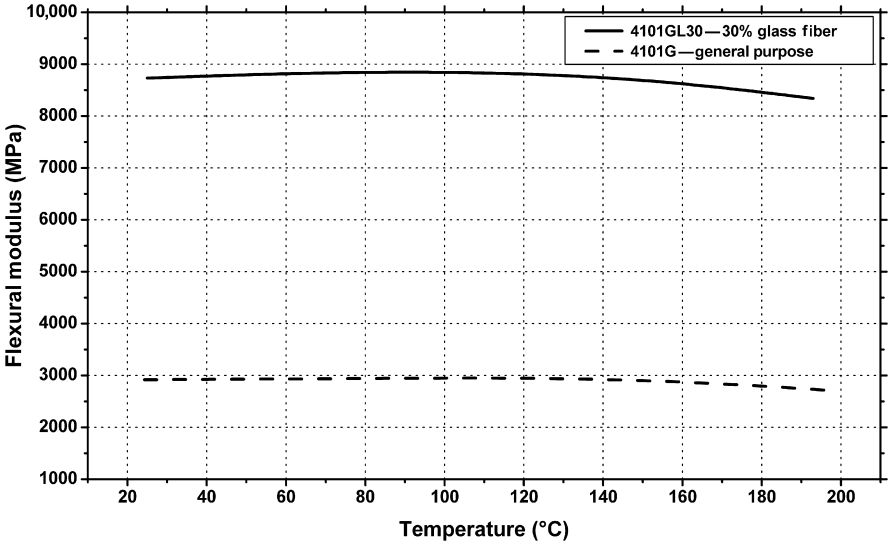


Figure 10.69 Flexural modulus vs. temperature for Sumitomo Chemical Sumika Excel® PES resins [7].

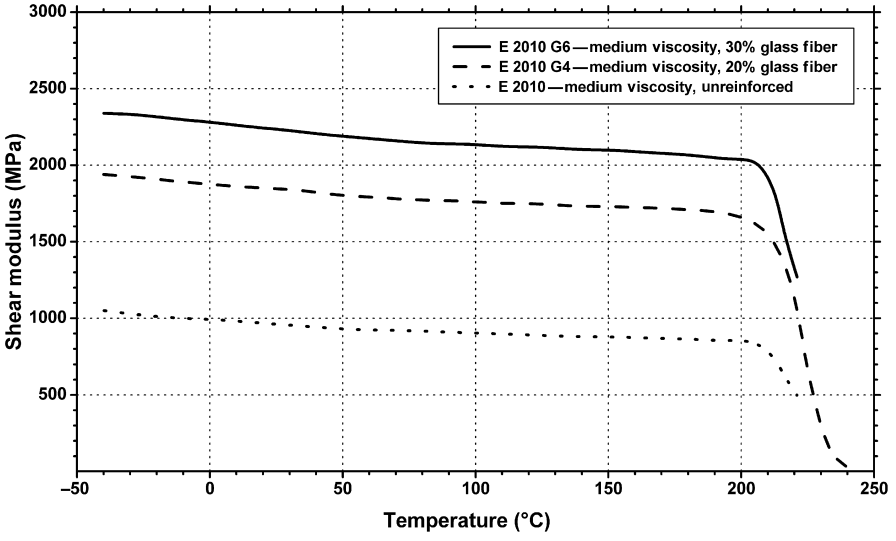


Figure 10.70 Shear modulus vs. temperature for BASF Ultrason® E 2010—medium viscosity PES resins (dry as molded).

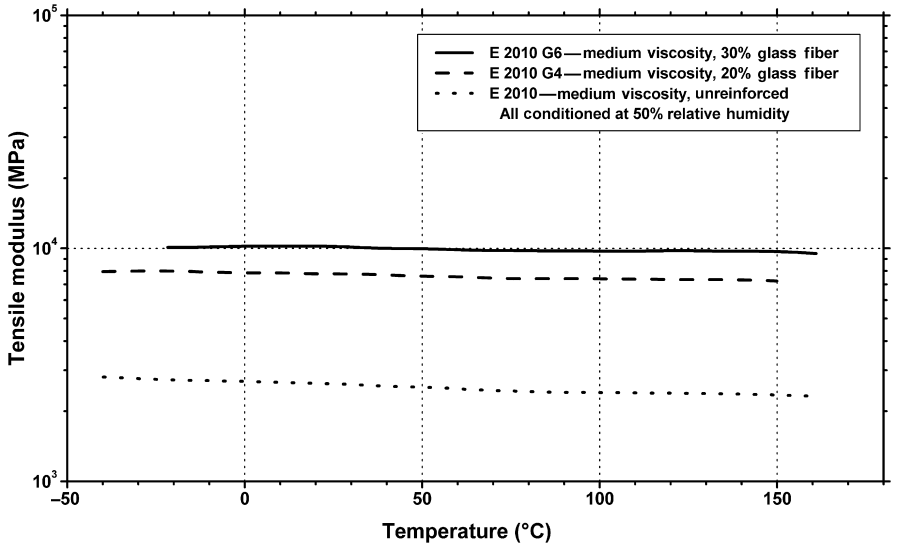


Figure 10.71 Tensile modulus vs. temperature for BASF Ultrason® E 2010—medium viscosity PES resins (conditioned at 50% RH).

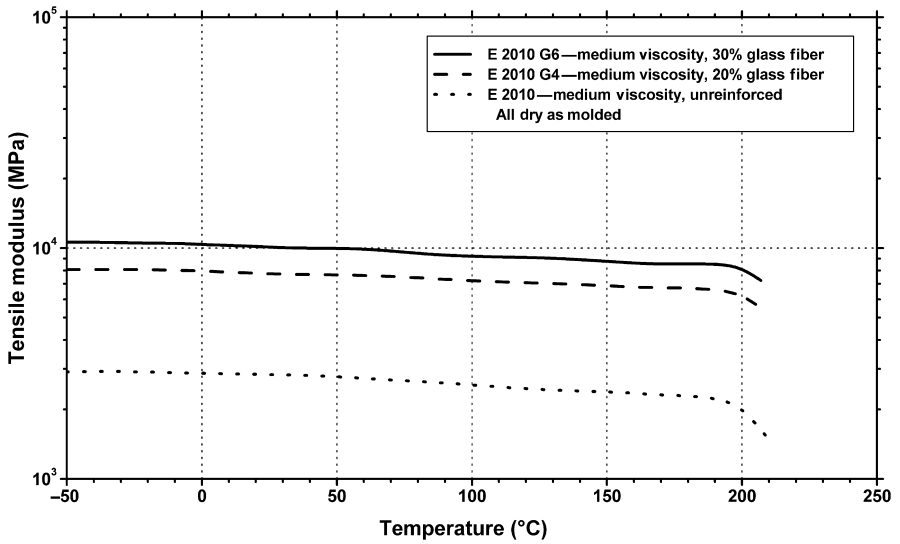


Figure 10.72 Tensile modulus vs. temperature for BASF Ultrason® E 2010—medium viscosity PES resins (dry as molded).

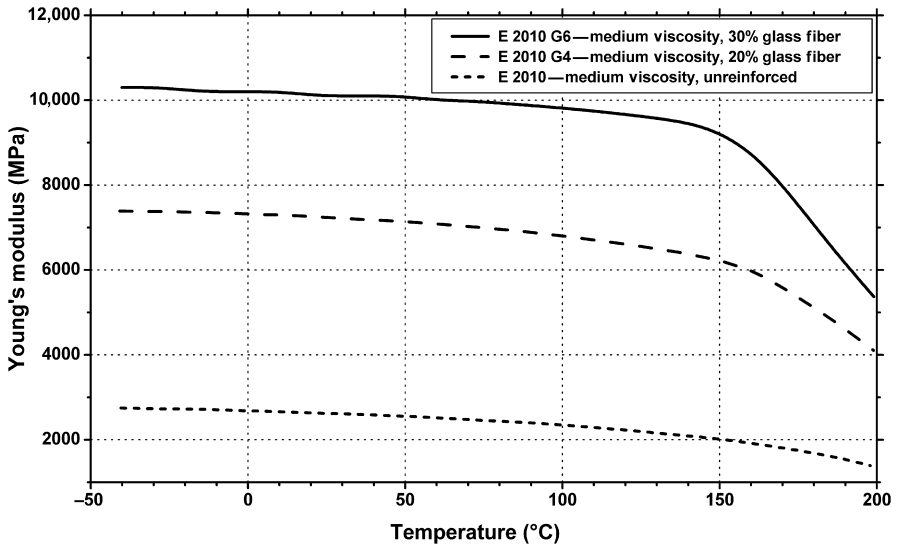


Figure 10.73 Young's modulus vs. temperature for BASF Ultrason® E 2010—medium viscosity PES resins.

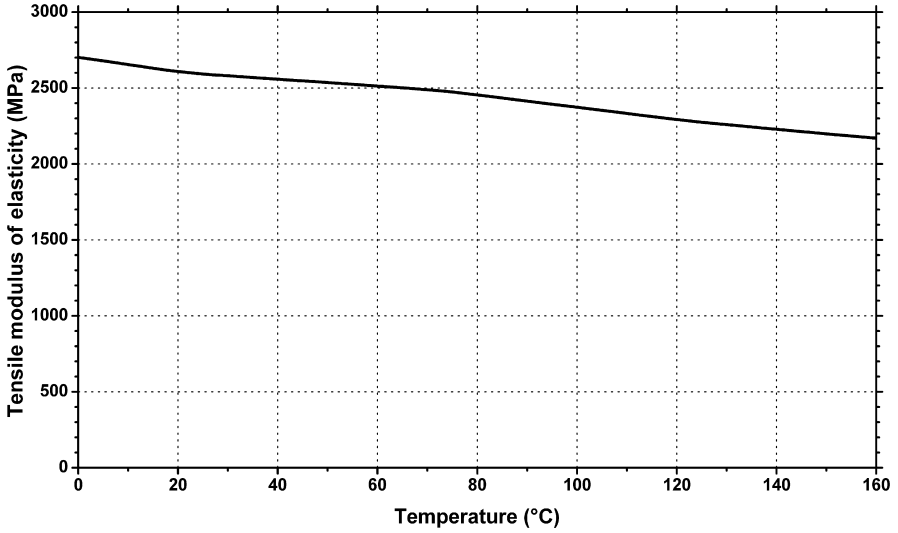


Figure 10.74 Modulus of elasticity (according to ISO 527) as a function of temperature (dry) of BASF Ultrason® E 3010 PES resin [6].

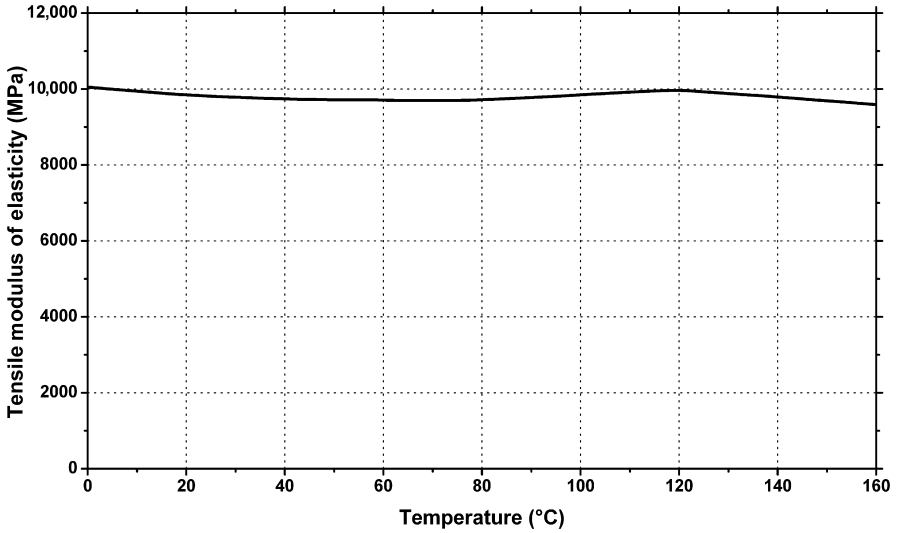


Figure 10.75 Modulus of elasticity (according to ISO 527) as a function of temperature (dry) of BASF Ultrason® E 2010 G6 30% glass fiber PES resin [6].

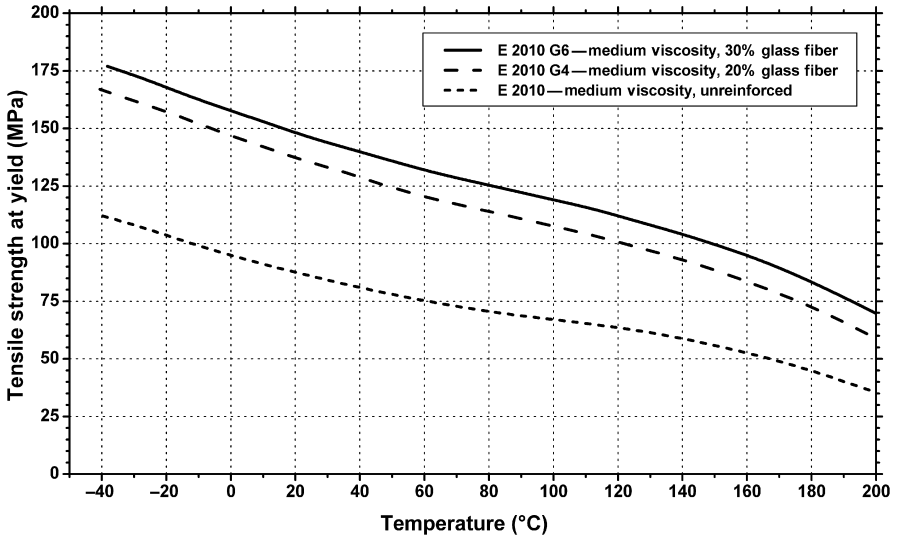


Figure 10.76 Tensile strength vs. temperature for BASF Ultrason® E 2010—medium viscosity PES resins.

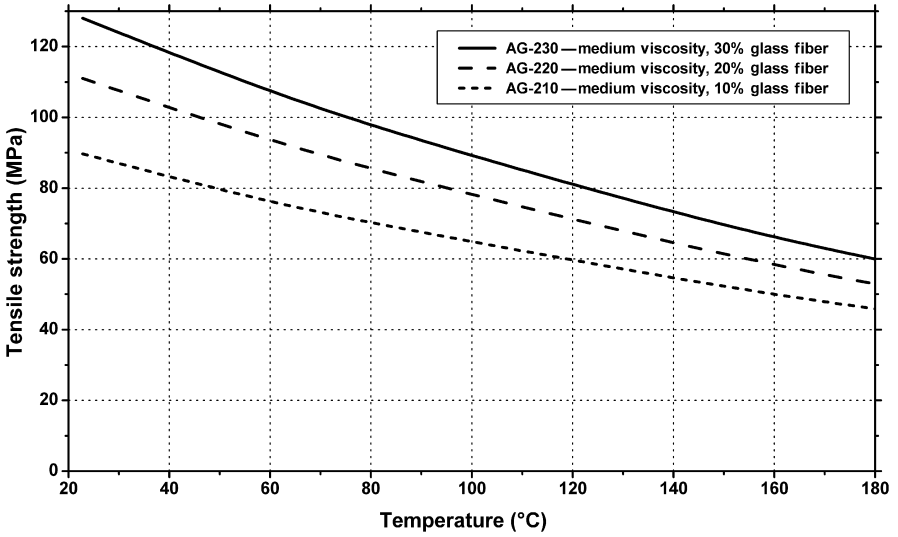


Figure 10.77 Tensile strength vs. temperature for Solvay Radel® A PES resins with different amounts of glass fiber filler.

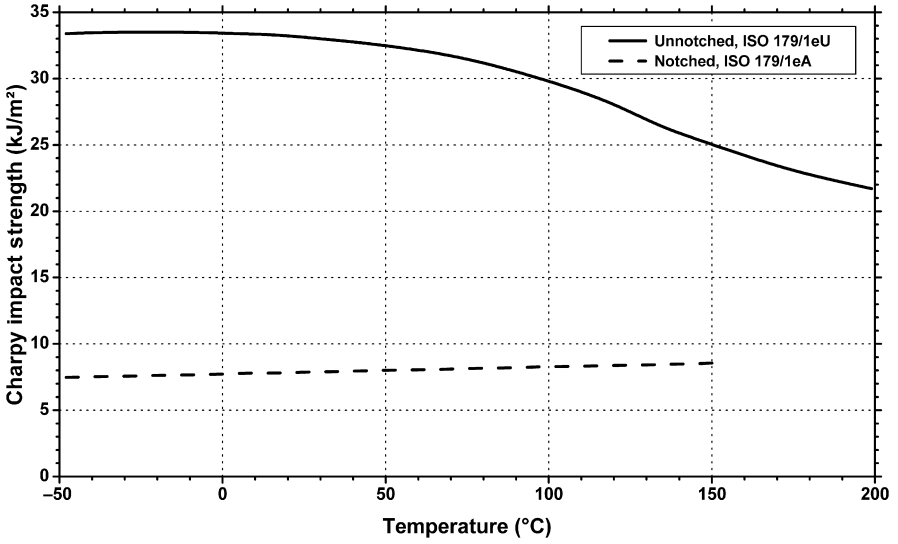


Figure 10.78 Charpy impact strength vs. temperature for BASF Ultrason® E 2010 G4—medium viscosity, 20% glass fiber-reinforced PES resins.

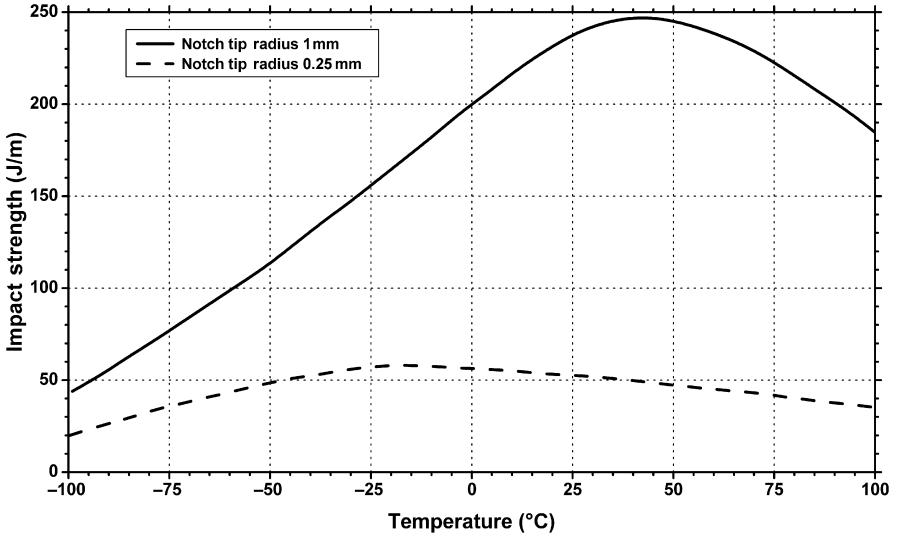


Figure 10.79 Charpy impact strength vs. temperature for Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general-purpose PES resin [7].

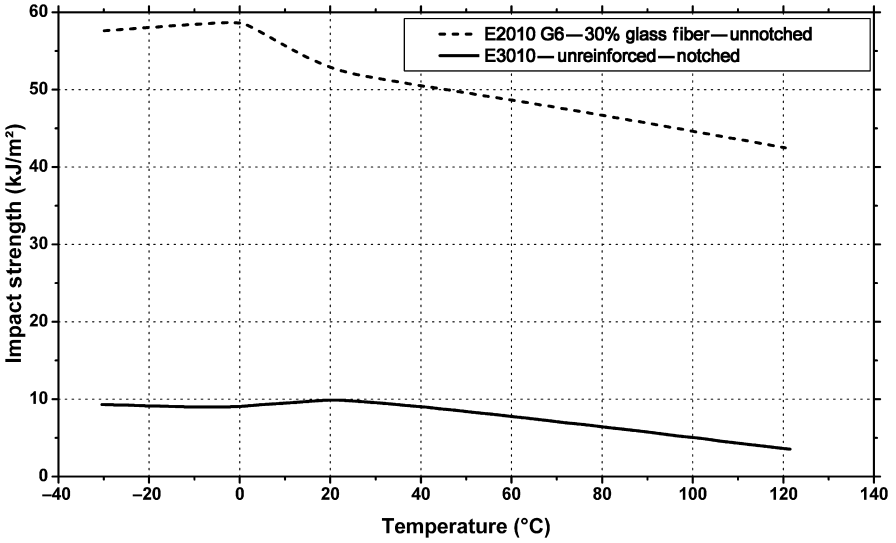


Figure 10.80 Impact strength as a function of temperature for BASF Ultrason® PES resins [6].

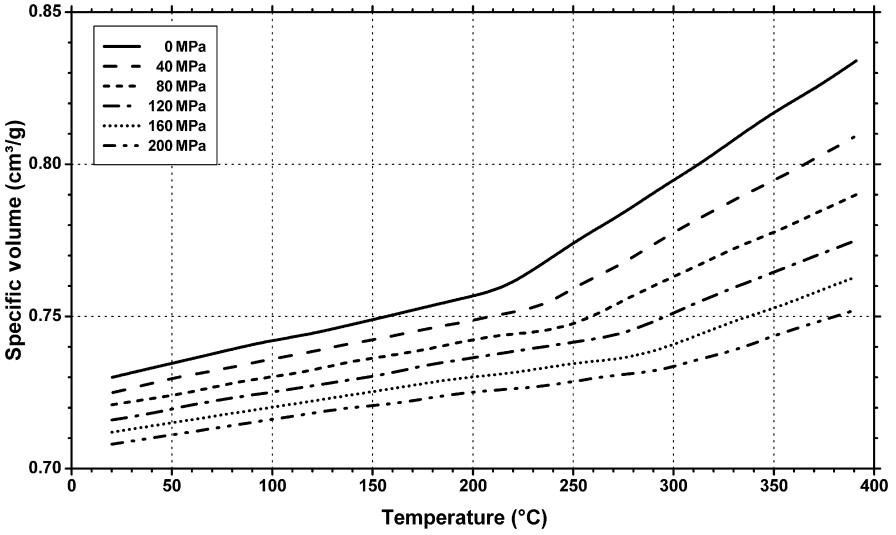


Figure 10.81 Specific volume as a function of temperature and pressure (PVT) of BASF Ultrason® E 1010—low viscosity, unreinforced PES resin.

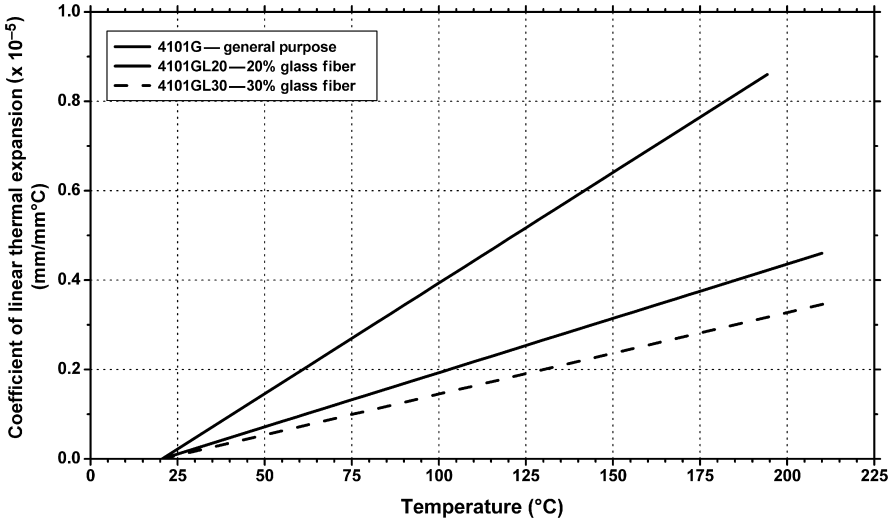


Figure 10.82 Coefficient of linear thermal expansion vs. temperature for Sumitomo Chemical Sumika Excel® PES resins.

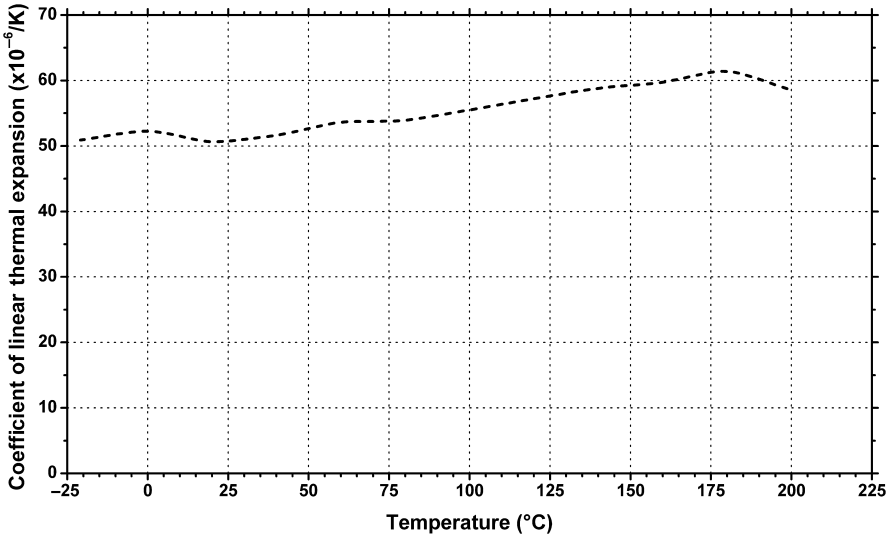


Figure 10.83 Coefficient of linear thermal expansion according to DIN 53752 of BASF Ultrason® E 2010 PES resin [6].

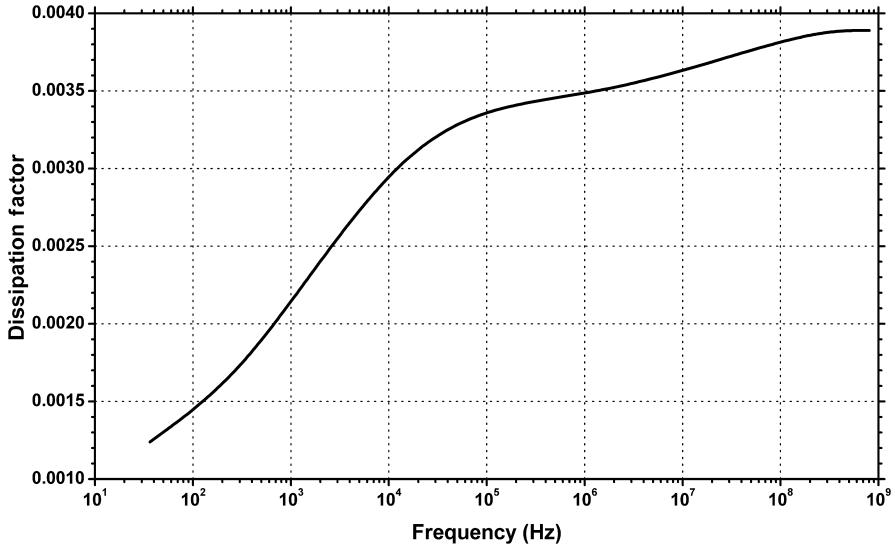


Figure 10.84 Dissipation factor vs. frequency for Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general-purpose PES resin [7].

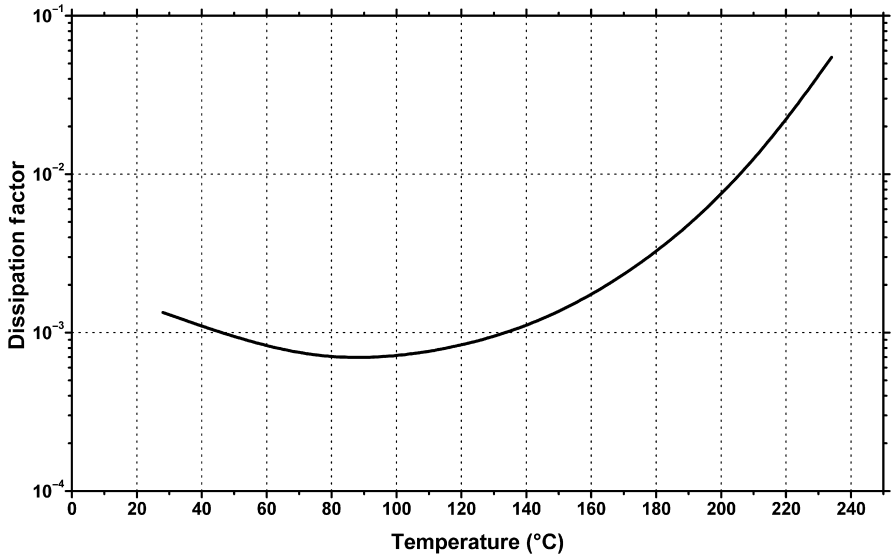


Figure 10.85 Dissipation factor vs. temperature for Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general-purpose PES resin [7].

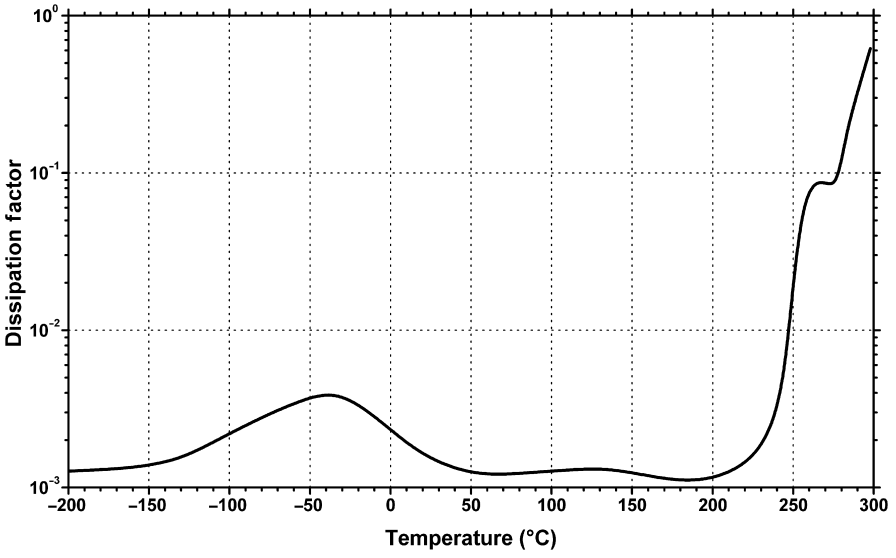


Figure 10.86 Dissipation factor vs. temperature at 1 kHz for BASF Ultrason® E 2010—medium viscosity, unreinforced PES resin [6].

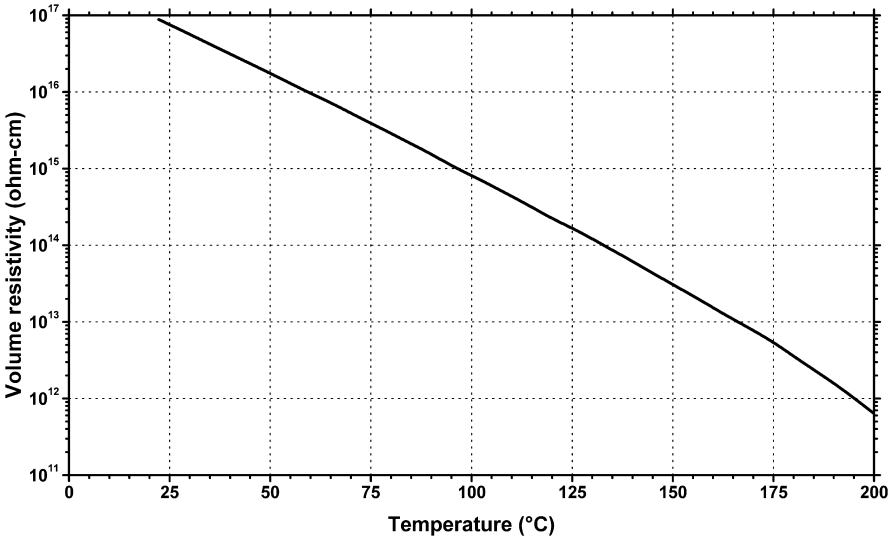


Figure 10.87 Volume resistivity vs. temperature for Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general-purpose PES resin [7].

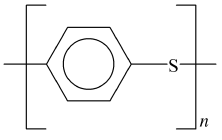


Figure 10.88 Structure of PPS.

- High molecular weight (HMW) linear PPS has a molecular weight about double of that of regular PPS. The higher molecular weight improves elongation and impact strength.
- HMW branched PPS has not only higher molecular weight than regular PPS but also polymer chain branches along the main molecule backbone. This provides improved mechanical properties.

PPS properties are summarized as follows:

- Continuous use temperature of 220°C
- Excellent dimensional properties
- Transparent
- Improved impact strength and toughness as compared to PES
- Excellent hydrolytic stability
- High stress cracking resistance
- Good chemical resistance
- Good surface release properties
- Expected continuous temperature of 180°C

Manufacturers and trade names: Dinippon Ink, Chevron Phillips Ryton®, Celanese Fortron®, Toray Torelina®.

Applications and uses: *automotive*: coolant, fuel, braking, transmission, engine, electrical and lighting components engine mounts; *electrical*: connectors, sockets, bobbins, relays, optical pickups, housings; *industrial and consumer*: hair straightener housings, hard disk drive components, chemical pumps, turbo charger air ducts, piping for downhole oilfield applications, pump and motor parts, sensors, thermostats, blower housings, hot water manifolds, nonstick cookware coatings.

The data for PPS plastics are given in Tables 10.12–10.19 and shown in Figures 10.89–10.116.

Table 10.12 Nominal Elongation at Break of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Elongation at Break in % at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	1.4	1.5	1.4	1.4	1.9	3.4	3.0
Ryton® R-4-220BL	1.4	1.4	1.4	1.4	2.0	3.3	3.0
Ryton® R-7-120BL	1.0	0.8	0.8	0.9	1.4	2.7	3.0
Ryton® R-7-220BL	1.1	1.0	1.1	1.1	1.4	2.3	2.2
Ryton® BR111BL	1.0	1.0	0.9	0.9	1.6	2.5	2.3
Ryton® BR42B	1.8	1.7	1.6	1.8	2.5	3.5	3.8
Xtel® XE5030BL	2.0	2.0	1.8	1.8	3.3	4.4	3.8
Xtel® XE4050BL	1.9	1.9	1.8	1.7	3.1	5.3	4.9
Xtel® XK2340	1.4	1.8	2.1	2.3	2.8	3.4	3.9

Note: *Test Method: ISO 527, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

Table 10.13 Nominal Flexural Modulus of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Flexural Modulus in GPa at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	15	14	16	15	11	6.0	5.0
Ryton® R-4-220BL	14	14	14	13	10	6.0	5.0
Ryton® R-7-120BL	19	19	18	17	–	7.0	6.5
Ryton® R-7-220BL	19	19	18	18	14	8.5	7.5
Ryton® BR111BL	19	19	18	18	14	7.5	6.5
Ryton® BR42B	14	14	13	13	10	6.5	5.5
Xtel® XE5030BL	10	9.0	9.0	8.5	6.0	3.5	2.0
Xtel® XE4050BL	10	9.5	8.5	8.5	6.5	3.5	2.5
Xtel® XK2340	14	12	10	9.0	7.5	6.0	5.5

Note: *Test Method: ISO 178, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

Table 10.14 Nominal Tensile Modulus of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Tensile Modulus in GPa at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	16	14	14	14	12	7.0	5.0
Ryton® R-4-220BL	15	14	14	14	11	6.0	5.5
Ryton® R-7-120BL	21	19	18	17	16	7.0	6.5
Ryton® R-7-220BL	17	17	16	16	12	8.0	7.0
Ryton® BR111BL	20	21	20	20	15	8.5	7.5
Ryton® BR42B	17	16	16	15	12	7.5	6.0
Xtel® XE5030BL	10	10	10	10	7.0	4.0	3.5
Xtel® XE4050BL	12	11	11	10	7.5	4.0	3.5
Xtel® XK2340	18	15	12	11	9.5	7.5	7.0

Note*: Test Method: ISO 527, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

Table 10.15 Nominal Flexural Strength of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Flexural Strength in MPa at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	300	280	265	245	190	110	80
Ryton® R-4-220BL	270	250	240	225	180	110	85
Ryton® R-7-120BL	240	210	200	200	175	110	80
Ryton® R-7-220BL	265	240	210	205	175	115	90
Ryton® BR111BL	250	230	210	195	165	100	75
Ryton® BR42B	310	275	250	230	180	120	85
Xtel® XE5030BL	240	195	175	165	120	75	55
Xtel® XE4050BL	255	190	170	150	115	75	55
Xtel® XK2340	275	265	220	195	175	135	110

Note*: Test Method: ISO 178, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

10.4 Polysulfone (PSU)

PSU is a rigid, strong, tough, high temperature amorphous thermoplastic. The structure of PSU is shown in Figure 10.117. Its CAS number is 25135-51-7.

Its properties are summarized as follows:

- High thermal stability
- High toughness and strength
- Good environmental stress crack resistance
- Inherent fire resistance
- Transparence

Manufacturers and trade names: Solvay Advanced Polymers Udel®, BASF Ultrason® S.

Applications and uses: analytical instrumentation, surgical and medical devices, semiconductor process equipment components.

Table 10.16 Nominal Tensile Strength of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Tensile Strength in MPa at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	195	180	160	140	105	65	45
Ryton® R-4-220BL	190	175	160	145	110	65	50
Ryton® R-7-120BL	175	135	120	120	100	70	50
Ryton® R-7-220BL	185	160	150	140	115	80	60
Ryton® BR111BL	180	155	140	125	110	70	45
Ryton® BR42B	220	190	165	155	120	75	55
Xtel® XE5030BL	160	130	110	95	75	45	35
Xtel® XE4050BL	175	130	110	95	75	50	40
Xtel® XK2340	205	195	165	140	120	90	75

Note*: Test Method: ISO 527, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

Table 10.17 Nominal Compressive Strength of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Compressive Strength in MPa at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	340	275	270	240	195	90	70
Ryton® R-7-120BL	–	260	250	275	195	110	70
Ryton® BR111BL	350	295	270	275	215	125	80
Ryton® BR42B	–	255	240	240	160	90	65
Xtel® XE5030BL	275	205	–	–	110	55	–
Xtel® XE4050BL	275	190	–	–	105	55	–
Xtel® XK2340	320	255	–	–	140	95	–

Test Method: ASTM D695, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.

Table 10.18 Nominal Unnotched Izod Impact Strength of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Unnotched Izod Impact Strength in kJ/m^2 at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	33	35	36	37	31	30	27
Ryton® R-4-220BL	28	30	–	–	–	28	–
Ryton® R-7-120BL	15	15	14	15	15	14	15
Ryton® R-7-220BL	20	20	–	–	–	22	–
Ryton® BR111BL	22	20	20	21	19	20	18
Ryton® BR42B	37	40	39	35	36	35	30
Xtel® XE5030BL	50	45	45	43	43	37	34
Xtel® XE4050BL	41	35	32	33	33	30	27
Xtel® XK2340	26	35	31	26	27	28	27

Note*: Test Method: ISO 180/U, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

Table 10.19 Nominal Notched Izod Impact Strength of Chevron Phillips Chemical Ryton® PPS and Xtel® PPS Alloy Compounds from −40°C to 200°C [8]

Product Code	Notched Izod Impact Strength in kJ/m^2 at Temperature						
	−40°C	23°C	50°C	75°C	100°C	150°C	200°C
Ryton® R-4-200BL	7.8	8.0	8.0	8.2	8.0	9.5	13
Ryton® R-4-220BL	7.9	7.5	–	–	–	9.7	–
Ryton® R-7-120BL	5.6	5.5	5.7	6.8	5.7	6.7	6.2
Ryton® R-7-220BL	9.9	8.0	–	–	–	7.5	–
Ryton® BR111BL	8.1	6.5	5.8	8.8	4.9	7.6	6.2
Ryton® BR42B	11	9.5	9.1	10	10	14	13
Xtel® XE5030BL	7.4	9.5	10	11	12	15	17
Xtel® XE4050BL	6.2	8.0	8.6	8.7	9.0	11	12
Xtel® XK2340	9.7	8.5	9.3	10	10	13	20

Note*: Test Method: ISO 180/A, Test Specimen Molding Conditions: Melt Temperature 315–343°C; Mold Temperature 135°C.*

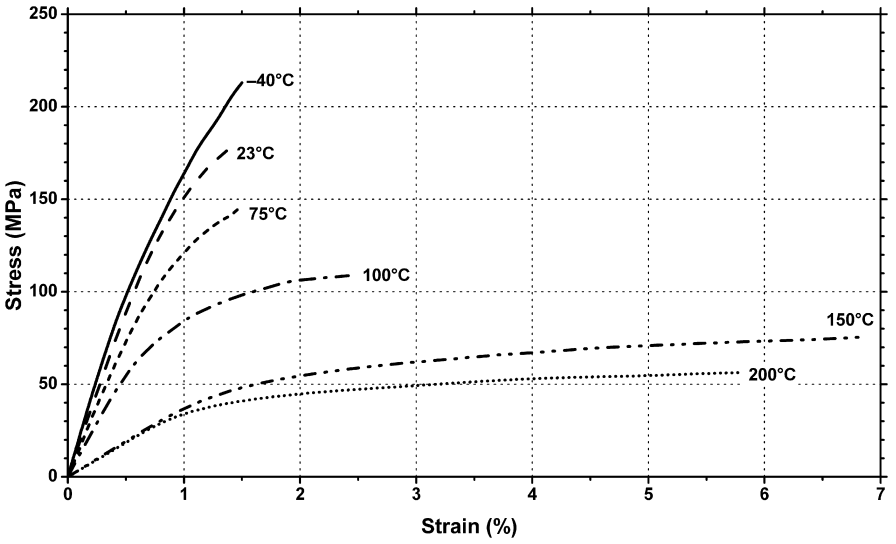


Figure 10.89 Stress vs. strain at several temperatures for Chevron Phillips Chemical Ryton® BR42B—40% glass fiber-filled, low friction PPS resin [9].

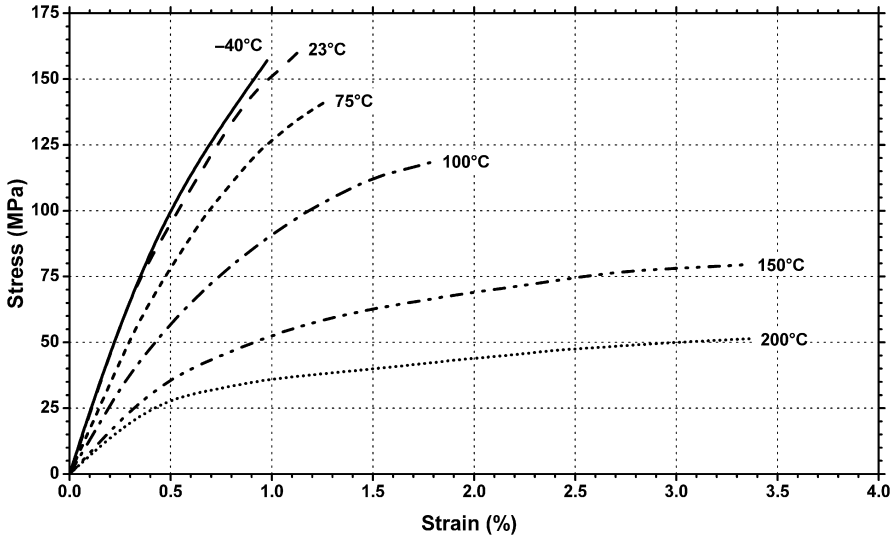


Figure 10.90 Stress vs. strain at several temperatures for Chevron Phillips Chemical Ryton® BR111—40% glass/mineral-filled PPS resin [9].

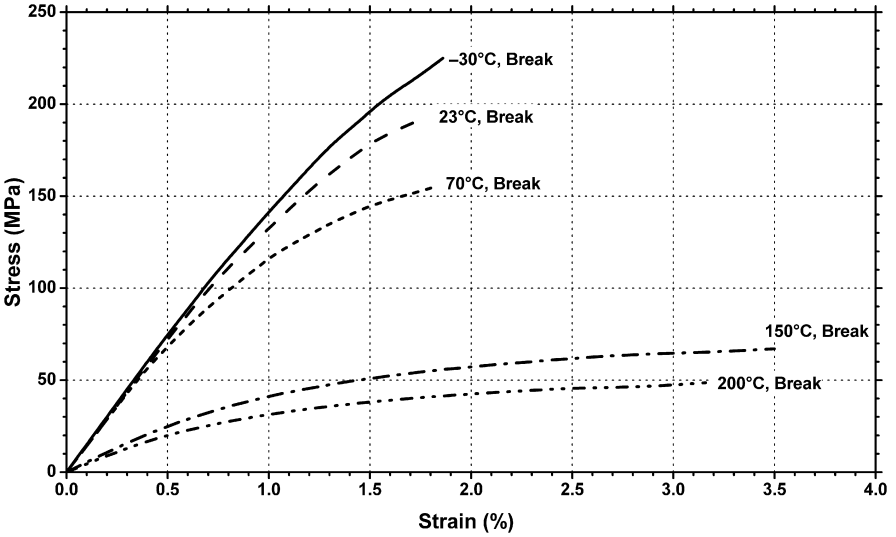


Figure 10.91 Stress vs. strain at several temperatures for Celanese Fortron® 1140L4—40% glass fiber-filled, medium melt viscosity PPS resin.

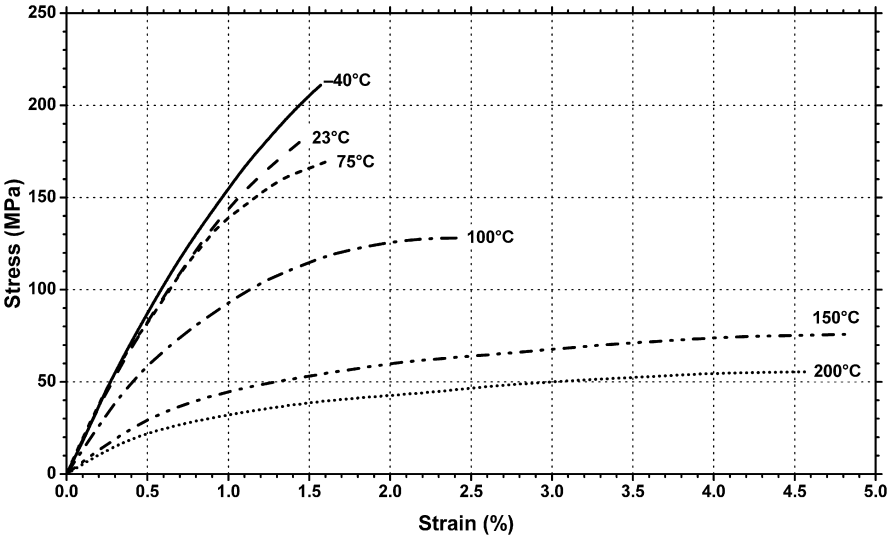


Figure 10.92 Stress vs. strain at several temperatures for Chevron Phillips Chemical Ryton® R-4-200BL—40% glass fiber-filled, high-strength PPS resin [9].

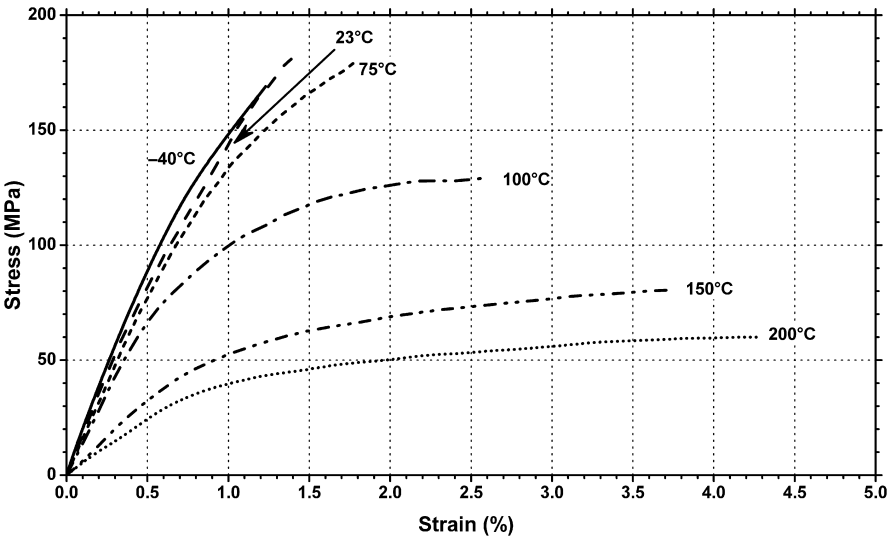


Figure 10.93 Stress vs. strain at several temperatures for Chevron Phillips Chemical Ryton® R-4-230NA—40% glass fiber-filled, high flow PPS resin [9].

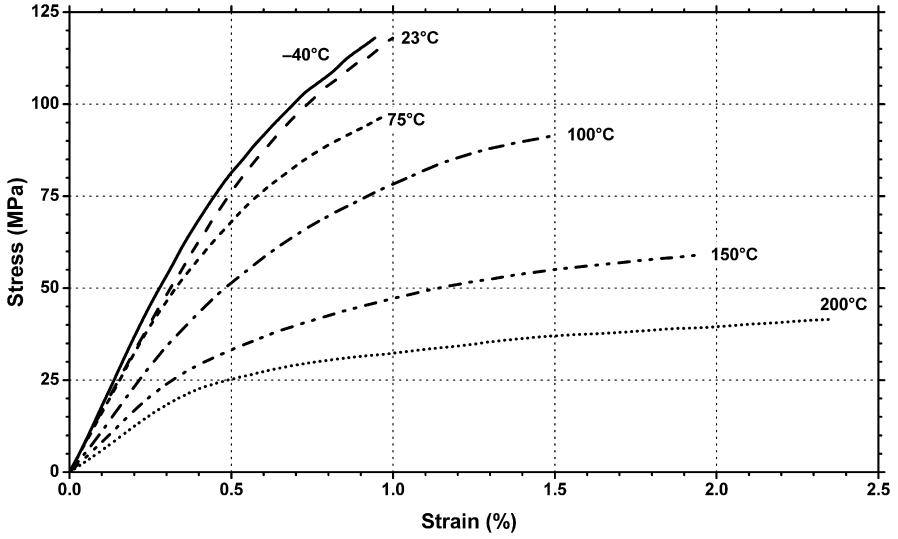


Figure 10.94 Stress vs. strain at several temperatures for Chevron Phillips Chemical Ryton® R-7-120BL—65% glass fiber/mineral-filled, arc resistant PPS resin [9].

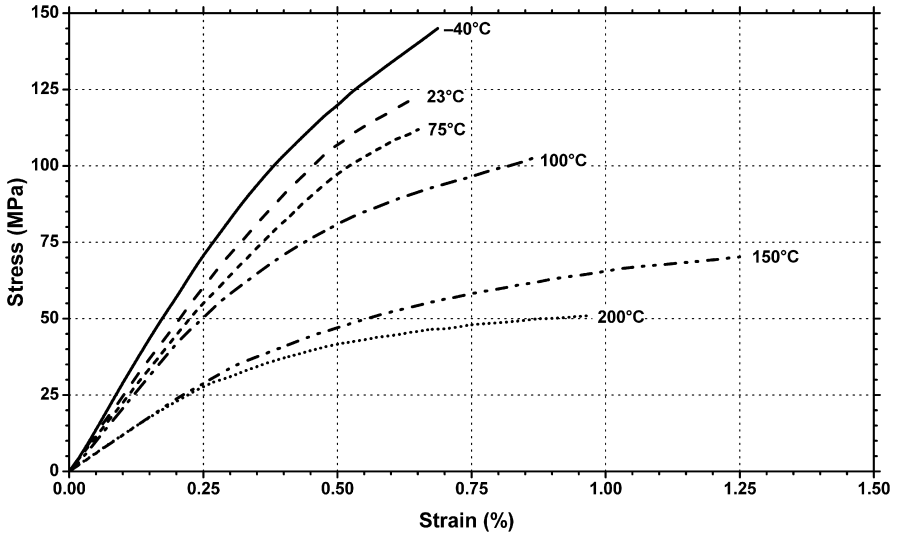


Figure 10.95 Stress vs. strain at several temperatures for Chevron Phillips Chemical Ryton® R-10-110BL—65% glass fiber/mineral-filled, lower cost PPS resin [9].

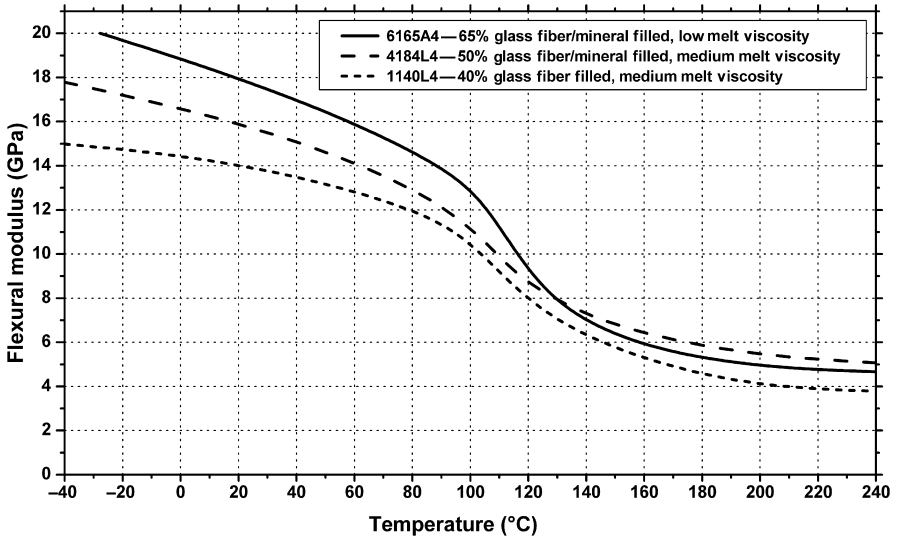


Figure 10.96 Flexural modulus vs. temperature for Celanese Fortron® glass fiber-filled PPS resins [10].

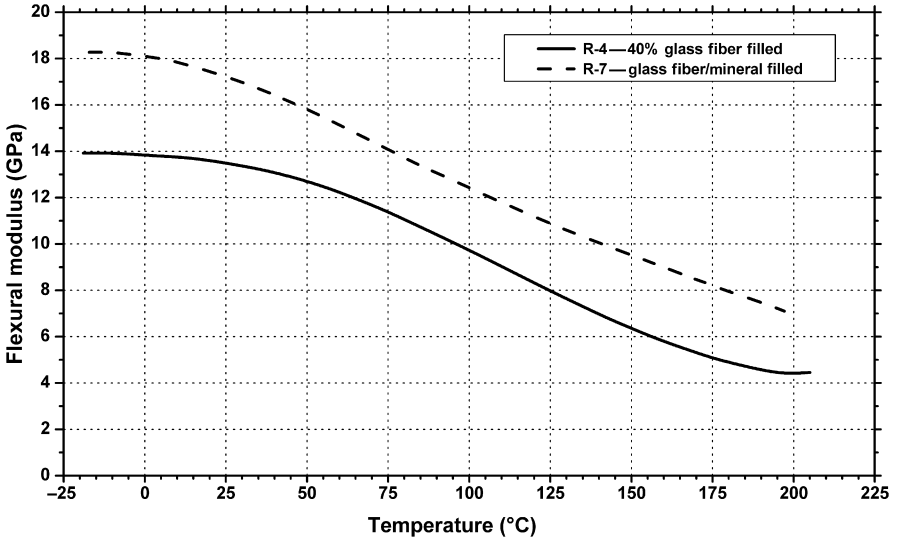


Figure 10.97 Flexural modulus vs. temperature for Chevron Phillips Chemical Ryton® PPS resins [11].

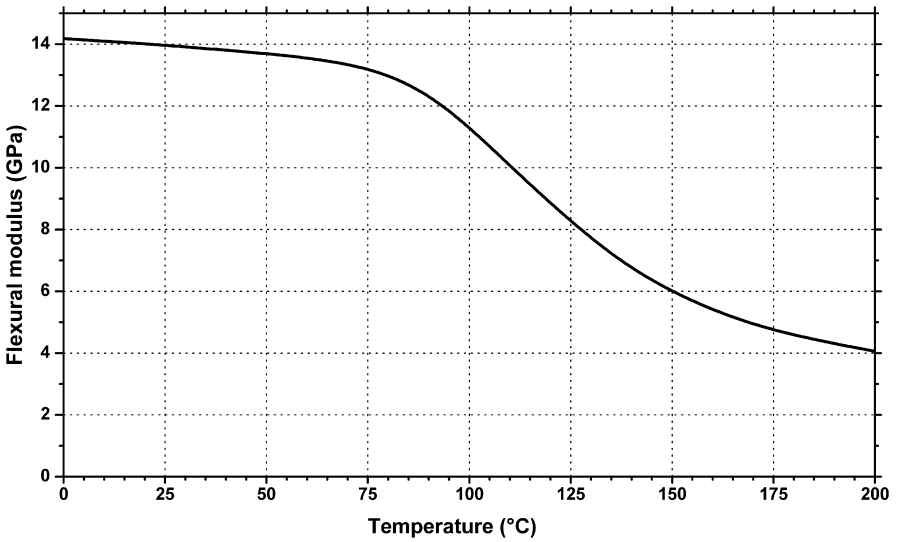


Figure 10.98 Flexural modulus vs. temperature for Toray Resin Company Torelina® A504—40% glass fiber-filled, standard grade PPS resin [12].

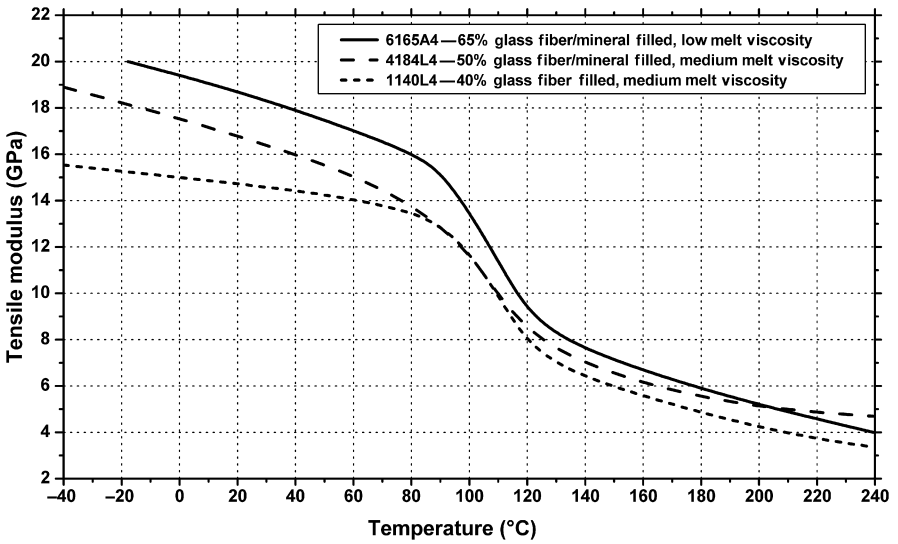


Figure 10.99 Tensile modulus vs. temperature for Celanese Fortron® filled PPS resins [10].

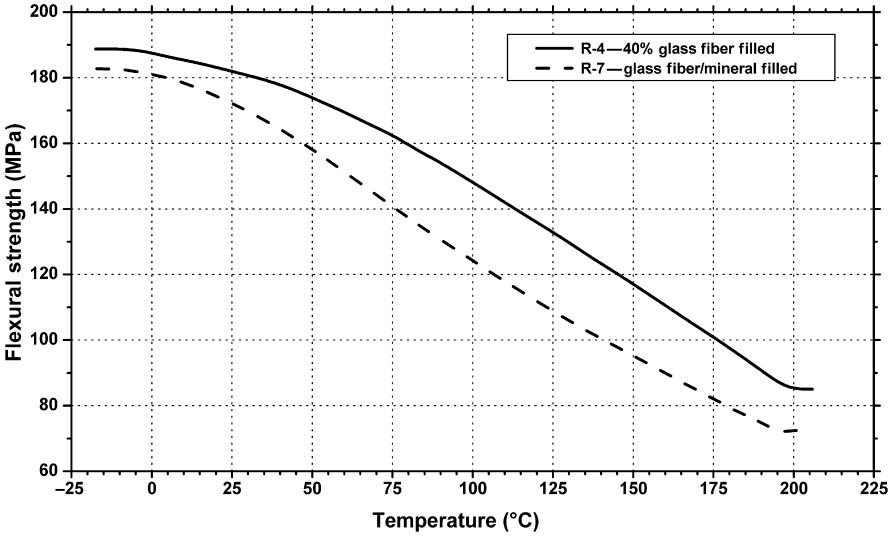


Figure 10.100 Flexural strength vs. temperature for Chevron Phillips Chemical Ryton® PPS resins [11].

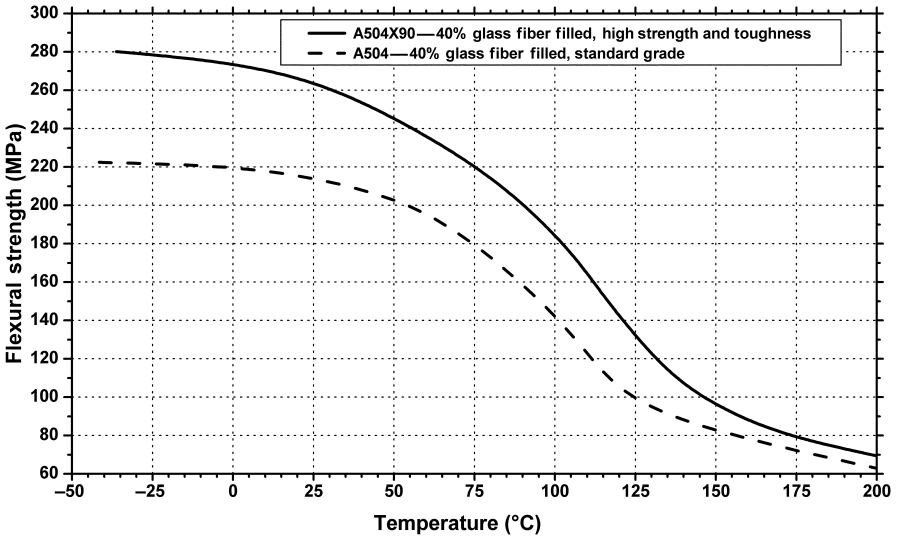


Figure 10.101 Flexural strength vs. temperature for Toray Resin Company Torelina® PPS resins [12].

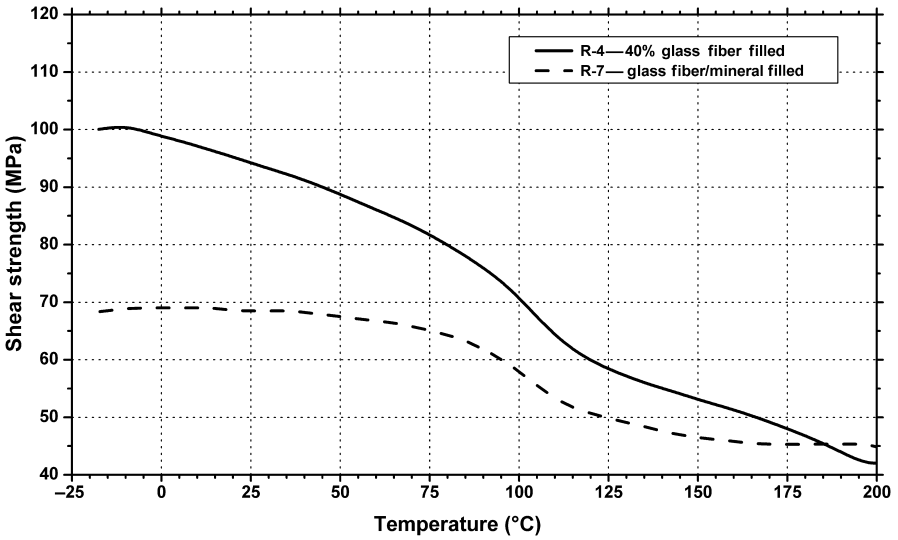


Figure 10.102 Shear strength vs. temperature for Chevron Phillips Chemical Ryton® PPS resins [11].

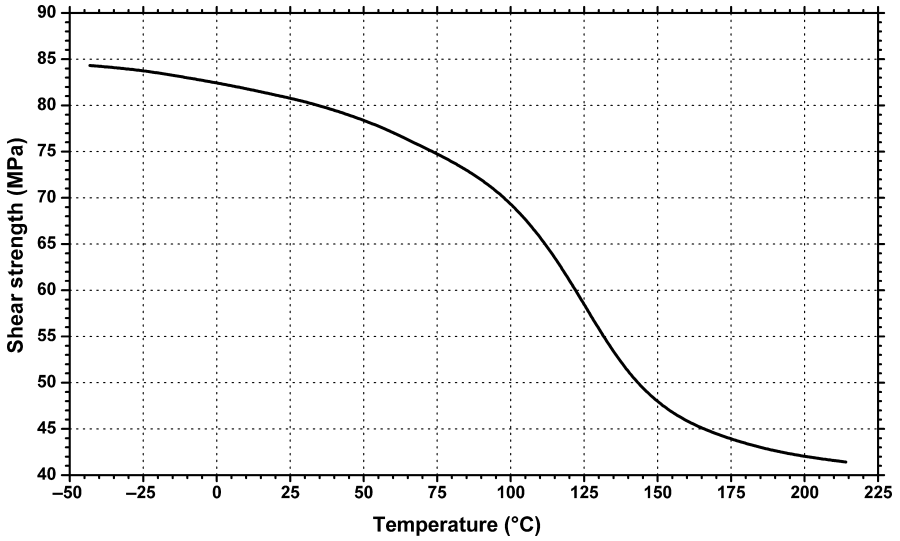


Figure 10.103 Shear strength vs. temperature for Toray Resin Company Torelina® A504—40% glass fiber-filled, standard grade PPS resin.

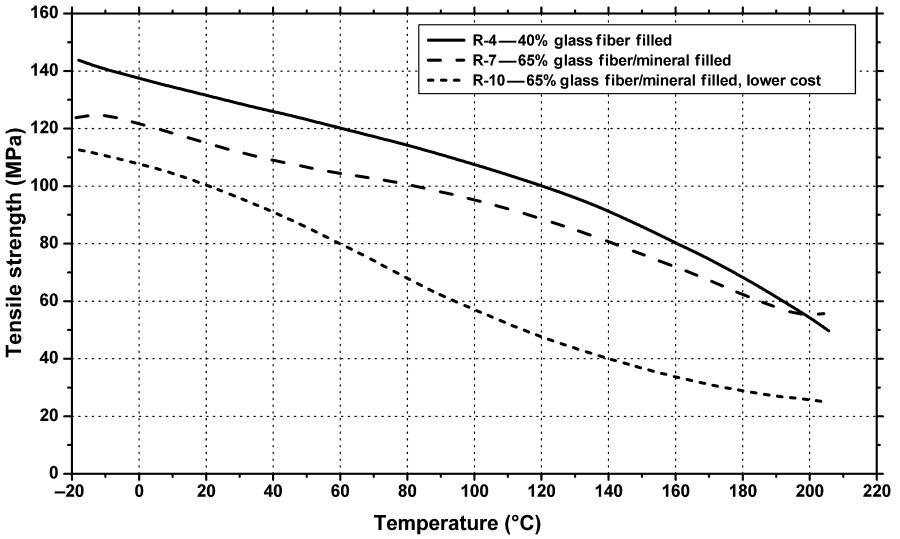


Figure 10.104 Tensile strength vs. temperature for Chevron Phillips Chemical Ryton® PPS resins [11].

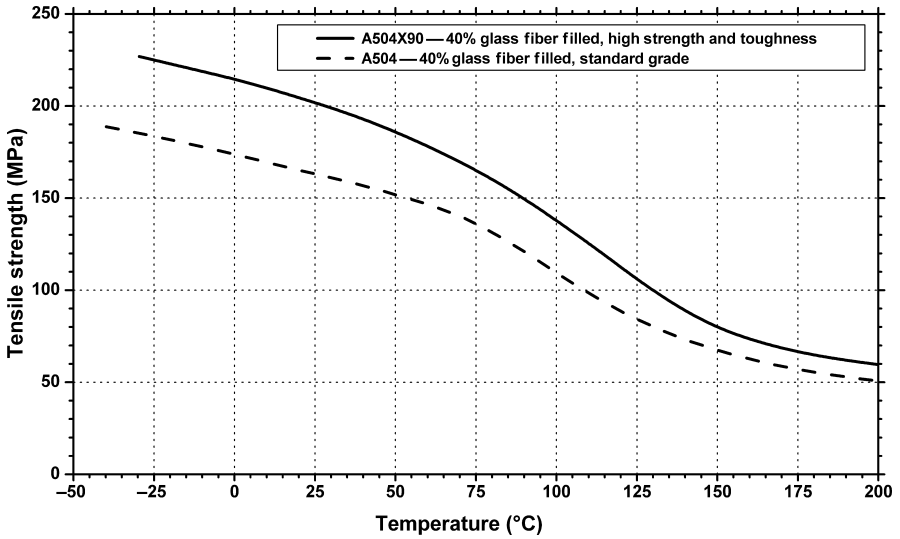


Figure 10.105 Tensile strength vs. temperature for Toray Resin Company Torelina® PPS resins [12].

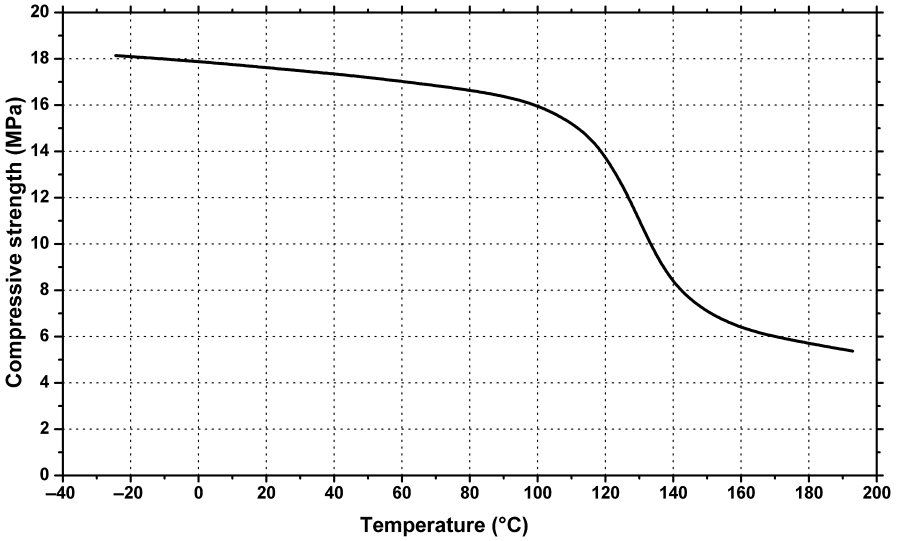


Figure 10.106 Compressive strength vs. temperature for Toray Resin Company Torelina® A504—40% glass fiber-filled, standard grade PPS resin [12].

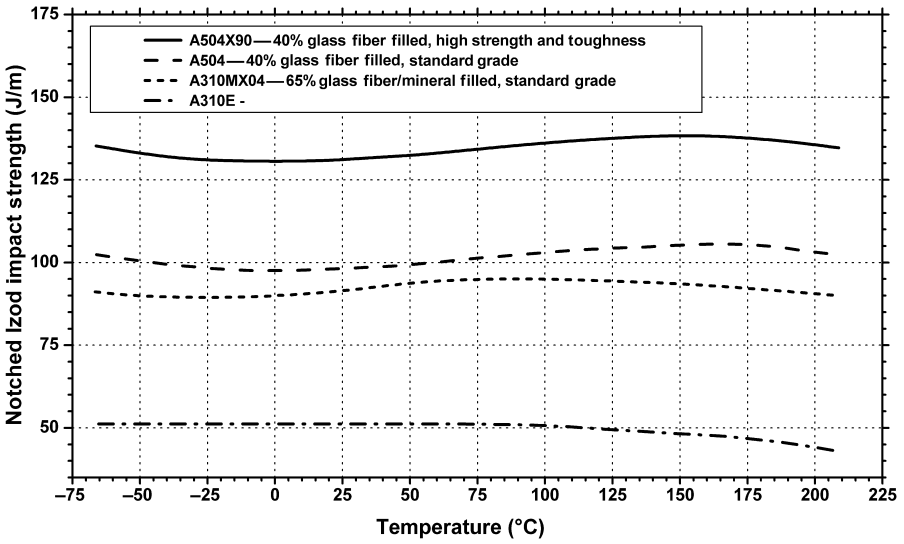


Figure 10.107 Notched Izod impact strength vs. temperature for Toray Resin Company Torelina® PPS resins [12].

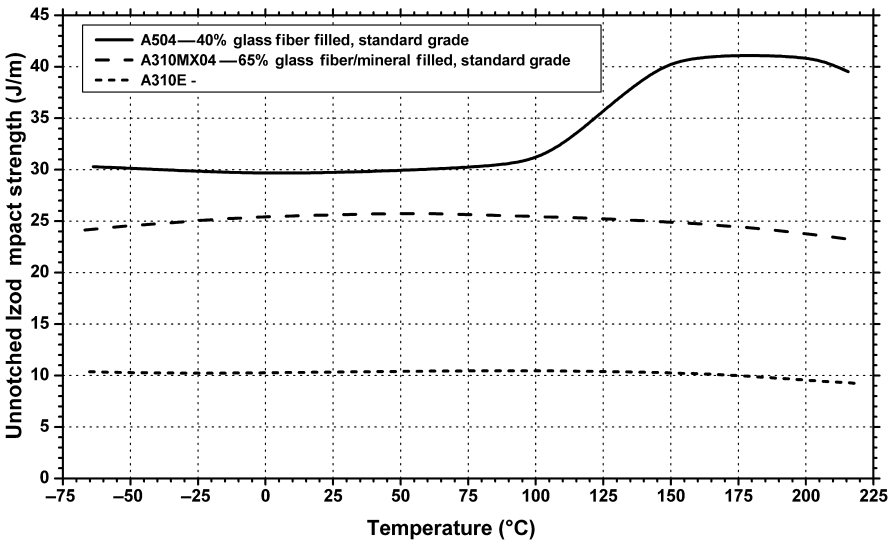


Figure 10.108 Unnotched Izod impact strength vs. temperature for Toray Resin Company Torelina® PPS resins [12].

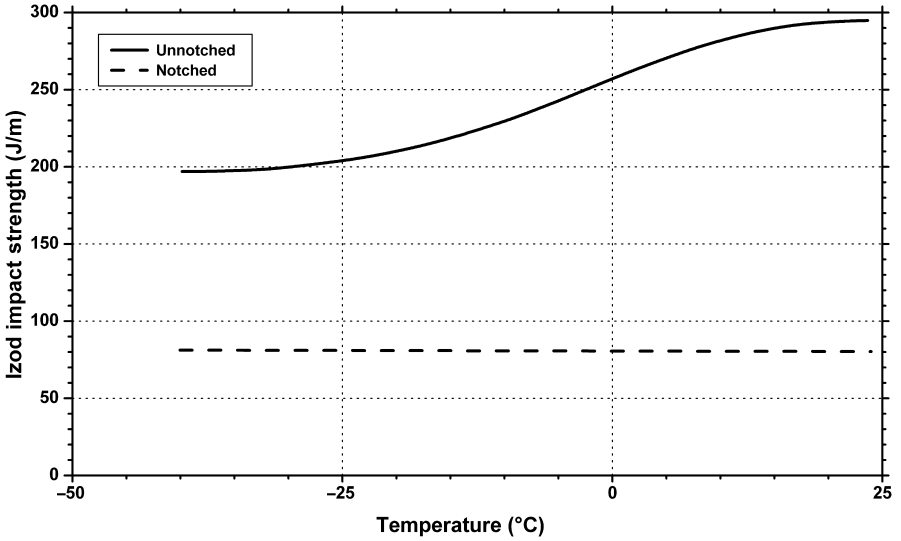


Figure 10.109 Izod impact strength vs. low temperature for Chevron Phillips Chemical Ryton® R-4—40% glass fiber-filled, high-strength PPS resin [11].

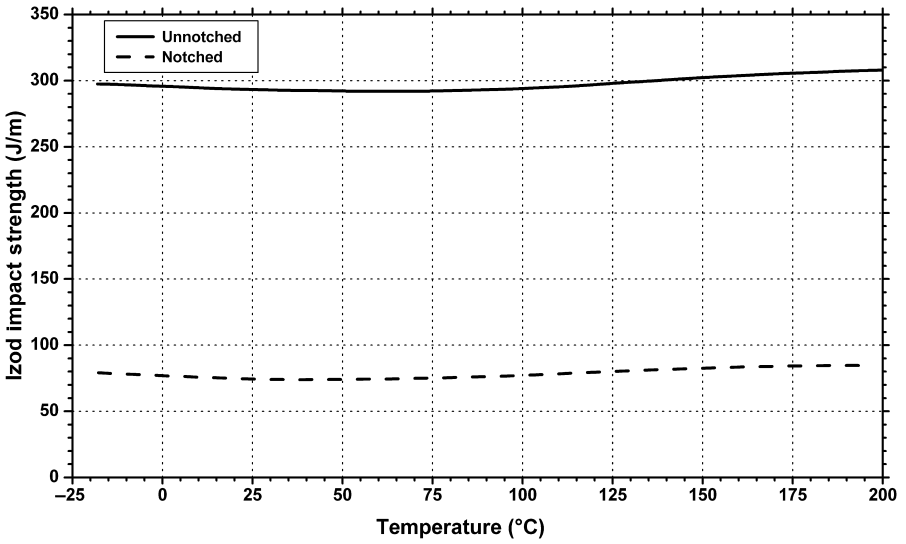


Figure 10.110 Izod impact strength vs. high temperature for Chevron Phillips Chemical Ryton® R-4—40% glass fiber-filled, high-strength PPS resin [11].

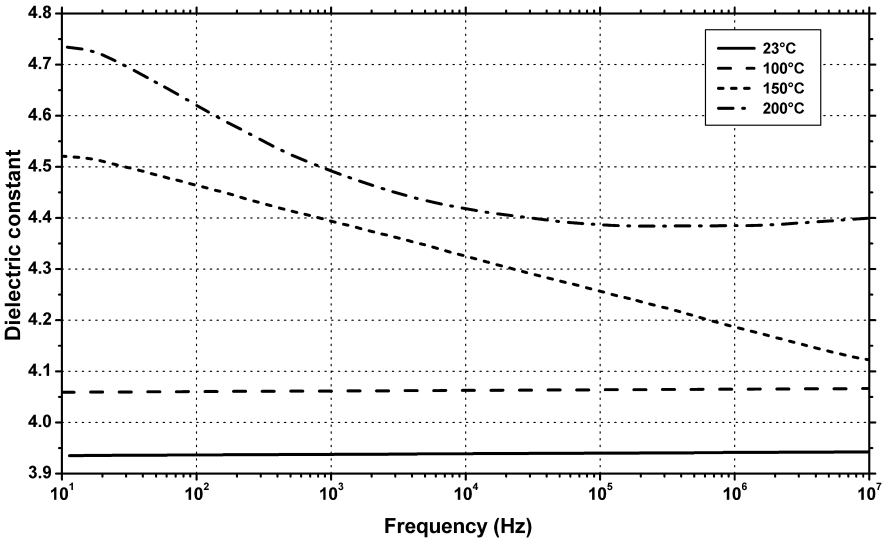


Figure 10.111 Dielectric constant vs. frequency and temperature for Chevron Phillips Chemical Ryton® R-4—40% glass fiber-filled, high-strength PPS resin [13].

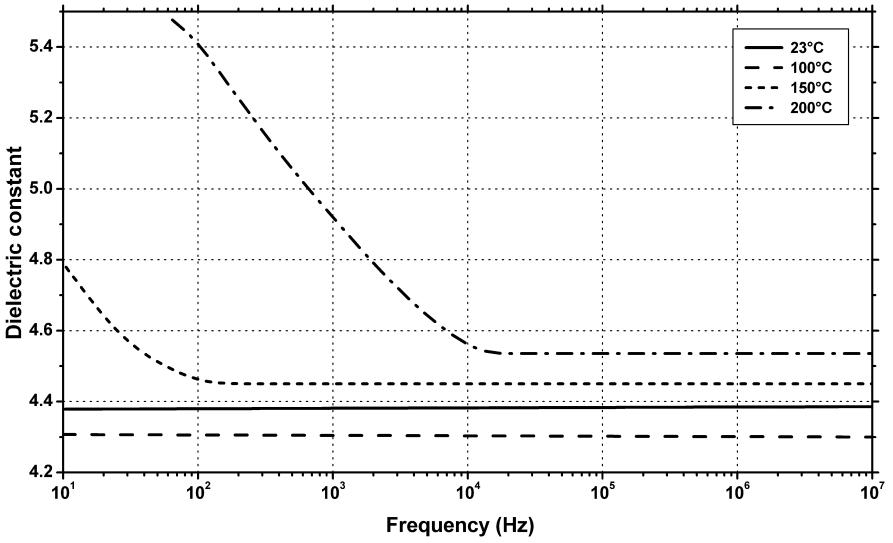


Figure 10.112 Dielectric constant vs. frequency and temperature for Chevron Phillips Chemical Ryton® R-7—65% glass fiber/mineral-filled PPS resin [13].

