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Dynamic Mechanical Analysis

for Plastics Engineering

Michael P. Sepe

Plastics Design Library

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Foreword & Acknowledgements

My first acquaintance with Mike Sepe in 1990 was through Karl Kirland, a senior editor at *Plastics World* magazine. *Plastics World* has now evolved into *Molding Systems* magazine and Karl has moved on to a senior editorial position at *Injection Molding* magazine. Mike remains true to his convictions and continues to educate users of plastics about the need for information that better reflects the real-world service life of a material. Dynamic Mechanical Analysis (DMA) testing provides such information.

Dynamic Mechanical Analysis for Plastics Engineering provides DMA data from Mike Sepe's own tests conducted in the materials lab at Dickten & Masch Manufacturing Co. All plastic materials have been tested using the same methods and therefore comparison of the results is very meaningful. In addition to providing performance data on a broad spectrum of plastics, Mike provides an excellent discussion of how to use DMA data and what it means, practically speaking, to the plastics engineer. After reading his manuscript, the versatility and necessity of using DMA data as a powerful engineering tool becomes apparent and clear.

Referring to Mike Sepe in a May 1990 article Karl Kirkland states, “the technical director of precision molders Dickten & Masch Manufacturing Co. went so far as to say ‘We're hanging ourselves with those property sheets.’ He joins a growing number of people who are challenging the validity of single-point, short-term materials property data to evaluate performance and to set the upper limits of a material in its end-use.”

As Plastics Design Library (PDL) continues its mission of providing information serving the practical needs of the technologist, we are very pleased to provide this new volume to the PDL Handbook Series. In addition to providing data which reflects the real world service life of materials, we are providing data which is truly comparable and not biased since all test results come from the same independent test laboratrory. In order to improve the ability to analyze the data, PDL offers a companion CD-ROM to the book which gives users the ability to compare curves and data according to their needs. The CD-ROM is an excellent product and I highly recommend it.

Some Notes about the Book and CD-ROM

In order to make the information most useful and accessible to users, PDL editors made a choice to present the DMA curves in full color. The use of color necessitated some compromises including the binding method used for the book. Special credit for the layout, typesetting and printing goes to Robert Hall and his staff at Paragon Communications.

The CD-ROM version of Dynamic Mechanical Analysis for Plastics Engineering provides an interactive tool for rapidly comparing the independent test data generated for this reference. Users can electronically access and compare data for different materials on one table or graph and print or export information to word processors, spreadsheets or other analysis tools.

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1 Introduction

Dynamic mechanical analysis (DMA) has emerged as one of the most powerful tools available for the study of the behavior of plastic materials. Simply stated, DMA measures the viscoelastic properties of materials. Since all polymers are viscoelastic in nature, this analytical method is perfectly suited to the task of evaluating the complex array of phenomena that polymeric materials present to us. Unfortunately, viscoelastic theory has been developed by the discipline of polymer physics and has been articulated in highly mathematical terms. While this work has been essential in promoting the understanding of the fundamental aspects of polymer structure, it has kept the tool of DMA confined to research and development circles. The early instrumentation was difficult to calibrate and use, and the meaning of the results was not always clear to professionals who worked outside the theoretical realm.

Over the last decade, DMA instrumentation has become more user friendly. With proper care, useful experiments can easily be run on a wide variety of materials and product shapes. At the same time, plastic materials are being used more than ever before in high-performance markets typically reserved for metals and ceramics. This has made it critical that designers and engineers understand the subtle aspects of polymer behavior. These subtle aspects are more likely to appear with extended service life and they relate directly to the phenomenon of viscoelasticity. Failure modes such as fatigue, creep rupture, excessive deformation, and environmental aging are all related to the viscoelastic properties of a plastic material. Fortunately, viscoelastic behavior can be readily measured and interpreted using dynamic mechanical analysis. The objective of this work is to describe the principles of dynamic mechanical analysis and present the results with an emphasis on the practical. Professionals working in the disciplines of design and engineering will discover a new tool for understanding polymer behavior. This understanding will improve the material selection process and assist in optimizing the cost/performance balance in both new and existing products made from plastic materials.

Test Method for DMA Data

All tests run to generate the DMA data were performed according to ASTM D4065-94 using a fixed frequency of oscillation of 1 Hz and a sample heating rate of 2°C/minute. Use of this heating rate allows the data to be directly related to deflection temperature under load (DTUL) data generated by ASTM D648 or ISO 75. All tests were initiated at -60°C and run through the T_g for amorphous materials and up to the melting point for semi-crystalline materials. The mode of stress is flexure and the fixture configuration is a single cantilever beam.

The complexity of polymer behavior relates ultimately to viscoelasticity. Most classical materials exhibit either elastic or viscous behavior in response to an applied stress. Elastic responses are typical in solid materials. When a stress is applied to an elastic system it deforms proportionally by a quantity identified as the strain. We can quantitatively express the relationship between the applied stress and the resulting strain as:

$$\tau = G \bullet \gamma$$

where t is the stress in shear, γ is the strain, and G is the shear modulus. The same equation can be written for other modes of stress such as tension. The response of an elastic system to applied stress is instantaneous and completely recoverable. We say that the system stores the energy and can return it to the system completely when the stress is removed. The above equation is familiar to us as Hooke's Law and a spring is used as the model for materials governed by this law. Figure 1 illustrates the behavior of an elastic system in time.

Viscous behavior is a characteristic of fluids, materials where the bond energies necessary for long-range translational order have been overcome. In these systems an applied stress results in a strain that increases proportionally with time until the stress is removed. The strain is not recoverable; when the stress is removed the deformation is completely retained. We say that the energy has been lost to the system. The model of a dashpot is frequently used as an analogy. Figure 2 shows this behavior graphically. Newton first defined the mathematical relationship between the applied stress and the resulting strain rate in a fluid and termed the resulting ratio the viscosity,

$$\tau = \eta \bullet \dot{\gamma}$$

where t is the stress, $\dot{\gamma}$ is the strain rate, and η is the viscosity.

The large size and conformational variety of polymer molecules prevent these materials from forming the fully ordered systems that we normally associate with solid materials. By the same token, in the fluid state, the high degree of chain entanglement that is possible in these systems produces behavior that departs significantly from that of classical Newtonian fluids. In both the solid and the fluid state, these materials exhibit a combination of elastic and viscous responses when placed under stress. In a solid plastic beam we can perform classical measurements of stress versus strain that allow us to calculatea modulus. However, if we maintain a constant applied load, we find that the resulting strain is not constant; it continues to increase as a function of time. In engineering terms we refer to this as creep or cold flow and it is actually a manifestation of viscous flow in the apparently solid polymer. A counterpart to this behavior

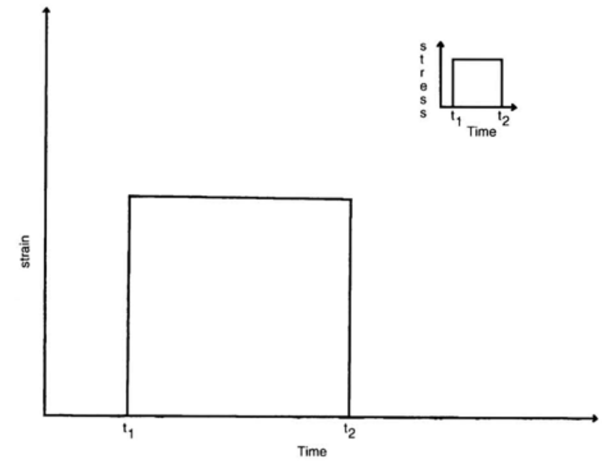


Figure 1. Relationship of stress and strain with time for a pure elastic system.

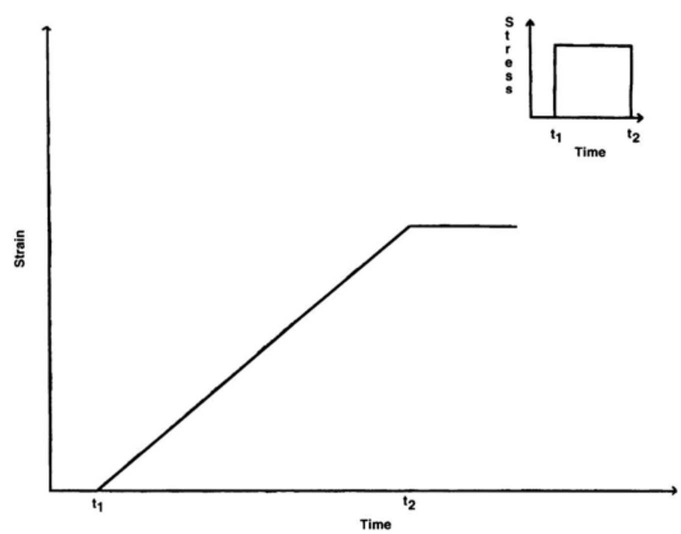


Figure 2. Relationship of stress and strain with time for a purely viscous system.

is known as stress relaxation. Here the strain is held as the constant and the stress required to maintain that strain is measured as a function of time. In a viscoelastic system the stress decreases with time. Since modulus is defined as the ratio of stress to strain, it can be seen that the modulus calculation in viscoelastic systems must incorporate a time function and cannot be considered as an immutable property independent of the period over which the measurement is made. At a structural level, the polymer chains are slowly rearranging in response to the applied stress. Knowledge of the rate at which this occurs is critical to an accurate determination of a material's fitness-for-use in a particular application.

Similarly, we can perform viscosity determinations on a polymer in the fluid state by applying a known stress and measuring the resulting strain rate or rate of flow. In a Newtonian fluid the viscosity is a constant that is independent of the strain rate. However, if we measure the viscosity of a polymer fluid at various strain rates, we find that it changes, becoming lower at higher strain rates. At a structural level this effect is produced when the long, entangled polymer chains become oriented in the direction of flow and the entire system moves with reduced resistance. When the strain is suddenly removed the long chains re-entangle and the fluid exhibits aspects of elastic recovery.

To further complicate the picture, the balance between the elastic and viscous response changes for a given material as a function of temperature. In the solid state this balance is reflected in terms of load-bearing properties — time-dependent behavior such as creep and stress relaxation, as well as impact properties. In the fluid state, viscoelasticity provides information on molecular weight, molecular weight distribution, thermal stability, and crosslinking. The equation relating stress and strain in a viscoelastic system introduces the aspect of time dependency

$$t = G(t) \bullet \gamma$$

where G(t) is the stress relaxation modulus. The material initially responds in an elastic manner, then as a viscous fluid. When the stress is removed, the elastic portion recovers over an extended period of time. Figure 3 provides a generalized illustration of this compound behavior.

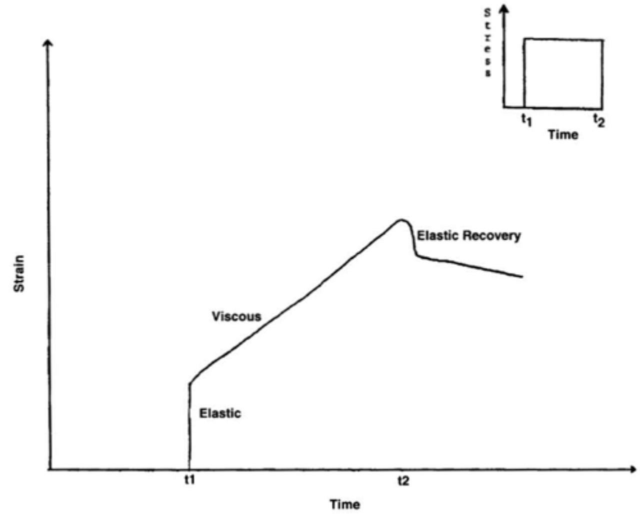


Figure 3. Relationship of stress and strain with time for a viscoelastic system.

Determining the proportion of the elastic and viscous components in a polymer, and the factors that cause that balance to change, is crucial to understanding how a material will perform in a given application environment. It can also provide valuable information regarding structure and composition. DMA accomplishes this resolution. While it is possible to perform dynamic mechanical measurements on solids and fluids, the focus of this work is improved material selection for end-use applications. Therefore, this work will concentrate on solid-state properties.

To this point, we have discussed the time-dependent aspects of material behavior. While the best

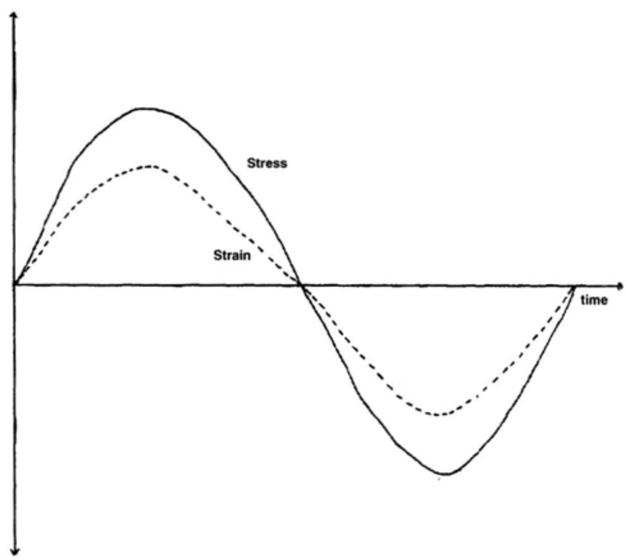


Figure 4. The behavior of an elastic system under oscillatory stress. Stress and strain and in phase.

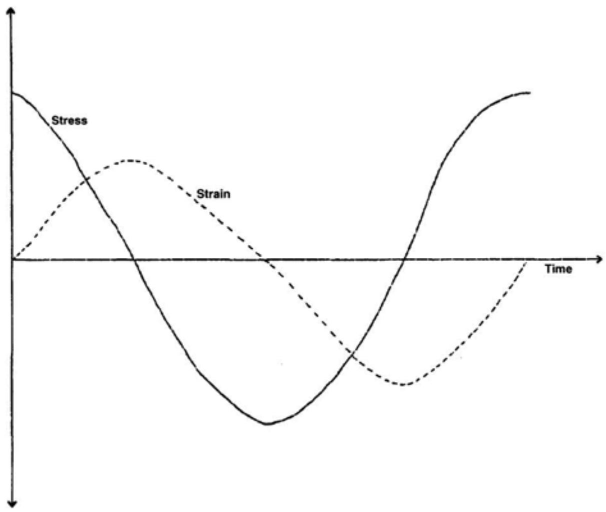


Figure 5. The behavior of a viscous system under oscillatory stress. Stress and strain are 90° out of phase.

dynamic mechanical analyzers can be operated in a controlled stress or controlled strain mode, the primary value of the method is in the dynamic experiment. In this mode of operation, the DMA instrument applies an oscillatory stress with a controlled frequency. Dynamic modulus values using this method are a function of frequency rather than time. The stress function is sinusoidal. In a perfectly elastic system the applied stress and the resulting strain will be in phase as shown in Figure 4. For an ideal fluid the stress will lead the strain by 90° ($\pi/2$ radians) as illustrated in Figure 5. A viscoelastic material will give some hybrid of these two responses. The stress and strain will be out of phase by some quantity known as the phase angle and commonly referred to as delta (δ). A small phase angle indicates high elasticity while a large phase angle is associated with highly viscous properties. The complex response of the material is resolved into the elastic or storage modulus (G') and the viscous or loss modulus (G") if the deformation is in the shear mode. If the deformation is in the tensile or flexural mode, then E' and E" are used. Table 1 provides a summary of the key terms.

Table 1
Key Viscoelastic Terms

Complex Modulus	G^* or $E^* = \sigma^*/\gamma$
Elastic Modulus	G' or E' $= \sigma'/\gamma = (\sigma^*/\gamma)\cos$
Viscous Modulus	G" or E" $= \sigma''/\gamma = (\sigma^*/\gamma)\sin$
Complex Viscosity	$n^* = G^*/\gamma$
Loss Tangent	$\tan\delta$ = G"/G' or E"/E'

When tensile, flexural, or shear modulus are measured by traditional methods, it is the complex modulus that is the result of the test. It is defined as the slope of the stress-strain curve in the linear region. The DMA resolves this complex modulus into the storage and loss component. The smaller the phase angle is, the closer the elastic modulus is to the complex modulus. It is convenient to think of the elastic and viscous component in the vector terms illustrated in Figure 6a-c. Figure 6a shows the relationship between the stress and strain vectors. Figure 6b shows the stress vectors resolved into their storage and loss component. The storage component is in phase with the strain. Figure 6c expresses the vectors in terms of the modulus. The transposed loss modulus shows that the complex modulus can be thought of as the hypotenuse of a right triangle and the storage and loss components as the two shorter legs that are perpendicular to each other. The tangent of the phase angle, often referred to as tan delta, can be used to deduce the shape of the right triangle. In the solid state, tan delta for a polymeric material rarely rises above 0.1 until the material approaches the softening temperature. A tan delta of 0.1 is analogous to a right triangle with a long side of 10 units and a short side of 1 unit. A triangle of these dimensions will have a hypotenuse 10.05 units long. This quantifies the relationship between the complex modulus measured by a classical stress-strain test and the elastic modulus measured by DMA. For the vast majority of the conditions at which DMA measurements are made on solid polymers, the complex modulus and the elastic modulus can be considered equivalent. Table 2 shows the relationship between tan delta and the degree of variation between the elastic and complex modulus.

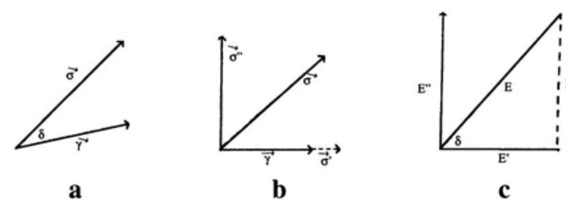


Figure 6. (a) Relationship of the stress and strain vectors in a dynamic experiment. **(b)** Stress vectors resolved into the loss and storage components. **(c)** Corresponding modulus vectors with loss vector transposed to form a right triangle.

