PDL HANDBOOK SERIES

The Effect of Temperature

and Other Factors on Plastics and Elastomers

Second Edition

Laurence W. McKeen

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NOTICE

Dedicated to my wife Linda

Contents

Preface

This book is an update to an “authorless” work of the same title, published in 1990. A lot has changed in the field since 1990 and a lot has not changed. There are new plastic materials. 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. Thus, this update is much more extensive than the usual “next edition.”

It has been reorganized from a chemistry point of view. Plastics of similar polymer types are grouped into nine chapters. Each of these chapters includes an introduction with a brief explanation of the chemistry of the polymers used in the plastics.

An extensive first chapter had been added. 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 databank that serves as an evaluation of plastics as they are exposed to varying operating conditions at different temperatures, humidity, and other factors. Over 900 uniform graphs for more than 45 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 first edition have only been removed if those products were discontinued, and many products were. Product names and manufacturers have been updated.

Larry McKeen
2007

Acknowledgments

This book is an update to an “authorless” work by the same title. It was published in 1990. Of course it was not really “authorless.” This was one of the first books published by the cofounder of William Andrew Publishing, William Woishnis. Bill Woishnis assembled this book and it was originally offered in loose leaf and binder form. His support and feedback on the content are greatly appreciated.

A number of teachers have greatly impacted my education and deserve special thanks. Ms. Anna Kruse was my high school chemistry teacher (Lyman Hall High School, Wallingford, CT) who not only was a great educator but also motivated this particular young student to study chemistry beyond the classroom. That included writing articles for an educational chemistry magazine while in high school and after school projects, one that eventually led to the 1969 International Science Fair. The many outstanding chemistry teachers at Rensselaer Polytechnic Institute (RPI) provided the best and most thorough undergraduate chemistry education in the country. RPI continues to do so in nearly all fields of science and engineering. Finally, my major professor at the University of Wisconsin, Professor James W. Taylor was a great educator and ultimately developed my teaching abilities.

The author is especially appreciative of the confidence, support, and patience of my friend and editor Sina Ebnesajjad. He was also the primary proofreader of the manuscript. I would not have been given the opportunity to do this work had it not been for the support of Martin Scrivener, President of William Andrew.

My family has been particularly supportive through the long hours of writing and research from my home office. My wife, Linda, has been behind this work 100 percent.

My daughter Lindsey graduates shortly from Rensselaer Polytechnic Institute with a Bachelor of Science in Biomedical Engineering. We talked often about polymers, plastics, and materials, as she has been studying those subjects. She will be entering the PhD program in Biology after graduation.

1 Introduction to Plastics and Elastomers

1.1 Plastics and Polymers

The most basic component of plastic and elastomer materials is polymers. The word polymer is derived from the Greek term for "many parts." Polymers are large molecules comprising many repeat units called monomers that are chemically bonded into long chains. Since World War II, the chemical industry has developed a large quantity of synthetic polymers to satisfy the need 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 2007, IDES The Plastics Web® (http://www.ides.com) listed over 65,900 different grades of plastic from over 560 suppliers.

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 addition and condensation polymerization.

In addition 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. Each new monomer unit creates an active site for the next attachment. The net result is shown in Fig. 1.1. 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, polyvinyl chloride (PVC), acrylics, polystyrene, and polyoxymethylene (acetal).

The other common method is condensation polymerization in which the reaction between monomer units and the growing polymer chain-end group releases a small molecule, often water as shown in Fig. 1.2. 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 provides 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) can degrade by a process called hydrolysis when exposed to acidic, basic, or even some neutral environments severing the polymer chains. As a result the polymer's properties are degraded.

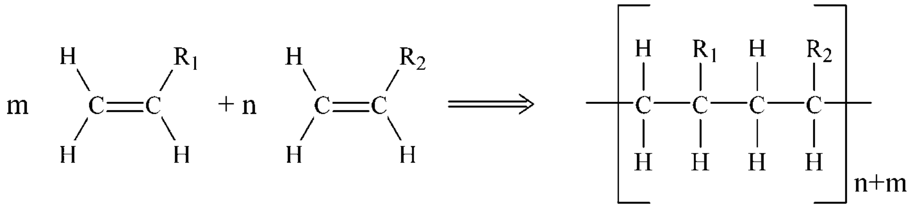


Figure 1.1. Addition polymerization.

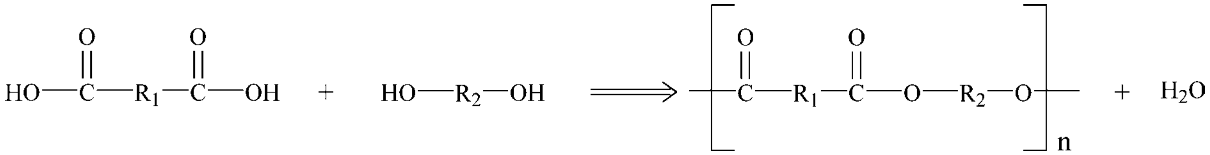


Figure 1.2. Condensation polymerization.

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

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 the following examples A and B are different monomers that do not have to be present in a one-to-one ratio. In a random copolymer, the two monomers may follow 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–

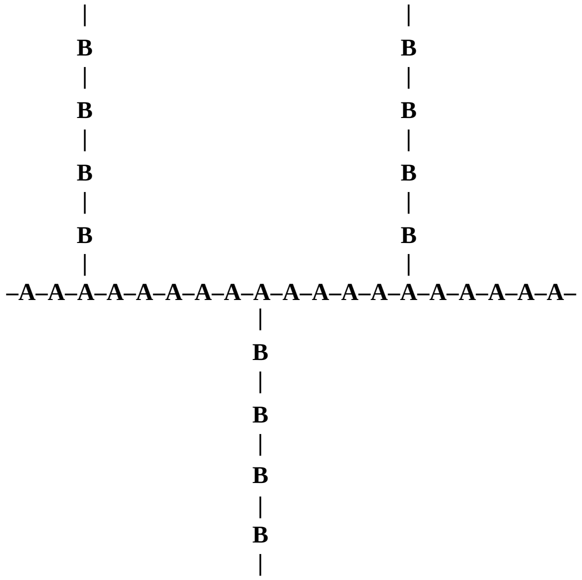
Block Copolymer

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

–A–A–A–A–A–A–B–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/Grafted Copolymer

High-impact polystyrene (HIPS) is a graft copolymer. It is a polystyrene backbone with chains of polybutadiene grafted onto the backbone. Polystyrene 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. Polyethylene, PVC, nylon 66, and polymethyl methacrylate are some of the commercial linear polymers 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 in turn may be branched and they do not connect to another polymer chain. The ends of the branches are not connected to anything. 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 at the ends. These three polymer structures are shown in Fig. 1.3.

1.1.4 Molecular Weight

A polymer's molecular weight is the sum of the atomic weights of individual atoms that comprise a molecule. It indicates the *average* length of the bulk

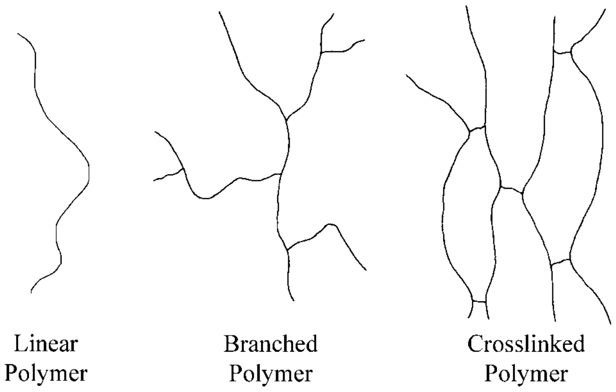


Figure 1.3. Linear, branched, and cross-linked polymers.

resin's polymer chains. All polymer molecules of a particular grade do not have exactly the same molecular weight. There is a range or distribution of molecular weights. The average molecular weight can be determined by several means, but this subject is beyond the scope of this book. Low molecular weight polyethylene chains have backbones as small as 1,000 carbon atoms long. Ultrahigh molecular weight polyethylene 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, higher molecular weight grades have higher melt viscosities. For example, in the viscosity test for polycarbonate, the melt flow rate (MFR) ranges from approximately 4 g/10 min for the highest molecular weight, standard grades to more than 60 g/10 min for 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 attack.

1.1.5 Thermosets vs. Thermoplastics

A plastic falls into one of the 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.

Unlike thermoplastics, thermosets react chemically to form crosslinks, 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.

1.1.6 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 Fig. 1.4.

Some plastics can be completely amorphous or crystalline. Often plastics specifications will report the percentage of its crystallinity (e.g., 73% crystallinity). Generally, polymer chains with bulky side groups cannot form crystalline regions. The degree of crystallinity depends on both the polymer and the processing technique. Some polymers such as polyethylene 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.

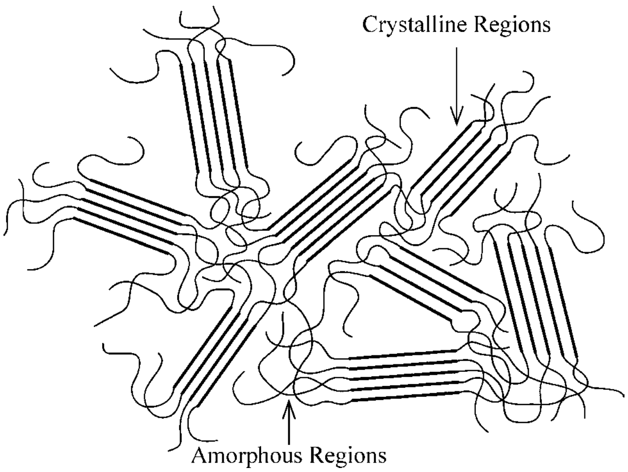


Figure 1.4. Plastics with crystalline and amorphous regions.

Crystalline and amorphous plastics have several characteristic differences. Amorphous polymers do not have a sharp melting point, but do have what is called a glass transition temperature (T_g). The glass transition temperature is the temperature at which a polymer changes from hard and brittle to soft and pliable. The force required 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. End use requirements usually dictate whether an amorphous or crystalline resin is preferred.

1.1.7 Blends

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

Sometimes a material that has some of the properties of one polymer and some of another is needed. Instead of going back to the lab and trying to synthesize a brand new polymer with all the required properties, 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 polystyrene and polyphenylene oxide. A few other examples of polymer pairs that will blend are:

- Polyethylene terephthalate with polybutylene terephthalate
- Polymethyl methacrylate with polyvinylidene fluoride

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

Polystyrene and polybutadiene are immiscible. When polystyrene is mixed with a small amount of polybutadiene, the two polymers do not blend. The polybutadiene separates from the polystyrene into little spherical blobs. Figure 1.5 illustrates the picture that would be seen if this mixture is viewed under a high power microscope.

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 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 polycarbonate resin and thermoplastic polyurethane elastomer gains rigidity from the polycarbonate resin and retains most of the flexibility and paintability of the polyurethane elastomer. For business machine housings, a blend of polycarbonate and acrylonitrile-butadiene-styrene (ABS) resins offers the enhanced performance of polycarbonate flame retardance and UV stability at a lower cost.

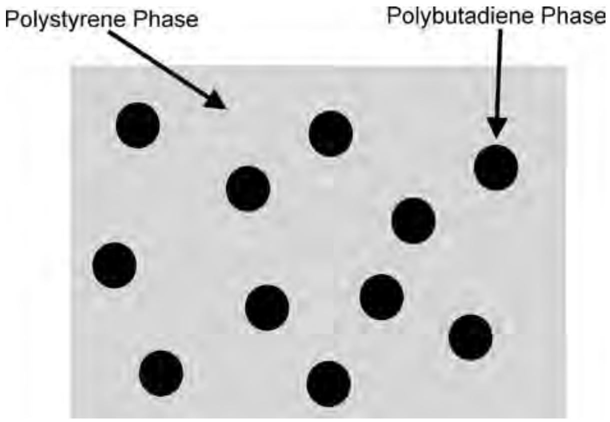


Figure 1.5. Immiscible blend of polystyrene and polybutadiene.

Additional information on the subject of polymer blends is available in the literature.[1, 2, 3]

1.1.8 Elastomers

Elastomers are a class of polymeric materials that can be repeatedly stretched to over twice the original length with little or no permanent deformation. Elastomers can be made of either thermoplastic or thermoset materials and generally are tested and categorized differently than rigid materials. They are commonly selected according to their hardness and energy absorption characteristics—properties rarely considered in rigid thermoplastics. Elastomers are found in numerous applications such as automotive bumpers and industrial hoses.

1.1.9 Additives

Additives encompass a wide range of substances that aid processing or add value to the final product.[4, 5] 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 polycarbonate 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. Most additives are added in very small amounts.

1.1.9.1 Fillers and Reinforcement

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.

1.1.9.2 Combustion Modifiers, Fire and 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 are often rated using an Underwriters Laboratories rating system. Use these ratings for comparison purposes only, as they may not accurately represent the hazard present under actual fire conditions.

1.1.9.3 Release Agents, Lubricants, Slip, and Antiblocking 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 composition of the release agent is rarely disclosed, but frequently they are fine fluoropolymer powders, called micropowders, silicone resins, or waxes.

1.1.9.4 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 less than 1%.

1.1.9.5 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 usage requirements. Addition of modifiers called impact modifiers or tougheners can significantly improve impact resistance. This is 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, for example, in the case of 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 low glass transition temperature.

Figure 1.6 shows the effect of one toughener on the izod performance of a common nylon 6 plastic. The toughener used in this graph is DuPont's Fusabond®N MN-493D. The graph shows the improvement in notched izod performance vs. temperature with differing levels of toughener additive. As shown in this figure, the performance can be dramatically improved.

1.1.9.6 UV 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 less than 1%.

1.1.9.7 Antistatic Agents

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

1.1.9.8 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.

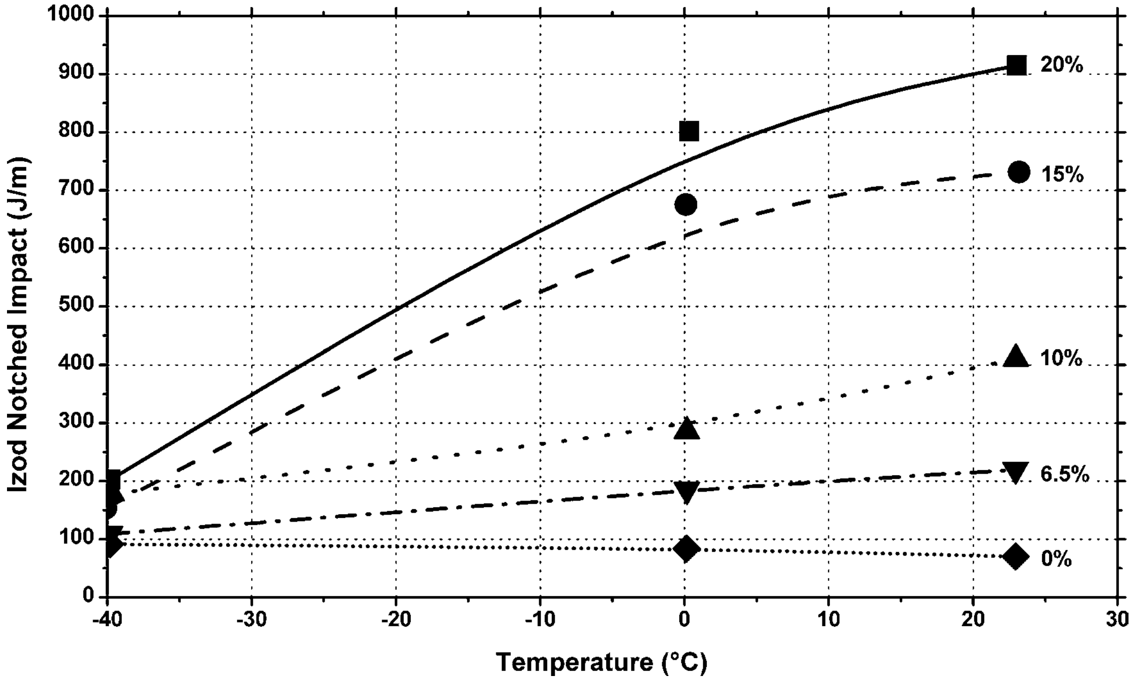


Figure 1.6. Notched izod of BASF Ultramid® B-3nylon 6 modified with various levels of DuPont Fusabond® NNM-493D toughener.

1.1.9.9 Pigments, Extenders, Dyes, Mica

Pigments are added to give color to plastic, but they may also affect the physical properties. Extenders are usually cheap materials added to reduce the cost of plastic resins. Dyes are colorants that are chemically different from pigments. Mica is a special pigment added to impart sparkle or metallic appearance.

1.1.9.10 Coupling Agents

The purpose of adding fillers is either to lower the cost of the polymer, make it tougher or stiffer, or to make it flame retardant so that it does not burn when it is ignited. Often the addition of the filler will reduce the elongation at break, the flexibility, and in many cases the toughness of the polymer because the fillers 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. Consequently, the polymer will be more compatible with the filler, the filler will adhere better to the polymer matrix, and the properties of the final mixture (e.g. elongation, flexibility) will be enhanced.

1.1.9.11 Thermal Stabilizers

The limiting factors in the use of plastics at high temperatures are their tendency to become softer and also to 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. Stabilizers can work in a variety of ways but discussion of these mechanisms is beyond the purpose of this book.

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

1.2 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 will follow.

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 (ISO), which is also well known. These organizations do not specify just plastics tests, but they both develop technical standards in the fields that 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 1.1–1.6.

Many plastics 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 1.7.

1.2.1 Mechanical Property Testing of Plastics

1.2.1.1 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 the Instron Universal Materials Testing Machine. Using 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

- 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 molding 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

Table 1.1. 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

Table 1.2. 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 1.3. 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 & 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 1.4. 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 1.5. 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 1.6. 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
Heat deflection temperature (HDT) at 8.0 MPa	–	ISO 75 Method C
HDT at 1.80 MPa	ASTM D648	ISO 75 Method A
HDT 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 (MFR)/Melt flow index (MFI)	ASTM D1238	ISO 1133

Table 1.7. ISO and ATSM Standards for Common Polymer Families

Polymer Family	ISO Standards[a]	ASTM Standards
Acrylonitrile-butadiene-styrene resin (ABS)	DIS 2580-1&2: 2003	D4673-02
Styrene-acrylonitrile resin (SAN)	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
Polymethylmethacrylate (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
E-CTFE		D3275-06
Poly (vinylidene fluoride) (PVDF)		D3222-05
Polytetrafluoroethylene (PTFE)		D4894-04
Ethylene-tetrafluoroethylene copolymer (ETFE)		D3159-06
Perfluoroalkoxy (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.

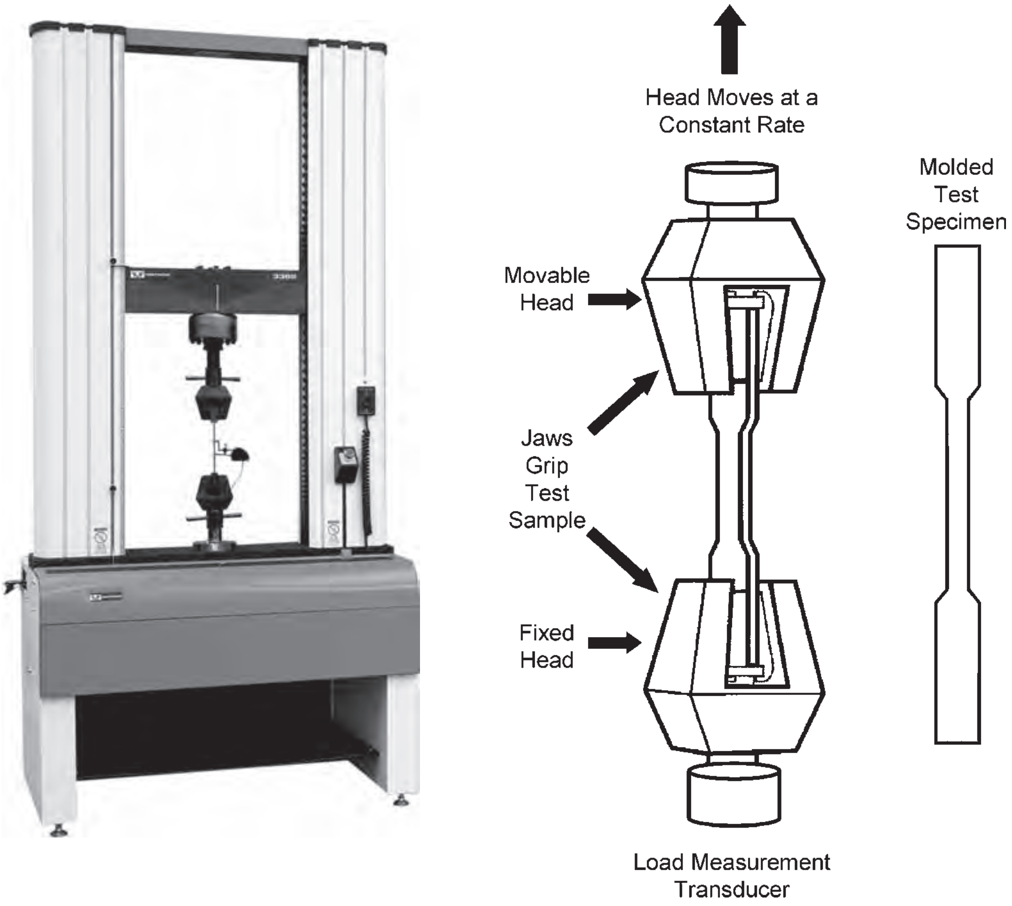
Figure 1.7 shows a picture of the Instron® Universal Materials Testing Machine (http://www.instron.com) and a diagram of the test plaque and details of the test configuration. The instrument can provide a stress–strain curve as shown in Fig. 1.8. Analysis of this curve leads to several useful mechanical measurements.

Figure 1.8 has several labeled points on the curve. These are called

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

Table 1.8 shows how some of the tensile measurements are made from the stress–strain curve in Fig. 1.8.

Most plastics when tested will show one of the four basic types of stress–strain behavior. These are shown in Fig. 1.9. The slopes of the curves and the actual measures of stress and strain may differ, but as the multipoint curves in the subsequent chapters of this book are viewed, the reader will recognize these forms. Table 1.9 lists several plastics that fit each of these behavior types.



Instron® 3300 Floor Model

Diagram of Test Specimen and Mounting Jaws

Figure 1.7. Instron Universal Materials Testing Machine (Photo Courtesy of Instron® Corporation).

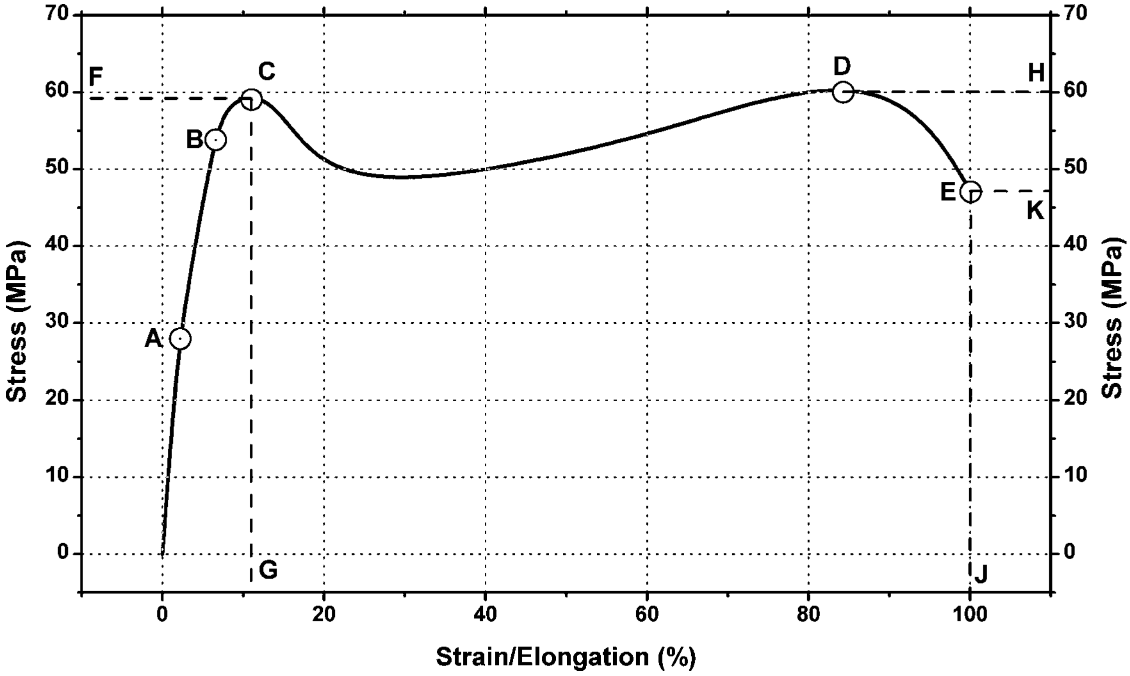


Figure 1.8. Typical stress–strain curve showing some important measurement points.

Table 1.8. 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 Fig. 1.8
Tensile elongation at yield	Tensile elongation corresponding to the yield (an increase in strain does not result in an increase in stress), "G" in Fig. 1.8
Tensile strength at break	Tensile stress corresponding to the point of rupture, "K" in Fig. 1.8
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 Fig. 1.8
Tensile strength	Tensile stress at a specified elongation
Tensile strength, ultimate	The highest tensile stress a material can support before failing, "H" in Fig. 1.8
Tensile modulus	The ratio of tensile stress to tensile strain of a material in the elastic region (from no strain to point "B" in Fig. 1.8) 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, 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

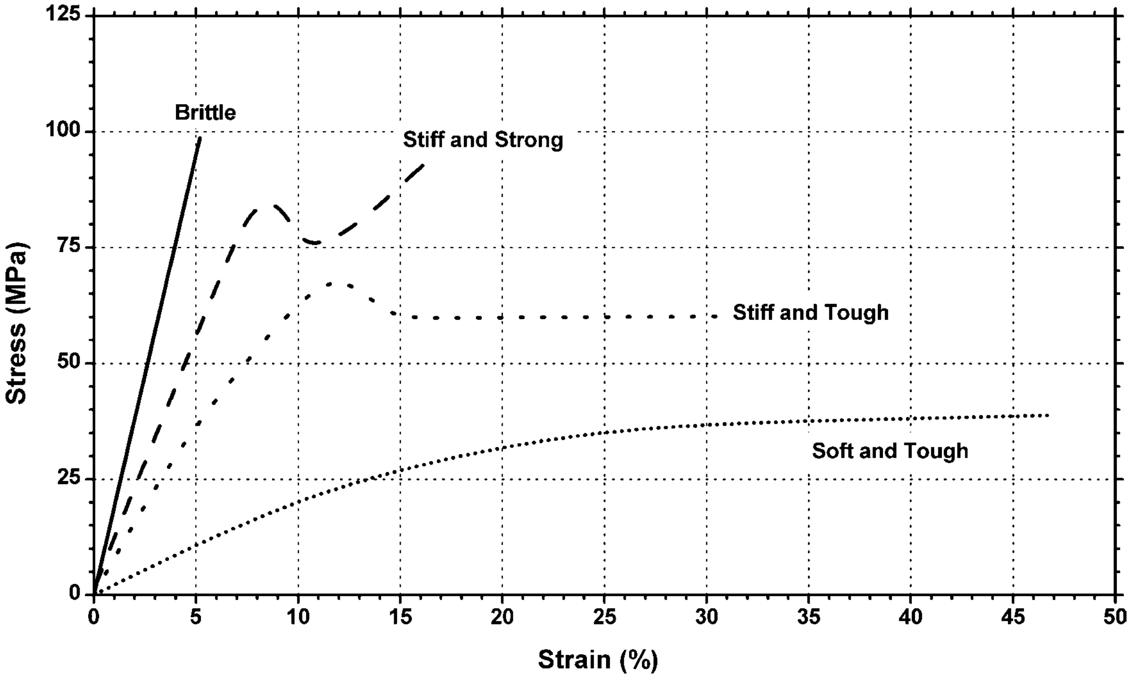


Figure 1.9. The range of stress vs. strain behaviors.

1.2.1.2 Compressive Properties

Compressive testing is similar to tensile testing except the strain is applied in the opposite direction. This is also done on the Instron® Universal Materials Testing Machine. Using 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 the compressive stress–strain curve. The standard test is the ASTM D695-02a Standard Test Method for Compressive Properties of Rigid Plastics.

1.2.1.3 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.

Table 1.9. Examples of Tensile Responses Exhibited by Various Plastics

Behavior	Examples
Brittle	Polystyrene, acrylics, SAN, highly reinforced material
Stiff and strong	ABS, polycarbonate, polyamides, highly filled resin
Stiff and tough	Impact modified polyamides, impact polystyrene
Soft and tough	Elastomers, low density

These tests are often done in the Instron® Universal Materials Testing Machine. The sample is a typically molded sheet that has been cut into a disk. The diagram of the apparatus used is shown in Fig. 1.10.

The test specimen, disk or plaque, is placed in a clamp such that its upper and lower surfaces are securely supported. The specimen thickness should be between 0.127 mm (0.005 in) and 12.7 mm (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 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 Fig. 1.10).

1.2.1.4 Flexural Properties

The measurement of flexural properties is described in the following standards:

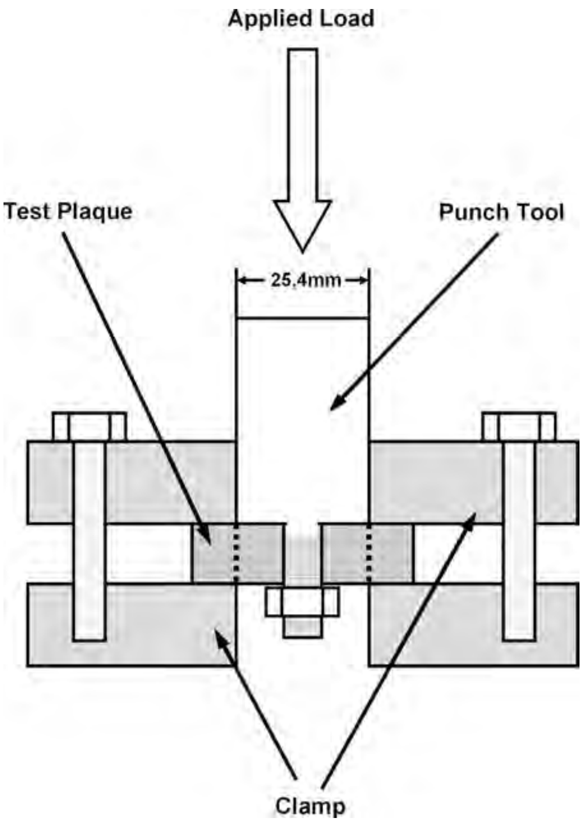


Figure 1.10. Apparatus used for shear property measurements.

- 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

A test specimen is held as a simply supported beam and is subjected to three-point bending as shown in Fig. 1.11. Typically, the Instron® is used. Maximum stress and strain occurs at the underside of the test specimen, directly under the applied force. The

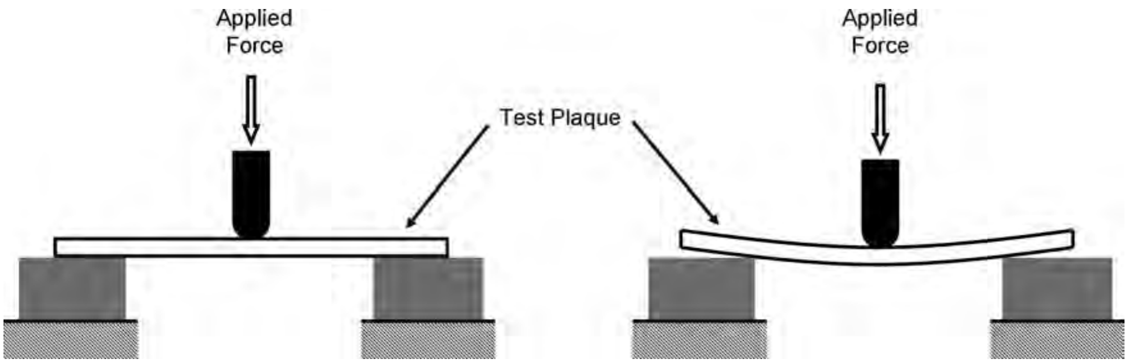


Figure 1.11. Principle used for flexural property measurements.

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.

1.2.2 Impact Property Testing of Plastics

Table 1.3 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 under two types: based on a pendulum or a falling object. The main differences are sample preparation and measurement units.

1.2.2.1 Izod Impact Strength and Charpy Impact Strength

The standard tests for Izod impact strength are given below:

- ISO 180:2000 Plastics—Determination of Izod impact strength
- ASTM D256-06a Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
- ISO 179-1:2000 Plastics—Determination of Charpy impact properties—Part 1: Noninstrumented impact test

Both Izod and Charpy tests are based on a swinging pendulum, as shown in Fig. 1.12

Basically, the pendulum is raised to a measured point and then released. The weighted end of the pendulum gains speed as it swings towards a mounted molded bar of the test plastic. It strikes the bar and breaks it; the pendulum loses energy while breaking the plastic bar. Therefore it does not swing 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 Fig. 1.13. Figure 1.14 shows the details of the notch. The

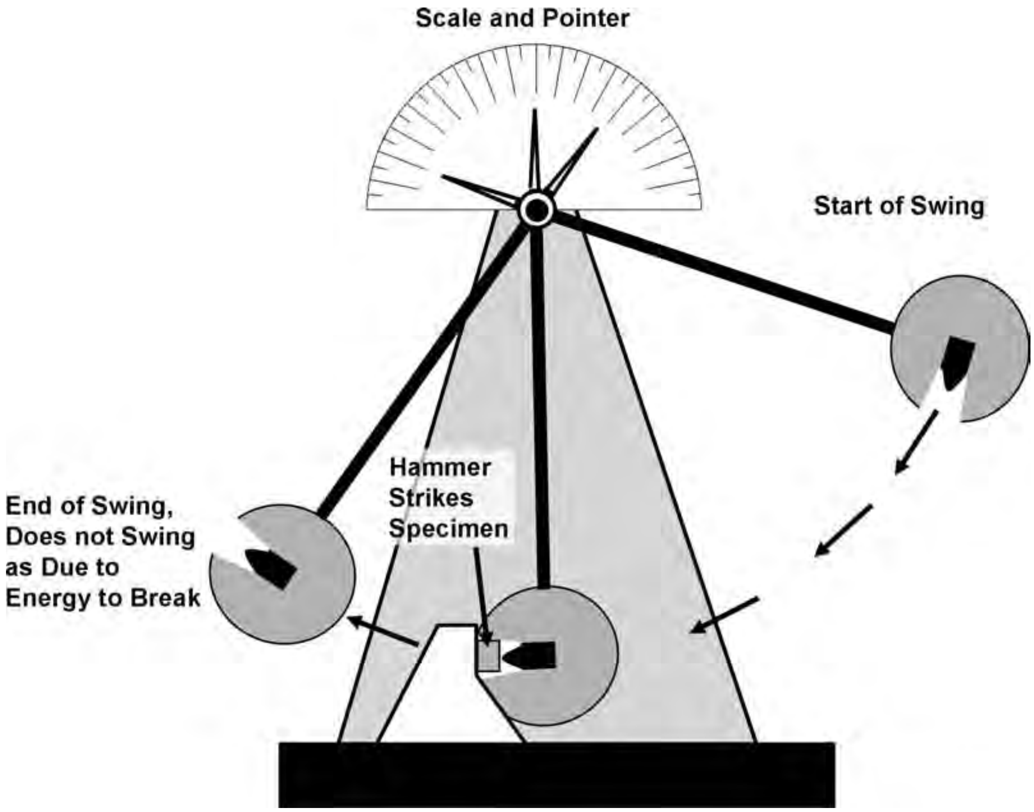


Figure 1.12. Pendulum type impact strength tester.

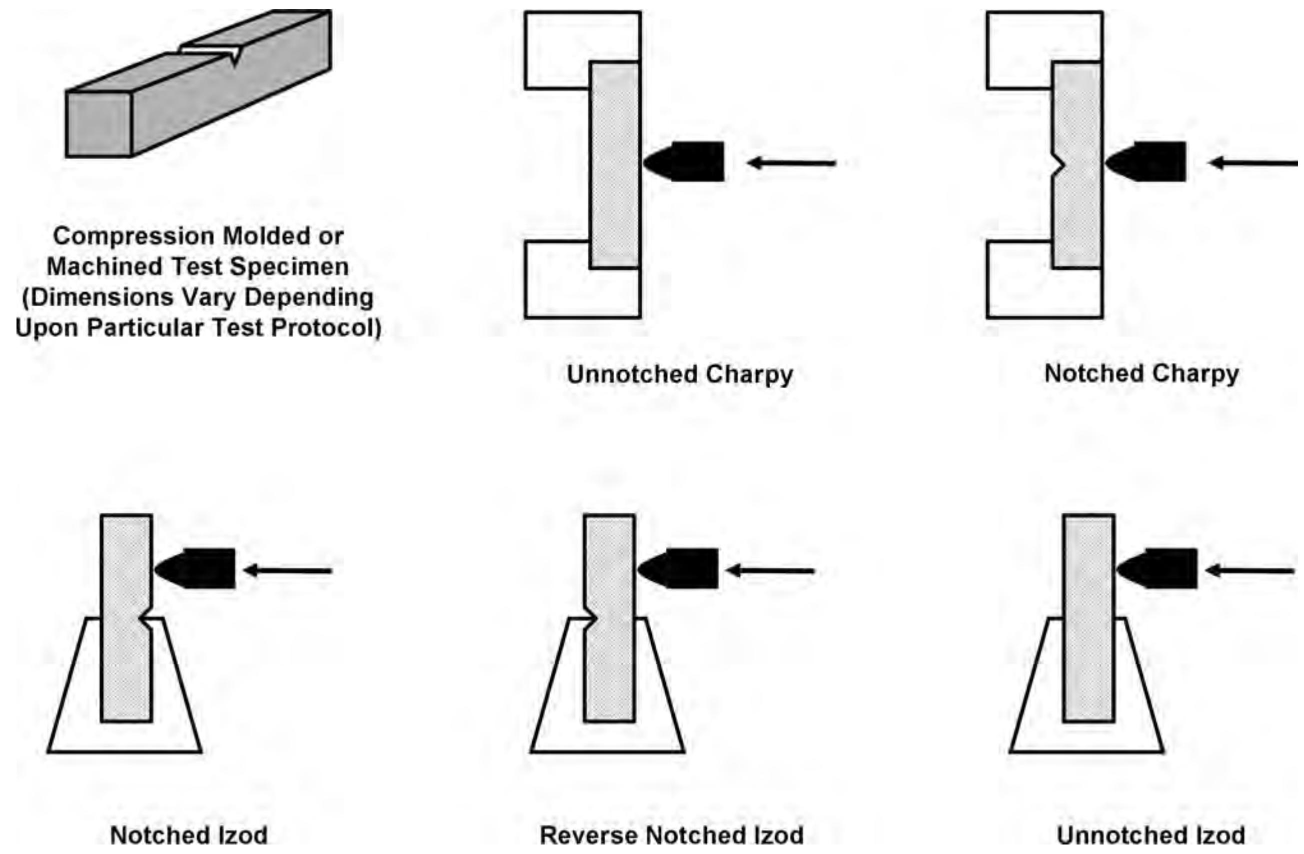


Figure 1.13. Izod and Charpy impact tests' sample configurations.

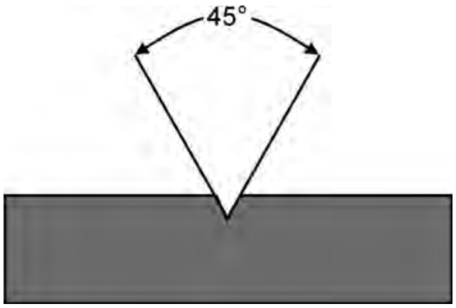


Figure 1.14. Izod and Charpy impact tests' notch details.

Table 1.10. Izod and Charpy Impact Notch Radii Options

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

sharpness of the bottom of the notch affects the test results. Table 1.10 shows the different notch radii possible.

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

1.2.2.2 Gardner and Falling Dart Impact Strength

Another impact strength test that uses gravity is the Gardner impact or the falling dart tests. These are described by 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)

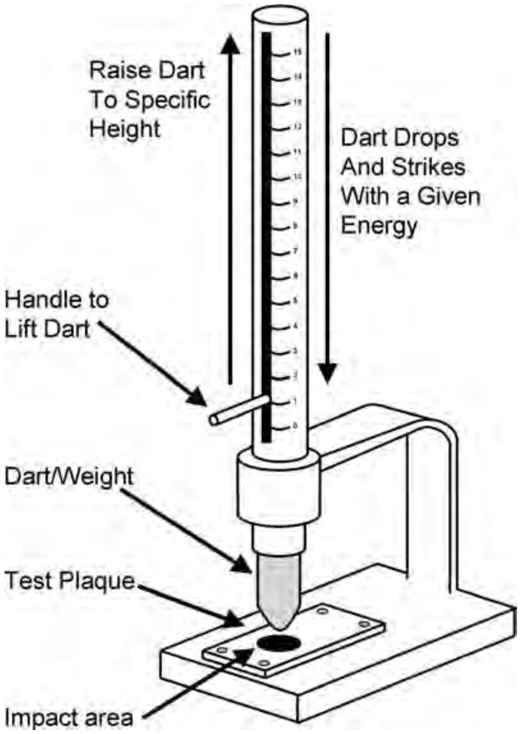


Figure 1.15. Gardner impact test apparatus.

- 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 similar to that shown in Fig. 1.15. A weight is lifted to a given height and 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.

1.2.3 Thermal Property Testing of Plastics

The standard tests for various thermal properties are given below:

- 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 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-fiber-reinforced plastics
- ISO 6603-2: Plastics—Determination of puncture impact behavior 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 (DSC)
- ISO 3146:2000 Plastics—Determination of melting behavior (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 (VST) of Plastics
- ISO 306:2004 Plastics—Thermoplastic materials—Determination of VST

- ASTM D1238-04c Standard Test Method for MFR of Thermoplastics by Extrusion Plastometer
- ISO 1133:2005 Plastics—Determination of the melt mass-flow rate and the melt volume-flow rate (MVR) of thermoplastics

1.2.3.1 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 diagramed in Fig. 1.16. A test bar is molded to a specific thickness and width. The test sample is submerged in oil that is gradually heated. The load is applied to the midpoint of the test bar that is supported near both ends. The temperature at which the bar is deformed by 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. The test using an 8 MPa load performed under ISO 75 Method C is less common.

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 duration of exposure to elevated temperatures, the rate of temperature increase, and the part geometry all affect the performance.

1.2.3.2 Vicat Softening Temperature

The Vicat softening temperature (VST) 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 as diagramed in Fig. 1.17. 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 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 and 120°C/h. This results in ISO values reported as A50, A120, B50, or B120.

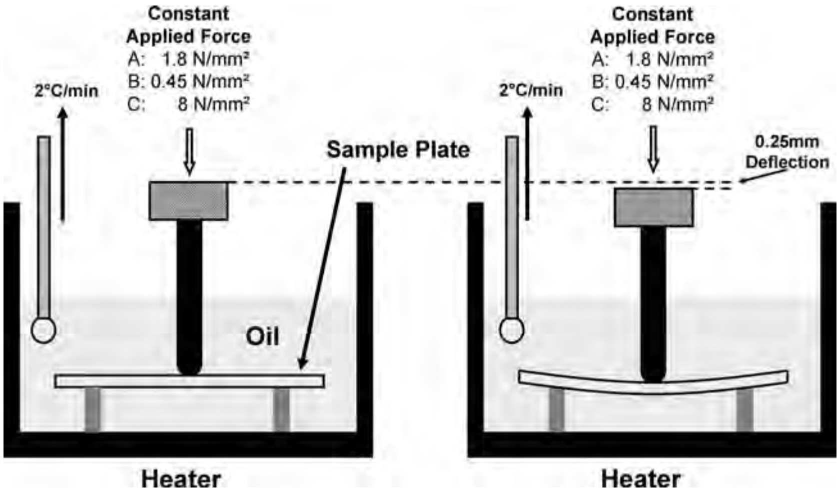


Figure 1.16. Heat deflection temperature (HDT) test apparatus.

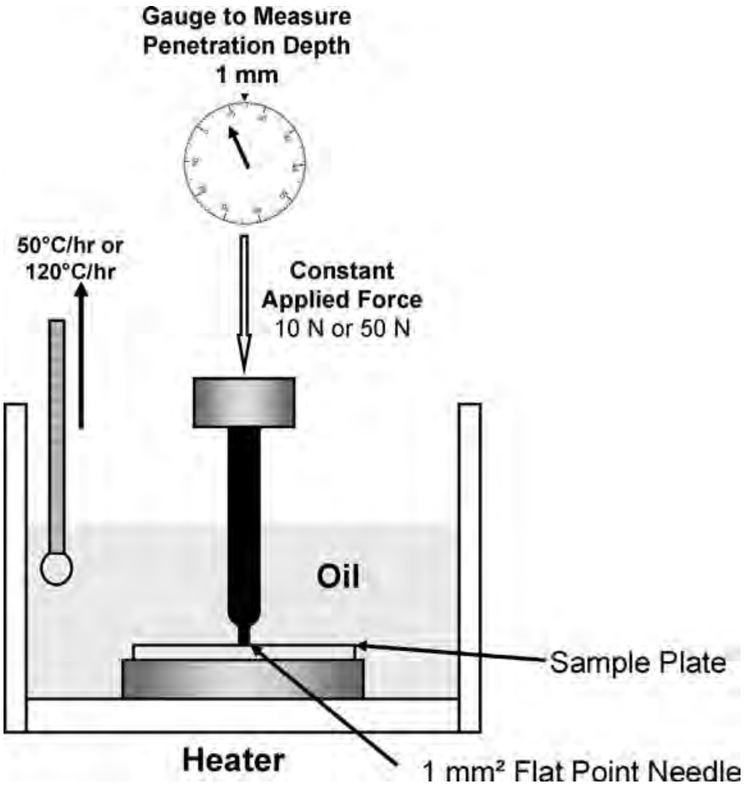


Figure 1.17. Vicat softening temperature test apparatus.

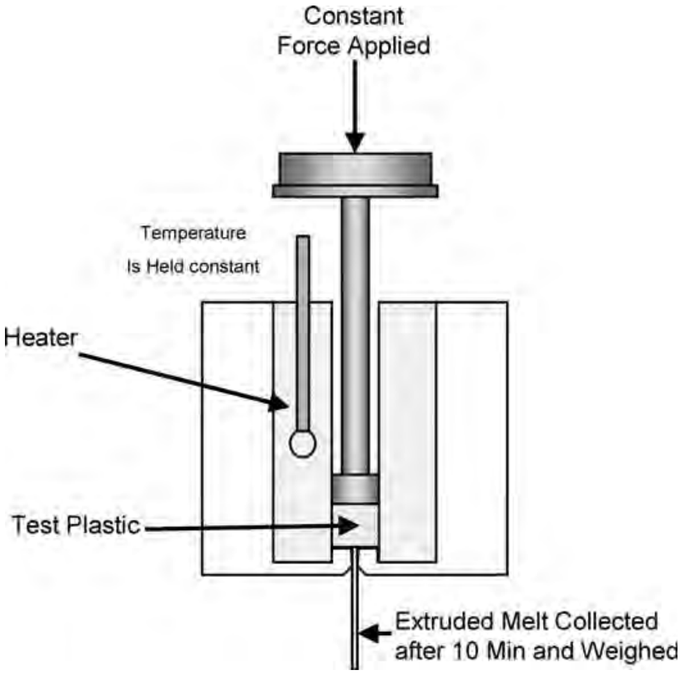


Figure 1.18. Melt flow index test apparatus.

1.2.3.3 Melt Flow Index

The MFI is a measure of the ease of flow of the melt of a thermoplastic polymer. It is defined as the weight of a 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 diagramed in Fig. 1.18.

The conditions of the test depend on the type of the polymers, some of which are shown in Table 1.11. The temperature should not be so high that the polymers in the plastic decompose. The MFR is an indirect measure of molecular weight, with high MFR corresponding to low molecular weight. Synonyms of MFI are melt flow rate and melt index, which are commonly abbreviated as MFI, MFR, and MI.

1.2.3.4 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, and so there cannot be an exact value for T_g.

1.2.3.4.1 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 Fig. 1.19. The frequency of the oscillation is important, since the value of T_g 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 the 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

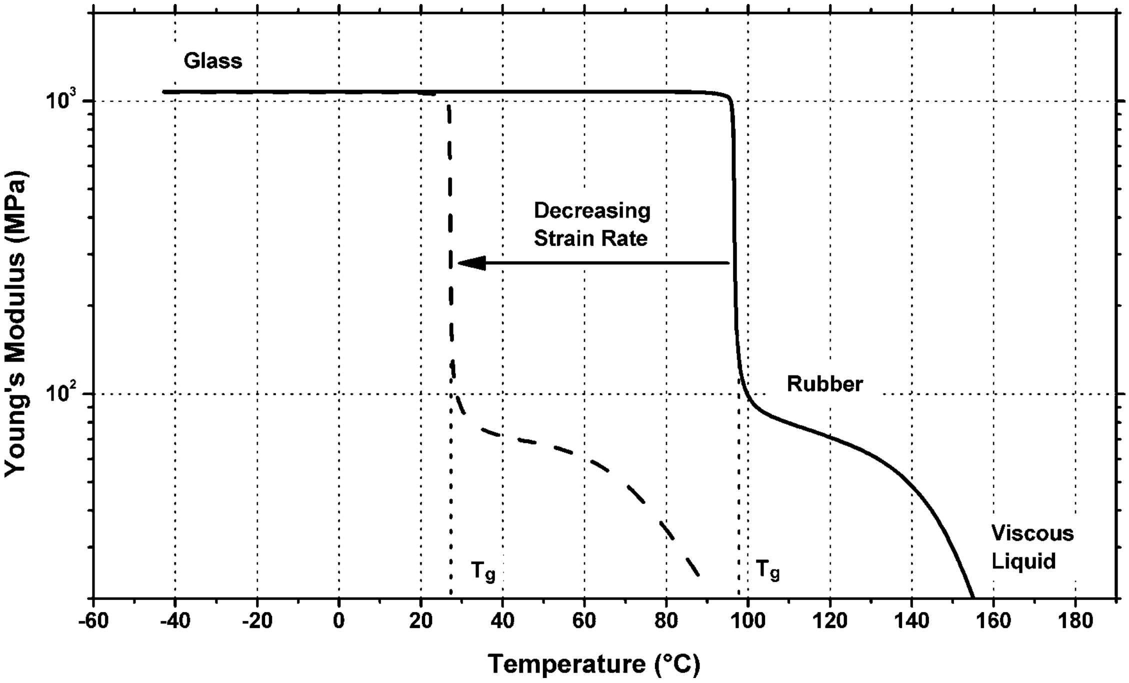


Figure 1.19. T_g estimate from an elastic modulus vs. temperature study.

Table 1.11. Recommended Conditions for Determination of MFR and MVR for Common Materials According to ISO and ASTM Guidelines (ex. 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, 2.16, 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	
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	
Polychlorotrifluorethylene (PCTFE)	265/12.5	
Polyether sulfone (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
Polyphenyl sulfone (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	
Poly(vinyl acetal)	150/21.6	
Poly(vinylidene fluoride) (PVF)	230/21.6, 230/5.0,	
Poly(phenylene sulfide) (PPS)	315/5.0	
Styrene acrylonitrile (SAN)	220/10, 230/10, 230/3.8,	220/10
Styrenic thermoplastic elastomer	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 (TEO)	230/2.16	
Vinylidene fluoride copolymers	230/21.6, 230/5.0	

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 Fig. 1.20. Figure 1.20 shows a series of blends of HIPS and polyphenylene oxide (PPO). As the amount of PPO is increased the T_g increases. The single T_g indicates that these blends are miscible.

1.2.3.4.2 *Thermal Methods of Estimating* T_g

Thermal methods of measuring T_g are based on DSC. In DSC, the thermal properties of a sample are compared against a standard reference material, typically inorganic, which has no transition such as a melting point in the temperature range of interest. The common reference material is powdered alumina. The sample and reference are each contained in a small holder within an adiabatic enclosure as illustrated in Fig. 1.21.

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 of the difference in energy supplied against the average temperature is recorded. As the temperature is slowly increased, thermal transitions may be identified.

The glass transition process for a glassy polymer that does not crystallize and is slowly heated from below T_g is illustrated in Fig. 1.22.

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 Fig. 1.23. The value of T_g depends on the heating or cooling rate of the calorimetry experiment.

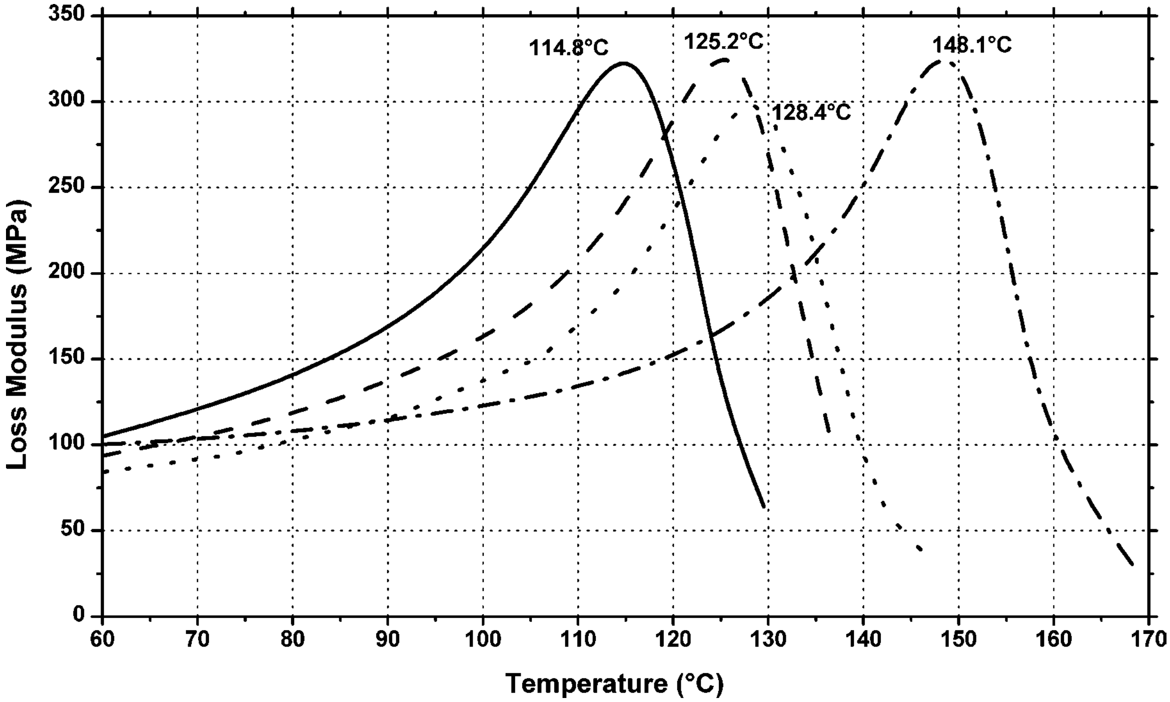


Figure 1.20. T_g estimate from dynamic mechanical thermal analysis (DMTA) study.

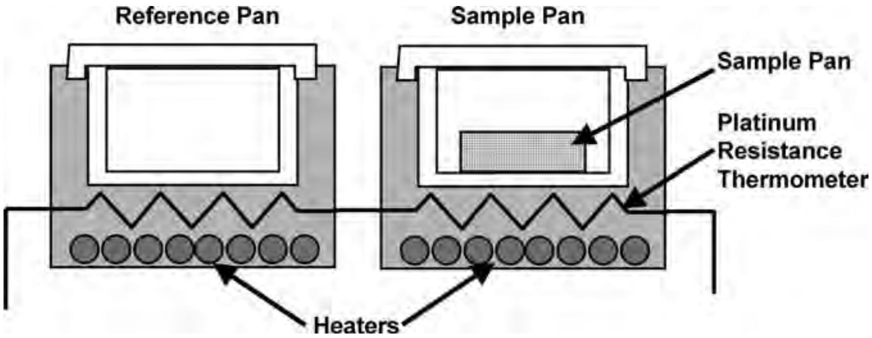


Figure 1.21. Diagram of a DSC sample and reference cell.

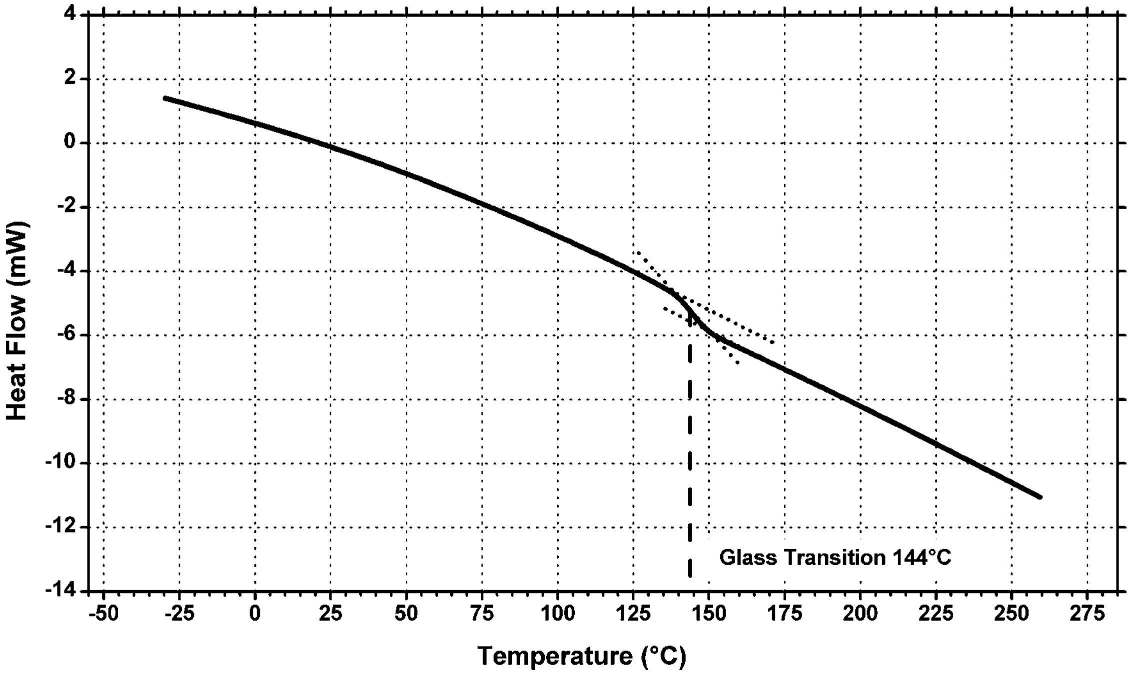


Figure 1.22. Schematic of a DSC showing a T_g.

1.2.3.4.3 Volume Methods of Determining T_g

The changes in conformation that occur above T_g require more volume; hence, plotting a graph of specific volume or thermal expansion coefficient vs. temperature will provide a value for T_g as shown in Fig. 1.24.

1.2.3.4.4 Electrical Methods of Determining T_g

Dielectric Constant: 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 bonds is not possible, so the permittivity will be low, with a large 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; hence, the glass transition occurs at a higher temperature. This is shown in Fig. 1.25.

1.2.3.5 Melting Point T_m

A melting process for the case of PET polymer is also illustrated in Fig. 1.26, which is slowly heated through its melting temperature, besides two other thermal transitions.

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

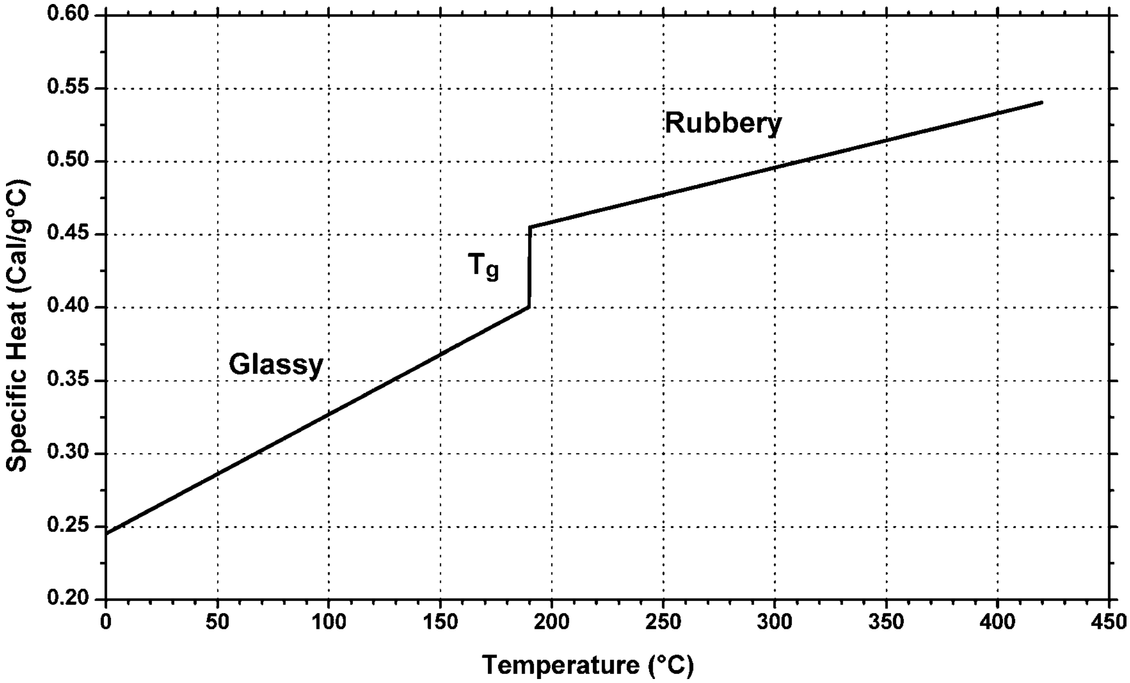


Figure 1.23. T_g estimate from the change in specific heat capacity vs. temperature for a commercial polysulfone.

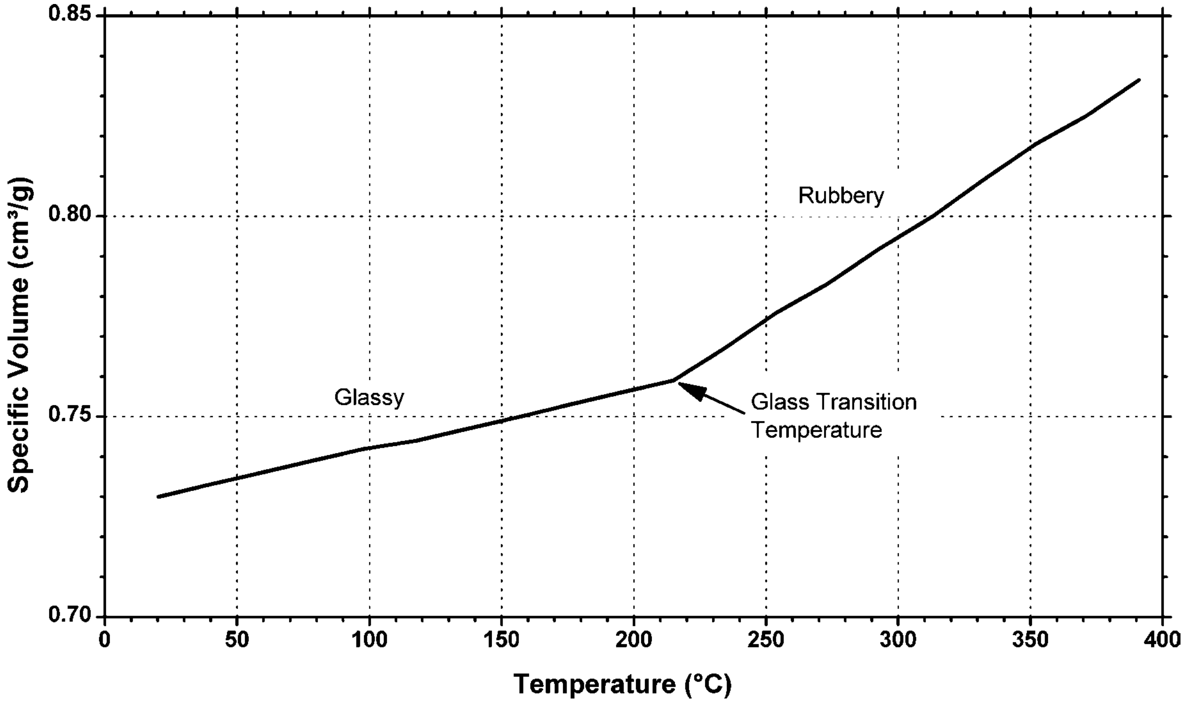


Figure 1.24. T_g estimate from the change in specific volume vs. temperature for a commercial polyethersulfone.

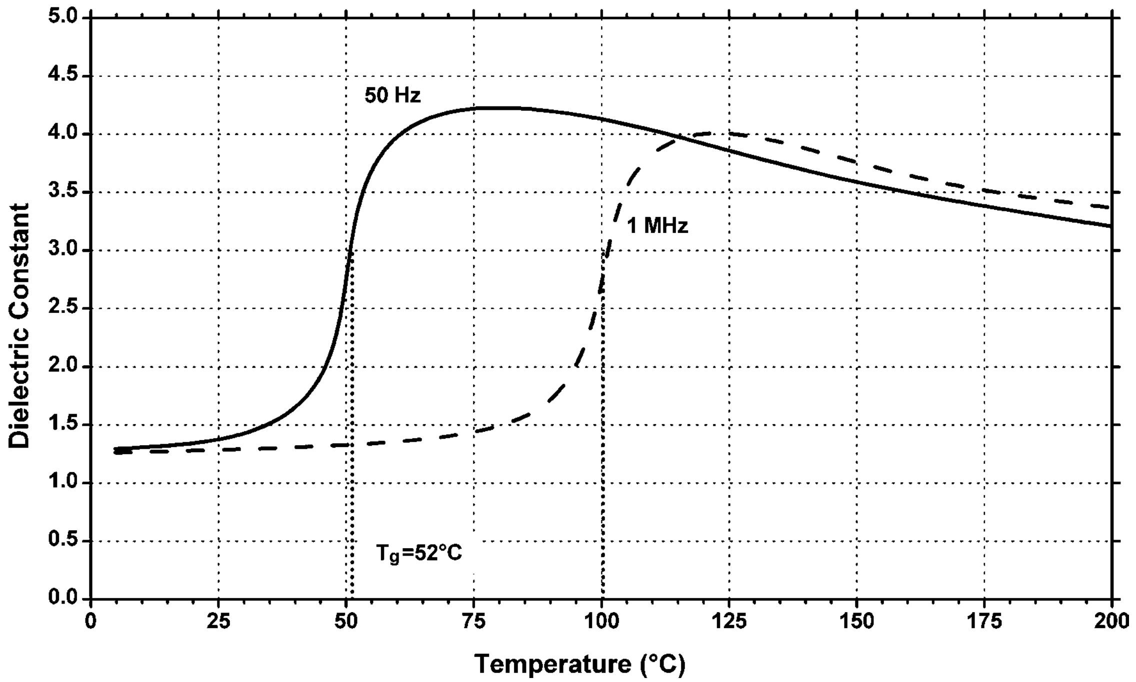


Figure 1.25. T_g estimate from the change in dielectric constant (relative permeability).

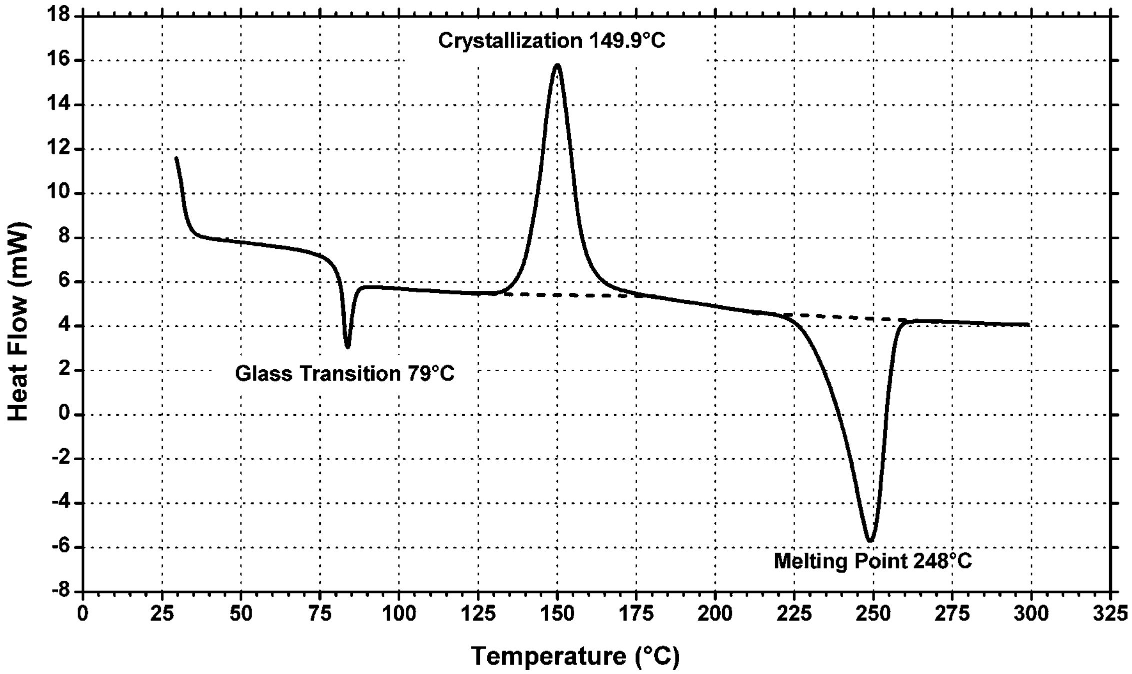


Figure 1.26. Melting point estimation from a DSC of PET.

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.

1.2.3.6 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 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 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

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 gage 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 gage 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 and 30°C. The CLTE (α) is calculated using the formula:

$$\alpha = \Delta L/(L_O{*}\Delta T)$$

where ΔL is the change in length of the specimen; L_o the original length of the specimen; and ΔT is the temperature change during the test.

Further information on polymer testing is available.[6, 7, 8]

1.3 Principles of Plastic Product Design

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

(1) requirements of the product, including usage environment, exposure conditions, performance needs;
(2) knowledge of the behavior of plastic materials;
(3) plastics processes and processing; and
(4) economic constraints.

Experience and training is required to relate this knowledge to meet 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 this 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; and
(5) resistance to thermal degradation, adversely affecting properties.

These must be at room temperature and 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; and

(11) dimensional stability.

1.3.1 Rigidity of Plastics 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 three 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 towards zero. However, in a high molecular weight plastic, such as cast poly(methyl 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 the cross-linking, 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 Fig. 1.27, where 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 has some crystallinity, and F has higher crystallinity.

Curves A, B, and C of Fig. 1.27 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 Fig. 1.27, 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 considerably on the test method used.

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, economy of the material, and ease of processing, it is important 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.

1.3.2 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. Let A "soften" at 120°C but have long-term thermal stability up 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 cannot 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 cannot be used for prolonged periods much above 70–80°C.

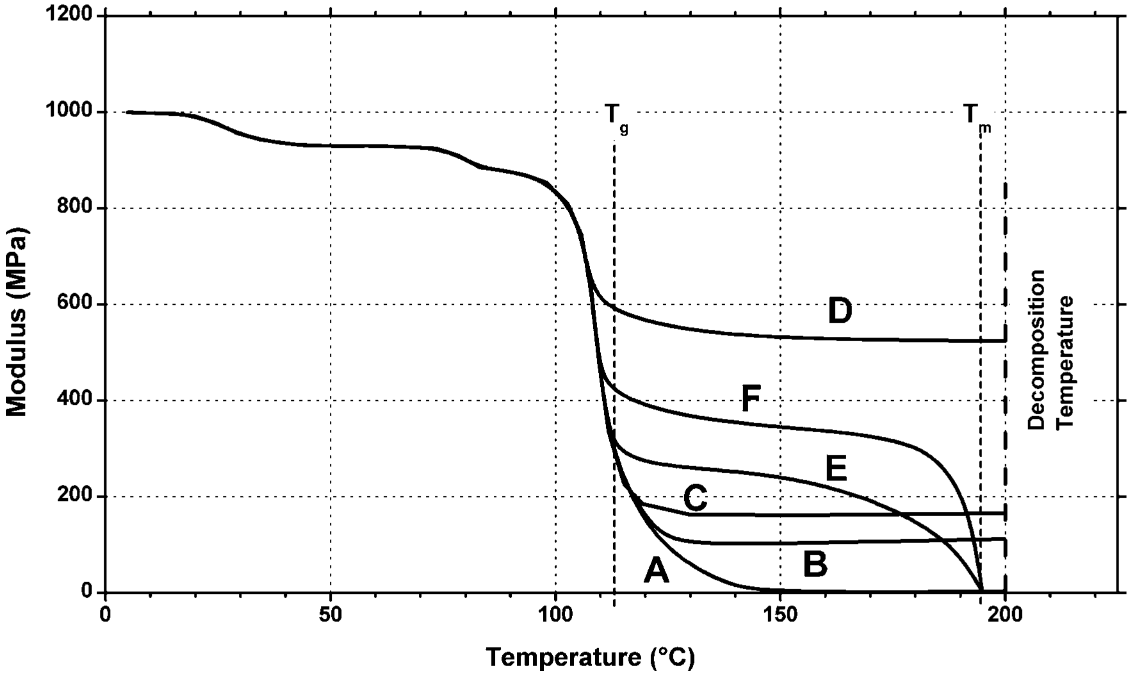


Figure 1.27. Schematic illustration of dependence of the modulus of a polymer on a variety of factors.

1.3.2.1 Assessment of Thermal Stability

Over the years many attempts have been made to provide some measure of the maximum service temperature at 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 duration of likely exposure of the material 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 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 that 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 Fig. 1.28, 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), and it is actually not linear but the inverse.

This long-term thermal performance of a material is tested alongside a control material that already has an established RTI and exhibits a good performance. Such a control is necessary because thermal degradation characteristics are sensitive to variables in the testing program. The control is not shown in Fig. 1.28. Since the control material may 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 three properties are assessed in UL 746B.

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

(2) "Mechanical without impact" by measuring tensile strength.

(3) "Electrical" by measuring dielectric strength.

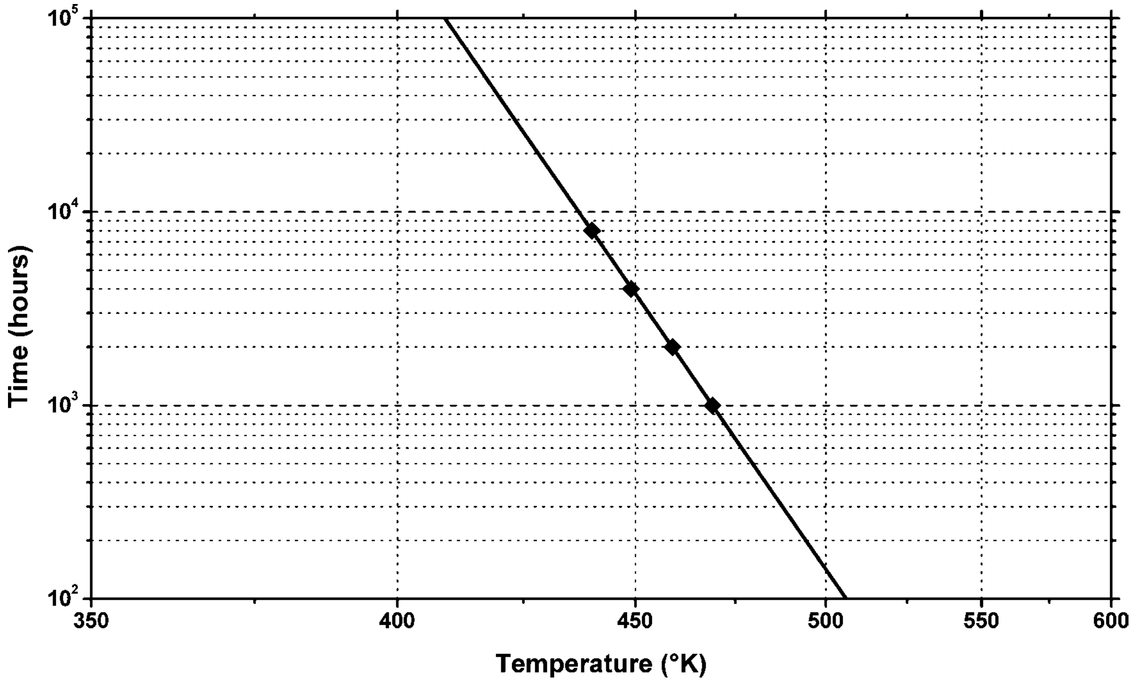


Figure 1.28. A relative temperature index plot for a commercial polyphthalamide.

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

In addition, the 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 on the type and amount of additives used. It is possible to obtain a Generic Temperature Index from the laboratory to cover a species of material but this will usually be considerably lower than that for many of the individual grades within that species.

Some collected values for RTI taken from the literature are given in Table 1.12. (These are given for guidance only and should not be taken to imply official UL ratings.)

Two particular test methods have become very widely used. They are the VST test and the HDT test (which is also widely known by the earlier name of heat distortion temperature test). These two tests were discussed earlier in Sections 1.2.3.1 and 1.2.3.2.

While the Vicat test usually gives the higher values, the differences are quite modest with many polymers (e.g. those of curves A, B, and C in Fig. 1.27). For example, in the case of the polycarbonate 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 Vicat softening point is about 165°C. In the case of an acetal homopolymer the temperatures are 100, 170, and 185°C, respectively. With nylon 66, the two ASTM heat distortion tests give values as different as 75 and 200°C. A low-density polyethylene may have a Vicat temperature of 90°C but a heat distortion temperature below normal ambient temperatures.

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. Reference to Fig. 1.27 shows that with some materials (e.g. of curve A in Fig. 1.27) this will not be of great importance but with other types (e.g. curves E or F in Fig. 1.27) 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” while 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 less often quoted than the other two tests.

Table 1.12. Some Collected Values for Relative Temperature Index (RTI) (Unless Otherwise Stated, Data are for "Mechanical Without Impact" and for Unreinforced Grades)

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

Some interesting differences are noted between amorphous and crystalline polymers when glass fiber reinforcement is incorporated into the polymer. In Fig. 1.29, it will be seen that incorporation of glass fiber has a minimal effect on the HDT of amorphous polymers (polystyrene, ABS, polycarbonate, and polysulfone) but large effects on crystalline polymers. It is particularly interesting, as well as being technically important, that for many crystalline polymers the unfilled polymer has a HDT (at 1.82 MPa stress) similar to T_g, whereas the filled polymers have values close to T_m (Table 1.13). Note that incorporation of glass fiber has a much greater effect with crystalline polymers than with amorphous ones.

1.3.3 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. In 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.

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 Fig. 1.30A. 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 as shown in Fig. 1.30B) will be much more, so that the material will be regarded as tough for many purposes.

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 a T_g well below the expected service temperature (e.g. polyethylene).

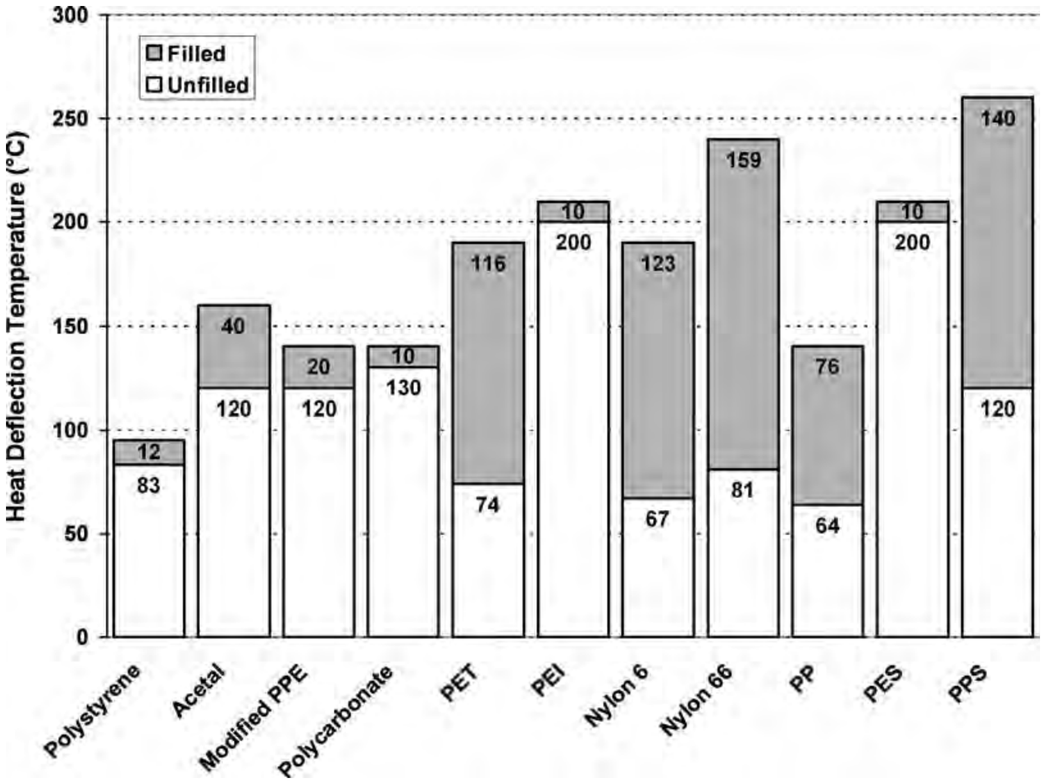


Figure 1.29. Heat deflection temperature under a load of 1.82 MPa for selected polymers showing the effect of added filler (30% glass fiber).

(2) By block copolymerization so that one component of the block copolymer has a T_g well below the expected service temperature range (e.g. polypropylene with small blocks of polyethylene or preferably polypropylene with small amorphous blocks of ethylene–propylene copolymer).

(3) By blending with semicompatible materials that have a T_g well below the expected service temperature range (e.g. HIPS).

(4) By the use of a polymer that has effective transitions at or below the expected service temperature range and is able to respond to stress by extensive deformation (e.g. polycarbonates).

(5) By plasticization. This in effect reduces the 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. Note 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 will also depend on the temperature and the rate of striking but more important 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 the processor must be to reduce such stress concentration to a minimum.

1.3.3.1 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

Table 1.13. 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 .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		

whether an article made from a specific material will or will not be satisfactory in service.

Some of the factors that will influence service performance are given below:

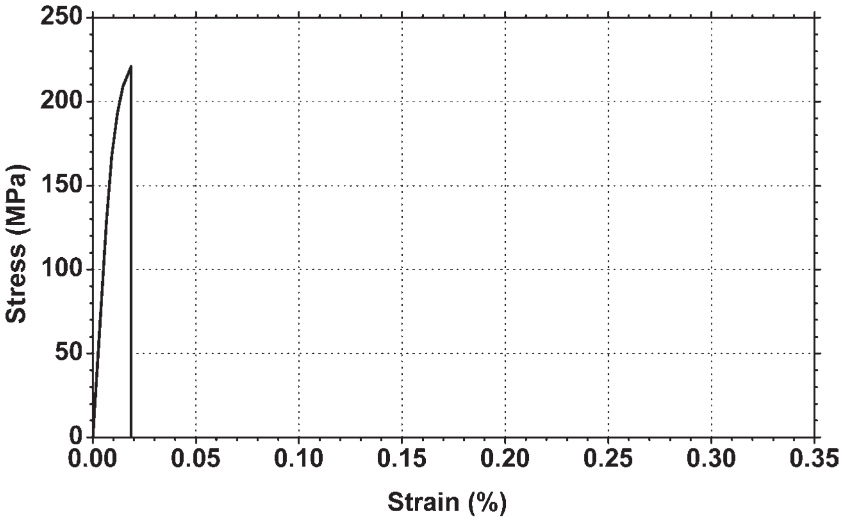
(1) The effect of additives and impurities;
(2) Temperature;
(3) Geometric size and shape;
(4) Orientation and morphology;
(5) Surface condition;
(6) Energy and speed of any impacting blow;
(7) The shape of the impacting instrument;
(8) The environment; and
(9) Strains in the article due to external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

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

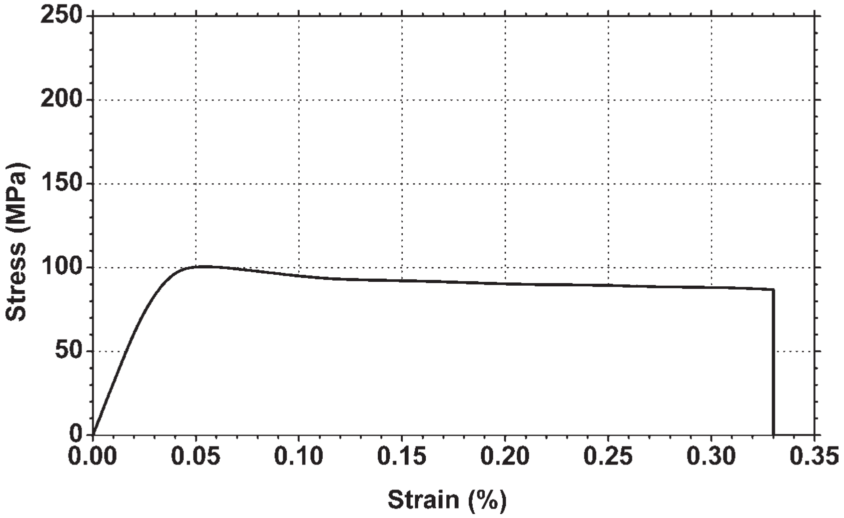
Impact tests are, however, used to try to compare the impact strength of different materials. Of these tests, four merit specific mention. These are the Izod test, the Charpy test, the falling weight tests, and the tensile impact test.

Of these, the most well known is the Izod test. This test is discussed in detail in Section 1.2.2.1. Because of the stress concentrations around the notch, much lower impact strengths are recorded with notched specimens than with unnotched specimens.

While 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



A) Rigid polymer, below T_g has very high tensile strength, but less area under the curve = less energy to break



B) Rigid polymer, above T_g has lower tensile strength, but more area under curve = more energy to break

Figure 1.30. Stress vs. strain curves for two plastics.

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 such units 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 1/2” to 1/8” the impact strength of a polycarbonate 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 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 subjected to an impact at 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 the use of 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 shown in Fig. 1.31. Materials like unplasticized PVC, nylon, polyacetals, and polycarbonates (not shown in the diagram) are very sensitive to 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. While the last named test provides results more amenable to theoretical study, plastics products are not commonly subjected to this type of impact and producer data are limited.

1.3.3.2 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.

1.3.3.3 Selection Guides

Selection and evaluation of materials can be very complex. The following series of questions is based on material from the 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?

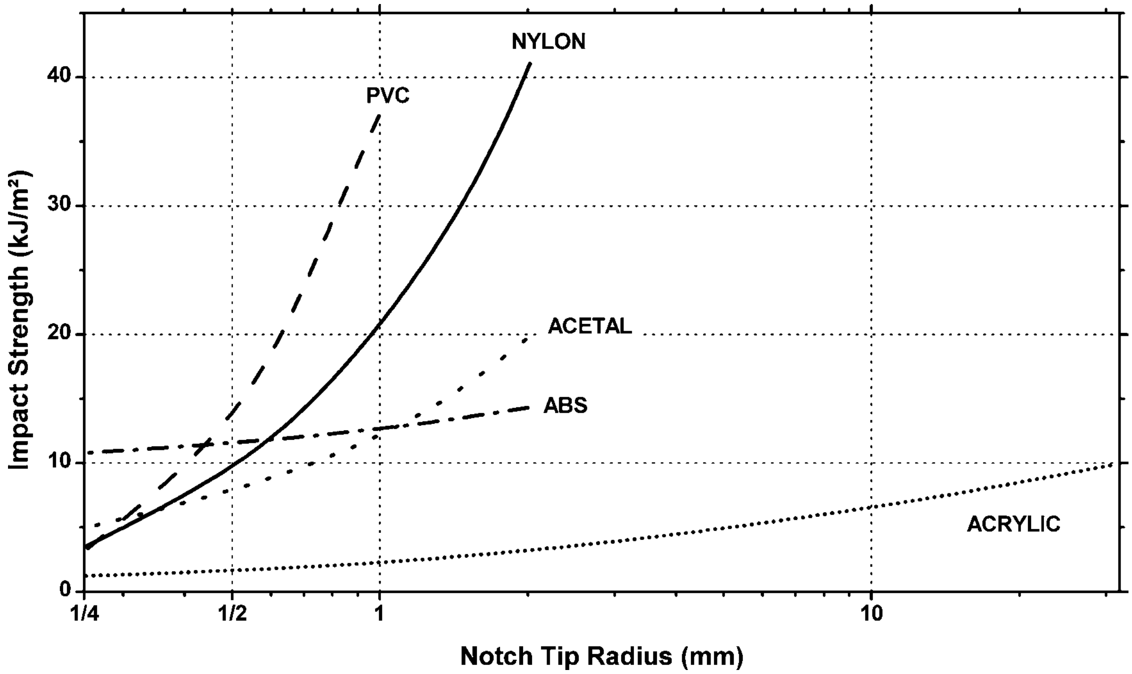


Figure 1.31. Impact strength vs. notch radius for various plastics.

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 closely duplicates the impact occurring in this application?

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

(3) WILL THE PART BE SUBJECTED TO 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 BE SUBJECTED TO AND FOR HOW LONG?
   (a) What is the maximum temperature the material will withstand while in use?
   (b) What is the minimum temperature the material will withstand while 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 withstand?
   (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 metals. They may also expand and contract to different extents 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 like flexible vinyls, urethanes, rubber, or a thermoplastic elastomer may be used.

(10) WILL THE PART HAVE TO MEET ANY REGULATORY REQUIREMENTS?

- (a) Is an Underwriter's Laboratories (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.

(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 subjects 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, polycarbonates, 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.

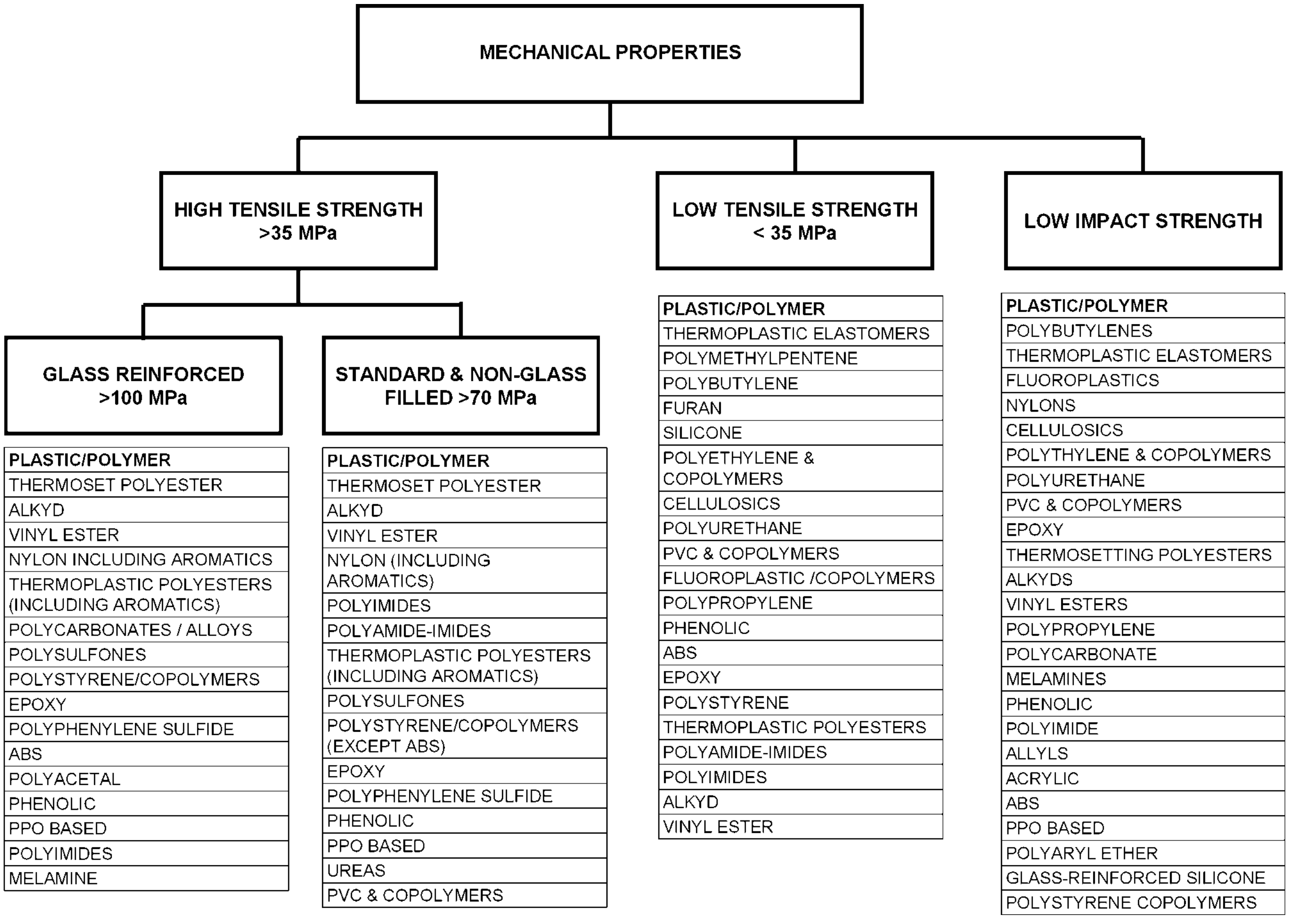
The remainder of this section contains several general selection guides in Figs. 1.32–1.36 in graphical form. There are plastics in these guides that are not discussed in this book. These are generally thermosets.

More detailed guides on material selection and product design are available from many of the large plastics manufacturers and the literature.[9, 10, 11]

1.4 Summary

The rest of this book consists of property data on many plastics and elastomers. Chapters 2 through 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, the chapter begins with the stress versus strain curves , 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. This data is described in the standard ISO 10350-1:1998, which



GLASS REINFORCED >100 MPa

PLASTIC/POLYMER
THERMOSET POLYESTER
ALKYD
VINYL ESTER
NYLON INCLUDING AROMATICS
THERMOPLASTIC POLYESTERS (INCLUDING AROMATICS)
POLYCARBONATES / ALLOYS
POLYSULFONES
POLYSTYRENE/COPOLYMERS
EPOXY
POLYPHENYLENE SULFIDE
ABS
POLYACETAL
PHENOLIC
PPO BASED
POLYIMIDES
MELAMINE

STANDARD & NON-GLASS FILLED >70 MPa

PLASTIC/POLYMER
THERMOSET POLYESTER
ALKYD
VINYL ESTER
NYLON (INCLUDING AROMATICS)
POLYIMIDES
POLYAMIDE-IMIDES
THERMOPLASTIC POLYESTERS (INCLUDING AROMATICS)
POLYSULFONES
POLYSTYRENE/COPOLYMERS (EXCEPT ABS)
EPOXY
POLYPHENYLENE SULFIDE
PHENOLIC
PPO BASED
UREAS
PVC & COPOLYMERS

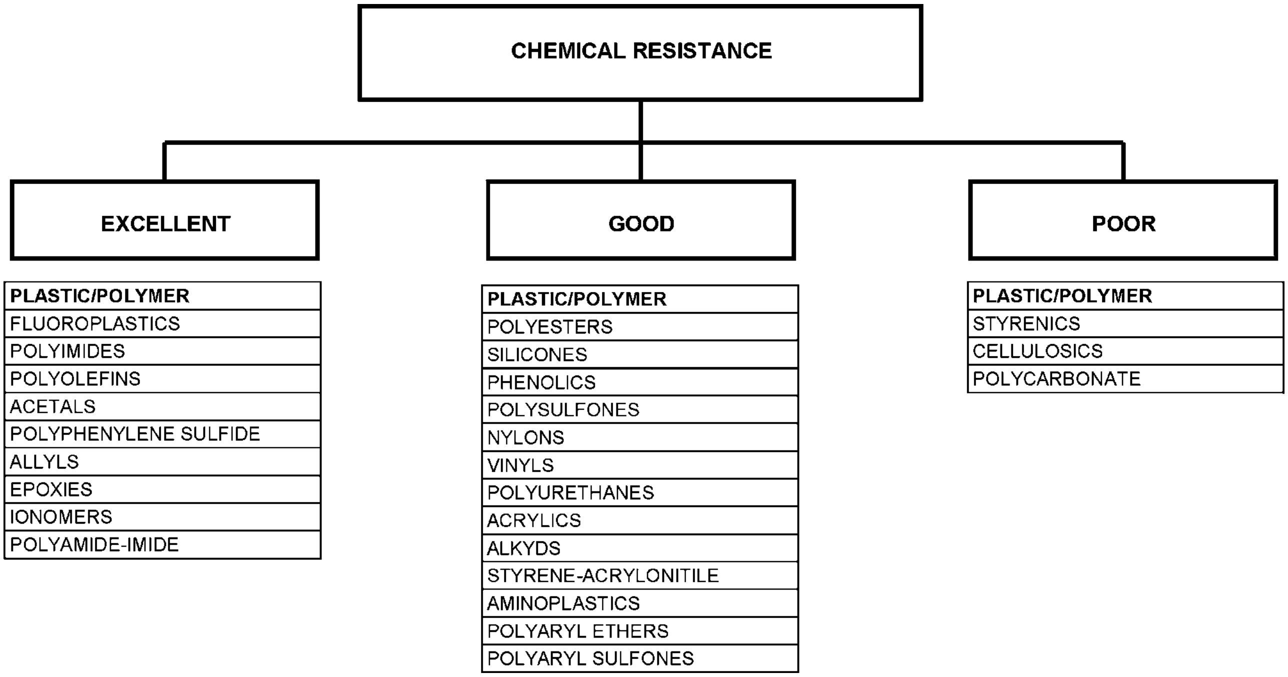
LOW TENSILE STRENGTH < 35 MPa

PLASTIC/POLYMER
THERMOPLASTIC ELASTOMERS
POLYMETHYLPENTENE
POLYBUTYLENE
FURAN
SILICONE
POLYETHYLENE & COPOLYMERS
CELLULOSICS
POLYURETHANE
PVC & COPOLYMERS
FLUOROPLASTIC /COPOLYMERS
POLYPROPYLENE
PHENOLIC
ABS
EPOXY
POLYSTYRENE
THERMOPLASTIC POLYESTERS
POLYAMIDE-IMIDES
POLYIMIDES
ALKYD
VINYL ESTER

LOW IMPACT STRENGTH

PLASTIC/POLYMER
POLYBUTYLENES
THERMOPLASTIC ELASTOMERS
FLUOROPLASTICS
NYLONS
CELLULOSICS
POLYTHYLENE & COPOLYMERS
POLYURETHANE
PVC & COPOLYMERS
EPOXY
THERMOSETTING POLYESTERS
ALKYDS
VINYL ESTERS
POLYPROPYLENE
POLYCARBONATE
MELAMINES
PHENOLIC
POLYIMIDE
ALLYLS
ACRYLIC
ABS
PPO BASED
POLYARYL ETHER
GLASS-REINFORCED SILICONE
POLYSTYRENE COPOLYMERS

Figure 1.32. Selection guide based on mechanical properties.



EXCELLENT

PLASTIC/POLYMER
FLUOROPLASTICS
POLYIMIDES
POLYOLEFINS
ACETALS
POLYPHENYLENE SULFIDE
ALLYLS
EPOXIES
IONOMERS
POLYAMIDE-IMIDE

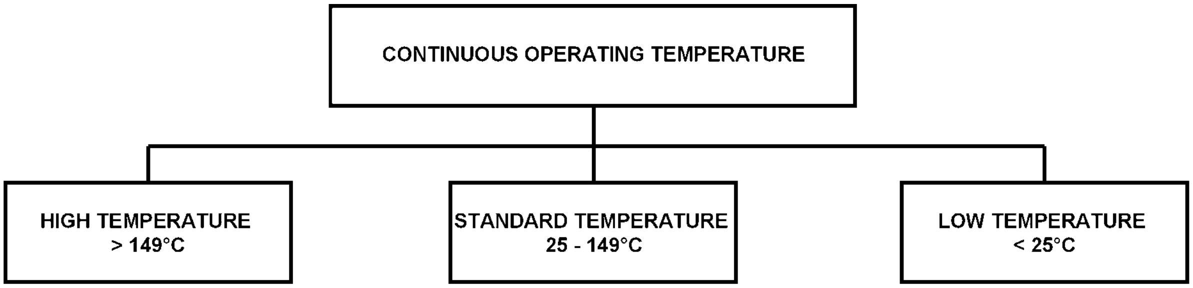
GOOD

PLASTIC/POLYMER
POLYESTERS
SILICONES
PHENOLICS
POLYSULFONES
NYLONS
VINYLS
POLYURETHANES
ACRYLICS
ALKYDS
STYRENE-ACRYLONITILE
AMINOPLASTICS
POLYARYL ETHERS
POLYARYL SULFONES

POOR

PLASTIC/POLYMER
STYRENICS
CELLULOSICS
POLYCARBONATE

Figure 1.33. 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 & SAN	71-104
POLYSTYRENE	52-96
ABS/POLYCARBONATE ALLOY	88-93
ACRYLICS	60-93
CELLULOSICS	49-93
POLYETHYLENE & COPOLYMER	49-82

PLASTIC/POLYMER	°C
CHLORINATED POLYETHYLENE	-51
POLYURETHANE	-65
FLUOROSILICONE	-68
SILICONE	-118
FLUOROPLASTICS	-184

Figure 1.34. Selection guide based on continuous operating temperature.

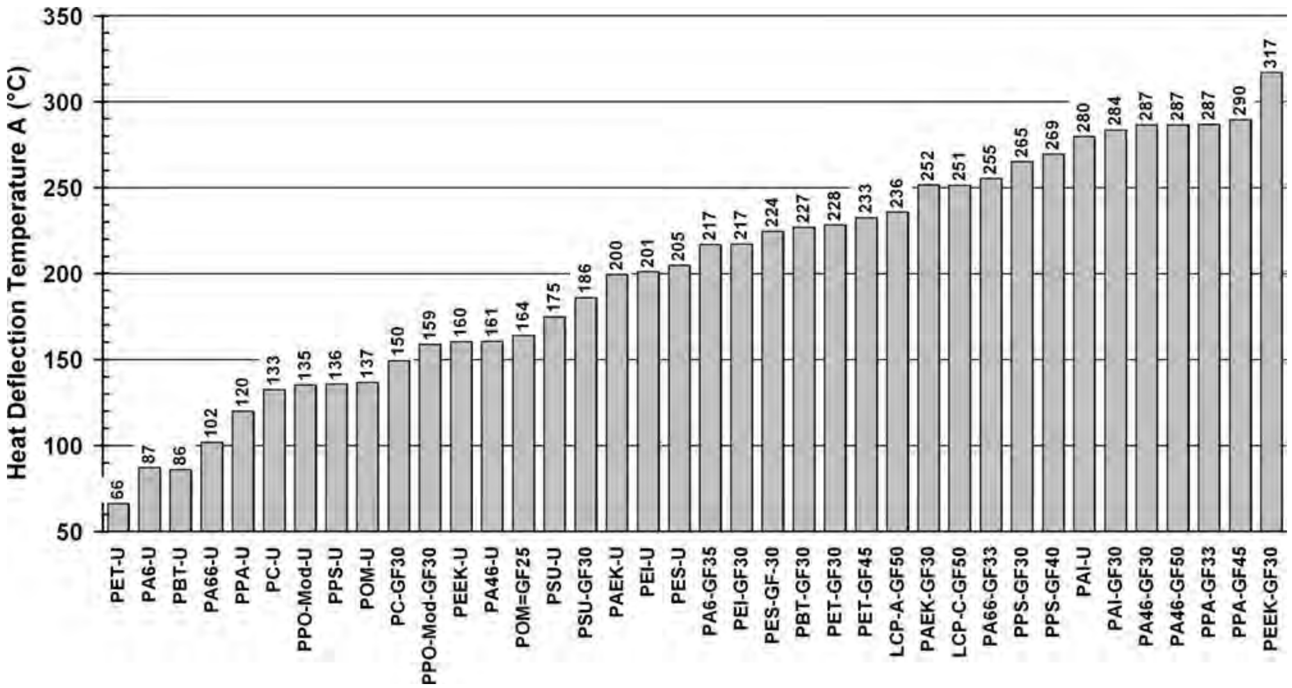


Figure 1.35. Heat deflection data on generic family of plastics.

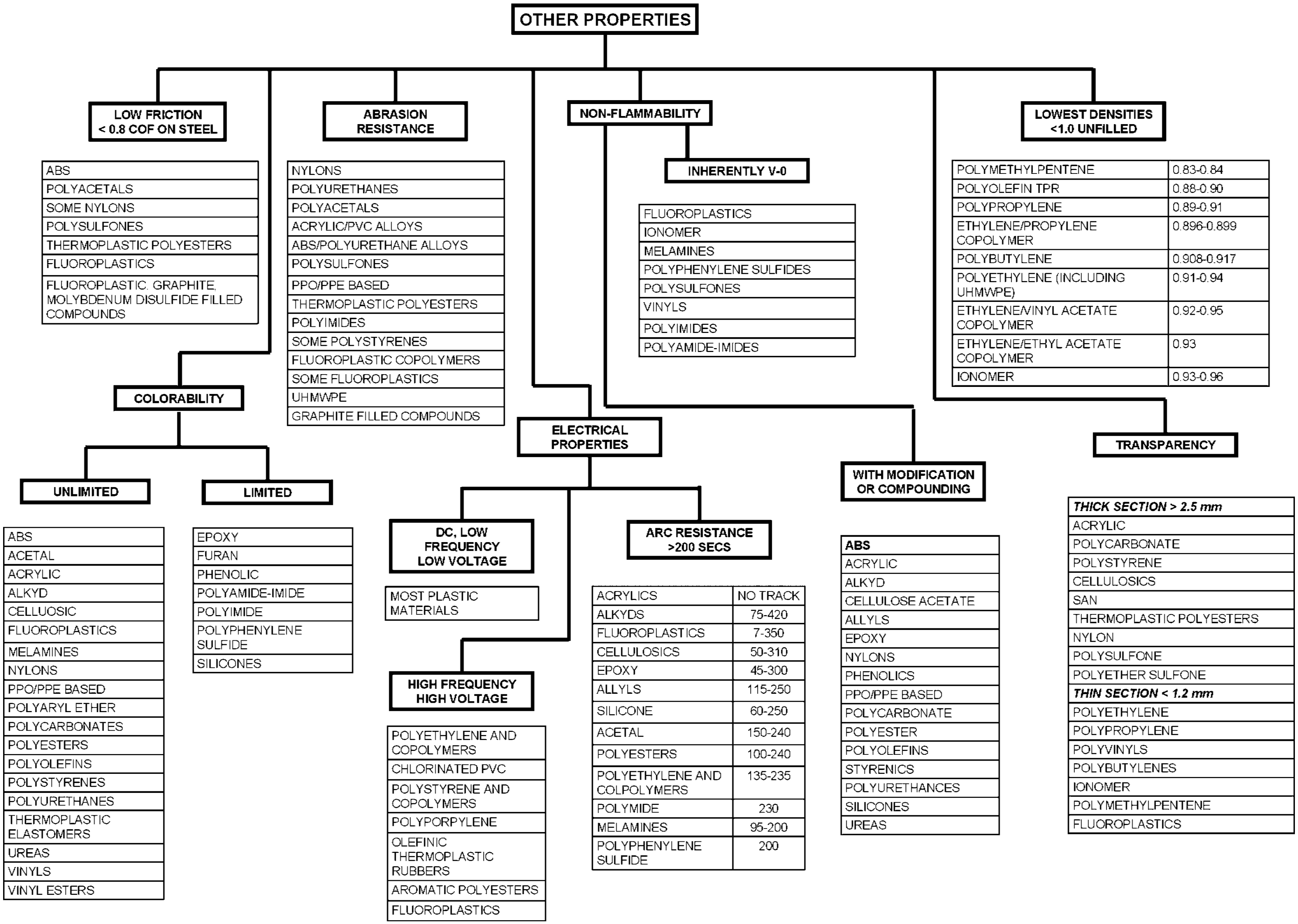


Figure 1.36. Selection guide based on other properties.

is titled: *Plastics—Acquisition and presentation of comparable single-point data—Part 1: Molding 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 the 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 in Chapter 11.

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2 Styrenic Plastics

2.1 Background

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 Fig. 2.1.

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

2.1.1 Polystyrene

Polystyrene is the simplest plastic based on styrene. Its structure is shown in Fig. 2.2.

Pure solid polystyrene is a colorless, hard plastic with limited flexibility. Polystyrene 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.

Polystyrene's most common use, however, is as expanded polystyrene (EPS). EPS is produced from a mixture of about 5%–10% gaseous blowing agent (most commonly pentane or carbon dioxide) and 90%–95% polystyrene by weight. The solid plastic beads are expanded into foam by using heat (usually steam). The heating is carried out in a large vessel having a capacity of 200–2,000 liters. An agitator is used to keep the beads from fusing together. The expanded beads being lighter than the unexpanded beads 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. Then, the pre-expanded 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 polystyrene (XPS), which is different from EPS, is commonly known by the trade name Styrofoam™. All these foams are not of interest in this book.

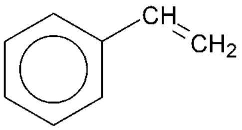


Figure 2.1. Chemical structure of styrene.

One of the most important plastics is high-impact polystyrene (HIPS). This is a polystyrene matrix that is imbedded with an impact modifier, which is basically a rubber-like polymer such as polybutadiene. This is shown in Fig. 2.3.

2.1.2 Acrylonitrile-Styrene-Acrylate (ASA)

ASA is the acronym for acrylate rubber modified styrene-acrylonitrile copolymer. ASA is a terpolymer that can be produced either by a reaction process of all three monomers or by a graft process. ASA is

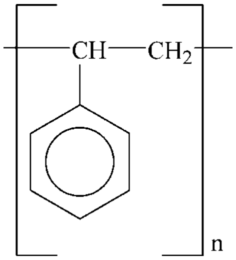


Figure 2.2. Chemical structure of polystyrene.

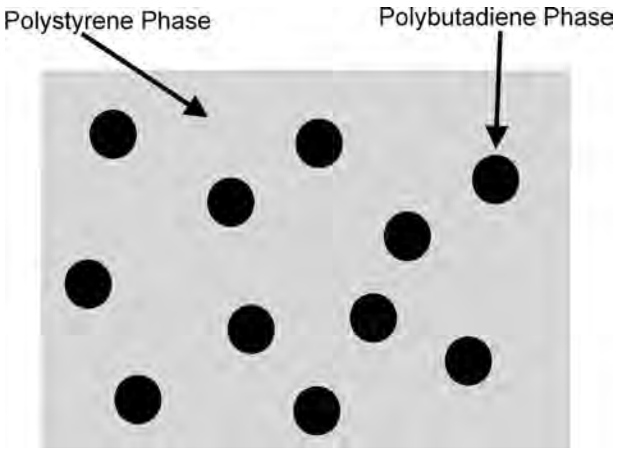


Figure 2.3. The structure of high-impact polystyrene.

usually prepared by introducing a grafted acrylic ester elastomer during the copolymerization of styrene and acrylonitrile, known as SAN. SAN is described in the next section of 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 2.1.4. 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. ASA is used in many products including lawn and garden equipments, sporting goods, automotive exterior parts, safety helmets, and building materials.

2.1.3 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 polystyrene, but it is not as clear as crystal polystyrene and its appearance tends to discolor more quickly. The general structure is shown in Fig. 2.4.

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

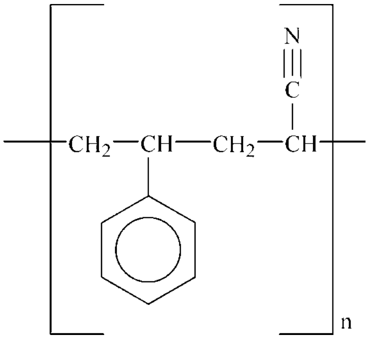


Figure 2.4. Chemical structure of styrene-acrylonitrile (SAN).

2.1.4 Acrylonitrile-Butadiene-Styrene (ABS)

Acrylonitrile-butadiene-styrene (ABS) is a common thermoplastic used to make light, rigid, molded products such as pipes, automotive body parts, wheel covers, enclosures, protective head gears, etc.

SAN copolymers are available since 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 the third monomer producing a range of materials popularly referred to as ABS plastics. These became available in the 1950s and the availability of these plastics and ease of processing led ABS to become one of the most popular of the engineering polymers.

The chemical structures of the monomers are shown in Fig. 2.5. The proportions of the monomers typically 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 free polybutadiene rubber.

2.1.5 Styrene-Maleic Anhydride (SMA)

Copolymerization of styrene with maleic anhydride creates a copolymer called styrene-maleic anhydride (SMA). This reaction is shown in Fig. 2.6. SMA has a higher glass-transition temperature than polystyrene and is chemically reactive because of active functional groups. Thus, SMA polymers are often used in blends or composites where interaction or reaction of the maleic anhydride causes desirable interfacial effects. The anhydride reaction with primary amines is particularly potent.

2.1.6 Styrenic Block Copolymers (SBCs)

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 polystyrene block, in the middle a long polybutadiene (or other elastomeric) block, followed by a second hard block of polystyrene. These blocks are immiscible, so they form discrete domains of polystyrene within a polybutadiene matrix. The separate domains are chemically connected. This is shown in Fig. 2.7, and it is similar to 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 polystyrene, allowing customization of properties.

2.1.7 Blends

While the number of styrenic blends might seem limitless, compatibility and morphology limit blend types. Styrenic blends are numerous but most are limited only to a couple of types. The most important blend is ABS and polycarbonate (PC). The next important blend is ABS and polyamide (or nylon, PA). Polystyrene and polyethylene are often used in expandable foams. Polystyrene 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.

Graphs showing the properties of styrene-based plastics as a function of temperature, moisture, and other factors are illustrated in Sections 2.2–2.8.

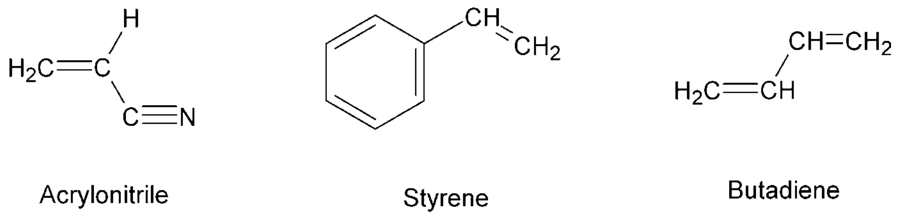


Figure 2.5. Chemical structure of acrylonitrile-butadiene-styrene (ABS) raw materials.

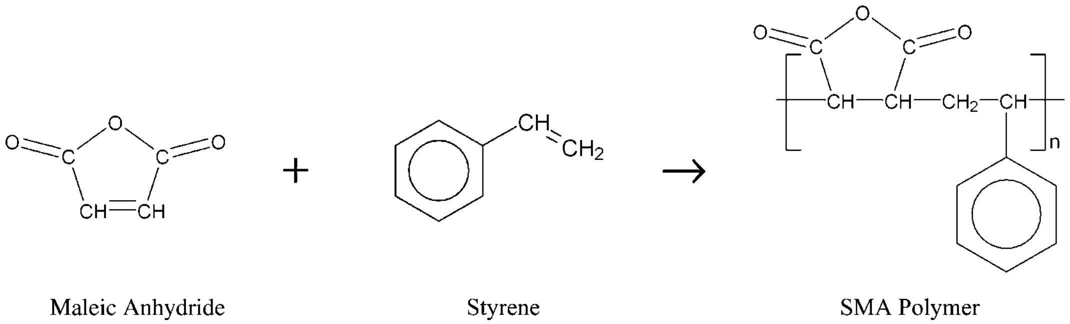


Figure 2.6. The production of styrene-maleic anhydride (SMA).

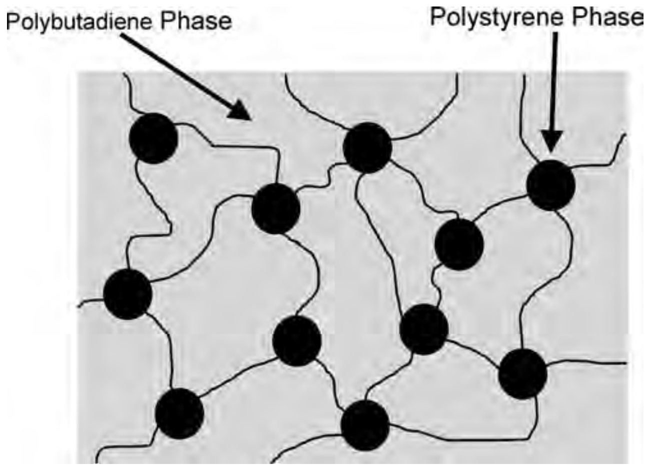


Figure 2.7. The “microscopic” structure of styrenic block copolymers (SBC).

2.2 Polystyrene

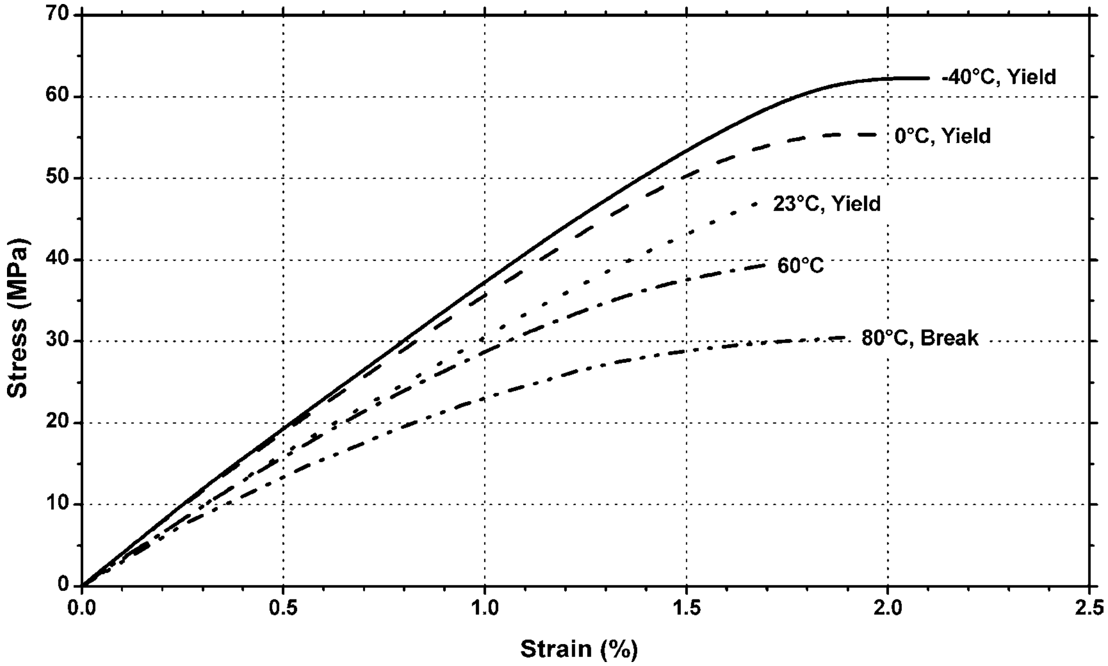


Figure 2.8. Stress vs. strain at various temperatures for BASF Polystyrene 158 K—general purpose, heat resistant polystyrene resin.

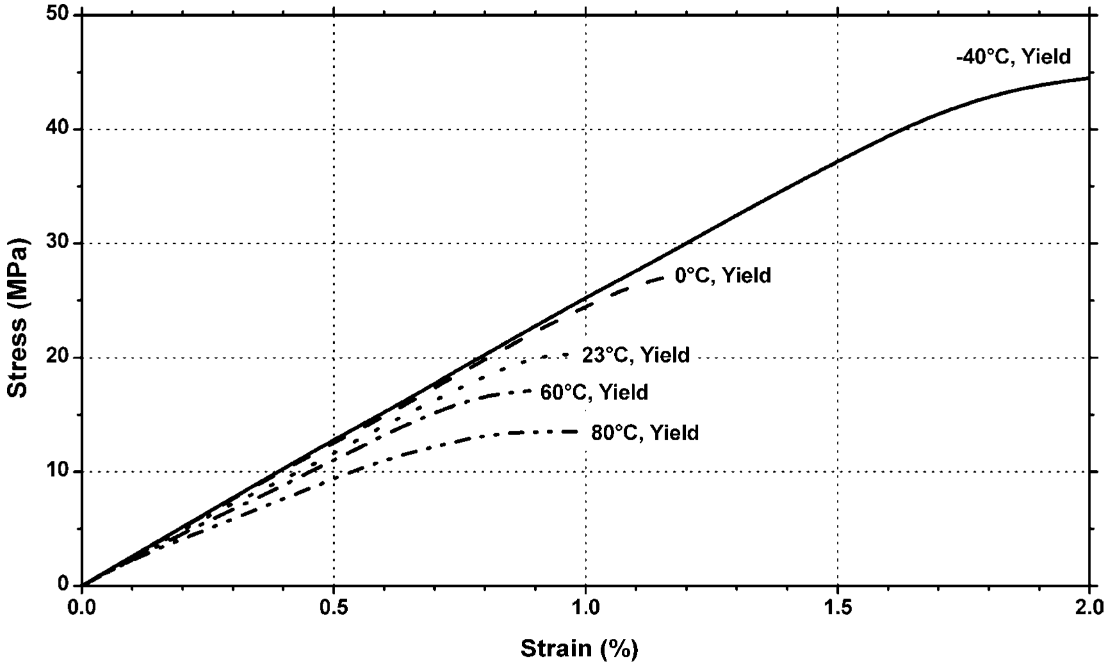


Figure 2.9. Stress vs. strain at various temperatures for BASF Polystyrene 454 C—impact resistant polystyrene resin.

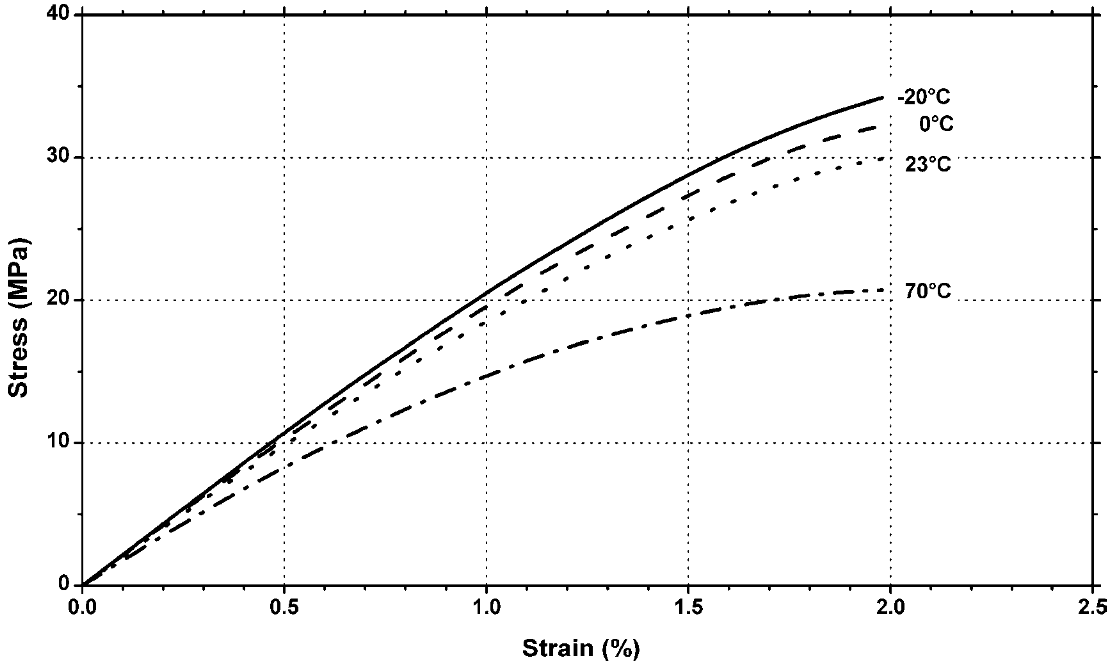


Figure 2.10. Stress vs. strain at various temperatures for Dow Styron™ 457—high-impact polystyrene resin.

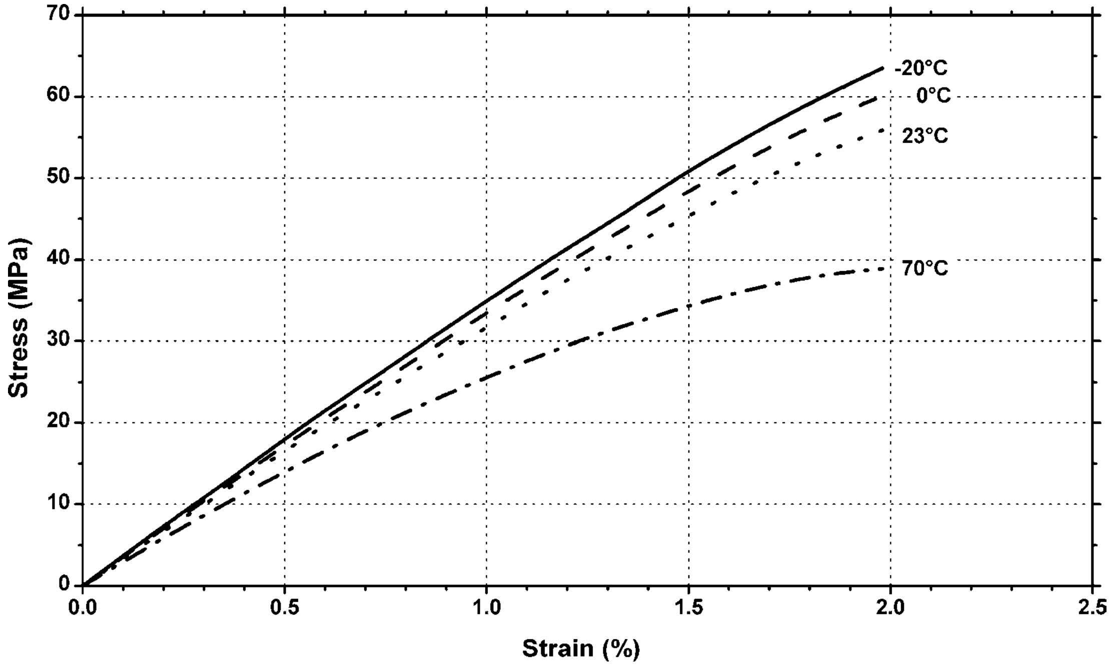


Figure 2.11. Stress vs. strain at various temperatures for Dow Styron™ 648—general purpose polystyrene resin.

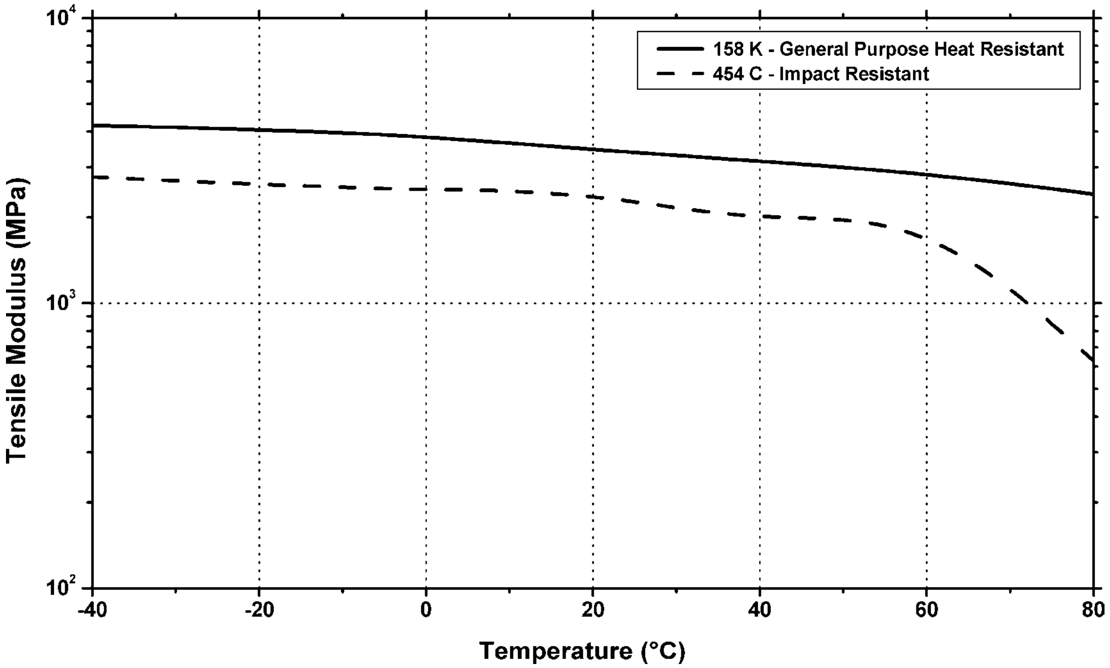


Figure 2.12. Tensile modulus vs. temperature for two BASF Polystyrene resins.

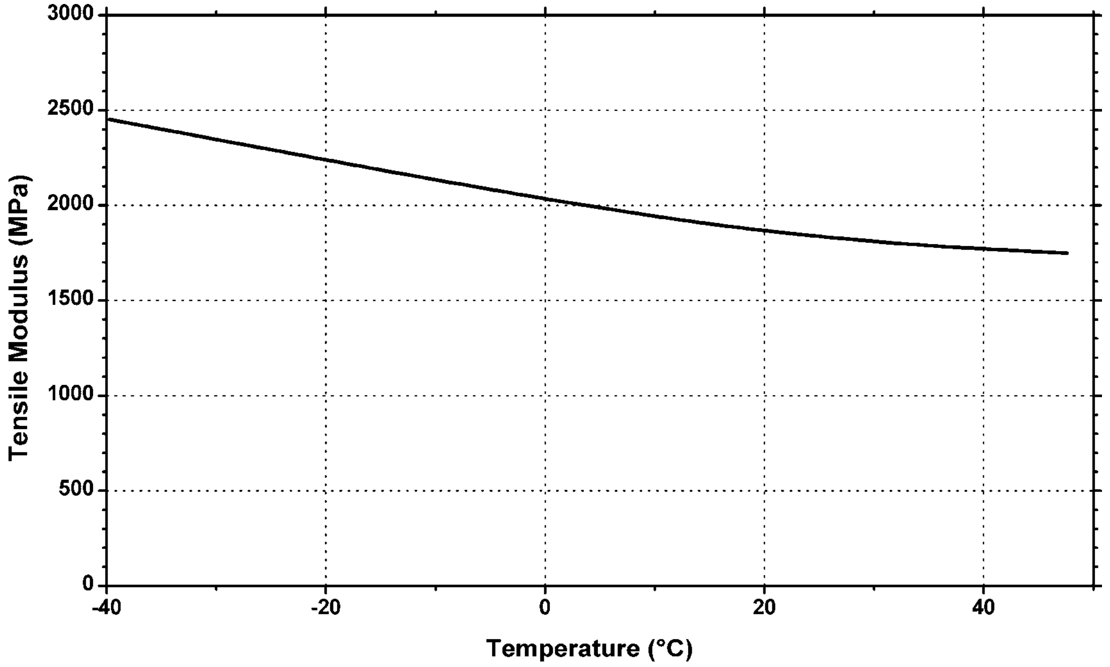


Figure 2.13. Tensile modulus vs. temperature for Dow Styron™ 6075—ignition resistant polystyrene resin.

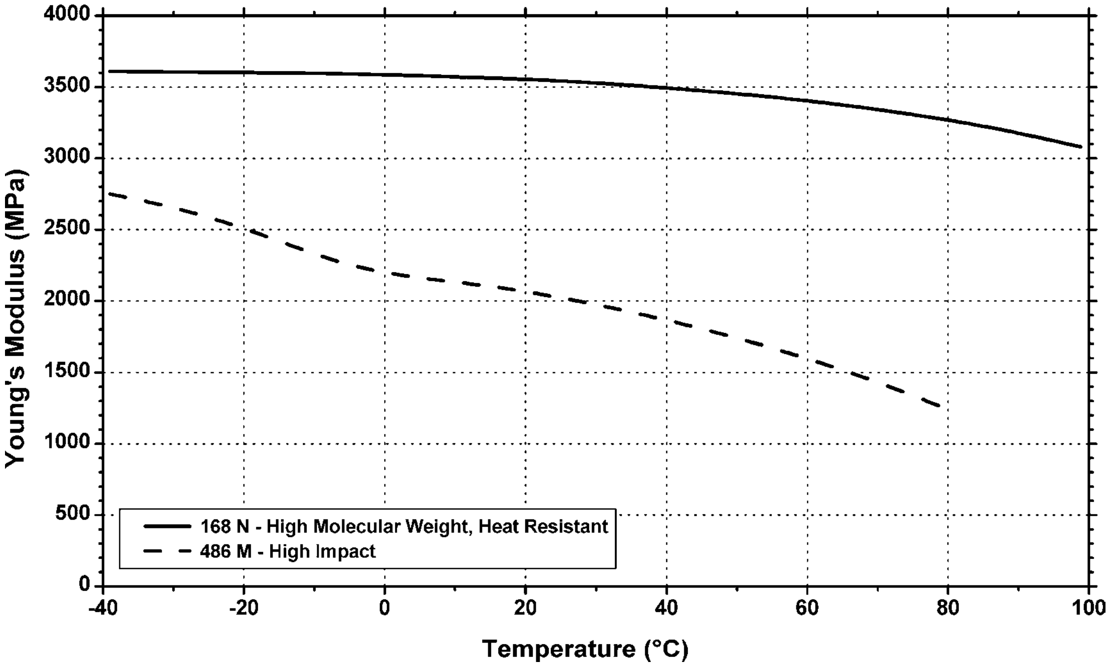


Figure 2.14. Young's modulus vs. temperature for two BASF Polystyrene resins.

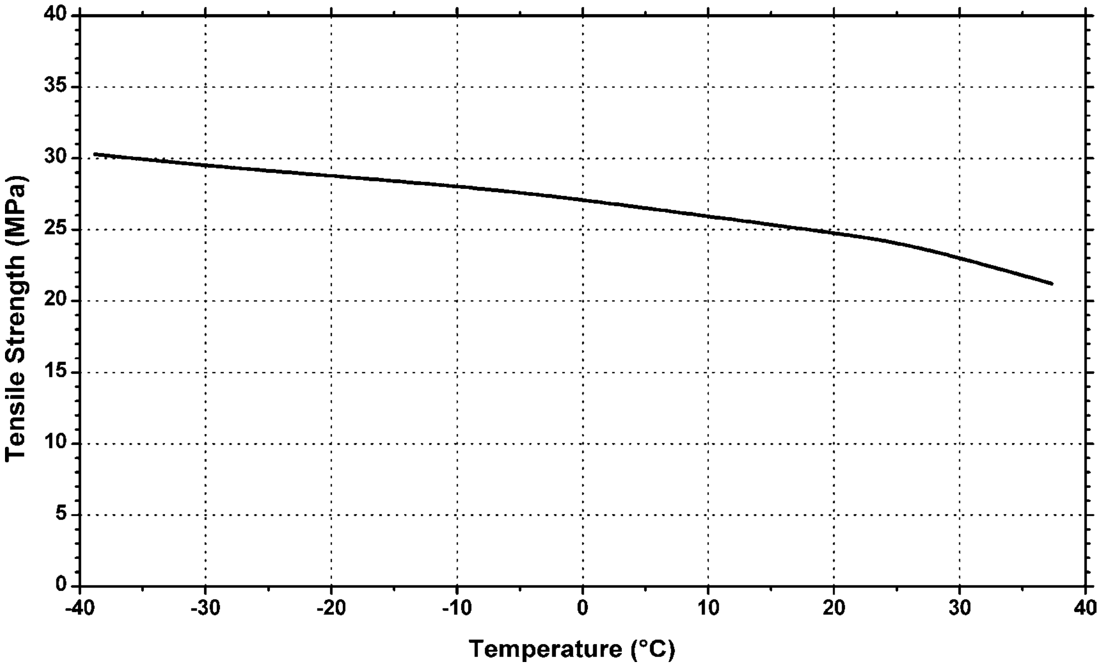


Figure 2.15. Tensile strength vs. temperature for Dow Styron™ 6075—ignition resistant polystyrene resin.

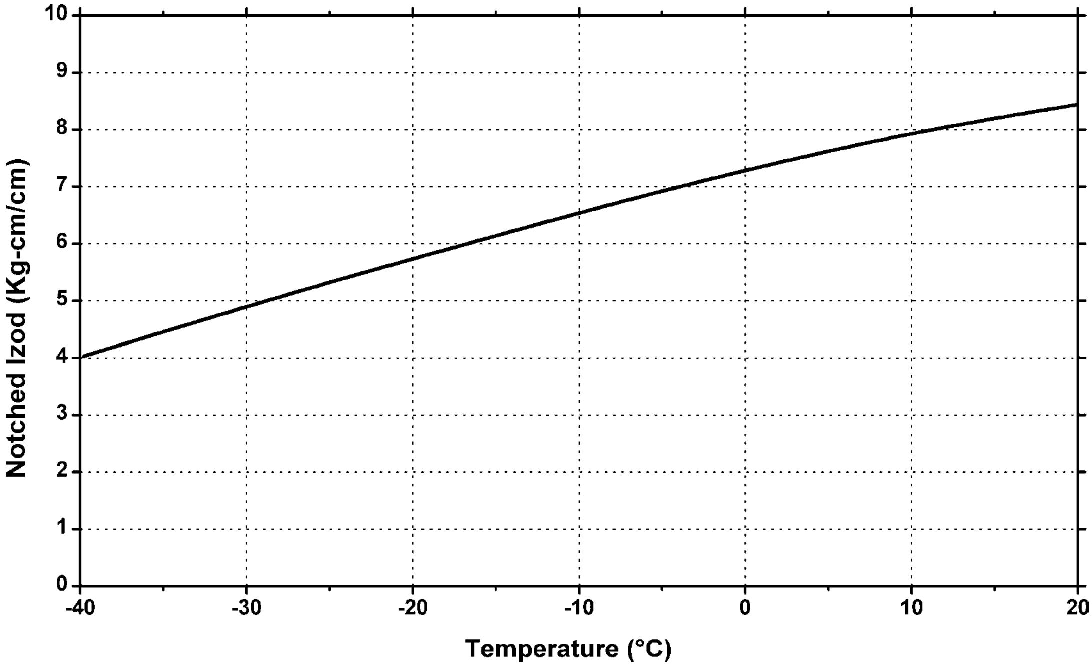


Figure 2.16. Notched Izod impact vs. temperature for Dow Styron™ 6075—ignition resistant polystyrene resin

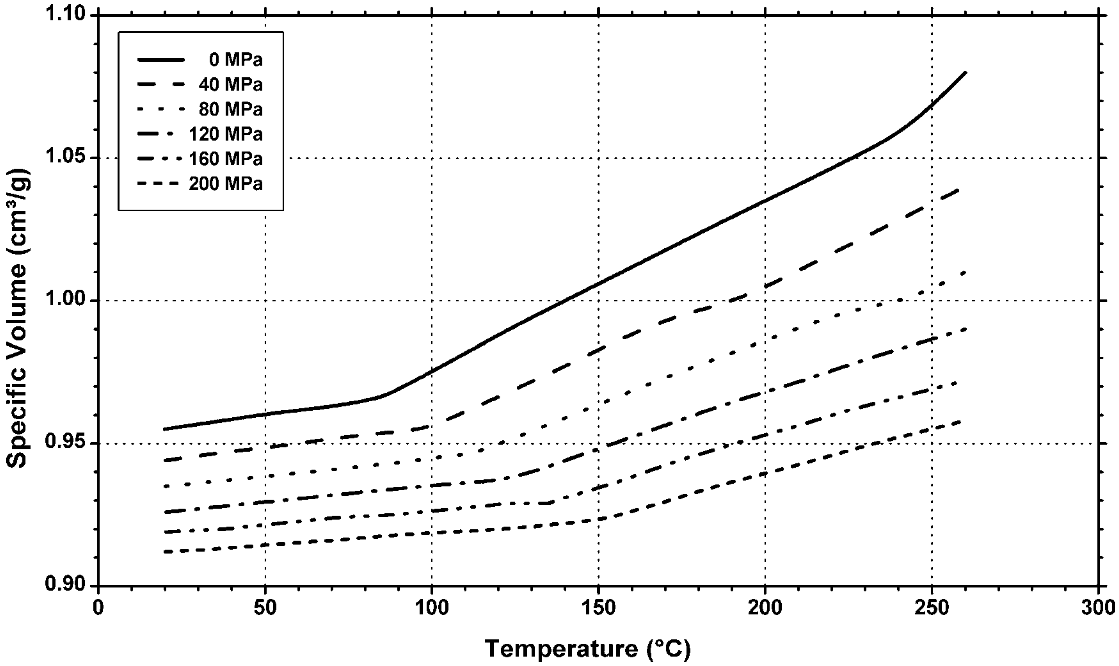


Figure 2.17. Specific volume as a function of temperature and pressure (PVT diagram) for BASF Polystyrene 454 C—impact resistant polystyrene resin.

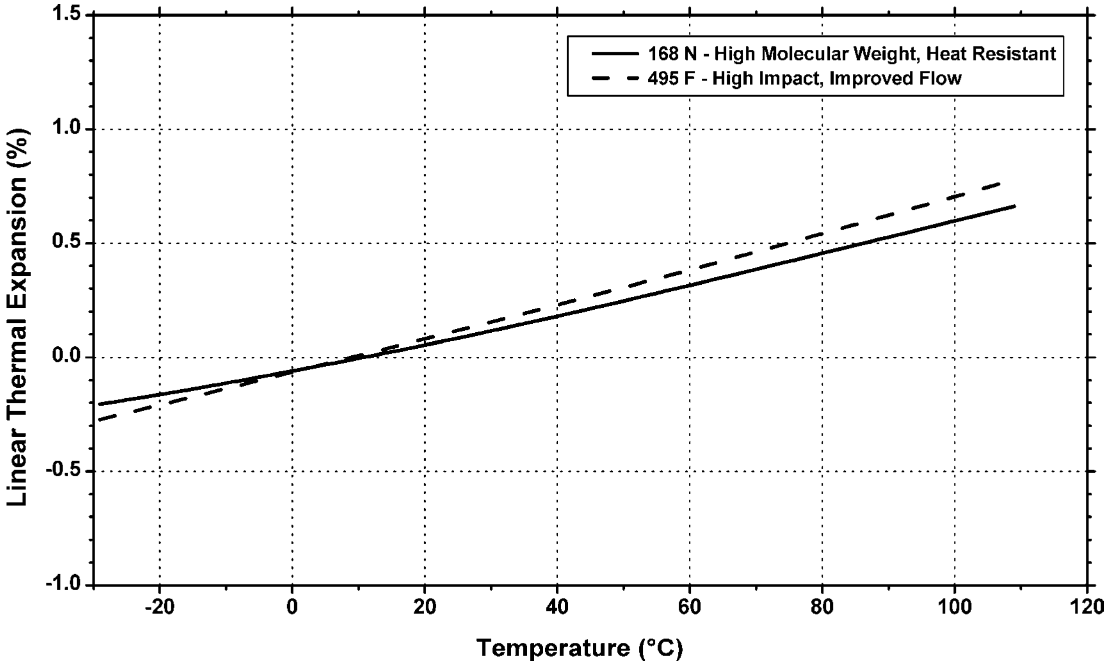


Figure 2.18. Linear thermal expansion vs. temperature for two BASF Polystyrene resins.

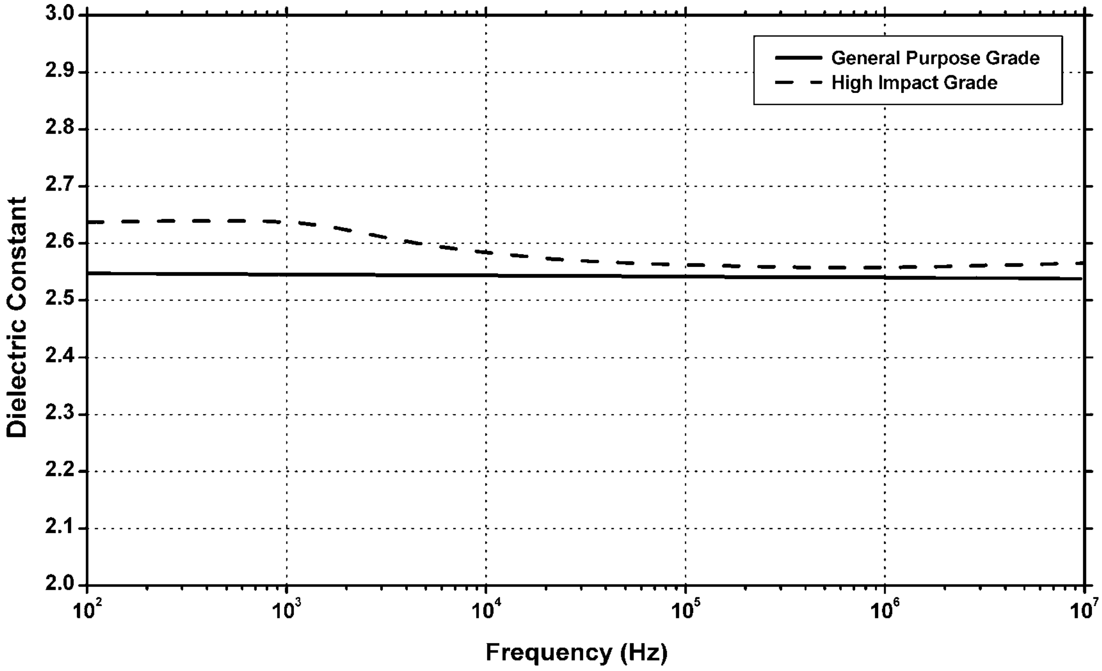


Figure 2.19. Dielectric constant vs. frequency for two Dow Styron™ Polystyrene resins.

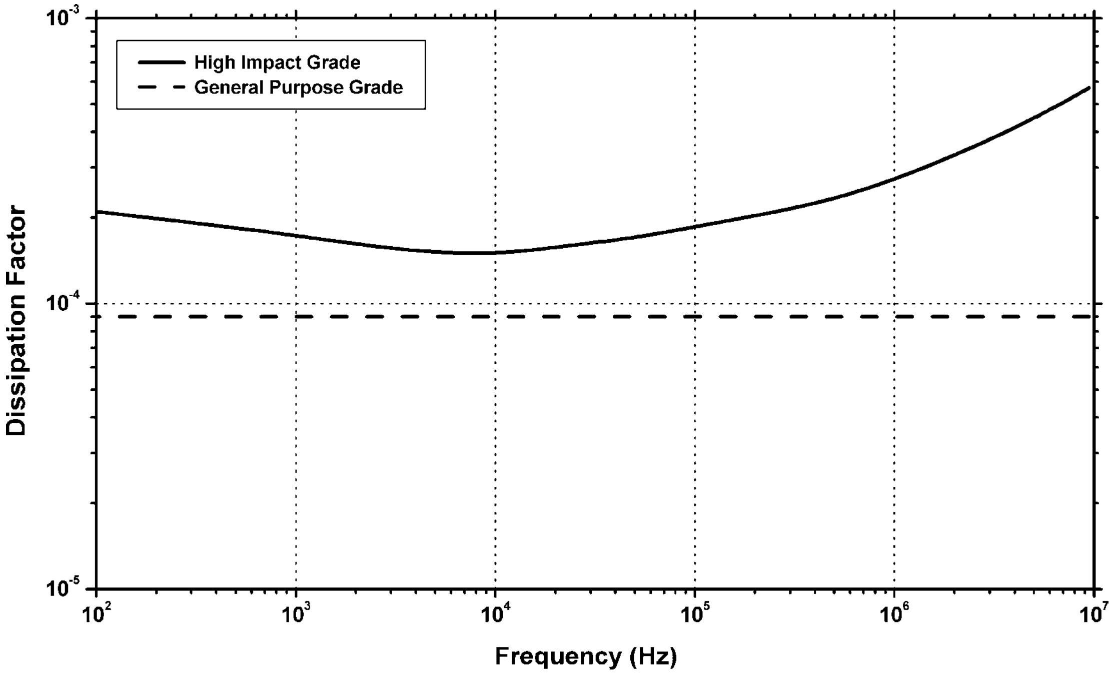


Figure 2.20. Dissipation factor vs. frequency for two Dow Styron™ Polystyrene resins.

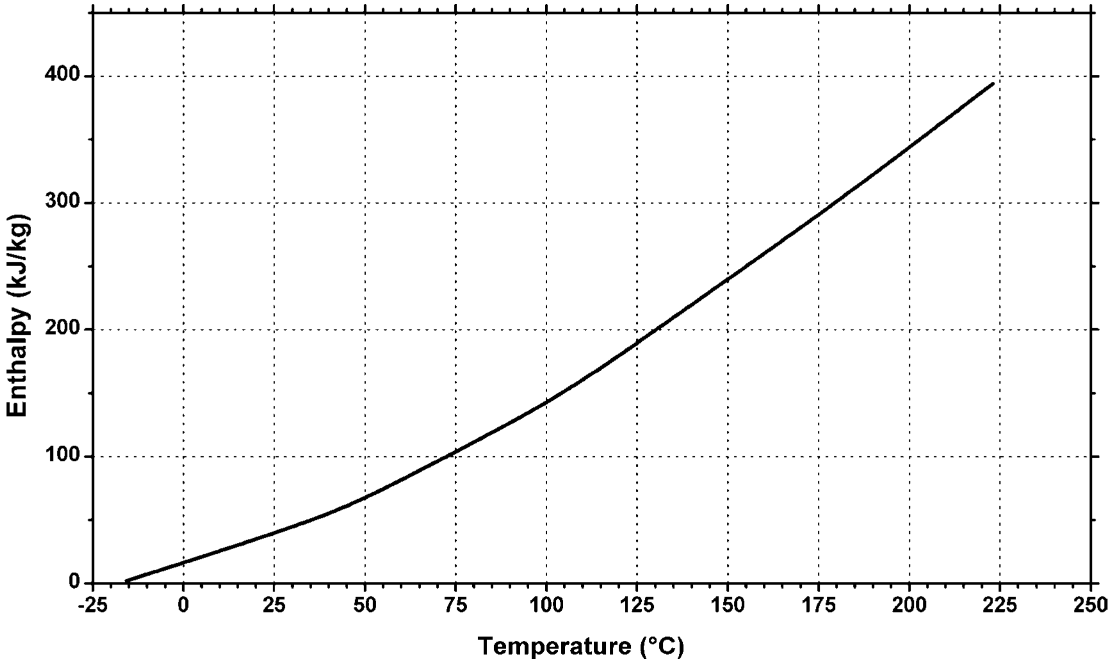


Figure 2.21. Enthalpy (heat content) vs. temperature for Dow Styron™ Polystyrene resins.

2.3 Acrylonitrile-Styrene-Acrylate (ASA)

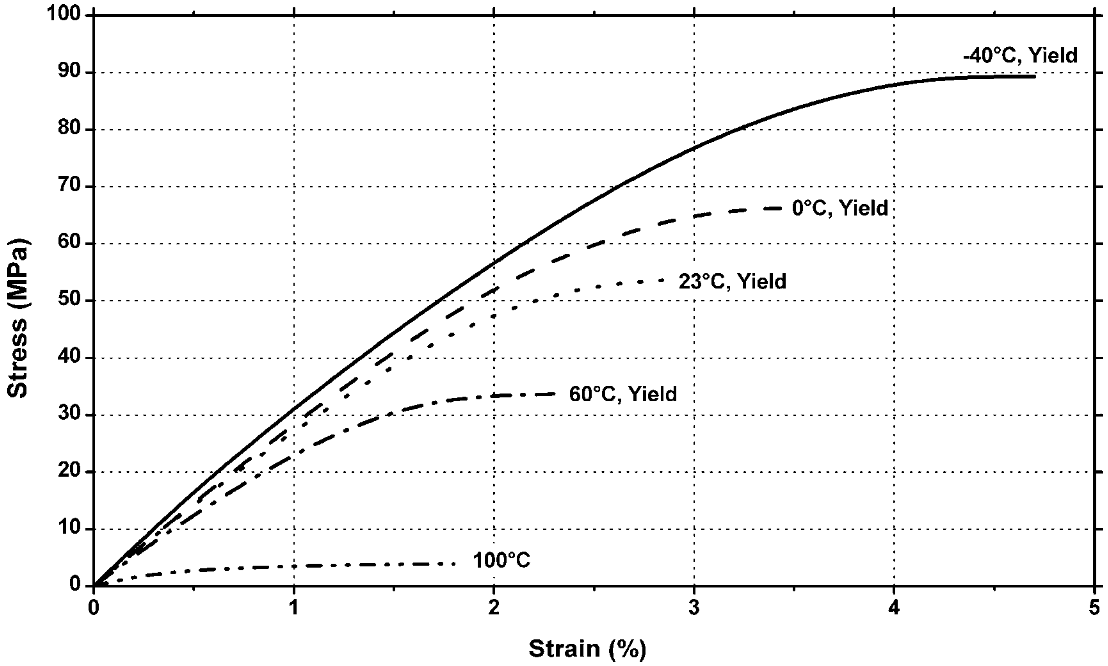


Figure 2.22. Tensile stress vs. strain for BASF Luran® S 757 R—general purpose molding grade ASA resin.

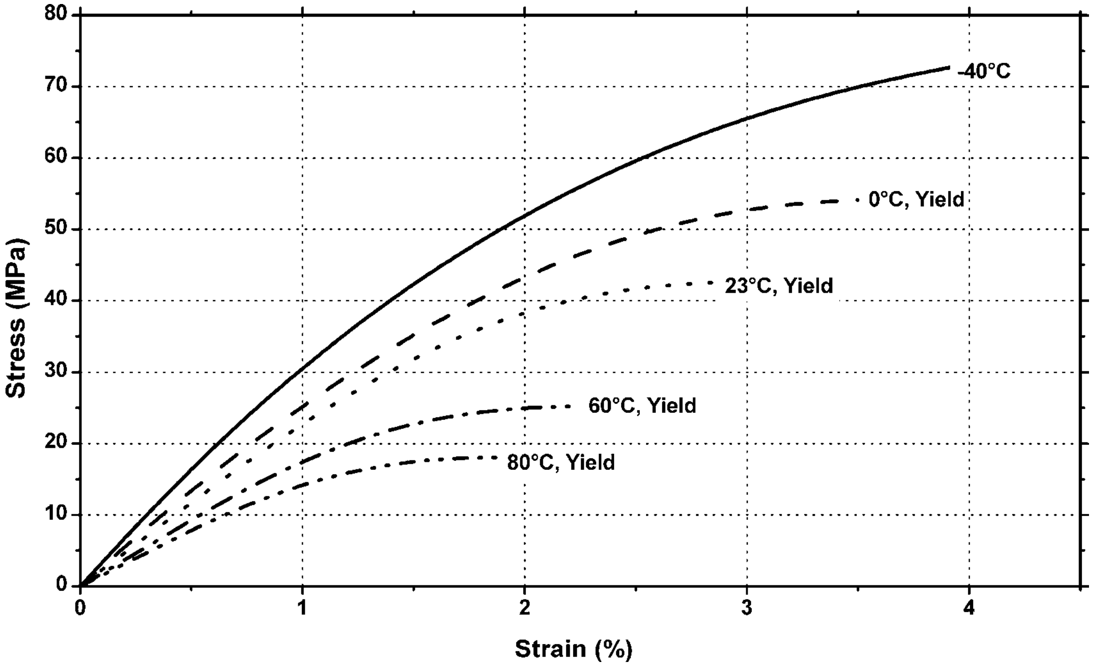


Figure 2.23. Tensile stress vs. strain for BASF Luran® S 757 S—tough and strong ASA resin.

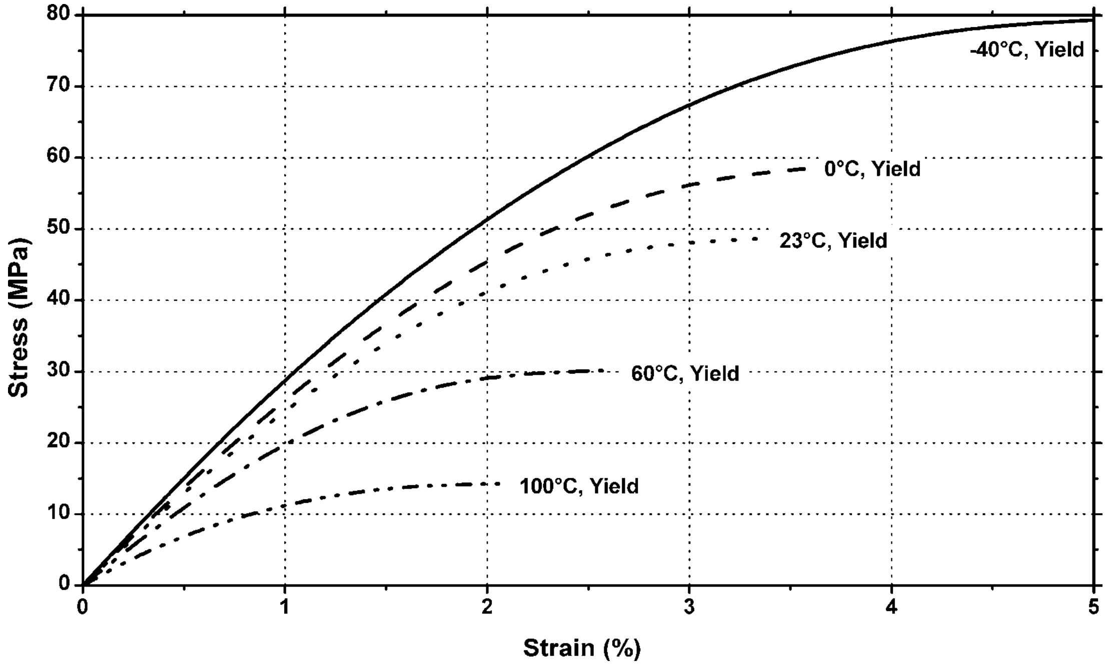


Figure 2.24. Tensile stress vs. strain for BASF Luran® S 778 T—tough and heat resistant ASA resin.

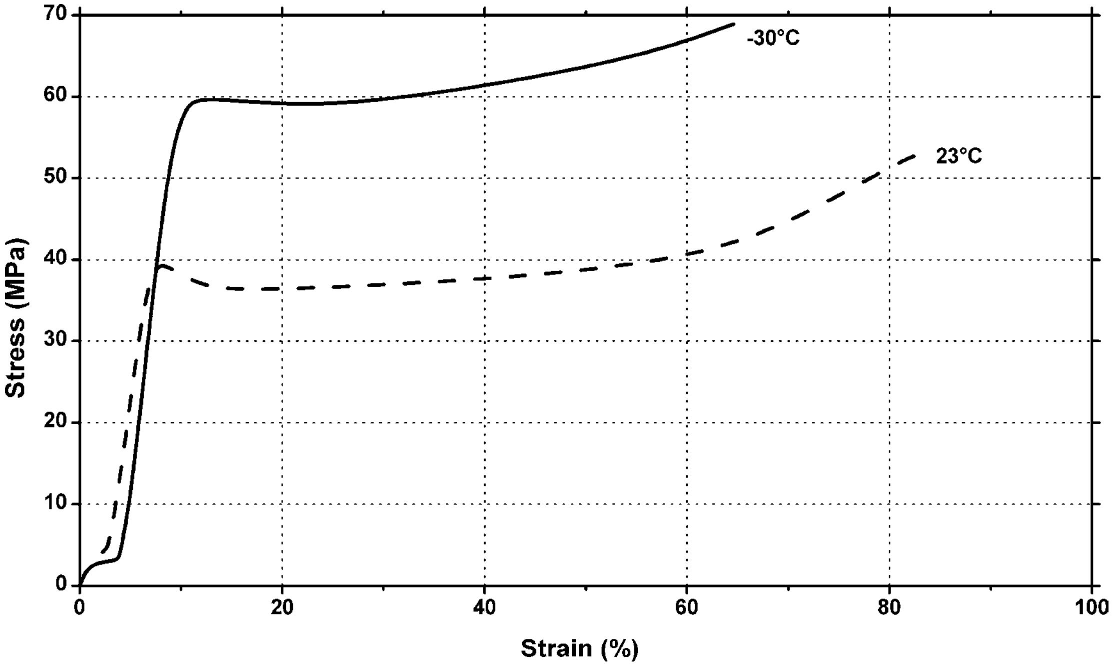


Figure 2.25. Stress vs. strain in compression for SABIC Innovative Plastics Geloy® CR7520—high impact automotive ASA resin.

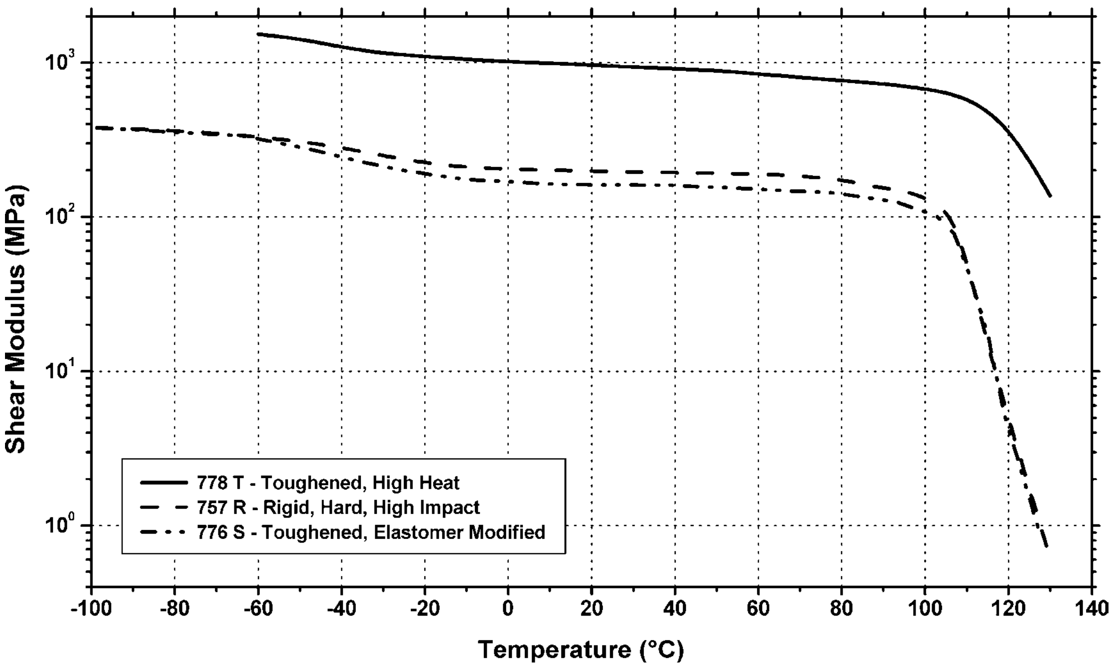


Figure 2.26. Shear modulus vs. temperature for BASF Luran® ASA resins.

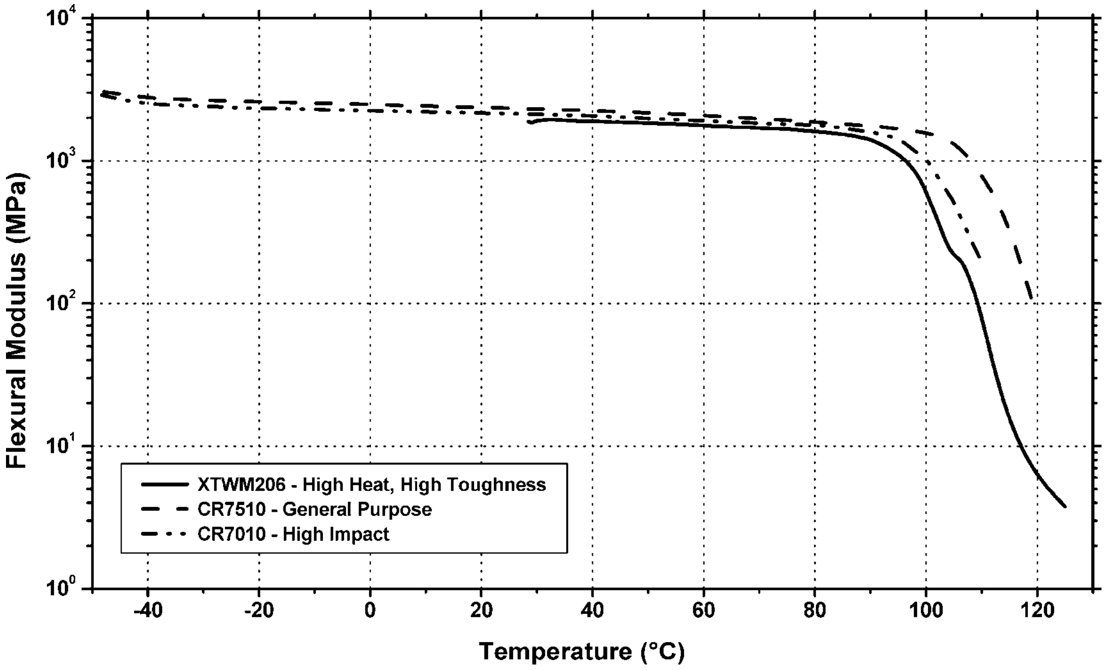


Figure 2.27. Flexural modulus vs. temperature for SABIC Innovative Plastics Geloy® ASA resins.

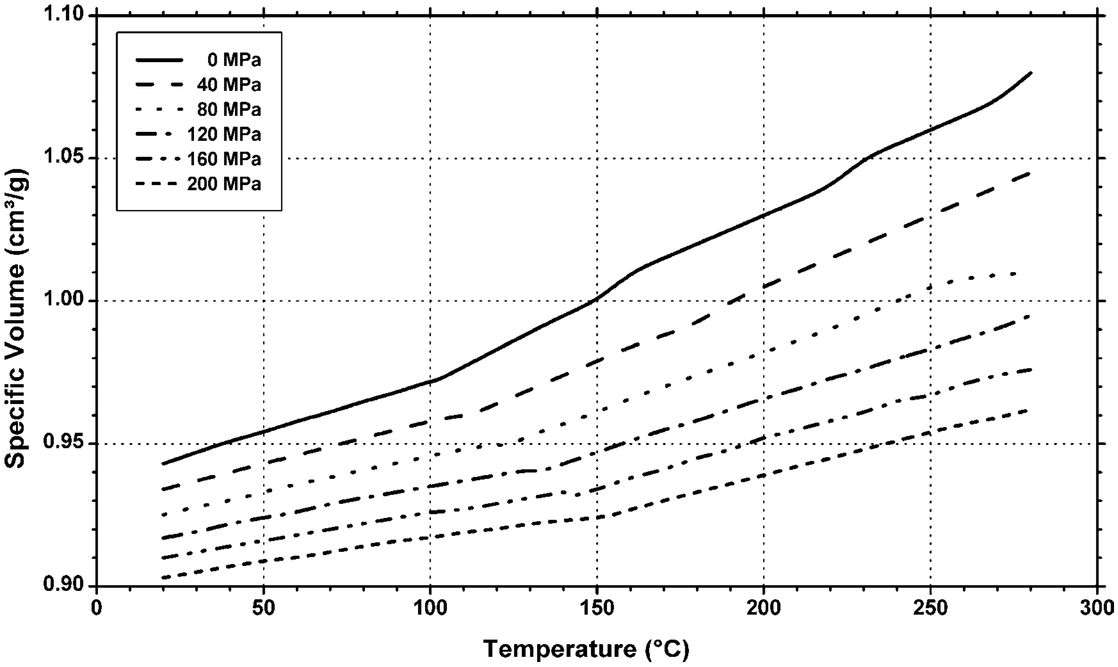


Figure 2.28. Specific volume as a function of temperature and pressure (PVT) for BASF Luran® S 757 R—general purpose molding grade ASA resin.

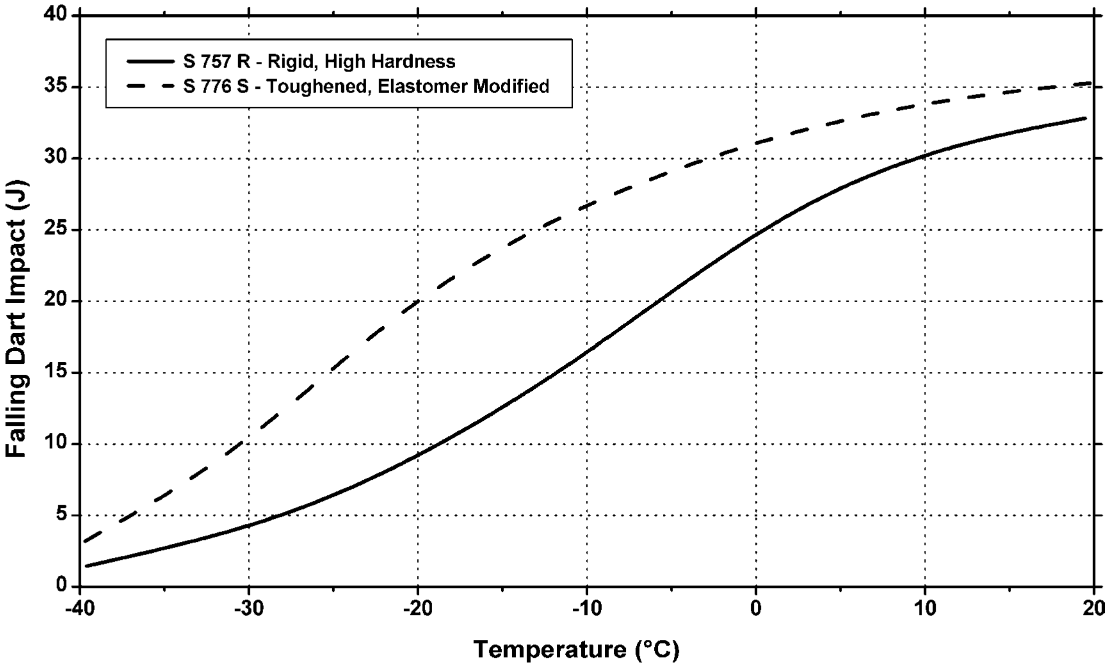


Figure 2.29. Falling dart impact vs. temperature for BASF Luran® ASA resins.

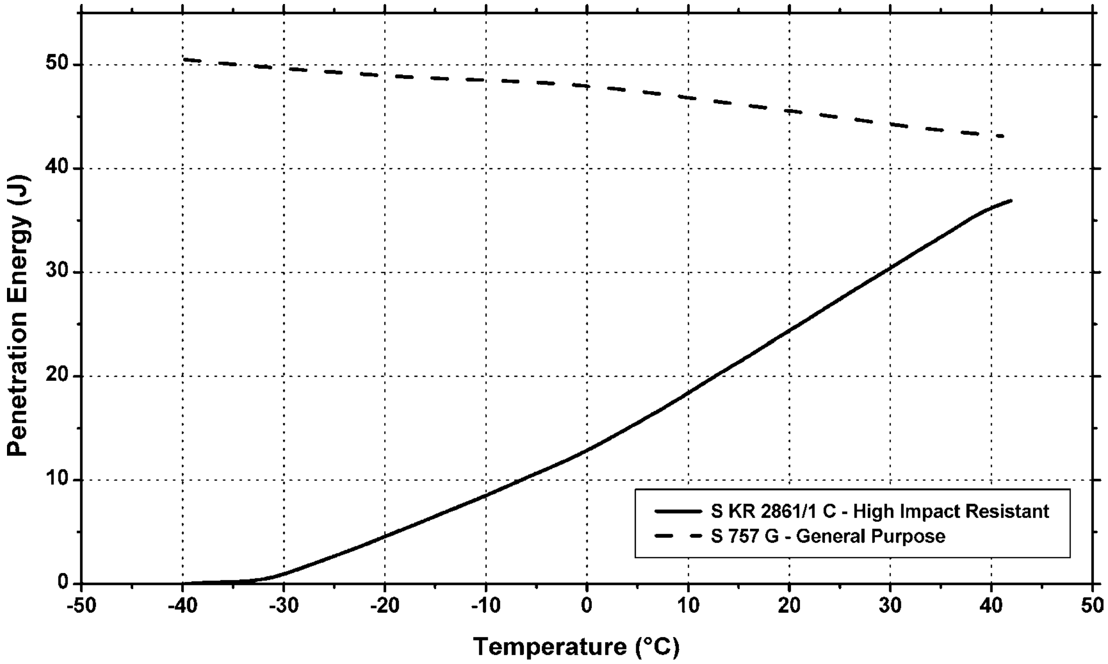


Figure 2.30. Penetration energy vs. temperature for BASF Luran® ASA resins.

2.4 Styrene-Acrylonitrile (SAN)

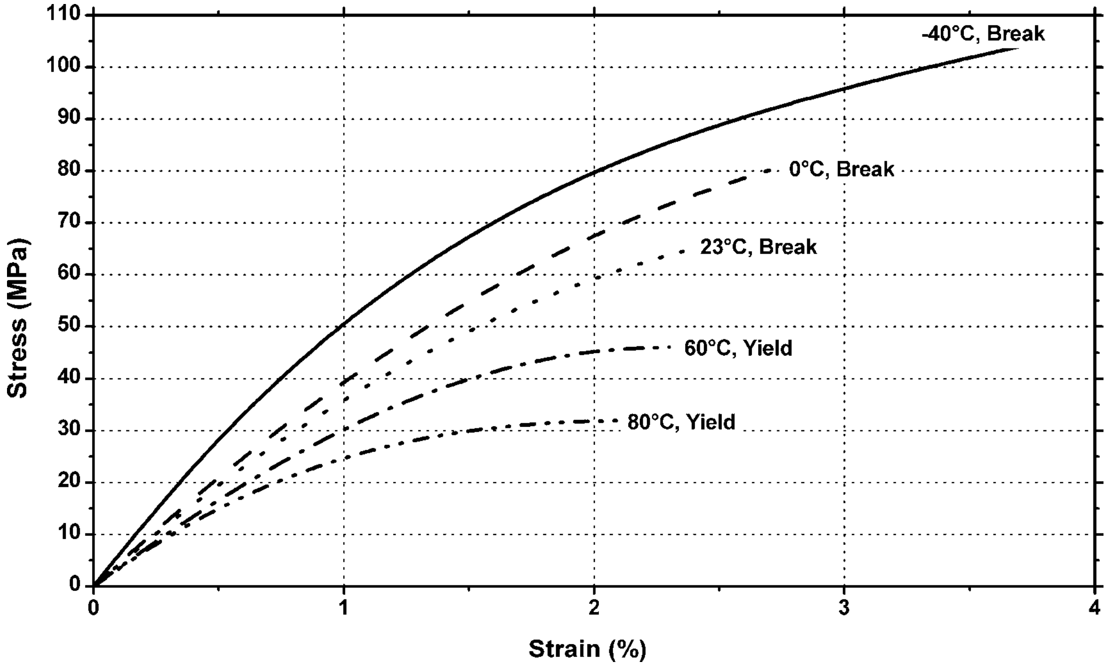


Figure 2.31. Tensile stress vs. strain for BASF Luran® 368 R—general purpose SAN resin.

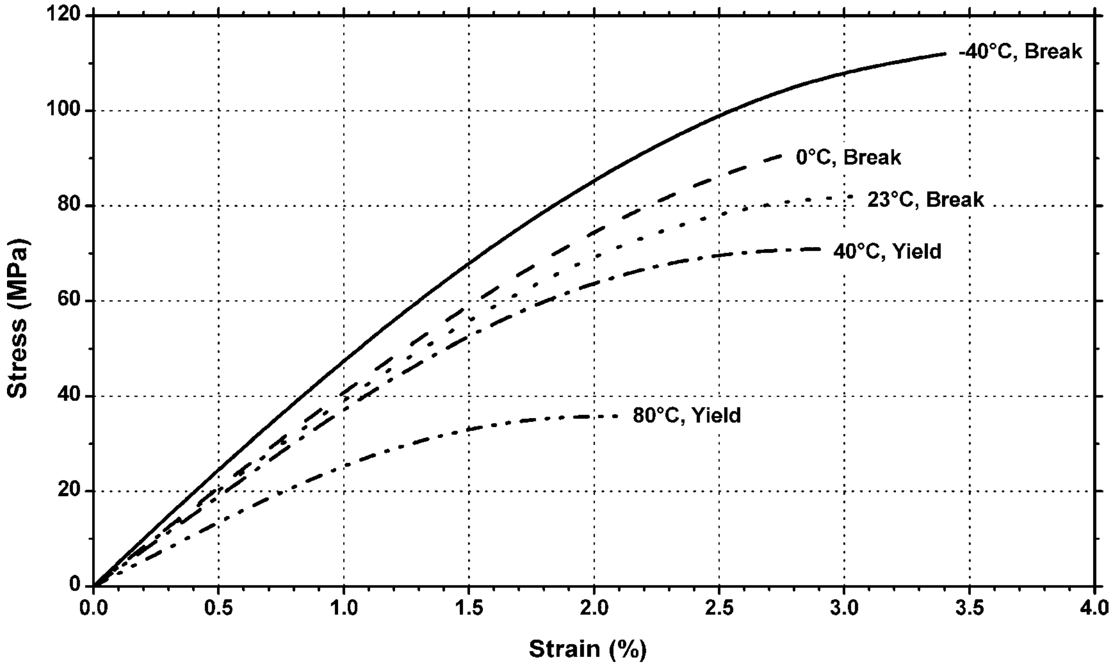


Figure 2.32. Tensile stress vs. strain for BASF Luran® 378P—easy flow, chemical resistant grade SAN resin.

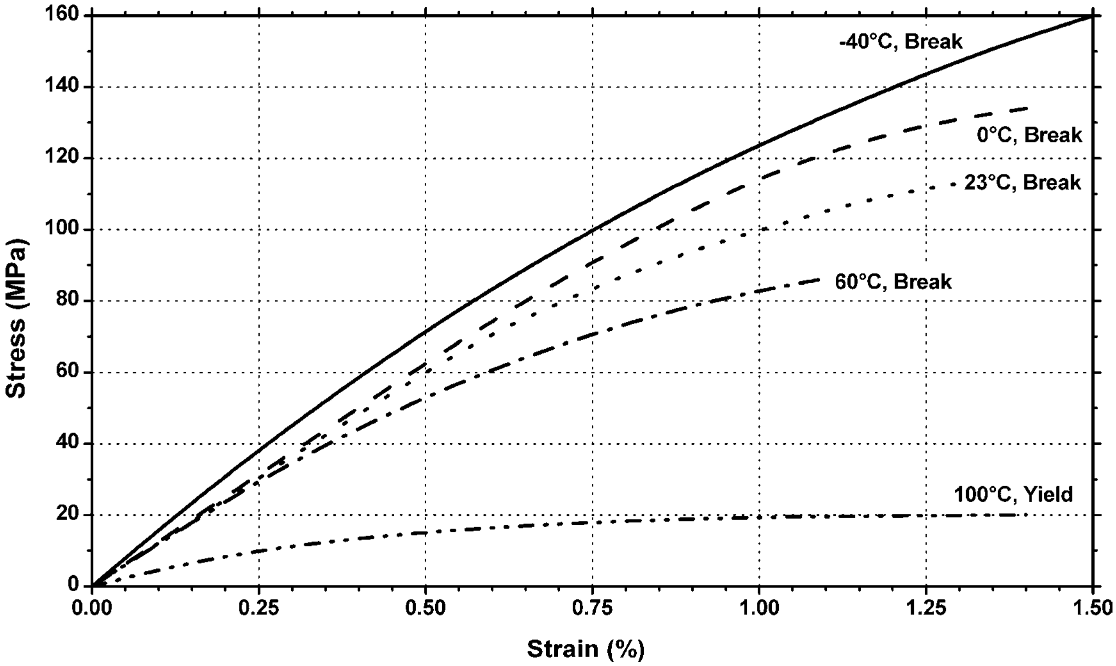


Figure 2.33. Tensile stress vs. strain for BASF Luran® 378P G7—glass reinforced grade SAN resin.

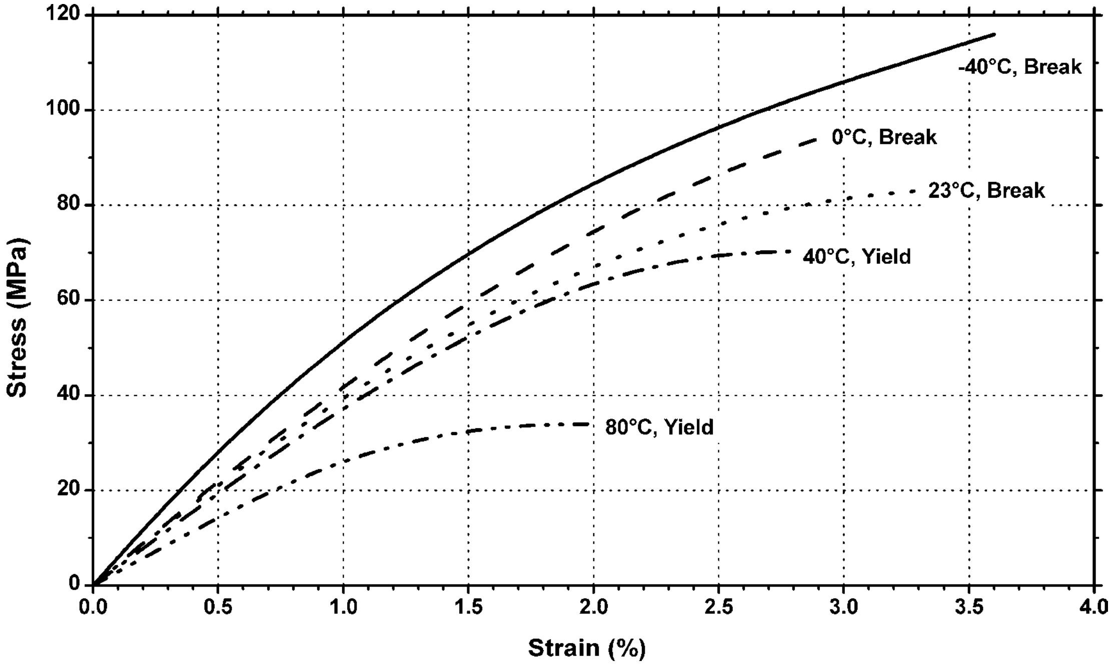


Figure 2.34. Tensile stress vs. strain for BASF Luran® 388S—high mechanical strength, chemical resistant grade SAN resin.

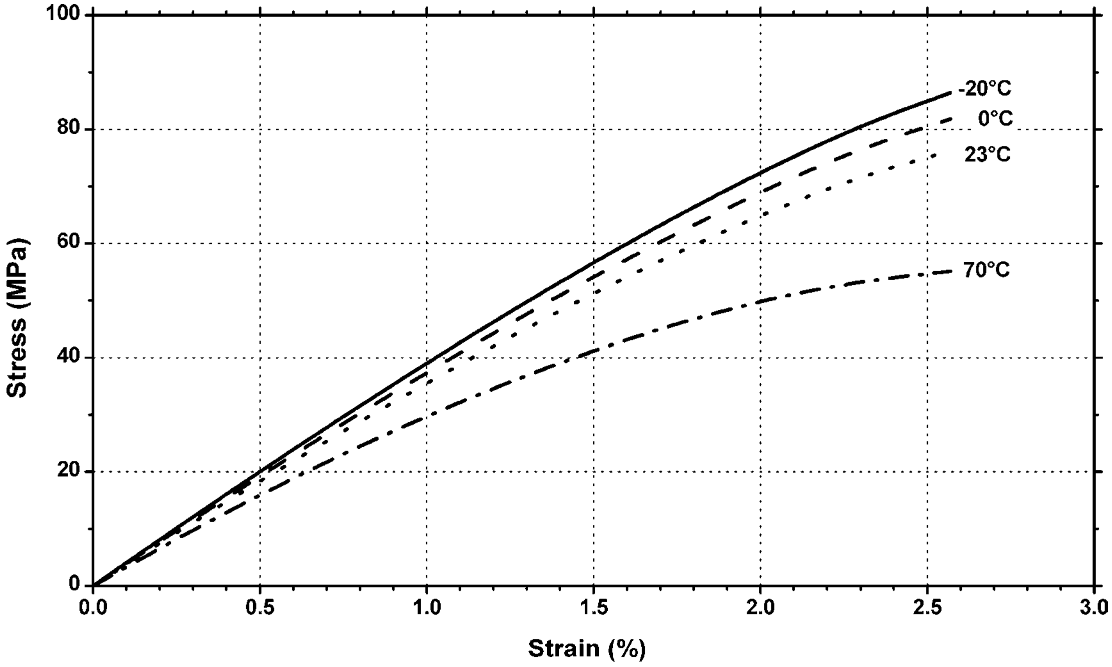


Figure 2.35. Tensile stress vs. strain for Dow Chemical Tyril™ 790—general purpose grade SAN resin.

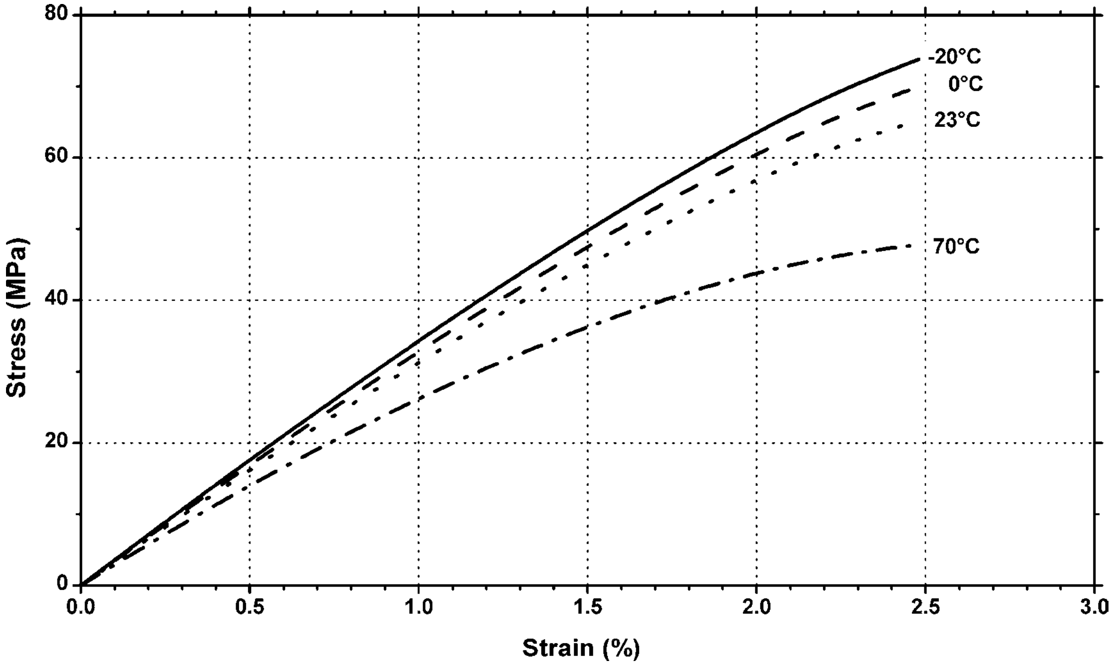


Figure 2.36. Tensile stress vs. strain for Dow Chemical Tyril™ 905—general purpose grade SAN resin.

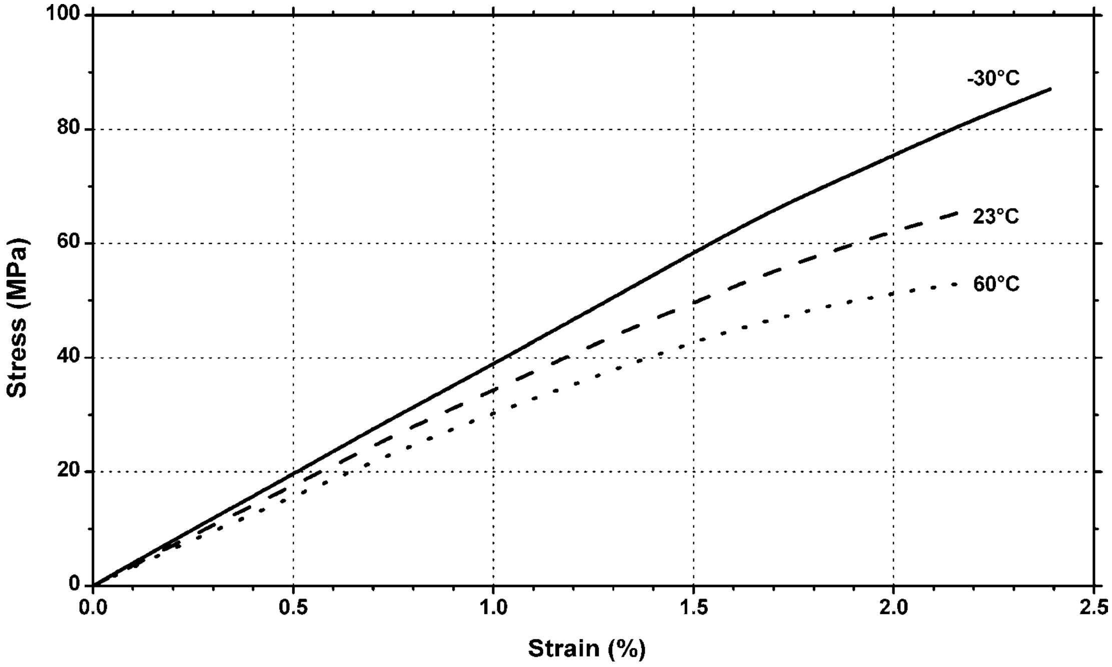


Figure 2.37. Tensile stress vs. strain for Polimeri Europa Kostil® B 265—general purpose SAN resin.

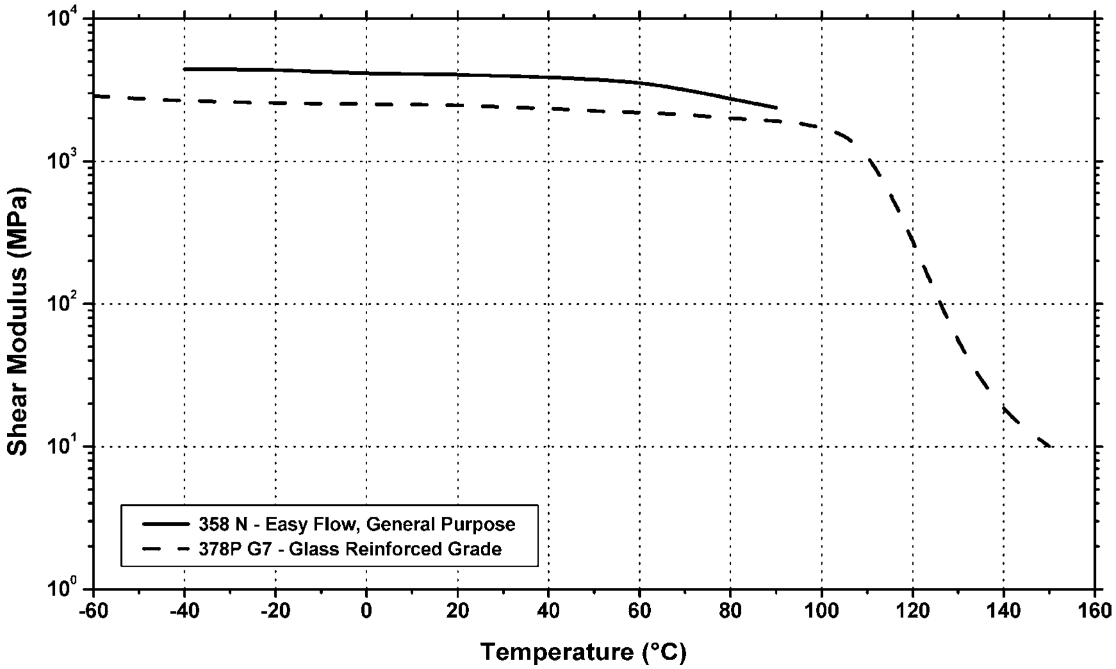


Figure 2.38. Shear modulus vs. temperature for BASF Luran® SAN resins.

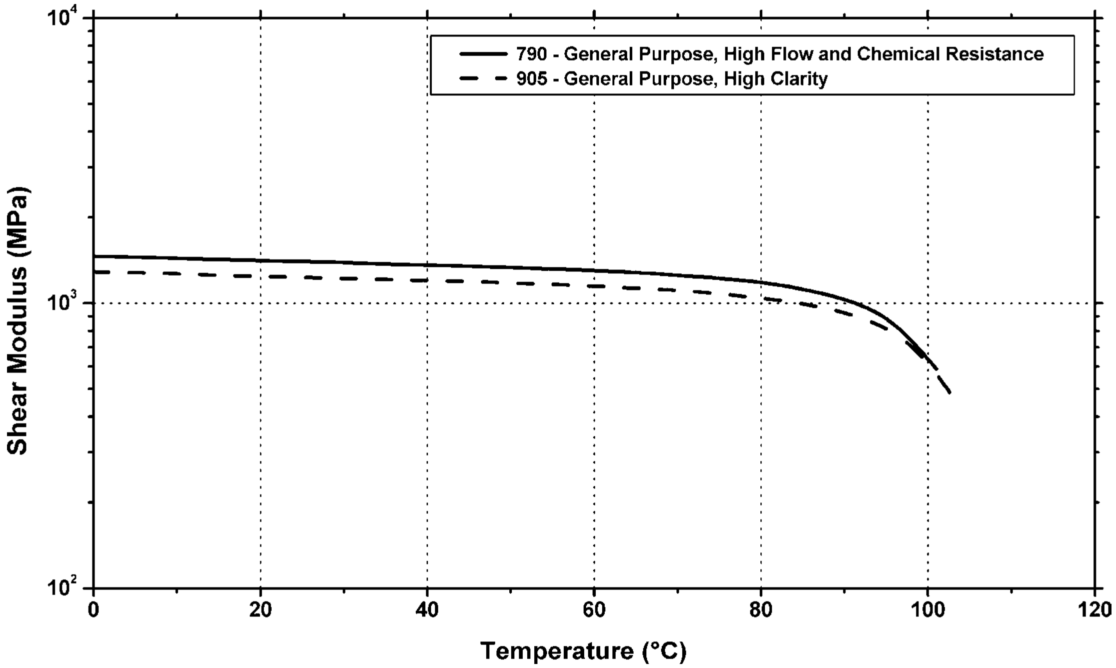


Figure 2.39. Shear modulus vs. temperature for Dow Chemical Tyril™ SAN resins.

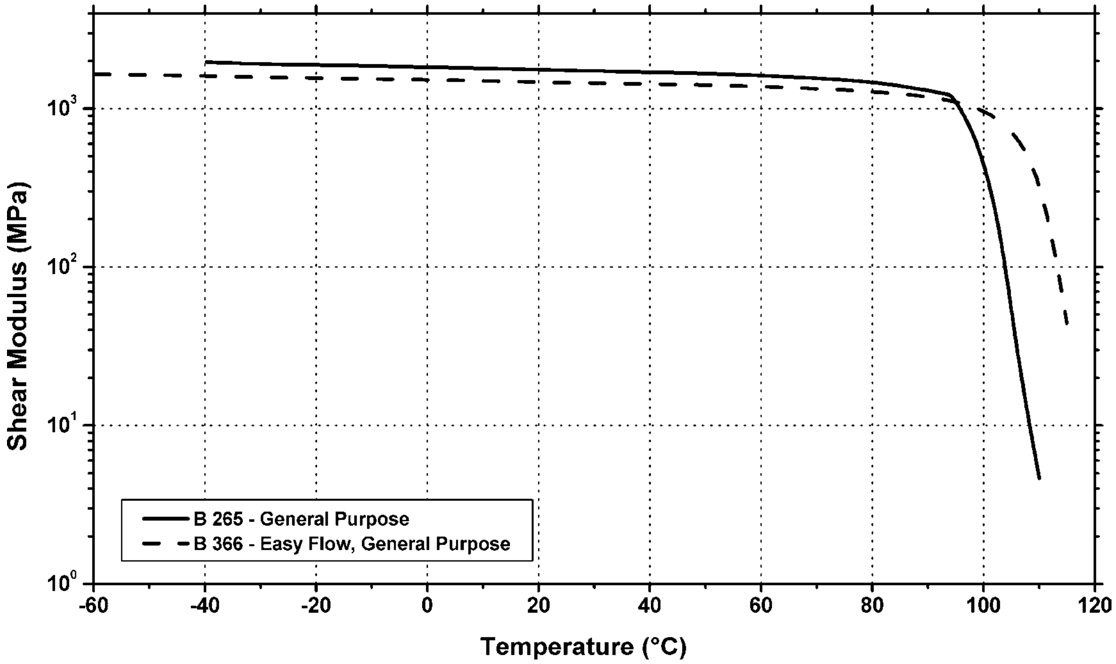


Figure 2.40. Shear modulus vs. temperature for Polimeri Europa Kostil® SAN resins

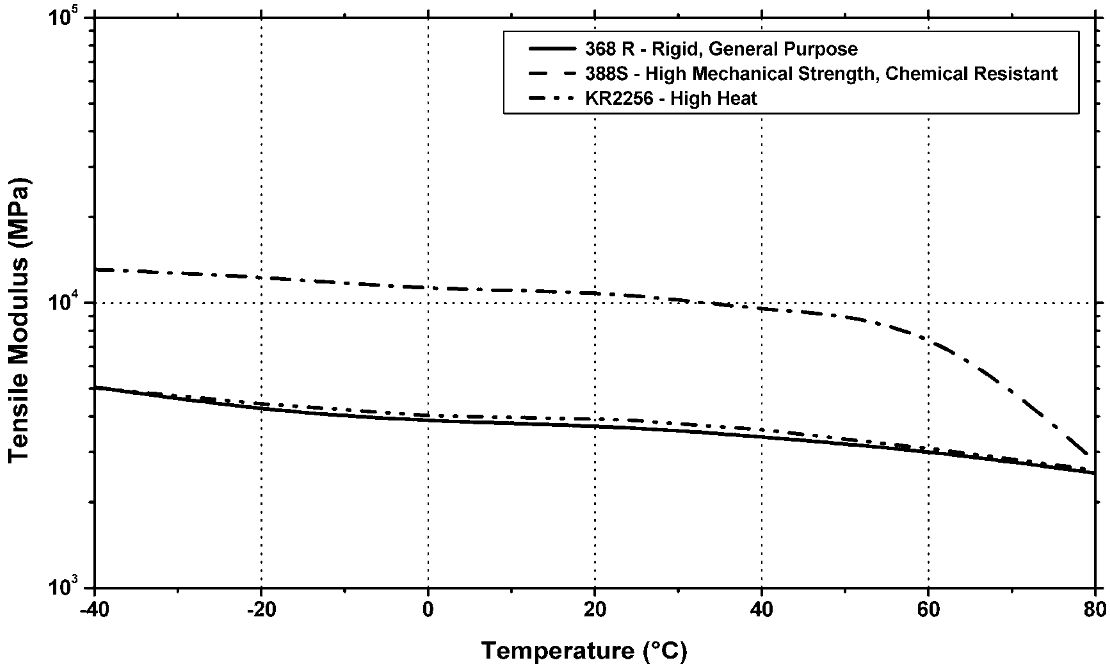


Figure 2.41. Tensile modulus vs. temperature for BASF Luran® SAN resins.

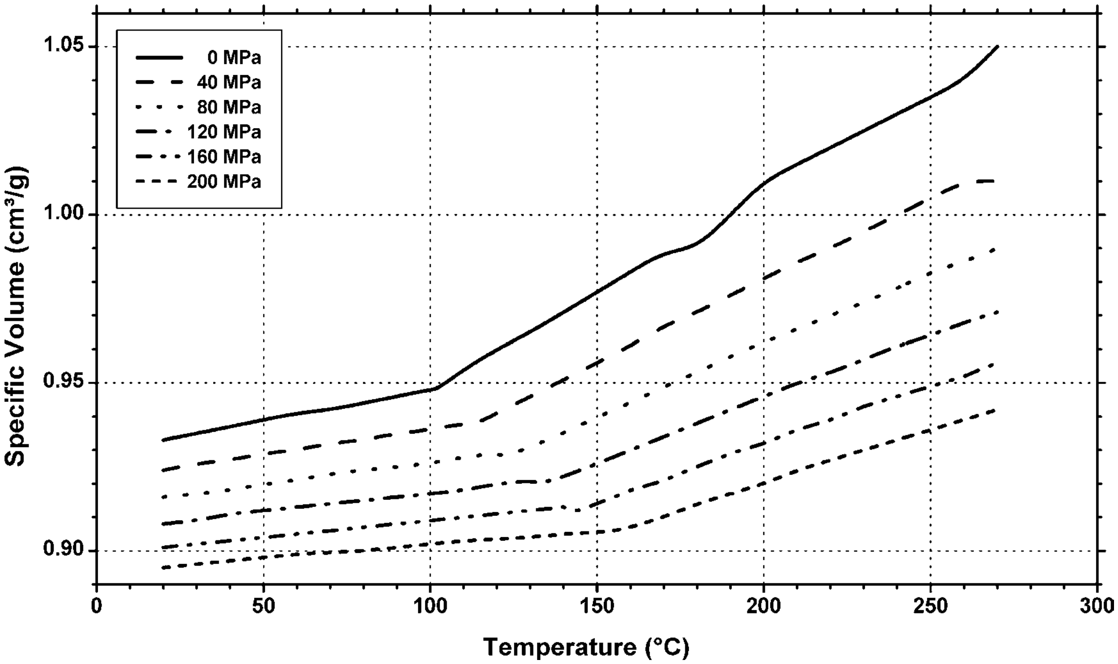


Figure 2.42. Specific volume as a function of temperature and pressure (PVT) for BASF Luran® 368 R—general purpose SAN resin.

2.5 Acrylonitrile-Butadiene-Styrene (ABS)

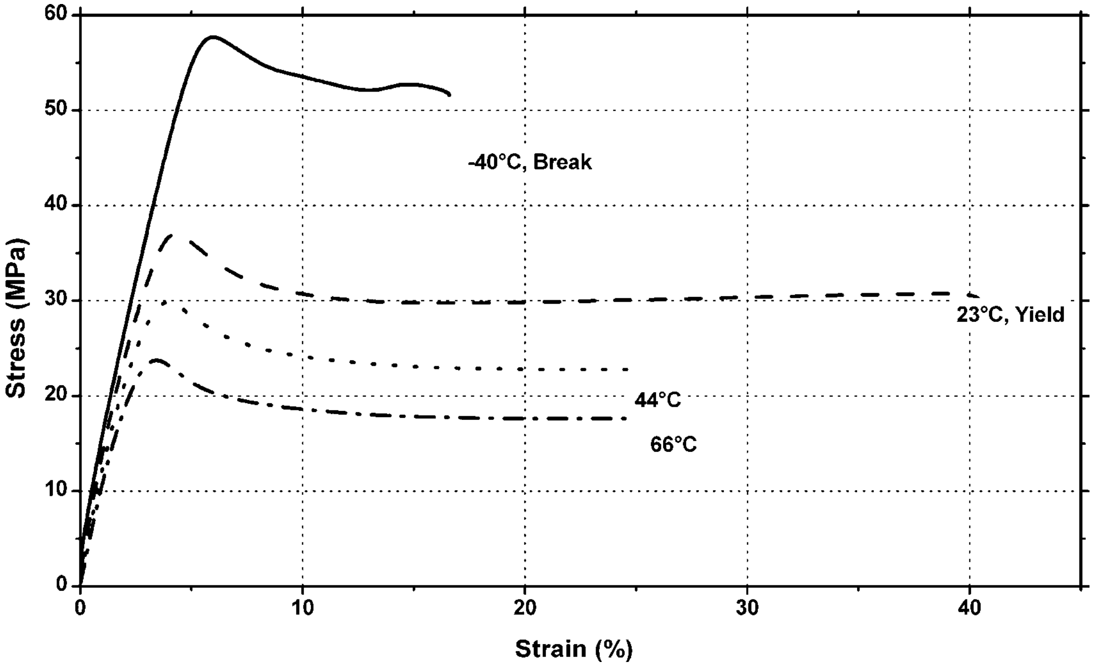


Figure 2.43. Tensile stress vs. strain for SABIC Innovative Plastics Cycolac® EX39—high impact extrusion ABS resin.

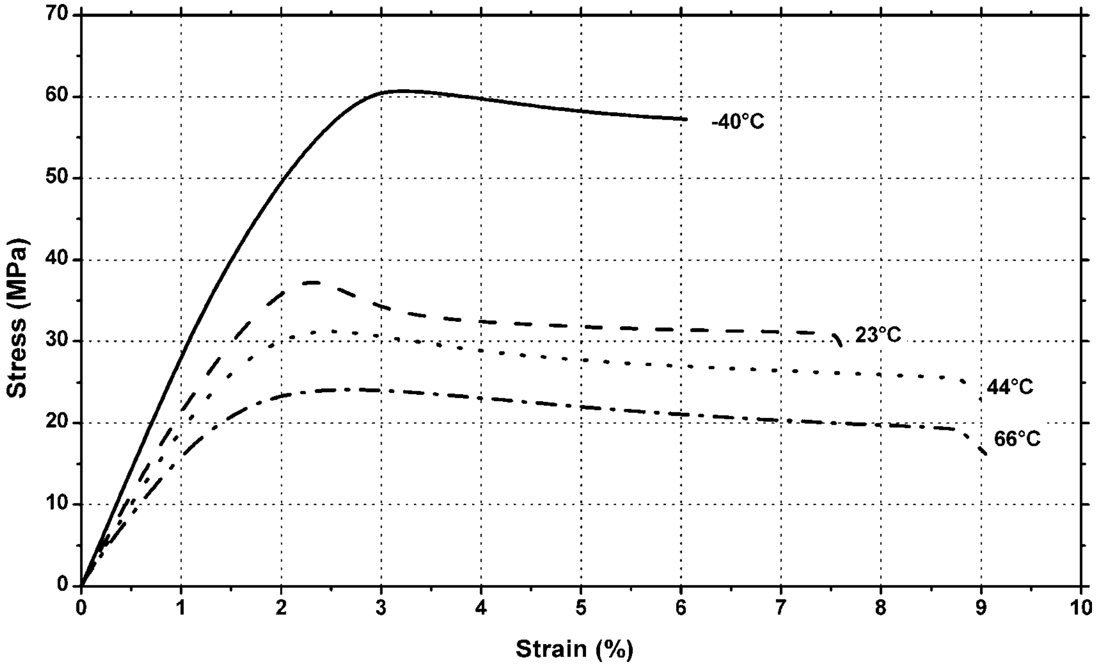


Figure 2.44. Tensile stress vs. strain for SABIC Innovative Plastics Cycolac® KJB—medium impact, wide processing range ABS resin.

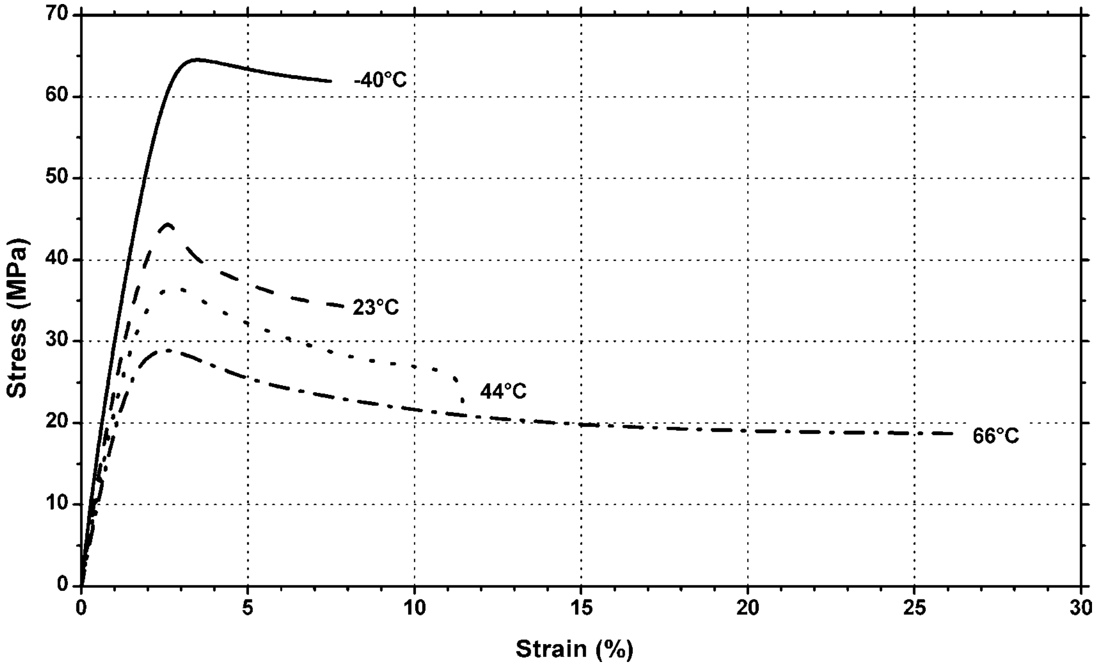


Figure 2.45. Tensile stress vs. strain for SABIC Innovative Plastics Cycolac® MGABS01—high impact, high gloss, good flow injection molding ABS resin.

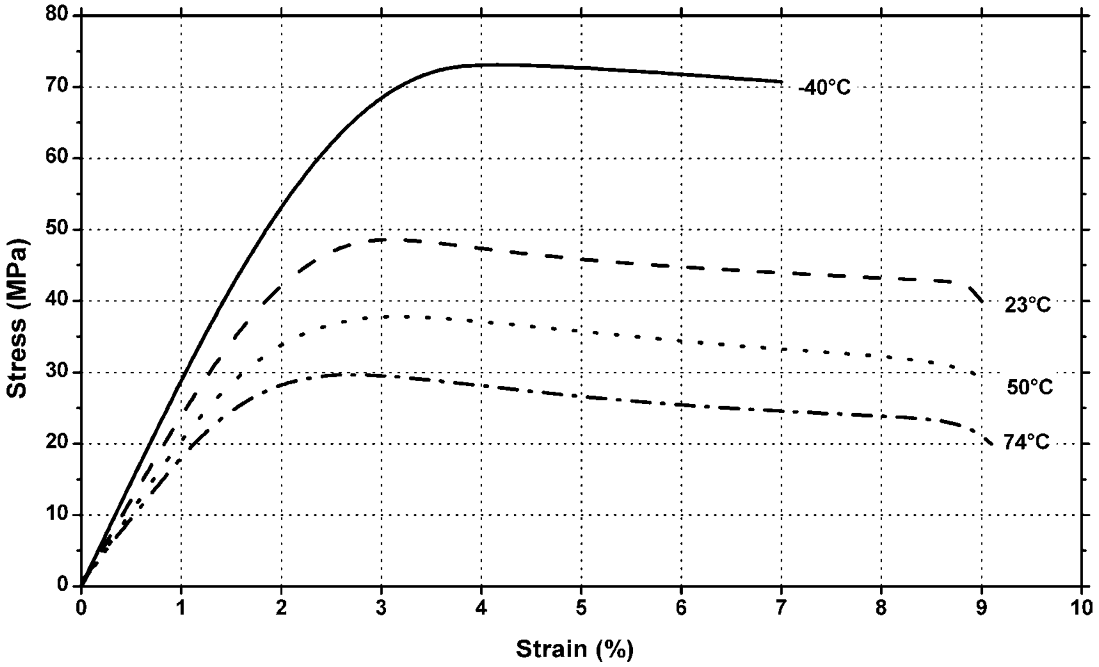


Figure 2.46. Tensile stress vs. strain for SABIC Innovative Plastics Cycolac® Z48—high heat resistant, medium impact, good strength ABS resin.

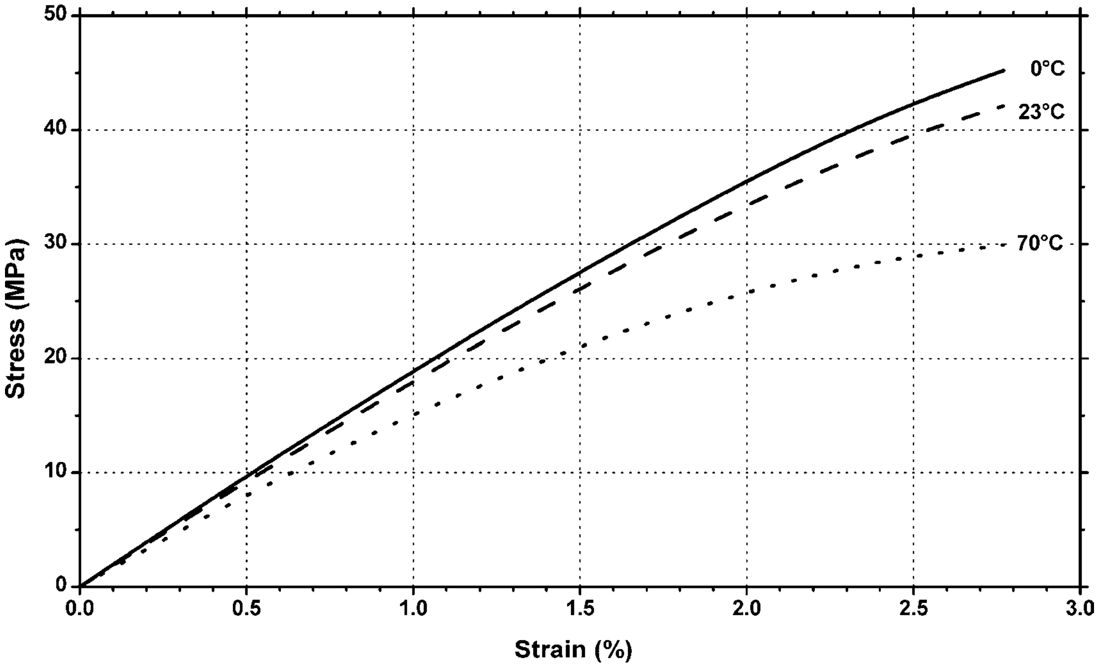


Figure 2.47. Tensile stress vs. strain for Dow Chemical Magnum™ 1040—high impact automotive ABS resin.

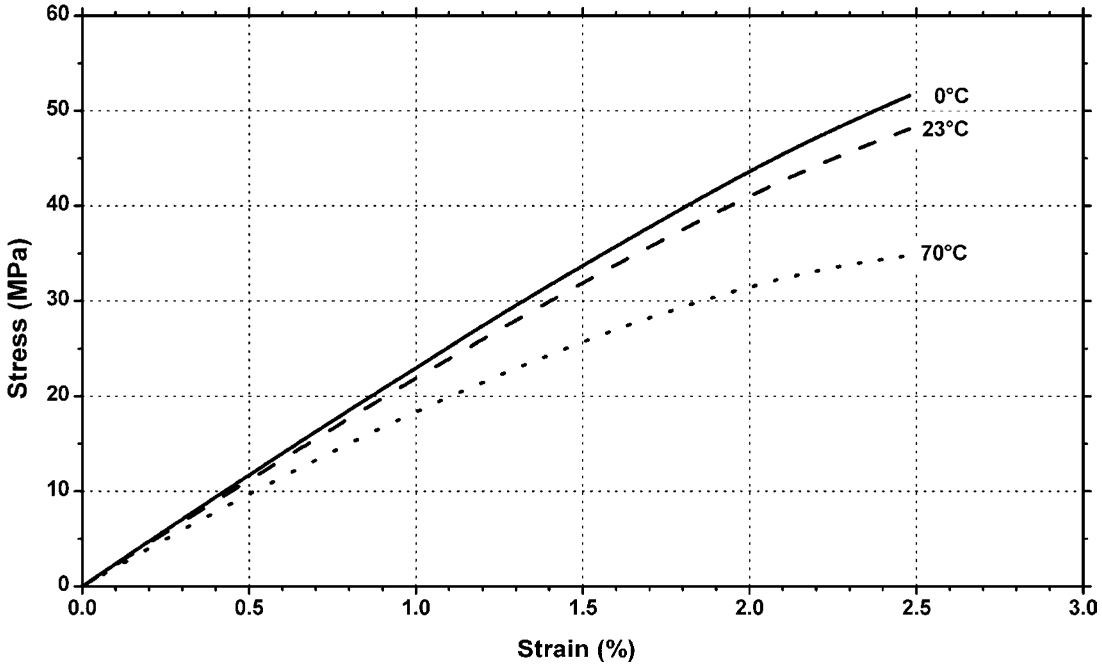


Figure 2.48. Tensile stress vs. strain for Dow Chemical Magnum™ 2620—healthcare ABS resin.

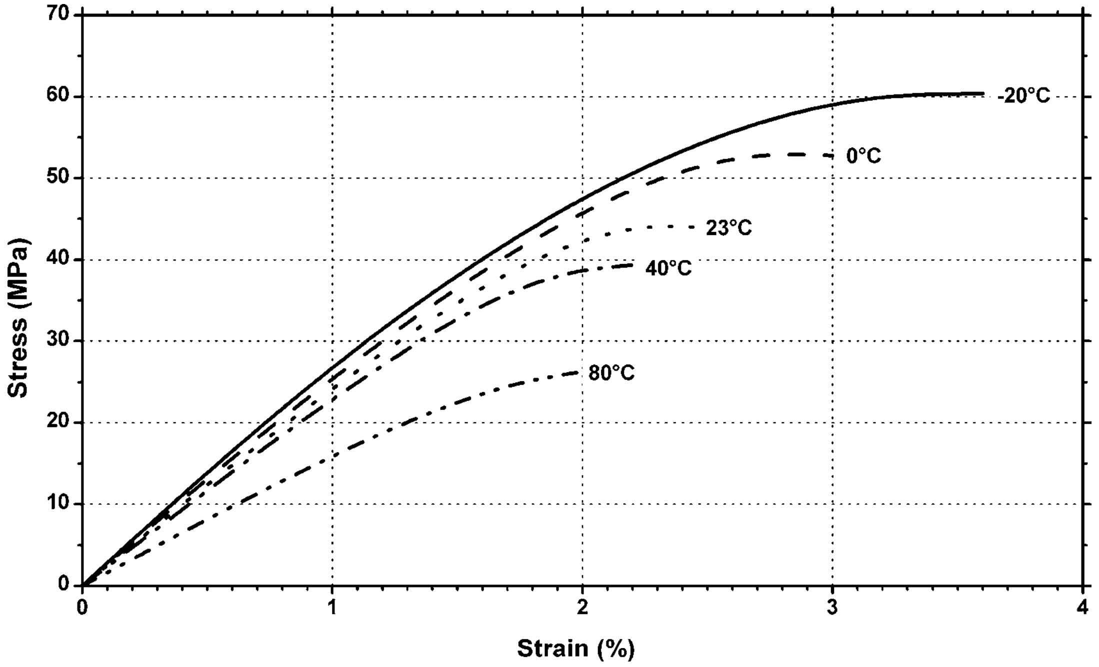


Figure 2.49. Tensile stress vs. strain for LANXESS AG Novodur® P2H-AT—standard impact, easy flow, high gloss, antistatic ABS resin.

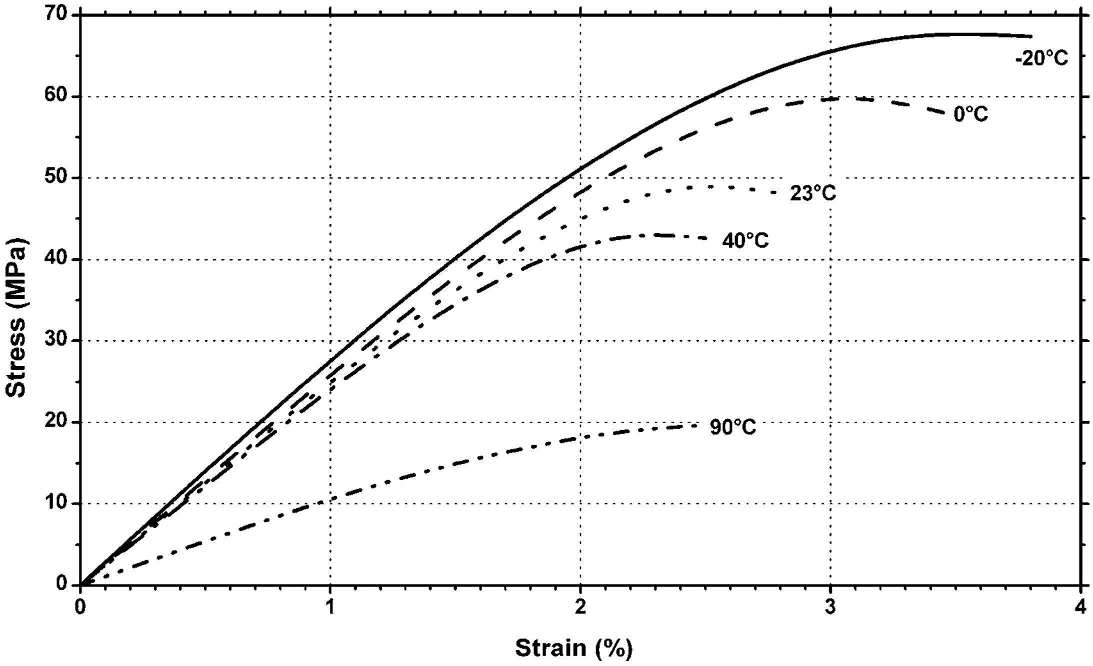


Figure 2.50. Tensile stress vs. strain for LANXESS AG Novodur® P3H-AT—improved chemical resistant, high gloss, antistatic ABS resin.

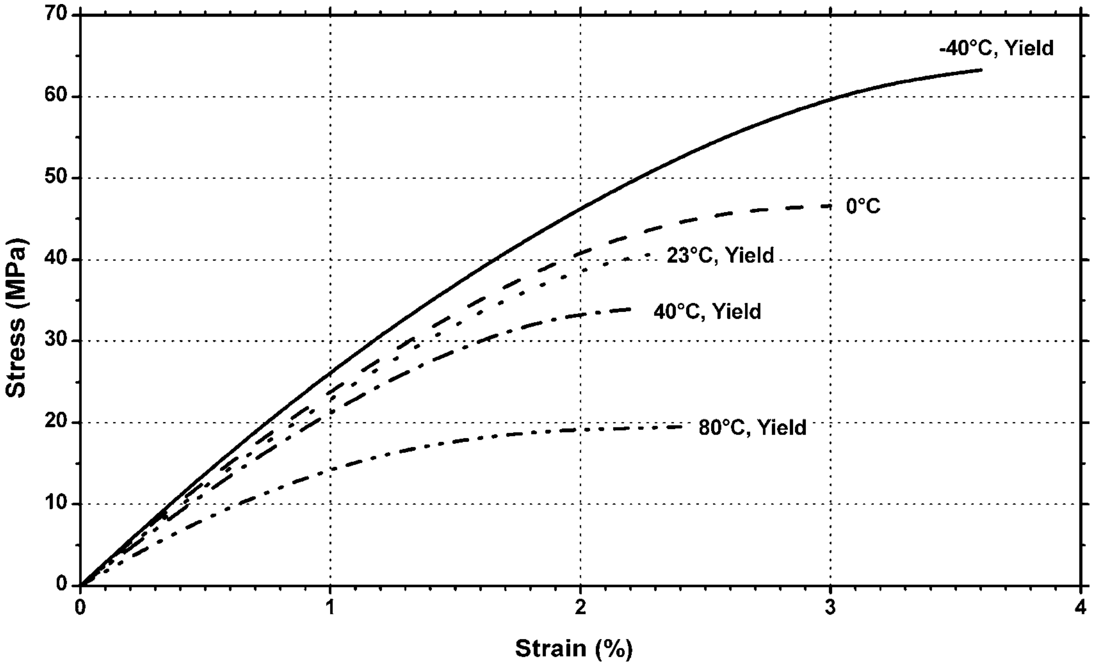


Figure 2.51. Tensile stress vs. strain for Terluran® GP-22—general purpose ABS resin.

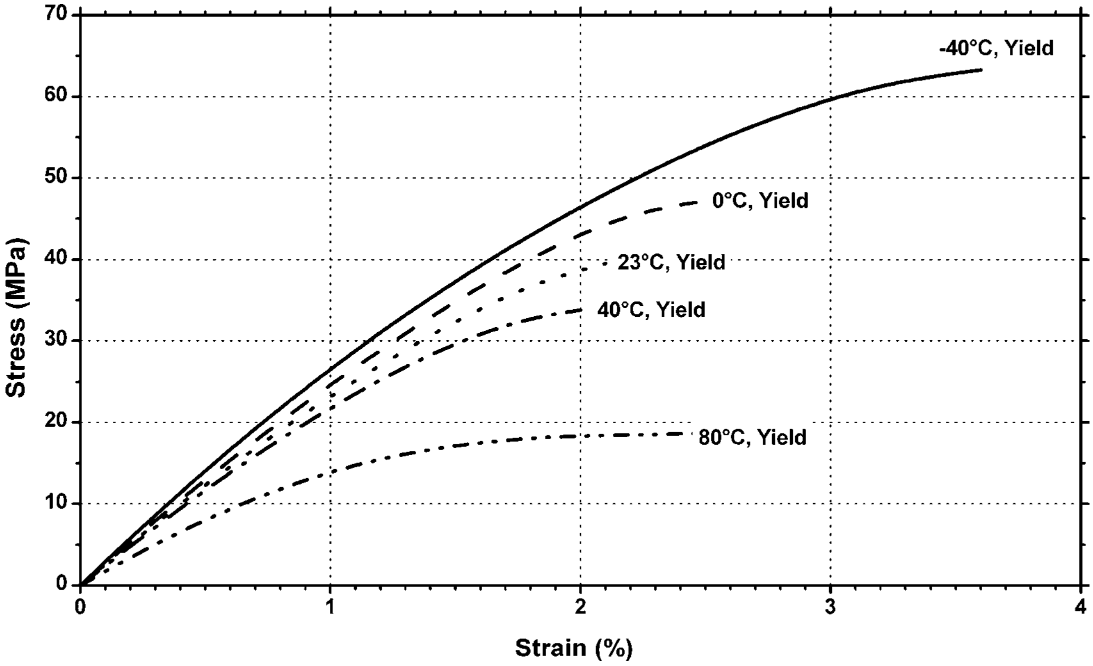


Figure 2.52. Tensile stress vs. strain for Terluran® GP-35—very high flow, high impact ABS resin.

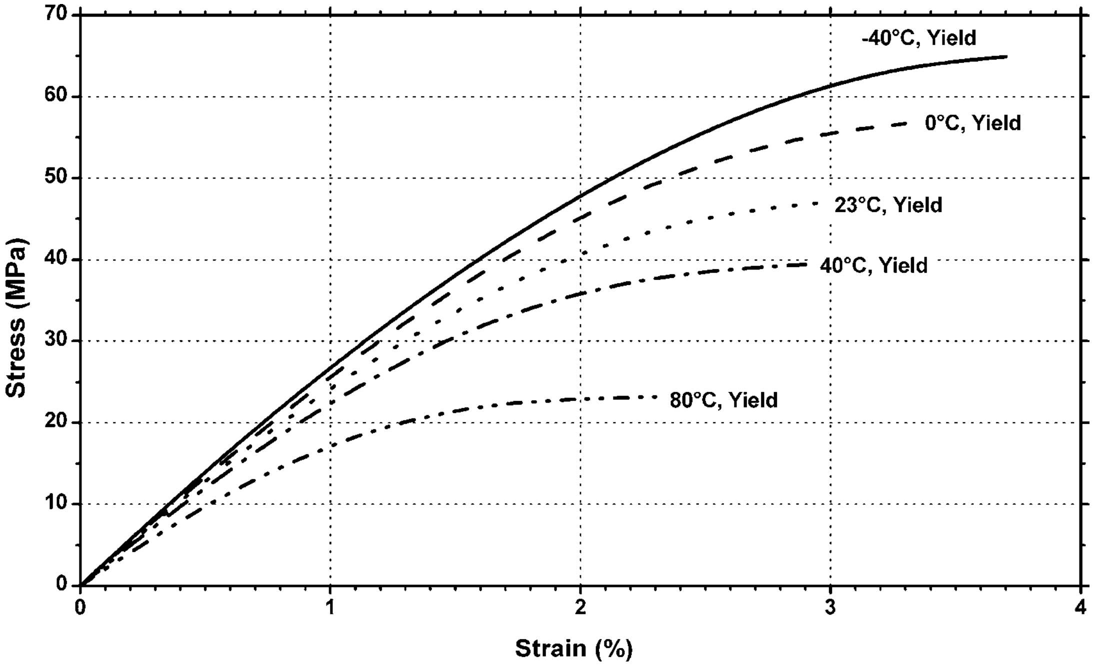


Figure 2.53. Tensile stress vs. strain for BASF Terluran® HH-106—high heat, high impact ABS resin.

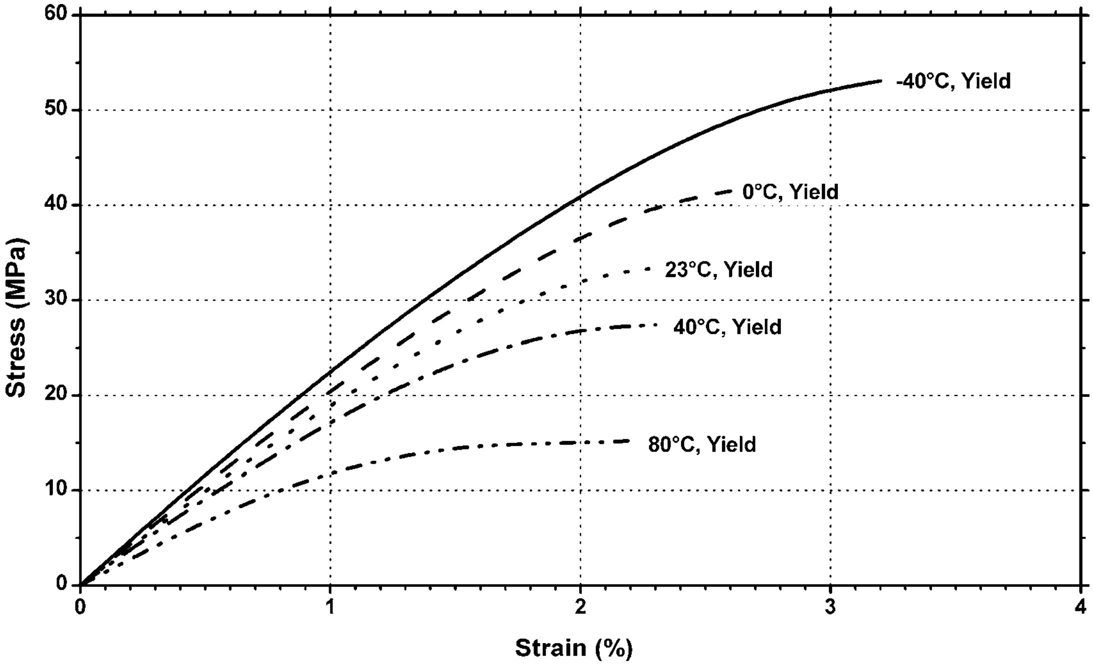


Figure 2.54. Tensile stress vs. strain for BASF Terluran® HI-10—high impact ABS resin.

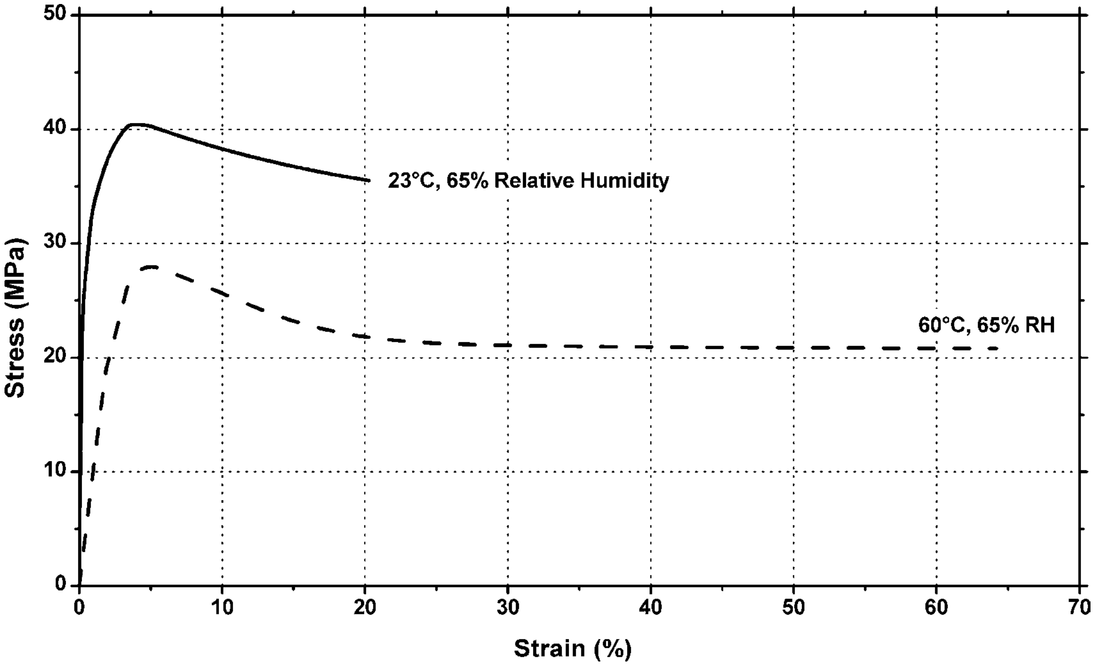


Figure 2.55. Tensile stress vs. strain for Toray Plastics Toyolac™ 100—general purpose, high impact strength ABS resin.

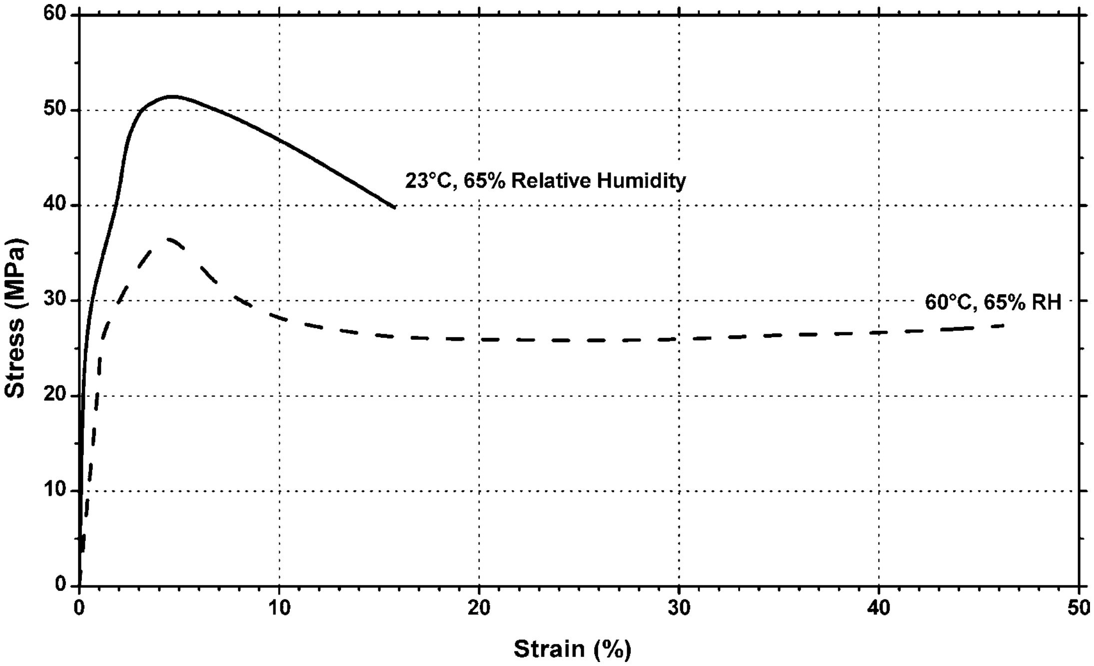


Figure 2.56. Tensile stress vs. strain for Toray Plastics Toyolac™ 500—general purpose, high rigidity ABS resin.

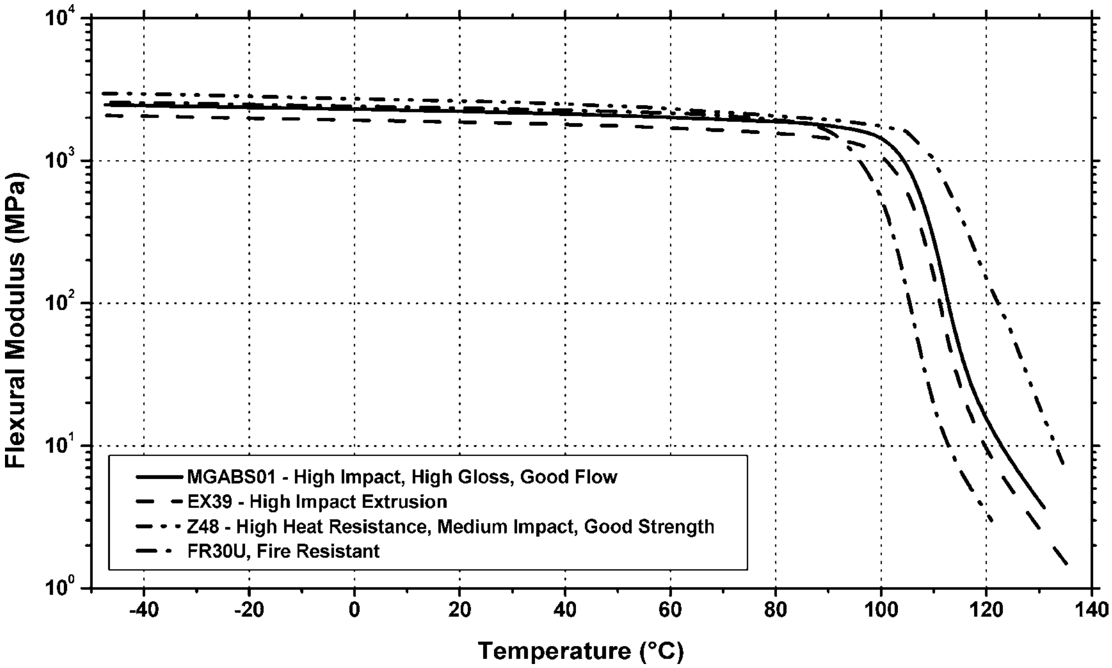


Figure 2.57. Flexural modulus vs. temperature for SABIC Innovative Plastics Cycolac® ABS resins.

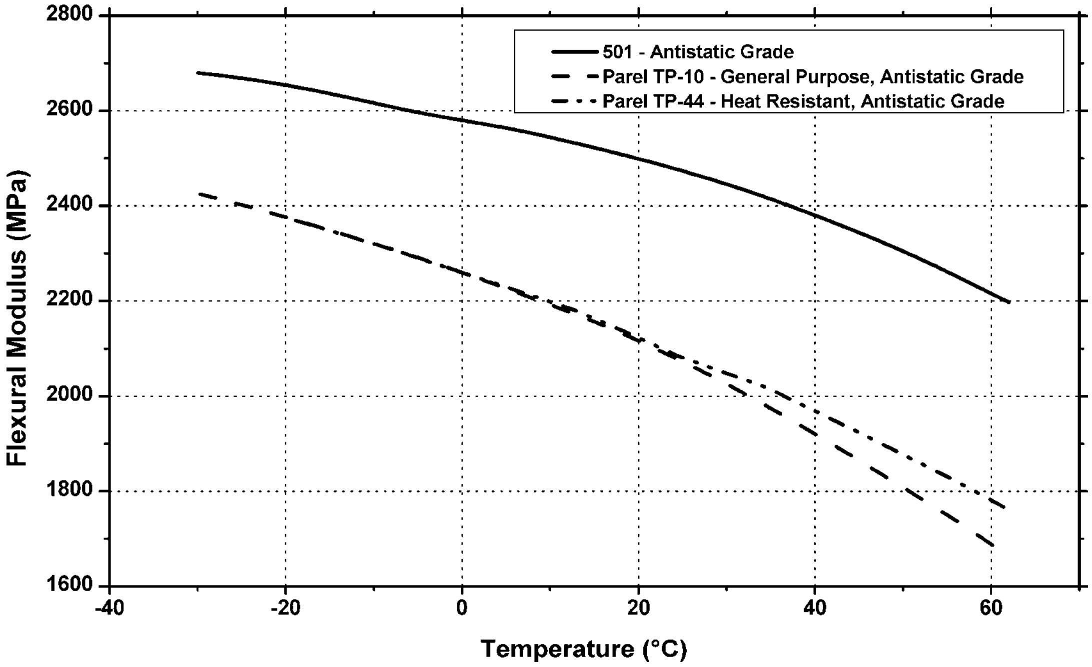


Figure 2.58. Flexural modulus vs. temperature for Toray Plastics Toyolac™ antistatic ABS resins.

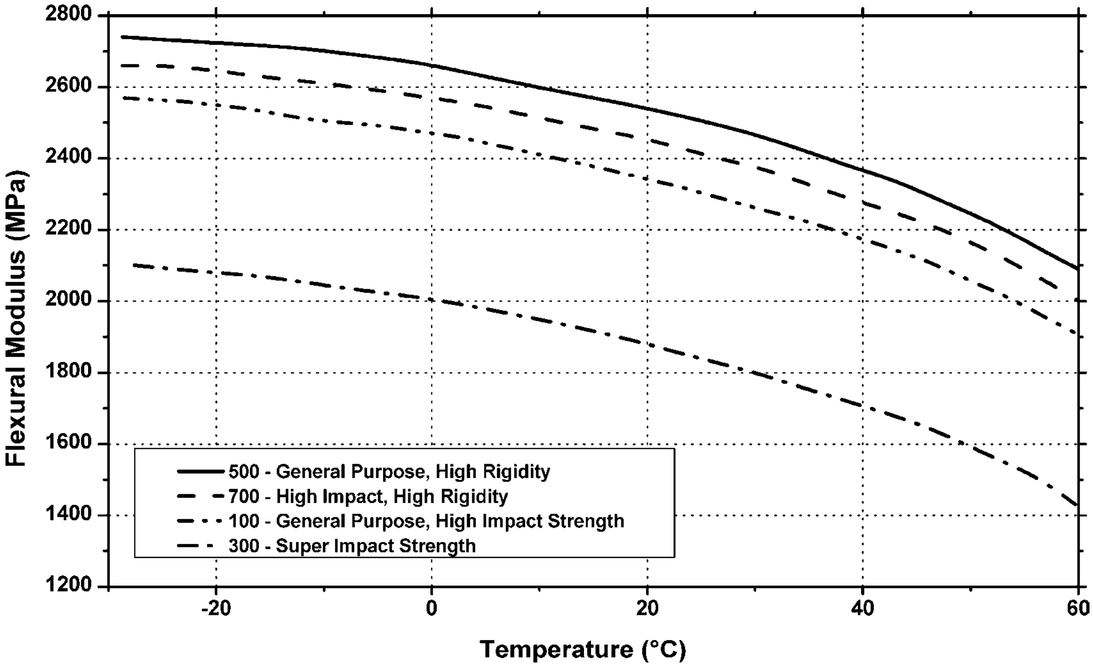


Figure 2.59. Flexural modulus vs. temperature for Toray Plastics Toyolac™ ABS resins.

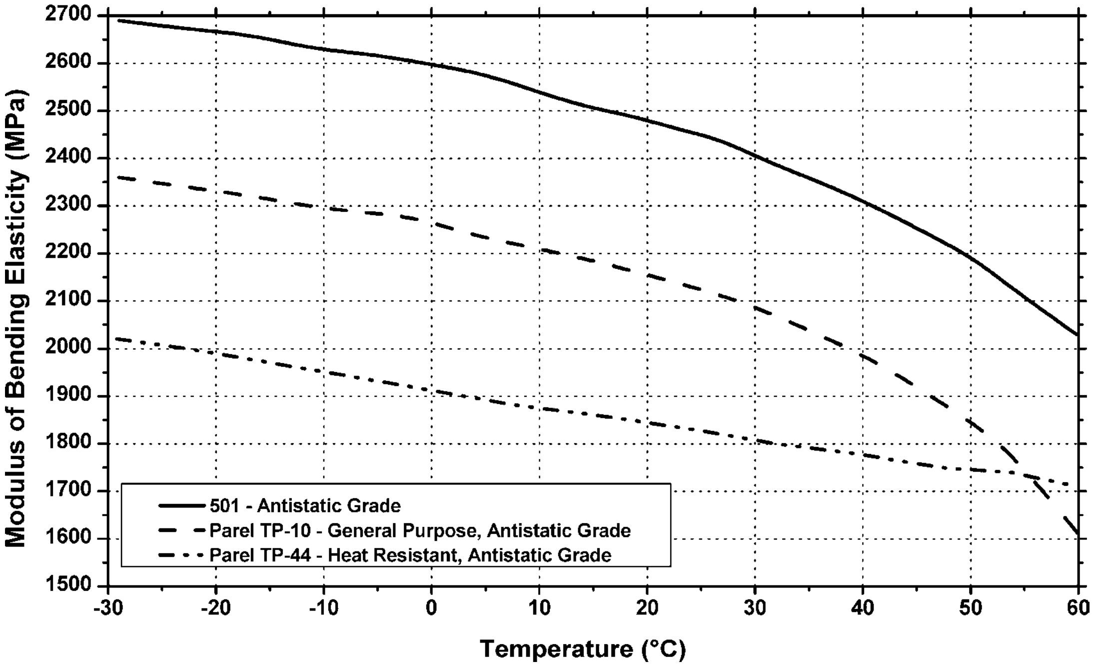


Figure 2.60. Modulus of bending elasticity vs. temperature for Toray Plastics Toyolac™ ABS resins.

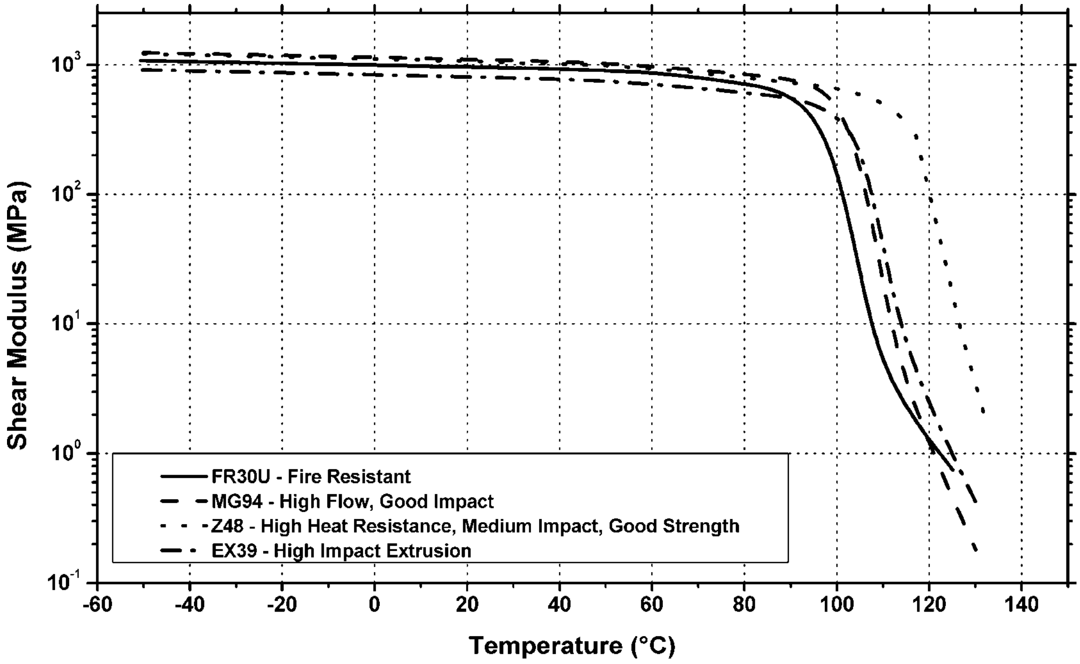


Figure 2.61. Shear modulus vs. temperature for SABIC Innovative Plastics Cycolac® ABS resinss.

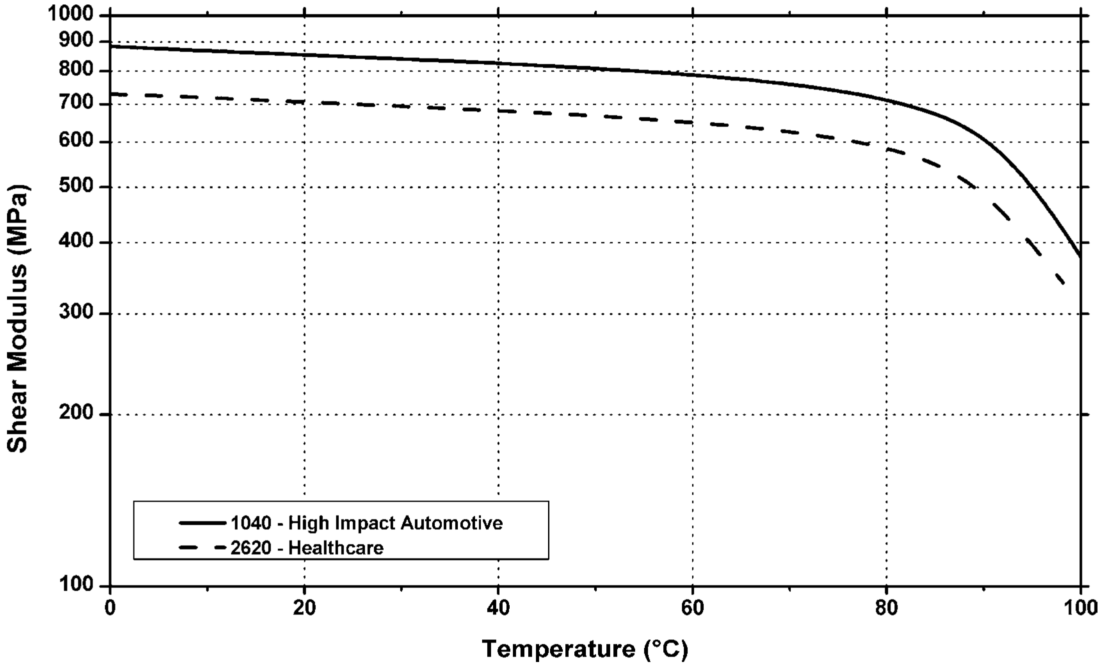


Figure 2.62. Shear modulus vs. temperature for Dow Chemical Magnum™ ABS resins.

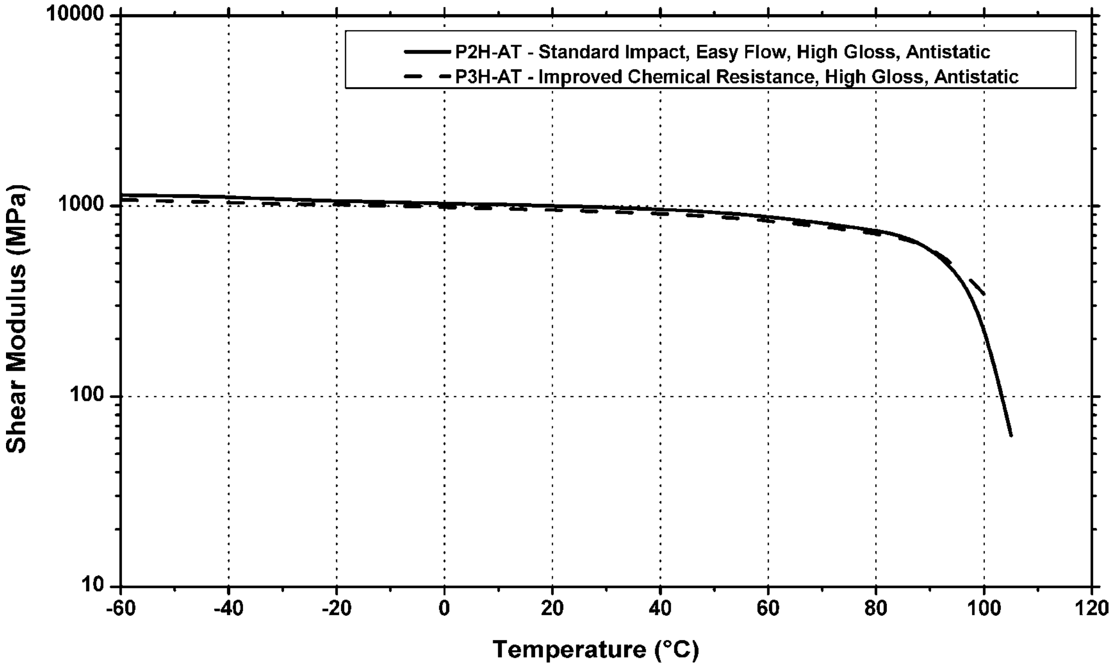


Figure 2.63. Shear modulus vs. temperature for LANXESS AG Novodur® ABS resins.

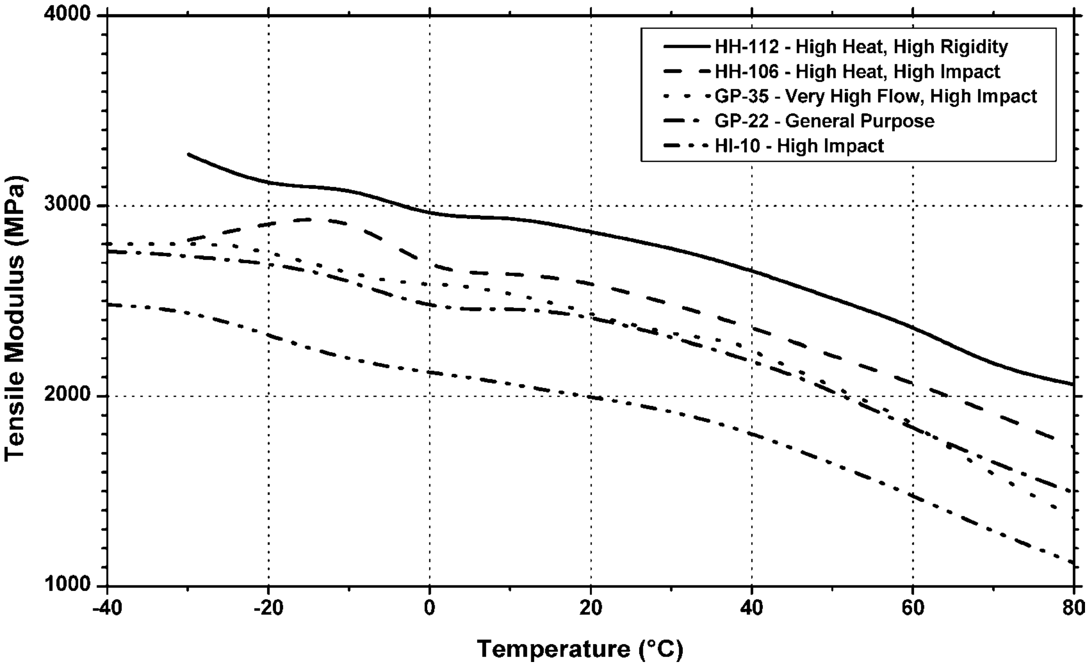


Figure 2.64. Tensile modulus vs. temperature for BASF Terluran® ABS resins.

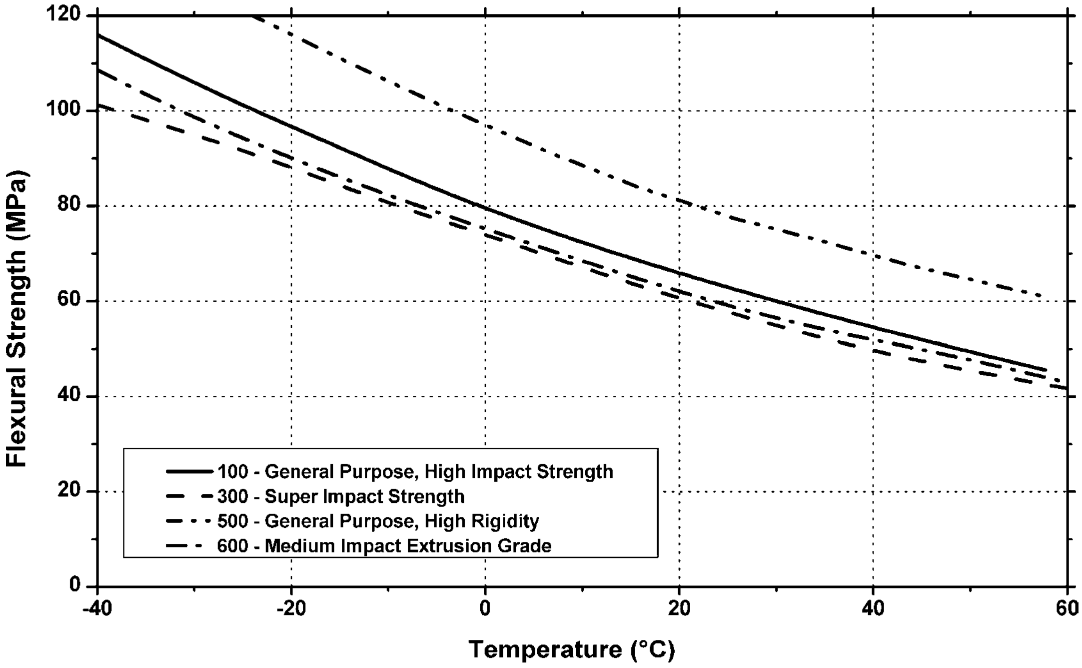


Figure 2.65. Flexural strength vs. temperature for Toray Plastics Toyolac™ ABS resins.

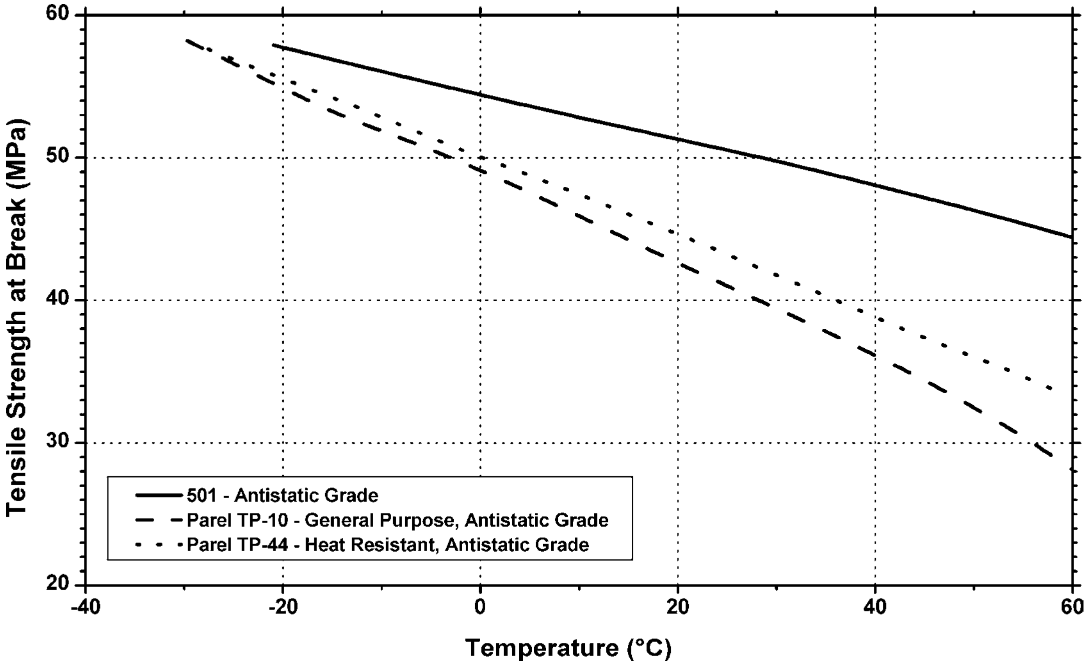


Figure 2.66. Tensile strength at break vs. temperature for Toray Plastics Toyolac™ antistatic ABS resins.

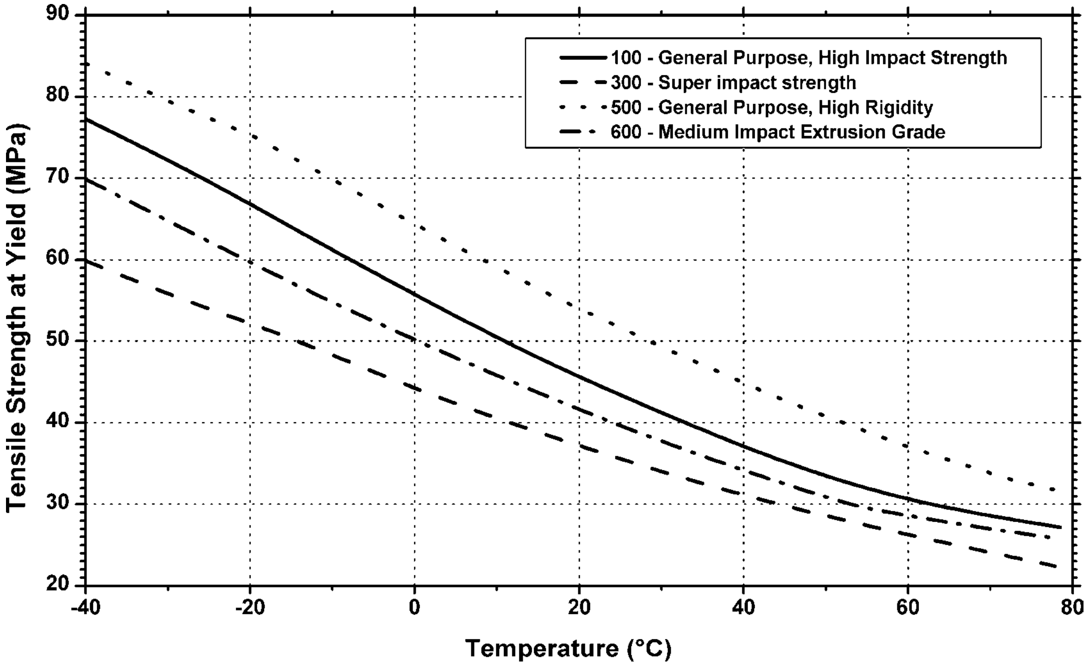


Figure 2.67. Tensile strength at yield vs. temperature for Toray Plastics Toyolac™ ABS resins.

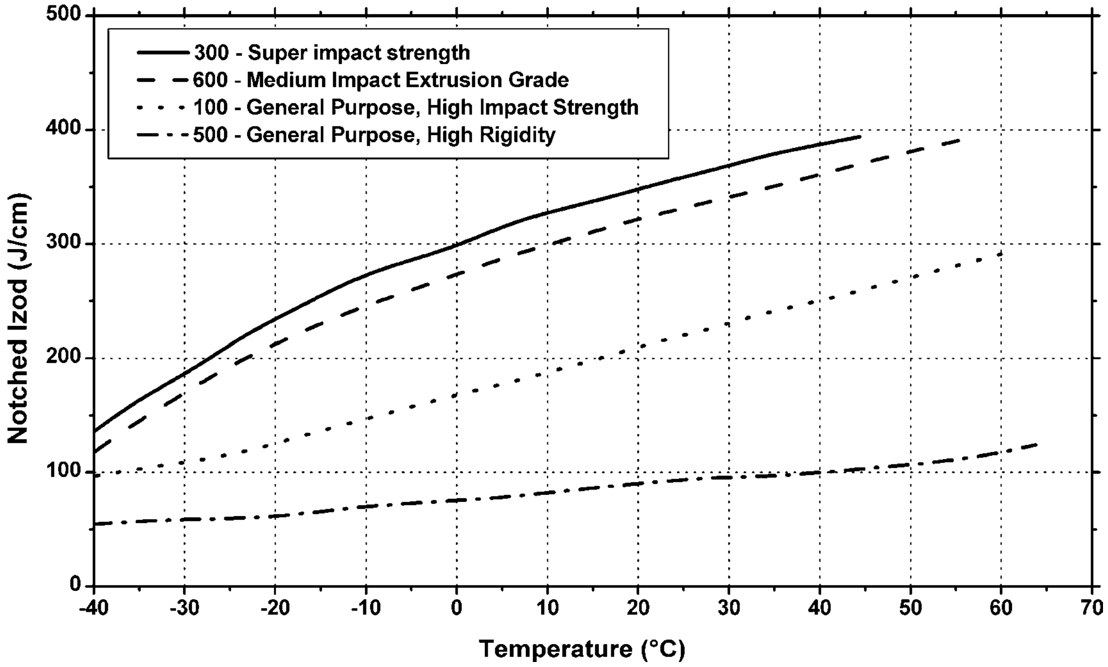


Figure 2.68. Izod impact strength vs. temperature for Toray Plastics Tyolac™ ABS resins.

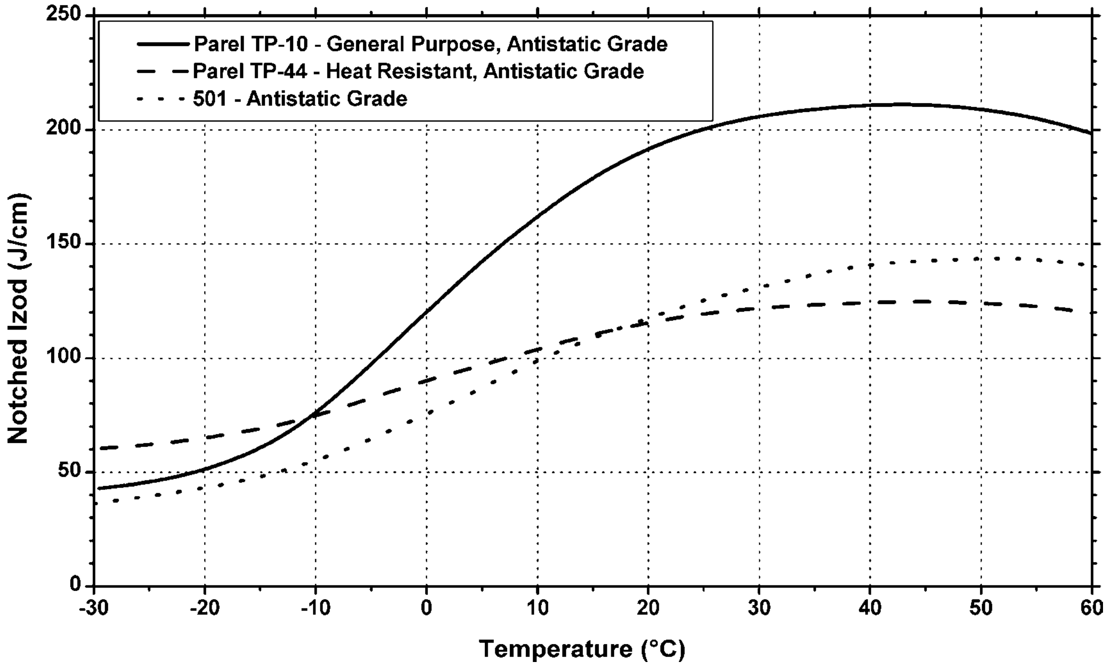


Figure 2.69. Izod impact strength vs. temperature for Toray Plastics Toyolac™ antistatic ABS resins.

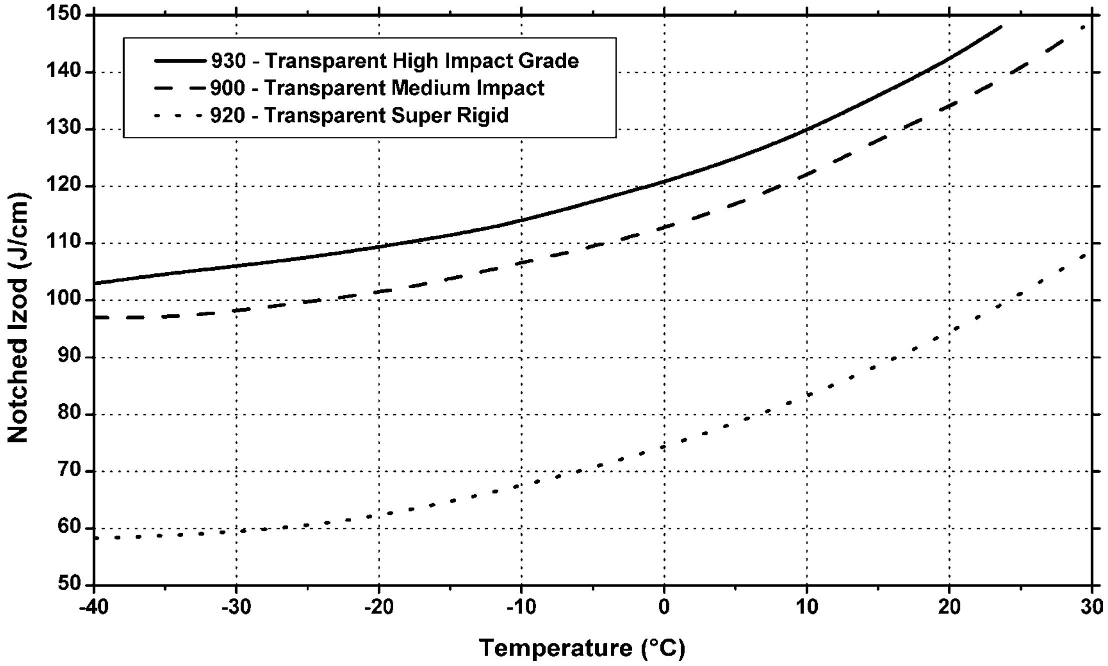


Figure 2.70. Izod impact strength vs. temperature for Toray Plastics Toyolac™ transparent ABS resins.

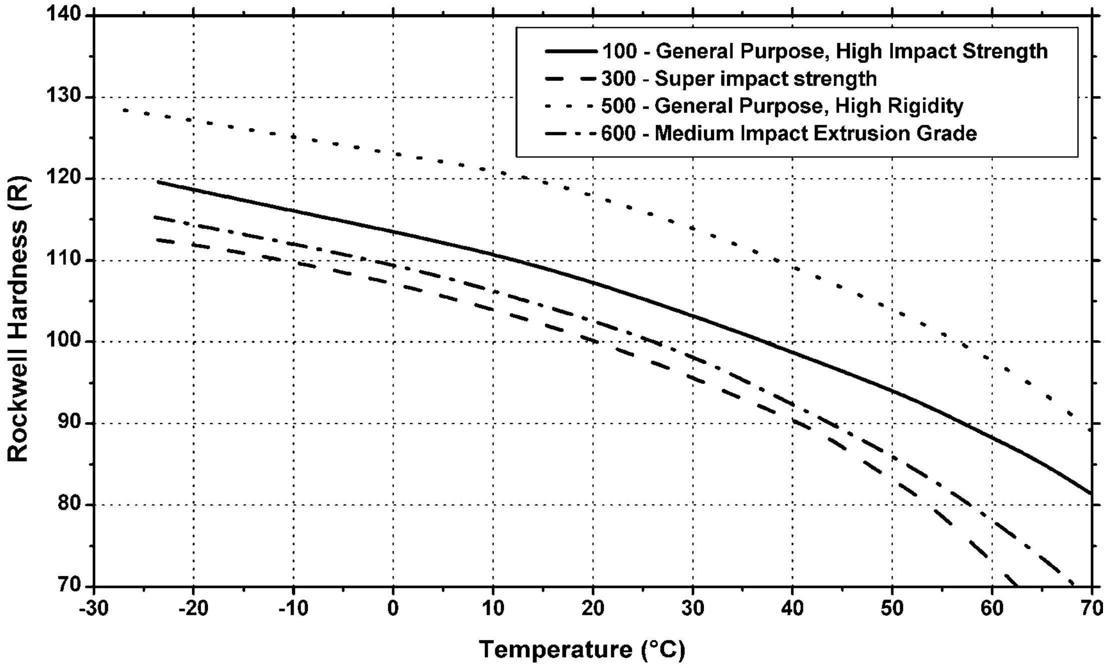


Figure 2.71. Rockwell hardness vs. temperature for Toray Plastics Toyolac™ ABS resins.

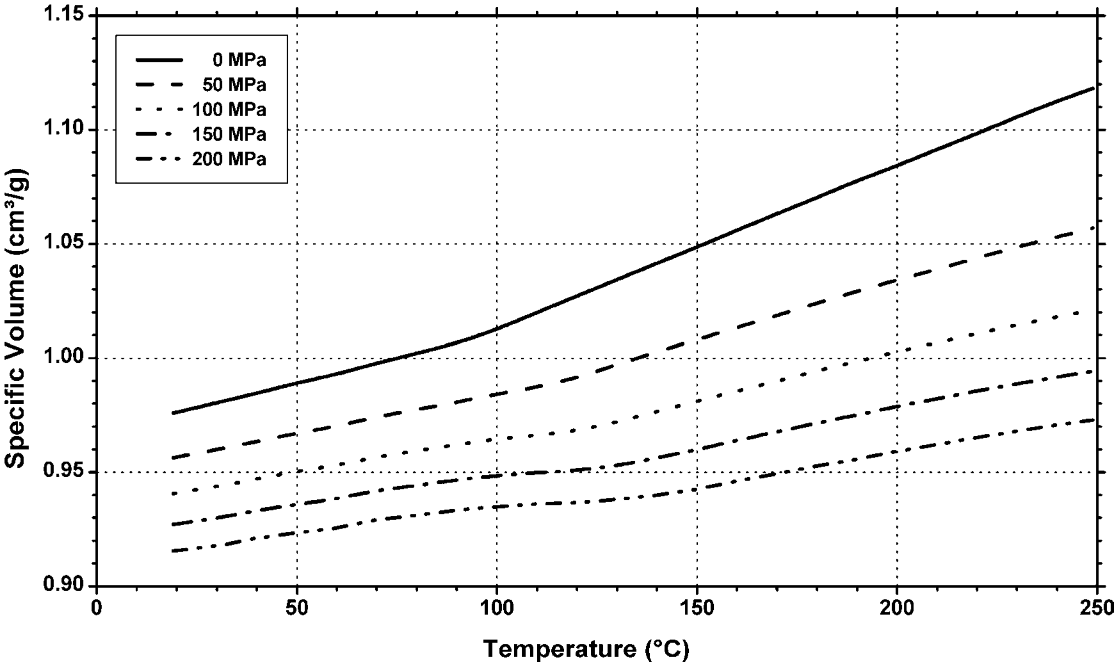


Figure 2.72. Specific volume as a function of temperature and pressure (PVT) for SABIC Innovative Plastics Cycolac® Z48—high heat resistant, medium impact, ABS resin.

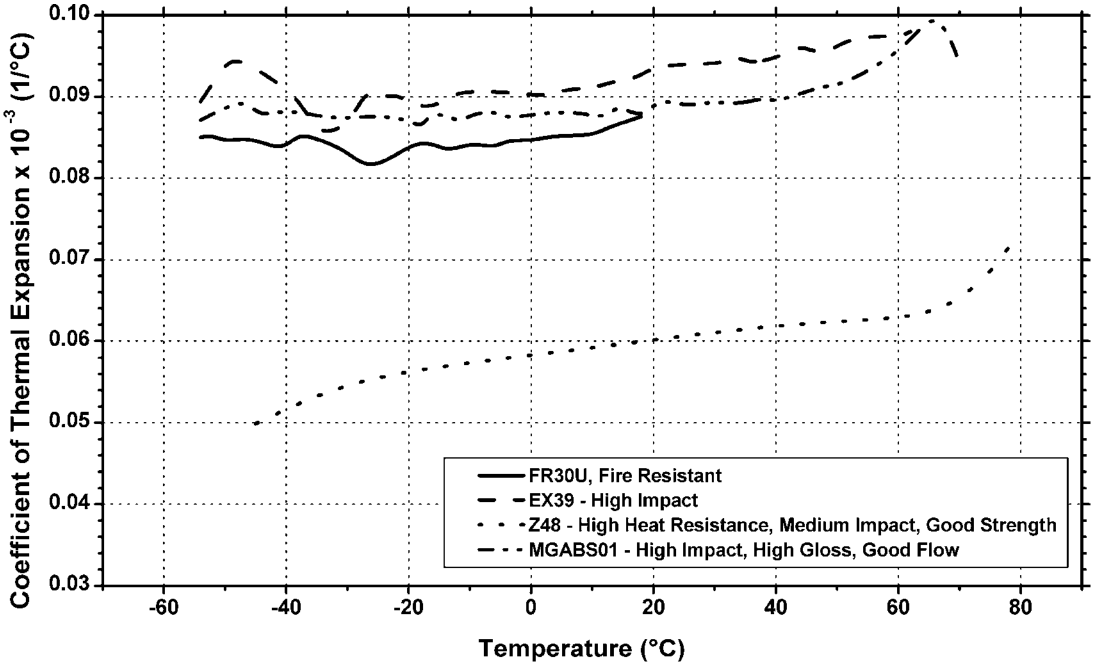


Figure 2.73. Coefficient of thermal expansion vs. temperature for SABIC Innovative Plastics Cycolac® ABS resins.

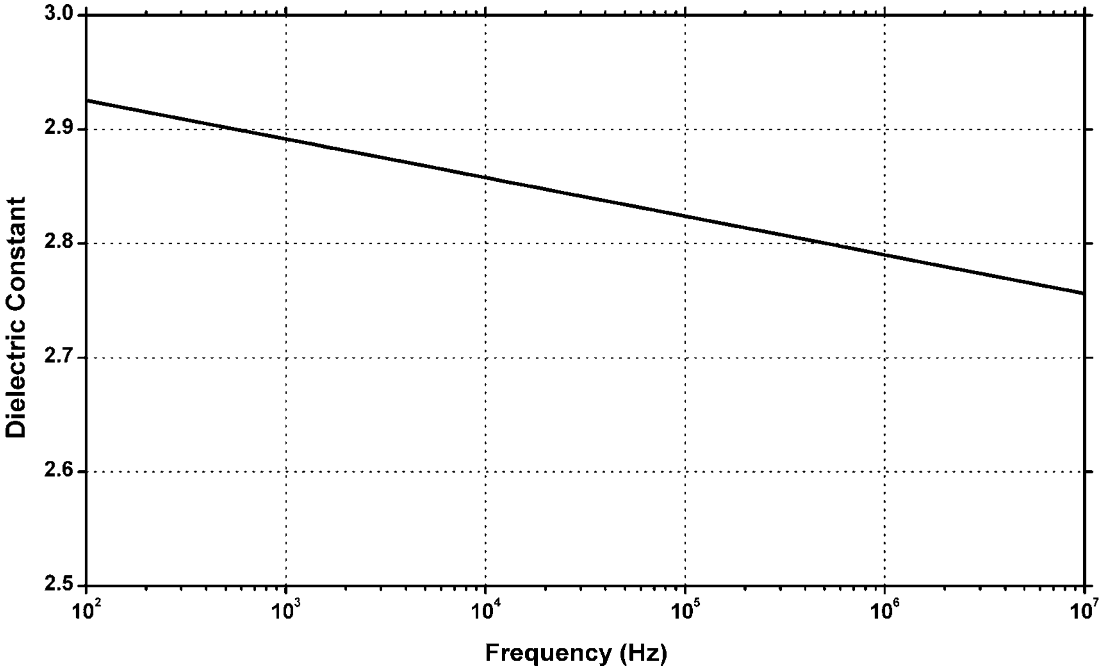


Figure 2.74. Dielectric constant vs. frequency for Dow Chemical Magnum™ ABS resins.

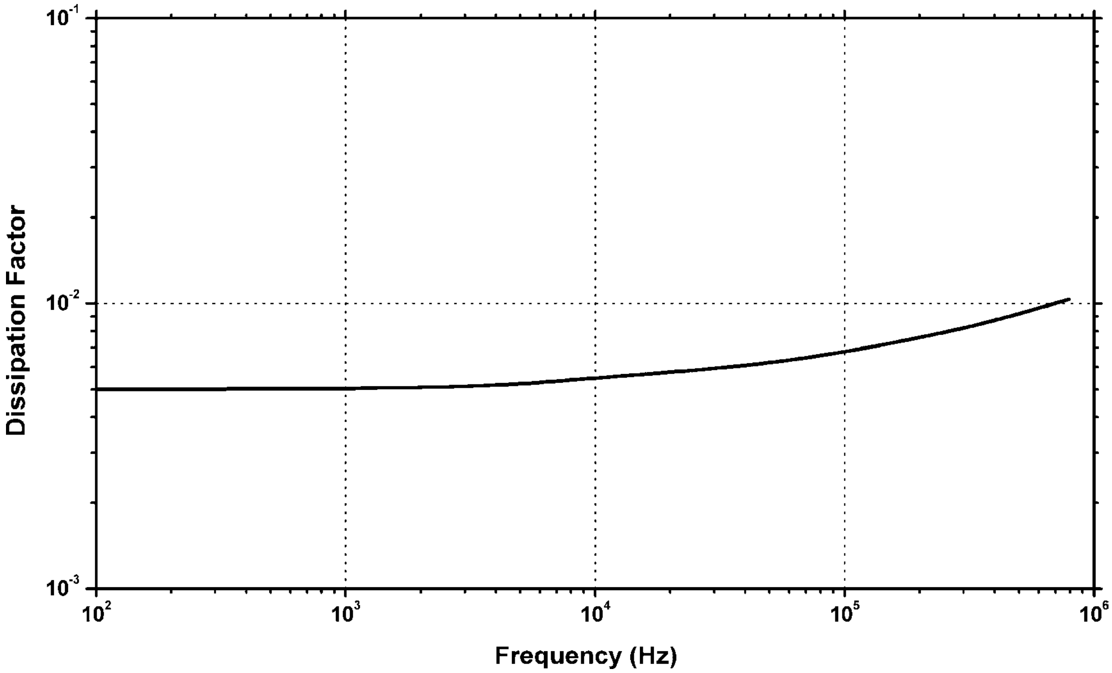


Figure 2.75. Dissipation factor vs. frequency for Dow Chemical Magnum ABS resins.

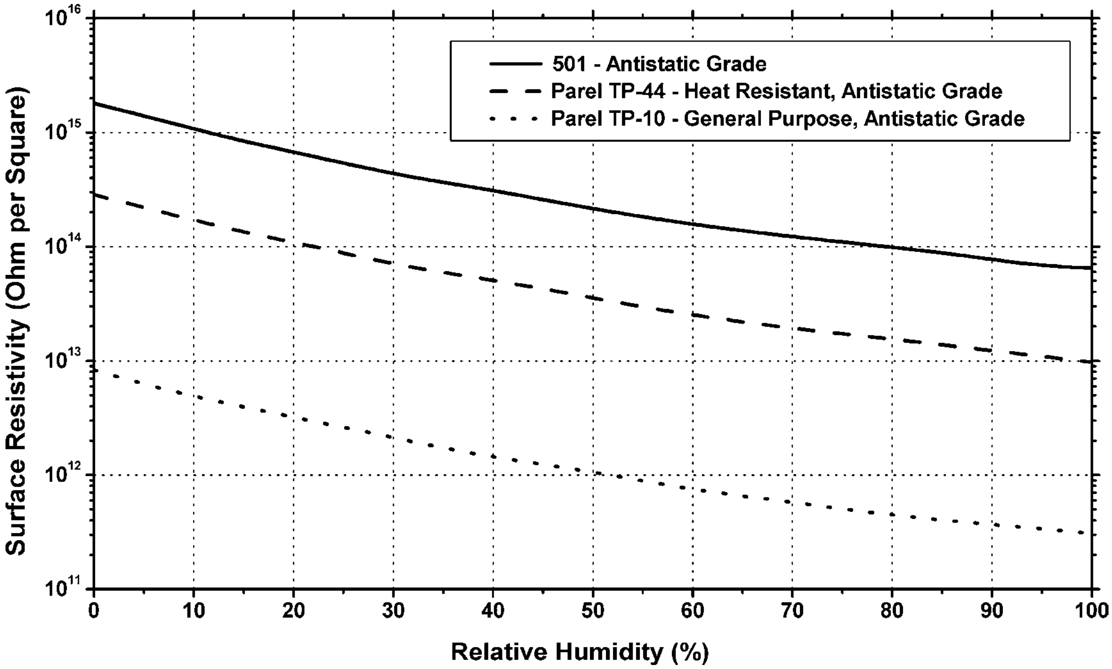


Figure 2.76. Surface resistivity vs. relative humidity for Toray Plastics Toyolac™ antistatic ABS resins.

2.6 Styrene-Maleic-Anhydride (SMA)

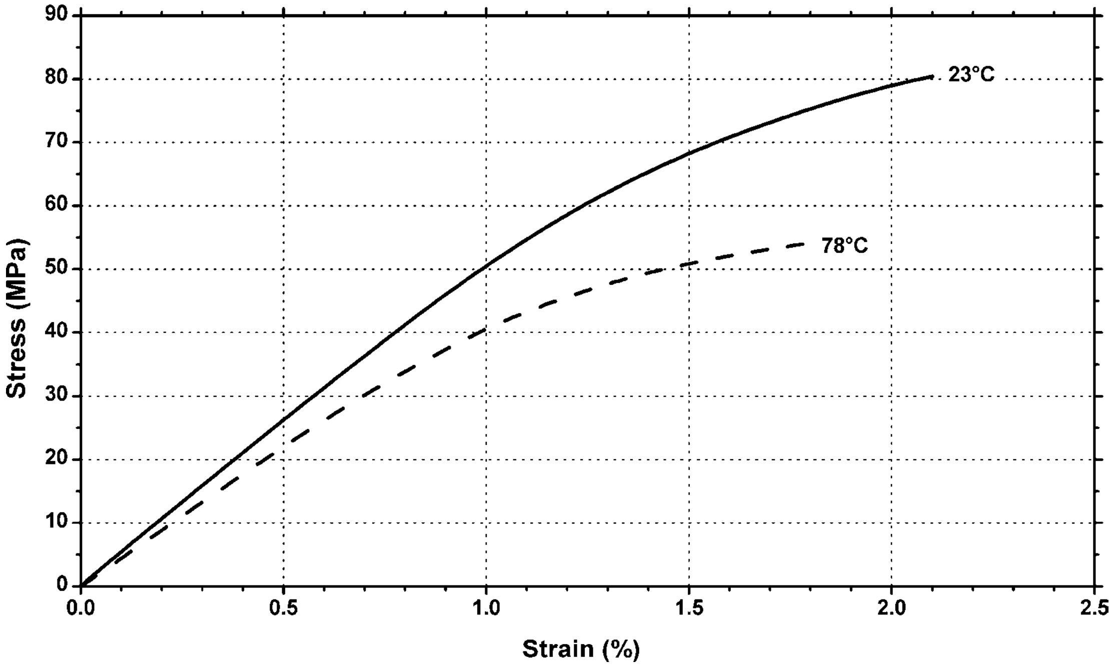


Figure 2.77. Tensile stress vs. strain for SABIC Innovative Plastics Prevex® IP-16 SMA resin.

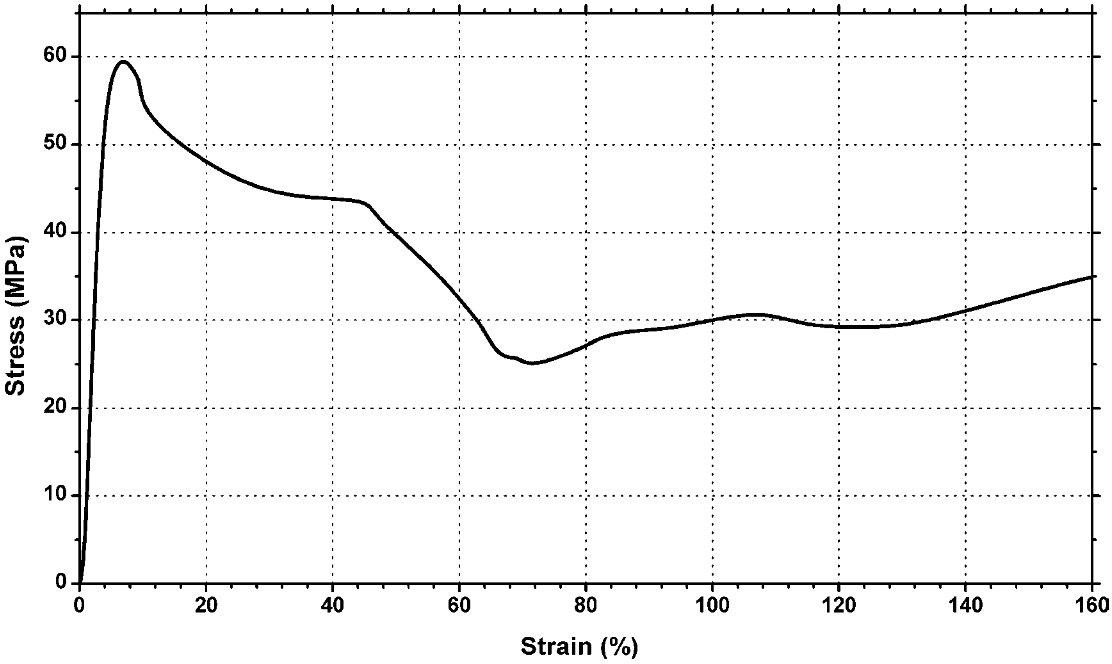


Figure 2.78. Tensile stress vs. strain in compression for SABIC Innovative Plastics Prevex® IP-16 SMA resin.

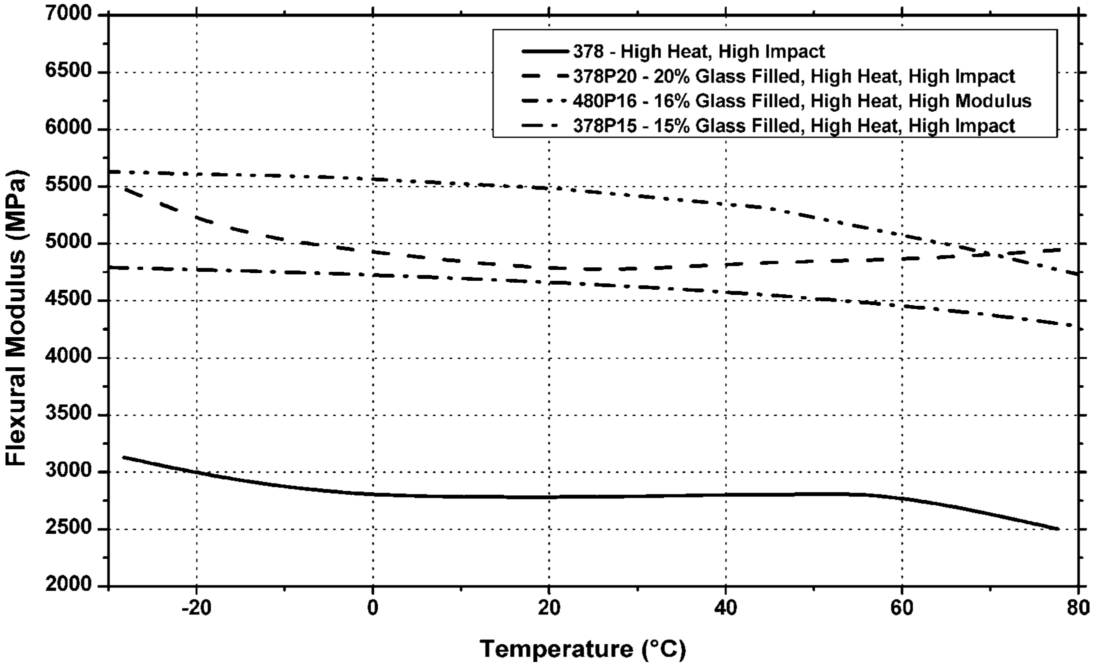


Figure 2.79. Flexural modulus vs. temperature for Dow Chemical Dylark® SMA resins.

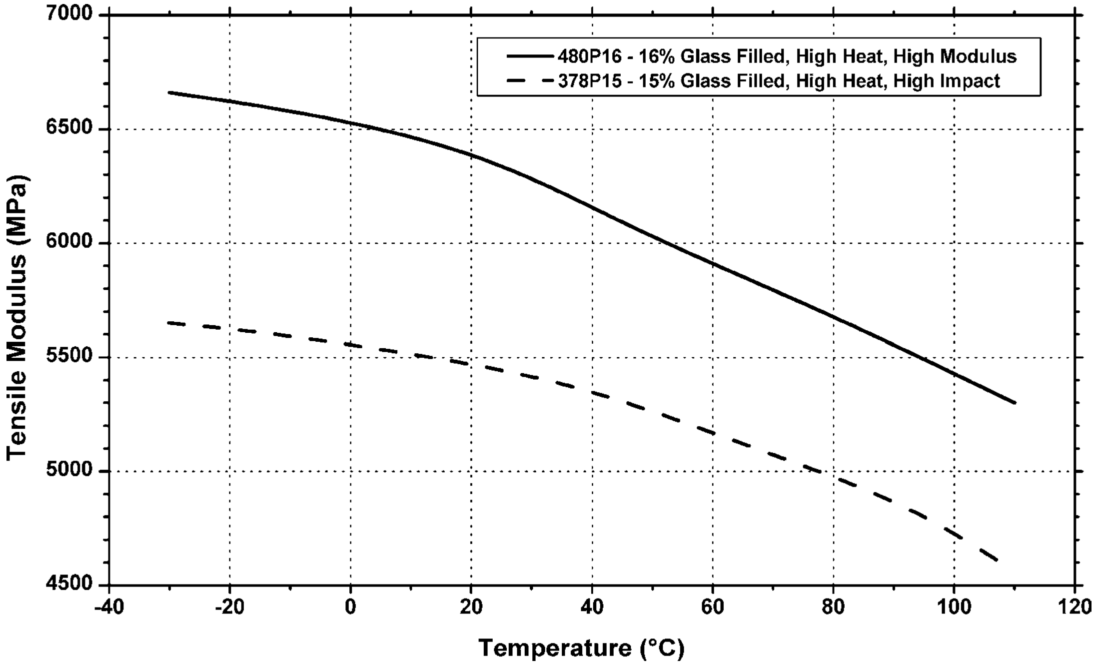


Figure 2.80. Tensile modulus vs. temperature for Dow Chemical Dylark SMA resins.

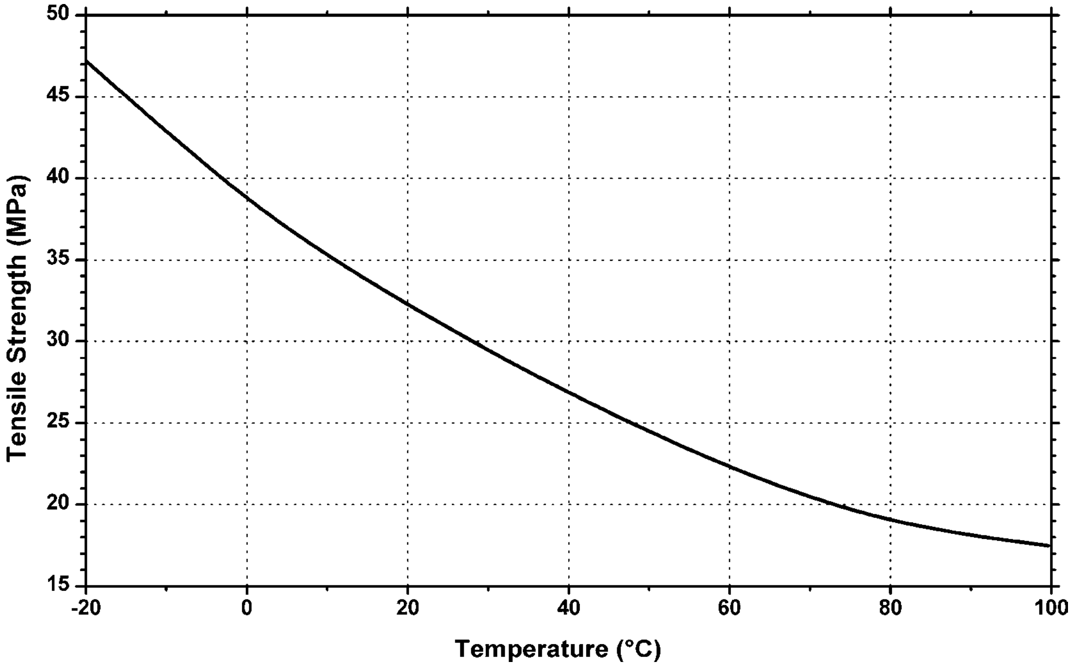


Figure 2.81. Tensile strength vs. temperature for Bayer Cadon® SMA resins.

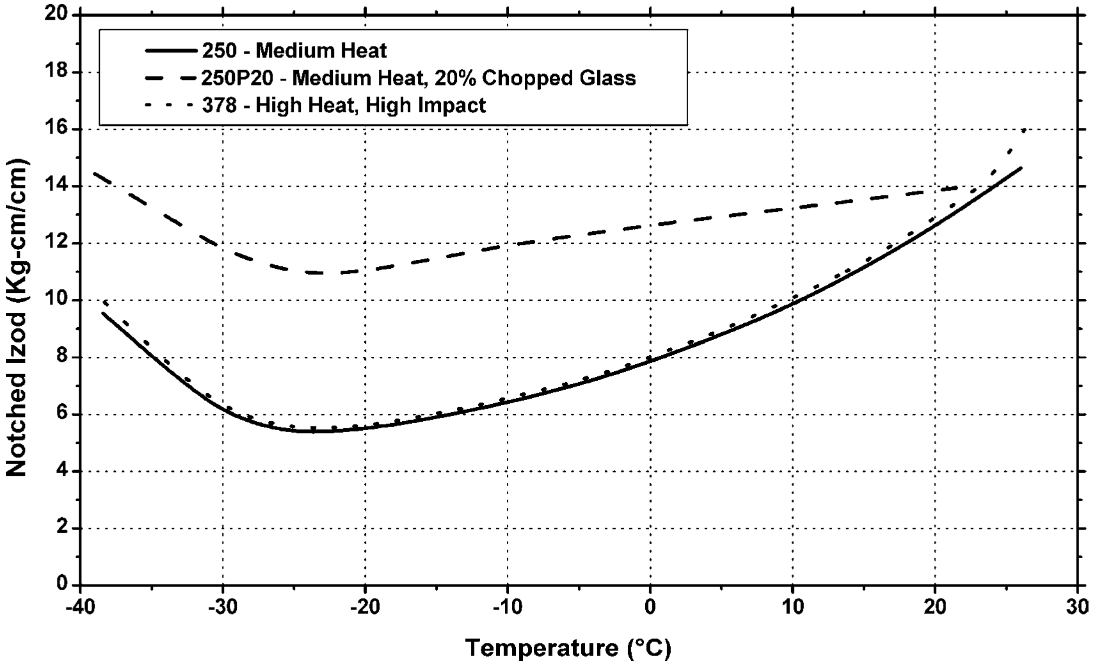


Figure 2.82. Notched Izod impact strength vs. temperature for Dow Chemical Dylark® SMA resins.

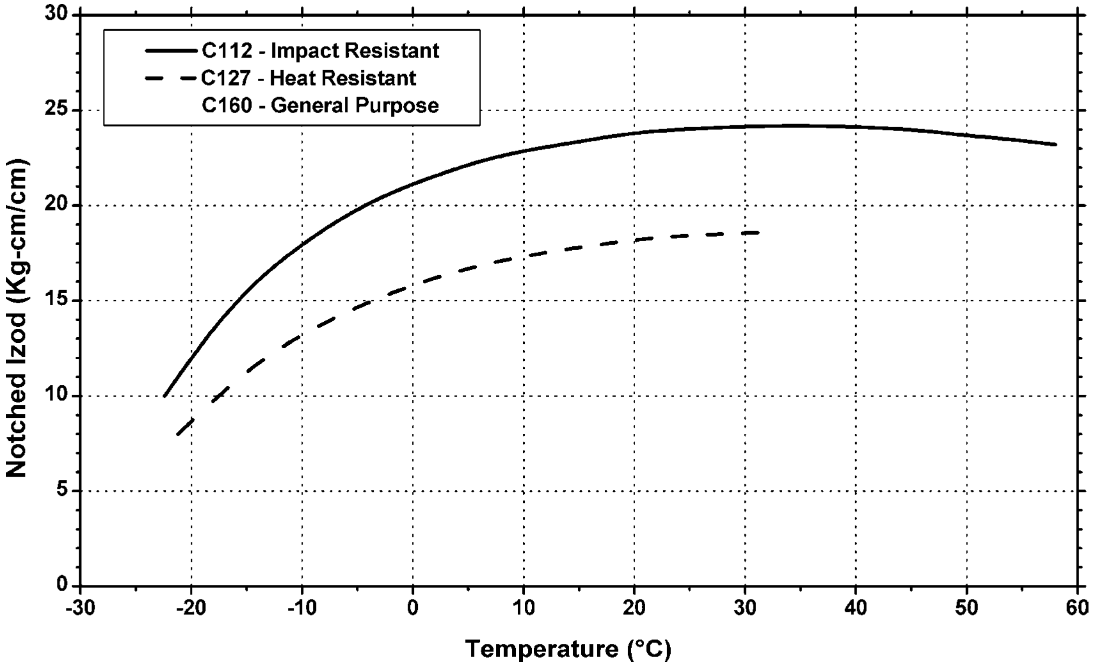


Figure 2.83. Notched Izod impact strength vs. temperature for Bayer Cadon® SMA resins.

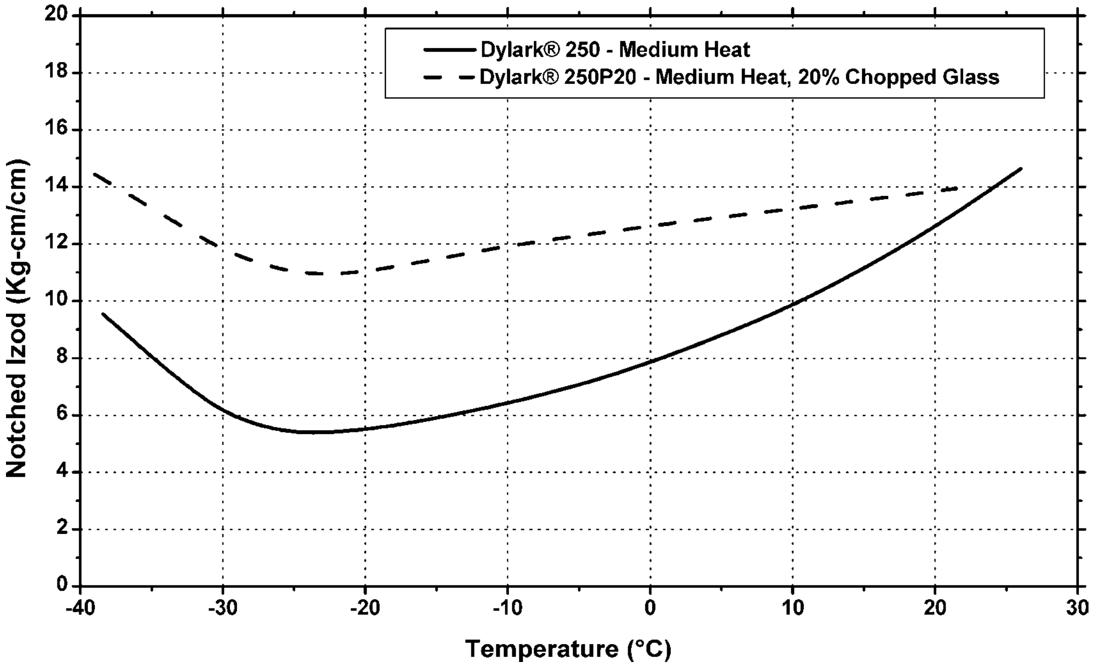


Figure 2.84. Notched Izod impact strength vs. temperature for Nova Chemicals Dylark® SMA resins.

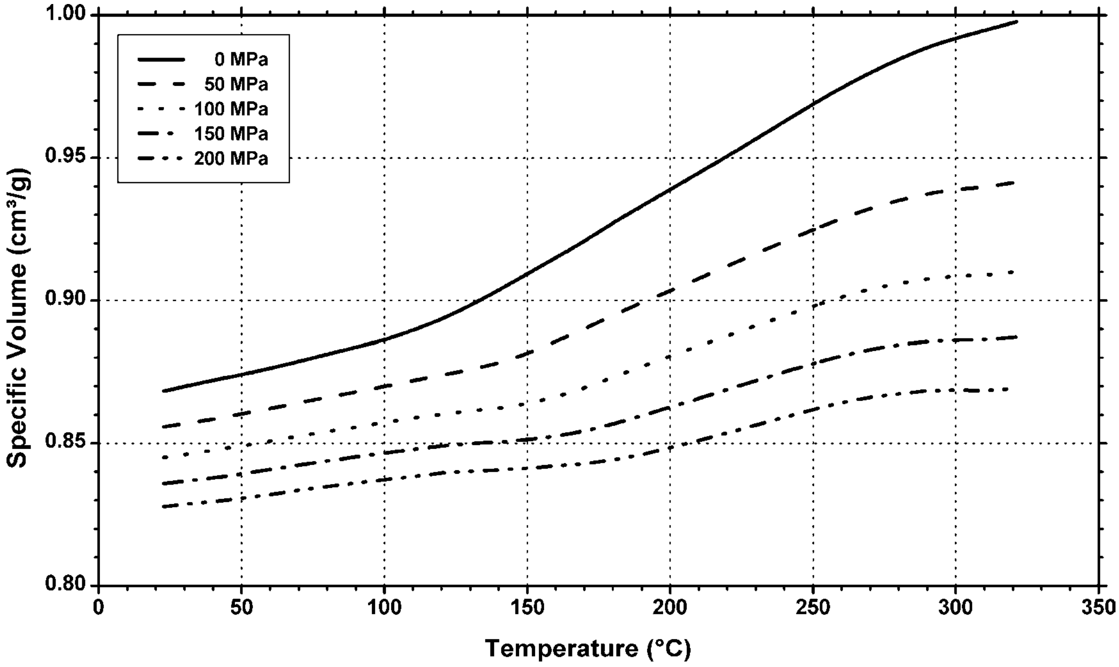


Figure 2.85. Specific volume as a function of temperature and pressure (PVT) for SABIC Innovative Plastics Prevex® IP-16 SMA resin.

2.7 Styrenic Block Copolymers (SBCs)

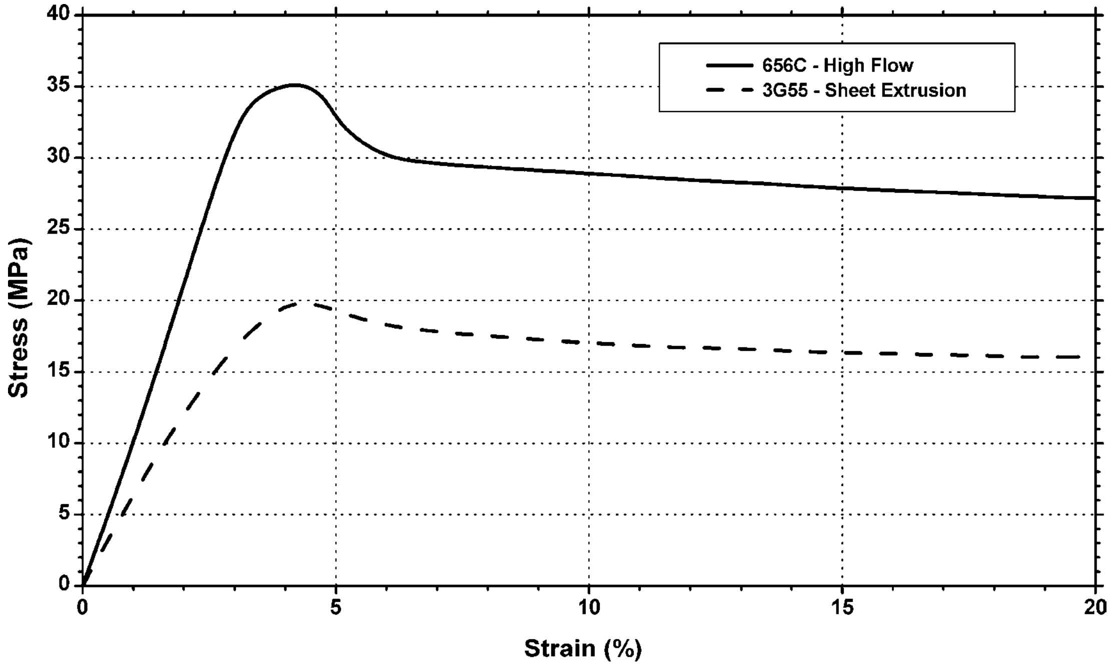


Figure 2.86. Stress vs. strain at 23°C for BASF Styrolux® SBC resins.

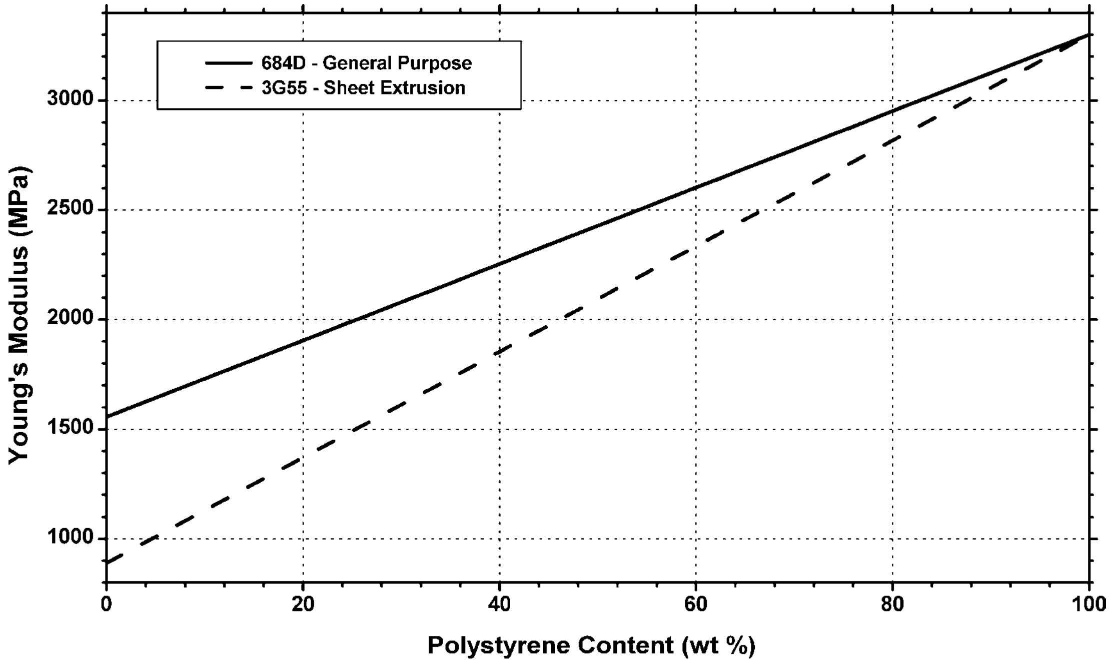


Figure 2.87. Young's modulus vs. polystyrene content for BASF Styrolux® 3G55—Sheet extrusion SBC resin.

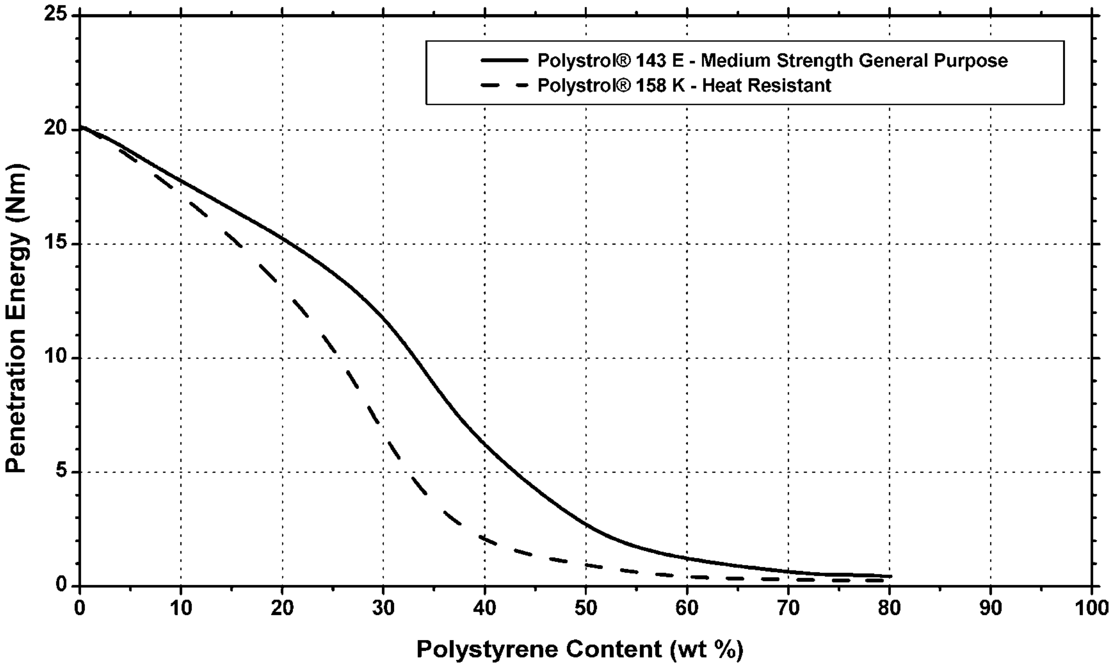


Figure 2.88. Penetration energy (ISO 6603-2) vs. polystyrene content for BASF Styrolux® 684D—general purpose SBC resin.

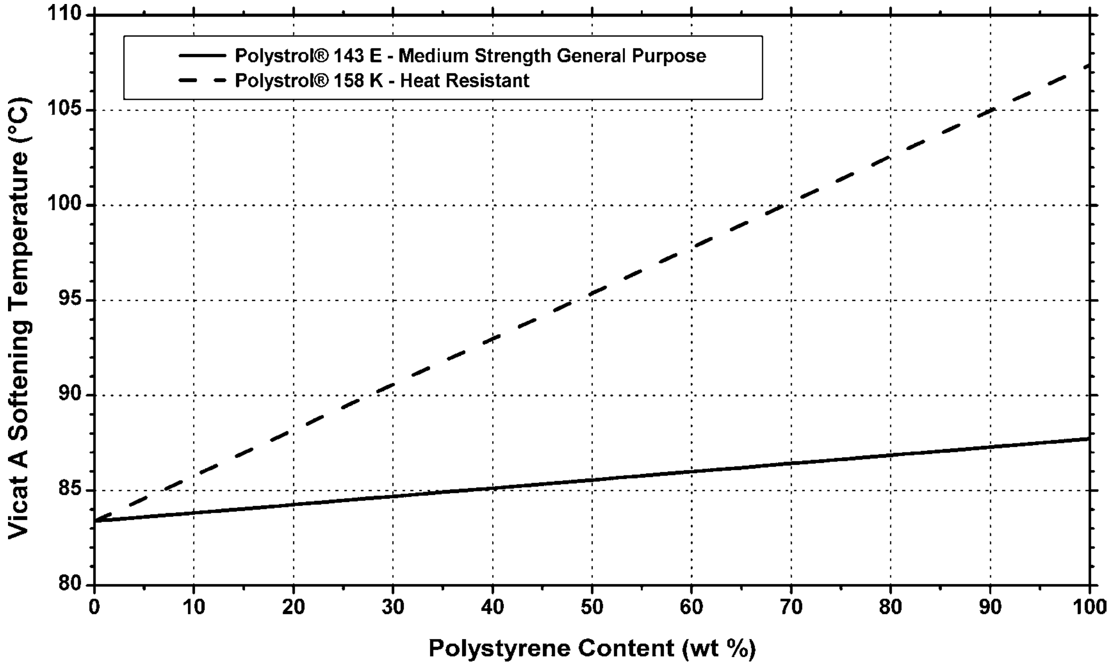


Figure 2.89. Vicat softening temperature vs. polystyrene content for BASF Styrolux® 684D—general purpose SBC resin.