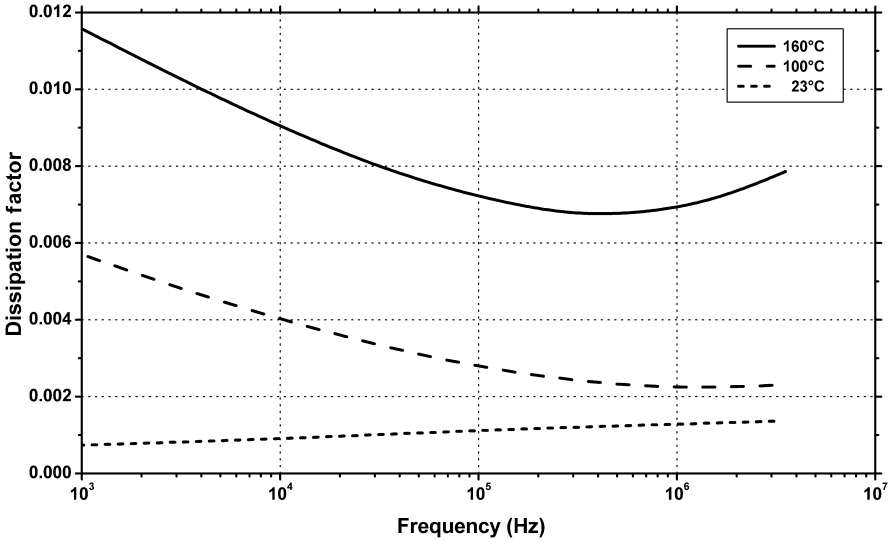


Figure 10.113 Dissipation factor vs. frequency at several temperatures for Celanese Fortron® 1140L4—40% glass fiber-filled, medium melt viscosity PPS resin [10].

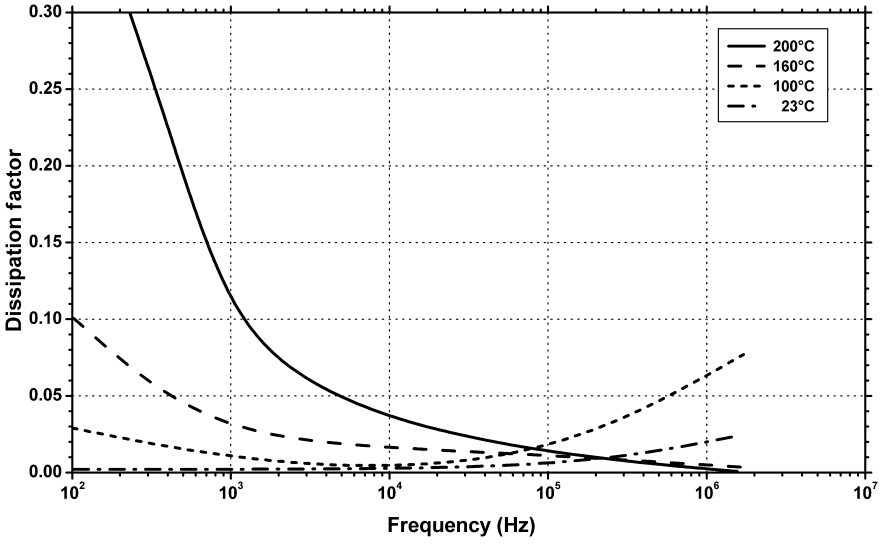


Figure 10.114 Dissipation factor vs. frequency at several temperatures for Celanese Fortron® 6160B4—60% glass fiber/mineral-filled PPS resin [10].

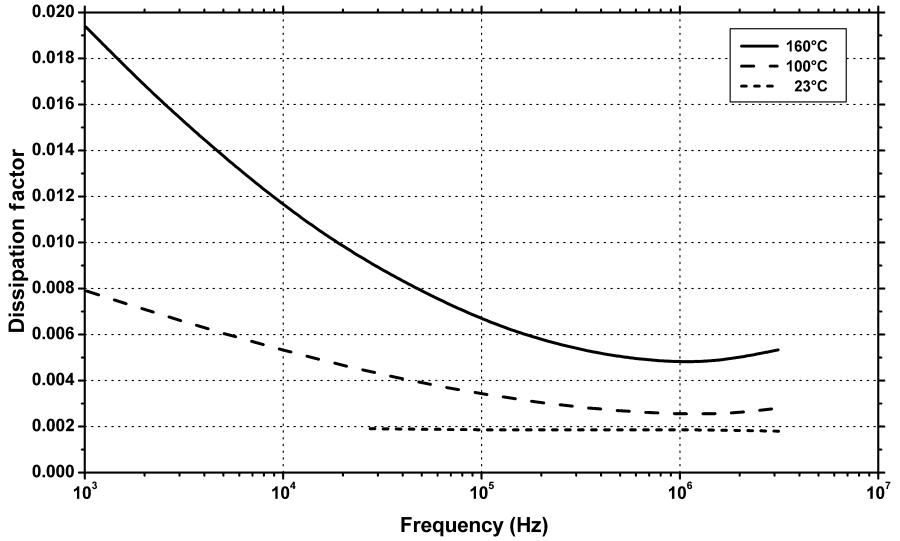


Figure 10.115 Dissipation factor vs. frequency at several temperatures for Celanese Fortron® 6165A4—65% glass fiber/mineral-filled, low melt viscosity PPS resin [10].

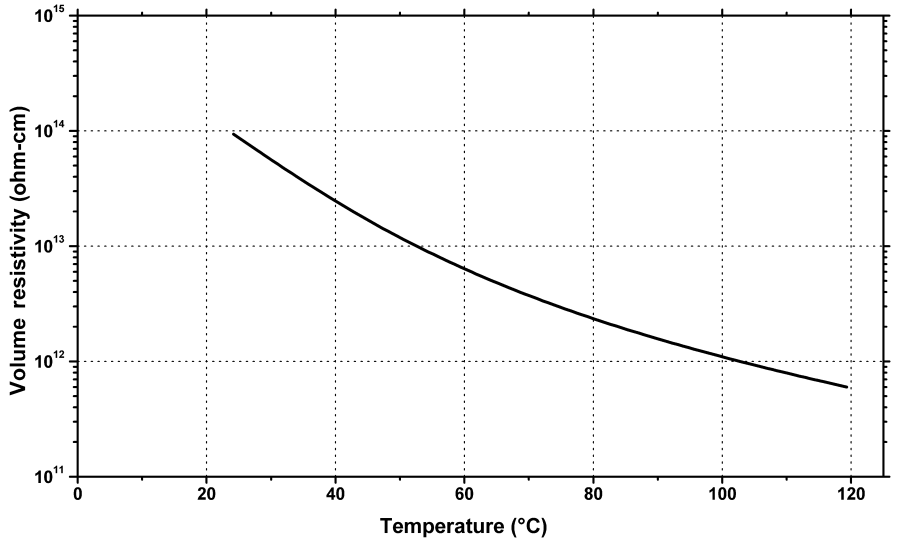


Figure 10.116 Volume resistivity vs. temperature for Celanese Fortron® 1140L4—40% glass fiber-filled, medium melt viscosity PPS resin.

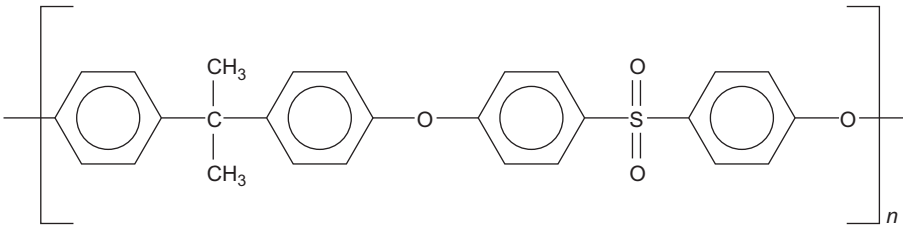


Figure 10.117 Structure of PSU.

The data for PSU plastics are shown in Figures 10.118–10.144.

10.5 Polyphenylsulfone (PPSU)

Polyphenylsulfone (PPSU) is a rigid, strong, tough, high temperature amorphous thermoplastic. It has a high heat deflection temperature of 405°F (207°C). It can withstand continuous exposure to heat and still absorb tremendous impact without cracking or breaking. It is inherently flame retardant and offers exceptional resistance to bases and other chemicals. The structure of PPSU is shown in Figure 10.145.

Its properties are summarized as follows:

- High deflection temperatures
- Steam sterilizable with high retention of impact properties

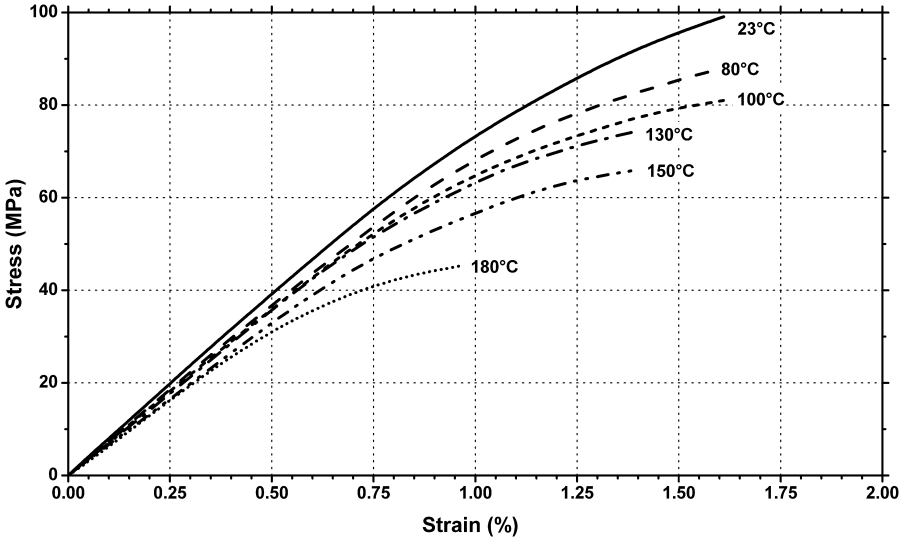


Figure 10.118 Stress vs. strain at several temperatures for Solvay Advanced Polymers Udel® GF-130—30% glass fiber-reinforced PSU resin.

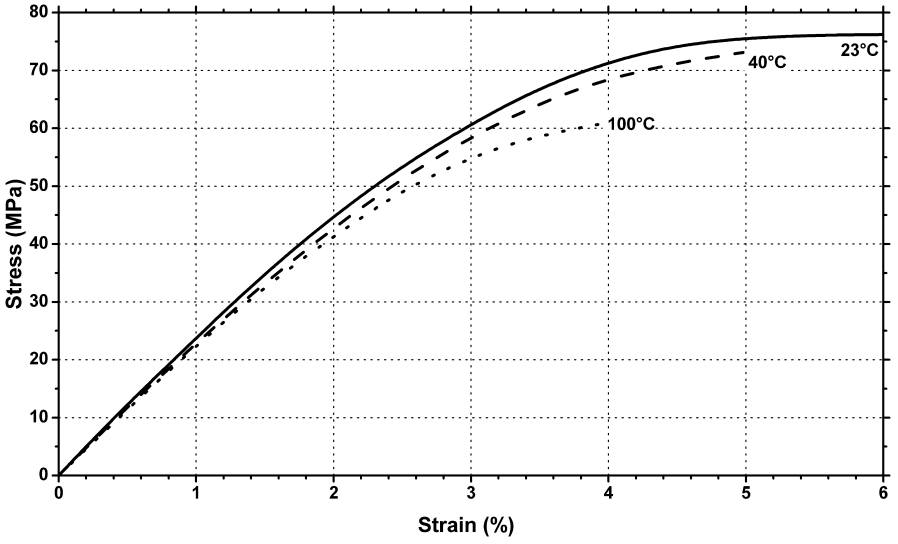


Figure 10.119 Stress vs. strain at several temperatures for Solvay Advanced Polymers Udel® P-1700—unreinforced, mid-viscosity PSU resin.

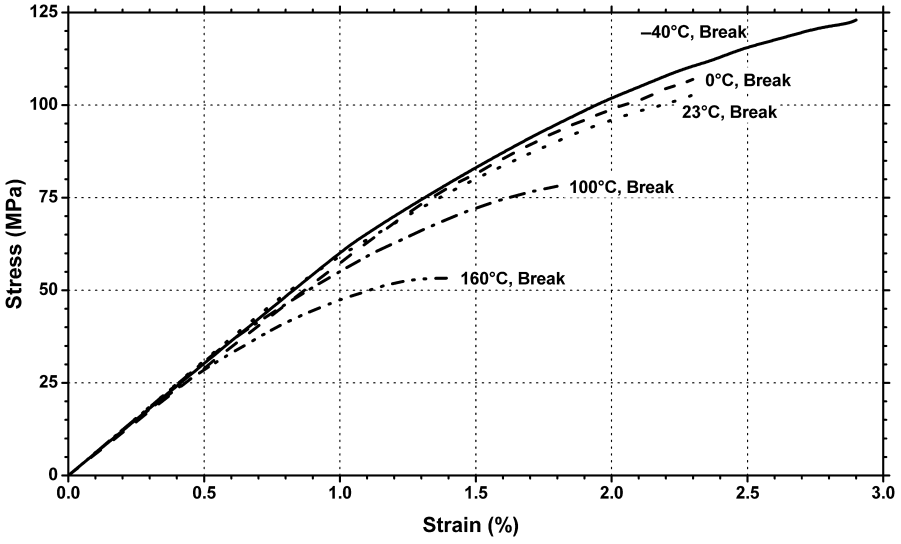


Figure 10.120 Stress vs. strain at several temperatures for BASF Ultrason® S 2010 G4—20% glass-reinforced, medium viscosity PSU resin.

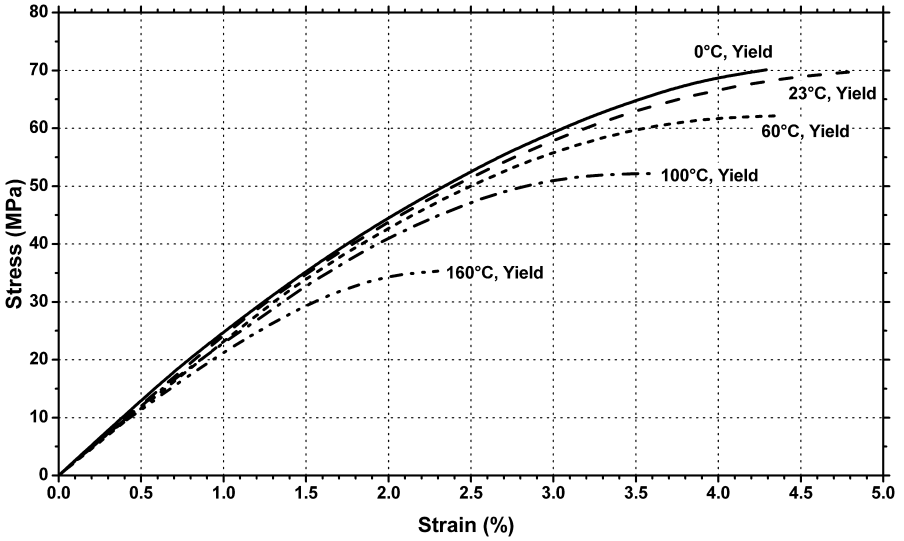


Figure 10.121 Stress vs. strain at several temperatures for BASF Ultrason® S 2010—unreinforced, medium viscosity PSU resin.

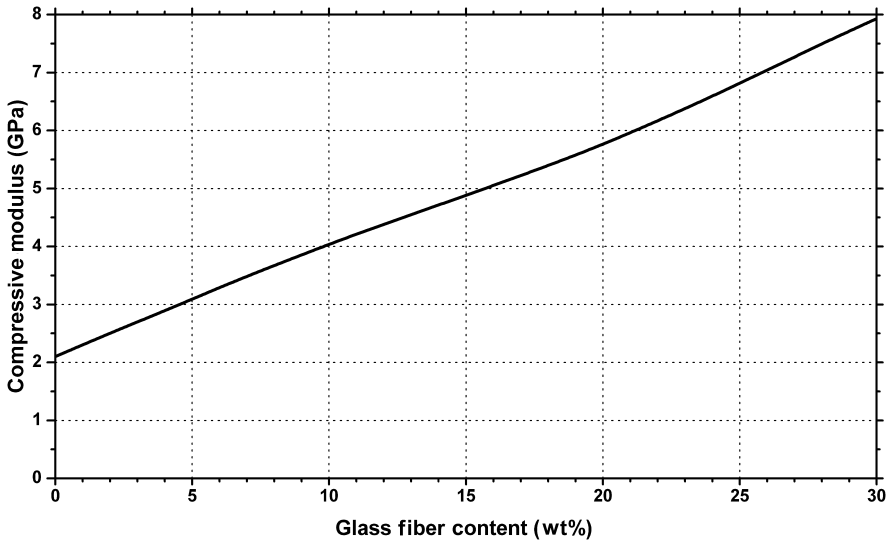


Figure 10.122 Compressive modulus vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

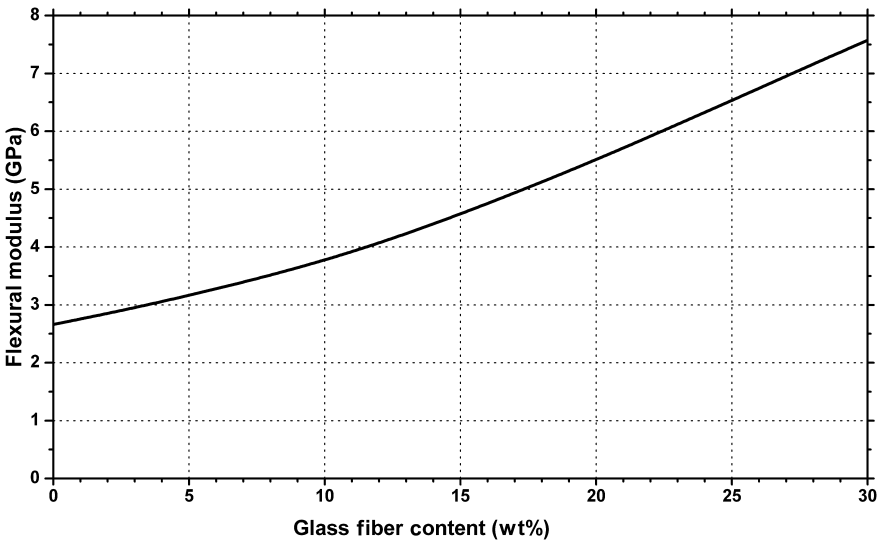


Figure 10.123 Flexural modulus vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

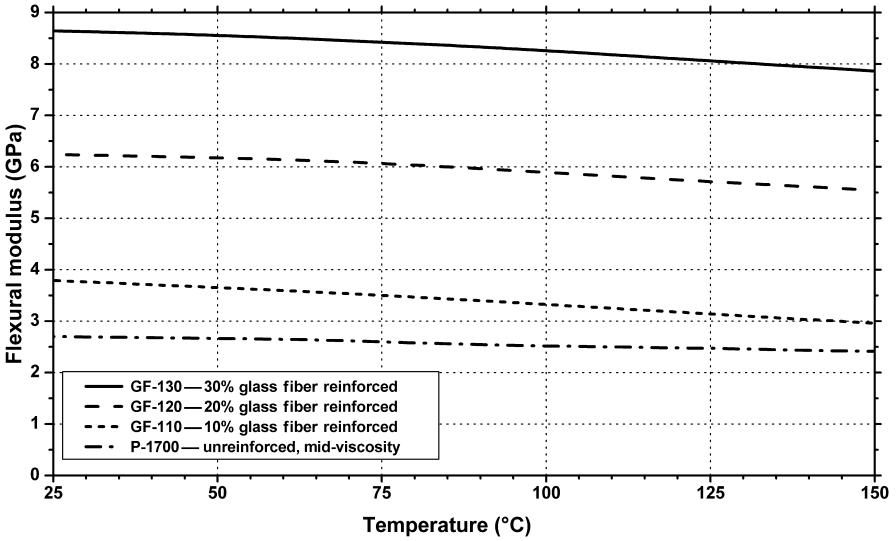


Figure 10.124 Flexural modulus vs. temperature for Solvay Advanced Polymers Udel® PSU resins [14].

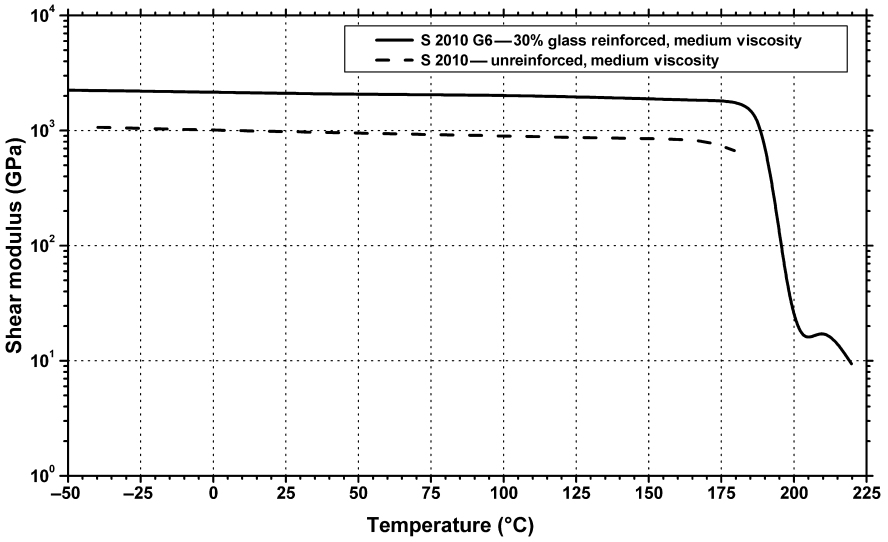


Figure 10.125 Shear modulus vs. temperature for BASF Ultrason® S PSU resins [14].

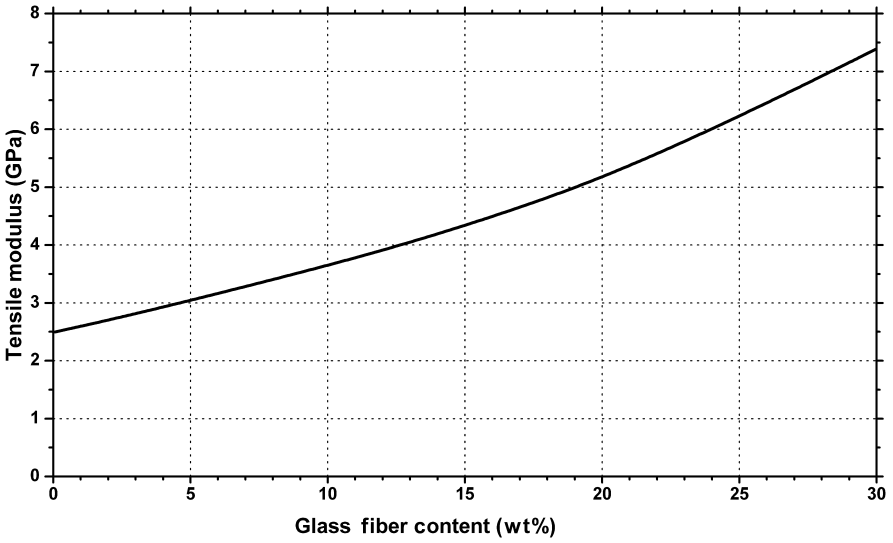


Figure 10.126 Tensile modulus vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

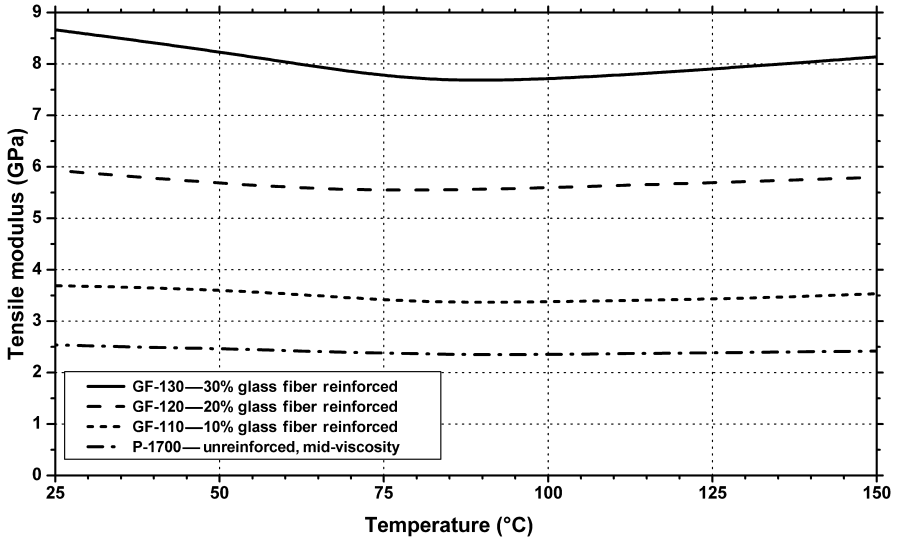


Figure 10.127 Tensile modulus vs. temperature for Solvay Advanced Polymers Udel® PSU resins [14].

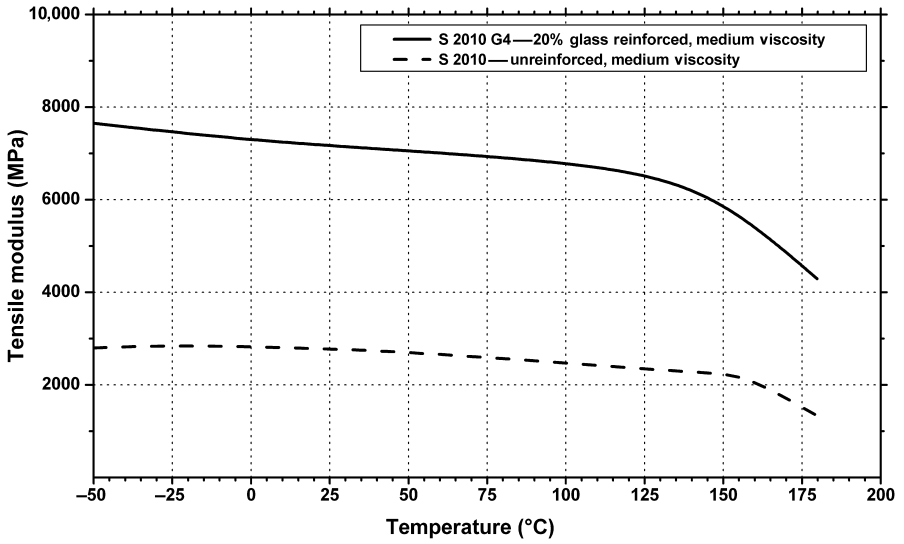


Figure 10.128 Tensile modulus vs. temperature for BASF Ultrason® S PSU resins.

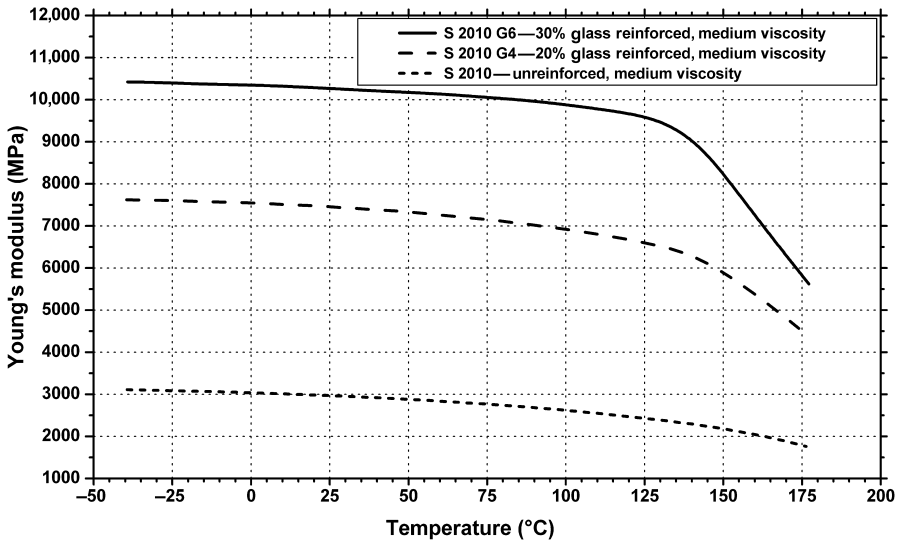


Figure 10.129 Young's modulus vs. temperature for BASF Ultrason® S PSU resins.

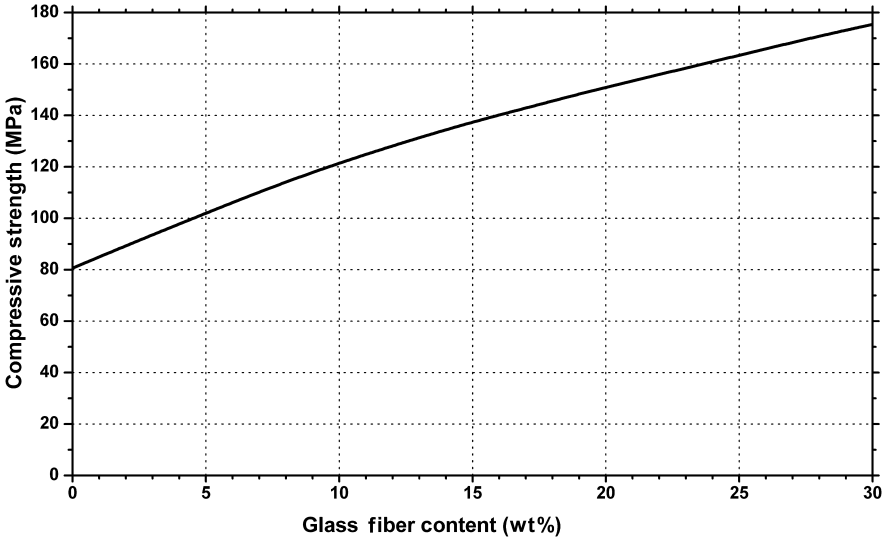


Figure 10.130 Compressive strength vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

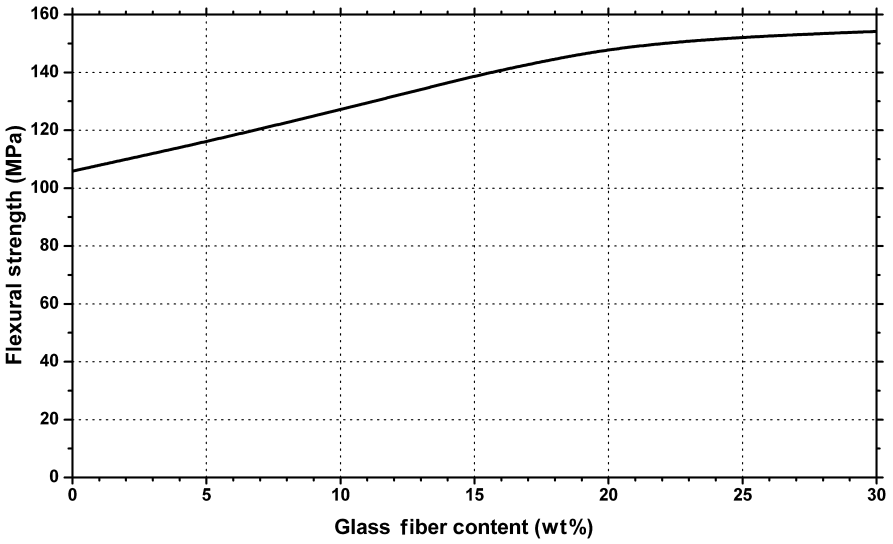


Figure 10.131 Flexural strength vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

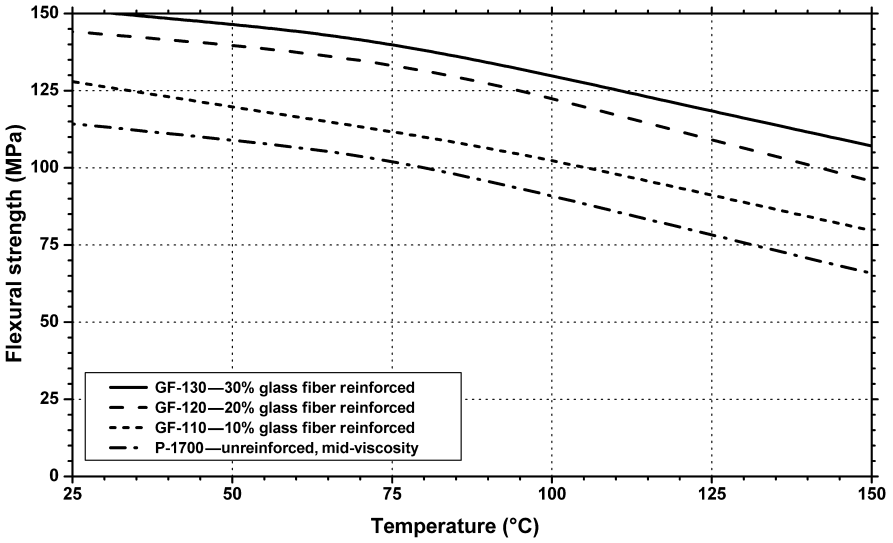


Figure 10.132 Flexural strength vs. temperature for Solvay Advanced Polymers Udel® PSU resins [14].

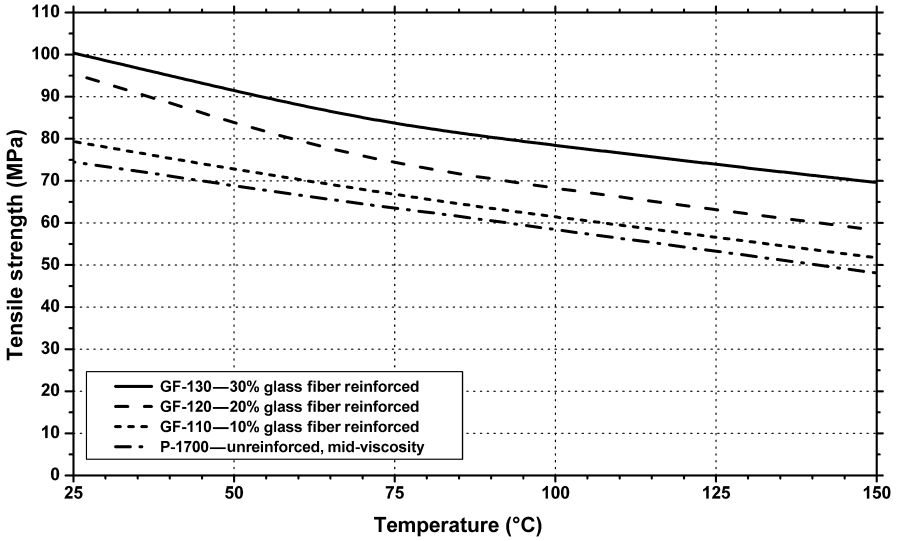


Figure 10.133 Tensile strength vs. temperature for Solvay Advanced Polymers Udel® PSU resins [14].

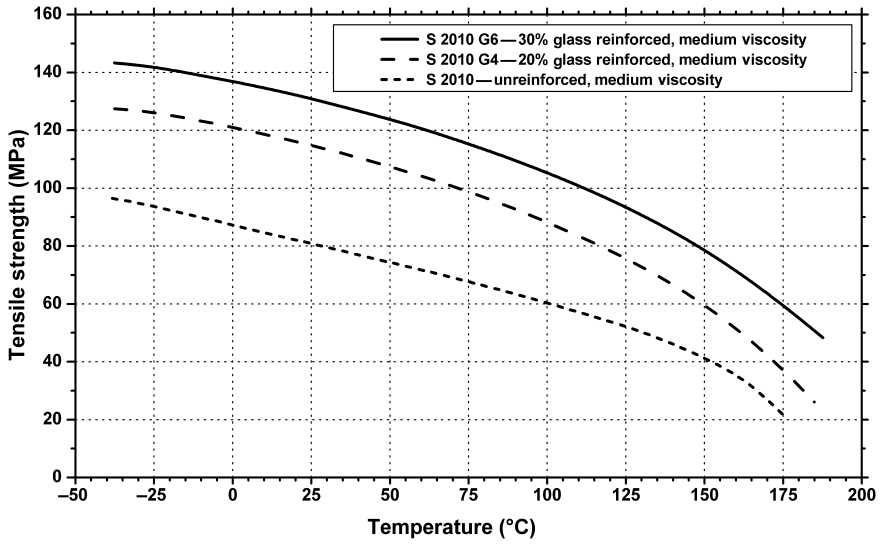


Figure 10.134 Tensile strength vs. temperature for BASF Ultrason® S PSU resins.

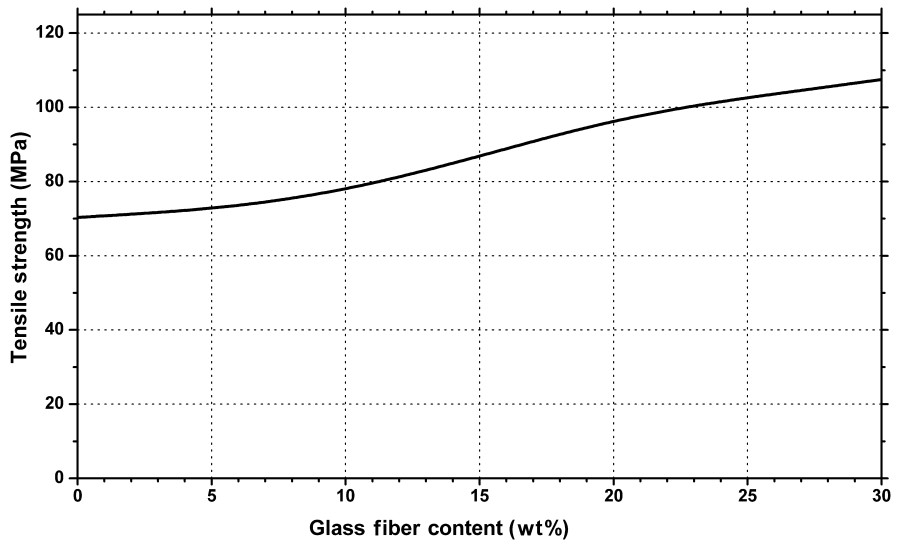


Figure 10.135 Tensile strength vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

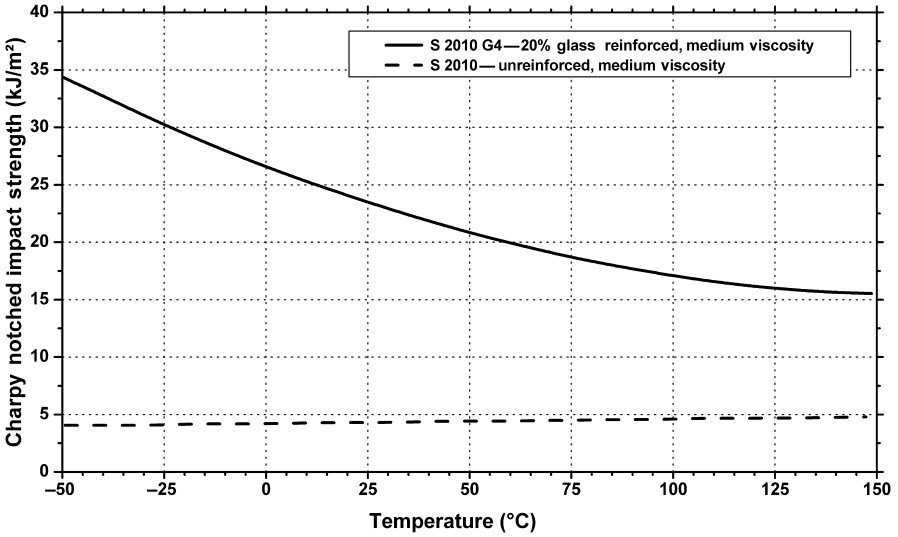


Figure 10.136 Charpy notched impact strength vs. temperature for BASF Ultrason® S 2010 PSU resins [15].

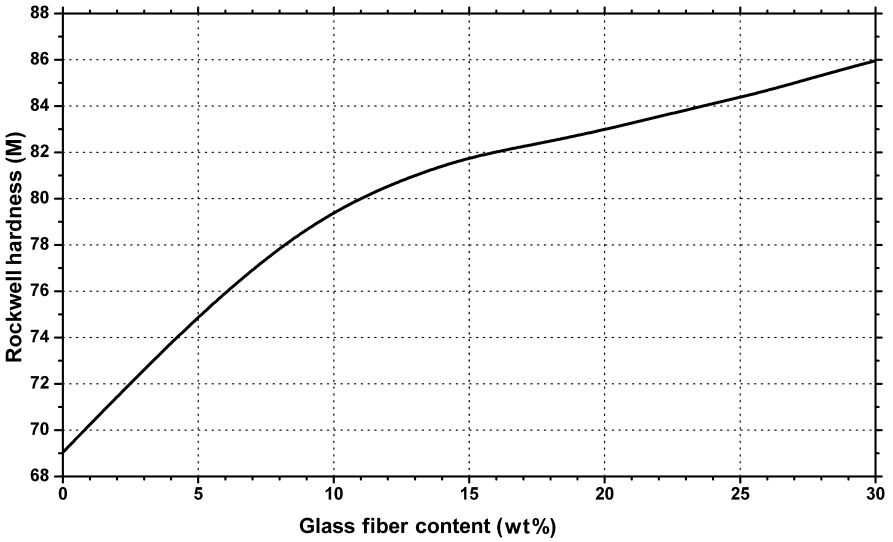


Figure 10.137 Rockwell hardness vs. glass fiber content for Solvay Advanced Polymers Udel® PSU resins [14].

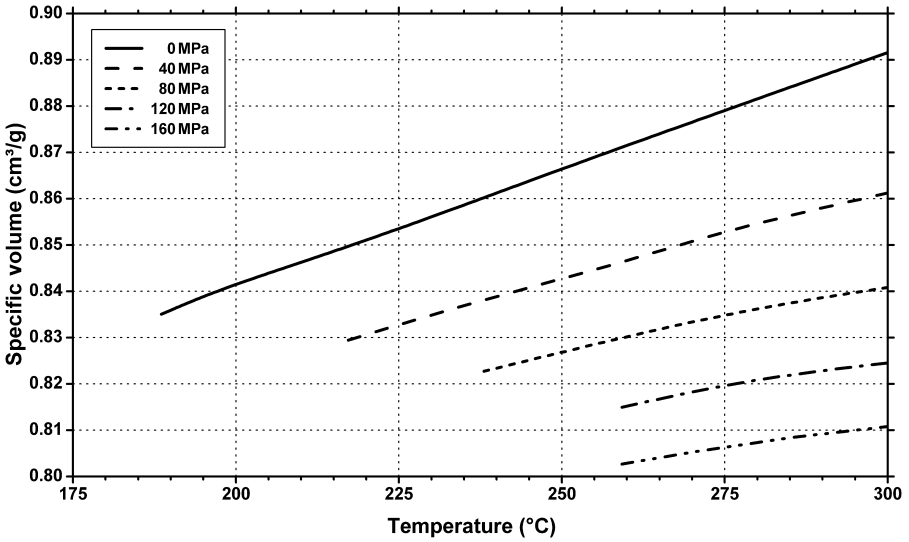


Figure 10.138 Specific volume as a function of temperature and pressure (PVT) of Solvay Advanced Polymers Udel® PSU resin [14].

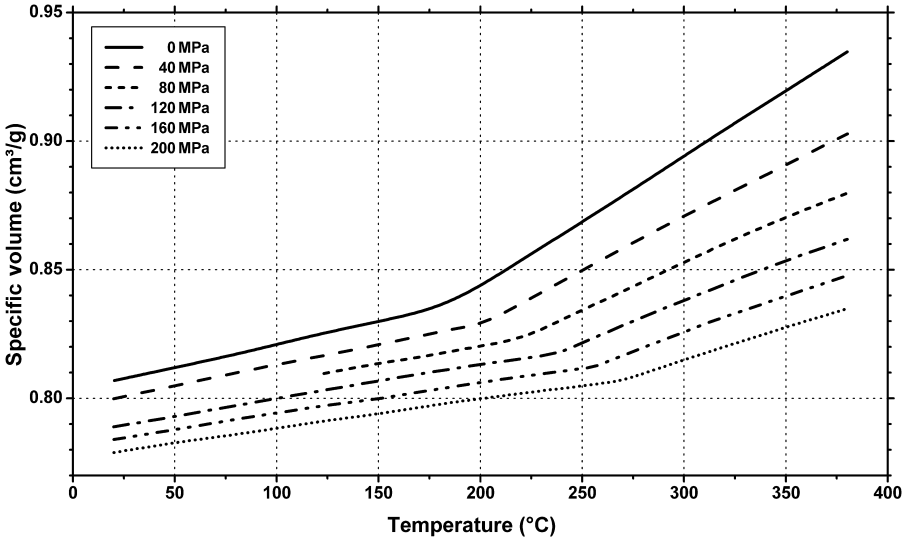


Figure 10.139 Specific volume as a function of temperature and pressure (PVT) of BASF Ultrason® S 2010—unreinforced, medium viscosity PSU resin.

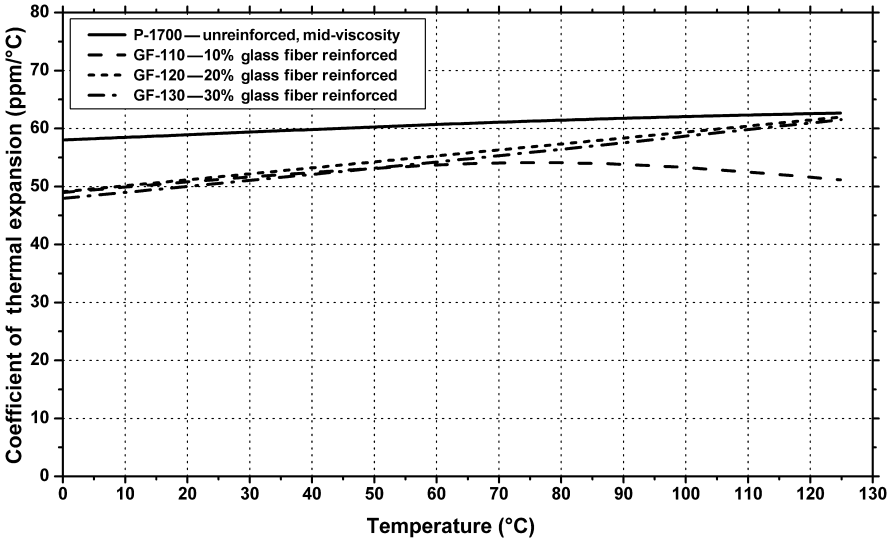


Figure 10.140 Coefficient of thermal expansion (cross flow direction) vs. temperature for Solvay Advanced Polymers Udel® PSU resins [14].

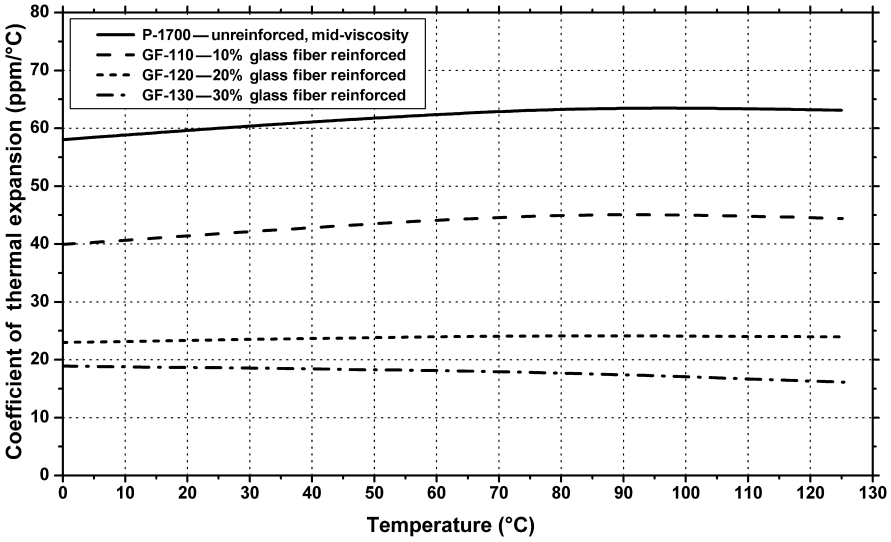


Figure 10.141 Coefficient of thermal expansion (flow direction) vs. temperature for Solvay Advanced Polymers Udel® PSU resins [14].

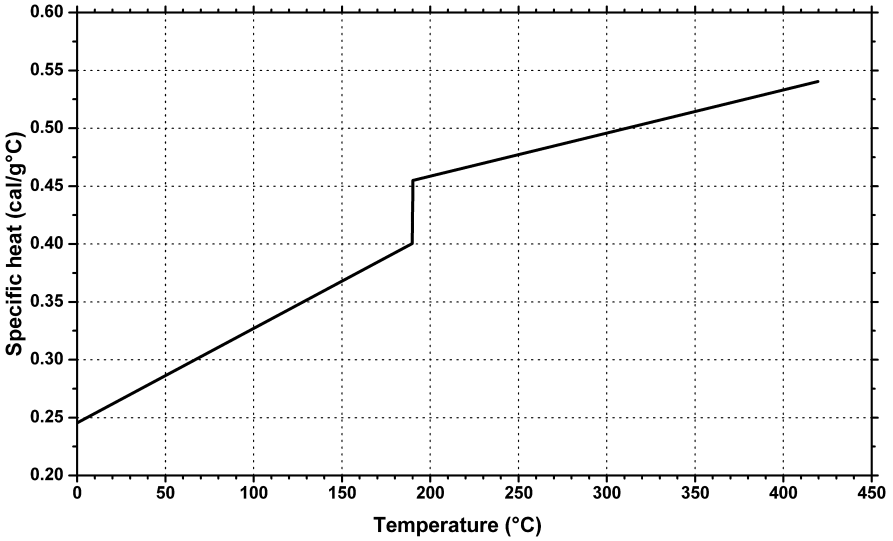


Figure 10.142 Specific heat vs. temperature for Solvay Advanced Polymers Udel® PSU resin [14].

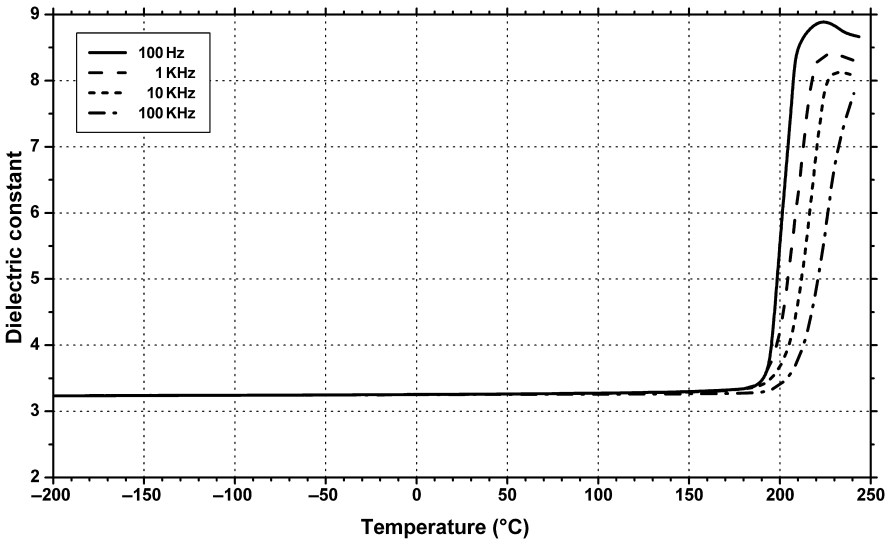


Figure 10.143 Dielectric constant vs. temperature and frequency for Ultrason® S 2010—unreinforced, medium viscosity PSU resins [15].

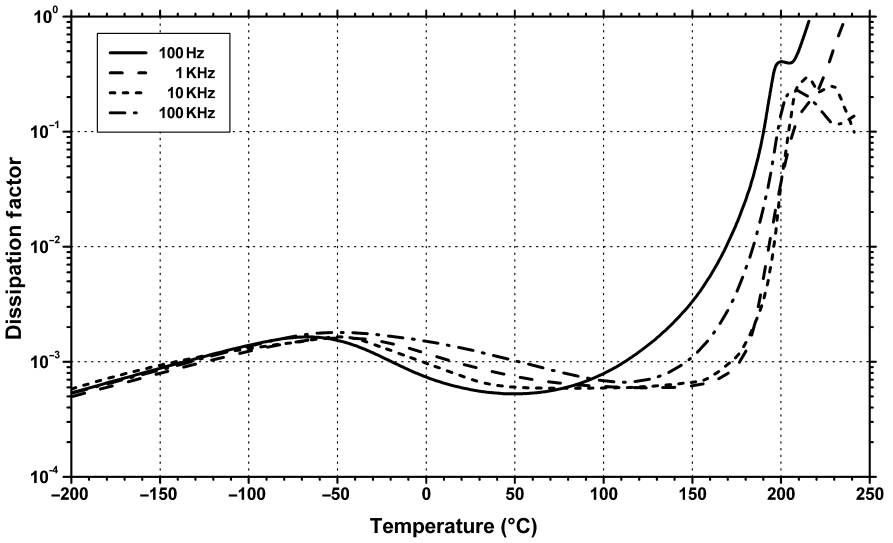


Figure 10.144 Dissipation factor vs. temperature and frequency for Ultrason® S 2010—unreinforced, medium viscosity PSU resins [15].

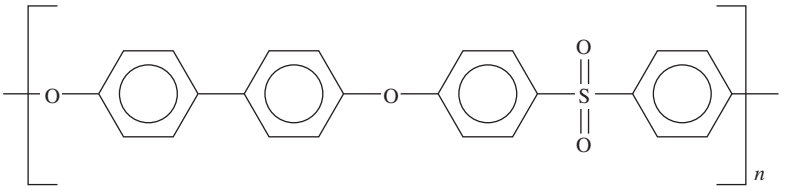


Figure 10.145 The structure of PPSU.

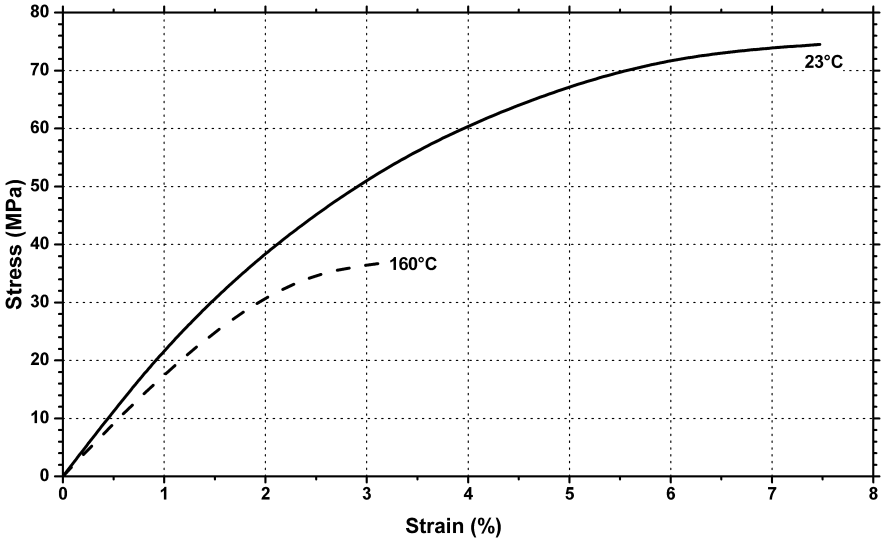


Figure 10.146 Stress–strain diagram (according to ISO 527) up to the yield point, at 23°C and 160°C for BASF Ultrason® P 3010 PPSU [6].

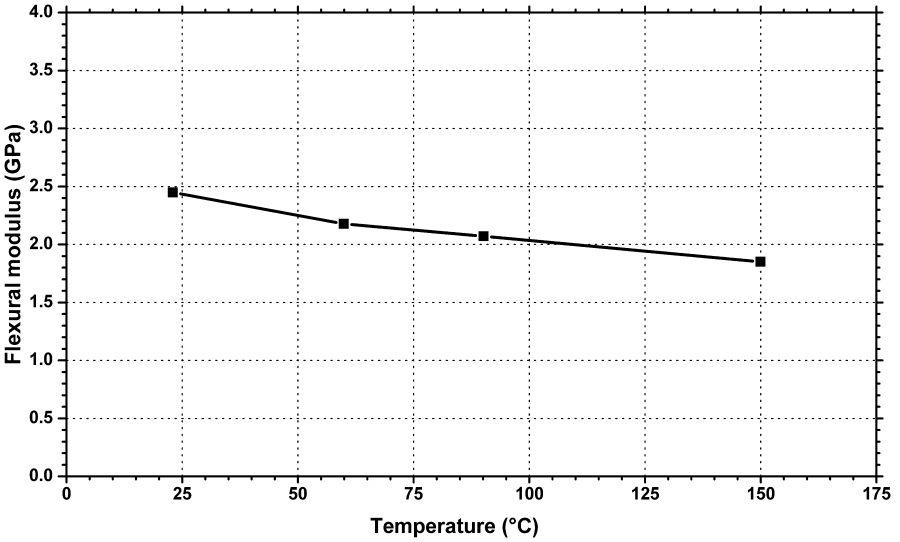


Figure 10.147 Flexural modulus vs. temperature for Solvay Radel® R unfilled PPSU [16].

- Inherently flame retardant
- Excellent thermal stability making films suitable
- For applications where very low shrink at high temperatures is needed
- Good electrical properties

Manufacturers and trade names: Solvay Advanced Plastics Radel® R, Evonik Industries Europlex®, BASF Ultrason® P.

Applications and uses: electrical/electronic, aircraft interiors, and automotive industry.

The data for PPSU plastics are shown in Figures 10.146–10.154.

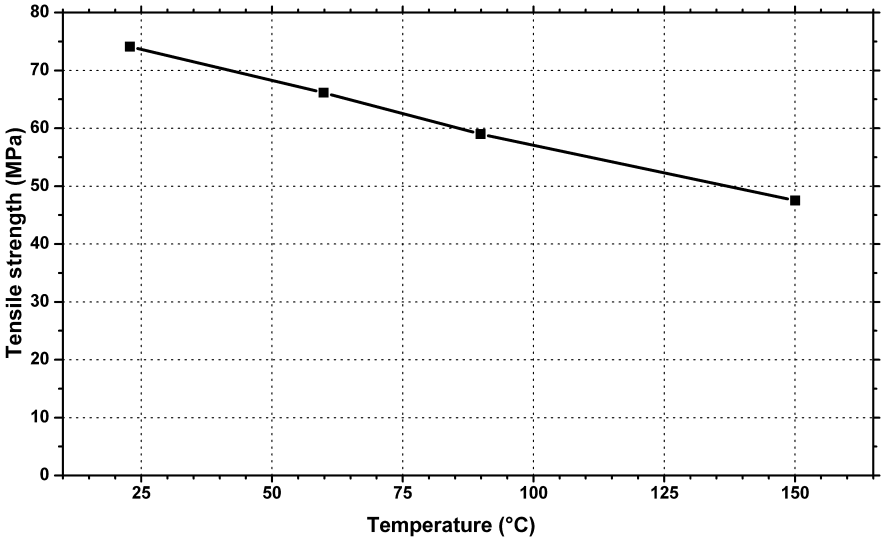


Figure 10.148 Tensile strength vs. temperature for Solvay Radel® R unfilled PPSU [16].

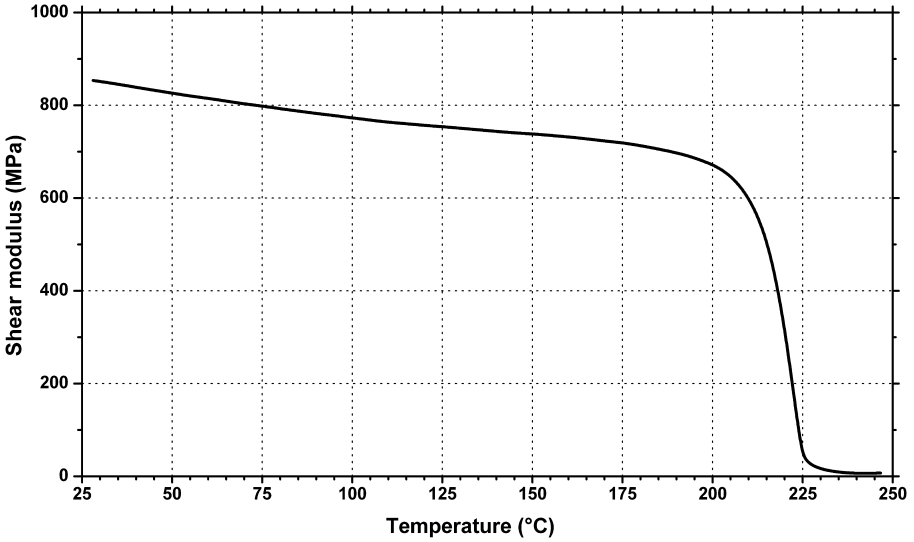


Figure 10.149 Shear modulus vs. temperature according to ISO 6721 for BASF Ultrason® P 3010 PPSU [6].

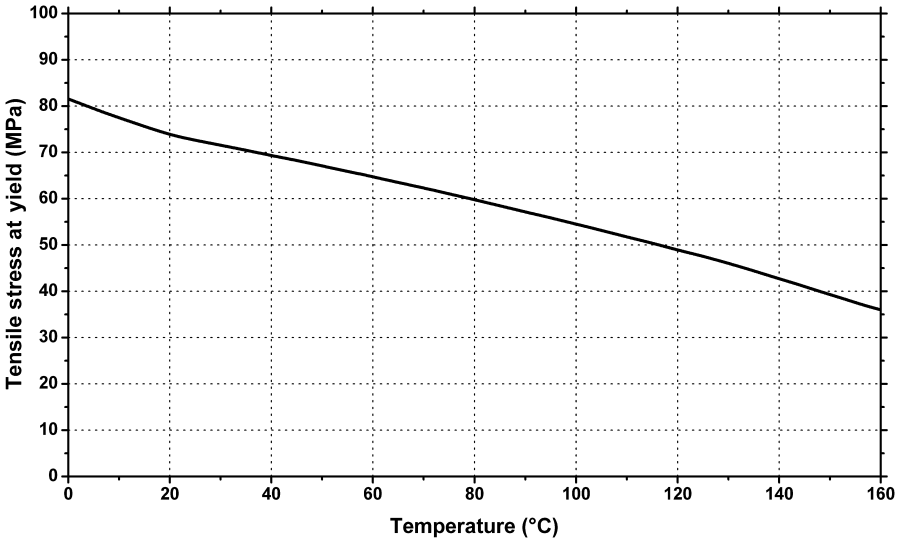


Figure 10.150 Temperature dependence of the tensile stress at yield (dry) of BASF Ultrason® P 3010 PPSU [6].

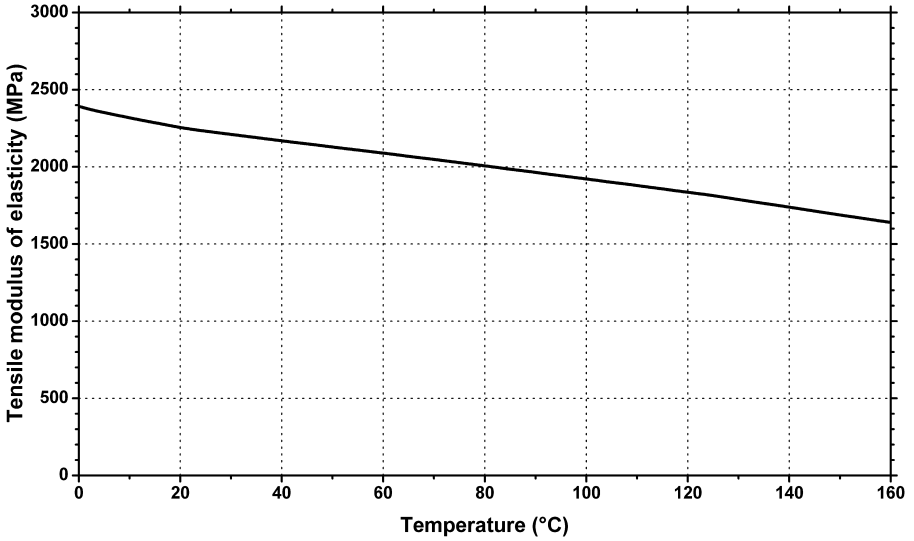


Figure 10.151 Modulus of elasticity (according to ISO 527) as a function of temperature (dry) of BASF Ultrason® P 3010 PPSU [6].

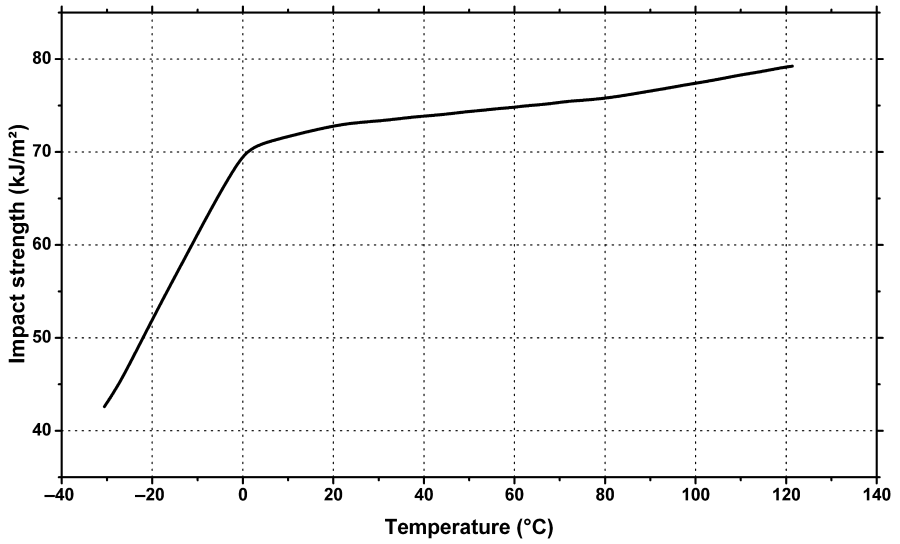


Figure 10.152 Impact strength as a function of temperature (unnotched according to ISO 179/1eU) of BASF Ultrason® P 3010 PPSU [6].

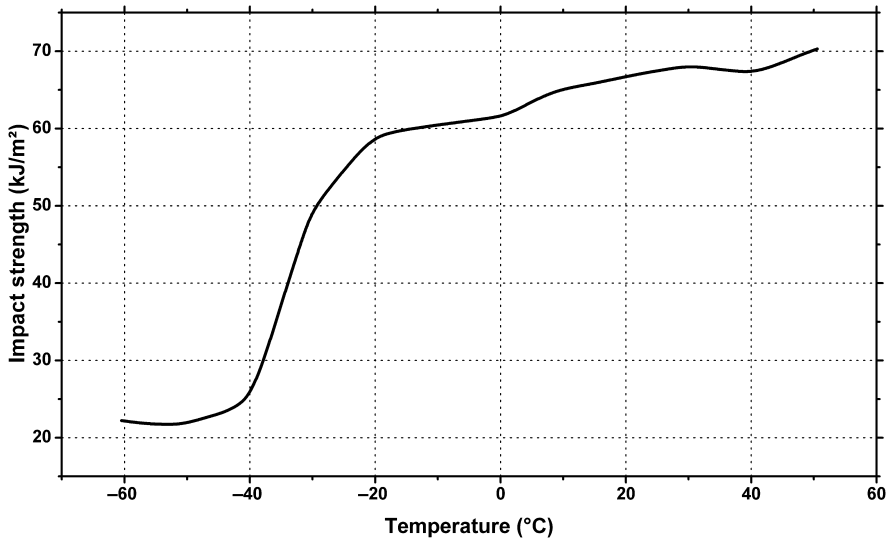


Figure 10.153 Notched impact strength as a function of temperature (ISO 179/1eA) of BASF Ultrason® P 3010 PPSU [6].

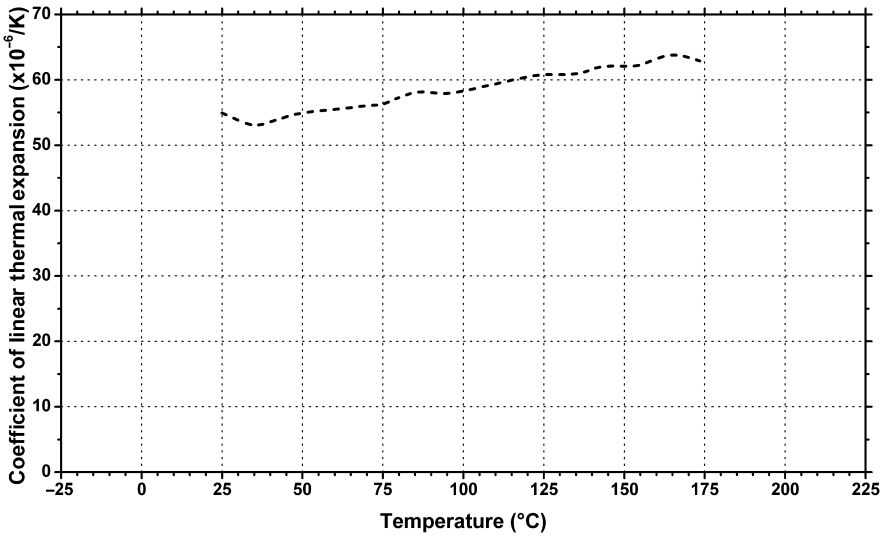


Figure 10.154 Coefficient of linear thermal expansion according to DIN 53752 of BASF Ultrason® P 3010 PPSU [6].

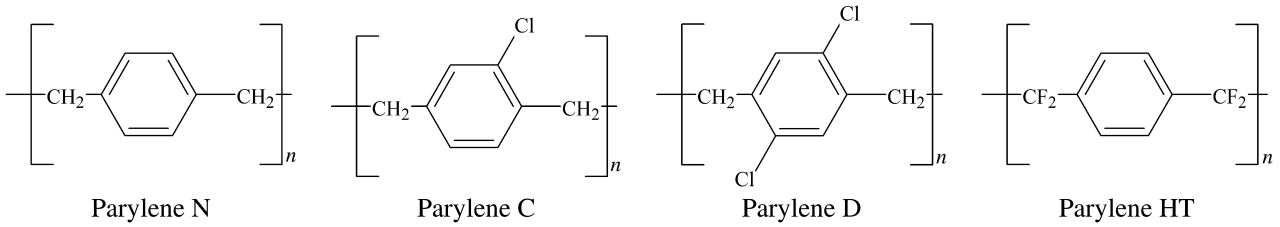


Figure 10.155 Structures of the Parylene polymer molecules.

10.6 Parylene (Poly(*p*-xylylene))

Parylene is the generic name for members of a series of polymers. The basic member of the series, called Parylene N, is poly(*para*-xylylene), a completely linear, highly crystalline material. The structures of four Parylene types are shown in Figure 10.155.

Parylene polymers are not manufactured and sold directly. They are deposited from the vapor phase by a process which in some respects resembles vacuum metalizing. Parylene polymers are formed at a pressure of about 0.1 torr from a reactive dimmer in the gaseous or vapor state. Unlike vacuum metalizing, the deposition is not line of sight, and all sides of an object to be encapsulated are uniformly impinged by the gaseous monomer. Due to the uniqueness of the vapor phase deposition, Parylene polymers can be formed as structurally continuous films from as thin as a fraction of a micrometer to as thick as several mils.

The first step is the vaporization of the solid dimer at approximately 150°C. The second step is the quantitative cleavage (pyrolysis) of the dimer vapor at the two methylene–methylene bonds at about 680°C to yield the stable monomeric diradical, *para*-xylylene. Finally, the monomeric vapor enters the room temperature deposition chamber where it spontaneously polymerizes on the substrate. The substrate temperature never rises more than a few degrees above ambient.

Parylene is used as a coating on electronics ranging from advanced military and aerospace electronics to general-purpose industrial products, medical devices ranging from silicone tubes to advanced coronary stents, synthetic rubber products ranging from medical grade silicone rubber to ethylene propylene diene monomer rubber (EPDM).

The manufacturer of coating equipment and starting materials is Para Tech Coating, Inc. They also offer coating services.

Manufacturers and trade names: Para Tech Coating, Inc. Parylene

Applications and uses: *electronics*: circuit boards, sensors, integrated circuits/hybrids, MEM devices, motor assemblies, coil forms, silicon wafers; *medical*: needles, prosthetic devices,

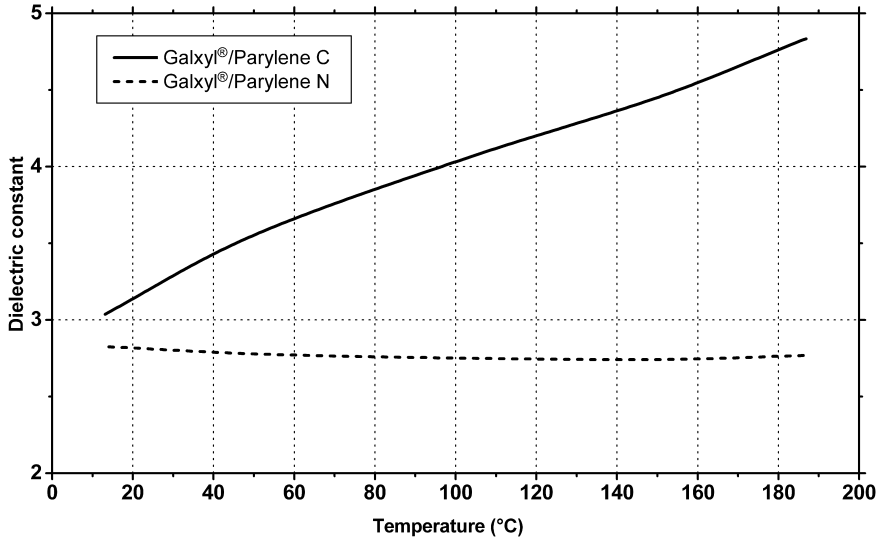


Figure 10.156 Dielectric constant vs. temperature for Galxyl® Parylene films [17].

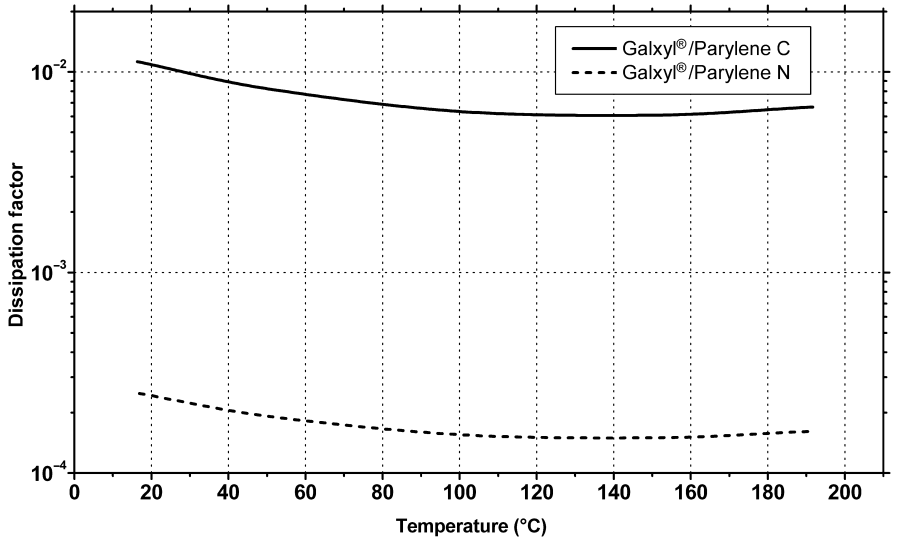


Figure 10.157 Dissipation factor vs. temperature for Galxyl® Parylene films [17].

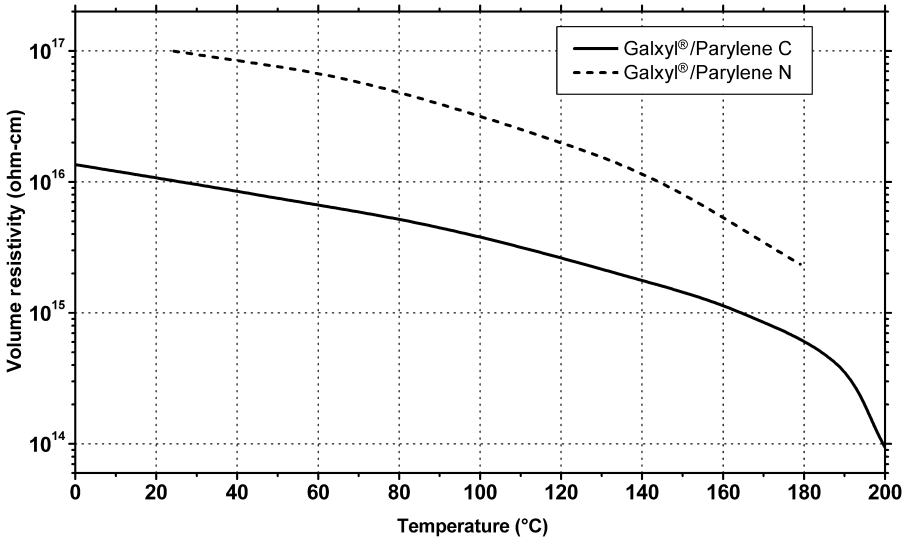


Figure 10.158 Volume resistivity vs. temperature for Galxyl® Parylene films [17].

implantable components, catheter, electrodes, stents, epidural probes, cannula assemblies; *aerospace*: deep space vision systems, navigation and controls, optical devices, satellite and spacecraft devices, flight deck controls.

The data for Parylene plastics are shown in Figures 10.156–10.158.

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11 Tables of Selected ISO 10350 Properties of Selected Plastics

This chapter contains data in tabular form. These data are described in the standard ISO 10350-1:1998, which is titled "Plastics—Acquisition and presentation of comparable single-point data—Part 1: Moulding materials." Standard ISO 10350 identifies specific test procedures for the acquisition and presentation of comparable data for many basic properties of plastics. The properties included are often in manufacturers' data sheets. In fact many manufacturers, particularly those based in Europe, provide an ISO 10350 Technical Data Sheet, along with a generalized technical data sheet that contains a mixture of ISO and ASTM data. All the data on ISO 10350 are defined by ISO standards rather than ASTM standards. Part 1 applies to unreinforced and reinforced thermoplastic and thermosetting materials, the subject of this book.

The tables in this section follow one or more of the following standards include where available:

- ISO 62, Plastics—Determination of water absorption
- ISO 179-1, Plastics—Determination of Charpy impact properties—Part 1: Noninstrumented impact test
- ISO 179-2:1997, Plastics—Determination of Charpy impact properties—Part 2: Instrumented impact test
- ISO 291:1997, Plastics—Standard atmospheres for conditioning and testing
- ISO 293:1986, Plastics—Compression moulding test specimens of thermoplastic materials
- ISO 294-1:1996, Plastics—Injection moulding of test specimens of thermoplastic materials—Part 1: General principles and moulding of multipurpose and bar test specimens
- ISO 294-3:1996, Plastics—Injection moulding of test specimens of thermoplastic materials—Part 3: Small plates
- ISO 295:1991, Plastics—Compression moulding of test specimens of thermosetting materials
- ISO 527-1:1993, Plastics—Determination of tensile properties—Part 1: General principles
- ISO 527-2:1993, Plastics—Determination of tensile properties—Part 2: Test conditions for moulding and extrusion plastics
- ISO 2818:1994, Plastics—Preparation of test specimens by machining
- ISO 3167:1993, Plastics—Multipurpose test specimens
- ISO 10724-1:1998, Plastics—Injection moulding of test specimens of thermosetting materials—Part 1: General principles and moulding of multipurpose test specimens
- ISO 10724-2:1998, Plastics—Injection moulding of test specimens of thermosetting materials—Part 2: Small plates
- ISO 11359-2, Plastics—Thermomechanical analysis (TMA)—Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature
- IEC 60250:1969, Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths

While similar ASTM standard-based data may be available, these tables do not include it. Materials without ISO measurements are not included in these tables.

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The tables are grouped in the same manner as the earlier chapter structure of this book.

These tables contain several notations besides numerical data. They are:

- * Inapplicable property, or a property not relevant to this material
- – Missing value, not applicable
- N No break in a Charpy Impact Test
- P Partial break

The descriptions of the plastics are structured in two parts. The first part is the base polymers that are abbreviated as in Table 11.1. The fillers are listed next, and they will be listed or abbreviated from those shown in Table 11.2, and they will be followed by a number indicating weight percent. Occasionally, the manufacturer only gives a combined weight, and in these cases the fillers are grouped in parentheses followed by the combined weight percent.