A brief note about the frequency of the measurement is in order here. Many DMA instruments provide the experimenter with the option of operating the device in either the fixed frequency or the resonant frequency mode. Many older instruments offer only the resonant frequency option. In the resonant frequency method, the instrument finds the natural frequency of the material and this frequency varies with the rigidity of the sample. As the sample is heated and the modulus changes, the change is measured in terms of a reduction in the frequency, which is then converted to modulus values. In rigid systems the resonant frequency will typically fall between 15-30 Hz. While this method can be useful for making rapid and approximate determinations of transition temperatures, it is primarily designed for handling very stiff samples that are rarely encountered when working with polymer systems. In addition, there are two disadvantages to operat-ing in the resonant frequency mode. First, subtle transitions that may appear in a multi-phase system such as a polymer blend do not resolve well at high frequencies. Second, since viscoelastic properties are time dependent and therefore frequency dependent, a method that allows the frequency to change during the scan will be inherently less accurate than a method that controls the frequency as a constant. For this reason, the ASTM method written for dynamic mechanical analysis specifies a frequency of 1 Hz. This standard is adhered to in the data contained in the appendix. This ensures that results from different experimenters will not contain discrepancies based on the frequency-dependent behavior of the materials. In section 4.3 advanced methods using multiple fixed frequencies will be discussed.

Table 2
Effect of Tan Delta on Variance Between Complex And Storage Modulus

Tan Delta	Variance (E*/E')
0.00	1.00000
0.01	1.00005
0.03	1.00045
0.05	1.00125
0.10	1.00499
0.20	1.01980
0.30	1.04403
0.50	1.11803
0.75	1.25000
1.00	1.41421

2.1 Data Presentation

The information from DMA tests can be configured in a variety of ways depending upon the design of the test. For solid materials, the most common experiment is a temperature sweep. A frequency and amplitude of oscillatory stress are selected and maintained as constants throughout the experiment. A heating routine is selected and the material temperature is raised from the desired starting temperature to an endpoint. Two types of heating routines are sanctioned by ASTM D-4065, the method governing dynamic mechanical analysis.

The first is a stairstep method where the sample temperature is raised in 5°C increments and allowed to equilibrate at each temperature for 3.5 minutes before performing the measurements. Since the sample thermocouple is typically 1 mm away from the face of the material, and the sample will have some thickness that may vary from 0.5-5 mm, this method is designed to overcome the problems associated with thermal lag between the measured temperature and the actual bulk temperature of the material. However, the method has the disadvantage of only providing a data point every 5ºC. This may be adequate for instances where the objective of the test is an approximate storage modulus value, since interpolation is possible for applications where the temperature of interest falls between measurement points. However, for identifying exact transition temperatures, which appear as peaks in the loss modulus and tan delta curves, this method is less satisfactory than a continuous heating method.

Continuous heating routines using heating rates of 1-2ºC are also permitted in the ASTM method. These typically provide 5-20 distinct data points per degree and allow for the study of materials where the temperature and the peak height of important transitions are critical. The heating rate of 2ºC/minute is particularly useful since it is also the heating rate used in determining the heat deflection temperature (HDT) of plastic materials by ASTM D-648 or ISO 75. Most users of DMA data for engineering purposes come from a tradition of short-term property charts where the only attempt to address elevated temperature performance comes in the form of an HDT value. We will discuss the relationship between HDT values and DMA data in section 3.3. In order to allow the user to readily relate HDT values to DMA data, the data provided in the appendix is generated using a heating rate of 2°C/minute. The stairstep method is useful for more advanced tests that will be discussed in section 4. These involve evaluations at multiple frequencies or stress relaxation and creep tests where multiple measurements or long-time measurements must be made at a constant temperature.

The most common graphic presentation involves plotting the elastic or storage modulus (E' or G'), the viscous or loss modulus (E" or G"), and tan delta as a function of temperature. The deformation mode for the data provided in the appendix is flexure and therefore E' and E" are used. From an engineering standpoint, these are more useful values for evaluating solid-state performance while shear results are more significant for flexible systems such as uncured crosslinkable materials, adhesives, pastes, and melts. In addition, experience has shown that tensile and flexural modulus values are nearly equivalent for a homogeneous system. It is therefore possible to approximate tensile modulus values from the flexural modulus data provided. Conventionally, the y-axis data is plotted on a logarithmic scale. This can be particularly useful for amorphous polymers where the glass transition may reduce the storage modulus of the material by 2-3 orders of magnitude and obscure changes related to molecular weight that may occur above the glass transition. However, in semi-crystalline systems the changes in stor-age modulus are typically less than an order of magnitude until the material approaches the melting point. If the softening of the material is included in the plot, it can obscure the effects of the glass transition. In addition, logarithmic scales tend to obscure differences between materials in a comparative plot. For loss properties, logarithmic scales tend to diminish the visual impact of transitions. For data that focuses on solid-state performance, clarity is enhanced by utilizing a linear scale for all y-axis data, and this convention has been chosen for the graphs in the appendix.

2.2 Structural Characteristics of Polymers

In order to make the best use of DMA data, it is useful to relate representative plots to the structural characteristics of different polymer families. Since this initial version of the database is devoted to rigid and semi-rigid thermoplastics, this discussion will focus on the two most important polymer families within this category — amorphous and semi-crystalline materials. Examples of a thermoplastic elastomer and a rigid crosslinked system will be reviewed for contrast.

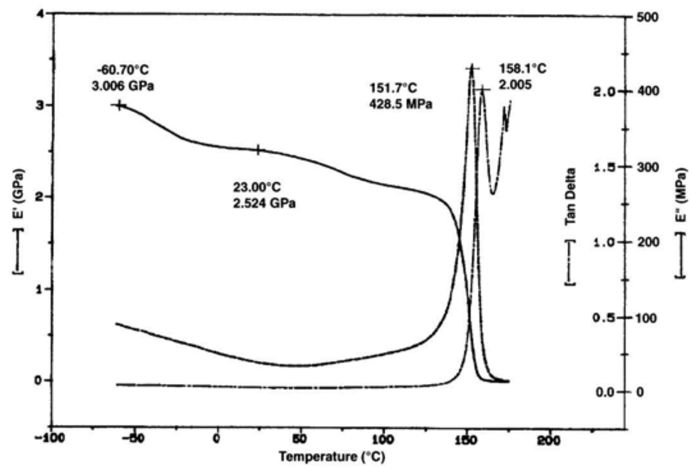


Figure 7a. Storage and loss properties for an unfilled polycarbonate.

Figure 7a shows a typical DMA result for polycarbonate, an amorphous thermoplastic. The full-scale plot begins at -60°C and ends at 175°C. It can be seen that there is little change in the storage modulus between the initial temperature and 140°C. However, between 140-160°C the storage modulus drops by over two orders of magnitude and the material has lost its usefulness as a structural material. This abrupt change in physical properties is associated with the onset of short-range molecular motions known as the glass transition. The amorphous structure in a polymer is often likened to that of glass because there is structural rigidity without the presence of a well-organized intermolecular structure. In an amorphous polymer the glass transition can be thought of as a softening temperature.

Figure 7b expands the graph to show the glass transition in more detail. We can see that the loss modulus rises to a maximum as the storage modulus is in its most rapid rate of descent. The peak of the loss modulus is conventionally identified as the glass transition temperature (T_g), even though the DMA plot clearly shows that the transition is a process that spans a temperature range. In most amorphous polymers the temperature range is relatively narrow, 25-40°C for materials that do not contain polymeric modifiers such as elastomeric toughening agents. The tan delta curve follows the

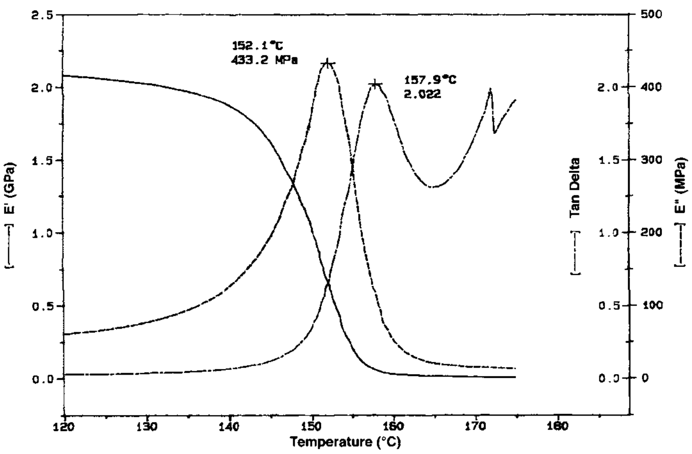


Figure 7b. Expanded plot of storage and loss properties for polycarbonate at T_g.

loss modulus curve closely and provides a running tally on the ratio of the elastic and viscous phases in the polymer. At low temperatures leading up to the glass transition, tan delta is well below 0.1. The rapid rise in the tan delta curve coincides with the rapid decline in the storage modulus. Above 150°C the tan delta curve rises rapidly and reaches a peak above 2.0. In this region the contribution of the loss modulus to the complex modulus is equal to or greater than that of the storage modulus. Once the glass transition is complete, the loss modulus drops back to a level close to the pre-transition values. However, because of the drastic reduction in elastic properties, the tan delta values do not decline significantly. The low storage modulus indicates that the material is easily deformed by an applied load. More significantly, the high tan delta values mean that once the deformation is induced, the material will not recover its original shape. It is considered to be soft and pliable. The pattern observed here for polycarbonate is typical of all amorphous materials. The key difference lies in the glass transition temperature (T_g) and the storage modulus below T_g.

Figure 8a shows a DMA plot for nylon 6, a semi-crystalline polymer. Semi-crystalline polymers are so named because the large extended chain molecules are not capable of achieving the perfect lattice order that is typical of the crystalline structure in lower molecular weight materials. We speak, therefore, in terms of degree of crystallinity. If the degree of crystallinity reaches 30-35% in a polymer matrix, then there is sufficient order to produce a material with an identifiable crystalline melting point. These materials are actually a mixture of amorphous and crystalline regions. Consequently, they exhibit both a melting point and a glass transition. The glass transition can be readily identified in the DMA plot. The storage modulus declines rapidly and the loss modulus and the tan delta curve rise to maximum values. However, because of the presence of a crystalline matrix, the material does not soften above the glass transition. The new mobility of the amorphous regions causes a reduction in the storage modulus, but the material exhibits useful solid-state properties until the material approaches the melting point, some 150°C above the glass transition. The diminished effect of

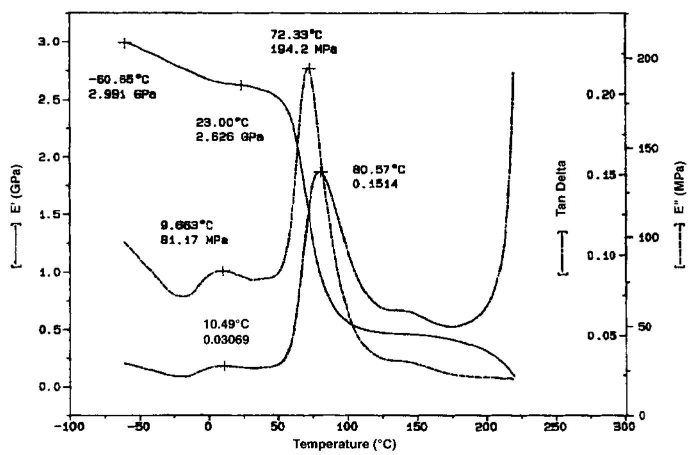


Figure 8a. Storage and loss properties for unfilled nylon 6.

the glass transition on the properties of the semi-crystalline material can also be seen in the tan delta peak value. Instead of rising above 1.0 as in most amorphous materials, the peak height for this material barely exceeds 0.15. Nylon 6 gives a result that is typical for a semi-crystalline polymer. The primary differences between semi-crystalline materials are in the actual glass transition temperatures, melting points, and degree of storage modulus decline associated with the glass transition. The glass transition can be thought of as the softening point of the amorphous regions, and the melting point represents the solid-liquid transition for the semi-crystalline structure. Therefore, the reduction in the storage modulus through the glass transition can serve as a relative indicator of degree of crystallinity. We will see later that there are other modifications that increase the elastic properties of a material and decrease the effect of the glass transition on the storage modulus. Therefore, care must be taken in interpreting the structural details behind DMA data. Once the semicrystalline material approaches the melting point, the tan delta value

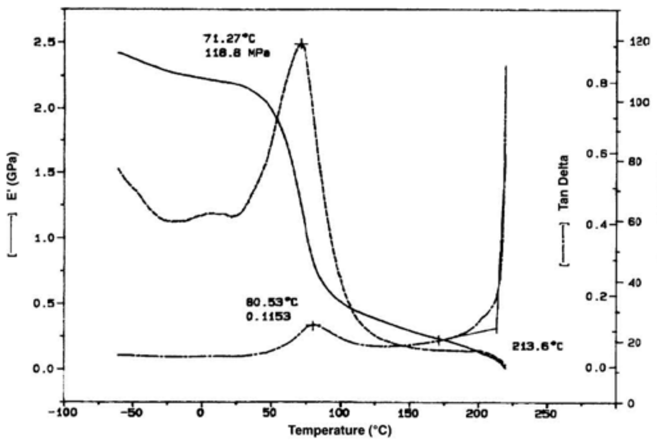


Figure 8b. Storage and loss properties for an unfilled nylon 6/12 showing the rapid rise in tan delta as the material softens.

will rapidly increase as the material changes from an elastic solid to a viscous fluid. Figure 8b shows a DMA plot for a nylon 6/12 heated above the melting point. The tan delta value above the melting point is great enough to dwarf the glass transition event. The onset temperature for the rapid increase in tan delta will agree closely with the melting point measured by calorimetric methods.

Crosslinked systems such as rigid thermosets produce DMA results that are somewhat unique to the type of matrix polymer. Epoxies and phenolics, for example, have distinct temperature-dependent behaviors that make them easily distinguishable. However, in general these materials all have a well-defined glass transition that produces the typical behavior of a declining storage modulus coincident with a rising loss modulus and tan delta. Figure 9 shows the storage and loss properties for an epoxy

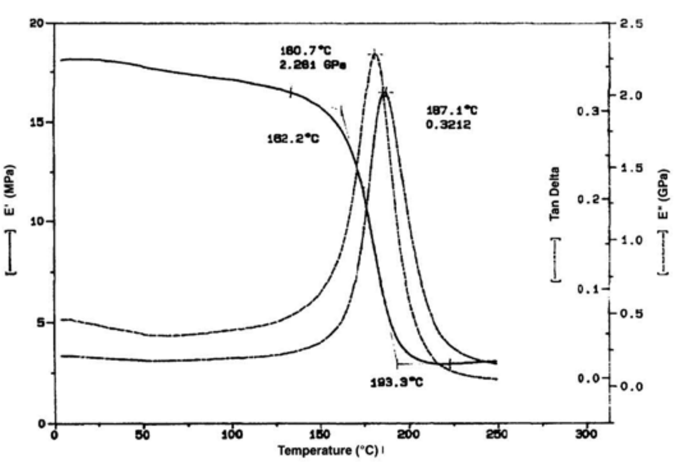


Figure 9. Storage and loss properties for an epoxy circuit board material.

material used in printed circuit boards. Since the material is crosslinked, it has no melting point and in this respect it resembles an amorphous material. However, due to the crosslinking, the plateau modulus beyond the glass transition does not decline to near zero. Instead, the material will still exhibit useful load-bearing characteristics even 50-75°C above T_g. Note also that in crosslinked systems the tan delta values above T_g return to pre-T_g levels.

Elastomers have glass transition temperatures below room temperature and their storage modulus properties are typically very low at ambient conditions. In this respect, they resemble a rigid amorphous material that has been heated above T_g. However, unlike the amorphous materials, elastomers exhibit relatively low tan delta properties above T_g, indicating that while little force is required to deform the material, recovery will be good once the applied load is removed. Intuitively this confirms our physical experience with elas-

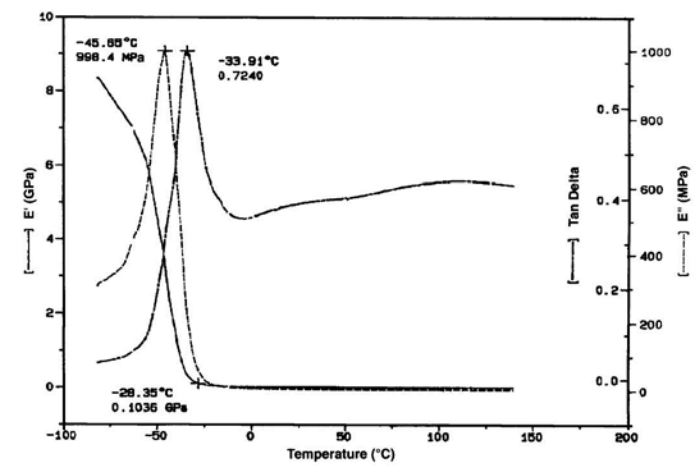


Figure 10. Storage and loss properties for a thermoset elastomer.

tomeric compounds. When the temperature is lowered, the material passes through the glass transition and presents itself as a rigid system. If the material is a crosslinked elastomer then it will have a low but measurable modulus to very high temperatures while a thermoplastic elastomer will exhibit a second modulus decline associated with the melting point. This difference is most easily observed by plotting the storage modulus on a logarithmic scale. In addition, the tan delta values will be much higher for the melted thermoplastic system than for the crosslinked thermoset elastomer. Figure 10 shows a typical DMA result for a crosslinked elastomer.

3.1 Storage Modulus Versus Temperature

From an engineering standpoint, the most useful and accessible information available from a DMA test is the plot of storage modulus versus temperature. As we have indicated above, it enables us to determine the basic structure of the polymer system. The ability to distinguish between a semi-crystalline and an amorphous material is not unique to DMA. However, DMA may be the only technique that provides this structural information and at the same time provides quantitative data regarding the modulus of the material at any temperature of interest. At a time when new designs are subjected to extensive structural analysis, it is important that the analyst have accurate material property data available in order to make the best use of the computer programs. For most plastic materials, the only modulus values readily available are the room temperature values from the short-term property charts. Because the storage modulus is nearly equivalent to the complex modulus, it will be observed that the property chart values at room temperature will agree closely with the room temperature DMA values. However, the property chart provides no information about material behavior above or below this single point.

Even in those rare cases where a property like modulus is measured at three or four temperatures, interpolation or extrapolation to a particular temperature of interest can be difficult due to the presence of transitions and the resulting non-linear behavior. Table 3 gives flexural modulus values for a PET polyester at four temperatures, -40, 23, 93, and 149°C (-40, 73, 200, and 300°F). Accurate interpolation to a modulus at 77°C (170°F) will be difficult since the slope of the modulus-temperature relationship obviously changes significantly between room temperature and 300°F. Figure 11 shows the actual storage modulus plot as a function of temperature. It provides direct information on the modulus-temperature relationship, identifies the glass transition region, and eliminates the guesswork. In the 99% of the cases where only the single point at room temperature is available, any attempt to estimate properties at different temperatures is futile.