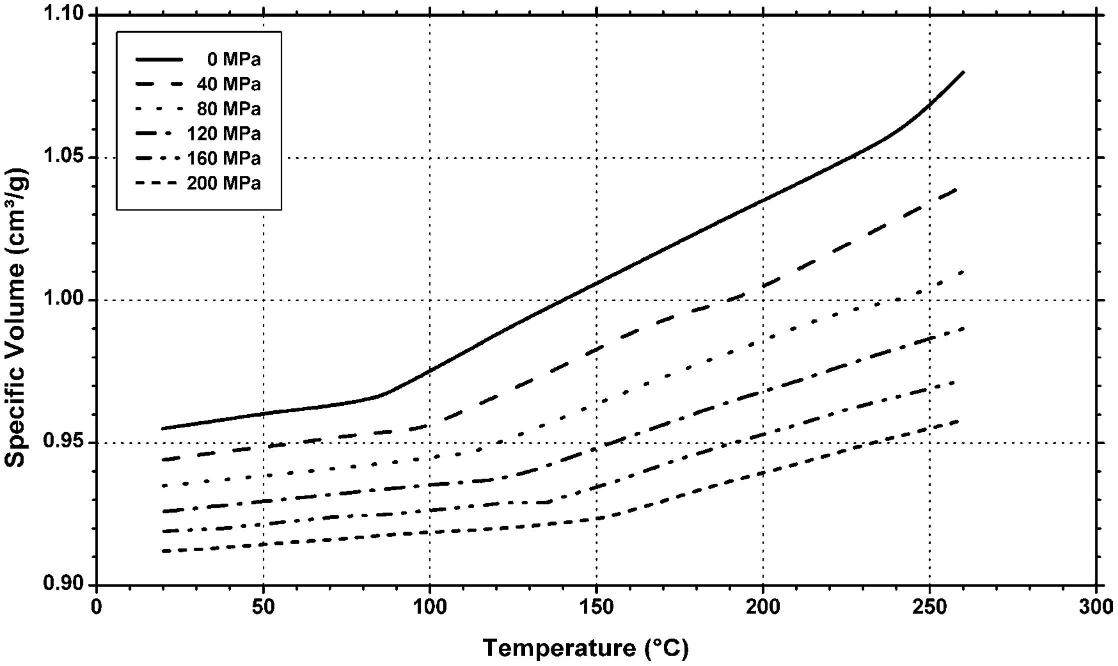


Figure 2.90. Specific volume as a function of temperature and pressure (PVT diagram) for BASF Styrolux® 656 C—high flow SBC resin.

2.8 Styrenic Blends and Alloys

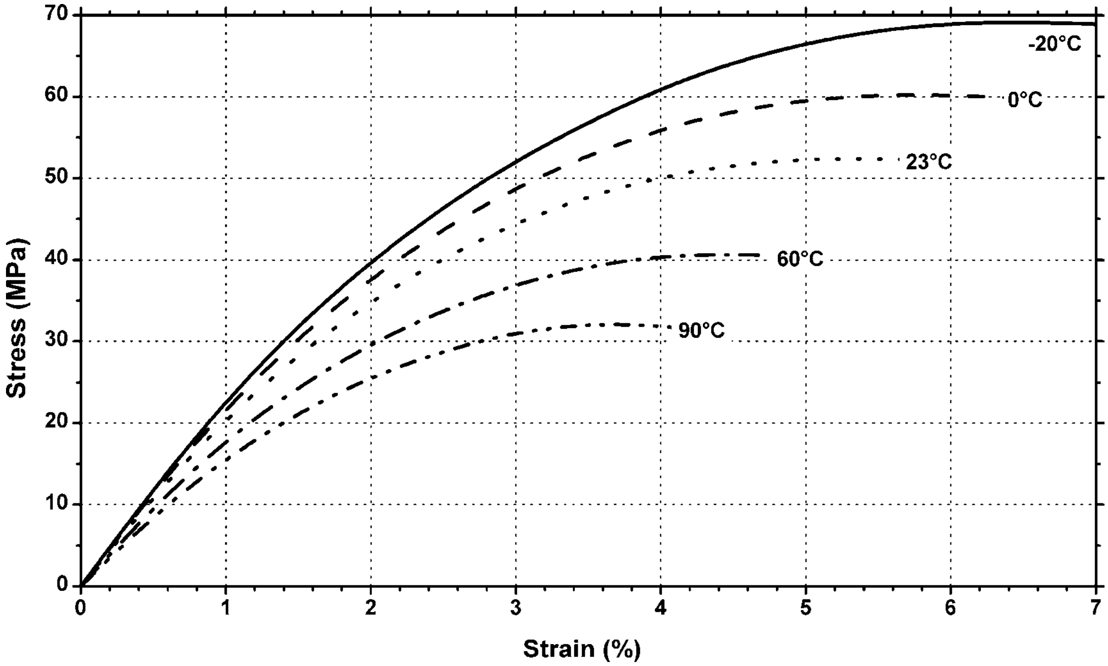


Figure 2.91. Stress vs. strain at various temperatures for Bayer MaterialScience Bayblend® T85—general purpose injection molding grade ABS/PC resin.

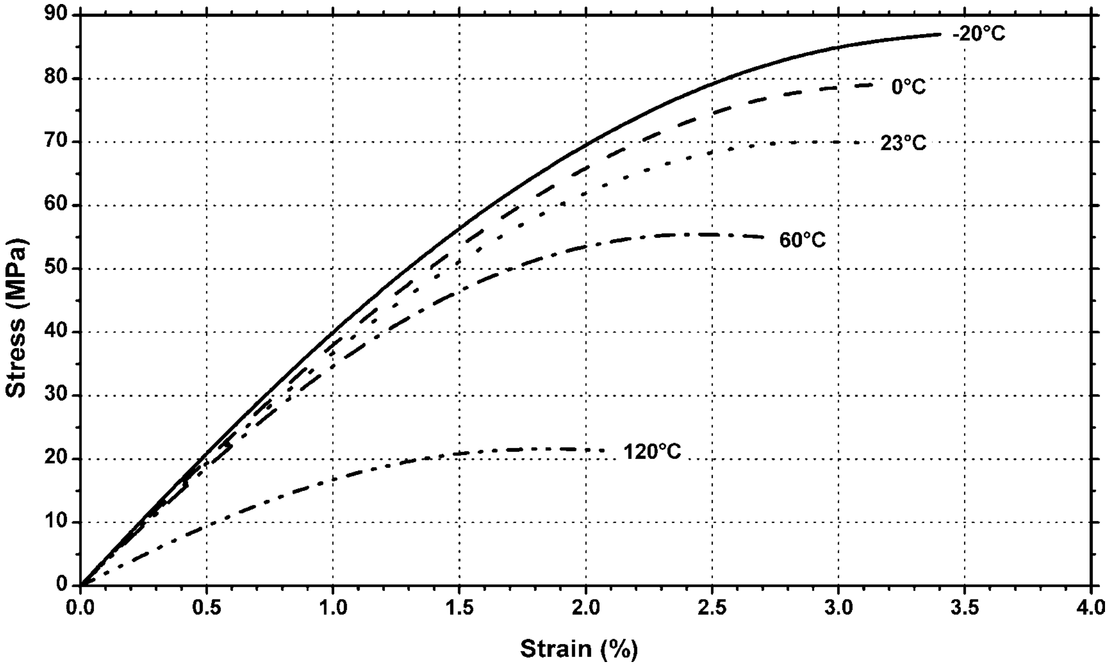


Figure 2.92. Stress vs. strain at various temperatures for Bayer MaterialScience Bayblend® T88-2N—10% glass fiber filled ABS/PC resin.

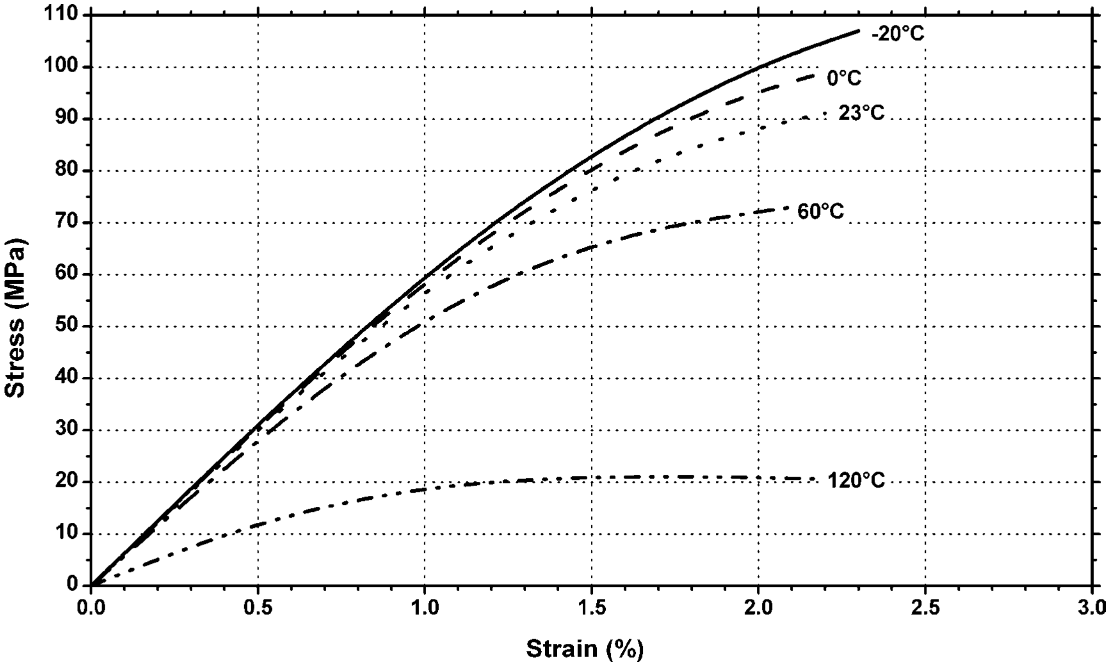


Figure 2.93. Stress vs. strain at various temperatures for Bayer MaterialScience Bayblend® T88-4N—20% glass fiber filled ABS/PC resin.

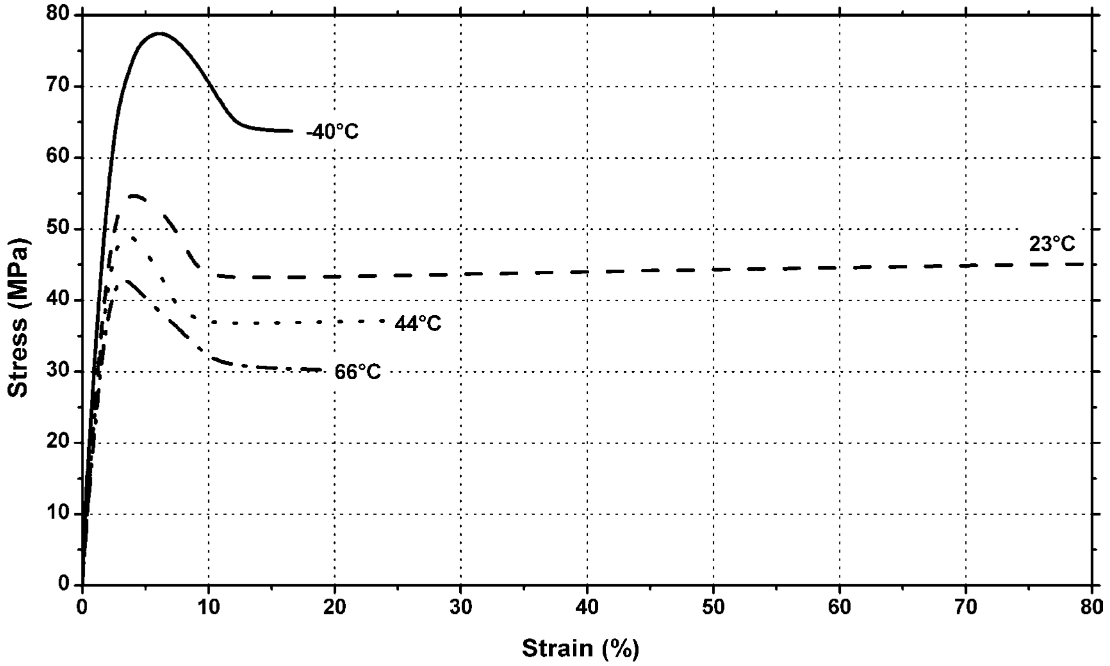


Figure 2.94. Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy C1000HF—general purpose, high flow ABS/PC resin.

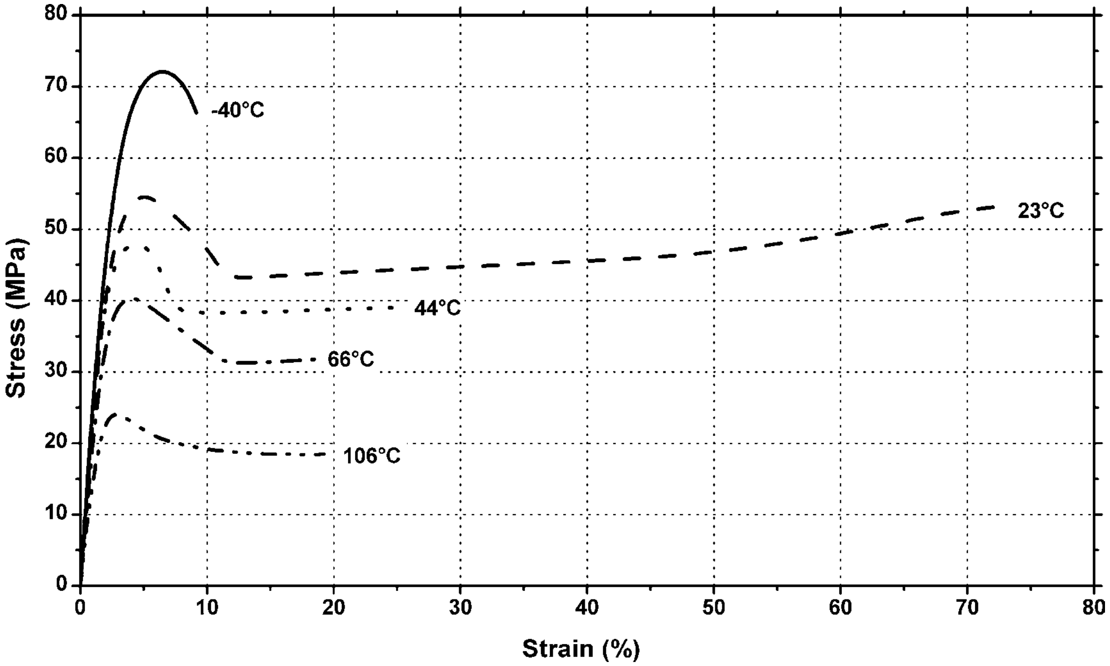


Figure 2.95. Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy C1200HF—general purpose, high heat, high flow ABS/PC resin.

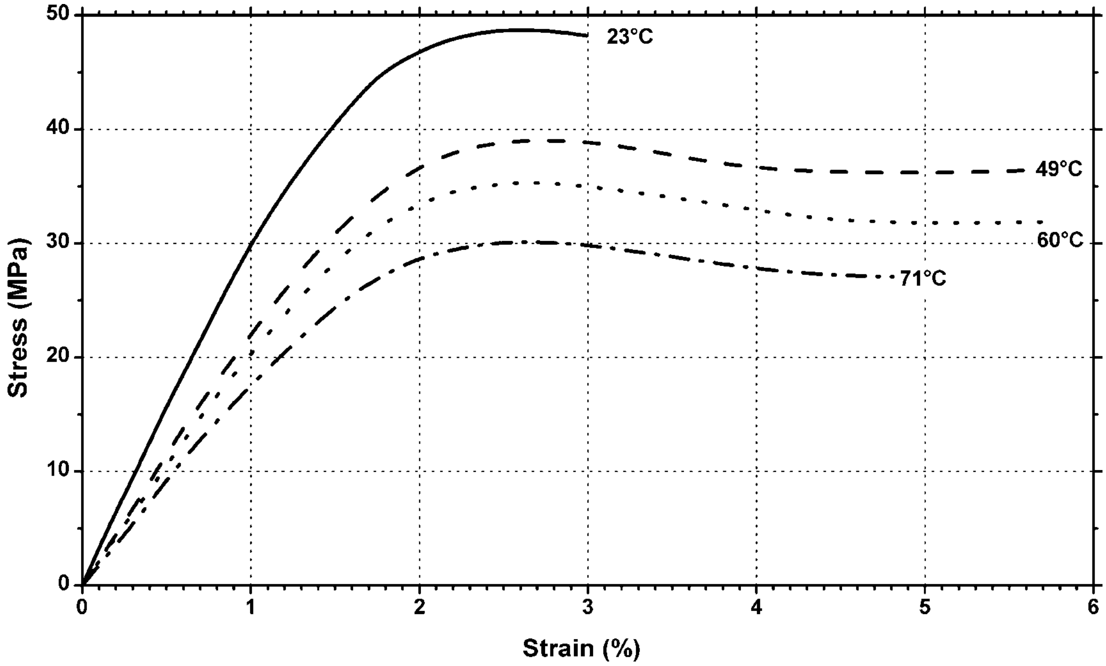


Figure 2.96. Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy EHA—platable, high heat ABS/PC resin (plated for test).

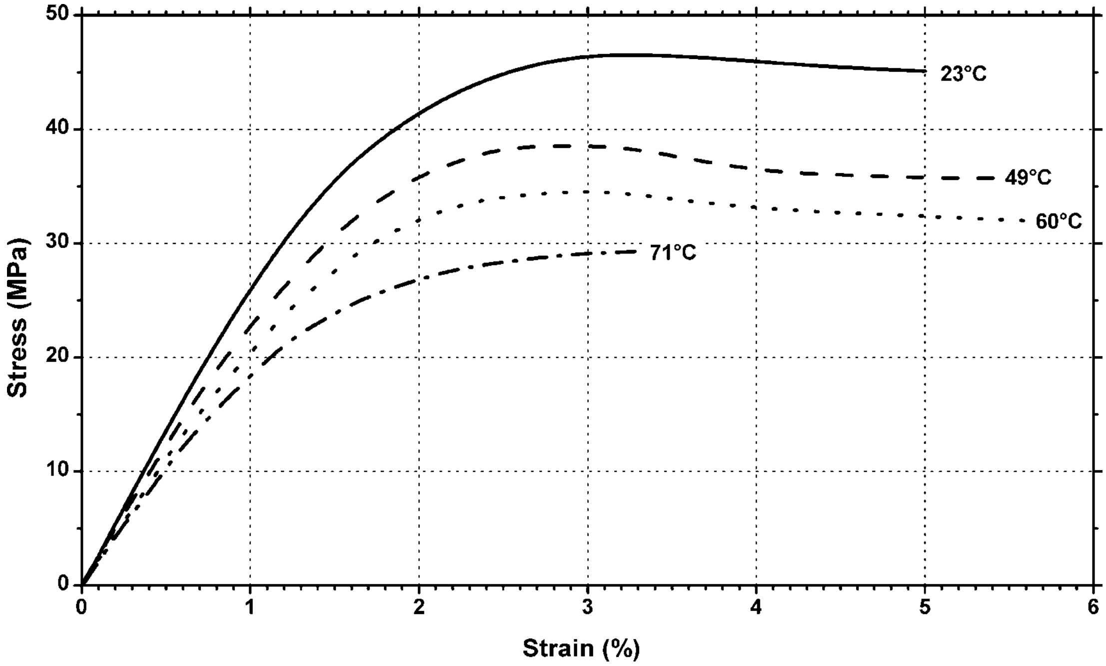


Figure 2.97. Stress vs. strain at various temperatures for SABIC Innovative Plastics Cycoloy EHA—platable, high heat ABS/PC resin (unplated for test).

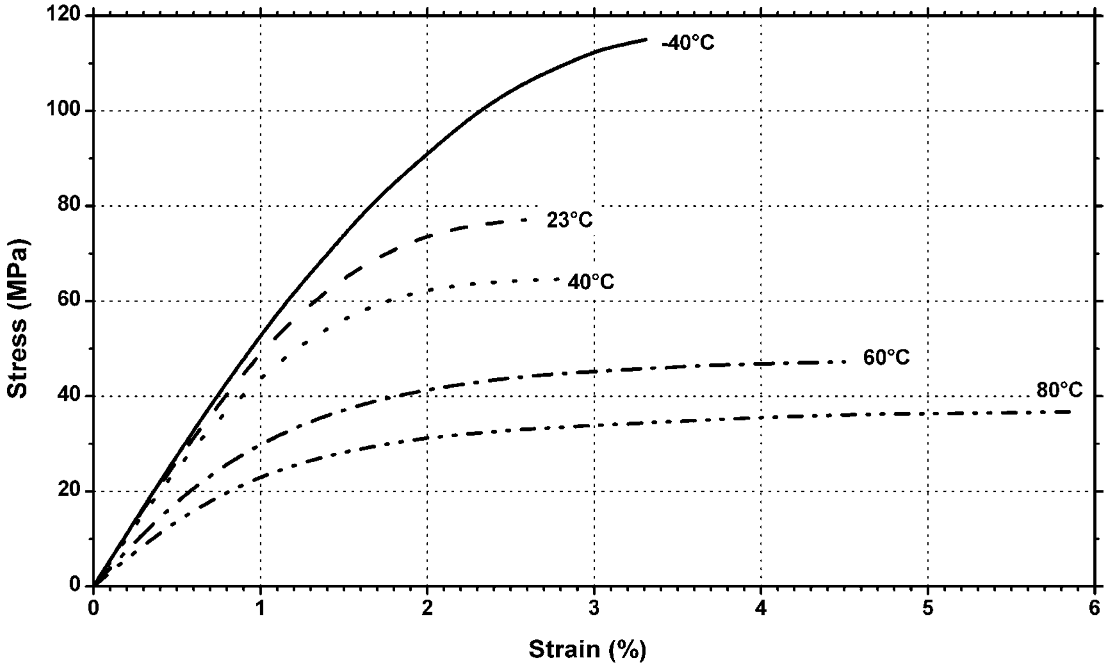


Figure 2.98. Stress vs. strain at various temperatures for BASF Terblend® N NG04—20% glass fiber ABS/PA resin.

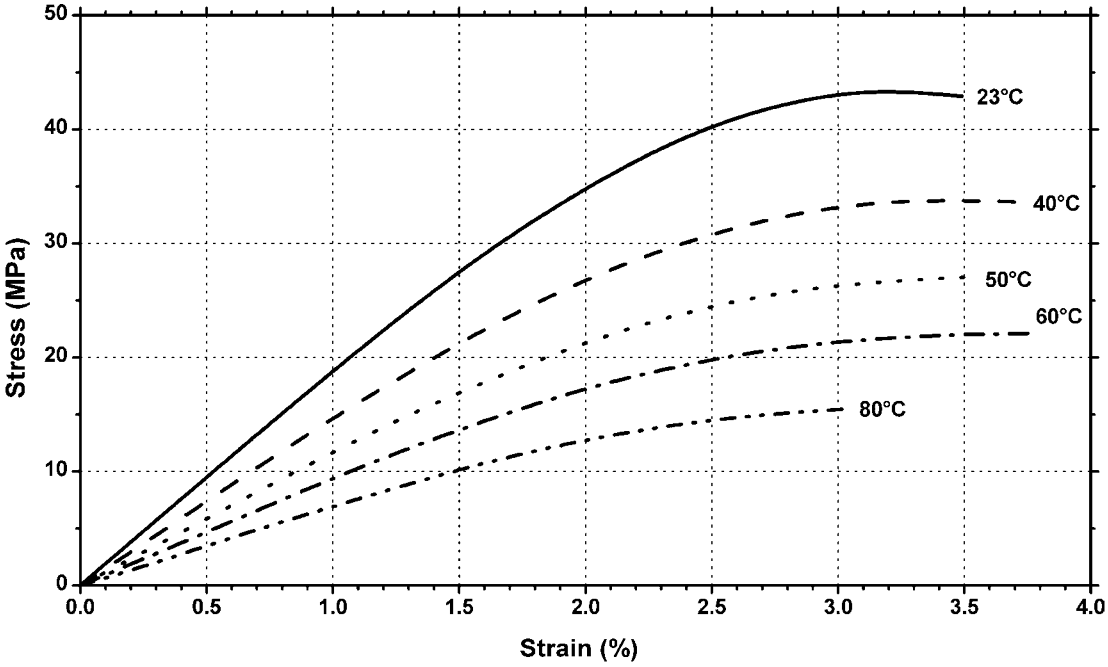


Figure 2.99. Stress vs. strain at various temperatures for LANXESS Triax® 1120—standard injection molding grade ABS/PA resin.

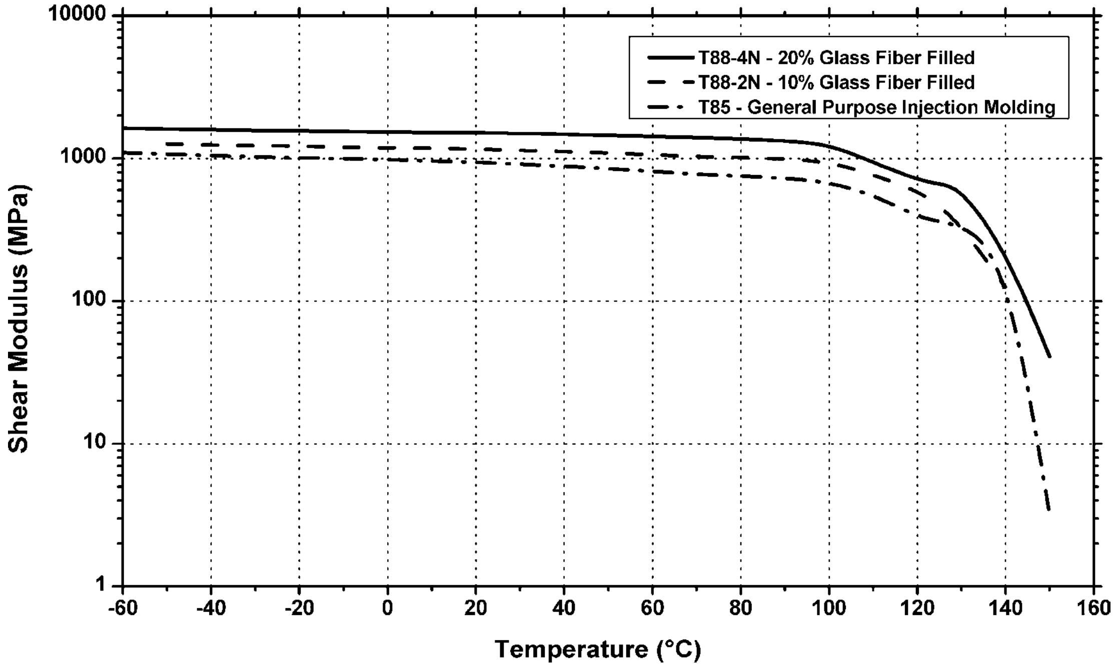


Figure 2.100. Shear modulus vs. temperature for several Bayer MaterialScience Bayblend® ABS/PC resins.

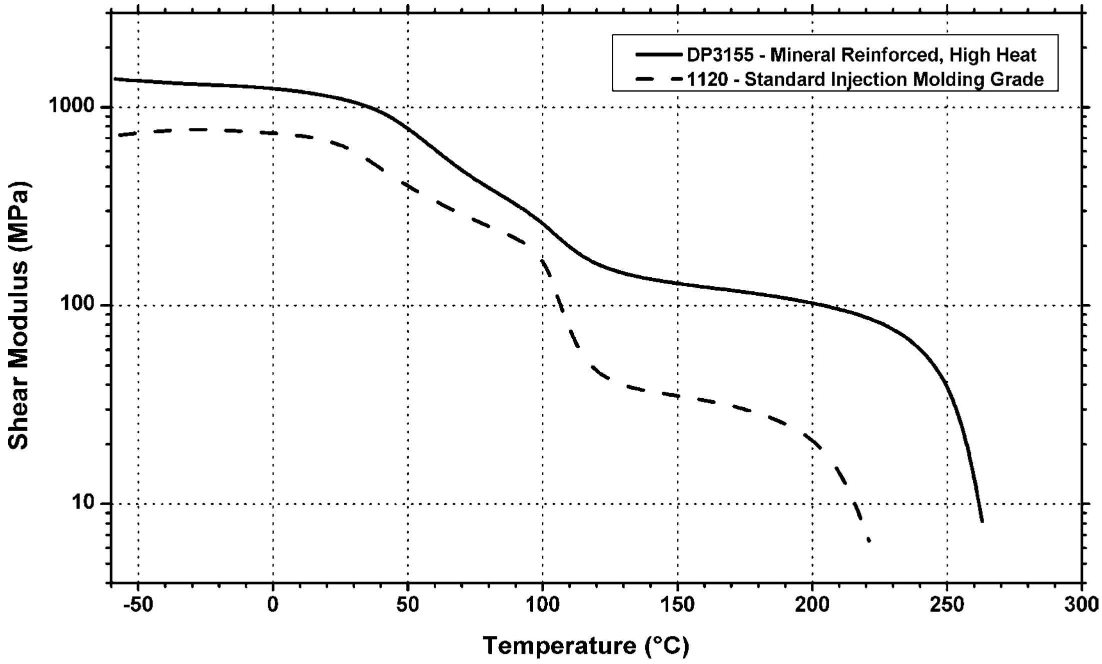


Figure 2.101. Shear modulus vs. temperature for two LANXESS Triax® ABS/PA resins.

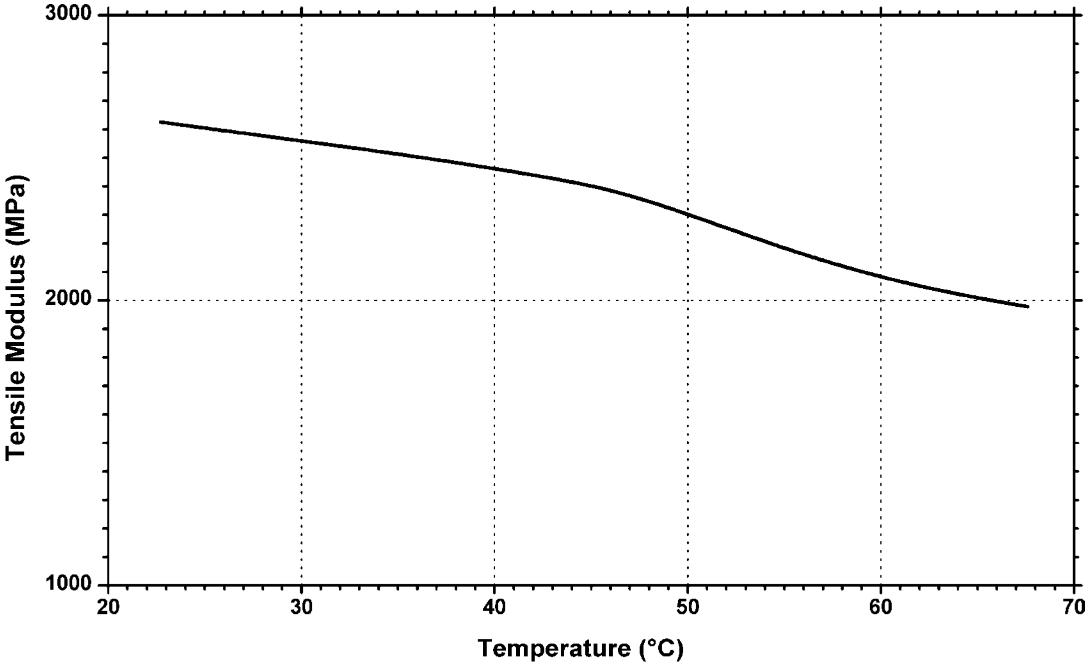


Figure 2.102. Tensile modulus vs. temperature for SABIC Innovative Plastics Cycoloy EHA—platable, high heat ABS/PC resin.

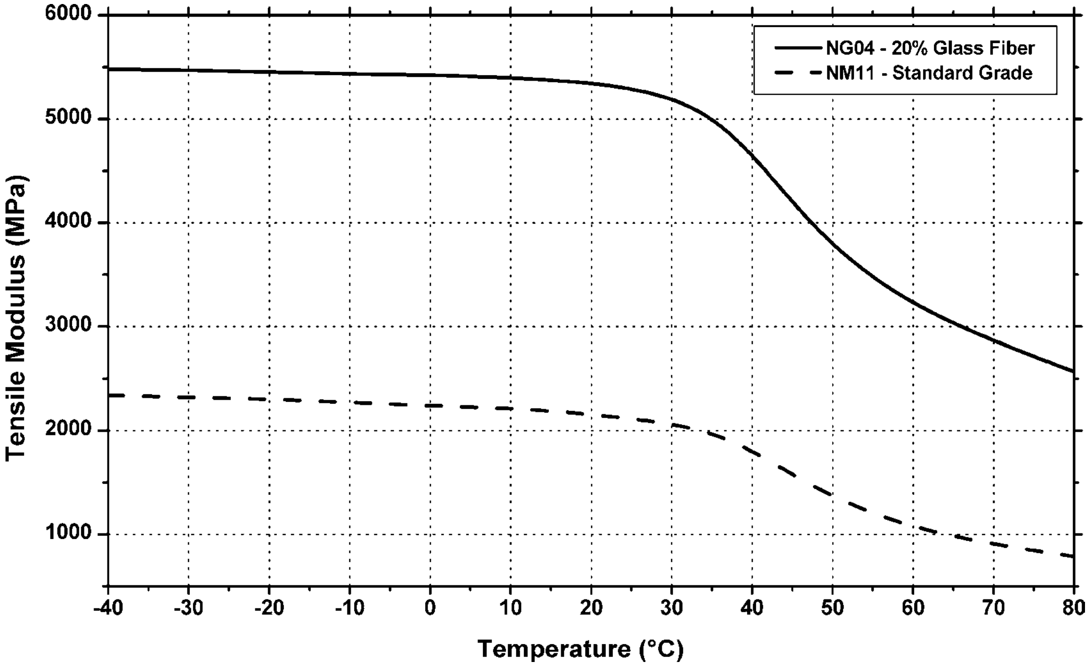


Figure 2.103. Tensile modulus vs. temperature for BASF Terblend® ABS/PA resins.

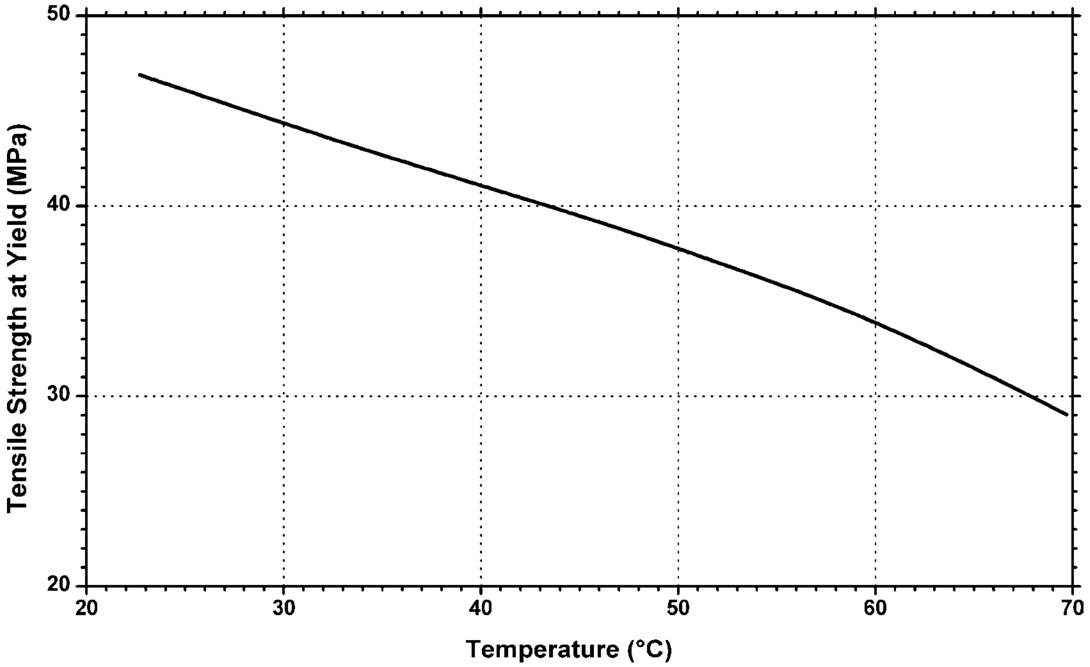


Figure 2.104. Tensile strength at yield vs. temperature for SABIC Innovative Plastics Cycoloy EHA—platable, high heat ABS/PC resin.

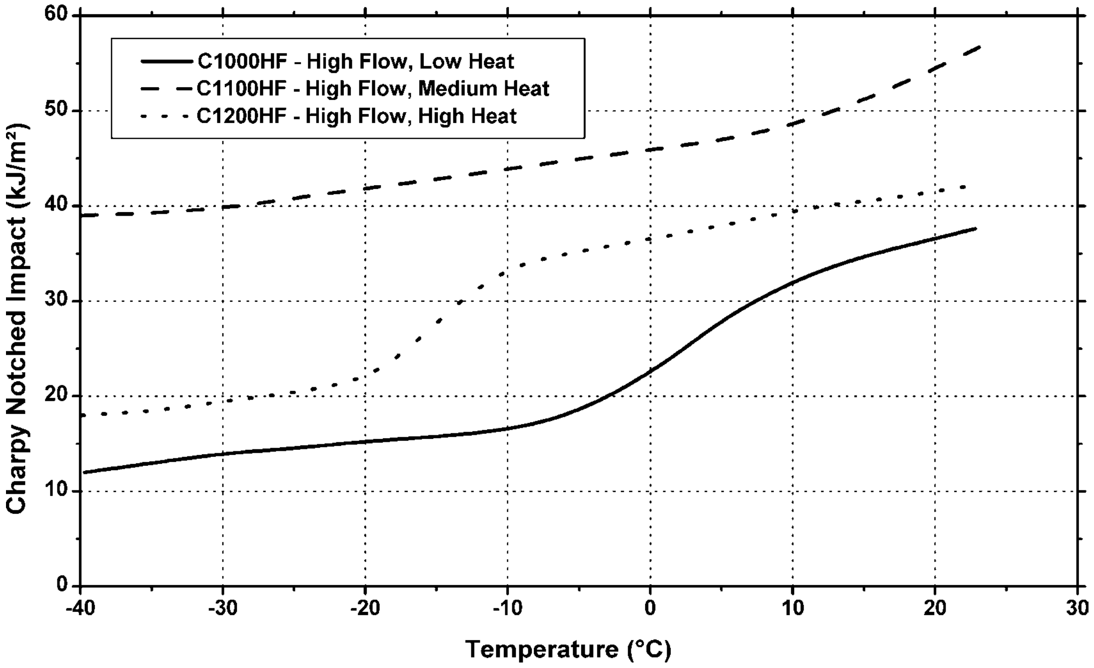


Figure 2.105. Charpy impact strength vs. temperature for SABIC Innovative Plastics Cycoloy ABS/PC resins.

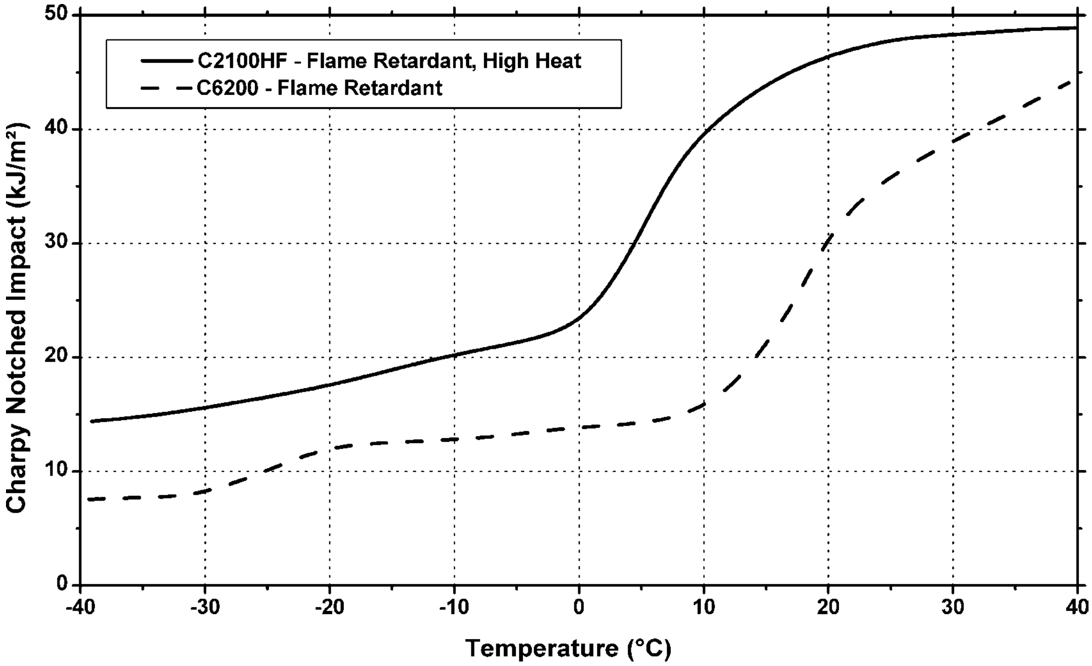


Figure 2.106. Charpy impact strength vs. temperature for SABIC Innovative Plastics Cycoloy ABS/PC resins.

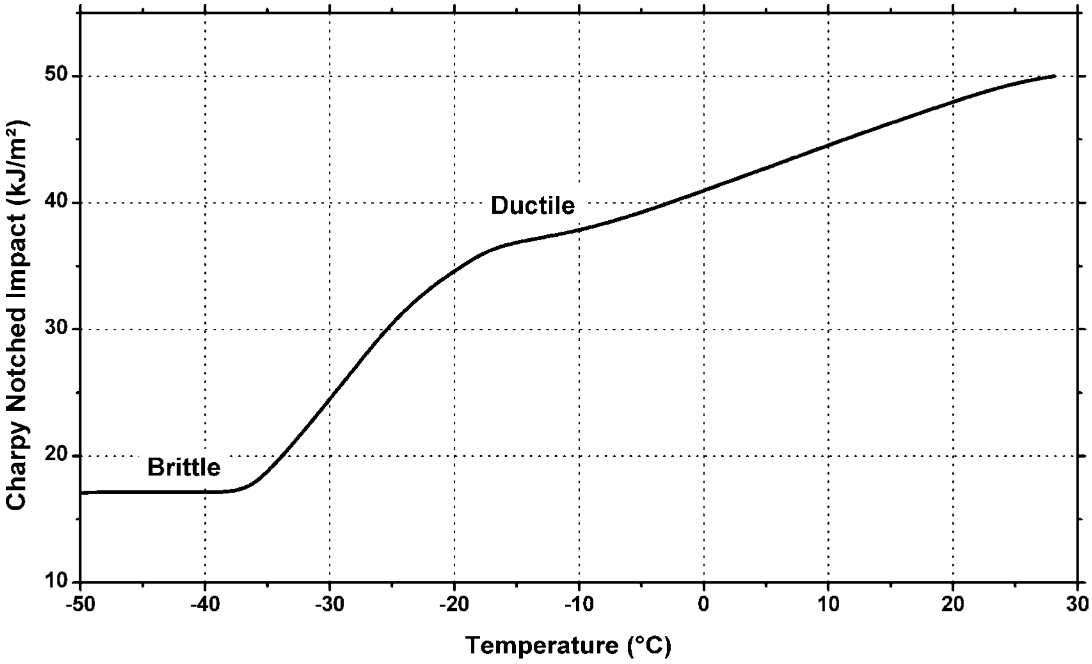


Figure 2.107. Notched Izod impact strength vs. temperature for SABIC Innovative Plastics Cycoloy C1100HF—general purpose medium heat ABS/PC resin.

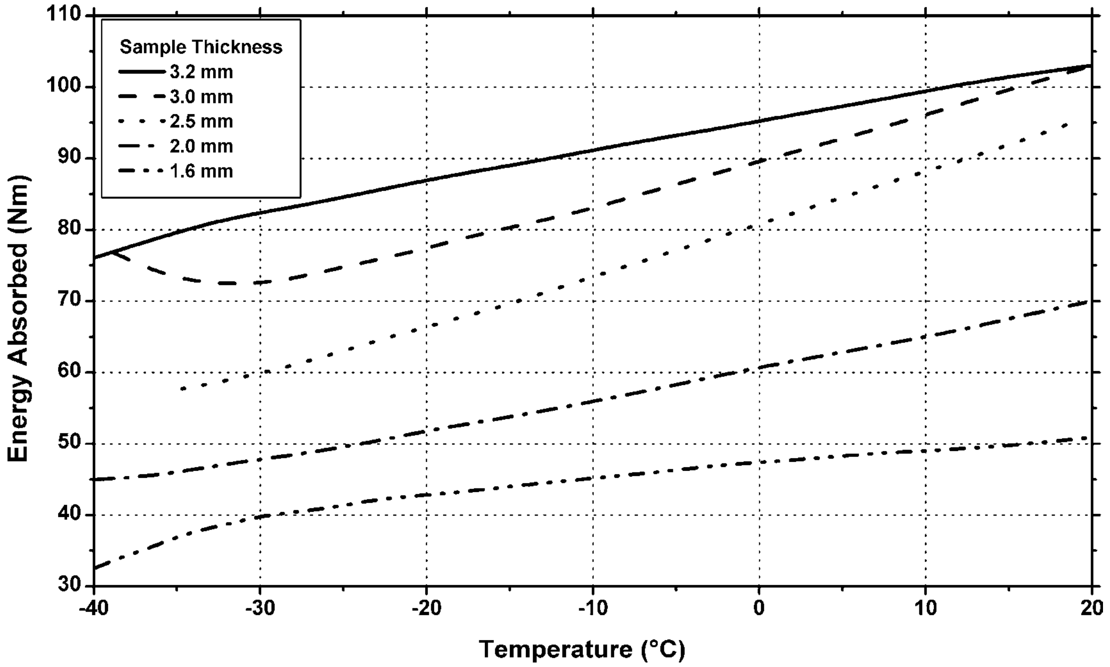


Figure 2.108. Puncture impact test (ISO 6603-2) vs. temperature for SABIC Innovative Plastics Cycoloy C1200HF—general purpose high heat ABS/PC resin.

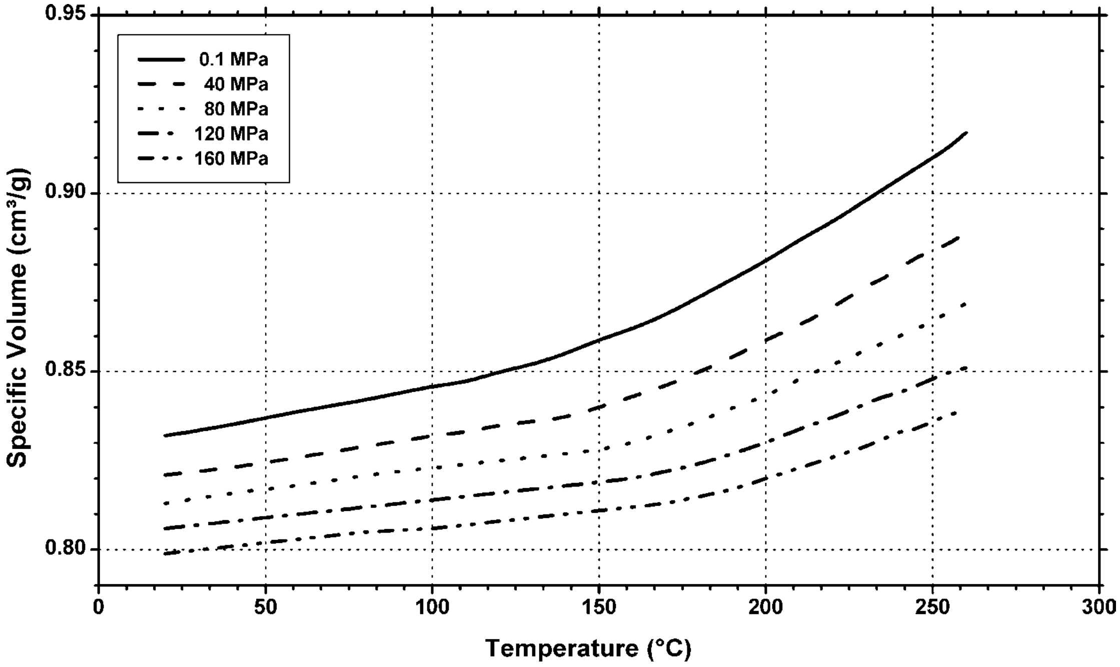


Figure 2.109. Pressure–volume–temperature (PVT) for Bayer MaterialScience Bayblend® T88-2N—10% glass fiber filled ABS/PC resin.

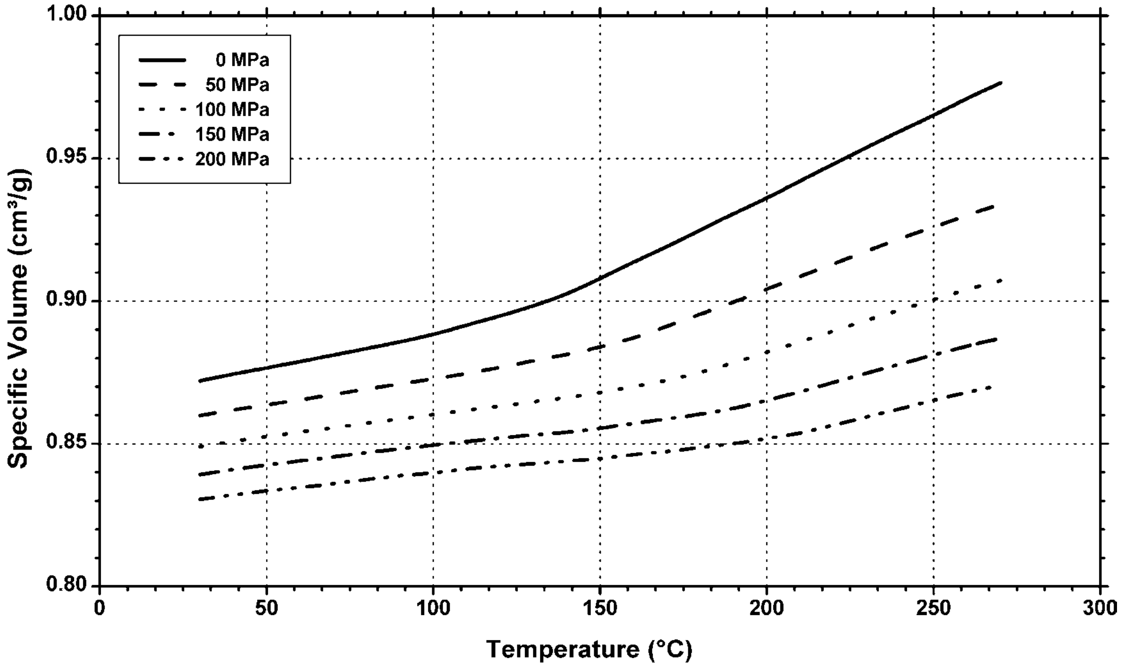


Figure 2.110. Pressure–volume–temperature (PVT) for SABIC Innovative Plastics Cycoloy C1200HF—general purpose, high heat ABS/PC resin.

3 Polyether Plastics

3.1 Background

This chapter covers polymers in which the most important linking group is the ether moiety, which is –O–.

3.1.1 Polyoxymethylene (POM or Acetal Homopolymer)

Acetal polymers, also known as polyoxymethylene (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 (now Ticona).

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 the acetate groups (CH_3COO–) at the ends of the polymer as shown in Fig. 3.1 which provide thermal protection against decomposition to formaldehyde.

Further stabilization of acetal polymers also includes the addition of antioxidants and acid scavengers.

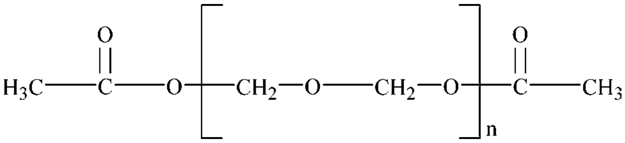


Figure 3.1. Chemical structure of acetal homopolymer.

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.

3.1.2 Polyoxymethylene Copolymer (POM-Co or Acetal Copolymer)

The Celanese method 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 Fig. 3.2. The polymer structure is given in Fig. 3.3.

.The improved thermal and chemical stability of the copolymer versus the homopolymer is a result of randomly distributed oxyethylene groups, which is circled

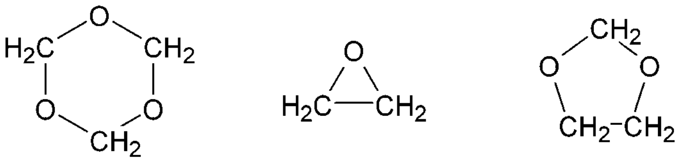


Figure 3.2. Chemical structure of polyoxymethylene copolymer monomers.

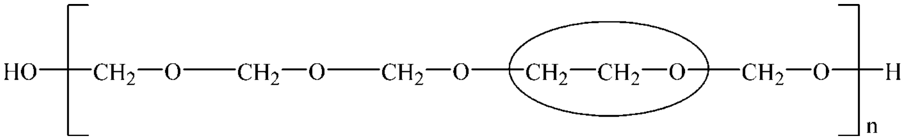


Figure 3.3. Chemical structure of acetal copolymer.

in Fig. 3.3. All polyacetals are subject to oxidative and acidic degradation which leads to molecular weight reduction. However, degradation of the copolymer ceases, 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.

The homopolymer is more crystalline than the copolymer. The homopolymer provides better mechanical properties, except 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.

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

The properties of polyacetals can be summarized as follows:

- Excellent wear resistance
- Very good strength and stiffness
- Good heat resistance
- Excellent chemical resistance
- Opaque
- Moderate to high price
- Restricted processing

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

Polyphenylene (PPE) plastics are also referred to as polyphenylene oxide (PPO). The structure of the polymer is shown in Fig. 3.4.

The PPE materials are always blended or alloyed with other plastics, so they are called modified PPE or PPO. PPE is compatible with polystyrene (PS) and is usually blended with high-impact PS over a wide range of ratios. Since 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 or PS alloys are supplied in flame-retardant, filled, and reinforced 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.

End-uses of PPE include automotive electrical applications, water pump impellers, HVAC equipment, solar heating systems, packaging, and circuit breakers.

Graphs showing the properties of polyether-based plastics as a function of temperature, moisture, and other factors are illustrated in Sections 3.2–3.4.

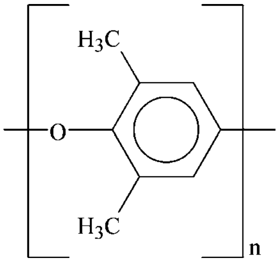


Figure 3.4. Chemical structure of polyphenylene ether/polyphenylene oxides (PPE or PPO).

3.2 Acetals—Polyoxymethylene POM

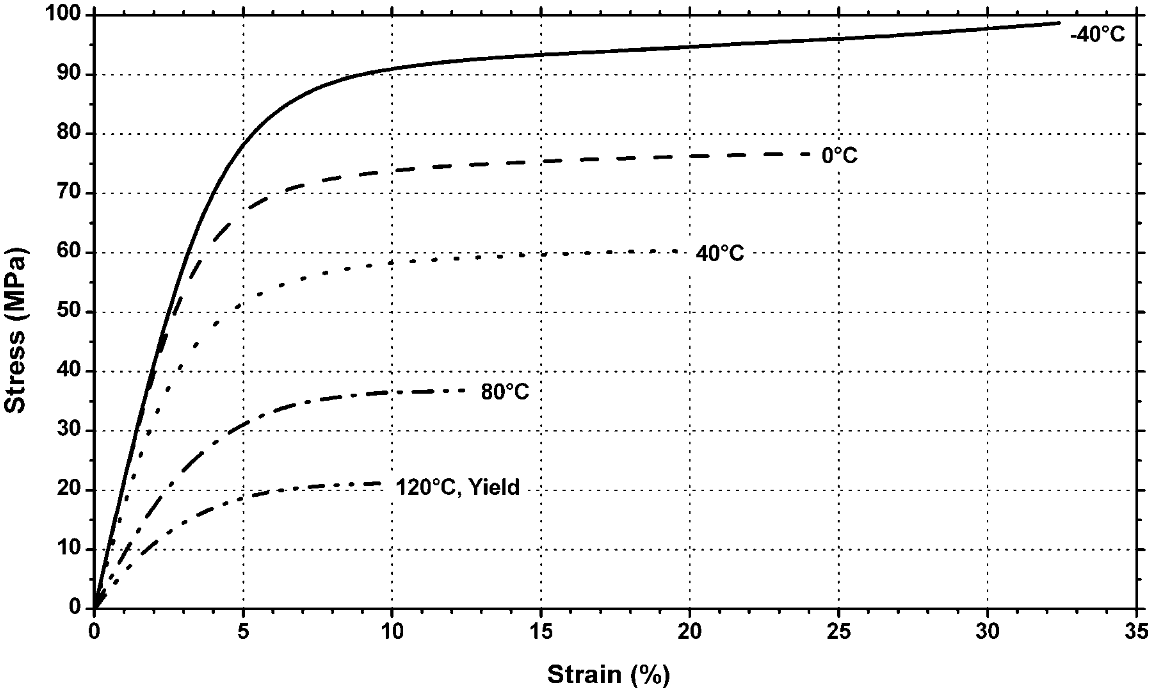


Figure 3.5. Stress vs. strain for DuPont Engineering Polymers Delrin® 100P NC010—general purpose, high viscosity with improved processing acetal resin.

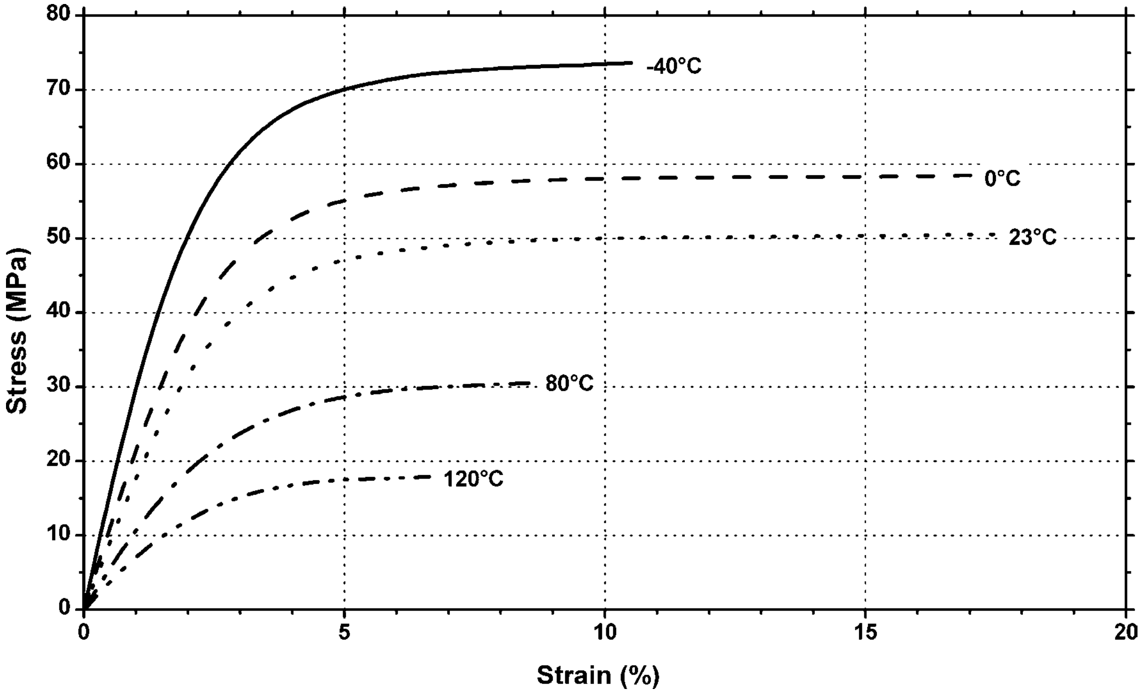


Figure 3.6. Stress vs. strain for DuPont Engineering Polymers Delrin® 500MP NC010—general purpose, medium viscosity, containing Teflon® PTFE micropowder acetal resin.

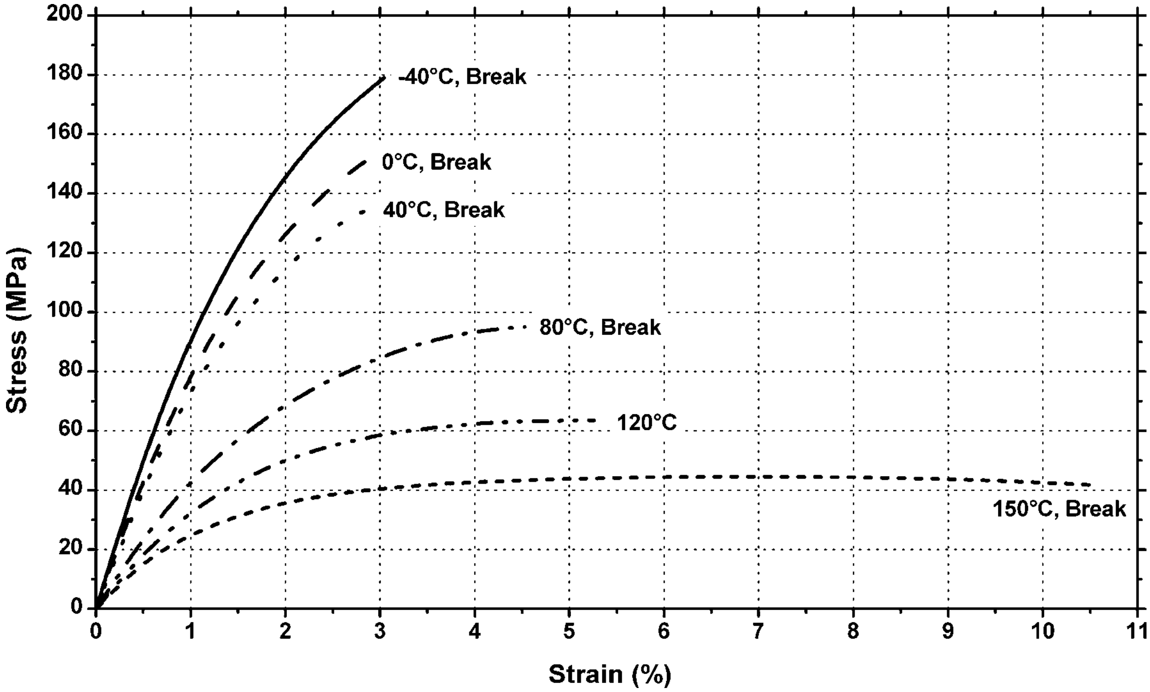


Figure 3.7. Stress vs. strain for DuPont Engineering Polymers Delrin® 525GR NC000—25% glass fiber reinforced acetal resin.

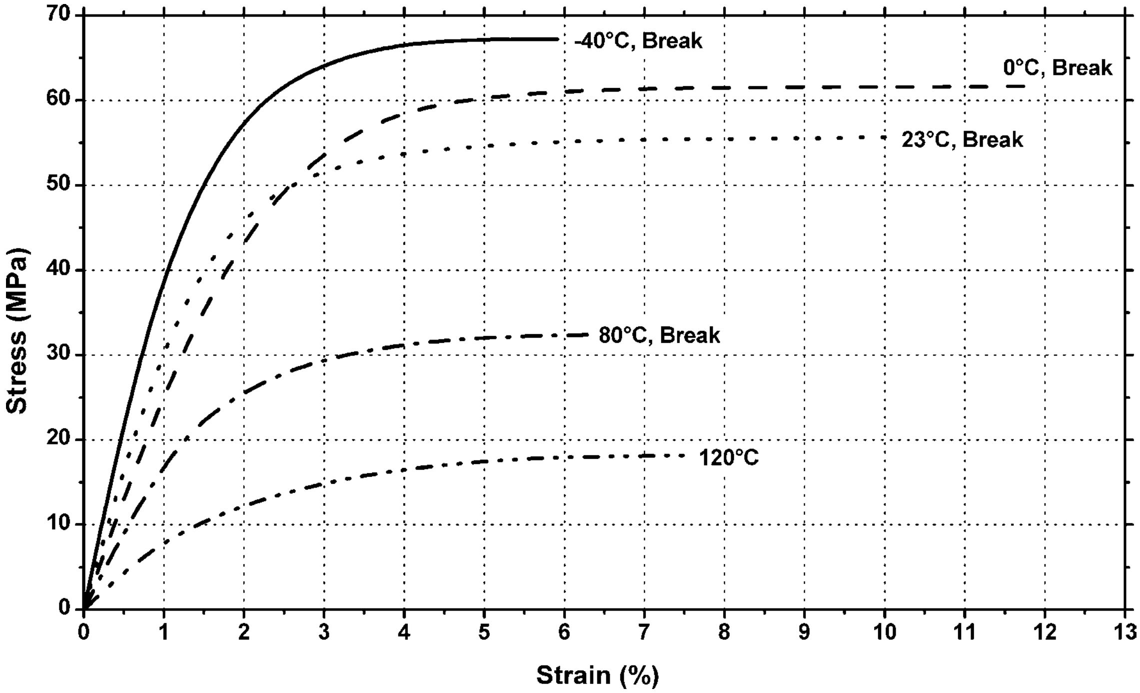


Figure 3.8. Stress vs. strain for DuPont Engineering Polymers Delrin® 570—medium viscosity, 20% glass fiber reinforced, high stiffness acetal resin.

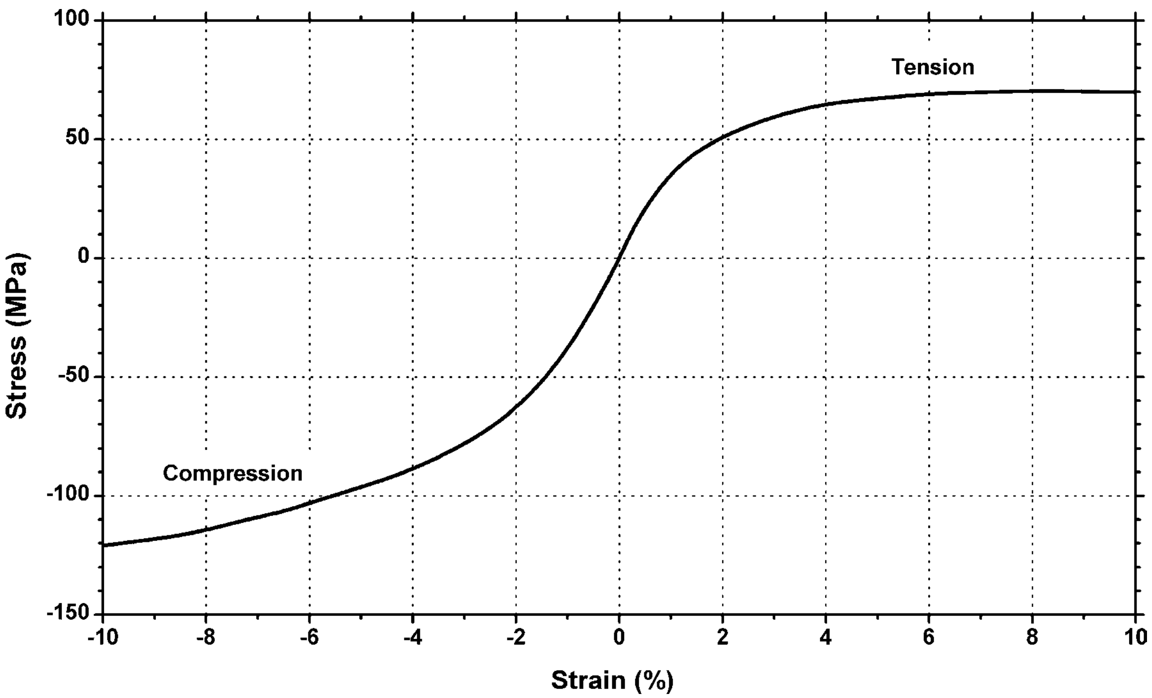


Figure 3.9. Stress vs. strain in tension and compression for DuPont Engineering Polymers Delrin® acetal resin at 23°C.

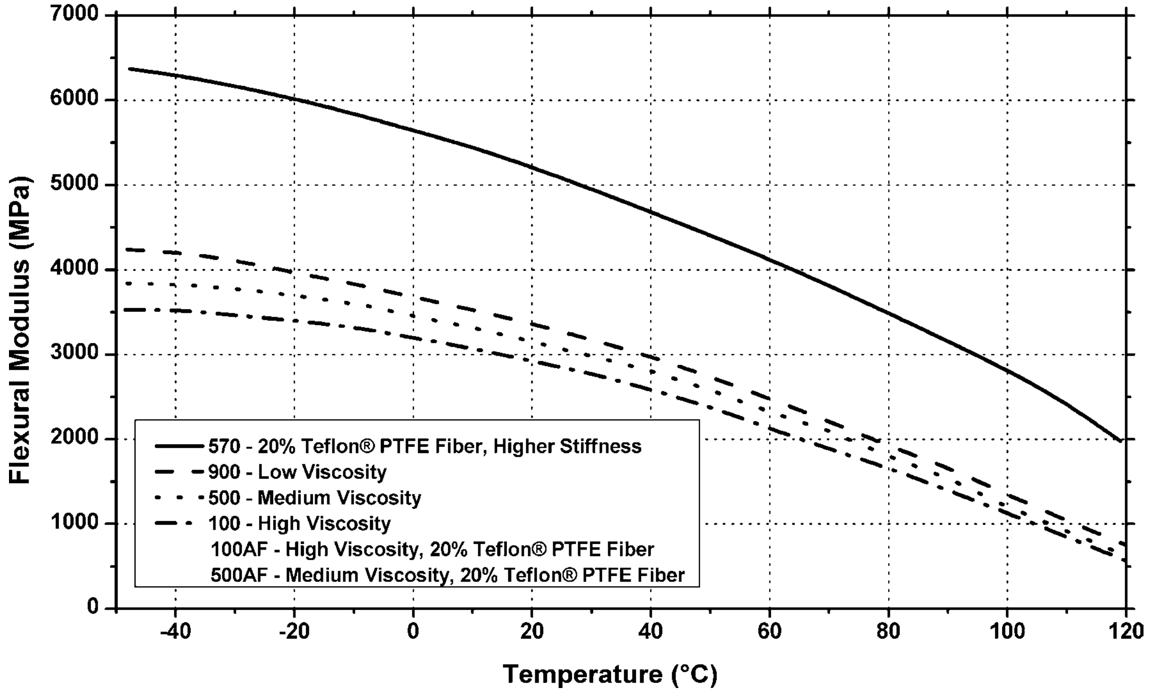


Figure 3.10. Flexural modulus vs. temperature for various DuPont Engineering Polymers Delrin® acetal resins.

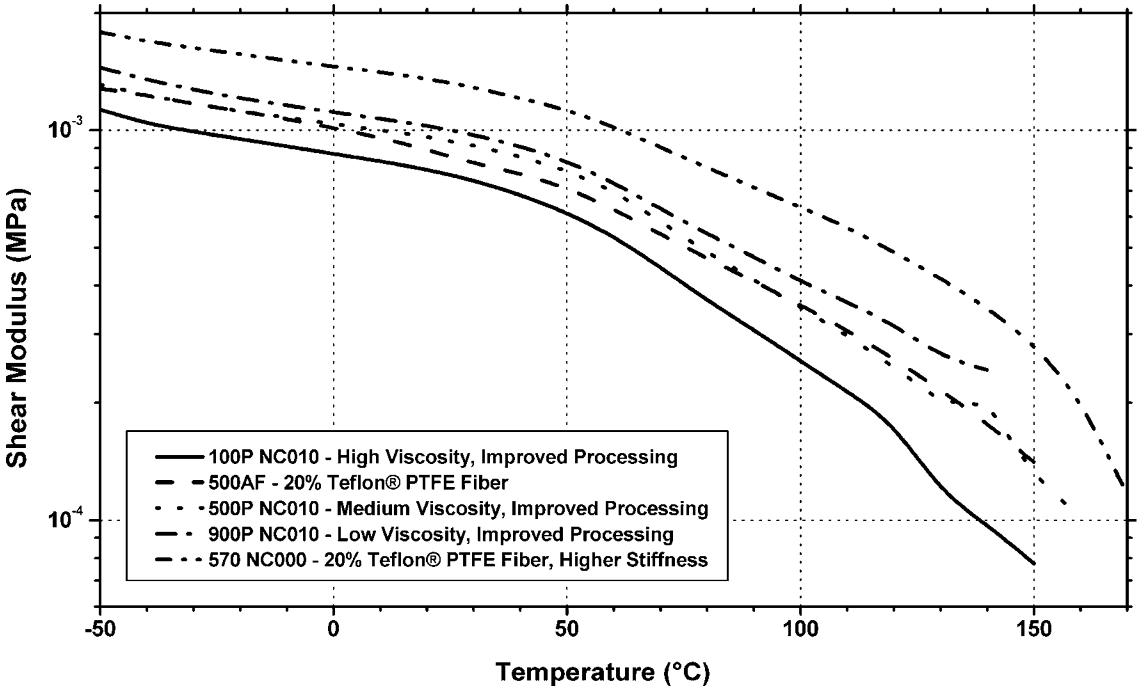


Figure 3.11. Shear modulus vs. temperature for DuPont Engineering Polymers Delrin® 100, 500, 900—acetal resins.

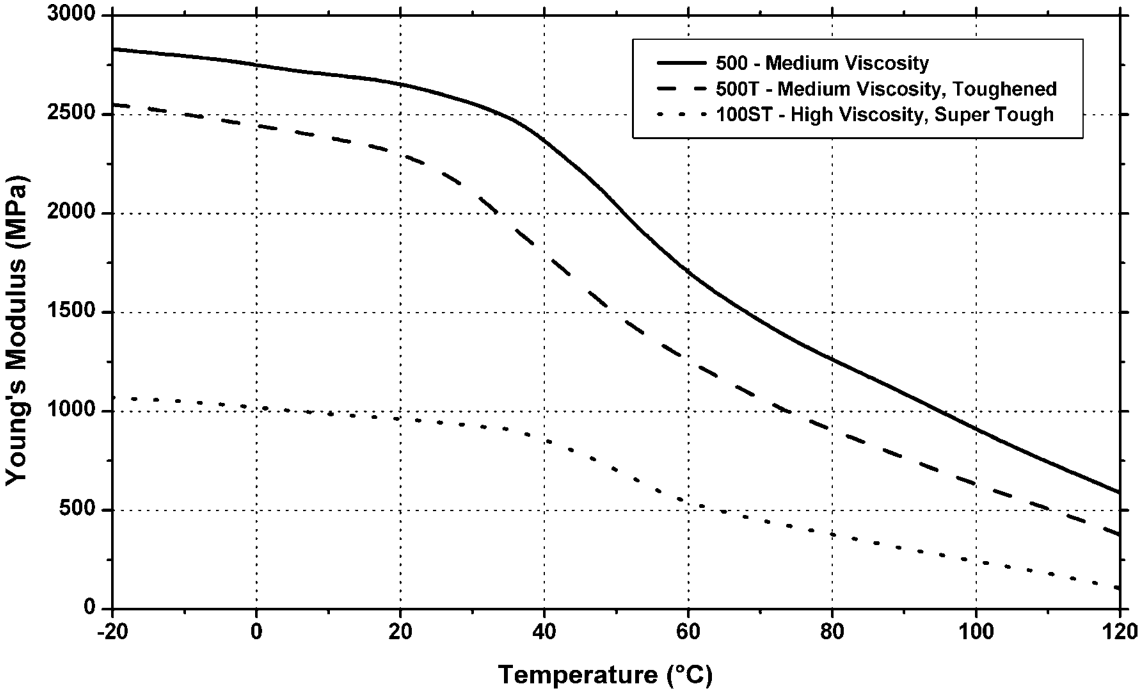


Figure 3.12. Young's modulus vs. temperature for DuPont Engineering Polymers Delrin® 100, 500T, 100ST—acetal resins (at 5 mm/min).

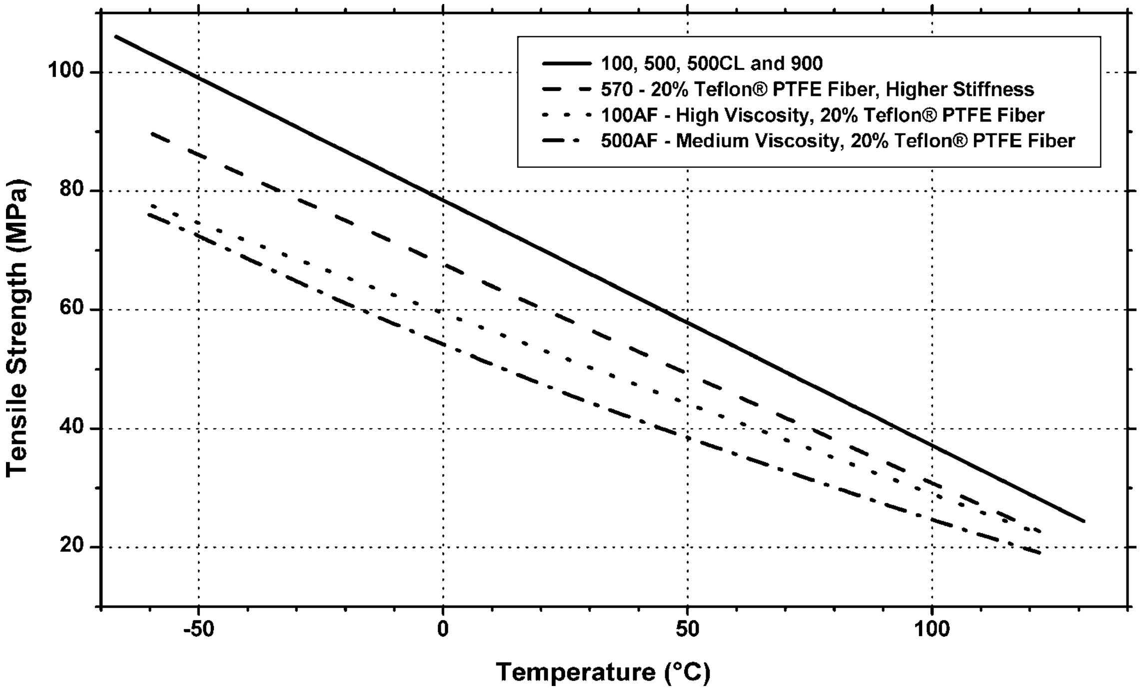


Figure 3.13. Tensile strength vs. temperature for DuPont Engineering Polymers Delrin® acetal resins (at 5.1 mm/min crosshead speed).

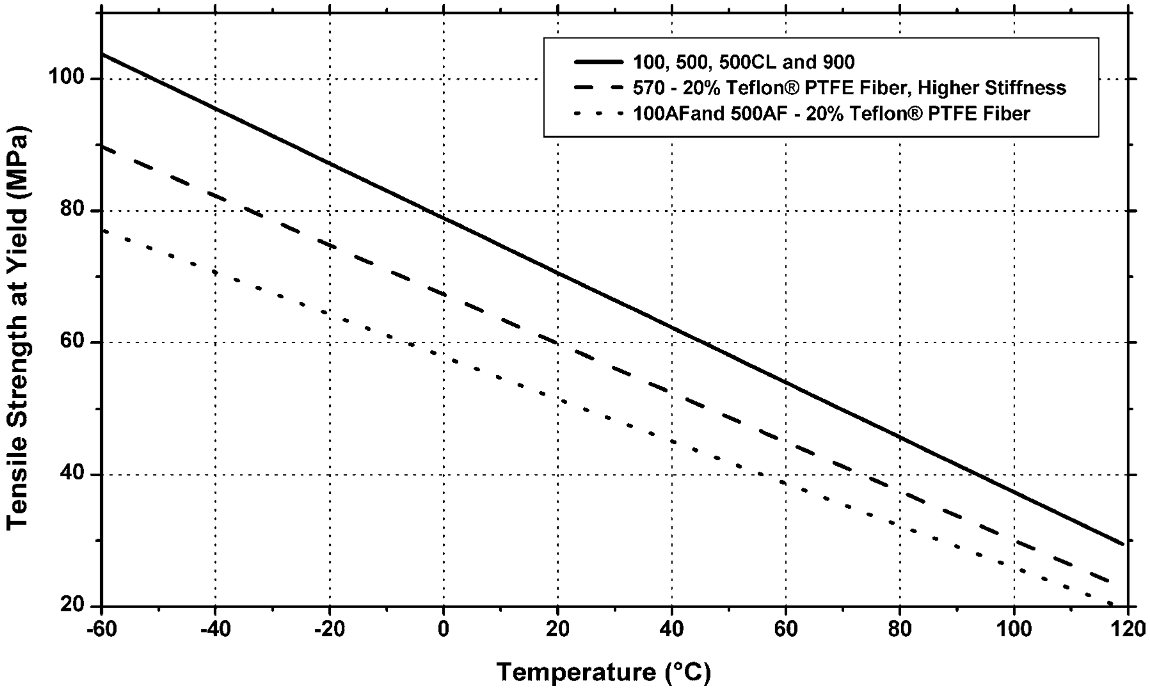


Figure 3.14. Tensile yield strength vs. temperature for DuPont Engineering Polymers Delrin® acetal resins (at 5.1 mm/min crosshead speed).

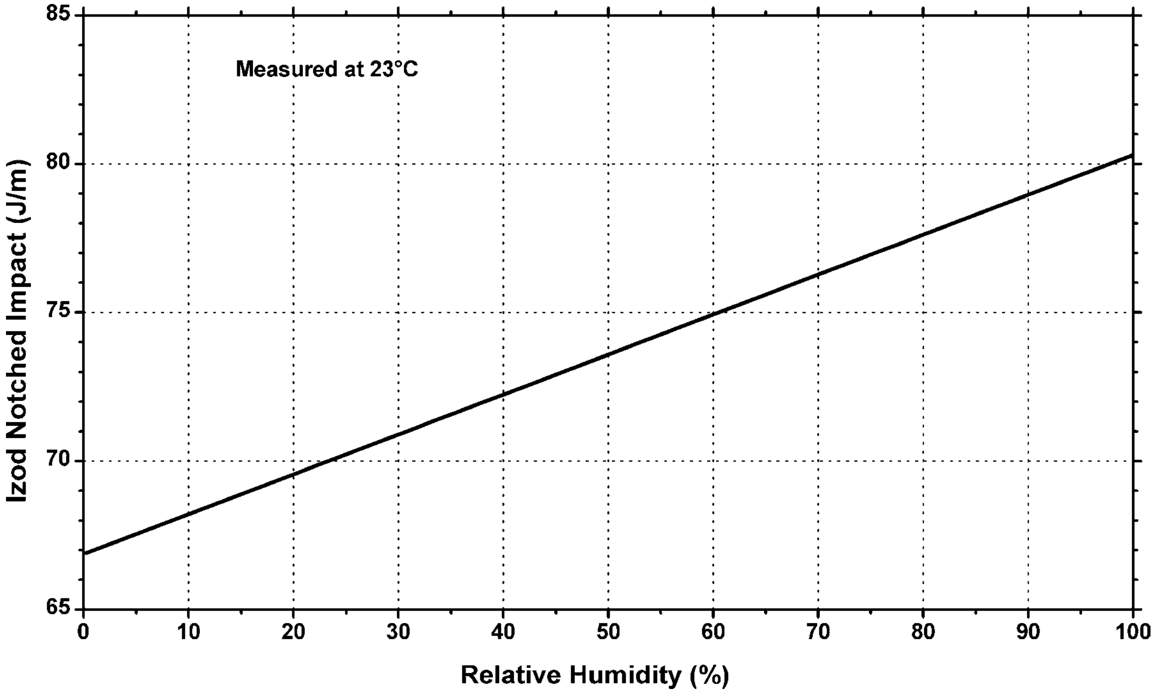


Figure 3.15. Notched Izod impact strength vs. humidity for DuPont Engineering Polymers Delrin® 500—medium viscosity acetal resin at 23°C.

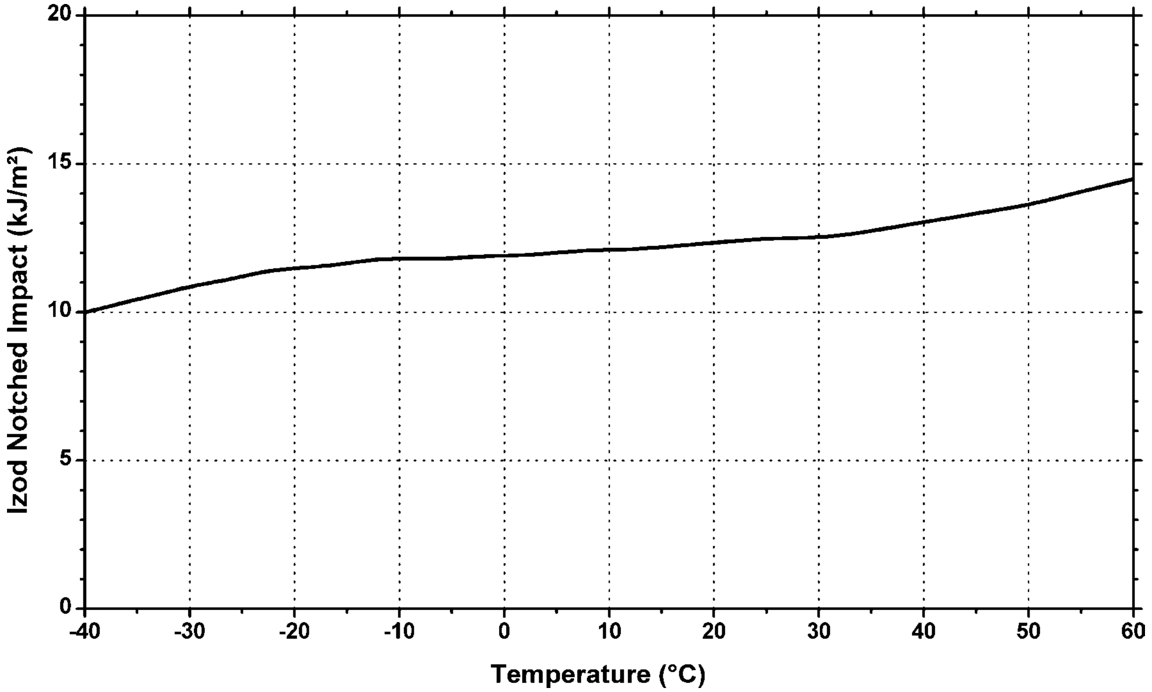


Figure 3.16. Notched Izod impact strength vs. temperature for DuPont Engineering Polymers Delrin® 100—high viscosity general purpose acetal resin.

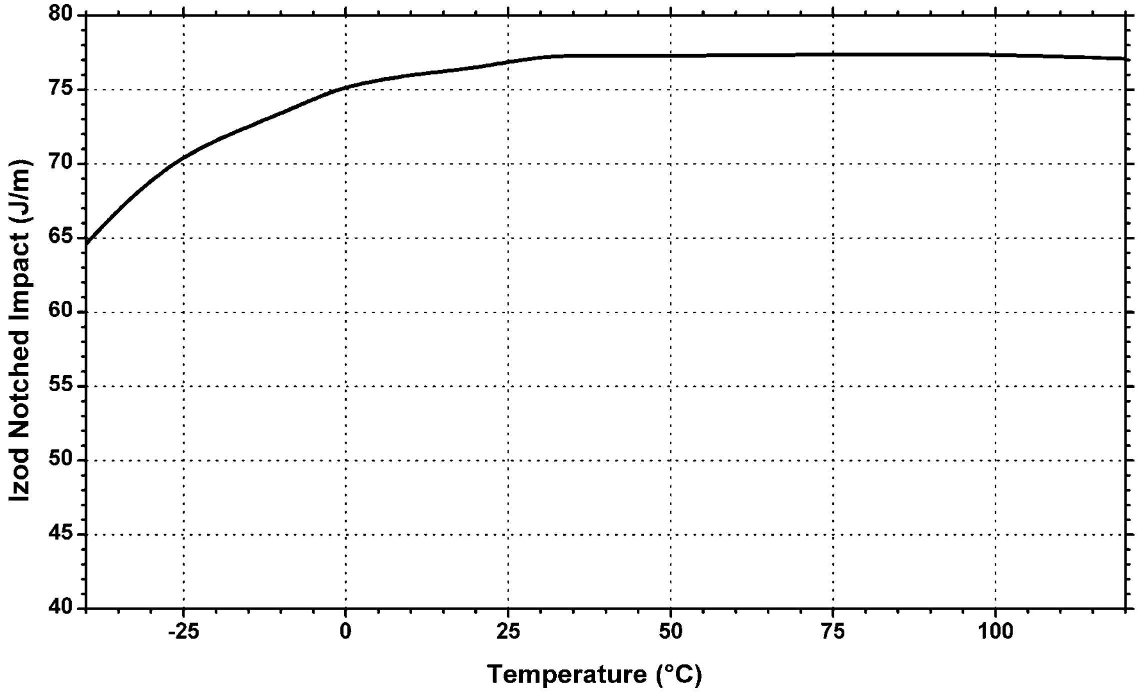


Figure 3.17. Notched Izod impact strength vs. temperature for DuPont Engineering Polymers Delrin® 500—medium viscosity acetal resin.

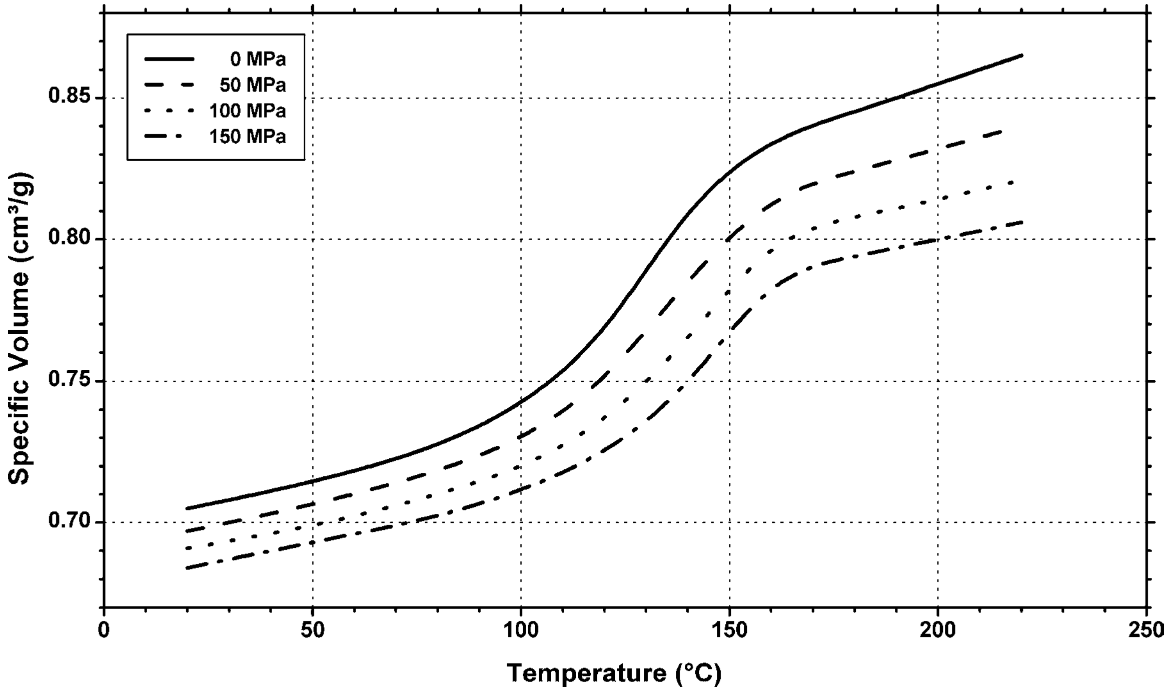


Figure 3.18. Specific volume as a function of temperature and pressure (PVT) for DuPont Engineering Polymers Delrin® 107 NC010—high viscosity, UV stabilized acetal resin.

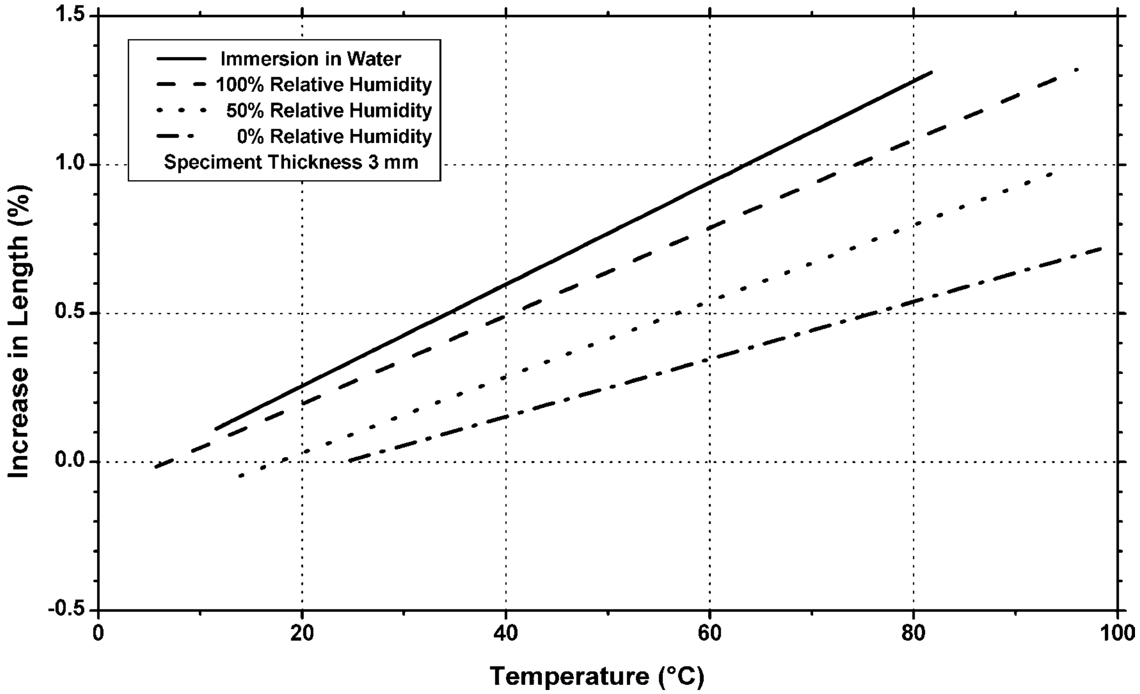


Figure 3.19. Change in length vs. temperature and humidity for DuPont Engineering Polymers Delrin® 100 and 500—acetal resins.

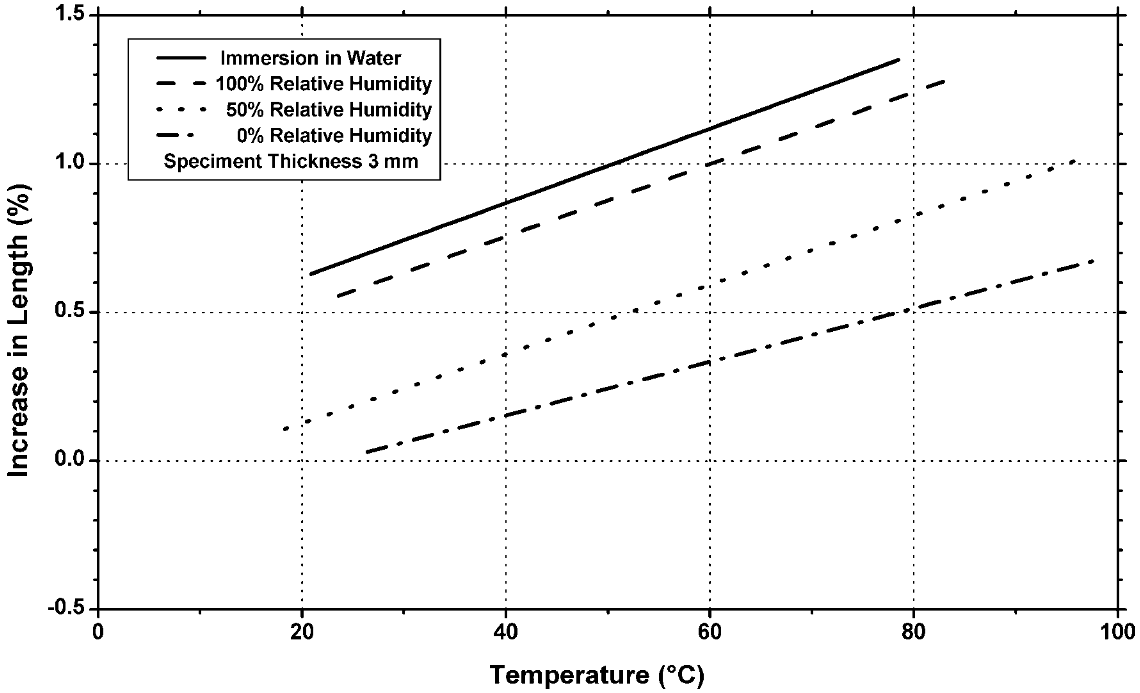


Figure 3.20. Change in length vs. temperature and humidity for DuPont Engineering Polymers Delrin® 100P, 500P, and 900P—acetal resins.

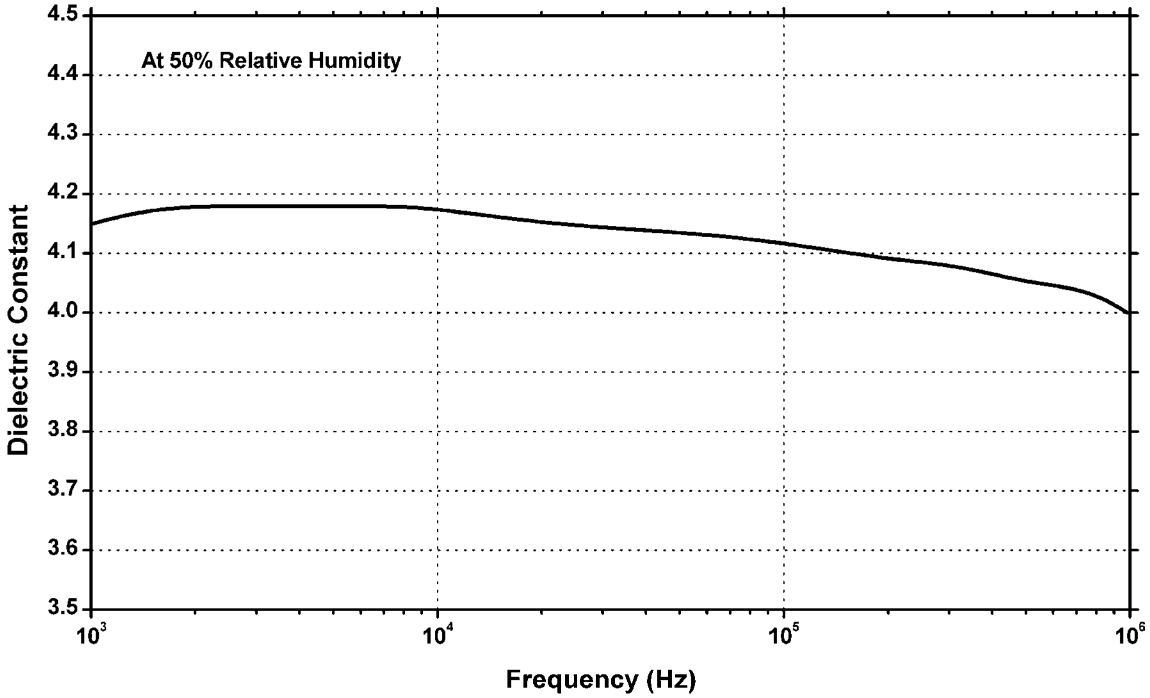


Figure 3.21. Dielectric constant vs. frequency at 50% relative humidity after immersion in water at 23°C for DuPont Engineering Polymers Delrin® 500P—medium viscosity with improved processing acetal resin.

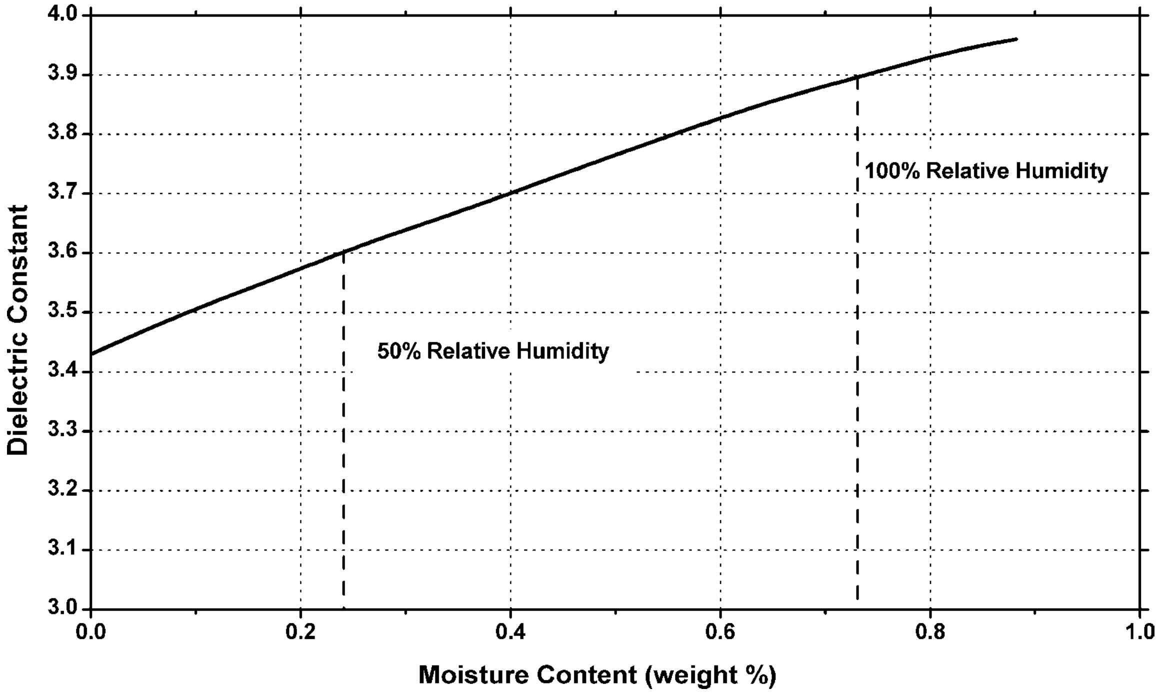


Figure 3.22. Dielectric constant vs. moisture content at 23°C for DuPont Engineering Polymers Delrin® 500 NC010—medium viscosity acetal resin.

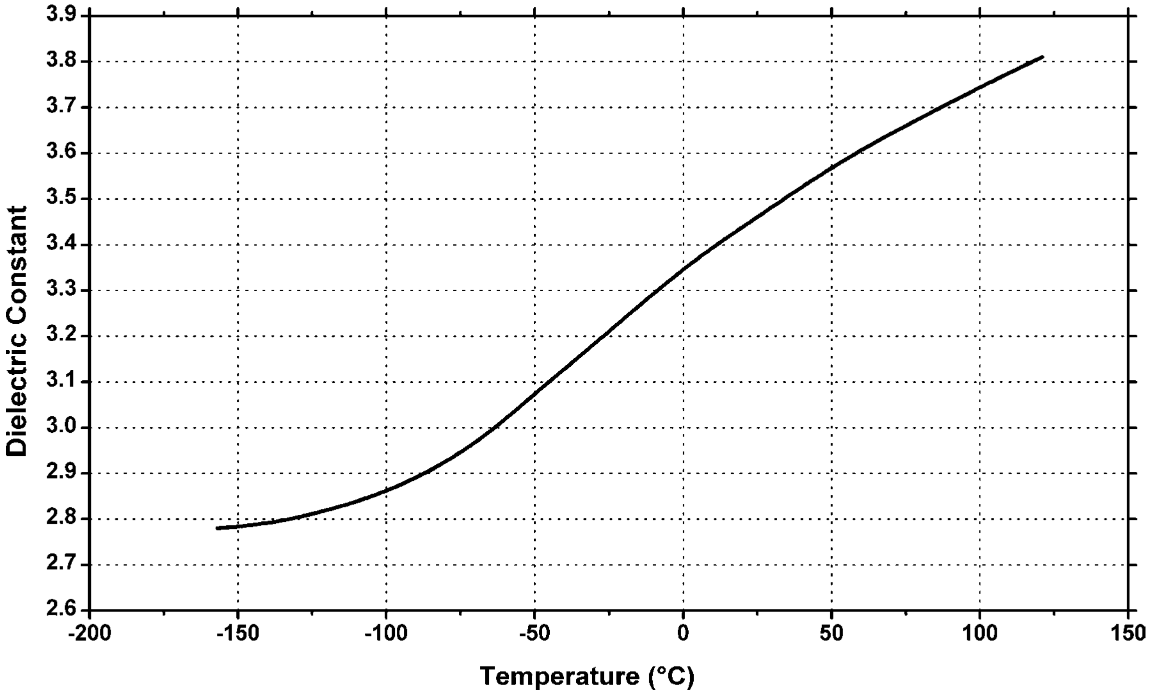


Figure 3.23. Dielectric constant vs. temperature for Delrin® 100 and 500 NC010—acetal resins.

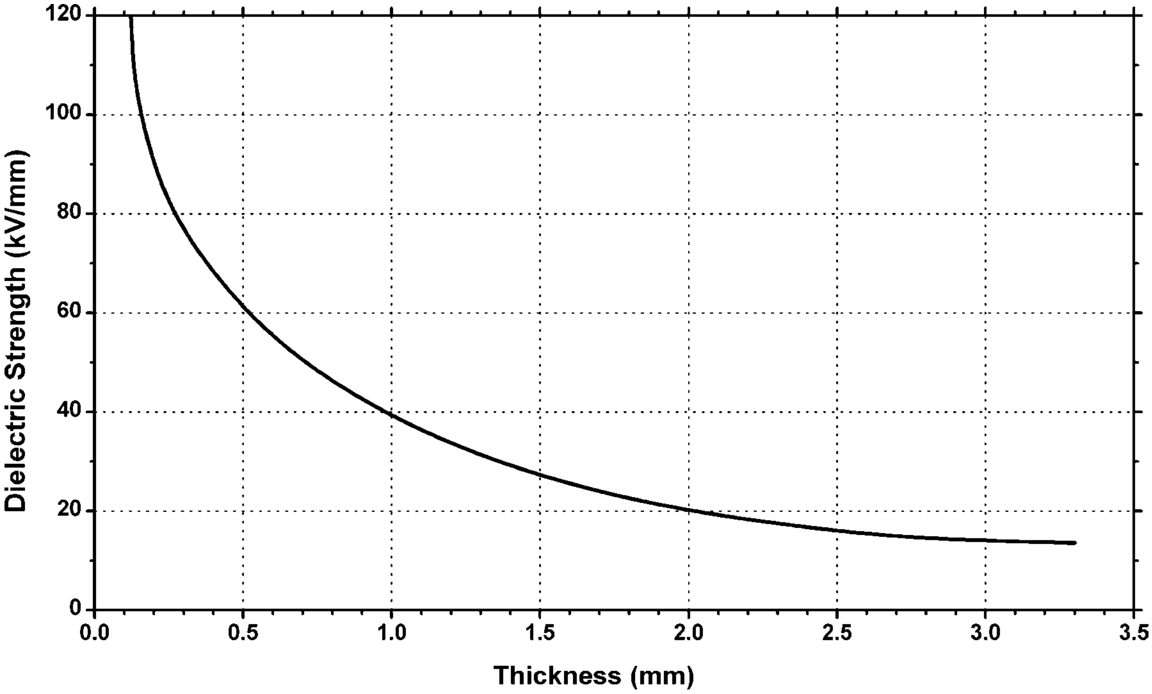


Figure 3.24. Dielectric strength vs. thickness at 23°C for DuPont Engineering Polymers Delrin® 500 NC010—medium viscosity acetal resin.

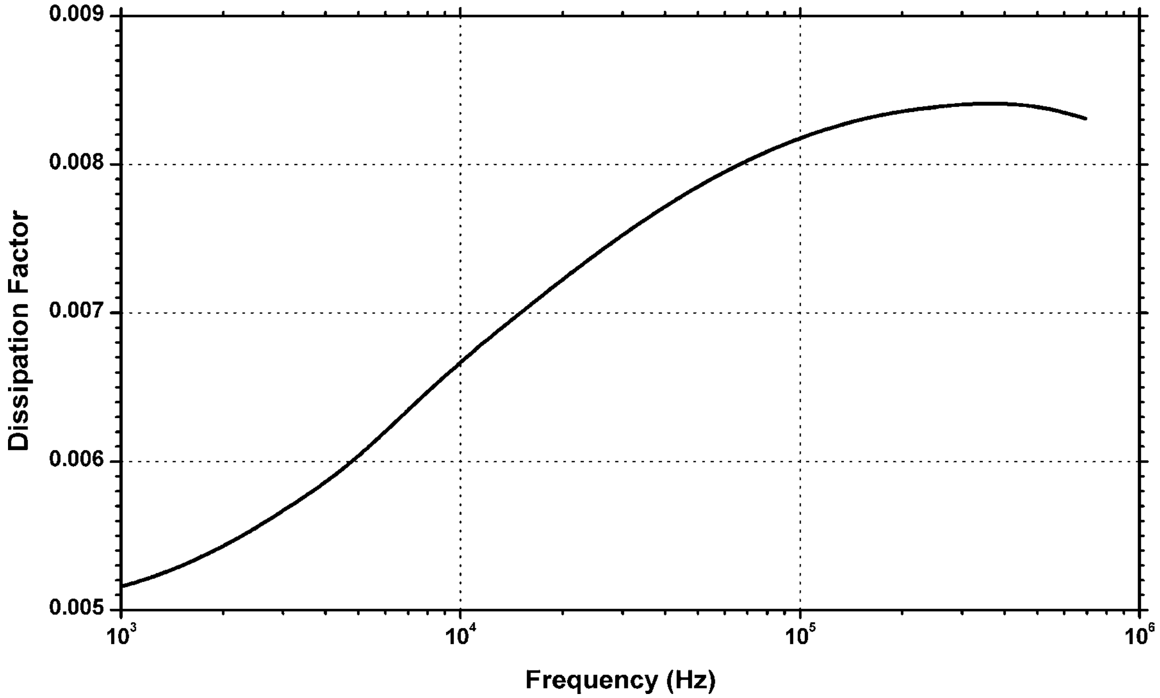


Figure 3.25. Dissipation factor vs. frequency at 50% relative humidity at 23°C for DuPont Engineering Polymers Delrin® 500—medium viscosity acetal resin.

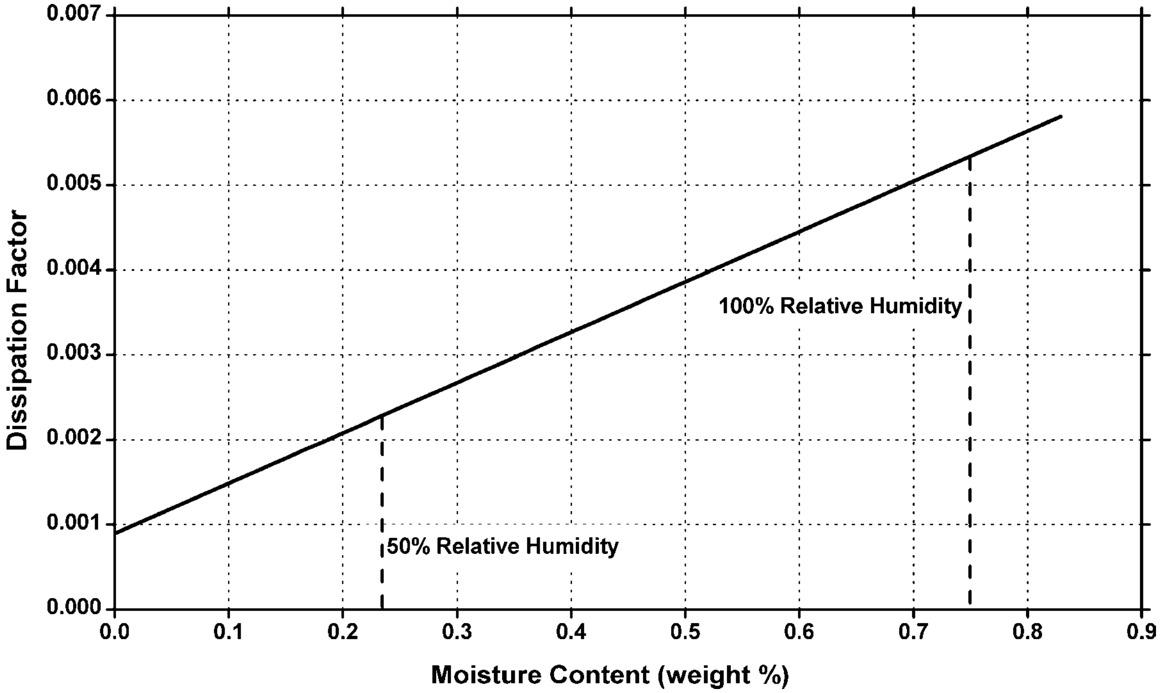


Figure 3.26. Dissipation factor vs. moisture content at 23°C for DuPont Engineering Polymers Delrin® 500 NC010—acetal resin.

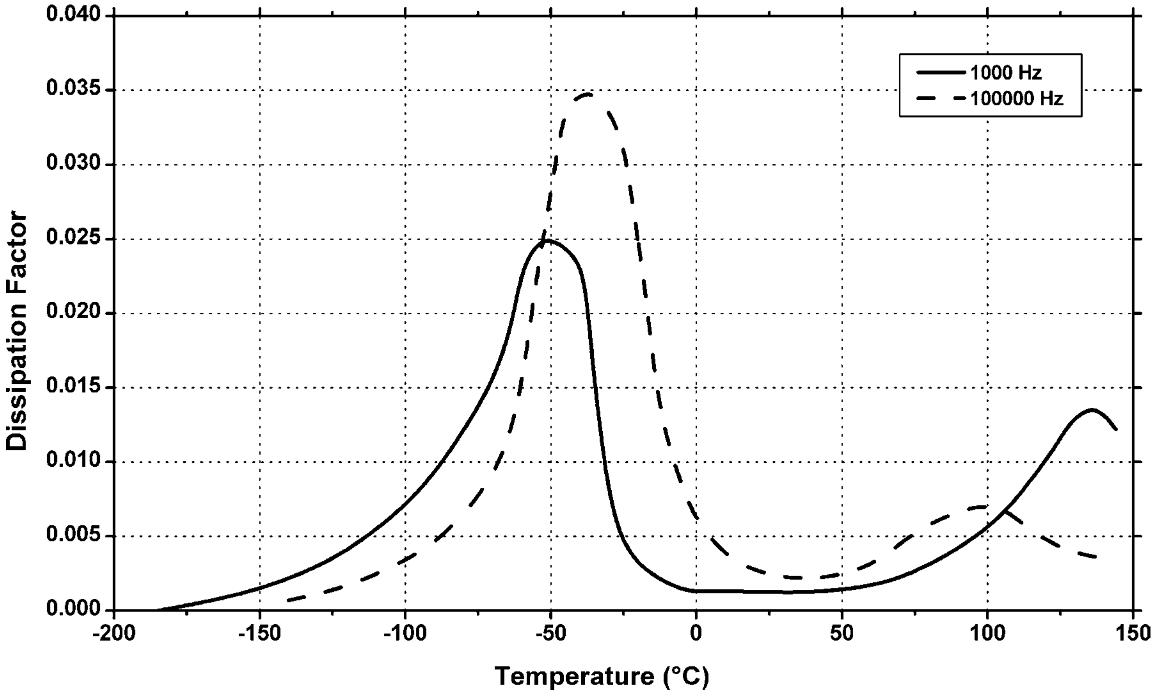


Figure 3.27. Dissipation factor vs. temperature for DuPont Engineering Polymers Delrin® 500 NC010—medium viscosity acetal resin.

3.3 Acetal-Copolymer

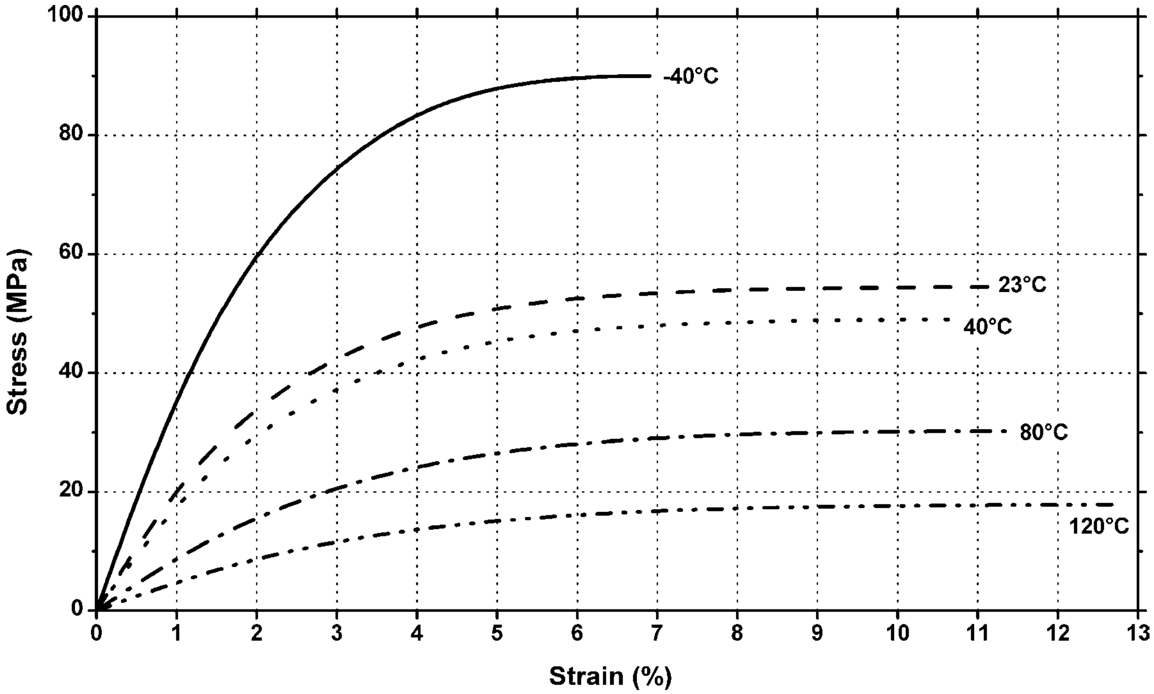


Figure 3.28. Stress vs. strain for Ticona Celcon® M25—high molecular weight, high toughness, high impact acetal copolymer resin.

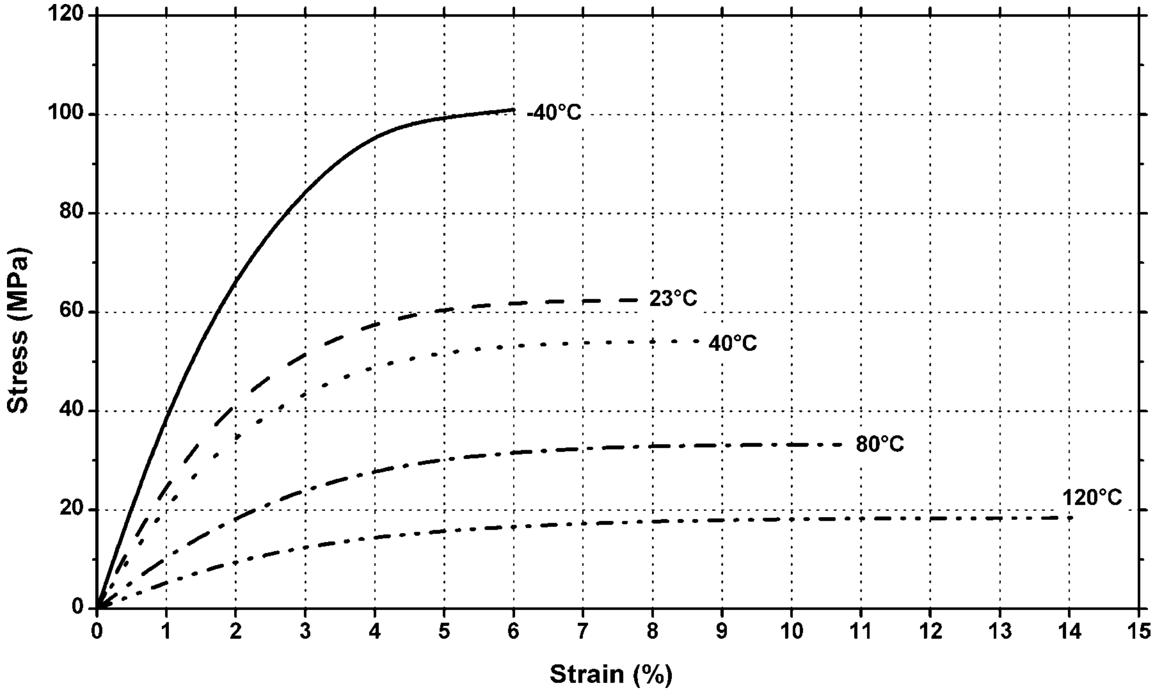


Figure 3.29. Stress vs. strain for Ticona Celcon® M90—medium viscosity, general purpose acetal copolymer resin.

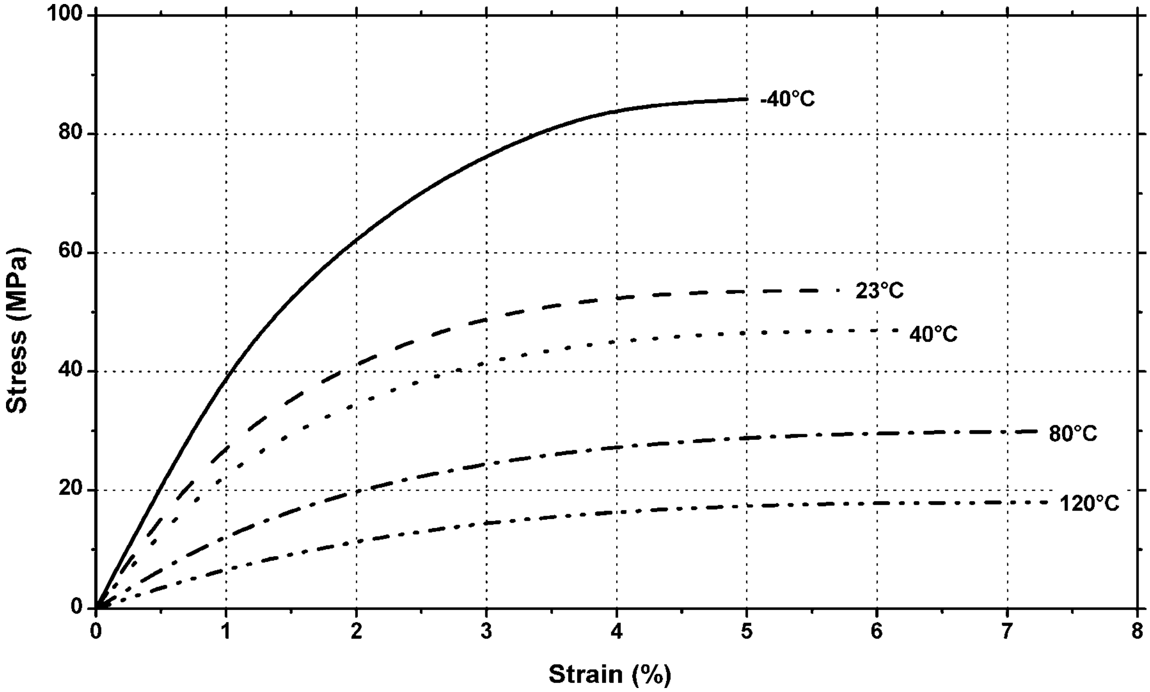


Figure 3.30. Stress vs. strain for Ticona Celcon® M270—low molecular weight, high flow acetal copolymer resin.

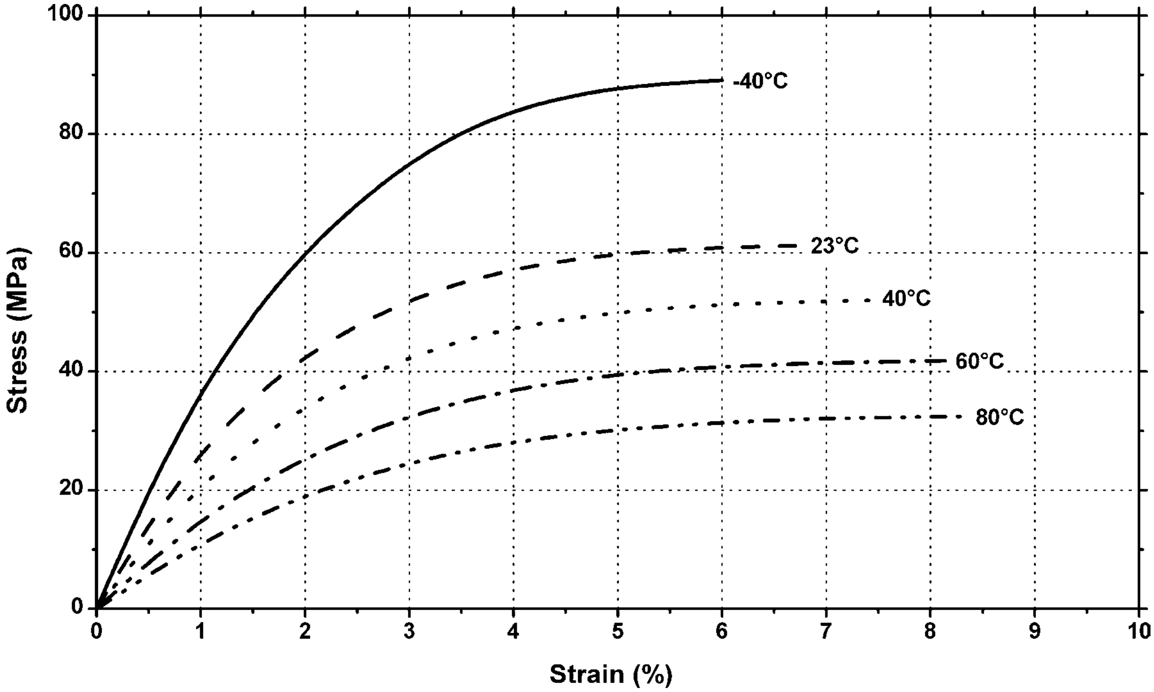


Figure 3.31. Stress vs. strain for Ticona Hostaform® C 9021—general purpose grade acetal copolymer resin.

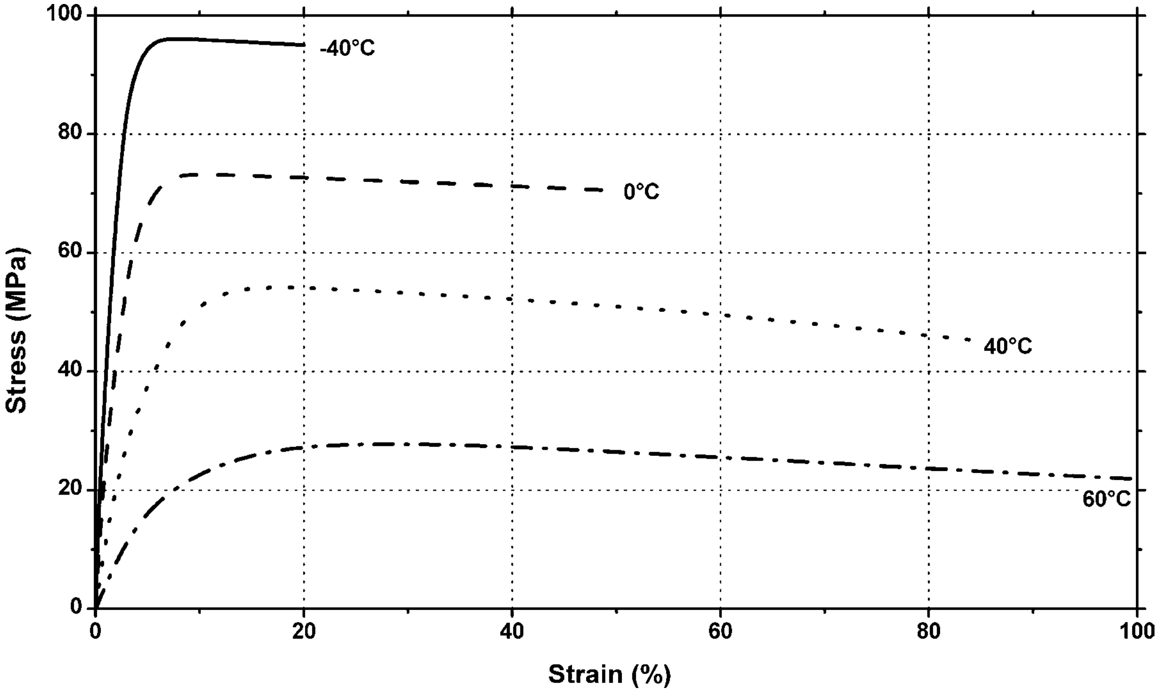


Figure 3.32. Stress vs. strain for Mitsubishi Engineering-Plastics Iupital F20-02—medium viscosity, general purpose acetal copolymer resin.

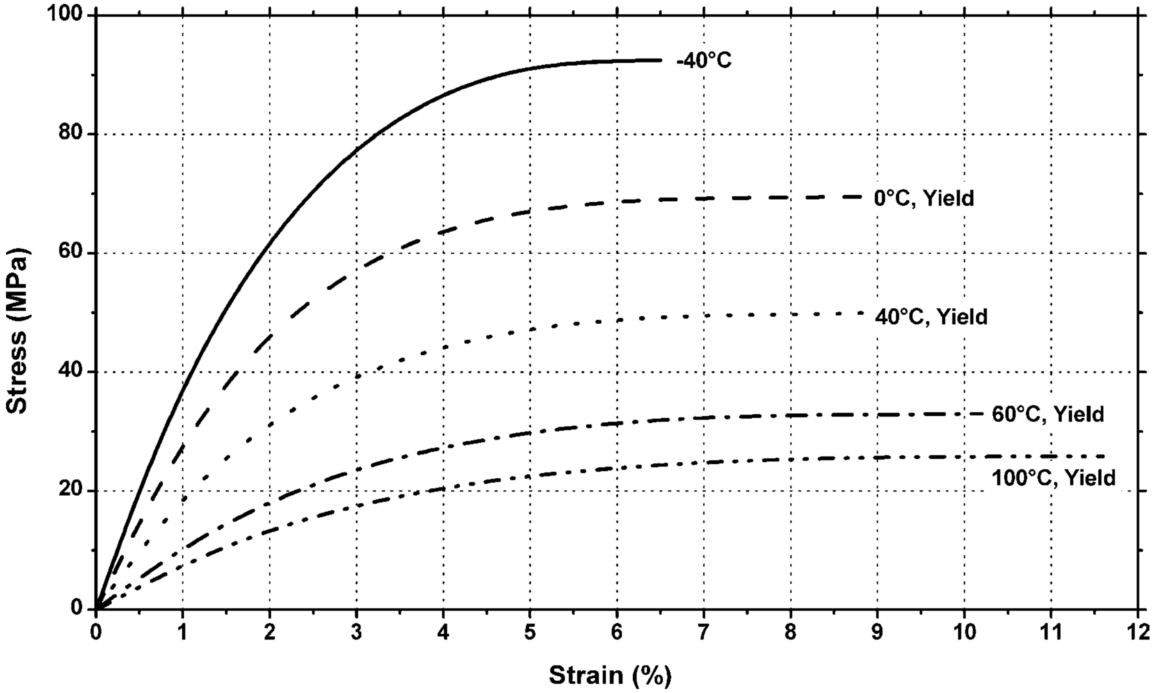


Figure 3.33. Stress vs. strain for BASF Ultraform® H 2320 006—high molecular weight injection molding grade acetal copolymer resin.

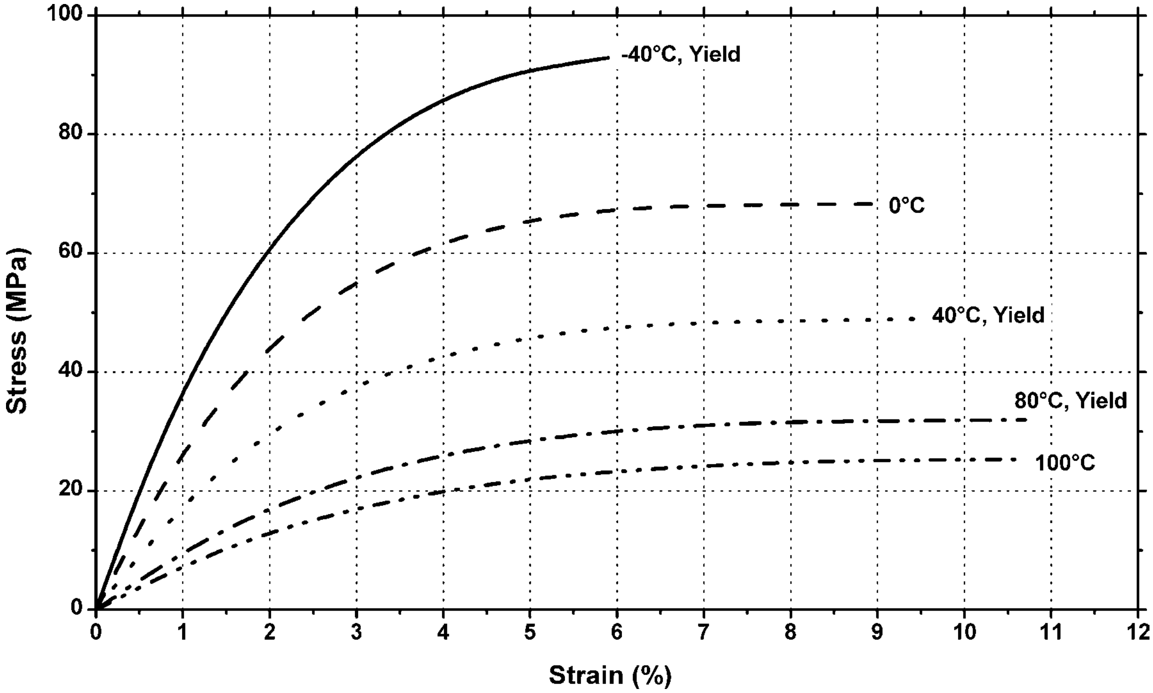


Figure 3.34. Stress vs. strain for BASF Ultraform® H 4320—high molecular weight, extrusion grade acetal copolymer resin.

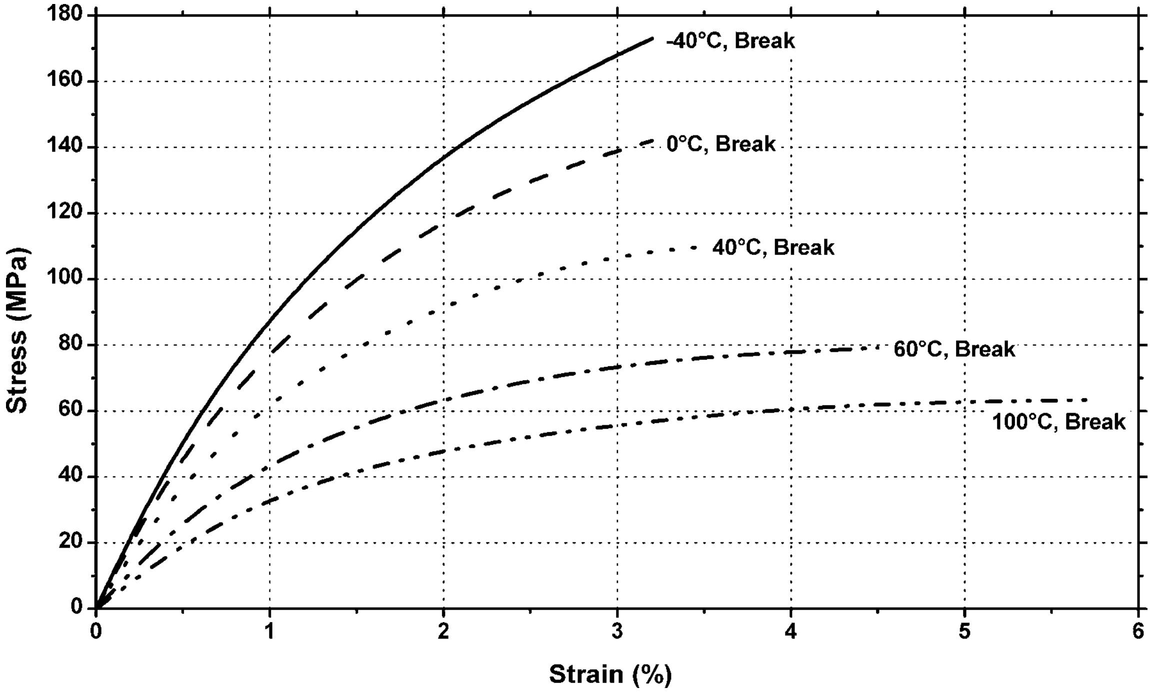


Figure 3.35. Stress vs. strain for BASF Ultraform® N 2200 G53—25% glass fiber reinforced, injection molding with enhanced stiffness and toughness acetal copolymer resin.

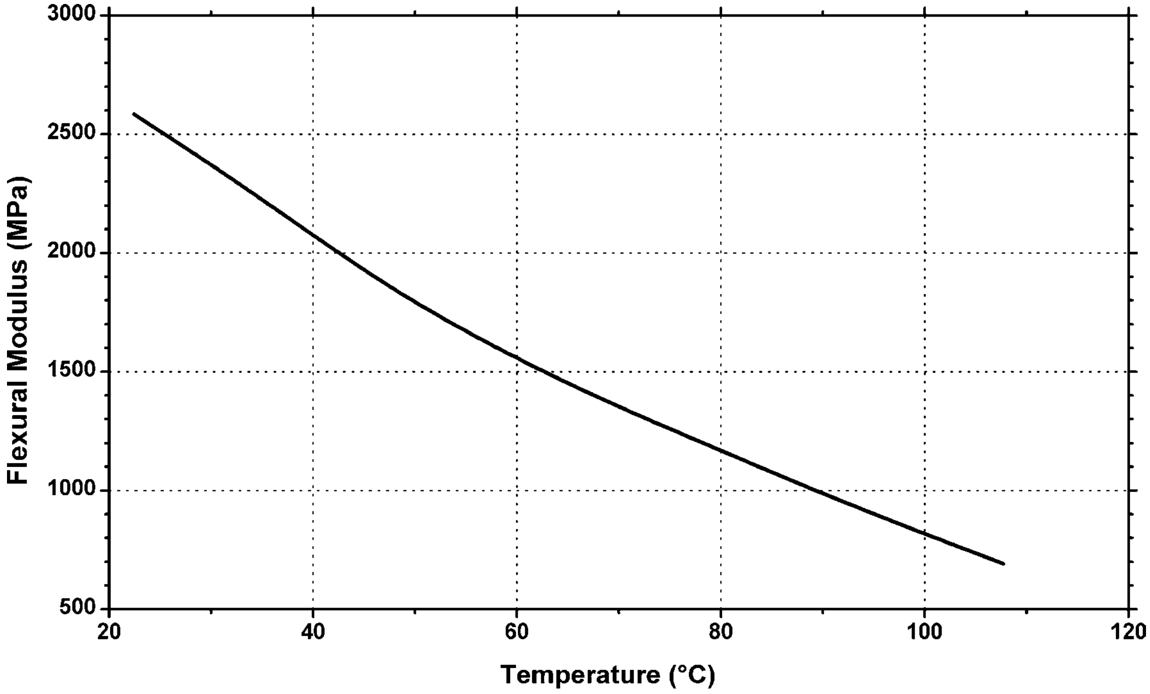


Figure 3.36. Flexural modulus vs. temperature for Ticona Celcon® M25/M90/M270—acetal copolymer resins.

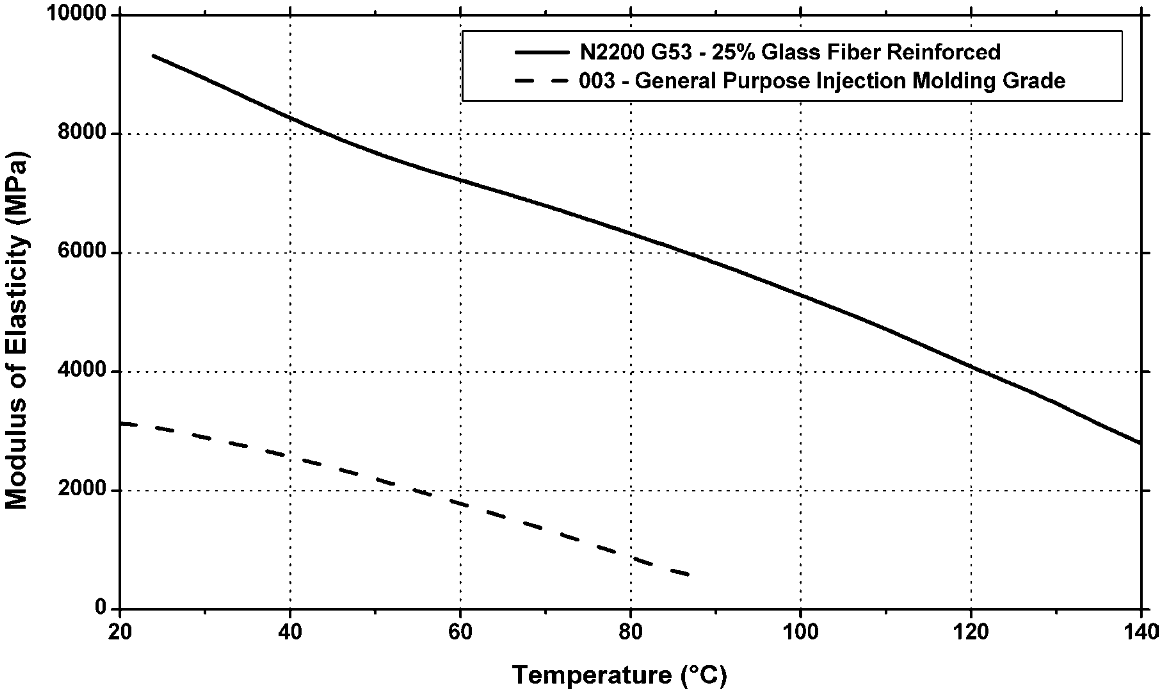


Figure 3.37. Modulus of elasticity vs. temperature for BASF Ultraform® acetal copolymer resins.

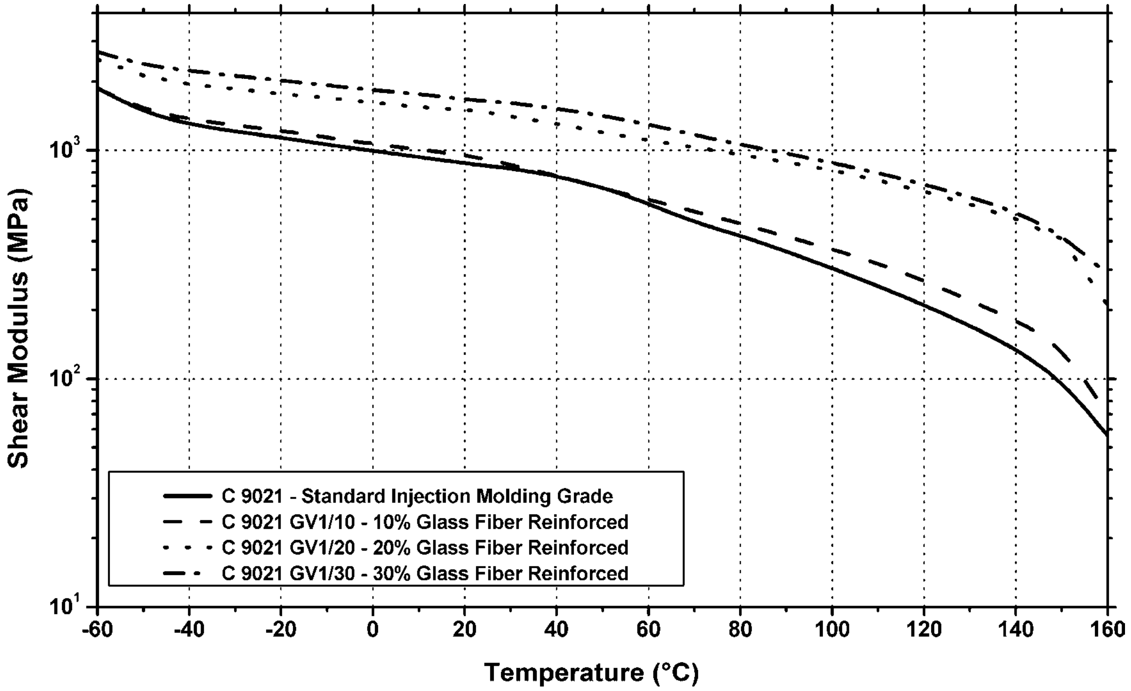


Figure 3.38. Shear modulus vs. temperature for Ticona Hostaform® acetal copolymer resins with different amounts of glass fiber reinforcement.

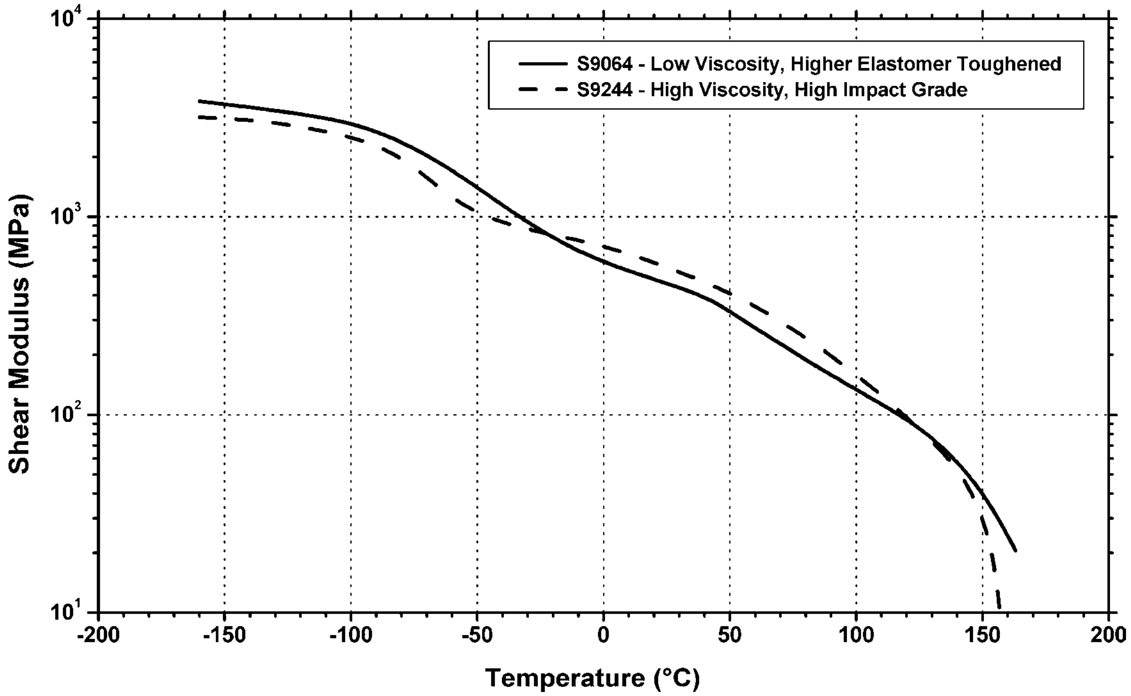


Figure 3.39. Shear modulus vs. temperature for Ticona Hostaform® acetal copolymer resins.

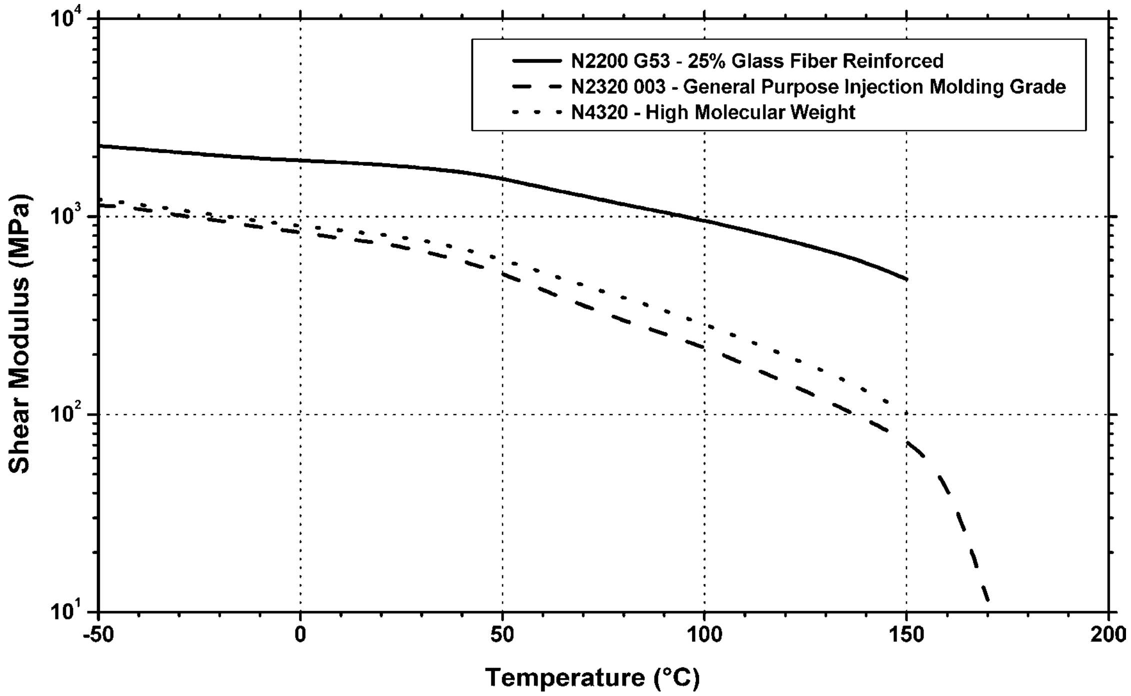


Figure 3.40. Shear modulus vs. temperature for several BASF Ultraform® acetal copolymer resins.

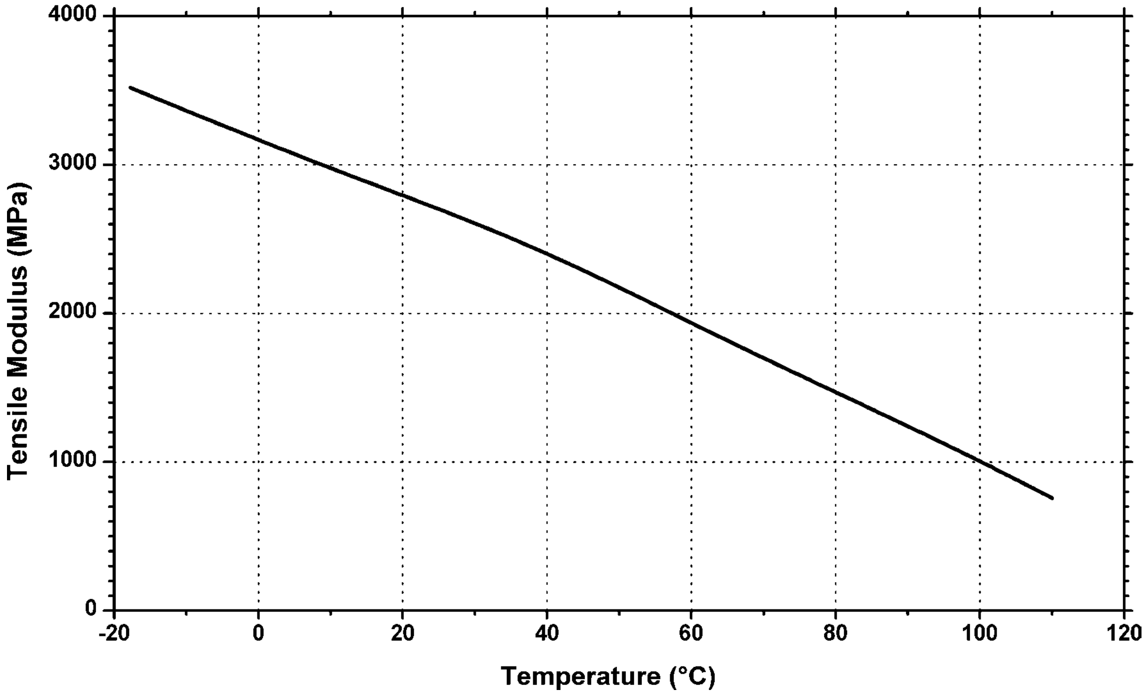


Figure 3.41. Tensile modulus vs. temperature for Ticona Celcon® M25/M90/M270—acetal copolymer resins.

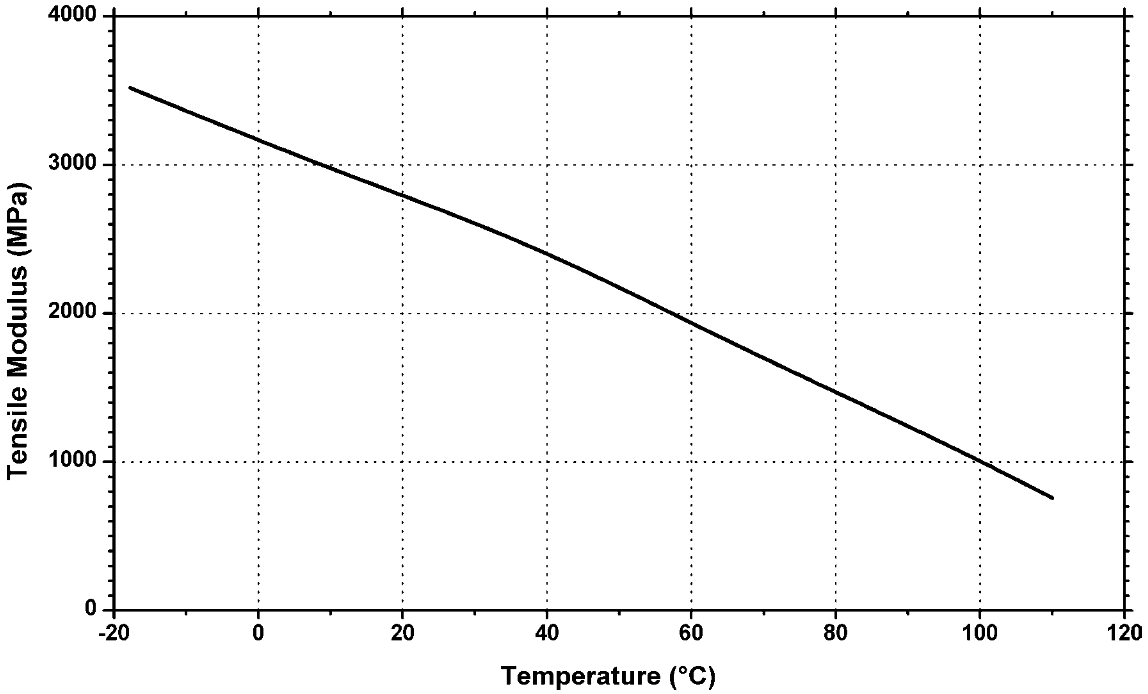


Figure 3.42. Tensile modulus vs. temperature for Ticona Hostform® C 9064 and S 9240—acetal copolymer resins.

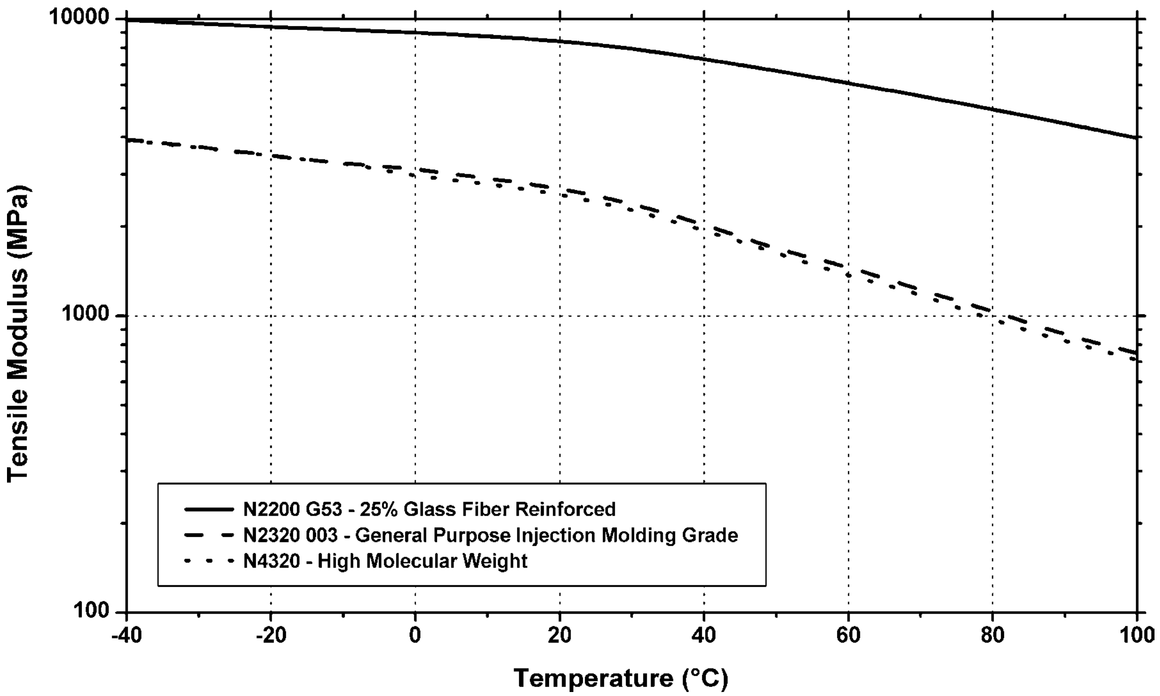


Figure 3.43. Tensile modulus vs. temperature for BASF Ultraform® acetal copolymer resins.

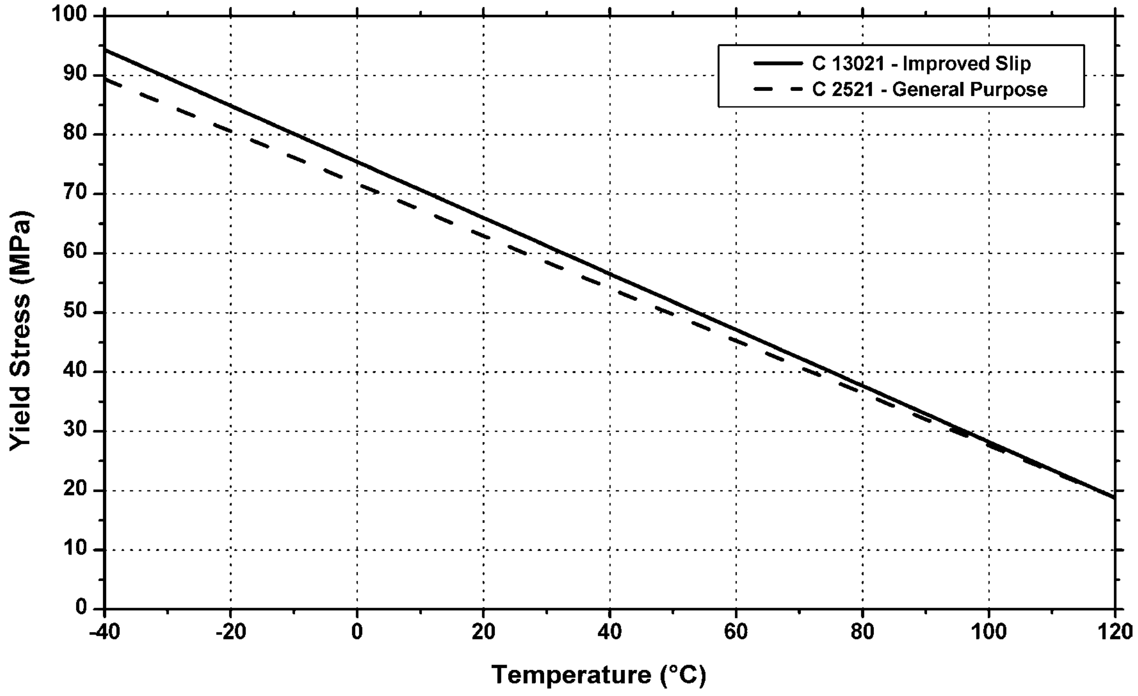


Figure 3.44. Yield stress vs. temperature for Ticona Hostaform® acetal copolymer resins.

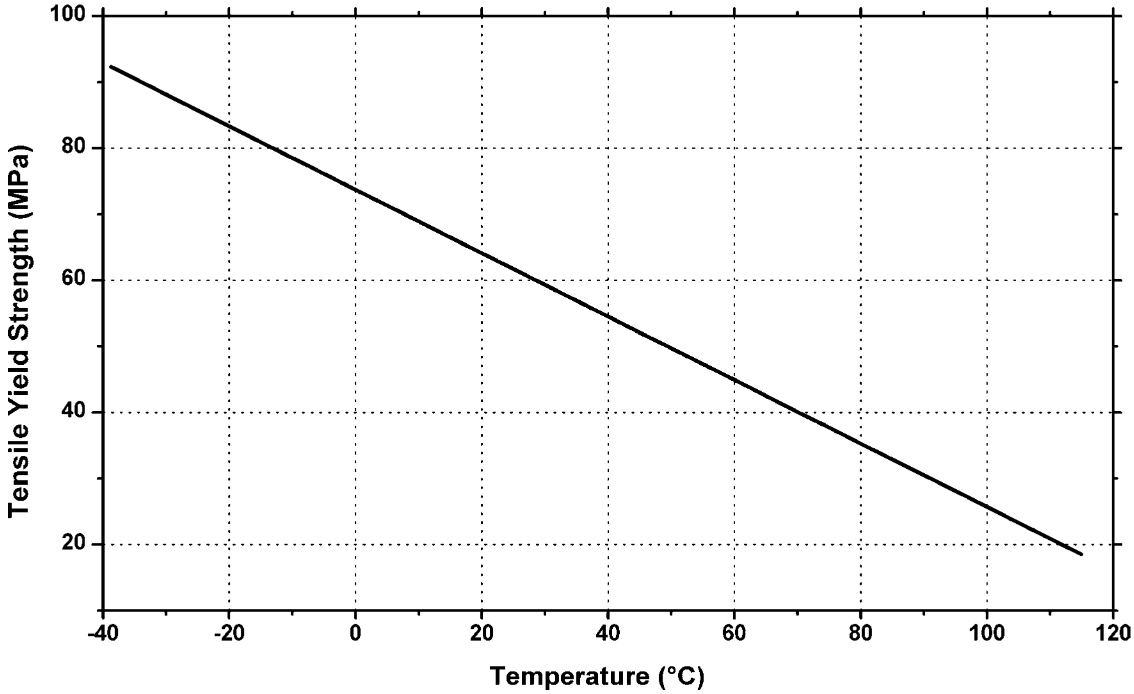


Figure 3.45. Tensile yield strength vs. temperature for Ticona Celcon® M90—medium viscosity, general purpose acetal copolymer resin.

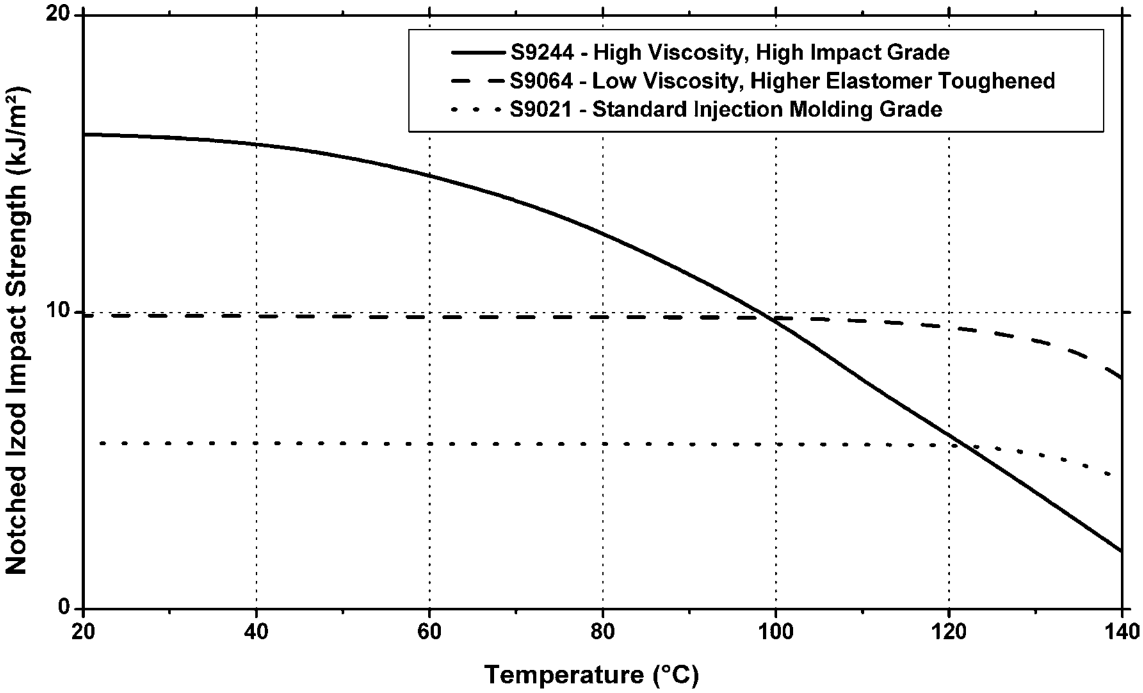


Figure 3.46. Izod notched impact strength vs. temperature for Ticona Hostaform® acetal copolymer resins after 1,000 h storage in air at temperature.

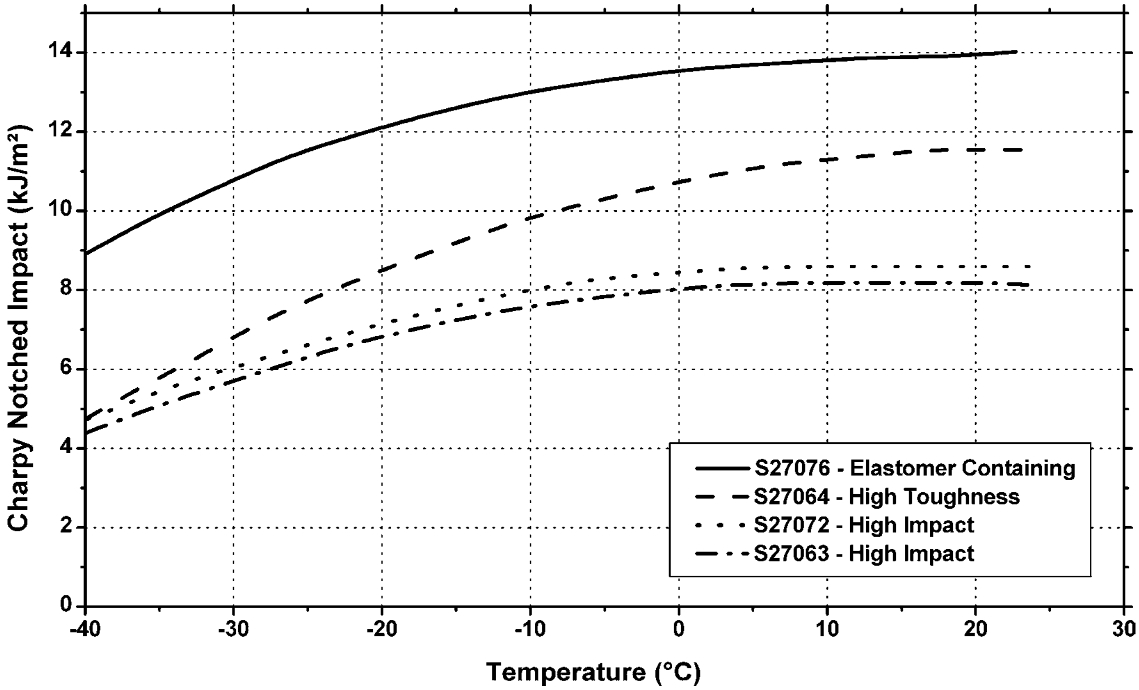


Figure 3.47. Charpy notched impact strength vs. temperature for Ticona Hostaform® S acetal copolymer resins.

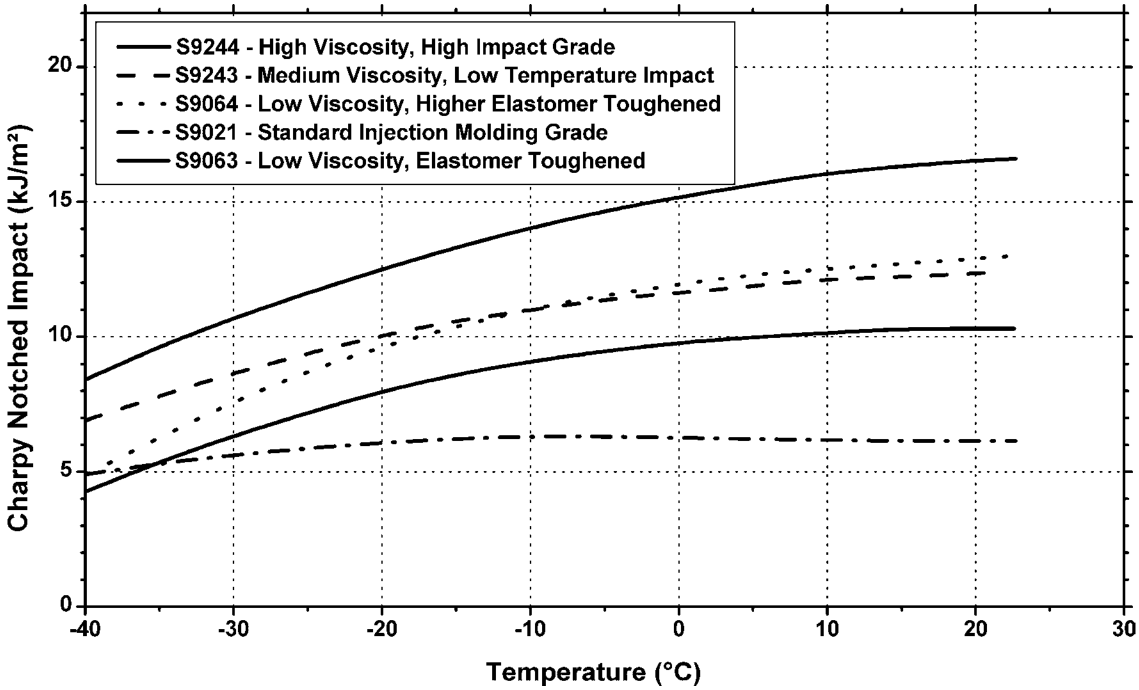


Figure 3.48. Charpy notched impact strength vs. temperature for additional Ticona Hostaform® S acetal copolymer resins.

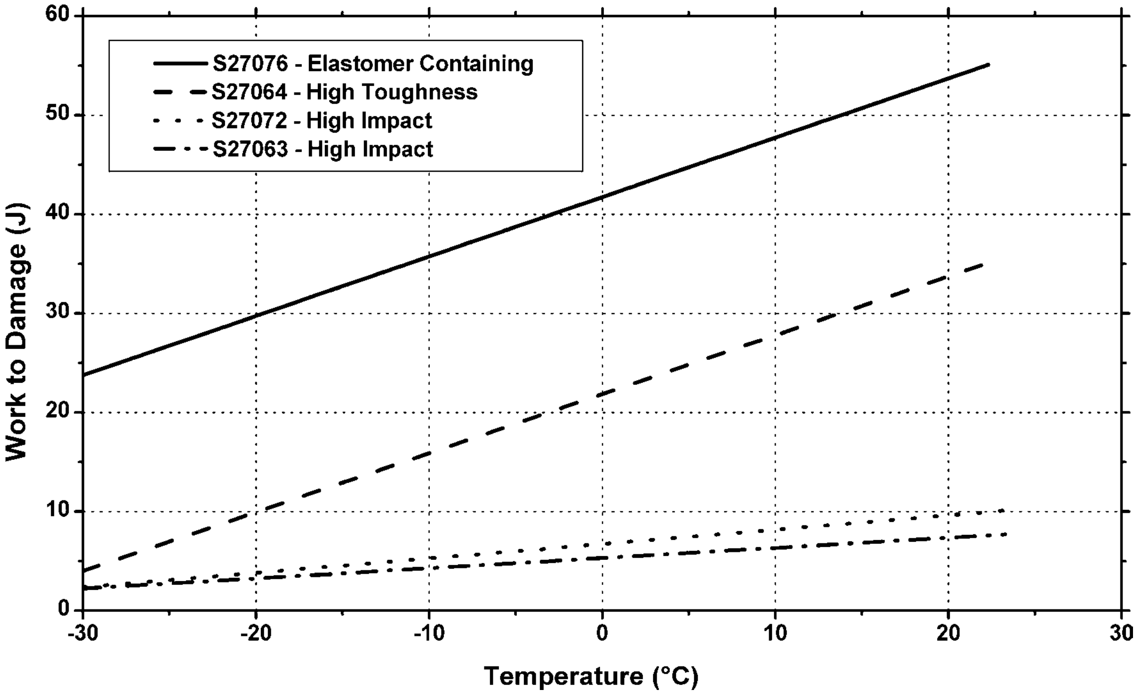


Figure 3.49. Work to damage (penetration test ISO 6603-2) vs. temperature for Ticona Hostaform® acetal copolymer resins.

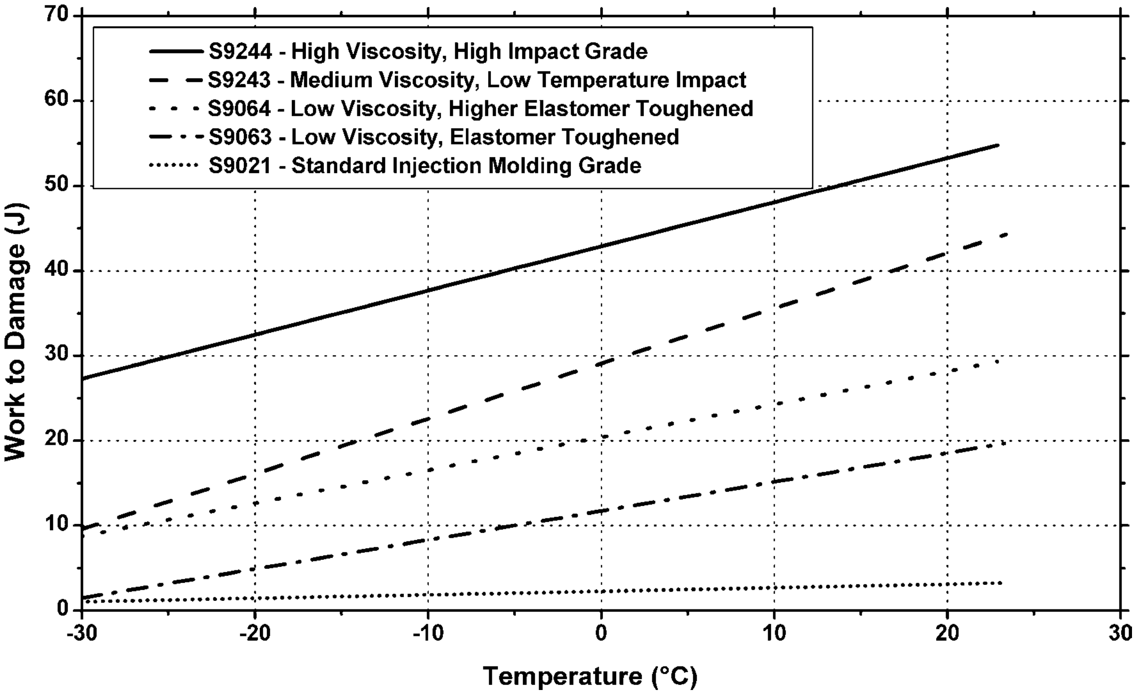


Figure 3.50. Work to damage (penetration test ISO 6603-2) vs. temperature for additional Ticona Hostaform® acetal copolymer resins.

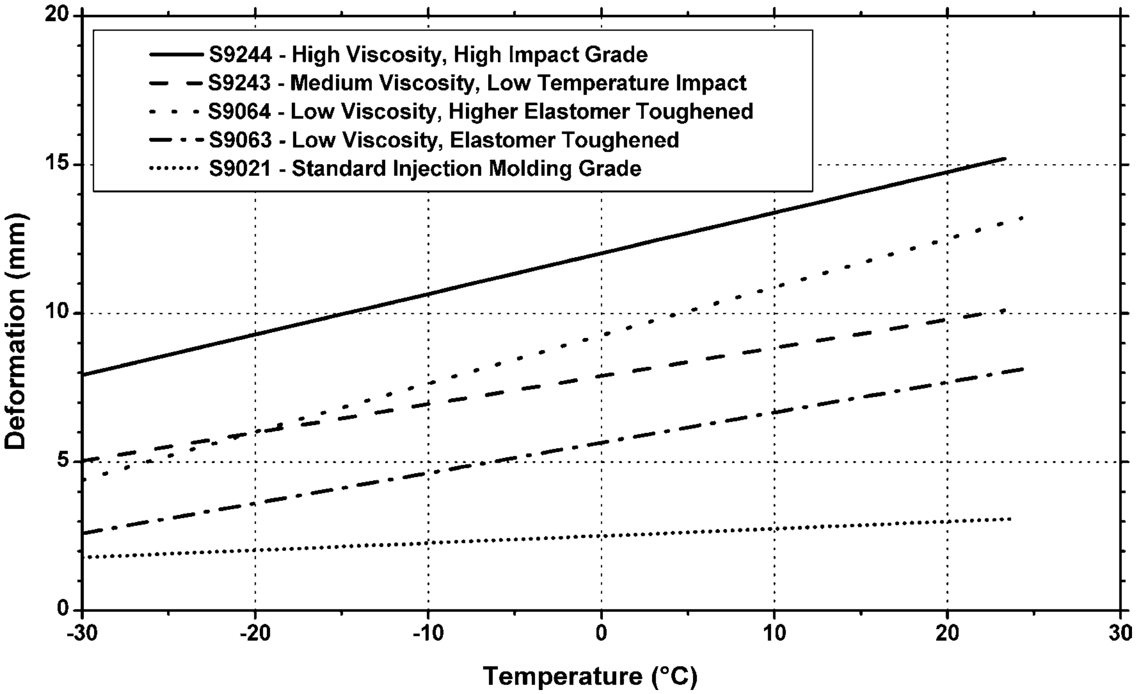


Figure 3.51. Deformation (penetration test ISO 6603-2) vs. temperature for Ticona Hostaform® acetal copolymer resins.

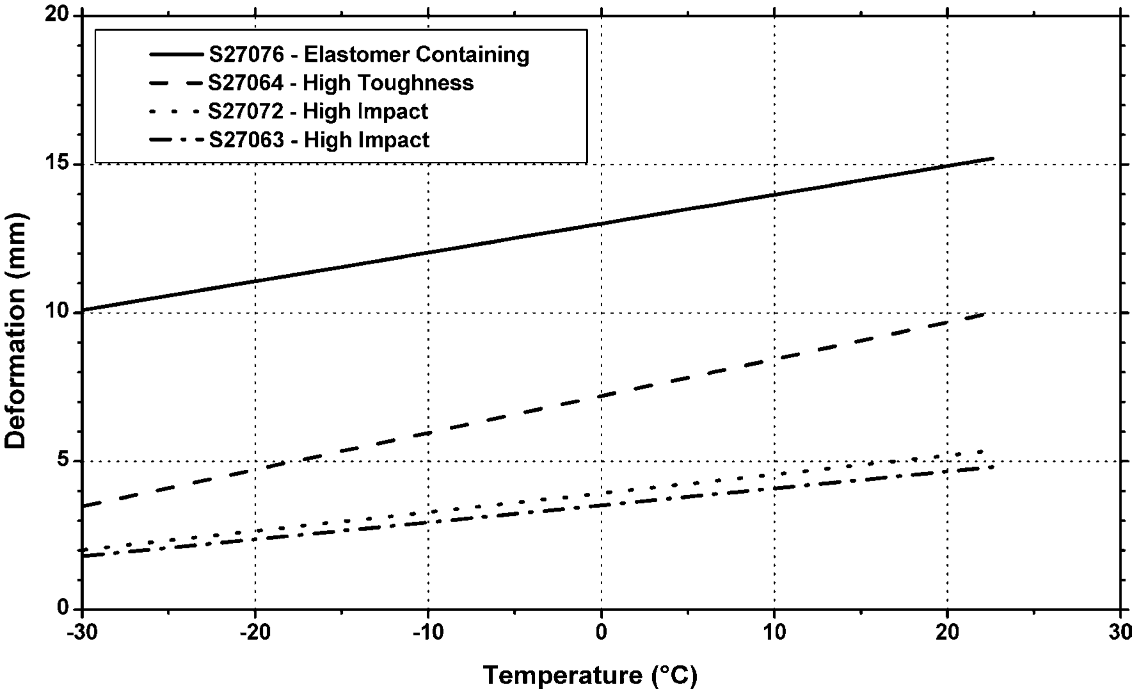


Figure 3.52. Deformation (penetration test ISO 6603-2) vs. temperature for additional Ticona Hostaform® acetal copolymer resins.

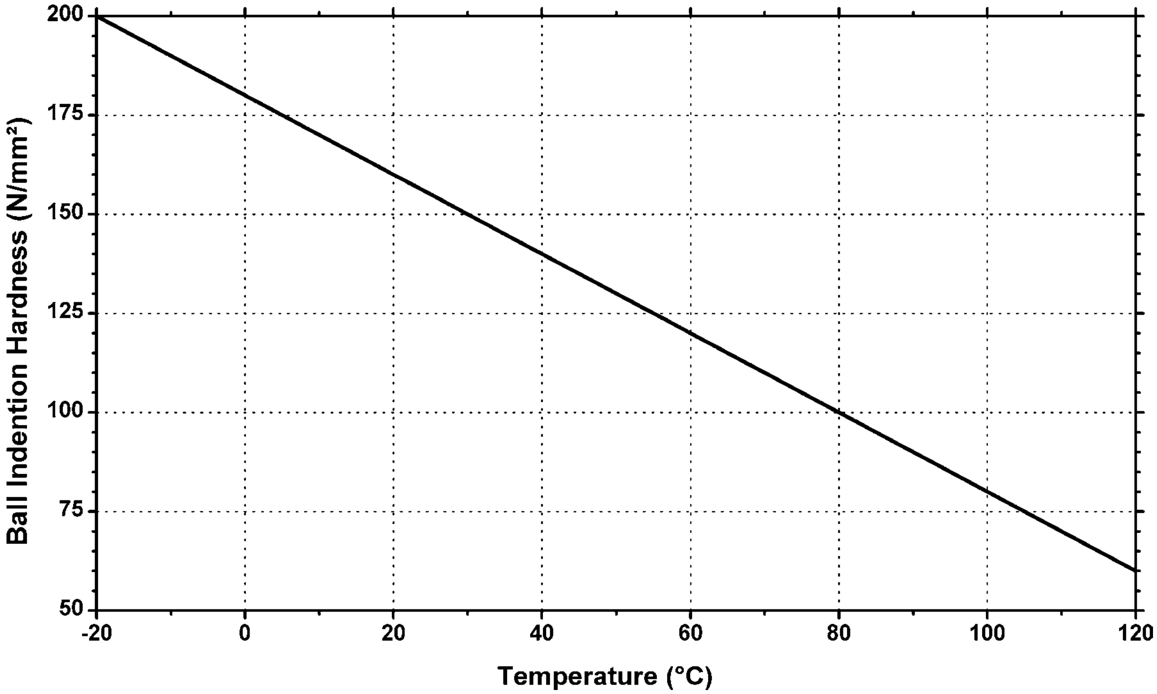


Figure 3.53. Ball indentation hardness vs. temperature for BASF Hostaform® C 9021—General purpose acetal copolymer resin (ISO 2039, Part 1).

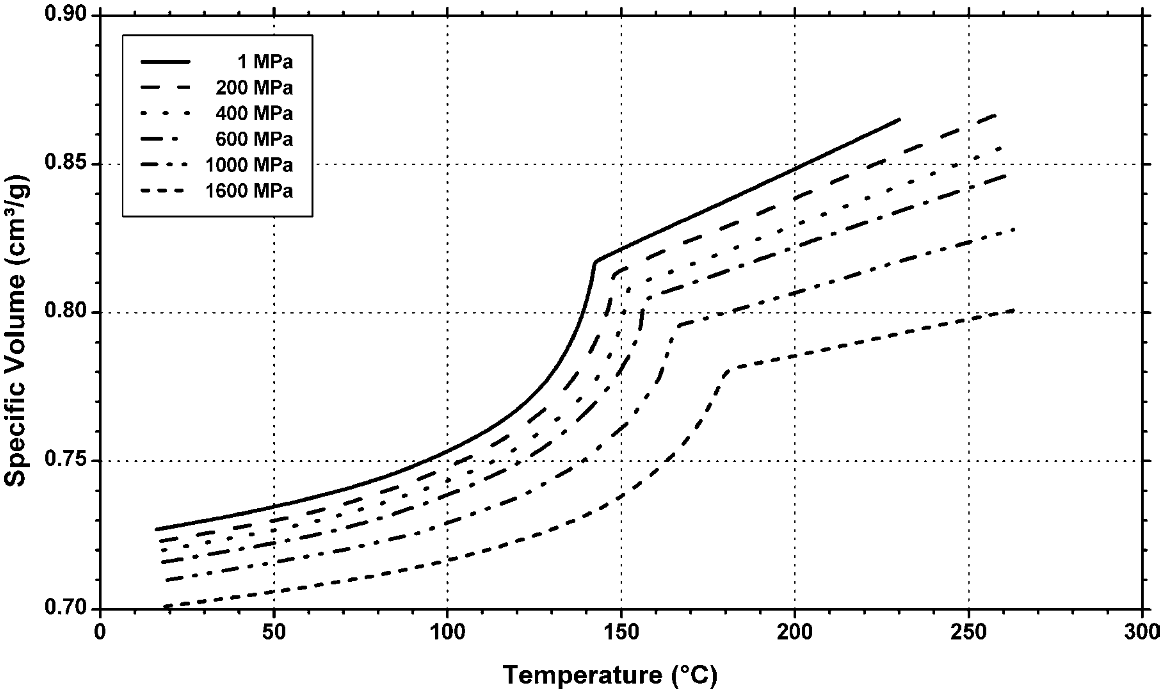


Figure 3.54. Specific volume as a function of temperature and pressure (PVT) for Ticona Hostaform® C 9021—general purpose grade acetal copolymer resin.

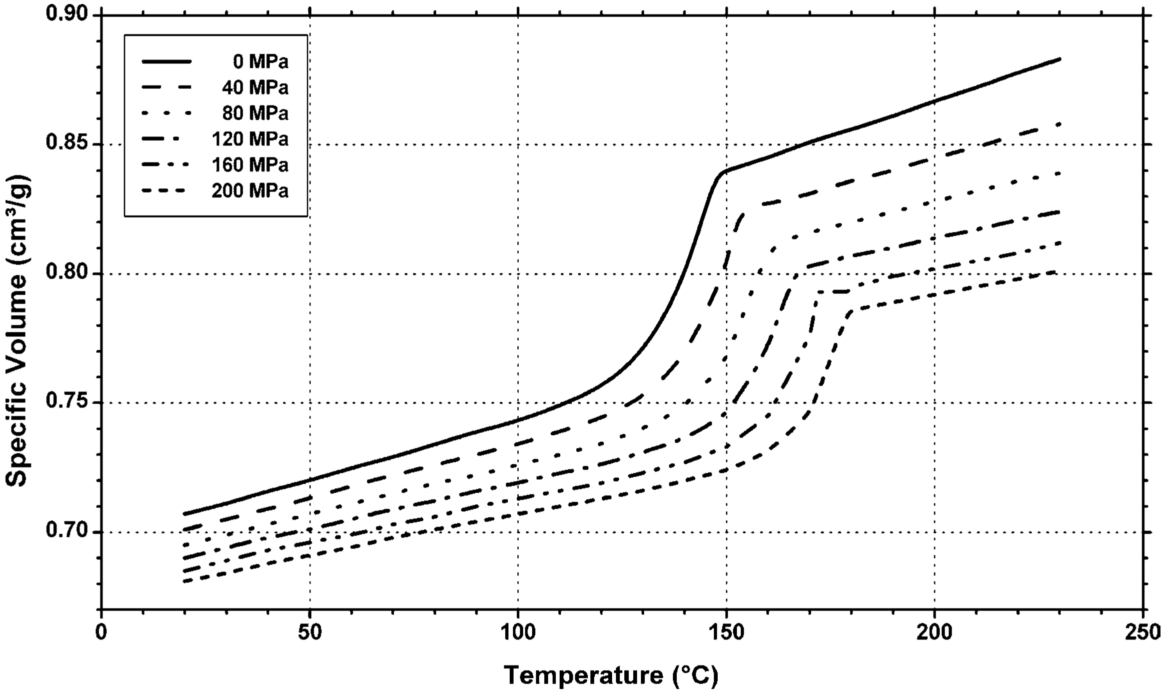


Figure 3.55. Specific volume as a function of temperature and pressure (PVT) for BASF Ultraform® H 2320 006—high molecular weight injection molding grade acetal copolymer resin.

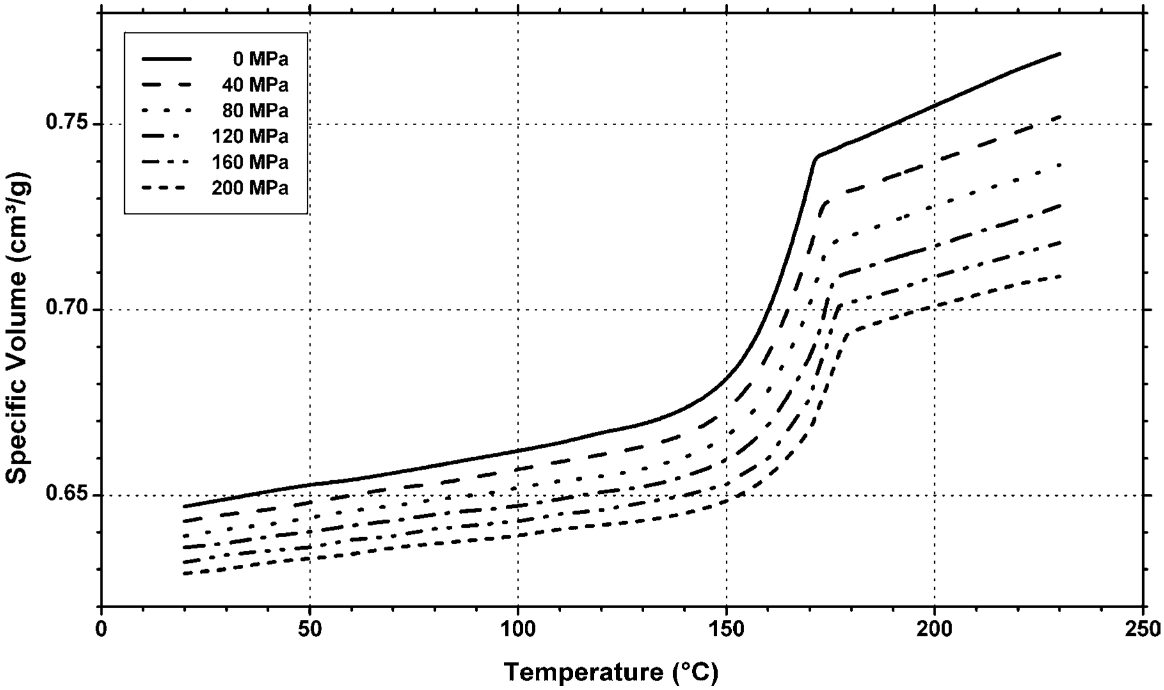


Figure 3.56. Specific volume as a function of temperature and pressure (PVT) for BASF Ultraform® N 2200 G53—25% glass fiber reinforced, injection molding with enhanced stiffness and toughness acetal copolymer resin.

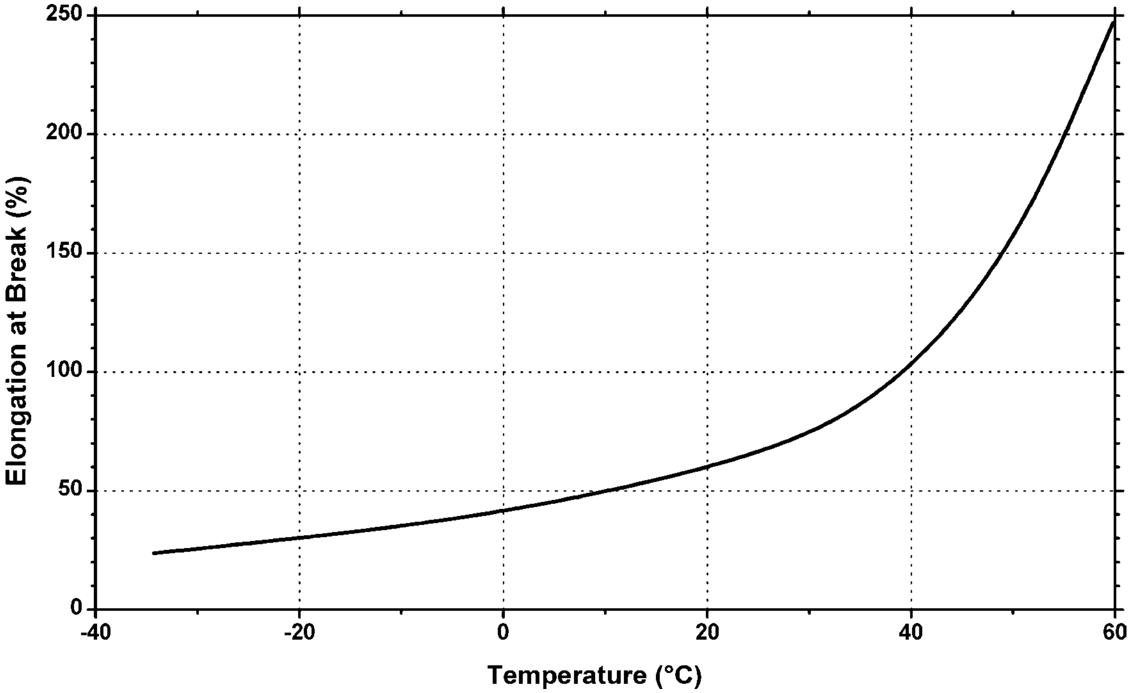


Figure 3.57. Elongation at break vs. temperature for Ticona Celcon® M90—general purpose acetal copolymer resin.

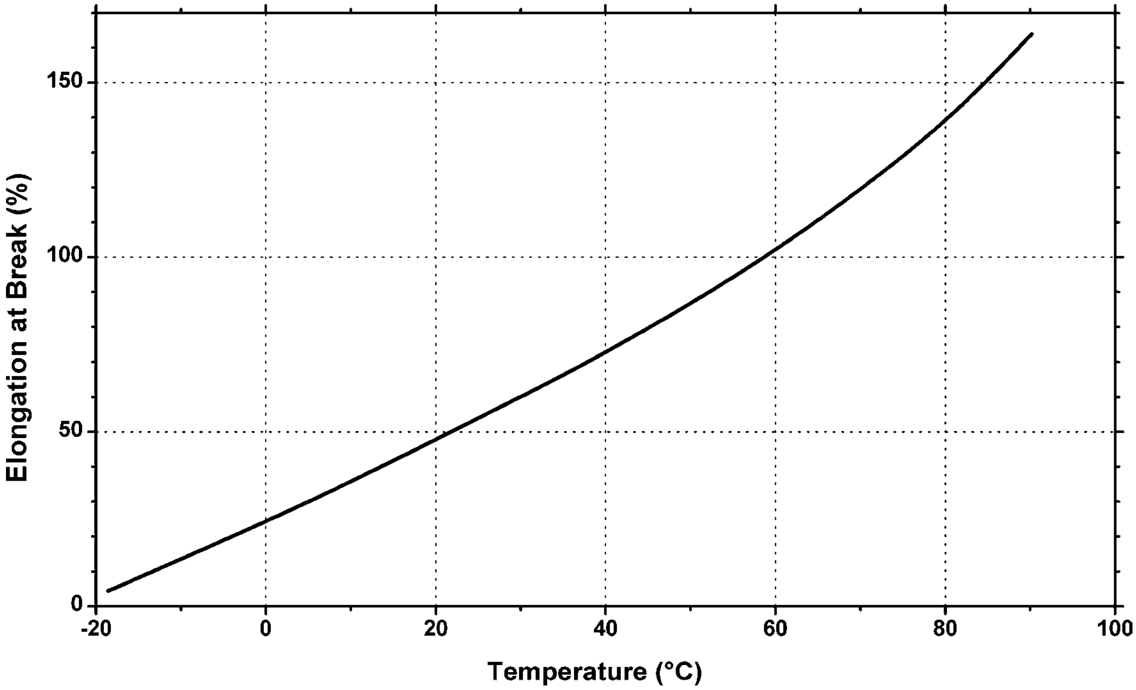


Figure 3.58. Elongation at break vs. temperature for BASF for Hostaform® C 2521—standard for sheet and tube acetal copolymer resin.

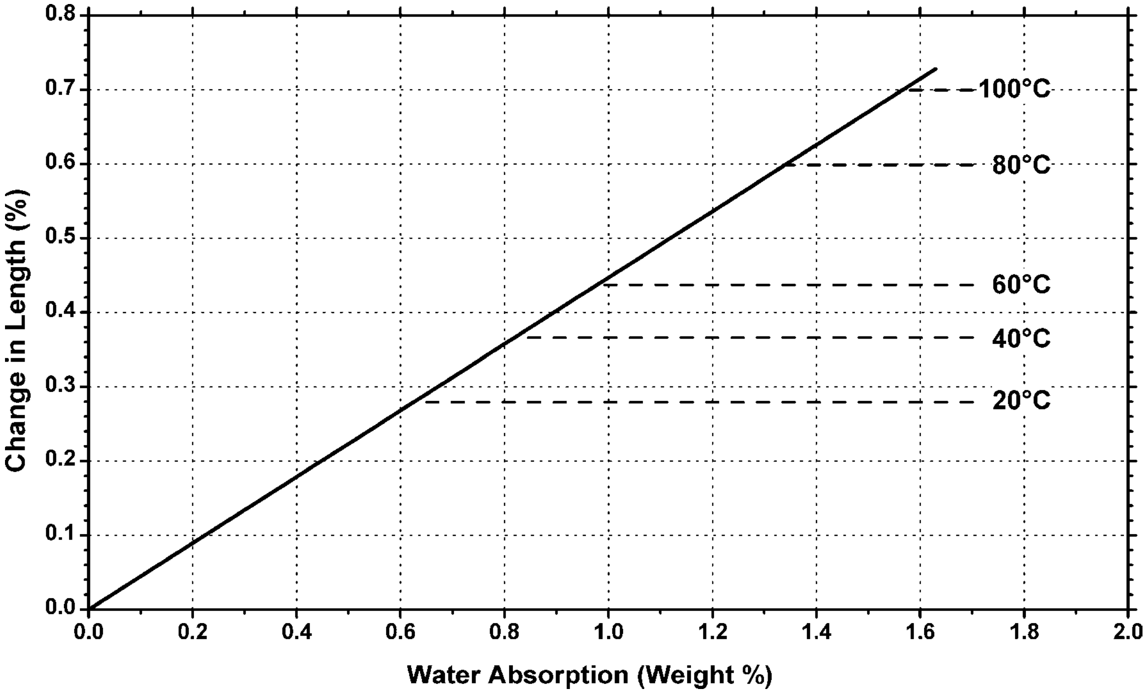


Figure 3.59. Change in length vs. water absorption for Hostaform® C 9021—general purpose acetal copolymer resin.

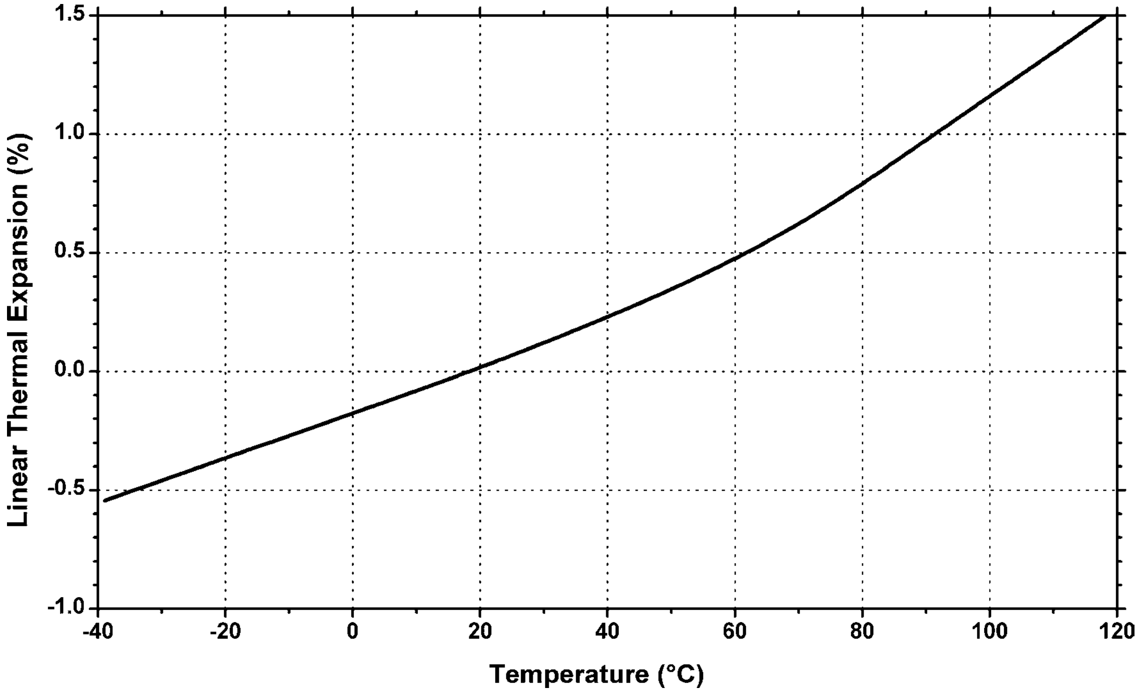


Figure 3.60. Linear thermal expansion vs. temperature for Ticona Celcon® M90—general purpose acetal copolymer resin.

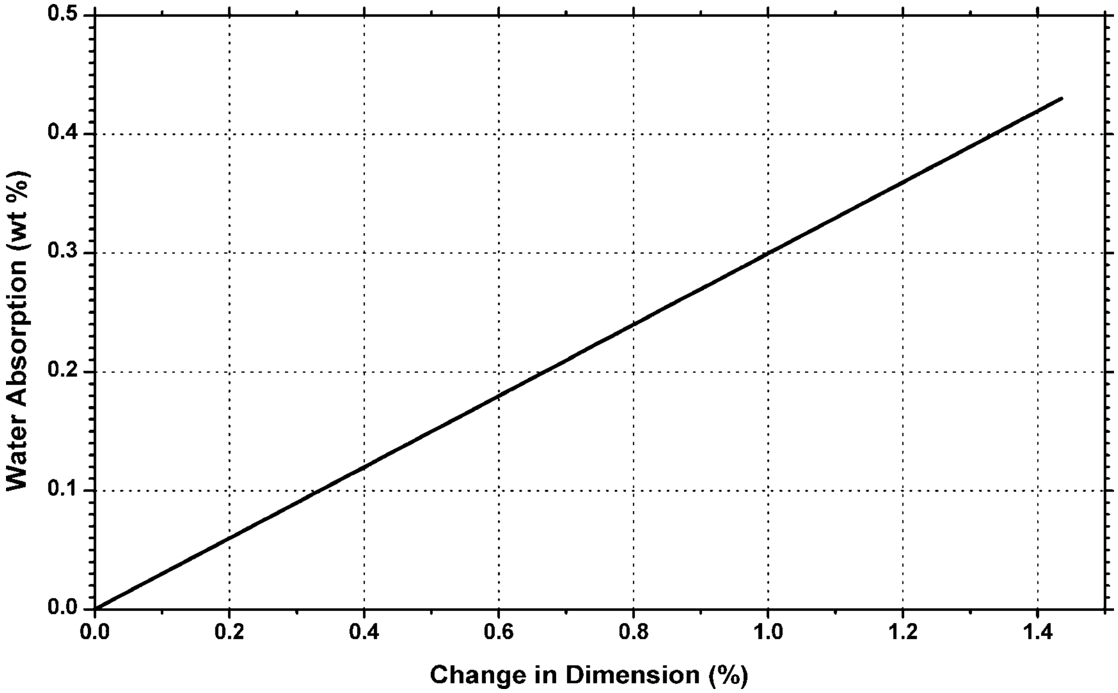


Figure 3.61. Water absorption vs. change of dimension for Mitsubishi Engineering Plastics Iupital F20-02—medium viscosity, general purpose acetal copolymer resin.

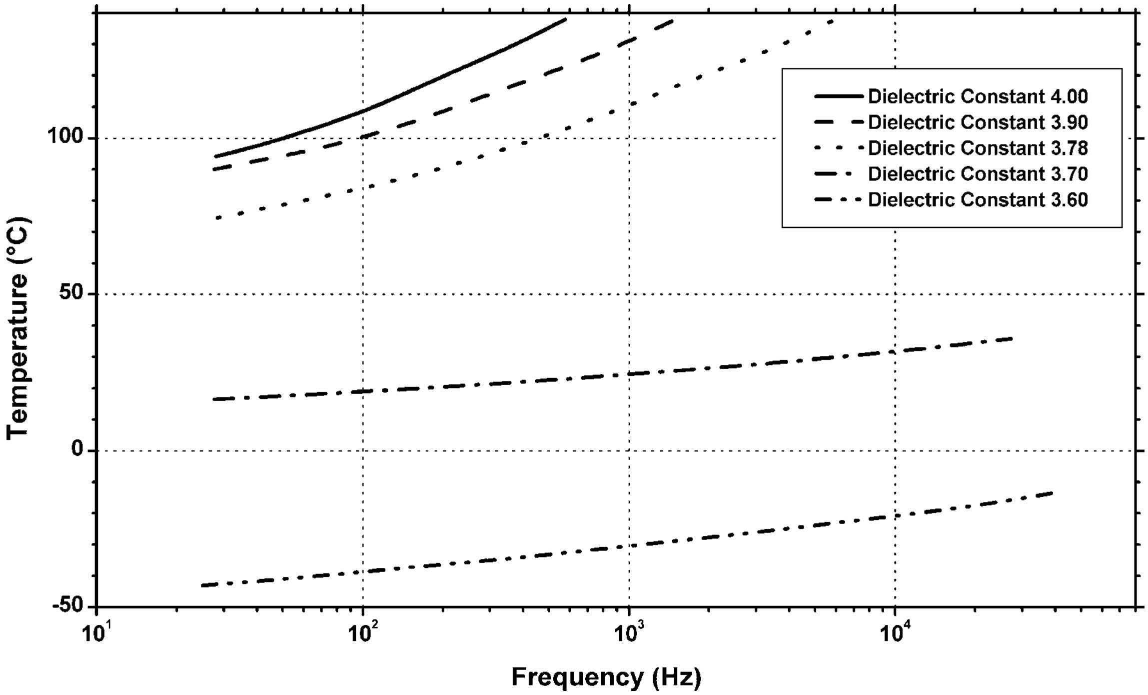


Figure 3.62. Dielectric constant variation with temperature and frequency for Ticona Celcon® M25/M90/M270—acetal copolymer resins.

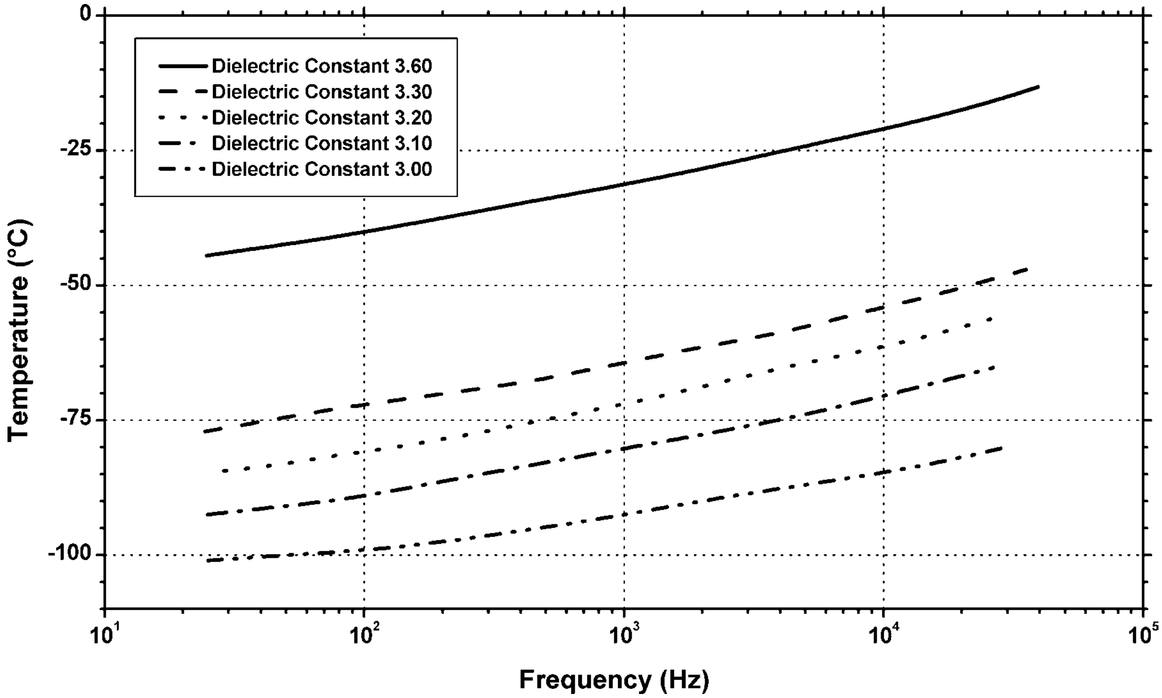


Figure 3.63. Dielectric constant variation with temperature and frequency for Ticona Celcon® M25/M90/M270—acetal copolymer resins at lower temperatures.

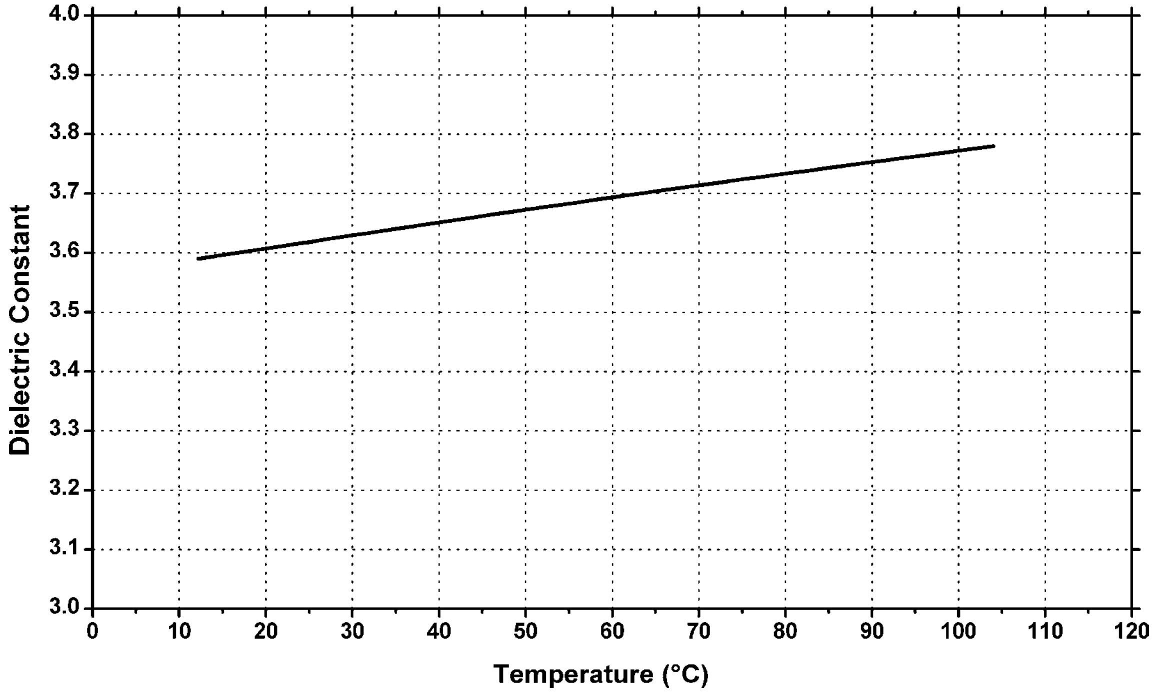


Figure 3.64. Dielectric constant vs. temperature for Mitsubishi Engineering Plastics Iupital F20-02 02—medium viscosity, general purpose acetal copolymer resin.

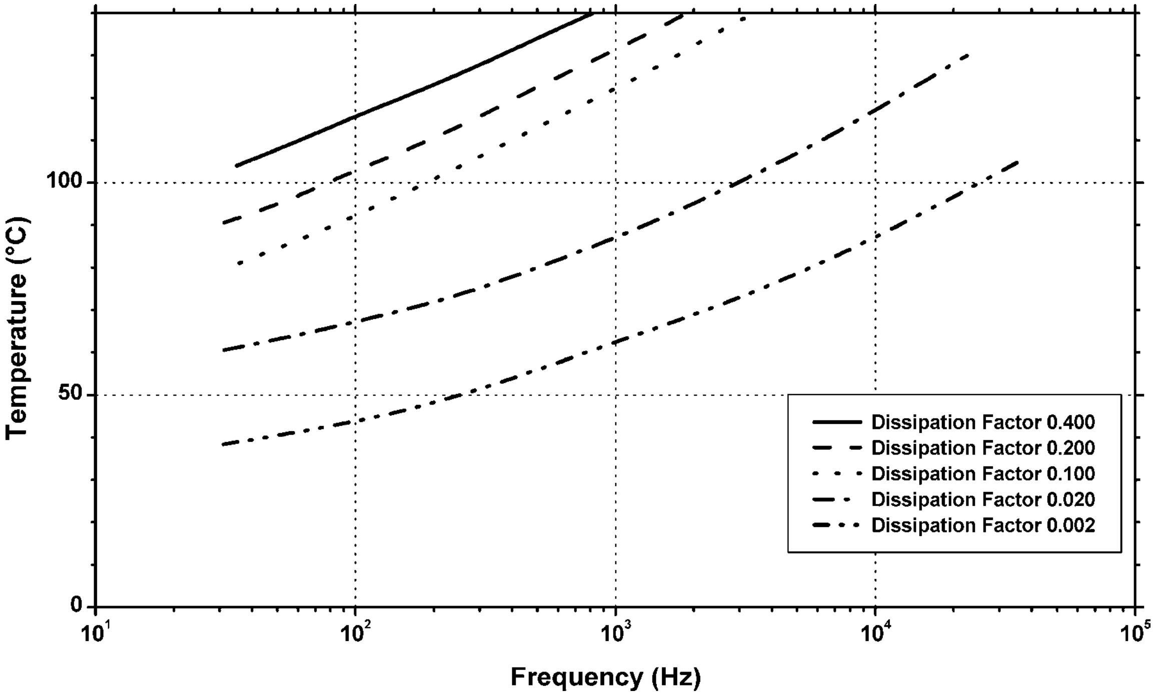


Figure 3.65. Dissipation factor variation with temperature and frequency for Ticona Celcon® M25/M90/M270—acetal copolymer resins.

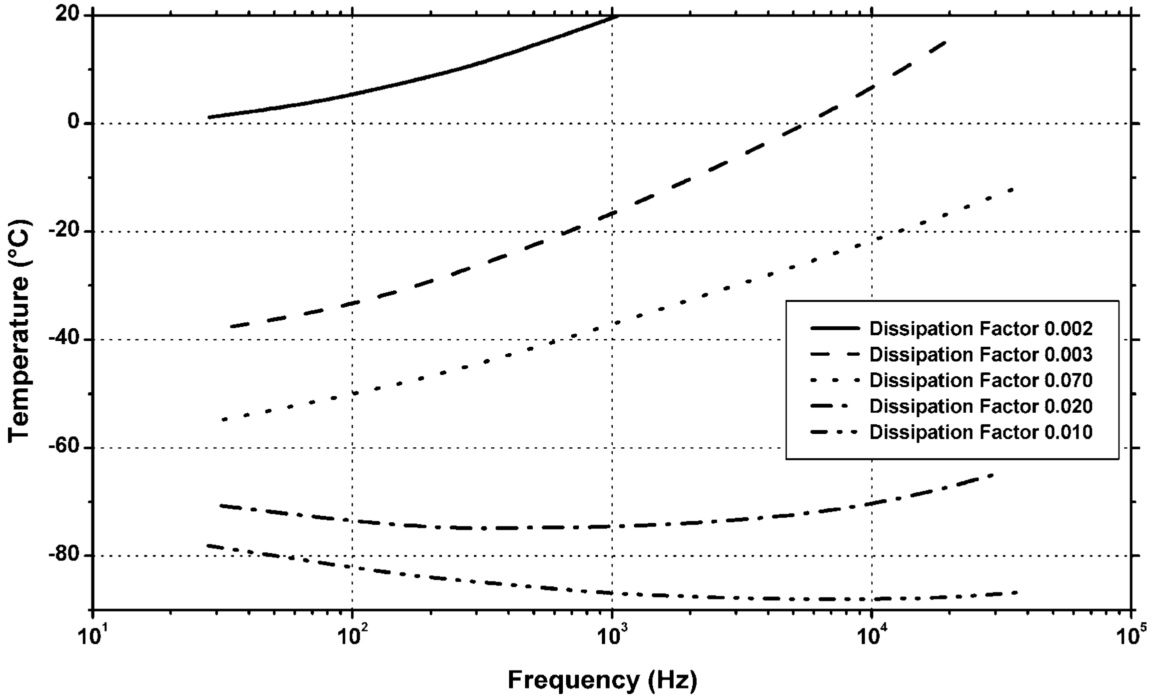


Figure 3.66. Dissipation factor variation with temperature and frequency for Ticona Celcon® M25/M90/M270—acetal copolymer resins at lower temperatures.

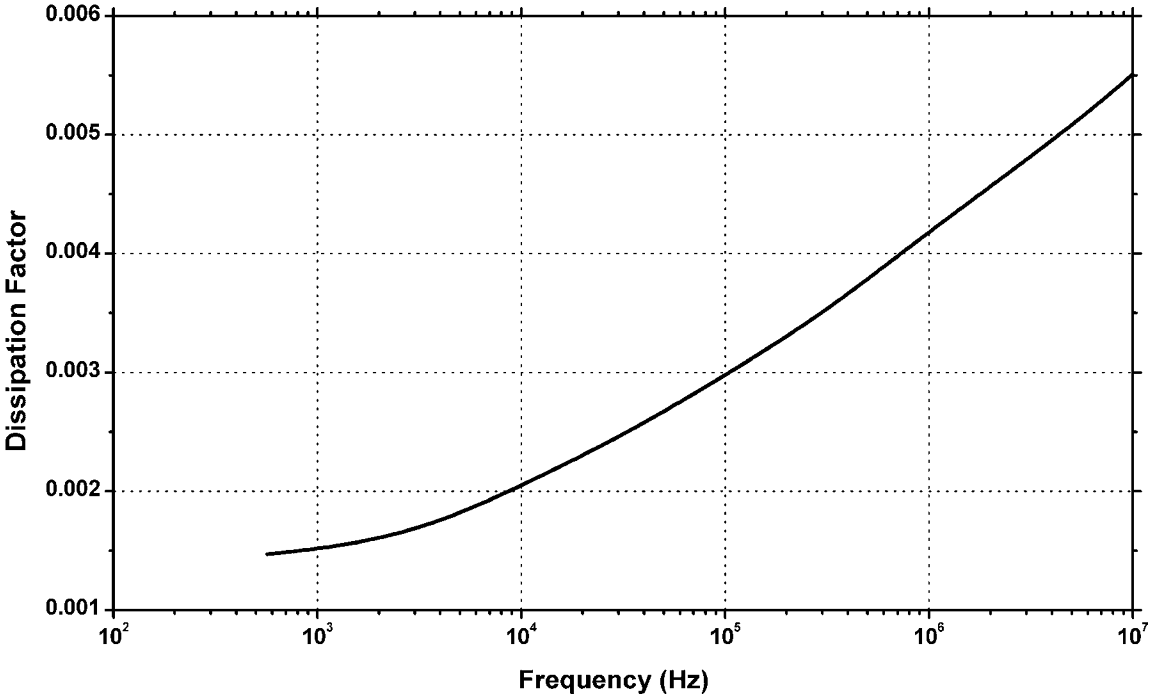


Figure 3.67. Dissipation factor vs. frequency at 25°C for BASF Hostaform® acetal copolymer resin.

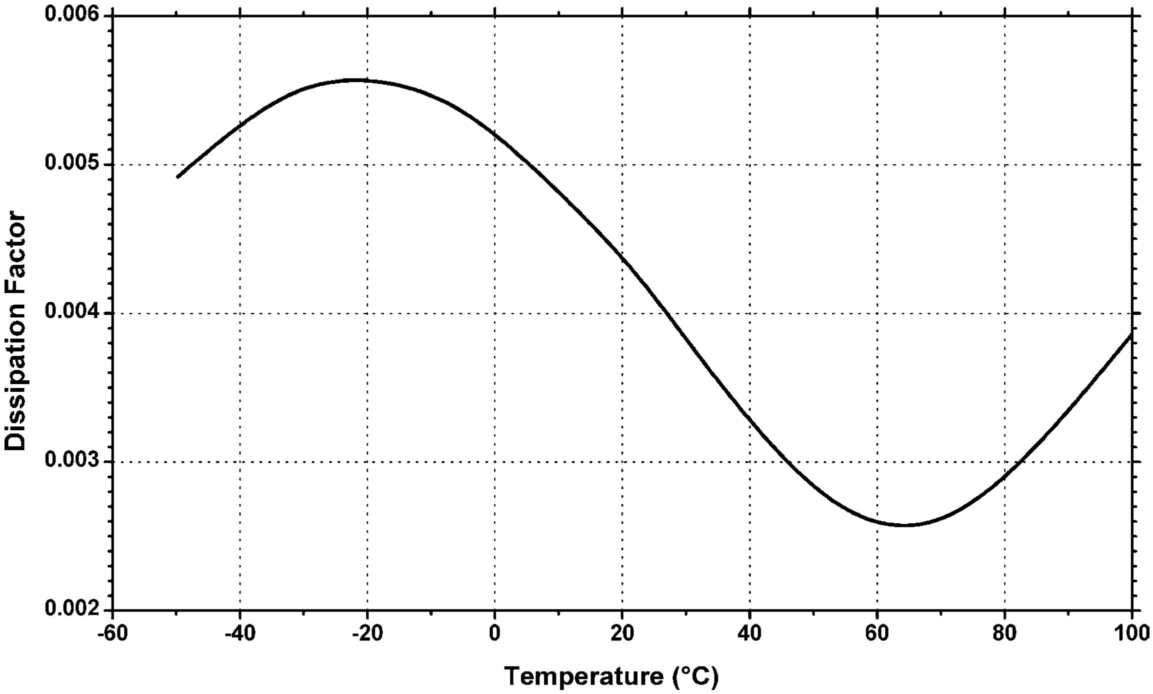


Figure 3.68. Dissipation factor vs. temperature at 10^5 Hz for BASF Hostaform® acetal copolymer resin.

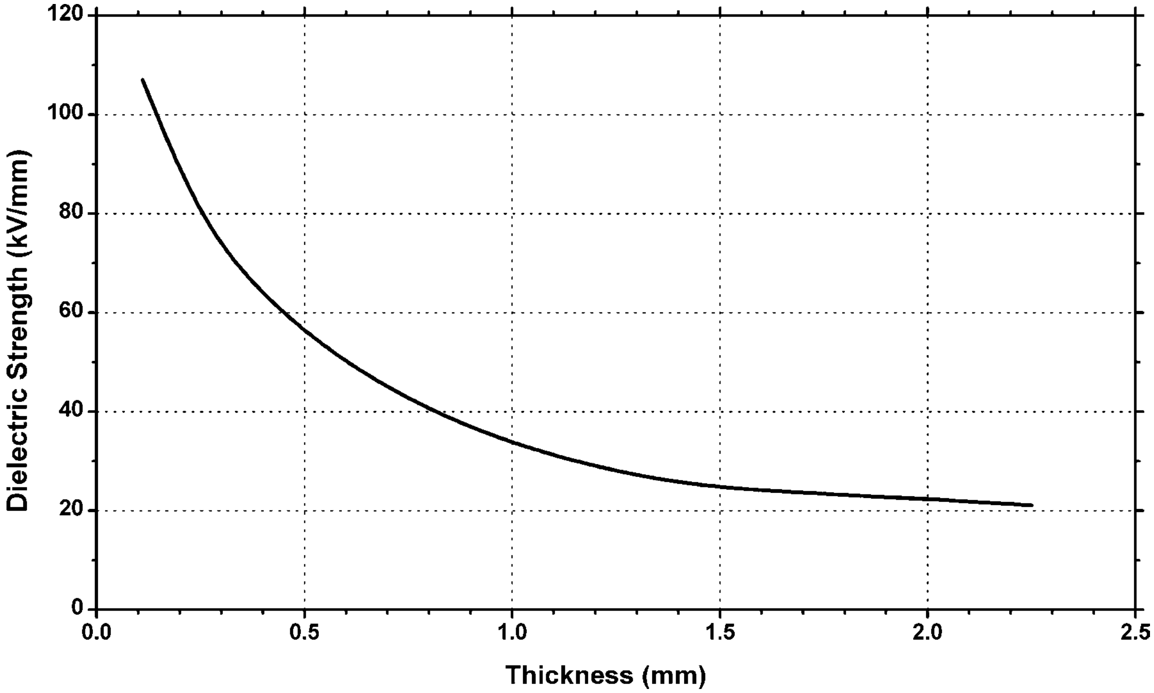


Figure 3.69. Dielectric strength vs. thickness for Ticona Celcon® M25/M90/M270 acetal copolymer resins.

3.4 Modified Polypropylene Ether (PPE)

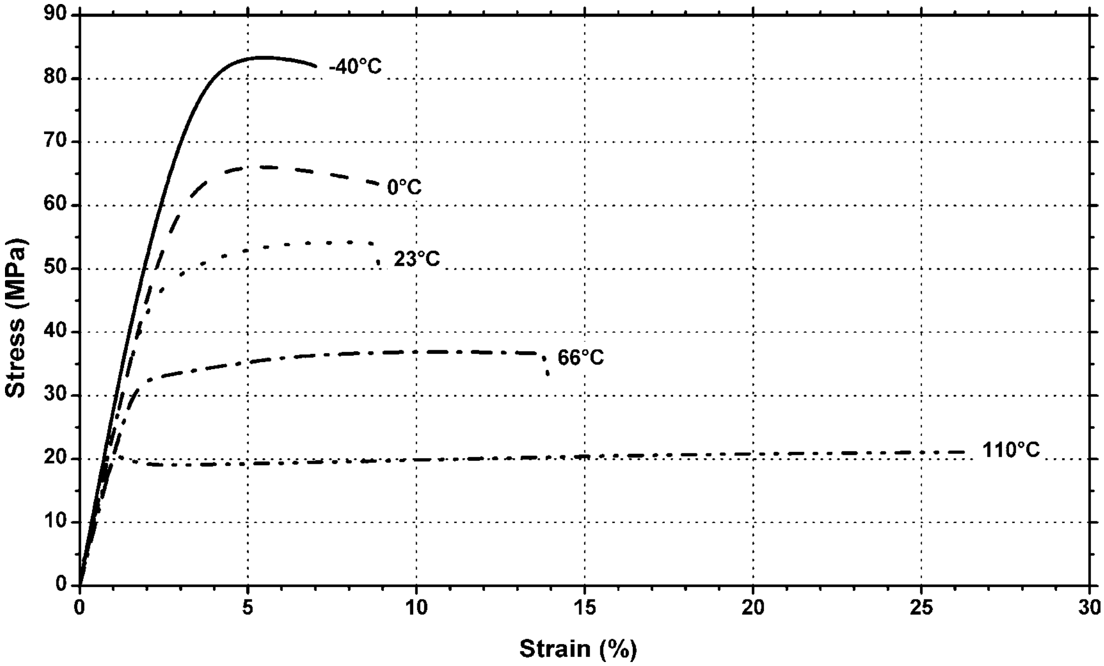


Figure 3.70. Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl® 731—general purpose, UL94 HB rated, PPE and polystyrene blend resin.

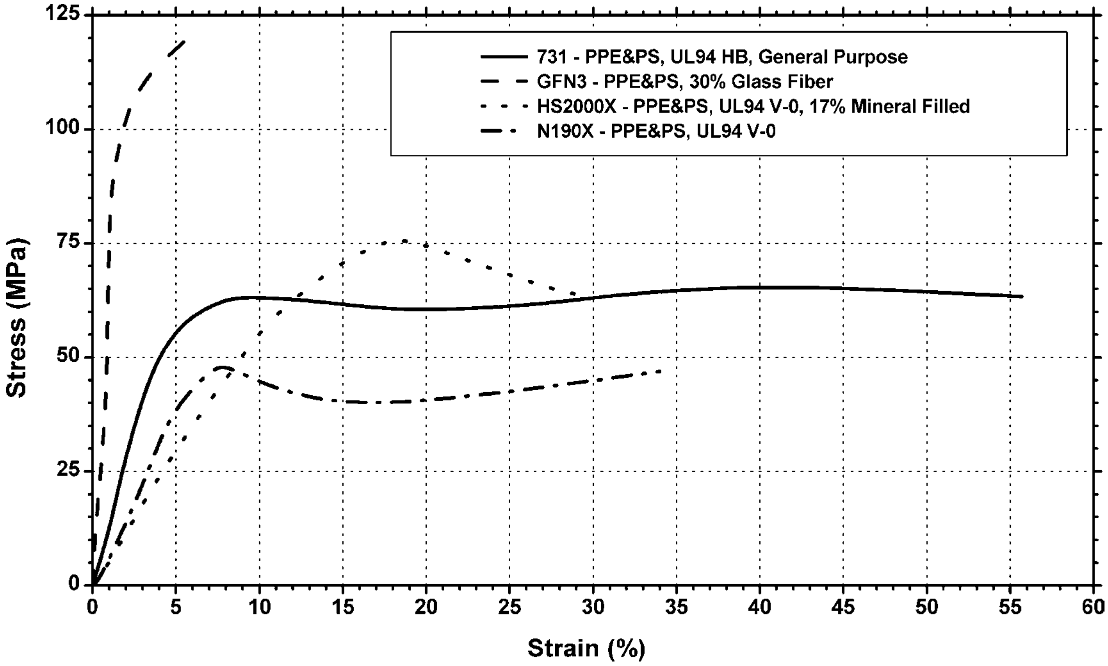


Figure 3.71. Stress vs. strain at 23°C for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

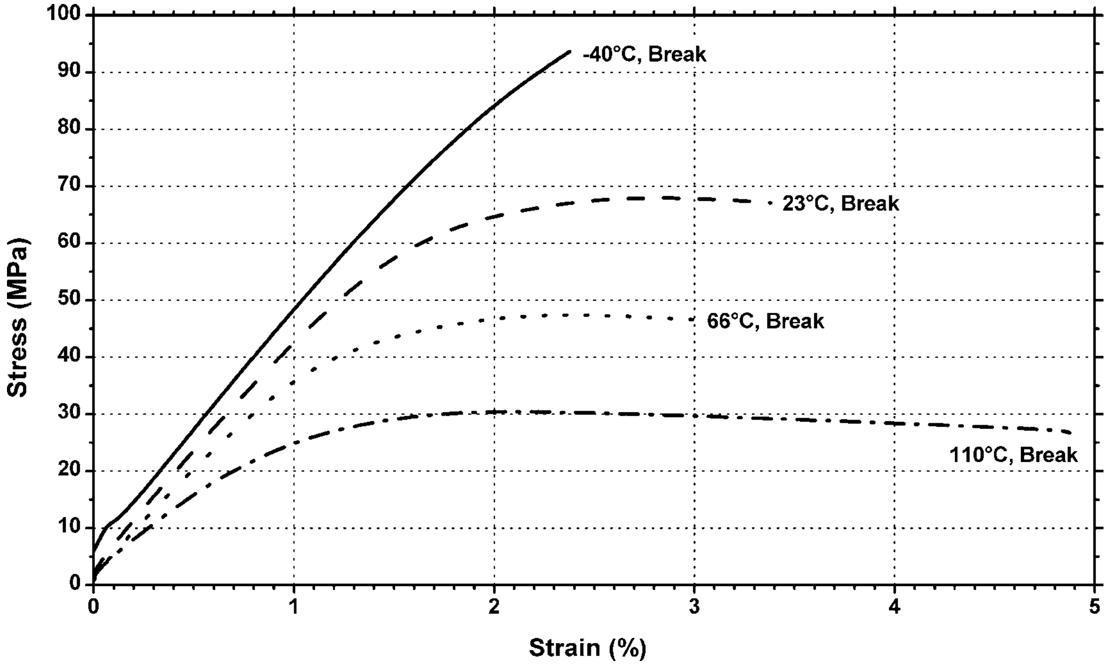


Figure 3.72. Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl® GFN1—10% glass fiber reinforced, PPE and polystyrene blend resin.

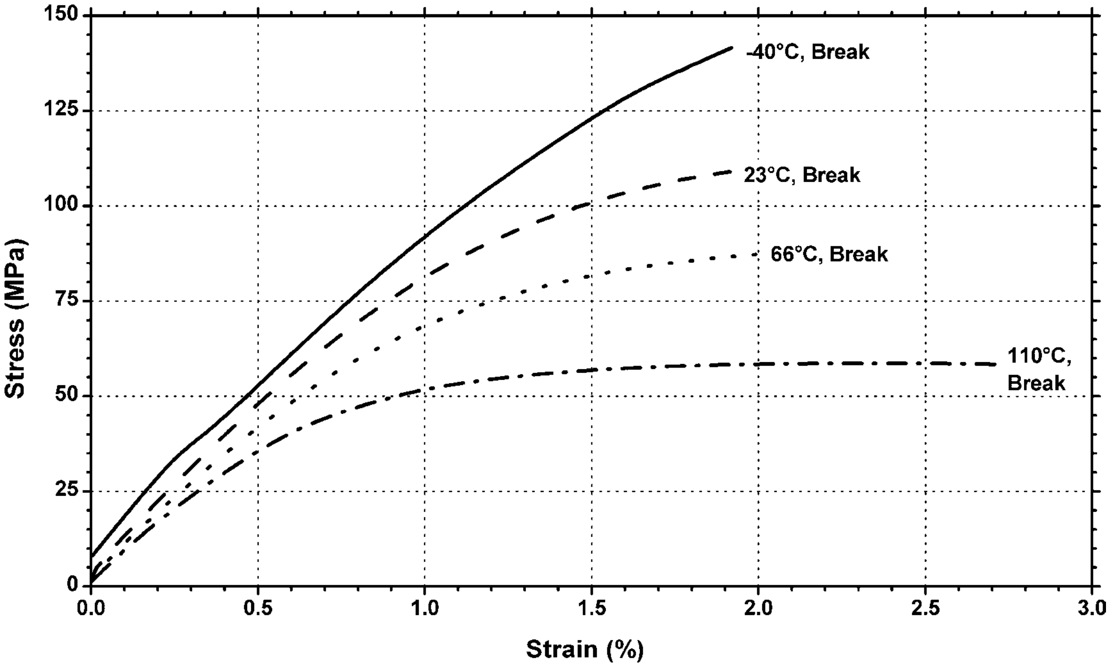


Figure 3.73. Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl® GFN3—30% glass fiber reinforced, PPE and polystyrene blend resin.

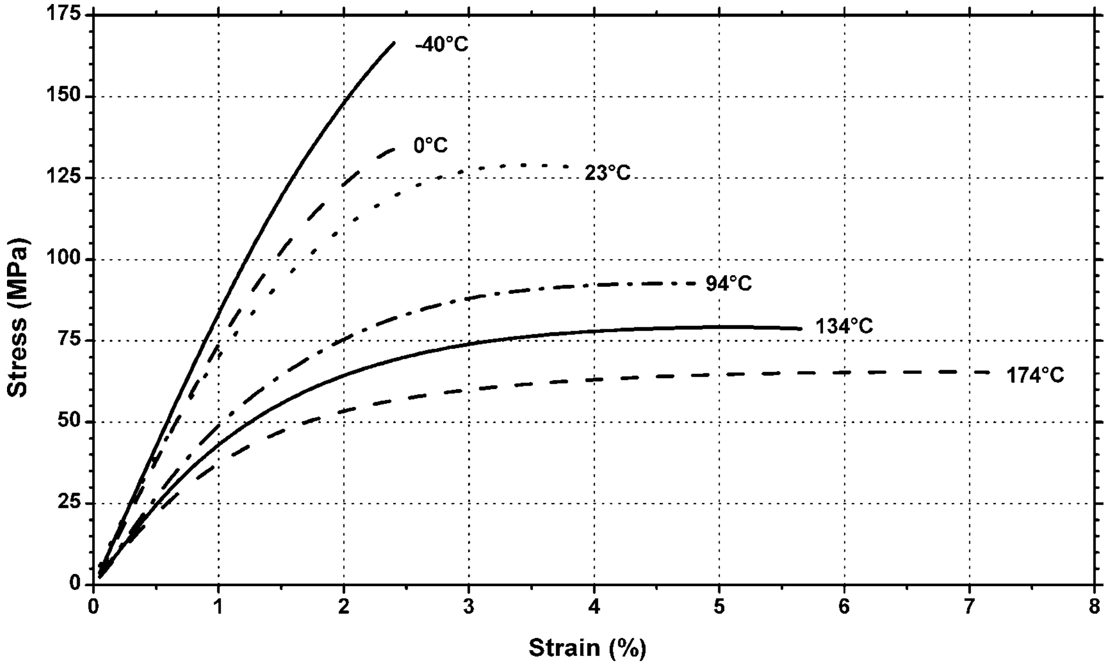


Figure 3.74. Stress vs. strain at various temperatures for SABIC Innovative Plastics Noryl GTX® GTX830—30% glass fiber reinforced, PPE, polystyrene, and polyamide blend resin.

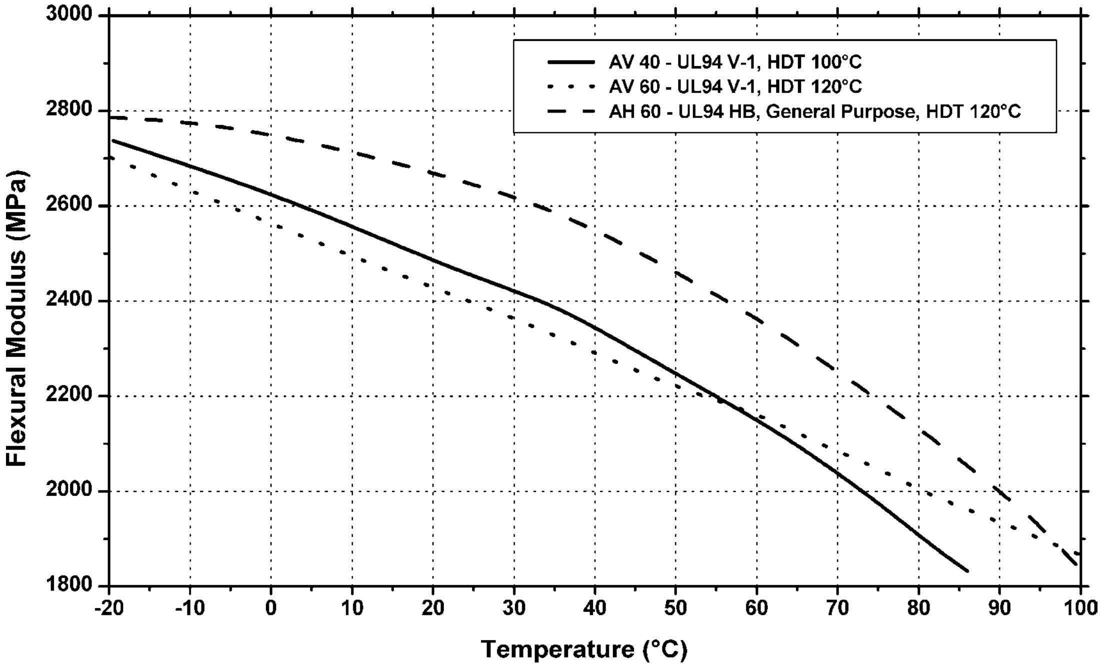


Figure 3.75. Flexural modulus vs. temperature for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

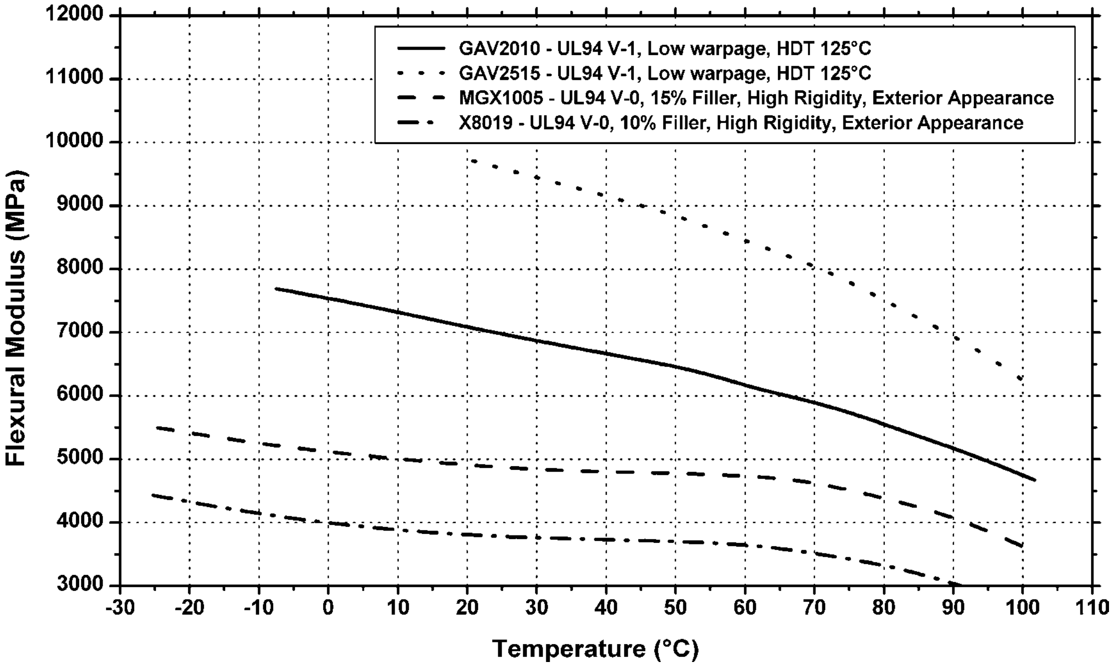


Figure 3.76. Flexural modulus vs. temperature for additional Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

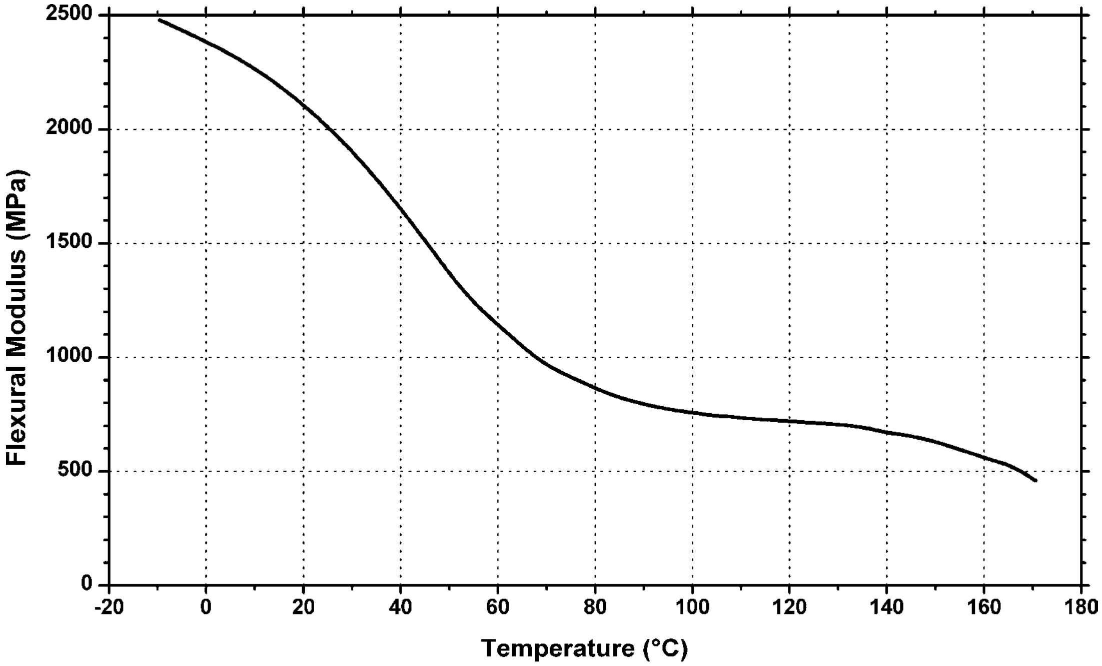


Figure 3.77. Flexural modulus vs. temperature for Mitsubishi Engineering Plastics Iupiace® NX-9000—heat and chemical resistant, SAE grade PPE and nylon 6 blend resin.

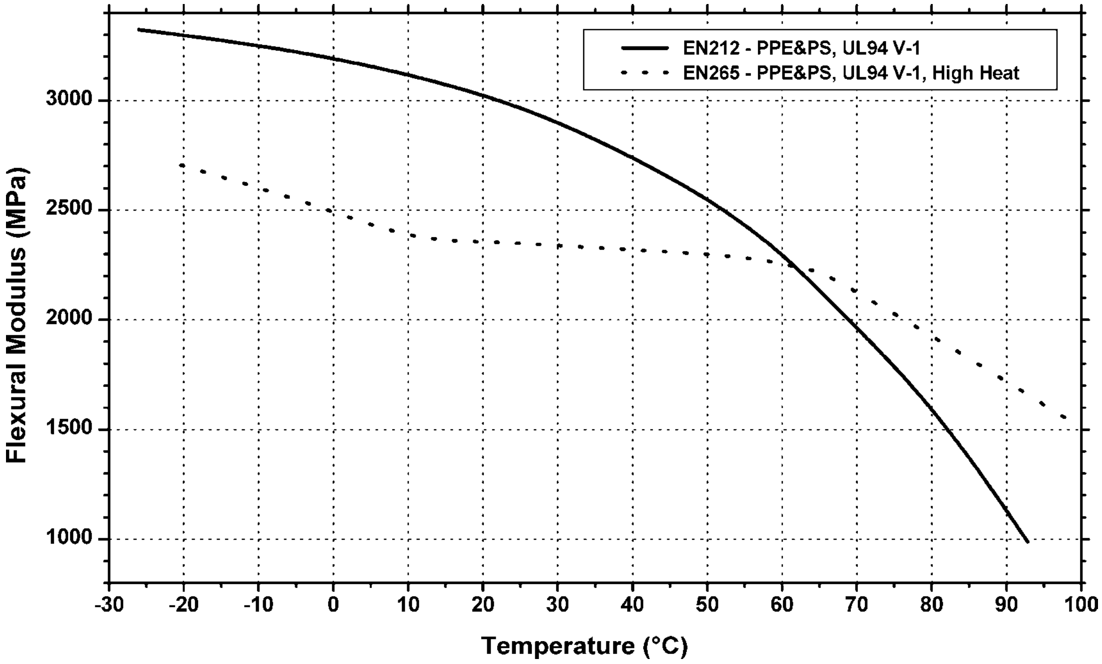


Figure 3.78. Flexural modulus vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

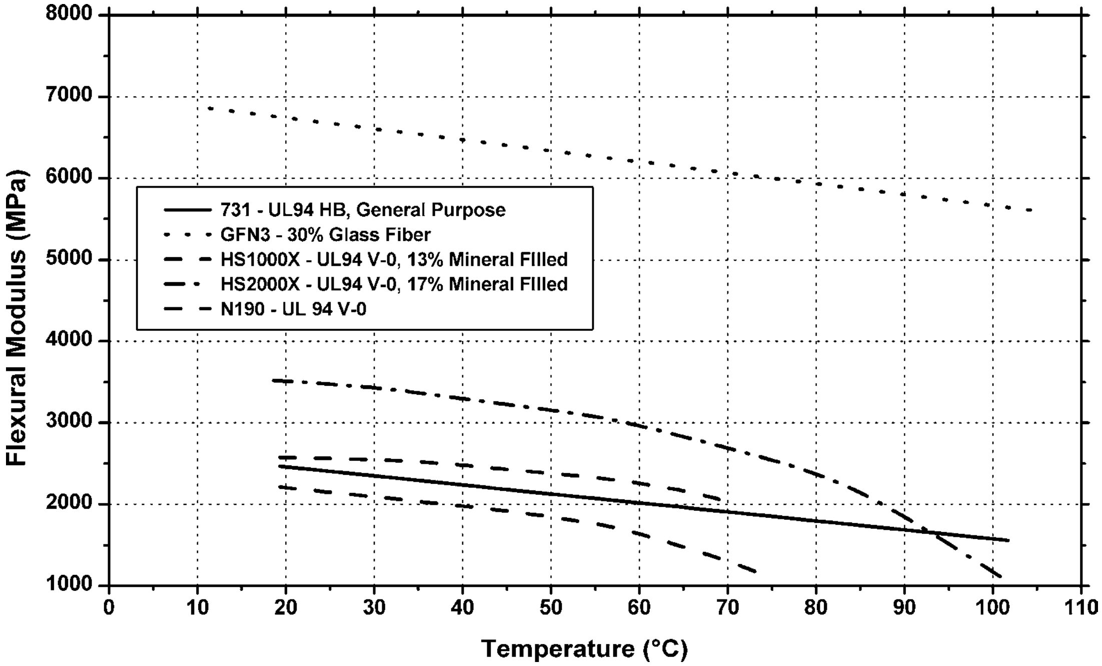


Figure 3.79. Flexural modulus vs. temperature for additional SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

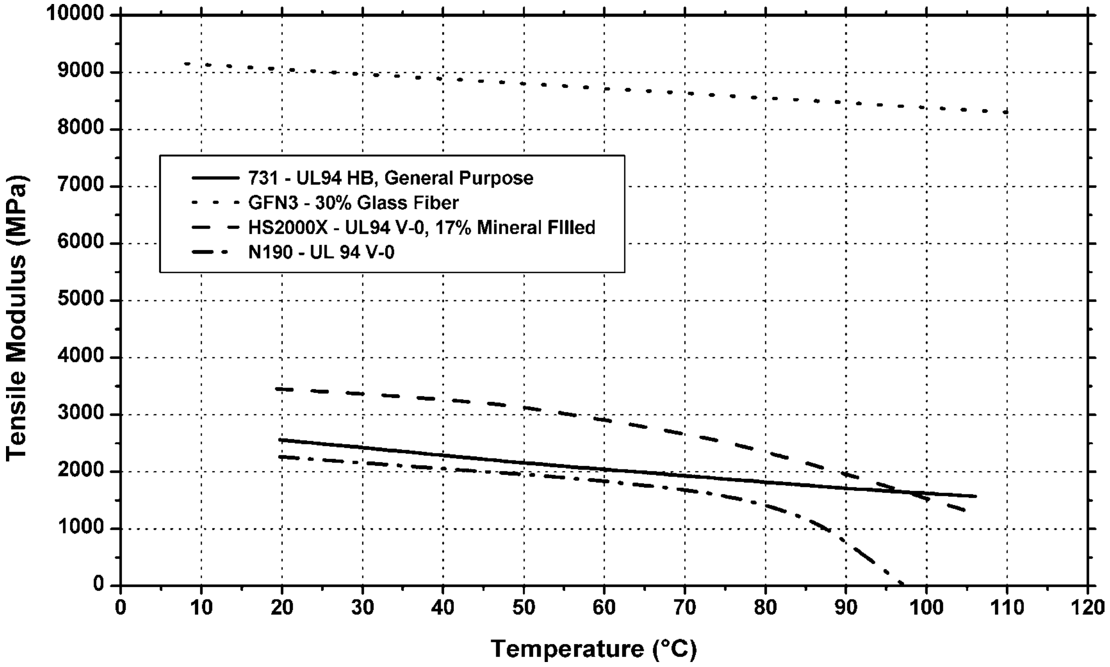


Figure 3.80. Tensile modulus vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

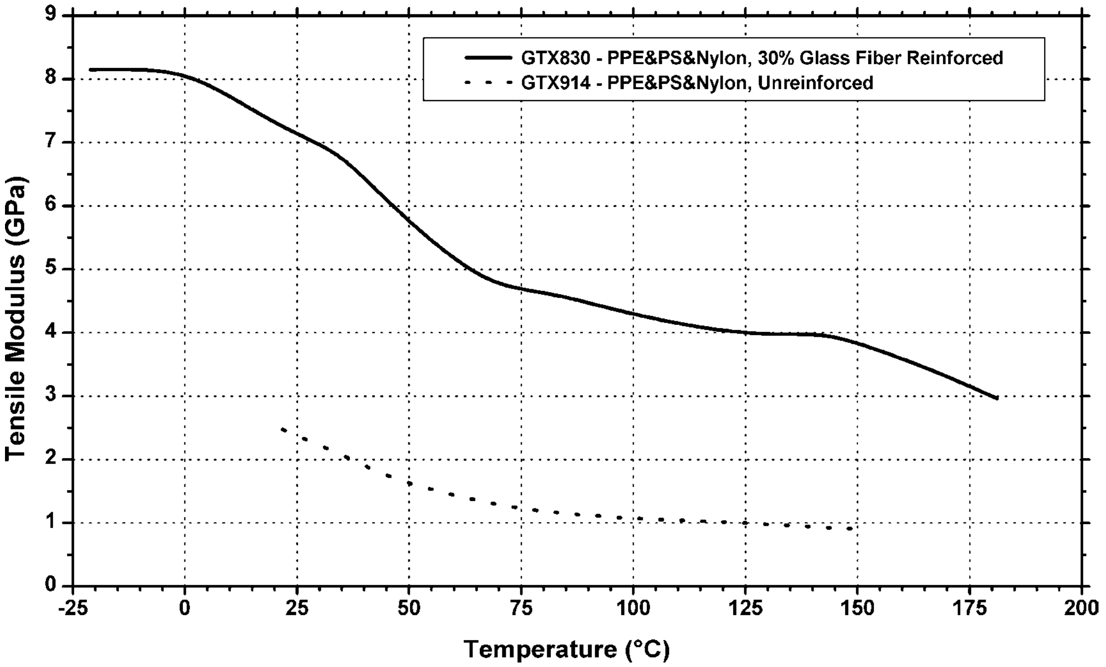


Figure 3.81. Tensile modulus vs. temperature for SABIC Innovative Plastics Noryl GTX® PPE, polystyrene, and polyamide blend resins.

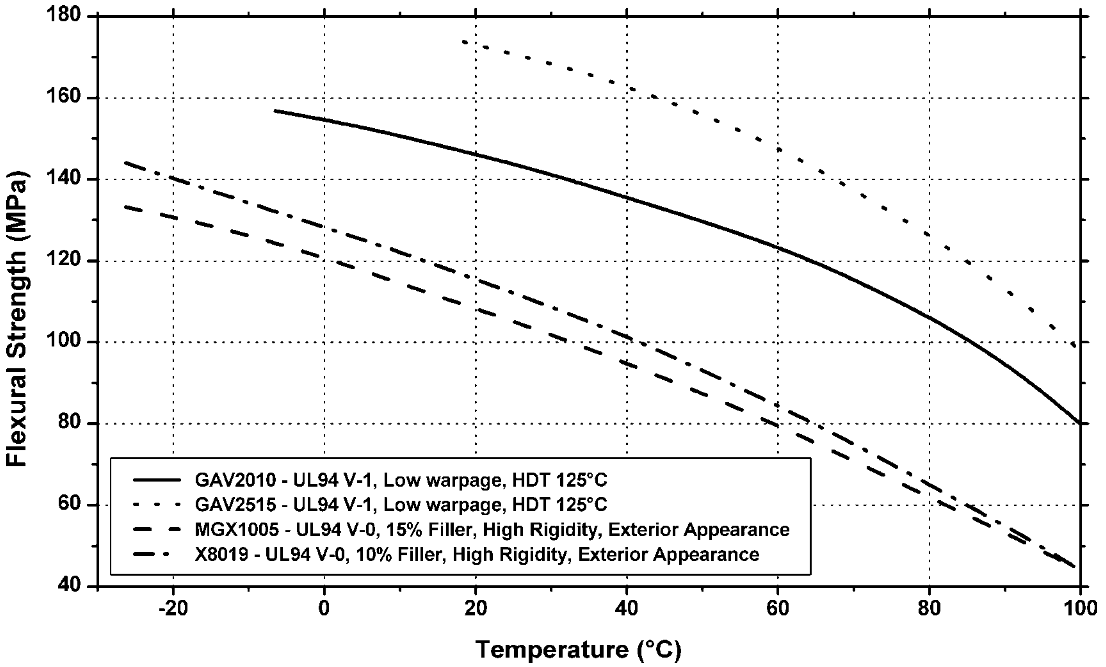


Figure 3.82. Flexural strength vs. temperature for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

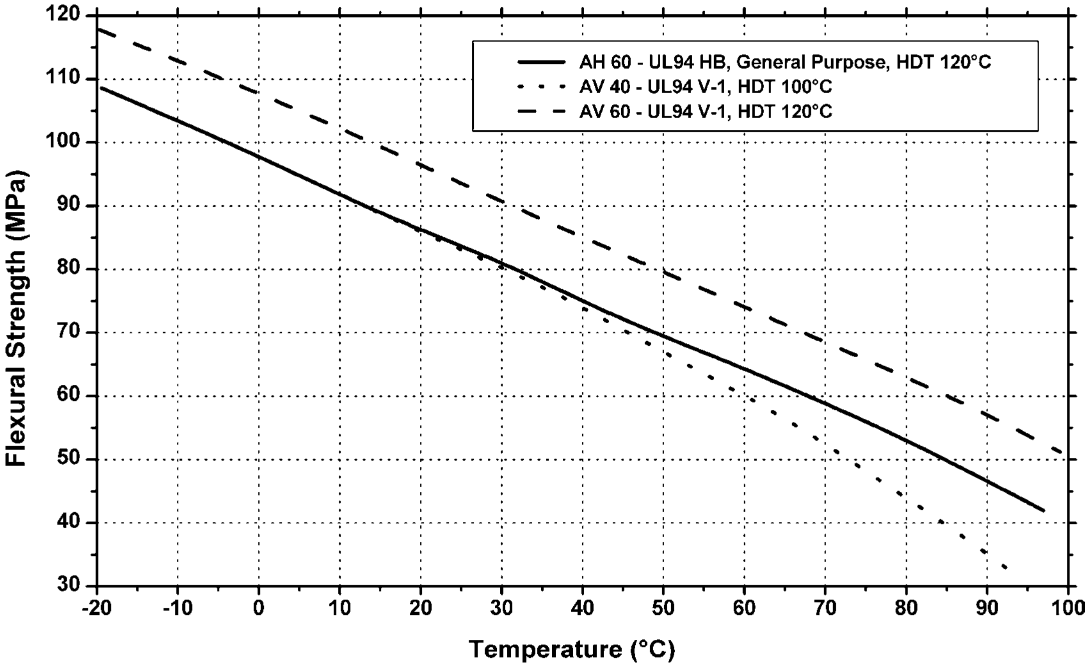


Figure 3.83. Flexural strength vs. temperature for additional Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

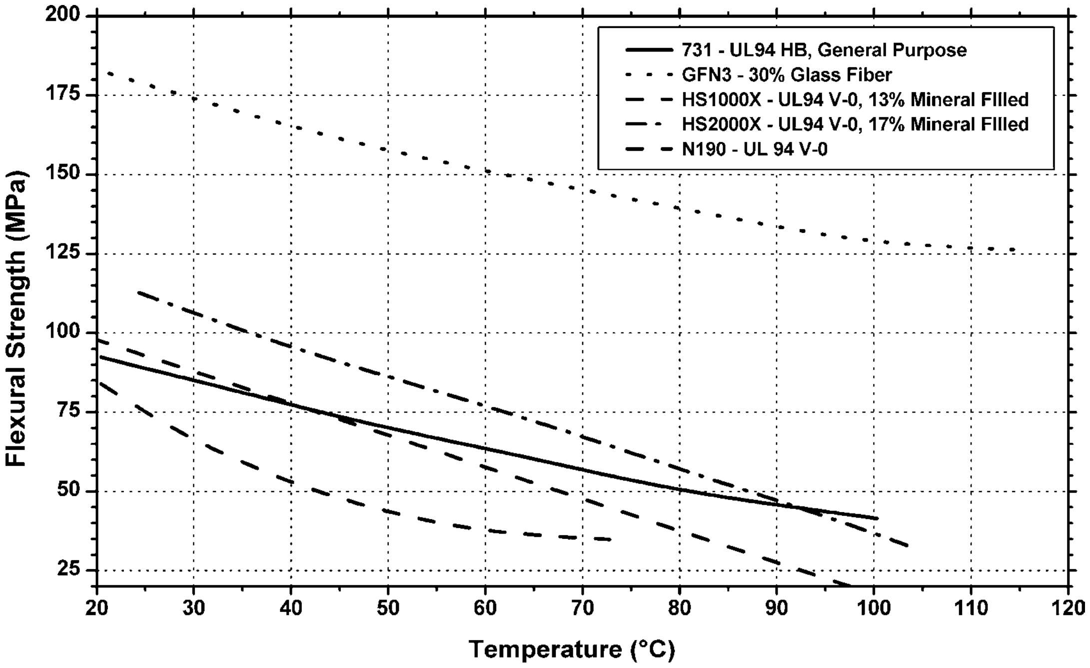


Figure 3.84. Flexural strength vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

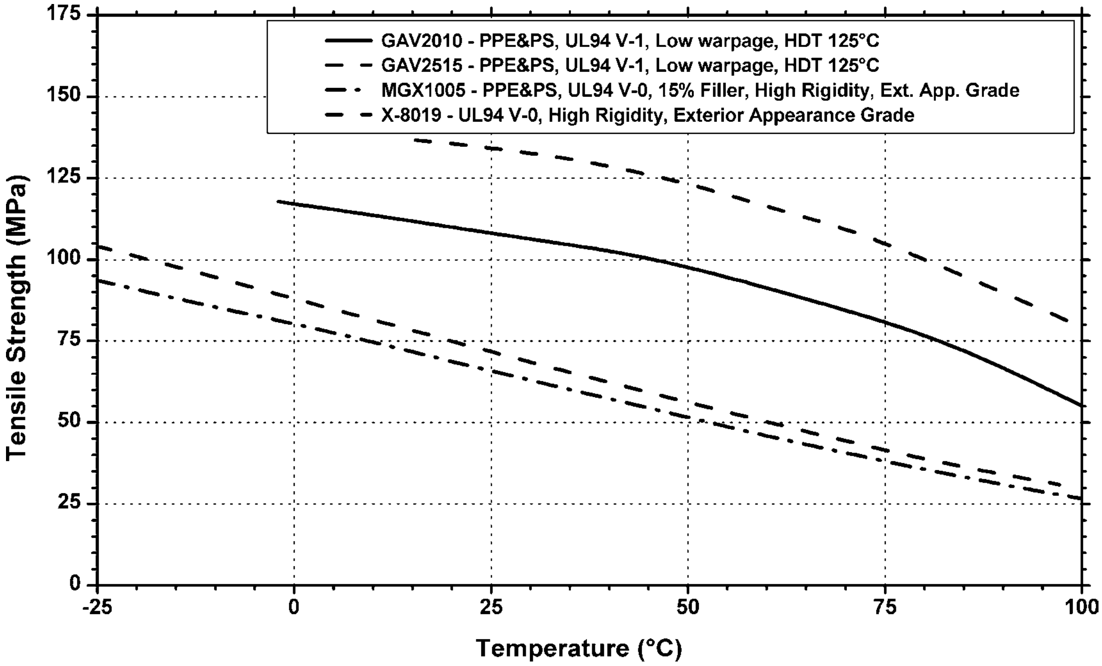


Figure 3.85. Tensile strength vs. temperature for additional Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

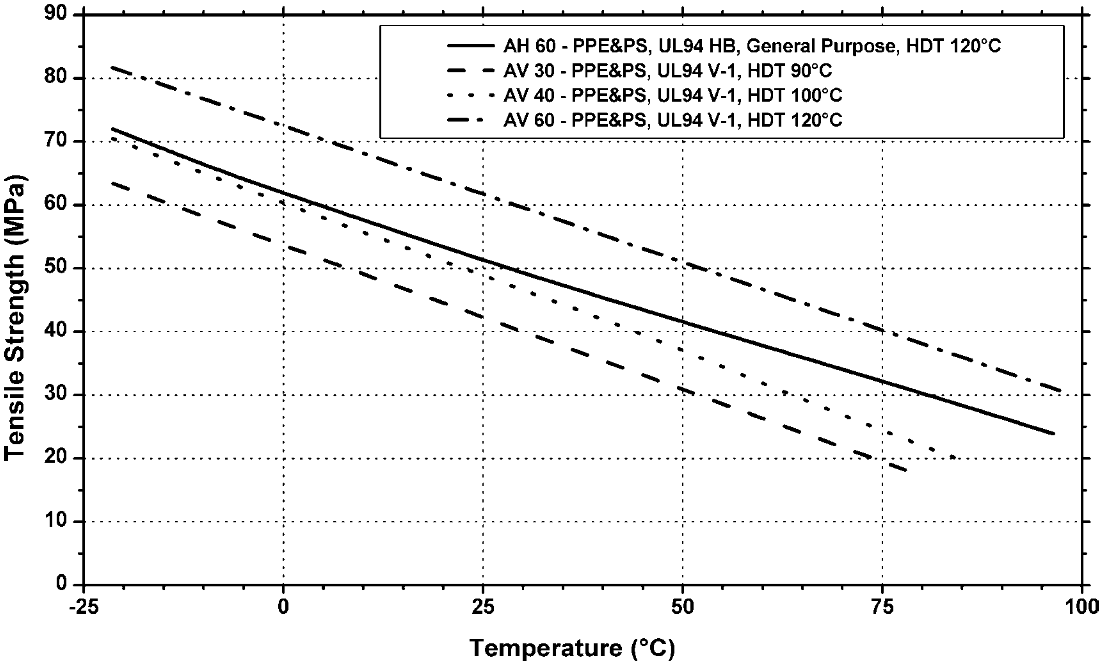


Figure 3.86. Tensile strength vs. temperature for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

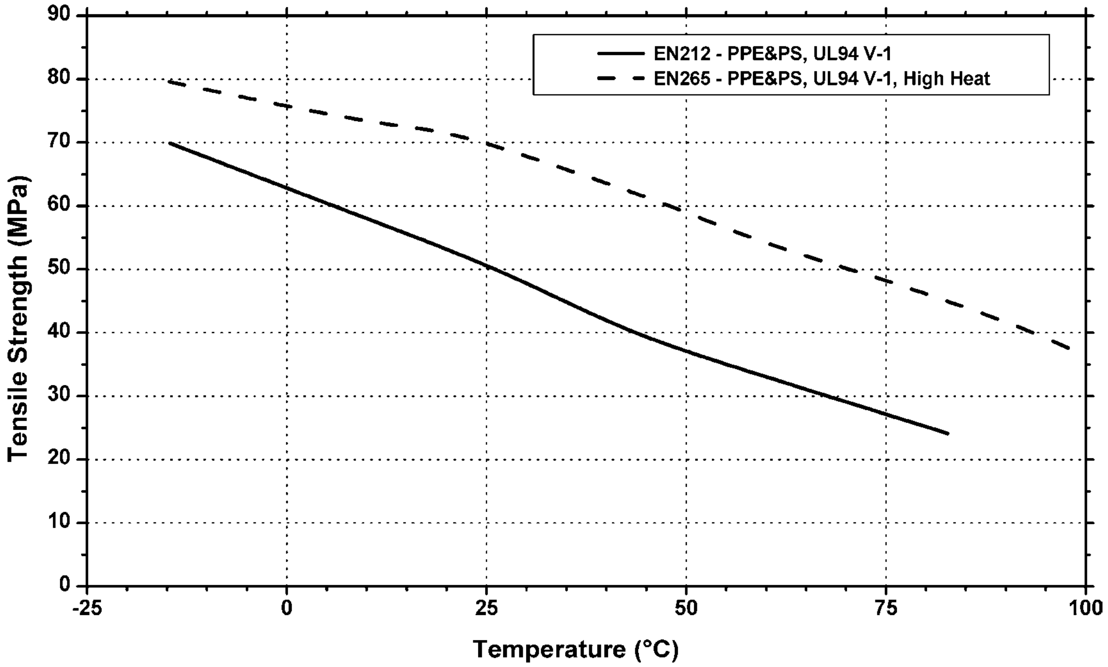


Figure 3.87. Tensile strength vs. temperature for additional SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

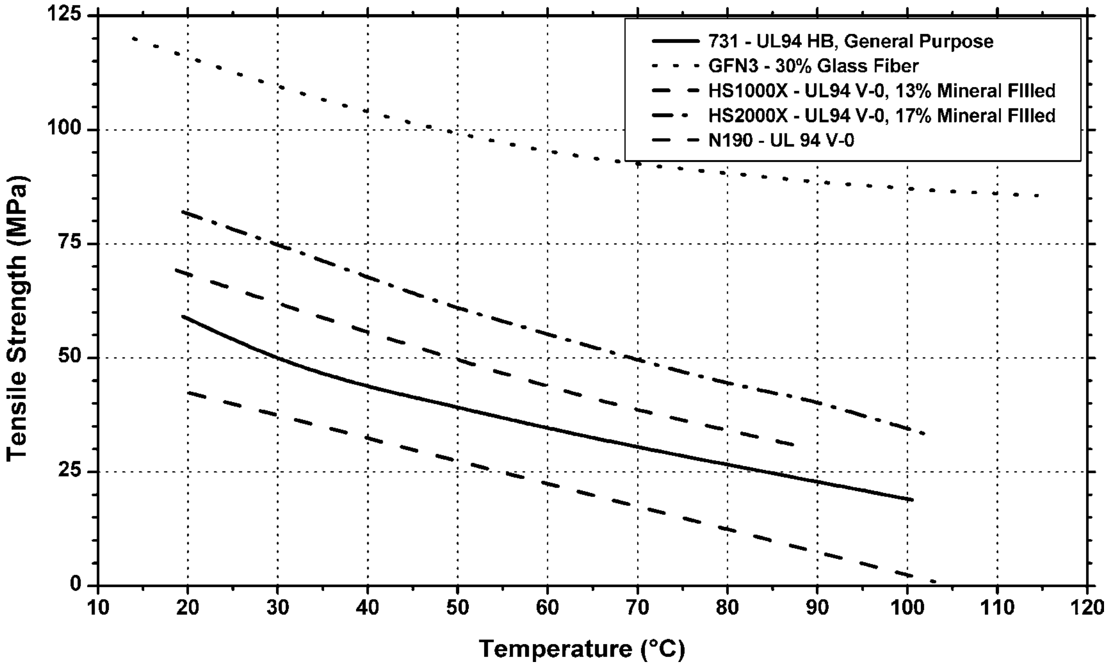


Figure 3.88. Tensile strength vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

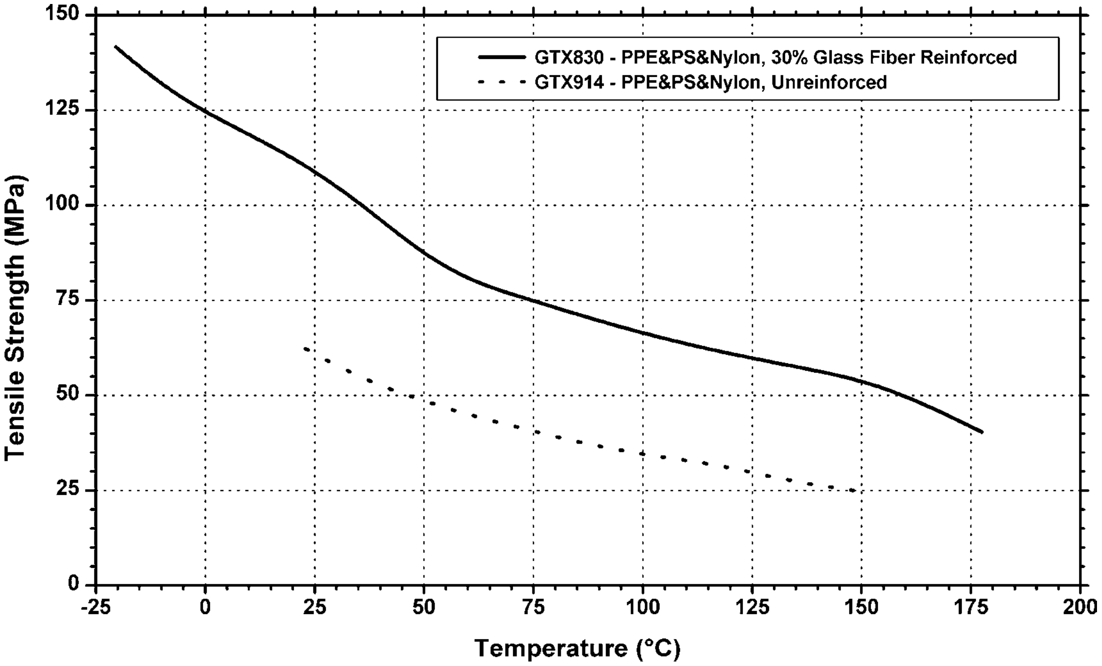


Figure 3.89. Tensile strength vs. temperature for SABIC Innovative Plastics Noryl GTX® PPE, polystyrene, and polyamide blend resins.

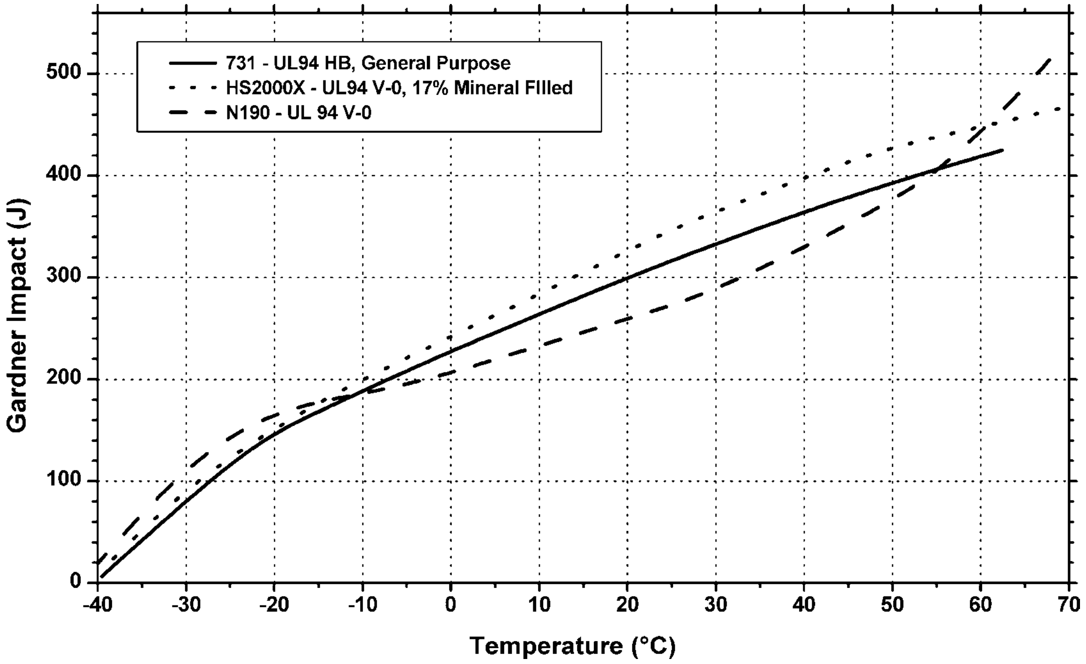


Figure 3.90. Gardner impact strength vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

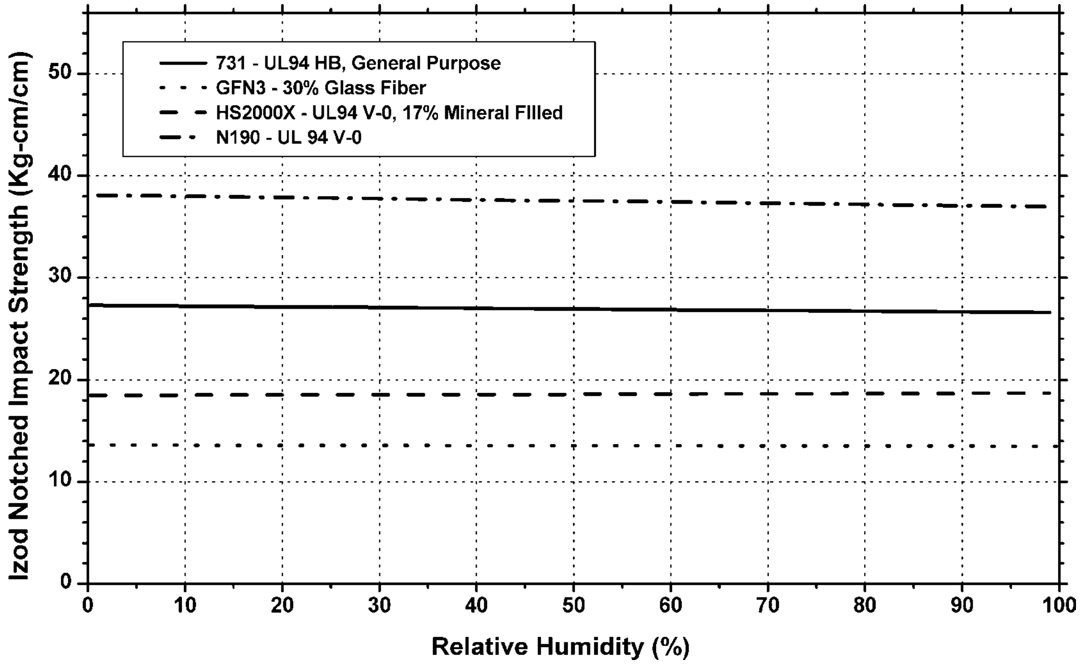


Figure 3.91. Izod impact strength vs. relative humidity for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

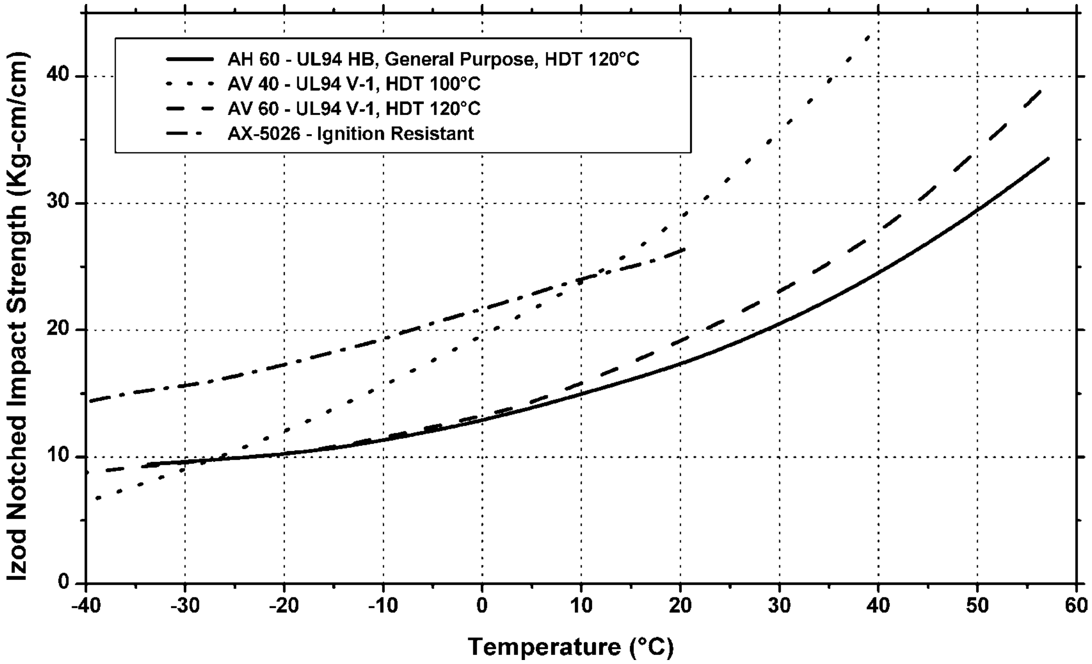


Figure 3.92. Izod impact strength vs. temperature for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

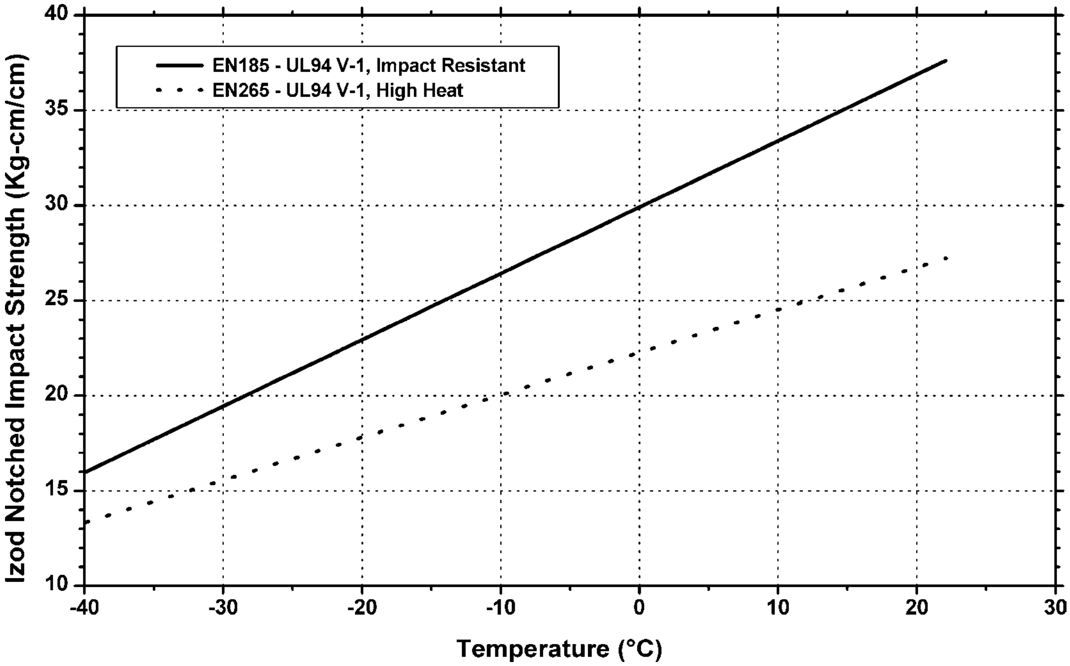


Figure 3.93. Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

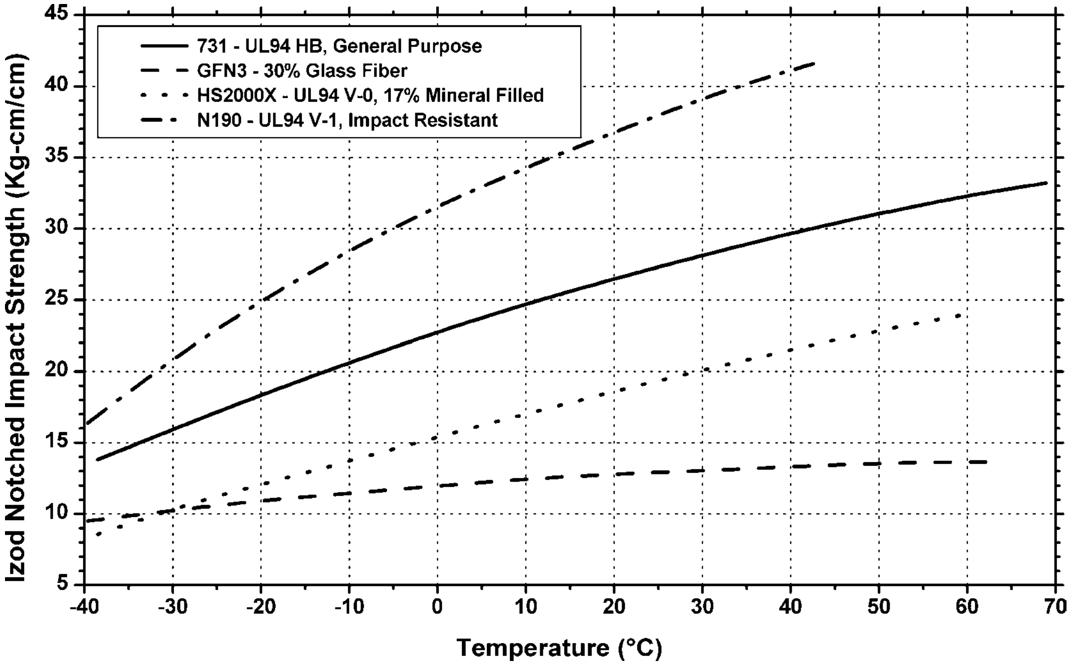


Figure 3.94. Izod impact strength vs. temperature for additional SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

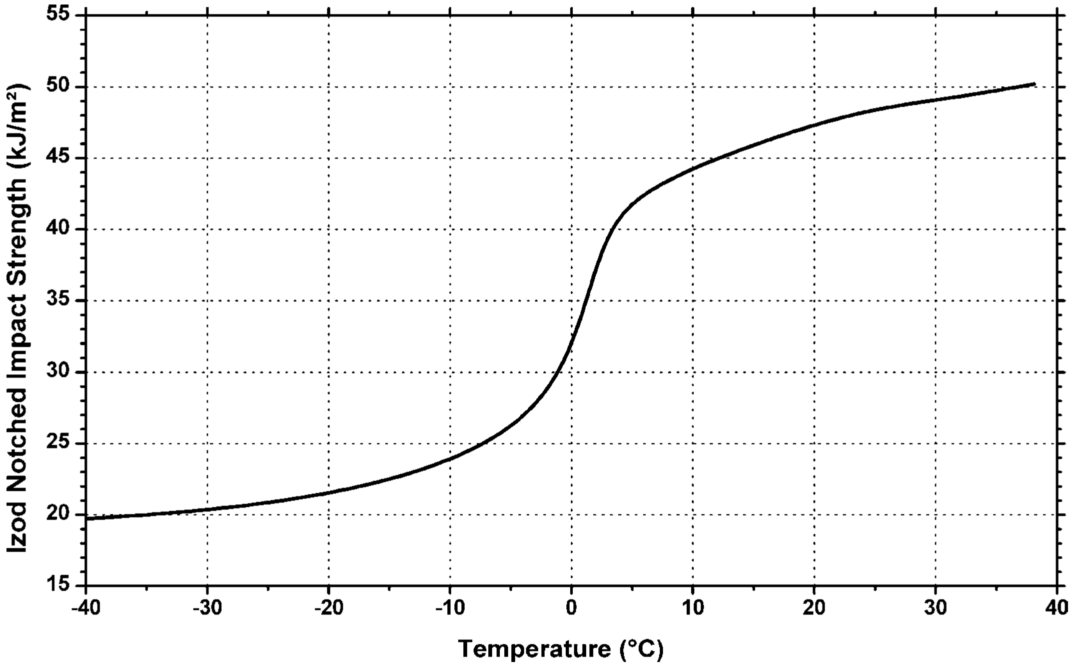


Figure 3.95. Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl GTX® GTX964—Unreinforced, impact modified PPE, polystyrene and polyamide blend resin.

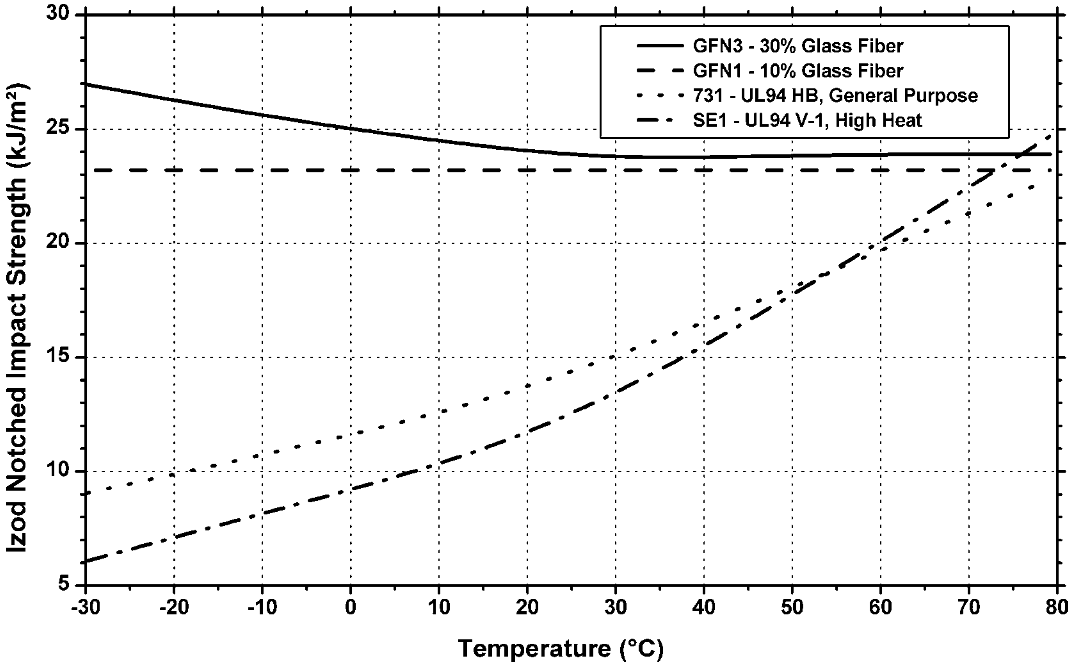


Figure 3.96. Izod impact strength vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

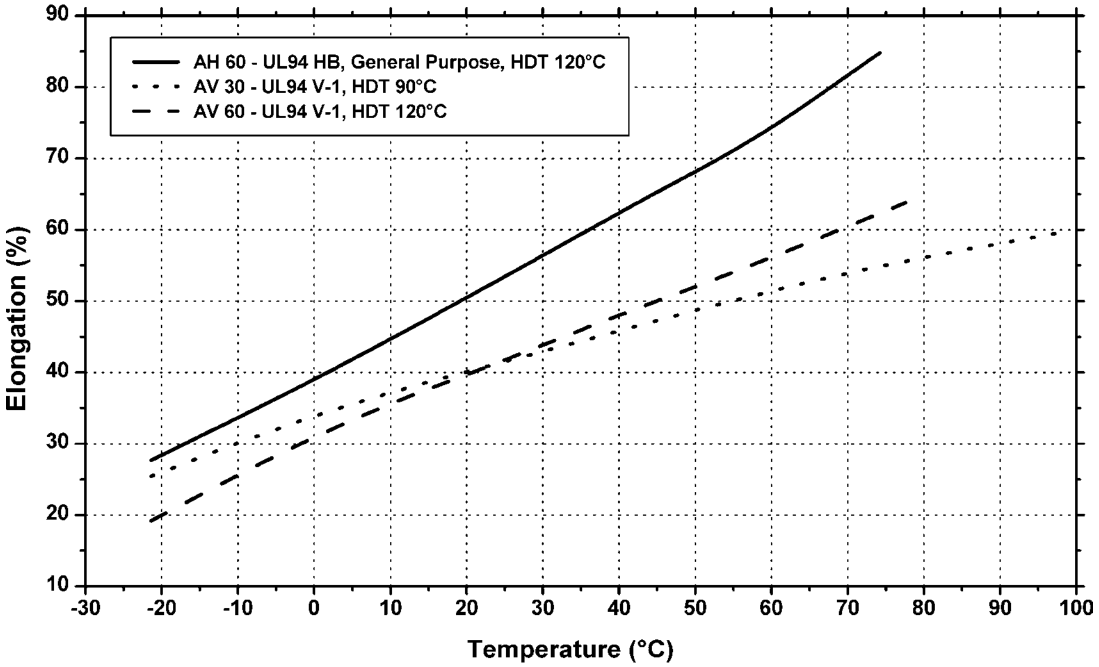


Figure 3.97. Elongation vs. temperature for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resin.

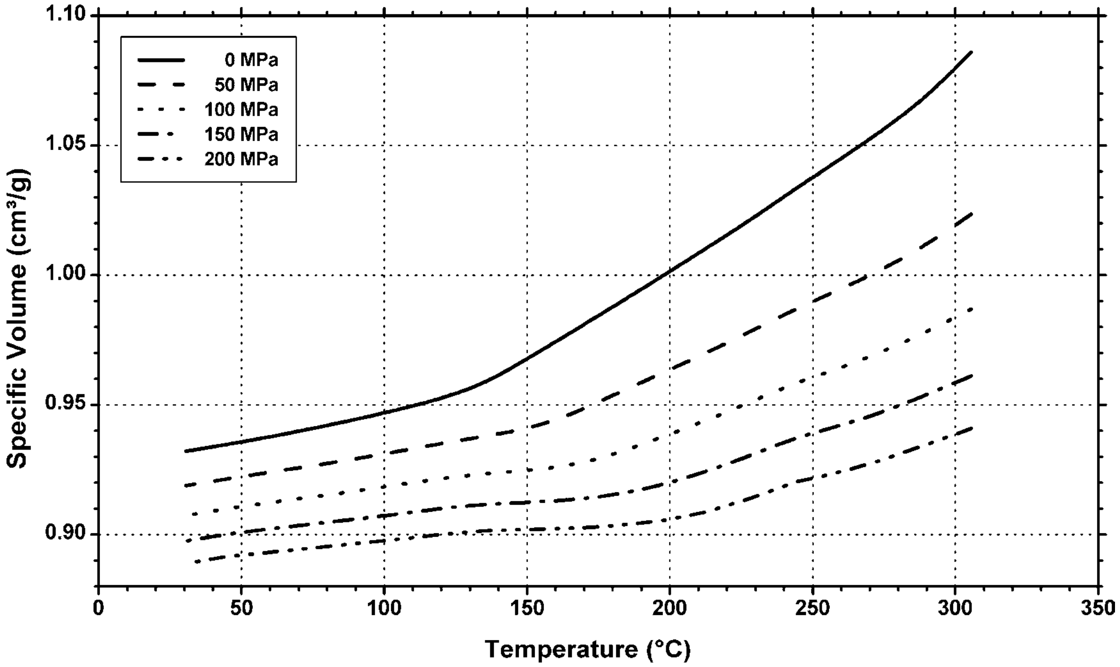


Figure 3.98. Pressure-specific volume-temperature (PVT) for SABIC Innovative Plastics Noryl® 731—general purpose, UL94 HB rated, PPE/polystyrene blend resin.

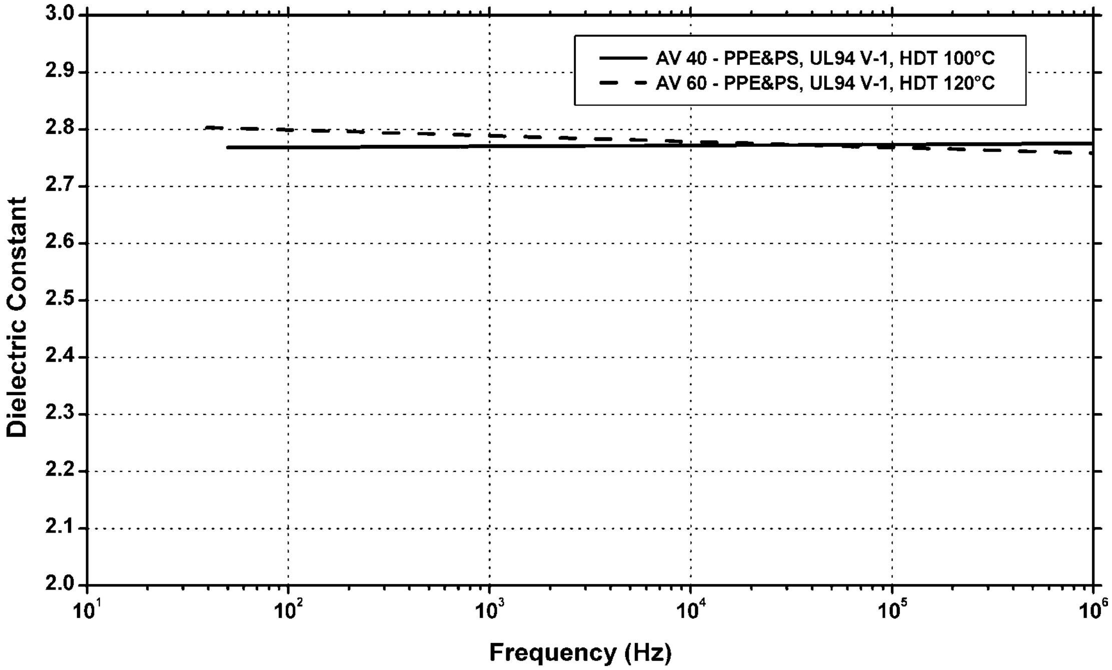


Figure 3.99. Dielectric constant vs. frequency for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

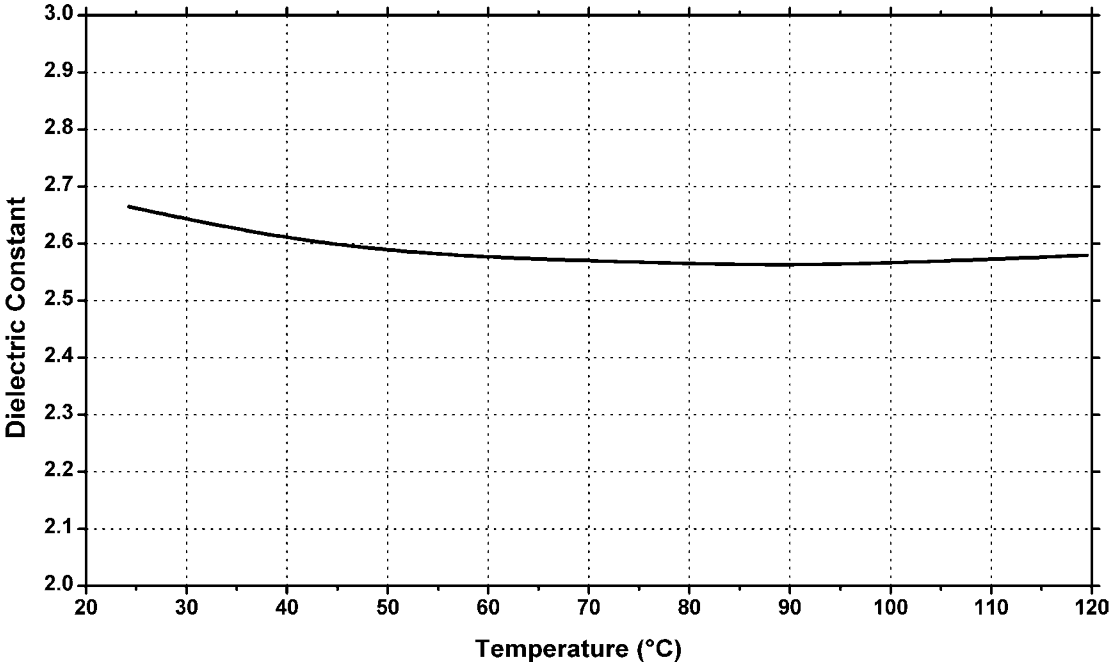


Figure 3.100. Dielectric constant vs. temperature for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

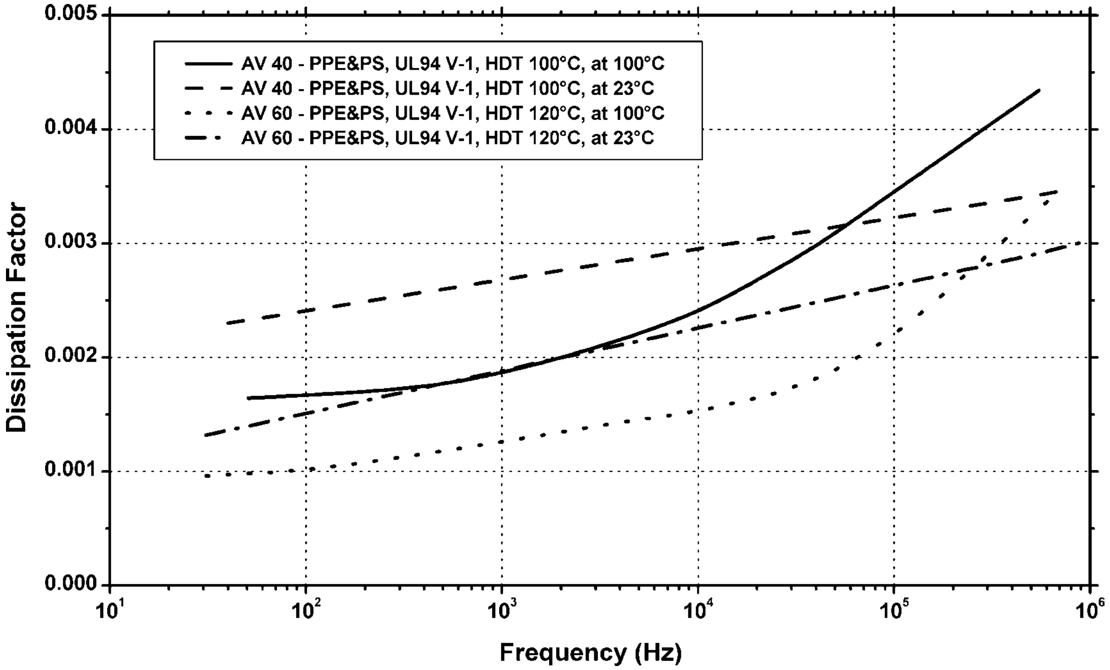


Figure 3.101. Dissipation factor vs. frequency and temperature for Mitsubishi Engineering Plastics Iupiace® AV 40—UL94 V-1 rated, HDT 100°C PPE and polystyrene blend resin.

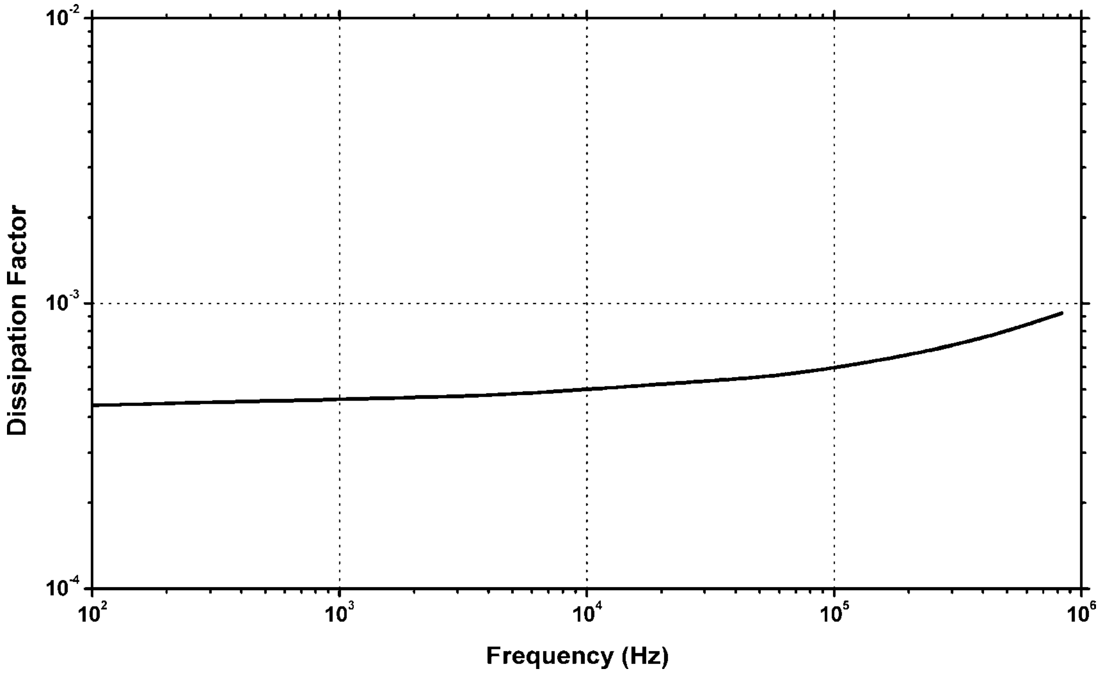


Figure 3.102. Dissipation factor vs. frequency for SABIC Innovative Plastics Noryl® PPE and polystyrene blend resins.

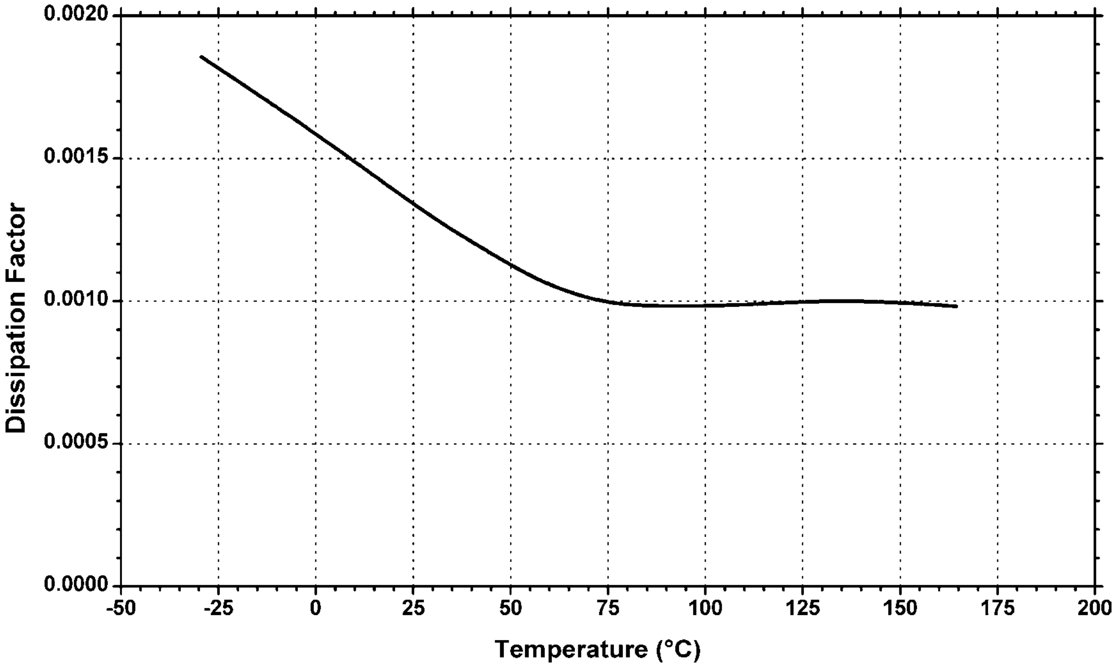


Figure 3.103. Dissipation factor vs. temperature at 60 Hz for Mitsubishi Engineering Plastics Iupiace® AV 60—UL94 V-1 rated, HDT 120°C PPE and polystyrene blend resin.

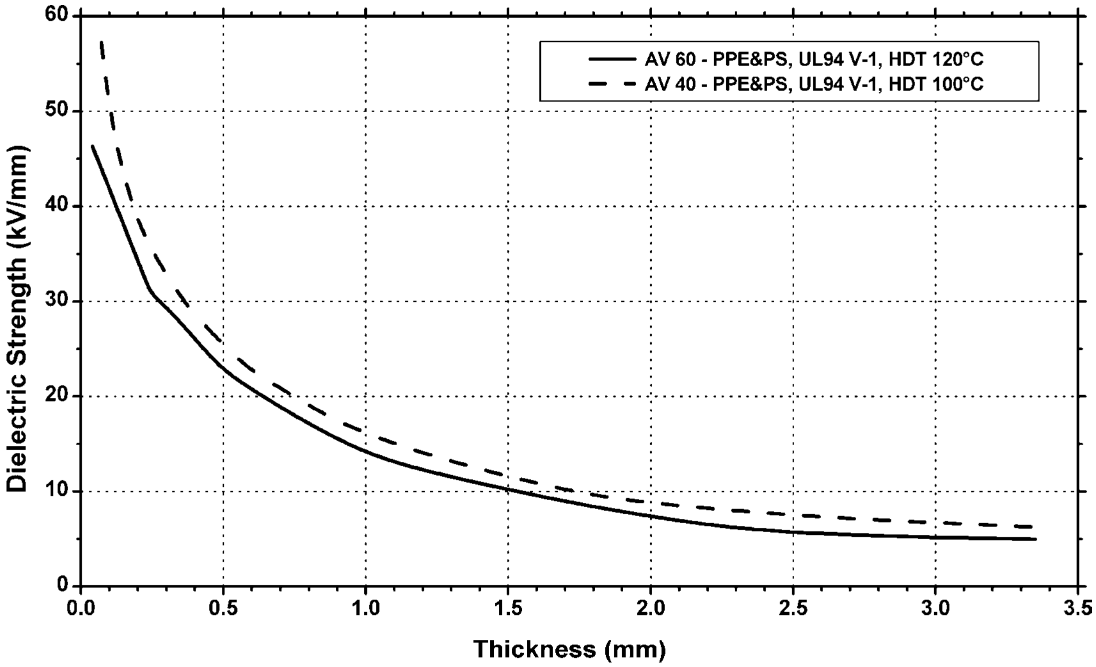


Figure 3.104. Dielectric strength vs. thickness for Mitsubishi Engineering Plastics Iupiace® PPE and polystyrene blend resins.

4 Polyesters

4.1 Background

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 Fig. 4.1.

While the actual commercial route of making the polyesters may be more involved, 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 dominant materials in this plastics family are PC, polyethylene terephthalate (PET), and polybutylene terephthalate (PBT). Thermoplastic polyesters are similar in properties to nylon 6 and nylon 66, but have lower water absorption and higher dimensional stability than the nylons.

4.1.1 Polycarbonate (PC)

Theoretically, PC is formed from the reaction of bis-phenol A and carbonic acid. The structures of these two monomers are given in Fig. 4.2.

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

PC performance properties include:

- High impact resistance, virtually no breakage, and toughness at low temperatures
- "Clear as glass" clarity
- High heat resistance
- Dimensional stability
- Resistant to ultraviolet light allowing exterior use
- Flame retardancy

Applications include glazing, safety shields, lenses, casings and housings, light fittings, microwavable kitchenwares, sterilizable medical apparatus, and CDs.

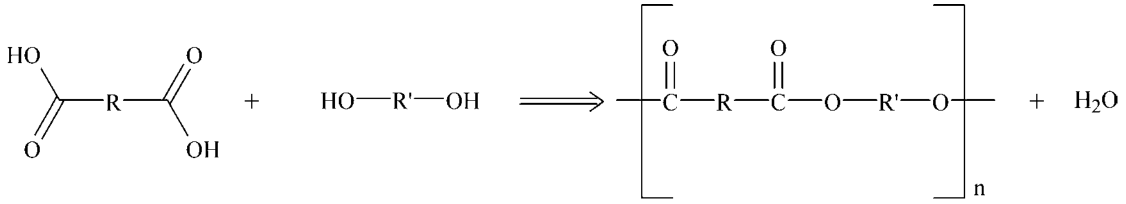


Figure 4.1. The formation of polyester by the condensation of a diacid and dialcohol.

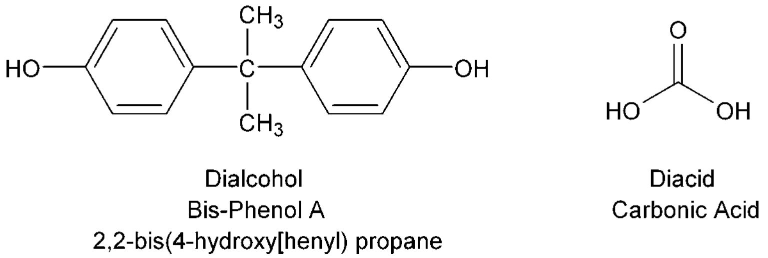


Figure 4.2. Chemical structures of monomers used to make polycarbonate polyester.

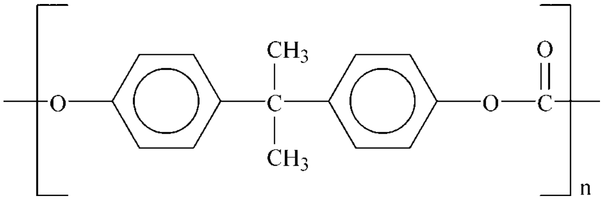


Figure 4.3. Chemical structure of polycarbonate polyester.

4.1.2 Polybutylene Terephthalate (PBT)

PBT is a semicrystalline, white, or off-white polyester similar to PET in composition as well as properties. 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 Fig. 4.4.

PBT performance properties include

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

4.1.3 Polyethylene Terephthalate (PET)

PET polyester 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 Fig. 4.5.

PET has good barrier properties against oxygen and carbon dioxide. Therefore, it is utilized in bottles for mineral water. Other applications include food trays for oven use, roasting bags, audio/video tapes, and mechanical components.

4.1.4 Liquid Crystalline Polymers (LCPs)

LCPs are a relatively unique class of partially crystalline aromatic polyesters based on 4-hydroxybenzoic acid and related monomers shown in Fig. 4.6. LCPs 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, 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. The 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 Ticona Vectra® A950 LCP is shown in Fig. 4.7.

4.1.5 Polycyclohexylene Dimethylene Terephthalate (PCT)

PCT is a high-temperature polyester that possesses the chemical resistance, processability, and dimensional stability of PET and PBT polyesters. However, the aliphatic cyclic ring as shown in Fig. 4.8 imparts

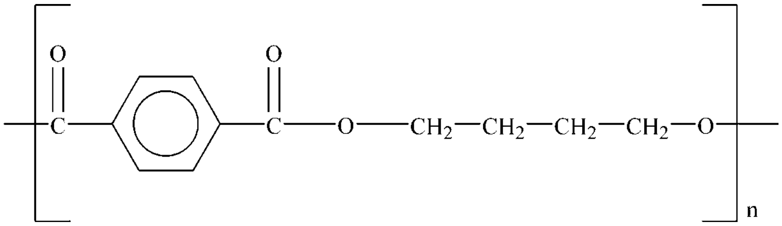


Figure 4.4. Chemical structure of polybutylene terephthalate (PBT) polyester.

added heat resistance. This puts it between the common polyesters and the LCP polyesters described in the previous section. At present, only DuPont makes the PCT plastic under the trade name Thermx®.

This material has found use in automotive, electrical, and houseware applications.

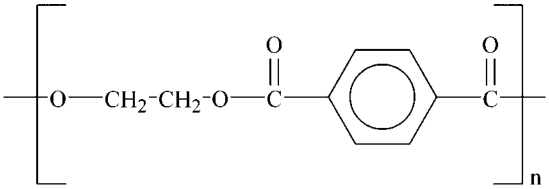
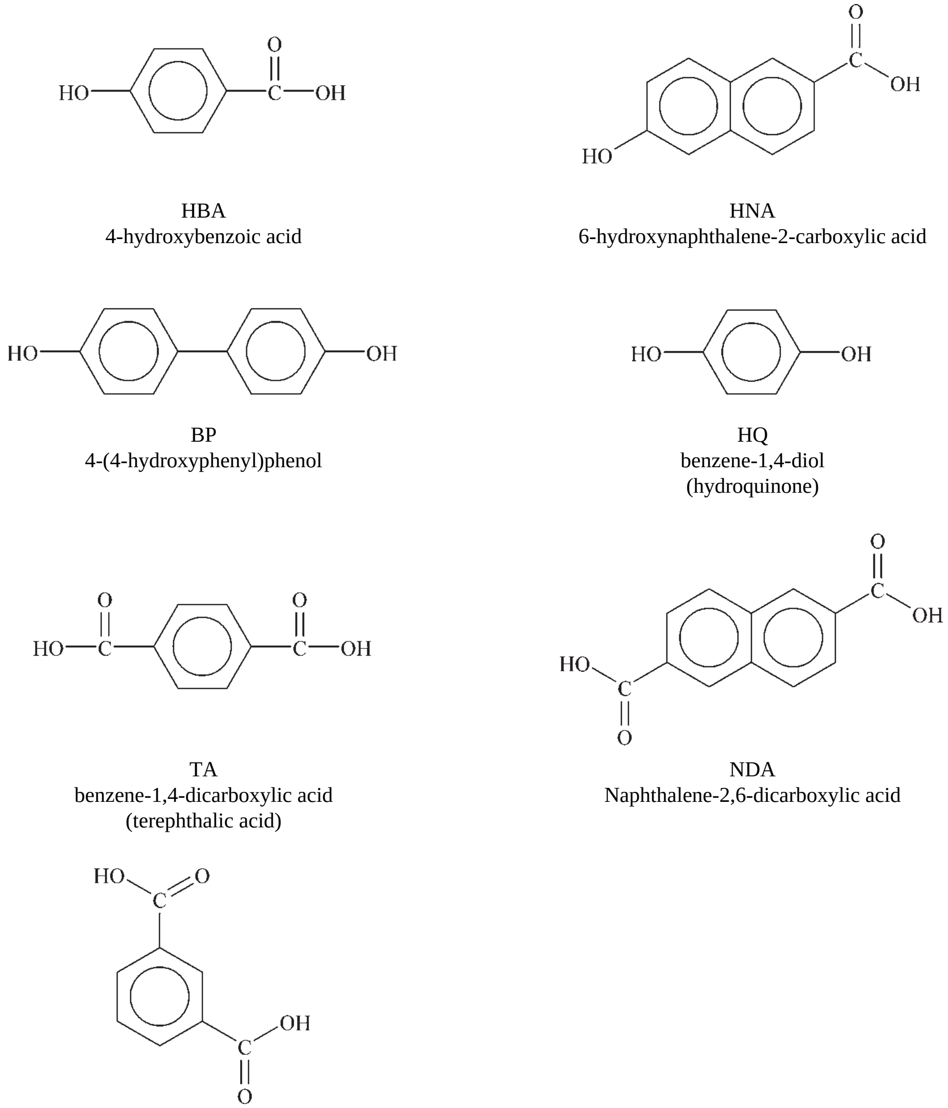


Figure 4.5. Chemical structure of polyethylene terephthalate (PET) polyester.