Table 11.1 Base Polymers Abbreviations

Abbreviation	Description
E/P	Ethylene–propylene
EVAC	Ethylene–vinyl acetate
MBS	Methacrylate–butadiene–styrene
ABS	Acrylonitrile–butadiene–styrene
ASA	Acrylonitrile–styrene–acrylate
C	Cellulose polymers
COC	Cycloolefin copolymer
EP	Epoxide; epoxy
HDPE	High density polyethylene
Imod	Impact modifier
LCP	Liquid crystalline polymer
MABS	Methyl methacrylate–acrylonitrile–butadiene–styrene
MF	Melamine–formaldehyde
MPF	Melamine–phenol–formaldehyde
PA11	Polyamide 11
PA12	Polyamide 12

(*Continued*)

Table 11.1 Base Polymers Abbreviations—*Cont'd*

Abbreviation	Description
PA12/MACMI	Copolyamide based on omega-aminododecanoic acid (laurolactame) and 3,3'-dimethyl-4,4'-diaminodicyclohexylmethane and isophthalic acid
PA46	Polyamide 46
PA6	Polyamide 6
PA6/6T	Copolyamide based on ε-caprolactam, hexamethylenediamine and terephthalic acid
PA610	Polyamide 610
PA612	Polyamide 612
PA66	Polyamide 66
PA66/6T	Copolyamide 66/6T
PA666	Copolyamide 666
PA6I/6T	Copolyamide based on hexamethylenediamine, isophthalic and terephthalic acid
PA6T/66	Copolyamide based on hexamethylenediamine, terephthalic acid and adipic acid
PA6T/6I	Copolyamide based on hexamethylenediamine, terephthalic and isophthalic acid
PA6T/XT	Polyamide 6 = hexamethylene diamine T = terephthalic acid X = different comonomers T = terephthalic acid
PAEK	Polyaryletherketone
PAI	Polyamideimide
PAIND/INDT	Polyamide NDT/INDT
PAMACM12	Homopolyamide based on 3,3'-dimethyl-4,4'-diaminodicyclohexylmethane and dodecanedioic acid
PAMXD6	Poly-*m*-xylylenadipamid
PAPACM12	Homopolyamide based on bis(*p*-aminocyclohexyl)methane and dodecanedioic acid
PBI	Polybenzimidazole
PBT	Polybutylene terephthalate
PC	Polycarbonate

(*Continued*)

Table 11.1 Base Polymers Abbreviations—*Cont'd*

Abbreviation	Description
PCCE	Polycyclohexylene dimethylene cyclohexanedicarboxylate, glycol and acid comonomer
PCTA	Polycyclohexylene dimethylene terephthalate, acid
PCTG	Polycyclohexylene dimethylene terephthalate, glycol
PE	Polyethylene
PEEK	Polyetheretherketone
PEI	Polyetherimide
PEN	Polyethylenenaphthalate
PES	Polyethersulfone
PET	Polyethylene terephthalate
PETG	Polyethylene terephthalate, glycol
PF	Phenol–formaldehyde
PI	Polyimide
PK	Polyketone
PMMA	Polymethyl methacrylate
PMMI	Polymethylmethyacrylimide
POM	Polyoxymethylene; polyformaldehyde
PP	Polypropylene
PPE	Polyphenylene ether
PPS	Polyphenylene sulfide
PPSU	Polyphenylsulfone
PS	Polystyrene
PS-SY	Syndiotactic polystyrene
PSU	Polysulfone
PTFE	Polytetrafluoroethylene
PUR	Polyurethane
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
SAN	Styrene acrylonitrile
SB	Styrene–butadiene
SMAH	Styrene–maleic anhydride
TEEE	Thermoplastic elastomer, ether-ester

(*Continued*)

Table 11.1 Base Polymers Abbreviations—*Cont'd*

Abbreviation	Description
TPA	Polyamide thermoplastic elastomer
TPC	Copolyester thermoplastic elastomer
TPO	Olefinic thermoplastic elastomer
TPS	Styrenic thermoplastic elastomer
TPU	Urethane thermoplastic elastomer
TPV	Thermoplastic rubber vulcanisate
TPZ	Unclassified thermoplastic elastomer, not grouped above
UHMWPE	Ultra high molecular weight polyethylene
UP	Unsaturated polyester

Table 11.2 Filler Abbreviations

Abbreviation	Description
CF	Carbon fiber
CD	Carbon fines, powder
GF	Glass fiber
GB	Glass beads, spheres, balls
GD	Glass fines, powder
GX	Glass not specified
K	Calcium carbonate
MD	Unspecified mineral
MeF	Metal fiber
MeD	Metal fines, powder
MiF	Mineral fiber
MiD	Mineral fines, powder
MiX	Mineral not specified
Moly	Molybdenum disulfide
NF	Natural organic fiber
P	Mica
Q	Silica
RF	Aramid fiber
T	Talcum, talc
X	Not specified
Z	Others not included in this list

11.1 Styrenic Plastics

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Polystyrene/Polimeri Europa													
EDISTIR N 1782	PS	3200	*	*	44	1.4	6.5	–	–	–	2.5	2	0.04
EDISTIR N 1840	PS	3200	*	*	37	1.3	6.5	–	–	–	2.5	2	0.04
EDISTIR N 1910	PS	3200	*	*	37	1.2	6.5	–	–	–	2.5	2	0.04
EDISTIR N 2380	PS	3300	*	*	47	2	8	–	–	–	2.5	2	0.04
EDISTIR N 2560	PS	3200	*	*	43	1.5	7	–	–	–	2.5	2	0.04
EDISTIR N 2982	PS	3200	*	*	26	1	6	–	–	–	2.5	2	0.04
EDISTIR R 321P	PS-I	2400	24	1.1	*	*	80	70	4	2	2.5	3	0.06
EDISTIR R 540E	PS-I	2000	24	1.6	*	*	N	–	9	–	2.5	3	0.06
EDISTIR R 850E	PS-I	1800	22	1.6	*	*	N	–	10	–	2.5	3	0.06
EDISTIR RC 3	PS-I	2000	29	1.5	*	*	130	–	10	–	2.5	3	0.06
EDISTIR RC 600	PS-I	1950	29	1.5	*	*	50	15	7	2	2.5	3	0.06
EDISTIR RCL 600	PS-I	1950	29	1.5	*	*	50	15	7	2	2.5	3	0.06
EDISTIR RK	PS-I	1900	24	1.7	*	*	70	60	6.5	4	2.5	4	0.06
EDISTIR RK 451G	PS-I	1950	21	1.3	*	*	70	–	7	–	2.5	4	0.06
EDISTIR RK 5512G	PS-I	2100	23	1.3	*	*	70	–	7	–	2.5	6	0.06
EDISTIR RKL	PS-I	1900	24	1.7	*	*	70	60	6.5	4	2.5	4	0.06
EDISTIR RT 441M	PS-I	1900	22	1.2	*	*	120	80	9	4	2.5	3	0.06
EDISTIR RT 461F	PS-I	2000	30	1.6	*	*	120	–	8	-	2.5	3	0.06
EDISTIR SR 550	PS-I	1900	18.5	1.2	*	*	N	–	8.5	–	2.5	3	0.06
KOBLEND P 475E	PS-I + PE	1600	25	2.7	*	*	N	–	–	–	–	–	–
KOBLEND P 477E	PS-I + PE	1200	20	3.1	*	*	N	N	29	11	–	–	–
Polystyrene/Styron													
STYRON 457	PS	2100	30	2	*	*	N	N	10	6	2.5	0.4	0
STYRON 485	PS	2000	20	1	*	*	N	N	7	5	2.5	0.4	0
STYRON 6335	PS	2000	26	2	*	*	N	N	11	6	–	–	0

STYRON 634	PS	3350	51	3	*	*	–	–	–	–	2.5	0.6	0
STYRON 637	PS	3300	48	2	*	*	–	–	–	–	2.5	0.6	0
STYRON 648	PS	3400	56	3	*	*	–	–	–	–	2.5	0.6	0
STYRON 660	PS	3350	46	2	*	*	–	–	–	–	2.5	0.6	0
STYRON 678E	PS	3300	42	2	*	*	–	–	–	–	2.5	0.6	0
STYRON 686E	PS	3650	55	3	*	*	–	–	–	–	2.5	0.6	0
STYRON A-TECH 1120	PS	2000	25	1.4	*	*	N	N	6	3	–	–	0
STYRON A-TECH 1175	PS	1650	16	1.4	*	*	N	N	11	–	–	–	0
STYRON A-TECH 1200	PS	1750	19	1.3	*	*	N	N	12	8	–	–	0
STYRON A-TECH 1400	PS	2000	20	1.3	*	*	N	N	10	6	–	–	0
Polystyrene/PolyOne													
Edgetek sPS® QT-10GB-10MN/000	PS-SY, GB10, MD10	4650	–	–	38	1.2	6	–	–	–	–	–	–
Edgetek sPS® QT-10GF/000	PS-SY, GF10	5580	–	–	63	1.1	7.3	–	2	–	–	–	–
Edgetek sPS® QT-10GF/000 FR	PS-SY, GF10	5800	–	–	60	1.7	13	–	1	–	–	–	–
Edgetek sPS® QT-10GF-10MN/000	PS-SY, GF10, MD10	6200	–	–	65	1.1	12	–	2	–	–	–	–
Edgetek sPS® QT-15GF-15GB/000	PS-SY, GF10, GB10	7950	–	–	85	1.4	22	–	5	–	–	–	–
Edgetek sPS® QT-20GB/000	PS-SY, GB20	4000	–	–	37	1	–	–	–	–	–	–	–
Edgetek sPS® QT-20GF/000	PS-SY, GF20	7800	–	–	80	1.1	28	–	5	–	–	–	–
Edgetek sPS® QT-22GF/000 FR	PS-SY, GF22	7000	–	–	95	1.5	35	–	8	–	–	–	–
Edgetek sPS® QT-22MN/000 HI	PS-SY, MD22	4850	–	–	44	1.2	10	–	1	–	–	–	–
Edgetek sPS® QT-25GF/000 FR	PS-SY, GF25	8000	–	–	90	1.5	22	–	6	–	–	–	–

(*Continued*)

11.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Edgetek sPS® QT-30GB/000	PS-SY, GB30	4550	–	–	38	1.2	6	–	–	–	–	–	–
Edgetek sPS® QT-30GF/000	PS-SY, GF30	10200	–	–	123	1.6	30	–	6	–	–	–	–
Edgetek sPS® QT-30GF/000 FR	PS-SY, GF30	10300	–	–	104	1.6	20	–	4.5	–	–	–	–
Edgetek sPS® QT-30GF/000 FR HC	PS-SY, GF30	10500	–	–	120	1.5	35	–	9	–	–	–	–
Edgetek sPS® QT-40GF/000	PS-SY, GF40	12500	–	–	140	1.6	36	–	7	–	–	–	–
ASA/Styrolution													
Luran® S 757 G	ASA	2400	51	3.3	*	*	190	80	12	3	3.2	250	1.65
Luran® S 757 R	ASA	2600	56	3.1	*	*	200	70	12	3	3.4	250	1.65
Luran® S 776 S	ASA	2200	47	3.3	*	*	270	150	30	3	3.4	340	1.65
Luran® S 776 SE	ASA	2200	47	3.3	*	*	270	150	30	3	3.4	340	1.65
Luran® S 777 K	ASA	2300	48	3.3	*	*	250	90	17	4	3.4	240	1.65
Luran® S 778 T	ASA	2500	54	3.4	*	*	250	90	15	4	3.5	330	1.65
Luran® S 778 TE	ASA	2500	54	3.4	*	*	250	90	15	4	3.5	330	1.65
Luran® S 796 M	ASA	2000	41	3.5	*	*	250	150	30	5	3.3	250	1.65
Luran® S 797 S	ASA	2000	42	3.5	*	*	250	180	40	9	3.3	260	1.65
Luran® S 797 SE	ASA	2000	42	3.5	*	*	250	180	40	9	3.3	260	1.65
Luran® S KR 2858 G3	ASA, GF15	6600	*	*	110	2.5	28	17	7	6	–	–	1.42
Luran® S KR 2859	ASA	2500	55	3.2	*	*	160	80	11	4	–	–	1.65
ASA/A. SCHULMAN													
POLYMAN® (ASA) E 1006	ASA	2400	53	3	*	*	–	–	11	–	3	90	1.2
POLYMAN® (ASA) E 1007 H	ASA	2400	53	3	*	*	–	–	7	–	3	90	1.2

POLYMAN® (ASA) E/M11010	ASA	2200	46	3.5	*	*	–	–	11	–	3	90	1.2
POLYMAN® (ASA) M/MI 2010	ASA	2200	46	4.0	*	*	–	–	10	–	3	90	1.20
SAN/INEOS													
Lustran SAN® 32	SAN	3700	*	*	70	2	16	16	–	–	2.9	70	–
Lustran SAN® 35	SAN	3700	*	*	80	2	20	20	–	–	3	60	–
SAN/A. SCHULMAN													
POLYMAN® (SAN) 24/5	SAN	3700	*	*	70	3	12	–	3	–	2.8	70	0.2
POLYMAN® (SAN) 29/10	SAN	3700	*	*	70	3	1	–	3	–	2.8	70	0.2
POLYMAN® FSAN 35 GF	SAN, GF25	11000	*	*	100	1.7	15	–	3.6	–	–	–	0.1
SAN/Styrolution													
Luran® 358 N	SAN	3700	*	*	72	3	16	16	2	*	2.7	70	–
Luran® 358 N Crystal Clear	SAN	3700	*	*	72	3	16	16	2	*	2.7	70	–
Luran® 368 R	SAN	3700	*	*	75	3	18	18	2	*	2.7	70	–
Luran® 368 R Crystal Clear	SAN	3700	*	*	75	3	18	18	2	*	2.7	70	–
Luran® 378 P	SAN	3800	*	*	75	3.5	19	19	2	*	2.7	80	–
Luran® 378 P G7	SAN, GF35	12000	*	*	110	2	17	17	4	*	3.2	100	–
Luran® 388 S	SAN	3800	*	*	79	3	21	19	2.5	*	2.8	80	–
Luran® KR 2556	SAN	3900	*	*	79	5	20	21	2	*	2.7	70	–
Luran® KR 2636	SAN	3600	*	*	70	2.5	14	14	1.5	*	2.8	70	–
SAN/Polimeri Europa													
KOSTIL B 265(0)	SAN	3450	*	*	67	2.5	16	16	–	–	–	–	0.5
KOSTIL B 266(1)	SAN	3450	*	*	67	2.5	16	16	–	–	–	–	0.5
KOSTIL B 361 R11	SAN	3350	60	3	*	*	18	18	–	–	–	–	0.5
KOSTIL B 365(0)	SAN	3450	*	*	65	2.2	14	14	–	–	–	–	0.5
KOSTIL B 366(1)	SAN	3450	*	*	65	2.2	14	14	–	–	–	–	0.5

(*Continued*)

11.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
KOSTIL B 361 R42	SAN	3200	51	3	*	*	24	21	–	–	–	–	0.5
KOSTIL C 266(1)	SAN	3500	*	*	70	3	18	18	–	–	–	–	0.5
KOSTIL PD C 166	SAN	3600	*	*	70	3	19	19	–	–	–	–	0.5
SAN/Styron													
TYRIL 100	SAN	3440	*	*	71	2.4	6	2	2	2	–	–	–
TYRIL 125	SAN	3500	*	*	56	1.6	10	10	2	1	–	–	–
TYRIL 790	SAN	3800	76	2.6	*	*	17	18	–	–	2.8	1	0.1
TYRIL 867 EUV	SAN	3700	72	2.6	*	*	17	18	–	–	3	–	0.1
TYRIL 867E	SAN	3700	72	2.6	*	*	17	18	–	–	3	–	0.1
TYRIL 880	SAN	3700	*	*	77	2.6	20	20	2	2	–	–	–
TYRIL 880B	SAN	3500	*	*	84	2.5	20	20	2	2	–	–	–
TYRIL 905	SAN	3350	65	2.5	*	*	16	17	–	–	3	–	0.2
TYRIL 905 UV	SAN	3350	65	2.5	*	*	16	17	–	–	3	–	0.2
TYRIL 990	SAN	3400	*	*	63	2	10	10	2	2	–	–	–
ABS/Styron													
MAGNUM 1040	ABS	1900	42	2.8	*	*	N	N	63	16	–	–	–
MAGNUM 2620	ABS	2300	48	2.5	*	*	N	80	24	8	–	–	–
MAGNUM 2630	ABS	2000	44	2.4	*	*	N	N	32	15	–	–	–
MAGNUM 2642	ABS	2100	41	2.1	*	*	N	100	13	7	–	–	–
MAGNUM 275	ABS	2000	44	2.6	*	*	N	N	22	9	–	–	–
MAGNUM 3404	ABS	2150	43	2.5	*	*	N	N	16	9	2.8	60	0.5
MAGNUM 3404 "Smooth"	ABS	2150	43	2.7	*	*	N	N	13	9	–	–	–
MAGNUM 3416SC	ABS	2280	40	2.4	*	*	N	N	18	9	–	–	–
MAGNUM 342EZ	ABS	1800	37	2.3	*	*	N	N	16	8	–	–	–
MAGNUM 344CC	ABS	2030	–	–	–	–	N	86	15	7	–	–	–
MAGNUM 344HP	ABS	2000	44	2.5	*	*	N	N	20	7	–	–	–

MAGNUM 3453	ABS	2280	45	2.5	*	*	N	N	19	10	–	–	–
MAGNUM 347EZ	ABS	1890	34	2.2	*	*	140	90	8	5	–	–	–
MAGNUM 348	ABS	1800	37	2.3	*	*	N	N	16	8	–	–	–
MAGNUM 3490	ABS	2200	49	2.4	*	*	N	80	17	5	–	–	–
MAGNUM 3504	ABS	2120	42	2.5	*	*	N	N	22	11	2.9	70	0.5
MAGNUM 3513	ABS	2600	47	2.4	*	*	N	N	22	11	2.7	80	0.7
MAGNUM 3525	ABS	2080	–	–	–	–	N	N	18	10	–	–	–
MAGNUM 357HP	ABS	2100	40	2.3	*	*	N	80	16	7	–	–	–
MAGNUM 358HP	ABS	2380	–	–	–	–	N	60	18	7	–	–	–
MAGNUM 3616	ABS	2200	38	3	*	*	N	N	25	10	–	–	–
MAGNUM 3904	ABS	1900	35	2.5	*	*	N	N	38	16	–	–	–
MAGNUM 3904 “Smooth”	ABS	1820	37	2.6	*	*	N	N	37	18	–	–	–
MAGNUM 5200	ABS	1980	35	2.4	*	*	140	60	15	6	–	–	–
MAGNUM 541	ABS	2200	45	2.4	*	*	N	100	24	9	–	–	–
MAGNUM 545	ABS	2200	45	2.4	*	*	N	100	24	9	–	–	–
MAGNUM 555	ABS	2200	47	2.6	*	*	N	N	40	12	–	–	–
MAGNUM 8391	ABS	2400	–	–	–	–	N	N	18	9	–	–	–
MAGNUM 8434	ABS	2200	–	–	–	–	N	N	–	–	–	–	–
MAGNUM 9010	ABS	2300	50	2.4	*	*	N	90	19	6	–	–	–
MAGNUM 9020	ABS	2300	48	2.5	*	*	N	80	24	8	–	–	–
MAGNUM 9030	ABS	2000	44	2.4	*	*	N	N	32	15	–	–	–
MAGNUM 941	ABS	1900	42	2.8	*	*	N	N	63	16	–	–	–
MAGNUM 9555	ABS	2400	50	2.3	*	*	N	N	29	9	–	–	–
MAGNUM 9575	ABS	2350	42	2.6	*	*	140	60	22	8	–	–	–
MAGNUM AG 700	ABS	2000	33	1.8	*	*	N	N	16	7	–	–	–
MAGNUM FG 960	ABS	2000	44	2.6	*	*	N	N	22	9	–	–	–
MAGNUM HPC 952	ABS	2100	45	2.6	*	*	N	N	44	18	–	–	–
MAGNUM PG 914	ABS	2000	44	2.6	*	*	N	N	22	9	–	–	–

(*Continued*)

11.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
ABS/A. SCHULMAN													
POLYFLAM® RABS 90000 UV5	ABS	2200	42	3	*	"	80	45	10	5	–	–	–
POLYFLAM® RABS 90000 UV6	ABS	2500	40	2.1	*	*	N	56	10	5	3	7	1
POLYFLAM® RABS 92000 UV5	ABS, GF15	2350	*	*	42	2.2	45	13	5.5	3.6	–	–	0.8
POLYMAN® (ABS) E/HI	ABS	1500	40	2.5	*	*	N	N	34	19	3	90	1.2
POLYMAN® (ABS) FABS 30 GB	ABS, GB30	2800	35	1.8	*	*	–	–	5	–	–	–	–
POLYMAN® (ABS) HH	ABS	1900	49	2.7	*	*	65	–	12	7	–	–	–
POLYMAN® (ABS) HH 2	ABS	1800	51	2.7	*	*	60	–	10	6	–	–	–
POLYMAN® (ABS) HH 3	ABS	1800	53	2.8	*	*	50	–	6	2	3	90	1.2
POLYMAN® (ABS) HH 3 D	ABS	2300	49	2.8	*	*	70	27	11	6	3	90	1.2
POLYMAN® (ABS) LC 145	ABS	2200	45	3	*	*	N	N	15	8	3	90	1.2
POLYMAN® (ABS) LC 165	ABS	2200	43	3	*	*	N	N	21	10	3	90	1.2
POLYMAN® (ABS) LC 185 A	ABS	2500	45	2.3	*	*	N	N	16	8	3	90	1.2
POLYMAN® (ABS) M/AQ	ABS	2300	45	2.8	*	*	N	–	20	7	3	90	1.2
POLYMAN® (ABS) M/HI-A	ABS	2200	48	2.1	*	*	N	71	20	9	3	90	1.2
POLYMAN® (ABS) M/HI-G	ABS	2100	45	2.5	*	*	N	–	15	–	–	–	–

POLYMAN® (ABS) M/HI-W	ABS	2200	50	3	*	*	85	71	20	11	3	90	1.2
POLYMAN® (ABS) M/MI-A 40	ABS	2300	41	2.5	*	*	70	–	15	–	–	–	–
POLYMAN® (ABS) M/MI-A K1452	ABS	2300	50	2.3	*	*	N	75	16	7	3	90	1.2
POLYMAN® (ABS) M/SHI	ABS	2200	45	2.3	*	*	N	93	27	11	3	90	1.2
POLYMAN® (ABS) M/TK	ABS	2500	52	2.5	*	*	N	80	15	7	–	–	–
POLYMAN® (ABS) M/TK-A	ABS	2500	52	2.5	*	*	N	80	15	7	3	90	1.2
POLYMAN® (ABS) M/TK-HH	ABS	2300	48	2.5	*	*	N	–	7	–	3	90	1.2
POLYMAN® (ABS) NWB/HI	ABS	1900	42	3	*	*	N	–	27	–	3	90	1.2
POLYMAN® FABS 20 GF	ABS, GF20	5500	*	*	65	2	13	18	6	4	3	–	–
POLYMAN® + A208 (ABS) NWB/MI		2100	47	3	*	*	N	–	16	–	3	90	1.2
ABS/INEOS													
Lustran ABS® E401	ABS	1900	40	2.5	*	*	210	170	30	16	2.9	90	–
Lustran ABS® H604	ABS	2400	45	2.6	*	*	180	110	20	11	2.9	90	–
Lustran ABS® H605	ABS	2400	47	2.5	*	*	90	80	17	7	3	80	–
Lustran ABS® H606LS	ABS	2550	48	2.6	–	–	100	80	18	9	3	100	–
Lustran ABS® H607AS	ABS	2400	46	2.5	*	*	130	90	19	9	2.9	90	–
Lustran ABS® H701	ABS	2150	41	2.7	*	*	180	120	24	13	3	90	–
Lustran ABS® H702	ABS	2500	46	2.6	*	*	100	90	16	8	2.9	90	–
Lustran ABS® H802	ABS	2700	51	2.8	*	*	100	80	15	7	3	100	–
Lustran ABS® H950	ABS	2600	50	2.9	*	*	140	90	16	7	3	100	–
Lustran ABS® M201AS	ABS	2400	47	2.5	*	*	140	80	19	10	2.9	90	–

(*Continued*)

11.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Lustran ABS® M202AS	ABS	2300	44	2.4	*	*	100	80	16	8	3	80	–
Lustran ABS® M203FC	ABS	2400	46	2.6	*	*	110	90	15	7	2.9	90	–
Lustran ABS® M301AS	ABS	2100	42	2.6	*	*	170	120	21	12	2.9	90	–
Lustran ABS® M301FC	ABS	2100	42	2.6	*	*	170	120	21	12	2.9	90	–
Lustran ABS® M305	ABS	2300	45	2.5	*	*	150	110	21	11	2.9	80	–
Novodur® P2H-AT	ABS	2500	44	2.1	*	*	100	80	16	7	2.9	90	–
Novodur® P2HE	ABS	2500	44	2.4	*	*	160	90	19	11	2.9	80	–
Novodur® P2HGV	ABS, GF16	5500	74	2	*	*	18	20	6	5	3.1	60	–
SBC/Styrolution													
Styrolux® 3G 46	SBC	1550	27	2	–	–	N	–	3	2	2.5	–	0.07
Styrolux® 3G 55	SBC	900	15	2	*	*	N	–	85	–	2.5	8	0.07
Styrolux® 656 C	SBC	1800	35	2	*	*	25	–	2	–	2.5	8	0.07
Styrolux® 684 D	SBC	1500	26	2	*	*	N	–	4	–	2.5	8	0.07
Styrenic Blends/A. SCHULMAN													
POLYFLAM® (ABS/PA) RMMK 125		2500	52	3	*	*	N	N	12	9	–	–	–
POLYFLAM® RMMB 40300	ABS + PC	2800	63	4	*	*	N	N	18	1	–	–	–
POLYFLAM® RMMB 4070	ABS + PC	2600	60	4.5	*	*	N	N	22	14	–	–	–
POLYFLAM® RMMB 4070 F FR 4	ABS + PC	2400	60	5.4	*	*	N	N	40	17	–	–	–
POLYFLAM® RMMB 4070 HF	ABS + PC	2600	60	4	*	*	N	N	13	–	–	–	–
POLYFLAM® RMMB 60300	ABS + PC	2200	40	3	*	*	N	86	10	–	–	–	–

POLYFLAM® RMMB 60500	ABS + PC	2400	48	4	*	*	N	N	16	9	–	–	–
SCHULABLEND® (ABS/PA) M/MK	ABS + PA6	1800	44	3	*	*	N	N	72	32	–	–	–
SCHULABLEND® (PC/ABS) M/MB 3	ABS + PC	2300	49	4	*	*	N	N	39	17	–	–	–
SCHULABLEND® (PC/ABS) M/MB 5	ABS + PC	2200	52	4	*	*	N	N	45	–	–	–	–
SCHULABLEND® (PC/ABS) M/MB 6	ABS + PC	2300	55	5	*	*	N	N	50	43	–	–	–
SCHULABLEND® (PC/ASA) WR 5	ABS + ASA	2400	55	4.5	*	*	N	N	3	–	–	–	–
SCHULABLEND® (PC/ASA) WR 5 UV	ABS + ASA	1900	44	4	*	*	N	N	37	20	–	–	–
SCHULABLEND® ABS/PA) M/MK 20GF	ABS + PA6, GF20	4900	*	*	77	4.5	36	–	9	–	–	–	–
Styrenic Blends/Styrolution													
Luran® S KR 2861/1 C	ASA + PC	2300	53	4.9	*	*	N	N	60	20	3.2	150	0.9
Luran® S KR 2863 C	ASA + PC	2500	62	4.9	*	*	N	N	60	17	3	100	0.6
Luran® S KR 2864 C	ASA + PC	2600	63	4.6	*	*	N	N	70	11	3	120	0.6
Luran® S KR 2866 C	ASA + PC	2600	60	3.4	*	*	N	160	35	5	–	–	0.9
Luran® S KR 2867 C WU	ASA + PC	2600	61	4	*	*	N	N	16	9	3	100	0.4
Luran® S KR 2950	ASA + PMMA	2100	49	3.6	–	–	120	54	9.5	3	–	–	–
Terblend® N NG 02 (cond.)	ABS + PA6, GF8	2400	*	*	40	4	–	–	–	–	3.6	500	*
Terblend® N NG 02 (dry)	ABS + PA6, GF8	3200	*	*	45	3.5	35	25	8	3	2.9	130	–
Terblend® N NG 04 (cond.)	ABS + PA6, GF20	4100	*	*	50	3.5	–	–	–	–	3.6	500	*

(*Continued*)

11.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Terblend® N NG 04 (dry)	ABS + PA6, GF20	5400	*	*	60	3.2	30	25	8	5	2.9	130	–
Terblend® N NG-06 (cond.)	ABS + PA6, GF30	6500	*	*	80	3.5	–	–	–	–	3.6	500	*
Terblend® N NG-06 (dry)	ABS + PA6, GF30	7500	*	*	90	3	35	30	9	6	2.9	130	3.4
Terblend® N NM-11 (cond.)	ABS + PA6	1600	34	5.5	*	*	–	–	–	–	3.3	550	*
Terblend® N NM-11 (dry)	ABS + PA6	2000	43	3.5	*	*	N	N	65	15	2.9	150	–
Terblend® N NM-12 (cond.)	ABS + PA6	1900	45	5	*	*	–	–	–	–	3.3	550	*
Terblend® N NM-12 (dry)	ABS + PA6	2200	50	3.2	*	*	N	-	17	9	2.9	150	–
Terblend® N NM-19 (cond.)	ABS + PA6	1600	34	5.5	*	*	–	–	–	–	3.3	550	*
Terblend® N NM-19 (dry)	ABS + PA6	2000	43	3.5	*	*	N	N	65	15	2.9	150	–
Terblend® N NMX04 (cond.)	ABS + PA6	1600	32	5.5	*	*	–	–	–	–	3.3	550	*
Terblend® N NMX04 (dry)	ABS + PA6	2000	40	3.5	*	*	N	N	65	20	2.9	150	–
Styrenic Blends/INEOS													
Lustran ABS® H801	ABS + PC	2400	49	3	*	*	220	160	30	12	3	90	–
Triax® 1120 (cond.)	ABS + PA6	1050	30	13	*	*	N	N	74	16	3.7	–	*
Triax® 1120 (dry)	ABS + PA6	1900	40	3.2	*	*	N	N	74	16	3.6	–	6
Triax® 1220 S (cond.)	ABS + PA6	950	29	13	*	*	N	N	72	25	–	–	*
Triax® 1220 S (dry)	ABS + PA6	1700	39	3.5	*	*	N	N	72	23	–	–	6
Triax® 1315 GF (cond.)	ABS + PA6, GF15	4000	*	*	70	5	36	36	10	6	4	–	*

Triax® 1315 GF (dry)	ABS + PA6, GF15	4800	*	*	82	4	36	36	10	6	3.8	–	3.8
Triax® DP 3155 (cond.)	ABS + PA6	2000	38	5.3	*	*	–	–	–	–	3.4	–	*
Triax® DP 3155 (dry)	ABS + PA6	3200	54	3.3	*	*	100	70	–	–	3.3	–	4.3
Triax® KU2-3050 (dry)	ABS + PA6	1900	40	3.2	*	*	N	N	74	16	3.6	–	6
Triax® KU2-3050 (cond.)	ABS + PA6	1050	30	13	*	*	N	N	74	16	3.7	–	*

11.2 Polyethers

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Acetal Homopolymer/DuPont													
Delrin® 100AL NC010	POM, Z	2700	70	18	*	*	150	100	9	7	–	–	–
Delrin® 100 NC010	POM	3100	71	27	–	–	N	N	14	11	3.7	50	0.9
Delrin® 100KM NC000	POM, RF5	2900	*	*	65	15	–	–	4.5	–	–	–	–
Delrin® 100P NC010	POM	2900	70	25	*	*	N	350	14	11	3.7	40	1.4
Delrin® 100ST NC010	POM + Imod	1400	43	30	*	*	N	N	100	20	3.8	–	0.9
Delrin® 100T NC010	POM + Imod	1900	52	26	*	*	N	N	25	14	3.1	90	0.9
Delrin® 107 NC010	POM	3200	72	25	–	–	N	350	14	11	3.8	50	0.9
Delrin® 111P NC010	POM	3200	72	20	*	*	210	200	11	8	–	43	1
Delrin® 1260 NC010	POM	2900	65	7	–	–	160	140	6	6	3.8	43	0.7

(*Continued*)

11.2 Polyethers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Delrin® 127UV NC010	POM	3000	70	23	*	*	400	350	15	11	3.4	60	1.2
Delrin® 150 NC010	POM	3100	72	23	–	–	–	–	12	–	–	50	1.4
Delrin® 300AS BK000	POM, CF	9000	58	5	–	–	–	–	4.5		–	400	3
Delrin® 311 DP NC010	POM	3300	74	15	–	–	32	–	10	9	3.8	–	0.4
Delrin® 460 NC010	POM	2800	64	9	–	–	200	180	7.1	6.4	3.9	44	0.75
Delrin® 460E NC010	POM	2700	63	9	–	–	–	–	6	–	–	700	6.8
Delrin® 500AF	POM, Z20	2900	50	12	–	–	40	35	3	3	3.1	90	1
Delrin® 500AL NC010	POM, Z	3100	63	11	–	–	150	120	7	6	–	650	6
Delrin® 500CL NC010	POM	3100	70	14	*	*	350	290	8	7	3.5	60	1
Delrin® 500MP NC010	POM	3400	70	12	–	–	–	–	5	5	–	–	–
Delrin® 500P NC010	POM	3100	71	14	*	*	300	300	9	8	3.9	60	1.4
Delrin® 500T NC010	POM + Imod	2500	58	16	*	*	N	340	15	12	3.6	160	0.8
Delrin® 500TL NC010	POM, Z	2300	71	14	*	*	170	160	5	4	–	600	0.9
Delrin® 510GR NC000	POM, GF10	5500	–	–	–	–	48	60	5	5	–	70	1.1
Delrin® 511P NC010	POM	3400	75	11	*	*	15	–	8	7	3.8	60	0.9
Delrin® 520MP NC010	POM, Z20	2800	54	16	–	–	7	–	4	–	–	–	1.4
Delrin® 525GR NC000	POM, GF25	9500	*	*	140	3	55	66	8	8	3.8	–	1.3
Delrin® 527UV NC010	POM	3100	70	15	*	*	270	260	8	8	3.8	60	1.2
Delrin® 542CM NC010	POM	3100	72	16	–	–	300	300	8	8	–	–	1.4

Delrin® 560 NC010	POM	2900	60	10	–	–	–	160	6.9	6	–	–	0.9
Delrin® 560HD OR729	POM	2950	63	8	*	*	–	–	6	–	–	–	5.8
Delrin® 570 NC000	POM, GF20	6000	*	*	59	12	54	50	4	3	3.9	50	0.8
Delrin® 900P NC010	POM	3200	71	12	*	*	200	200	7	6	3.8	50	1.4
Delrin® 911 P NC010	POM	3400	–	–	–	–	–	–	7	–	–	–	1
Delrin® 911AL NC010	POM, Z	3200	70	9	*	*	–	–	6	–	–	–	–
Delrin® II100 NC010	POM	3100	71	25	*	*	N	–	15	12	–	–	–
Acetal Copolymer/Celanese													
CELCON AM90S	POM	2500	–	–	–	–	–	–	7	–	–	–	–
CELCON AM90S Plus	POM	2500	–	–	–	–	–	–	7	–	–	–	–
CELCON AS270	POM	2750	–	–	–	–	4	–	–	–	–	–	–
CELCON C13031 XAS	POM	2710	–	–	–	–	–	–	7.5	–	–	–	–
CELCON C13031 XF	POM	2900	–	–	–	–	–	–	6.7	–	–	–	–
CELCON CF801	POM	2450	–	–	–	–	–	–	4.4	–	–	–	–
CELCON CF802	POM	3100	–	–	–	–	60	70	4.5	4.1	–	–	–
CELCON EC-90PLUS	POM	1880	37	6	–	–	–	–	4.3	–	–	–	2.8
CELCON EF10	POM	8470	–	–	67	2	–	–	4.2	–	–	–	–
CELCON GB10	POM, GB10	3100	–	–	–	–	–	–	3.5	–	–	–	–
CELCON GB25	POM, GB25	3700	–	–	–	–	–	–	2.4	2.2	–	–	0.65
CELCON GC10	POM, GF10	4750	–	–	75	3	30	45	4.5	–	–	–	–
CELCON GC15	POM, GF15	5950	–	–	91	2.5	–	–	4.9	–	–	–	–
CELCON GC20	POM, GF20	7300	–	–	99	2.2	30	40	6	–	–	–	–
CELCON GC25A	POM, GF25	8600	–	–	106	2	25	35	6.4	–	–	–	0.65
CELCON GC25T	POM, GF25	8630	–	–	129	3	50	55	8.7	7.2	–	–	–
CELCON GC25TF	POM, GF25	8720	–	–	120	2	–	–	6.4	–	–	–	–
CELCON GC90UV	POM, GF10	4170	–	–	59	9	–	–	3.7	–	–	–	–

(*Continued*)

11.2 Polyethers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
CELCON LM25	POM	2490	–	–	–	–	–	–	5.7	–	–	–	–
CELCON LM90	POM	2750	–	–	–	–	–	–	4.7	–	–	–	–
CELCON LM90Z	POM	2700	–	–	–	–	–	–	4.7	–	–	–	–
CELCON LU02	POM	2530	56	9	–	–	–	–	3.7	–	–	–	–
CELCON LW25-S2	POM	2350	–	–	–	–	–	–	8.5	–	–	–	–
CELCON LW90	POM	2500	–	–	–	–	–	–	–	–	–	–	0.65
CELCON LW90-F1	POM, PTFE	2800	–	–	–	–	5.3	–	–	–	–	–	–
CELCON LW90-F2	POM, PTFE	2650	–	–	–	–	120	120	5	–	–	–	–
CELCON LW90-F4	POM, PTFE	2600	–	–	–	–	70	75	4	4.3	–	–	–
CELCON LW90-F5	POM, PTFE	2540	–	–	–	–	56	61	3.5	–	–	–	–
CELCON LW90GPK	POM	2590	–	–	–	–	–	–	3.9	–	–	–	–
CELCON LW90-S2	POM, Si2	2500	–	–	–	–	–	–	6.8	4.5	–	–	–
CELCON LWGC-F4	POM, PTFE4, GF25	8700	–	–	85	1.5	–	–	5	–	–	–	–
CELCON LWGC-S2	POM, Si2, GF22	8200	–	–	94	2	–	–	6	–	–	–	–
CELCON M140	POM	2740	–	–	–	–	–	–	6	–	–	–	0.65
CELCON M140-L1	POM	2630	–	–	–	–	–	–	6.2	–	–	–	–
CELCON M15HP	POM	2800	–	–	–	–	280	240	10	6	–	–	–
CELCON M25	POM	2460	–	–	–	–	250P	190	9.1	–	–	–	0.65
CELCON M25UV	POM	2480	–	–	–	–	–	–	8.5	–	–	–	–
CELCON M270™	POM	2820	–	–	–	–	120	110	5.2	–	–	–	–
CELCON M270UV	POM	2800	–	–	–	–	–	–	4.5	–	–	–	–
CELCON M30AE	POM	2420	–	–	–	–	–	–	8.5	–	–	–	–
CELCON M450	POM	2890	–	–	–	–	–	–	4.4	–	–	–	0.65
CELCON M50	POM	2500	–	–	–	–	–	–	8.7	–	–	–	–
CELCON M90-34	POM	2560	–	–	–	–	–	–	7.4	–	–	–	–

CELCON M90AW	POM	2430	–	–	–	–	90	91	5	–	–	–	–
CELCON M90SW	POM	2600	–	–	–	–	110	90	5	–	–	–	–
CELCON M90™	POM	2760	–	–	–	–	190	180	6	6	–	–	0.65
CELCON M90UV	POM	2610	–	–	–	–	–	–	6.1	–	–	–	0.65
CELCON MC270	POM, MD	3150	–	–	–	–	–	–	5.4	–	–	–	–
CELCON MC270-HM	POM, MD	3750	–	–	–	–	–	–	4.8	–	–	–	–
CELCON MC90	POM, MD	3010	–	–	–	–	–	–	6.8	–	–	–	–
CELCON MC90-HM	POM, MD	3570	–	–	–	–	–	–	6.3	4.9	–	–	–
CELCON MR15HPB	POM	2900	–	–	–	–	150	140	10	9	–	–	–
CELCON MR50B	POM	2600	–	–	–	–	140	120	8.3	–	–	–	–
CELCON MR90B	POM	2800	–	–	–	–	110	110	5.1	–	–	–	–
CELCON MT12R01	POM	2900	65	9	–	–	140	130	6.5	6	–	–	0.65
CELCON MT12U01	POM	2900	65	9	–	–	150	140	6	6	–	–	0.65
CELCON MT12U03	POM	3100	70	8	–	–	120	120	6	6	–	–	0.65
CELCON MT24F01	POM	2600	–	–	–	–	80	–	–	–	–	–	–
CELCON MT24U01	POM	2900	65	7.5	–	–	120	120	5.5	5.5	–	–	0.65
CELCON MT2U01	POM	2600	62	9	–	–	220	200	8.5	7	–	–	0.65
CELCON MT8F01	POM	2600	58	9	–	–	–	–	5.2	–	–	–	–
CELCON MT8F02	POM	2500	48	7	–	–	60	60	4	4	–	–	0.2
CELCON MT8R02	POM	2700	62	9	–	–	–	–	8	–	–	–	–
CELCON MT8U01	POM	2850	64	9	–	–	180	160	6.5	6	–	–	0.65
CELCON TX90	POM	2150	–	–	–	–	N	160	11	3	–	–	0.65
CELCON TX90PLUS	POM	1700	–	–	–	–	N	210	11	3	–	–	0.65
CELCON UV140LG	POM	1950	41	10	–	–	–	–	3.1	–	–	–	–
CELCON UV25Z	POM	2460	–	–	–	–	–	–	8.1	–	–	–	–
CELCON UV270Z	POM	2700	–	–	–	–	–	–	4.7	–	–	–	–
CELCON UV90Z	POM	2700	64	9	–	–	100	–	6	–	–	–	0.65
CELCON WR25Z	POM	2620	–	–	–	–	–	–	6.4	–	–	–	–
CELCON WR9OZ	POM	2660	–	–	–	–	99	–	5.5	–	–	–	–

(*Continued*)

11.2 Polyethers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
HOSTAFORM C 13021	POM	2900	65	8.5	–	–	150	140	6.5	6	4	50	0.65
HOSTAFORM C 13021 RM	POM	2900	65	9	–	–	140	130	6.5	6	4	50	0.65
HOSTAFORM C 13031	POM	3050	68	8	–	–	120	120	6.7	6	4	50	0.65
HOSTAFORM C 13031 K	POM	3100	64	8	–	–	–	–	5	5	4.2	80	0.65
HOSTAFORM C 2521	POM	2600	62	9	–	–	220P	200	8.5	7	4	50	0.65
HOSTAFORM C 2521 G	POM	2100	44	12	–	–	50	50	5	4.5	3.8	70	0.8
HOSTAFORM C 2552	POM	2500	60	9.5	–	–	220P	200	9	7	4	50	0.65
HOSTAFORM C 27021	POM	2900	65	7.5	–	–	120	120	6	4.5	4	50	0.65
HOSTAFORM C 27021 AST	POM	2800	63	8	–	–	120	120	6	5.5	*	*	0.7
HOSTAFORM C 27021 GV3/30	POM, GB30	3800	38	6	–	–	30	30	2.5	3	4.5	80	0.9
HOSTAFORM C 52021	POM	3000	65	7	–	–	100	100	5.5	5	4	50	0.65
HOSTAFORM C 9021	POM	2850	64	9	–	–	180P	160	6.5	6	4	50	0.65
HOSTAFORM C 9021 10/1570	POM	3000	64	8	–	–	110	110	6.5	6	*	*	0.65
HOSTAFORM C 9021 AW	POM	2600	58	8	–	–	150	130	6	5	3.8	50	0.65
HOSTAFORM C 9021 G	POM	2300	45	9	–	–	30	30	3.5	3	3.8	70	0.8
HOSTAFORM C 9021 GV1/10	POM, GF10	4800	–	–	90	4	40	50	6.5	6.5	4.1	60	0.85

HOSTAFORM C 9021 GV1/20	POM, GF20	7200	–	–	120	3	35	40	8	8	4.3	60	0.85
HOSTAFORM C 9021 GV1/30	POM, GF30	9200	–	–	135	2.5	30	35	8	8	4.3	60	0.9
HOSTAFORM C 9021 GV1/40	POM, GF40	13000	–	–	140	2	20	25	9	9	4.5	60	0.9
HOSTAFORM C 9021 GV3/10	POM, GB10	3100	52	7.5	–	–	60	60	4	4	4.1	60	0.8
HOSTAFORM C 9021 GV3/20	POM, GB20	3400	46	6.5	–	–	50	50	3.5	3.5	4.2	70	0.8
HOSTAFORM C 9021 GV3/30	POM, GB30	3700	37	6	–	–	40	40	3	3	4.5	80	0.9
HOSTAFORM C 9021 K	POM	3000	60	8	–	–	100	100	5	5	4.2	60	0.65
HOSTAFORM C 9021 M	POM	2800	65	9	–	–	120	120	6	6	4.2	80	0.75
HOSTAFORM C 9021 SW	POM	2850	53	7	–	–	90	85	4	4	4.1	75	–
HOSTAFORM C 9021 TF	POM	2500	48	7	–	–	60	60	4	4	3.7	80	0.65
HOSTAFORM MT12U01	POM	2900	65	9	–	–	150	140	6	6	–	–	0.65
HOSTAFORM MT12U03	POM	3100	70	8	–	–	120	120	6	6	–	–	0.65
HOSTAFORM MT24U01	POM	2900	65	7.5	–	–	120	120	55	5.5	–	–	0.65
HOSTAFORM MT8U01	POM	2850	64	9	–	–	180	160	6.5	6	–	–	0.65
HOSTAFORM S 27063	POM	2200	54	9	–	–	140	90	9	6	4.2	150	0.65
HOSTAFORM S 27064	POM	1700	44	10	–	–	150P	110	11	6	4.4	200	0.65
HOSTAFORM S 27072 WS10/1570	POM	2000	46	8	–	–	150P	110	11	8	*	*	0.7
HOSTAFORM S 27076	POM	900	–	–	–	>50	N	N	12	9	5.3	250	0.8

(*Continued*)

11.2 Polyethers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
HOSTAFORM S 9063	POM	2100	53	9	–	–	250P	220	12	7	4.2	150	0.65
HOSTAFORM S 9064	POM	1700	45	12	–	–	N	300P	13	8	4.4	200	0.65
HOSTAFORM S 9243	POM	2100	44	7	–	–	N	200P	14	10	3.8	60	1
Acetal Copolymer/A. Schulman													
SCHULAFORM® 9 A	POM	2800	63	13	*	*	N	N	7	–	4.2	0.02	0.8
SCHULAFORM® 9 A GF 25	POM, GF25	9000	*	*	125	3	47		8	–	4.2	0.02	0.6
SCHULAFORM® 9 b	POM	2800	63	11	*	*	N	N	6	–	4.2	0.02	0.8
SCHULAFORM® 9 d	POM	2900	64	8	*	*	N	N	5	–	4.2	0.02	0.8
SCHULAFORM® 9 E HI	POM	1600	42	18	*	*	180	160	15	–	4.2	0.02	0.8
SCHULAFORM® 9 f	POM	2600	61	14	*	*	N	N	8	5.5	4.2	0.02	0.8
PPE/Degussa													
VESTORAN 1900 nf	PPE	2000	60	6	*	*	200	–	25	–	2.9	16	–
VESTORAN 1900 sw	PPE	2000	60	6	*	*	200	–	25	–	2.9	16	–
VESTORAN 1900-GF20 sw	PPE, GF20	5600	*	*	110	3	26	–	8	–	2.7	18	0.35
VESTORAN X4893 sw	PPE	2400	45	3	*	*	60	–	13	–	2.8	10	0.25
VESTORAN X7342 nf	PPE, GF20	5700	*	*	100	2	3	–	7	–	3.5	17	–
VESTORAN X9801 sw	PPE	3200	*	*	63	5	45	–	12	–	–	–	–
PPE Modified/Mitsubishi Engineering-Plastics													
Iupiace AH40	PPE + PS	2500	43	3.2	*	*	153	–	17	–	–	–	0.07
Iupiace AH40	PPE + PS	2500	49	5	*	*	155	–	18	–	–	–	0.07

Iupiace AH50	PPE + PS	2500	55	5	*	*	119	–	19	–	–	–	0.07
Iupiace AH60	PPE + PS	2500	62	5.4	*	*	N	–	18	–	–	–	0.07
Iupiace AH70	PPE + PS	2500	67	5.5	*	*	150	–	11	–	–	–	0.07
Iupiace AH80	PPE + PS	2700	70	5.5	*	*	140	–	8	–	–	–	0.07
Iupiace AH8P	PPE + PS	2600	56	3.2	*	*	–	–	7	–	–	–	0.06
Iupiace AHF6005	PPE + PS, PTFE5	2400	53	5	*	*	45	–	10	–	–	–	0.06
Iupiace AHF6010	PPE + PS, PTFE10	2400	51	5	*	*	43	–	8	–	–	–	0.06
Iupiace AHF6015	PPE + PS, PTFE15	2400	49	5	*	*	40	–	6	–	–	–	0.06
Iupiace AN60	PPE + PS	2700	70	6	*	*	–	–	10	–	–	–	0.07
Iupiace AN70	PPE + PS	2700	75	6.1	*	*	–	–	9	–	–	–	0.07
Iupiace AN80	PPE + PS	2700	79	6.1	*	*	–	–	8	–	–	–	0.07
Iupiace AN90	PPE + PS	2700	83	6.1	*	*	–	–	27	–	–	–	0.07
Iupiace AP4	PPE + PS	2400	49	3.2	*	*	–	–	15	–	–	–	0.07
Iupiace AP6GM2	PPE + PS, (GF + MD) 10	4000	*	*	65	3	–	–	7	–	–	–	0.06
Iupiace AP6GM4	PPE + PS, (GF + MD) 20	5700	*	*	80	2.7	–	–	6	–	3.1	0.0067	0.06
Iupiace AP6GM6	PPE + PS, (GF + MD) 30	7800	*	*	91	3.1	–	–	6	–	3.3	0.0077	0.06
Iupiace AP6GM8	PPE + PS, (GF + MD) 40	9500	*	*	91	1	–	–	5	–	3.5	0.0048	0.06
Iupiace AV60	PPE + PS	2600	62	5.6	*	*	–	–	17	–	–	–	0.07
Iupiace AV70	PPE + PS	2600	66	5.6	*	*	–	–	12	–	–	–	0.07
Iupiace AV90	PPE + PS	2600	68	5.6	*	*	–	–	9	–	–	–	0.07
Iupiace EHM1010A	PPE + PS, CF	4100	*	*	64	2.2	18	–	3	–	–	–	0.06

(*Continued*)

11.2 Polyethers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Iupiace GAV2010	PPE + PS, (GF + MD) 30	8700	*	*	98	1.6	–	–	6	–	3.3	0.0077	0.06
Iupiace GAV2515	PPE + PS, (GF + MD) 40	11000	*	*	104	1.4	–	–	6	–	3.5	0.0048	0.06
Iupiace GH10	PPE + PS, GF10	4500	*	*	75	2.6	29	–	6	–	–	–	0.06
Iupiace GH20	PPE + PS, GF20	6600	*	*	89	1.5	31	–	7	–	–	–	0.06
Iupiace GH30	PPE + PS, GF30	8900	*	*	103	1.3	33	–	8	–	–	–	0.06
Iupiace GHF3005	PPE + PS, PTFE5	8600	*	*	96	1.8	30	–	8	–	–	–	0.1
Iupiace GHF3010	PPE + PS, PTFE10	8600	*	*	100	1.8	30	–	8	–	–	–	0.1
Iupiace GHF3015	PPE + PS, PTFE15	8600	*	*	100	1.8	30	–	7	–	–	–	0.1
Iupiace GN10	PPE + PS, GF10	4500	*	*	83	2.5	36	–	7	–	–	–	0.06
Iupiace GN15	PPE + PS, GF15	5600	*	*	91	2.5	34	–	7	–	–	–	0.06
Iupiace GN20	PPE + PS, GF20	6700	*	*	99	2.5	32	–	7	–	3.3	0.0045	0.06
Iupiace GN30	PPE + PS, GF30	9000	*	*	110	1.5	30	–	7	–	–	–	0.06
Iupiace GV10	PPE + PS, GF10	4500	*	*	83	2.5	33	–	8	–	–	–	0.06
Iupiace GV15	PPE + PS, GF15	5500	*	*	90	2.5	32	–	7	–	–	–	0.06
Iupiace GV20	PPE + PS, GF20	6700	*	*	103	2.5	30	–	7	–	3.2	0.0027	0.06

Iupiace GV30	PPE + PS, GF30	8900	*	*	110	1.5	28	–	9	–	–	–	0.06
Iupiace GX1050	PPE + PS, (GF + MD) 20	6100	*	*	75	2.7	–	–	5	–	–	–	0.06
Iupiace GX1100	PPE + PS, (GF + MD) 35	11000	*	*	115	3	–	–	5	–	–	–	0.06
Iupiace NX7000	PPE + PA6	8600	68	4.1	*	*	–	–	30	–	–	–	–
Iupiace NX7201	PPE + PA6, GF20	6300	*	*	97	2.2	–	–	6	–	–	–	–
Iupiace TGV2010	PPE + PS, (GF + MD) 30	7100	*	*	95	1.5	–	–	5	–	3.3	0.0077	0.06
Iupiace TX403	PPE + PS, X	2900	51	2.6	*	*	N	–	26	–	–	–	0.06
Iupiace VSG635V	PPE + PS, (GF + MD) 35	8600	*	*	74	1.2	–	–	6	–	–	–	0.06

11.3 Polyesters

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Polycarbonate/Bayer													
Apec® 1600	PC	2300	65	7	–	–	N	N	10	10	3	87	0.4
Apec® 1605	PC	2300	65	7	–	–	N	N	10	10	3	87	0.4
Apec® 1695	PC	2300	65	7	–	–	N	N	10	10	3	80	0.4
Apec® 1700	PC	2300	65	7	–	–	N	N	9	9	2.9	81	0.4

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Apec® 1703	PC	2300	65	7	–	–	N	N	9	9	2.9	81	0.4
Apec® 1705	PC	2300	65	7	–	–	N	N	9	9	2.9	81	0.4
Apec® 1745	PC	2300	65	7	–	–	N	N	9	9	2.9	81	0.4
Apec® 1795	PC	2300	65	7	–	–	N	N	9	9	3	80	0.4
Apec® 1800	PC	2300	65	7	–	–	N	N	8	8	2.9	100	0.4
Apec® 1803	PC	2300	65	7	–	–	N	N	8	8	2.9	100	0.4
Apec® 1805	PC	2300	65	7	–	–	N	N	8	8	2.9	100	0.4
Apec® 1895	PC	2300	65	7	–	–	N	N	8	8	3	80	0.4
Apec® 1897	PC	2300	65	7	–	–	N	N	8	8	3	80	0.4
Apec® 2095	PC	2300	65	7	–	–	N	N	6	6	2.9	70	0.4
Apec® 2097	PC	2300	65	7	–	–	N	N	6	6	2.9	70	0.4
Apec® DP1-9354	PC	2300	65	7	–	–	N	N	8	8	2.9	80	0.4
Apec® DP1-9354/1	PC	2300	65	7	–	–	N	N	8	8	2.9	84	0.4
Apec® DP1-9379	PC	2300	65	7	–	–	N	N	6	6	2.01	70	0.4
Apec® DP1-9389	PC	2300	65	7	–	–	N	N	6	6	2.9	60	0.4
Makrolon® 1095	PC, GF15	4600	–	–	45	12	100	90	–	–	3.2	85	0.24
Makrolon® 1239	PC	2350	65	6.4	–	–	N	N	–	–	3	90	0.3
Makrolon® 1243	PC	2400	67	6.2	–	–	N	N	–	–	3	85	0.3
Makrolon® 1260	PC	2300	63	5.8	–	–	N	N	–	–	3.1	95	0.3
Makrolon® 1804	PC	2400	66	6.2	–	–	N	N	–	–	3	95	0.3
Makrolon® 2205	PC	2400	65	6	–	–	N	N	–	–	3	90	0.3
Makrolon® 2207	PC	2400	66	6	–	–	N	N	–	–	3	85	0.3
Makrolon® 2405	PC	2400	65	6	–	–	N	N	–	–	3	90	0.3
Makrolon® 2407	PC	2400	66	6	–	–	N	N	–	–	3	85	0.3
Makrolon® 2458	PC	2400	65	6	–	–	N	N	–	–	3	90	0.3
Makrolon® 2558	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2605	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2607	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3

Makrolon® 2658	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2665	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2667	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® 2805	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2807	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® 2858	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2865	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 2867	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® 3103 MAS157	PC	2350	65	6.3	–	–	N	N	–	–	3	95	0.3
Makrolon® 3105	PC	2400	66	6.2	–	–	N	N	–	–	3	90	0.3
Makrolon® 3107	PC	2400	67	6.2	–	–	N	N	–	–	3	85	0.3
Makrolon® 3108	PC	2350	65	6.3	–	–	N	N	–	–	3	95	0.3
Makrolon® 3158	PC	2400	66	6.2	–	–	N	N	–	–	3	90	0.3
Makrolon® 6265	PC	2400	65	6	–	–	N	N	–	–	3	90	0.3
Makrolon® 6267	PC	2400	65	6	–	–	N	N	–	–	3	90	0.3
Makrolon® 6455	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 6485	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 6487	PC	2400	66	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® 6555	PC	2400	66	6.1	–	–	N	N	–	–	3	90	0.3
Makrolon® 6557	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® 8025	PC, GF20	4000	–	–	55	5	50P	55P	–	–	3.3	80	0.22
Makrolon® 8035	PC, GF30	5000	–	–	55	4	45P	50P	–	–	3.5	80	0.2
Makrolon® 8315	PC, GF10	3800	–	–	45	10	100	100	–	–	3.2	85	0.26
Makrolon® 8325	PC, GF20	5800	–	–	90	3.5	60P	65P	–	–	3.3	80	0.22
Makrolon® 8345	PC, GF35	9300	–	–	110	2	45P	50P	–	–	3.6	80	0.2
Makrolon® 9125	PC, GF20	5800	–	–	85	2.5	40P	45P	–	–	3.3	80	0.22
Makrolon® 9415	PC, GF10	3800	–	–	45	14	100	100	–	–	3.2	85	0.26
Makrolon® 9425	PC, GF20	5900	–	–	90	3	45P	50P	–	–	3.3	80	0.22
Makrolon® AG2677	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Makrolon® AL2447	PC	2400	66	6	–	–	N	N	–	–	3	85	0.3
Makrolon® AL2647	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® DP1-1265	PC	2350	64	5.9	–	–	N	N	–	–	3	85	0.3
Makrolon® DP1-1837	PC	2300	58	6	–	–	N	N	–	–	–	–	–
Makrolon® DP1-1853	PC	2400	67	6.3	–	–	N	N	–	–	3	90	0.3
Makrolon® DP1-1857	PC	2400	65	6	–	–	N	N	–	–	3	90	0.3
Makrolon® DP1-1870	PC	2400	66	6	–	–	N	N	–	–	3	85	0.3
Makrolon® KU1-1248	PC	2250	60	6.1	–	–	N	N	–	–	3	110	0.4
Makrolon® LQ2647	PC	2400	67	6.1	–	–	N	N	–	–	3	85	0.3
Makrolon® LQ3147	PC	2400	67	6.2	–	–	N	N	–	–	3	85	0.3
Makrolon® LQ3187	PC	2400	67	6.2	–	–	N	N	–	–	3	85	0.3
Makrolon® LTG2623	PC	2350	65	6.2	–	–	N	N	–	–	3	95	0.3
Makrolon® LTG3123	PC	2350	65	6.3	–	–	N	N	–	–	3	95	0.3
Makrolon® OD2015	PC	2350	64	5.9	–	–	N	N	–	–	3	85	0.3
Makrolon® Rx1805	PC	2350	66	6.3	–	–	N	N	–	–	–	–	0.3
Polycarbonate/Styron													
CALIBRE 1080 DVD	PC	2240	–	–	–	–	310	140	8	2	–	–	–
CALIBRE 200 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 200 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 200 22 MFR	PC	2300	60	6	*	*	N	N	70	11	3	20	–
CALIBRE 200 4 MFR	PC	2300	60	6	*	*	N	N	100	15	3	20	–
CALIBRE 200 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 201 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–

CALIBRE 201 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 201 22 MFR	PC	2300	60	6	*	*	N	N	70	11	3	20	–
CALIBRE 201 4 MFR	PC	2300	60	6	*	*	N	N	55	–	3	20	–
CALIBRE 201 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 202 10 MFR	PC	2300	60	6	*	*	N	N	35	–	3	20	–
CALIBRE 202 15 MFR	PC	2300	60	6	*	*	N	N	25	–	3	20	–
CALIBRE 202 22 MFR	PC	2300	60	6	*	*	N	N	20	–	3	20	–
CALIBRE 202 4 MFR	PC	2300	60	6	*	*	N	N	55	–	3	20	–
CALIBRE 202 6 MFR	PC	2300	60	6	*	*	N	N	55	–	3	20	–
CALIBRE 203 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 203 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 203 22 MFR	PC	2300	60	6	*	*	N	N	70	11	3	20	–
CALIBRE 203 4 MFR	PC	2300	60	6	*	*	N	N	55	–	3	20	–
CALIBRE 203 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 2060 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 2060 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 2061 10 MFR	PC	2300	60	6	*	*	N	N	90	13	–	–	–
CALIBRE 2061 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
CALIBRE 2071 15 MFR	PC	2300	60	6	*	*	N	N	80	12	2.95	100	–
CALIBRE 300 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 300 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 300V 10 MFR	PC	2300	60	6	*	*	N	N	35	–	3	20	–
CALIBRE 300V 15 MFR	PC	2300	60	6	*	*	N	N	25	–	3	20	–
CALIBRE 300V 6 MFR	PC	2300	60	6	*	*	N	N	55	–	3	20	–
CALIBRE 301 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 301 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 301 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 301EP 22 MFR	PC	2300	60	6	*	*	N	N	70	11	3	20	–
CALIBRE 301EP 31 MFR	PC	2300	60	6	*	*	N	N	15	–	3	20	–
CALIBRE 301V 10 MFR	PC	2300	60	6	*	*	N	N	35	–	3	20	–
CALIBRE 301V 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 301V 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 302 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 302 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–

CALIBRE 302 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 302EP 22 MFR	PC	2300	60	6	*	*	N	N	70	11	3	20	–
CALIBRE 302EP 31 MFR	PC	2300	60	6	*	*	N	N	15	–	3	20	–
CALIBRE 302V 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 302V 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 302V 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 303 10 MFR	PC	2300	60	6	*	*	N	N	90	13	3	20	–
CALIBRE 303 15 MFR	PC	2300	60	6	*	*	N	N	80	12	3	20	–
CALIBRE 303 6 MFR	PC	2300	60	6	*	*	N	N	95	14	3	20	–
CALIBRE 303 8 MFR	PC	2300	60	6	*	*	N	N	35	–	3	20	–
CALIBRE 303EP 22 MFR	PC	2300	60	6	*	*	N	N	70	11	3	20	–
CALIBRE 303EP 31 MFR	PC	2300	60	6	*	*	N	N	15	–	3	20	–
CALIBRE 303V 10 MFR	PC	2300	60	6	*	*	N	N	90	13	–	–	–
CALIBRE 303V 15 MFR	PC	2300	60	6	*	*	N	N	25	–	–	–	–
CALIBRE 303V 4 MFR	PC	2300	60	6	*	*	N	N	55	–	–	–	–
CALIBRE 303V 6 MFR	PC	2300	60	6	*	*	N	N	55	–	–	–	–
CALIBRE 303V 8 MFR	PC	2300	60	6	*	*	N	N	55	–	–	–	–
CALIBRE 3041 35 MFR	PC	2300	60	6	*	*	N	–	–	–	–	–	–

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
CALIBRE 3043 35 MFR	PC	2300	60	6	*	*	N	–	–	–	–	–	–
CALIBRE 5101 15 MFR	PC, 10GF	3600	60	4	*	*	N	N	–	–	–	–	–
CALIBRE 5210 15 MFR	PC, GF20	6500	105	4	*	*	N	N	7	–	–	–	–
CALIBRE 5210 8 MFR	PC, GF20	6500	105	4	*	*	N	N	9	–	–	–	–
CALIBRE 600 2 MFR	PC	2300	60	6	*	*	–	–	25	–	–	–	–
CALIBRE 600 3 MFR	PC	2300	60	6	*	*	–	–	25	–	–	–	–
CALIBRE 603 3 MFR	PC	2300	60	6	*	*	–	–	25	–	–	–	–
CALIBRE 701 10 MFR	PC	2300	60	6	*	*	N	N	17	15	–	–	0.03
CALIBRE 701 15 MFR	PC	2300	60	6	*	*	N	N	17	15	–	–	0.03
CALIBRE 7101 15 MFR	PC, GF10	3500	60	4	*	*	–	–	–	–	–	–	–
CALIBRE 7101 8 MFR	PC, GF10	3500	60	4	*	*	–	–	–	–	–	–	–
CALIBRE 7211 5 MFR	PC, GF20	6000	60	4	*	*	–	–	15	–	–	–	–
CALIBRE 891 10 MFR	PC	2300	60	6	*	*	N	N	30	15	–	–	–
CALIBRE 891 19 MFR	PC	2300	60	6	*	*	N	N	30	15	–	–	–
CALIBRE 893 19 MFR	PC	2300	60	6	*	*	N	N	30	15	–	–	–
CALIBRE IM 401 11	PC, Imod	2200	55	6	*	*	N	N	70	40	–	–	–
CALIBRE IM 401 18	PC, Imod	2300	60	6	*	*	N	N	60	30	–	–	–

CALIBRE MegaRad 2080 10 MFR	PC	2300	62	6	*	*	N	N	90	13	3	20	–
CALIBRE MegaRad 2080 15 MFR	PC	2300	62	6	*	*	N	N	80	12	3	20	–
CALIBRE MegaRad 2081 10 MFR	PC	2300	62	6	*	*	N	N	35	–	3	20	–
Polycarbonate/A. Schulman													
POLYMAN® (PC) XP 01 RN	PC	2300	62	6	*	*	N	–	61	–	–	–	34
POLYMAN® (PC) XP 11 RN	PC	2300	62	6	*	*	N	–	63	17	–	–	34
POLYMAN® (PC) XP 21 RN	PC	2250	61	6	*	*	N	–	74	34	–	–	35
POLYMAN® (PC) XP 31 RN	PC	2300	61	7	*	*	N	–	79	–	–	–	35
POLYMAN® (PC) XP 41 R 10 GF	PC, GF10	3800	*	*	85	4	–	–	12	–	–	–	–
POLYMAN® (PC) XP 41 R 20 GF	PC, GF20	5500	*	*	110	3	61	72	13	12	–	–	29
Polycarbonate/DSM													
Xantar® 18 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 18 SR D	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 18 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 19 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 19 SR D	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 19 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 22 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 22 SR FD	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 22 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 23 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 23 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 24 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 24 SR D	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Xantar® 24 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 25 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 25 SR D	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 25 U	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 25 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 27 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 27 SR D	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 27 U	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® 27 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® FC 22 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® FC 22 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® FC 23 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® FC 23 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® FC 25 R	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® FC 25 UR	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® G2 23 R	PC, GF10	3500	65	5	*	*	–	–	–	–	3	–	0.31
Xantar® G2 23 UR	PC, GF10	3500	65	5	*	*	–	–	–	–	3	–	0.31
Xantar® G4 22 R	PC, GF20	6000	*	*	90	4	–	–	–	–	3.2	–	0.29
Xantar® G4 23 R	PC, GF20	6000	*	*	95	4	–	–	–	–	3.2	–	0.29
Xantar® G4 23 UR	PC, GF20	6000	*	*	95	4	–	–	–	–	3.2	–	0.29
Xantar® G4 25 UR	PC, GF20	6000	*	*	95	4	–	–	–	–	3.2	–	0.29
Xantar® G4F 22 UR	PC, GF20	6000	*	*	90	4	–	–	–	–	3.2	–	0.29
Xantar® G6 23 R	PC, GF30	9500	*	*	110	2	–	–	–	–	3.4	–	0.26
Xantar® G6 23 UR	PC, GF30	9500	*	*	110	2	–	–	–	–	3.4	–	0.26
Xantar® G8 23 R	PC, GF40	10500	*	*	135	1.5	–	–	–	–	3.4	–	0.23
Xantar® G8 23 UR	PC, GF40	10500	*	*	135	1.5	–	–	–	–	3.4	–	0.23
Xantar® MX 1000	PC, Imod	2200	55	6	*	*	–	–	–	–	2.8	–	0.35
Xantar® MX 1001	PC, Imod	2200	55	6	*	*	–	–	–	–	2.8	–	0.35

Xantar® MX 1002	PC, Imod	2200	55	6	*	*	–	–	–	–	2.8	–	0.35
Xantar® MX 1004	PC, Imod	2200	55	6	*	*	–	–	–	–	3	–	0.35
Xantar® MX 1020	PC	2100	52	6	*	*	–	–	–	–	–	–	0.35
Xantar® MX 1021	PC	2100	52	6	*	*	–	–	–	–	–	–	–
Xantar® MX 1021 D	PC	2100	52	6	*	*	–	–	–	–	–	–	–
Xantar® MX 1061	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® MX 1081	PC, GF10	3500	*	*	80	5	–	–	–	–	3	–	–
Xantar® MX 1082	PC, GF20	6000	*	*	90	4	–	–	–	–	3.2	–	0.29
Xantar® MX 1094	PC, GF9	3200	65	5	*	*	–	–	–	–	3	–	0.31
Xantar® MX 2015	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® MX 2021	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® MX 2032	PC	2300	60	6	*	*	–	–	–	–	2.8	–	0.35
Xantar® MX 2042 D	PC	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Xantar® RX 1045	PC	2300	60	6	*	*	–	–	–	–	–	–	0.35
PBT/Celanese													
CELANEX 1300A	PBT	2500	–	–	60	8	–	–	–	–	3.2	200	0.08
CELANEX 1400A	PBT	2700	60	4	–	–	–	–	–	–	3.2	200	0.08
CELANEX 1462Z	PBT, GF30	–	–	–	135	2.6	–	–	7.2	–	–	–	–
CELANEX 1600A	PBT	2550	60	5	–	–	N	210	7	6.5	3.5	210	0.45
CELANEX 1602Z	PBT	2550	60	5	–	–	N	210	7	6.5	3.5	210	–
CELANEX 1612Z	PBT, GF7	4200	–	–	66	9	–	–	3.4	–	–	–	–
CELANEX 1632Z	PBT, GF15	5200	–	–	95	5.4	–	–	5.4	–	–	–	–
CELANEX 1662Z	PBT, GF20	9200	–	–	130	3.1	–	–	11	–	–	–	–
CELANEX 1700A	PBT, GF30	2500	60	6	–	–	N	220	7.5	7	3.6	210	0.08
CELANEX 2000	PBT	2700	60	4	–	–	100	90	4	3.5	3.5	200	0.09
CELANEX 2000−2	PBT	2700	60	4	–	–	100	90	4	3.5	3.5	200	0.09
CELANEX 2000−K	PBT	2700	60	4	–	–	100	90	4	3.5	3.5	200	–
CELANEX 2001	PBT	2600	60	6	–	–	–	–	–	–	3.2	200	0.45
CELANEX 2001 HP	PBT	–	56	11	–	–	N	–	4.2	–	–	–	–
CELANEX 2002	PBT	2600	60	4	–	–	N	190	6	6	3.5	220	0.09
CELANEX 2002−2	PBT	2600	60	4	–	–	N	190	6	6	3.5	220	0.09

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
CELANEX 2002AP	PBT	2600	60	4	–	–	N	190	6	6	3.5	220	–
CELANEX 2002UV	PBT	2600	60	4	–	–	N	190	6	6	3.5	220	–
CELANEX 2003	PBT	2700	60	4	–	–	210	58	4.3	4.3	3.2	200	0.09
CELANEX 2003–2	PBT	2700	60	4	–	–	210	58	4.3	4.3	3.2	200	0.09
CELANEX 2003HR	PBT	2700	60	4	–	–	210	58	4.3	4.3	3.2	200	–
CELANEX 2004	PBT	2400	54	4	–	–	220P	45	4.5	4.5	3.5	210	0.08
CELANEX 2004–2	PBT	2400	54	4	–	–	220P	45	4.5	4.5	3.5	210	0.08
CELANEX 2008	PBT	–	–	–	60	5	–	–	–	–	3.2	200	0.08
CELANEX 2012	PBT	–	60	3.2	–	–	–	–	–	–	3.3	200	0.09
CELANEX 2014	PBT	3000	64	7	–	–	–	–	4	–	3.5	185	–
CELANEX 2016	PBT	3000	60	3	–	–	55	55	4.5	4.5	3.5	185	0.45
CELANEX 2025	PBT	1200	41	16	–	–	–	–	6.3	–	–	–	–
CELANEX 2300 GV1/10	PBT, GF10	4700	–	–	90	3.5	26	26	5	5	3.9	190	0.45
CELANEX 2300 GV1/20	PBT, GF20	7400	–	–	125	3	46	43	7.5	7	4.1	190	0.4
CELANEX 2300 GV1/30	PBT, GF30	10300	–	–	150	2.5	60	60	9.5	9	4.3	190	0.4
CELANEX 2300 GV1/50	PBT, GF50	17000	–	–	165	2	70	65	12	12	4.1	190	0.35
CELANEX 2300 GV3/20	PBT, GB20	3500	–	–	50	4	34	34	3.5	3.5	4.2	180	0.45
CELANEX 2300 GV3/30	PBT, GB30	4000	–	–	50	3	22	23	3.3	3.3	4.4	120	0.4
CELANEX 2302 GV1/15	PBT, GF15	6100	–	–	110	3	35	35	6.5	6.5	4	180	0.45
CELANEX 2302 GV1/20	PBT, GF20	7800	–	–	135	3	43	43	8.5	8	4.1	180	0.4
CELANEX 2302 GV1/30	PBT, GF30	10500	–	–	150	2.5	56	58	10	10	4.1	170	0.4

CELANEX 2360 FL	PBT	3000	–	–	55	2.5	26	26	3	3	3.6	185	0.45
CELANEX 2360 GV1/10 FL	PBT, GF10	5600	–	–	90	3	24	24	5.5	5.5	3.5	160	0.45
CELANEX 2360 GV1/20 FL	PBT, GF20	8000	–	–	120	2.5	40	40	7.5	7	3.9	160	0.4
CELANEX 2360 GV1/30 FL	PBT, GF30	11000	–	–	145	2.5	58	58	9.5	9	4.4	150	0.4
CELANEX 2401 MT	PBT	2600	60	4	–	–	N	190	6	6	3.5	220	–
CELANEX 2402 MT	PBT	2700	60	4	–	–	140	130	5	4.5	–	–	–
CELANEX 2403 MT	PBT	2600	60	4	–	–	N	190	6	6	3.5	220	–
CELANEX 2404 MT	PBT	2600	56	7	–	–	–	–	3.3	–	–	–	–
CELANEX 2500	PBT	2700	60	4	–	–	140	130	5	4.5	3.8	200	0.45
CELANEX 3100	PBT, GF7	–	–	–	78	8	N	190	6	5.5	3.6	200	0.6
CELANEX 3109HR	PBT, GF7	–	–	–	78	8	N	190	6	5.5	3.6	200	–
CELANEX 3114	PBT, GF14	5100	–	–	–	–	–	–	2.9	–	–	–	–
CELANEX 3116	PBT, GF7	4700	–	–	75	3.5	21	21	4.5	4.5	3.4	165	0.45
CELANEX 3200	PBT, GF15	5800	–	–	100	3.5	20	20	5.5	5	3.8	200	0.45
CELANEX 3200−2	PBT, GF15	5800	–	–	100	3.5	20	20	5.5	5	3.8	200	0.45
CELANEX 3200HR	PBT, GF15	5800	–	–	100	3.5	20	20	5.5	5	3.8	200	–
CELANEX 3201	PBT, GF15	6000	–	–	100	3.5	–	–	6.5	–	–	–	0.5
CELANEX 3210−2	PBT, GF20	7500	–	–	115	2.5	–	–	6.5	–	3.3	100	0.45
CELANEX 3214	PBT, GF15	6200	–	–	100	2.9	26	–	5.4	–	3.5	160	–
CELANEX 3216	PBT, GF15	6700	–	–	100	2.5	28	28	6	6	3.5	160	0.4
CELANEX 3226	PBT	7200	–	–	115	2.5	35	35	7	6.5	3.9	160	0.4
CELANEX 3300	PBT, GF30	9200	–	–	130	2.5	46	45	8.5	8.5	4.1	160	0.4
CELANEX 3300−2	PBT, GF30	9200	–	–	130	2.5	46	45	8.5	8.5	4.1	160	0.4
CELANEX 3300D	PBT	9200	–	–	130	2.5	46	45	8.5	8.5	4.1	160	0.4
CELANEX 3300HR	PBT, GF30	9200	–	–	139	2.7	46	45	8.5	8.5	4.1	160	–
CELANEX 3300LM	PBT, GF30	9200	–	–	130	2.5	46	45	8.5	8.5	4.1	160	0.4
CELANEX 3309HR	PBT, GF30	9200	–	–	139	2.7	46	45	8.5	8.5	4.1	160	0.15
CELANEX 3309HRT	PBT, GF30	8300	–	–	115	3.3	–	–	10	–	–	–	–
CELANEX 3310	PBT, GF30	10800	–	–	140	2.1	–	–	7.2	–	3.3	100	–

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
CELANEX 3314	PBT, GF30	10000	–	–	136	2.6	–	–	7.9	–	–	–	0.5
CELANEX 3316	PBT, GF30	10700	–	–	135	2.5	42	42	8.5	8.5	3.6	145	0.4
CELANEX 3325HRT	PBT, GF30	7600	–	–	100	3.9	–	–	1	–	–	–	–
CELANEX 3400	PBT, GF40	12100	–	–	140	2.4	–	–	1	–	–	–	–
CELANEX 3409HR	PBT, GF40	12500	–	–	140	2.4	–	–	1	–	–	–	–
CELANEX 4016	PBT	2800	55	3.7	–	–	250	110	8.1	8.1	3.1	200	0.08
CELANEX 4202	PBT, GF15	5200	–	–	86	4.4	–	–	1	–	–	–	–
CELANEX 4300	PBT, GF30	9300	–	–	130	3.1	40	–	11	8.5	–	–	–
CELANEX 4300LM	PBT, GF30	9300	–	–	130	3.1	40	–	11	8.5	–	–	–
CELANEX 4302	PBT, GF30	–	–	–	120	2.8	–	–	–	–	–	–	–
CELANEX 4302HS	PBT, GF30	–	–	–	120	2.8	–	–	–	–	–	–	–
CELANEX 4302LM	PBT, GF30	–	–	–	120	2.8	–	–	–	–	–	–	–
CELANEX 4305	PBT, GF33	9500	–	–	110	3	54	54	13	13	–	–	–
CELANEX 4306	PBT, GF30	9200	–	–	120	2.9	60	45	12	11	–	–	–
CELANEX 5200	PBT, GF15	6000	–	–	120	3	35	35	8	8	4	190	0.45
CELANEX 5200-2	PBT, GF15	6000	–	–	120	3	35	35	8	8	4	190	0.45
CELANEX 5201	PBT, GF15	5900	–	–	100	2.5	–	–	–	–	–	–	–
CELANEX 5202	PBT, GF15	6100	–	–	100	2.5	–	–	4.7	–	–	–	–
CELANEX 5203	PBT, GF20	7200	–	–	115	2.7	–	–	5.5	–	–	–	–
CELANEX 5300	PBT, GF30	10000	–	–	135	3	49	48	9.5	9	4.2	–	0.4
CELANEX 5300-2	PBT, GF30	10000	–	–	135	3	49	48	9.5	9	4.2	–	0.4
CELANEX 602AC	PBT	–	–	–	83	3.5	–	–	–	–	–	–	–
CELANEX 6400-2	PBT	12000	–	–	110	1.8	34	34	5	5	4.3	170	0.4
CELANEX 6406	PBT, (GF + Mica) 40	7800	–	–	75	2.5	–	–	12	–	–	–	0.5
CELANEX 6407	PBT, (GF + Mica) 30	8000	–	–	85	2.1	–	–	–	–	–	–	–