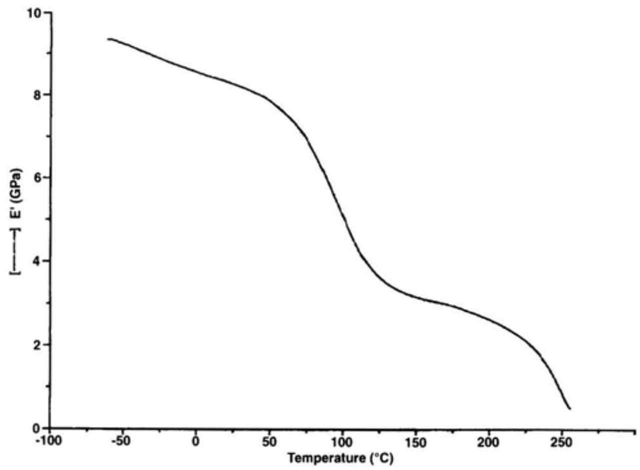


Figure 11. Storage modulus vs. temperature for a 30% glass fiber-reinforced PET polyester.

Table 3

Modulus Data For 30% Glass Fiber-Reinforced PET Polyester

Temperature (°C)/(°F)	Flexural Modulus (GPa)/(psi)
-40/-40	10.335/1,500,000
23/73	8.960/1,300,000
93/200	3.580/ 520,000
149/300	2.690/ 390,000

Plots of storage modulus allow for the direct comparison of a variety of materials that may be considered as candidates for an application. While there are many considerations in selecting the correct plastic material for an application, load-bearing capability is typically an important criterion. If a part will experience a particular operating temperature, DMA plots provide a quantitative comparison of the elastic modulus at that temperature. More importantly, the DMA plots provide a picture of those temperature regions where material properties are very stable with temperature and those regions where rapid changes may occur that could render the product useless. Figure 12 provides a comparison of four glass fiber-reinforced semi-crystalline thermoplastics that may be considered for a particular high-temperature application. All contain 30% glass fiber and are based on PBT polyester, PET polyester, nylon 6, and nylon 6/6. If the planned operating temperature of the application is 75°C (167°F) then the PET clearly has the advan-

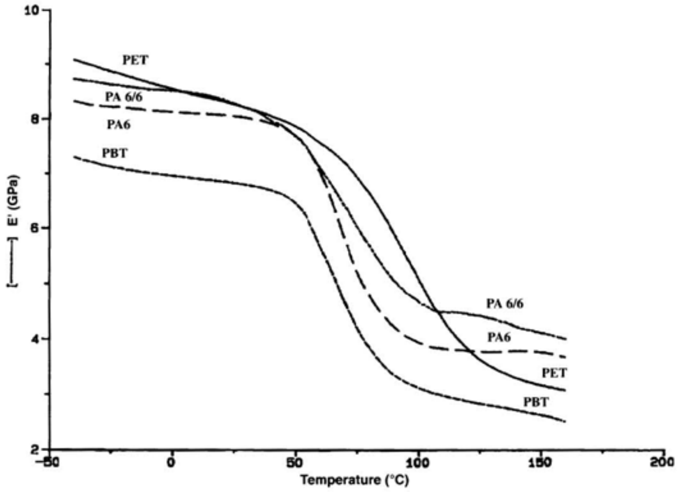


Figure 12. Comparison of storage modulus properties for PET polyester, PBT polyester, nylon 6, and nylon 6/6, all with 30% glass fiber reinforcement.

tage in terms of load-bearing properties. However, all of these materials have relatively low glass transition temperatures and are in the middle of a rapid change in properties at this temperature. If occasional temperature excursions to 120°C are expected, then the degree of change in modulus as a function of the glass transition becomes a critical factor. At this higher temperature all the materials are through their transitions, and the nylon 6/6 has the highest modulus. Ultimately, the nylon 6 also has a higher elastic modulus after all of the transitions are complete. If the design engineer determines that the modulus loss associated with the glass transition is unacceptable, then a material with a T_g above 120°C can be selected in order to retain the highest possible modulus. DMA results are the best tool for such a search.

A generalized plot of storage modulus versus temperature is shown in Figure 13. The y-axis is logarithmic in this case in order to depict the full range of possible behavior exhibited by amorphous, semi-crystalline, and crosslinked polymers. This graph shows that above the glass transition there are key relationships between storage modulus and structure that can directly affect product performance. For amorphous thermoplastics the modulus increases with molecular weight. These measurements are made at very low modulus values when the polymer is essentially a viscous melt. Therefore, these determinations are difficult to make with a DMA designed for solid-state measurements and are best accomplished in an instrument designed to handle melts. In semi-crystalline resins the modulus above the glass transition increases with degree of crystallinity. This provides a very useful method for comparing polymer families, evaluating differences between materials within a given polymer family, and even determining structural changes in a specific grade of material subjected to different thermal histories during processing or end use. For crosslinked systems the relationship is found between post-T_g modulus and the degree of crosslinking.

3.2 The Meaning of Loss Modulus and Tan Delta

In section 2.2 we reviewed the key differences between semi-crystalline and amorphous thermoplastics as they manifest in DMA data. This section is designed to provide a more detailed interpretation of the loss properties of a polymer. As has been stated above, the loss modulus is the contribution of the viscous component in the polymer, that portion of the material that will flow under conditions of stress. In engineering terms we encounter this behavior as creep (cold flow) or as stress relaxation depending upon whether the application involves a constant stress or a constant strain. Tan delta is a ratio expressed as E"/E'. Since it is dimensionless, it provides a convenient means for comparing polymers where storage and loss modulus values may be subject to change because of alterations in composition, geometry, or processing conditions. Tan delta can be thought of as an index of viscoelasticity.

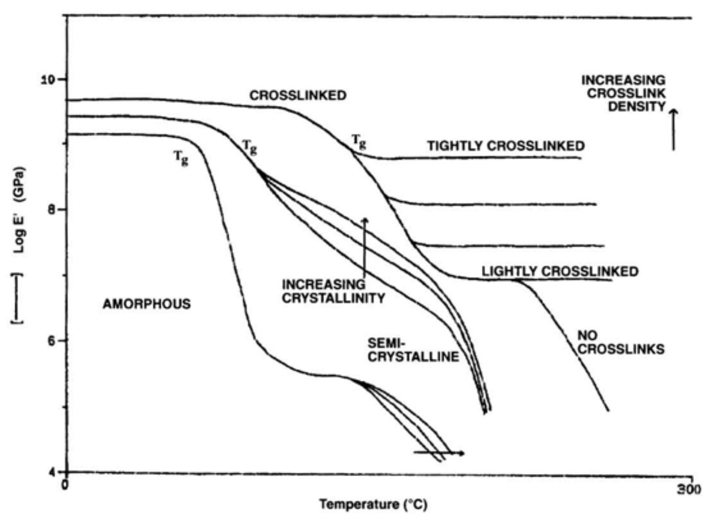


Figure 13. Generalized plot of the effects of structure on storage modulus properties.

In solid plastic materials, tan delta is typically below 0.1 and frequently below 0.03 when the material is below the glass transition. However, during a transition both the loss modulus and tan delta rise as the storage modulus goes into a rapid decline. In fact, the coincidence of these events is so pronounced that it is tempting to think of the loss modulus as the derivative of the storage modulus. However, this misses the true significance of the viscous flow properties in a plastic material. The rapid rise in the loss modulus indicates an increase in the structural mobility of the polymer, a relaxation process that permits motion along larger portions of the individual polymer chains than would be possible below the transition temperature. During the glass transition, which is the largest and most important of these relaxations, those regions within the polymer structure that are not either crystallized or crosslinked, become capable of an increased degree of freedom. Under an applied load this new mobility will take the form of organized movement or flow. The magnitude of the loss modulus and tan delta peaks varies with the severity of the decline in the storage modulus. Thus in an amorphous polymer, which loses 99%+ of its storage modulus as it passes through the glass transition, tan delta values will typically peak above 1.0 and often above 2.0. This means that during the glass transition the loss modulus equals or exceeds the storage modulus. Under these conditions, the material is soft and pliable and is no longer serviceable as a load-bearing material. In an unfilled semi-crystalline thermoplastic, where the modulus decline is typically 60-90%, tan delta values crest at 0.1-0.2, a full order of magnitude lower than for a fully amorphous system. While molecular mobility is increased, the crystalline network maintains a portion of the elasticity needed for structural applications.

Assigning an exact value to T_g has historically been the subject of some disagreement. If the primary concern is the practical effect of the transition on the load-bearing characteristics of the material, the onset of a sharp reduction in the storage modulus may be used. However for some material families such as polypropylene, unsaturated polyesters, and liquid crystal polymers, no well defined onset exists. Alternatively, the peak temperature of either the loss modulus or tan delta is used. Of these, the loss modulus provides the best agreement with determinations made by other thermal analysis methods and ASTM has recently codified this into D-4065.

Once the glass transition is complete the decline in the storage modulus slows or even stops for a certain temperature interval. At the same time, the loss modulus returns to pre-T_g levels. However, as illustrated in section 2.2, the tan delta values do not. In some amorphous materials such as acrylics and amorphous nylons, no tan delta peak accompanies the loss modulus peak. Instead, the tan delta curve exhibits a sharp onset that coincides with the loss modulus peak temperature. Above this temperature the value rises rapidly. Figure 14 shows this behavior for an amorphous nylon. For semi-crystalline materials, the post-T_g tan delta values will also be higher, 2-4 times greater than they are below T_g. Then, as the semi-crystalline materials approach the melting point tan delta rises again, this time to values well above 1.0 as the material changes from solid to liquid. Because the values are so high compared to those achieved during the solid-state evaluation, this portion of the curve is usually omitted to make the glass transition more visible.

While the glass transition is the most important solid-solid transition in plastic materials, it is not the only significant event revealed by DMA. Any change in the mobility of the polymer structure will appear as a peak in the loss modulus and tan delta curves and a step reduction in the storage modulus. These secondary relaxations are typically due to the onset of rotational motion in the polymer and many of them occur at temperatures below the range of practical interest. In addition, the magnitude of these transitions is much smaller than that of the glass transition. Nevertheless, some of these

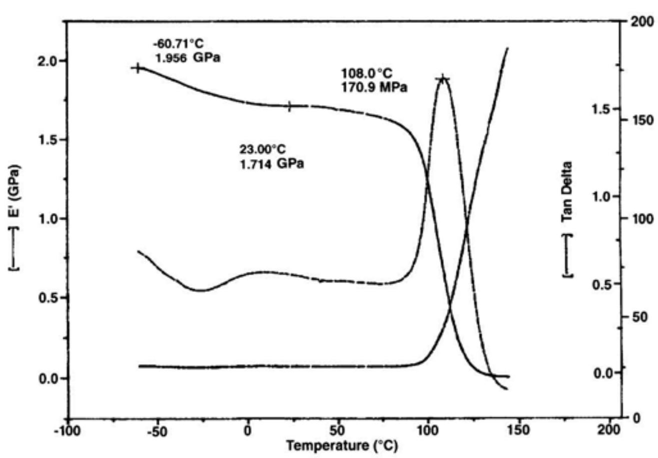


Figure 14. Storage and loss properties for amorphous nylon. Tan delta does not resolve to a peak in the glass transition region but rises rapidly starting at T_g.

events help to explain differences in impact performance. Short-range molecular mobility below room temperature, which appears as sub-ambient transitions in DMA tests, provides a mechanism for energy absorption that can manifest as improved toughness in a polymer. Figure 15 shows a comparison of tan delta curves for two high-performance amorphous polymers, polyethersulfone (PES) and polyetherimide (PEI). Both materials have similar chemical structures and comparable storage modulus properties as a function of temperature. However, in impact tests the polyethersulfone exhibits greater impact resistance and a more ductile failure mode. The tan delta curves for the two polymers show that the PES has a weak but measurable relaxation at 4°C while the low-temperature transition in the PEI occurs well above room temperature at 96°C. In addition, the tan delta values for the PES are consistently higher than for the PEI throughout the scan, particularly below room temperature. Therefore, at room temperature the PES polymer matrix is more mobile and the greater tendency for viscous flow results in increased toughness.

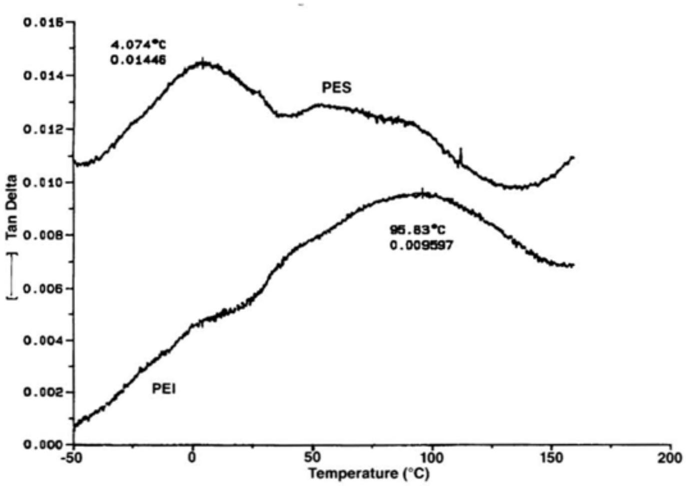


Figure 15. Comparison of tan delta properties for PES and PEI from -50 to 160°C. The higher tendency for viscous flow is part of the reason for the superior impact resistance of PES.

In some polymers, a low-temperature transition is due to the glass transition of a rubbery impact modifier. Figure 16 shows this phenomenon for a toughened acrylic. The loss modulus peak at 108.6°C is attributable to the acrylic while the broader transition that crests at -7.7°C is caused by the impact modifier. Similarly, ABS materials will display a high temperature glass transition for the styrene-acrylonitrile (SAN) backbone and a low-temperature transition (near -90°C) for the butadiene rubber phase. Prior knowledge of the composition of a material is helpful in interpreting the transitions in a DMA plot.

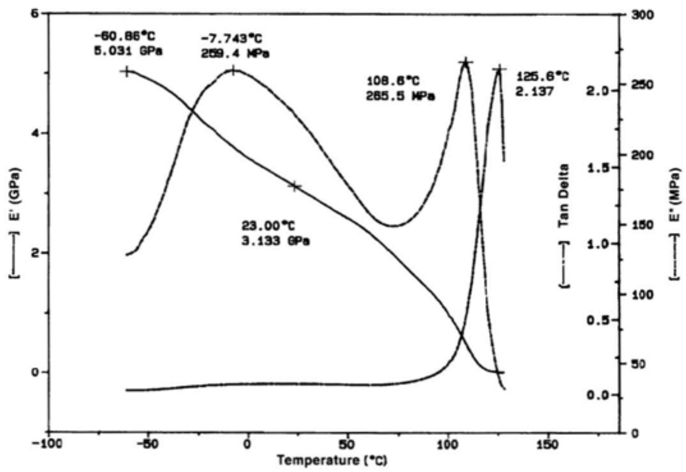


Figure 16. Storage and loss properties for an impact-modified acrylic. The low-temperature transition in the loss modulus curve is due to the rubbery impact modifier.

3.3 The Relationship of DMA To HDT and Vicat Softening

Professionals who come from an engineering discipline and who have experience with plastic materials have typically become accustomed to working with short-term properties. The heat deflection temperature (HDT) and Vicat softening test, both described by ASTM D-648, represent the only systematic attempts in standardized testing to characterize elevated temperature performance in plastic materials. While these tests describe particular responses to temperature under very specific sets of conditions, these single points are often used in the material selection process as maximum continuous use temperatures. The HDT test is essentially designed to evaluate the temperature at which a specific deformation occurs in a 3-point bending mode under a specific load. The load may either be 0.455 MPa (66 psi) or 1.82 MPa (264 psi). The sample and appropriate fixturing are immersed in an oil bath that serves as the heat transfer mechanism and the temperature of the fluid is raised at a constant rate of 2°C/minute. Since the HDT defines a temperature at which a given sample geometry exhibits a specific deformation, the test essentially measures the temperature at which a material achieves a certain modulus. Takemori (1) has calculated the modulus values to be 800 MPa (116,000 psi) for the applied load of 1.82 MPa and 200 MPa (29,000 psi) for the applied load of 0.455 MPa. The new ISO 75 standard defines three stress levels for measuring the heat deflection temperature. Method A corresponds to the high-load conditions for ASTM D-648 while Method B uses the low-load conditions. Method C employs an applied load of 8 MPa (1160 psi). Under these conditions, the modulus-at-temperature is 3520 MPa (510,000 psi). This will significantly lower the measured HDT of filled semi-crystalline materials that fall below this modulus value either during the glass transition or in the early stages of the crystalline plateau. The Vicat softening point is determined by applying a specified pressure on a needle with a standardized surface area until a certain penetration is achieved. This test is used most often with amorphous materials where there is no well defined melting point and the softening process is relatively gradual.

Since the HDT test is a measurement of modulus at temperature, it should be possible to determine the HDT by locating the specific modulus values of 800 and 200 MPa on the storage modulus plot. For several reasons this technique does not always produce precise agreement with Takemori's modulus. First, there may be differences in part geometry, most notably in wall thickness, between the samples used for DMA testing and the samples used by the material supplier for HDT testing. Second, sample preparation methods have a significant effect on the HDT result (2). An injection molded specimen may contain molded-in stresses that cause the sample to warp as it is heated. This warpage can be interpreted by the HDT test as deflection and this will produce a lower value. Third, the HDT often occurs in a region where the storage modulus is dropping by as much as 100 MPa/°C. This rapid change, combined with differences in the heat transfer mechanism between the oil bath of the HDT test and the air gap of a DMA instrument can lead to discrepancies. Fourth, the flexural modulus measured by the HDT test is the complex modulus while the DMA measures the elastic modulus. In amorphous materials, where the loss modulus contributes significantly to the complex modulus near T_g, the complex modulus will be considerably higher than the storage modulus and an allowance must be made for this discrepancy in correlating the HDT to the precise modulus calculated by Takemori. Finally, as we will see in section 4.3, the storage modulus is dependent upon the frequency at which the measurement is made. This frequency-dependent behavior is most noticeable in the glass transition region. The use of an oscillatory stress by DMA as opposed to a static load in the conventional HDT test can lead to some discrepancies.