4.1.6 Polyester Blends and Alloys

There are numerous commercial polymer blends and alloys using polyesters. One important compounded blend is that of polycarbonate and ABS. The PC contributes impact and heat distortion resistance, while the ABS contributes processability and chemical stress resistance, and cost reduction. ASA is often blended with polyesters such as PBT to improve exterior weatherability and impact strength. Blends of different types of polyesters are also very common. These are blended to balance cost, optimize processing and performance properties.



HBA
4-hydroxybenzoic acid

HNA
6-hydroxynaphthalene-2-carboxylic acid

BP
4-(4-hydroxyphenyl)phenol

HQ
benzene-1,4-diol
(hydroquinone)

TA
benzene-1,4-dicarboxylic acid
(terephthalic acid)

NDA
Naphthalene-2,6-dicarboxylic acid

IA
benzene-1,3-dicarboxylic acid
(isophthalic acid)

Figure 4.6. Chemical structures of monomers used to make liquid crystalline polymer (LCP) polyesters.

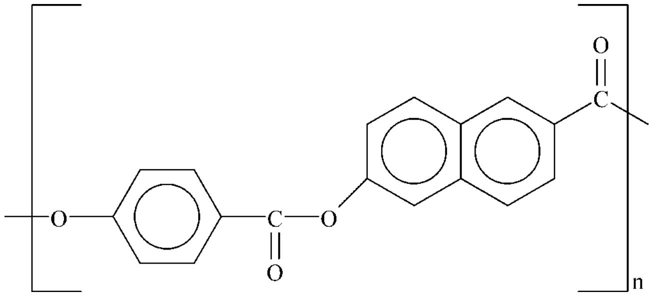


Figure 4.7. Chemical structure of Ticona Vectra® A950 LCP.

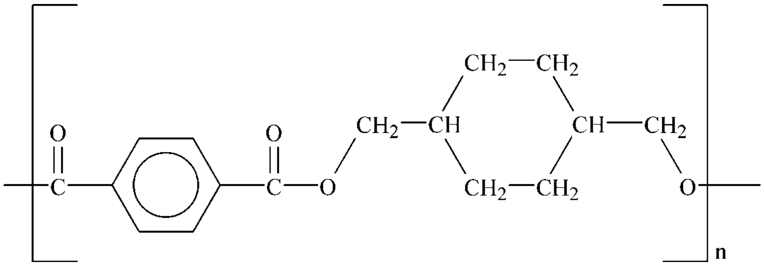


Figure 4.8. Chemical structure of polycyclohexylene dimethylene terephthalate (PCT) Polyester.

4.2 Polycarbonate (PC)

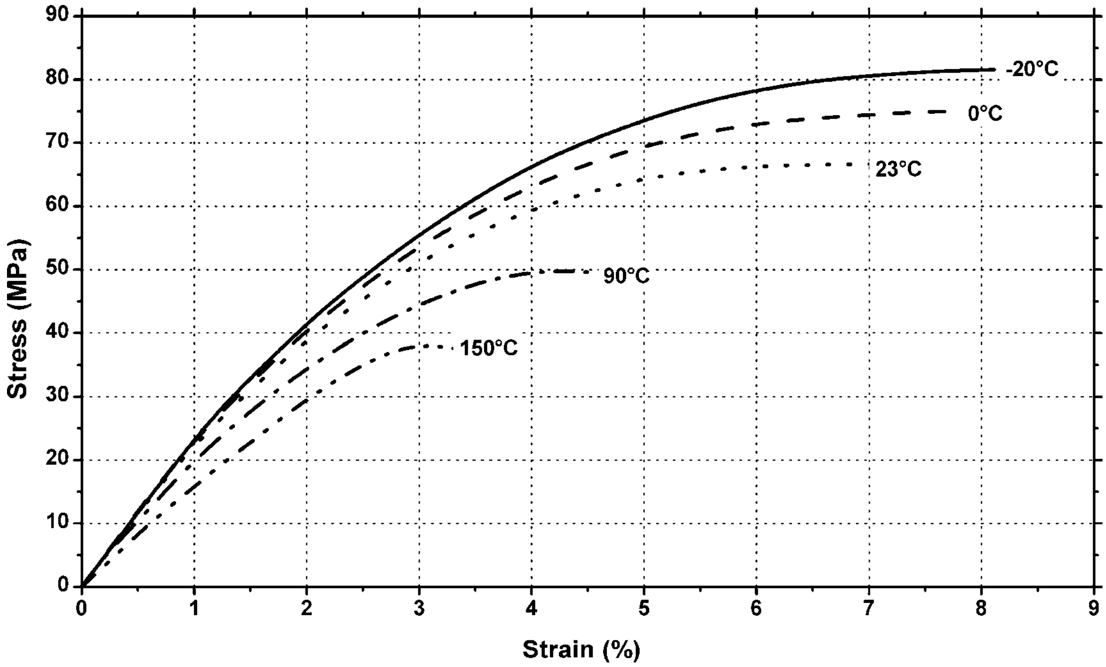


Figure 4.9. Stress vs. strain at various temperatures for Bayer MaterialScience Apec® 1600—high heat polycarbonate (PC) resin.

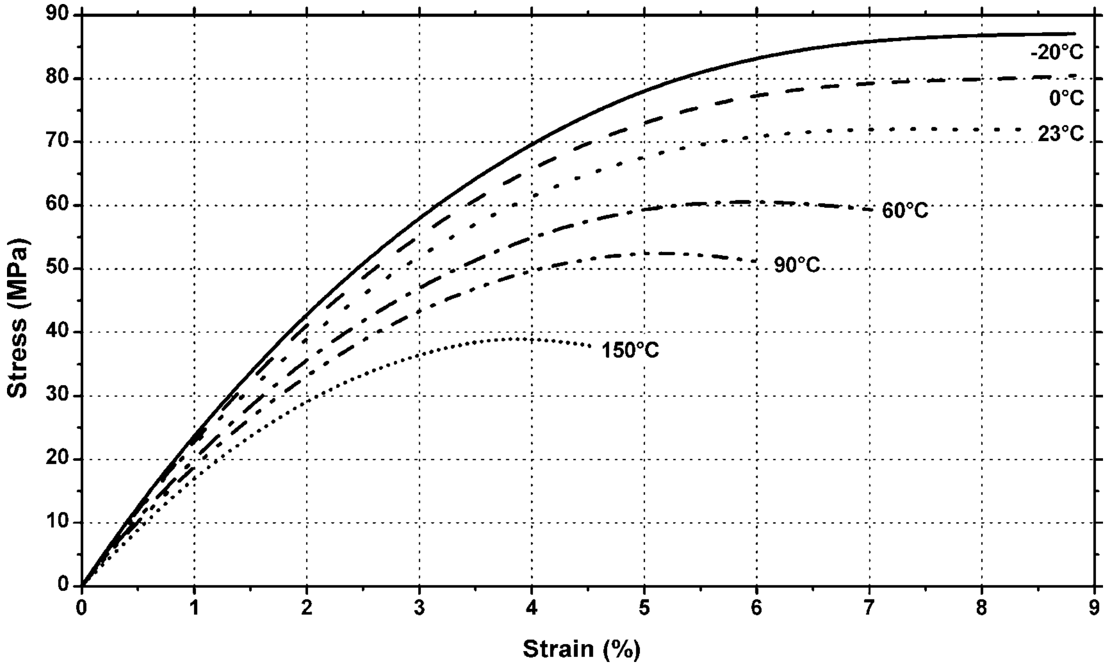


Figure 4.10. Stress vs. strain at various temperatures for Bayer MaterialScience Apec® 1700—high heat PC resin.

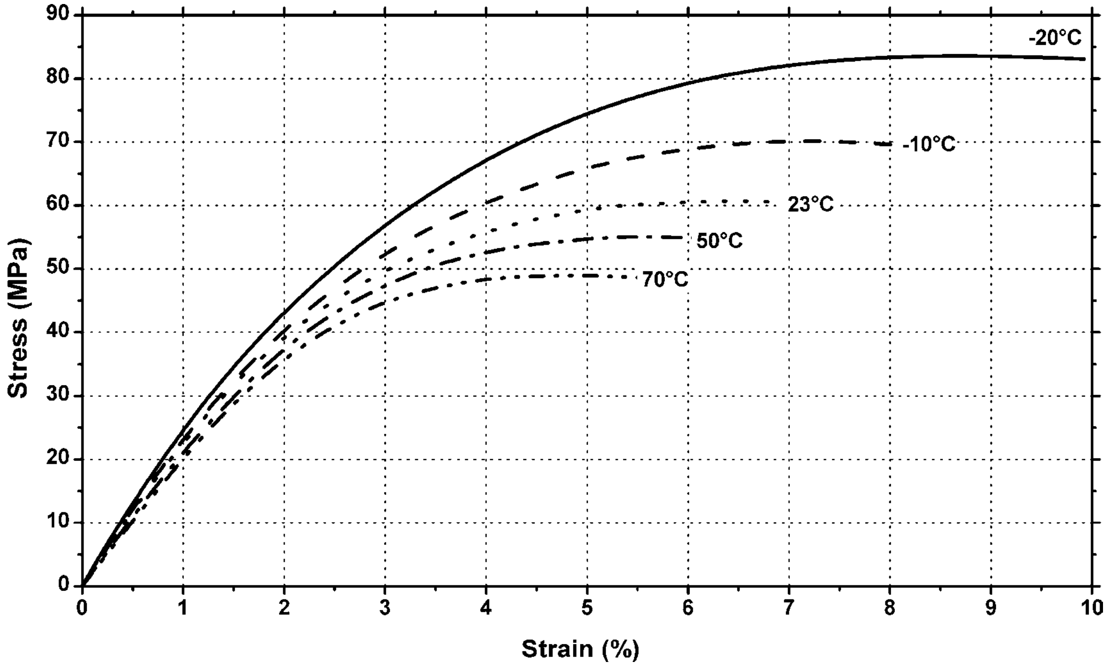


Figure 4.11. Stress vs. strain at various temperatures for LG-Dow Calibre™ 300-10—general purpose 10 melt flow rate (MFR) PC resin.

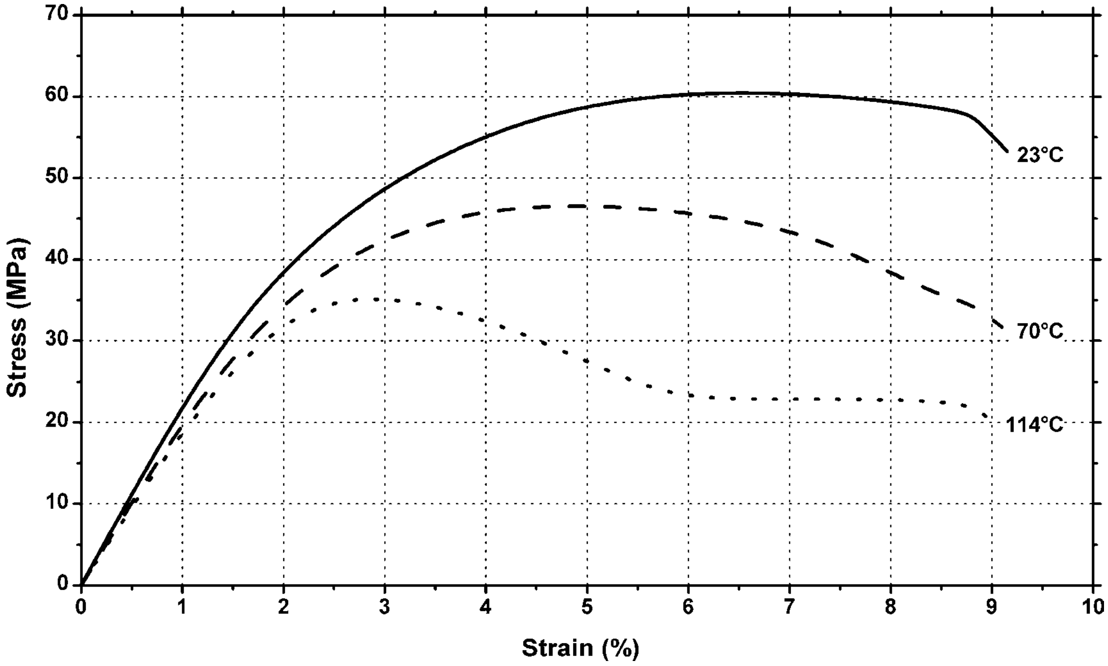


Figure 4.12. Stress vs. strain at various temperatures for SABIC Innovative Plastics Lexan® 101—general purpose PC resin.

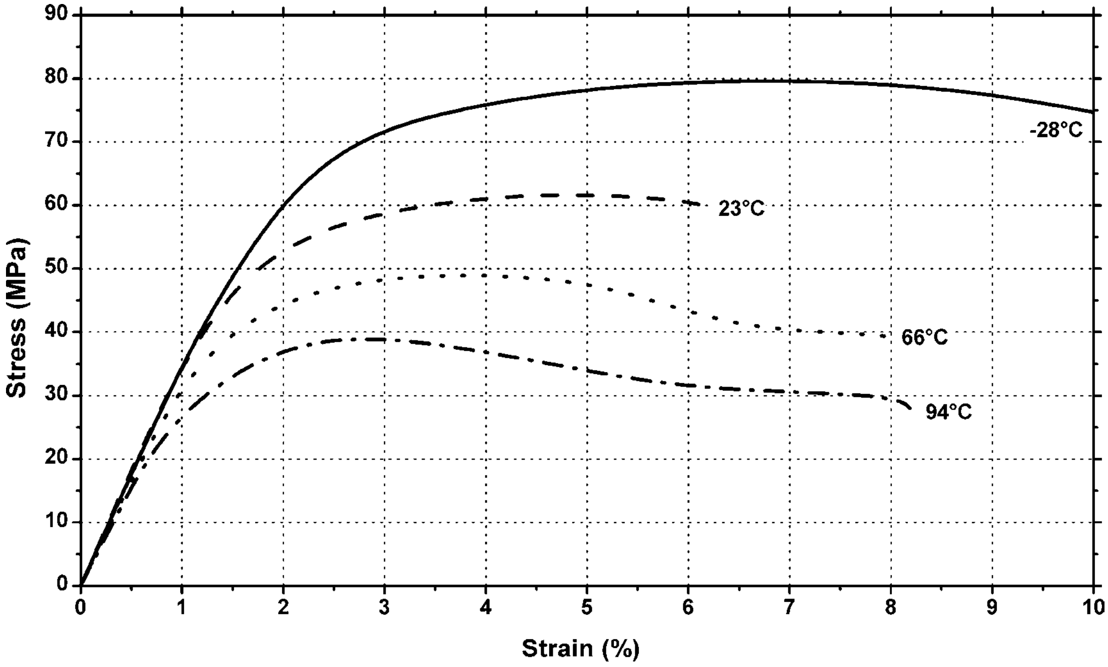


Figure 4.13. Stress vs. strain at various temperatures for SABIC Innovative Plastics Lexan® 500R—10% glass fiber reinforced PC resin.

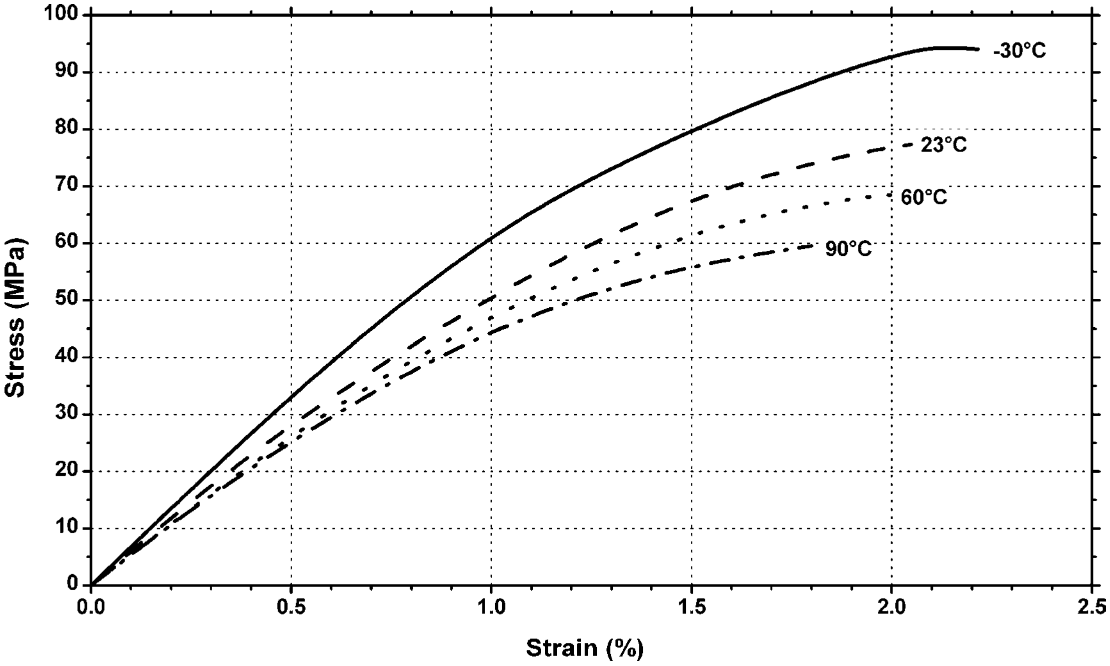


Figure 4.14. Stress vs. strain at various temperatures for SABIC Innovative Plastics Lexan® 3412R—high viscosity, 20% glass reinforced PC resin.

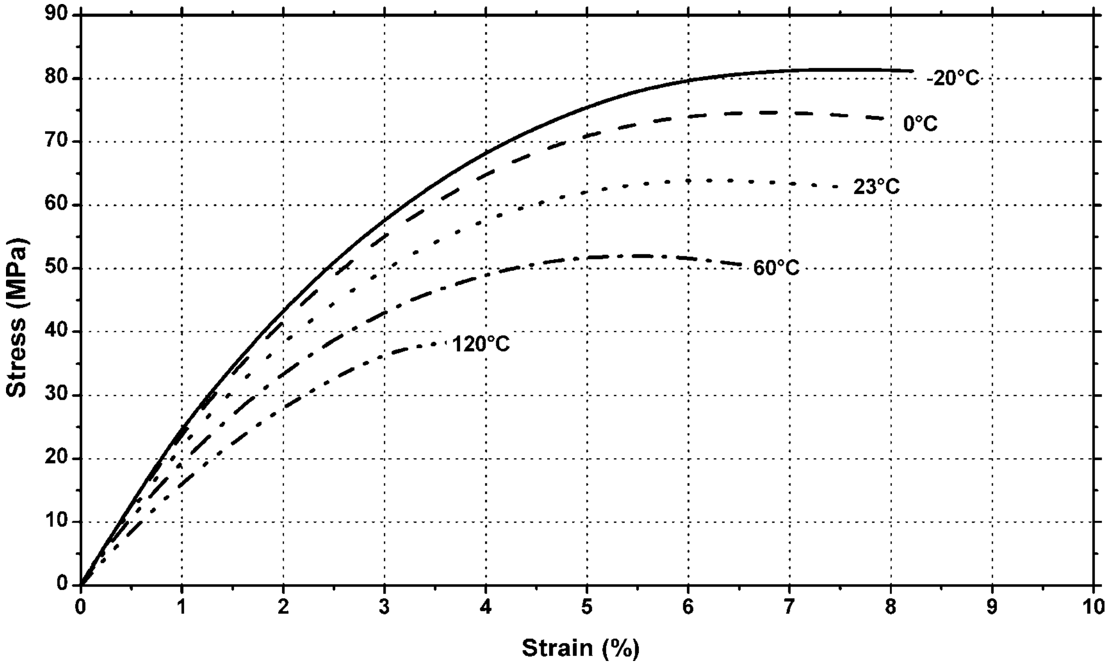


Figure 4.15. Stress vs. strain at various temperatures for Bayer MaterialScience Makrolon® 2205—general purpose, low viscosity PC resin.

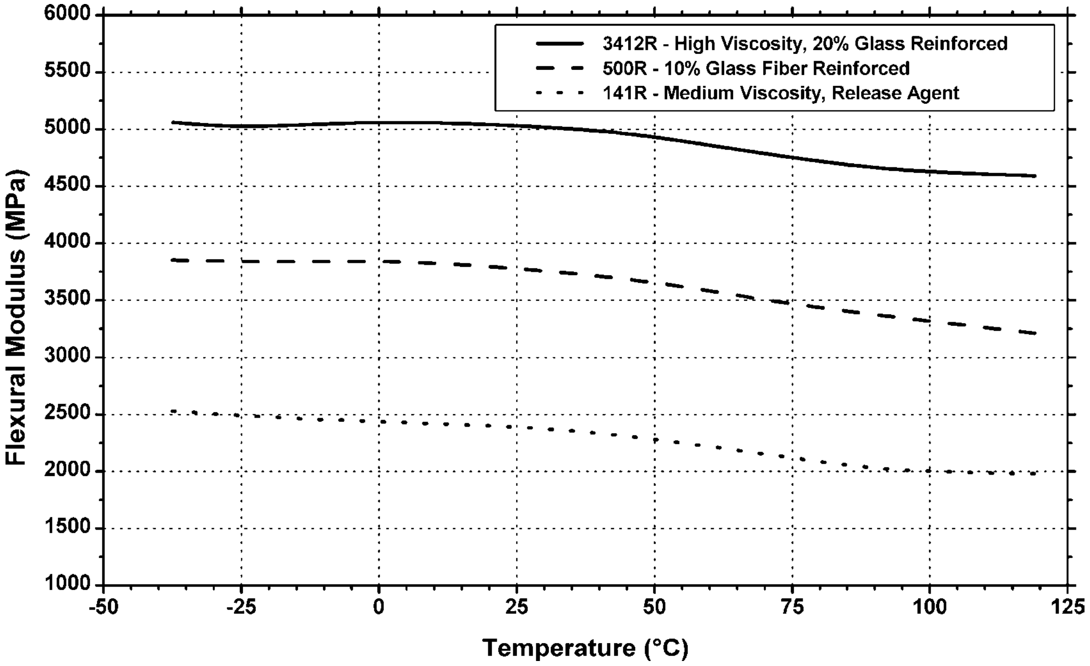


Figure 4.16. Flexural modulus vs. temperature for SABIC Innovative Plastics Lexan® PC resins.

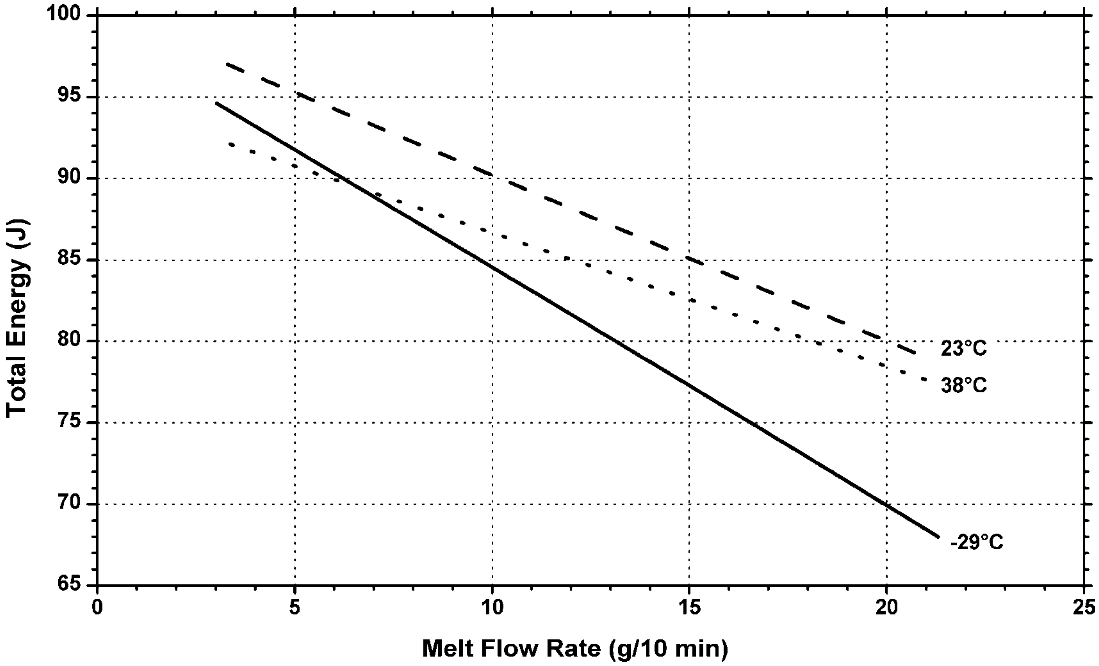


Figure 4.17. Instrumented dart impact vs. MFR for LG-Dow Polycarbonate Calibre™ 300-10—general purpose 10 MFR PC resin.

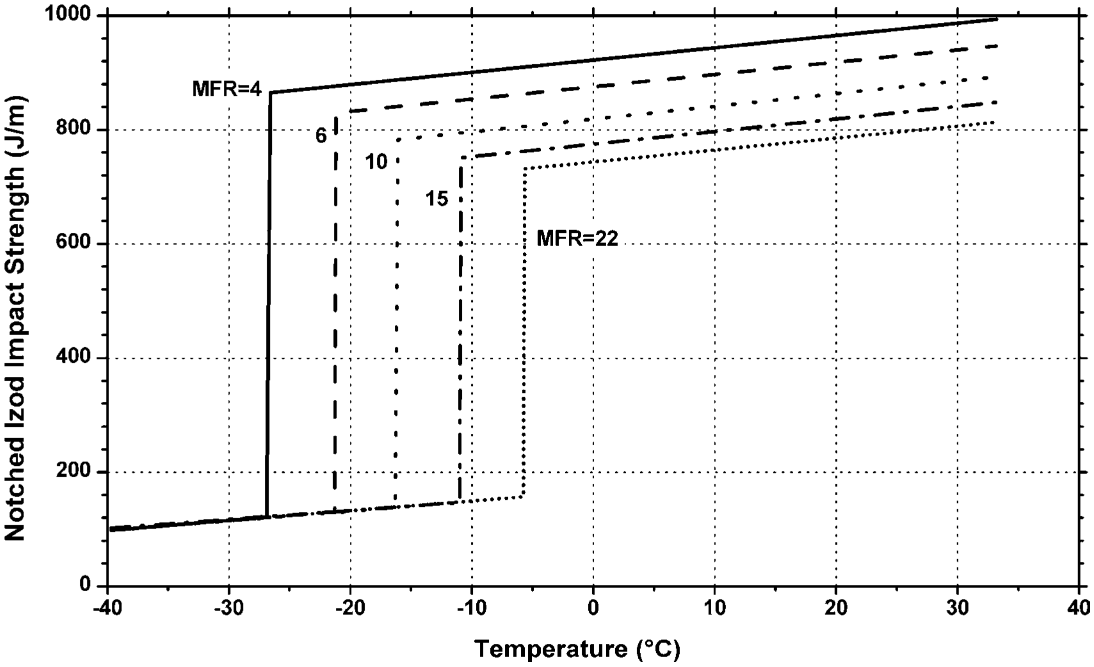


Figure 4.18. Notched Izod impact strength vs. temperature and MFR for LG-Dow Polycarbonate Calibre™ 300 general purpose PC resin.

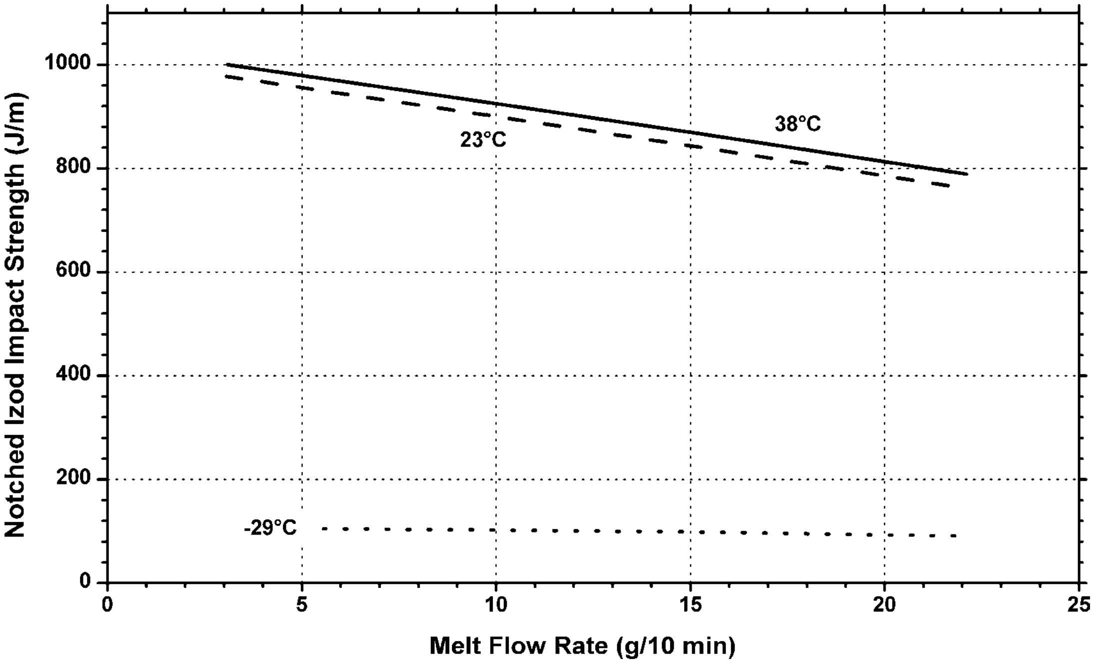


Figure 4.19. Notched Izod impact strength vs. MFR and temperature for LG-Dow Polycarbonate Calibre™ 300 general purpose PC resin.

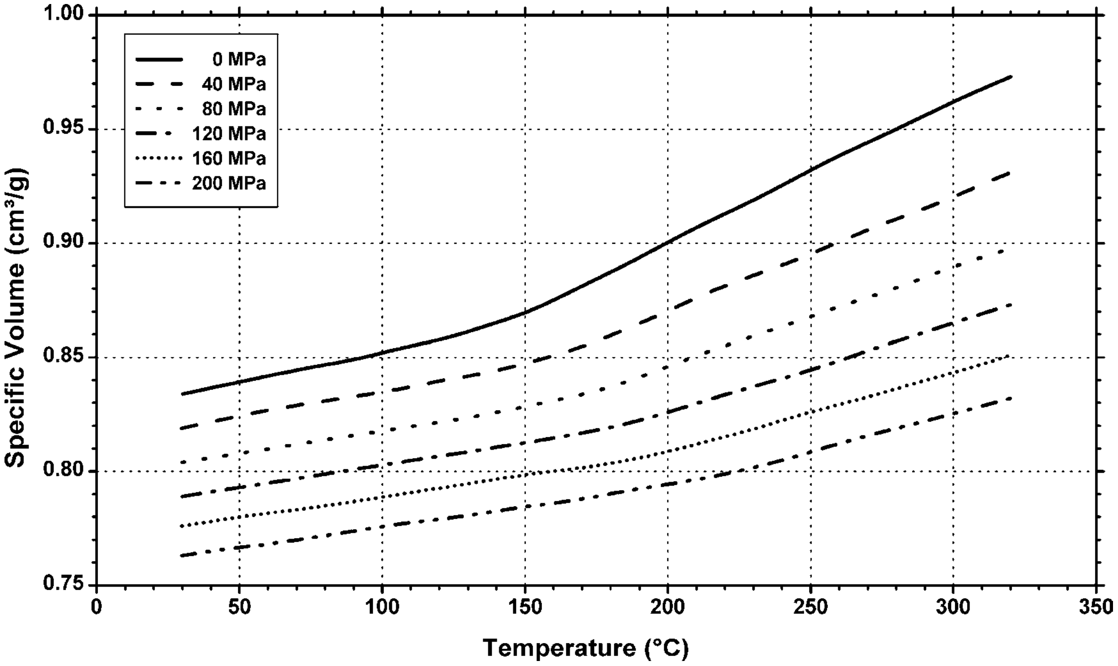


Figure 4.20. Pressure-specific volume-temperature (PVT) for Bayer MaterialScience Makrolon® 2205—general purpose, low viscosity PC resin.

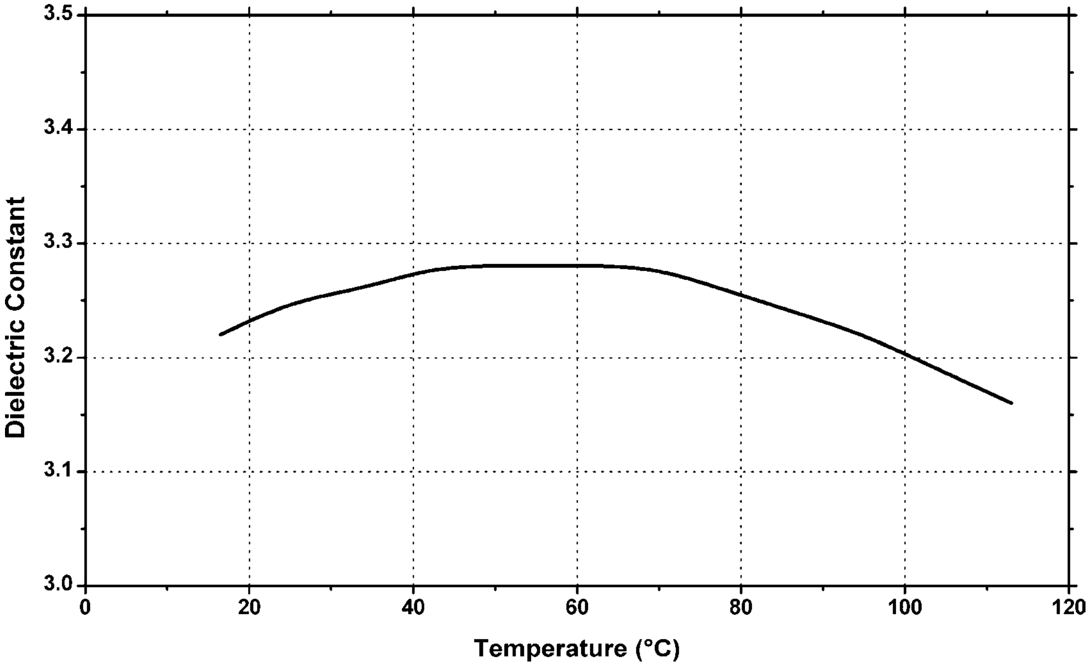


Figure 4.21. Dielectric constant vs. temperature for SABIC Innovative Plastics Lexan® PC resins.

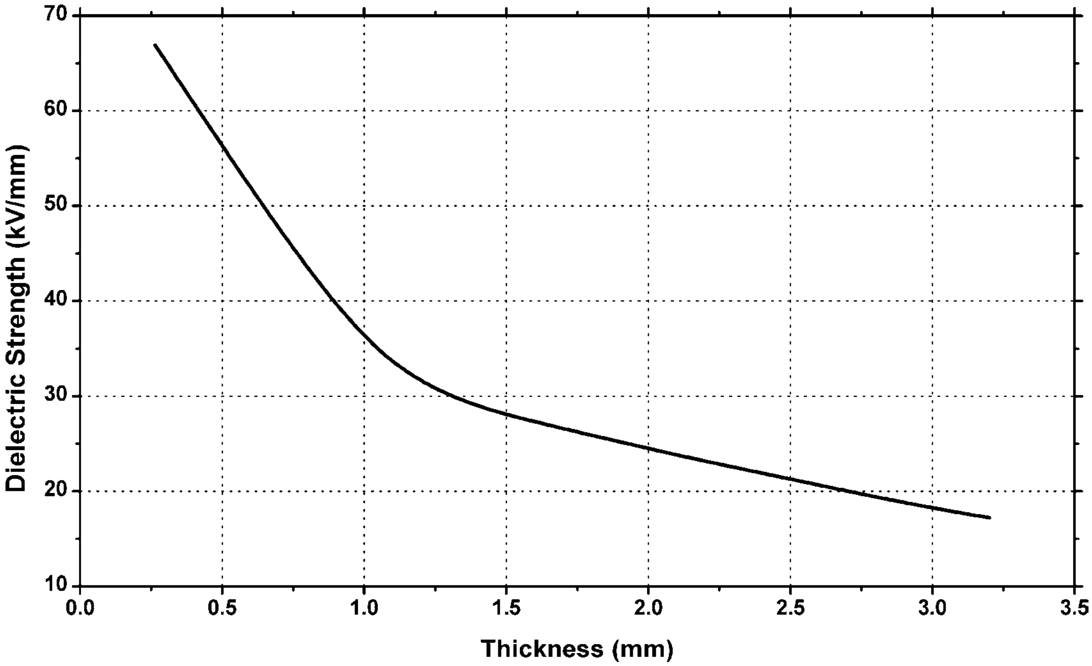


Figure 4.22. Dielectric strength vs. thickness for SABIC Innovative Plastics Lexan® PC resins.

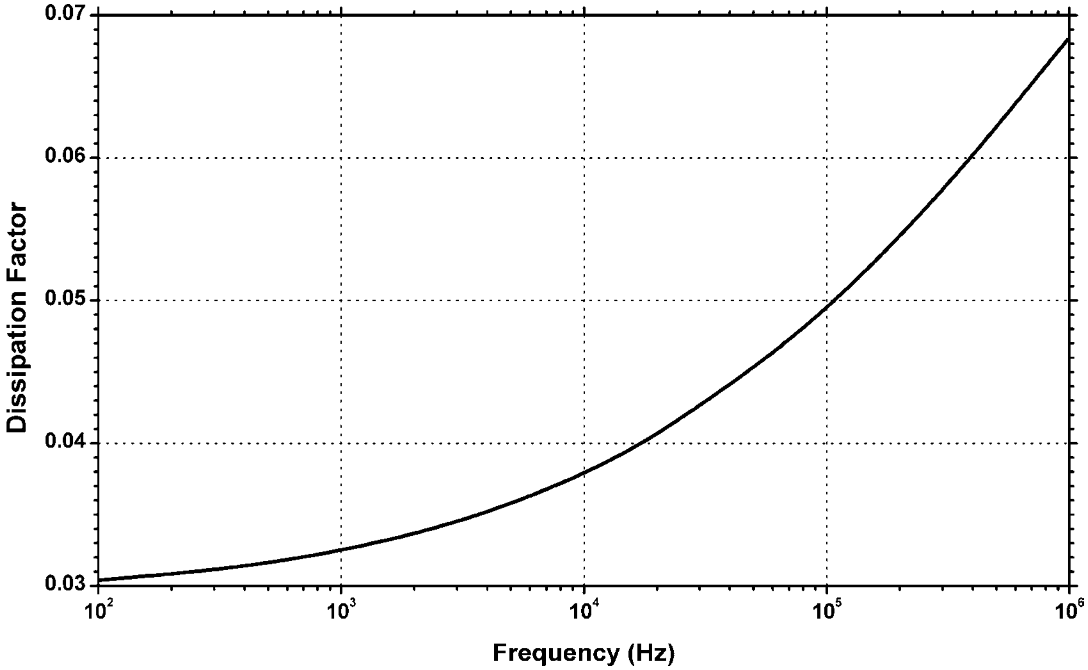


Figure 4.23. Dissipation factor vs. frequency for SABIC Innovative Plastics Lexan® PC resins.

4.3 Polybutylene Terephthalate (PBT)

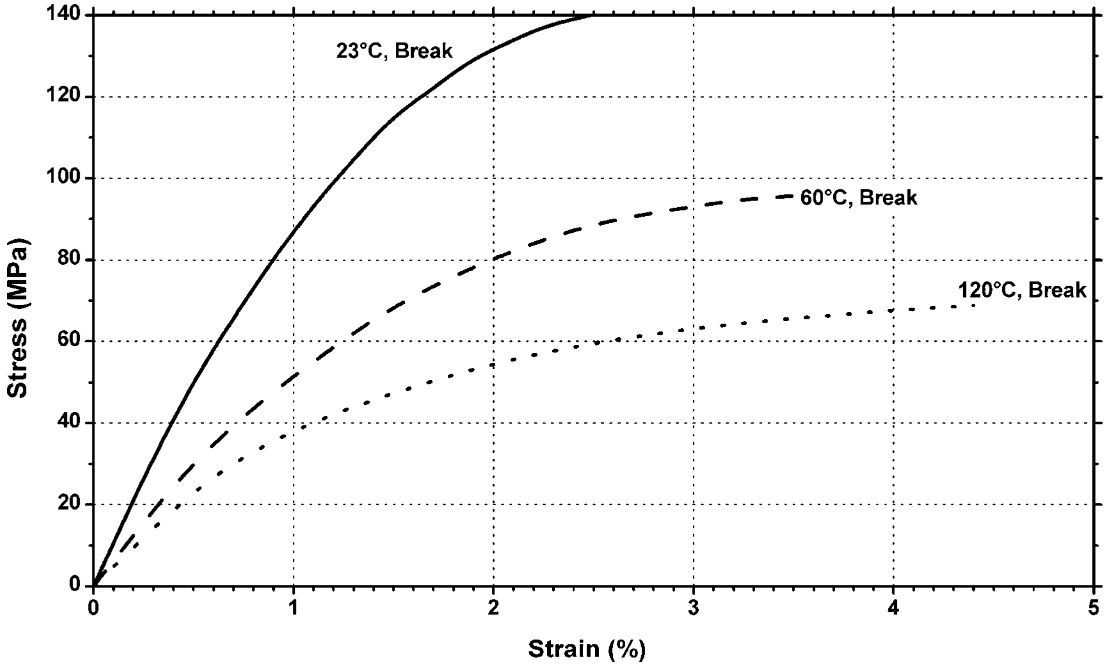


Figure 4.24. Stress vs. strain at various temperatures for Ticona Celanex® 2300 GV/30—general purpose, 30% glass fiber reinforced PBT resin.

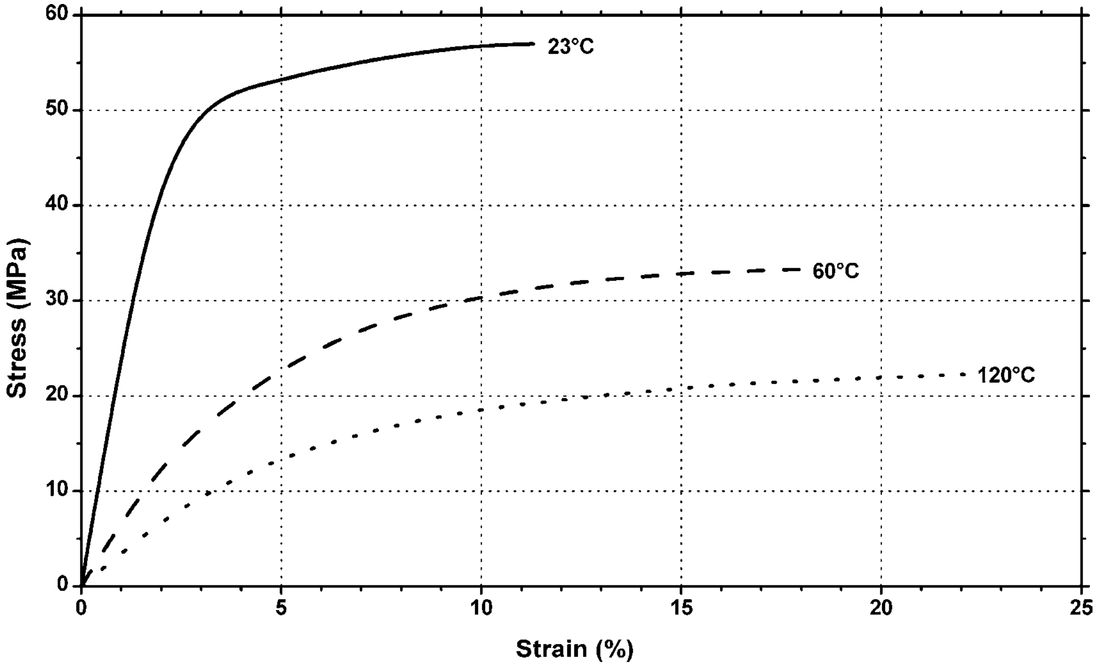


Figure 4.25. Stress vs. strain at various temperatures for Ticona Celanex® 2500—general purpose, nucleated, easy flow PBT resin.

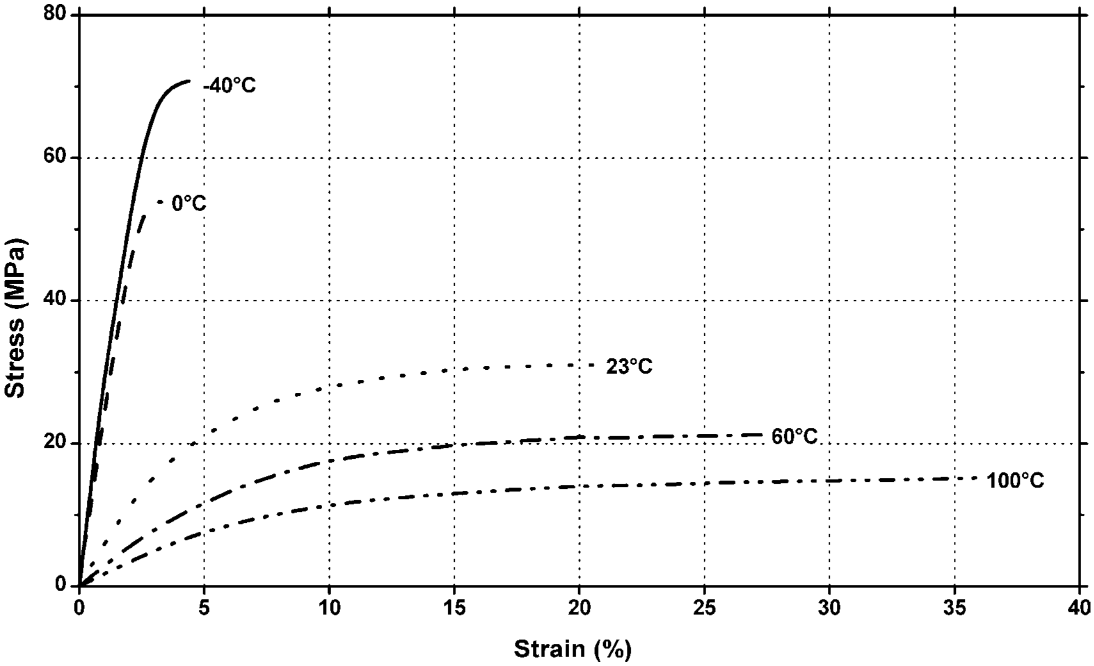


Figure 4.26. Stress vs. strain at various temperatures for DuPont Crastin® S600F10 NC010—medium viscosity lubricated PBT resin.

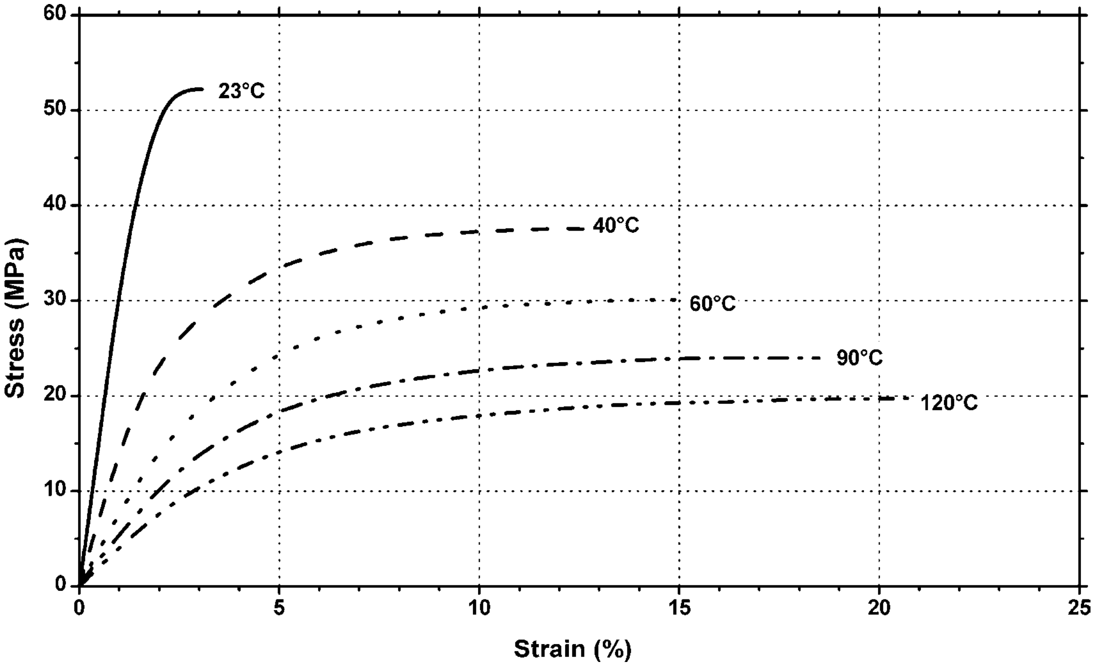


Figure 4.27. Stress vs. strain at various temperatures for DuPont Crastin® SO653 NC010—20% glass bead filled, lubricated PBT resin.

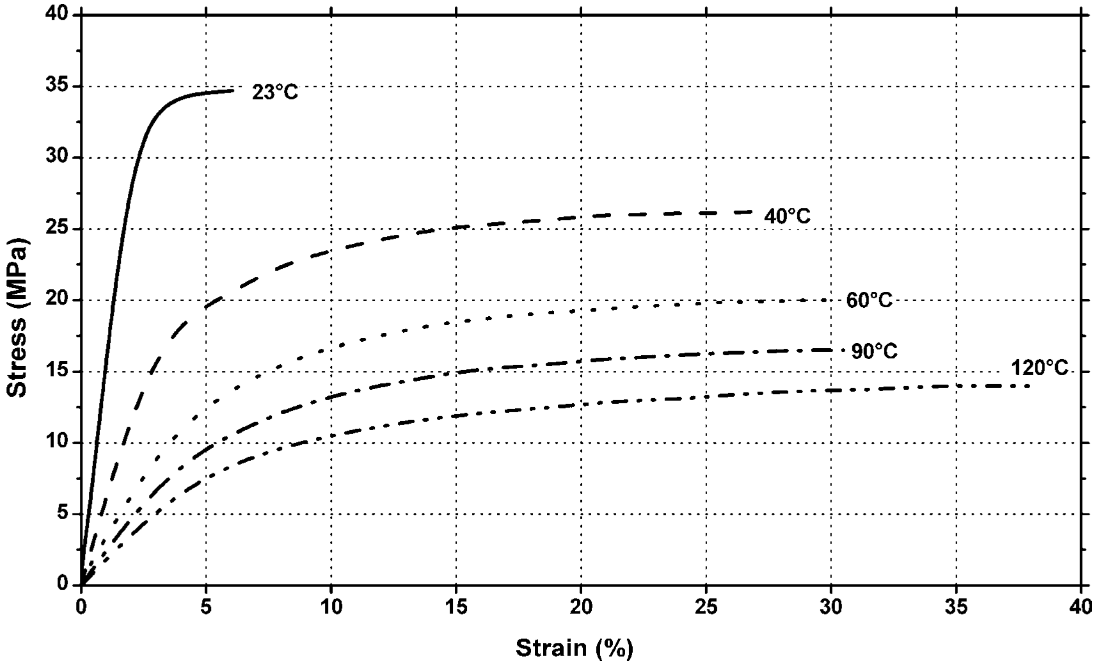


Figure 4.28. Stress vs. strain at various temperatures for DuPont Crastin® ST820 NC010—super tough lubricated PBT resin.

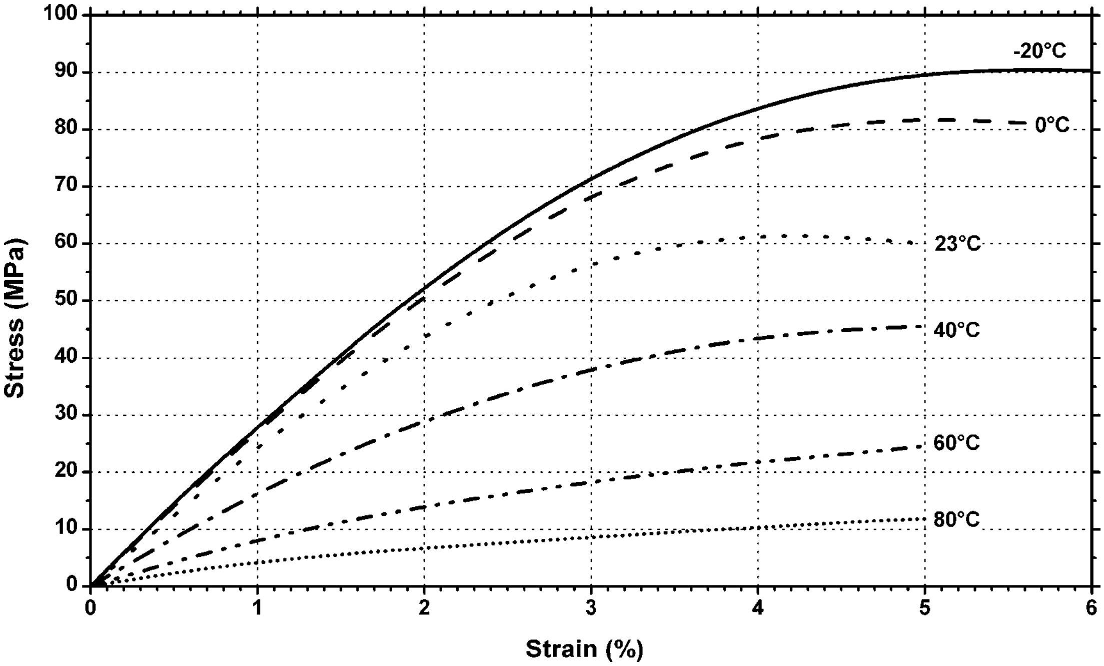


Figure 4.29. Stress vs. strain at various temperatures for Lanxess Pocan® B1505—high viscosity, nucleated, heat stabilized PBT resin.

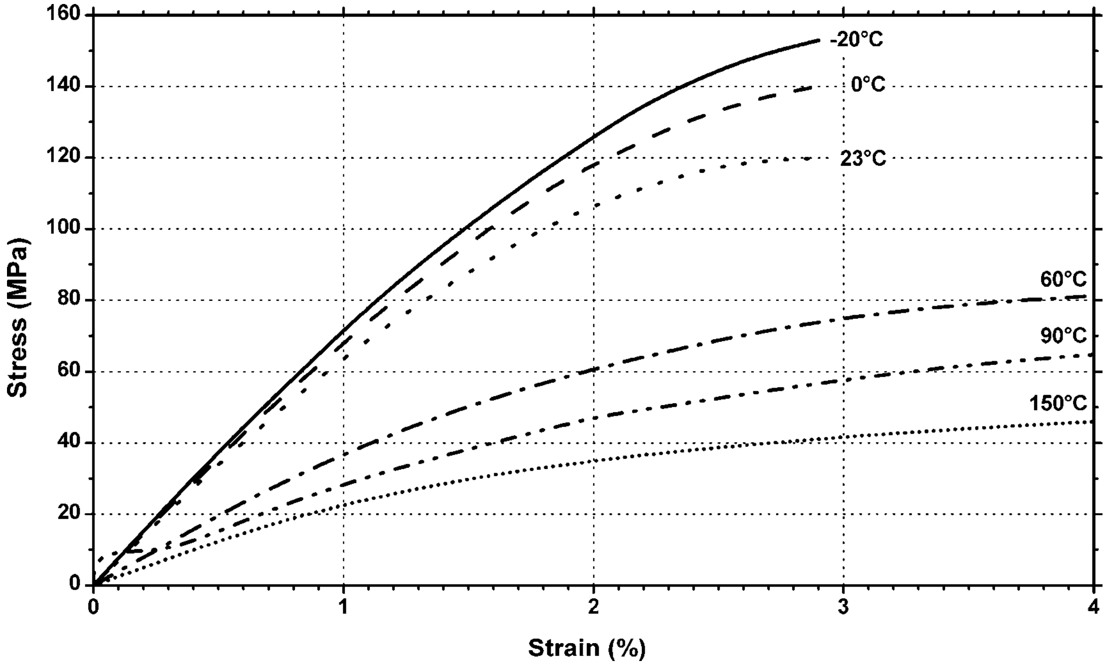


Figure 4.30. Stress vs. strain at various temperatures for Lanxess Pocan® B3225—20% glass fiber reinforced PBT resin.

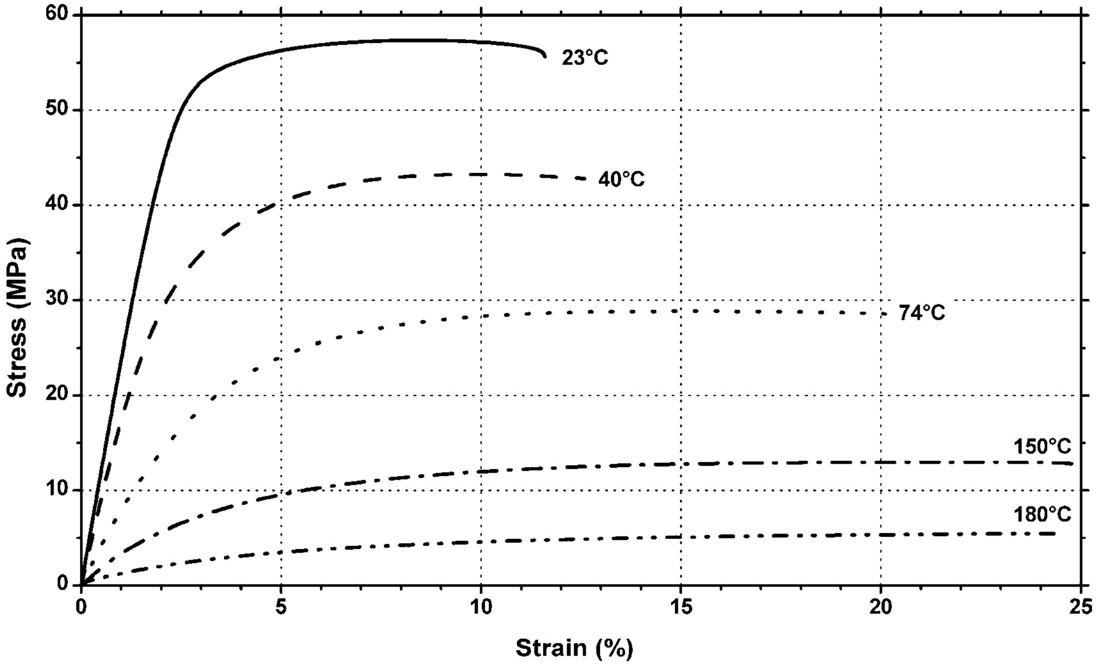


Figure 4.31. Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® 310-SEO—unreinforced, UL94 V-0 rated PBT resin.

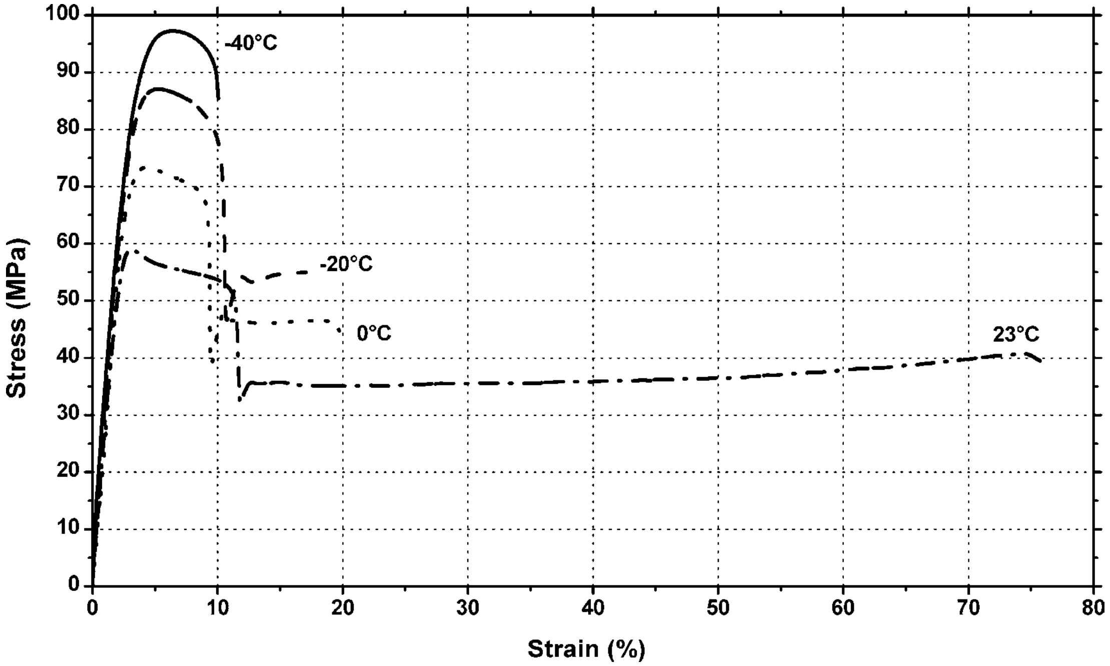


Figure 4.32. Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® 325—unreinforced, improved processing PBT resin.

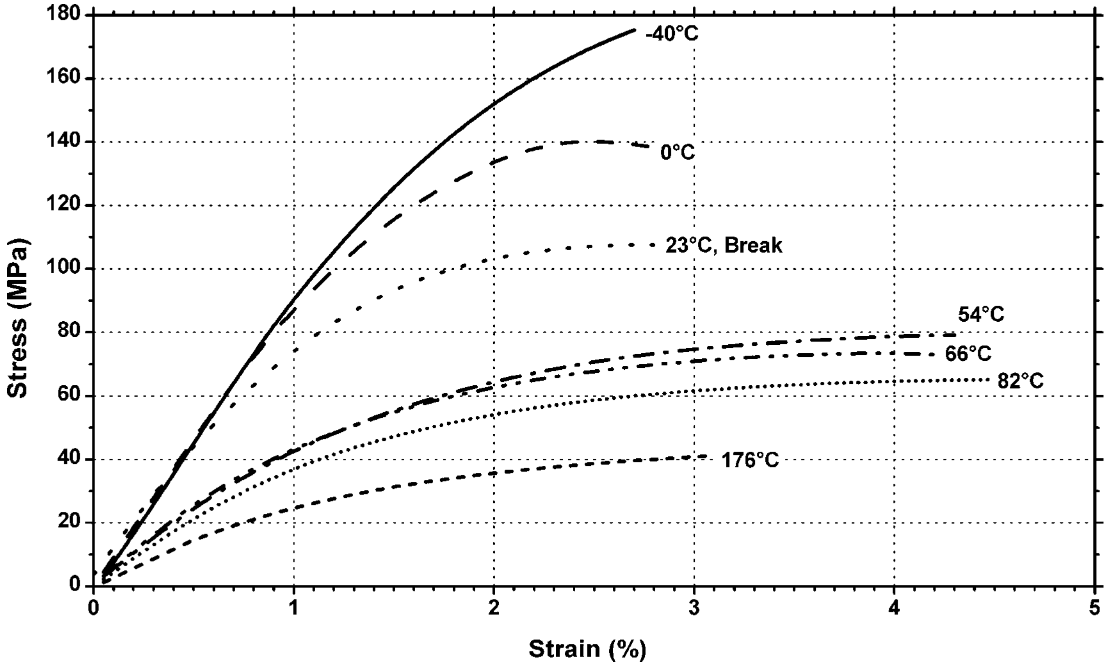


Figure 4.33. Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® 420—30% glass fiber reinforced, high heat PBT resin.

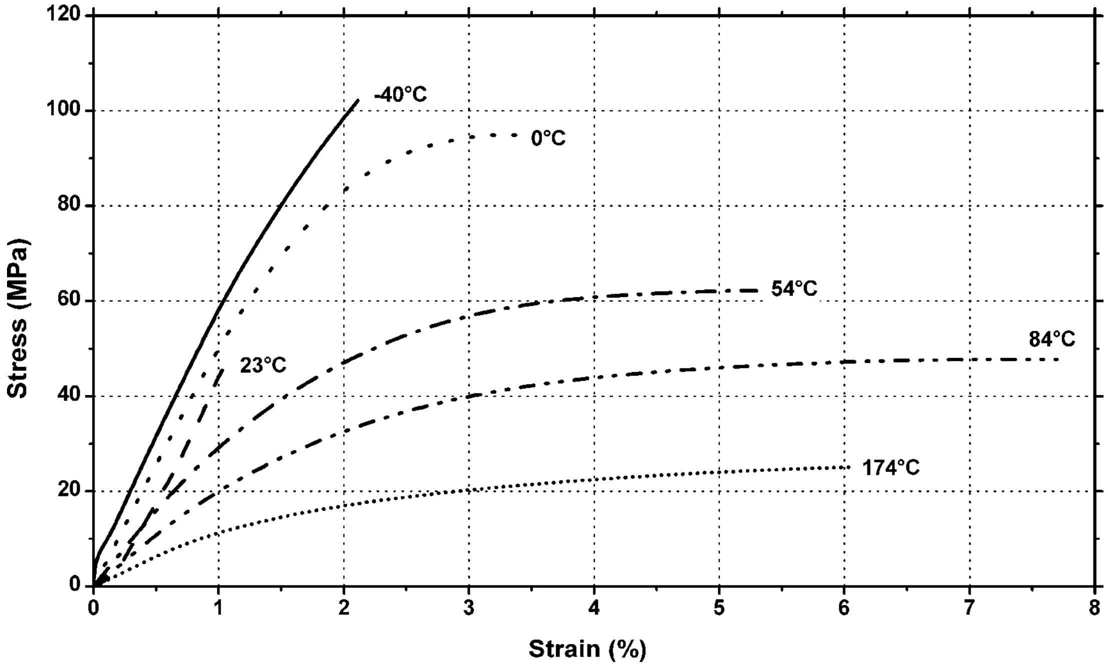


Figure 4.34. Stress vs. strain at various temperatures for SABIC Innovative Plastics Valox® DR-51—15% glass fiber reinforced PBT resin.

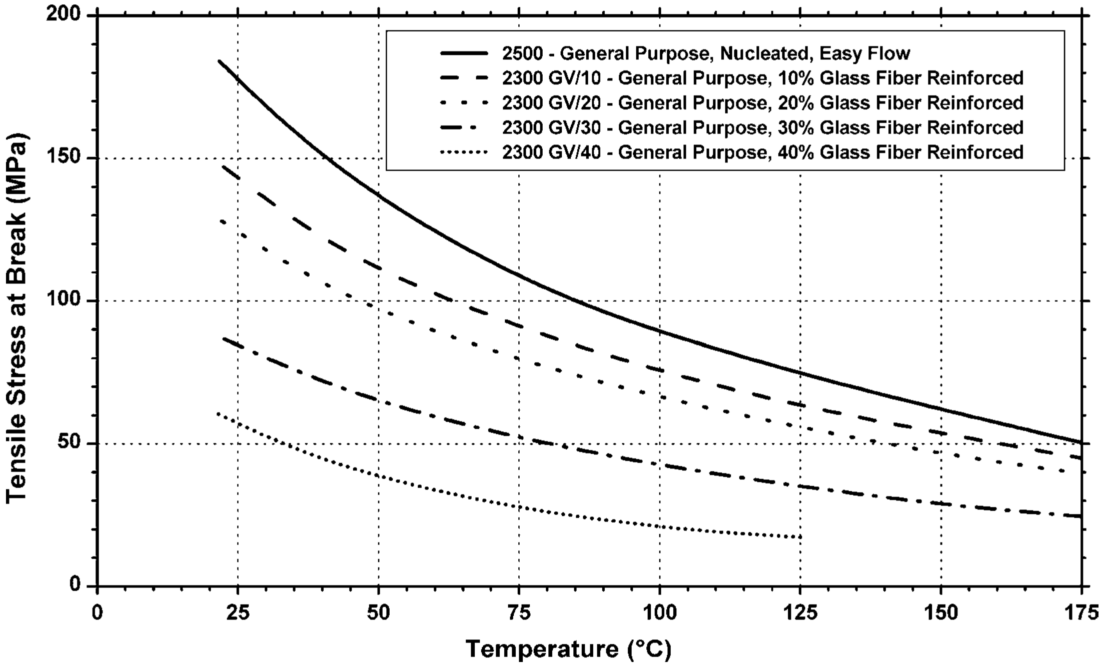


Figure 4.35. Tensile stress at break vs. temperature for Ticona Celanex® general purpose PBT resins.

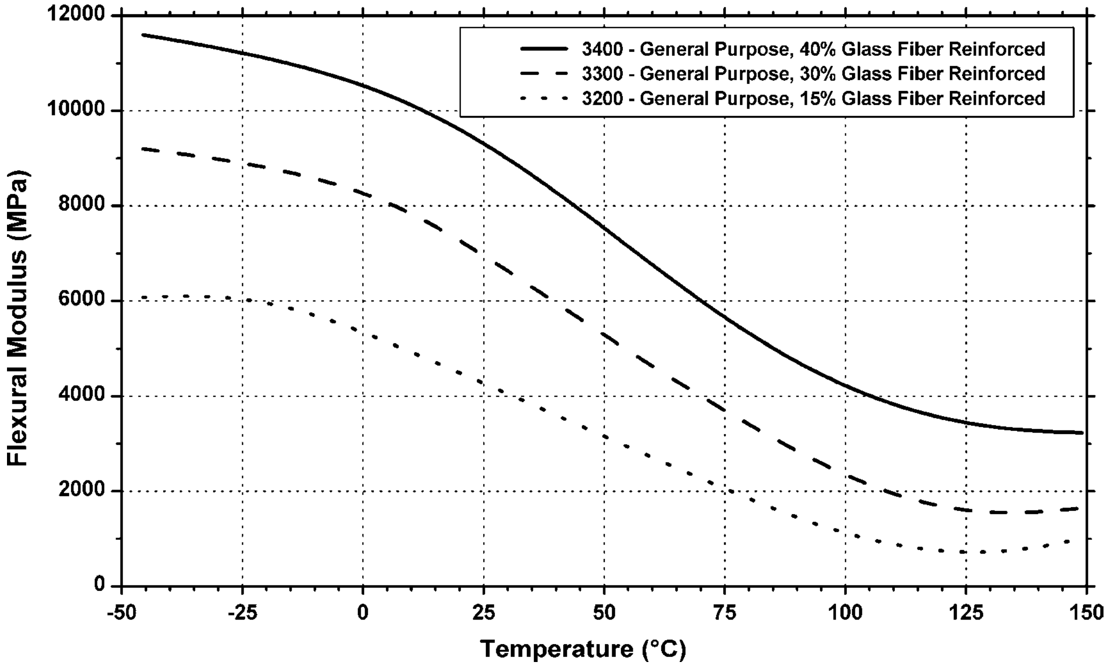


Figure 4.36. Flexural modulus vs. temperature for Ticona Celanex® general purpose, glass fiber reinforced PBT resins.

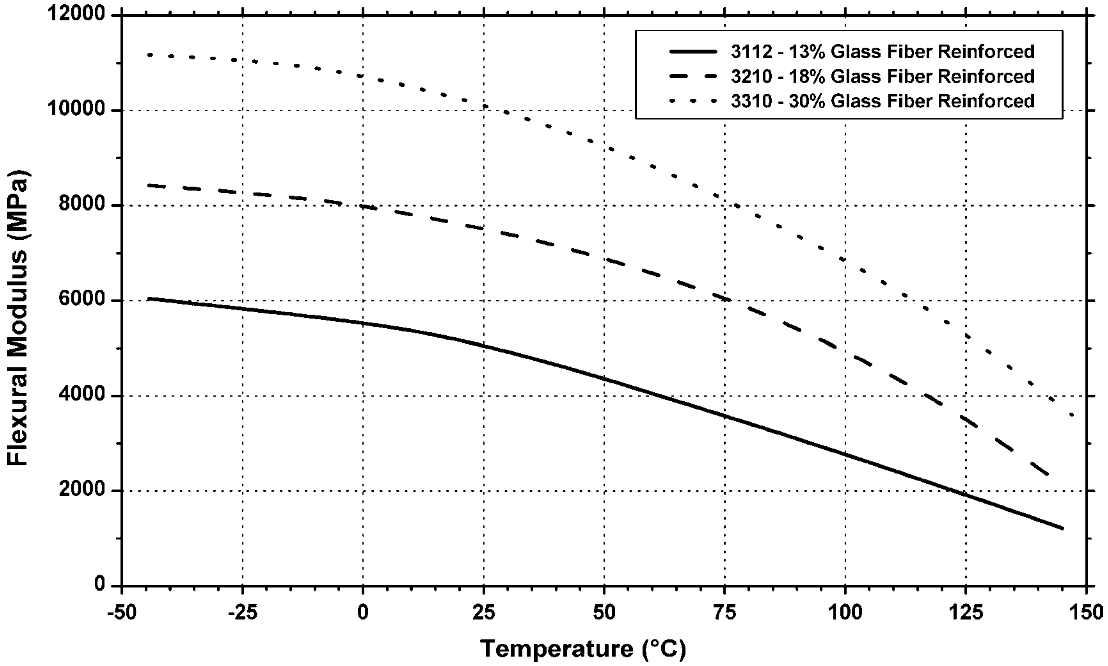


Figure 4.37. Flexural modulus vs. temperature for Ticona Celanex® flame retardant, glass fiber reinforced PBT resins.

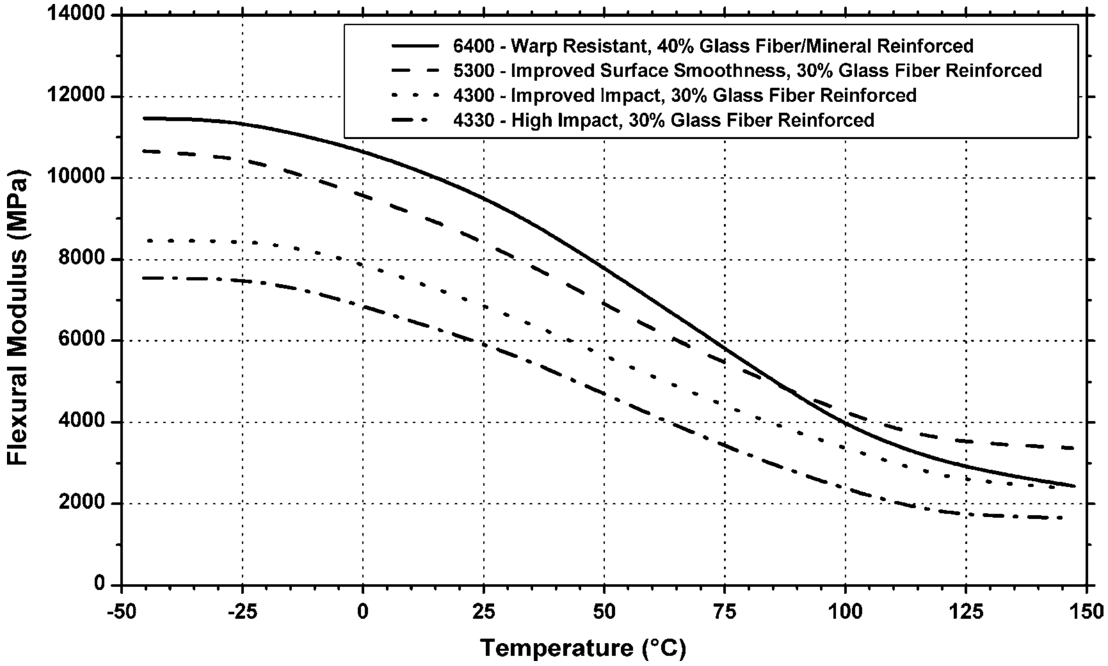


Figure 4.38. Flexural modulus vs. temperature for Ticona Celanex® high impact, glass fiber reinforced PBT resins.

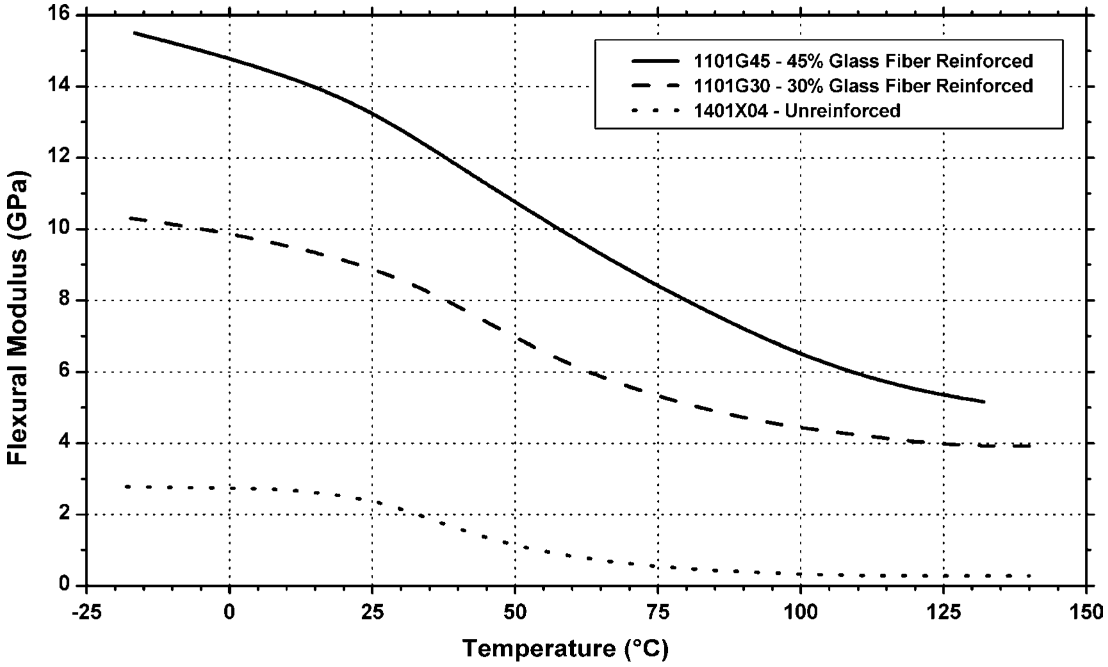


Figure 4.39. Flexural modulus vs. temperature for Toray Toraycon® PBT resins.

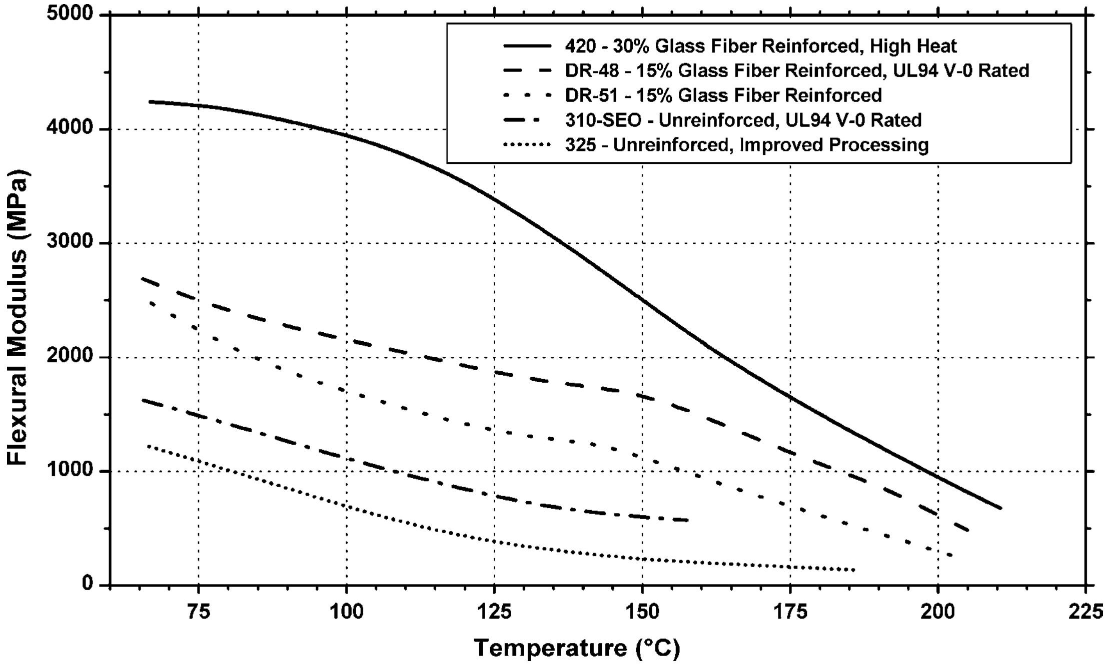


Figure 4.40. Flexural modulus vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

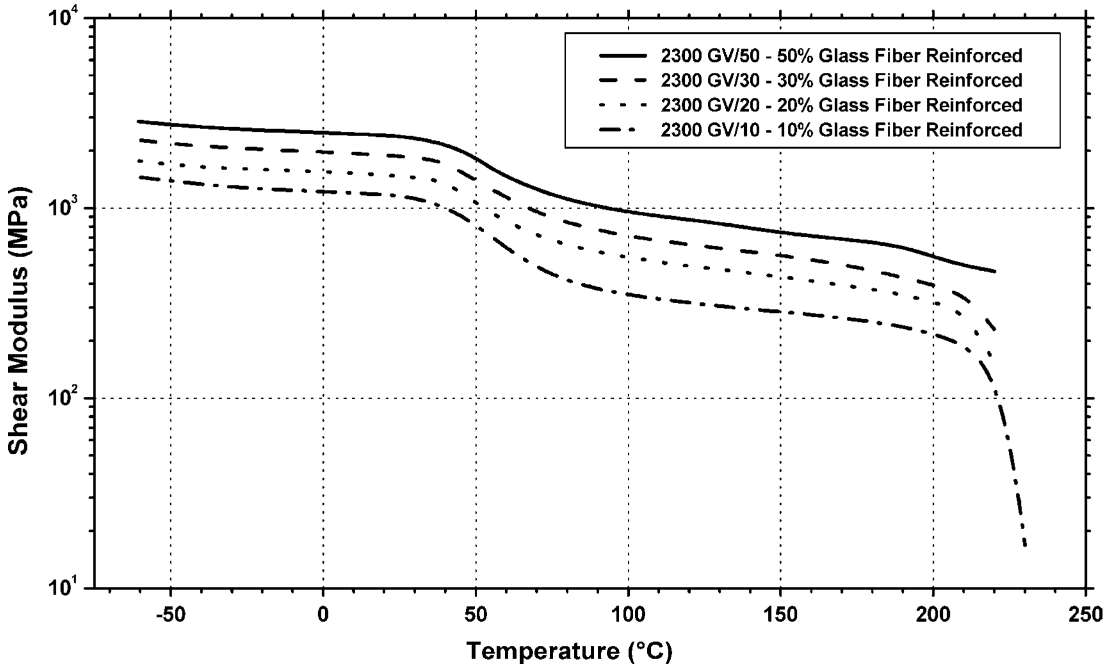


Figure 4.41. Shear modulus vs. temperature for Ticona Celanex® 2300 series—general purpose, glass fiber reinforced PBT resins.

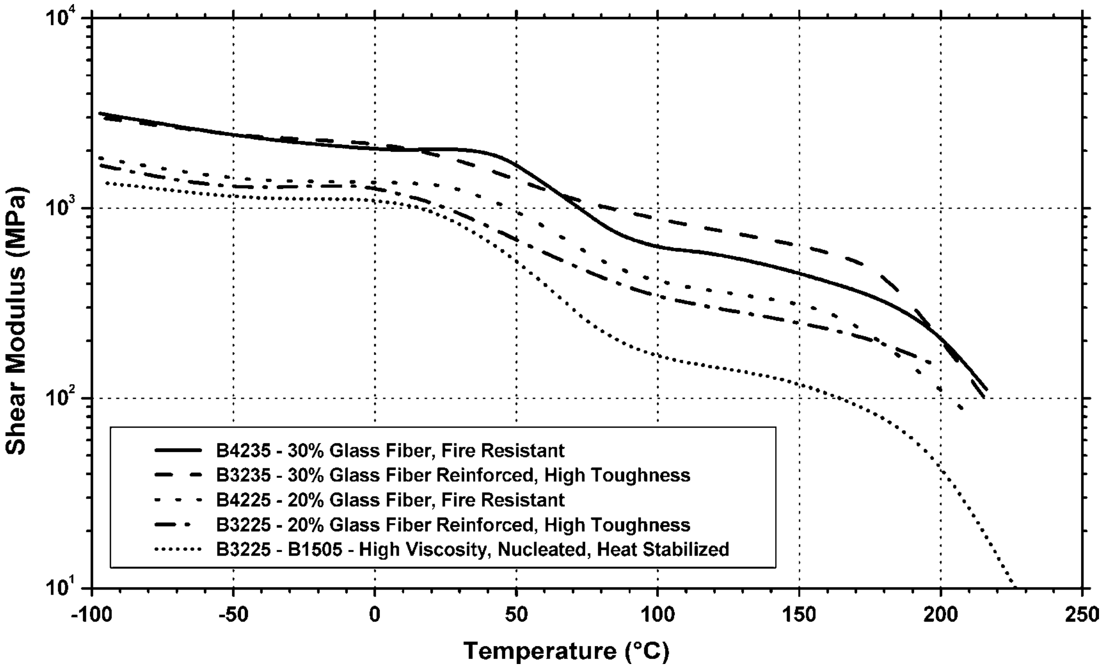


Figure 4.42. Shear modulus vs. temperature for Lanxess Pocan® reinforced PBT resins.

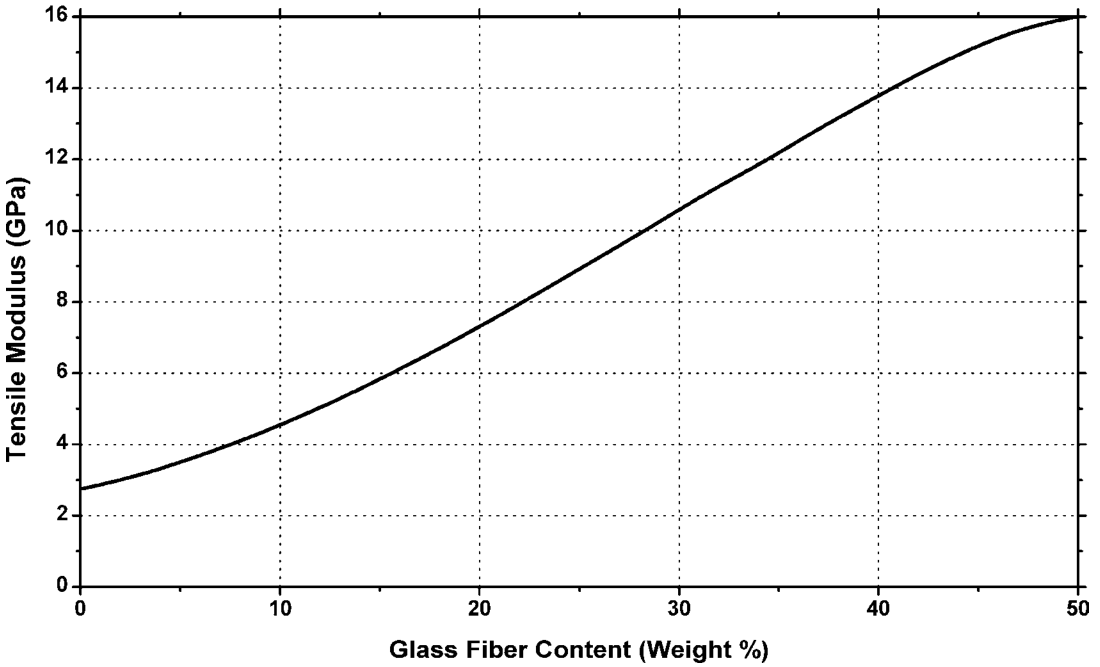


Figure 4.43. Tensile modulus vs. fiber glass reinforcement content for Dupont Crastin® SK glass reinforced, injection molding PBT resins.

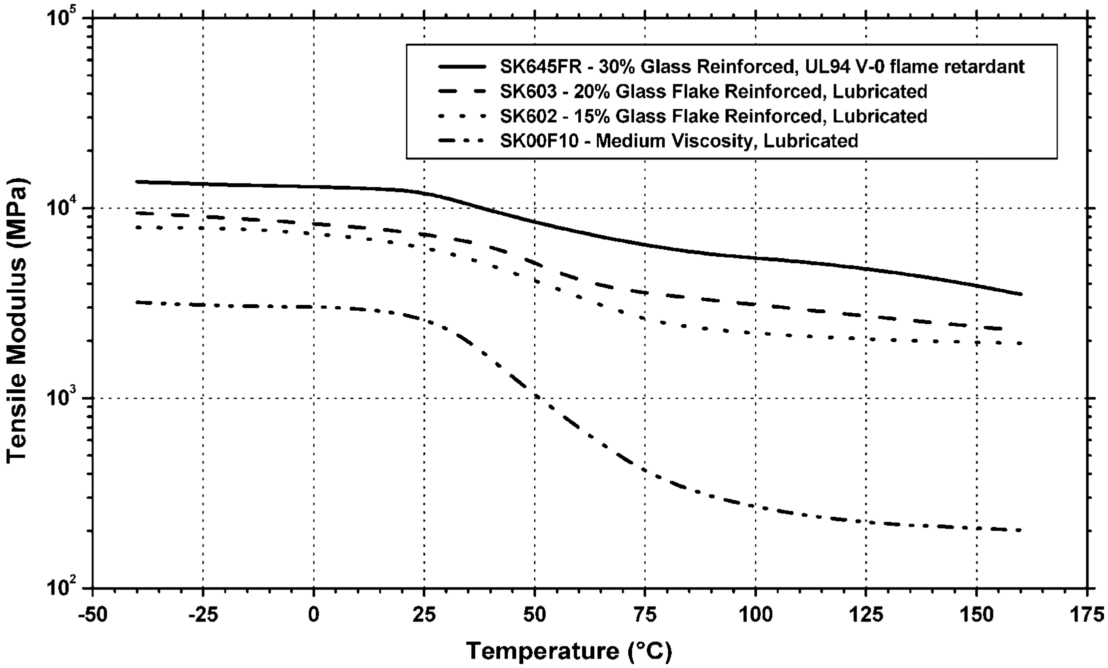


Figure 4.44. Tensile modulus vs. temperature for Dupont Crastin® SK glass reinforced, injection molding PBT resins.

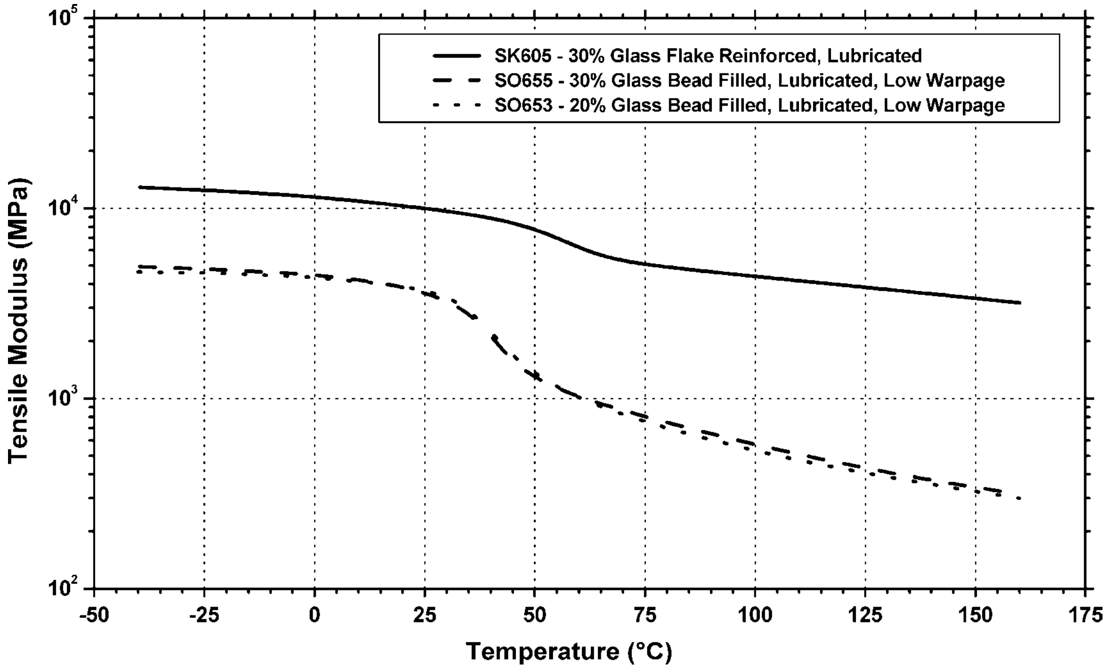


Figure 4.45. Tensile modulus vs. temperature for Dupont Crastin® glass reinforced PBT resins.

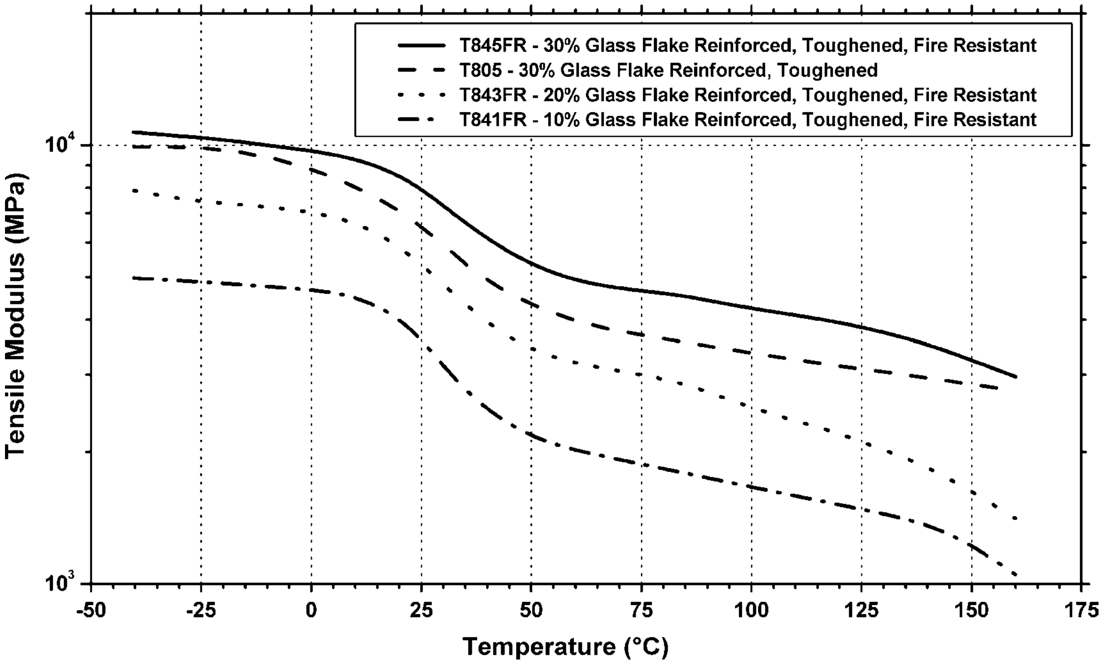


Figure 4.46. Tensile modulus vs. temperature for Dupont Crastin® high impact/toughened PBT resins.

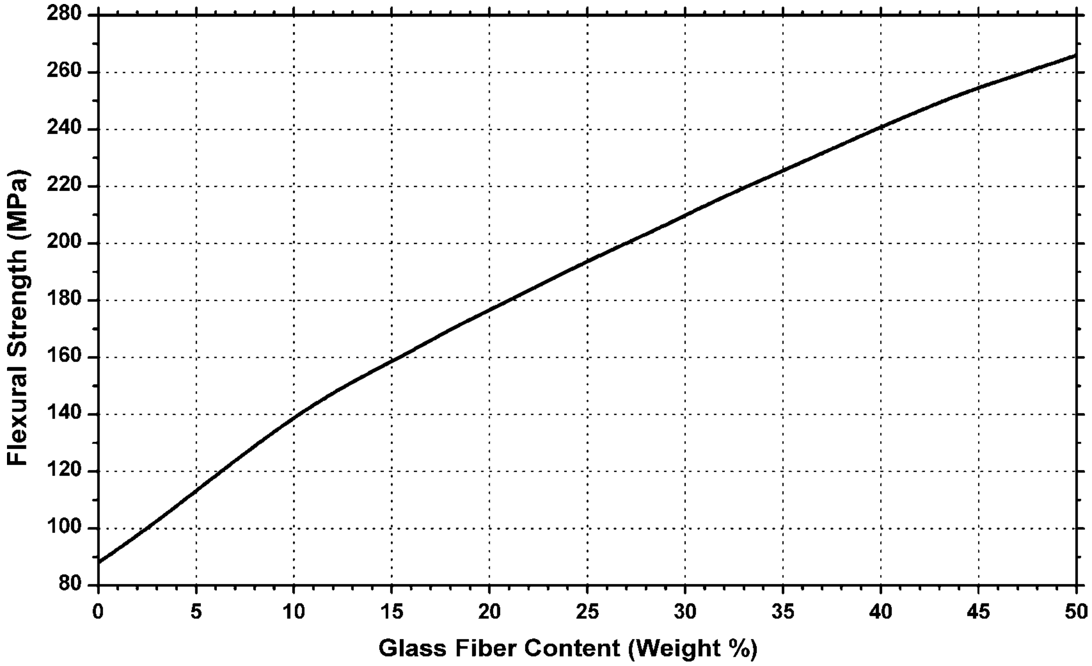


Figure 4.47. Flexural strength vs. glass fiber content for Dupont Crastin® SK glass reinforced, injection molding PBT resins.

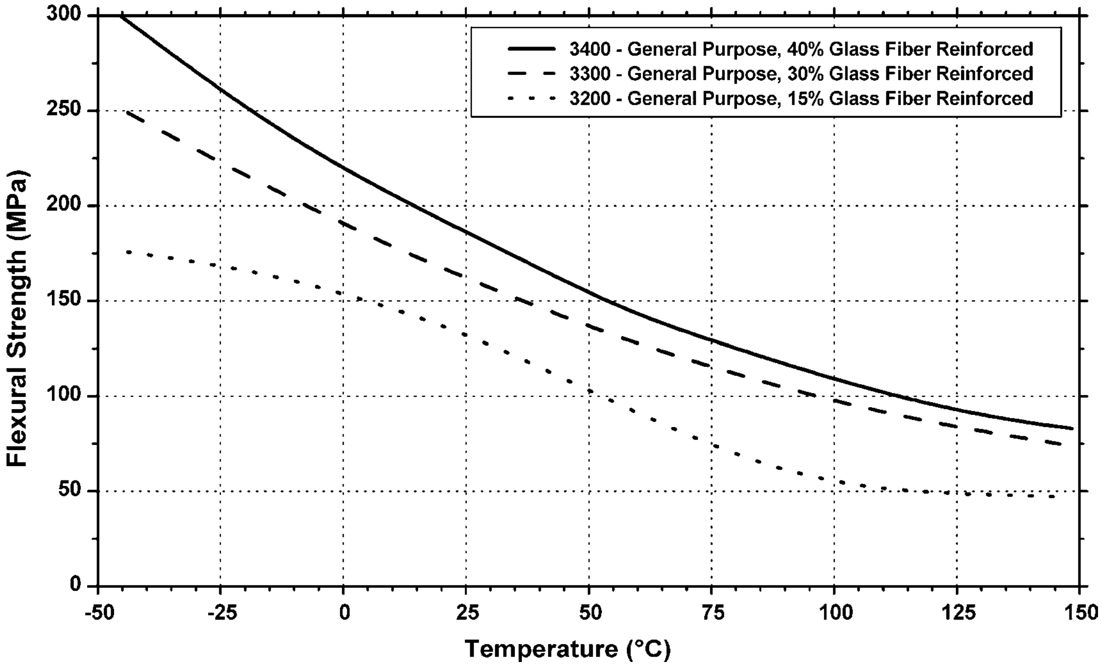


Figure 4.48. Flexural strength vs. temperature for Ticona Celanex® general purpose, glass fiber reinforced PBT resins.

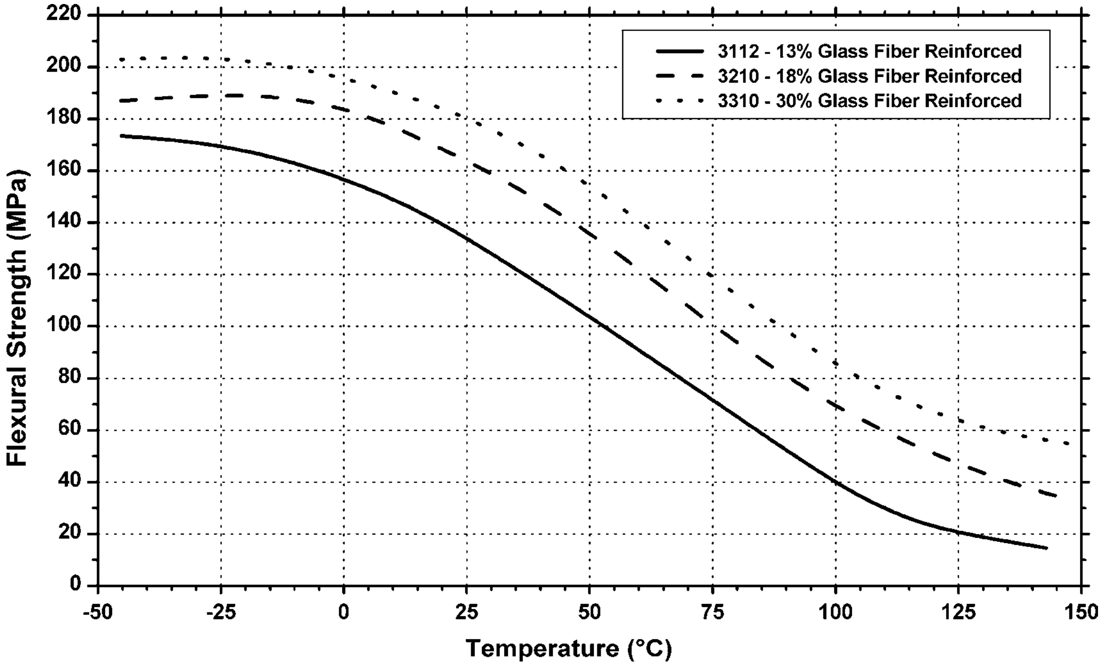


Figure 4.49. Flexural strength vs. temperature for Ticona Celanex® flame retardant, glass fiber reinforced PBT resins.

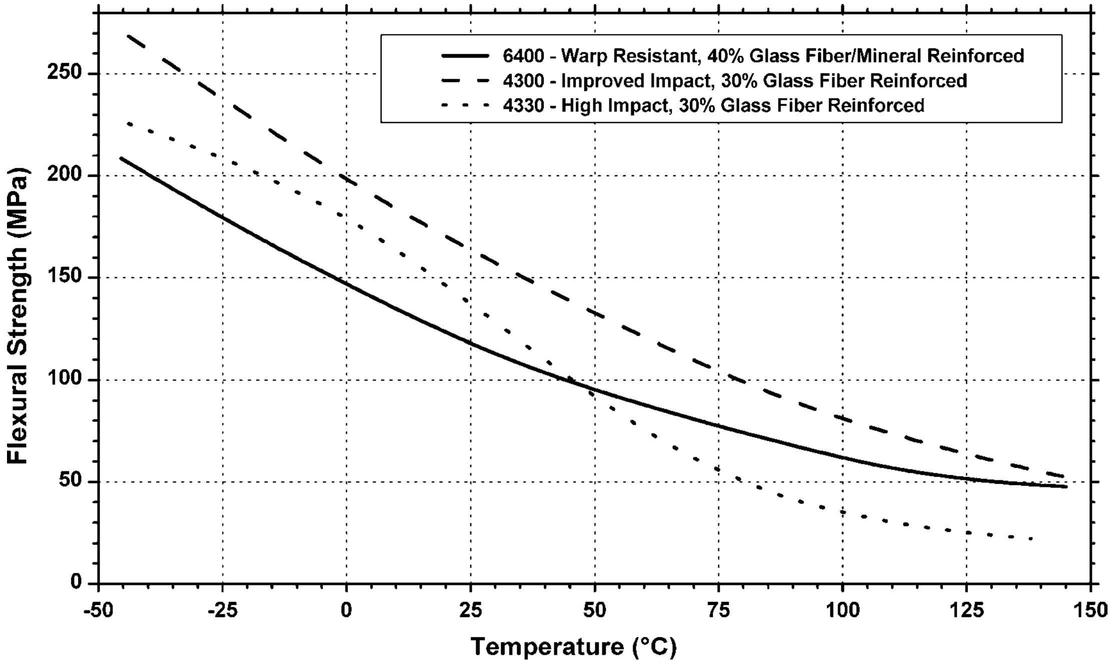


Figure 4.50. Flexural strength vs. temperature for Ticona Celanex® high impact, glass fiber reinforced PBT resins.

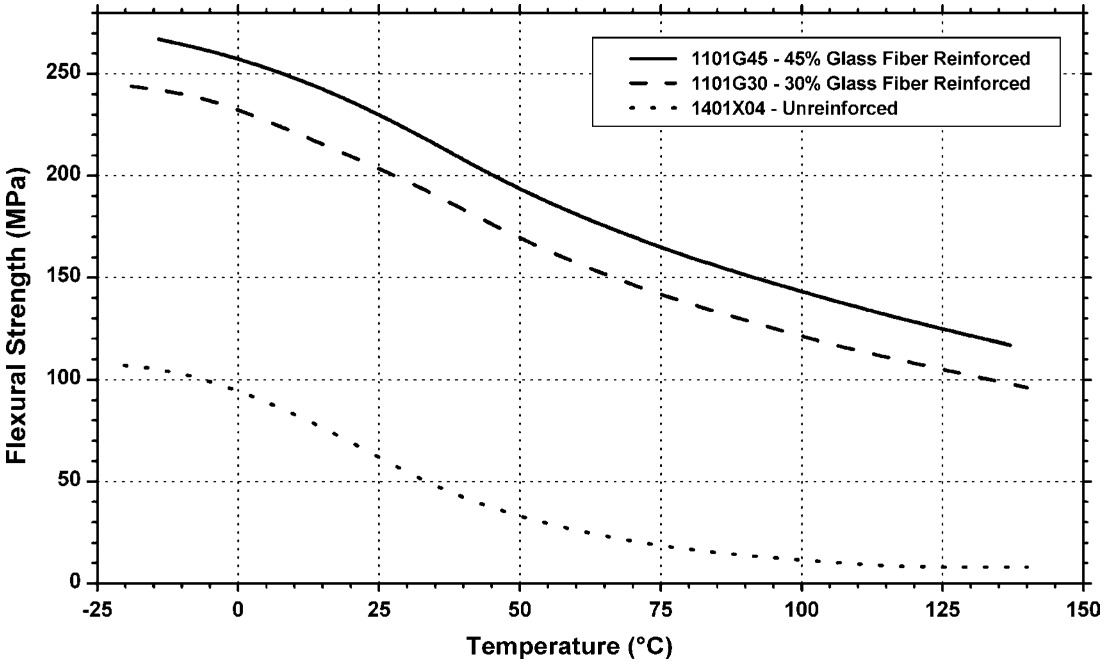


Figure 4.51. Flexural strength vs. temperature for Toray Toraycon® PBT resins.

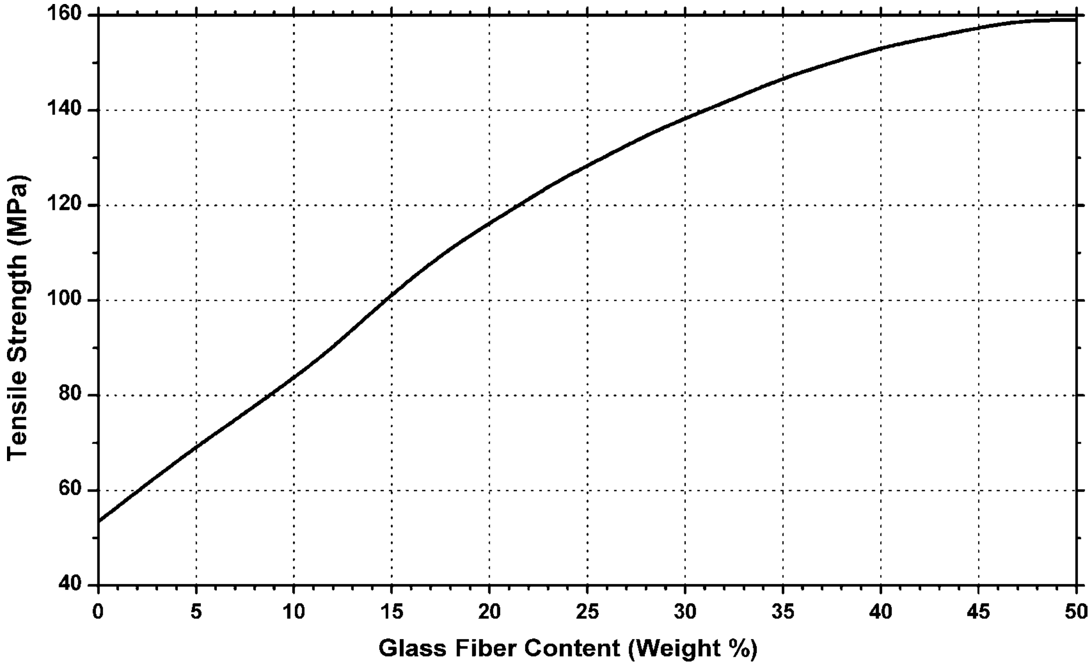


Figure 4.52. Tensile strength vs. fiber glass reinforcement content for Dupont Crastin® SK glass reinforced, injection molding PBT resins.

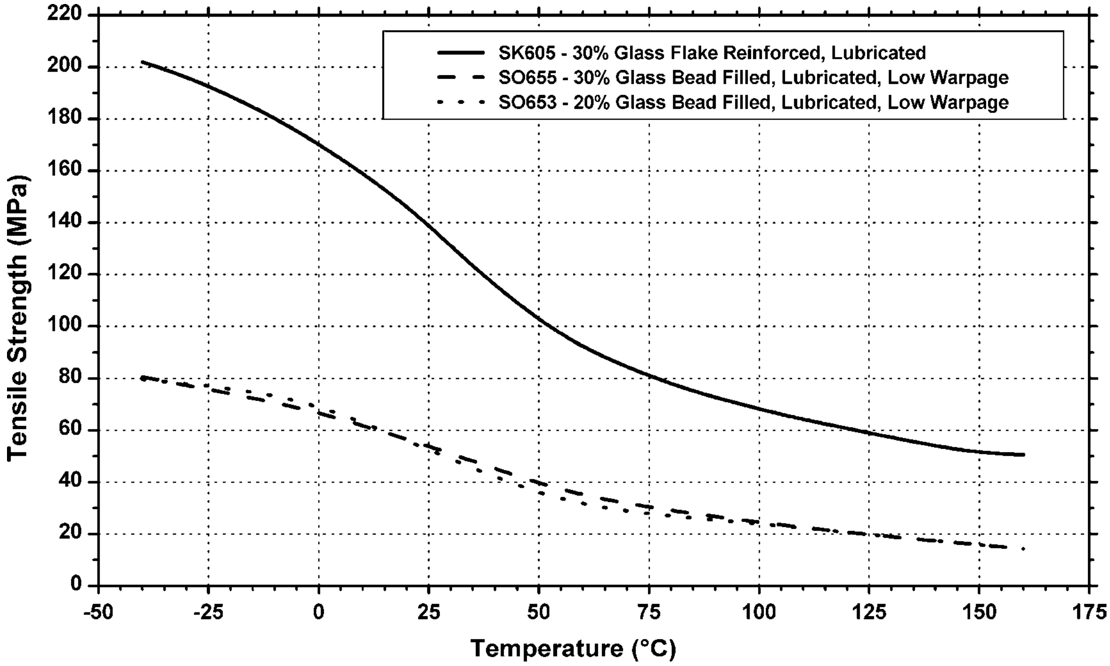


Figure 4.53. Tensile strength vs. temperature for Dupont Crastin® glass reinforced PBT resins.

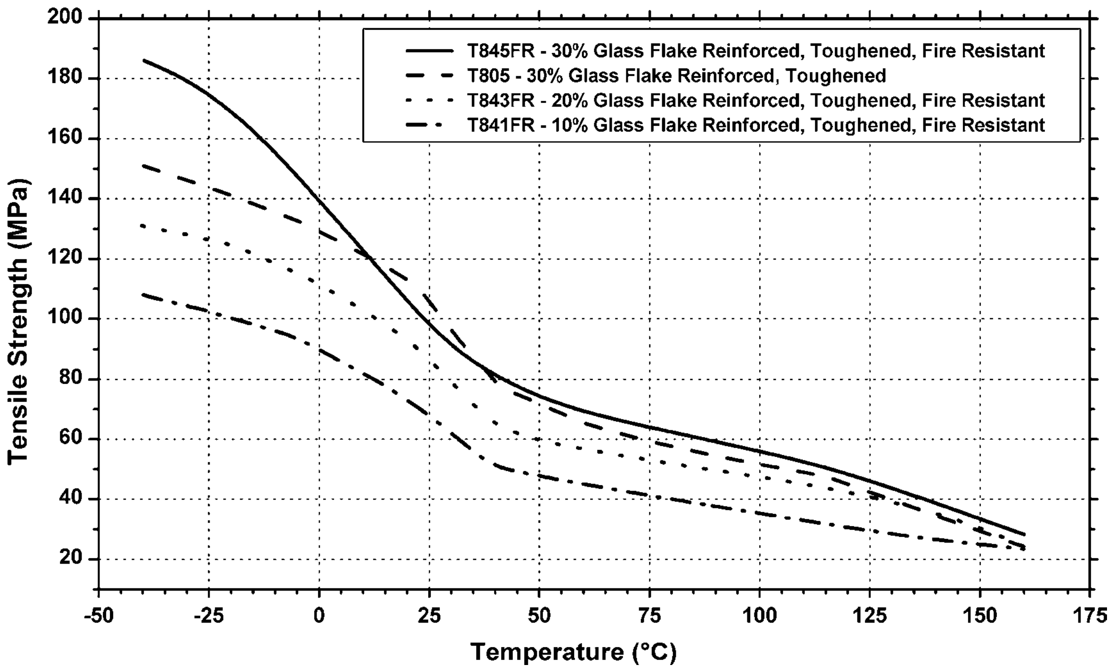


Figure 4.54. Tensile strength vs. temperature for Dupont Crastin® high impact/toughened PBT resins.

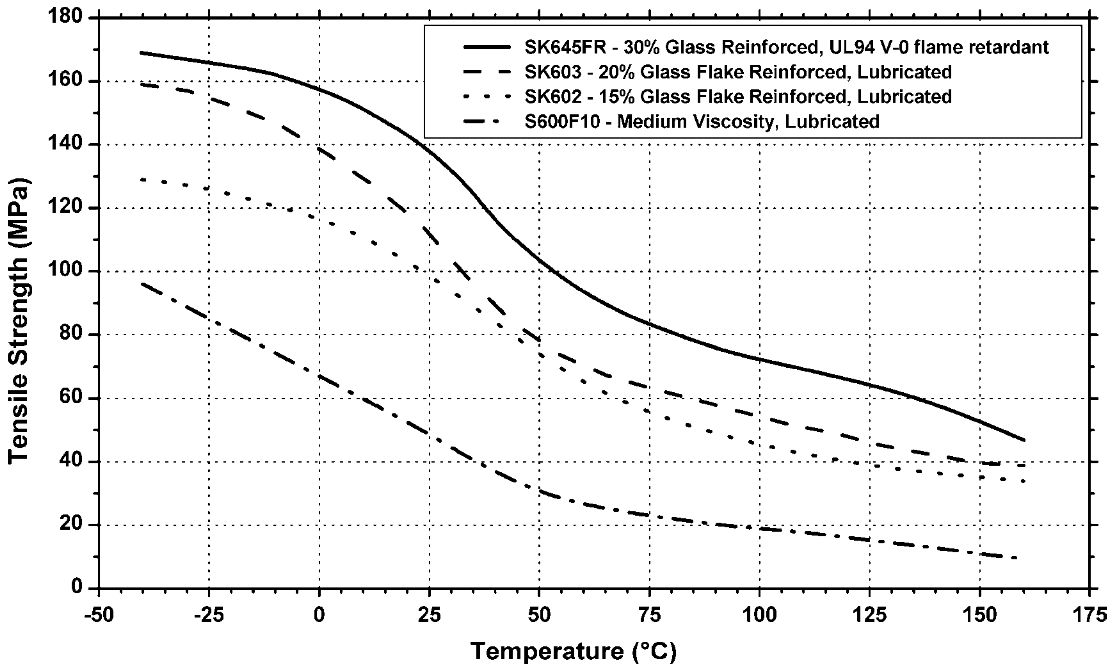


Figure 4.55. Tensile strength vs. temperature for Dupont Crastin® SK glass reinforced, injection molding PBT resins.

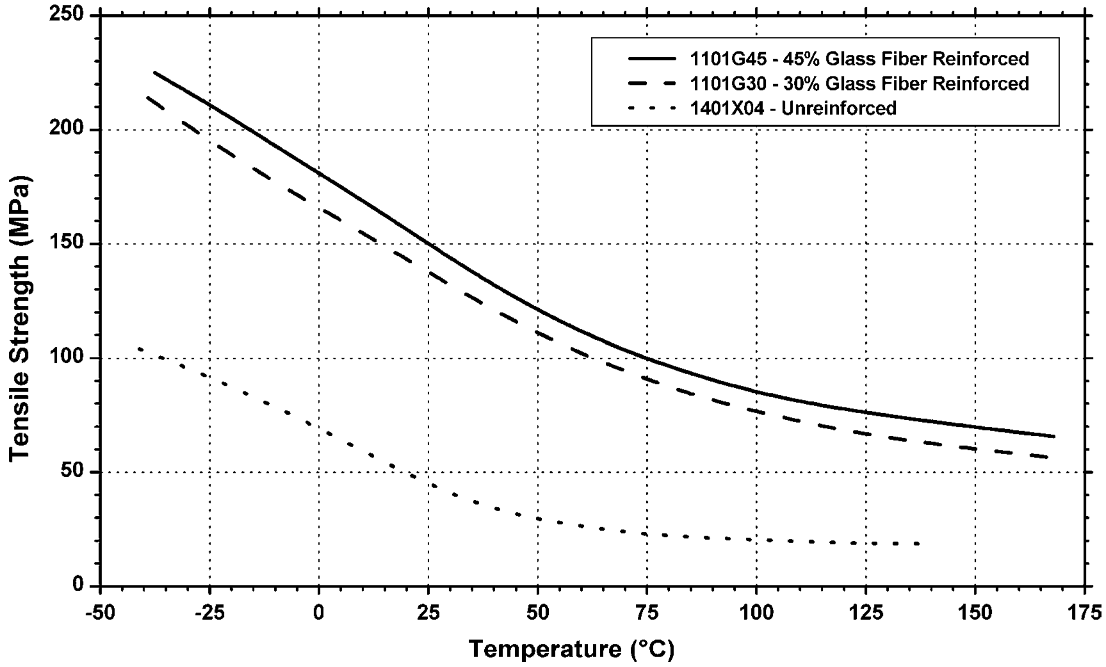


Figure 4.56. Tensile strength vs. temperature for Toray Toraycon® PBT resins.

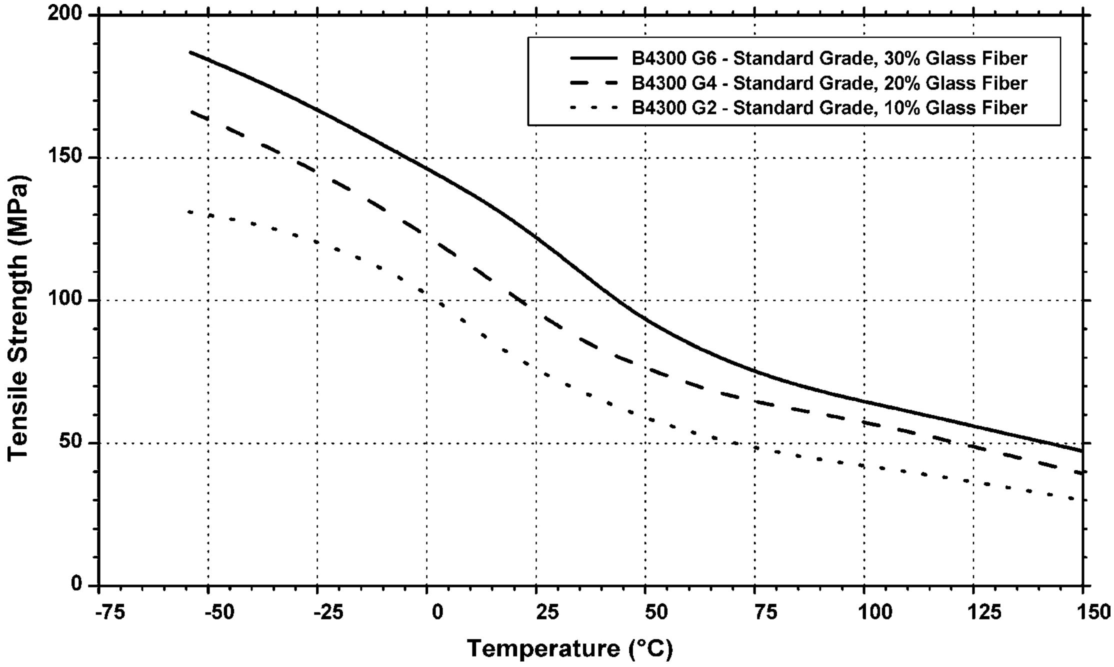


Figure 4.57. Tensile strength vs. temperature for BASF Ultradur® standard grade, fiber glass reinforced PBT resins.

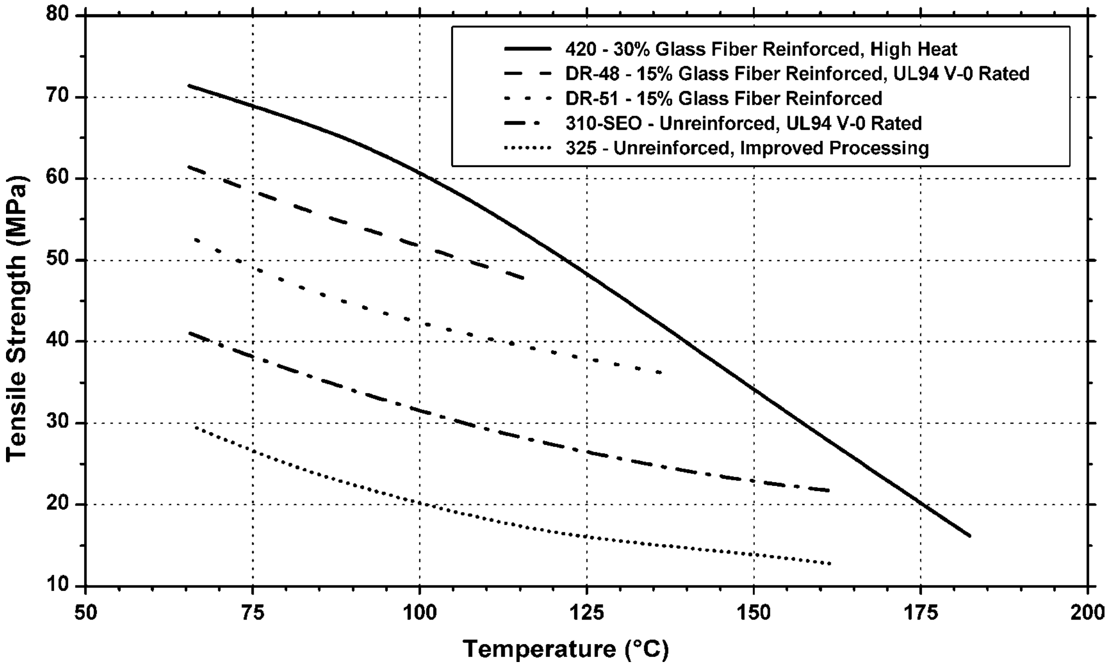


Figure 4.58. Tensile strength vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

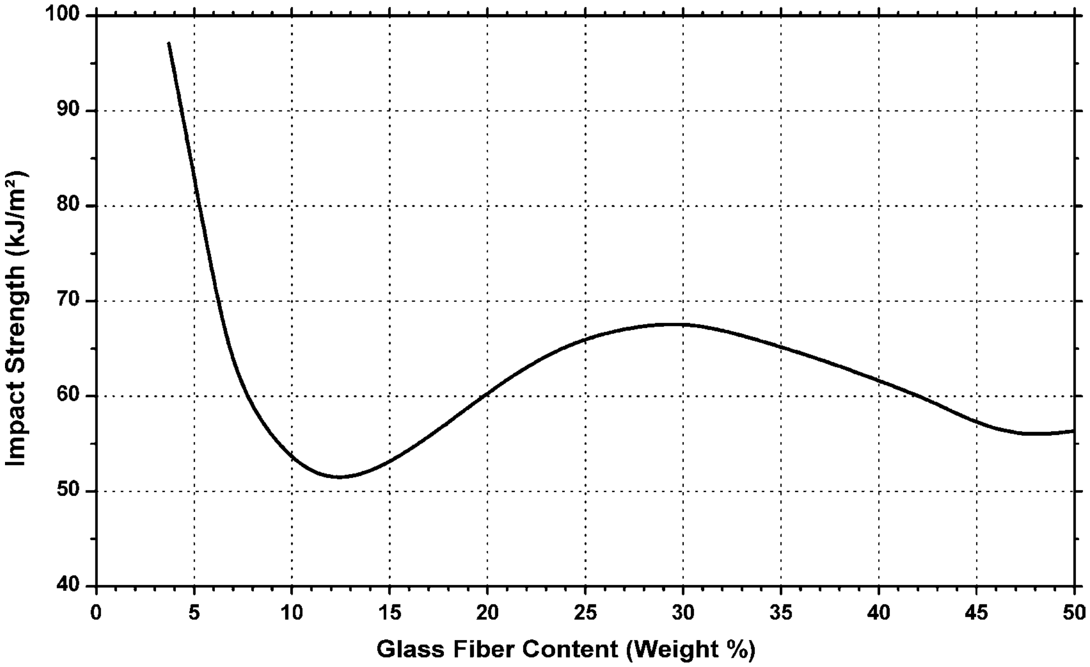


Figure 4.59. Impact strength vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins.

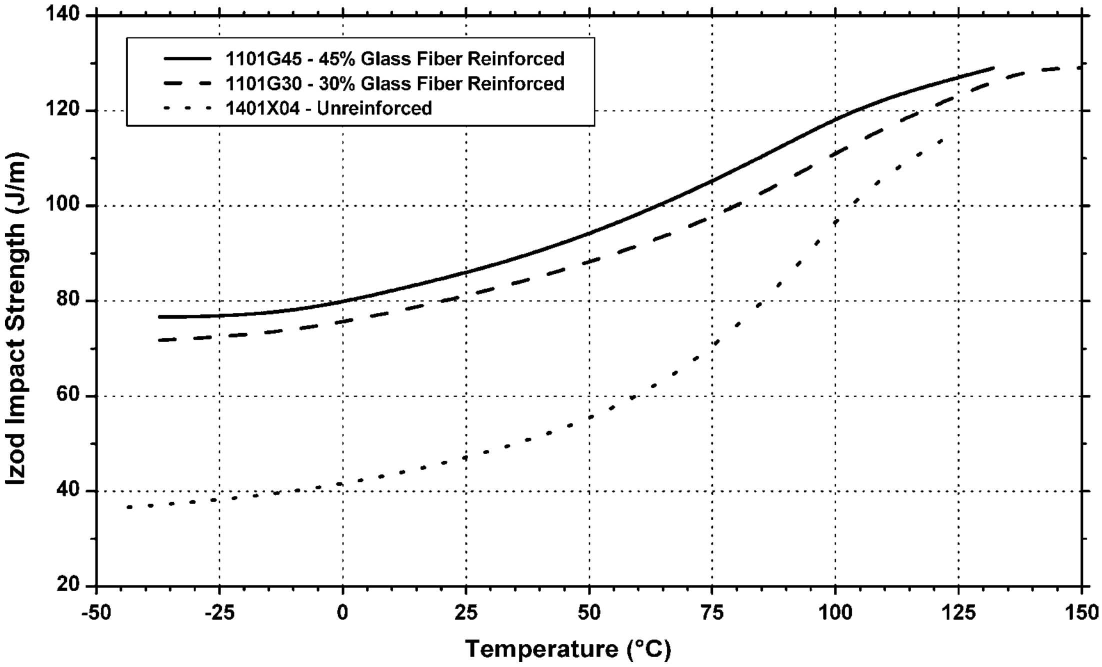


Figure 4.60. Izod impact strength vs. temperature for Toray Toraycon® PBT resins.

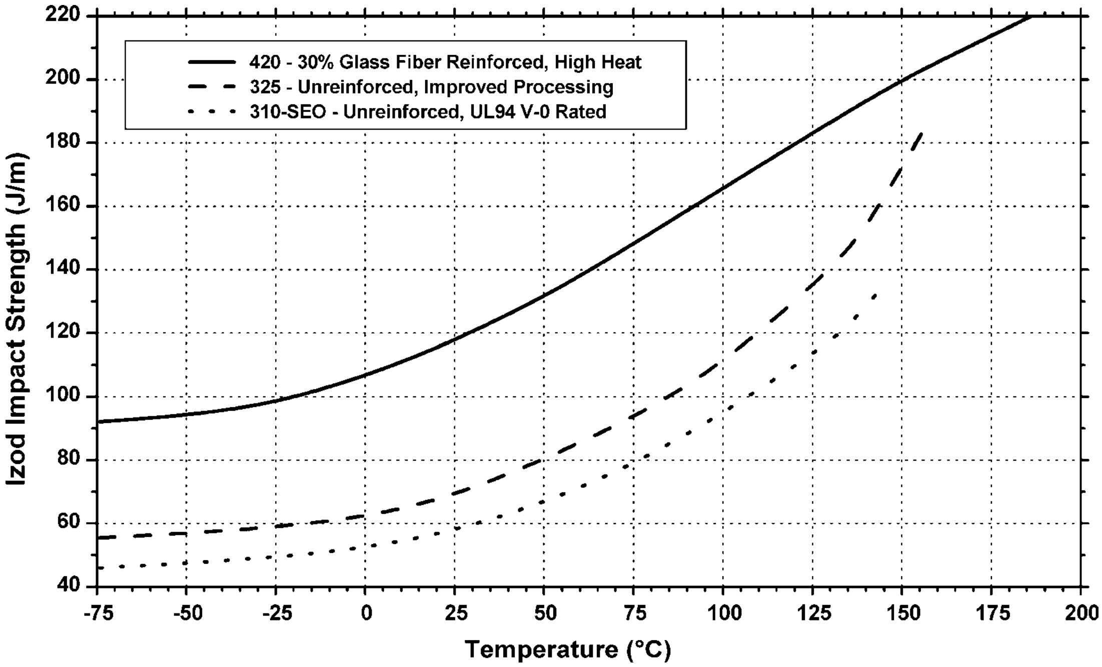


Figure 4.61. Izod impact strength vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

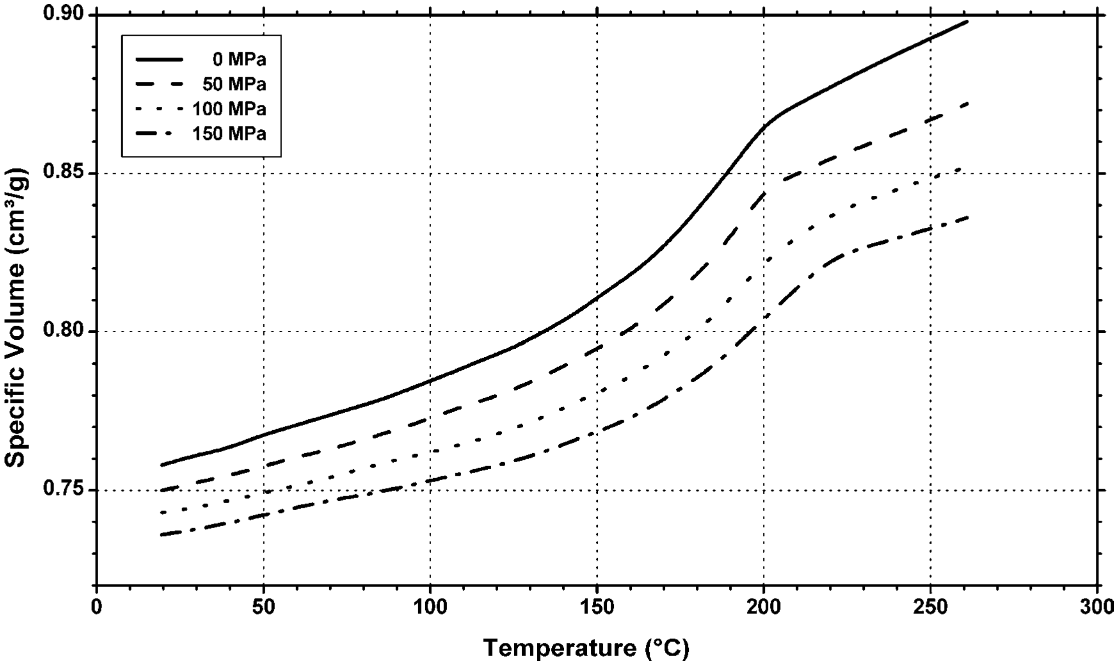


Figure 4.62. Pressure-specific volume-temperature (PVT) for DuPont Crastin® S600LF NC010—PTFE lubricated PBT resin.

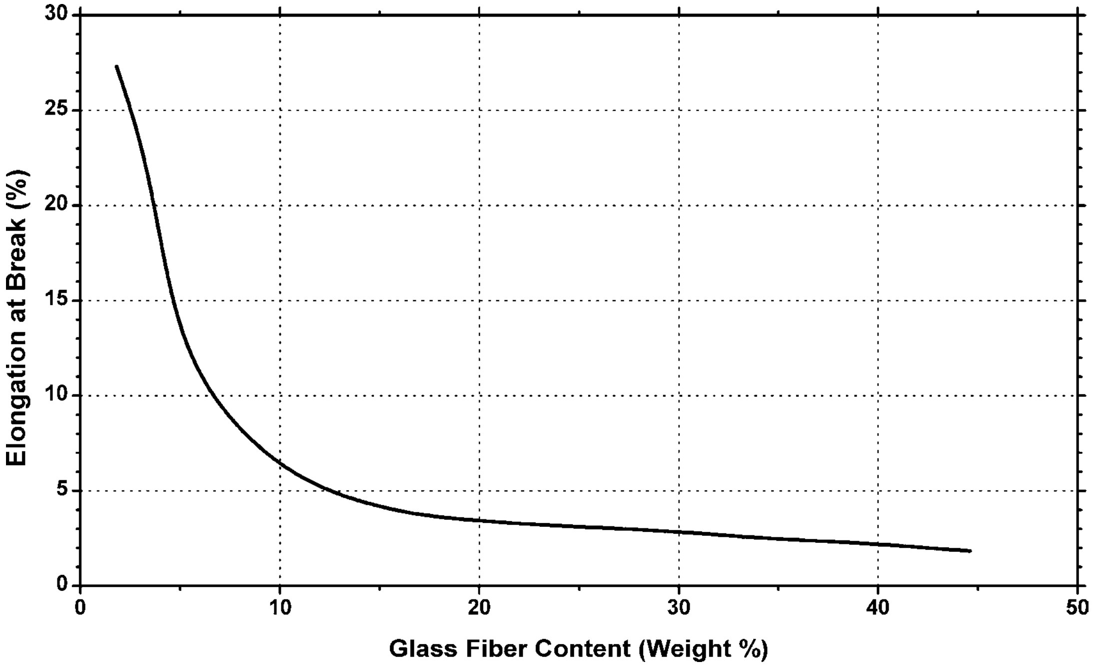


Figure 4.63. Elongation at break vs. fiber glass reinforcement content for DuPont Crastin® SK—glass reinforced, injection molding PBT resins.

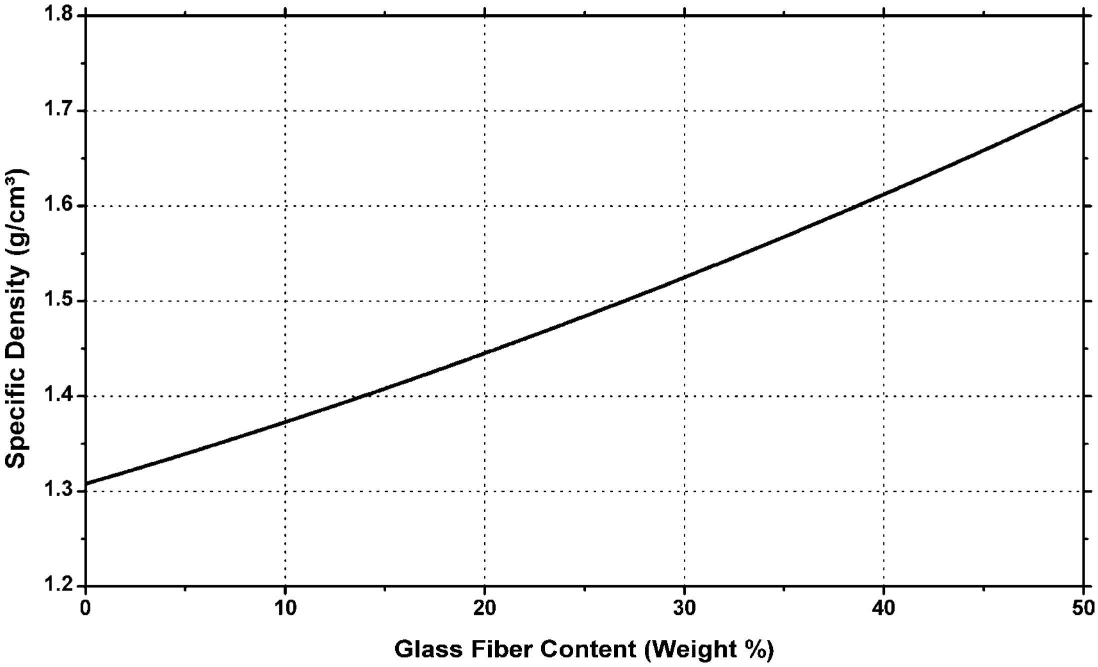


Figure 4.64. Specific density vs. fiber glass reinforcement content for DuPont Crastin® SK glass reinforced, injection molding PBT resins.

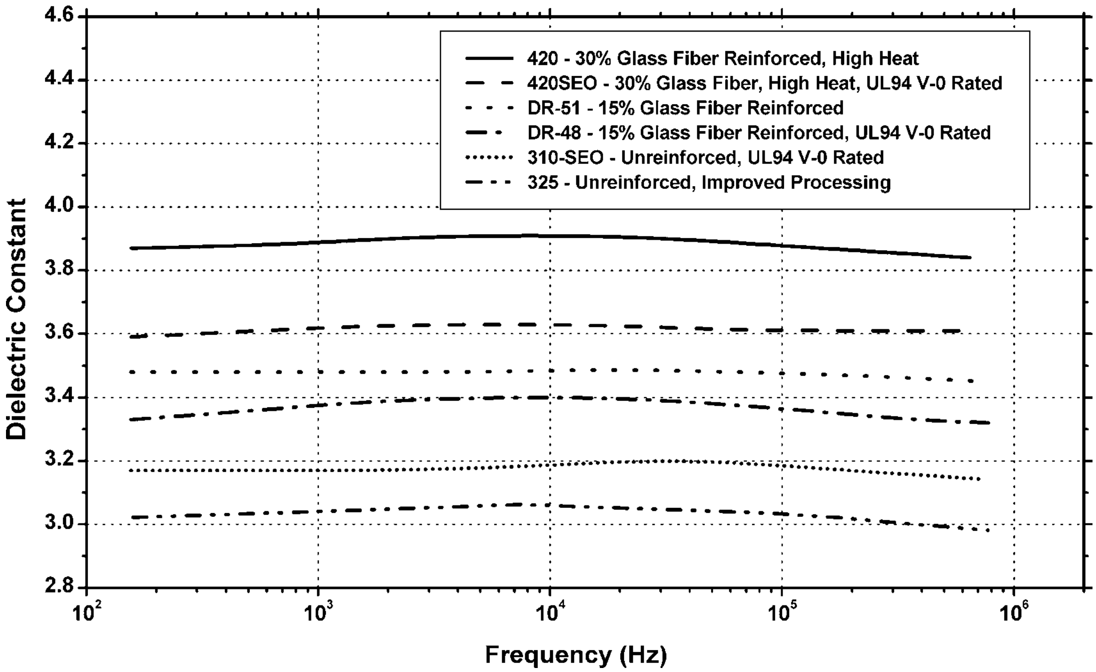


Figure 4.65. Dielectric constant vs. frequency at 23°C for SABIC Innovative Plastics Valox® PBT resins.

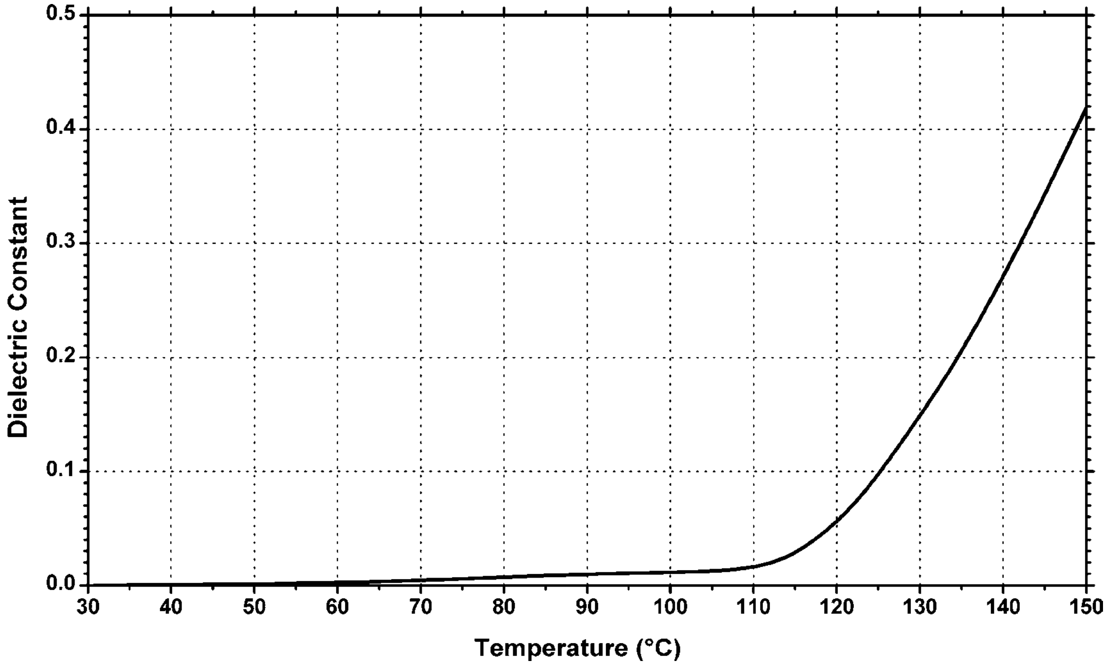


Figure 4.66. Dielectric constant vs. temperature for Toray Toraycon® PBT resins.

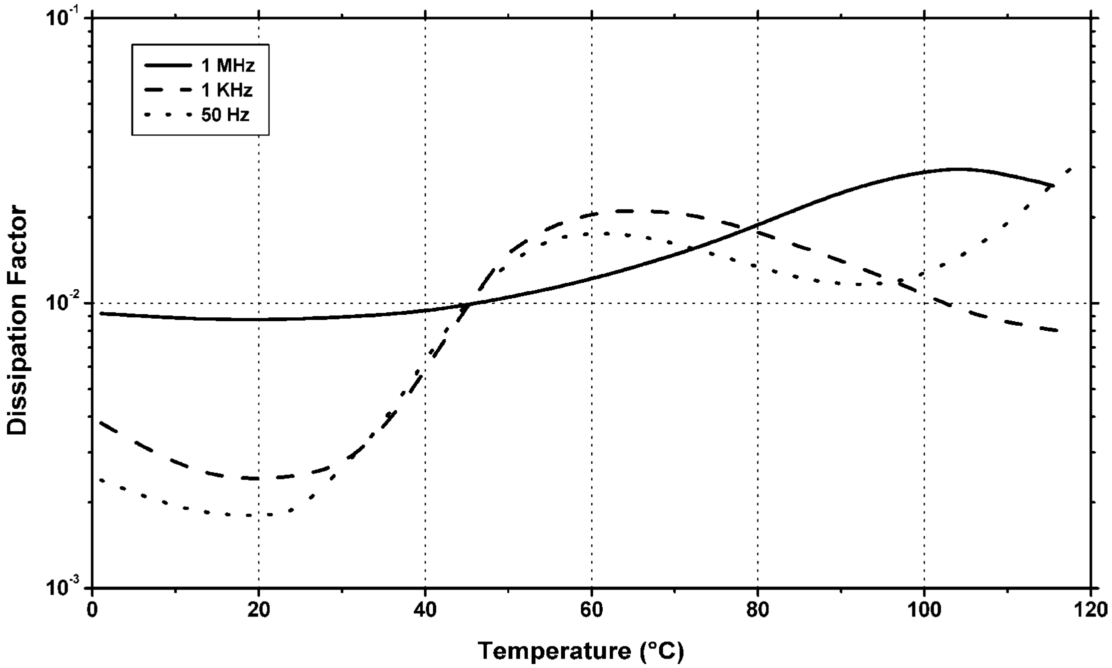


Figure 4.67. Dissipation factor vs. temperature and frequency for Lanxess Pocan® B3235—30% glass fiber reinforced, high toughness PBT resin.

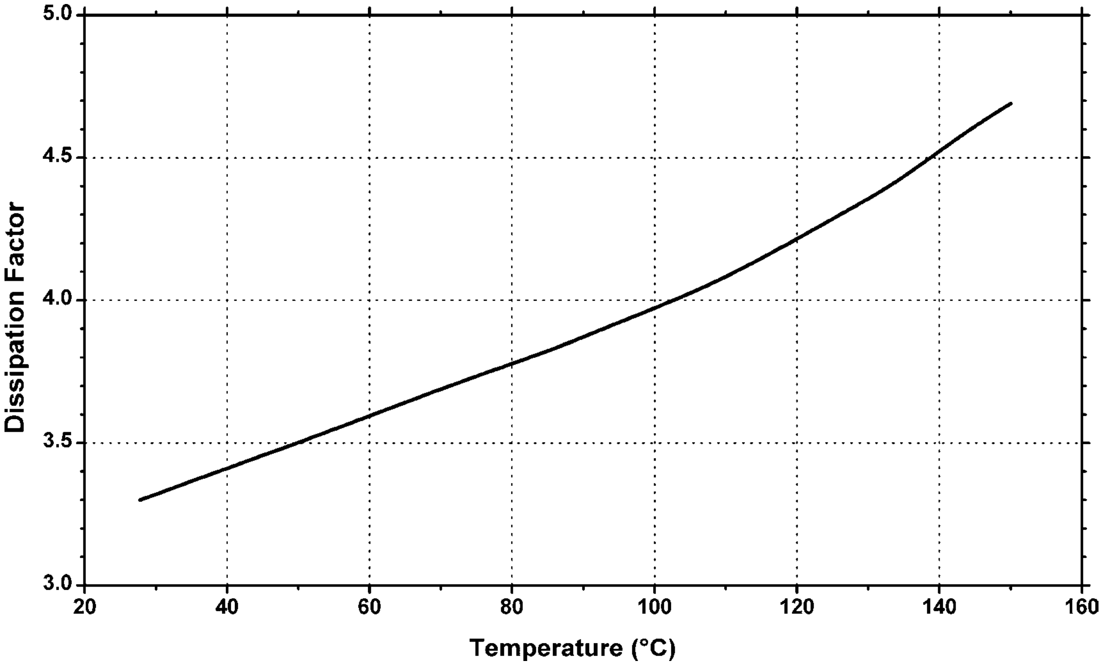


Figure 4.68. Dissipation factor vs. temperature for Toray Toraycon® PBT resins.

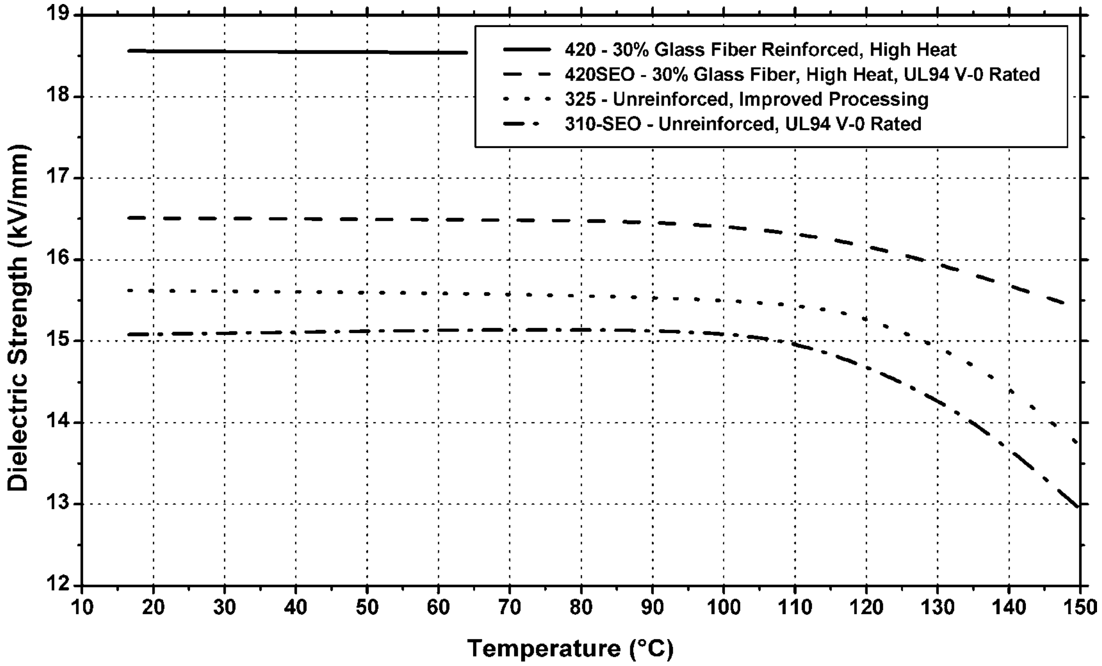


Figure 4.69. Dielectric strength vs. temperature for SABIC Innovative Plastics Valox® PBT resins.

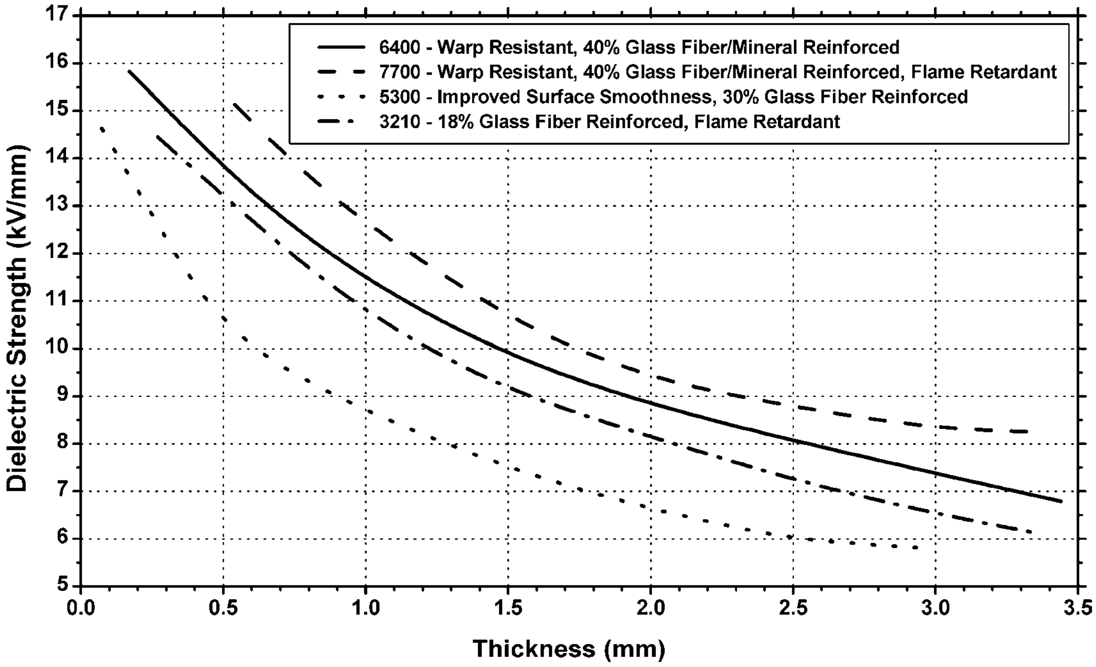


Figure 4.70. Dielectric strength vs. thickness for Ticona Celanex® PBT resins.

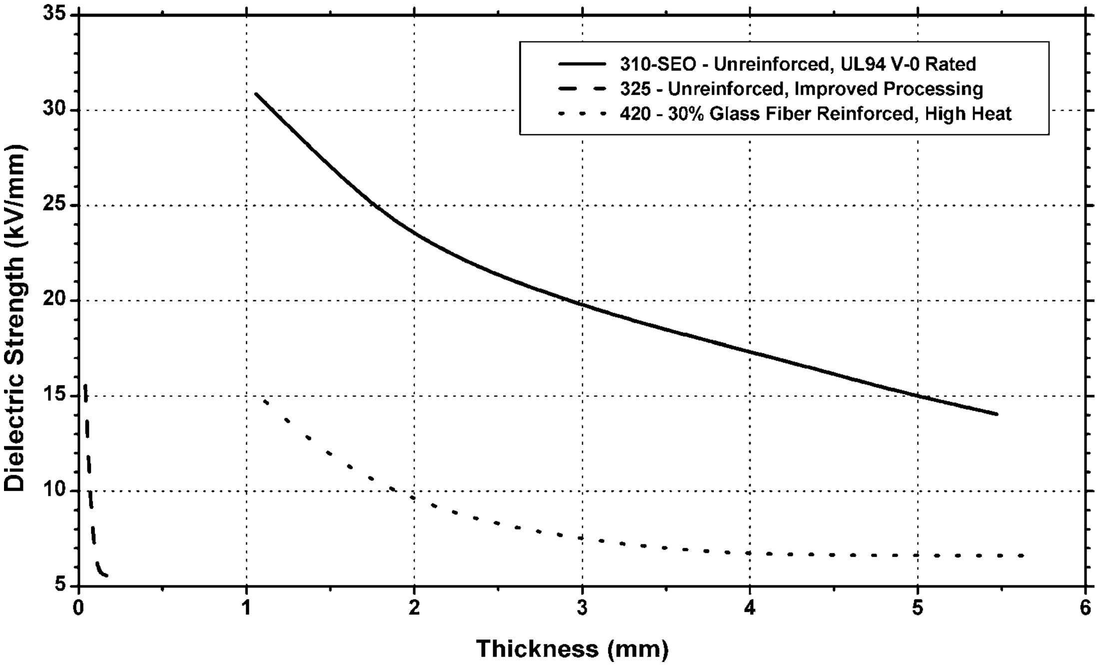


Figure 4.71. Dielectric strength vs. thickness for SABIC Innovative Plastics Valox® PBT resins.

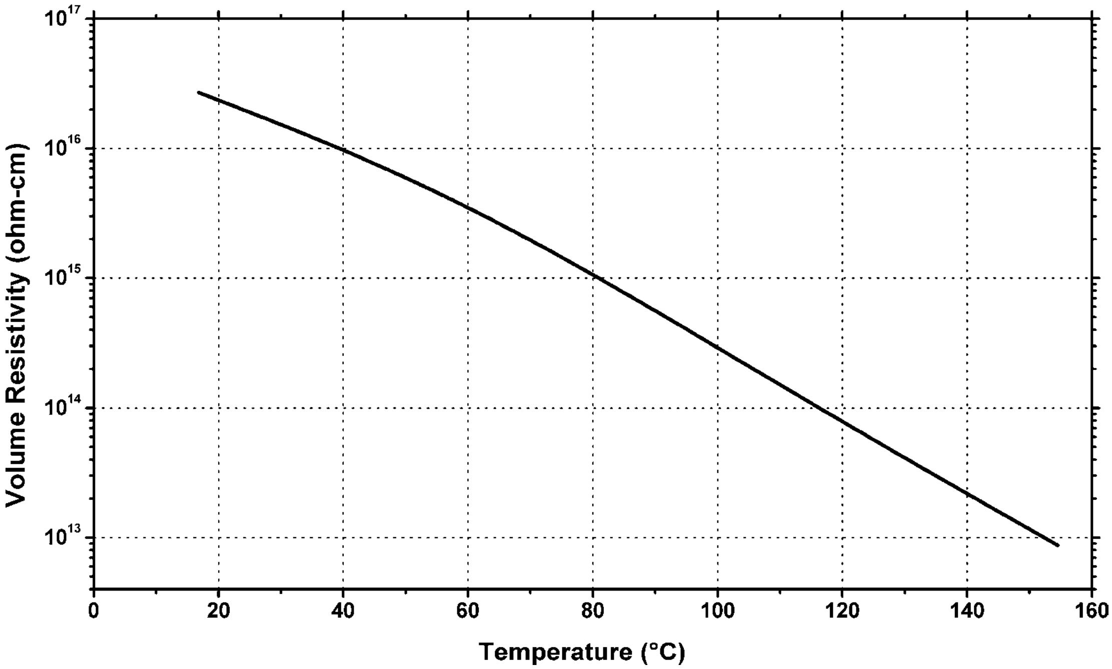


Figure 4.72. Volume resistivity vs. temperature for SABIC Innovative Plastics Valox® 420SEO—30% glass fiber, high heat, UL94 V-0 rated PBT resin.

4.4 Polyethylene Terephthalate (PET)

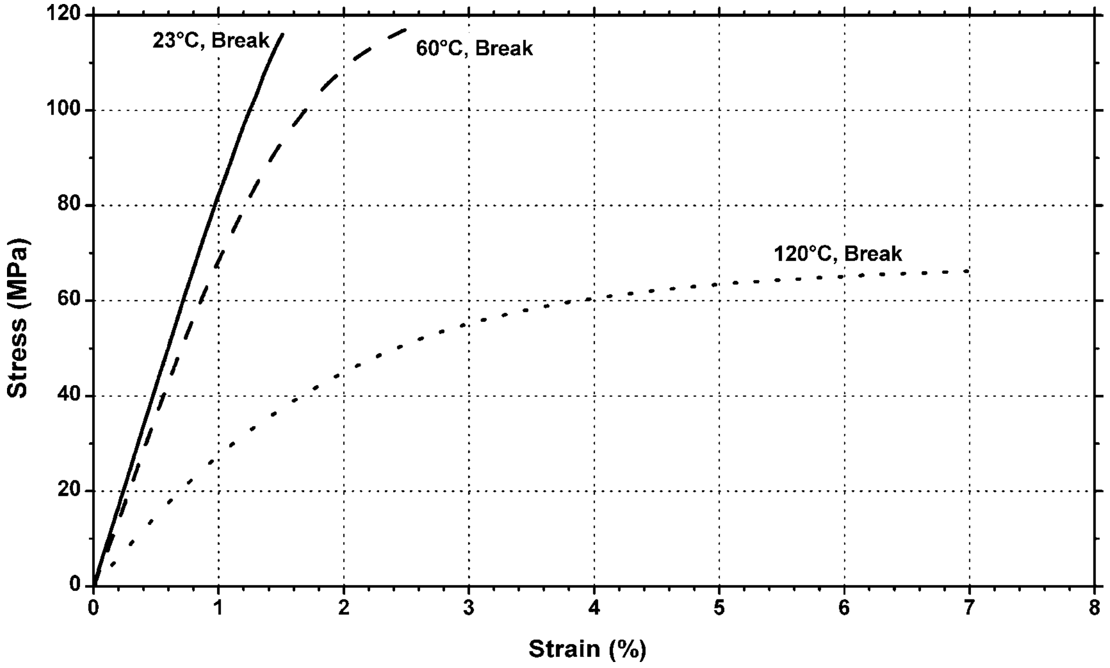


Figure 4.73. Stress vs. strain at various temperatures for Ticona Impet® 2700 GV1/20—20% glass fiber reinforced PET resin.

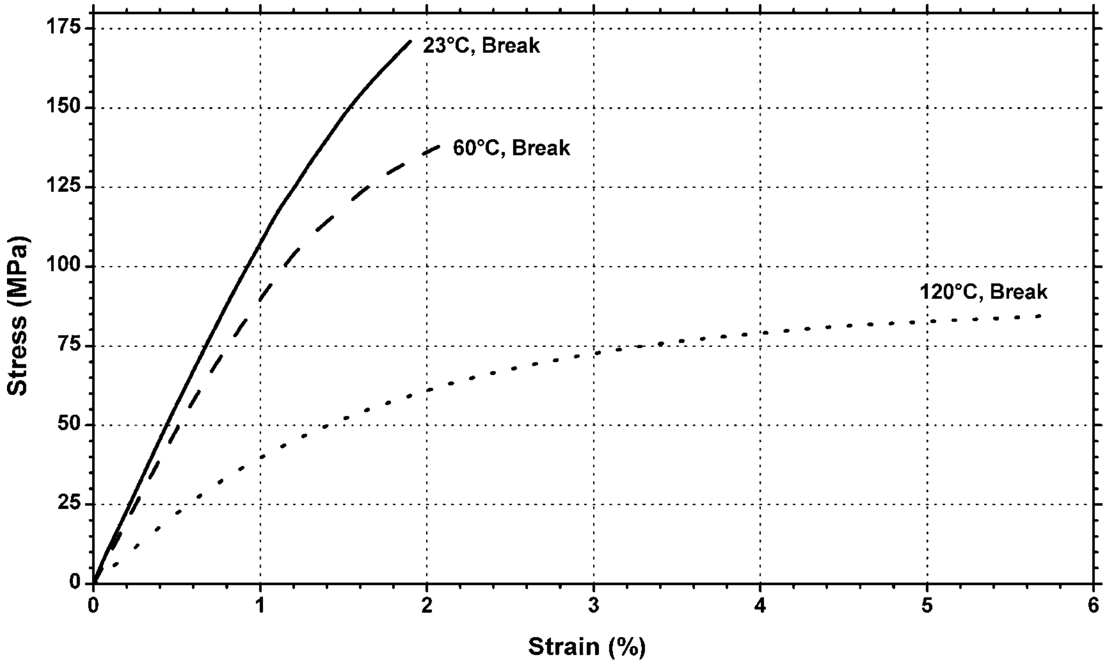


Figure 4.74. Stress vs. strain at various temperatures for Ticona Impet® 2700 GV1/30—30% glass fiber reinforced PET resin.

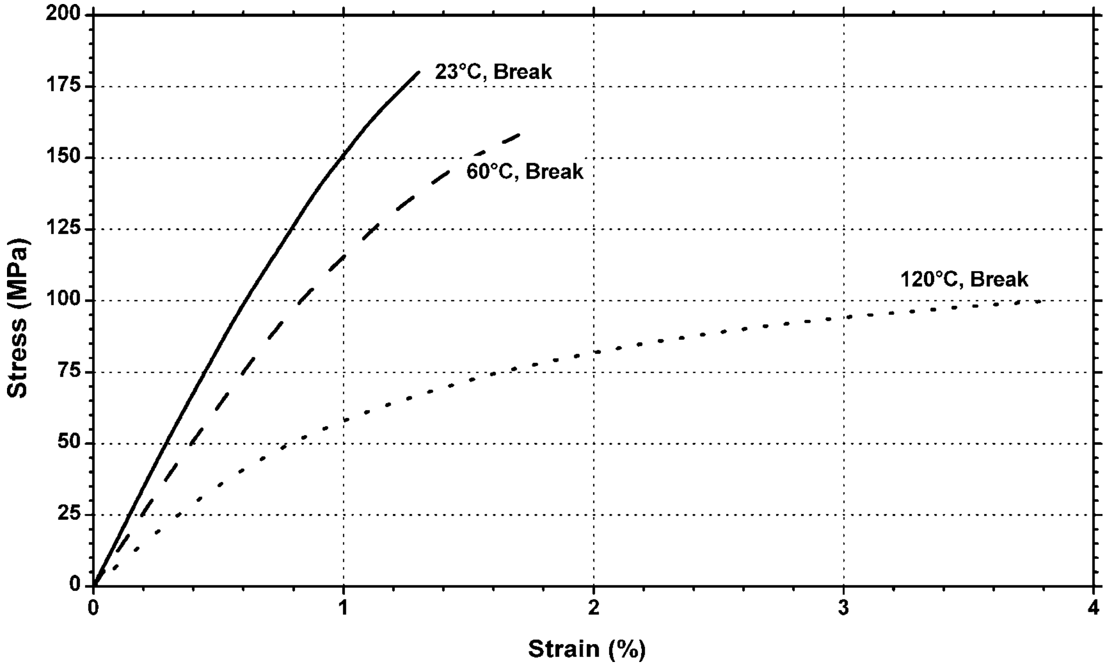


Figure 4.75. Stress vs. strain at various temperatures for Ticona Impet® 2700 GV1/45—45% glass fiber reinforced PET resin.

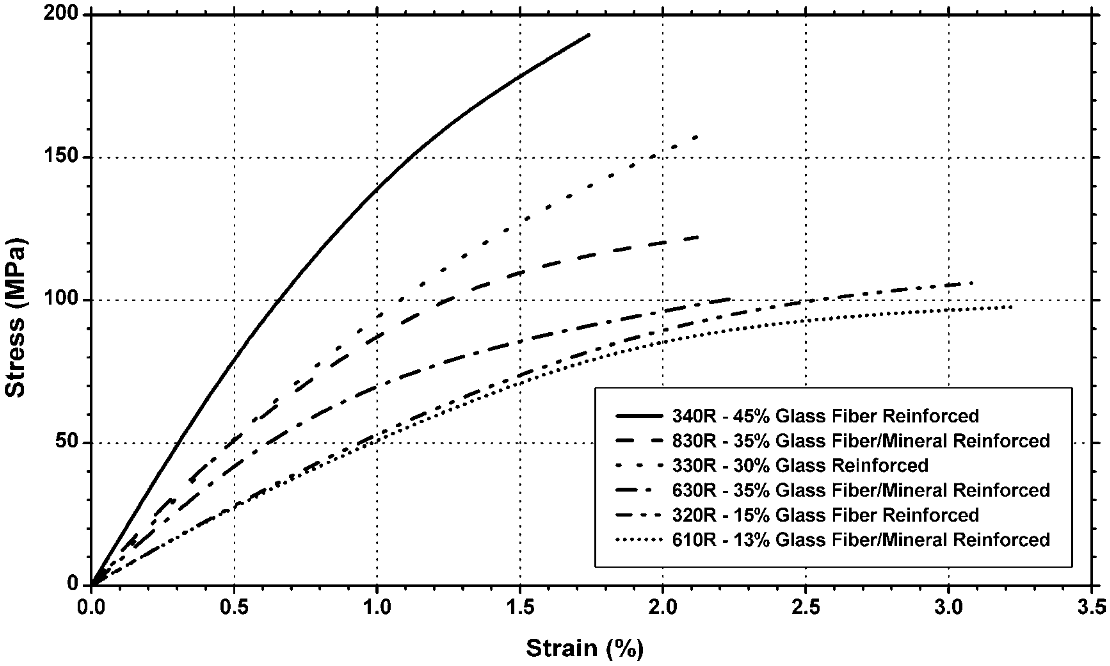


Figure 4.76. Stress vs. strain at 23°C for several Ticona Impet® reinforced PET resins.

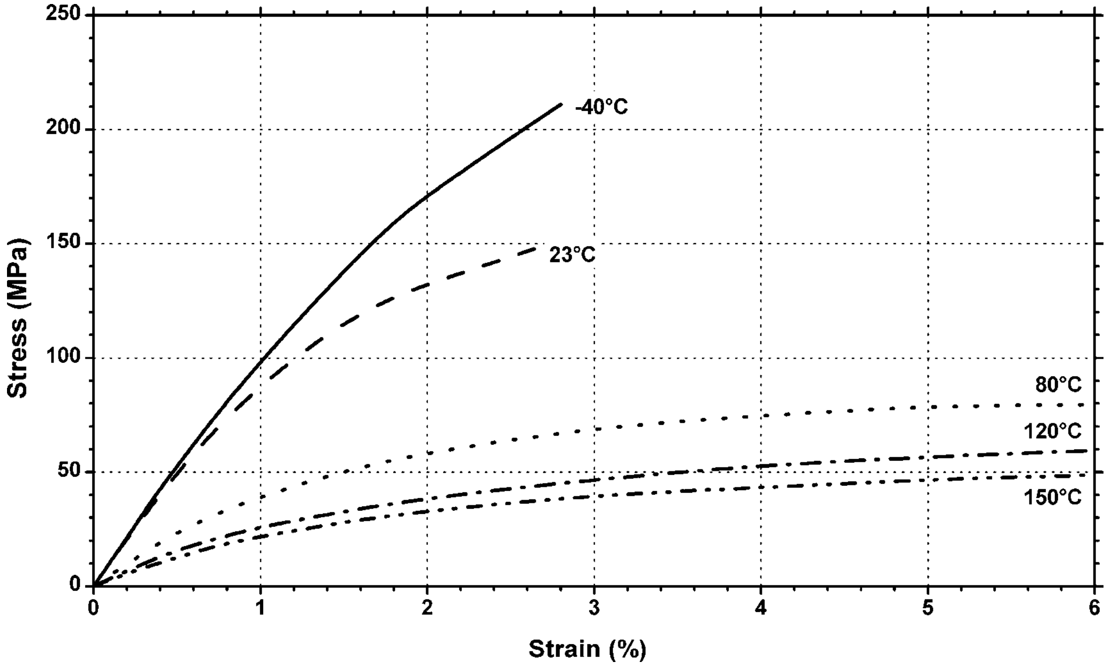


Figure 4.77. Stress vs. strain at various temperatures for BASF Petra® 130—30% glass fiber reinforced recycled PET resin.

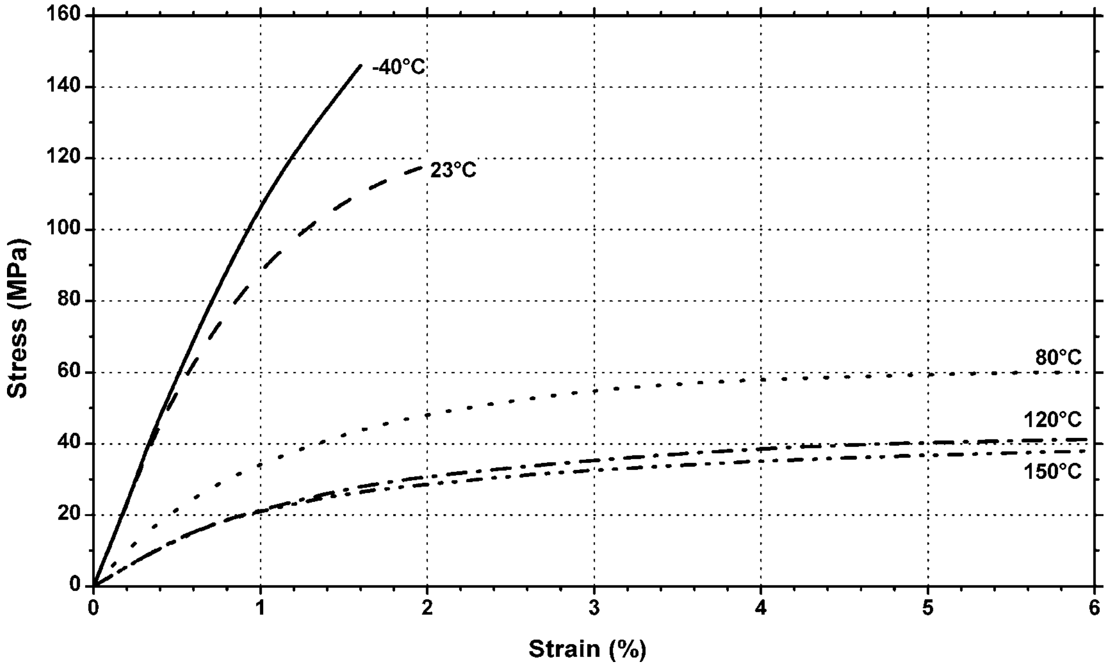


Figure 4.78. Stress vs. strain at various temperatures for BASF Petra® 30 BK-112—35% mineral/glass fiber reinforced, black, injection molding, recycled PET resin.

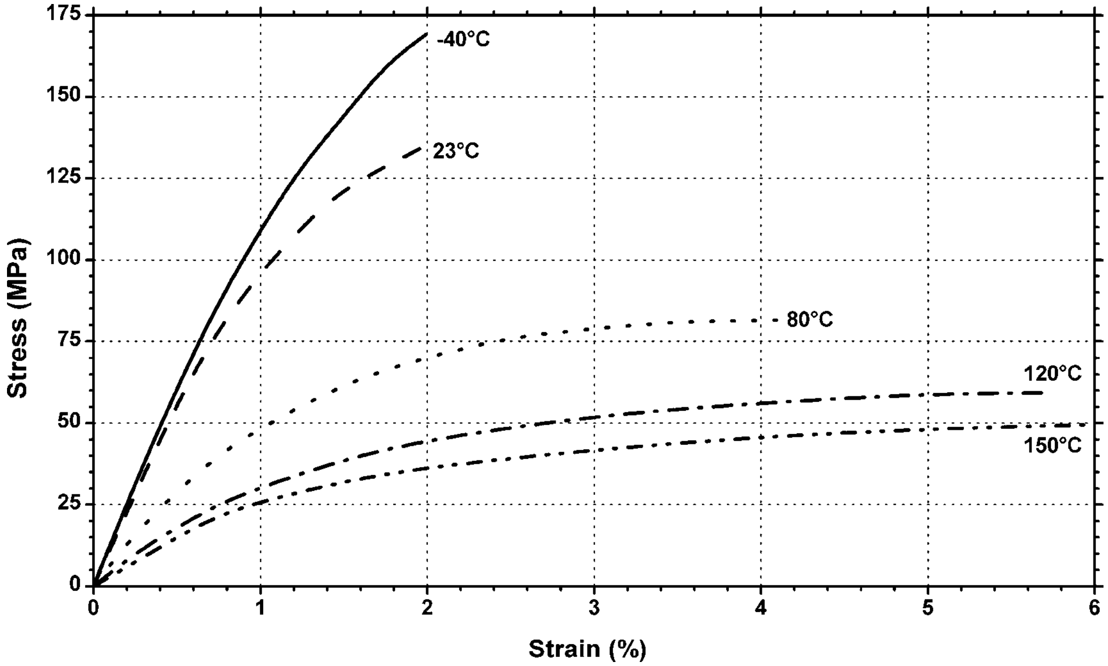


Figure 4.79. Stress vs. strain at various temperatures for BASF Petra® 330 FR BK—112%–30% glass reinforced, flame retardant, black, injection molding, UL94 V-0 rated, recycled PET resin.

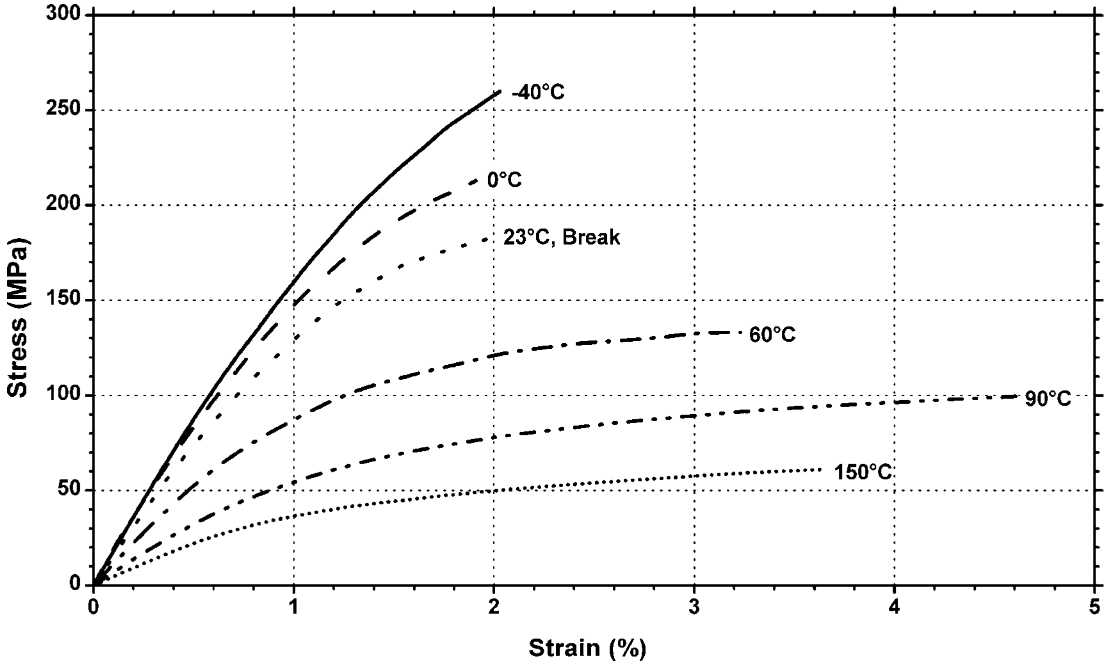


Figure 4.80. Stress vs. strain at various temperatures for DuPont Rynite® 545—general purpose, 45% glass fiber reinforced PET resin.

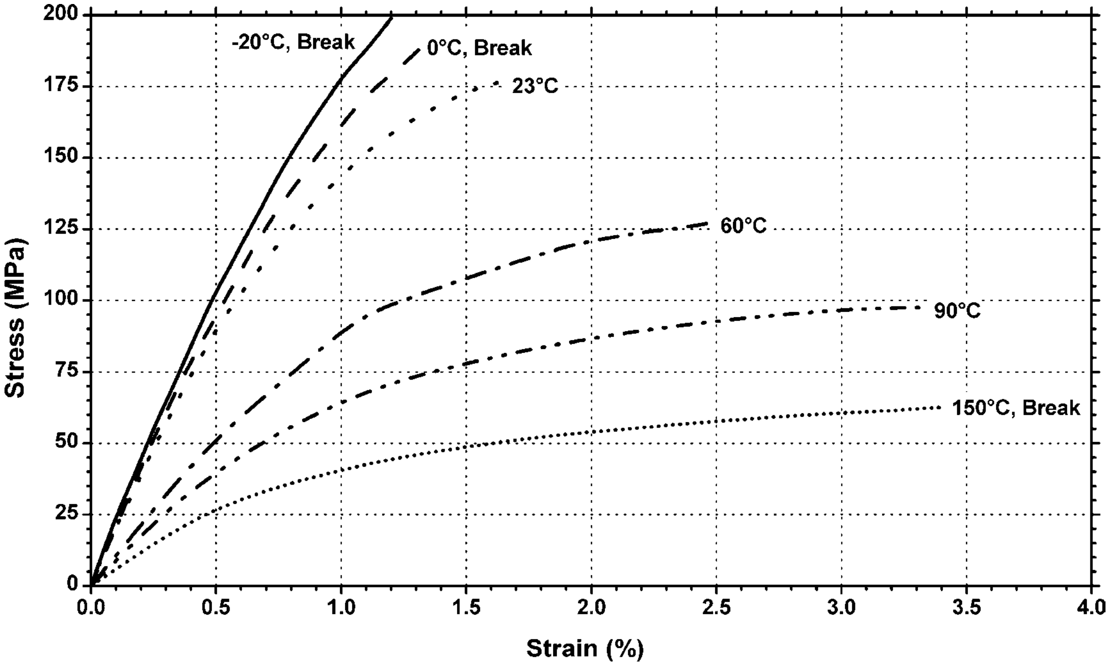


Figure 4.81. Stress vs. strain at various temperatures for DuPont Rynite® 555—general purpose, 55% glass fiber reinforced PET resin.

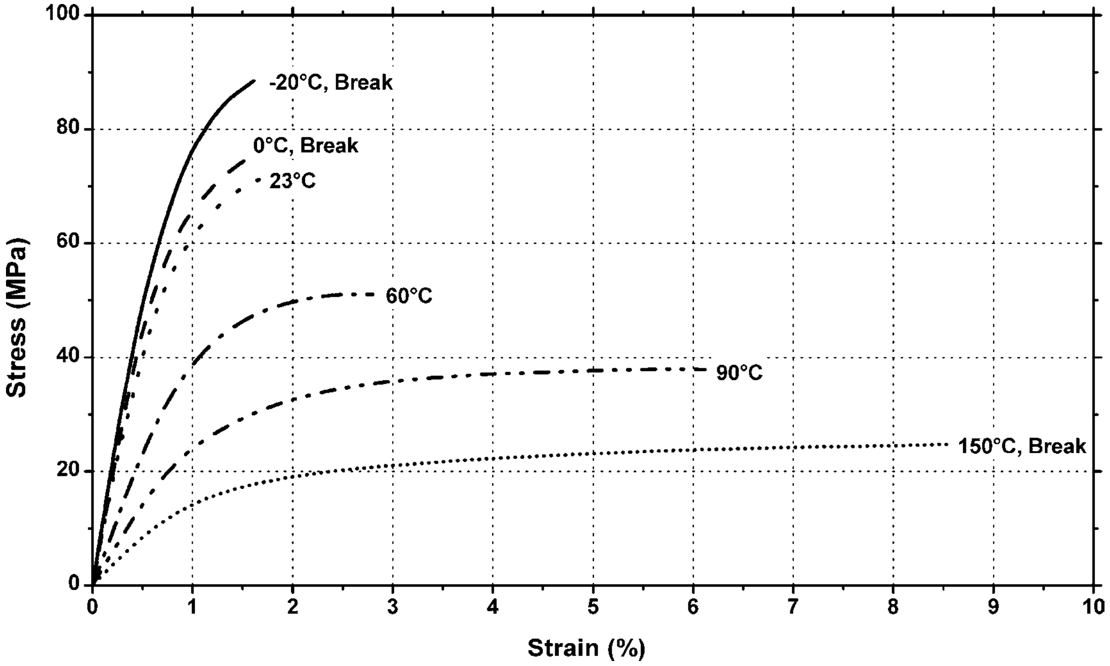


Figure 4.82. Stress vs. strain at various temperatures for DuPont Rynite® 935—low warp, 35% mica/glass reinforced PET resin.

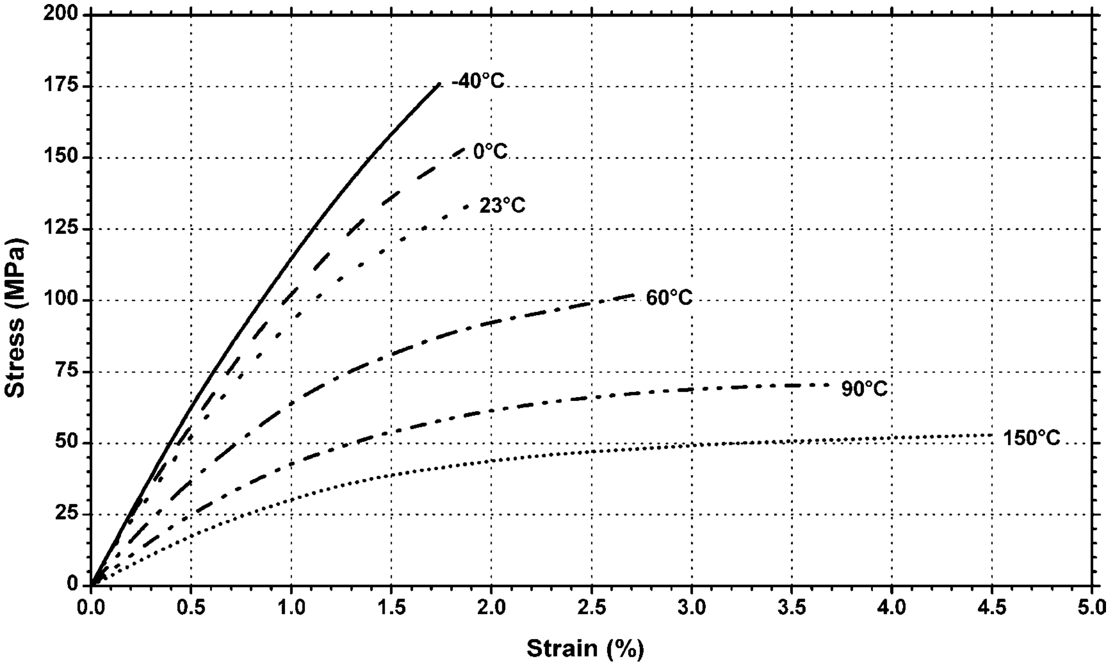


Figure 4.83. Stress vs. strain at various temperatures for DuPont Rynite® FR530L—flame retardant, 30% glass reinforced, higher heat, lubricated PET resin.

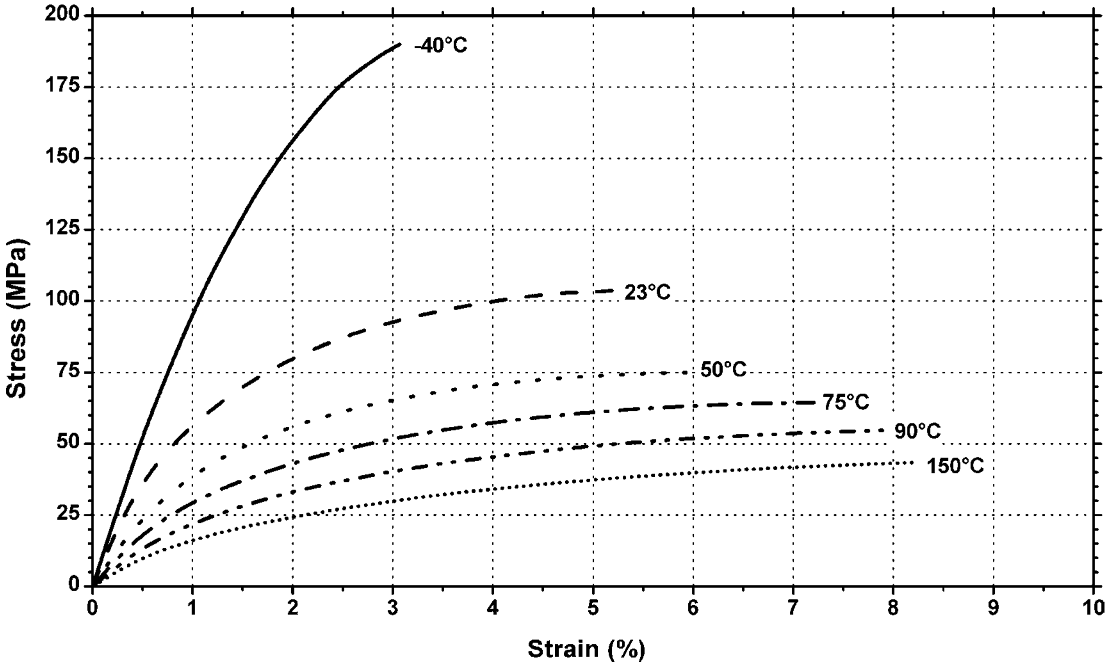


Figure 4.84. Stress vs. strain at various temperatures for DuPont Rynite® SST35—super tough, 35% glass reinforced PET resin.

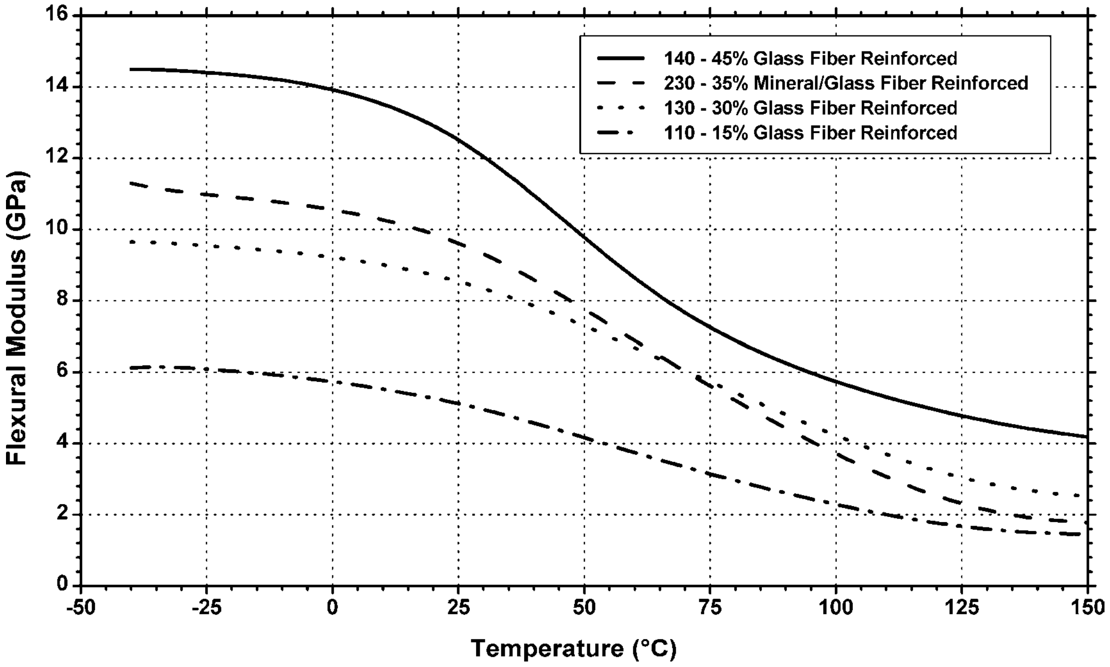


Figure 4.85. Flexural modulus vs. temperature for BASF Petra® reinforced recycled PET resins.

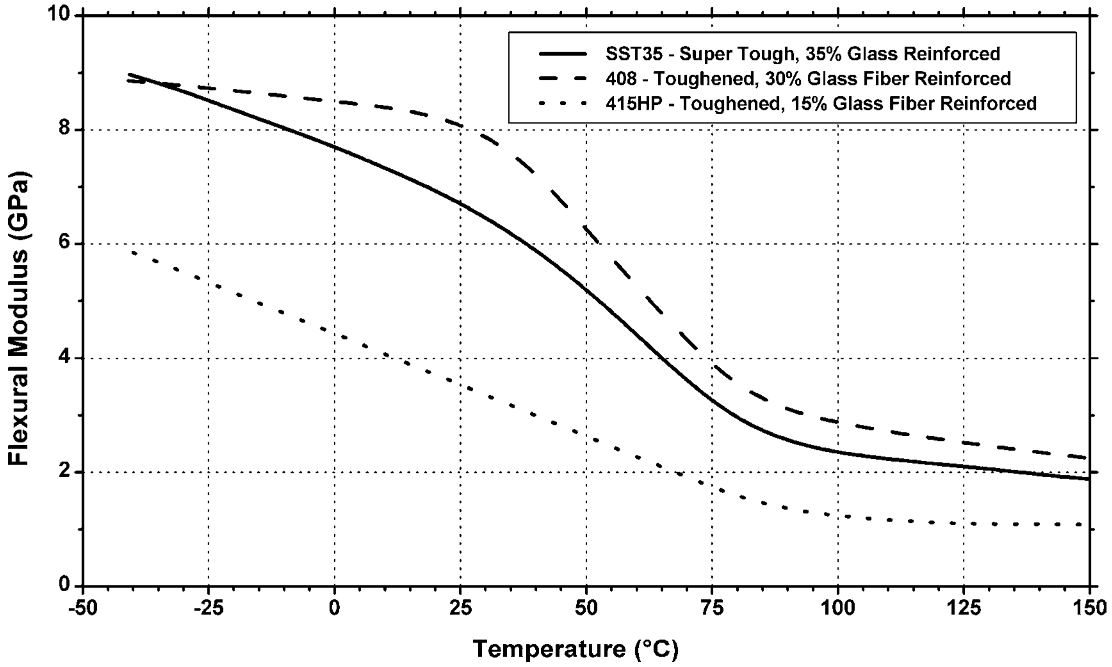


Figure 4.86. Flexural modulus vs. temperature for DuPont Rynite® toughened, reinforced PET resins.

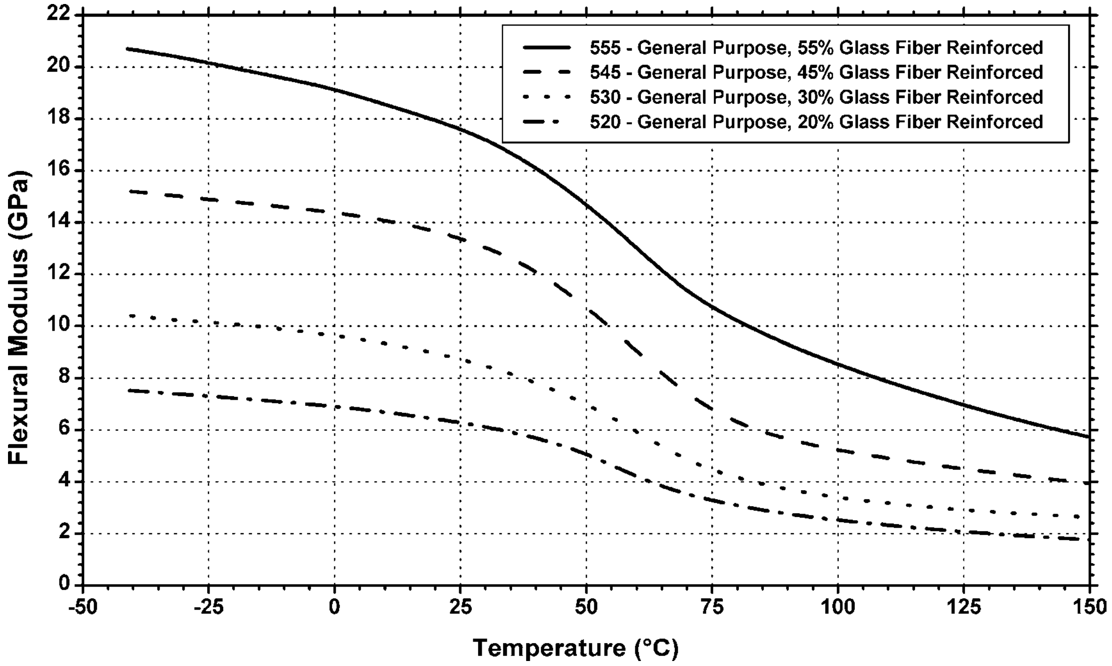


Figure 4.87. Flexural modulus vs. temperature for DuPont Rynite® 500 series of toughened, reinforced PET resins.

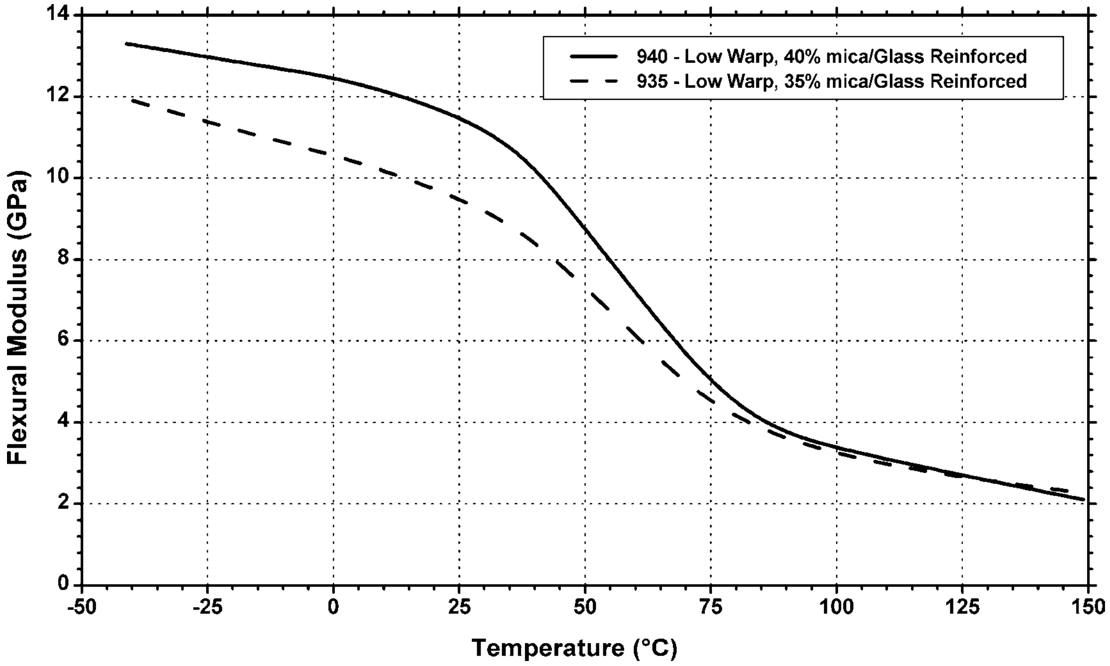


Figure 4.88. Flexural modulus vs. temperature for DuPont Rynite® 900 series of low warp PET resins.

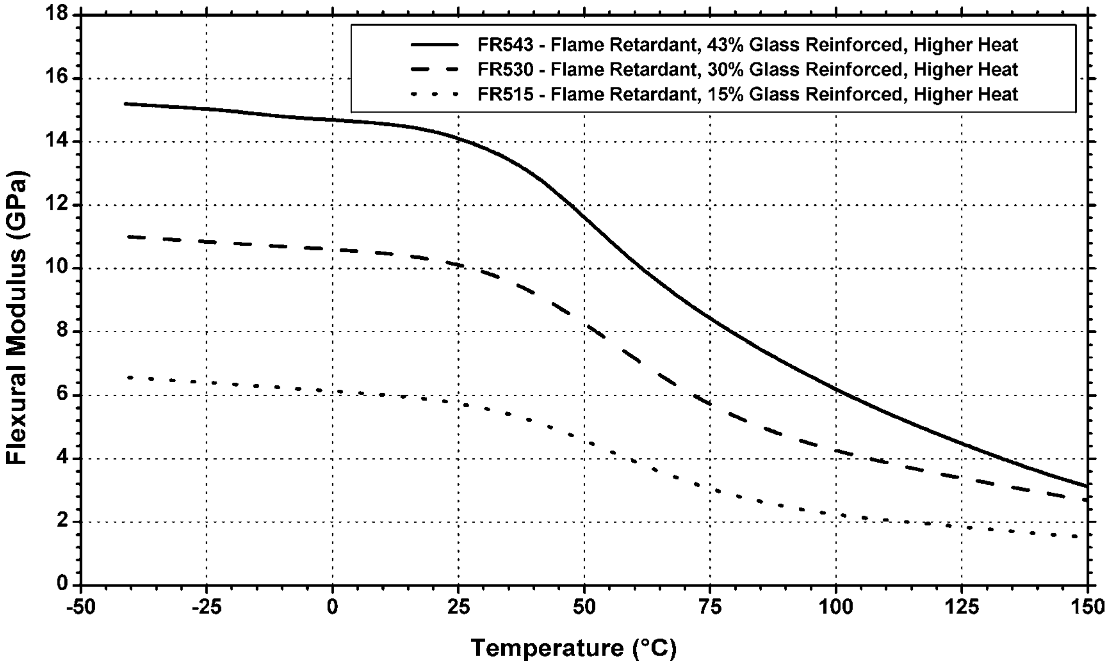


Figure 4.89. Flexural modulus vs. temperature for DuPont Rynite® FR500 series of flame retardant PET resins.

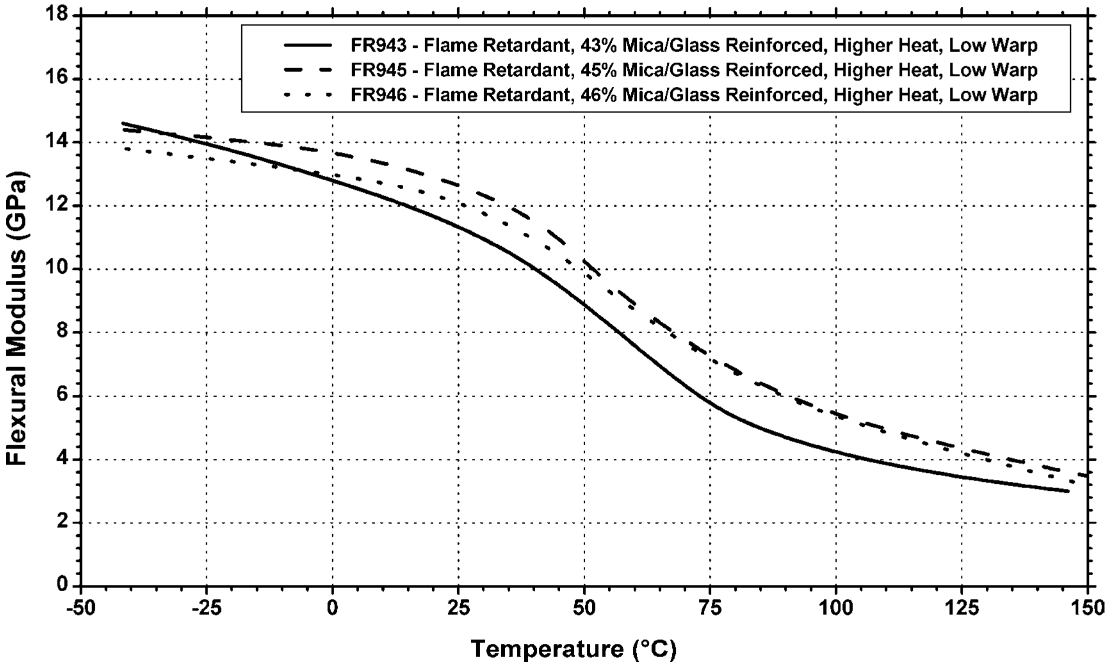


Figure 4.90. Flexural modulus vs. temperature for DuPont Rynite® FR900 series of flame retardant, low warp PET resins.

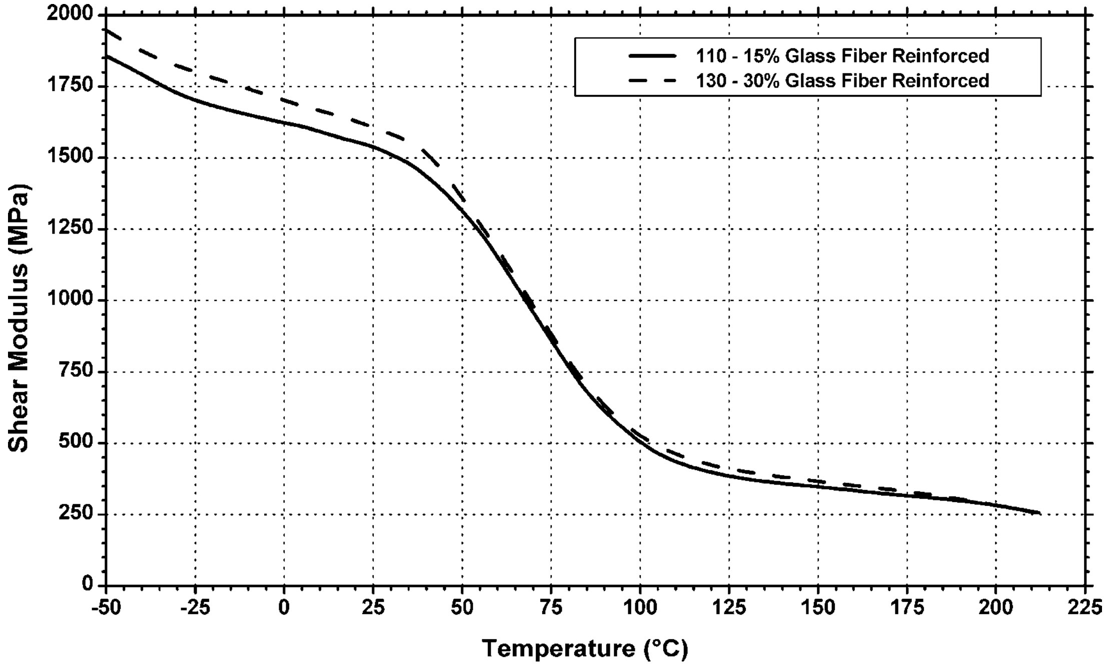


Figure 4.91. Shear modulus vs. temperature for BASF Petra® reinforced recycled PET resins.

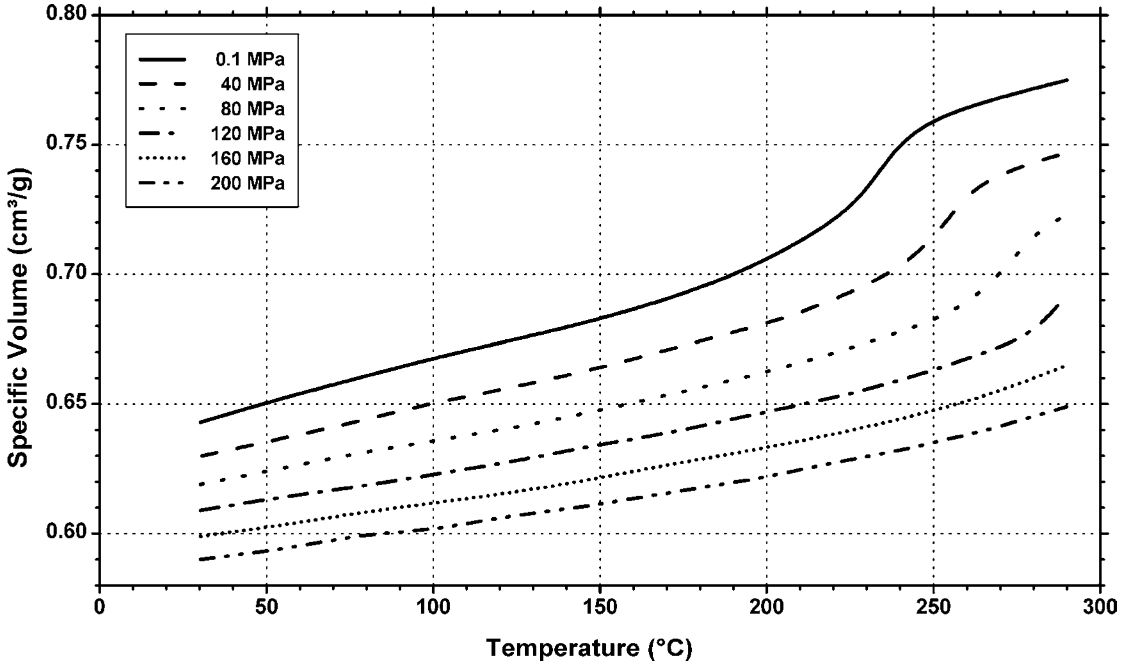


Figure 4.92. PVT for DSM Engineering Plastics Arnite® AV2 372—35% glass fiber reinforced PET resin.

4.5 Liquid Crystalline Polymers (LCPs)

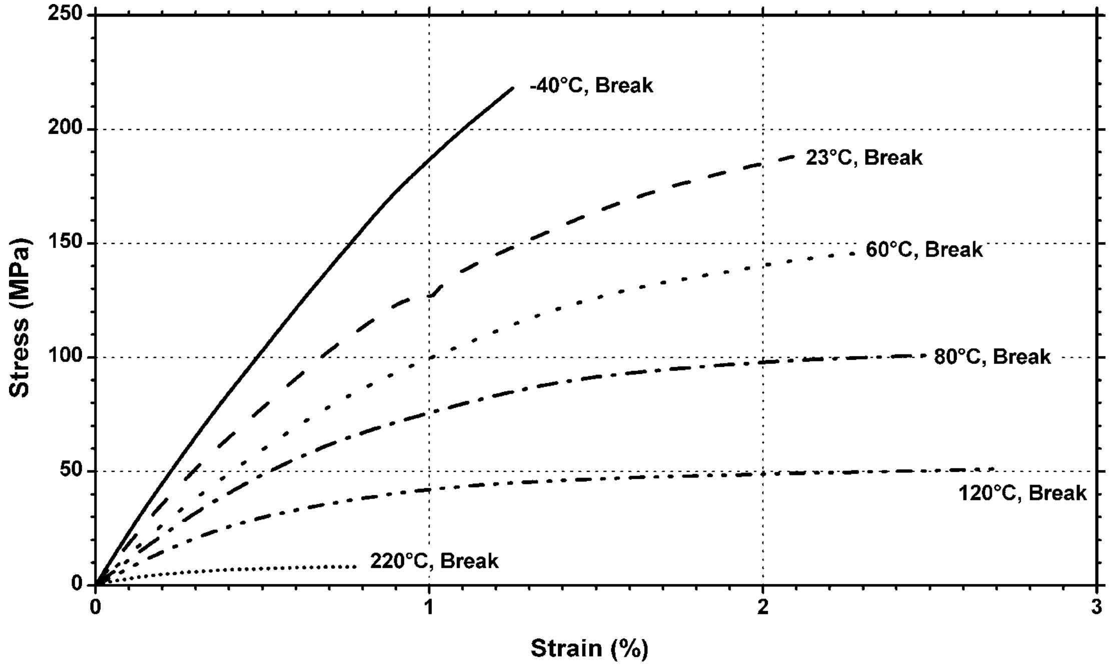


Figure 4.93. Stress vs. strain at various temperatures of Ticona Vectra® A130—30% glass fiber reinforced, standard grade LCP.

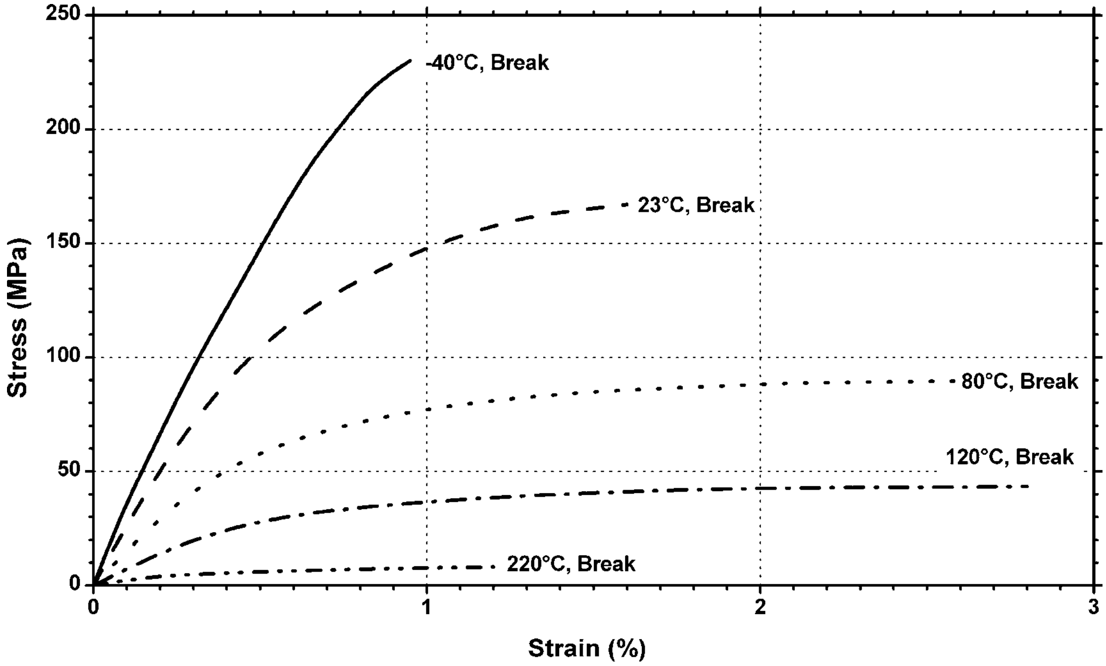


Figure 4.94. Stress vs. strain at various temperatures of Ticona Vectra® A230—30% carbon fiber reinforced, high stiffness LCP.

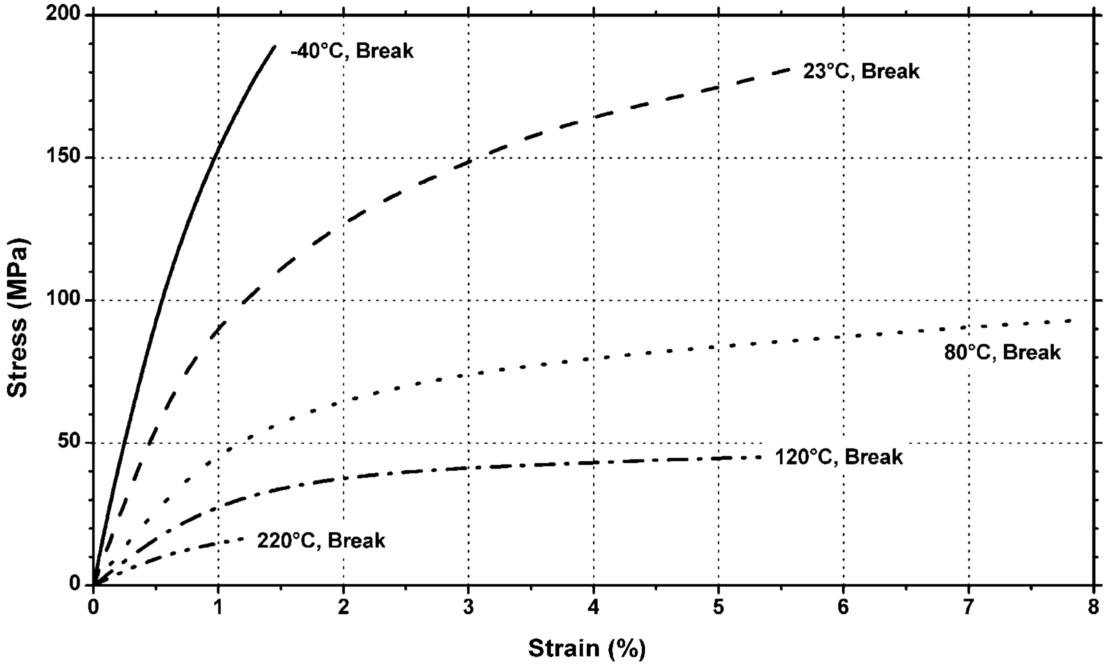


Figure 4.95. Stress vs. strain at various temperatures of Ticona Vectra® A530—30% mineral reinforced, standard grade LCP.

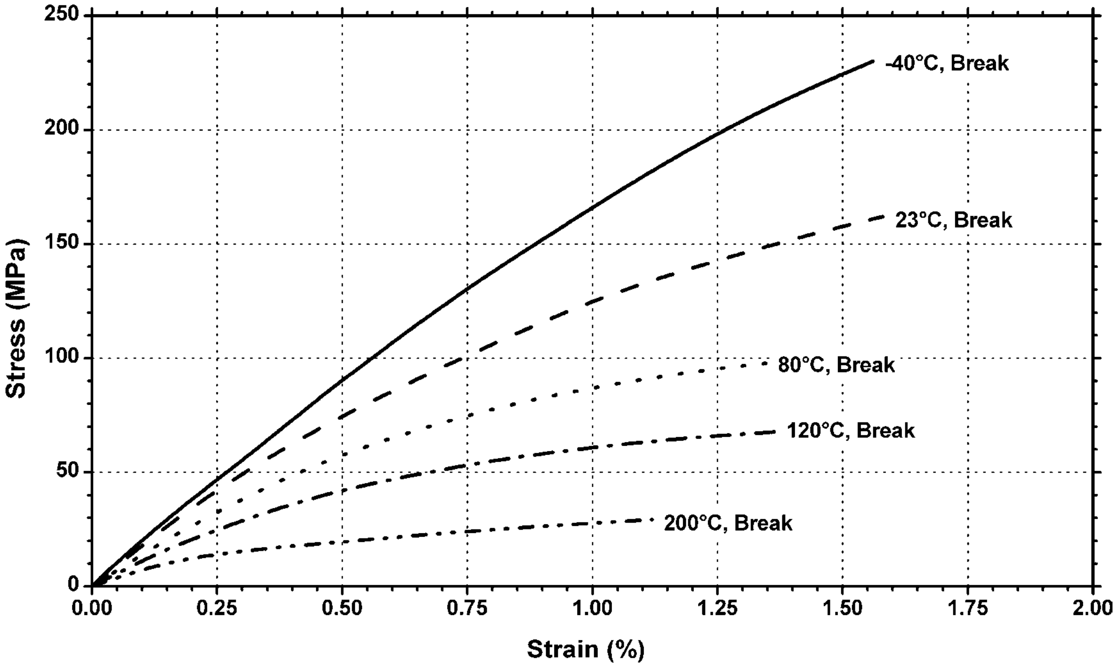


Figure 4.96. Stress vs. strain at various temperatures of Ticona Vectra® E130i—30% glass fiber reinforced, easy flow, high temperature LCP.

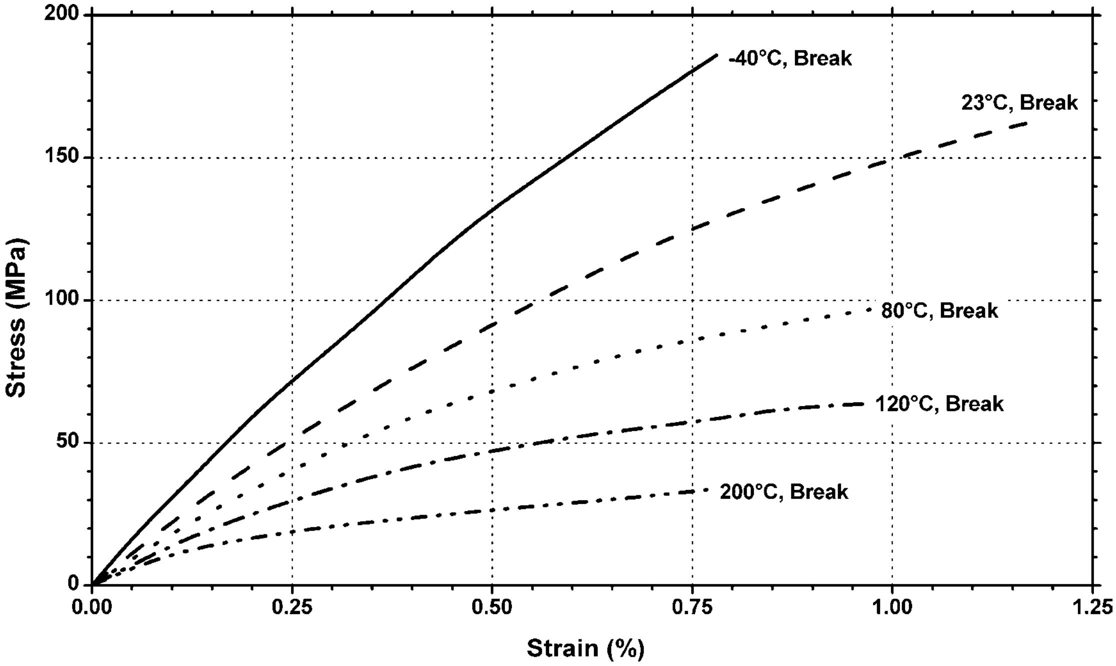


Figure 4.97. Stress vs. strain at various temperatures of Ticona Vectra® H140—40% glass fiber reinforced, highest temperature LCP.

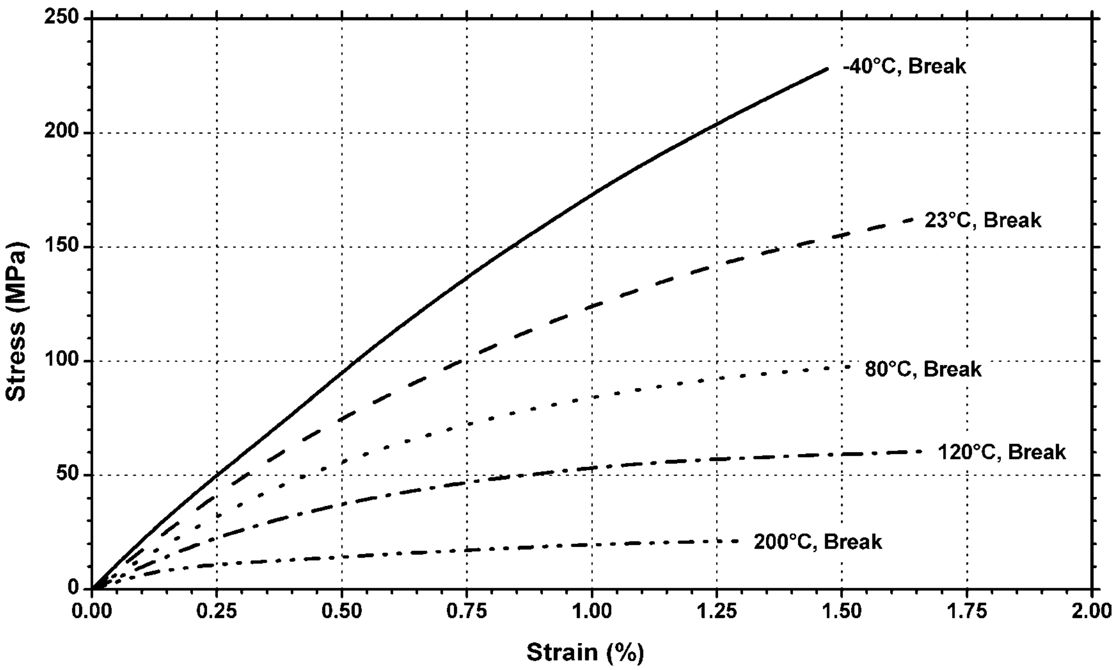


Figure 4.98. Stress vs. strain at various temperatures of Ticona Vectra® L130—30% glass fiber reinforced, high flow LCP.

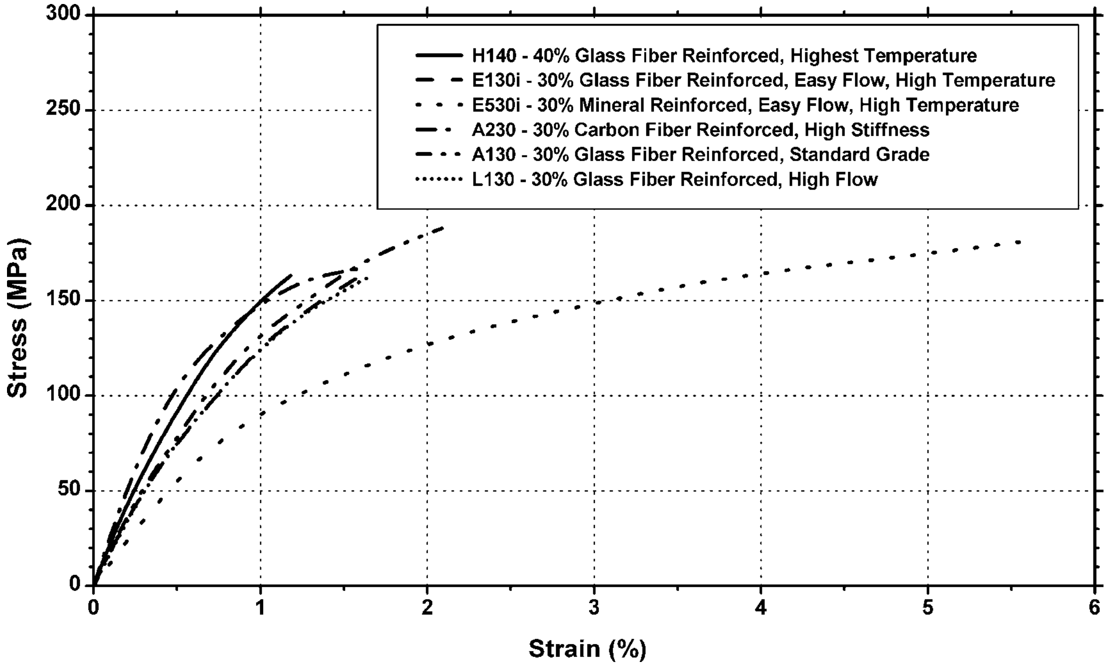


Figure 4.99. Stress vs. strain at 23°C of several Ticona Vectra® L130—30% glass fiber reinforced, high flow LCP.

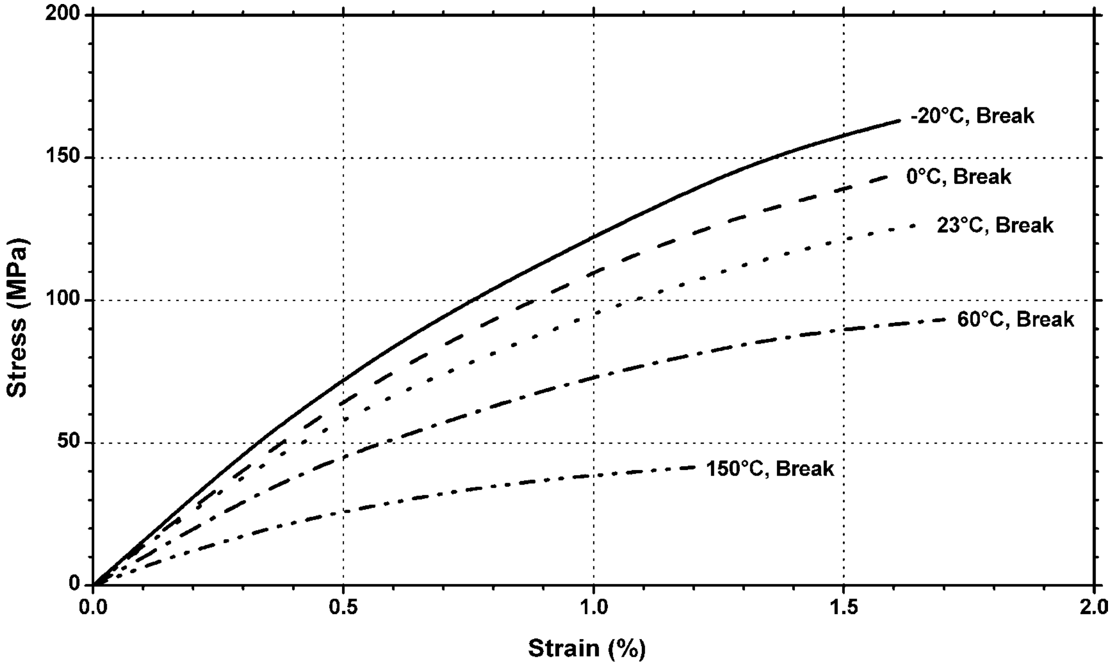


Figure 4.100. Stress vs. strain at various temperatures of DuPont Zenite® 6130L BK010—30% glass reinforced, lubricated LCP.

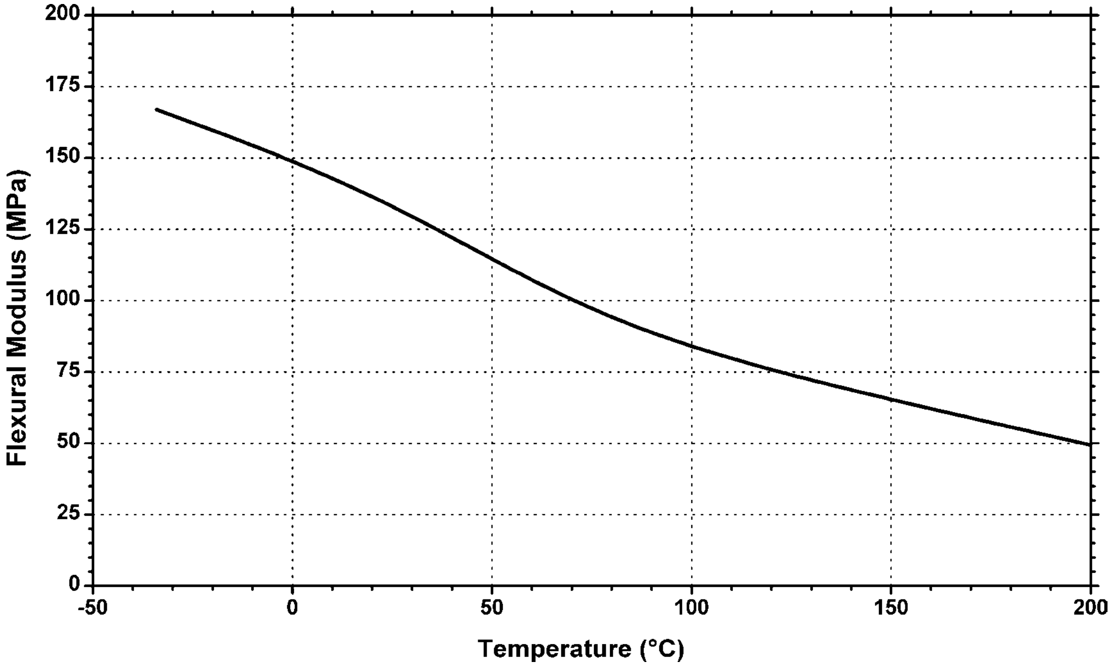


Figure 4.101. Flexural modulus vs. temperature of Toray Siveras® L204G35—35% glass fiber reinforced, standard grade LCP.

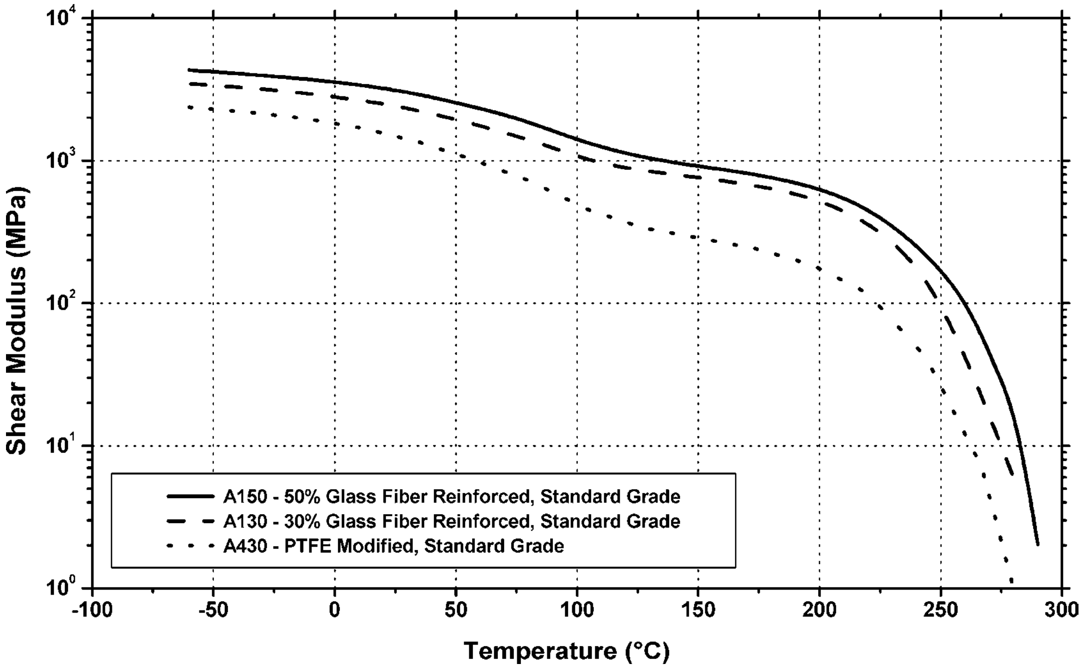


Figure 4.102. Shear modulus vs. temperature of various Ticona Vectra® LCPs.

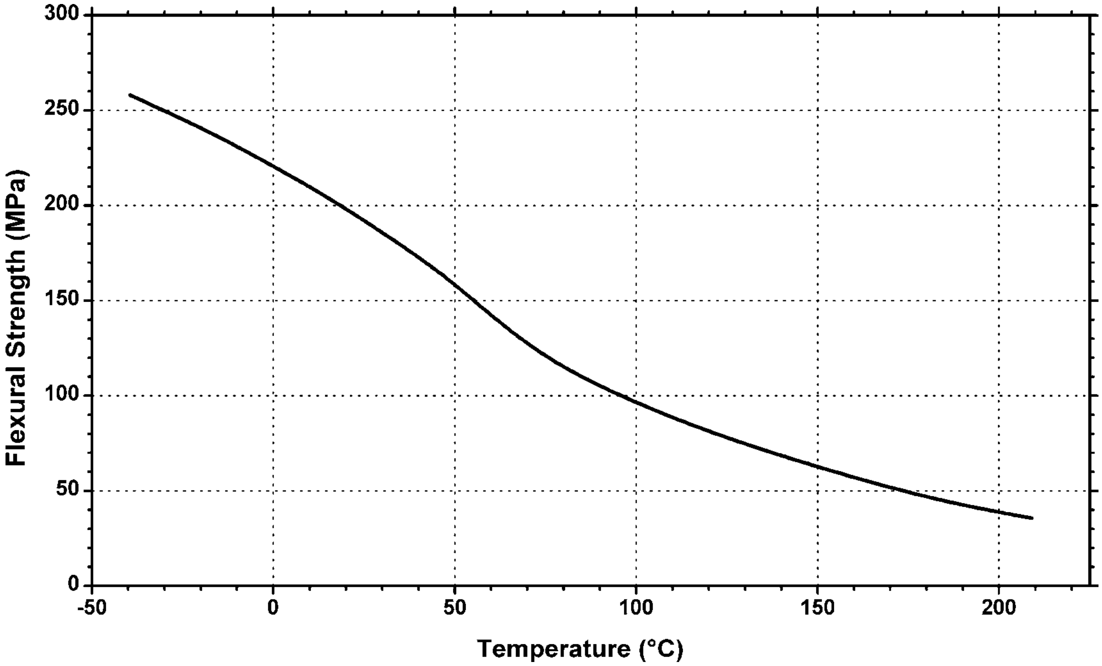


Figure 4.103. Flexural strength vs. temperature of Toray Siveras® L204G35—35% glass fiber reinforced, standard grade LCP.

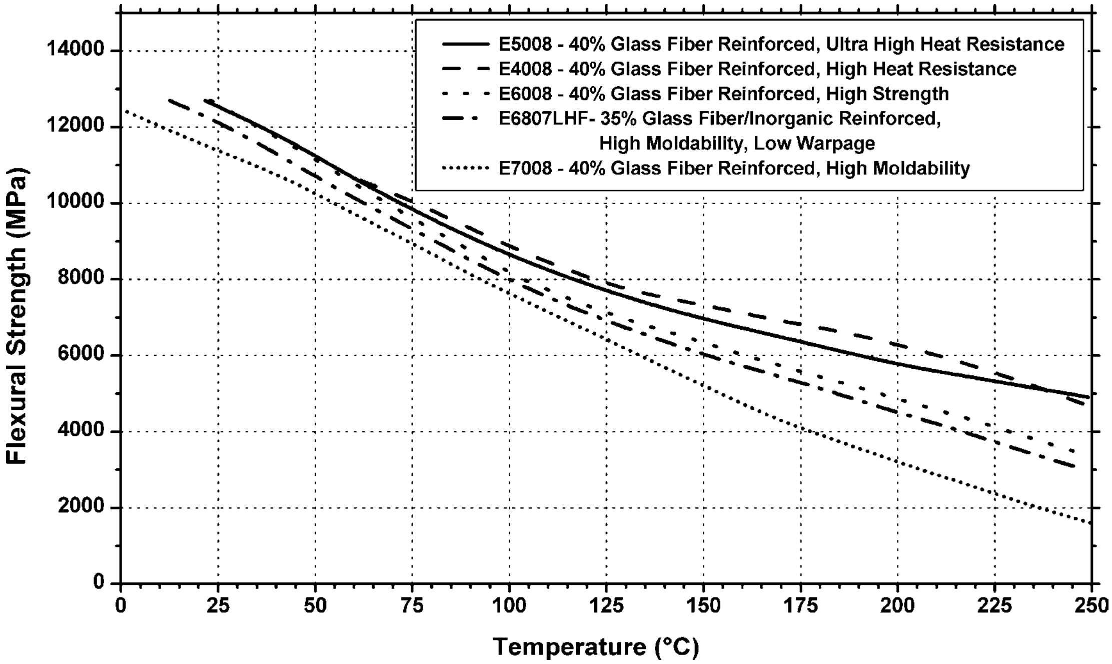


Figure 4.104. Flexural strength vs. temperature of various Sumitomo Chemical Sumikasuper® LCPs.

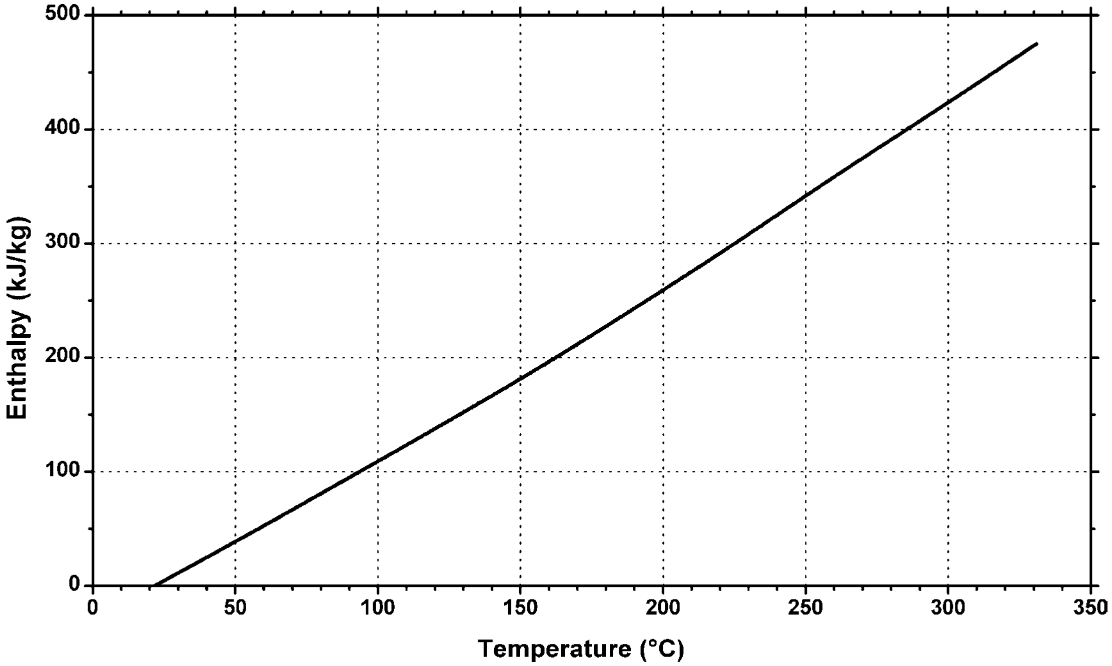


Figure 4.105. Enthalpy vs. temperature of Ticona Vectra® A130—30% glass fiber reinforced, standard grade LCP.

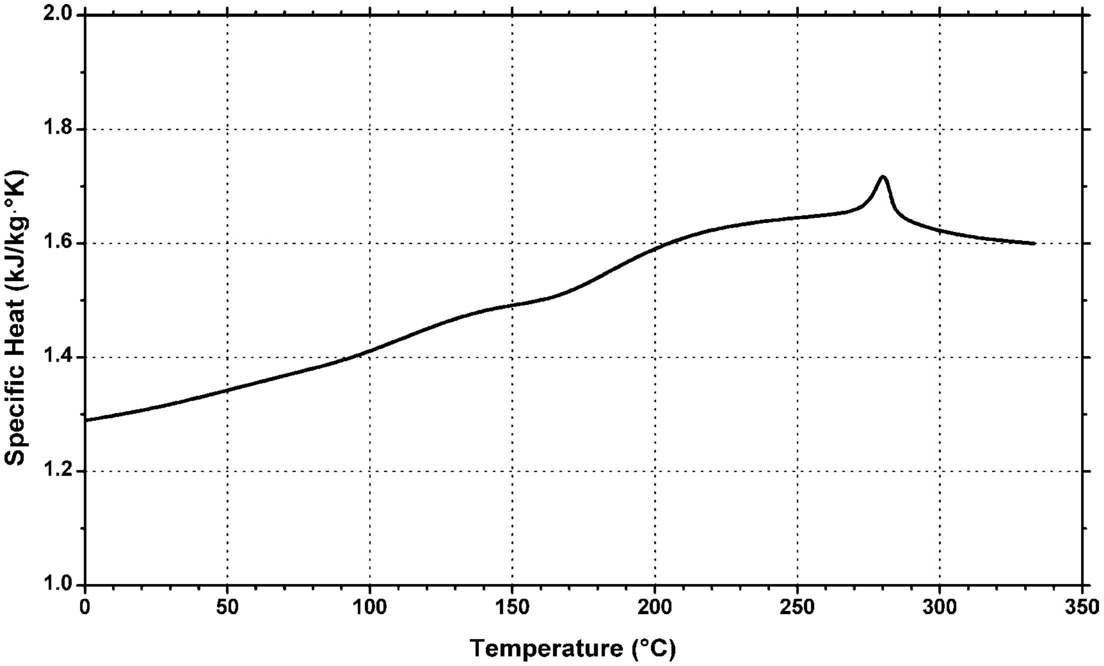


Figure 4.106. Specific heat vs. temperature of Ticona Vectra® A130—30% glass fiber reinforced, standard grade LCP.

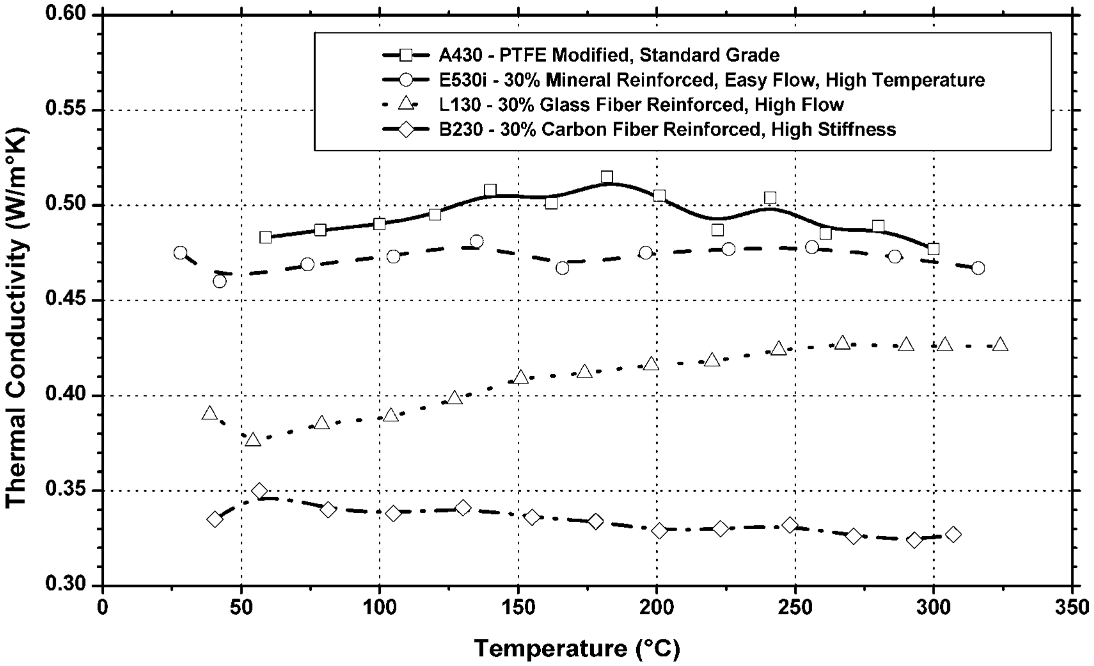


Figure 4.107. Thermal conductivity vs. temperature of various Ticona Vectra® LCPs.

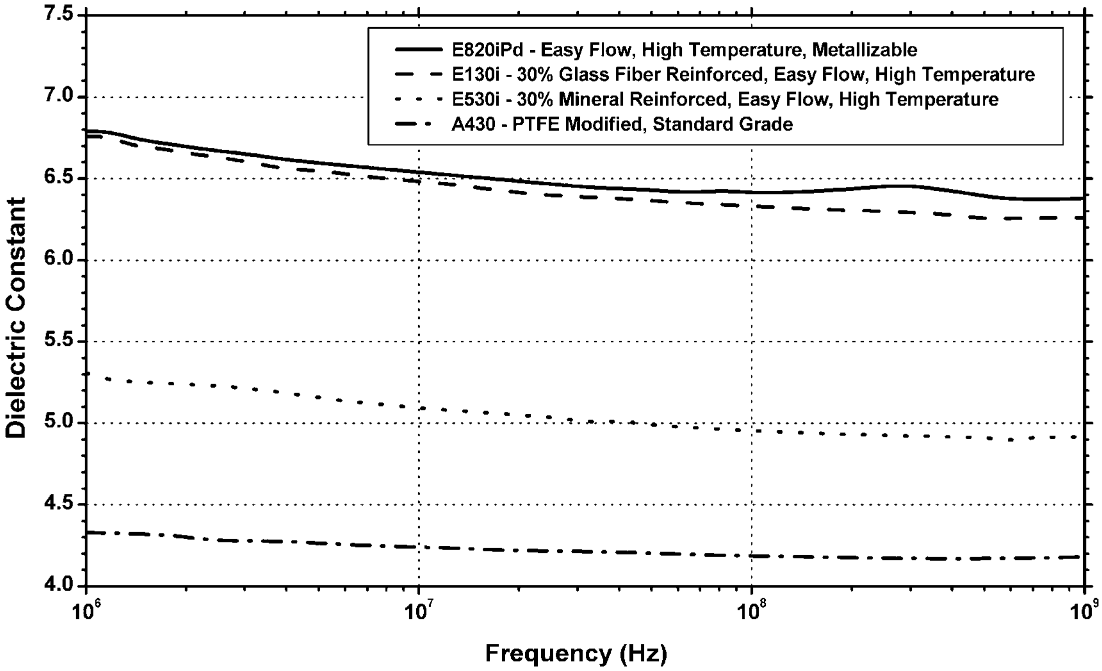


Figure 4.108. Dielectric constant vs. frequency at 23°C of various Ticona Vectra® LCPs.

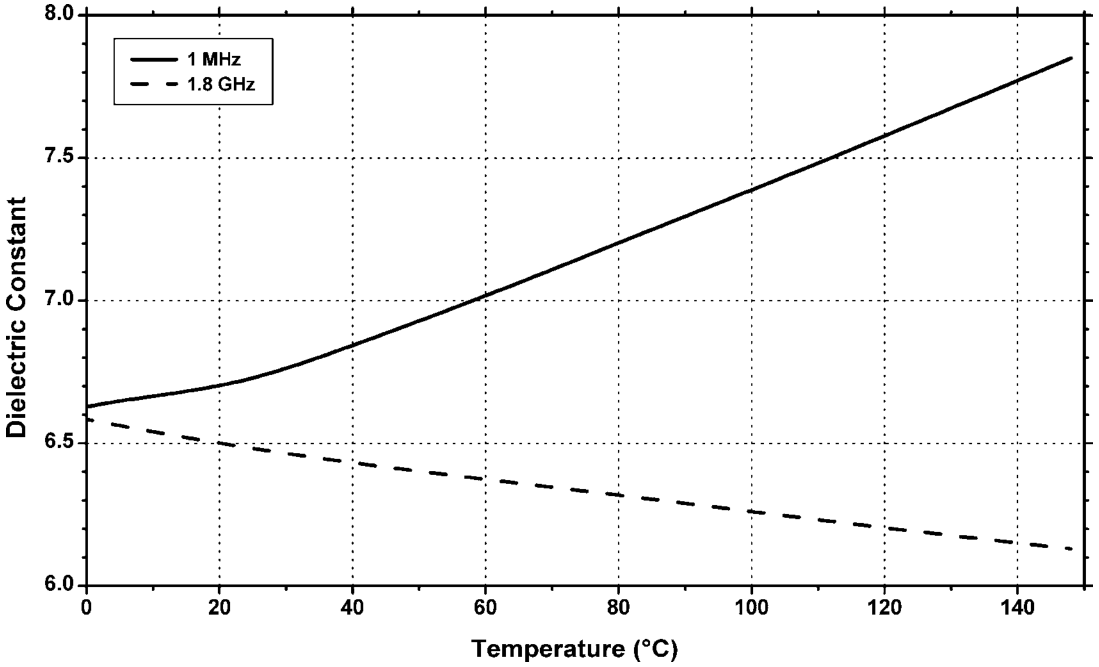


Figure 4.109. Dielectric constant vs. temperature of Ticona Vectra® E820iPd—easy flow, high temperature, metallizable LCP.

4.6 Polycyclohexylene Dimethylene Terephthalate (PCT)

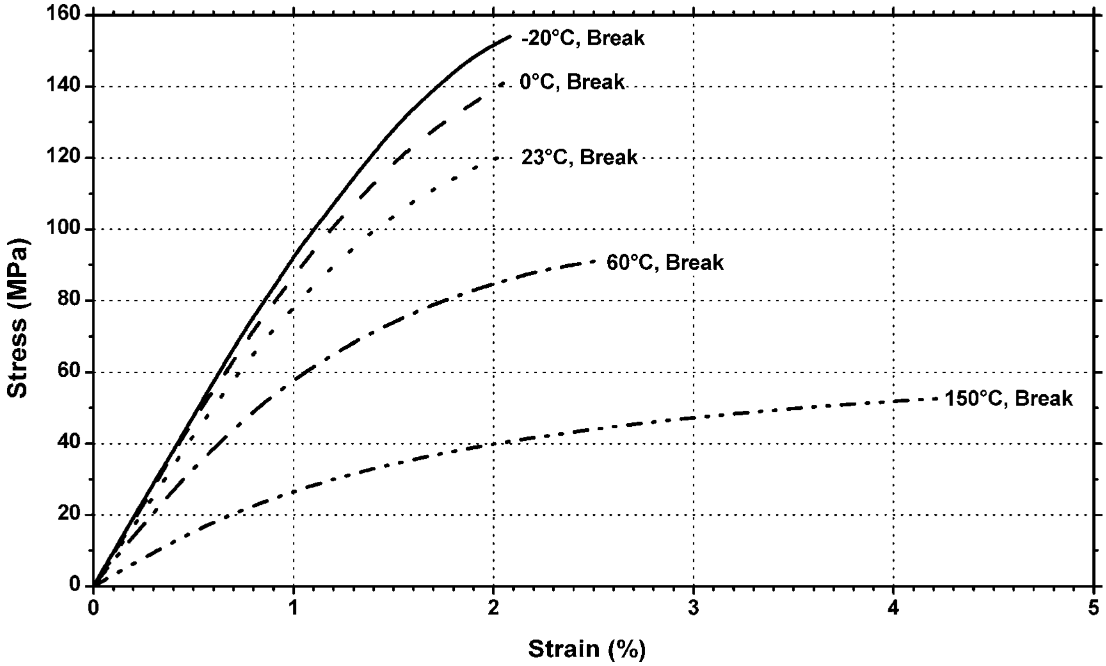


Figure 4.110. Stress vs. strain at various temperatures for DuPont Thermx® CG033—20% glass reinforced, general purpose PCT resin.

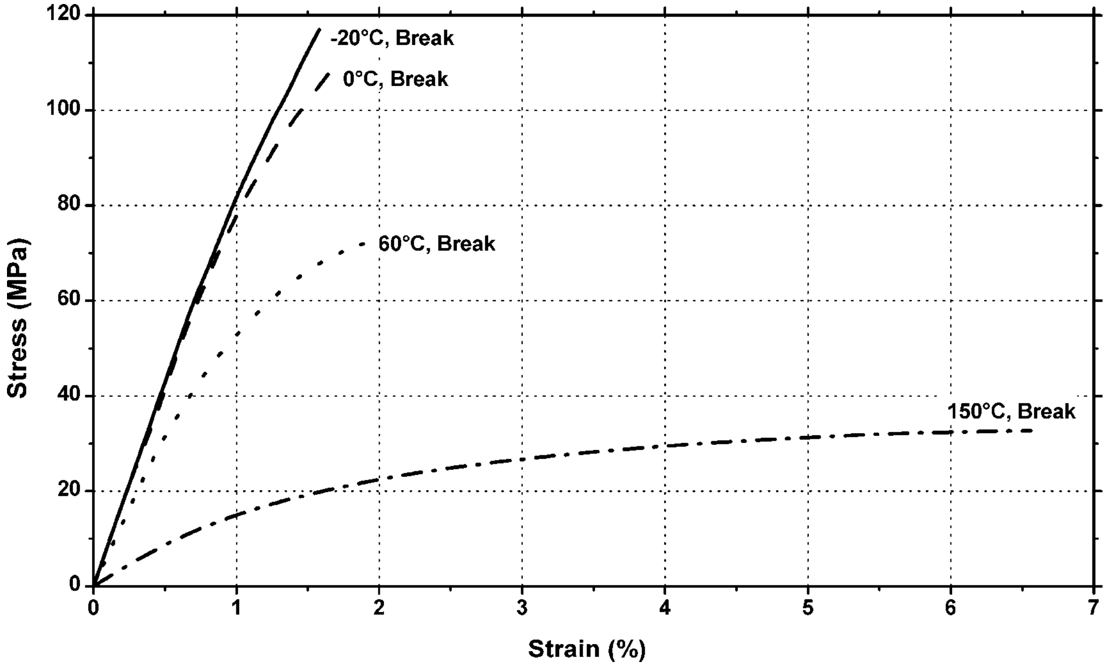


Figure 4.111. Stress vs. strain at various temperatures for DuPont Thermx® CG923—20% glass reinforced, flame retardant PCT resin.

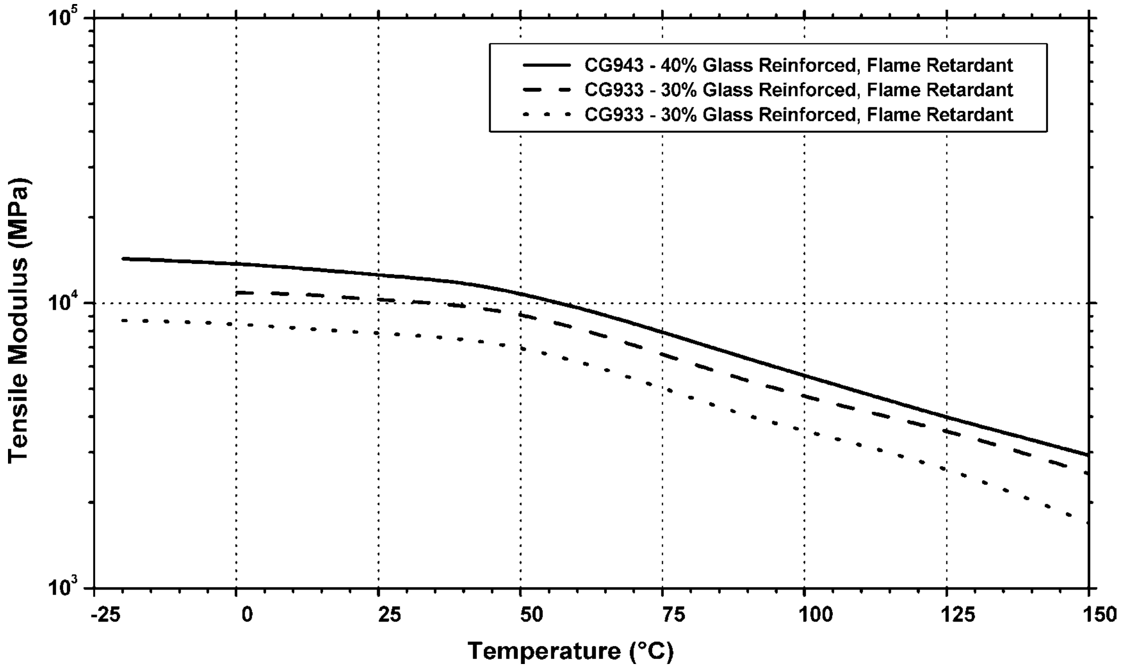


Figure 4.112. Tensile modulus vs. temperature for DuPont Thermx® glass reinforced, flame retardant PCT resins.

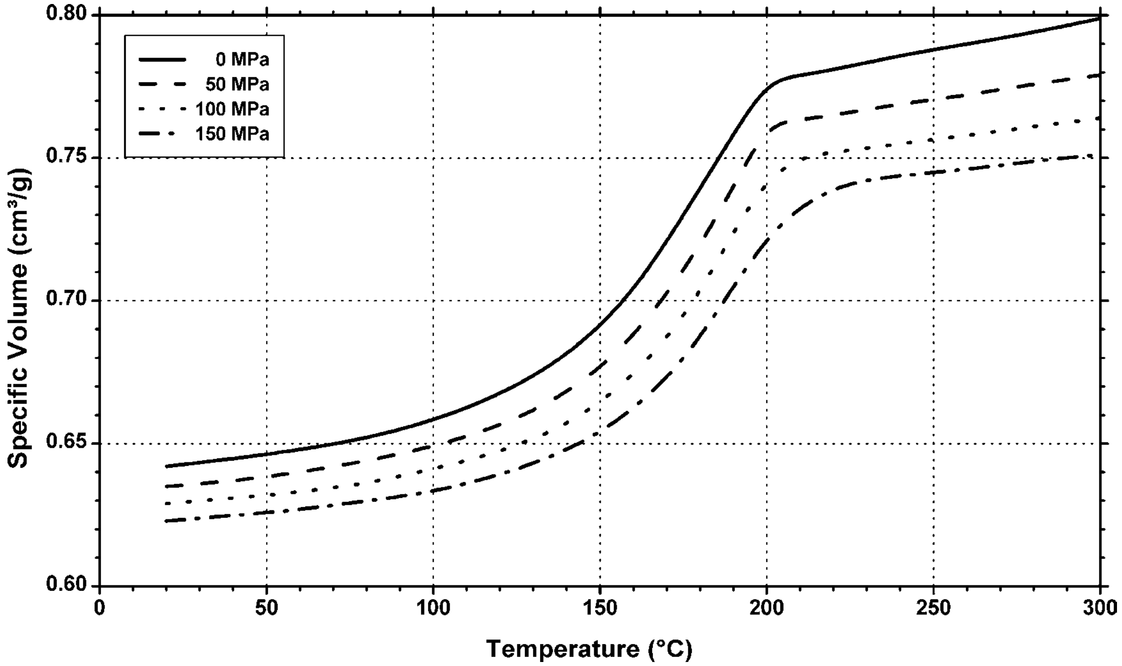


Figure 4.113. Pressure–specific volume–temperature for DuPont Thermx® CG923—20% glass reinforced, flame retardant PCT resin.

4.7 Polyester Blends and Alloys

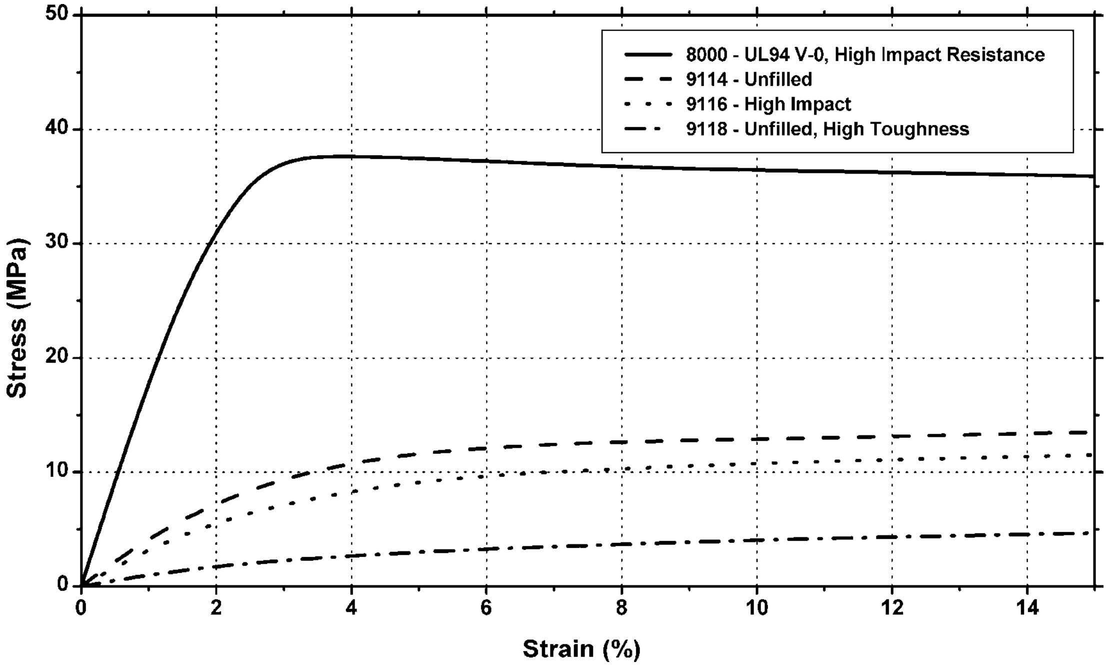


Figure 4.114. Stress vs. strain at 23°C for Ticona Vandar® polyester alloy/blend resins (alloy type unspecified).

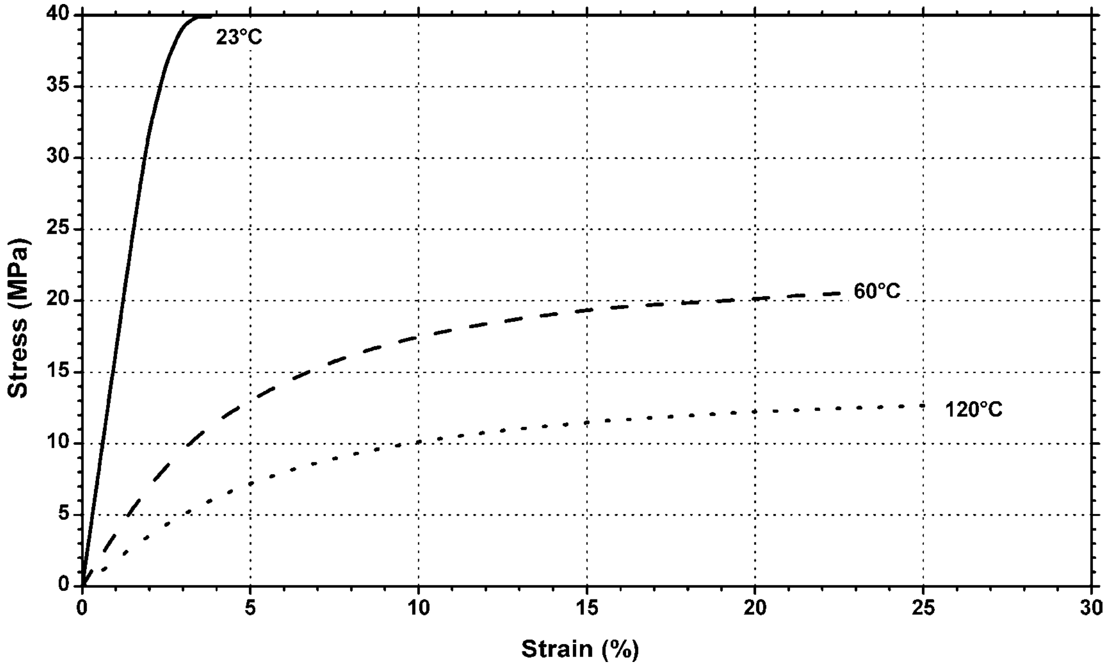


Figure 4.115. Stress vs. strain at various temperatures for Ticona Vandar® 2100—unreinforced (alloy type unspecified) polyester alloy/blend resin.

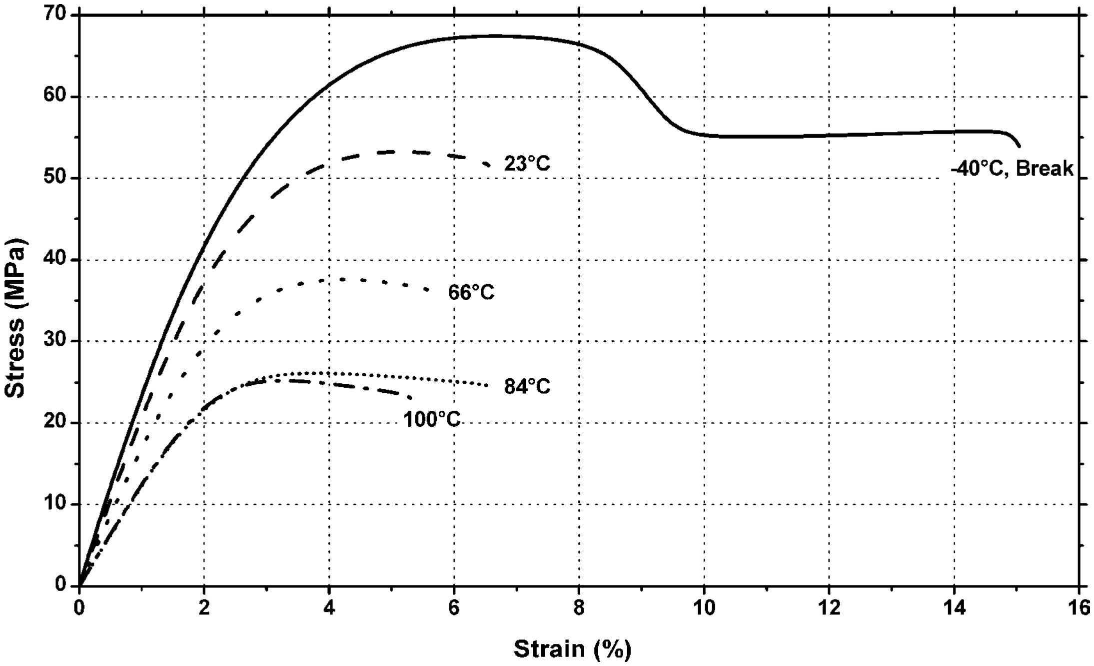


Figure 4.116. Stress vs. strain at various temperatures for SABIC Innovative Plastics Xenoy® 2230—polyethylene terephthalate (PET)/polycarbonate (PC) alloy polyester alloy/blend resin.

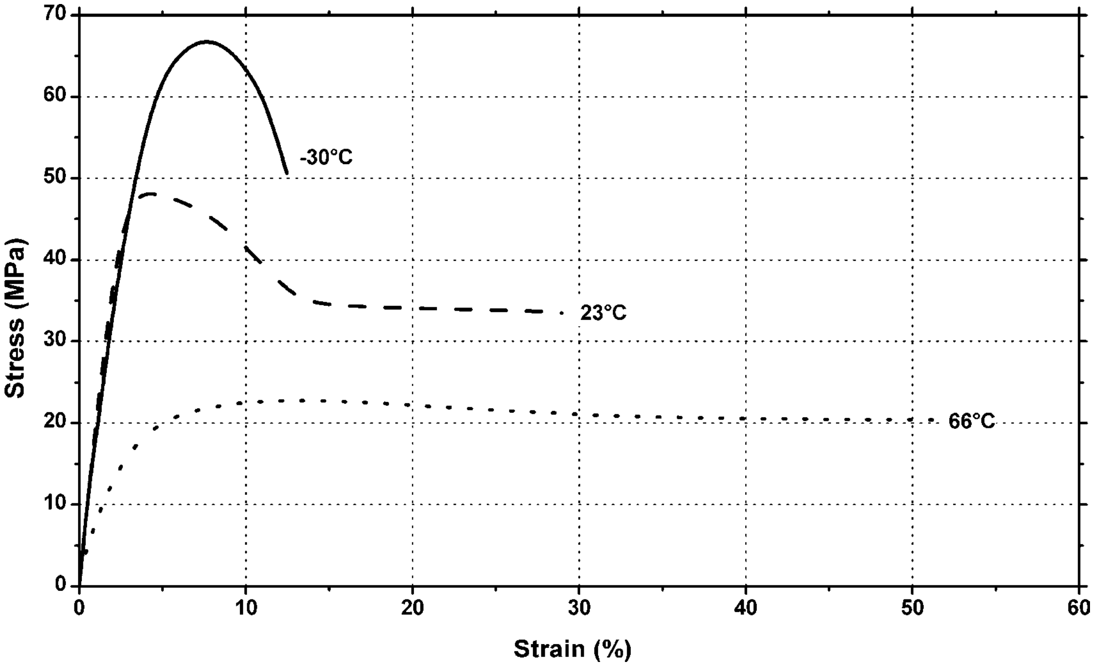


Figure 4.117. Stress vs. strain at various temperatures for SABIC Innovative Plastics Xenoy® 6127—polybutylene terephthalate (PBT)/PC alloy, unreinforced polyester alloy/blend resin.

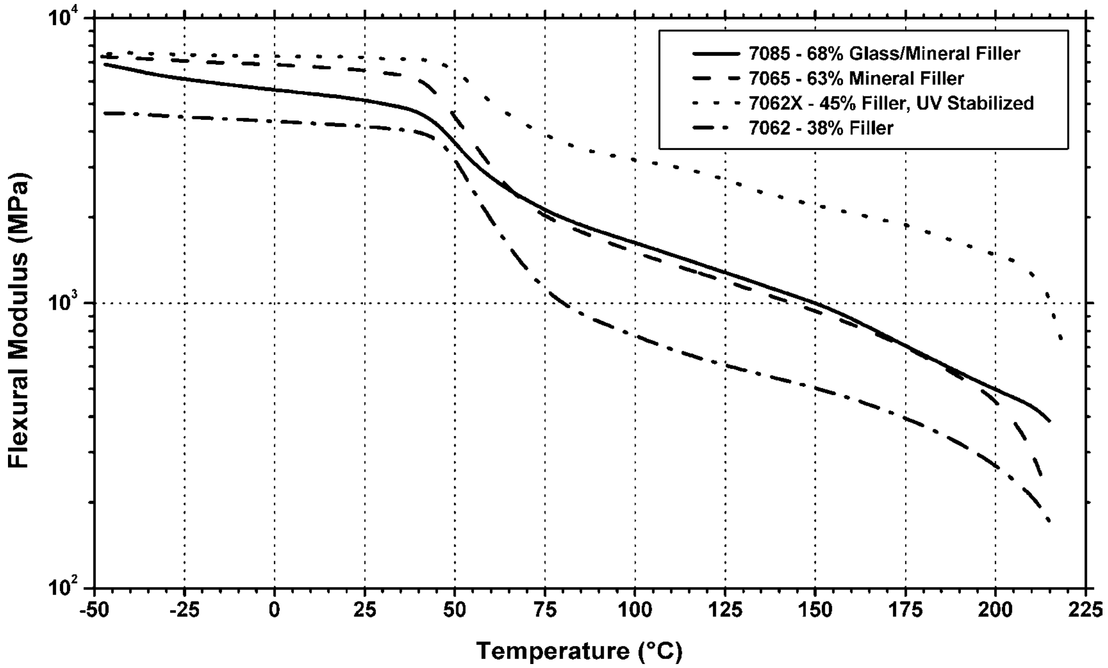


Figure 4.118. Flexural modulus vs. temperature for SABIC Innovative Plastics Enduran® PBT/PET blend polyester alloy/blend resins.

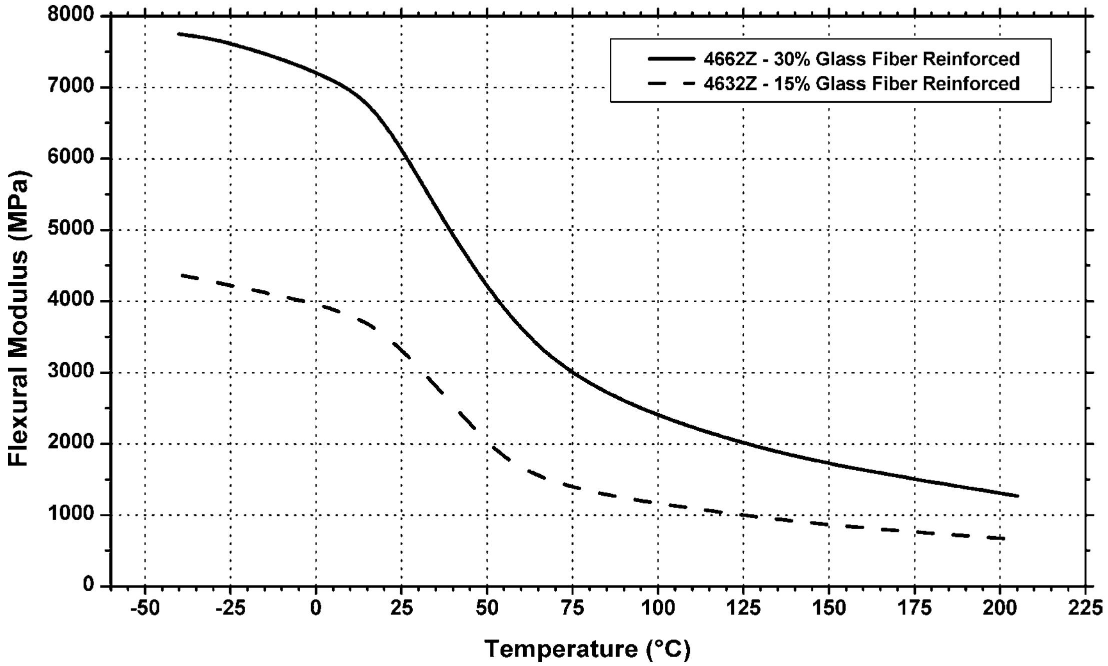


Figure 4.119. Flexural modulus vs. temperature for Ticona Vandar® high stiffness polyester alloy/blend resins.

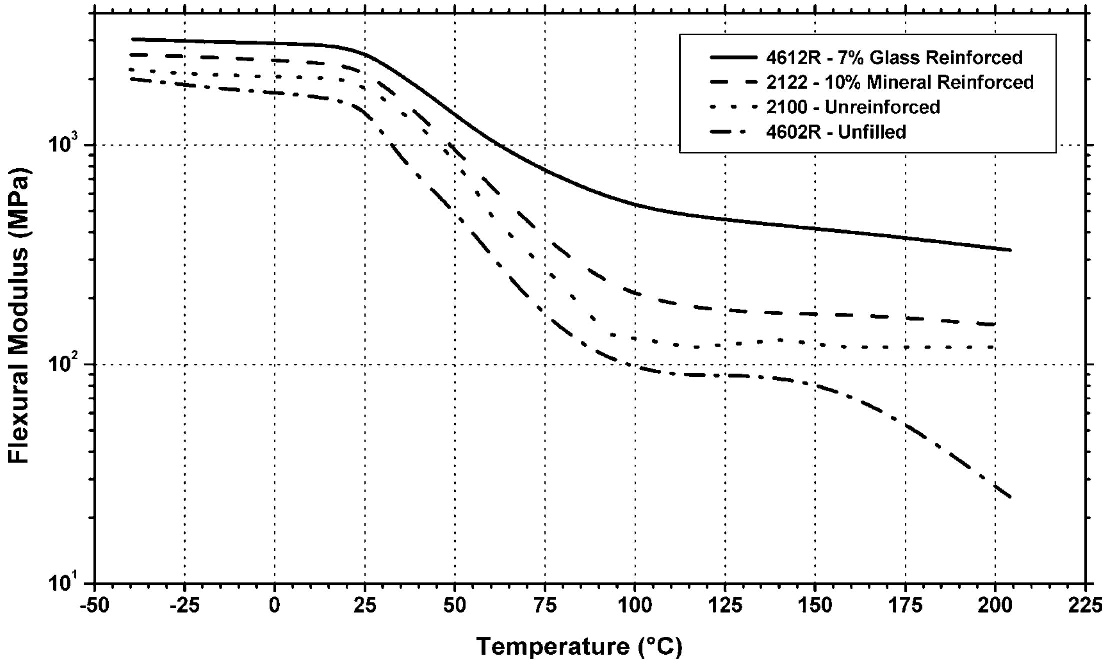


Figure 4.120. Flexural modulus vs. temperature for Ticona Vandar® low stiffness polyester alloy/blend resins.

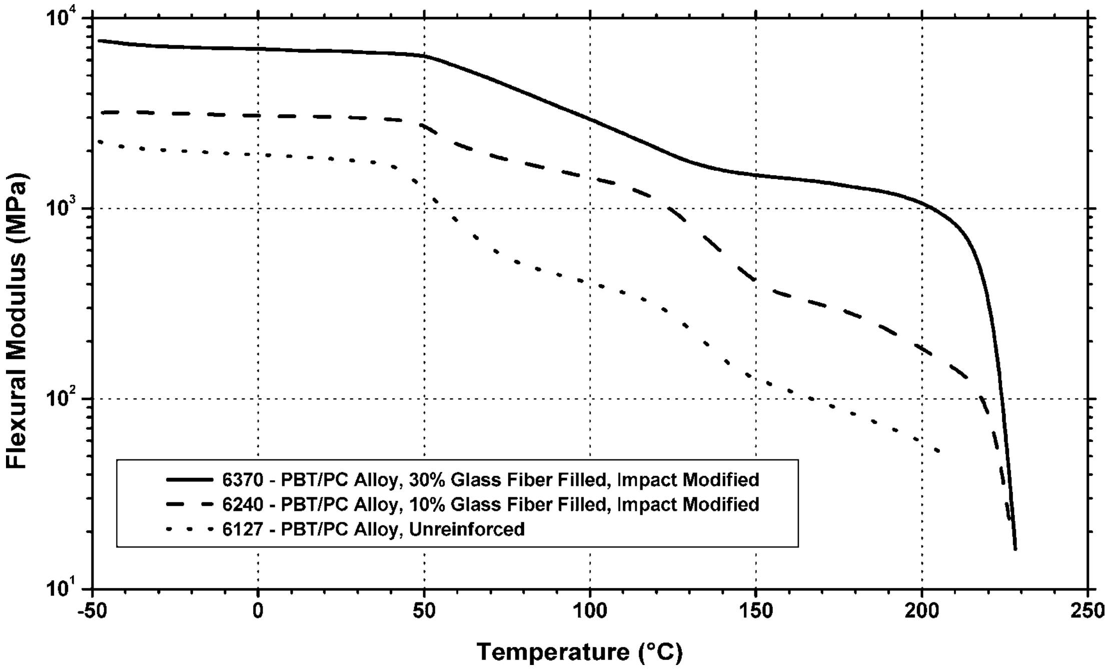


Figure 4.121. Flexural modulus vs. temperature for SABIC Innovative Plastics Xenoy® PBT/PC alloy polyester alloy/blend resins.

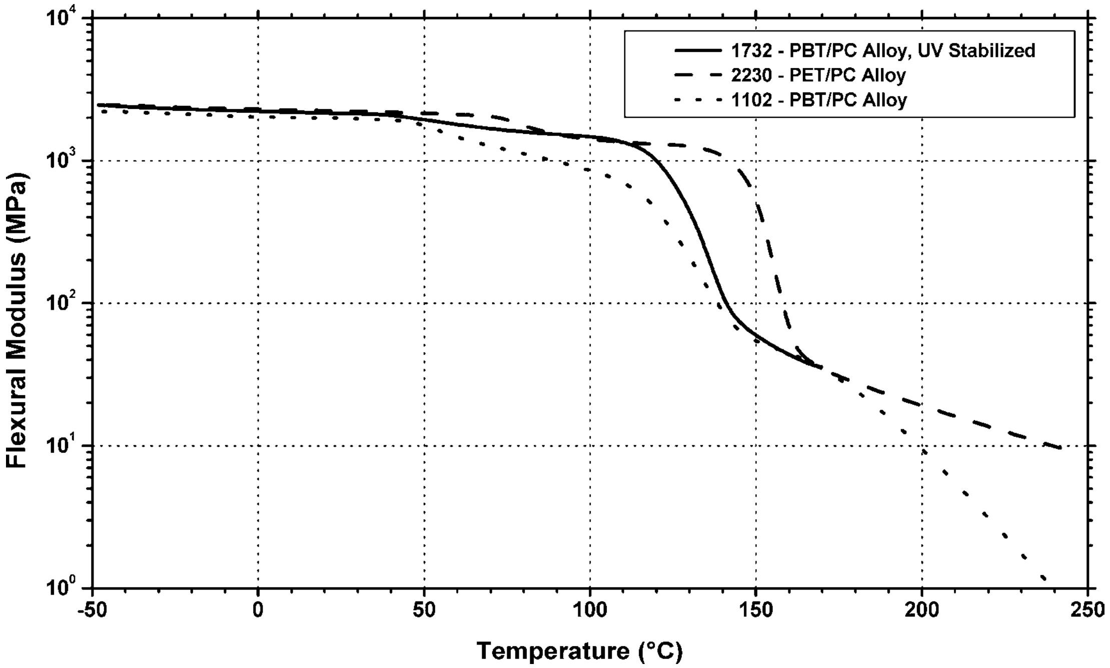


Figure 4.122. Flexural modulus vs. temperature for SABIC Innovative Plastics Xenoy® polyester alloy/ blend resins.

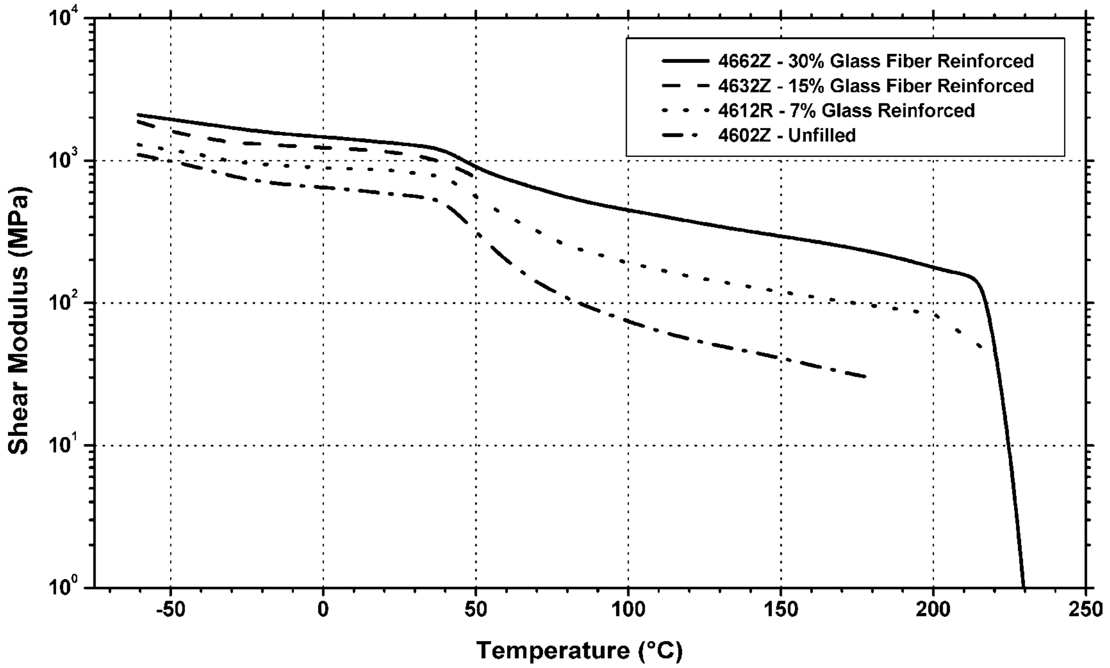


Figure 4.123. Shear modulus vs. temperature for Ticona Vandar® polyester alloy/blend resins.

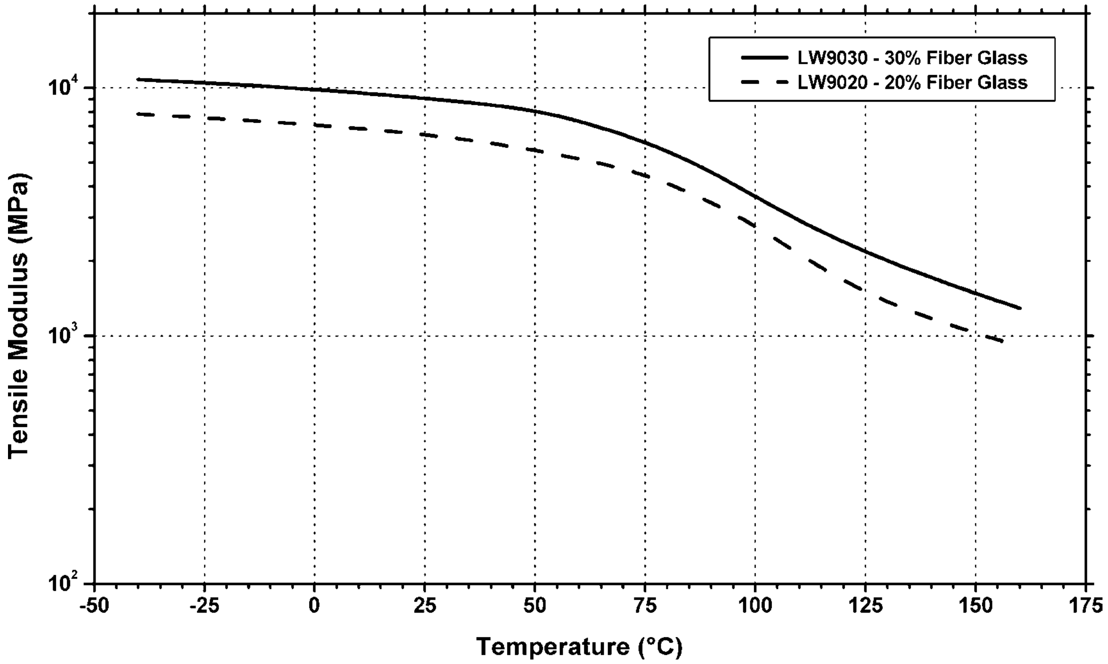


Figure 4.124. Tensile modulus vs. temperature for DuPont Crastin® PBT/acrylonitrile-styrene-acrylate (ASA) polyester alloy/blend resins.

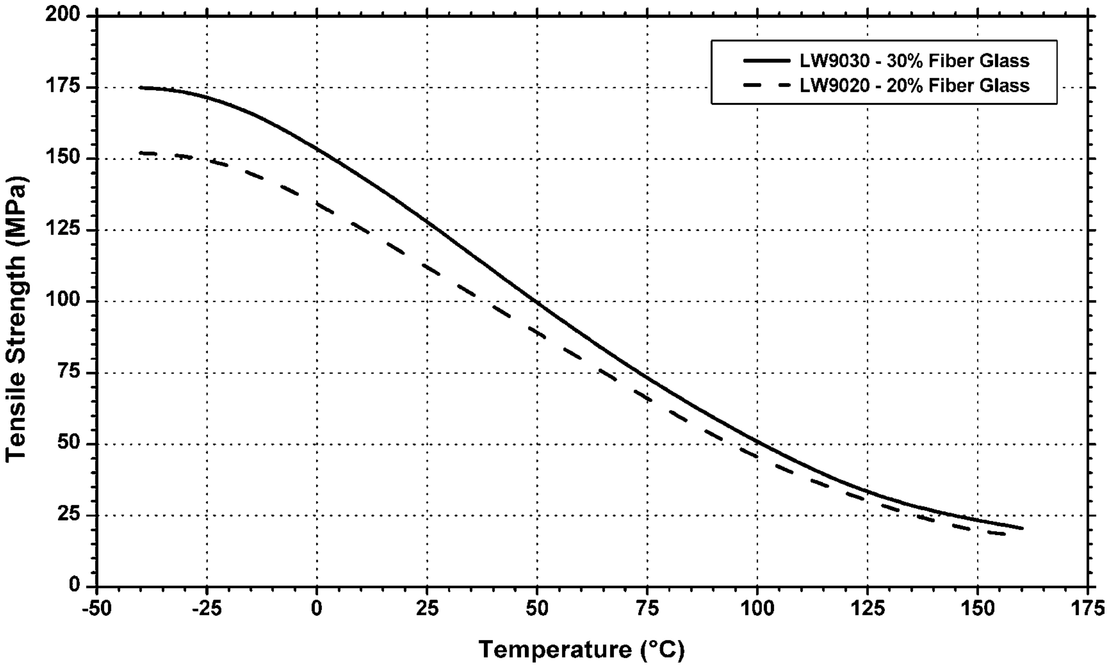


Figure 4.125. Tensile strength vs. temperature for DuPont Crastin® PBT/ASA polyester alloy/blend resins.

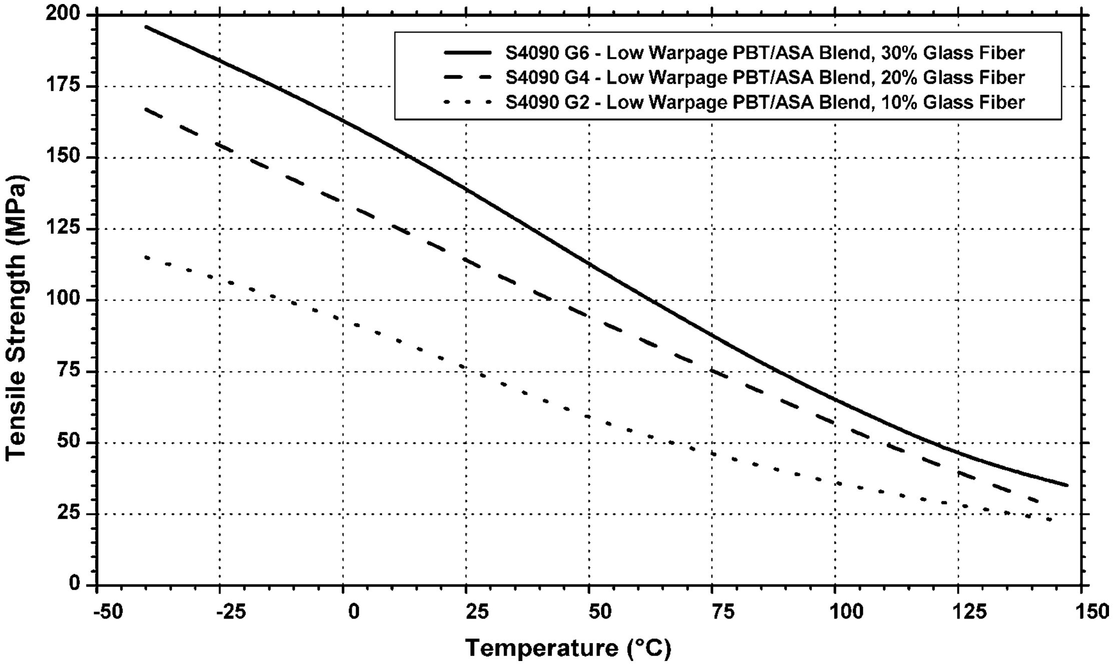


Figure 4.126. Tensile strength vs. temperature for BASF Ultradur® S4090—low warpage PBT/ASA blend polyester alloy/blend resin.

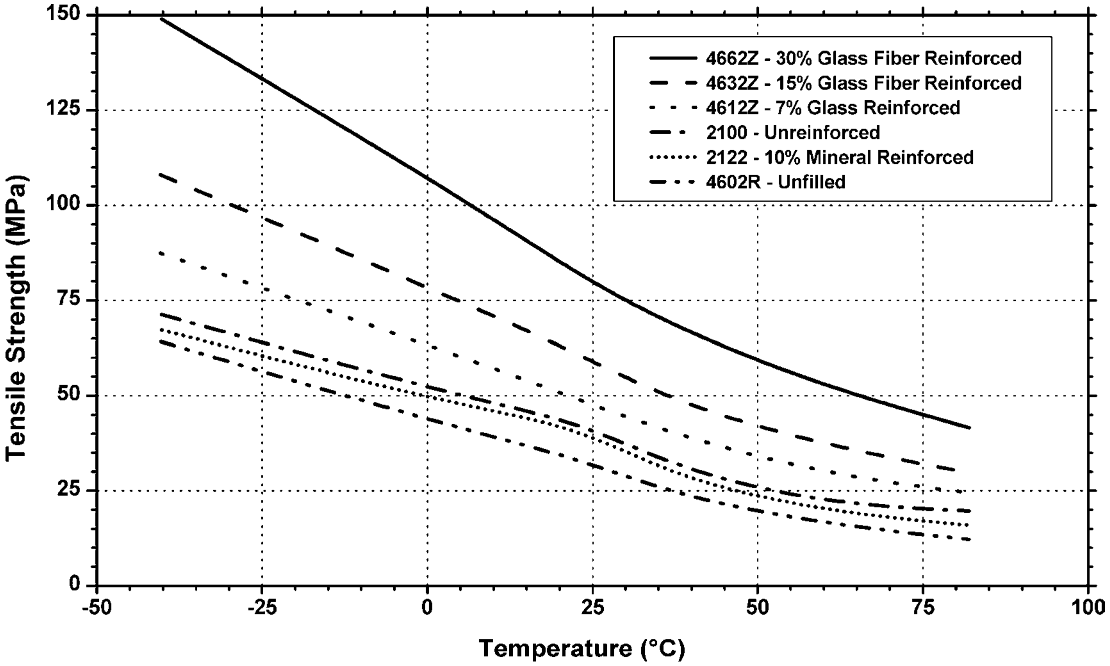


Figure 4.127. Tensile strength vs. temperature for Ticona Vandar® polyester alloy/blend resins.

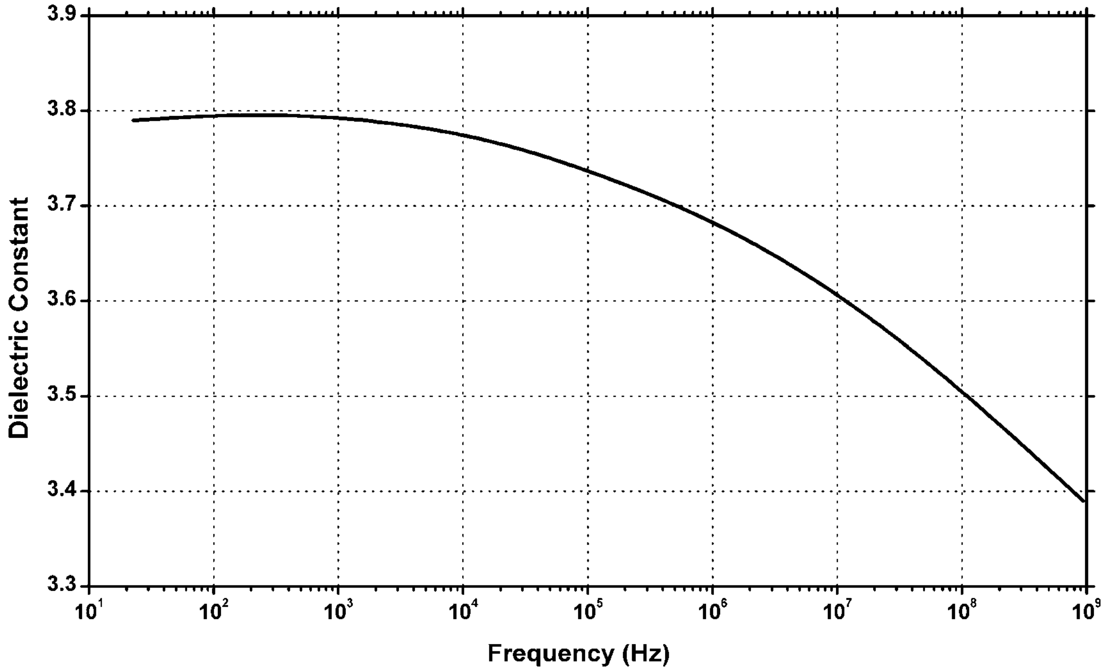


Figure 4.128. Dielectric constant vs. frequency at 23°C for BASF Ultradur® S4090 G4—low warpage PBT/ASA blend, 20% glass fiber polyester alloy/blend resin.

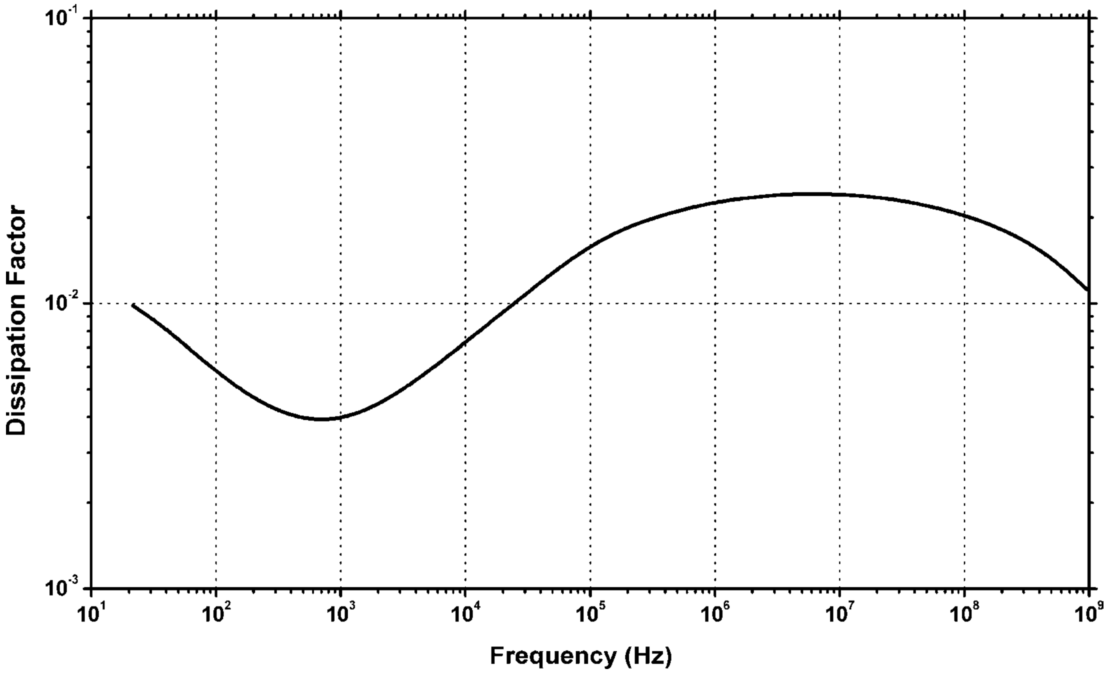


Figure 4.129. Dissipation factor vs. frequency at 23°C for BASF Ultradur® S4090 G4—low warpage PBT/ASA blend, 20% glass fiber polyester alloy/blend resin.

5 Polyimides

5.1 Background

This chapter covers a series of plastics in which the imide group is an important part of the molecule. The imide group is formed by the condensation reaction of an aromatic anhydride group with an aromatic amine as shown in Fig. 5.1.

This group is thermally very 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 polymer.

5.1.1 *Polyetherimide (PEI)*

Polyetherimide (PEI) is an amorphous engineering thermoplastic. Thermoplastic PEIs provide strength, heat resistance, and flame retardancy of traditional polyimides with the ease of simple melt processing seen in standard injection-molding resins like polycarbonate and acrylonitrile-butadiene-styrene (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 polymer structures that are used as PEI plastics. The structures of these polymers are shown in Figs. 5.2–5.6 with reference to one of the product lines that utilize the 4,4’-bisphenol A dianhydride (BPADA) molecule.

The acid dianhydride used to make most of the PEIs is 4,4’-bisphenol A dianhydride, the structure of which is shown in Fig. 5.7.

Some of the other monomers used in these PEI are shown in Fig. 5.8.

5.1.2 *Polyamide-Imide (PAI)*

Polyamide-imides (PAI) are thermoplastic amorphous polymers that have useful properties which include:

- 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 Fig. 5.9.

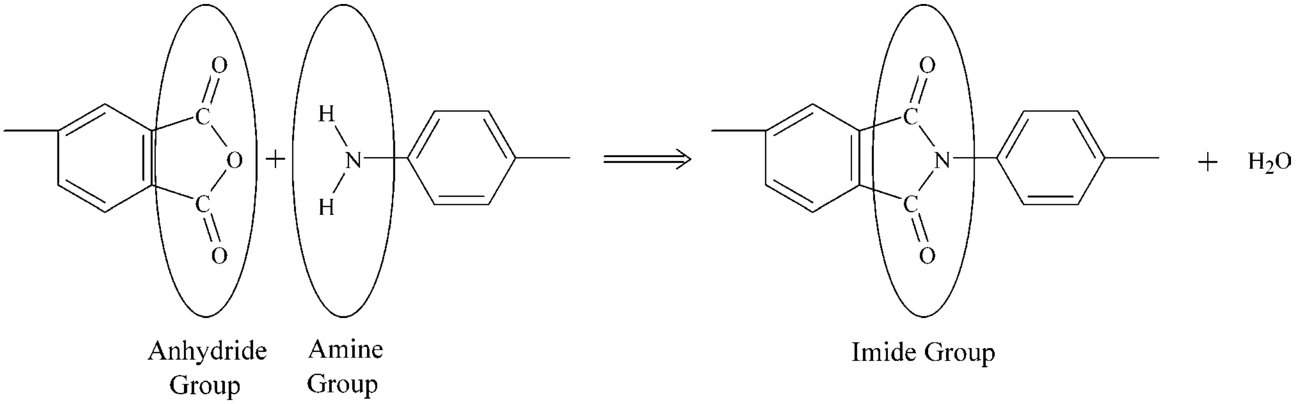


Figure 5.1. Reaction of amine with anhydride to form an imide.

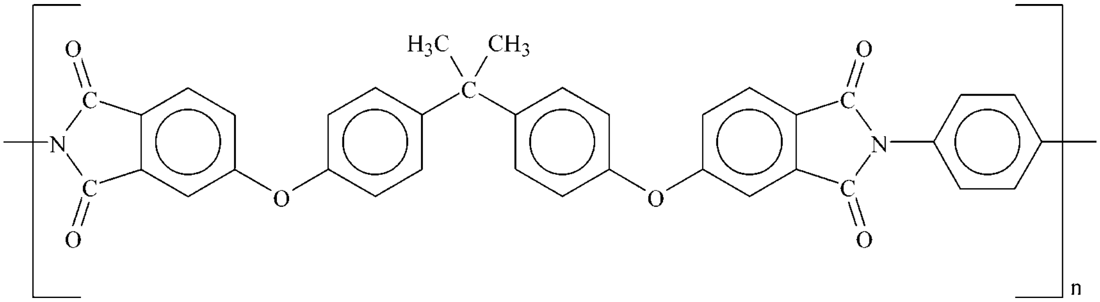


Figure 5.2. Chemical structure of BPADA-PPD polyetherimide (Ultem® 5000 series).

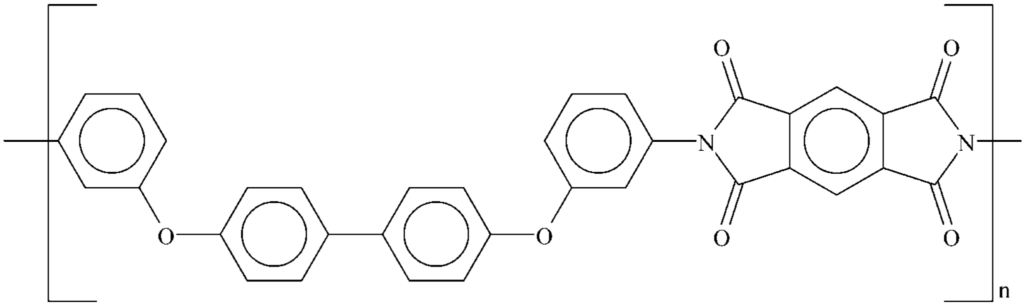


Figure 5.3. Chemical structure of biphenol diamine PMDA polyetherimide (Aurum®).

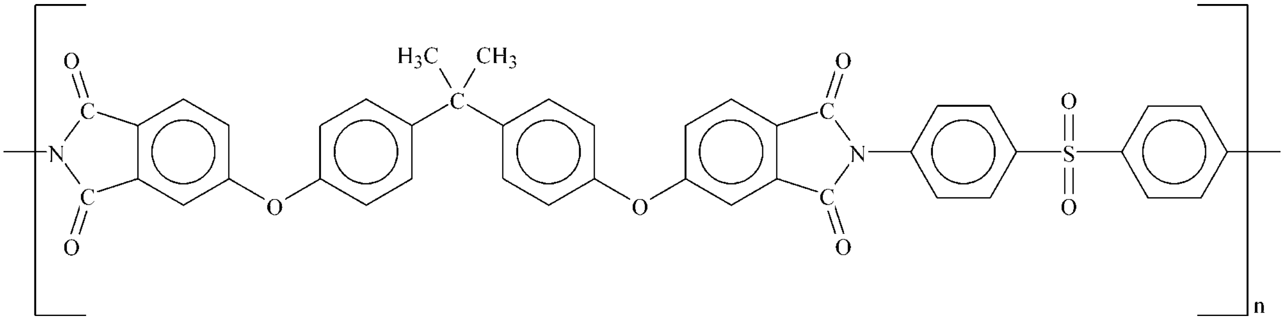


Figure 5.4. Chemical structure of BPADA-DDS polyetherimide sulfone (Ultem® XH6050).

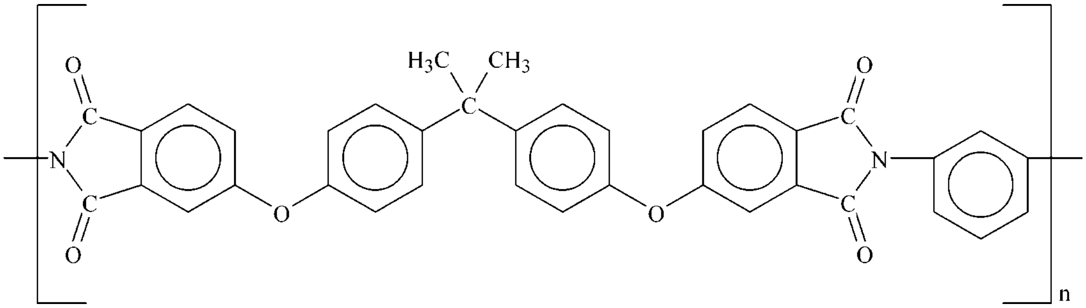


Figure 5.5. Chemical structure of BPADA-MPD polyetherimide (Ultem® 1000 series).

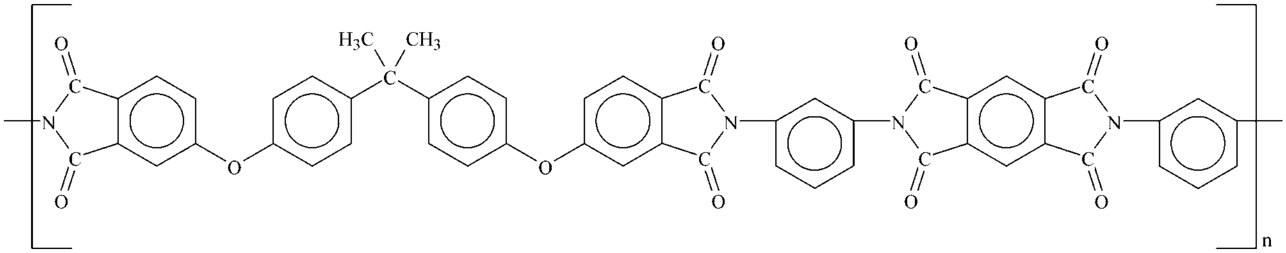


Figure 5.6. Chemical structure of BPADA-PMDA-MPD copolyetherimide (Ultem® 6000 series).

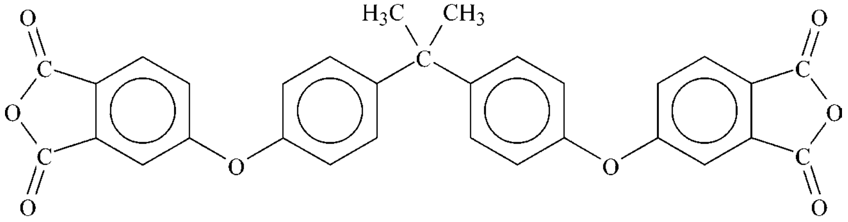
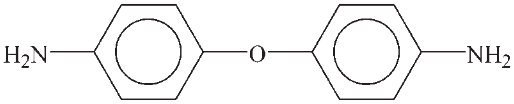
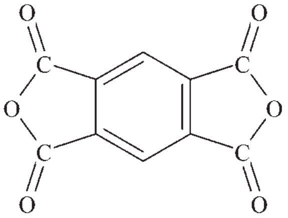


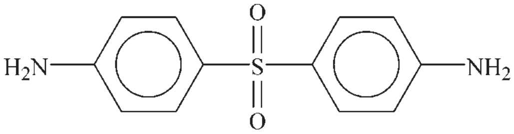
Figure 5.7. Chemical Structure of BPADA monomer.



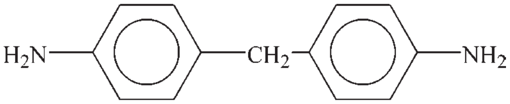
Oxydianiline
(ODA)



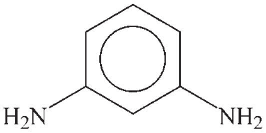
Pyromellitic Dianhydride (PMDA)



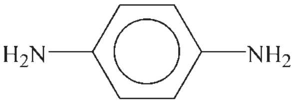
Diamino Diphenyl Sulfone
(DDS)



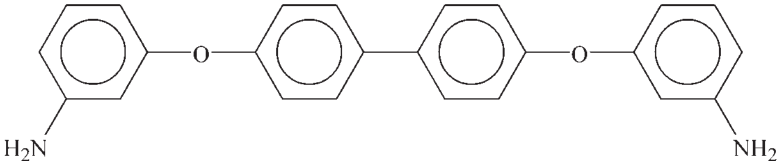
Methylene Dianiline
(MDA)



m-Phenylene Diamine
(MPD)

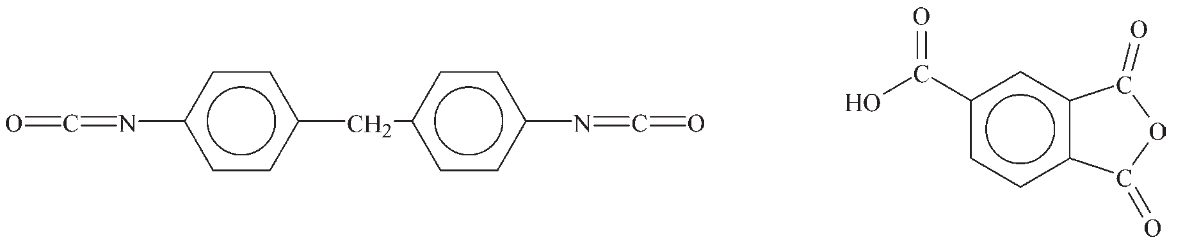


p-Phenylene Diamine
(PDA)



Biphenol Diamine
(BP Diamine)

Figure 5.8. Chemical structures of other monomers used to make polyimides.



4,4’-diphenyl methane diisocyanate (MDI)

trimellitic anhydride (TMA)

Figure 5.9. Chemical structures of monomers used to make PAI.

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 Fig. 5.10.

5.1.3 Polyimide (PI)

Polyimides (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 inherently low-coefficient of thermal expansion. They are formed from diamines and dianhydrides as shown in Fig. 5.11.

Many other diamines and several other dianhydrides may be chosen to tailor the final properties of a polymer whose structure is shown in Fig. 5.12.

5.1.4 Imide Polymer Blends

PI based resins, especially PEI and PAI polymers, may also be combined with other polymers. The PEI resins have produced a surprising number of miscible (one-phase) and compatible blends. Compatible blends are phase-separated mixtures having sufficient attraction between phases to provide some level of molecular adhesion, resulting in stable morphology and giving rise to good mechanical properties.

PEI forms miscible blends with polyesters such as polybutylene terephthalate (PBT) and polyethylene terephthalate (PET). These blends have a single glass transition temperature between that of the PEI and polyester. However, few of these are commercial products yet.

Blends of BPADA-based PIs are also miscible with polyaryl ether ketones such as polyetheretherketone (PEEK). As injection molded, many PEEK-PEI blends are transparent.

Graphs showing multipoint properties of these PI-based polymers as a function of temperature, moisture, and other factors are illustrated in Sections 5.2–5.4.

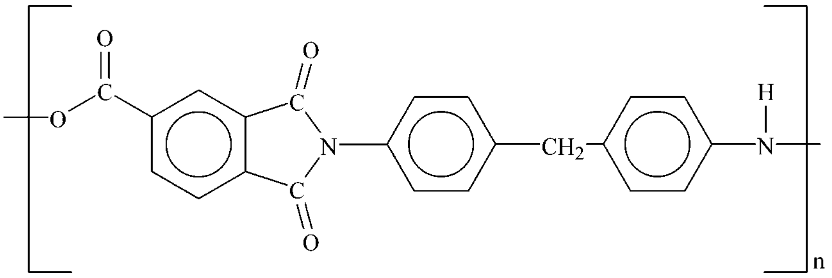
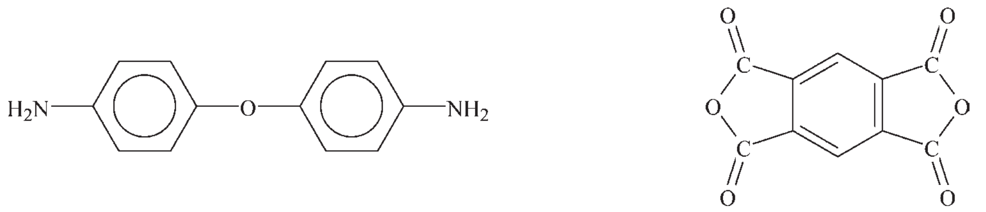


Figure 5.10. Chemical structure of a typical PAI.



4,4’-diaminodiphenyl ether
oxydianiline (ODA)

Pyromellitic Dianhydride (PMDA)

Figure 5.11. Chemical structures of monomers used to make PIs.

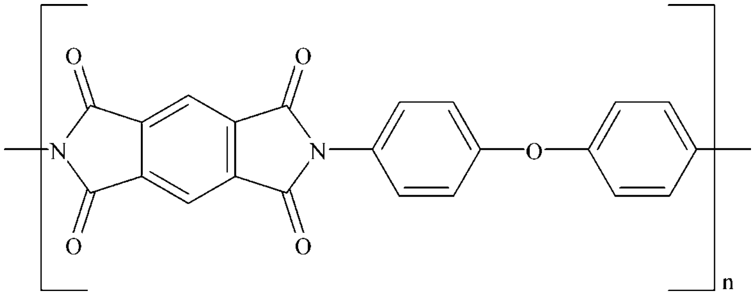


Figure 5.12. Chemical structure of a typical polyimide.

5.2 Polyetherimide (PEI)

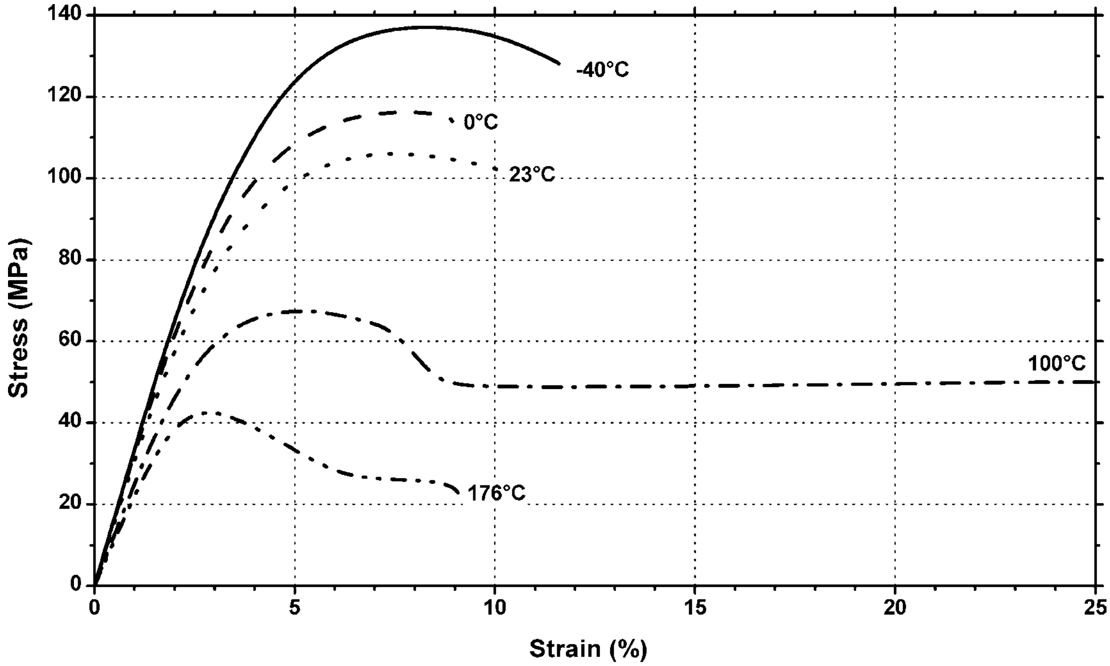


Figure 5.13. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

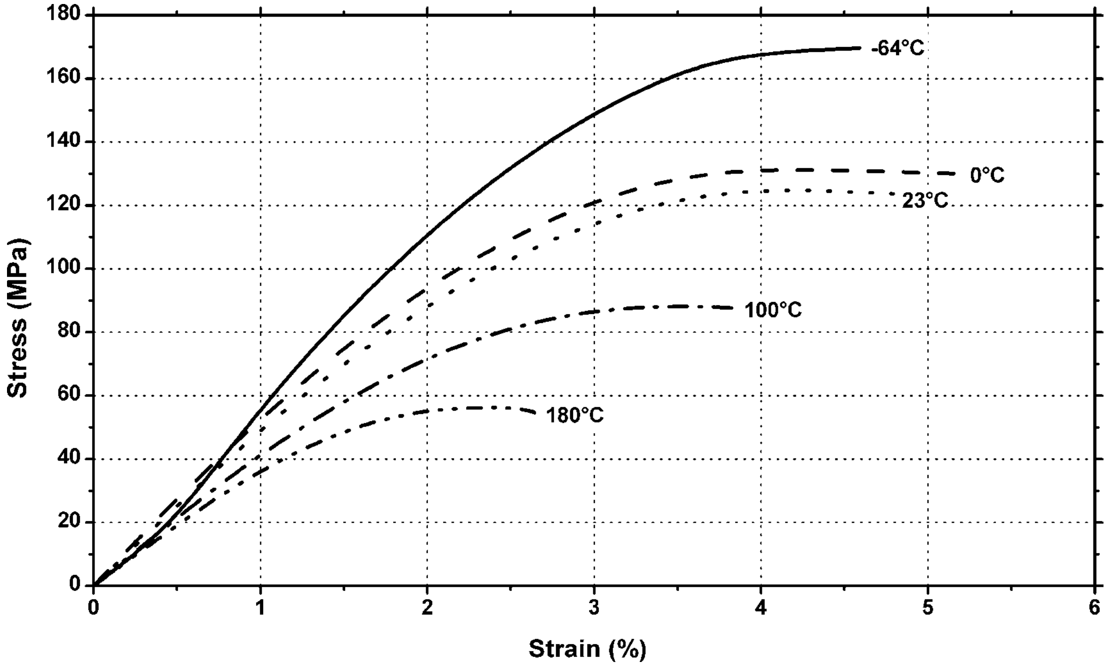


Figure 5.14. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 2100—10% glass reinforced PEI resin.