CELANEX 6500	PBT, (GF + Mica) 30	9700	–	–	125	2.2	30	30	7.1	6.4	–	–	–
CELANEX 6500LM	PBT, (GF + Mica) 30	9700	–	–	125	2.2	30	30	7.1	6.4	–	–	–
CELANEX 7316	PBT, (GF + Mica) 35	9200	–	–	80	1.8	29	29	6.7	6.7	–	–	–
CELANEX 7700	PBT, (GF + Mica) 35	12900	–	–	90	1.4	–	–	5.4	–	3.7	100	–
CELANEX 7716	PBT, (GF + Mica) 35	10800	–	–	83	1.6	22	–	5	5	–		–
PBT/BASF													
Ultradur® B 2550	PBT	2500	60	3.7	*	*	250	*	6	4	3.3	200	0.5
Ultradur® B 4030 G6	PBT, GF30	9100	*	*	125	3.6	78	83	16	–	3.7	193	0.4
Ultradur® B 4300 G10	PBT, GF50	16000	*	*	140	1.5	55	69	11	*	4	150	0.4
Ultradur® B 4300 G2	PBT, GF10	4500	*	*	90	3.5	40	38	5	*	3.6	150	0.4
Ultradur® B 4300 G3	PBT, GF15	6000	*	*	93	4	–	–	–	–	–	–	0.4
Ultradur® B 4300 G4	PBT, GF20	7100	*	*	120	3	58	54	8	*	3.7	150	0.4
Ultradur® B 4300 G6	PBT, GF30	10000	*	*	135	2.5	67	74	11	*	3.8	170	0.4
Ultradur® B 4300 K4	PBT, GB20	3500	*	*	50	5	35	26	4	*	3.7	190	0.4
Ultradur® B 4300 K6	PBT, GB30	4000	*	*	50	4	35	24	4	*	3.8	190	0.4
Ultradur® B 4400 G5	PBT, GF25	11000	*	*	104	1.9	41	41	7.5	*	3.9	137	0.4
Ultradur® B 4406	PBT	3000	65	3.9	*	*	50	*	4	4	3.3	170	0.4
Ultradur® B 4406 G2	PBT, GF10	5500	*	*	95	3.3	30	30	6	*	3.5	150	0.4
Ultradur® B 4406 G4	PBT, GF20	8200	*	*	125	2.6	48	50	9	*	3.6	170	0.4
Ultradur® B 4406 G6	PBT, GF30	11300	*	*	145	2.3	60	55	10	*	3.9	150	0.4
Ultradur® B 4500	PBT	2500	60	3.7	*	*	290	*	6	4	3.3	200	0.5
Ultradur® B 4520	PBT	2400	60	3.7	*	*	N	*	6	3	3.3	200	0.5
Ultradur® B 4520 Z2	PBT	1700	35	4.2	*	*	N	200	15	7.6	3.3	200	0.3

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Ultradur® B 6550	PBT	2400	54	3.5	*	*	N	*	6	*	3.3	200	0.5
Ultradur® B 6550 L	PBT	2500	50	3.5	*	*	N	*	7	–	3.2	221	0.5
Ultradur® B 6550 LN	PBT	2600	56	3.5	*	*	N	220	6	5.3	3.2	219	0.4
Ultradur® B 6550 N	PBT	2600	60	3.5	*	*	N	*	5	*	3.3	221	0.5
Ultradur® KR 4001		4000	*	*	60	4.5	70	70	4	*	3.6	150	0.4
PBT/LANXESS													
Pocan® B 1300	PBT	2700	55	4	*	*	220	150	10	10	3.2	190	0.5
Pocan® B 1305	PBT	2800	55	4	*	*	200	100	10	10	3.2	190	0.5
Pocan® B 1501	PBT	2600	60	4	*	*	N	200	10	10	3.2	200	0.5
Pocan® B 1505	PBT	2600	55	4	*	*	N	180	10	10	3.2	200	0.5
Pocan® B 1600	PBT	2600	55	4	*	*	N	200	10	10	3.2	200	0.5
Pocan® B 2505	PBT	2900	60	3	*	*	100	80	10	10	3.2	150	0.4
Pocan® B 3215	PBT, GF10	5000	*	*	100	3	35	30	10	10	3.4	180	–
Pocan® B 3215 Z	PBT, GF10	4500	*	*	85	4	–	–	–	–	–	–	–
Pocan® B 3225	PBT, GF20	7000	*	*	120	2.6	50	45	10	10	3.6	200	0.4
Pocan® B 3225 Z	PBT, GF20	6700	*	*	115	3.3	60	–	10	10	–	–	0.4
Pocan® B 3235	PBT, GF30	10000	*	*	150	2.5	65	60	10	10	3.8	180	0.4
Pocan® B 4215	PBT, GF12	5700	*	*	100	2.5	30	30	10	10	3.4	190	0.4
Pocan® B 4225	PBT, GF20	7500	*	*	120	2.2	40	40	10	10	3.6	180	0.4
Pocan® B 4235	PBT, GF30	11500	*	*	140	1.8	50	50	10	10	3.9	160	0.4
Pocan® B 4239	PBT, GF30	10600	*	*	125	2.2	60	70	12	11	3.8	520	0.35
Pocan® B 7375	PBT, X25	3500	*	*	55	3	100	50	10	10	4.2	170	0.4
Pocan® B 7425	PBT, GB20	3400	*	*	50	3.5	30	30	10	10	3.6	170	0.4
Pocan® KU2-7503/1 Z	PBT	2800	55	6	*	*	200	–	10	10	3.2	160	0.3
Pocan® KU2-7755	PBT, GF7	4700	*	*	75	3.7	35	35	10	10	3.6	600	0.35
Pocan® S 1506	PBT	1700	35	4.5	*	*	N	N	75	25	3.1	170	0.4
Pocan® S 1517	PBT	2000	45	4	*	*	N	N	60	15	3.1	190	0.4

PBT/DSM													
Arnite® T06 200	PBT	2700	55	3.5	*	*	N	N	5	5	3.2	200	0.45
Arnite® T06 200 (extrusion)	PBT	2700	55	3.5	*	*	N	N	5	5	3.2	200	0.45
Arnite® T06 200 SNF	PBT	2600	45	4.5	*	*	N	–	12	–	3.2	220	0.45
Arnite® T06 202	PBT	2700	55	3.5	*	*	N	N	5	5	3.2	200	0.45
Arnite® T06 202 XL	PBT	2700	58	4	*	*	N	N	5	5	3.2	200	0.45
Arnite® T06 204 SN	PBT	3200	65	5	*	*	N	–	5	–	–	–	0.45
Arnite® T06 204 XL	PBT	2700	62	8.7	*	*	N	–	3.7	–	3.2	200	0.45
Arnite® T06 206 T	PBT, Imod	1600	35	4	–	–	N	N	20	12	–	–	–
Arnite® T08 200	PBT	2800	55	3.5	*	*	N	N	6	6	3.2	200	0.45
Arnite® T08 200 (extrusion)	PBT	2800	55	3.5	*	*	N	N	6	6	3.2	200	0.45
Arnite® TV4 220	PBT, GF10	4500	*	*	80	5	30	30	7	7	–	–	0.35
Arnite® TV4 230	PBT, GF15	6000	*	*	100	3	35	35	8	8	3.4	180	0.3
Arnite® TV4 230 SF	PBT, GF15	7000	*	*	95	2.5	40	40	6	6	3.5	140	0.3
Arnite® TV4 240	PBT, GF20	7500	*	*	120	3	45	45	7	7	3.5	180	0.3
Arnite® TV4 240 S	PBT, GF20	8500	*	*	110	2.5	50	50	9	9	3.7	150	0.3
Arnite® TV4 260 S	PBT, GF30	11500	*	*	130	2.5	55	55	10	10	3.9	150	0.3
Arnite® TV4 260 SF	PBT, GF30	11000	*	*	130	2.5	50	50	8	8	3.8	140	0.3
Arnite® TV4 261	PBT, GF30	10000	*	*	140	3	60	60	10	10	3.7	170	0.3
Arnite® TV4 264 SN	PBT, GF30	11500	*	*	130	2.2	55	55	12	11	3.5	160	–
Arnite® TV4 270	PBT, GF35	11500	*	*	145	2.5	65	65	13	13	–	–	0.25
Arnite® TV6 241 T	PBT, Imod, GF20	6000	–	–	85	4	55	–	17	–	–	–	0.3
PBT/DuPont													
Crastin® 6129 NC010	PBT	2600	58	5	–	–	N	N	5.5	4	3.2	200	0.4
Crastin® 6129C NC010	PBT	2600	58	5	–	–	N	N	5.5	4	3.2	200	0.4
Crastin® 6130 NC010	PBT	2600	59	8	–	–	–	–	5	–	–	–	–

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Crastin® 6130C NC010	PBT	2600	59	8	–	–	–	–	5	–	–	–	–
Crastin® 6131 NC010	PBT	2600	59	6	–	–	–	–	4	–	–	–	–
Crastin® 6131C NC010	PBT	2600	59	6	–	–	–	–	4	–	–	–	–
Crastin® 6134 NC010	PBT	2600	59	4	–	–	–	–	4	–	–	–	–
Crastin® 6134C NC010	PBT	2600	59	4	–	–	–	–	4	–	–	–	–
Crastin® BM6450XD BK560	PBT, Imod	1600	34	9.3	–	–	N	N	120	–	–	–	–
Crastin® CE2055 BKB580	PBT	2600	60	9	–	–	90	–	3.5	3	–	–	–
Crastin® CE2548 GY740	PBT	2600	–	–	46	15	–	–	5		–	–	–
Crastin® HR5315HF BK503	PBT, GF15	5200	–	–	92	3	50	–	10	6	–	–	–
Crastin® HR5315HF NC010	PBT, GF15	5200	–		95	3	60	–	10	7	–	–	–
Crastin® HR5330HF BK503	PBT, GF30	8400	–	–	120	3.5	65	–	11	9	–	–	–
Crastin® HR5330HF NC010	PBT, GF30	8400	–	–	132	3.5	75	–	13	12	–	200	–
Crastin® HTI668FR NC010	PBT, (GF + MD) 45	6800	*	*	77	2.1	28	22	5	4	4.1	305	0.5
PET/Celanese													
IMPET 2700 GV1/20	PET, GF20	8600	–	–	135	2	30	28	8.5	8.5	4.1	190	0.45
IMPET 2700 GV1/30	PET, GF30	11500	–	–	175	2	41	40	11	11	4.2	180	0.4
IMPET 320R	PET, GF15	–	–	–	115	2.5	–	–	5.1	–	–	–	–

IMPET 330	PET, GF30	–	–	–	170	2.6	–	–	–	–	–	–	–
IMPET 330R	PET, GF30	11000	–	–	170	2.6	48	45	10	10	–	–	–
IMPET 340R	PET, GF45	16800	–	–	190	2.1	–		15	–	–	–	–
IMPET 610R	PET, GF13	5100	–	–	97	3	–	–	5	–	–	–	0.09
IMPET 630R	PET, GF35	8600	–	–	85	2	–	–	–	–	–	–	–
IMPET 740	PET, GF45	15700	–	–	140	1.4	59	38	6.4	6.4	–	–	–
IMPET 830R	PET, GF35	10700	–	–	118	2.1	–		7	–	–	–	–
IMPET 840R	PET, GF45	15700	–	–	140	1.3	–	–	6.4	–	–	–	–
IMPET Hi430	PET, Imod, GF15	4800	–	–	73	3	53	38	16	8.4	–	–	0.12
PET/DuPont													
Rynite® 425LW BK505	PET	5370	–	–	60	4	35	–	6.3	–	4.2	–	–
Rynite® 530 NC010	PET, GF30	11000	*	*	158	2.5	60	45	11	11	3.9	70	0.7
Rynite® 530CS NC011	PET, GF30	11000	*	*	180	2.3	50	–	11	–	–	–	–
Rynite® 536 NC010	PET, GF36	14000	*	*	205	2.4	65	–	12	–	–	–	–
Rynite® 545 NC010	PET, GF45	15500	*	*	182	2	60	40	11	11	4.4	110	0.62
Rynite® 555 NC010	PET	19500	*	*	190	2	50	45	12	12	4.7	70	0.59
Rynite® 935 NC010	PET, (GF + P)35	10200	*	*	85	2	25	20	6	4	4.1	250	0.83
Rynite® 936CS NC011	PET, (GD + GF) 36	11200	*	*	120	2	20	–	5	–	–	–	–
Rynite® 940 BK505	PET, (MD + GF) 40	12500	*	*	110	1.8	35	–	–	–	3.7	150	–
Rynite® FR515 NC010	PET, GF15	6800	*	*	107	2.6	40	35	8	7	3.7	150	–
Rynite® FR530L NC010	PET, GF30	11500	*	*	135	2	40	33	8.5	8.5	4.7	100	0.77
Rynite® FR543 NC010	PET, GF43	17000	*	*	170	1.8	43	30	10	10	4.1	170	0.62
Rynite® FR943 NC010	PET, GF45	14000	–	*	124	1.5	30	25	7	5	4.1	150	1

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PET/DSM													
Amite® A06 300	PET	2500	–	–	–	–	–	–	–	–	–	–	0.75
Arnite® A04 900	PET	2800	80	4	–	–	N	–	3	–	3.2	21	0.5
Arnite® A06 101	PET	2500	55	4	*	*	–	–	6.5	–	–	–	–
Arnite® A06 700	PET	2250	50	4	–	–	–	–	10	–	–	–	–
Arnite® AV2 340	PET, GF20	8500	–	–	150	2.5	35	–	9	–	–	–	0.5
Arnite® AV2 360 S	PET, GF33	13000	*	*	165	2	40	40	10	10	3.4	120	0.4
Arnite® AV2 365 SN	PET, GF33	13500	*	*	165	2	50	50	10	10	3.8	140	0.4
Arnite® AV2 370	PET, GF35	13000	*	*	185	2.5	50	50	12	12	3.5	130	0.45
Arnite® AV2 370/B	PET, GF35	13000	*	*	185	2.5	50	50	12	12	3.5	130	0.45
Arnite® AV2 372	PET, GF35	13000	*	*	190	2.5	50	50	12	12	3.1	130	0.45
Arnite® AV2 390	PET, GF50	19000	*	*	210	2	55	55	14	14	3.5	110	0.3
Arnite® D00 301	PET	2500	60	3.5	*	*	N	–	6	–	3.4	250	0.8
PCT/Celanese													
Thermx® CG023 NC010	PCT, GF20	6400	–	–	–	–	35	–	6	–	–	–	–
Thermx® CG033 NC010	PCT, GF30	8500	*	*	120	2	50	–	–	–	–	–	0.8
Thermx® CG043 NC010	PCT, GF40	–	–	–	–	–	–	–	–	–	–	–	–
Thermx® CG923 NC010	PCT, GF20	7500	–	–	–	–	40	–	–	–	–	–	–
Thermx® CG933 NC010	PCT, GF30	10000	*	*	110	1.5	–	–	–	–	–	–	–
Thermx® CG943 NC010T	PCT, GF40	13000	*	*	115	1.3	–	–	–	–	–	–	–
LCP/Celanese													
Zenite® 5145L BK010	LCP, GF45	15000	–	–	–	–	–	–	–	–	–	–	–
Zenite® 6130 BK010	LCP, GF30	13000	–	–	–	–	40	30	35	30	4	310	–

Zenite® 6130LX BK010	LCP, GF30	15000	*	*	146	2.1	40	–	20	–	–	–	–
Zenite® 6140L BK010	LCP, GF40	–	–	–	–	–	23	20	15	15	–	–	–
Zenite® 6330 BK010	LCP, MD30	8800	*	*	125	4	60	40	9	8	3.4	310	–
Zenite® 7130 BK010	LCP, GF30	–	–	–	–	–	30	22	20	20	–	300	–
Zenite® 7145L BK010	LCP, GF45	18000	*	*	120	0.9	18	13	10	12	4.4	240	–
Zenite® 9140HT NC010	LCP, GF40	18000	–	–	175	1.5	–	–	15	–	–	–	–
Zenite® ZE16130A BK010	LCP, GF30	–	–	–	–	–	–	–	–	–	–	130	0.7
Zenite® ZE16401 BK010	LCP, MD30	8500	–	–	–	–	–	–	9	–	–	–	–
LCP/Ticona													
VECTRA A115	LCP, GF15	12000	–	–	–200	3.1	48	–	42	–	3	180	–
VECTRA A130	LCP, GF30	15000	–	–	–190	2.1	33	–	26	–	3.7	180	–
VECTRA A150	LCP, GF50	22000	–	–	–160	1.1	16	–	12	–	4.1	180	–
VECTRA A230	LCP, CF30	23500	–	–	–130	0.8	20	–	13	–	16.1	257	–
VECTRA A410	LCP, GF25, X25	20000	–	–	150	1.9	24	–	12	–	4.2	140	–
VECTRA A430	LCP, PTFE	7000	–	–	–160	6.2	86	–	28	–	2.7	160	–
VECTRA A435	LCP, PTFE, GF	11000	–	–	–175	3.3	38	–	26	–	3.1	160	–
VECTRA A515	LCP, X15	10500	–	–	–175	4.5	100	–	59	–	3.2	200	–
VECTRA A530	LCP, X30	11000	–	–	–160	4.6	50	–	25	–	3.2	160	–
VECTRA A625	LCP, Graphite25	10400	–	–	140	5.7	67	–	11	–	13	1500	–
VECTRA A700	LCP, Z25	14000	–	–	–140	1.5	15	–	7	–	–	–	–
VECTRA A725	LCP	8100	–	–	–92	4.2	31	–	17	–	–	–	–
VECTRA A950	LCP, GF15	10600	–	–	–182	3.4	270	53	95	–	3	200	–
VECTRA B130	LCP, GF30	22000	–	–	205	1	18	–	12	–	3.5	80	–
VECTRA B230	LCP, CF30	31800	–	–	200	0.7	15	–	6	–	32	–	–

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
VECTRA C115	LCP, GF15	13000	–	–	–160	2.5	42	–	34	–	3.1	200	–
VECTRA C130	LCP, GF30	15000	–	–	–160	1.9	28	–	25	–	3.7	180	–
VECTRA C150	LCP, GF50	22000	–	–	–150	1	15	–	13	–	4.1	180	–
VECTRA C550	LCP, X50	17800	–	–	–115	2.3	17	–	4	–	4	100	–
VECTRA C810	LCP, X	11400	–	–	–100	3.4	25	–	3	–	3.7	140	–
VECTRA D130M	LCP, Milled Glass30	9500	–	–	–92	1.5	6	–	–	2	3.9	220	–
VECTRA E130i	LCP, GF30	15000	–	–	–150	1.6	43	–	22	–	3.3	250	–
VECTRA E471i	LCP	13800	–	–	–140	2	55	–	20	–	3.8	320	–
VECTRA E530i	LCP, X30	11500	–	–	150	3.5	84	–	29	–	3.2	257	–
VECTRA E540i	LCP, X40	9800	–	–	105	3.2	–	–	–	–	3.6	310	–
VECTRA E820i	LCP, X40	8500	–	–	–100	3.5	54	–	8	–	3.6	165	–
VECTRA E820i Pd	LCP, X40	8000	–	–	–90	3.6	35	–	4	–	–	163	–
VECTRA H130	LCP, GF30	16500	–	–	170	1.5	29	–	24	–	5.6	221	–
VECTRA H140	LCP, GF40	17000	–	–	–160	1.2	24	–	14	–	3.6	200	–
VECTRA L130	LCP, GF30	15000	–	–	155	1.6	45	–	23	–	3.5	240	–
VECTRA L140	LCP, GF40	17300	–	–	130	1.1	32	–	1	–	3.6	200	–
VECTRA MT1300	LCP	10600	–	–	182	3.4	270	53	9	–	3	200	–
VECTRA MT1310	LCP, GF30	15000	–	–	190	2.1	33	–	2	–	3.7	180	–
VECTRA MT1335	LCP, GF, PTFE	11000	–	–	175	3.3	38	–	2	–	3.1	160	–
VECTRA MT1340	LCP, X15	10500	–	–	175	4.5	100	–	5	–	3.2	200	–
VECTRA MT1345	LCP, X30	11000	–	–	160	4.6	50	–	2	–	3.2	160	–
VECTRA MT1355	LCP	23500	–	–	130	0.8	20	–	1	–	16.1	257	–
VECTRA MT2310	LCP, GF30	22000	–	–	205	1	18	–	1	–	3.5	80	–
VECTRA MT2355	LCP	31800	–	–	200	0.7	15	–		–	32	–	–
VECTRA MT3310	LCP, GF30	15000	–	–	160	1.9	28	–	2	–	3.7	180	–
VECTRA MT4310	LCP, GF30	15000	–	–	150	1.6	43	–	22		3.3	250	–

VECTRA MT4350	LCP, X40	9800	–	–	105	3.2	–	–	–	–	3.6	310	–
VECTRA T130	LCP, GF30	16000	–	–	140	1.5	50	–	3	–	3.6	290	–
VECTRA V100P	LCP	13400	–	–	150	1.7	110	–	7	–	–	–	–
VECTRA V300P	LCP	11500	–	–	153	2.4	–	–	–	–	–	–	–
LCP/Solvay													
XYDAR G-430	LCP, GF30	15900	–	–	135	1.3	–	–	–	–	–	–	–
XYDAR G-930	LCP, GF30	15800	–	–	135	1.6	18	–	11	–	3.9	–	–
XYDAR M-345	LCP, T45	12100	–	–	86	3.5	–	–	–	–	–	–	–
Polyester Blends/Bayer													
Bayblend® DP T50	PC + ABS	2400	50	3.8	–	–	–	–	–	–	3	–	0.7
Bayblend® DP T65 TX	PC + ABS	2200	54	4.5	–	–	–	–	–	–	–	–	–
Bayblend® DP T90	PC + ABS	2300	–	–	–	–	–	–	–	–	–	–	–
Bayblend® DP W65	PC + AES	2000	46	4	–	–	–	–	–	–	3	–	0.7
Bayblend® KU 1-1446	PC + ABS	1800	45	4.5	–	–	–	–	–	–	2.9	–	0.7
Bayblend® KU 2-1514	PC + ABS	2400	60	5	–	–	–	–	–	–	3.1	–	0.5
Bayblend® KU 2-1514 BBS073	PC + ABS	2400	57	5	–	–	–	–	–	–	3.1	–	0.5
Bayblend® KU 2-1522	PC + ABS, GF10	4200	–	–	68	3	–	–	–	–	3.2	–	0.6
Bayblend® KU 2-3020	PC + ABS	2900	65	4	–	–	–	–	–	–	–	–	0.5
Bayblend® R-R 610	PC + ABS	2600	55	4	–	–	–	–	–	–	3.1	–	0.5
Bayblend® T45	PC + ABS	2100	49	3.7	–	–	–	–	–	–	3	–	0.7
Bayblend® T45 PG	PC + ABS	2100	49	3.7	–	–	–	–	–	–	3	–	0.7
Bayblend® T65	PC + ABS	2200	52	4.2	–	–	–	–	–	–	3	–	0.7
Bayblend® T85	PC + ABS	2300	55	4.7	–	–	–	–	–	–	3	–	0.7
Bayblend® T88-2N	PC + ABS, GF10	3900	–	–	63	4	–	–	–	–	3.2	–	0.6
Bayblend® T88-4N	PC + ABS, GF20	5900	–	–	77	2	–	–	–	–	3.2	–	0.6

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Bayblend®R 2000	PC + ABS	2700	60	4	–	–	–	–	–	–	3.1	–	0.5
Bayblend®R 2000 BBS052	PC + ABS	2700	60	4	–	–	–	–	–	–	3.1	–	0.5
Bayblend®R 2010	PC + ABS	2700	60	4	–	–	–	–	–	–	3.1	–	0.5
Bayblend®R 3000	PC + ABS	2700	60	3.5	–	–	–	–	–	–	3.1	–	0.5
Bayblend®R 3030	PC + ABS	2700	69	5	–	–	–	–	–	–	3.1	–	0.5
Makroblend® DP 2-7655	PC + PET, MD10	3100	–	–	45	20	N	–	–	–	–	–	–
Makroblend® DP 7645	PC + PET, Imod	2200	50	4.2	–	–	N	N	5	–	–	–	–
Makroblend® DP 7665	PC + PET, Imod, MD20	4200	–	–	50	7	–	–	–	–	–	–	–
Makroblend® KU 2–7608	PC + PBT, Imod, MD10	2600	40	3	–	–	N	–	–	–	–	–	0.3
Makroblend® KU 2-7609	PC + PBT, Imod, MD20	3400	47	3	–	–	–	–	–	–	–	–	0.3
Makroblend® KU 2-7912	PC + PBT, Imod	2200	50	4	–	–	N	N	60	25	–	–	0.4
Makroblend® KU 2-7912/4	PC + PBT, Imod	2150	50	4	–	–	N	N	60	45	–	–	0.4
Makroblend® KU 2-7912/5	PC + PBT, Imod	2100	53	4.2	–	–	N	N	60	40	–	–	0.4
Makroblend® KU 2-7915	PC + PBT, Imod	2200	50	4	–	–	N	N	70	50	3.1	–	0.6
Makroblend® KU 2-7940	PC + PBT, Imod	2100	55	4.6	–	–	N	N	52	50	–	–	0.4
Makroblend® S 7916	PC + PBT, Imod	1700	40	4	–	–	N	N	80	60	2.9	–	0.4
Makroblend® S 7916/2	PC + PBT, Imod	1800	45	4	–	–	N	N	90	25	3	–	0.4

Polyester Blends/LANXESS													
Pocan® DP 4035	PBT + PET, GF30	9500	*	*	120	2.5	–	–	–	–	–	–	0.4
Pocan® DP 7041	PBT + ASA, GF15	5900	*	*	90	3	–	–	–	–	–	–	0.4
Pocan® DP 7042	PBT + ASA, GF20	7000	*	*	100	3	–	–	–	–	–	–	0.4
Pocan® DP 7043	PBT + ASA, GF30	9200	*	*	120	2.8	–	–	–	–	–	–	0.4
Pocan® KU1-7313	PBT + PET, GF15	6500	*	*	110	3	30	30	10	10	3.5	–	0.4
Pocan® KU1-7341	PBT + PET, (GF + MD) 40	8600	*	*	80	1.2	20	20	10	10	3.9	–	0.3
Pocan® KU1-7625	PBT + PC, GF20	5100	*	*	75	4	35	–	–	–	–	–	0.3
Pocan® KU1-7635	PBT + PC, GF30	8500	*	*	100	2.5	50	–	–	–	–	–	0.3
Pocan® KU2-7125	PBT + ABS, GF20	6500	*	*	100	2.8	35	30	10	10	3.6	–	0.4
Pocan® KU2-7604	PBT + PC	2000	45	3.5	*	*	N	N	–	–	–	–	0.3
Polyester Blends/DSM													
Arnite® TM4 440	PBT + PET, MD20	4700	–	–	57	2.4	35	–	4	–	–	–	–
Arnite® TV4 441	PBT + PET, GF20	7300	*	*	112	2.7	25	25	7	7	–	–	0.3
Arnite® TV4 461	PBT + PET, GF30	9900	*	*	130	2.4	45	45	9	9	3.9	160	0.3
Arnite® TV4 461 KL	PBT + PET, GF30	9900	*	*	130	2.4	45	45	9	9	3.9	160	0.3
Stapron® E EM 605	PC + PET	2200	55	6	*	*	N	N	55	25	–	–	0.35
Xantar® C CE 407	PC + ABS	2700	60	4	–	–	N	N	–	–	3	–	0.6
Xantar® C CF 107	PC + ABS	2850	60	4	–	–	N	N	–	–	3	–	0.6
Xantar® C CF 407	PC + ABS	2700	60	4	–	–	N	N	–	–	3	–	0.6
Xantar® C CM 206	PC + ABS	2100	45	4	–	–	N	N	35	15	2.9	–	0.7

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Xantar® C CM 206 U	PC + ABS	2100	45	4	–	–	N	N	35	15	2.9	–	0.7
Xantar® C CM 406	PC + ABS	2200	50	4	–	–	N	N	40	20	2.9	–	0.6
Xantar® C CM 406 FD	PC + ABS	2200	50	4	–	–	N	N	40	20	2.9	–	0.6
Xantar® C CM 406 U	PC + ABS	2200	50	4	–	–	N	N	40	20	2.9	–	0.6
Xantar® C CM 506	PC + ABS	2300	55	5	–	–	N	N	40	20	2.9	–	0.5
Xantar® C CM 506 U	PC + ABS	2300	55	5	–	–	N	N	40	20	2.9	–	0.5
Xantar® C MC 3433	PC + ABS	2850	60	4	–	–	N	N	–	–	3	–	0.6
Xantar® C MC 3700	PC + ABS	2300	55	5	–	–	N	N	40	–	2.9	–	0.5
Xantar® C RC 3012	PC + ABS	2200	50	4	–	–	N	N	40	20	2.9	–	0.6
Xantar® FC 19 R	PC + ABS	2300	60	6	*		–	–	–	–	2.9	–	0.35
Xantar® FC 19 UR	PC + ABS	2300	60	6	*	*	–	–	–	–	2.9	–	0.35
Polyester Blends/BASF													
Ultradur® B 4040 G10	PBT + PET, GF50	18700	*	*	165	1.5	52	58	10	*	4.5	150	0.4
Ultradur® B 4040 G2	PBT + PET, GF10	5000	*	*	96	2.9	26	*	3.8	*	–	–	0.4
Ultradur® B 4040 G4	PBT + PET, GF20	7500	*	*	120	2.5	40	*	6	*	3.5	180	0.4
Ultradur® B 4040 G6	PBT + PET, GF30	10500	*	*	145	2.4	55	*	8	*	3.8	170	0.4
Ultradur® B 4406 G4 Q113	PBT, GF10	8350	*	*	117	2.2	36	–	6.1	–	3.5	170	0.4
Ultradur® B 4406 G6 Q113	PBT, GF20	11500	*	*	135	2.1	50	–	8	–	3.7	158	0.4
Ultradur® S 4090 G2	PBT + ASA, GF10	4500	*	*	75	2.9	45	27	6	*	3.4	205	0.4
Ultradur® S 4090 G4	PBT + ASA, GF20	6900	*	*	100	2.5	55	43	7	*	3.6	190	0.4
Ultradur® S 4090 G4X	PBT + ASA, GF20	6800	*	*	100	2.6	49	–	6.6	–	–	–	0.4

Ultradur® S 4090 G6	PBT + ASA, GF30	9700	*	*	125	2.2	59	50	9	*	3.7	180	0.4
Ultradur® S 4090 G6X	PBT + ASA, GF30	9800	*	*	132	2.5	64	55	9	*	3.7	202	0.4
Ultradur® S 4090 GX	PBT + ASA, GF14	5500	*	*	100	3.2	52	–	8	–	3.4	208	0.4
Polyester Blends/DuPont													
Crastin® LW9020 NC010	PBT + ASA, GF20	7000	*	*	110	2.9	60	43	9.5	7.6	3.4	180	0.8
Crastin® LW9020FR NC010	PBT + ASA, GF20	8500	*	*	115	2.1	40	35	7	6.5	–	150	0.78
Crastin® LW9030 NC010	PBT + ASA, GF30	9500	*	*	130	2.5	60	66	10	9.3	3.6	170	0.7
Crastin® LW9030FR NC010	PBT + ASA, GF30	10500	*	*	125	1.8	–	–	–	–	–	30	0.72
Crastin® LW9320 NC010	PBT + SAN, GF20	7400	*	*	120	2.7	55	50	8.5	–	–	–	–
Crastin® LW9330 NC010	PBT + SAN, GF30	9800	*	*	135	2.3	55	–	9	9	–	–	1
Polyester Blends/Dow													
PULSE 1310	PC + ABS	2300	52	4.1	*	*	N	N	65	15	–	–	–
PULSE 1350	PC + ABS	2400	56	4.2	*	*	N	N	56	22	–	–	–
PULSE 1370	PC + ABS	2300	55	4	*	*	N	N	66	25	–	–	–
PULSE 1550	PC + ABS, GF10	3800	59	3.4	*	*	90	50	18	8	–	–	–
PULSE 1718GF	PC + ABS, GF20	7600	*	*	95	2	–	–	6		–	–	–
PULSE 2000	PC + ABS	2360	52	5	*	*	N	N	45	5	–	–	–
PULSE 2000EZ	PC + ABS	2350	54	4.4	*	*	N	N	40	14	–	–	–
PULSE 2100LG	PC + ABS	2090	48	4.9	*	*	N	N	45	30	–	–	–
PULSE 2200BG	PC + ABS	2200	52	5.1	*	*	N	N	50	18	–	–	–
PULSE 830	PC + ABS	2300	55	4	*	*	N	N	66	25	–		–
PULSE 920MG	PC + ABS	2050	48	4.6	*	*	N	N	45	3	–	–	0.03

(*Continued*)

11.3 Polyesters—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PULSE 979	PC + ABS, GF10	4000	*	*	76	3	30	30	9		–	–	–
PULSE A20-95	PC + ABS	2250	44	5	*	*	N	N	25	1	–	–	–
PULSE A35-105	PC + ABS	2200	52	5	*	*	N	N	35	2	–	–	–
PULSE A35-110	PC + ABS	2350	57	4.8	*	*	N	N	35	15	–	–	–
Polyester Blends/A. Schulman													
SCHULADUR® PCR GF 10	PBT + PET, GF10	4500	*	*	80	3.5	28	–	4	–	–	–	–
SCHULADUR® PCR GF 20	PBT + PET, GF20	8100	*	*	125	2.5	30	–	6	–	–	–	0.3
SCHULADUR® PCR GF 30	PBT + PET, GF30	10500	*	*	145	2.5	55	50	8	8	3.85	0.0161	0.3
SCHULADUR® PCR GF 45	PBT + PET, GF45	15500	*	*	132	1.5	43	–	6	–	–	–	–
Polyester Blends/Ticona													
VANDAR 2100	PBT Alloy	1600	40	4	–	–	N	N	70	16	3.6	200	0.45
VANDAR 2100UV	PBT Alloy	1600	40	4	–	–	N	N	70	16	3.6	200	0.45
VANDAR 2122	PBT Alloy, P10	–	–	–	–	>50	–	–	–	–	–	–	–
VANDAR 2500	PBT Alloy	1450	35	5	–	–	200	170	88	9	–	–	0.45
VANDAR 4602Z	PBT Alloy	1500	40	6	–	–	N	N	70	10	3.9	310	0.45
VANDAR 4612R	PBT Alloy, GF7	2800	50	4	–	–	60	50	14	5	3.8	290	0.45
VANDAR 4632Z	PBT Alloy, GF15	4000	–	–	60	4	65	62	18	8	4.1	290	0.45
VANDAR 4662Z	PBT Alloy, GF30	7000	–	–	80	3.5	70	70	20	10	4.3	260	0.45
VANDAR 6000	PBT Alloy	1750	45	4.5	–	–	–	–	–	–	–	–	–
VANDAR 8000	PBT Alloy	1700	30	4.5	–	–	N	N	75	15	3.6	170	0.45

11.4 Polyimides

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PEI/SABIC Innovative Plastics													
Ultem® 1000	PEI	3200	105	6	85	60	N	N	4	4	2.9	0.5	0.7
Ultem® 1010	PEI	3200	105	6	85	60	N	N	5	5	2.9	0.6	0.7
Ultem® 1100	PEI	3500	110	6	85	10	–	–	–	–	–	–	0.65
Ultem® 1110	PEI	3500	110	6	80	10	–	–	–	–	–	–	1.2
Ultem® 1285	PEI Blend	3300	110	6	75	36	N	N	3	3	2.94	0.0103	0.5
Ultem® 2100	PEI, GF10	4500	*	*	115	4	30	30	–	7	2.9	0.0025	1
Ultem® 2110	PEI, GF10	4500	*	*	115	4	35	35	–	7	2.9	0.0025	0.6
Ultem® 2200	PEI, GF20	6800	*	*	140	2	35	35	–	–	3	0.0025	1
Ultem® 2210	PEI, GF20	6800	*	*	140	2	35	35	–	9	3	0.0025	1
Ultem® 2212	PEI, Milled GF20	4500	*	*	75	8			–	–	–	–	–
Ultem® 2300	PEI, GF30	9500	*	*	165	2	40	40	–	10	3.4	0.0023	0.9
Ultem® 2310	PEI, GF30	9500	*	*	165	2	40	40	–	10	3.4	0.0023	0.9
Ultem® 2312	PEI, Milled GF30	6000	*	*	85	3	25	25	–	4	–	–	0.9
Ultem® 2400	PEI, GF40	11500	*	*	180	2	40	40	–	–	3.1	0.0019	0.8
Ultem® 2410	PEI, GF40	11500	*	*	180	2	40	40	–	–	3.1	0.0019	0.8
Ultem® 2412EPR	PEI, GF40	10100	90	2	90	2	20	21	5	5	–	–	0.8
Ultem® 3452	PEI, (GF + MD) 45	12500	*	*	100	1.5	14	14	4.4	4	3.6	0.015	–
Ultem® 4000	PEI, (GF + PTFE + Graphite)	9900	*	*	90	1	15	15	8	8	6.2	0.022	0.7
Ultem® 4001	PEI, PTFE	3000	95	6	75	30	–	–	9	11	–	–	1.1
Ultem® 4002	PEI, PTFE	3300	100	6	80	25	–	–	–	11	–	–	1.1
Ultem® 9011	PEI	3200	105	6	85	60	–	–	–	3	–	–	1.3

(*Continued*)

11.4 Polyimides—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Ultem® 9070	PEI	3000	100	6	90	20	–	–	–	–	–	–	0.5
Ultem® 9075	PEI	3200	90	6	75	25	–	–	6	7	–	–	1.3
Ultem® 9076	PEI	3000	95	6	70	50	–	–	6	6	2.8	–	1.3
Ultem® CRS5001	PEI	3200	100	8	95	50	–	–	–	–	3	0.0043	1.2
Ultem® CRS5011	PEI	2900	100	8	85	50	–	–	–	–	–	–	1.2
Ultem® CRS5201	PEI, GF20	7200	*	*	135	3	–	–	–	–	3	0.0043	1
Ultem® CRS5311	PEI, GF30	10000	*	*	160	2	–	–	–	–	3.1	0.003	0.9
Ultem® DT1800E	PEI	2500	98	7	80	80	–	–	–	2	–	0.0061	0.37
Ultem® DT1810E	PEI	2500	98	7	80	80	–	–	–	2	–	–	0.36
Ultem® EXUM0169	PEI	2500	98	7	80	80	–	–	–	2	–	0.0061	0.36
Ultem® LTX300A	PEI	3200	90	6	75	25	N	N	6	7	–	–	1.3
Ultem® LTX931A	PEI	9200	115	2	115	2	–	–	4	4	–	–	0.4
Ultem® MD130A	PEI	3500	110	6	85	10	–	–	–	–	–	–	1.2
Ultem® XH6050	PEI	3120	95	8.5	78	17	N	N	–	–	–	0.007	1.8

11.5 Polyamides (Nylons)

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PA6/DuPont														
Minion® 73GM40 NC010	(dry)	PA6, (MD + GF)40	8400	*	*	140	3	60	50	7	5.5	–	38	5.6
Minion® 73GM40 NC010	(cond.)	PA6, (MD + GF)40	4900	*	*	84	5.5	65	50	13	4	–	–	–

Minion® 73M30 NC010	(dry)	PA6, MD30	4900	*	*	82	14	130	85	6.5	3.5	–	–	6.3
Minion® 73M30 NC010	(cond.)	PA6, MD30	1800	*	*	56	46	N	85	13	3.5	–	–	*
Minion® 73M30HSL BK489	(dry)	PA6, MD30	–	–	–	–	–	–	–	–	–	–	150	6.3
Minion® 73M40 NC010	(dry)	PA6, MD40	6000	*	*	87	11	130	95	6.5	4	–	–	5.4
Minion® 73M40 NC010	(cond.)	PA6, MD40	2300	*	*	59	29	N	95	9.5	5	–	–	*
Zytel® 7331T NC010A	(dry)	PA6, Imod	2400	62	4.4	*	*	–	–	16	8	–	–	–
Zytel® 7331T NC010A	(cond.)	PA6, Imod	970	39	26	*	*	–	–	35	6	–	–	*
Zytel® 73G15HSL BK363	(dry)	PA6, GF15	6500	*	*	140	4	40	40	6	5	–	–	7.6
Zytel® 73G15HSL BK363	(cond.)	PA6, GF15	3500	*	*	60	8	70	40	7	7	–	–	*
Zytel® 73G15L NC010	(dry)	PA6, GF15	6000	*	*	140	4	50	45	7	6	–	–	7.6
Zytel® 73G15L NC010	(cond.)	PA6, GF15	3500	*	*	61	8	90	50	14	14	–	–	*
Zytel® 73G15THSL BK240	(dry)	PA6, GF15, Imod	5500	*	*	120	2.9	–	–	9.5	5.7		–	–
Zytel® 73G15THSL BK240	(cond.)	PA6, GF15, Imod	–	*	*	55	19	–	–	13	5.2	–	–	*
Zytel® 73G20L NC010	(dry)	PA6, GF30	7000	*	*	150	4	70	70	10	10	3.9	–	7.2
Zytel® 73G20L NC010	(cond.)	PA6, GF30	4300	*	*	83	6.5	90	60	16	16	–	–	*
Zytel® 73G30HSL NC010	(dry)	PA6, GF30	9500	*	*	190	3.5	100	–	13	–	–	–	6.3
Zytel® 73G30HSL NC010	(cond.)	PA6, GF30	5500	*	*	110	5.5	100	–	20		–	–	*
Zytel® 73G30L NC010	(dry)	PA6, GF30	9500	*	*	190	3.5	100	80	13	10	–	–	6.3

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Zytel® 73G30L NC010	(cond.)	PA6, GF30	6000	*	*	120	5.5	100	80	21	21	–	–	*
Zytel® 73G30T NC010	(dry)	PA6, GF30, Imod	9500	*	*	170	3	110	90	19	19	–	–	6.2
Zytel® 73G30T NC010	(cond.)	PA6, GF30, Imod	6000	*	*	100	5	100	90	25	25	–	–	*
Zytel® 73G45L NC010	(dry)	PA6, GF45	14000	*	*	220	2.5	110	120	21	21	–	–	4.9
Zytel® 73G45L NC010	(cond.)	PA6, GF45	10000	*	*	150	4	110	100	23	23	–	–	–
Zytel® BK262 73G35HSL	(dry)	PA6, GF35, Imod	11000	*	*	190	3	90	90	16	10	–	–	5.8
Zytel® BK262 73G35HSL	(cond.)	PA6, GF35, Imod	7000	*	*	120	6	90	90	22	10	–	–	*
Zytel® BM73G15THS BK317	(dry)	PA6, GF15, Imod	5100	*	*	107	5.7	85	–	27	–	–	160	–
Zytel® BM73G15THS BK317	(cond.)	PA6, GF15, Imod	2500	*	*	65	22	120	–	33	–	–	–	*
Zytel® FN727 NC010	(dry)	PA6	770	23	44	*	*	–	–	130	–	–	–	–
Zytel® FN727 NC010	(cond.)	PA6	350	–	–	–	–	–	–	–	–	–	–	*
Zytel® FR73G20GWF NC010	(dry)	PA6, GF20	6000	*	*	90	4	30	66	4	3	–	–	–
Zytel® FR73G20GWF NC010	(cond.)	PA6, GF20	4300	*	*	83	6.5	110	60	6.5	–	–	–	*
Zytel® ST7301 NC010	(dry)	PA6, Imod	1800	–	–	–	–	–	–	78	17	–	–	–
Zytel® ST7301 NC010	(cond.)	PA6, Imod	–	–	–	–	–	–	–	120	18	–	–	*

PA6/BASF														
Ultramid® 8200	(dry)	PA6	2700	80	5	*	*	N	–	3.5	–	–	–	9.5
Ultramid® 8200	(cond.)	PA6	–	39	16	*	*	–	–	–	–	–	–	*
Ultramid® 8200 HS BK-102	(dry)	PA6	–	80	5	*	*	90	N	3.8	–	–	–	9.5
Ultramid® 8202	(dry)	PA6	2700	78	4	*	*	N	51	3.5	–	3.3	0.02	9.5
Ultramid® 8202	(cond.)	PA6	970	36	16	*	*	–	–	–	–	–	–	*
Ultramid® 8202 HS	(dry)	PA6	2700	78	4	*	*	N	51	3.5	–	–	–	9.5
Ultramid® 8202 HS	(cond.)	PA6	970	36	16	*	*	–	–	–	–	–	–	*
Ultramid® 8202C	(dry)	PA6	3700	88	4	*	*	N	–	3.5	–	–	–	9.3
Ultramid® 8202C	(cond.)	PA6	1360	43	22	*	*	–	–	–	–	–	–	*
Ultramid® 8202C HS BK-102	(dry)	PA6	3700	88	4	*	*	N	–	3.5	–	–	–	9.3
Ultramid® 8202C HS BK-102	(cond.)	PA6	1360	43	22	*	*	–	–	–	–	–	–	*
Ultramid® 8231G HS	(dry)	PA6, GF14	5960	*	*	140	4	40	–	6.5	–	3.4	0.02	8.1
Ultramid® 8231G HS	(cond.)	PA6, GF14	2640	*	*	80	9	–	–	–	–	–	–	*
Ultramid® 8233G HS	(dry)	PA6, GF33	10100	*	*	185	3.5	88	–	15	–	3.6	0.02	6.4
Ultramid® 8233G HS	(cond.)	PA6, GF33	5840	*	*	125	6	–	–	–	–	–	–	*
Ultramid® 8253 HS	(dry)	PA6	2300	60	4	*	*	N	–	18	–	–	–	8.1
Ultramid® 8253 HS	(cond.)	PA6	730	32	15	*	*	–	–	–	–	–	–	*
Ultramid® 8254 HS BK 102	(dry)	PA6	875	34	7	*	*	–	–	–	–	–	–	7.1
Ultramid® 8254 HS BK 102	(cond.)	PA6	460	28	30	*	*	–	–	–	–	–	–	*
Ultramid® 8255 HS	(dry)	PA6	–	36	7	*	*	–	–	–	–	–	–	7.1
Ultramid® 8260	(cond.)	PA6, MD40	2390	*	*	60	30	–	–	–	–	–	–	*
Ultramid® 8262G HS BK-102	(dry)	PA6, (MD + GF)20	5200	*	*	100	3	–	–	3	–	–	–	7.9
Ultramid® 8266G HS BK-102	(dry)	PA6, (MD + GF)40	9780	*	*	125	3	–	–	4	–	–	–	5.7
Ultramid® 8266G HS BK-102	(cond.)	PA6, (MD + GF)40	5610	*	*	70	6	–	–	–	–	–	–	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Ultramid® 8267G HS BK-102	(dry)	PA6, (MD + GF)40	8500	*	*	128	3.5	55	–	5	–	–	–	5.7
Ultramid® 8267G HS BK-102	(cond.)	PA6, (MD + GF)40	4860	*	*	76	6	–	–	–	–	–	–	*
Ultramid® 8272G HS BK-102	(dry)	PA6, GF12	5220	–	–	–	–	–	–	–	–	–	–	8.3
Ultramid® 8272G HS BK-102	(cond.)	PA6, GF12	3100	65	15	–	–	–	–	–	–	–	–	*
Ultramid® 8333G HI	(dry)	PA6, GF33	9300	*	*	145	3.5	78	–	20	–	3.4	0.01	5.5
Ultramid® 8333G HI	(cond.)	PA6, GF33	4610	*	*	90	6	–	–	–	–	–	–	*
Ultramid® 8350 HS	(dry)	PA6	1800	53	5	*	*	N	–	100	–	–	–	6.7
Ultramid® 8350 HS	(cond.)	PA6	675	32	9	*	*	–	–	–	–	–	–	*
Ultramid® 8351 HS BK-102	(dry)	PA6	1800	49	5	*	*	N	–	92	–	–	–	6.7
Ultramid® B3	(dry)	PA6	3000	90	4.5	*	*	N	N	8	–	3.5	230	9.5
Ultramid® B3	(cond.)	PA6	1000	45	20	*	*	N	–	60	–	7	3000	*
Ultramid® B32	(dry)	PA6	2700	80	4.5	*	*	N	N	9	–	3.5	310	9.5
Ultramid® B32	(cond.)	PA6	900	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® B32 Q128	(dry)	PA6	2700	80	4.5	*	*	N	N	9	–	3.5	310	9.5
Ultramid® B32 Q128	(cond.)	PA6	900	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® B35	(dry)	PA6	2700	80	4.5	*	*	N	N	9	–	3.5	310	9.5
Ultramid® B35	(cond.)	PA6	900	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® B35EG3	(dry)	PA6, GF15	5800	*	*	130	4	60	55	9	8	3.8	250	8
Ultramid® B35EG3	(cond.)	PA6, GF15	3500	*	*	70	18	110	–	25	–	7	2400	*
Ultramid® B35F	(dry)	PA6	3000	90	4.5	*	*	N	N	8	–	3.5	310	9.5
Ultramid® B35F	(cond.)	PA6	1000	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® B35G3 bk 564	(dry)	PA6, GF15	6100	–	–	126	2.9	47	–	5.9	–	–	–	8

Ultramid® B35G3 bk 564	(cond.)	PA6, GF15	3200	–	–	67	13	110	–	15	–	–	300	9.5
Ultramid® B36FN Q99	(dry)		3200	90	4.5	*	*	–	–	–	–	3.3	3000	*
Ultramid® B36FN Q99	(cond.)		1700	60	20	*	*	–	–	–	–	7	250	8
Ultramid® B3EG3	(dry)	PA6, GF15	5800	*	*	130	3.5	50	45	8	7	3.8	2400	*
Ultramid® B3EG3	(cond.)	PA6, GF15	3500	*	*	70	15	110	–	20	–	7	250	7.1
Ultramid® B3EG5	(dry)	PA6, GF25	8000	*	*	160	3.5	80	75	12	10	3.8	2400	*
Ultramid® B3EG5	(cond.)	PA6, GF25	5500	*	*	105	8.5	110	–	25	–	7	230	6.6
Ultramid® B3EG6	(dry)	PA6, GF30	9500	*	*	185	3.5	95	80	15	11	3.8	2200	*
Ultramid® B3EG6	(cond.)	PA6, GF30	6200	*	*	115	8	110	–	30	–	6.8	–	*
Ultramid® B3G8	(dry)	PA6, GF40	13000	*	*	205	2.8	90	75	14	11	4	140	5.7
Ultramid® B3G8	(cond.)	PA6, GF40	8200	*	*	135	4.6	110	–	22	–	6	1300	*
Ultramid® B3GK24	(dry)	PA6, (GF + GB)30	6000	*	*	110	3.5	40	39	5	5	3.9	200	6.6
Ultramid® B3GK24	(cond.)	PA6, (GF + GB)30	3000	*	*	60	15	90	–	11	–	4.6	700	*
Ultramid® B3GM35	(dry)	PA6, (GF + MD)40	8000	*	*	120	3	50	50	8	6	3.9	200	6.6
Ultramid® B3GM35	(cond.)	PA6, (GF + MD)40	5000	*	*	65	12		–	–	–	6.2	2000	*
Ultramid® B3GM35 bk 30564	(dry)	PA6, (MD + GF)40	8300	*	*	125	2.8	50	50	6	4	3.9	200	6.6
Ultramid® B3GM35 bk 30564	(cond.)	PA6, (MD + GF)40	4300	*	*	70	7.5	70	–	8	–	6.2	2000	*
Ultramid® B3GM35 Q224	(dry)	PA6, (GF + MD)40	8000	*	*	120	3	65	50	8	–	3.9	200	2
Ultramid® B3GM35 Q611	(dry)	PA6, (GF + MD)40	8000	*	*	120	3	50	50	8	6	3.9	200	6.6
Ultramid® B3GM35 Q611	(cond.)	PA6, (GF + MD)40	5000	*	*	65	12	–	–	–	–	6.2	200	*
Ultramid® B3K	(dry)	PA6	3000	85	4.5	*	*	N	100	5.5	4	3.5	230	9.5
Ultramid® B3K	(cond.)	PA6	1000	40	20	*	*	N	–	60	–	7	3000	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Ultramid® B3L	(dry)	PA6	2800	70	3.5	*	*	N	N	10	6	3.5	240	9
Ultramid® B3L	(cond.)	PA6	900	35	18	*	*	N	–	N	–	6.4	2400	*
Ultramid® B3L Q235	(dry)	PA6	2800	70	4	*	*	N	N	10	–	3.5	200	9
Ultramid® B3M6 bk 30564	(dry)	PA6, MD30	4600	*	*	75	12	190	100	9	5	3.5	200	6.2
Ultramid® B3M6 bk 30564	(cond.)	PA6, MD30	1700	*	*	45	45	N	–	18	–	6.2	2000	*
Ultramid® B3M6 bk 60564	(dry)	PA6, MD30	4600	*	*	75	15	N	150	9	–	3.5	240	6.2
Ultramid® B3M6 LS	(dry)	PA6, MD30	4600	*	*	75	15	220	150	9	7	3.5	200	6.2
Ultramid® B3M6 LS	(cond.)	PA6, MD30	1700	*	*	45	45	N		24	–	6.2	2000	*
Ultramid® B3M6 Q252	(dry)	PA6, MD30	4600	*	*	75	15	N	150	9	–	3.5	240	6.2
Ultramid® B3M6 Q256	(dry)	PA6, MD30	4600	*	*	75	15	N	150	9	–	3.5	200	6.2
Ultramid® B3M6 Q94	(dry)	PA6, MD30	4600	*	*	75	15	220	150	9	7	3.5	200	6.2
Ultramid® B3M6 Q94	(cond.)	PA6, MD30	1700	*	*	45	45	N	–	24	–	6.2	2000	*
Ultramid® B3S	(dry)	PA6	3400	90	4	*	*	250	200	4	3	3.3	300	9.5
Ultramid® B3S	(cond.)	PA6	1200	45	20	*	*	N	–	50	–	7	3000	*
Ultramid® B3UG4	(dry)	PA6, GF20	6000	*	*	95	3	40	35	3	3.4	3.8	150	6.9
Ultramid® B3UG4	(cond.)	PA6, GF20	3000	*	*	50	6	110	–	9	–	–	–	*
Ultramid® B3WG10 bk 564	(dry)	PA6, GF50	16700	*	*	225	2.5	90	88	19	14	4.2	140	4.8
Ultramid® B3WG10 bk 564	(cond.)	PA6, GF50	11000	*	*	150	4.5	100	–	27	–	6.1	1400	*
Ultramid® B3WG5	(dry)	PA6, GF25	8000	*	*	160	3.5	80	70	12	10	3.8	250	7.1
Ultramid® B3WG5	(cond.)	PA6, GF25	5000	*	*	105	8.5	110	–	25	–	7	2400	*
Ultramid® B3WG6	(dry)	PA6, GF30	9500	*	*	185	3.5	95	80	15	11	3.8	230	6.6
Ultramid® B3WG6	(cond.)	PA6, GF30	6200	*	*	115	8	110	–	30	–	6.8	2200	*

Ultramid® B3WG6 BGVW bk 564	(dry)	PA6, GF30	9600	–	–	180	3	80	65	12	9	–	–	6.6
Ultramid® B3WG6 BGVW bk 564	(cond.)	PA6, GF30	5600	–	–	90	6	80	–	20	–	–	–	*
Ultramid® B3WG6 GP bk 23210	(dry)	PA6, GF30	9600	–	–	180	3.5	95	–	15	–	–	–	6.6
Ultramid® B3WG6 GP bk 23210	(cond.)	PA6, GF30	5600	–	–	100	7.5	100	–	–	–	–	–	*
Ultramid® B3WG7	(dry)	PA6, GF35	11000	*	*	195	3.5	100	90	18	13	3.9	210	6.2
Ultramid® B3WG7	(cond.)	PA6, GF35	7200	*	*	130	7	110	–	33	–	6.2	1900	*
Ultramid® B3Z Q263	(dry)	PA6	–	45	5	*	*	N	–	13	–	–	–	–
Ultramid® B3ZG3	(dry)	PA6, GF15	5500	*	*	110	4	75	55	16	7	3.7	250	7.5
Ultramid® B3ZG3	(cond.)	PA6, GF15	2900	*	*	60	18	110	–	30	–	6.2	2000	*
Ultramid® B3ZG6	(dry)	PA6, GF30	9000	*	*	150	3.6	95	90	20	15	3.8	200	6.2
Ultramid® B3ZG6	(cond.)	PA6, GF30	5300	*	*	100	10	110	–	35	–	6.8	2000	*
Ultramid® B4F	(dry)		3000	90	4.5	*	*	N	N	9	–	3.5	310	9.5
Ultramid® B4F	(cond.)		1000	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® B5	(dry)		3000	90	4.5	*	*	N	N	9	–	3.5	230	9.5
Ultramid® B5	(cond.)		1000	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® B5W	(dry)		3000	90	4.5	*	*	N	N	9	–	3.5	230	9.5
Ultramid® B5W	(cond.)		1000	45	20	*	*	N	–	N	–	7	3000	*
Ultramid® BG40GM45 HS BK-130	(dry)	PA6, (MD + GF)45	10500	*	*	140	2	48	–	6	–	–	–	–
Ultramid® HMG13 HS BK-102	(dry)	PA6, GF63	22400	*	*	245	2	–	–	–	–	–	–	–
Ultramid® HMG13 HS BK-102	(cond.)	PA6, GF63	13400	–	–	–	–	–	–	–	–	–	–	–
Ultramid® HPN 9350 HS	(dry)	PA6	1700	45	4.5	*	*	N	–	40	–	–	–	6.8
Ultramid® HPN 9362	(dry)	PA6, MD40	4330	65	3	*	*	–	–	6	–	–	–	4.9
Ultramid® HPN 9362	(cond.)	PA6, MD40	2900	45	27	*	*	–	–	–	–	–	–	*
Ultramid® SEGM35HI BK-126	(dry)	PA6, (MD + GF)40	8290	–	–	119	2.6	–	–	4	–	–	–	5.7

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PA11/Arkema														
RILSAN BAZ 8 O TL	(dry)	PA11, GF8	2200	68	4	*	*	85	92	11	5	–	–	–
RILSAN BAZ 8 O TL	(cond.)	PA11, GF8	1950	65	4	*	*	100	100	10	4	–	–	*
RILSAN BECN O TL	(dry)	PA11	1470	43	5	*	*	–	–	–	–	3	166	1.9
RILSAN BECN O TL	(cond.)	PA11	1250	41	10	*	*	N	N	14	11	–	–	*
RILSAN BESN G9 TL	(dry)	PA11, CD10	2230	48	5	*	*	N	140	5	4	–	–	1.7
RILSAN BESN G9 TL	(cond.)	PA11, CD10	2100	45	7	*	*	N	150	5	5	–	–	*
RILSAN BESN O P20 TL	(dry)	PA11	500	32	20	*	*	–	–	–	–	–	–	1.8
RILSAN BESN O P20 TL	(cond.)	PA11	440	29	20	*	*	N	N	N	9	–	–	*
RILSAN BESN O P40 TL	(dry)	PA11	330	27	30	*	*	–	–	–	–	4	1040	1.6
RILSAN BESN O P40 TL	(cond.)	PA11	360	25	32	*	*	N	N	N	7	–	–	*
RILSAN BESN O TL	(dry)	PA11	1450	42	6	*	*	–	–	–	–	3	183	1.9
RILSAN BESN O TL	(cond.)	PA11	1230	40	8	*	*	N	N	23	13	–	–	*
RILSAN BESVO A FDA	(dry)	PA11	1420	41	5	*	*	–	–	–	–	–	–	1.9
RILSAN BESVO A FDA	(cond.)	PA11	1230	38	6	*	*	N	N	25	13	–	–	*
RILSAN BMN O P20 D	(dry)	PA11	540	31	35	*	*	N	N	19	5	3	614	1.8
RILSAN BMN O P20 D	(cond.)	PA11	480	29	30	*	*	N	N	37	7	–	–	*
RILSAN BMN O P40 D	(dry)	PA11	405	27	42	*	*	–	–	–	–	4	964	1.6
RILSAN BMN O P40 D	(cond.)	PA11	350	25	42	*	*	N	N	N	6	–	–	*

RILSAN BMN O TLD	(dry)	PA11	1260	40	21	*	*	–	–	–	–	3	262	1.9
RILSAN BMN O TLD	(cond.)	PA11	1070	40	22	*	*	N	N	14	11	–	–	*
RILSAN BMN Y TLD	(dry)	PA11, Molybdenum	1490	46	19	*	*	–	–	–	–	3	212	1.9
RILSAN BMN Y TLD	(cond.)	PA11, Molybdenum	1420	40	18	*	*	–	–	–	–	–	–	*
RILSAN BUM 30 O	(dry)	PA11, GB30	2100	42	4	*	*	52	58	5	5	–	–	1.3
RILSAN BUM 30 O	(cond.)	PA11, GB30	1940	39	4	*	*	N	73	5.1	5	–	–	*
RILSAN BZM 23 G9	(dry)	PA11, GF23, CD7	4700	*	*	110	5	78	84	13	10	5	208	1.2
RILSAN BZM 23 G9	(cond.)	PA11, GF23, CD7	4300	*	*	108	5	74	83	13	10	–	–	*
RILSAN BZM 30 O TL	(dry)	PA11, GF30	5800	*	*	115	7	–	–	–	–	4	210	1.4
RILSAN BZM 30 O TL	(cond.)	PA11, GF30	5300	*	*	112	8	86	84	21	12	–	–	*
RILSAN BZM 43 G9	(dry)	PA11, GF43, Graphite7	9000	*	*	146	4	67	75	12	10	–	–	1.1
RILSAN BZM 43 G9	(cond.)	PA11, GF43, Graphite7	8300	*	*	143	4	74	73	12	10	–	–	*
RILSAN MB 3000	(dry)	PA11	2070	51	5	*	*	–	8.5	4	4	2	–	–
RILSAN MB 3000	(cond.)	PA11	1920	48	5	*	*	N	–	5	5	*	–	–
RILSAN NAT HP 3504 MB	(dry)	PA11	610	32	32	*	*	N	N	55	7	–	–	–
RILSAN NAT HP 3504 MB	(cond.)	PA11	520	30	33	*	*	N	N	N	10	*	–	–
PA12/Evonik														
LAURAMID A		PA12	1900	56	9	*	*	N	N	25	13	–	–	1.4
LAURAMID B		PA12	2100	60	8	*	*	180	85	6	4	–	–	1.4
VESTAMID L1670 nf		PA12	1400	46	6	*	*	N	N	4	5	2.2	280	1.4
VESTAMID L1723 sw	(dry)	PA12	480	30	27	*	*	N	N	24	5	3.7	1200	*
VESTAMID L1723 sw	(cond.)	PA12	450	28	26	*	*	N	N	41	5	4.7	1700	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
VESTAMID L1833 nf	(dry)	PA12, GF23	5000	110	4.5	*	*	90	95	25	16	3.4	260	1.2
VESTAMID L1833 nf	(cond.)	PA12, GF23	4800	95	5	*	*	70	75	23	17	4	450	*
VESTAMID L1930 nf		PA12, GD30	4000	69	4	*	*	70	65	10	11	3.4	240	1.1
VESTAMID L1940 nf		PA12, GD30	1350	45	5	*	*	N	N	6	9	2.5	310	1.5
VESTAMID L2101 F nf	(dry)	PA12	1400	45	5	*	*	N	N	32	9	3	280	1.6
VESTAMID L2101 F nf	(cond.)	PA12	1100	38	10	*	*	N	N	51	9	3.3	500	*
VESTAMID L2106F nf	(dry)	PA12	1300	45	5	*	*	N	N	7	7	3	280	1.8
VESTAMID L2106F nf	(cond.)	PA12	1100	36	11	*	*	N	N	12	10	3.1	600	*
VESTAMID L2121 nf		PA12	700	35	20	*	*	N	N	40	7	3.4	550	*
VESTAMID L2121 sw 9.7507	(dry)	PA12	700	35	20	*	*	N	N	40	7	3.4	550	*
VESTAMID L2121 sw 9.7507	(cond.)	PA12	700	33	21	*	*	N	N	N	6	3.4	550	*
VESTAMID L2122 nf	(dry)	PA12	490	30	26	*	*	N	N	68	6	3.3	1000	*
VESTAMID L2122 nf	(cond.)	PA12	420	24	25	*	*	N	N	N	7	3.3	1400	*
VESTAMID L2122 sw 9.7507		PA12	550	31	27	*	*	N	N	55	6	3.3	1000	*
VESTAMID L2123 nf	(dry)	PA12	370	24	32	*	*	N	N	N	13	3.6	1100	*
VESTAMID L2123 nf	(cond.)	PA12	370	22	31	*	*	N	N	N	8	4	1100	*
VESTAMID L2123 sw 9.7507	(dry)	PA12	370	24	32	*	*	N	N	N	13	3.6	1100	*
VESTAMID L2123 sw 9.7507	(cond.)	PA12	400	25	30	*	*	N	N	N	8	3.6	1100	*
VESTAMID L2124 nf	(dry)	PA12	400	24	31	*	*	N	N	N	6	3.8	1500	*
VESTAMID L2124 nf	(cond.)	PA12	350	22	27	*	*	N	N	N	6	4.2	2000	*

VESTAMID L2124 sw 9.7507	(dry)	PA12	400	24	31	*	*	N	N	N	6	3.8	1500	*
VESTAMID L2124 sw 9.7507	(cond.)	PA12	420	27	29	*	*	N	N	N	7	4.1	1900	*
VESTAMID L2128 nf	(dry)	PA12	230	18	45	*	*	N	N	N	6	3.8	2400	*
VESTAMID L2128 nf	(cond.)	PA12	220	15	35	*	*	N	N	N	7	4	2800	*
VESTAMID L2140 nf		PA12	1200	38	11	*	*	N	N	55	10	3.4	500	1.6
VESTAMID L2140 sw 9.7504	(dry)	PA12	1500	48	5	*	*	N	N	11	7	3	260	1.5
VESTAMID L2140 sw 9.7504	(cond.)	PA12	1300	41	13	*	*	N	N	12	10	3.3	500	*
VESTAMID L2141 sw 9.7504	(dry)	PA12	1500	46	5	*	*	N	N	10	8	4	1100	1.5
VESTAMID L2141 sw 9.7504	(cond.)	PA12	1300	42	12	*	*	N	N	12	8	3.5	500	*
VESTAMID L-CD22-M sw	(dry)	PA12, CD22	2900	45	5	*	*	34	34	6	6	5	330	1.2
VESTAMID L-CD22-M sw	(cond.)	PA12, CD22	2800	45	6	*	*	37	40	6	5	5.1	550	*
VESTAMID L-CF15 sw	(dry)	PA12, CF15	7500	120	6	*	*	65	70	20	12	*	*	1.3
VESTAMID L-GB30 nf	(dry)	PA12, CB30	2000	47	5	*	*	N	N	6	6	3.5	230	1.1
VESTAMID L-GB30 nf	(cond.)	PA12, CB30	1800	37	5	“	*	N	N	6	6	4	370	*
VESTAMID L-GF15 nf	(dry)	PA12, GF15	3900	100	5	*	*	75	80	17	11	3.4	260	1.3
VESTAMID L-GF30 nf	(dry)	PA12, GF30	6500	130	4.5	*	*	85	100	23	21	3.4	330	1
VESTAMID L-GF30 nf	(cond.)	PA12, GF30	5500	110	5	*	“	75	95	24	22	4	400	*
VESTAMID L-R1-MHI sw		PA12	1600	37	5	*	*	N	80	60	8	–	–	–
VESTAMID L-R2-GF25 sw		PA12, GF25	6500	*	*	120	4.5	75	70	12	11	*	*	1.2

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
VESTAMID L-R3-EI sw	(dry)	PA12	1500	42	9	*	*	N	N	21	9	*	*	1.2
VESTAMID L-R3-EP sw	(dry)	PA12	800	*	*	*	>50	N	N	38	4	*	*	*
VESTAMID L-R3-EP sw	(cond.)	PA12	750	*	*	*	>50	N	N	21	5	*	*	*
VESTAMID L-R3-MHI sw		PA12	1600	38	5	*	*	N	N	55	15	*	*	1.5
VESTAMID L-R4-MHI sw		PA12	1250	36	8	*	*	N	N	55	12	–	–	–
VESTAMID L-R7-MHI sw	(dry)	PA12	1400	36	6	*	*	N	N	60	12	*	*	1.5
VESTAMID L-R7-MHI sw	(cond.)	PA12	1200	34	10	*	*	N	N	34	8	*	*	*
VESTAMID L-R9-MHI sw		PA12	1400	37	6	*	*	N	N	60	12	–	–	–
VESTAMID LX9013nf		PA12	400	*	*	*	>50	N	N	140P	7	–	–	–
VESTAMID X7166 nf		PA12	1800	47	5	*	*	65	80	3	5	3.6	340	1.3
VESTAMID X7167 nf		PA12	1700	48	5	*	*	N	N	9	6	3.6	380	1.5
VESTAMID X7229 nf		PA12	1000	36	17	*	*	N	N	11	5	5	1700	–
VESTAMID X7293 nf		PA12	400	27	32	*	*	N	N	N	7	4.6	1900	*
VESTAMID X7293 sw		PA12	400	27	32	*	*	N	N	N	7	4.6	1900	*
VESTAMID X7373 nf		PA12	1500	47	5	*	*	N	N	6	6	3.8	520	1.5
PA12/EMS-Grivory														
Grilamid L 16 LM		PA12	1100	45	15	*	*	N	N	7	6	3	400	1.5
Grilamid L 20 EC		PA12, CD25	1900	50	10	*	*	N	50	2	2	*	*	1.1
Grilamid L 20 G		PA12	1100	40	12	*	*	N	N	7	6	3	300	1.5
Grilamid L 20 H FR		PA12	1500	40	10	*	*	N	N	7	6	2	250	1.4

Grilamid L 20 HL black 9563		PA12	1100	40	12	*	*	N	N	7	6	3	400	1.5
Grilamid L 20 L		PA12	1100	40	12	*	*	N	N	7	6	3	400	1.5
Grilamid L 20 LF grey		PA12	2000	45	12	*	*	N	N	4	3	4	400	1.5
Grilamid L 20 LM		PA12	1100	40	12	*	*	N	N	4	3	3	300	1.5
Grilamid L 20 W 20		PA12	500	30	20	*	*	N	N	40	3	3	850	1.5
Grilamid L 25		PA12	1100	40	12	*	*	N	N	10	7	3	300	1.5
Grilamid L 25 NZ ESD		PA12	1000	35	12	*	*	N	N	80	20	*	*	1.1
Grilamid L 25 W 20 X		PA12	450	30	20	*	*	N	N	N	6	4	900	1.5
Grilamid L 25 W 20 Y		PA12	450	30	25	*	*	N	N	N	7	4	1300	1.5
Grilamid L 25 W 40		PA12	400	25	20	*	*	N	N	N	4	4	1300	1.4
Grilamid L 25 W 40 ESD		PA12	350	25	20	*	*	N	N	N	9	*	*	1.1
Grilamid L 25 W 40 X		PA12	360	25	20	*	*	N	N	N	13	4	1300	1.4
Grilamid L 25 Z		PA12	900	35	12	*	*	N	N	55	13	3	350	1.5
Grilamid L 25A H		PA12	1100	40	12	*	*	N	N	10	7	3	300	1.5
Grilamid L 25A NZ		PA12	750	30	15	*	*	N	N	100	75	3	300	1.3
Grilamid LC-3H		PA12, CF30	12000	*	*	140	3	60	60	13	8	*	*	1.1
Grilamid LKN-3H		PA12, CB30	1600	45	10	*	*	N	45	5	3	3	300	1.2
Grilamid LKN-5H		PA12, CB50	2300	45	7	*	*	N	65	5	4	3	300	0.8
Grilamid LV-23 ESD		PA12, GF23	5000	*	*	95	5	70	40	8	6	*	*	1
Grilamid LV-23H		PA12, GF23	5000	*	*	100	15	80	85	20	12	3	300	1.2
Grilamid LV-25 HM		PA12, GF25	5400	*	*	70	5	30	30	10	8	–	–	1.1
Grilamid LV-2A NZ		PA12, GF20	3500	*	*	80	15	N	N	30	20	–	–	1.1
Grilamid LV-2H		PA12, GF20	4400	*	*	90	10	70	70	20	15	3	300	1.2
Grilamid LV-3A H		PA12, GF30	6000	*	*	105	8	80	80	20	15	–	–	1.1
Grilamid LV-3H		PA12, GF30	6000	*	*	105	8	80	80	20	15	3	300	1.1

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PA46/DSM														
Stanyl® 46HF4130	(dry)	PA46, GF30	10000	–	–	210	3	60	60	13	12	–	–	9.5
Stanyl® 46HF4130	(cond.)	PA46, GF30	6000	–	–	115	6	90	60	17	12	–	–	*
Stanyl® 46HF4530	(dry)	PA46, GF40	10000	–	–	210	3	60	60	13	12	–	–	9.5
Stanyl® 46HF4530	(cond.)	PA46, GF40	6000	–	–	115	6	90	60	17	12	–	–	*
Stanyl® 46HF5030	(dry)	PA46, GF30	12000	*	*	170	1.9	40	*	13	12	*	*	–
Stanyl® 46HF5040	(dry)	PA46, GF40	15000	*	*	190	1.7	60	–	12	12	4	0.016	4.5
Stanyl® 46HF5040	(cond.)	PA46, GF40	12000	–	–	130	2.5	70	–	14	12	–	–	*
Stanyl® 46HF5041LW	(dry)	PA46, GF40	16000	–	–	150	1.3	25	–	8	–	–	–	–
Stanyl® 46HF5050	(dry)	PA46, GF50	18000	–	–	200	1.5	50	–	17	–	4	0.016	3.9
Stanyl® 46HF5050	(cond.)	PA46, GF50	15000	–	–	135	2.3	–	–	19	–	–	–	*
Stanyl® TE200F6	(dry)	PA46, GF30	10000	*	*	210	4	80	70	12	10	4	230	9.5
Stanyl® TE200F6	(cond.)	PA46, GF30	6000	*	*	115	7	90	70	19	10	4.6	900	*
Stanyl® TE200F8	(dry)	PA46, GF40	13000	*	*	230	3	85	75	14	11	4	230	8
Stanyl® TE200F8	(cond.)	PA46, GF40	8000	*	*	140	6	95	75	22	11	4.6	900	*
Stanyl® TE250F3	(dry)	PA46, GF15	8000	–	–	140	3	–	–	6	–	–	–	–
Stanyl® TE250F6	(dry)	PA46, GF30	12000	*	*	180	2.5	50	50	10	9	4	160	5.9
Stanyl® TE250F6	(cond.)	PA46, GF30	8000	*	*	125	3.5	60	50	11	9	4.5	700	*
Stanyl® TE250F8	(dry)	PA46, GF40	15000	*	*	180	1.9	60	50	12	12	4	160	4.5
Stanyl® TE250F8	(cond.)	PA46, GF40	12000	*	*	130	2.5	70	50	14	12	4.5	700	*
Stanyl® TE250F9	(dry)	PA46, GF45	17000	*	*	200	2	65	50	13	13	4	160	4.5
Stanyl® TE250F9	(cond.)	PA46, GF45	12000	*	*	130	3	75	50	15	13	4.5	700	*
Stanyl® TE263F6	(dry)	PA46, Imod, GF30	–	–	–	140	5	–	–	–	–	–	–	–
Stanyl® TE263F6	(cond.)	PA46, Imod, GF30	–	–	–	85	10	–	–	–	–	–	–	*
Stanyl® TE300	(dry)	PA46	3300	100	10	–	–	N	N	12	9	3.6	260	13.5

Stanyl® TE300	(cond.)	PA46	1000	55	20	–	–	N	N	45	12	4.3	1000	*
Stanyl® TE351	(dry)	PA46	3000	60	4	–	–	–	–	9	–	–	–	–
Stanyl® TE351	(cond.)	PA46	1200	45	15	–	–	–	–	14	–	–	–	*
Stanyl® TE373	(dry)	PA46	2800	85	10	–	–	–	–	7	4	–	–	12.4
Stanyl® TE373	(cond.)	PA46	1000	50	20	–	–	–	–	–	–	–	–	*
Stanyl® TS200F6	(dry)	PA46, GF30	10000	–	–	210	4	80	70	12	10	–	–	9.5
Stanyl® TS200F6	(cond.)	PA46, GF30	6000	–	–	115	7	90	70	19	10	–	–	*
Stanyl® TS250F4D	(dry)	PA46, GF20	9200	–	–	150	2	–	–	8	8	–	–	–
Stanyl® TS250F4D	(cond.)	PA46, GF20	6000	–	–	100	4	–	–	10	8	–	–	*
Stanyl® TS250F6D	(dry)	PA46, GF30	12000	–	–	180	2.5	50	–	10	9	4	160	–
Stanyl® TS250F6D	(cond.)	PA46, GF30	8000	–	–	125	3.5	60	–	11	9	4.5	700	*
Stanyl® TS250F8	(dry)	PA46, GF40	15000	–	–	195	2	–	–	10	10	4	160	–
Stanyl® TS250F8	(cond.)	PA46, GF40	12000	–	–	140	2.6	–	–	12	10	4.5	700	*
Stanyl® TS256F8	(dry)	PA46, GF40	14000	–	–	180	1.5	–	–	8	8	–	–	–
Stanyl® TS256F8	(cond.)	PA46, GF40	11000	–	–	145	2	–	–	10	8	–	–	*
Stanyl® TW200B6	(dry)	PA46, CF30	24000	–	–	240	2	–	–	7	–	–	–	9.5
Stanyl® TW200B6	(cond.)	PA46, CF30	–	–	–	150	4	–	–	13	–	–	–	*
Stanyl® TW200F3	(dry)	PA46, GF15	6100	*	*	140	4	50	45	6	5.5	–	–	11.5
Stanyl® TW200F3	(cond.)	PA46, GF15	2800	*	*	70	8	100	50	13	5.5	–	–	*
Stanyl® TW200F6	(dry)	PA46, GF30	10000	*	*	210	4	80	65	12	10	4	200	9.5
Stanyl® TW200F6	(cond.)	PA46, GF30	6000	*	*	115	7	100	80	21	10	4.7	1000	*
Stanyl® TW200F8	(dry)	PA46, GF40	13000	*	*	230	3	85	75	14	11	4	200	8
Stanyl® TW200F8	(cond.)	PA46, GF40	8000	*	*	140	6	95	75	22	11	4.7	1000	*
Stanyl® TW200FM33	(dry)	PA46, (GF + MD)30	7800	*	*	140	3	–	–	4	4	–	–	9.5
Stanyl® TW200FM33	(cond.)	PA46, (GF + MD)30	3200	*	*	70	6	–	–	–	4	–	–	*
Stanyl® TW241 B3	(dry)	PA46, CF15	13000	–	–	185	2	–	–	5	–	–	–	11.5
Stanyl® TW241 B3	(cond.)	PA46, CF15	–	–	–	110	4	–	–	–	–	–	–	*
Stanyl® TW241 F12	(dry)	PA46, GF60	20000	–	–	255	2	90	80	19	19	–	–	5.5
Stanyl® TW241 F12	(cond.)	PA46, GF60	12000	–	–	170	3	100	80	20	19	–	–	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Stanyl® TW241 F3	(dry)	PA46, GF15	6100	–	–	140	4	50	45	6	5.5	–	–	11.5
Stanyl® TW241 F3	(cond.)	PA46, GF15	2800	–	–	70	8	100	50	13	5.5	–	–	*
Stanyl® TW241 F6	(dry)	PA46, GF30	10000	–	–	210	4	80	65	12	10	4	200	9.5
Stanyl® TW241 F6	(cond.)	PA46, GF30	6000	–	–	115	7	100	80	21	10	4.7	1000	*
Stanyl® TW241 F8	(dry)	PA46, GF40	13000	–	–	230	3	85	75	14	11	4	200	8
Stanyl® TW241 F8	(cond.)	PA46, GF40	8000	–	–	140	6	95	75	22	11	4.7	1000	*
Stanyl® TW241F10	(dry)	PA46, GF50	16000	*	*	250	2.7	90	80	16	12	4	200	6.75
Stanyl® TW241F10	(cond.)	PA46, GF50	10000	*	*	160	5	100	80	24	12	4.7	1000	*
Stanyl® TW242FM10	(dry)	PA46, (GF + MF)50	14500	–	–	160	2	–	–	6	4.5	–	–	6.75
Stanyl® TW242FM10	(cond.)	PA46, (GF + MF)50	–	–	–	–	–	–	–	–	–	–	–	*
Stanyl® TW250F6	(dry)	PA46, GF30	12000	*	*	180	2.5	50	50	10	9	4	180	5.9
Stanyl® TW271 F6	(dry)	PA46, GF30	9000	*	*	190	3.7	–	–	13	11	–	–	7.4
Stanyl® TW271 F6	(cond.)	PA46, GF30	6000	*	*	110	7	–	–	15	11	–	–	*
Stanyl® TW271B3	(dry)	PA46, CF15	12500	–	–	185	2	–	–	6	–	–	–	9.5
Stanyl® TW271B3	(cond.)	PA46, CF15	–	–	–	110	4	–	–	–	–	–	–	*
Stanyl® TW275F6	(dry)	PA46, GF30	–	–	–	205	3.5	–	–	–	–	–	–	9
Stanyl® TW275F6	(cond.)	PA46, GF30	–	–	–	115	7	–	–	–	–	–	–	*
Stanyl® TW341	(dry)	PA46	3300	100	10	*	–	N	N	12	9	3.6	260	13.5
Stanyl® TW341	(cond.)	PA46	1000	55	20	*	–	N	N	45	12	4.5	1200	*
Stanyl® TW341 B	(dry)	PA46	3300	100	10	*	–	N	N	10	–	–	–	13.5
Stanyl® TW341 B	(cond.)	PA46	1000	55	20	*	–	N	N	35	–	–	–	*
Stanyl® TW341–N	(dry)	PA46	3300	100	10	*	–	N	N	12	9	3.6	260	13.5
Stanyl® TW341–N	(cond.)	PA46	1000	55	20	*	–	N	N	45	12	4.5	1200	*
Stanyl® TW363	(dry)	PA46, Imod	1850	60	20	*	–	N	N	75	26	3.2	190	11
Stanyl® TW363	(cond.)	PA46, Imod	600	45	25	*	–	N	N	130	30	4	1000	*
Stanyl® TW371	(dry)	PA46	2900	90	10	*	*	–	–	5	–	–	–	11.4
Stanyl® TW371	(cond.)	PA46	1000	50	15	*	*	–	–	30	–	–	–	*