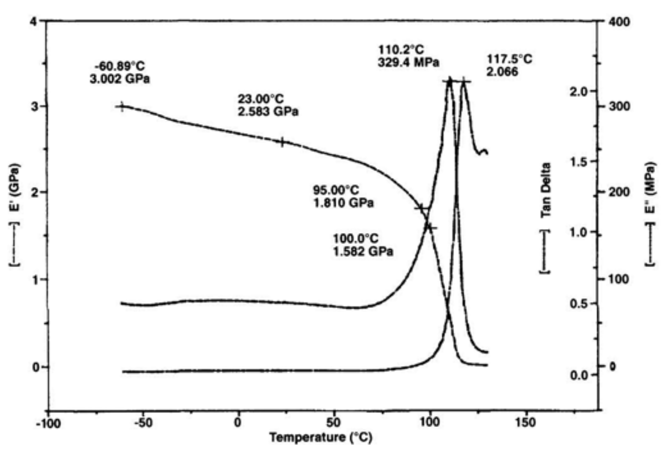


Figure 17. Storage and loss properties for a flame-retardant ABS/polycarbonate blend. The HDT values are shown on the storage modulus plot.

Figure 17 shows test results for a flame-retardant alloy of polycarbonate/ABS. The property chart values of 100°C for the HDT at 66 psi and 95°C for the HDT at 264 psi are shown on the storage modulus curve. However, Bayblend FR110 reaches a modulus of 800 MPa at 108°C and a modulus of 200 MPa at 113°C. While this represents an error of 13°C for this material, the relationship between the deflection temperatures and the structural changes associated with T_g are unmistakable.

A general appreciation of the structural changes associated with the HDT are apparent from an examination of different DMA plots. Since the modulus of an amorphous material declines by over 99% as it passes through the glass transition, it is reasonable to expect that the temperatures at which the material achieves moduli of 800 and 200 MPa would be close together. Figure 17 confirms this and shows that the HDT of an amorphous material typically occurs in the middle of the decline in the storage modulus or on the high-modulus part of the curve just prior to the decline.

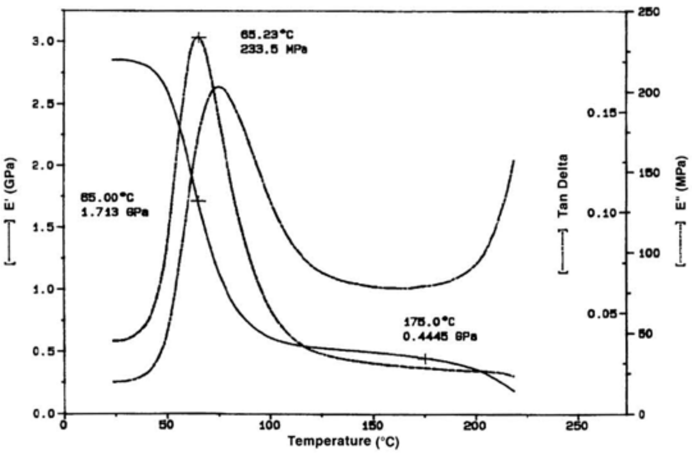


Figure 18. Storage and loss modulus plot for unfilled nylon 6 showing the two HDT values in relation to T_g and the melting point.

If we examine the tabular data for HDT in an unfilled semi-crystalline system, however, we find a great difference between the values measured at 0.455 MPa and 1.82 MPa. In nylon 6, for example, the HDT at 0.455 MPa is 175°C while the value at 1.82 MPa is only 65°C. Figure 18 clearly shows the mechanism behind this phenomenon. As the material enters the glass transition region, the modulus drops rapidly from 2.8 GPa (406,000 psi) to 0.56 GPa (81,200 psi) between 40-90°C. The loss modulus peak puts the T_g at 65°C. In this transition region, therefore, the modulus of the nylon 6 has passed through one HDT modulus threshold, but the crystalline structure of the material prevents it from falling through the second one. This second threshold is not reached until the material approaches the melting point. Therefore, in unfilled semi-crystalline systems, the low-load HDT is associated with the early stages of the crystal melting process while the high-load HDT is related to the glass transition. If we add a filler to an amorphous system, we do not appreciably change the threshold temperatures as can be seen in Figure 19. However, in a semi-crystalline system, the high-load HDT increases significantly and becomes almost equivalent to the low-load HDT simply because the material is now rigid enough to remain above the 800 MPa threshold until the material is near the melting point. This is illustrated in Figure 20. Figure 20a shows the effect that the new ISO 75 Method C will have on materials like the 14% glass-reinforced nylon 6. By raising the stress level on the sample, the critical modulus value is increased to the point where it will now coincide with the glass transition temperature and not the softening point. To the user of short-term data, this will appear to be a substantial downgrading of the material properties. However, the DMA plot provides insight into the reasons for the apparent shift.

The Vicat softening temperature involves an actual penetration of the material as opposed to the deflection of a solid beam. The softening point, therefore, will be higher than the HDT. In an amorphous material, the HDT values will typically be 15-20°C below the Vicat softening point. Figure 21 shows a DMA plot for an unfilled polycarbonate with both HDT values and the Vicat softening point annotated on the storage modulus curve. Placing HDT values on a DMA curve shows that by the time a plastic material reaches its HDT, it has already lost 70-90% of its room-temperature modulus or is within a few degrees of doing so. This understanding during the material selection process will enable the engineer to select the appropriate material for an application with greater care and precision.

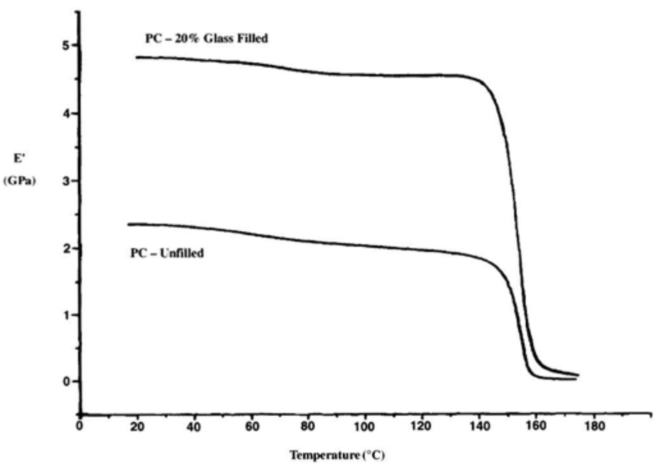


Figure 19. Storage modulus versus temperature behavior showing the effect of filler content on the softening point for polycarbonate.

3.4 The Effect of Fillers

In the discussion of HDT we have already alluded to the effect that fillers and reinforcements have on the viscoelastic characteristics of plastic materials. Fillers and reinforcements are typically inorganic materials such as talc or glass fiber with softening points well above the temperature at which organic polymers degrade. Even systems like carbon fiber

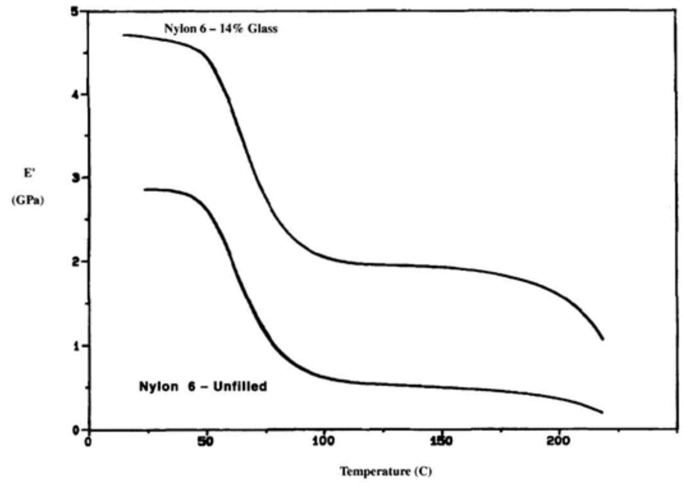


Figure 20. Storage modulus versus temperature behavior showing the effect of filler content on the properties of nylon 6.

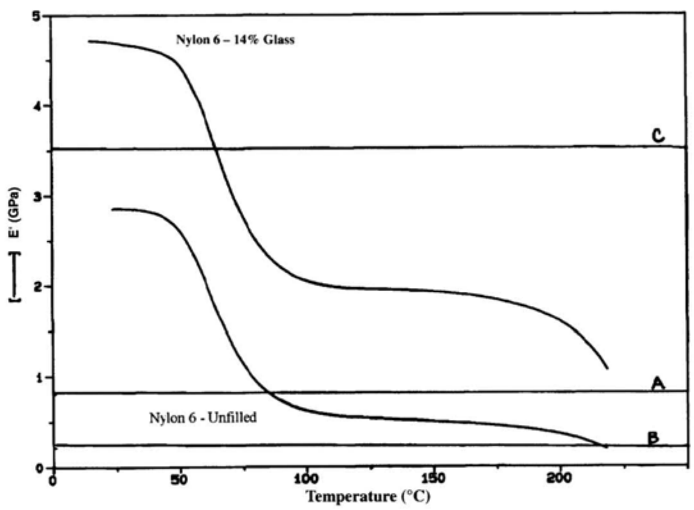


Figure 20a. Figure 20 showing the modulus levels for the HDT measured by ISO 75 Methods A, B, and C.

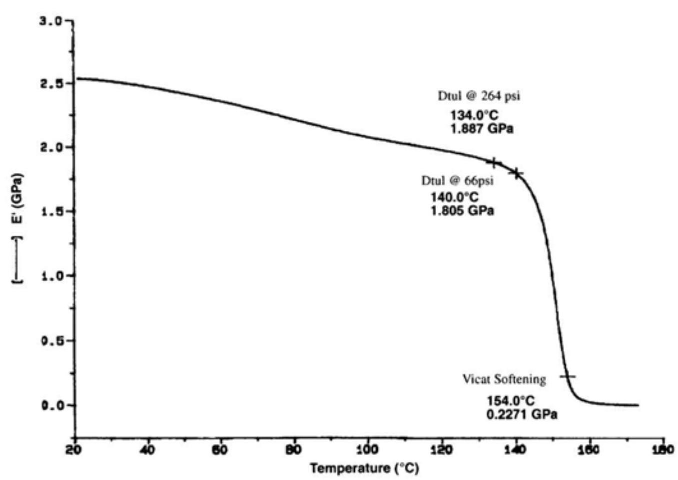


Figure 21. Storage modulus versus temperature for an unfilled polycarbonate showing the two HDT values and the Vicat softening point.

or calcium carbonate which are based either entirely or in part on carbon, have extremely high thermal resistance. Most fillers and reinforcements, therefore, respond as purely elastic systems while the polymer and the filler/polymer interface are viscoelastic.

It is well documented that adding a filler or a reinforcement to a polymer increases the modulus of the system. However, DMA scans of unfilled materials and their filled counterparts show that the increase in room temperature properties is only a small part of the improvement. Figure 22 shows storage modulus plots of unfilled nylon 6 and four analogs that contain different amounts of filler and reinforcement. Fibrous glass acts as a true reinforcement and provides a more efficient energy-transfer mechanism than a particulate mineral filler. The elastic contribution can be seen in the reduced effect that the glass transition has on the reduction in elastic modulus. Table 4 gives some key properties for the five materials.

Steady improvements result from increased use of glass fiber. However, substitution of mineral for glass fiber in the highly filled system produces a material with lower performance than the 14% glass-filled material when it is evaluated in terms of modulus retention above the glass transition. Note that the T_g does not change significantly with filler content. Note also that all of the filled materials, when evaluated by HDT, appear to be virtually equivalent while the DMA results show a wide array of load-bearing capabilities. The changes observed above can be seen in the viscous proper-

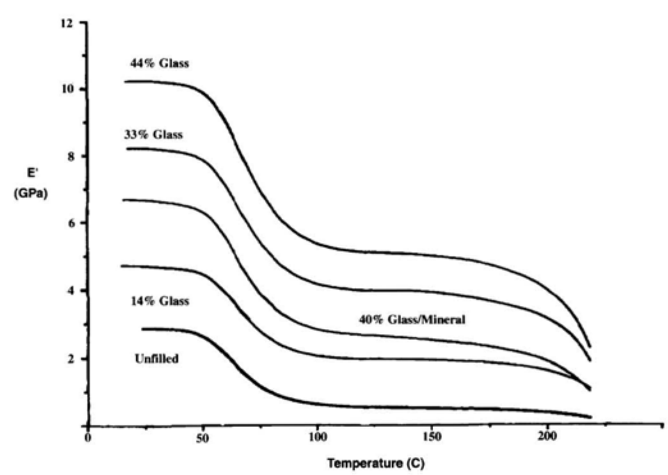


Figure 22. Effect of filler type and level on the storage modulus properties of nylon 6.

Table 4

Combined HDT & DMA Data For Nylon 6

Filler Type & Amt.	HDT@ 1.82 MPa(°C)	T_g (°C)	Pre- T_gE' (GPa)	Post- T_gE' (GPa)	% Decline
None	65	65	2.81	0.56	80.1
14% Glass	200	69	4.46	1.98	55.6
33% Glass	210	70	7.87	3.99	49.3
44% Glass	210	71	10.04	5.13	48.9
40% Glass/ Mineral	206	69	6.44	2.69	58.2

ties as well as the elastic ones. Figure 23 shows the tan delta curves for the five nylon compounds in Table 4. As the modulus decline associated with T_g decreases, the peak height of the tan delta curves is also reduced.

Polymer-filler systems with the same amount and type of filler can be compared in this manner. Figure 24 shows tan delta plots for two PBT polyesters reinforced with 30% glass fiber. One material uses conventional short fiber compounded with the polymer in an extruder while the other material makes use of long glass fibers that are coated individually with resin to improve the integrity of the fiber/polymer interface. The lower tan delta values throughout the scan, and in particular the lower peak height associated with the glass transition, reflects theimproved load-bearing properties of the long glass system. Fillers and reinforcements and

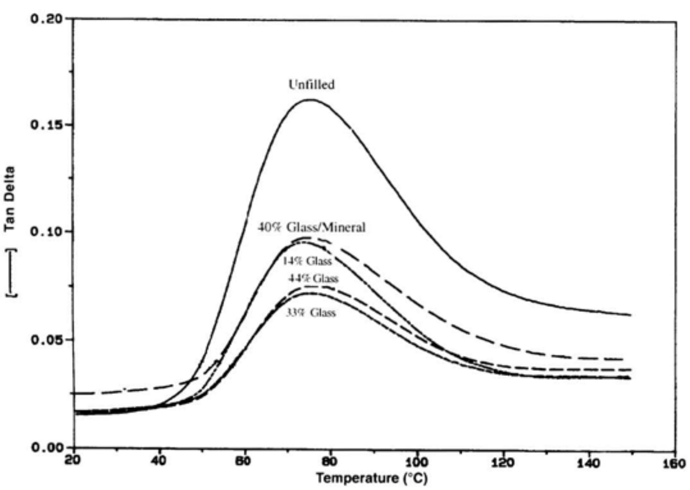


Figure 23. Effect of filler type and level on the tan delta properties of nylon 6. Note the reduction in peak heights as the elastic contributions of the filler increase.

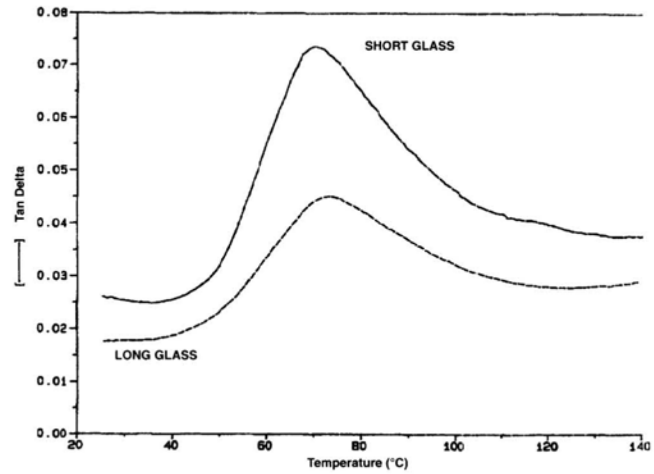


Figure 24. Effect of fiber length and coupling technology on the tan delta properties of a short glass and long glass PBT polyester. The long glass system has higher elastic properties using the same amount of reinforcement.

the chemistries for establishing the polymer/filler interface may vary in quality. Comparisons of this kind permit an evaluation of competitive materials that may appear to be equivalent based on short-term property evaluations.

3.5 Polymer Blends

Polymer blends have become important to many industries, particularly where a combination of a semi-crystalline and an amorphous component has produced a property synergism. Polyester/polycarbonate alloys are a good example. The amorphous polycarbonate provides good impact resistance while the polyester contributes good chemical resistance. While some synergy results from blending, some trade-offs also occur. These are made apparent through the use of DMA.

Three types of polymer blends are recognized. The first is a miscible blend, a compound where the two individual polymers combine to form a homogeneous mixture and the individual phases are indistinguishable. This is considered ideal for enhancement of impact properties, but often involves a sacrifice in heat resistance. A well-known example of a miscible blend is PPO/HIPS, commercially known as Noryl produced by General Electric. Figure 25 shows loss modulus plots for four grades of Noryl that incorporate different amounts of high-impact polystyrene (HIPS) and poly(phenylene oxide) (PPO). Pure PPO has a very high T_g while pure HIPS has a much lower

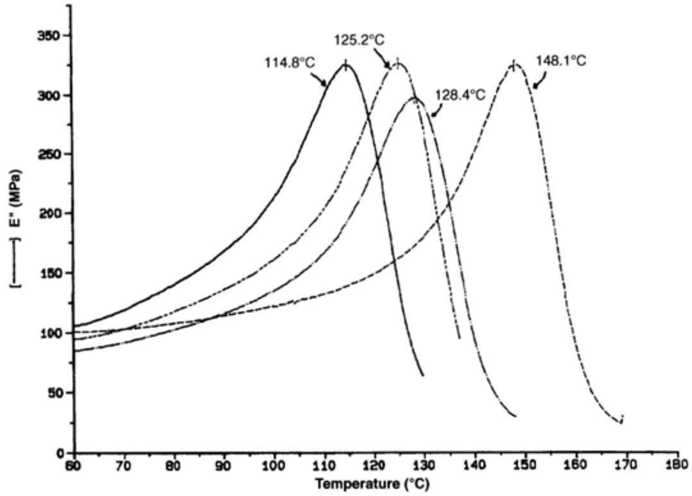


Figure 25. Loss modulus versus temperature plots for various blends of PPO and high impact polystyrene. The single T_g indicates a miscible blend with T_g rising as PPO content increases.