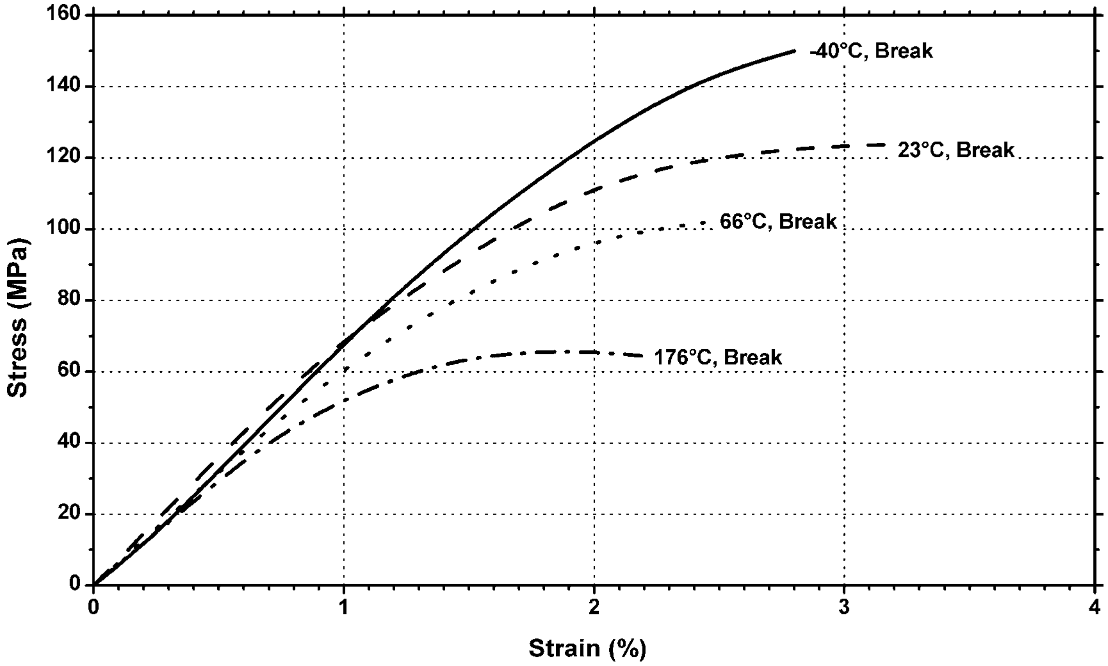


Figure 5.15. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 2200—20% glass reinforced PEI resin.

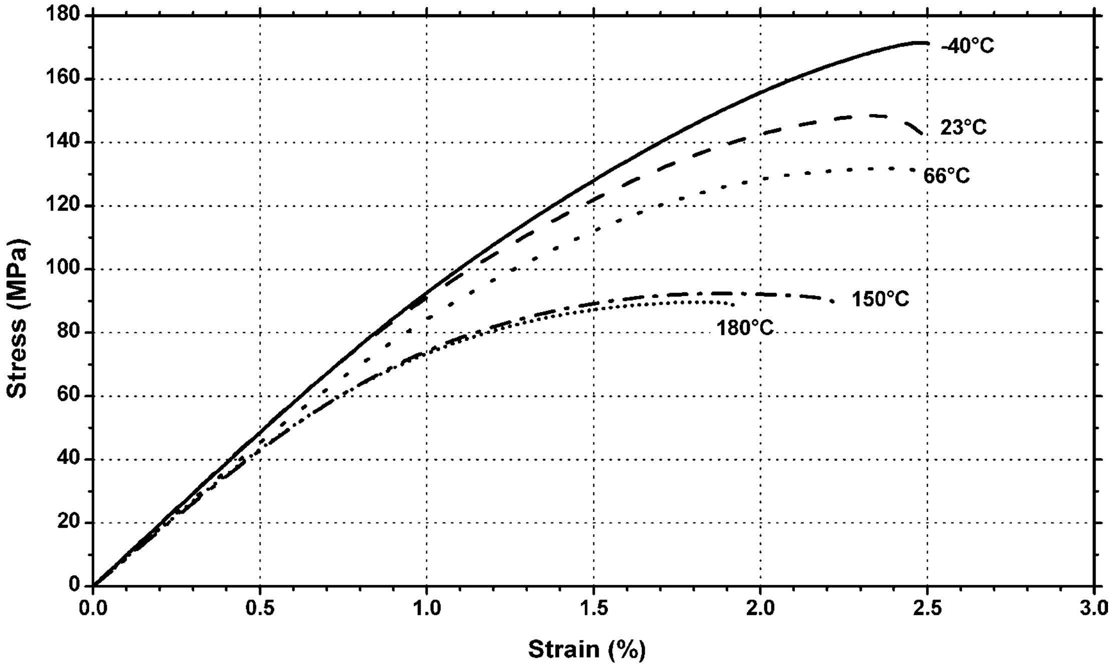


Figure 5.16. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 2300—30% glass reinforced PEI resin.

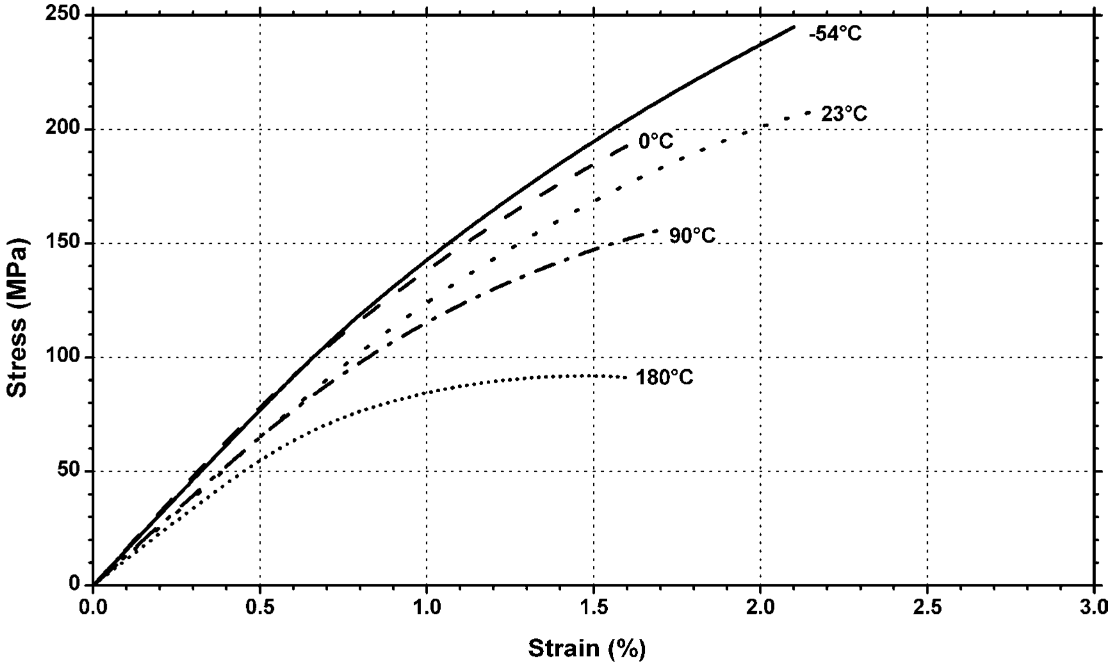


Figure 5.17. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 2400—40% glass reinforced polyetherimide resin.

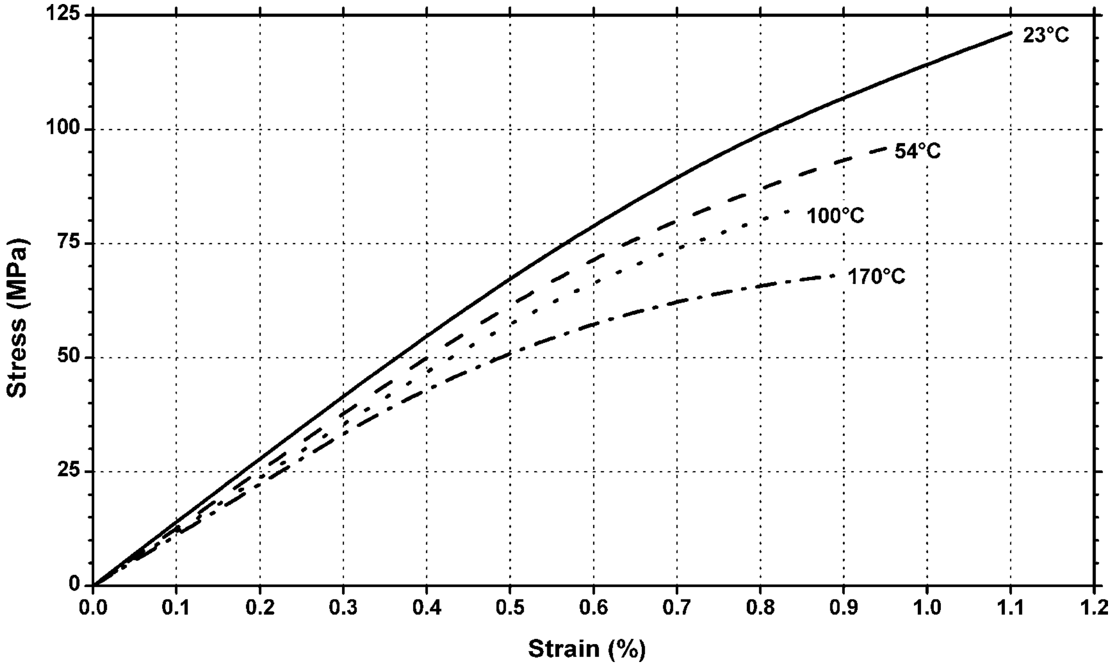


Figure 5.18. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 3452—45% glass/mineral reinforced PEI resin.

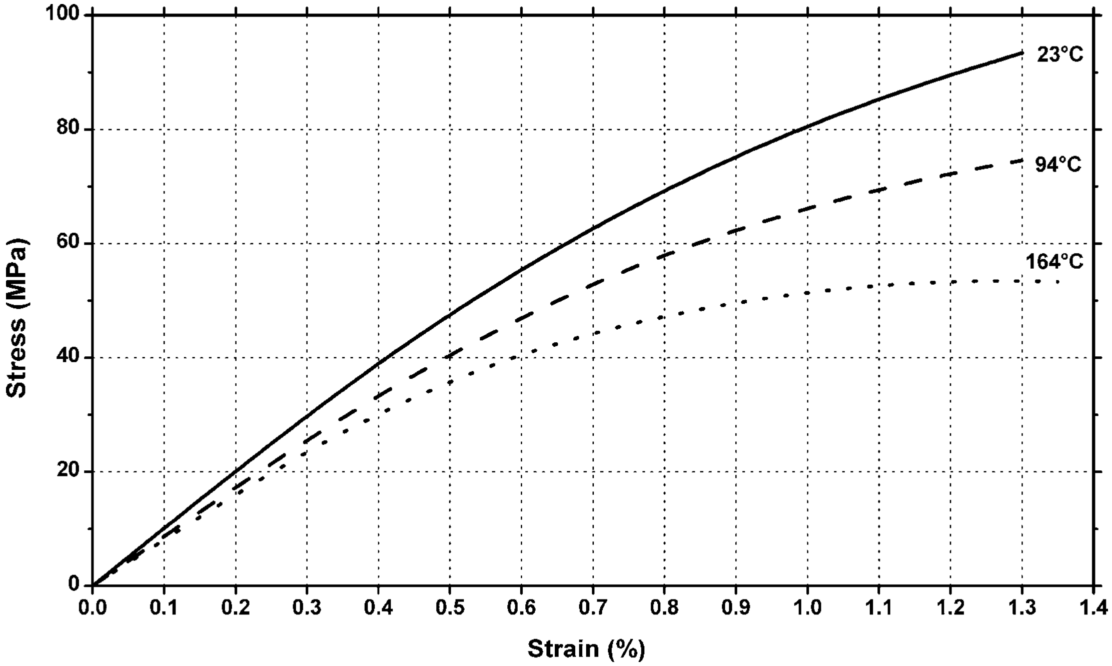


Figure 5.19. Stress vs. strain at various temperatures of SABIC Innovative Plastics Ultem® 4000—wear resistant, 25% glass, 15% PTFE PEI resin.

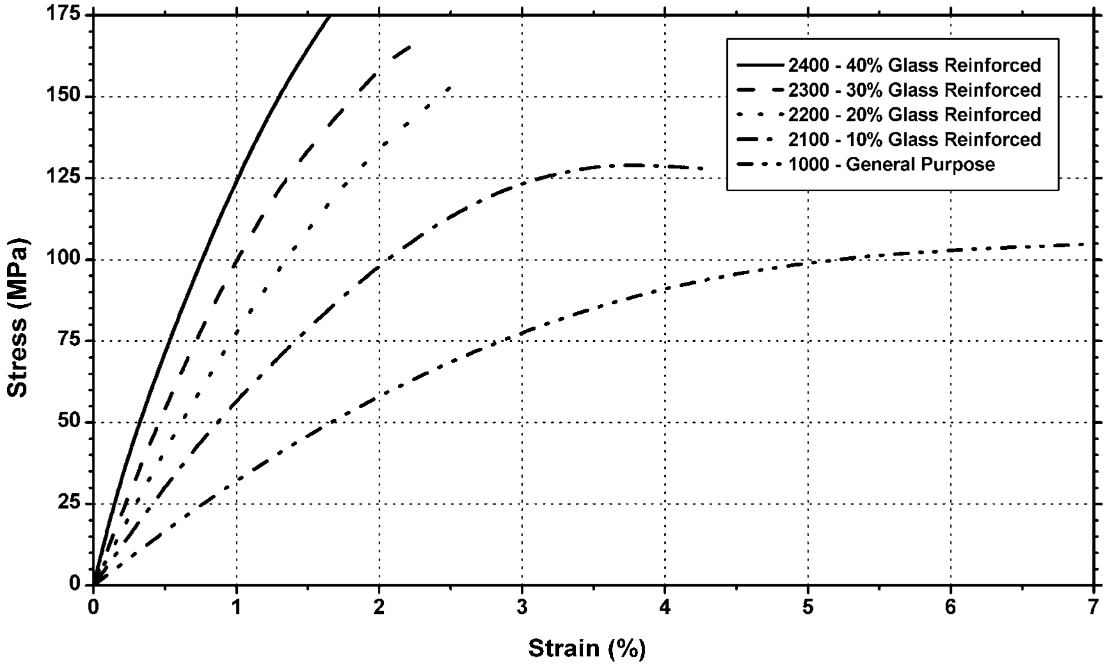


Figure 5.20. Stress vs. strain at 23°C of several SABIC Innovative Plastics Ultem® PEI resins.

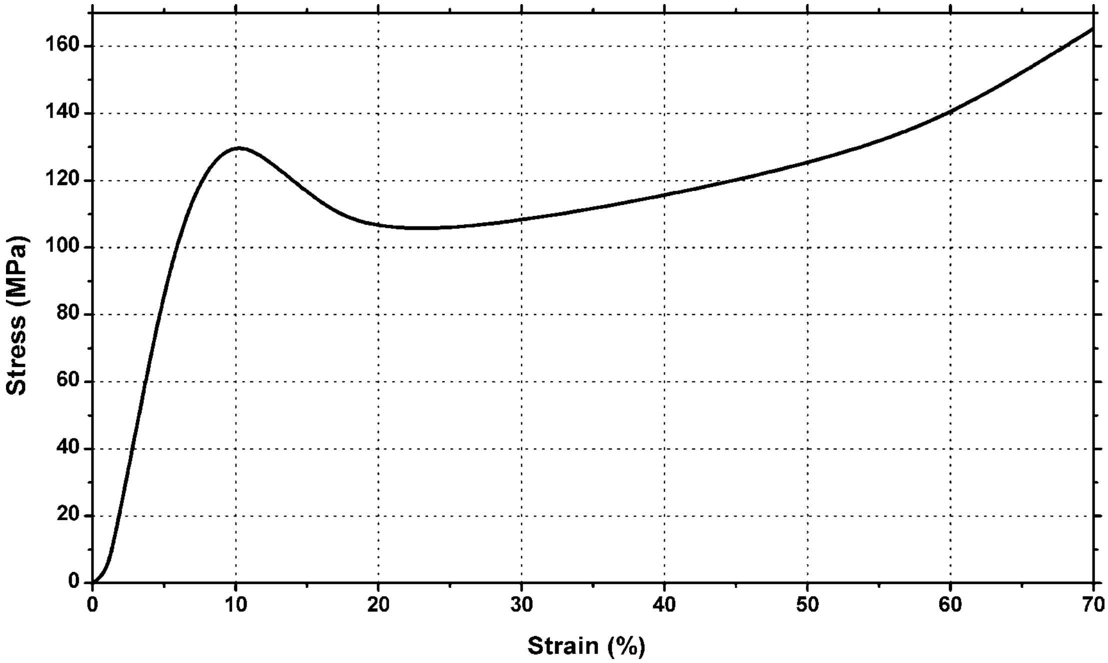


Figure 5.21. Stress vs. strain in compression of SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

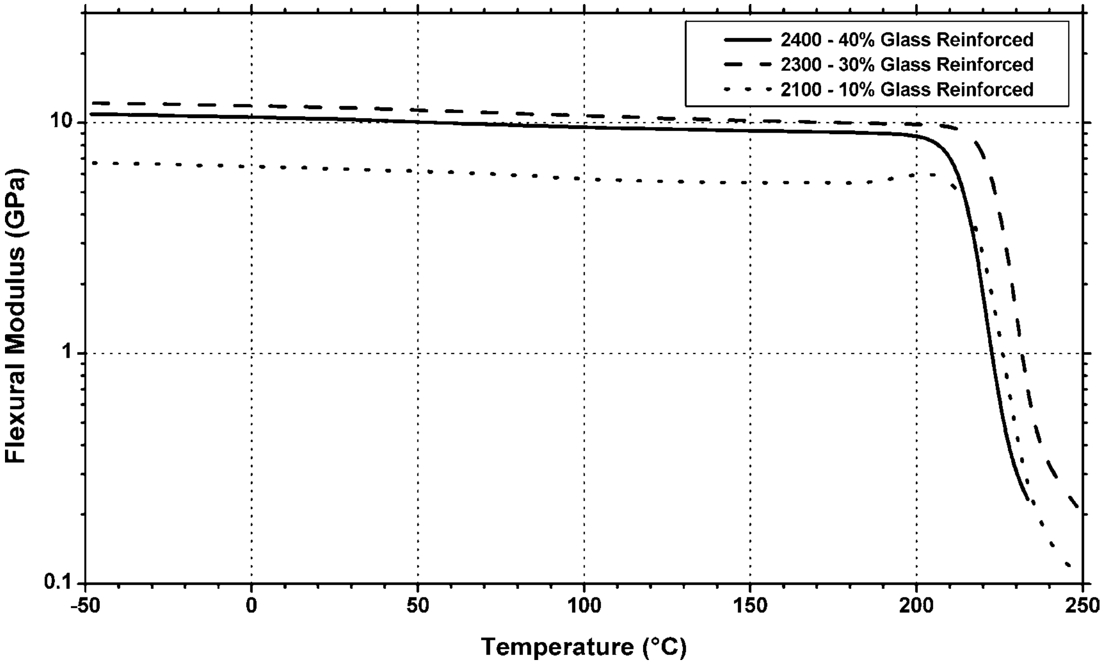


Figure 5.22. Flexural modulus vs. temperature of several SABIC Innovative Plastics Ultem® glass reinforced PEI resins.

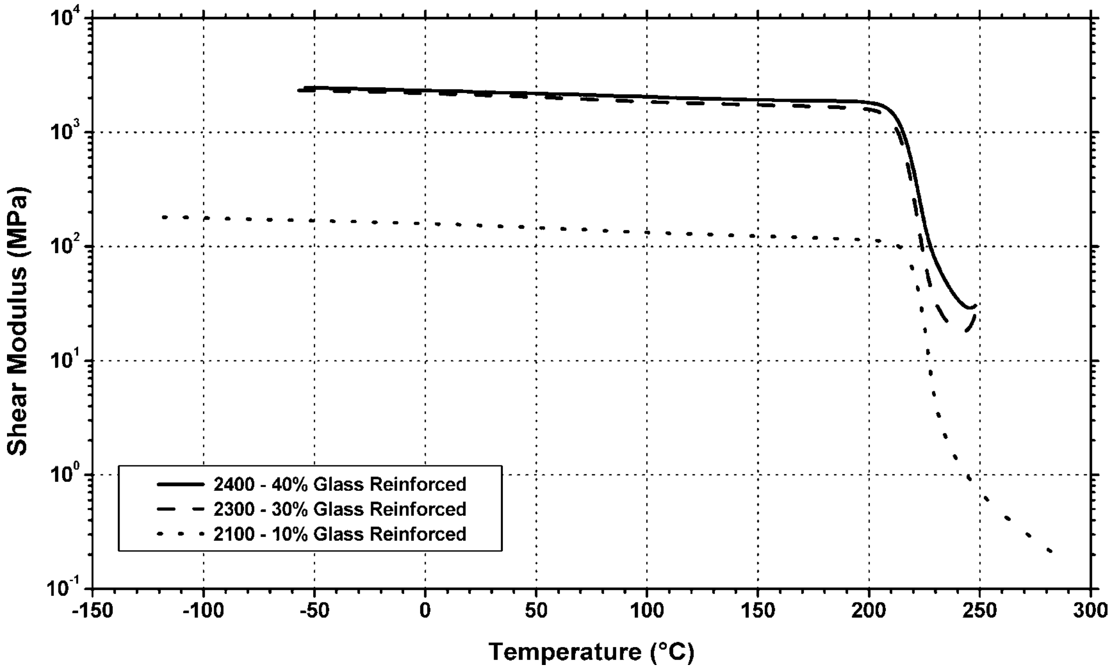


Figure 5.23. Shear modulus vs. temperature of several SABIC Innovative Plastics Ultem® glass reinforced PEI resins.

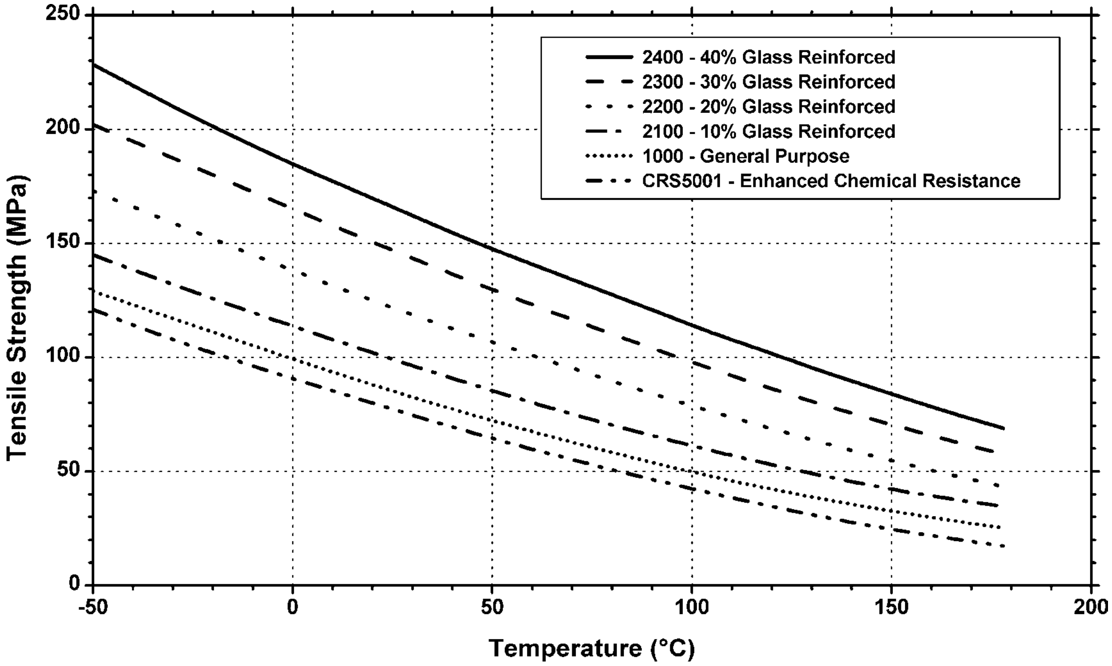


Figure 5.24. Tensile strength vs. temperature of several SABIC Innovative Plastics Ultem® PEI resins.

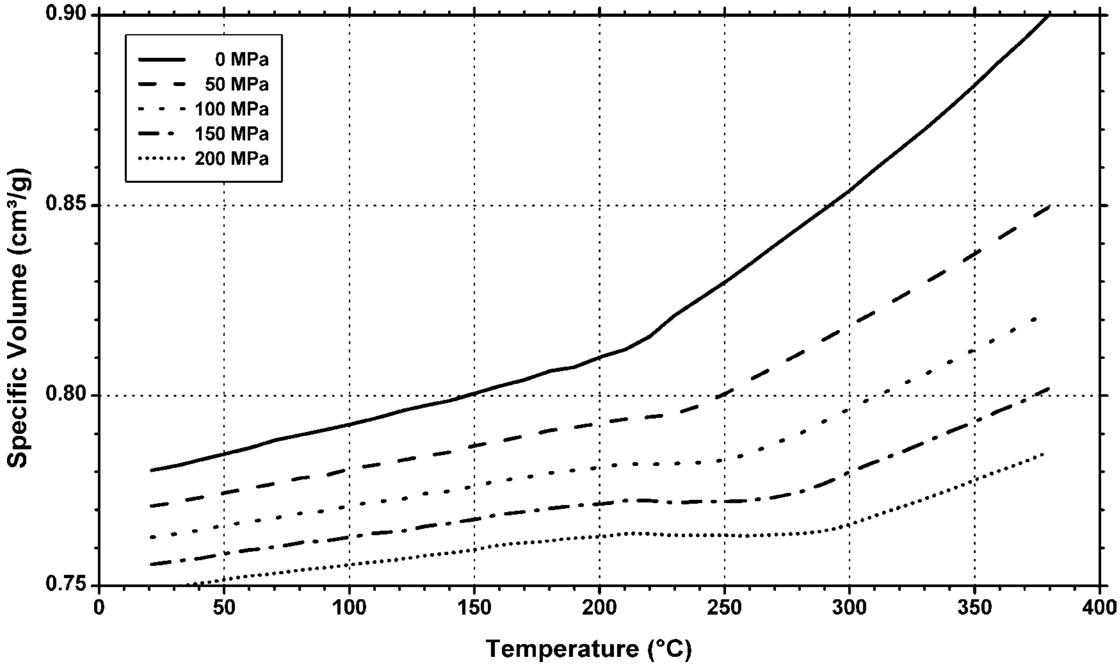


Figure 5.25. Pressure–specific volume–temperature (PVT) of SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

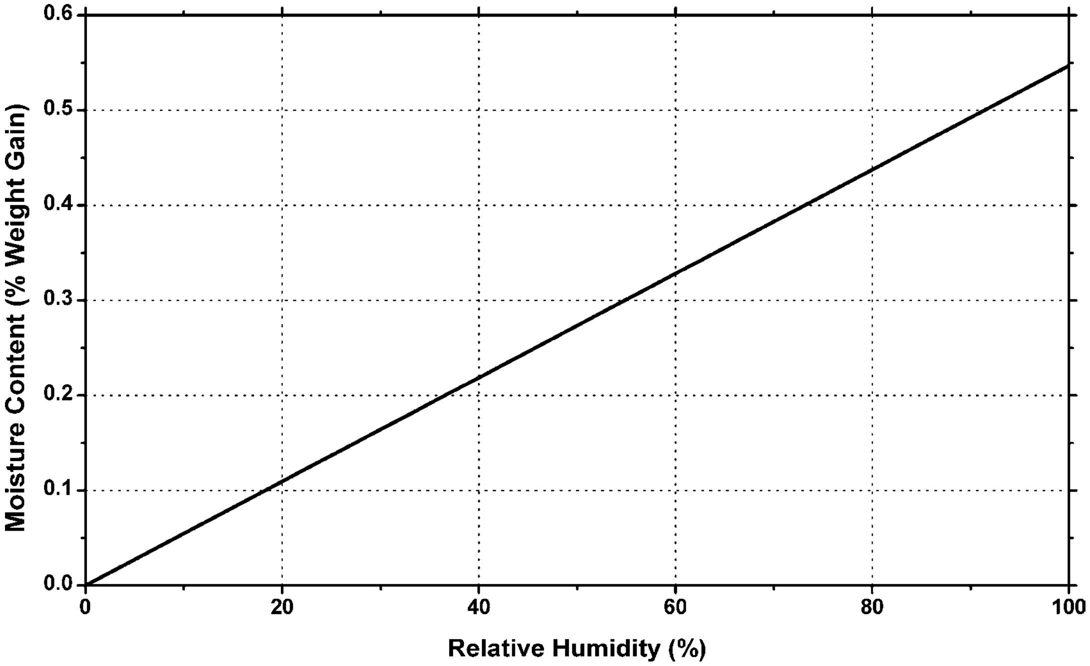


Figure 5.26. Moisture absorption vs. relative humidity of SABIC Innovative Plastics Ultem® 1000—general purpose PEI resin.

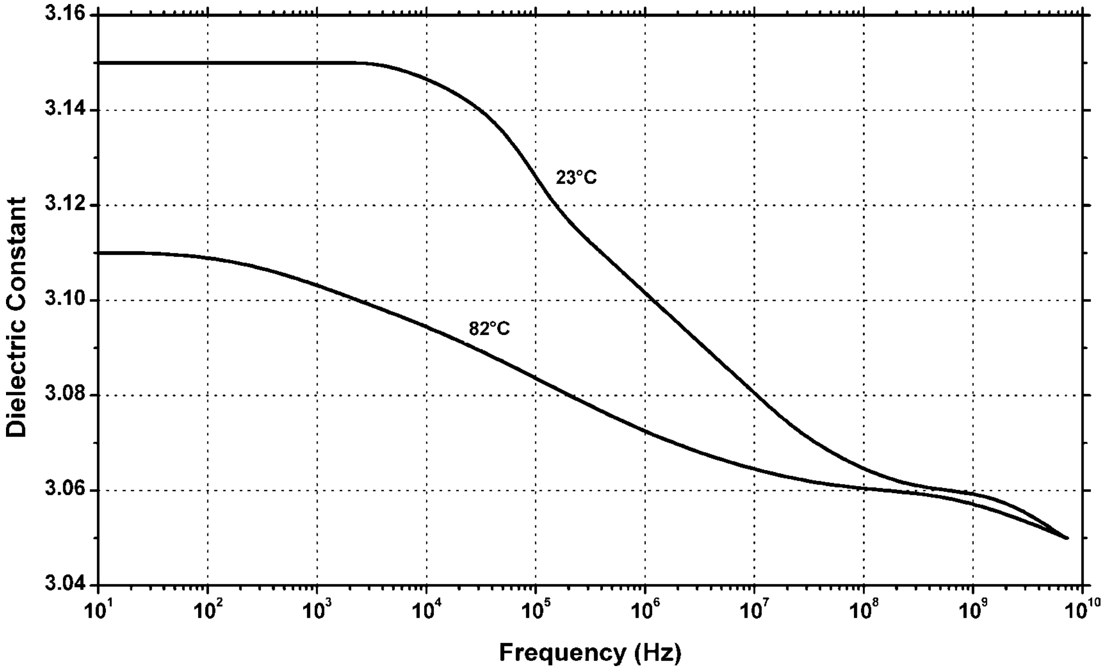


Figure 5.27. Dielectric constant vs. frequency and temperature of SABIC Innovative Plastics Ultem® PEI resins.

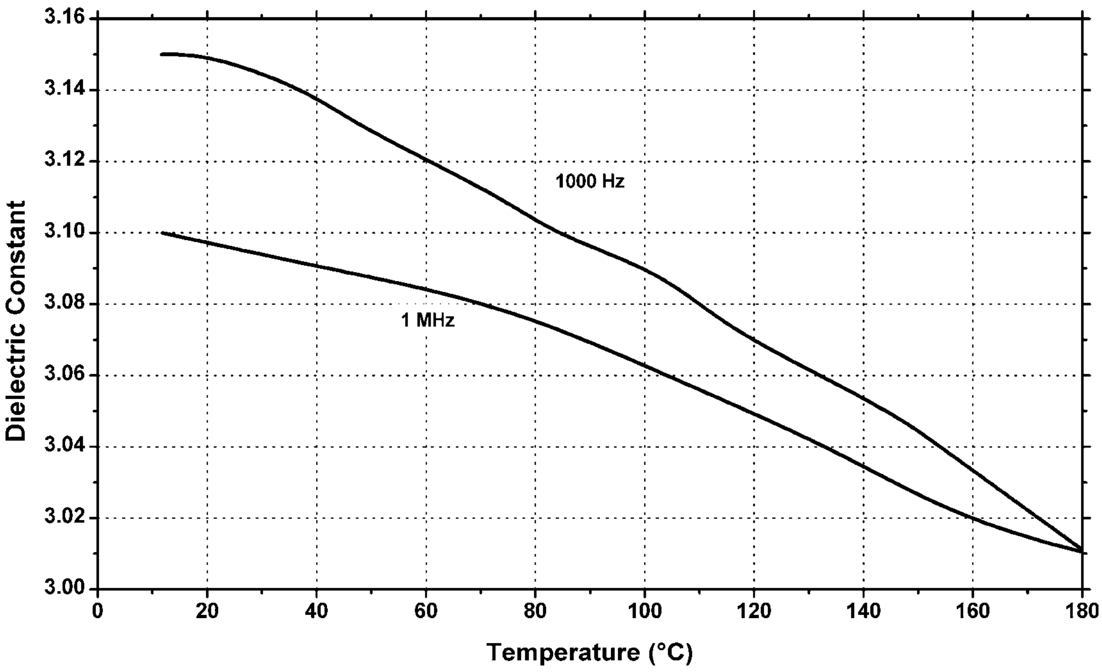


Figure 5.28. Dielectric constant vs. temperature and frequency of SABIC Innovative Plastics Ultem® PEI resins.

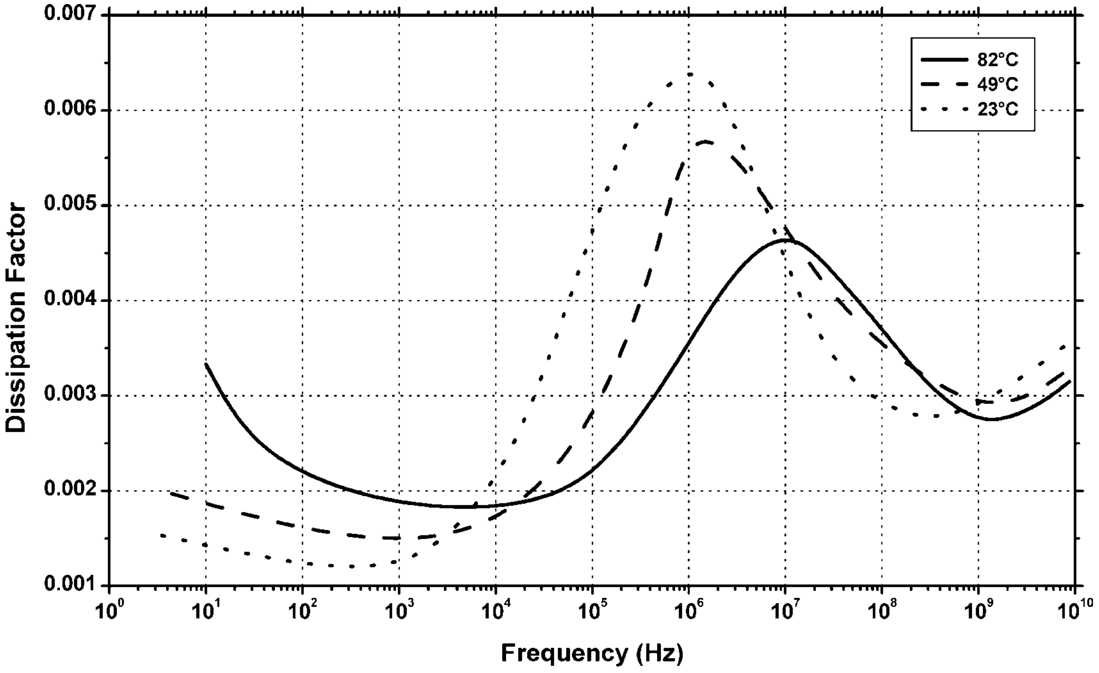


Figure 5.29. Dissipation factor vs. temperature and frequency of SABIC Innovative Plastics Ultem® PEI resins.

5.3 Polyamide-Imide (PAI)

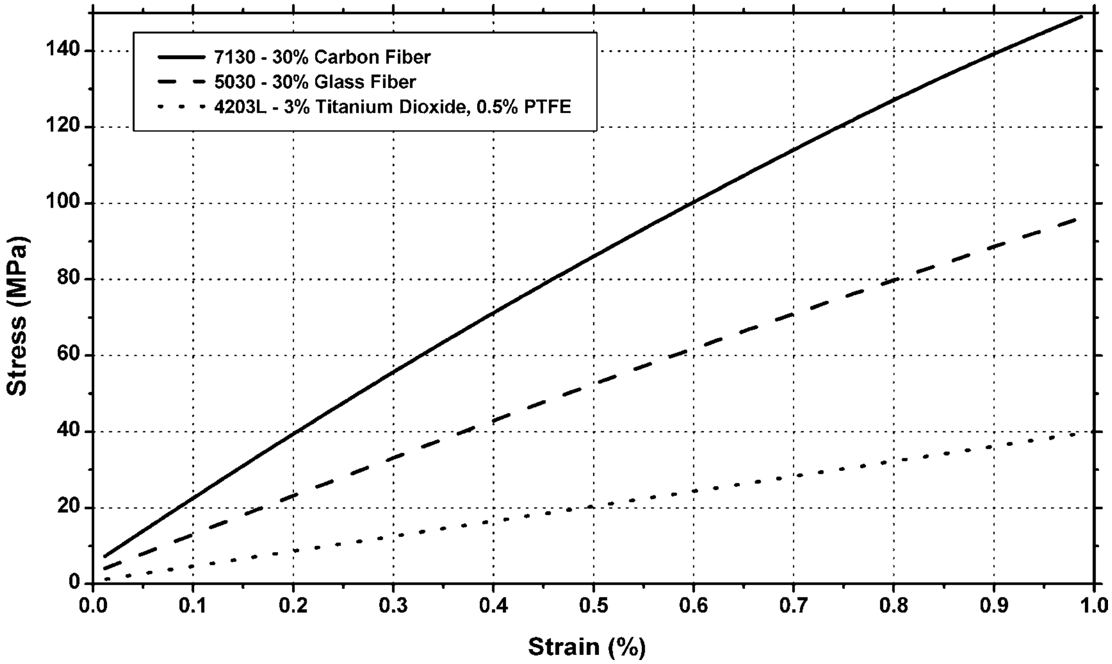


Figure 5.30. Stress vs. strain at 23°C and small stress for Solvay Advanced Polymers Torlon® PAI resins.

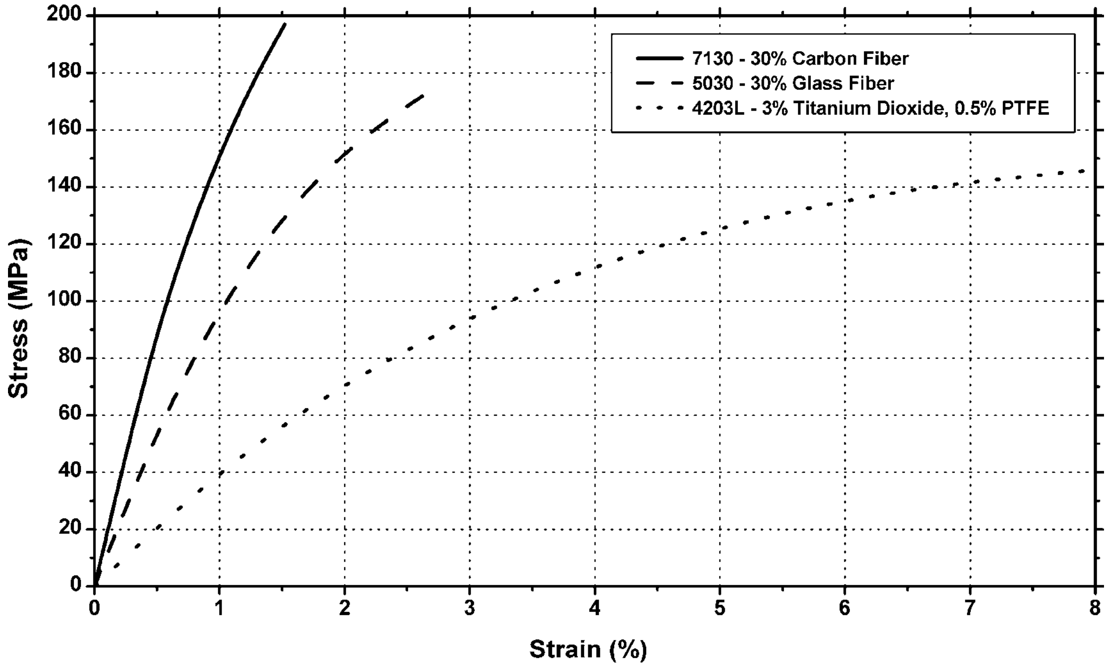


Figure 5.31. Stress vs. strain at 23°C for Solvay Advanced Polymers Torlon® PAI resins.

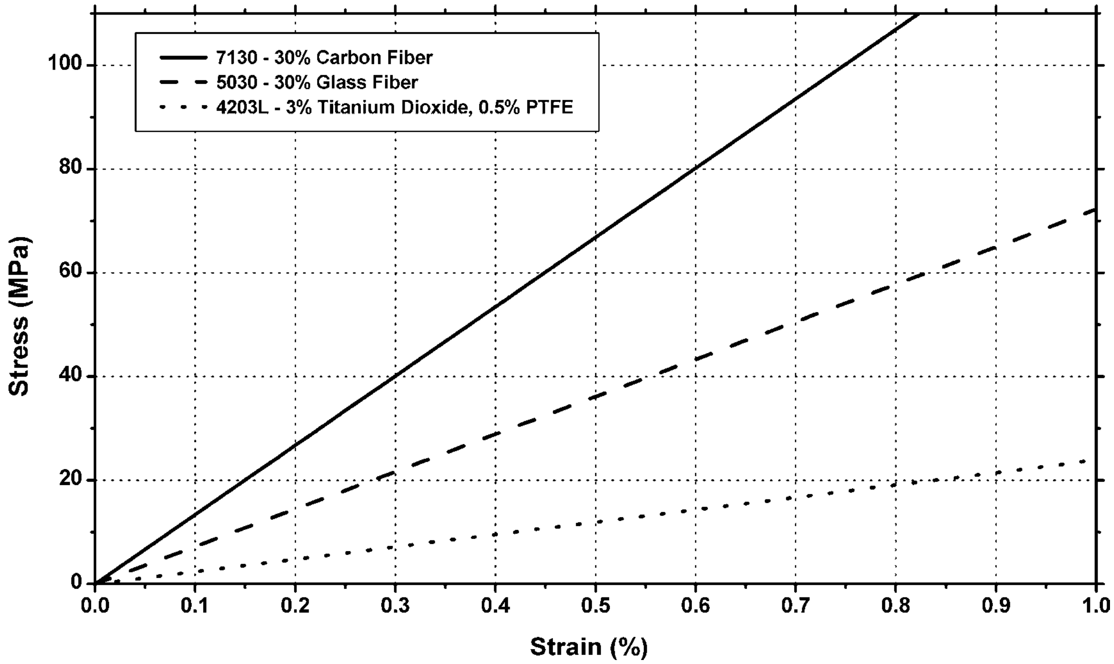


Figure 5.32. Stress vs. strain at 135°C for Solvay Advanced Polymers Torlon® PAI resins.

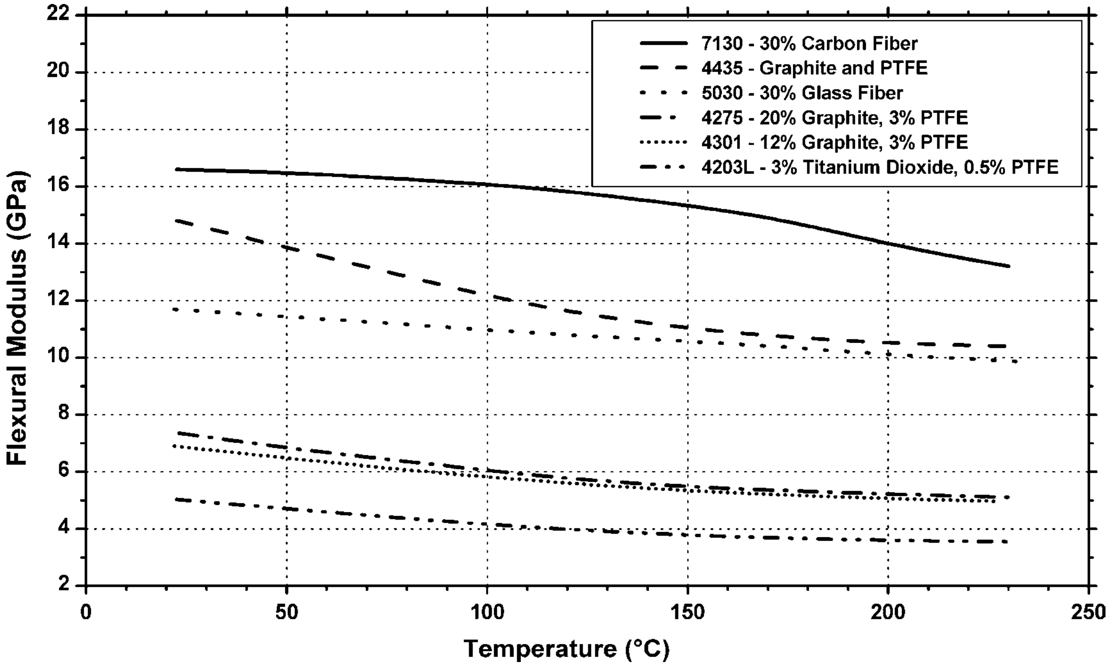


Figure 5.33. Flexural modulus vs. temperature for Solvay Advanced Polymers Torlon® PAI resins.

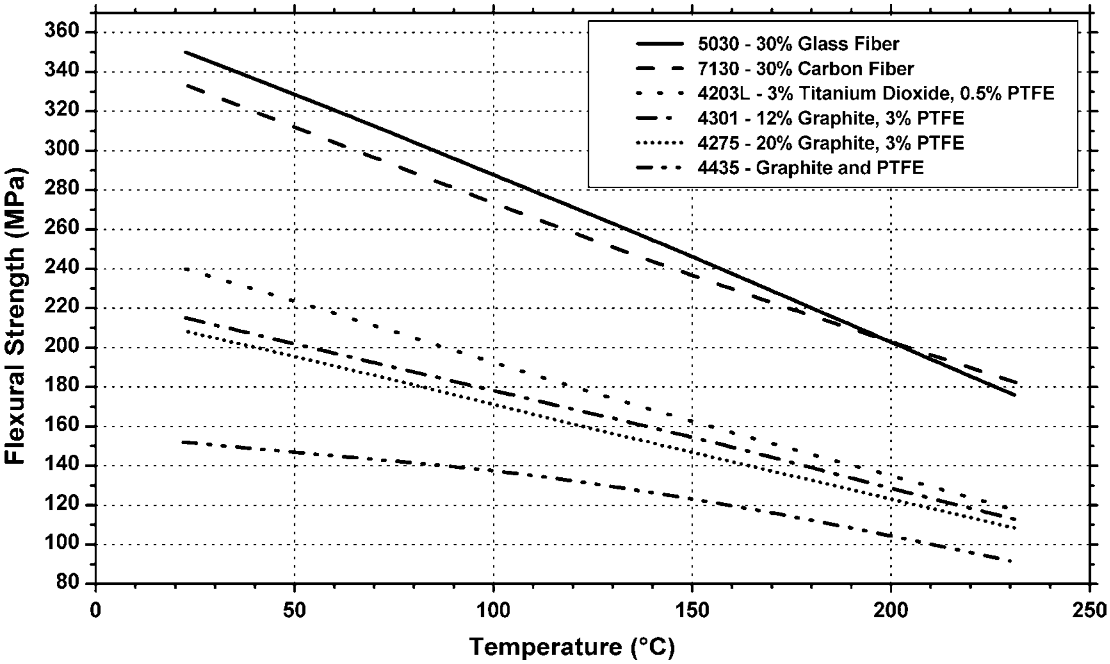


Figure 5.34. Flexural strength vs. temprature for Solvay Advanced Polymers Torlon® PAI resins.

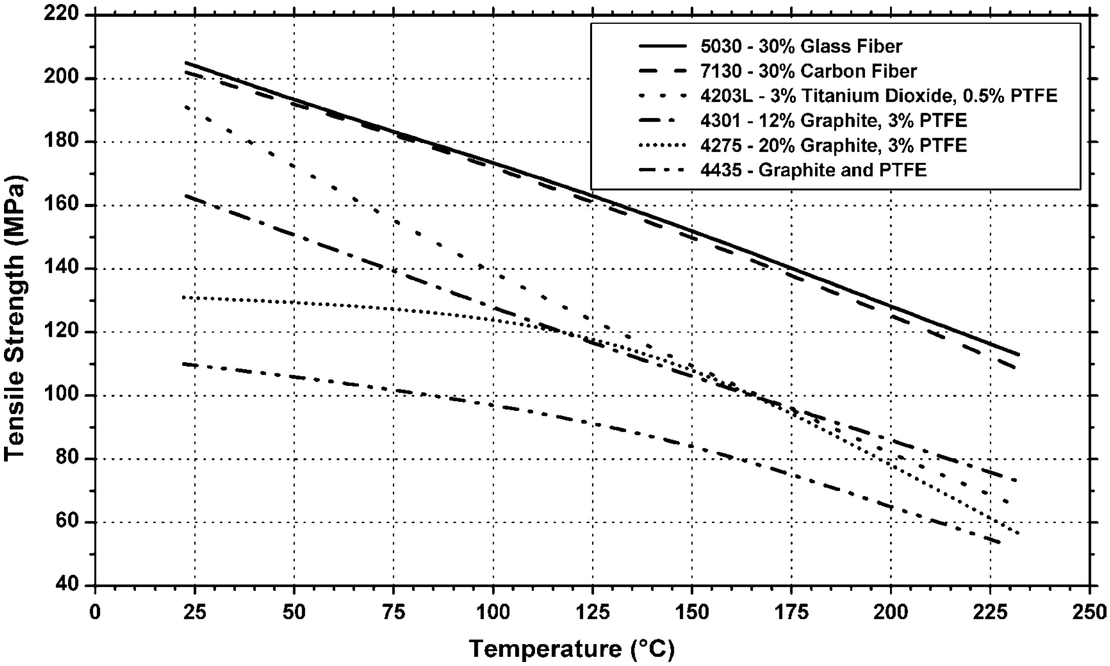


Figure 5.35. Tensile strength vs. temperature for Solvay Advanced Polymers Torlon® PAI resins.

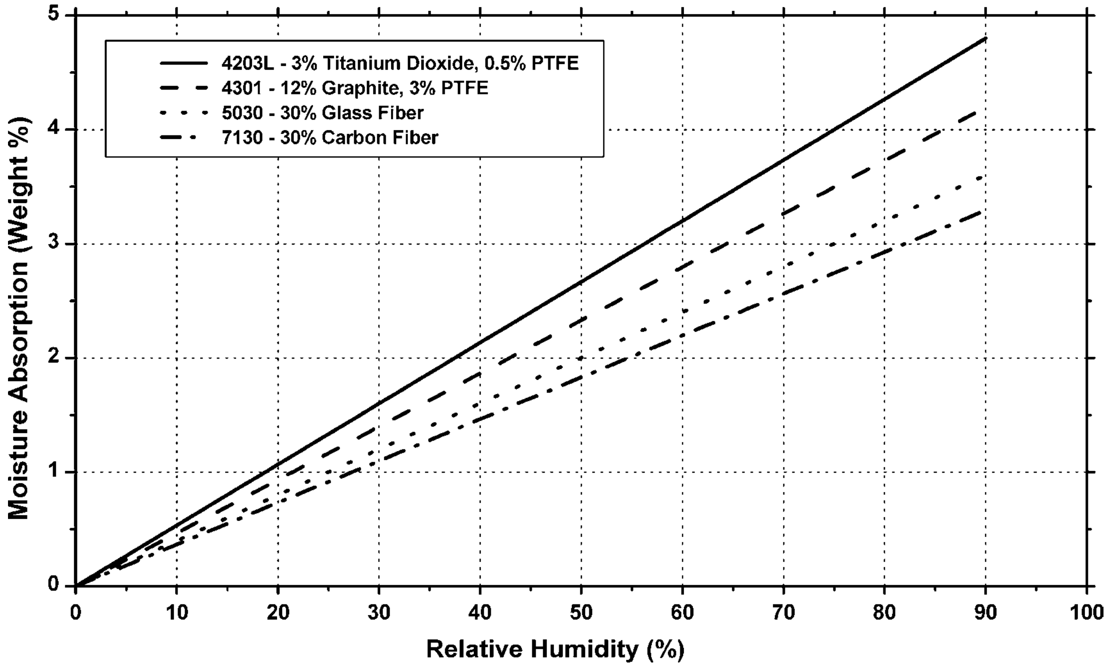


Figure 5.36. Moisture absorption vs. relative humidity for Solvay Advanced Polymers Torlon® PAI resins.

5.4 Polyimide (PI)

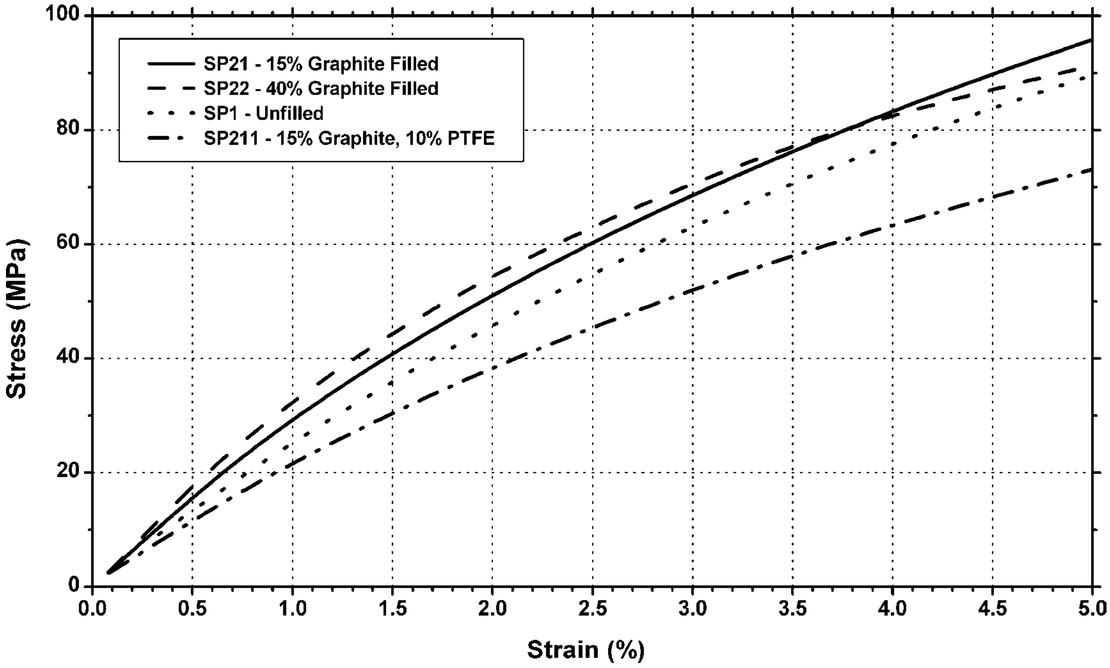


Figure 5.37. Stress vs. strain at 23°C in compression for DuPont Vespel® machined PI.

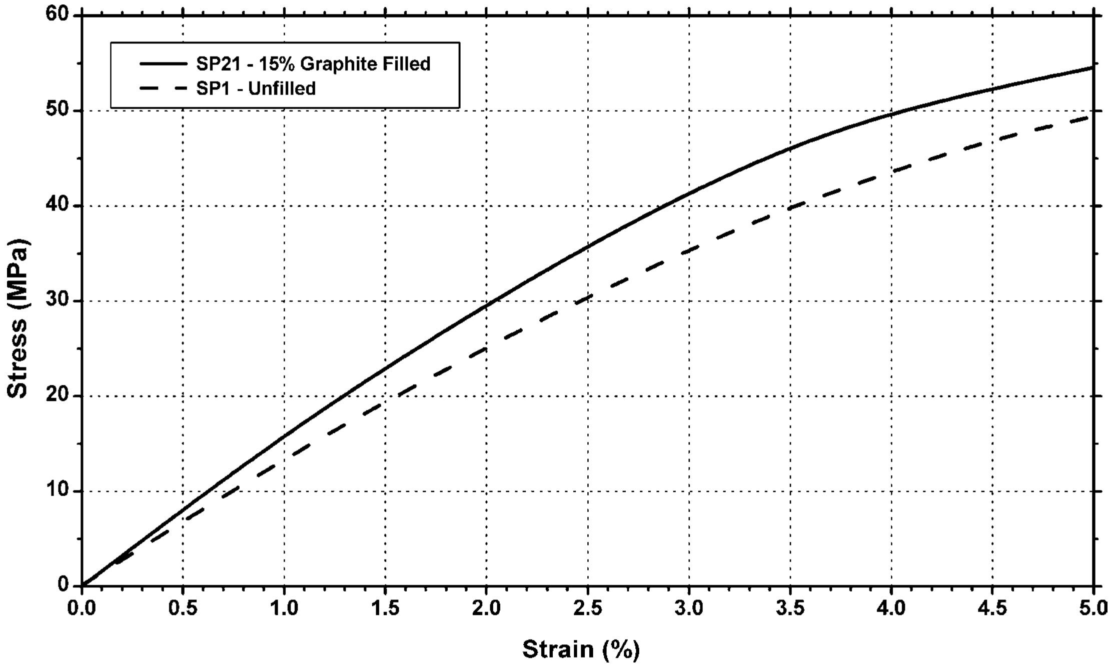


Figure 5.38. Stress vs. strain at 300°C in compression for DuPont Vespel® machined PI.

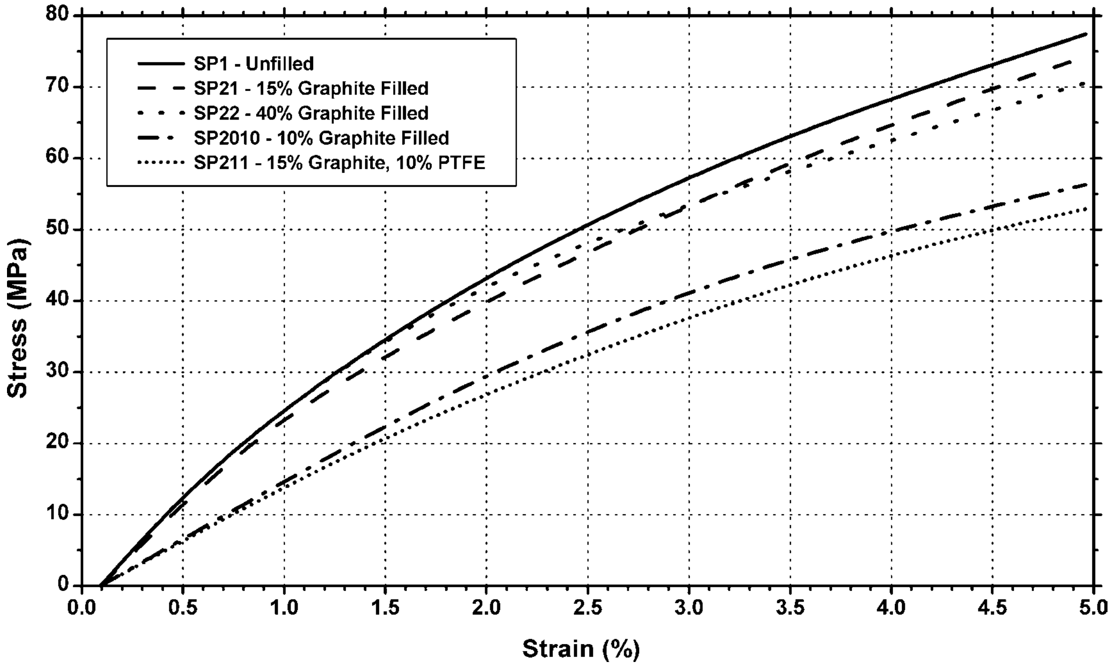


Figure 5.39. Stress vs. strain at 23°C in compression parallel to forming for DuPont Vespel® direct-formed PI.

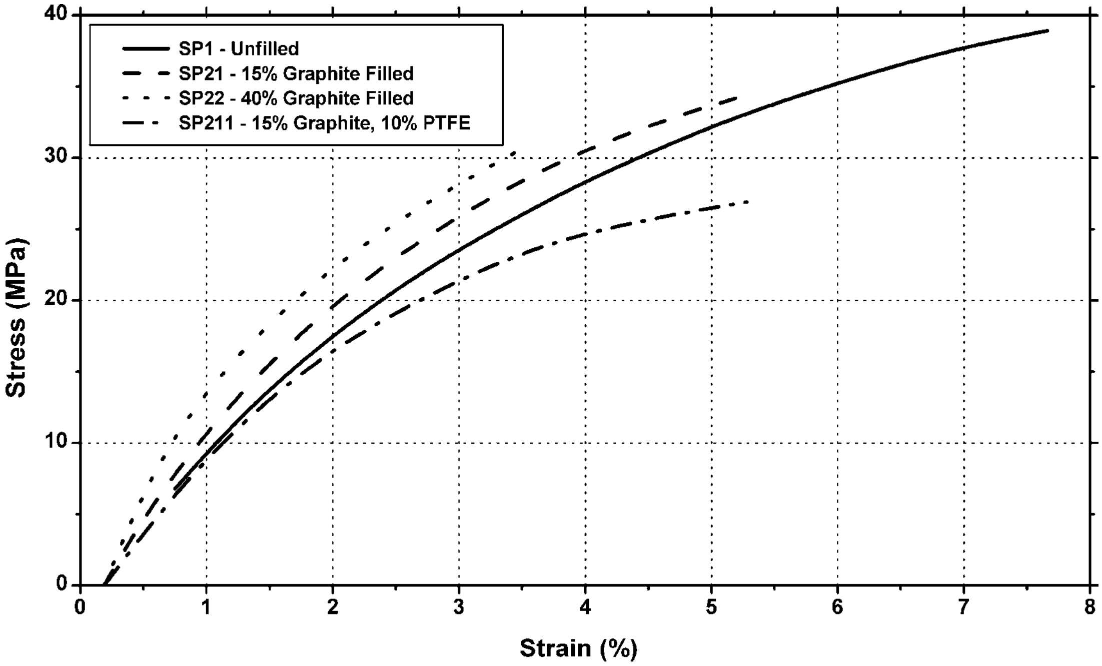


Figure 5.40. Stress vs. strain at 260°C in tension parallel to forming for DuPont Vespel® direct-formed PI.

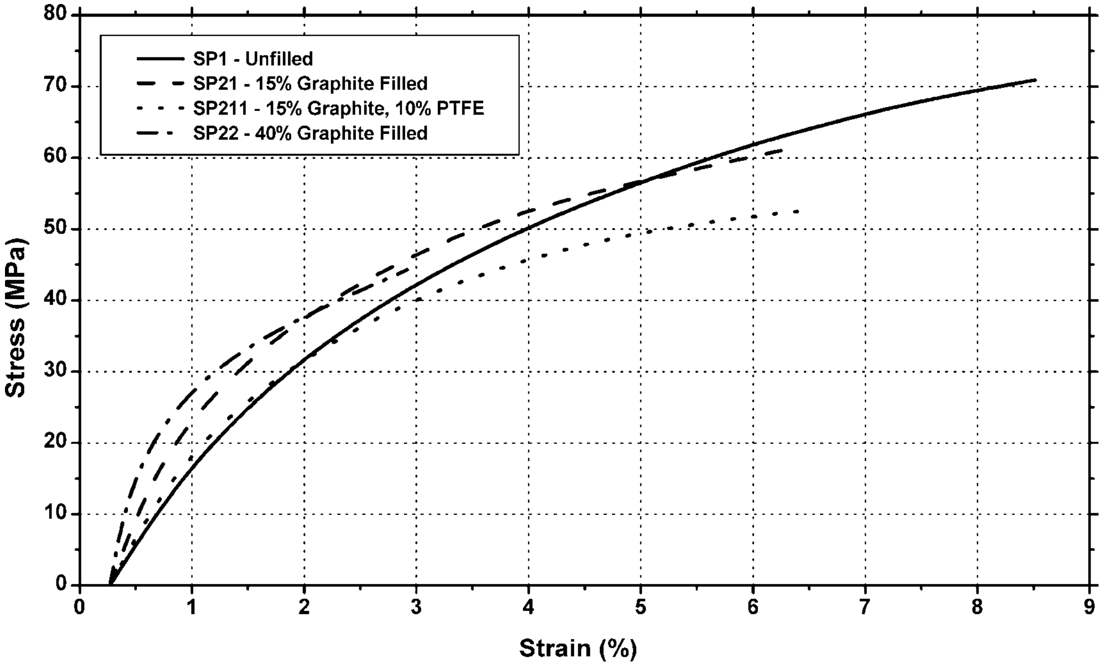


Figure 5.41. Stress vs. strain at 23°C in tension perpendicular to forming for DuPont Vespel® direct-formed PI.

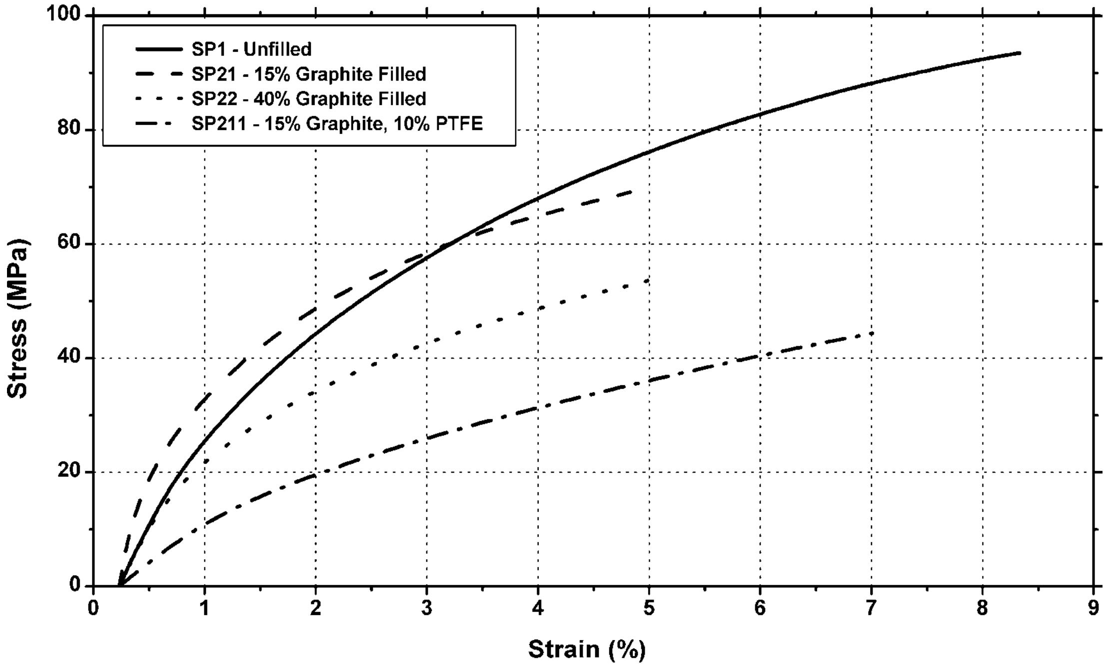


Figure 5.42. Stress vs. strain at 23°C in tension perpendicular to forming for DuPont Vespel® machined PI.

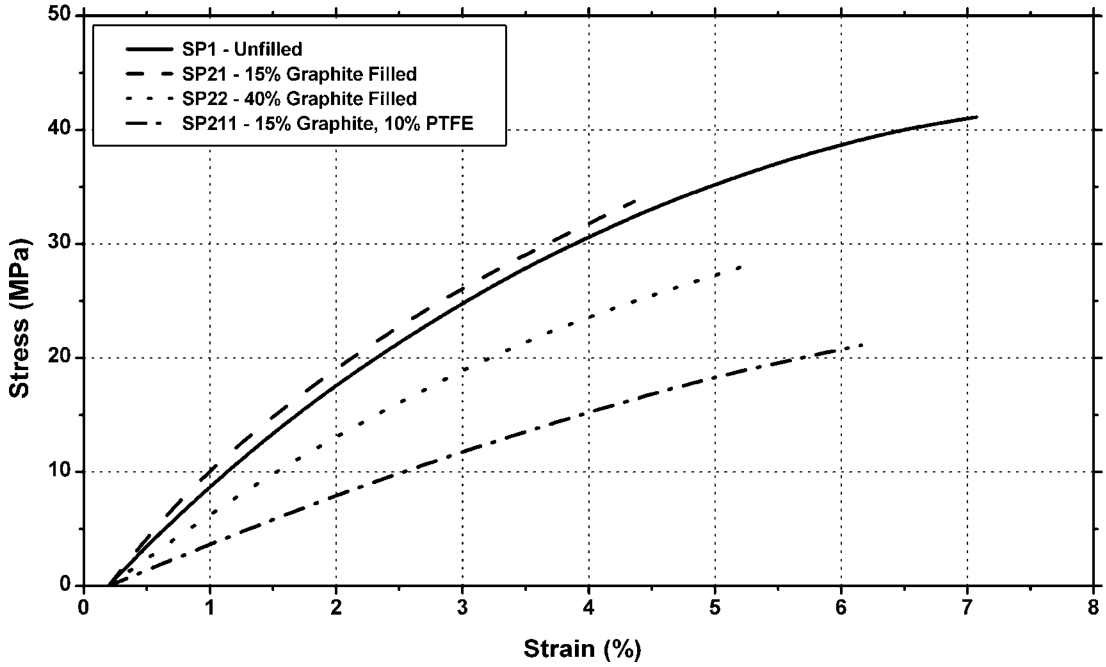


Figure 5.43. Stress vs. strain at 260°C in tension for DuPont Vespel® machined PI.

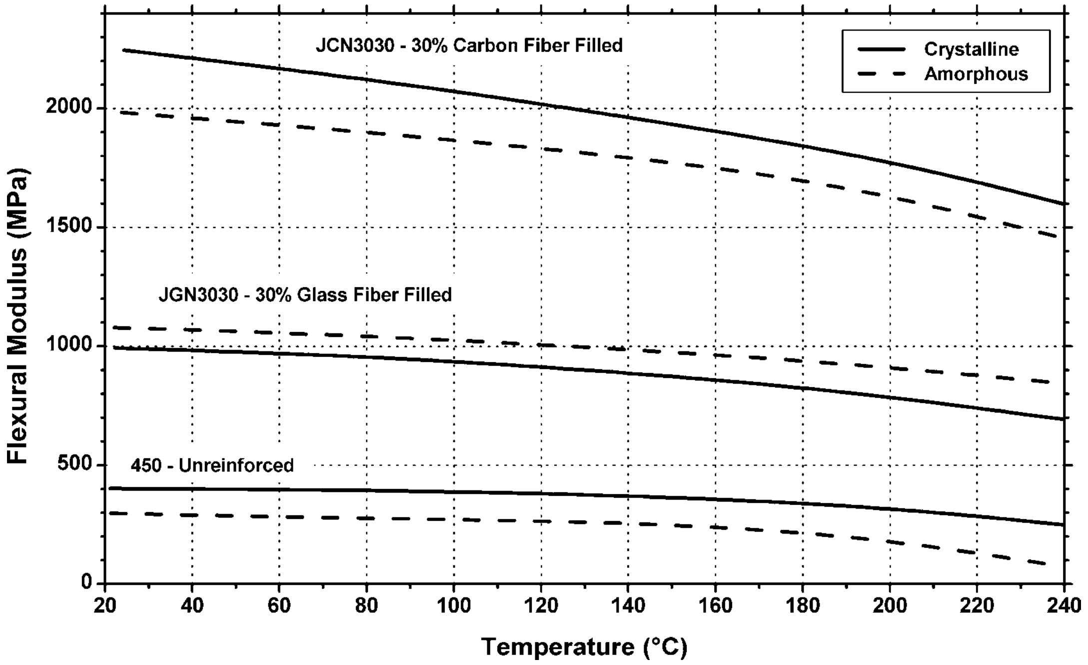


Figure 5.44. Flexural modulus vs. temperature for Mitsui Chemicals Aurum® PI resins.

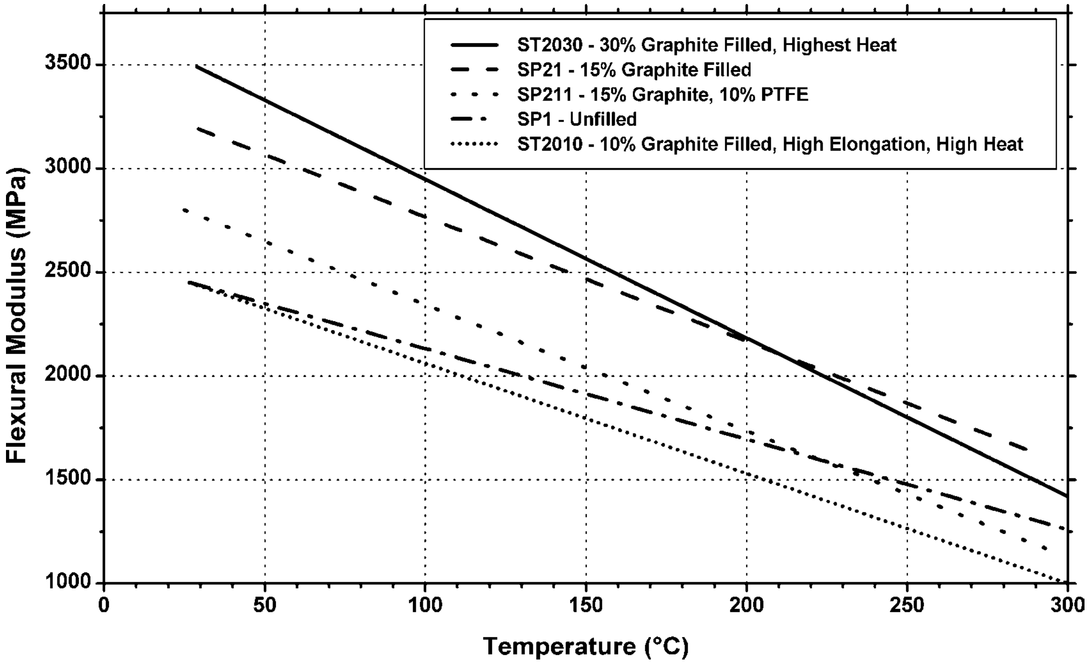


Figure 5.45. Flexural modulus vs. temperature for DuPont Vespel® direct-formed PI.

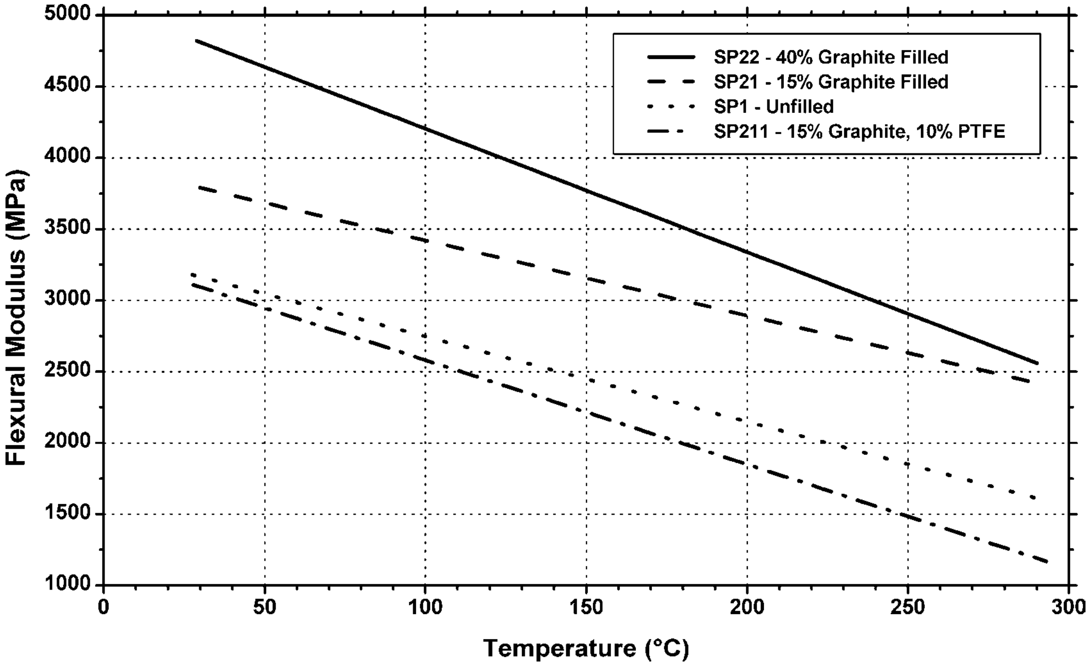


Figure 5.46. Flexural modulus vs. temperature for DuPont Vespel® machined PI.

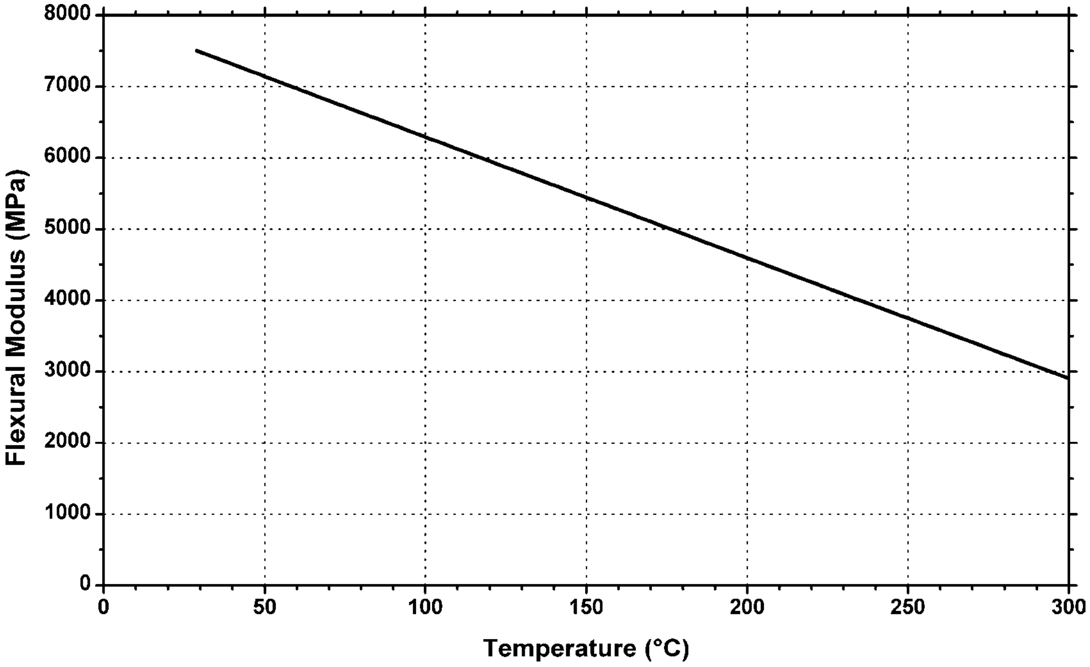


Figure 5.47. Flexural modulus vs. temperature Ube Industries Upitol® SA 101 PI.

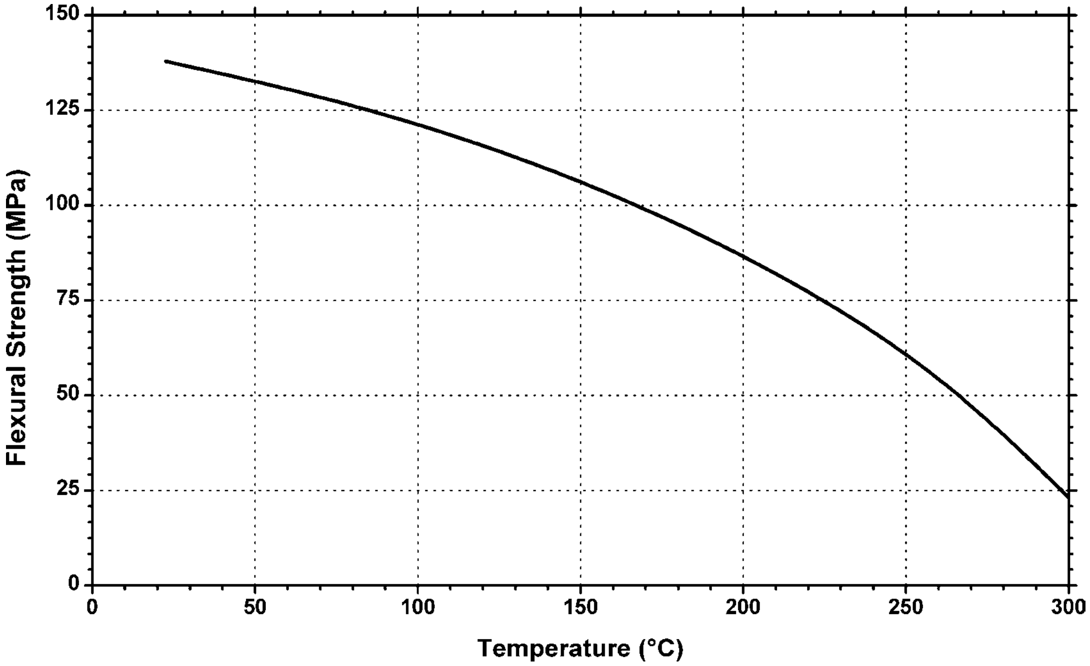


Figure 5.48. Flexural strength vs. temperature Ube Industries Upitol® SA 101 PI.

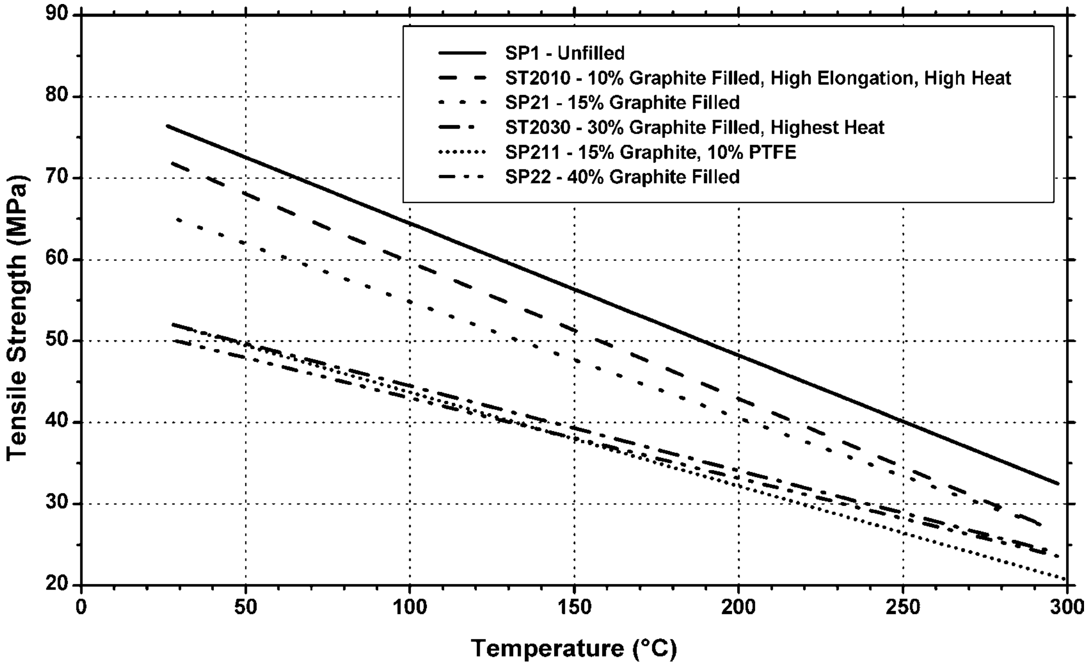


Figure 5.49. Tensile strength vs. temperature for DuPont Vespel® direct-formed PI.

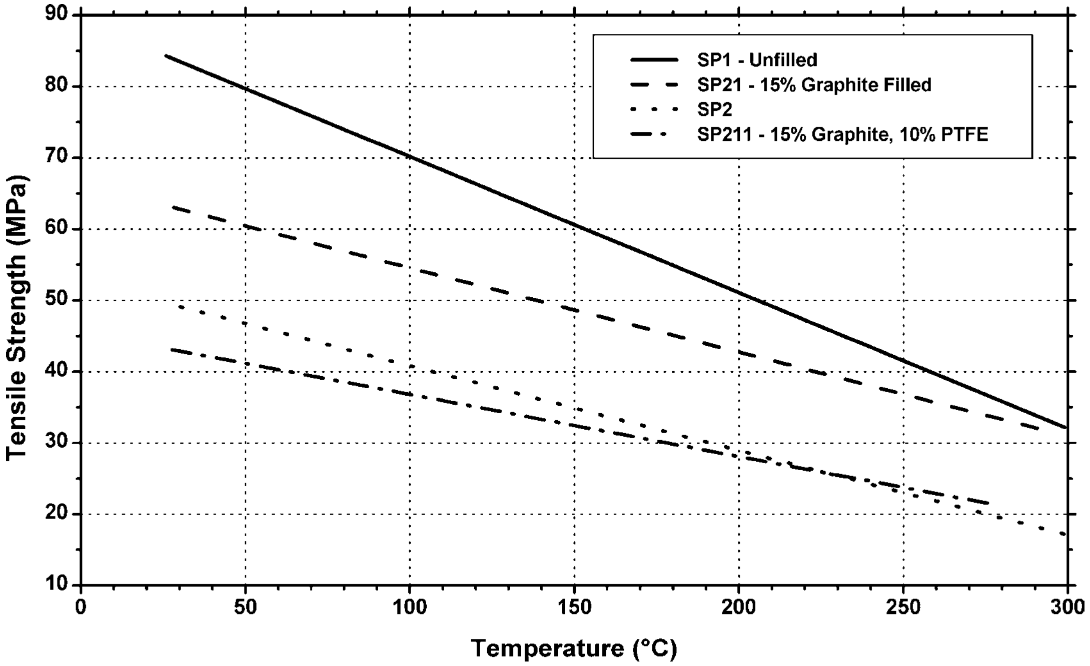


Figure 5.50. Tensile strength vs. temperature for DuPont Vespel® machined PI.

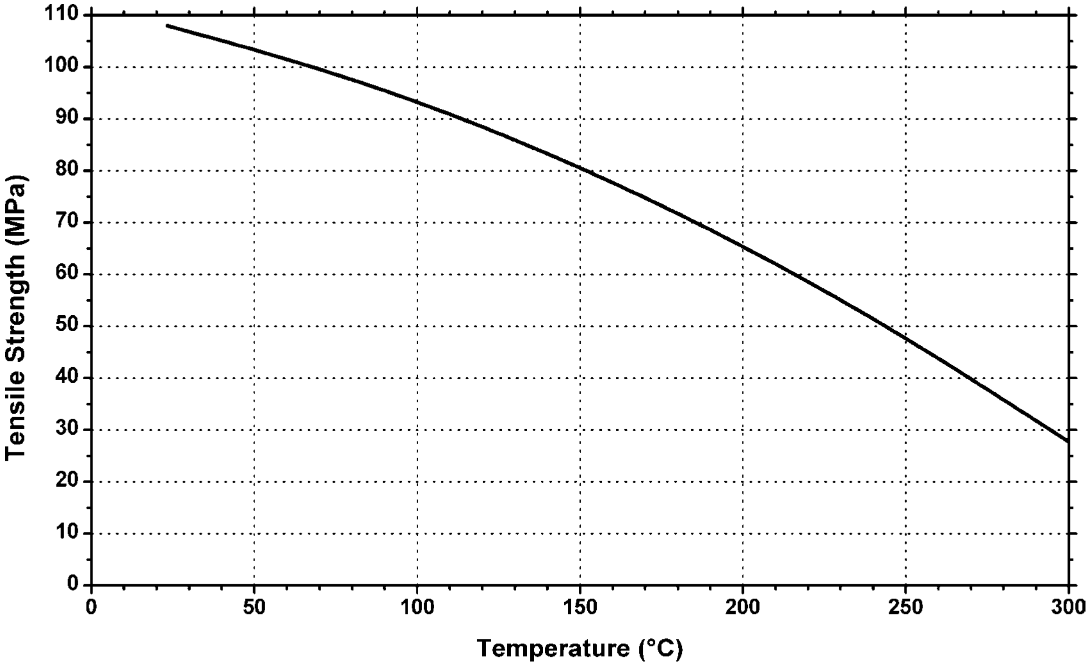


Figure 5.51. Tensile strength vs. temperature Ube Industries Upitol® SA 101 PI.

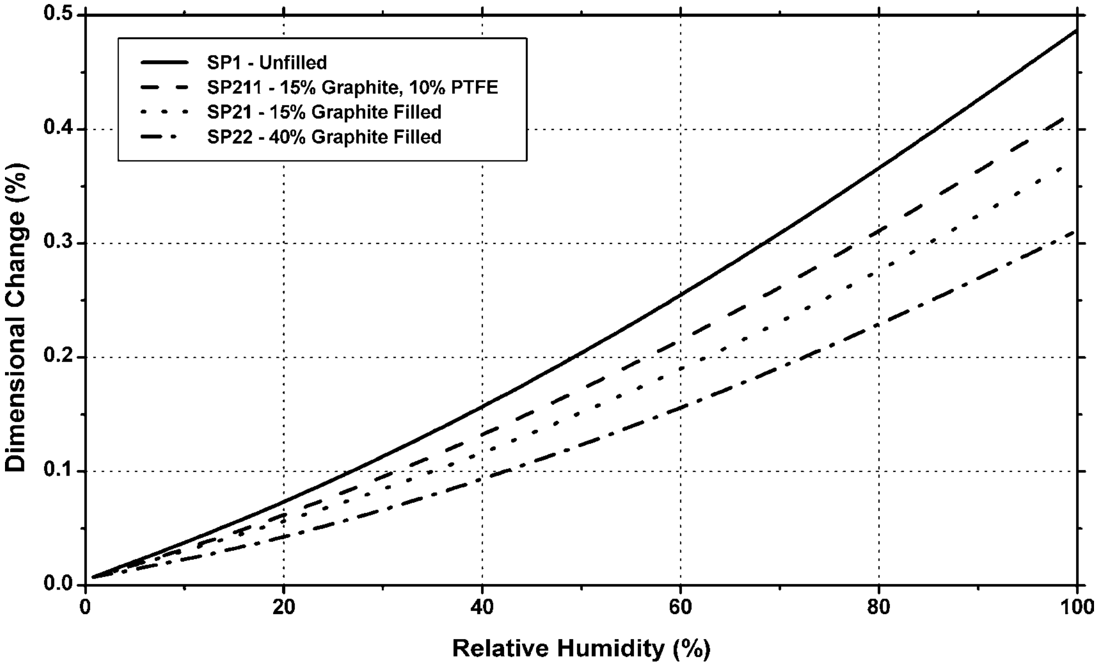


Figure 5.52. Dimension change vs. relative humidity at 23°C for DuPont Vespel® direct-formed PI.

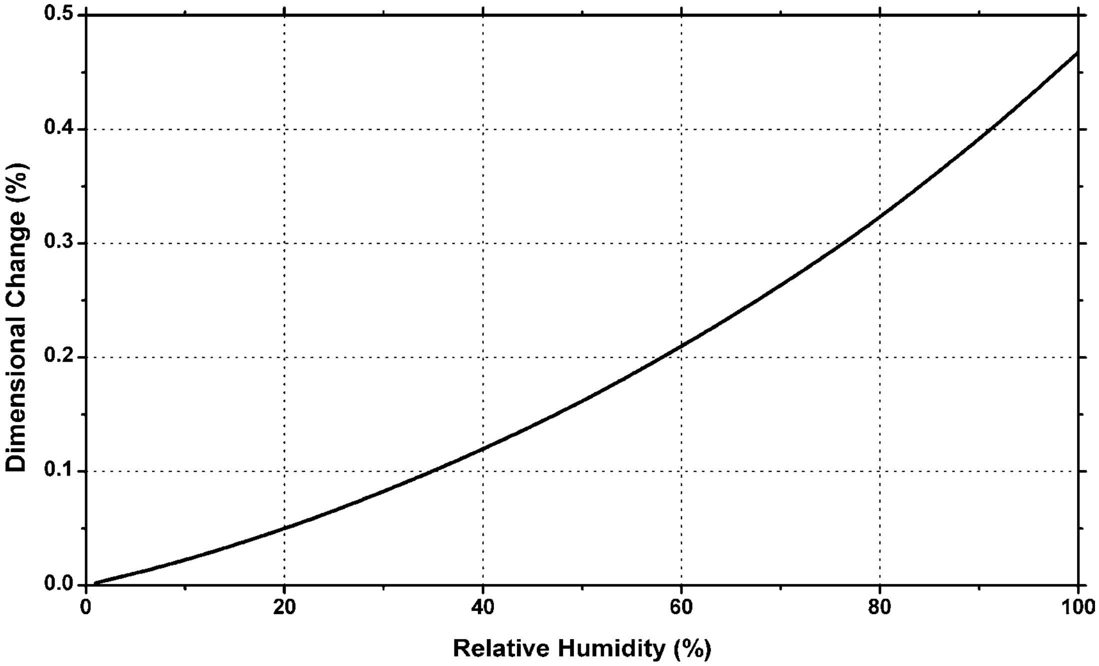


Figure 5.53. Dimension change vs. relative humidity at 23°C for DuPont Vespel® machined PI.

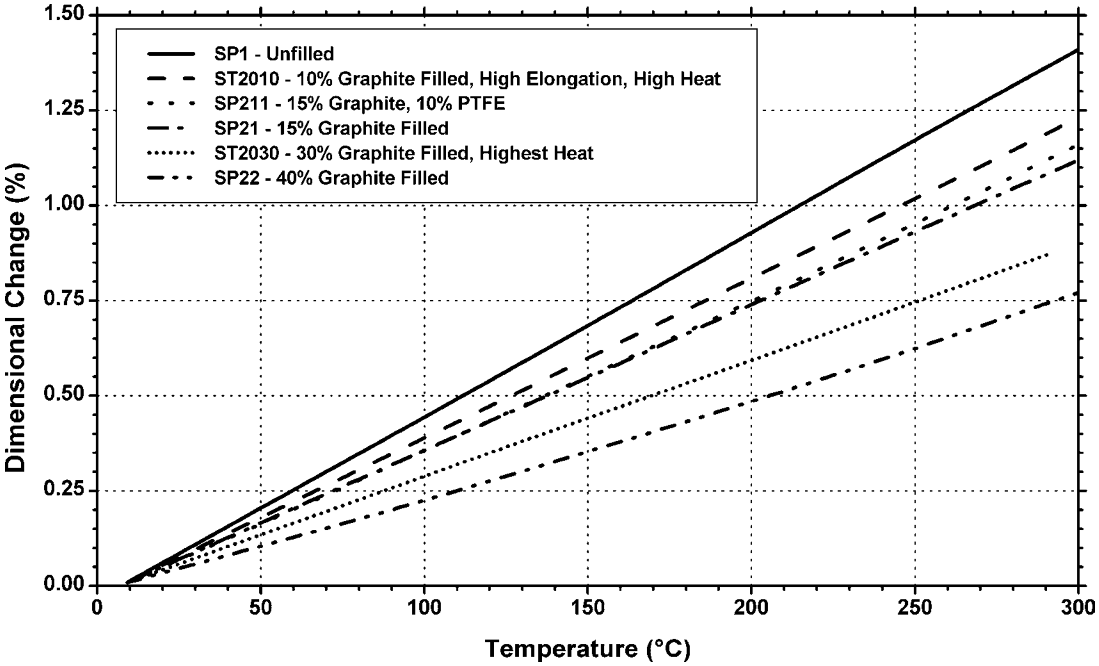


Figure 5.54. Dimension change vs. temperature perpendicular to forming for DuPont Vespel® direct-formed PI.

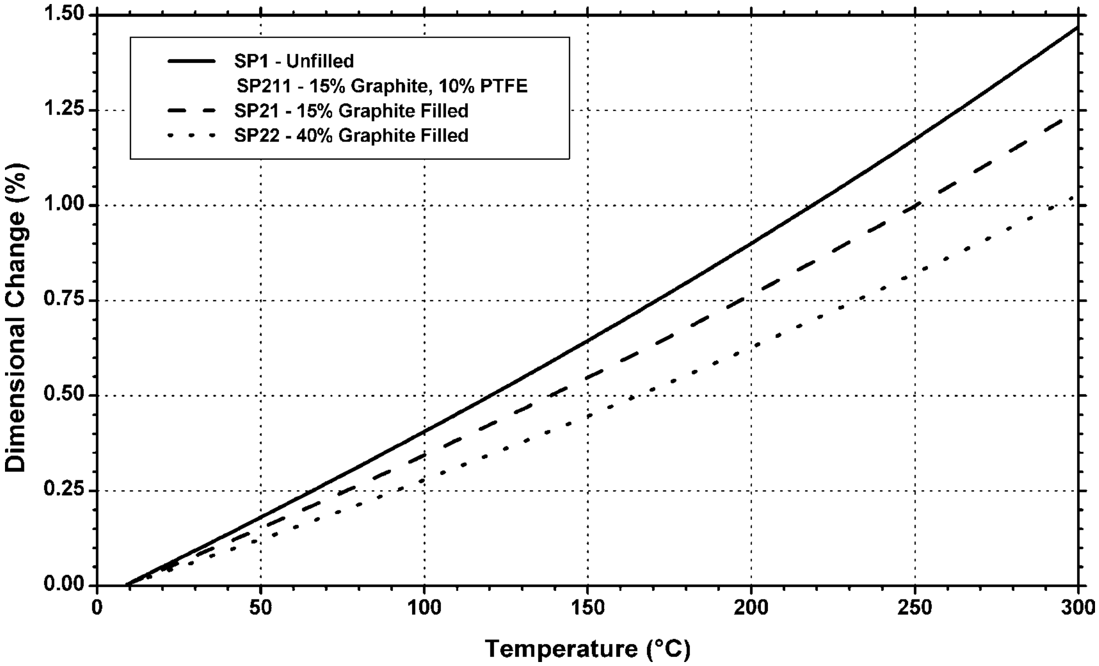


Figure 5.55. Dimension change vs. temperature for DuPont Vespel® machined PI.

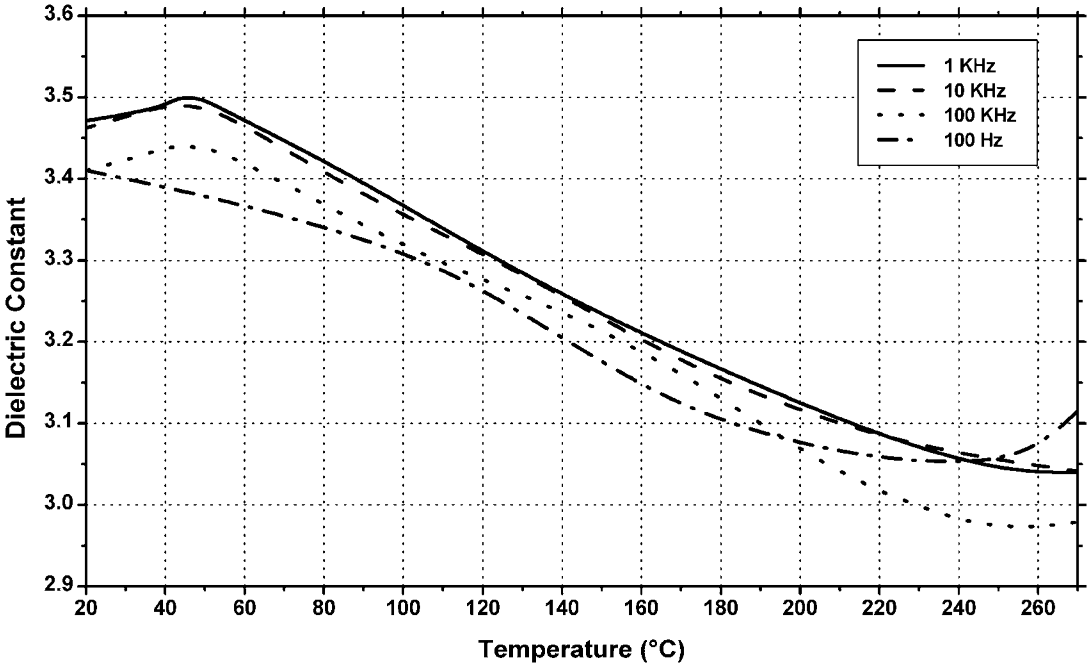


Figure 5.56. Dielectric constant vs. temperature for DuPont Vespel® SP1 PI.

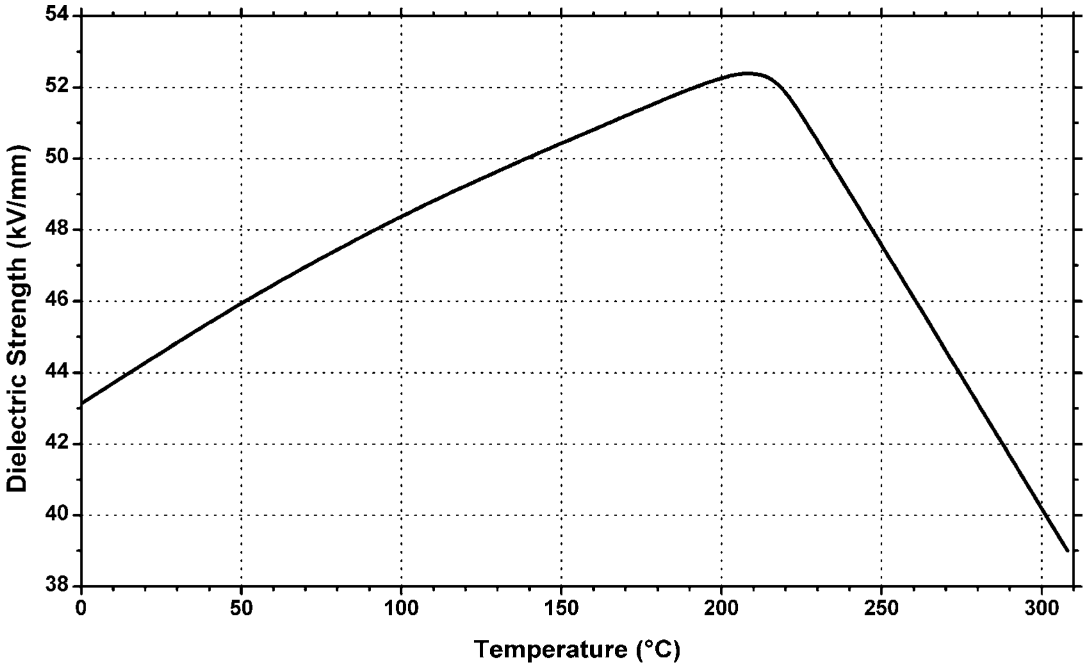


Figure 5.57. Dielectric strength vs. temperature for DuPont Vespel® SP1 PI.

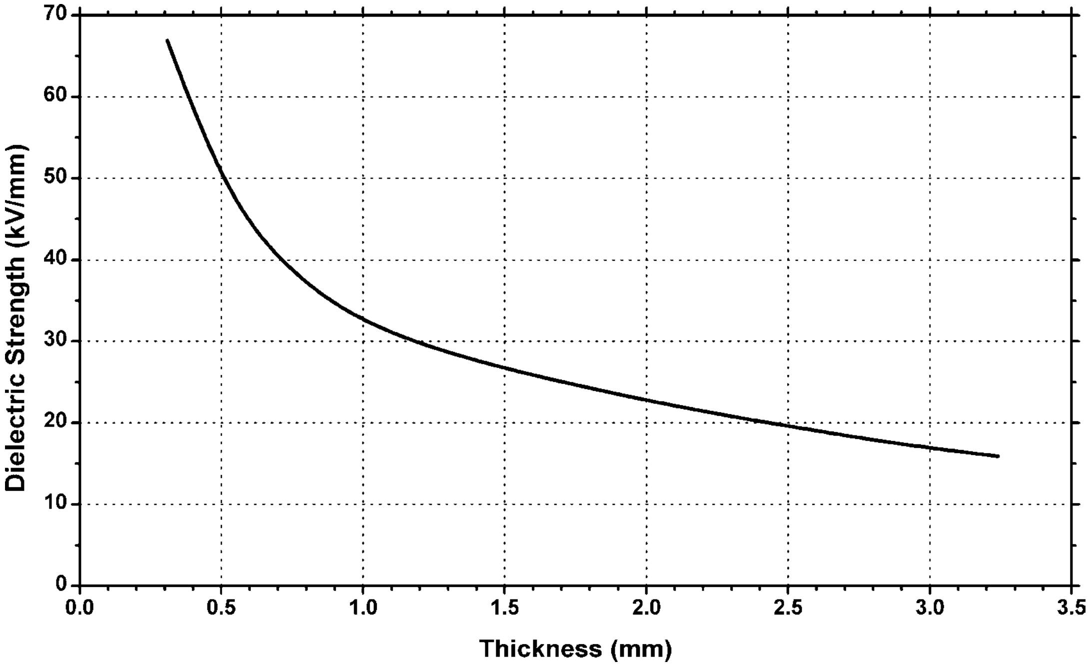


Figure 5.58. Dielectric strength vs. thickness for DuPont Vespel® SP1 PI.

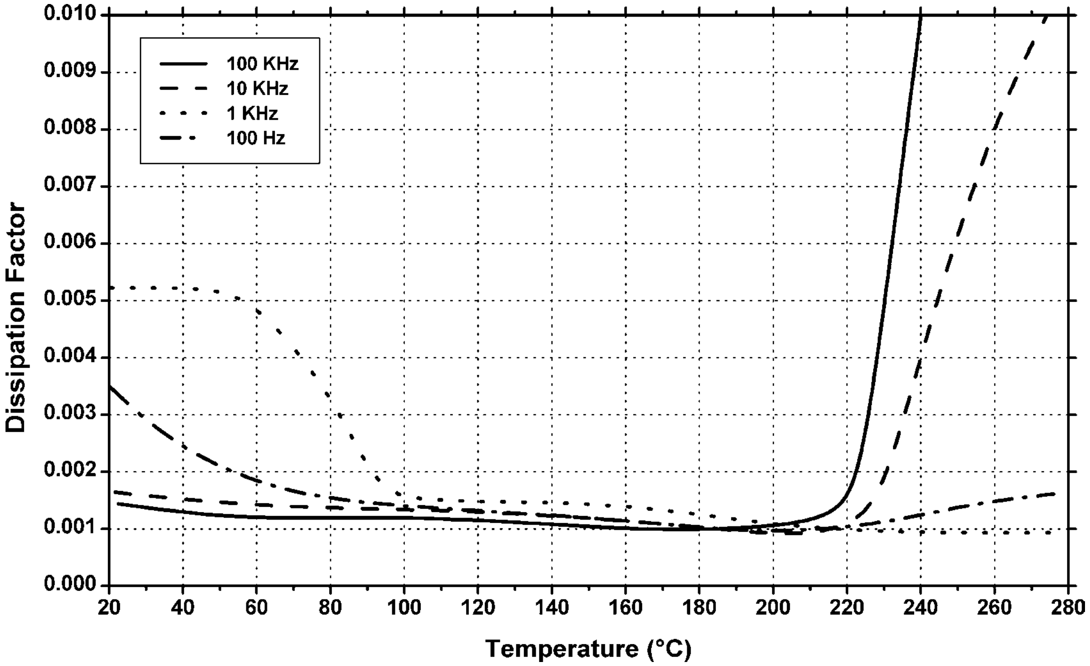


Figure 5.59. Dissipation factor vs. temperature and frequency for DuPont Vespel® SP1 PI.

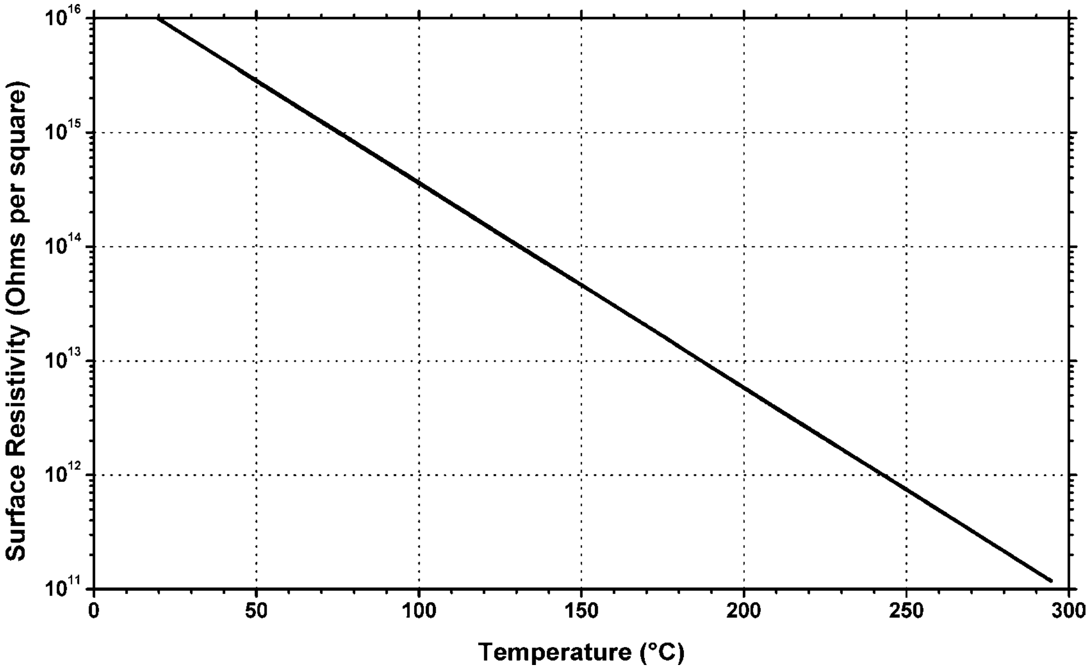


Figure 5.60. Surface resistivity vs. temperature for DuPont Vespel® SP1 PI.

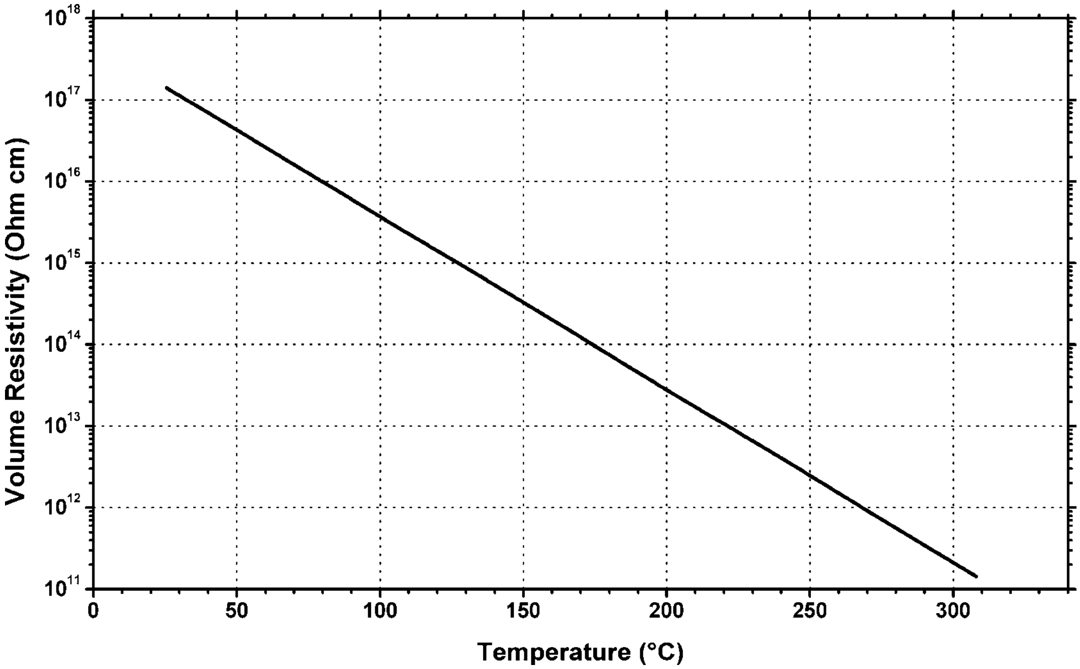


Figure 5.61. Volume resistivity vs. temperature for DuPont Vespel® SP1 PI.

6 Polyamides (Nylons)

6.1 Background

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 Fig. 6.1.

The –COOH acid group reacts with the $–NH_2$ amine group to form the 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' = 6 carbon alkane and R = 4 carbon alkane, but one also has to include the two carboxyl carbons in the diacid to get the number it designates to the chain.

The structures of these diamine monomers are shown in Fig. 6.2, the diacid monomers are shown in Fig. 6.3. Figure 6.4 shows the aminoacid 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 their properties. Properties are often reported as DAM (dry as molded) or conditioned (usually at equilibrium in 50% Relative Humidity 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 terephthalic acid
Polyphthalamide	Any diamine and isophthalic acid and/or terephthalic Acid

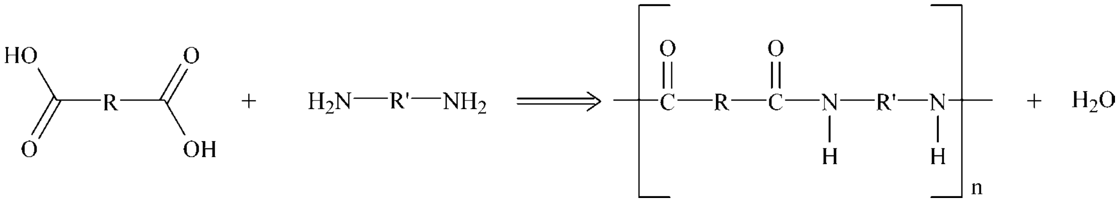
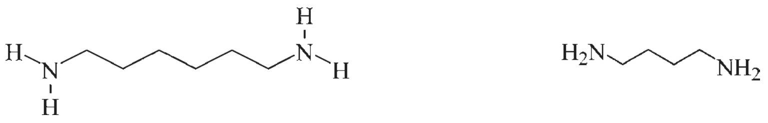


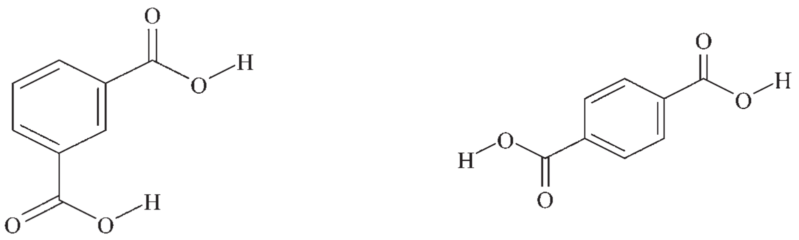
Figure 6.1. Generalized polyamide reaction.



1,6-hexamethylene diamine

1,4-diaminobutane

Figure 6.2. Chemical structures of diamines used to make polyamides.

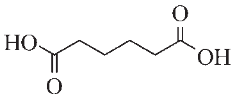


Isophthalic Acid

Terephthalic Acid

1,12-Dodecanediotic Acid

Sebacic Acid

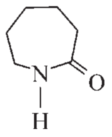


Adipic Acid

Figure 6.3. Chemical structures of diacids used to make polyamides.

Aminoundecanoic Acid

Aminolauric Acid



Caprolactam

Figure 6.4. Chemical structures of aminoacids used to make polyamides.

6.1.1 Nylon 6

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 6 carbon atoms, the nylon that is produces is called nylon 6, which is nearly the same as nylon 66 described in Section 6.1.4. The structure of nylon 6 is shown in Fig. 6.5 below with the repeating unit in the brackets.

Some of the nylon 6 characteristics include:

- Outstanding balance of mechanical properties.
- Outstanding toughness in equiliblium moisture content.
- Outstanding chemical resistance and oil resistance.
- Outstanding wear and abrasion resistance.

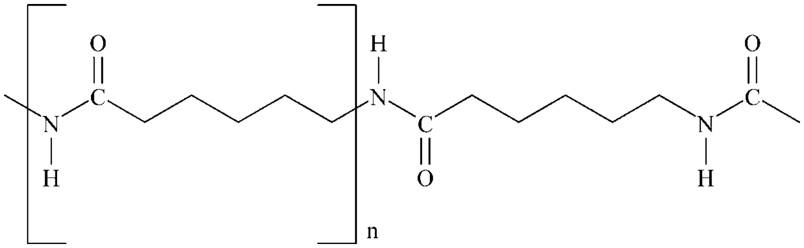


Figure 6.5. Chemical structure of nylon 6.

- Almost all grades are self-extinguishing. The flame-resistant grades are rated UL 94VO.
- Outstanding long-term heat-resistance (at a long-term continuous maximum temperature ranging between 80 and 150°C).
- Grades reinforced with glass-fiber and other materials offer superior elastic modulus and strength.
- 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.

6.1.2 Nylon 11

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 with itself to produce the polyamide containing eleven carbons between the nitrogen of the amide groups. Its structure is shown in Fig. 6.6.

Some of the nylon 11 characteristics are

- Low water absorption for a nylon (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 6/6
- Relatively low impact strength

6.1.3 Nylon 12

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 Fig. 6.7.

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.

Some of the Polyamide 12 characteristics are

- Lowest moisture absorption (~2%): Parts show largest dimensional stability under conditions of changing humidity
- 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

6.1.4 Nylon 66

The structure of nylon 66 is shown in Fig. 6.8.

Some of the nylon 66 characteristics are

- Outstanding balance of mechanical properties.

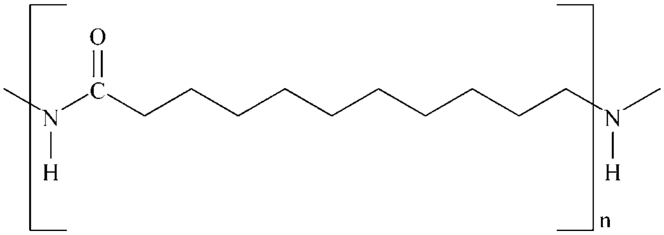


Figure 6.6. Chemical structure of nylon 11.

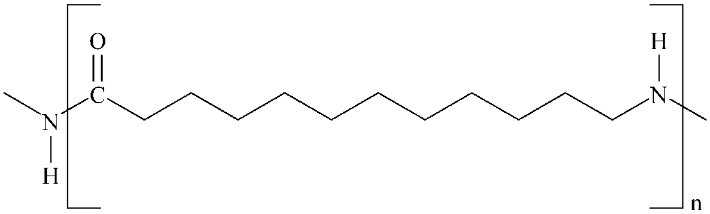


Figure 6.7. Chemical structure of nylon 12.

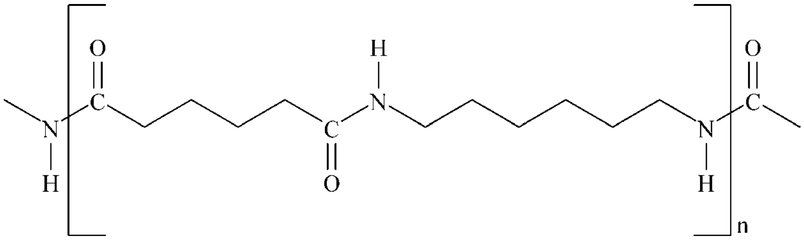


Figure 6.8. Chemical structure of nylon 66.

- 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.
- Offers low gasoline permeability and outstanding gas barrier properties.
- High water absorption.
- Poor chemical resistance to strong acids and bases.

6.1.5 Nylon 610

The structure of nylon 610 is given in Fig. 6.9. Some of the nylon 610 characteristics are

- Outstanding suppleness and impact strength at low temperature
- Relatively low hygroscopic properties
- Outstanding flex fatigue properties

6.1.6 Nylon 612

The structure of nylon 612 is given in Fig. 6.10. Some of the nylon 612 characteristics are

- High-impact strength
- Very good resistance to greases, oils, fuels, hydraulic fluids, water, alkalis, and saline

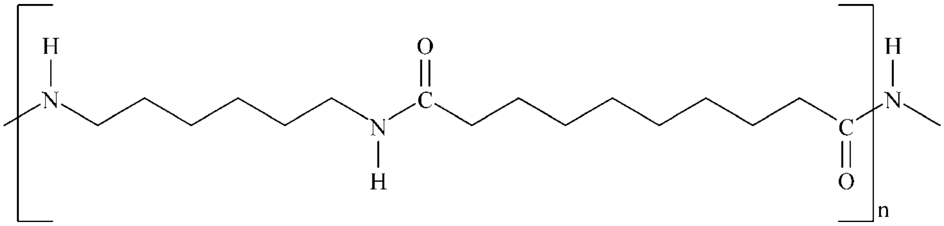


Figure 6.9. Chemical structure of nylon 610.

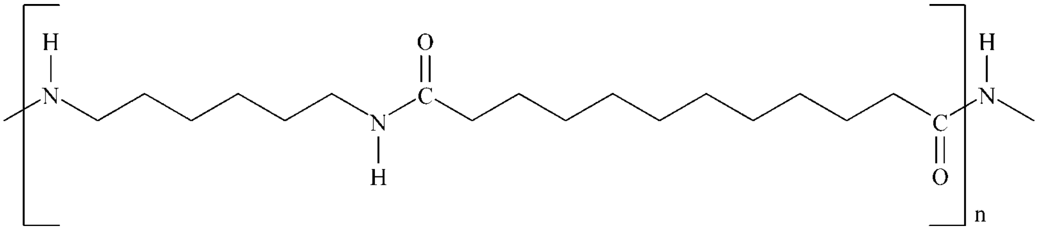


Figure 6.10. Chemical structure of nylon 612.

- 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
- Outstanding recovery at high wet strength

6.1.7 Nylon 666 or 66/6

This is the name given to copolyamides made from PA6 and PA66 building blocks. A precise structure cannot be drawn.

6.1.8 Amorphous Nylon

Amorphous nylon is designed to give no crystalinity to the polymer structure. One such amorphous nylon is shown in Fig. 6.11.

The tertiary butyl group attached to the amine molecule is bulky and distrupts 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.

Some of the amorphous nylon characteristics are

- 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

6.1.9 Nylon 46

The structure of nylon 46 is given in Fig. 6.12.
Some of the nylon 46 characteristics are

- Higher heat distortion temperature than nylon 6 or nylon 6/6
- Higher crystallinity than nylon 6 or nylon 6/6
- Better chemical resistance, particularly to acidic salts
- Similar moisture absorption to nylon 6/6, but dimensional increase is less
- High processing temperature
- Highest mechanical properties at high temperatures

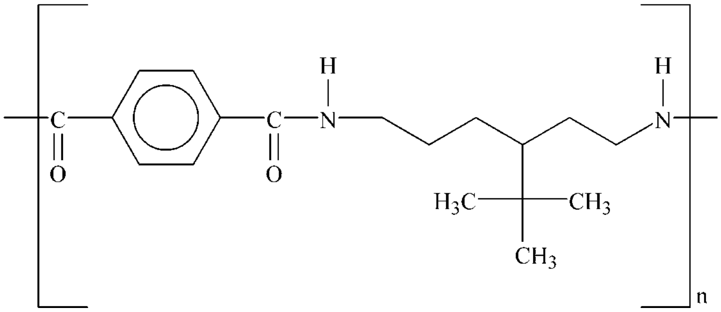


Figure 6.11. Chemical structure of amorphous nylon.

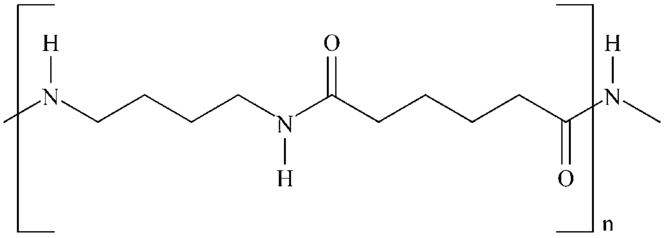


Figure 6.12. Chemical structure of nylon 46.

- Excellent resistance to wear and low friction
- Outstanding flow for easy processing

6.1.10 Polyphthalamide/ High-Performance Polyamide(PPA)

As a member of the nylon family, it is a semicrystalline material composed from a diacid and a diamine. However, the diacid portion contains at least 55% terephthalic acid (TPA) or isophthalic acid (IPA). TPA or IPA are aromatic components which serve to raise the melting point, 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 Fig. 6.13.

Some of the PPA characteristics are

- 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

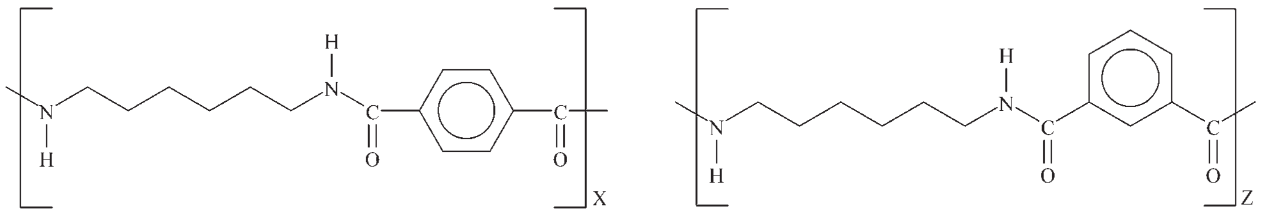
6.1.11 Polyarylamide (PAA)

Another partially aromatic high performance polyamide is polyarylamide (PAA). The primary commercial polymer, PAMXD6, is formed by the reaction of m-xylylenediamine and adipic acid giving the structure shown in Fig. 6.14. It is a semi-crystalline polymer.

Some of the PAA characteristics are

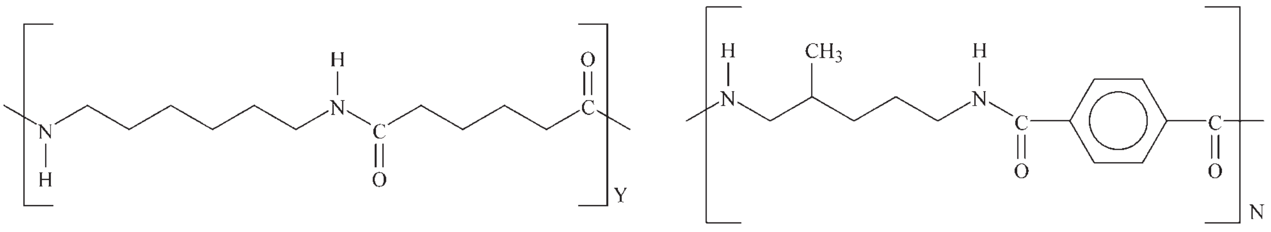
- Very high rigidity
- High strength
- Very low creep
- Excellent surface finish even for a reinforced product even with a high glass fiber content
- Ease of processing
- Good dimensional stability
- Slow rate of water absorption

Graphs of multipoint properties of polyamides as a function of temperature, moisture, and other factors are illustrated in Sections 6.2–6.13. Because the polyamides do absorb water, and that affects the properties, some of the data are dry, or better dry as molded. Some of the data are for conditioned specimen; they have reached equilibrium water absorption from 50% relative humidity at 23°C.



6T Segment

6I Segment



66 Segment

DT Segment

Figure 6.13. Chemical structures of block used to make PPA.

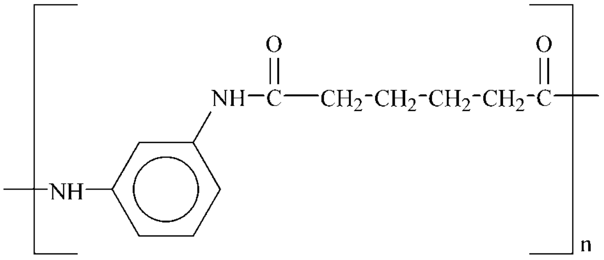


Figure 6.14. Chemical structure of PAMXD6 PAA.

6.2 Nylon 6 (PA6)

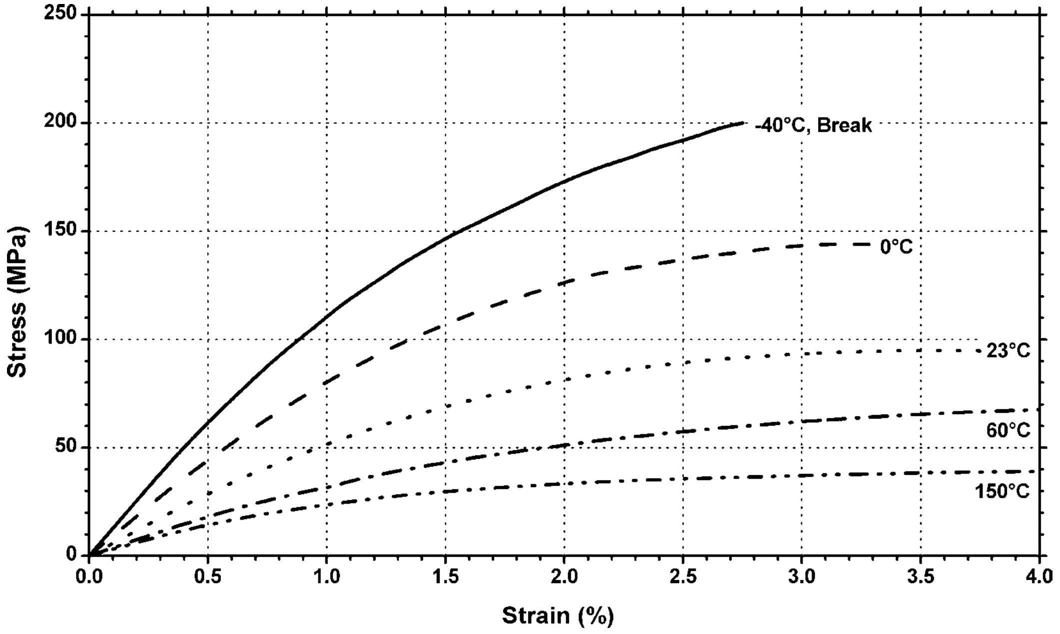


Figure 6.15. Stress vs. strain at various temperatures for BASF Ultramid® B3EG5—stabilized, 25% glass fiber reinforced PA6 resin (conditioned at 50% RH).

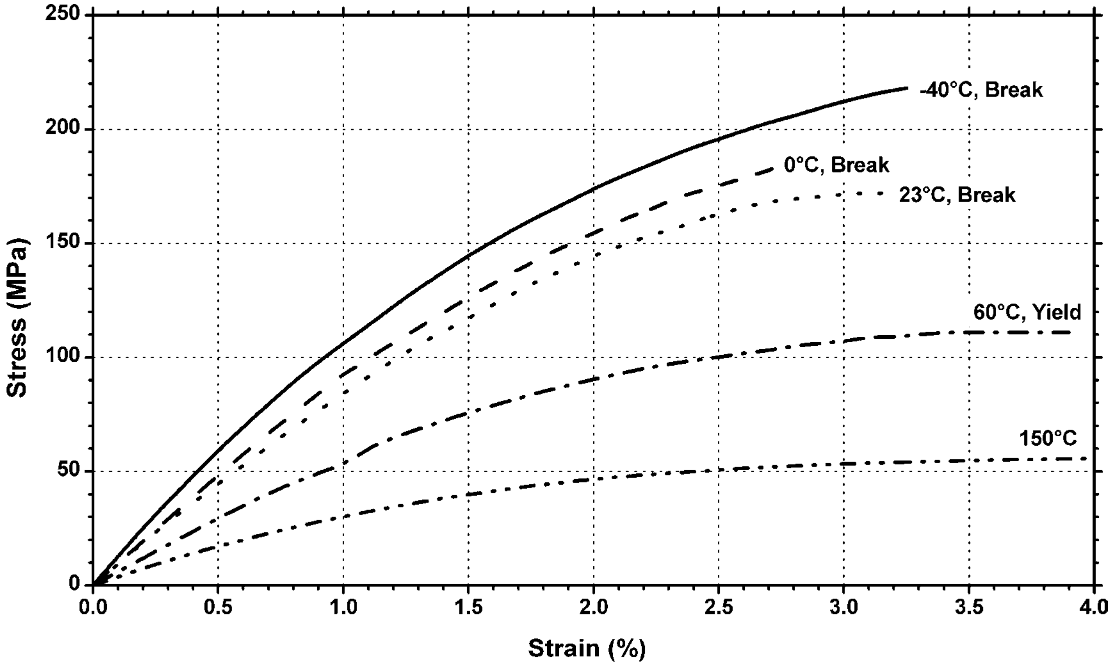


Figure 6.16. Stress vs. strain at various temperatures for BASF Ultramid® B3EG5—stabilized, 25% glass fiber reinforced PA6 resin (DAM).

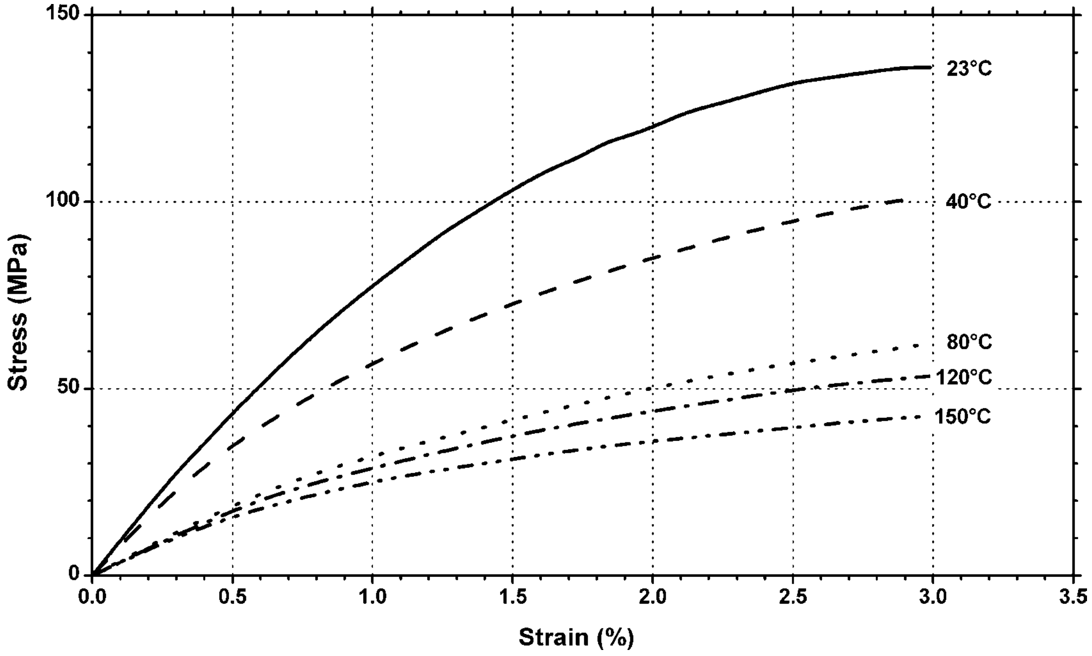


Figure 6.17. Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp® PF-1006—30% glass fiber reinforced PA6 resin (DAM).

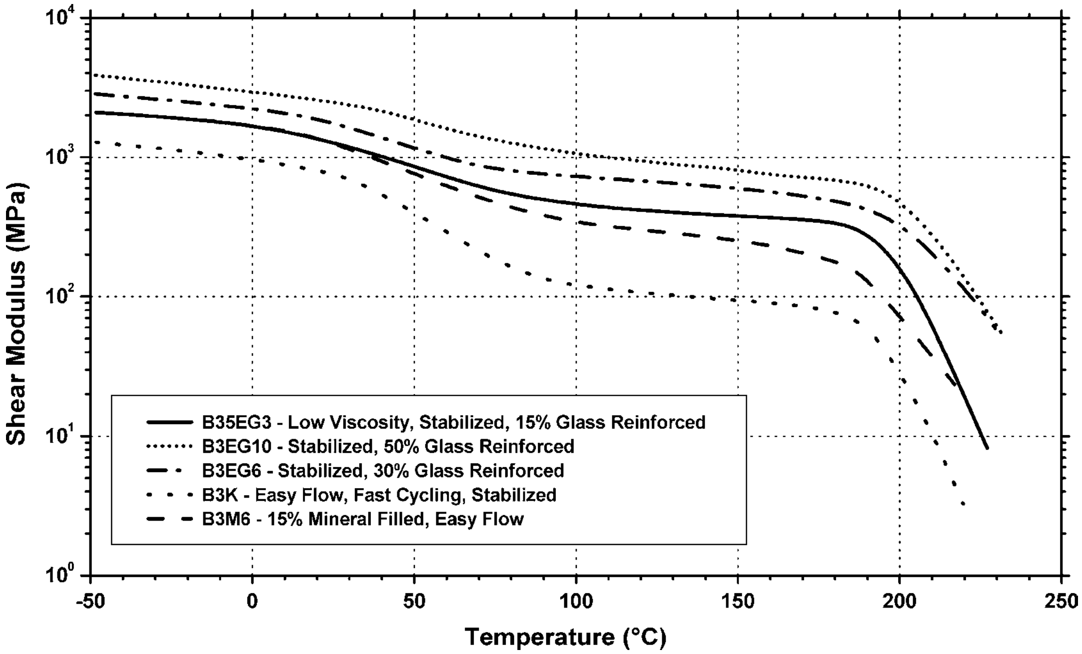


Figure 6.18. Shear modulus vs. temperature for several BASF Ultramid® PA6 Resins.

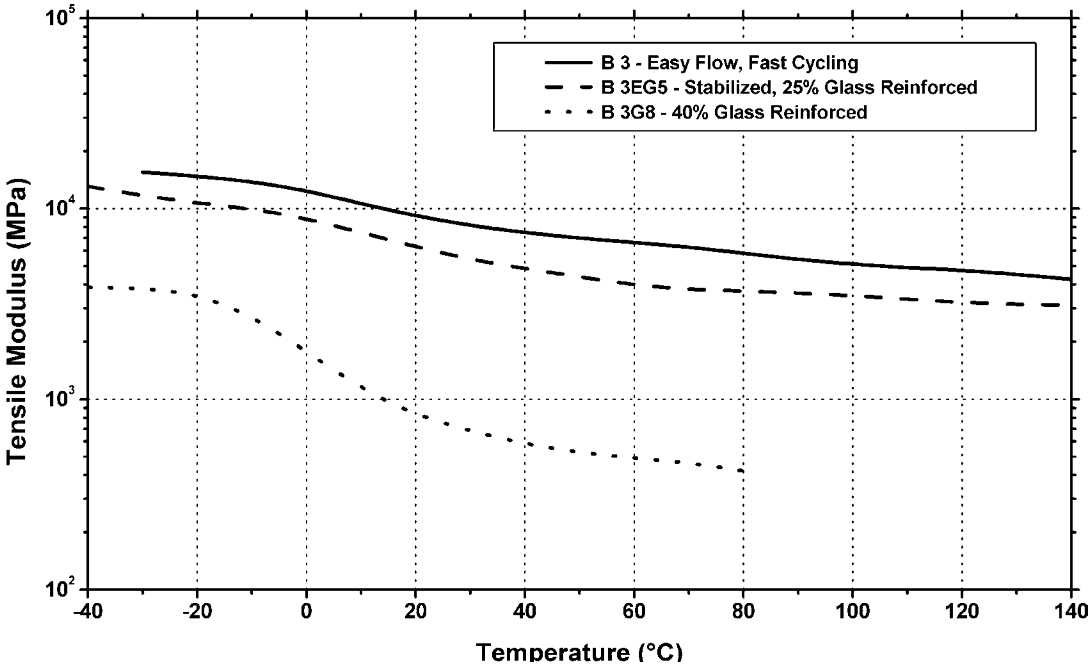


Figure 6.19. Tensile modulus vs. temperature for BASF PA6 resins conditioned at 50% relative humidity.

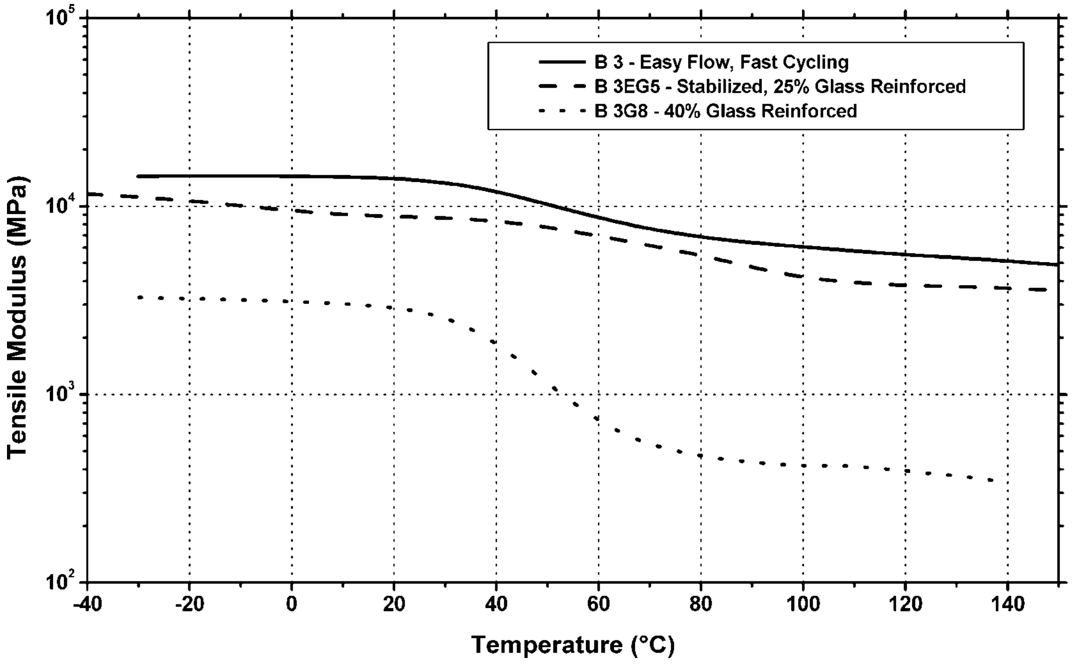


Figure 6.20. Tensile modulus vs. temperature for BASF PA6 resins (DAM).

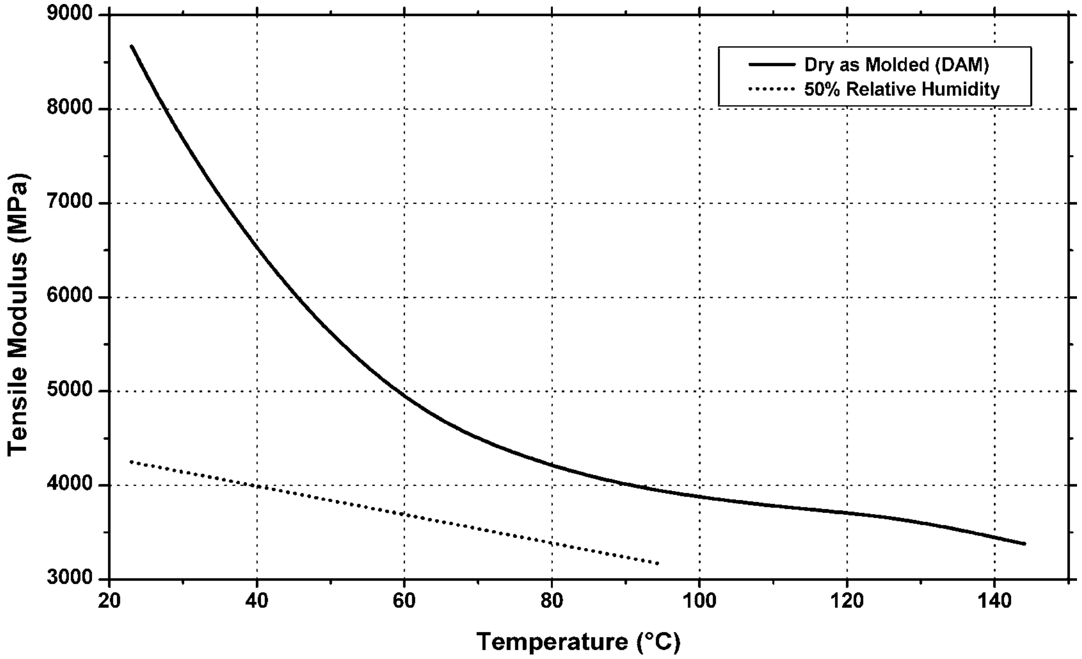


Figure 6.21. Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp® PF-1006—30% glass fiber reinforced PA6 resin.

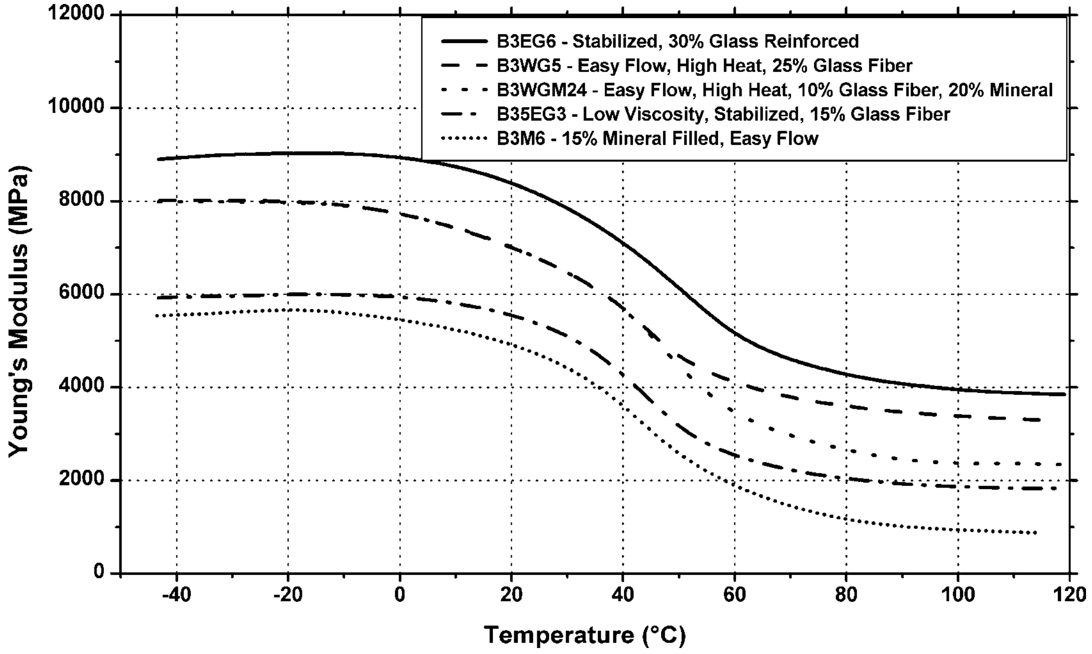


Figure 6.22. Young's modulus vs. temperature for BASF Ultramid® reinforced PA6 resins.

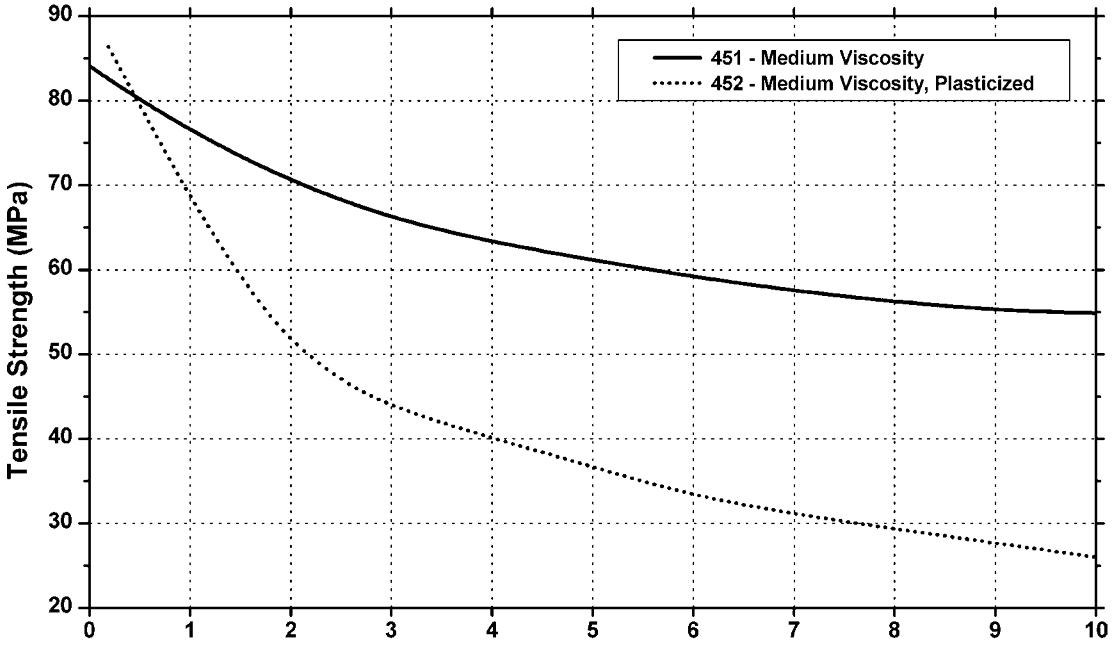


Figure 6.23. Tensile strength vs. moisture content for custom resins nylene® PA6 resins.

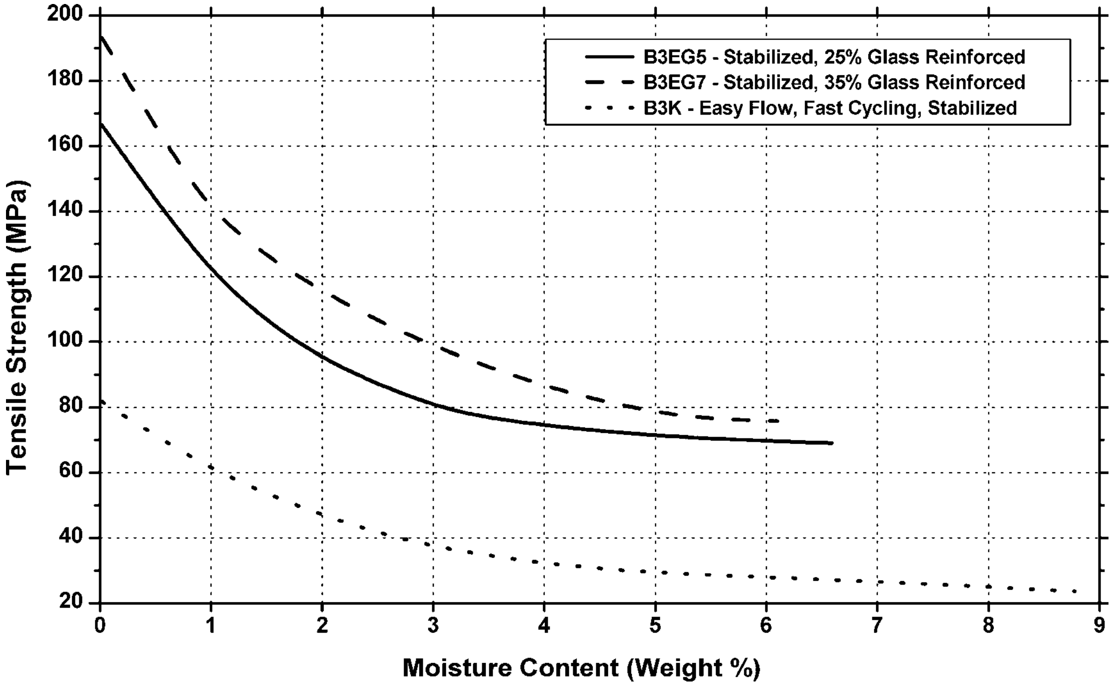


Figure 6.24. Tensile strength vs. moisture content for several BASF Ultramid® PA6 resins.

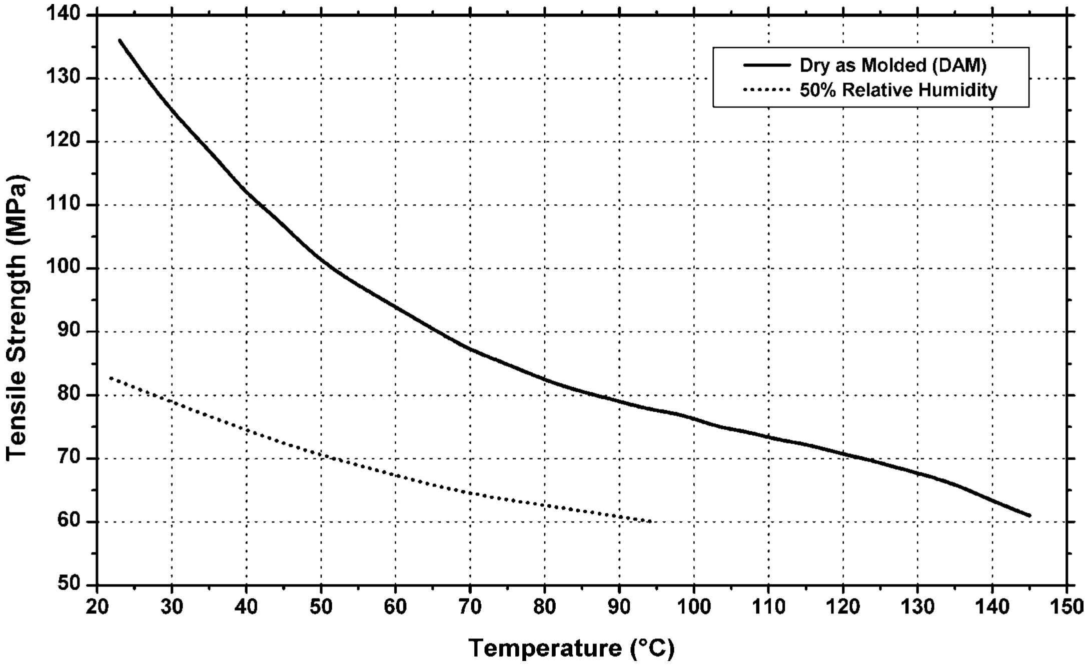


Figure 6.25. Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp® PF-1006—30% glass fiber reinforced PA6 resin.

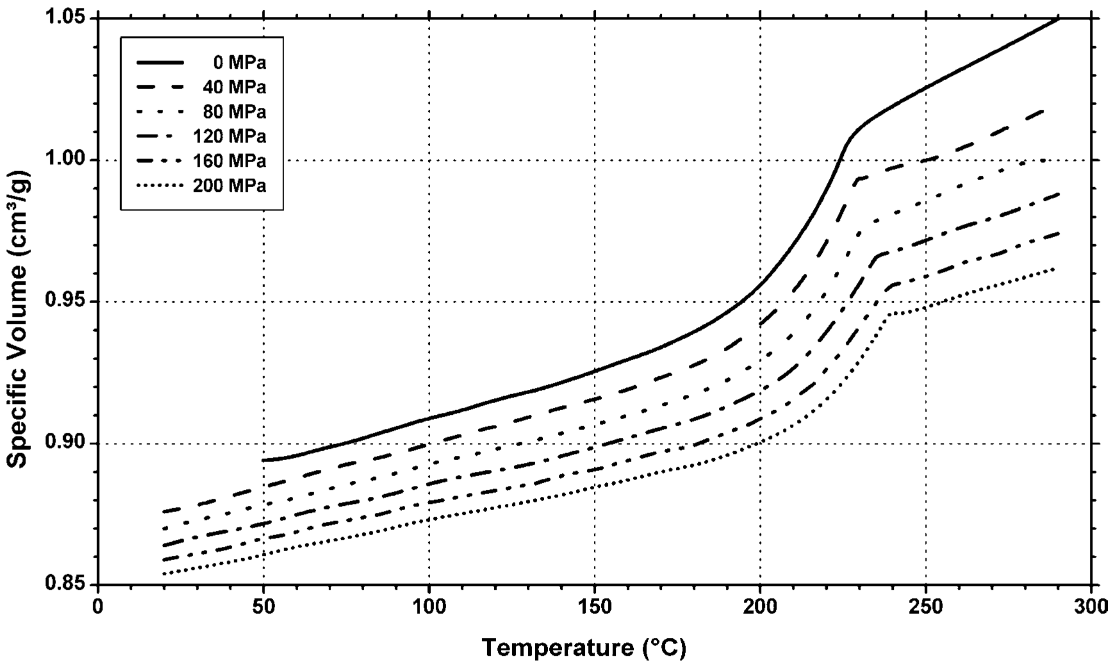


Figure 6.26. Pressure–specific volume-temperature (PVT) for BASF Ultramid® B3K easy flow, fast cycling PA6 resin.

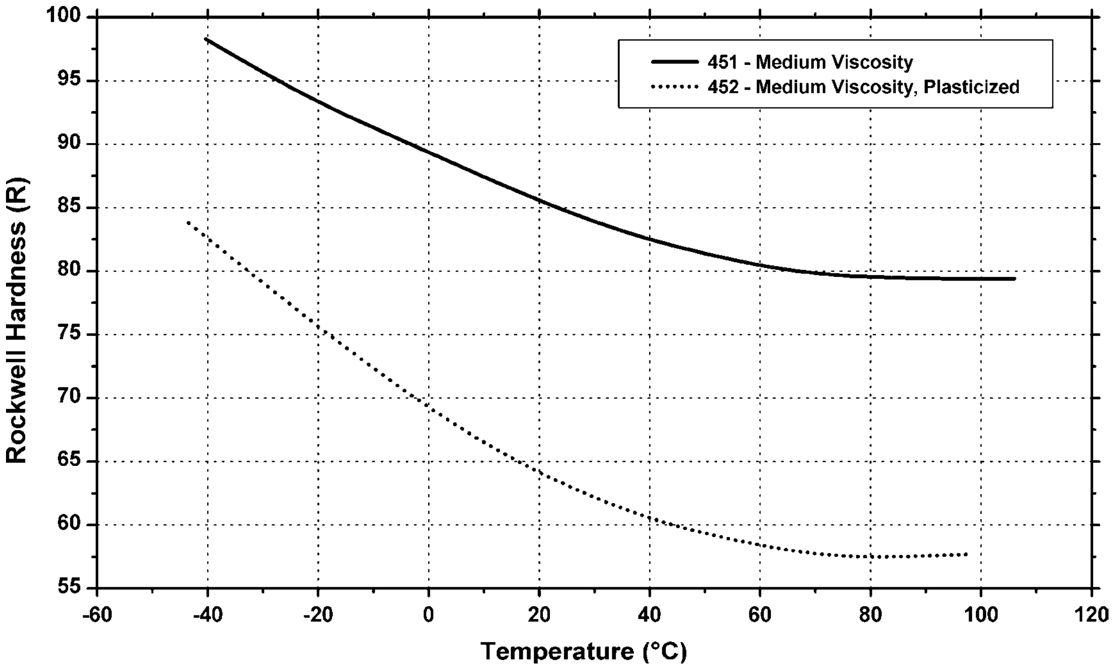


Figure 6.27. Rockwell hardness vs. temperature for custom resins nylene® PA6 resins.

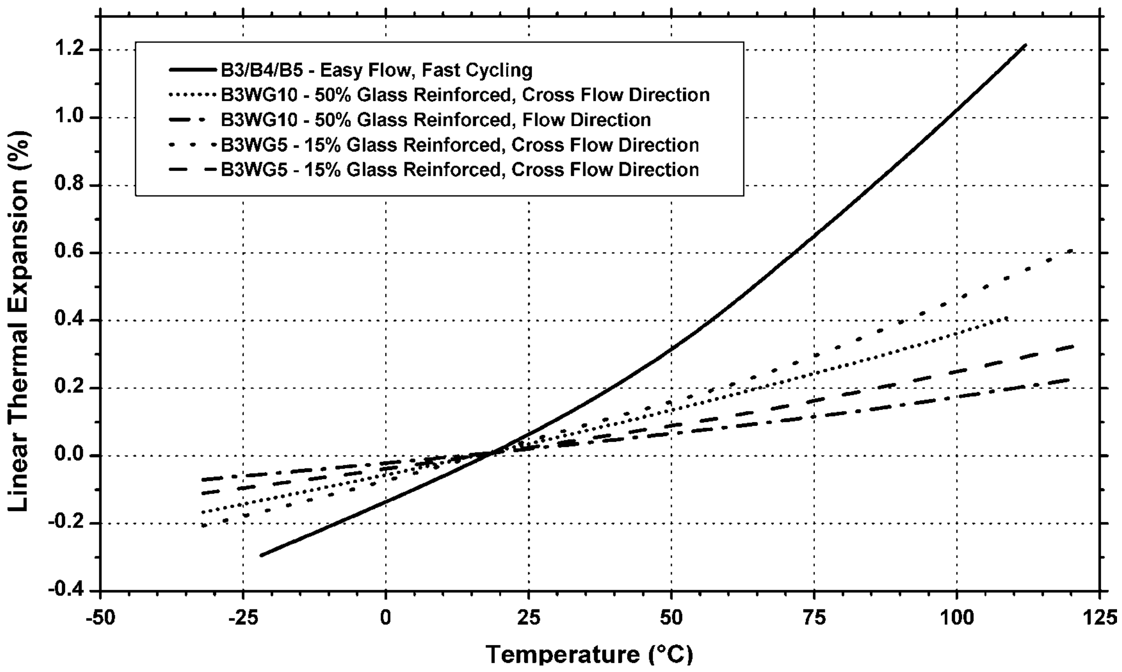


Figure 6.28. Linear thermal expansion vs. temperature for several BASF Ultramid® PA6 resins.

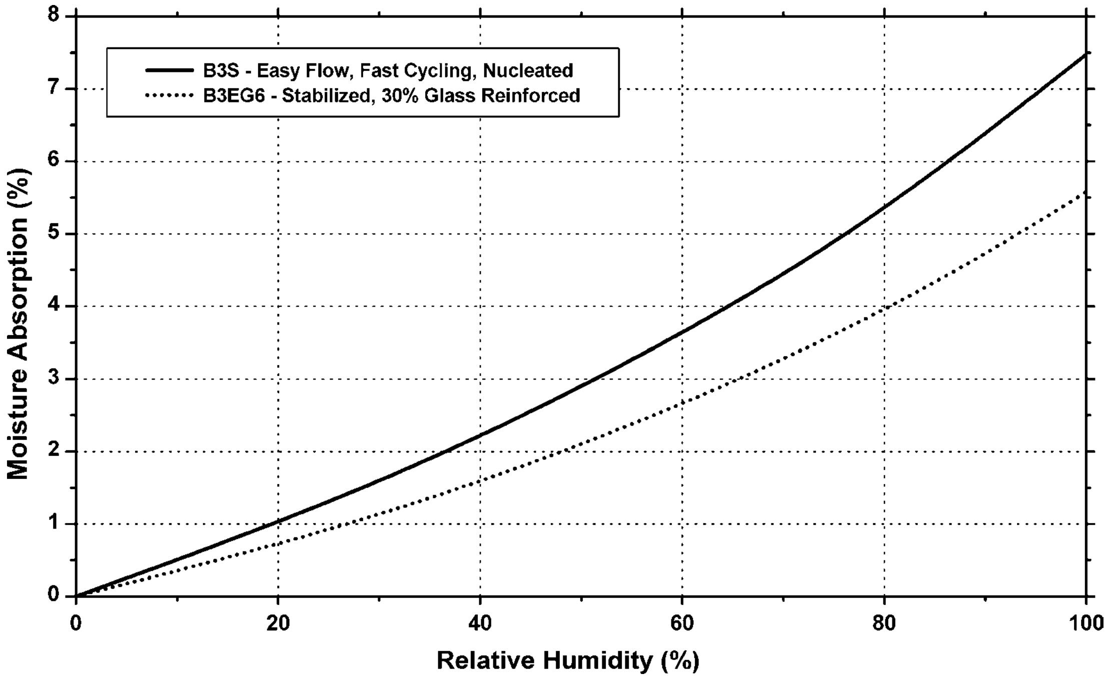


Figure 6.29. Water absorption vs. relative humidity for several BASF Ultramid® PA6 resins.

6.3 Nylon 11 (PA11)

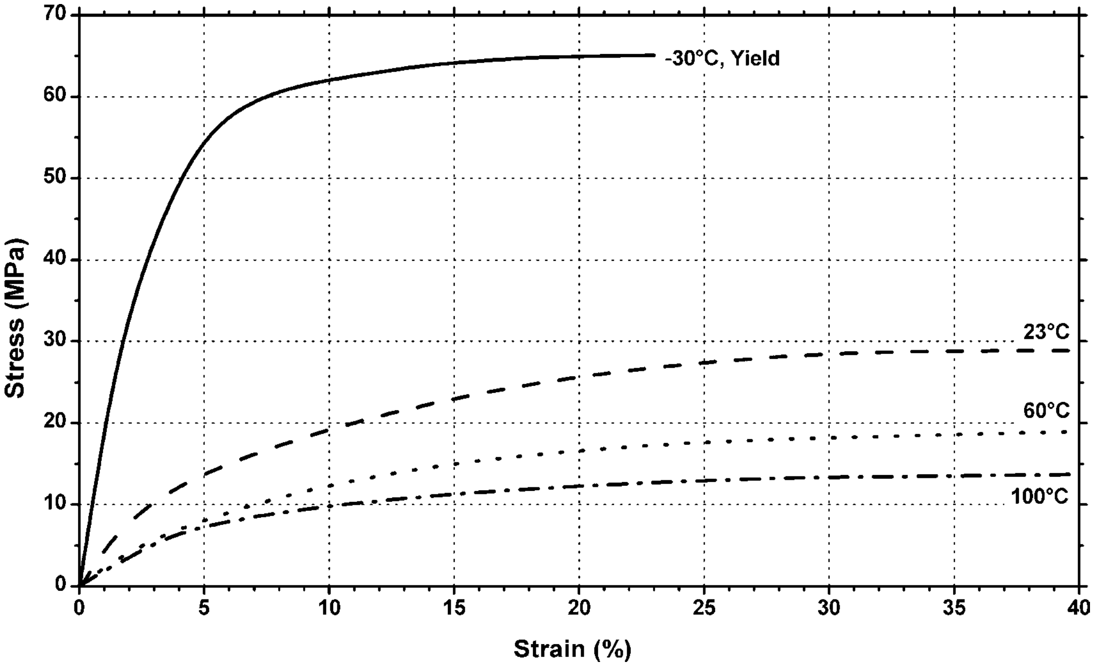


Figure 6.30. Stress vs. strain at temperatures for Arkema Rilsan® BMN P20—medium flexibility grade PA11 resin (conditioned at 50% RH).

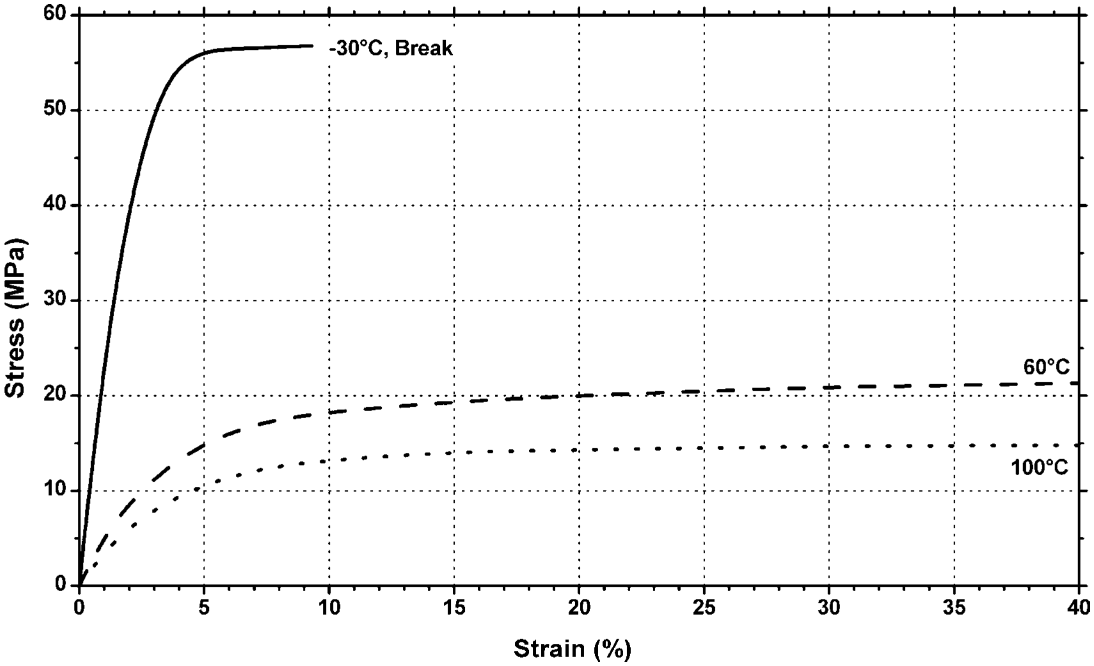


Figure 6.31. Stress vs. strain at various temperatures for Arkema Rilsan® BUM 30 O—rigid grade, 30% glass bead reinforced PA11 resin.

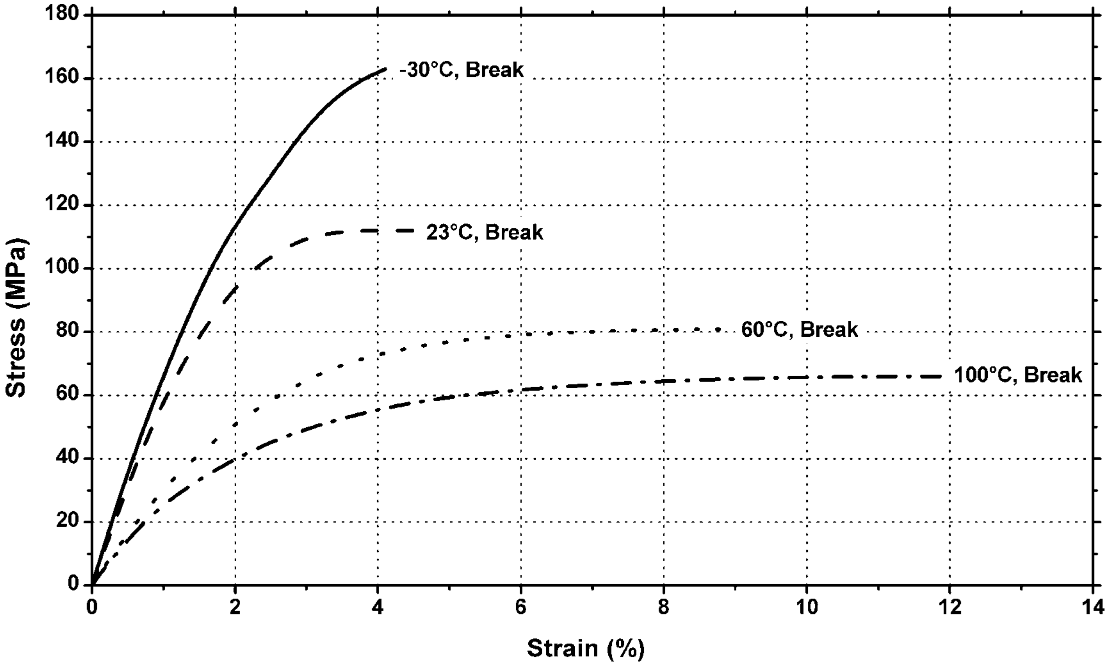


Figure 6.32. Stress vs. strain at various temperatures for Arkema Rilsan® BZM 23 G9—rigid grade, 23% glass and 9% graphite reinforced PA11 resin.

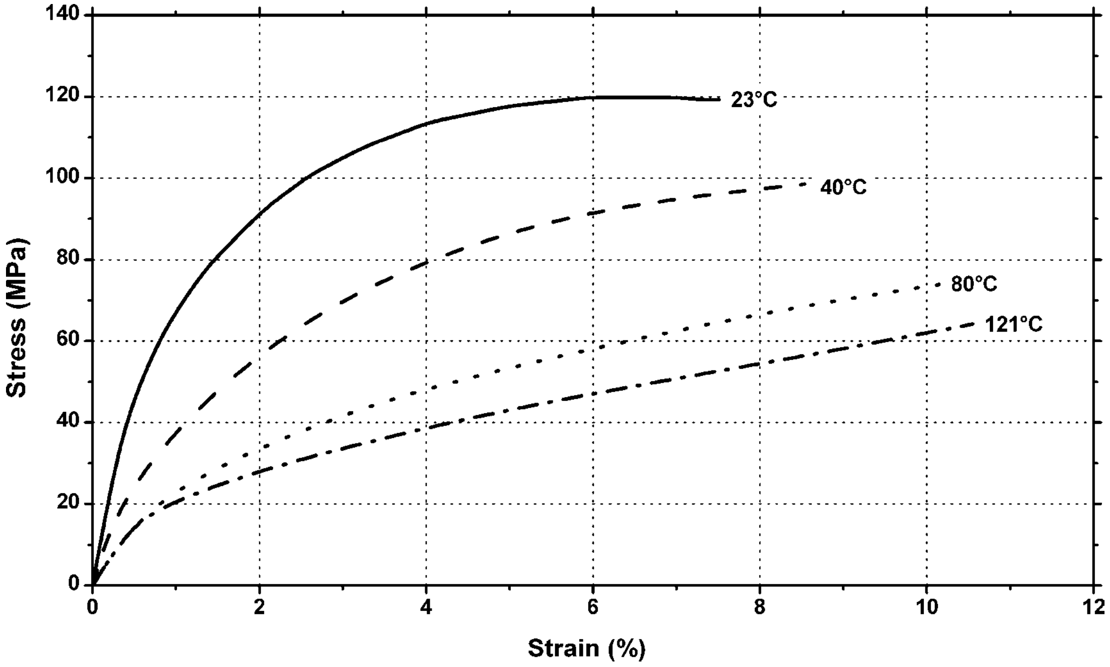


Figure 6.33. Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp® HF–1006—30% glass filled PA11 resin.

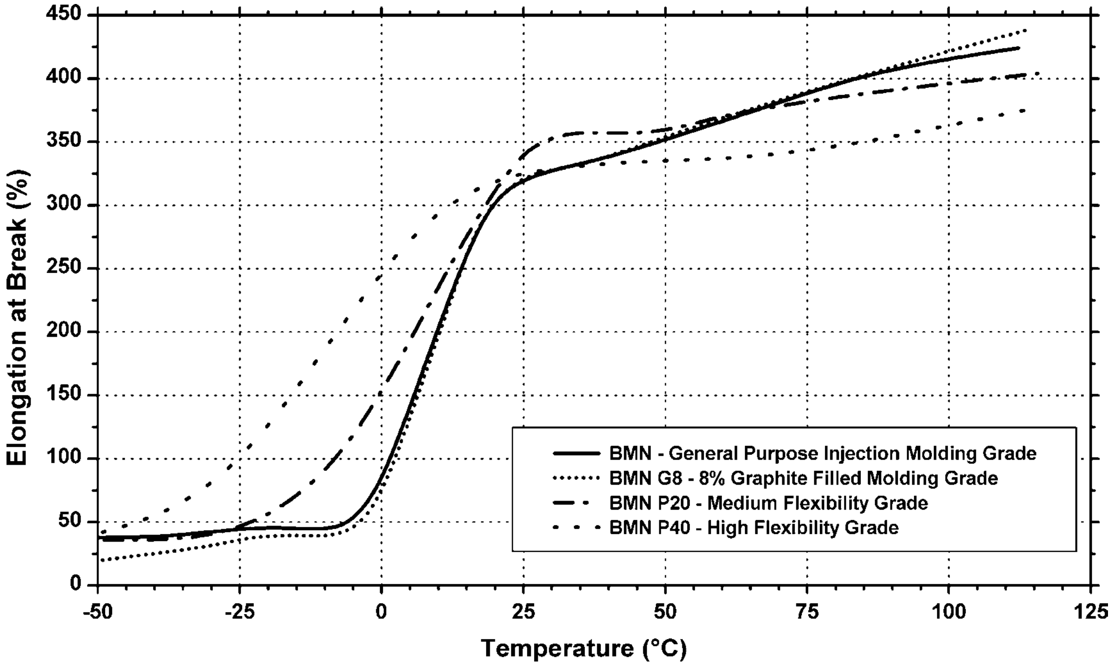


Figure 6.34. Elongation at break vs. temperature for several Arkema Rilsan® BMN PA11 resins.

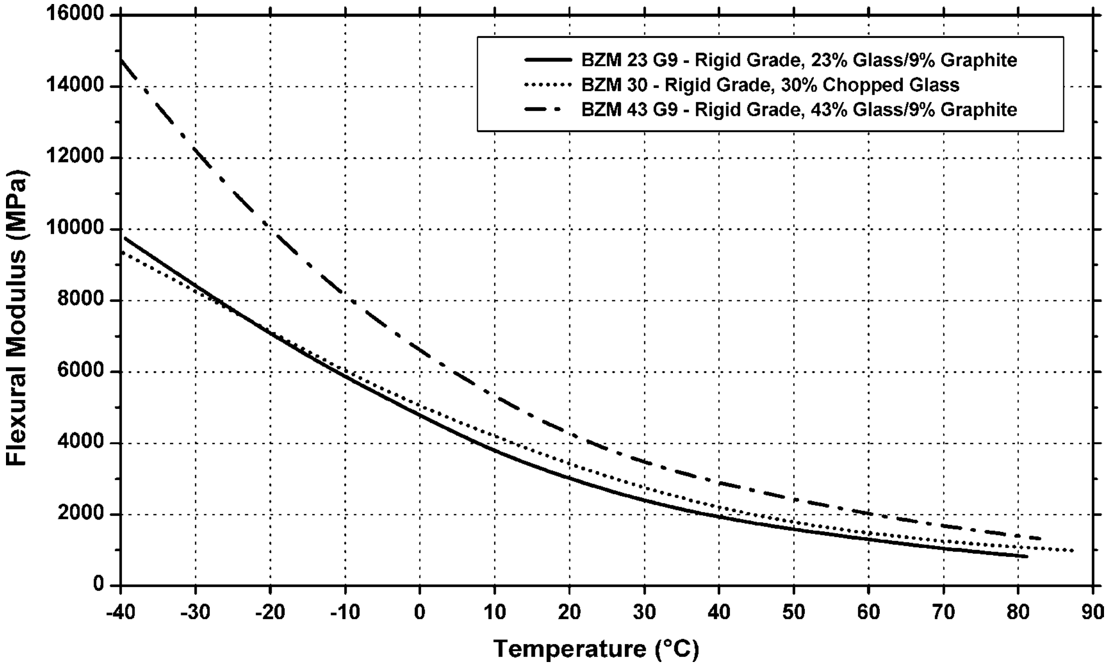


Figure 6.35. Flexural modulus vs. temperature for Arkema several rigid Rilsan® BMZ PA11 resins.

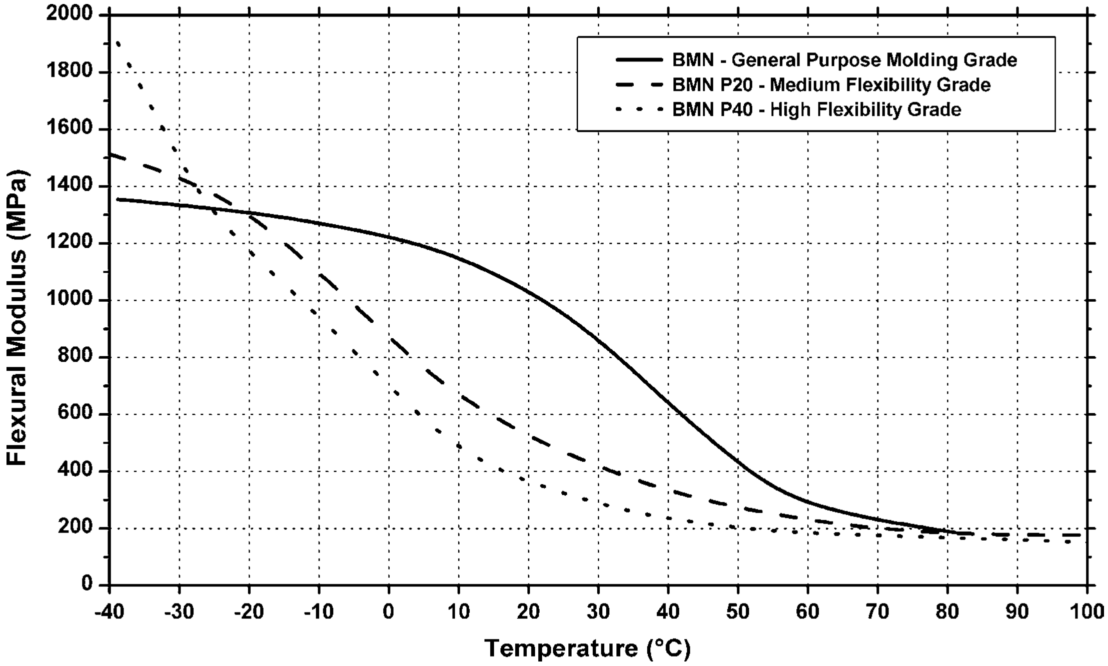


Figure 6.36. Flexural modulus vs. temperature for several Arkema Rilsan® BMN PA11 resins.

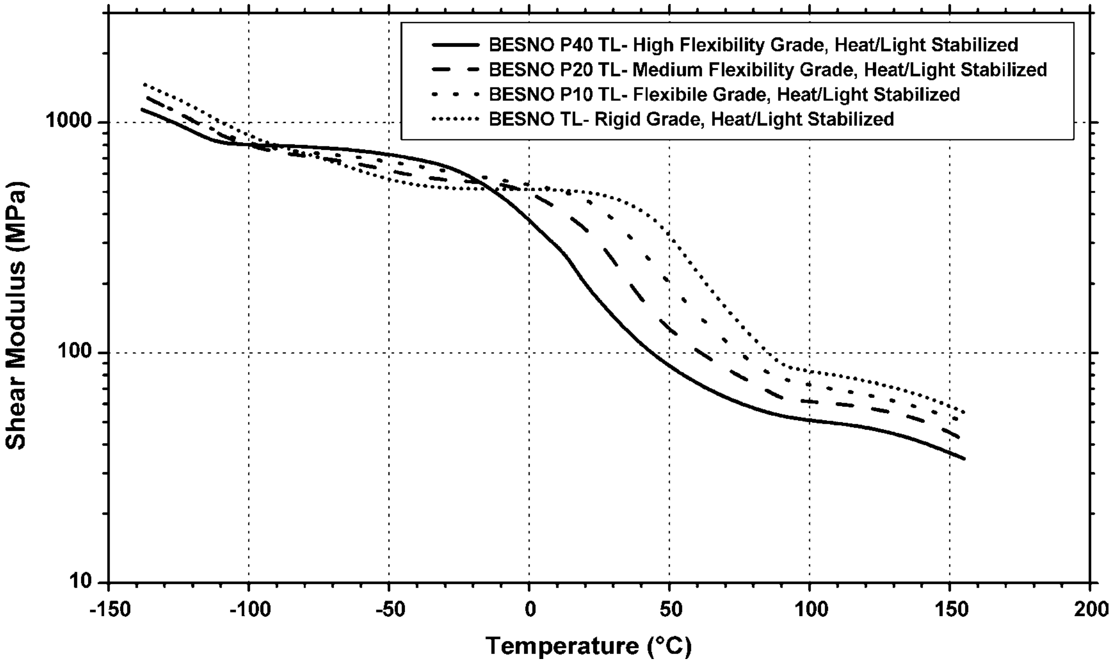


Figure 6.37. Shear modulus vs. temperature for several Arkema Rilsan® BESNO PA11 resins.

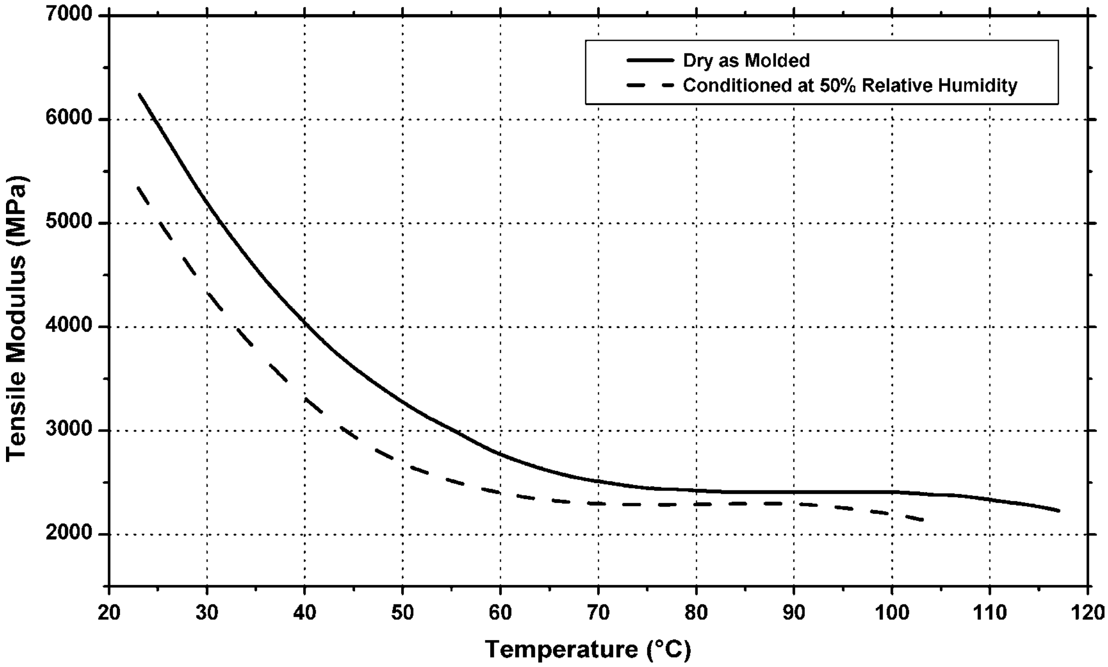


Figure 6.38. Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp® HF-1006—30% glass filled PA11 resin.

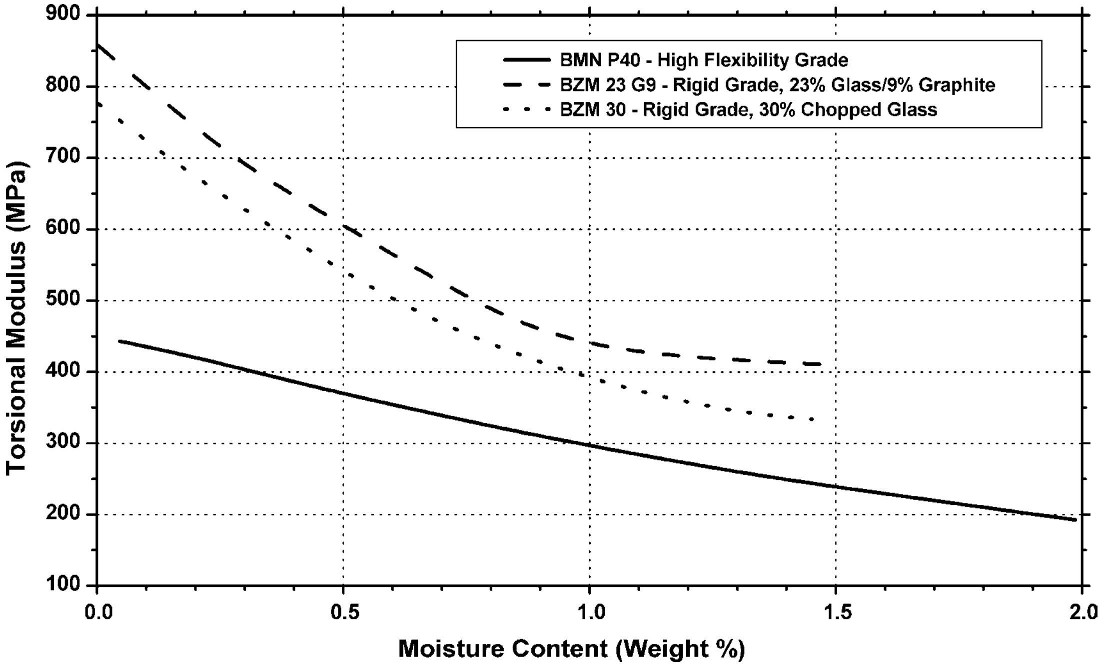


Figure 6.39. Torsional modulus vs. moisture content for several Arkema Rilsan® PA11 resins.

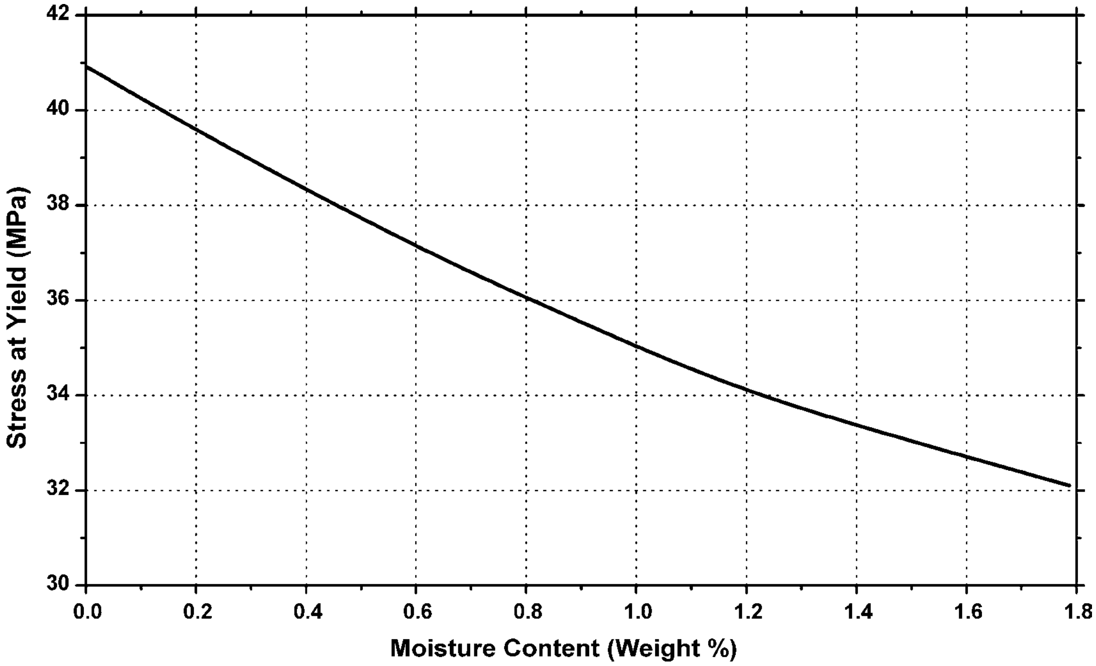


Figure 6.40. Stress at yield vs. moisture content for Arkema Rilsan® BMN PA11 resin.

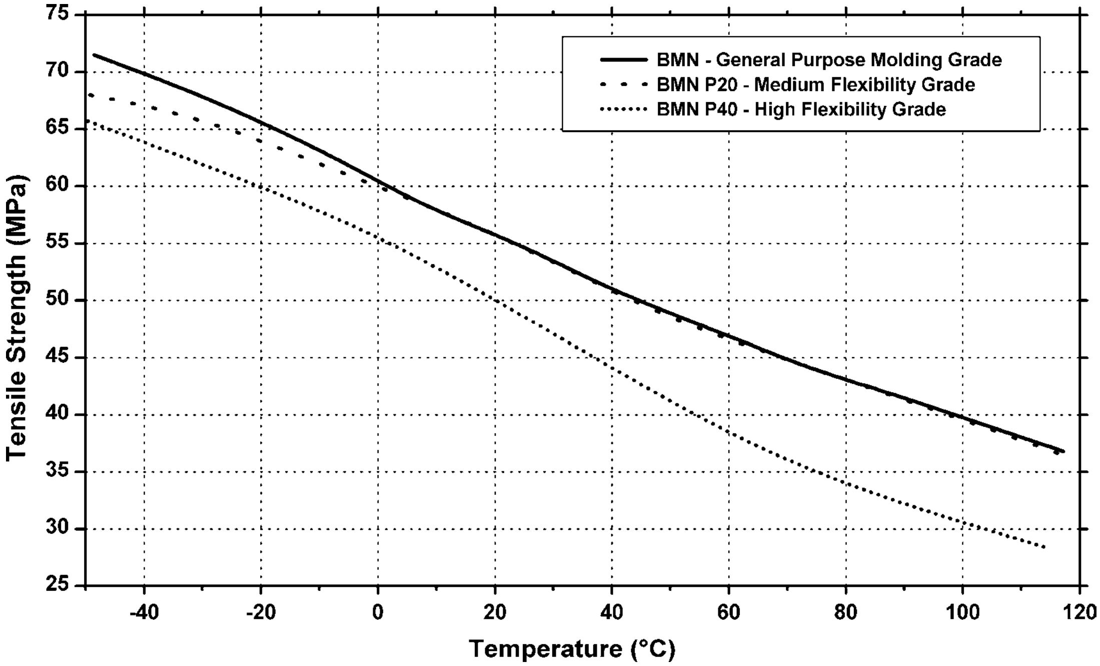


Figure 6.41. Tensile strength vs. temperature for several Arkema Rilsan® BMN PA11 resins.

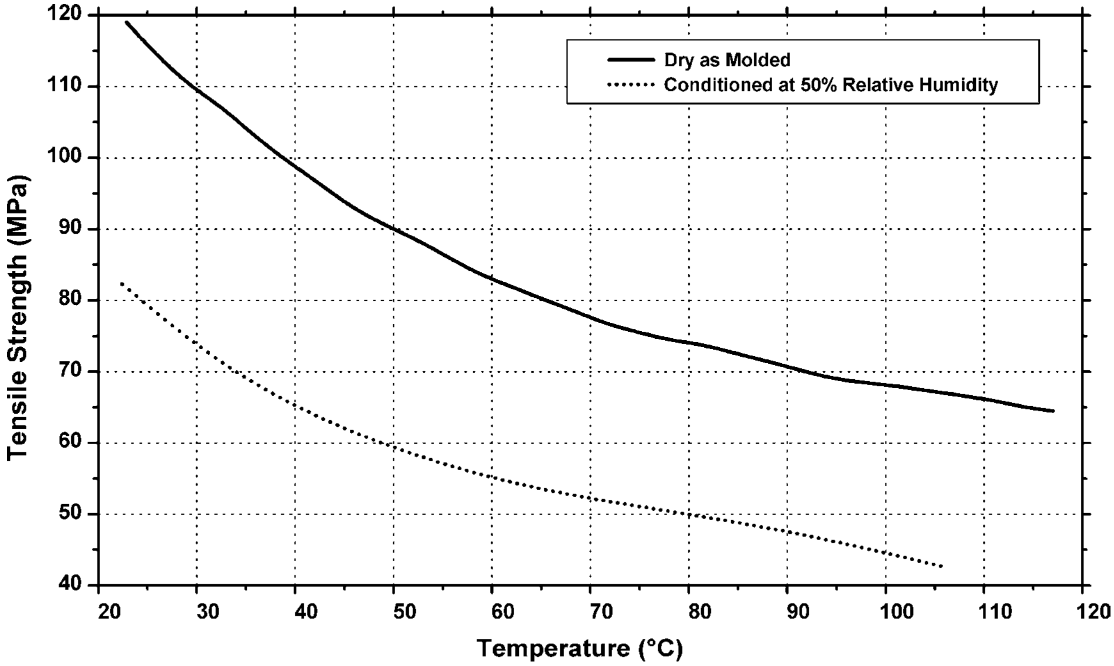


Figure 6.42. Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp® HF-1006—30% glass filled PA11 resin.

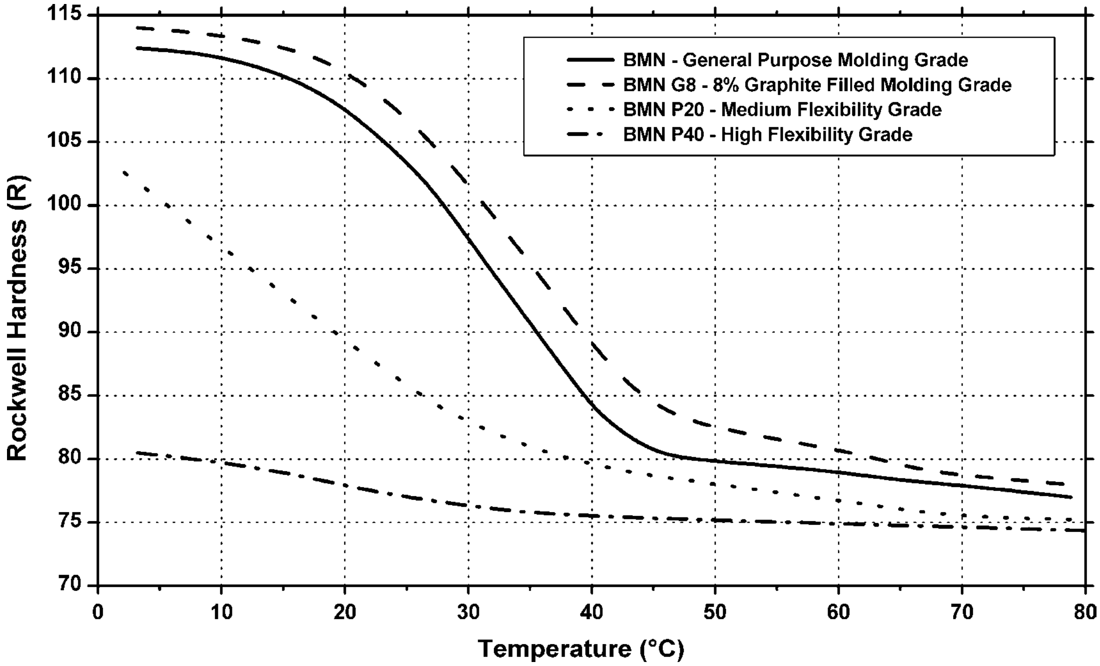


Figure 6.43. Rockwell hardness vs. temperature for several Arkema Rilsan® BMN PA11 resins.

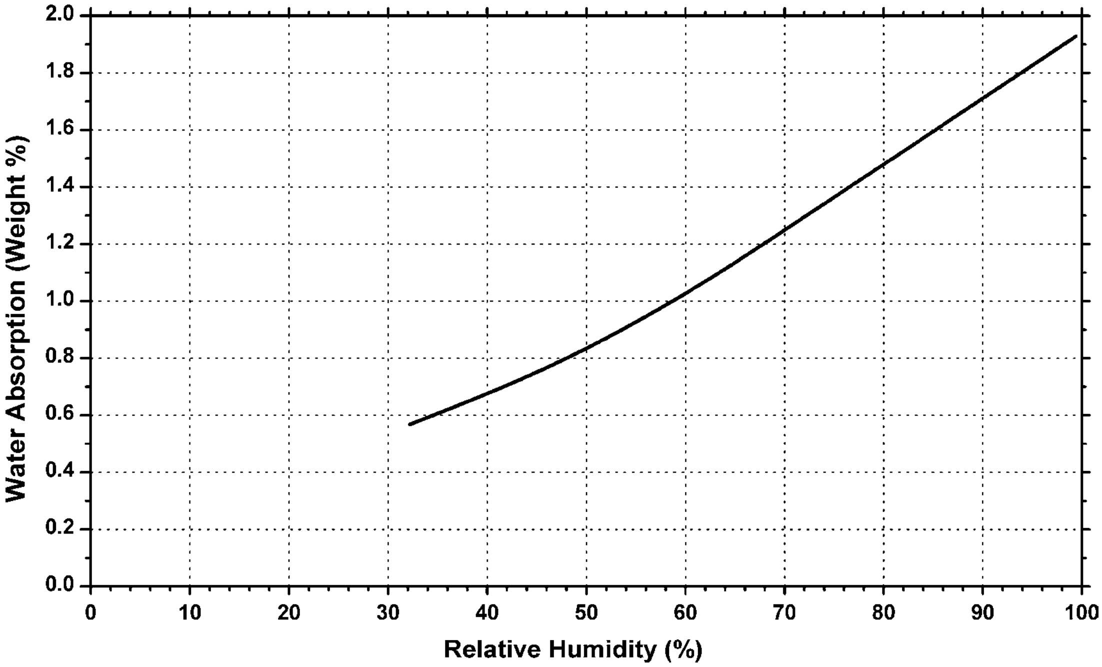


Figure 6.44. Equilibrium water absorption vs. relative humidity for Arkema Rilsan® BMN PA11 resin.

6.4 Nylon 12 (PA12)

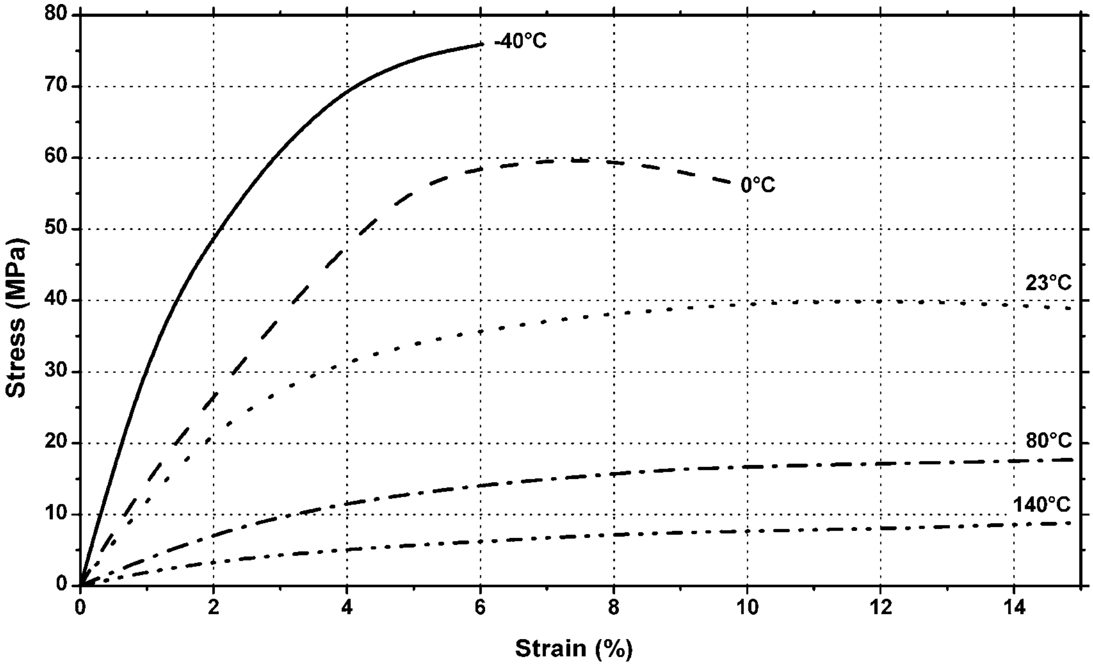


Figure 6.45. Stress vs. strain at various temperatures for EMS-GRIVORY Grilamid® L 20 G—Medium viscosity, lubricated PA12 resin.

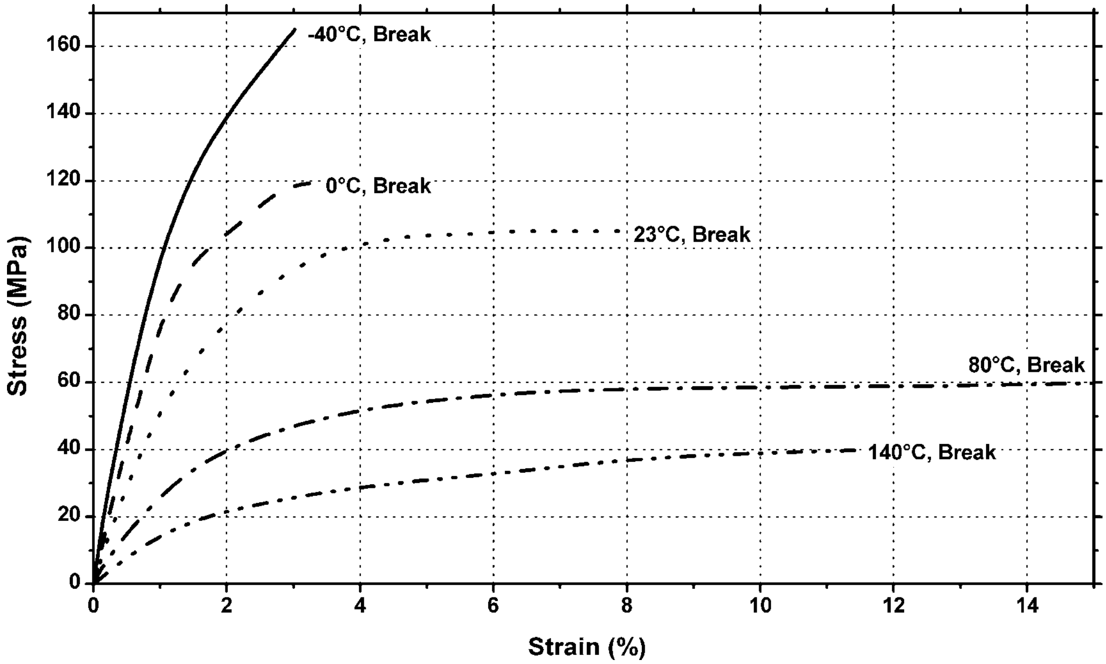


Figure 6.46. Stress vs. strain at various temperatures for EMS-GRIVORY Grilamid® LV-3H—30% glass fiber, heat stabilized PA12 resin.

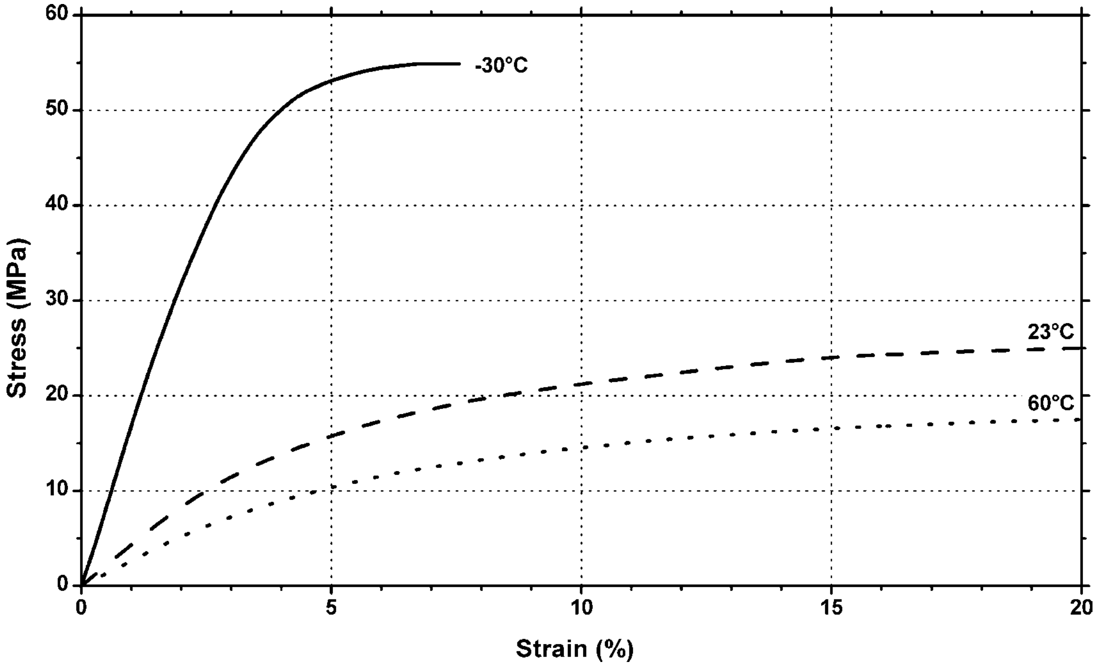


Figure 6.47. Stress vs. strain at various temperatures for Degussa Vestamid® L1723 sw (DAM) low viscosity, plasticized, heat stabilized PA12 resin.

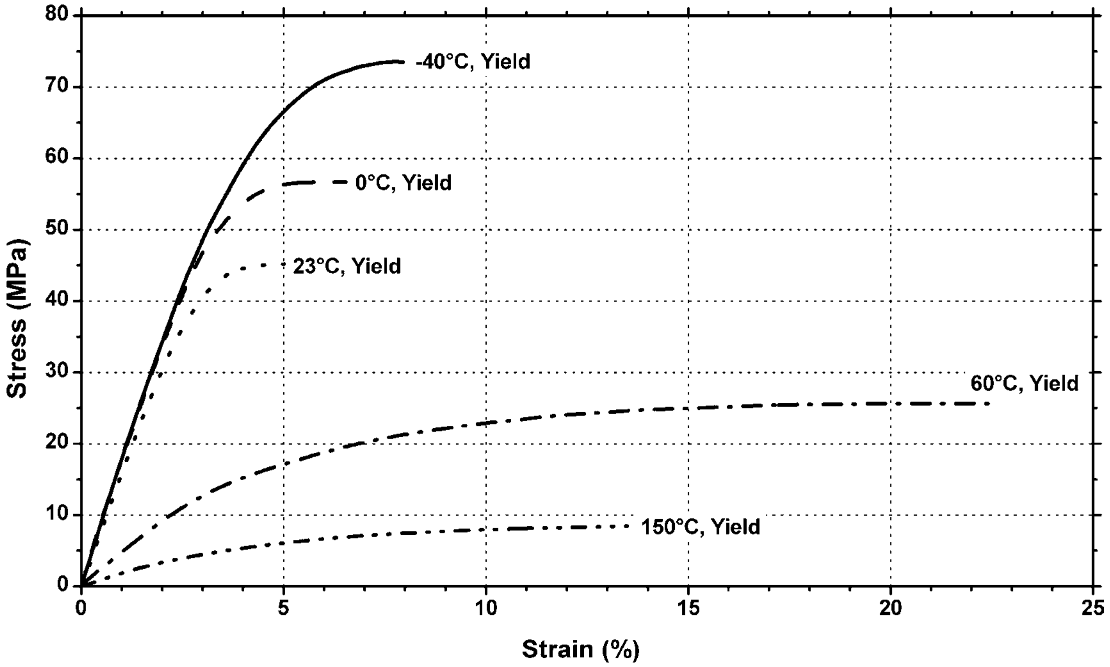


Figure 6.48. Stress vs. strain at various temperatures for Degussa Vestamid® L2141 sw (DAM) high viscosity, high heat PA12 resin.

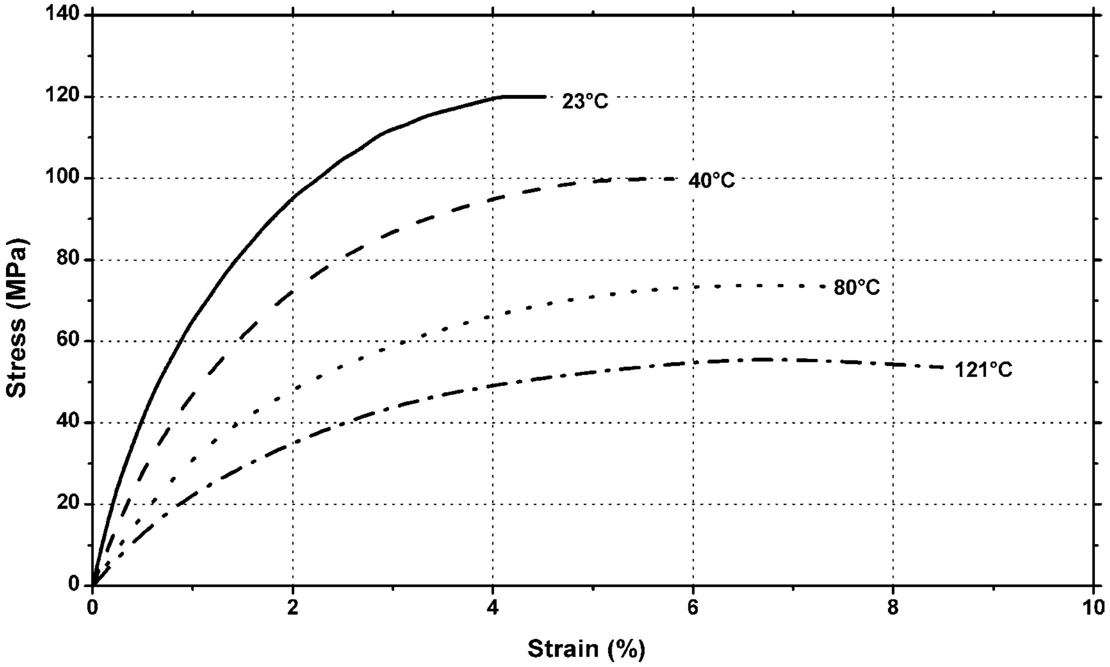


Figure 6.49. Stress vs. strain at various temperatures for SABIC Innovative Plastics Thermocomp® SF—1006 (DAM) 30% glass filled PA12 resin.

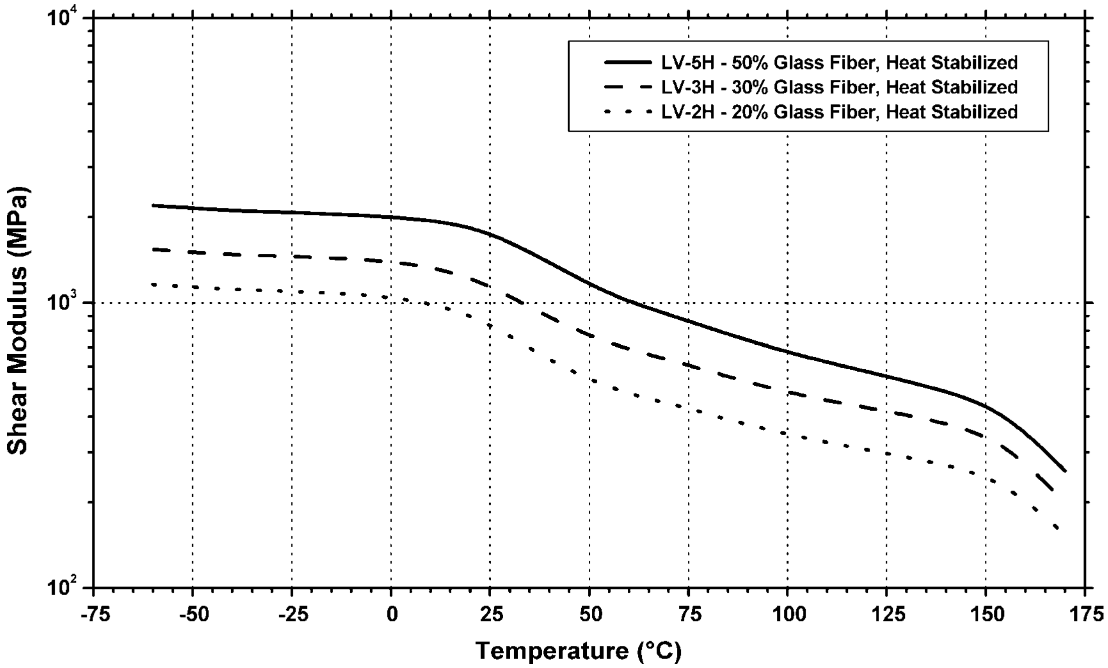


Figure 6.50. Shear modulus vs. temperature for several EMS-GRIVORY Grilamid® LV PA12 resins.

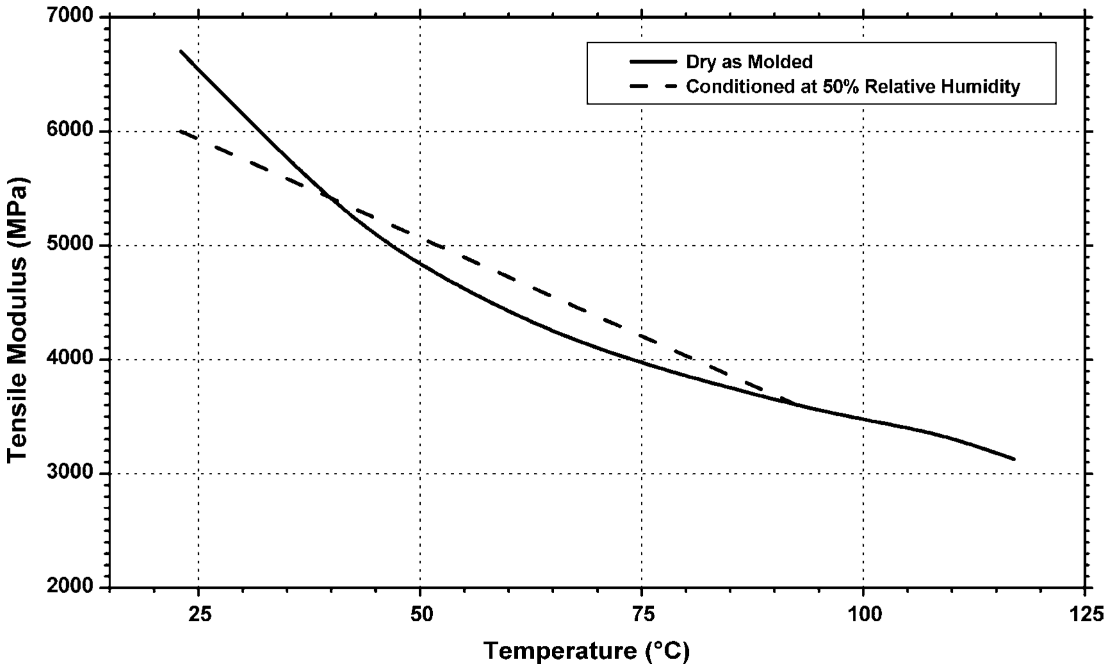


Figure 6.51. Tensile modulus vs. temperature for SABIC Innovative Plastics Thermocomp® S—1006 30% glass filled PA12 resin.

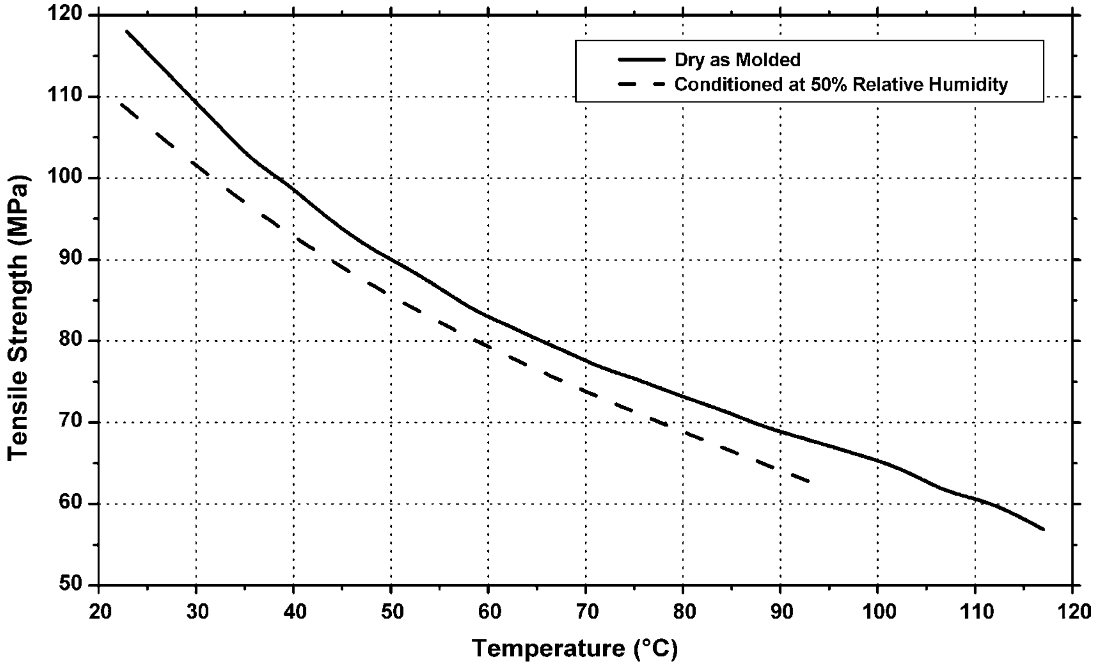


Figure 6.52. Tensile strength vs. temperature for SABIC Innovative Plastics Thermocomp® SF—1006 30% glass filled PA12 resin.

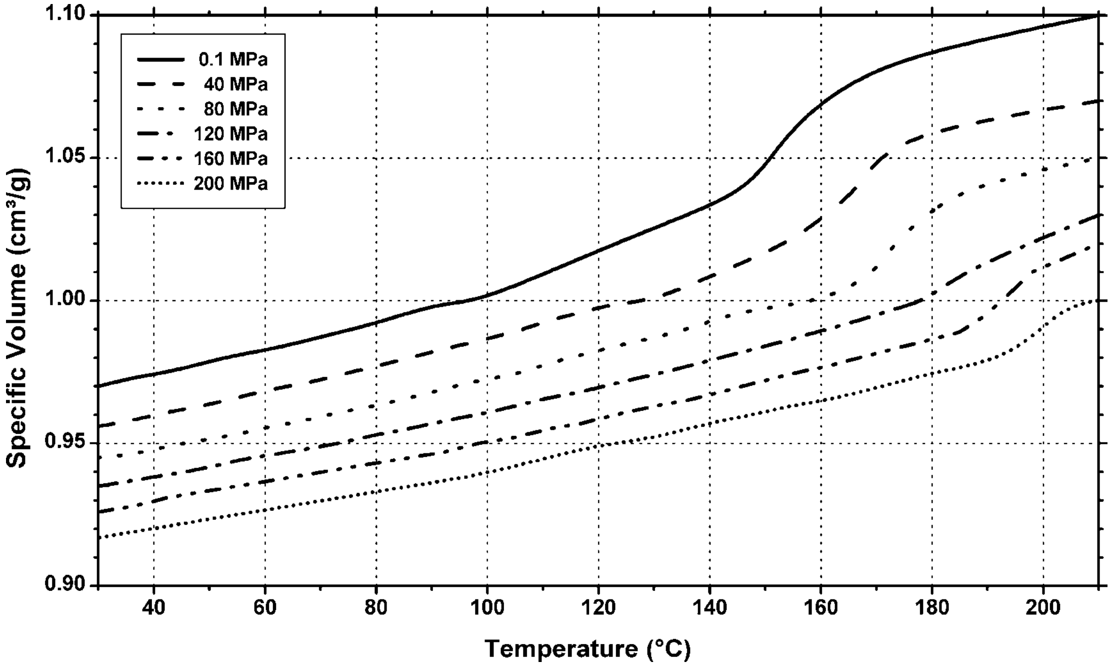


Figure 6.53. Pressure-specific volume-temperature (PVT) for Degussa Vestamid® L1723 sw (dry as molded) low viscosity, plasticized, heat stabilized PA12 resin.

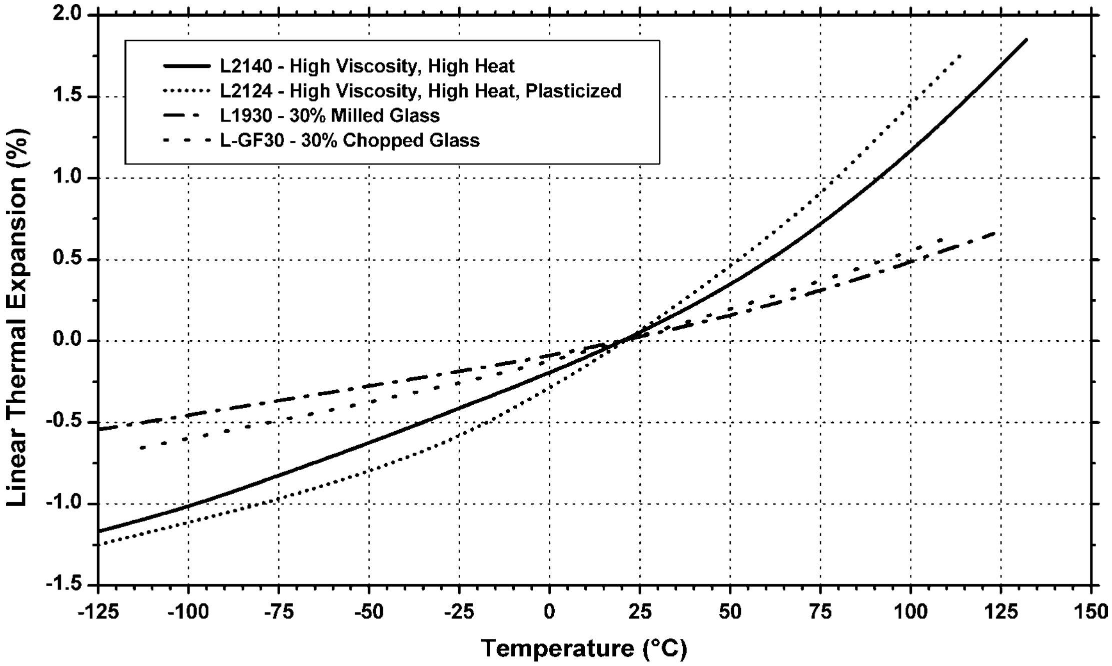


Figure 6.54. Thermal expansion vs. temperature for Degussa Several Vestamid® PA12 resins.

6.5 Nylon 66 (PA66)

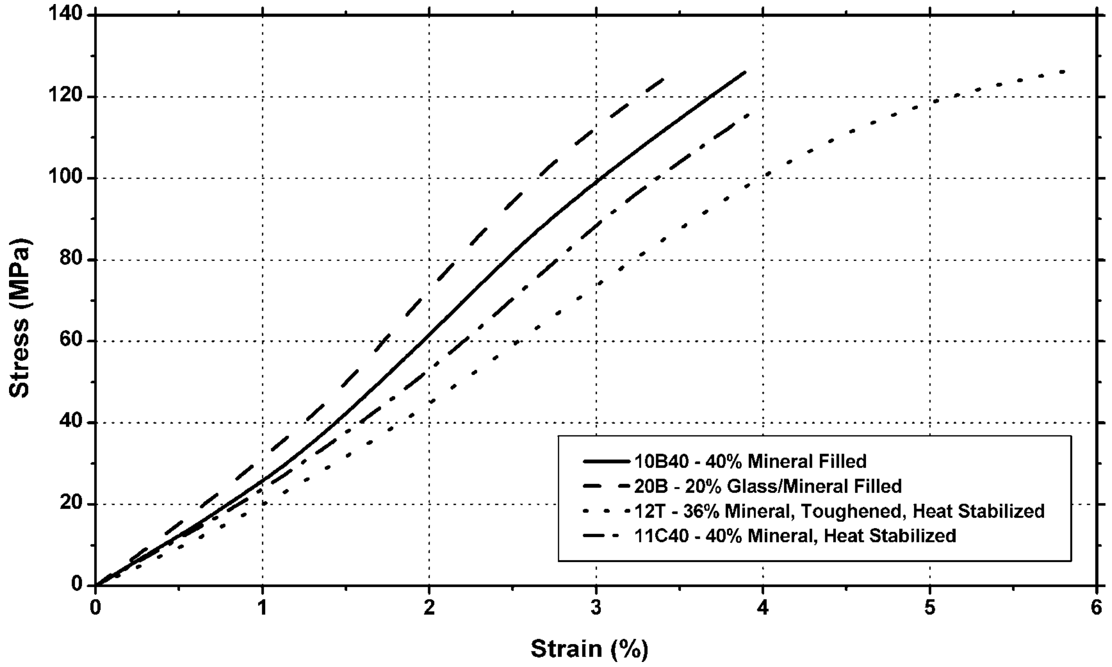


Figure 6.55. Stress vs. strain in compression at 23°C for several DuPont Minlon® mineral reinforced PA66 resins.

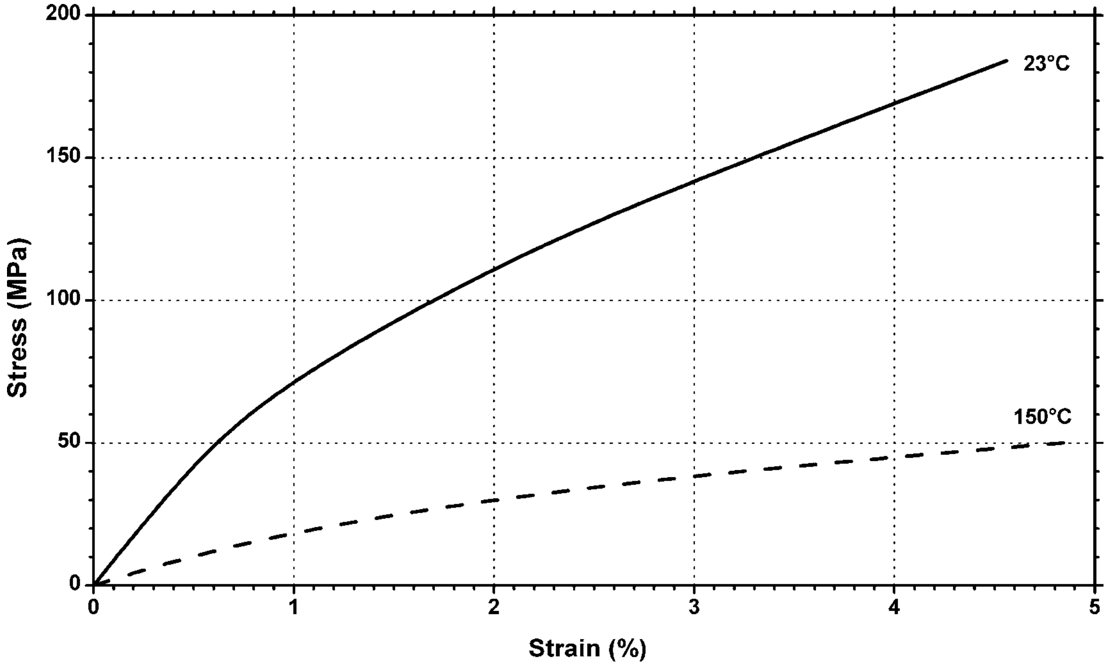


Figure 6.56. Stress vs. strain in compression at various temperatures for DuPont Zytel® 70G-33L—33% glass reinforced, lubricated PA66 resin.

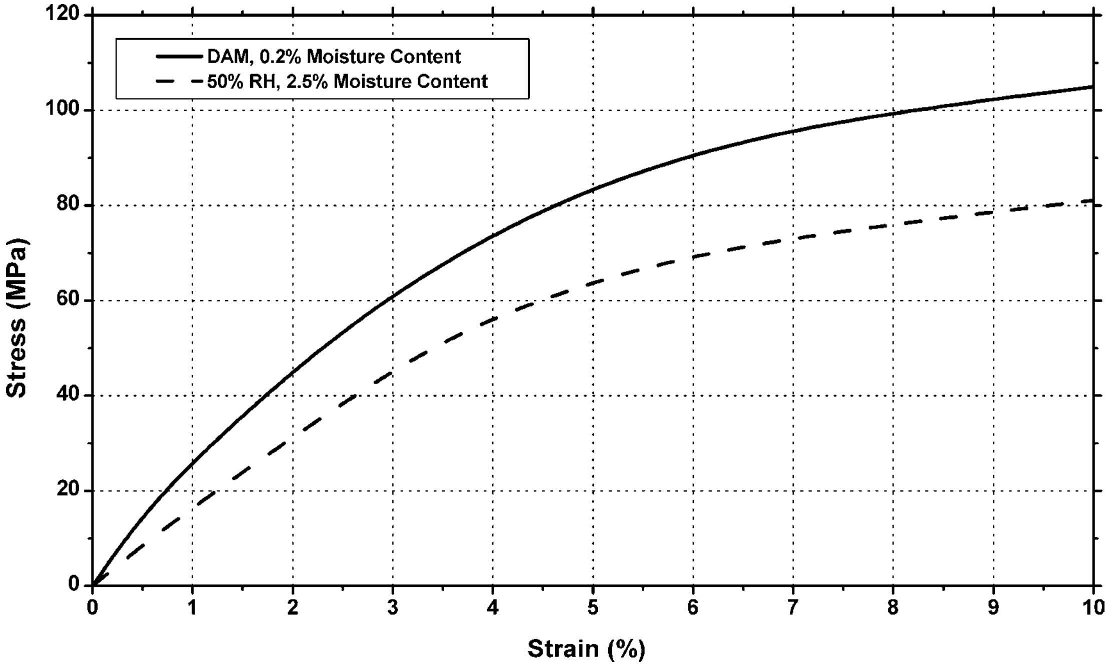


Figure 6.57. Stress vs. strain in compression at 23°C for DuPont Zytel® 101—general purpose PA66 resin.

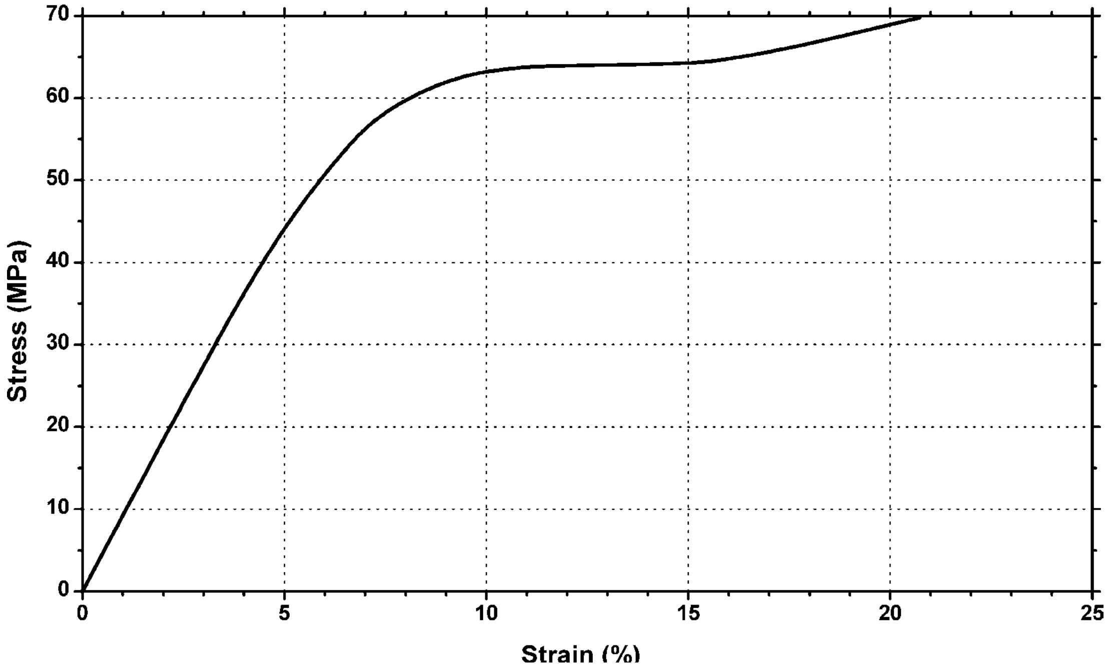


Figure 6.58. Stress vs. strain in compression at 23°C for DuPont Zytel® ST-801—super tough PA66 resin.

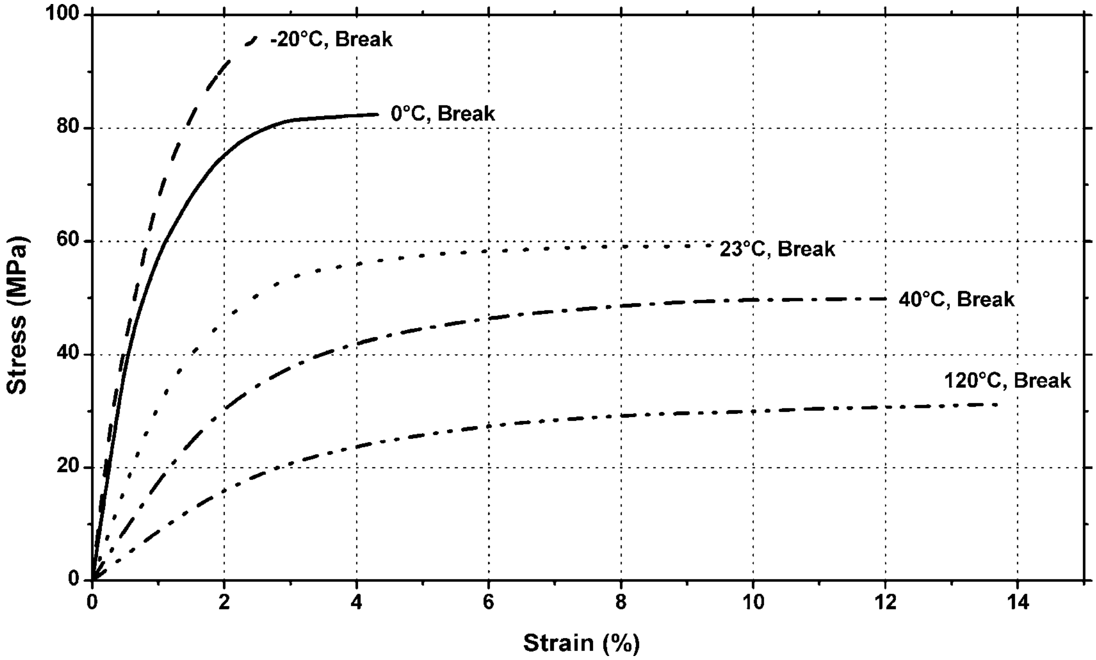


Figure 6.59. Stress vs. strain at various temperatures for DuPont Minlon® 10B140 NC010—40% mineral reinforced PA66 resin (conditioned at 50% RH).

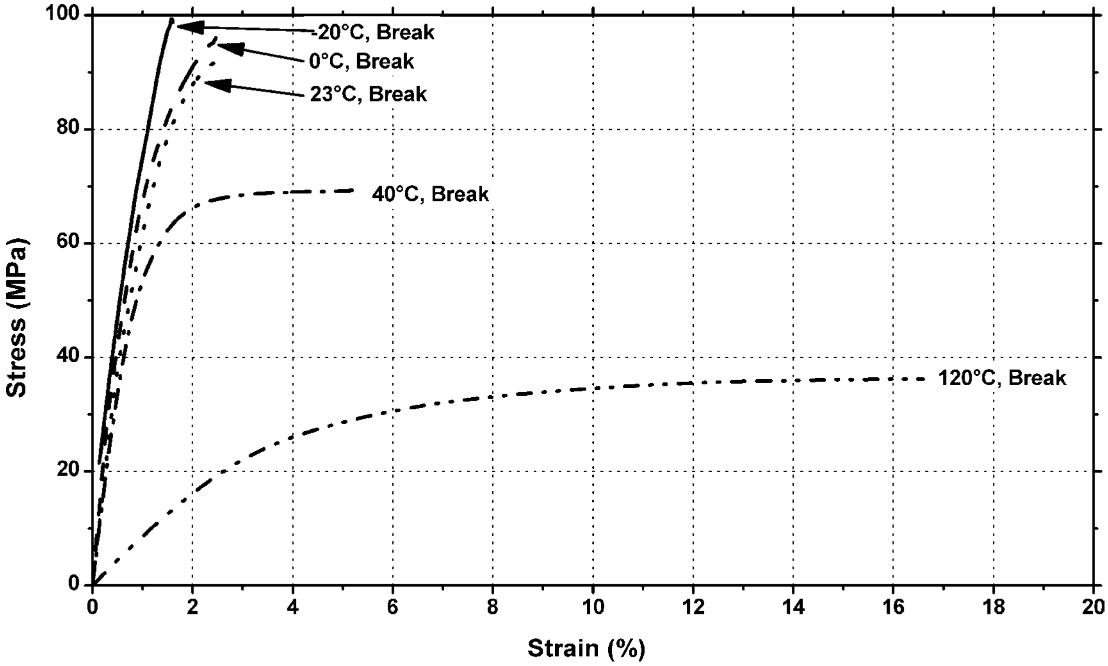


Figure 6.60. Stress vs. strain at various temperatures for DuPont Minlon® 10B140 NC010—40% mineral reinforced PA66 resin (DAM).

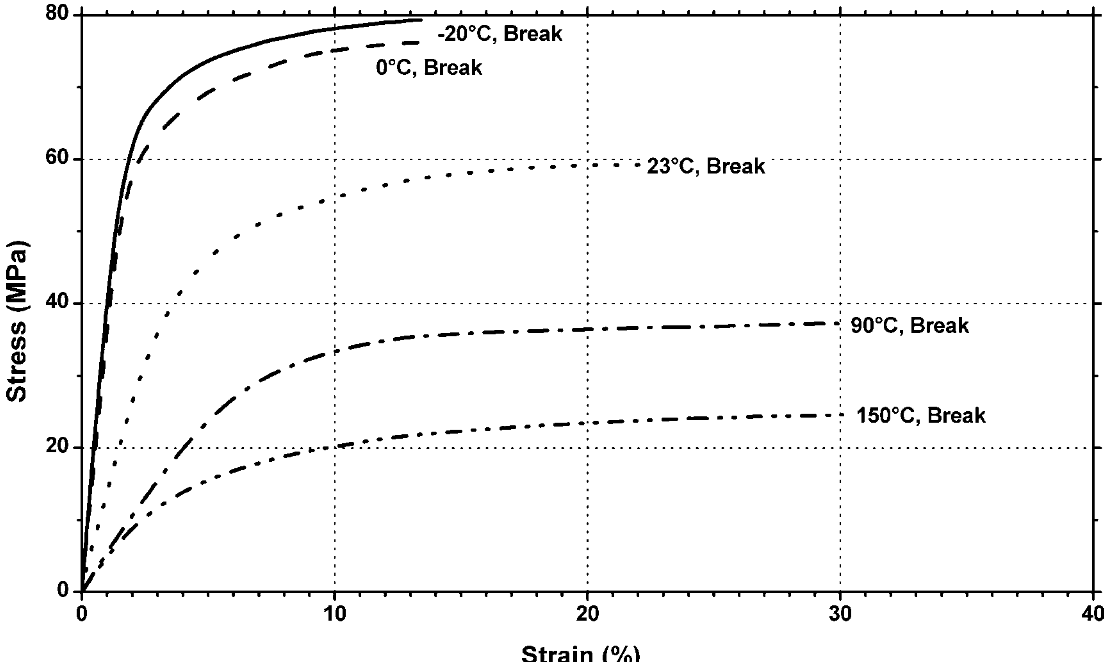


Figure 6.61. Stress vs. strain at various temperatures for DuPont Minlon® 11C140 NC010—40% mineral reinforced PA66 resin (conditioned at 50% RH).

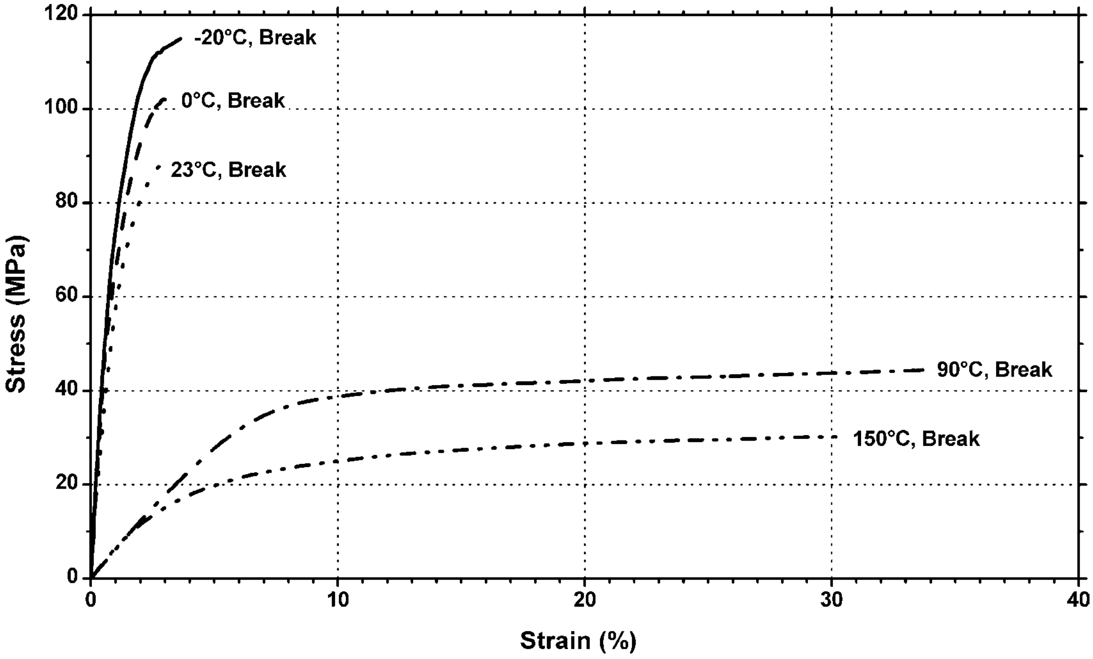


Figure 6.62. Stress vs. strain at various temperatures for DuPont Minlon® 11C140 NC010—high impact, 40% mineral reinforced PA66 resin (DAM).

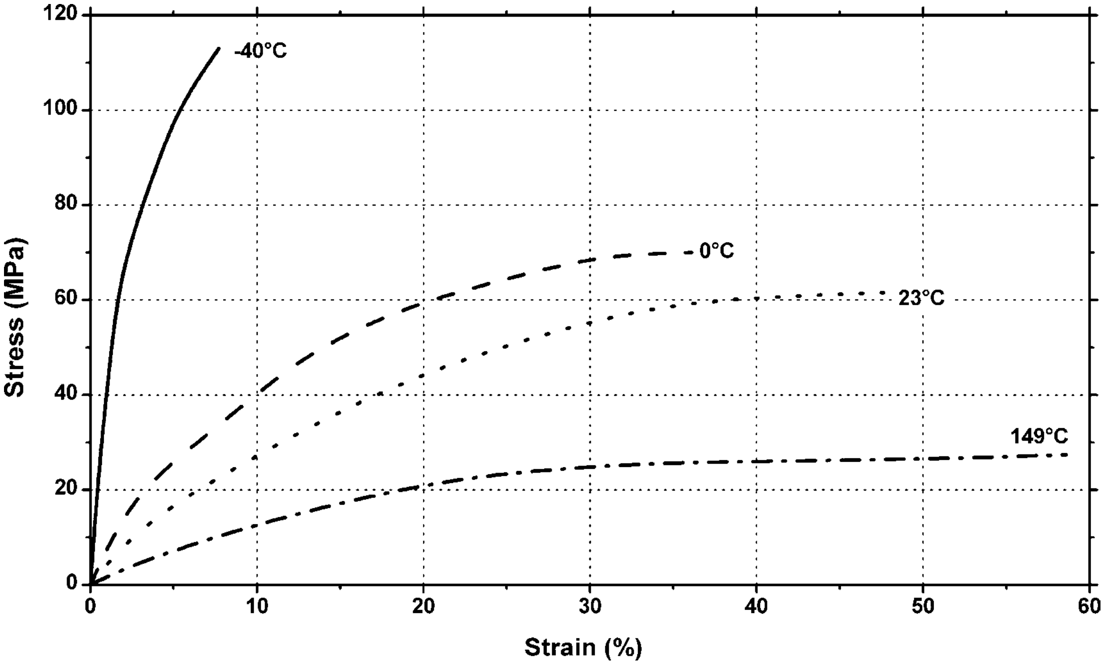


Figure 6.63. Stress vs. strain at various temperatures for DuPont Minlon® 12T—super high impact, 40% mineral reinforced PA66 resin (conditioned at 50% RH).

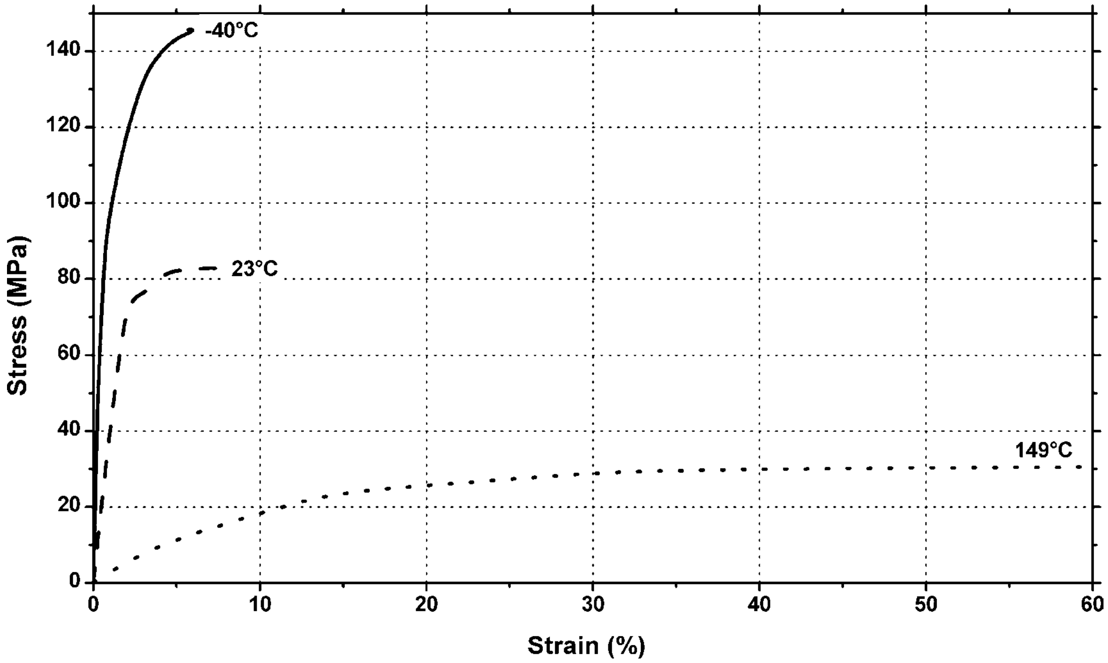


Figure 6.64. Stress vs. strain at various temperatures for DuPont Minlon® 12T—super high impact, 40% mineral reinforced PA66 resin (DAM).

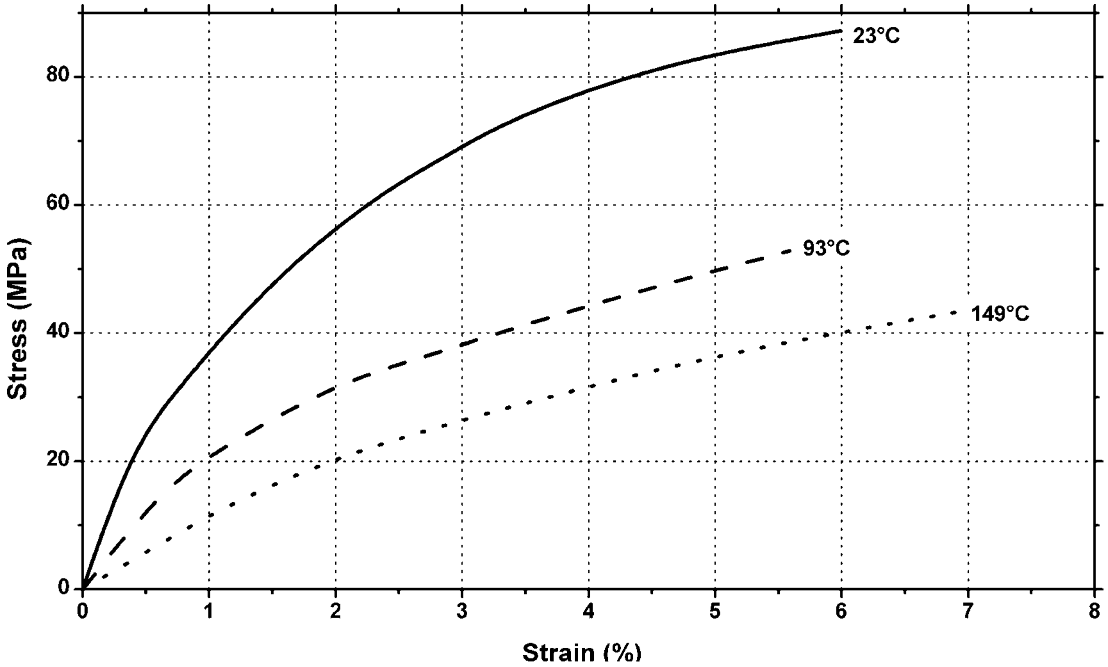


Figure 6.65. Stress vs. strain at various temperatures for DuPont Minlon® 20B—40% glass/mineral reinforced PA66 resin (conditioned at 50% RH).

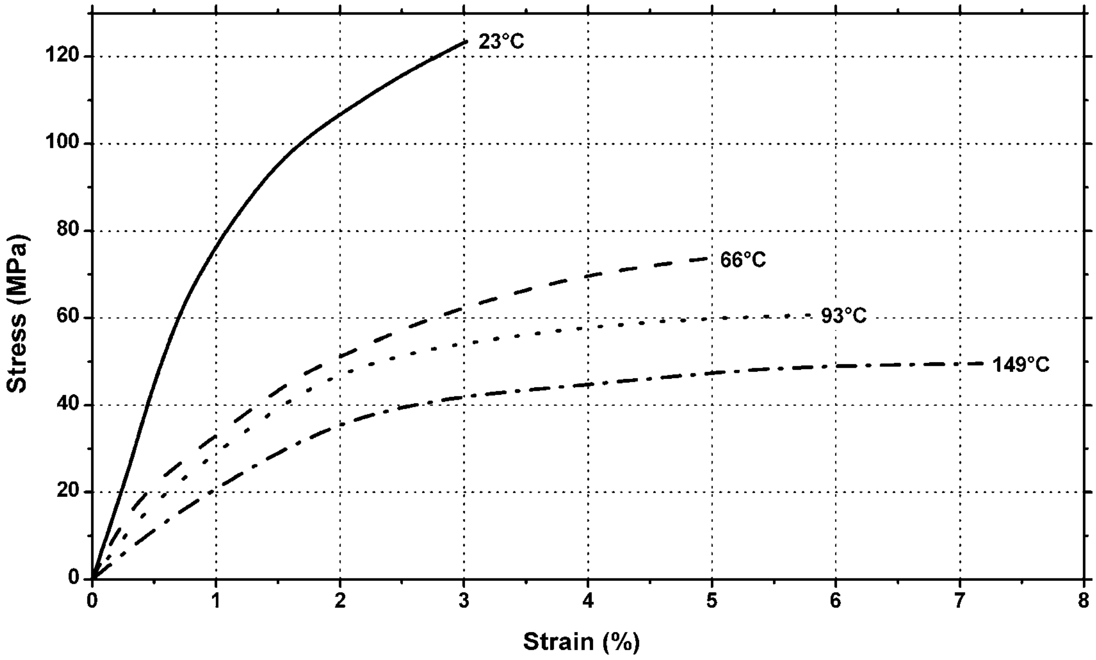


Figure 6.66. Stress vs. strain at various temperatures for DuPont Minlon® 20B—40% glass/mineral reinforced PA66 resin (DAM).

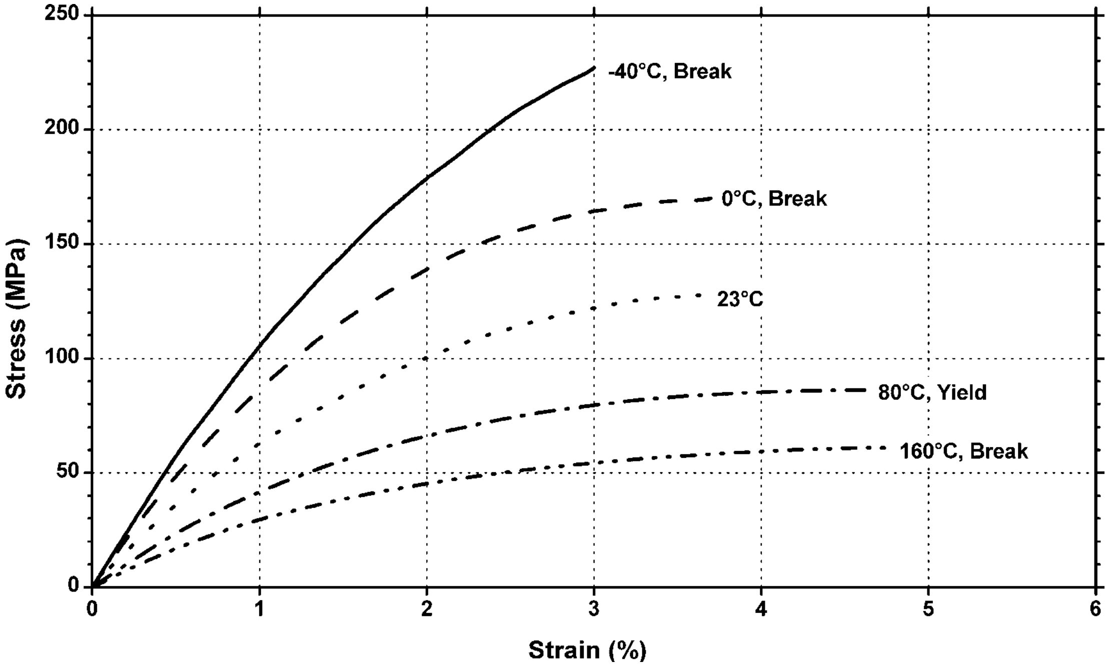


Figure 6.67. Stress vs. strain at various temperatures for BASF Ultramid® A3EG6—high stiffness, 30% glass fiber filled PA66 resin (conditioned at 50% RH).

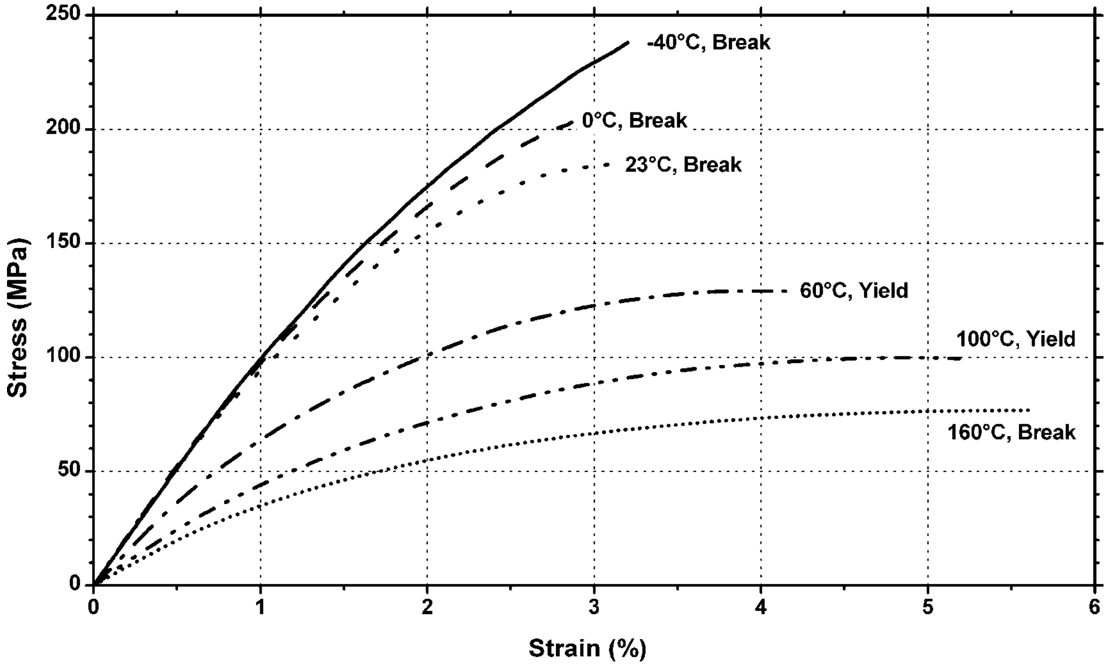


Figure 6.68. Stress vs. strain at various temperatures for BASF Ultramid® A3EG6—high stiffness, 30% glass fiber filled PA66 resin (DAM).

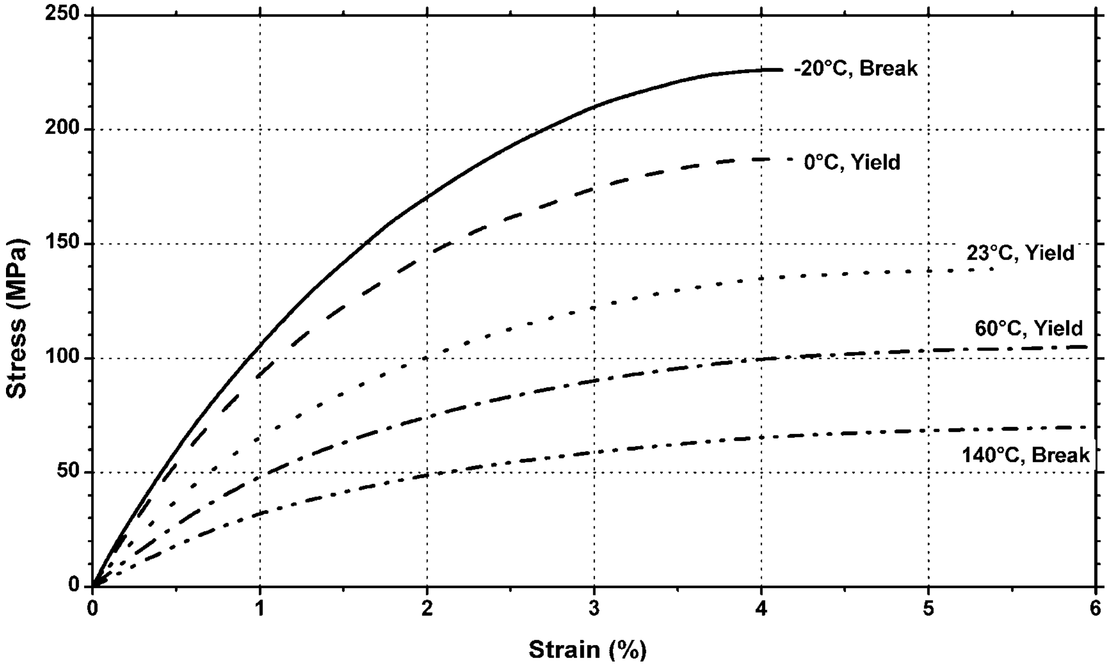


Figure 6.69. Stress vs. strain at various temperatures for BASF Ultramid® A3WG7—heat resistant, 35% glass fiber filled PA66 resin (conditioned at 50% RH).

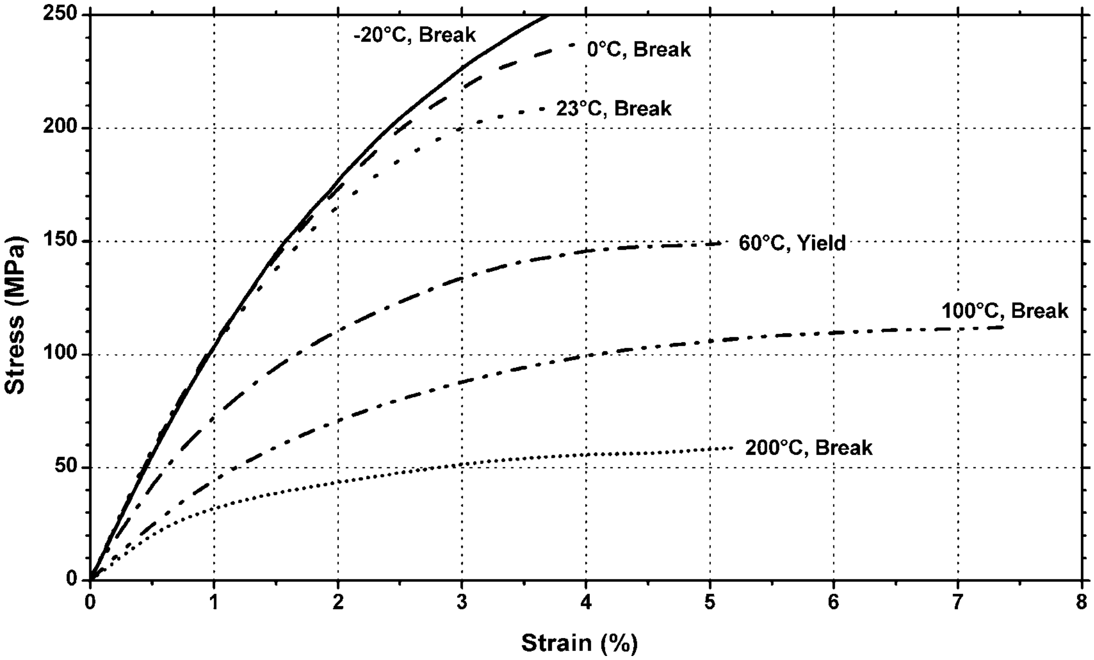


Figure 6.70. Stress vs. strain at various temperatures for BASF Ultramid® A3WG7—heat resistant, 35% glass fiber filled PA66 resin (DAM).

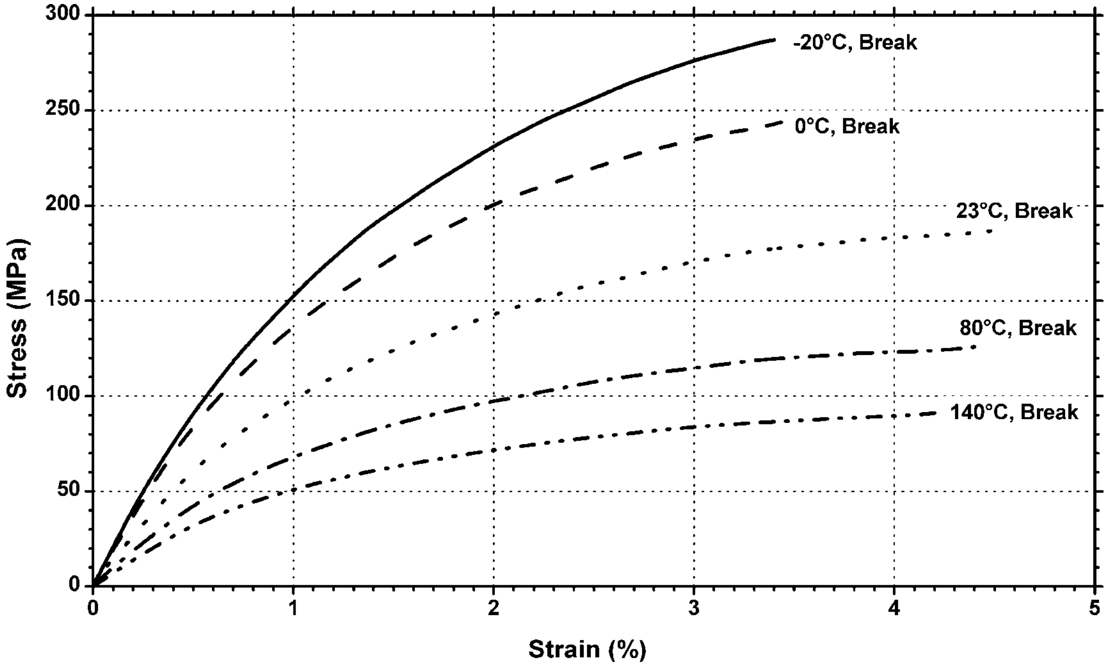


Figure 6.71. Stress vs. strain at various temperatures for BASF Ultramid® A3EG10—rigid, 50% glass fiber filled PA66 resin (conditioned at 50% RH).

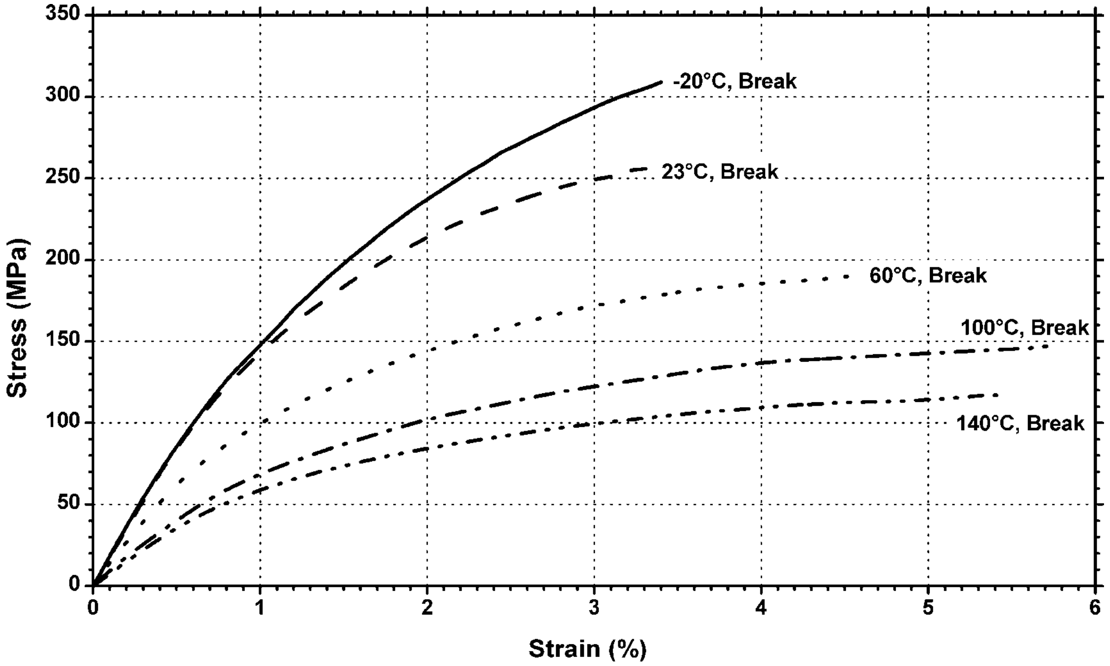


Figure 6.72. Stress vs. strain at various temperatures for BASF Ultramid® A3EG10—rigid, 50% glass fiber filled PA66 resin (DAM).

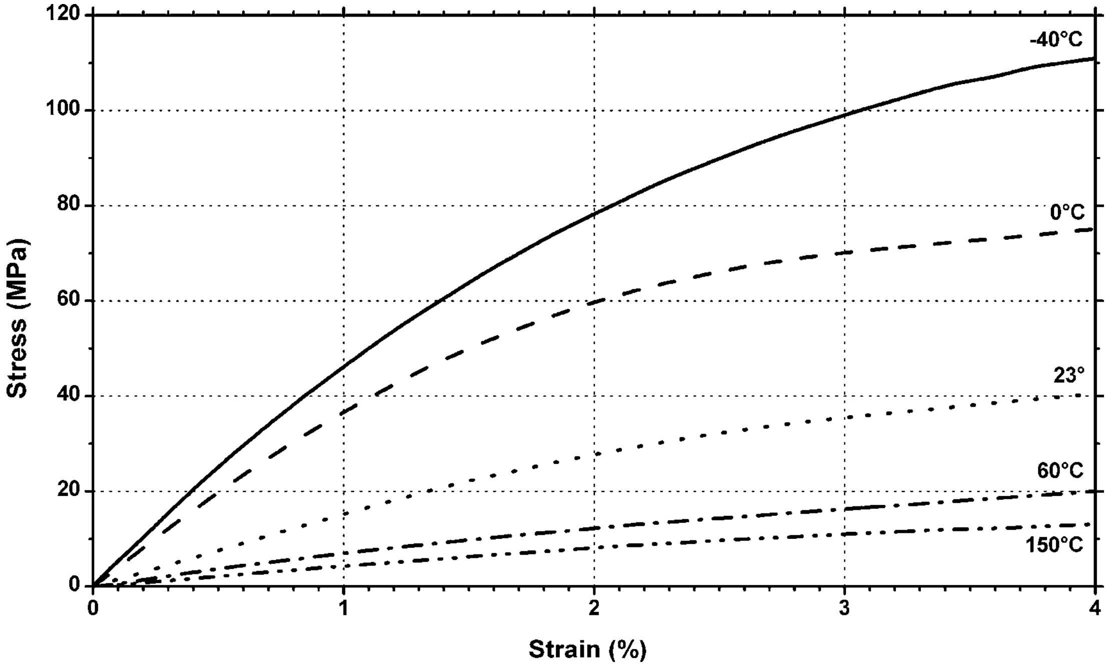


Figure 6.73. Stress vs. strain at various temperatures for BASF Ultramid® A3K—easy flowing, injection molding PA66 resin (conditioned at 50% RH).

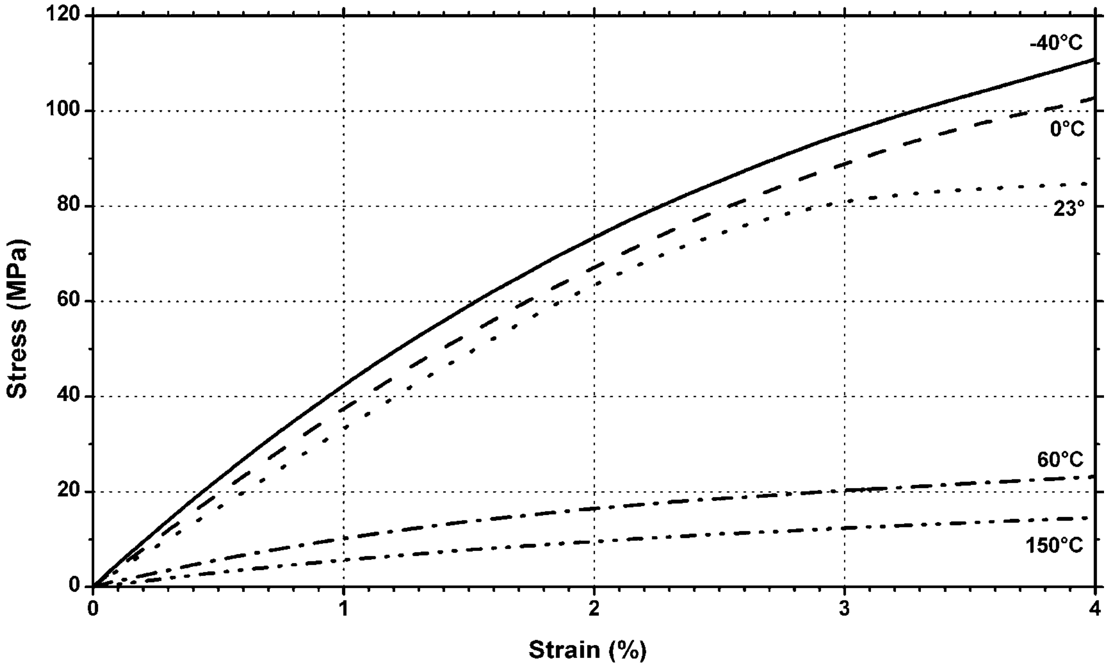


Figure 6.74. Stress vs. strain at various temperatures for BASF Ultramid® A3K—easy flowing, injection molding PA66 resin (DAM).

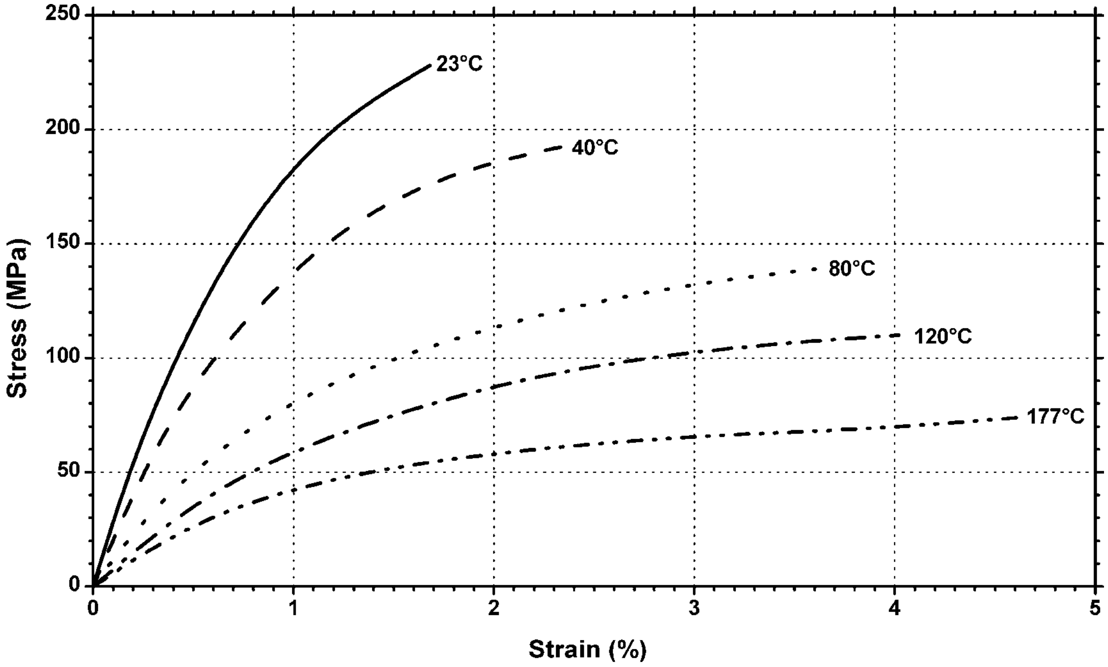


Figure 6.75. Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp® RC-1006—electrically conductive, 30% carbon fiber filled PA66 resin (DAM).

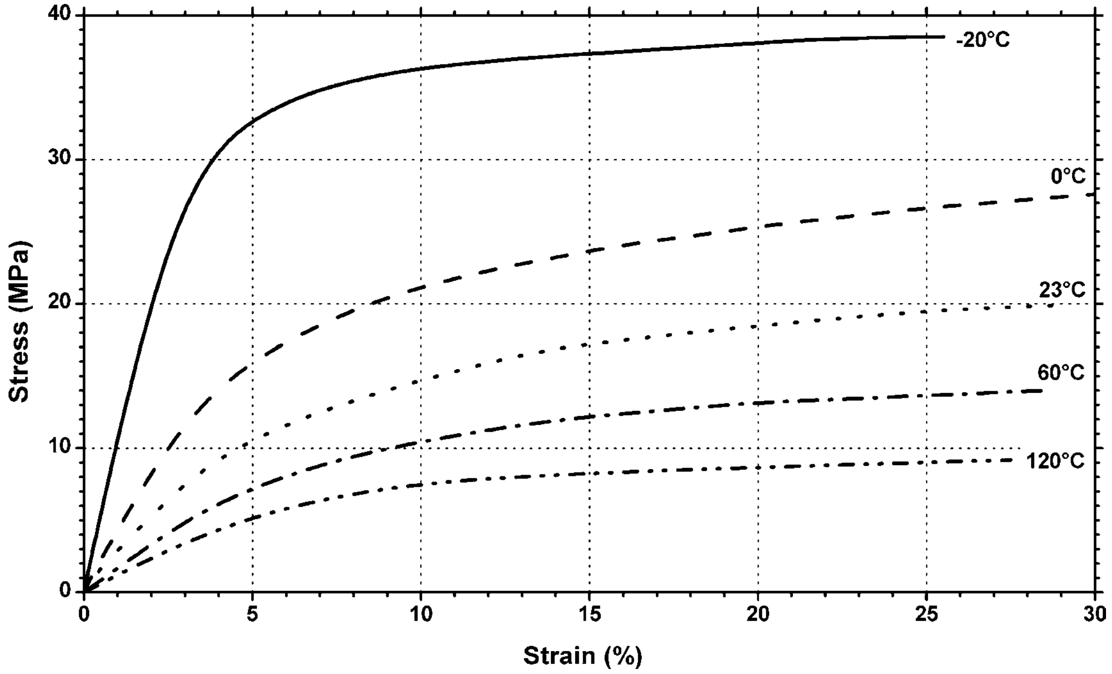


Figure 6.76. Stress vs. strain at various temperatures for DuPont Zytel® ST811 HS NC010—super tough PA66 resin (conditioned at 50% RH).

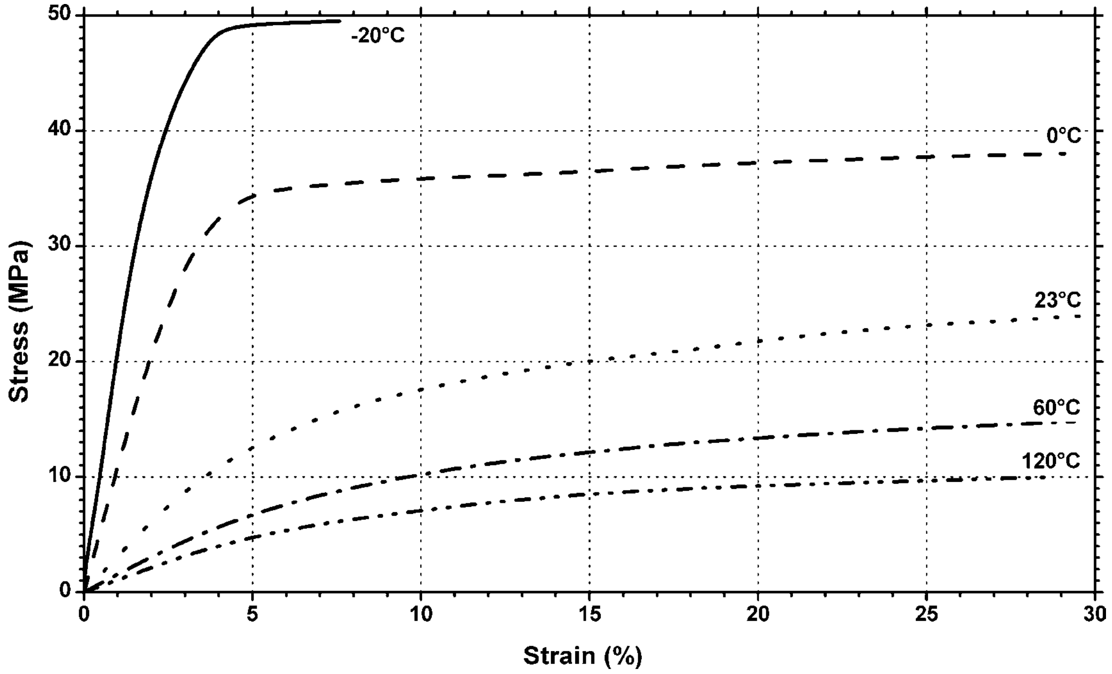


Figure 6.77. Stress vs. strain at various temperatures for DuPont Zytel® ST811 HS NC010—super tough PA66 resin (DAM).

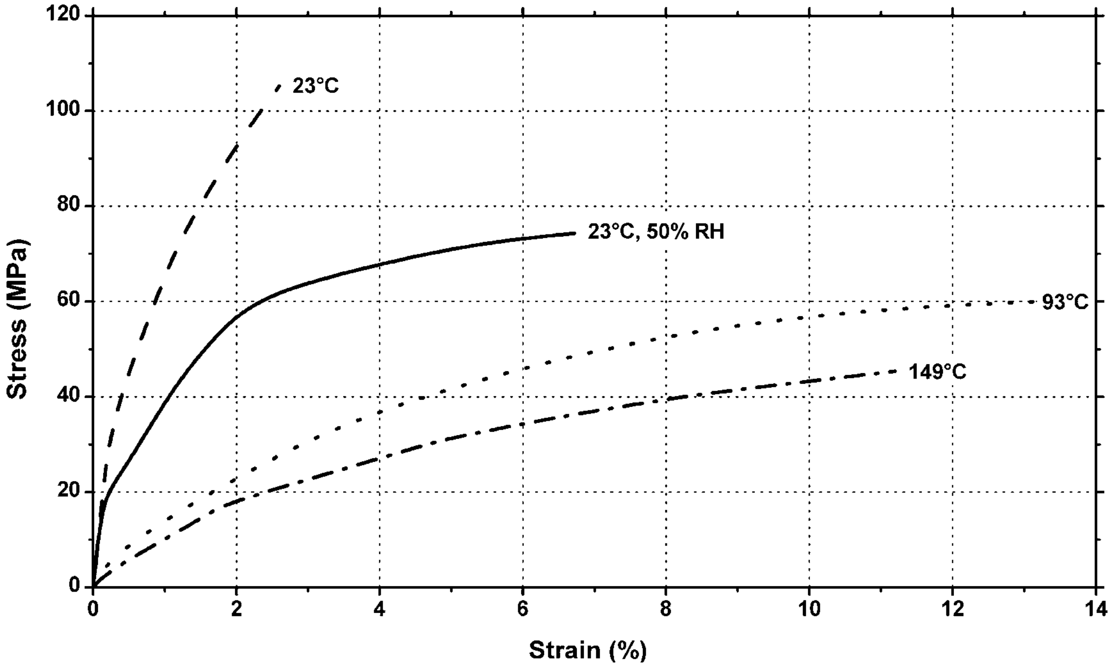


Figure 6.78. Stress vs. strain at various temperatures for DuPont Zytel® 70G-13L—13% chopped glass filled, lubricated PA66 resin.

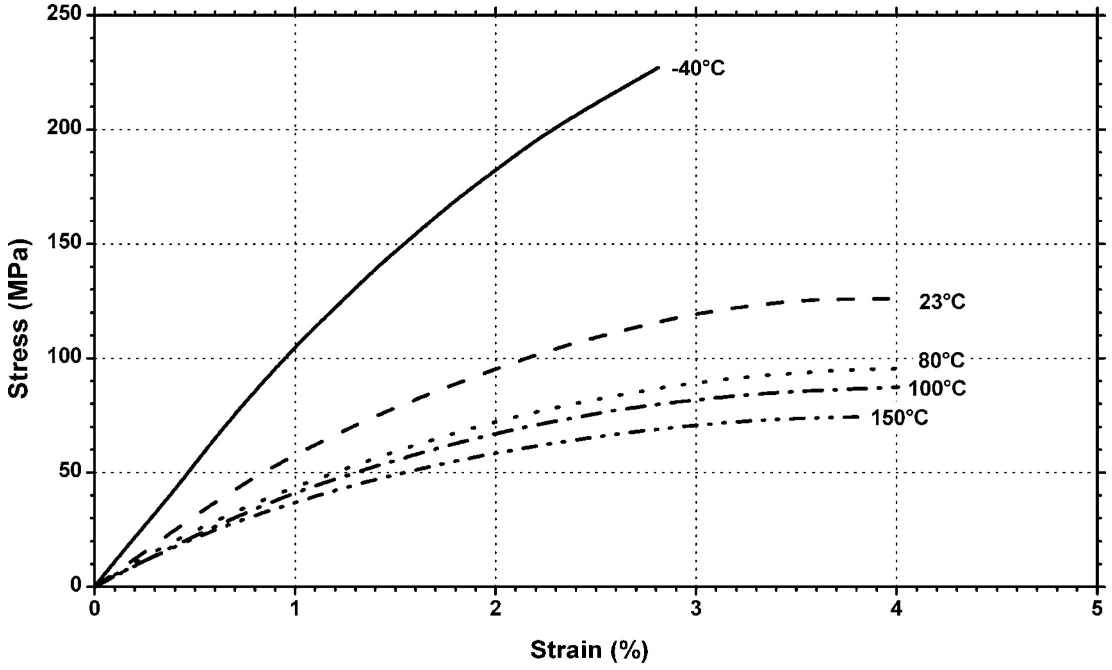


Figure 6.79. Stress vs. strain at various temperatures for DuPont Zytel® 70G-33L NC010—33% chopped glass filled, lubricated PA66 resin (conditioned at 50% RH).

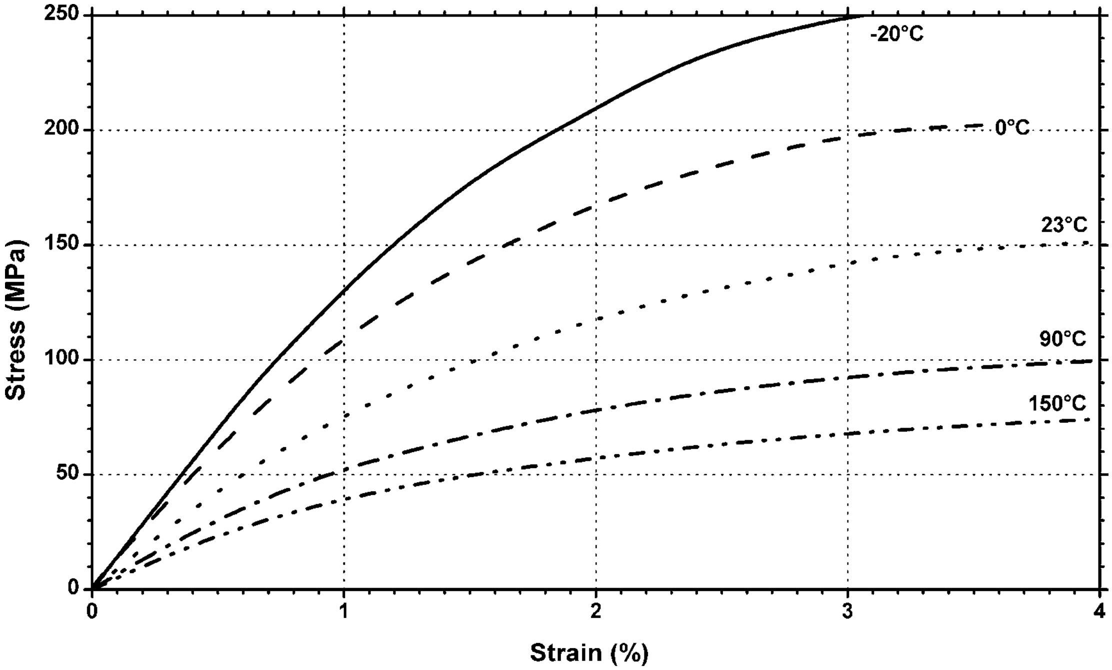


Figure 6.80. Stress vs. strain at various temperatures for DuPont Zytel® 70G-43LNC010—43% chopped glass filled, lubricated PA66 resin (conditioned at 50% RH).

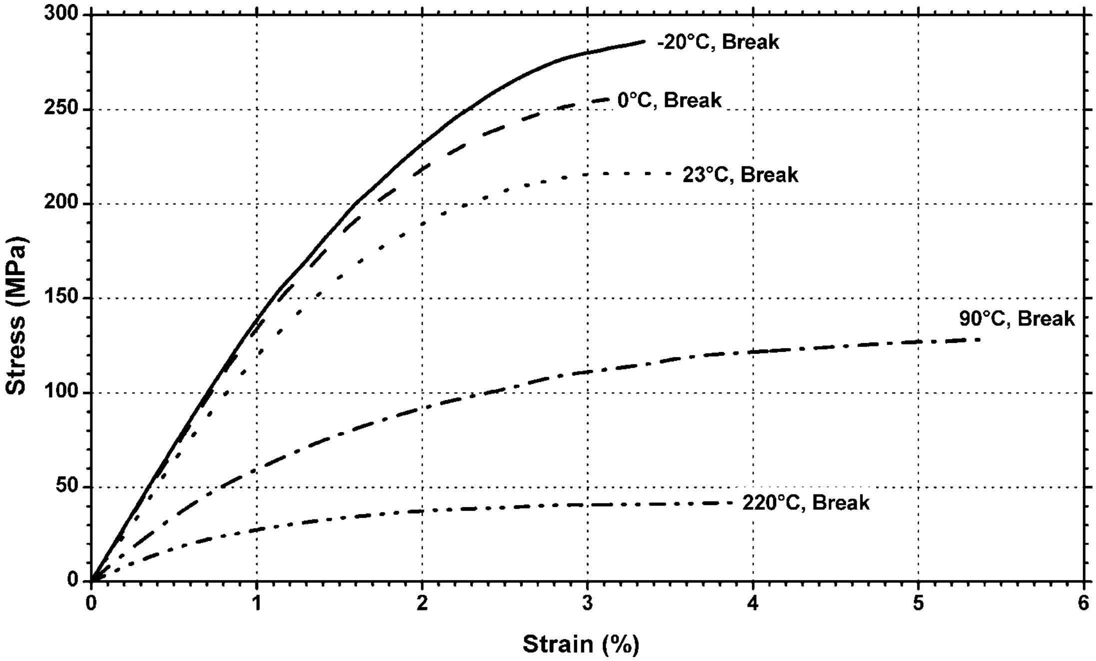


Figure 6.81. Stress vs. strain at various temperatures for DuPont Zytel® 70G-43L NC010—43% chopped glass filled, lubricated PA66 resin (DAM).

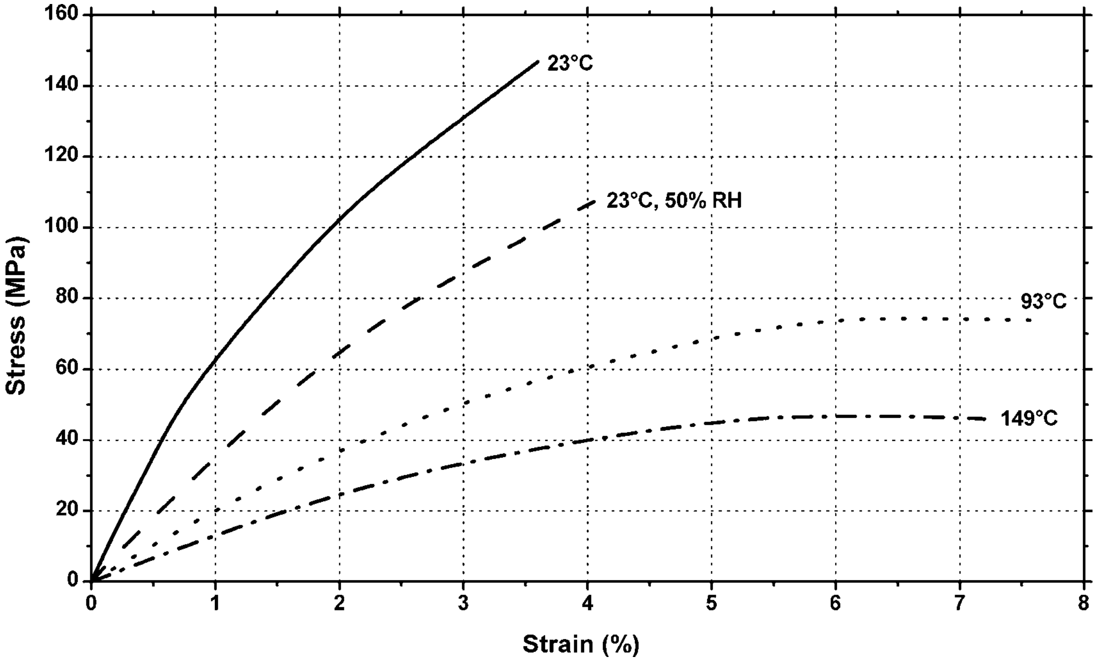


Figure 6.82. Stress vs. strain at various temperatures for DuPont Zytel® 71G-33L—toughened, 33% chopped glass filled, lubricated PA66 resin.

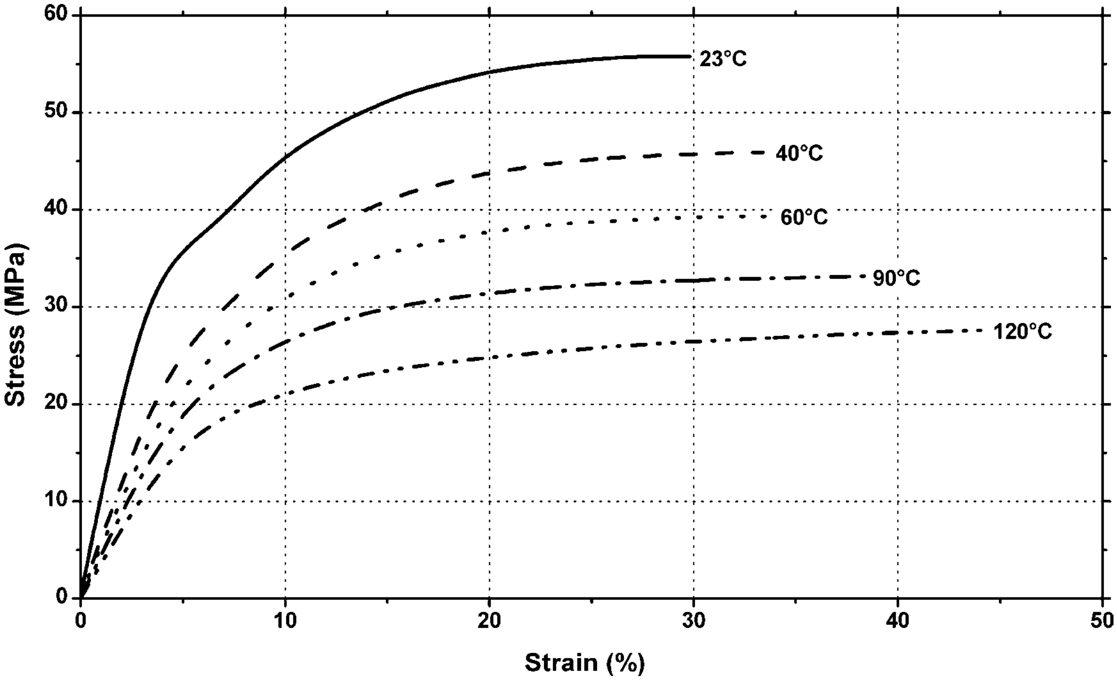


Figure 6.83. Stress vs. strain at various temperatures for DuPont Zytel® 101L NC010—lubricated, general purpose PA66 resin (conditioned at 50% RH).

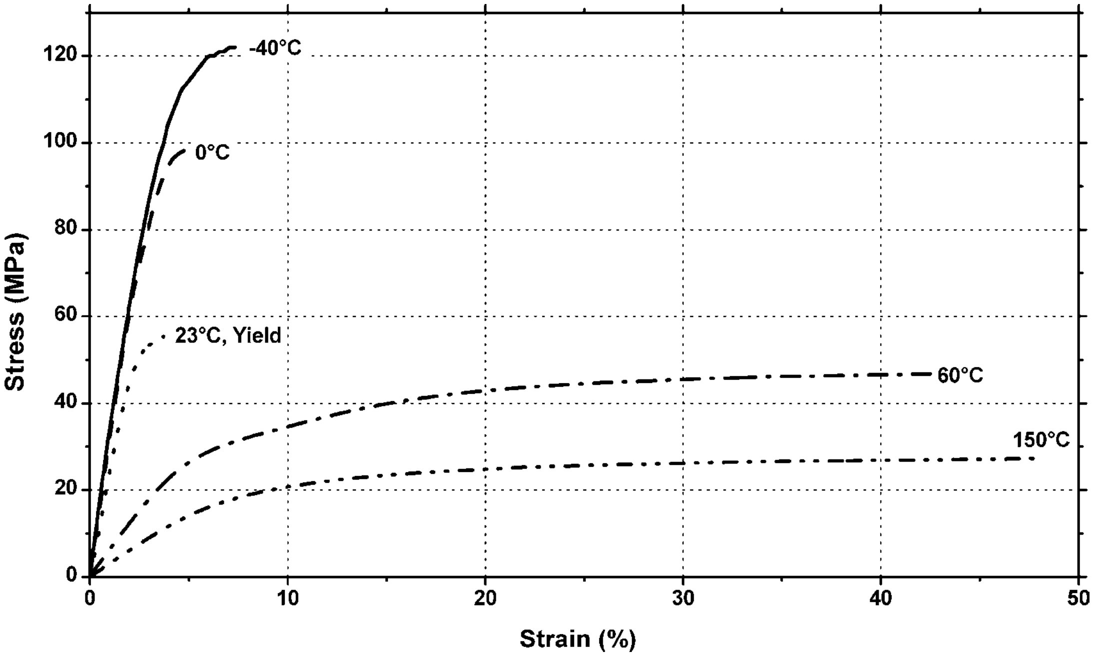


Figure 6.84. Stress vs. strain at various temperatures for DuPont Zytel® 101L NC010—lubricated, general purpose PA66 resin (DAM).

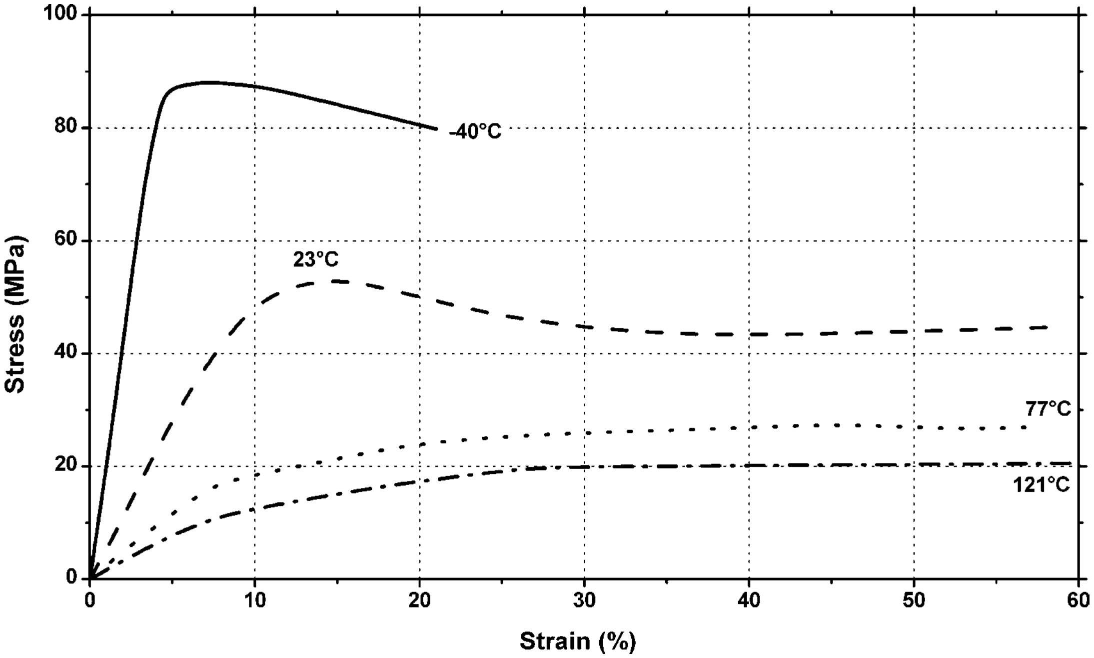


Figure 6.85. Stress vs. strain at various temperatures for DuPont Zytel® 408—toughened PA66 resin (conditioned at 50% RH).

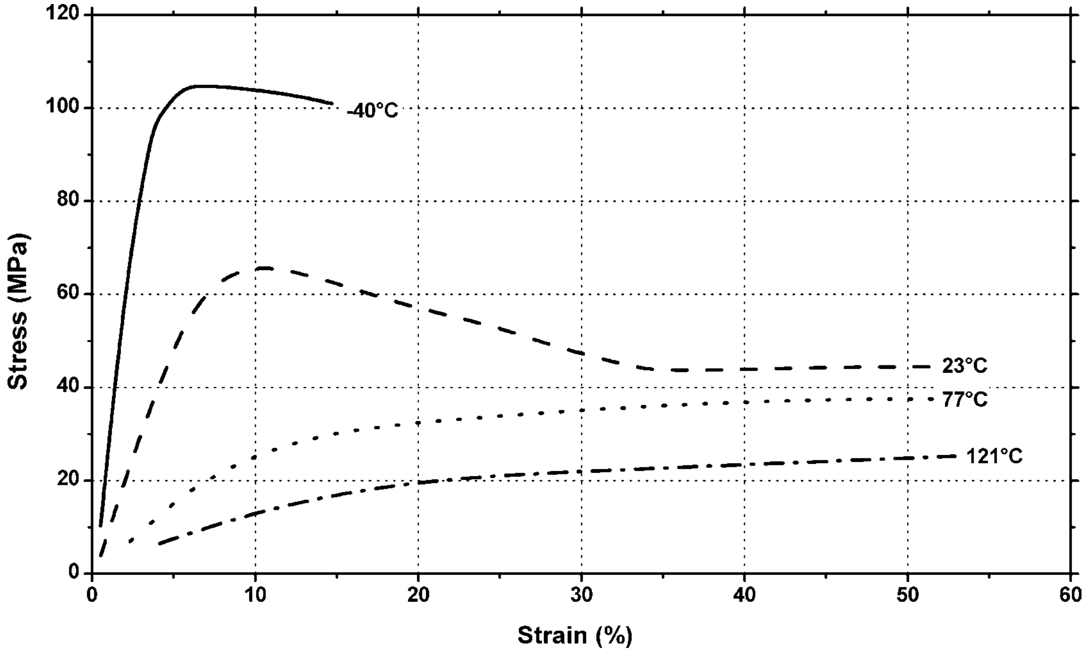


Figure 6.86. Stress vs. strain at various temperatures for DuPont Zytel® 408—toughened PA66 resin (DAM).

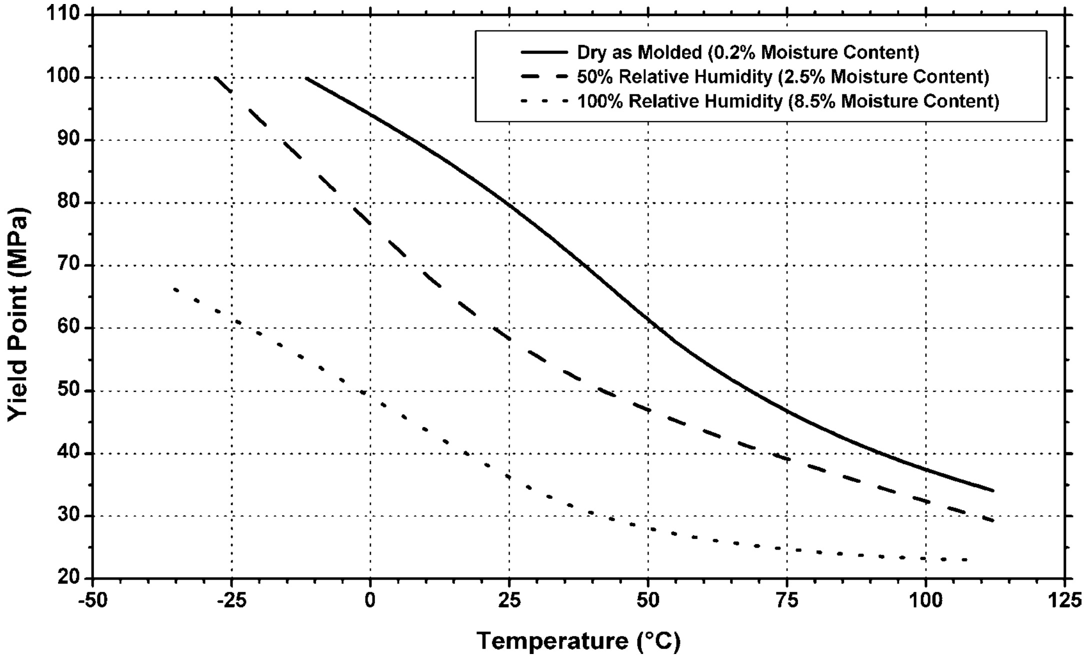


Figure 6.87. Yield point vs. temperature and moisture content for DuPont Zytel® 101—general purpose PA66 resin.

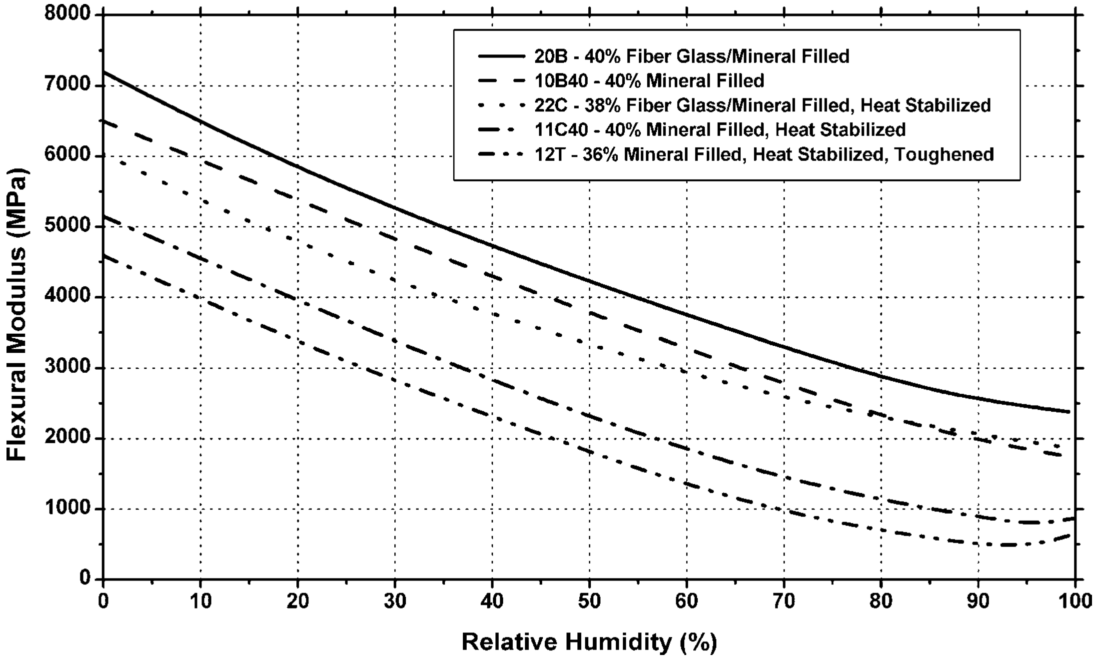


Figure 6.88. Flexural modulus vs. relative humidity at 23°C for several DuPont Minlon® mineral filled PA66 resins.

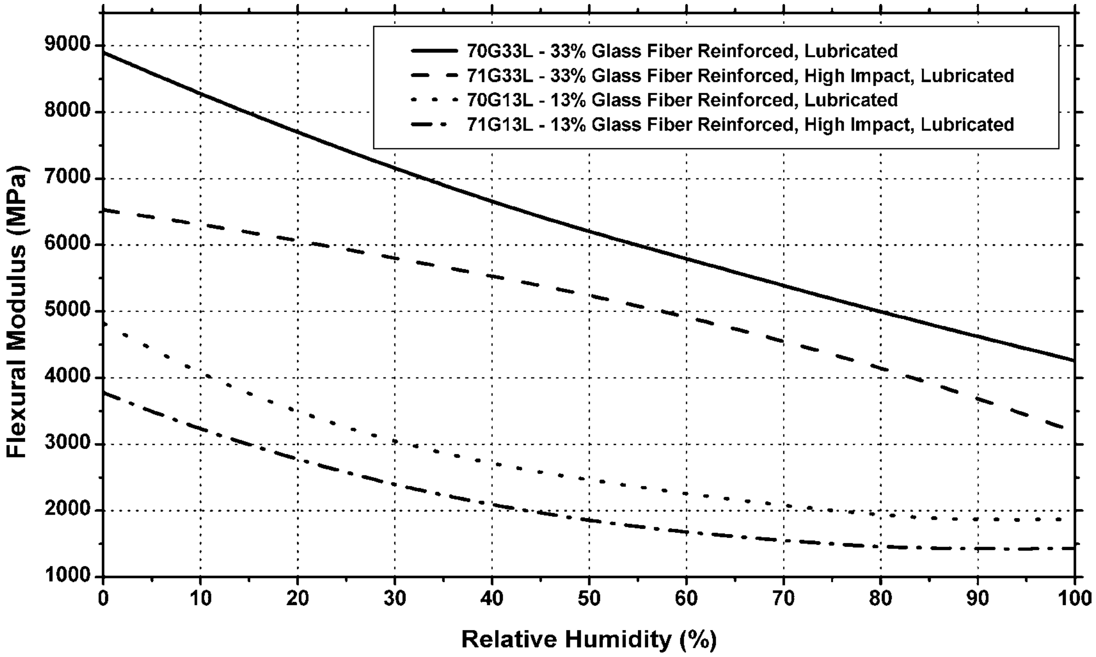


Figure 6.89. Flexural modulus vs. relative humidity at 23°C for several DuPont Zytel® glass filled PA66 resins.

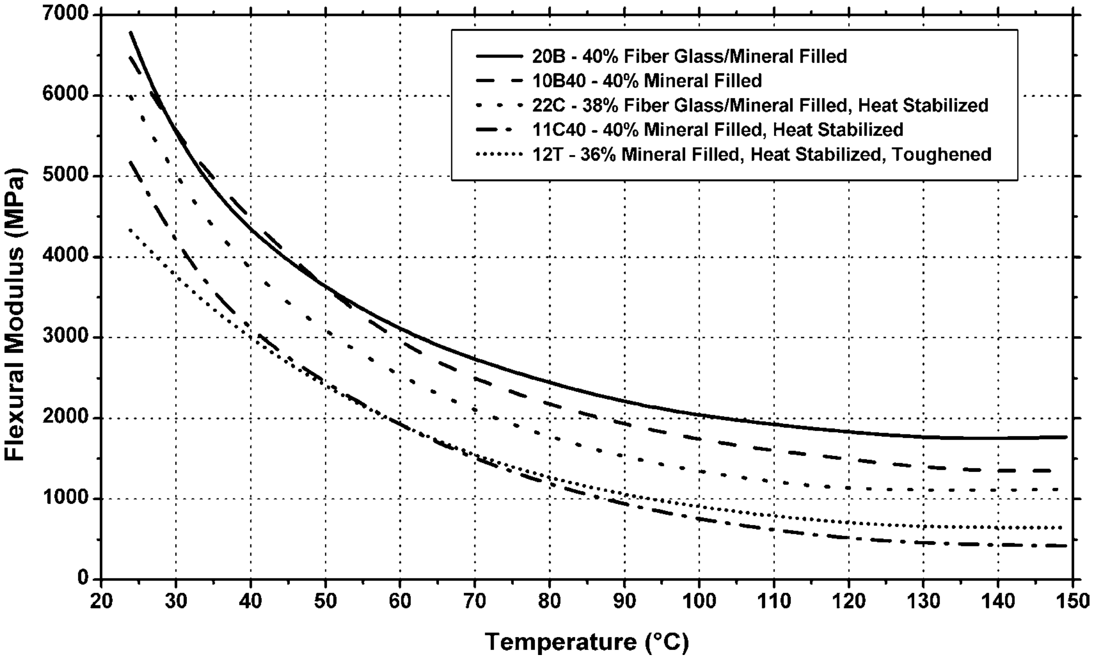


Figure 6.90. Flexural modulus vs. temperature for DuPont Minlon® mineral filled PA66 resins.