PA66/DuPont														
Minlon® 10B140 NC010	(dry)	PA66, MD40	6500	“	*	89	4	40	25	3.5	3.5	3.9	230	5
Minlon® 10B140 NC010	(cond.)	PA66, MD40	4000	*	*	60	9	60	25	4	2	4.5	550	*
Minlon® 10B40 NC010	(dry)	PA66, MD40	9600	–	–	92	2.5	25	18	3	2	–	200	0.45
Minlon® 10B40 NC010	(cond.)	PA66, MD40	5400	–	–	58	8	40	–	2	2	–	–	*
Minlon® 11C140 NC010	(dry)	PA66, Imod, MD40	5800	*	*	89	10	130	80	6.5	5	3.6	240	5.7
Minlon® 11C140 NC010	(cond.)	PA66, Imod, MD40	2500	*	*	60	24	N	80	9	4	4.5	750	*
Minlon® 22C NC010	(dry)	PA66, (MD + GF)38	7500	–	–	130	3.5	50	40	4	3	–	100	5.4
Minlon® 22C NC010	(cond.)	PA66, (MD + GF)38	5300	–	–	82	10	45	–	4	4	–	500	*
Minlon® EFE6053 BK413	(dry)	PA66, (MD + GF)40	10000	*	*	160	2.3	45	40	4.5	4	4.8	130	5
Minlon® EFE6053 BK413	(cond.)	PA66, (MD + GF)40	6500	*	*	95	4.6	50	40	6.5	4	5	700	*
Minlon® EFE6096 GY090A	(dry)	PA66, Imod, MD15	3800	*	*	76	21	100	6	7.5	–	–	230	7.7
Minlon® EFE6096 GY090A	(cond.)	PA66, Imod, MD15	1800	*	*	*	>50	N	–	15	–	–	550	*
Zytel® 101 NC001	(dry)	PA66	3100	82	4.5	*	*	N	400	5.5	4.5	–	–	8.5
Zytel® 101 NC001	(cond.)	PA66	1400	53	25	*	*	N	N	15	3	–	–	*
Zytel® 101F NC010	(dry)	PA66	3100	82	4.5	*	*	N	400	6	5	3.5	180	8.5
Zytel® 101F NC010	(cond.)	PA66	1500	53	25	*	*	N	N	15	4	4.6	1000	*
Zytel® 101L NC010	(dry)	PA66	3100	82	4.5	*	*	N	400	5.5	4.5	3.5	180	8.5
Zytel® 101L NC010	(cond.)	PA66	1400	53	25	*	“	N	N	15	4	4	750	*
Zytel® 103FHS NC010	(dry)	PA66	3100	85	4.5	–	–	N	350	5.5	5	–	–	8.5
Zytel® 103FHS NC010	(cond.)	PA66	1500	54	25	–	–	N	N	14	4	–	–	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Zytel® 103HSL NC010	(dry)	PA66	3100	85	4.5	*	*	N	400	5	4.5	3.5	165	8.5
Zytel® 103HSL NC010	(cond.)	PA66	1500	54	25	*	*	N	N	14	4	4	700	*
Zytel® 132F NC010	(dry)	PA66	3400	91	4.4	–	–	300	200	4	3	–	–	8.5
Zytel® 132F NC010	(cond.)	PA66	1600	60	18	–	–	–	–	8	2.5	–	–	*
Zytel® 135F NC010	(dry)	PA66	3600	98	4.5	*	*	N	N	4	3	3.8	200	8.5
Zytel® 135F NC010	(cond.)	PA66	2100	69	18	*	*	N	N	9	3	3.9	600	*
Zytel® 145 BK010	(dry)	PA66	3100	79	4	*	*	–	–	6	–	4	95	–
Zytel® 145 BK010	(cond.)	PA66	1100	50	26	*	*	–	–	28	–	–	–	*
Zytel® 42A NC010	(dry)	PA66	3100	83	4.4	*	*	N	N	6	6	–	150	8.5
Zytel® 42A NC010	(cond.)	PA66	1200	52	27	*	*	N	N	20	4	–	750	*
Zytel® 45HSB NC010	(dry)	PA66	3100	83	4	–	–	–	–	6	5.5	–	–	–
Zytel® 70G13HS1L NC010	(dry)	PA66, GF13	5500	*	*	120	2.9	32	30	4.5	–	–	70	7.6
Zytel® 70G13HS1L NC010	(cond.)	PA66, GF13	3500	*	*	75	13	70	30	6	4	–	2400	*
Zytel® 70G13L NC010	(dry)	PA66, GF13	5500	*	*	120	2.9	40	40	5	4.5	4	150	7.6
Zytel® 70G13L NC010	(cond.)	PA66, GF13	3500	*	*	75	13	70	30	6	4	–	–	*
Zytel® 70G25HSLR NC010	(dry)	PA66, GF25	8400	*	*	188	3	60	60	10	7	–	–	6.4
Zytel® 70G25HSLR NC010	(cond.)	PA66, GF25	6100	*	*	115	5	80	45	11	7	–	–	*
Zytel® 70G30HSLR NC010	(dry)	PA66, GF30	10000	*	*	200	3.4	70	70	12	10	4.1	150	6
Zytel® 70G30HSLR NC010	(cond.)	PA66, GF30	7000	*	*	130	5	90	70	16	10	4.6	650	*

Zytel® 70G30HSR2 BK309	(dry)	PA66, GF30	10000	*	*	200	3.3	75	–	12	–	–	–	–
Zytel® 70G30HSR2 BK309	(cond.)	PA66, GF30	7200	*	*	130	5	9	–	15	–	–	–	*
Zytel® 70G30L NC010	(dry)	PA66, GF30	9800	*	*	195	3.5	80	–	13	–	–	160	6.9
Zytel® 70G30L NC010	(cond.)	PA66, GF30	7000	*	*	130	5	9	–	15	–	–	–	*
Zytel® 70G33GRA BK350	(dry)	PA66, GF33	12500	*	*	190	2.5	80	–	12	–	–	132	0.7
Zytel® 70G33GRA BK350	(cond.)	PA66, GF33	8500	*	*	135	4	9	–	16	–	–	–	*
Zytel® 70G33HS1L NC010	(dry)	PA66, GF33	11000	*	*	200	3.5	90	70	12	10	4	150	5.7
Zytel® 70G33HS1L NC010	(cond.)	PA66, GF33	8000	*	*	140	5	100	80	17	10	–	–	*
Zytel® 70G33L NC010	(dry)	PA66, GF33	10500	*	*	200	3.5	85	70	13	10	–	150	5.7
Zytel® 70G33L NC010	(cond.)	PA66, GF33	8000	*	*	140	5	100	75	17	10	–	–	*
Zytel® 70G35HSL NC010	(dry)	PA66, GF35	11000	*	*	210	3.2	90	80	15	10	4.1	140	5.5
Zytel® 70G35HSL NC010	(cond.)	PA66, GF35	8500	*	*	140	4.6	100	80	18	10	4.7	620	*
Zytel® 70G35HSLRA4 BK267	(dry)	PA66, GF35	11200	*	*	210	3	80	80	15	10	–	–	5.5
Zytel® 70G35HSLRA4 BK267	(cond.)	PA66, GF35	7500	*	*	140	5	95	75	18	10	–	–	*
Zytel® 70G35HSLX BK357	(dry)	PA66, GF35	11000	*	*	200	3	90	80	13	10	–	–	5.5
Zytel® 70G35HSLX BK357	(cond.)	PA66, GF35	8500	*	*	130	4	90	7	–	10	–	–	*
Zytel® 70G43HSLA BK099	(dry)	PA66, GF43	–	–	–	220	3	–	–	15	*	*	150	7.6

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Zytel® 70G43HSLA BK099	(cond.)	PA66, GF43	–	–	–	–	–	–	–	*	*	*	–	*
Zytel® 70G43L NC010	(dry)	PA66, GF43	14000	*	*	220	3	100	90	15	12	4.1	145	4.7
Zytel® 70G43L NC010	(cond.)	PA66, GF43	11000	*	*	160	4	110	80	18	12	4.9	600	*
Zytel® 70G60HSL BK359	(dry)	PA66, GF60	20000	*	*	230	1.6	70	60	11	12	–	300	3.4
Zytel® 70G60HSL BK359	(cond.)	PA66, GF60	15000	*	*	180	2.1	80	60	12	10	–	–	*
Zytel® 70K20HSL BK284	(dry)	PA66, RF20	5500	*	*	110	5	50	–	6	–	–	140	–
Zytel® 70K20HSL BK284	(cond.)	PA66, RF20	3500	*	*	85	7.2	70	–	9	–	–	–	*
Zytel® 74G20HSL NC010	(dry)	PA66 + PA6, GF20	7500	*	*	150	2.8	45	–	6	–	–	–	9
Zytel® 74G20HSL NC010	(cond.)	PA66 + PA6, GF20	4500	*	*	90	8	80	–	11	–	–	–	*
Zytel® 74G30L NC010	(dry)	PA66 + PA6, GF30	10000	*	*	180	3	90	–	12	–	–	250	–
Zytel® 74G30L NC010	(cond.)	PA66 + PA6, GF30	5500	*	*	110	6	–	–	–	–	–	–	*
Zytel® 75LG40HSL BK031	(dry)	PA66, GF40	13000	–	–	240	2.3	70	65	35	35	–	–	–
Zytel® 75LG40HSL BK031	(cond.)	PA66, GF40	–	–	–	–	–	90	70	38	38	–	–	*
Zytel® 75LG40L NC010	(dry)	PA66, GF40	12500	*	*	240	2.3	80	–	40	–	–	300	9
Zytel® 75LG50HSL BK031	(dry)	PA66, GF50	17000	–	–	–	–	95	80	50	50	–	–	7.6
Zytel® 75LG50HSL BK031	(cond.)	PA66, GF50	–	–	–	–	–	110	87	53	53	–	–	*

Zytel® 75LG50L NC010	(dry)	PA66, GF50	16500	*	*	260	1.9	95	–	50	–	–	–	–
Zytel® 75LG60HSL BK031	(dry)	PA66, GF60	22000	–	–	–	–	110	100	60	60	–	–	–
Zytel® 75LG60HSL BK031	(cond.)	PA66, GF60	–	–	–	–	–	110	95	62	62	–	–	*
Zytel® 75LG60L NC010	(dry)	PA66, GF60	22000	*	*	250	1.4	100	–	55	–	–	–	
Zytel® 80G14A NC010A	(dry)	PA66, Imod, GF14	–	–	–	–	–	–	–	–	–	–	10	6.2
Zytel® 80G14AHS NC010	(dry)	PA66, Imod, GF14	5100	*	*	105	4	73	–	19	9	–	–	–
Zytel® 80G14AHS NC010	(cond.)	PA66, Imod, GF14	3300	*	*	69	11	74	–	20	8	–	–	–
Zytel® 80G25HS NC010	(dry)	PA66, Imod, GF25	7000	*	*	110	4	80	90	23	14	–	–	5.8
Zytel® 80G25HS NC010	(cond.)	PA66, Imod, GF25	4500	*	*	80	8	80	90	24	13	–	–	*
Zytel® 80G33HS1L NC010	(dry)	PA66, Imod, GF33	8500	*	*	140	3.5	90	100	20	16	3.6	130	4.5
Zytel® 80G33HS1L NC010	(cond.)	PA66, Imod, GF33	5800	*	*	95	5	80	80	22	14	4.3	600	*
Zytel® 80G33L NC010	(dry)	PA66, Imod, GF33	8500	–	–	140	3.5	80	80	20	14	–	–	–
Zytel® 80G33L NC010	(cond.)	PA66, Imod, GF33	6000	–	–	95	5	80	80	22	14	–	–	*
Zytel® 80G43HS1L BK104	(dry)	PA66, Imod, GF43	11700	–	–	–	–	90	–	23	–	–	–	4.9
Zytel® CFE8005HS BK010	(dry)	PA66, Imod	2000	–	–	–	–	–	–	–	–	–	150	1.8
Zytel® CFE8005HS BK010	(cond.)	PA66, Imod	1120	–	–	–	–	–	–	–	–	–	200	*
Zytel® E51 HSB NC010	(dry)	PA66	3100	84	4.3	*		N	–	7	5.5	–	–	8.5
Zytel® E51 HSB NC010	(cond.)	PA66	1200	55	29	*	*	–	–	21	–	–	–	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Zytel® EFE1068 NC010T	(dry)	PA66	3000	85	4.5	*	*	N	–	5	–	–	100	8.5
Zytel® EFE1068 NC010T	(cond.)	PA66	1500	59	25	*	*	N	–	12	–	–	–	*
Zytel® EFE8089B BK416	(dry)	PA66, Imod, GF33	8900	*	*	143	4.5	100	–	27	–	–	–	–
Zytel® EFE8089B BK416	(cond.)	PA66, Imod, GF33	6000	*	*	104	8.5	98	–	28	–	–	–	*
Zytel® FE5480HS BK32N	(dry)	PA66, GF26	9300	–	–	172	2.5	–	–	8.5	–	–	–	–
Zytel® FE5555 BK538	(dry)	PA66 + PA6, GF35	11000	–	–	195	2.8	–	–	10	9	–	–	–
Zytel® FN714 NC010	(dry)	PA66	550	*	–	–	>50	–	–	–	–	–	–	6.5
Zytel® FN714 NC010	(cond.)	PA66	240	*	–	–	>50	–	–	–	–	–	–	*
Zytel® FN718 NC010	(dry)	PA66	960	*	*	–	>50	–	–	130	–	–	–	6.4
Zytel® FN718 NC010	(cond.)	PA66	420	–	–	–	>50	–	–	–	–	–	–	*
Zytel® FR50 NC010	(dry)	PA66, GF25	10000	–	–	180	2.6	40	–	11	–	3.8	180	–
Zytel® FR7026V0F NC010	(dry)	PA66	3600	60	21	*	*	N	400	4	3	–	–	8
Zytel® FR7026V0F NC010	(cond.)	PA66	1800	–	–	–	–	N	N	7	2	–	–	*
Zytel® FR70M30V0 NC010	(dry)	PA66, MD30	8500	*	*	73	2	21	21	2.5	2	3.7	140	4
Zytel® FR70M30V0 NC010	(cond.)	PA66, MD30	4500	*	*	54	6	24	19	3	2	4.2	500	–
Zytel® MT409AHS NC010	(dry)	PA66, Imod	2500	62	4.4	–	–	–	–	19	–	3.4	120	4.9
Zytel® MT409AHS NC010	(cond.)	PA66, Imod	1000	41	30	–	–	–	–	–	–	3.7	440	–
Zytel® ST801A NC010	(dry)	PA66, Imod	2000	48	5.8	*	*	–	–	–	–	–	50	–

Zytel® ST801A NC010	(cond.)	PA66, Imod	907	43	11	*	*	–	–	–	–	–	380	–
Zytel® ST801AHS NC010	(dry)	PA66, Imod	2000	50	5.7	–	–	–	–	–	–	3.3	110	6.7
Zytel® ST801AHS NC010	(cond.)	PA66, Imod	–	43	37	–	–	–	–		–	3.6	400	*
Zytel® ST801AW NC010	(cond.)	PA66, Imod	1200	*	*	*	>50	–	–	–	–	3.5	380	–
Zytel® WRF403 NC010	(dry)	PA66, GF30, PTFE15	10300	*	*	185	2.8	80	–	11	–	–	–	–
PA66/BASF														
Capron® AG40C	(dry)		3700	92	5	*	*	N	–	4	–	–	–	–
Capron® AG50G6 HS BK0100	(dry)		9600	–	–	–	–	45	–	7	–	–	–	–
Ultramid® A3	(dry)	PA66	3100	80	4	*	*	–	–	–	–	3.6	260	8.5
Ultramid® A3	(cond.)	PA66	1600	60	20	*	*	–	–	–	–	5	2000	*
Ultramid® A3EG10	(dry)	PA66, GF50	16800	*	*	240	2.5	95	90	18	13	3.8	150	4
Ultramid® A3EG10	(cond.)	PA66, GF50	12500	*	*	180	3.5	100	–	25	–	6.6	1700	*
Ultramid® A3EG5	(dry)	PA66, GF25	8600	*	*	175	3	65	55	12	9	3.5	140	6
Ultramid® A3EG5	(cond.)	PA66, GF25	6500	*	*	120	6	90	–	18	–	5.5	1600	*
Ultramid® A3EG6	(dry)	PA66, GF30	10000	*	*	190	3	85	70	13	11	3.5	140	5.5
Ultramid® A3EG6	(cond.)	PA66, GF30	7200	*	*	130	5	100	–	22	–	5.6	1600	*
Ultramid® A3EG7	(dry)	PA66, GF35	11500	*	*	210	3	95	75	14	12	3.5	200	5
Ultramid® A3EG7	(cond.)	PA66, GF35	8500	*	*	150	5	110	–	22	–	5.7	1500	*
Ultramid® A3EG7 Q206	(dry)	PA66, GF35	11500	*	*	210	3	95	75	14	–	3.5	200	5
Ultramid® A3HG5	(dry)	PA66, GF25	8600	*	*	170	3	65	55	12	9	3.5	140	6
Ultramid® A3HG5	(cond.)	PA66, GF25	6500	*	*	120	6	90	–	18	–	5.5	1600	*
Ultramid® A3HG6 HR bk 23591	(dry)	PA66, GF30	10000	*	*	190	3.2	80	65	11	9	3.5	–	5.5
Ultramid® A3HG6 HR bk 23591	(cond.)	PA66, GF30	6800	*	*	120	5.4	90	–	1	–	5.6	3000	*
Ultramid® A3HG7	(dry)	PA66, GF35	11200	*	*	200	3	95	75	13	12	3.5	200	5

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Ultramid® A3HG7	(cond.)	PA66, GF35	8500	*	*	150	5	110	–	22	–	5.7	1500	*
Ultramid® A3K	(dry)	PA66	3100	85	5	*	*	N	N	5	4	3.2	250	8.5
Ultramid® A3K	(cond.)	PA66	1100	50	20	*	*	N	–	20	–	5	2000	*
Ultramid® A3K Q202	(dry)	PA66	3000	85	5	–	–	N	–	5.5	–	3.2	50	8.5
Ultramid® A3SK	(dry)	PA66	3500	95	4.3	*	*	N	–	4	–	3.2	250	8.5
Ultramid® A3SK	(cond.)	PA66	1600	60	20	*	*	N	–	1	–	5	2000	*
Ultramid® A3SK Q202	(dry)	PA66	3500	95	4	*	*	N	–	4	–	3.2	250	8.5
Ultramid® A3W	(dry)	PA66	3000	85	4.4	*	*	N	N	6	5	3.2	250	8.5
Ultramid® A3W	(cond.)	PA66	1100	50	20	*	*	N	–	2	–	5	2000	*
Ultramid® A3WG10	(dry)	PA66, GF50	16800	*	*	240	2.5	95	90	18	13	3.8	150	4
Ultramid® A3WG10	(cond.)	PA66, GF50	12500	*	*	180	3.5	100	–	2	–	6.6	3000	*
Ultramid® A3WG3	(dry)	PA66, GF15	6000	*	*	130	3	45	43	8	7	3.5	140	7
Ultramid® A3WG3	(cond.)	PA66, GF15	4500	*	*	85	10	70	–	11		5.5	3000	*
Ultramid® A3WG5	(dry)	PA66, GF25	8600	*	*	180	3	65	55	12	9	3.5	140	6
Ultramid® A3WG5	(cond.)	PA66, GF25	6500	*	*	120	6	90	–	1	–	5.5	3000	*
Ultramid® A3WG6	(dry)	PA66, GF30	10000	*	*	190	3	85	70	13	10	3.5	140	5.5
Ultramid® A3WG6	(cond.)	PA66, GF30	7200	*	*	130	5	100	–	2	–	5.6	3000	*
Ultramid® A3WG7	(dry)	PA66, GF35	11500	*	*	210	3	95	75	14	12	3.5	200	5
Ultramid® A3WG7	(cond.)	PA66, GF35	8500	*	*	150	5	110	–	2	–	5.7	3000	*
Ultramid® A3WGM53 bk 20560	(dry)	PA66, (GF + MD)40	12100	*	*	160	2.3	55	50	8	6.7	4	200	5.1
Ultramid® A3WGM53 bk 20560	(cond.)	PA66, (GF + MD)40	6100	*	*	80	6	62	–	16	–	–	–	*
Ultramid® A3X2G10	(dry)	PA66, GF50	16000	*	*	180	2	55	50	13	11	3.6	200	4
Ultramid® A3X2G10	(cond.)	PA66, GF50	12000	*	*	130	3	55	–	1	–	5	200	*
Ultramid® A3X2G5	(dry)	PA66, GF25	8000	*	*	140	3	65	60	13	–	3.7	200	6
Ultramid® A3X2G5	(cond.)	PA66, GF25	6000	*	*	100	4.5	70	65	17	–	5	1000	*

Ultramid® A3X2G7	(dry)	PA66, GF35	11000	*	*	160	3	70	65	14	10	3.6	200	4.7
Ultramid® A3X2G7	(cond.)	PA66, GF35	8500	*	*	120	4	70	–	18	–	5	2000	*
Ultramid® A3X3G5	(dry)	PA66, GF25	8500	*	*	140	3	70	65	13	–	3.7	200	6
Ultramid® A3X3G5	(cond.)	PA66, GF25	6000	*	*	100	4.5	75	–	18	–	5	1000	*
Ultramid® A3XZG5	(dry)	PA66, GF25	6500	*	*	105	6	90	85	25	–	3.8	200	5
Ultramid® A3XZG5	(cond.)	PA66, GF25	4500	*	*	70	11	100	–	30	–	4	300	*
Ultramid® A3Z	(dry)	PA66	1900	48	5	*	*	N	–	N	31	3.1	160	7.2
Ultramid® A3Z	(cond.)	PA66	850	40	18	*	*	N	–	N	–	3.6	700	*
Ultramid® A3ZG6 bk 20591	(dry)	PA66, GF30	8500	*	*	140	3.5	90	85	19	10	3.5	140	5
Ultramid® A3ZG6 bk 20591	(cond.)	PA66, GF30	6000	*	*	100	6	95	–	26	–	5.5	1600	*
Ultramid® A4	(dry)	PA66	3200	80	4.2	*	*	N	–	–	–	3.2	260	8.5
Ultramid® A4	(cond.)	PA66	1600	60	20	*	*	N	–	–	–	5	2000	*
Ultramid® A4H	(dry)	PA66	3100	85	4.2	*	*	N	–	5.7	5	3.2	250	8.5
Ultramid® A4H	(cond.)	PA66	1200	50	20	*	*	N	–	25	–	5	2000	*
PA610/Toray Resin Company														
Amilan® CM2001	(dry)	PA610	–	55	–	–	50	N	–	40	–	3.1	0.02	4
Amilan® CM2001	(cond.)	PA610	–	40	50	–	>50	N	–	–	–	–	–	–
Amilan® CM2006	(dry)	PA610	–	60	50	–	50.0	N	–	40	–	–	–	4
Amilan® CM2006	(cond.)	PA610	–	–	–	–	50	N	–	–	–	–	–	–
Amilan® CM2401		PA610	–	60	50	–	>50	–	–	–	–	–	–	–
PA612/DuPont														
Zytel® 151 L NC010	(dry)	PA612	2400	62	4.5	*	*	N	N	3.5	3.5	3.2	160	3
Zytel® 151 L NC010	(cond.)	PA612	1700	54	18	*	*	N	40	4	3	4	400	*
Zytel® 153HSL NC010	(dry)	PA612	2400	60	4.4	*	*	N	N	4	5	3.2	160	3
Zytel® 153HSL NC010	(cond.)	PA612	1600	50	19	*	*	N	N	7	4	3.4	400	*
Zytel® 157HSL BK010	(dry)	PA612	2500	65	4.4	*	*	N	–	4	–	–	–	–
Zytel® 157HSL BK010	(cond.)	PA612	1500	53	18	*	*	N	–	7	–	–	–	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Zytel® 158 NC010	(dry)	PA612	2400	62	4.3	*	*	N	N	4.2	4.2	3.2	165	3
Zytel® 158 NC010	(cond.)	PA612	1500	52	19	*	*	N	N	8	4	4	1000	*
Zytel® 158L NC010	(dry)	PA612	2400	62	4.5	*	*	N	N	4	5	–	160	0.02
Zytel® 158L NC010	(cond.)	PA612	1500	52	19	*	*	N	–	6	4	–	–	*
Zytel® 159 NC010	(dry)	PA612	2400	62	4.5	*	*	–	–	5	–	–	–	–
Zytel® 159L NC010	(dry)	PA612	2400	62	4.5	*	*	–	–	5	–	–	–	–
Zytel® 350PHS2 NC010	(dry)	PA612, Imod	800	–	–	–	–	–	–	70	–	–	–	–
Zytel® 77G33L NC010	(dry)	PA612, GF33	9500	*	*	170	3	70	60	12	10	3.8	150	1.8
Zytel® 77G33L NC010	(cond.)	PA612, GF33	8000	*	*	140	3	70	40	12	10	–	–	*
Zytel® 77G43L NC010	(dry)	PA612, GF43	12000	*	*	190	2.8	100	90	15	15	3.6	200	1.7
Zytel® 77G43L NC010	(cond.)	PA612, GF43	12000	*	*	170	5	–	–	–	–	–	–	*
PA666/BASF														
Ultramid® 1C	(dry)	PA666	2400	80	5	–	–	140	200	7.5	8	–	–	–
Ultramid® 1C	(cond.)	PA666	1400	48	–	–	–	N	–	8.5	–	–	–	*
Ultramid® C35	(dry)	PA666	2200	80	5	*	*	–	–	–	–	3.7	300	10
Ultramid® C35	(cond.)	PA666	1000	45	20	*	*	–	–	–	–	–	–	*
Ultramid® C3U	(dry)	PA666	3500	75	4	*	*	80	–	6	4	3.6	200	8.5
Ultramid® C3U	(cond.)	PA666	1500	45	20	*	*	N	–	35	–	6	3000	*
PPA/DuPont														
Zytel® HTN51G25HSL BK083	(dry)	PA6T/XT, GF25	9100	*	*	170	2.2	47	47	9	8.7	–	–	5
Zytel® HTN51G25HSL BK083	(cond.)	PA6T/XT, GF25	–	–	–	–	–	47		7	–	–	–	*

Zytel® HTN51G35HSL NC010	(dry)	PA6T/XT, GF35	12000	*	*	220	2.4	70	60	12	11	4	120	5.5
Zytel® HTN51G35HSL NC010	(cond.)	PA6T/XT, GF35	12000	*	*	210	2.1	60		11	–	–	–	*
Zytel® HTN51G35HSLR BK420	(dry)	PA6T/XT, GF35	12500	*	*	220	2.4	65	–	12	–	–	–	–
Zytel® HTN51G35HSLR BK420	(cond.)	PA6T/XT, GF35	12500	*	*	210	2.1	44	–	11	–	–	–	*
Zytel® HTN51G45HSL NC010	(dry)	PA6T/XT, GF45	15000	*	*	240	2.4	90	60	11	12	4.5	180	3.6
Zytel® HTN51G45HSL NC010	(cond.)	PA6T/XT, GF45	15000	*	*	230	2.1	80		11	–	–	–	*
Zytel® HTN51G45HSLR BK420	(dry)	PA6T/XT, GF45	–	*	*	235	2.4	74	–	9.2	–	–	200	–
Zytel® HTN51G45HSLR BK420	(cond.)	PA6T/XT, GF45	–	–	–	–	–	–	–	–	–	–	700	*
Zytel® HTN51GM60THS BK083	(dry)	PA6T/XT, Imod, (GF + MD)60	17000	–	–	–	–	–	–	–	–	–	–	8.5
Zytel® HTN51LG50HSL BK083	(dry)	PA6T/XT, GF50	18000	*	*	250	1.5	70	–	50	–	–	8400	3.4
Zytel® HTN52G35HSL NC010	(dry)	PA6T/66, GF35	–	–	–	–	–	–	–	–	–	–	–	8.5
Zytel® HTN52G45HSL NC010	(dry)	PA6T/66, GF35	16000	–	–	–	–	60	–	–	–	–	140	4
Zytel® HTN52G45HSL NC010	(cond.)	PA6T/66, GF45	–	–	–	–	–	–	–	–	–	–	500	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Zytel® HTNFE150005 BK083	(dry)	PA6T/XT, (MD + GF)40	–	–	–	–	–	–	–	–	–	–	–	3.6
Zytel® HTNFE150005 BK083	(cond.)	PA6T/XT, (MD + GF)40	–	–	–	–	–	–	–	–	–	–	–	*
Zytel® HTNFE16502 BK001	(dry)	PA6T/XT, MD40	12600	*	*	145	1.8	–	–	2.4	–	–	90	3.6
Zytel® HTNFE250020 NC010	(dry)	PA6T/XT, Imod, MD30	4600	*	*	99	5	100	–	5	–	–	–	–
Zytel® HTNFE350006 NC010	(dry)	PA6T/XT, Imod, MD30	–	*	*	87	6.5	–	–	–	–	–	–	–
Zytel® HTNFE350015 NC010	(dry)	PA6T/XT, Imod	–	*	*	73	3.3	–	–	–	–	–	–	–
Zytel® HTNFE8200 NC010	(dry)	PA6T/XT, Imod	2190	–	–	–	–	–	–	–	–	–	–	6.3
Zytel® HTNFR51G35L NC010	(dry)	PA6T/XT, GF35	15000	*	*	170	1.4	40	35	11	13	–	–	–
Zytel® HTNFR51G35L NC010	(cond.)	PA6T/XT, GF35	–	*	*	130	1.1	–	–	–	–	–	–	*
Zytel® HTNWRF51 G30 NC010	(dry)	PA6T/XT, GF30	10000	–	–	–	–	–	–	10	–	–	–	–
PPA/Solvay														
AMODEL A-1133 HS	(dry)	PA66/6T, GF33	13400	–	–	233	2.5	73	58	9.5	8.8	4.2	0.017	–
AMODEL A-1133 HS	(cond.)	PA66/6T, GF33	13400	–	–	193	2.1	44	46	6.7	5.8	4.3	0.022	*
AMODEL A-1145 HS	(dry)	PA66/6T, GF45	16800	–	–	259	2.7	93	65	10	11	4.4	0.016	–

AMODEL A-1145 HS	(cond.)	PA66/6T, GF45	16800	–	–	225	2.1	69	56	9.7	9.5	4.5	0.021	*
AMODEL A-1230 L	(dry)	PA66/6T, MD30	6900	–	–	96	1.6	26	–	2.2	2.6	3.9	0.018	–
AMODEL A-1230 L	(cond.)	PA66/6T, MD30	6900	–	–	80	1.2	–	–	–	–	4	0.02	*
AMODEL A-1240 HS	(dry)	PA66/6T, MD40	8970	–	–	107	1.6	36	44	3.7	3.5	4	0.017	–
AMODEL A-1240 HS	(cond.)	PA66/6T, MD40	8280	–	–	93	1.2	36	35	3.3	2.8	4	0.019	*
AMODEL A-1240 L	(dry)	PA66/6T, MD40	10100	–	–	104	1.6	29	31	4.1	3.2	4	0.017	–
AMODEL A-1240 L	(cond.)	PA66/6T, MD40	9350	–	–	91	1.2	31	30	3.8	2.2	4	0.019	*
AMODEL A-1565 HS	(dry)	PA66/6T	20000	–	–	138	1	–	–	3.1	–	–	–	–
AMODEL AF-1133 V0	(dry)	PA66/6T, GF33	14000	–	–	179	2	38	38	5.1	4.9	4.9	0.008	–
AMODEL AF-1133 V0	(cond.)	PA66/6T, GF33	13800	–	–	–	–	29	28	4.6	4.6	–	–	*
AMODEL AF-1145 V0	(dry)	PA66/6T, GF45	18000	–	–	203	1	33	35	6.6	6.3	5.2	0.008	–
AMODEL AF-1145 V0	(cond.)	PA66/6T, GF45	18000	–	–	–	–	28	29	5.9	6	–	–	*
AMODEL AF-4133 V0	(dry)	PA66/6T, GF33	13800	–	–	178	1.8	44	42	5.9	5.8	3.81	0.0111	–
AMODEL AF-4133 V0	(cond.)	PA66/6T, GF33	–	–	–	–	–	35	32	5.4	5.3	–	–	*
AMODEL AF-4145 V0	(dry)	PA66/6T, GF45	18600	–	–	196	1.5	32	35	6.4	6.4	4.1	0.0127	–
AMODEL AF-4145 V0	(cond.)	PA66/6T, GF45	–	–	–	–	–	28	26	6.1	6.2	–	–	*
AMODEL AFA-4133 V0 Z	(dry)	PA66/6T, GF33	–	–	–	165	1.6	43	38	7.4	7.5	4.2	0.01	–
AMODEL AFA−6133 V0 Z	(dry)	PA66/6T, GF33	–	–	–	170	1.7	37	39	6.9	6.7	4.1	0.011	–

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
AMODEL AFA-6145 V0 Z	(dry)	PA66/6T, GF45	–	–	–	193	1.5	33	–	7.8	–	4.1	0.011	–
AMODEL AP-9240 NL NT	(dry)	PA66/6T, Imod, MD40	4900	–	–	67	3	49	–	4.6	–	–	–	–
AMODEL AS-1133 HS	(dry)	PA66/6T, GF33	12200	–	–	225	3	82	62	11	9.2	4.2	0.017	–
AMODEL AS-1133 HS	(cond.)	PA66/6T, GF33	12200	–	–	196	2.5	50	40	6.4	4.9	4.3	0.022	*
AMODEL AS-1145 HS	(dry)	PA66/6T, GF45	16000	–	–	263	2.7	85	76	12	9.4	4.4	0.016	–
AMODEL AS-1145 HS	(cond.)	PA66/6T, GF45	16000	–	–	232	2	56	54	10	6.9	4.5	0.021	*
AMODEL AS-1566 HS	(dry)	PA66/6T, (GF + MD)65	22800	–	–	200	1.4	34	34	6.2	5.9	4.7	0.004	–
AMODEL AS-1566 HS	(cond.)	PA66/6T, (GF + MD)65	22800	–	–	170	1.2	32	33	5.2	5.1	4.7	0.014	*
AMODEL AS-1933 HS	(dry)	PA66/6T, GF33	12600	–	–	212	2.5	76	–	10	–	–	–	–
AMODEL AS-1945 HS	(dry)	PA66/6T, GF45	15100	–	–	244	2.5	86	–	9.7	–	–	–	–
AMODEL AS-4133 HS	(dry)	PA66/6T, GF33	12600	–	–	211	2.6	68	63	11	10	3.6	0.012	–
AMODEL AS-4133 HS	(cond.)	PA66/6T, GF33	12600	–	–	181	2.3	55	52	9.8	9.2	3.4	0.019	*
AMODEL AS-4145 HS	(dry)	PA66/6T, GF45	16100	–	–	224	2.2	64	80	10	8.3	3.7	0.011	–
AMODEL AS-4145 HS	(cond.)	PA66/6T, GF45	16100	–	–	183	1.9	60	63	8.9	8.2	4	0.037	*
AMODEL AT-1001 L	(dry)	PA66/6T, Imod	1900	–	–	–	–	N	N	93	26	–	–	–
AMODEL AT-1001 L	(cond.)	PA66/6T, Imod	2000	–	–	–	–	N	N	97	25	–	–	*

AMODEL AT-1116 HS	(dry)	PA66/6T, GF16	6900	–	–	160	3.7	–	–	9.1	–	–	–	–
AMODEL AT-1116 HS	(cond.)	PA66/6T, GF16	6900	–	–	120	3.2	–	–	6.5	–	–	–	*
AMODEL AT-1125 HS	(dry)	PA66/6T, GF25	8900	–	–	190	3.2	67	53	8.8	5.7	–	–	–
AMODEL AT-1125 HS	(cond.)	PA66/6T, GF25	8900	–	–	143	2.4	47	37	6	4.1	–	–	*
AMODEL AT-5001	(dry)	PA66/6T	2300	–	–	–	–	N	N	20	11	3.2	0.016	–
AMODEL AT-5001	(cond.)	PA66/6T	2500	–	–	–	–	N	N	23	9.5	3.6	0.027	*
AMODEL ET-1001 HS	(dry)	PA66/6T, Imod	2400	–	–	–	–	N	N	19	15	–	–	–
AMODEL ET-1001 HS	(cond.)	PA66/6T, Imod	2300	–	–	–	–	N	N	18	13	–	–	*
AMODEL ET-1001 L	(dry)	PA66/6T, Imod	2400	–	–	–	–	N	N	19	15	–	–	–
AMODEL ET-1001 L	(cond.)	PA66/6T, Imod	2300	–	–	–	–	N	N	18	13	–	–	*
Polyarylamide/Mitsubishi Engineering-Plastics Corp														
Reny 1002H	(dry)	PAMXD6, GF30	12100	*	*	181	1.7	35	–	6.3	–	–	–	1.5
Reny 1002H	(cond.)	PAMXD6, GF30	11100	*	*	148	1.8	33	–	6.2	–	–	–	–
Reny 1012H	(dry)	PAMXD6, GF40	16600	*	*	218	1.8	52	–	8.5	–	–	–	1.8
Reny 1012H	(cond.)	PAMXD6, GF40	13600	*	*	177	1.8	52	–	8.9	–	–	–	–
Reny 1021UCS	(dry)	PAMXD6, GF50	17800	*	*	252	2.5	87	–	14.1	–	–	–	1.3
Reny 1021UCS	(cond.)	PAMXD6, GF50	14400	*	*	184	3.4	101	–	16.4	–	–	–	–
Reny 1022H	(dry)	PAMXD6, GF50	20400	*	*	260	2	72	–	11.3	–	–	–	1.1
Reny 1022H	(cond.)	PAMXD6, GF50	19300	*	*	214	2.1	58	–	12.2	–	5	0.017	–

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Reny 1025	(dry)	PAMXD6, GF50	19600	*	*	275	1.9	77	–	14.2	–	–	–	1
Reny 1025	(cond.)	PAMXD6, GF50	18300	*	*	229	2	82	–	13.1	–	–	–	–
Reny 1027	(dry)	PAMXD6, GF50	18700	*	*	227	1.6	45	–	9	–	–	–	0.8
Reny 1027	(cond.)	PAMXD6, GF50	17200	*	*	197	1.7	45	–	9.2	–	–	–	–
Reny 1032	(dry)	PAMXD6, GF60	24700	*	*	249	1.4	54	–	14	–	–	–	0.9
Reny 1032	(cond.)	PAMXD6, GF60	22400	*	*	204	1.4	61	–	13.9	–	5	0.013	–
Reny 1071	(dry)	PAMXD6, GF55	24900	*	*	264	1.6	83	–	17	–	–	–	1.5
Reny 1071	(cond.)	PAMXD6, GF55	23700	*	*	237	1.6	66	–	16	–	–	–	–
Reny 1313	(cond.)	PAMXD6, GF40	11000	*	*	136	2.4	55	–	12.7	–	4	0.015	–
Reny 1501AH	(dry)	PAMXD6, GF30	13300	*	*	162	1.6	37	–	5.3	–	–	–	1.2
Reny 1501AH	(cond.)	PAMXD6, GF30	11700	*	*	135	1.6	29	–	5.5	–	4	0.014	–
Reny 1511AH	(dry)	PAMXD6, GF30	16500	*	*	197	1.8	45	–	7.7	–	4.42	0.00866	1.1
Reny 1521AH	(dry)	PAMXD6, GF50	20600	*	*	215	1.5	49	–	9.3	–	–	–	1.1
Reny 1722F	(dry)	PAMXD6, GF50	20700	*	*	244	2	58	–	11.4	–	–	–	0.7
Reny 1722F	(cond.)	PAMXD6, GF50	19100	*	*	208	1.7	54	–	10.4	–	–	–	–
Reny 2502A	(dry)	PAMXD6, (GF + MD)20	18400	*	*	150	1.2	27	–	4.1	–	–	–	0.9

Reny 2502A	(cond.)	PAMXD6, (GF + MD)20	14900	*	*	120	1.3	29	–	4.3	–	5	0.017	–
Reny 2620	(dry)	PAMXD6, GF20	17600	*	*	139	1.1	27	–	4.1	–	–	–	1.3
Reny 2620	(cond.)	PAMXD6, GF20	11500	*	*	86	1.3	35	–	5.1	–	–	–	–
Reny 4011	(dry)	PAMXD6, GF40	21600	*	*	152	1	16	–	7.3	–	–	–	0.9
Reny 4011	(cond.)	PAMXD6, GF40	18600	*	*	143	1.1	16	–	7.5	–	–	–	–
Reny 4511	(dry)	PAMXD6, GF40	20900	*	*	130	0.6	12	–	6.9	–	–	–	0.7
Reny 4511	(cond.)	PAMXD6, GF40	20600	*	*	125	0.8	12	–	8.9	–	–	–	–
Reny C36	(dry)	PAMXD6, CF30	27200	*	*	249	1.2	45	–	4.7	–	–	–	1.4
Reny C36	(cond.)	PAMXD6, CF30	24200	*	*	230	1.3	48	–	4.9	–	–	–	–
Reny G07S	(dry)	PAMXD6, GF20	9200	*	*	155	2.5	38	–	6	–	–	–	1.1
Reny G07S	(cond.)	PAMXD6, GF20	9100	*	*	136	2.5	37	–	5.9	–	–	–	–
Reny G16S	(dry)	PAMXD6, CF20	20200	*	*	230	1.6	50	–	4.4	–	–	–	1.1
Reny G16S	(cond.)	PAMXD6, CF20	19900	*	*	205	1.6	39	–	4.5	–	–	–	–
Reny N252	(dry)	PAMXD6, GF25	25700	*	*	174	11	31	–	5.9	–	5	0.008	1.1
Reny N252	(cond.)	PAMXD6, GF25	22200	*	*	138	1.4	33	–	6.6	–	5	0.018	–
Reny W110	(dry)	PAMXD6, Whisker	44700	*	*	231	0.7	24	–	3.3	–	–	0.0068	0.75
Reny W110	(cond.)	PAMXD6, Whisker	40000	*	*	202	0.6	19	–	3	–	–	–	–
Reny W38S2	(dry)	PAMXD6, MD30	16200	*	*	121	0.9	18	–	1.8	–	–	–	1

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Reny W38S2	(cond.)	PAMXD6, MD30	15900	*	*	111	0.8	22	–	2.1	–	–	–	–
IXEF® 1002	(dry)	PAMXD6, GF30	11500	*	*	190	2	29	–	7.4	–	–	–	–
IXEF® 1022	(dry)	PAMXD6, GF50	20000	*	*	280	1.9	61	–	9	–	–	–	3.3
IXEF® 1022	(cond.)	PAMXD6, GF50	20000	–	–	260	2.2	–	–	–	–	–	–	*
IXEF® 1023	(dry)	PAMXD6, GF50	20000	*	*	250	1.9	–	–	–	–	–	–	–
IXEF® 1025	(dry)	PAMXD6, GF50	17000	*	*	230	1.9	–	–	–	–	–	–	–
IXEF® 1027	(dry)	PAMXD6, GF50	20000	*	*	235	1.8	–	–	–	–	–	–	–
IXEF® 1028	(dry)	PAMXD6, GF50	20000	*	*	250	1.8	–	–	–	–	–	–	0.17
IXEF® 1032	(dry)	PAMXD6, GF60	24000	*	*	280	1.8	61	–	11	–	–	–	2.8
IXEF® 1032	(cond.)	PAMXD6, GF60	23000		–	250	2	–	–	–	–	–	–	*
IXEF® 1313	(dry)	PAMXD6, GF40	11000	*	*	190	3.1	47	–	27	–	–	–	–
IXEF® 1501	(dry)	PAMXD6, GF30	13000	*	*	185	2.3	29	–	–	–	–	–	–
IXEF® 1521	(dry)	PAMXD6, GF50	20000	*	*	230	1.9	40	–	–	–	–	–	–
IXEF® 1622	(dry)	PAMXD6, Imod, GF50	17000	*	*	235	2.6	85	–	13	–	–	–	3.2
IXEF® 1622	(cond.)	PAMXD6, Imod, GF50	16000	*	*	200	2.7	–	–	–	–		–	*
IXEF® 2011	(dry)	PAMXD6, MD42	18000	*	*	140	1.3	35	–	2	–	–	–	0.35

IXEF® 2030	(dry)	PAMXD6, MD55	21500	*	*	140	1.2	25	–	3.7	–	–	–	–
IXEF® 2057	(dry)	PAMXD6, MD45	12000	*	*	100	1.6	–	–	–	–	–	–	–
IXEF® 2530	(dry)	PAMXD6, (MD + GF)55	20000	*	*	150	1.2	19	–	–	–	–	–	–
IXEF® 3006	(dry)	PAMXD6, CF30	26000	*	*	250	1.3	–	–	4.4	–	–	–	–
Polyamide Alloys/Arkema														
ORGALLOY LE 6000	(dry)	PA6 Alloy	–	–	–	–	–	–	–	–	–	–	–	6.4
ORGALLOY LE 6000	(cond.)	PA6 Alloy	1300	35	4	*	*	–	–	30	–	–	–	*
ORGALLOY LE 60HM	(dry)	PA6 Alloy	–	–	–	–	–	–	–	–	–	–	–	6.4
ORGALLOY LE 60HM	(cond.)	PA6 Alloy	1550	39	5	*	*	–	–	28	–	–	–	*
ORGALLOY LE 60LM	(dry)	PA6 Alloy	–	–	–	–	–	–	–	–	–	–	–	6.4
ORGALLOY LE 60LM	(cond.)	PA6 Alloy	700	32	6	*	*	N	–	N	–	–	–	*
ORGALLOY LE 60LMXV	(cond.)	PA6 Alloy	600	30	7	*	*	N		N	–	–	–	*
ORGALLOY LE 60SF	(dry)	PA6 Alloy	–			–	–	–	–	–	–	–	–	5.5
ORGALLOY LE 60SF	(cond.)	PA6 Alloy	1350	36	4	*	*	–	–	29	–	–	–	*
ORGALLOY LE 60THM	(dry)	PA6 Alloy	–	–	–	–	–	–	–	–	–	–	–	6
ORGALLOY LE 60THM	(cond.)	PA6 Alloy	1750	40	5	*	*	–	–	23	–	–	–	*
ORGALLOY LT 4060	(dry)	PA6 Alloy	–	–	–	–	–	N	–	N	–	–	–	5
ORGALLOY LT 4060	(cond.)	PA6 Alloy	300	*	*	*	>50	N	–	N	22	–	–	*
ORGALLOY LT 4060ES noir T6L	(dry)	PA6 Alloy	–		–	–	–	N	–	N	–	–	–	5

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
ORGALLOY LT 4060ES noir T6L	(cond.)	PA6 Alloy	300	*	*	*	>50	N	–	N	–	–	–	*
ORGALLOY LT 5050 T6L	(dry)	PA6 Alloy	–		–	–	–	N	–	N	–	–	–	–
ORGALLOY LT 5050 T6L	(cond.)	PA6 Alloy	460	*	*	*	>50	N	–	N	–	4	500	*
ORGALLOY LT 5050ES noir	(dry)	PA6 Alloy	–		–	–	–	N	–	N	–	–	–	–
ORGALLOY LT 5050ES noir	(cond.)	PA6 Alloy	460	*	*	*	>50	N	–	N	–	4	500	*
ORGALLOY R 60ES	(dry)	PA6 Alloy	–	–	–	–	–	–		16	–	–	–	3.3
ORGALLOY R 60ES	(cond.)	PA6 Alloy	2010	50	3.4	*	*	–		20	–	3	250	*
ORGALLOY RS 6000	(dry)	PA6 Alloy	–	–		–	–	–	–	16	–	–	–	3.3
ORGALLOY RS 6000	(cond.)	PA6 Alloy	2300	50	4	*	*	–		20	–	3	250	*
ORGALLOY RS 6010	(dry)	PA6 Alloy, GF10	–	–		–	–	–	–	20	–	–	–	3
ORGALLOY RS 6010	(cond.)	PA6 Alloy, GF10	3300	*	*	80	5	–	–	21	–	3	240	*
ORGALLOY RS 6015ES noir T6L	(dry)	PA6 Alloy, GF15												2.8
ORGALLOY RS 6015ES noir T6L	(cond.)	PA6 Alloy, GF15	2850	*	*	75	6.5	–	–	14	5	3	240	*
ORGALLOY RS 6030	(dry)	PA6 Alloy, GF30	–	–	–	–	–	–	–	20	–	–	–	2.3
ORGALLOY RS 6030	(cond.)	PA6 Alloy, GF30	7500	*	*	130	4	–	–	22	–	4	230	*
ORGALLOY RS 60E10	(dry)	PA6 Alloy, Imod	–	–	–			–	–	27	–	–		3.2
ORGALLOY RS 60E10	(cond.)	PA6 Alloy, Imod	1620	42	5	*		–	–	32	–	3	250	*

ORGALLOY RS 6600	(cond.)	PA6 Alloy	2600	52	4	*		–	–	20	–	3	170	*
ORGALLOY RS 6620	(dry)	PA6 Alloy, GF20								–	–	–		2.3
ORGALLOY RS 6620	(cond.)	PA6 Alloy, GF20	5500	*	*	110	4.5	–	–	16	–	4	170	*
ORGALLOY RS 6630	(dry)	PA6 Alloy, GF30	–	–	–				–	18	–	–		1.9
ORGALLOY RS 6630	(cond.)	PA6 Alloy, GF30	8800	*	*	140		–	–	20	–	4	160	*
Polyamide Alloys/Rhodia														
Technyl® Alloy KC 216	(dry)	PA6 + ABS	2700	–	–	–	–	N	–	6.5	–	–	–	–
Technyl® Alloy KC 216	(cond.)	PA6 + ABS	1300	–	–	–	–	N	–	18	–	–	–	*
Technyl® Alloy KC 216 V12 Black	(dry)	PA6 + ABS, GF12	4800	–	–	95	3.3	50	–	7	–	–	–	–
Technyl® Alloy KC 216 V12 Black	(cond.)	PA6 + ABS, GF12	2800	–	–	55	8	90	–	15	–	–	–	*
Technyl® Alloy KC 226 BLACK	(dry)	PA6 + ABS	3000	–	–	–	–	N	–	6	–	–	–	–
Technyl® Alloy KC 226 BLACK	(cond.)	PA6 + ABS	1400	–	–	–	–	N	–	16	–	–	–	*
Technyl® Alloy KC 246 BLACK	(dry)	PA6 + ABS, Imod	2250	–	–	–	–	N	–	60	–	–	–	–
Technyl® Alloy KC 246 BLACK	(cond.)	PA6 + ABS, Imod	1200	–	–	–	–	N	–		–	–	–	*
PA Alloy/EMS-Grivory														
Grilon TS FR	(dry)	PA66 + PA6	3300	85	4	*	*	N	N	10	10	3	150	8
Grilon TS FR	(cond.)	PA66 + PA6	1200	50	15	*	*	N	80	20	5	4	750	*
Grilon TS V0	(dry)	PA66 + PA6	3600	85	4	*	*	75	70	4	3	3	150	8
Grilon TS V0	(cond.)	PA66 + PA6	1600	50	15	*	*	N	N	15	3	4	700	*
Grilon TSC-10/4 EC	(dry)	PA66 + PA6, CF10	9200	*	*	170	3	50	40	5	4	4	450	5

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Grilon TSC-10/4 EC	(cond.)	PA66 + PA6, CF10	6500	*	*	120	7	80	40	12	4	5	1200	*
Grilon TSC-20/4 EC	(dry)	PA66 + PA6, CF20	16000	*	*	230	3	65	60	8	5	*	*	5
Grilon TSC-20/4 EC	(cond.)	PA66 + PA6, CF20	10000	*	*	160	6	90	60	15	5	*	*	*
Grilon TSC-30/4 EC	(dry)	PA66 + PA6, CF30	23000	*	*	250	2.5	60	60	10	7	*	*	5
Grilon TSC-30/4 EC	(cond.)	PA66 + PA6, CF30	15000	*	*	180	5	85	70	16	7	*	*	*
Grilon TSC-30/4 LF 15	(cond.)	PA66 + PA6, CF30	16000	*	*	170	4.5	60	45	13	7	*	*	*
Grilon TSC-40/4 EC	(dry)	PA66 + PA6, CF40	26000	*	*	260	2	60	50	10	7	*	*	5
Grilon TSC-40/4 EC	(cond.)	PA66 + PA6, CF40	17000	*	*	200	4	85	50	16	7	*	*	*
Grilon TSG-30	(dry)	PA66 + PA6, GF30	9700	*	*	175	3	75	65	13	10	3	130	6.5
Grilon TSG-30	(cond.)	PA66 + PA6, GF30	6000	*	*	120	6	85	65	20	10	4	450	*
Grilon TSG-30 FR	(dry)	PA66 + PA6, GF30	7100	*	*	105	5	50	40	4	3	4	150	7
Grilon TSG-30 FR	(cond.)	PA66 + PA6, GF30	4000	*	*	65	15	N	50	8	3	4	600	*
Grilon TSG-30/4	(dry)	PA66 + PA6, GF30	9700	*	*	190	3	70	60	10	7	4	100	5
Grilon TSG-30/4	(cond.)	PA66 + PA6, GF30	6000	*	*	125	8	80	60	12	6	4	800	*
Grilon TSG-35/4	(dry)	PA66 + PA6, GF35	11000	*	*	195	3	75	60	10	8	4	100	5
Grilon TSG-35/4	(cond.)	PA66 + PA6, GF35	7500	*	*	130	6	85	70	13	8	4	550	*

Grilon TSG-50	(dry)	PA66 + PA6, GF50	16500	*	*	240	3	90	80	15	11	4	150	6
Grilon TSG-50	(cond.)	PA66 + PA6, GF50	10000	*	*	150	5	100	90	20	12	4	650	*
Grilon TSG-50/4	(dry)	PA66 + PA6, GF50	17500	*	*	250	2.5	80	70	14	12	4	150	5
Grilon TSG-50/4	(cond.)	PA66 + PA6, GF50	12500	*		170	4.5	85	80	20	12	4	650	*
Grilon TSGK-30 X	(dry)	PA66 + PA6, (GF + GB)30	8500	*	*	155	3	50	45	8	7	3	120	7.5
Grilon TSGK-30 X	(cond.)	PA66 + PA6, (GF + GB)30	5000	*	*	85	10	75	45	13	7	3	390	*
Grilon TSGZ-15	(dry)	PA66 + PA6, Imod, GF15	5600	*	*	110	4	75	60	12	5	3	150	8
Grilon TSGZ-15	(cond.)	PA66 + PA6, Imod, GF15	2900	*	*	65	10	90	70	17	5	4	700	*
Grilon TSGZ-30	(dry)	PA66 + PA6, Imod, GF30	9000	*	*	180	4	80	80	15	10	3	150	7
Grilon TSGZ-30	(cond.)	PA66 + PA6, Imod, GF30	5400	*	*	90	8	90	80	25	10	4	700	*
Grilon TSK-30/4	(dry)	PA66 + PA6, GB30	4100	*	*	75	10	30	25	4	2	4	150	5
Grilon TSK-30/4	(cond.)	PA66 + PA6, GB30	1800	*	*	45	35	85	25	8	3	4	600	*
Grilon TSM-30	(dry)	PA66 + PA6, MD30	5800	*	*	75	3	45	35	5	5	3	140	6.5
Grilon TSM-30	(cond.)	PA66 + PA6, MD30	2300	*	*	45	15	N	35	7	3	3	450	*
Grilon TSS	(cond.)	PA66 + PA6	750	40	15	*	*	N	N	35	7	3	500	*
Grilon TSS/4	(dry)	PA66 + PA6	3000	80	5	*	*	N	N	6	6	3	200	8
Grilon TSS/4	(cond.)	PA66 + PA6	1100	50	15	*	*	N	N	40	5	4	800	*
Grilon TSS/4 LF 2	(dry)	PA66 + PA6, Moly2	3300	90	5	*	*	N	N	4	4	3	200	7
Grilon TSS/4 LF 2	(cond.)	PA66 + PA6, Moly2	1400	50	15	*	*	N	N	20	4	4	750	*

(*Continued*)

11.5 Polyamides (Nylons)—*Cont'd*

Name and Grade		Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Grilon TSS/4 LF 20	(dry)	PA66 + PA6, (PTFE + Si) 20	2700	60	4	*	*	N	45	4	4	3	150	5
Grilon TSS/4 LF 20	(cond.)	PA66 + PA6, (PTFE + Si) 20	1200	35	10	*	*	N	55	8	4	3	550	*
Grilon TSZ 1	(dry)	PA66 + PA6, Imod	2400	65	4	*	*	N	N	11	10	3	150	8.5
Grilon TSZ 1	(cond.)	PA66 + PA6, Imod	750	35	20	*	*	N	N	45	8	3	450	*

11.6 Polyolefins and Acrylics

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PE/Celanese													
CELSTRAN PEHD-GF40-01	HDPE, GF40	6800	–	–	80	2.3	–	–	24	–	–	–	–
CELSTRAN PEHD-GF60-01-US	HDPE, GF60	10500	–	–	91	1.4	–	–	30	–	–	–	–
PE/Bassell Polyolefins													
Hostalen GD9555	HDPE	1050	25	10	41	490	–	–	6	–	–	–	–
Hostalen GD9555 F	HDPE	950	23	10	44	580	–	–	9	–	–	–	–
Hostalen GF9145 X	HDPE	800	21	10	28	520	–	–	8	–	–	–	–
Lupolen 1800 H	LDPE	200	9	–	–	–	–	–	–	–	–	–	–
Lupolen 1800 S	LDPE	150	8	–	–	–	–	–	–	–	–	–	–

Lupolen 1810 E	LDPE	200	9	–	–	–	–	–	–	–	–	–	–
Lupolen 1840 D	LDPE	200	9	–	20	600	–	–	–	–	–	–	–
Lupolen 18P FAX	LDPE	300	10	–	65	850	–	–	–	–	–	–	–
Lupolen 18P FFX	LDPE	300	10	–	45	850	–	–	–	–	–	–	–
Lupolen 2420 D	LDPE	240	10	–	20	600	–	–	–	–	–	–	–
Lupolen 4261 A Q 416	HDPE	850	24	10	–	–	–	–	–	–	–	–	–
Lupolen 5021 D	HDPE	1000	25	9	–	–	–	–	–	–	–	–	–
Lupolen 5031 L Q 449	HDPE	1000	26	8	–	–	–	–	–	–	–	–	–
Lupolen 5031 L Q 449 K	HDPE	1100	26	10	–	–	–	–	5	–	–	–	–
Lupolen 5661 A	HDPE	1270	28	9	–	–	–	–	–	–	–	–	–
UHMWPE/Celanese													
GUR 2122	UHMWPE	790	17	20	–	–	–	–	–	–	3	10	0.01
GUR 4113	UHMWPE	750	17	20	–	–	–	–	–	–	3	10	0.01
GUR 4120	UHMWPE	720	17	20	–	–	–	–	–	–	3	10	0.01
GUR 4130	UHMWPE	680	17	20	–	–	–	–	–	–	3	10	0.01
GUR 4150	UHMWPE	680	17	20	–	–	–	–	–	–	3	10	0.01
GUR 4152	UHMWPE	680	17	20	–	–	–	–	–		3	10	–
GUR 4170	UHMWPE	570	17	20	–	–	–	–	–	–	3	10	0.01
GUR 5113	UHMWPE	750	–	–	–	–	–	–	100P	100P	–	–	–
GUR GHR 8020	UHMWPE	–	19	10	–	–	*	*	*	*	*	*	–
GUR GHR 8110	UHMWPE	1060	21	10	–	–	–	–	–	–	2.9	4	0.01
PP/Albis Plastic GmgH													
ALTECH® PP-B A 1000/120 UV	PP	–	–	–	–	–	N	–	4.5	–	–	–	–
ALTECH® PP-B A 2020/150 GF20 CP	PP, GF20	4000	–	–	53	6	50	–	20	–	–	–	–
ALTECH® PP-B A 2030/150 GF30 CP	PP, GF30	5300	–	–	65	4.5	50	–	20	–	–	–	–
ALTECH® PP-B A 2040/150 GF40 CP	PP, GF40	7500	–	–	80	4.5	60	–	15	–	–	–	–

(*Continued*)

11.6 Polyolefins and Acrylics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
ALTECH® PP-B A 4430/120 MR30 UV	PP, Chalk20, T10	2400	–	–	20	30	55	–	4	–	–	–	–
ALTECH® PP-B A 4815/100 MR15	PP, MD15	1500	–	–	23	>50	100	–	5.8	–	–	–	–
ALTECH® PP-B A 4920/100 MR20	PP, T20	1800	–	–	20	>50	N	–	N	–	–	–	–
ALTECH® PP-H A 1000/100 DS	PP	1400	–	–	30	>50	N	–	4	–	–	–	–
ALTECH® PP-H A 1000/140 FR	PP	2000	–	–	40	14	60	–	2.2	–	–	–	–
ALTECH® PP-H A 1000/149 FR	PP	1300	–	–	30	>50	80	–	4	–	–	–	–
ALTECH® PP-H A 2020/100 GF20	PP, GF20	4100	–	–	45	2	20	–	4.5	–	–	–	–
ALTECH® PP-H A 2020/150 GF20 CP	PP, GF20	4100	–	–	60	3.5	40	–	9	–	–	–	–
ALTECH® PP-H A 2030/100 GF30	PP, GF30	5200	–	–	55	2	55	–	14	–	–	–	–
ALTECH® PP-H A 2030/150 GF30 CP	PP, GF30	5500	–	–	75	3	50	–	11	–	–	–	–
ALTECH® PP-H A 2030/156 GF30 CP	PP, GF30	6400	–	–	–	–	60	–	13	–	–	–	–
ALTECH® PP-H A 2030/157 GF30 CP	PP, GF30	6700	–	–	90	3	40	–	8	–	–	–	–
ALTECH® PP-H A 2030/158 GF30 CP	PP, GF30	5900	–	–	–	–	55	–	11	–	–	–	–
ALTECH® PP-H A 2030/250 GF30 CP	PP, GF30	6000	–	–	80	4	50	–	14	–	–	–	–
ALTECH® PP-H A 2030/252 GF30 UV CP	PP, GF30	–	–	–	–	–	25	–	10	–	–	–	–
ALTECH® PP-H A 2040/150 GF40 CP	PP, GF40	6000	–	–	70	1	55	–	12	–	–	–	–

ALTECH® PP-H A 3020/100 GB20	PP, GB20	1500	–	–	24	>50	30	–	3	–	–	–	–
ALTECH® PP-H A 3030/100 GB30	PP, GB30	2000	–	–	19	>50	30	–	4	–	–	–	–
ALTECH® PP-H A 4818/100 MR18 DS	PP, Chalk18	1700	–	–	26	>50	80	–	4	–	–	–	–
ALTECH® PP-H A 4920/100 MR20	PP, T20	2800	–	–	32	25	60	–	4.5	–	–	–	–
ALTECH® PP-H A 4920/106 MR20	PP, T20	2800	–	–	32	25	60	–	4	–	–	–	–
ALTECH® PP-H A 4920/170 MR20	PP, T20	2700	–	–	34	10	22	–	2.5	–	–	–	–
ALTECH® PP-H A 4930/100 MR30	PP, T30	3500	–	–	32	20	27	–	3.9	–	–	–	–
ALTECH® PP-H A 4930/106 MR30	PP, T30	3400	–	–	32	20	25	–	4	–	–	–	–
ALTECH® PP-H A 4940/100 MR40	PP, T40	4000	–	–	32	15	20	–	3.5	–	–	–	–
PP/A. Schulman													
POLYFLAM® RIPP 3125 CS1	PP, T25	2400	17	1.7	*	*	33	13	8	2.4	–	–	–
POLYFLAM® RIPP 374 ND CS1	PP, T20	2100	17	1.7	*	*	60	19	6	2.4	–	–	–
POLYFLAM® RIPP 490	PP	1900	22	3	*	*	37	11	3	3	–	–	–
POLYFLAM® RIPP 5000 E	PP	1200	26	7	*	*	N	65	20	5	–	–	–
POLYFLAM® RIPP 5440	PP	1500	29	5	*	*	N	35	13	3	–	–	–
POLYFLAM® RLD 10 D	PP	200	15	12	*	*	N	N	60	4	–	–	–
PP/Celanese													
CELSTRAN PP-GF30-02	PP, GF30	5800	–	–	92	2.5	–	–	20	–	–	–	–
CELSTRAN PP-GF30-03	PP, GF30	6000	–	–	90	2.3	–	–	17	–	–	–	–

(*Continued*)

11.6 Polyolefins and Acrylics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
CELSTRAN PP-GF30-04	PP, GF30	6600	–	–	95	2.3	48	44	18	20	–	–	–
CELSTRAN PP-GF30-05	PP, GF30	5980	–	–	85	2.9	66	80	26	24	–	–	–
CELSTRAN PP-GF30-10	PP, GF30	6070	–	–	85	2.1	–	–	15	–	–	–	–
CELSTRAN PP-GF40-02	PP, GF40	7700	–	–	102	2.1	–	–	23	–	–	–	–
CELSTRAN PP-GF40-03	PP, GF40	7900	–	–	100	2	–	–	20	–	–	–	–
CELSTRAN PP-GF40-04	PP, GF40	9100	–	–	110	2	59	55	16	13	–	–	–
CELSTRAN PP-GF40-0414P10/10	PP, GF40	8900	–	–	109	1.9	53	44	16	19	–	–	–
CELSTRAN PP-GF40-05	PP, GF40	7300	–	–	100	2.3	70	–	25	–	–	–	–
CELSTRAN PP-GF40-10	PP, GF40	7850	–	–	96	1.9	–	–	18	–	–	–	–
CELSTRAN PP-GF50-02	PP, GF50	10200	–	–	110	1.7	–	–	26	–	–	–	–
CELSTRAN PP-GF50-03	PP, GF50	10300	–	–	115	1.8	–	–	2	–		–	–
CELSTRAN PP-GF50-04	PP, GF50	11100	–	–	120	1.9	59	57	19	14	–	–	–
CELSTRAN PP-GF50-0403P10/10	PP, GF50	11800	–	–	127	1.9	55	54	18	25	–	–	–
CELSTRAN PP-GF50-0405P10/10	PP, GF50	12000	–	–	125	1.7	–	–	–	–	–	–	–
CELSTRAN PP-GF50-0453P10/10	PP, GF50	11800	–	–	126	1.9	57	53	18	24	–	. –	–
CELSTRAN PP-GF50-0455P10/10	PP, GF50	12000	–	–	124	1.7	–	–	–	–	–	–	–
CELSTRAN PP-GF50-10	PP, GF50	11000	–	–	107	1.7	–	–	1	–	–	–	–

PP/Bassell Polyolefins													
Hostalen PP H2150	PP Homopolymer	1300	30	9	–	–	N	26	9	2.2	–	–	–
Hostalen PP H2222 36	PP Impact Copolymer	1150	26	11	–	–	N	85	40	3.2	–	–	–
Hostalen PP H2250 36	PP Homopolymer	1350	31	10	–	–	N	26	11	2.9	–	–	–
Hostalen PP H2464	PP Impact Copolymer	1350	29	10	–	400	–	–	–	–	–	–	–
Hostalen PP H5416	PP Random Copolymer	850	24	10	–	–	N	43	22	2.5	–	–	–
Hostalen PP H5416 E61349	PP Random Copolymer	850	24	10	–	–	N	43	22	2.5	–	–	–
Hostalen PP H7050FL G51337	PP Homopolymer	1300	30	10	–	–	N	28	10	2.4	–	–	–
Hostalen PP H7350FLS 303064	PP Homopolymer	1300	30	10	–	–	N	28	10	2.4	–	–	–
Hostalen PP W2080	PP Homopolymer	1350	30	9	–	–	90	–	–	–	–	–	–
Acrylic/Arkema													
ALTUGLAS DRM	PMMA	1800	45	5	*	*	60	–	6	–	3	400	2
ALTUGLAS DRT	PMMA	1700	45	5	*	*	70	–	7	–	3	400	2
ALTUGLAS HFI-10	PMMA	1700	42	5	*	*	60	–	6	–	3	400	2
ALTUGLAS HFI-7	PMMA	2300	65	5	*	*	45	–	4	–	3	400	2
ALTUGLAS HT 121	PMMA	3450	*	*	70	5	20	–	2	–	3	400	2.5
ALTUGLAS MI-2T	PMMA	3000	78	4	*	*	25	–	3	–	3	400	2
ALTUGLAS MI-4T	PMMA	2800	76	4	*	*	35	–	3	–	3	400	2
ALTUGLAS MI-7T	PMMA	2400	65	5	*	*	45	–	4	–	3	400	2
ALTUGLAS SG 10	PMMA	1700	42	5	*	*	60	–	6	–	3	400	2
ALTUGLAS SG 7	PMMA	2300	65	5	*	*	45	–	4	–	3	400	2
ALTUGLAS V 044	PMMA	3300	*	*	70	6	20	–	2	–	3	400	1.9
ALTUGLAS V 045	PMMA	3300	*	*	70	6	20	–	2	–	3	400	1.9
ALTUGLAS V 825 HID	PMMA	3300	*	*	70	6	20	–	2	–	3	400	1.9

(*Continued*)

11.6 Polyolefins and Acrylics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
ALTUGLAS V 825 T	PMMA	3300	*	*	70	6	20	–	2	–	3	400	1.9
ALTUGLAS V 920 T	PMMA	3300	*	*	70	6	20	–	2	–	3	400	1.9
ALTUGLAS VM	PMMA	3100	*	*	65	5	19	–	2	–	3	400	1.8
Acrylic/Evonik													
PLEXALLOY® NTA-1	PMMA, Imod	2700	68	5	*	*	33	–	–	–	–	–	–
PLEXALLOY® NTA-3	PMMA, Imod	2900	60	0	*	*	16	–	–	–	–	–	–
PLEXIGLAS® 6N	PMMA	3200	*	*	67	3	20	–	–	–	2.9	200	1.8
PLEXIGLAS® 7H	PMMA	3200	*	*	76	5.5	20	–	–	–	2.8	200	1.9
PLEXIGLAS® 7M	PMMA	3200	*	*	69	4	20	–	–	–	2.8	200	2
PLEXIGLAS® 7N	PMMA	3200	*	*	73	3.5	20	–	–	–	2.8	200	2
PLEXIGLAS® 8H	PMMA	3300	*	*	78	6.5	20	–	–	–	2.7	200	1.9
PLEXIGLAS® 8N	PMMA	3300	*	*	77	5.5	20	–	–	–	2.7	200	2
PLEXIGLAS® FT15	PMMA	3500	*	*	50	3.1	18	–	–	–	–	–	–
PLEXIGLAS® df21 8N	PMMA	3300	*	*	71	4.5	18	–	–	–	–	–	–
PLEXIGLAS® df22 7H	PMMA	3400	*	*	70	6	20	–	–	–	–	–	–
PLEXIGLAS® df22 7N	PMMA	3400	*	*	65	2.5	17	–	–	–	–	–	–
PLEXIGLAS® df22 8N	PMMA	3300	*	*	67	3.5	18	–	–	–	–	–	–
PLEXIGLAS® df22 zk6BR	PMMA	1800	45	5	*	*	54	–	–	–	–	–	–
PLEXIGLAS® df23 7H	PMMA	3400	*	*	70	6	20	–	–	–	–	–	–
PLEXIGLAS® df23 7N	PMMA	3400	*	*	65	2.5	1	–	–	–	–	–	–
PLEXIGLAS® df23 8N	PMMA	3300	*	*	65	2.5	1	–	–	–	–	–	–

PLEXIGLAS® df23 zk6BR	PMMA	1900	46	5	*	*	50	–	–	–	–	–	–
PLEXIGLAS® hw55	PMMA	3600	*	*	80	3.5	20	20	–	–	2.9	200	2.2
PLEXIGLAS® zk20	PMMA, Imod	2400	62	4.5	*	*	25	–	–	–	2.9	300	1.7
PLEXIGLAS® zk30	PMMA, Imod	2000	51	4.5	*	*	55	–	–	–	2.9	300	1.7
PLEXIGLAS® zk40	PMMA, Imod	1600	42	4.5	*	*	80	–	–	–	2.9	300	1.5
PLEXIGLAS® zk4BR	PMMA, Imod	2800	71	4.5	*		25	–	–	–	2.9	200	2
PLEXIGLAS® zk4HC	PMMA, Imod	2900	68	4.5	*	*	25	–	–	–	2.9	300	2
PLEXIGLAS® zk5BR	PMMA, Imod	2400	62	4.5	*	*	50	–	–	–	2.9	300	2
PLEXIGLAS® zk5HC	PMMA, Imod	2500	63	5	*	*	55	–	–	–	2.9	300	1.9
PLEXIGLAS® zk5HF	PMMA, Imod	2500	55	4.5	*	*	50	–	–	–	2.9	300	1.9
PLEXIGLAS® zk6BR	PMMA, Imod	1800	45	5	*	*	80	–	–	–	2.9	300	1.9
PLEXIGLAS® zk6HC	PMMA, Imod	2000	47	5.5	*	*	80	–	–	–	2.9	300	1.8

11.7 Thermoplastic Elastomers

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
TPE/DuPont													
Hytrel® 3078		–	*	*	*	>50	N	N	N	N	4.8	125	0.8
Hytrel® 4056	TEEE	55	*	*	*	>50	N	N	N	N	4.7	525	0.7
Hytrel® 4068	TEEE	30	*	*	*	>50	N	N	N	N	–	380	0.7
Hytrel® 4069	TEEE	–	–	–	–	–	N	N	N	N	–	130	0.7
Hytrel® 40CB	TEEE, CD	–	–	–	–	–	–	–	–	–	–	100	–
Hytrel® 4556	TEEE	85	–	–	–	–	–	–	N	–	4.5	300	0.6
Hytrel® 5526	TEEE	190	–	–	–	–	N	N	N	90	4.6	375	0.6
Hytrel® 5555HS	TEEE	180	–	–	–	–	N	–	84	–	–	–	0.6

(*Continued*)

11.7 Thermoplastic Elastomers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Hytrel® 5556	TEEE	180	16	32	*	*	N	N	N	85	4.4	375	0.6
Hytrel® 6356	TEEE	280	–	–	–	–	–	–	N	15	4.1	360	0.6
Hytrel® 7246	TEEE	530	–	–	–	–	–	–	33	10	3.7	300	0.6
Hytrel® 8238	TEEE	1180	–	–	–	–	–	–	15	5	3.7	175	0.6
Hytrel® DYM350BK	TEEE + PBT	370	15	20	*	*	N	N	–	–	4.4	230	0.6
Hytrel® G3548L	TEEE	20	–	–	–	–	–	–	–	–	–	–	–
Hytrel® G4074	TEEE	55	*	*	*	>50	N	N	N	N	5	530	3.7
Hytrel® G4774	TEEE	110	*	*	*	>50	N	N	N	N	4.7	–	–
Hytrel® G4778	TEEE	110	*	*	*	>50	N	N	N	N	–	–	–
Hytrel® G5544	TEEE	190	*	*	*	>50	N	–	N	20	4.5	400	2.2
TPE/DSM													
Arnitel® 3103	TPC	570	23.8	20	*	*	–	–	23	7	–	–	–
Arnitel® 3104	TPC	60	–	–	–	–	–	–	N	N	4.4	810	7
Arnitel® EB460	TPC	105	–	–	–	–	N	N	N	N	–	–	0.6
Arnitel® EB463	TPC	115	*	*	*	>50	N	N	N	N	–	–	0.7
Arnitel® EB464	TPC	115	*	*	*	>50	–	–	N	N	–	–	0.7
Arnitel® EB464-01	TPC	75	*	*	*	>50	–	–	N	N	–	–	0.7
Arnitel® EB500	TPC	225	*	*	*	>50	–	–	N	N	–	–	0.6
Arnitel® EL550	TPC	200	14	20	*	*	–	–	N	25	4	400	0.65
Arnitel® EL630	TPC	310	19	16	*	*	–	–	N	12	3.4	340	0.6
Arnitel® EL695-G4	TPC, GF20	3650	*	*	65	9	–	–	22	11	–	–	0.3
Arnitel® EL740	TPC	1000	34	10	*	*	–	–	10	6	3.3	300	0.6
Arnitel® EL740-H/A	TPC	1100	38	20	–	–	–	–	10	4	–	–	0.6
Arnitel® EM400	TPC	50	7	74	*	*	–	–	N	N	4	170	0.75
Arnitel® EM401	TPC	–	–	–	–	–	–	–	–	–	–	–	–
Arnitel® EM402-L	TPC	50	7	74	*	*	–	–	N	N	4	170	0.7
Arnitel® EM460	TPC	100	9	30	*	*	–	–	N	N	4.4	350	0.7

Arnitel® EM550	TPC	200	14	20	*	*	–	–	N	25	4	400	0.65
Arnitel® EM630	TPC	310	20	29	*	*	–	–	N	12	3.4	340	0.6
Arnitel® EM630-H	TPC	310	20	29	*	*	–	–	N	12	4.1	170	0.63
Arnitel® EM740	TPC	1000	35	20	*	*	–	–	15	6	3.4	400	0.6
Arnitel® PB420	TPC	100	*	*	*	>50	–	–	N	N	–	–	–
Arnitel® PB582-H	TPC	300	–	–	–	–	–	–	N	14	–	–	–
Arnitel® PL380	TPC	60	–	–	–	–	–	–	N	N	4.4	810	7
Arnitel® PL381	TPC	60	–	–	–	–	–	–	N	N	4.4	810	7
Arnitel® PL420-H	TPC	100	–	–	–	–	–	–	N	N	–	–	–
Arnitel® PL460-S	TPC	240	–	–	–	–	–	–	60	22	4.8	–	3.5
Arnitel® PL461	TPC	165	–	–	–	–	–	–	N	N	–	–	–
Arnitel® PL471	TPC	240	–	–	–	–	–	–	N	N	–	–	–
Arnitel® PL581	TPC	300	–	–	–	–	–	–	N	16	4	400	2.5
Amitel® PL650	TPC	570	–	–	–	–	–	–	23	7	–	–	–
Arnitel® PM381	TPC	60	–	–	–	–	–	–	N	N	4.4	810	7
Arnitel® PM460	TPC	200	–	–	–	–	–	–	N	N	–	–	–
Arnitel® PM460−B	TPC	200	–	–	–	–	–	–	N	N	–	–	–
Arnitel® PM471	TPC	175	–	–	–	–	–	–	N	N	–	–	–
Arnitel® PM581	TPC	300	–	–	–	–	–	–	N	16	4.4	810	2.5
Arnitel® PM650	TPC	520	26.5	26	–	–	–	–	37	11	–	–	–
Arnitel® UM551	TPC	200	15	22	*	*	–	6	N	6	–	–	0.6
Arnitel® UM551-V	TPC	250	15	22	*	*	–	–	N	–	–	–	0.6
PEBA/Arkema													
PEBAX 2533 SN 01 (dry)	TPA	13	*	*	*	>50	–	–	–	–	6	378	1.2
PEBAX 2533 SN 01 (cond.)	TPA	10	*	*	*	>50	N	N	N	N	–	–	*
PEBAX 3533 SN 01 (dry)	TPA	19	*	*	*	>50	–	–	–	–	6	434	1.2
PEBAX 3533 SN 01 (cond.)	TPA	18	*	*	*	>50	N	N	N	N	–	–	*

(*Continued*)

11.7 Thermoplastic Elastomers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PEBAX 4033 SN 01 (dry)	TPA	73	*	*	*	>50	–	–	–	–	5	604	1.2
PEBAX 4033 SN 01 (cond.)	TPA	71	*	*	*	>50	N	N	N	N	–	–	*
PEBAX 5533 SN 01 (dry)	TPA	165	12	25	*	*	N	N	N	N	5	1020	1.2
PEBAX 5533 SN 01 (cond.)	TPA	161	12	25	*	*	N	N	N	N	–	–	*
PEBAX 5533 SN 70 NOIR(dry)	TPA, CD	305	18	31	*	*	N	N	N	18	–	–	1.2
PEBAX 5533 SN 70 NOIR(cond.)	TPA, CD	298	17	36	*	*	–	–	–	–	–	–	*
PEBAX 6333 SN 01 (dry)	TPA	307	19	22	*	*	N	N	N	–	4	757	1.1
PEBAX 6333 SN 01 (cond.)	TPA	280	18	22	*	*	N	N	N	20	–	–	*
PEBAX 7033 SN 01 (dry)	TPA	414	23	22	*	*	N	N	N	–	–	–	0.9
PEBAX 7033 SN 01 (cond.)	TPA	384	22	20	*	*	N	N	N	10	–	–	*
PEBAX 7233 SN 01 (dry)	TPA	–	–	–	–	–	–	–	–	–	4	586	0.9
PEBAX 7233 SN 01 (cond.)	TPA	522	26	18	*	*	N	N	15	10	–	–	*
PEBAX MH 1657 (dry)	TPA	90	*	*	*	>50	N	N	N	–	–	–	120
PEBAX MH 1657 (cond.)	TPA	80	*	*	*	>50	N	N		–	–	–	*
PEBAX MV 1041 SN 01(dry)	TPA	253	17	26	*	*	N	N	N	11	5	957	12
PEBAX MV 1041 SN 01(cond.)	TPA	227	15	28	*	*	N	N	–	–	–	–	*

PEBAX MV 1074 SN 01(dry)	TPA	97	*	*	*	>50	N	N	N	N	–	–	48
PEBAX MV 1074 SN 01(cond.)	TPA	89	*	*	*	>50	N	N	N	–	–	–	*
PEBA/Evonik													
VESTAMID E40-S3 nf (dry)	TPA	80	*	*	*	>50	N	N	N	N	4.9	1200	1
VESTAMID E40-S3 nf (cond.)	TPA	–	–	–	–	–	N	N	N	N	5.5	1200	*
VESTAMID E47-S3 nf	TPA	120	*	*	*	>50	N	N	N	N	4.7	1300	1
VESTAMID E55-S3 nf	TPA	230	*	*	*	>50	N	N	N	N	4.3	1100	1.1
VESTAMID E62-S3 nf (dry)	TPA	370	24	31	*	*	N	N	N	N	4	1200	1.1
VESTAMID E62-S3 nf (cond.)	TPA	360	22	29	*	*	N	N	N	N	4.3	1300	*