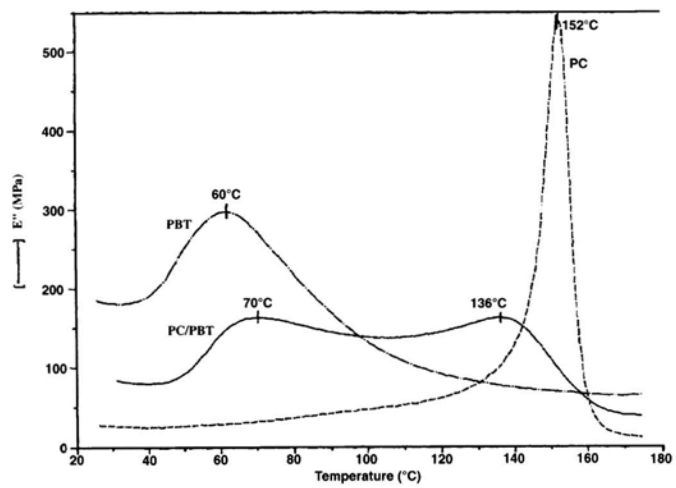


Figure 26. Loss modulus plots for PBT polyester, polycarbonate, and a PBT/PC blend. Two phases are detectable but the shift of T_g's toward one another indicates a semi-miscible blend.

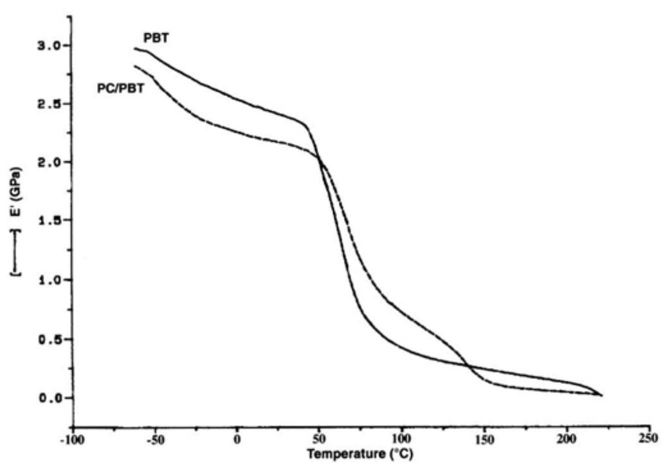


Figure 27. Storage modulus plot comparing an unfilled PBT with a PBT/PC blend.

T_g. When they are blended a single T_g results. This T_g increases as the PPO content increases. These materials are generally quite tough and are not prone to phase separation under aggressive processing conditions.

Polyester/polycarbonate blends are a good example of a semi-miscible blend. In these cases there is some affinity between the two polymer phases, but a compatibilizer may be required to prevent phase separation and an additional impact modifier is often required to achieve the desired toughness. Figure 26 shows the loss modulus plots for a pure PBT polyester, a pure polycarbonate, and a blend of the two materials. The partial miscibility is indicated by the shift of the glass transitions closer together. While these materials are very tough, they tend to sacrifice load-bearing characteristics because of the high loss modulus properties over a broad temperature range between the two glass transitions. Figure 27 shows the storage modulus plot for an unfilled polycarbonate/PBT blend and a pure PBT. No well-defined plateau occurs in the modulus because of the overlap in glass transitions. By the time the material has passed through the polycarbonate glass transition, the modulus is extremely low as evidenced by the HDT of 116°C (240°F) at 66 psi. The presence of the PBT prevents the material from melting until it reaches 225°C (437°F), but the modulus of the blend above 130°C is lower than for the pure PBT.

Immiscible blends incorporate two polymers that normally have no affinity with each other. To be commercially successful, materials of this type rely heavily on chemical modifiers to promote adhesion between the phases and considerable levels of impact modifier to achieve even a modicum of toughness. Figure 28 shows both storage and loss modulus plots for a nylon 6/6 and a commercial alloy of nylon 6/6 and PPO. The lack of a shift in the glass transition temperatures indicates that this is an immiscible blend. While immiscible blends are often seen as less valuable than miscible or semi-miscible blends, they offer the advantage of a distinct plateau modulus between the glass transition temperatures of the two polymers. The corresponding decline in the loss modulus properties between the two T_g's indicates that a material of this type will have good load-bearing characteristics up to the point where the PPO goes through its glass transition. The storage modulus of the blend between T_g's is superior to that of the pure nylon

6/6 and shows that the PPO acts almost as a polymeric reinforcement in the nylon.

Since the balance of properties achieved by a blend are influenced considerably by the miscibility of the two phases, DMA characterization is particularly important in predicting the utility of a blend for particular applications. The relative strength of the glass transitions can also help determine the relative concentration of the two polymers and quantify the benefits of using the blend over a pure polymer. For example, some blends incorporate a relatively small amount of a high-cost polymer in a blend with a lower-cost material. By assigning the trade name of the high-priced material to the alloy, the supplier can command a price for the new grade that is not in proportion with the presence of the high-performance phase. DMA will distinguish between real and imagined benefits. In addition, accurate identification of the glass transition temperatures can help to identify particular polymers used in a blend. For example, many polyester/polycarbonate blends do not specify which type of polyester is used. However, whether the polyester is a PBT, a PET, or a PCT, will have a significant effect upon processing considerations as well as fitness-for-use determinations. Since all three polyesters have different glass transition temperatures, DMA can assist in the identification process.

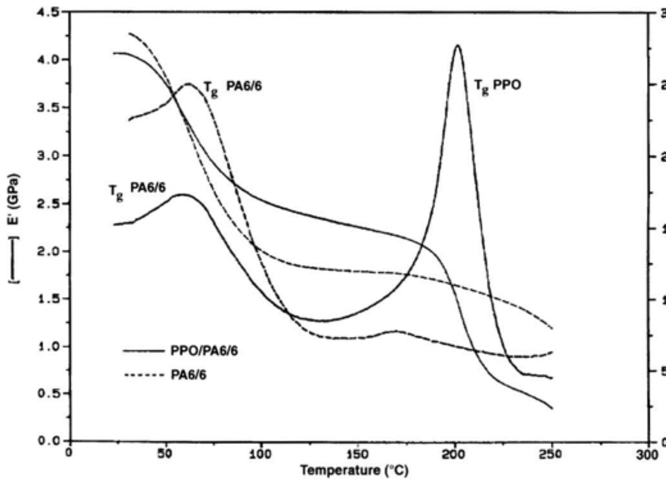


Figure 28. Storage and loss modulus plots of a nylon 6/6 and a blend of nylon 6/6 and PPO. The lack of a shift in the T_g of the nylon and the well-defined modulus plateau between transitions indicates an immiscible blend.

4.1 The Equivalency of Temperature and Time

While the appendix of DMA data focuses on temperature-dependent behavior, useful comparisons of time-dependent properties can be made by referring to the property versus temperature results. In section 2 we discussed the importance of the time factor in evaluating the modulus of a viscoelastic material. Whether the evaluation is performed in the constant stress mode where strain increases with time, or the constant strain mode where stress decreases with time, the measured modulus of a viscoelastic system is dependent upon the time scale over which the measurement is made.

Up to this point we have focused on measurements of modulus as a function of temperature in a constant time frame, that is at a constant frequency. Frequency is the inverse of time and the two can be related by the equation

$$t = \frac{1}{2\pi f}$$

However, modern DMA instruments can also be programmed to operate in a constant stress or constant strain mode at isothermal conditions, allowing the measurement of modulus as a function of time at constant temperature. Figure 29 shows a plot of a 100-hour creep test (constant stress) with apparent modulus plotted as a function of time. Because the change in apparent modulus is very rapid in the early stages of the test and becomes more protracted at longer time frames, it is convention that this relationship is shown in a semi-logarithmic plot of apparent modulus versus time as in Figure 30. An alternate method of data presentation is to place both apparent modulus and time on a logarithmic scale as in Figure 31.

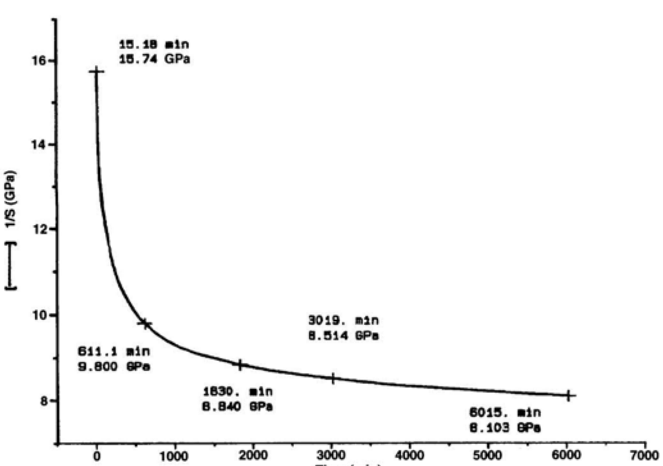


Figure 29. A linear plot of apparent modulus vs. time for a 100-hour creep test.

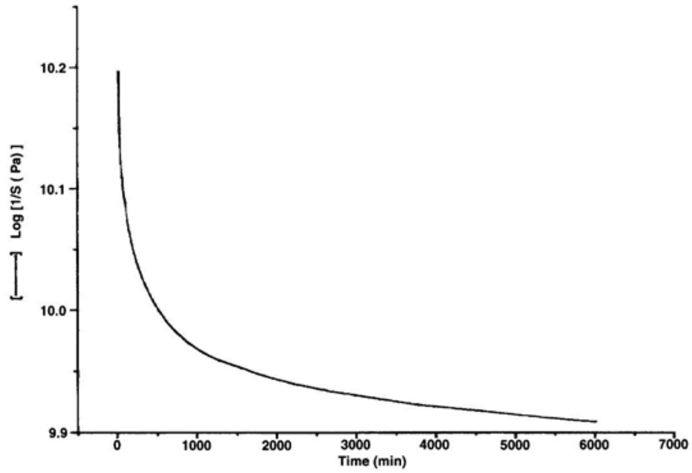


Figure 30. A semi-log plot of apparent modulus vs. time for the 100-hour creep test shown in Figure 29.

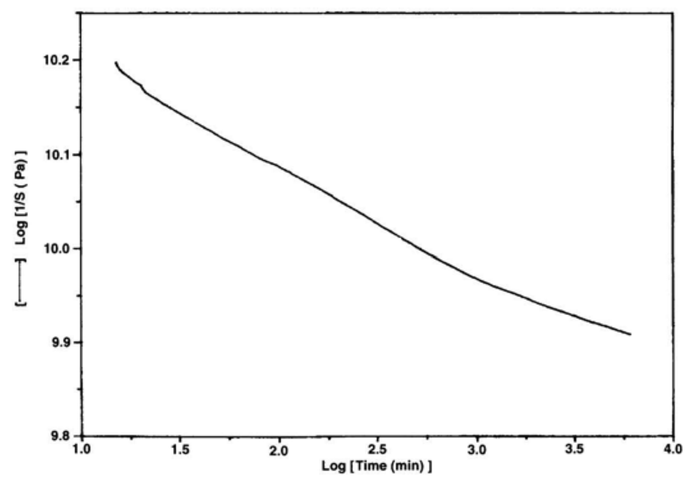


Figure 31. A log-log plot of apparent modulus vs. time for the 100-hour creep test shown in Figure 29.

If this is done for short-term measurements at multiple temperatures, it is possible to observe graphically one of the most powerful laws governing viscoelastic behavior, the equivalency of time and temperature. Figure 32 shows a series of thirty-minute creep tests conducted on a crosslinked vinyl ester between 101-136°C at 5°C intervals. As expected, the initial or zero-time modulus declines as the temperature is increased.In addition, the modulus at any given temperature decreases as the

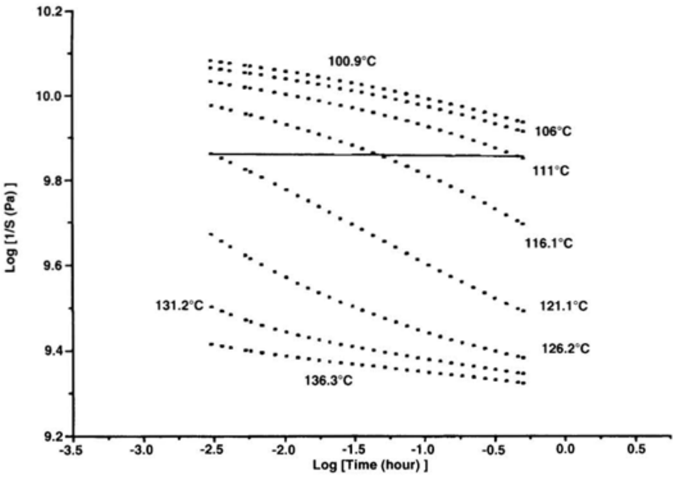


Figure 32. Apparent modulus vs. time data for short-term creep tests conducted on a thermoset vinyl ester at multiple temperatures. The data is plotted in log-log format. The equivalency between time and temperature is shown for a thirty minute loading at 111°C and a temperature increase of 10°C.

increasing strain is measured over the thirty-minute period of each test. We can quantify the equivalency of the relationship between time and temperature for this particular material over this specific temperature range using this data. For example, we can see that the modulus declines in thirty minutes at 111°C by an amount that is equivalent to the decline in the zero-time modulus if the temperature is raised from 111°C to 121°C. We can also see that this quantitative relationship changes due to the non-linear behavior of modulus with temperature. It is apparent that during this experiment the material has undergone a significant change in properties. The apparent modulus plots at the lower test temperatures are clustered together, an indication of relative stability. As the temperature is increased the zero-time modulus values begin to decline more rapidly. At the same time, the effect of time at any given temperature becomes more significant. This shows graphically that there is a correspondence between the effect of temperature and the effect of time. Near the end of the test, the zero-time values once again cluster together at a reduced level and the time-dependent effects also become less significant. If we were to examine a modulus-temperature plot for this same temperature range we would see that the material has undergone a significant transition. The loss modulus and tan delta curves would show peaks typical of such a transition.

We can look at this time-temperature relationship in another way. Figure 33 shows the viscoelastic properties of a glass fiber-reinforced poly(ether ether ketone) (PEEK). The glass transition is readily identified by the sharp decline in the storage modulus and the rapid rise of the loss modulus and tan delta to a maximum. We can conduct a series of thirty-minute creep tests on a sample of the same material and plot the apparent modulus as a function of each temperature step on the same linear scale we used for the temperature scan. In Figure 34 we superimpose the apparent modulus from the creep test on the storage modulus from the temperature scan. Since the x-axis is temperature in this graph, the apparent modulus plots measured at each temperature appear as vertical lines. Short vertical lines indicate low levels of time-dependent defor-

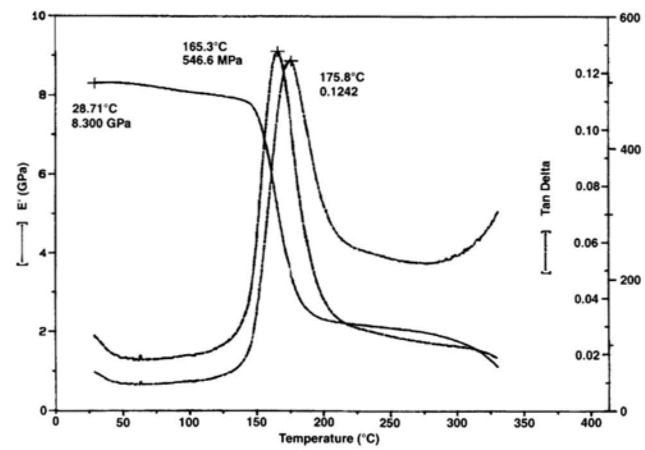


Figure 33. Storage and loss properties for a 30% glass fiber-reinforced PEEK.

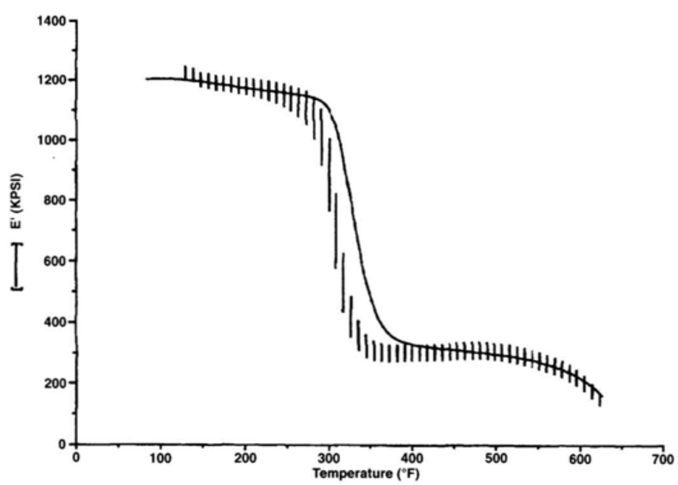


Figure 34. Apparent modulus data at multiple temperatures superimposed over the storage modulus plot from Figure 33. The short-term time-dependent behavior parallels the temperature-dependent properties.

mation while longer lines denote regions where significant creep occurs. Note that in the temperature region below T_g the storage modulus is very stable with respect to temperature. In this same region, the changes in apparent modulus at any given temperature are small and the decline in zero-time modulus at each successive temperature is also small. As the material approaches the glass transition, however, the changes in apparent modulus become more substantial. Even before the zero-time modulus values begin to decline appreciably, the time-dependent behavior is already showing signs of a relaxation that is occurring over an ever shorter time scale. Again there is an obvious correspondence between time-dependent behavior at constant temperature and temperature dependent behavior at constant time.