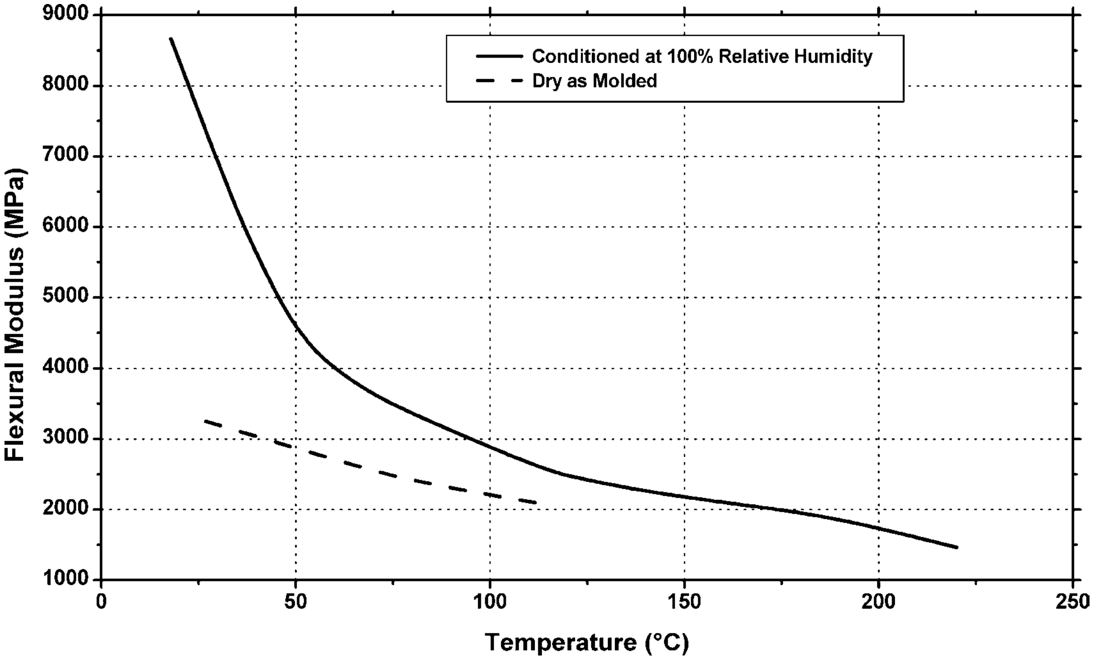


Figure 6.91. Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® 71G—33L, toughened, 33% chopped glass filled, lubricated PA66 resin.

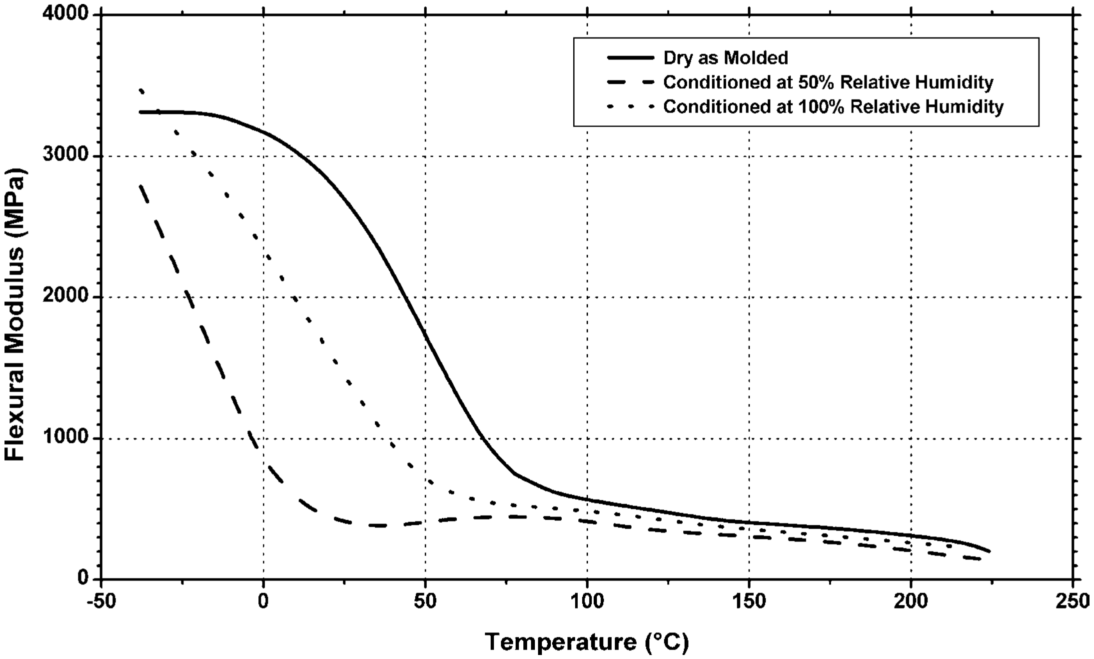


Figure 6.92. Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® 101 general purpose PA66 resin.

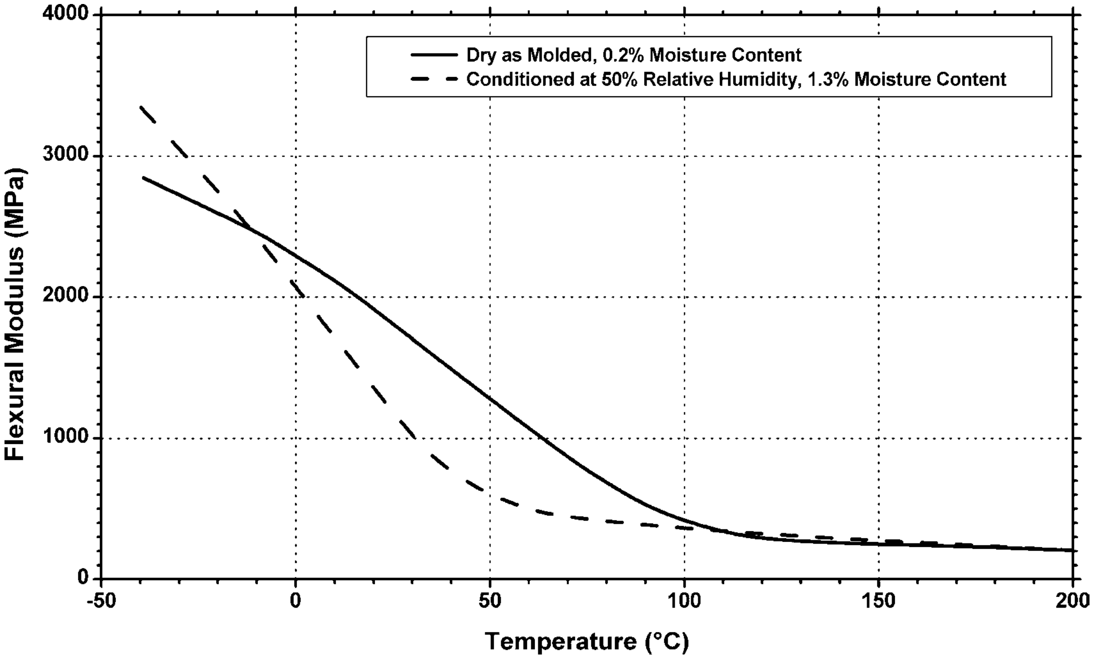


Figure 6.93. Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® 408, toughened PA66 resin.

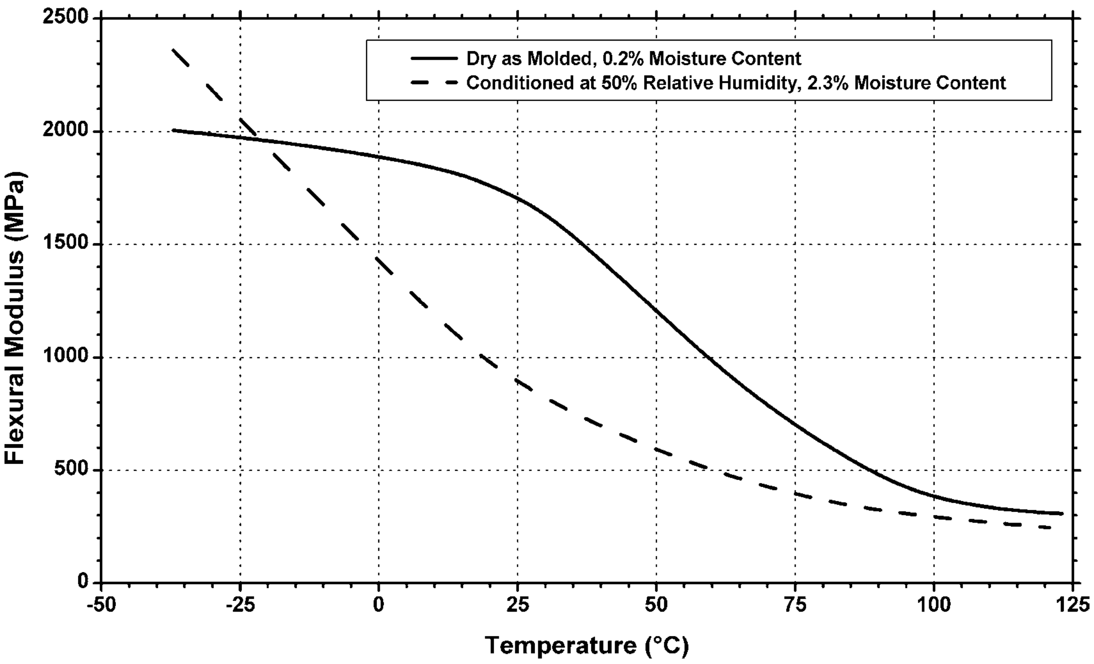


Figure 6.94. Flexural modulus vs. temperature at different humidity levels for DuPont Zytel® ST-801, super tough PA66 resin.

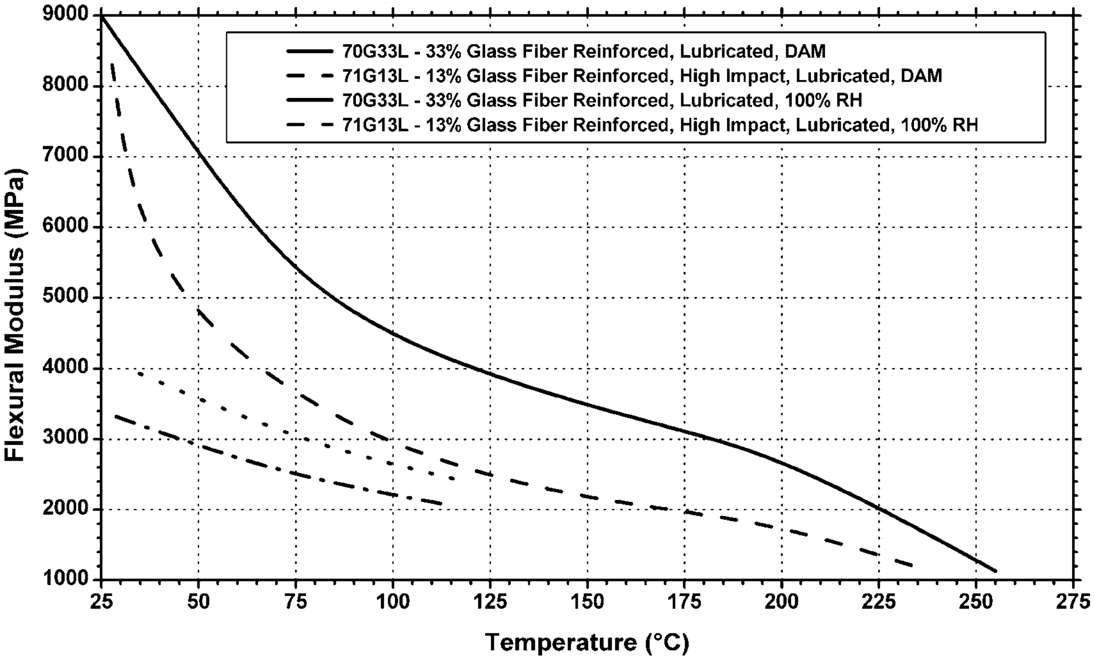


Figure 6.95. Flexural modulus vs. temperature and relative humidity for several DuPont Zytel® PA66 resins.

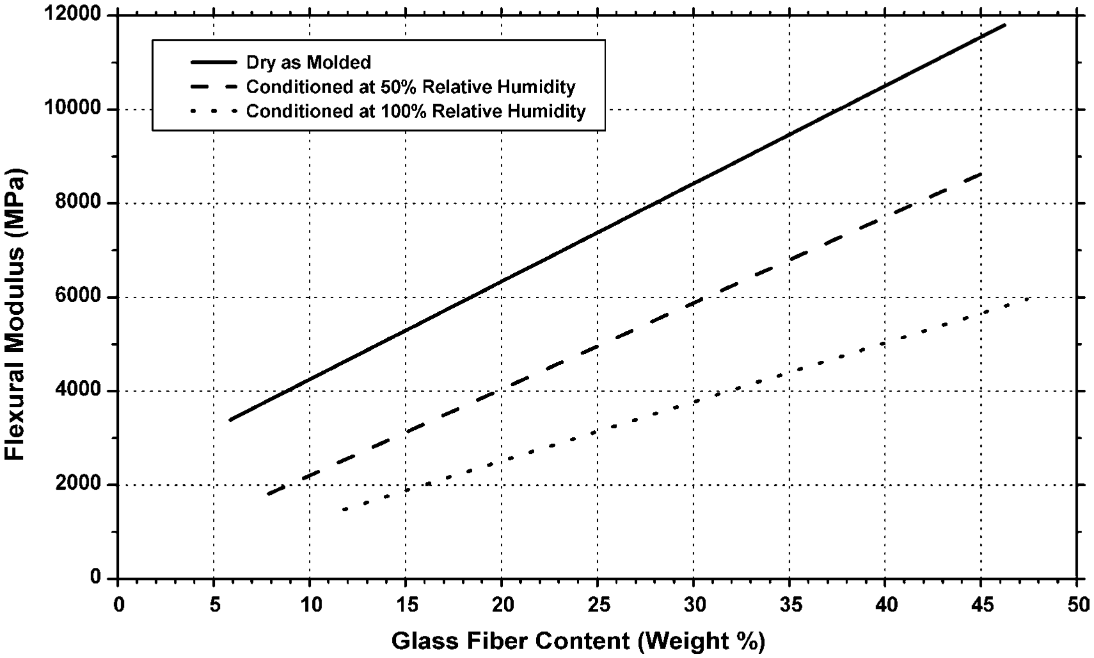


Figure 6.96. Flexural modulus vs. fiber glass content at 23°C for several DuPont Zytel® 70G series PA66 resins.

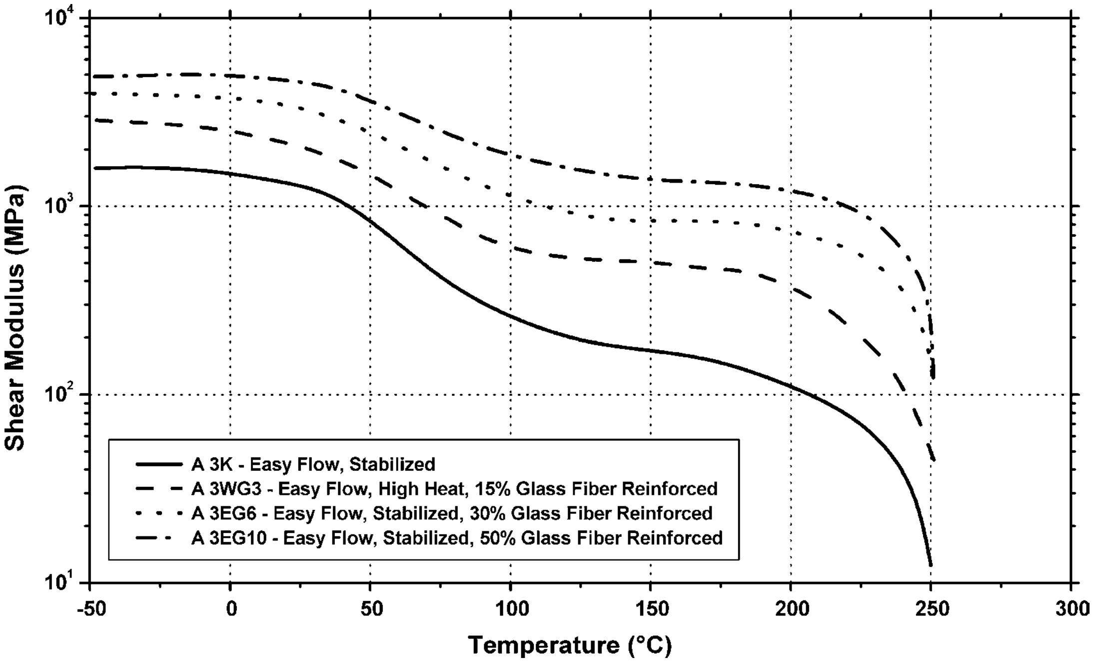


Figure 6.97. Shear modulus vs. temperature for several BASF Ultramid® PA66 resins.

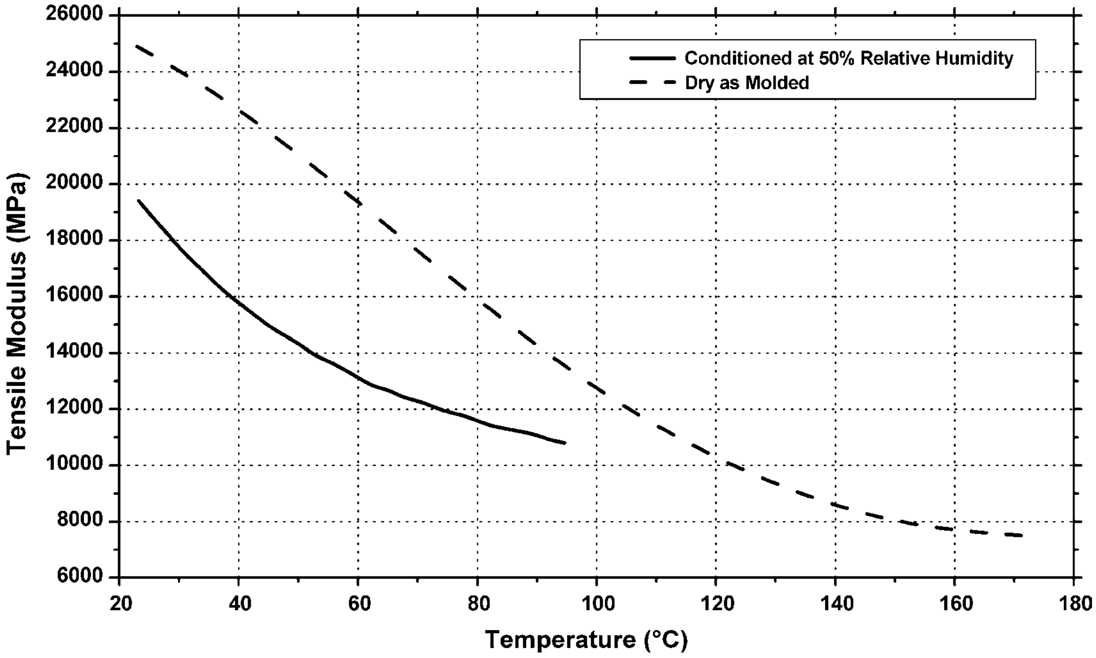


Figure 6.98. Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp® RC-1006—electrically conductive, 30% carbon fiber filled PA66 resin.

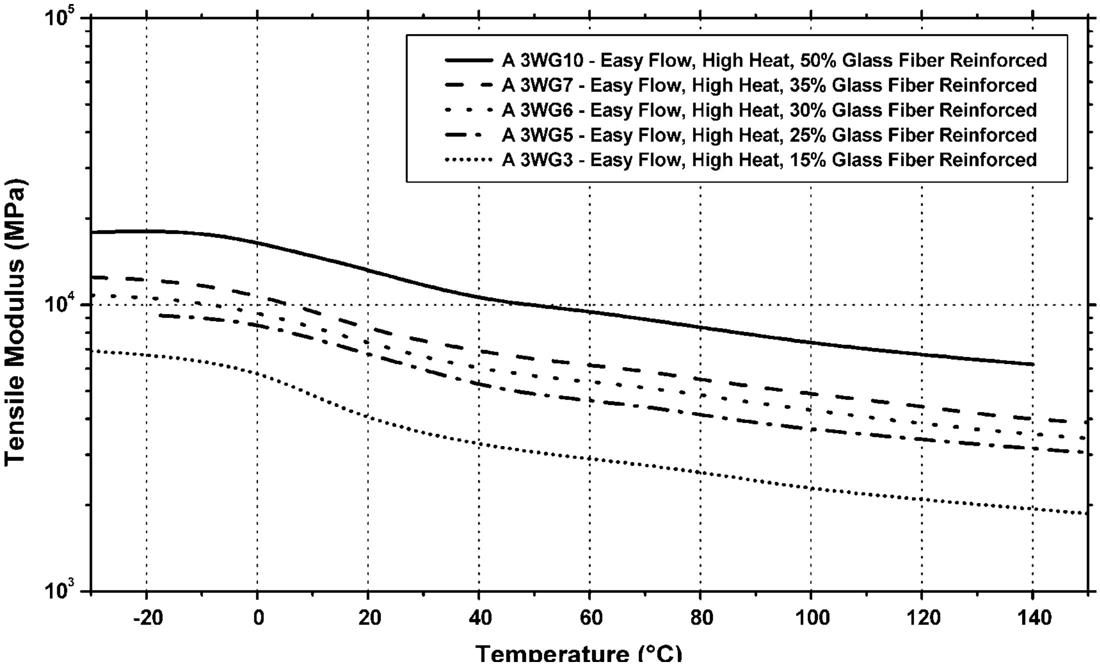


Figure 6.99. Tensile modulus vs. temperature for several BASF Ultramid® PA66 resins (conditioned at 50% relative humidity).

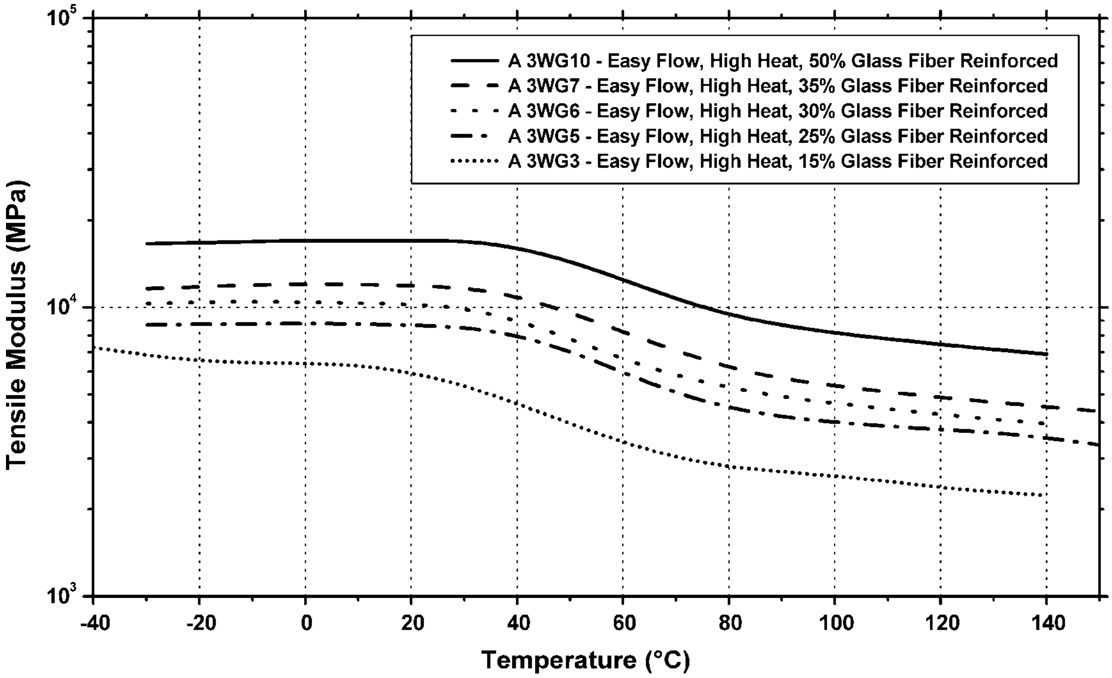


Figure 6.100. Tensile modulus vs. temperature for several BASF Ultramid® PA66 resins (DAM).

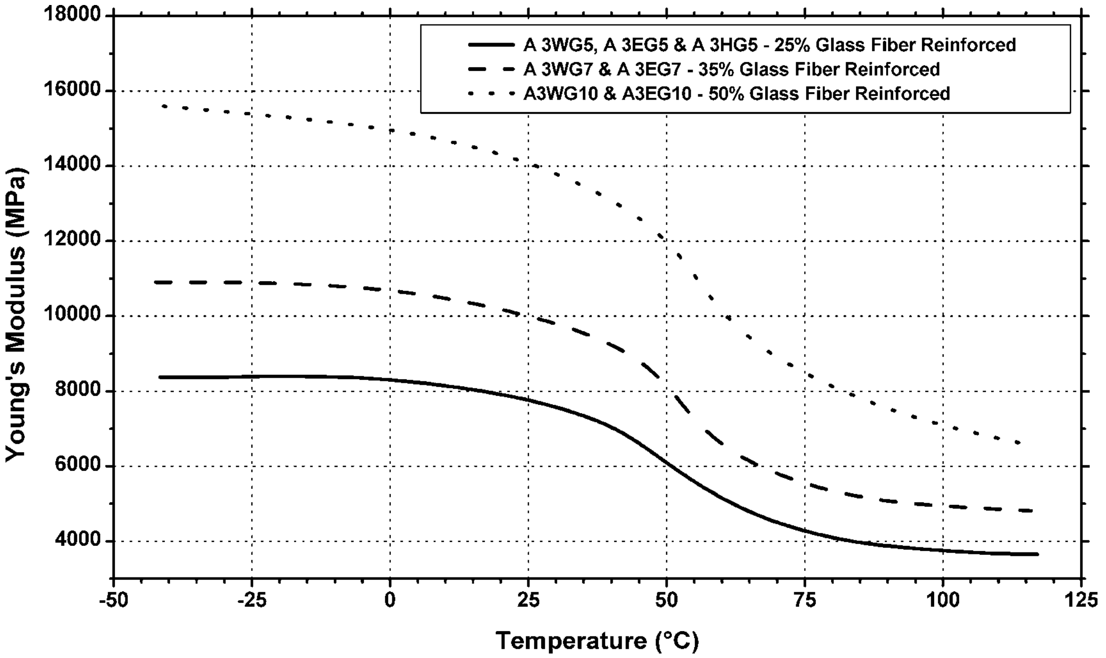


Figure 6.101. Young’s modulus vs. temperature for several BASF Ultramid® PA66 resins (DAM).

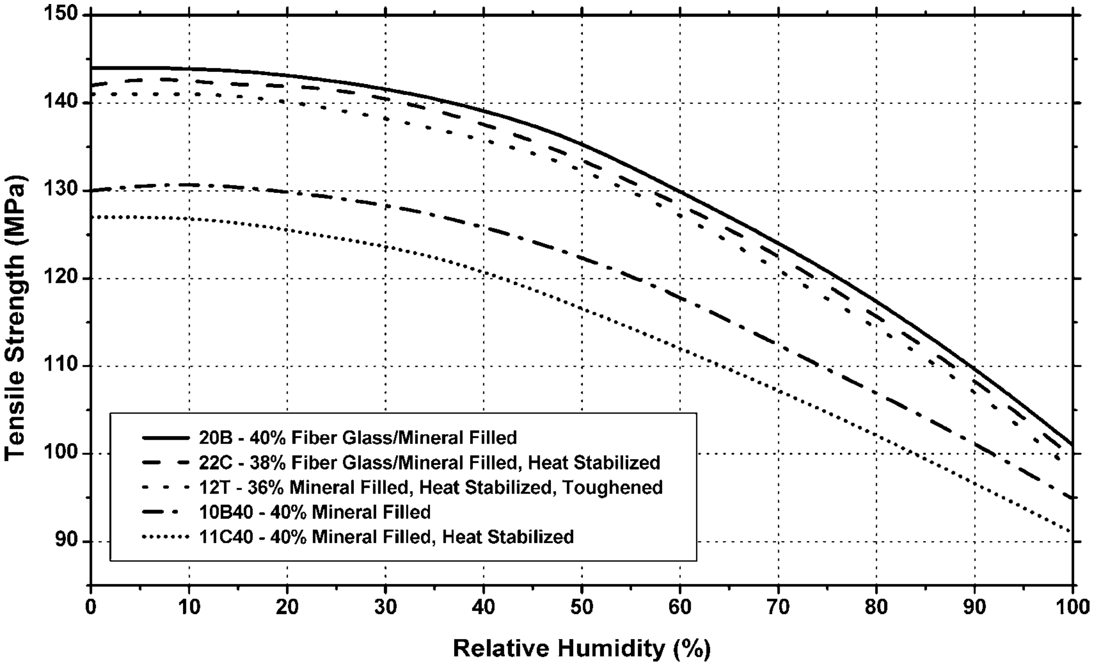


Figure 6.102. Tensile strength vs. humidity at –40°C for several DuPont Minlon® PA66 resins.

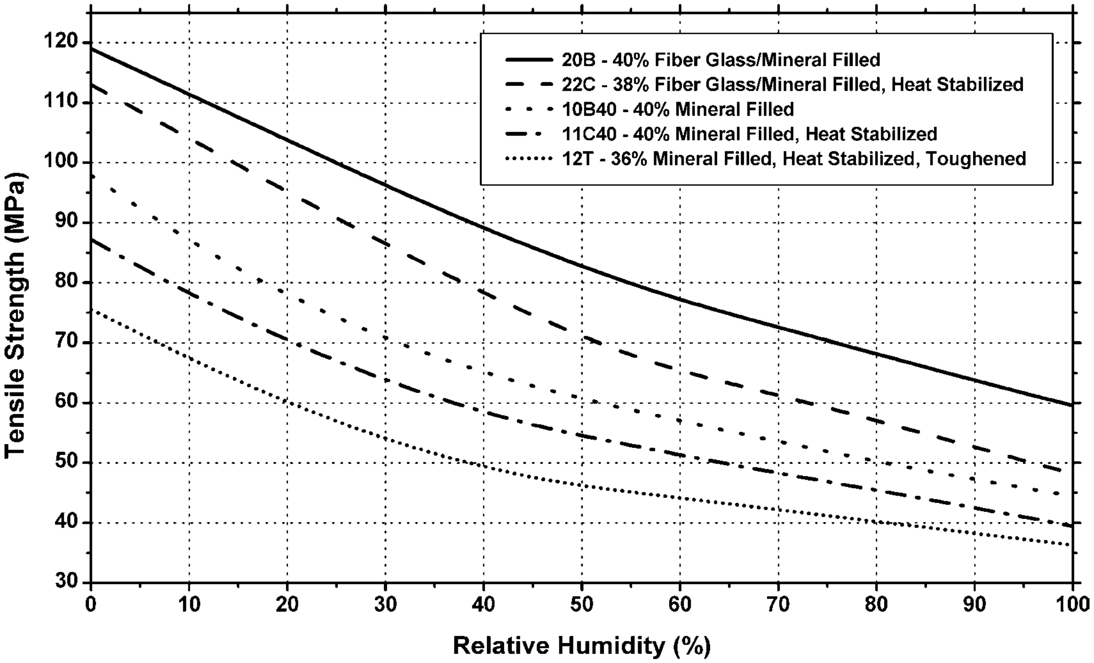


Figure 6.103. Tensile strength vs. humidity at 23°C for several DuPont Minlon® PA66 resins.

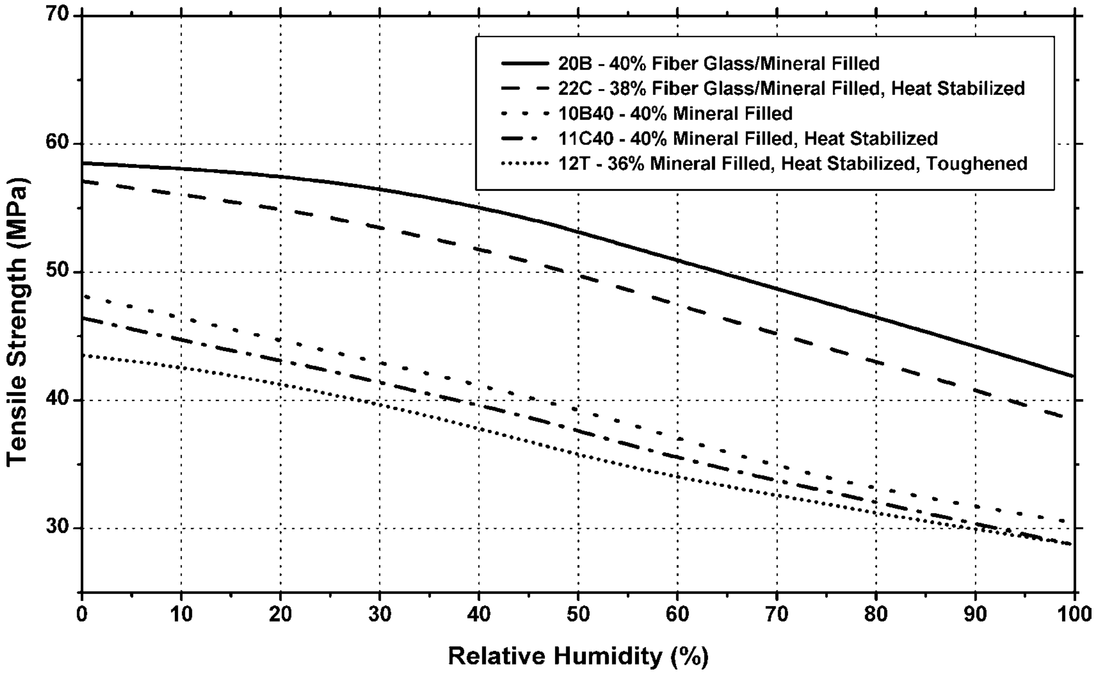


Figure 6.104. Tensile strength vs. humidity at 93°C for several DuPont Minlon® PA66 resins.

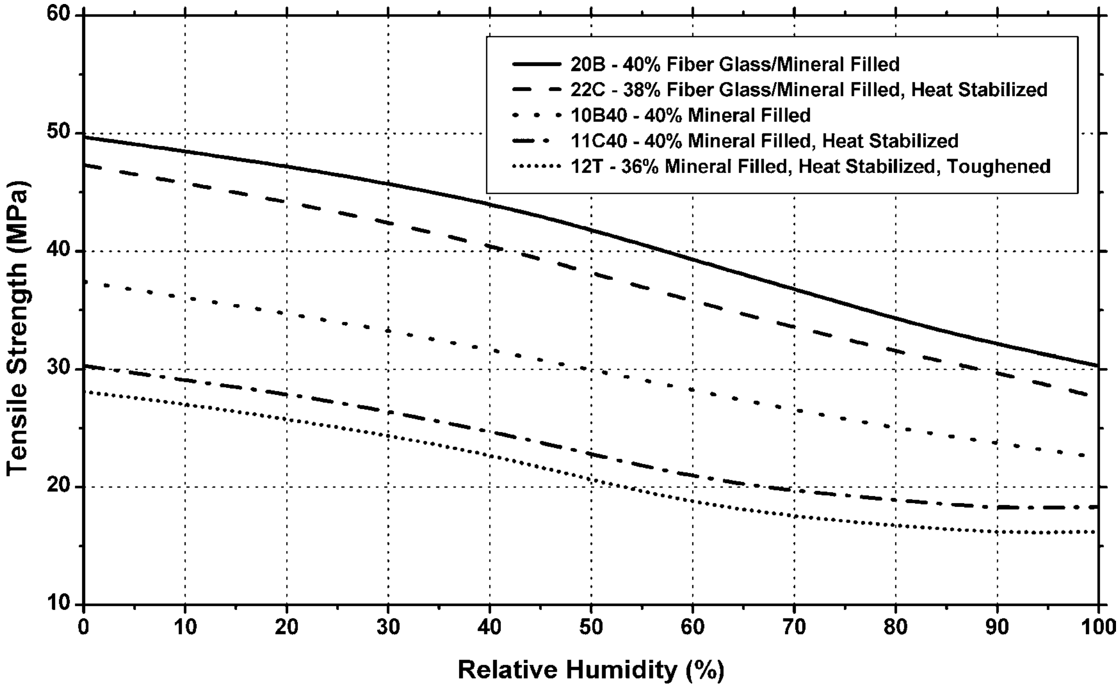


Figure 6.105. Tensile strength vs. humidity at 149°C for several DuPont Minlon® PA66 resins.

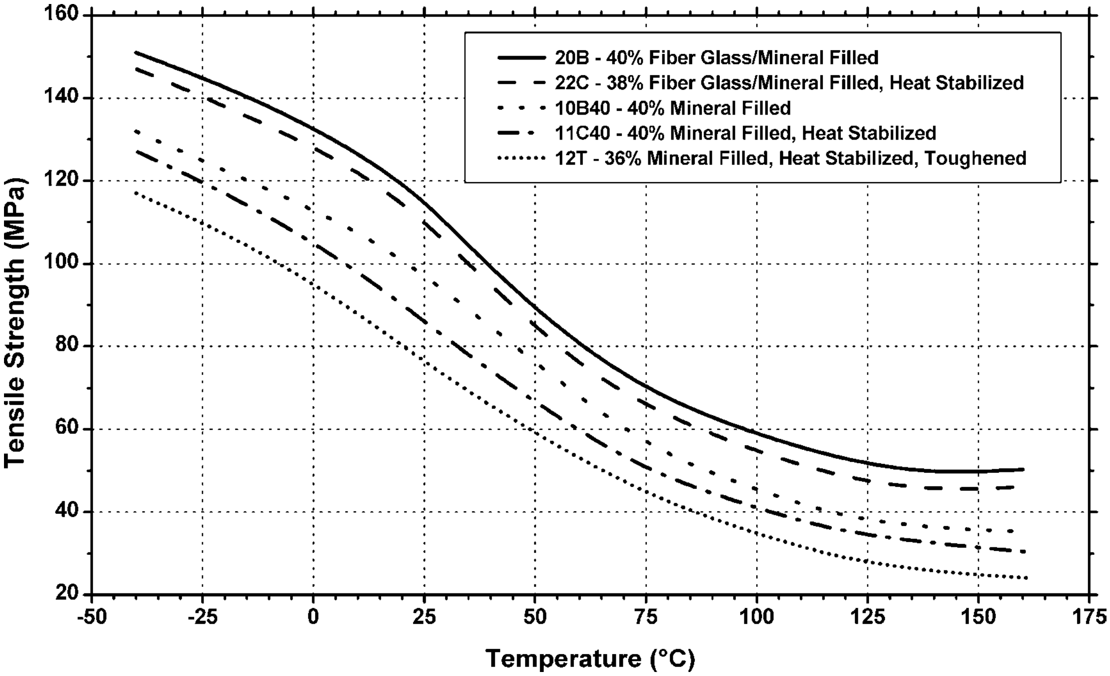


Figure 6.106. Tensile strength vs. temperature for several DuPont Minlon® PA66 resins.

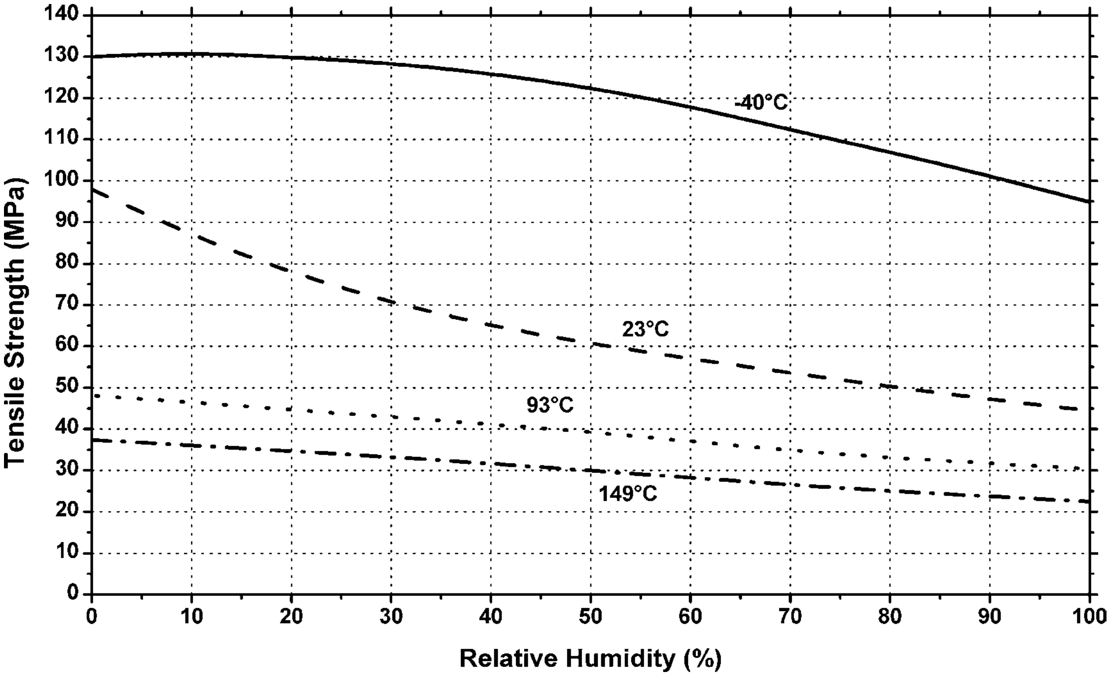


Figure 6.107. Tensile strength vs. humidity at various temperatures for DuPont Minlon® 10B40—40% mineral filled, stiffened PA66 resin.

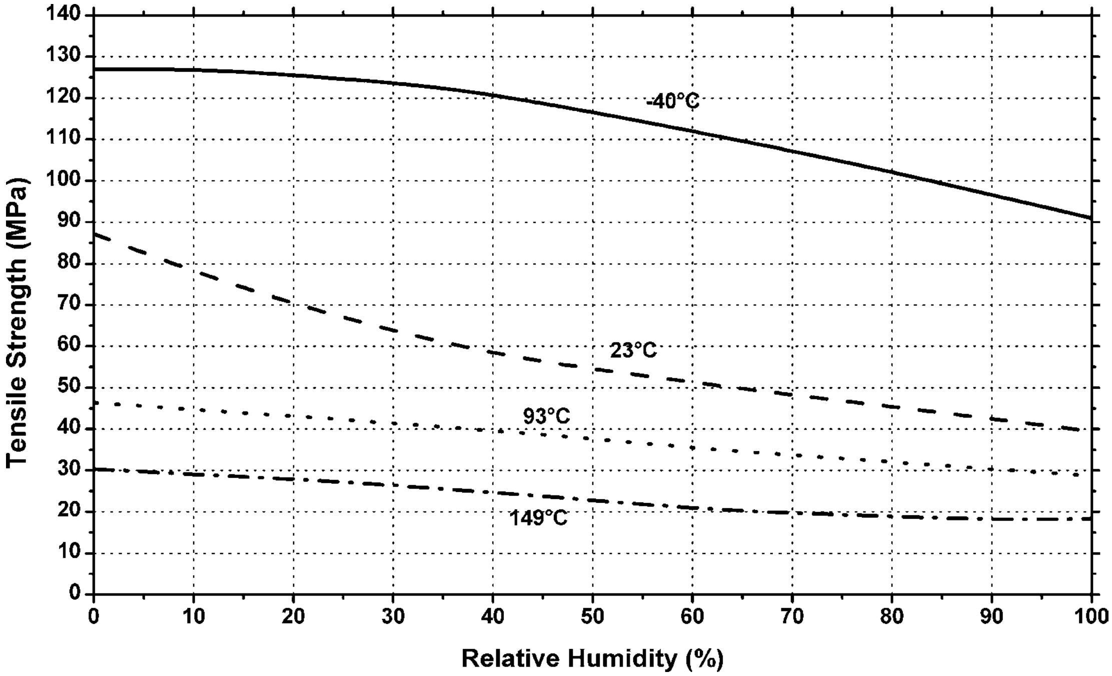


Figure 6.108. Tensile strength vs. humidity at various temperatures for DuPont Minlon® 11C40—40% mineral filled, high impact PA66 resin.

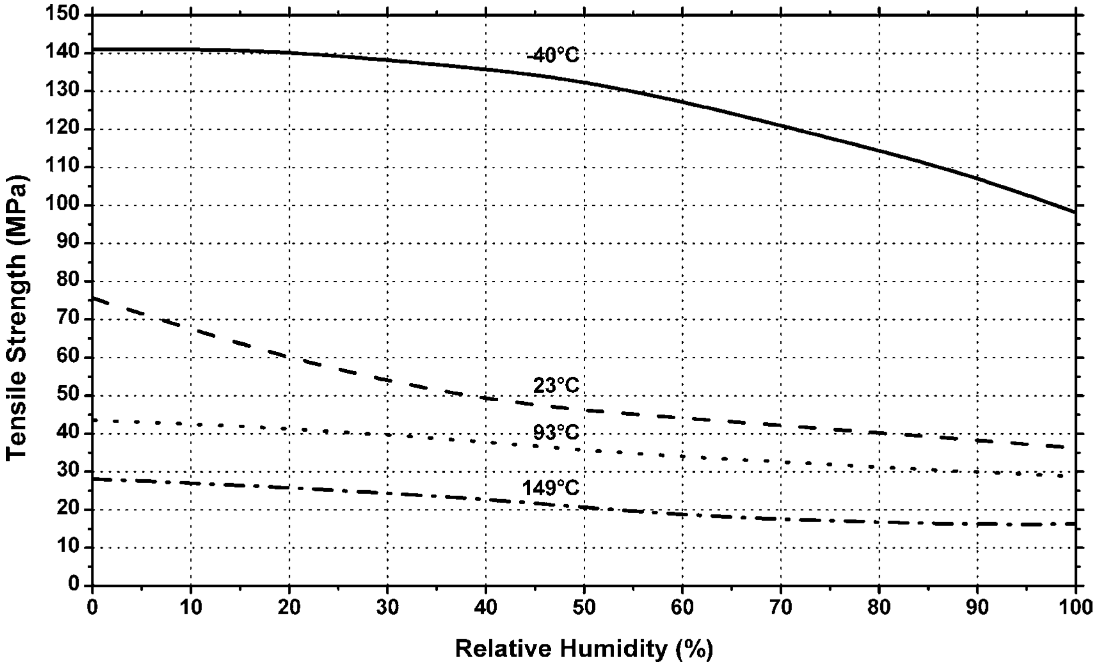


Figure 6.109. Tensile strength vs. humidity at various temperatures for DuPont Minlon® 12T—40% mineral filled, super impact PA66 resin.

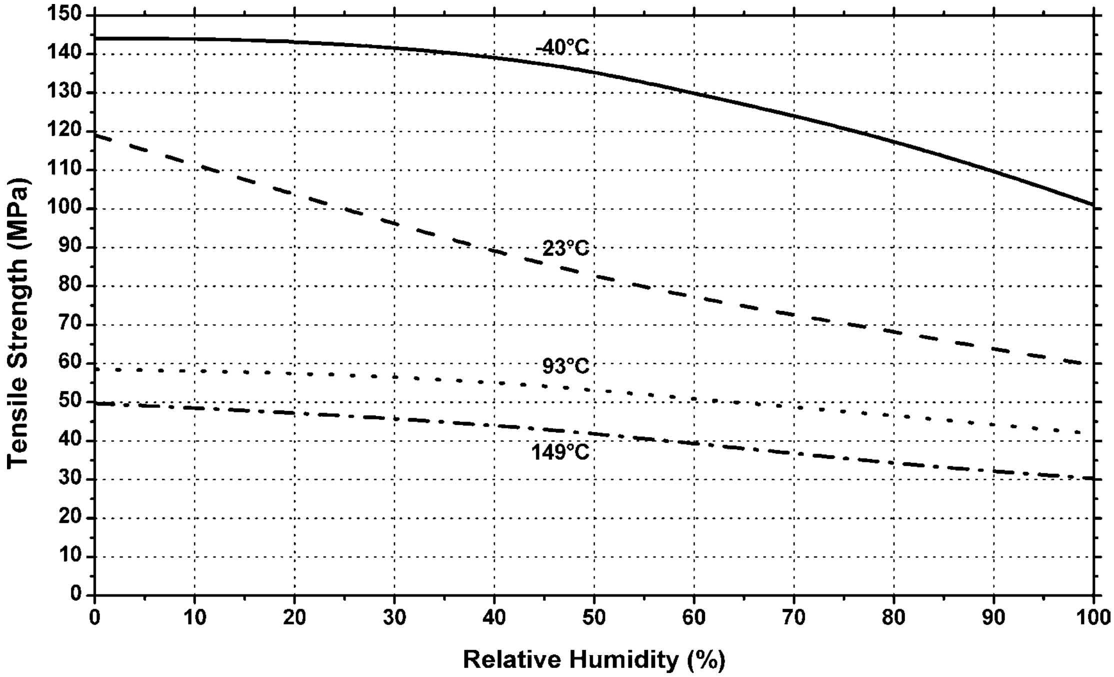


Figure 6.110. Tensile strength vs. humidity at various temperatures for DuPont Minlon® 20B—40% glass fiber/mineral filled, stiffened, strength high PA66 resin.

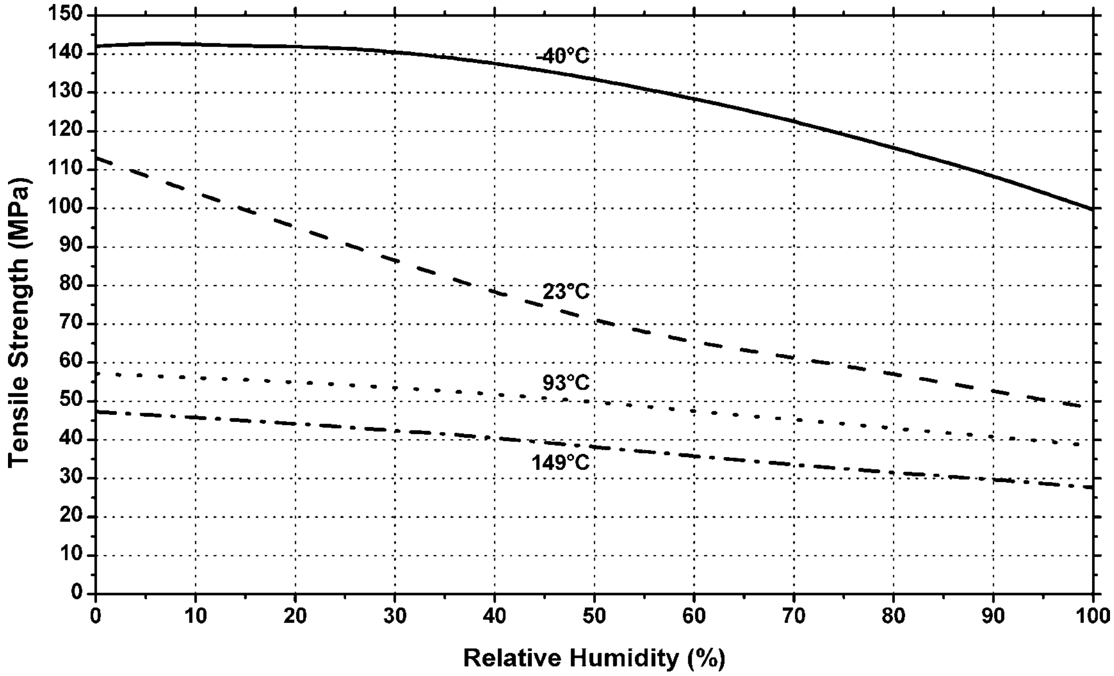


Figure 6.111. Tensile strength vs. humidity at various temperatures for DuPont Minlon® 22C—40% glass fiber/mineral filled, low warpage high PA66 resin.

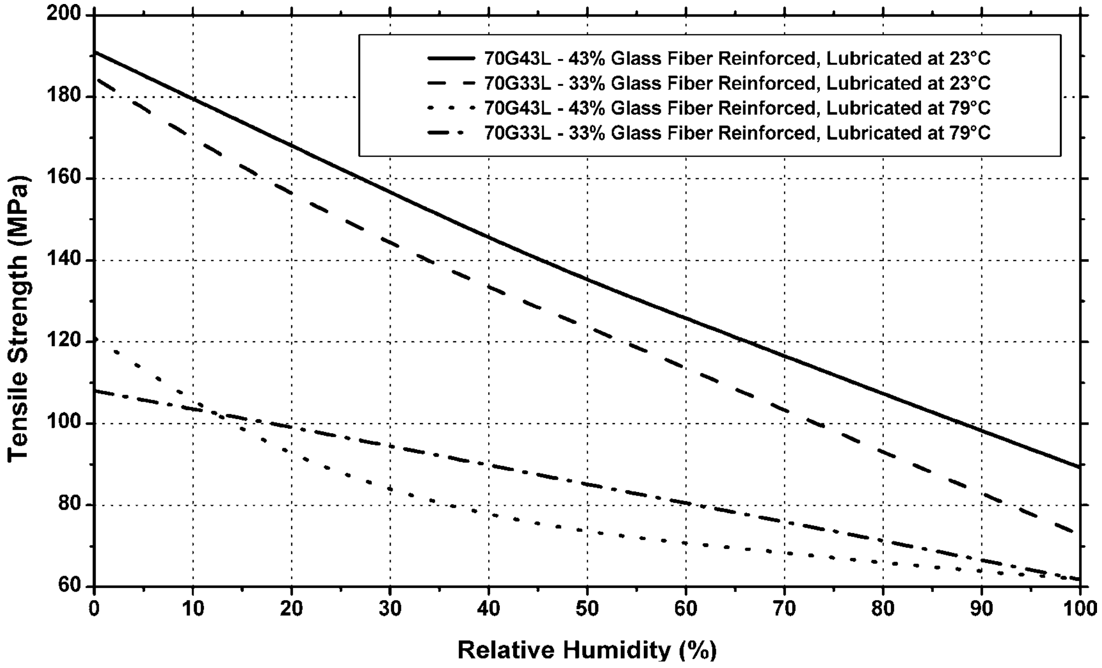


Figure 6.112. Tensile strength vs. humidity at two temperatures for two DuPont Zytel® glass fiber filled PA66 resins.

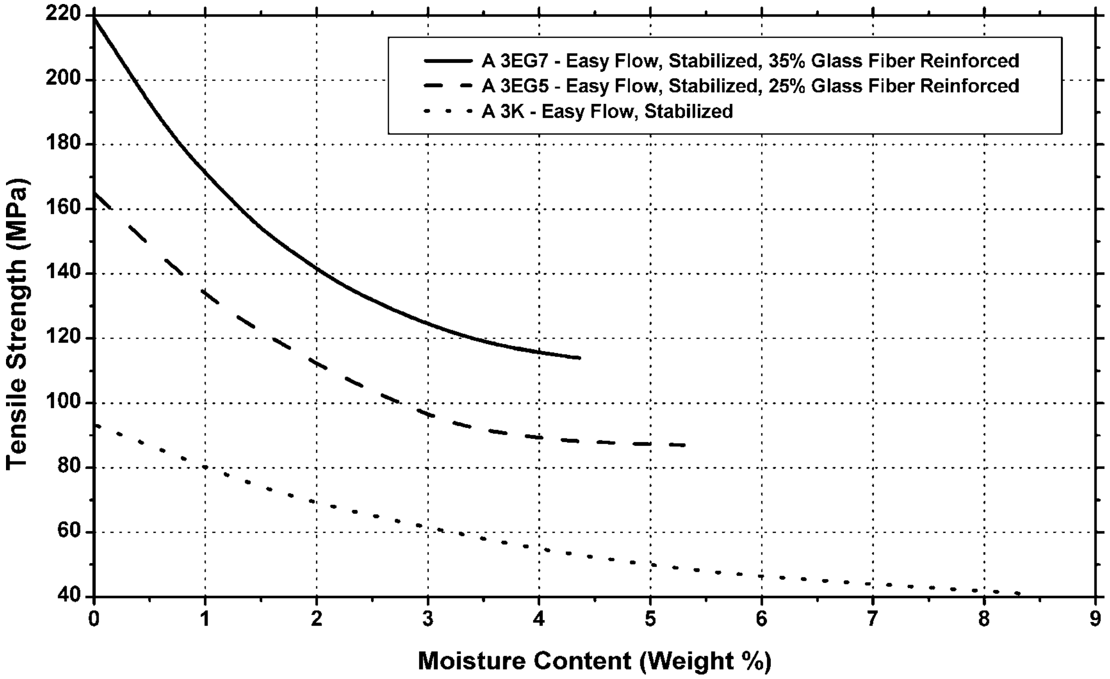


Figure 6.113. Tensile strength vs. moisture content for several BASF Ultramid® PA66 resins.

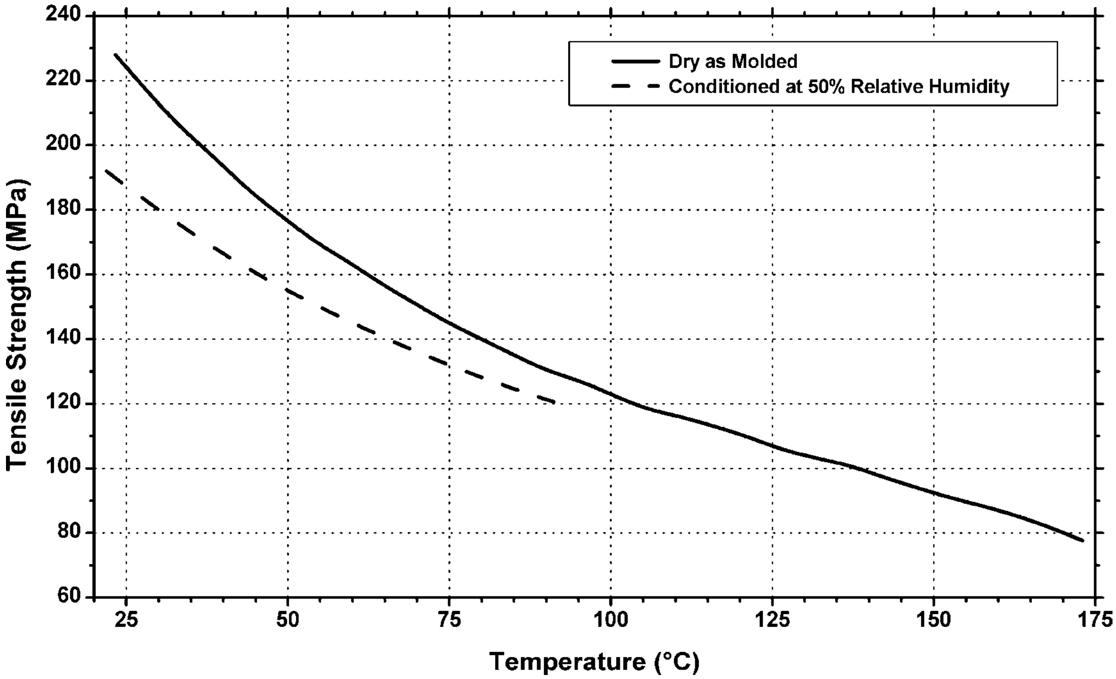


Figure 6.114. Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp® RC-1006—electrically conductive, 30% carbon fiber filled PA66 resin.

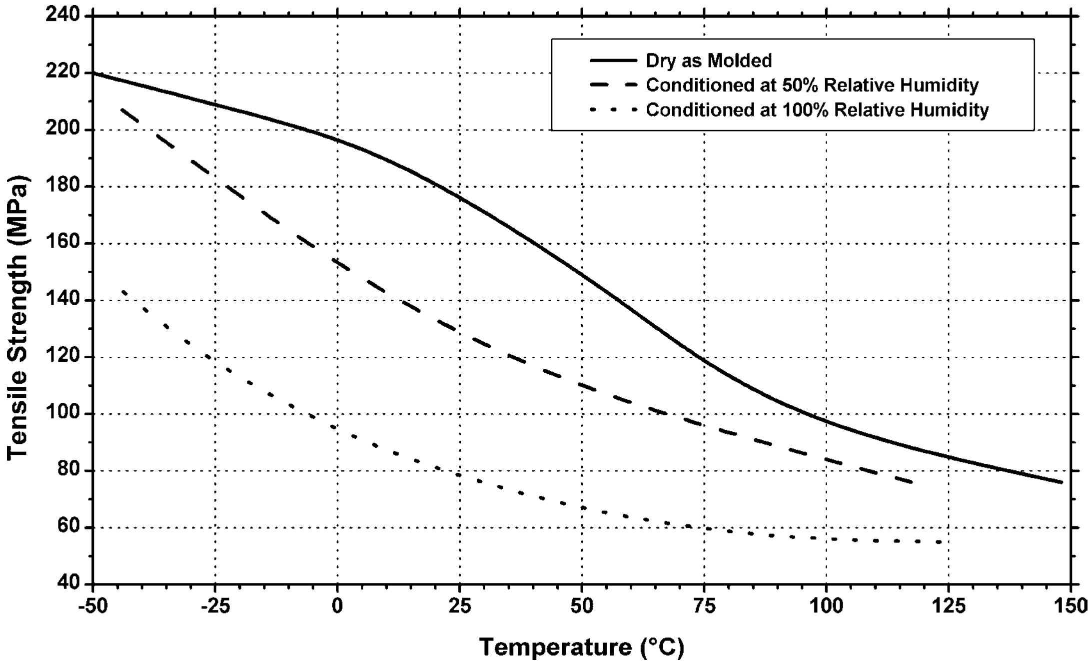


Figure 6.115. Tensile strength vs. temperature and moisture content for DuPont Zytel® 70G-33L—33% glass filled, lubricated PA66 resin.

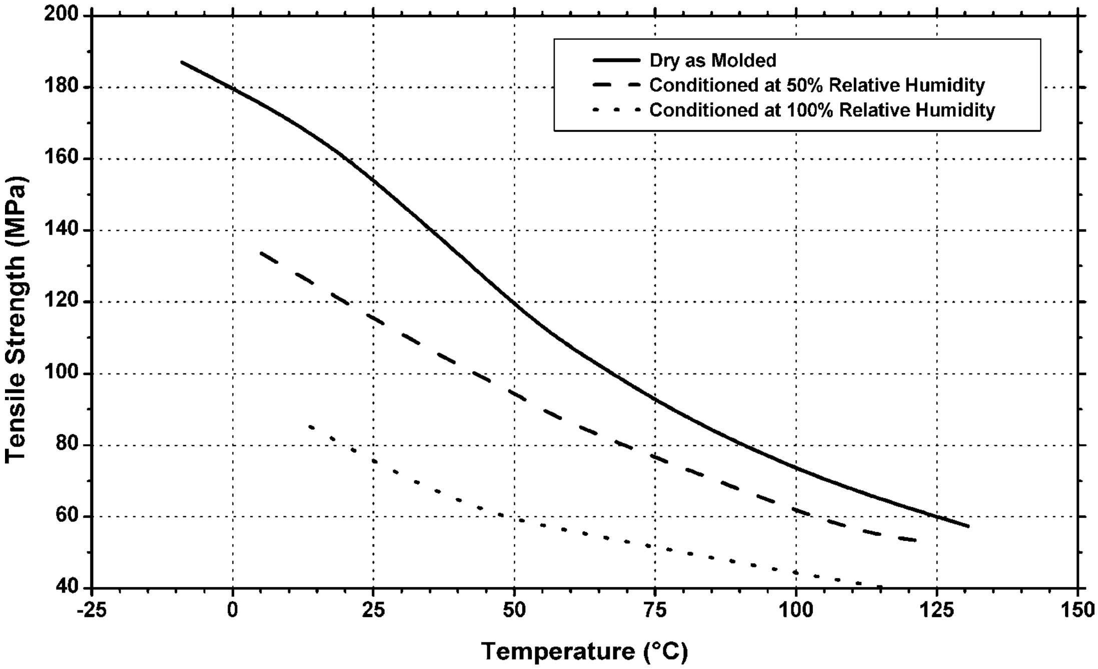


Figure 6.116. Tensile strength vs. temperature and moisture content for DuPont Zytel® 71G-33L—33% glass filled, toughened lubricated PA66 resin.

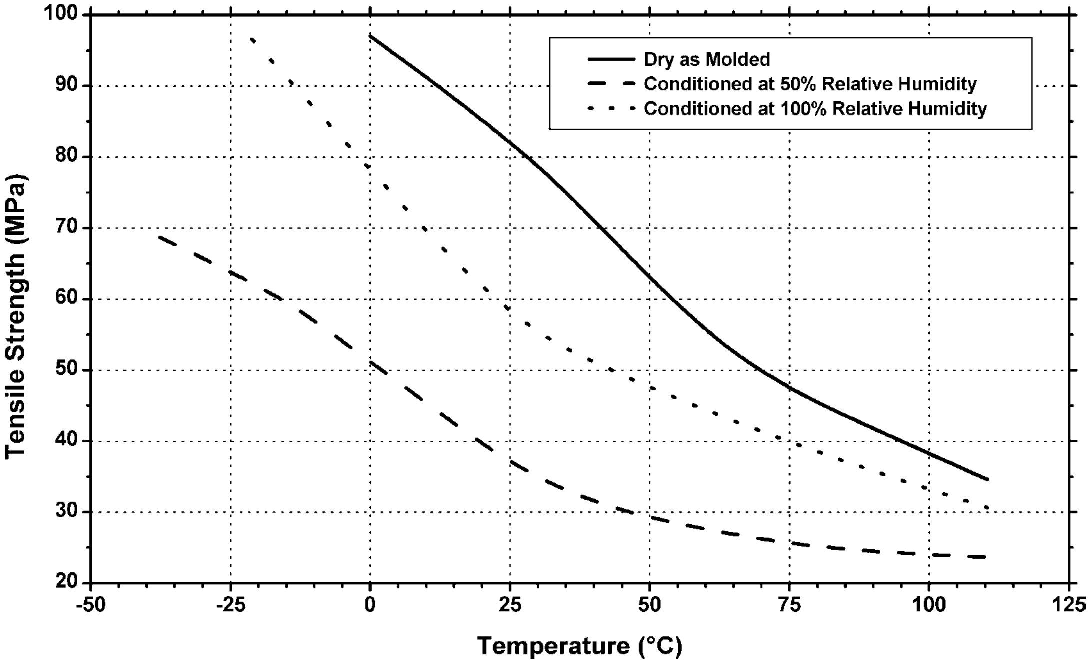


Figure 6.117. Tensile strength vs. temperature and moisture content for DuPont Zytel® 101—general purpose PA66 resin.

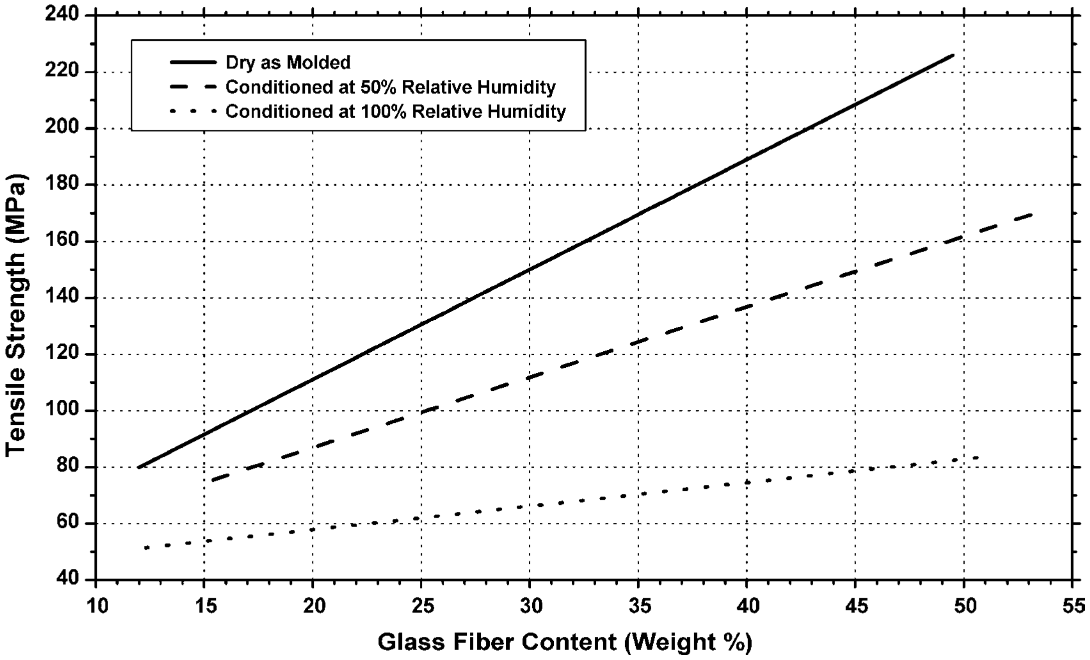


Figure 6.118. Tensile strength vs. fiber glass content of Zytel® 70G series PA66 resins.

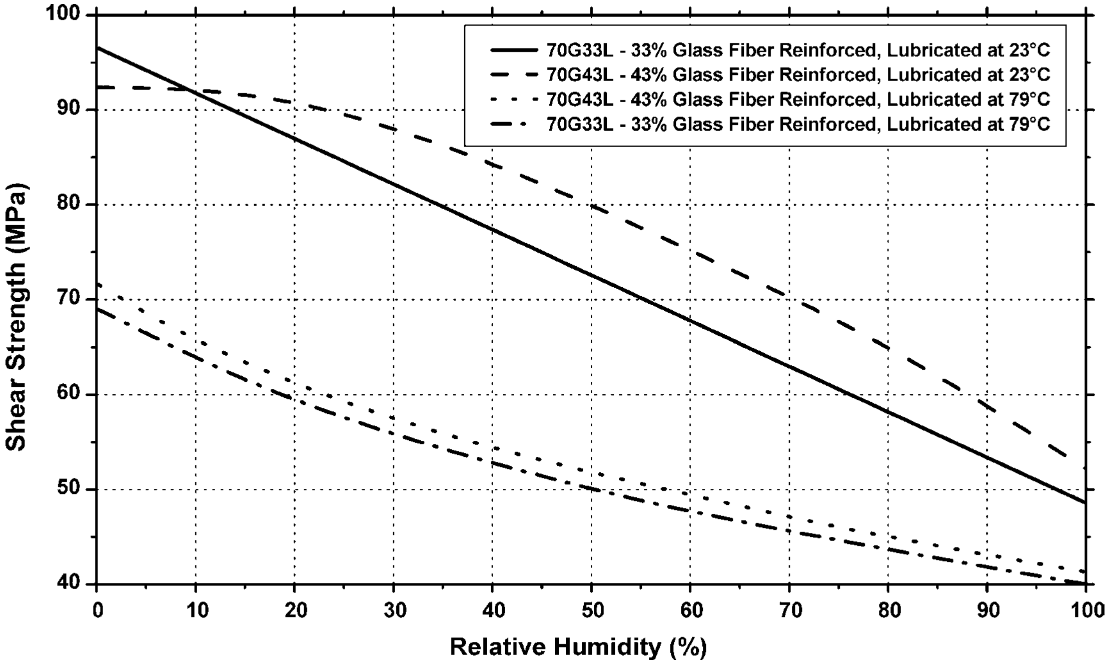


Figure 6.119. Shear strength vs. humidity at two temperatures for two DuPont Zytel® PA66 resins.

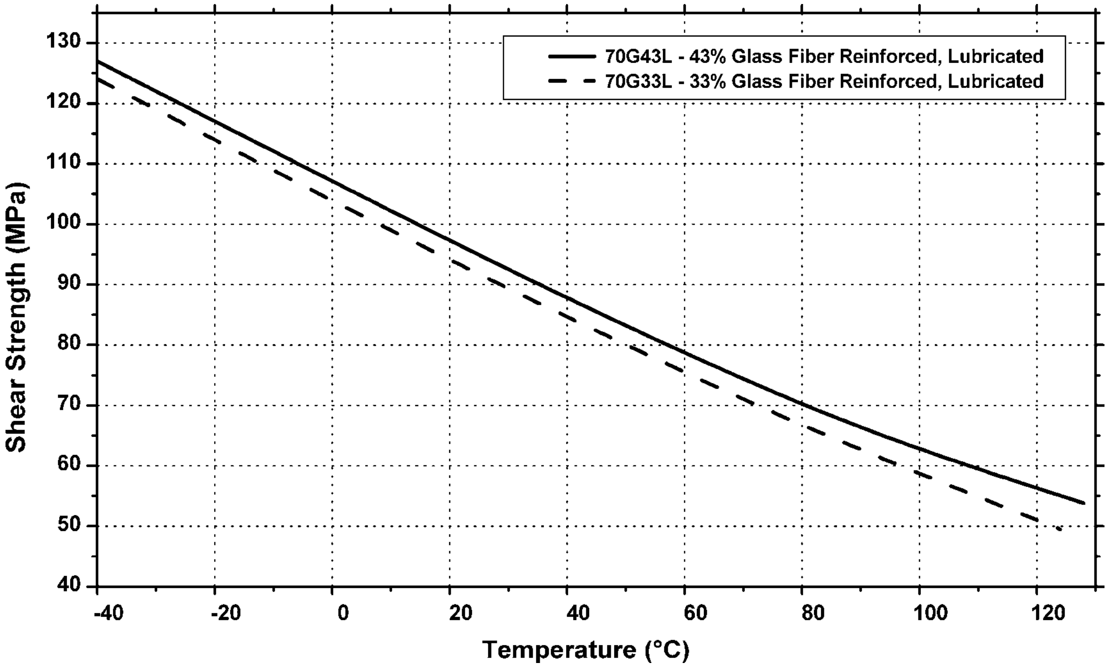


Figure 6.120. Shear strength vs. temperature for two DuPont Zytel® PA66 resins (DAM).

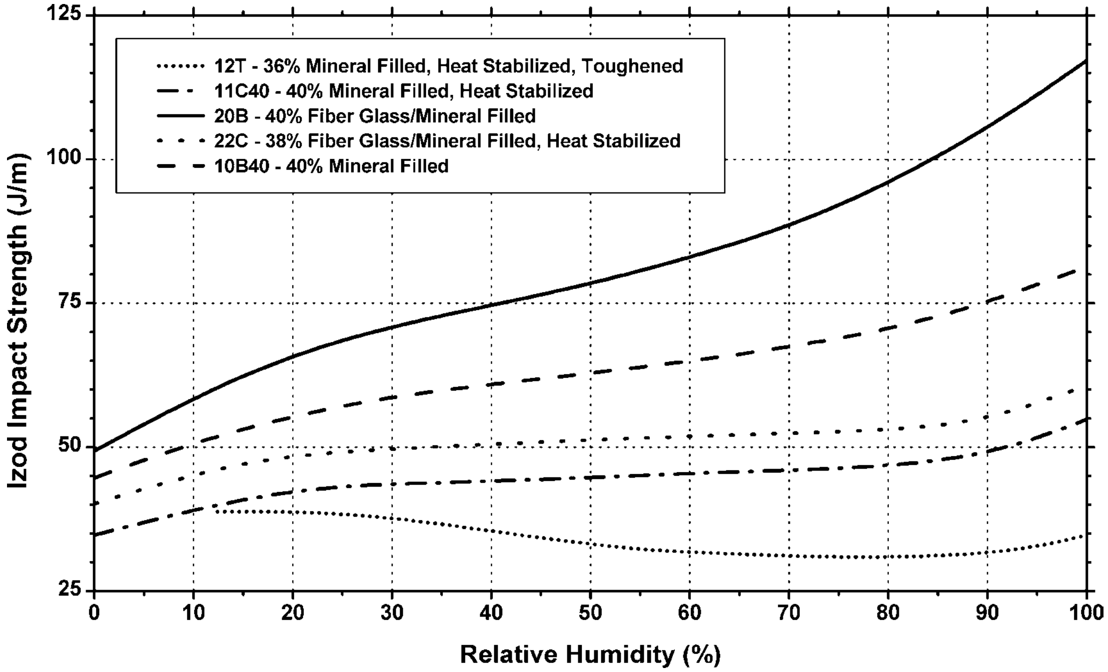


Figure 6.121. Izod impact strength vs. humidity at –40°C for several DuPont Minlon® PA66 resins.

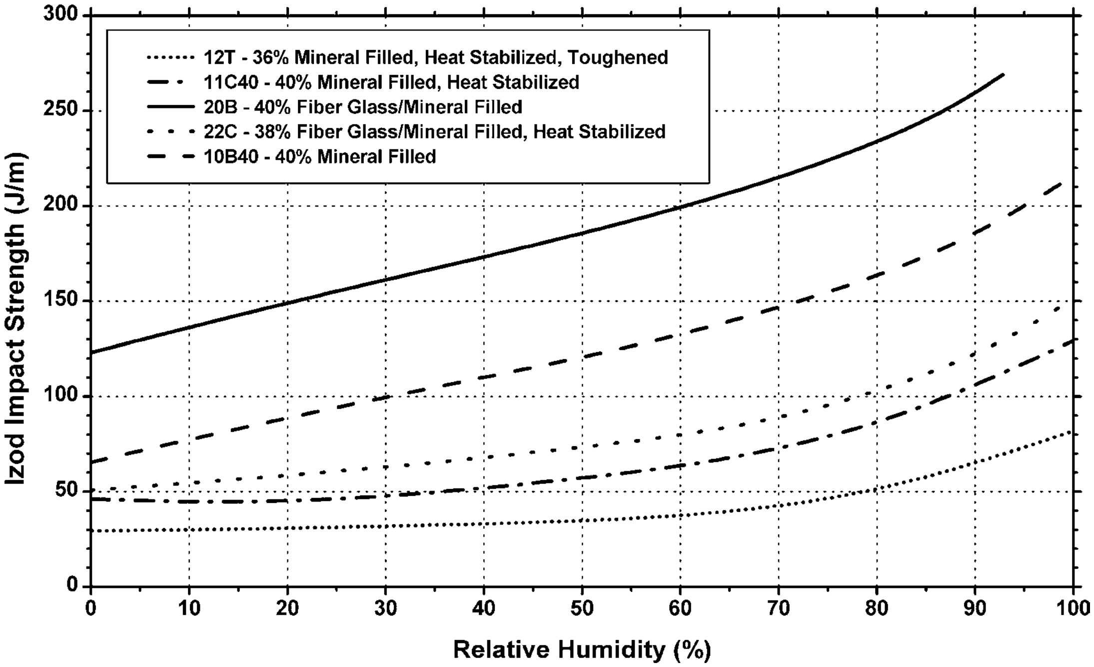


Figure 6.122. Izod impact strength vs. humidity at 23°C for several DuPont Minlon® PA66 resins.

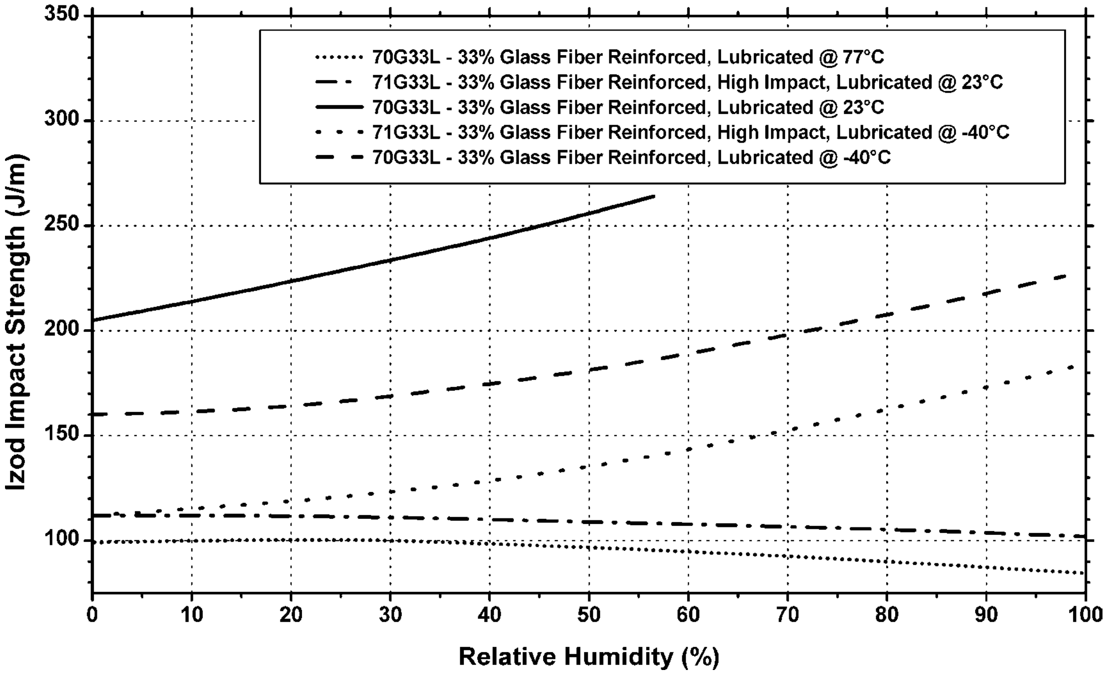


Figure 6.123. Izod impact strength vs. humidity and temperture for two DuPont Zytel® glass filled PA66 resins.

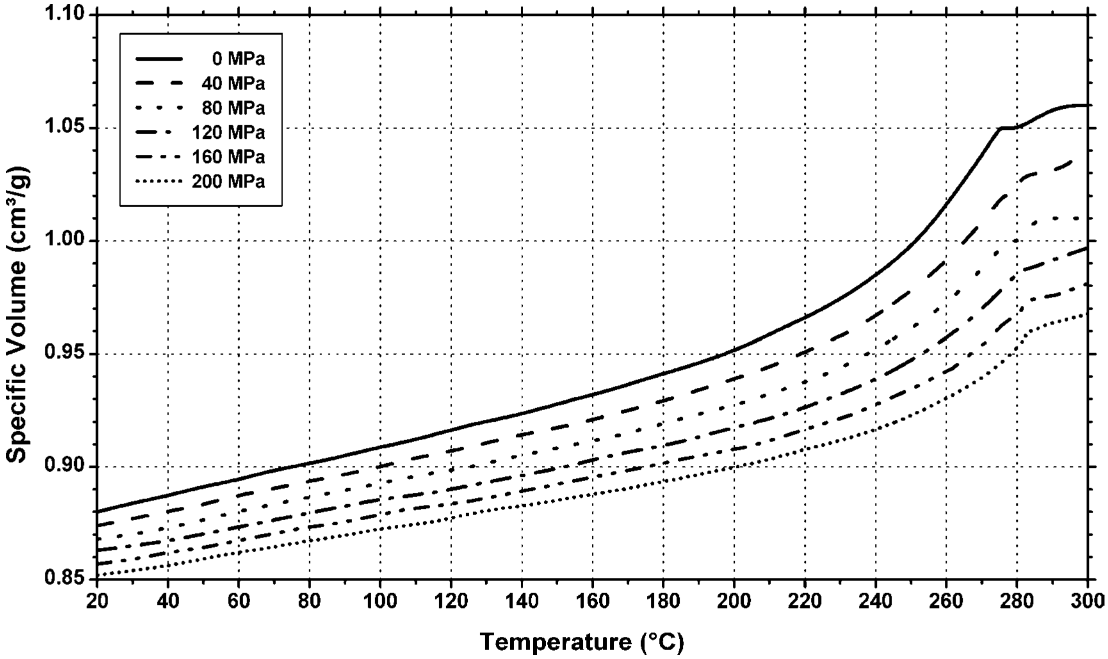


Figure 6.124. Pressure-specific volume-temperature (PVT) for BASF Ultramid® A3K—high flow, fast cycling, high impact PA66 resin.

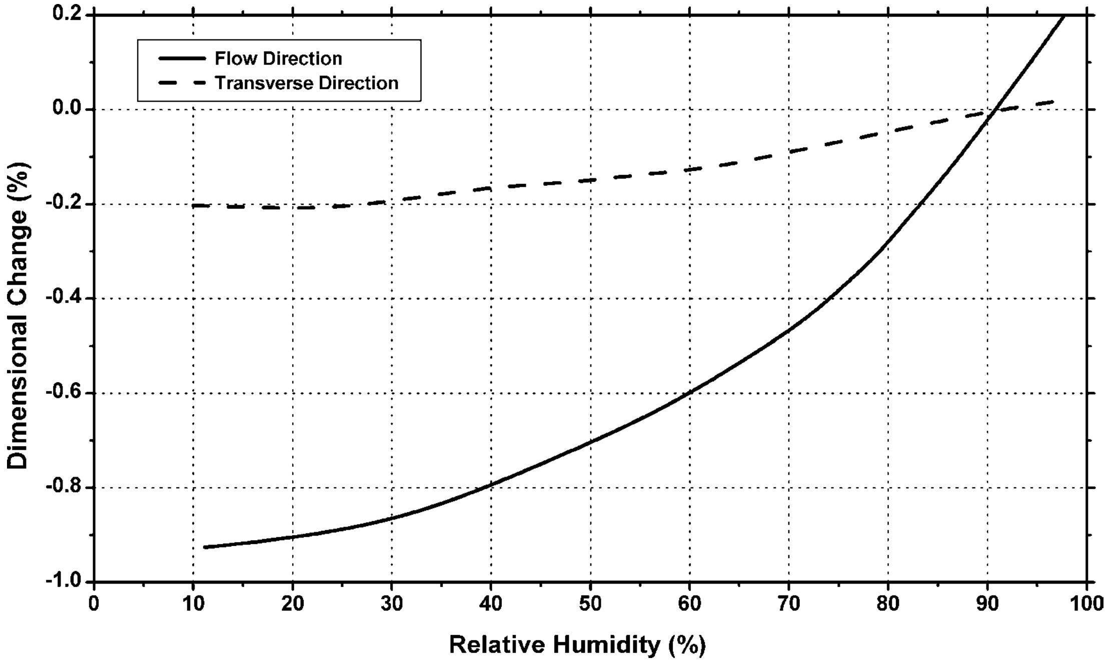


Figure 6.125. Dimensional change vs. humidity for DuPont Zytel® 70G-33L—33% glass filled, lubricated PA66 resin.

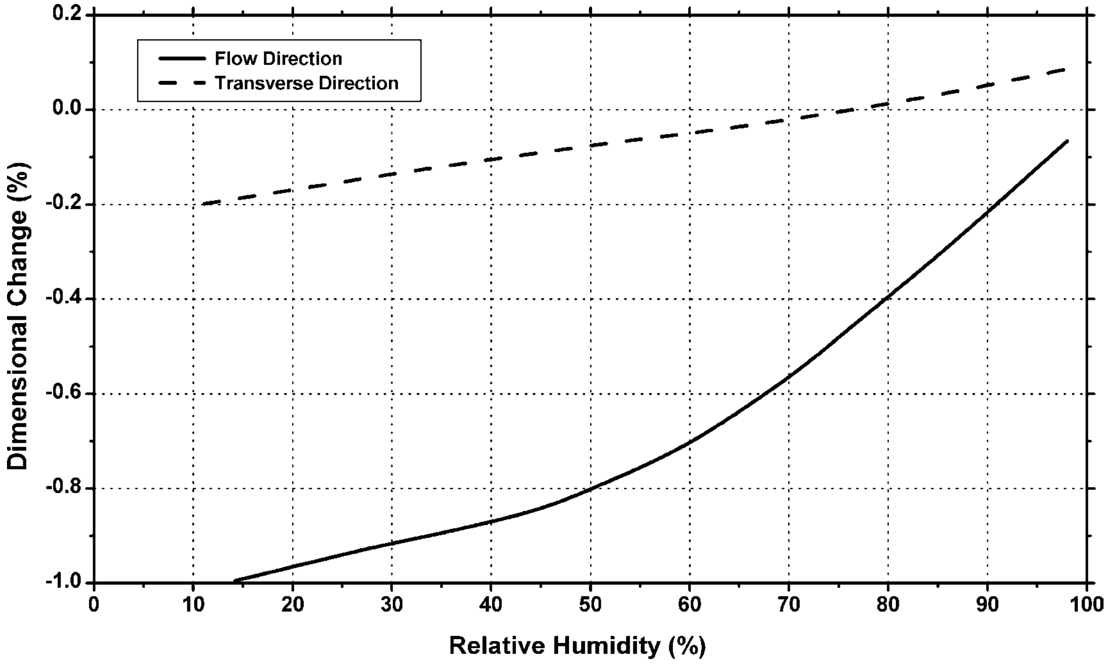


Figure 6.126. Dimensional change vs. humidity for DuPont Zytel® 71G-33L—33% glass filled, lubricated, toughened PA66 resin.

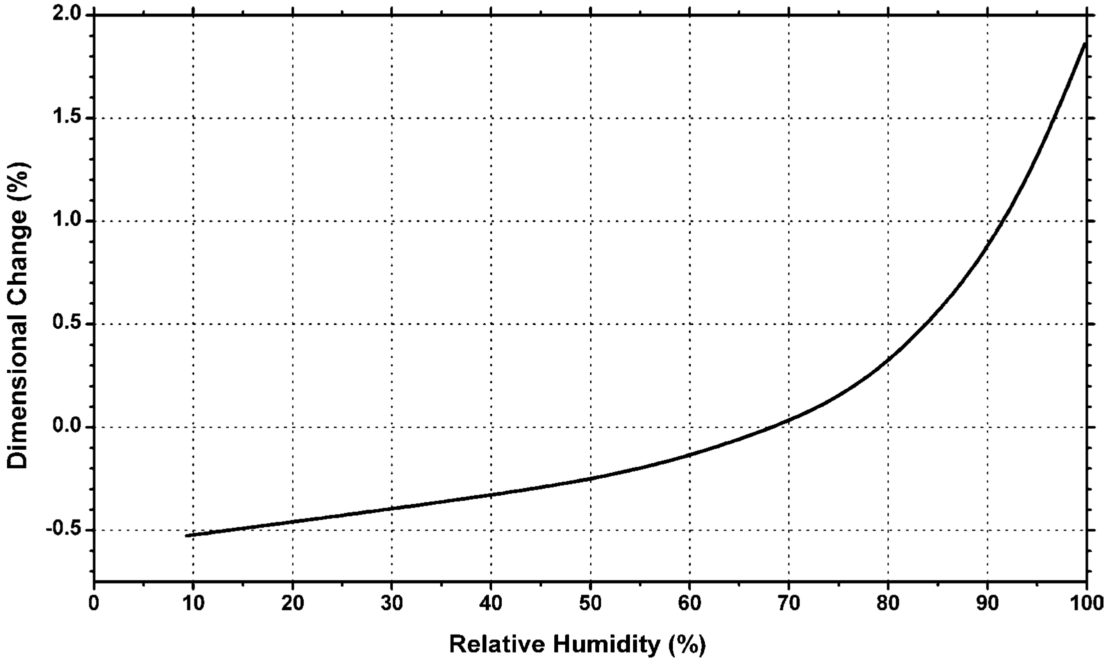


Figure 6.127. Dimensional change vs. humidity for DuPont Zytel® 101—general purpose PA66 resin.

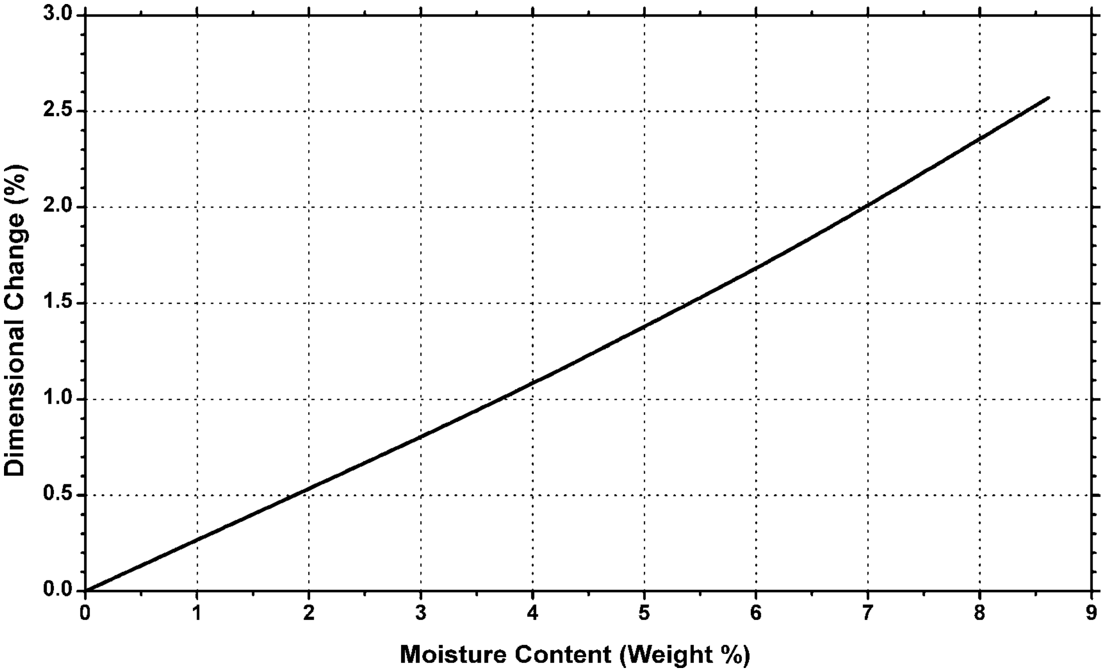


Figure 6.128. Dimensional change vs. moisture content for DuPont Zytel® 101—general purpose PA66 resin.

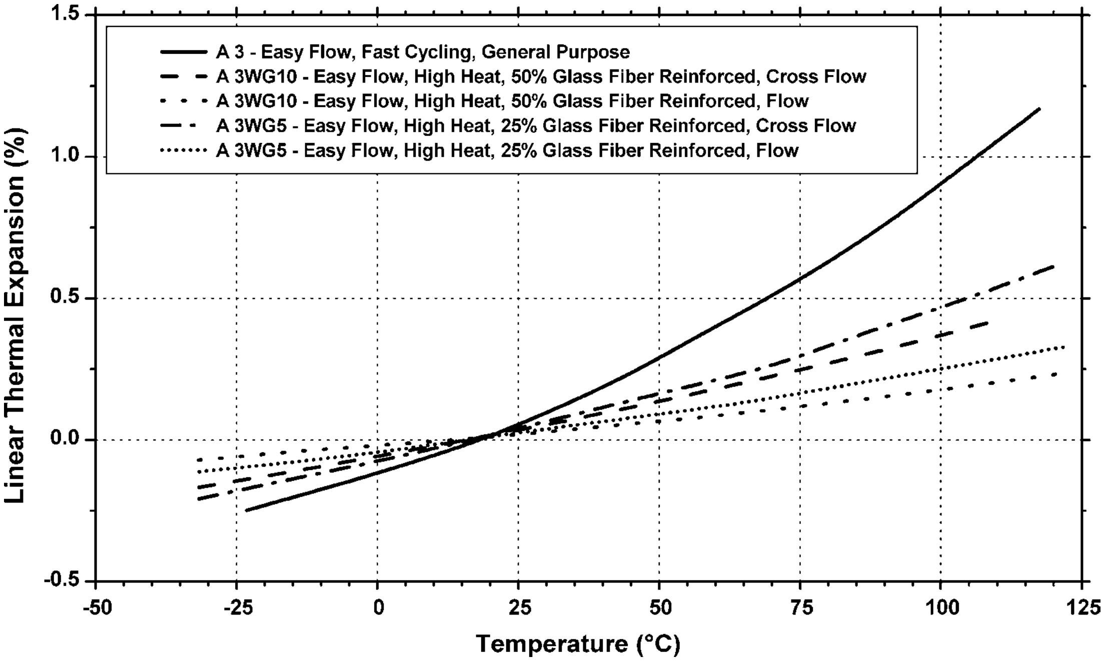


Figure 6.129. Linear thermal expansion vs. temperature for BASF Ultramid® PA66 resins.

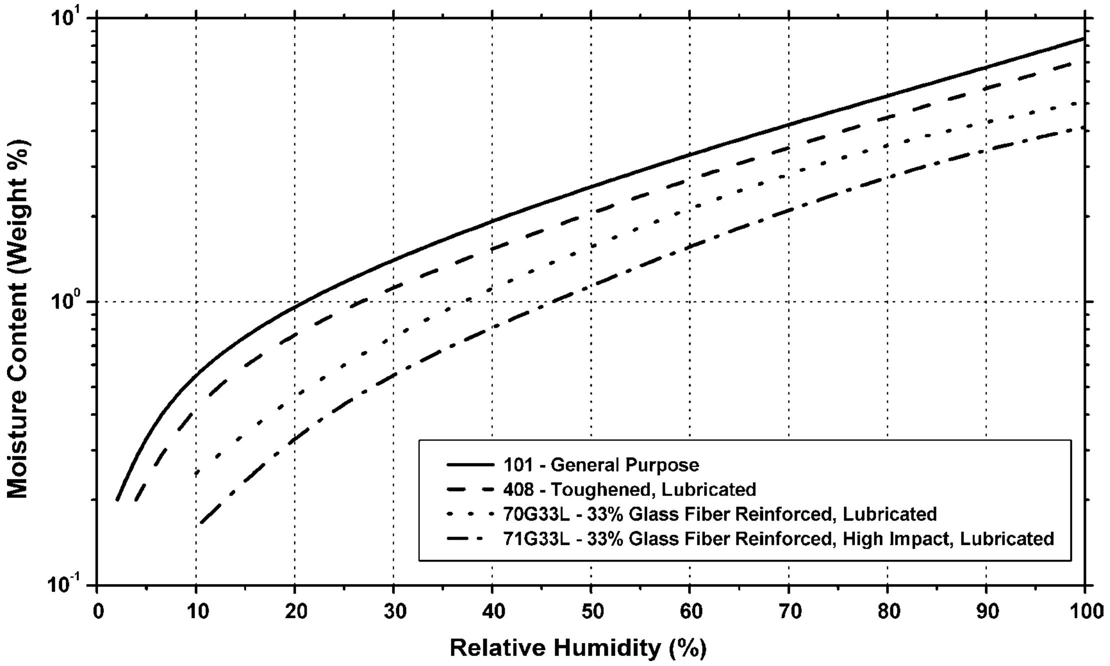


Figure 6.130. Moisture content vs. relative humidity for DuPont Zytel® PA66 resins.

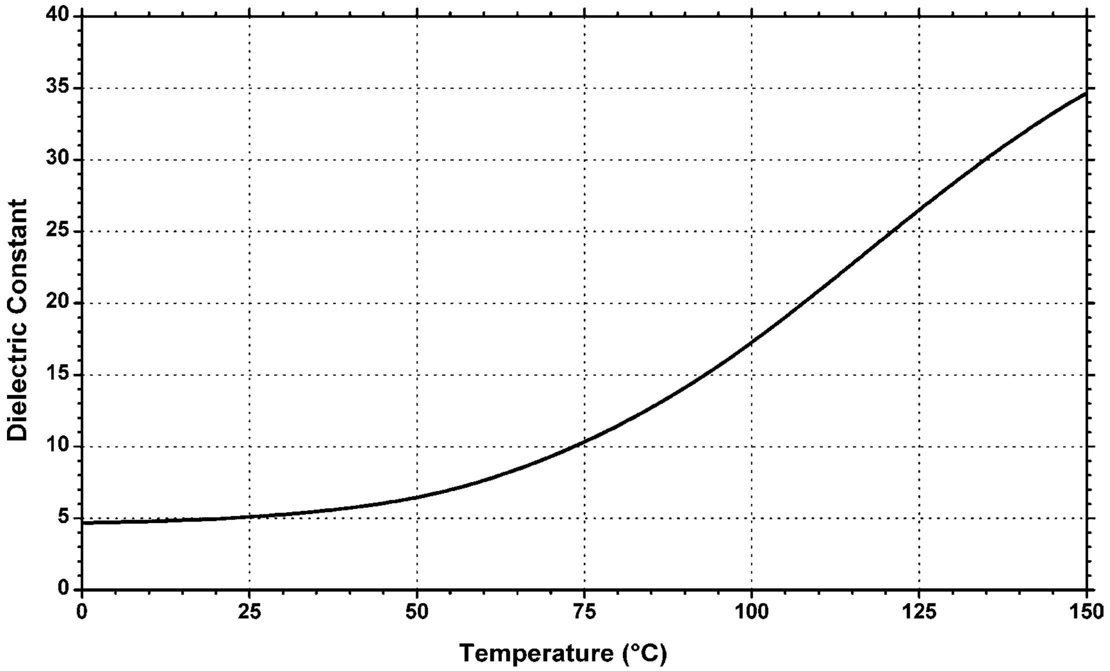


Figure 6.131. Dielectric constant vs. temperature at 100 Hz for DuPont Zytel® 101—general purpose PA66 resins.

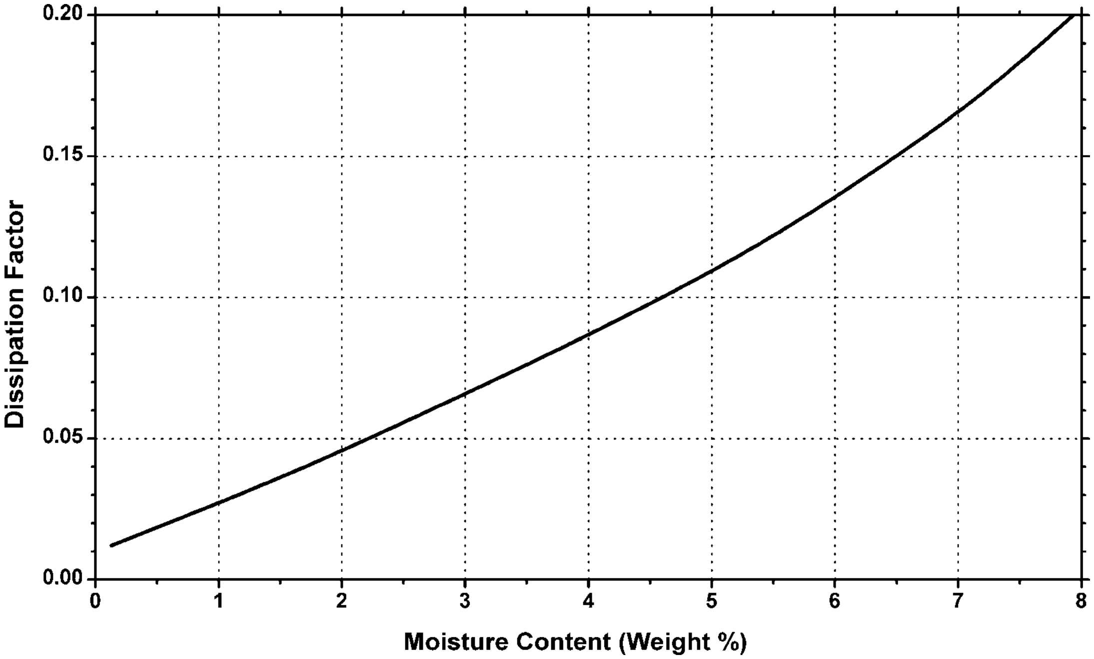


Figure 6.132. Dissipation factor vs. moisture content at 100 Hz and 23°C for DuPont Zytel® 101 general purpose PA66 resin.

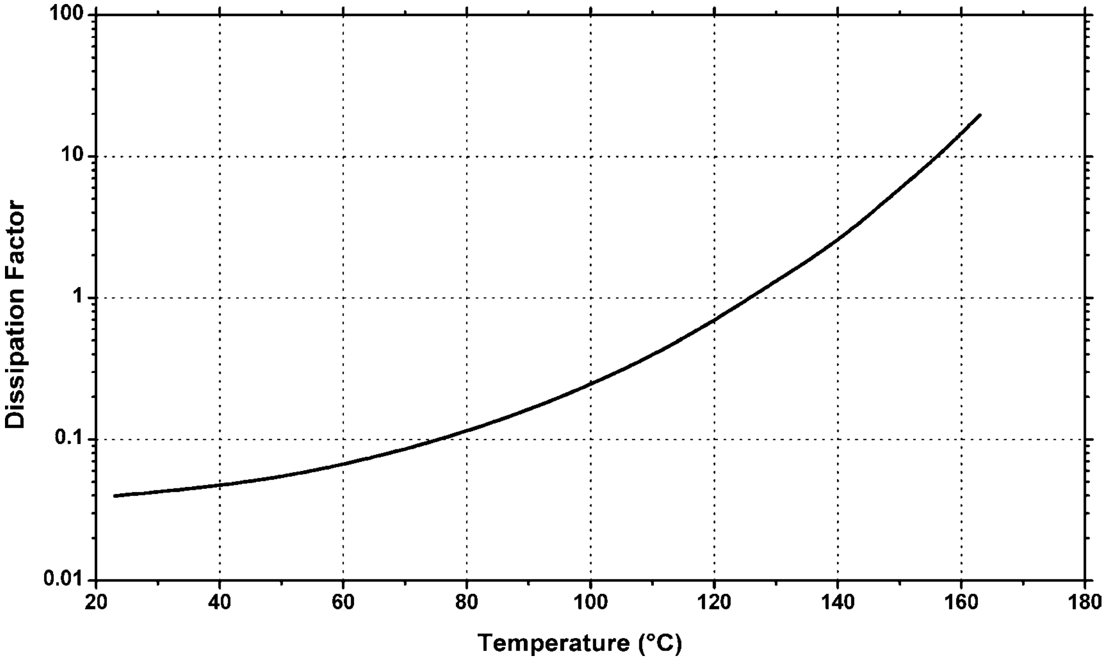


Figure 6.133. Dissipation factor vs. temperature at 100 Hz for DuPont Zytel® 101 general purpose PA66 resins.

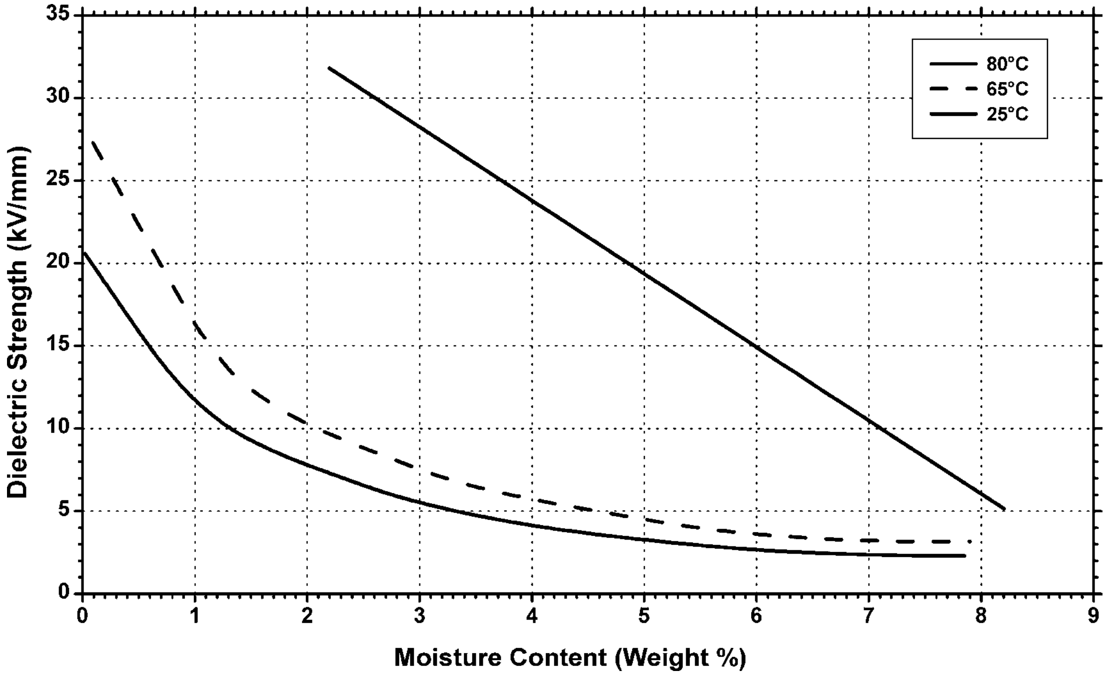


Figure 6.134. Dielectric strength vs. moisture content and temperature for BASF Ultramid® A3EG6—30% glass fiber, heat stabilized PA66 resin.

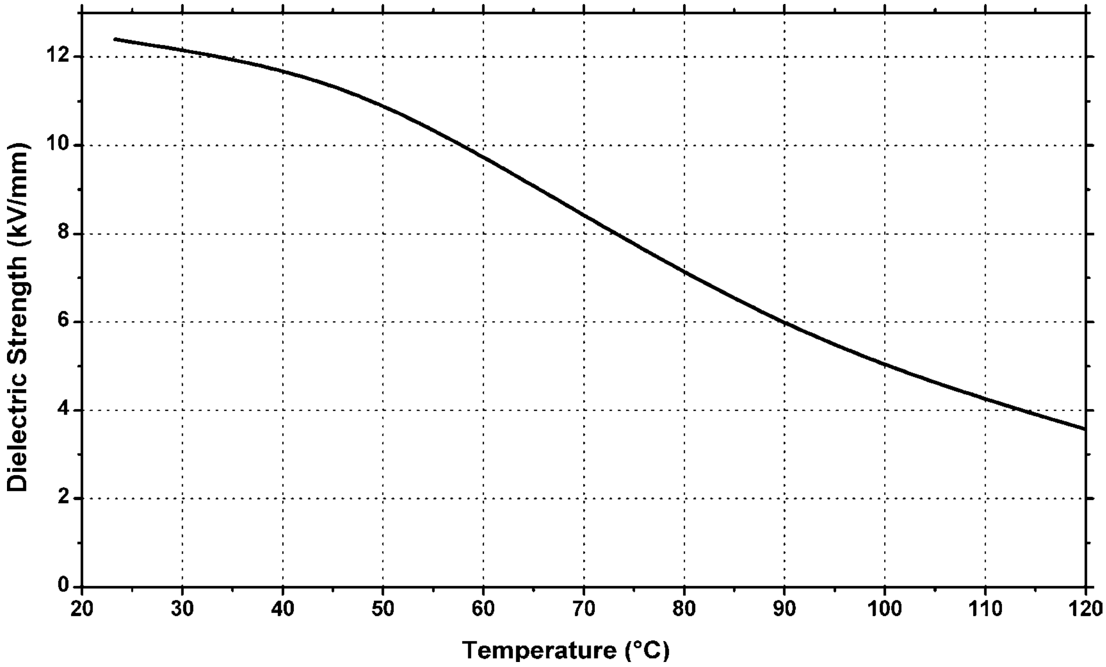


Figure 6.135. Dielectric strength vs. temperature for DuPont Zytel® 101—general purpose PA66 resin.

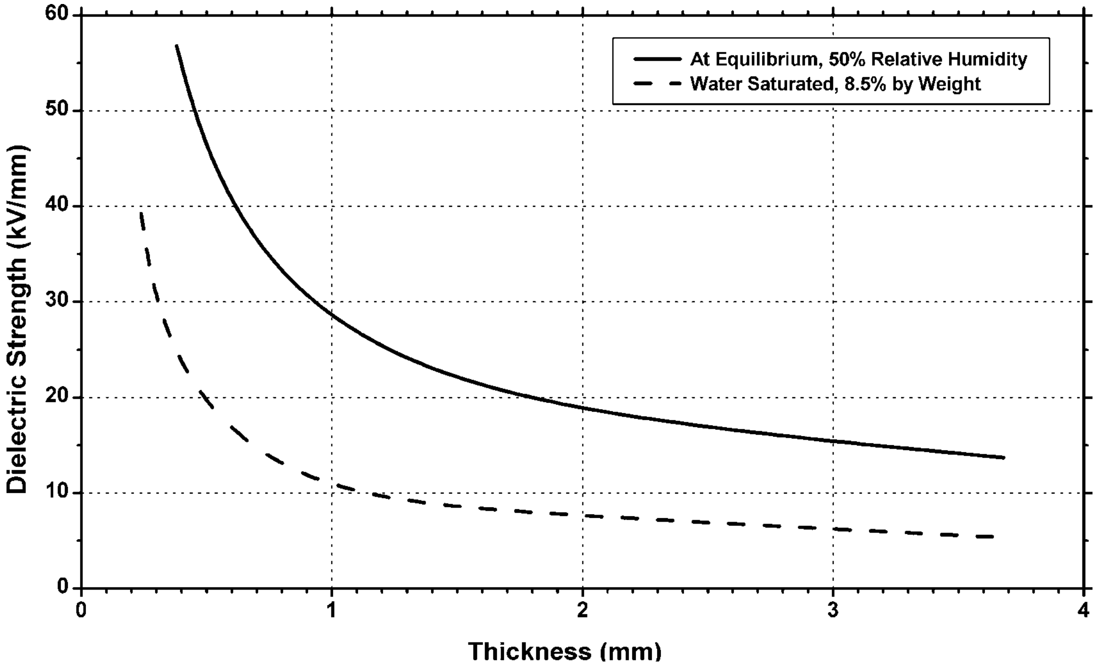


Figure 6.136. Dielectric strength vs. thickness for DuPont Zytel® 101—general purpose PA66 resin.

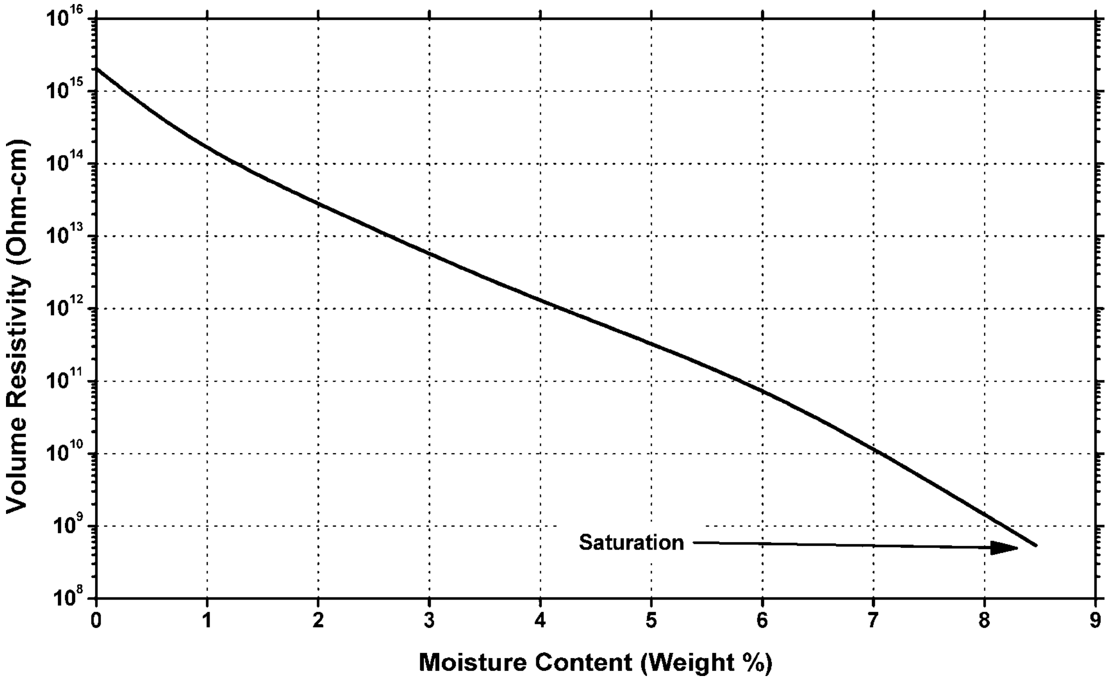


Figure 6.137. Volume resistivity vs. moisture content for DuPont Zytel® 101—general purpose PA66 resin.

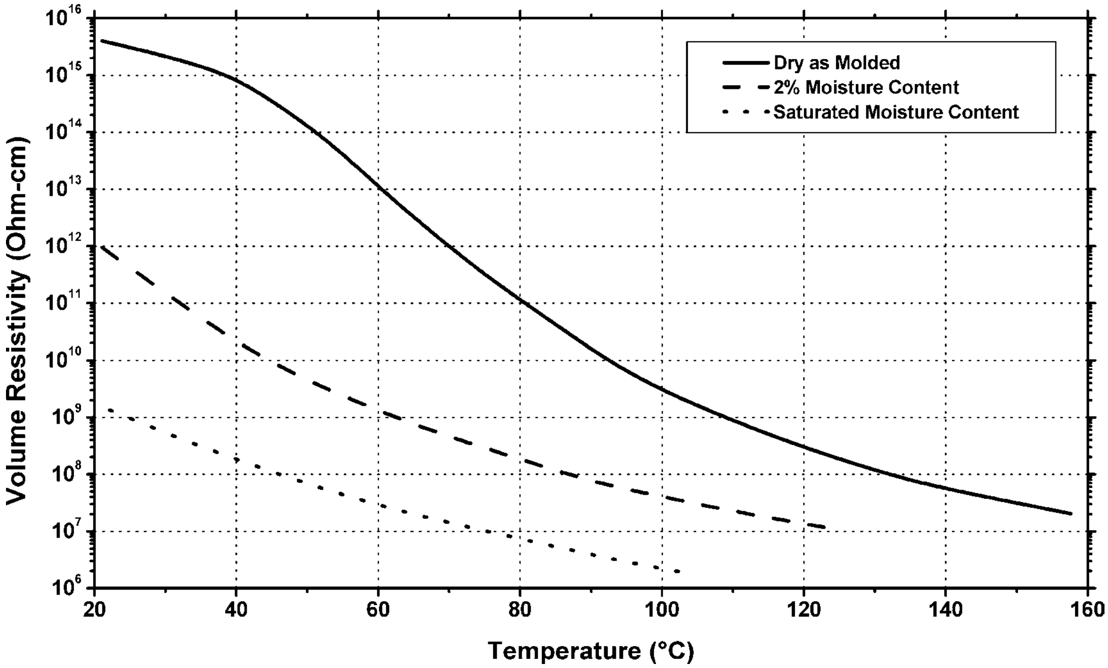


Figure 6.138. Volume resistivity vs. temperature and various moisture levels for BASF Ultramid® A3EG6—high stiffness, 30% glass fiber filled PA66 resin.

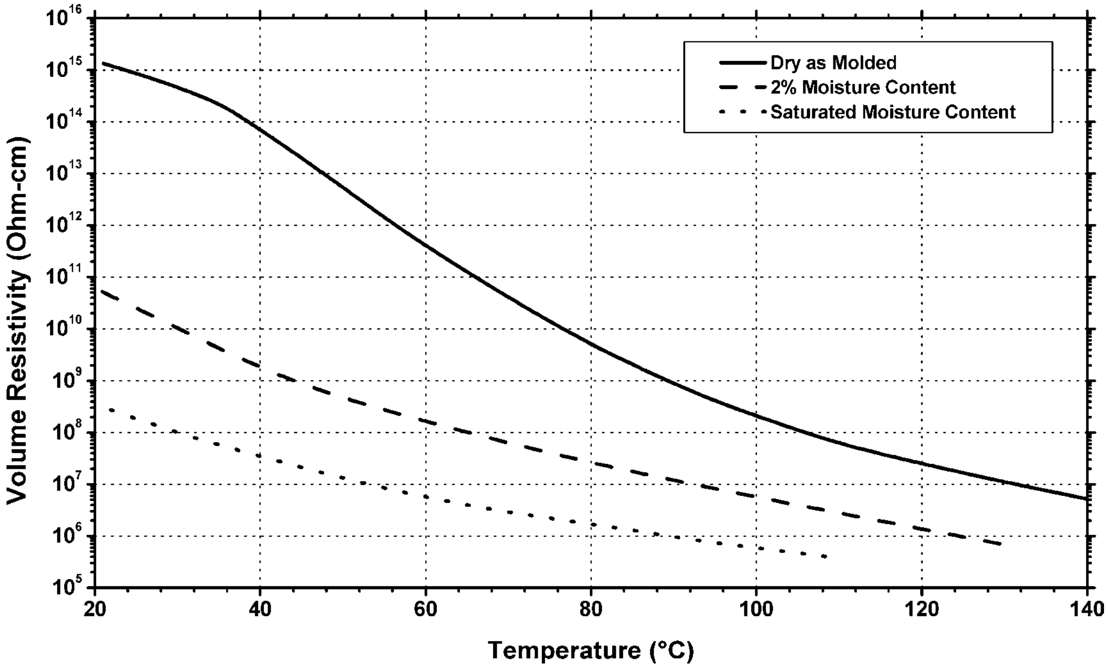


Figure 6.139. Volume resistivity vs. temperature and various moisture levels for BASF Ultramid® A3XG6—30% glass fiber filled PA66 resin.

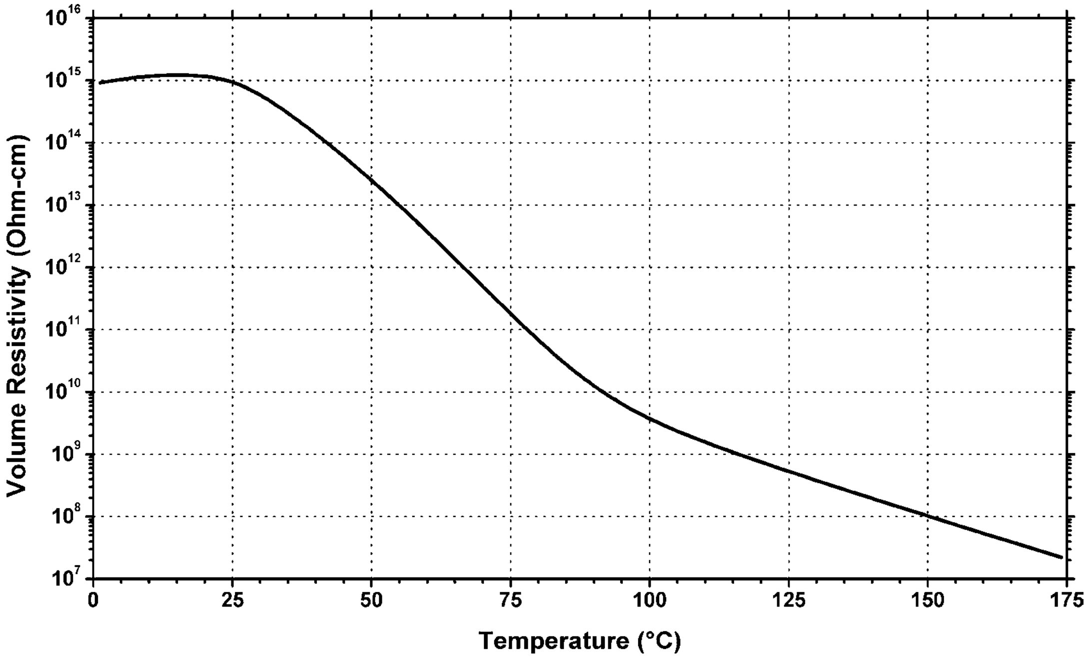


Figure 6.140. Volume resistivity vs. temperature (DAM) for DuPont Zytel® 101—general purpose PA66 resin.

6.6 Nylon 610 (PA610)

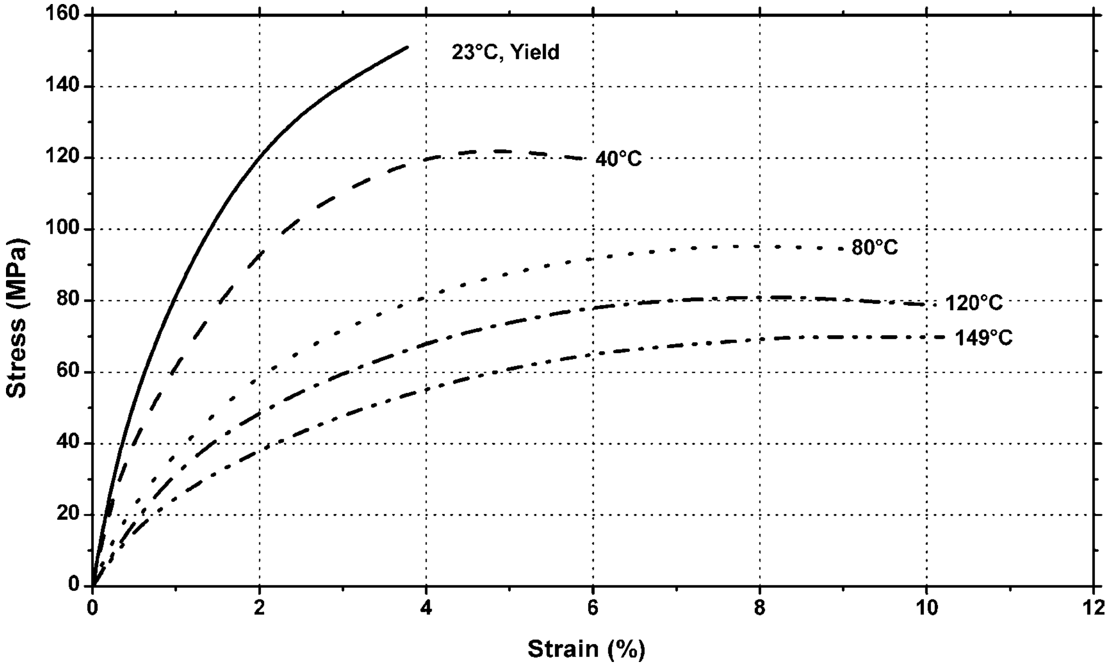


Figure 6.141. Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp® QF-1006—30% glass fiber reinforced PA610 resin (DAM).

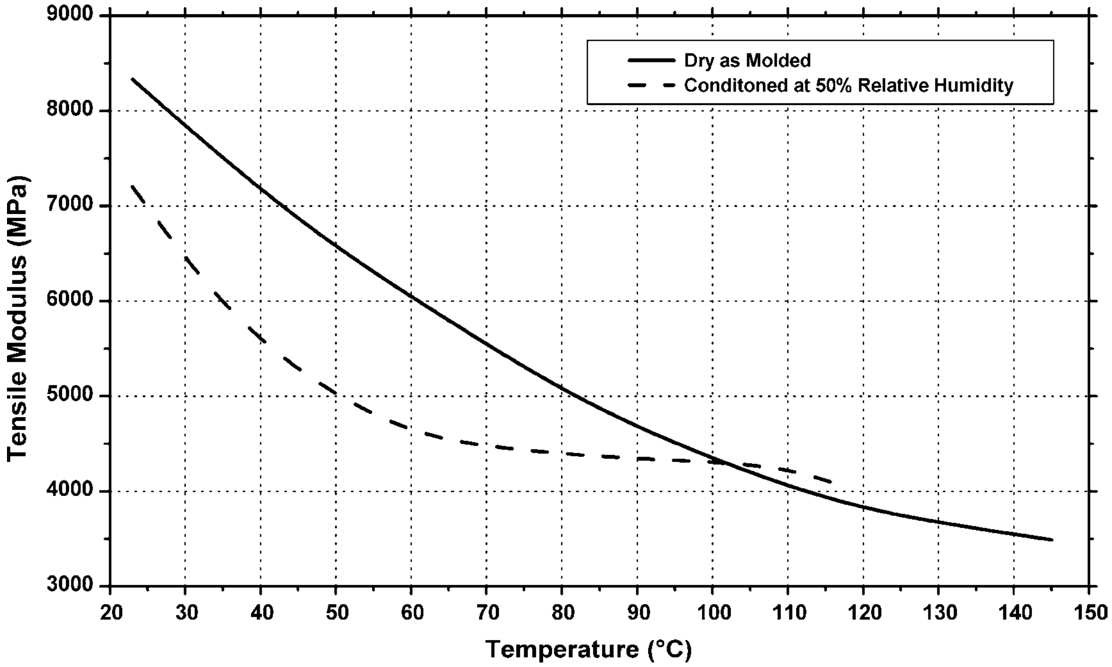


Figure 6.142. Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp® QF-1006—30% glass fiber reinforced PA610 resin (DAM).

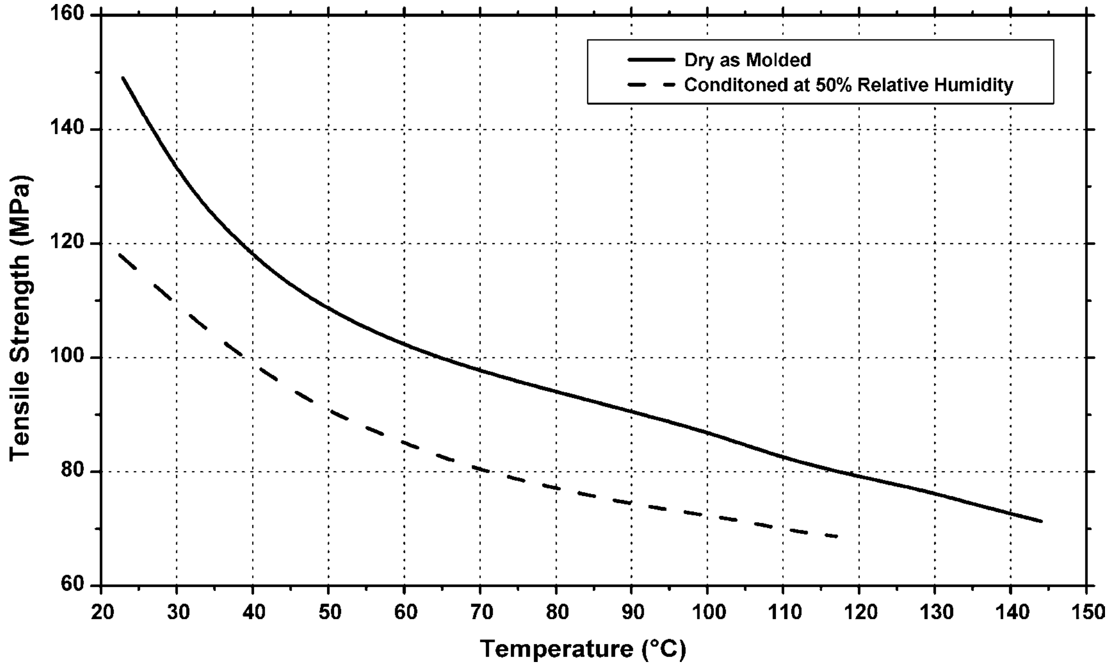


Figure 6.143. Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp® QF-1006—30% glass fiber reinforced PA610 resin (DAM).

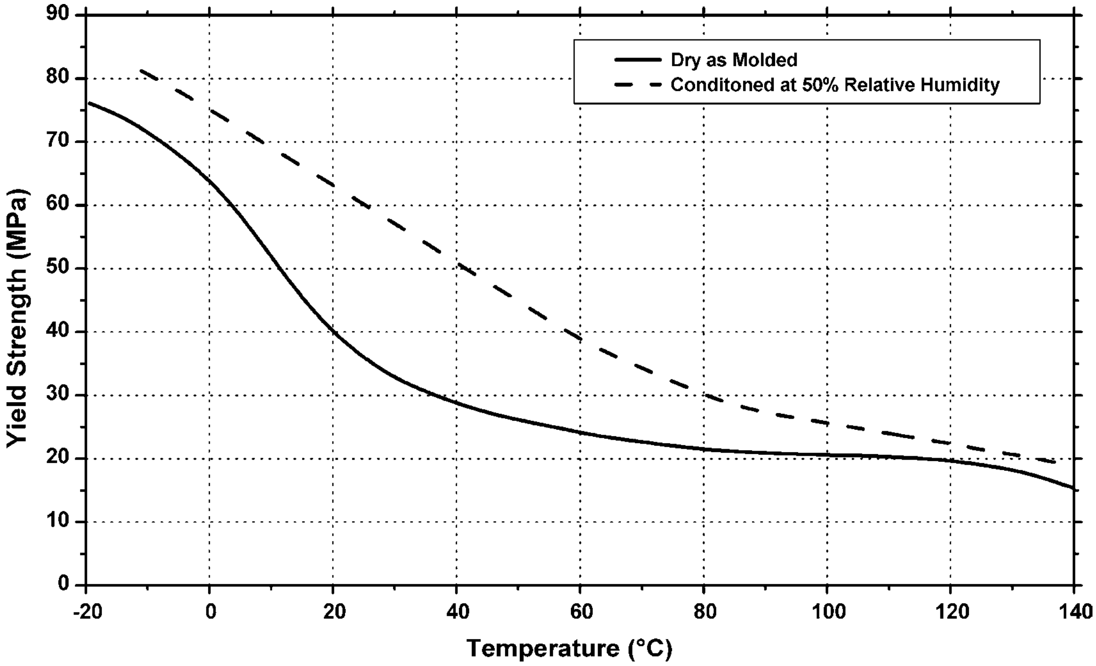


Figure 6.144. Tensile yield strength vs. temperature for Toray Resin Company Amilan® CM2001—25% crystallinity, standard grade PA610 resin.

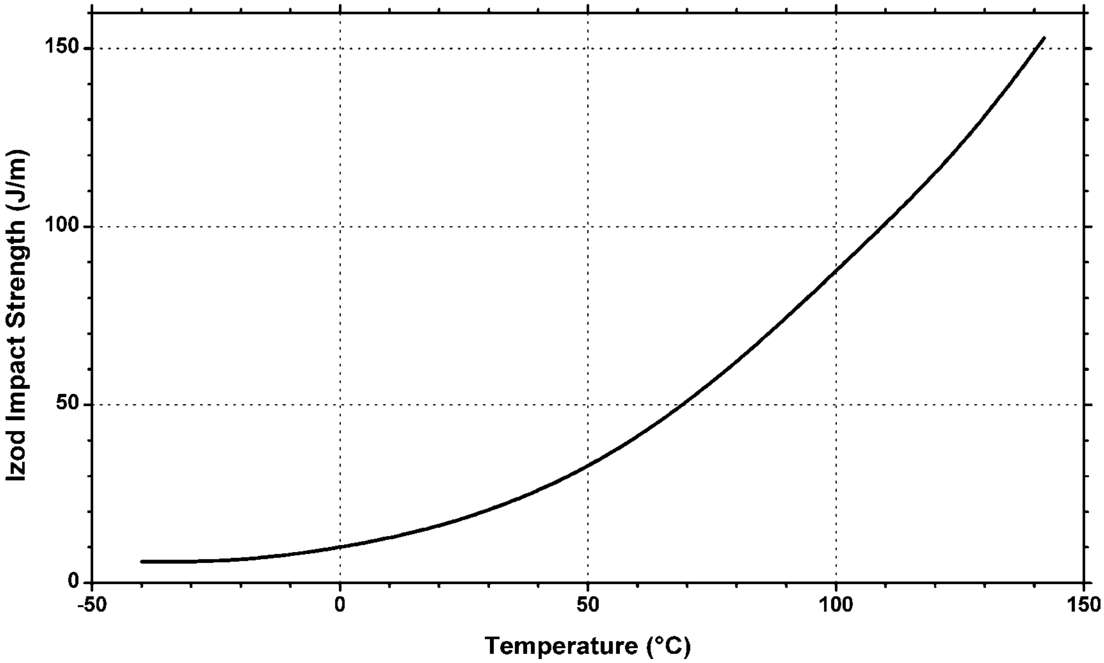


Figure 6.145. Izod impact strength vs. temperature for Toray Resin Company Amilan® CM2001—25% crystallinity, standard grade PA610 resin.

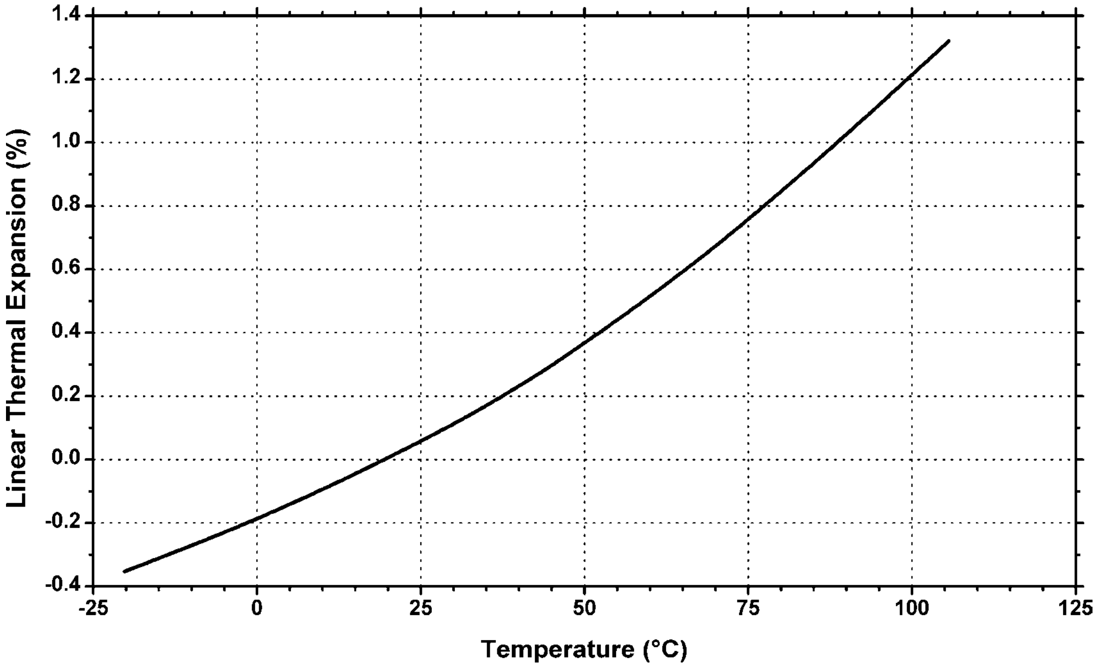


Figure 6.146. Linear thermal expansion vs. temperature for BASF Ultramid® S3 and S4 PA610 resins.

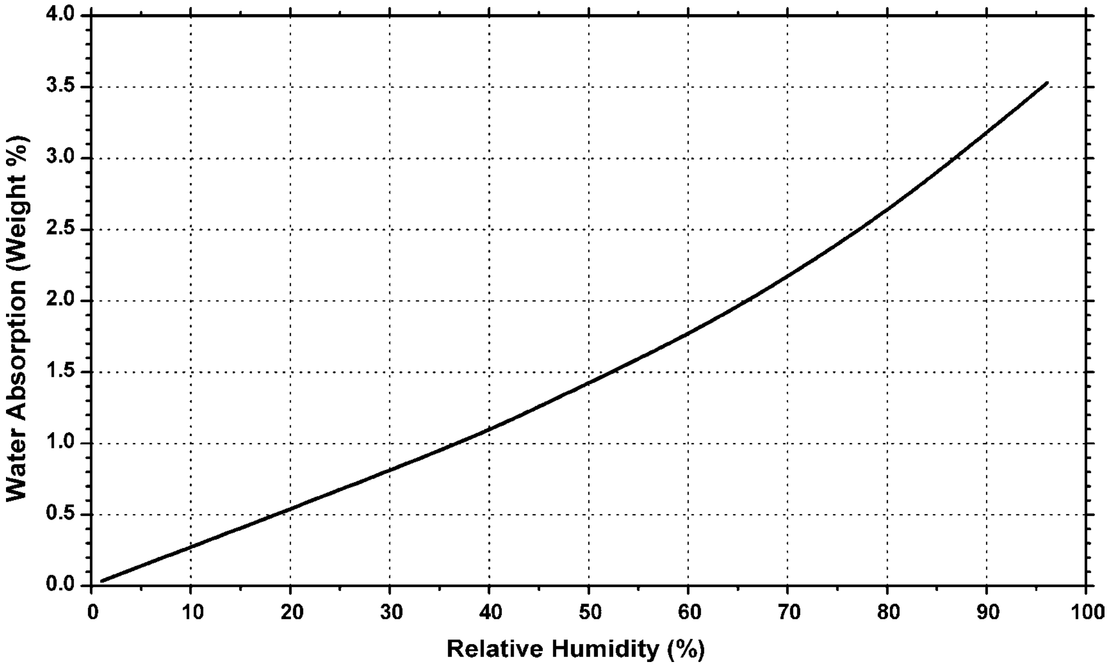


Figure 6.147. Water absorption vs. relative humidity for BASF Ultramid® S3 and S4 PA610 resins.

6.7 Nylon 612 (PA612)

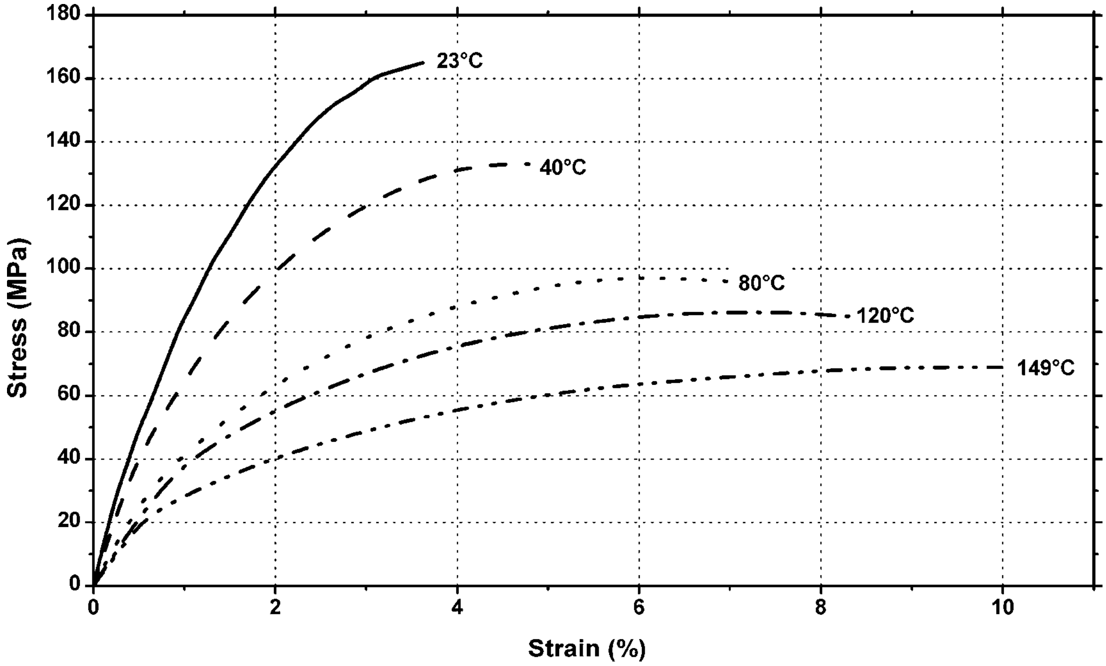


Figure 6.148. Stress vs. strain at various temperatures for SABIC Innovative Plastics LNP Thermocomp® IF-1006—30% glass fiber reinforced PA612 resin (DAM).

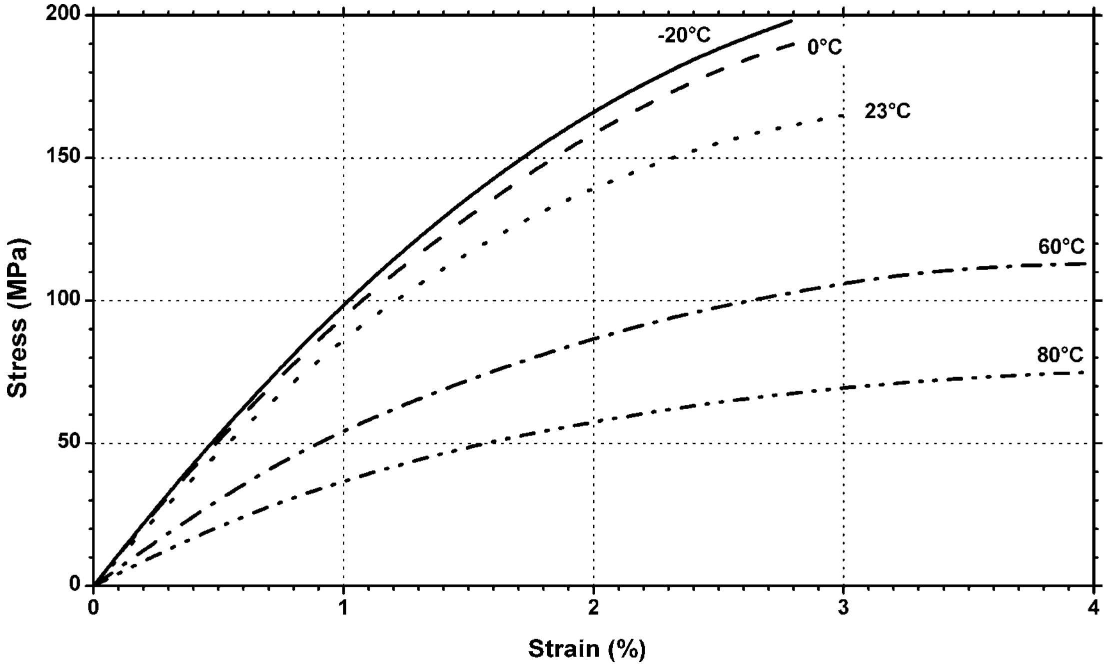


Figure 6.149. Stress vs. strain for DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin (DAM).

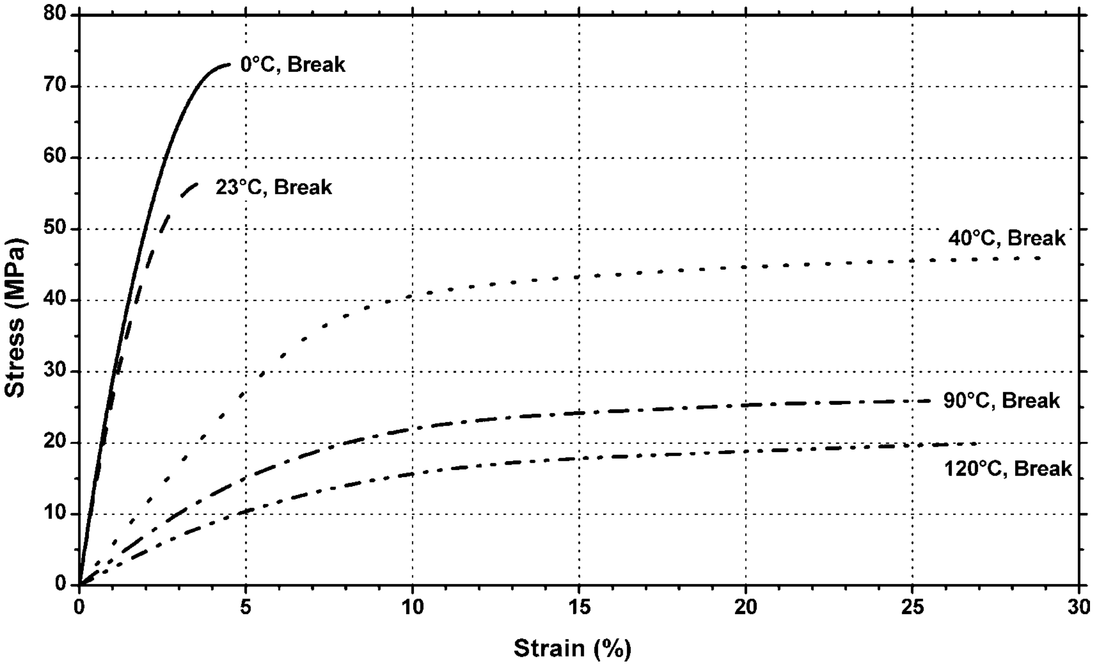


Figure 6.150. Stress vs. strain at various temperatures for DuPont Zytel® 158 NC010—general purpose, lubricated PA612 resin (DAM).

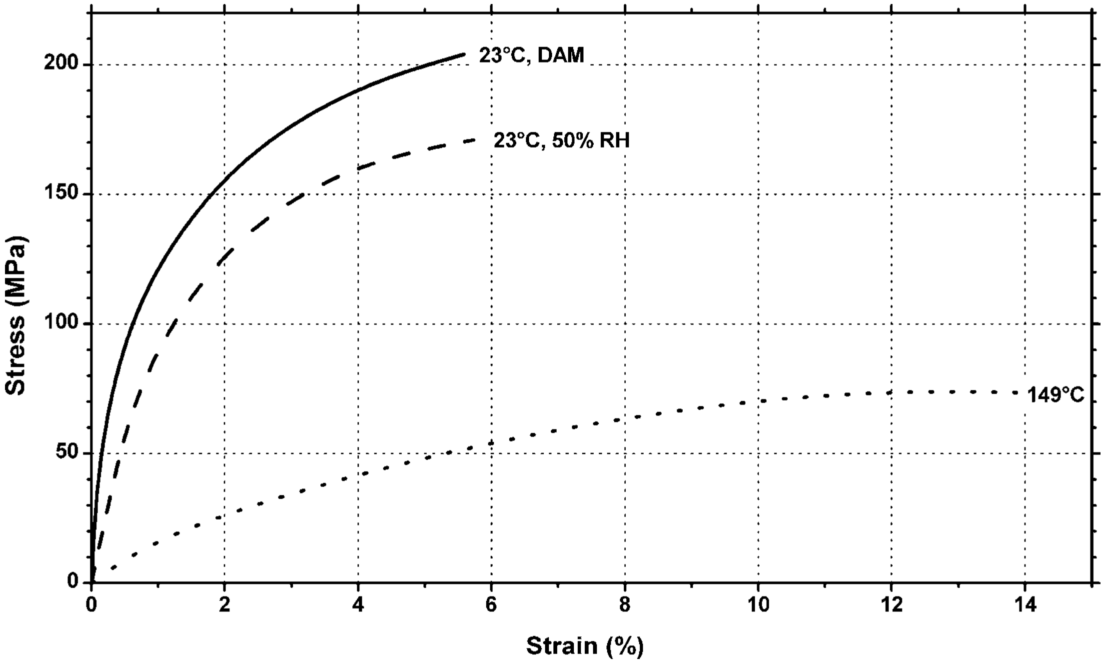


Figure 6.151. Stress vs. strain for DuPont Zytel® 77G43L—general purpose, lubricated, 43% short glass fiber reinforced PA612 resin.

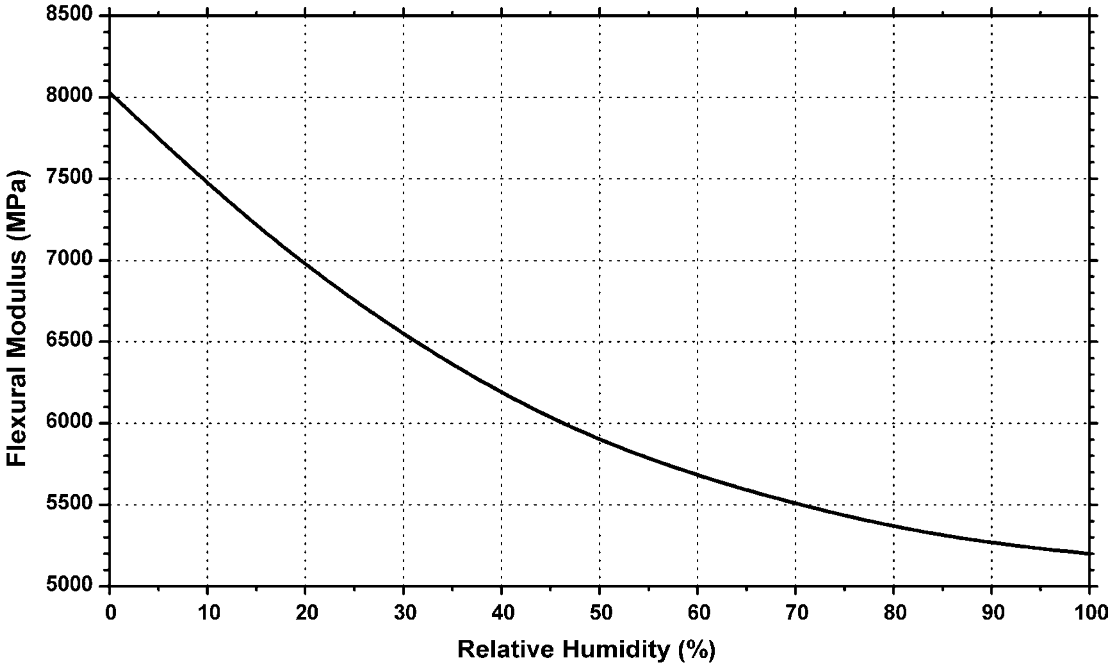


Figure 6.152. Flexural modulus vs. humidity DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin.

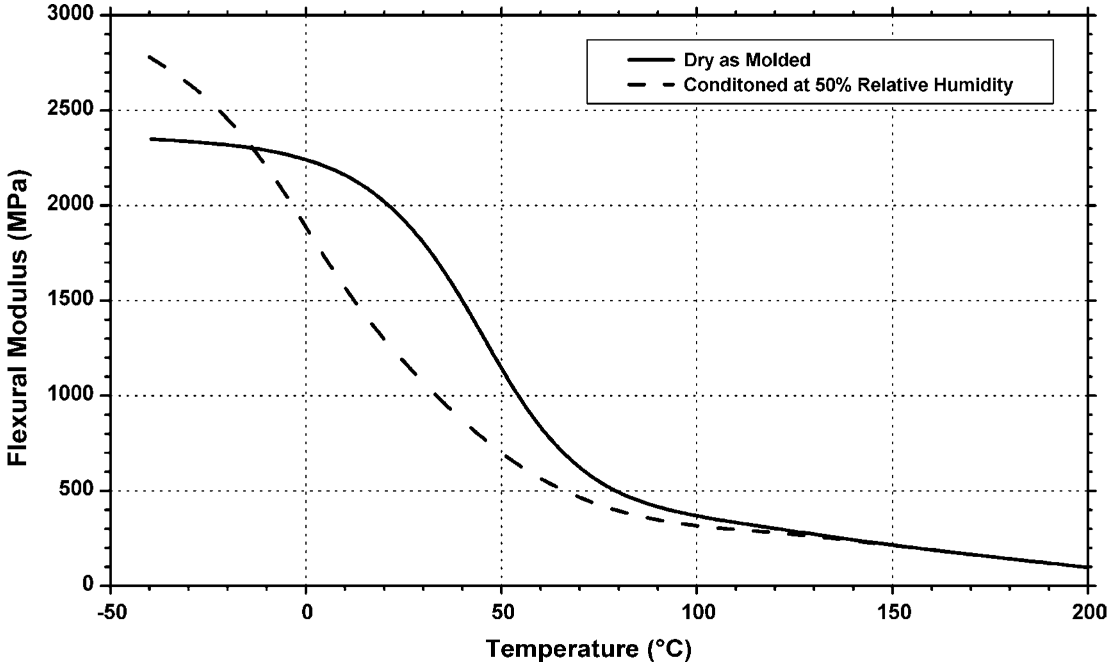


Figure 6.153. Flexural modulus vs. temperature and moisture content DuPont Zytel® 158L—general purpose, lubricated PA612 resin.

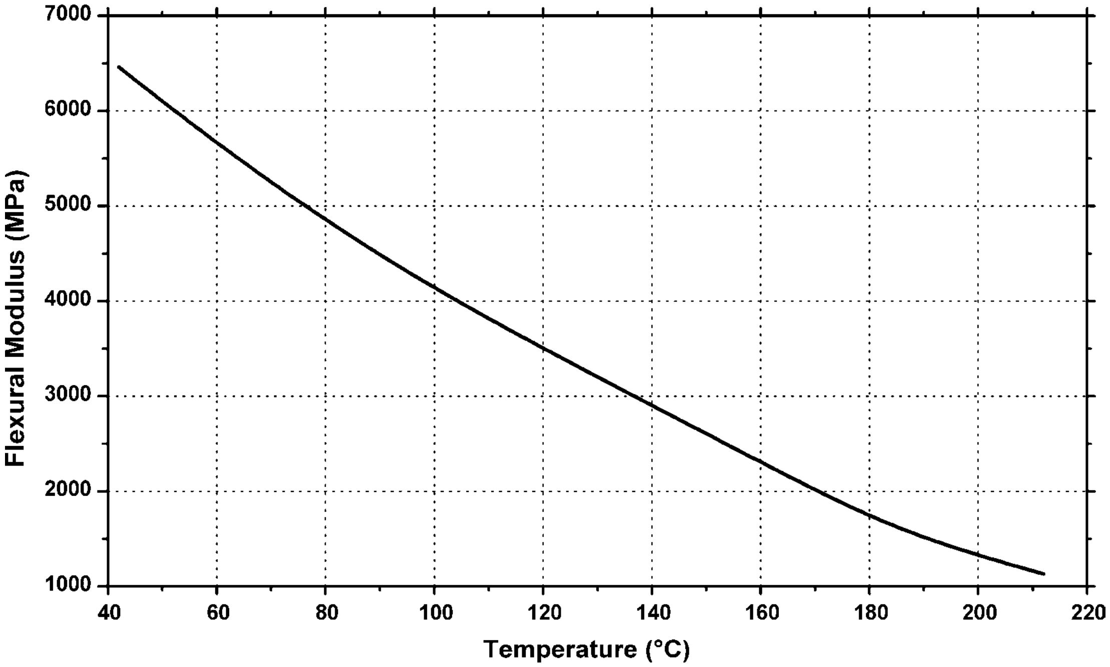


Figure 6.154. Flexural modulus vs. temperature of DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin.

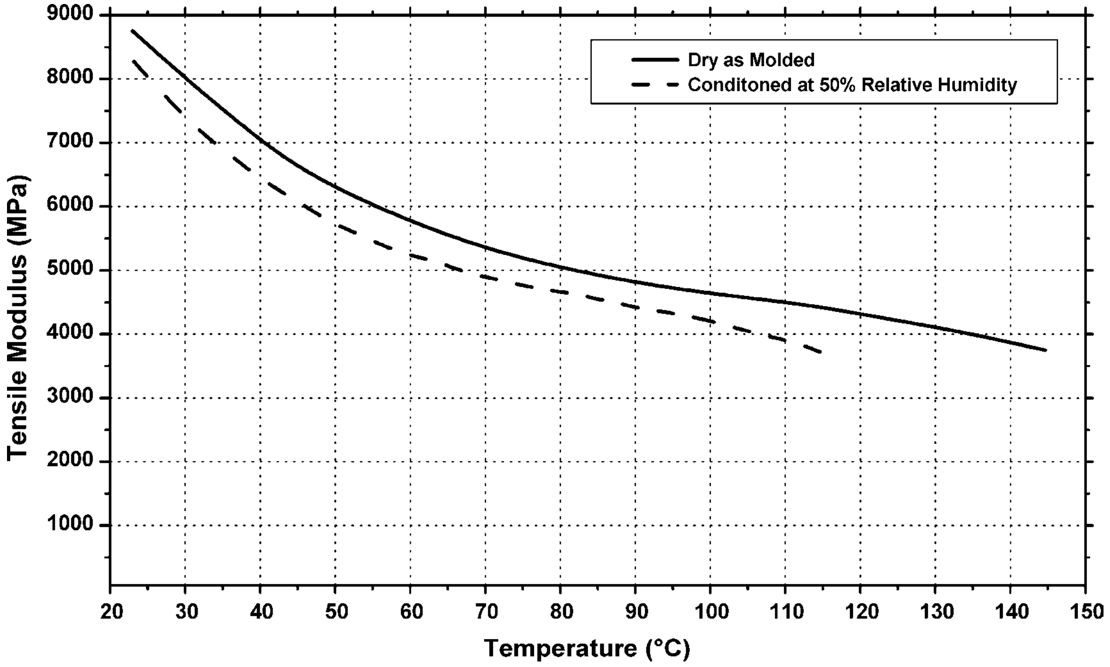


Figure 6.155. Tensile modulus vs. temperature SABIC Innovative Plastics LNP Thermocomp® IF—1006, 33% glass filled PA612 resin.

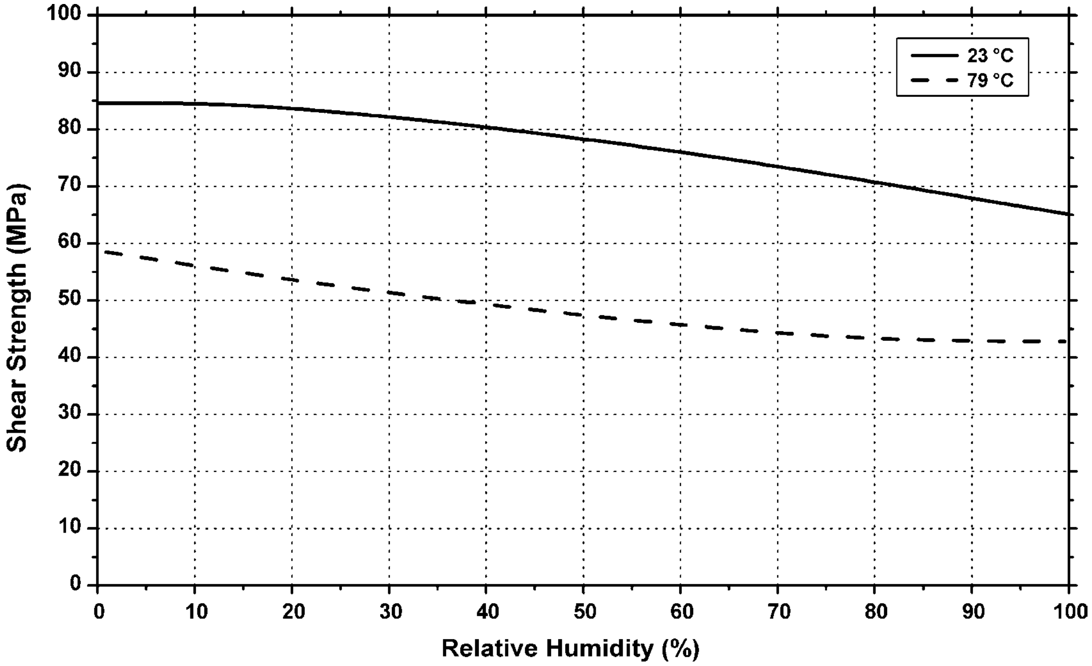


Figure 6.156. Shear strength vs. relative humidity of DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin.

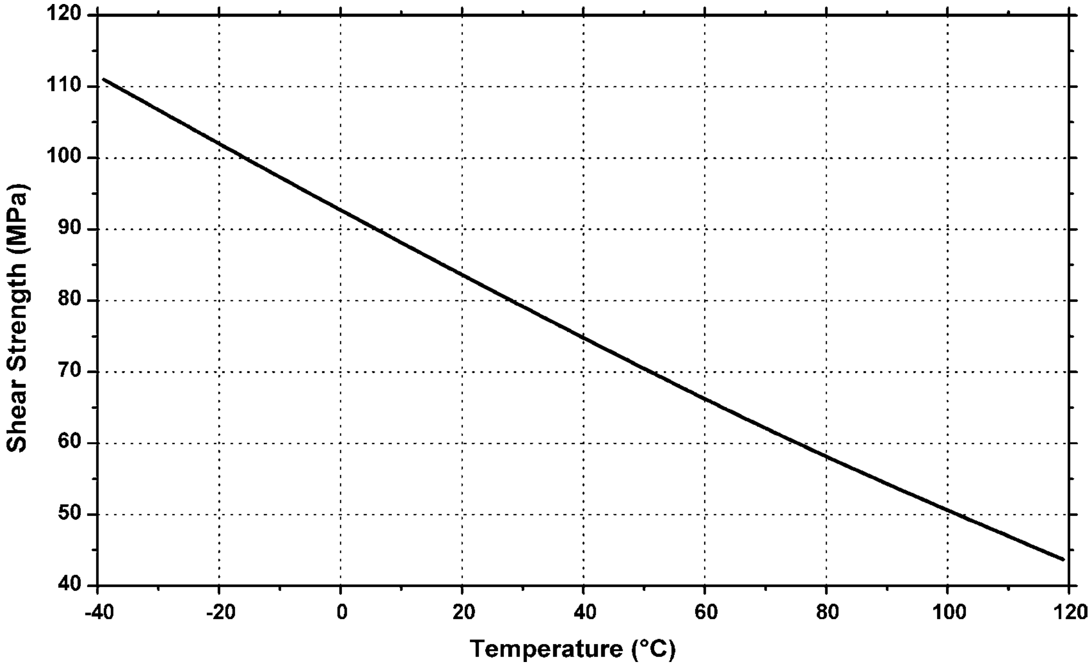


Figure 6.157. Shear strength vs. temperature of DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin.

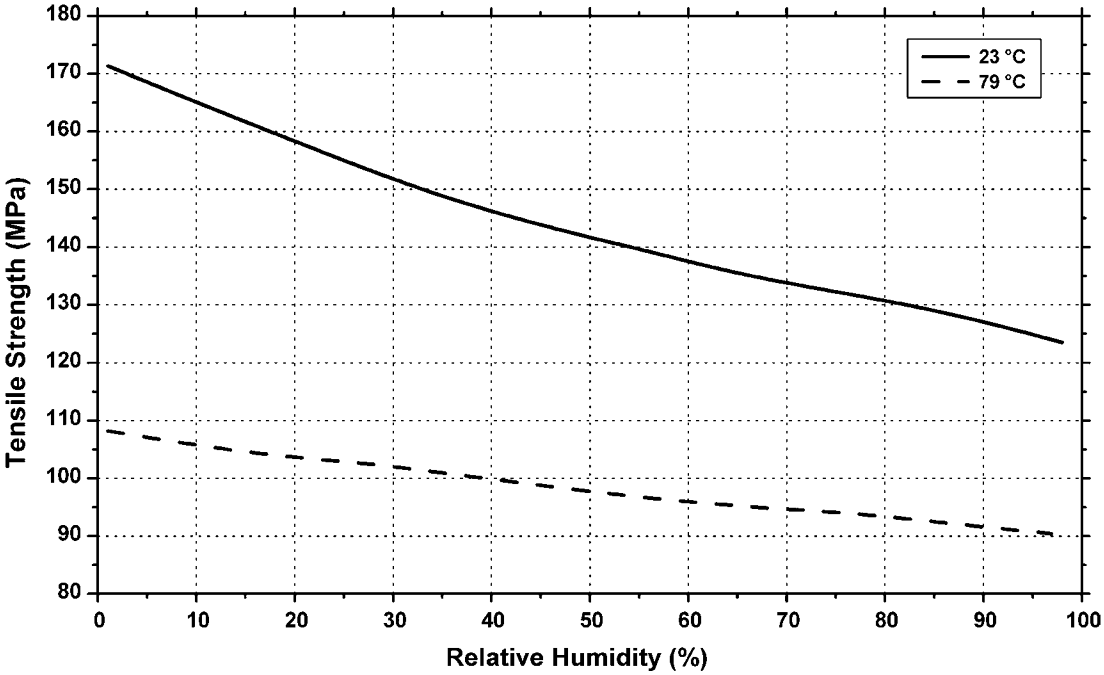


Figure 6.158. Tensile strength vs. relative humidity of DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin.

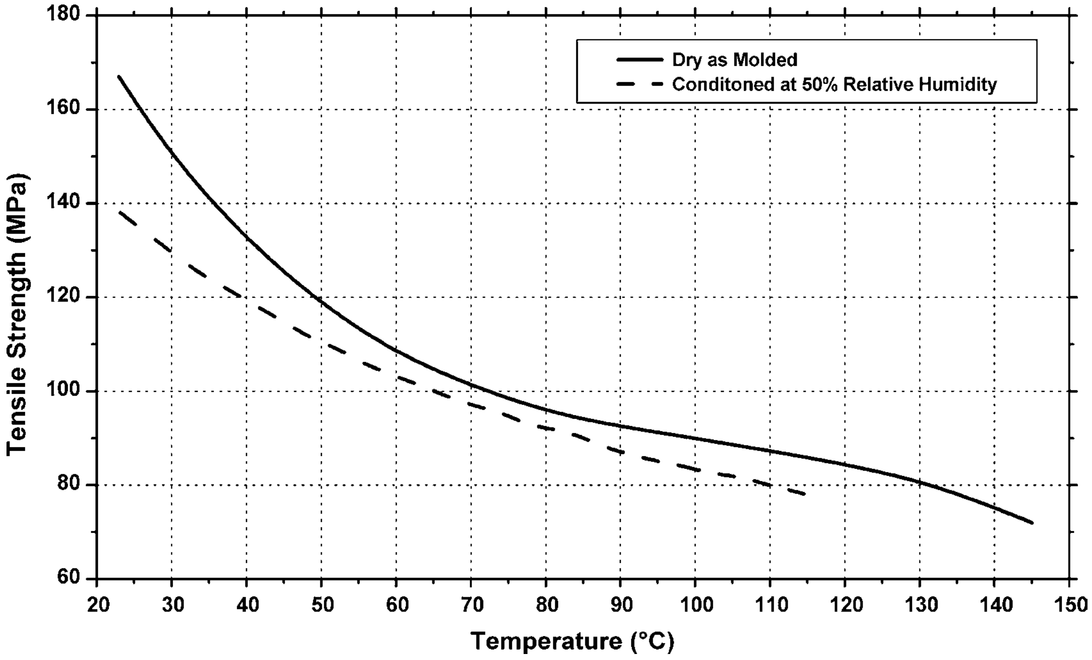


Figure 6.159. Tensile strength vs. temperature SABIC Innovative Plastics LNP Thermocomp® IF—1006, 33% glass filled PA612 resin.

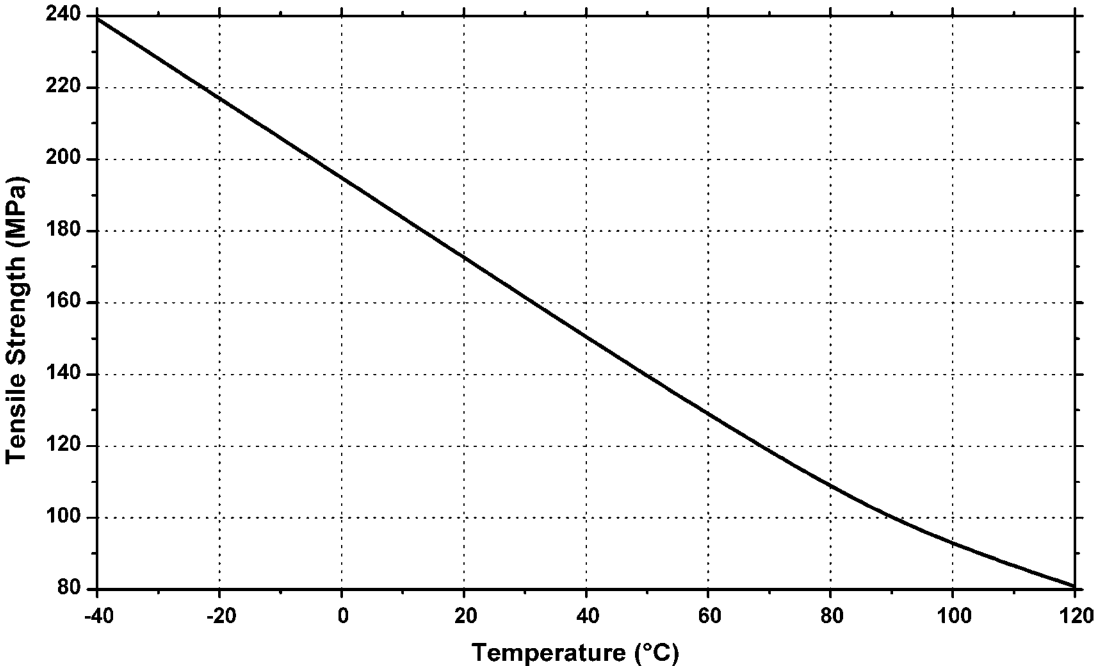


Figure 6.160. Tensile strength vs. temperature of DuPont Zytel® 77G33L NC010—general purpose, lubricated, 33% short glass fiber reinforced PA612 resin.

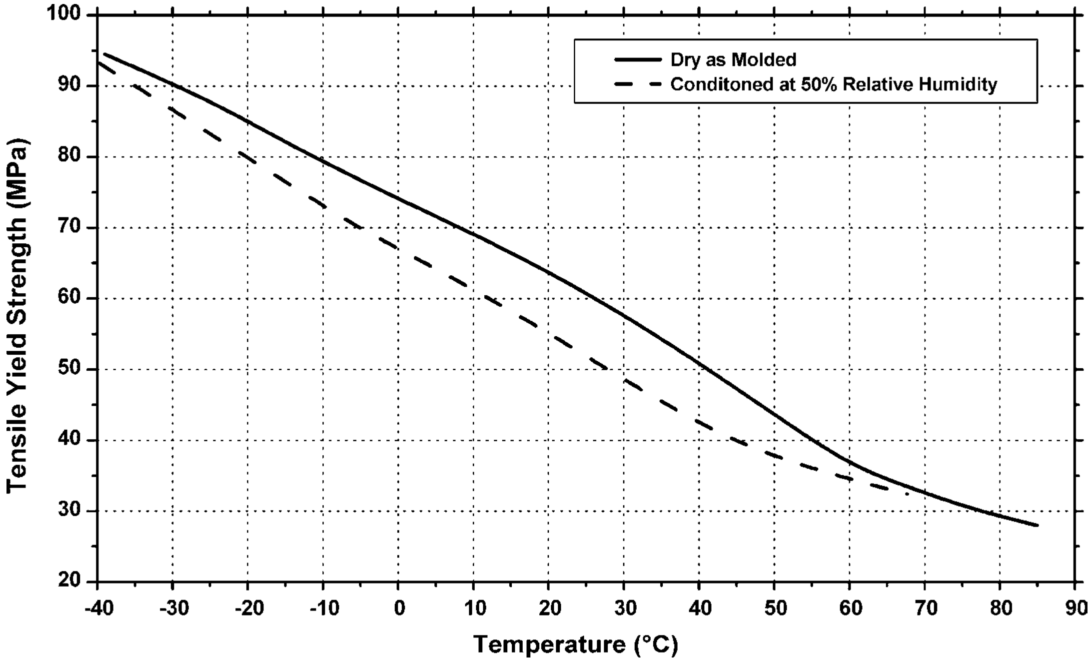


Figure 6.161. Tensile yield strength vs. temperature of DuPont Zytel® 158 NC010—general purpose, lubricated PA612 resin.

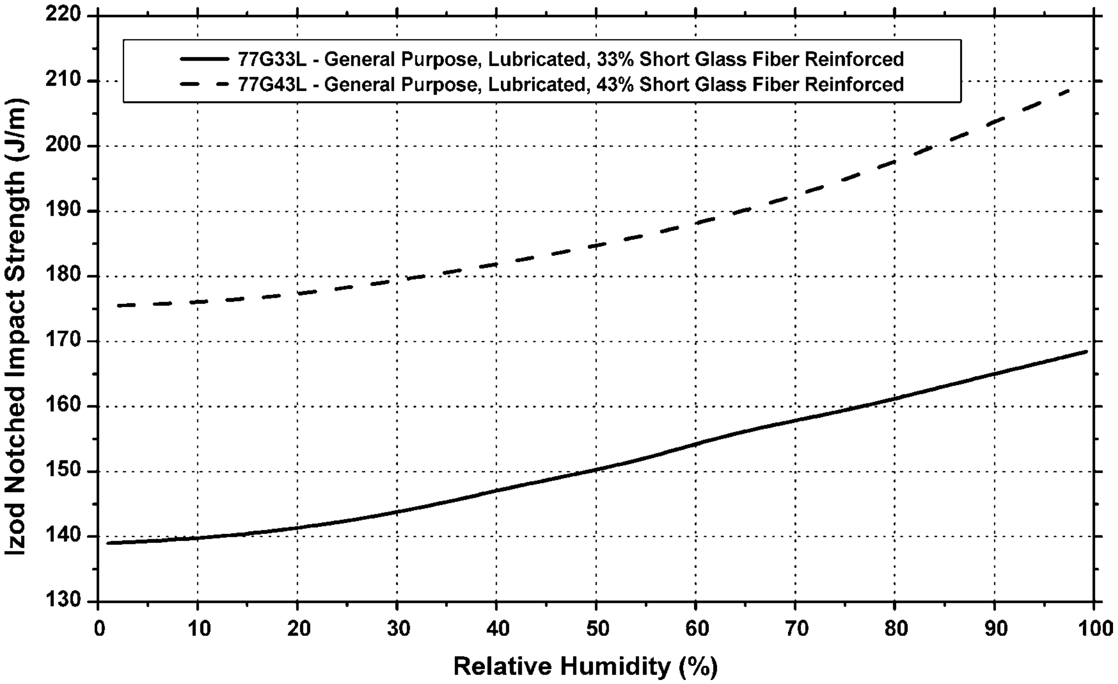


Figure 6.162. Izod notched impact strength vs. relative humidity at 23°C of two DuPont Zytel® PA612 resins.

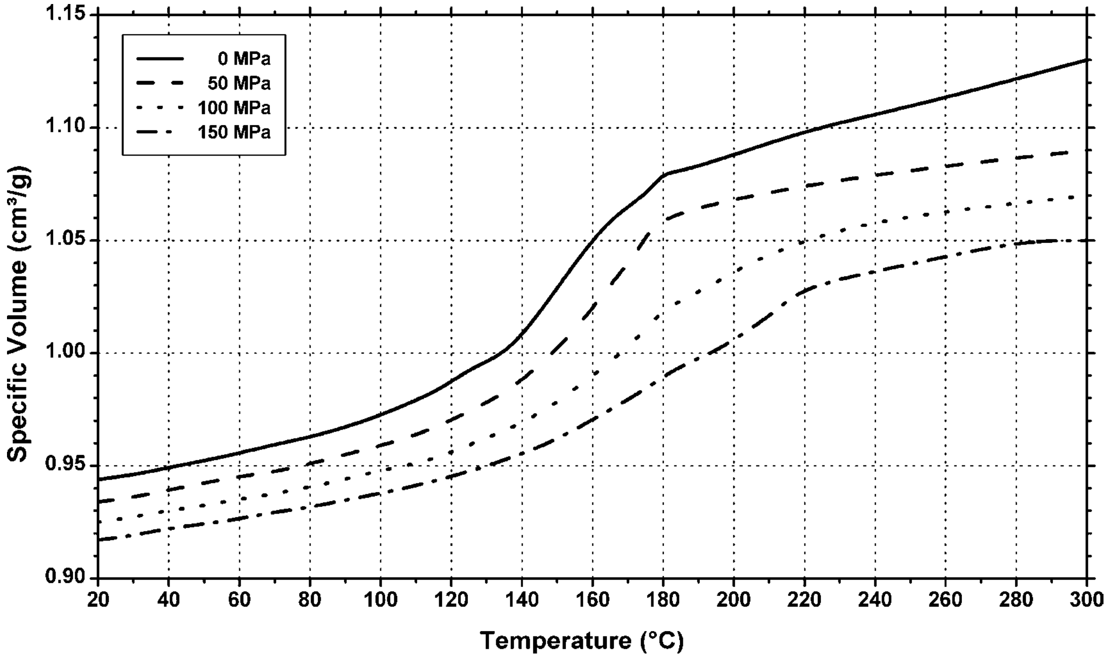


Figure 6.163. Pressure-specific volume-temperature of DuPont Zytel® 158 NC010—general purpose, lubricated PA612 resin.

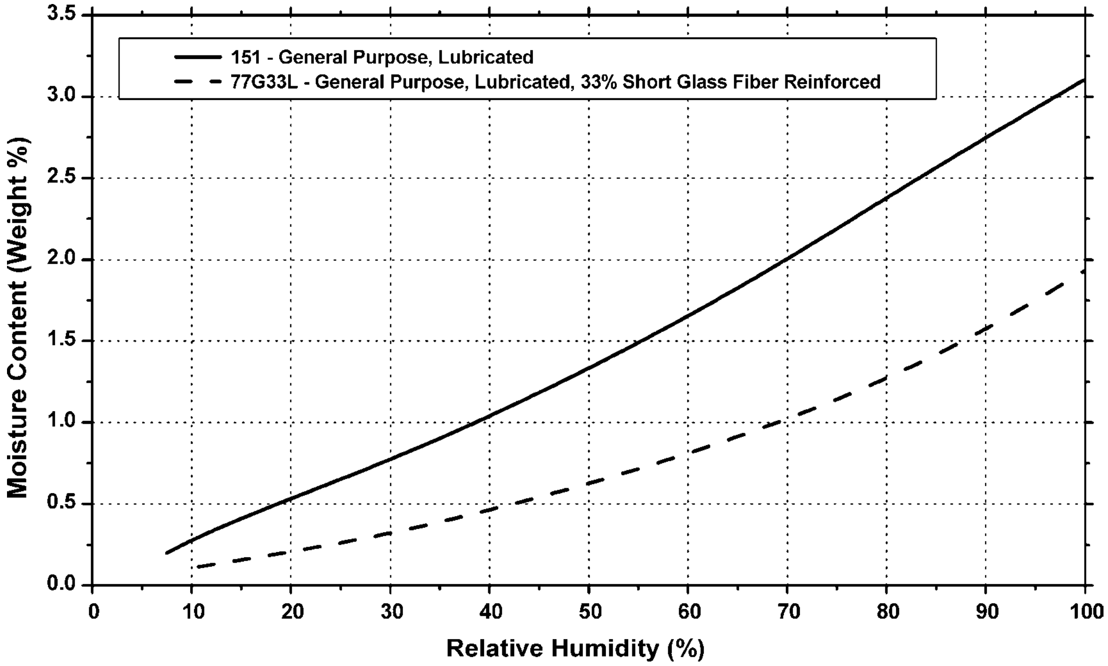


Figure 6.164. Equilibrium moisture content vs. relative humidity of two DuPont Zytel® PA612 resins.

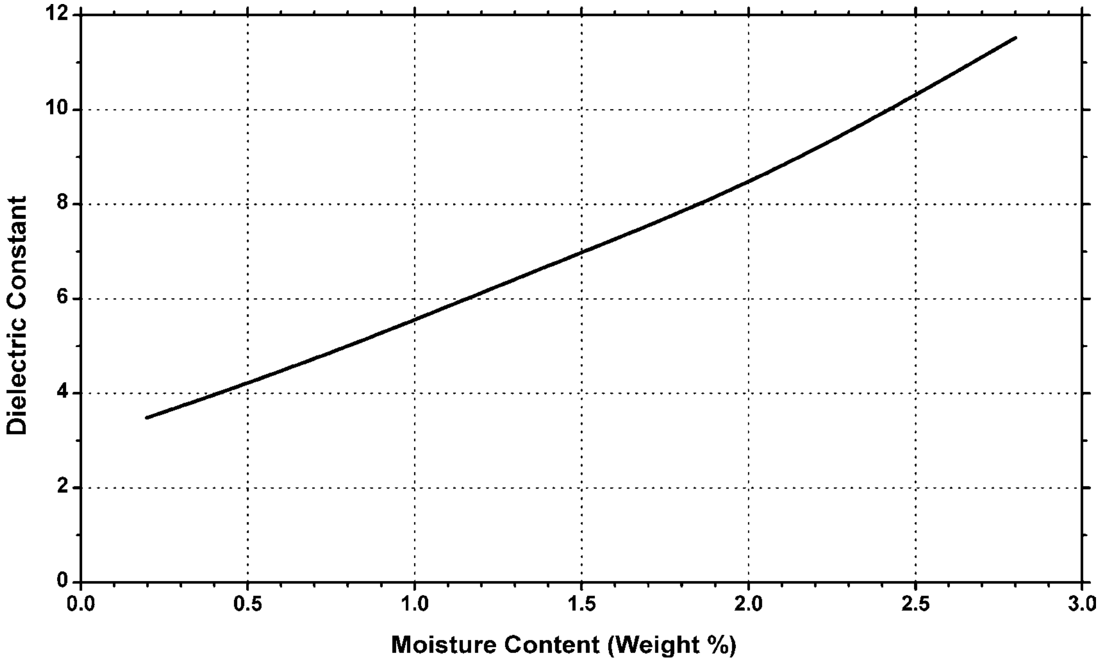


Figure 6.165. Dielectric constant vs. moisture content for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

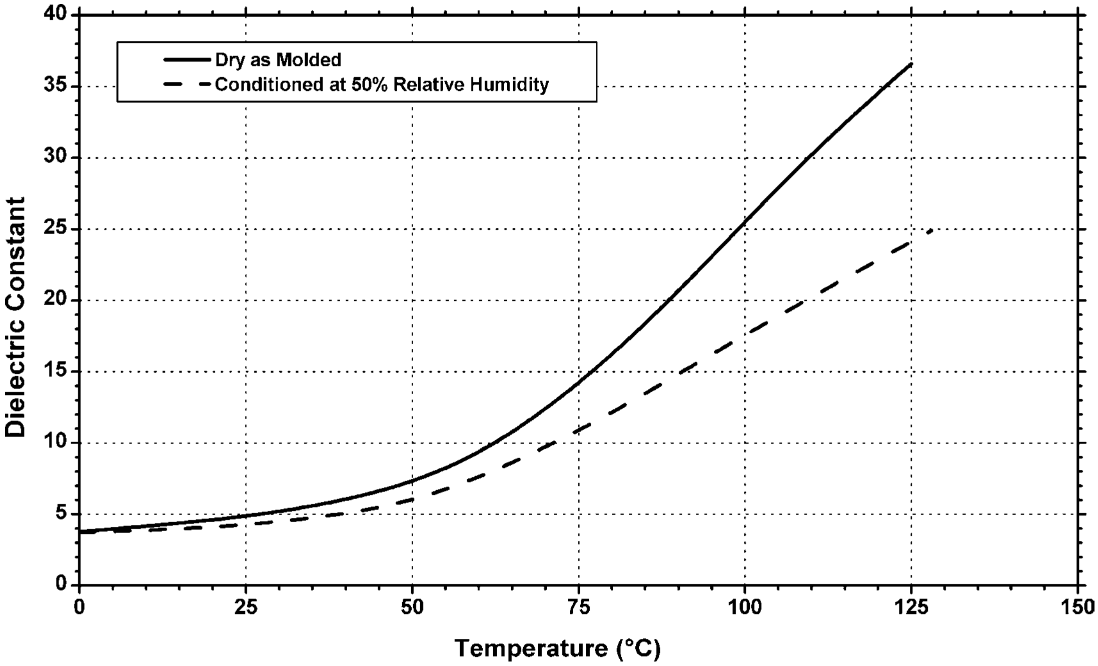


Figure 6.166. Dielectric constant vs. temperature for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

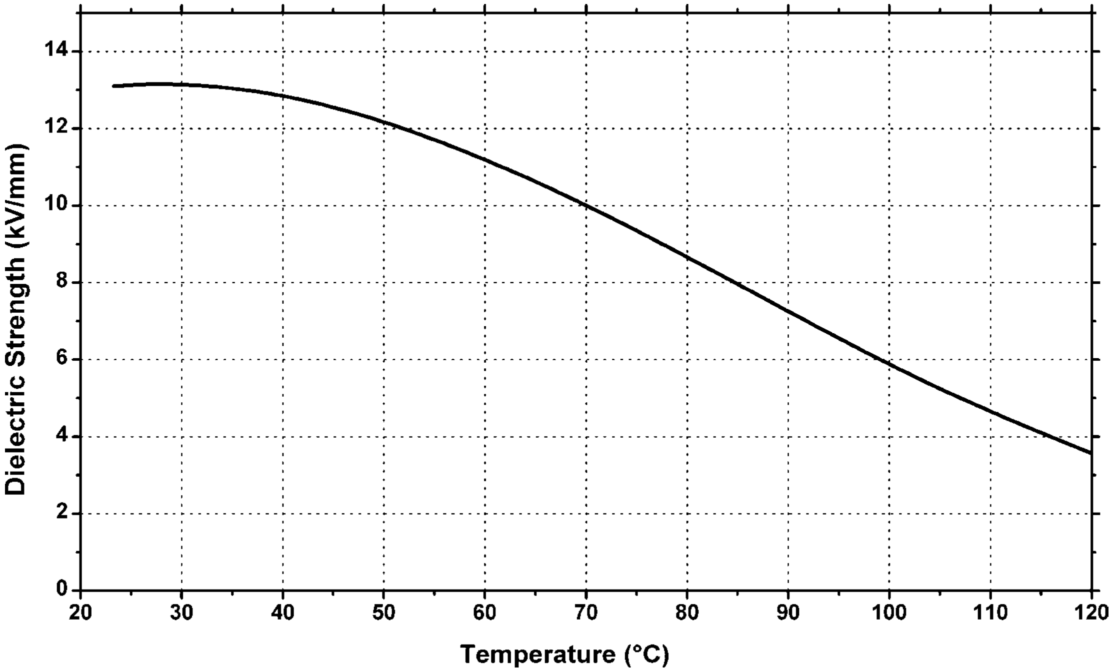


Figure 6.167. Dielectric strength vs. temperature for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

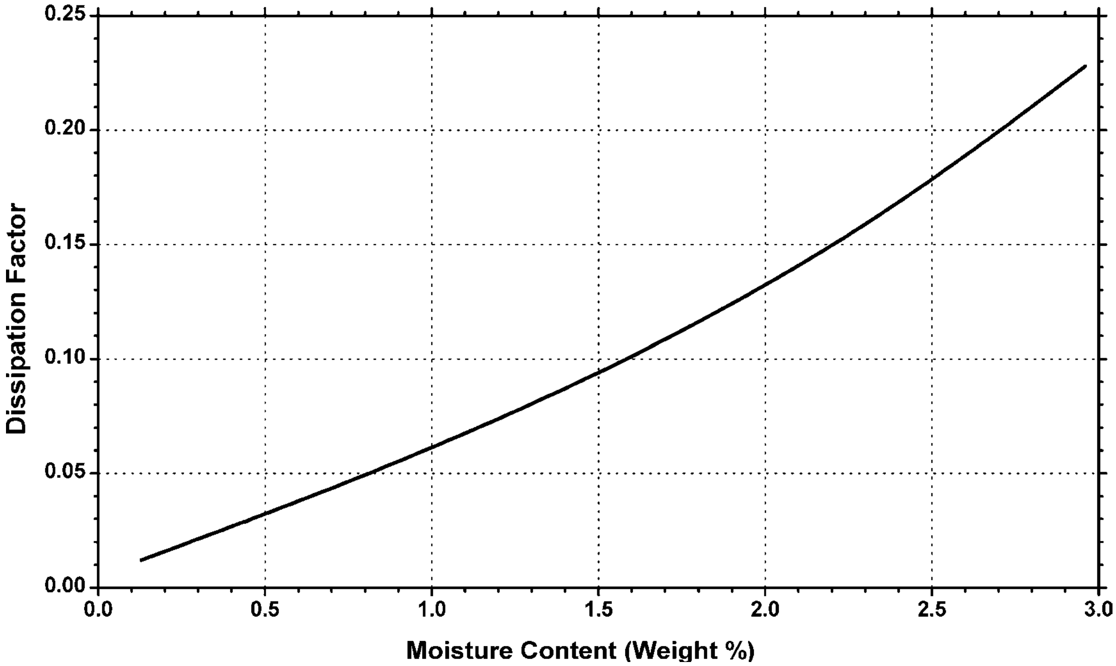


Figure 6.168. Dissipation factor vs. moisture content at 100 Hz for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

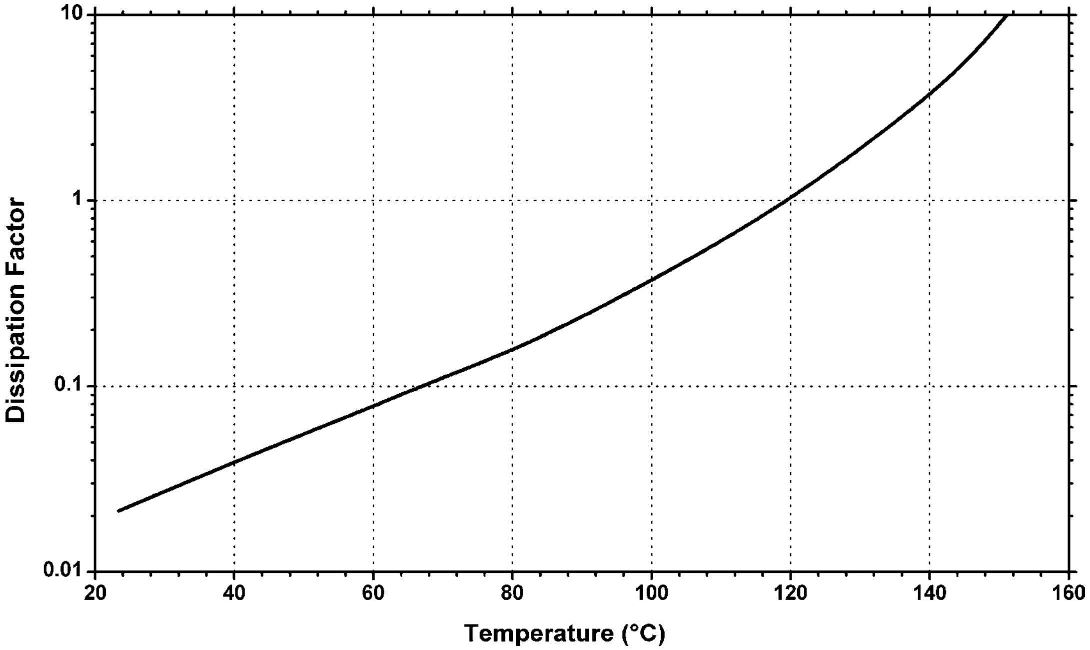


Figure 6.169. Dissipation factor vs. temperature at 100 Hz for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

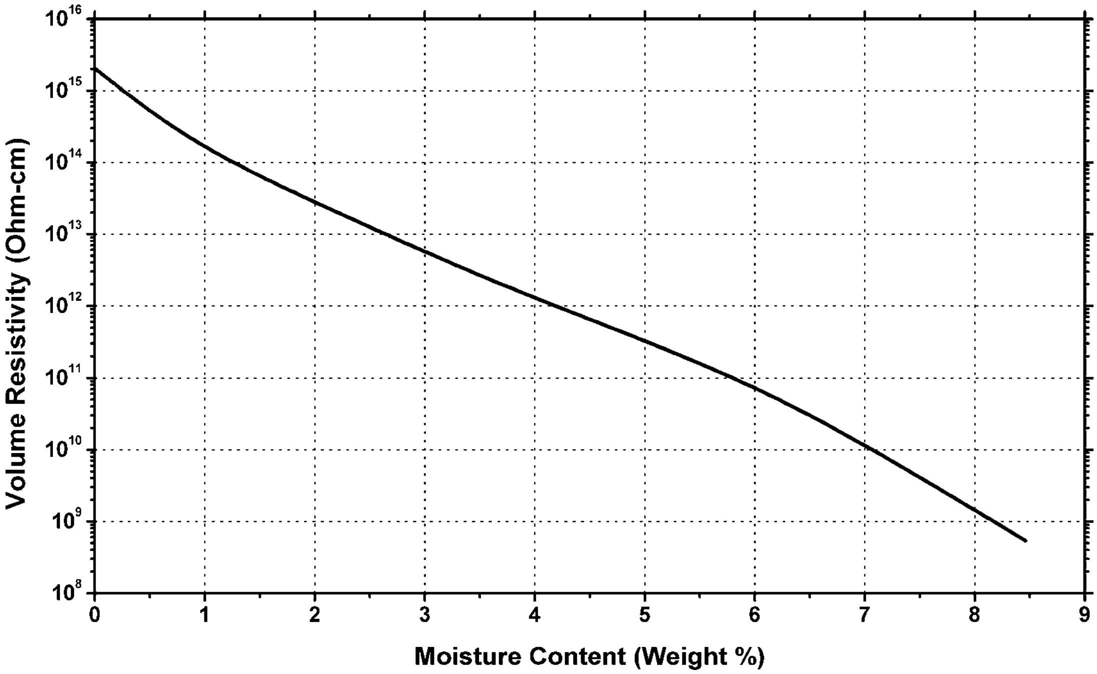


Figure 6.170. Volume resistivity vs. moisture content for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

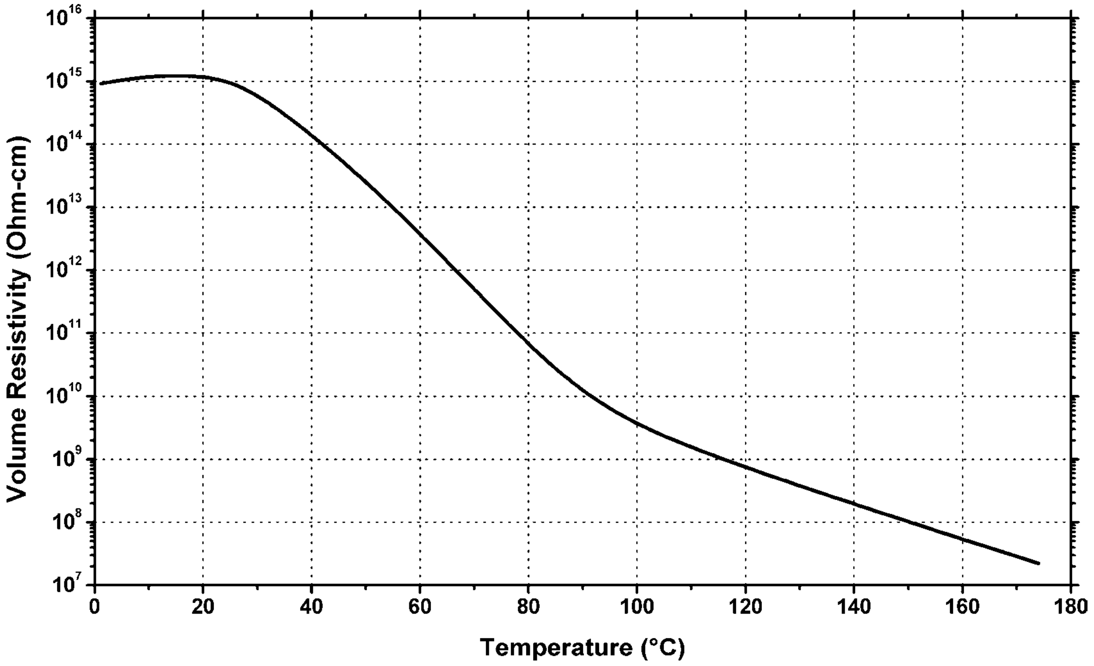


Figure 6.171. Volume resistivity vs. temperature for DuPont Zytel® 151L—general purpose, lubricated PA612 resin.

6.8 Nylon 6/66 (PA666)

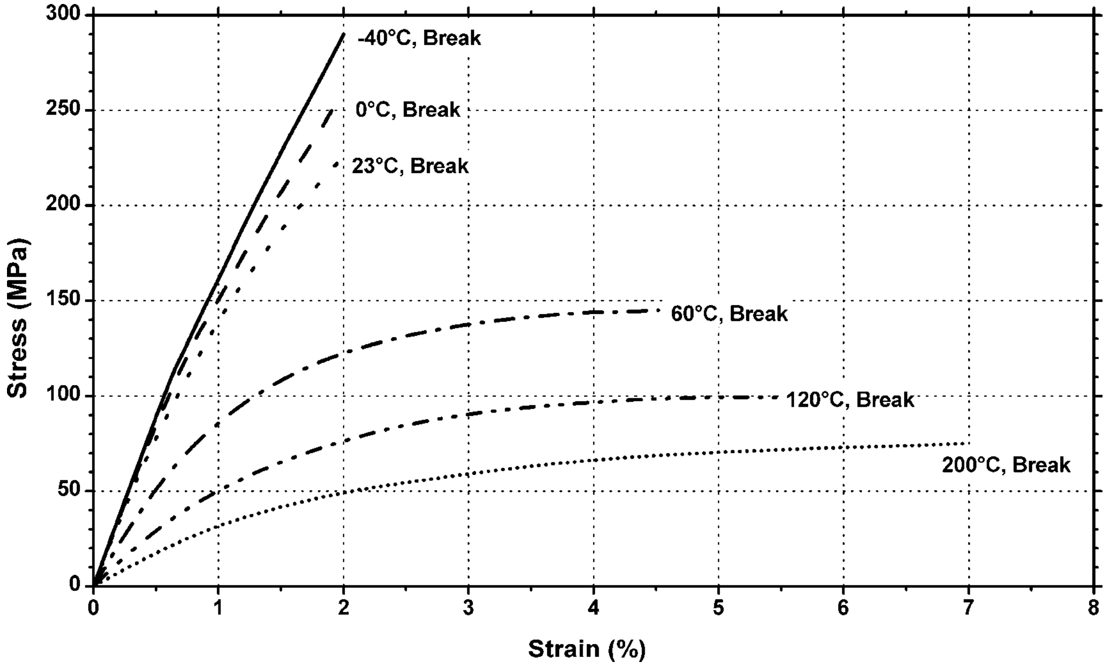


Figure 6.172. Stress vs. strain at various temperatures for EMS-Grivory Grivory® HT2V-5H—(PA 6T/66) 50% glass fiber, heat stabilized PA666 resin (conditioned at 50% relative humidity).

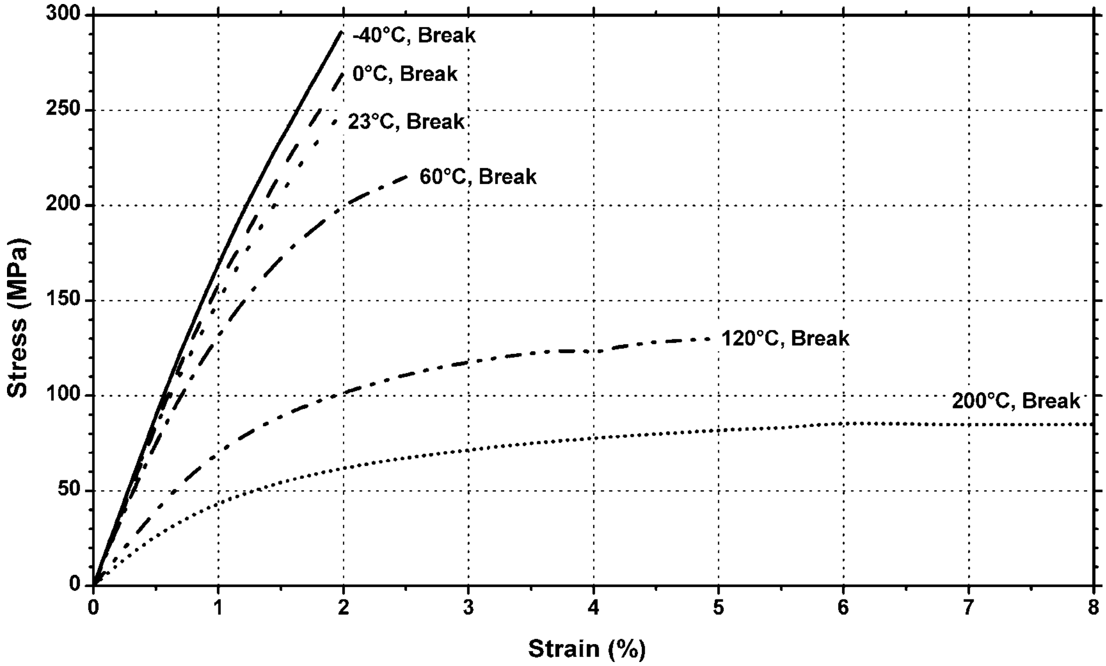


Figure 6.173. Stress vs. strain at various temperatures for EMS-Grivory Grivory® HT2V-5H—(PA 6T/66) 50% glass fiber, heat stabilized PA666 resin (DAM).

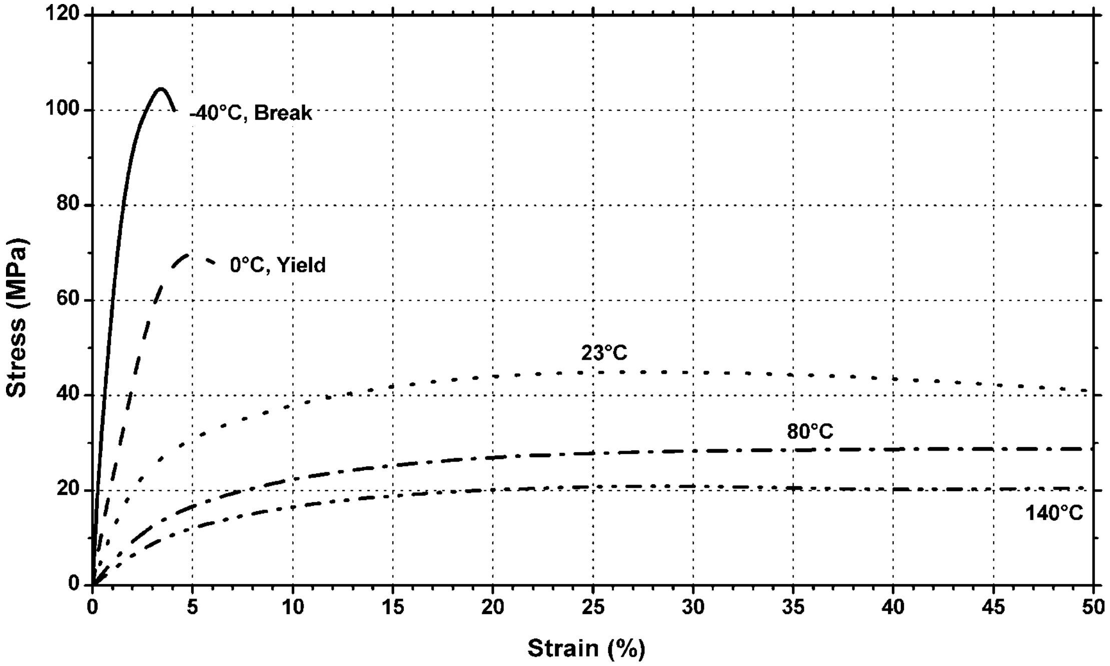


Figure 6.174. Stress vs. strain at various temperatures for EMS-Grivory Grilon® TS V0—heat stabilized, flame retardant PA666 resin (conditioned at 50% relative humidity).

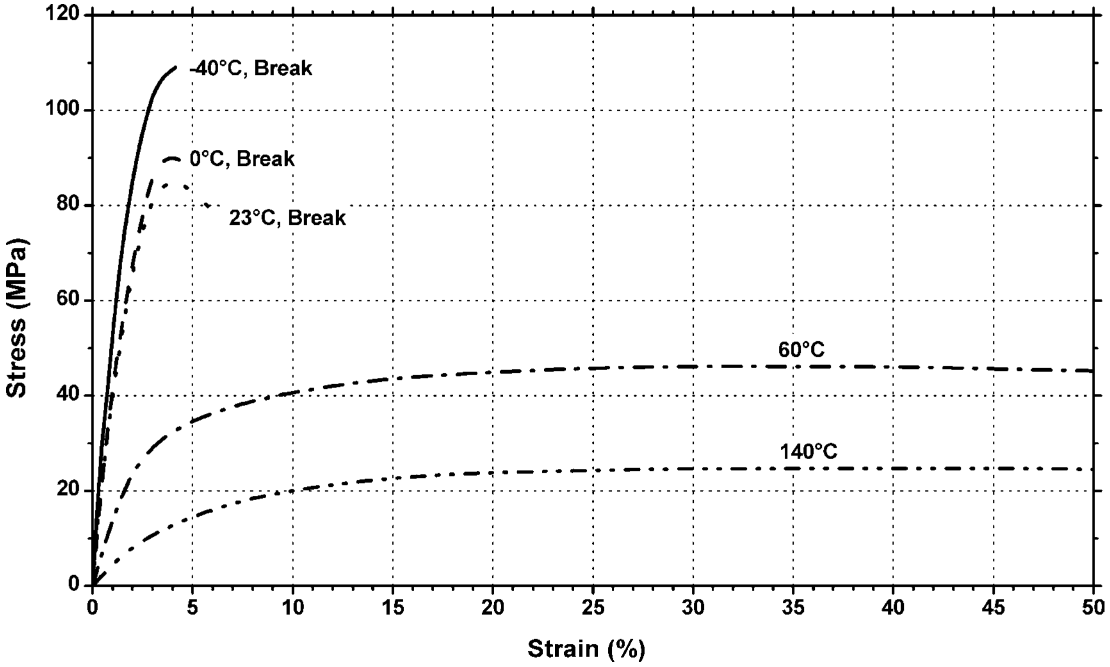


Figure 6.175. Stress vs. strain at various temperatures for EMS-Grivory Grilon® TS V0—heat stabilized, flame retardant PA666 resin (DAM).

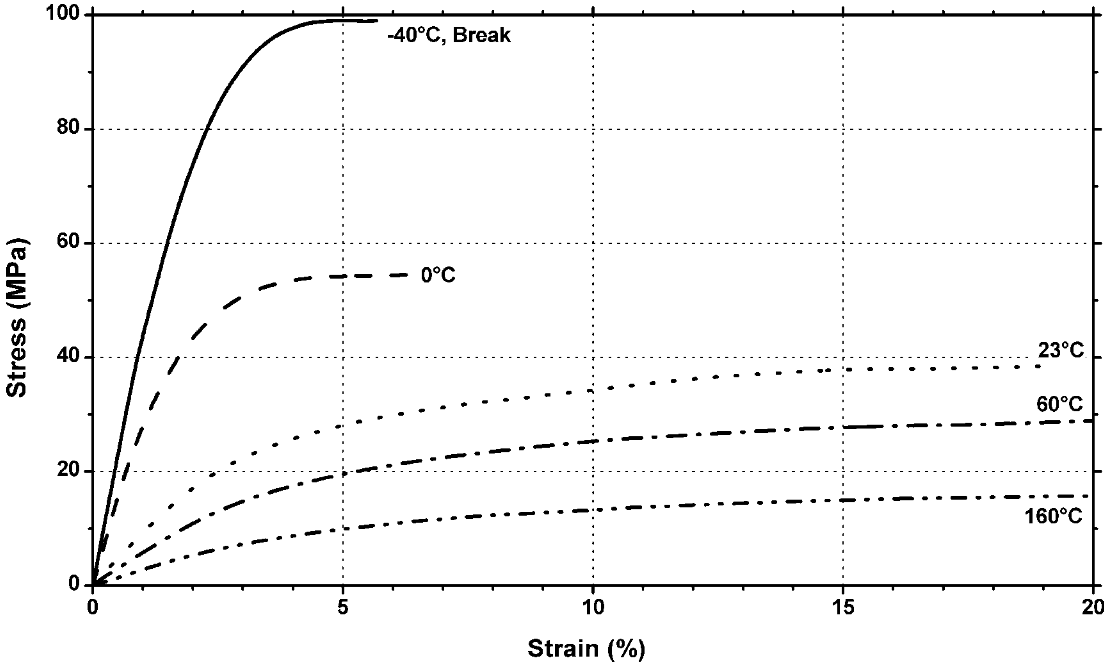


Figure 6.176. Stress vs. strain at various temperatures for BASF Ultramid® C3U—general purpose injection molding grade with improved flame retardance PA666 resin (conditioned at 50% relative humidity).

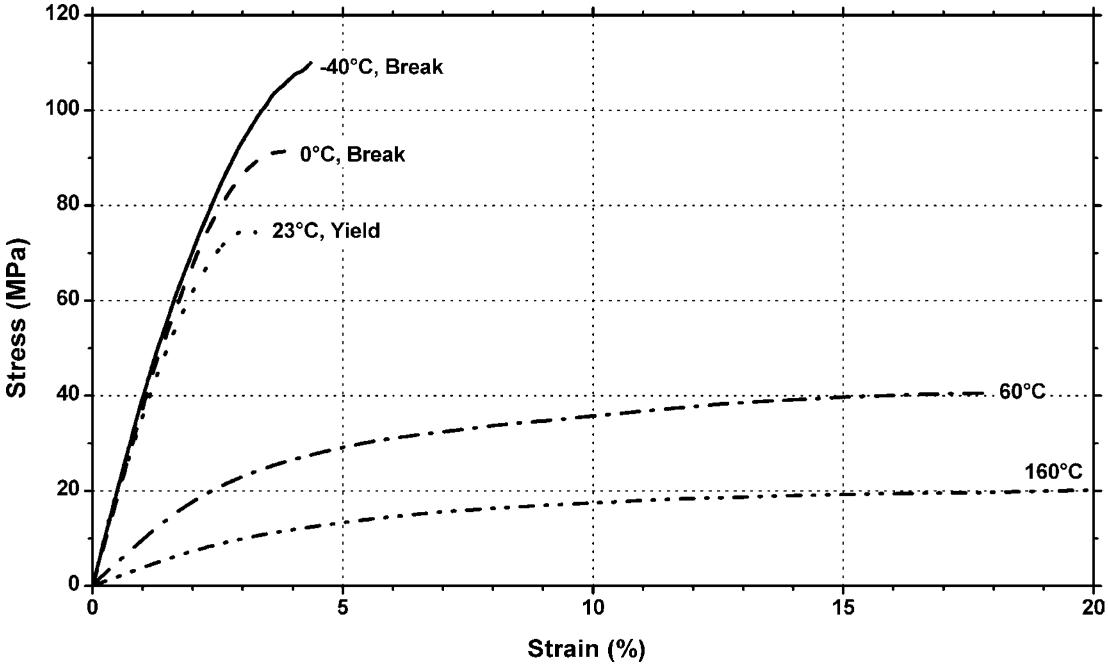


Figure 6.177. Stress vs. strain at various temperatures for BASF Ultramid® C3U—general purpose injection molding grade with improved flame retardance PA666 resin (DAM).

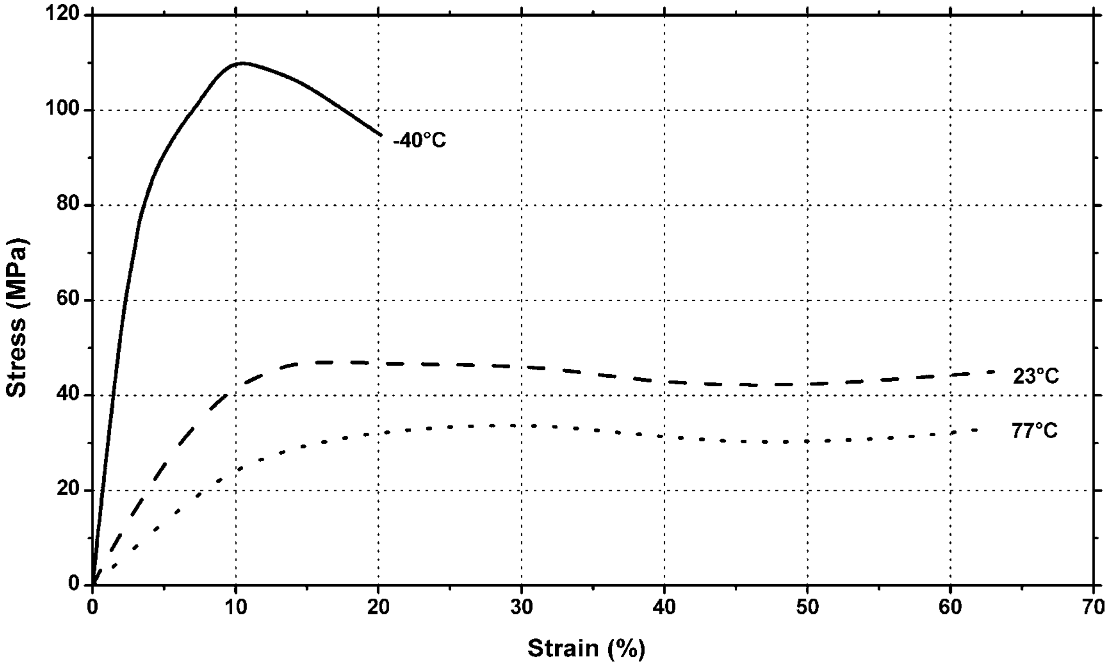


Figure 6.178. Stress vs. strain at various temperatures for DuPont Zytel® 109L—nucleated, lubricated PA666 resin (conditioned at 50% relative humidity).

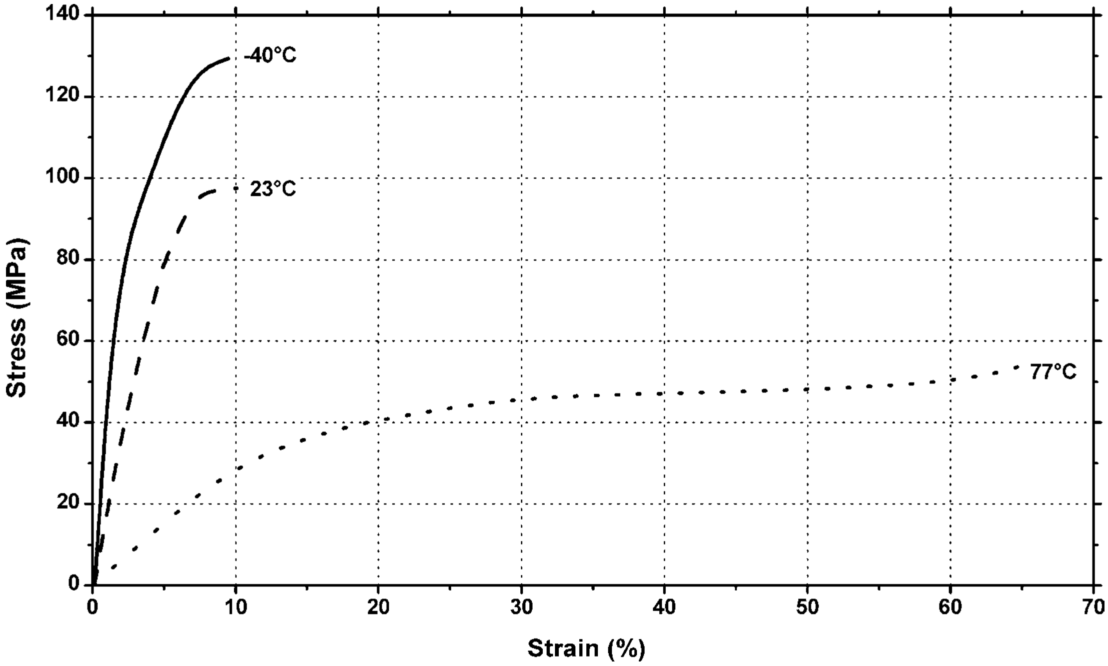


Figure 6.179. Stress vs. strain at various temperatures for DuPont Zytel® 109L—nucleated, lubricated PA666 resin (DAM).

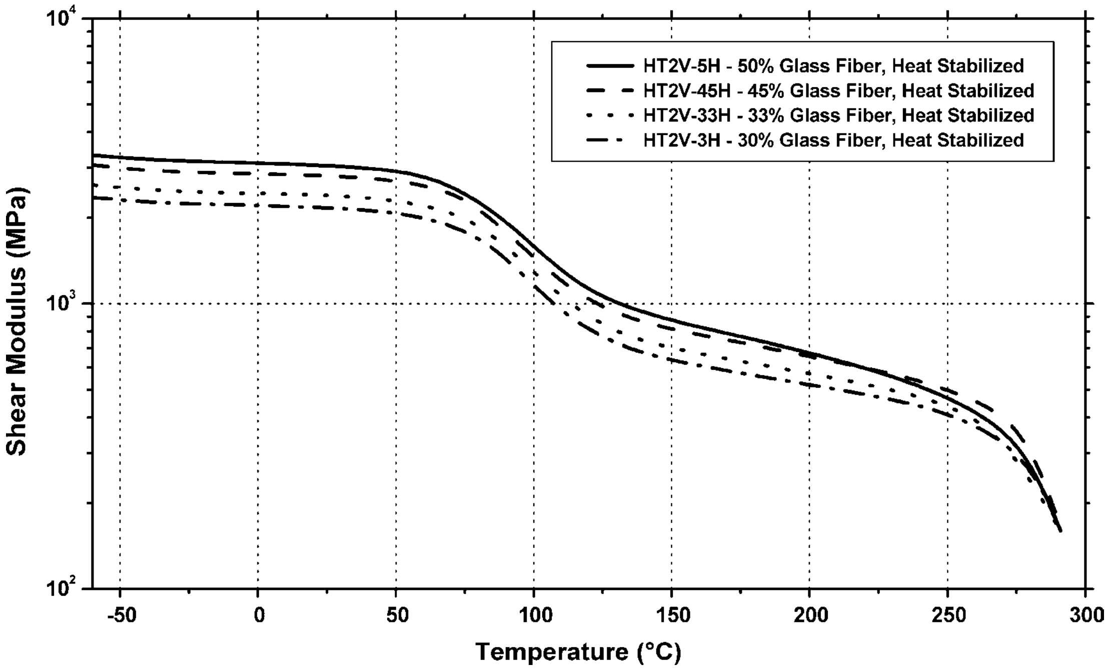


Figure 6.180. Shear modulus vs. temperature of EMS-Grivory Grivory® HT2V Series of PA666 resins.

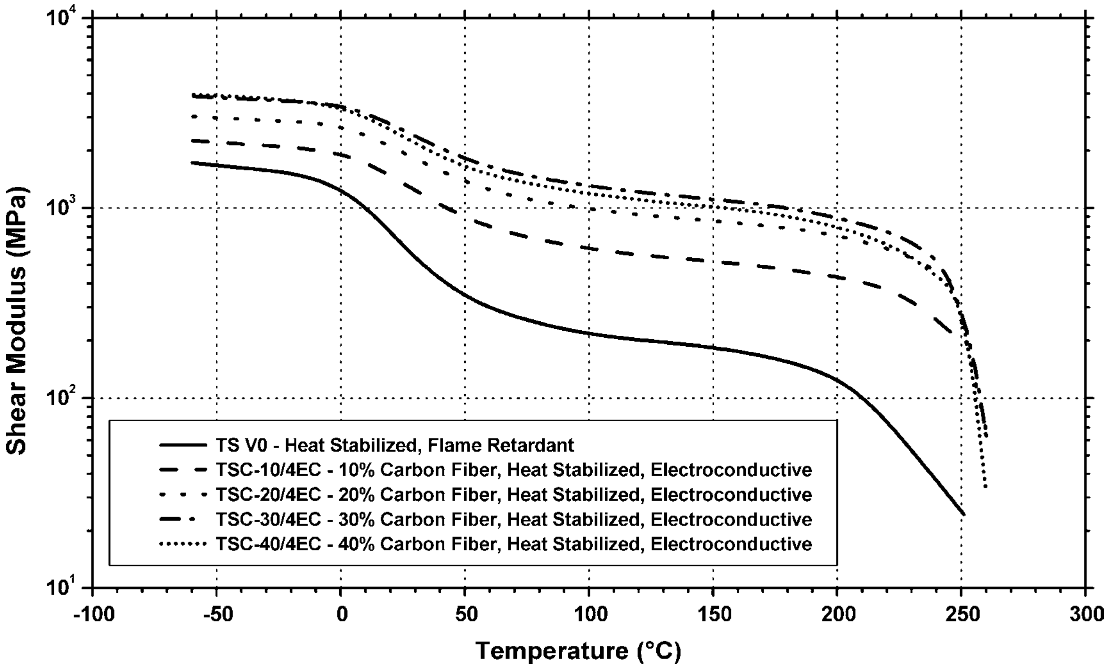


Figure 6.181. Shear modulus vs. temperature of EMS-Grivory Grilon® TS Series of PA666 resins (conditioned at 50% relative humidity).

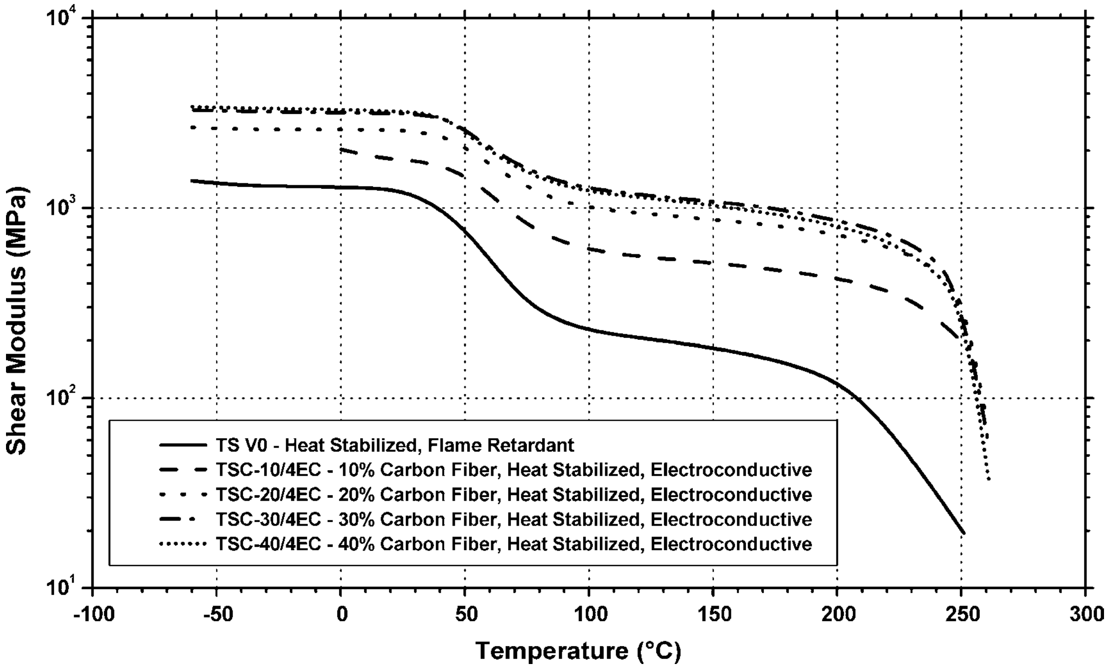


Figure 6.182. Shear modulus vs. temperature of EMS-Grivory Grilon® TS Series of PA666 resins (DAM).

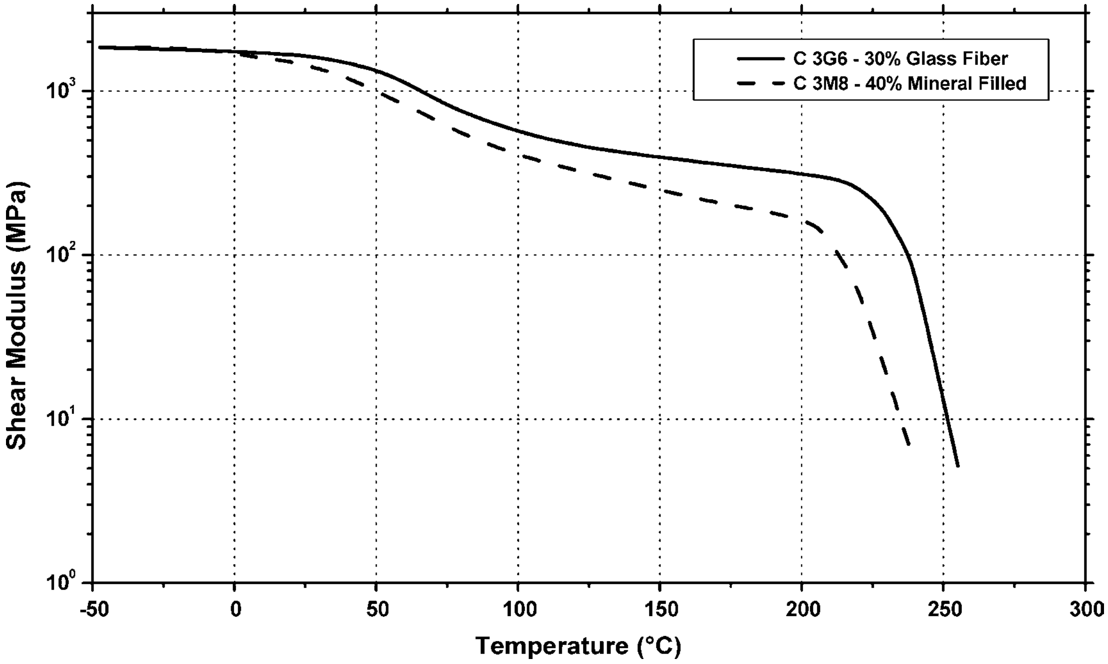


Figure 6.183. Shear modulus vs. temperature for BASF Ultramid® PA666 resins.

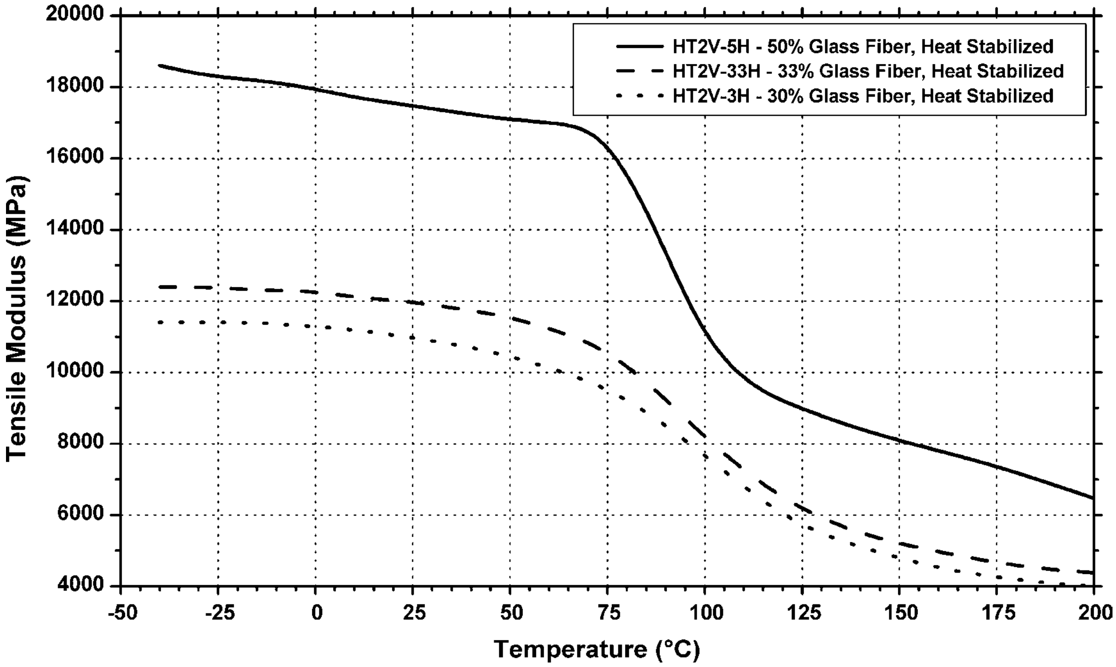


Figure 6.184. Tensile modulus vs. temperature of EMS-Grivory Grivory® HT2V series PA666 resins.

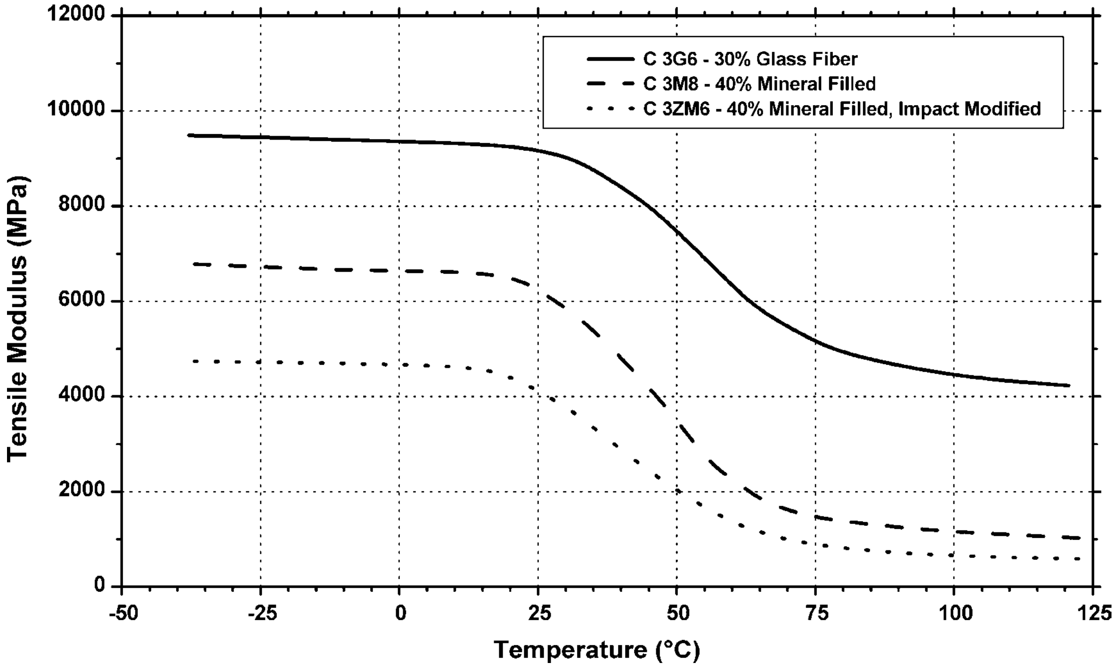


Figure 6.185. Tensile modulus vs. temperature for BASF Ultramid® PA666 resins.

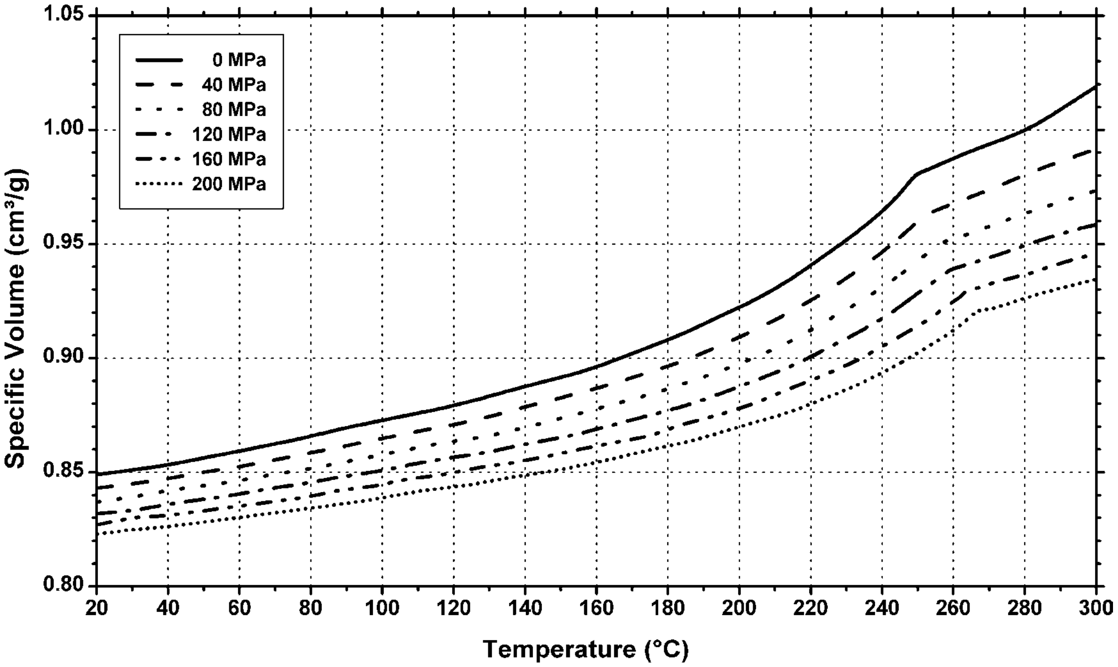


Figure 6.186. Pressure-specific volume-temperature (PVT) for BASF Ultramid® C3U-C 3U—general purpose, injection molding, improved flame retardance PA666 resin.

6.9 Nylon Amorphous

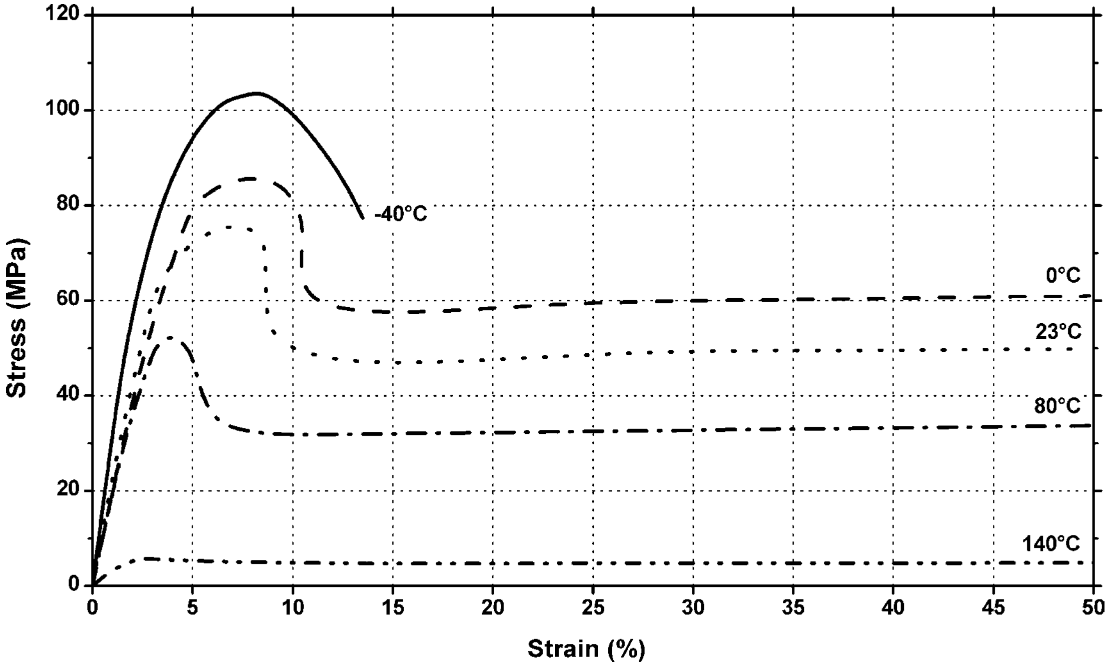


Figure 6.187. Stress vs. strain at various temperatures for EMS-Grivory Grilamid® TR55—standard grade amorphous nylon (conditioned at 50% relative humidity).

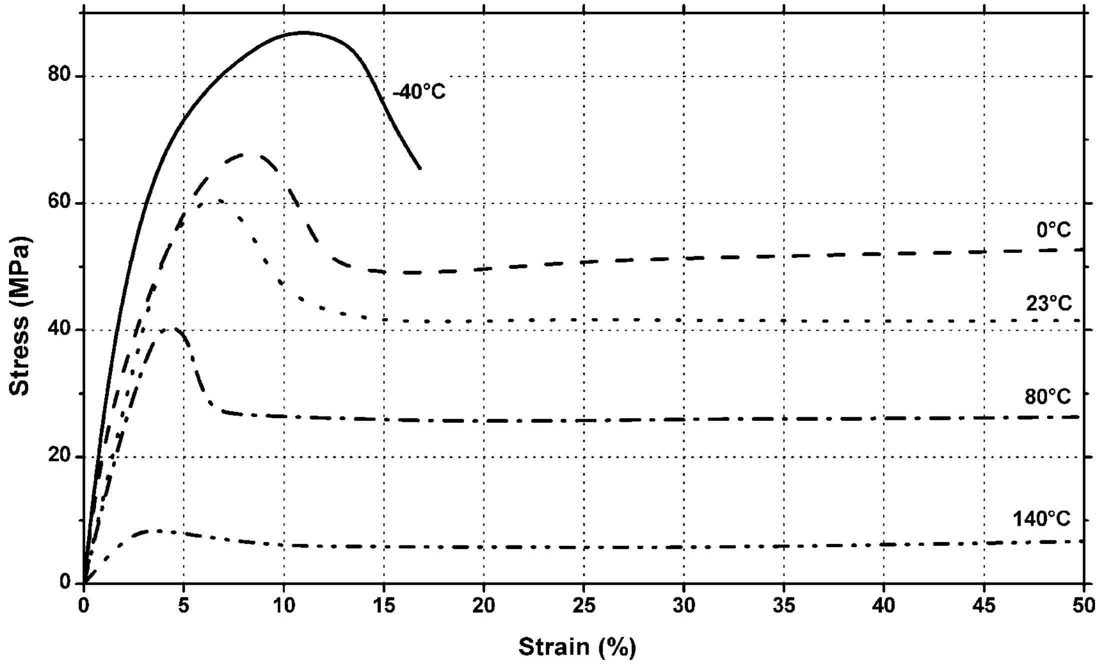


Figure 6.188. Stress vs. strain at various temperatures for EMS-Grivory Grilamid® Grilamid® TR90—high strength amorphous nylon (conditioned at 50% relative humidity).

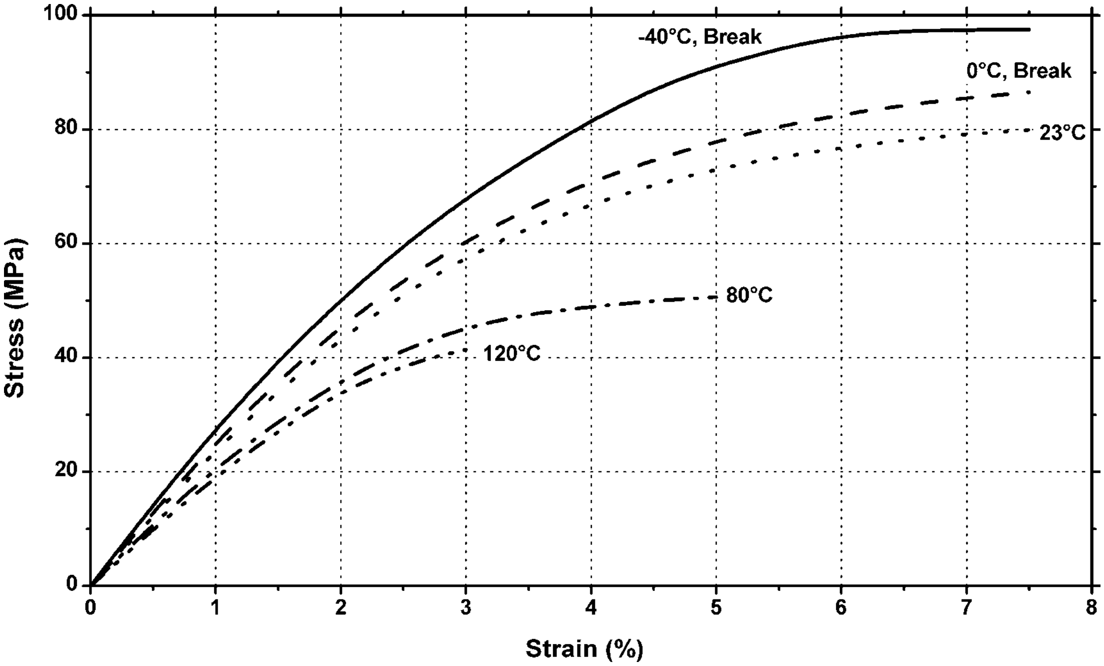


Figure 6.189. Stress vs. strain at various temperatures for Degussa Trogamid® T5000—standard grade amorphous nylon.

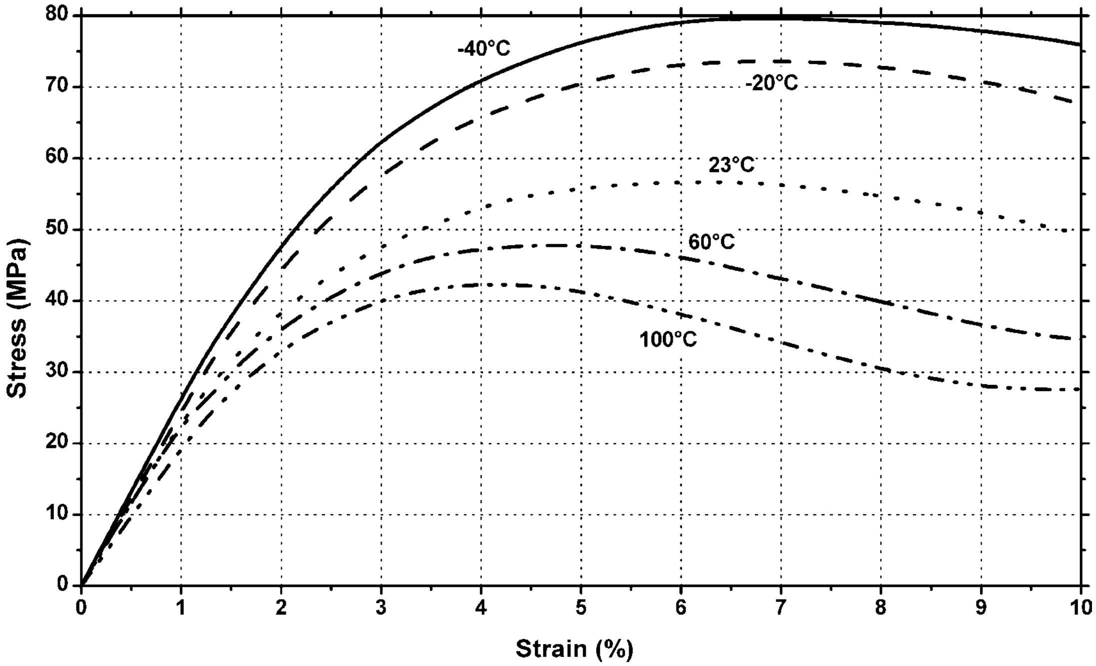


Figure 6.190. Stress vs. strain at yield at various temperatures for Degussa Trogamid® T5000—standard grade amorphous nylon.

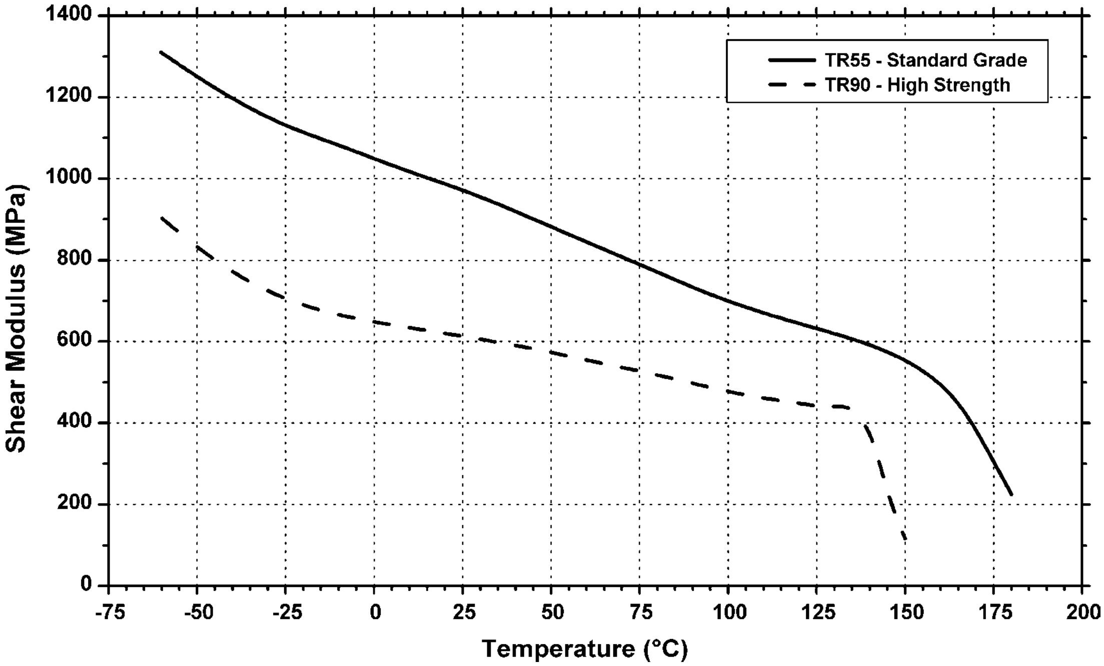


Figure 6.191. Shear modulus vs. temperature for two EMS-Grivory Grilamid® amorphous nylons.

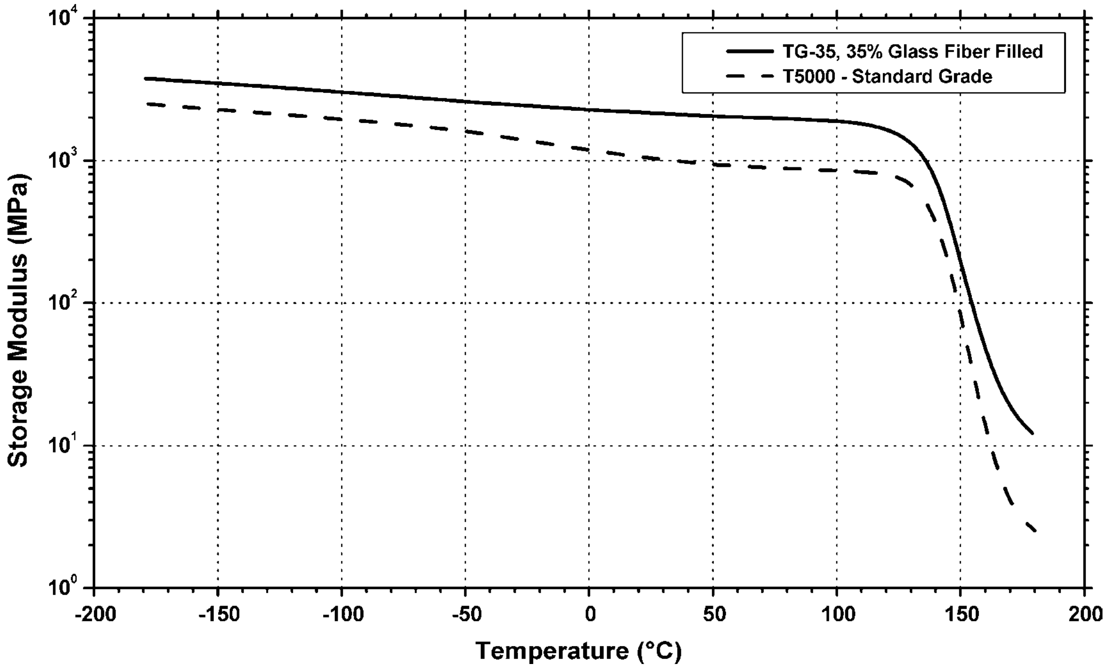


Figure 6.192. Storage modulus vs. temperature for two Degussa Trogamid® amorphous nylons.

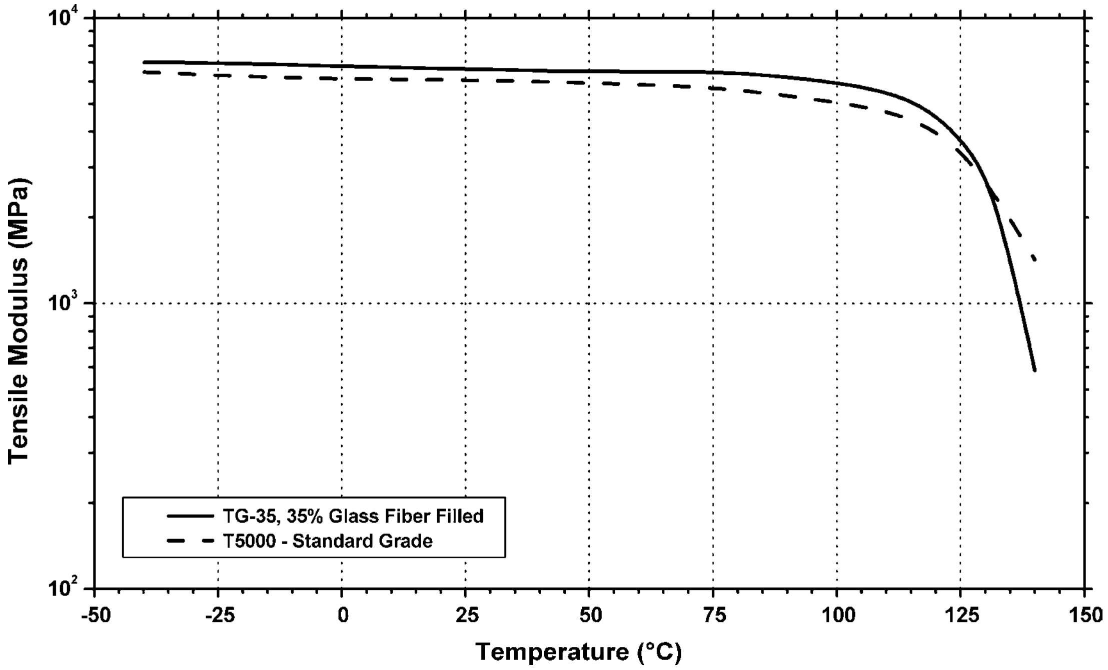


Figure 6.193. Tensile modulus vs. temperature for two EMS-Grivory Grilamid® amorphous nylons.

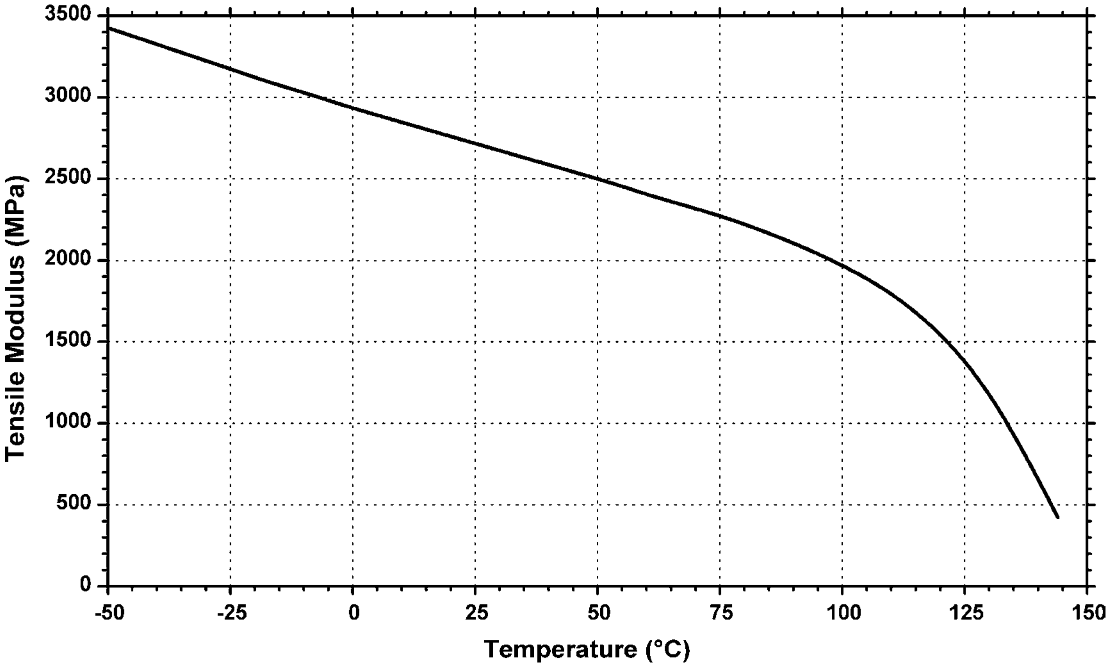


Figure 6.194. Tensile modulus vs. temperature for Degussa Trogamid® amorphous nylon.

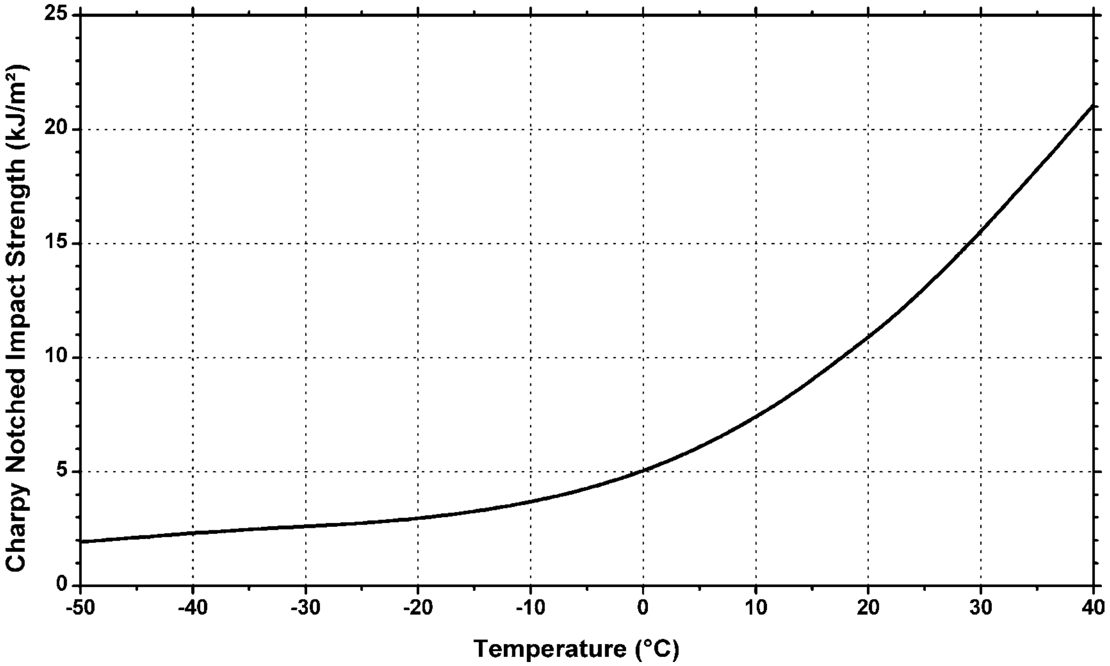


Figure 6.195. Charpy notched impact strength vs. temperature for Degussa Trogamid® T5000—standard grade amorphous nylon.

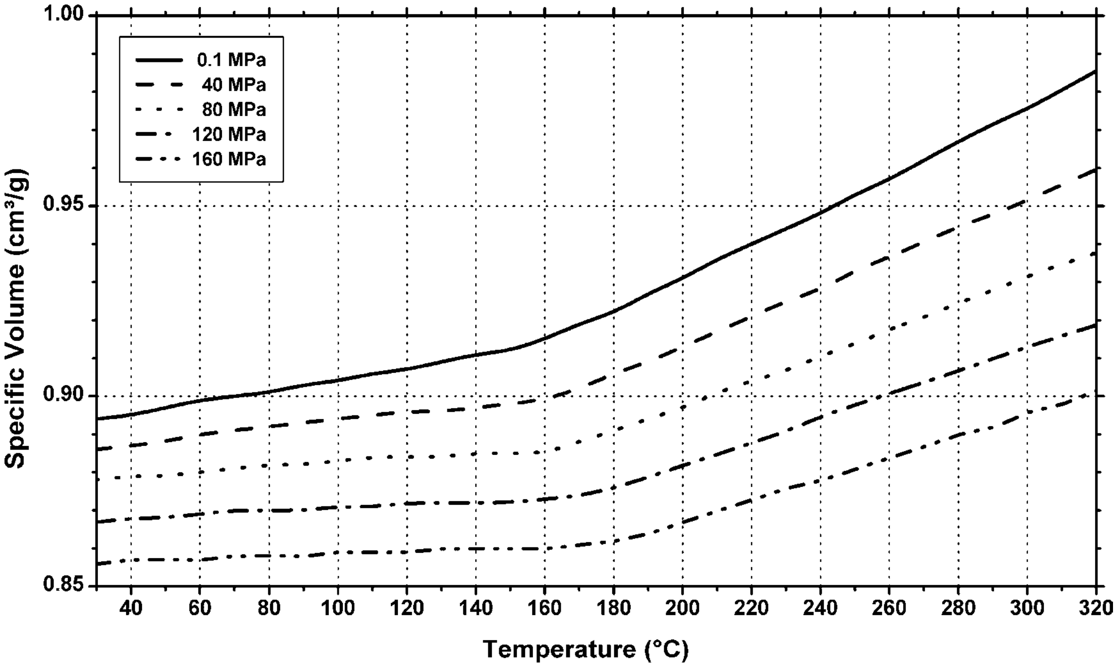


Figure 6.196. Pressure-specific volume-temperature (PVT) for Degussa Trogamid® T5000—standard grade amorphous nylon.

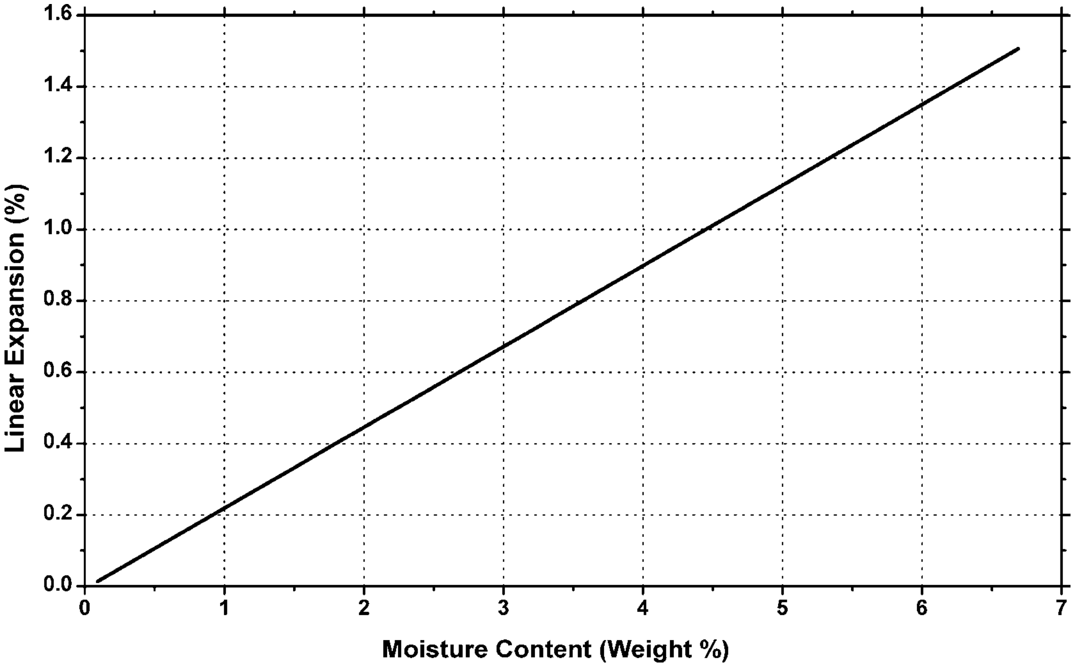


Figure 6.197. Linear expansion vs. moisture content for Degussa Trogamid® amorphous nylon.

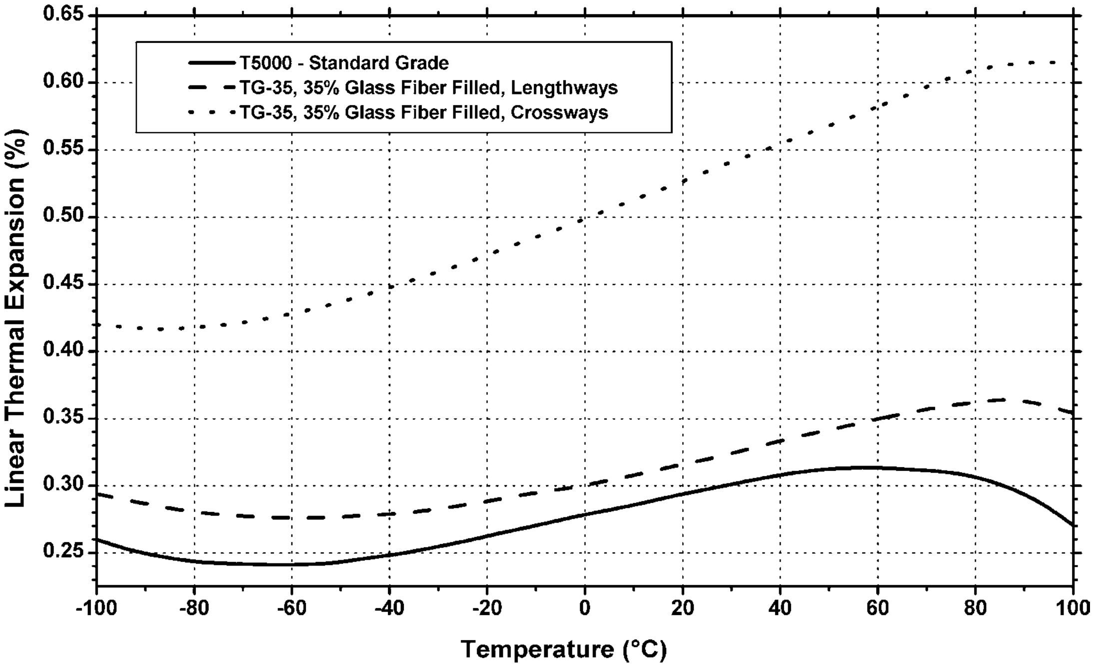


Figure 6.198. Linear thermal expansion vs. temperature for Degussa Trogamid® amorphous nylons.

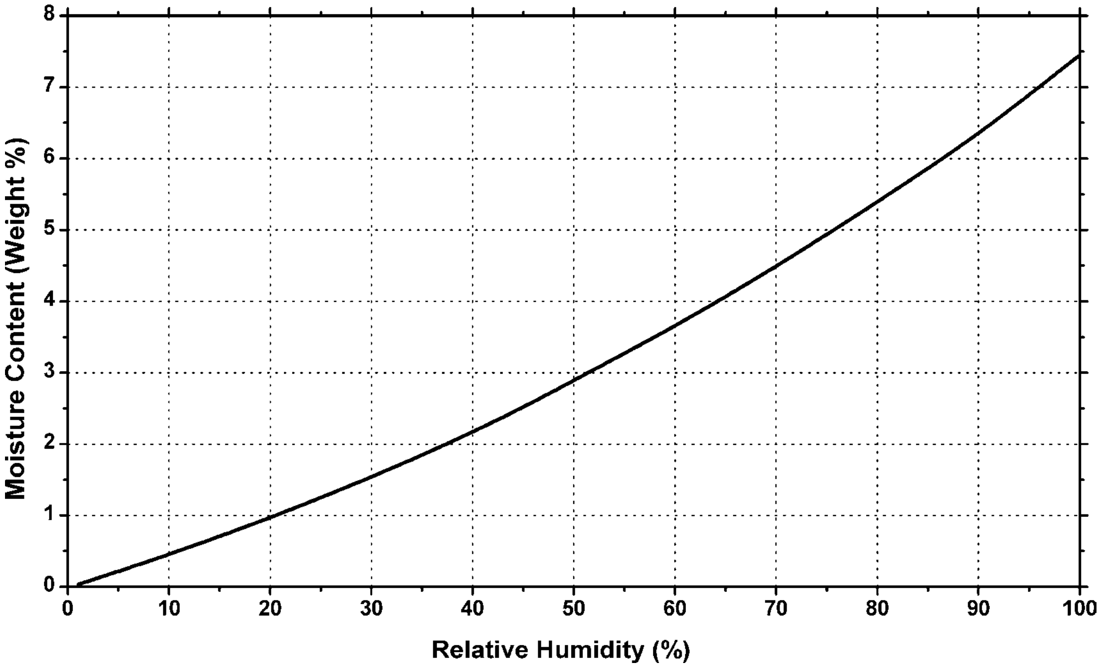


Figure 6.199. Moisture content vs. relative humidity for Degussa Trogamid® amorphous nylon.

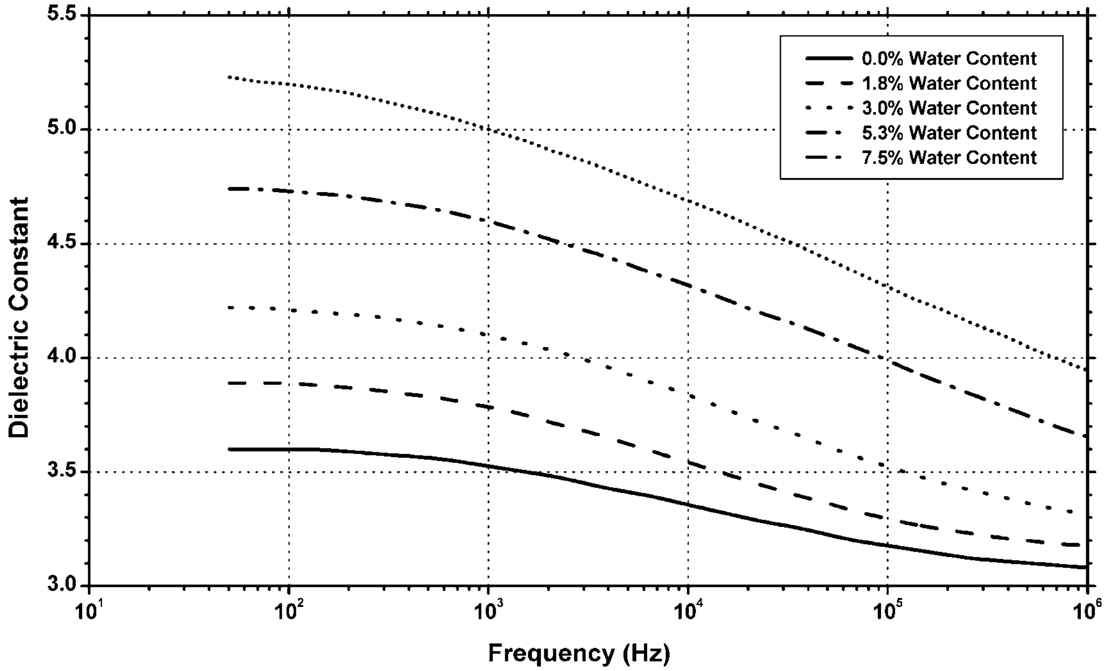


Figure 6.200. Dielectric constant vs. frequency and water content for Degussa Trogamid® T5000—standard grade amorphous nylon.

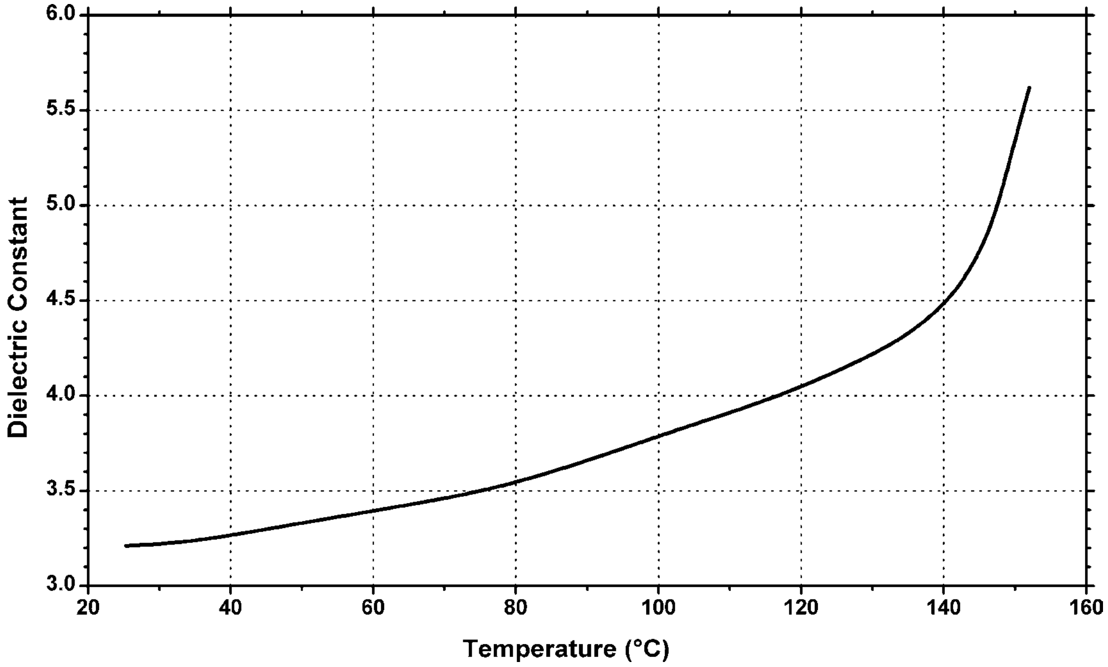


Figure 6.201. Dielectric constant vs. temperature for Degussa Trogamid® T5000—standard grade amorphous nylon.

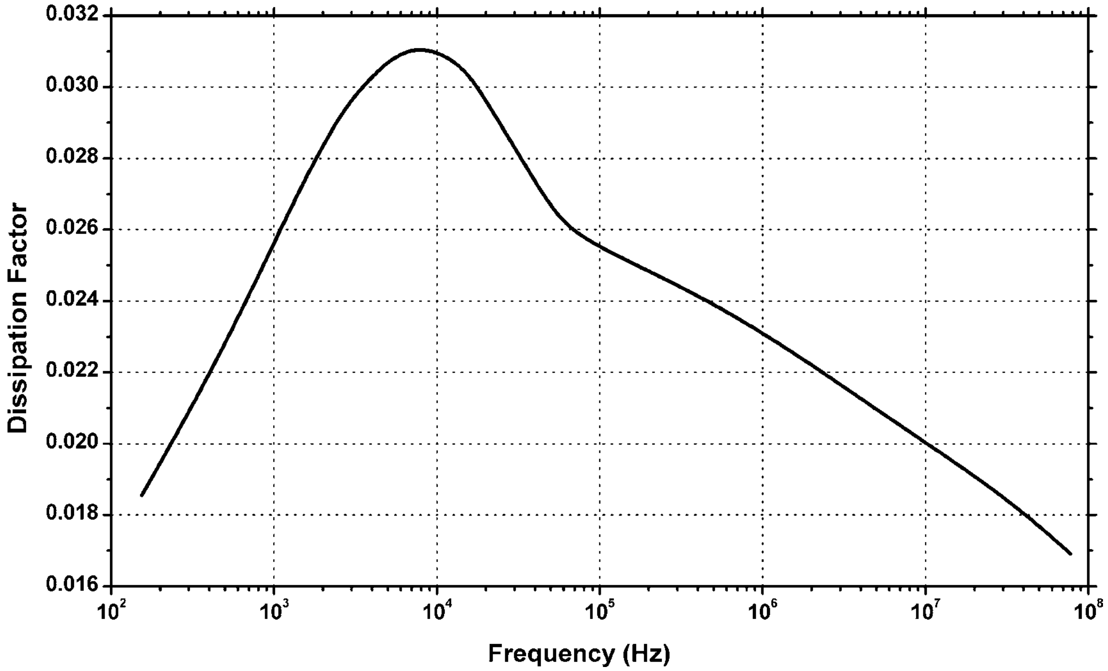


Figure 6.202. Dissipation factor vs. frequency for Degussa Trogamid® T5000—standard grade amorphous nylon.

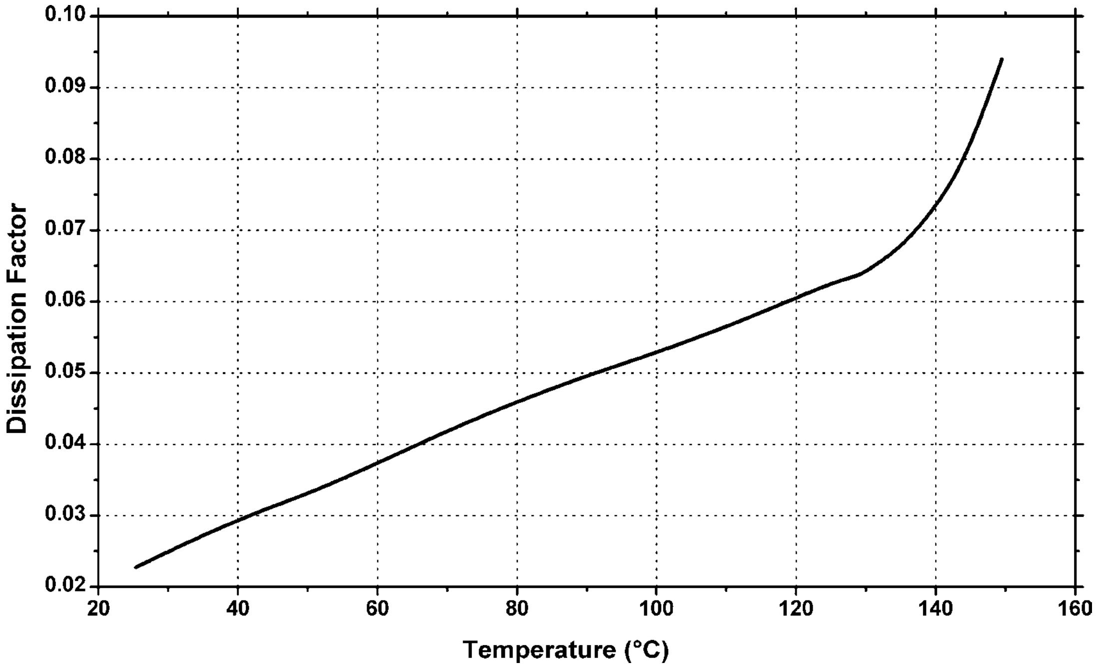


Figure 6.203. Dissipation factor vs. temperature for Degussa Trogamid® T5000—standard grade amorphous nylon.

6.10 Nylon 46 (PA46)

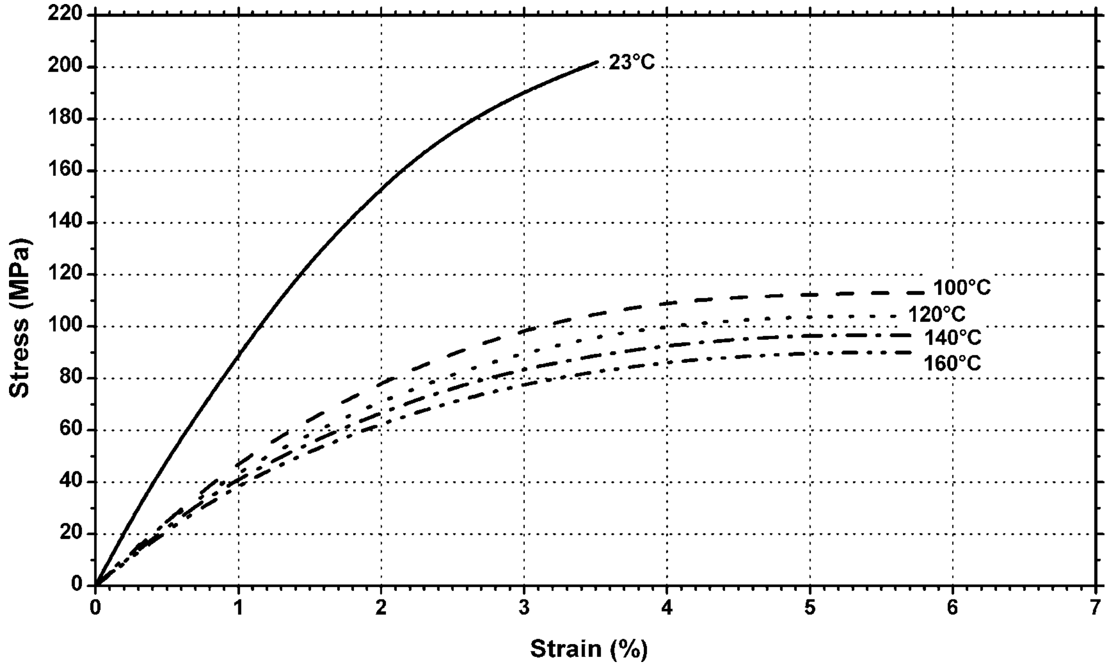


Figure 6.204. Stress vs. strain at various temperatures for DSM Engineering Plastics Stanyl® TE200F6—30% glass fiber reinforced, heat stabilized PA46 resin.

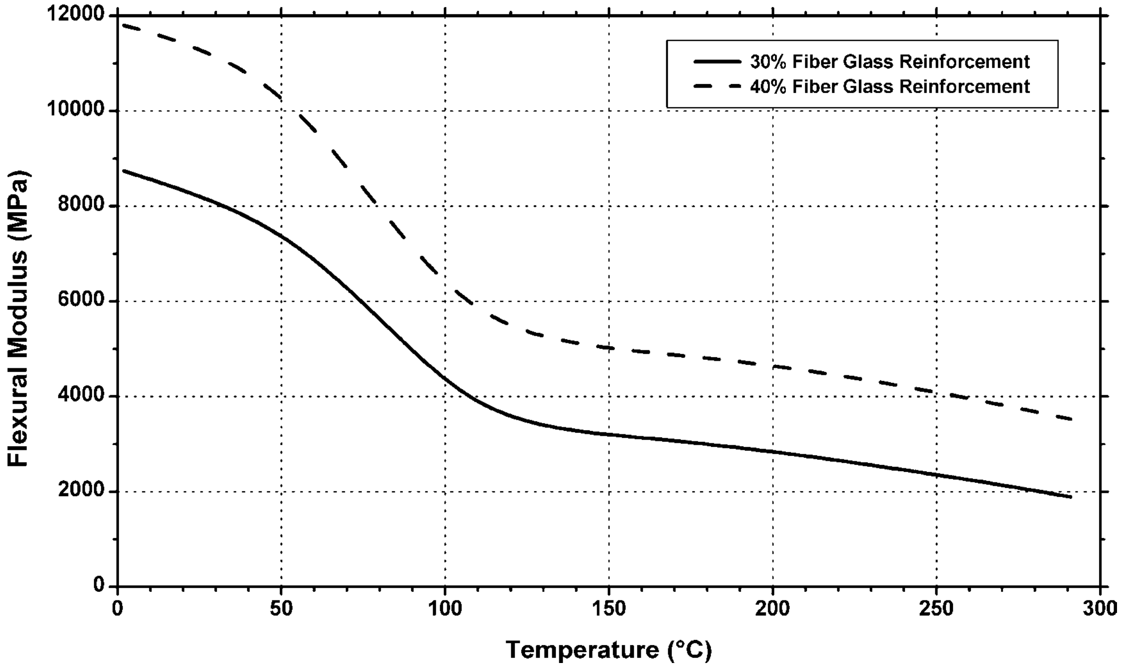


Figure 6.205. Flexural modulus vs. temperature for DSM Engineering Plastics Stanyl® PA46 resins.

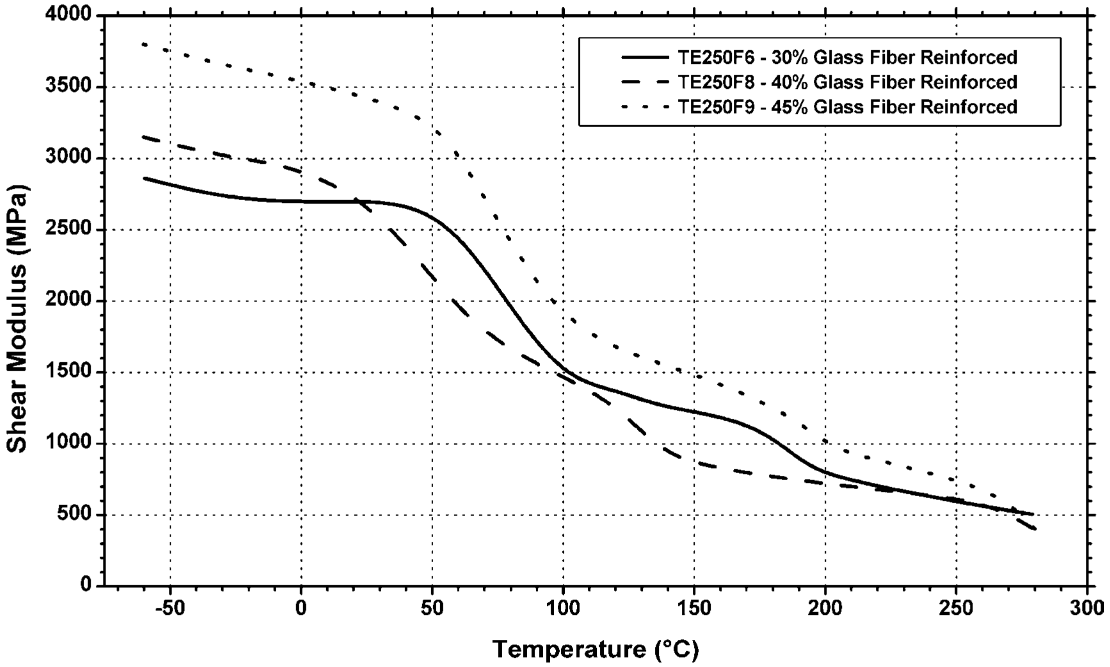


Figure 6.206. Shear modulus vs. temperature for DSM Engineering Plastics Stanyl® TE250 Series—fiber glass filled, heat stabilized, fire retardant PA46 resins.

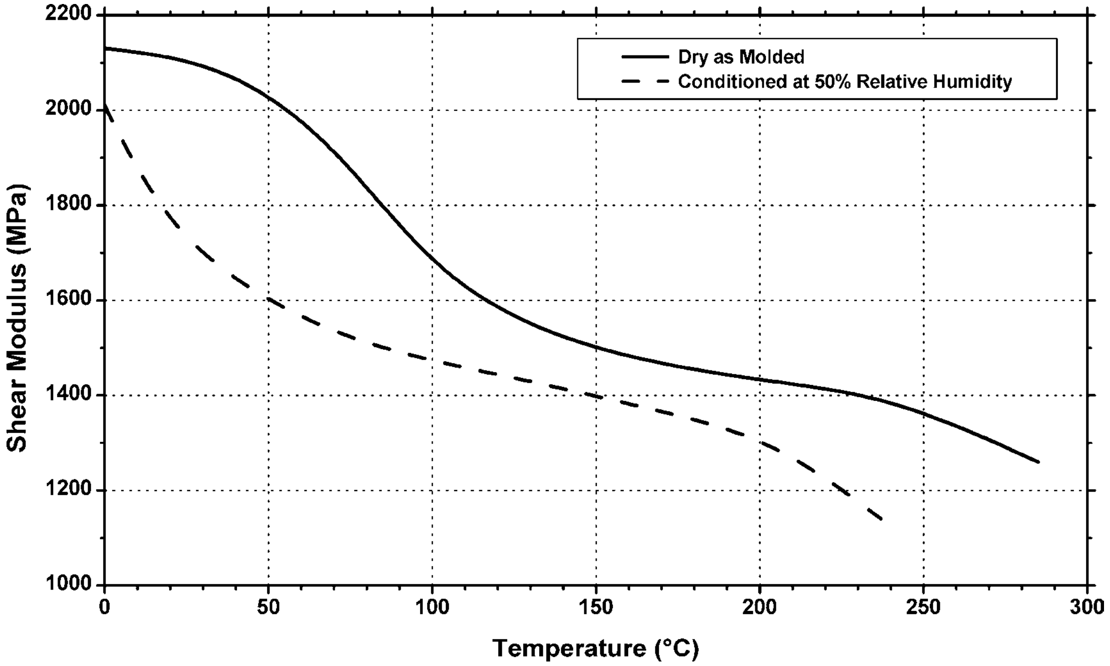


Figure 6.207. Shear modulus vs. temperature and humidity for DSM Engineering Plastics Stanyl® PA46 resins.

6.11 Polyphthalamide (PPA)

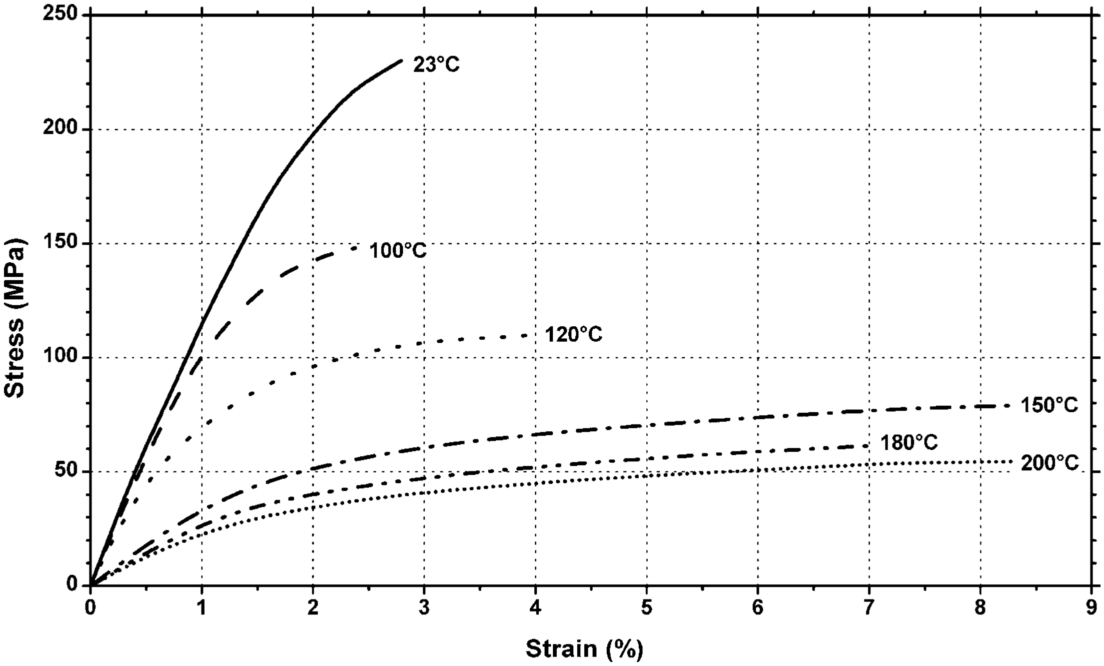


Figure 6.208. Stress vs. strain at various temperatures for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin (DAM).

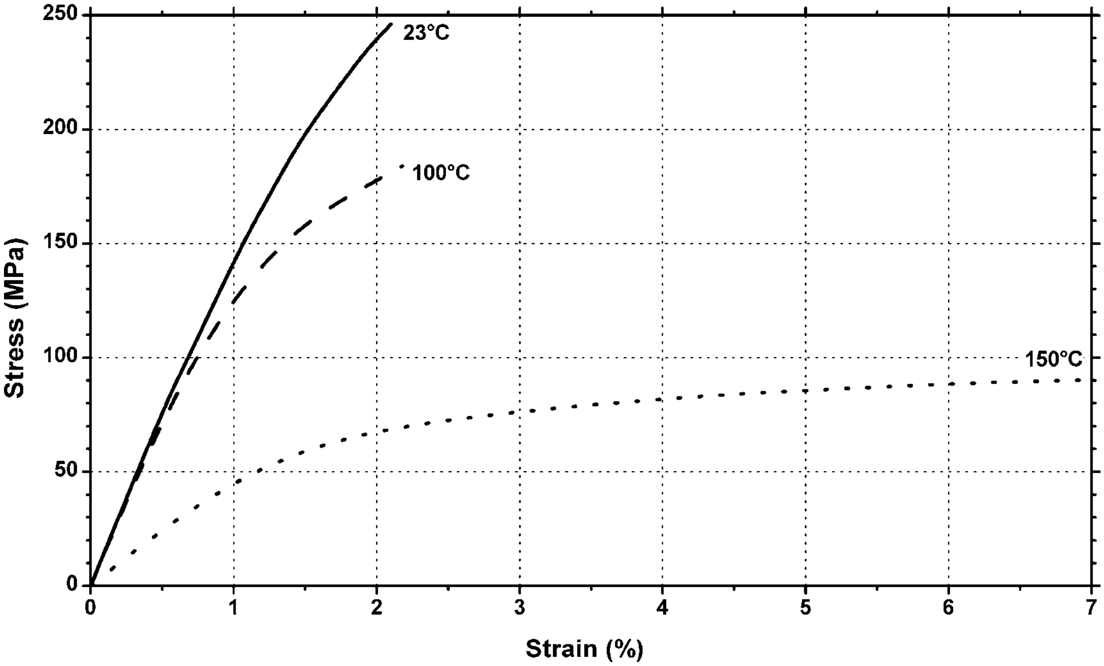


Figure 6.209. Stress vs. strain at various temperatures for Solvay Amodel® A-1145 HS—45% glass reinforced, heat stabilized PPA resin (DAM).

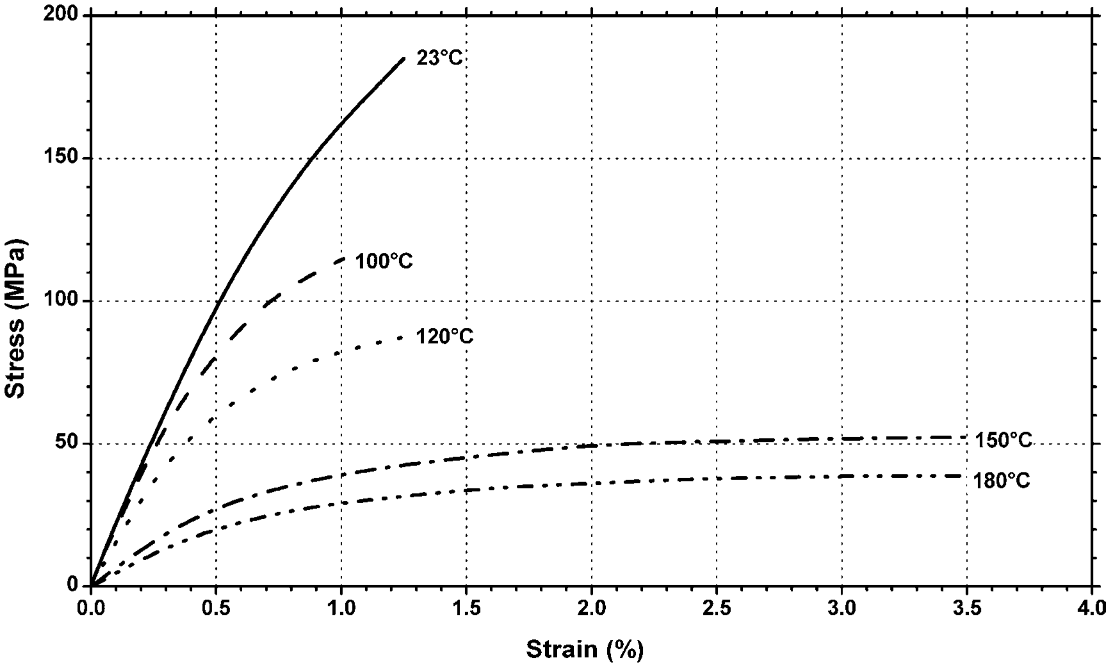


Figure 6.210. Stress vs. strain at various temperatures for Solvay Amodel® AS-1566 HS—65% glass/mineral reinforced, heat stabilized PPA resin (DAM).

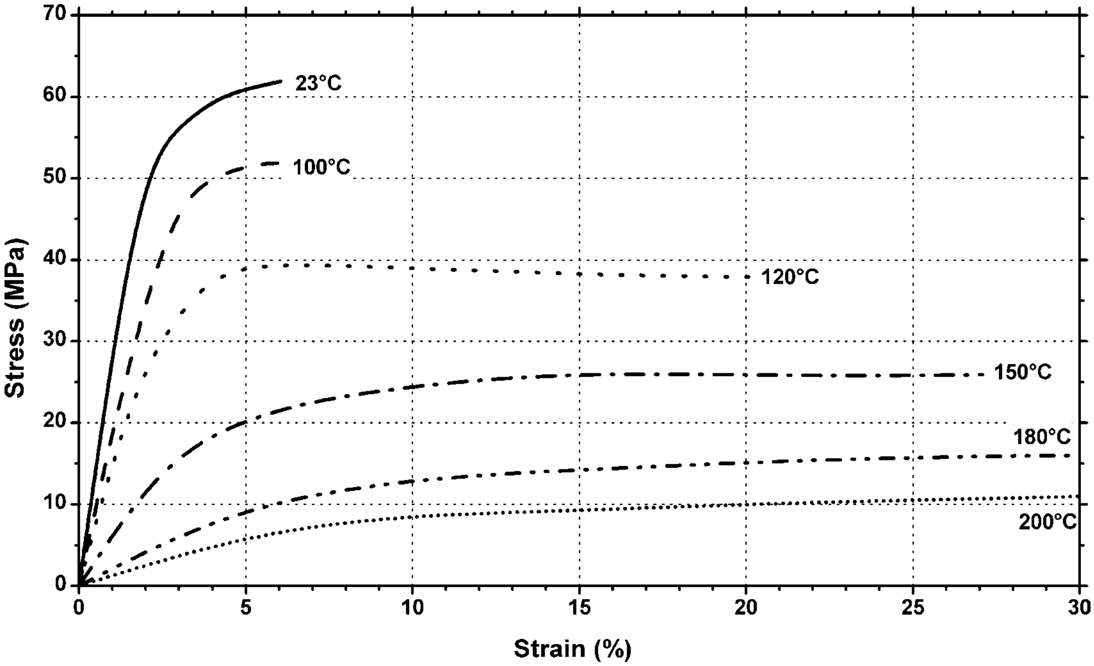


Figure 6.211. Stress vs. strain at various temperatures for Solvay Amodel® AT-5001—High impact PPA resin (DAM).

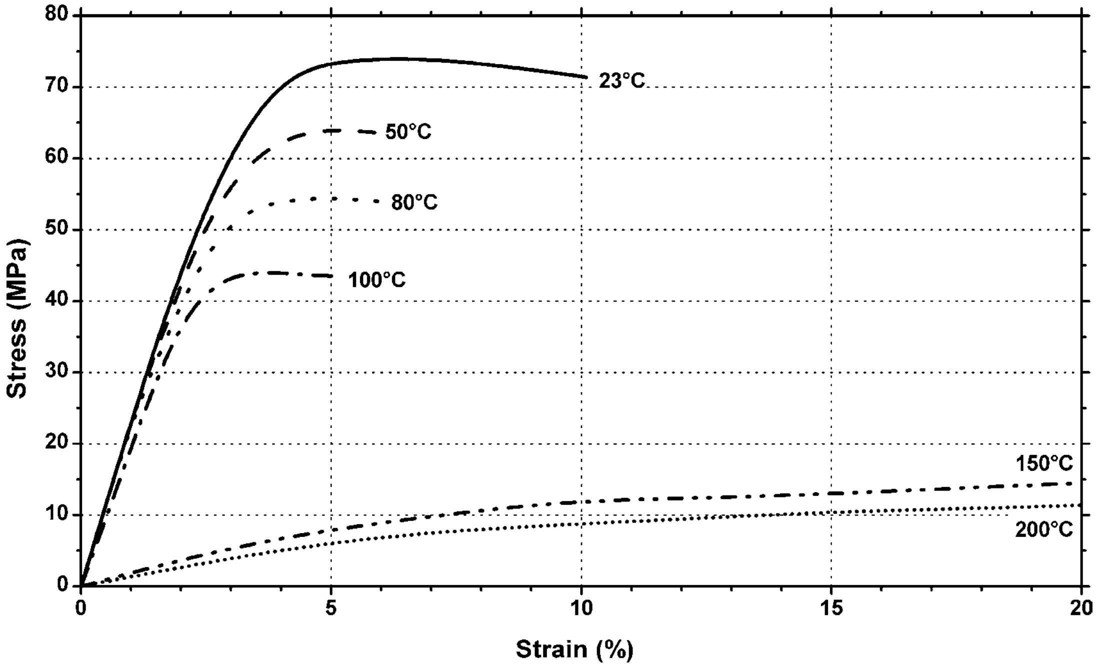


Figure 6.212. Stress vs. strain at various temperatures for Solvay Amodel® ET-1001 HS—Impact-modified, heat stabilized PPA resin (DAM).

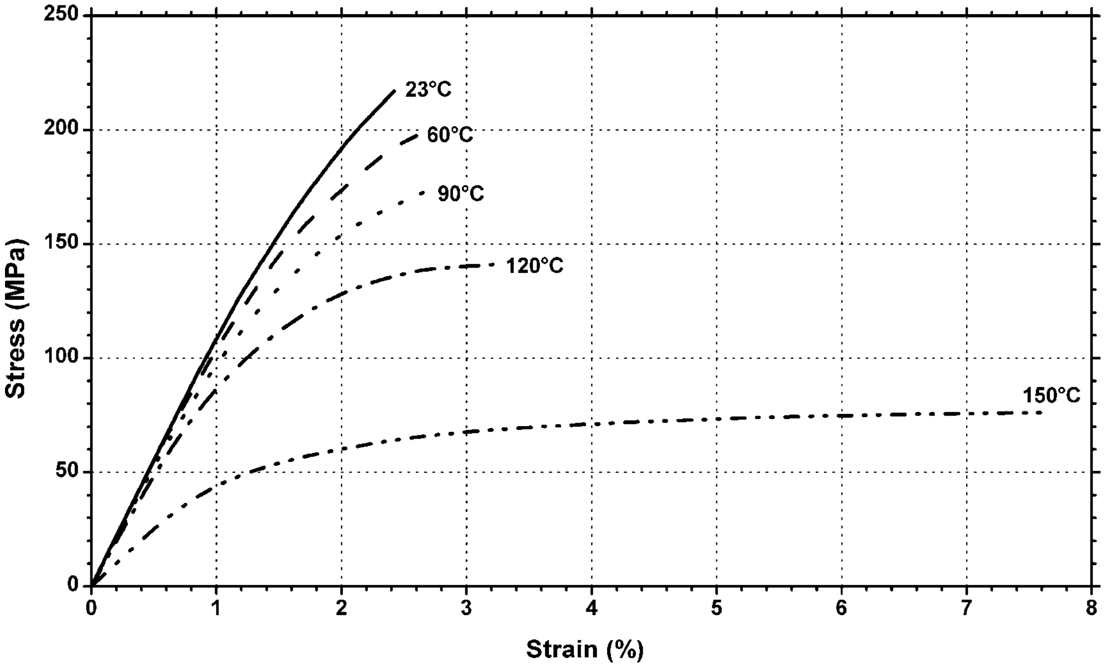


Figure 6.213. Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G35HSL—35% glass reinforced, heat stabilized, lubricated PPA resin (DAM).

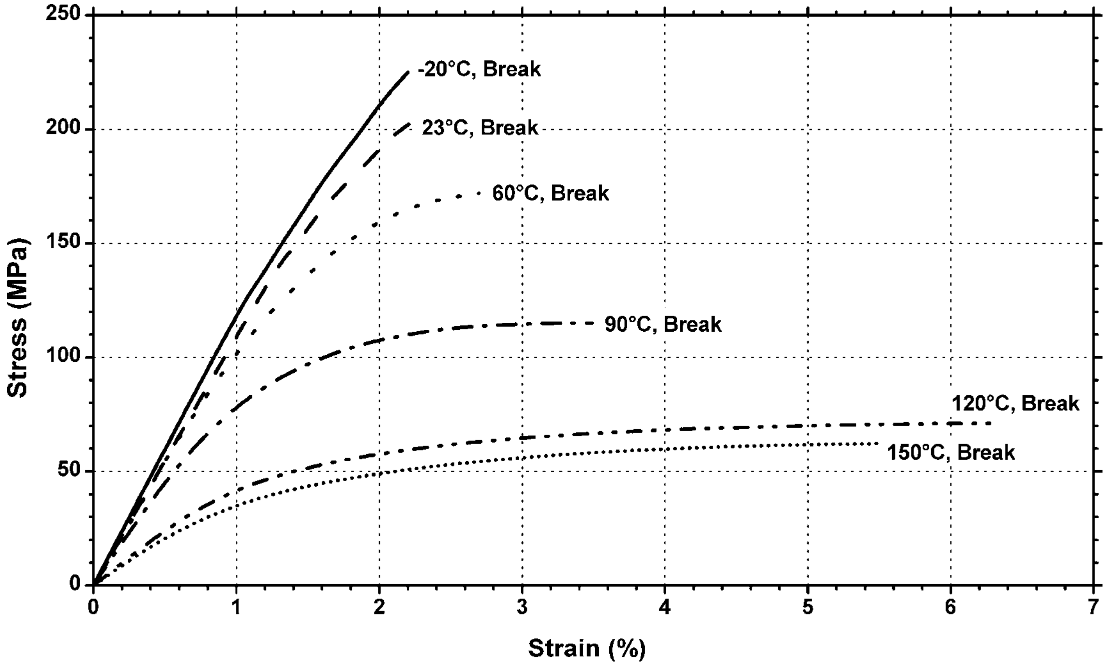


Figure 6.214. Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G35HSL—35% glass reinforced, heat stabilized, lubricated PPA resin (conditioned at 50% RH).

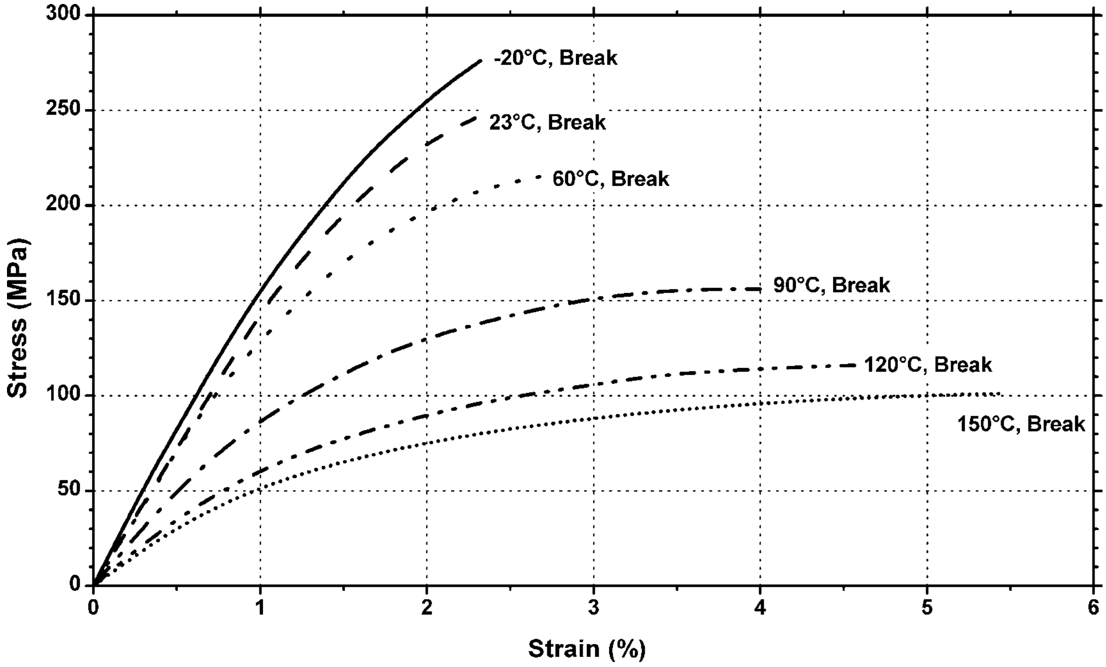


Figure 6.215. Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G45HSL—45% glass reinforced, heat stabilized, lubricated PPA resin (DAM).

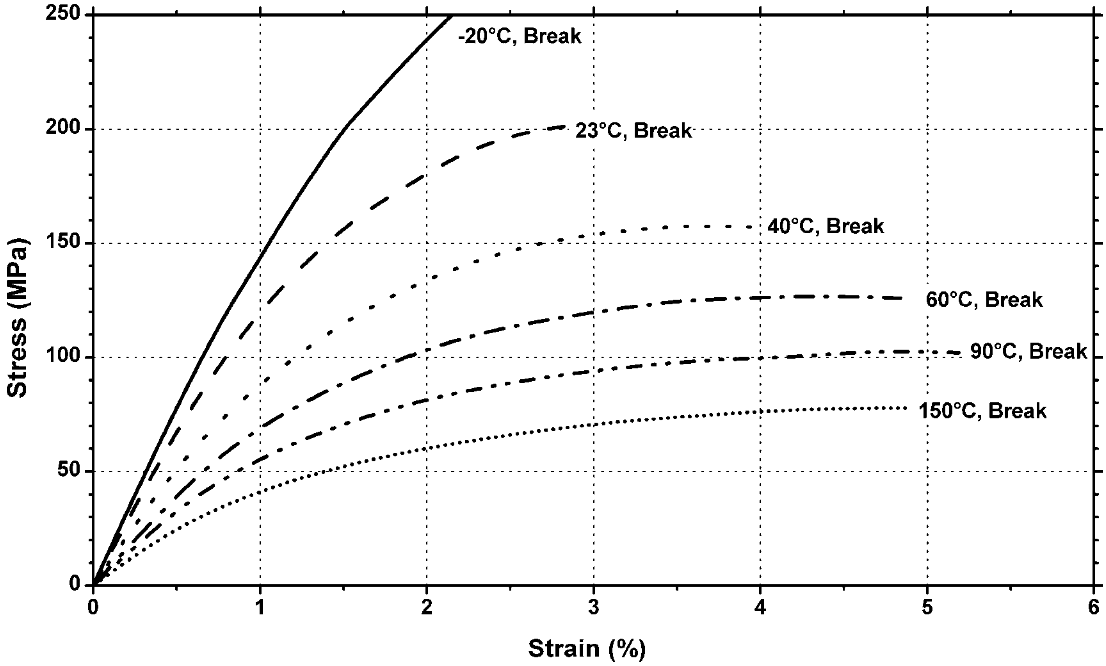


Figure 6.216. Stress vs. strain at various temperatures for DuPont Engineering Plastics Zytel® HTN51G45HSL—45% glass reinforced, heat stabilized, lubricated PPA resin (conditioned at 50% RH).

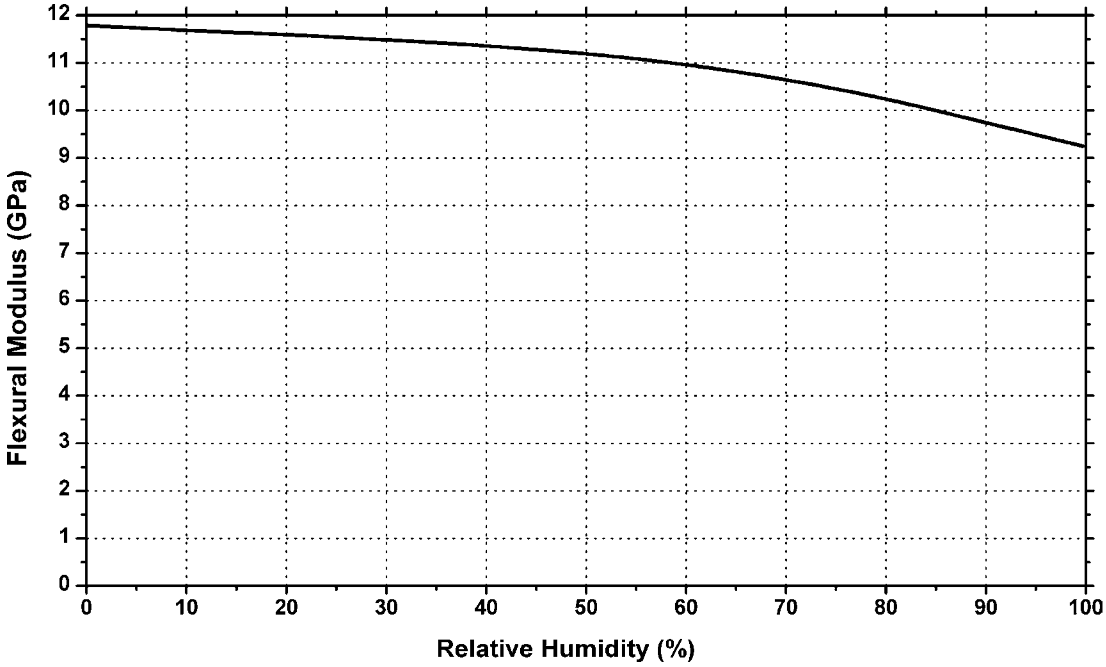


Figure 6.217. Flexural modulus vs. relative humidity for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin.

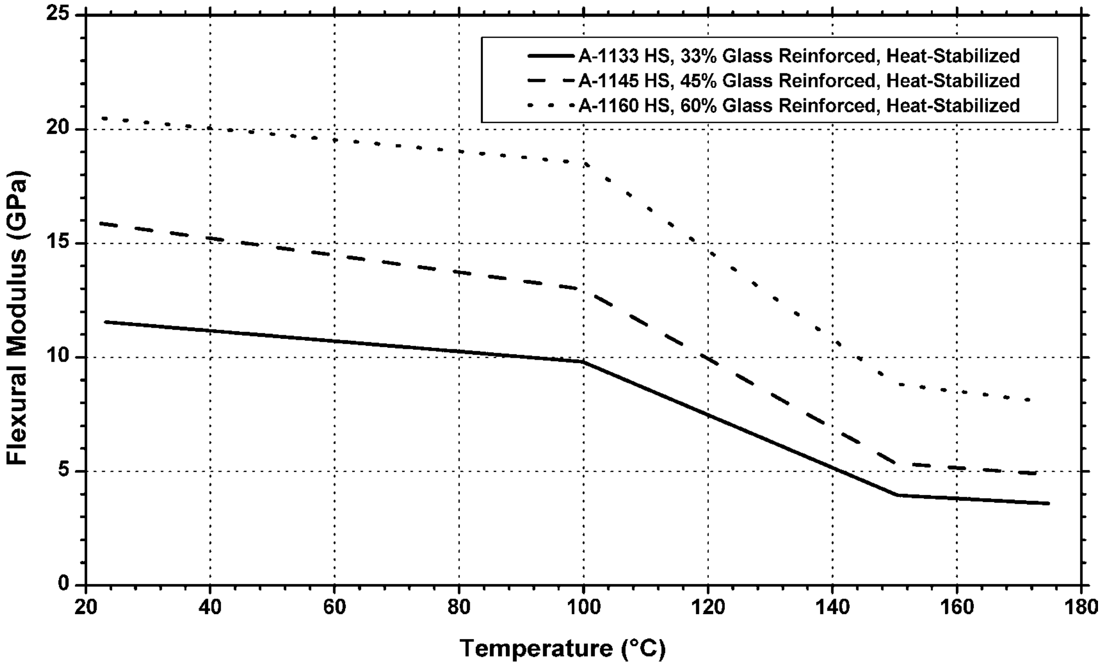


Figure 6.218. Flexural modulus vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

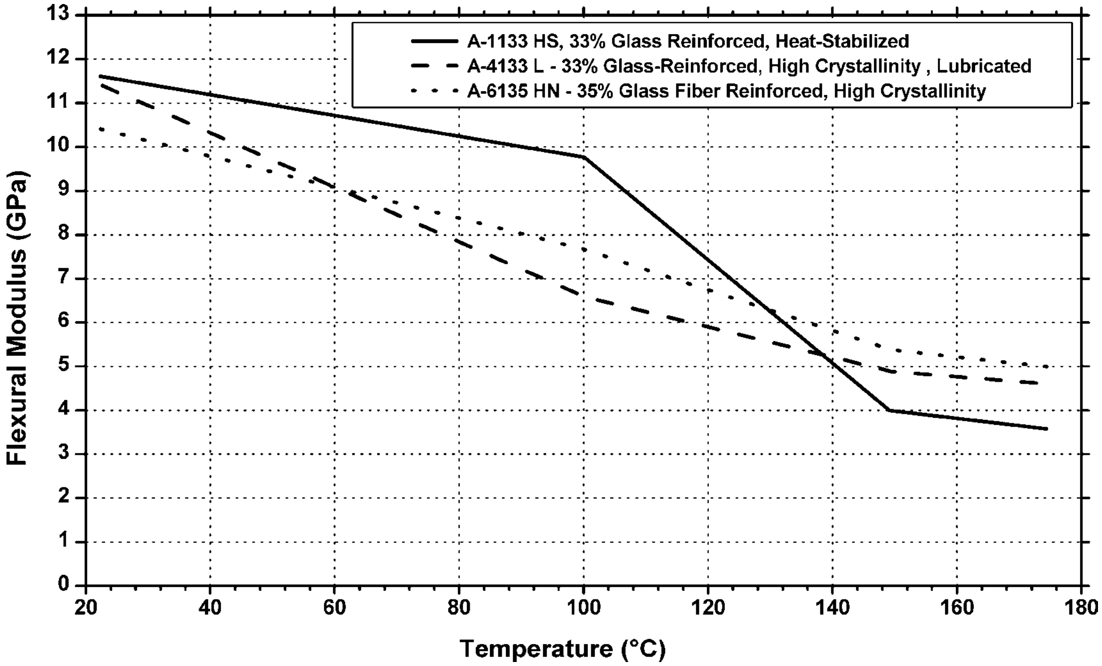


Figure 6.219. Flexural modulus vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins.

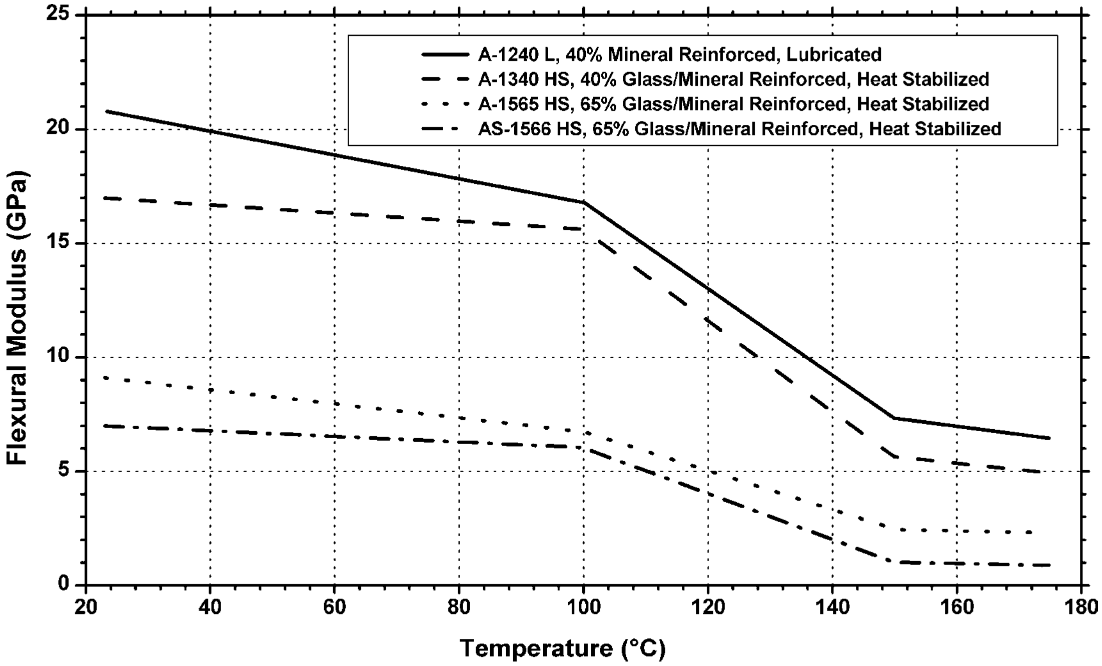


Figure 6.220. Flexural modulus vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins.