11.8 Fluoropolymers

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PVDF/Arkema													
KYNAR 1000 HD	PVDF	2000	50	9	*	*	250	200	22	5	7	2400	0.03
KYNAR 1000 HDC N 118	PVDF	2000	52	9	*	*	–	–	–	–	6.5	2460	–
KYNAR 6000 HD	PVDF	2300	52	9	*	*	230	220	12	5	7	2200	0.02
KYNAR 710	PVDF	2300	54	9	*	*	190	210	8	5	6	2060	0.03
KYNAR 720	PVDF	2200	54	8	*	*	210	190	8	5	7	2140	0.03
KYNAR 740	PVDF	1700	50	7	*	*	240	190	14	5	8	2310	0.03

(*Continued*)

11.8 Fluoropolymers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
KYNAR 9000 HD	PVDF	2500	54	8	*	*	230	220	11	5	7.5	2160	0.03
KYNAR 9000 HDC N 123	PVDF, CF	7000	*	*	70	2	–	–	–	–	*	*	0.15
KYNAR FLEX 2750	PVDF	480	20	16	*	*	–	–	120	6	7	–	–
KYNAR FLEX 2800	PVDF	700	26	12	*	*	–	–	86	5	7	2330	0.03
KYNAR FLEX 2801	PVDF	700	26	12	*	*	–	–	–	–	7	2330	0.03
KYNAR FLEX 2820	PVDF	680	24	12	*	*	180	240	60	5	6	2340	0.03
KYNAR FLEX 2821	PVDF	680	24	12	*	*	–	–	–	–	6	2340	0.03
KYNAR FLEX 2822	PVDF	680	24	12	*	*	–	–	–	–	6	2340	0.03
KYNAR FLEX 2850	PVDF	1000	35	10	*	*	–	190	29	5	6.5	2340	0.03
PVDF/Solvay Solexis													
SOLEF 1008	PVDF	2480	59.1	6.9	–	–	89	98	7.6	2.3	–	–	0.04
SOLEF 1010	PVDF	2440	58.1	7.3	–	–	120	110	8.3	3.4	–	–	0.04
SOLEF 1012	PVDF	2300	56	8.2	–	–	N	150	19	3.6	–	–	0.04
SOLEF 11008	PVDF	1020	33.3	9.4	–	–	N	110	12	3.4	–	–	0.04
SOLEF 11010	PVDF	1100	34.8	11	–	–	N	150	48P	3.4	–	–	0.04
SOLEF 21508	PVDF	420	19.9	14	–	–	N	N	84P	3	–	–	0.04
SOLEF 31008	PVDF	895	27.9	9.4	–	–	N	150	65P	3.7	–	–	0.04
SOLEF 31508	PVDF	576	18.3	11	–	–	N	250	110P	4.1	–	–	0.04
SOLEF 6010	PVDF	2400	56.8	7.2	–	–	120	97	8.9	3.1	–	–	0.04
SOLEF 6012	PVDF	2130	52.9	8.4	–	–	N	220	48P	3.9	–	–	0.04
PVDF/Dyneon 3M													
Dyneon™ PVDF 6010	PVDF	–	–	–	35–50	20–50	–	–	–	–	7	–	–
Dyneon™ PVDF 11008	PVDF	–	–	–	20–40	200–600	–	–	–	–	7	0.2	–
Dyneon™ PVDF 21508	PVDF	–	–	–	14–30	350–600	–	–	–	–	7	0.2	–
Dyneon™ PVDF 60512	PVDF	–	–	–	35–40	100–350	–	–	–	–	7	–	–

PCTFE/Arkema													
VOLTALEF 302	PCTFE	1400	43	7	–	–	–	–	80	–	–	–	0.01
PTFE/DuPont													
Teflon® 7A	PTFE	–	–	–	34.5	380	–	–	–	–	–	–	–
Teflon® 7B	PTFE	–	–	–	36.5	400	–	–	–	–	–	–	–
Teflon® 7C	PTFE	–	–	–	37.9	400	–	–	–	–	–	–	–
Teflon® 8	PTFE	–	–	–	27.6	300	–	–	–	–	–	–	–
Teflon® 850-A	PTFE	–	–	–	27.6	300	–	–	–	–	–	–	–
Teflon® 8A	PTFE	–	–	–	27.6	300	–	–	–	–	–	–	–
Teflon® 8B	PTFE	–	–	–	27.6	300	–	–	–	–	–	–	–
PTFE/Solvay Solexis													
Algoflon® F5	PTFE	–	–	–	39	370	–	–	–	–	–	–	–
Algoflon® F5/S	PTFE	–	–	–	40	400	–	–	–	–	–	–	–
Algoflon® F6	PTFE	–	–	–	40	380	–	–	–	–	–	–	–
Algoflon® F7	PTFE	–	–	–	41	400	–	–	–	–	–	–	–
Algoflon® F3140 X	PTFE	–	–	–	35	500	–	–	–	–	–	–	–
Algoflon® S 111	PTFE	–	–	–	37	350	–	–	–	–	–	–	–
Algoflon® S 121	PTFE	–	–	–	37	350	–	–	–	–	–	–	–
Algoflon® S 131	PTFE	–	–	–	35	340	–	–	–	–	–	–	–
Algoflon® DF 210	PTFE	–	–	–	30	300	–	–	–	–	–	–	–
Algoflon® DF 230	PTFE	–	–	–	30	300	–	–	–	–	–	–	–
Algoflon® DF 280X	PTFE	–	–	–	30	300	–	–	–	–	–	–	–
Algoflon® DF 380	PTFE	–	–	–	30	375	–	–	–	–	–	–	–
Algoflon® DF 381	PTFE	–	–	–	30	375	–	–	–	–	–	–	–
Algoflon® DF 680X	PTFE	–	–	–	28	270	–	–	–	–	–	–	–
Algoflon® 15GL	PTFE, GF15	–	–	–	24	280	–	–	–	–	–	–	–
Algoflon® 25GL	PTFE, GF25	–	–	–	20	220	–	–	–	–	–	–	–
Algoflon® 25CAR	PTFE, (Graphite & Coke)25	–	–	–	19	80	–	–	–	–	–	–	–

(*Continued*)

11.8 Fluoropolymers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Algoflon® 25 CAR B	PTFE, (Graphite & Carbon)25	–	–	–	21	220	–	–	–	–	–	–	–
Algoflon® 15GR	PTFE, Graphite15	–	–	–	24	230	–	–	–	–	–	–	–
Algoflon® 60BZ	PTFE, Bronze60	–	–	–	20	230	–	–	–	–	–	–	–
Algoflon® 50 INOX	PTFE, Stainless Steel50	–	–	–	20	220	–	–	–	–	–	–	–
Algoflon® 25CAR + 5CER	PTFE, Coke25, Ceramic5	–	–	–	17	45	–	–	–	–	–	–	–
Algoflon® 55BZ + 5Mos	PTFE, Bronze55, Moly5	–	–	–	17	90	–	–	–	–	–	–	–
PTFE/Dyneon 3M													
Dyneon™ TFM 1700	PTFE Modified	650	–	–	33	450	–	–	–	–	–	–	–
Dyneon™ TFM 1705	PTFE Modified	650	–	–	33	450	–	–	–	–	–	–	–
Dyneon™ TFM 1600	PTFE Modified	650	–	–	31.7	450	–	–	–	–	–	–	–
Dyneon™ TF 1750	PTFE	600	–	–	≥27.6	450	–	–	–	–	–	–	–
Dyneon™ TF 1620	PTFE	600	–	–	≥27.6	450	–	–	–	–	–	–	–
Dyneon™ TF 1641	PTFE	600	–	–	≥27.6	450	–	–	–	–	–	–	–
Dyneon™ TF 1645	PTFE	600	–	–	≥27.6	450	–	–	–	–	–	–	–
Dyneon™ TF 1105	PTFE	650	–	–	27.6	400	–	–	–	–	–	–	–
Dyneon™ TF 4103	PTFE, GF15	97	–	–	20.7	375	–	–	–	–	–	–	–
Dyneon™ CC603	PTFE, GF15	93	–	–	20.7	280	–	–	–	–	–	–	–
Dyneon™ CC605	PTFE, GF25	159	–	–	17.2	230	–	–	–	–	–	–	–

Dyneon™ CCM605	PTFE, (GF + PTFE) 25	165	–	–	15.2	300	–	–	–	–	–	–	–
Dyneon™ CCX1029	PTFE, CF10	121	–	–	27.6	280	–	–	–	–	–	–	–
Dyneon™ CC503	PTFE, MD15	121	–	–	19.3	250	–	–	–	–	–	–	–
Dyneon™ CC622	PTFE, Graphite10	131	–	–	19.3	220	–	–	–	–	–	–	–
Dyneon™ CC6467/S	PTFE, Bronze60	245	–	–	16.5	110	–	–	–	–	–	–	–
Dyneon™ CC655	PTFE, Stainless Steel50	176	–	–	20.7	220	–	–	–	–	–	–	–
Dyneon™ CC174/N	PTFE, GF15, Moly5	152	–	–	23.4	240	–	–	–	–	–	–	–
Dyneon™ CC191−HE	PTFE, Carbon23, Graphite2	217	–	–	13.8	160	–	–	–	–	–	–	–
Dyneon™ CCX6380	PTFE, Polyimide10	97	–	–	18.6	270	–	–	–	–	–	–	–
Dyneon™ CC085	PTFE, PPS	69	–	–	11	150	–	–	–	–	–	–	–
PFA/DuPont													
Teflon® C PFA 510	PFA	–	–	–	13.8	100	–	–	–	–	–	–	–
Teflon® C PFA 560	PFA	–	–	–	16.5	250	–	–	–	–	–	–	–
Teflon® C PFA 580	PFA	–	–	–	18.6	250	–	–	–	–	–	–	–
Teflon® PFA 340	PFA	–	–	–	24.8	300	–	–	–	–	2.03	0.0001	0.03
Teflon® PFA 345	PFA	–	–	–	29	300	–	–	–	–	2.1	0.0006	0.01
Teflon® PFA 350	PFA	–	15.2	–	28	300	–	–	–	–	2.03	0.0001	–
Teflon® PFA 440 HP	PFA Fluorinated	–	13.8	–	24.8	300	–	–	–	–	2.03	0.0001	0.03
Teflon® PFA 445 HP	PFA Fluorinated	–	13.8	–	26.2	320	–	–	–	–	2.1	0.0001	0.03
Teflon® PFA 450 HP	PFA Fluorinated	–	15.2	–	27.6	300	–	–	–	–	2.03	0.0001	0.03

(*Continued*)

11.8 Fluoropolymers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
Teflon® PFA 940 HP Plus	PFA Fluorinated	–	13.8	–	28.3	310	–	–	–	–	2.05	0.0003	0.05
Teflon® PFA 950 HP Plus	PFA Fluorinated	–	13.8	–	28.3	260	–	–	–	–	2.05	0.0003	0.05
PFA/Diakin													
Neoflon™ AP-201	PFA	–	–	–	21.6	300	–	–	–	–	–	–	–
Neoflon™ AP-210	PFA	–	–	–	27.9	400	–	–	–	–	–	–	–
Neoflon™ AP-211SH	PFA	–	–	–	33.3	420	–	–	–	–	–	–	–
Neoflon™ AP-215SH	PFA	–	–	–	27.9	400	–	–	–	–	–	–	–
Neoflon™ AP-230	PFA	–	–	–	32	350	–	–	–	–	–	–	–
Neoflon™ AP-231SH	PFA	–	–	–	32.4	370	–	–	–	–	–	–	–
PFA/Solvay Solexis													
Hyflon® MFA 1041	PFA	550	–	–	20	280	N	–	–	–	2	0.002	–
Hyflon® MFA 620	PFA	550	–	–	26	300	N	–	–	–	2	0.0005	–
Hyflon® MFA 640	PFA	550	–	–	21	280	N	–	–	–	2	0.0005	–
Hyflon® MFA 720	PFA	550	–	–	23	300	–	–	–	–	–	–	–
PFA/Dyneon 3M													
Dyneon™ PFA 6502N	PFA	–	–	–	30	380	–	–	–	–	≤2.10	≤0.0005	–
Dyneon™ PFA 6505N	PFA	–	–	–	30	410	–	–	–	–	≤2.10	≤0.0005	–
Dyneon™ PFA 6515N	PFA	–	–	–	26	450	–	–	–	–	≤2.10	≤0.0005	–
Dyneon™ PFA 6525N	PFA	–	–	–	21	350	–	–	–	–	≤2.10	≤0.0005	–
Dyneon™ PFA–FLEX 8502 UHP	PFA	–	–	–	35	330	–	–	–	–	2.02–2.08	≤0.003	–
Dyneon™ PFA–FLEX 8515 UHP	PFA	–	–	–	34	350	–	–	–	–	2.02–2.08	≤0.003	–

FEP/DuPont													
Teflon® FEP 100	FEP	–	–	–	27.6	340	–	–	–	–	–	–	–
Teflon® FEP 140	FEP	–	–	–	31	350	–	–	–	–	2.05	0.0006	–
Teflon® FEP 160	FEP	–	–	–	34.5	320	–	–	–	–	2.05	0.0006	–
Teflon® FEP 3100	FEP	–	–	–	23.4	350	–	–	–	–	2.1	0.001	0.01
Teflon® FEP 5100	FEP	–	–	–	21.4	310	–	–	–	–	2.1	0.0005	–
Teflon® FEP 6100	FEP	–	–	–	20.7	300	–	–	–	–	2.03	0.00057	–
Teflon® FEP CJ92	FEP	–	–	–	27.6	320	–	–	–	–	2.1	0.001	0.01
Teflon® FEP CJ95	FEP	–	–	–	26	300	–	–	–	–	2.02	0.0007	–
FEP/Diakin													
Neoflon™ NP-101	FEP	–	–	–	27	350	–	–	–	–	–	–	–
Neoflon™ NP-120	FEP	–	–	–	31	370	–	–	–	–	–	–	–
Neoflon™ NP-12X	FEP	–	–	–	27	350	–	–	–	–	–	–	–
Neoflon™ NP-130	FEP	–	–	–	32.1	370	–	–	–	–	–	–	–
Neoflon™ NP-20	FEP	–	–	–	27	350	–	–	–	–	–	–	–
Neoflon™ NP-30	FEP	–	–	–	27	350	–	–	–	–	–	–	–
Neoflon™ NP-40	FEP	–	–	–	27	350	–	–	–	–	–	–	–
PFA/Dyneon 3M													
Dyneon™ FEP 6301	FEP	–	–	–	30	350	–	–	–	–	–		–
Dyneon™ FEP 6303	FEP	–	–	–	28	350	–	–	–	–	≤ 2.15	≤ 0.0007	–
Dyneon™ FEP 6307	FEP	–	–	–	25	350	–	–	–	–	≤ 2.15	≤ 0.0007	–
Dyneon™ FEP 6322	FEP	–	–	–	20	300	–	–	–	–	≤ 2.15	≤ 0.0009	–
ETFE/Diakin													
Neoflon™ EP-521	ETFE	–	–	–	44.5	440	–	–	–	–	–	–	–
Neoflon™ EP-541	ETFE	–	–	–	44.5	440	–	–	–	–	–	–	–
Neoflon™ EP-543	ETFE	–	–	–	45	420	–	–	–	–	–	–	–
Neoflon™ EP-610	ETFE	–	–	–	30.5	250	–	–	–	–	–	–	–
Neoflon™ EP-620	ETFE	–	–	–	30.5	350	–	–	–	–	–	–	–

(*Continued*)

11.8 Fluoropolymers—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
ETFE/Dyneon 3M													
Dyneon™ ETFE ET 6235	ETFE	–		–	46	425	–	–	–	–	2.58	–	–
Dyneon™ ETFE ET 5236	ETFE	–	22	–	46	430	–	–	–	–	–	–	–
ETFE/DuPont													
Tefzel® 200	ETFE	–	–	–	44.8	300	–	–	–	–	2.55	0.0031	0.007
Tefzel® 207	ETFE	–	–	–	40	300	–	–	–	–	2.7	0.009	0.007
Tefzel® 210	ETFE	–	–	–	40	300	–	–	–	–	2.55	0.0054	0.007
Tefzel® 280	ETFE	–	–	–	46.2	300	–	–	–	–	2.55	0.0072	0.007
Tefzel® 750	ETFE	–	–	–	37.9	300	–	–	–	–	–	–	–
Tefzel® HT-2004	ETFE, GF25	–	–	–	82.7	9	–	–	–	–	–	–	–
Tefzel® HT-2127	ETFE	–	–	–	37.9	300	–	–	–	–	–	–	–
Tefzel® HT-2129	ETFE	–	–	–	34.5	300	–	–	–	–	–	–	–
Tefzel® HT-2160	ETFE, Conductive	–	–	–	34.5	200	–	–	–	–	–	–	–
Tefzel® HT-2170	ETFE, Conductive	–	–	–	27.6	200	–	–	–	–	–	–	–
Tefzel® HT-2181	ETFE	–	–	–	42.1	300	–	–	–	–	2.55	0.06	0.007
Tefzel® HT-2183	ETFE	–	–	–	42.1	300	–	–	–	–	2.55	0.0072	0.007
Tefzel® HT-2185	ETFE	–	–	–	41.4	300	–	–	–	–	2.55	0.0054	0.007
Tefzel® HT-2202	ETFE	–	–	–	34.5	250	–	–	–	–	–	–	0.007
PCTFE/Diakin													
Neoflon™ M-300P	PCTFE	–	–	–	34.5	130	–	–	–	–	–	–	–
Neoflon™ M-400H	PCTFE	–	–	–	36.5	180	–	–	–	–	–	–	–

ECTFE/Solvay Solexis													
Halar 300	ECTFE	1650	30	5.0	53.8	250	–	–	–	–	2.6	0.014	0.1
Halar 500	ECTFE	1650	29	5.0	45.5	260	–	–	–	–	2.59	0.013	0.1
Halar 520	ECTFE	1650	31	5.0	48.3	200	–	–	–	–	2.5	0.013	0.005
Halar 558	ECTFE	1650	31	5.0	48.3	200	–	–	–	–	2.5	0.013	0.005
Halar 600	ECTFE	–	33.1	4.5	49.3	290	–	–	–	–	2.595	0.018	–
Halar 6014	ECTFE	–	32.4	5.0	45.5	330	–	–	–	–	2.57	0.017	0.1
Halar 700	ECTFE	–	33.1	4.5	47.9	340	–	–	–	–	2.595	0.018	–
Halar 801	ECTFE, Copolymer	1480	32	–	51.5	230	–	–	–	–	–	–	–
Halar 812	ECTFE, Copolymer	–	–	–	41.4	200	–	–	–	–	–	–	–
Halar 901	ECTFE, Copolymer	–	29.6	5.0	53.8	250	–	–	–	–	2.59	0.014	0.1
Halar 930 LC	ECTFE, Copolymer	–	29	5.0	50	260	–	–	–	–	2.57	0.013	0.1
HTE/Dyneon 3M													
Dyneon™ HTE 1510	HTE	–	–	–	32	520	–	–	–	–	2.3	0.006	–
Dyneon™ HTE 1705	HTE	–	–	–	44	450	–	–	–	–	2.2	0.004	–
THV/Dyneon 3M													
Dyneon™ THV™ 220 FP	THV	–	–	–	20	600	–	–	–	–	5.72	0.14	–
Dyneon™ THV™ 500 FP	THV	–	–	–	28	500	–	–	–	–	4.82	0.1	–
Dyneon™ THV™ 610 FP	THV	–	–	–	28	500	–	–	–	–	4.66	0.09	–
Dyneon™ THV™ 815 FP	THV	–	–	–	29	420	–	–	–	–	–	–	–

11.9 High Temperature Plastics

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PEEK/Evonik													
VESTAKEEP 4000 CF30 nf	PEEK, CF30	20000	*	*	210	2	55	55	9	8	17	23	0.39
VESTAKEEP 4000 FC30 nf	PEEK, PTFE10, Graphite10, CF10	11500	*	*	140	2.5	45	45	8	7	4.9	1.9	0.37
VESTAKEEP 4000 G nf	PEEK	3500	95	5.3	*	*	N	N	6.5	6.5	2.8	0.5	0.48
VESTAKEEP 4000 GF30 nf	PEEK, GF30	11000	*	*	165	2.5	70	75	10	9	3.2	0.42	0.38
PEEK/Victrex													
Victrex® TU-60	PEEK + PBI	5000	*	*	90	2	25	–	3	–	–	–	6.5
Victrex® TF-60V	PEEK + PBI	11500	*	*	150	1.9	25	–	5	–	–	–	4.6
Victrex® TL-60	PEEK + PBI	16000	*	*	110	1.1	15	–	3.5	–	–	–	3.8
Victrex® 150G	PEEK	3500	105	5	–	22	N	–	–	–	–	0.003	0.5
Victrex® 381G	PEEK	3500	100	5	–	31	N	–	8.2	–	–	0.003	0.5
Victrex® 450G	PEEK	3500	100	5	–	34	N	–	8.2	–	–	0.003	0.5
Victrex® 150GL30	PEEK, GF30	11400	*	*	156	1.9	–	–	–	–	–	0.004	0.11
Victrex® 450GL30	PEEK, GF30	11400	*	*	155	2	–	–	8.9	–	–	0.004	0.11
Victrex® 150CA30	PEEK, CF30	22300	*	*	224	1.7	–	–	–	–	–	–	0.06
Victrex® 450CA30	PEEK, CF30	22300	*	*	220	1.8	–	–	5.4	–	–	–	0.06
Victrex® 150FC30	PEEK, (CF + PTFE + Graphite)30	11200	*	*	137	1.8	–	–	–	–	–	–	0.06
Victrex® 450FC30	PEEK, (CF + PTFE + Graphite)30	10100	*	*	134	2.2	–	–	–	–	–	–	0.06
Victrex® HT G22	PEEK	–	*	*	110	20	–	–	–	–	–	0.0035	–

Victrex® HT G22GL30	PEEK, GF30	–	*	*	164	2.9	–	–	–	–	–	–	–
Victrex® HT G22CA30	PEEK, CF30	–	*	*	218	2	–	–	–	–	–	–	–
PES/BASF													
Ultrason® E 1010 NAT(dry)	PES	–	–	–	–	–	–	–	–	*	*	*	2.1
Ultrason® E 1010 NAT(cond.)	PES	2700	90	6.7	*	*	N	N	6.5	7	3.8	140	*
Ultrason® E 2010 G4 UN(dry)	PES, GF20	–	–	–	–	–	–	–	–	*	*	*	1.7
Ultrason® E 2010 G4 UN(cond.)	PES, GF20	7500	–	*	130	2.4	47	45	6.5	8	4.2	100	*
Ultrason® E 2010 G6 UN(dry)	PES, GF30	–	–	–	–	–	–	–	–	*	*	*	1.5
Ultrason® E 2010 G6 UN(cond.)	PES, GF30	10200	*	*	140	1.9	45	45	8	8	4.3	100	*
Ultrason® E 2010 NAT(dry)	PES	–	–	–	–	–		–	–	*	*	*	2.1
Ultrason® E 2010 NAT(cond.)	PES	2700	90	6.7	*	*	N	N	7	7	3.8	140	*
Ultrason® E 3010 NAT(dry)	PES	–	–	–	–	–	–	–	–	*	–	*	2.1
Ultrason® E 3010 NAT(cond.)	PES	2700	90	6.7	*	*	N	N	7.5	7.5	3.8	140	*
PES/Solvay													
RADEL A-100	PES	2600	–	–	–	–	N	N	6.8	7.5	3.54	0.0056	–
RADEL A-200	PES	2600	–	–	–	–	N	N	6.8	7.5	3.54	0.0056	–
RADEL A-300	PES	2660	–	–	–	–	N	N	6.8	7.5	3.54	0.0056	–
RADEL AG-320	PES, GF20	5690	–	–	105	3.2	–	–	–	–	3.88	0.0081	–
RADEL AG-330	PES, GF30	8630	–	–	130	1.9	–	–	–	–	4.17	0.0094	–
RADEL AG-360	PES, GF30	–	–	–	120	3	–	–	–	–	4.2	0.003	–

(*Continued*)

11.9 High Temperature Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
PPS/Solvay													
PRIMEF 4002	PPS, GF40	13000	–	–	160	1.6	–	–	–	–	3.9	20	–
PRIMEF 4010	PPS, GF40	14000	–	–	180	1.7	–	–	–	–	3.9	20	–
PRIMEF 5084	PPS, GF30	12000	–	–	140	1.8	–	–	–	–	–	–	–
PRIMEF 7002	PPS, (GF + MD)65	20000	–	–	160	1.2	–	–	–	–	4.9	90	–
PRIMEF 7010	PPS, (GF + MD)65	21000	–	–	160	1.2	–	–	–	–	4.9	90	–
PPS/Albis													
Tedur® L 9107-1	PPS, GF40	14500	–	–	180	1.8	55	55	9	9	–	–	–
Tedur® L 9113-2	PPS, GF60	22000	–	–	170	1.4	28	28	7.5	7.5	–	–	–
Tedur® L 9200-1	PPS, (GF + MD)60	17000	–	–	180	1.7	35	35	8	8	–	–	–
Tedur® L 9214-1	PPS, (GF + MD)65	22000	–	–	145	0.9	25	25	6	6	–	–	–
Tedur® L 9217-1	PPS, GF65	19000	–	–	130	0.8	25	–	7	–	–	–	–
Tedur® L 9300-1	PPS, (GF + GB)40	13500	–	–	170	1.8	40	40	7.5	7.5	–	–	–
Tedur® L 9310-4	PPS, (GF + MD)60	11000	–	–	50	0.5	8.5	8.5	1.5	1.5	–	–	–
Tedur® L 9400-1	PPS, CF15	13500	–	–	135	1	20	20	5.5	5.5	–	–	–
Tedur® L 9401-1	PPS, PTFE5, GF40	14500	–	–	165	1.5	38	–	7.5	–	–	–	–
Tedur® L 9404-1	PPS, CF30	26000	–	–	170	0.6	22	22	5	5	–	–	–
Tedur® L 9510-1	PPS, GF40	14000	–	–	180	1.7	45	45	8.5	8.5	–	–	–
Tedur® L 9511	PPS, GF45	16500	–	–	180	1.4	38	38	7.5	7.5	–	–	–
Tedur® L 9512	PPS, GF42	15500	–	–	180	1.4	40	40	8	8	–	–	–
Tedur® L 9521-1	PPS, (GF + MD)60	19000	–	–	120	1	14	14	4.5	4.5	–	–	–

Tedur® L 9523	PPS, (GF + MD)60	20000	–	–	115	0.9	18	18	4	4	–	–	–
Tedur® L 9530	PPS, MD55	10000	–	–	55	0.7	7	7	1.2	1.2	–	–	–
Tedur® L 9560	PPS, MD50	8500	–	–	65	0.8	11	11	2.5	2.5	–	–	–
Tedur® P 9007	PPS, (GF + MD)65	19000	–	–	140	1	23	23	7.5	7.5	–	–	–
PPS/Celanese													
FORTRON 0203	PPS	4200	–	–	33	1	–	–	–	–	4	84	0.02
FORTRON 0203HS	PPS	4200	–	–	33	1	–	–	–	–	4	–	0.02
FORTRON 0205	PPS	4000	–	–	66	2	–	–	–	–	–	–	0.02
FORTRON 0214	PPS	3800	–	–	90	3	–	–	–	–	–	–	0.02
FORTRON 0320	PPS	–	–	–	90	8	–	–	–	–	4.6	11	0.02
FORTRON 1115L0	PPS, GF15	7700	–	–	120	2	32	–	5	–	–	–	0.02
FORTRON 1130L4	PPS, GF30	12000	–	–	170	1.9	34	34	9	9	–	–	0.02
FORTRON 1131L4 ITT	PPS, GF30	12200	–	–	165	1.9	42	42	8	8	–	–	0.02
FORTRON 1140E7	PPS, GF40	15700	–	–	150	1.2	28	28	7	7	4.7	200	0.02
FORTRON 1140EC	PPS, GF40	–	–	–	170	1.4	–	–	–	–	4.1	20	0.02
FORTRON 1140L0	PPS, GF40	–	–	–	185	1.9	–	–	10	10	–	–	0.02
FORTRON 1140L4	PPS, GF40	14700	–	–	195	1.9	53	53	10	10	4.6	62	0.02
FORTRON 1140L6	PPS, GF40	14700	–	–	195	1.9	53	53	10	10	4.1	20	0.02
FORTRON 1140L7	PPS, GF40	14500	–	–	170	1.6	–	–	–	–	–	–	0.02
FORTRON 1141L4	PPS, GF40	15500	–	–	195	1.9	53	53	12	12	–	–	0.02
FORTRON 1342L4	PPS, PTFE, GF40	14400	–	–	165	1.6	44	–	8.5	8.5	–	–	0.02
FORTRON 4184L4	PPS, (GF + MD)53	16600	–	–	165	1.4	29	29	7	7	4.7	20	0.02
FORTRON 4184L6	PPS, (GF + MD)53	16600	–	–	165	1.4	29	29	7	7	4.7	20	0.02
FORTRON 4332D4	PPS, (GF + MD)65	21500	–	–	145	1	–	–	–	–	–	–	0.02
FORTRON 4665B6	PPS, (GF + MD)65	17300	–	–	110	1.2	18	18	6	6	5.3	20	0.02

(*Continued*)

11.9 High Temperature Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
FORTRON 6160B4	PPS, (GF + MD)60	17300	–	–	145	1	27	27	7	7	4.9	10	0.02
FORTRON 6165A4	PPS, (GF + MD)65	19000	–	–	130	1.2	20	20	7	7	5.6	20	0.02
FORTRON 6165A6	PPS, (GF + MD)65	19000	–	–	130	1.2	20	20	7	7	5.6	20	0.02
FORTRON 6165D8	PPS, PTFE, (GF + MD)65	–	–	–	115	1	–	–	–	–	–	–	0.02
FORTRON 6345L4	PPS, PTFE, GF30	–	–	–	150	1.9	–	–	–	–	–	–	–
FORTRON 6450A6	PPS, (GF + MD)51	–	–	–	90	1.5	18	–	6	–	–	–	0.02
FORTRON 6850L6	PPS, (GF + MD)50	18500	–	–	125	1	16	16	4	4	–	10	0.02
FORTRON MT 9120L4	PPS, GF20	–	–	–	120	1.5	–	–	–	–	–	–	0.02
FORTRON MT 9140L4	PPS, GF40	–	–	–	190	1.8	48	–	9	–	–	–	0.02
FORTRON MT 9140L6	PPS, GF40	–	–	–	190	1.8	48	–	9	–	–	–	0.02
FORTRON MT 9203HS	PPS	4200	–	–	30	1	–	–	–	–	4	–	0.02
FORTRON MT 9205C4	PPS	4000	–	–	65	2	–	–	–	–	3.2	–	0.02
PPSU/Solvay													
RADEL R-4300	PPSU	2340	70	7.2	–	–	N	N	12	1	–	–	–
RADEL R-5000	PPSU	2300	–	–	–	–	N	N	58	25	–	–	–
RADEL R-5100	PPSU	2300	–	–	–	–	N	N	58	25	–	–	–
RADEL R-5500	PPSU	2300	–	–	–	–	N	–	–	–	–	–	–
RADEL R-5700	PPSU	2300	–	–	–	–	N	–	–	–	–	–	–
RADEL R-7000 A	PPSU	2790	–	–	76	20	N	–	–	–	–	–	–

RADEL R-7200	PPSU	2350	–	–	–	–	N	–	–	–	–	–	–
RADEL R-7300	PPSU	2800	–	–	–	–	–	–	–	–	–	–	–
PSU/BASF													
Ultrason® S 2010 G4 UN (dry)	PSU, GF20	–	–	–	–	–	–		*	*	*	*	0.6
Ultrason® S 2010 G4 UN (cond.)	PSU, GF20	7000	*	*	2.2	37	–	6	–	–	3.5	60	*
Ultrason® S 2010 G6 UN (dry)	PSU, GF30	–	–		–	–	–		–	–	*	*	0.5
Ultrason® S 2010 G6 UN (cond.)	PSU, GF30	9600	*	*	1.8	33	–	7	–	–	3.7	60	*
Ultrason® S 2010 NAT (dry)	PSU	–	–		–	–	–	–	*	*	*	*	0.8
Ultrason® S 2010 NAT (cond.)	PSU	2600	80	5.7	*	N	N	5.5	–	–	3.1	64	*
Ultrason® S 3010 NAT (dry)	PSU	–	–		–	–	–	–	*	*	*	*	0.8
Ultrason® S 3010 NAT (cond.)	PSU	2600	80	5.7	*	N	N	5.5	–	–	3.1	64	*
PSU/Solvay													
UDEL GF-110	PSU, GF10	3660	–	–	78	4	–	–	–	–	3.4	0.005	–
UDEL GF-120	PSU, GF20	5170	–	–	97	3	–	–	–	–	3.5	0.005	–
UDEL GF-130	PSU, GF30	7380	–	–	108	2	28	31	5.8	5.3	3.7	0.005	–
UDEL P-1700	PSU	2480	–	–	–	–	N	N	5.3	5.2	3.03	0.003	–
UDEL P-1720	PSU	2480	–	–	–	–		–	11	–	3.06	0.0056	–
UDEL P-3500	PSU	2480	–	–	–	–	–	–	–	–	3.03	0.0034	–
UDEL P-3703	PSU	2480	–	–	–	–	–	–	–	–	–	–	–
MINDEL B–310	PSU, GF10	–	–	–	88	3.3	–	–	–	–	3.34	0.01	–
MINDEL B–322	PSU, GF22	–	–	–	103	2.5	38	36	6.6	5.7	3.7	0.009	–
MINDEL B–340	PSU, GF40	–	–	–	124	1.3	–	–	–	–	3.9	0.01	–
MINDEL B–360	PSU, GF30	–	–	–	121	1.9	–	–	–	–	3.8	0.01	–
MINDEL B-390	PSU, MD	2760	–	–	–	–	–	–	–	–	3.4	0.007	–

(*Continued*)

11.9 High Temperature Plastics—*Cont'd*

Name and Grade	Description	Tensile Modulus (MPa)	Yield Stress (MPa)	Yield at Strain (%)	Stress at Break (MPa)	Strain at Break (%)	Charpy Impact 23°C (kJ/m^2)	Charpy Impact 30°C (kJ/m^2)	Charpy Notched Impact 23°C (kJ/m^2)	Charpy Notched Impact 30°C (kJ/m^2)	Relative Permittivity @1 MHz	Dissipation Factor @1 MHz	Water Absorption (%)
MINDEL B-430	PSU, GF30	8970	–	–	121	2.5	–	–	–	–	3.7	0.009	–
MINDEL M-800	PSU, MD40	4480	–	–	66	2	–	–	–	–	3.8	0.003	–
MINDEL M-825	PSU, MD25	3790	–	–	68	5	–	–	–	–	3.7	0.006	–
MINDEL S-1000	PSU	2410	–	–	–	–	N	N	7.8	8.7	3.5	0.007	–
MINDEL S-1010	PSU, GF10	3370	–	–	69	6.9	–	–	–	–	3.24	0.006	–

12 Tables of Selected Thermal Properties of Selected Plastics

This contains data in tabular form.

The tables in this section follow one or more of the following standards include where available:

- ASTM D746-04 Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
- ISO 812:2006 Rubber, vulcanized or thermoplastic—Determination of low-temperature brittleness
- ISO 974:2000 Plastics—Determination of the brittleness temperature by impact
- ASTM D696-03 Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C with a Vitreous Silica Dilatometer
- ASTM E831-06 Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- ISO 11359-1: Plastics—Thermomechanical analysis (TMA)—Part 1: General principles
- ISO 11359-2: Plastics—Thermomechanical analysis (TMA)—Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature
- ISO 75-1: Plastics—Determination of temperature of deflection under load—Part 1: General test method
- ISO 75-2: Plastics—Determination of temperature of deflection under load—Part 2: Plastics and ebonite
- ISO 75-3: Plastics—Determination of temperature of deflection under load—Part 3: High-strength thermosetting laminates and long-fibre-reinforced plastics
- ISO 6603-2: Plastics—Determination of puncture impact behaviour of rigid plastics—Part 2: Instrumented impact testing
- ASTM E1356-03 Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
- ISO 3146:2000 Plastics—Determination of melting behaviour (melting temperature or melting range) of semi-crystalline polymers by capillary tube and polarizing-microscope methods
- ASTM C351-92b(1999) Standard Test Method for Mean Specific Heat of Thermal Insulation
- ASTM C177-04 Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
- ISO 8302:1991 Thermal insulation—Determination of steady-state thermal resistance and related properties—Guarded hot plate apparatus
- ASTM D1525-06 Standard Test Method for Vicat Softening Temperature of Plastics
- ISO 306:2004 Plastics—Thermoplastic materials—Determination of Vicat softening temperature (VST)

The tables are grouped in the same manner as in the earlier chapter structure of this book.

The descriptions of the plastics are structured in two parts. The first part is the base polymers that are abbreviated as in Table 11.1. The fillers are listed next, and they will be listed or abbreviated from those shown in Table 11.2, and they will be followed by a number indicating weight percent. Occasionally, the manufacturer only gives a combined weight, and in these cases the fillers are grouped in parentheses followed by the combined weight percent.

These tables contain several notations besides numerical data. They are:

* Inapplicable property, or a property not relevant to this material

– Missing value, not applicable

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12.1 Styrenic Plastics

Name and Grade	Description	Melt Points (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Polystyrene/Polimeri Europa								
EDISTIR N 1782	PS	*	102	80	–	101	0.7	–
EDISTIR N 1840	PS	*	89	71	–	88	0.7	–
EDISTIR N 1910	PS	*	83	69	–	85	0.7	–
EDISTIR N 2380	PS	*	102	80	–	101	0.7	–
EDISTIR N 2560	PS	*	92	75	–	93	0.7	–
EDISTIR N 2982	PS	*	100	80	–	100	0.7	–
EDISTIR R 321P	PS-I	*	87	70	–	85	0.9	–
EDISTIR R 540E	PS-I	*	96	73	–	92	0.9	–
EDISTIR R 850E	PS-I	*	95	72	–	91	0.9	–
EDISTIR RC 3	PS-I	*	95	74	–	90	0.9	–
EDISTIR RC 600	PS-I	*	95	73	–	90	0.9	–
EDISTIR RCL 600	PS-I	*	95	73	–	90	0.9	–
EDISTIR RK	PS-I	*	93	74	–	89	0.9	–
EDISTIR RK 451G	PS-I	*	95	74	–	89	0.9	–
EDISTIR RK 5512G	PS-I	*	95	74	–	89	0.9	–
EDISTIR RKL	PS-I	*	93	74	–	89	0.9	–
EDISTIR RT 441M	PS-I	*	92	72	–	89	0.9	–
EDISTIR RT 461F	PS-I	*	97	75	–	95	0.9	–
EDISTIR SR 550	PS-I	*	88	68	–	83	0.9	–
Polystyrene/Styron								
STYRON 457	PS	–	–	78	88	94	0.8	0.7
STYRON 485	PS	–	–	73	80	87	0.9	0.7

STYRON 6335	PS	–	–	73	89	93	0.4	0.7
STYRON 634	PS	–	–	80	90	95	0.8	0.7
STYRON 637	PS	–	–	75	93	92	0.8	0.7
STYRON 648	PS	–	–	83	96	100	0.8	0.7
STYRON 660	PS	–	–	83	95	100	0.8	0.6
STYRON 678E	PS	–	–	71	82	86	0.8	0.8
STYRON 686E	PS	–	–	83	96	100	0.8	0.7
STYRON A-TECH 1120	PS	–	–	69	80	88	0.9	0.7
STYRON A-TECH 1175	PS	–	–	68	8	–	0.9	0.7
STYRON A-TECH 1200	PS	–	–	66	79	85	0.9	0.7
Polystyrene/PolyOne								
Edgetek sPS® QT-10GB-10MN/000	PS-SY, GB10, MD10	270	–	190	–	–	–	–
Edgetek sPS® QT-10GF/000	PS-SY, GF10	270	–	210	–	–	0.29	0.52
Edgetek sPS® QT-10GF/000 FR	PS-SY, GF10	270	–	190	–	–	–	–
Edgetek sPS® QT-10GF-10MN/000	PS-SY, GF10, MD10	270	–	210	–	–	–	–
Edgetek sPS® QT-15GF-15GB/000	PS-SY, GF10, GB10	270	–	210	–	–	0.19	0.46
Edgetek sPS® QT-20GB/000	PS-SY, GB20	270	–	190	–	–	0.29	0.42
Edgetek sPS® QT-20GF/000	PS-SY, GF20	270	–	220	–	–	0.25	0.49
Edgetek sPS® QT-22GF/000 FR	PS-SY, GF22	270	–	215	–	–	0.31	0.51
Edgetek sPS® QT-22MN/000 HI	PS-SY, MD22	270	–	190	–	–	0.63	0.53
Edgetek sPS® QT-25GF/000 FR	PS-SY, GF25	270	–	215	–	–	0.31	0.53
Edgetek sPS® QT-30GB/000	PS-SY, GB30	270	–	200	–	–	0.3	0.4
Edgetek sPS® QT-30GF/000	PS-SY, GF30	270	–	240	–	–	0.18	0.45
Edgetek sPS® QT-30GF/000 FR	PS-SY, GF30	270	–	220	–	–	0.3	0.54
Edgetek sPS® QT-30GF/000 FR HC	PS-SY, GF30	270	–	225	–	–	0.3	0.54
Edgetek sPS® QT-40GF/000	PS-SY, GF40	270	–	240	–	–	–	–
ASA/Styrolution								
Luran® S 757 G	ASA	*	*	96	101	97	0.95	*
Luran® S 757 R	ASA	*	*	97	101	98	0.95	*

(*Continued*)

12.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Melt Points (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Luran® S 776 S	ASA	*	*	96	101	92	0.95	*
Luran® S 776 SE	ASA	*	*	96	101	92	0.95	*
Luran® S 777 K	ASA	*	*	97	101	97	0.95	*
Luran® S 778 T	ASA	*	*	103	106	104	0.95	*
Luran® S 778 TE	ASA	*	*	103	106	104	0.95	*
Luran® S 796 M	ASA	*	*	95	100	90	0.95	*
Luran® S 797 S	ASA	*	*	95	100	90	0.95	*
Luran® S 797 SE	ASA	*	*	95	100	90	0.95	*
Luran® S KR 2858 G3	ASA, GF15	*	*	110	115	115	0.3	*
ASA/A. SCHULMAN								
POLYMAN® (ASA) E 1006	ASA	–	103	71	86	100	0.9	0.9
POLYMAN® (ASA) E 1007 H	ASA	–	103	*	105	–	0.9	0.9
POLYMAN® (ASA) E/M11010	ASA	–	103	87	104	102	0.9	0.9
POLYMAN® (ASA) M/MI 2010	ASA	–	103	84	96	96	0.9	0.9
SAN/INEOS								
Lustran SAN® 32	SAN	*	–	101	103	103	0.62	0.62
Lustran SAN® 35	SAN	*	–	102	104	103	0.6	0.6
SAN/A. SCHULMAN								
POLYMAN® (SAN) 24/5	SAN	*	106	98	102	101	0.7	0.7
POLYMAN® (SAN) 29/10	SAN	*	106	100	103	102	0.7	0.7
POLYMAN® FSAN 35 GF	SAN, GF25	*	106	*	–	112	–	–
SAN/Styrolution								
Luran® 358 N	SAN	*	*	98	102	106	0.7	*
Luran® 358 N Crystal Clear	SAN	*	*	98	102	106	0.7	*
Luran® 368 R	SAN	*	*	98	102	106	0.7	*

Luran® 368 R Crystal Clear	SAN	*	*	98	102	106	0.7	*
Luran® 378 P	SAN	*	*	98	103	107	0.7	*
Luran® 378 P G7	SAN, GF35	*	*	105	108	109	0.25	*
Luran® 388 S	SAN	*	*	99	103	107	0.7	*
Luran® KR 2556	SAN	*	*	104	110	120	0.7	*
SAN/Polimeri Europa								
KOSTIL B 265(0)	SAN	*	106	86	–	105	0.7	–
KOSTIL B 266(1)	SAN	*	106	86	–	105	0.7	–
KOSTIL B 361 R11	SAN	*	106	85	–	101	0.7	–
KOSTIL B 361 R42	SAN	*	–	82	–	100	0.7	–
KOSTIL B 365(0)	SAN	*	105	86	–	105	0.7	–
KOSTIL B 366(1)	SAN	*	105	86	–	105	0.7	–
KOSTIL C 266(1)	SAN	*	106	86	–	106	0.7	–
SAN/Styron								
TYRIL 100	SAN	–	–	88	98	104	0.58	–
TYRIL 125	SAN	–	–	88	100	107	0.63	–
TYRIL 790	SAN	–	–	101	–	101	0.5	0.6
TYRIL 867 EUV	SAN	–	–	101	–	104	0.5	0.6
TYRIL 867E	SAN	–	–	–	–	104	0.5	0.6
TYRIL 880	SAN	–	–	87	99	105	0.61	–
TYRIL 880B	SAN	–	–	88	100	106	0.57	–
TYRIL 905	SAN	–	–	100	–	104	0.4	0.6
TYRIL 905 UV	SAN	–	–	–	–	102	0.4	0.6
ABS/Styron								
MAGNUM 1040	ABS	–	–	80	93	98	0.8	–
MAGNUM 2620	ABS	–	–	82	95	101	1.02	–
MAGNUM 2630	ABS	–	–	84	93	99	1	–
MAGNUM 2642	ABS	–	–	80	87	95	0.78	–

(*Continued*)

12.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Melt Points (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
MAGNUM 275	ABS	–	–	85	95	99	0.79	–
MAGNUM 3325MT	ABS	–	–	101	–	101	–	–
MAGNUM 3404	ABS	–	–	101	104	100	0.7	0.65
MAGNUM 3404 "Smooth"	ABS	–	–	101	–	102	–	–
MAGNUM 3416SC	ABS	–	–	108	–	108	–	–
MAGNUM 342EZ	ABS	–	–	80	89	94	0.78	–
MAGNUM 344CC	ABS	–	–	80	94	96	–	–
MAGNUM 344HP	ABS	–	–	83	91	97	0.78	–
MAGNUM 3453	ABS	–	–	100	–	97	0.9	–
MAGNUM 347EZ	ABS	–	–	77	88	94	0.76	–
MAGNUM 348	ABS	–	–	80	89	94	0.78	–
MAGNUM 3490	ABS	–	–	82	95	101	0.97	–
MAGNUM 3504	ABS	–	–	101	104	100	0.7	–
MAGNUM 3513	ABS	–	–	100	103	99	0.8	0.6
MAGNUM 3525	ABS	–	–	101	–	101	–	–
MAGNUM 357HP	ABS	–	–	90	104	109	0.8	–
MAGNUM 358HP	ABS	–	–	85	102	103	–	–
MAGNUM 3616	ABS	–	–	95	–	107	0.8	0.6
MAGNUM 3904	ABS	–	–	97	–	97	–	–
MAGNUM 3904 "Smooth"	ABS	–	–	97	–	97	–	–
MAGNUM 5200	ABS	–	–	74	88	93	0.79	–
MAGNUM 541	ABS	–	–	81	90	94	0.79	–
MAGNUM 545	ABS	–	–	81	90	94	0.79	–
MAGNUM 555	ABS	–	–	82	95	98	0.79	–

MAGNUM 8391	ABS	–	–	95	–	92	–	–
MAGNUM 8434	ABS	–	–	102	–	100	–	–
MAGNUM 9010	ABS	–	–	82	95	101	0.92	–
MAGNUM 9020	ABS	–	–	82	95	101	1.02	–
MAGNUM 9030	ABS	–	–	84	93	99	1	–
MAGNUM 941	ABS	–	–	80	93	98	0.8	–
MAGNUM 9555	ABS	–	–	81	93	98	0.91	–
MAGNUM 9575	ABS	–	–	78	93	97	0.92	–
MAGNUM AG 700	ABS	–	–	83	91	96	0.74	–
MAGNUM FG 960	ABS	–	–	85	95	99	0.79	–
MAGNUM HPC 952	ABS	–	–	83	94	98	0.82	–
ABS/A. SCHULMAN								
POLYFLAM® RABS 90000 UV5	ABS	–	–	80	92	96	–	–
POLYFLAM® RABS 90000 UV6	ABS	*	115	80	85	84	0.7	0.7
POLYFLAM® RABS 90350 UV5	ABS, GF15	–	–	77	92	93	–	–
POLYFLAM® RABS 90950 UV5	ABS, GF20	–	–	91	98	94	–	–
POLYFLAM® RABS 92000 UV5	ABS, GF15	–	115	88	102	105	–	–
POLYMAN® (ABS) E/HI	ABS	*	102	88	93	92	0.8	0.8
POLYMAN® (ABS) FABS 30 GB	ABS, GB30	–	–	93	102	98	–	–
POLYMAN® (ABS) HH	ABS	–	–	103	108	108	–	–
POLYMAN® (ABS) HH 2	ABS	–	–	104	109	110	–	–
POLYMAN® (ABS) HH 3	ABS	*	115	105	110	110	0.8	0.8
POLYMAN® (ABS) HH 3 D	ABS	*	118	104	109	110	0.8	0.8
POLYMAN® (ABS) LC 145	ABS	*	105	101	104	100	0.8	0.8
POLYMAN® (ABS) LC 165	ABS	*	105	99	–	102	0.8	0.8
POLYMAN® (ABS) LC 185 A	ABS	*	105	95	101	96	0.8	0.8
POLYMAN® (ABS) M/AQ	ABS	*	116	98	102	103	0.8	0.8
POLYMAN® (ABS) M/HI-A	ABS	*	105	91	95	94	0.8	0.8

(*Continued*)

12.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Melt Points (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
POLYMAN® (ABS) M/HI-G	ABS	–	–	88	93	90	–	–
POLYMAN® (ABS) M/HI-W	ABS	*	106	95	101	101	0.8	0.8
POLYMAN® (ABS) M/MI-A 40	ABS	–	–	*	–	95	–	–
POLYMAN® (ABS) M/MI-A K1452	ABS	*	105	92	96	97	0.8	0.8
POLYMAN® (ABS) M/SHI	ABS	*	105	90	94	94	0.8	0.8
POLYMAN® (ABS) M/TK	ABS	–	–	–	96	98	–	–
POLYMAN® (ABS) M/TK-A	ABS	*	105	92	96	98	0.8	0.8
POLYMAN® (ABS) M/TK-HH	ABS	–	116	102	106	105	0.8	0.8
POLYMAN® (ABS) NWB/HI	ABS	–	103	80	91	93	–	–
ABS/INEOS								
Lustran ABS® E401	ABS	–	–	94	100	99	0.9	–
Lustran ABS® H604	ABS	–	–	98	102	102	0.8	–
Lustran ABS® H605	ABS	–	–	98	102	10	–	–
Lustran ABS® H606LS	ABS	–	–	98	103	101	0.8	–
Lustran ABS® H607AS	ABS	–	–	96	101	100	0.8	–
Lustran ABS® H701	ABS	–	–	99	105	104	0.9	–
Lustran ABS® H702	ABS	–	–	99	104	104	0.8	–
Lustran ABS® H802	ABS	–	–	101	107	109	0.8	–
Lustran ABS® H950	ABS	–	–	105	112	113	0.7	–
Lustran ABS® M201AS	ABS	–	–	96	100	98	0.8	–
Lustran ABS® M202AS	ABS	–	–	94	98	100	0.9	–
Lustran ABS® M203FC	ABS	–	–	94	98	99	0.9	–
Lustran ABS® M301AS	ABS	–	–	96	100	100	0.9	–
Lustran ABS® M301FC	ABS	–	–	96	100	99	0.9	–

Lustran ABS® M305	ABS	–	–	94	98	99	0.9	–
Novodur® P2H-AT	ABS	*	–	93	97	98	0.9	–
Novodur® P2HE	ABS	*	–	96	100	99	0.9	–
Novodur® P2HGV	ABS, GF16	*	–	102	106	105	0.4	0.8
Novodur® P2M-AT	ABS	*	–	93	97	98	1	–
Styrenic Blends/A. SCHULMAN								
Styrolux® 3G 46	SBC	–	–	58	75	51	–	–
Styrolux® 3G 55	SBC	–	–	51	62	35	0.75	*
Styrolux® 656 C	SBC	–	–	67	77	63	0.75	*
Styrolux® 684 D	SBC	–	–	65	75	59	0.75	*
Styrenic Blends/A. SCHULMAN								
POLYFLAM® (ABS/PA) RMMK 125	ABS + PA6	–	–	60	113	156	–	–
POLYFLAM® RMMB 40300	ABS + PC	–	–	84	118	100	–	–
POLYFLAM® RMMB 4070	ABS + PC	–	–	91	102	108	–	–
POLYFLAM® RMMB 4070 F FR 4	ABS + PC	–	–	114	134	140	–	–
POLYFLAM® RMMB 4070 HF	ABS + PC	–	–	86	97	101	–	–
POLYFLAM® RMMB 60300	ABS + PC	–	–	95	107	106	–	–
POLYFLAM® RMMB 60500	ABS + PC	–	–	94	118	120	–	–
SCHULABLEND® (ABS/PA) M/MK	ABS + PA6	–	–	65	93	106	–	–
SCHULABLEND® (PC/ABS) M/MB 3	ABS + PC	–	–	101	179	128	–	–
SCHULABLEND® (PC/ABS) M/MB 5	ABS + PC	*	141	99	105	115	–	–
SCHULABLEND® (PC/ABS) M/MB 6	ABS + PC	*	141	105	125	125	–	–
SCHULABLEND® (PC/ASA) WR 5	ABS + ASA	*	141	110	130	130	–	–
SCHULABLEND® (PC/ASA) WR 5 UV	ABS + ASA	*	141	97	130	110	–	–
SCHULABLEND® ABS/PA) M/MK 20GF	ABS + PA6, GF20	–	–	98	118	111	–	–

(*Continued*)

12.1 Styrenic Plastics—*Cont'd*

Name and Grade	Description	Melt Points (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Styrenic Blends/Styrolution								
Luran® S KR 2861/1 C	ASA + PC	–	*	106	125	120	0.8	*
Luran® S KR 2863 C	ASA + PC	–	*	109	130	130	0.8	*
Luran® S KR 2864 C	ASA + PC	–	*	105	124	120	0.8	*
Luran® S KR 2866 C	ASA + PC	–	–	102	113	110	0.9	*
Terblend® N NG 02	ABS + PA6, GF8	–	–	80	105	108	0.6	–
Terblend® N NG 04	ABS + PA6, GF20	–	–	100	164	114	0.4	–
Terblend® N NG-06	ABS + PA6, GF30	–	–	107	188	120	–	–
Terblend® N NM-11	ABS + PA6	–	–	65	85	102	1	–
Terblend® N NM-12	ABS + PA6	–	–	66	88	105	0.9	–
Terblend® N NM-13	ABS + PA6	–	–	58	80	94	1	–
Terblend® N NM-19	ABS + PA6	–	–	65	85	102	1	–
Terblend® N NMX04	ABS + PA6	–	–	72	97	97	1	–
Styrenic Blends/INEOS								
Lustran ABS® H801	ABS + PC	–	–	99	106	105	0.8	–
Triax® 1120	ABS + PA6	–	–	68	91	102	1.05	1.15
Triax® 1220 S	ABS + PA6	–	–	64	91	97	1.05	1.15
Triax® 1315 GF	ABS + PA6, GF15	–	–	95	175	112	0.4	1.2
Triax® DP 3155	ABS + PA6	–	–	80	175	163	0.7	0.9
Triax® KU2-3050	ABS + PA6	–	–	68	91	102	1.05	1.15

12.2 Polyethers

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Acetal Homopolymer/DuPont								
Delrin® 100AL NC010	POM, Z	178	–	94	165	–	–	–
Delrin® 100 NC010	POM	178	–	100	165	160	1.1	1.1
Delrin® 100KM NC000	POM, RF5	178	–	100	–	–	–	–
Delrin® 100P NC010	POM	179	–	95	160	160	1.1	1.1
Delrin® 100ST NC010	POM + Imod	178	–	60	100	115	1.3	1.4
Delrin® 100T NC010	POM + Imod	178	–	80	160	–	1.2	–
Delrin® 107 NC010	POM	178	–	100	165	160	1.2	1.2
Delrin® 111P NC010	POM	178	–	100	165	160	1.1	1.1
Delrin® 1260 NC010	POM	168	–	95	155	158	1.1	1.2
Delrin® 127UV NC010	POM	178	–	95	165	160	1.2	1.2
Delrin® 150 NC010	POM	178	–	100	165	–	–	–
Delrin® 300AS BK000	POM, CF	166	–	140	155	–	0.24	1.8
Delrin® 311 DP NC010	POM	178	–	105	165	160	1.1	1.1
Delrin® 460 NC010	POM	168	–	95	155	155	1.1	1.2
Delrin® 460E NC010	POM	168	–	92	165	150	–	–
Delrin® 500AF	POM, Z20	178	–	100	165	–	1	1
Delrin® 500AL NC010	POM, Z	178	–	97	165	–	1.2	1.2
Delrin® 500CL NC010	POM	178	–	90	160	160	1.1	1.1
Delrin® 500MP NC010	POM	178	–	100	163	–	1	1
Delrin® 500P NC010	POM	178	–	95	160	155	1.1	1.1
Delrin® 500T NC010	POM + Imod	178	–	80	155	140	1.3	1.2
Delrin® 500TL NC010	POM, Z	178	–	104	165	–	–	–

(*Continued*)

12.2 Polyethers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Delrin® 510GR NC000	POM, GF10	178	–	164	174	159	–	–
Delrin® 511P NC010	POM	178	–	110	165	160	1.1	1.1
Delrin® 520MP NC010	POM, Z20	178	–	94	165	–	1	0.95
Delrin® 525GR NC000	POM, GF25	178	–	170	175	–	0.4	1
Delrin® 527UV NC010	POM	178	–	95	165	160	1.2	1.2
Delrin® 542CM NC010	POM	178	–	95	160	–	–	–
Delrin® 560 NC010	POM	168	–	100	156	155	1	1.1
Delrin® 560HD OR729	POM	168	–	98	158	–	–	–
Delrin® 570 NC000	POM, GF20	178	–	130	165	160	0.6	0.85
Delrin® 900P NC010	POM	178	–	95	165	160	1.2	1.2
Delrin® 911AL NC010	POM, Z	178	–	100	160	–	–	–
Delrin® 911P NC010	POM	178	–	110	165	160	1.2	1.2
Acetal Copolymer/Celanese								
CELCON AM90S	POM	167	–	90	–	–	1	1.1
CELCON AM90S Plus	POM	167	–	90	–	–	1.1	1.1
CELCON C13031 XAS	POM	168	–	102	–	161	0.94	1
CELCON CF801	POM	165	–	90	–	161	1.1	1.1
CELCON CF802	POM	167	–	100	–	161	1	1.2
CELCON EC-90PLUS	POM	164	–	70	–	161	1	1.1
CELCON EF10	POM	165	–	158	–	161	0.27	1.2
CELCON GB10	POM, GB10	166	–	94	–	–	–	–
CELCON GB25	POM, GB25	165	–	105	–	161	0.71	0.81
CELCON GC10	POM, GF10	166	–	155	–	161	0.53	1.2
CELCON GC15	POM, GF15	166	–	159	–	161	0.46	1

CELCON GC20	POM, GF20	165	–	160	–	161	0.43	1.1
CELCON GC25A	POM, GF25	165	–	160	–	161	0.25	1.2
CELCON GC25T	POM, GF25	165	–	161	–	161	0.27	1.25
CELCON GC25TF	POM, GF25	165	–	162	–	161	0.26	1
CELCON GC90UV	POM, GF10	167	–	141	–	16	–	–
CELCON LM25	POM	167	–	98	–	161	1.1	1.1
CELCON LM90Z	POM	167	–	95	–	161	1	1.1
CELCON LU02	POM	167	–	90	–	16	–	–
CELCON LW25-S2	POM	166	–	90	–	–	1.1	1.1
CELCON LW90	POM	–	–	98	–	161	1.1	1.2
CELCON LW90-F2	POM, PTFE	166	–	98	–	161	1	0.9
CELCON LW90-F3	POM, PTFE	166	–	98	–	161	1.1	1.1
CELCON LW90-F4	POM, PTFE	167	–	94	–	–	1	1
CELCON LW90-F5	POM, PTFE	167	–	91	–	161	1	1
CELCON LW90FS-K	POM, PTFE, Si	166	–	87	–	–	–	–
CELCON LW90GPK	POM	167	–	91	–	–	1	1.1
CELCON LW90-S2	POM, Si2	166	–	94	–	161	1.1	1.2
CELCON LW90-SC	POM, Si	165	–	–	–	–	–	–
CELCON LWGC-F4	POM, PTFE4, GF25	167	–	160	–	–	0.33	0.94
CELCON LWGC-S2	POM, Si2, GF22	165	–	161	–	161	0.24	1.3
CELCON M140	POM	166	–	102	–	161	1	1
CELCON M140-L1	POM	166	–	100	–	161	1.1	1.2
CELCON M15HP	POM	172	–	101	–	166	1.1	1.2
CELCON M25	POM	166	–	94	–	161	1.2	1.2
CELCON M25UV	POM	166	–	93	–	161	1.2	1.2
CELCON M270™	POM	166	–	103	–	161	1.1	1.2
CELCON M270UV	POM	167	–	102	–	161	1.1	1.2

(*Continued*)

12.2 Polyethers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
CELCON M30AE	POM	163	–	91	–	161	1.1	1
CELCON M450	POM	166	–	103	–	161	–	–
CELCON M50	POM	165	–	97	–	161	1	1
CELCON M90-34	POM	165	–	100	–	–	–	–
CELCON M90AW	POM	167	–	86	–	161	1.1	1.1
CELCON M90SW	POM	166	–	90	–	161	1	1
CELCON M90™	POM	165	–	101	–	161	1.2	1.2
CELCON M90UV	POM	165	–	101	–	161	1.1	1.2
CELCON M90XAP	POM	167	–	100	–	160	1.2	1.2
CELCON MC270	POM, MD	165	–	91	–	161	0.97	1.2
CELCON MC270-HM	POM, MD	165	–	105	–	161	0.6	0.9
CELCON MC90	POM, MD	165	–	97	–	161	1	1.2
CELCON MC90-HM	POM, MD	165	–	103	–	161	0.64	0.92
CELCON MR15HPB	POM	172	–	–	–	–	0.94	0.96
CELCON MR270B	POM	166	–	100	–	–	–	–
CELCON MR50B	POM	166	–	93	–	–	0.9	0.9
CELCON MR90B	POM	166	–	100	–	–	0.89	1
CELCON MT12R01	POM	166	–	102	–	151	1.1	–
CELCON MT12U01	POM	166	–	106	–	151	1.1	–
CELCON MT12U03	POM	170	–	112	–	158	1.2	–
CELCON MT24F01	POM	–	–	100	–	146	–	–
CELCON MT24U01	POM	166	–	106	–	151	1.1	–
CELCON MT2U01	POM	165	–	101	–	151	1.1	–
CELCON MT8F01	POM	166	–	–	–	–	–	–

CELCON MT8F02	POM	166	–	98	–	145	1.1	–
CELCON MT8R02	POM	166	–	82	–	–	–	–
CELCON MT8U01	POM	166	–	104	–	150	1.1	–
CELCON TF-10XAP	POM, Imod	165	–	75	139	–	1.2	1.1
CELCON TX25E	POM	164	–	69	137	–	–	–
CELCON TX90	POM	165	–	84	–	161	1.2	1.2
CELCON TX90PLUS	POM	165	–	80	–	161	1.2	1.4
CELCON UV140LG	POM	165	–	80	138	161	1.3	1.3
CELCON UV25Z	POM	166	–	90	–	161	1.1	1.1
CELCON UV270Z	POM	167	–	90	–	161	1.1	1.2
CELCON UV90Z	POM	165	–	91	155	161	1.1	1.2
CELCON UV90Z Metallics	POM	166	–	88	–	–	–	–
CELCON WR25Z	POM	166	–	92	–	161	1	1.1
CELCON WR90Z	POM	166	–	95	152	161	1	1.1
HOSTAFORM C 13021	POM	166	*	106	–	151	1.1	–
HOSTAFORM C 13021 RM	POM	166	*	102	–	151	1.1	–
HOSTAFORM C 13031	POM	170	*	107	–	158	1.1	–
HOSTAFORM C 13031 K	POM	170	*	105	–	156	1.1	–
HOSTAFORM C 13031 XF	POM	170	–	102	159	–	0.9	0.9
HOSTAFORM C 2521	POM	165	*	101	–	151	1.1	–
HOSTAFORM C 2521 G	POM	165	*	84	–	140	1	–
HOSTAFORM C 2552	POM	162	*	96	–	150	1.1	–
HOSTAFORM C 27021	POM	166	*	106	–	151	1.1	–
HOSTAFORM C 27021 AST	POM	166	*	100	–	150	1.1	–
HOSTAFORM C 27021 GV3/30	POM, GB30	166	*	112	–	151	0.8	–
HOSTAFORM C 52021	POM	166	*	106	–	151	1.1	–
HOSTAFORM C 9021	POM	166	*	104	–	150	1.1	1.1
HOSTAFORM C 9021 10/1570	POM	167	*	105	–	150	1.1	–

(*Continued*)

12.2 Polyethers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
HOSTAFORM C 9021 AW	POM	166	*	88	–	145	1.1	–
HOSTAFORM C 9021 G	POM	166	*	88	–	140	1.2	–
HOSTAFORM C 9021 GV1/10	POM, GF10	166	*	154	–	156	0.8	0.9
HOSTAFORM C 9021 GV1/20	POM, GF20	166	*	159	–	157	0.5	0.8
HOSTAFORM C 9021 GV1/30	POM, GF30	166	*	160	–	158	0.4	0.8
HOSTAFORM C 9021 GV1/40	POM, GF40	166	*	161	–	160	0.2	–
HOSTAFORM C 9021 GV3/10	POM, GB10	166	*	108	–	151	1.1	–
HOSTAFORM C 9021 GV3/20	POM, GB20	166	*	110	–	151	1	–
HOSTAFORM C 9021 GV3/30	POM, GB30	166	*	112	–	151	0.9	0.9
HOSTAFORM C 9021 K	POM	166	*	100	–	150	1.1	–
HOSTAFORM C 9021 M	POM	166	*	100	–	150	1.1	–
HOSTAFORM C 9021 SW	POM	166	*	80	–	140	1.2	–
HOSTAFORM C 9021 TF	POM	166	*	98	–	145	1.1	–
HOSTAFORM EC140XF	POM	166	–	91	–	–	1	1.1
HOSTAFORM LM90	POM	167	–	98	–	161	1	1.1
HOSTAFORM MR130ACS	POM	170	–	100	–	154	0.94	1
HOSTAFORM MT12U01	POM	166	–	106	–	151	1.1	–
HOSTAFORM MT12U03	POM	170	–	112	–	158	1.2	–
HOSTAFORM MT24U01	POM	166	–	106	–	151	1.1	–
HOSTAFORM MT8U01	POM	166	–	104	–	150	1.1	–
HOSTAFORM S 27063	POM	166	*	84	–	140	1.2	–
HOSTAFORM S 27064	POM	166	*	77	–	125	1.3	–
HOSTAFORM S 27072 WS10/1570	POM	166	*	84	–	135	1.2	–
HOSTAFORM S 9063	POM	166	*	82	–	140	1.2	–

HOSTAFORM S 9064	POM	166	*	76	–	125	1.2	1.2
HOSTAFORM S 9243	POM	166	*	75	–	130	1.2	–
HOSTAFORM S 9244	POM, Imod	166	*	68	–	115	1.3	–
Acetal Copolymer/A. Schulman								
SCHULAFORM® 9 A	POM	–	–	105	–	150	–	–
SCHULAFORM® 9 A GF 25	POM, GF25	–	–	160	–	–	–	–
SCHULAFORM® 9 b	POM	–	–	80	122	130	–	–
SCHULAFORM® 9 d	POM	–	–	105	–	150	–	–
SCHULAFORM® 9 E HI	POM	–	–	105	–	150	–	–
SCHULAFORM® 9 f	POM	–	–	98	–	148	–	–
SCHULAFORM® AF 9 natur	ROM, RF9	–	–	95	–	–	–	–
PPE/Degussa								
VESTORAN 1900 nf	PPE	–	–	170	190	190	0.8	0.8
VESTORAN 1900 sw	PPE	–	–	170	190	190	0.8	0.8
VESTORAN 1900-GF20 sw	PPE, GF20	–	–	185	190	190	0.4	0.5
VESTORAN X4893 sw	PPE	–	–	110	122	130	0.8	0.8
VESTORAN X7342 nf	PPE, GF20	–	–	162	165	168	0.4	0.3
PPE Modified/Mitsubishi Engineering-Plastics								
Iupiace AH40	PPE + PS	–	–	93	108	–	0.67	0.71
Iupiace AH50	PPE + PS	–	–	105	120	–	0.66	0.69
Iupiace AH60	PPE + PS	–	–	115	130	–	0.66	0.69
Iupiace AH70	PPE + PS	–	–	124	142	–	0.66	0.69
Iupiace AH80	PPE + PS	–	–	135	150	–	0.66	0.69
Iupiace AH8P	PPE + PS	–	–	88	98	–	0.6	0.6
Iupiace AHF6005	PPE + PS, PTFE5	–	–	115	125	–	0.6	0.6
Iupiace AHF6010	PPE + PS, PTFE10	–	–	111	129	–	0.6	0.6
Iupiace AHF6015	PPE + PS, PTFE15	–	–	115	125	–	0.6	0.6
Iupiace AN60	PPE + PS	–	–	115	130	–	0.55	0.58

(*Continued*)

12.2 Polyethers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Iupiace AN70	PPE + PS	–	–	128	145	–	0.55	0.58
Iupiace AN80	PPE + PS	–	–	139	154	–	0.55	0.58
Iupiace AN91	PPE + PS	–	–	145	160	–	0.55	0.58
Iupiace AP4	PPE + PS	–	–	78	87	–	–	–
Iupiace AP6GM2	PPE + PS, (GF + MD)10	–	–	98	108	–	0.47	0.58
Iupiace AP6GM4	PPE + PS, (GF + MD)20	–	–	115	123	–	0.37	0.68
Iupiace AP6GM8	PPE + PS, (GF + MD)40	–	–	117	123	–	0.34	0.53
Iupiace AV60	PPE + PS	–	–	112	128	–	0.63	0.66
Iupiace AV70	PPE + PS	–	–	125	140	–	0.6	0.63
Iupiace AV90	PPE + PS	–	–	145	160	–	0.6	0.63
Iupiace EHM1010A	PPE + PS, CF	–	–	160	176	–	0.53	0.55
Iupiace GAV2010	PPE + PS, (GF + MD)30	–	–	120	126	–	0.25	0.6
Iupiace GAV2515	PPE + PS, (GF + MD)40	–	–	129	135	–	0.23	0.52
Iupiace GH10	PPE + PS, GF10	–	–	132	141	–	0.45	0.75
Iupiace GH20	PPE + PS, GF20	–	–	132	138	–	0.3	0.68
Iupiace GH30	PPE + PS, GF30	–	–	134	140	–	0.35	0.6
Iupiace GHF3005	PPE + PS, PTFE5	–	–	115	125	–	0.25	0.6
Iupiace GHF3010	PPE + PS, PTFE10	–	–	132	137	–	0.25	0.6
Iupiace GHF3015	PPE + PS, PTFE15	–	–	132	137	–	0.25	0.6
Iupiace GN10	PPE + PS, GF10	–	–	125	130	–	0.45	0.75

Iupiace GN15	PPE + PS, GF15	–	–	125	135	–	0.35	0.72
Iupiace GN20	PPE + PS, GF20	–	–	130	138	–	0.3	0.68
Iupiace GN30	PPE + PS, GF30	–	–	133	140	–	0.25	0.6
Iupiace GV10	PPE + PS, GF10	–	–	125	130	–	0.45	0.75
Iupiace GV15	PPE + PS, GF15	–	–	130	136	–	0.4	0.7
Iupiace GV20	PPE + PS, GF20	–	–	130	136	–	0.3	0.68
Iupiace GV30	PPE + PS, GF30	–	–	135	140	–	0.25	0.6
Iupiace GX1050	PPE + PS, (GF + MD)20	–	–	105	110	–	0.37	0.68
Iupiace GX1100	PPE + PS, (GF + MD)35	–	–	110	116	–	0.23	0.56
Iupiace NX7000	PPE + PA6	–	–	123	177	–	0.7	–
Iupiace TGV2010	PPE + PS, (GF + MD)30	–	–	105	110	–	0.25	0.6
Iupiace TX403	PPE + PS, X	–	–	92	104	–	0.6	0.6
Iupiace VSG635V	PPE + PS, (GF + MD)35	–	–	115	120	–	0.25	0.61

12.3 Polyesters

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Polycarbonate/Bayer								
Apec® 1600	PC	–	–	140	152	–	0.7	0.7
Apec® 1605	PC	–	–	138	150		0.7	0.7
Apec® 1695	PC	–	–	138	150	–	0.7	0.7

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Apec® 1700	PC	–	–	150	162	–	0.7	0.7
Apec® 1703	PC	–	–	149	161	–	0.7	0.7
Apec® 1705	PC	–	–	148	160	–	0.7	0.7
Apec® 1745	PC	–	–	148	160	–	0.7	0.7
Apec® 1795	PC	–	–	148	160	–	0.7	0.7
Apec® 1800	PC	–	–	162	174	–	0.7	0.7
Apec® 1803	PC	–	–	161	173	–	0.7	0.7
Apec® 1805	PC	–	–	160	172	–	0.7	0.7
Apec® 1895	PC	–	–	158	173	–	0.7	0.7
Apec® 1897	PC	–	–	157	172	–	0.7	0.7
Apec® 2095	PC	–	–	173	192	–	0.7	0.7
Apec® 2097	PC	–	–	172	191	–	0.7	0.7
Apec® DP1-9354	PC	–	–	162	174	–	0.7	0.7
Apec® DP1-9379	PC	–	–	162	174	–	0.7	0.7
Apec® DP1-9389	PC	–	–	175	194	–	0.7	0.7
Apec® DP1-9354/1	PC	–	–	185	208	–	0.7	0.7
Makrolon® 1095	PC, GF15	–	–	136	142	145	0.35	0.65
Makrolon® 1239	PC	–	148	130	142	148	0.7	0.7
Makrolon® 1243	PC	–	145	124	137	143	0.7	0.7
Makrolon® 1260	PC	–	–	122	135	142	0.7	0.7
Makrolon® 1804	PC	–	148	127	140	148	0.65	0.65
Makrolon® 2205	PC	–	145	124	137	145	0.65	0.65
Makrolon® 2207	PC	–	145	123	137	144	0.65	0.65
Makrolon® 2405	PC	–	145	125	138	145	0.65	0.65
Makrolon® 2407	PC	–	145	124	137	144	0.65	0.65

Makrolon® 2458	PC	–	145	125	138	145	0.65	0.65
Makrolon® 2558	PC	–	145	124	137	144	0.65	0.65
Makrolon® 2605	PC	–	145	124	137	144	0.65	0.65
Makrolon® 2607	PC	–	145	123	136	143	0.65	0.65
Makrolon® 2658	PC	–	145	124	137	144	0.65	0.65
Makrolon® 2665	PC	–	145	124	137	144	0.65	0.65
Makrolon® 2667	PC	–	145	123	136	143	0.65	0.65
Makrolon® 2805	PC	–	145	125	138	145	0.65	0.65
Makrolon® 2807	PC	–	145	124	137	144	0.65	0.65
Makrolon® 2858	PC	–	145	125	138	145	0.65	0.65
Makrolon® 2865	PC	–	145	125	138	145	0.65	0.65
Makrolon® 2867	PC	–	145	124	137	144	0.65	0.65
Makrolon® 3103 MAS157	PC	–	148	127	140	148	0.65	0.65
Makrolon® 3105	PC	–	146	126	139	147	0.65	0.65
Makrolon® 3107	PC	–	146	125	138	146	0.65	0.65
Makrolon® 3108	PC	–	148	128	141	149	0.65	0.65
Makrolon® 3158	PC	–	146	126	139	147	0.65	0.65
Makrolon® 6265	PC	–	–	124	137	145	0.65	0.65
Makrolon® 6267	PC	–	–	124	137	145	0.65	0.65
Makrolon® 6455	PC	–	145	124	137	144	0.65	0.65
Makrolon® 6485	PC	–	–	125	138	145	0.65	0.65
Makrolon® 6487	PC	–	–	125	138	145	0.65	0.65
Makrolon® 6555	PC	–	145	124	137	144	0.65	0.65
Makrolon® 6557	PC	–	145	123	136	143	0.65	0.65
Makrolon® 8025	PC, GF20	–	–	135	142	147	0.45	0.6
Makrolon® 8035	PC, GF30	–	–	135	142	147	0.4	0.6
Makrolon® 8315	PC, GF10	–	–	138	144	147	0.4	0.65
Makrolon® 8325	PC, GF20	–	–	140	144	149	0.25	0.65

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Makrolon® 8345	PC, GF35	–	–	140	144	149	0.2	0.6
Makrolon® 9125	PC, GF20	–	–	138	142	145	0.25	0.65
Makrolon® 9415	PC, GF10	–	–	135	142	145	0.4	0.65
Makrolon® 9425	PC, GF20	–	–	138	142	147	0.25	0.65
Makrolon® AG2677	PC	–	145	123	136	143	0.65	0.65
Makrolon® AL2447	PC	–	145	124	137	144	0.65	0.65
Makrolon® AL2647	PC	–	145	123	136	143	0.65	0.65
Makrolon® DP1-1265	PC	–	145	123	137	144	0.65	0.65
Makrolon® DP1-1837	PC	–	–	120	134	–	–	–
Makrolon® DP1-1853	PC	–	–	125	138	146	0.7	0.7
Makrolon® DP1-1857	PC	–	145	124	137	145	0.65	0.65
Makrolon® DP1-1870	PC	–	145	124	137	144	0.65	0.65
Makrolon® KU1-1248	PC	–	–	126	139	147	0.7	0.7
Makrolon® LQ2647	PC	–	145	123	136	143	0.65	0.65
Makrolon® LQ3147	PC	–	146	125	138	146	0.65	0.65
Makrolon® LQ3187	PC	–	146	125	138	146	0.65	0.65
Makrolon® LTG2623	PC	–	147	125	138	145	0.65	0.65
Makrolon® LTG3123	PC	–	148	127	140	148	0.65	0.65
Makrolon® OD2015	PC	–	145	123	137	145	0.65	0.65
Makrolon® Rx1805	PC	–	–	126	137	145	0.65	0.65
Polycarbonate/Styron								
CALIBRE 1080 DVD	PC	–	–	122	136	142	0.64	–
CALIBRE 200 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 200 15 MFR	PC	–	–	130	144	148	0.7	–

CALIBRE 200 22 MFR	PC	–	–	128	142	147	0.7	–
CALIBRE 200 4 MFR	PC	–	–	132	146	151	0.7	–
CALIBRE 200 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 201 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 201 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 201 22 MFR	PC	–	–	128	142	147	0.7	–
CALIBRE 201 4 MFR	PC	–	–	143	146	151	0.7	–
CALIBRE 201 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 202 10 MFR	PC	–	–	141	144	149	0.7	–
CALIBRE 202 15 MFR	PC	–	–	140	143	148	0.7	–
CALIBRE 202 22 MFR	PC	–	–	143	146	151	0.7	–
CALIBRE 202 4 MFR	PC	–	–	143	146	151	0.7	–
CALIBRE 202 6 MFR	PC	–	–	143	146	151	0.7	–
CALIBRE 203 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 203 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 203 22 MFR	PC	–	–	128	142	147	0.7	–
CALIBRE 203 4 MFR	PC	–	–	143	146	151	0.7	–
CALIBRE 203 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 2060 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 2060 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 2061 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 2061 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 2071 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 300 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 300 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 300V 10 MFR	PC	–	–	138	141	146	0.7	–
CALIBRE 300V 15 MFR	PC	–	–	137	140	145	0.7	–
CALIBRE 300V 6 MFR	PC	–	–	140	143	148	0.7	–

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12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (×10E4/°C)	CLTE Normal (×10E 4/°C)
CALIBRE 301 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 301 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 301 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 301EP 22 MFR	PC	–	–	128	142	147	0.7	–
CALIBRE 301EP 31 MFR	PC	–	–	138	142	145	0.7	–
CALIBRE 301V 10 MFR	PC	–	–	138	141	146	0.7	–
CALIBRE 301V 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 301V 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 302 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 302 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 302 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 302EP 22 MFR	PC	–	–	128	142	147	0.7	–
CALIBRE 302EP 31 MFR	PC	–	–	138	142	145	0.7	–
CALIBRE 302V 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 302V 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 302V 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 303 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 303 15 MFR	PC	–	–	130	144	148	0.7	–
CALIBRE 303 6 MFR	PC	–	–	131	145	151	0.7	–
CALIBRE 303 8 MFR	PC	–	–	141	144	149	0.7	–
CALIBRE 303EP 22 MFR	PC	–	–	128	142	147	0.7	–
CALIBRE 303EP 31 MFR	PC	–	–	138	142	145	0.7	–
CALIBRE 303V 10 MFR	PC	–	–	131	145	149	0.7	–
CALIBRE 303V 15 MFR	PC	–	–	137	140	145	0.7	–