In qualitative terms, the storage modulus-temperature plot is a predictor of time-dependent behavior. If a projection of time-dependent behavior is sought, it can be estimated by selecting the appropriate temperature and then examining the behavior of the storage modulus as the temperature is increased above that reference point. Thus, if a material is to be used at a temperature, and above that temperature the modulus is very stable, then time-dependent deformation will be small. However, if a material is evaluated just below the glass transition, a large reduction in apparent modulus can be expected in a short period of time even if the material is very rigid at the beginning of the evaluation. Consequently, it is possible to make qualitative comparisons of creep resistance or stress decay between materials by examining the storage modulus-temperature curve. As a simple example, Figure 35 shows a modulus plot for two amorphous materials, ABS and polycarbonate. For any temperature we wish to select, the lower T_g of the ABS and the tendency for the modulus of the ABS to fall off more rapidly with temperature allows us to conclude that polycarbonate will have superior creep resistance in spite of the higher modulus of the ABS at room temperature.

4.2 Creep and Stress Relaxation

These qualitative determinations can be made quantitative by using a technique known as time-temperature superpositioning. This tool capitalizes on the principle that in viscoelastic materials a relaxation process that occurs rapidly at elevated temperatures will occur to the same degree over longer periods of time at lower temperatures. Consequently, there are two experimental options for observing the time-dependent behavior of a polymer. The conventional method involves directly measuring the time-dependent response over longer time periods. This is obviously time-consuming and in the current climate of rapid product development and compression in the time-to-market cycle, long-term testing is considered undesirable. However, the increased use of plastic materials in critical engineering applications makes it unwise to forgo the characterization of long-term behavior. The second option involves running the short-term experiment, whether it be constant stress (creep) or constant strain (stress decay), at progressively higher temperatures. The higher temperature data sets are then shifted to the right (to longer times) until they fall on the same line with the reference temperature. The resulting plot represents a prediction of time-dependent behavior called a master curve. This analysis is carried out on data plotted as apparent modulus versus time on a logarithmic scale.

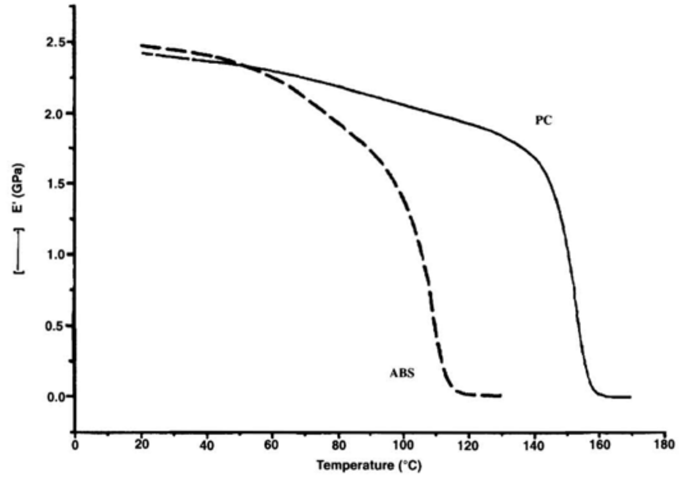


Figure 35. Comparison of storage modulus properties of ABS and polycarbonate. The more stable modulus and higher T_g of the polycarbonate equate to superior time-dependent properties.

Figure 36a shows raw data from a creep experiment for the crosslinked vinyl ester shown previously in Figure 32. Temperatures between 101 and 136°C at 5°C increments were used and each step in the experiment took thirty minutes. A fifteen minute relaxation period was incorporated at the end of each stress period and an additional fifteen minutes was allocated between steps to allow the sample to equilibrate at each temperature step. Thus the entire test took ten hours to conduct.

Figure 36b shows the master curve in its early stages of construction. At this point the first three temperature steps above the reference curve of 100ºC have been moved into position so that they fall on the same line. As additional temperature steps are shifted, the curve is extended to increasingly longer times. Figure 36c shows the completed master curve extending to over 100,000 hours.

Whenever accelerated testing of this type is conducted, it is natural to inquire about the agreement of such results with actual long-term testing. Figure 37 shows a comparison of the first 125 hours of the master curve for a crosslinked polyurethane developed at room temperature with three conventional creep tests conducted on the same material using astandard tensile testing machine. The plot is placed on a linear scale in order to maximize the visual appearance of discrepancies. Even with this treatment, the DMA master curve shows excellent agreement with classical creep test results. The difference between the master curve and creep test #3 (E-3) is smaller than the random variation that exists between the triplicate creep tests.

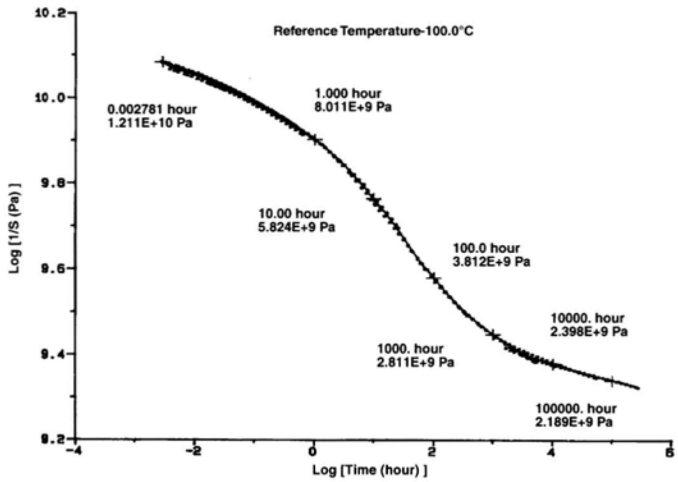


Figure 36c. Completed master curve for a reference temperature of 100ºC.

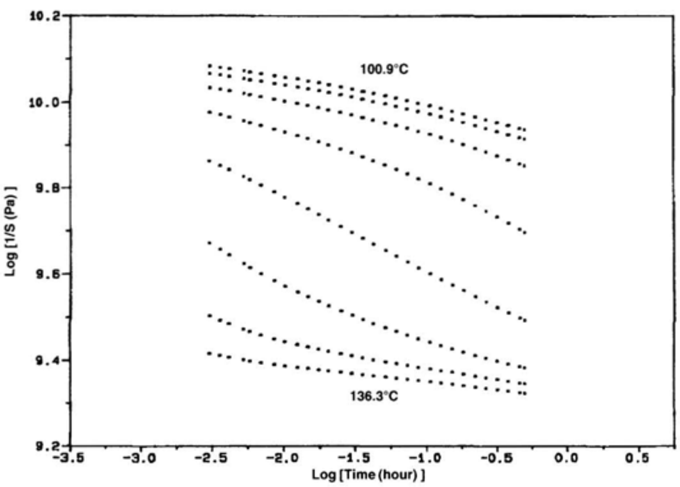


Figure 36a. Raw apparent modulus data shown in Figure 32.

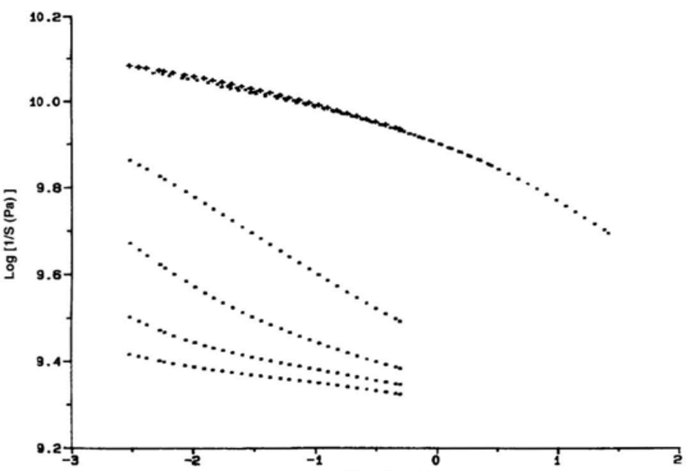


Figure 36b. Master curve in process for a reference temperature of 100ºC.

Figure 38a shows the raw data for a stress relaxation test conducted on a polycarbonate. Figure 38b shows the completed master curve for a reference temperature of 135ºC. Any test temperature can be used as a reference temperature for constructing a master curve. However, the extent of the projection will be limited by the number of tests run at temperatures higher than the reference temperature. In

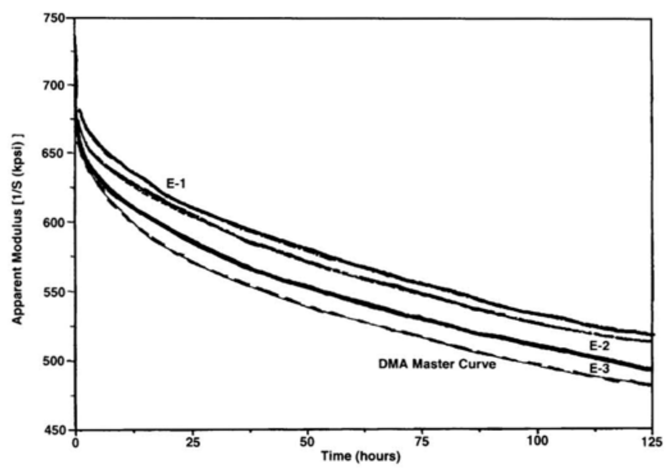


Figure 37. Comparison of first 125 hours of master curve prediction for a rigid thermoset polyurethane with three real-time 125-hour creep tests. Data is shown on linear scales.

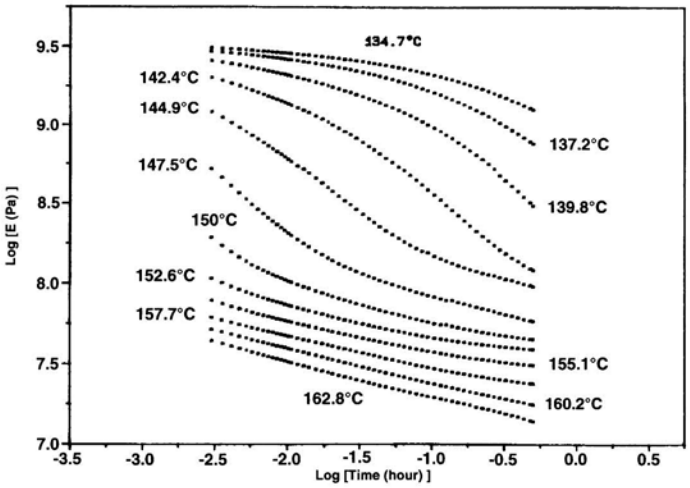


Figure 38a. Raw apparent modulus data from a stress relaxation test on polycarbonate.

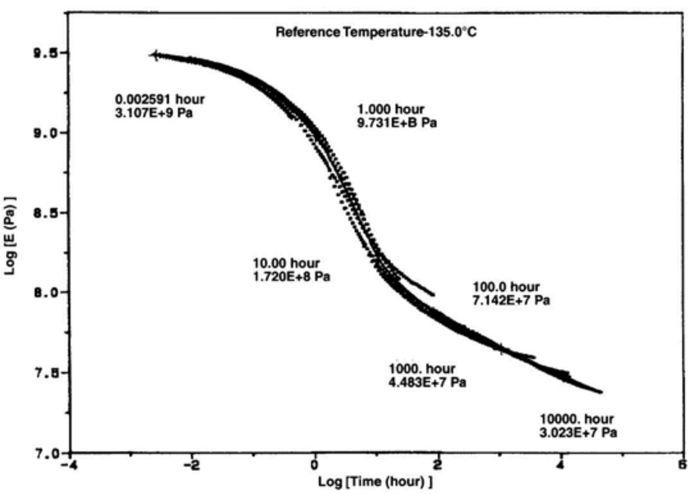


Figure 38b. Stress relaxation master curve for polycarbonate in Figure 38a using a reference temperature of 135°C.

this case, twelve temperature steps comprising a fifteen-hour test provide a projection that extends to 30,000 hours.

Some useful models have been developed governing the mathematical description of the shift factors used to develop the master curves. These are valuable to the research scientist in developing theories of polymer structure, however the application of these various models to the shift factors for any given experiment has little effect on the actual results. In addition, theoreticians have shown that this technique is not quantitatively precise when the end point of the master curve is more than an order of magnitude greater than the end point of the individual steps. Nevertheless, experimentalists have demonstrated that excellent agreement between accelerated tests and long-term relaxation experiments is possible out to thousands of hours using individual steps of 20-60 minutes. Finally, much of the literature on this subject claims that the time-temperature superpositioning technique is only useful in amorphous systems and does not apply to semi-crystalline or multiphase systems. Once again, however, experi-ments have shown that these techniques work extremely well for these more complex systems.

In spite of the power and success of the master curve in predicting long-term time-dependent behavior, some precautions are necessary. Some of these considerations, such as corrections for changing temperature and density, result in minor changes in actual test results. These can be accounted for by incorporating into the analysis software material-specific data produced by other thermal analysis methods. Of much greater importance is the effect that irreversible structural changes can have on the accuracy of master curves. Events such as solid-state crystallization, post-curing, oxidative degradation, stress relief, or the melting of imperfect crystals can occur within the time frame of the short-term tests at elevated temperatures. However, these same events may never occur at the reference temperature. Incorporating the results of these structural changes into the long-term predictions can introduce serious error into the test results and accounts for poor results. These errors will be far more serious than subtle theoretical considerations based on correction factors and model selection.

4.3 The Relationship of Time To Frequency

As stated above, frequency and time are inversely related. Since viscoelastic responses are time-dependent they will also be frequency-dependent. Multiple-frequency experiments, often referred to as frequency sweeps, are capable of generating data similar to that obtained through short-term creep experiments. In addition, multiple frequency experiments provide information on loss properties while creep experiments only supply data on the load-bearing component. Figures 39 and 40 show loss modulus versus temperature plots in the glass

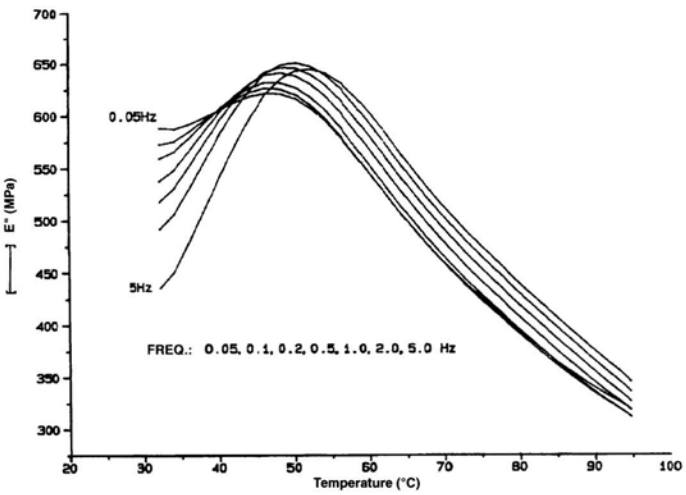


Figure 39. Loss modulus measurements at multiple frequencies for the glass transition region of a 50% long glass fiber-reinforced nylon 6. The T_g shifts to slightly higher temperatures as the frequency increases.

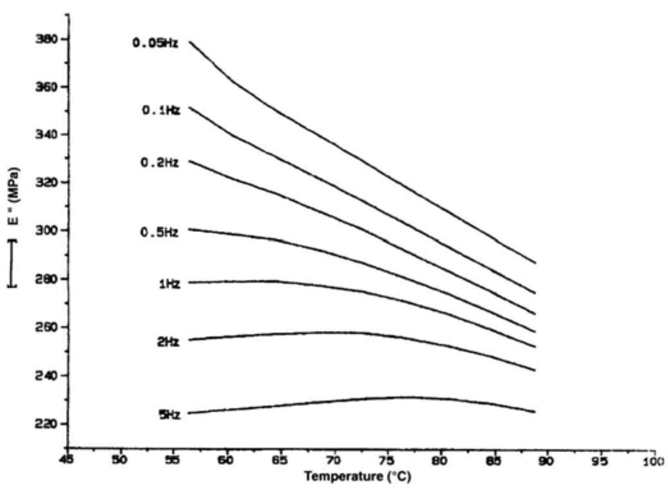


Figure 40. Loss modulus measurements at multiple frequencies for a 40% long glass fiber-reinforced polypropylene.

transition region for a 50% glass fiber-reinforced nylon 6 and a 40% glass fiber-reinforced polypropylene, respectively. In Figure 39, the glass transition for the nylon 6 is well defined by the peaks in the loss modulus curves. The curves were generated at seven frequencies covering two orders of magnitude between 0.05 and 5.0 Hz. As the frequency is increased (time scale is decreased), the glass transition temperature increases slightly from 45-53°C. In Figure 40, the polypropylene glass transition is barely perceptible as a maximum in the loss modulus. Nevertheless, it can be seen that at 0.05 Hz the T_g is below the initial temperature of the test (55°C) while at 5 Hz the peak is near 80°C. Thus, the polypropylene is much more sensitive than the nylon to the effects of the time scale of the measurement.

It is important to remember that the glass transition is a region where loss properties increase and storage properties decrease. The T_g can be thought of as the temperature at which the elastic modulus is declining at the maximum rate. Therefore, an increase in the T_g represents a retardation of viscous flow. We would expect, therefore, that the storage modulus of a polymer would increase as the frequency of the measurement increases since a higher frequency equates to a shorter measurement time frame. Figure 41 shows a multiple frequency sweep between 0.02-2.0 Hz for the storage modulus of a polycarbonate. The temperature range is 97-175°C. As expected, the storage modulus increases with increasing frequency. Below the glass transition, the effects are small. At 97°C the modulus only increases by 6% across the frequency range used in the experiment. Above the glass transition,the storage modulus also appears to be affected very little by frequency. However, in the glass transition region, the effect of the measurement frequency is pronounced. The time scale of the measurement has a profound effect on how the transition is perceived. The shift to higher apparent stiffness with increasing frequency correlates to the increase in T_g that is measured by the loss modulus. Figure 42 shows the same phenomenon for another grade of polycarbonate evaluated between 125-165°C. The smaller temperature range pro-

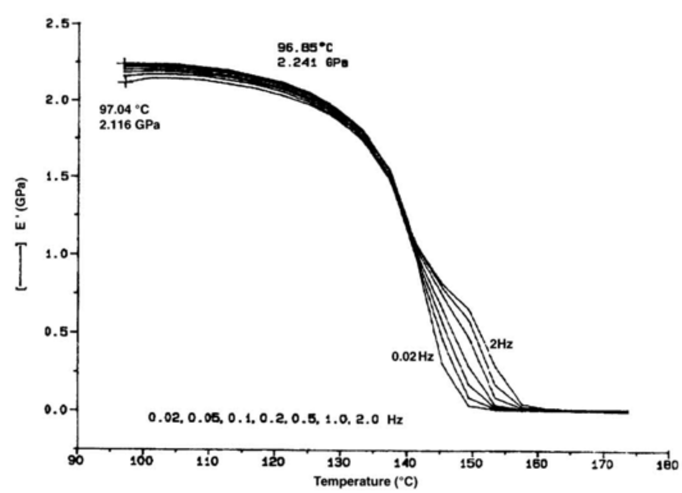


Figure 41. Storage modulus measurements at multiple frequencies for an unfilled polycarbonate. Modulus increases with frequency. Frequency-dependent behavior is most pronounced in the glass transition region.