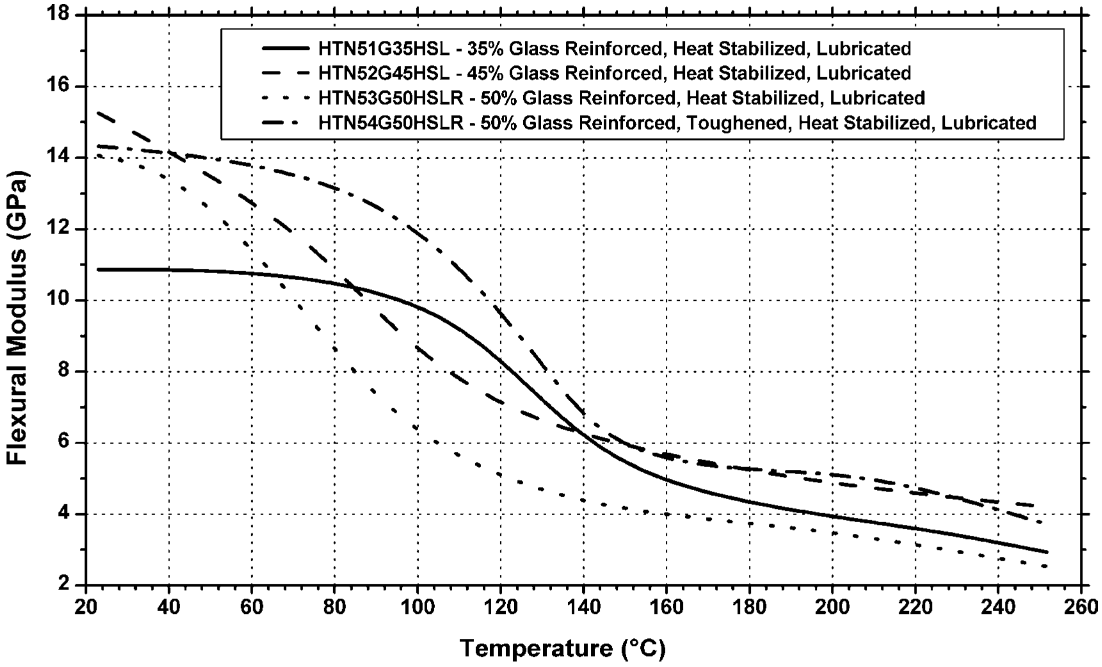


Figure 6.221. Flexural modulus vs. temperature for DuPont Engineering Plastics Zytel® glass fiber reinforced, heat stabilized PPA resins.

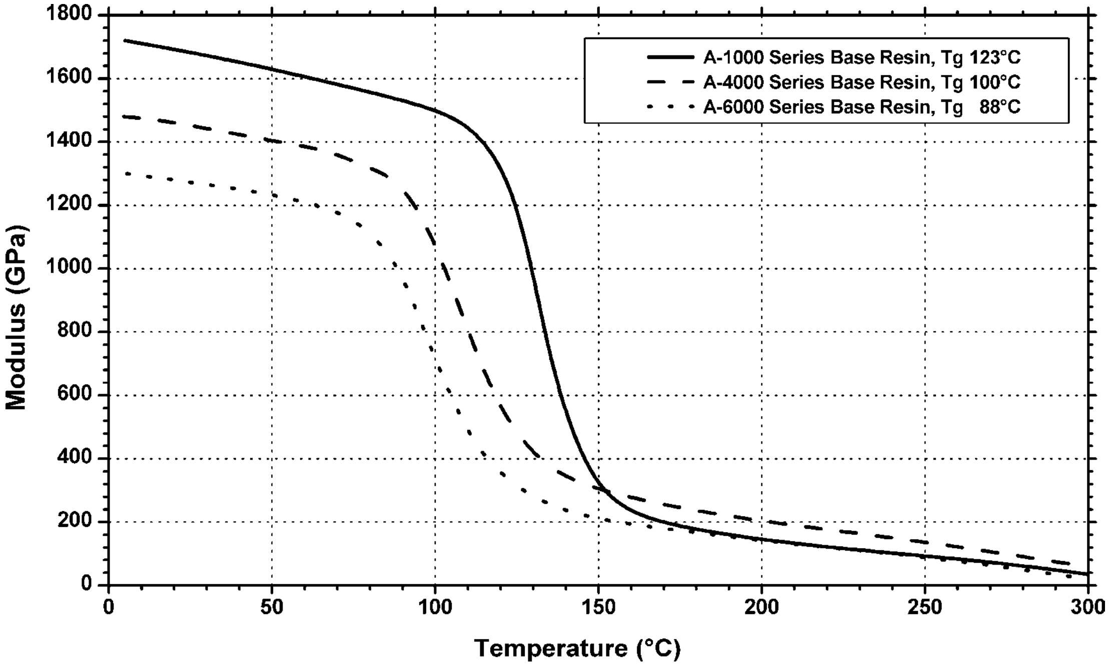


Figure 6.222. Modulus vs. temperature for Solvay Amodel® unreinforced base PPA resins.

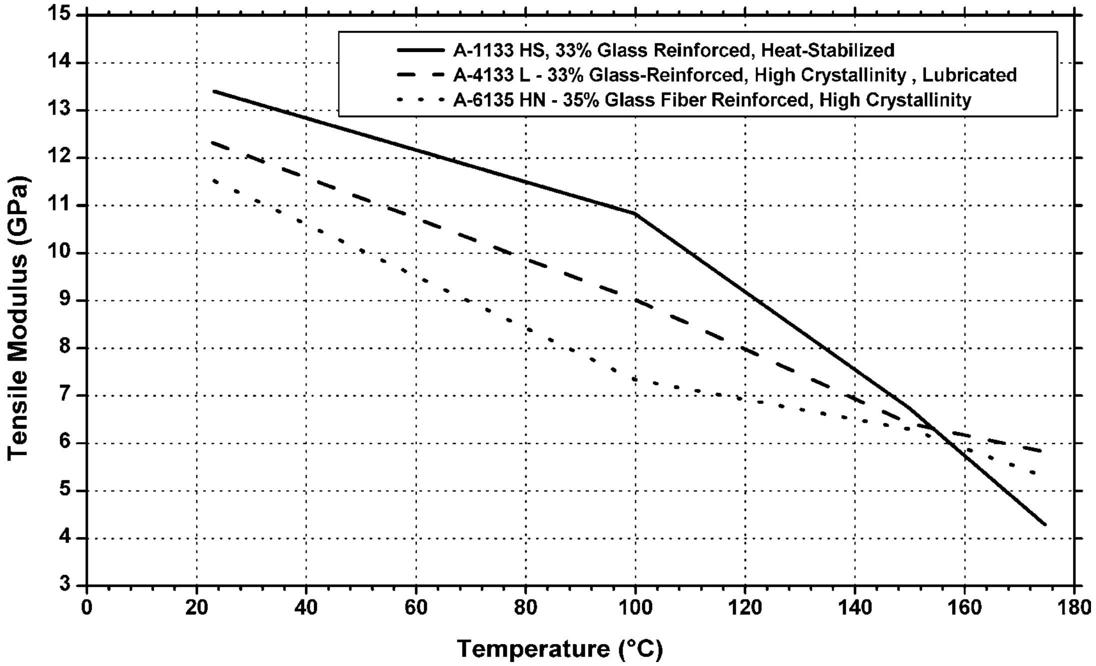


Figure 6.223. Tensile modulus vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins.

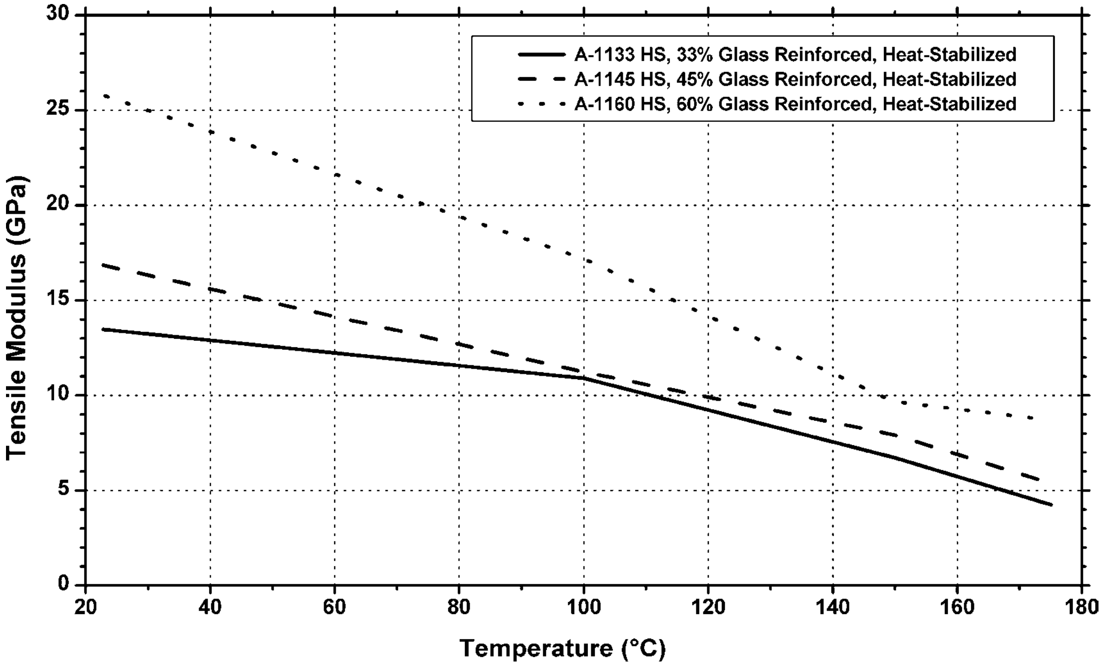


Figure 6.224. Tensile modulus vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

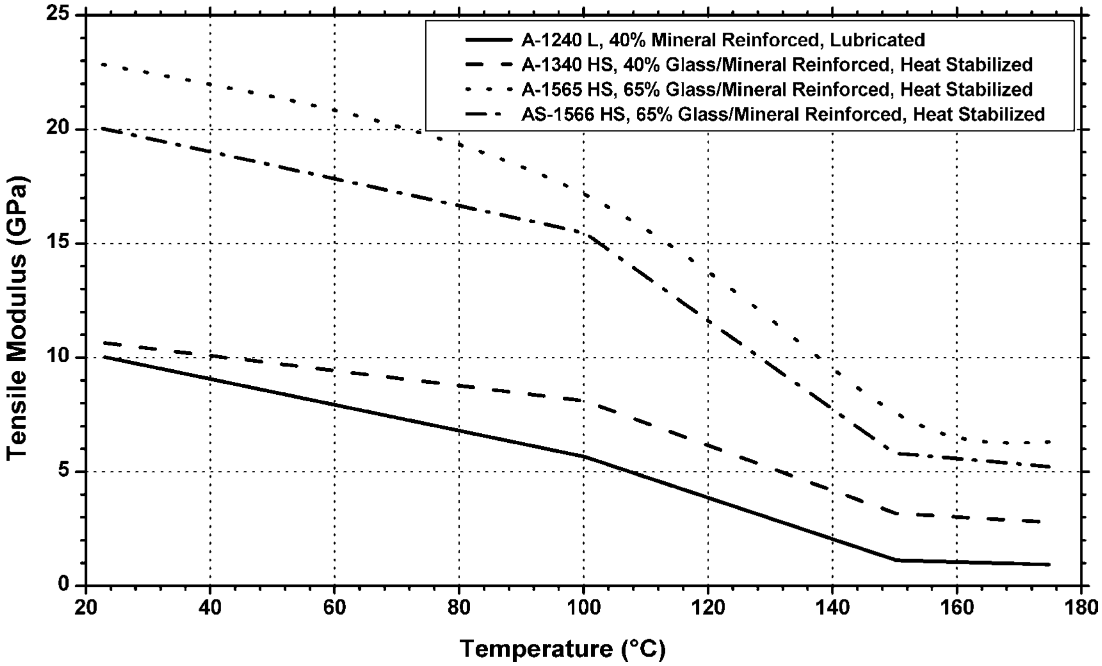


Figure 6.225. Tensile modulus vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins.

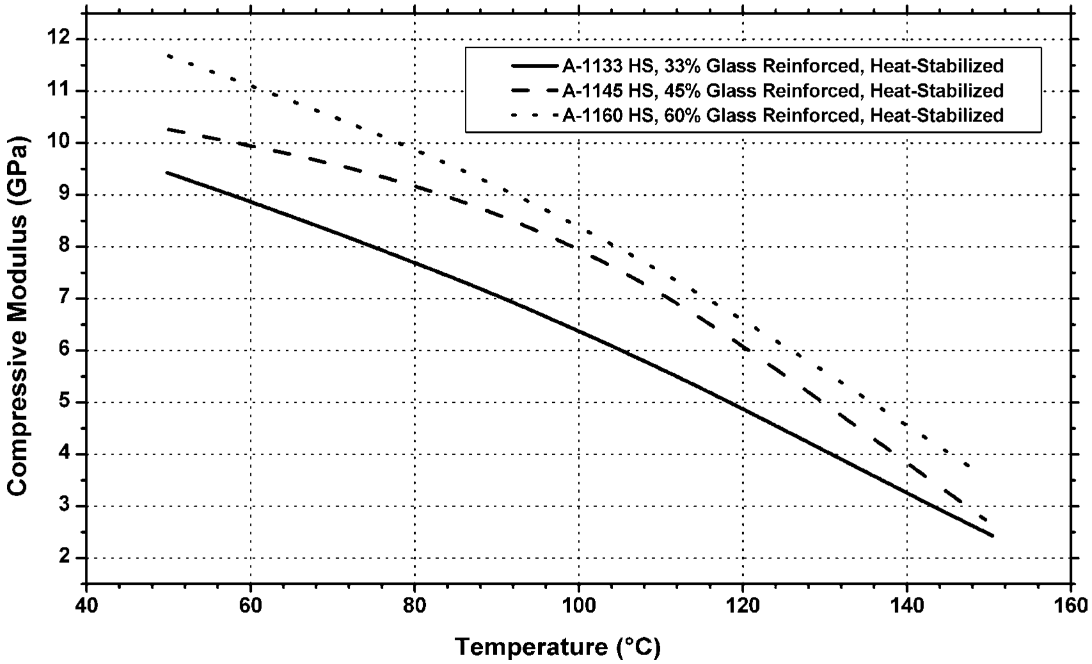


Figure 6.226. Compressive modulus vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

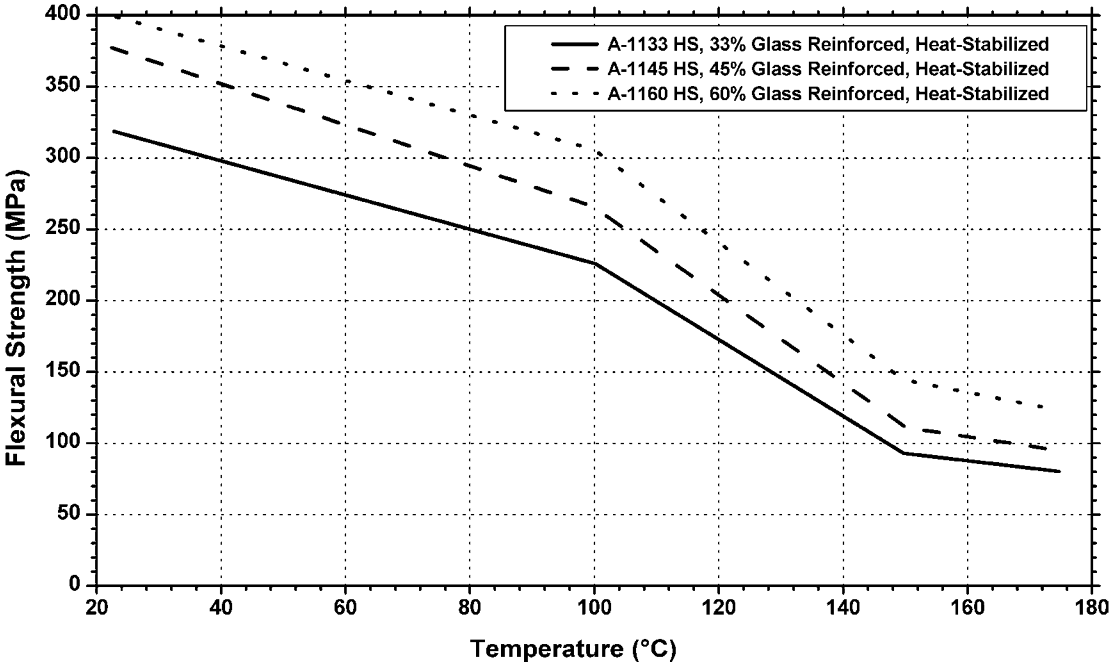


Figure 6.227. Flexural strength vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

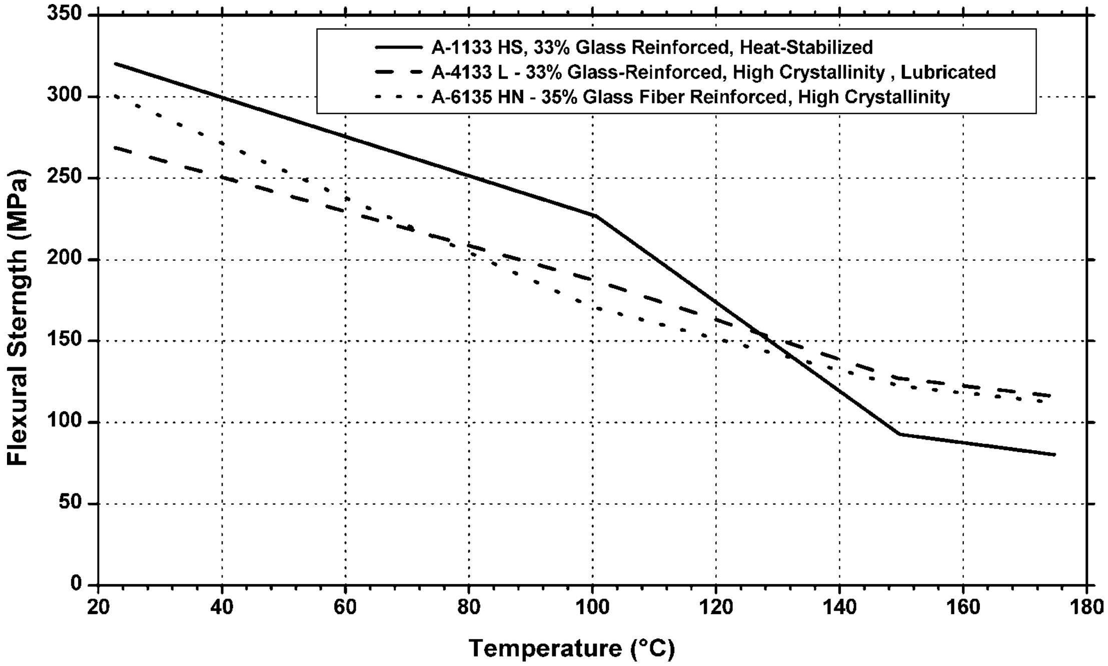


Figure 6.228. Flexural strength vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins.

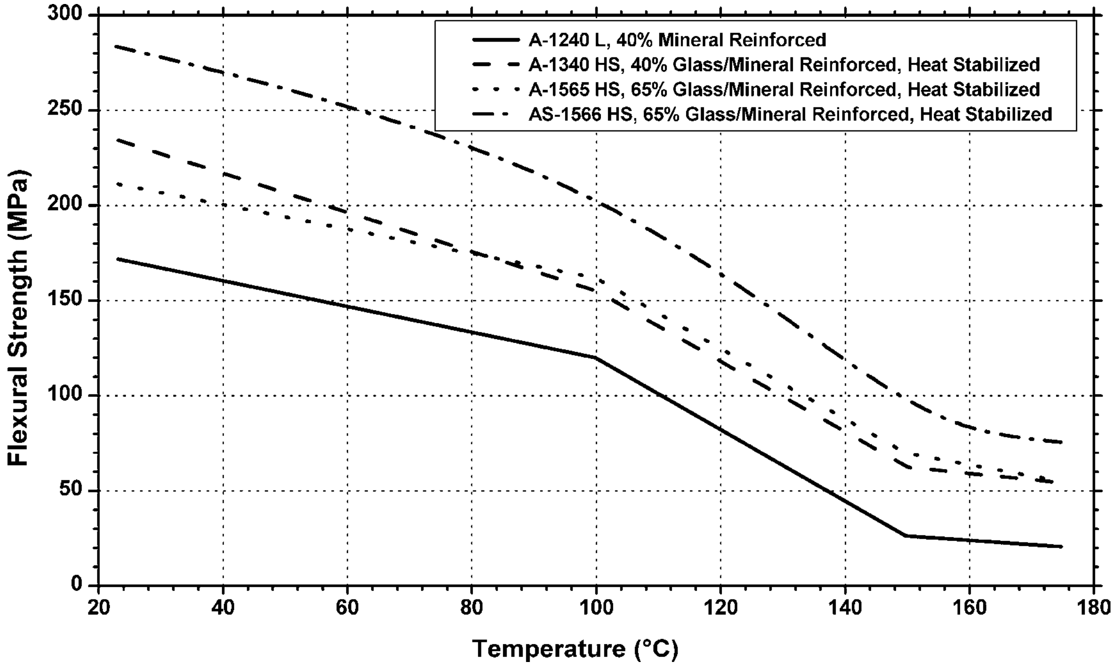


Figure 6.229. Flexural strength vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins.

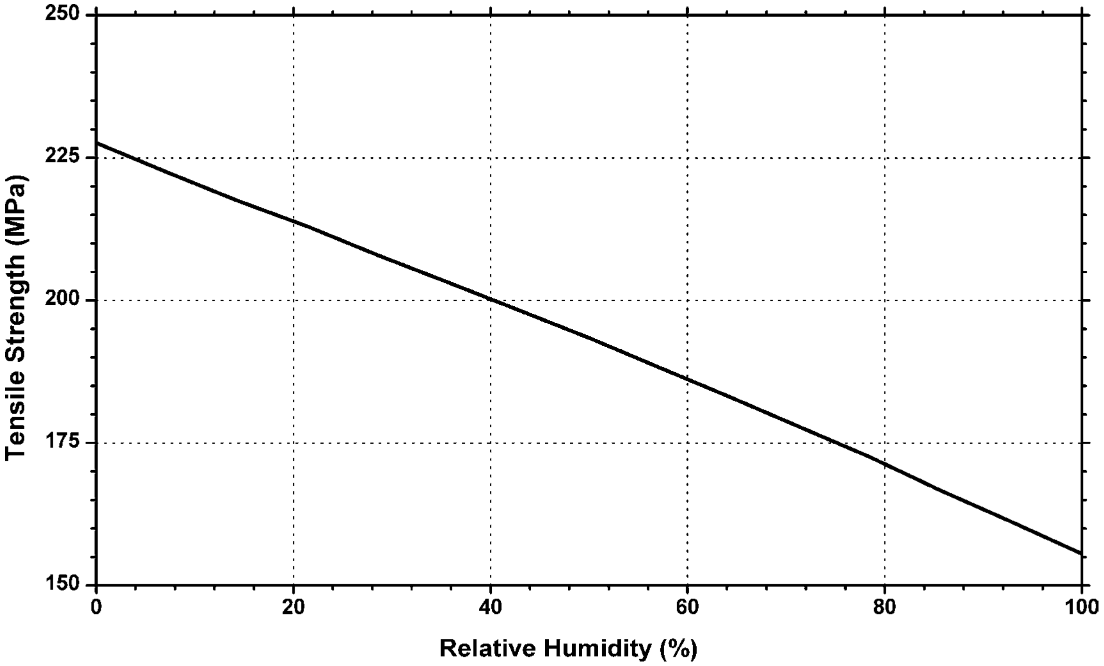


Figure 6.230. Tensile strength vs. relative humidity for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin.

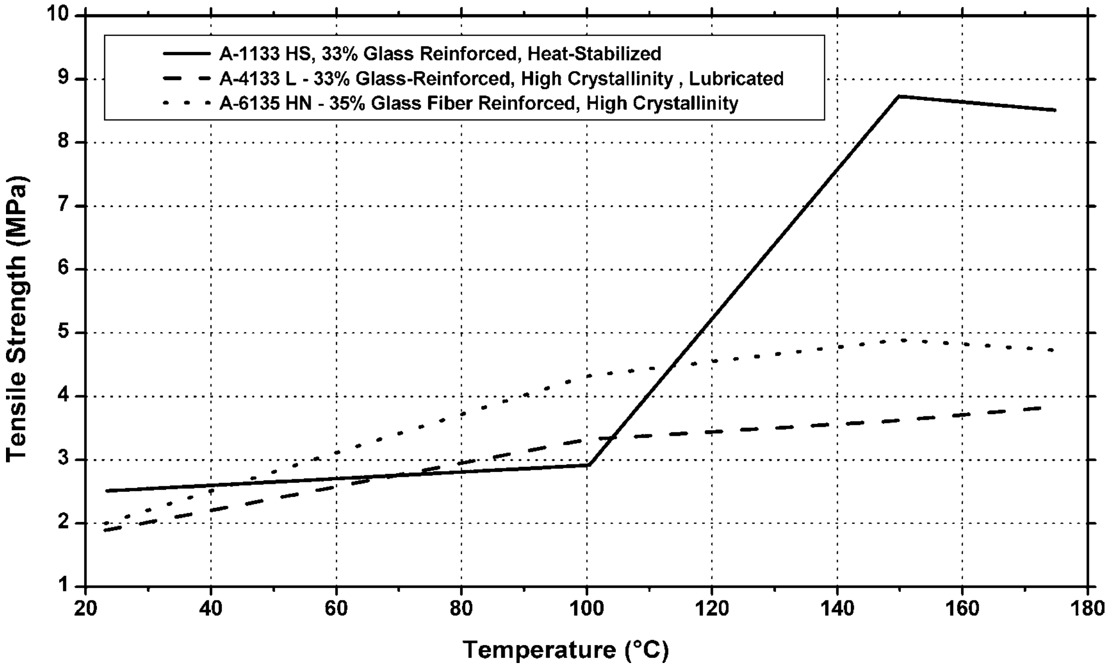


Figure 6.231. Tensile strength vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins.

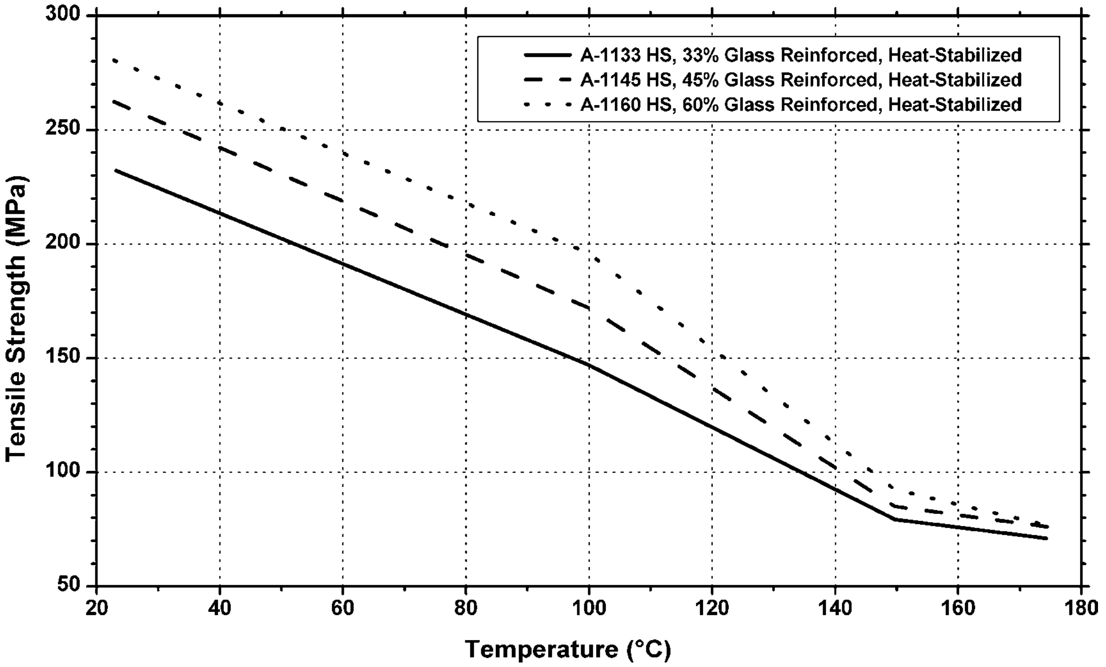


Figure 6.232. Tensile strength vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

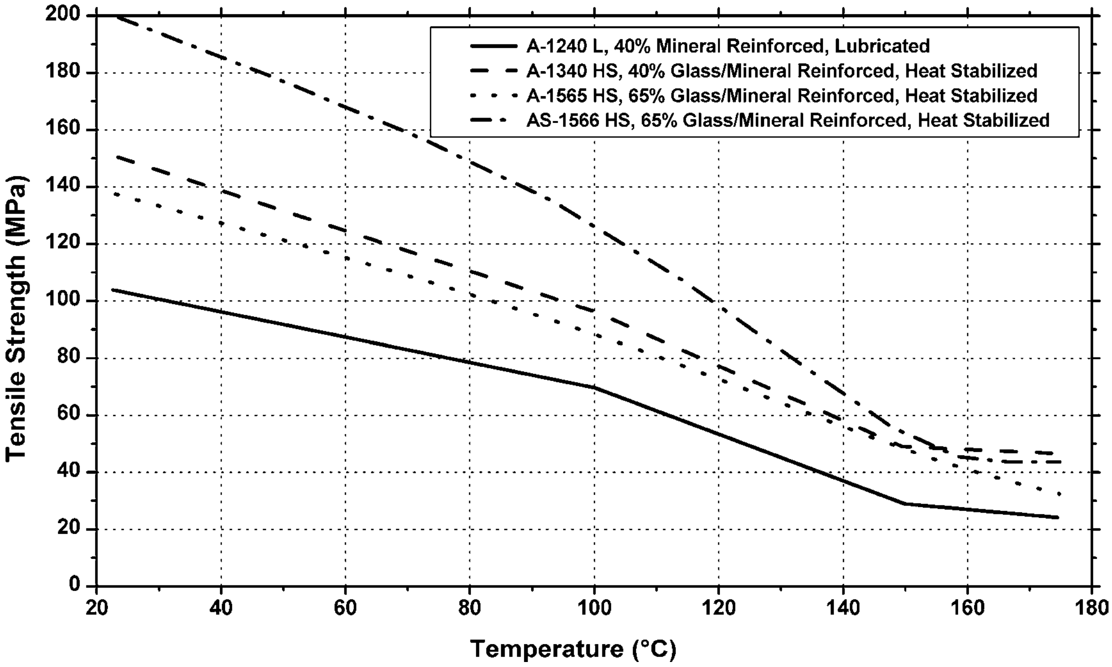


Figure 6.233. Tensile strength vs. temperature for Solvay Amodel® glass and mineral reinforced, heat stabilized PPA resins.

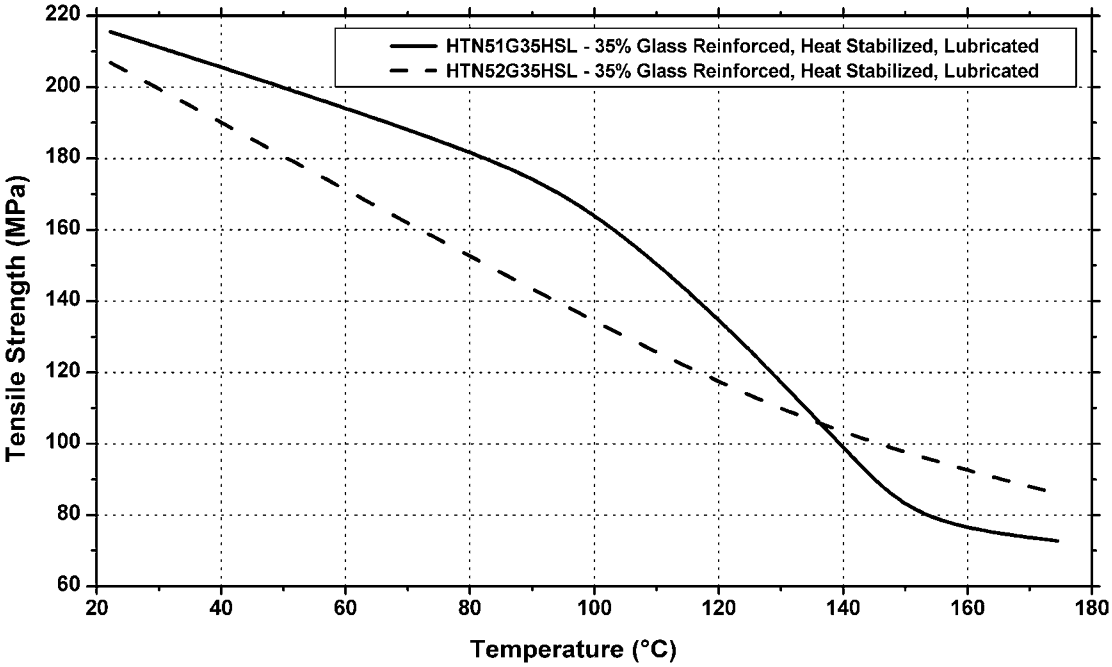


Figure 6.234. Tensile strength vs. temperature for DuPont Engineering Plastics Zytel® glass fiber reinforced, heat stabilized PPA resins.

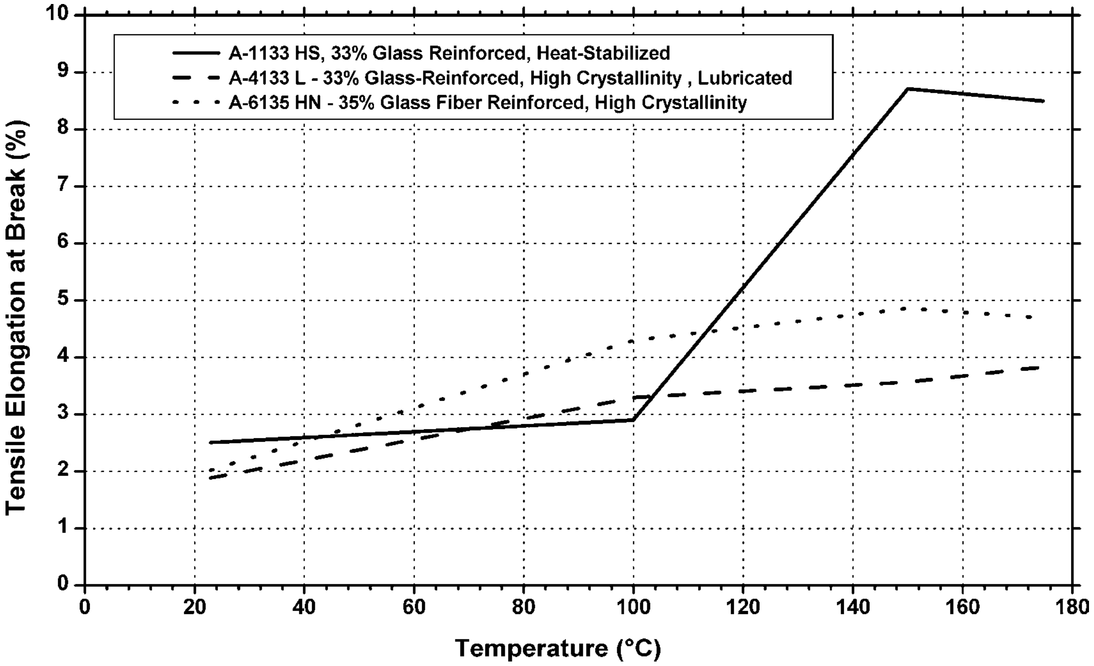


Figure 6.235. Tensile elongation at break vs. temperature for Solvay Amodel® glass fiber reinforced PPA resins.

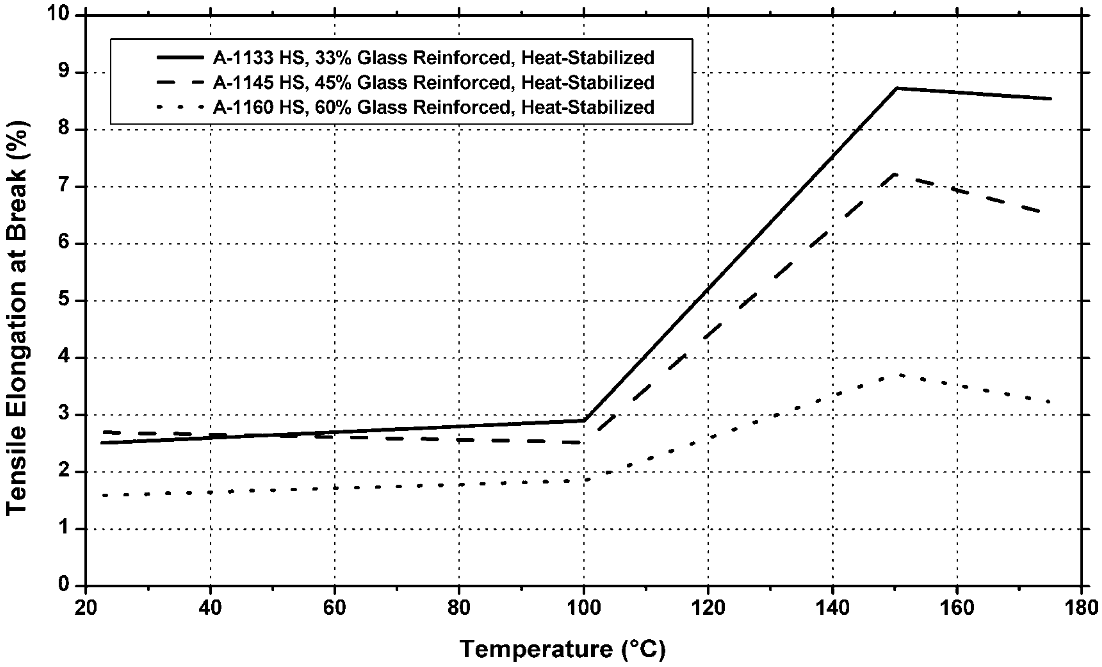


Figure 6.236. Tensile elongation at break vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

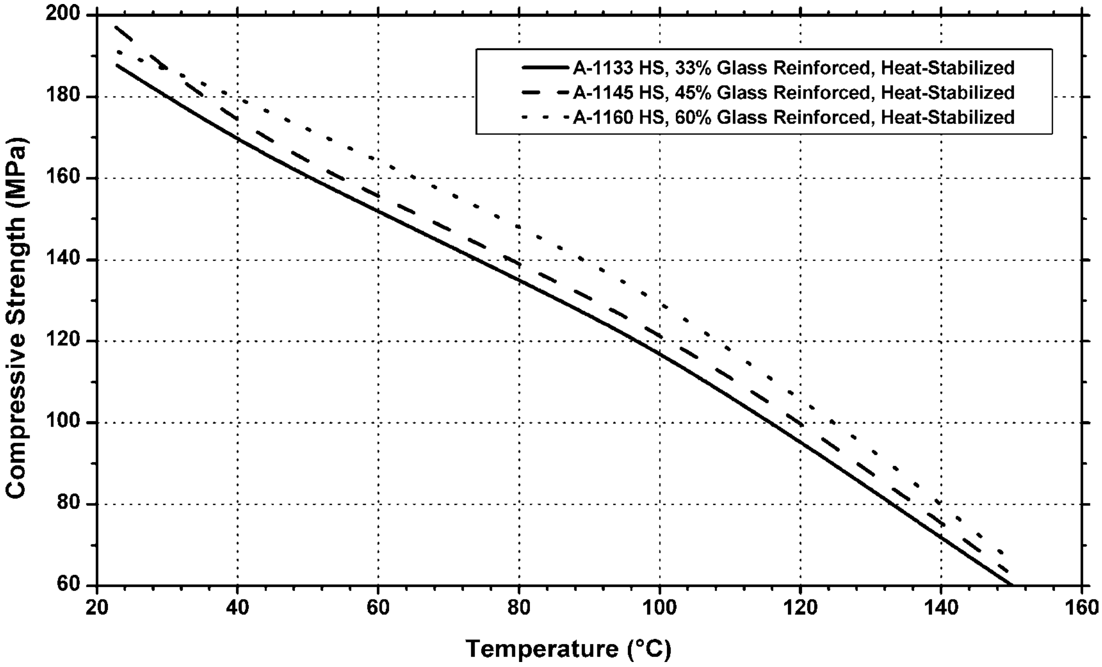


Figure 6.237. Compressive strength vs. temperature for Solvay Amodel® A—1000 series glass fiber reinforced, heat stabilized PPA resins.

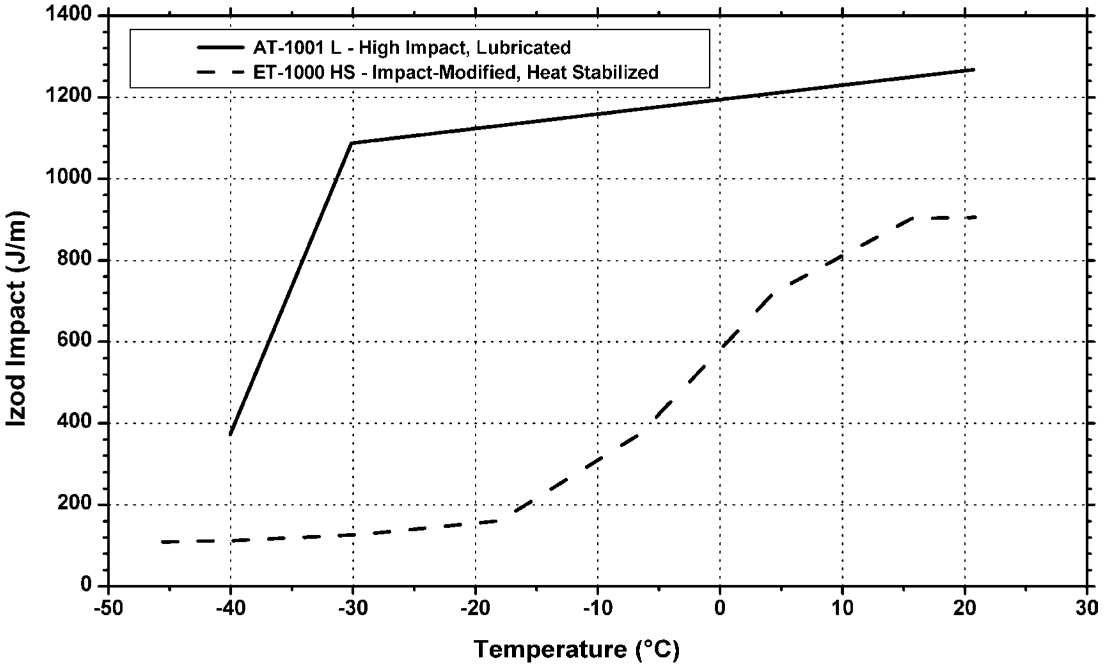


Figure 6.238. Izod impact strength vs. temperature for Solvay Amodel® PPA resins.

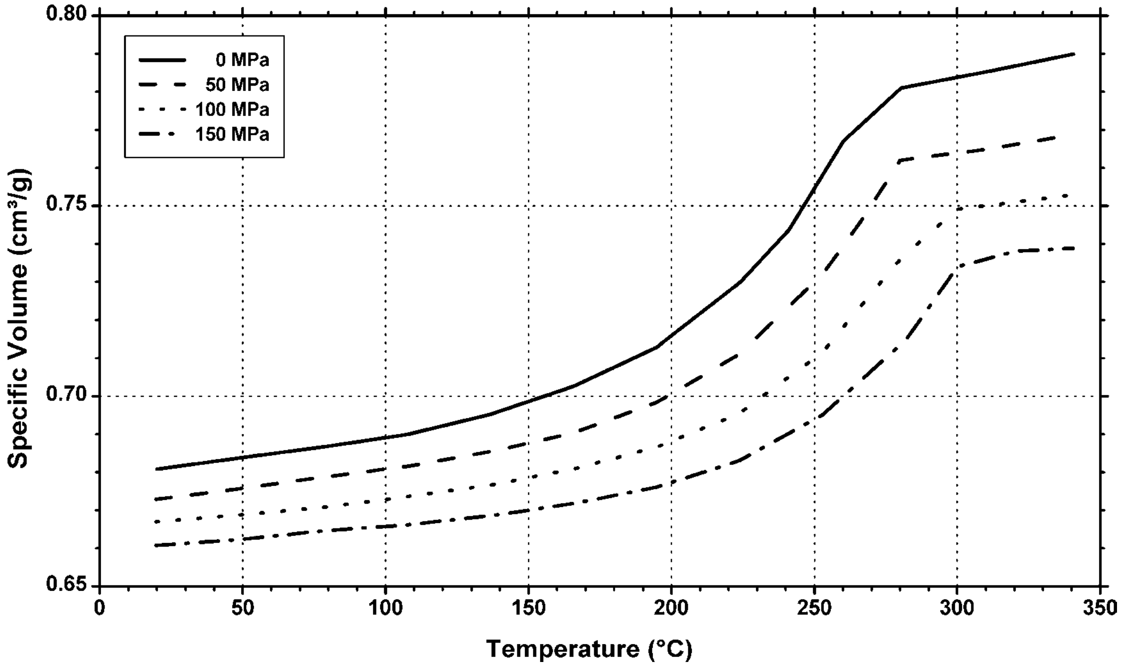


Figure 6.239. Pressure-specific volume-temperature (PVT) for DuPont Engineering Plastics Zytel® HTN51G35HSL—35% glass reinforced, heat stabilized, lubricated PPA resins.

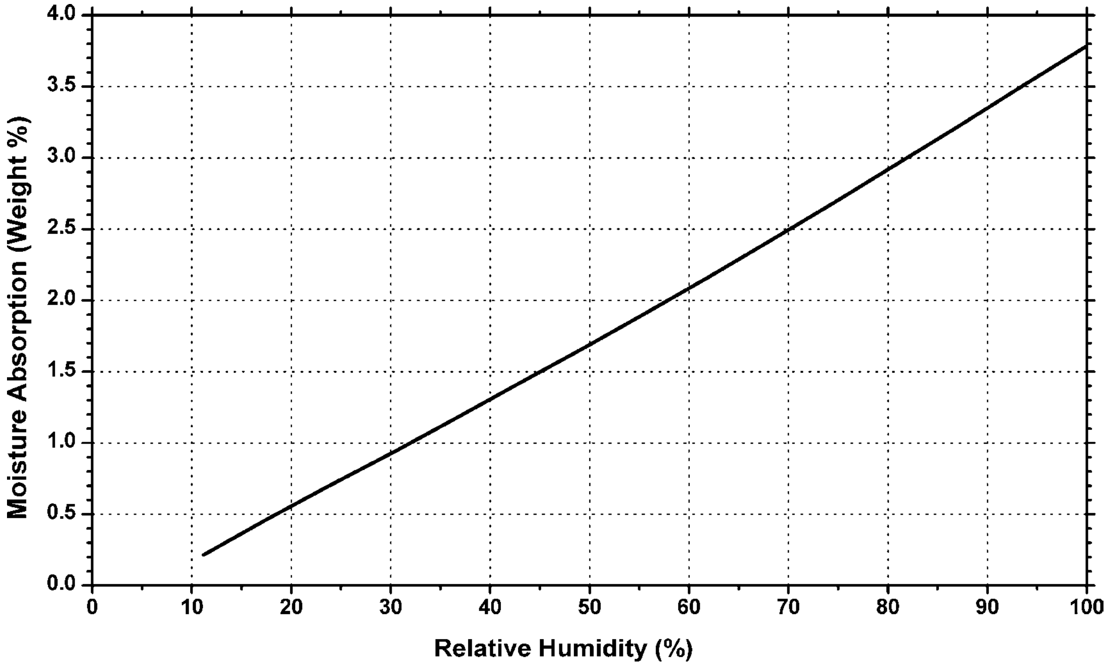


Figure 6.240. Moisture absorption vs. relative humidity for Solvay Amodel® A-1133 HS—33% glass reinforced, heat stabilized PPA resin.

6.12 Polyarylamide (PAA)

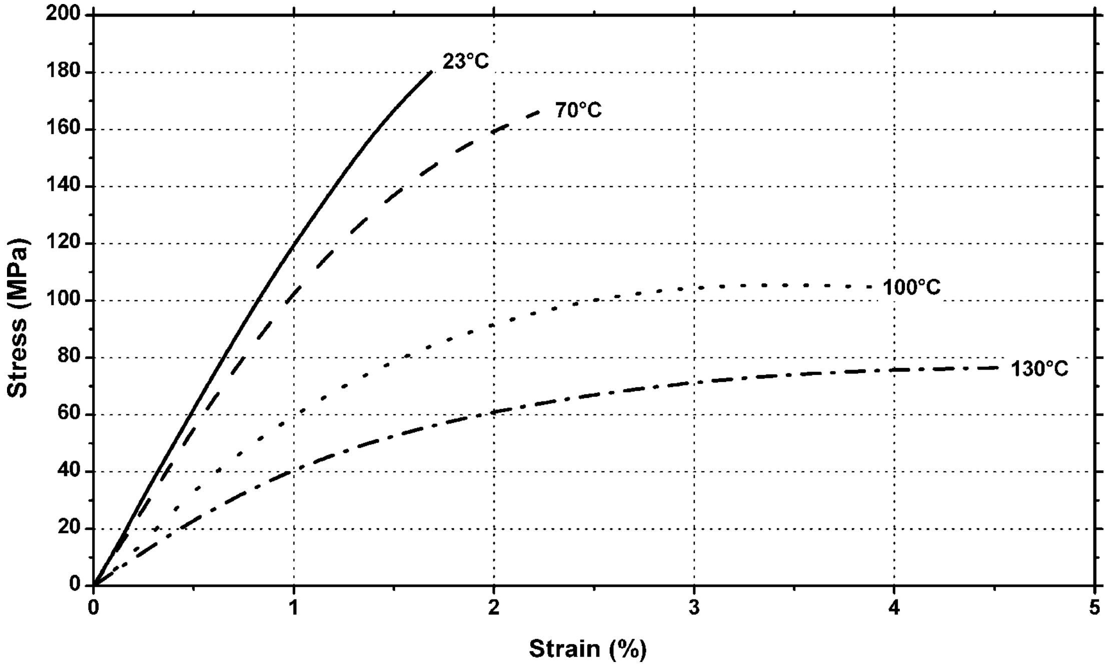


Figure 6.241. Stress vs. strain at various temperatures for Solvay IXEF® 1002—30% glass fiber reinforced PAA resin (DAM).

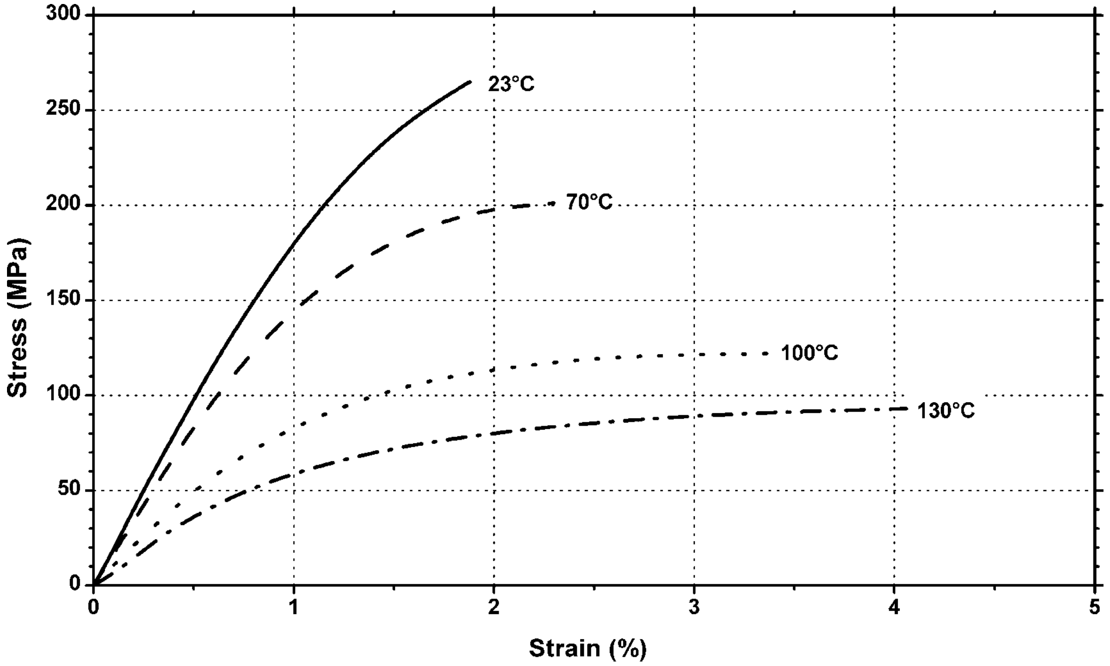


Figure 6.242. Stress vs. strain at various temperatures for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin (DAM).

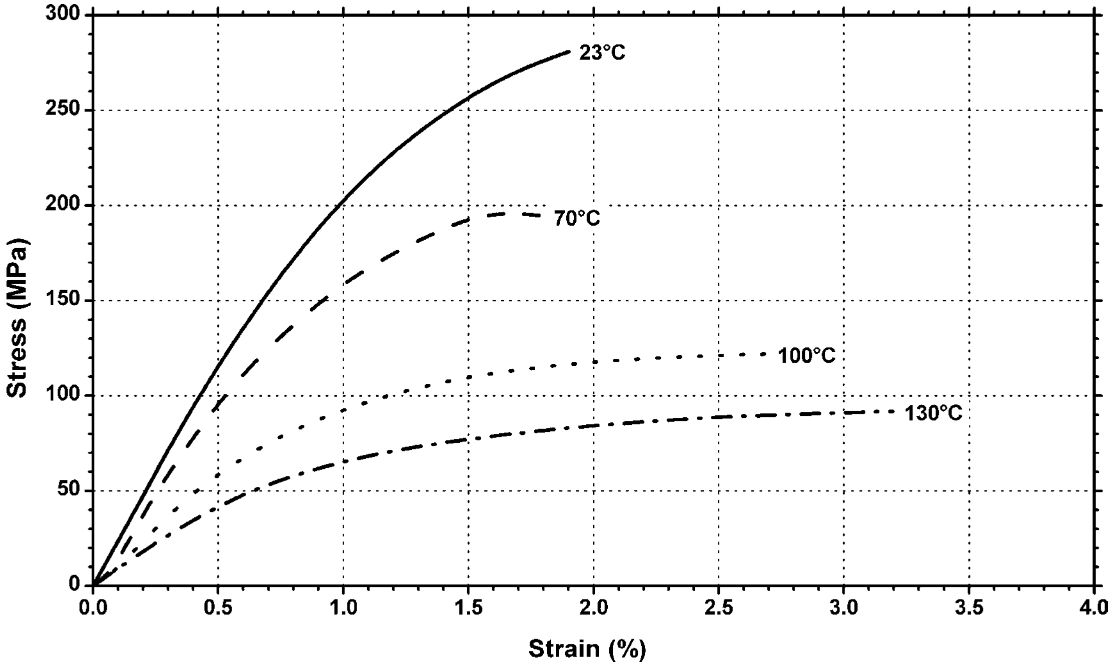


Figure 6.243. Stress vs. strain at various temperatures for Solvay IXEF® 1032—60% glass fiber reinforced PAA resin (DAM).

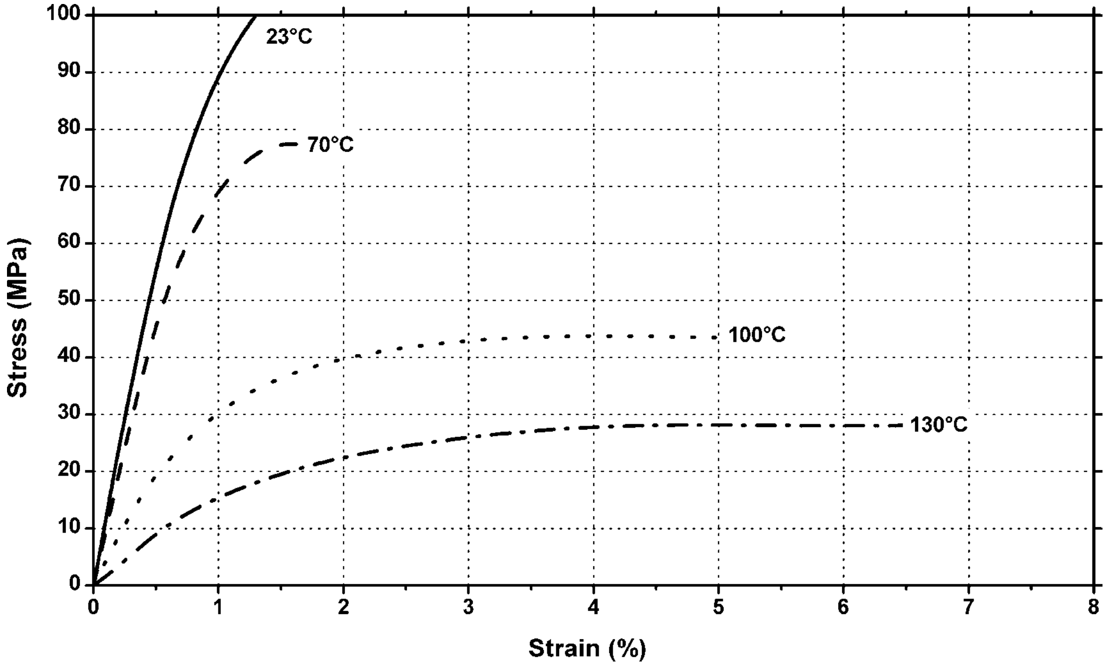


Figure 6.244. Stress vs. strain at various temperatures for Solvay IXEF® 2057—45% mineral reinforced PAA resin (DAM).

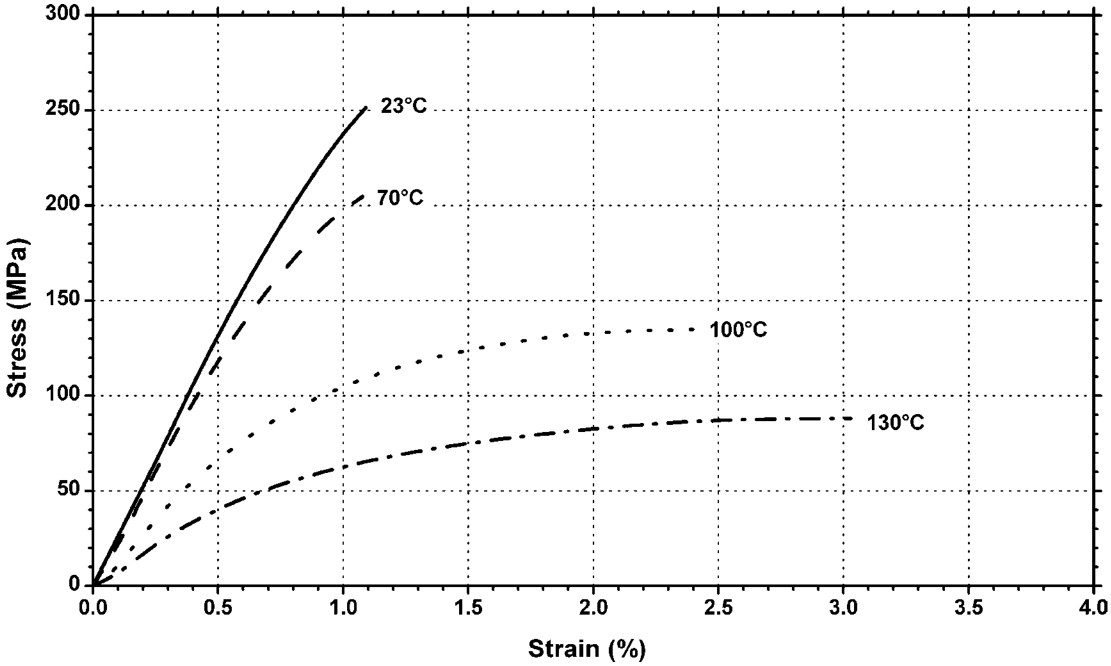


Figure 6.245. Stress vs. strain at various temperatures for Solvay IXEF® 3006—30% carbon fiber reinforced PAA resin (DAM).

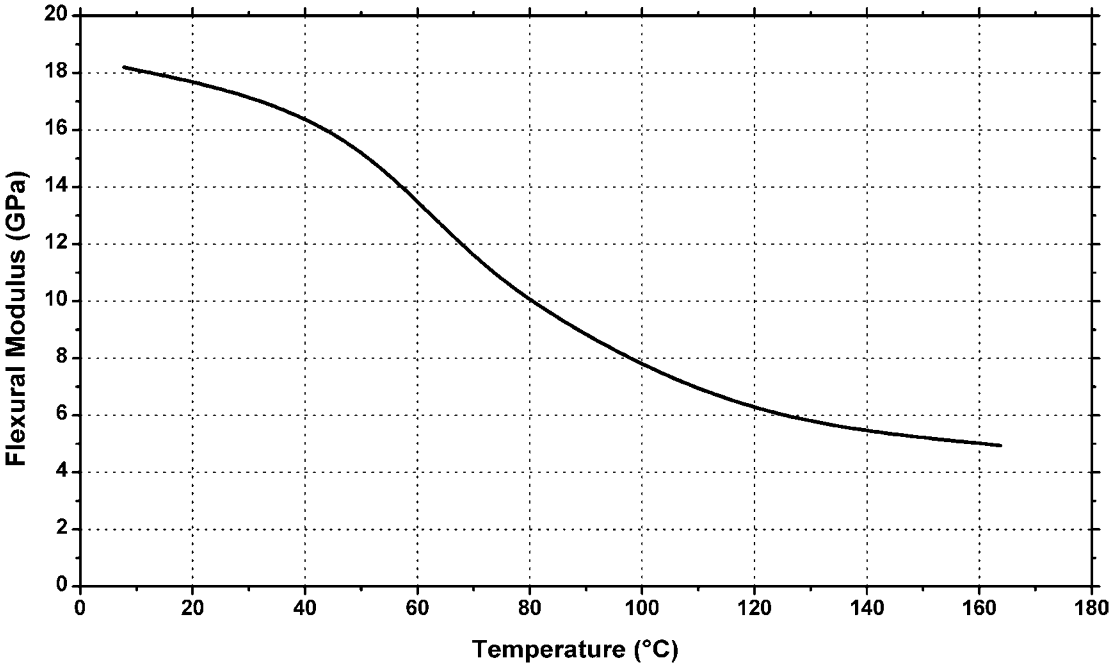


Figure 6.246. Flexural modulus vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

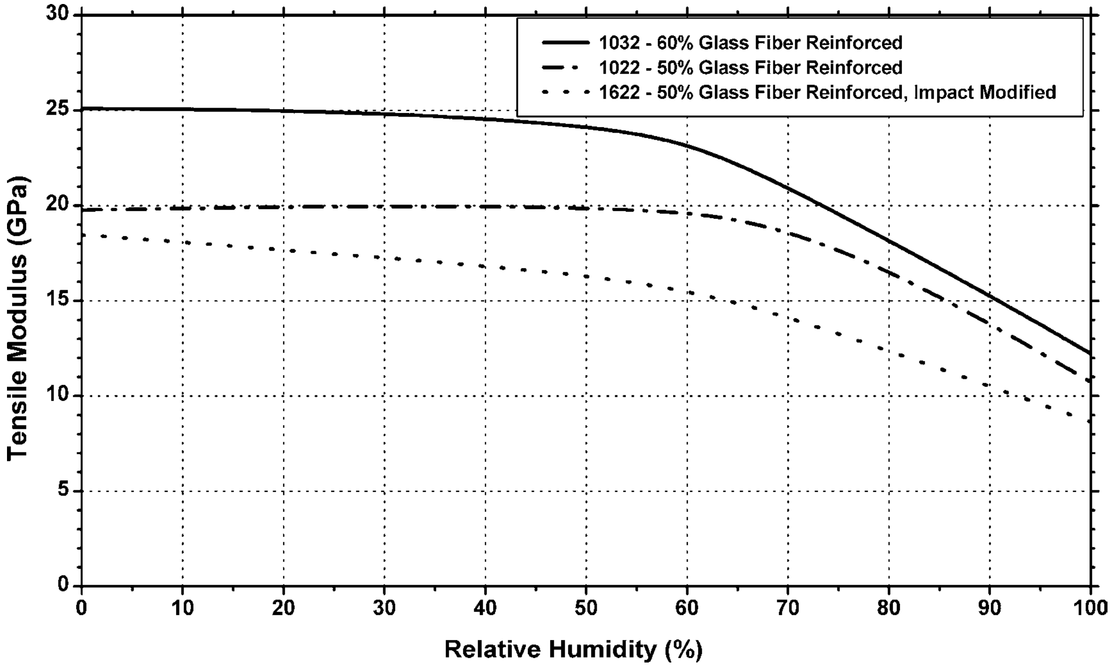


Figure 6.247. Tensile modulus vs. relative humidity at 23°C for Solvay IXEF® reinforced PAA resins.

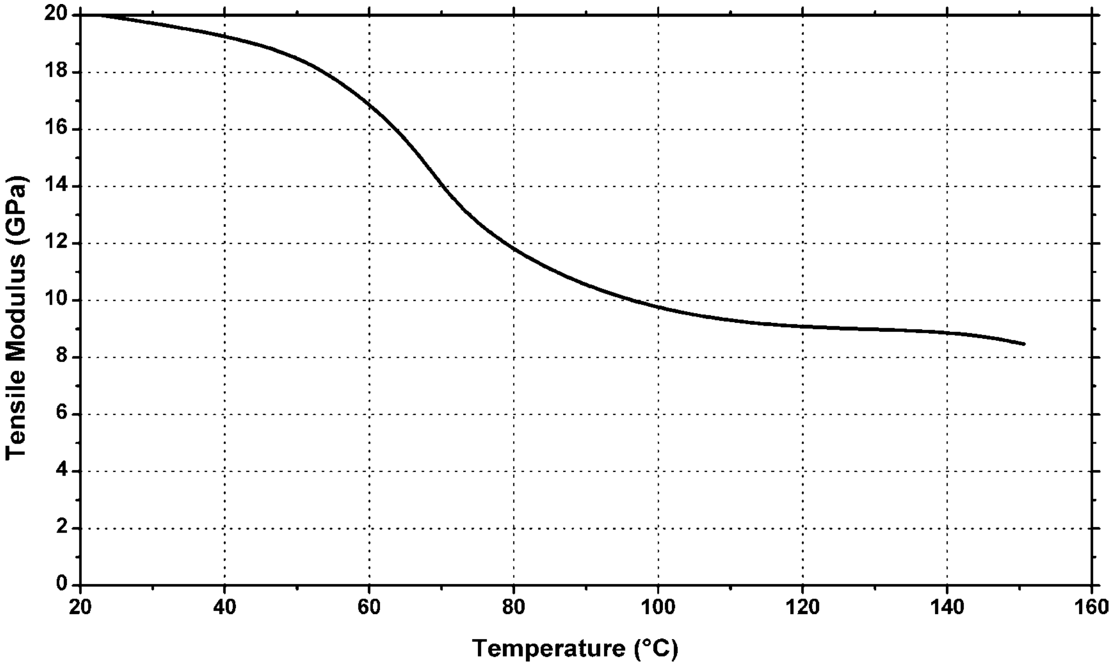


Figure 6.248. Tensile modulus vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

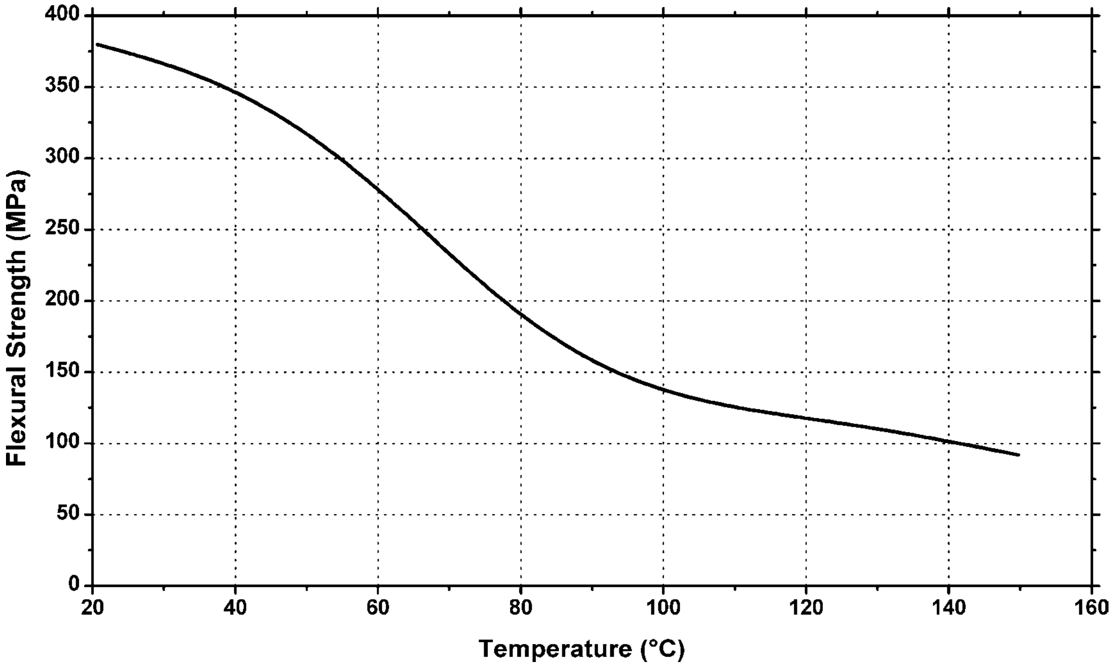


Figure 6.249. Flexural strength vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

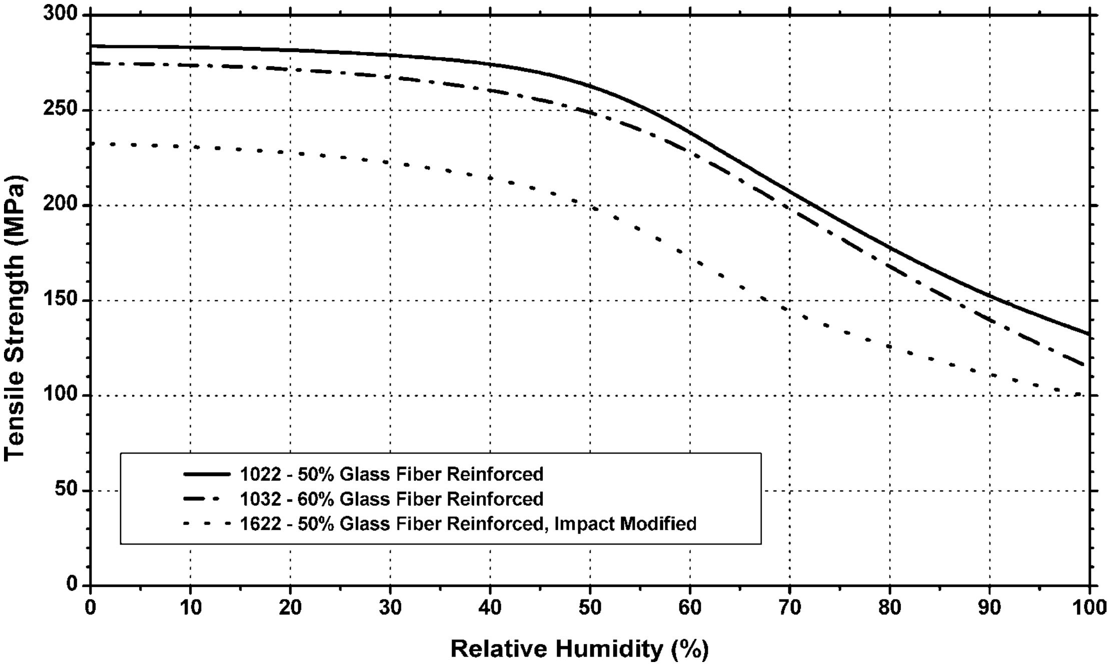


Figure 6.250. Tensile strength vs. relative humidity at 23°C for Solvay IXEF® reinforced PAA resins.

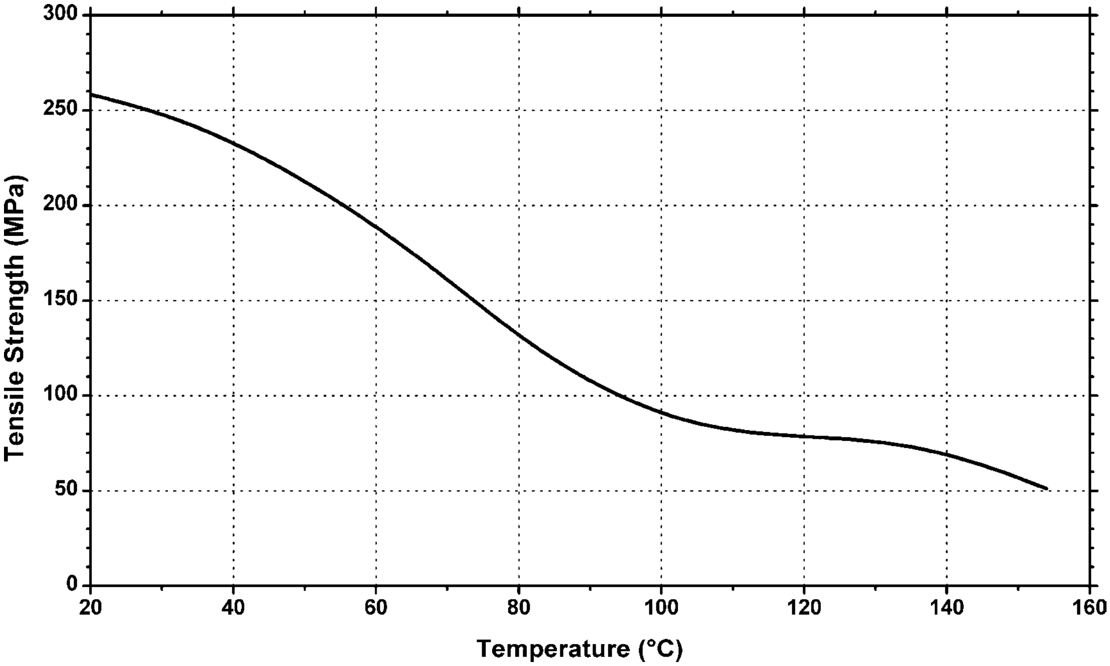


Figure 6.251. Tensile strength vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

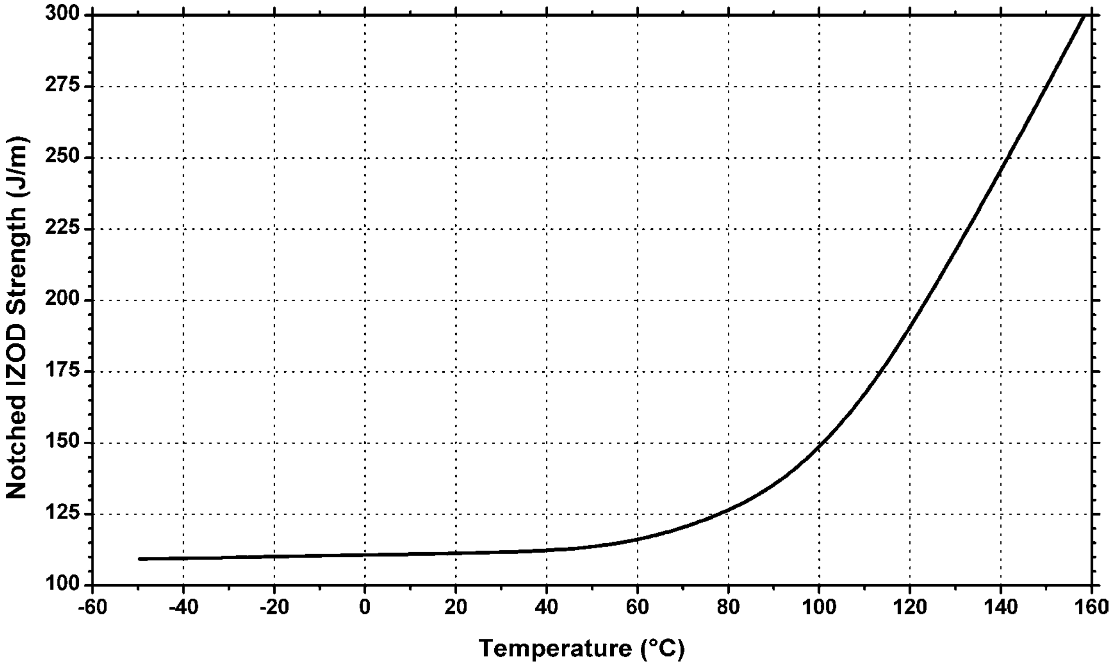


Figure 6.252. Notched IZOD strength vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

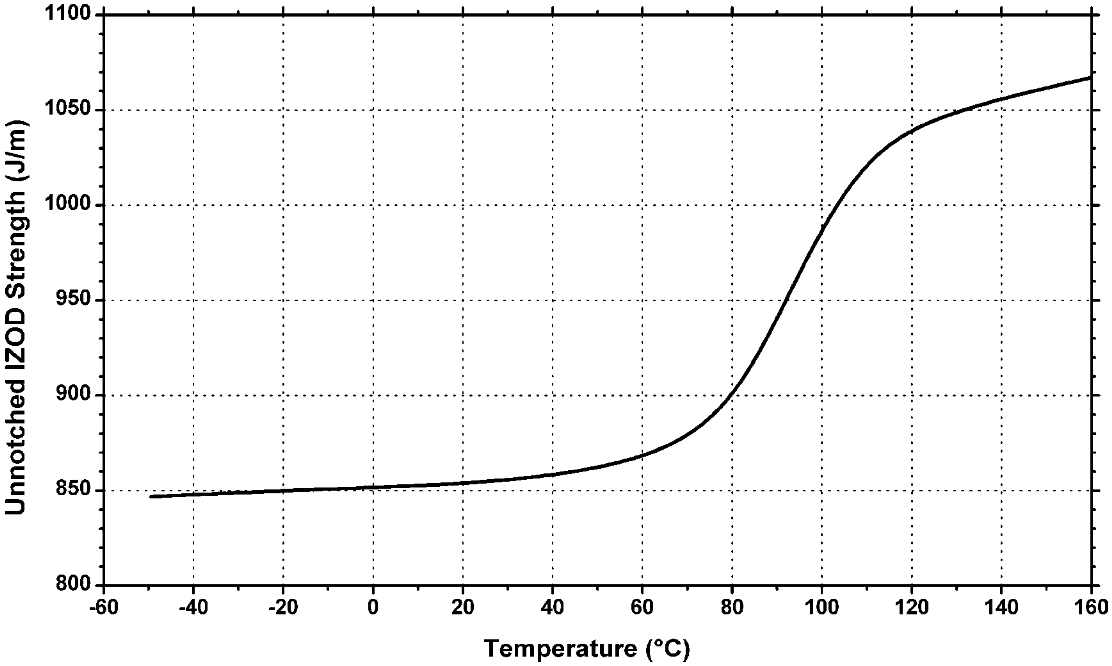


Figure 6.253. Unnotched IZOD strength vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

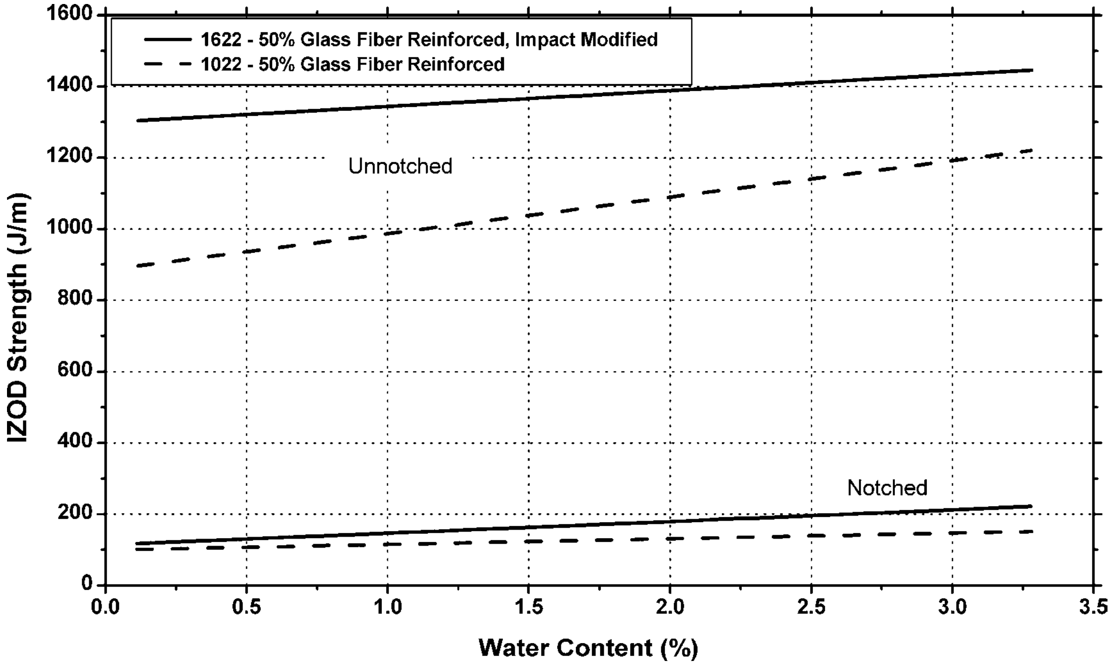


Figure 6.254. IZOD strength vs. water content for Solvay IXEF® PAA resins.

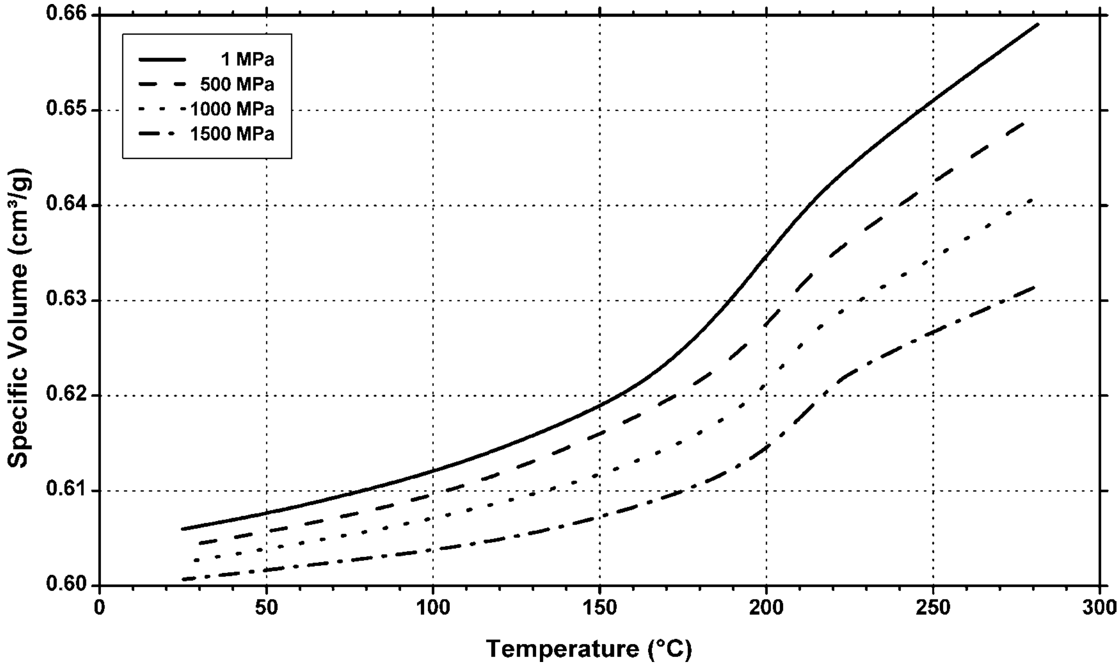


Figure 6.255. Pressure-specific volume-temperature (PVT) for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

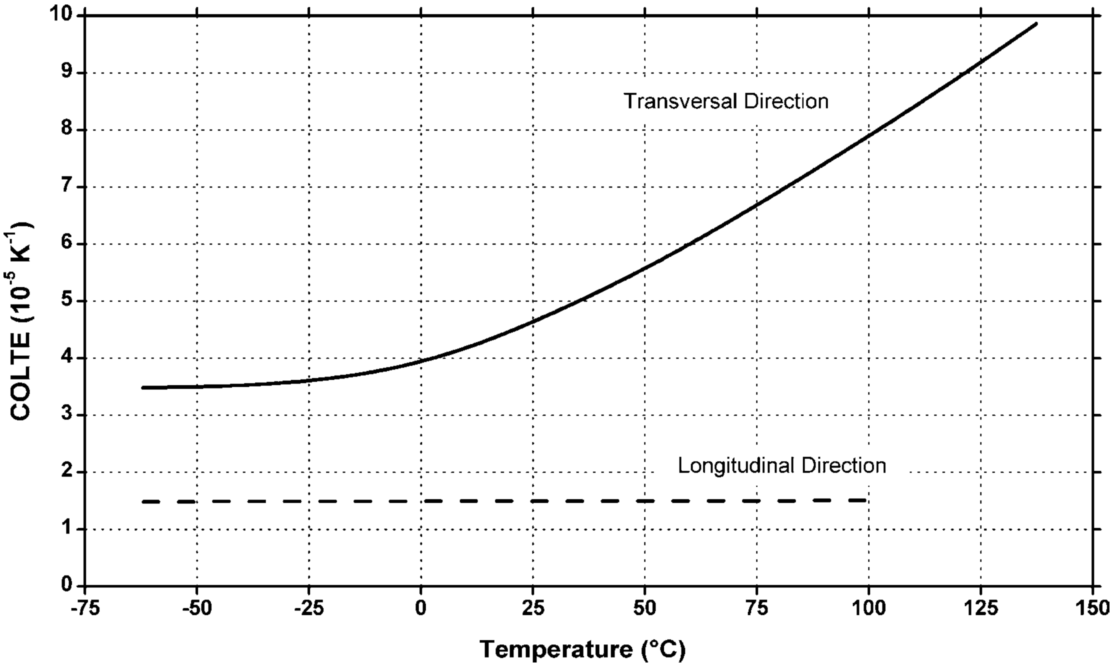


Figure 6.256. Coefficient of linear thermal expansion (COLTE) vs. temperature for Solvay IXEF® 1022—50% glass fiber reinforced PAA resin.

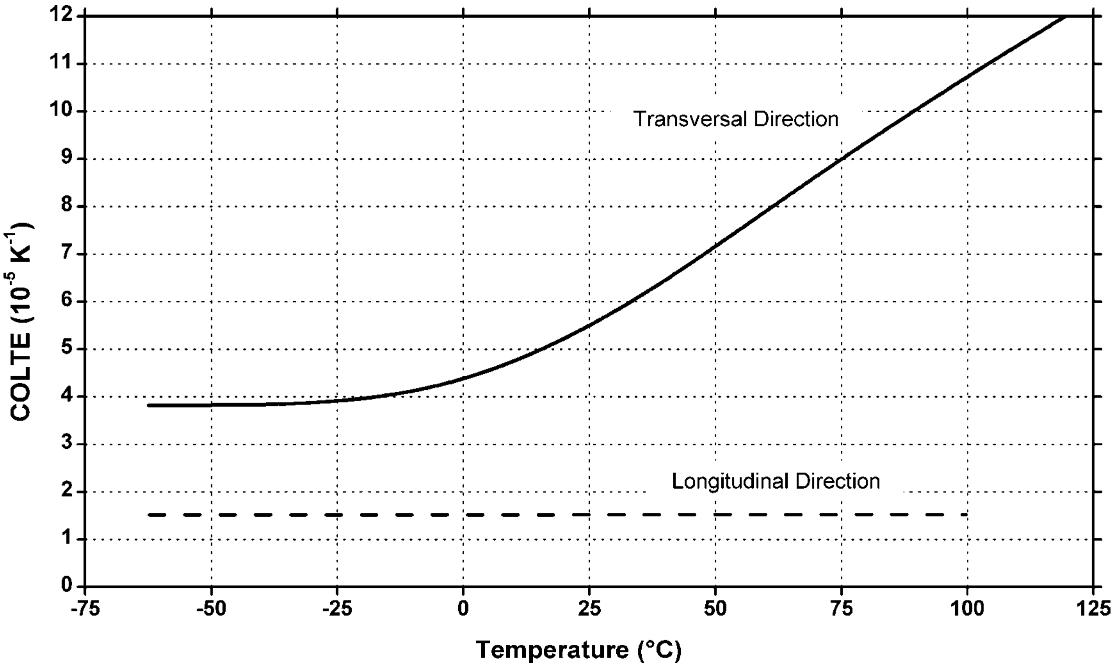


Figure 6.257. Coefficient of linear thermal expansion (COLTE) vs. temperature for Solvay IXEF® 1622—50% glass fiber reinforced, impact modified PAA resin.

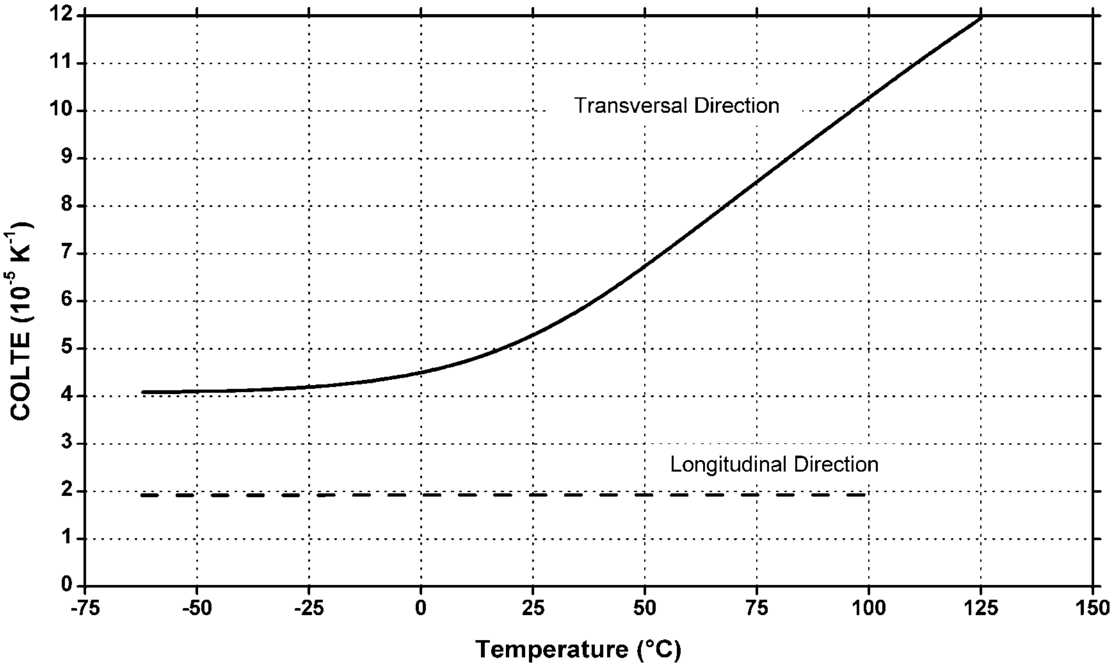


Figure 6.258. Coefficient of linear thermal expansion (COLTE) vs. temperature for Solvay IXEF® 2011—42% mineral reinforced PAA resin.

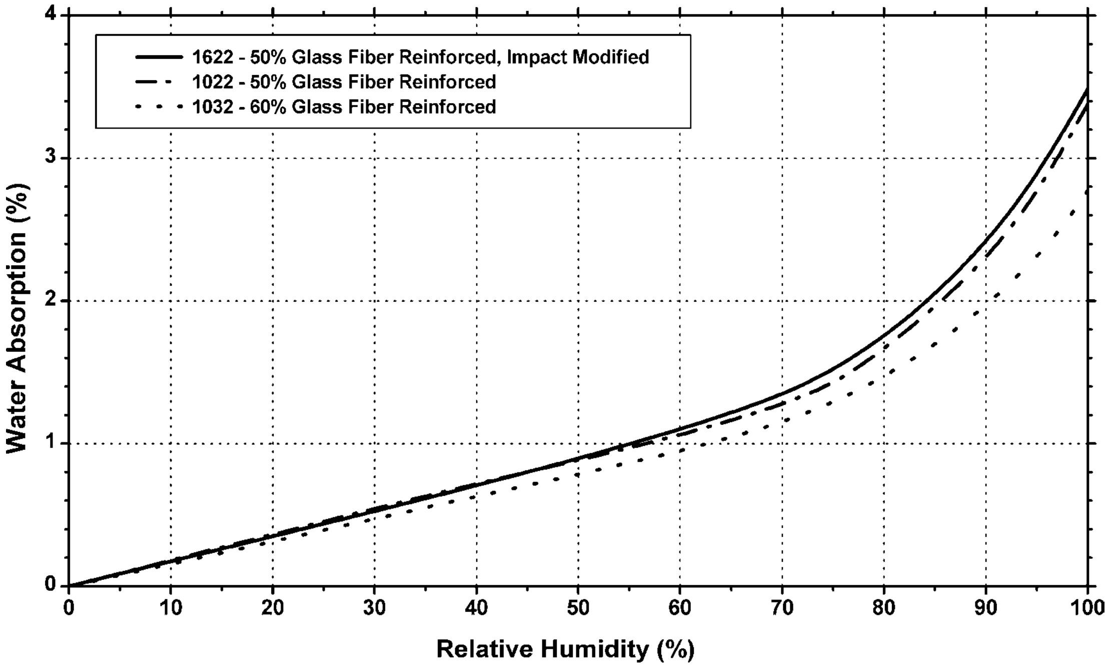


Figure 6.259. Water absorption vs. relative humidity for Solvay IXEF® PAA resins.

6.13 Polyamide Blend (PPA)

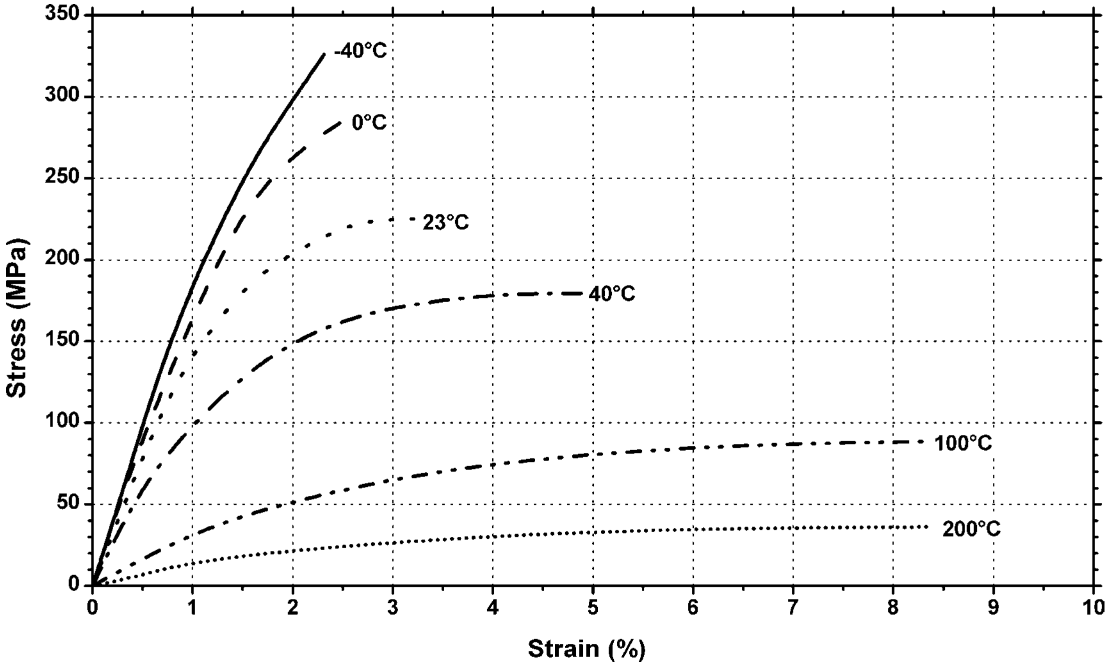


Figure 6.260. Stress vs. strain at various temperatures for EMS-Grivory Grivory GC-4H—PA66/PPA alloy, 40% carbon fiber reinforced PPA resin (conditioned).

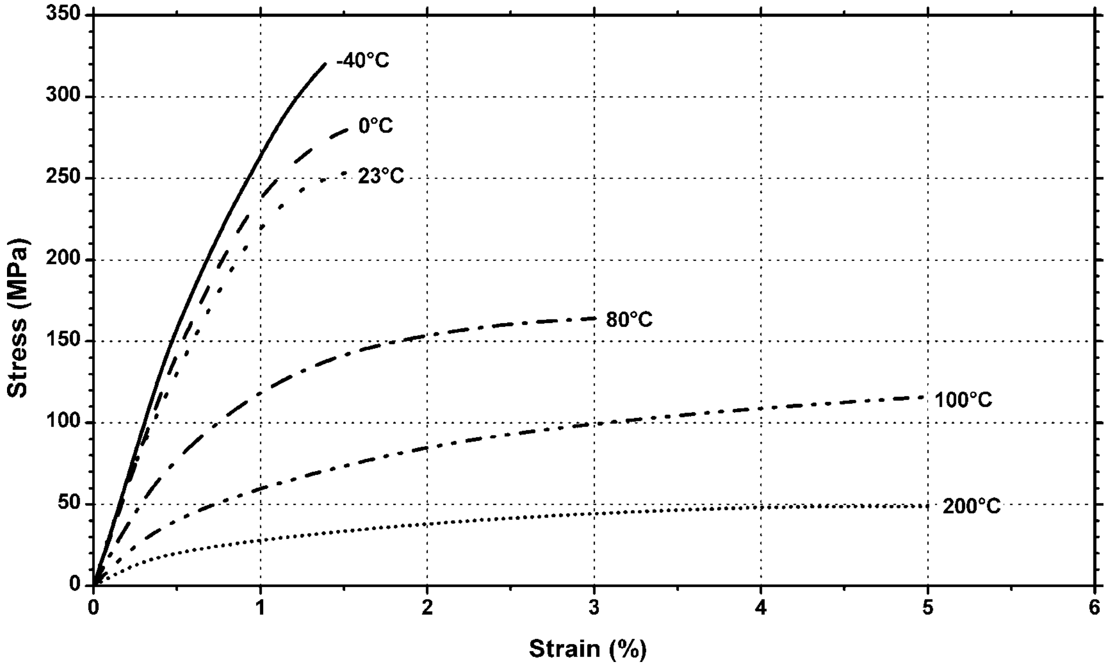


Figure 6.261. Stress vs. strain at various temperatures for EMS-Grivory Grivory GC-4H—PA66/PPA alloy, 40% carbon fiber reinforced PPA resin (DAM).

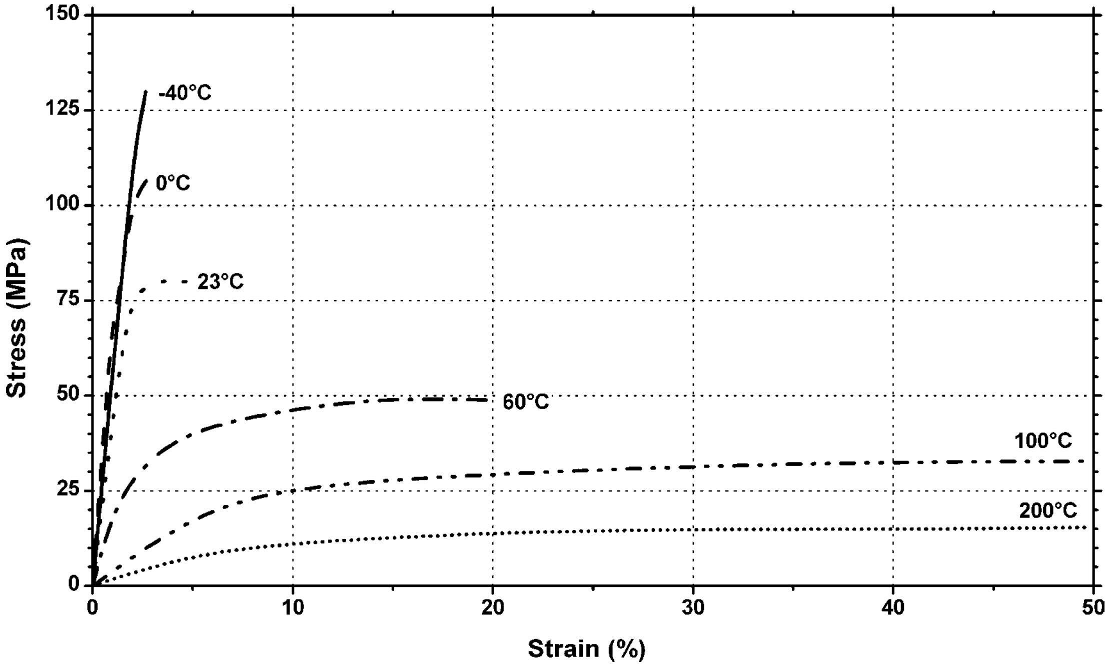


Figure 6.262. Stress vs. strain at various temperatures for EMS-Grivory Grivory GM-4H—PA66/PPA alloy, 40% mineral reinforced PPA resin (conditioned).

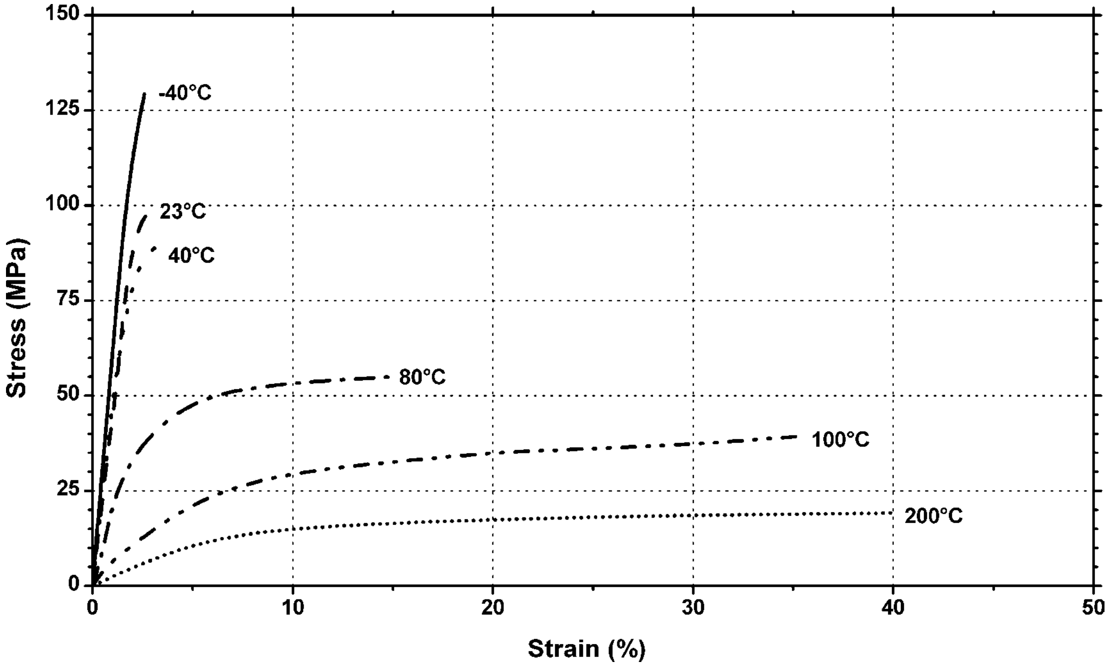


Figure 6.263. Stress vs. strain at various temperatures for EMS-Grivory Grivory GM-4H—PA66/PPA alloy, 40% mineral reinforced PPA resin (DAM).

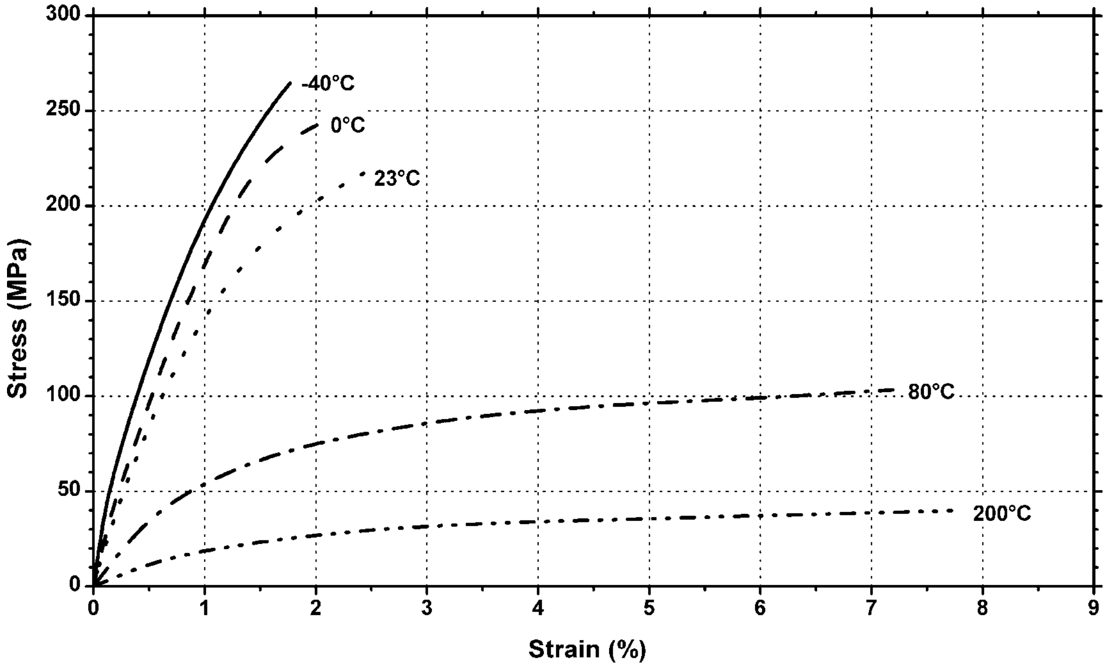


Figure 6.264. Stress vs. strain at various temperatures for EMS-Grivory Grivory GV-5H—PA66/PPA alloy, 50% glass fiber reinforced PPA resin (conditioned).

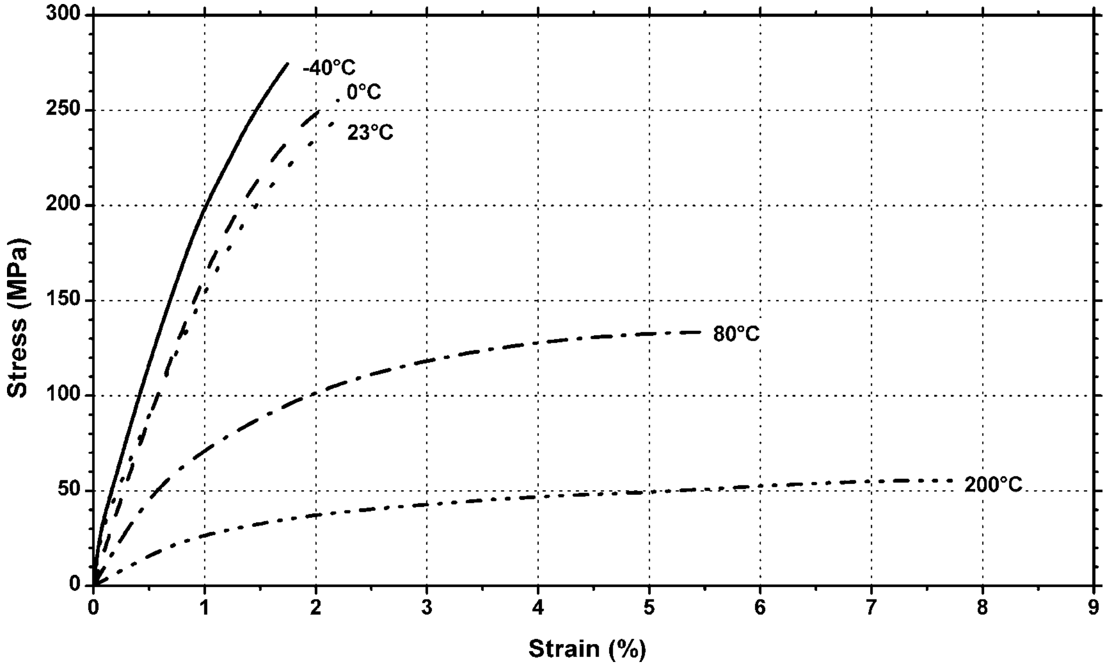


Figure 6.265. Stress vs. strain at various temperatures for EMS-Grivory Grivory GV-5H—PA66/PPA alloy, 50% glass fiber reinforced PPA resin (DAM).

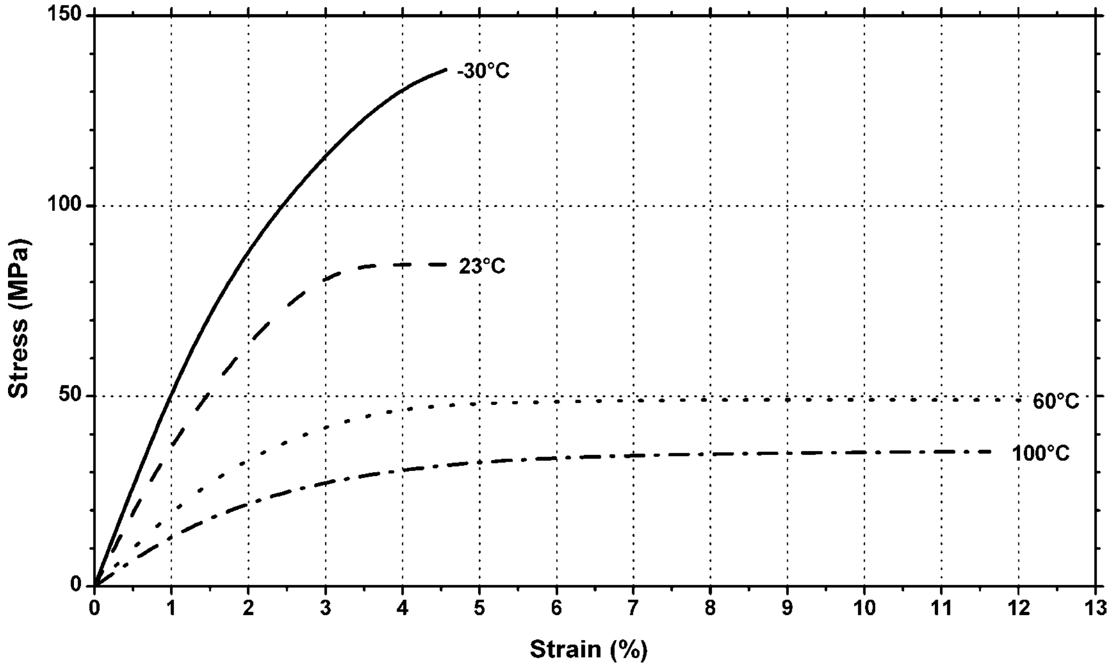


Figure 6.266. Stress vs. strain at various temperatures for Arkema Orgalloy® RS 6010—PA6 alloy, 10% glass fiber reinforced PPA resin (DAM).

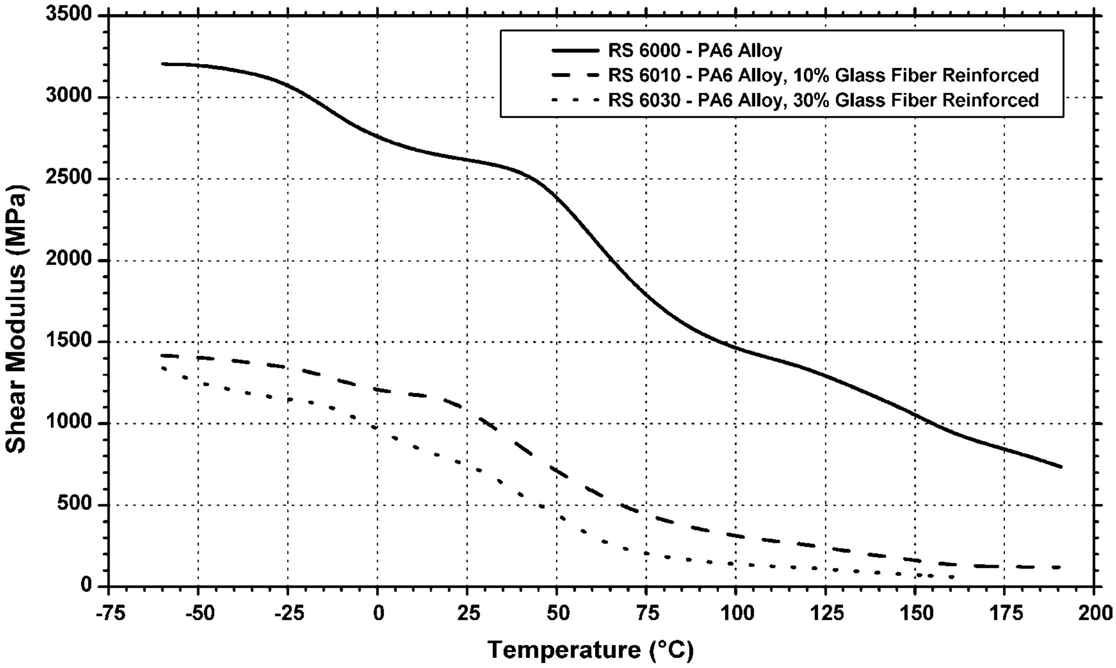


Figure 6.267. Shear modulus vs. temperature for Arkema Orgalloy® PPA resins (DAM).

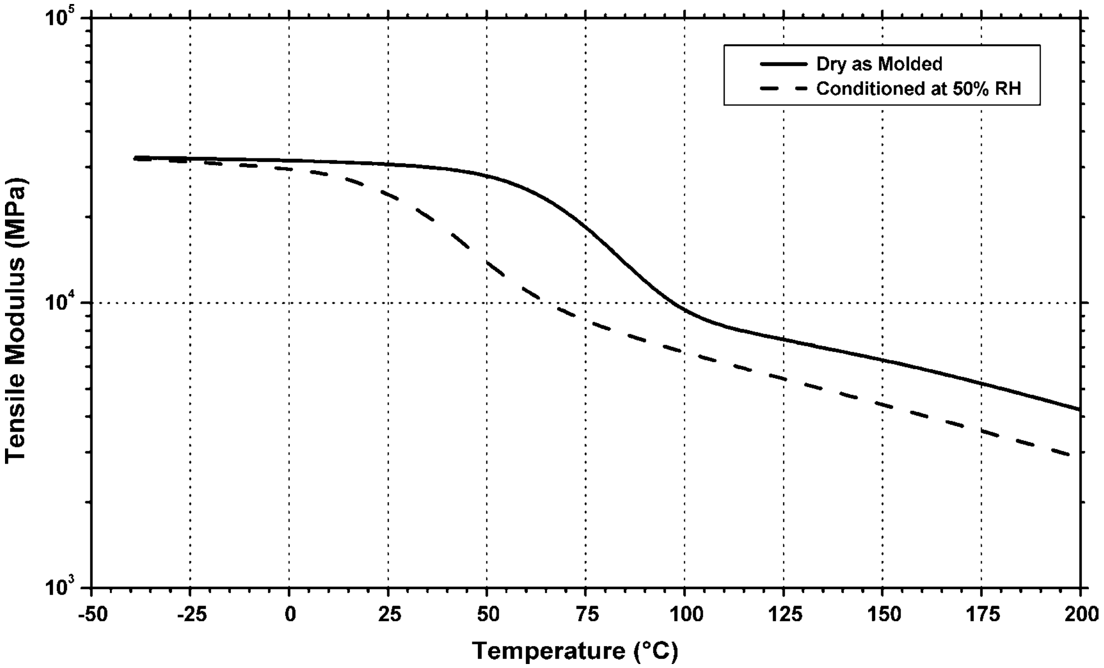


Figure 6.268. Tensile modulus vs. temperature for EMS-Grivory Grivory GC-4H—PA66/PPA alloy, 40% carbon fiber reinforced PPA resin.

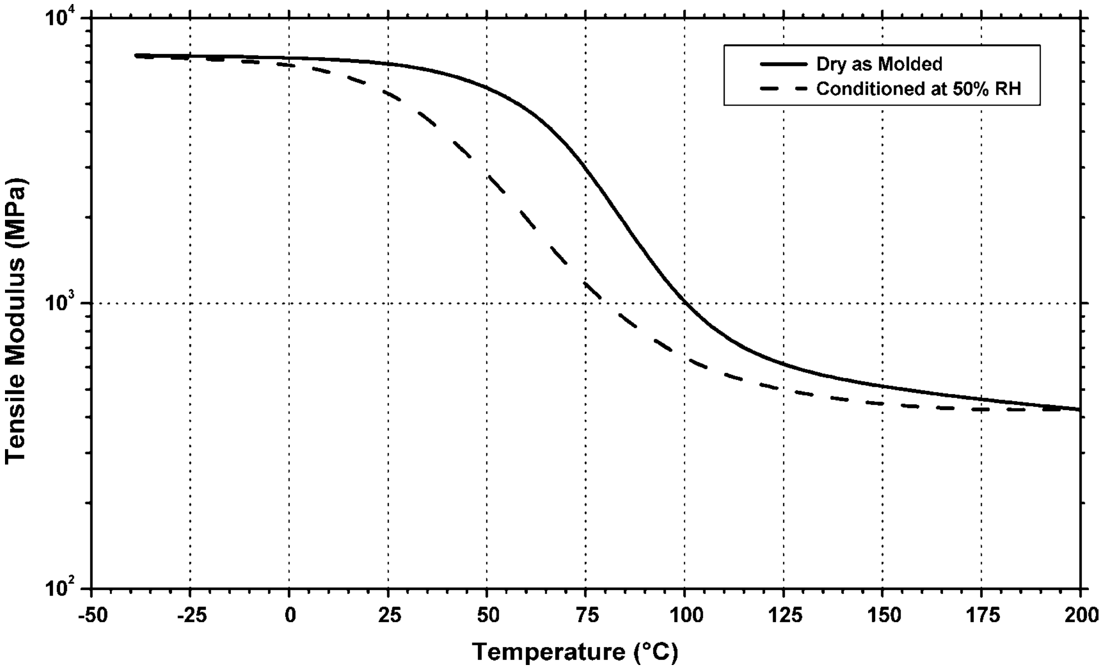


Figure 6.269. Tensile modulus vs. temperature for EMS-Grivory Grivory GM-4H—PA66/PPA alloy, 40% mineral reinforced PPA resin.

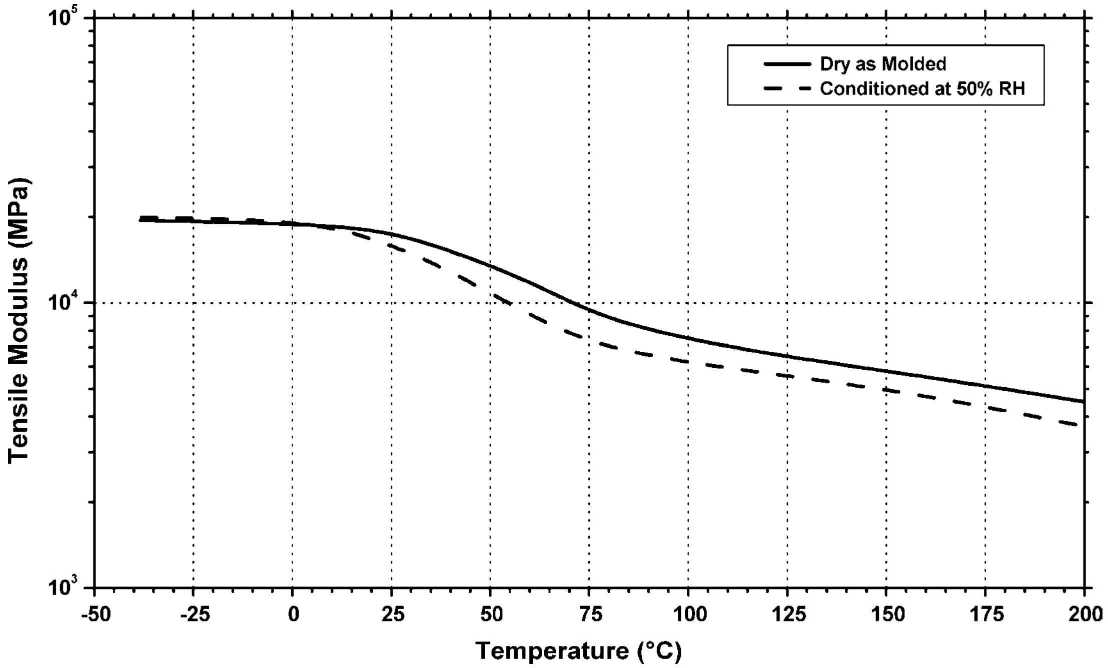


Figure 6.270. Tensile modulus vs. temperature for EMS-Grivory Grivory GV-5H—PA66/PPA alloy, 50% glass fiber reinforced PPA resin.

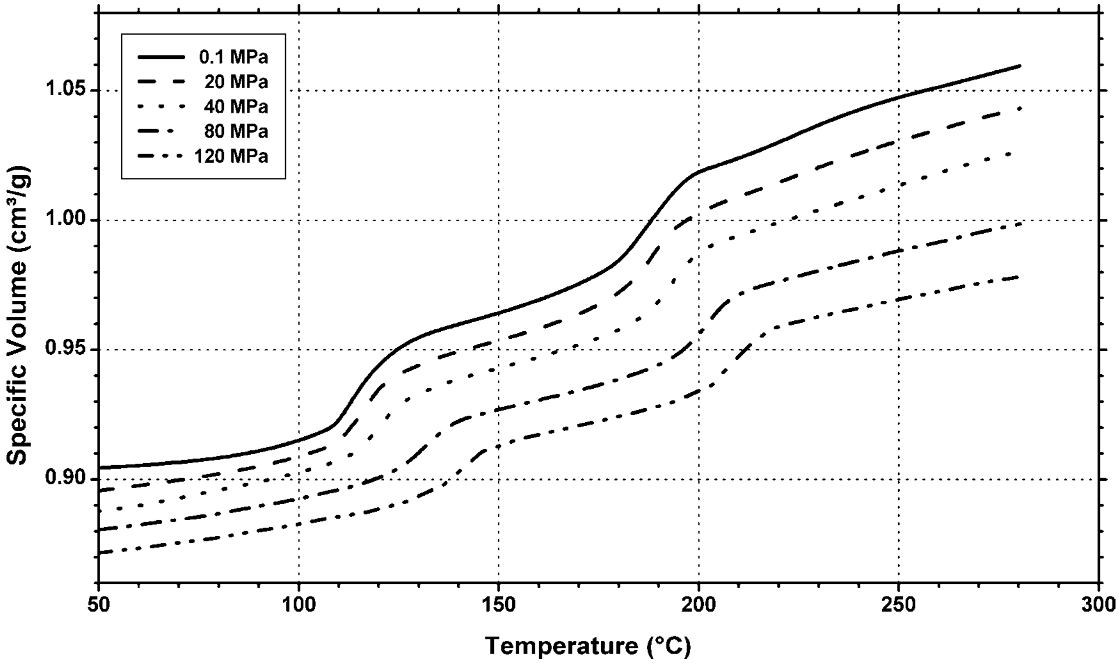


Figure 6.271. Pressure-specific volume-temperature (PVT) for Arkema Orgalloy® RS 6010—PA6 alloy, 10% glass fiber reinforced PPA resin.

7 Polyolefins and Acrylics

7.1 Background

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 and polypropylene, which are two of the plastics discussed in this chapter. A slightly more complex alkene is 4-methylpentene-1, the basis of poly (methyl pentene), known by 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, (PVC). Acrylic polymers are also polymerized through the carbon-carbon double bond. Methyl methacrylate is the monomer used to make polymethyl methacrylate (PMMA).

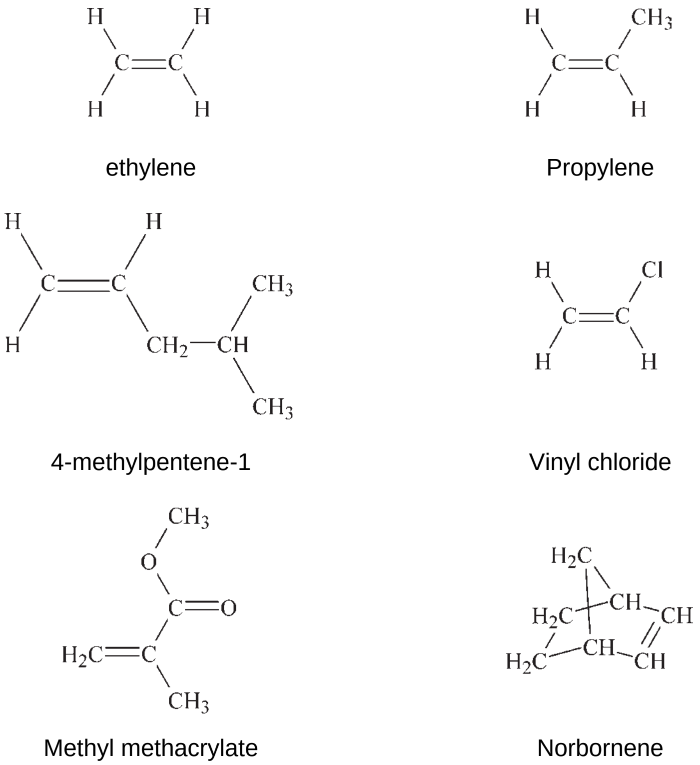
The structures of these monomers are shown in Fig. 7.1, and of their polymers are shown in Fig. 7.2. The copolymer structure using the norbornene monomer is shown later in Fig. 7.5.

7.1.1 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 can alter its structure and properties.

The basic types or classifications of PE, according to the American Society for Testing and Materials (ASTM) 1248, are as follows:

- Ultra low density polyethylene (ULDPE), polymers with densities ranging from 0.890 to 0.905 g/cc, contain comonomer


ethylene

Propylene

4-methylpentene-1

Vinyl chloride

Methyl methacrylate

Norbornene

Figure 7.1. Chemical structures of monomers used to make polyolefins.

- Very low density polyethylene (VLDPE), polymers with densities ranging from 0.905 to 0.915 g/cc, contain comonomer
- Linear low density polyethylene (LLDPE), polymers with densities ranging from 0.915 to 0.935 g/cc, contain comonomer
- Low density polyethylene (LDPE), polymers with densities ranging from 0.915 to 0.935 g/cc
- Medium density polyethylene (MDPE), polymers with densities ranging from 0.926 to 0.940 g/cc, may or may not contain comonomer
- High-density polyethylene (HDPE), polymers with densities ranging from 0.940 to 0.970 g/cc, may or may not contain comonomer

Figure 7.3 shows the differences graphically. The differences in terms of number and length of the branches affect the density and melting points of some of the types.

Branching affects the crystallinity. A diagram of a representation of the crystal structure of PE is shown in Fig. 7.4. One can imagine how branching in the polymer chain can disrupt the crystalline regions.

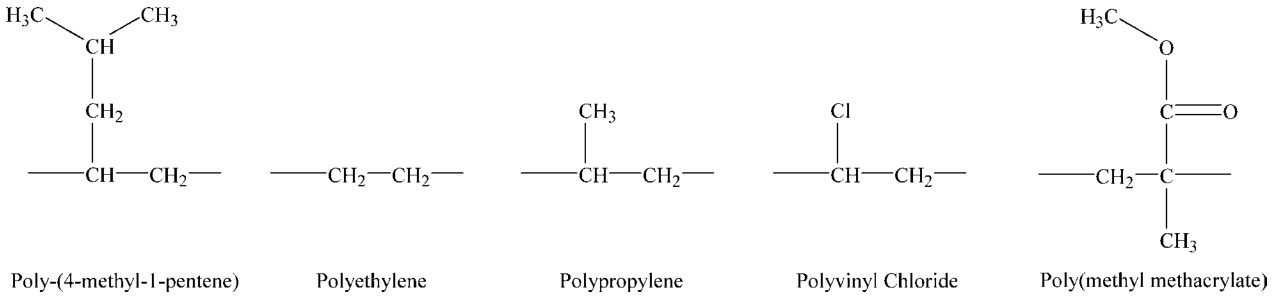


Figure 7.2. Structures of polyolefin polymers.

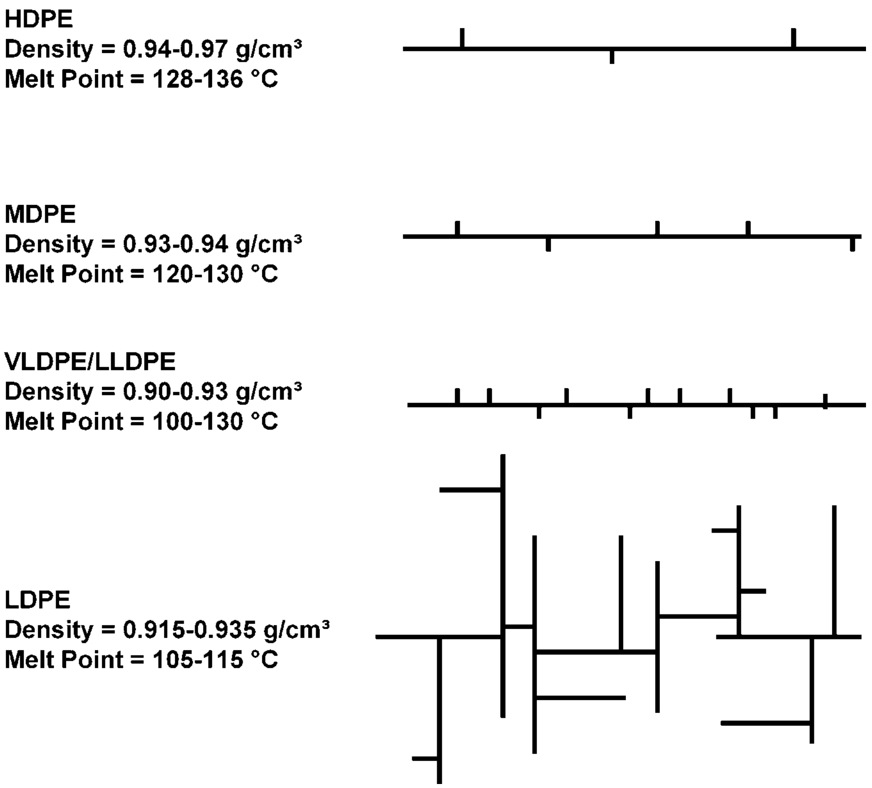


Figure 7.3. Graphical depictions of PE types.

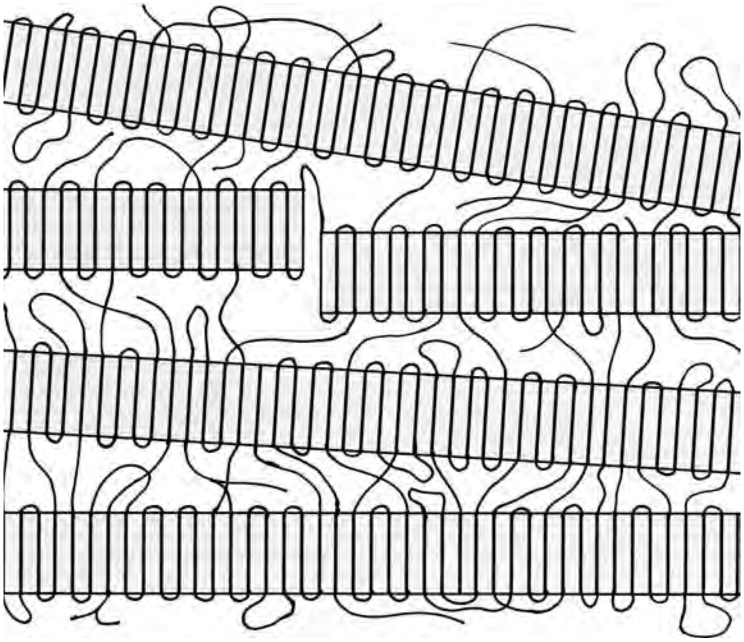


Figure 7.4. Graphical diagram of PE crystal structure.

The crystalline regions are the highly ordered areas in the shaded rectangles of Fig. 7.4. A high degree of branching reduces the size of the crystalline regions, and leads to lower crystallinity.

7.1.2 Polypropylene (PP)

The three main types of PP generally available are:

- Homopolymers: They are made in a single reactor with propylene and a catalyst. They are the stiffest of the three propylene types and have the highest tensile strength at yield. In the natural state (no colorant added), they are translucent and have excellent see through or contact clarity with liquids. In comparison to the other two types they have less impact resistance, especially below 0°C.
- Random Copolymers (homophasic copolymers): They are made in a single reactor adding a small amount of ethylene (<5%), which disrupts the crystallinity of the polymer, allowing this type to be the clearest. They are also the most flexible with the lowest tensile strength of the three. They have better room temperature impact than homopolymers but share the same relatively poor impact resistance at low temperatures.
- Impact Copolymers (heterophasic copolymers): They 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 the ethylene monomer added, the greater the impact resistance with correspondingly lower stiffness and tensile strength.

7.1.3 Polytrimethyl Pentene (PTP)

4-Methylpentene-1 based polyolefin is manufactured and marketed solely by Mitsui Chemicals, Inc. by the trade name TPX™. This lightweight, functional polymer displays a unique combination of physical properties and characteristics due to its distinctive molecular structure, which includes a bulky side chain as shown in Fig. 7.2. PTP possesses many characteristics inherent in traditional polyolefins such as excellent electrical insulating properties and strong hydrolysis resistance. Moreover, it features low dielectric, superb clarity, transparency, gas permeability, heat and chemical resistance and release qualities.

It can be used for extruded and film products, injection molded, and blow molded application items, including:

- Paper coatings and baking cartons
- Release film and release paper
- High frequency films
- Microwave cookware
- Food packaging such as gas permeable packages for fruit and vegetables
- LED molds

7.1.4 Ultra High Molecular Weight Polyethylene (UHMWPE)

Thermoplastic UHMWPE is also known as high modulus polyethylene (HMPE) or high performance polyethylene (HPPE). It has extremely long chains, with molecular weight numbering in millions (usually between 3.1 and 5.67 million). The high molecular weight leads to a very good packing of the chains into the crystal structure. This makes UHMWPE a very tough material, with the highest impact strength of any thermoplastic presently made. It is highly resistant to corrosive chemicals, with exception of oxidizing acids. It has extremely low moisture absorption and is highly resistant to abrasion. Its coefficient of friction is significantly lower than nylon and acetal.

7.1.5 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.

There are three broad classifications for rigid PVC compounds: Type I, Type II, and CPVC. Type II differs from Type I by having 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.

7.1.6 Cyclic Olefin Copolymer (COC)

COC is an amorphous polyolefin made by reaction of ethylene and norbornene in varying ratios. Its structure is given in Fig. 7.5. 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
- Variable heat deflection temperature up to 170°C
- Very good resistance to acids and alkalis

7.1.7 Polyacrylics

While a large number of acrylic polymers are manufactured, PMMA is the most common. It is popular by the trade name, Plexiglas®. PMMA has two very distinct properties that set the product apart from others. First, it is optically clear and colorless. It has a light transmission of 92%. The 4% reflection loss at each surface in unavoidable. Second, its surface is extremely hard. They are also highly weather resistant.

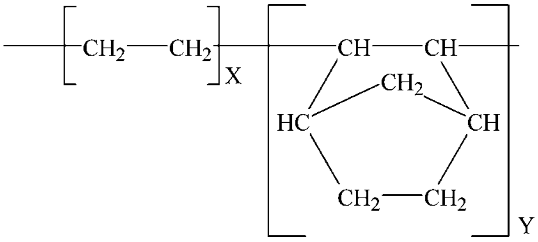


Figure 7.5. Chemical structure of COC.

7.1.8 Other Olefin/Acrylic Polymers

There are a large number of acrylic/olefin copolymers manufactured. One of the best known is the copolymer of ethylene and methacrylic acid forming a polymer known as ethylene-methacrylic-acid (EMAA). This is more commonly known by its trade name, Surlyn®, made by DuPont. Generally, there is little multipoint data publicly available for these polymers, so they are not included in this book.

Graphs of the properties of polyolefin plastics as a function of temperature, moisture, and other factors are illustrated in Sections 7.2–7.8.

7.2 Polyethylene (PE)

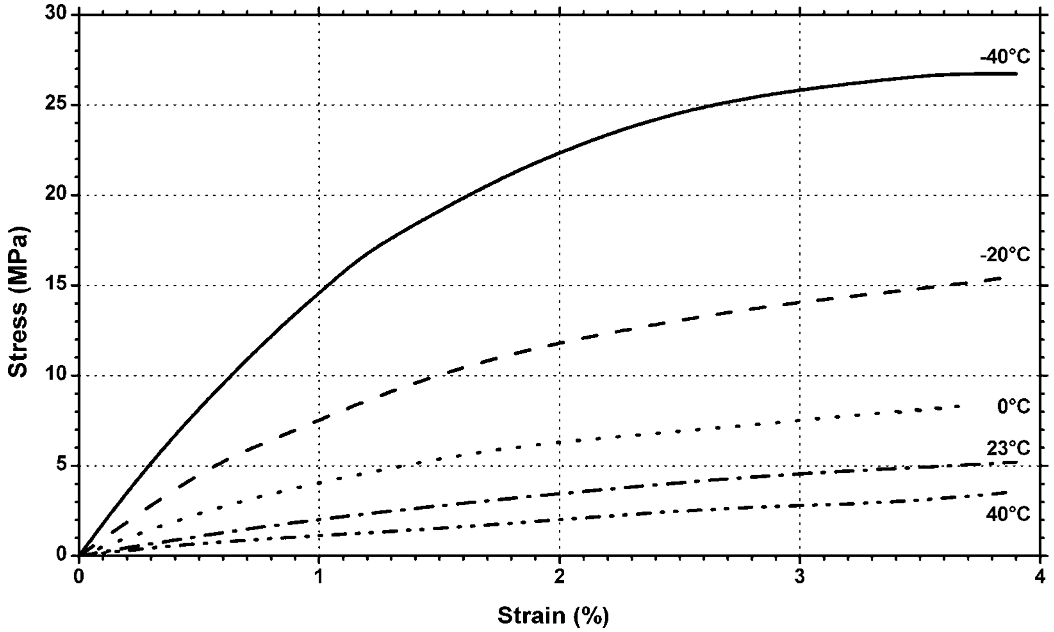


Figure 7.6. Stress vs. strain at various temperatures of Basell Polyolefins Lupolen® 1810H—low density (0.918 g/cc), MFR 1.5 g/10 min PE resin.

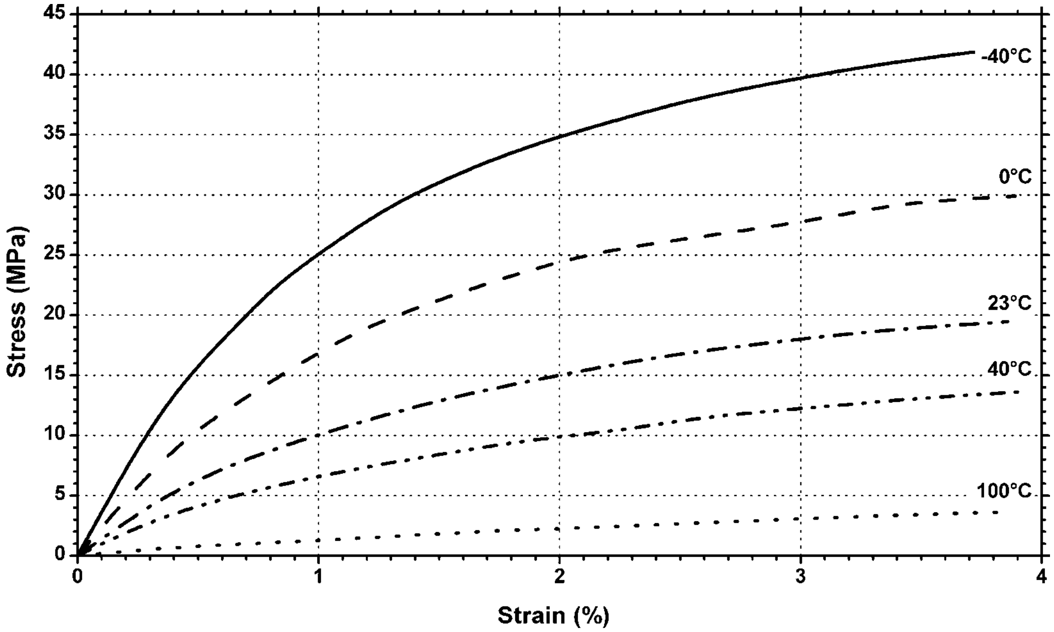


Figure 7.7. Stress vs. strain at various temperatures of Basell Polyolefins Lupolen® 5031L—high density (0.950 g/cc), MFR 6.5 g/10min, stabilized PE resin.

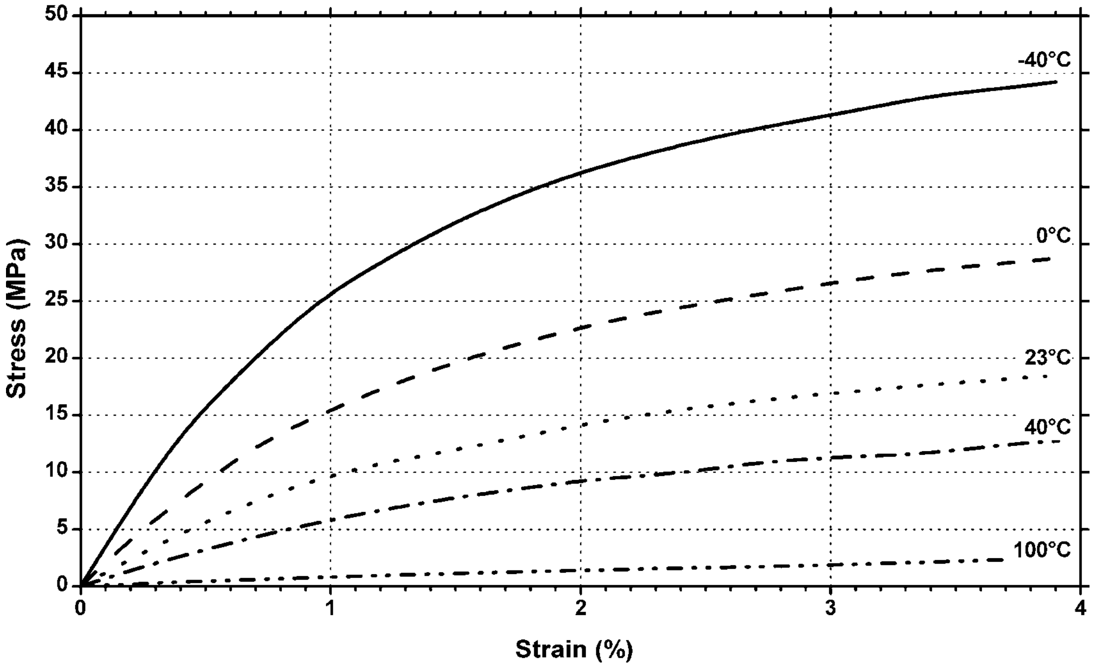


Figure 7.8. Stress vs. strain at various temperatures of Basell Polyolefins Lupolen® 5041H—high density (0.950 g/cc), MFR 1.5 g/10 min, stabilized PE resin.

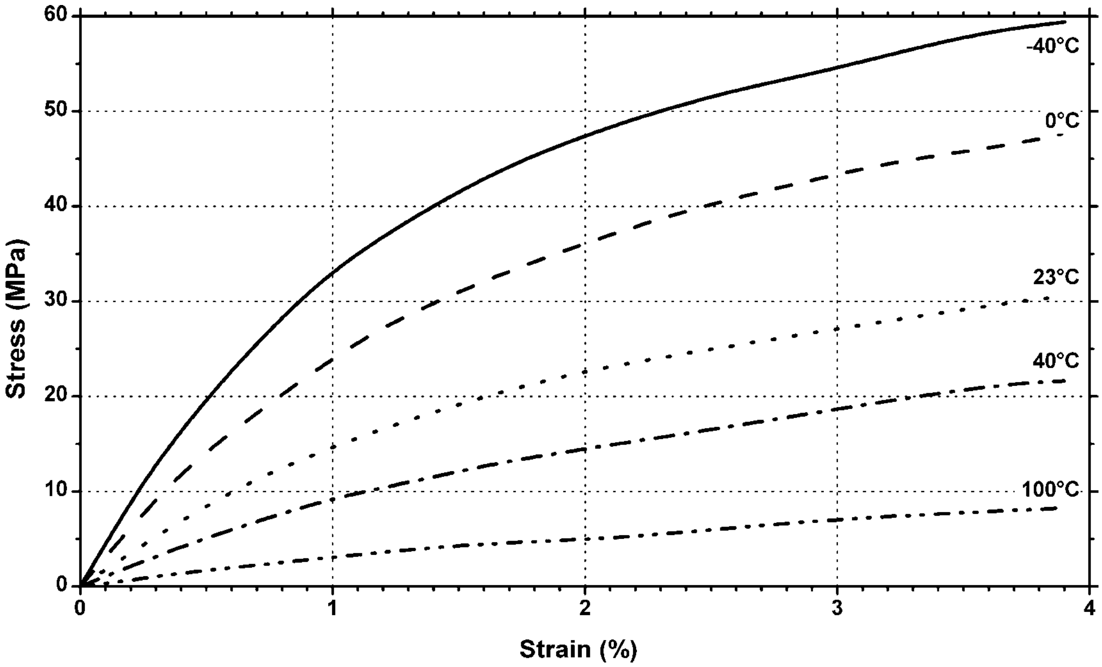


Figure 7.9. Stress vs. strain at various temperatures of Basell Polyolefins Lupolen® 5261Z—high density (0.952 g/cc), MFR 2 g/10 min, stabilized PE resin.

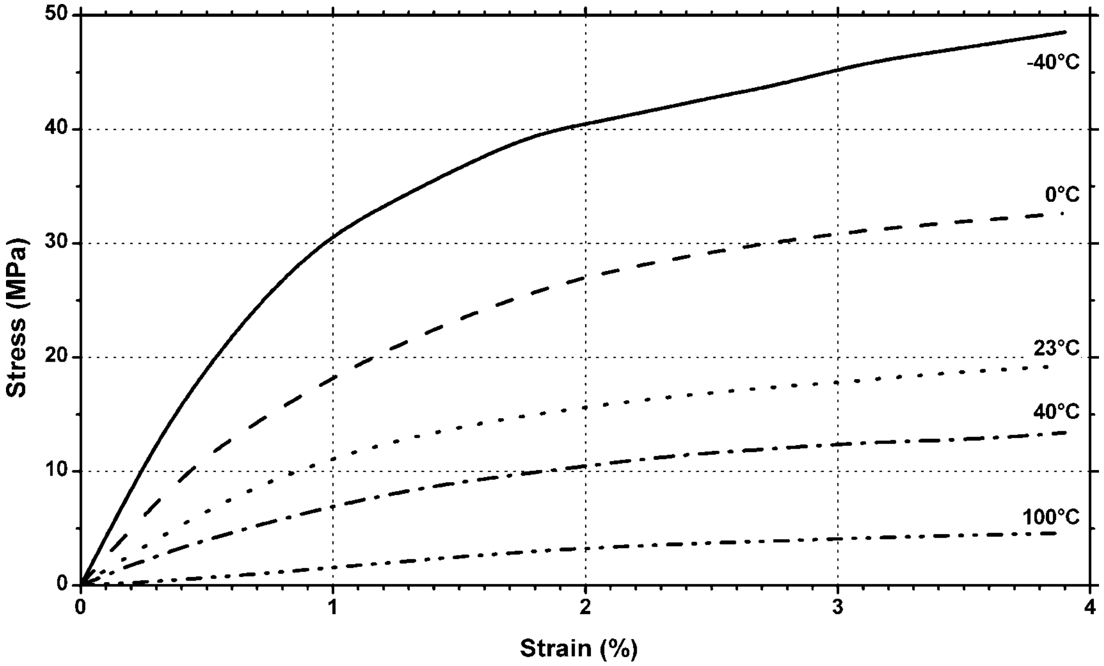


Figure 7.10. Stress vs. strain at various temperatures of Basell Polyolefins Lupolen® 6031M—high density (0.960 g/cc), MFR 8 g/10 min, stabilized PE resin.

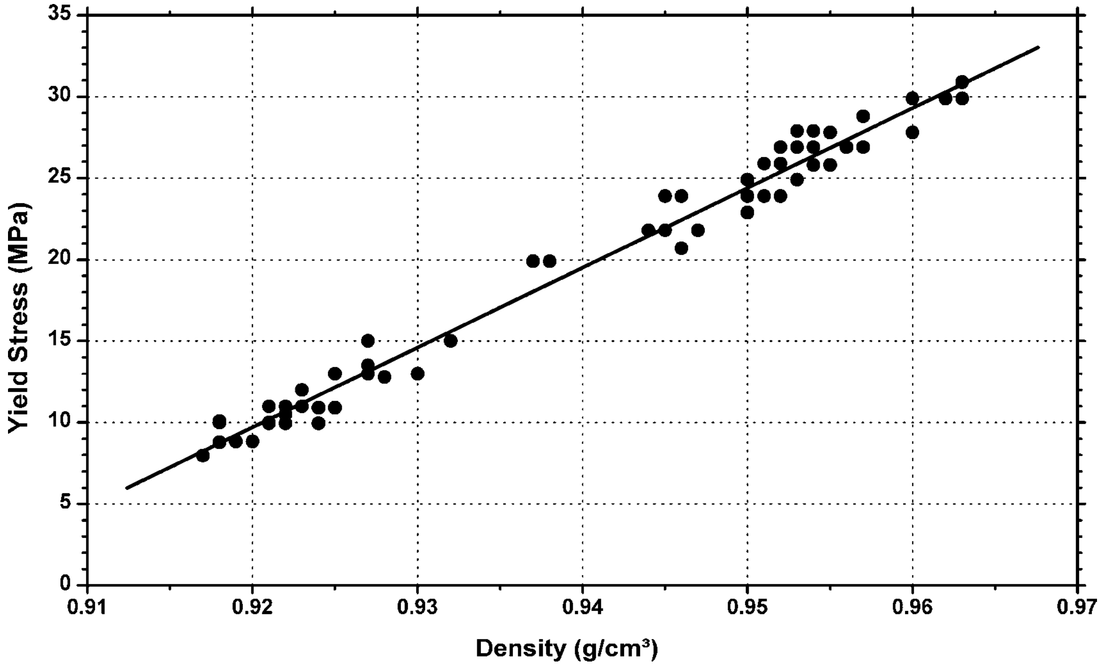


Figure 7.11. Yield stress vs. density of Basell Polyolefins—PE resin.

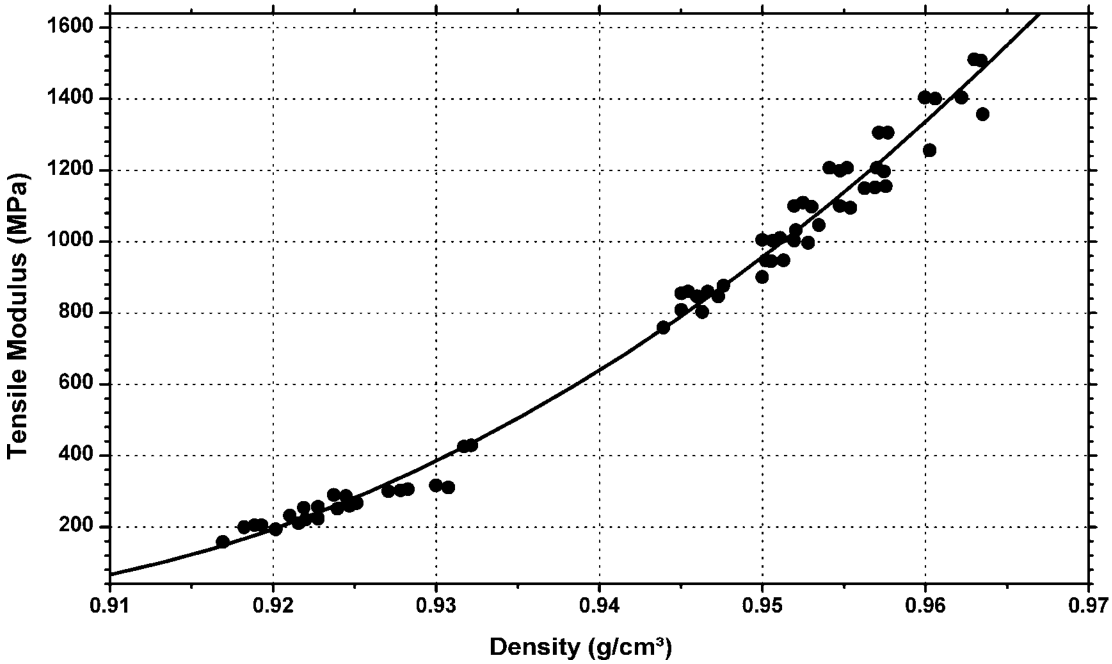


Figure 7.12. Tensile modulus vs. density of Basell Polyolefins—PE resin.

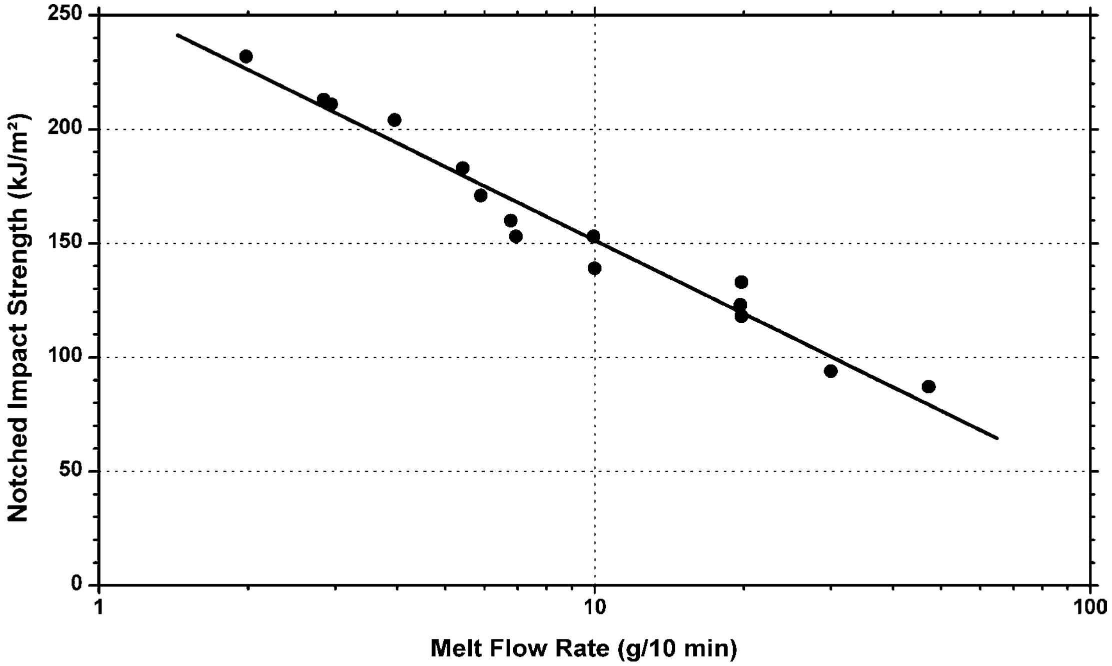


Figure 7.13. Notched tensile impact strength vs. melt flow rate (MFR) of Basell Polyolefins—PE resin.

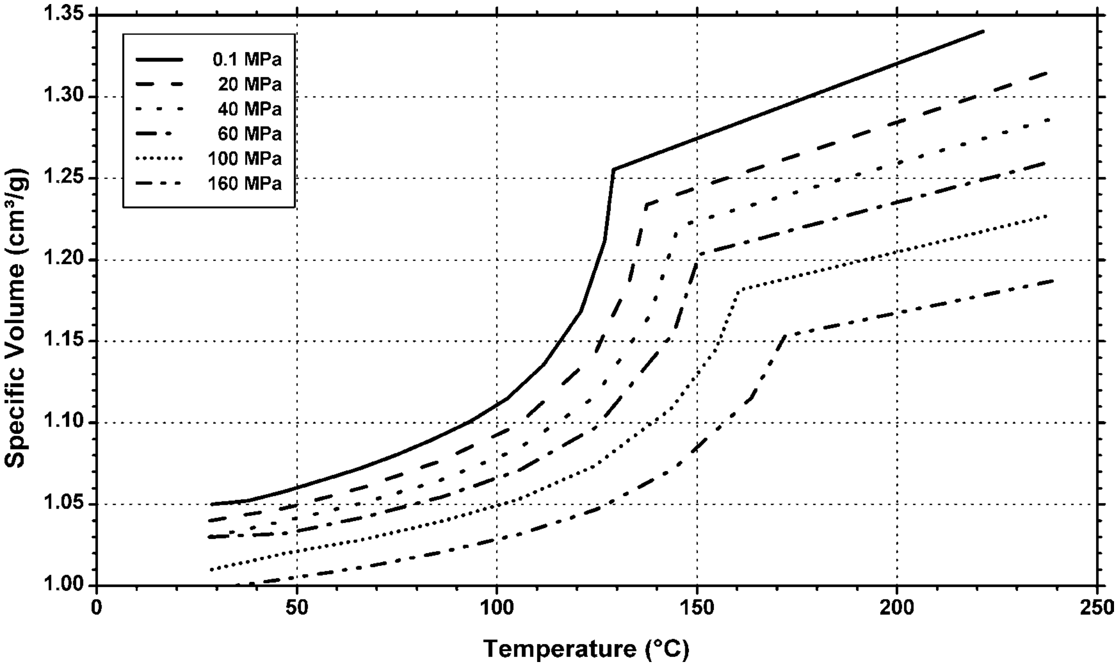


Figure 7.14. Specific volume vs. temperature and pressure (PVT) of Basell Polyolefins—PE resin.

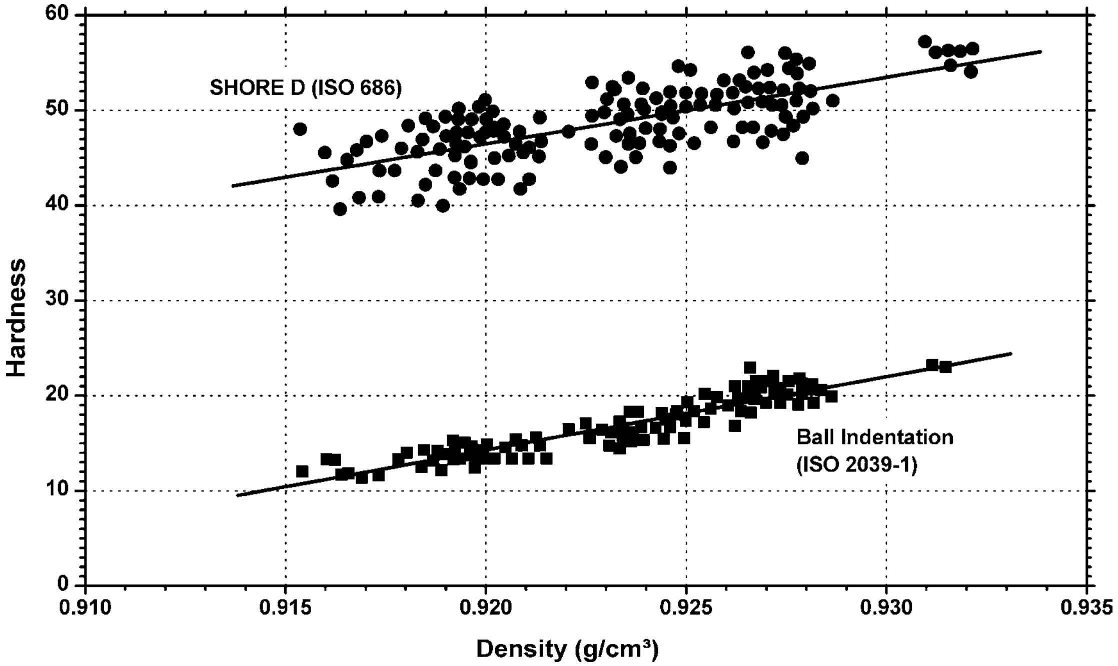


Figure 7.15. Hardness vs. density of Basell Polyolefins—PE resin.

7.3 Polypropylene (PP)

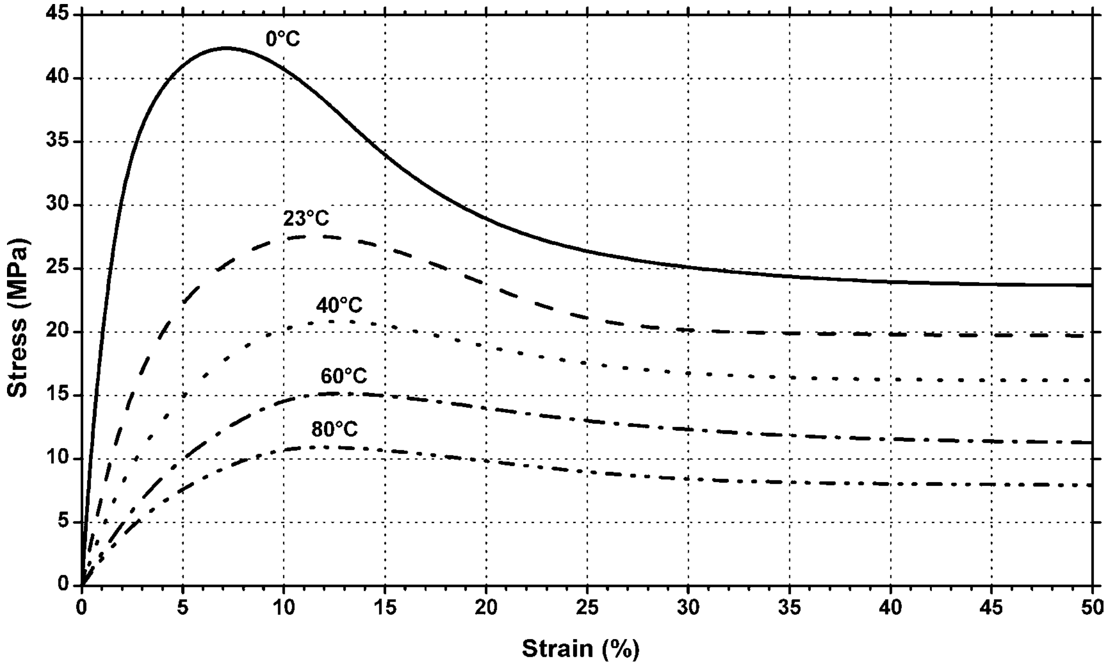


Figure 7.16. Stress vs. strain at various temperatures of Basell Polyolefins Hostalen® H1022—easy flow, high impact PP resin.

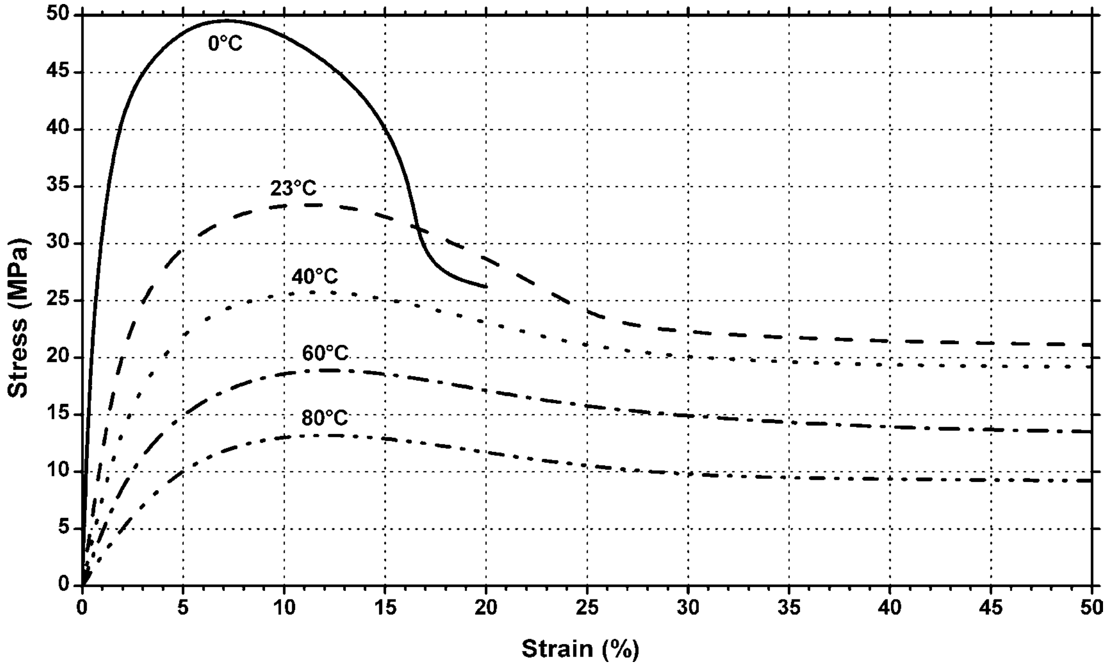


Figure 7.17. Stress vs. strain at various temperatures of Basell Polyolefins Hostalen® H2250—easy flow, high heat PP resin.

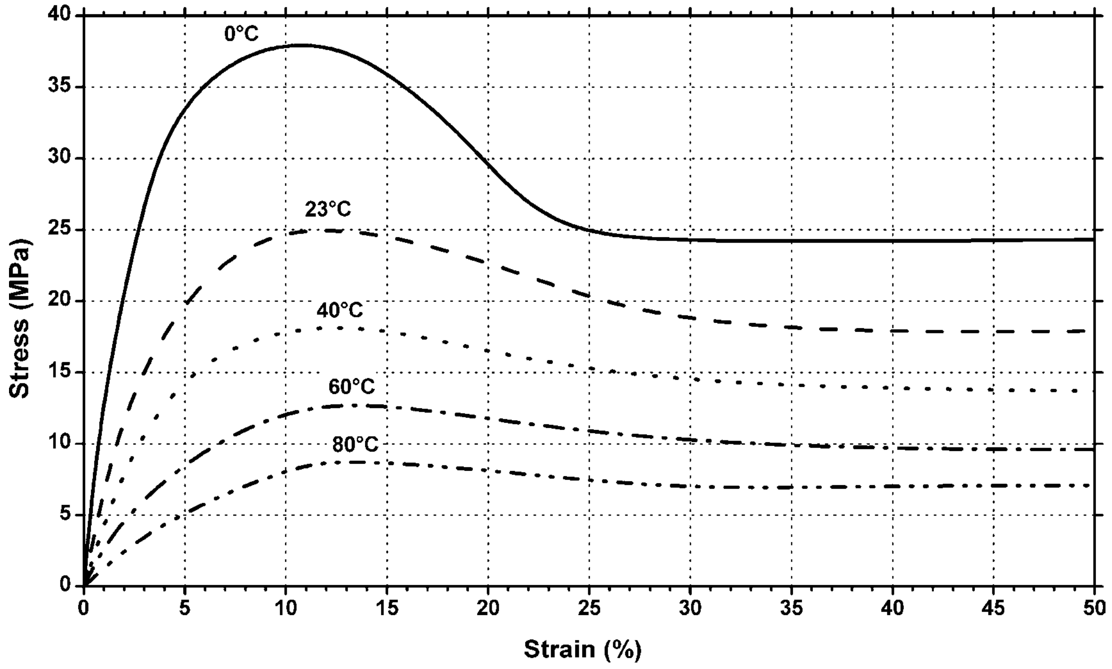


Figure 7.18. Stress vs. strain at various temperatures of Basell Polyolefins Hostalen® H5216—easy flow, random copolymer PP resin.

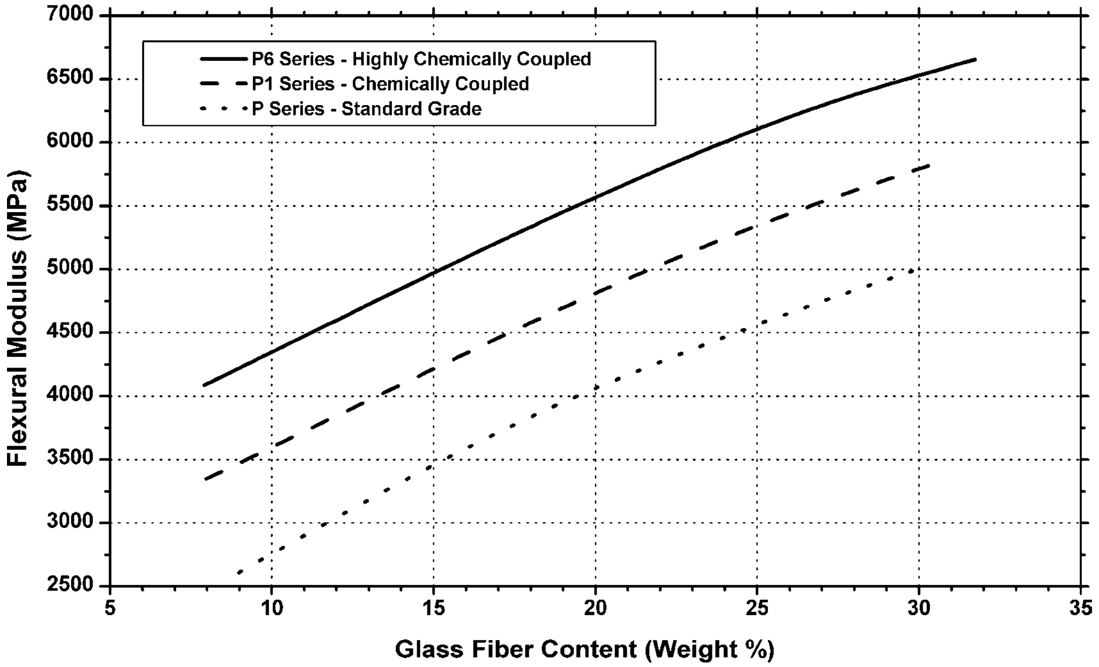


Figure 7.19. Flexural modulus at 23°C vs. glass fiber content of Asahi Kasei Thermylene®—PP resins.

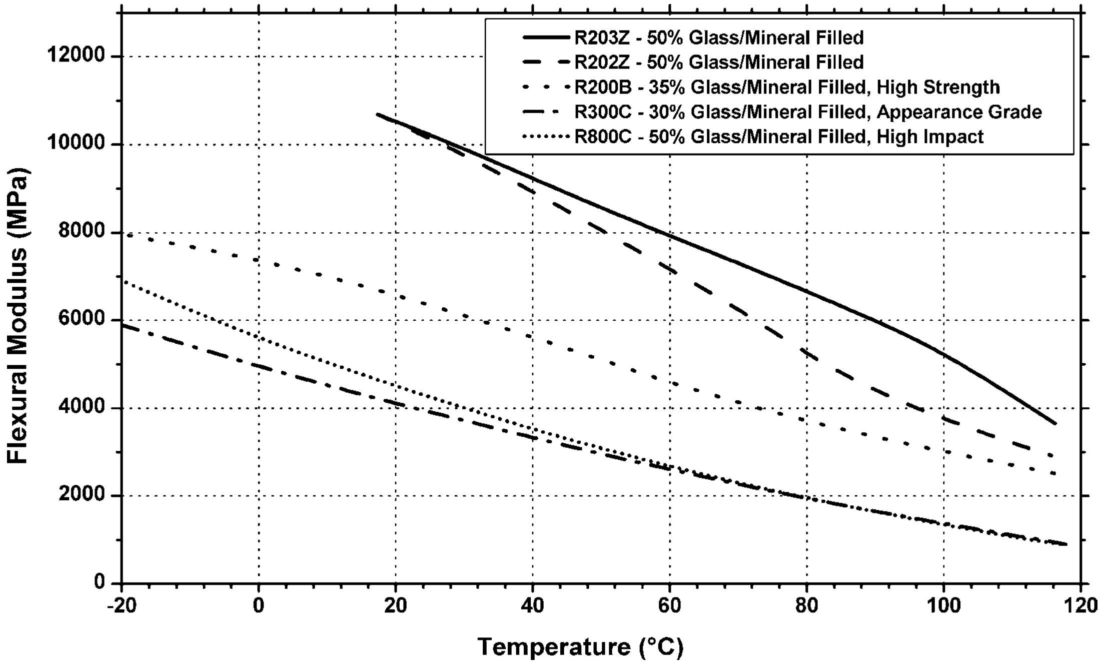


Figure 7.20. Flexural modulus vs. temperature of Chisso America Olehard®—glass and mineral filled PP resin.

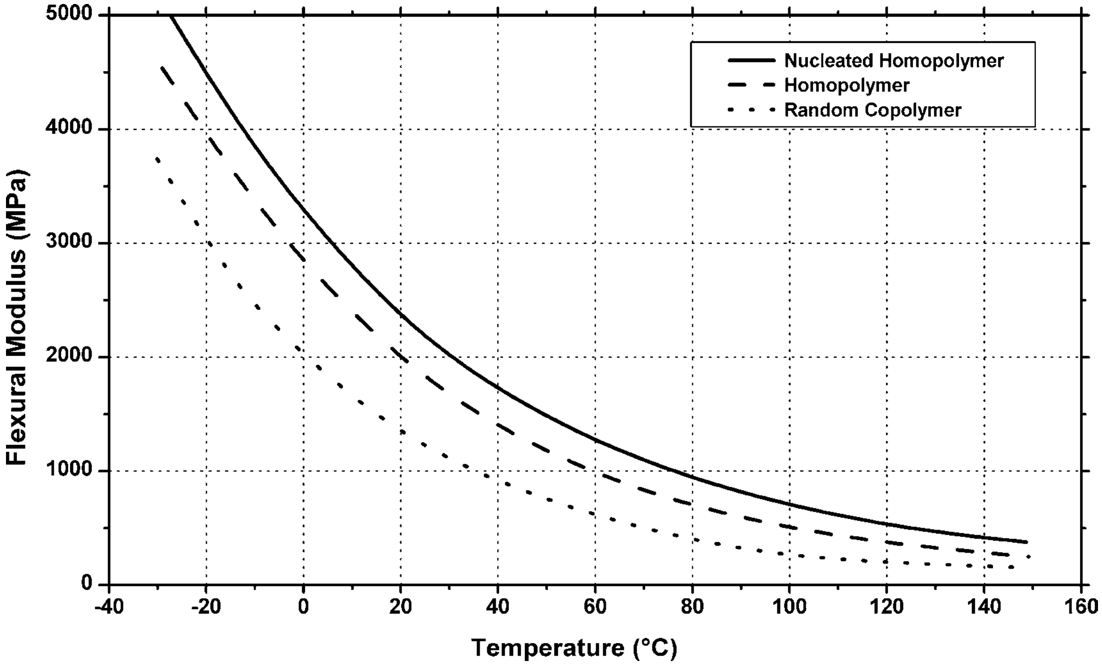


Figure 7.21. Flexural modulus vs. temperature of Chevron Phillips Chemical Marlex®—PP resin.

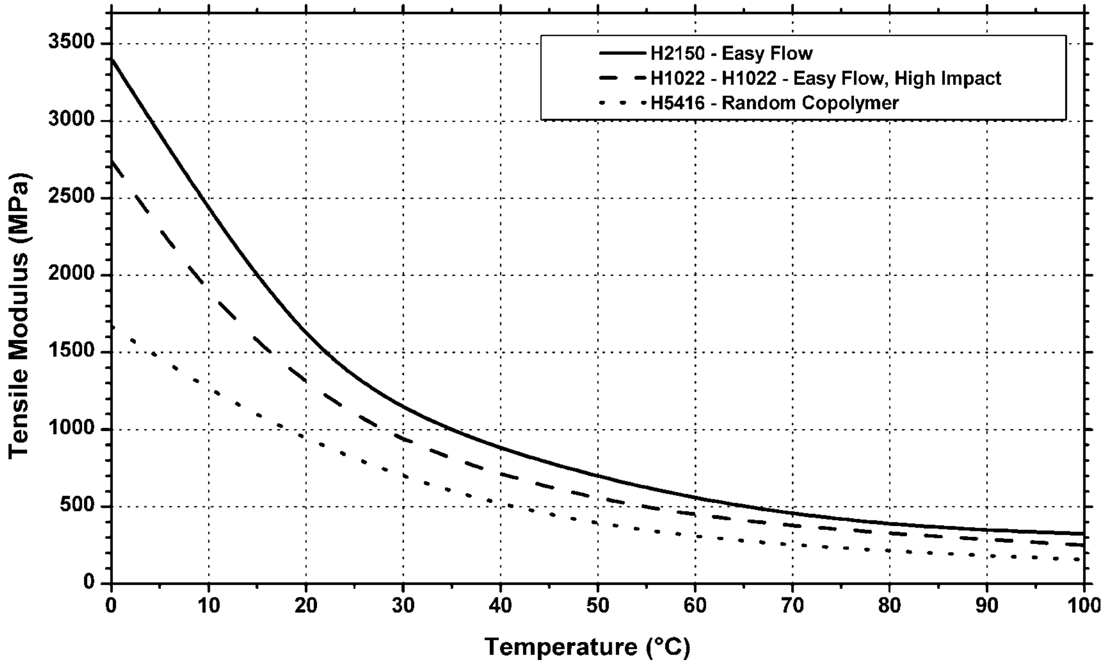


Figure 7.22. Tensile modulus vs. temperature of Basell Polyolefins Hostalen®—PP resin.

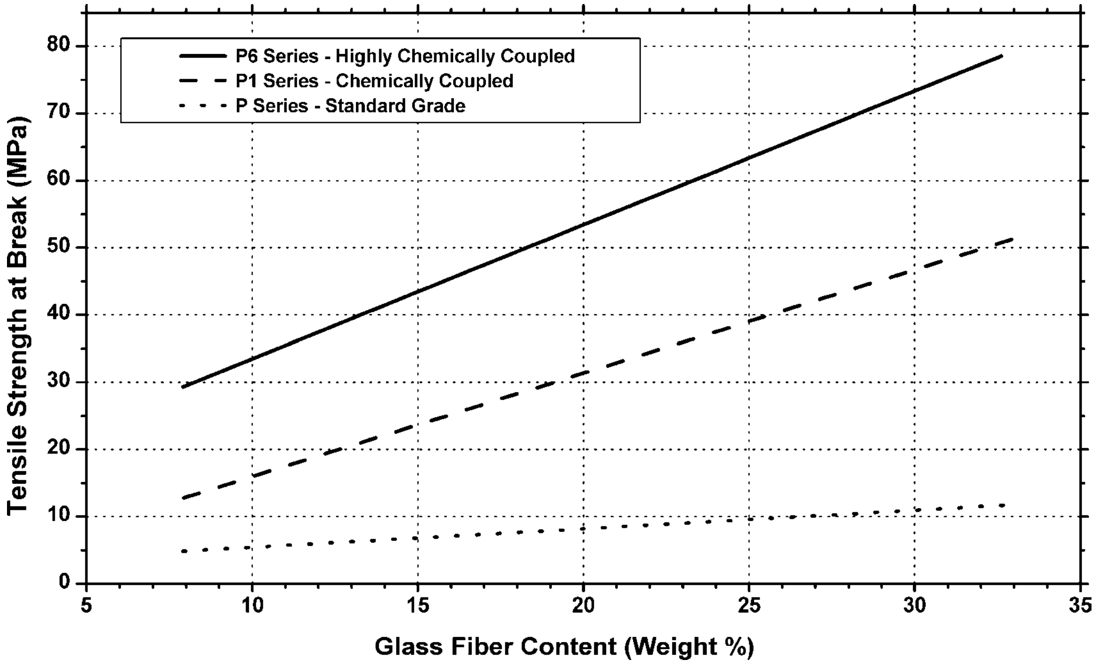


Figure 7.23. Tensile strength at break vs. glass fiber content at 23°C of Asahi Kasei Thermylene®—PP resins.

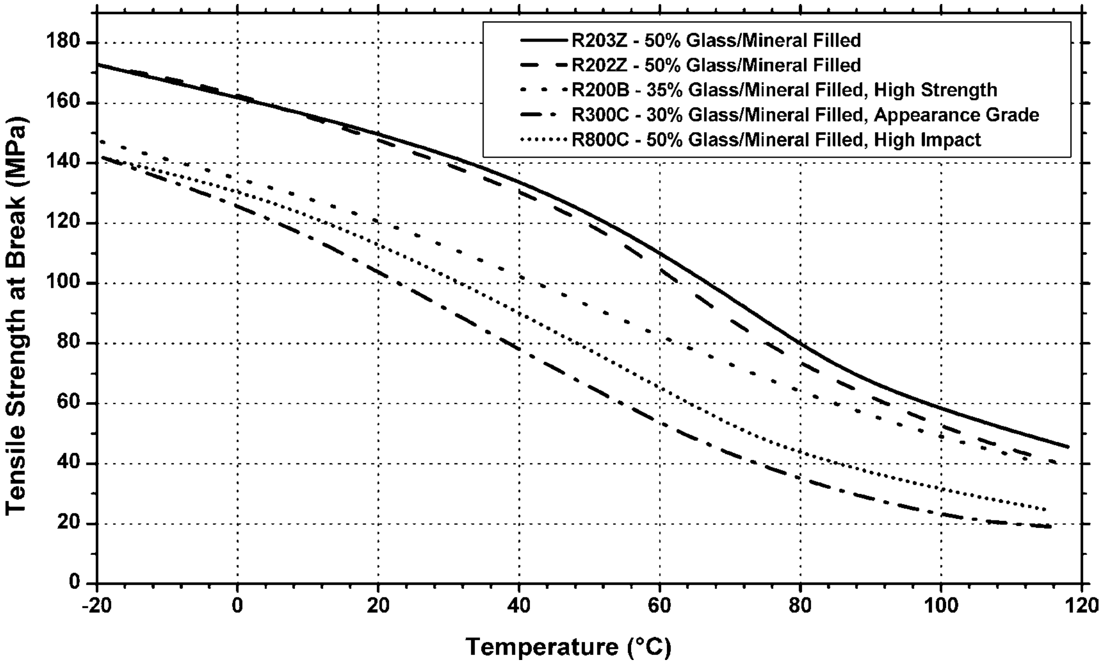


Figure 7.24. Tensile strength at break vs. temperature of Chisso America Olehard®—glass and mineral filled PP resin.

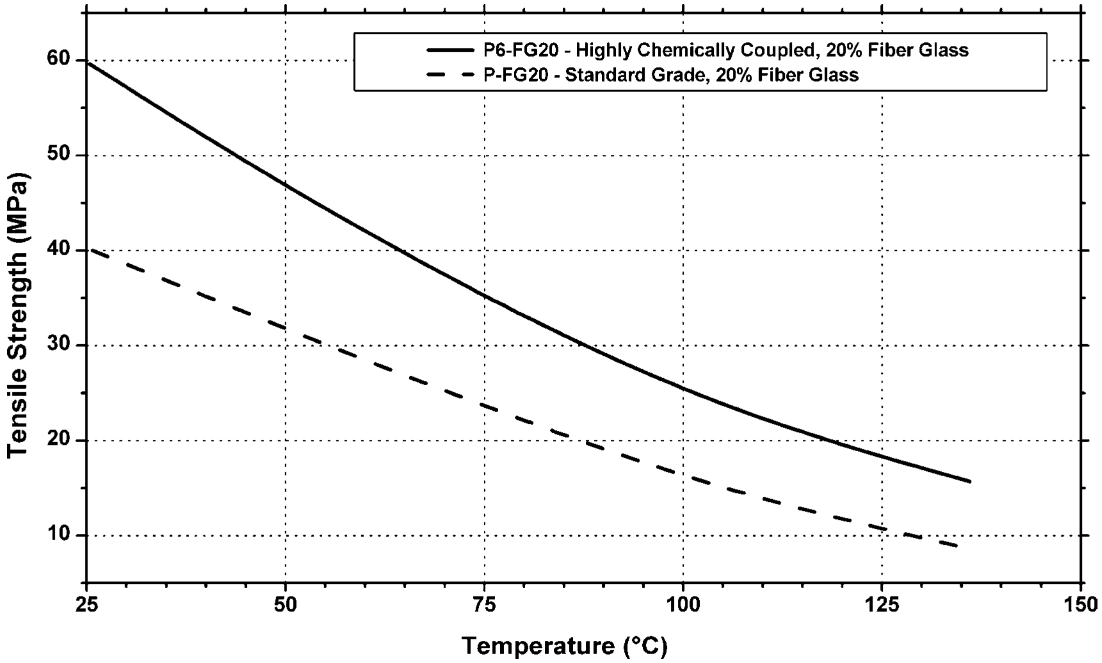


Figure 7.25. Tensile strength vs. temperature of Asahi Kasei Thermylene®—PP resins.

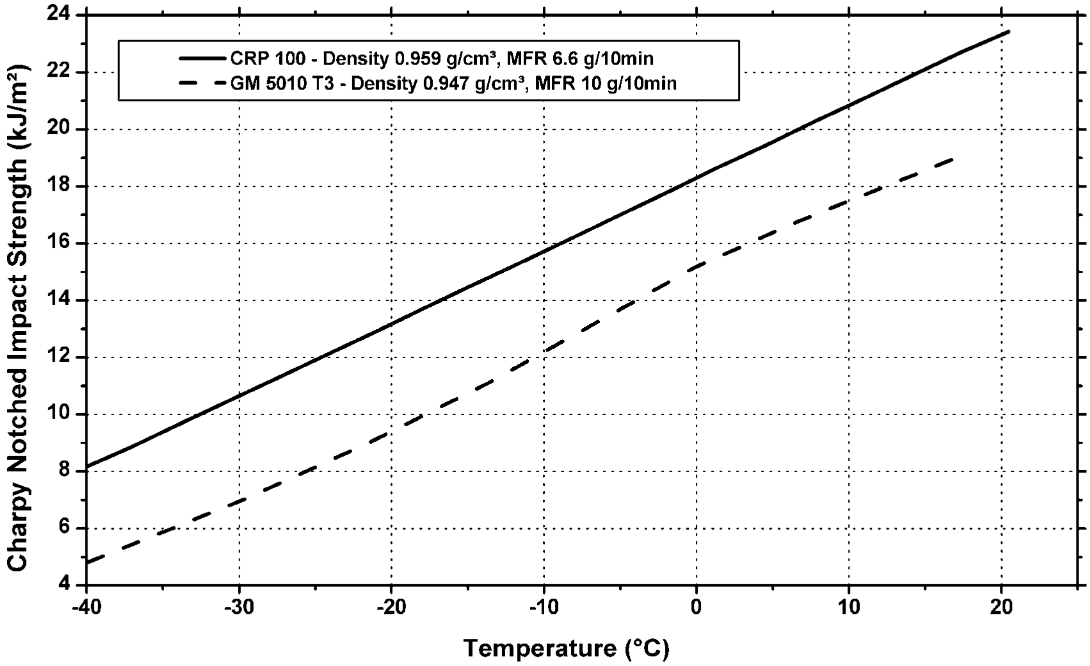


Figure 7.26. Notched charpy impact strength vs. temperature of Basell Polyolefins Hostalen®—PP resins.

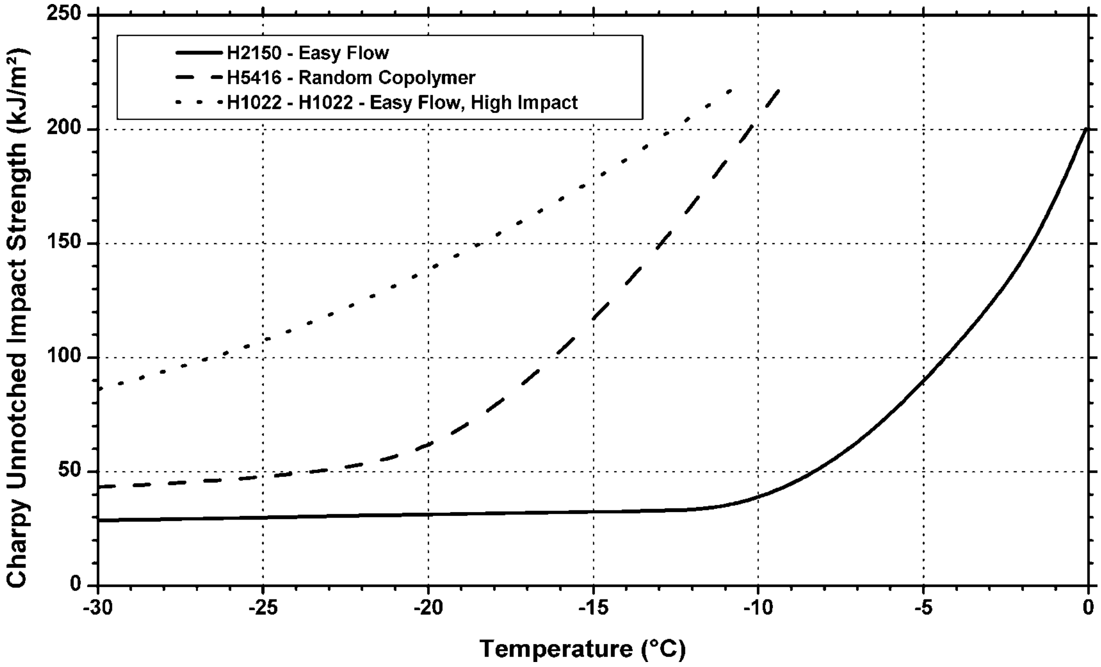


Figure 7.27. Notched charpy impact strength vs. temperature of easy flow Basell Polyolefins Hostalen®—PP resins.

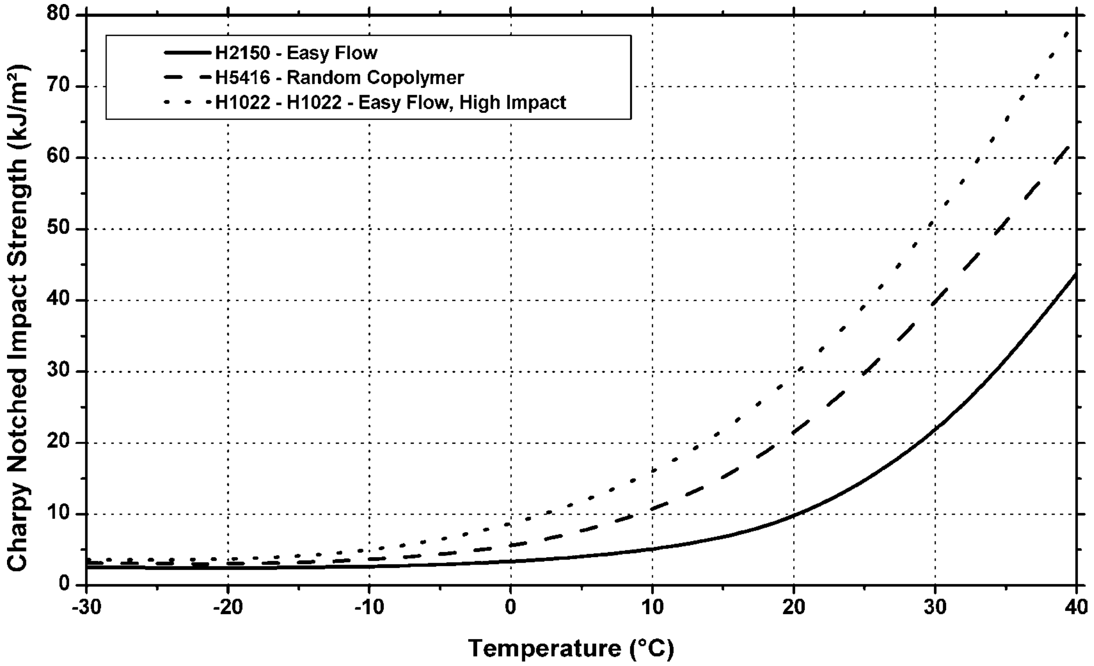


Figure 7.28. Notched charpy impact strength vs. temperature of additional Basell Polyolefins Hostalen®—PP resins.

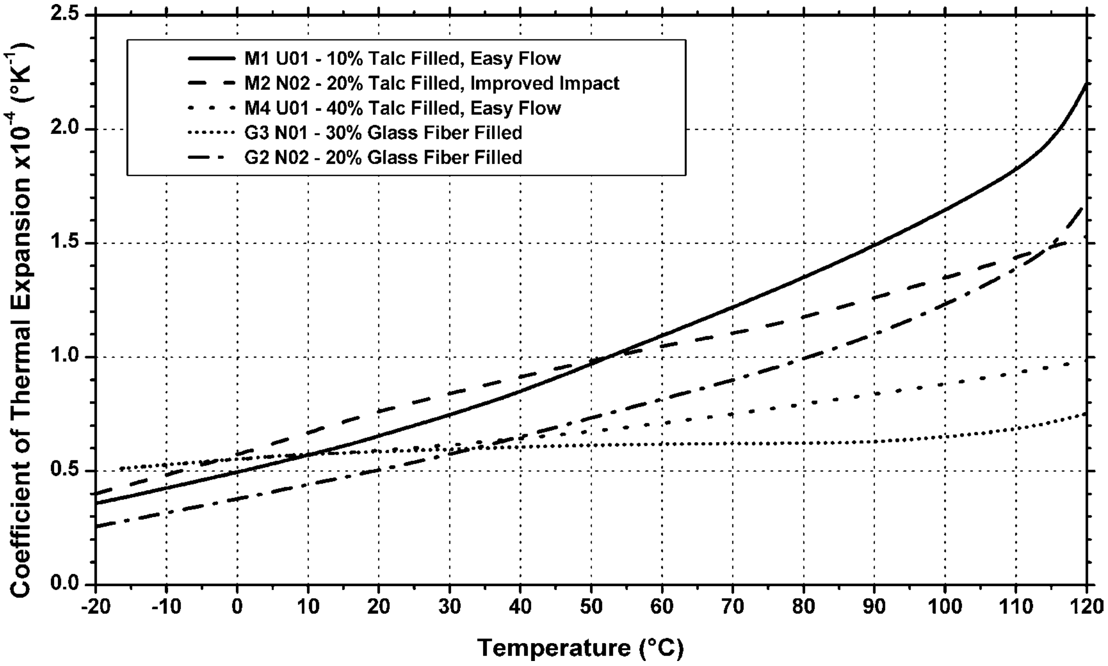


Figure 7.29. Coefficient of thermal expansion (in flow direction) vs. temperature of Basell Polyolefins Hostalen®—PP resins.

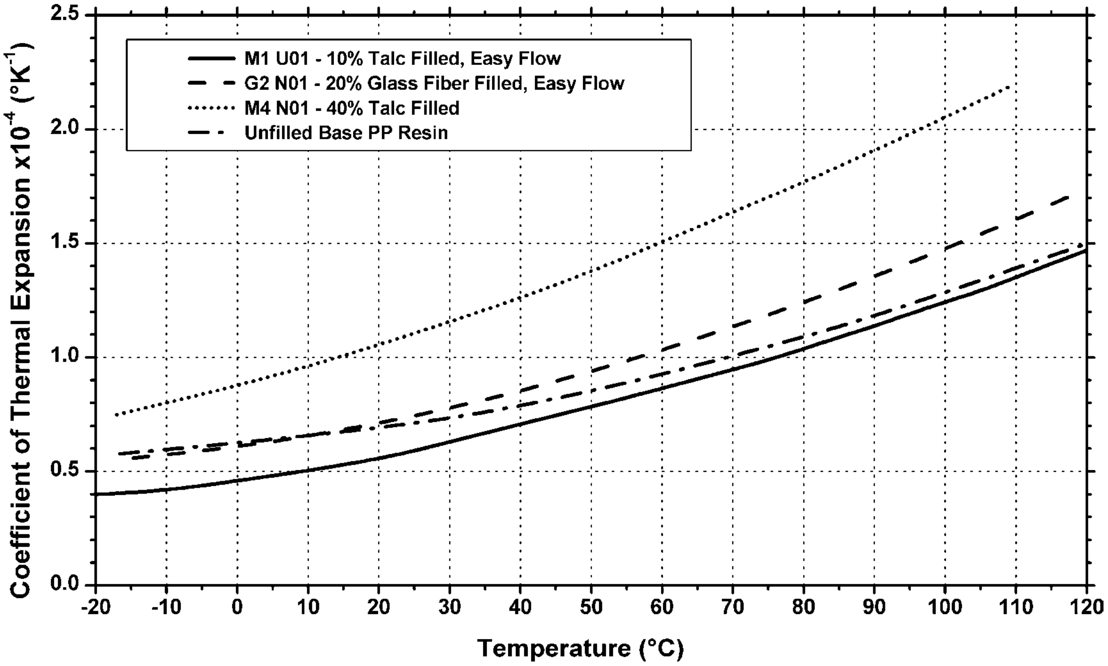


Figure 7.30. Coefficient of thermal expansion (in flow direction) vs. temperature of Basell Polyolefins Hostalen®—PP resins.

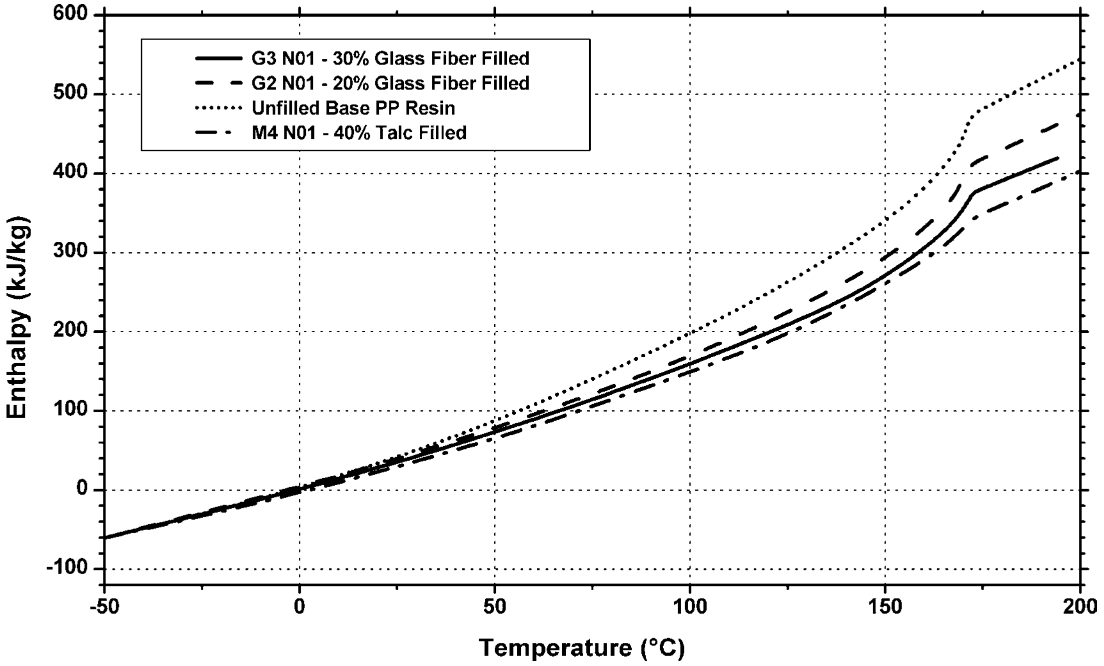


Figure 7.31. Enthalpy vs. temperature of Basell Polyolefins Hostalen®—PP resins.

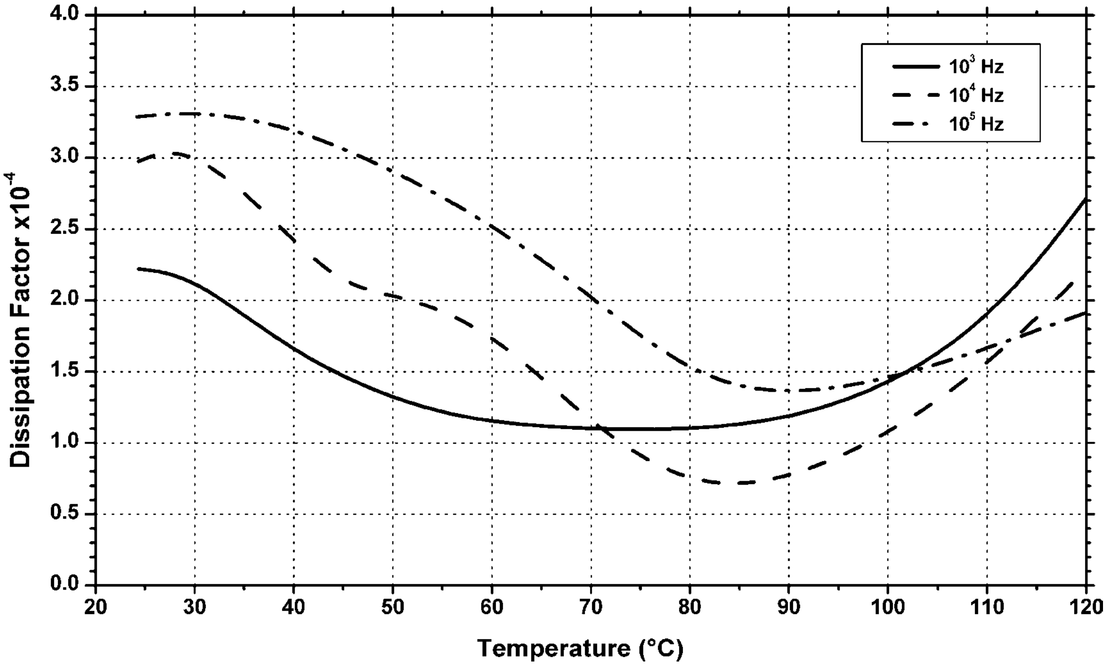


Figure 7.32. Dissipation factor vs. temperature and frequency of Basell Polyolefins Hostalen® PPN 1060 F—PP resins.

7.4 Polymethylpentene (PMP)

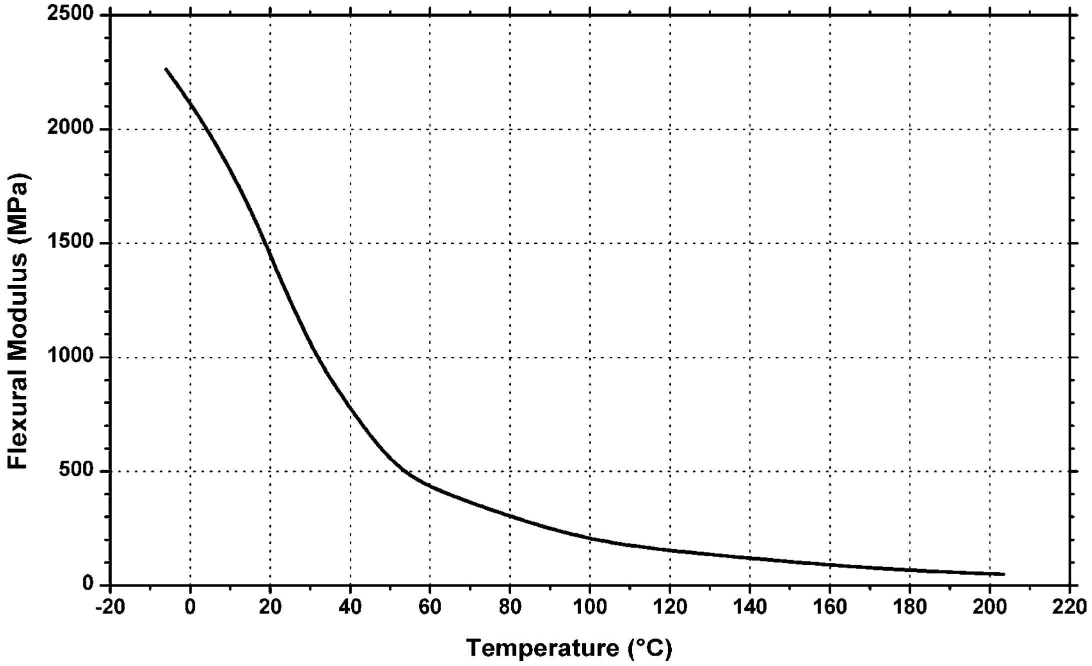


Figure 7.33. Flexural modulus vs. temperature of Mitsui Chemicals TPX™ RT18—general purpose, unfilled PMP resin.

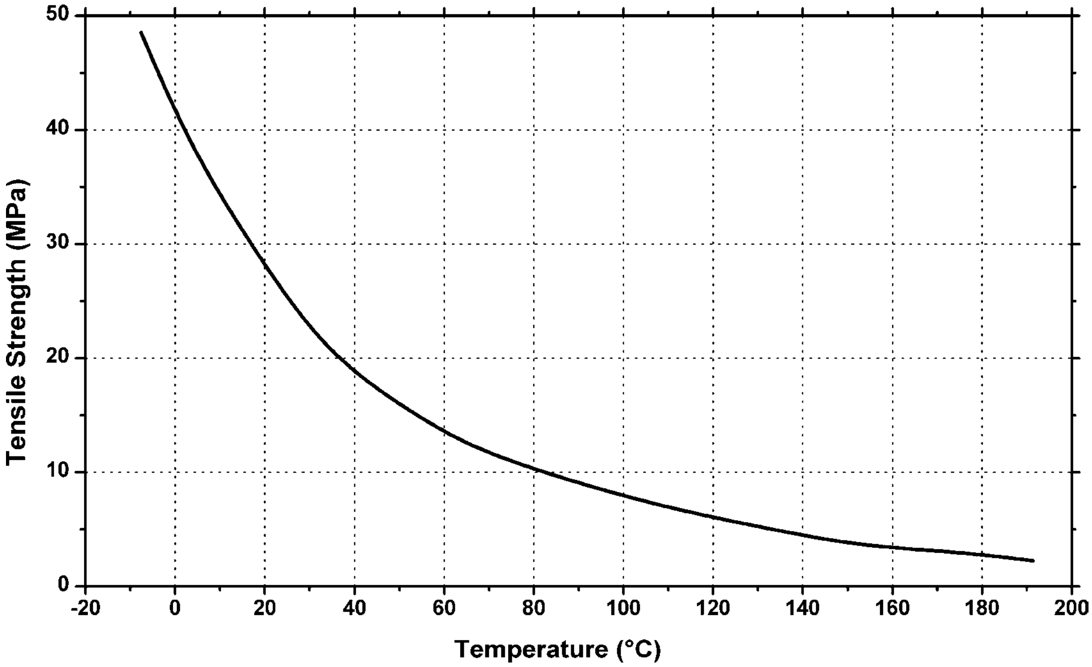


Figure 7.34. Tensile strength vs. temperature of Mitsui Chemicals TPX™ RT18—general purpose, unfilled PMP resin.

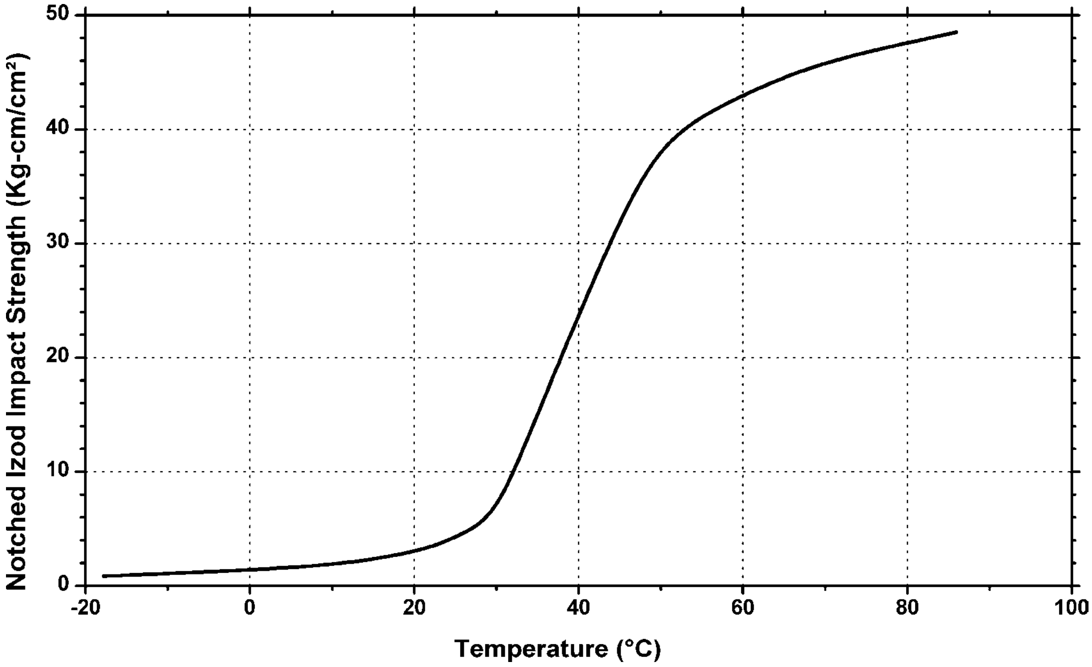


Figure 7.35. Notched Izod impact strength vs. temperature of Mitsui Chemicals TPX™ RT18—general purpose, unfilled PMP resin.

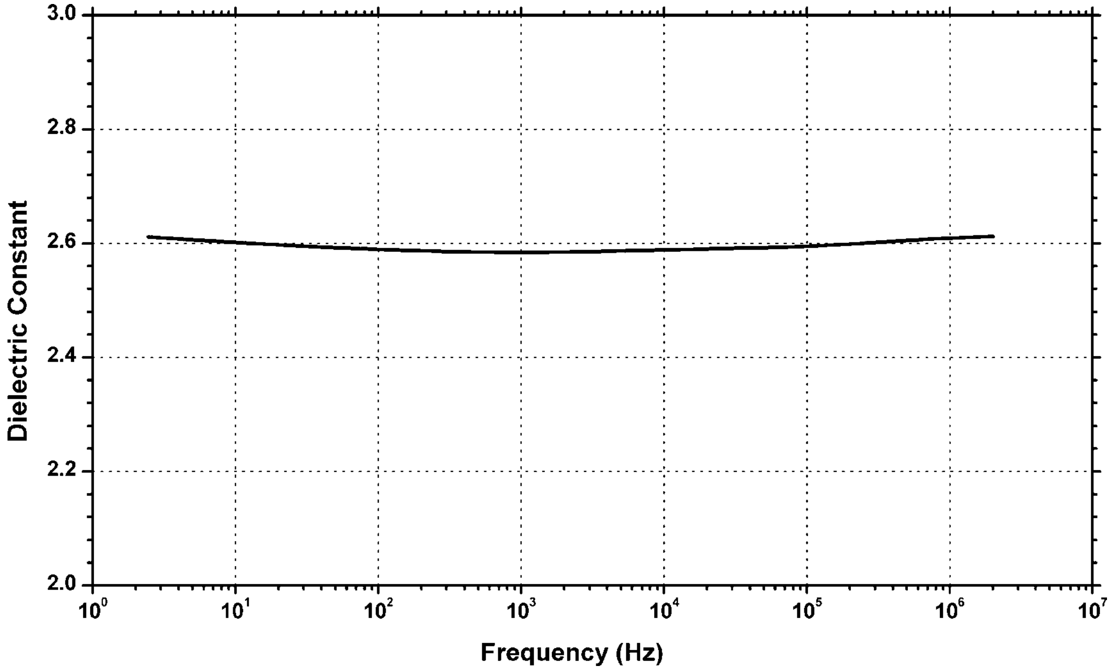


Figure 7.36. Dielectric constant vs. frequency at 20°C of Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

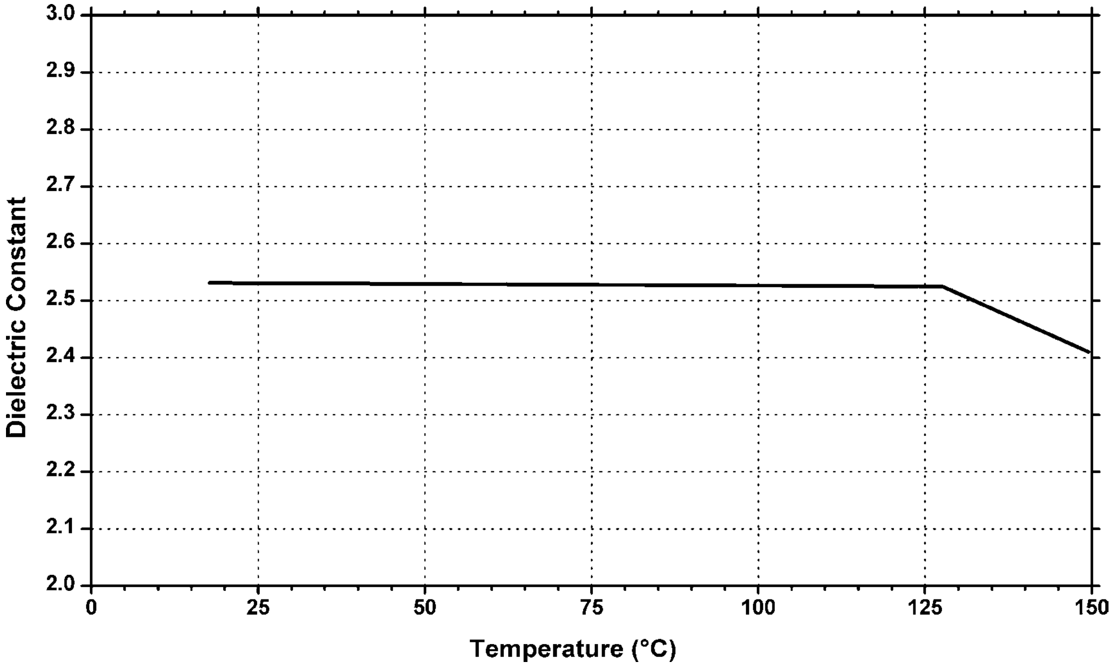


Figure 7.37. Dielectric constant at 1 MHz vs. temperature of Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

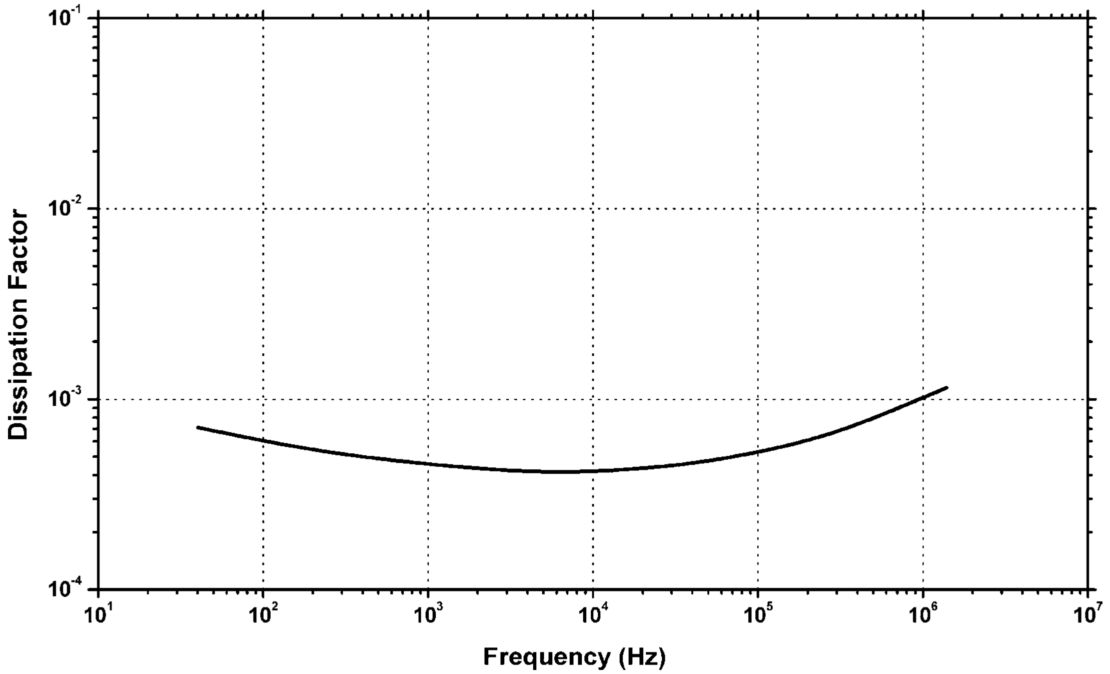


Figure 7.38. Dissipation factor vs. frequency at 20°C of Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

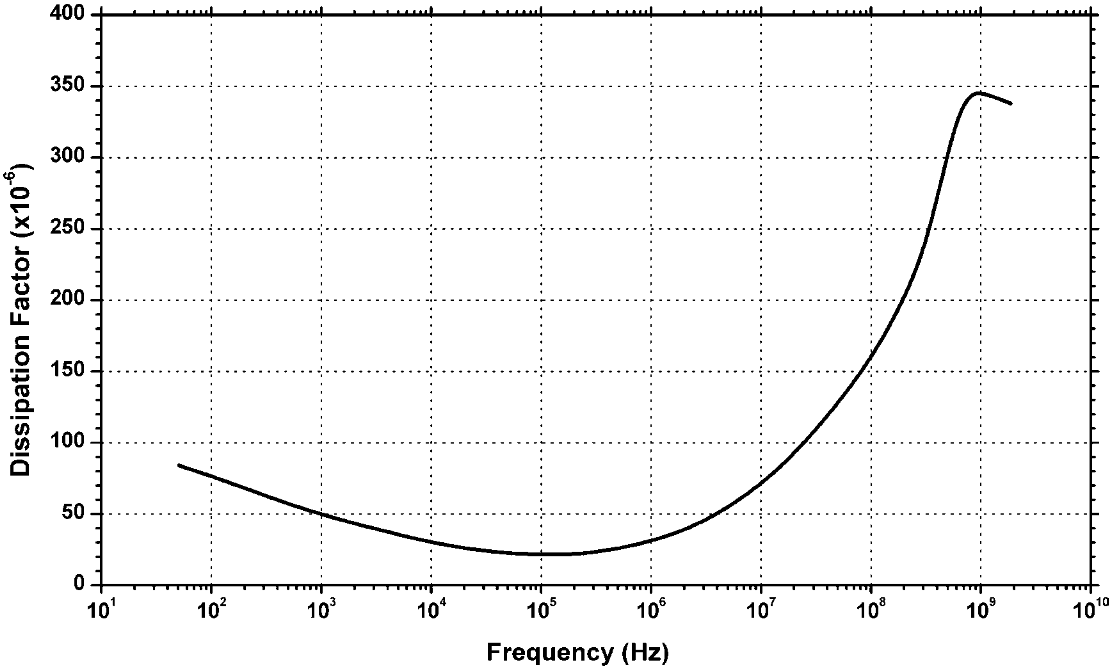


Figure 7.39. Dissipation factor vs. frequency of Mitsui Chemicals TPX™ RT18—general purpose, unfilled PMP resin.

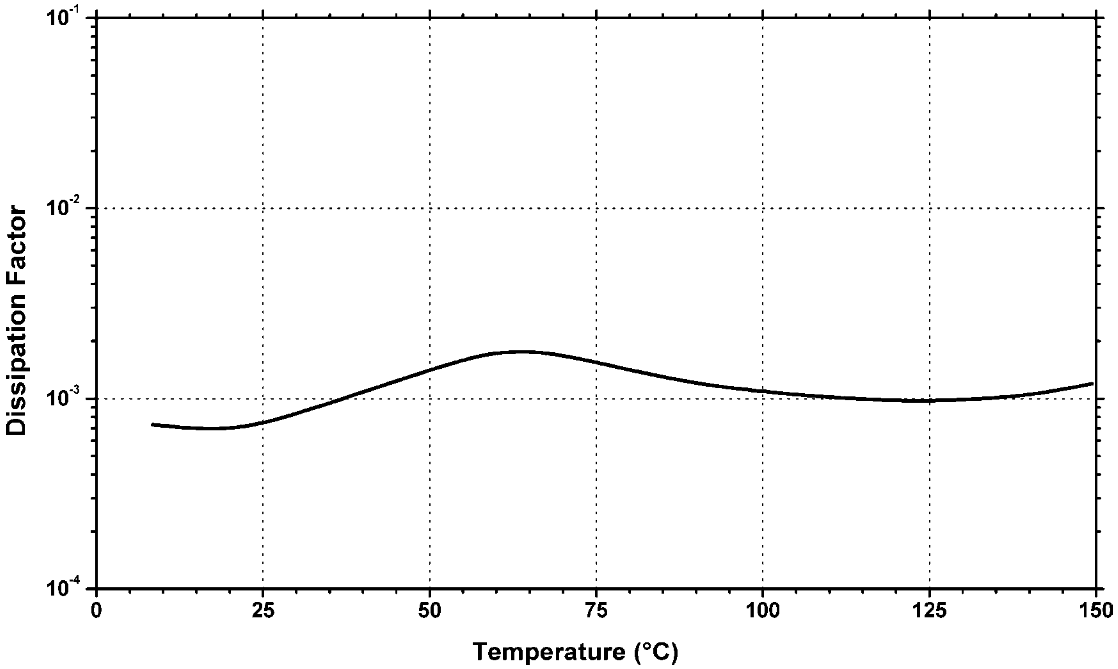


Figure 7.40. Dissipation factor vs. temperature at 1 MHz of Mitsui Chemicals FR-TPX™ T130—30% chopped glass filled PMP resin.

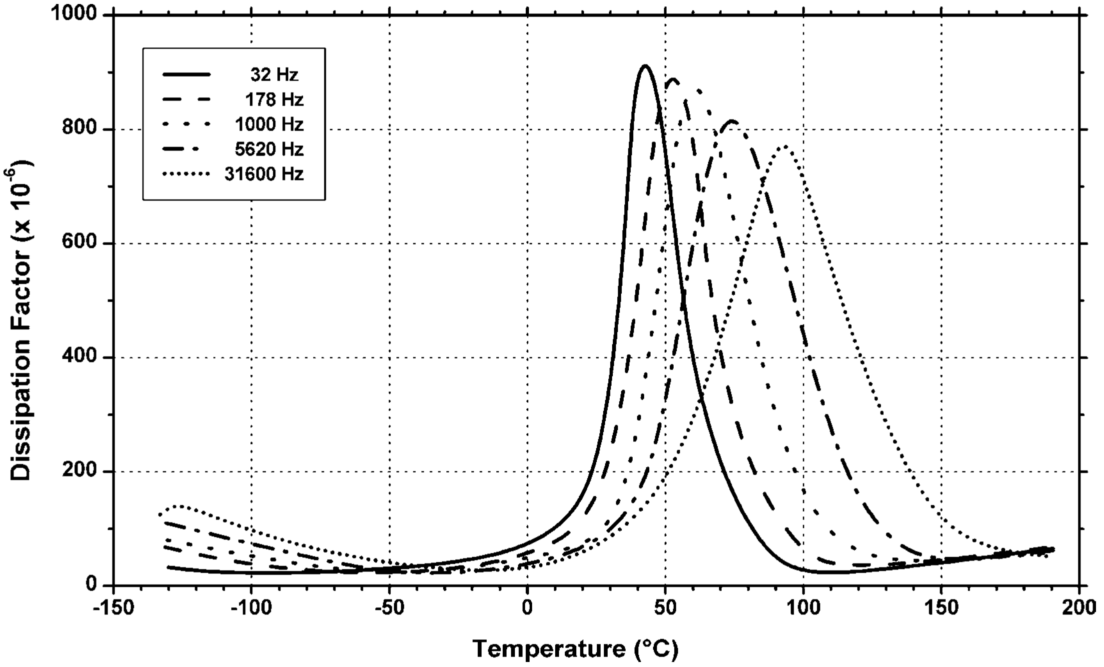


Figure 7.41. Dissipation factor vs. temperature and frequency of Mitsui Chemicals TPX™ RT18—general purpose, unfilled PMP resin.

7.5 Ultra High Molecular Weight Polyethylene (UHMWPE)

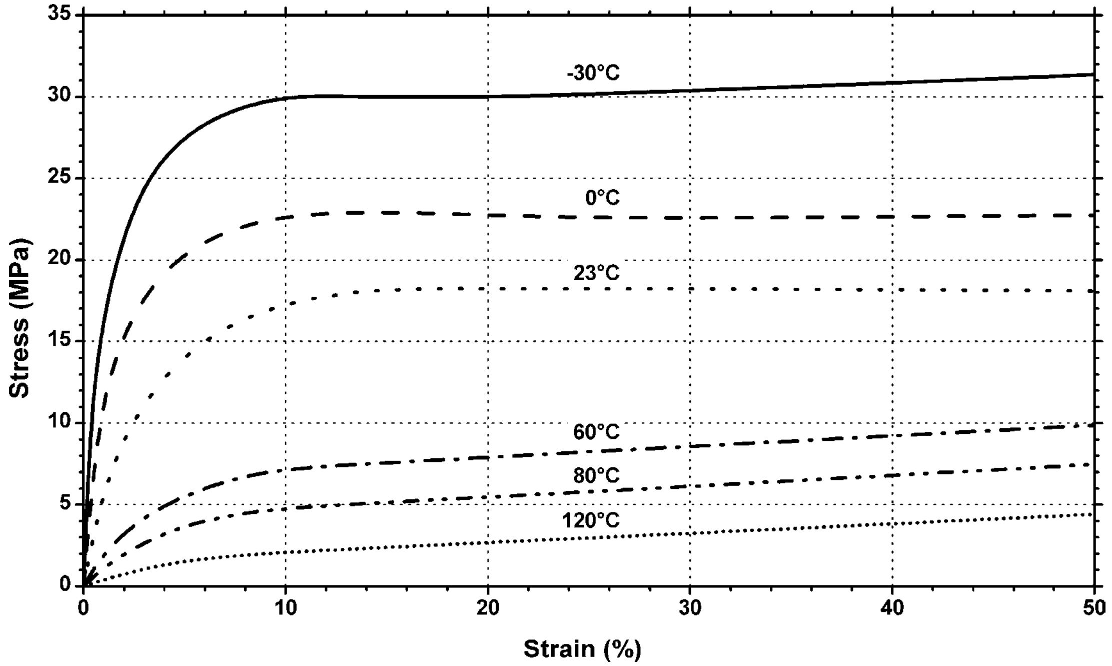


Figure 7.42. Stress vs. strain at various temperatures of Ticona GUR® 4120—high bulk density, corrosion stabilized UHMWPE resin.

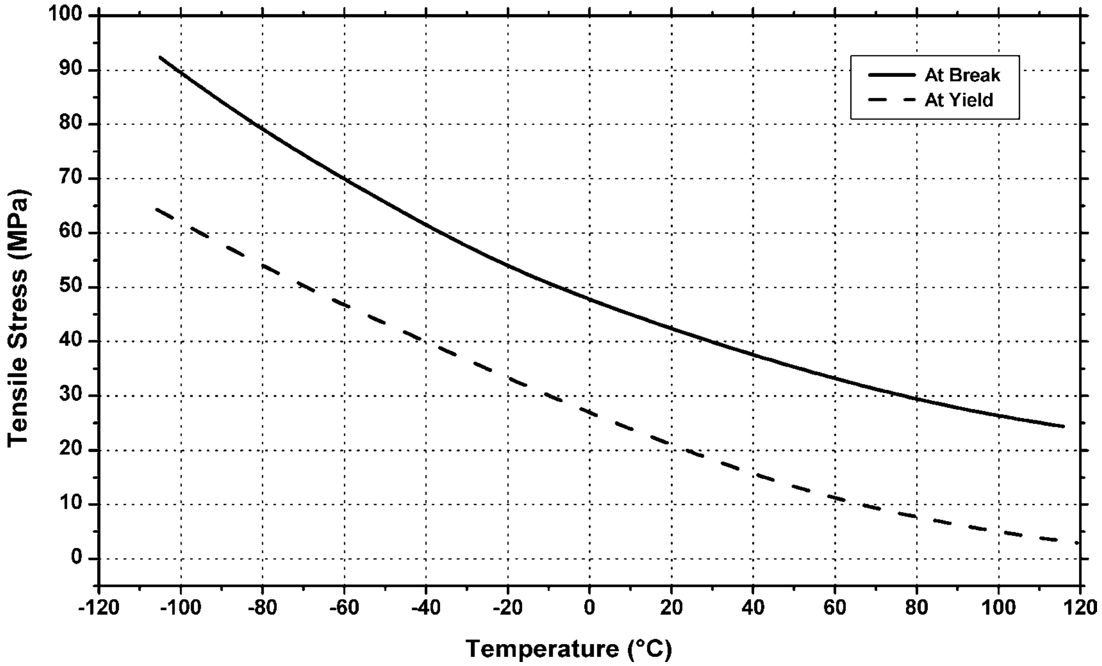


Figure 7.43. Tensile strength vs. temperature of Ticona—UHMWPE resin.

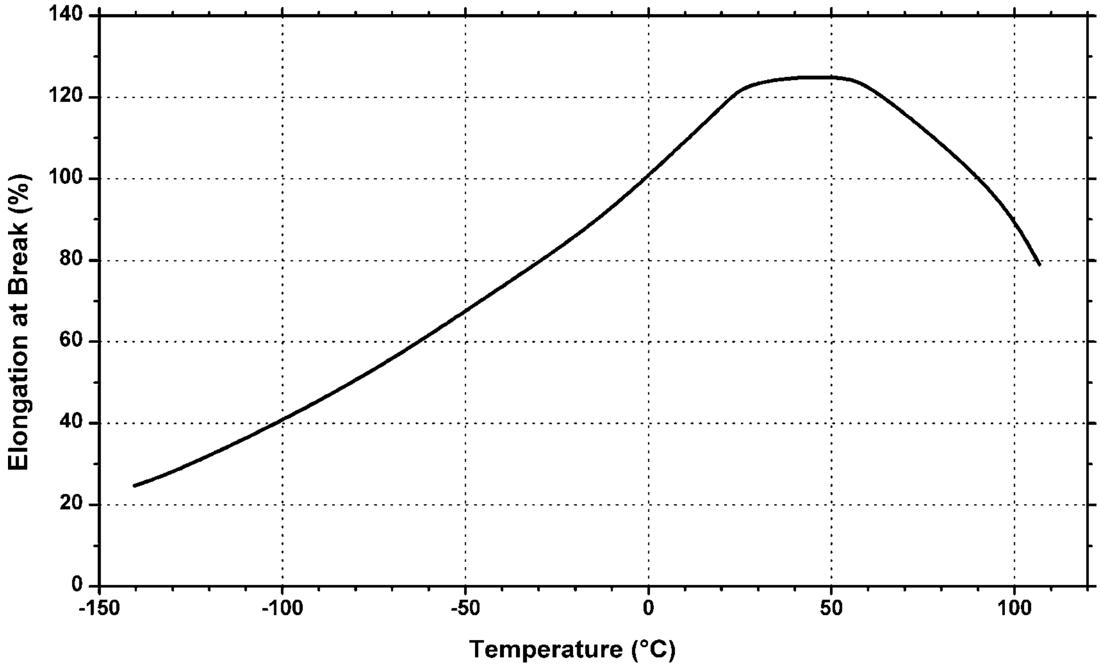


Figure 7.44. Elongation at break vs. temperature of Ticona—UHMWPE resin.

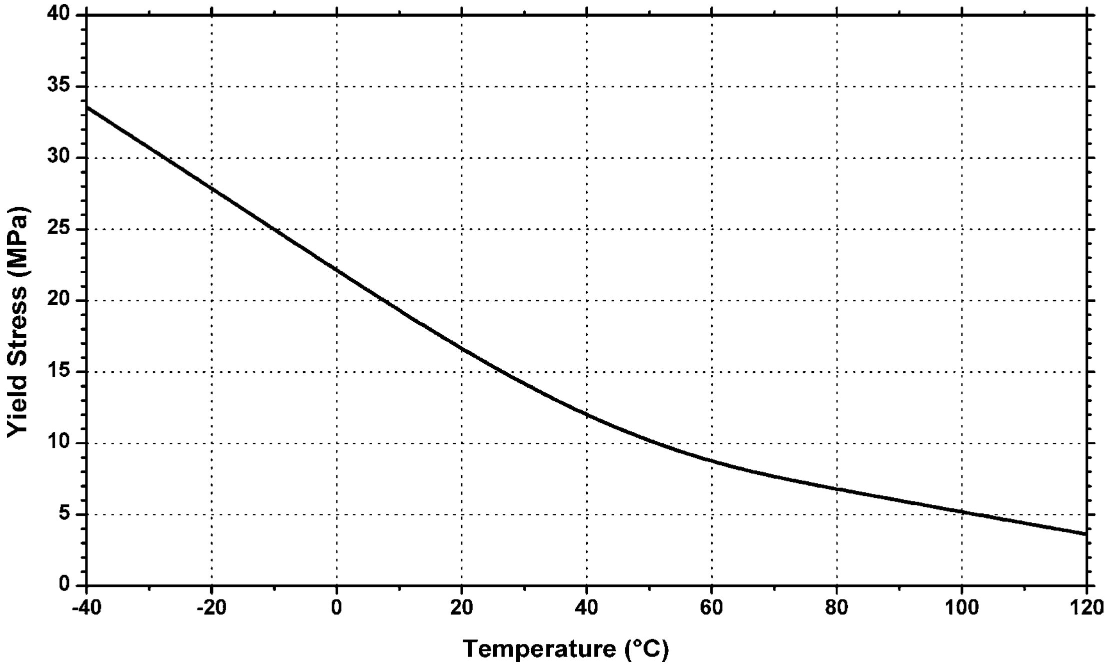


Figure 7.45. Yield stress vs. temperature of Ticona GUR® 4120—high bulk density, corrosion stabilized UHMWPE resin.

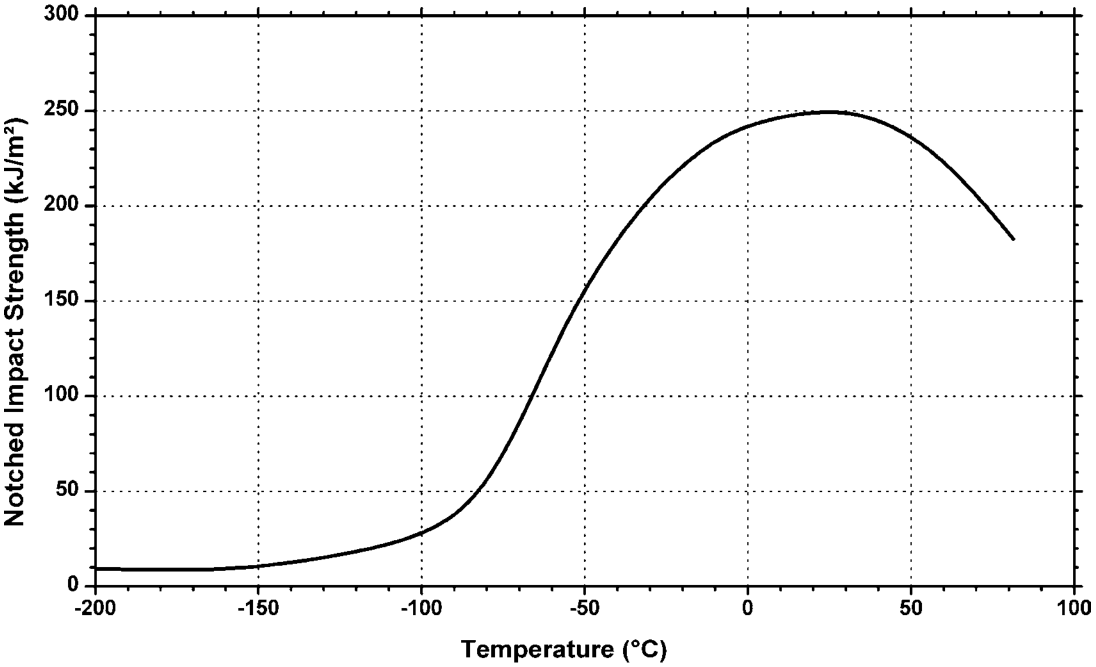


Figure 7.46. Notched charpy impact strength vs. temperature of Ticona GUR® 4120—high bulk density, corrosion stabilized UHMWPE resin.

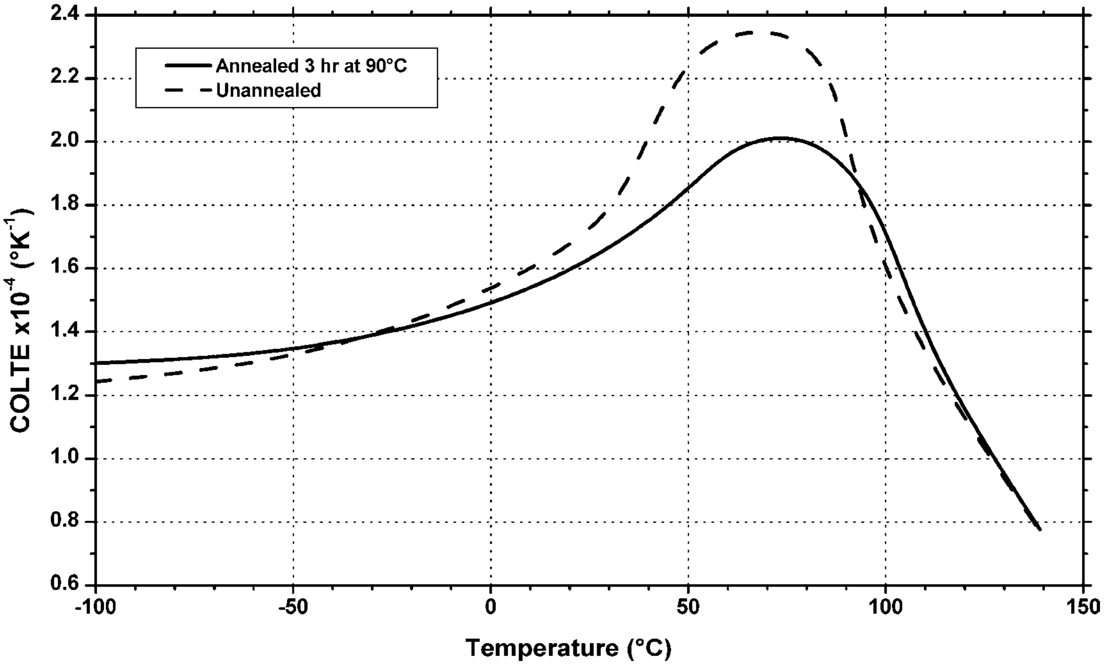


Figure 7.47. Coefficient of linear thermal expansion vs. temperature of Ticona GUR® 4120—high bulk density, corrosion stabilized UHMWPE resin.

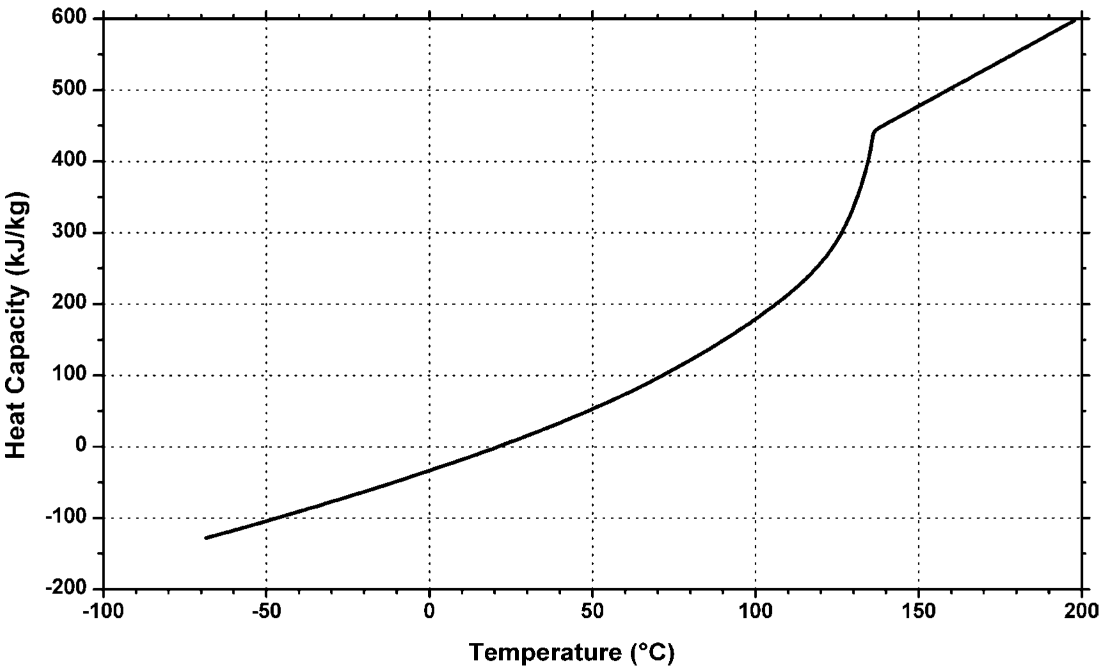


Figure 7.48. Heat capacity (enthalpy) vs. temperature of Ticona GUR®—UHMWPE resin.

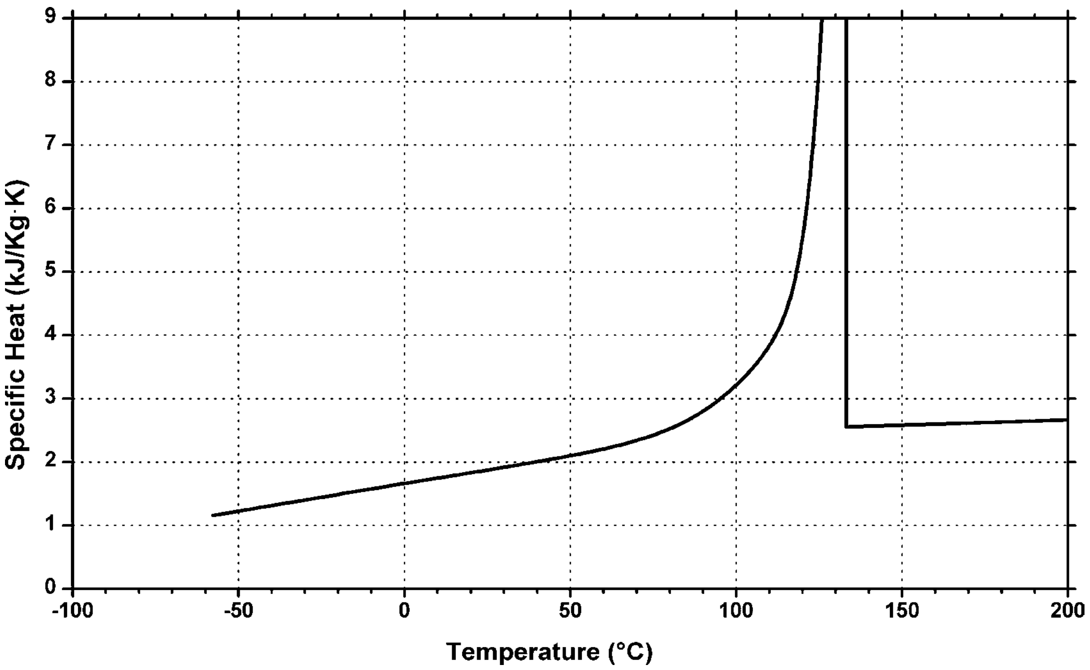


Figure 7.49. Specific heat vs. temperature of Ticona GUR®—UHMWPE resin.

7.6 Rigid Polyvinyl-Chloride (PVC)

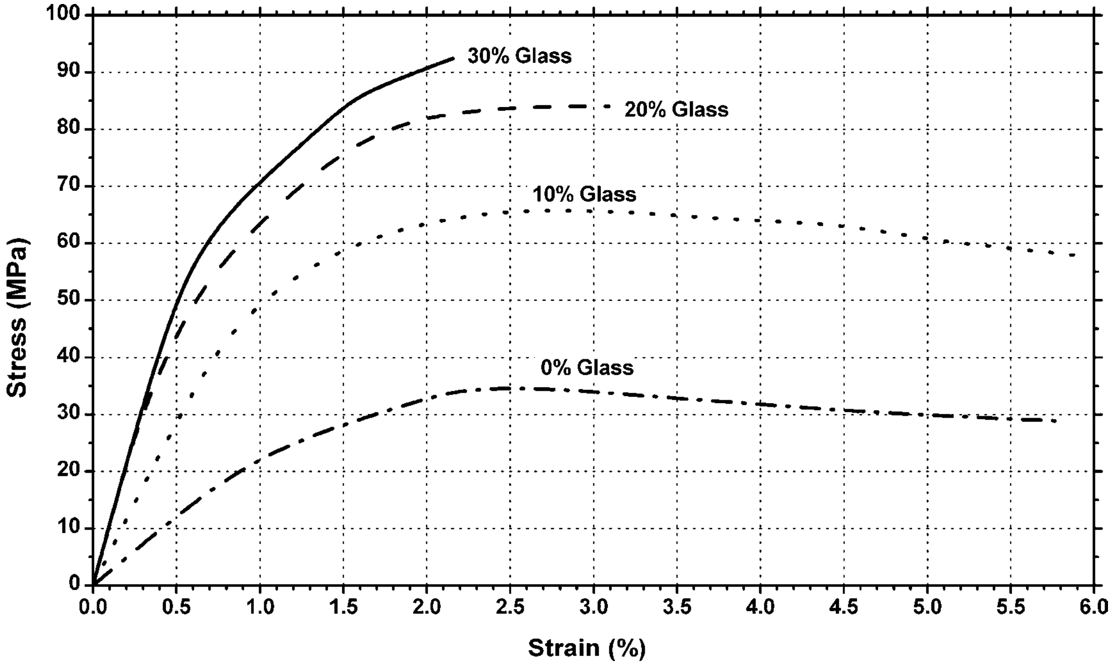


Figure 7.50. Stress vs. strain at 23°C of PolyOne Fiberloc™—rigid PVC resins with different amounts of glass fiber reinforcement.

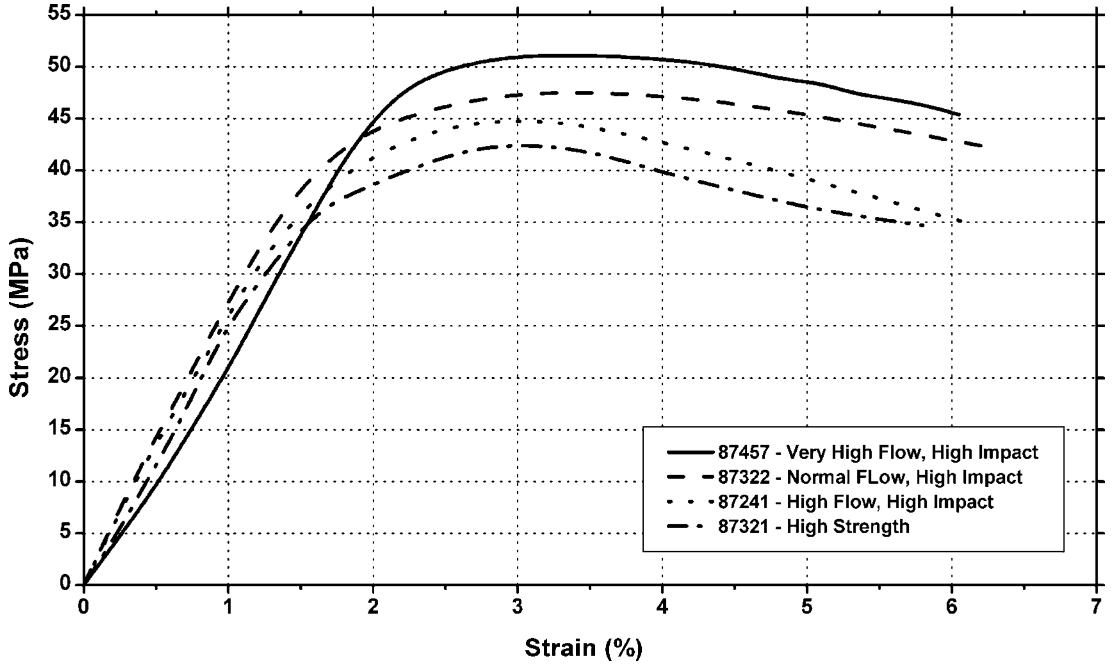


Figure 7.51. Stress vs. strain at 23°C of Various PolyOne Geon® rigid PVC resins.

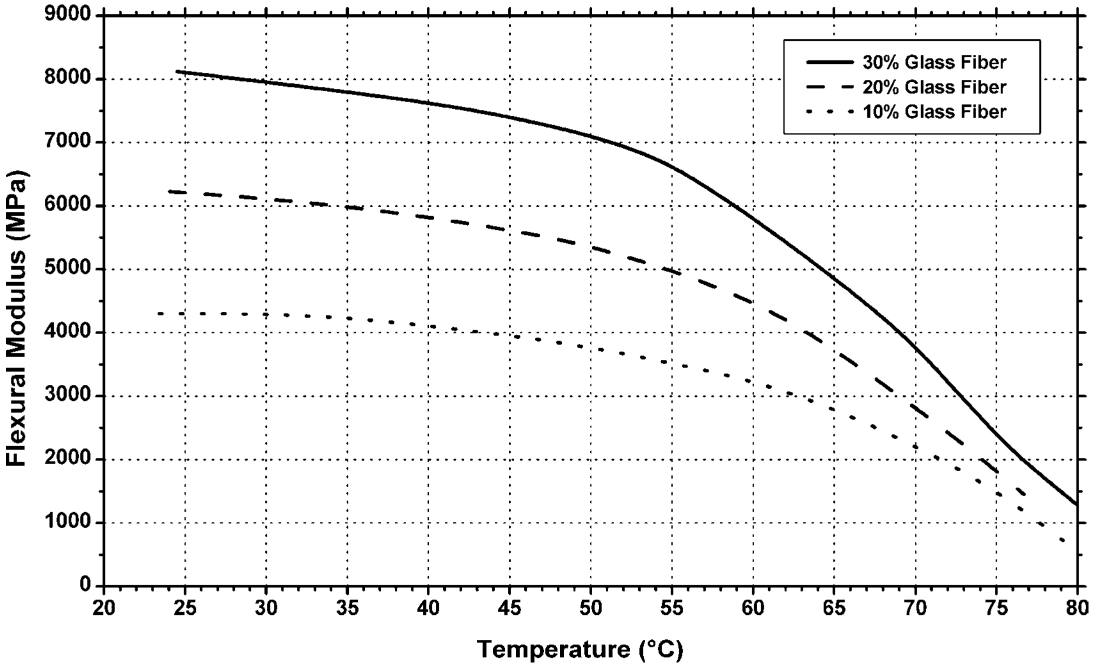


Figure 7.52. Flexural modulus vs. temperature of PolyOne Fiberloc™—Rigid PVC resins with different amounts of glass fiber reinforcement.

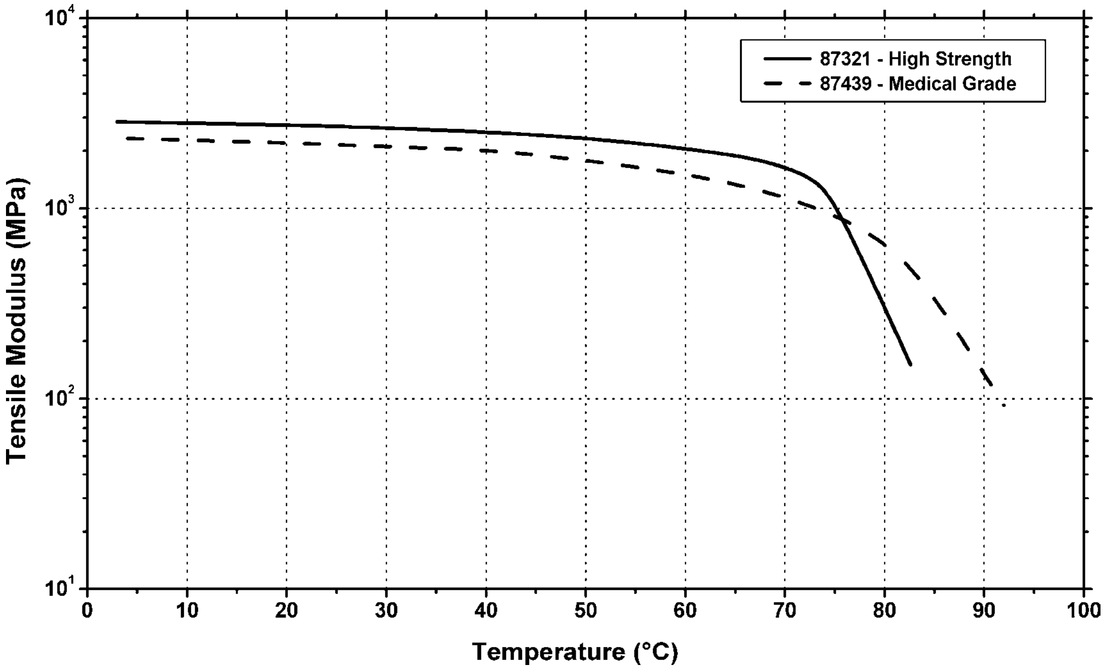


Figure 7.53. Tensile modulus vs. temperature of two PolyOne Geon® rigid PVC resins[j5].

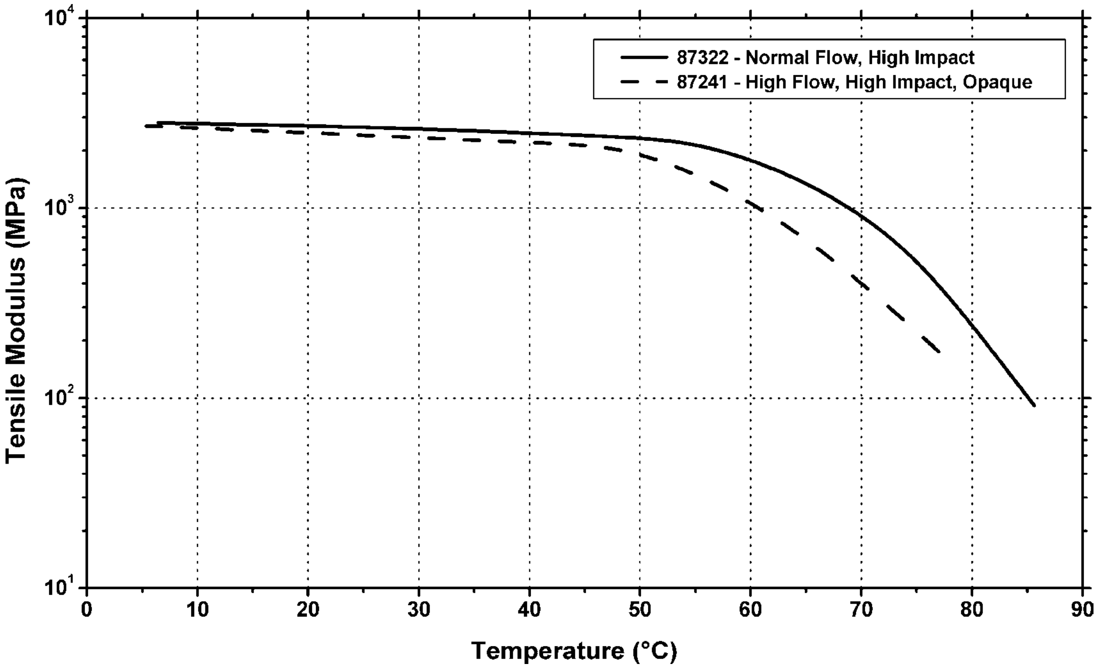


Figure 7.54. Tensile modulus vs. temperature of two additional PolyOne Geon® rigid PVC resins.

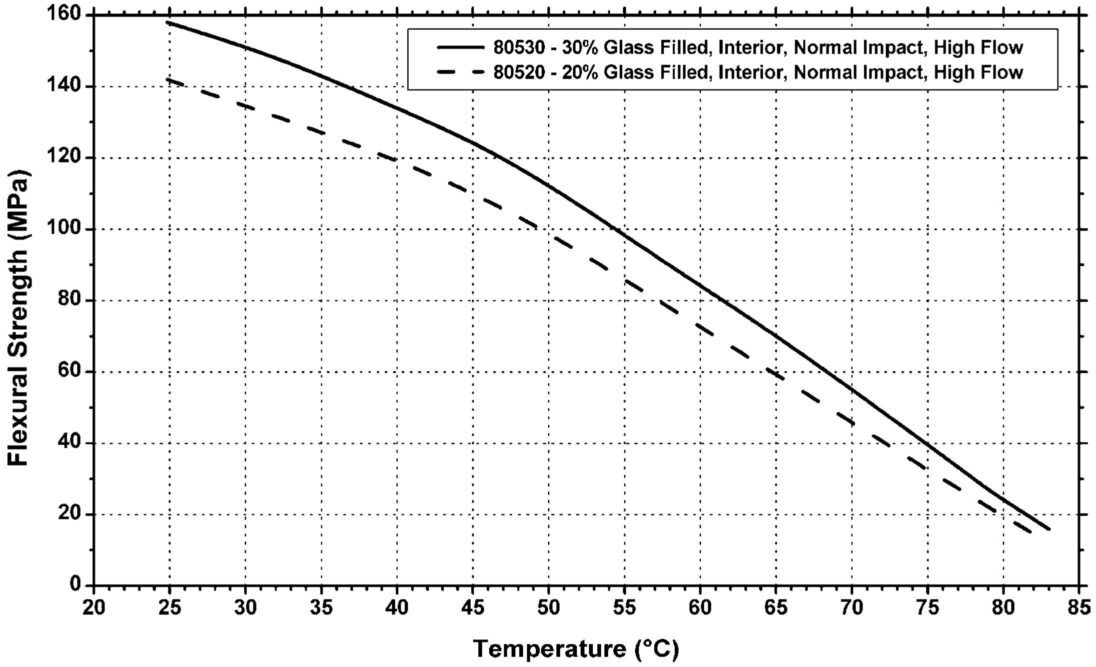


Figure 7.55. Flexural strength vs. temperature of PolyOne Fiberloc™—rigid PVC resins with different amounts of glass fiber reinforcement.

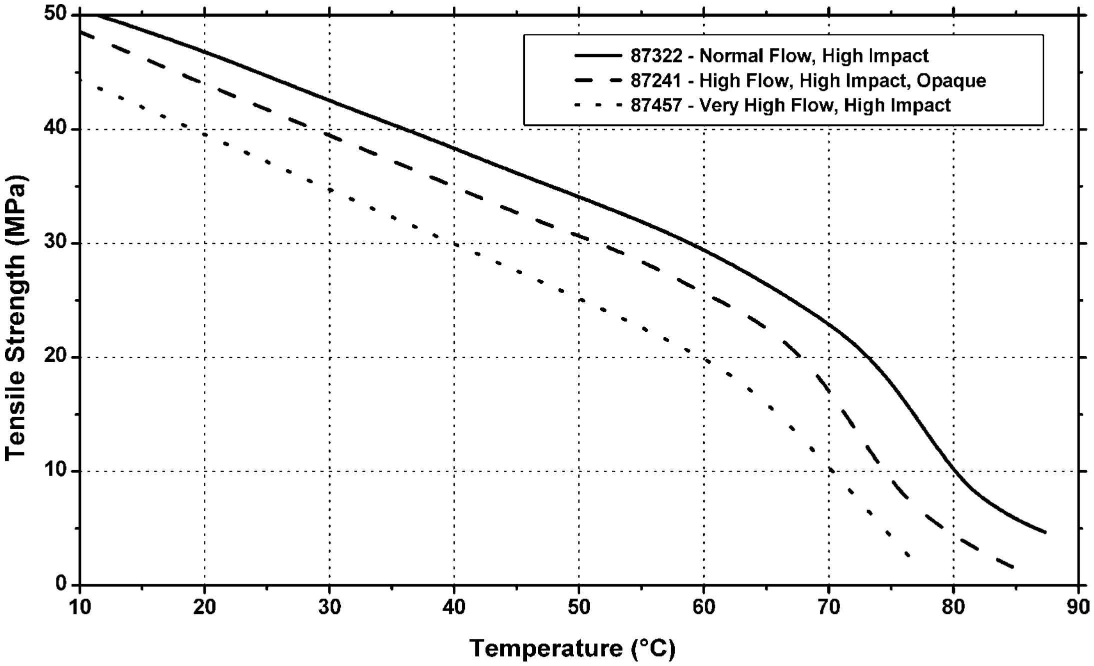


Figure 7.56. Tensile strength vs. temperature of two PolyOne Geon® rigid PVC resins.

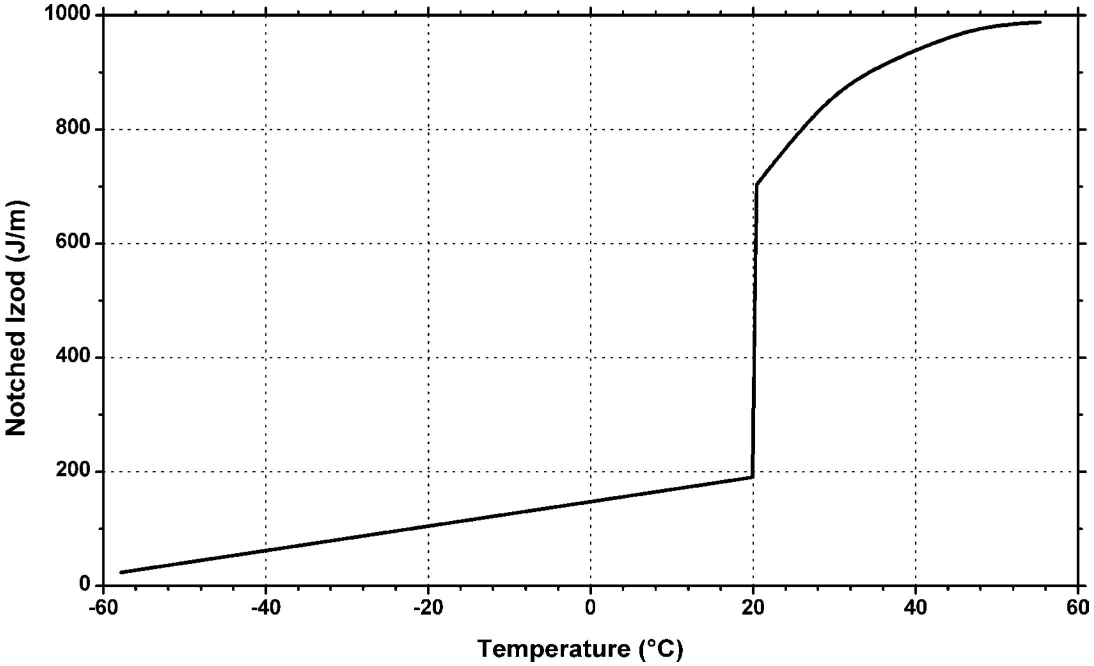


Figure 7.57. Notched Izod strength vs. temperature of PolyOne Geon® 87241—high flow, high impact, opaque rigid PVC resin.

7.7 Cyclic-Olefin-Copolymer (COC)

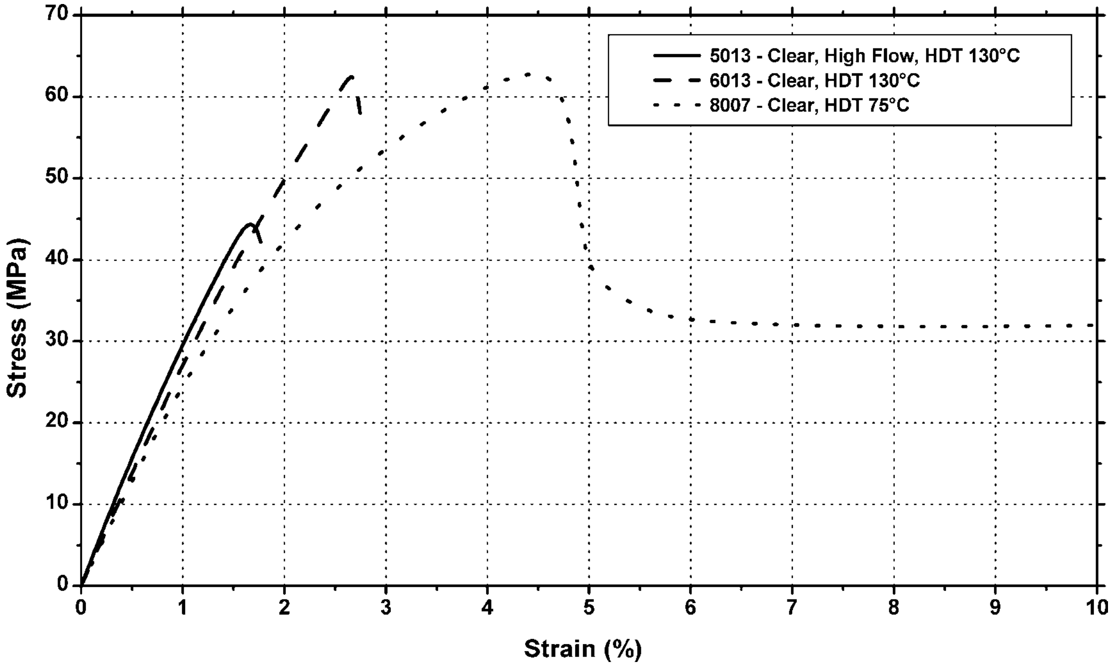


Figure 7.58. Stress vs. strain at 23°C of several Ticona Topas®—COC resins.

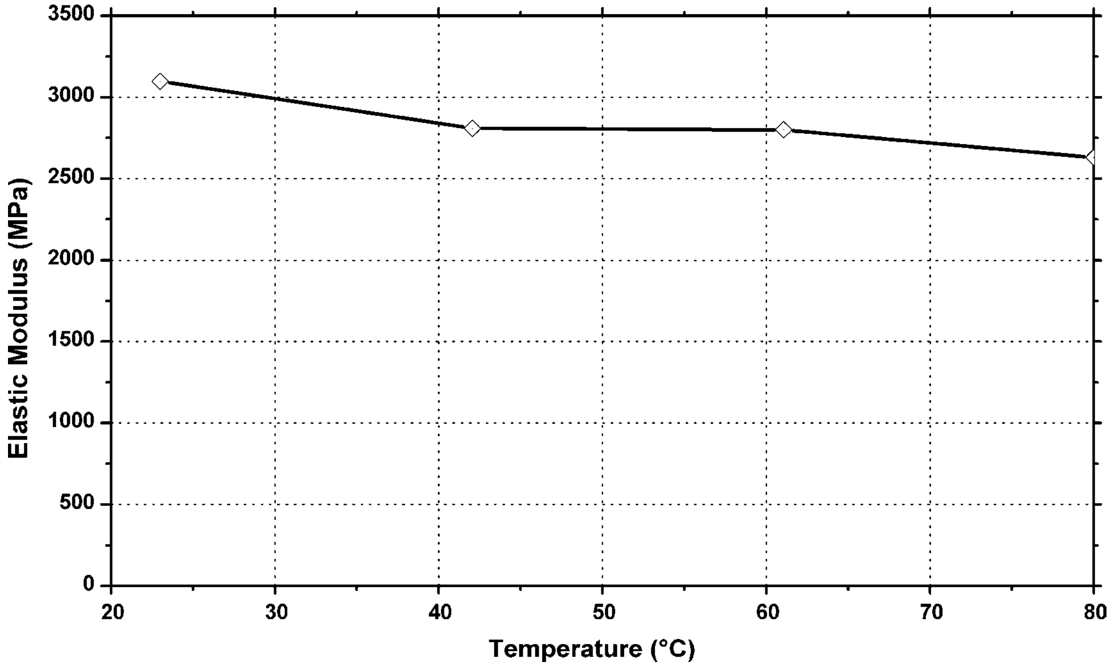


Figure 7.59. Elastic modulus vs. temperature of Ticona Topas® 5013, 6013, 6015 and 6017—COC resins.

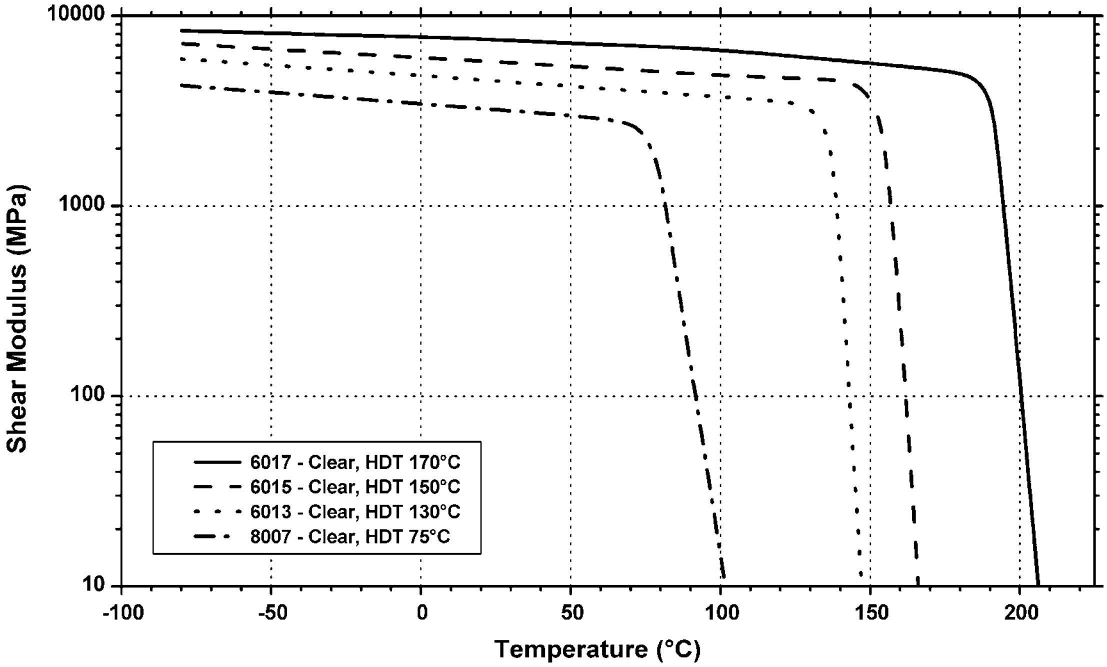


Figure 7.60. Shear modulus vs. temperature of Ticona Topas®—COC resin.

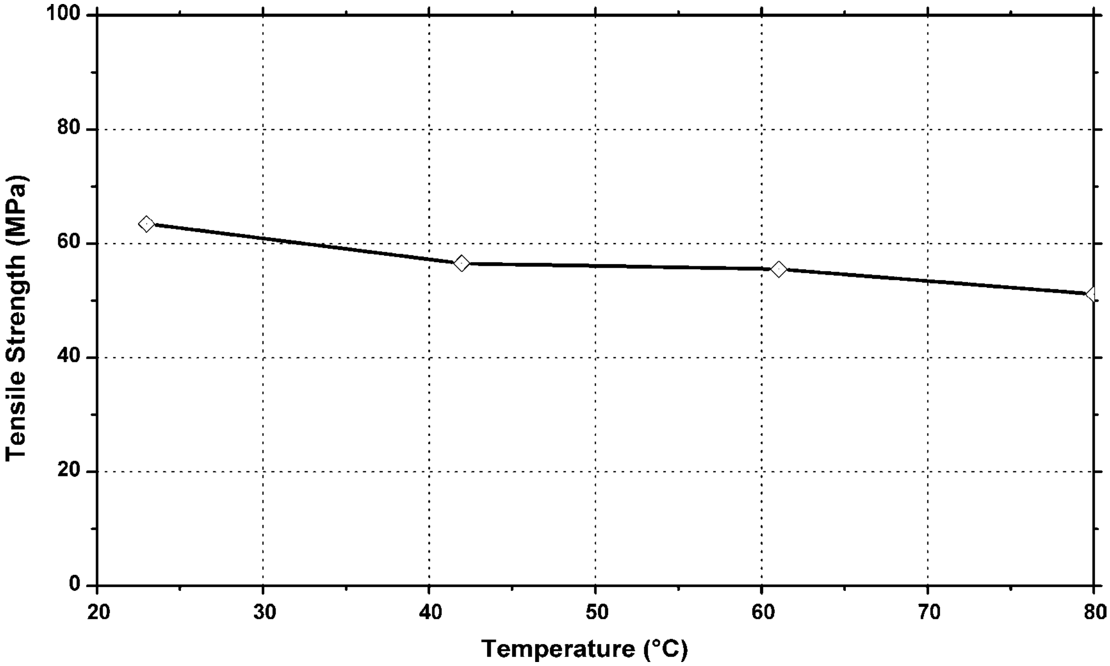


Figure 7.61. Tensile strength vs. temperature of Ticona Topas® 5013, 6013, 6015 and 6017—COC resins.

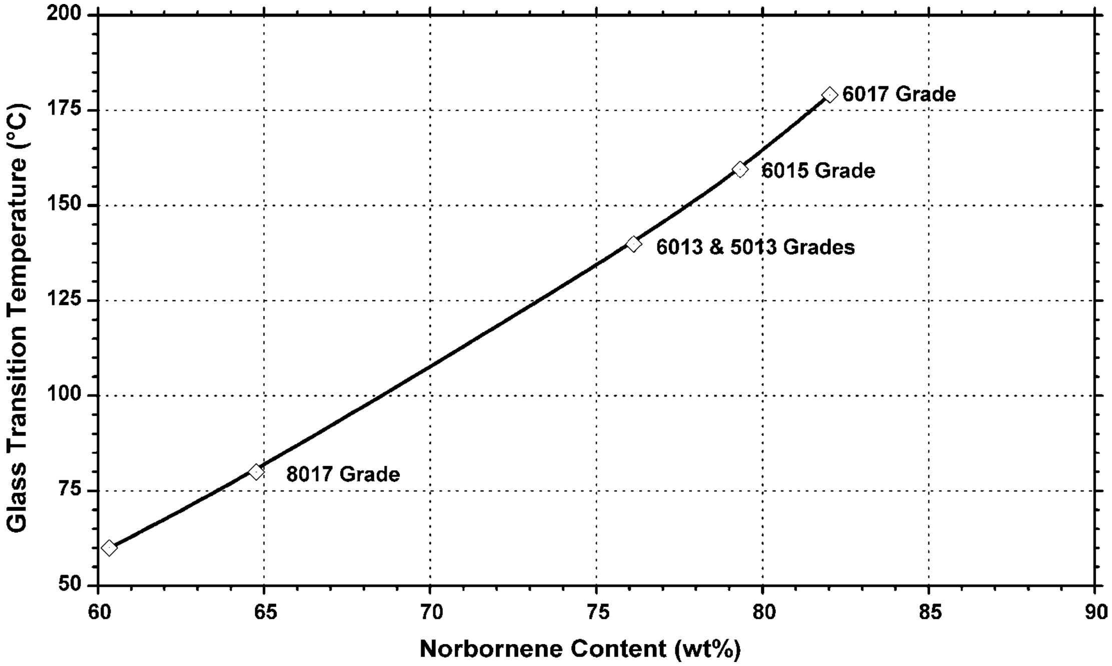


Figure 7.62. Glass transition temperature vs. norbornene content of Ticona Topas®—COC resins.

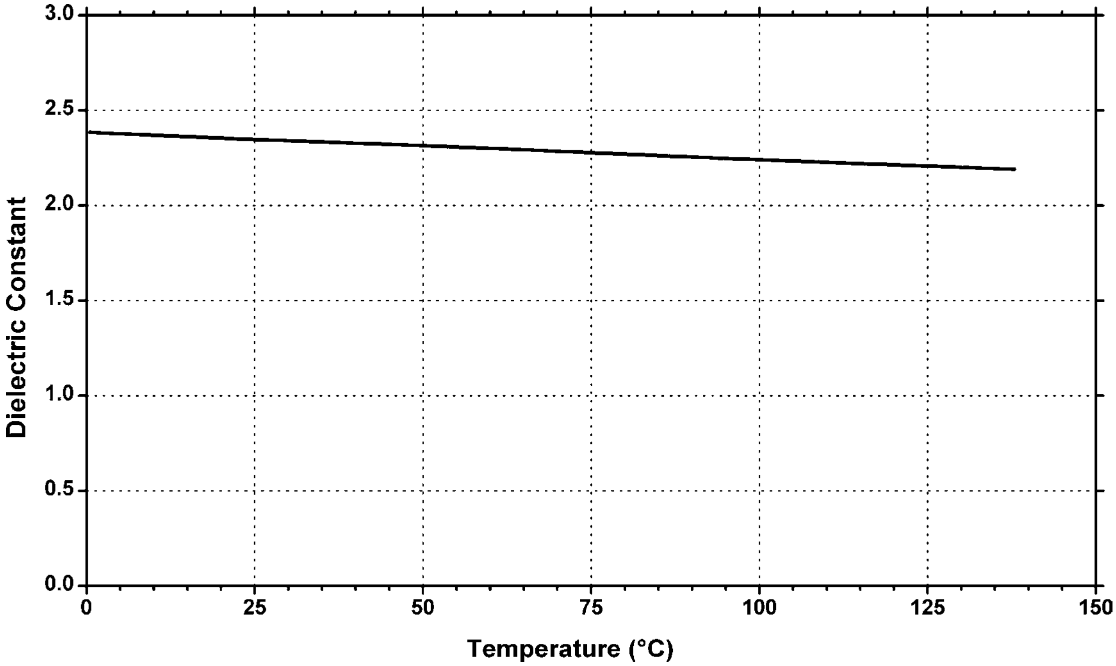


Figure 7.63. Dielectric content vs. temperature of Ticona Topas® 6015—Clear, HDT 150°C COC resin.

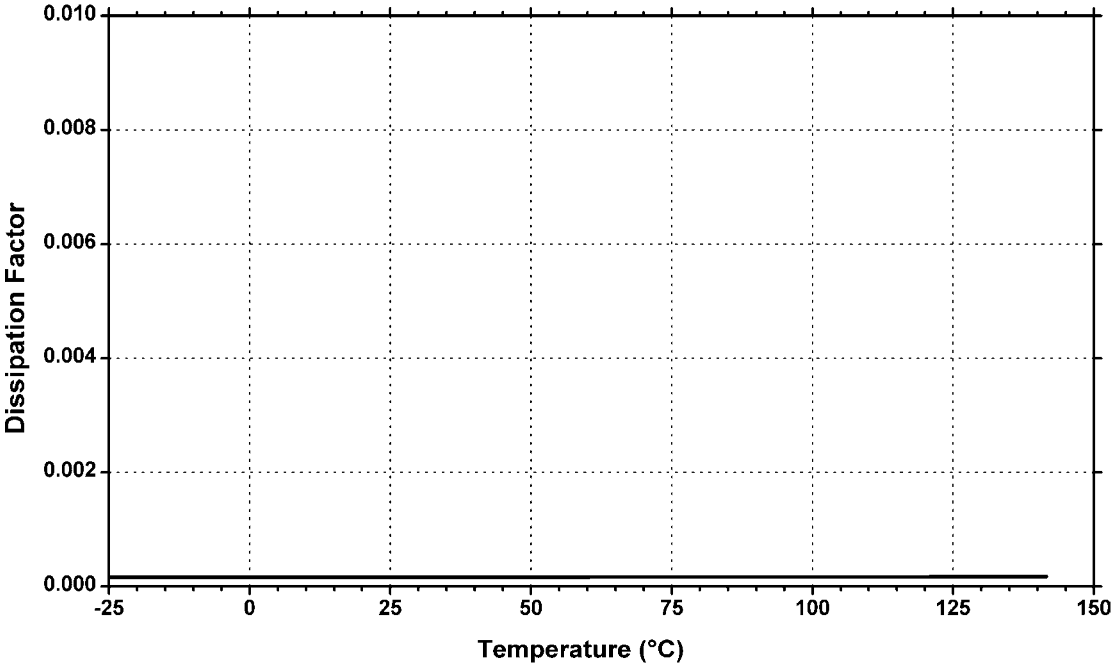


Figure 7.64. Dissipation factor vs. temperature of Ticona Topas® 6015—Clear, HDT 150°C COC resin.

7.8 Polyacrylics

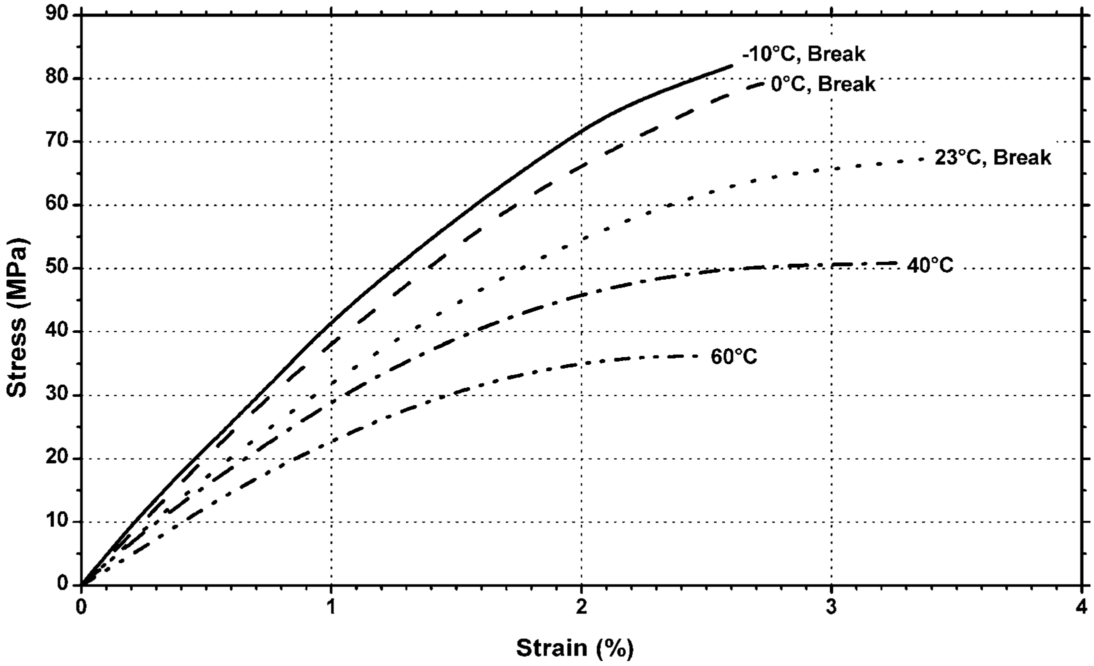


Figure 7.65. Stress vs. strain at various temperatures of Röhm GmbH Plexiglas® 6N—standard grade acrylic resin.

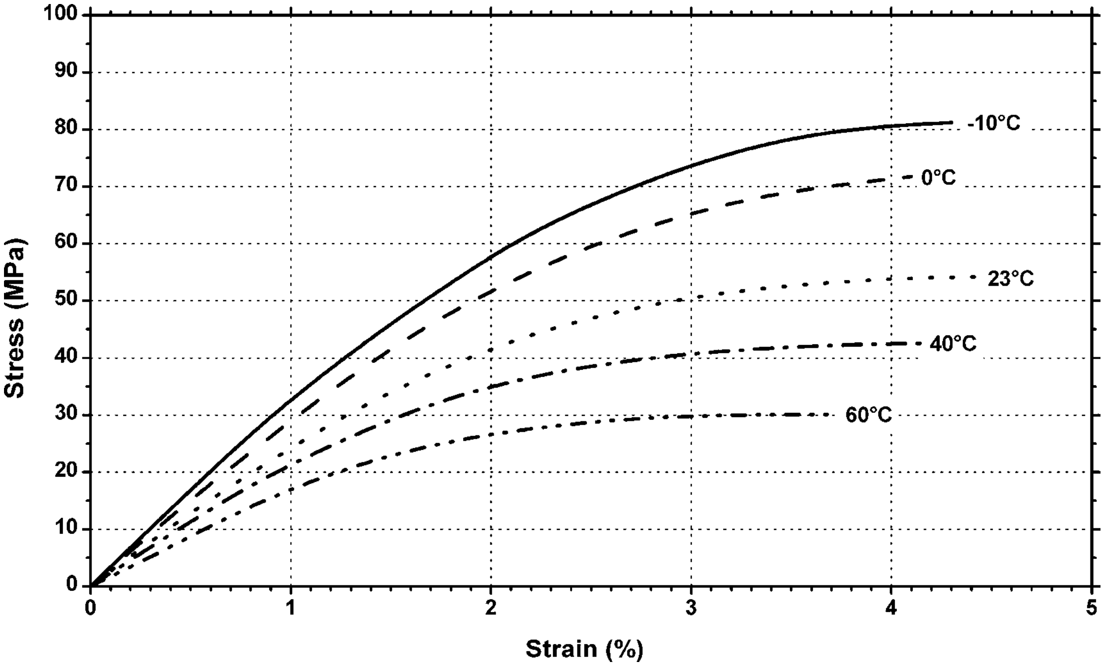


Figure 7.66. Stress vs. strain at various temperatures of Röhm GmbH Plexiglas® zk20—high impact grade acrylic resin.

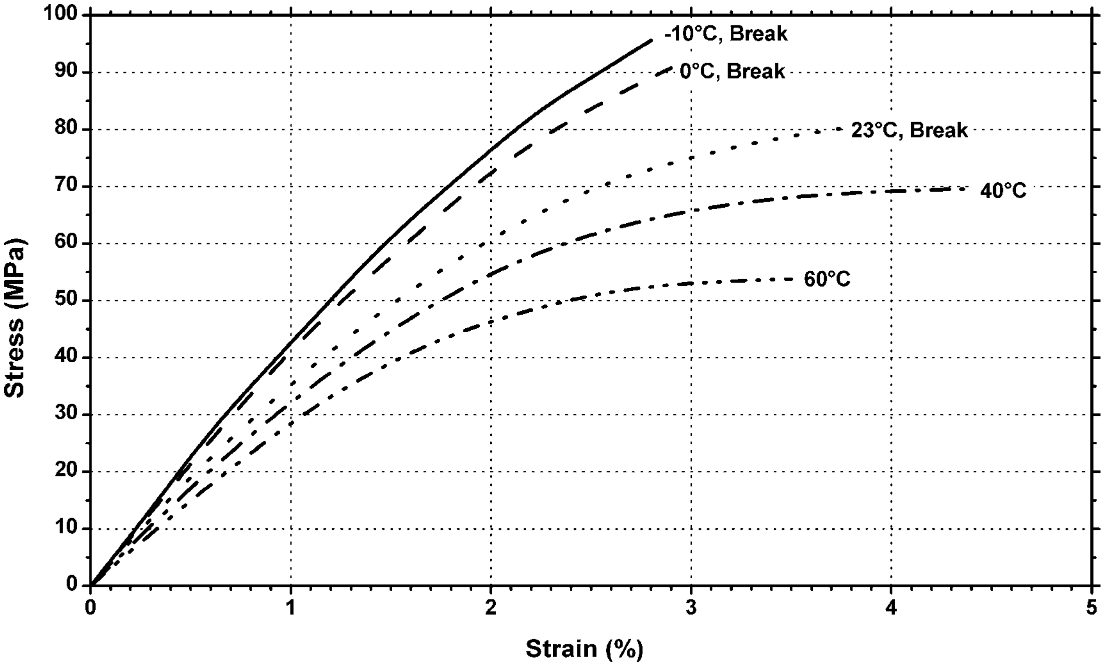


Figure 7.67. Stress vs. strain at various temperatures of Röhm Plexiglas® hw55—heat resistant grade acrylic resin.

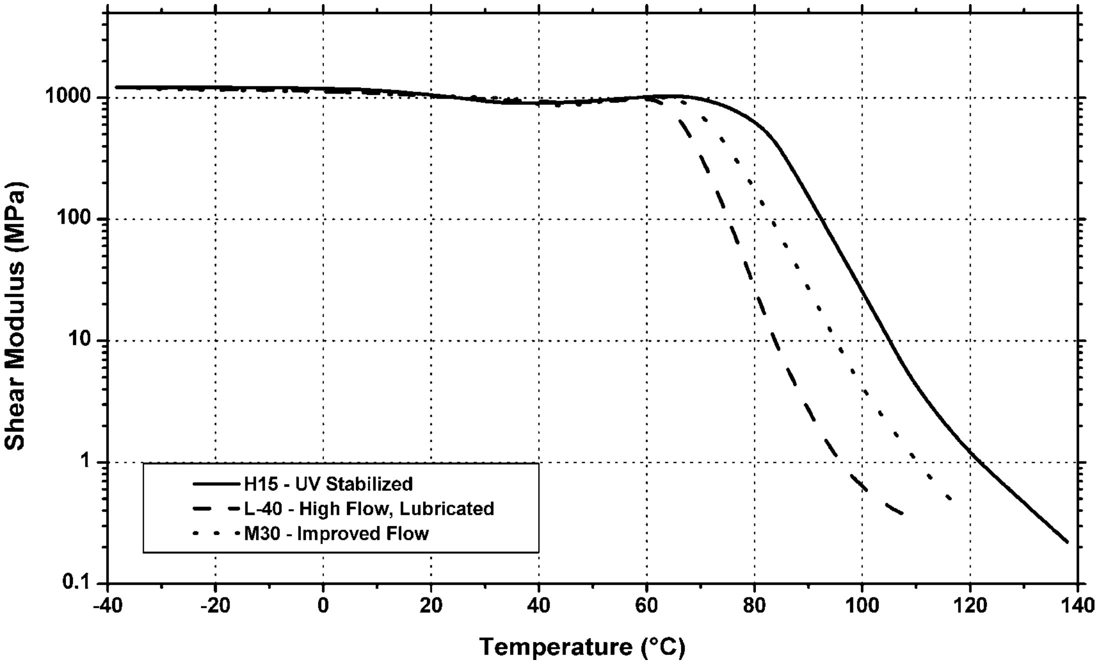


Figure 7.68. Shear modulus vs. temperature of Cyro Industries Acrylite® acrylic resin.

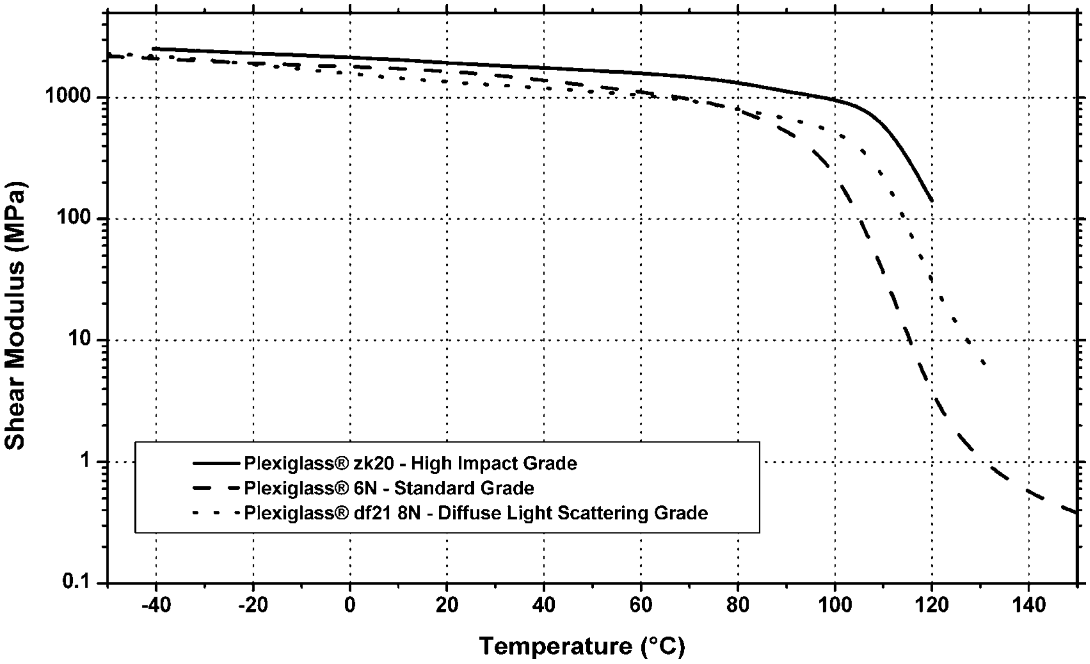


Figure 7.69. Shear modulus vs. temperature of Röhm GmbH Plexiglas® acrylic resins.

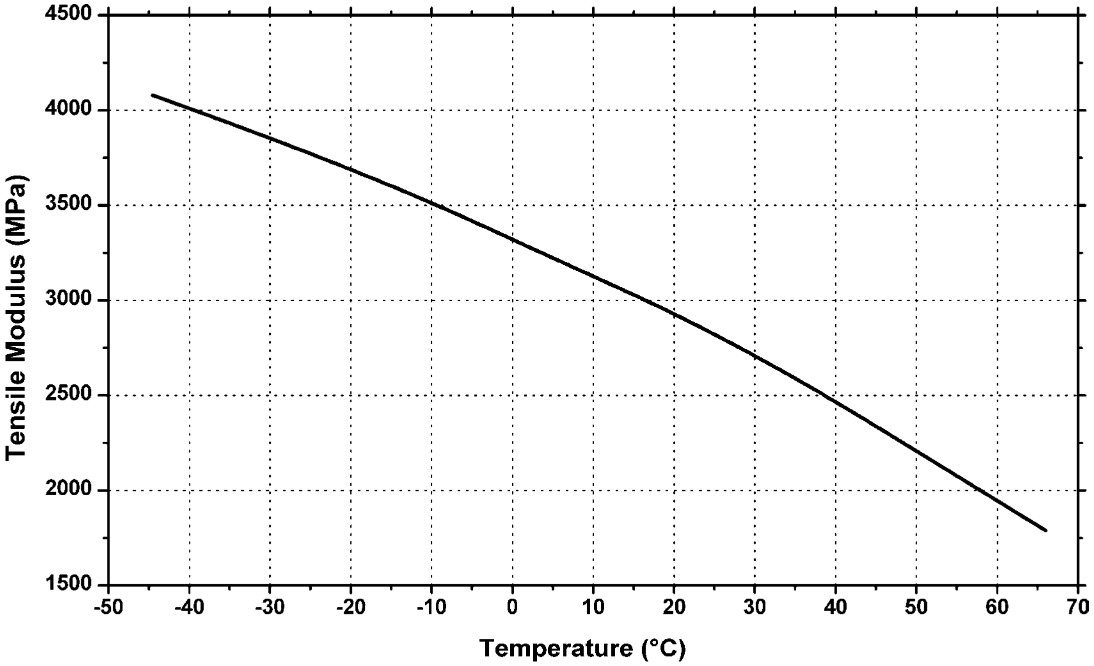


Figure 7.70. Tensile modulus vs. temperature—general purpose acrylic resin.

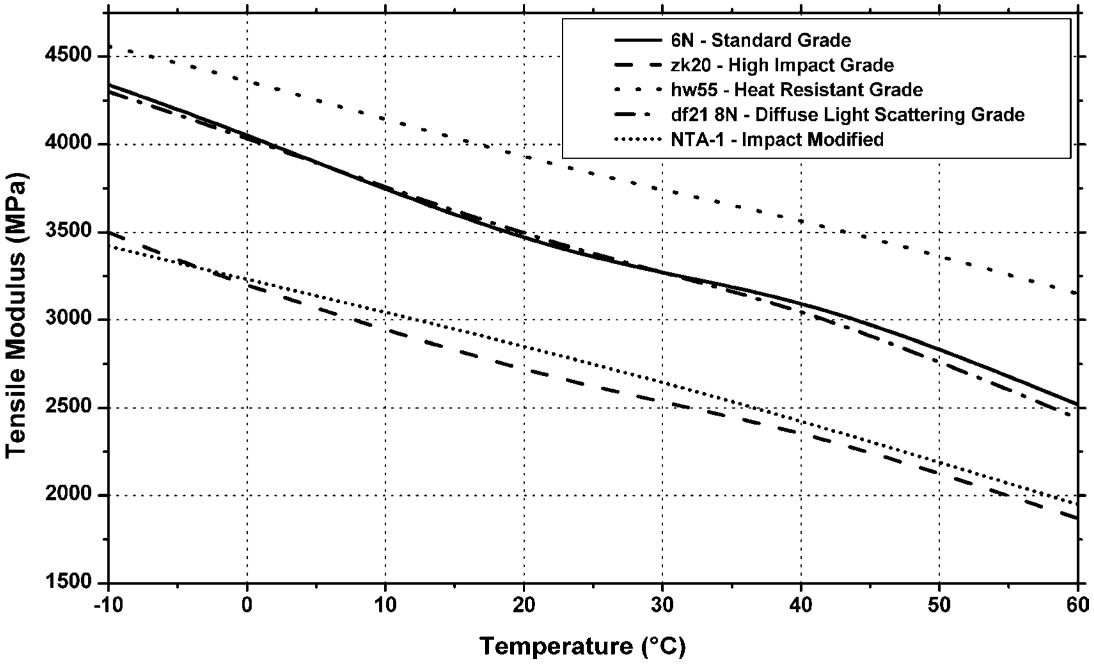


Figure 7.71. Tensile modulus vs. temperature of Röhm GmbH Plexiglas® acrylic resins.

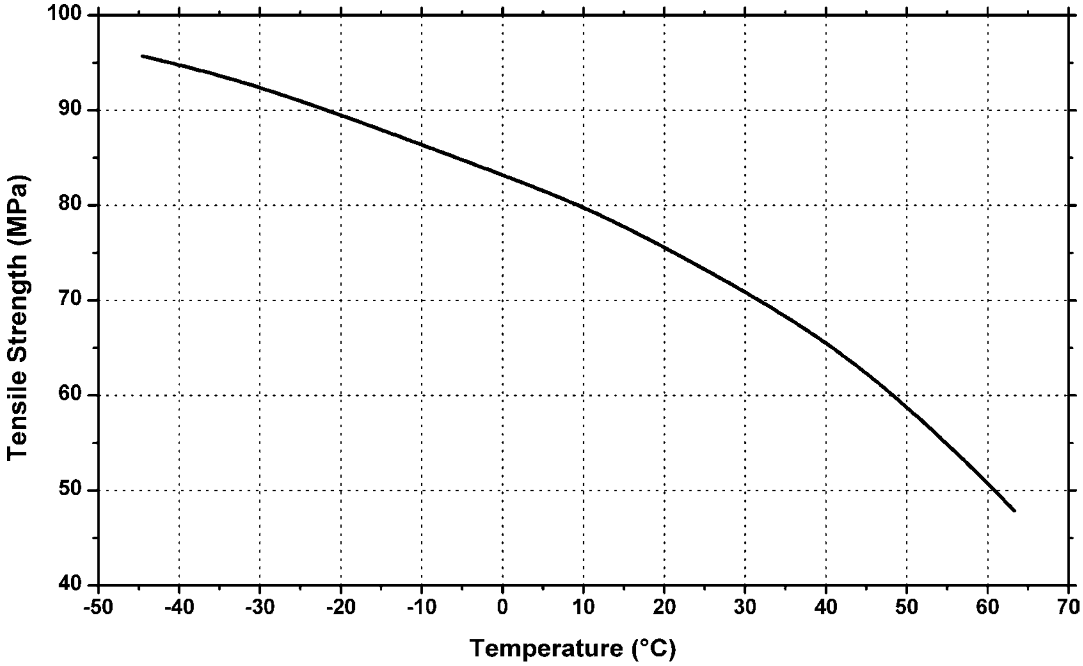


Figure 7.72. Tensile strength vs. temperature—general purpose acrylic resin.

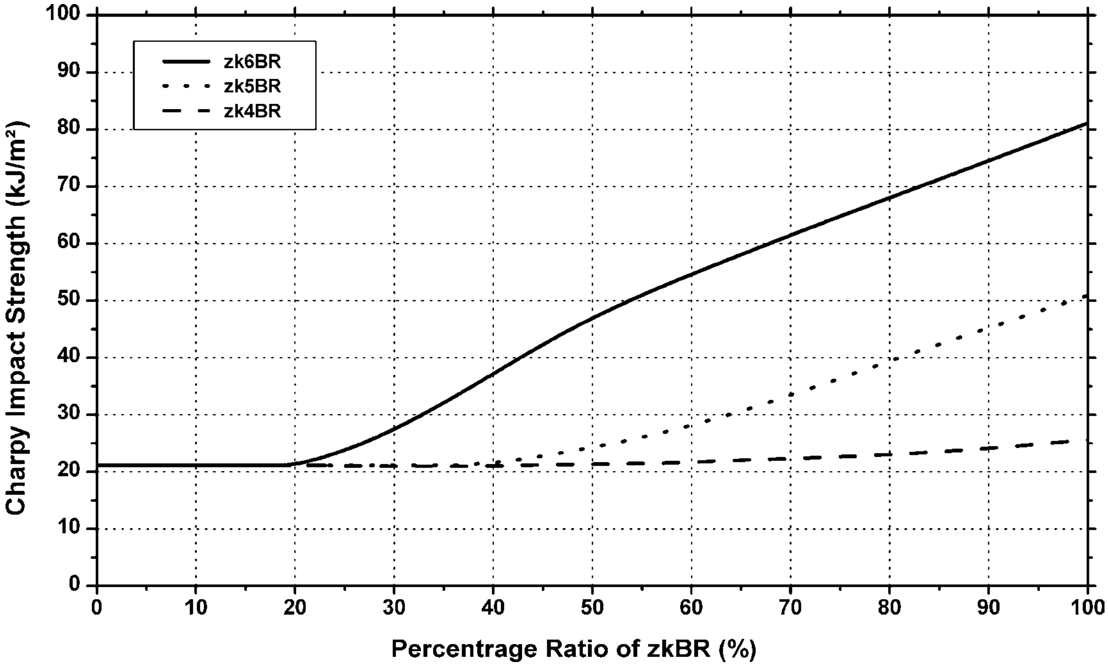


Figure 7.73. Charpy impact strength of Röhm GmbH Plexiglas® 7N—general purpose extrusion grade acrylic resin vs. percentage of Plexiglas® zkBR additives.

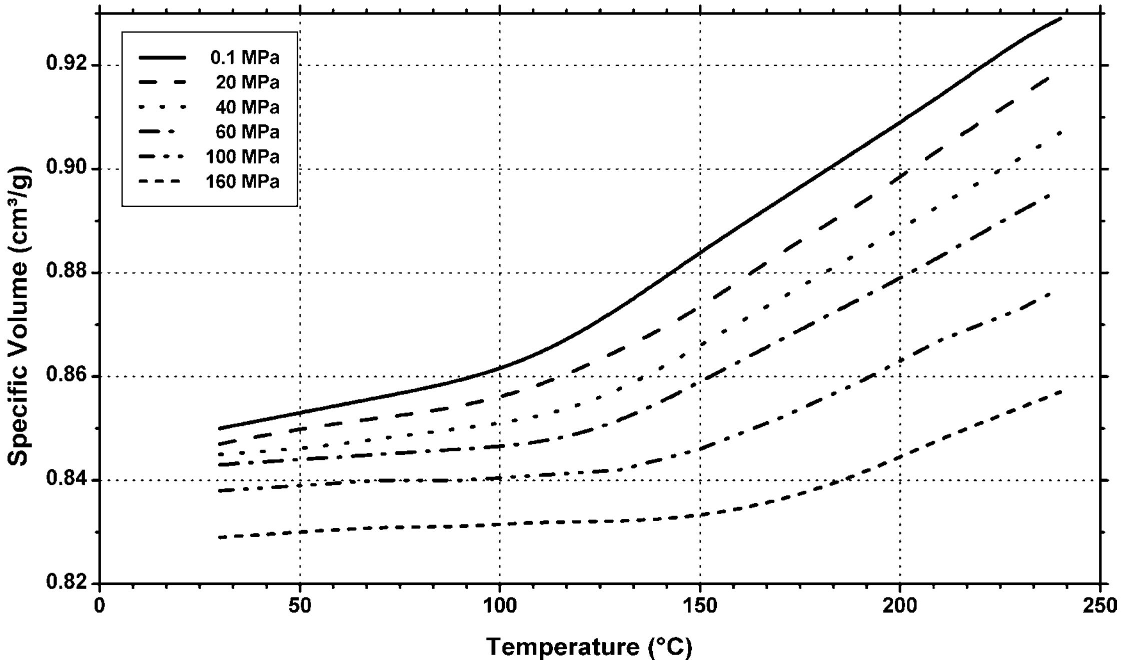


Figure 7.74. Specific volume as a function of temperature and pressure (PVT) for Röhm GmbH Plexiglas® 7N—general purpose extrusion grade acrylic resin.

8 Thermoplastic Elastomers

8.1 Background

Thermoplastic elastomers (TPEs) have two big advantages over the conventional thermoset (vulcanized) elastomers. The advantages being 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 (generally not 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 as:

“Hard phase”—plastic properties

(1) Processing temperatures
(2) Continuous-use temperature
(3) Tensile strength
(4) Tear strength
(5) Chemical and fluid resistance
(6) Adhesion to inks, adhesives, and overmolding substrates

“Soft phase”—elastomeric properties

(1) Lower service temperature limits
(2) Hardness
(3) Flexibility
(4) Compression set and tensile set

Three high performance types of TPEs make up this chapter.

8.1.1 Thermoplastic Polyurethane Elastomers (TPUs)

Urethanes are a reaction product of a diisocyanate and a long- and short-chain polyether, polyester, or caprolactone glycols. The polyols and the short-chain diols react with the diisocyanates to form linear polyurethane molecules. This combination of a diisocyanate and a 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.

The properties of the resin depends 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

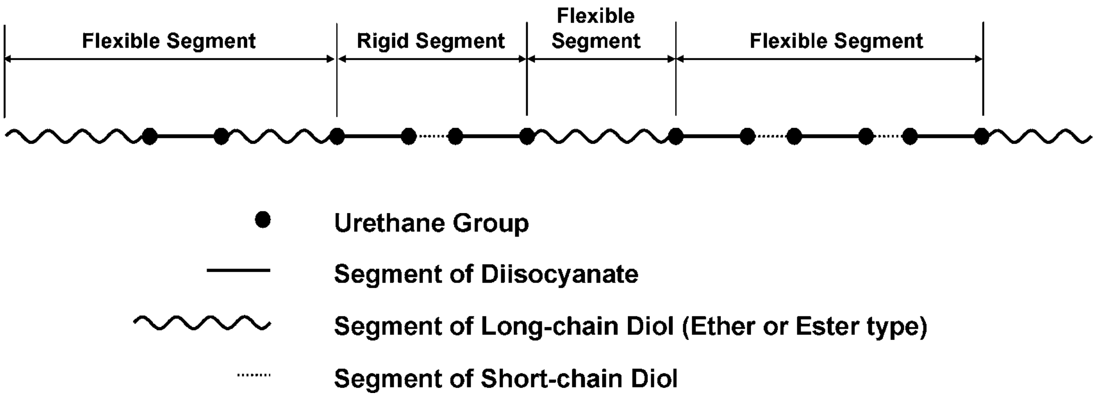


Figure 8.1. Molecular structure (schematic form) of a TPU.

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
- Heat/UV stabilizers
- Plasticizers

The polyether types are slightly more expensive and have better hydrolytic stability and low-temperature flexibility than the polyester types.

8.1.2 Thermoplastic Copolyester Elastomers (TPE-Es or COPEs)

These TPEs are generally tougher over a broader temperature range than the urethanes described in Section 8.1.1. Also, they are easier and more forgiving in processing.

They have the following characteristic features:

- 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 the ordinary rubbers, but also better heat resistance. These TPEs can have low viscosity above the melting temperature of the crystalline regions, and can be molded easily in both 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.

In DuPont Hytrel® polyester TPEs, the resin is a block copolymer. The hard phase is polybutylene terephthalate. The soft segments are long chain polyether glycols.

8.1.3 Polyether Block Amide (PEBA) Thermoplastic Elastomers

Polyether block amides 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 by 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.

They have the following characteristic features:

(1) Light weight
(2) Great flexibility (extensive range)
(3) Resiliency
(4) Very good dynamic properties
(5) High strength
(6) Outstanding impact resistance properties at low temperature

(7) Easy processing

(8) Good resistance to most chemicals

Graphs showing multipoint properties of TPEs as a function of temperature, moisture, and other factors are illustrated in Sections 8.2–8.4.

8.2 Thermoplastic Polyurethane Elastomers (TPU)

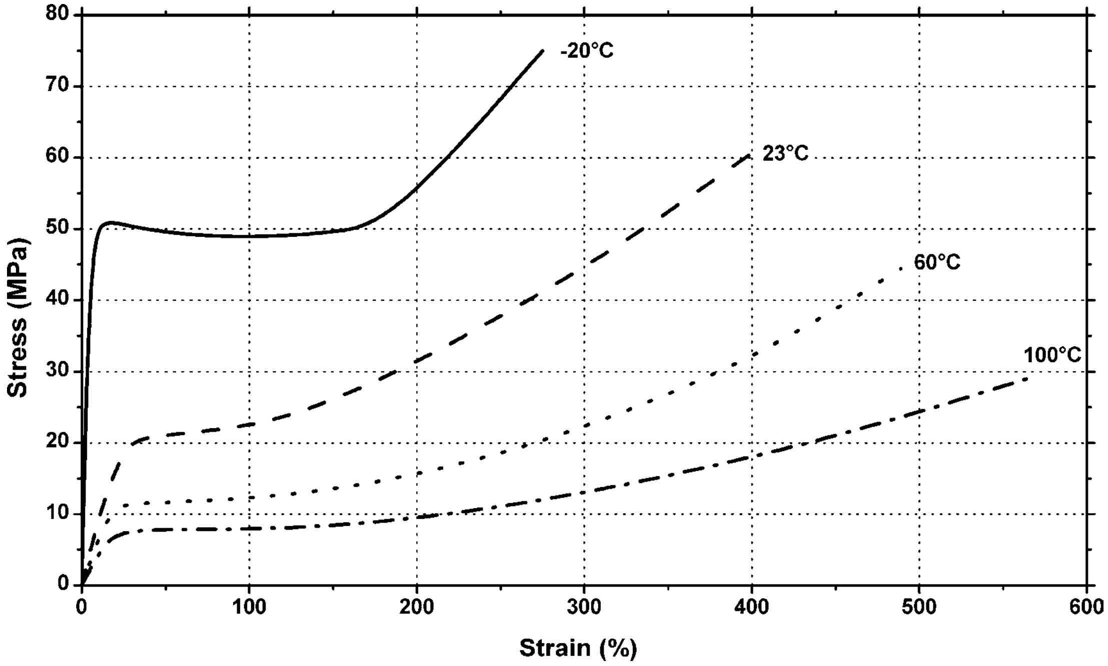


Figure 8.2. Stress vs. strain at various temperatures for BASF Elastollan® 1164 D—polyether resin, Shore hardness 64D TPU resin.

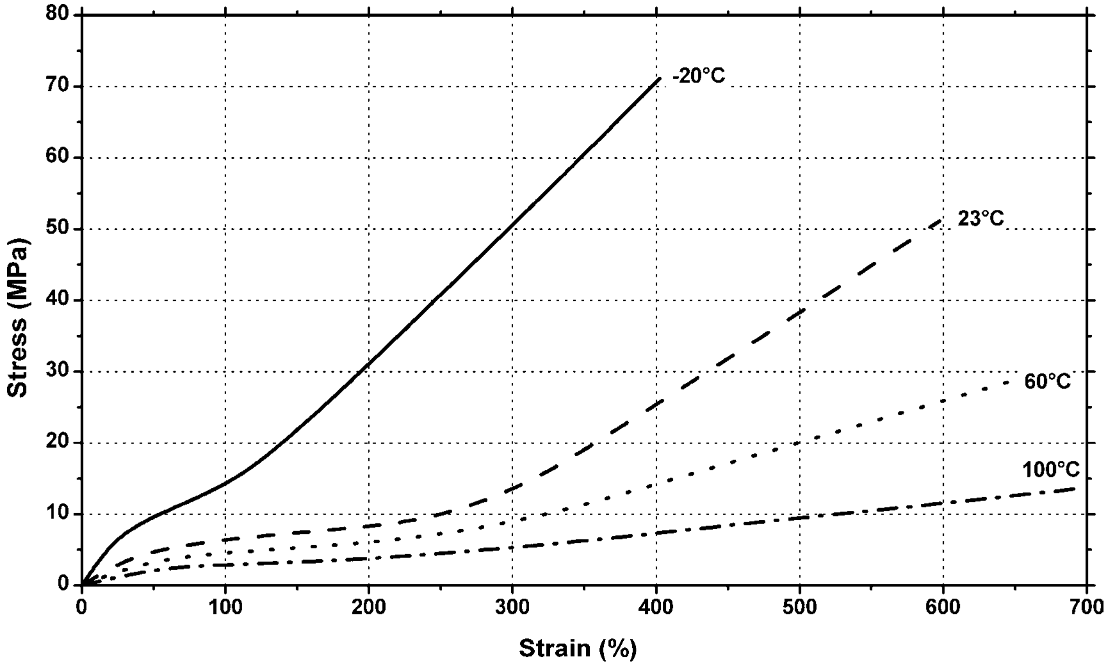


Figure 8.3. Stress vs. strain at various temperatures for BASF Elastollan® 1185 A—polyether resin, Shore hardness 85A TPU resin.

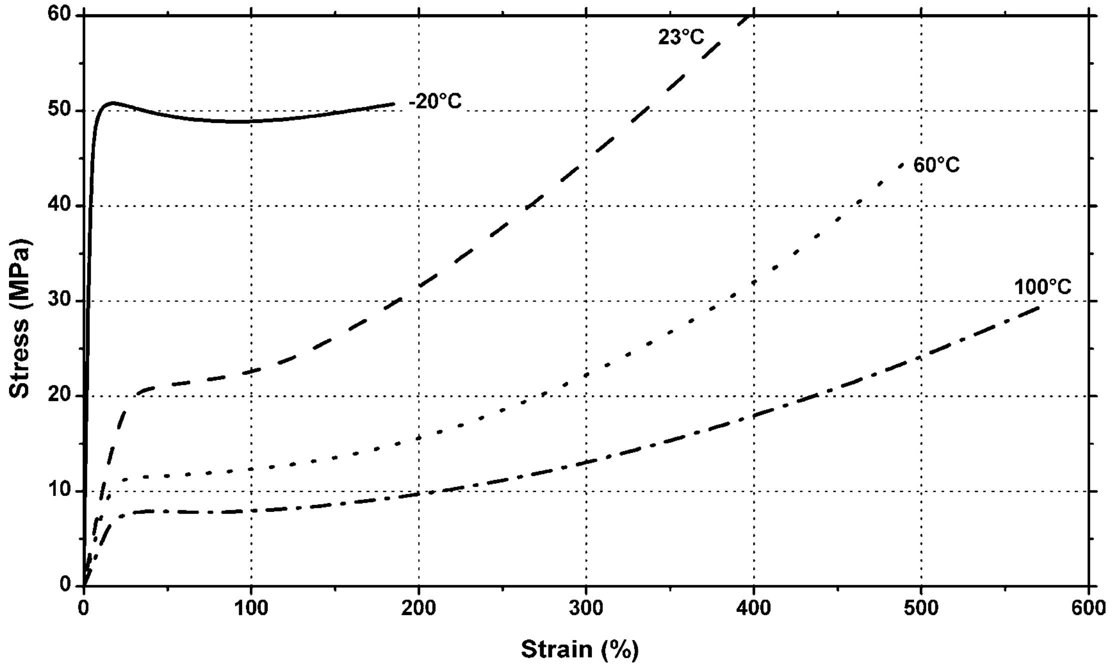


Figure 8.4. Stress vs. strain at various temperatures for BASF Elastollan® C 64 D—polyester resin, high crystallinity, Shore hardness 64D TPU resin.

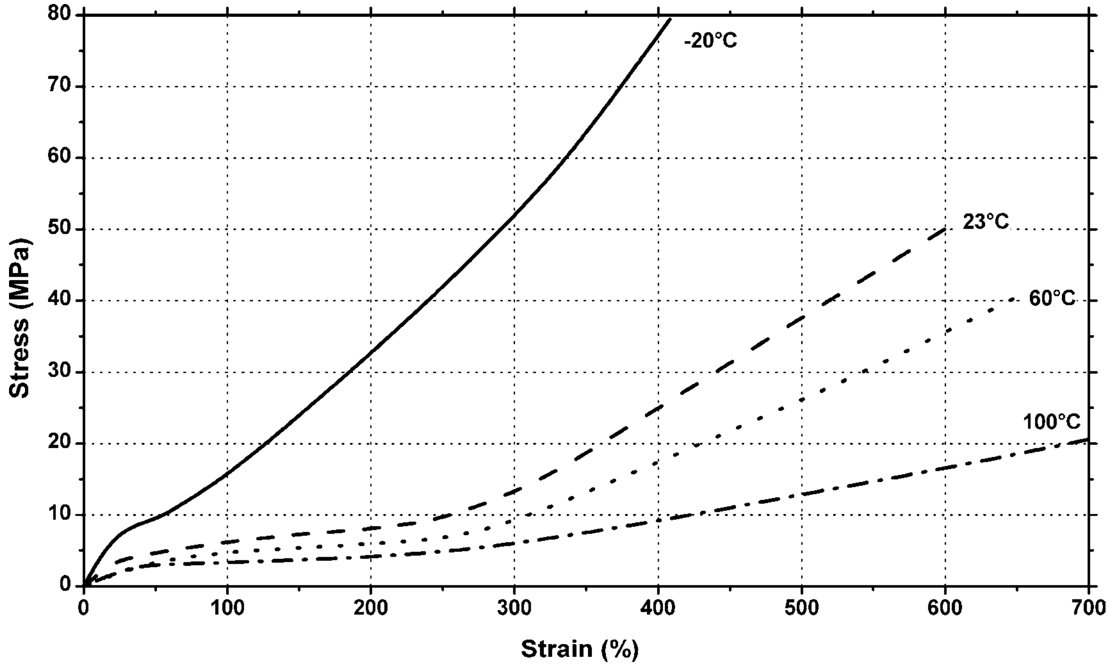


Figure 8.5. Stress vs. strain at various temperatures for BASF Elastollan® C 85 A—polyester resin, high crystallinity, Shore hardness 85A TPU resin.