CALIBRE 303V 4 MFR	PC	–	–	140	143	148	0.7	–
CALIBRE 303V 6 MFR	PC	–	–	140	143	148	0.7	–
CALIBRE 303V 8 MFR	PC	–	–	138	141	146	0.7	–
CALIBRE 3041 35 MFR	PC	–	–	135	138	144	0.7	–
CALIBRE 3043 35 MFR	PC	–	–	135	138	144	0.7	–
CALIBRE 5101 15 MFR	PC, 10GF	–	–	137	147	148	0.38	–
CALIBRE 5210 15 MFR	PC, GF20	–	–	134	146	153	–	–
CALIBRE 5210 8 MFR	PC, GF20	–	–	135	147	154	–	–
CALIBRE 600 2 MFR	PC	–	–	143	146	150	–	–
CALIBRE 600 3 MFR	PC	–	–	142	145	150	–	–
CALIBRE 603 3 MFR	PC	–	–	132	–	150	–	–
CALIBRE 701 10 MFR	PC	–	–	123	140	149	–	–
CALIBRE 701 15 MFR	PC	–	–	122	140	147	–	–
CALIBRE 7101 15 MFR	PC, GF10	–	–	138	–	150	–	–
CALIBRE 7101 8 MFR	PC, GF10	–	–	138	–	150	–	–
CALIBRE 7211 5 MFR	PC, GF20	–	–	143	–	150	–	–
CALIBRE 891 10 MFR	PC	–	–	127	–	151	0.7	–
CALIBRE 891 19 MFR	PC	–	–	127	–	151	0.7	–
CALIBRE 893 19 MFR	PC	–	–	127	–	151	0.7	–
CALIBRE IM 401 11	PC, Imod	–	–	119	138	145	0.73	–
CALIBRE IM 401 18	PC, Imod	–	–	119	134	140	0.7	–
CALIBRE MegaRad 2080 10 MFR	PC	–	–	124	140	143	0.7	–
CALIBRE MegaRad 2080 15 MFR	PC	–	–	123	137	143	0.7	–
CALIBRE MegaRad 2081 10 MFR	PC	–	–	123	137	143	0.7	–
Polycarbonate/A. Schulman								
POLYMAN® (PC) XP 01 RN	PC	*	150	123	137	149	0.7	–
POLYMAN® (PC) XP 11 RN	PC	*	150	123	137	149	0.7	–
POLYMAN® (PC) XP 21 RN	PC	*	150	126	138	150	0.7	–

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12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
POLYMAN® (PC) XP 31 RN	PC	*	150	127	138	147	0.7	–
POLYMAN® (PC) XP 41 R 10 GF	PC, GF10	*	150	138	144	150	0.4	–
POLYMAN® (PC) XP 41 R 20 GF	PC, GF20	*	150	138	145	152	0.4	–
POLYMAN® (PC) XP 41 R 30 GF	PC, GF30	*	150	139	147	151	0.4	–
Polycarbonate/DSM								
Xantar® 18 R	PC	–	–	130	–	145	0.65	–
Xantar® 18 SR D	PC	–	–	130	–	145	0.65	–
Xantar® 18 UR	PC	–	–	130	–	145	0.65	–
Xantar® 19 R	PC	–	–	130	–	145	0.65	–
Xantar® 19 SR D	PC	–	–	130	–	145	0.65	–
Xantar® 19 UR	PC	–	–	130	–	145	0.65	–
Xantar® 22 R	PC	–	–	130	–	148	0.65	–
Xantar® 22 SR FD	PC	–	–	130	–	148	0.65	–
Xantar® 22 UR	PC	–	–	130	–	148	0.65	–
Xantar® 24 R	PC	–	–	130	–	150	0.65	–
Xantar® 24 SR D	PC	–	–	130	–	150	0.65	–
Xantar® 24 UR	PC	–	–	130	–	150	0.65	–
Xantar® 25 R	PC	–	–	130	–	150	0.65	–
Xantar® 25 SR D	PC	–	–	130	–	150	0.65	–
Xantar® 25 U	PC	–	–	130	–	150	0.65	–
Xantar® 25 UR	PC	–	–	130	–	150	0.65	–
Xantar® 27 R	PC	–	–	130	–	150	0.65	–
Xantar® 27 SR D	PC	–	–	130	–	150	0.65	–
Xantar® 27 U	PC	–	–	130	–	150	0.65	–

Xantar® 27 UR	PC	–	–	130	–	150	0.65	–
Xantar® F 22 R	PC	–	–	130	–	148	0.65	–
Xantar® F 22 UR	PC	–	–	130	–	148	0.65	–
Xantar® F 23 R	PC	–	–	130	–	148	0.65	–
Xantar® F 23 UR	PC	–	–	130	–	148	0.65	–
Xantar® F 25 R	PC	–	–	130	–	150	0.65	–
Xantar® F 25 UR	PC	–	–	130	–	150	0.65	–
Xantar® FC 19 R	PC	–	–	130	–	145	0.65	–
Xantar® FC 19 UR	PC	–	–	130	–	145	0.65	–
Xantar® FC 22 R	PC	–	–	130	–	148	0.65	–
Xantar® FC 22 UR	PC	–	–	130	–	148	0.65	–
Xantar® FC 23 R	PC	–	–	130	–	148	0.65	–
Xantar® FC 23 UR	PC	–	–	130	–	148	0.65	–
Xantar® FC 25 R	PC	–	–	130	–	150	0.65	–
Xantar® FC 25 UR	PC	–	–	130	–	150	0.65	–
Xantar® G2F 23 R	PC, GF10	–	–	147	–	150	0.45	–
Xantar® G2F 23 UR	PC, GF10	–	–	147	–	150	0.45	–
Xantar® G4F 22 R	PC, GF20	–	–	145	–	152	0.25	–
Xantar® G4F 22 UR	PC, GF20	–	–	145	–	152	0.25	–
Xantar® G4F 23 R	PC, GF20	–	–	147	–	150	0.3	–
Xantar® G4F 23 UR	PC, GF20	–	–	147	–	150	0.3	–
Xantar® G4F 25 R	PC, GF20	–	–	147	–	150	0.3	–
Xantar® G4F 25 UR	PC, GF20	–	–	147	–	150	0.3	–
Xantar® G6F 23 R	PC, GF30	–	–	145	–	152	0.25	–
Xantar® G6F 23 UR	PC, GF30	–	–	145	–	152	0.25	–
Xantar® G8F 23 R	PC, GF40	–	–	145	–	153	0.2	–
Xantar® G8F 23 UR	PC, GF40	–	–	145	–	153	0.2	–
Xantar® MX 1000	PC, Imod	–	–	115	–	135	0.65	–

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12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Xantar® MX 1001	PC, Imod	–	–	115	–	135	0.65	–
Xantar® MX 1002	PC, Imod	–	–	115	–	135	0.65	–
Xantar® MX 1004	PC, Imod	–	–	115	–	135	0.65	–
Xantar® MX 1020	PC	–	–	129	–	140	0.65	–
Xantar® MX 1021	PC	–	–	129	–	140	0.65	–
Xantar® MX 1021 D	PC	–	–	129	–	140	0.65	–
Xantar® MX 1061	PC	–	–	130	–	150	0.65	–
Xantar® MX 1081	PC, GF10	–	–	143	–	150	0.4	–
Xantar® MX 1082	PC, GF20	–	–	147	–	150	0.25	–
Xantar® MX 1094	PC, GF9	–	–	135	–	145	0.45	–
Xantar® MX 2015	PC	–	–	130	–	145	0.65	–
Xantar® MX 2021	PC	–	–	140	–	150	0.65	–
Xantar® MX 2032	PC	–	–	135	–	145	0.65	–
Xantar® MX 2034	PC	–	–	130	–	145	0.65	–
Xantar® MX 2042 D	PC	–	–	135	–	145	0.65	–
Xantar® RX 1045	PC	–	–	130	–	145	0.65	–
PBT/Celanese								
CELANEX 1300A	PBT	225	60	62	156	190	1.1	–
CELANEX 1400A	PBT	225	60	58	142	–	1.1	–
CELANEX 1462Z	PBT, GF30	225	60	207	225	–	0.25	1.28
CELANEX 1600A	PBT	225	60	50	150	185	1.1	1.03
CELANEX 1602Z	PBT	225	–	50	150	–	1.1	–
CELANEX 1612Z	PBT, GF7	–	–	–	–	–	–	–
CELANEX 1632Z	PBT, GF15	225	60	189	217	–	0.4	1.1
CELANEX 1642Z	PBT, GF20	–	–	–	–	–	0.31	1.2

CELANEX 1662Z	PBT, GF30	225	–	205	225	–	0.19	1.13
CELANEX 1700A	PBT	225	60	50	150	182	1	–
CELANEX 2000	PBT	225	60	55	155	190	1.1	0.86
CELANEX 2000-2	PBT	225	60	55	155	190	1.1	0.86
CELANEX 2000-K	PBT	225	60	55	155	190	1.1	0.86
CELANEX 2001	PBT	225	60	50	150	185	1.3	0.88
CELANEX 2001 HP	PBT	225	60	58	152	–	–	–
CELANEX 2002	PBT	225	60	55	150	190	1.1	1.38
CELANEX 2002-2	PBT	225	60	55	150	190	1.1	1.27
CELANEX 2002-3	PBT	–	–	55	150	190	1.3	1.2
CELANEX 2002AP	PBT	225	60	55	150	190	1.1	–
CELANEX 2002UV	PBT	225	60	55	150	190	1.1	1.2
CELANEX 2003	PBT	225	60	55	150	190	1.1	–
CELANEX 2003-2	PBT	225	60	55	150	190	1.1	–
CELANEX 2003HR	PBT	225	–	55	150	190	1.1	–
CELANEX 2004	PBT	225	60	54	166	175	1.1	–
CELANEX 2004-2	PBT	225	60	54	166	175	1.1	–
CELANEX 2008	PBT	225	60	57	155	–	–	–
CELANEX 2012	PBT	225	–	57	152	–	1.3	–
CELANEX 2014	PBT	225	60	66	134	–	1.39	1.04
CELANEX 2016	PBT	225	60	60	165	190	0.63	0.77
CELANEX 2025	PBT	206	–	98	128	–	–	–
CELANEX 2300 GV1/10	PBT, GF10	225	–	190	–	205	0.6	–
CELANEX 2300 GV1/20	PBT, GF20	225	–	195	–	215	0.35	–
CELANEX 2300 GV1/30	PBT, GF30	225	–	210	–	220	0.25	–
CELANEX 2300 GV1/50	PBT, GF50	225	–	215	–	225	0.15	–
CELANEX 2300 GV3/20	PBT, GB20	225	–	70	180	190	1.1	–
CELANEX 2300 GV3/30	PBT, GB30	225	–	90	190	195	1	–

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (×10E4/°C)	CLTE Normal (×10E 4/°C)
CELANEX 2302 GV1/15	PBT, GF15	255	–	190	–	210	0.35	–
CELANEX 2302 GV1/20	PBT, GF20	255	–	195	–	220	0.35	–
CELANEX 2302 GV1/30	PBT, GF30	255	–	200	–	225	0.2	–
CELANEX 2360 FL	PBT	225	–	65	165	190	1.1	–
CELANEX 2360 GV1/10 FL	PBT, GF10	225	–	195	–	210	0.45	–
CELANEX 2360 GV1/20 FL	PBT, GF20	225	–	206	–	220	0.35	–
CELANEX 2360 GV1/30 FL	PBT, GF30	225	–	209	–	225	0.25	–
CELANEX 2401 MT	PBT	225	60	55	150	190	1.1	–
CELANEX 2402 MT	PBT	225	60	60	160	190	1.1	–
CELANEX 2403 MT	PBT	225	60	55	150	190	1.1	–
CELANEX 2404 MT	PBT	225	60	55	–	190	–	–
CELANEX 2500	PBT	225	–	60	160	190	1.1	–
CELANEX 3100	PBT, GF7	225	60	143	206	185	1.3	–
CELANEX 3109HR	PBT, GF7	225	60	143	206	185	1.3	–
CELANEX 3112-2	PBT, GF14	224	–	183	–	–	–	–
CELANEX 3114	PBT, GF7	225	60	–	–	–	–	–
CELANEX 3116	PBT, GF7	225	60	150	–	200	0.6	–
CELANEX 3200	PBT, GF15	225	60	195	–	215	0.4	1.1
CELANEX 3200-2	PBT, GF15	225	60	195	–	215	0.4	1.1
CELANEX 3200HR	PBT, GF15	225	–	195	–	22	–	–
CELANEX 3201	PBT, GF15	225	60	195	218	220	0.35	–
CELANEX 3209H	PBT	–	–	180	220	–	–	–
CELANEX 3210-2	PBT, GF20	225	60	203	223	–	0.3	1.1
CELANEX 3214	PBT, GF15	225	60	192	215	–	0.42	0.98

CELANEX 3216	PBT, GF15	225	60	200	–	206	0.4	–
CELANEX 3224	PBT	–	–	198	218	–	–	–
CELANEX 3226	PBT	225	–	203	–	220	0.35	0.35
CELANEX 3300	PBT, GF30	225	60	205	–	220	0.25	1
CELANEX 3300-2	PBT, GF30	225	60	205	–	220	0.25	1
CELANEX 3300D	PBT	225	60	205	–	220	0.25	1
CELANEX 3300HR	PBT, GF30	225	60	205	225	220	0.25	1
CELANEX 3300LM	PBT, GF30	225	60	205	225	220	0.25	1
CELANEX 3309HR	PBT, GF30	225	60	205	225	220	0.25	1
CELANEX 3309HRHF	PBT, GF30	–	–	210	222	–	–	–
CELANEX 3309HRT	PBT, GF30	225	–	204	–	–	–	–
CELANEX 3310	PBT, GF30	225	60	205	222	–	0.2	1.1
CELANEX 3314	PBT, GF30	–	–	210	220	225	0.2	0.75
CELANEX 3316	PBT, GF30	225	–	208	–	225	0.25	0.77
CELANEX 3325HRT	PBT, GF30	–	–	184	–	–	–	–
CELANEX 3400	PBT, GF40	225	–	212	226	–	0.15	1.01
CELANEX 3409HR	PBT, GF40	225	60	212	226	–	0.15	–
CELANEX 4016	PBT	225	–	62	159	–	1	1
CELANEX 4202	PBT, GF15	225	–	183	–	–	0.36	1
CELANEX 4300	PBT, GF30	225	–	200	220	–	0.25	–
CELANEX 4300LM	PBT, GF30	–	–	200	–	–	–	–
CELANEX 4302	PBT, GF30	225	–	173	–	–	0.18	1.25
CELANEX 4302HS	PBT, GF30	225	–	173	–	–	–	–
CELANEX 4302LM	PBT, GF30	225	–	173	–	–	–	–
CELANEX 4305	PBT, GF33	225	–	206	224	–	0.2	0.65
CELANEX 4306	PBT, GF30	225	–	164	210	–	0.2	0.87
CELANEX 5200-2	PBT, GF15	225	95	190	–	210	0.35	–

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
CELANEX 5201	PBT, GF15	–	–	180	215	–	–	–
CELANEX 5202	PBT, GF15	–	–	180	215	–	–	–
CELANEX 5203	PBT, GF20	–	–	189	218	–	–	–
CELANEX 5300	PBT, GF30	225	60	200	–	225	0.2	–
CELANEX 5300-2	PBT, GF30	225	60	200	–	225	0.2	–
CELANEX 602AC	PBT	225	–	139	202	–	–	–
CELANEX 6400-2	PBT	–	–	200	220	220	0.25	–
CELANEX 6406	PBT, (GF + Mica)40	225	–	160	205	150	0.25	0.97
CELANEX 6407	PBT, (GF + Mica)30	–	–	172	209	–	0.19	0.7
CELANEX 6500	PBT, (GF + Mica)30	225	–	202	223	–	0.28	0.85
CELANEX 6500LM	PBT, (GF + Mica)30	225	–	202	223	–	0.28	0.85
CELANEX 7316	PBT, (GF + Mica)35	225	60	184	212	–	0.3	0.55
CELANEX 7700	PBT, (GF + Mica)35	225	60	204	223	–	0.14	0.79
CELANEX 7714	PBT, (GF + Mica)35	–	–	213	184	–	–	–
CELANEX 7716	PBT, (GF + Mica)35	225	60	194	222	–	–	–
CELANEX J235	PBT	225	–	–	–	–	–	–
CELANEX J600	PBT, (GF + Mica)40	225	95	190	–	205	0.2	0.68
CELSTRAN PBT-GF40-08	PBT, GF40	–	–	225	226	–	0.16	0.87
PBT/BASF								
Ultradur® B 2550	PBT	223	–	65	165	–	1.45	–
Ultradur® B 4030 G6	PBT, GF30	223	–	205	220	–	0.25	–
Ultradur® B 4300 G10	PBT, GF50	223	–	215	220	–	0.25	–
Ultradur® B 4300 G2	PBT, GF10	223	–	200	220	–	0.45	–
Ultradur® B 4300 G3	PBT, GF15	223	–	200	220	–	0.4	–

Ultradur® B 4300 G4	PBT, GF20	223	–	205	220	–	0.35	–
Ultradur® B 4300 G6	PBT, GF30	223	–	215	220	–	0.25	–
Ultradur® B 4300 GM42	PBT, (GF + MF)30	223	–	210	223	–	0.4	–
Ultradur® B 4300 K4	PBT, GB20	223	–	70	170	–	0.85	–
Ultradur® B 4300 K6	PBT, GB30	223	–	95	200	–	0.75	–
Ultradur® B 4400 G5	PBT, GF25	223	–	90	195	–	0.9	–
Ultradur® B 4406	PBT	223	–	212	224	–	0.305	–
Ultradur® B 4406 G2	PBT, GF10	223	–	60	170	170	0.55	–
Ultradur® B 4406 G4	PBT, GF20	223	–	190	215	–	0.5	–
Ultradur® B 4406 G6	PBT, GF30	223	–	200	223	220	0.5	–
Ultradur® B 4500	PBT	223	–	65	165	–	1.45	–
Ultradur® B 4520	PBT	223	–	65	165	–	1.45	–
Ultradur® B 4520 Z2	PBT	223	–	50	120	130	1.35	–
PBT/LANXESS								
Pocan® B 1300	PBT	225	–	60	160	170	1.3	1.3
Pocan® B 1305	PBT	225	–	60	160	180	1.2	1.2
Pocan® B 1501	PBT	225	–	70	170	170	1.3	1.1
Pocan® B 1505	PBT	225	–	70	170	180	1.2	1.2
Pocan® B 1600	PBT	225	–	60	160	170	1.3	1.3
Pocan® B 2505	PBT	225	–	70	160	190	0.8	0.8
Pocan® B 3215	PBT, GF10	225	–	190	*	205	0.5	1.1
Pocan® B 3215 Z	PBT, GF10	225	–	–	–	–	0.5	1.1
Pocan® B 3225	PBT, GF20	225	–	210	220	215	0.3	0.9
Pocan® B 3225 Z	PBT, GF20	225	–	–	–	–	0.3	0.9
Pocan® B 3235	PBT, GF30	225	–	210	220	215	0.3	0.9
Pocan® B 4215	PBT, GF12	225	–	185	205	205	0.4	1
Pocan® B 4225	PBT, GF20	225	–	210	220	205	0.3	0.8

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Pocan® B 4235	PBT, GF30	225	–	210	220	210	0.2	0.8
Pocan® B 4239	PBT, GF30	225	–	205	*	205	0.2	0.8
Pocan® B 7375	PBT, X25	225	–	70	160	185	0.8	0.8
Pocan® B 7425	PBT, GB20	225	–	70	*	190	1	1.1
Pocan® DP 1105	PBT	–	–	65	160	19	–	–
Pocan® DP 7139	PBT	225	–	200	215	21	–	–
Pocan® KL1-7033	PBT, GF30	225	–	200	220	185	0.3	1
Pocan® KL1-7265	PBT, GF15	225	–	195	215	205	0.4	0.9
Pocan® KL1-7835	PBT, (GB + GF)30	225	–	180	*	200	0.3	0.7
Pocan® KU1-7301	PBT	225	–	60	160	170	1.2	1.2
Pocan® KU2-7020/1	PBT, Imod	225	–	–	–	140	–	–
Pocan® KU2-7209	PBT, GF15	225	–	–	–	205	–	–
Pocan® KU2-7240	PBT, GF20	225	–	–	–	205	–	–
Pocan® KU2-7241	PBT, GF25	225	–	190	*	200	0.3	0.9
Pocan® KU2-7503/1 Z	PBT	225	–	–	–	–	–	–
Pocan® KU2-7755	PBT, GF7	225	–	145	*	205	0.6	0.9
Pocan® S 1506	PBT	225	–	55	100	130	1	1.1
Pocan® S 1517	PBT	225	–	60	120	140	1.3	1.3
PBT/DSM								
Arnite® T06 200	PBT	225	–	55	165	*	0.7	0.7
Arnite® T06 200 SNF	PBT	225	–	60	140	*	–	–
Arnite® T06 202	PBT	225	–	55	165	*	0.7	0.7
Arnite® T06 202 XL	PBT	225	–	60	170	*	0.7	0.7
Arnite® T06 204 SN	PBT	225	–	75	165	*	0.7	0.7

Arnite® T06 204 XL	PBT	225	–	60	170	*	0.7	0.7
Arnite® T08 200	PBT	225	–	55	170	*	0.7	0.7
Arnite® TV4 220	PBT, GF10	225	–	–	–	*	–	–
Arnite® TV4 230	PBT, GF15	225	–	195	220	*	0.5	0.8
Arnite® TV4 230 SF	PBT, GF15	225	–	190	215	*	0.4	0.8
Arnite® TV4 240	PBT, GF20	225	–	205	220	*	0.5	0.8
Arnite® TV4 240 S	PBT, GF20	225	–	210	220	*	0.4	0.8
Arnite® TV4 260 S	PBT, GF30	225	–	210	220	*	0.4	0.7
Arnite® TV4 260 SF	PBT, GF30	225	–	210	220	*	0.4	0.7
Arnite® TV4 261	PBT, GF30	225	–	205	220	*	0.4	0.7
PBT/DuPont								
Crastin® 6129 NC010	PBT	225	–	60	160	175	1.3	1.3
Crastin® 6130 NC010	PBT	225	–	60	180	–	1.1	1.4
Crastin® 6131 NC010	PBT	225	–	60	180	175	–	–
Crastin® 6134 NC010	PBT	225	–	60	180	–	–	–
Crastin® BM6450XD BK560	PBT, Imod	220	–	50	130	–	–	–
Crastin® HR5315HF NC010	PBT, Imod, GF15	225	–	200	220	–	–	–
Crastin® HR5330HF NC010	PBT, Imod, GF30	225	–	205	220	–	–	–
Crastin® HTI668FR NC010	PBT, (MD + GF)45	205	–	185	–	170	0.4	1
Crastin® S600F10 NC010	PBT	225	–	60	160	175	1.3	1.3
Crastin® S600F20 NC010	PBT	225	–	60	180	175	1.3	1.3
Crastin® S600F40 NC010	PBT	225	–	60	180	175	1.3	1.3
Crastin® S600LF NC010	PBT	225	–	60	185	175	–	–
Crastin® S620F20 NC010	PBT	225	–	60	180	175	1.3	1.3
Crastin® S660FR NC010	PBT	225	–	55	165	–	–	–
Crastin® SK601 NC010	PBT, GF10	225	–	175	–	205	0.6	1.2
Crastin® SK602 NC010	PBT, GF15	225	–	195	–	205	0.5	1.1
Crastin® SK603 NC010	PBT, GF20	225	–	205	–	210	0.4	1

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (×10E4/°C)	CLTE Normal (×10E 4/°C)
Crastin® SK605 NC010	PBT, GF30	225	–	205	220	215	0.3	0.9
Crastin® SK608 BK509	PBT, GF45	225	–	205	220	215	0.2	0.8
Crastin® SK609 NC010	PBT, GF50	225	–	205	–	215	0.2	0.8
Crastin® SK662FR NC010	PBT, GF15	209	–	200	220	–	1	0.3
Crastin® SK665FR BK507	PBT, GF30	225	–	210	220	–	0.2	0.9
Crastin® SO653 NC010	PBT, GF20	225	–	60	185	195	1.1	1.1
Crastin® ST820 NC010	PBT, Imod	225	–	48	105	125	1.9	1.9
Crastin® ST830FR NC010	PBT, Imod	224	–	58	130	–	–	–
Crastin® ST830FRUV NC010	PBT, Imod	225	–	55	125	–	–	–
Crastin® T803 NC010	PBT, GF20	205	–	180	–	–	0.35	1.6
Crastin® T805 NC010	PBT, GF30	205	–	185	–	190	0.3	1.2
Crastin® T835FRUV NC010	PBT, Imod, GF5	223	–	120	–	–	–	–
Crastin® T841FR NC010	PBT, Gf10	205	–	170	–	180	0.7	1.4
PET/Celanese								
IMPET 2700 GV1/20	PET, GF20	255	–	215	–	255	0.3	–
IMPET 2700 GV1/30	PET, GF30	255	–	225	–	260	0.2	–
IMPET 2700 GV1/45	PET, GF45	255	–	228	–	260	0.15	–
IMPET 320R	PET, GF15	250	–	203	235	–	0.34	0.76
IMPET 330	PET, GF30	250	–	224	240	–	0.32	0.77
IMPET 330R	PET, GF30	250	–	224	240	–	0.32	0.77
IMPET 340R	PET, GF45	250	–	229	252	–	0.68	0.65
IMPET 610R	PET, GF13	250	–	164	223	–	0.38	0.59
IMPET 630R	PET, GF35	250	–	175	230	–	0.31	0.5
IMPET 740	PET, GF45	246	–	228	–	–	0.15	1

IMPET 830R	PET, GF35	–	–	216	235	–	0.31	0.72
IMPET 840R	PET, GF45	250	–	228	244	–	0.15	1
PET/DuPont								
Rynite® 408 NC010	PET, Imod, GF30	250	–	220	–	–	0.14	0.85
Rynite® 415HP NC010	PET, Imod, GF15	250	–	207	238	206	0.2	1.17
Rynite® 425LW BK505	PET	–	–	170	–	–	0.28	0.89
Rynite® 530 NC010	PET, GF30	252	–	224	245	228	0.1	0.81
Rynite® 530CS NC011	PET, GF30	245	–	225	245	–	–	–
Rynite® 536 NC010	PET, GF36	246	–	230	–	–	–	–
Rynite® 545 NC010	PET, GF45	252	–	226	250	230	0.13	0.71
Rynite® 555 NC010	PET	252	–	229	*	230	0.08	0.75
Rynite® 935 NC010	PET, (GF + P)35	252	–	200	230	204	0.16	0.52
Rynite® 936CS NC011	PET, (GD + GF)36	247	–	205	–	225	–	–
Rynite® 940 BK505	PET, (MD + GF)40	250	–	220	241	–	0.15	0.6
Rynite® FR515 NC010	PET, GF15	254	–	200	240	210	0.18	0.88
Rynite® FR530L NC010	PET, GF30	252	–	222	243	218	0.25	1.1
Rynite® FR543 NC010	PET, GF43	254	–	224	240	224	0.11	0.79
Rynite® FR943 NC010	PET, GF45	250	–	220	240	214	0.19	0.65
PET/DSM								
Arnite® A04 900	PET	255	–	80	115	*	0.7	0.7
Arnite® A06 300	PET	255	–	–	–	*	0.8	0.8
Arnite® A06 700	PET	255	–	–	–	*	0.75	0.75
Arnite® AV2 340	PET, GF20	255	–	225	245	*	0.3	0.7
Arnite® AV2 360 S	PET, GF33	255	–	235	250	*	0.2	0.65
Arnite® AV2 365 SN	PET, GF33	255	–	240	250	*	0.2	0.65
Arnite® AV2 370	PET, GF35	255	–	235	250	*	0.3	0.7
Arnite® AV2 370 /B	PET, GF35	255	–	235	250	*	0.3	0.7

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12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Arnite® AV2 372	PET, GF35	255	–	235	250	*	0.3	0.7
Arnite® AV2 390	PET, GF50	255	–	240	255	*	0.2	0.6
Arnite® D00 301	PET	255	–	70	75	*	0.8	0.8
PCT/Celanese								
Thermx® CG033 NC010	PCT, GF30	–	–	262	270	–	0.32	0.85
Thermx® CG043 NC010	PCT, GF40	–	–	–	–	–	0.24	0.75
Thermx® CG923 NC010	PCT, GF20	–	–	234	–	–	0.15	1.1
Thermx® CG933 NC010	PCT, GF30	285	–	103	–	–	0.06	1
LCP/Celanese								
Zenite® 5145L BK010	LCP, GF45	319	–	–	–	–	0.07	0.36
Zenite® 6130 BK010	LCP, GF30	335	–	265	300	–	–	–
Zenite® 6130LX BK010	LCP, GF30	335	–	209	–	–	–	–
Zenite® 6140L BK010	LCP, GF40	335	–	235	–	–	–	–
Zenite® 6330 BK010	LCP, MD30	335	120	245	275	–	–	–
Zenite® 6635 BK010	LCP, (GF + MD)35	335	–	229	–	–	–	–
Zenite® 7130 BK010	LCP, GF30	353	–	295	–	–	0.11	0.21
Zenite® 7145L BK010	LCP, GF45	355	–	295	–	–	0.07	0.24
Zenite® 9140HT NC010	LCP, GF40	–	–	356	–	–	–	–
Zenite® ZE16130A BK010	LCP, GF30	335	–	–	–	–	–	–
Zenite® ZE16401 BK010	LCP, MD30	335	–	240	–	–	–	–
Zenite® ZE17101 BK010	LCP, GF30	352	–	295	–	–	–	–
Zenite® ZE55201 BK010	LCP, (GF + MD)50	335	–	265	300	–	–	–

LCP/Ticona								
VECTRA A115	LCP, GF15	280	–	230	–	162	0.1	0.18
VECTRA A130	LCP, GF30	280	–	235	–	160	0.06	0.23
VECTRA A150	LCP, GF50	280	–	240	–	177	0.07	0.19
VECTRA A230	LCP, CF30	280	–	225	–	158	0.02	0.18
VECTRA A410	LCP, GF25, X25	280	–	235	–	165	0.07	0.24
VECTRA A430	LCP, PTFE	280	–	165	–	138	0.01	0.46
VECTRA A435	LCP, PTFE, GF	280	–	230	–	146	0	0.19
VECTRA A515	LCP, X15	280	–	185	–	149	0	0.3
VECTRA A530	LCP, X30	280	–	190	–	151	0.1	0.3
VECTRA A625	LCP, Graphite25	280	–	185	–	159	0.05	0.19
VECTRA A700	LCP, Z25	280	–	232	–	156	0.08	0.25
VECTRA A725	LCP	280	–	160	–	–	0.1	0.31
VECTRA A950	LCP, GF15	280	–	187	–	145	0.04	0.38
VECTRA B130	LCP, GF30	280	–	235	–	169	0.03	0.13
VECTRA B230	LCP, CF30	280	–	235	–	167	0.01	0.04
VECTRA C115	LCP, GF15	325	–	250	–	176	0.03	0.22
VECTRA C130	LCP, GF30	325	–	255	–	192	0.06	0.18
VECTRA C150	LCP, GF50	325	–	255	–	192	0.04	0.17
VECTRA C550	LCP, X50	325	–	225	–	184	0.1	0.37
VECTRA C810	LCP, X	325	–	197	–	180	0.23	0.4
VECTRA D130M	LCP, Milled Glass30	330	–	220	–	–	0.12	0.38
VECTRA E130i	LCP, GF30	335	–	276	–	195	0.07	0.2
VECTRA E471i	LCP	335	–	265	–	200	0.06	0.18
VECTRA E480i	LCP, GF40	335	–	270	–	–	–	–
VECTRA E530i	LCP, X30	335	–	235	–	–	0.02	0.34
VECTRA E540i	LCP, X40	335	–	230	–	195	0.11	0.11
VECTRA E820i	LCP, X40	335	–	220	–	203	0.17	0.57

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (×10E4/°C)	CLTE Normal (×10E 4/°C)
VECTRA E820i Pd	LCP, X40	–	–	220	–	–	0.23	0.49
VECTRA H130	LCP, GF30	330	–	298	–	221	0.02	0.22
VECTRA H140	LCP, GF40	330	–	306	–	224	0.04	0.18
VECTRA L130	LCP, GF30	300	–	235	–	175	0.05	0.19
VECTRA L140	LCP, GF40	300	–	240	–	176	0.05	0.34
VECTRA MT1300	LCP	280	–	187	–	145	0.04	0.38
VECTRA MT1305	LCP, GF15	280	–	230	–	162	0.1	0.18
VECTRA MT1310	LCP, GF30	280	–	235	–	160	0.06	0.23
VECTRA MT1335	LCP, GF, PTFE	280	–	230	–	146	0	0.19
VECTRA MT1340	LCP, X15	280	–	185	–	149	0	0.3
VECTRA MT1345	LCP, X30	280	–	190	–	151	0.1	0.3
VECTRA MT2310	LCP, GF30	280	–	235	–	169	0.03	0.13
VECTRA MT3310	LCP, GF30	325	–	255	–	192	0.06	0.18
VECTRA MT4310	LCP, GF30	335	–	276	–	195	0.07	0.2
VECTRA MT4350	LCP, X40	335	–	230	–	–	0.11	0.11
VECTRA S135	LCP, GF35	350	–	335	–	–	0.01	0.23
VECTRA T130	LCP, GF30	370	–	300	–	226	0.03	0.19
VECTRA V100P	LCP	–	–	140	–	–	–	–
VECTRA V300P	LCP	–	–	105	–	–	–	–
LCP/Solvay								
XYDAR G-430	LCP, GF30			298				−0.01
XYDAR G-930	LCP, GF30			271				0.05
XYDAR M-345	LCP, T45			229				

Polyester Blends/Bayer								
Bayblend® DP T50	PC + ABS	–	–	97	116	116	0.8	0.85
Bayblend® DP T65 TX	PC + ABS	–	–	–	–	118	–	–
Bayblend® DP T90	PC + ABS	–	–	–	–	125	–	–
Bayblend® FR 2000	PC + ABS	–	–	80	90	93	0.76	0.8
Bayblend® FR 2000 BBS052	PC + ABS	–	–	78	88	91	0.76	0.8
Bayblend® FR 2010	PC + ABS	–	–	90	100	106	0.76	0.8
Bayblend® FR 3000	PC + ABS	–	–	82	92	95	0.76	0.8
Bayblend® FR 3005	PC + ABS	–	–	78	87	93	0.76	0.8
Bayblend® FR 3030	PC + ABS	–	–	96	106	113	0.76	0.8
Bayblend® KU 1-1446	PC + ABS	–	–	98	118	118	0.9	0.95
Bayblend® KU 2-1514	PC + ABS	–	–	115	126	134	0.68	0.68
Bayblend® KU 2-1514 BBS073	PC + ABS	–	–	115	126	134	0.68	0.68
Bayblend® KU 2-1522	PC + ABS, GF10	–	–	121	134	132	0.4	0.75
Bayblend® KU 2-3020	PC + ABS	–	–	86	96	10	–	–
Bayblend® R-R 610	PC + ABS	–	–	85	95	108	0.76	0.8
Bayblend® T45	PC + ABS	–	–	95	112	110	0.85	0.9
Bayblend® T45 PG	PC + ABS	–	–	95	112	110	0.85	0.9
Bayblend® T65	PC + ABS	–	–	100	122	118	0.8	0.85
Bayblend® T85	PC + ABS	–	–	109	127	129	0.75	0.8
Bayblend® T88-2N	PC + ABS, GF10	–	–	118	130	129	0.42	0.8
Bayblend® T88-4N	PC + ABS, GF20	–	–	122	134	132	0.3	0.8
Makroblend® DP 2-7655	PC + PET, MD10	–	–	109	*	–	0.7	0.8
Makroblend® DP 7645	PC + PET, Imod	–	–	–	–	–	0.84	0.9
Makroblend® DP 7665	PC + PET, Imod, MD20	–	–	–	–	–	0.55	0.7
Makroblend® KU 2-7608	PC + PBT, Imod, MD10	225	–	–	–	–	0.7	0.75
Makroblend® KU 2-7609	PC + PBT, Imod, MD20	225	–	–	–	–	0.5	0.55

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Makroblend® KU 2-7912	PC + PBT, Imod	–	–	80	120	–	0.9	0.9
Makroblend® KU 2-7912/4	PC + PBT, Imod	–	–	88	122	–	0.9	0.9
Makroblend® KU 2-7912/5	PC + PBT, Imod	–	–	82	120	–	0.9	0.9
Makroblend® KU 2-7915	PC + PBT, Imod	222	–	85	*	–	0.9	1
Makroblend® KU 2-7940	PC + PBT, Imod	225	–	–	–	122	0.9	0.9
Makroblend® S 7916	PC + PBT, Imod	225	–	60	110	115	1.3	1.3
Makroblend® S 7916/2	PC + PBT, Imod	225	–	60	115	120	1.4	1.4
Polyester Blends/LANXESS								
Pocan® B 7616	PBT + PC, GF30	225	–	100	–	145	0.4	0.7
Pocan® DP 7041	PBT + ASA, GF15	–	–	170	–	–	–	–
Pocan® DP 7042	PBT + ASA, GF20	–	–	175	–	–	–	–
Pocan® DP 7043	PBT + ASA, GF30	–	–	185	–	–	–	–
Pocan® KU1-7313	PBT + PET, GF15	–	–	195	220	195	0.5	1.1
Pocan® KU1-7341	PBT + PET, (GF + MD)40	–	–	180	215	205	0.3	0.6
Pocan® KU1-7625	PBT + PC, GF20	225	–	–	–	–	–	–
Pocan® KU1-7635	PBT + PC, GF30	225	–	–	–	–	–	–
Pocan® KU2-7125	PBT + ABS, GF20	–	–	135	200	130	0.3	0.8
Pocan® KU2-7604	PBT + PC	225	–	–	–	–	1	1
Pocan® T 7323	PBT + PET, GF20	–	–	200	220	205	0.4	0.7
Pocan® T 7331	PBT + PET, GF30	–	–	205	220	210	0.3	0.6
Polyester Blends/DSM								
Arnite® TM4 440	PBT + PET, MD20	225	–	100	195	–	–	–
Arnite® TV4 441	PBT + PET, GF20	–	–	200	–	–	–	–
Arnite® TV4 461	PBT + PET, GF30	–	–	205	225	–	0.4	0.6

Arnite® TV4 461 KL	PBT + PET, GF30	–	–	205	225	–	0.4	0.6
Stapron® E EM 605	PC + PET	–	–	120	–	130	0.8	–
Xantar® C CE 407	PC + ABS	–	–	100	–	120	–	–
Xantar® C CF 107	PC + ABS	–	–	90	–	104	–	–
Xantar® C CF 407	PC + ABS	–	–	100	–	120	–	–
Xantar® C CM 206	PC + ABS	–	–	95	–	110	0.8	–
Xantar® C CM 206 U	PC + ABS	–	–	95	–	110	0.8	–
Xantar® C CM 406	PC + ABS	–	–	105	–	120	–	–
Xantar® C CM 406 FD	PC + ABS	–	–	105	–	120	–	–
Xantar® C CM 406 U	PC + ABS	–	–	105	–	12	–	–
Xantar® C CM 506	PC + ABS	–	–	110	–	13	–	–
Xantar® C CM 506 U	PC + ABS	–	–	110	–	13	–	–
Xantar® C MC 3433	PC + ABS	–	–	90	–	10	–	–
Xantar® C MC 3700	PC + ABS	–	–	110	–	13	–	–
Polyester Blends/BASF								
Ultradur® B 4040 G10	PBT + PET, GF50	235	–	205	221	–	0.25	–
Ultradur® B 4040 G2	PBT + PET, GF10	235	–	168	216	–	–	–
Ultradur® B 4040 G4	PBT + PET, GF20	235	–	180	215	–	–	–
Ultradur® B 4040 G6	PBT + PET, GF30	235	–	202	220	–	–	–
Ultradur® B 4406 G4 Q113	PBT, GF10	223	–	180	215	–	0.35	–
Ultradur® B 4406 G6 Q113	PBT, GF20	223	–	195	220	–	0.28	–
Ultradur® S 4090 G2	PBT + ASA, GF10	223	–	105	190	150	0.55	–
Ultradur® S 4090 G4	PBT + ASA, GF20	223	–	160	205	157	0.4	–
Ultradur® S 4090 G4X	PBT + ASA, GF20	223	–	190	210	–	–	–
Ultradur® S 4090 G6	PBT + ASA, GF30	223	–	175	210	160	0.3	–
Ultradur® S 4090 G6X	PBT + ASA, GF30	223	–	205	220	–	0.3	–
Ultradur® S 4090 GX	PBT + ASA, GF14	223	–	170	210	–	0.52	–

(*Continued*)

12.3 Polyesters—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Tempera-ture (°C)	CLTE Parallel (× 10E4/°C)	CLTE Normal (× 10E 4/°C)
Polyester Blends/DuPont								
Crastin® LW9020 NC010	PBT + ASA, GF20	225	–	170	–	145	0.3	1
Crastin® LW9020FR NC010	PBT + ASA, GF20	225	–	175	–	–	–	–
Crastin® LW9030 NC010	PBT + ASA, GF30	225	–	180	–	150	0.25	1
Crastin® LW9030FR NC010	PBT + ASA, GF30	225	–	190	–	–	–	–
Crastin® LW9320 NC010	PBT + SAN, GF20	220	–	180	–	–	0.3	1
Crastin® LW9330 NC010	PBT + SAN, GF30	220	–	185	–	–	–	–
Polyester Blends/Dow								
PULSE 1310	PC + ABS	–	–	98	122	121	0.65	–
PULSE 1350	PC + ABS	–	–	104	125	128	0.66	–
PULSE 1370	PC + ABS	–	–	105	129	134	0.72	–
PULSE 1550	PC + ABS, GF10	–	–	117	131	131	0.34	–
PULSE 1718GF	PC + ABS, GF20	–	–	113	–	120	–	–
PULSE 2000	PC + ABS	–	–	107	130	130	0.72	–
PULSE 2000EZ	PC + ABS	–	–	105	126	124	0.69	–
PULSE 2100LG	PC + ABS	–	–	104	126	128	0.75	–
PULSE 2200BG	PC + ABS	–	–	109	131	131	0.72	–
PULSE 830	PC + ABS	–	–	105	129	134	0.72	–
PULSE 920MG	PC + ABS	–	–	102	126	128	–	–
PULSE 979	PC + ABS, GF10	–	–	–	–	131	–	–
PULSE A20-95	PC + ABS	–	–	96	110	109	–	–
PULSE A35-105	PC + ABS	–	–	105	126	122	–	–
PULSE A35-110	PC + ABS	–	–	110	130	132	–	–

Polyester Blends/A. Schulman								
SCHULADUR® PCR GF 10	PBT + PET, GF10	–	–	169	–		–	–
SCHULADUR® PCR GF 20	PBT + PET, GF20	–	–	200	225	–	–	–
SCHULADUR® PCR GF 30	PBT + PET, GF30	–	–	205	225	–	–	–
SCHULADUR® PCR GF 45	PBT + PET, GF45	–		202	–		–	–
Polyester Blends/Ticona								
VECTRA V140	LCP + PPS, GF40	280	–	270	–	–	0.11	0.21
VECTRA V143XL	LCP + PPS, GF40	335	–	260	–	–	0.08	0.31
VANDAR 2100	PBT Alloy	225	60	50	110	137	1.3	–
VANDAR 2100UV	PBT Alloy	225	60	50	110	137	1.3	–
VANDAR 2122	PBT Alloy, P10	225	–	53	128	–	–	–
VANDAR 2500	PBT Alloy	225	–	50	125	–	1.3	1.34
VANDAR 4602Z	PBT Alloy	225	60	48	110	130	1.3	–
VANDAR 4612R	PBT Alloy, GF7	225	60	92	200	170	0.4	1.38
VANDAR 4632Z	PBT Alloy, GF15	225	60	154	210	180	0.25	1.41
VANDAR 4662Z	PBT Alloy, GF30	225	60	175	218	190	0.15	1.27
VANDAR 6000	PBT Alloy	–	–	74	106	–	0.9	–
VANDAR 8000	PBT Alloy	225	–	52	127	–	1.1	–

12.4 Polyimides

Name and Grade	Description	Melt Point (°C)	Glass Transi-tion Tempera-ture (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
PEI/SABIC Innovative Plastics								
Ultem® 1000	PEI	–	217	201	210	218	0.558	0.54
Ultem® 1010	PEI	–	217	198	207	218	0.558	–
Ultem® 1100	PEI	–	217	198	–	–	–	–

(*Continued*)

12.4 Polyimides—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Ultem® 1110	PEI	–	217	198	–	–	–	–
Ultem® 1285	PEI Blend	–	–	165	–	181	0.486	0.486
Ultem® 2100	PEI, GF10	–	217	208	210	223	0.324	–
Ultem® 2110	PEI, GF10	–	217	207	–	–	–	–
Ultem® 2200	PEI, GF20	–	217	210	210	220	0.252	–
Ultem® 2210	PEI, GF20	–	217	211	210	225	–	–
Ultem® 2212	PEI, Milled GF20	–	217	205	–	–	–	–
Ultem® 2300	PEI, GF30	–	217	210	212	227	0.198	–
Ultem® 2310	PEI, GF30	–	217	210	–	–	0.162	0.414
Ultem® 2312	PEI, Milled GF30	–	217	207	–	–	0.234	0.27
Ultem® 2400	PEI, GF40	–	217	212	215	234	0.144	–
Ultem® 2410	PEI, GF40	–	217	212	215	234	0.144	–
Ultem® 2412EPR	PEI, GF40	–	217	203	213	222	0.25	0.3
Ultem® 3452	PEI, (GF + MD)45	–	217	212	–	–	–	–
Ultem® 4000	PEI, (GF + PTFE + Graphite)	–	217	212	–	233	0.162	1.62
Ultem® 4001	PEI, PTFE	–	–	200	–	–	–	–
Ultem® 4002	PEI, PTFE	–	–	200	–	219	0.39	0.4
Ultem® 9011	PEI	–	217	–	–	–	–	–
Ultem® CRS5001	PEI	–	225	201	–	–	–	–
Ultem® CRS5011	PEI	–	225	204	–	–	–	–
Ultem® CRS5201	PEI, GF20	–	225	218	–	–	–	–
Ultem® CRS5311	PEI, GF30	–	225	218	–	–	–	–
Ultem® DT1800E	PEI	–	200	178	–	192	0.55	0.55
Ultem® DT1810E	PEI	–	200	178	–	192	0.55	0.55

Ultem® EXUM0169	PEI	–	200	178	–	192	0.55	0.55
Ultem® LTX300A	PEI	–	–	189	204	210	0.5	0.5
Ultem® MD130A	PEI	–	217	198	–	–	–	–
Ultem® XH6050	PEI	–	247	217	237	242	0.5	0.5
PAI/Solvay								
Torlon® 4203L	PAI, X3, PTFE0.5	–	–	278	–	–	0.31	–
Torlon® 4275	PAI, Graphite20, PTFE3			290			0.25	
Torlon® 4301	PAI, Graphite12, PTFE3			279			0.25	
Torlon® 4435	PAI			278			0.144	
Torlon® 5030	PAI, GF30			282			0.16	
Torlon® 7130	PAI, CF30			282			0.09	
PI/DuPont								
Vespel® SP1 DF	PI	–	–	360	–	–	0.31	–
Vespel® ST-2010	PI, Graphite10	–	–	–	–	–	0.5	–
Vespel® SP21	PI, Graphite15	–	–	360	–	–	0.28	–
Vespel® ST-2030	PI, Graphite30	–	–	–	–	–	0.31	–
Vespel® SP22	PI, Graphite40	–	–	–	–	–	0.15	–
Vespel® SP211	PI, Graphite15, PTFE10	–	–	–	–	–	0.54	–
Vespel® SP3	PI, Moly15	–	–	–	–	–	0.47	–

12.5 Polyamides (Nylons)

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
PA6/DuPont								
Minion® 73GM40 NC010	PA6, (MD + GF)40	221	–	195	–	212	0.41	0.77
Minion® 73M30 NC010	PA6, MD30	221	–	78	196	210	0.88	1.02
Minion® 73M30HSL BK489	PA6, MD30	221	–	78	–		–	–
Minion® 73M40 NC010	PA6, MD40	221	–	110	196	210	0.65	0.75
Zytel® 7301J NC010	PA6	221	–	55	160	–	–	–
Zytel® 7331T NC010A	PA6, Imod	221	–	50	150	–	–	–
Zytel® 7335F NC010	PA6	221	–	65	175	200	0.76	0.92
Zytel® 73G15HSL BK363	PA6, GF15	221	–	204	–	–	–	–
Zytel® 73G15L NC010	PA6, GF15	221	–	200	220	215	0.37	1.09
Zytel® 73G15THSL BK240	PA6, GF15, Imod	221	–	200	–	–	–	–
Zytel® 73G30HSL BK416	PA, GF30	221	–	204	220	–	–	–
Zytel® 73G30HSL BK261	PA, GF30	221	–	205	220	–	–	–
Zytel® 73G30HSL NC010	PA6, GF30	221	–	210	220	215	0.22	1.02
Zytel® 73G30L NC010	PA6, GF30	221	–	210	220	–	0.14	1.02
Zytel® 73G30T NC010	PA6, GF30, Imod	221	–	206	–	–	–	–
Zytel® 73G35HSL BK262	PA6, GF35	221	–	208	–	–	–	–
Zytel® 73G45L NC010	PA6, GF45	221	–	213	221	215	0.16	1
Zytel® BM73G15THS BK317	PA6, GF15, Imod	221	–	180	–	–	–	–
Zytel® FR73G20GWF NC010	PA6, GF20	221	–	150	200	–	–	–
Zytel® ST7301 BK356	PA6, Imod	221	–	45	88	–	–	–
Zytel® ST7301 NC010	PA6, Imod	221	–	51	95	–	–	–

PA6/BASF								
Ultramid® 8200	PA6	220	–	60	–	–	–	–
Ultramid® 8200 HS BK-102	PA6	220	–	56	–	–	–	–
Ultramid® 8202	PA6	220	–	60	–	–	–	–
Ultramid® 8202 HS	PA6	220	–	60	–	–	–	–
Ultramid® 8202C	PA6	220	–	65	–	–	–	–
Ultramid® 8202C HS BK-102	PA6	220	–	65	–	–	–	–
Ultramid® 8231G HS	PA6, GF14	220	–	195	217	–	0.39	0.78
Ultramid® 8233G HS	PA6, GF33	220	–	205	215	–	0.21	0.7
Ultramid® 8253 HS	PA6	220	–	55	–	–	0.88	0.93
Ultramid® 8254 HS BK 102	PA6	220	–	43	–	–	0.93	1.11
Ultramid® 8260	PA6, MD40	220	–	–	195	–	0.46	0.58
Ultramid® 8262G HS BK-102	PA6, (MD + GF)20	220	–	163	211	–	–	–
Ultramid® 8266G HS BK102	PA6, (MD + GF)40	220	–	205	217	–	0.21	0.58
Ultramid® 8267G HS BK-102	PA6, (MD + GF)40	220	–	200	215	–	0.3	0.67
Ultramid® 8272G HS BK-102	PA6, GF12	220	–	170	210	–	0.28	0.72
Ultramid® 8333G HI	PA6, GF33	220	–	205	220	–	0.24	0.84
Ultramid® 8350 HS	PA6	220	–	51	–		–	–
Ultramid® 8351 HS BK-102	PA6	220	–	49	–		–	–
Ultramid® B32 Q128	PA6	220	55	65	160	204	0.85	–
Ultramid® B35EG3	PA6, GF15	220	–	190	215	210	0.325	0.75
Ultramid® B35G3 bk 564	PA6, GF15	220	–	187	214	–	–	–
Ultramid® B3EG3	PA6, GF15	220	–	190	215	210	0.325	0.75
Ultramid® B3EG5	PA6, GF25	220	–	210	220	220	0.225	0.65
Ultramid® B3EG6	PA6, GF30	220	–	210	220	220	0.225	0.65
Ultramid® B3G8	PA6, GF40	220	–	215	220	220	0.125	0.625
Ultramid® B3GK24	PA6, (GF + GB)30	220	–	200	215	–	0.375	–
Ultramid® B3GM35 bk 30564	PA6, (MD + GF)40	220	–	190	210	–	0.375	–

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Ultramid® B3GM35 Q224	PA6, (GF + MD)40	260	–	200	215	–	0.375	–
Ultramid® B3GM35 Q611	PA6, (GF + MD)40	220	–	200	215	–	0.38	–
Ultramid® B3K	PA6	220	60	65	180	204	0.85	–
Ultramid® B3L	PA6	220	–	55	150	204	0.85	–
Ultramid® B3L Q235	PA6	220	–	65	150	204	0.85	–
Ultramid® B3M6 bk 30564	PA6, MD30	220	–	70	195	–	0.65	0.6
Ultramid® B3M6 bk 60564	PA6, MD30	220	–	65	190	–	0.65	0.6
Ultramid® B3M6 LS	PA6, MD30	220	–	65	195	–	0.65	0.6
Ultramid® B3M6 Q252	PA6, MD30	220	–	65	190	–	0.65	0.6
Ultramid® B3M6 Q256	PA6, MD30	220	–	65	190	–	0.65	0.6
Ultramid® B3M6 Q94	PA6, MD30	220	–	65	195	–	0.65	0.6
Ultramid® B3S	PA6	220	60	65	180	204	0.85	–
Ultramid® B3UG4	PA6, GF20	220	–	170	210	–	0.525	0.55
Ultramid® B3WG10 bk 564	PA6, GF50	220	–	215	220	–	0.125	0.55
Ultramid® B3WG5	PA6, GF25	220	–	200	220	220	0.225	0.65
Ultramid® B3WG6	PA6, GF30	220	–	210	220	220	0.225	0.65
Ultramid® B3WG6 BGVW bk 564	PA6, GF30	220	–	205	218	–	–	–
Ultramid® B3WG6 GP bk 23210	PA6, GF30	220	–	210	220	–	–	–
Ultramid® B3WG7	PA6, GF35	220	–	215	220	220	0.175	0.65
Ultramid® B3Z Q263	PA6	220	–	40	55	–	–	–
Ultramid® B3ZG3	PA6, GF15	220	–	180	200	–	0.325	0.75
Ultramid® B3ZG6	PA6, GF30	220	–	200	220	220	0.225	0.65
Ultramid® B3ZG8 bk 20560	PA6, GF40	220	–	205	220	–	0.15	0.55
Ultramid® BG40GM45 HS BK-130	PA6, (MD + GF)45	220	–	200	215	–	–	–

Ultramid® HMG13 HS BK-102	PA6, GF63	220	–	214	–	–	–	–
Ultramid® HPN 9350 HS	PA6	220	–	50	–	–	–	–
Ultramid® SEGM35HI BK-126	PA6, (MD + GF)40	220	–	190	215	–	–	–
PA11/Arkema								
RILSAN BECN O TL	PA11	189	–	55	150	160	0.9	–
RILSAN BESN G9 TL	PA11, CD10	189	–	56	168	162	0.9	–
RILSAN BESN O P20 TL	PA11	187	–	47	135	146	1	–
RILSAN BESN O P40 TL	PA11	182	–	45	130	140	1.1	–
RILSAN BESN O TL	PA11	189	–	50	145	160	0.85	–
RILSAN BESVO A FDA	PA11	189	–	50	145	160	0.85	–
RILSAN BMN O P20 D	PA11	187	–	47	135	145	1	–
RILSAN BMN O P40 D	PA11	182	–	45	130	140	1.1	–
RILSAN BMN O TLD	PA11	189	–	50	145	160	0.85	–
RILSAN BMN Y TLD	PA11, Molybdenum	189	–	50	155	162	0.9	–
RILSAN BUM 30 O	PA11, GB30	189	–	60	165	165	0.7	–
RILSAN BZM 23 G9	PA11, GF23, CD7	189	–	170	178	170	0.5	–
RILSAN BZM 30 O TL	PA11, GF30	189	–	175	180	170	0.5	–
RILSAN BZM 43 G9	PA11, GF43, Graphite7	189	–	175	180	180	0.3	–
RILSAN MB 3000	PA11	189	–	–	–	–	1.02	–
RILSAN NAT HP 3504 MB	PA11	185	–	40	–	–	1.38	–
PA12/Evonik								
LAURAMID A	PA12	–	–	127	186	176	–	–
LAURAMID B	PA12	–	–	190	194	188	–	–
VESTAMID L1670 nf	PA12	178	–	50	120	140	1.5	1.5
VESTAMID L1723 sw	PA12	173	–	45	95	130	1.8	1.8
VESTAMID L1833 nf	PA12, GF23	178	–	160	175	175	0.7	0.8
VESTAMID L1930 nf	PA12, GD30	178	–	130	170	170	0.5	0.5
VESTAMID L1940 nf	PA12, GD30	178	–	50	110	140	1.5	1.5

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
VESTAMID L2101 F nf	PA12	178	–	50	110	140	1.5	1.5
VESTAMID L2106F nf	PA12	178	–	40	80	130	1.5	1.5
VESTAMID L2121 nf	PA12	176	–	45	110	130	1.6	1.7
VESTAMID L2121 sw 9.7507	PA12	176	–	45	110	130	1.6	1.5
VESTAMID L2122 nf	PA12	173	–	45	95	125	1.7	1.7
VESTAMID L2122 sw 9.7507	PA12	–	–	45	95	130	1.7	1.6
VESTAMID L2123 nf	PA12	171	–	45	80	120	1.8	1.7
VESTAMID L2124 nf	PA12	–	–	45	90	125	1.8	1.7
VESTAMID L2124 sw 9.7507	PA12	–	–	45	90	125	1.7	1.6
VESTAMID L2128 nf	PA12	164	–	40	70	100	1.8	1.8
VESTAMID L2140 nf	PA12	178	–	50	110	140	1.4	1.4
VESTAMID L2140 sw 9.7504	PA12	–	–	50	110	140	1.4	1.4
VESTAMID L2141 sw 9.7504	PA12	178	–	50	110	140	1.5	1.4
VESTAMID L-CD22-M sw	PA12, CD22	178	–	80	160	160	0.8	–
VESTAMID L-CF15 sw	PA12, CF15	178	–	170	175	175	1.5	1.5
VESTAMID L-GB30 nf	PA12, CB30	178	–	55	150	155	1.3	1.3
VESTAMID L-GF15 nf	PA12, GF15	178	–	160	175	170	0.8	0.8
VESTAMID L-GF30 nf	PA12, GF30	178	–	165	175	175	0.6	0.7
VESTAMID L-R1-MHI sw	PA12	178	–	50	130	140	–	–
VESTAMID L-R2-GF25 sw	PA12, GF25	178	–	170	175	170	1	0.8
VESTAMID L-R3-EI sw	PA12	178	–	60	130	140	1.5	1.5
VESTAMID L-R3-EP sw	PA12	178	–	60	120	140	1.5	1.4
VESTAMID L-R3-MHI sw	PA12	178	–	50	130	140	1.8	1.7
VESTAMID L-R4-MHI sw	PA12	178	–	50	130	140	1.8	–

VESTAMID L-R7-MHI sw	PA12	178	–	50	130	140	1.7	1.8
VESTAMID L-R9-MHI sw	PA12	–	–	50	130	140	–	–
VESTAMID LX9013nf	PA12	172	–	–	–	–	–	–
VESTAMID X7166 nf	PA12	178	–	50	140	150	–	–
VESTAMID X7167 nf	PA12	172	–	50	130	150	0.9	0.8
VESTAMID X7229 nf	PA12	175	–	40	130	150	0.8	–
VESTAMID X7293 nf	PA12	172	–	45	100	130	1.8	1.8
VESTAMID X7293 sw	PA12		–	45	100	130	1.8	1.8
VESTAMID X7373 nf	PA12	178	–	50	130	150	1.5	1.4
PA12/EMS-Grivory								
Grilamid L 16 LM	PA12	178	*	50	125	145	1.2	1.4
Grilamid L 20 EC	PA12, CD25	178	*	65	135	160	1.2	1.3
Grilamid L 20 G	PA12	178	*	45	115	138	1.2	1.4
Grilamid L 20 H FR	PA12	178	*	50	130	138	0.9	1.2
Grilamid L 20 HL black 9563	PA12	178	*	45	115	138	1.2	1.4
Grilamid L 20 L	PA12	178	*	45	115	138	1.2	1.4
Grilamid L 20 LF grey	PA12	178	*	65	140	156	0.8	1.3
Grilamid L 20 LM	PA12	178	*	50	125	143	1.2	1.4
Grilamid L 20 W 20	PA12	174	*	45	100	135	1.4	1.6
Grilamid L 25	PA12	178	*	45	115	138	1.2	1.4
Grilamid L 25 NZ ESD	PA12	178	*	45	95	*	1.3	1.5
Grilamid L 25 W 20 X	PA12	174	*	45	95	128	1.4	1.8
Grilamid L 25 W 20 Y	PA12	178	*	45	95	*	1.4	1.8
Grilamid L 25 W 40	PA12	173	*	45	95	128	1.4	1.8
Grilamid L 25 W 40 ESD	PA12	173	*	45	95	*	1.4	1.8
Grilamid L 25 W 40 X	PA12	173	*	45	95	116	1.4	1.8
Grilamid L 25 Z	PA12	178	*	40	85	*	1.2	1.4

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Grilamid L 25A H	PA12	178	*	45	115	138	1.2	1.4
Grilamid L 25A NZ	PA12	178	*	45	80	*	1.2	1.4
Grilamid LC-3H	PA12, CF30	178	*	165	*	*	0.1	1.3
Grilamid LKN-3H	PA12, CB30	178	*	50	–	*	1.4	1.4
Grilamid LKN-5H	PA12, CB50	178	*	65	*	160	1.2	1.2
Grilamid LV-23 ESD	PA12, GF23	178	*	150	*	*	0.2	1.5
Grilamid LV-23H	PA12, GF23	178	*	155	–	*	0.2	1.5
Grilamid LV-25 HM	PA12, GF25	178	*	135	*	*	0.4	1.5
Grilamid LV-2A NZ	PA12, GF20	178	*	130	160	*	0.4	1.5
Grilamid LV-2H	PA12, GF20	178	*	150	*	*	0.3	1.5
Grilamid LV-3A H	PA12, GF30	178	*	160	*	*	0.2	1.5
Grilamid LV-3H	PA12, GF30	178	*	160	*	170	0.2	1.5
PA46/DSM								
Stanyl® 46HF4130	PA46, GF30	295	75	270	290	290	0.2	0.4
Stanyl® 46HF4530	PA46, GF40	295	75	290	290	290	0.25	0.6
Stanyl® 46HF5040	PA46, GF40	295	75	290	290	290	0.25	0.6
Stanyl® 46HF5041LW	PA46, GF40	295	75	290	290	290	0.2	0.45
Stanyl® 46HF5050	PA46, GF50	295	75	290	290	290	0.2	0.3
Stanyl® TE200F6	PA46, GF30	295	75	290	290	290	0.25	0.6
Stanyl® TE200F8	PA46, GF40	295	75	290	290	290	0.25	0.5
Stanyl® TE250F3	PA46, GF15	295	75	290	290	290	0.4	0.6
Stanyl® TE250F6	PA46, GF30	295	75	290	290	290	0.25	0.55
Stanyl® TE250F8	PA46, GF40	295	75	290	290	290	0.25	0.5
Stanyl® TE250F9	PA46, GF45	295	75	290	290	290	0.2	0.45

Stanyl® TE263F6	PA46, Imod, GF30	295	75	280	–	–	0.2	0.8
Stanyl® TE300	PA46	295	75	190	280	290	0.85	1.1
Stanyl® TE351	PA46	295	75	160	–	–	0.9	0.9
Stanyl® TE373	PA46	295	75	190	–	–	0.85	1.1
Stanyl® TS200F6	PA46, GF30	295	75	290	290	290	0.25	0.6
Stanyl® TS250F4D	PA46, GF20	295	75	290	290	290	0.4	0.6
Stanyl® TS250F6D	PA46, GF30	295	75	290	290	290	0.25	0.55
Stanyl® TS250F8	PA46, GF40	295	75	290	290	290	0.25	0.5
Stanyl® TS256F8	PA46, GF40	295	75	290	290	290	0.2	0.7
Stanyl® TW200B6	PA46, CF30	295	75	290	–	–	0.08	0.34
Stanyl® TW200F3	PA46, GF15	295	75	275	290	290	0.5	0.8
Stanyl® TW200F6	PA46, GF30	295	75	290	290	290	0.25	0.6
Stanyl® TW200F8	PA46, GF40	295	75	290	290	290	0.25	0.5
Stanyl® TW200FM33	PA46, (GF + MD)30	295	75	275	290	290	0.4	0.7
Stanyl® TW241 B3	PA46, CF15	295	75	290	–	–	0.25	0.5
Stanyl® TW241 F12	PA46, GF60	295	75	290	290	290	0.2	0.35
Stanyl® TW241 F3	PA46, GF15	295	75	275	290	290	0.5	0.8
Stanyl® TW241 F6	PA46, GF30	295	75	290	290	290	0.25	0.6
Stanyl® TW241 F8	PA46, GF40	295	75	290	290	290	0.25	0.5
Stanyl® TW242FM10	PA46, (GF + MF)50	295	75	285	290	*	0.25	0.5
Stanyl® TW250F6	PA46, GF30	295	75	290	290	290	0.25	0.55
Stanyl® TW271 F6	PA46, GF30	295	75	290	–	–	0.25	0.5
Stanyl® TW271B3	PA46, CF15	295	75	290	290	290	0.25	0.6
Stanyl® TW275F6	PA46, GF30	295	75	285	290	290	0.25	0.6
Stanyl® TW341	PA46	295	75	190	280	290	0.85	1.1
Stanyl® TW341 B	PA46	295	75	190	280	290	0.85	1.1
Stanyl® TW341-N	PA46	295	75	190	280	290	0.85	1.1

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Stanyl® TW363	PA46, Imod	295	75	90	200	250	1.8	2
Stanyl® TW371	PA46	295	75	190	290	290	0.85	1.1
PA66/DuPont								
Minion® 10B140 BK061	PA66, MD40	263	–	170	240	–		–
Minlon® 10B140 NC010	PA66, MD40	263	–	170	240	245	0.65	0.9
Minlon® 10B40 NC010	PA66, MD40	263	–	200	245	–	0.36	0.66
Minion® 10B40HS1 BK061	PA66, MD40	263	–	200	–	–	0.36	0.66
Minion® 11C140 BK086	PA66, Imod, MD40	256	–	95	–	–	–	–
Minlon® 11C140 NC010	PA66, Imod, MD40	256	–	110	220	235	0.86	0.86
Minion® 11C40 BKB086	PA66, Imod, MD40	256	–	90	210	–	0.64	0.65
Minion® 11C40 NC010	PA66, Imod, MD40	256	–	100	215	–	0.64	0.65
Minion® 12T BKB100	PA66, Imod, MD36	256	–	80	–	–	0.64	0.65
Minion® 12T NC010	PA66, Imod, MD36	256	–	80	205	–	0.64	0.65
Minion® 12TA BKB124	PA66, Imod, MD32	257	–	80	–	–	–	–
Minion® 22C BK086	PA66, (MD + GF)38	263	–	225	–	–	0.41	0.62
Minlon® 22C NC010	PA66, (MD + GF)38	263	–	225	255	–	0.41	0.62
Minlon® EFE6053 BK413	PA66, (MD + GF)40	262	–	240	256	250	0.28	0.87
Minlon® EFE6096 GY090A	PA66, Imod, MD15	263	–	235	–	–	0.34	0.81
Minion® IG38C1 BK434	PA66, (MD + GF)38	263	–	222	–	–	–	–
Zytel® 101 NC001	PA66	262	–	70	200	–	–	–
Zytel® 101F BKB009	PA66	262	–	70	195	–	–	–
Zytel® 101F NC010	PA66	262	–	70	200	238	1	1.1
Zytel® 101L BKB038	PA66	262	–	70	200	–	–	–
Zytel® 101L NC010	PA66	262	–	70	200	238	1	1.1

Zytel® 103FHS BKB009	PA66	262	–	70	195	–	–	–
Zytel® 103FHS NC010	PA66	262	–	70	200	–	1	1.1
Zytel® 103HSL BKB038	PA66	262	–	70	200	–	–	–
Zytel® 103HSL NC010	PA66	262	–	70	200	238	1	1.1
Zytel® 114HSL BK000	PA66, Imod	263	–	65	195	–	–	
Zytel® 132F NC010	PA66	262	–	75	225	–	–	–
Zytel® 135F NC010	PA66	263	–	88	210	243	1.21	1.21
Zytel® 145 BK010	PA66	262	–	65	190	–	1.1	1.1
Zytel® 42A NC010	PA66	262	–	70	200	–	1	1
Zytel® 450HSLX 52 BK1	PA66, Imod	263	–	63	210	–	–	–
Zytel® 45HSB NC010	PA66	262	–	70	–	–	1	1
Zytel® 70G13HS1L BK031	PA66, GF13	262	–	238	258	–	0.4	0.96
Zytel® 70G13HS1L NC010	PA66, GF13	262	–	238	258	–	0.4	0.96
Zytel® 70G13L NC010	PA66, GF13	262	–	238	258	–	0.4	0.96
Zytel® 70G25HSLR BK099	PA66, GF25	262	–	252	–		–	–
Zytel® 70G25HSLR NC010	PA66, GF25	262	–	252	261	257	0.33	1.12
Zytel® 70G30HSL BK039B	PA66, GF30	263	–	250	258	–	–	–
Zytel® 70G30HSLR BK099	PA66, GF30	262	–	253	–		–	–
Zytel® 70G30HSLR NC010	PA66, GF30	262	–	253	261	250	0.22	1.07
Zytel® 70G30HSR2 BK309	PA66, GF30	263	–	–	–	–	–	–
Zytel® 70G30L NC010	PA66, GF30	262	–	253	–	–	–	–
Zytel® 70G33L BK031	PA66, GF33	262	–	252	261	–	0.18	0.83
Zytel® 70G33L NC010	PA66, GF33	262	–	252	261	–	0.18	0.83
Zytel® 70G35HSL BK039B	PA66, GF35	263	–	250	260	–	–	–
Zytel® 70G35HSL NC010	PA66, GF35	262	–	252	261	255	0.2	1
Zytel® 70G35HSLRA4 BK267	PA66, GF35	260	–	250	–	–	–	
Zytel® 70G35HSLX BK357	PA66, GF35	263	–	252	–	–	–	

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Zytel® 70G43HSLA BK099	PA66, GF43	262	–	255	–	–	–	–
Zytel® 70G43L NC010	PA66, GF43	262	–	255	262	255	0.15	0.79
Zytel® 70G50HSLA BK039B	PA66, GF50	262	–	253	–	–	–	–
Zytel® 70G60HSL BK359	PA66, GF60	263	–	255	260	250	–	–
Zytel® 70K20HSL NC010	PA66, RF20	263	–	222	255	250	–	–
Zytel® 70K20HSL BK284	PA66, RF20	263	–	–	–	–	–	–
Zytel® 80G14AHS NC010	PA66, Imod, GF14	263	–	238	255	–	0.4	1.04
Zytel® 80G25HS NC010	PA66, Imod, GF25	262	–	245	–	–	–	–
Zytel® 80G33L NC010	PA66, Imod, GF33	262	–	247	262	–	0.15	1.19
Zytel® 80G43HS1L BK104	PA66, Imod, GF43	262	–	250	261	–	–	–
Zytel® CDV595 BK409	PA66, GF	263	–	248	260	–	0.16	0.72
Zytel® CDV805 BK409	PA66, Imod, GF	250	–	225	–	–	–	–
Zytel® CDV808 BK409	PA66, Imod	–	–	185	230	–	–	–
Zytel® E51 HSB NC010	PA66	262	–	70	200	–	–	–
Zytel® EFE1068 NC010T	PA66	263	–	70	–	–	–	–
Zytel® EFE8089B BK416	PA66, Imod, GF33	262	–	245	–	–	–	–
Zytel® FE3071 NC010	PA66	262	–	70	200	–	–	–
Zytel® FE3757 NC010	PA66	263	–	66	195	–	0.8	0.9
Zytel® FE5480HS BK32N	PA66, GF26	263	–	253	–	–	–	–
Zytel® FE5555 BK538	PA66 + PA6, GF35	260	–	250	–	–	–	–
Zytel® FR50 NC010	PA66, GF25	–	–	239	–	–	–	–
Zytel® FR7026V0F NC010	PA66	263	–	70	–	–	–	
Zytel® FR70M30V0 NC010	PA66, MD30	263	–	200	238	235	0.64	0.81
Zytel® MT409AHS BK010	PA66, Imod	262	–	65	187	–	1	1

Zytel® MT409AHS NC010	PA66, Imod	262	–	66	205	–	1	1.2
Zytel® ST801A NC010	PA66, Imod	262	–	63	157	–	1.4	1.3
Zytel® ST801AHS BK01 0	PA66, Imod	262	–	61	147	–	1.4	1.2
Zytel® ST801AHS NC010	PA66, Imod	262	–	62	157	–	0.9	1.2
Zytel® ST801AW BK195	PA66, Imod	262	–	62	162	–	1.5	1.3
Zytel® ST801AW NC010	PA66, Imod	262	–	60	155	–	1.4	1.2
PA66/BASF								
Ultramid® A3EG10	PA66, GF50	260	–	250	250	250	0.125	0.55
Ultramid® A3EG5	PA66, GF25	260	–	245	250	250	0.3	0.65
Ultramid® A3EG6	PA66, GF30	260	–	250	250	250	0.25	0.65
Ultramid® A3EG7	PA66, GF35	260	–	250	250	250	0.175	0.65
Ultramid® A3EG7 Q206	PA66, GF35	260	–	250	250	250	0.175	0.65
Ultramid® A3HG5	PA66, GF25	260	–	245	250	250	0.3	0.65
Ultramid® A3HG6 HR bk 23591	PA66, GF30	260	–	250	250	250	0.25	0.65
Ultramid® A3HG7	PA66, GF35	260	–	250	250	250	0.175	0.65
Ultramid® A3K	PA66	260	72	75	220	250	0.85	–
Ultramid® A3K Q202	PA66	260	72	75	220	250	0.85	–
Ultramid® A3SK	PA66	260	–	75	220	250	0.85	–
Ultramid® A3SK Q202	PA66	260	–	75	220	–	0.85	–
Ultramid® A3W	PA66	260	–	75	220	250	0.85	–
Ultramid® A3WG10	PA66, GF50	260	–	250	250	250	0.125	0.55
Ultramid® A3WG3	PA66, GF15	260	–	240	250	250	0.325	0.75
Ultramid® A3WG5	PA66, GF25	260	–	245	250	250	0.3	0.65
Ultramid® A3WG6	PA66, GF30	260	–	250	250	250	0.25	0.65
Ultramid® A3WG7	PA66, GF35	260	–	250	250	250	0.175	0.65
Ultramid® A3WGM53 bk 20560	PA66, (GF + MD)40	260	–	225	250	–	0.15	0.65
Ultramid® A3X2G10	PA66, GF50	260	–	250	250	–	0.175	0.45
Ultramid® A3X2G7	PA66, GF35	260	–	250	250	–	0.175	0.65

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Ultramid® A3X3G5	PA66, GF25	260	–	250	250	–	0.3	0.7
Ultramid® A3XZG5	PA66, GF25	260	–	250	250	–	0.3	0.7
Ultramid® A3Z	PA66	260	–	60	125	–	0.85	–
Ultramid® A3ZG6 bk 20591	PA66, GF30	260	–	240	250	–	0.3	0.65
PA610/Toray Resin Company								
Amilan® CM2001	PA610	225	–	–	180	–	1.2	–
Amilan® CM2006	PA610	225	–	–	180	–	1	–
Amilan® CM2401	PA610	220	–	–	–	–	–	–
PA612/DuPont								
Zytel® 151 L NC010	PA612	218	–	62	135	181	1.1	1.2
Zytel® 153HSL NC010	PA612	218	–	62	135	181	1.2	1.2
Zytel® 157HSL BK010	PA612	218	–	62	–	–	–	
Zytel® 158 NC010	PA612	218	–	62	135	181	1.2	1.2
Zytel® 158L NC010	PA612	218	–	62	135	–	1.2	1.2
Zytel® 159 NC010	PA612	216	–	62	–	–	–	–
Zytel® 159L NC010	PA612	216	–	62	–	–	–	–
Zytel® 350PHS2 NC010	PA612, Imod	215	–	45	120	–	–	–
Zytel® 77G33HS1L NC010	PA612, GF33	218	–	200	216	–	0.17	1.13
Zytel® 77G33L BK031	PA612, GF33	218	–	200	–	–	0.17	1.13
Zytel® 77G33L NC010	PA612, GF33	218	–	200	216	–	0.17	1.13
Zytel® 77G43L BK031	PA612, GF43	218	–	205	217	–	0.1	1.04
Zytel® 77G43L NC010	PA612, GF43	218	–	203	217	–	0.1	1.04

PA666/BASF								
Ultramid® 1C	PA666	–	–	–	–	–	–	–
Ultramid® C3U	PA666	243	–	70	210	250	0.8	0.9
Ultramid® CC4	PA666	196	–	–	–	–	–	–
PPA/DuPont								
Zytel® HTN51G25HSL BK083	PA6T/XT, GF25	300	–	263	–	–	–	–
Zytel® HTN51G35HSL NC010	PA6T/XT, GF35	300	–	265	275	–	0.15	0.5
Zytel® HTN51G35HSLR BK420	PA6T/XT, GF35	300	–	264	276	–	–	–
Zytel® HTN51G45HSL NC010	PA6T/XT, GF45	300	–	265	275	–	0.15	0.45
Zytel® HTN51G45HSLR BK420	PA6T/XT, GF45	300	–	–	–	–		–
Zytel® HTN51GM60THS BK083	PA6T/XT, Imod, (GF + MD)60	300	–	260	280	–	–	–
Zytel® HTN51LG50HSL BK083	PA6T/XT, GF50	300	–	243	–	–		–
Zytel® HTN52G45HSL NC010	PA6T/66, GF35	–	–	285	–	–	–	–
Zytel® HTNFE150005 BK083	PA6T/XT, (MD + GF) 40	300	–	250	–	–	–	–
Zytel® HTNFE16502 BK001	PA6T/XT, MD40	300	–	250	276	–	–	–
Zytel® HTNFE250020 NC010	PA6T/XT, Imod, MD30	301	–	264	280	–	–	–
Zytel® HTNFE350006 NC010	PA6T/XT, Imod, MD30	304	–	260	278	–	–	–
Zytel® HTNFE350015 NC010	PA6T/XT, Imod	304	–	–	–	–	–	–
Zytel® HTNFE8200 NC010	PA6T/XT, Imod	300	–	206	220	–	–	–
Zytel® HTNFR51G35L NC010	PA6T/XT, GF35	295	–	255	270	–	0.2	0.5
Zytel® HTNWRF51 G30 NC010	PA6T/XT, GF30	300	–	260	–	–	–	–
Zytel® HTNWRF51 K20 NC010	PA6T/XT, RF20	300	–	220	–	–	–	–
PPA/Solvay								
AMODEL A-1133 HS	PA66/6T, GF33	313	127	280	297	–	0.239	0.599
AMODEL A-1145 HS	PA66/6T, GF45	312	127	287	301	–	0.15	0.5
AMODEL A-1230 L	PA66/6T, MD30	312	127	171	260	301	0.41	0.49
AMODEL A-1240 HS	PA66/6T, MD40	312	127	179	260	–	0.34	0.4

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
AMODEL A-1240 L	PA66/6T, MD40	312	127	150	260	–	0.34	0.4
AMODEL A-1565 HS	PA66/6T	312	127	271	–	–	0.212	0.304
AMODEL AF-1133 V0	PA66/6T, GF33	326	95	294	–	–	0.2	0.661
AMODEL AF-1145 V0	PA66/6T, GF45	326	95	298	–	–	0.12	0.571
AMODEL AF-4133 V0	PA66/6T, GF33	312	127	273	–	–	0.2	0.391
AMODEL AF-4145 V0	PA66/6T, GF45	312	127	275	–	295	–	–
AMODEL AFA-4133 V0 Z	PA66/6T, GF33	325	95	295	–		–	–
AMODEL AFA-6133 V0 Z	PA66/6T, GF33	310	90	277	–		–	
AMODEL AFA-6145 V0 Z	PA66/6T, GF45	310	90	277	–		–	–
AMODEL AP-9240 NL NT	PA66/6T, Imod, MD40	313	–	115	–	–	–	–
AMODEL AS-1133 HS	PA66/6T, GF33	312	127	277	297	298	0.239	0.599
AMODEL AS-1145 HS	PA66/6T, GF45	312	127	287	301	–	0.15	0.5
AMODEL AS-1566 HS	PA66/6T, (GF+MD) 65	312	127	271	–	–	0.11	0.38
AMODEL AS-1933 HS	PA66/6T, GF33	312	127	278	–	–	–	–
AMODEL AS-1945 HS	PA66/6T, GF45	312	127	282	–	–	–	–
AMODEL AS-4133 HS	PA66/6T, GF33	326	95	298	320	–	0.22	0.59
AMODEL AS-4145 HS	PA66/6T, GF45	320	95	298	320	–	0.16	0.59
AMODEL AT-1001 L	PA66/6T, Imod	312	127	120	–	–	0.95	0.9
AMODEL AT-1116 HS	PA66/6T, GF16	312	127	256	300	–	–	–
AMODEL AT-1125 HS	PA66/6T, GF25	312	127	280	300	–	–	–
AMODEL AT-5001	PA66/6T	300	90	88	185	–	0.94	–
AMODEL AT-6115 HS	PA66/6T, GF15	307	90	265	298	–	–	–
AMODEL ET-1001 HS	PA66/6T, Imod	312	127	120	–	–	–	–
AMODEL ET-1001 L	PA66/6T, Imod	312	127	120	–	–	–	–