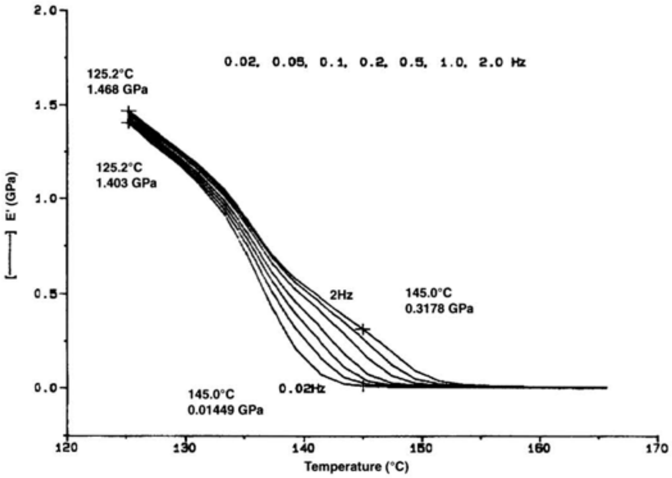


Figure 42. Storage modulus measurements at multiple frequencies for a polycarbonate showing the effects of T_g in greater detail.

vides more detail. At 125°C the modulus increases by 5% across the two decades of frequency. However, the curves begin to separate at 135°C. At 145°C, when the modulus measured at 0.02 Hz has reached the rubbery plateau, the modulus at 2 Hz is over twenty times higher. At 2 Hz, the rubbery plateau is not attained until the test temperature reaches 155°C.

Loss modulus data can be superposed in the same manner as the apparent modulus data from the creep and stress relaxation experiments. If we focus the analysis on the glass transition region we can develop a quantitative relationship between temperature and relaxation time. Figures 43 and 44 show master curve plots of the loss modulus, E", as

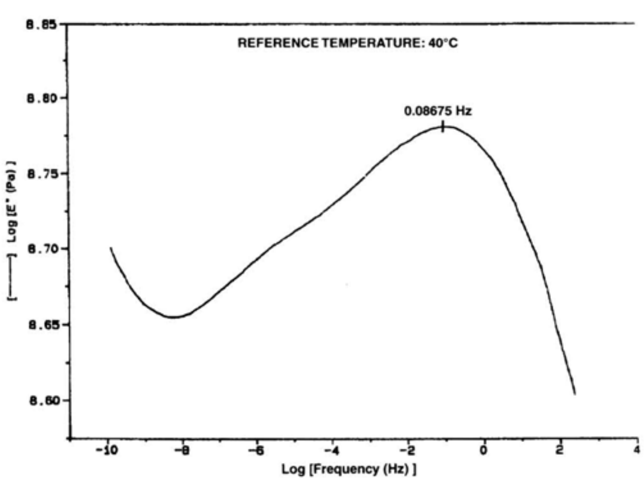


Figure 43. Loss modulus master curve vs. frequency for a 30% carbon fiber-reinforced nylon 6/6 at a reference temperature of 40°C.

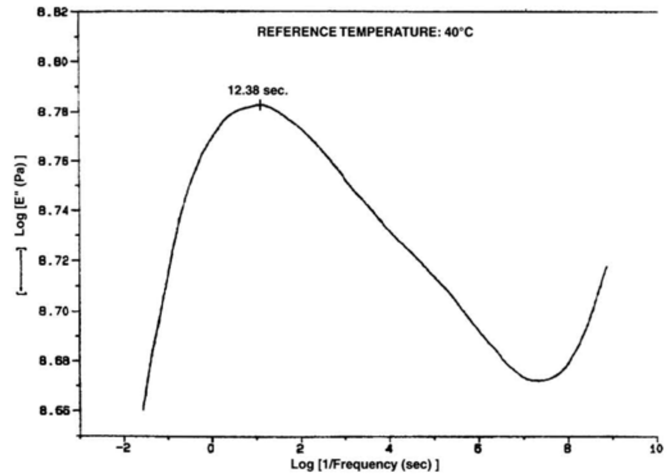


Figure 44. Loss modulus master curve vs. time for the material characterized in Figure 43. Time and frequency are related inversely and this plot is a mirror image of Figure 43. The time at peak is the relaxation time associated with the glass transition when the material is at the reference temperature.

a function of frequency and time (reciprocal frequency), respectively. These results are for a 30% carbon fiber-reinforced nylon 6/6 at a reference temperature of 40°C. Note that the two curves are mirror images of each other. Figure 44 is of particular interest since the time at the peak of the reference curve represents the relaxation time associated with the glass transition when the polymer is at 40°C. Lower reference temperatures will result in longer relaxation times while higher reference temperatures will give shorter relaxation times.

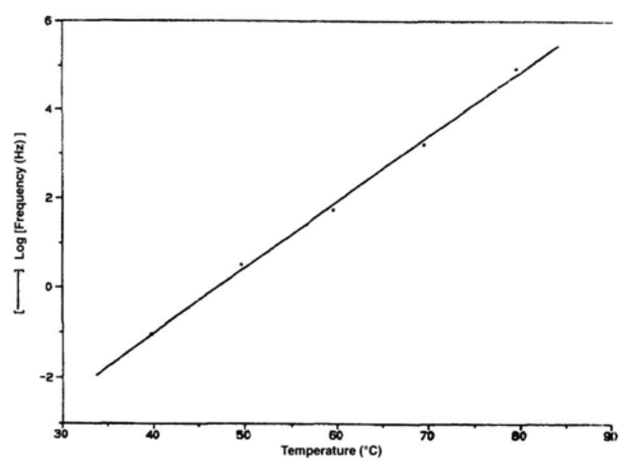


Figure 45. Plot of peak frequency vs. reference temperature for the material characterized in Figures 43 and 44. The data points describe a straight line and the slope of the line is the activation energy of the glass transition.

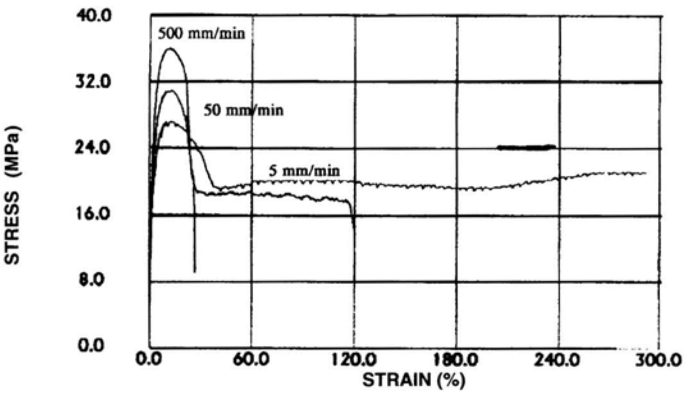


Figure 46a. Tensile stress-strain curves for an unfilled polypropylene copolymer tested at strain rates of 5, 50, and 500 mm/min. Note the increase in modulus and peak stress and the decrease in ultimate elongation as strain rate increases.

Figure 45 shows a plot of the log of the peak frequency of the glass transition versus reference temperature. This is equivalent to a classical Arrhenius plot of log of peak time versus reciprocal temperature. The actual points describe a straight line and the slope of the line is the activation energy of the glass transition.

While this type of information may appear to have its greatest use in the realms of research and development, there is practical significance as well. Materials with low activation energies such as polypropylene are very rate-sensitive; that is the viscoelastic balance is shifted significantly as a function of the rate at which stress is applied. This behavior is measurable in physical terms that are easily understood at the engineering level. If a classical tensile stress-strain test is conducted on a rate-sensitive material like polypropylene, the peak stress and the modulus increase as a function of increasing strain rate. At the same time, the ultimate elongation, a relative measure of toughness, decreases with increasing strain rate. Figure 46a shows this behavior for the full scale of a series of tensile tests. Figure 46b expands the plot to show the detail of the yield section of the test. In Figure 46a it can be seen that the yield stress increases from 26 MPa (3770 psi) at 5 mm/minute to 36 MPa at 500 mm/minute. And while the elongation at yield is virtually unaffected, the ultimate elongation drops from 290% to less than 30%. The slope of the stress-strain plot in the linear region also increases with increasing strain rate. In engineering terms, the material behaves as a stronger, stiffer, and less impact resistant system at higher strain rates; the elastic properties are more dominant. At lower strain rates the material is weaker, more flexible, and tougher; the loss properties become more important. This shift in properties is related to the shift to a lower T_g at lower frequencies (lower strain rates) and a higher T_g at higher frequencies (higher strain rates). In an impact test, higher impact velocities will result in a more brittle failure mode while lower velocities will produce a more ductile break. Here again, the relationship between time and temperature is apparent. It is well known that impact testing at lower temperatures is more likely to produce a brittle failure while tests conducted at higher temperatures will result in a more ductile failure. Thus, reducing the test temperature has the same effect as increasing the strain rate (decreasing the time scale) of the experiment, while increasing the test temperature produces the same result as reducing the strain rate (increasing the time scale) of the test. Materials with higher activation energies, such as polycarbonate, will be less rate-sensitive.

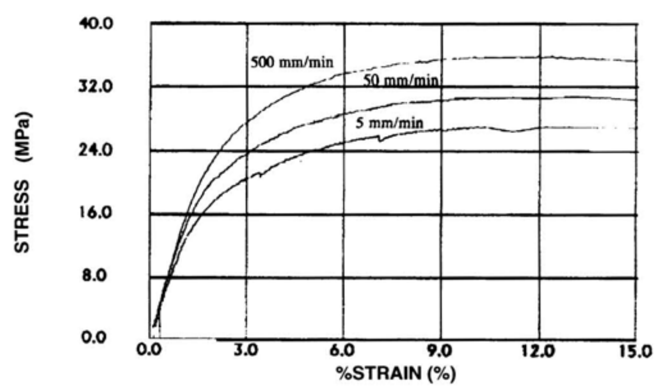


Figure 46b. Tensile stress-strain curves for an unfilled polypropylene copolymer tested at strain rates of 5, 50, and 500 mm/min. The curves have been expanded to show the detail of the yield section of the test.

4.4 Using the Master Curve for Practical Problem Solving

Once a master curve has been constructed, it can be converted to more readily usable terms. For a creep master curve, the apparent modulus versus time plot can be converted into a strain versus time plot by selecting a specific stress. For a stress relaxation master curve, the apparent modulus versus time plot can be changed to a stress versus time plot by selecting a specific strain. It is important to note, however, that these predictive curves will begin to lose accuracy if the selected stresses and strains fall outside the linear elastic region. For this reason, these predictions are best made in conjunction with a stress-strain plot generated at the reference temperature. Even for very rigid systems where the stress-strain plot is essentially linear up to the point of failure, ignoring the practical elongation limits of a material can lead to nonsensical results. As a simple example, refer back to the crosslinked vinyl ester in Figure 36c. The master curve shows a reduction in the apparent modulus of 80% over a 10,000 hour period. Let us assume that the stress-strain behavior of the material is completely linear to the point of failure and that ultimate elongation is 2.5%. An 80% reduction in apparent modulus corresponds to a five-fold increase in the total strain. Since the material can only tolerate an ultimate elongation of 2.5%, the initial elongation cannot exceed 0.5%. Stresses that produce an initial elongation greater than 0.5% will result in creep rupture prior to 10,000 hours. It will be possible to estimate the time to creep rupture from the master curve for initial strains exceeding this limit.

In cases where plastic deformation occurs before yielding or failure, stresses and strains that exceed the proportional limit will cause actual creep or stress relaxation behavior to deviate from the performance predicted by the master curve. Under these circumstances, the master curve will under-predict the time-dependent strain in a creep experiment and under-predict the rate of stress decay in a stress relaxation experiment. Accuracy can be improved by transposing points in the plastic deformation region of the stress-strain curve to an extension of the tangent modulus line and treating the yield point in the curve as the point of failure for the material. Figure 47a and 47b provide an illustration of this technique. Figure 47a shows a creep master curve for a 43% glass-reinforced nylon 6/6 developed at 50°C. Figure 47b shows a stress-strain curve for the same material created at the same temperature. The stress-strain curve identifies the ultimate strain at 3%, however a significant portion of the stress-strain curve departs from linear behavior. If the strain at failure is transposed to the modulus line, the actual strain limit that can be used in conjunction with the master curve is only 1.3%. The maximum initial strain can then be calculated for any given time frame by taking the ratio of the creep moduli at time t_1 and time t_0 and multiplying it by the transposed strain limit. For example, at 10,000 hours the apparent modulus has declined from the initial value of 999,900 psi to 533,600 psi. If the final strain at 10,000 hours cannot exceed 1.3%, then the initial strain cannot exceed 0.69%. The maximum allowable strain can then be taken directly from the stress-strain curve as the point at which the material strain is 0.69%. This would be just below 8000 psi. Further improvements can be made in accuracy by developing stress-strain properties at three different strain rates that are two orders of magnitude apart as shown in Figure 46a. This permits the inclusion of a time function into the evaluation of the proportional limit, peak stress, and elongation at yield/failure.

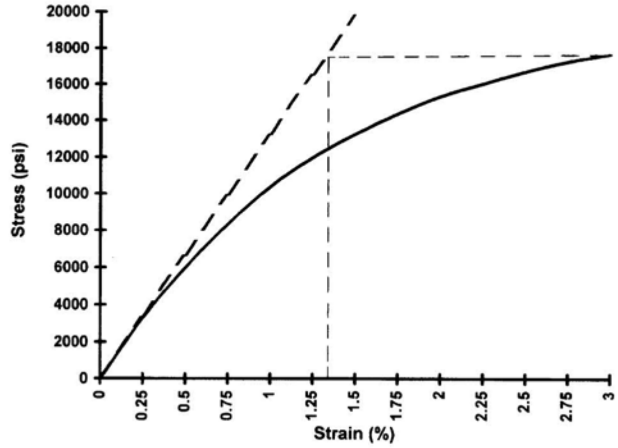


Figure 47b. A stress-strain curve for a 43% glass-reinforced nylon 6/6 generated at 50°C. The maximum strain is transposed to the modulus line in order to simulate the linear behavior characterized by the creep master curve.

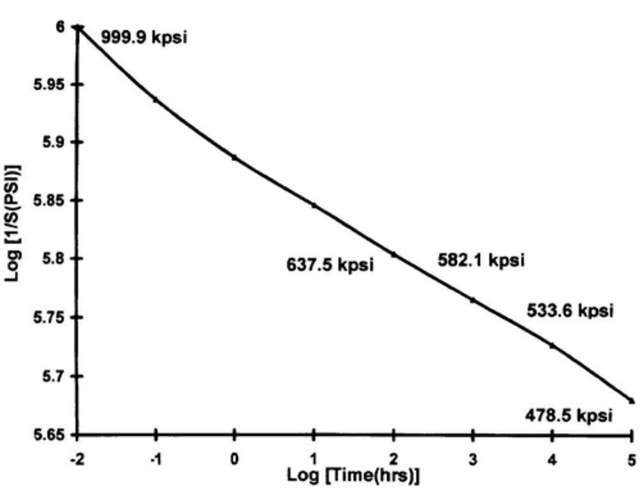


Figure 47a. A creep master curve for a 43% glass-reinforced nylon 6/6 generated at 50°C.

Because dynamic mechanical analysis is such a sensitive structural probe, changes in properties brought about by processing and environmental exposure are readily observed. Most test specimens are injection molded, and orientation of the polymer flow front is an unavoidable consequence of the rapid flow of polymer into the mold cavity. If the material is cooled rapidly to freeze in this orientation, the increased stiffness of the resulting structure is measurable in the storage modulus. If the mold is cold, this frozen-in layer is thicker and contributes even more significantly to the bulk properties of the molded part. Figure 48 shows the effect of melt temperature on the properties of a polypropylene copolymer. The material has a melting point of 165°C. Molding the material just above the melting point produces a relatively rigid system. If the material is heated to 205°C, then the material takes longer to cool from the melt and the frozen-in orientation has time to relax. This produces a more flexible product. If the same molding is conducted with a mold temperature of 70°C instead of 30°C, as in Figure 49, the differences are still apparent but much less significant. The properties of the part molded with a melt temperature of 205°C are virtually unchanged while the part molded with a melt temperature of 170°C is significantly influenced by the slower cooling rate associated with the higher mold temperature.

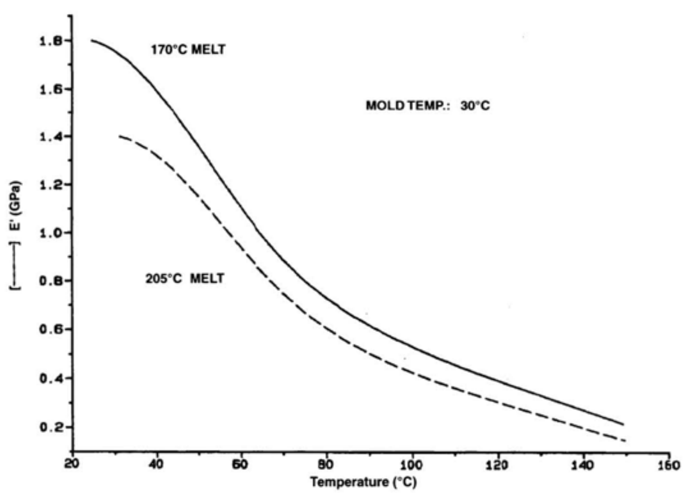


Figure 48. Effects of melt temperature on the storage modulus properties of an unfilled polypropylene run in a cool mold.