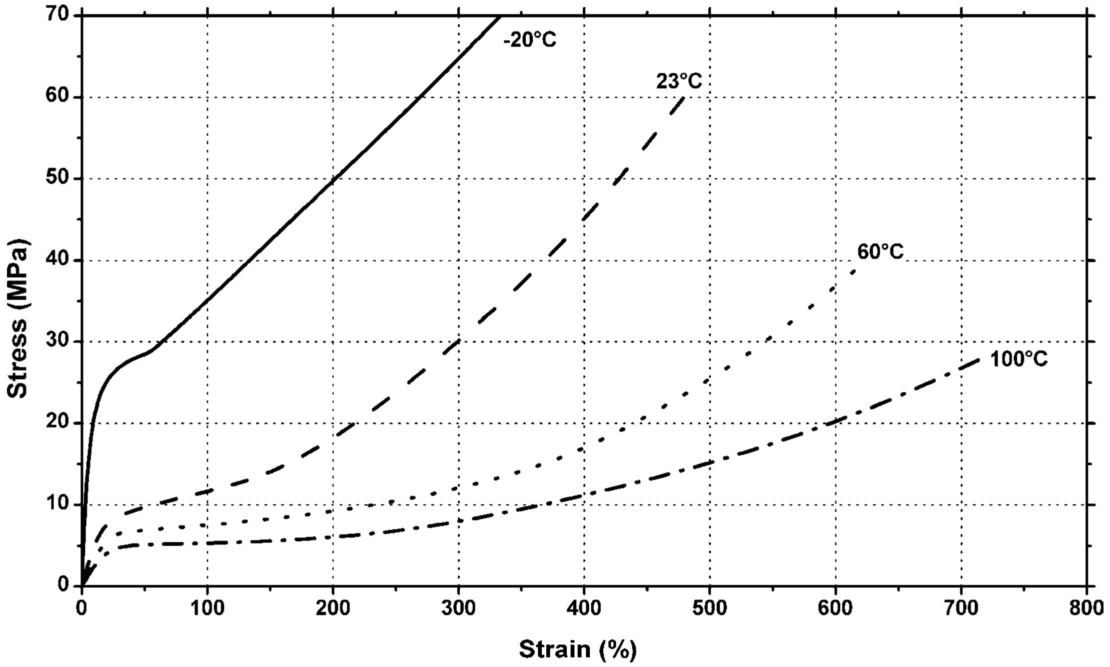


Figure 8.6. Stress vs. strain at various temperatures for BASF Elastollan® C 95 A—polyester resin, high crystallinity, Shore hardness 95A TPU resin.

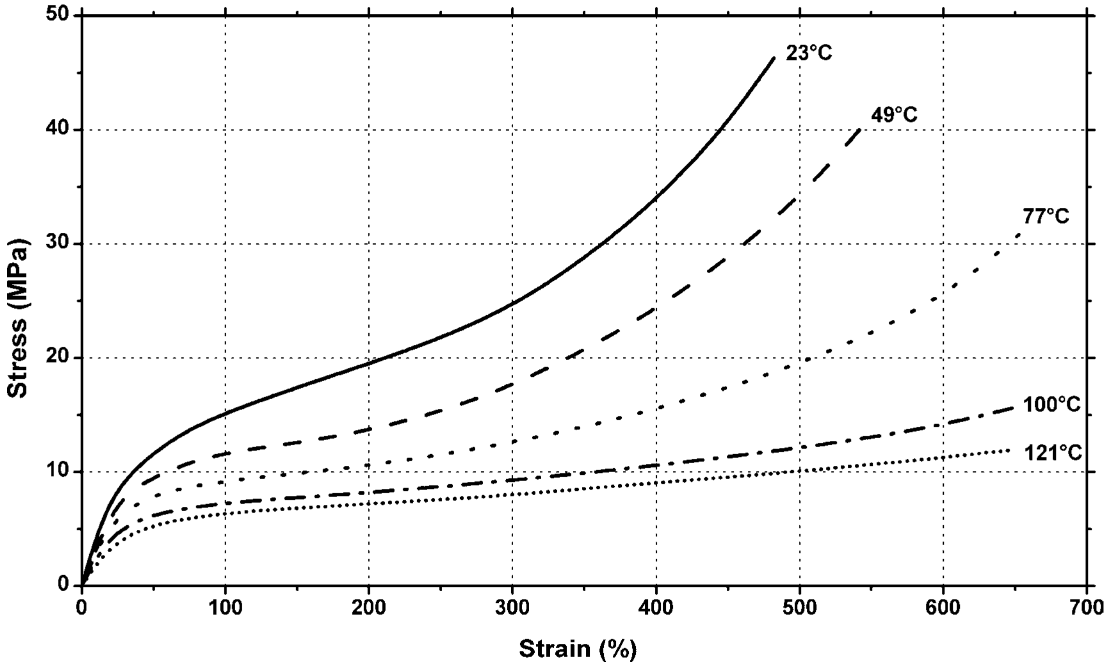


Figure 8.7. Stress vs. strain at various high temperatures for Bayer Desmopan® 453—polyester resin, Shore hardness 53D TPU resin.

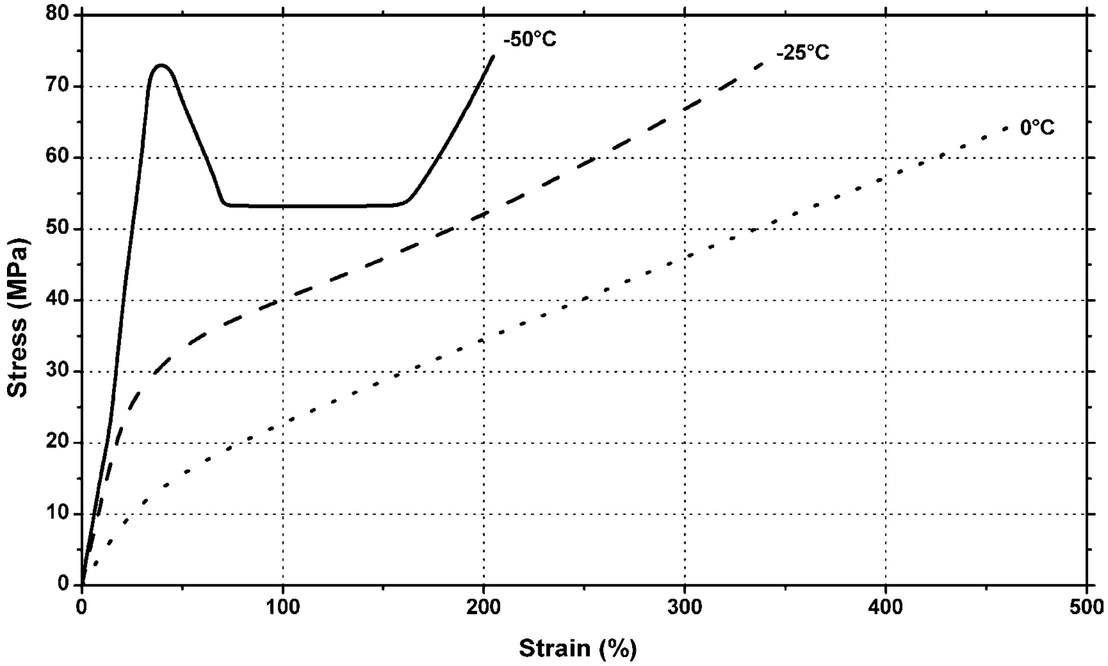


Figure 8.8. Stress vs. strain at various low temperatures for Bayer Desmopan® 453—polyester resin, Shore hardness 53D TPU resin.

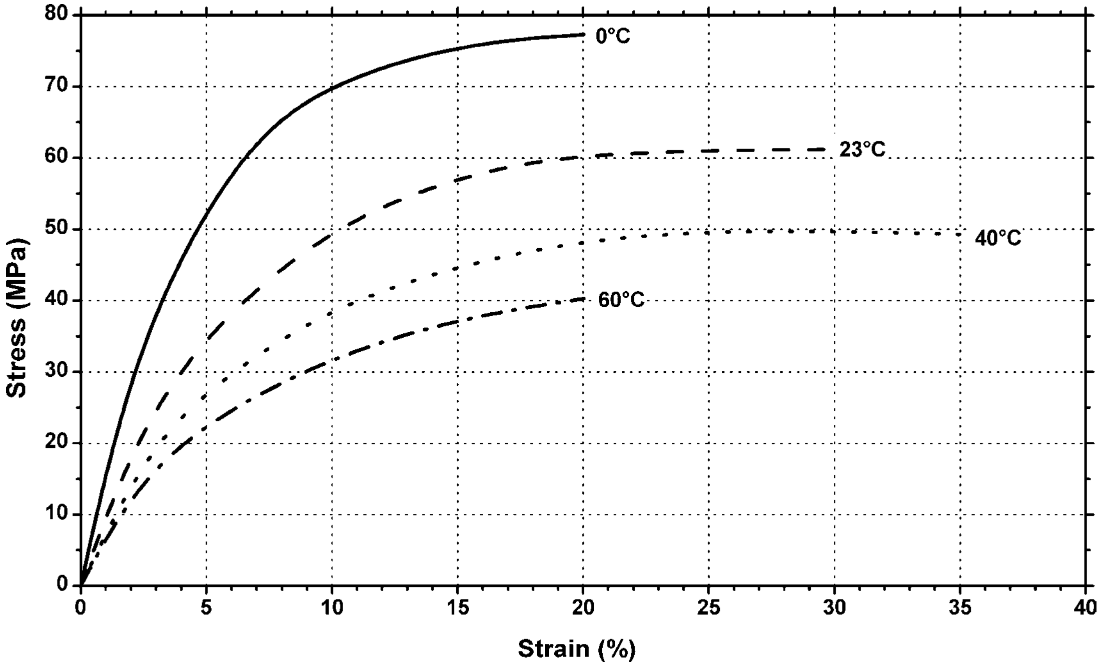


Figure 8.9. Stress vs. strain at various temperatures for BASF Elastollan® R 1000—20% glass fiber, Shore hardness 60D TPU resin.

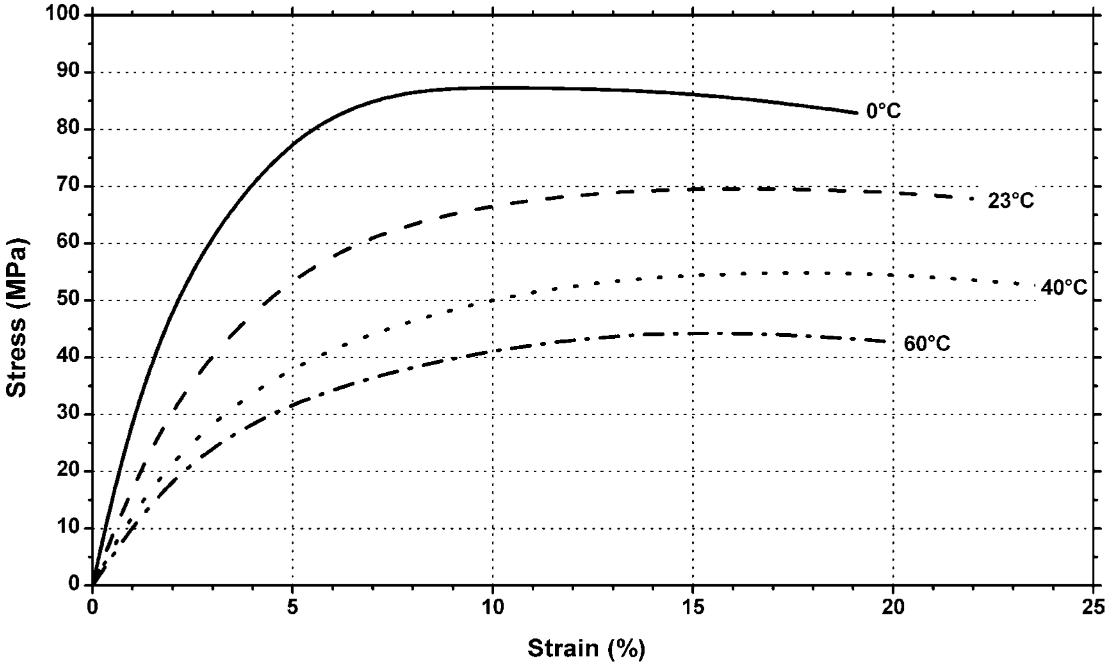


Figure 8.10. Stress vs. strain at various temperatures for BASF Elastollan® R 2000—20% glass fiber, Shore hardness 67D TPU resin.

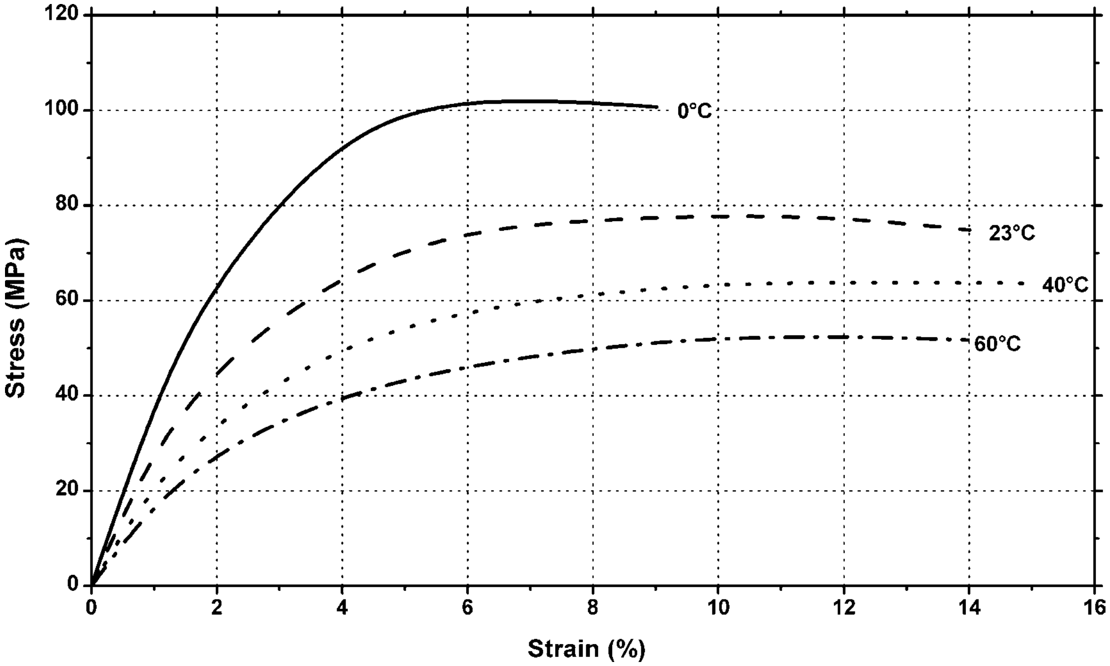


Figure 8.11. Stress vs. strain at various temperatures for BASF Elastollan® R 3000—20% glass fiber, Shore hardness 73D TPU resin.

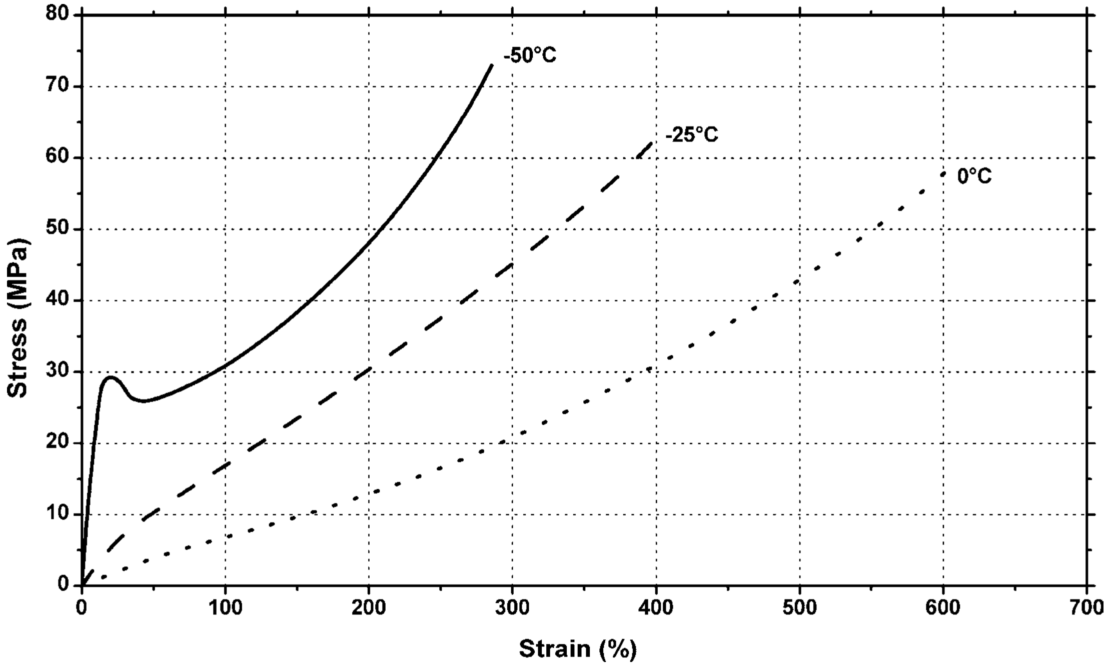


Figure 8.12. Stress vs. strain at various low temperatures for Bayer Texin® 285—polyester resin, Shore hardness 85A TPU resin.

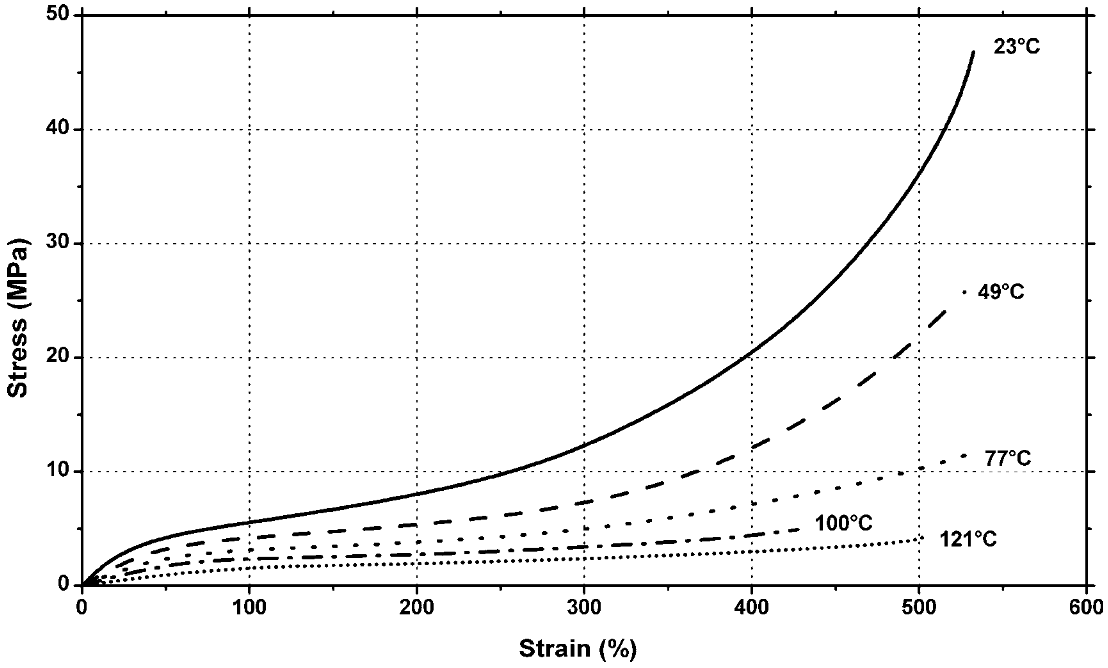


Figure 8.13. Stress vs. strain at various high temperatures for Bayer Texin® 285—polyester resin, Shore hardness 85A TPU resin.

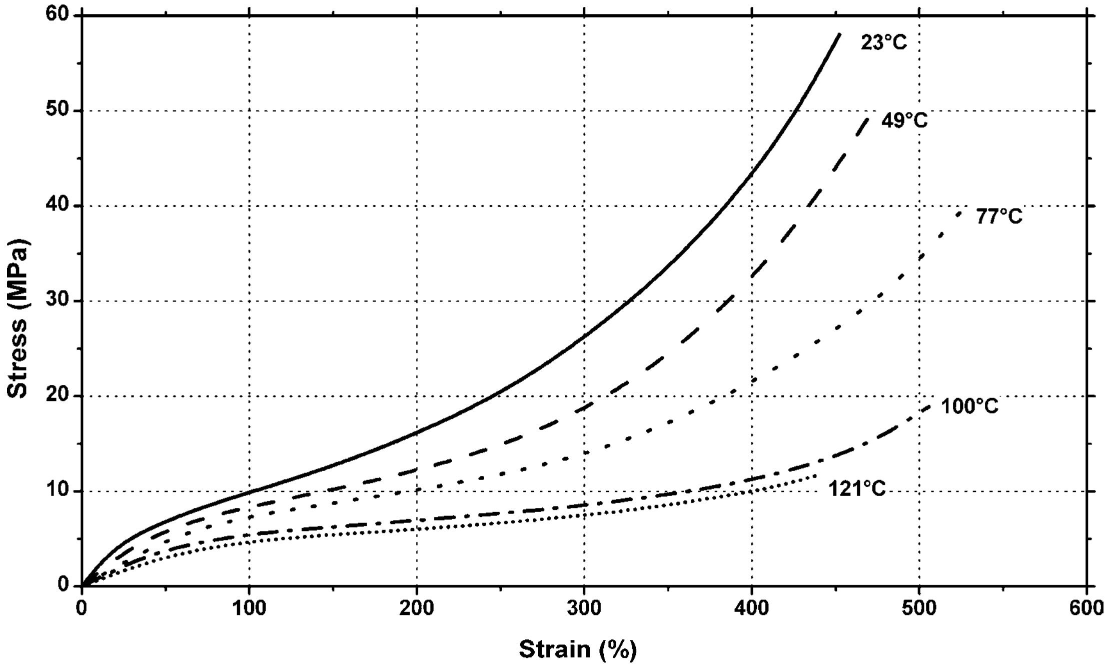


Figure 8.14. Stress vs. strain at various high temperatures for Bayer Texin® 390—polyester resin, Shore hardness 88A TPU resin.

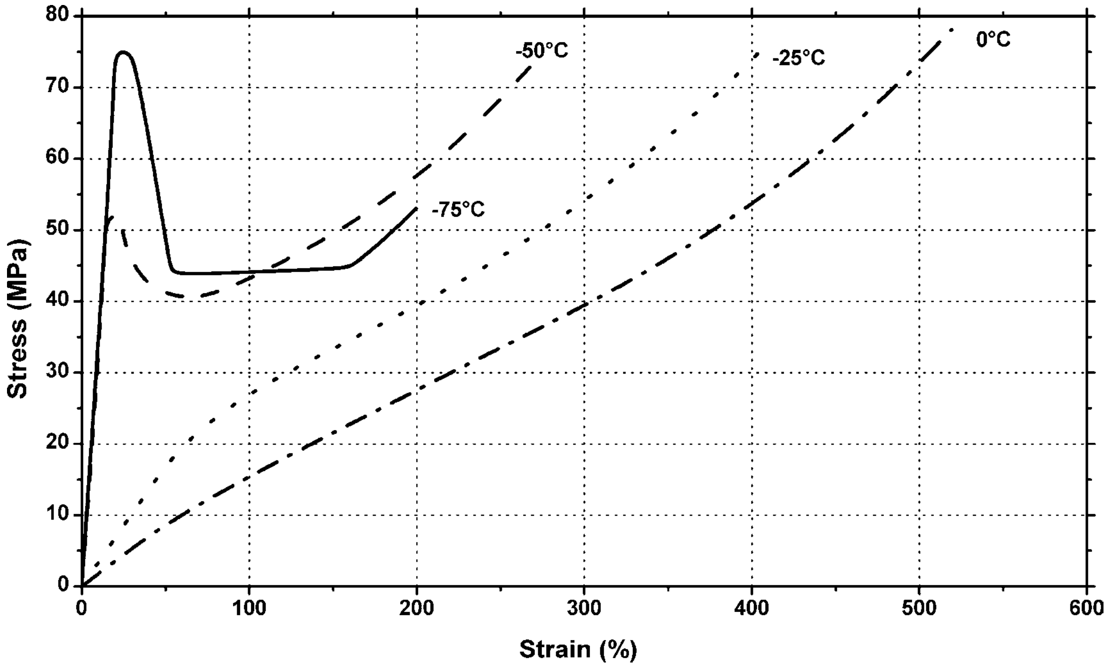


Figure 8.15. Stress vs. strain at various low temperatures for Bayer Texin® 390—polyester resin, Shore hardness 88A TPU resin.

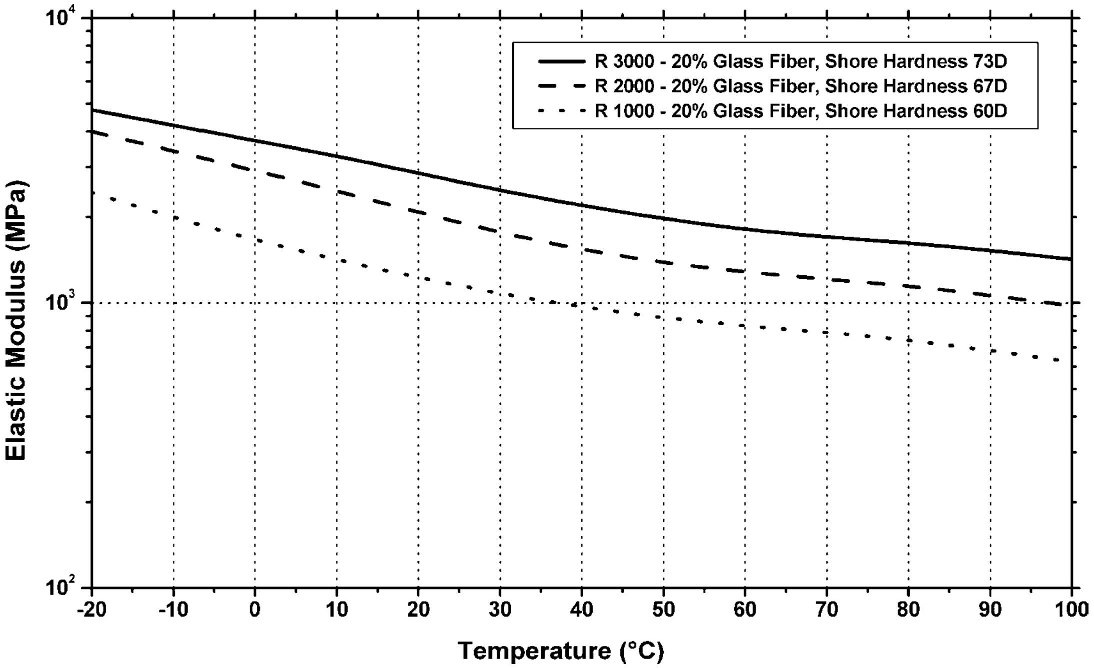


Figure 8.16. Elastic modulus vs. temperature for BASF Elastollan® R glass fiber filled TPU resins.

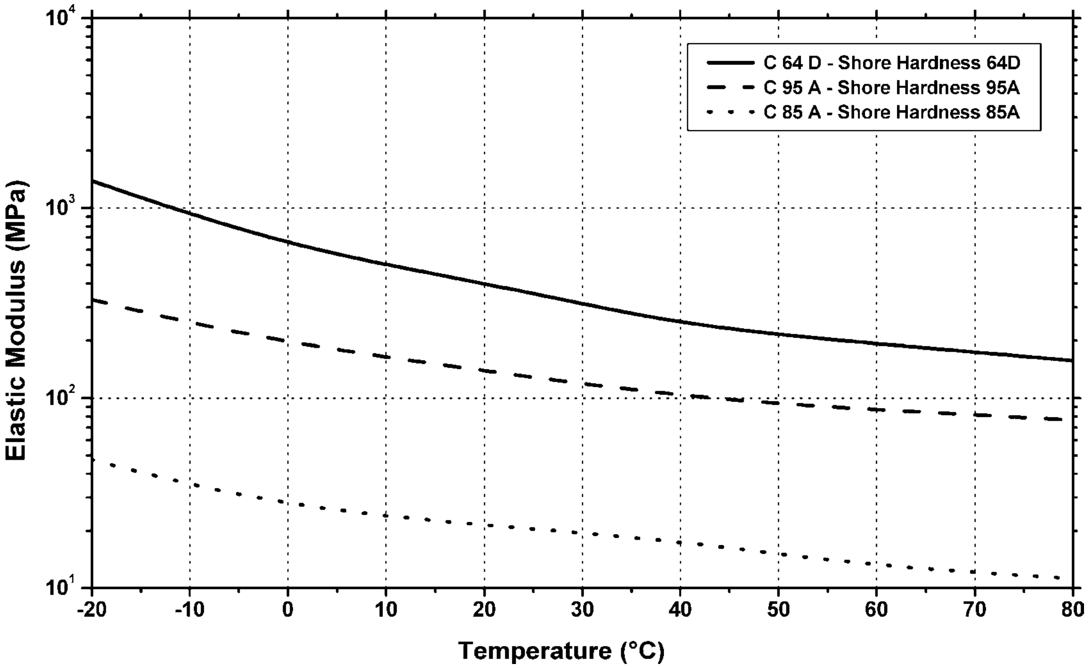


Figure 8.17. Elastic modulus vs. temperature for BASF Elastollan® polyester TPU resins.

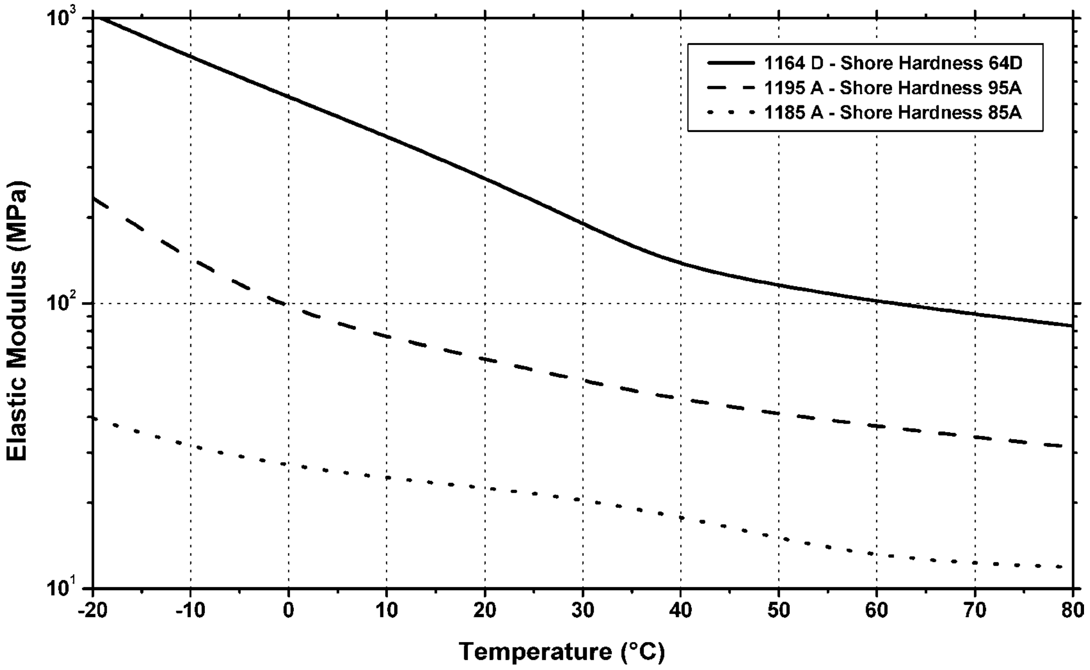


Figure 8.18. Elastic modulus vs. temperature for BASF Elastollan® polyether TPU resins.

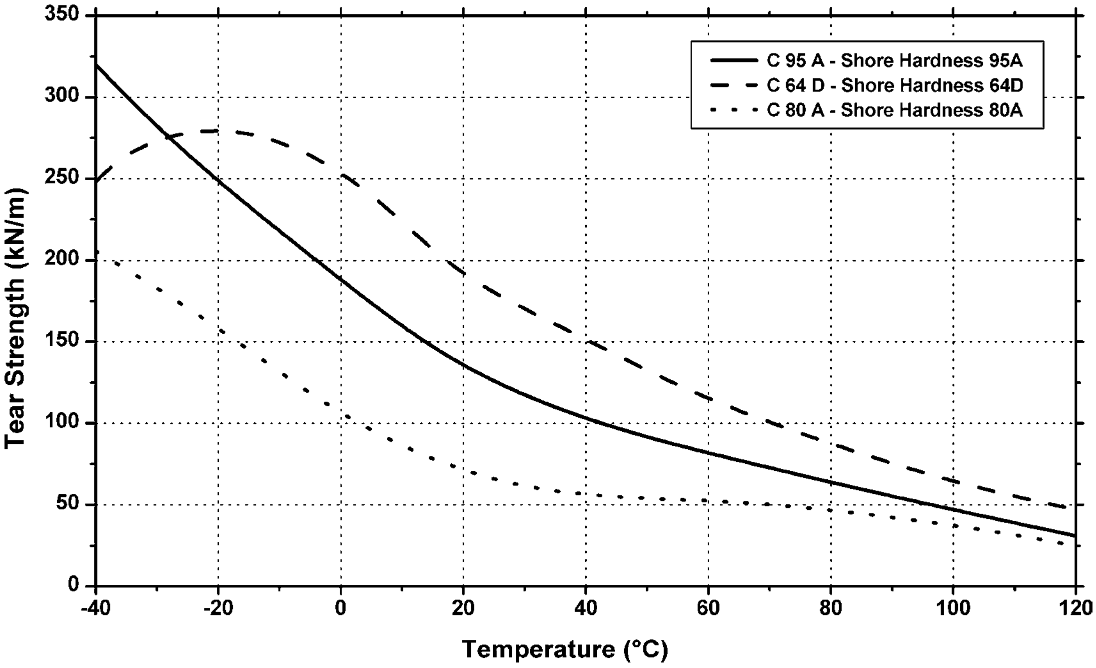


Figure 8.19. Tear strength vs. temperature for BASF Elastollan® polyester TPU resins.

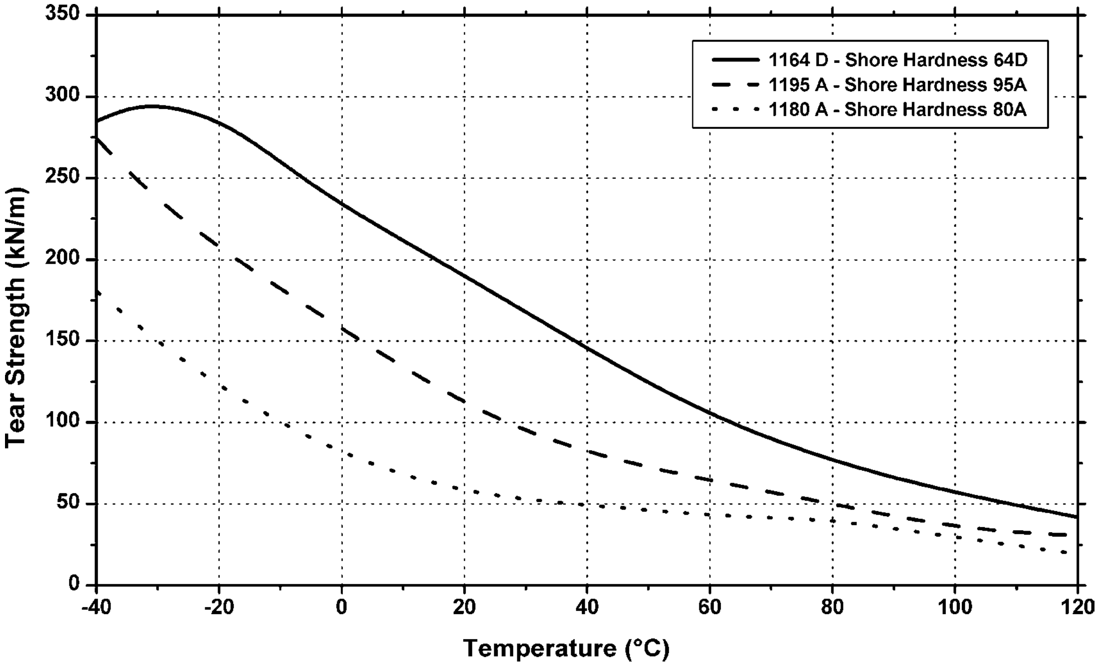


Figure 8.20. Tear strength vs. temperature for BASF Elastollan® polyether TPU resins.

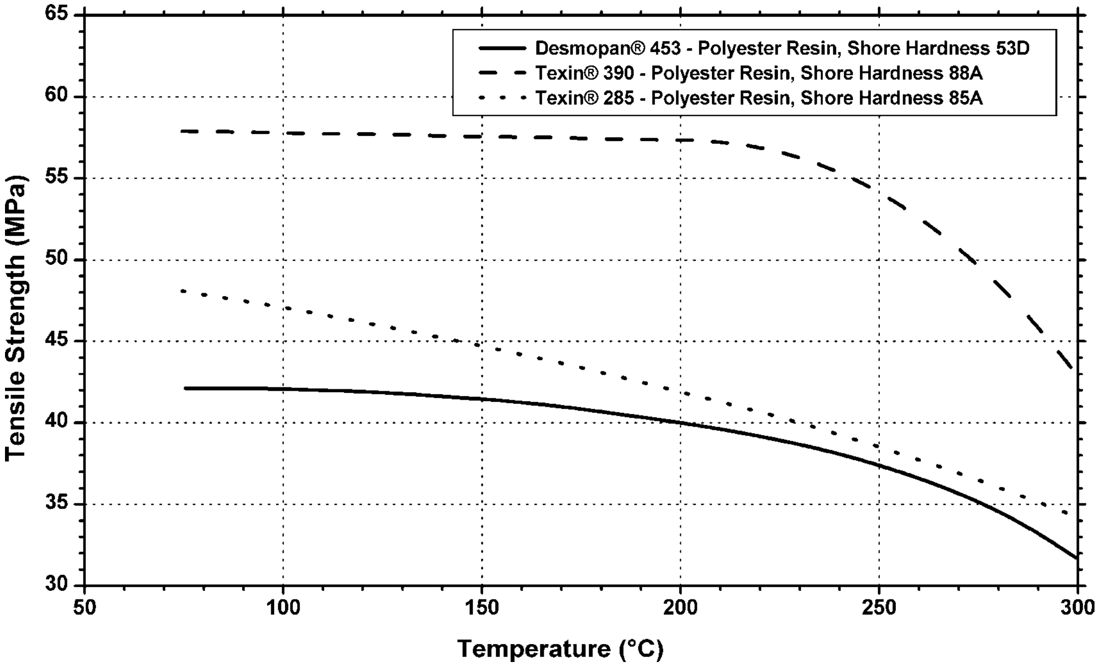


Figure 8.21. Tensile strength vs. temperature for Bayer TPU resins.

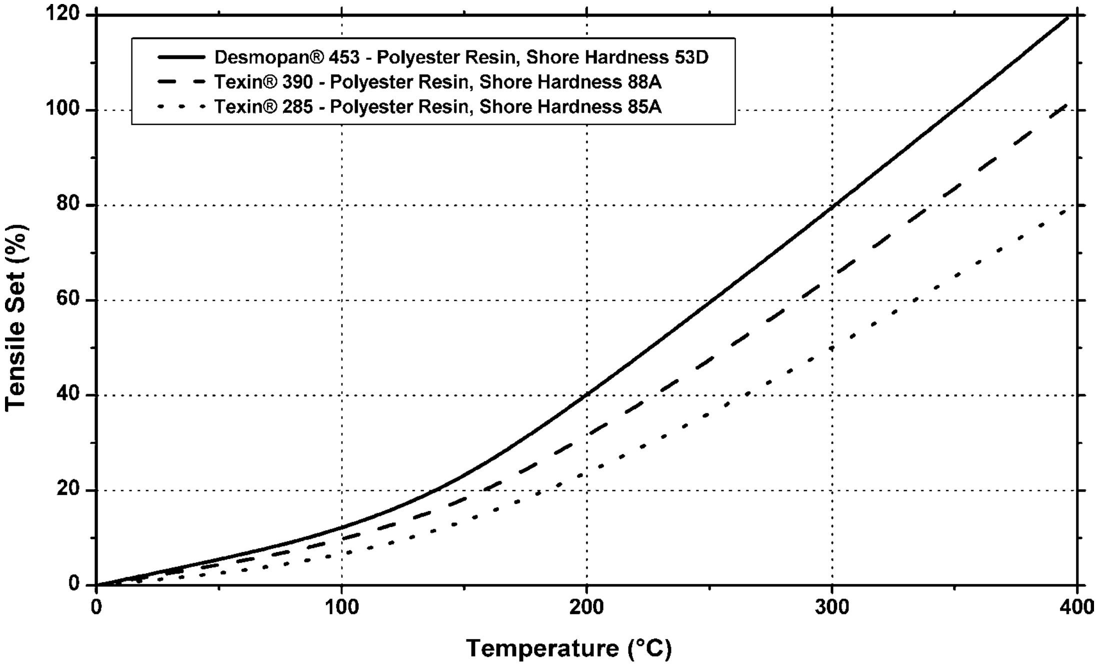


Figure 8.22. Tensile set vs. temperature for Bayer TPU resins.

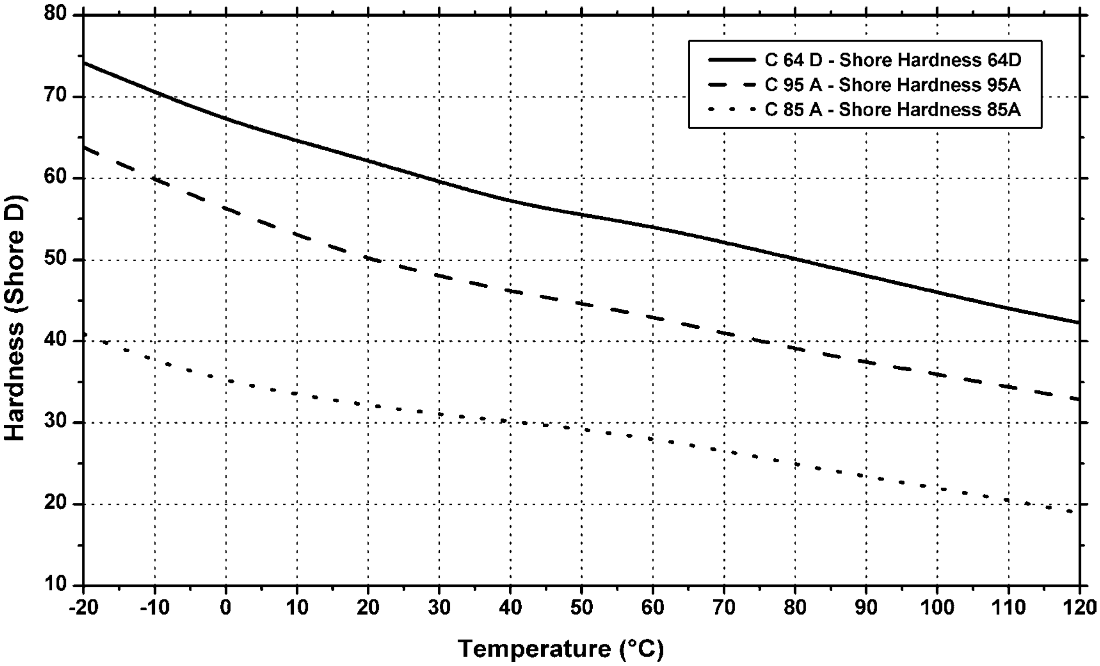


Figure 8.23. Hardness vs. temperature for BASF Elastollan® polyester TPU resins.

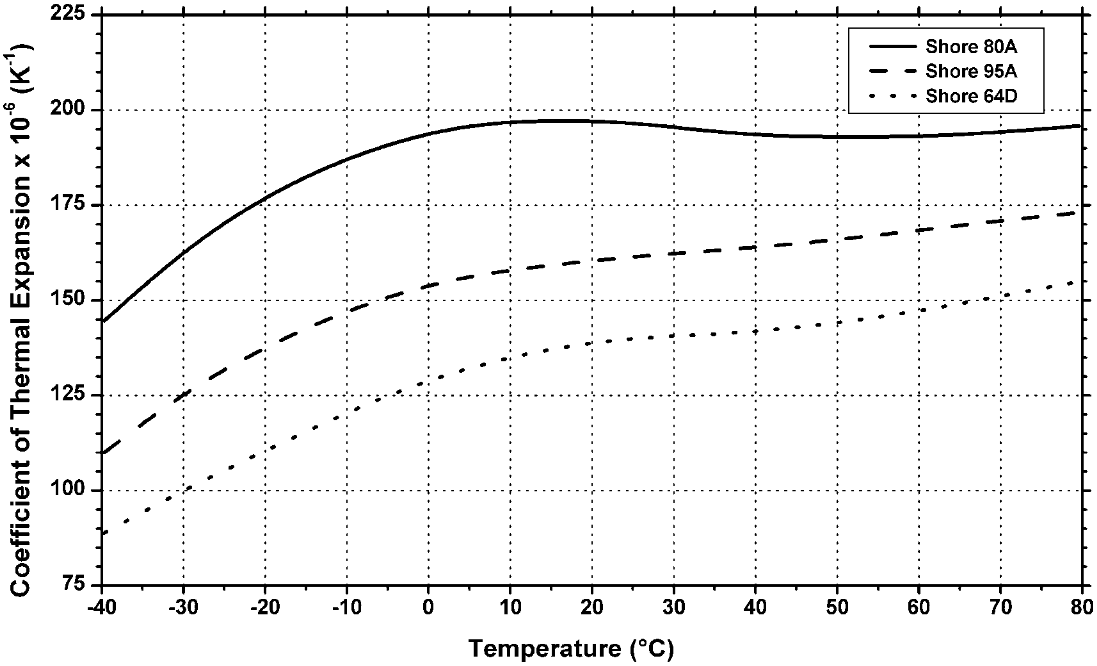


Figure 8.24. Coefficient of linear thermal expansion vs. temperature for BASF Elastollan® TPU resins.

8.3 Thermoplastic Copolyester Elastomers (TPE-Es or COPEs)

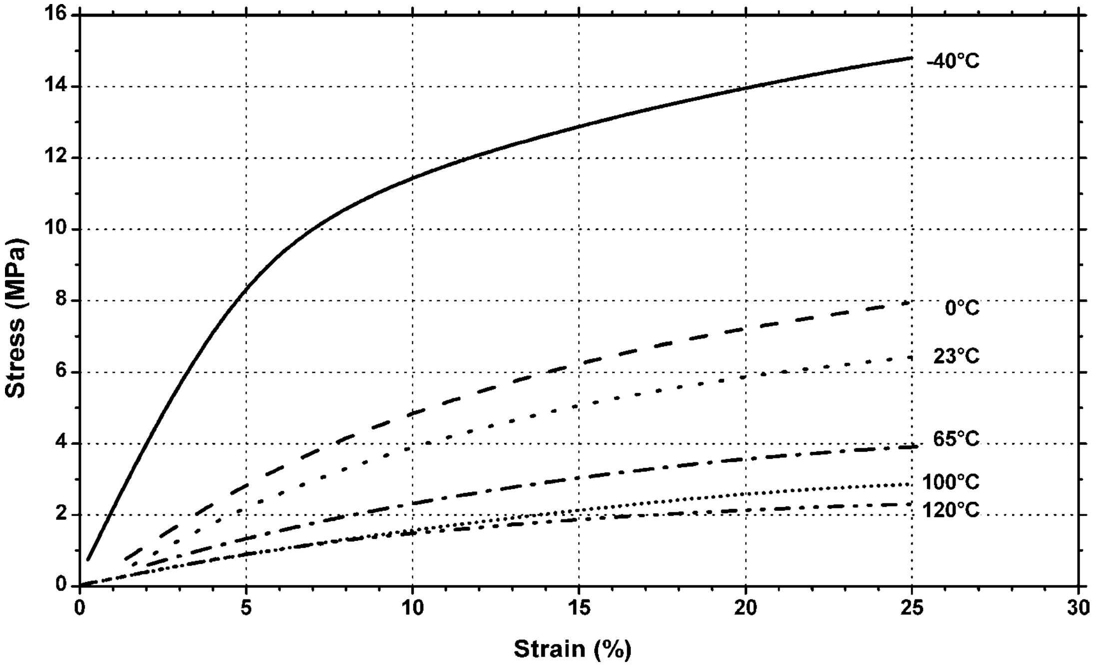


Figure 8.25. Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® G4075—general purpose, low modulus, Shore D40 TPE-E resin.

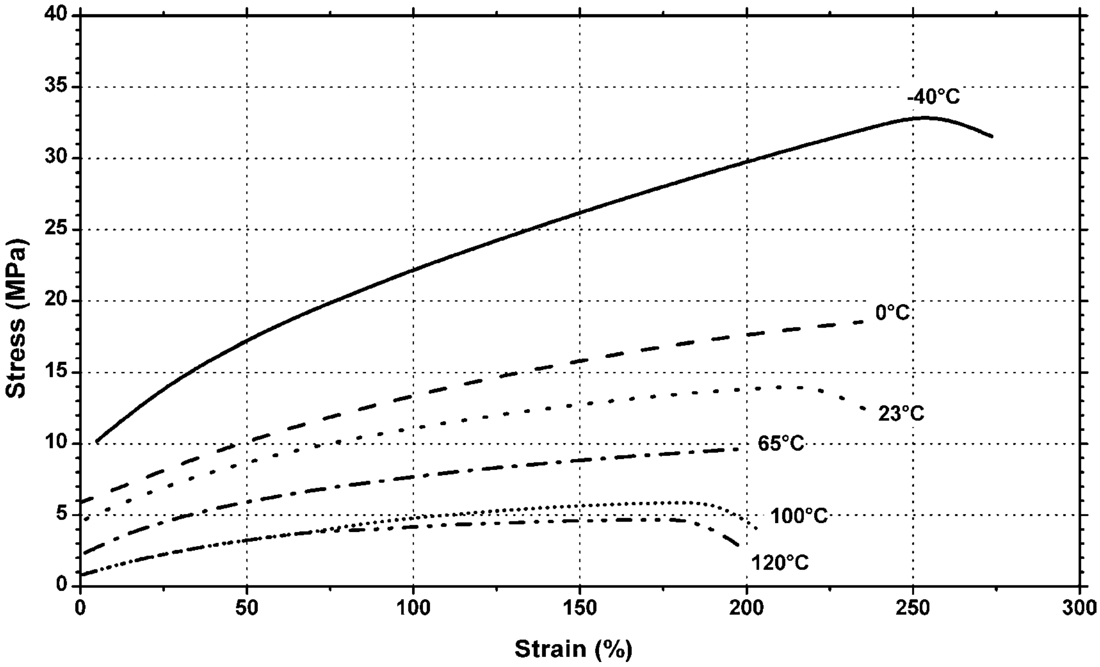


Figure 8.26. Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® G4075—general purpose, low modulus, Shore D40 TPE-E resin.

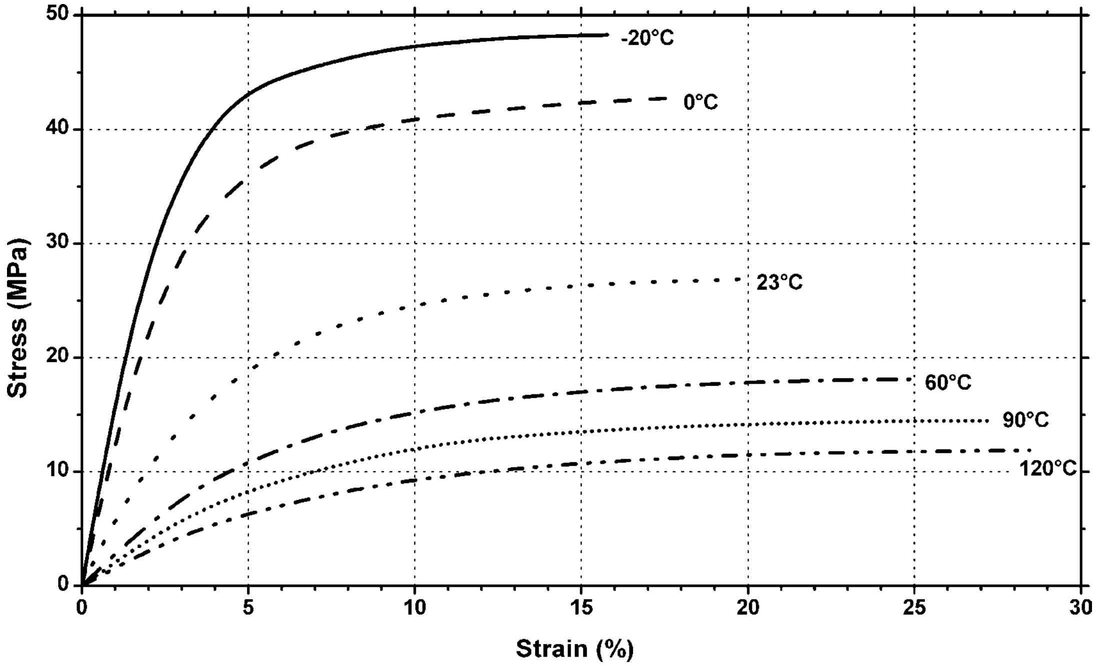


Figure 8.27. Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 7246—high performance, high modulus, Shore D72 TPE-E resin.

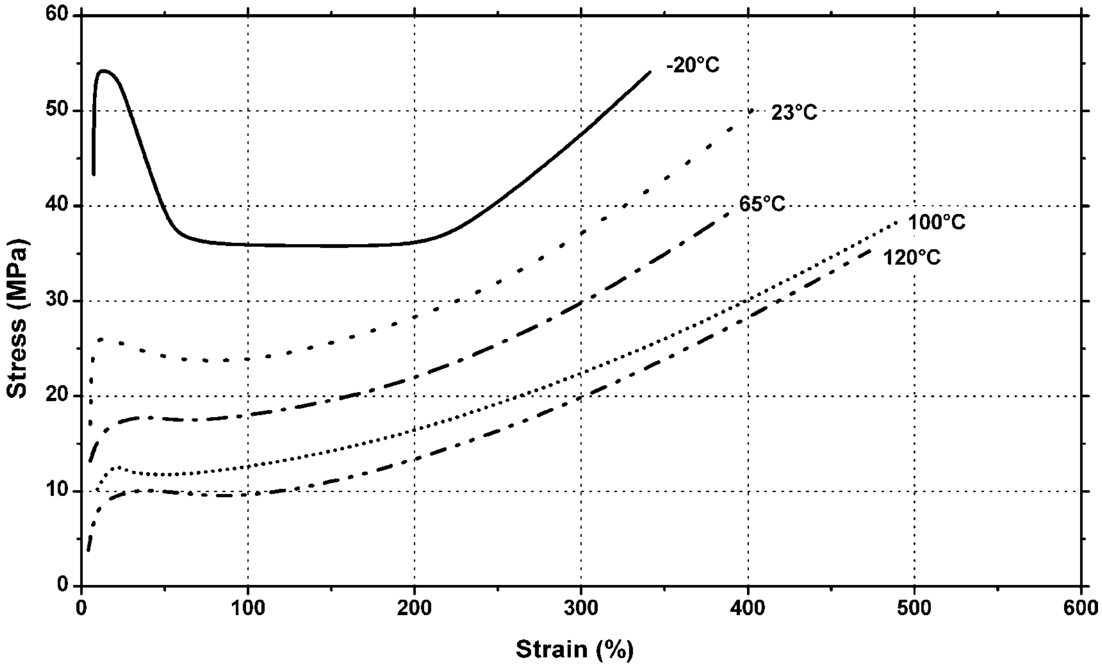


Figure 8.28. Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 7246—high performance, high modulus, Shore D72 TPE-E resin.

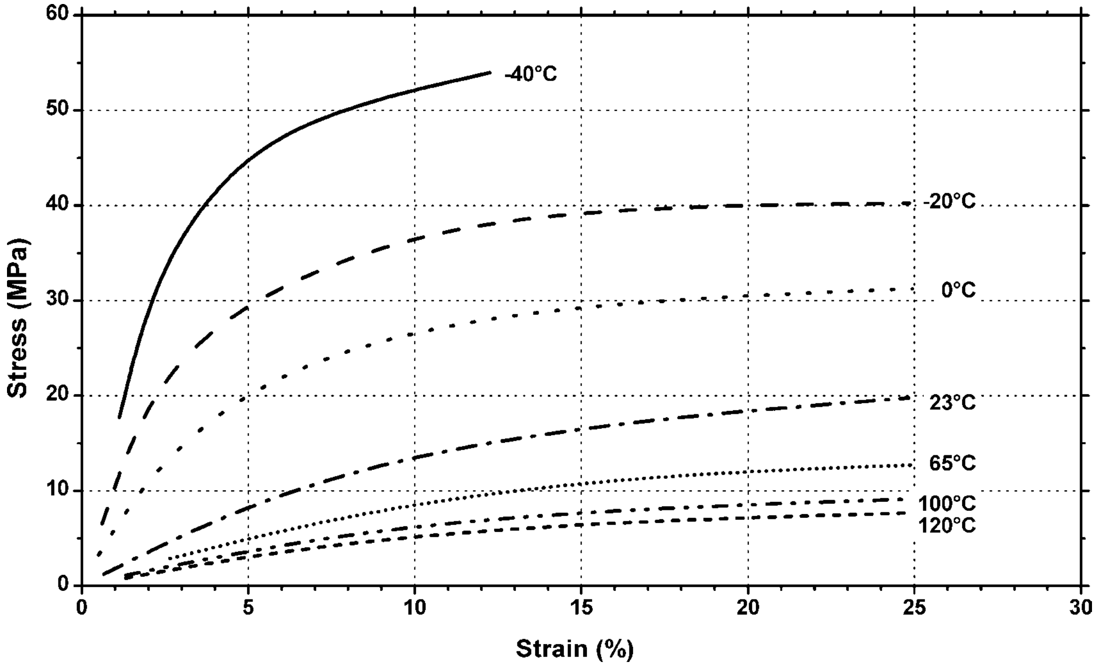


Figure 8.29. Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 6356—high performance, medium-high modulus, Shore D63 TPE-E resin.

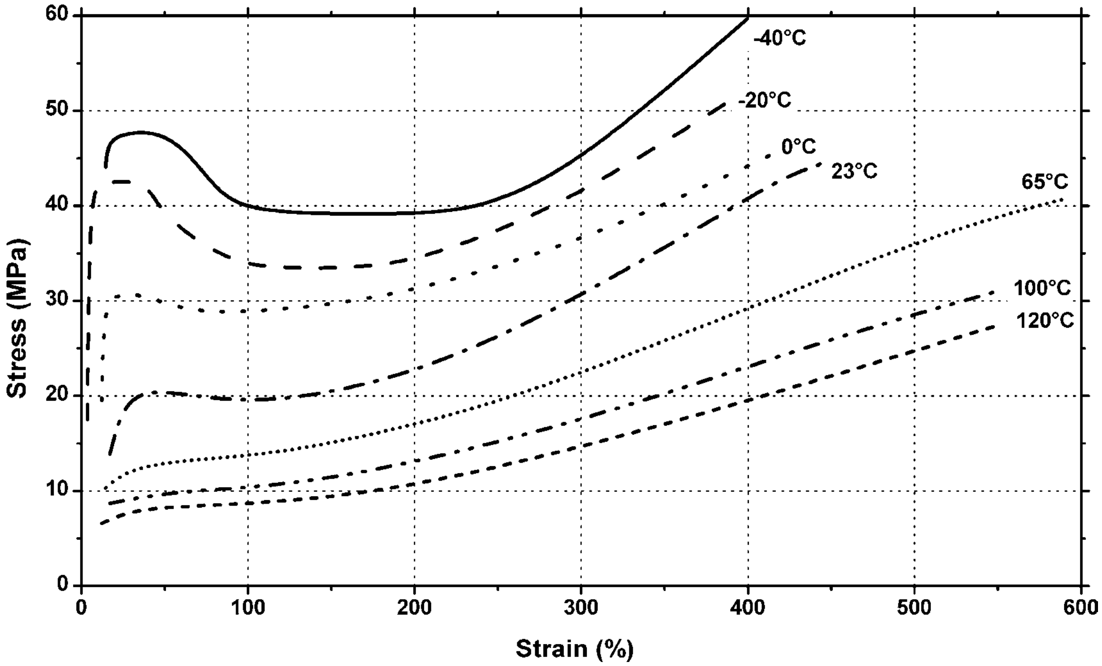


Figure 8.30. Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 6356—high performance, medium-high modulus, Shore D63 TPE-E resin.

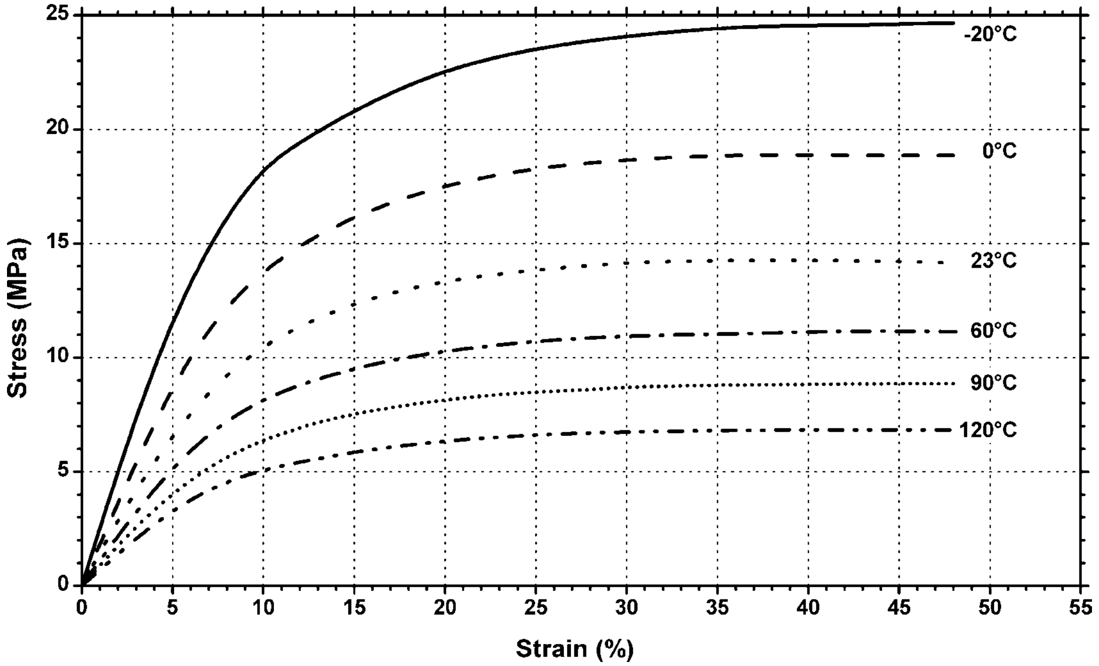


Figure 8.31. Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 5556—high performance, medium-high modulus, Shore D55 TPE-E resin.

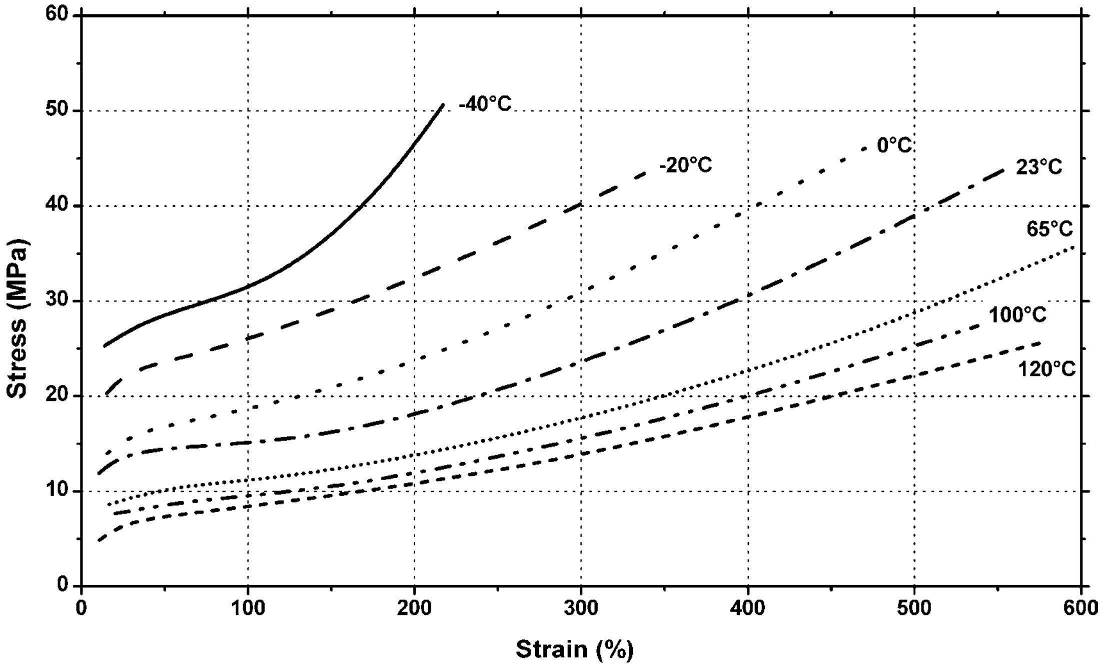


Figure 8.32. Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 5556—high performance, medium-high modulus, Shore D55 TPE-E resin.

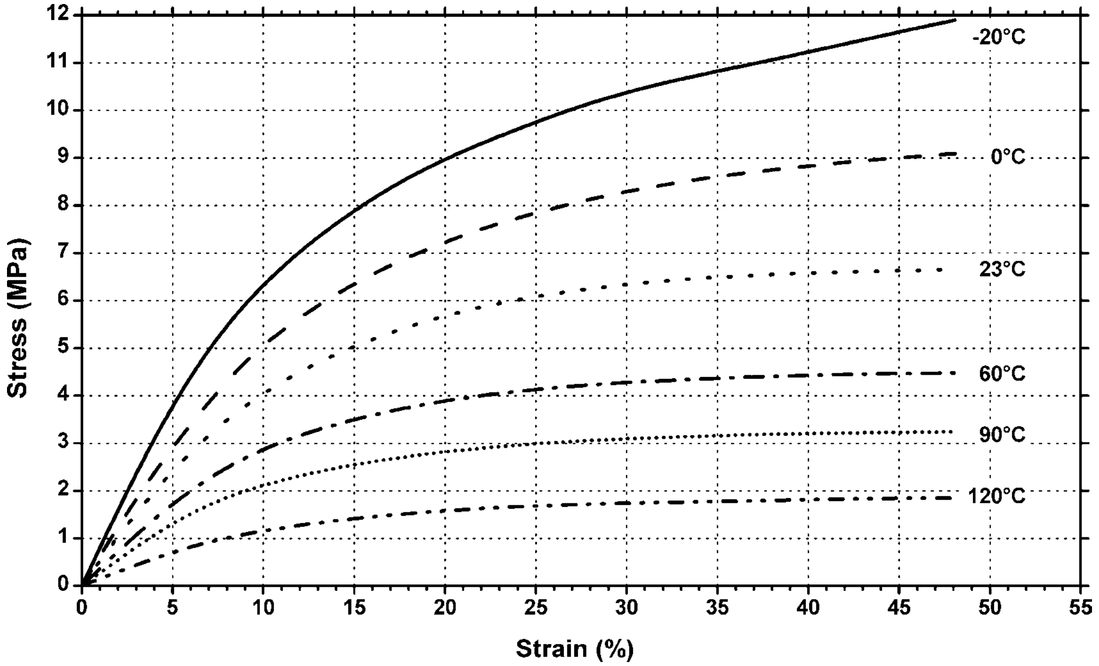


Figure 8.33. Stress vs. strain at various temperatures (low strain) for DuPont Hytrel® 4056—high performance, low modulus, Shore D40 TPE-E resin.

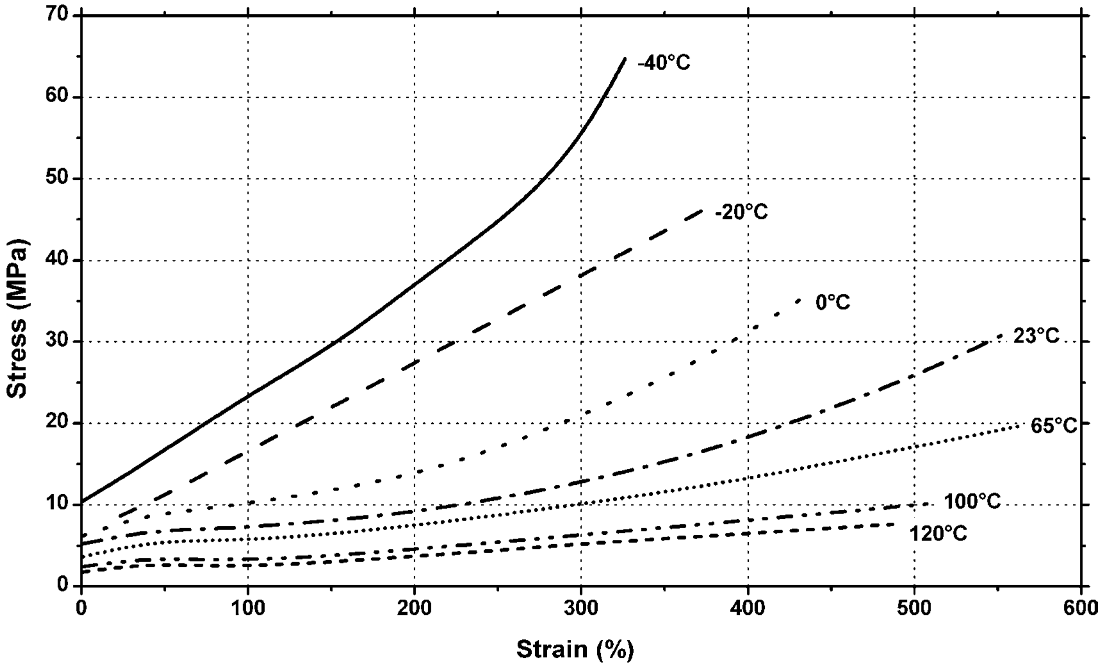


Figure 8.34. Stress vs. strain at various temperatures (high strain) for DuPont Hytrel® 4056—high performance, low modulus, Shore D40 TPE-E resin.

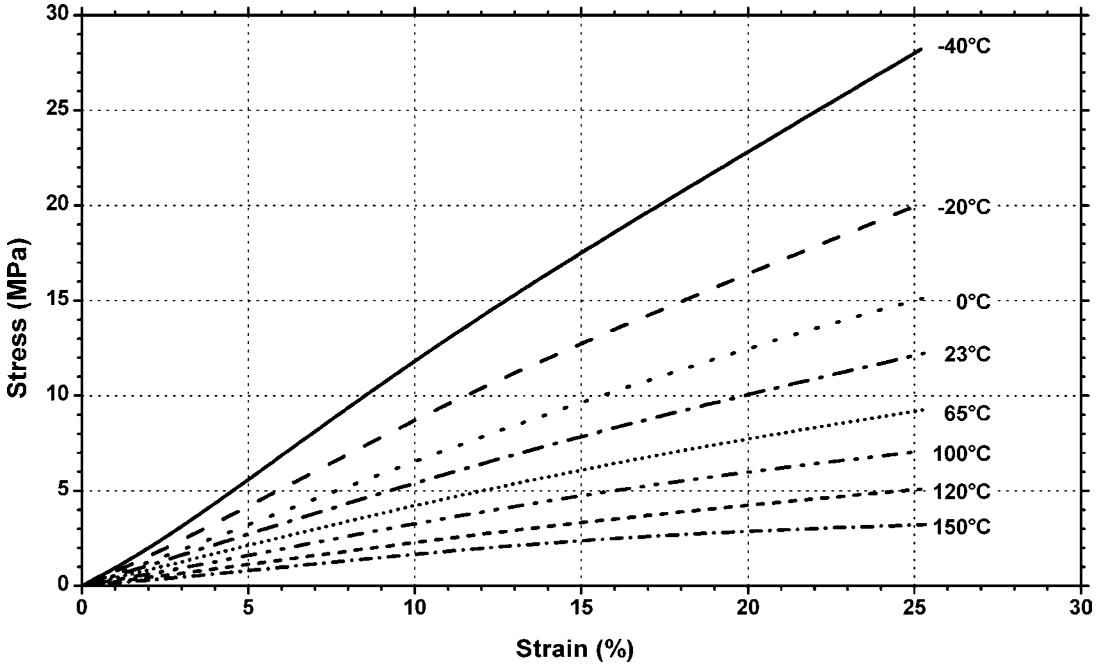


Figure 8.35. Stress vs. strain at various temperatures in compression for DuPont Hytrel® G4075—general purpose, low modulus, Shore D40 TPE-E resin.

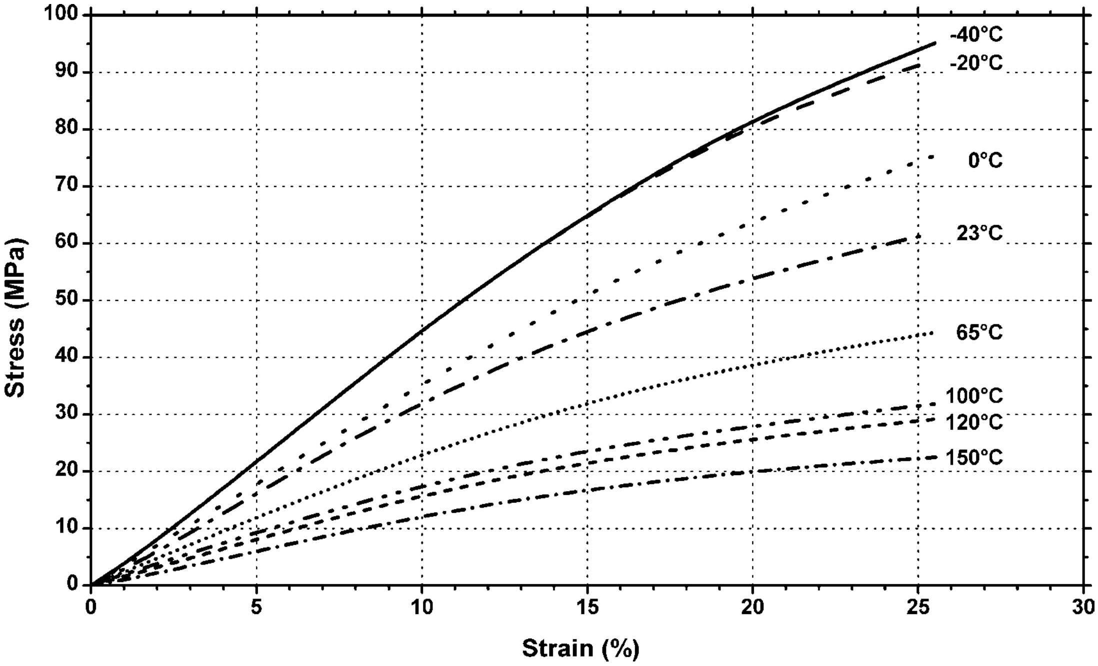


Figure 8.36. Stress vs. strain at various temperatures in compression for DuPont Hytrel® 7246—high performance, high modulus, Shore D72 TPE-E resin.

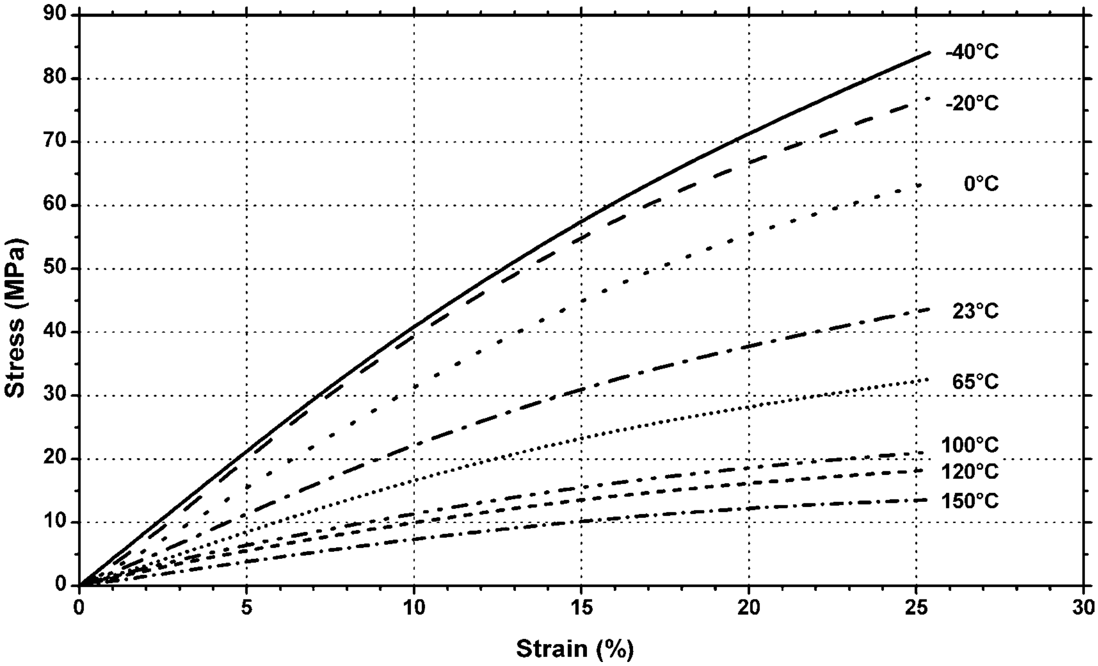


Figure 8.37. Stress vs. strain at various temperatures in compression for DuPont Hytrel® 6356—high performance, medium-high modulus, Shore D63 TPE-E resin.

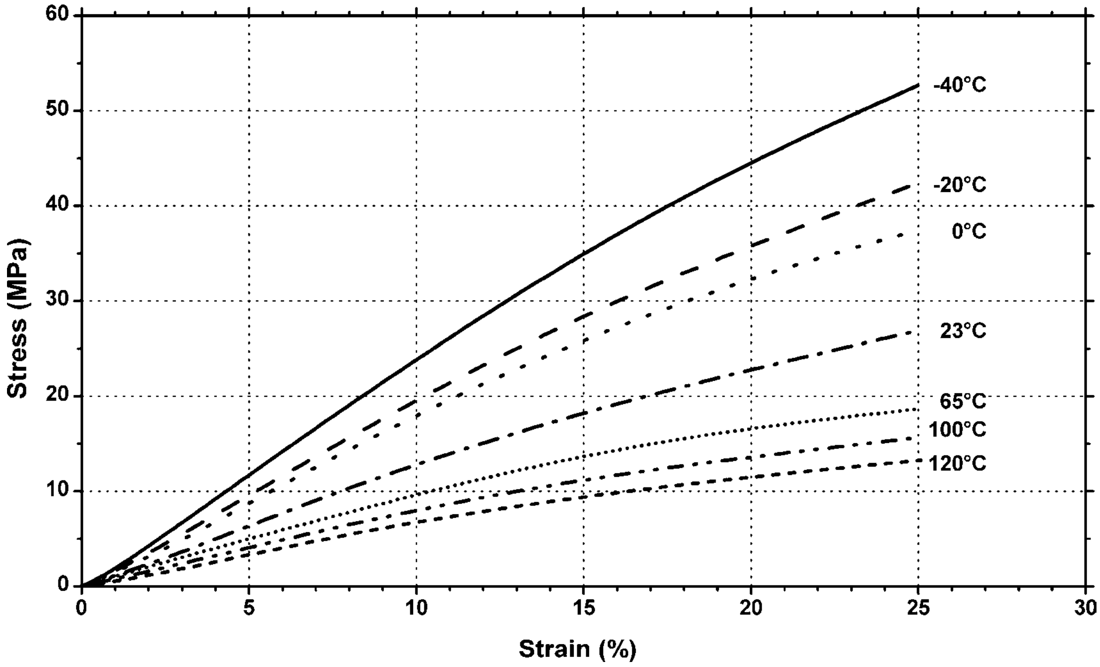


Figure 8.38. Stress vs. strain at various temperatures in compression for DuPont Hytrel® 5556—high performance, medium-high modulus, Shore D55 TPE-E resin.

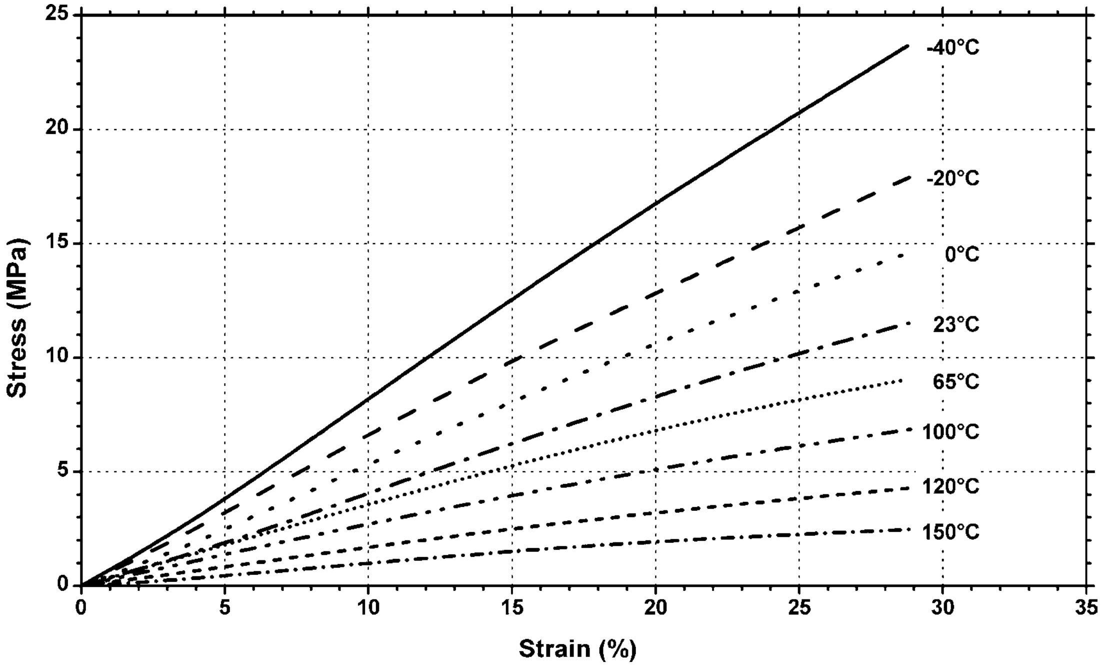


Figure 8.39. Stress vs. strain at various temperatures in compression for DuPont Hytrel® 4056—high performance, low modulus, Shore D40 TPE-E resin.

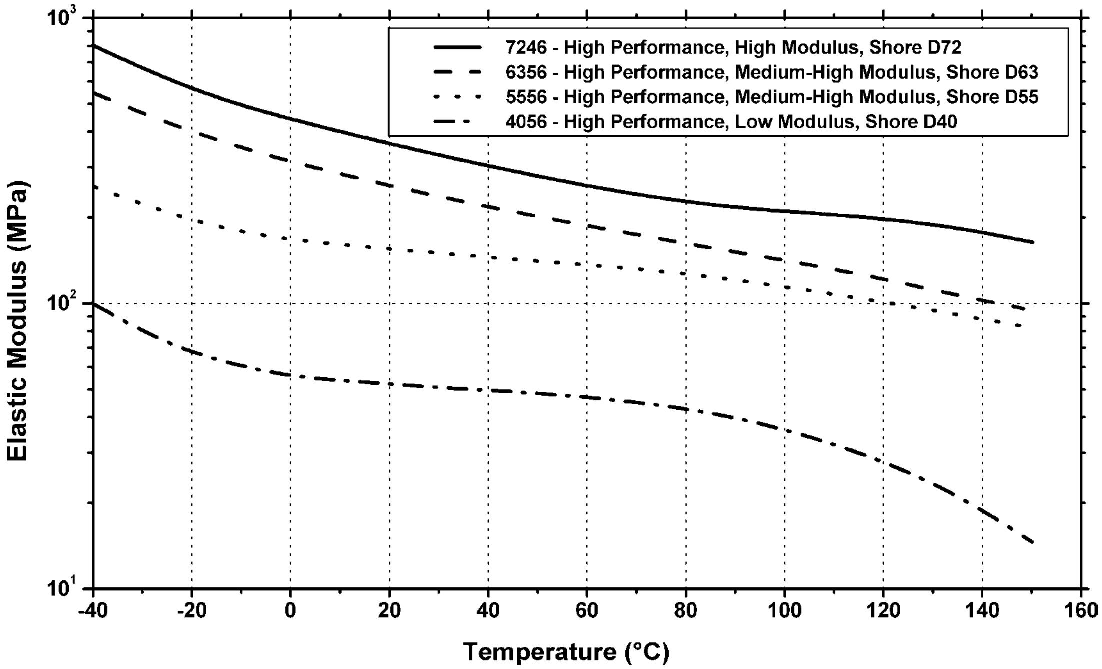


Figure 8.40. Elastic modulus in compression vs. temperature for DuPont Hytrel® TPE-E resins.

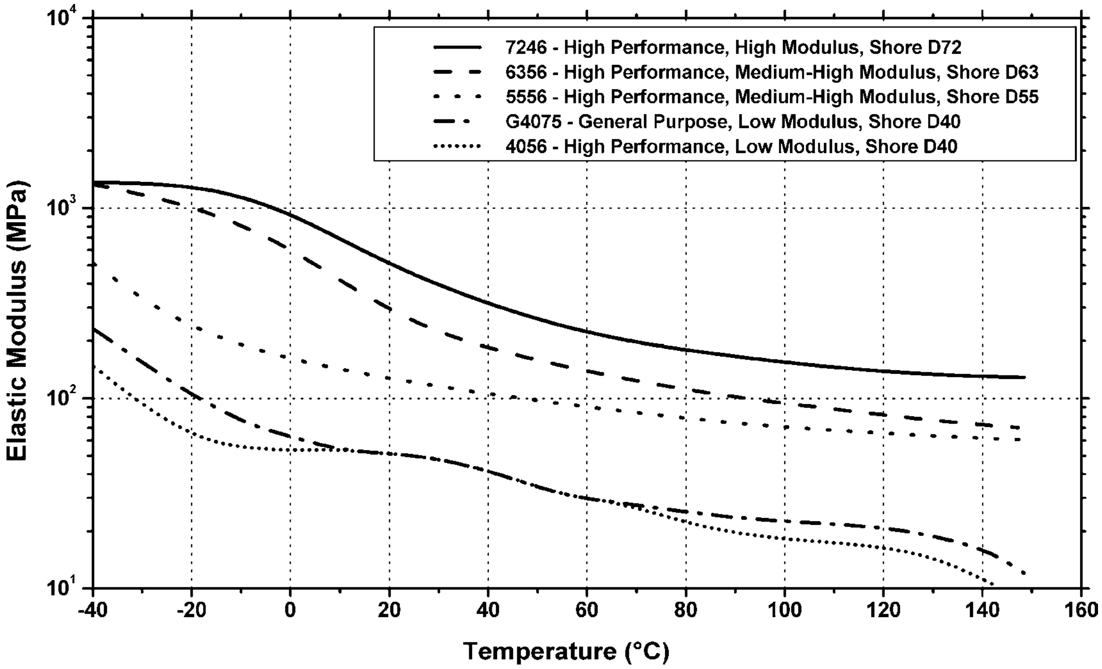


Figure 8.41. Elastic modulus vs. temperature for DuPont Hytrel® TPE-E resins.

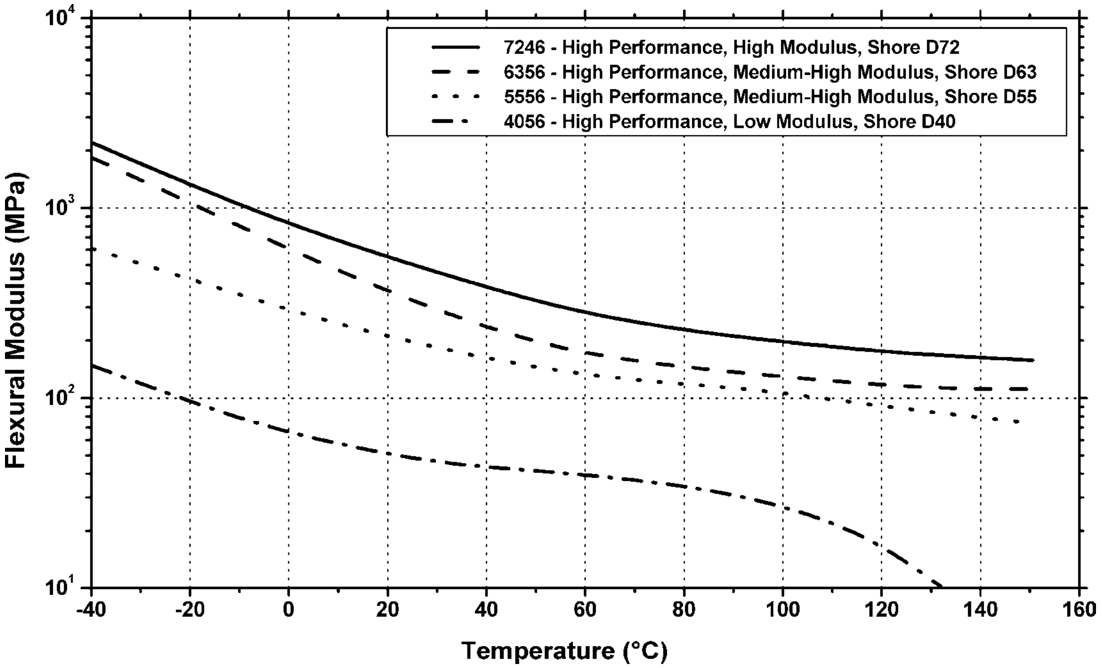


Figure 8.42. Flexural modulus vs. temperature for DuPont Hytrel® TPE-E resins.

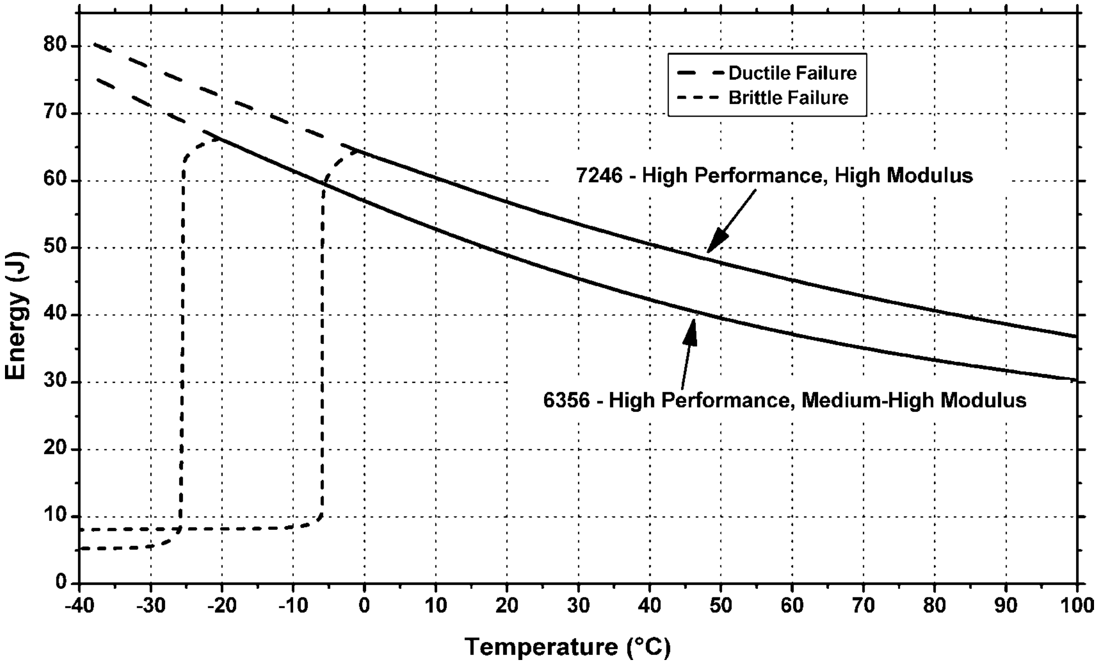


Figure 8.43. Dropped weight impact failure energy vs. temperature for DuPont Hytrel® TPE-E resins.

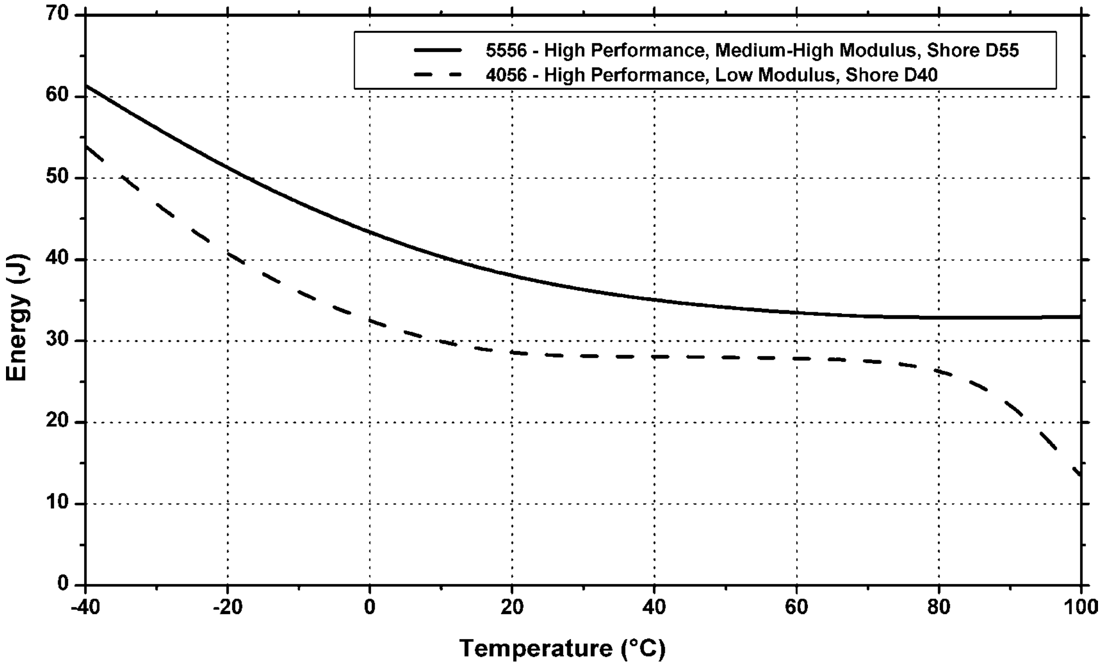


Figure 8.44. Dropped weight impact failure energy vs. temperature for additional DuPont Hytrel® TPE-E resins.

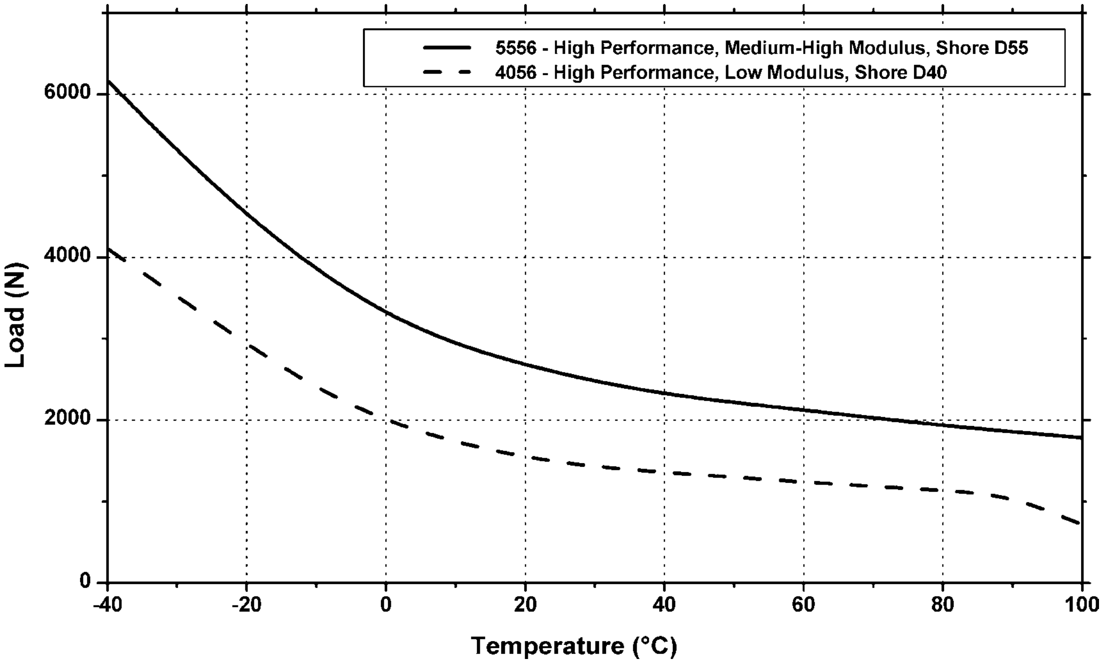


Figure 8.45. Dropped weight impact failure load vs. temperature for DuPont Hytrel® TPE-E resins.

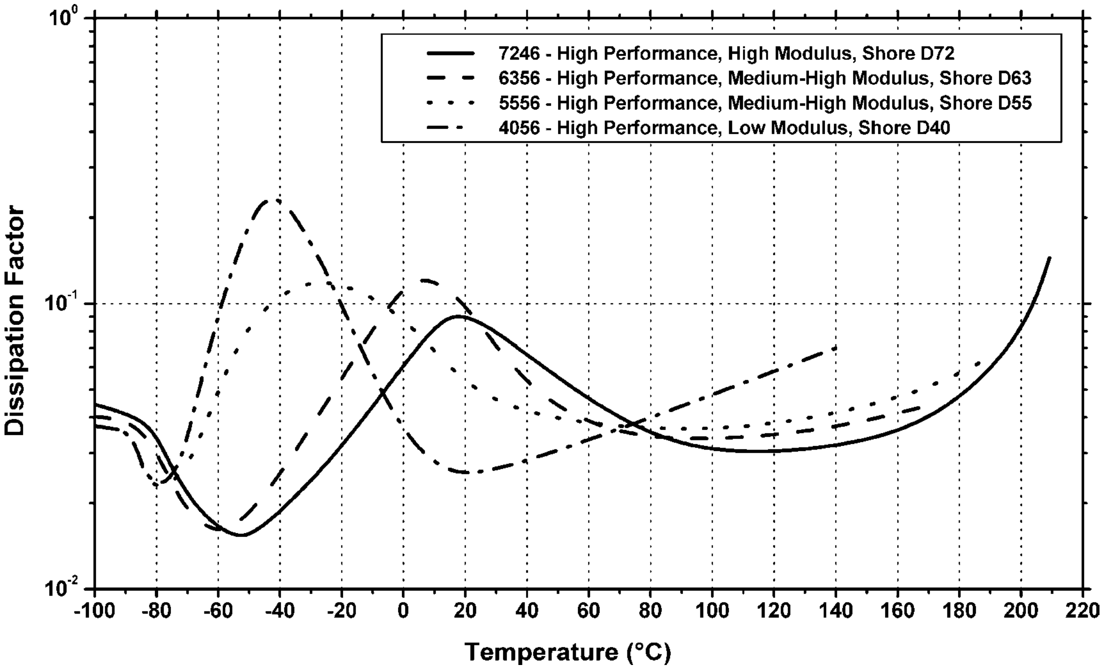


Figure 8.46. Dissipation factor vs. temperature for DuPont Hytrel® TPE-E resins.

8.4 Polyether Block Amide (PEBA) Thermoplastic Elastomers

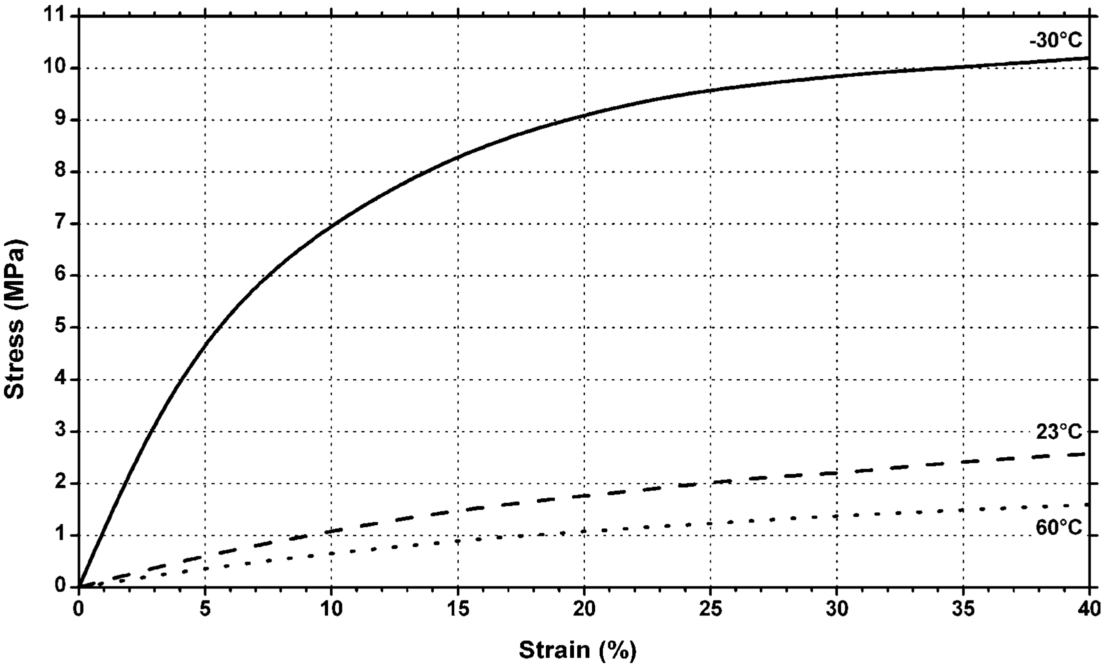


Figure 8.47. Stress vs. strain at various temperatures for Arkema Pebax® 2533 SN 01—Shore hardness 25 PEBA thermoplastic elastomer resin.

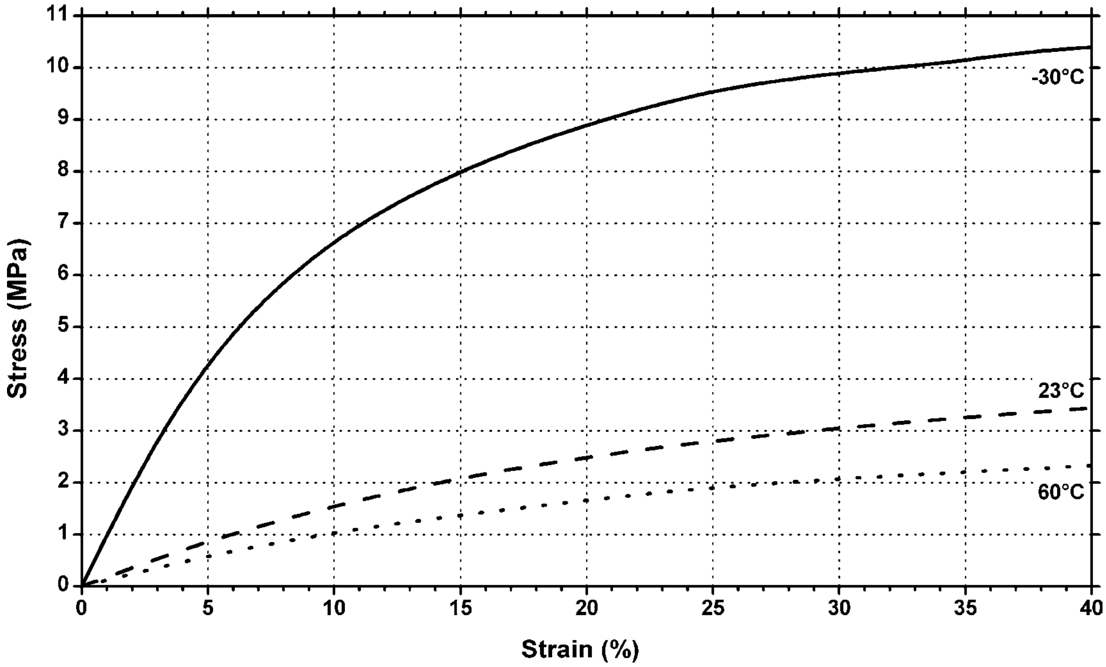


Figure 8.48. Stress vs. strain at various temperatures for Arkema Pebax® 3533 SN 01—Shore hardness 35 PEBA thermoplastic elastomer resin.

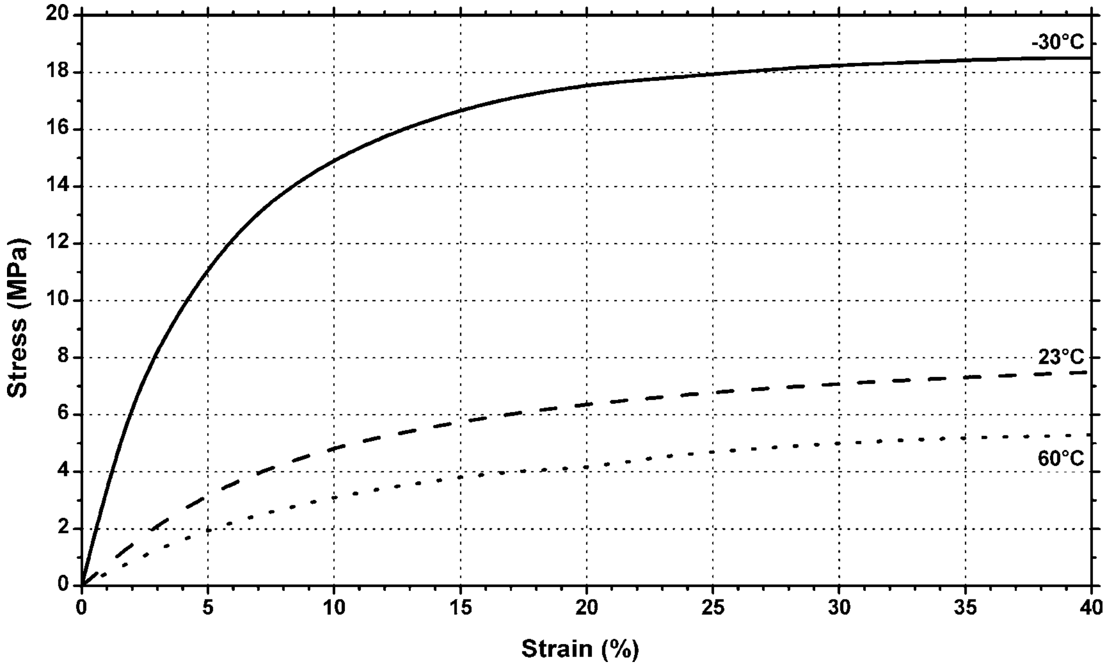


Figure 8.49. Stress vs. strain at various temperatures for Arkema Pebax® 4033 SN 01—Shore hardness 40 PEBA thermoplastic elastomer resin.

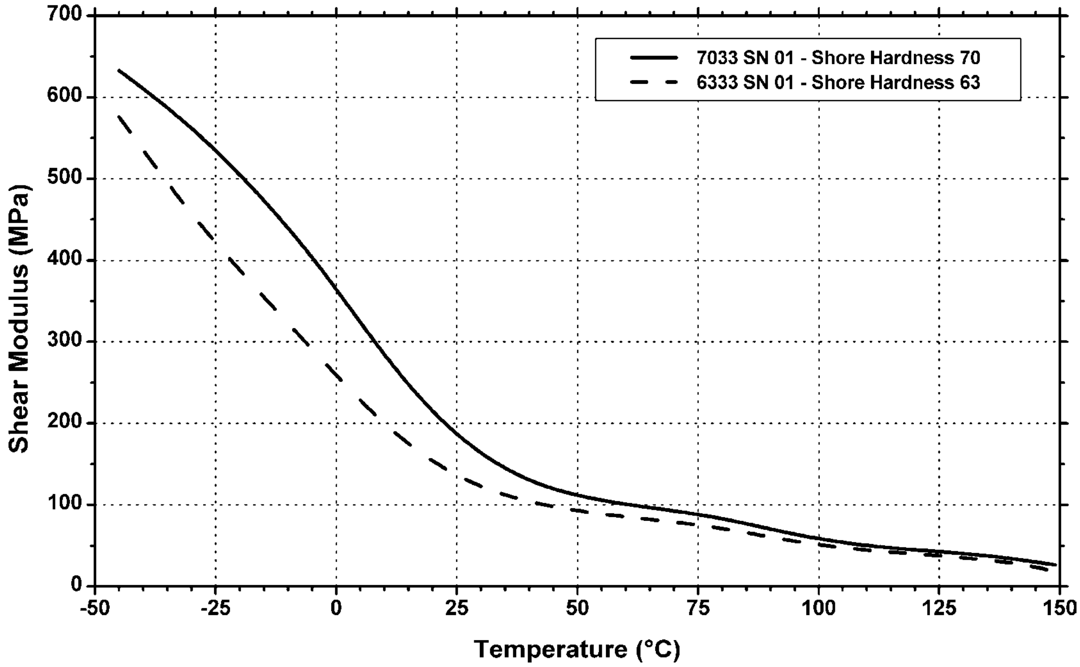


Figure 8.50. Shear modulus vs. temperature for Arkema Pebax® PEBA thermoplastic elastomer resins.

9 Fluoropolymers

9.1 Background

The following sections will briefly explain the structures and properties of various fluoropolymers. It is important to note that there are variations in most of these polymers. The most common variations are the molecular weight, which will affect the melting point to some extent, and the viscosity of the polymer above its melting point, properties that are important in determining processing conditions and use.

Traditionally, a fluoropolymer or fluoroplastic is defined as a polymer consisting of carbon (C) and fluorine (F) atoms. 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.

9.1.1 Polytetrafluoroethylene (PTFE)

Polytetrafluoroethylene polymer (PTFE) is an example of a linear fluoropolymer. Its structure in simplistic form is shown in Fig. 9.1.

Formed by the polymerization of tetrafluoroethylene (TFE), the (–CF_2–CF_2–) groups repeat many thousand 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 made up 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 (0.05–0.08, 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.

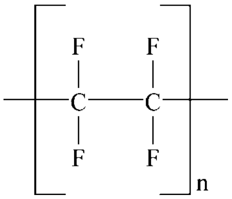


Figure 9.1. Chemical structure of PTFE.

The PTFE molecule is simple and quite ordered, and so it can align itself with other molecules or with 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. Generally, polymers made from two monomers are called copolymers, but fluoropolymer manufacturers call these grades modified homopolymer at below 1% by weight of the additional monomer. DuPont grades of this type are called *Teflon® NXT* resins. These modified granular PTFE materials retain the exceptional chemical, thermal, antistick, and low-friction properties of conventional PTFE resin, but offer some improvements.

- Ability to weld
- Improved permeation resistance
- Less creep
- Smoother, less porous surfaces
- Better high-voltage insulation

The copolymers described in the following sections contain significantly more of the non-TFE monomers.

9.1.2 Polyethylene Chlorotrifluoroethylene (ECTFE)

Polyethylene chlorotrifluoroethylene (ECTFE) is a copolymer of ethylene and chlorotrifluoroethylene. Figure 9.2 shows the molecular structure of ECTFE.

This simplified structure shows that the ratio of the monomers is 1:1 and strictly alternating, which is the desirable proportion. Commonly known by the tradename, Halar®, ECTFE is an expensive, melt processable, semicrystalline, whitish semiopaque thermoplastic with good chemical resistance, and barrier properties. It also has good tensile and creep properties and good high-frequency electrical characteristics. Applications include chemically resistant linings, valve and pump components, barrier films, and release/vacuum bagging films.

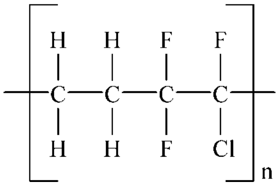


Figure 9.2. Chemical structure of ECTFE.

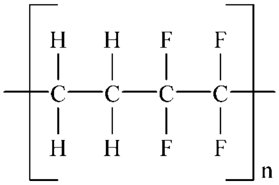


Figure 9.3. Chemical structure of ETFE.

9.1.3 Polyethylene Tetrafluoroethylene (ETFE)

Polyethylene tetrafluoroethylene (ETFE) is a copolymer of ethylene and tetrafluoroethylene. The basic molecular structure of ETFE is shown in Fig. 9.3.

The structure in Fig. 9.3 shows alternating units of TFE and ethylene. While this polymer can be readily made, in many grades of ETFE the ratio of the two monomers are varied slightly to optimize properties for specific end uses.

ETFE is a fluoroplastic with excellent electrical and chemical properties. It also has excellent mechanical properties. ETFE is specially 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 fluorinated-ethylene-propylene (FEP). ETFE has the following characteristic features:

- Excellent resistance to extremes of temperature
- A working temperature range from –200°C to 150°C
- Excellent chemical resistance

Mechanical strength of ETFE is good with excellent tensile strength and elongation and has superior physical properties compared to most fluoropolymers.

With 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

9.1.4 Fluorinated-Ethylene-Propylene (FEP)

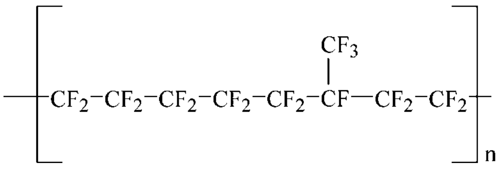
If one of the fluorine atoms on tetrafluoroethylene is replaced with a trifluoromethyl group ($–CF_3$) then the new monomer is called hexafluoropropylene (HFP). Polymerization of monomers (HFP) and TFE yield a different fluoropolymer, called FEP. The number of HFP groups is typically 13% by weight or less and its structure is shown in Fig. 9.4.

The effect of using HFP is to put a ‘bump’ along the polymer chain. This bump disrupts the crystallization of the FEP, which has atypical as-polymerized crystallinity of 70% versus 92%–98% for PTFE. It also lowers its melting point. The reduction of the melting point depends mainly 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. 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.

9.1.5 Perfluoro-Alkoxy (PFA)

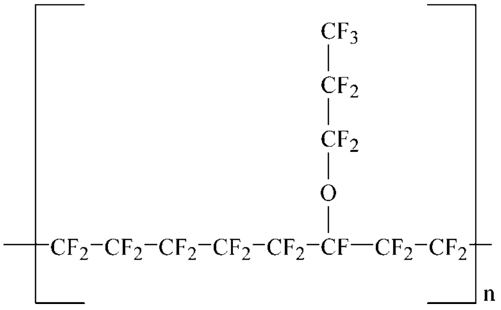
Making a more dramatic change in the side-group than that done in making FEP, chemists put a perfluoroalkoxy group on the polymer chain. This group is signified as $–O–R_f$, where R_f can be any number of totally fluorinated carbons. A typical one is perfluoropropyl ($–O–CF_2–CF_2–CF_3$). These polymers are called PFA and the perfluoroalkylvinylether group is typically added at 3.5% or less. Another common perfluoroalkoxy group is perfluoromethylvinylether ($–O–CH_3$) making a polymer called MFA. A structure of PFA is shown in Fig. 9.5.

The large side group reduces the crystallinity drastically. The melting point is generally between 305 and 310°C (581–590°F) depending on the molecular weight. The melt viscosity is also dramatically dependent on the molecular weight. Since PFA is also perfluorinated like FEP, its high chemical resistance, low surface energy, and good electrical insulation properties are retained.



$$-\!\left[CF_2-CF_2-CF_2-CF_2-CF_2-\overset{\displaystyle CF_3}{\overset{|}{C}F}-CF_2-CF_2 \right]_n\!-$$

Figure 9.4. Chemical structure of FEP.



$$-\!\left[CF_2-CF_2-CF_2-CF_2-CF_2-\overset{\displaystyle CF_3}{\overset{|}{\overset{\displaystyle CF_2}{\overset{|}{\overset{\displaystyle CF_2}{\overset{|}{\overset{\displaystyle O}{\overset{|}{C}F}}}}}}}-CF_2-CF_2 \right]_n\!-$$

Figure 9.5. Chemical structure of PFA.

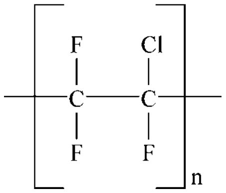
9.1.6 Polychlorotrifluoroethylene (PCTFE)

PCTFE is a homopolymer of chlorotrifluoroethylene, characterized by the following structure shown in Fig. 9.6.

The addition of one chlorine atom contributes to lowering of 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 also be used at low temperatures.

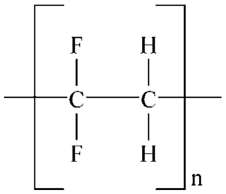
9.1.7 Polyvinylidene-Fluoride (PVDF)

The polymers made from 1,1-di-fluoro-ethene (or vinylidene fluoride) are known as PVDF—polyvinylidene fluoride. They are resistant to oils and fats, water and steam, and gas and odors, 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 chiefly used in the production and coating of equipments used in aggressive environments, and where high levels of mechanical and thermal resistance are required. It is also 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 Fig. 9.7.



$$-\!\left[\underset{\displaystyle F}{\underset{|}{\overset{\displaystyle F}{\overset{|}{C}}}}-\underset{\displaystyle F}{\underset{|}{\overset{\displaystyle Cl}{\overset{|}{C}}}} \right]_n\!-$$

Figure 9.6. Chemical structure of PCTFE.



$$-\!\left[\underset{\displaystyle F}{\underset{|}{\overset{\displaystyle F}{\overset{|}{C}}}}-\underset{\displaystyle H}{\underset{|}{\overset{\displaystyle H}{\overset{|}{C}}}} \right]_n\!-$$

Figure 9.7. Chemical structure of PVDF.

One of the tradenames of PVDF is Kynar®. The alternating CH_2 and CF_2 groups along the polymer chain provide a unique polarity that influences its 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 processable
- 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

9.1.8 THV™

THV™ is a polymer of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride. It is made by 3M Dyneon. It has the following properties:

- Low processing temperature
- Bonds to elastomers and hydrocarbon plastics
- Good flexibility
- Permeation resistance
- Excellent clarity and light transmission

There are no multipoint charts available, but some tabular data is included in Chapter 11.

9.1.9 HTE

HTE is a polymer of hexafluoropropylene, tetrafluoroethylene, and ethylene. It is made by 3M Dyneon. It has the following properties:

- Broad processing range
- Very good chemical resistance
- Permeation resistance
- High light transmission in visible and UV regions
- Excellent dimensional stability and toughness
- Good electrical properties

There are no multipoint charts available, but included here for completeness.

9.1.10 Fluoroplastic Melting Points

The melting point ranges of the fluoropolymers are given in Table 9.1. These are useful in determining minimum processing temperatures (usually 25°C above the melt point) and maximum use temperatures (generally 25–40°C below the melting

Table 9.1. Melting Point Ranges of Various Fluoroplastics

Fluoroplastic	Melting Point °C
Polytetrafluoroethylene (PTFE)	320–340
Polyethylene chlorotrifluoroethylene (ECTFE)	240
Polyethylene tetrafluoroethylene (ETFE)	255–280
Fluorinated-ethylene-propylene (FEP)	260–270
Perfluoro alkoxy (PFA)	302–310
Perfluoro alkoxy (MFA)	280–290
Polychlorotrifluoroethylene (PCTFE)	210–212
Polyvinylidene fluoride (PVDF)	155–170
THV™	115–235
HTE	155–215

points). Graphs showing the properties of fluoropolymer-based plastics as a function of temperature, moisture, and other factors are illustrated in Sections 9.2–9.8.

9.2 Polytetrafluoroethylene (PTFE)

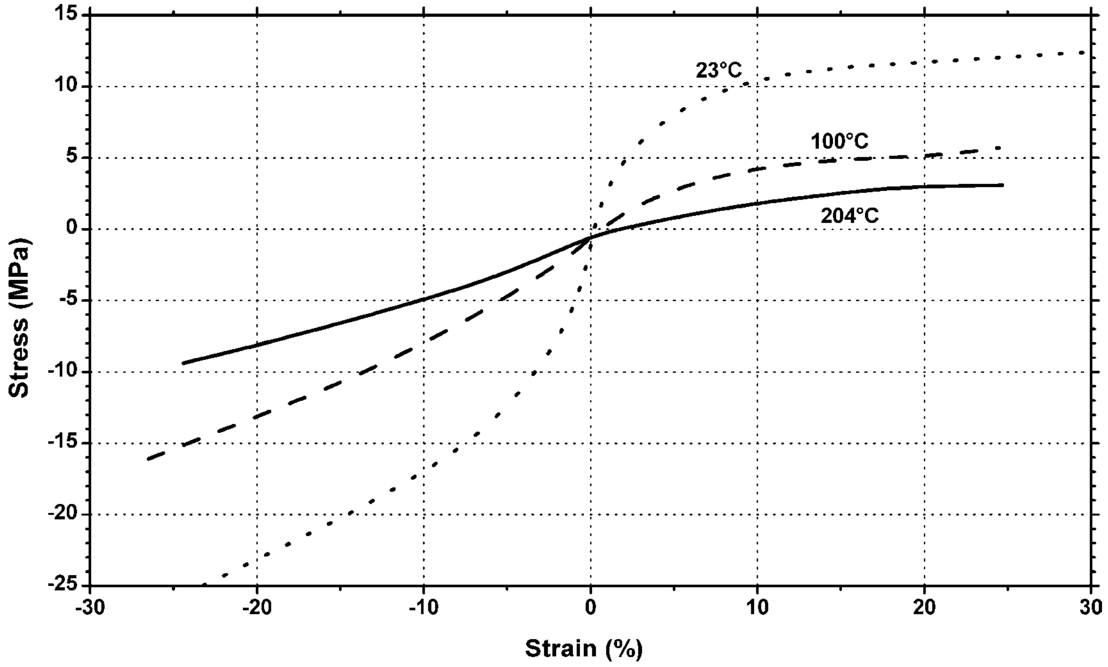


Figure 9.8. Stress vs. strain in tension and compression for DuPont Co. General Purpose Teflon® PTFE resin.

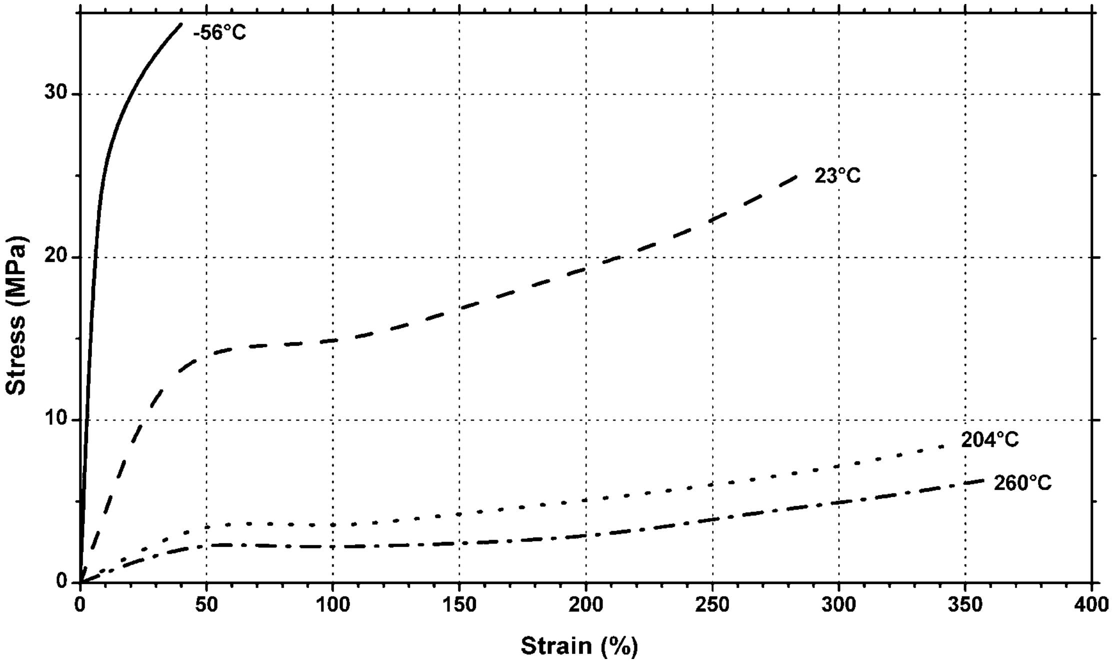


Figure 9.9. Stress vs. strain at high strain rate for DuPont Co. General Purpose Teflon® PTFE resin.

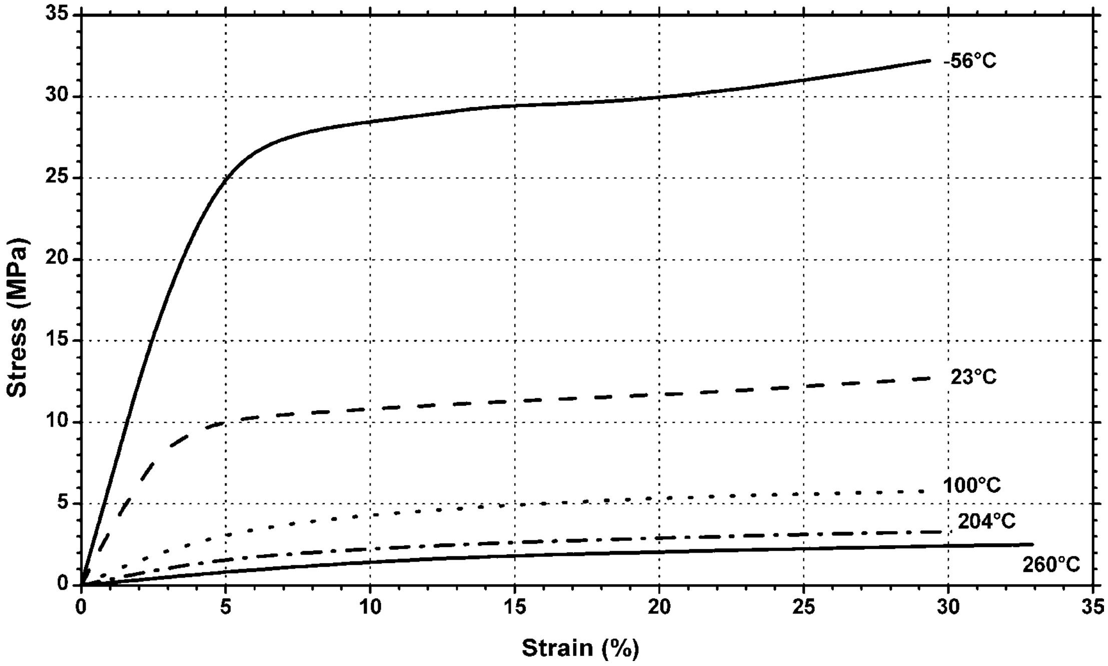


Figure 9.10. Stress vs. strain at low strain rate for DuPont Co. General Purpose Teflon® PTFE resin.

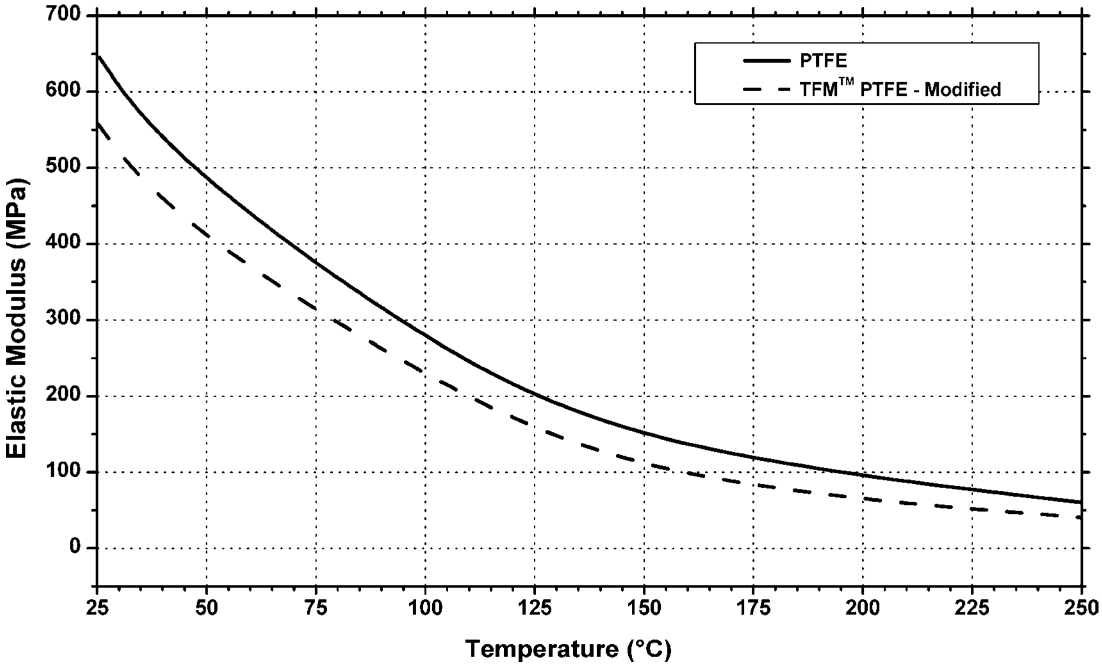


Figure 9.11. Young's modulus vs. temperature for 3M Dyneon™ PTFE resins.

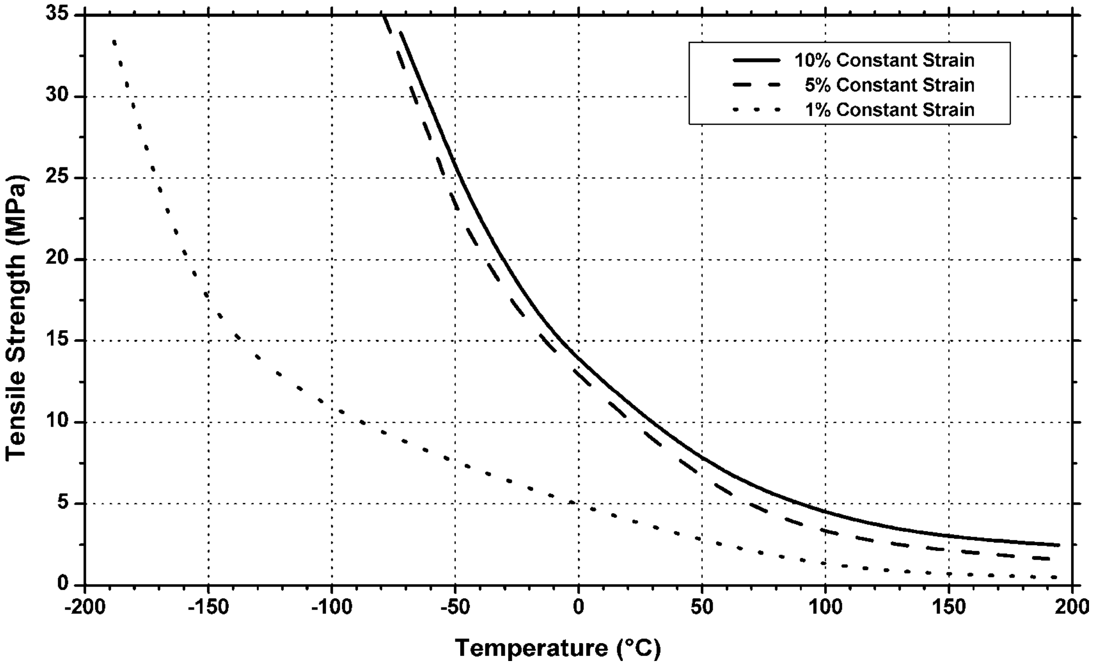


Figure 9.12. Tensile strength vs. temperature for DuPont Co. General Purpose Teflon® PTFE resin.

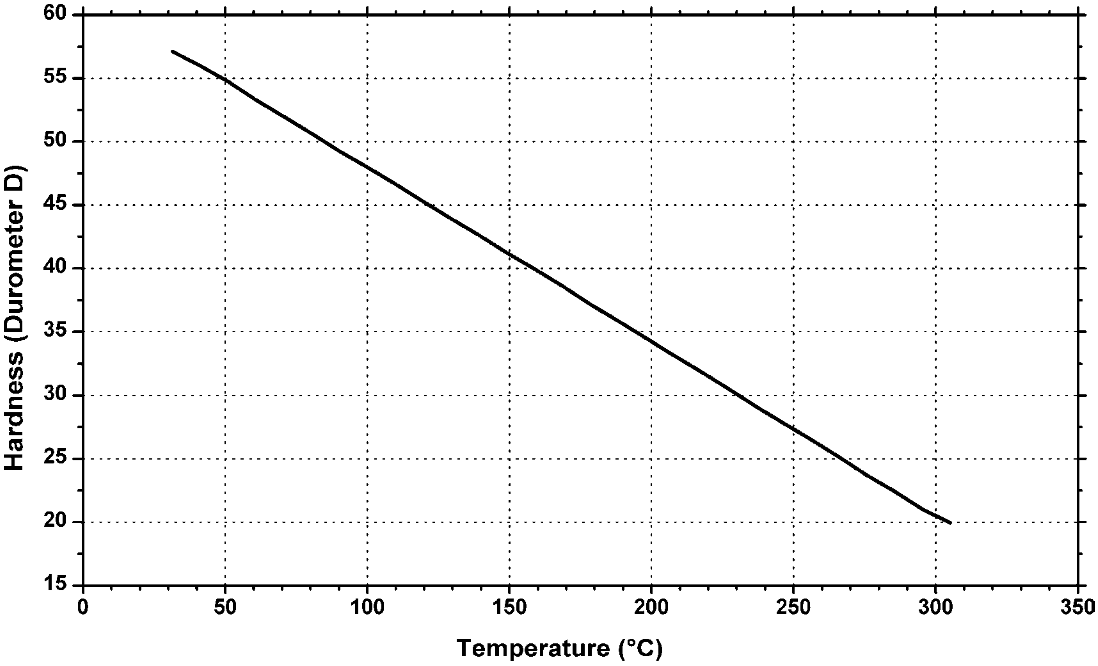


Figure 9.13. Hardness vs. temperature for DuPont Co. General Purpose Teflon® PTFE resin.

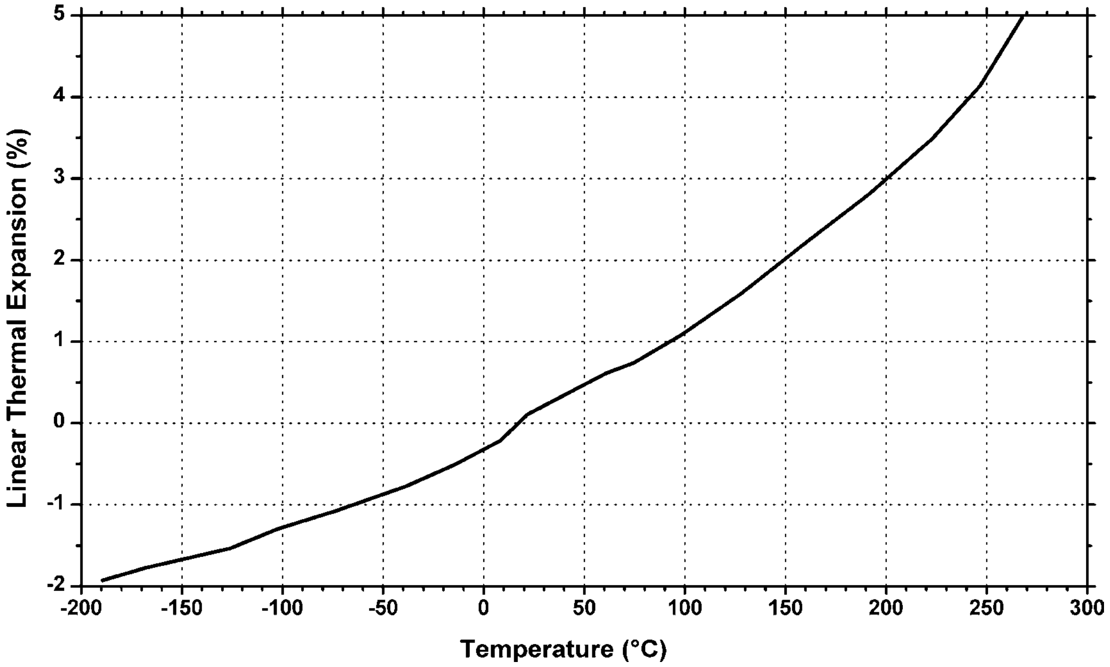


Figure 9.14. Linear thermal expansion vs. temperature for DuPont Co. General Purpose Teflon® PTFE resin.

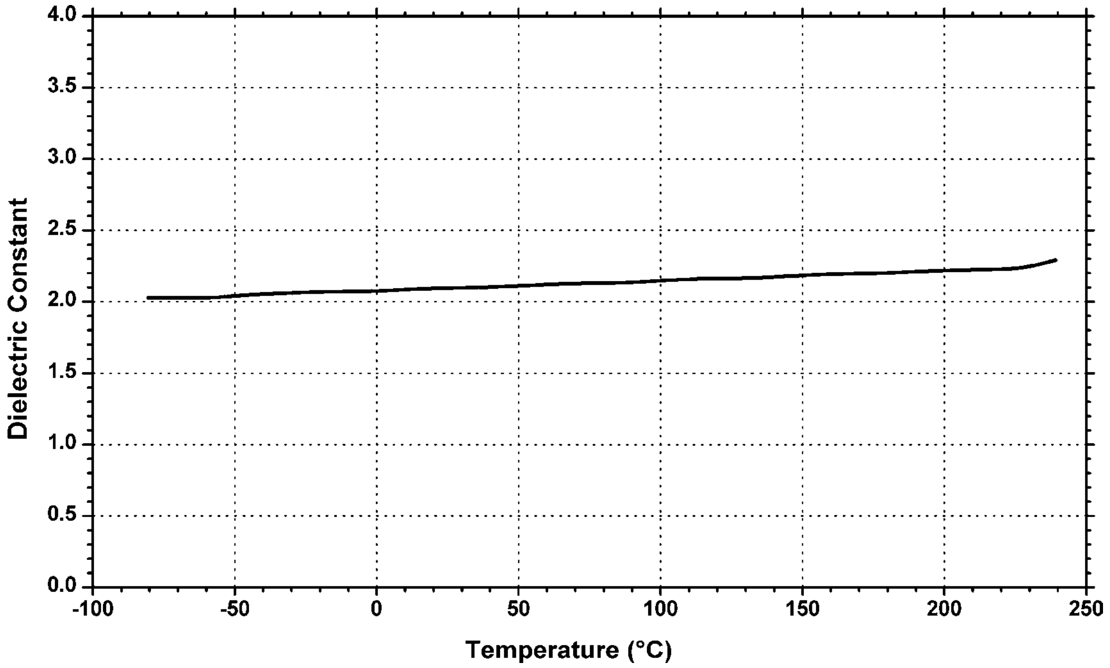


Figure 9.15. Dielectric constant vs. temperature for DuPont Co. General Purpose Teflon® PTFE resin.

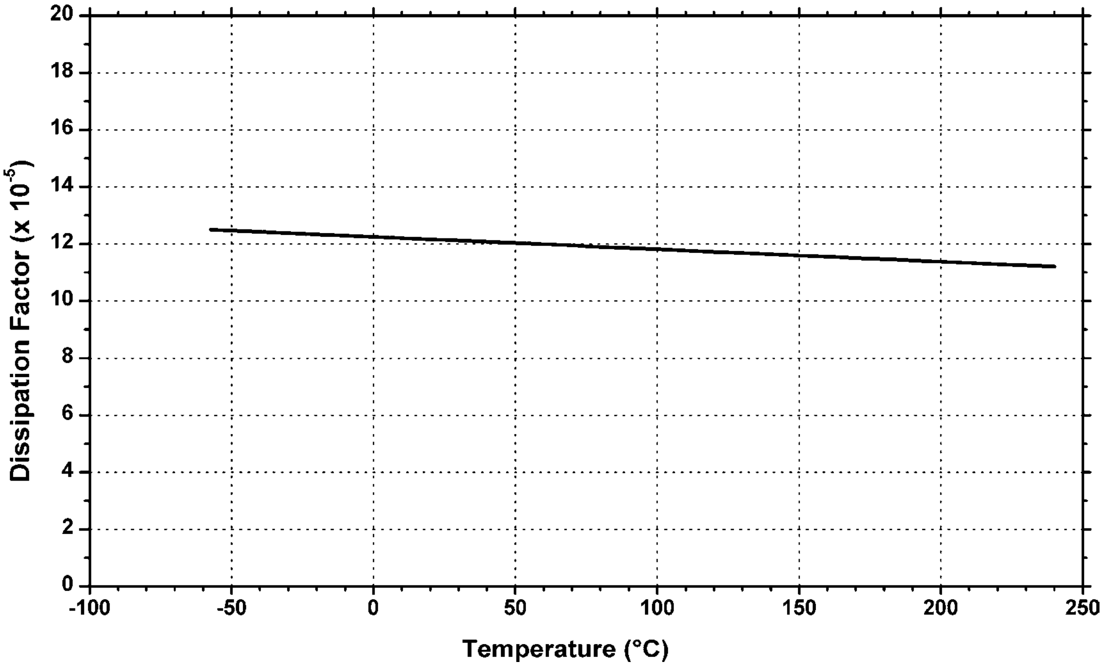


Figure 9.16. Dissipation factor vs. temperature for DuPont Co. General Purpose Teflon® PTFE resin.

9.3 Ethylene Chlorotrifluoroethylene (ECTFE)

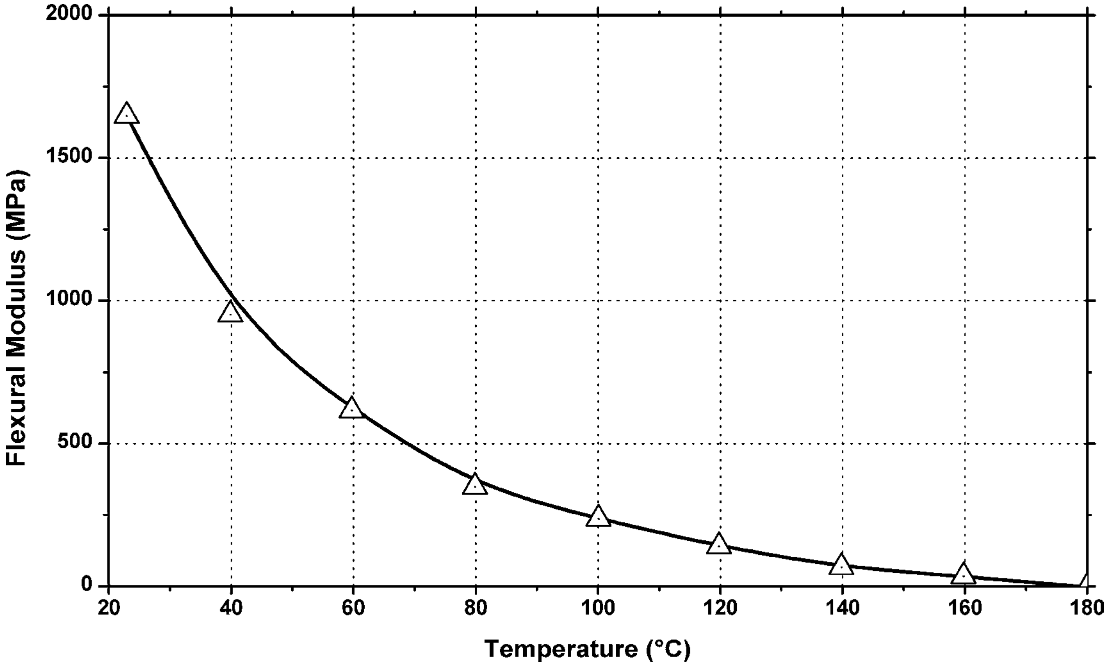


Figure 9.17. Flexural modulus vs. temperature for Solvay Solexis Halar® ECTFE resins.

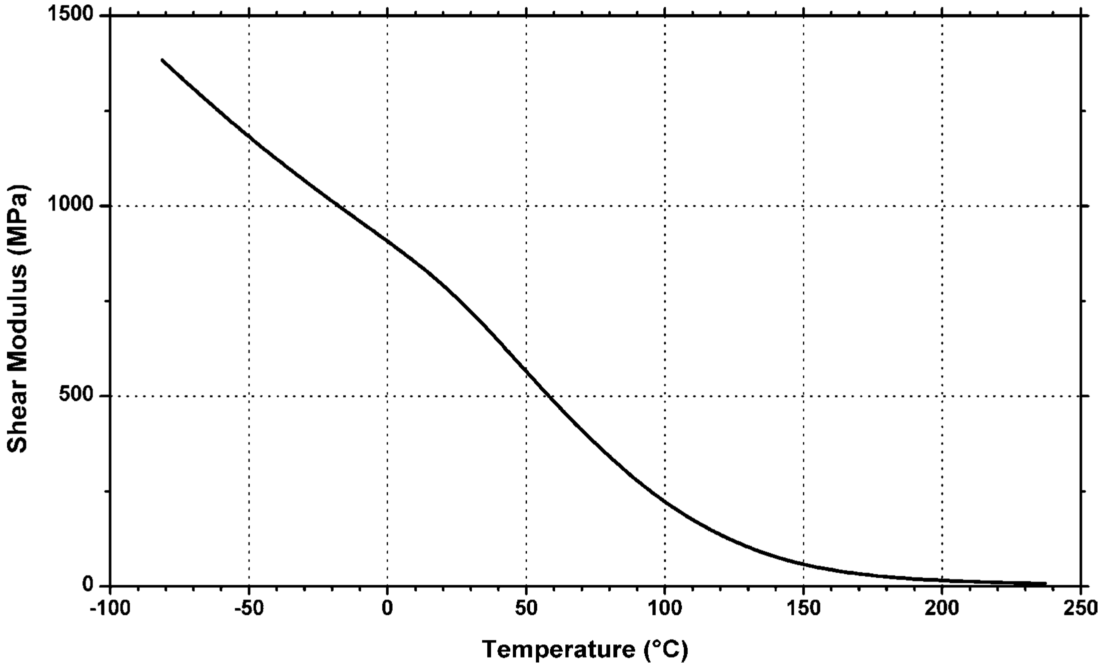


Figure 9.18. Shear modulus vs. temperature for Solvay Solexis Halar® ECTFE resins.

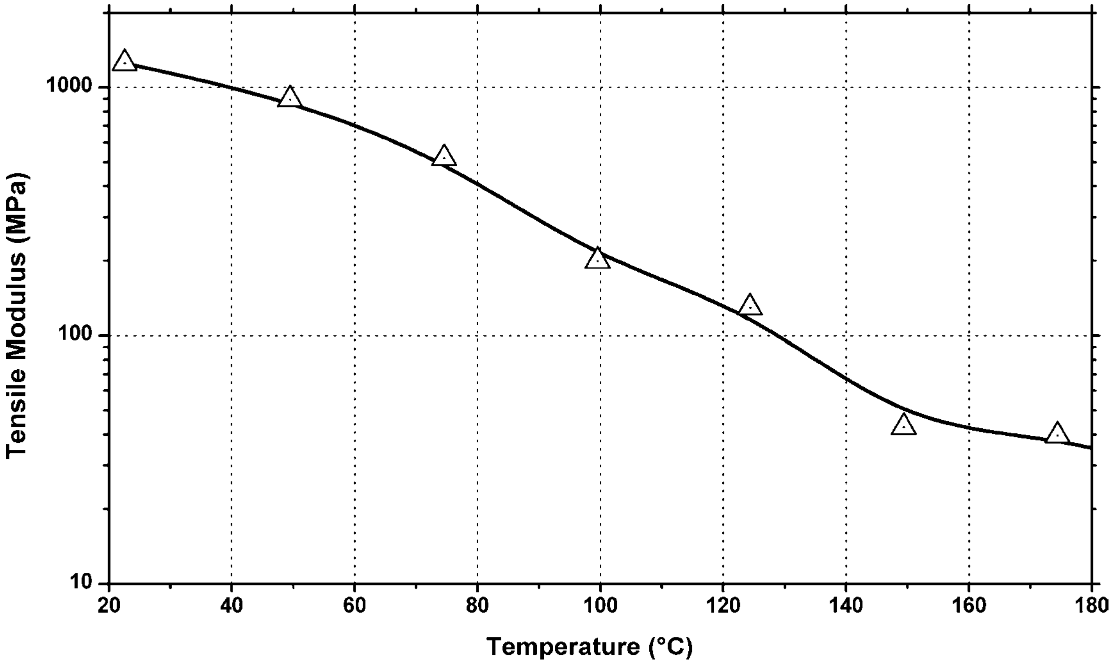


Figure 9.19. Tensile modulus vs. temperature for Solvay Solexis Halar® ECTFE resins.

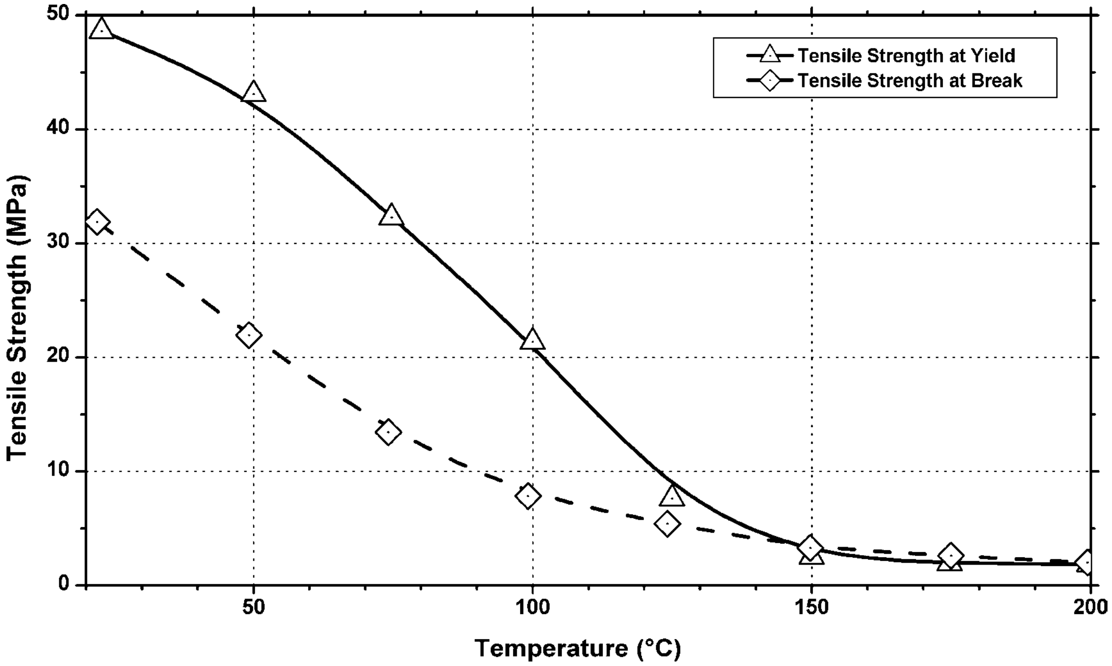


Figure 9.20. Tensile strength vs. temperature for Solvay Solexis Halar® ECTFE resins.

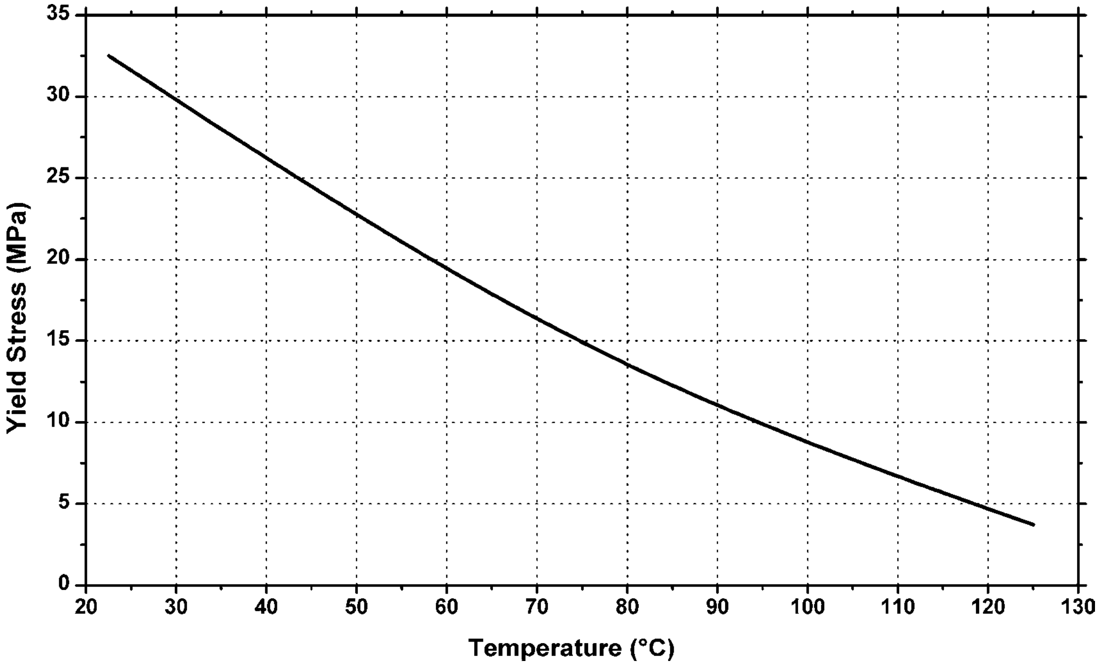


Figure 9.21. Yield stress vs. temperature for Solvay Solexis Halar® ECTFE resins.

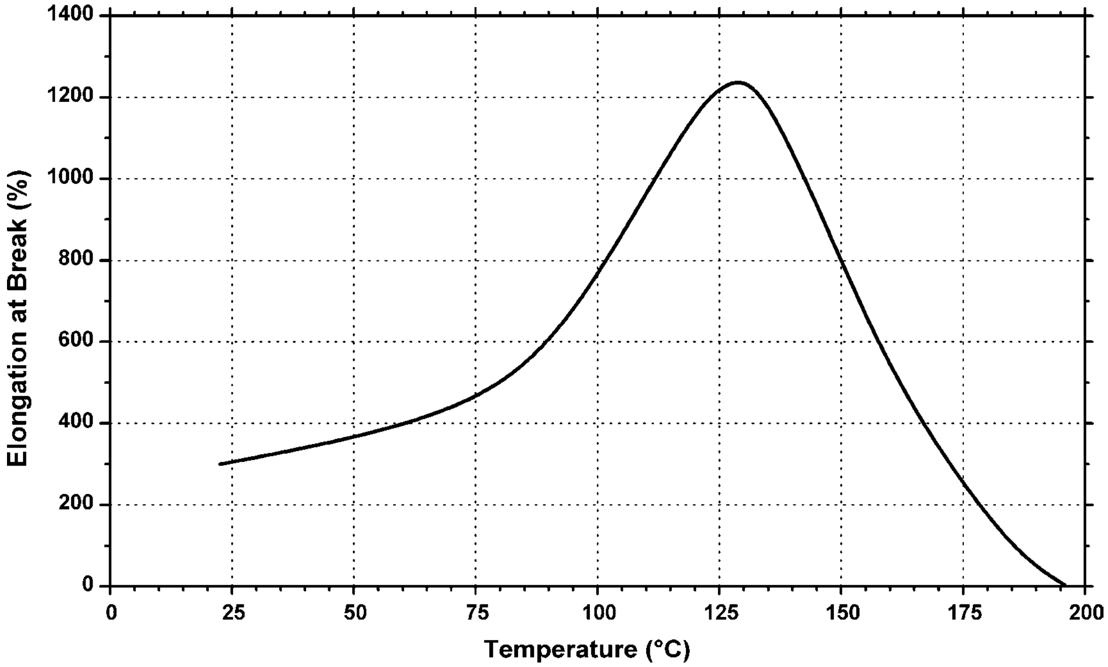


Figure 9.22. Elongation at break vs. temperature for Solvay Solexis Halar® ECTFE resins.

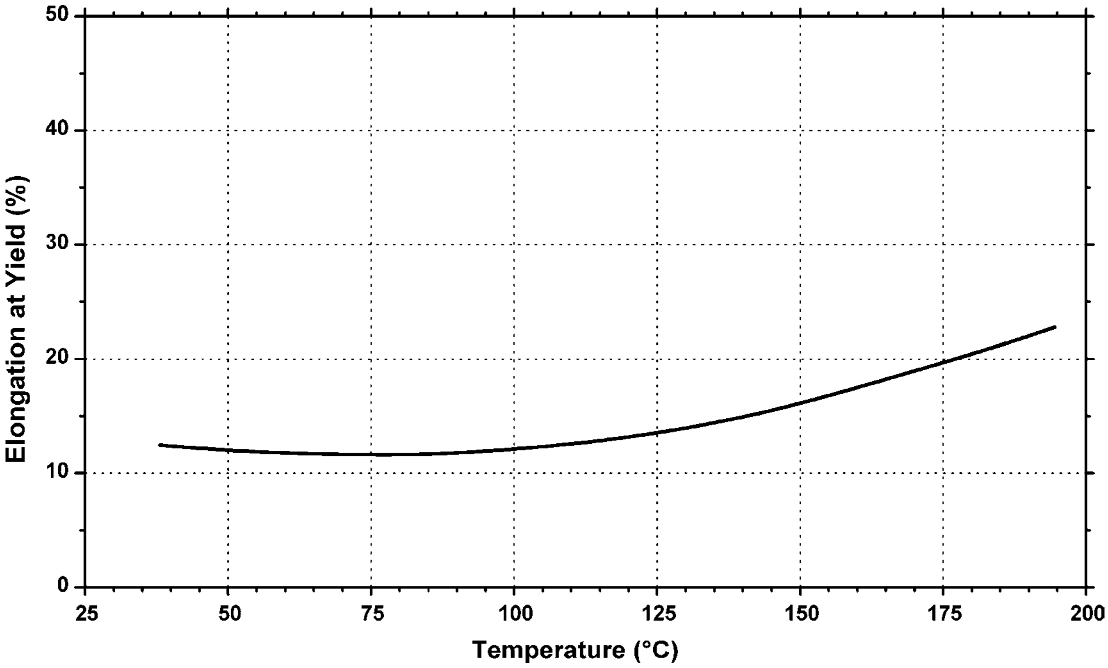


Figure 9.23. Elongation at yield vs. temperature for Solvay Solexis Halar® ECTFE resins.

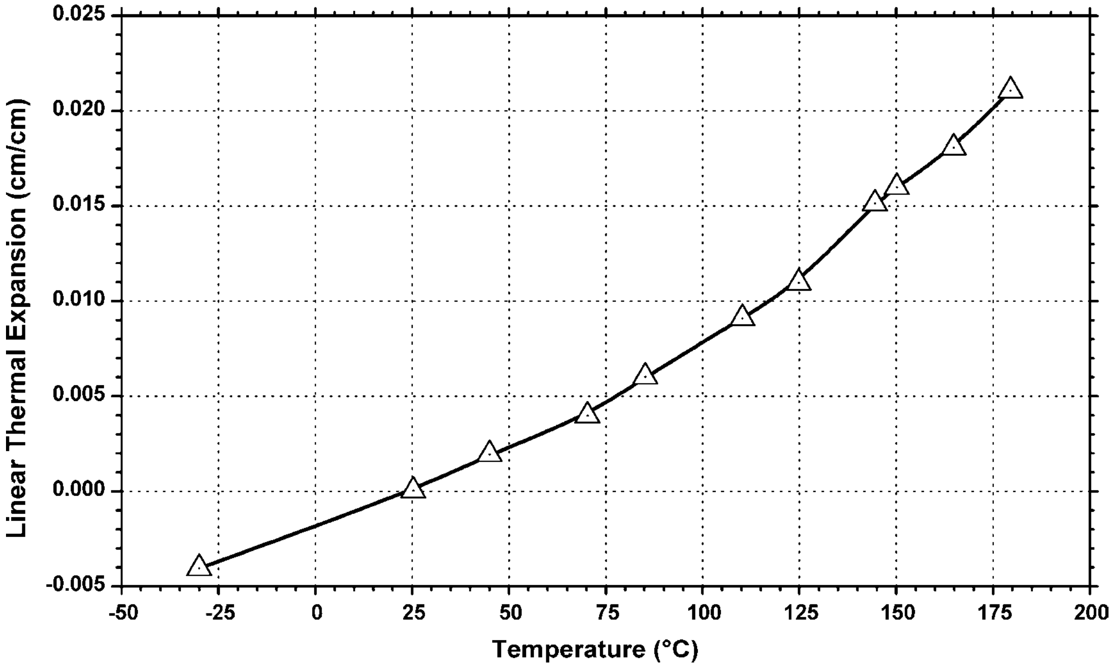


Figure 9.24. Linear thermal expansion vs. temperature for Solvay Solexis Halar® ECTFE resins.

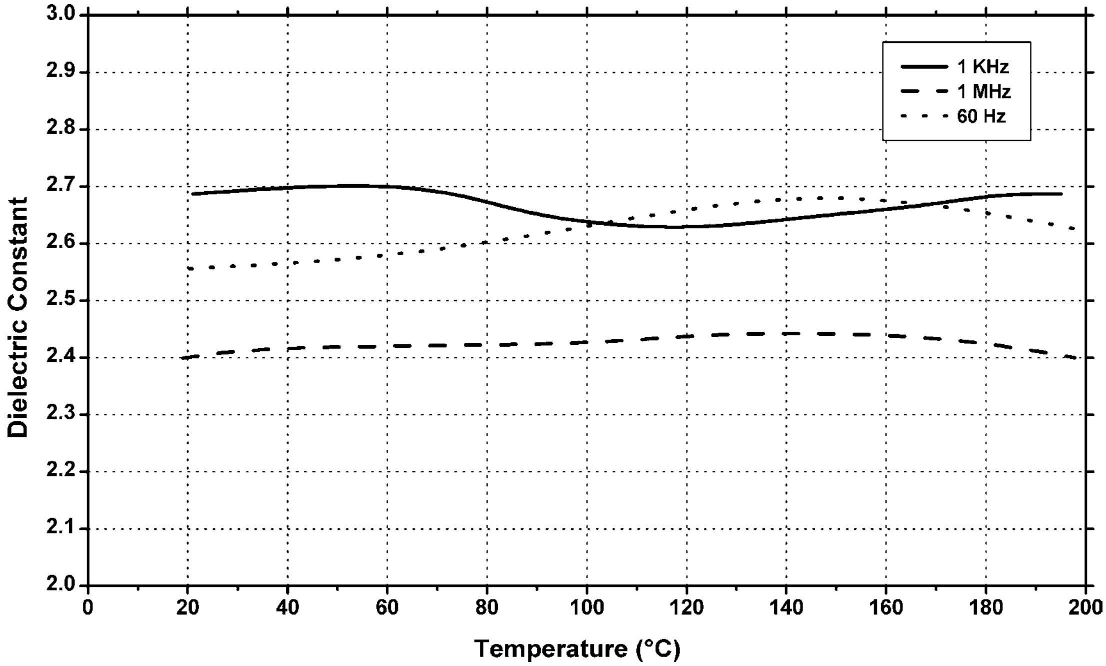


Figure 9.25. Dielectric constant vs. temperature at various frequencies for Solvay Solexis Halar® ECTFE resins.

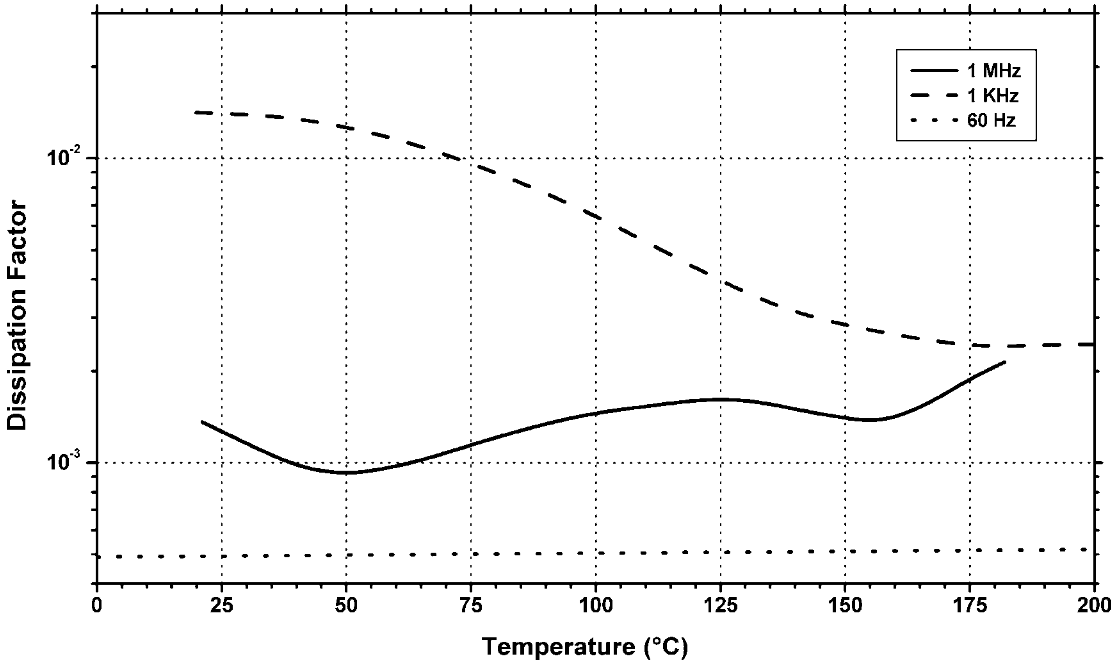


Figure 9.26. Dissipation factor vs. temperature at various frequencies for Solvay Solexis Halar® ECTFE resins.

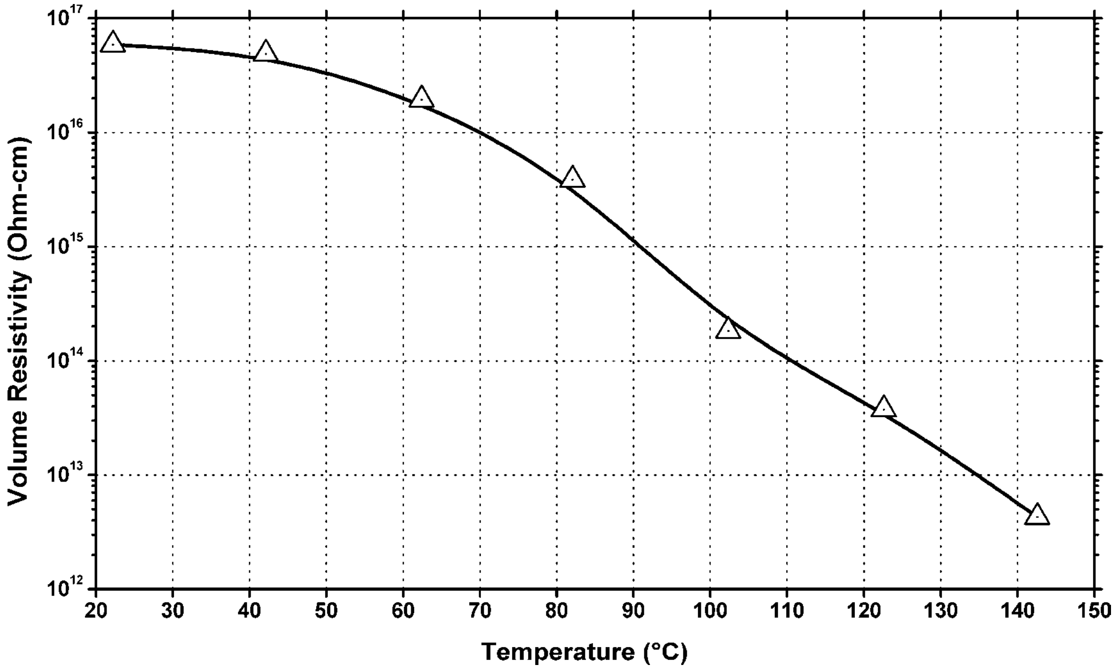


Figure 9.27. Volume resistivity vs. temperature for Solvay Solexis Halar® ECTFE resins.

9.4 Ethylene Tetrafluoroethylene (ETFE)

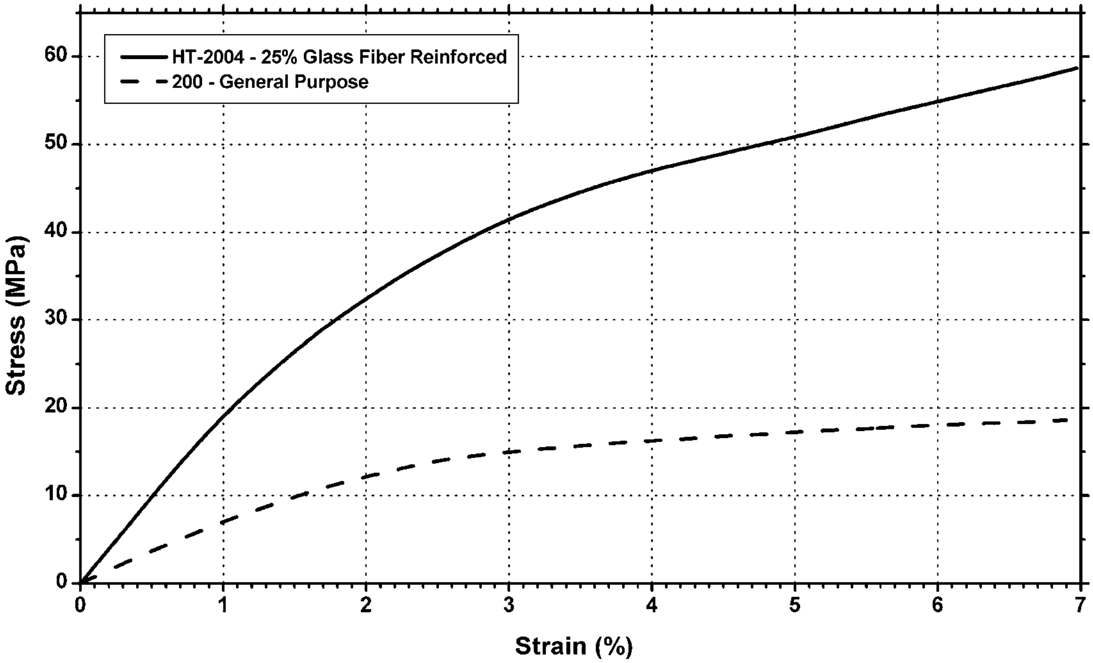


Figure 9.28. Stress vs. strain in compression at 23°C for DuPont Tefzel® ETFE resins.

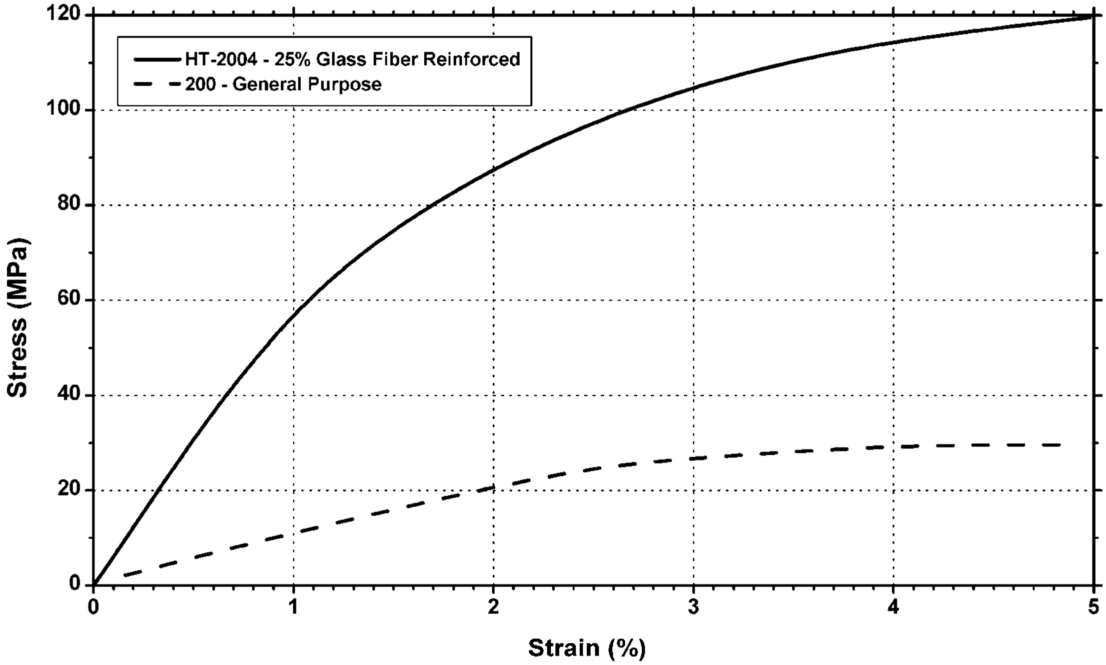


Figure 9.29. Stress vs. strain in flexure at 23°C for DuPont Tefzel® ETFE resins.

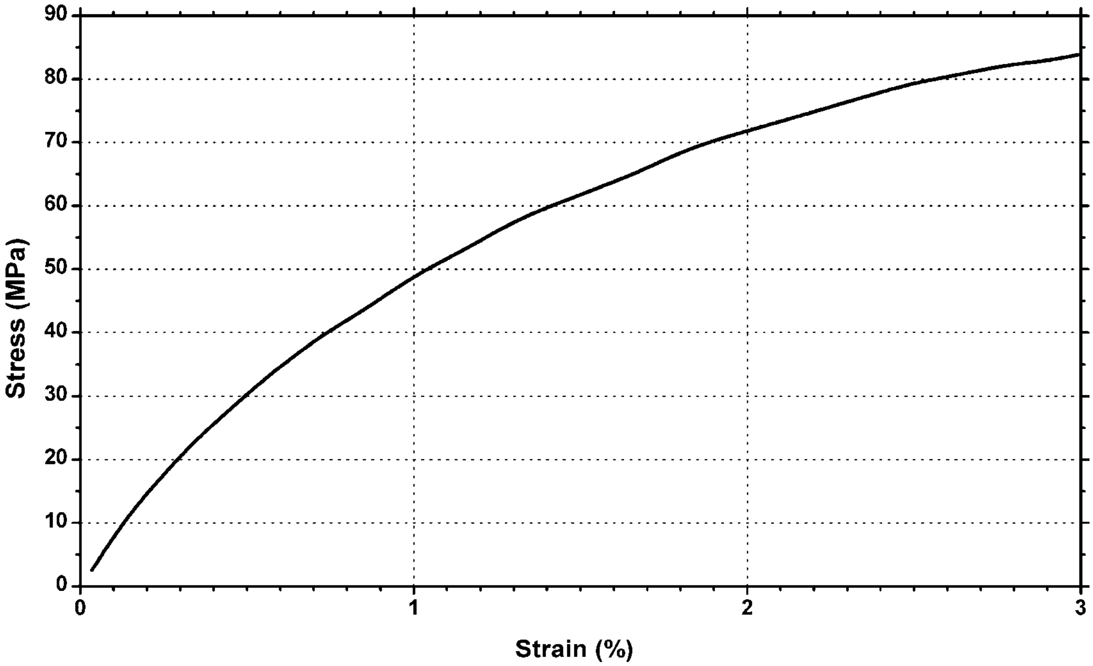


Figure 9.30. Tensile stress vs. strain and temperature for SABIC Innovative Plastics LNP Thermocomp FP-EC-1004 electrically conductive carbon fiber filled ETFE resin.

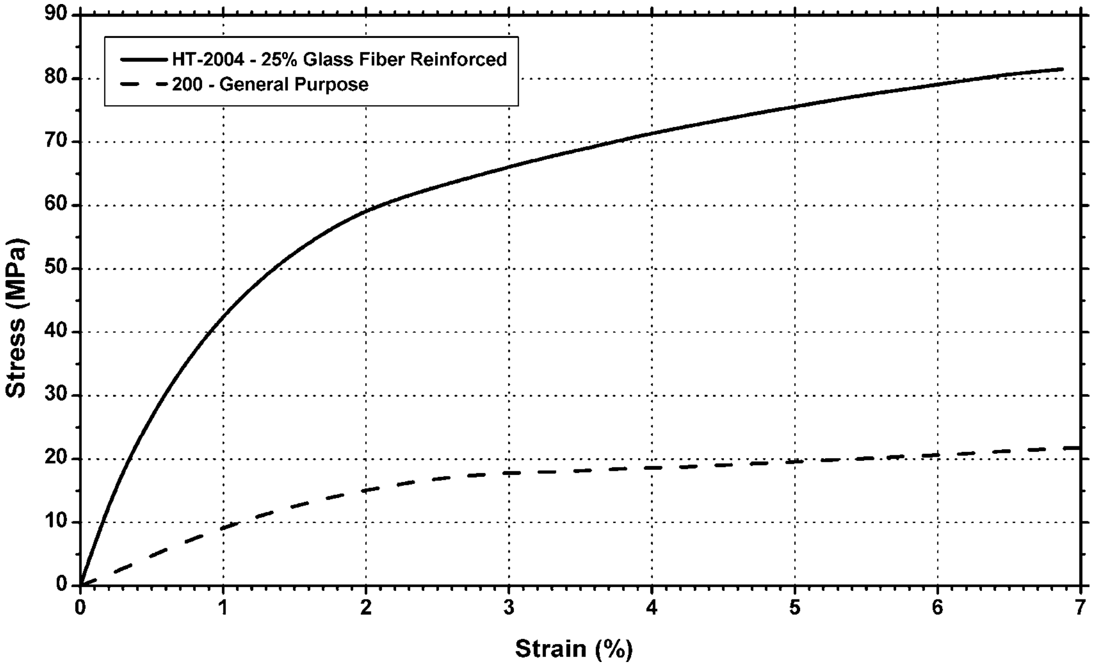


Figure 9.31. Tensile stress vs. strain at 23°C for DuPont Tefzel® ETFE resins.

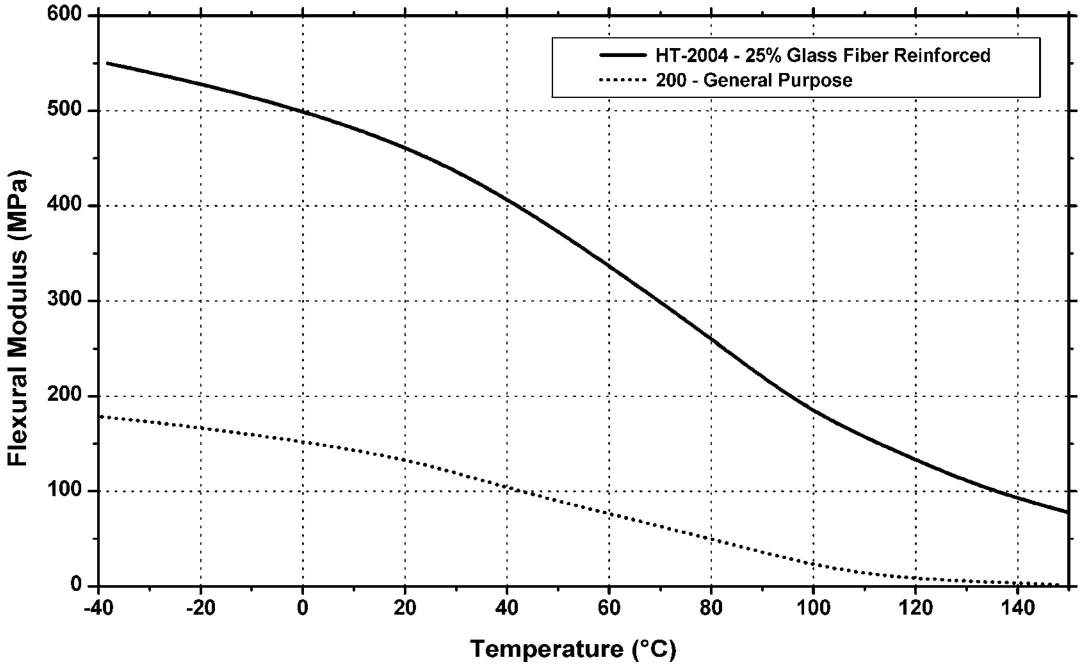


Figure 9.32. Flexural modulus vs. temperature for DuPont Tefzel® ETFE resins.

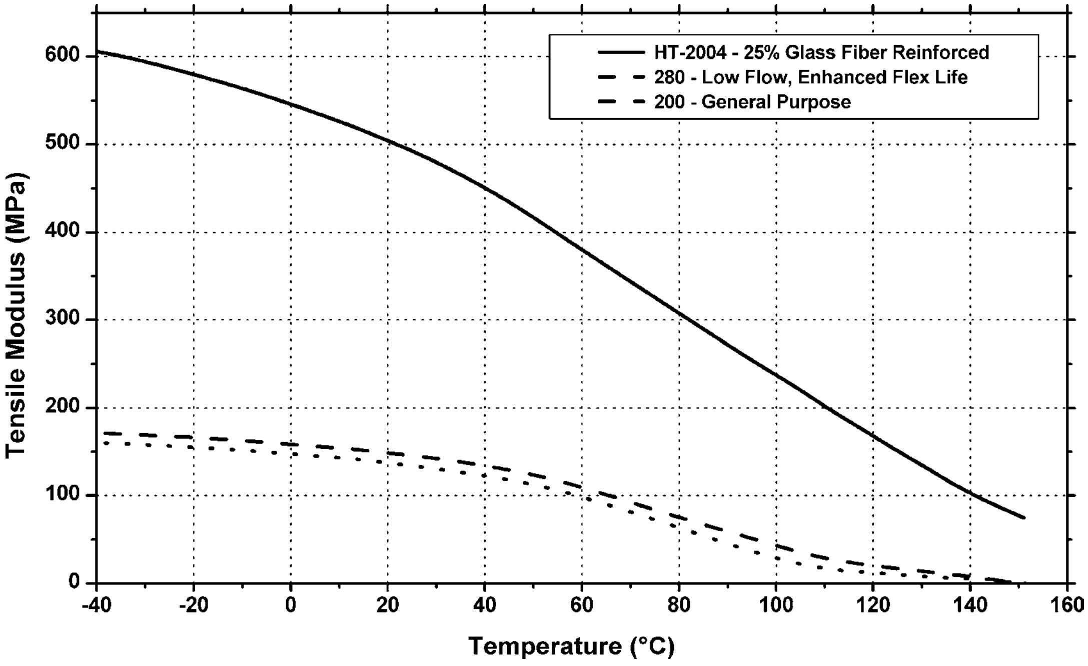


Figure 9.33. Tensile modulus vs. temperature for DuPont Tefzel® ETFE resins.

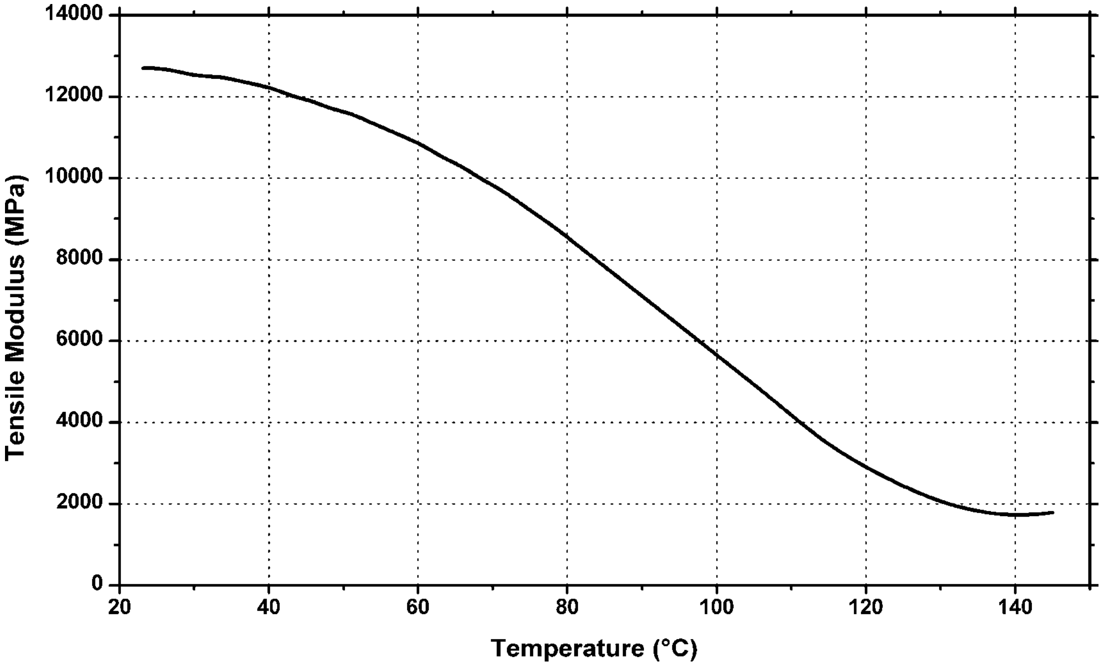


Figure 9.34. Tensile modulus vs. temperature for SABIC Innovative Plastics LNP Thermocomp FP-EC-1004 electrically conductive carbon fiber filled ETFE resin.

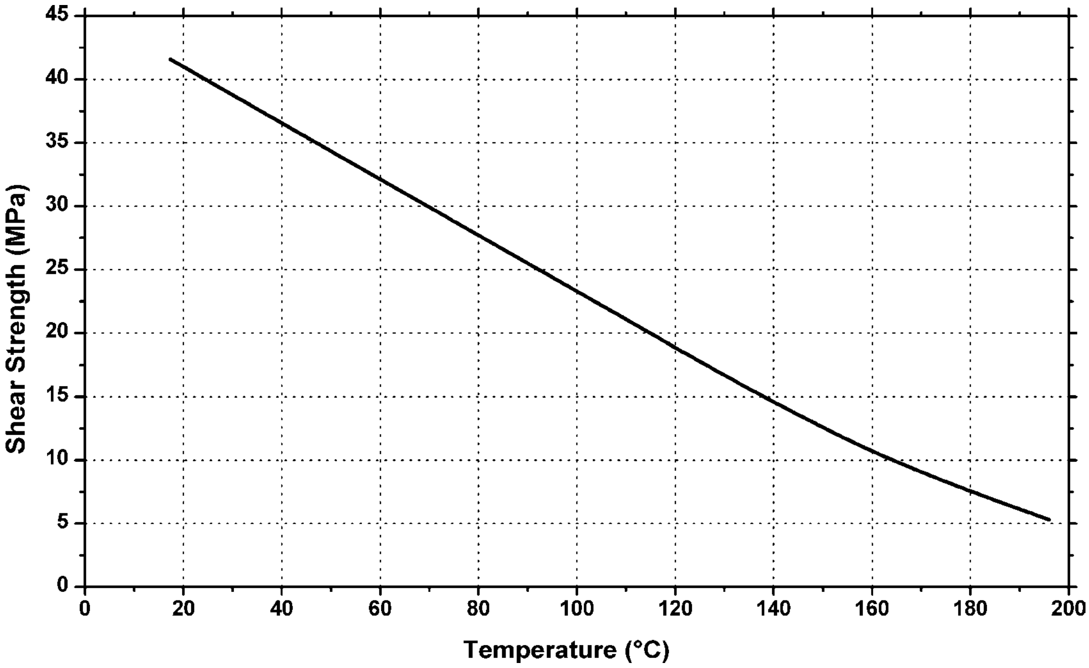


Figure 9.35. Shear strength vs. temperature for DuPont General Purpose Tefzel® 200 ETFE resin.

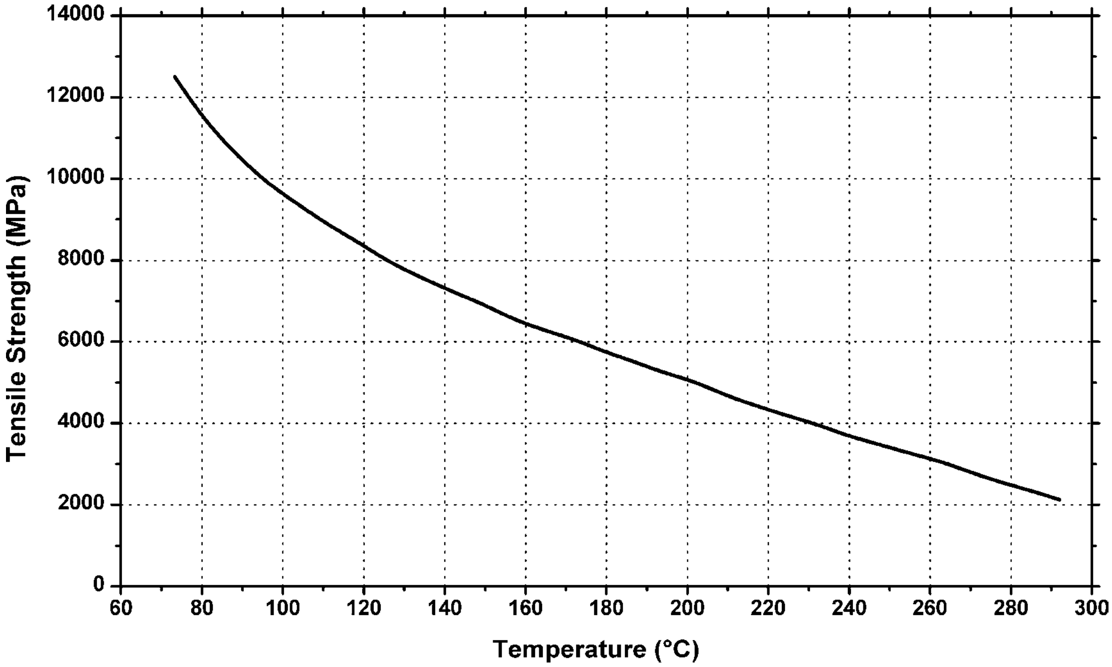


Figure 9.36. Tensile strength vs. temperature for SABIC Innovative Plastics LNP Thermocomp FP-EC-1004 electrically conductive carbon fiber filled ETFE resin.

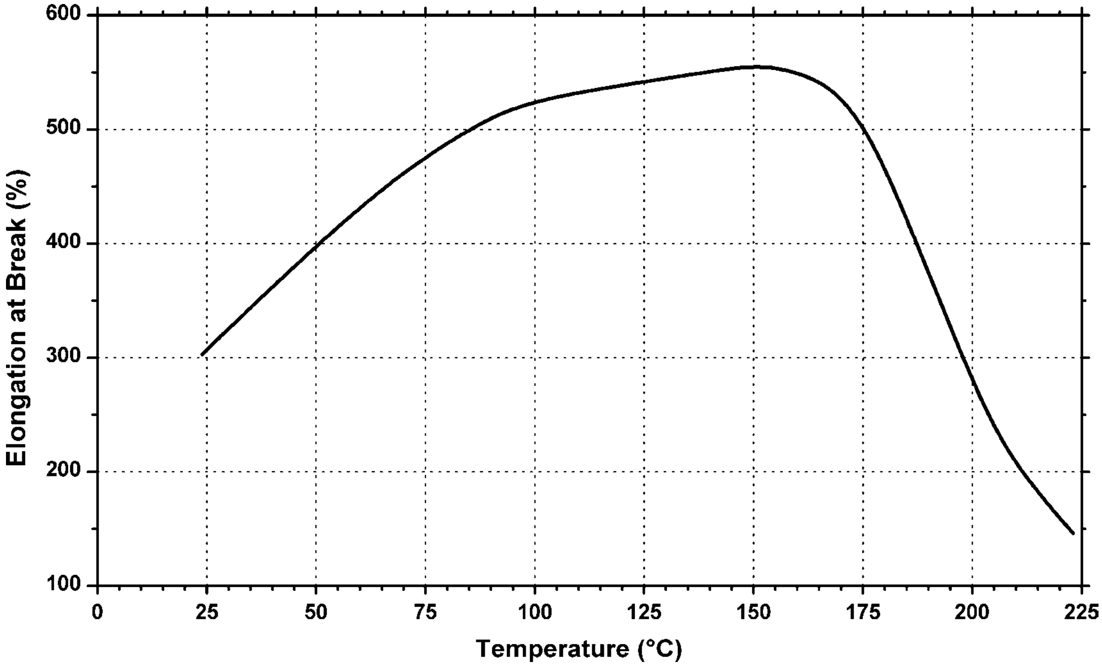


Figure 9.37. Elongation at break vs. temperature DuPont General Purpose Tefzel® 200 ETFE resin.

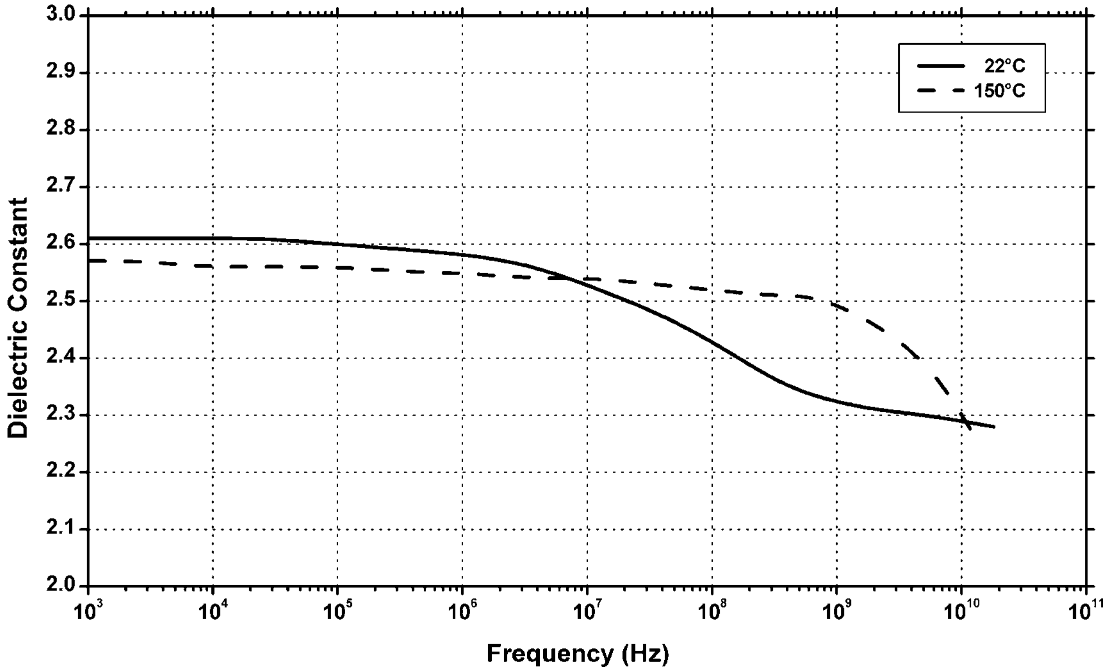


Figure 9.38. Dielectric constant vs. frequency DuPont General Purpose Tefzel® 200 ETFE resin.

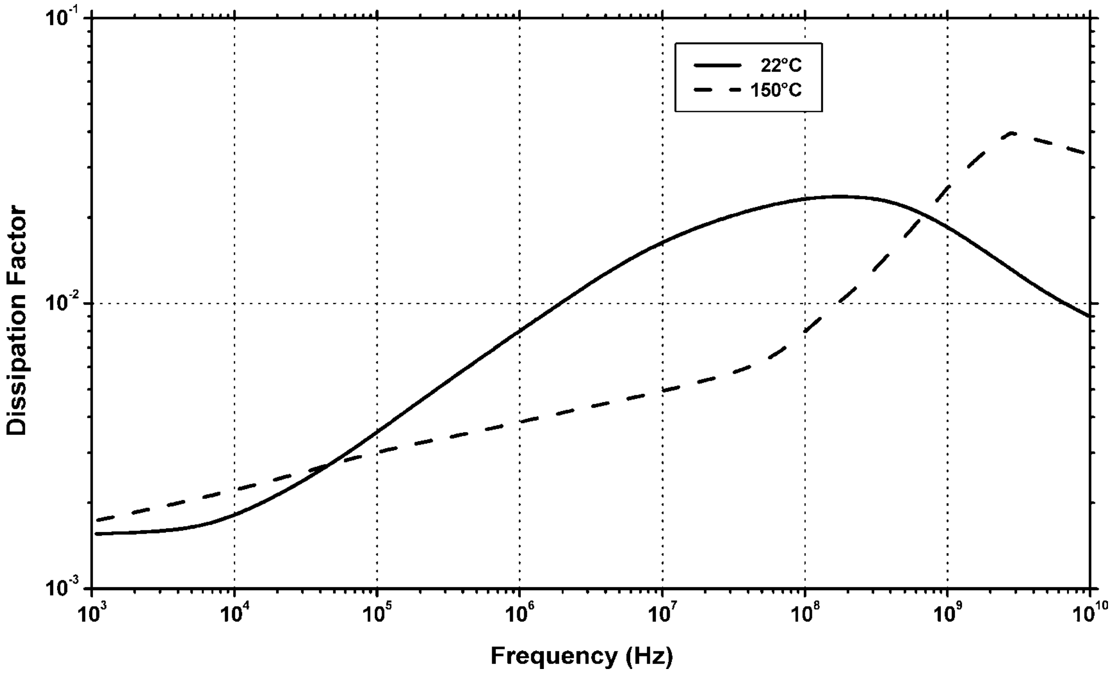


Figure 9.39. Dissipation factor vs. frequency DuPont General Purpose Tefzel® 200 ETFE resin.

9.5 Fluorinated-Ethylene-Propylene (FEP)

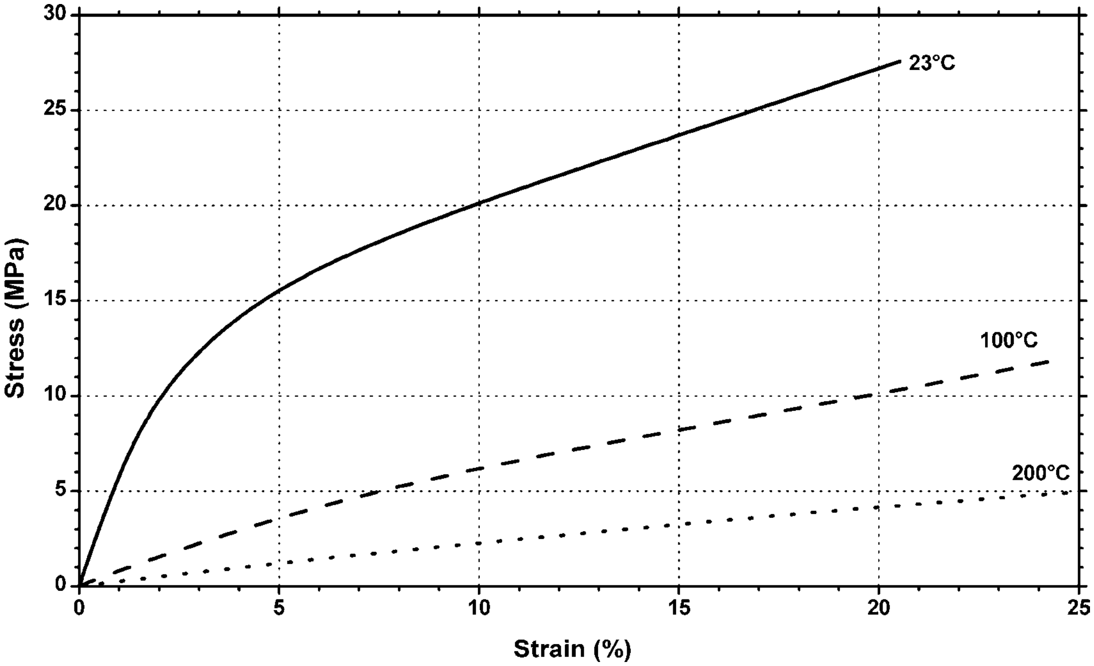


Figure 9.40. Tensile stress vs. strain in compression at various temperatures for DuPont general purpose FEP resins.

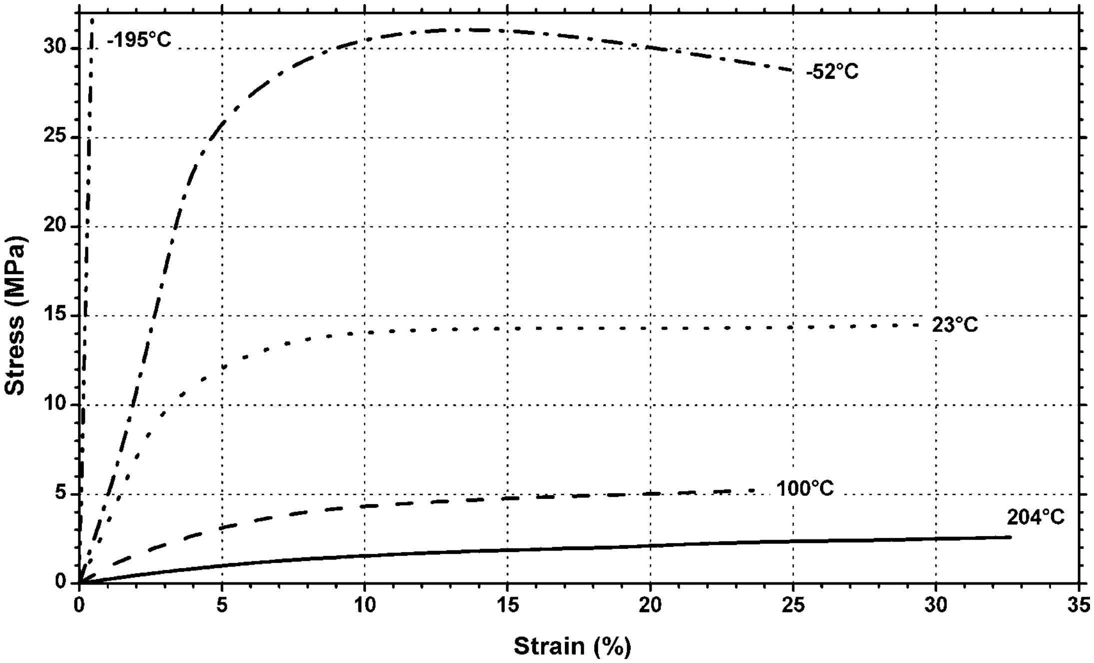


Figure 9.41. Tensile stress vs. strain at various temperatures for DuPont general purpose FEP resins.

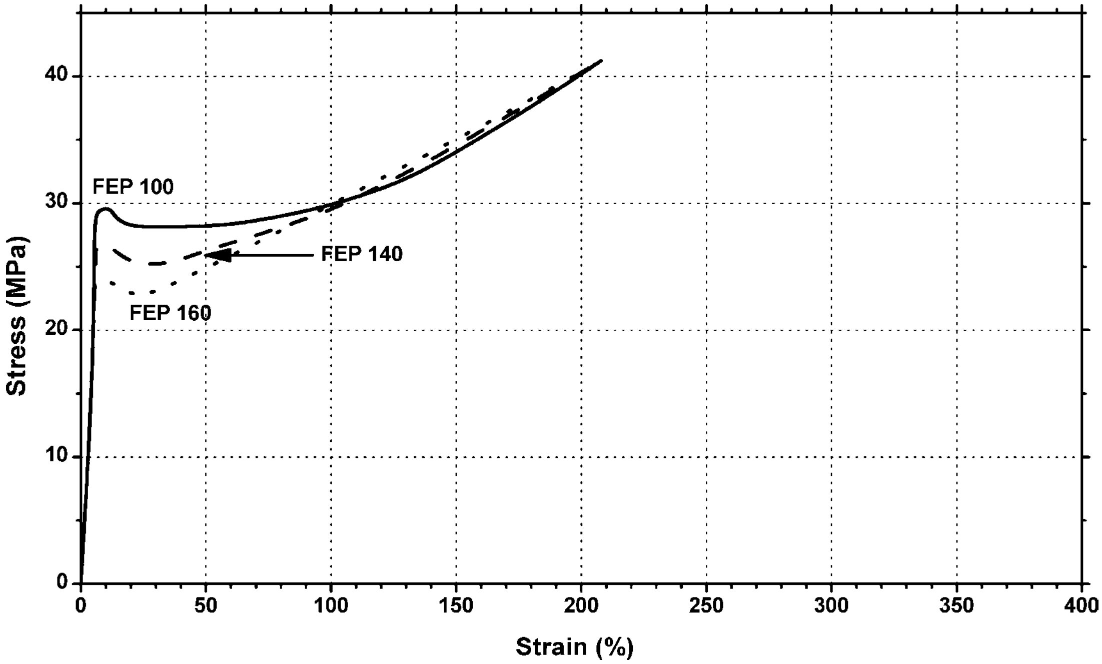


Figure 9.42. Tensile stress vs. strain at –52°C for DuPont FEP resins.

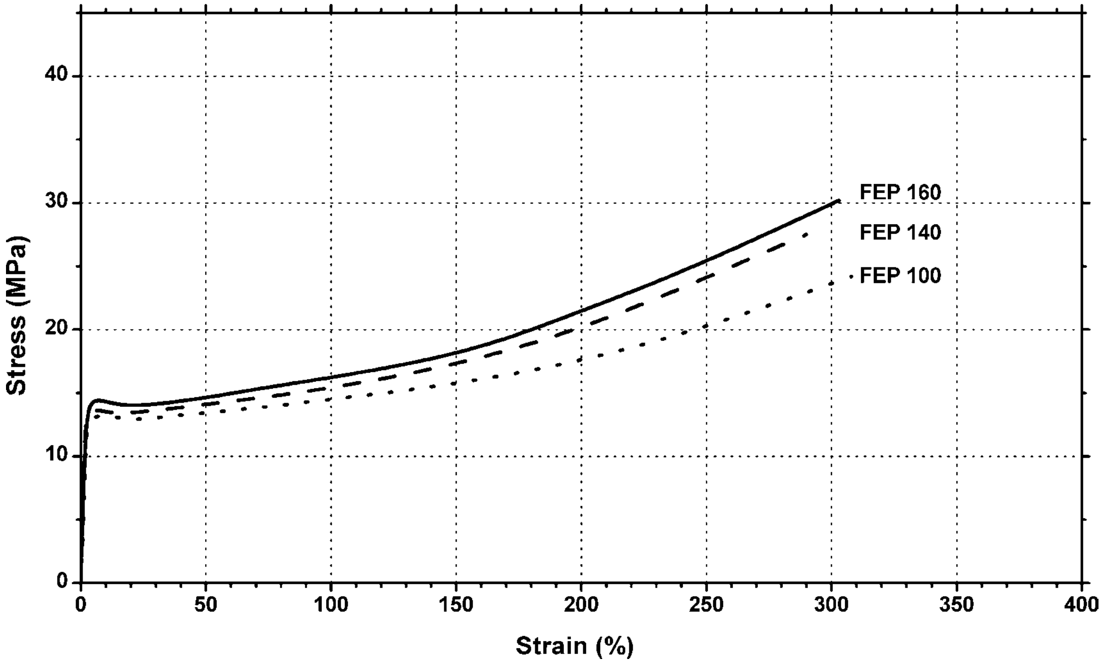


Figure 9.43. Tensile stress vs. strain at 23°C for DuPont FEP resins.

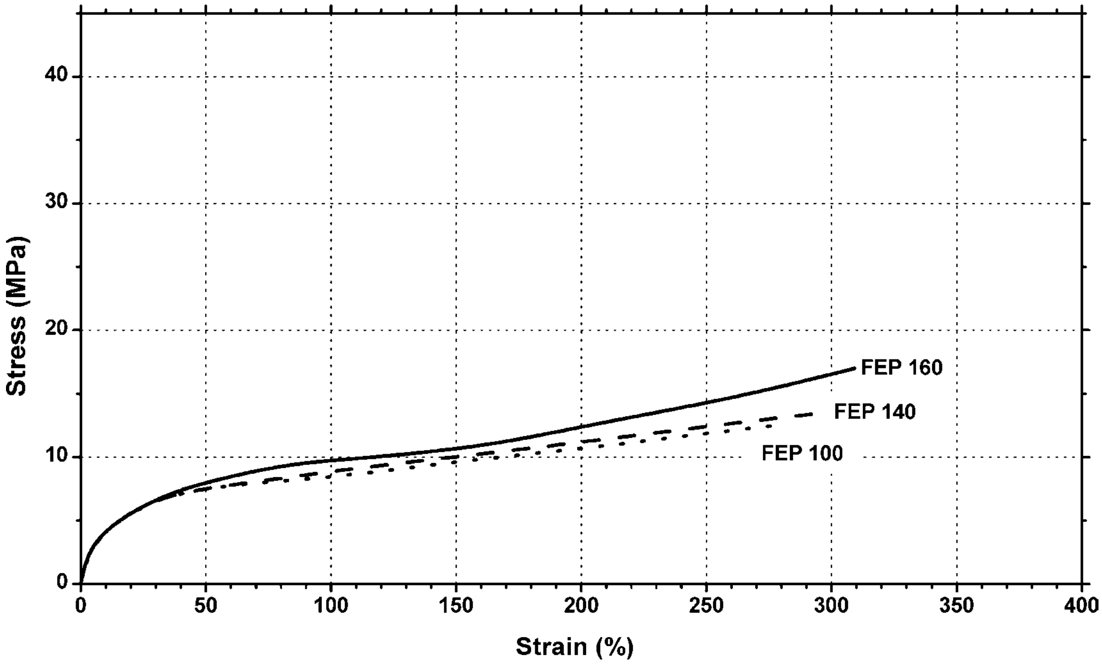


Figure 9.44. Tensile stress vs. strain at 100°C for DuPont FEP resins.

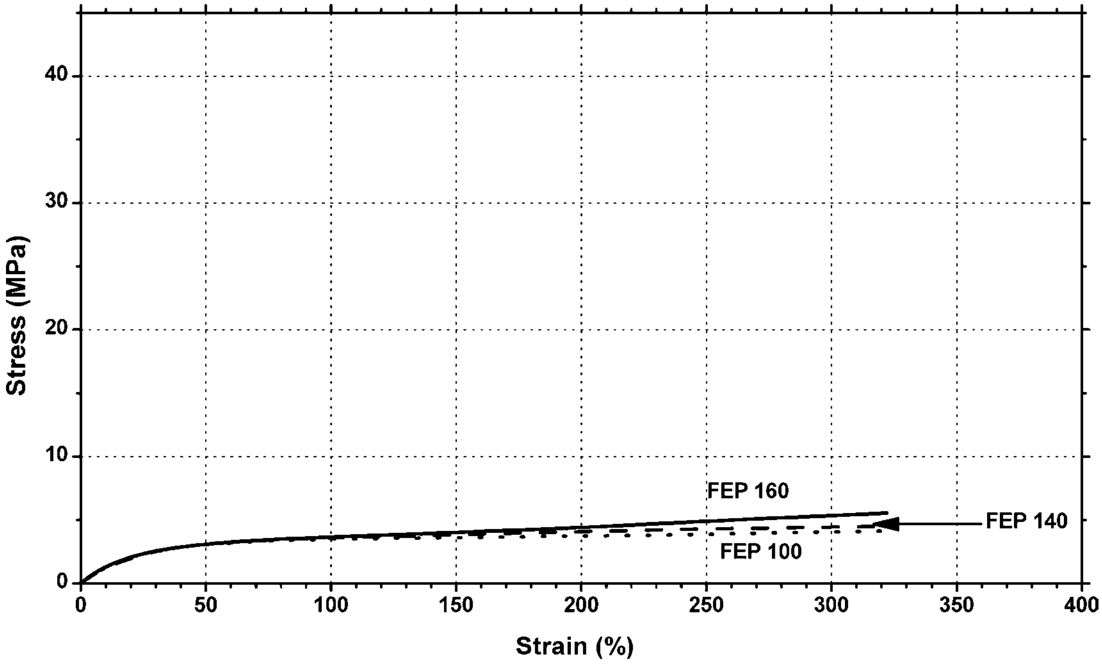


Figure 9.45. Tensile stress vs. strain at 200°C for DuPont FEP resins.

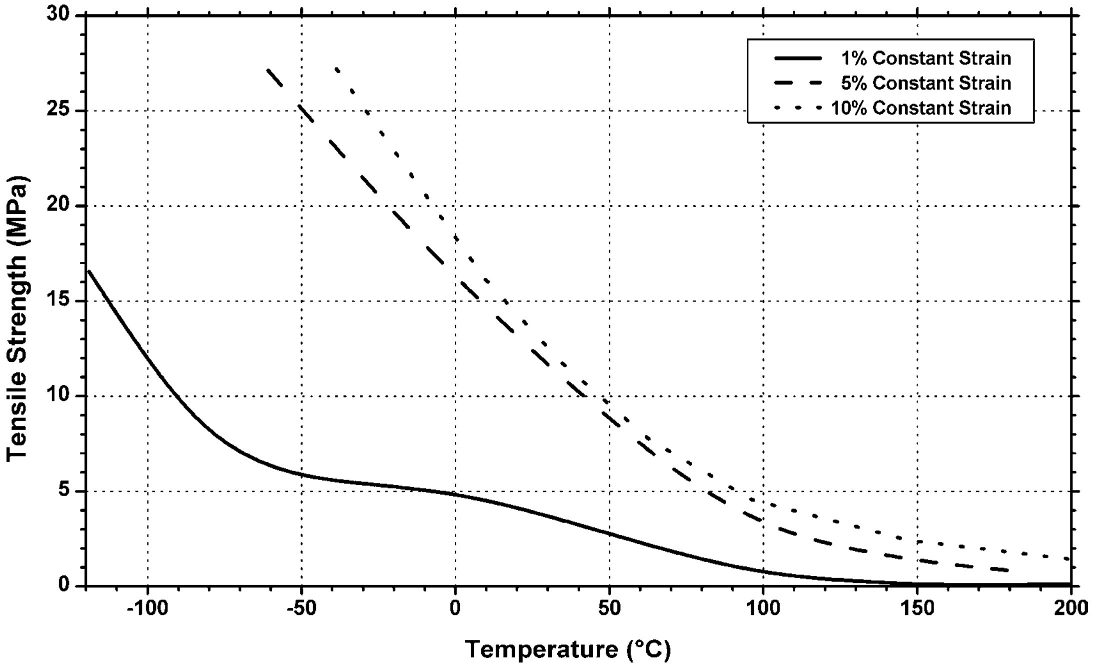


Figure 9.46. Tensile strength vs. temperature and various strain levels for DuPont general purpose FEP resin.

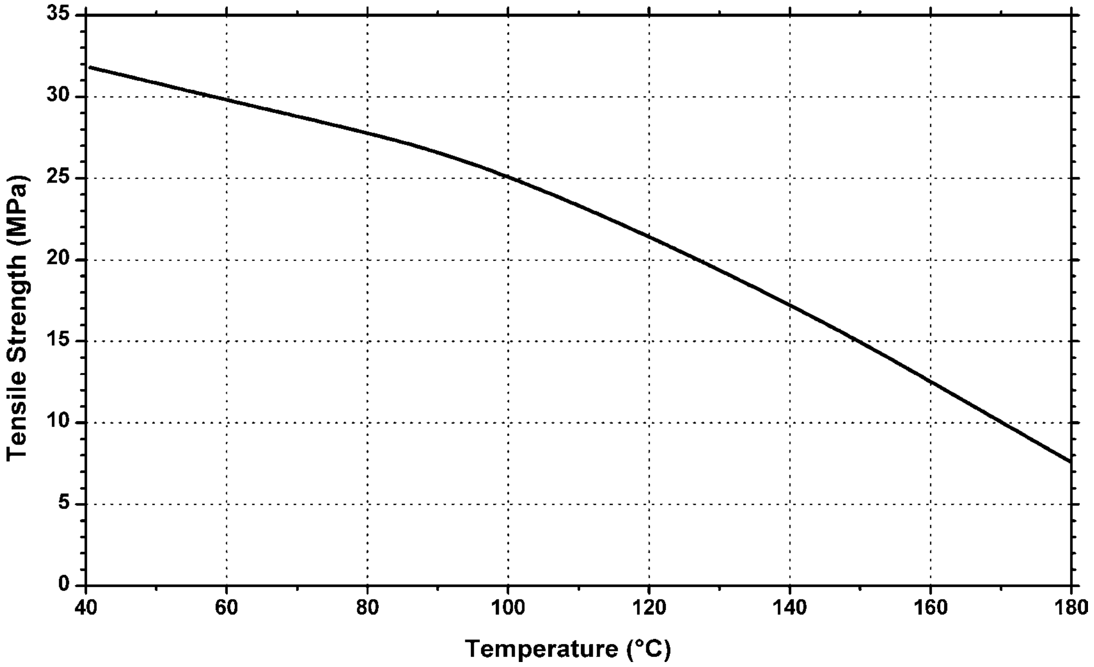


Figure 9.47. Tensile strength vs. temperature for SABIC Innovative Plastics LNP FEP resin with 20% glass fiber.

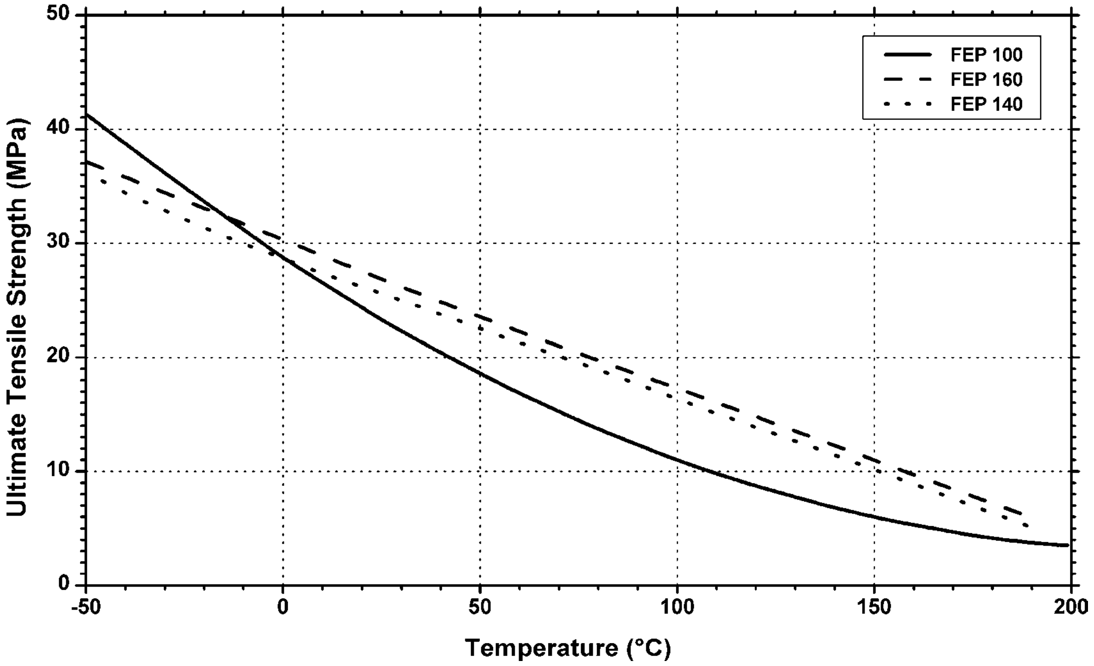


Figure 9.48. Ultimate tensile strength vs. temperature for DuPont FEP resins.

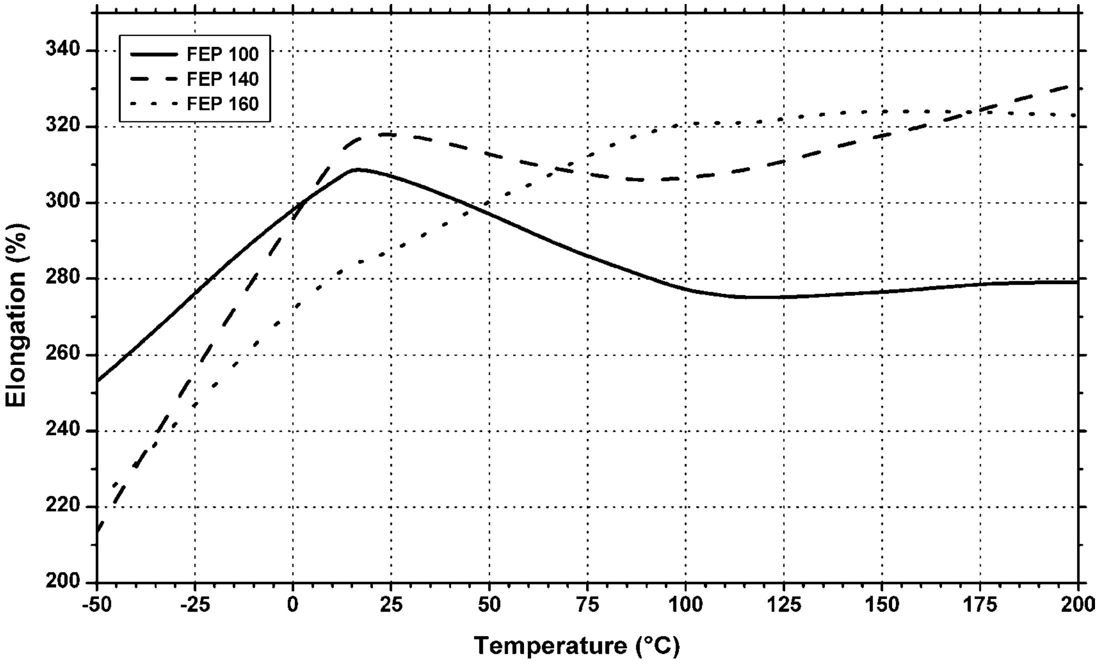


Figure 49. Ultimate elongation vs. temperature for DuPont FEP resins.

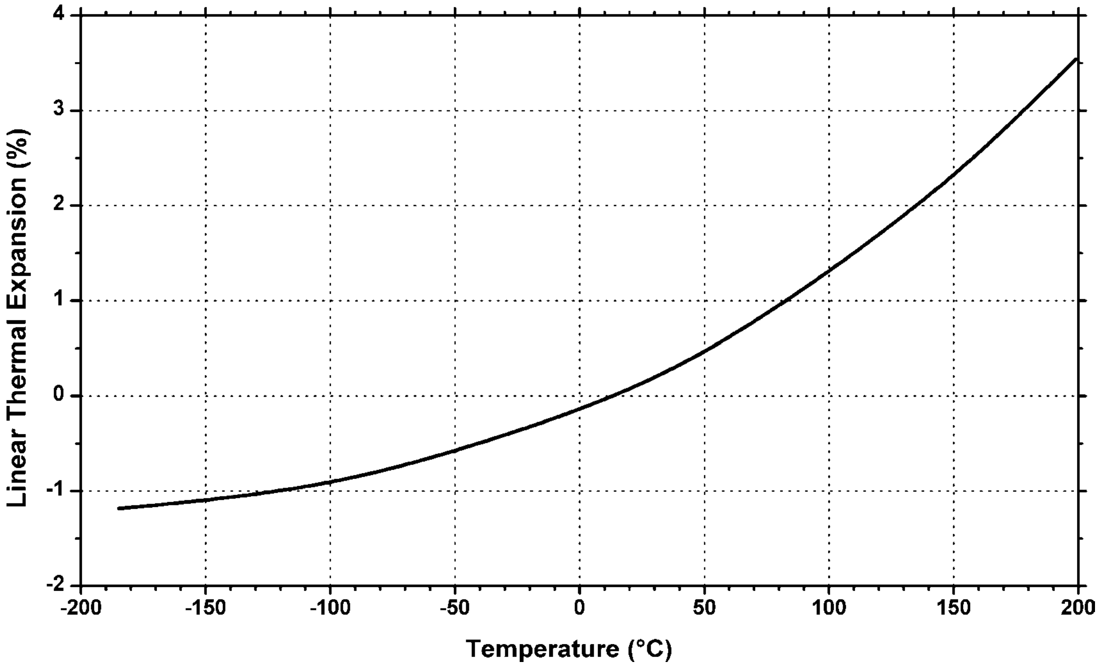


Figure 9.50. Linear thermal expansion vs. temperature for DuPont general purpose FEP resins.

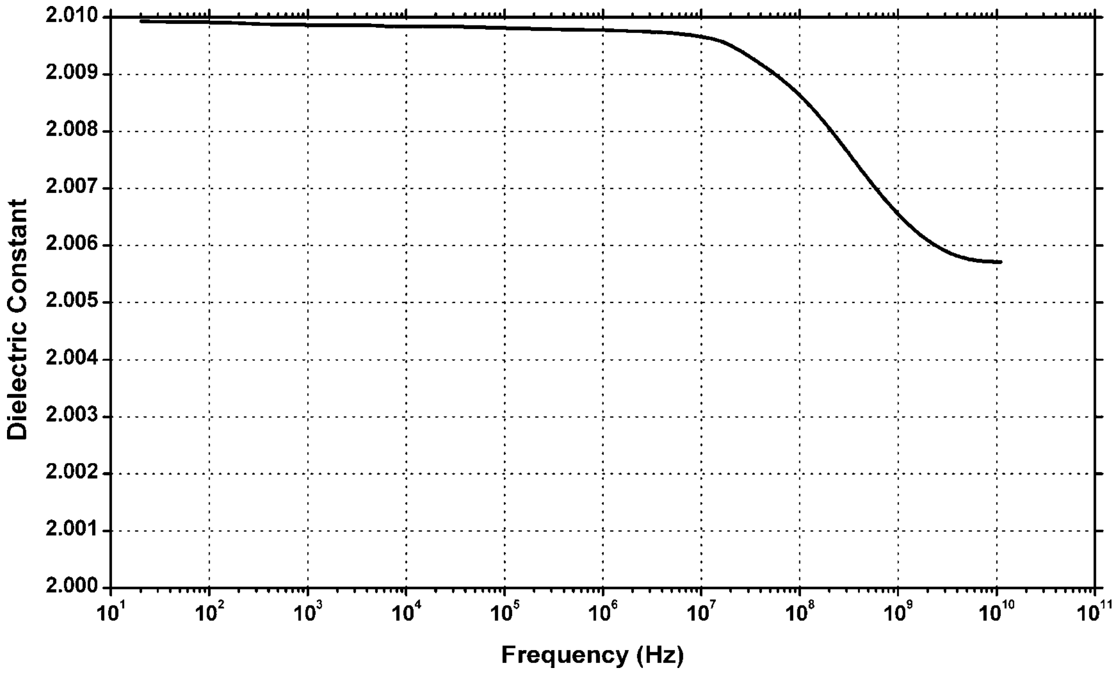


Figure 9.51. Dieletric constant vs. frequency for DuPont general purpose FEP resins.

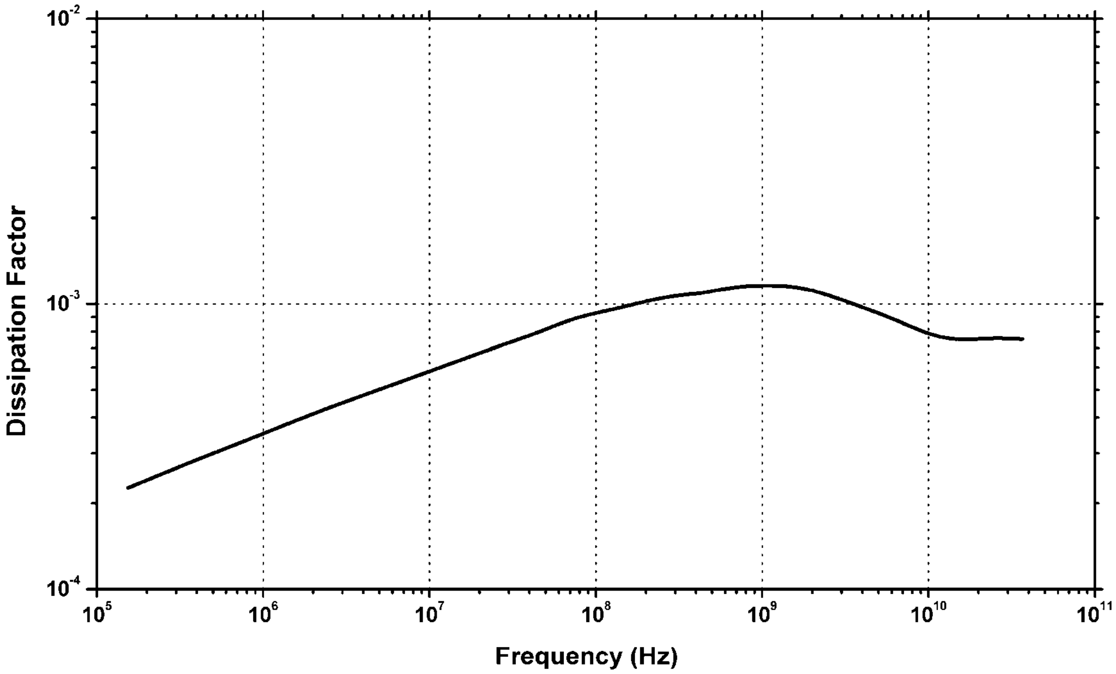


Figure 9.52. Dissipation factor vs. frequency for DuPont general purpose FEP resins.

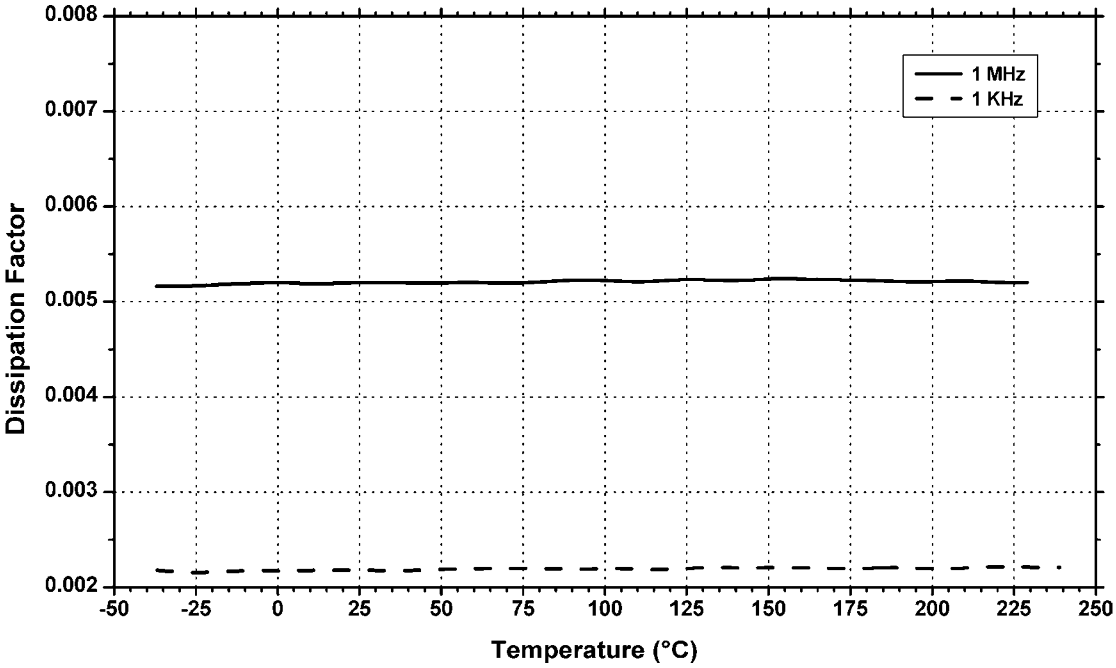


Figure 9.53. Dissipation factor vs. temperature for DuPont general purpose FEP resins.

9.6 Perfluoro Alkylvinylether (PFA)

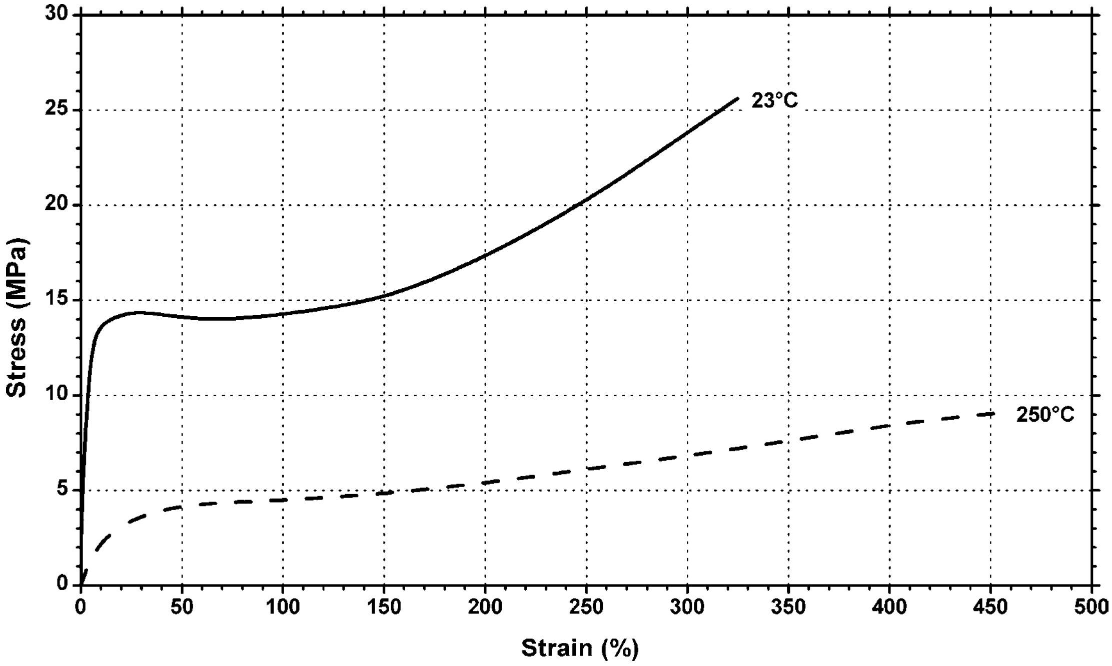


Figure 9.54. Stress vs. strain at two temperatures for Solvay Solexis Hyflon® PFA resins.

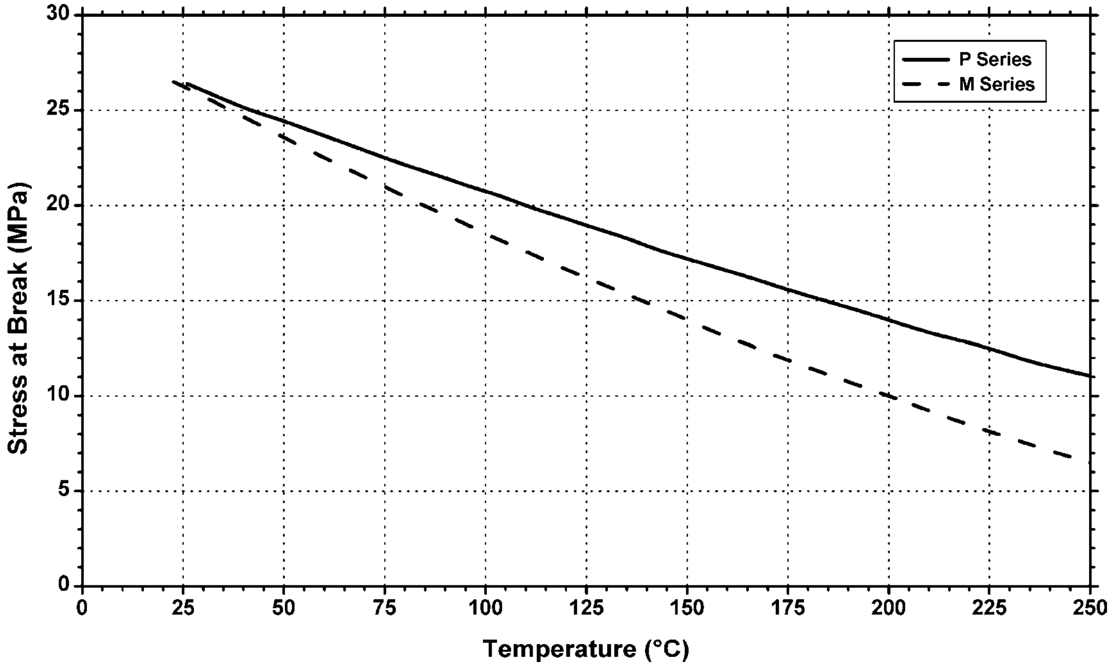


Figure 9.55. Stress at break vs. temperature for Solvay Solexis Hyflon® PFA resins.

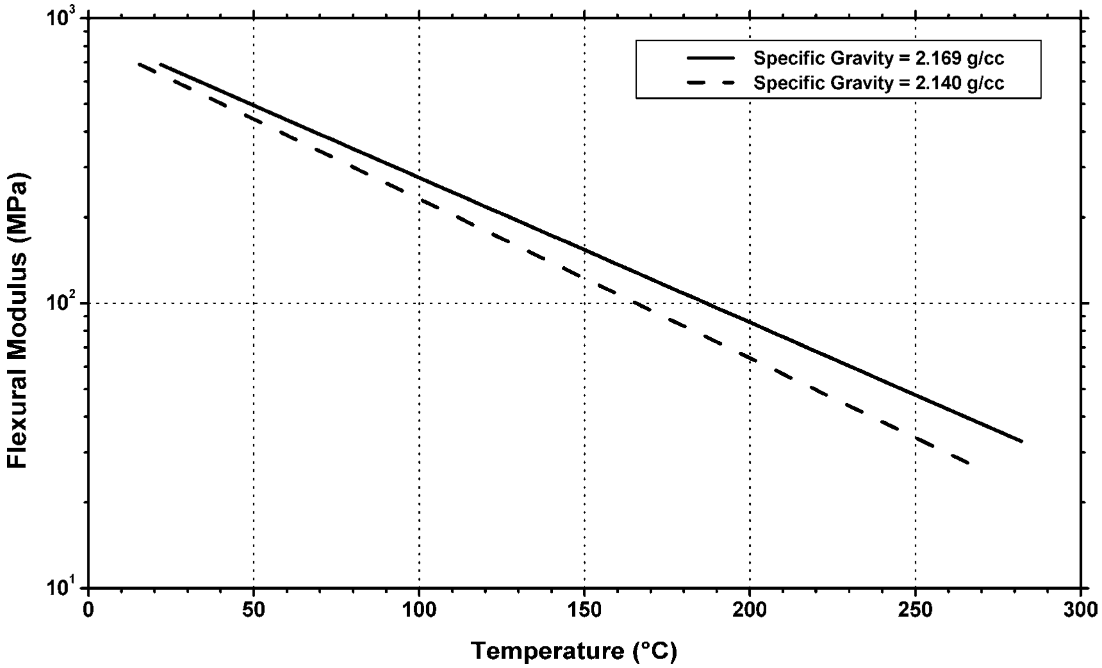


Figure 9.56. Flexural modulus vs. temperature for DuPont Teflon® PFA 340 and 350 grade resins.

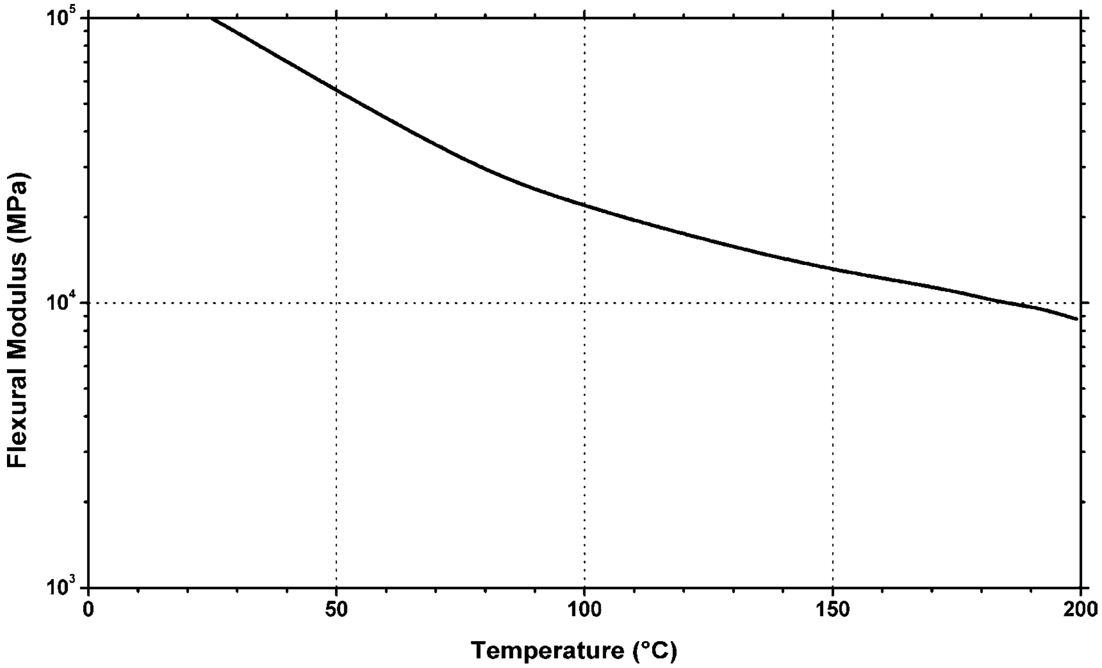


Figure 9.57. Flexural modulus vs. temperature for DuPont Teflon® PFA HP plus resins.

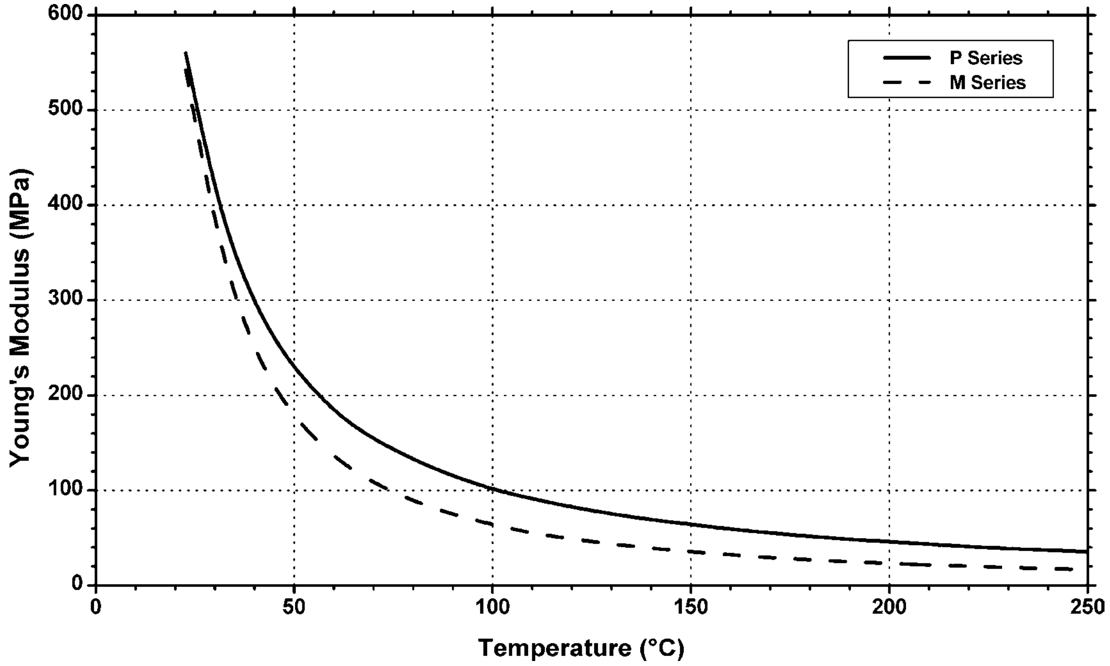


Figure 9.58. Young's modulus vs. temperature for Solvay Solexis Hyflon® PFA resins.

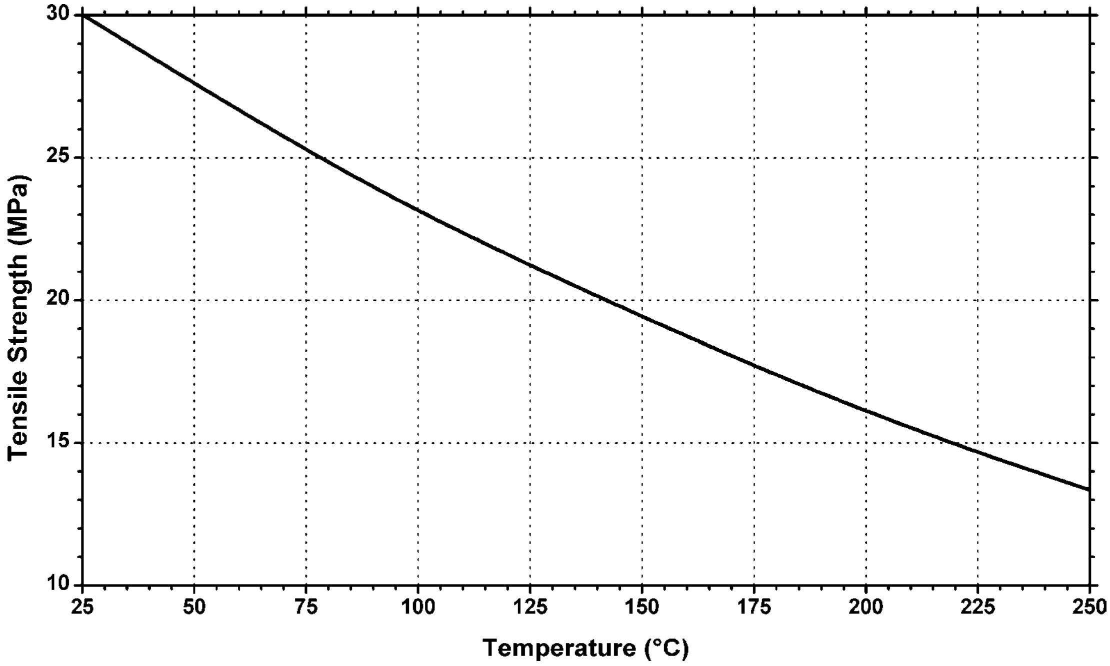


Figure 9.59. Tensile strength vs. temperature for DuPont Teflon® PFA 340 and 350 grade resins.

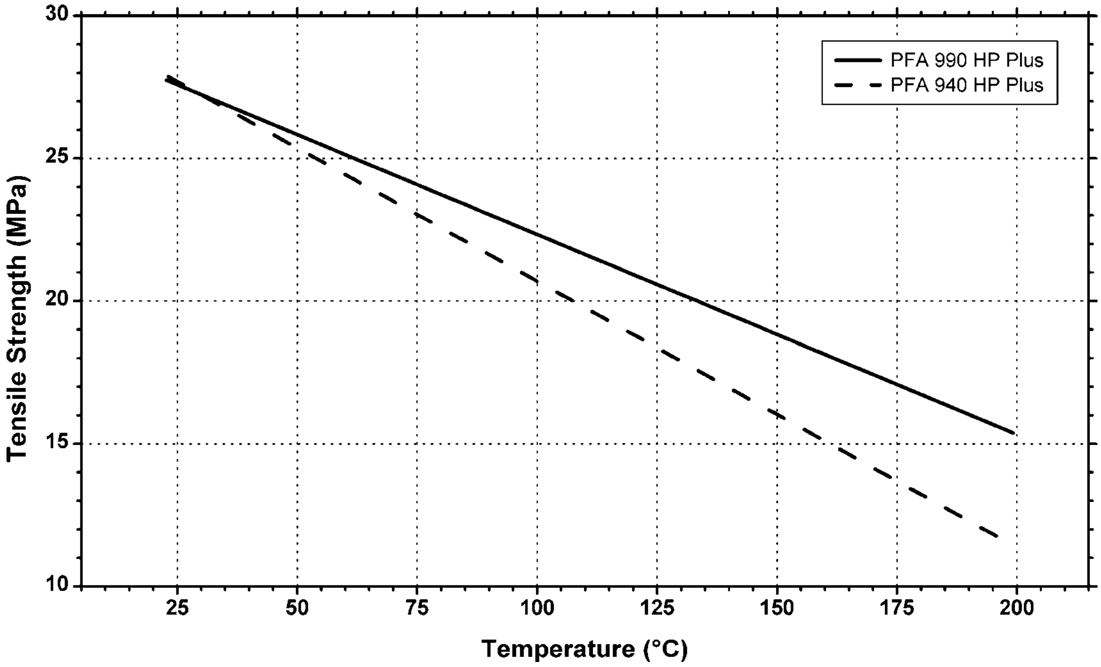


Figure 9.60. Tensile strength vs. temperature for DuPont Teflon® PFA HP plus resins.

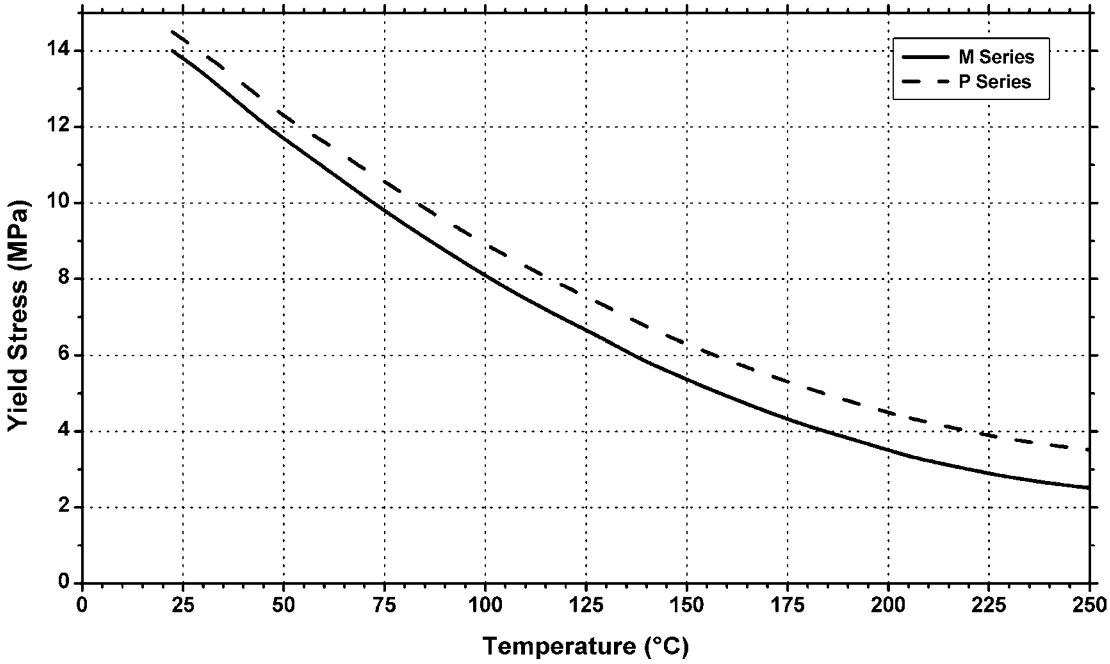


Figure 9.61. Yield stress vs. temperature for Solvay Solexis Hyflon® PFA resins.

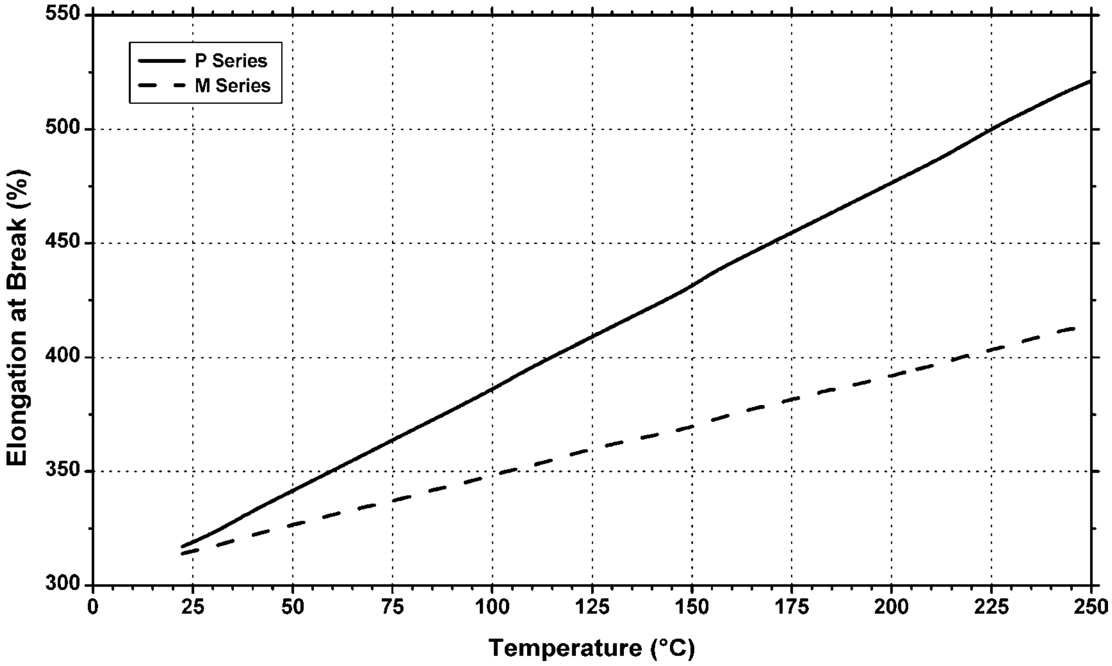


Figure 9.62. Elongation at break vs. temperature Solvay Solexis Hyflon® PFA resins.

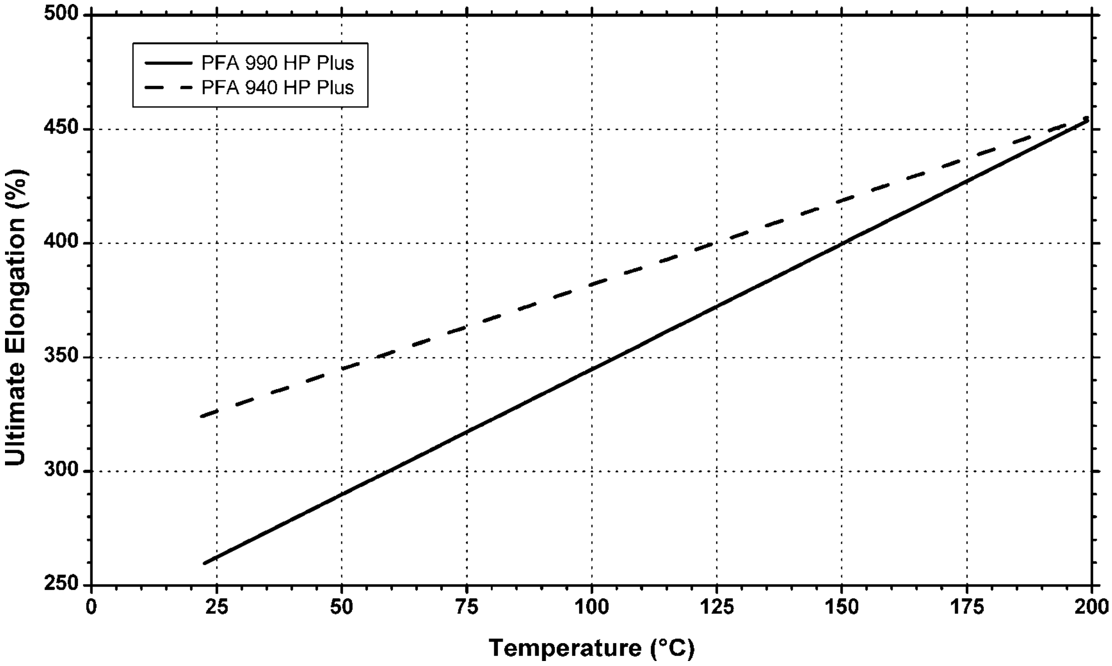


Figure 9.63. Ultimate elongation vs. temperature for DuPont Teflon® PFA HP plus resins.

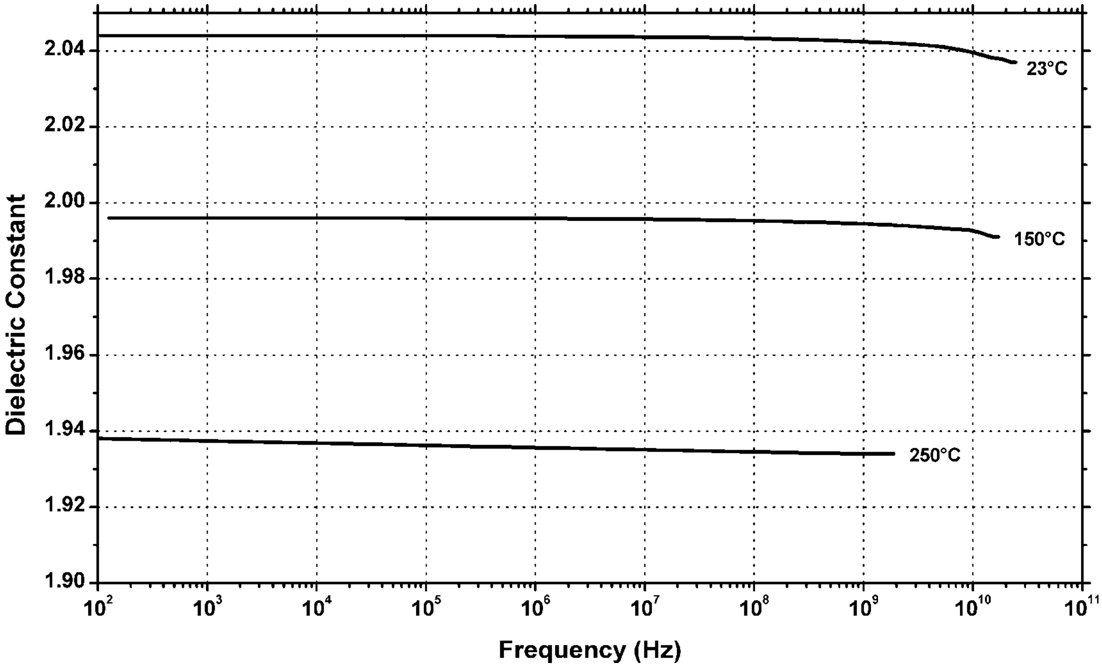


Figure 9.64. Dielectric constant vs. frequency for DuPont Teflon® PFA 340 and 350 grade resins.

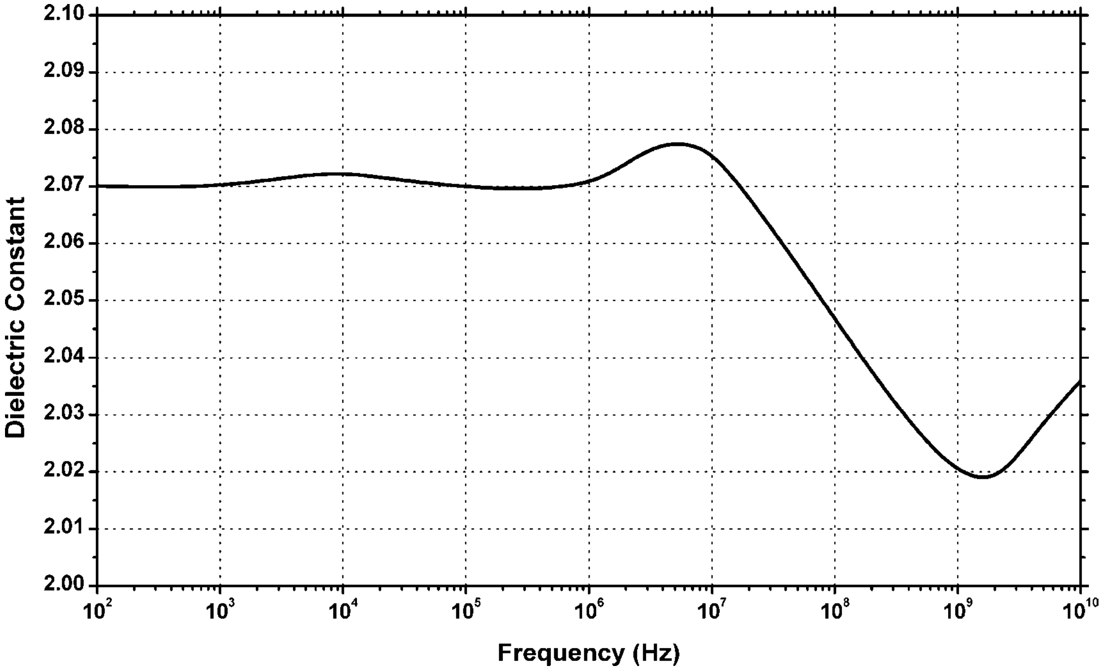


Figure 9.65. Dielectric constant vs. frequency for DuPont Teflon® PFA HP plus resins.

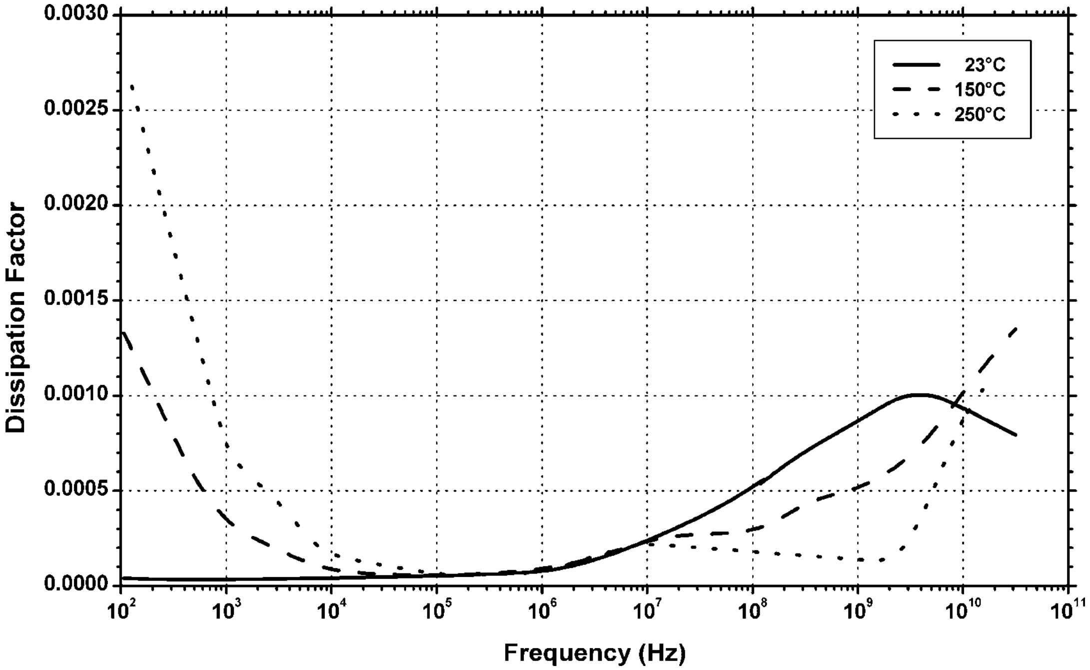


Figure 9.66. Dissipation factor vs. frequency and temperature for DuPont Teflon® PFA 340 and 350 grade resins.

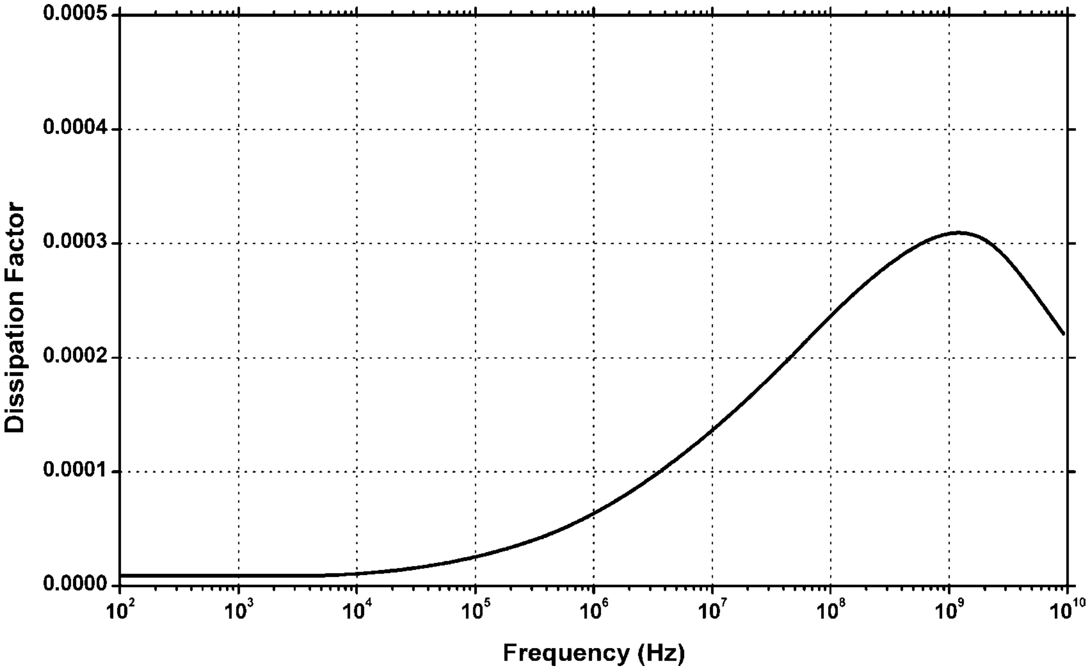


Figure 9.67. Dissipation factor vs. frequency and temperature for DuPont Teflon® PFA HP plus resins.

9.7 Polychlorotrifluoroethylene (PCTFE)

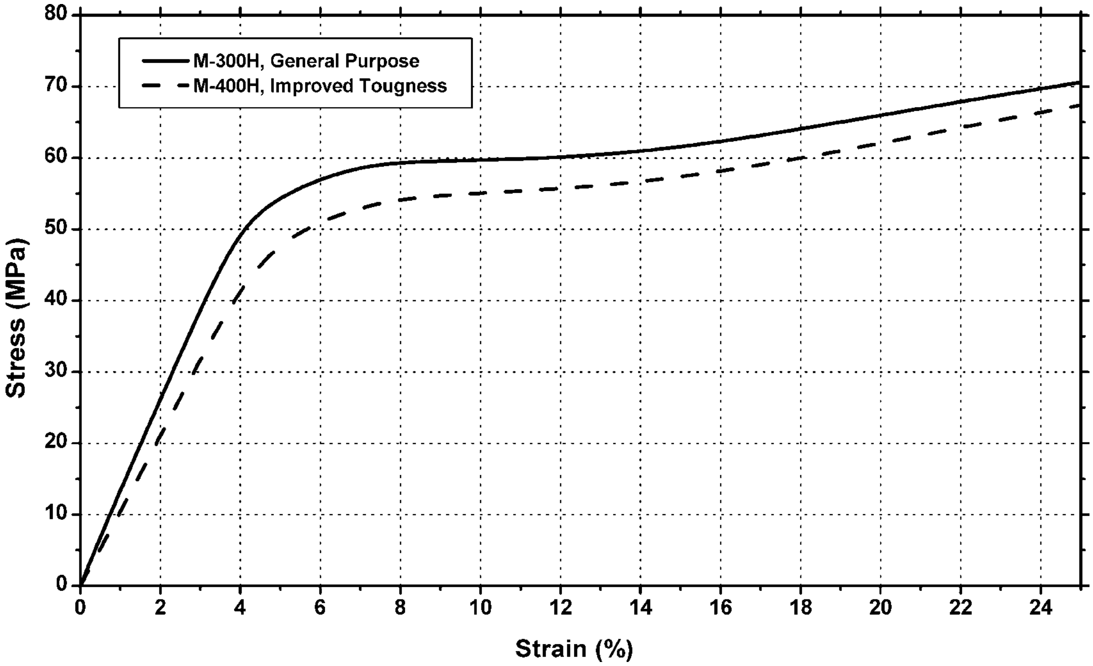


Figure 9.68. Stress vs. strain for at 23°C for Daikin Neoflon™ PCTFE resins.

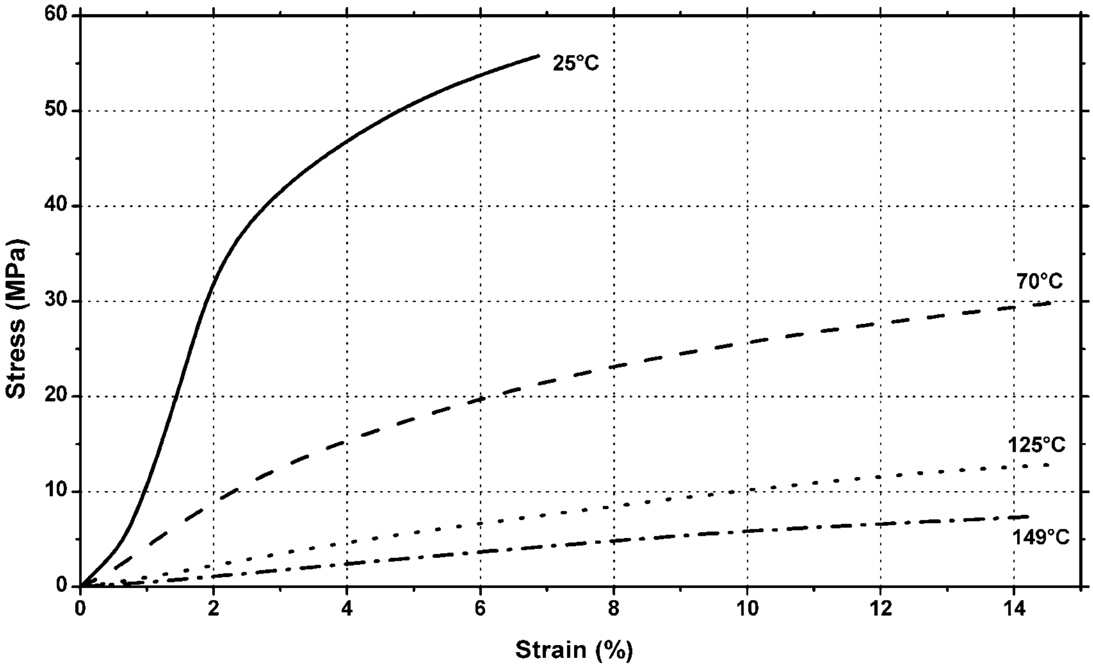


Figure 9.69. Stress vs. strain in compression at various temperatures for Dyneon PCTFE resins.

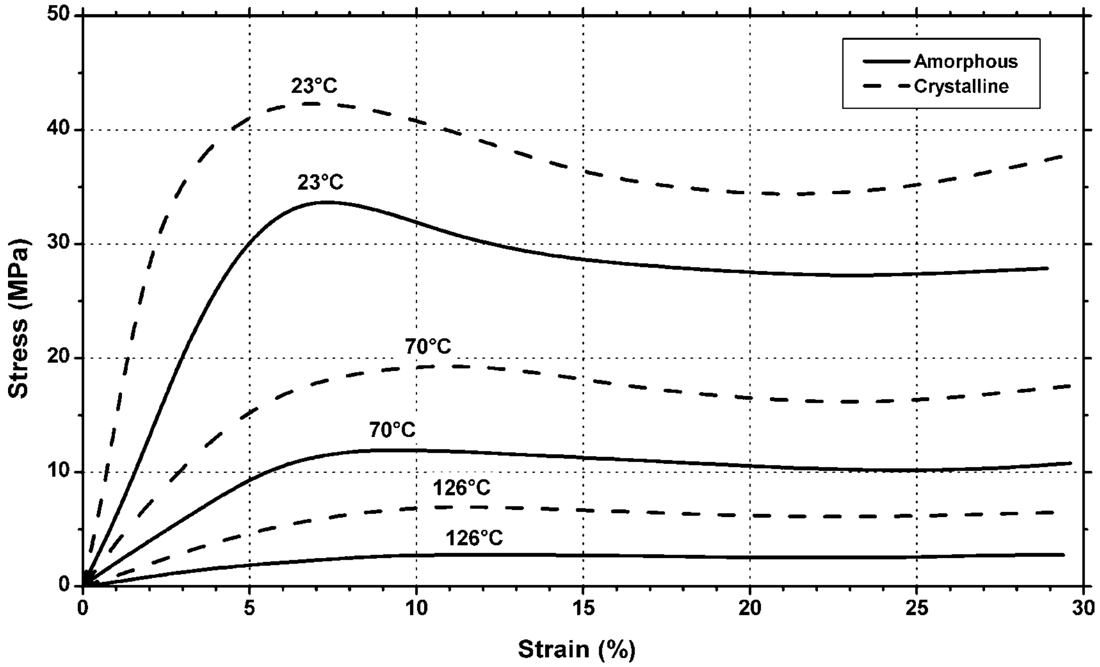


Figure 9.70. Stress vs. strain at various temperatures for Dyneon crystalline and amorphous PCTFE resins.

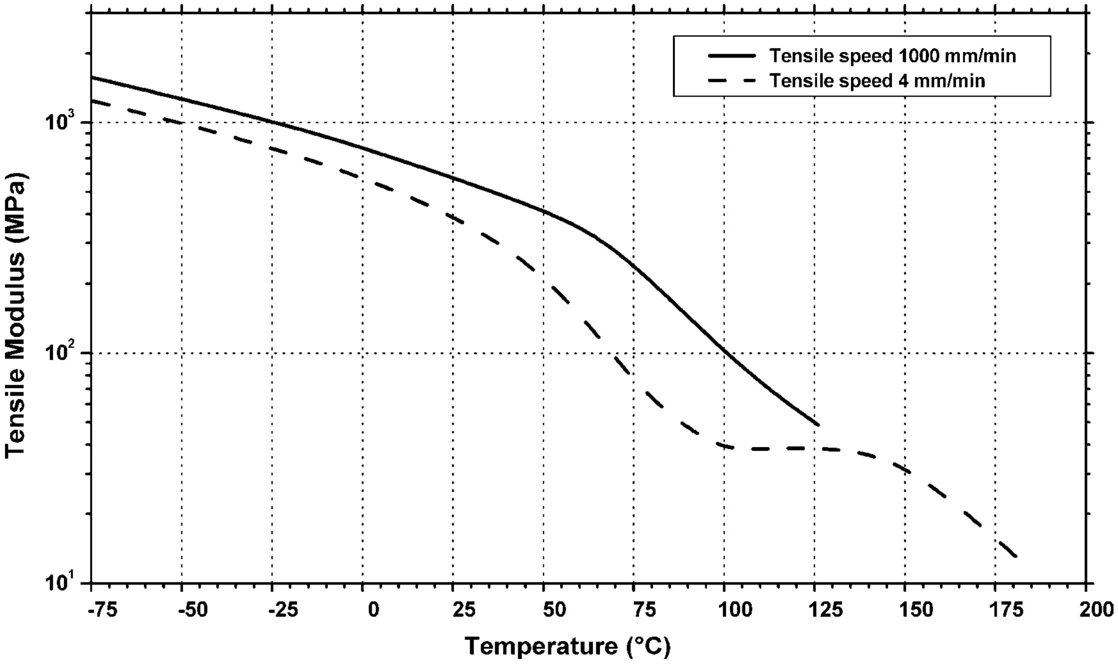


Figure 9.71. Tensile modulus vs. temperature for Daikin Neoflon™ PCTFE resins.

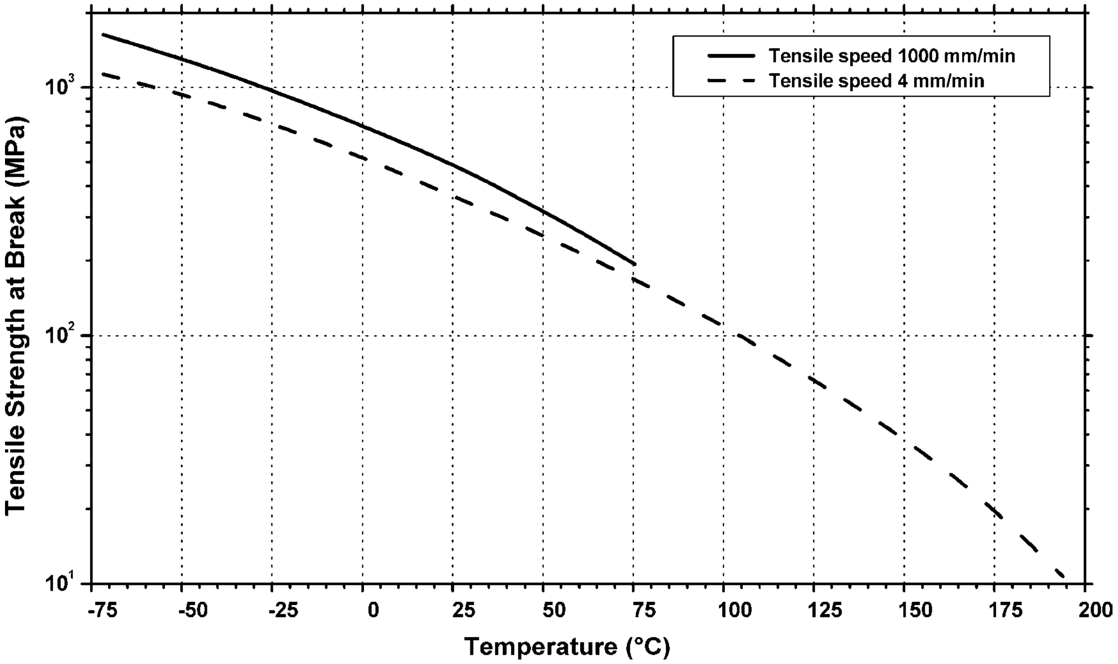


Figure 9.72. Tensile strength at break vs. temperature for Daikin Neoflon™ PCTFE resins.

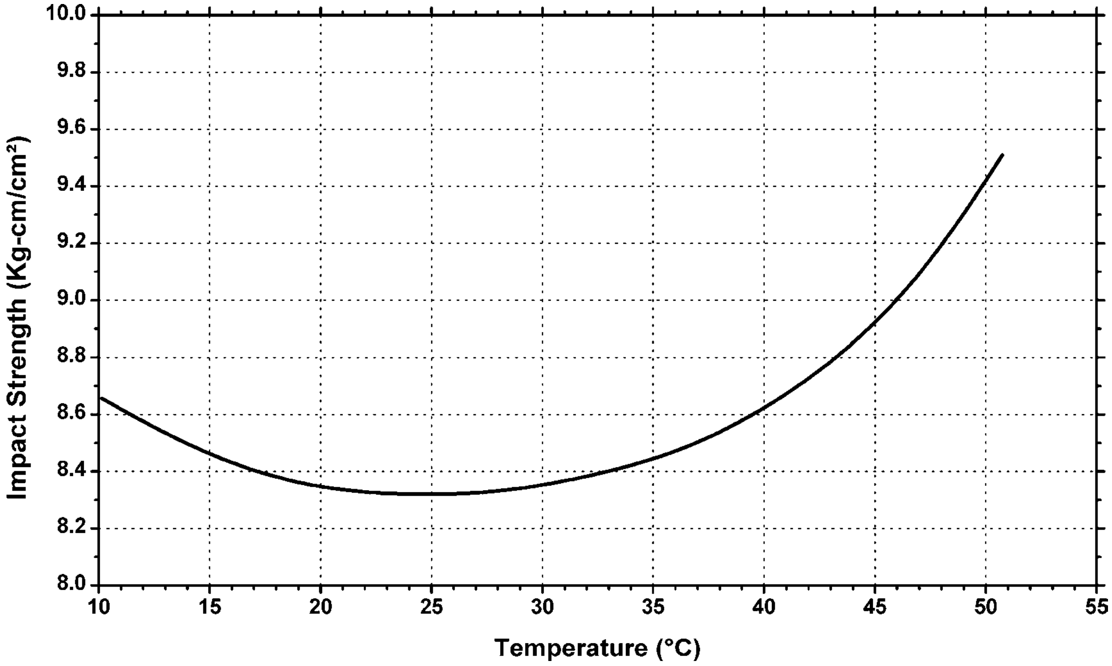


Figure 9.73. Izod impact strength vs. temperature for Daikin Neoflon™ PCTFE resins.

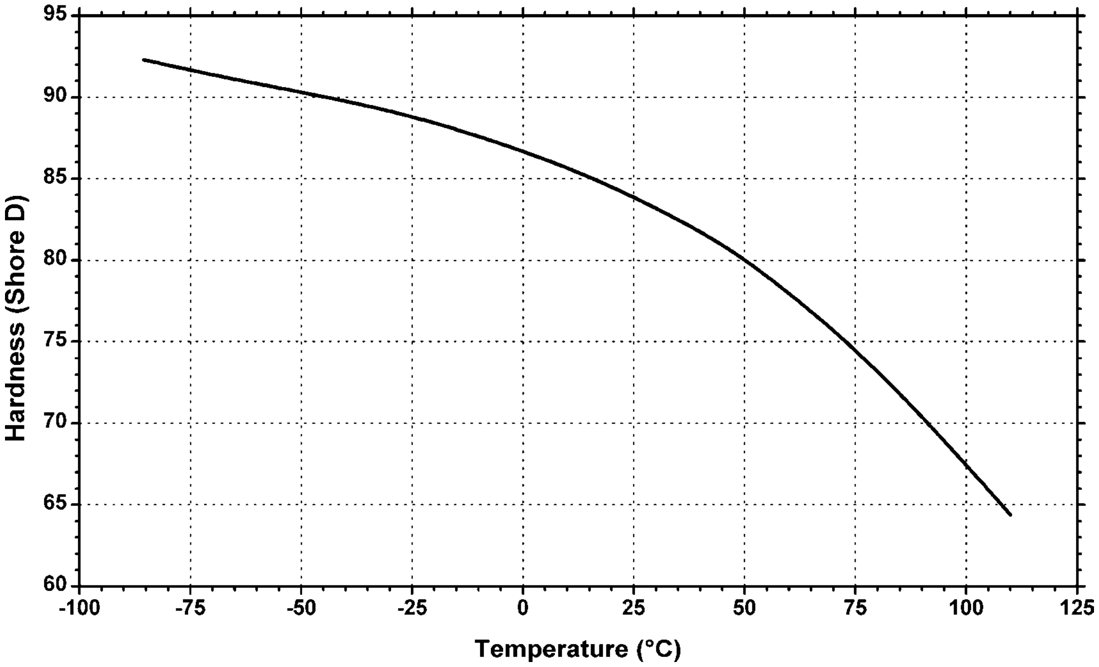


Figure 9.74. Shore D harness vs. temperature for Daikin Neoflon™ M-300H—general purpose and M-400H—higher molecular weight, increased toughness PCTFE resins.

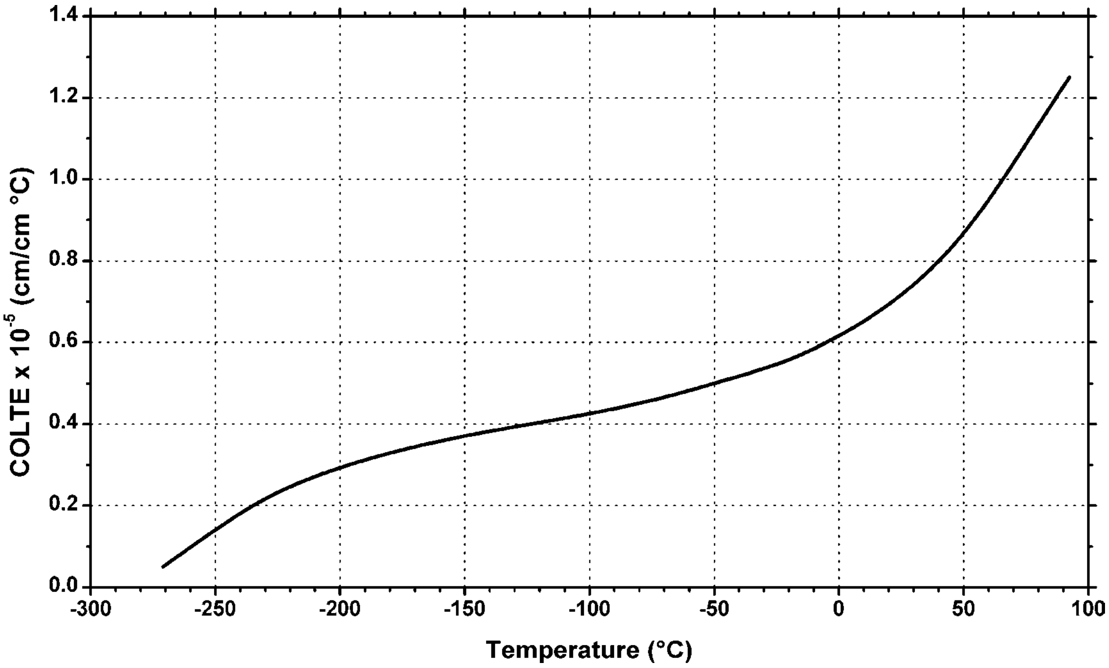


Figure 9.75. Coefficient of linear thermal expansion vs. temperature for Dyneon PCTFE resin.

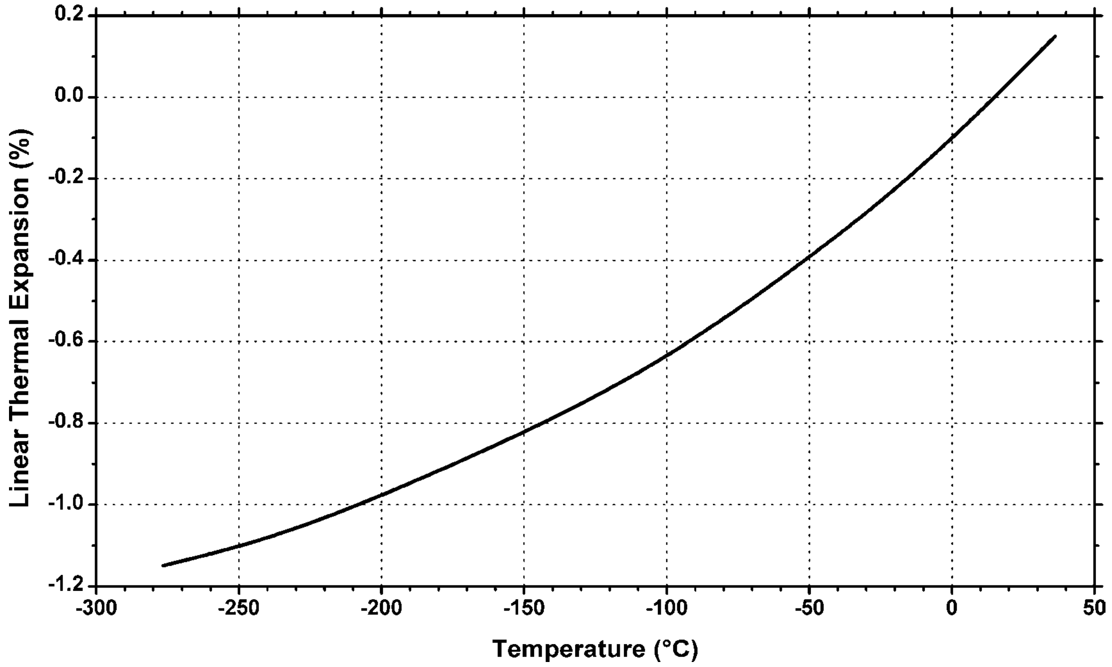


Figure 9.76. Linear thermal expansion vs. temperature for Daikin Neoflon™ PCTFE resins.

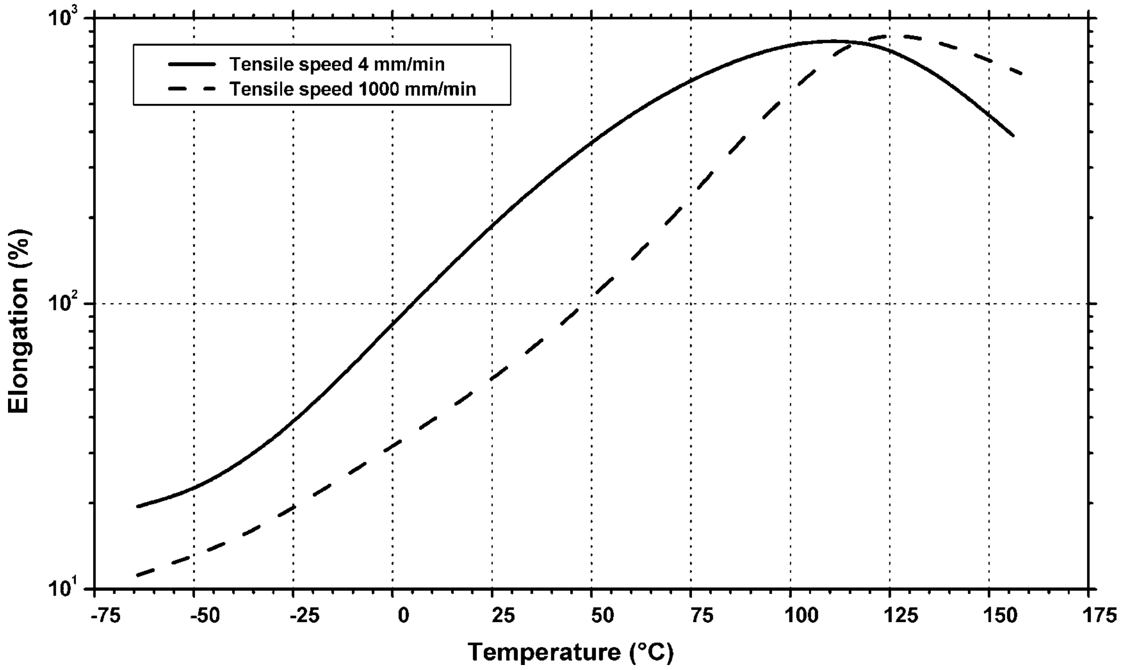


Figure 9.77. Elongation vs. temperature for Daikin Neoflon™ M-300H—general purpose PCTFE resin.

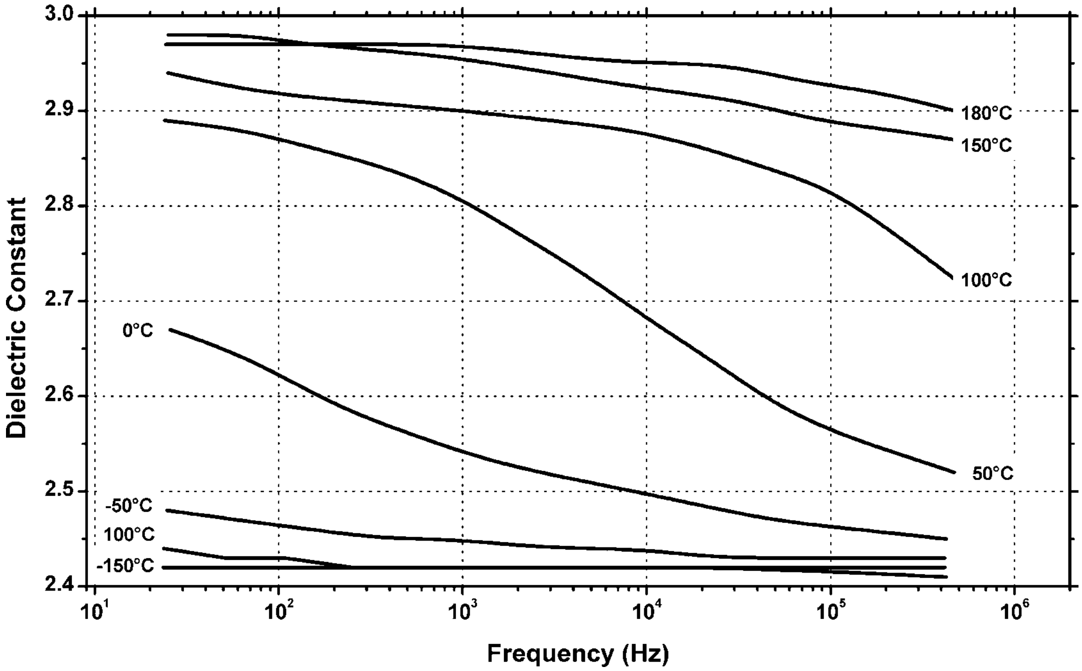


Figure 9.78. Dielectric constant vs. frequency and temperature for Daikin Neoflon™ PCTFE resin.

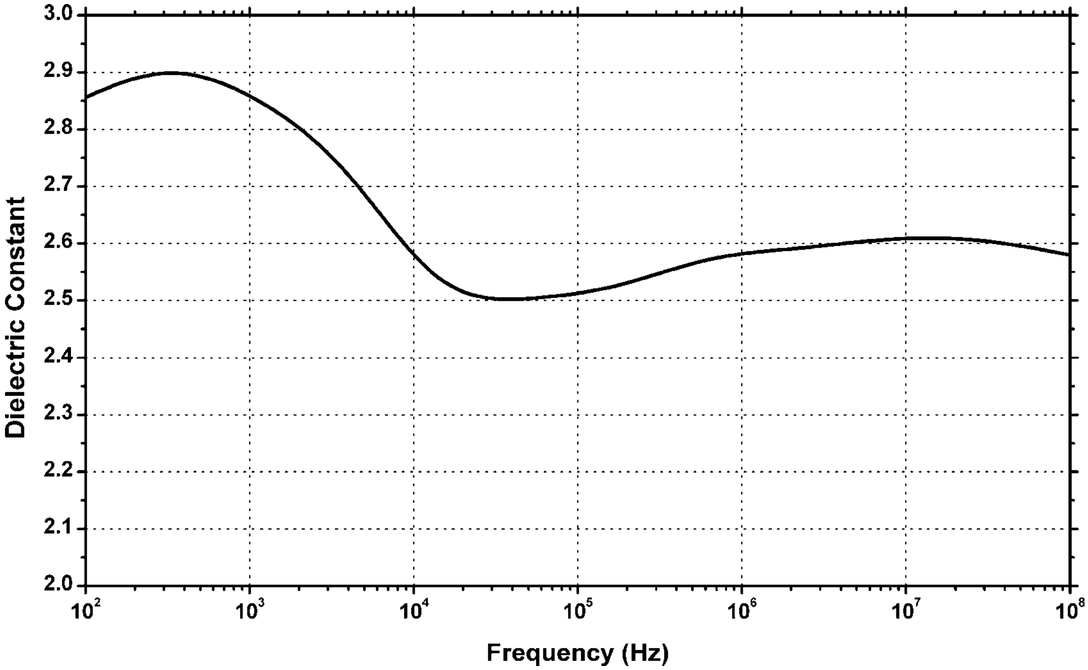


Figure 9.79. Dielectric constant vs. frequency at 25°C for Arkema Voltalef® 302 PCTFE resin.

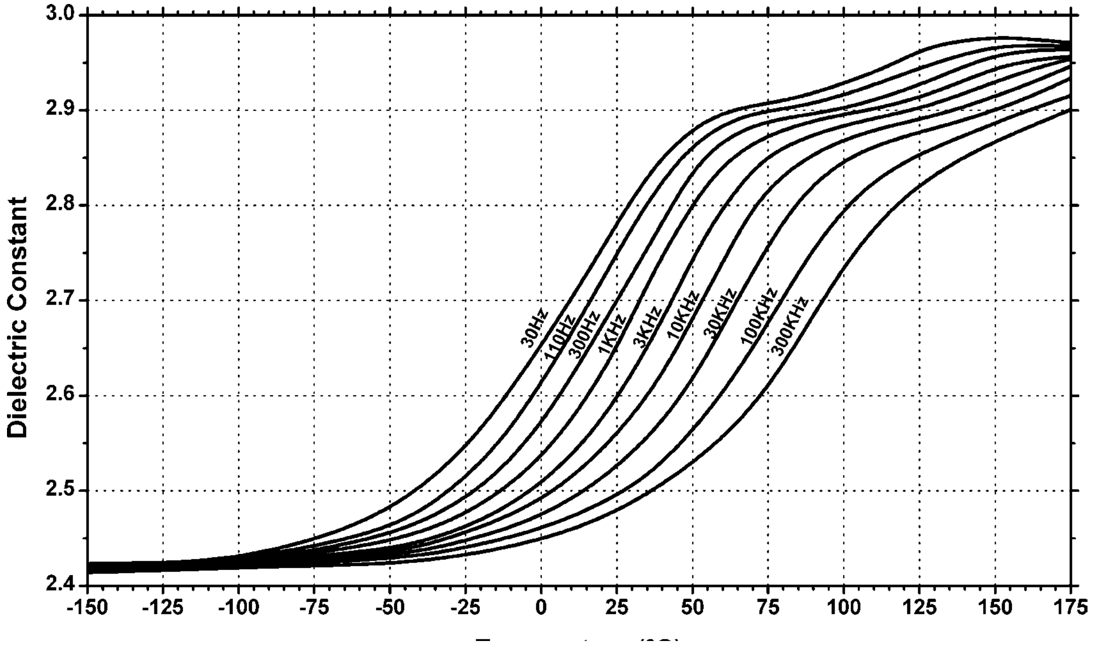


Figure 9.80. Dielectric constant vs. temperature and frequency for Daikin Neoflon™ PCTFE resin.

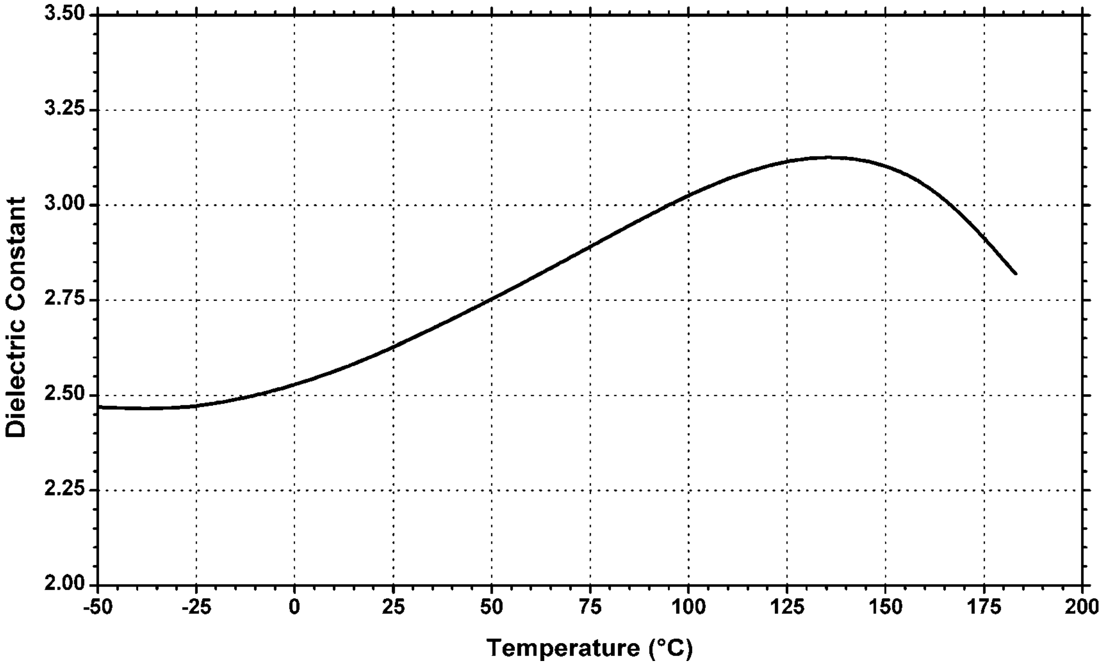


Figure 9.81. Dielectric constant vs. temperature at 25°C for Arkema Voltalef® 302 PCTFE resin.

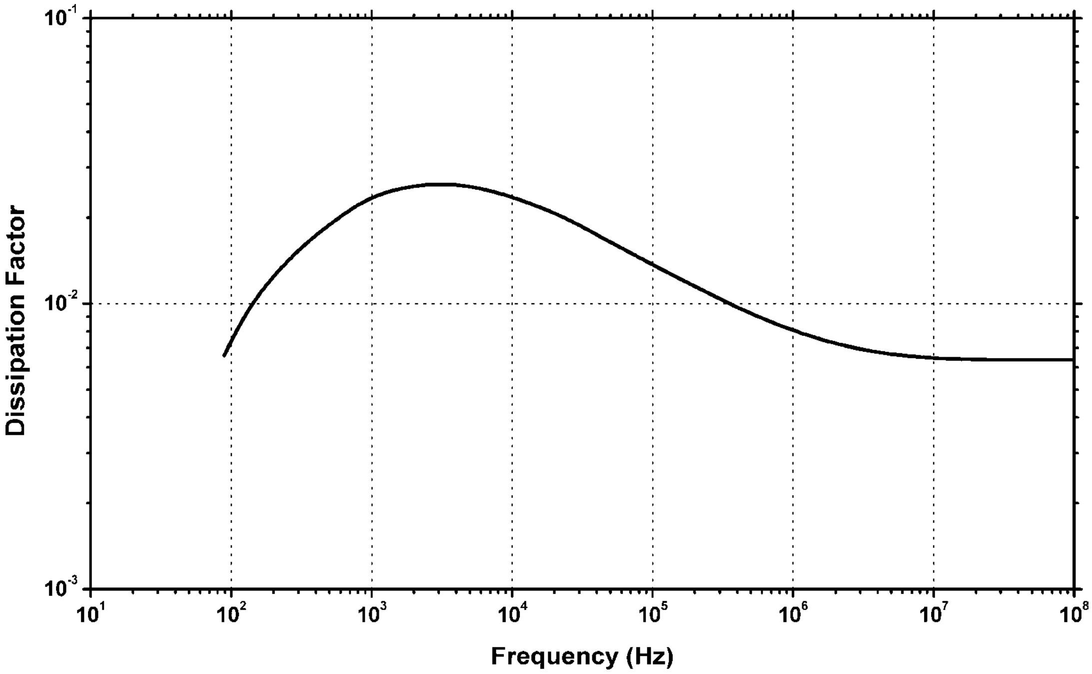


Figure 9.82. Dissipation factor vs. frequency at 25°C for Arkema Voltalef® 302 PCTFE resin.

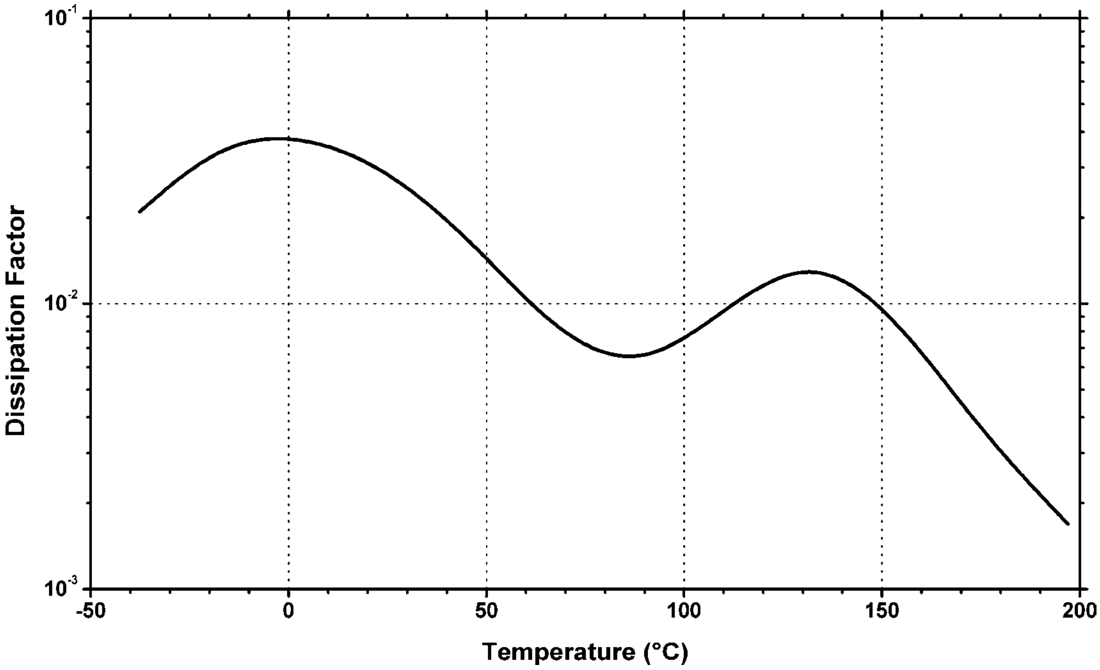


Figure 9.83. Dissipation factor vs. temperature at 60 Hz for Arkema Voltalef® 302 PCTFE resin.

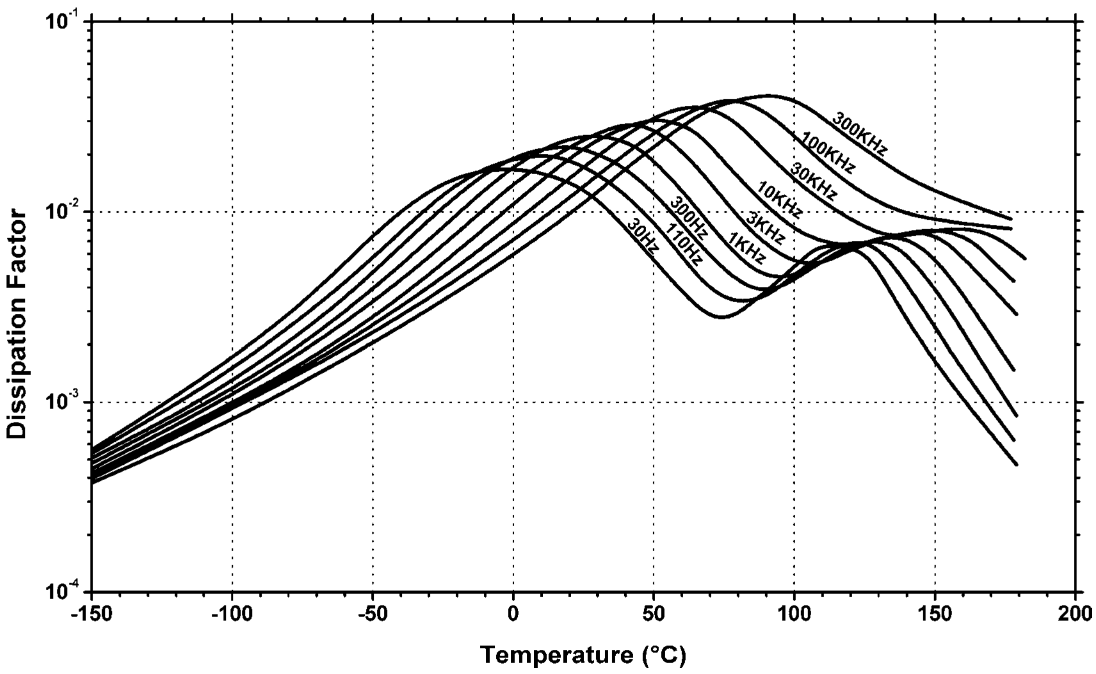


Figure 9.84. Dissipation factor vs. temperature and frequency for Daikin Neoflon™ PCTFE resins.

9.8 Polyvinylidene Fluoride (PVDF)

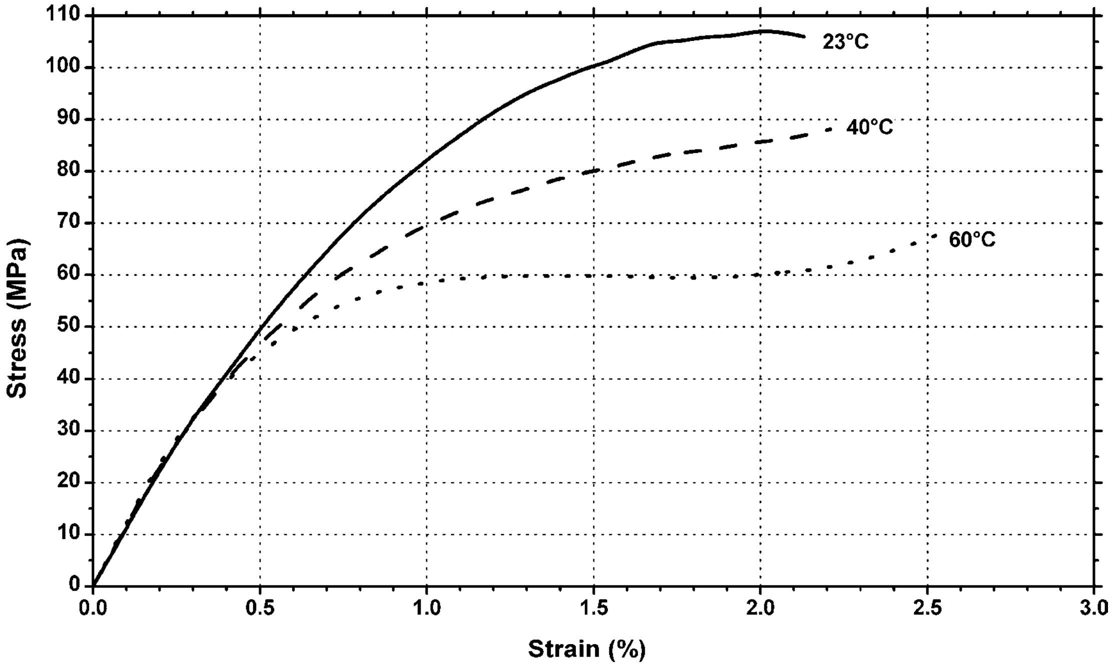


Figure 9.85. Stress vs. strain at various temperatures for SABIC Innovative Plastics Thermocomp® FP VC-1003—electrically conductive, carbon fiber filled PVDF resin.

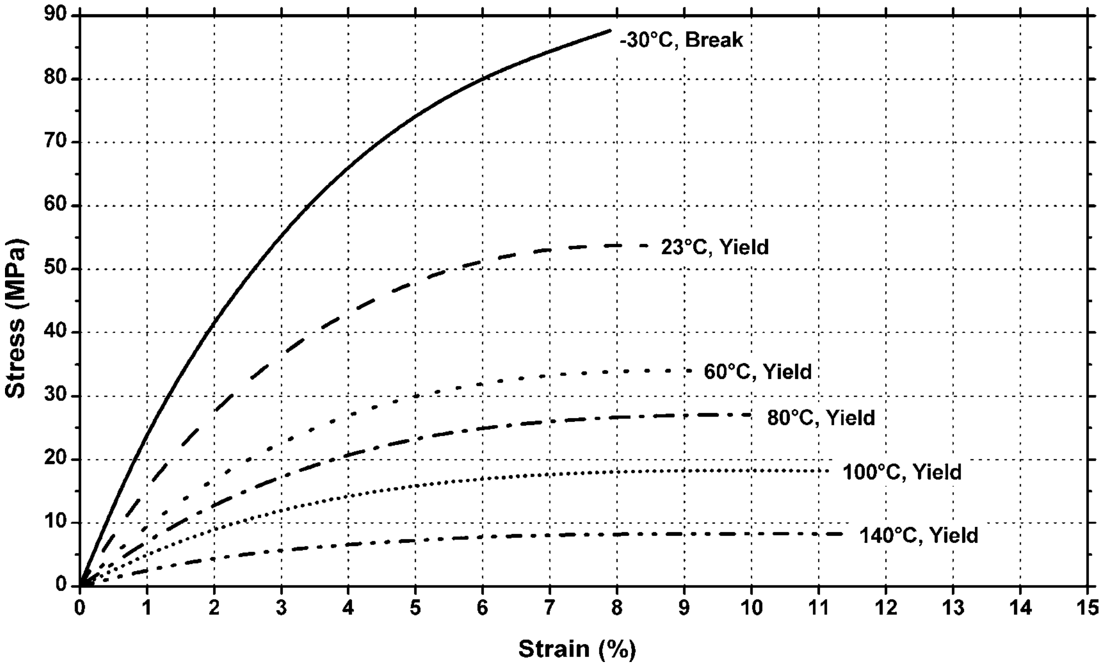


Figure 9.86. Stress vs. strain at various temperatures for Arkema Kynar Flex® 710—homopolymer PVDF resin.

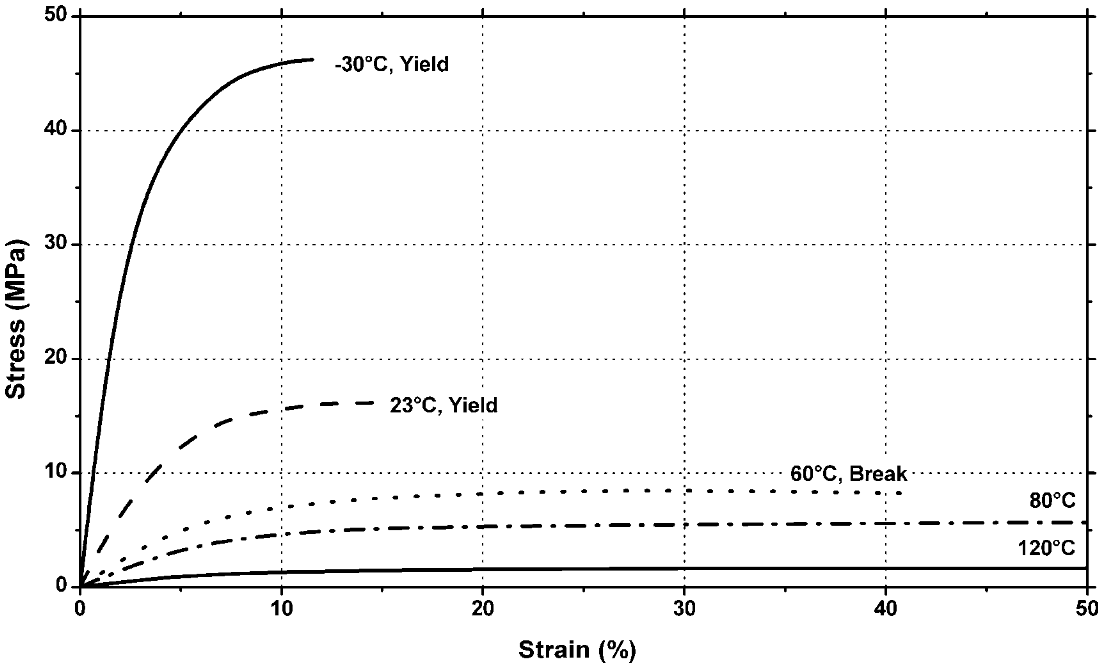


Figure 9.87. Stress vs. strain at various temperatures for Arkema Kynar Flex® 2750—copolymer PVDF resin.

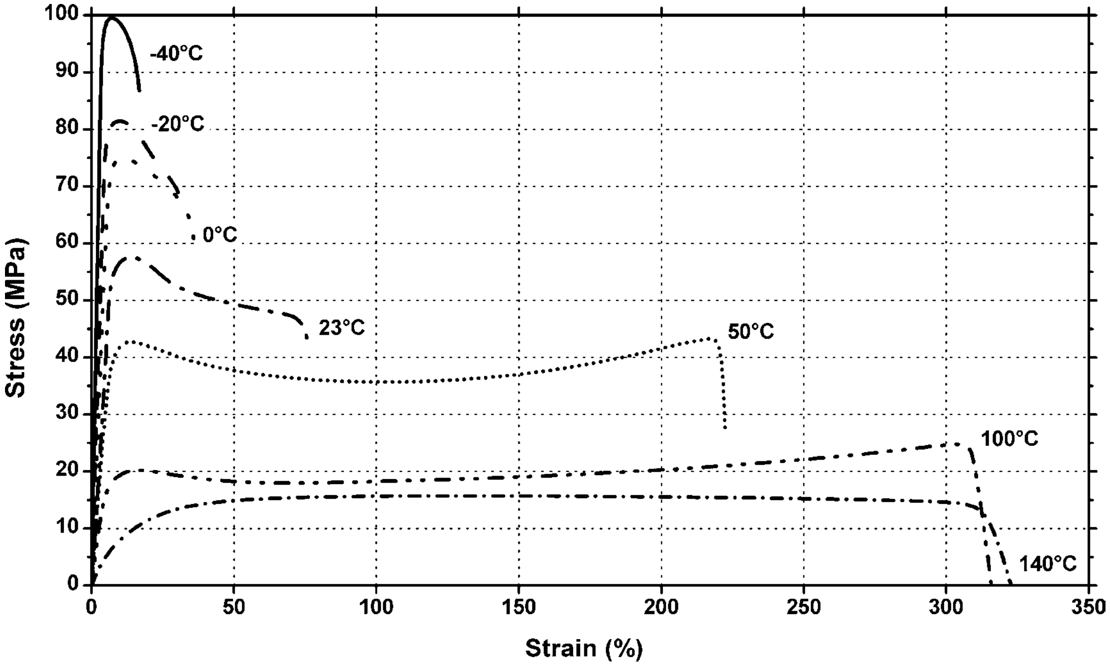


Figure 9.88. Stress vs. strain at various temperatures for Solvay Solexis Solef® 1008—general purpose homopolymer injection molding PVDF resin.