Polyarylamide/Mitsubishi Engineering-Plastics Corp								
Reny 1002H	PAMXD6, GF30	–	–	224	237	–	0.2	0.5
Reny 1012H	PAMXD6, GF40	–	–	226	237	–	0.2	0.5
Reny 1021UCS	PAMXD6, GF50	–	–	217	227	–	–	–
Reny 1022H	PAMXD6, GF50	–	–	230	238	–	0.1	0.4
Reny 1025	PAMXD6, GF50	–	–	231	238	–	0.1	0.4
Reny 1027	PAMXD6, GF50	–	–	221	233	–	–	–
Reny 1032	PAMXD6, GF60	–	–	230	237	–	0.1	0.4
Reny 1071	PAMXD6, GF55	–	–	230	–	–	0.1	0.3
Reny 1313	PAMXD6, GF40	–	–	217	235	–	0.2	0.6
Reny 1501AH	PAMXD6, GF30	–	–	220	237	–	0.2	0.5
Reny 1511AH	PAMXD6, GF30	–	–	224	237	–	–	–
Reny 1521AH	PAMXD6, GF50	–	–	228	238	–	–	–
Reny 1722F	PAMXD6, GF50	–	–	226	237	–	–	–
Reny 2502A	PAMXD6, (GF + MD) 20	–	–	217	235	–	0.2	0.3
Reny 2620	PAMXD6, GF20	–	–	214	234	–	0.1	0.4
Reny 4011	PAMXD6, GF40	–	–	226	235	–	0.1	0.08
Reny 4511	PAMXD6, GF40	–	–	223	234	–	0.4	0.4
Reny C36	PAMXD6, CF30	–	–	224	236	–	0.05	0.5
Reny G07S	PAMXD6, GF20	–	–	236	255	–	–	–
Reny G16S	PAMXD6, CF20	–	–	240	–	–	–	–
Reny N252	PAMXD6, GF25	–	–	227	236	–	0.2	0.4
Reny W110	PAMXD6, Whisker	–	–	218	–	–	0.04	0.3
Reny W38S2	PAMXD6, MD30	–	–	210	239	–	0.2	0.4
Polyarylamide/Solvay								
IXEF® 1002	PAMXD6, GF30	–	–	230	*	–	0.18	–
IXEF® 1022	PAMXD6, GF50	–	–	230	*	210	0.17	0.41
IXEF® 1023	PAMXD6, GF50	–	–	230	*	–	0.17	0.41

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
IXEF® 1025	PAMXD6, GF50	–	–	230	*	–	0.17	0.41
IXEF® 1027	PAMXD6, GF50	–	–	220	*	–	0.17	0.41
IXEF® 1028	PAMXD6, GF50	–	–	225	*	–	0.17	0.42
IXEF® 1032	PAMXD6, GF60	–	–	230	*	–	0.14	0.35
IXEF® 1313	PAMXD6, GF40	–	–	215	*	–	0.18	–
IXEF® 1501	PAMXD6, GF30	–	–	230	*	–	0.18	–
IXEF® 1521	PAMXD6, GF50	–	–	230		–	0.17	0.41
IXEF® 1622	PAMXD6, Imod, GF50	–	–	220	*		0.15	0.43
IXEF® 2011	PAMXD6, MD42	–	–	185	*		0.18	0.45
IXEF® 2030	PAMXD6, MD55	–	–	220	*	–	0.18	0.33
IXEF® 2057	PAMXD6, MD45	–	–	150		–	0.14	0.35
IXEF® 2530	PAMXD6, (MD + GF) 55	–	–	205	*	–	–	–
IXEF® 3006	PAMXD6, CF30	–	–	230	*	–	–	–
Polyamide Alloys/Arkema								
ORGALLOY LE 6000	PA6 Alloy	220	*	45	–	97	–	–
ORGALLOY LE 60HM	PA6 Alloy	220	*	–	–	–	–	–
ORGALLOY LE 60LM	PA6 Alloy	220	*	–	–	–	–	–
ORGALLOY LE 60LMXV	PA6 Alloy	220	*	–	–	60	2	–
ORGALLOY LE 60SF	PA6 Alloy	220	*	–	–	99	–	–
ORGALLOY LE 60THM	PA6 Alloy	220	*	50	80	–	–	–
ORGALLOY LT 4060	PA6 Alloy	220	*	–	60	–	–	–
ORGALLOY LT 4060ES noir T6L	PA6 Alloy	220	*	–	60	–	–	–
ORGALLOY LT 5050 T6L	PA6 Alloy	220	*	–	–	–	1.7	1.8

ORGALLOY LT 5050ES noir	PA6 Alloy	220	*	–	–	–	1.7	1.8
ORGALLOY R 60ES	PA6 Alloy	220	*	75	130	130	0.93	1.33
ORGALLOY RS 6000	PA6 Alloy	220	*	75	130	129	0.93	1.33
ORGALLOY RS 6010	PA6 Alloy, GF10	220	*	190	210	–	–	–
ORGALLOY RS 6015ES noir T6L	PA6 Alloy, GF15	220	*	175	210	–	–	–
ORGALLOY RS 6030	PA6 Alloy, GF30	220	*	190	210	183	0.19	1.26
ORGALLOY RS 60E10	PA6 Alloy, Imod	220	*	50	90	–	1.1	1.43
ORGALLOY RS 6600	PA6 Alloy	255	*	80	160	165	0.65	1.1
ORGALLOY RS 6620	PA6 Alloy, GF20	255	*	220	240	160	–	–
ORGALLOY RS 6630	PA6 Alloy, GF30	255	*	225	245	195	0.18	1.1
Polyamide Alloys/Rhodia								
Technyl® Alloy KC 216	PA6 + ABS	220	–	70	110	–	–	–
Technyl® Alloy KC 216 V12 Black	PA6 + ABS, GF12	220	–	145	200	–	–	–
Technyl® Alloy KC 226 BLACK	PA6 + ABS	220	–	75	115	–	–	–
PA Alloy/EMS-Grivory								
Grilon TS FR	PA66 + PA6	260	–	60	205	*	0.7	0.9
Grilon TS V0	PA66 + PA6	260	–	70	210	*	0.7	0.9
Grilon TSC-10/4 EC	PA66 + PA6, CF10	260	–	240	*	*	0.2	1
Grilon TSC-20/4 EC	PA66 + PA6, CF20	260	–	240	*	*	0.2	0.9
Grilon TSC-30/4 EC	PA66 + PA6, CF30	260	–	240	*	–	0.1	0.8
Grilon TSC-30/4 LF 15	PA66 + PA6, CF30	260	–	235	*	*	0.1	0.8
Grilon TSC-40/4 EC	PA66 + PA6, CF40	260	–	240	*	*	0.1	0.7
Grilon TSG-30	PA66 + PA6, GF30	260	*	220	*	–	0.2	1.1
Grilon TSG-30 FR	PA66 + PA6, GF30	260	–	180	*	–	0.2	1
Grilon TSG-30/4	PA66 + PA6, GF30	260	–	235	*	*	0.2	1
Grilon TSG-35/4	PA66 + PA6, GF35	260	–	240	*	–	0.2	1
Grilon TSG-50	PA66 + PA6, GF50	260	*	220	*	–	0.15	1
Grilon TSG-50/4	PA66 + PA6, GF50	260	–	250	*	*	0.15	0.9

(*Continued*)

12.5 Polyamides (Nylons)—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Grilon TSGK-30 X	PA66 + PA6, (GF + GB)30	260		215	*	–	0.6	0.8
Grilon TSGZ-15	PA66 + PA6, Imod, GF15	260	–	215	*	–	0.2	1.1
Grilon TSGZ-30	PA66 + PA6, Imod, GF30	260	–	215	*	–	0.2	1.1
Grilon TSK-30/4	PA66 + PA6, GB30	260	–	70	*	*	0.8	0.8
Grilon TSM-30	PA66 + PA6, MD30	260	–	110	*	*	0.8	0.8
Grilon TSS	PA66 + PA6	260	–	55	140	*	0.8	1.2
Grilon TSS/4	PA66 + PA6	260	–	65	220	*	0.7	0.8
Grilon TSS/4 LF 2	PA66 + PA6, Moly2	260	–	85	220	–	0.6	0.9
Grilon TSS/4 LF 20	PA66 + PA6, (PTFE + Si)20	260	–	85	*	*	0.8	0.9
Grilon TSZ 1	PA66 + PA6, Imod	260	*	55	*	*	1.2	1.5
Grilon TSZ 3	PA66 + PA6, Imod	260	–	55	*	*	1.2	1.5
Grivory GC-4H	PA66 + PA6I/6T, CF40	260	*	235	*	*	0.1	0.8
Grivory GM-4H	PA66 + PA6I/6T, MD40	260	*	105	*	*	0.9	0.9
Grivory GV-2H	PA66 + PA6I/6T, GF20	260	*	230	*	237	0.1	1
Grivory GV-4H	PA66 + PA6I/6T, GF40	260	*	235	*	245	0.15	0.9
Grivory GV-5H	PA66 + PA6I/6T, GF50	260	*	235	*	245	0.15	0.9
Grivory GV-6H	PA66 + PA6I/6T, GF60	260	*	235	*	245	0.15	0.9

12.6 Polyolefins and Acrylics

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
PE/Celanese								
GUR GHR 8020	HDPE	133	–	–	–	–	–	–
GUR GHR 8110	HDPE	–	–	44	75	80	2	–
GUR HOSTALLOY 731	HDPE	–	–	–	–	80	2	–
GUR 2122	UHMWPE	–	–	42	65	80	2	–
GUR 4113	UHMWPE	–	–	42	65	80	2	–
GUR 4120	UHMWPE	–	–	42	65	80	2	–
GUR 413	UHMWPE	–	–	42	65	80	2	–
GUR 415	UHMWPE	–	–	42	65	80	2	–
PP/Albis Plastic GmgH								
ALCOM® PP 620/8 GF/MRX	PP, GF	–	–	110	–	110	–	–
ALTECH® PP-B A 1000/120 UV	PP	–	–	–	–	82	–	–
ALTECH® PP-B A 2020/150 GF20 CP	PP, GF20	–	–	125	–	107	–	–
ALTECH® PP-B A 2030/150 GF30 CP	PP, GF30	–	–	–	–	105	–	–
ALTECH® PP-B A 2040/150 GF40 CP	PP, GF40	–	–	145	–	120	–	–
ALTECH® PP-B A 4430/120 MR30 UV	PP, Chalk20, T10	–	–	–	–	75	–	–
ALTECH® PP-B A 4815/100 MR15	PP, MD15	–	–	65	–	76	–	–
ALTECH® PP-B A 4920/100 MR20	PP, T20	–	–	56	–	64	–	–
ALTECH® PP-H A 1000/100 DS	PP	163	–	50	–	90	–	–
ALTECH® PP-H A 1000/140 FR	PP	–	–	73	–	100	–	–
ALTECH® PP-H A 1000/149 FR	PP	163	–	54	85	85	–	–
ALTECH® PP-H A 2020/100 GF20	PP, GF20	163	–	134	–	105	–	–

(*Continued*)

12.6 Polyolefins and Acrylics—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
ALTECH® PP-H A 2020/150 GF20 CP	PP, GF20	163	–	130	–	126	–	–
ALTECH® PP-H A 2030/100 GF30	PP, GF30	163	–	138	–	110	–	–
ALTECH® PP-H A 2030/150 GF30 CP	PP, GF30	163	–	140	–	130	–	–
ALTECH® PP-H A 2030/156 GF30 CP	PP, GF30	–	–	148	–	138	–	–
ALTECH® PP-H A 2030/157 GF30 CP	PP, GF30	–	–	148	–	135	–	–
ALTECH® PP-H A 2030/158 GF30 CP	PP, GF30	–		145	–	135	–	–
ALTECH® PP-H A 2030/250 GF30 CP	PP, GF30	–	–	138	–	135	–	–
ALTECH® PP-H A 2030/252 GF30 UV CP	PP, GF30	–	–	140	–	130	–	–
ALTECH® PP-H A 2040/150 GF40 CP	PP, GF40	163	–	140	–	135	–	–
ALTECH® PP-H A 3020/100 GB20	PP, GB20	163	–	60	95	95	–	–
ALTECH® PP-H A 3030/100 GB30	PP, GB30	–	–	65	–	90	–	–
ALTECH® PP-H A 4818/100 MR18 DS	PP, Chalk18	163	–	60	100	98	–	–
ALTECH® PP-H A 4920/100 MR20	PP, T20	163	–	75	120	100	–	–
ALTECH® PP-H A 4920/106 MR20	PP, T20	163	–	75	120	100	–	–
ALTECH® PP-H A 4920/170 MR20	PP, T20	–	–	77	–	108	–	–
ALTECH® PP-H A 4930/100 MR30	PP, T30	–	–	85	–	10		–
ALTECH® PP-H A 4930/106 MR30	PP, T30	–	–	–	–	100	:	–
ALTECH® PP-H A 4940/100 MR40	PP, T40	163	–	95	135	105	–	–
PP/A. Schulman								
POLYFLAM® RIPP 3125 CS1	PP, T25	–	–	66	102	6	–	–
POLYFLAM® RIPP 374 ND CS1	PP, T20	165	−15	67	101	5	–	–
POLYFLAM® RIPP 490	PP	–	–	58	108	7	–	–
POLYFLAM® RIPP 5000 E	PP	–	–	57	89	6	–	–
POLYFLAM® RIPP 5440	PP	–	–	52	85	7	–	–

POLYFLAM® RLD 10 D	PP	–	–	34	46	3	–	–
POLYFLAM® RPP 3130 CS1	PP, T30	–	–	72	105	73	–	–
POLYFLAM® RPP 3230 CS1	PP, GF30	–	–	145	157	129	–	–
POLYFLAM® RPP 371 ND	PP, T20	167	−10	63	110	77	–	–
POLYFLAM® RPP 374 ND CS1	PP, T20	165	−10	84	118	82	–	–
POLYFLAM® RPP 374 ND CS1 5V	PP, T20	165	−10	80	118	92	–	–
POLYFLAM® RPP 490 CS1	PP	–	–	60	105	98	–	–
POLYFLAM® RPP 500 D	PP	165	−10	85	120	94	–	–
POLYFORT® AFP 2934	PP	–	–	42	61	45	–	–
POLYFORT® AFP 3306 Rezyklat	PP	–	–	49	–	–	–	–
POLYFORT® AFP 3318	PP, Imod, T20	–	–	50	88	56	–	–
POLYFORT® FIP 20 M K1033	PP, MD20	165	−10	62	105	94	0.8	–
POLYFORT® FIP 20 MA K1469	PP, MD20	–	–	55	92	97	–	–
POLYFORT® FIP 40 MA K1544	PP, MD40	–	–	*	93	98	–	–
POLYFORT® FIPP 15 M HSR 3329	PP, MD15	162	−20	52	88	61	0.8	–
POLYFORT® FIPP 15 M HSR K1757	PP, MD15	–	–	51	88	–	–	–
POLYFORT® FIPP 20 M HSR 3329	PP, MD20	162	−20	66	105	66	0.8	–
POLYFORT® FIPP 20 T	PP, T20	162	−21	64	103	70	0.8	–
POLYFORT® FIPP 20 T LE K1731	PP, T20	–	–	60	99	67	–	–
POLYFORT® FIPP 20 T LE K1756	PP, T20	162	−21	*	–	–	0.8	–
POLYFORT® FIPP 20 T LE K1832	PP, T20	–	–	48	103	–	0.8	–
POLYFORT® FIPP 20 TSP UVA/2	PP, T20	162	−21	52	83	70	0.8	–
POLYFORT® FIPP 30 T K1005	PP, T30	163	−20	69	113	75	0.8	–
POLYFORT® FIPP 30 TF	PP, T30	–	–	79	117	74	–	–
POLYFORT® FIPP 65/10 BSGF	PP, Barium Sulfate55, GF10	–	–	114	149	–	–	–
POLYFORT® FPP 10 T WLB	PP, T10	165	−10	56	93	88	0.8	–
POLYFORT® FPP 20 GB	PP, GB20	165	−10	81	119	95	0.6	–

(*Continued*)

12.6 Polyolefins and Acrylics—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
POLYFORT® FPP 20 GF	PP, GB20	165	−10	105	142	101	0.6	–
POLYFORT® FPP 20 GFC	PP, GB20	165	−10	136	153	115	0.6	–
POLYFORT® FPP 20 GFC K1400	PP, GB20	–	–	129	156	126	0.6	–
POLYFORT® FPP 20 GFC SHH LW	PP, GB20	165	−10	126	150	–	0.7	–
POLYFORT® FPP 20 GFM HI	PP, GB20	167	−10	64	115	–	0.8	–
POLYFORT® FPP 20 T	PP, T20	–	–	70	125	95	–	–
POLYFORT® FPP 20 T K1534 natur	PP, T20	165	−10	65	105	70	8	–
POLYFORT® FPP 20 T K1751	PP, T20	–	–	57	102	65	–	–
POLYFORT® FPP 20 T Recyclat	PP, T20	–	–	54	8	–	–	–
POLYFORT® FPP 20 T SHH LW	PP, T20	–	–	72	–	97	–	–
POLYFORT® FPP 20 T WLB	PP, T20	–	–	64	105	91	–	–
POLYFORT® FPP 20 TF WLB	PP, T20	–	–	64	107	95	–	–
POLYFORT® FPP 20/10 GFM	PP, GF30	–	–	120	145	–	–	–
POLYFORT® FPP 22 T K1093	PP, T22	165	−10	66	118	95	0.8	–
POLYFORT® FPP 22 T LE K1684	PP, T22	–	–	68	114	94	–	–
POLYFORT® FPP 30 GF	PP, GF30	165	−10	110	148	105	0.8	–
POLYFORT® FPP 30 GFC	PP, GF30	165	−10	144	159	127	0.8	–
POLYFORT® FPP 30 GFC BOW	PP, GF30	165	−10	144	159	127	0.8	–
POLYFORT® FPP 30 GFC HI	PP, GF30	165	−10	120	150	90	0.8	–
POLYFORT® FPP 30 GFC K1079	PP, GF30	165	−10	145	160	136	0.8	–
POLYFORT® FPP 30 GFC-F WLB	PP, GF30	–	–	144	161	140	–	–
POLYFORT® FPP 30 T SHH REC	PP, T30	–	–	*	105	–	–	–
POLYFORT® FPP 30/10 GBGF	PP, (GF + GB)40	–	–	112	150	–	–	–
POLYFORT® FPP 38 T K1419	PP, T38	165	−10	80	133	95	0.8	–
POLYFORT® FPP 38 T K1785	PP, T38	–	–	73	–	–	–	–

POLYFORT® FPP 40 GFC HI	PP, GF40	–	–	141	158	131	–	–
POLYFORT® FPP 40 GFC schwarz	PP, GF40	165	−10	147	–	140	–	–
POLYFORT® FPP 40 K	PP, Chalk40	–	–	56	90	91	–	–
POLYFORT® FPP 40 T	PP, T40	167	−10	80	133	97	0.8	–
POLYFORT® FPP 40 T K1442	PP, T40	167	−10	85	135	–	0.8	–
POLYFORT® FPP 40 T REC	PP, T40	–	–	*	110	–	0.8	–
POLYFORT® FPP 40 T WLB	PP, T40	–	–	74	125	94	–	–
POLYFORT® FPP 70 BS	PP, Barium Sulfate75	165	−10	55	–	–	0.8	–
POLYFORT® FPP 75 M schwarz	PP, MD75	–	–	52	81	–	–	–
PP/Celanese								
CELSTRAN PP-GF30-02	PP, GF30	–	–	150	–	–	–	–
CELSTRAN PP-GF30-04	PP, GF30	–	–	148	–	–	–	–
CELSTRAN PP-GF30-05	PP, GF30	–	–	156	–	–	–	–
CELSTRAN PP-GF30-10	PP, GF30	–	–	157	161	–	–	–
CELSTRAN PP-GF40-02	PP, GF40	–	–	152	–	–	–	–
CELSTRAN PP-GF40-04	PP, GF40	162	–	152	–	–	–	–
CELSTRAN PP-GF40-0414P10/10	PP, GF40	166	–	157	–	–	–	–
CELSTRAN PP-GF50-04	PP, GF50	162	–	155	–	–	–	–
CELSTRAN PP-GF50-0403P10/10	PP, GF50	164	–	158	–	–	–	–
CELSTRAN PP-GF50-0453P10/10	PP, GF50	170	–	158	–	–	–	–
Acrylic/Arkema								
ALTUGLAS DRM	PMMA	*	*	84	90	95	0.9	–
ALTUGLAS DRT	PMMA	*	*	88	93	100	1	–
ALTUGLAS HFI-10	PMMA	*	*	81	85	90	1	–
ALTUGLAS HFI-7	PMMA	*	*	83	88	90	0.8	–
ALTUGLAS HT 121	PMMA	*	*	110	119	121	0.65	–
ALTUGLAS MI-2T	PMMA	*	*	99	102	107	0.7	–
ALTUGLAS MI-4T	PMMA	*	*	98	102	106	0.75	–
ALTUGLAS MI-7T	PMMA	*	*	93	98	103	0.8	–

(*Continued*)

12.6 Polyolefins and Acrylics—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
ALTUGLAS SG 10	PMMA	*	*	80	85	90	1	–
ALTUGLAS SG 7	PMMA	*	*	85	90	90	0.8	–
ALTUGLAS V 044	PMMA	*	*	93	96	102	0.65	–
ALTUGLAS V 045	PMMA	*	*	93	96	102	0.65	–
ALTUGLAS V 825 HID	PMMA	*	*	98	102	104	0.65	–
ALTUGLAS V 825 T	PMMA	*	*	100	103	108	0.65	–
ALTUGLAS V 920 T	PMMA	*	*	95	100	103	0.65	–
ALTUGLAS VM	PMMA	*	*	77	82	90	0.7	–
Acrylic/Evonik								
PLEXALLOY® NTA-1	PMMA, Imod	–	120	102	103	110	0.785	–
PLEXALLOY® NTA-3	PMMA, Imod	–	125	106	106	116	0.75	–
PLEXIGLAS® 6N	PMMA	–	99	90	95	96	0.8	–
PLEXIGLAS® 7H	PMMA	–	112	95	100	103	0.8	–
PLEXIGLAS® 7M	PMMA	–	108	–	–	104	0.8	–
PLEXIGLAS® 7N	PMMA	–	110	95	100	103	0.8	–
PLEXIGLAS® 8H	PMMA	–	115	98	103	108	0.8	–
PLEXIGLAS® 8N	PMMA	–	117	98	103	108	0.8	–
PLEXIGLAS® FT15	PMMA	–	–	105	107	115	0.66	–
PLEXIGLAS® df21 8N	PMMA	–	111	98	103	109	0.63	–
PLEXIGLAS® df22 7H	PMMA	–	108	97	101	105	0.63	–
PLEXIGLAS® df22 7N	PMMA	–	108	97	101	105	0.63	–
PLEXIGLAS® df22 8N	PMMA	–	110	98	103	109	0.63	–
PLEXIGLAS® df22 zk6BR	PMMA	–	109	93	99	98	0.9	–
PLEXIGLAS® df23 7H	PMMA	–	106	97	101	105	0.63	–
PLEXIGLAS® df23 7N	PMMA	–	108	97	101	105	0.63	–

PLEXIGLAS® df23 8N	PMMA	–	108	98	103	109	0.63	–
PLEXIGLAS® df23 zk6BR	PMMA	–	107	93	99	91	0.9	–
PLEXIGLAS® hw55	PMMA	–	122	106	109	119	0.7	–
PLEXIGLAS® zk20	PMMA, Imod	–	112	96	100	102	1	–
PLEXIGLAS® zk30	PMMA, Imod	–	114	91	96	98	1.1	–
PLEXIGLAS® zk40	PMMA, Imod	–	115	85	92	94	1.2	–
PLEXIGLAS® zk4BR	PMMA, Imod	–	108	95	99	102	0.8	–
PLEXIGLAS® zk4HC	PMMA, Imod	–	108	–	–	102	0.8	–
PLEXIGLAS® zk50	PMMA, Imod	–	115	70	73	75	1.5	–
PLEXIGLAS® zk5BR	PMMA, Imod	–	109	93	98	100	0.9	–
PLEXIGLAS® zk5HC	PMMA, Imod	–	108	–	–	100	0.9	–
PLEXIGLAS® zk5HF	PMMA, Imod	–	95	93	102	96	0.9	–
PLEXIGLAS® zk6BR	PMMA, Imod	–	109	88	93	95	1.1	–
PLEXIGLAS® zk6HC	PMMA, Imod	–	95	93	98	97	1.1	–

12.7 Thermoplastic Elastomers

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
TPE/DuPont								
Hytrel® 4056	TEEE	150	−50	–	50	110	1.3	1.6
Hytrel® 4068	TEEE	–	–	–	–	135	2.3	2.3
Hytrel® 4069	TEEE	–	–	–	–	–	2.3	2.3
Hytrel® 40CB	TEEE, CD	203	−20	45	65	180	1.97	1.86
Hytrel® 4556	TEEE	203	–	40	60	177	1.8	1.77

(*Continued*)

12.7 Thermoplastic Elastomers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Hytrel® 5526	TEEE	203	−20	45	70	180	1.8	1.77
Hytrel® 5555HS	TEEE	211	0	45	85	195	1.78	1.76
Hytrel® 5556	TEEE	211	–	45	85	19	–	–
Hytrel® 6356	TEEE	218	25	45	95	205	1.8	1.71
Hytrel® 7246	TEEE	221	50	45	105	210	1.47	1.49
Hytrel® 8238	TEEE	222	−60	40	50	170		–
Hytrel® DYM350BK	TEEE + PBT	154	–	–	–	–	1.8	2.4
Hytrel® G3548L	TEEE	170	−35	–	–	115	2.17	2.05
Hytrel® G4074	TEEE	170	−30	–	–	115	2.15	2.07
Hytrel® G4774	TEEE	208	–	–	60	168	2.2	1.94
Hytrel® G4778	TEEE	208	–	–	60	–	2.2	1.94
Hytrel® G5544	TEEE	215	−35	–	77	190	2.11	1.86
Hytrel® HTR4275 BK316	TEEE	196	–	–	50	170	1.81	1.85
TPE/DSM								
Arnitel® 3103	TPC	221	–	–	–	–	–	–
Arnitel® 3104	TPC	212	–	–	–	–	1.5	1.5
Arnitel® 3107	TPC	220	–	45	7	–	–	–
Arnitel® EB460	TPC	217	–	–	–	–	–	–
Arnitel® EB463	TPC	203	–	–	–	–	–	–
Arnitel® EB464	TPC	210	–	–	–	–	–	–
Arnitel® EB464-01	TPC	214	–	–	–	–	–	–
Arnitel® EB500	TPC	215	–	–	–	–	–	–
Arnitel® EL550	TPC	207	−64	–	110	90	2	2
Arnitel® EL630	TPC	212	−60	–	115	125	1.85	1.85

Arnitel® EL695-G4	TPC, GF20	219	–	–	165	165	0.2	–
Arnitel® EL740	TPC	221	–	–	120	160	1.65	1.65
Arnitel® EL740-H/A	TPC	220	–	–	–	–	1.1	1.1
Arnitel® EM400	TPC	195	−78			–	2.2	2.2
Arnitel® EM401	TPC	–	–	–	–	–	–	–
Arnitel® EM402-L	TPC	195	−78		*	–	2.2	2.2
Arnitel® EM460	TPC	185	–	–	–	50	1.6	1.6
Arnitel® EM550	TPC	207	–	–	–	90	1.5	1.5
Arnitel® EM630	TPC	212	–	–	–	125	1.85	1.85
Arnitel® EM630-H	TPC	212	–	–	–	125	1.5	1.5
Arnitel® EM740	TPC	221	–	–	–	160	1.65	1.65
Arnitel® PB420	TPC	211	–	–	6	–	–	–
Arnitel® PB582-H	TPC	220	–	–	100	105	–	–
Arnitel® PL380	TPC	212	–	–	–	–	1.5	1.5
Arnitel® PL381	TPC	212	–	–	–	–	1.5	1.5
Arnitel® PL420-H	TPC	220	–	–	–		–	–
Arnitel® PL460-S	TPC	220	–	–	–	–	–	–
Arnitel® PL461	TPC	220	–	–	6	–	–	–
Arnitel® PL471	TPC	224	–	–	–	–	–	–
Arnitel® PL581	TPC	218	–	–	100	105	1.1	1.1
Amitel® PL650	TPC	221	–	–	–	–	–	–
Arnitel® PM381	TPC	212	–	–	–	–	1.5	1.5
Arnitel® PM460	TPC	216	–	–	6	–	–	–
Arnitel® PM460-B	TPC	216	–	–	6	–	–	–
Arnitel® PM471	TPC	217	–	–	–	–	–	–
Arnitel® PM581	TPC	218	–	100	–	105	1.1	1.1
Arnitel® PM650	TPC	221		–	–	–	–	–

(*Continued*)

12.7 Thermoplastic Elastomers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Arnitel® UM551	TPC	195	–	–	80	85	1.6	–
Arnitel® UM551-V	TPC	200	–	–	85	90	–	–
PEBA/Arkema								
PEBAX 2533 SN 01	TPA	134	−65	–	42	–	2	–
PEBAX 3533 SN 01	TPA	144	−65	–	46	–	2.1	–
PEBAX 4033 SN 01	TPA	160	−65	–	52	–	1.95	–
PEBAX 5533 SN 01	TPA	159	–	–	66	–	1.7	–
PEBAX 5533 SN 70 NOIR	TPA, CD	159	–	–	–	–	2.2	–
PEBAX 6333 SN 01	TPA	169	–	–	90	–	1.4	–
PEBAX 7033 SN 01	TPA	172	–	–	99	–	1.6	–
PEBAX 7233 SN 01	TPA	174	–	–	106	–	1.2	–
PEBAX MH 1657	TPA	204	−40	–	–	–	–	–
PEBAX MV 1041 SN 01	TPA	170	–	–	–	–	–	–
PEBAX MV 1074 SN 01	TPA	158	−40	–	–	–	–	–
PEBA/Evonik								
VESTAMID E40-S3 nf	TPA	–	–	*	55	60	2.4	2.1
VESTAMID E47-S3 nf	TPA	–	–	45	65	70	2.3	2.1
VESTAMID E55-S3 nf	TPA	–	–	45	90	100	2	2
VESTAMID E62-S3 nf	TPA	–	–	45	100	110	2	2

12.8 Fluoropolymers

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature. (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
PVDF/Arkema								
KYNAR 1000 HD	PVDF	169	−40	104	–	138	1.5	–
KYNAR 1000 HDC N 118	PVDF	169	−40	104	–	–	–	–
KYNAR 6000 HD	PVDF	171	−40	108	–	140	1.5	–
KYNAR 710	PVDF	168	−40	110	130	140	1.5	–
KYNAR 720	PVDF	168	−40	110	132	139	1.5	–
KYNAR 740	PVDF	168	−40	105	135	135	1.5	–
KYNAR 9000 HD	PVDF	171	−40	110	–	141	1.36	–
KYNAR 9000 HDC N 123	PVDF, CF	170	−42	125	–	–	–	–
KYNAR FLEX 2750	PVDF	135	−34	–	–	61	1.77	–
KYNAR FLEX 2800	PVDF	142	−36	48	68	79	1.6	–
KYNAR FLEX 2801	PVDF	142	−36	48	–	79	1.6	–
KYNAR FLEX 2820	PVDF	142	−36	48	68	76	1.6	–
KYNAR FLEX 2821	PVDF	142	−36	48	–	76	1.6	–
KYNAR FLEX 2822	PVDF	142	−36	48	–	76	1.6	–
KYNAR FLEX 2850	PVDF	158	−38	–	114	107	1.6	–
PVDF/Solvay								
SOLEF 1008	PVDF	175	−43.5	115	148	138	–	–
SOLEF 1010	PVDF	175	−42	113	147	140	–	–
SOLEF 1012	PVDF	175	−42	112	145	140	–	–
SOLEF 11008	PVDF	161	−33.5	52	100	89.6	–	–
SOLEF 11010	PVDF	159	−37	52	100	95.2	–	–

(*Continued*)

12.8 Fluoropolymers—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature. (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
SOLEF 21508	PVDF	134	−33	40	62	58.2	–	–
SOLEF 31008	PVDF	170	−35.5	48	82	79.6	–	–
SOLEF 31508	PVDF	165	−31	36	49	49.9	–	–
SOLEF 6010	PVDF	174	−42	110	145	14	–	–

12.9 Miscellaneous High Temperature Plastics

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
PEEK/Evonik								
VESTAKEEP 4000 CF30 nf	PEEK, CF30	343	143	–	–	–	0.11	–
VESTAKEEP 4000 FC30 nf	PEEK, PTFE10, Graphite10, CF10	343	143	–	–	–	0.17	–
VESTAKEEP 4000 G nf	PEEK	343	143	153	176	–	0.58	–
VESTAKEEP 4000 GF30 nf	PEEK, GF30	343	143	–	–	–	0.26	–
PEEK/Victrex								
Victrex® 150G	PEEK	343	143	155	–	–	0.47	–
Victrex® 381G	PEEK	340	143	160	–	–	0.47	–
Victrex® 450G	PEEK	340	143	160	–	–	0.47	–
Victrex® 150GL30	PEEK, GF30	343	143	316	–	–	0.22	–
Victrex® 450GL30	PEEK, GF30	340	143	316	–	–	0.22	–
Victrex® 150CA30	PEEK, CF30	343	143	316	–	–	0.14	–

Victrex® 450CA30	PEEK, CF30	340	143	316	–	–	0.14	–
Victrex® 150FC30	PEEK, (CF + PTFE + Graphite)30	343	143	277	–	–	0.22	–
Victrex® 450FC30	PEEK, (CF + PTFE + Graphite)30	340	143	277	–	–	0.22	–
PES/BASF								
Ultrason® E 1010 NAT	PES	*	225	195	216	215	0.55	*
Ultrason® E 2010 G4 UN	PES, GF20	*	225	212	224	217	0.24	*
Ultrason® E 2010 G6 UN	PES, GF30	*	225	212	224	217	0.15	*
Ultrason® E 2010 NAT	PES	*	225	195	218	215	0.55	*
Ultrason® E 3010 NAT	PES	*	228	195	218	215	0.55	*
PES/Solvay								
RADEL A-100	PES	–	220	204	214	215	0.486	0.486
RADEL A-200	PES	–	220	204	214	215	0.486	0.486
RADEL A-300	PES	–	220	204	214	215	0.486	0.486
RADEL AG-320	PES, GF20	–	220	214	218	217	0.31	0.31
RADEL AG-330	PES, GF30	–	220	216	220	218	0.31	0.31
PPS/Solvay								
PRIMEF 4002	PPS, GF40	–	–	260	–	–	–	–
PRIMEF 4010	PPS, GF40	–	–	260	–	–	0.18	0.41
PRIMEF 5084	PPS, GF30	–	–	260	–	–	–	–
PRIMEF 7002	PPS, (GF + MD)65	–	–	260	–	–	0.15	0.27
PPS/Albis								
Tedur® L 9107-1	PPS, GF40	280	–	–	–	–	–	–
Tedur® L 9113-2	PPS, GF60	280	–	–	–	–	–	–
Tedur® L 9200-1	PPS, (GF + MD)60	280	–	–	–	–	–	–
Tedur® L 9214-1	PPS, (GF + MD)65	280	–	–	–	–	–	–
Tedur® L 9217-1	PPS, GF65	280	–	260	–	–	–	–

(*Continued*)

12.9 Miscellaneous High Temperature Plastics—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Tedur® L 9300-1	PPS, (GF + GB)40	280	–	260	–	–	–	–
Tedur® L 9310-4	PPS, (GF + MD)60	280	–	–	240	–	–	–
Tedur® L 9400-1	PPS, CF15	280	–	260	–	–	–	–
Tedur® L 9401-1	PPS, PTFE5, GF40	280	–	260	–	–	–	–
Tedur® L 9404-1	PPS, CF30	280	–	260	–	–	–	–
Tedur® L 9510-1	PPS, GF40	280	–	260	–	–	–	–
Tedur® L 9511	PPS, GF45	280	–	260	–	–	–	–
Tedur® L 9512	PPS, GF42	280	–	260	–	–	–	–
Tedur® L 9521-1	PPS, (GF + MD)60	280	–	260	–	–	–	–
Tedur® L 9523	PPS, (GF + MD)60	280	–	–	260	–	–	–
Tedur® L 9530	PPS, MD55	280	–	200	–	–	–	–
Tedur® L 9560	PPS, MD50	280	–	–	235	–	–	–
Tedur® P 9007	PPS, (GF + MD)65	280	–	260	–	–	–	–
PPS/Celanese								
FORTRON 0203	PPS	280	90	120	–	*	0.55	0.53
FORTRON 0203HS	PPS	280	90	120	–	*	0.55	0.53
FORTRON 0205	PPS	280	90	115	–	*	0.53	0.52
FORTRON 0214	PPS	280	90	110	–	*	0.52	0.53
FORTRON 0320	PPS	280	90	115	–	*	0.52	0.53
FORTRON 1115L0	PPS, GF15	–	–	220	–	–	–	–
FORTRON 1130L4	PPS, GF30	*	90	255	–	*	0.29	0.52
FORTRON 1131L4 ITT	PPS, GF30	280	90	265	–	*	0.29	0.62
FORTRON 1140E7	PPS, GF40	280	90	270	–	*	0.2	0.41
FORTRON 1140EC	PPS, GF40	–	–	270	–	–	–	–
FORTRON 1140L0	PPS, GF40	280	90	–	–	*	–	–
FORTRON 1140L4	PPS, GF40	280	90	270	–	*	0.26	0.62

FORTRON 1140L6	PPS, GF40	280	90	270	–	*	0.26	0.42
FORTRON 1140L7	PPS, GF40	280	90	270	–	*	–	–
FORTRON 1141L4	PPS, GF40	280	90	270	–	*	–	–
FORTRON 1342L4	PPS, PTFE, GF40	280	90	270	–	*	0.22	0.4
FORTRON 4184L4	PPS, (GF + MD)53	280	90	270	–	*	0.24	0.32
FORTRON 4184L6	PPS, (GF + MD)53	280	90	270	–		0.24	0.32
FORTRON 4332D4	PPS, (GF + MD)65	280	90	270	–	–	–	–
FORTRON 4665B6	PPS, (GF + MD)65	280	90	270	–	*	–	–
FORTRON 6160B4	PPS, (GF + MD)60	280	90	270	–	*	–	–
FORTRON 6165A4	PPS, (GF + MD)65	280	90	270	–	*	0.19	0.24
FORTRON 6165A6	PPS, (GF + MD)65	280	90	270	–	*	0.19	0.24
FORTRON 6165D8	PPS, PTFE, (GF + MD)65	280	90	270	–	–	0.19	0.24
FORTRON 6345L4	PPS, PTFE, GF30	–	–	260	–	–	–	–
FORTRON 6450A6	PPS, (GF + MD)51	–	–	260	–	–	–	–
FORTRON 6850L6	PPS, (GF + MD)50	280	90	270	–		0.15	0.17
FORTRON MT 9120L4	PPS, GF20	280	90	255	–	–	–	–
FORTRON MT 9140L4	PPS, GF40	280	90	270	–	–	–	–
FORTRON MT 9140L6	PPS, GF40	280	90	270	–	–	–	–
FORTRON MT 9203HS	PPS	280	90	120	–	*	0.55	0.53
FORTRON MT 9205C4	PPS	280	90	115	–	–	–	–
PPSU/Solvay								
RADEL R-4300	PPSU	–	–	207	–	–		–
RADEL R-5000	PPSU	–	220	207	214	–	0.558	0.558
RADEL R-5100	PPSU	–	220	207	214	225	0.56	0.56
RADEL R-5500	PPSU	–	220	207	214	–	0.558	0.558
RADEL R-5700	PPSU	–	220	207	214	–	0.56	0.56
RADEL R-7000 A	PPSU	–	–	182	193		–	–
RADEL R-7200	PPSU	–	–	188	–	–	–	–

(*Continued*)

12.9 Miscellaneous High Temperature Plastics—*Cont'd*

Name and Grade	Description	Melt Point (°C)	Glass Transition Temperature (°C)	HDT @ 1.8 MPa (°C)	HDT @ 0.45 MPa (°C)	Vicat Softening Temperature (°C)	CLTE Parallel (×10E 4/°C)	CLTE Normal (×10E 4/°C)
RADEL R-7300	PPSU	–	–	182	–	–	–	–
PSU/BASF								
Ultrason® S 2010 G4 UN	PSU, GF20	*	187	183	188	187	0.25	–
Ultrason® S 2010 G6 UN	PSU, GF30	*	187	183	187	190	0.21	*
Ultrason® S 2010 NAT	PSU	*	187	167	181	180	0.55	*
Ultrason® S 3010 NAT	PSU	*	187	169	186	183	0.55	*
PSU/Solvay								
MINDEL B-310	PSU, GF10	–	–	158	–		–	–
MINDEL B-322	PSU, GF22	–	–	160	–	184	0.27	0.27
MINDEL B-340	PSU, GF40	–	–	160	–		0.239	0.239
MINDEL B-360	PSU, GF30	–	–	160	–		0.54	0.54
MINDEL B-390	PSU, MD	–	–	169	–	183	0.529	0.529
MINDEL B-430	PSU, GF30	–	–	166	–		0.31	0.31
MINDEL M-800	PSU, MD40	–	190	179	–	190	0.34	0.34
MINDEL M-825	PSU, MD25	–	190	174	–		0.391	0.391
MINDEL S-1000	PSU	–	–	149	–	170	1.03	1.03
MINDEL S-1010	PSU, GF10	–	–	151	–		0.439	0.439
MINDEL S-1020	PSU, GF20	–	–	153	–		0.434	0.434
MINDEL S-1030	PSU, GF30	–	–	155	–	–	0.382	0.382
UDEL GF-110	PSU, GF10	–	190	179	–	–	0.36	0.36
UDEL GF-120	PSU, GF20	–	190	180	–	–	0.252	0.252
UDEL GF-130	PSU, GF30	–	190	181	–	193	0.198	0.198
UDEL P-1700	PSU	–	190	174	181	188	0.56	0.56
UDEL P-1720	PSU	–	190	174	181	–	0.56	0.56
UDEL P-3500	PSU	–	190	174	–	–	0.56	0.56

Appendix 1: Abbreviations

ABS	Acrylonitrile Butadiene Styrene
ASA	Acrylonitrile Styrene Acrylate
COC	Cyclic Olefin Copolymer
ECTFE	Polyethylene Chlorotrifluoroethylene
ETFE	Polyethylene Tetrafluoroethylene
EVA	Ethylene Vinyl Acetate
FEP	Fluorinated Ethylene Propylene
HDPE	High Density Polyethylene
HPPA	High Performance Polyamide
LCP	Liquid Crystalline Polymer
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
MDPE	Medium Density Polyethylene
PA	Polyamide (Nylon)
PAI	Polyamide–Imide
PAMXD6	Polyarylamide, Polyxylylene Adipamide
PBI	Polybenzimidazole
PBT	Polybutylene Terephthalate
PC	Polycarbonate
PCE	Perchloroethylene
PCT	Polycyclohexylene–Dimethylene Terephthalate
PCTFE	Polychlorotrifluoroethylene
PE	Polyethylene
PEBA	Thermoplastic Polyether Block Amide Elastomers
PEEK	Polyether Ether Ketone
PEI	Polyetherimide
PES	Polyethersulfone
PET	Polyethylene Terephthalate
PFA	Perfluoroalkoxy
PI	Polyimide
PMMA	Polymethyl Methacrylate
POM	Polyoxymethylene or Acetal Homopolymer
POM-Co	Polyoxymethylene Copolymer or Acetal Copolymer
PP	Polypropylene
PPA	Polyphthalamide
PPE	Polyphenylene Ether, same as PPO
PPO	Polyphenylene Ether, same as PPE
PPS	Polyphenylene Sulfide
PPSU	Polyphenylsulfone
PS	Polystyrene
PSU	Polysulfone
PTFE	Polytetrafluoroethylene
PTP	Polytrimethyl Pentene
PUR	Polyurethane
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene Fluoride
SAN	Styrene Acrylonitrile
SMA	Styrene Maleic Anhydride
TEEE	Thermoplastic Elastomer Ether Ester Block Copolymer
TPE	Thermoplastic Elastomers
TPE-E	Thermoplastic Copolyester Elastomers
COPE	Thermoplastic Copolyester Elastomers
TPU	Thermoplastic Polyurethane Elastomers
UHMWPE	Ultrahigh Molecular Weight Polyethylene
ULDPE	Ultra Low Density Polyethylene
VLDPE	Very Low Density Polyethylene

Appendix 2: Conversion Factors

Unit Conversion Tables

The following tables show conversion factors to convert most of the units used in this book from SI units to various English units. SI units are the International System of Units (abbreviated SI from Système Internationale d'Unités, the French version of the name). The conversion factors are reported only to four significant figures.

Pressure, Stress, Modulus

Convert from	Convert to	Multiply by
gigapascal (GPa)	MPa	1000
kilopascal (kPa)	atmosphere, standard (atm)	0.009869
kilopascal (kPa)	bar (bar)	0.01
kilopascal (kPa)	kilogram-force per square centimeter (kgf/cm^2)	0.01020
kilopascal (kPa)	pound-force per square inch (psi) (lbf/in^2)	0.1450
megapascal (MPa)	kilogram-force per square millimeter (kgf/mm^2)	0.1020
megapascal (MPa)	pound-force per square inch (psi) (lbf/in^2)	145.0
pascal (Pa)	atmosphere, standard (atm)	9.869×10^{-06}
pascal (Pa)	bar (bar)	0.00001
pascal (Pa)	dyne per square centimeter (dyn/cm^2)	10
pascal (Pa)	gram-force per square centimeter (gf/cm^2)	0.01020
pascal (Pa)	kilogram-force per square centimeter (kgf/cm^2)	1.020×10^{-05}
pascal (Pa)	kilogram-force per square meter (kgf/m^2)	0.1020
pascal (Pa)	kilogram-force per square millimeter (kgf/mm^2)	1.020×10^{-07}
pascal (Pa)	pound-force per square foot (lbf/ft^2)	0.02089
pascal (Pa)	pound-force per square inch (psi) (lbf/in^2)	0.0001450

Energy

Convert from	Convert to	Multiply by
joule (J)	British thermal unit (Btu)	0.0009471
joule (J)	erg (erg)	10000000
joule (J)	foot pound-force (ft lbf)	0.7376
joule (J)	kilocalorie (mean) (kcal)	0.0002387
joule (J)	kilowatt hour (kW h)	2.778×10^{-07}
joule (J)	watt hour (W h)	0.0002778
joule (J)	watt second (W s)	1
megajoule(MJ)	kilowatt hour (kW h)	0.2778
watt per square meter (W/m^2)	erg per square centimeter second	1000
watt per square meter (W/m^2)	watt per square centimeter (W/cm^2)	0.0001
watt per square meter (W/m^2)	watt per square inch (W/in^2)	0.0006452

Force

Convert from	Convert to	Multiply by
newton (N)	dyne (dyn)	100000
newton (N)	kilogram-force (kgf)	0.1020
newton (N)	pound-force (lbf)	0.2248
newton per kilogram (N/kg)	pound-force per pound (lbf/lb)	0.1020
newton per meter (N/m)	pound-force per foot (lbf/ft)*	0.06852
newton per meter (N/m)	pound-force per inch (lbf/in)	0.005710

** Pound force-foot is often called a foot pound.*

Impact Resistance

Convert from	Convert to	Multiply by
kilojoule per square meter (kJ/m^2)	pound-force per square inch (lbf/in^2)	0.4758
kilojoule per square meter (kJ/m^2)	pound-force per square foot (lbf/ft^2)	68.52
kilogram centimeter per square centimeter (kg-cm/cm^2)	joules per square centimeter (J/cm^2)	0.09804
kilogram centimeter per square centimeter (kg-cm/cm^2)	pound-force per square inch (lbf/in^2)	0.4666
kilogram centimeter per centimeter (kg-cm/cm)	joules per centimeter (J/cm)	0.09804
kilogram centimeter per centimeter (kg-cm/cm)	pound-force per inch (lbf/in)	0.1837
joules per centimeter (J/cm)	pound-force per inch (lbf/in)	1.873
joules per meter (J/m)	pound-force per foot (lbf/ft)	0.2248

Linear Expansion

Convert from	Convert to	Multiply by
Millimeters per millimeter per degree centigrade (mm/mm/°C)	Inches per inch per degree Fahrenheit (in/in/°F)	0.5556

Tear Strength

Convert from	Convert to	Multiply by
kilonewtons/meter (kN/m)	pound-force per foot (lbf/ft)	68.52
kilonewtons/meter (kN/m)	pound-force per inch (lbf/in)	5.710

Specific Heat

Convert from	Convert to	Multiply by
kilojoules/kilogram K (kJ/kg K)	Btu/pound °F (Btu/lb °F)	0.2388

Dielectric Strength

Convert from	Convert to	Multiply by
kilovolts per millimeter (kV/mm)	volts per mil (V/mil)	25.4

Index

1PP/Celanese, 625–626
3M Dyneon™ PTFE resins, 403
4,4′-diphenyl methane diisocyanate (MDI), 216
4-hydroxybenzoic acid (HBA), 179
4-methylpentene-1, 341, 343
6-hydroxynaphthalene-2-carboxylic acid (HNA), 179

A
ABS/A. SCHULMAN, 538–539, 655–656
ABS/INEOS, 539–540, 656–657
ABS/Styron, 536, 653–655
Acetal copolymer. *See* Polyoxymethylene copolymer (POM-Co)
Acetal Copolymer/A. Schulman, 550, 665
Acetal Copolymer/Celanese, 545–550, 660–665
Acetal homopolymer. *See* Polyoxymethylene (POM)
Acetal Homopolymer/DuPont, 543–545, 659–660
Acrylic resin, general-purpose, 368
Acrylic/Arkema, 627–628, 719–720
Acrylic/Evonik, 628, 720–721
Acrylics, 341–370
Acrylite®, 367
Acrylonitrile butadiene styrene (ABS), 10, 47–48
  polymerization of, 48
Acrylonitrile-styrene-acrylate (ASA), 60, 62, 195
Addition polymerization, 1
Additives, 13
ALCOM®, 715
Algoflon®, 635–636
ALTECH®, 623–625, 715–716
Alternating copolymer, 2
ALTUGLAS, 627–628, 719–720
American Society for Testing and Materials (ASTM), 15, 341
Amide–Imide Polymers, 217–218
Amilan®, 607, 708
Amite®, 572
Amitel®, 631, 723
AMODEL, 610–613, 709–710
Amorphous fluoropolymer, 452, 457–458
Amorphous nylon, 308
Antiblocking agents, 13
Antistatic agents, 15
Apec®, 553–554, 667–668
Arkema Kynar Flex®, 443, 445–446
Arkema Orgalloy®, 337–339
Arkema Pebax®, 395–397
Arkema Rilsan®, 247–251
Arkema VOLTALEF® 302 PCTFE resin, 440–441
Arnite®, 178, 569, 572, 577, 682–683, 685–686, 690–691
Arnitel®, 630–631, 722–724
ASA/A. SCHULMAN, 534–535, 652
ASA/Styrolution, 534, 651–652
Asahi Glass Fluon®, 402–404, 412–419
Asahi Kasei Thermylene® PP resins, 351–353
ASTM Standard Test Method, 5–23, 32, 649
Atactic polypropene, 6
AvaSpire®, 479, 481–482
AviSpire®, 472

B
Base polymers abbreviations, 530–531
Basell Polyolefins Hostalen®, 350–355
Basell Polyolefins Lupolen®, 344–345
Basell Polyolefins PE resin, 346–347
BASF AG Terluran®, 48
BASF Elastollan®, 373–376, 378–381
BASF Hostaform®, 128–129
BASF Nylon 6 resins, 240
BASF Petra®, 172–173, 175, 177
BASF Polystyrene, 66–71
BASF Terluran®, 51–52, 56
BASF Ultradur®, 164, 195–196
BASF Ultraform®, 112–113, 115–117, 123–124
BASF Ultramid®, 236–237, 239, 242–245, 262–265, 272–274, 278, 282–283, 286–287, 290, 302–303, 305, 307
BASF Ultrason®, 491–499, 513–516, 518–520, 522–525
BASF's Polystyrol, 78–79
Bayblend®, 575–576, 689
Bayer Cadon®, 81–82
Bayer Desmopan®, 375
Bayer MaterialScience Apec®, 145
Bayer MaterialScience Bayblend®, 84, 87, 90
Bayer MaterialScience Makrolon®, 147, 151
Bayer Texin®, 376–377
Bayer TPU resins, 379–380
Biphenol diamine (BP diamine), 225
Biphenol diamine PMDA PEI, 224
Blends, 482, 489
Blends, polymer, immiscible, multiphase, 10
Block copolymerization, 2, 37
BPADA
  chemical structure of, 224–5
Branched polymers, 3, 7–8
  isomers, 5–7
  polarity, 3–5

C
CALIBRE, 556–561, 670–673
Capron®, 605
Carbon Fiber-Reinforced AvaSpire® PAEK Grades, 480
Catalysts, 13
Celanese Celanex®, 153, 156–157, 161–162
Celanese Celcon®, 111, 113–114, 116–119, 124–129
Celanese Fortron®, 504–506, 511–512
Celanese GUR® 4120, 346
Celanese Hostaform®, 112, 115, 119–125, 127
Celanese Impet®, 171–172
Celanese method, 91
Celanese Thermx®, 188–190
Celanese Vectra®, 179–182, 184–187
CelaneseCelanex®, 169
CELANEX, 563–567, 676–680
CELCON, 545–547, 660–663

CELSTRAN, 622, 625–626, 680, 719
Chain entanglement, 8
Chain initiation, propagation, termination, 1
Chain-growth polymerization. *See* Addition polymerization
Charpy impact strength testing, 22–23, 39
Chevron Phillips Chemical Marlex®, 352
Chevron Phillips Chemical Ryton®, 500–508, 511
Chevron Phillips K-Resin®, 72
Chisso America Olehard® resin, 351, 353
Coefficient of linear thermal expansion (CLTE), 32
Coefficient of thermal expansion, 32
  ASTM standard test methods, 32
  ISO 11359-2:1999 plastics, 32
Combustion modifiers, 11–12
Compressive properties, plastics, 18–19
Condensation polymerization, 1–2
Copolymers, 2
Coupling agents, 14
Crastin®, 569–570, 683–684, 692
Cross-linked polymers, 3
  inter- and intramolecular attractions in polymers, 7
    chain entanglement, 8
    hydrogen bonding, 7
    Van der Waals forces, 7–8
  isomers, 5–7
  polarity, 3
  steric hindrance, 5
  unsaturation, 3–5
Crystalline vs. amorphous thermoplastics, 9–10
Cyclic olefin copolymer (COC), 362–363

D
D3763-06 standard test method, 23
D5420-04 standard test method, 23
D5628-06 standard test method, 23
Daikin Industries Neoflon™, 422–426, 430–432, 436–441
Delrin®, 103–110, 543–545, 659–660
Designing, plastics, 32–44
  experience, 32
  impact strength, assessment, 39–40
  knowledge requirement, 32
  maximum service temperature assessment, 34
  requirements, 32
  rigidity of plastics materials, 33–34
  selection guides, 40–42
  thermal stability assessment, 34–36
  time dependent behavior, 40
  toughness, 36–39
  training, 32
Diamino diphenyl sulfone (DDS), 225
Dielectric constant, 31
Dissipation factor vs. frequency for Styron Magnum™ ABS resin, 60
DSM Arnitel EM400 and Arnitel EM550 TPE-E resins, 392
DSM Arnitel PL 380 TPE, 393
DSM Engineering Plastics Stanyl®, 255–257
DuPont Aurum®, 224
DuPont Co, 401–405
DuPont Crastin®, 153–154, 159–161, 163–167, 195
DuPont Delrin® Acetal Resins, 92–95
DuPont Delrin® POM
  mechanical properties at various temperatures, 97–99
DuPont Delrin® POM ISO Data
  mechanical properties at various temperatures, 100–102
DuPont Engineering Plastics Zytel®, 325–326, 328, 333, 335
DuPont Engineering Polymers Delrin®, 103
DuPont FEP resins, 422
DuPont Hytrel®, 387–394
DuPont Minlon®, 258, 260–261, 269–270, 274–277, 281
DuPont P Type Delrin®, 96
DuPont Rynite®, 173–176
DuPont Tedlar®, 452–457
DuPont Teflon®, 428–429, 432–433, 460
DuPont Tefzel®, 410–414, 416–418
DuPont Vespel®, 200–216
DuPont Zenite®, 182–185
DuPont Zytel®, 258–259, 265–272, 278–288, 292–301, 303, 308, 329
Dyes, 14
Dynamic mechanical analysis (DMA), 28
Dynamic mechanical thermal analysis (DMTA), 28
Dyneon crystalline and amorphous PCTFE resins, 436
Dyneon PCTFE resin, 436, 438
Dyneon™, 634, 636–641

E
ECTFE/Solvay Solexis, 641
Edgetek sPS®, 533–534, 651
EDISTIR, 532, 650
Elastomers, 10
Electrical tests, 18
EMS Grivory Grilon®, 235–239, 241–242, 259, 273, 302, 304, 306
EMS-Grivory Grilamid®, 252–253, 309–311
EMS-Grivory Grivory®, 301, 304–305, 335–339
EMS-Grivory®, 323–324, 330
Enduran®, 193
Ensinger Tecafine PMP, 356
ETFE/Diakin, 639
ETFE/DuPont, 640
ETFE/Dyneon 3M, 640
Ethylene, 341
Evonik Corporation Vestamid®, 396–398
Evonik Industries Plexiglas®, 366–370
Evonik Industries Trogamid®, 310–314
Evonik Industries Vestamid®, 252–255, 293, 297–298
Evonik Vestodur®, 160–161
Extem®, 230
Extenders, 14
ExxonMobil Santoprene®, 382–386

F
Falling dart impact strength testing, 23
FEP/Diakin, 639
FEP/DuPont, 639
Filler abbreviations, 531
Fillers, 11
Fire retardants, 11–12
Flame retardants, 11–12, 372
Flexural properties, plastics, 22
Fluorinated-ethylene-propylene (FEP), 410, 419–424, 426
Fluoroplastic melting points, 400
Fluoropolymers, 399–460, 633–641, 725–726
FORTRON, 645–646, 728–729

G
Galxyl®, 526
Gardner impact strength testing, 23
Geometric isomers, 5–6
Glass Fiber-Reinforced AvaSpire®, 480
Glass transition temperature (Tg)/Tg estimation, 28–30
Graft copolymer, 2
Greene, Tweed Arlon®, 471, 473
Grilamid®, 308, 594–595, 701–702
Grilon, 619–622, 713–714
Grivory, 714
GUR, 623, 715

H
Halar, 641
Hardness tests, 17
Heat deflection data, 44
Heat deflection temperature (HDT), 25–26
Hexafluoropropylene (HFP), 410
High impact BASF Polystyrene resin, 68
High temperature plastics, 642–648
High temperature polymers, 465
High-density polyethylene (HDPE), 341
High-impact polystyrene (HIPS), 3
Homopolymers, 342
HOSTAFORM, 548–550, 663–665
Hostalen, 622, 627
HTE/Dyneon 3M, 641
Hydrogen bonding, 7
Hyflon®, 638
Hytrel®, 629–630, 721–722

I
Immiscible blends, polymer, 10
Impact copolymers, 342
Impact modifiers, 13
Impact property testing of plastics, 22–23
Impact strength assessment, 39–40
Impact tests, 17
IMPET, 570–571, 684–685
INEOS Lustran®, 48, 82
Instron universal materials testing machine, 16, 18, 20
Inter- and intramolecular attractions in polymers, 7–8
ISO 75, 25, 649
ISO 178:2001 plastics, 22
ISO 306:2004 Plastics, 25, 649
ISO 812:2006 rubber, 24, 649
ISO 974:2000 Plastics, 24, 649
ISO 1133:2005 Plastics, 25
ISO 3146:2000 Plastics, 25, 649
ISO 6603-2, 25, 649
ISO 7765-2:1994 plastics, 23
ISO 8302:1991 Thermal insulation, 25, 649
ISO 10350 properties, 529–648
  IEC 60250:1969, 529
  ISO 10724:1998, 529
  ISO 11359-2, 529
  ISO 179:1997, 529
  ISO 2818:1994, 529
  ISO 291:1997, 529
  ISO 293:1986, 529
  ISO 294:1996, 529
  ISO 295:1991, 529
  ISO 3167:1993, 529
  ISO 527:1993, 529
  ISO 62, 529
ISO 11359-1, 24, 649
ISO 11359-2, 25, 32, 649
ISO and ATSM standards for common polymer families, 19
Isomers, 5–7
Isophthalic acid (IPA), 315
Isotactic polypropene, 6
Iupiace®, 132, 134–135, 137, 139–141, 550–553, 665–667
Iupital F20-02 02 resin, 112, 126–127
IXEF®, 616–617, 711–712
Izod impact strength testing, 22–23
Izod test, 39

K
KetaSpire®, 463
KOBLEND, 532
KOSTIL, 535–536, 653
Kraton Polymers Kraton, 72
KYNAR, 633–634, 725

L
LANXESS Pocan®, 154–155, 159, 168
LANXESS Triax®, 86–87
LAURAMID A, 591, 699
LAURAMID B, 591, 699
LCP/Celanese, 572–573, 686
LCP/Solvay, 575, 688
LCP/Ticona, 573–575, 687–688
Lexan®, 146–147, 151–152
LG-Dow Calibre™, 145
LG-Dow Polycarbonate Calibre™, 150
Linear low density polyethylene (LLDPE), 341, 344
Linear polymers, 3, 7–8
  isomers, 5–7
  polarity, 3
  steric hindrance, 5
  unsaturation, 3–5
Liquid crystalline polymers (LCPs), 144, 152, 170
LNP FEP resin, 423
LNP Thermocomp FP-EC, 411, 413–414
Low density polyethylene (LDPE), 341
Lubricants, 12
Lucite® Diakon® ST grades, 370
Lucite® International Diakon® acrylic resins, 367, 369
Lupolen, 622–623
Luran®, 65, 70, 76, 534–535, 541, 651–653, 658
Lustran ABS®, 535, 539–540, 542, 652, 656–658

M
MAGNUM, 536–537, 653–655
Makroblend®, 576, 689–690
Makrolon® 1095, 554–556, 668–670
Maximum service temperature assessment, 34
Mechanical methods of estimating Tg, 28–29
Mechanical property testing of plastics, 15–19, 22
Medium density polyethylene (MDPE), 341
Melt flow index (MFI), 26–28
Melting point (Tm), 31–32
Methyl methacrylate, 341
Methyl methacrylate–acrylonitrile–butadiene–styrene (MABS) polymer, 48, 60
Methylene dianiline (MDA) chemical structure of, 225
MFA, 419, 434–435
Mica, 14
MINDEL, 647–648, 730
Minion®, 582–583, 599, 696, 704
Miscellaneous High Temperature Plastics, 726–730
Mitsubishi Engineering-Plastics Corporation Iupilon®/Novarex® PC, 147–149, 151
Mitsubishi Engineering-Plastics Iupital®, 114, 118, 126
Mitsubishi Polyester Film Hostaphan® PET film, 177–178
Mitsui Chemicals Aurum®, 203
Mitsui Chemicals FR-TPX™ T130, 357–359
Mitsui Chemicals TPX™ RT18, 356–359
Molar mass dispersity index, 8
Molecular weight, polymers, 8–9
Monomers, 2
m-Phenylene diamine (MPD), 225

N
Neoflon™, 638–640
Norbornene, 342
Noryl GTX®, 134, 137–138
Noryl®, 133, 135–141
Nova Chemicals Dylark®, 81–83
Novodur®, 48, 540, 657
Nylon 6 (PA6), 233–235
Nylon 6/66 (PA666), 233, 291
Nylon 11 (PA11), 233–245
Nylon 12 (PA12), 233, 245, 251
Nylon 46 (PA46), 233, 251, 256
Nylon 66 (PA66), 233, 256–257
Nylon 610 (PA610), 233, 257, 287, 291
Nylon 612 (PA612), 233, 257, 291
Nylon 1010 (PA1010), 291, 307
Nylon amorphous, 233, 308–309

O
Olefinic thermoplastic elastomers (TPO), 381
ORGALLOY, 617–619, 712–713
Oxydianiline (ODA), 225

P
PA Alloy/EMS-Grivory, 619–621, 713–714
PA6/BASF, 585–589, 697–699
PA6/DuPont, 582–584, 696
PA11/Arkema, 590–591, 699
PA12/EMS-Grivory, 594–596, 701–702
PA12/Evonik, 591–594, 699–701
PA46/DSM, 596–598, 702–704
PA66/BASF, 605–607, 707–708
PA66/DuPont, 599–605, 704–707
PA610/Toray Resin Company, 607, 708
PA612/DuPont, 607–608, 708
PA666/BASF, 608, 709
PAI/Solvay, 695
PAMXD6 PAA, 315
Parylene (poly(*p*-xylylene)), 525, 527
PBT/BASF, 567–568, 680–681
PBT/Celanese, 563–567, 676–680
PBT/DSM, 569, 682–683
PBT/DuPont, 569–570, 683–684
PBT/LANXESS, 568, 681–682
PCT/Celanese, 572, 686

PCTFE/Arkema, 635
PCTFE/Diakin, 640
PE/Bassell Polyolefins, 622
PE/Celanese, 622, 715
PEBA/Arkema, 631–633, 724
PEBA/Evonik, 633, 724
PEBAX, 631–633, 724
PEEK/Evonik, 642, 726
PEEK/Victrex, 642, 726–727
PEI/SABIC Innovative Plastics, 581–582, 693–695
Perfluoroalkoxy, 419, 427
Perfluoroalkyl vinyl ether (PFA/MFA), 419, 427, 434
Perrite Ronfalin®, 48
PES/BASF, 643, 727
PES/Solvay, 643, 727
PET/Celanese, 570–571, 684–685
PET/DSM, 572, 685–686
PET/DuPont, 571, 685
PFA/Diakin, 638
PFA/DuPont, 637–638
PFA/Dyneon 3M, 638–639
PFA/Solvay Solexis, 638
PI/DuPont, 695
Pigments, 14
Plastic chemistry
  polymers and, 1–10
Plasticization, 14, 37
Plasticizer, 372
Plastics, 1–45
  basic component, 1
  designing, 32–44
  polymers and copolymers, 2–3
  rigidity of, 33–34
  testing, 15–32
PLEXALLOY®, 628, 720
Plexiglas®, 363, 628–629, 720–721
Pocan®, 568, 577, 590, 681–682, 690
Polimeri Europa Kostil®, 75–76
Poly Olefins and Acrylics, 715–721
Poly(methyl methacrylate) (PMMA), 3, 341, 363, 365
Polyacrylics, 363
Polyamide, 12, 245, 251
Polyamide Alloys/Arkema, 617–619, 712–713
Polyamide Alloys/Rhodia, 619, 713
Polyamide blend resins, 134, 137
Polyamide blends and alloys, 339
Polyamide–Imide (PAI), 199, 220
Polyamides (Nylons), 233–339, 582–622, 696–714
Polyarylamide (PAA), 309, 315
Polyarylamide/Mitsubishi Engineering-Plastics Corp, 613–617, 711
Polyarylamide/Solvay, 711–712
Polyaryletherketones (PAEK), 479–482
Polybenzimidazole (PBI), 482, 489
Polybutadiene, 10
Polybutylene naphthalate (PBN), 178–179, 190
Polybutylene PCT polyester, 188
Polybutylene terephthalate (PBT), 143–144, 152
Polycaprolactone, 372
Polycarbonate (PC), 143, 192
Polycarbonate/A. Schulman, 561, 673–674
Polycarbonate/Bayer, 553–556, 667–670
Polycarbonate/DSM, 561–563, 674–676
Polycarbonate/Styron, 556–561, 670–673
Polychlorotrifluoroethylene (PCTFE), 434–435
Polycyclohexylene–dimethylene terephthalate (PCT), 170, 178
Polydispersity index (PDI), 8
Polyester based TPUs, 372
Polyester blends and alloys, 179
Polyester Blends/A. Schulman, 580, 693
Polyester Blends/BASF, 578–579, 691
Polyester Blends/Bayer, 575–577, 689–690
Polyester Blends/Dow, 579–580, 692
Polyester Blends/DSM, 577–578, 690–691
Polyester Blends/DuPont, 579, 692
Polyester Blends/Lanxess, 577, 690
Polyester Blends/Ticona, 580, 693
Polyester polyols, 372
Polyesters, 1, 143–196, 371, 553–580, 667–693
Polyether block amide (PEBA) thermoplastic elastomers, 395
Polyether ether ketone ketone (PEEKK), 464
Polyether ether ketones (PEEK), 463–465
Polyether ketone ether ketone ketones (PEKEKK), 464–465
Polyether ketone ketone (PEKK), 464
Polyether ketones (PEK), 464–465
Polyether plastics, 91–142
Polyetherimide (PEI), 210
Polyethers, 371–372, 543–553, 659–667
Polyethersulfone (PES), 489–490
Polyethylene (PE), 341–342
Polyethylene chlorotrifluoroethylene (ECTFE), 401, 405
Polyethylene naphthalate (PEN), 178–179
  dielectric constants of, 191
  dissipation factors of, 191
  structure of, 190
Polyethylene terephthalate (PET), 1–2, 143–144, 170, 192
Polyethylene tetrafluoroethylene (ETFE), 405, 409–410
POLYFLAM®, 538, 540–541, 625, 655, 657, 716–717
POLYFORT®, 717–719
Polyimides (PI), 199–200, 580–582, 693–695
Polyketones (PAEK), 463–465, 479–482
  POLYMAN®, 534–535, 538–539, 561, 652, 655–656, 673–674
Polymeric Resources Corporation Nylene®, 243–244
Polymerization, 1
Polymers, 1–45
  blends, 10
  linear, branched, and cross-linked polymers, 3
  molecular weight, 8–9
  and plastics, 1–10
    crystalline vs. amorphous, 9–10
    thermosets vs. thermoplastics, 9
Polymethylpentene (PMP), 343, 356
Polyolefin polymers, 342
Polyolefins, 341–370
  and Acrylics, 622–629
PolyOne Fiberloc™, 360–361
PolyOne Geon®, 360–362
Polyoxymethylene (POM), 91
  polyphenylene ether/polyphenylene oxides (PPE or PPO), modified, 102
Polyoxymethylene copolymer (POM-Co), 91, 94, 110
Polyphenylene ether (PPE), 102
Polyphenylene oxide (PPO), 10, 28, 102
Polyphenylene sulfide (PPS), 489–490, 499–500
Polyphenylsulfone (PPSU), 512, 522
Polyphthalamide (PPA), 233, 315, 322
Polypropylene, 137, 342
Polypropylene ether (PPE), 130–142
Polystyrene (PS), 10, 62, 65–66, 133–135
Polystyrene blend resins, 132, 134–141
Polystyrene/Polimeri Europa, 532, 650
Polystyrene/PolyOne, 533–534, 651
Polystyrene/Styron, 532–533, 650–651
Polysulfone (PSU), 501, 512
Polytetrafluoroethylene (PTFE), 399–401
Polyvinyl chloride (PVC), 1, 341, 356, 359
Polyvinyl fluoride (PVF), 442, 451–452
Polyvinylidene fluoride (PVDF), 435, 442
PP/A. Schulman, 625, 716–719
PP/Albis Plastic GmgH, 623–625, 715–716
PP/Bassell Polyolefins, 627
PP/Celanese, 719
PPA/DuPont, 608–610, 709
PPA/Solvay, 610–613, 709–710
PPE Modified/Mitsubishi Engineering-Plastics, 550–553, 665–667
PPE/Degussa, 550, 665
P-Phenylene diamine (PDA), 225
PPS/Albis, 644–645, 727–728

PPS/Celanese, 645–646, 728–729
PPS/Solvay, 644, 727
PPSU/Solvay, 646–647, 729–730
PRIMEF, 644, 727
Propylene, 342
PSU/BASF, 647, 730
PSU/Solvay, 647–648, 730
PTFE/Dyneon 3M, 636–637
PTFE/Solvay Solexis, 635–636
PULSE, 579–580, 692
PVDF/Arkema, 633–634, 725
PVDF/Dyneon 3M, 634
PVDF/Solvay, 725–726
PVDF/Solvay Solexis, 634
Pyromellitic dianhydride (PMDA), 225

R
RADEL, 643, 646–647, 727, 729–730
Random copolymers, 2, 342
Reinforcement, 11
Relative temperature index (RTI), 34
  commercial polyphthalamide, 34
Release agents, 12
Reny, 613–616, 711
Rigidity of plastics, 33–34
Rilsan®, 245, 590–591, 699
Rynite®, 571, 685

S
SABIC Innovative Plastics Cycolac™, 49–50, 53, 55, 59
SABIC Innovative Plastics Cycoloy, 85–90
SABIC Innovative Plastics Geloy®, 63–64
SABIC Innovative Plastics LNP Thermocomp™, 238, 240, 243, 247, 249–250, 265, 273, 278, 288–289, 291, 294–295
SABIC Innovative Plastics Noryl GTX® GTX830, 131
SABIC Innovative Plastics Noryl®, 130–131, 136
SABIC Innovative Plastics Prevex® IP-16 SMA resin, 80, 83
SABIC Innovative Plastics Thermocomp, 253–254, 442, 445
SABIC Innovative Plastics Ultem®, 226–232
SABIC Innovative Plastics Xenoy®, 192
SABIC Innovative Polymers Cycolac™, 49
Samsung Stare®, 60
SAN/A. SCHULMAN, 535, 652
SAN/INEOS, 535, 652
SAN/Polimeri Europa, 535, 653
SAN/Styrolution, 535, 652–653
SAN/Styron, 536, 653
SBC/Styrolution, 540
SCHULABLEND®, 541, 657
SCHULADUR®, 580, 693
SCHULAFORM®, 550, 665
Selection guides, in plastics designing, 40–42
  based on abrasion resistance, 44
  based on chemical resistance, 43
  based on colorability, 44
  based on continuous operating temperature, 43
  based on densities, 44
  based on electrical properties, 44
  based on friction, 44
  based on mechanical properties, 42
  based on non-flammability, 44
  based on transparency, 44
Shear properties, plastics, 19
  measurement, apparatus for, 19–20
Slip, 12–13
Smoke suppressants, 11–12
SOLEF, 634, 725–726
Solexis Solef® 1008
  PVT plot for Solvay, 448
Solvay Advanced Polymers AvaSpire®, 482–489
Solvay Advanced Polymers Udel®, 513–521
Solvay Amodel®, 324–335
Solvay Ixef®, 315–321
Solvay KetaSpire®, 465–470, 472, 474–475
Solvay Radel®, 496, 522–523
Solvay Solexis Halar®, 406–409
Solvay Solexis Hyflon®, 428–431, 435
Solvay Solexis Solef®, 443–451
Standard elastomer tests, 17
Stanyl®, 596–598, 702–704
Stapron®, 577, 691
Step-growth polymerization. *See* Condensation polymerization
Stereoisomerism, 6–7
Stress vs. strain curves, 18, 38
  breakpoint, 18
  elastic limit, 18
  proportional limit, 18
  stress vs. strain behaviors, range, 21
  tensile properties determined from, 21
  ultimate strength, 18
  yield point, 18
Structural isomers, 5–6
Styrene acrylonitrile (SAN), 66, 72
Styrene maleic anhydride (SMA), 72, 77, 79–80
Styrenic blends and alloys, 83
Styrenic Blends/A. SCHULMAN, 540–541, 657
Styrenic Blends/INEOS, 542–543, 658
Styrenic Blends/Styrolution, 541–542, 658
Styrenic butadiene block copolymers (SBC), 72
  "microscopic" structure of, 77
Styrenic plastics, 532–543, 650–658
  acrylonitrile butadiene styrene (ABS), 47–48
  acrylonitrile styrene acrylate (ASA), 60, 62
  chemical structure of, 48
  methyl methacrylate–acrylonitrile–butadiene–Styrene (MABS) Polymer, 48, 60
  polystyrene (PS), 62, 65–66
  styrene acrylonitrile (SAN), 66, 72
  styrene maleic anhydride (SMA), 72, 80
  styrenic blends and alloys, 83
  styrenic butadiene block copolymers (SBC), 72
Styrolution Luran®, 62–65, 73–77
Styrolution Novodur®, 51, 55
Styrolution Styrolux®, 72, 78–79
Styrolution Terblend®, 86, 88
Styrolution Terlux®, 60–61
Styrolux®, 540, 657
STYRON, 533–534, 650–651
Styron Magnum™, 48, 52–53, 55, 59
Styron Styron™, 67–69, 71–72
Styron Tyril™, 74–75
Sumikasuper®, 185
Sumitomo Chemical Sumika Excel®, 493, 496–499
Syndiotactic polypropene, 7

T
Technyl®, 619, 713
Tedlar, 442, 451–452
Tedur®, 644–645, 727–728
Teflon AF®, 452, 457–458
Teflon®, 425, 635, 637–639
Tefzel®, 640
Tensile strength vs. temperature for BASF Ultrason®, 495
Tensile testing, plastics, 16–18
  ASTM D412-98a(2002)el, 16
  ASTM D638-03, 16
  ISO 37 Rubber, 16
  ISO 527:1993 Plastics, 16
  standard elastomer tests, 17
  standard electrical tests, 18
  standard hardness tests, 17
  standard impact tests, 17
  standard mechanical tests, 16
  standard thermal tests, 18
  stress–strain curves, 18
Terblend®, 541–542, 658
Terephthalic acid (TPA), 315
Terpolymer, 2
Testing of plastics, 15–32
  impact property testing, 22–23
  mechanical property testing, 15–18
  thermal property testing, 23–32

Tetrafluoroethylene (TFE), 399
Thermal methods of estimating Tg, 28–30
Thermal property testing of plastics, 23–32
  coefficient of thermal expansion, 32
  glass transition temperature (Tg), 28–29
  heat deflection temperature (HDT), 25–26
  melt flow index test, 26–28
  melting point (Tm), 31–32
  Vicat softening temperature (VST), 26
Thermal stability assessment, 34–36
Thermal tests, 18
Thermoplastic Copolyester Elastomers (TPE-Es/COPEs), 381, 386
Thermoplastic elastomers (TPEs), 371–398, 629–633, 721–724
Thermoplastic polyurethane elastomers (TPU), 371–373
Thermosets vs. thermoplastics, 9
Thermx®, 572, 686
THV/Dyneon 3M, 641
Ticona Celanex®, 158
Ticona GUR®, 348–350
Ticona Riteflex® TPE-Es, 386
Ticona Topas® 5013, 6013, 6015 and 6017 COC resins, 363
Ticona UHMWPE resin, 348
Ticona Vandar®, 191–194, 196
Ticona Vectra® A130, 186
Time dependent behavior, in plastics designing, 40
Topas Advanced Polymers Topas®, 363–365
Toray Plastics Toyolac™, 53–54, 56–58, 60
Toray Resin Company Amilan®, 289–290
Toray Resin Company Torelina®, 506–509
Toray Siveras®, 183–184
Toray Toraycon®, 158, 162, 164–165, 168–169
Torlon®, 219–223, 695
Tougheners, 13
Toughness, plastics designing and, 36–39
Toyolac™, 50
TPE/DSM, 630–631, 722–724
TPE/DuPont, 629–630, 721–722
Triax®, 542–543, 658
Trimellitic anhydride (TMA), 216
TYRIL, 536, 653

U
UDEL, 647, 730
UHMWPE/Celanese, 623
UL 746B relative temperature index test, 34
Ultem®, 224, 581–582, 693–695
Ultra High Molecular Weight Polyethylene (UHMWPE), 341
Ultra low density polyethylene (ULDPE), 341
Ultradur®, 567–568, 578–579, 680–681, 691
Ultraform®, yield stress or tensile strength of, 119
Ultramid®, 585–589, 605–608, 697–699, 707–709
Ultrason®, 521, 643, 647, 727, 730
Upitol®, 204–205
Urethanes, 371
UV stabilizers, 14

V
Valox®, 155–156, 158, 165–166, 168–170
Van der Waals forces, 7–8
VANDAR, 580, 693
VECTRA, 573–575, 687–688, 693
Very low density polyethylene (VLDPE), 341
Vespel®, 695
VESTAKEEP, 642, 726
VESTAMID, 591–594, 633, 699–701, 724
Vestodur®, 167
VESTORAN, 550, 665
Vicat softening temperature (VST), 26
Vicat test, 35
Victrex®, 464–465, 471–474, 476–478, 490, 642–643, 726–727
Vinyl chloride, 341–342
VOLTALEF, 302, 635

W
Wear-Resistant Solvay Advanced Polymers AvaSpire® PAEK Grades, 481

X
Xantar®, 561–563, 577–578, 674–676, 691
Xenoy®, 194
XYDAR, 575, 688

Z
Zenite®, 572–573, 686
Zytel®, 583–584, 599–605, 607–610, 696, 704–709