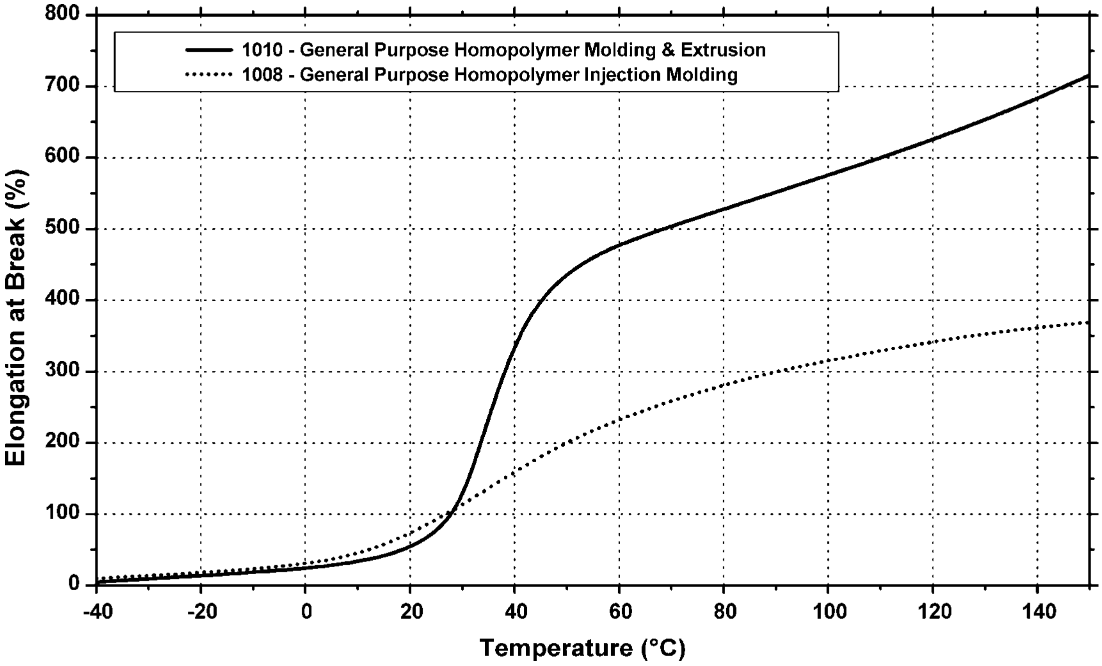


Figure 9.89. Elongation at break vs. temperature for Solvay Solexis Solef® PVDF resins.

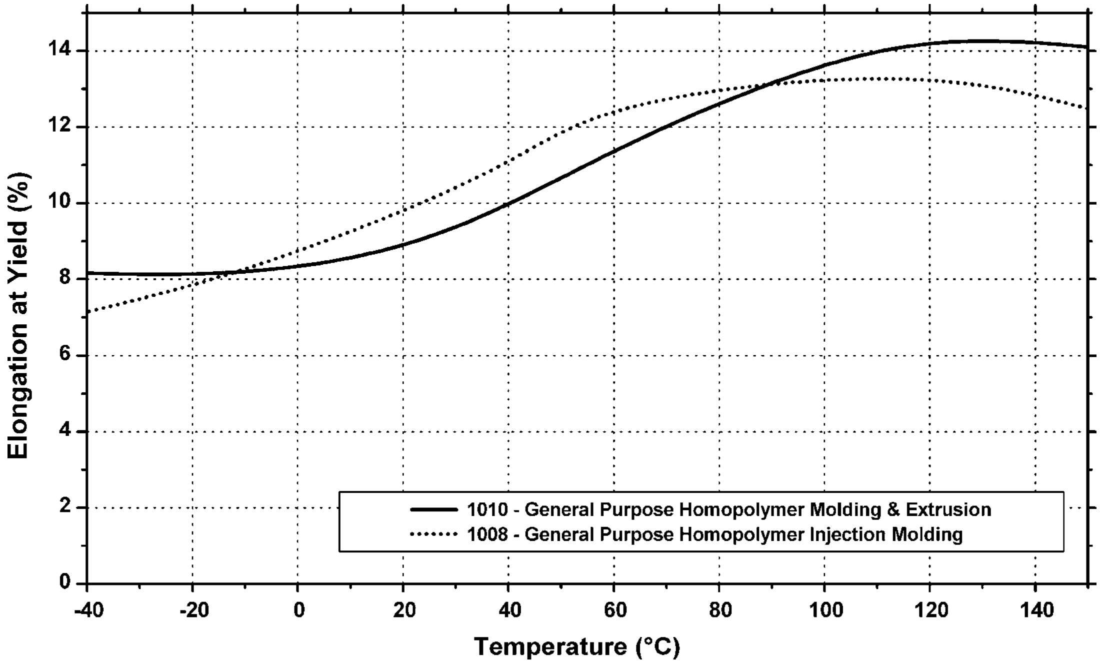


Figure 9.90. Elongation at yield vs. temperature for Solvay Solexis Solef® PVDF resins.

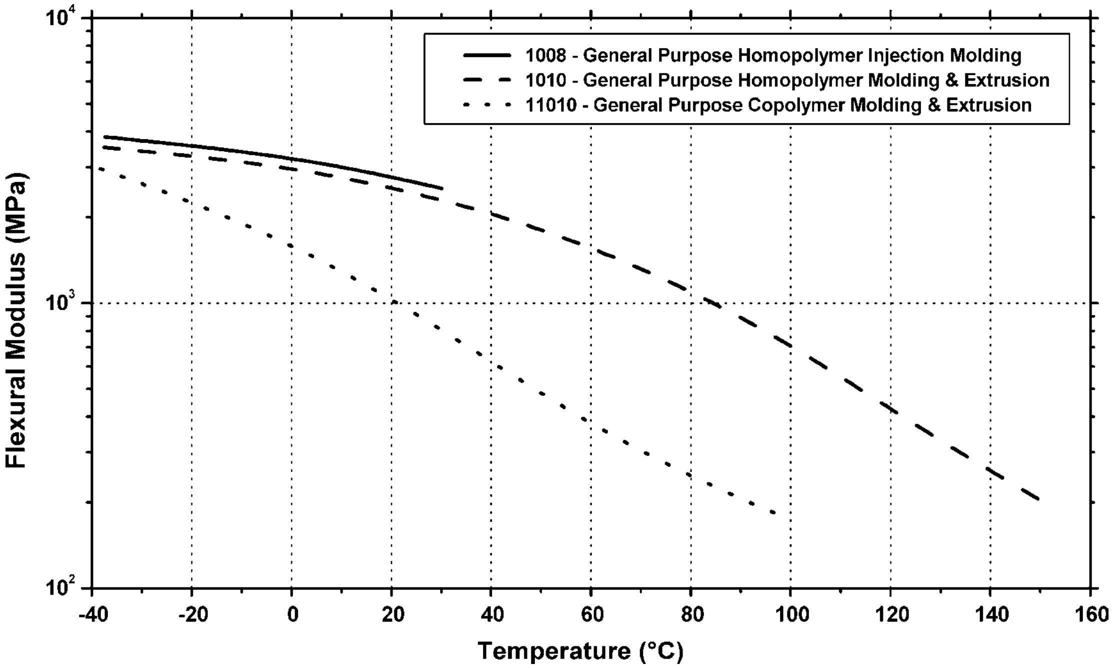


Figure 9.91. Flexural modulus vs. temperature for Solvay Solexis Solef® PVDF resins.

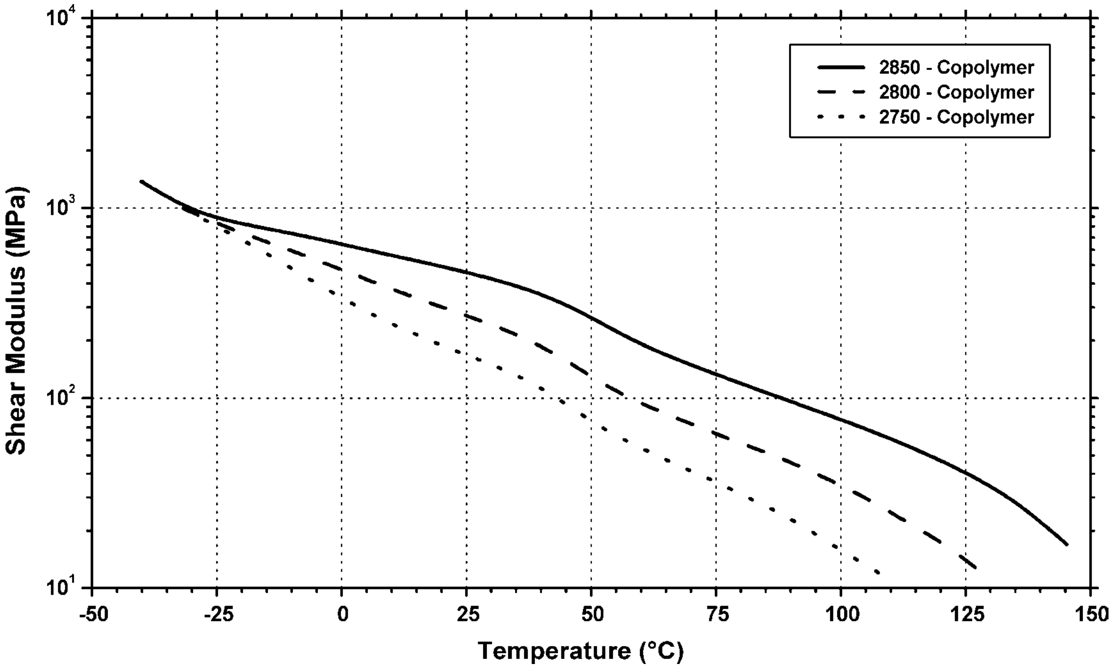


Figure 9.92. Shear modulus vs. temperature for Arkema Kynar Flex® copolymer PVDF resins.

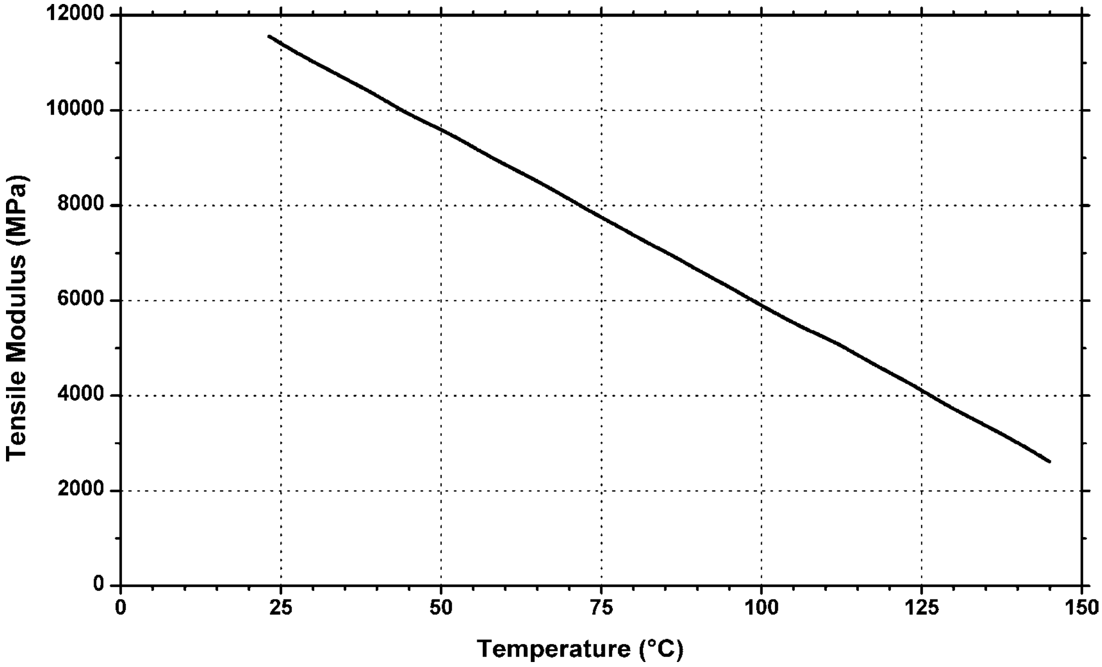


Figure 9.93. Tensile modulus vs. temperature for SABIC Innovative Plastics Thermocomp® FP VC-1003—electrically conductive, carbon fiber filled PVDF resin.

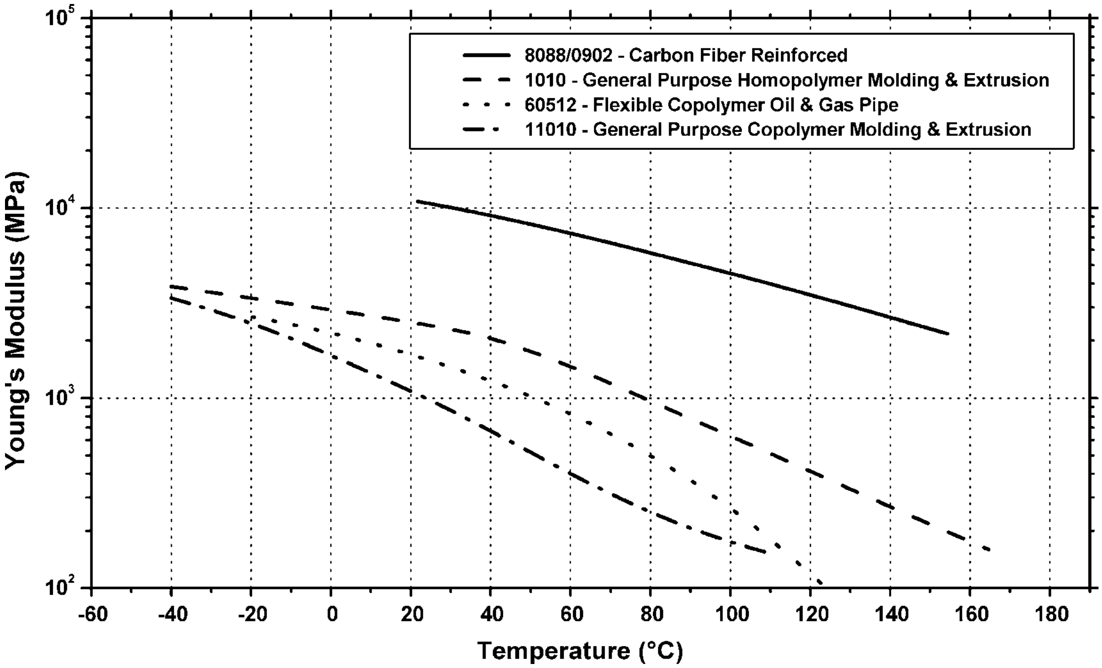


Figure 9.94. Young's modulus vs. temperature for Solvay Solexis Solef® PVDF resins.

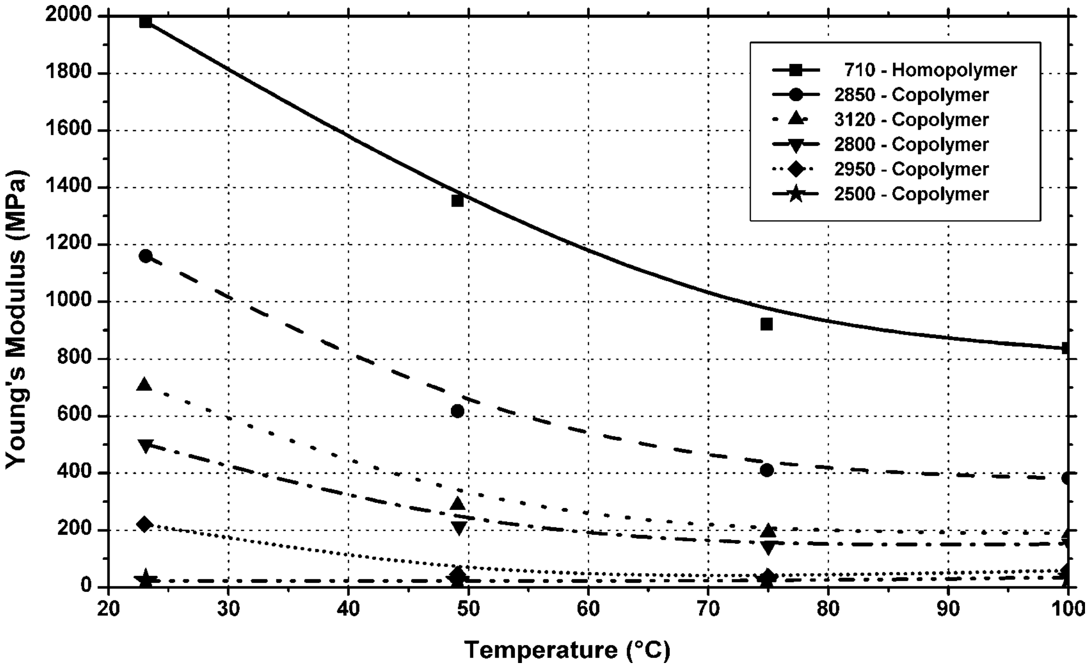


Figure 9.95. Young's modulus vs. temperature for Arkema Kynar Flex®—PVDF resins.

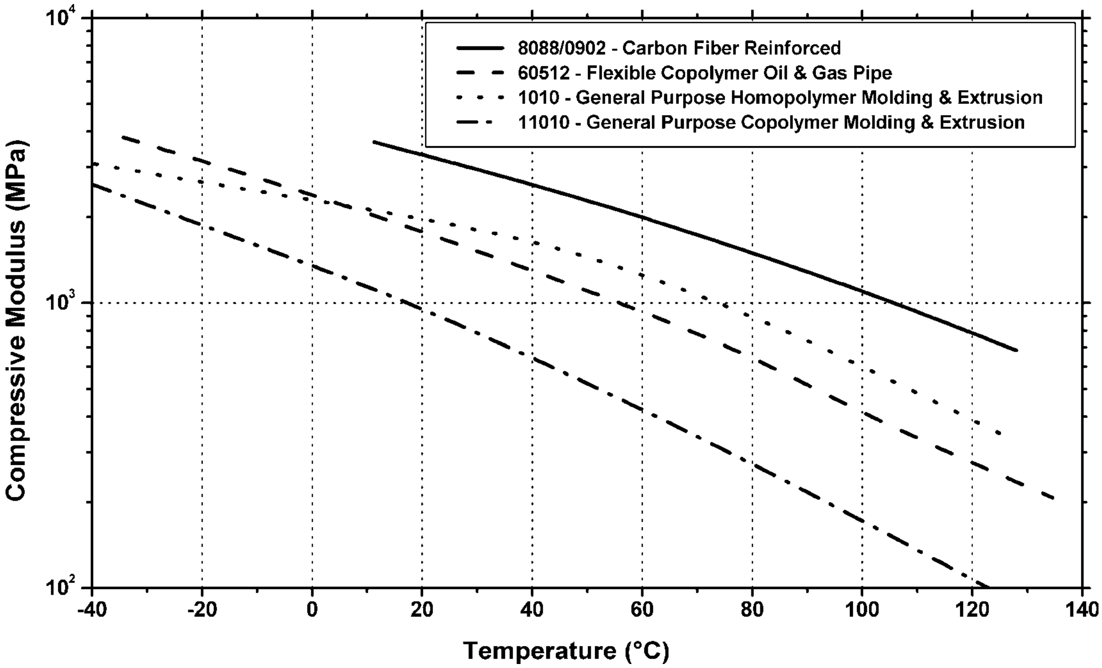


Figure 9.96. Compressive modulus vs. temperature for Solvay Solexis Solef® PVDF resins.

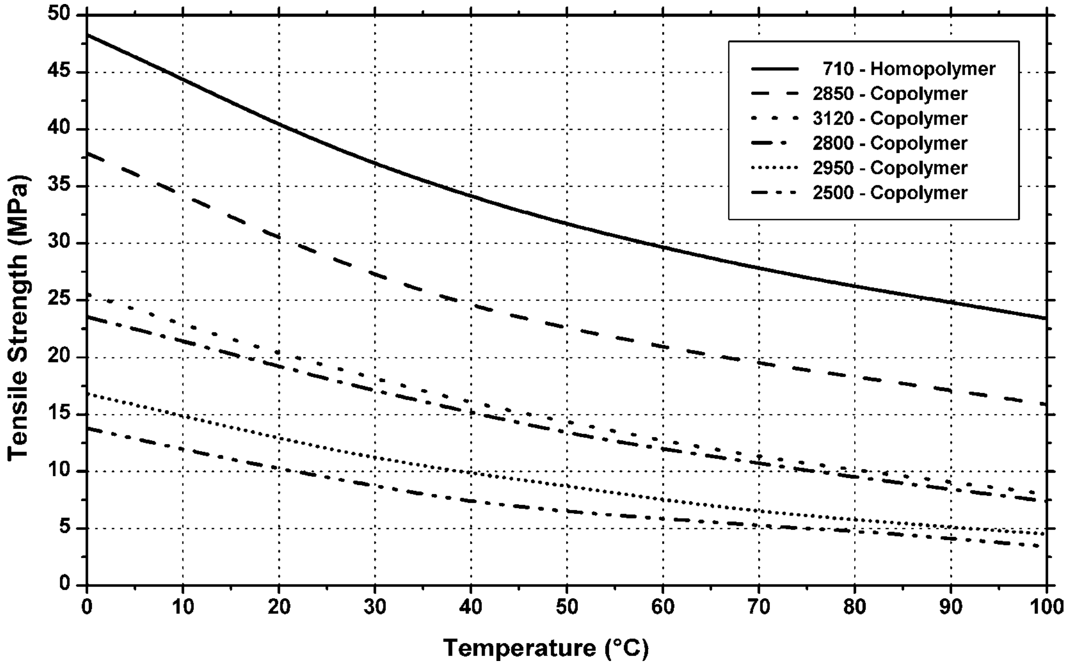


Figure 9.97. Tensile strength vs. temperature for Arkema Kynar Flex®—PVDF resins.

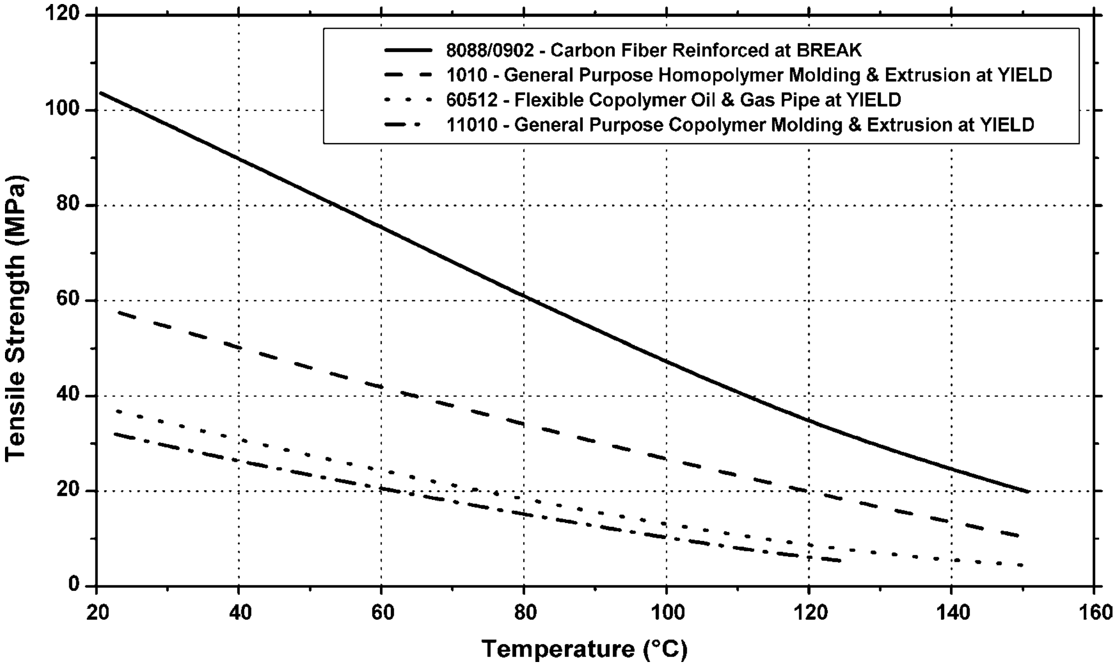


Figure 9.98. Tensile strength vs. temperature for Solvay Solexis Solef® PVDF resins.

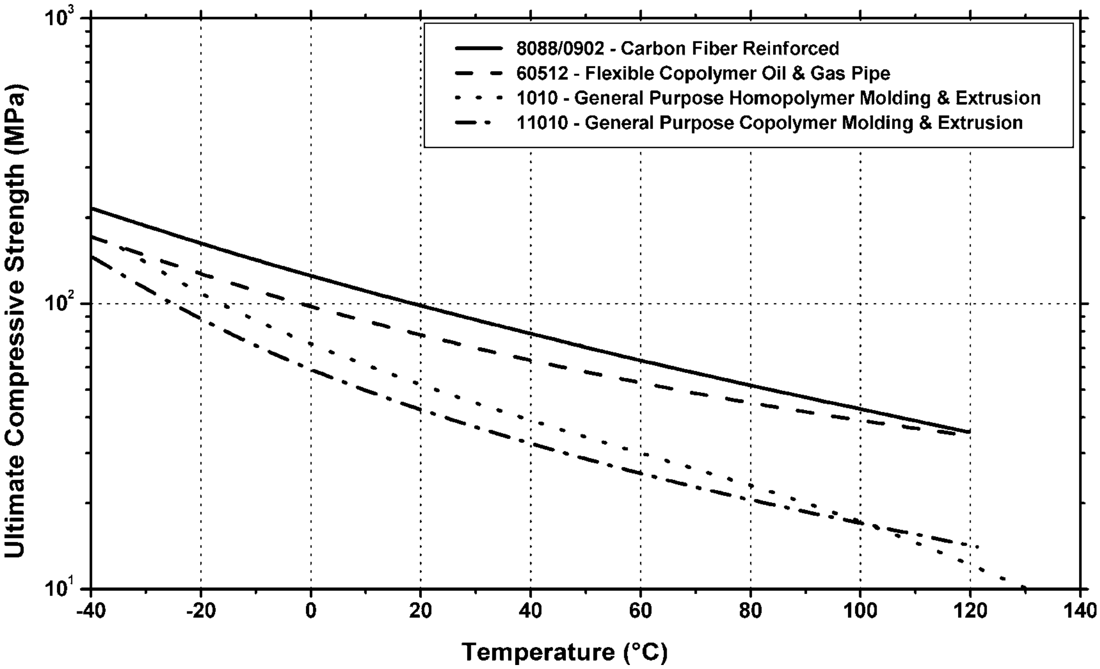


Figure 9.99. Ultimate compressive strength vs. temperature for Solvay Solexis Solef® PVDF resins.

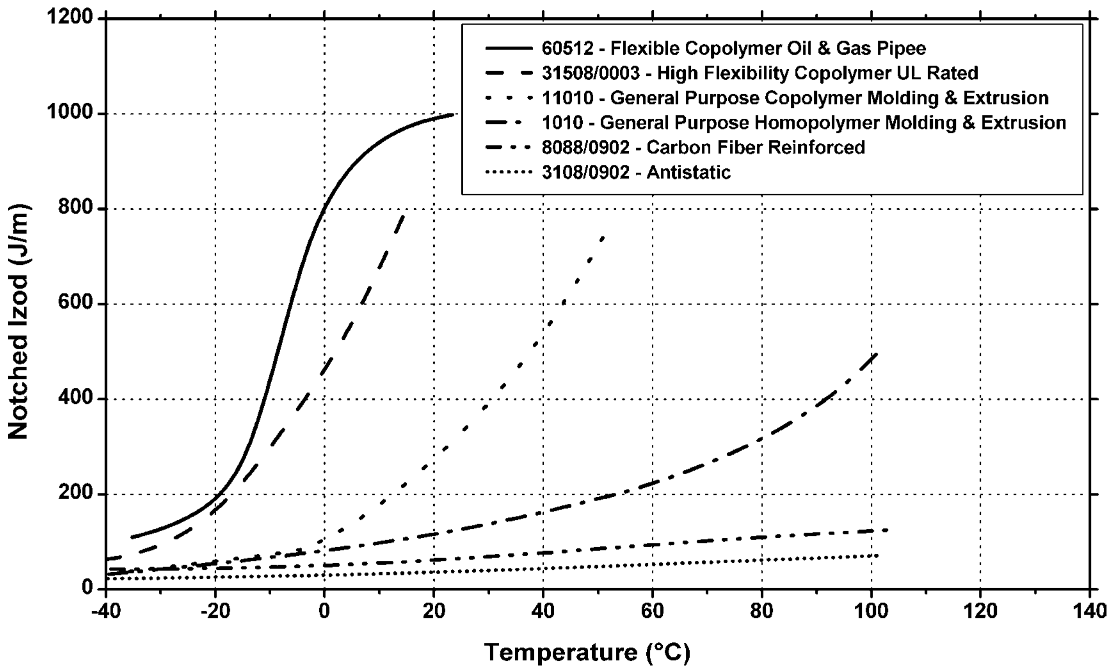


Figure 9.100. Notched Izod impact strength vs. temperature for Solvay Solexis Solef® PVDF resins.

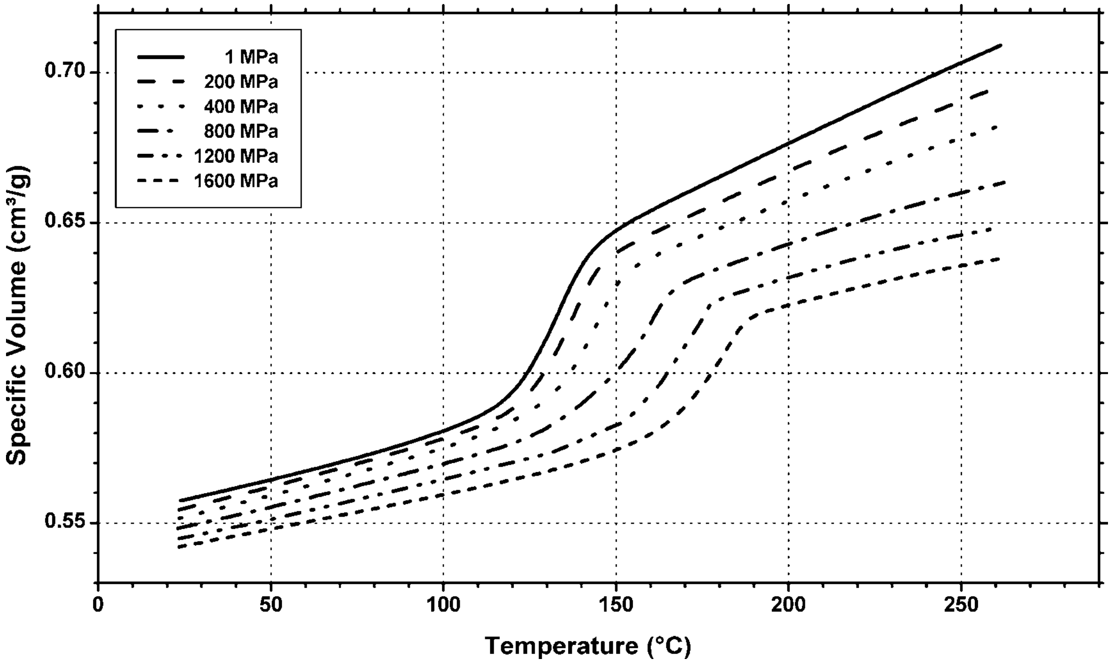


Figure 9.101. Pressure–volume–temperature (PVT) plot for Solvay Solexis Solef® 1008—general purpose homopolymer injection molding PVDF resin.

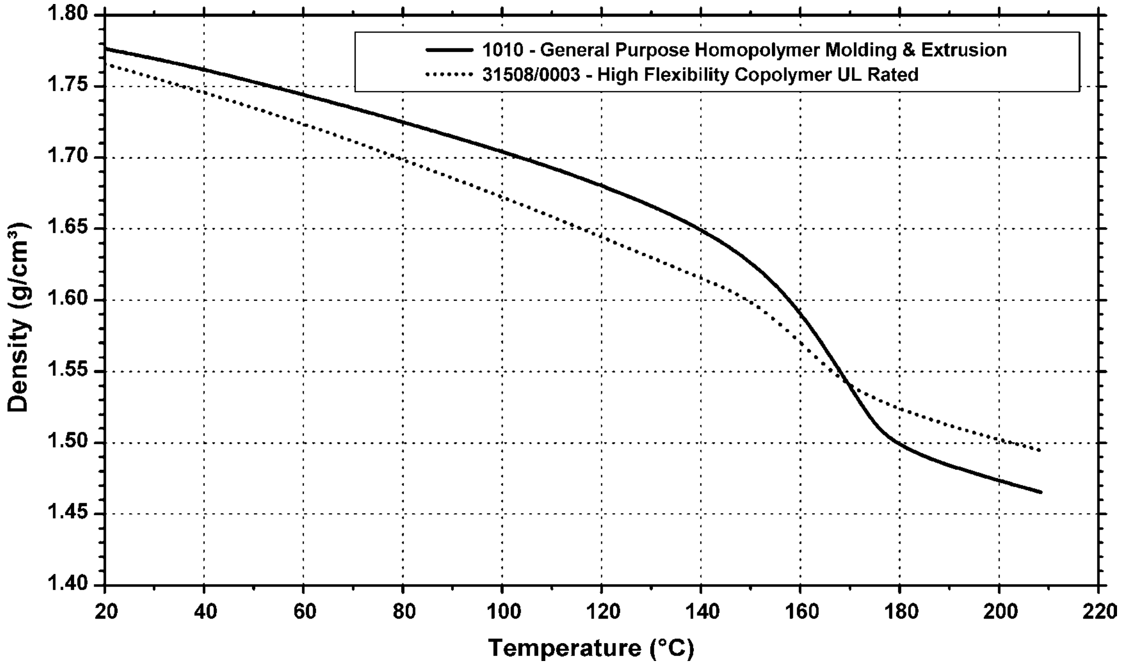


Figure 9.102. Density vs. temperature for Solvay Solexis Solef® PVDF resins.

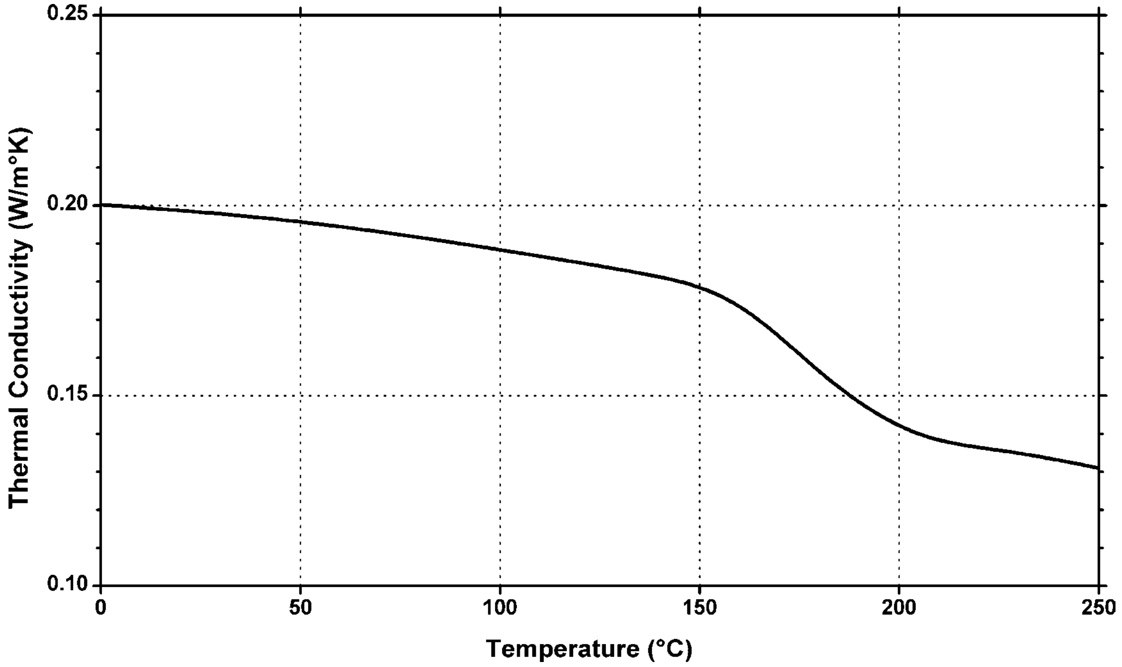


Figure 9.103. Thermal conductivity vs. temperature for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin.

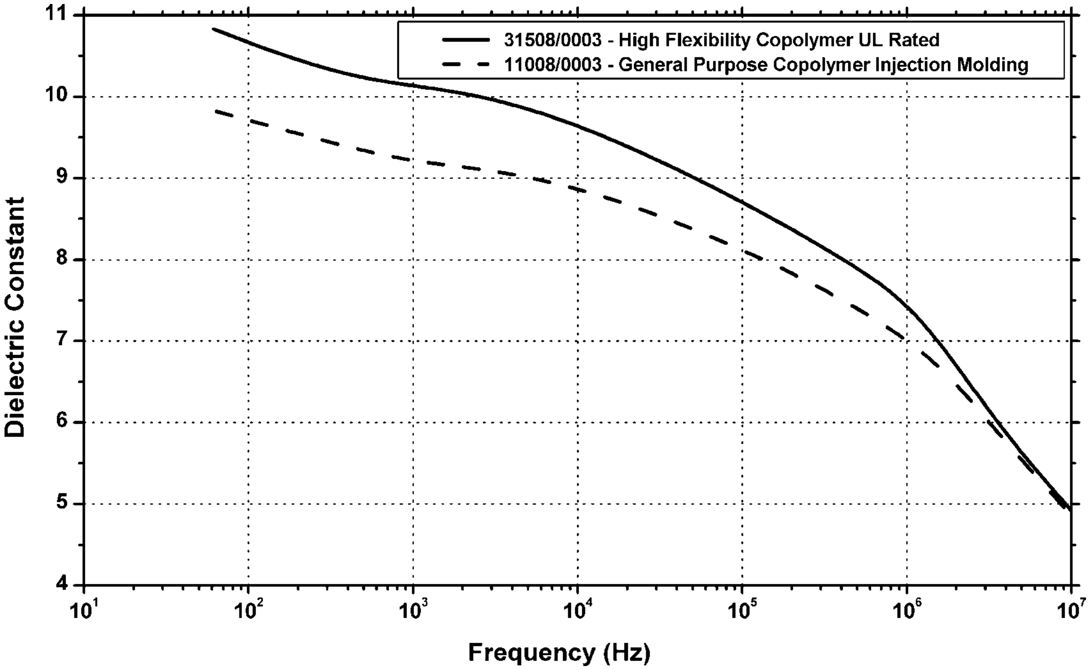


Figure 9.104. Dielectric constant vs. frequency for Solvay Solexis Solef® PVDF resins.

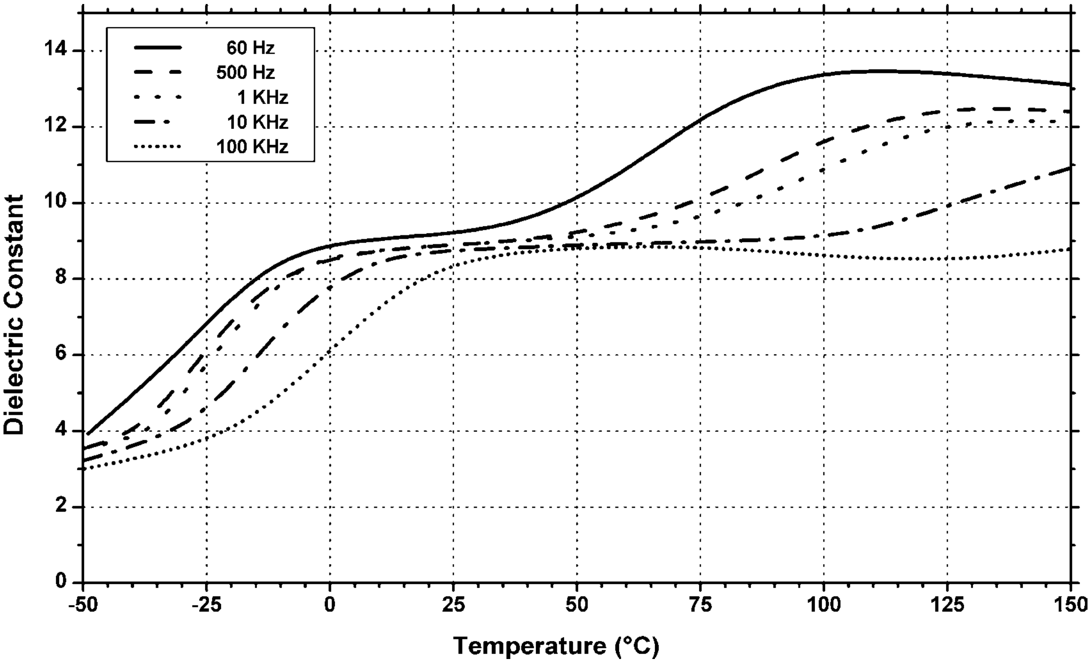


Figure 9.105. Dielectric constant vs. temperature and frequency for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin.

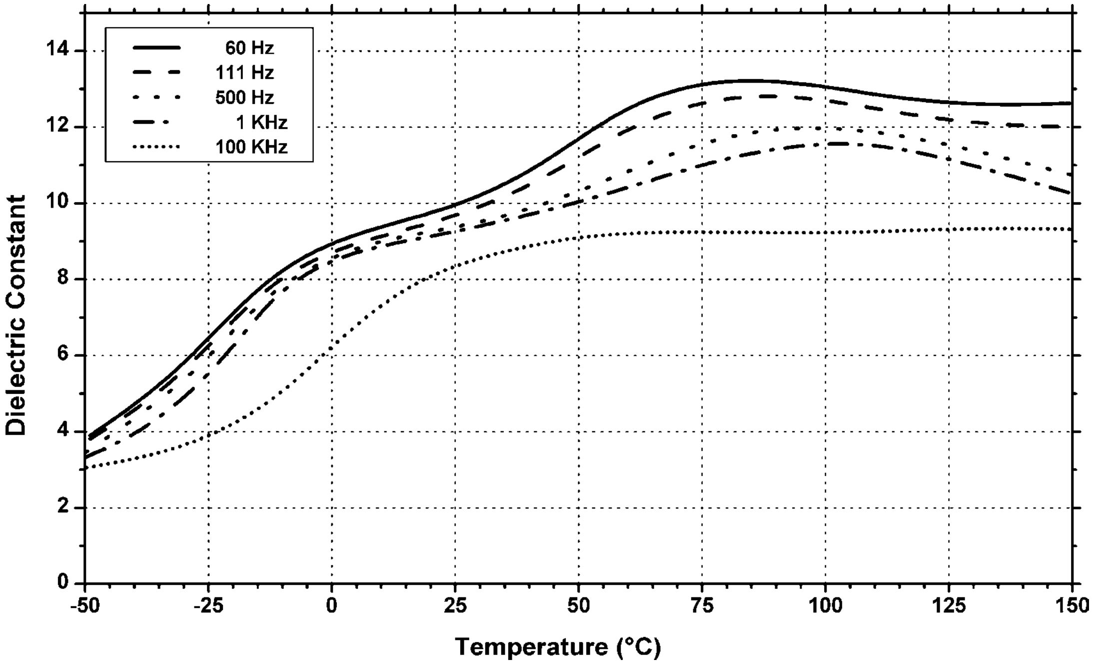


Figure 9.106. Dielectric constant vs. temperature and frequency for Solvay Solexis Solef® 11008—general purpose copolymer injection molding PVDF resin.

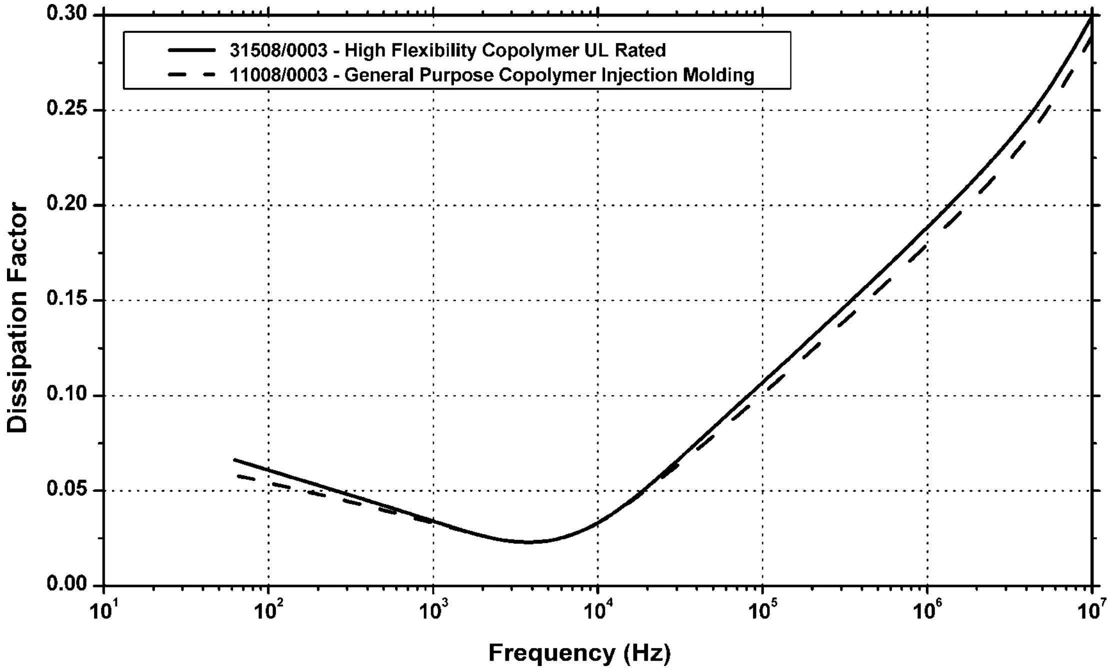


Figure 9.107. Dissipation factor vs. frequency for Solvay Solexis Solef® PVDF resins.

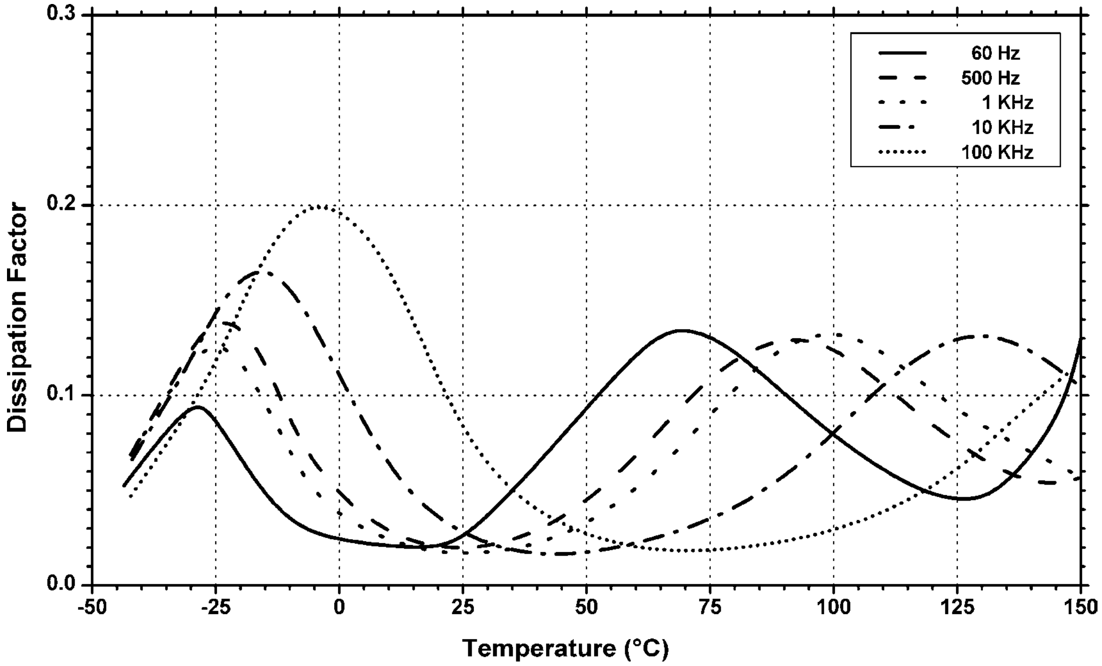


Figure 9.108. Dissipation factor vs. temperature and frequency for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin.

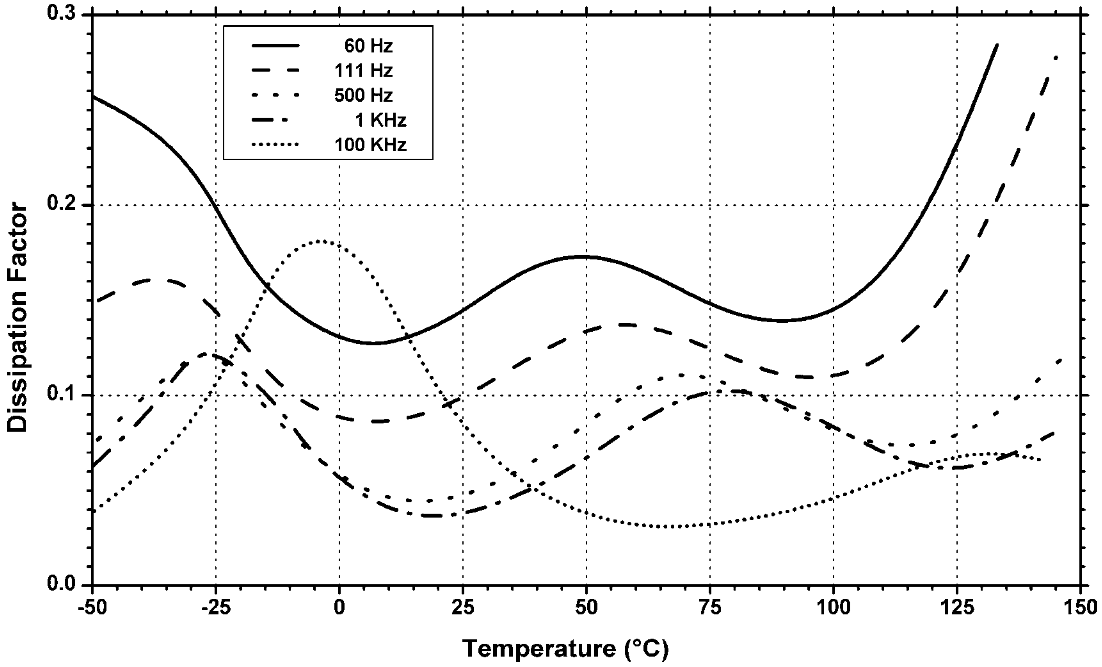


Figure 9.109. Dissipation factor vs. temperature and frequency for Solvay Solexis Solef® 11008—general purpose copolymer injection molding PVDF resin.

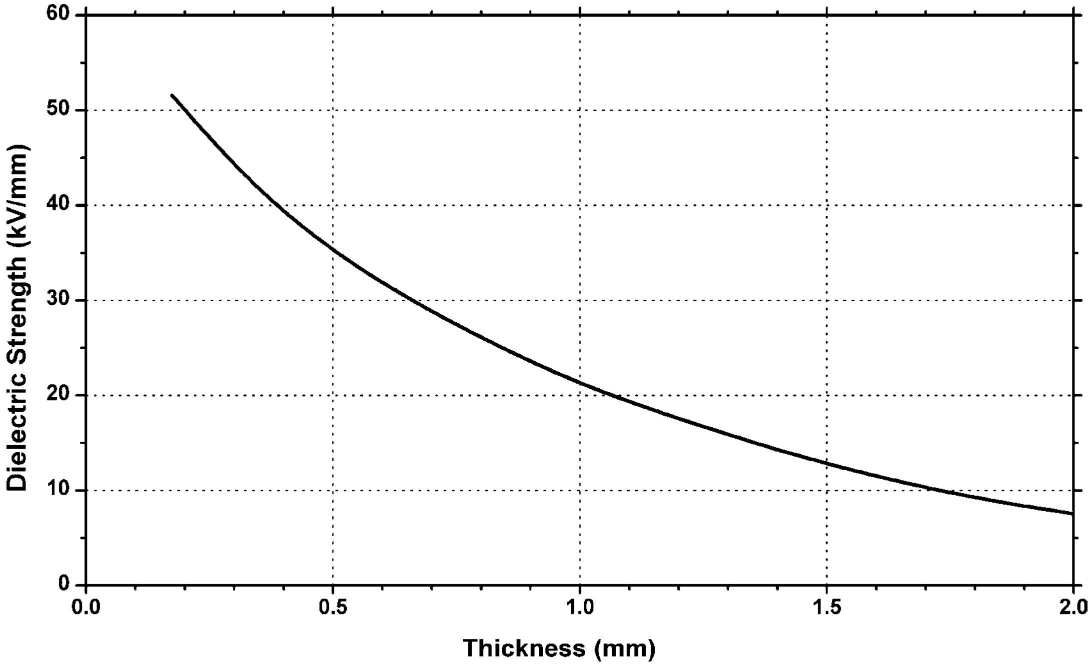


Figure 9.110. Dielectric strength vs. thickness for Solvay Solexis Solef® 1010—general purpose homopolymer molding and extrusion PVDF resin.

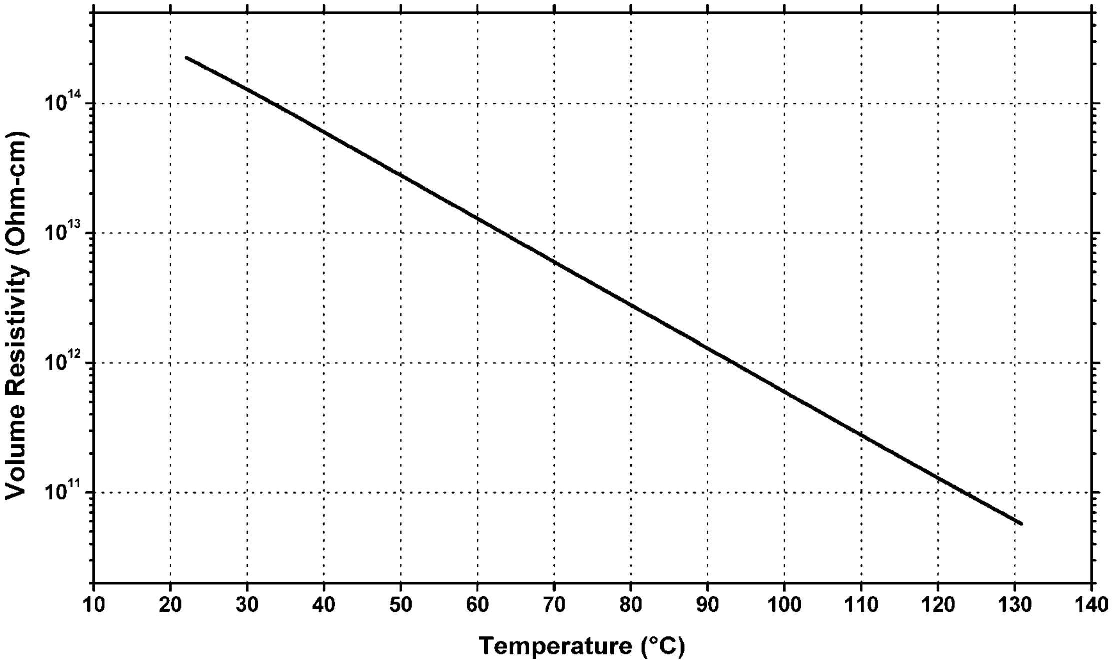


Figure 9.111. Volume resistivity vs. temperature for Solvay Solexis Solef® PVDF resins.

10 High Temperature Polymers

10.1 Background

This section contains information and multipoint properties for several high-temperature, high-performance plastics. They might be classified or included in another chapter, but they are grouped in this chapter because of their performance levels.

10.1.1 Polyetheretherketone (PEEK)

Polyetheretherketones (PEEKs) are also referred to as polyketones. The most common structure is given in Fig. 10.1.

PEEK is a thermoplastic with extraordinary mechanical properties. The Young's modulus of elasticity is 3.6 GPa and its tensile strength is 170 MPa. PEEK is partially crystalline, melts at around 350°C and is highly resistant to thermal degradation. The material is also resistant to both organic and aqueous environments, and is used in bearings, piston parts, pumps, compressor plate valves, and cable insulation applications. It is one of the few plastics compatible with ultra-high vacuum applications.

In summary, the properties of PEEK include:

- Outstanding chemical resistance
- Outstanding wear resistance
- Outstanding resistance to hydrolysis
- Excellent mechanical properties
- Outstanding thermal properties
- Very good dielectric strength, volume resistivity, and tracking resistance
- Excellent radiation resistance

10.1.2 Polyethersulfone (PES)

Polyethersulfone (PES) is an amorphous polymer and a high-temperature engineering thermoplastic. Even though PES has high-temperature performance, it can be processed on conventional plastics processing equipments. Its chemical structure is shown in Fig. 10.2. 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 is suitable for applications requiring close tolerances and little dimensional changes over a wide temperature range.

The properties of PES 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

10.1.3 Polyphenylene Sulfide (PPS)

Polyphenylene sulfide (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. Due to its outstanding flame resistance, PPS is ideal for high-temperature

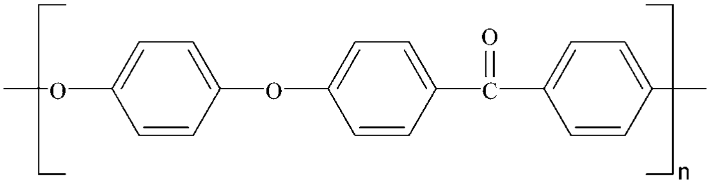


Figure 10.1. The structure of PEEK.

electrical applications. It is unaffected by all industrial solvents. The structure of PPS is shown in Fig. 10.3.

The properties of PPS include:

- 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

10.1.4 Polysulfone (PSU)

Polysulfone (PSU) is a rigid, strong, tough, and high-temperature amorphous thermoplastic. The structure of PSU is shown in Fig. 10.4.

In summary, the properties of PSU include:

- High thermal stability
- High toughness and strength
- Good environmental stress crack resistance
- Inherent fire resistance
- Transparence

10.1.5 Polybenzimidazole (PBI)

Polybenzimidazole (PBI) is a unique and highly stable linear heterocyclic polymer. The chemical structure is shown in Fig. 10.5. 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.

Ideally suited for its application in extreme environments, PBI can be formed into stock shapes and subsequently machined into high-precision finished parts. Since PBI does not have a melt point, moldings from virgin PBI polymer can only be formed in a high temperature, high pressure compression molding process.

PBI is highly resistant to deformation, and has low hysterisis loss and high elastic recovery. PBI exhibits ductile failure, and may be compressed to over 50% strain without fracture. Celazole® PBI has the highest compressive strength of any thermoplastic or thermosetting resin at 400 MPa. There is no weight loss or change in compressive strength of Celazole® PBI exposed to 260°C in air for 500 h. At 371°C, no weight or strength change takes place for 100 h. In spite of these unusual properties, PBI is usually blended with other plastics, particularly polyesters.

Graphs showing the properties of these high performance plastics as a function of temperature, moisture, and other factors are illustrated in Sections 10.5–10.2

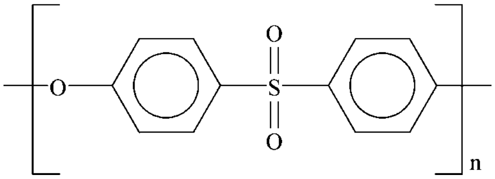


Figure 10.2. The structure of PES.

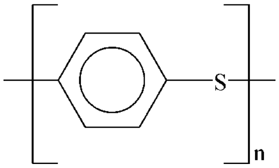


Figure 10.3. The structure of PPS.

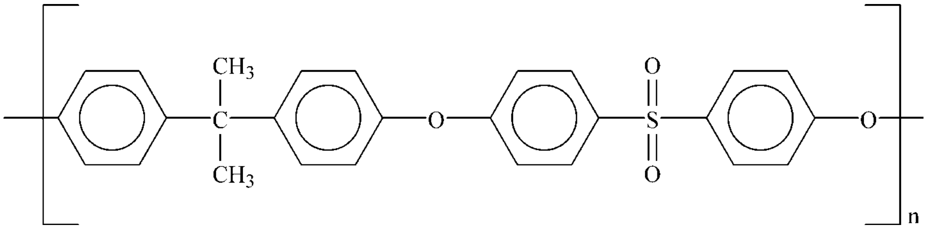


Figure 10.4. The structure of PSU.

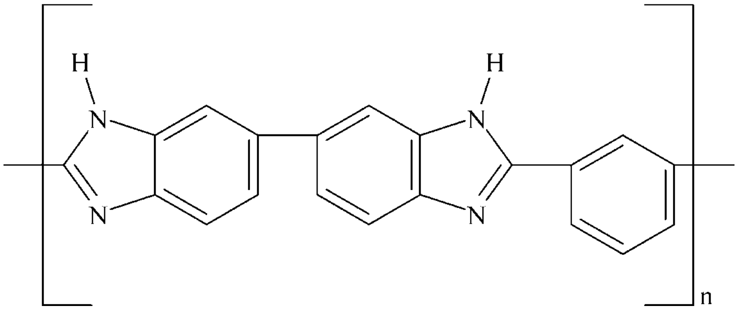


Figure 10.5. The structure of PBI.

10.2 Polyetheretherketone (PEEK)

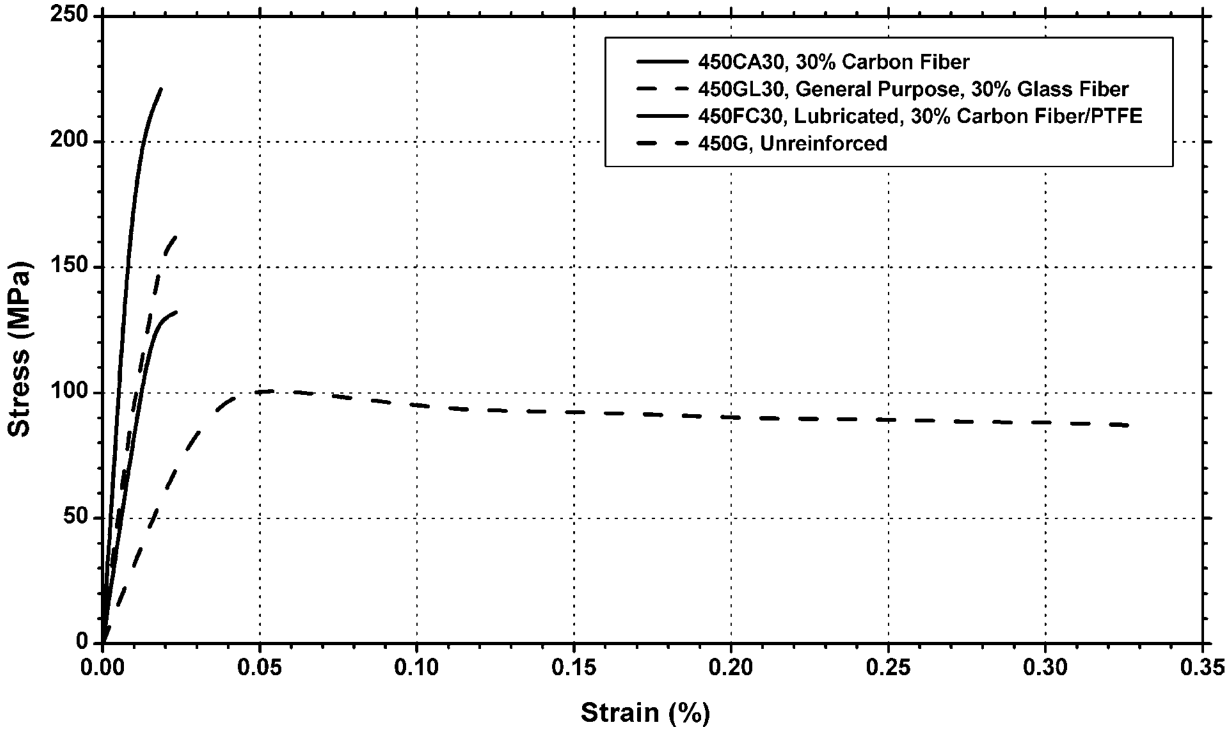


Figure 10.6. Stress vs. strain at 23°C of various Victrex® PEEK resins.

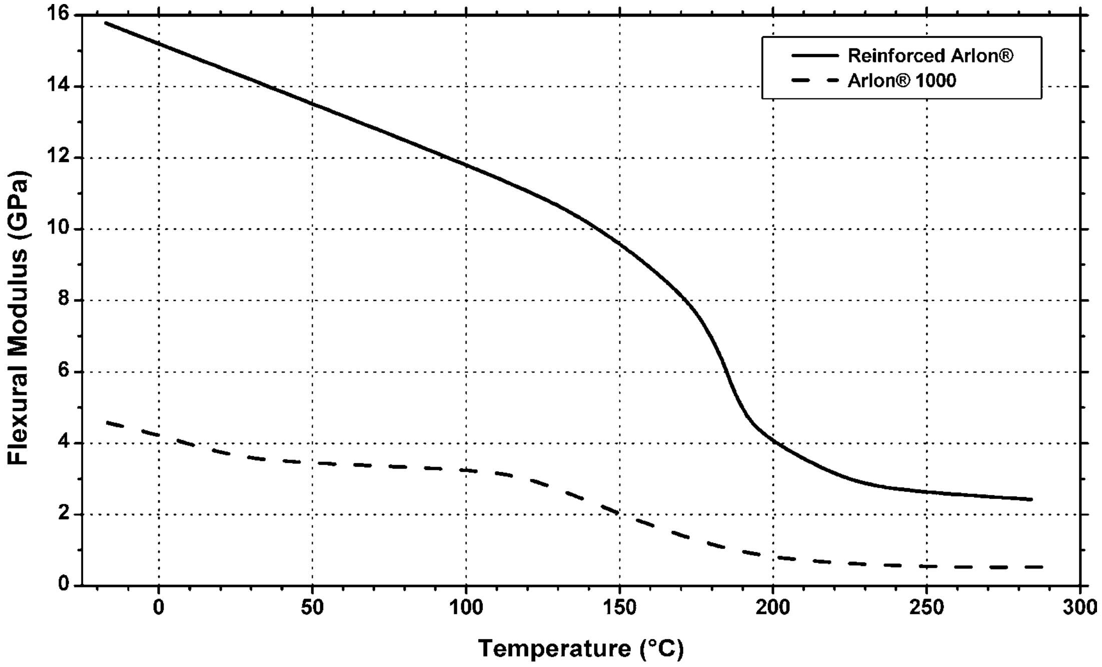


Figure 10.7. Flexural modulus vs. temperature of Greene, Tweed Arlon® PEEK resins.

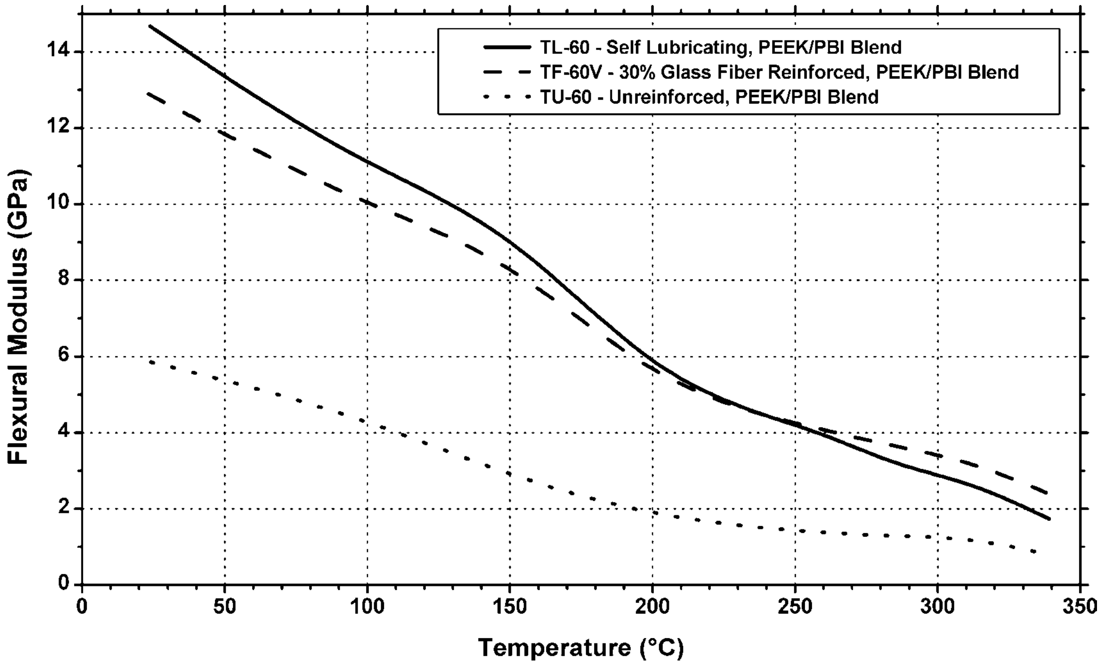


Figure 10.8. Flexural modulus vs. temperature of various Victrex® PEEK resins.

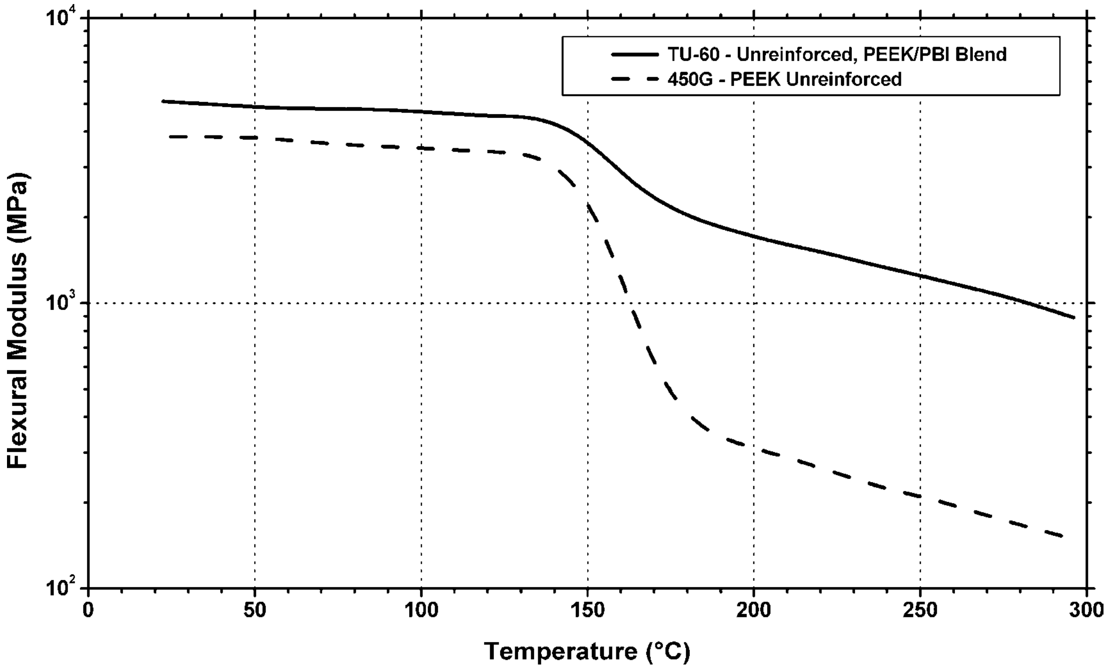


Figure 10.9. Flexural modulus vs. temperature of Victrex® PEEK resins, comparing a polybenzimidazole/PEEK blend to PEEK resin.

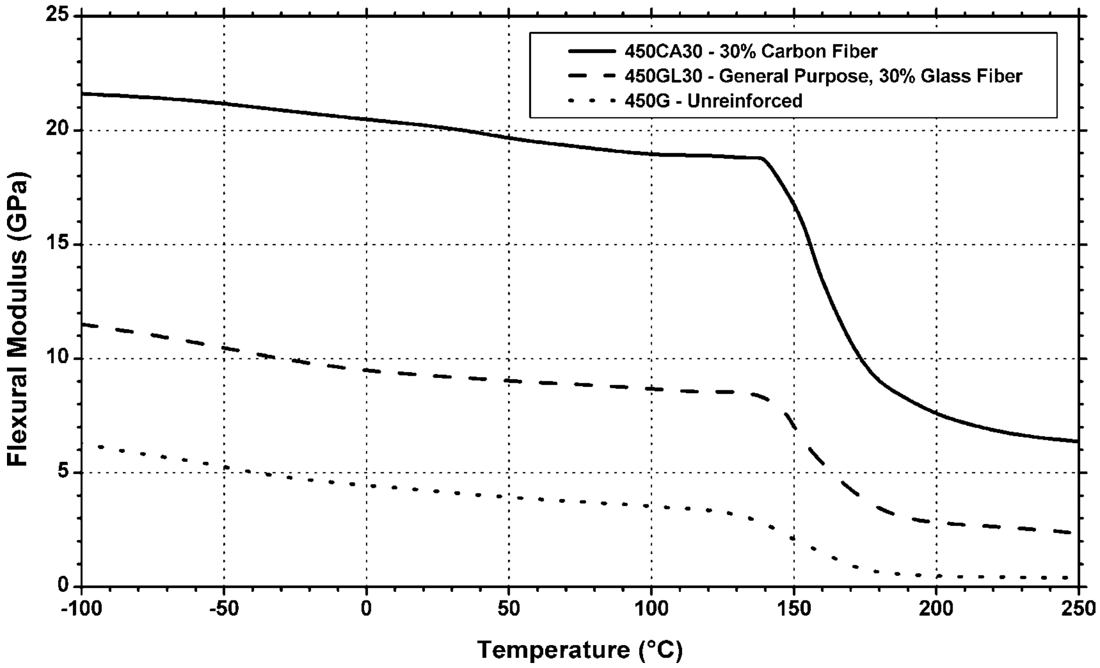


Figure 10.10. Flexural modulus vs. temperature of different fiber-filled Victrex® PEEK resins.

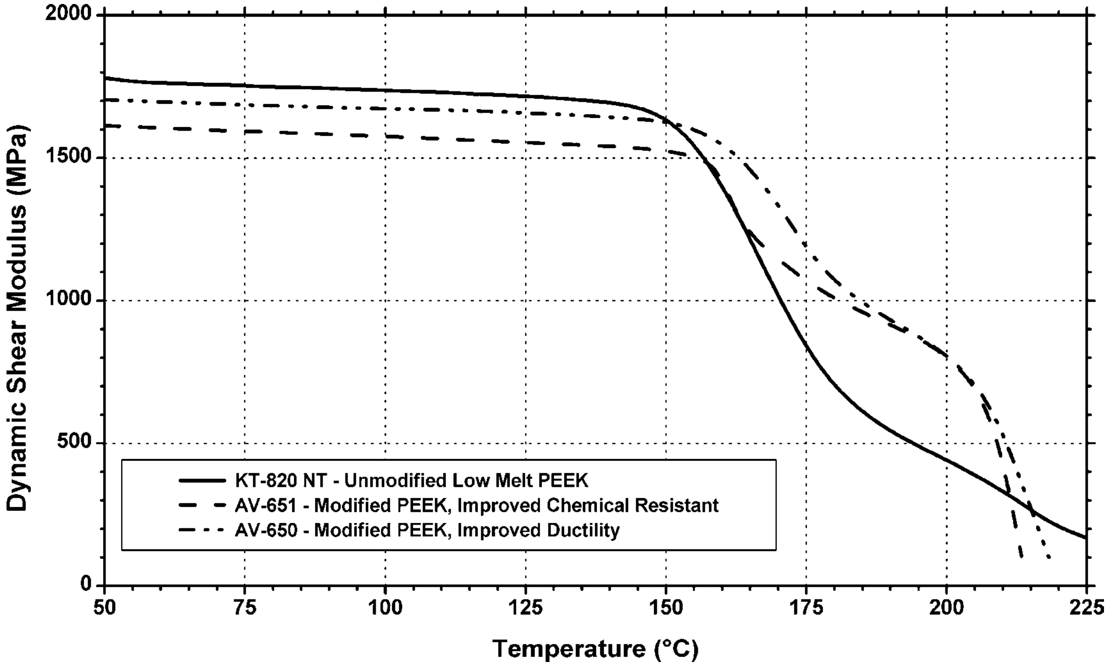


Figure 10.11. Dynamic shear modulus vs. temperature of Solvay KetaSpire® and AviSpire® PEEK resins.

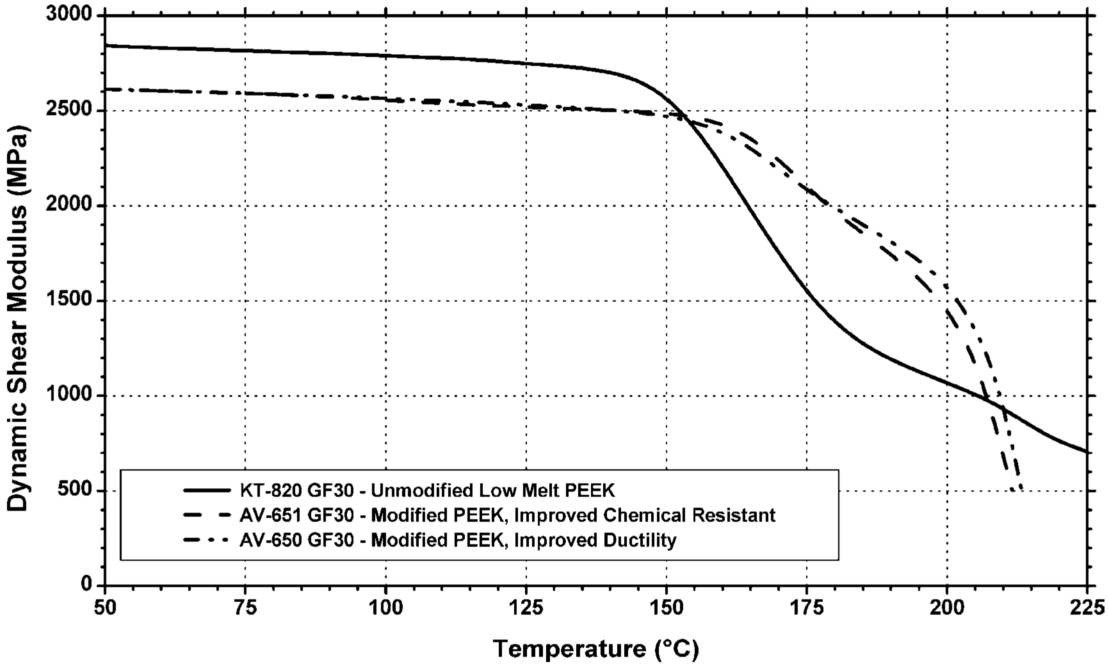


Figure 10.12. Dynamic shear modulus vs. temperature of Solvay KetaSpire® and AviSpire® 30% glass fiber reinforced PEEK resins.

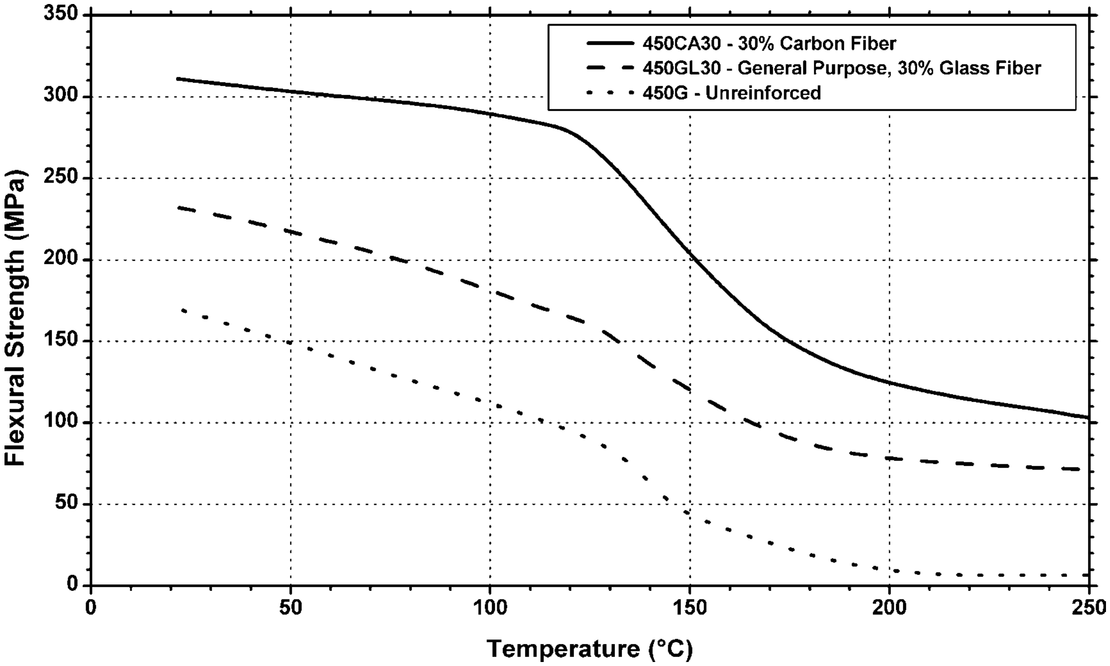


Figure 10.13. Flexural strength vs. temperature of different fiber-filled Victrex® PEEK resins.

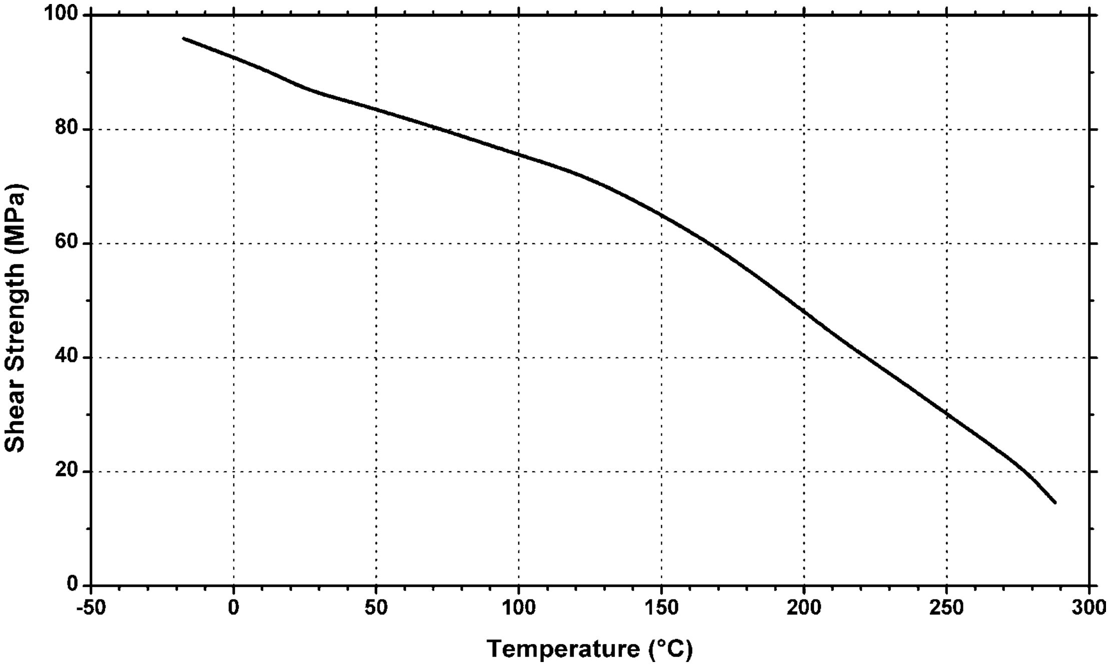


Figure 10.14. Shear strength vs. temperature of Greene, Tweed Arlon® 1000—unreinforced, general purpose PEEK resin.

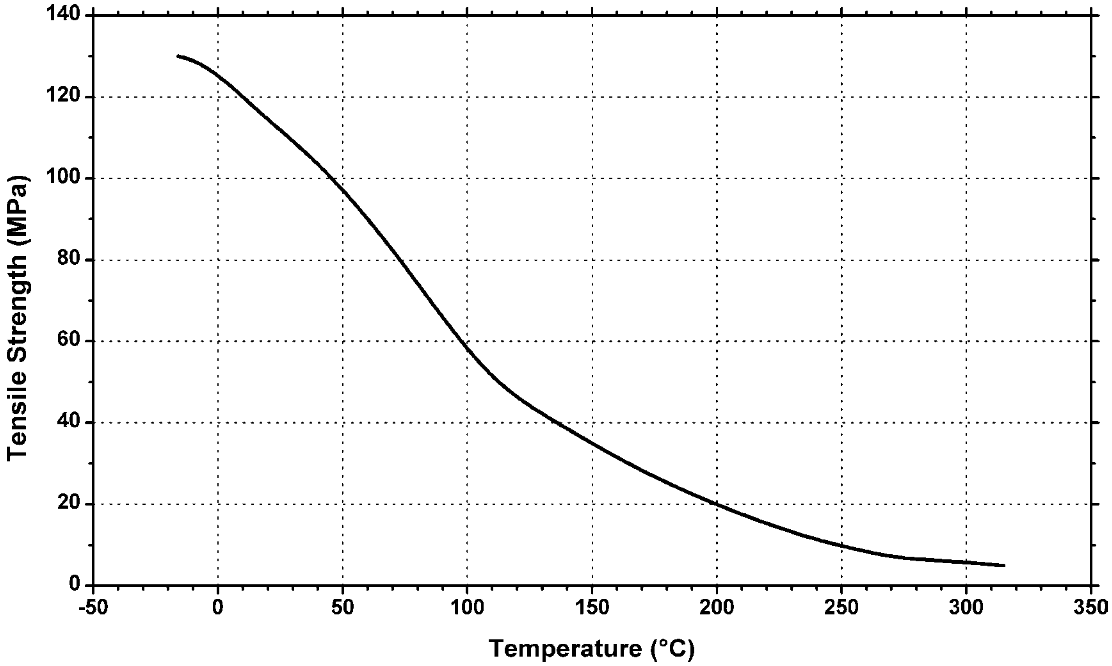


Figure 10.15. Tensile strength vs. temperature of Greene, Tweed Arlon® 1000—unreinforced, general purpose PEEK resin.

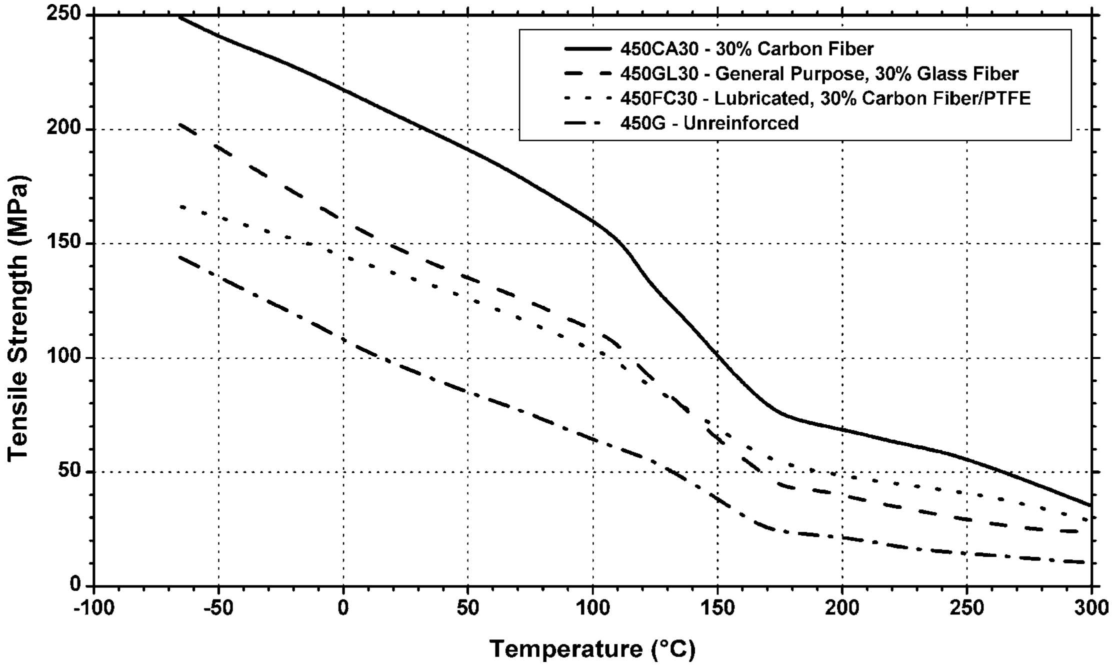


Figure 10.16. Tensile strength vs. temperature of Victrex® PEEK resins.

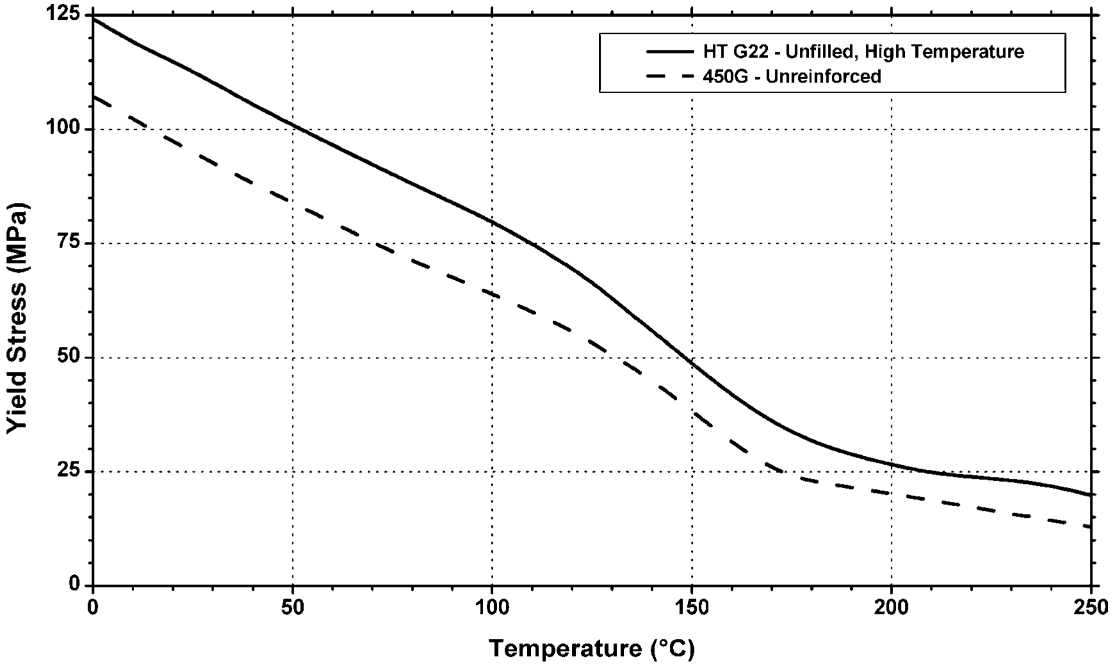


Figure 10.17. Yield stress vs. temperature of Victrex® PEEK resins.

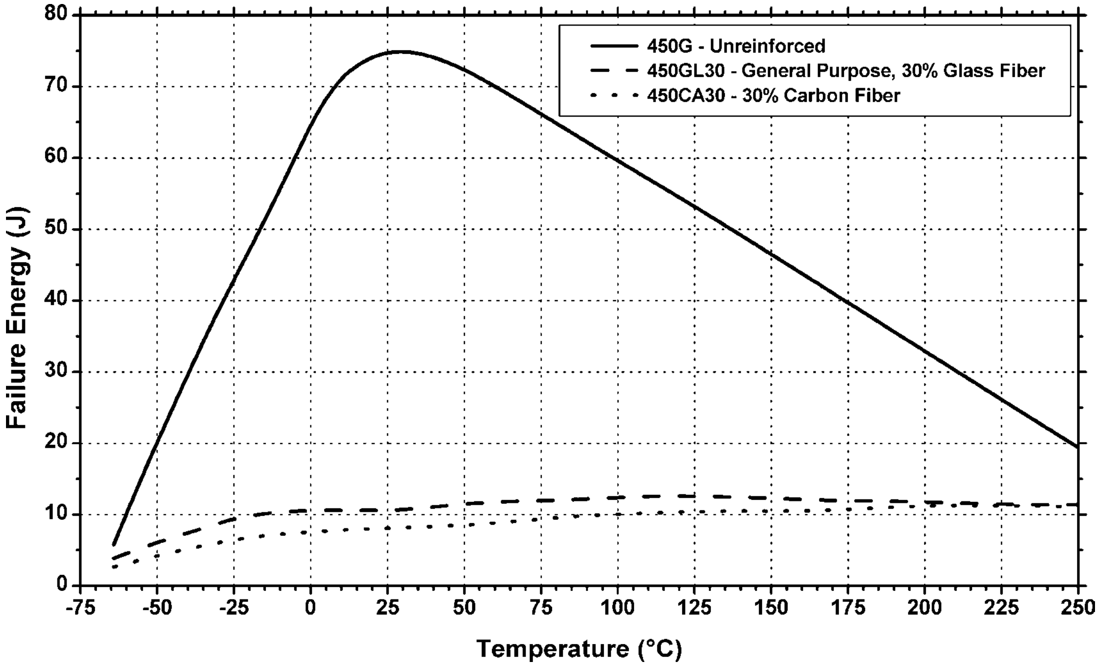


Figure 10.18. Falling weight impact failure energy vs. temperature of Victrex® PEEK resins.

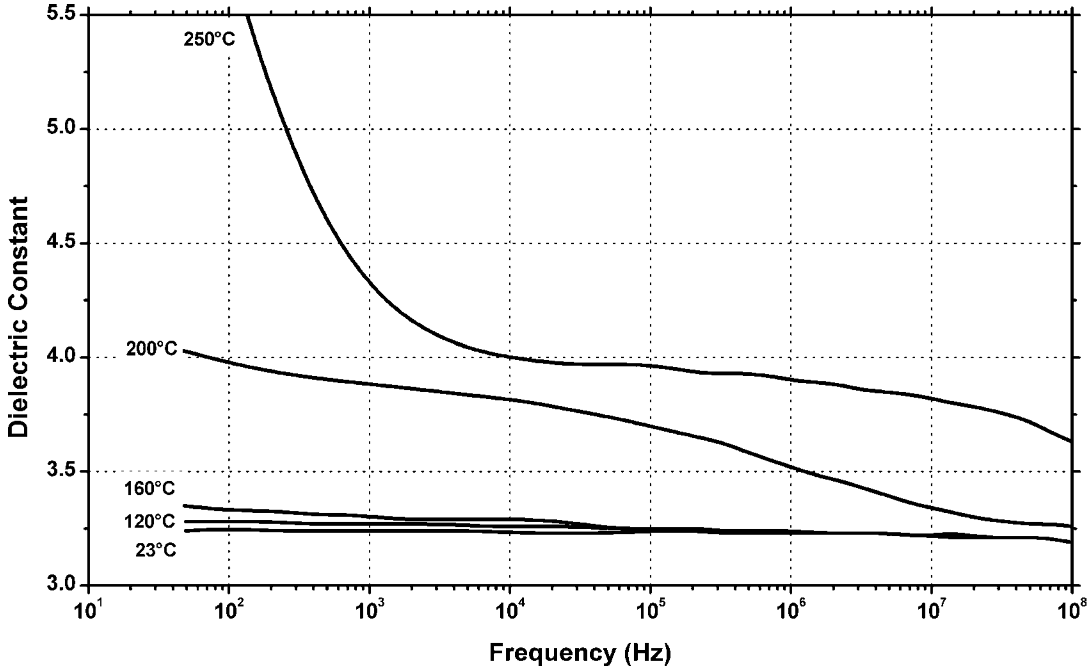


Figure 10.19. Dielectric constant vs. frequency and temperature of Victrex® 450G—unreinforced PEEK resin.

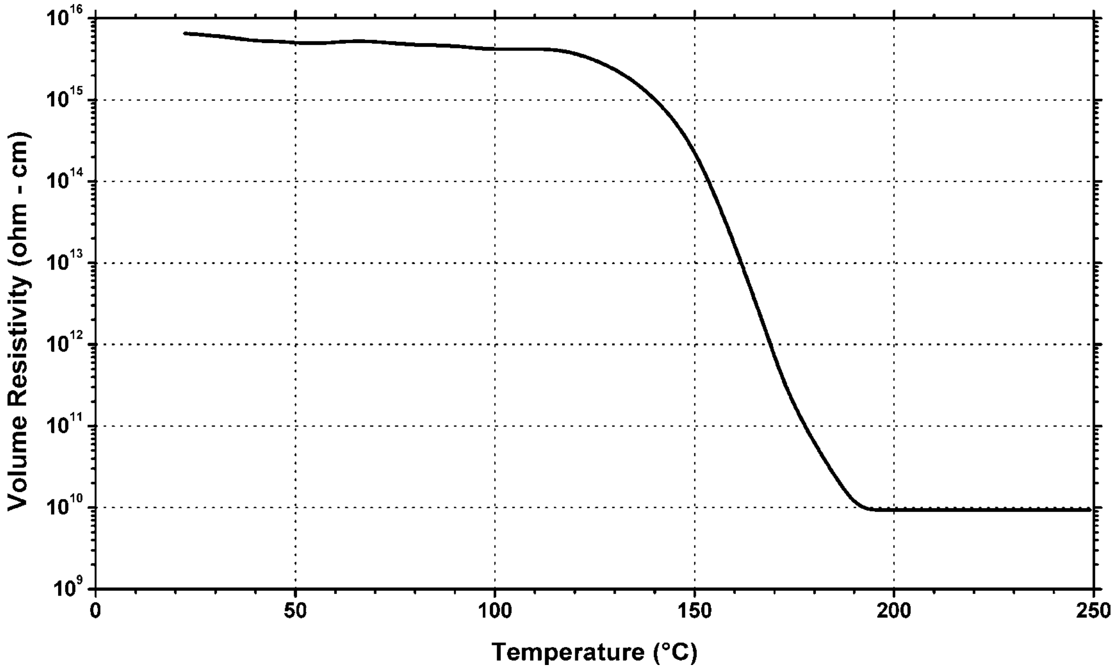


Figure 10.20. Volume resistivity vs. temperature of Victrex® 450G—unreinforced PEEK resin.

10.3 Polyether Sulfone (PES)

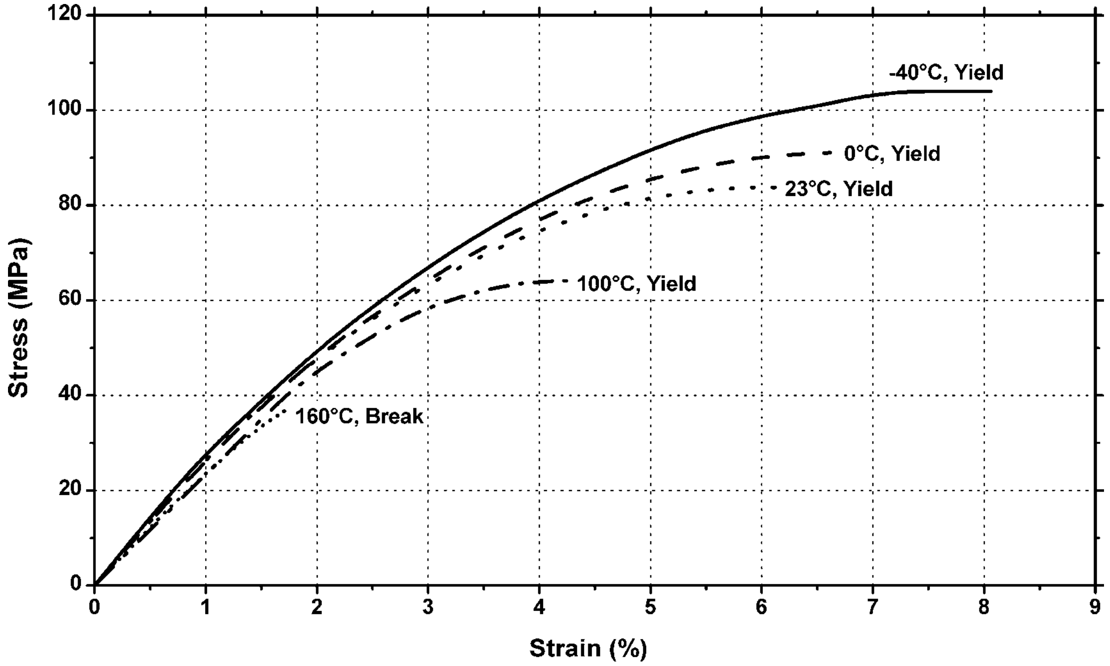


Figure 10.21. Stress vs. strain at several temperatures of BASF Ultrason® E 1010—low viscosity, unreinforced PES resin (conditioned at 50% RH).

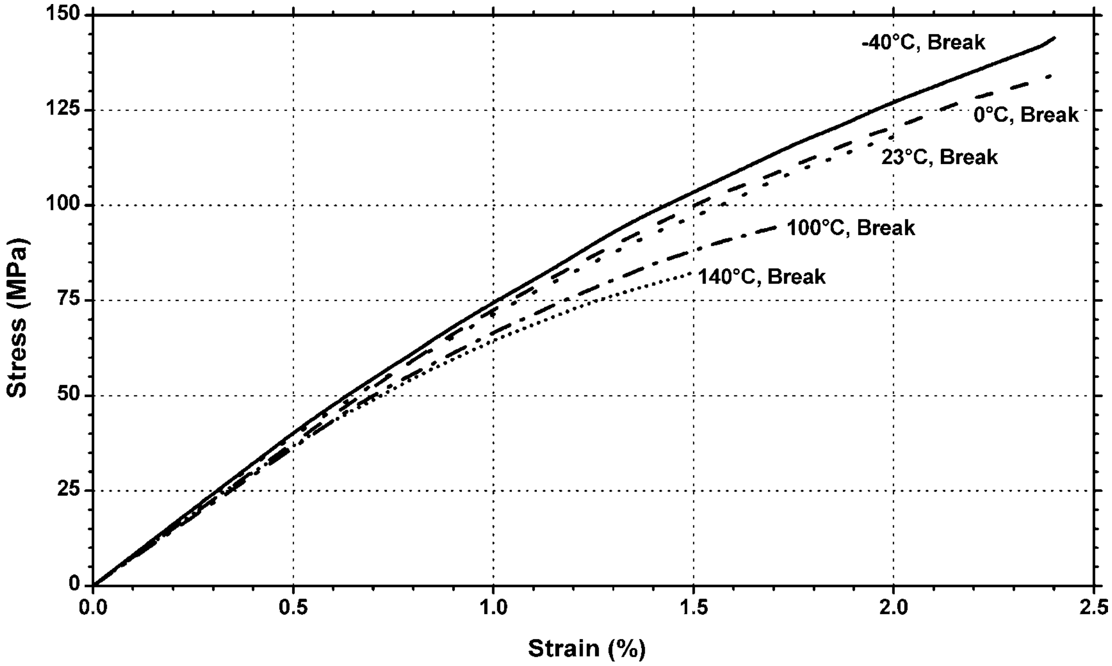


Figure 10.22. Stress vs. strain at several temperatures of BASF Ultrason® E 2010 G4—medium viscosity, 20% glass fiber reinforced PES resin (conditioned at 50% RH).

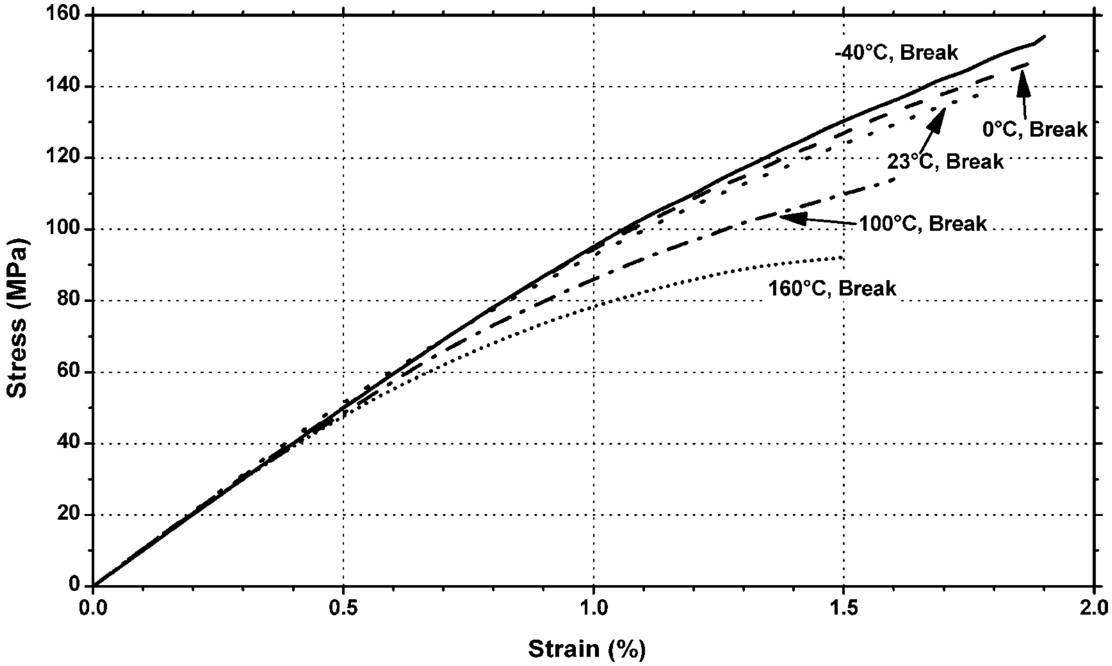


Figure 10.23. Stress vs. strain at several temperatures of BASF Ultrason® E 2010 G6—medium viscosity, 30% glass fiber reinforced PES resin (conditioned at 50% RH).

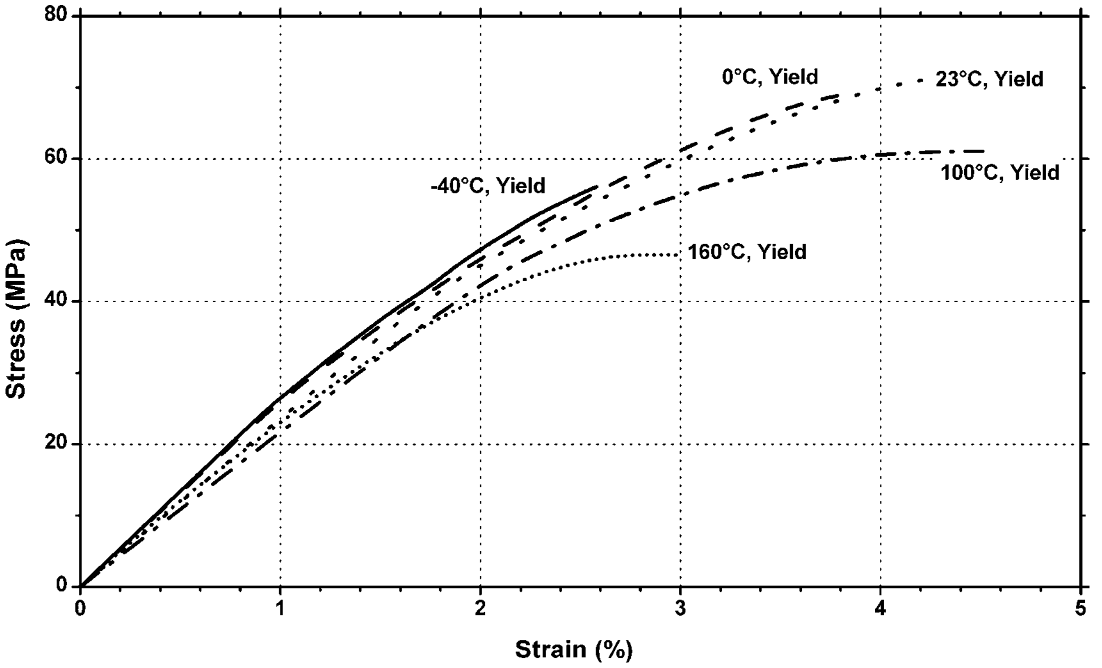


Figure 10.24. Stress vs. strain at several temperatures of BASF Ultrason® E 2010—medium viscosity, unreinforced PES resin (conditioned at 50% RH).

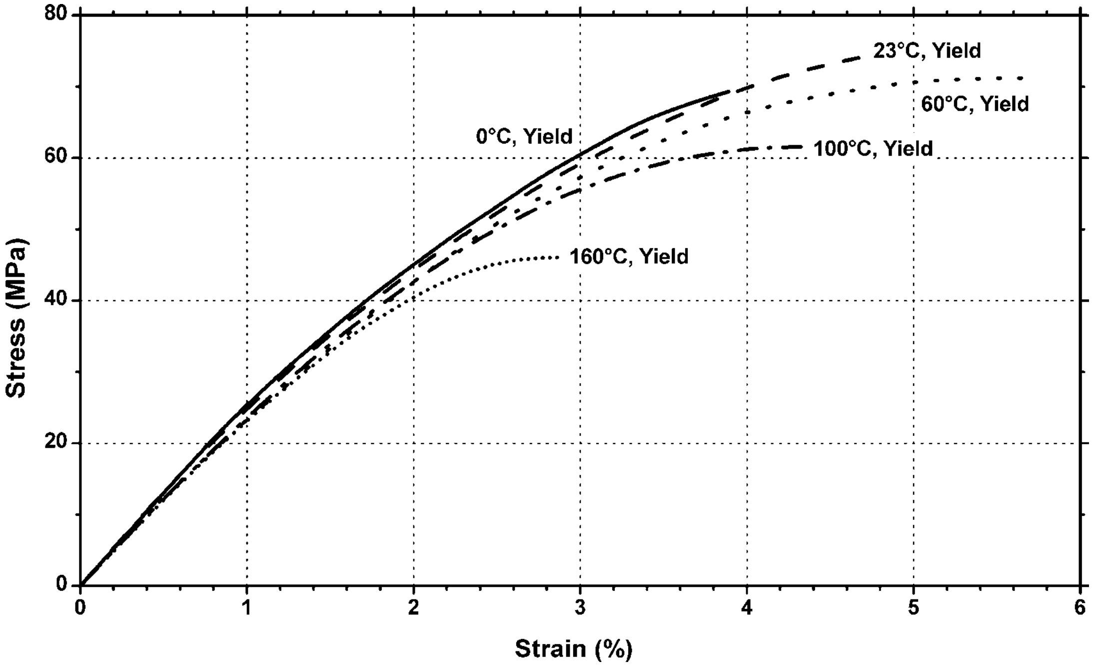


Figure 10.25. Stress vs. strain at several temperatures of BASF Ultrason® E 3010—high viscosity, unreinforced PES resin (conditioned at 50% RH).

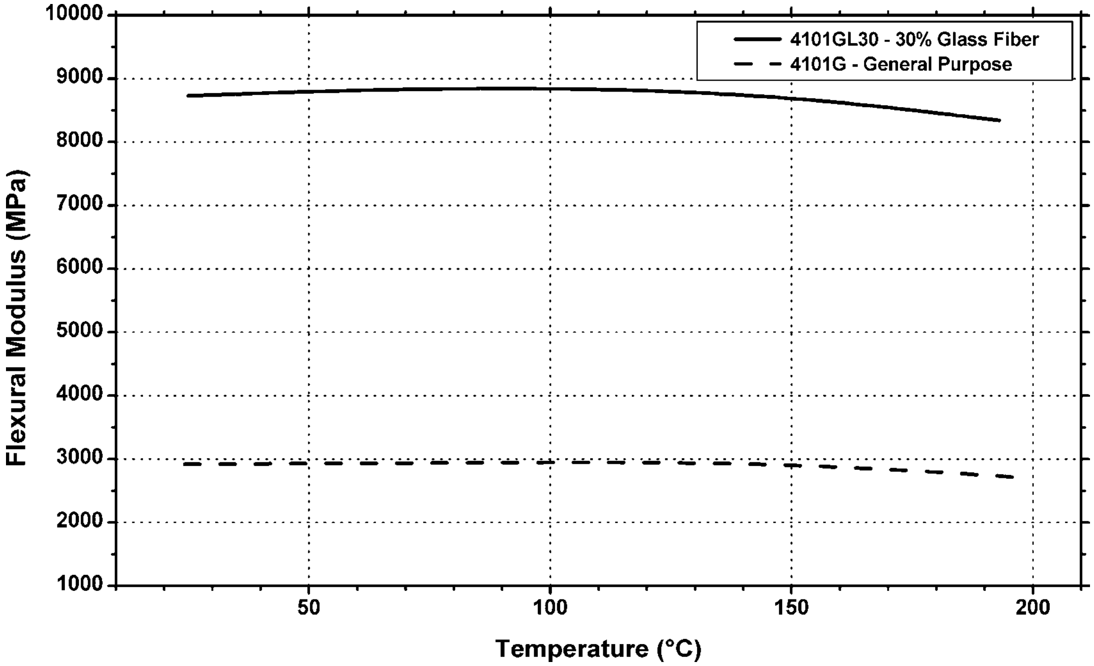


Figure 10.26. Flexural modulus vs. temperature of Sumitomo Chemical Sumika Excel® PES resins.

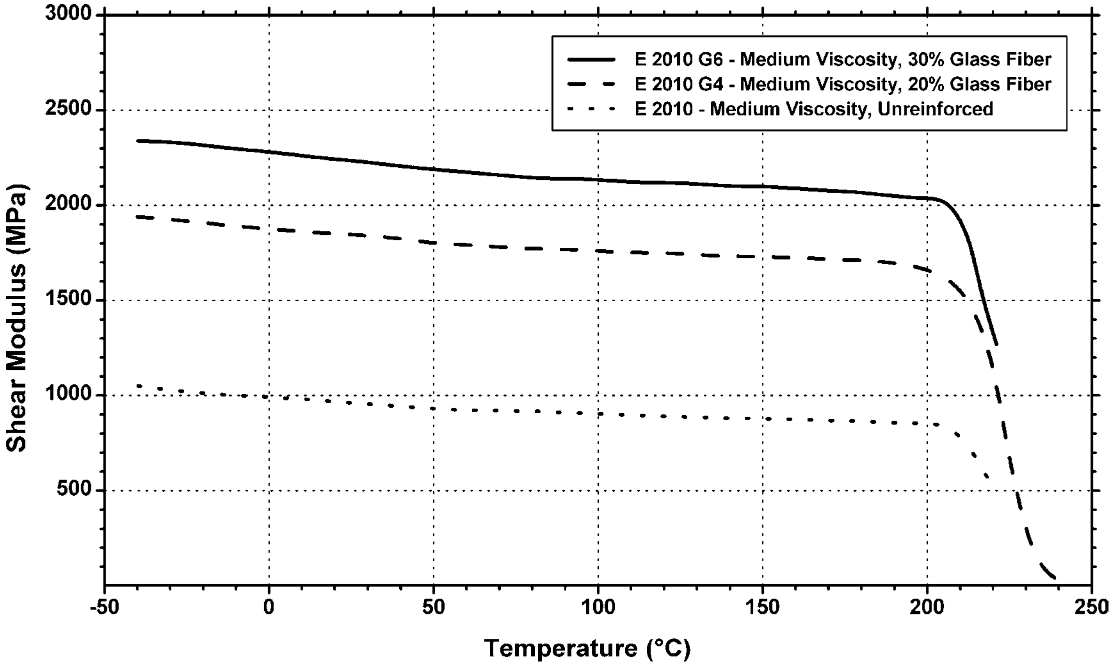


Figure 10.27. Shear modulus vs. temperature of BASF Ultrason® E 2010—medium viscosity PES resin (dry as molded).

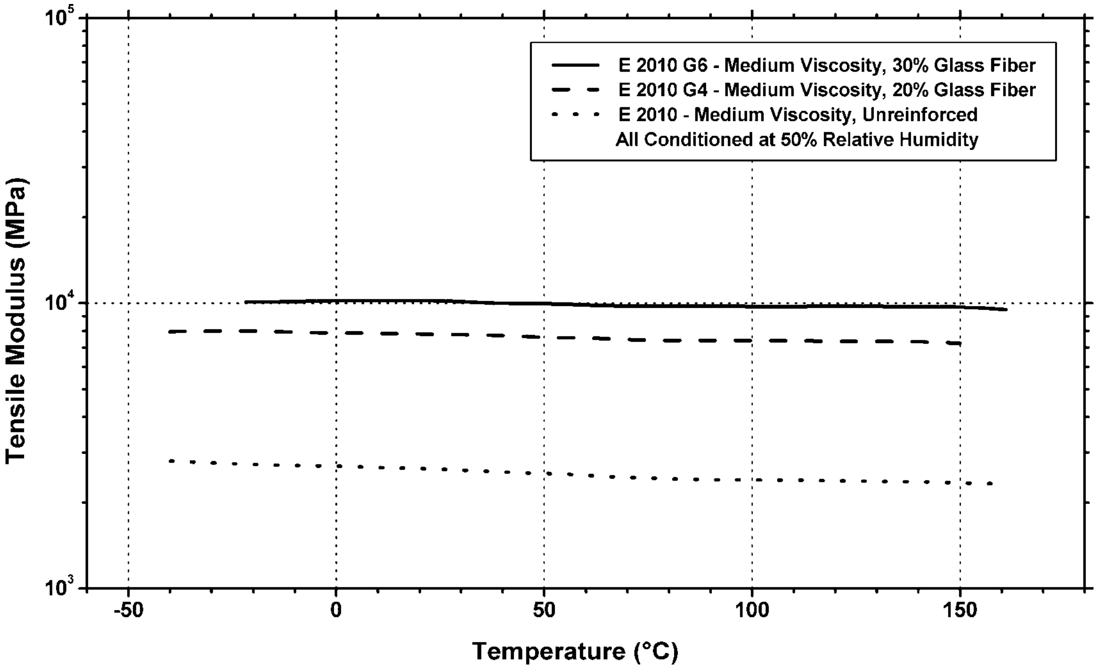


Figure 10.28. Tensile modulus vs. temperature of BASF Ultrason® E 2010—medium viscosity PES resin (conditioned at 50% RH).

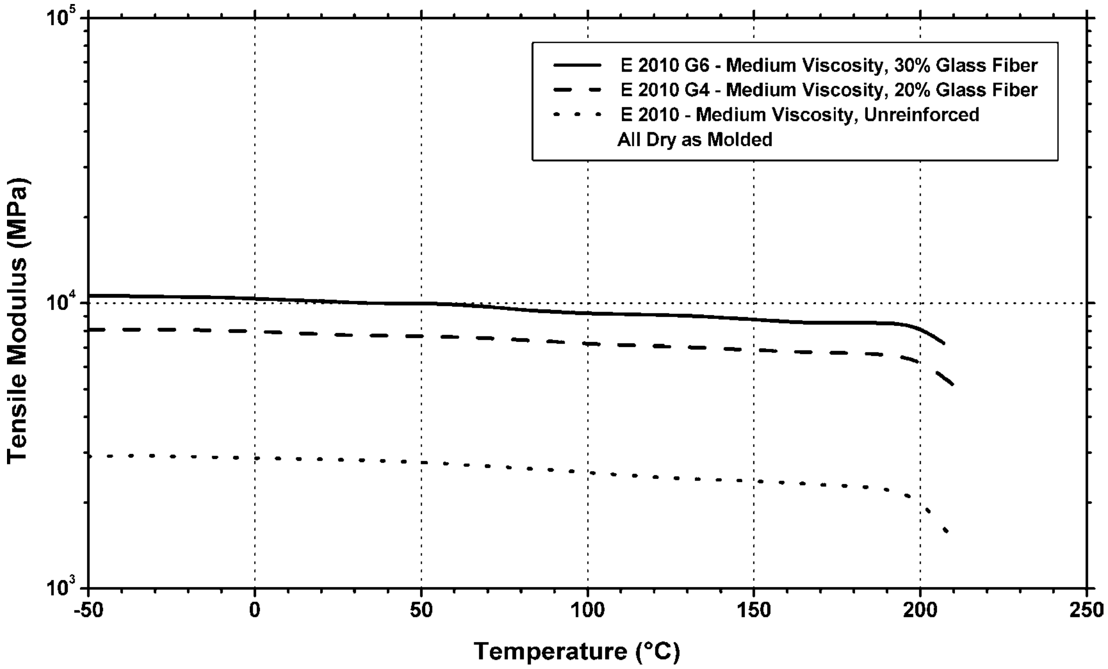


Figure 10.29. Tensile modulus vs. temperature of BASF Ultrason® E 2010—medium viscosity PES resin (dry as molded).

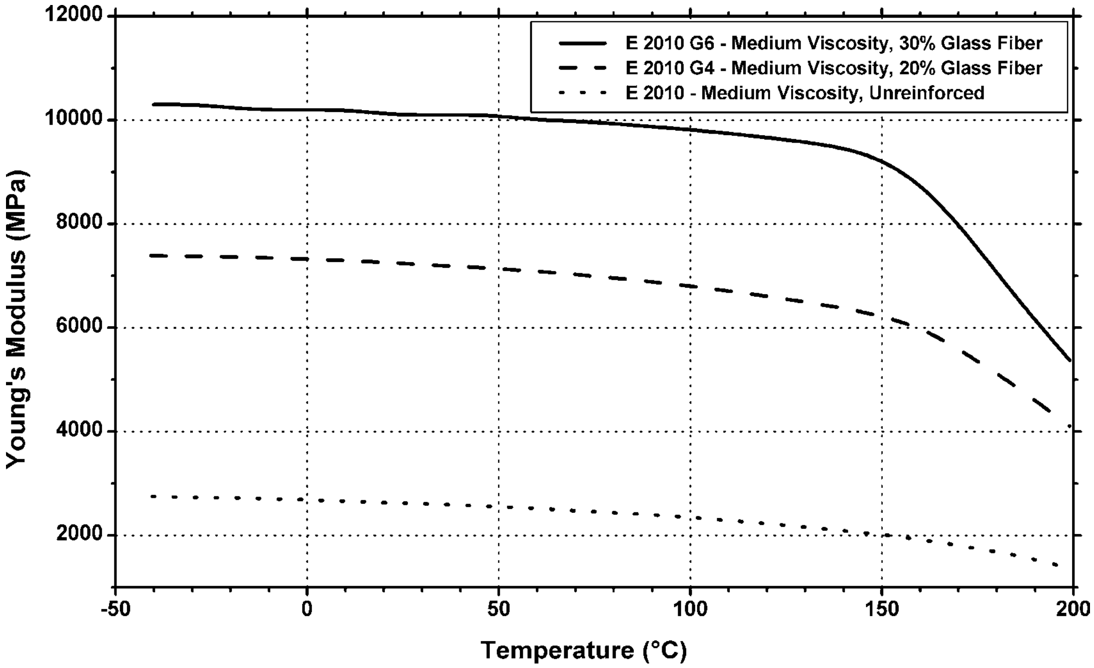


Figure 10.30. Young's modulus vs. temperature of BASF Ultrason® E 2010—medium viscosity PES resin.

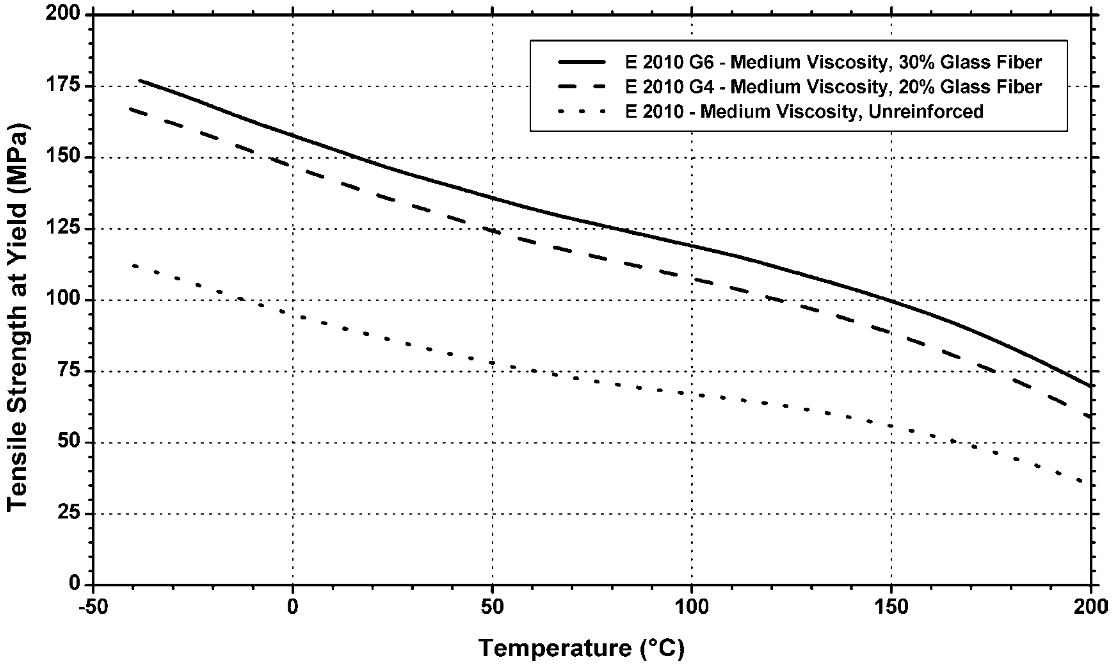


Figure 10.31. Tensile strength vs. temperature of BASF Ultrason® E 2010—medium viscosity PES resin.

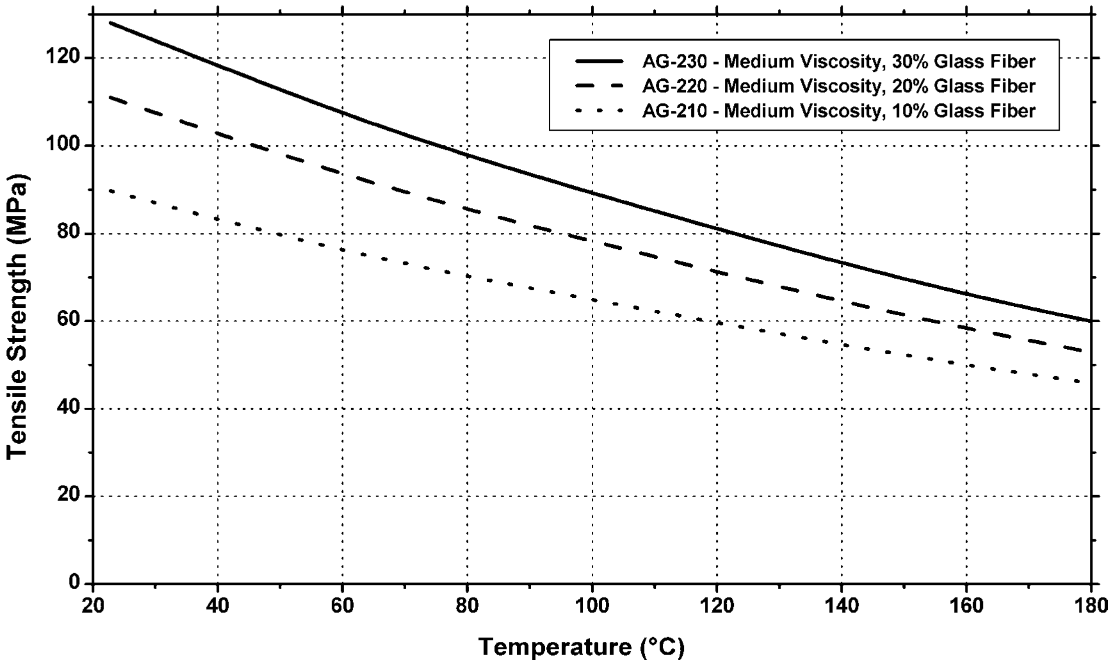


Figure 10.32. Tensile strength vs. temperature of Solvay Radel® A PES resins with different amounts of glass fiber filler.

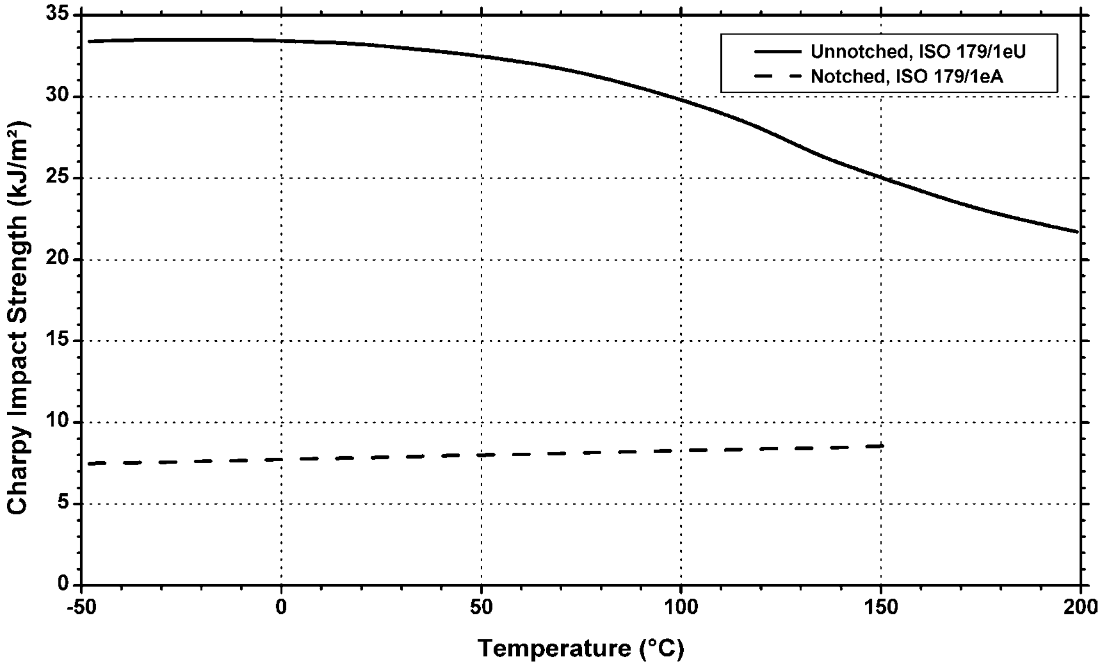


Figure 10.33. Charpy impact strength vs. temperature of BASF Ultrason® E 2010 G4—medium viscosity, 20% glass fiber reinforced PES resin.

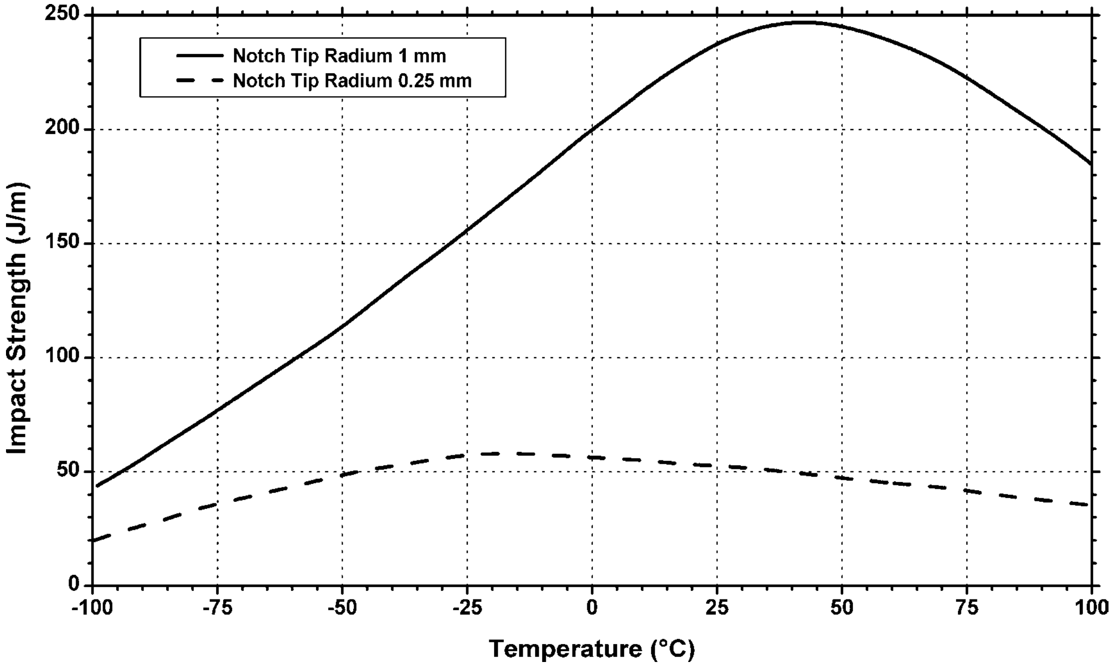


Figure 10.34. Charpy impact strength vs. temperature of Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general purpose PES resin.

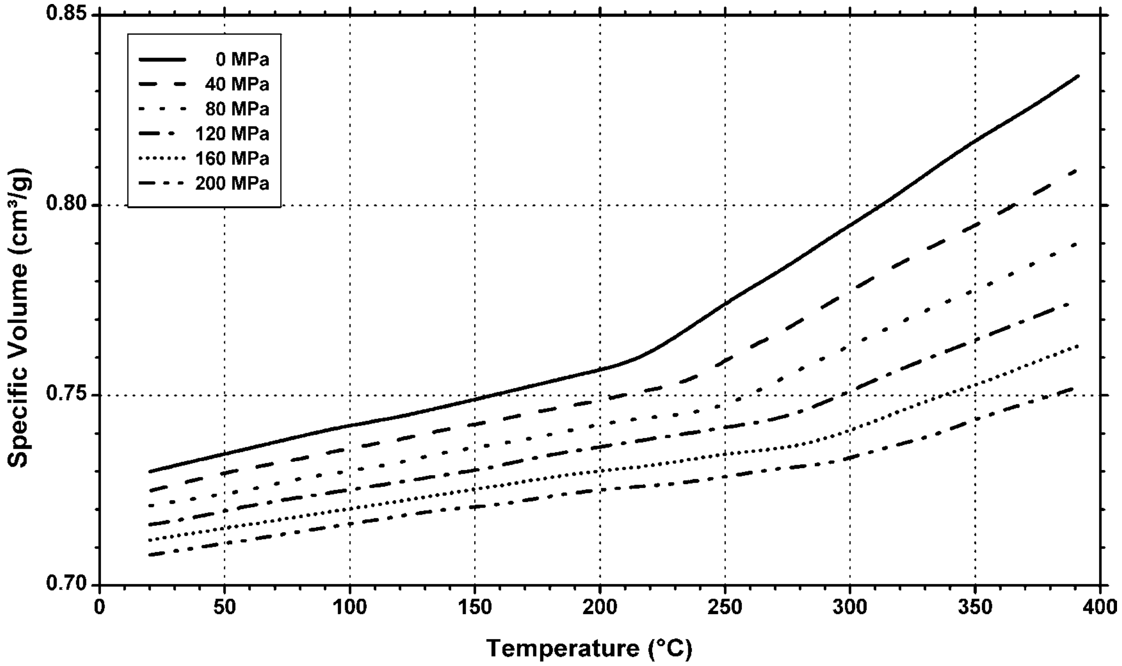


Figure 10.35. Specific volume as a function of temperature and pressure (PVT) for SF Ultrason® E 1010—low viscosity, unreinforced PES resin.

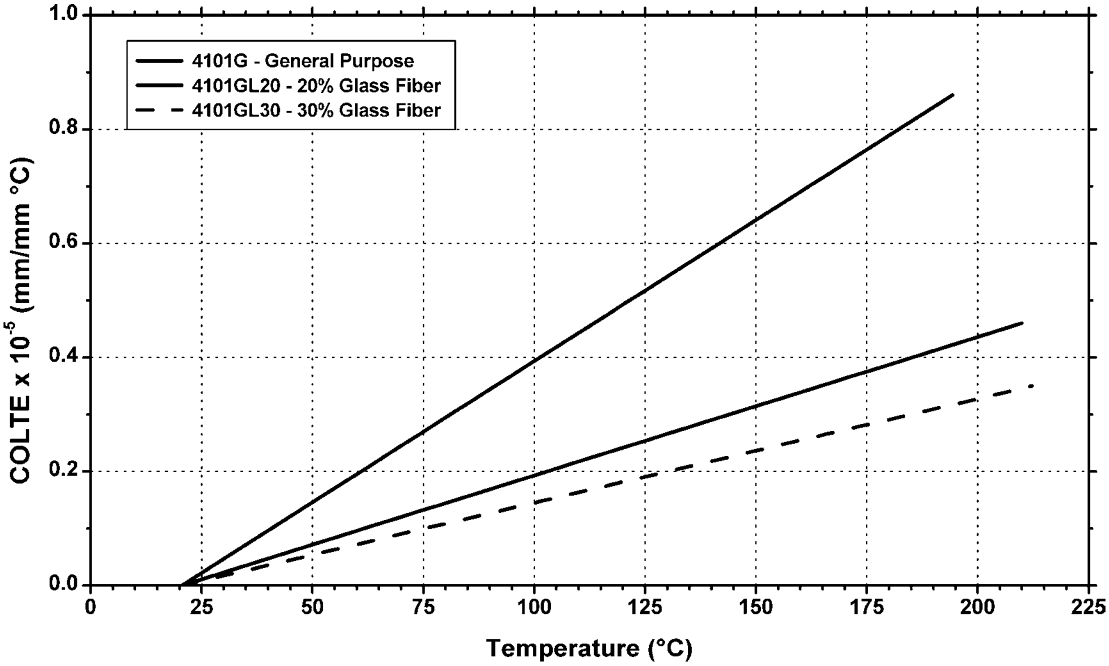


Figure 10.36. Coefficient of linear thermal expansion vs. temperature of Sumitomo Chemical Sumika Excel® PES resin.

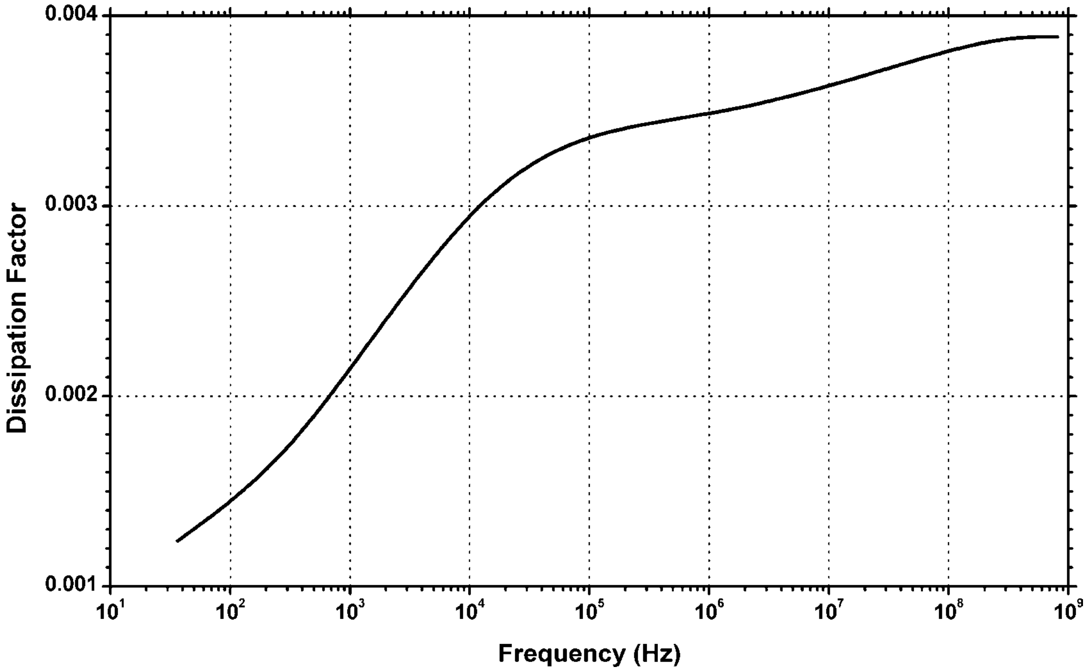


Figure 10.37. Dissipation factor vs. frequency of Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general purpose PES resin.

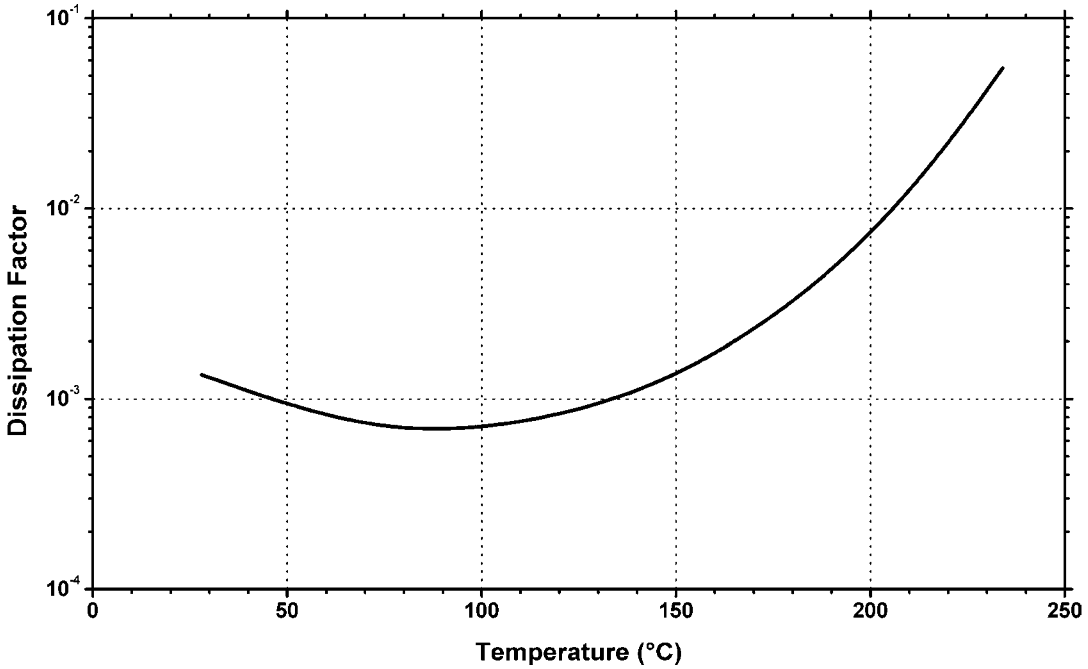


Figure 10.38. Dissipation factor vs. temperature of Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general purpose PES resin.

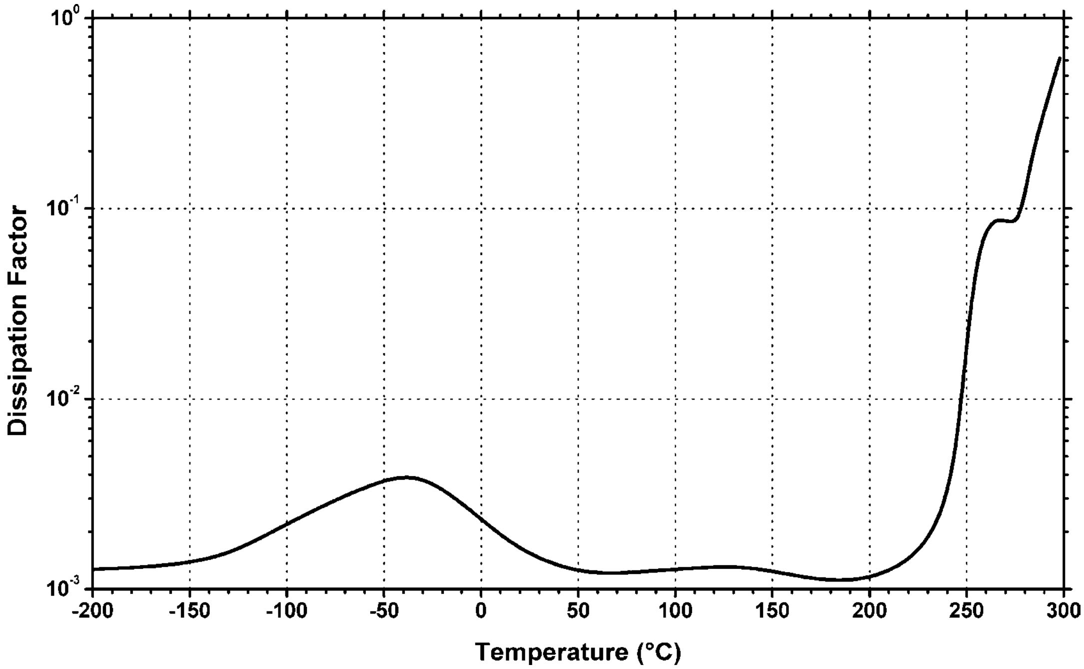


Figure 10.39. Dissipation factor vs. temperature at 1 kHz of BASF Ultrason® E 2010—medium viscosity, unreinforced PES resin.

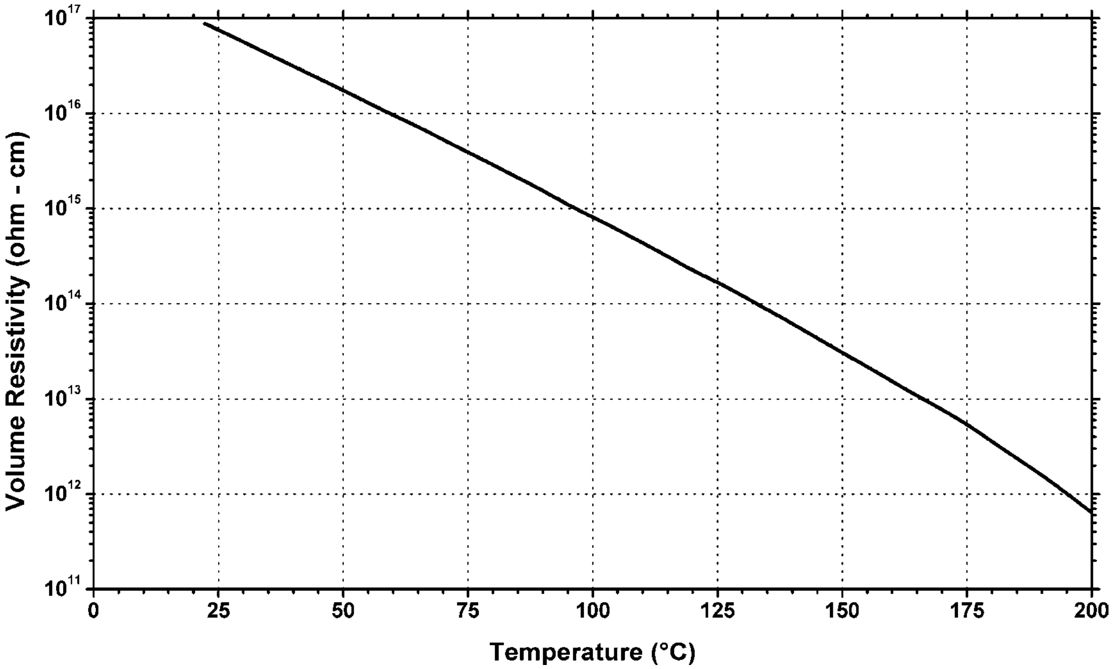


Figure 10.40. Volume resistivity vs. temperature of Sumitomo Chemical Sumika Excel® 4800G—high viscosity, general purpose PES resin.

10.4 Polyphenylene Sulfide (PPS)

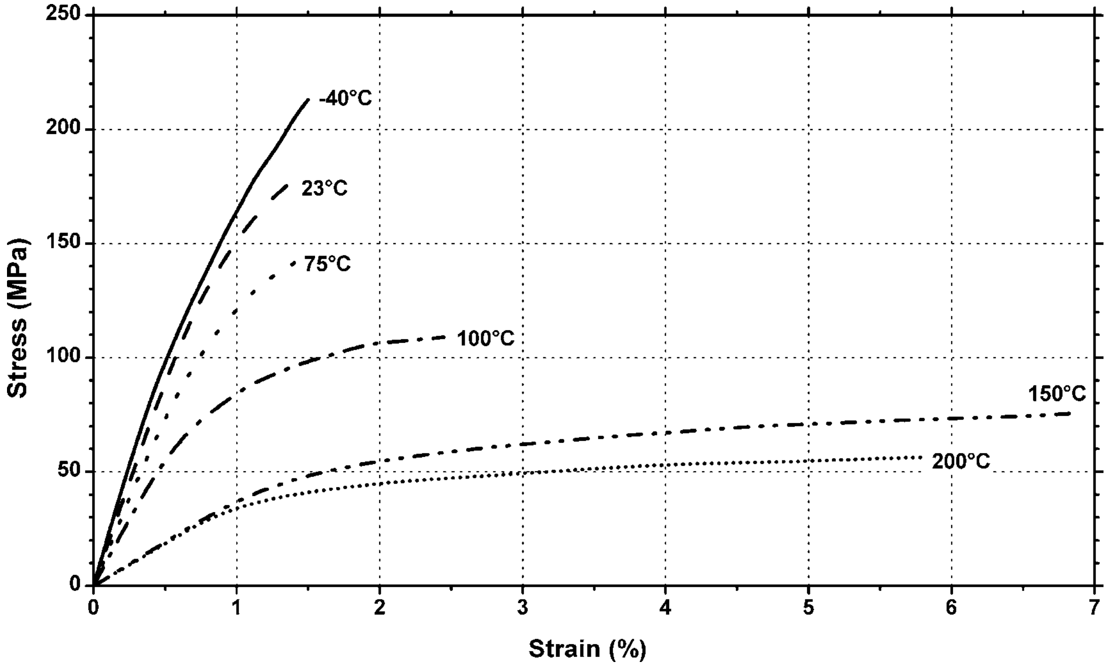


Figure 10.41. Stress vs. strain at several temperatures of Chevron Phillips Chemical Ryton® BR42B—40% glass fiber filled, low friction PPS resin.

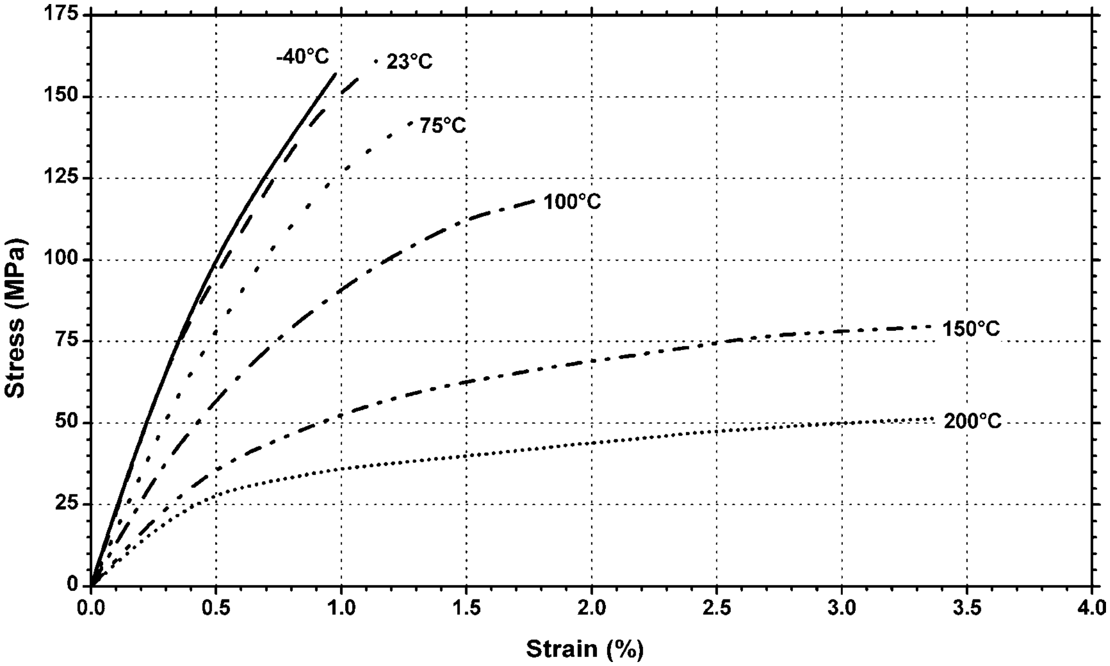


Figure 10.42. Stress vs. strain at several temperatures of Chevron Phillips Chemical Ryton® BR111—40% glass/mineral filled PPS resin.

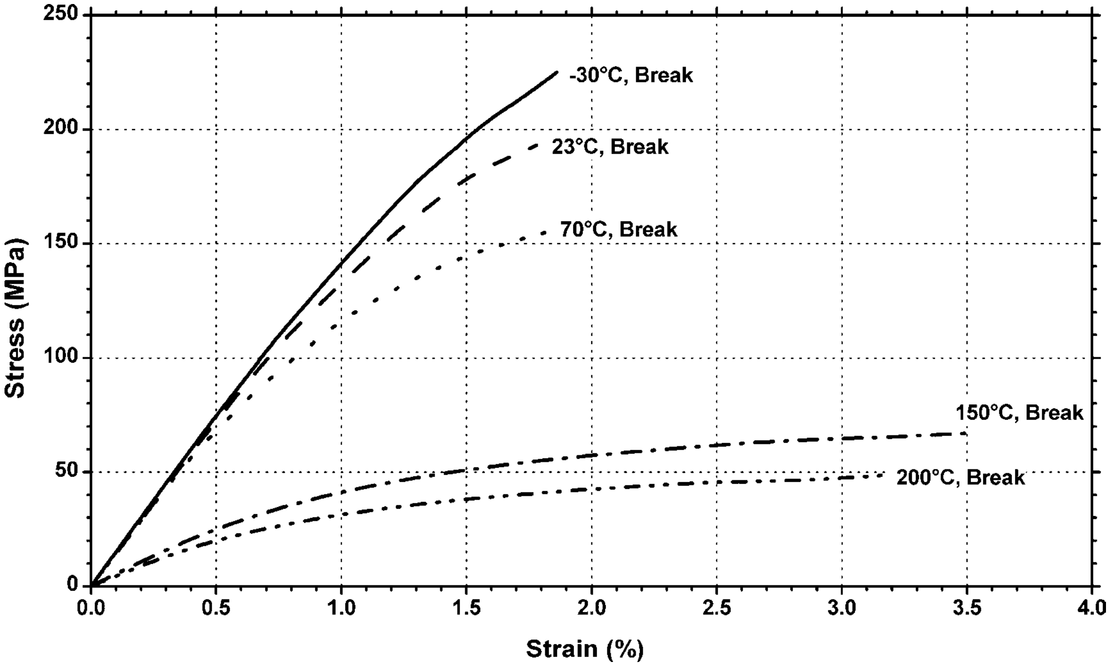


Figure 10.43. Stress vs. strain at several temperatures of Ticona Fortron® 1140L4—40% glass fiber filled, medium melt viscosity PPS resin.

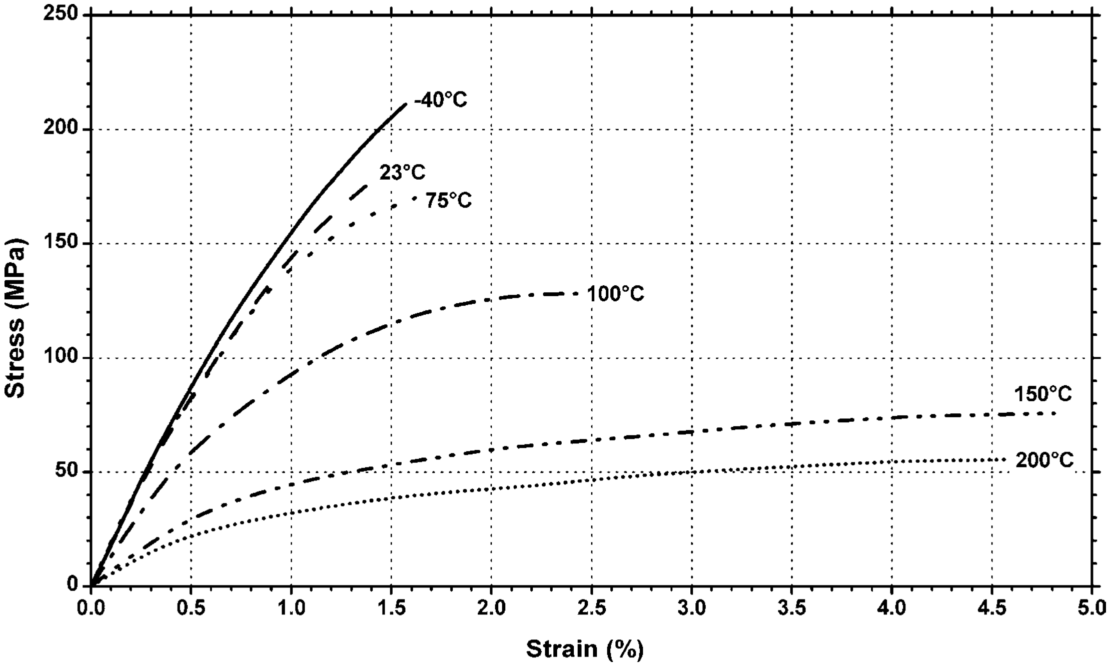


Figure 10.44. Stress vs. strain at several temperatures of Chevron Phillips Chemical Ryton® Ryton® R-4-200BL—40% glass fiber filled, high strength PPS resin.

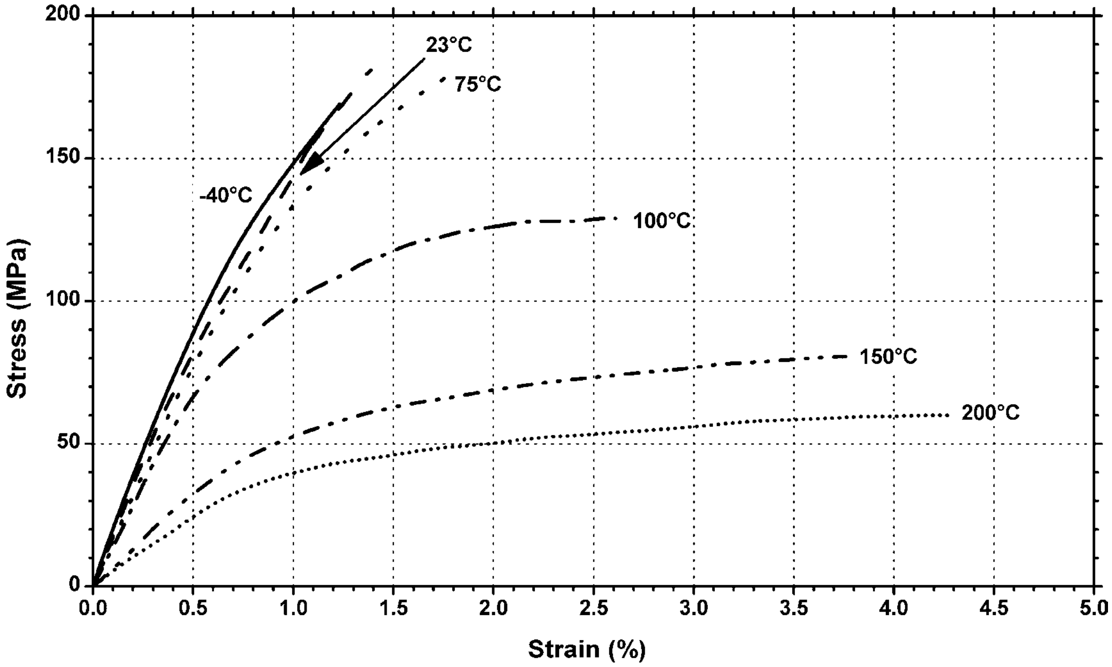


Figure 10.45. Stress vs. strain at several temperatures of Chevron Phillips Chemical Ryton® Ryton® R-4-230NA—40% glass fiber filled, high flow PPS resin.

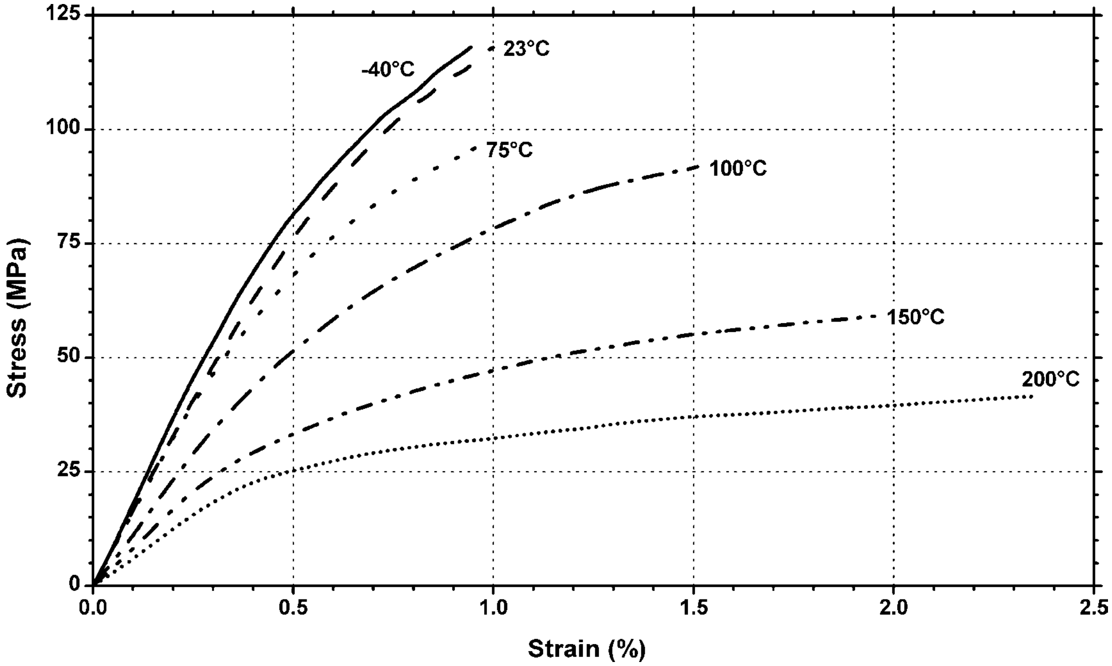


Figure 10.46. Stress vs. strain at several temperatures of Chevron Phillips Chemical Ryton® Ryton® R-7-120BL—65% glass fiber/mineral filled, arc resistant PPS resin.

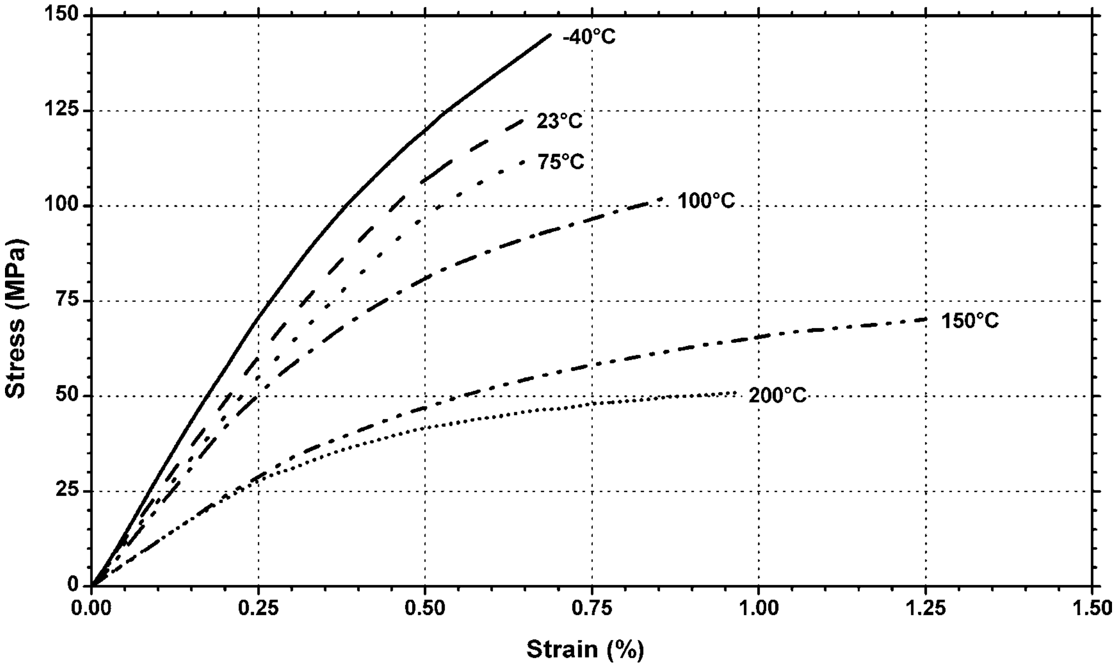


Figure 10.47. Stress vs. strain at several temperatures of Chevron Phillips Chemical Ryton® Ryton® R-10-110BL—65% glass fiber/mineral filled, lower cost PPS resin.

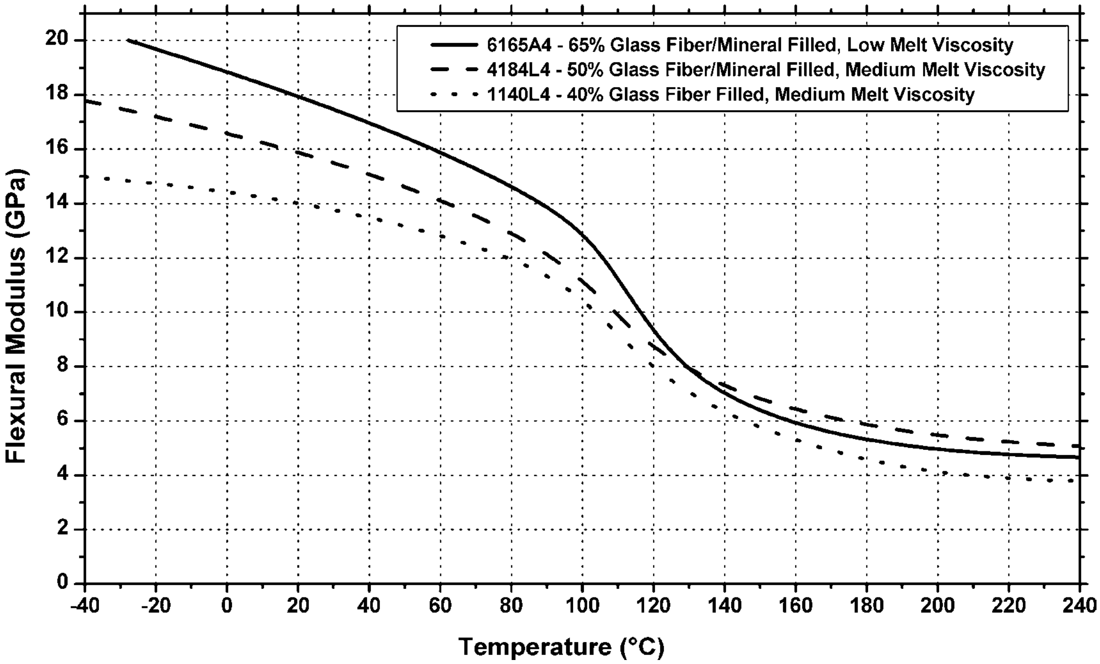


Figure 10.48. Flexural modulus vs. temperature of Ticona Fortron® glass fiber filled PPS resins.

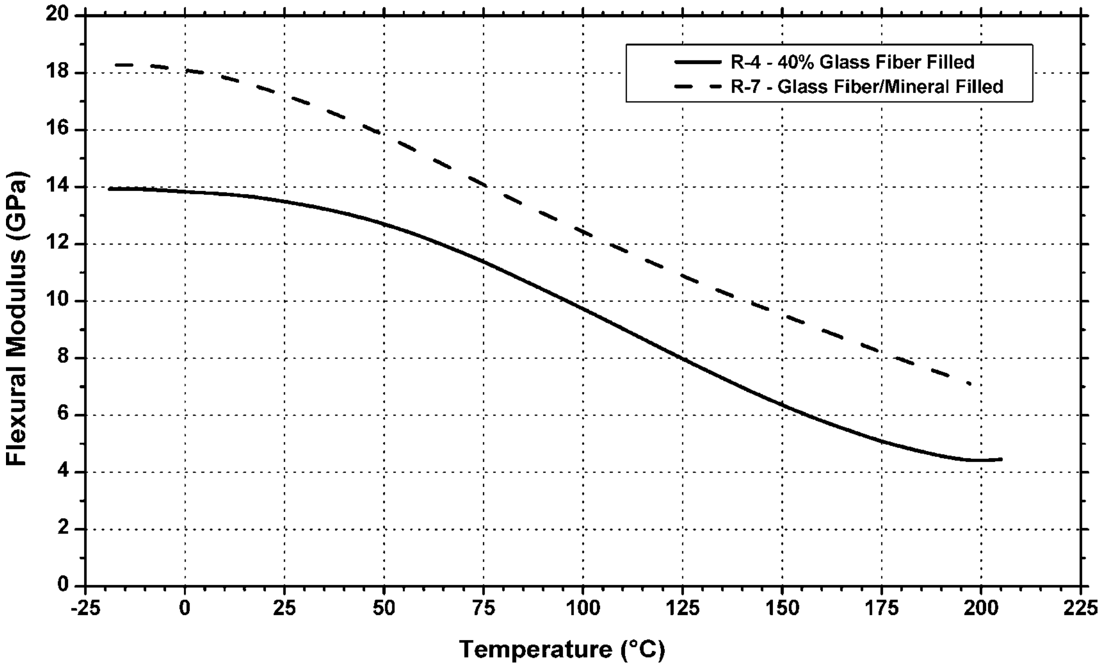


Figure 10.49. Flexural modulus vs. temperature of Chevron Phillips Chemical Ryton® PPS resins.

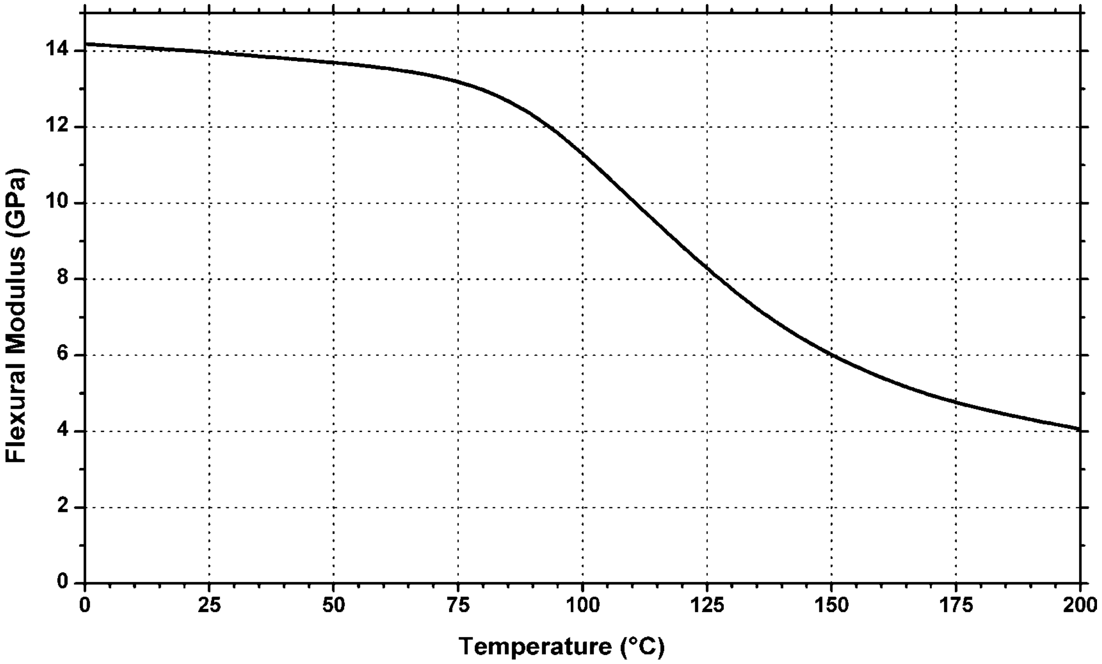


Figure 10.50. Flexural modulus vs. temperature of Toray Resin Company Torelina® A504—40% glass fiber filled, standard grade PPS resin.

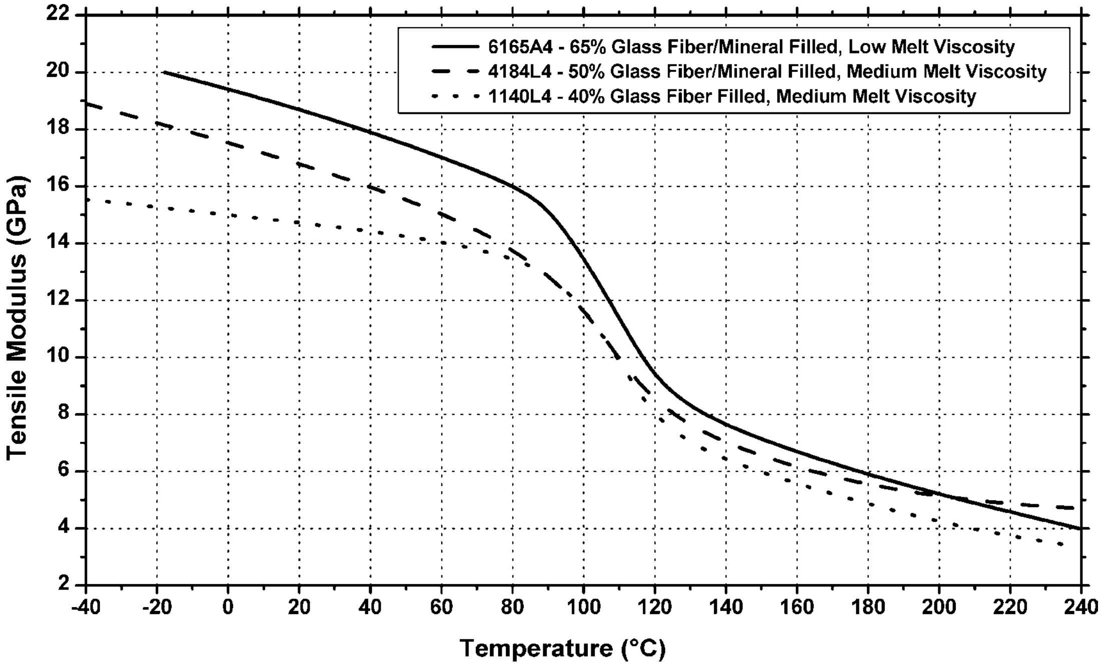


Figure 10.51. Tensile modulus vs. temperature of Ticona Fortron® filled PPS resins.

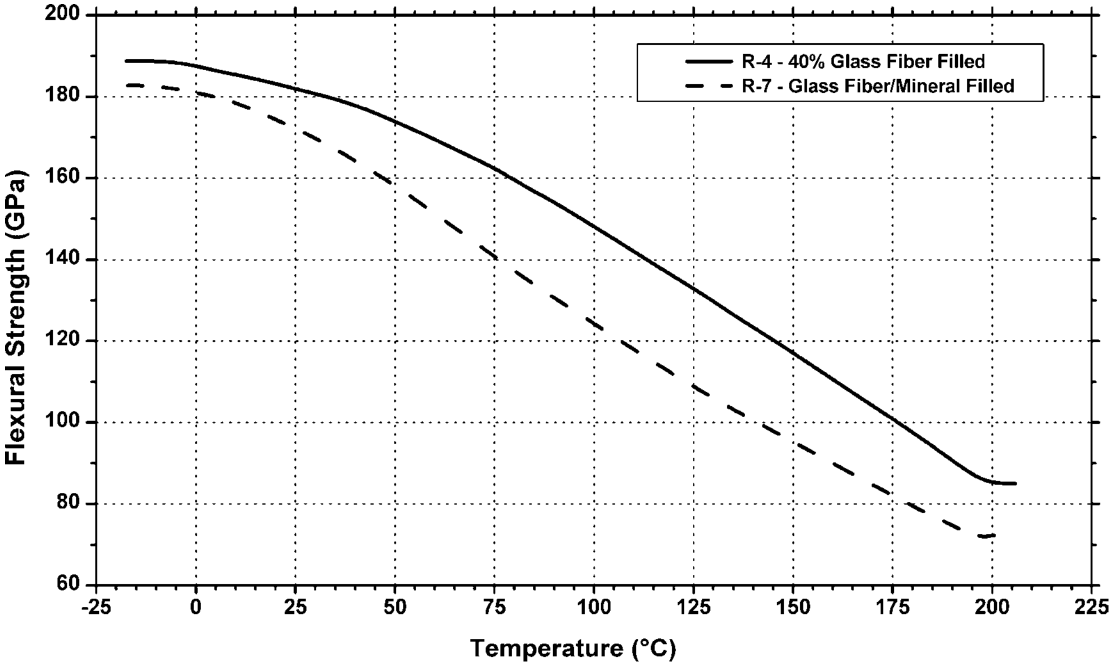


Figure 10.52. Flexural strength vs. temperature of Chevron Phillips Chemical Ryton® PPS resins.

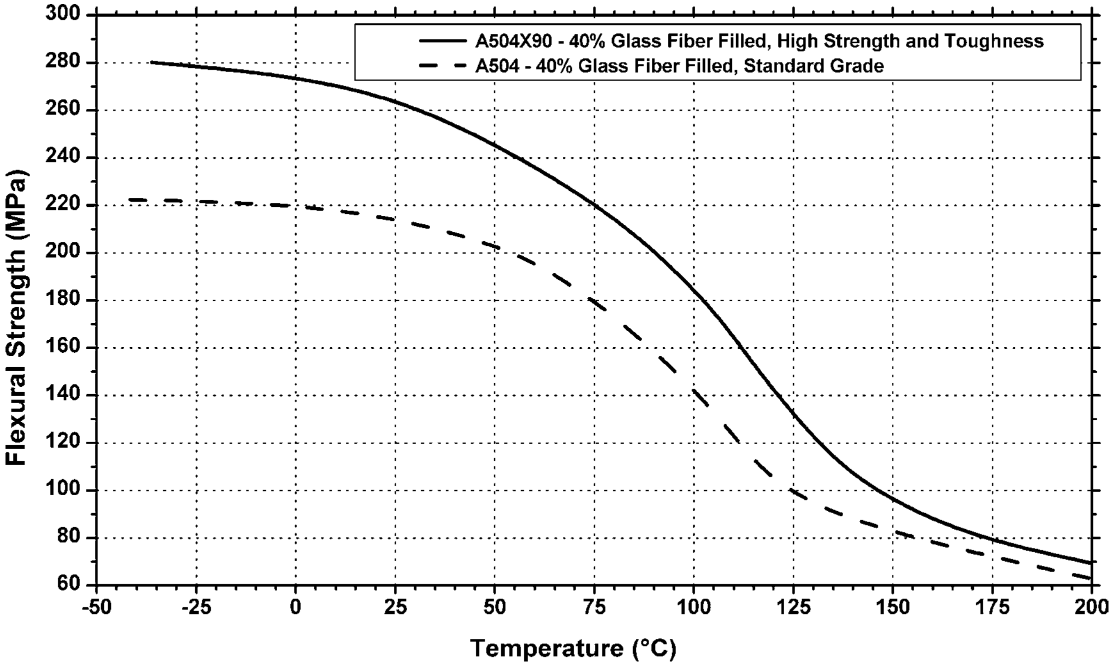


Figure 10.53. Flexural strength vs. temperature of Toray Resin Company Torelina® PPS resins.

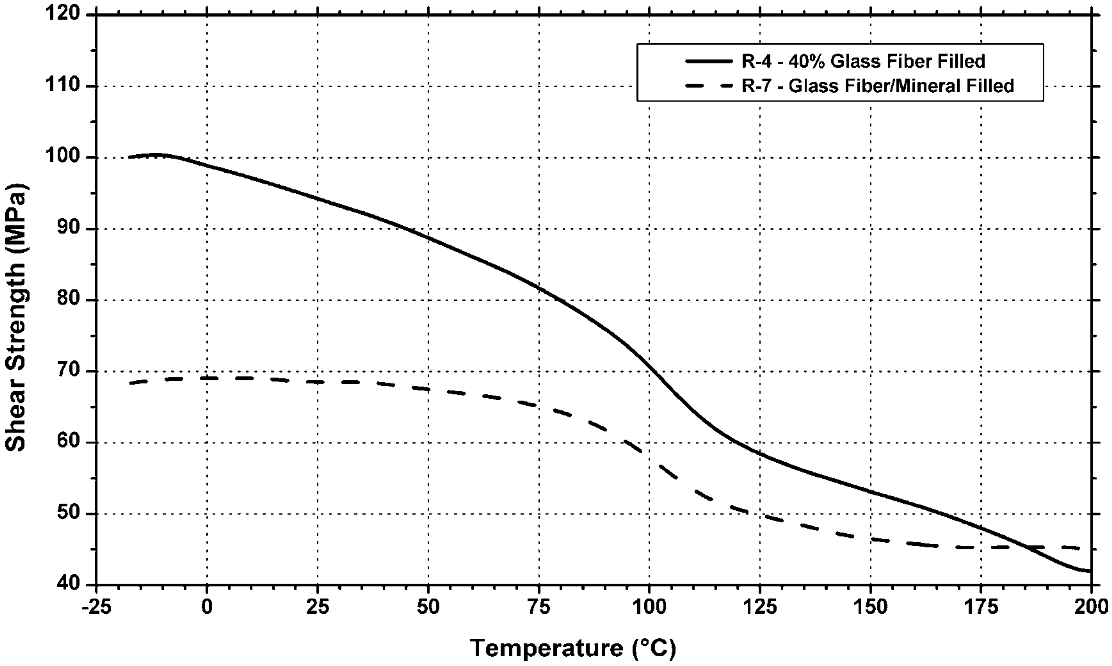


Figure 10.54. Shear strength vs. temperature of Chevron Phillips Chemical Ryton® PPS resins.

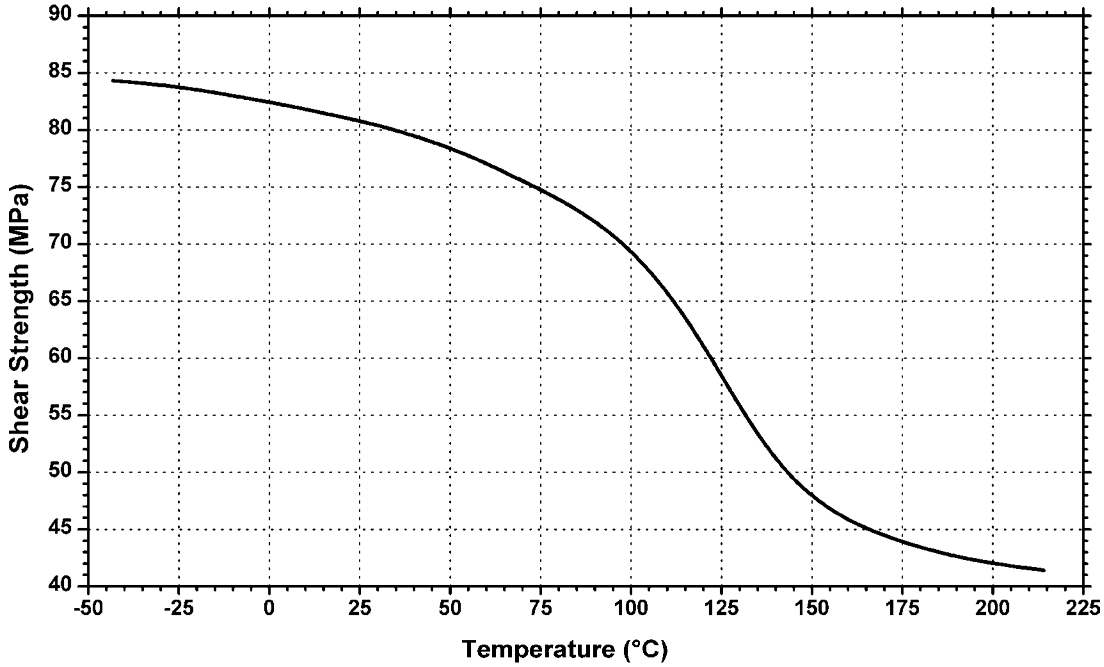


Figure 10.55. Shear strength vs. temperature of Toray Resin Company Torelina® A504—40% glass fiber filled, standard grade PPS resin.

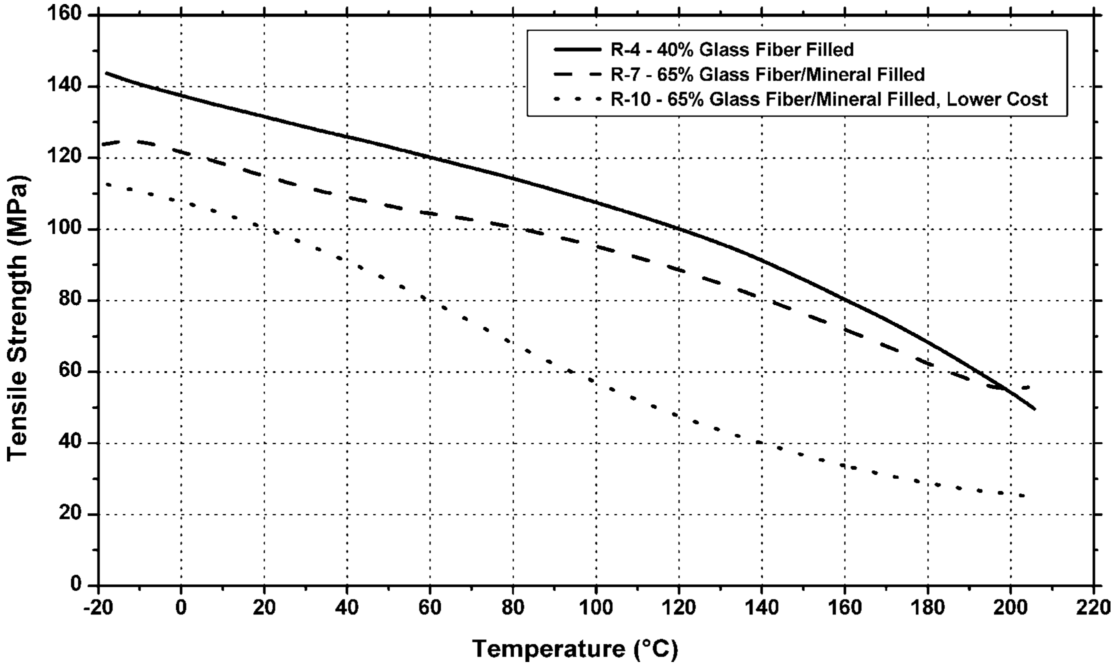


Figure 10.56. Tensile strength vs. temperature of Chevron Phillips Chemical Ryton® PPS resins.

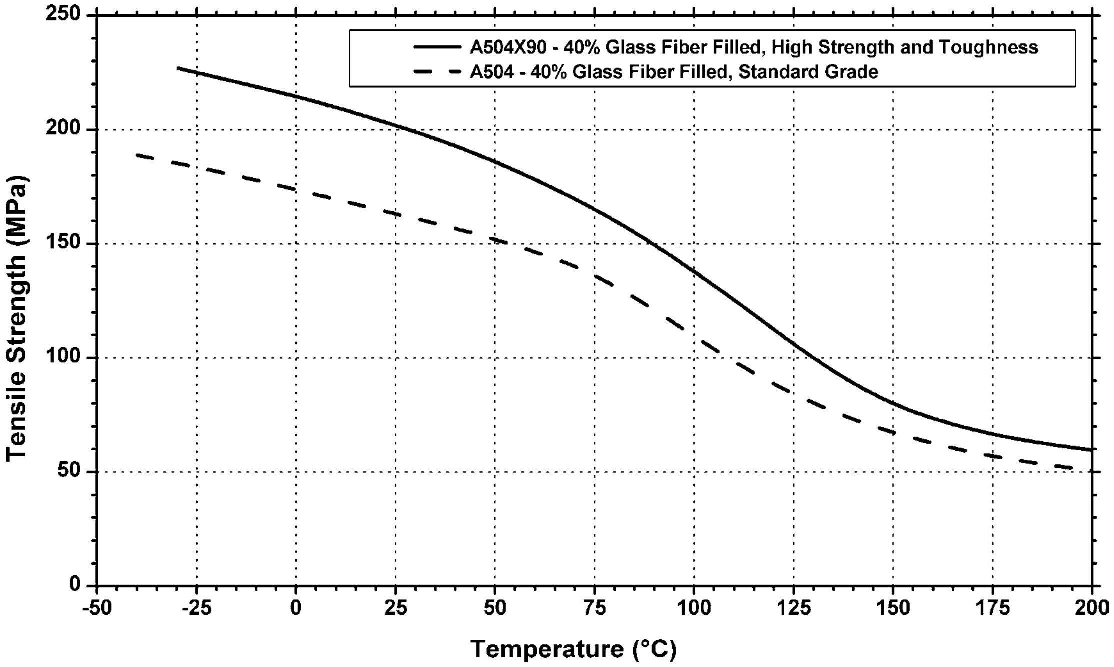


Figure 10.57. Tensile strength vs. temperature of Toray Resin Company Torelina® PPS resins.

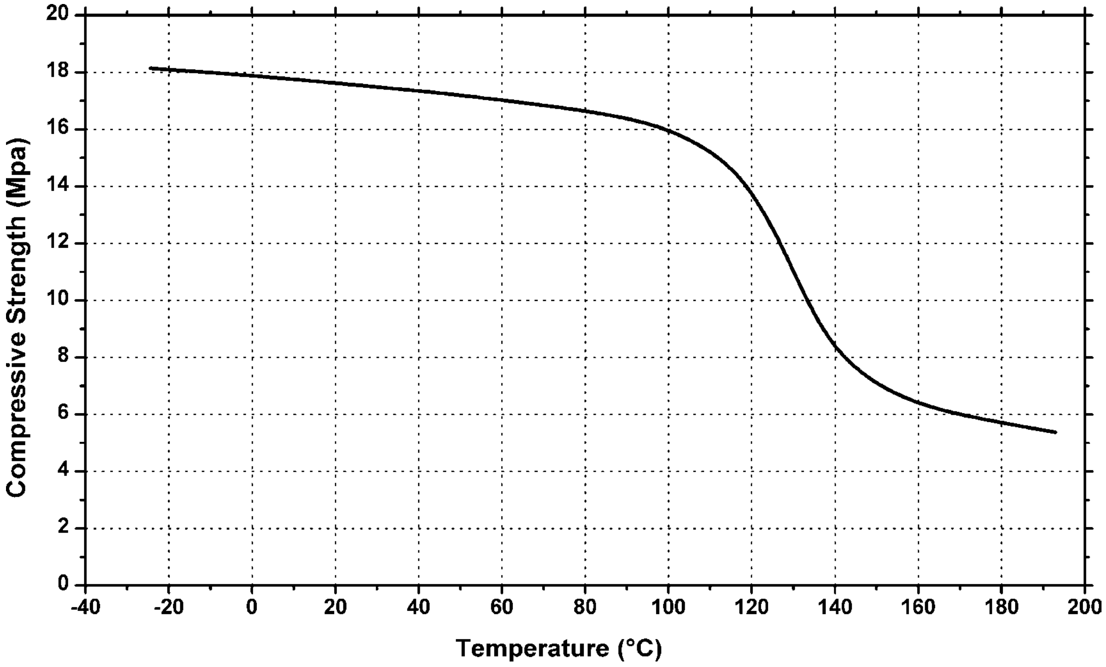


Figure 10.58. Compressive strength vs. temperature of Toray Resin Company Torelina® A504—40% glass fiber filled, standard grade PPS resin.

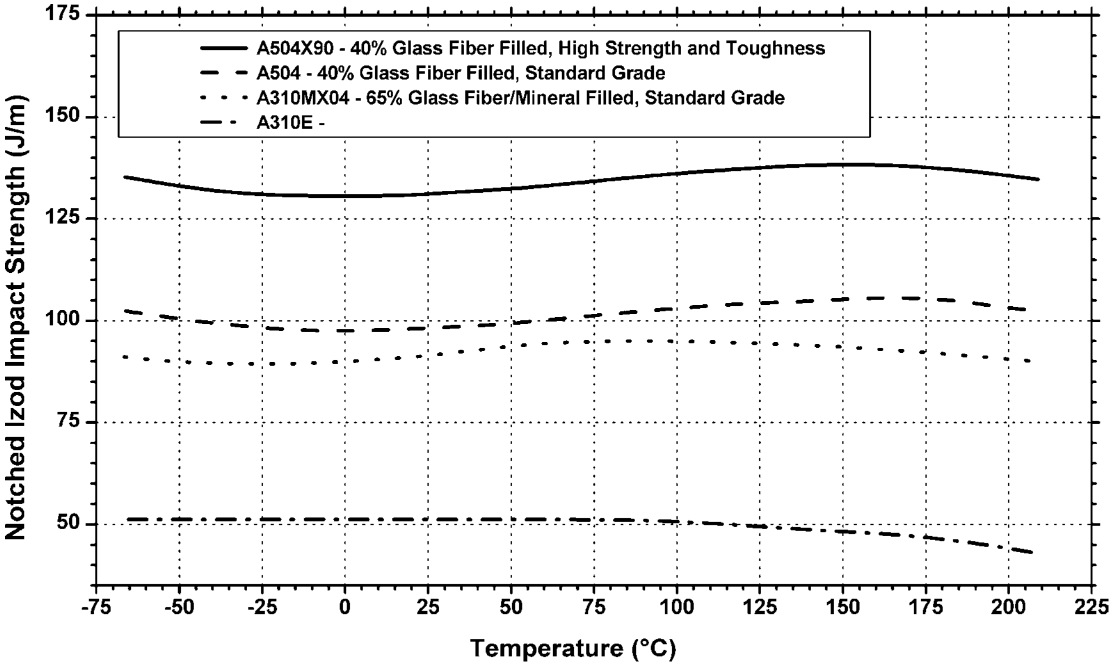


Figure 10.59. Notched Izod impact strength vs. temperature of Toray Resin Company Torelina® PPS resins.

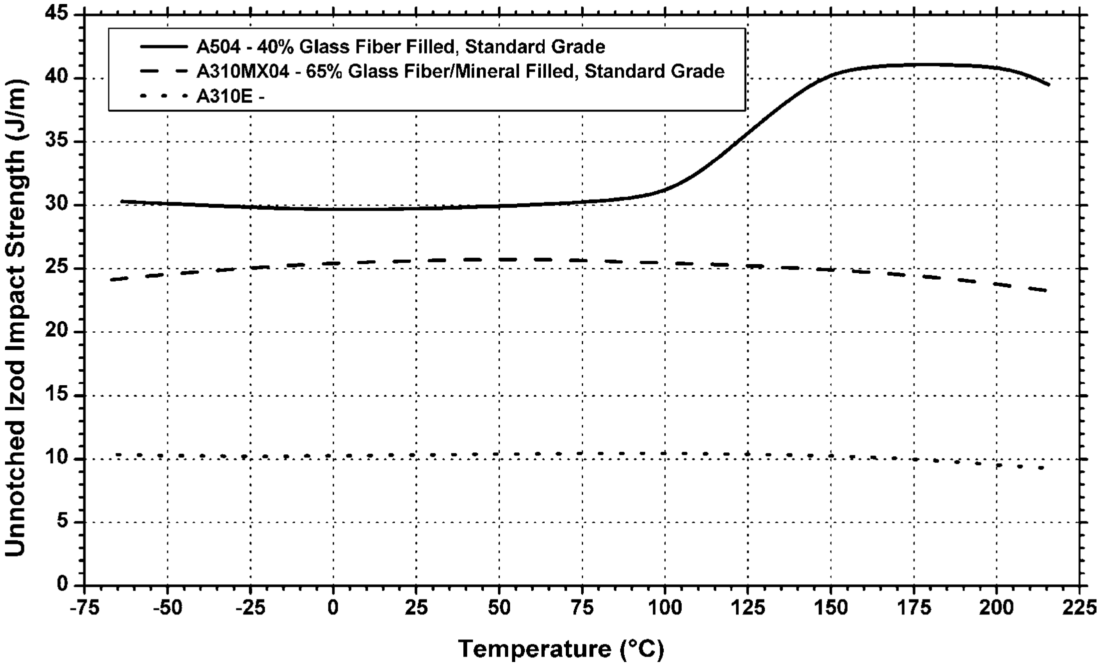


Figure 10.60. Unnotched Izod impact strength vs. temperature of Toray Resin Company Torelina® PPS resins.

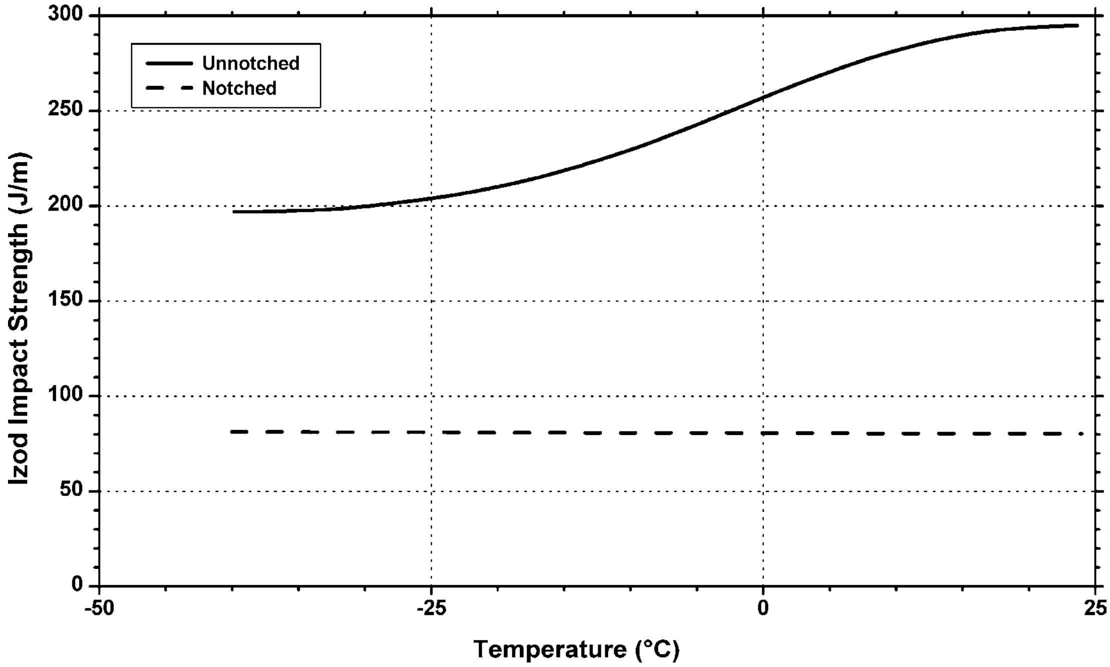


Figure 10.61. Izod impact strength vs. low temperature of Chevron Phillips Chemical Ryton® R-4—40% glass fiber filled, high strength PPS resin.

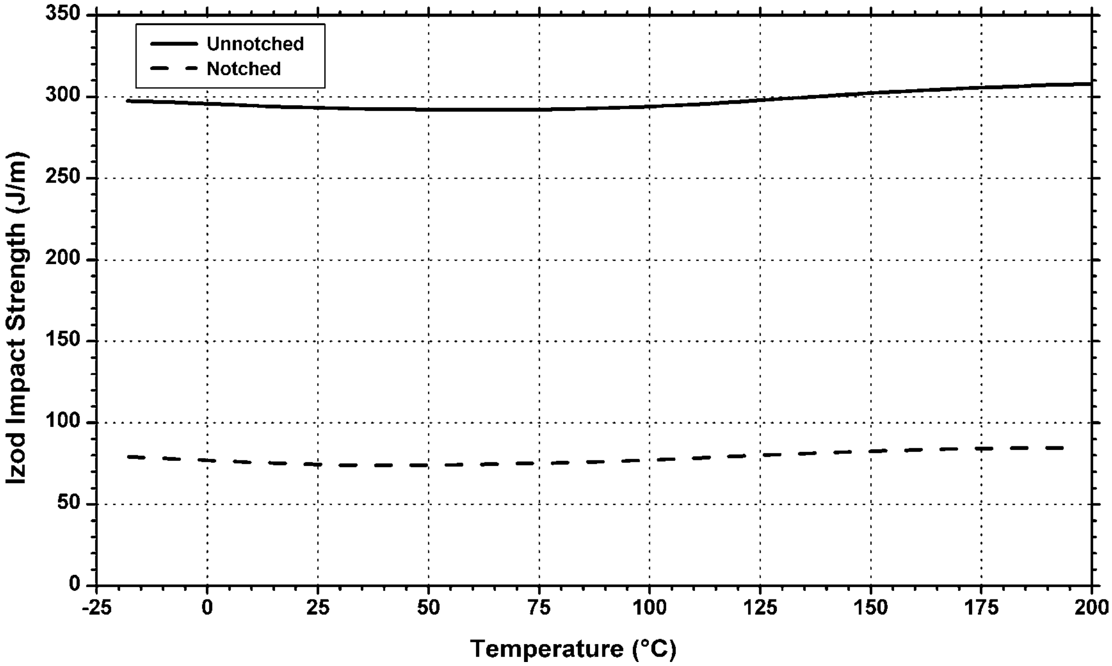


Figure 10.62. Izod impact strength vs. high temperature of Chevron Phillips Chemical Ryton® R-4—40% glass fiber filled, high strength PPS resin.

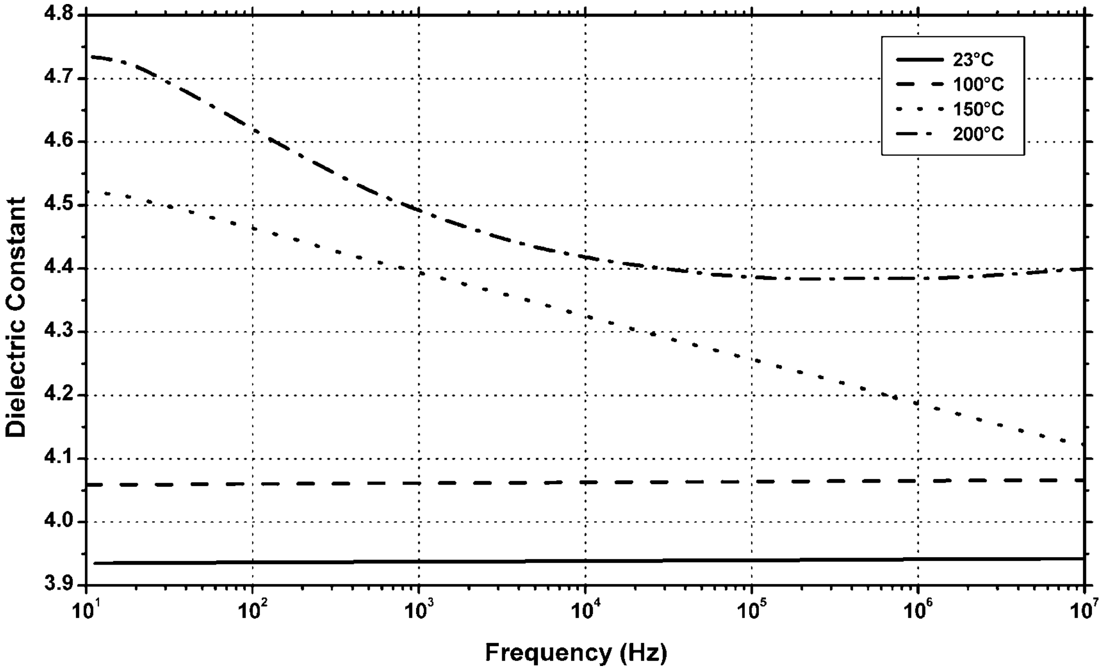


Figure 10.63. Dielectric constant vs. frequency and temperature of Chevron Phillips Chemical Ryton® R-4—40% glass fiber filled, high strength PPS resin.

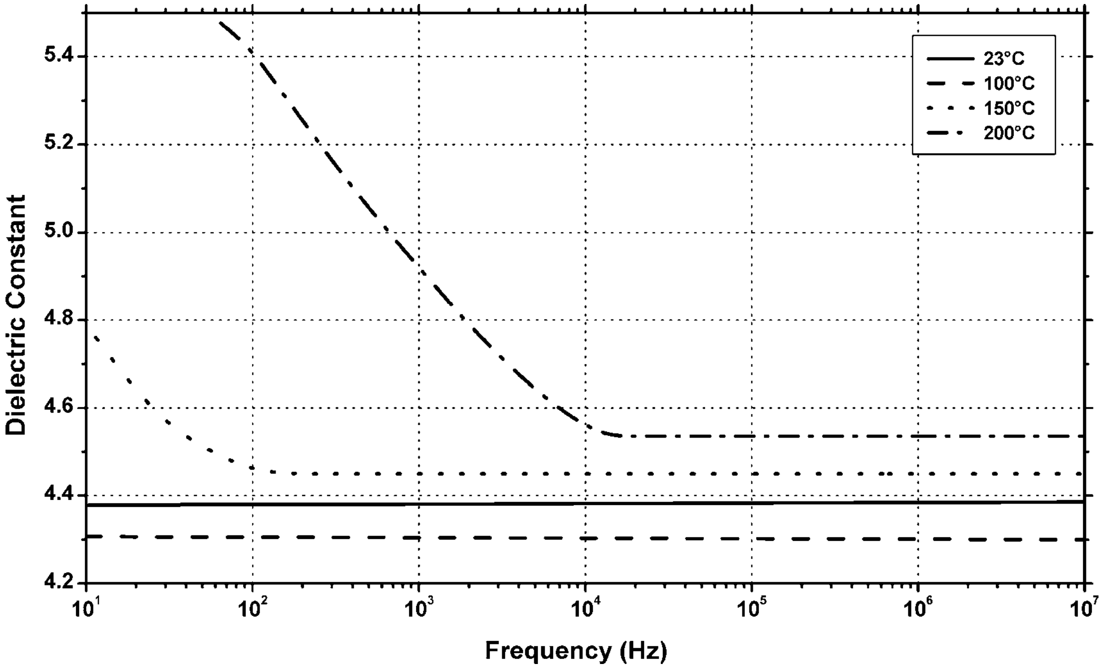


Figure 10.64. Dielectric constant vs. frequency and temperature of Chevron Phillips Chemical Ryton® R-7—65% glass fiber/mineral filled PPS resin.

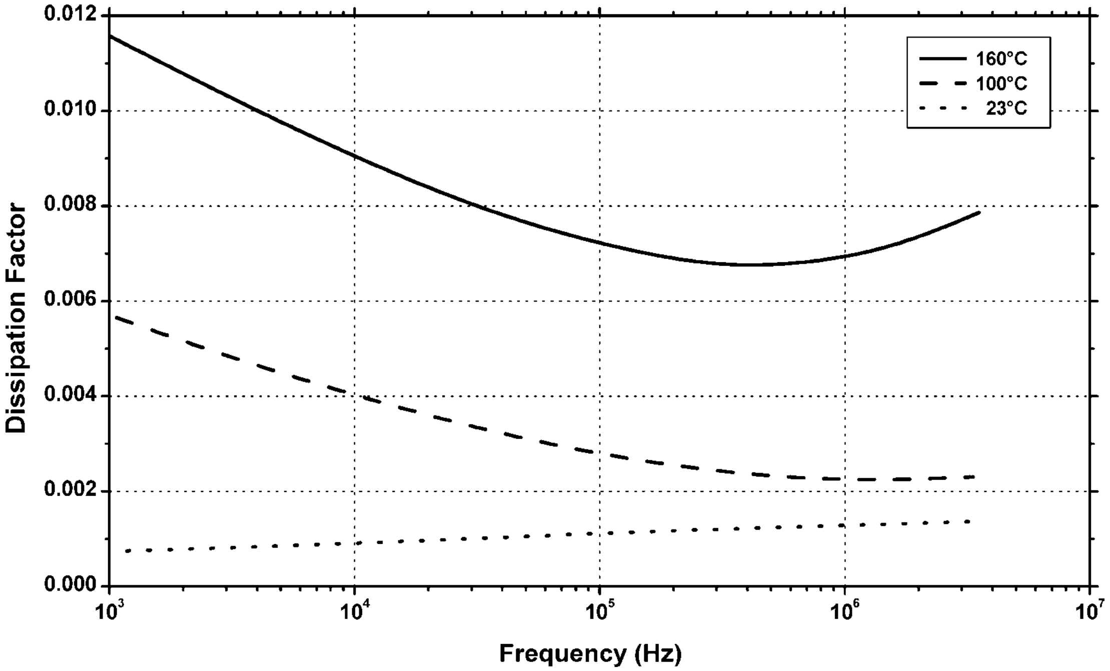


Figure 10.65. Dissipation factor vs. frequency at several temperatures of Ticona Fortron® 1140L4—40% glass fiber filled, medium melt viscosity PPS resin.

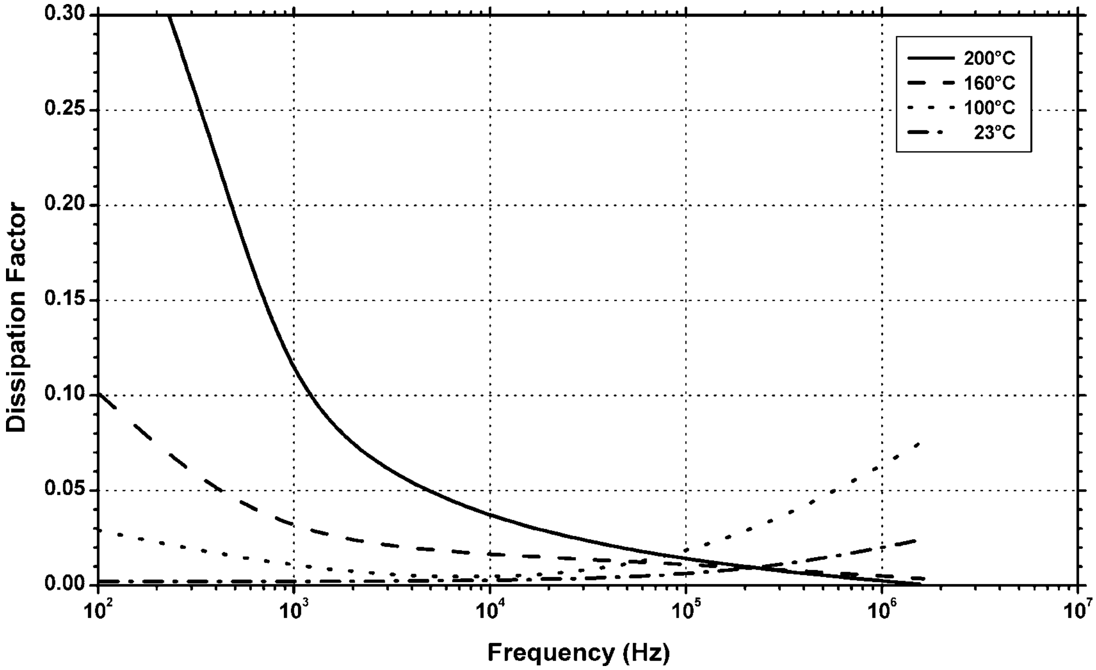


Figure 10.66. Dissipation factor vs. frequency at several temperatures of Ticona Fortron® 6160B4—60% glass fiber/mineral filled PPS resin.

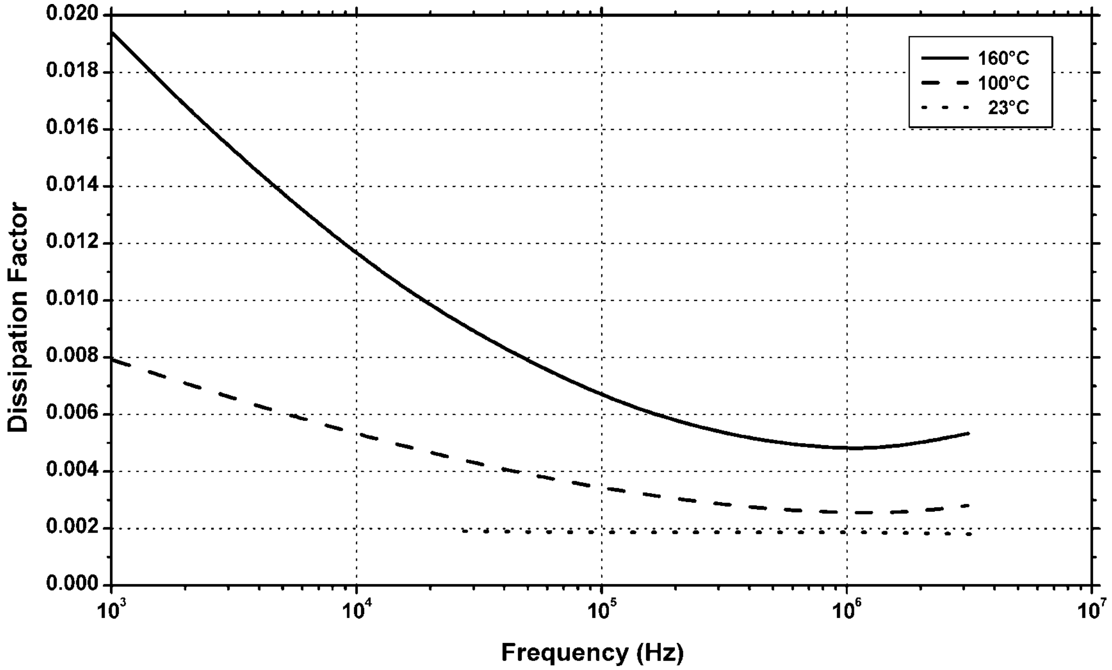


Figure 10.67. Dissipation factor vs. frequency at several temperatures of Ticona Fortron® 6165A4—65% glass fiber/mineral filled, low melt viscosity PPS resin.

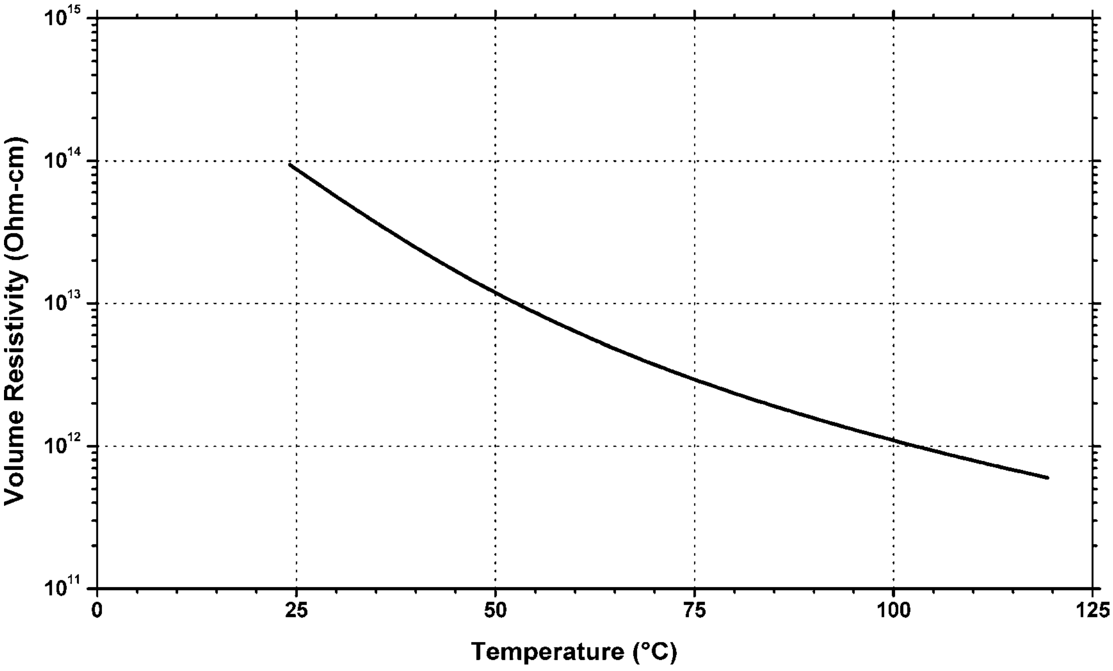


Figure 10.68. Volume resistivity vs. temperature of Ticona Fortron® 1140L4—40% glass fiber filled, medium melt viscosity PPS resin.

10.5 Polysulfone (PSU)

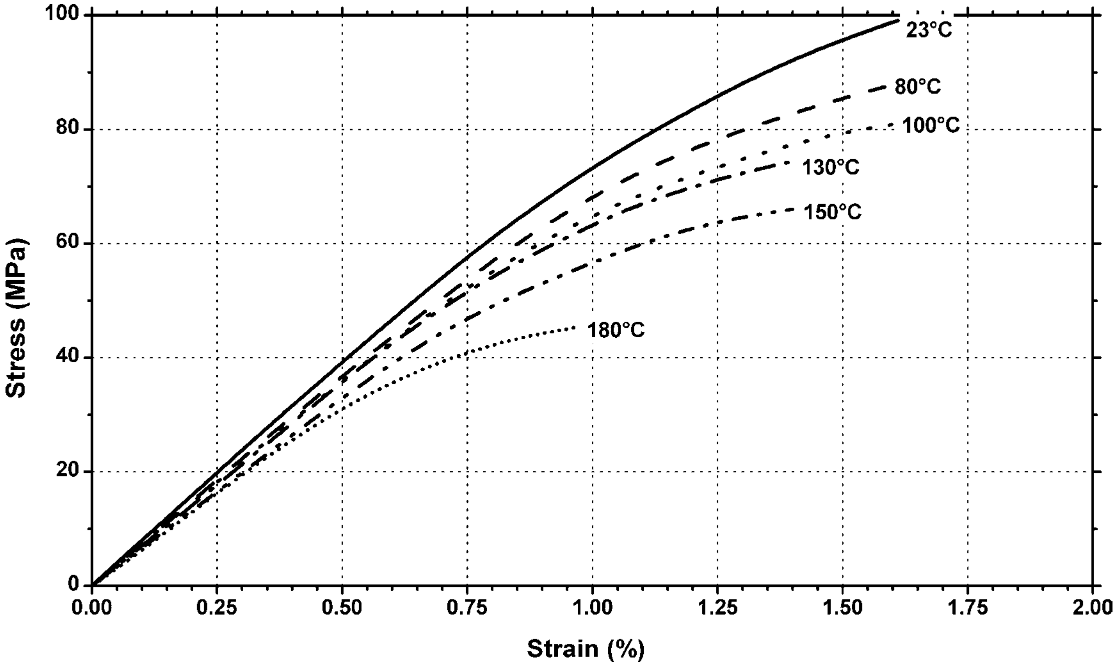


Figure 10.69. Stress vs. strain at several temperatures of Solvay Advanced Polymers Udel® GF-130—30% glass fiber reinforced PSU resin.

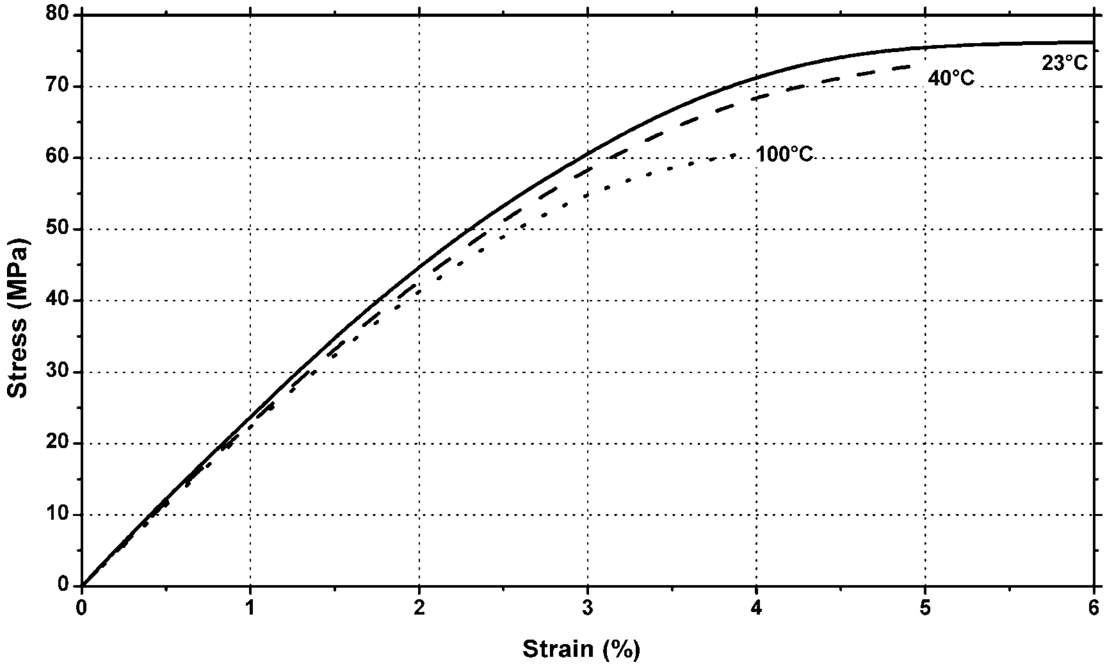


Figure 10.70. Stress vs. strain at several temperatures of Solvay Advanced Polymers Udel® P-1700—unreinforced, mid-viscosity PSU resin.

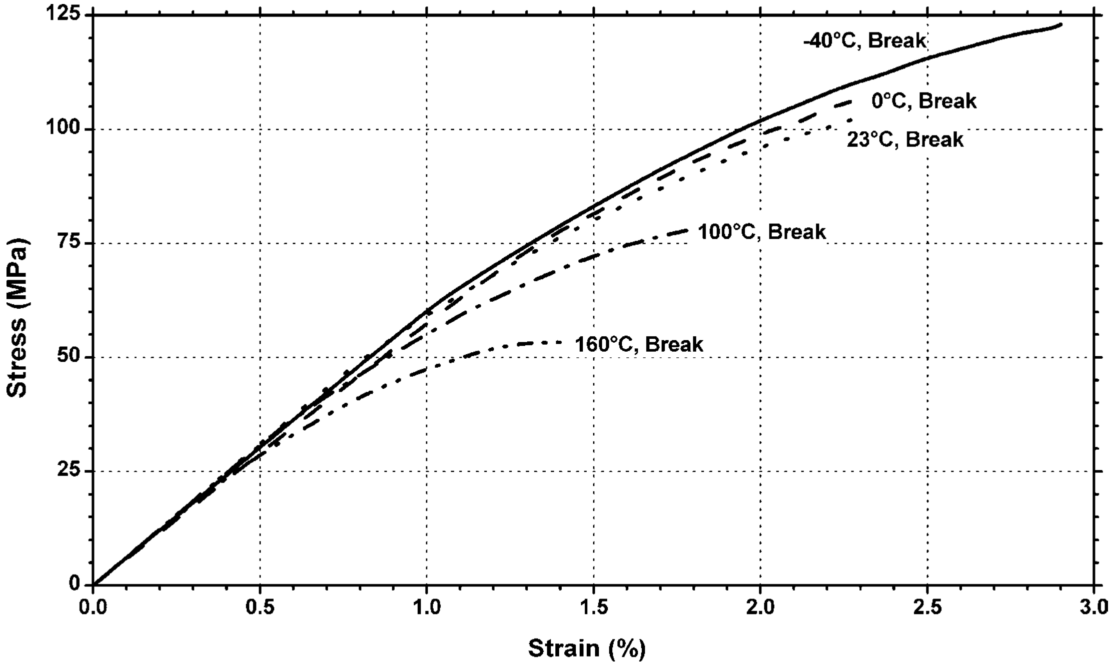


Figure 10.71. Stress vs. strain at several temperatures of BASF Ultrason® S 2010 G4—20% glass reinforced, medium viscosity PSU resin.

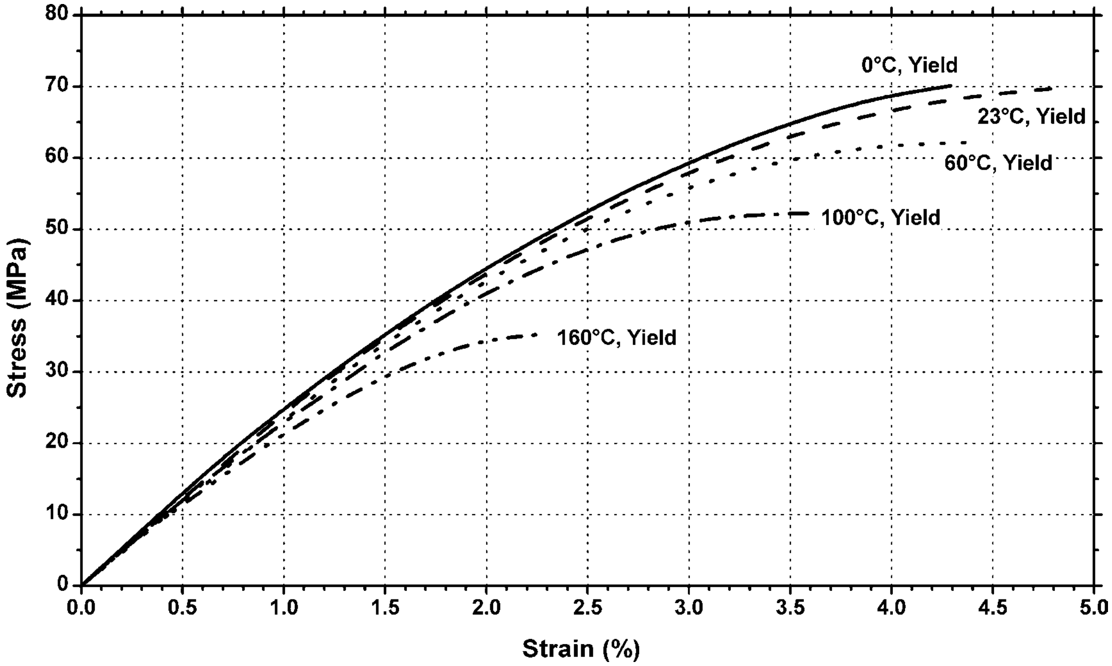


Figure 10.72. Stress vs. strain at several temperatures of BASF Ultrason® S 2010—unreinforced, medium viscosity PSU resin.

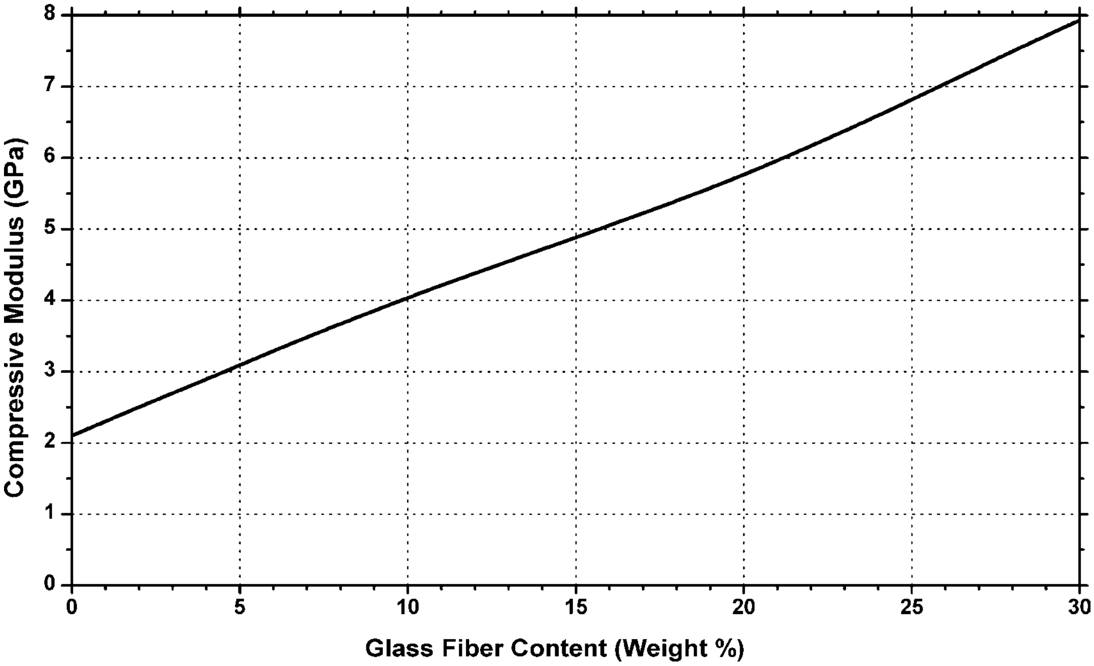


Figure 10.73. Compressive modulus vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

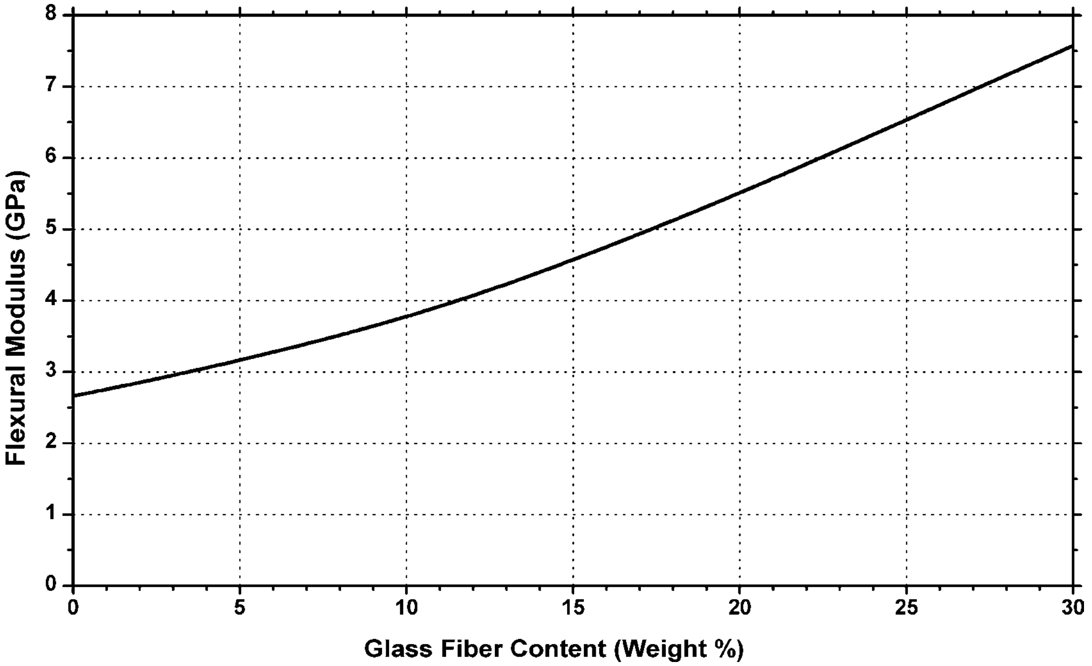


Figure 10.74. Flexural modulus vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

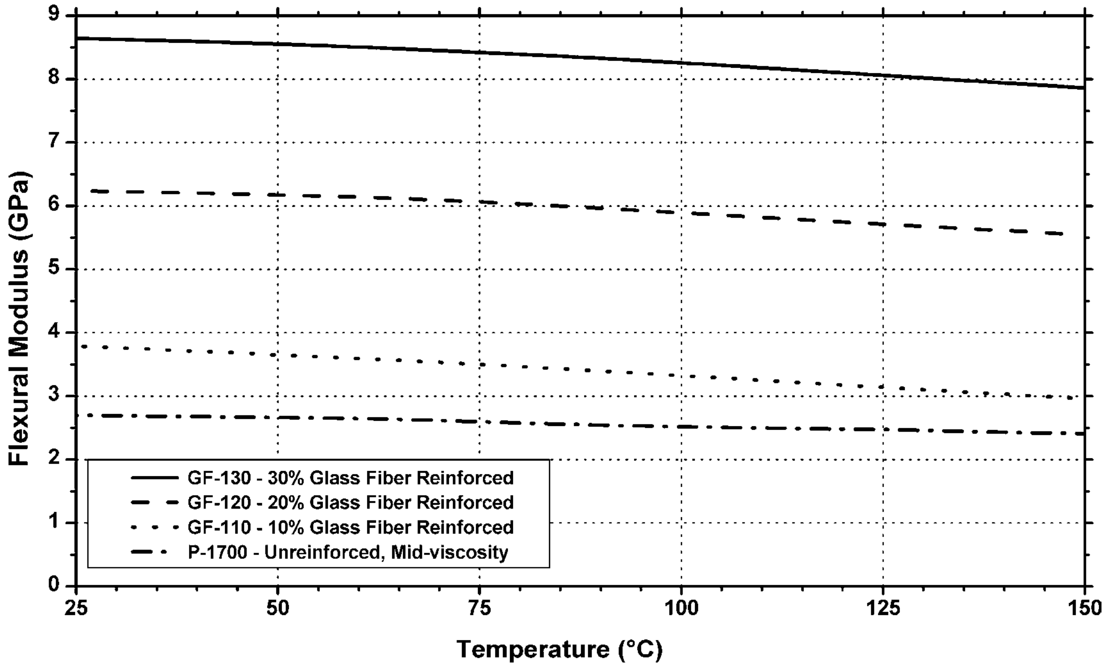


Figure 10.75. Flexural modulus vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

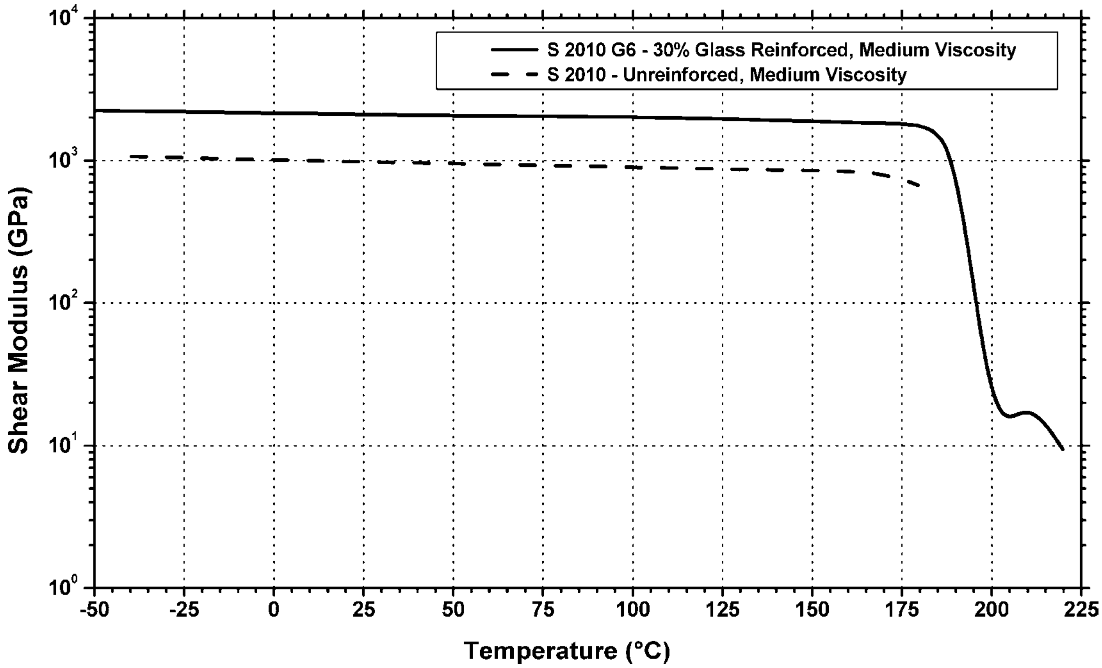


Figure 10.76. Shear modulus vs. temperature of BASF Ultrason® S PSU resins.

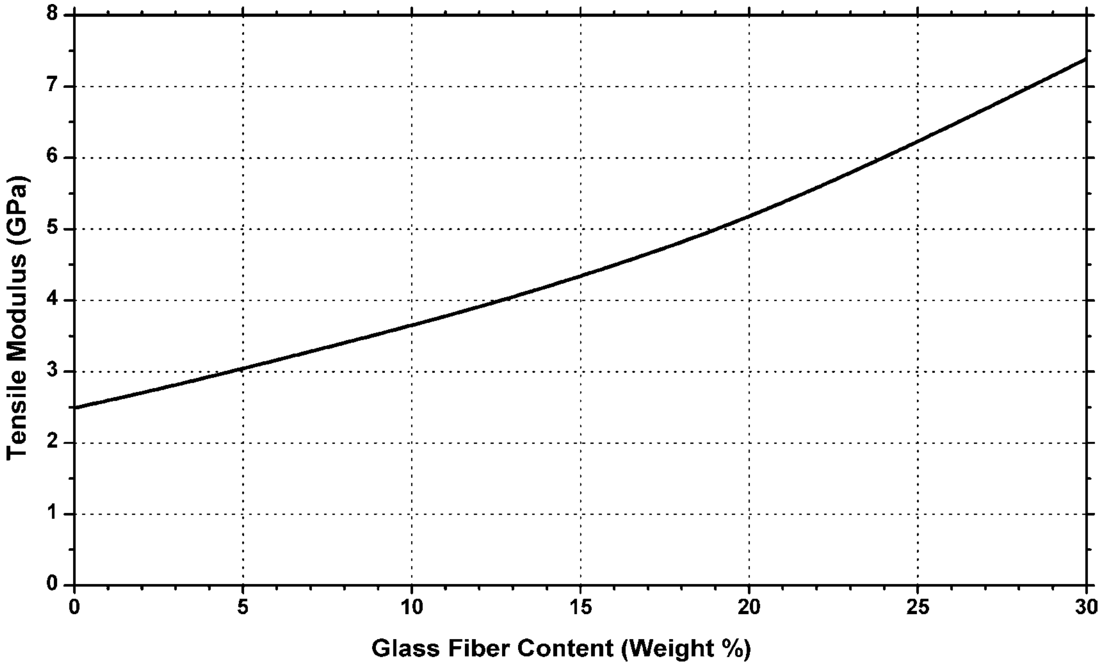


Figure 10.77. Tensile modulus vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

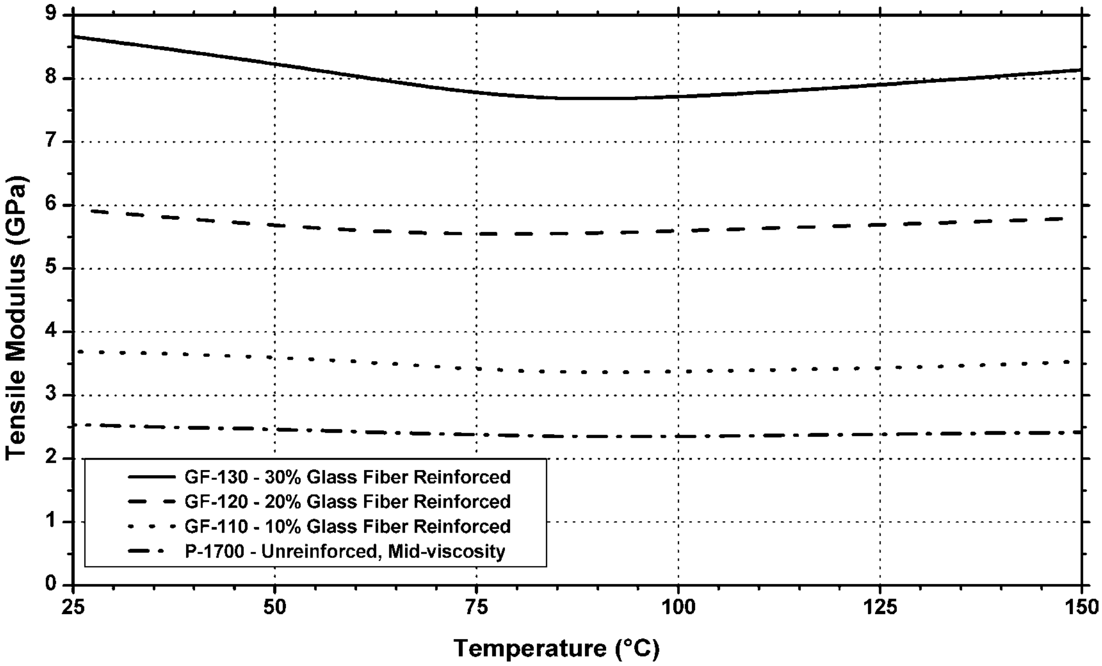


Figure 10.78. Tensile modulus vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

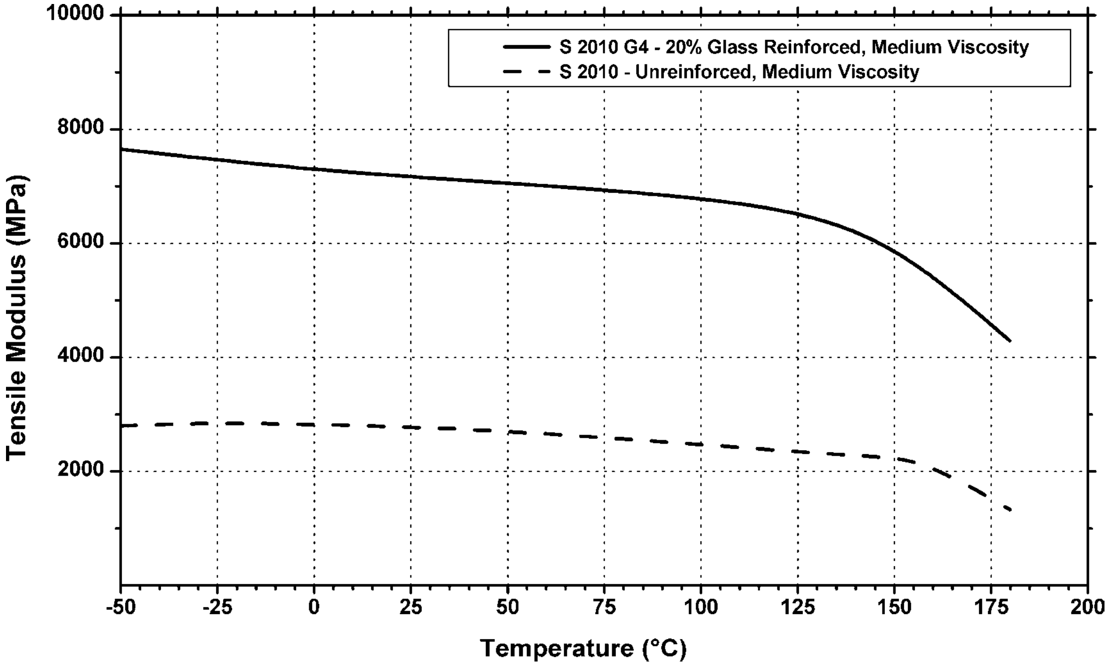


Figure 10.79. Tensile modulus vs. temperature of BASF Ultrason® S PSU resins.

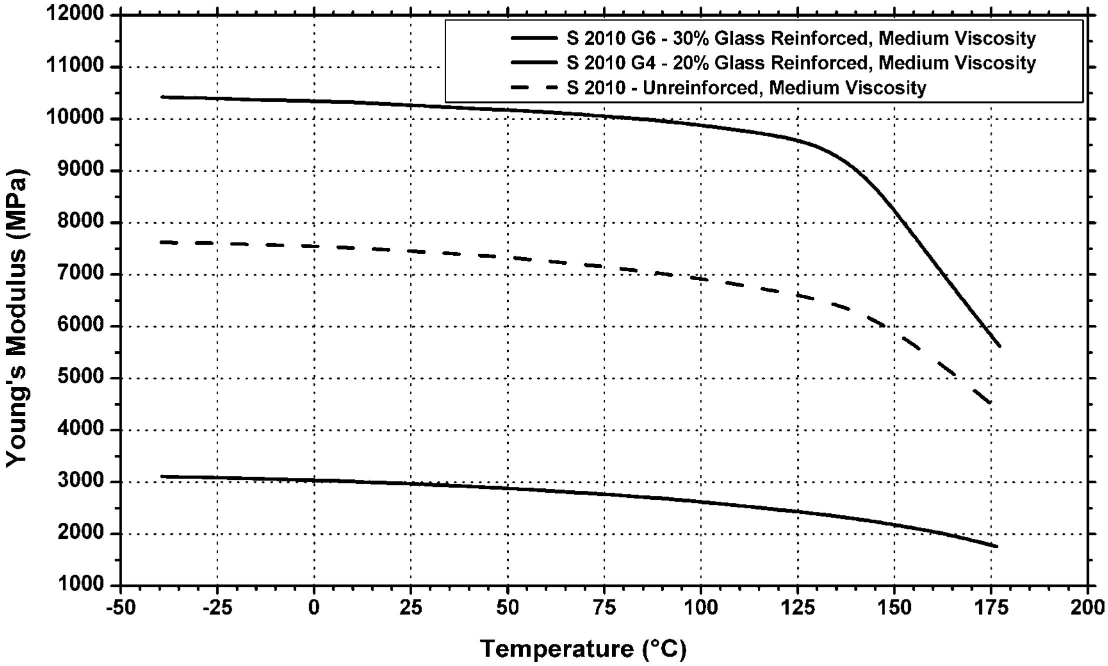


Figure 10.80. Young's modulus vs. temperature of BASF Ultrason® S PSU resins.

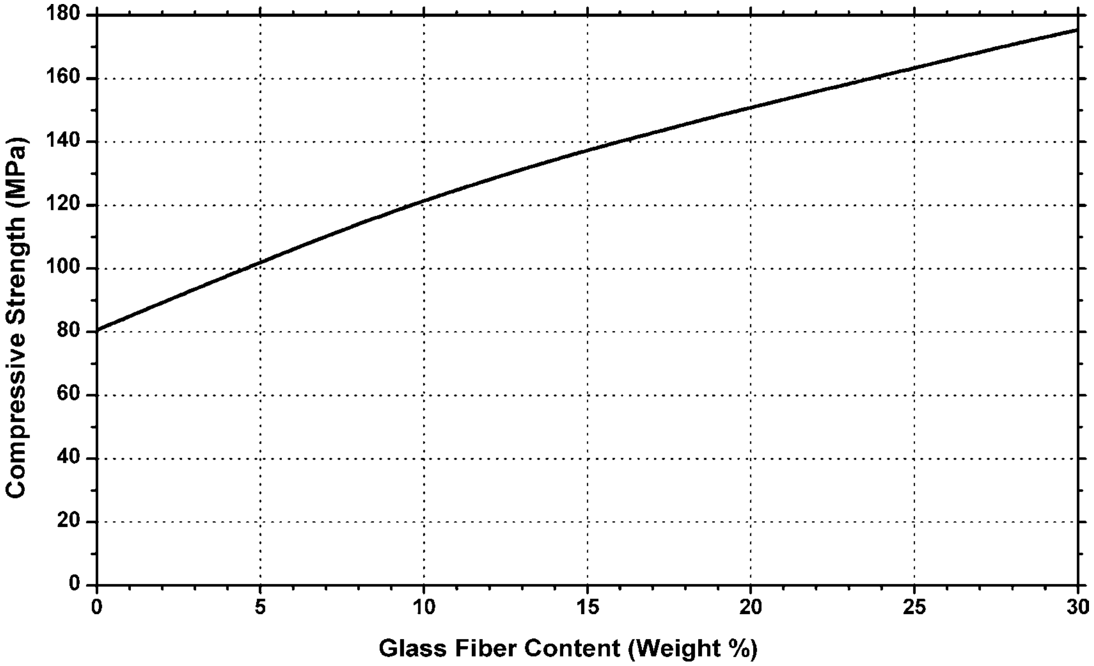


Figure 10.81. Compressive strength vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

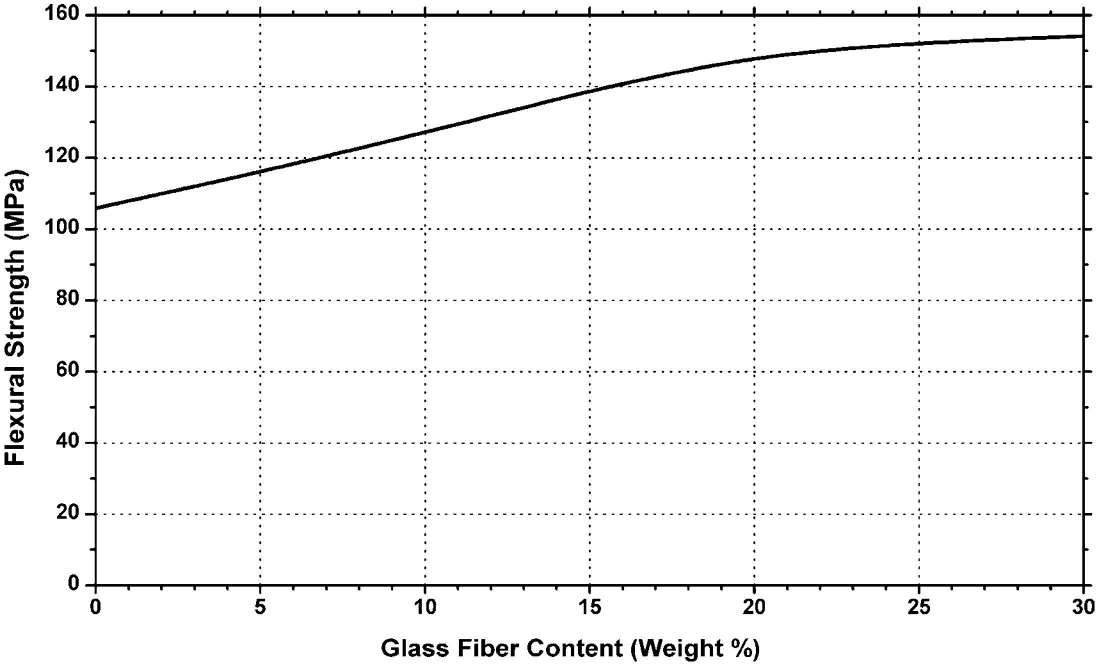


Figure 10.82. Flexural strength vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

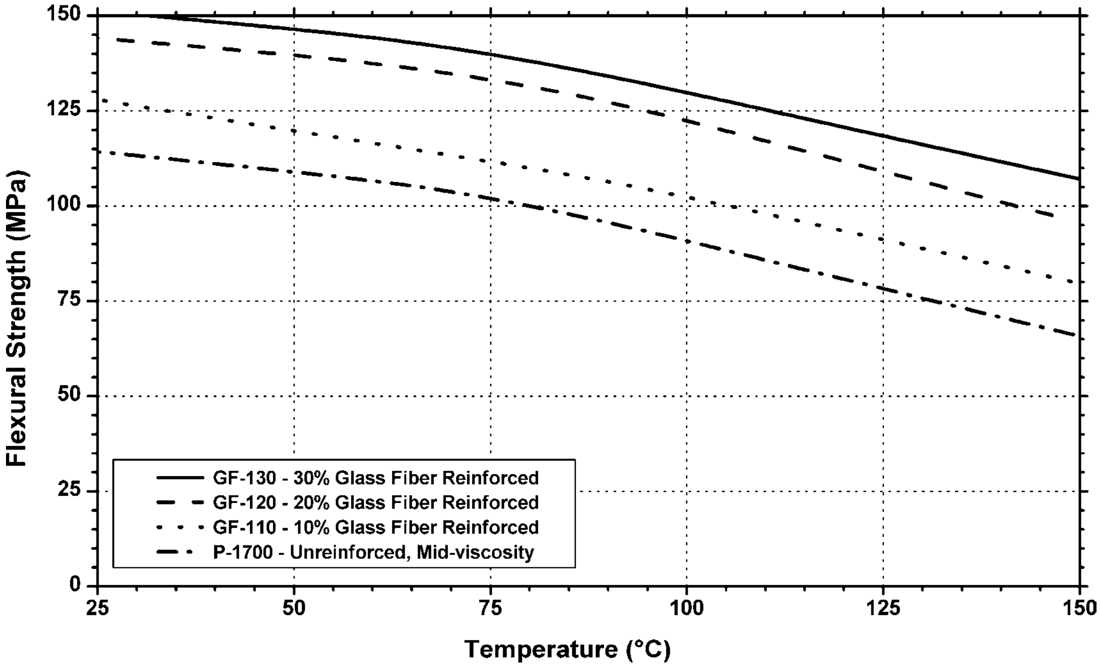


Figure 10.83. Flexural strength vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

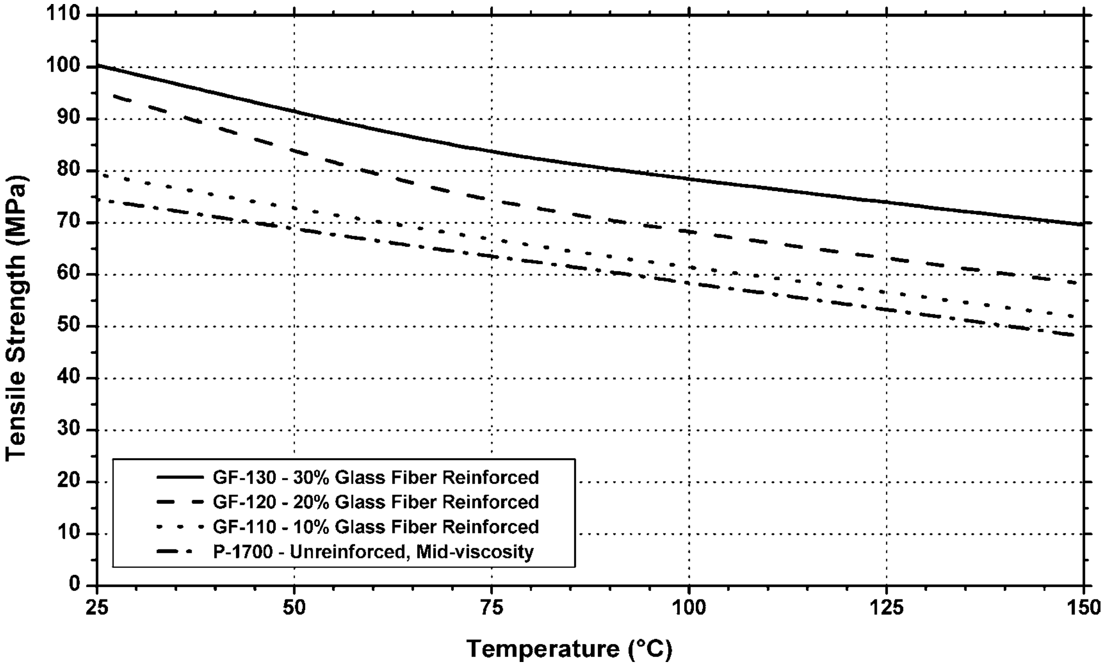


Figure 10.84. Tensile strength vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

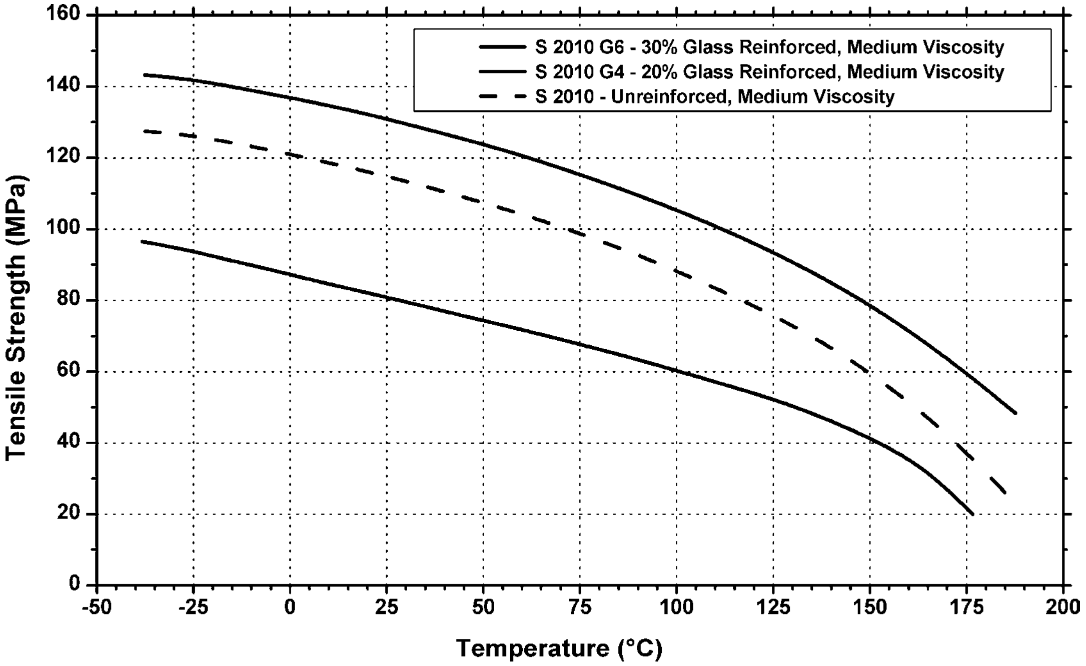


Figure 10.85. Tensile strength vs. temperature of BASF Ultrason® S PSU resins.

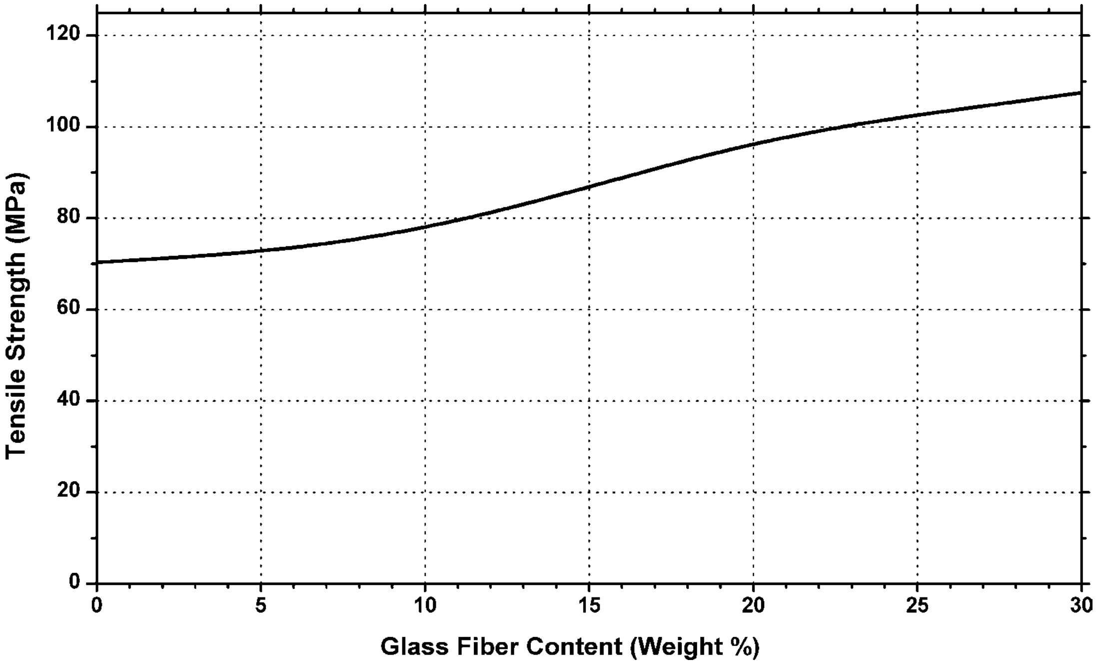


Figure 10.86. Tensile strength vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

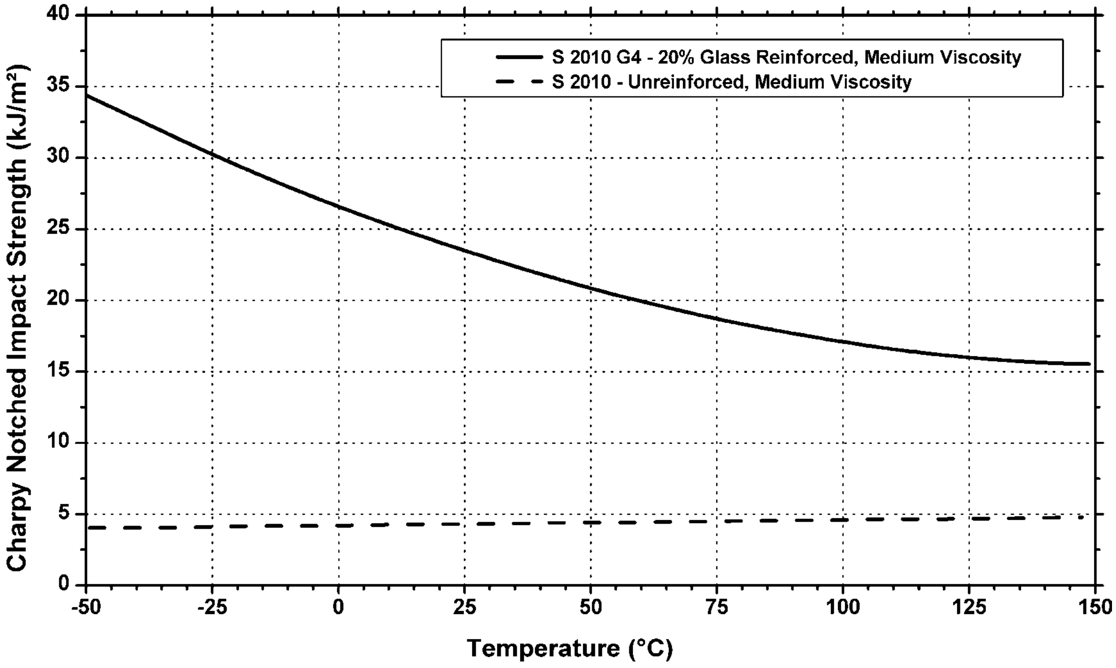


Figure 10.87. Charpy notched impact strength vs. temperature of BASF Ultrason® S 2010 PSU resins.

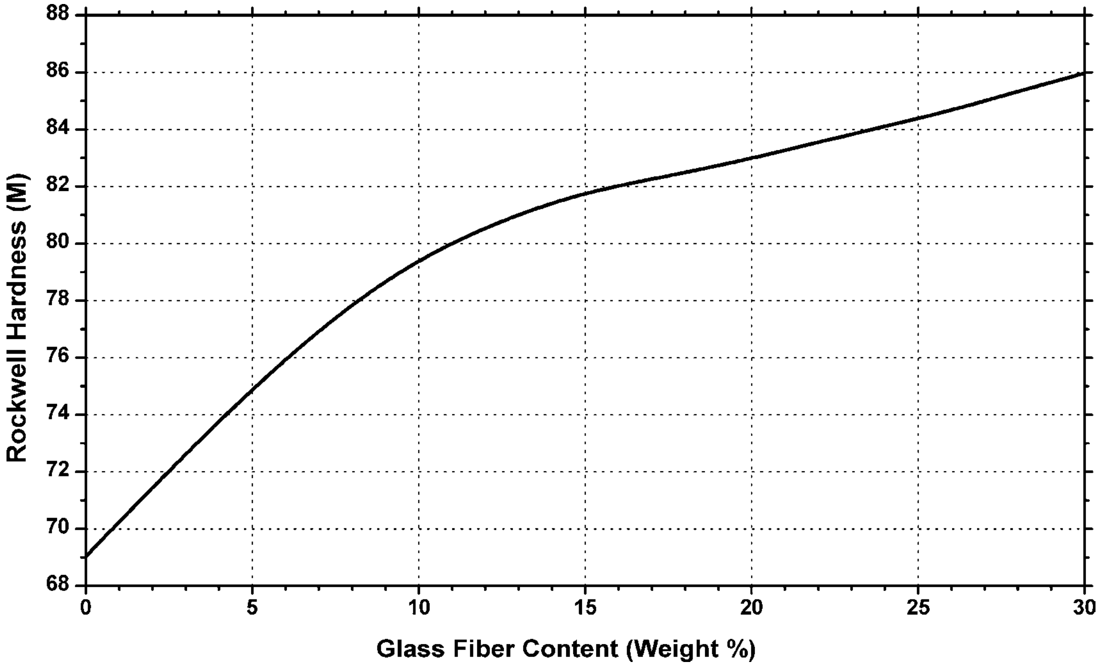


Figure 10.88. Rockwell hardness vs. glass fiber content of Solvay Advanced Polymers Udel® PSU resins.

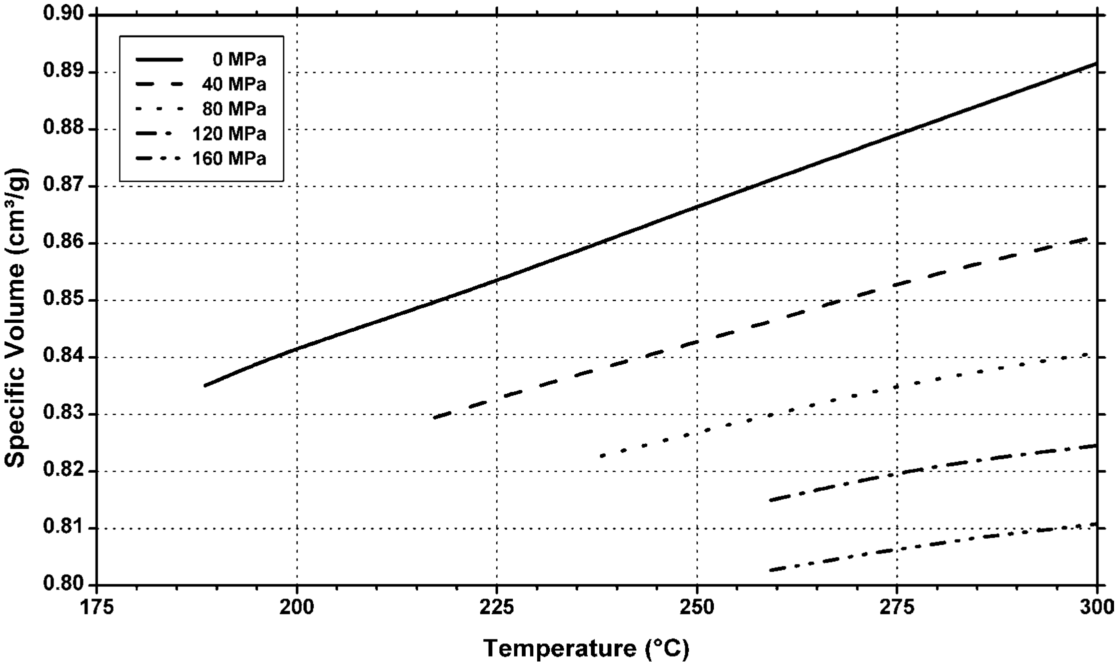


Figure 10.89. Specific volume as a function of temperature and pressure (PVT) of Solvay Advanced Polymers Udel® PSU resins.

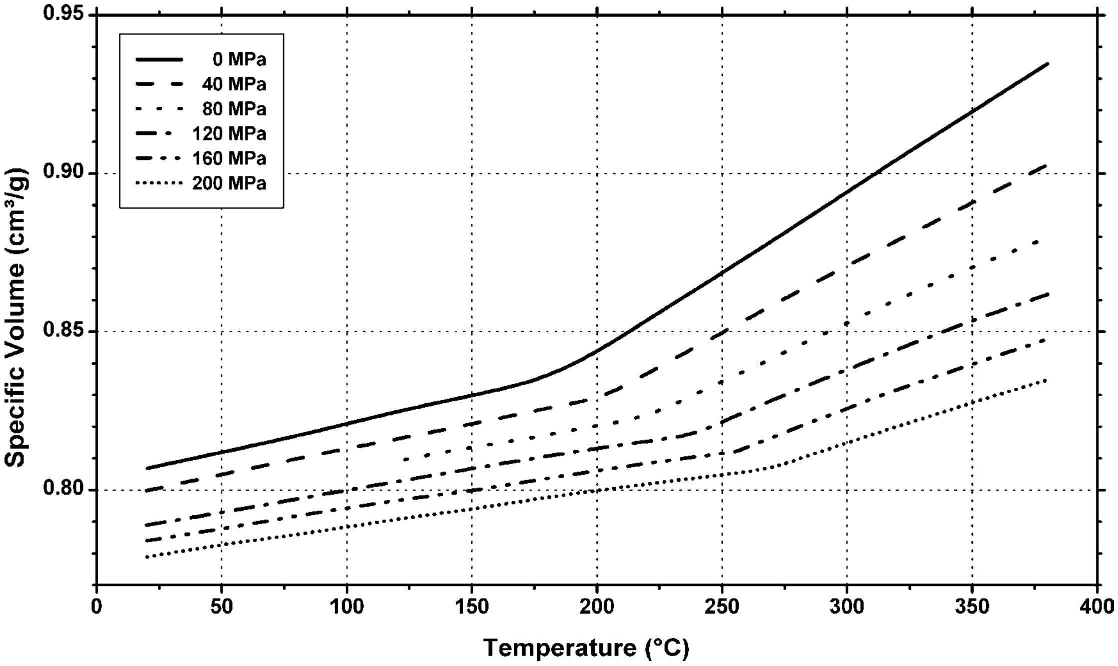


Figure 10.90. Specific volume as a function of temperature and pressure (PVT) of BASF Ultrason® S 2010—unreinforced, medium viscosity PSU resin.

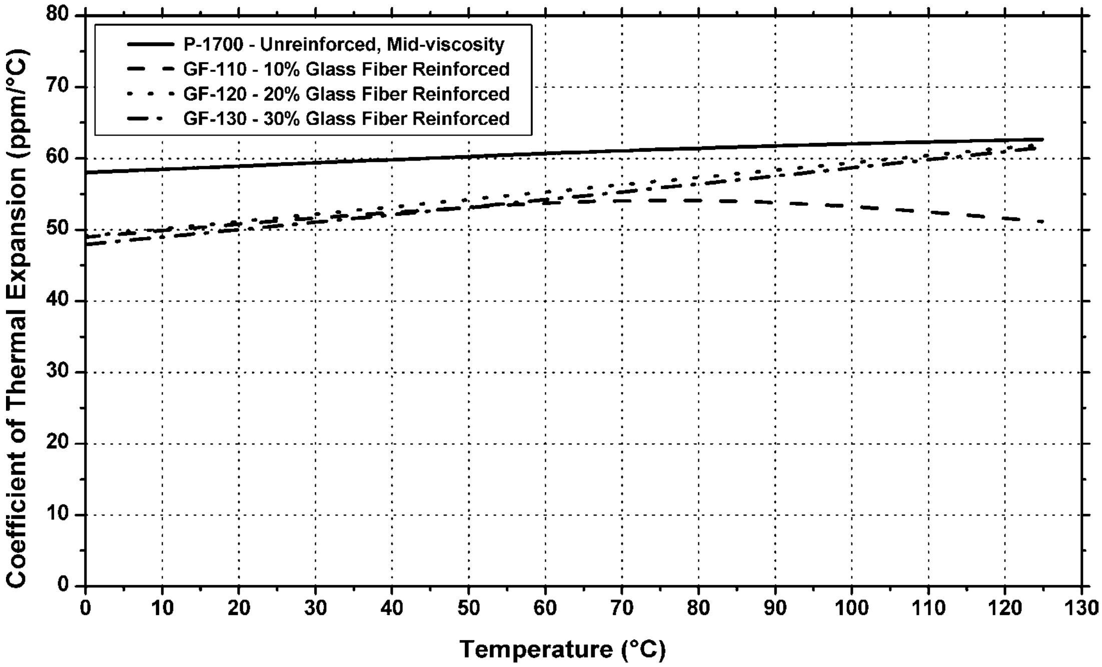


Figure 10.91. Coefficient of thermal expansion (crossflow direction) vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

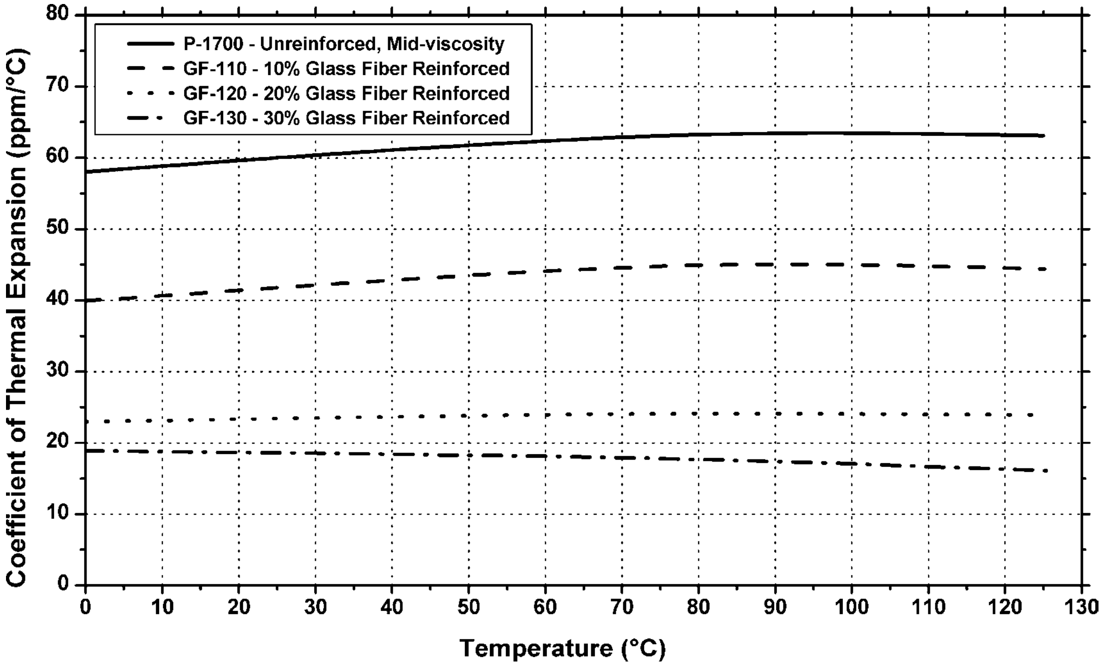


Figure 10.92. Coefficient of thermal expansion (flow direction) vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

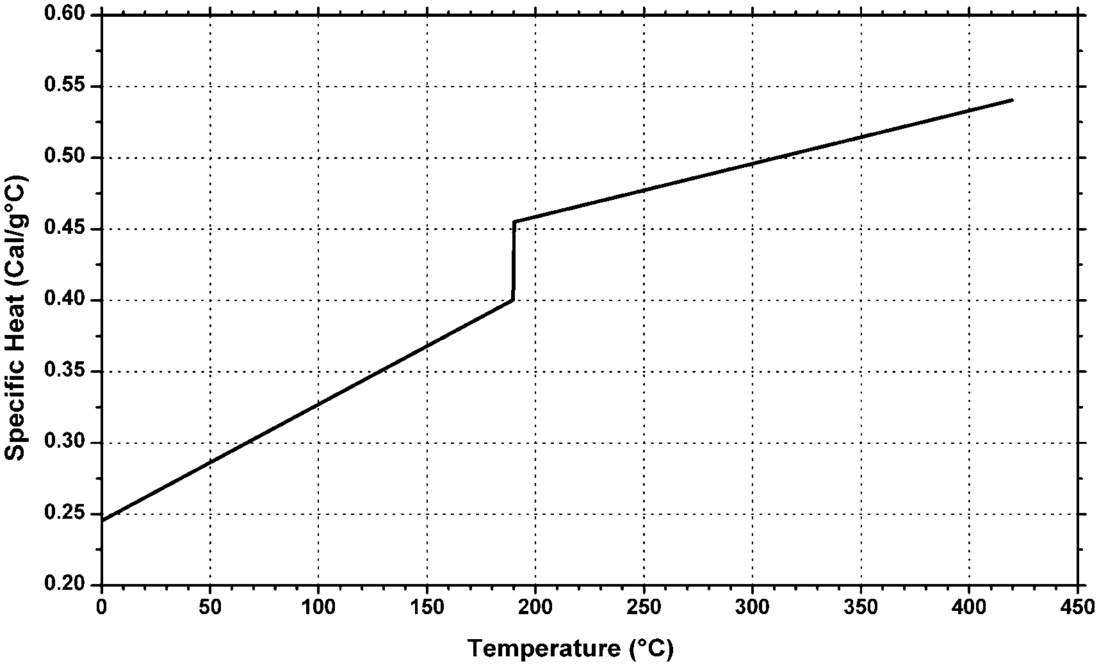


Figure 10.93. Specific heat vs. temperature of Solvay Advanced Polymers Udel® PSU resins.

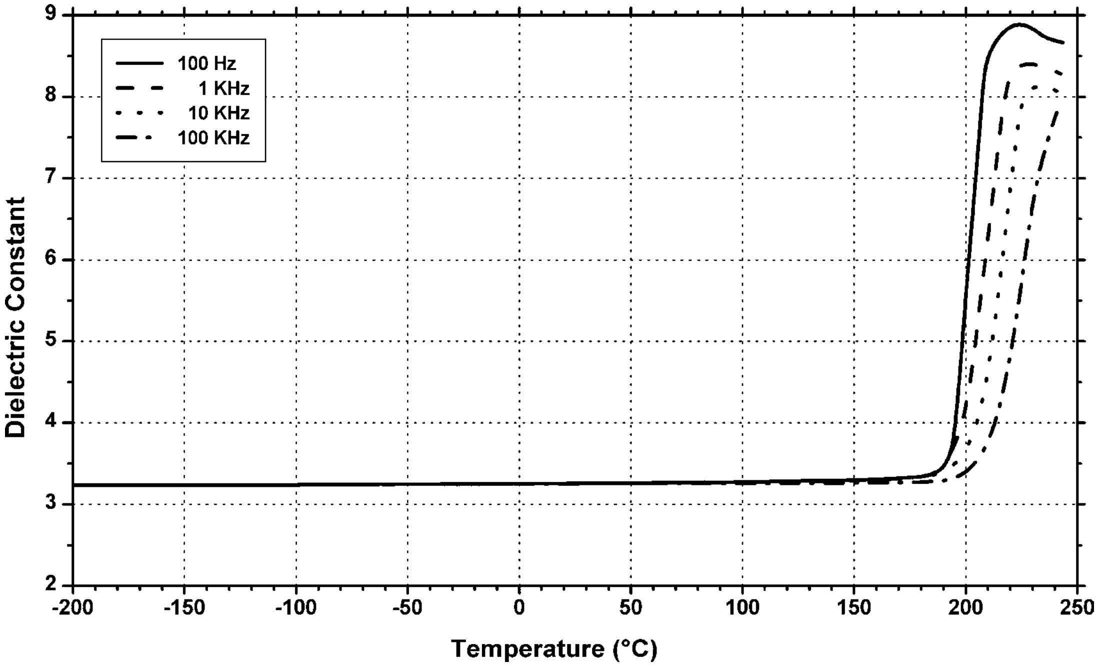


Figure 10.94. Dielectric constant vs. temperature and frequency of Ultrason® S 2010—unreinforced, medium viscosity PSU resin.

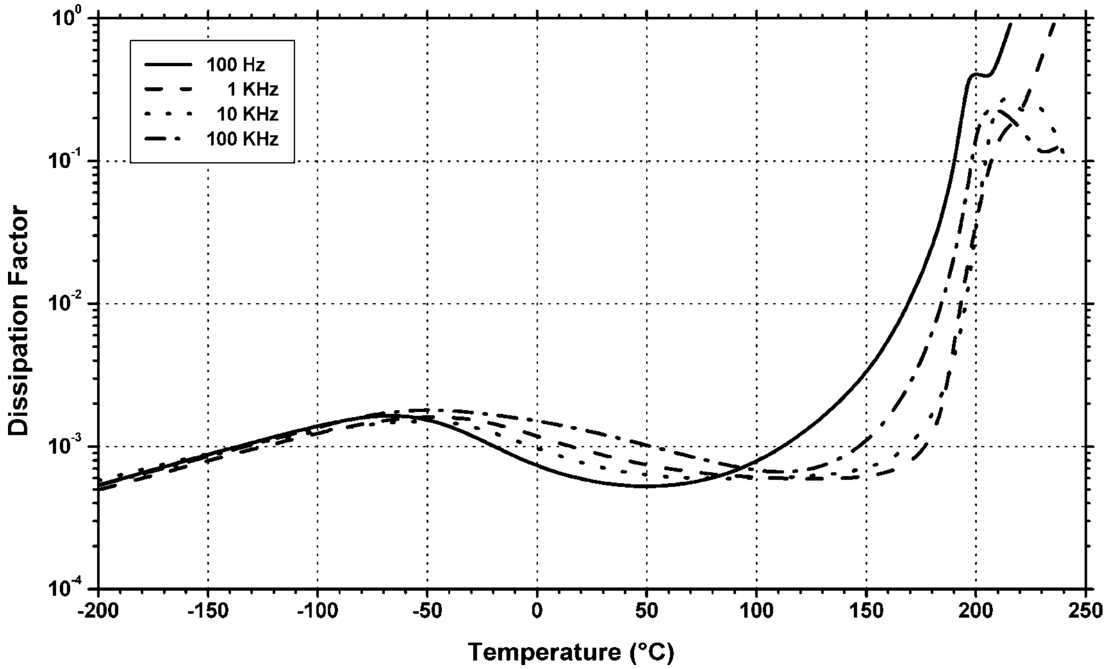


Figure 10.95. Dissipation factor vs. temperature and frequency of Ultrason® S 2010—unreinforced, medium viscosity PSU resin.

11 Tables of Selected ISO 10350 Properties

11.1 Background

This chapter contains data in tabular form. This data is described in the standard ISO 10350-1:1998, which is titled: "Plastics – Acquisition and presentation of comparable single-point data – Part 1: Molding 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 the 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, which is the subject of this book.

The tables in this section follow one or more of the following standards:

- 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 molding test specimens of thermoplastic materials.
- ISO 294-1:1996, Plastics—Injection molding of test specimens of thermoplastic materials—Part 1: General principles and molding of multipurpose and bar test specimens.
- ISO 294-3:1996, Plastics—Injection molding of test specimens of thermoplastic materials—Part 3: Small plates.
- ISO 295:1991, Plastics—Compression molding 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 molding 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 molding of test specimens of thermosetting materials—Part 1: General principles and molding of multipurpose test specimens.
- ISO 10724-2:1998, Plastics—Injection molding 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 meter 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.

The tables are grouped in Sections 11.2–11.10 in the same manner as in the earlier chapters of this book.

These tables contain several notations besides numerical data. These 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 11.1.1. The fillers are listed next, and they are listed or abbreviated as those shown in Table 11.1.2, and are 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 11.1.1 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
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 e-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=terephtalic acid x=different co-monomers t=terephtalic acid
PAEK	Polyaryletherketone
PAI	Polyamideimide
PAIND/INDT	Polyamide NDT/INDT
PAMACM12	Homopolyamide based on 3,3′-dimethyl – 4,4′-diaminodicyclohexylmethane and dodecandioic acid
PAMXD6	Poly-m-xylyleneadipamide

(*Continued*)

Table 11.1.1 Base Polymers Abbreviations (cont'd)

Abbreviation	Description
PAPACM12	Homopolyamide based on bis(p-aminocyclohexyl)methane and dodecandioic acid
PBI	Polybenzimidazole
PBT	Poly(butylene terephthalate)
PC	Polycarbonate
PCCE	Poly(cyclohexylene dimethylene cyclohexanedicarboxylate), glycol and acid comonomer
PCTA	Poly(cyclohexylene dimethylene terephtalate), acid
PCTG	Poly(cyclohexylene dimethylene terephtalate), glycol
PE	Polyethylene
PEEK	Polyetheretherketone
PEI	Polyetherimide
PEN	Polyethylenenaphthalate
PES	Polyethersulfone
PET	Poly(ethylene terephthalate)
PETG	Poly(ethylene terephthalate), glycol
PF	Phenol – formaldehyde
PI	Polyimide
PK	Polyketone
PMMA	Poly(methyl methacrylate)
PMMI	Polymethylmethyacrylimide
POM	Poly(oxymethylene); polyformaldehyde
PP	Polypropylene
PPE	Poly(phenylene ether)
PPS	Poly(phenylene sulfide)
PPSU	Poly(phenylene sulfone)
PS	Polystyrene
PS-SY	Syndiotactic polystyrene
PSU	Polysulfone
PTFE	Polytetrafluoroethylene
PUR	Polyurethane
PVC	Poly(vinyl chloride)
PVDF	Poly(vinylidene fluoride)
SAN	Styrene acrylonitrile
SB	Styrene-butadiene
SMAH	Styrene-maleic anhydride
TEEE	Thermoplastic elastomer, ether-ester
TPA	Polyamide thermoplastic elastomer
TPC	Copolyester thermoplastic elastomer
TPO	Olefinic thermoplastic elastomer
TPS	Styrenic thermoplastic elastomer

(*Continued*)

Table 11.1.1 Base Polymers Abbreviations (cont'd)

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 11.1.2 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

11.2 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 Permitivity @1MHz	Dissipation Factor @1MHz	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	–	–	–	–	–	–

(*Continued*)

11.2 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
Koblend P 477E	PS-I + PE	1200	20	3.1	*	*	N	N	29	11	–	–	–
Polystyrene/DOW													
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	–	–	–	–
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/BASF													
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

(*Continued*)

11.2 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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/Lanxess													
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/BASF													
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
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/DOW													
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/DOW													
Magnum 1040	ABS	1900	42	2.8	*	*	N	N	63	16	–	–	–
Magnum 2620	ABS	2300	48	2.5	*	*	N	80	24	8	–	–	–

(*Continued*)

11.2 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 3325MT	ABS	2080	–	–	–	–	N	N	18	10	–	–	–
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	–	–	–
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

(*Continued*)

11.2 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° (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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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/Lanxess													
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	–
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/BASF													
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	–	–	–

(*Continued*)

11.2 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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/BASF													
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	*
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/Lanxess													
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

(*Continued*)

11.2 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	*

11.3 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	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
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

(*Continued*)

11.3 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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
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/Ticona													
Celcon AM90S	POM	2500	–	–	–	–	–	–	7	–	–	–	–
Celcon AM90S Plus	POM	2500	–	–	–	–	–	–	7	–	–	–	–
Celcon AS270	POM	2750	–	–	–	–	4	–	–	–	–	–	–
Celcon C13031 XAS	POM	2710	–	–	–	–	–	–	7.5	–	–	–	–

(*Continued*)

11.3 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–
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

(*Continued*)

11.3 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–
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

(*Continued*)

11.3 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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*)

11.3 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 Permitivity @1MHz	Dissipation Factor @1MHz	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

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	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
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

(*Continued*)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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/Dow													
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	–

(Continued)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–
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	–

(*Continued*)

11.4 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–	–	–
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	–

(Continued)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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 R	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

(*Continued*)

11.4 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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/Ticona													
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
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

(Continued)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–
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	–	–	–	–	–	–	–

(*Continued*)

11.4 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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*)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	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

(*Continued*)

11.4 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–
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/Ticona													
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 2700 GV1/45	PET, GF45	17000	–	–	140	1.5	44	44	14	14	4.5	165	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	–	–

(*Continued*)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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/DuPont													
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/DuPont													
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	–	–	–

(*Continued*)

11.4 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–
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	–

(*Continued*)

11.4 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 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
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 3005	PC+ABS	2800	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

(*Continued*)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 -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® KU27604	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
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

(*Continued*)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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*)

11.4 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 Permitivity @1MHz	Dissipation Factor @1MHz	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 A35105	PC+ABS	2200	52	5	*	*	N	N	35	2	–	–	–
Pulse A35110	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

*I napplicable property or a property not relevant to this material.
–Missing value, not applicable.
N No break in a Charpy impact test.
P Partial break

11.5 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	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

(Continued)

11.5 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	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
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	–	–	–	–

(Continued)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 (dry)	PA6, MD40	6400	*	*	85	10	120	–	3	–	–	–	5.7
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	–	–	–	–	–	–	*
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	–	–	–	–	–	–	*

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	*

(*Continued*)

11.6 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	*
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	–	–	–	–	–	*

(*Continued*)

11.6 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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/Degussa													
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	*
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	*

(*Continued*)

11.6 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
Vestamid L-R3-EI sw (dry)	PA12	1500	42	9	*	*	N	N	21	9	*	*	1.2

(*Continued*)

11.6 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
PA46/DSM													
Stanyl® 46HF4130 (dry)	PA46, GF30	10000	–	–	210	3	60	60	13	12	–	–	9.5

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	*

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	*
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® TW250F6 (cond.)	PA46, GF30	8000	*	*	125	3.5	60	50	11	9	4.7	800	*
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	–	–	–	*

(*Continued*)

11.6 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	*
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

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	*

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
Zytel® 70G43HSLA BK099 (dry)	PA66, GF43	–	–	–	220	3	–	–	15	*	*	150	7.6
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	–	–	*

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	*
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 (dry)	PA66, Imod	1700	*	*	–	>50	N	N	83	23	3.2	110	–
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	–	–	–	–

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	*
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	*

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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/ASF													
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

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
Zytel® HTN52G45HSL NC010 (cond.)	PA6T/66, GF45	–	–	–	–	–	–	–	–	–	–	500	*
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® HTNFE250020 NC010 (cond.)	PA6T/XT, Imod, MD30	5400	*	*	98	4.2	60	–	3	–	–	–	*
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 A1230 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	–	–	*

(Continued)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–
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

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–
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 (dry)	PAMXD6, GF40	12000	*	*	162	2	66	–	12.2	–	–	–	1.2
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
Reny W38S2 (cond.)	PAMXD6, MD30	15900	*	*	111	0.8	22	–	2.1	–	–	–	–
Polyarylamide/Solvay													
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	–	–	–	–	–	–	–

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 (dry)	PA6 alloy	–			–	–	–	–	–	–	–	–	5.5
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
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	*

(*Continued*)

11.6 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 (dry)	PA6 alloy	–	–	–	–		–	–	17	–	–		2.9
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
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	*	*	*

(*Continued*)

11.6 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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 (dry)	PA66+PA6, CF30	23000	*	*	230	2.5	45	45	10	7	*	*	5
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 (dry)	PA66+PA6	2700	70	4	*	*	N	N	8	6	3	150	9
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	*
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	*

11.7 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
PE/Ticona													
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/Ticona													
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	–	–	–	–
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	–	–	–	–
AltechO 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	–	–	–	–

(*Continued*)

11.7 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–
AltechO 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	–	–	–	–
AltechO 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	–	–	–	–
AltechO 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/Ticona													
Celstran PP-GF30-02	PP, GF30	5800	–	–	92	2.5	–	–	20	–	–	–	–
Celstran PP-GF30-03	PP, GF30	6000	–	–	90	2.3	–	–	17	–	–	–	–
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	–	–	–	–

(*Continued*)

11.7 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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/Degussa													
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

(*Continued*)

11.7 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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® zk50	PMMA, Imod	950	25	5	*	*	N	–	13	–	2.9	400	1.2
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

11.8 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	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
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

(*Continued*)

11.8 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	*
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/Degussa													
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

(*Continued*)

11.8 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	*

11.9 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	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
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

(Continued)

11.9 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–	–	–	–
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	–	–	–	–	–	–	–

(Continued)

11.9 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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
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	–	–	–	–	–	–	–

(*Continued*)

11.9 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–	–	–	–
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

(*Continued*)

11.9 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/m2)	Charpy Impact −30°C (kJ/m2)	Charpy Notched Impact 23°C (kJ/m2)	Charpy Notched Impact −30°C (kJ/m2)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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	–	–	–	–	–	–	–

11.10 Miscellaneous 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
PEEK/Degussa													
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	–

(*Continued*)

11.10 Miscellaneous 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
Radel AG-330	PES, GF30	8630	–	–	130	1.9	–	–	–	–	4.17	0.0094	–
Radel AG-360	PES, GF30	–	–	–	120	3	–	–	–	–	4.2	0.003	–
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/Ticona													
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
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

(*Continued*)

11.10 Miscellaneous 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 Permitivity @1MHz	Dissipation Factor @1MHz	Water Absorption (%)
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*)

11.10 Miscellaneous 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/m²)	Charpy Impact −30°C (kJ/m²)	Charpy Notched Impact 23°C (kJ/m²)	Charpy Notched Impact −30°C (kJ/m²)	Relative Permitivity @1MHz	Dissipation Factor @1MHz	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

12.1 Background

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-fiber-reinforced plastics
- ISO 6603-2: Plastics—Determination of puncture impact behavior 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 behavior (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 (VST) of Plastics
- ISO 306:2004 Plastics—Thermoplastic materials—Determination of Vicat softening temperature (VST)

The tables are grouped in Sections 12.2–12.10 in the same manner as in the earlier chapters 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 11.1.1. The fillers are listed next, and they are listed or abbreviated as those shown in Table 11.1.2, and are 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. These are:

* Inapplicable property or a property not relevant to this material.

– Missing value, not applicable.

12.2 Styrenic 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)
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/DOW								
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/BASF								
Luran® S 757 G	ASA	*	*	96	101	97	0.95	*
Luran® S 757 R	ASA	*	*	97	101	98	0.95	*
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	*

(*Continued*)

12.2 Styrenic 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)
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/LANXESS								
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/BASF								
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/DOW								
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/DOW								
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	–
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	–	–

(Continued)

12.2 Styrenic 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)
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
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/LANXESS								
Lustran ABS® E401	ABS	–	–	94	100	99	0.9	–
Lustran ABS® H604	ABS	–	–	98	102	102	0.8	–

(*Continued*)

12.2 Styrenic 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)
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 20 GF	ABS+PA6, GF20	–	–	98	118	111	–	–
Styrenic Blends/BASF								
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/Lanxess								
Lustran ABS® H801	ABS+PC	–	–	99	106	105	0.8	–
Triax® 1120	ABS+PA6	–	–	68	91	102	1.05	1.15

(*Continued*)

12.2 Styrenic 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)
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

12.3 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 (×10E4/°C)	CLTE Normal (×10E4/°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	–	–	–
Delrin® 510GR NC000	POM, GF10	178	–	164	174	159	–	–
Delrin® 511P NC010	POM	178	–	110	165	160	1.1	1.1

(*Continued*)

12.3 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 (×10E4/°C)	CLTE Normal (×10E4/°C)
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/Ticona								
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
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

(*Continued*)

12.3 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 (×10E4/°C)	CLTE Normal (×10E4/°C)
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	–
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	–

(*Continued*)

12.3 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 (×10E4/°C)	CLTE Normal (×10E4/°C)
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
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

(Continued)

12.3 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 (×10E4/°C)	CLTE Normal (×10E4/°C)
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

12.4 Polyesters

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)
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
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

(*Continued*)

12.4 Polyesters (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)
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
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/Dow								
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	–

(*Continued*)

12.4 Polyesters (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)
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	–

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	–

(*Continued*)

12.4 Polyesters (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)
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	–
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	–

(*Continued*)

12.4 Polyesters (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)
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	–
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/Ticona								
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	–

(*Continued*)

12.4 Polyesters (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)
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	–
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

(*Continued*)

12.4 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 (×10E 4/°C)	CLTE Normal (×10E 4/°C)
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	–
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

(*Continued*)

12.4 Polyesters (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)
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
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
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

(*Continued*)

12.4 Polyesters (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)
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/Ticona								
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
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/DuPont								
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

(Continued)

12.4 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 (×10E 4/°C)	CLTE Normal (×10E 4/°C)
LCP/DuPont								
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
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

(*Continued*)

12.4 Polyesters (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)
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
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	–	–	–

(*Continued*)

12.4 Polyesters (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)
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	–
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	–		–	–

(*Continued*)

12.4 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 (×10E 4/°C)	CLTE Normal (×10E 4/°C)
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	–

12.5 Polyimides

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 (×10E 4/°C)	CLTE Normal (×10E 4/°C)
PEI/GE 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	–	–	–	–
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	–	–	–	–

(*Continued*)

12.5 Polyimides (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 (×10E 4/°C)	CLTE Normal (×10E 4/°C)
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	–

–Missing value, not applicable.

12.6 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	–	–	–	–

(*Continued*)

12.6 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® 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	–

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	–

(*Continued*)

12.6 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)
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/Degussa								
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
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

(*Continued*)

12.6 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)
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
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

(*Continued*)

12.6 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® 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
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

(*Continued*)

12.6 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® 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	–	–	–	
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

(*Continued*)

12.6 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® 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
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
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

(*Continued*)

12.6 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 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
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

(*Continued*)

12.6 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® 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
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

(*Continued*)

12.6 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)
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

12.7 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/Ticona								
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	–	–
ALTECHO 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	–	–
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	–	–
ALTECHO PP-H A 2030/150 GF30 CP	PP, GF30	163	–	140	–	130	–	–

(*Continued*)

12.7 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 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	–	–
ALTECHO PP-H A 2030/250 GF30 CP	PP, GF30	–	–	138	–	135	–	–
ALTECH® PP-H A 2030/252 GF30 UV CP	PP, GF30	–	–	140	–	130	–	–
ALTECHO 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	–
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	–

(*Continued*)

12.7 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 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/Ticona								
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	–
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	–

(*Continued*)

12.7 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)
Acrylic/Degussa								
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	–

12.8 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
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

(*Continued*)

12.8 Thermoplastic Elastomers (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 (×10E 4/°C)	CLTE Normal (×10E 4/°C)
Arnitel® PM650	TPC	221		–	–	–	–	–
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/Degussa								
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

12.9 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	–	–
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	–	–

12.10 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/Degussa								
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	–
PEEK/Solvay								
Ketaspire™ KT-820P	PEEK	340	150	162	–	–	0.43	–
Ketaspire™ KT-820 NT	PEEK	340	150	162	–	–	0.43	–
Ketaspire™ KT-880P	PEEK	343	147	129	–	–	0.5	–
Ketaspire™ KT-880 NT	PEEK	343	147	129	–	–	0.5	–
Ketaspire™ KT-820 GF30	PEEK, GF30	340	150	315	–	–	0.17	–
Ketaspire™ KT-880 GF30	PEEK, GF30	343	147	315	–	–	0.19	–
Ketaspire™ KT-820 CF30	PEEK, CF30	340	150	315	–	–	0.052	–
Ketaspire™ KT-880 CF30	PEEK, CF30	343	147	315	–	–	0.067	–
Avaspire™ AV-650	PEEK Modified	340	158	193	–	–	0.5	–

Avaspire™ AV-651	PEEK Modified	340	158	190	–	–	0.47	–
Avaspire™ AV-650 GF30	PEEK Modified, GF30	340	158	209	–	–	0.19	–
Avaspire™ AV-651 GF30	PEEK Modified, GF30	340	158	213	–	–	0.17	–
Avaspire™ AV-750 GF40	PEEK Modified, GF40	345	150	285	–	–	0.15	–
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	–	–	–	–
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	–	–	–	–

(*Continued*)

12.10 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 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/Ticona								
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	–	–	–	–
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	*

(Continued)

12.10 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)
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
COPE	Thermoplastic Copolyester Elastomers, same as TPE-E
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	Polyether Block Amide Thermoplastic Elastomers
PEEK	Polyetheretherketone
PEI	Polyetherimide
PES	Polyethersulfone
PET	Polyethylene Terephthalate
PFA	Perfluoro Alkoxy
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 Oxide, same as PPE
PPS	Polyphenylene Sulfide
PPSU	Polyphenylene Sulfone
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, same as COPE
TPU	Thermoplastic Polyurethane Elastomers
UHMWPE	Ultra High Molecular Weight Polyethylene
ULDPE	Ultra Low Density Polyethylene
VLDPE	Very Low Density Polyethylene

Appendix 2: Trade Names

Product	Polymer Types	Manufactured by
A. Schulman PE	PE	A. Schulman GmbH
A. Schulman PP	PP	A. Schulman GmbH
ACRYLITE PLUS®	Acrylic (PMMA)	CYRO Industries
ACRYLITE®	Acrylic (PMMA)	CYRO Industries
ACUDEL™	PPSU	Solvay Advanced Polymers, L.L.C.
Akulon®	Nylon 6, Nylon 66	DSM Engineering Plastics
Akulon® Ultraflow™	Nylon 6	DSM Engineering Plastics
Algoflon	PTFE	Solvay Solexis, Inc.
Amilan®	Nylon 6, Nylon 610, Nylon 66, Nylon Copolymer, Nylon	Toray Resin Company
Amilus™	Acetal	Toray Resin Company
AMODEL®	PPA	Solvay Advanced Polymers, L.L.C.
Apec®	PC	Bayer MaterialScience AG
Aqualoy®	Nylon 66, PP	A. Schulman GmbH
Arlon	PEEK	Greene, Tweed & Co.
Arnite®	PBT, PBT+PET, PET	DSM Engineering Plastics
Arnitel®	TEEE	DSM Engineering Plastics
ASHLENE®	ABS, ABS+PC, Acetal, Nylon 11, Nylon 12, Nylon 6, Nylon 610, Nylon 612, Nylon 66, Nylon 66/6, PBT, PC, PC+PBT, PET, PPE, PPE+PS, PPE+PS+Nylon, SAN	Ashley Polymers, Inc.
AURUM®	PI	Mitsui Chemicals America, Inc.
AvaSpire™	PEEK	Solvay Advanced Polymers, L.L.C.
Bayblend®	ABS+PC	Bayer MaterialScience AG
Bayfol®	PC, PC+PBT	Bayer MaterialScience LLC
Bergadur®	PBT	PolyOne Corporation
Bergaform®	Acetal	PolyOne Corporation
Bergamid®	Nylon 6, Nylon 66, Nylon 66/6	PolyOne Corporation
CALIBRE™	PC	Dow Plastics
Capron®	Nylon 6	BASF Corporation
Celanex®	PBT	Ticona
Celazole®	PBI	Quadrant Engineering Plastic Products
Celcon®	Acetal	Ticona
Celstran®	PE, Nylon 6, Nylon 66, PBT, PPS, TPU	Ticona
Centrex®	AES, ASA, ASA+AES, ASA+PC	Lustran Polymers

Product	Polymer Types	Manufactured by
Chisso Polypro	PP	Chisso America Inc.
Clearflex®	PE	Polimeri Europa
ComAlloy®	ABS, Nylon 6, Nylon 66, PP	A. Schulman GmbH
Compel®	PP	Ticona
Comshield®	ABS, Nylon 66, PC, PPS	A. Schulman GmbH
Comtuf®	ABS+PC, Nylon 6, Nylon 612, Nylon 66, PBT, PBT Alloy, PC, PC+PET, PC+Polyester, PC+Styrenic, PET, PP	A. Schulman GmbH
Crastin®	PBT, PBT Alloy	DuPont Engineering Polymers
Cristamid®	Nylon 12	Arkema
CYCOLAC®	ABS	SABIC Innovative Plastics
CYCOLOY®	ABS+PC, PC	SABIC Innovative Plastics
CYREX®	PC+Acrylic	CYRO Industries
CYRO® MCR	Acetal	CYRO Industries
CYROLITE®	Acrylic (PMMA)	CYRO Industries
Cyrolon®	PC	CYRO Industries
CYROVU® HP2	Acrylic	CYRO Industries
Delrin®	Acetal	DuPont Engineering Polymers
Desmopan®	TPU, TPU-Ester/Ether, TPU-Polyester	Bayer MaterialScience AG
Duracap™	PVC	PolyOne Corporation
Durethan®	Nylon 6, Nylon 66, Nylon Copolymer, Nylon	LANXESS AG
Durethan® A	Nylon 66	LANXESS AG
Durethan® B	Nylon 6	LANXESS AG
Durethan® T	Nylon 6	LANXESS AG
Dutral	EPDM, EPM, Polyolefin	Polimeri Europa
Dyflor	PVDF	Degussa AG
DYLARK®	SMA	NOVA Chemicals
Dyneon™ ETFE	ETFE	Dyneon
Dyneon™ PFA	Fluorelastomer	Dyneon
Dyneon™ THV	ETFE, FEP, Fluorelastomer, Fluoropolymer, PFA	Dyneon
Edgetek™	ABS, Acetal, PE, LCP, Nylon 6, Nylon 610, Nylon 612, Nylon 66, PBT, PC, PC+PSU, PEEK, PEI, PES, PPA, PPS, PPSU, PSU	PolyOne Corporation
Edgetek™ XT	PC+PBT	PolyOne Corporation
Edistir®	PS, SBC	Polimeri Europa
Elastollan®	TPU, TPU-Ester/Ether, TPU-Polyester, TPU-Polyether	BASF Corporation
Elvamide®	Nylon	DuPont Engineering Polymers
EMERGE™	ABS, ABS+PC, PC	Dow Plastics
ENDURAN®	PBT, PBT+PC+PET, PBT+PET	SABIC Innovative Plastics

Product	Polymer Types	Manufactured by
ENGAGE™	TPO	Dow Plastics
Enpnite	TP	Chisso America Inc.
EpiSpire™	PSU	Solvay Advanced Polymers, L.L.C.
Fiberloc™	PVC	PolyOne Corporation
GAFONE™	PES	Gharda Chemicals Limited (Solvay)
GAFONE™ B	PSS	Gharda Chemicals Limited (Solvay)
GAFONE™ P	PPSU	Gharda Chemicals Limited (Solvay)
GAFONE™ S	PSU	Gharda Chemicals Limited (Solvay)
GAFONE™ T	PSS	Gharda Chemicals Limited (Solvay)
GATONE™	PEEK	Gharda Chemicals Limited (Solvay)
GELOY®	ASA, ASA+AMSAN, ASA+PC, ASA+PVC, ASA+SAN	SABIC Innovative Plastics
Geon®	PVC Alloy, PVC Elastomer, PVC+NBR	PolyOne Corporation
Geon® HTX™	PVC	PolyOne Corporation
GESAN®	SAN	SABIC Innovative Plastics
Grilamid®	PE, Nylon 12, Nylon 12 Elast, Nylon, PPA, TP	EMS-GRIVORY
Grilon®	Nylon 6, Nylon 6 Elast, Nylon 6/69, Nylon 610, Nylon 612, Nylon 66, Nylon 66/6, Nylon Copolymer, Nylon, TPE	EMS-GRIVORY
Grivory®	Nylon Copolymer, PPA	EMS-GRIVORY
GUR	PE, Polyolefin, UHMWPE	Ticona
Halar	ECTFE	Solvay Solexis, Inc.
Halon	ETFE	Solvay Solexis, Inc.
Hiloy®	ABS, Nylon 6, Nylon 612, Nylon 66, PBT, PBT Alloy, PC, PET, Polyester Alloy, PPE+PS+Nylon, PPS, SAN, SMA	A. Schulman GmbH
Hostacom	Polyolefin, PP, TPO	Basell Polyolefins
Hostaform	Acetal	Ticona
Hostalen	PE, PP	Basell Polyolefins
Hostalen PP	PP	Basell Polyolefins
HSPP	PP	Chisso America Inc.
Hyflon® MFA	PFA	Solvay Solexis, Inc.
Hyflon® PFA	PFA	Solvay Solexis, Inc.
Hylar®	PVDF	Solvay Solexis, Inc.
Hytrel®	TPC-ET	DuPont Engineering Polymers
Impet®	PET	Ticona
Reny	PAMXD6	Mitsubishi Engineering-Plastics Corp
Iupiace®	PPE+PS	Mitsubishi Engineering-Plastics Corp
Iupilon®	ABS+PC, PC, PC Alloy, PC+PBT, PC+PET	Mitsubishi Engineering-Plastics Corp
Iupital®	Acetal	Mitsubishi Engineering-Plastics Corp
IXEF®	PAMXD6	Solvay Advanced Polymers, L.L.C.

Product	Polymer Types	Manufactured by
KADEL®	PEEK	Solvay Advanced Polymers, L.L.C.
Kapton	PI	DuPont Packaging & Industrial Polymers
KetaSpire™	PEEK	Solvay Advanced Polymers, L.L.C.
Koblend®	ABS+PC, PS+PE	Polimeri Europa
Kostil®	SAN	Polimeri Europa
Kynar Flex®	PVDF	Arkema
Kynar®	PVDF	Arkema
LEXAN®	ABS+PC, PC, PC+PBT, PC+Polyester, PC+PPC, PC+SAN, PPC	SABIC Innovative Plastics
Lubricomp®	ABS, Acetal, Nylon 12, Nylon 6, Nylon 610, Nylon 612, Nylon 66, Nylon, PBT, PC, PEEK, PEI, PES, PPA, PPE+PS, PPSU, PVDF, SAN, TPEE	LNP Engineering Plastics Inc. (SABIC Innovative Plastics)
Lubrilon®	Nylon 6, Nylon 612, Nylon 66, Nylon, PBT Alloy, PC, PPS	A. Schulman GmbH
Lubriloy®	Acetal, Nylon 66, PC, PPA, PPE+PS	LNP Engineering Plastics Inc. (SABIC Innovative Plastics)
Lubri-Tech™	Acetal, Nylon 612, Nylon 66, PC, PPS	PolyOne Corporation
LUCITE®	Acrylic (PMMA)	Lucite International Inc.
LUCITE® Acritherm™	Acrylic (PMMA)	Lucite International Inc.
LUCITE® SuperTuf™	Acrylic (PMMA)	Lucite International Inc.
Lupolen	PE	Basell Polyolefins
Lupolex	PE	Basell Polyolefins
Luran®	SAN	BASF Corporation
Luran® S	ASA	BASF Corporation
Lustran® ABS	ABS, ABS+Acrylic	Lustran Polymers
Lustran® Elite	ABS	Lustran Polymers
Lustran® SAN	SAN	Lustran Polymers
Lustran® Ultra	ABS, ABS+PC	Lustran Polymers AG
MAGNUM™	ABS	Dow Plastics
Makroblend®	PC Alloy, PC+PET	Bayer MaterialScience LLC
Makrofol®	PC	Bayer MaterialScience LLC
Makrolon®	PC, PC+PET	Bayer MaterialScience AG
Malen	PE	Basell Polyolefins
MarFlex™ HiD®	PE	Chevron Phillips Chemical Company LLC
MarFlex™ PE	PE+PE	Chevron Phillips Chemical Company LLC
Marlex®	PE	Chevron Phillips Chemical Company LLC
Maxxam™	PP	PolyOne Corporation
Maxxam™ FR	PE, PP	PolyOne Corporation
Metocene	PP	Basell Polyolefins
MINDEL®	PSU, PSU Alloy, PSU+ABS	Solvay Advanced Polymers, L.L.C.
Minlon®	Nylon 6, Nylon 66	DuPont Engineering Polymers
MonTor Nylon	Nylon 6, Nylon 610, Nylon 66, Nylon	Toray Resin Company

Product	Polymer Types	Manufactured by
Moplen	PP, TPU	Basell Polyolefins
Norpex®	PPE	Custom Resins Group
NORYL GTX®	PPE+PS+Nylon, PPS+PPE	SABIC Innovative Plastics
NORYL PPX®	PPE+PS+PP	SABIC Innovative Plastics
NORYL®	PPE, PPE+Polyolefin, PPE+PS, PPE+PS+PPS+PPE, PS	SABIC Innovative Plastics
Novodur®	ABS	Lustran Polymers
Nylatron®	Nylon 66	DSM Engineering Plastics
Nylene®	Nylon 6, Nylon 612, Nylon 66, Nylon 66/6, Nylon,	Custom Resins Group
Oleform	PP	Chisso America Inc.
Olehard	PP	Chisso America Inc.
Orgalloy®	Nylon 6, Nylon 6 Alloy, Nylon 66 Alloy	Arkema
Pebax®	PEBA	Arkema
PELLETHANE™	TPU-Ester/Ether, TPU-Polyester, TPU-Polyether	Dow Plastics
Petra®	PET	BASF Corporation
Plexalloy®	ABS+Acrylic	Rohm GmbH & Co. KG
POCAN®	PBT, PBT+ASA, PBT+PET, PC+PBT, PET	LANXESS AG
Polyaxis®	EVA, PE, Polyolefin, PP	A. Schulman GmbH
Polybatch™	PET, Polyolefin, PP, PS	A. Schulman GmbH
Polyfabs®	ABS	A. Schulman GmbH
Polyflam®	ABS, ABS+PC, PE, PP, PS	A. Schulman GmbH
Polyfort®	PE, Nylon+PP, Polyolefin, PP	A. Schulman GmbH
Polyman®	ABS, ABS+PC, Acrylic (PMMA), ASA, PC, SAN	A. Schulman GmbH
PREVAIL™	ABS+TPU	Dow Plastics
PREVEX®	PPE+PS, SMA	SABIC Innovative Plastics
PULSE™	ABS+PC	Dow Plastics
RADEL®A	PES	Solvay Advanced Polymers, L.L.C.
RADEL®R	PES, PPSU	Solvay Advanced Polymers, L.L.C.
REMEX®	PBT, PC+PBT	SABIC Innovative Plastics
RETAIN	ABS+PC, PC	Dow Plastics
Rilsan®	Nylon 11, Nylon 12	Arkema
Rilsan® Fine Powders	Nylon 11	Arkema
Riteflex®	TEEE	Ticona
Rynite®	PBT, PET	DuPont Engineering Polymers
Ryton®	PPS	Chevron Phillips Chemical Company LLC
Schulablend®	ABS+Nylon, ABS+PC, Nylon 6, Nylon+PP	A. Schulman GmbH
Schuladur®	PBT, PBT+PET, PET	A. Schulman GmbH
Schulaform®	Acetal	A. Schulman GmbH
Schulamid®	Nylon 6, Nylon 66, Nylon 66/6, Nylon	A. Schulman GmbH

Product	Polymer Types	Manufactured by
Schulatec®	PPS, SPS	A. Schulman GmbH
Sinkral®	ABS	Polimeri Europa
Siveras™	LCP	Toray Resin Company
SOLEF®	PVDF	Solvay Solexis, Inc.
Stanyl®	Nylon 46	DSM Engineering Plastics
Stapron® E	PC+PET	DSM Engineering Plastics
Stat-Kon®	ABS, ABS+PC, Acetal, Nylon 12, Nylon 6, Nylon 610, Nylon 66, PBT, PC, PEEK, PEI, PES, Polyolefin, PPA, PPE+PS, PPS, PUR	LNP Engineering Plastics Inc. (SABIC Innovative Plastics)
Stat-Loy®	ABS, ABS+PC, Acetal, Acrylic (PMMA), Nylon 6, PBT, PP	LNP Engineering Plastics Inc. (SABIC Innovative Plastics)
STYRON A-TECH™	PS	Dow Plastics
STYRON™	PS	Dow Plastics
SUMIKAEXCEL® PES	PES	Sumitomo Chemical America, Inc.
SUMIKASUPER® LCP	LCP	Sumitomo Chemical America, Inc.
Teflon® AF	Fluoropolymer	DuPont Fluoropolymers
Teflon® C PFA	PFA	DuPont Fluoropolymers
Teflon® FEP	FEP	DuPont Fluoropolymers
Teflon® PFA	PFA	DuPont Fluoropolymers
Teflon® PTFE	PTFE	DuPont Fluoropolymers
Tefzel	ETFE	DuPont Fluoropolymers
Terblend® N	Nylon 6+ABS	BASF Corporation
Terluran®	ABS	BASF Corporation
Texin®	ABS+TPU, PC+TPU, TPU, TPU-Ester/Ether, TPU-Polyester, TPU-Polyether	Bayer MaterialScience LLC
Thermocomp®	ABS, ABS+PC, Acetal, ETFE, Nylon 11, Nylon 12, Nylon 6, Nylon 610, Nylon 612, Nylon 66, PBT, PC, PC+PBT, PEEK, PEI, PES, Polyester, TP, PPA, PPE+PS, PPS, PPSU, PSU, PUR, PVDF, SAN, TP, TPEE	LNP Engineering Plastics Inc. (SABIC Innovative Plastics)
Thermotuf®	Nylon 6, Nylon 610, Nylon 612, Nylon 66, Nylon, PBT, PC, Polyester, TP, PPS	LNP Engineering Plastics Inc. (SABIC Innovative Plastics)
Thermx®	PCT	DuPont Engineering Polymers
Thermylene®	PP	Asahi Kasei Plastics North America Inc.
Toraycon®	PBT	Toray Resin Company
Torelina®	PPS	Toray Resin Company
TORLON®	PAI	Solvay Advanced Polymers, L.L.C.
Toyolac®	ABS, ABS+Nylon, ABS+PBT, ABS+PC	Toray Resin Company
Toyolacparel	ABS	Toray Resin Company
Triax®	ABS, ABS+Nylon, Nylon 6+ABS	Lustran Polymers
Trogamid	Nylon 6/3T, Nylon	Degussa AG
TYRIL™	SAN	Dow Plastics

Product	Polymer Types	Manufactured by
UDEL®	PSU	Solvay Advanced Polymers, L.L.C.
ULTEM®	PEI, PEI+PCE	SABIC Innovative Plastics
Ultradur®	PBT, PBT+ASA, PBT+PET	BASF Corporation
Ultraform®	Acetal	BASF Corporation
Ultramid®	Nylon 6, Nylon 66	BASF Corporation
Ultramid® A	Nylon 66	BASF Corporation
Ultramid® B	Nylon 6	BASF Corporation
Ultramid® C	Nylon 66/6	BASF Corporation
Ultrason® E	PES	BASF Corporation
Ultrason® S	PSU	BASF Corporation
VALOX®	ABS+PBT, ABS+PBT+PET, PBT, PBT+PC+PET, PBT+PET, PC+PBT, PET	SABIC Innovative Plastics
Vandar®	PBT, TEEE	Ticona
Vespel®	PI	DuPont Engineering Polymers
Vestamid®	Nylon 12, Nylon 12 Elast, Nylon 612, PEBA	Degussa AG
Voloy®	Nylon 6, Nylon 66, Nylon 66 Alloy, PBT, PBT Alloy, PET, PP	A. Schulman GmbH
Voltalef®	PTFE	Arkema
Xantar®	PC	DSM Engineering Plastics
Xantar® C	ABS+PC	DSM Engineering Plastics
XENOY®	ABS+PBT+PC, PBT+PET, PC+PBT, PC+PET, PC+Polyester	SABIC Innovative Plastics
XT® Polymer	Acrylic (PMMA)	CYRO Industries
XYDAR®	LCP	Solvay Advanced Polymers, L.L.C.
XYLEX®	PC+Polyester	SABIC Innovative Plastics
Yparex®	PE	DSM Engineering Plastics
Zenite®	LCP	DuPont Engineering Polymers
Zytel®	Nylon 6, Nylon 612, Nylon 66, Nylon 66/6	DuPont Engineering Polymers
Zytel® HTN	PPA	DuPont Engineering Polymers

Appendix 3: Unit Conversion Tables

The following tables show conversion factors to convert most of the units used in this book from SI units (Système International) to various English units. 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^{-6}
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^{-5}
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^{-7}
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^{-7}
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

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