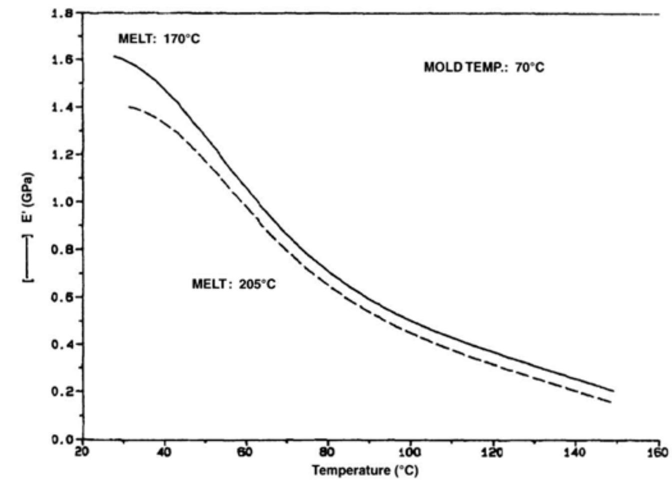


Figure 49. Effects of melt temperature on the storage modulus properties of an unfilled polypropylene run in a hot mold. Note that the modulus of the cold melt samples is reduced significantly in the hotter mold while the high melt product is unchanged.

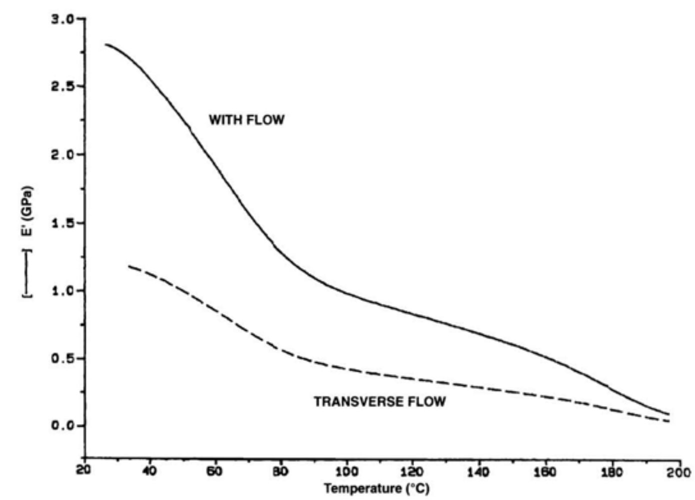


Figure 50. The effects of fiber orientation on the storage modulus properties of a 30% glass fiber-reinforced polyurethane.

Orientation of fillers, and particularly fibrous reinforcements, has a substantial effect on the storage modulus. Figure 50 shows a modulus plot for samples cut in the direction of flow and transverse to the direction of flow for a 30% glass fiber-reinforced polyurethane. The loss of fiber orientation reduces the room temperature modulus by 60% and the properties do not converge until the material is near the melting point.

Some semi-crystalline materials have backbone structures that require longer times in order to develop the full potential of the crystalline matrix. This additional time is provided by slowing the rate of cooling in the polymer, an adjustment achieved by raising the temperature of the mold into which the polymer is injected. Failure to use the correct mold temperature results in a system that is under-crystallized. Reductions in storage modulus and the glass transition temperature are typical consequences. In addition, the degree of decline in the storage modulus as the material passes through the glass transition will be exaggerated. In extreme cases modulus increases above T_g give evidence of solid-state crystallization as the polymer attempts to achieve the crystallinity that was supposed to have been established during the molding process. Figure 51 shows a storage modulus plot for poly(phenylene sulfide) (PPS) samples molded at five different mold temperatures. The most significant problems are apparent in the material molded at the lowest mold temperature. Room-temperature modulus is 35% below normal, T_g is reduced by 20ºC, and the modulus drops to 1 GPa (145,000 psi) at the end of the glass transition before undergoing residual crystallization. As the mold temperature is increased, the room temperature properties improve, but the modulus reductions associated with T_g are still excessive and residual crystallization is still apparent. At the highest mold temperature, the post-T_g modulus is optimized, a direct result of achieving a high degree of crystallinity

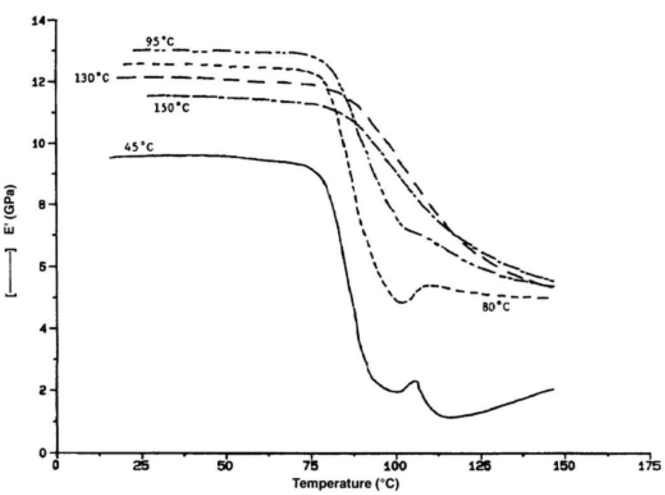


Figure 51. Effect of mold temperature on the storage modulus properties of a 40% glass fiber-reinforced PPS. The reduced modulus and lower glass transition temperature are the result of incomplete crystallization during molding.

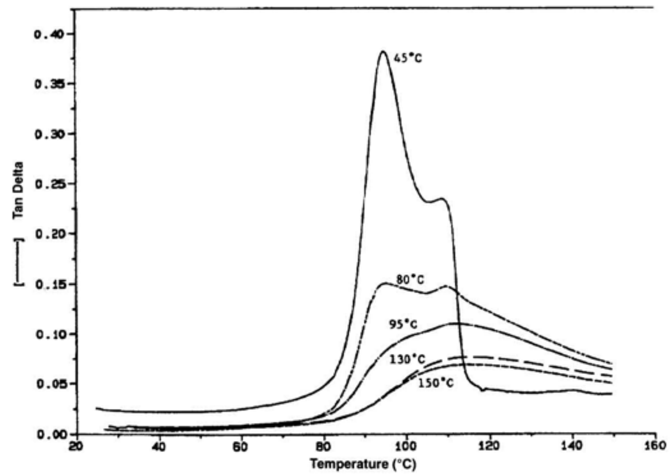


Figure 52. Tan delta properties for the samples from Figure 50. The reduced crystallinity results in a higher potential for viscous flow as the material passes through T_g.

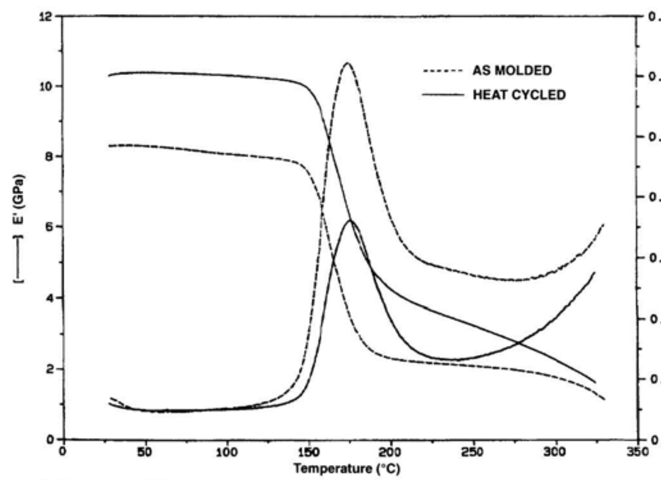


Figure 53. Effects of short-term heat aging on the viscoelastic properties of 30% glass fiber-reinforced PEEK. The increased storage modulus and decreased tan delta values indicate the occurrence of secondary crystallization.

during the molding process. Figure 52 shows the tan delta properties associated with the five samples. The highest tan delta peak values and lowest peak temperatures are associated with the lowest degrees of crystallinity.

Prolonged heat aging can also produce changes in crystal structure. Figure 53 shows a semi-crystalline PEEK material in the as-molded state and after a brief exposure to temperatures near the HDT. Both the storage modulus and tan delta curves are shown. These illustrate that the material is stiffer both above and below the T_g after aging. The tan delta peak temperatures do not change, indicating that the T_g remains the same. However, the lower tan delta peak height confirms that the material has undergone residual crystallization due to the high temperature exposure. Similar phenomena are detectable in almost all semi-crystalline systems. Post-curing of crosslinked thermoset polymers produces similar results.

Absorption of solvents and plasticizers can also produce structural changes detectable by DMA. Figure 54 shows the effect of absorbed moisture on the storage modulus of an unfilled nylon 6. As the moisture content increases, the room temperature modulus decreases. A plot of the loss modulus would show that the glass transition is being reduced by the presence of the moisture, the water acting as a plasticizer for the nylon. Note, however, that the modulus above T_g is unchanged. This is an indication that the moisture is absorbed preferentially by those regions of the nylon polymer that do not crystallize. The modulus attributable to the crystalline portion of the polymer is unaffected by the presence of the water. Figure 55 shows the storage and loss modulus plots for a plasticized PVC in its new state and after field exposure that had turned the product brittle. The loss of plasticizer in the field material had increased the T_g to the point where the product was no longer flexible at room temperature and the product began to crack under the effect of applied stresses.

Figure 56 shows the effects of the absorption of methyl ethyl ketone (MEK) on the storage modulus properties of a PBT polyester/polycarbonate alloy. After immersion for thirty days the material loses 70% of its room-temperature modulus and has little

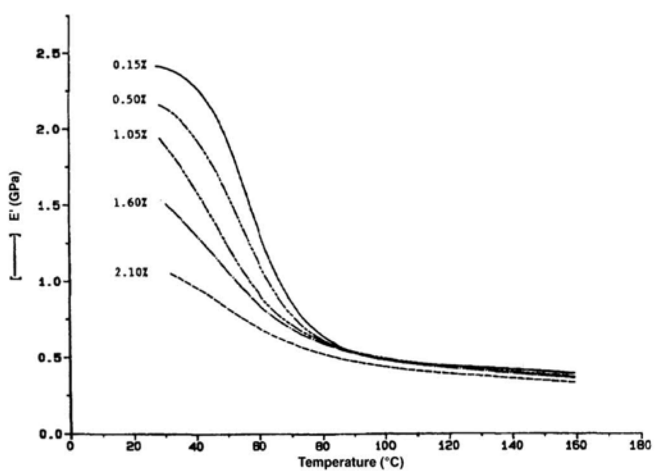


Figure 54. The effect of moisture content on the storage modulus properties of an unfilled nylon 6.

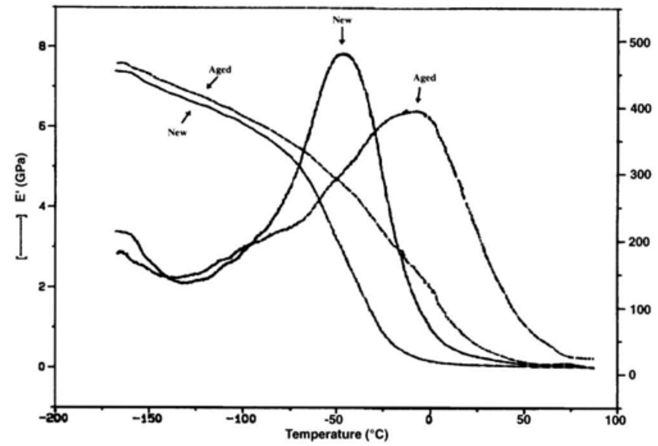


Figure 55. The effect of plasticizer loss on the storage and loss properties of a flexible PVC. The rise in T_g results in the embrittlement of the compound.

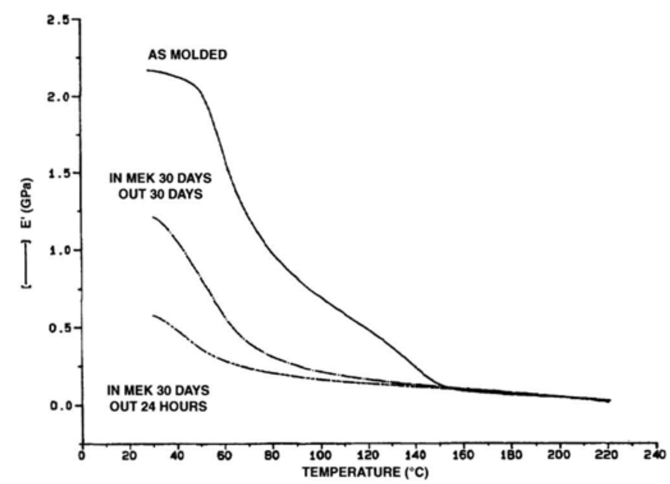


Figure 56. Effects of immersion in methyl ethyl ketone (MEK) on the storage properties of an unfilled PBT/polycarbonate blend. Properties are partially restored after a 30-day drying out period.

usefulness as a load-bearing material. After drying out, some of the properties are restored but somedamage is still evident. Figure 57 shows the tan delta plots for the three materials. The as-molded material shows the two glass transitions, a shoulder near 70°C for the PBT and a strong peak near 150°C for the polycarbonate. Both transitions are absent after the thirty days of immersion. Upon drying out, the PBT glass transition once again appears, however the polycar-bonate T_g has not returned. This allows us to conclude that while the PBT may have absorbed some of the MEK, the effects were reversible. The polycarbonate, however, was chemically attacked by the MEK

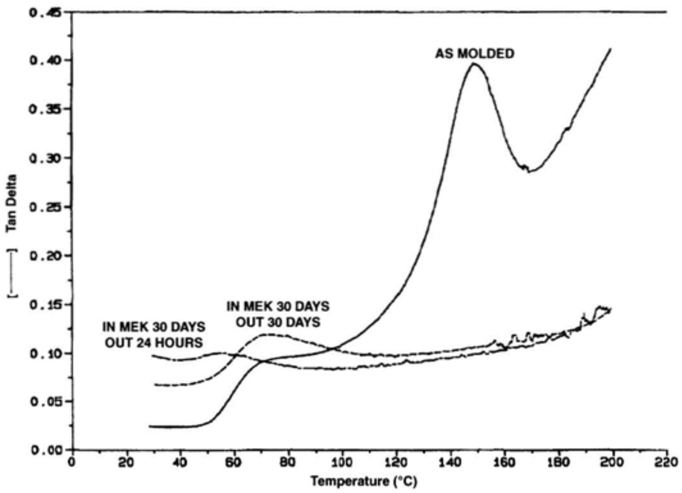


Figure 57. Effects of solvent immersion on tan delta properties of PBT/polycarbonate blend. The disappearance of the polycarbonate T_g indicates that permanent damage was done to this phase of the blend.

and suffered permanent damage. The property recovery was solely due to the drying out of the PBT phase. These are a few of the major changes in structure brought about by processing and environmental conditions that can be interpreted by dynamic mechanical analysis.

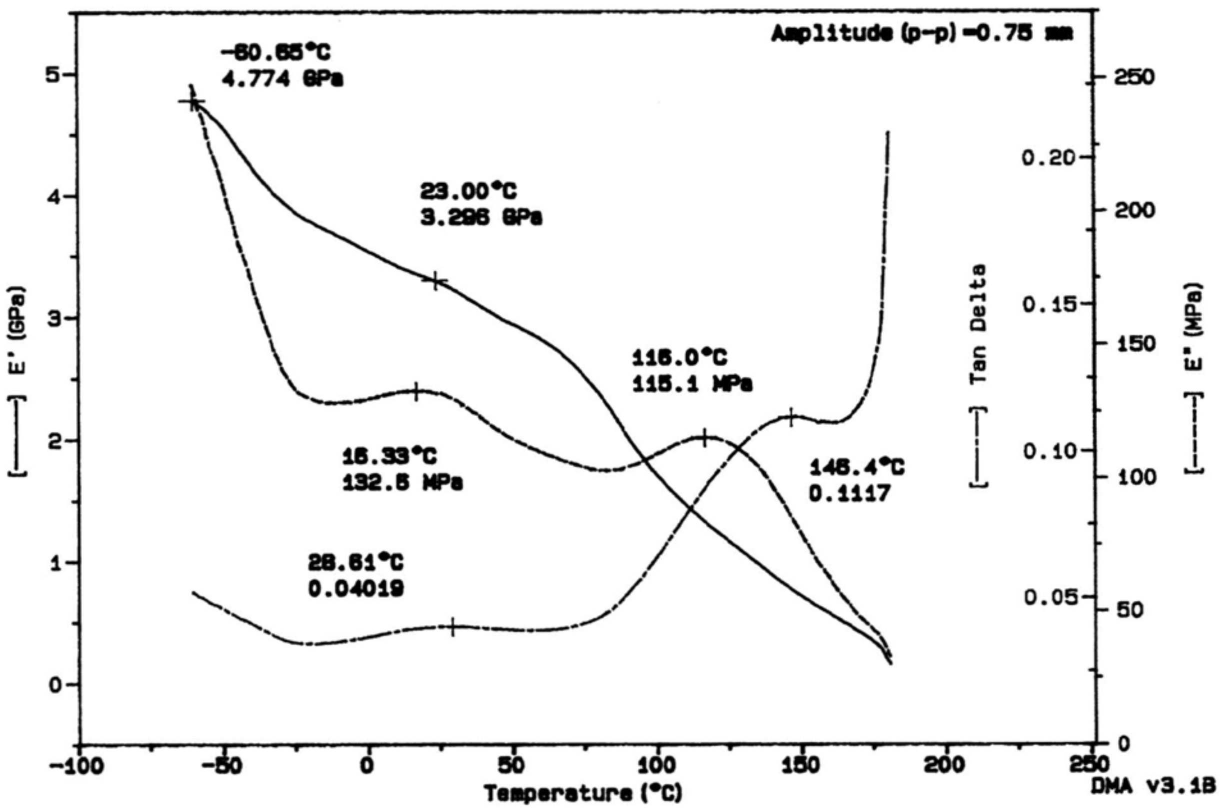
6 Conclusions

Dynamic mechanical analysis is a powerful tool for probing the fundamental structure of polymeric materials. At the same time, the technique produces valuable practical information on the temperature-dependent and time-dependent properties that are so essential to an informed material selection process. With the development of structural analysis programs for plastic materials, the need for accurate property profiles has become even greater. DMA data contributes significantly to the information gap that currently exists in the study of plastic materials.

References

1. M. Takemori, SPE ANTEC, 24, 216. (1978)
2. J. Bozzelli & P. Tiffany, SPE ANTEC, 32, 120. (1986)
3. W. J. Sichina, SPE ANTEC, 34, 1139. (1988)

Graph 1: Storage and loss properties for DuPont Delrin 500 unfilled acetal homopolymer (POM).



Graph 2: Storage and loss properties for DuPont Delrin 577 20% glass fiber filled, UV stable acetal homopolymer (POM).

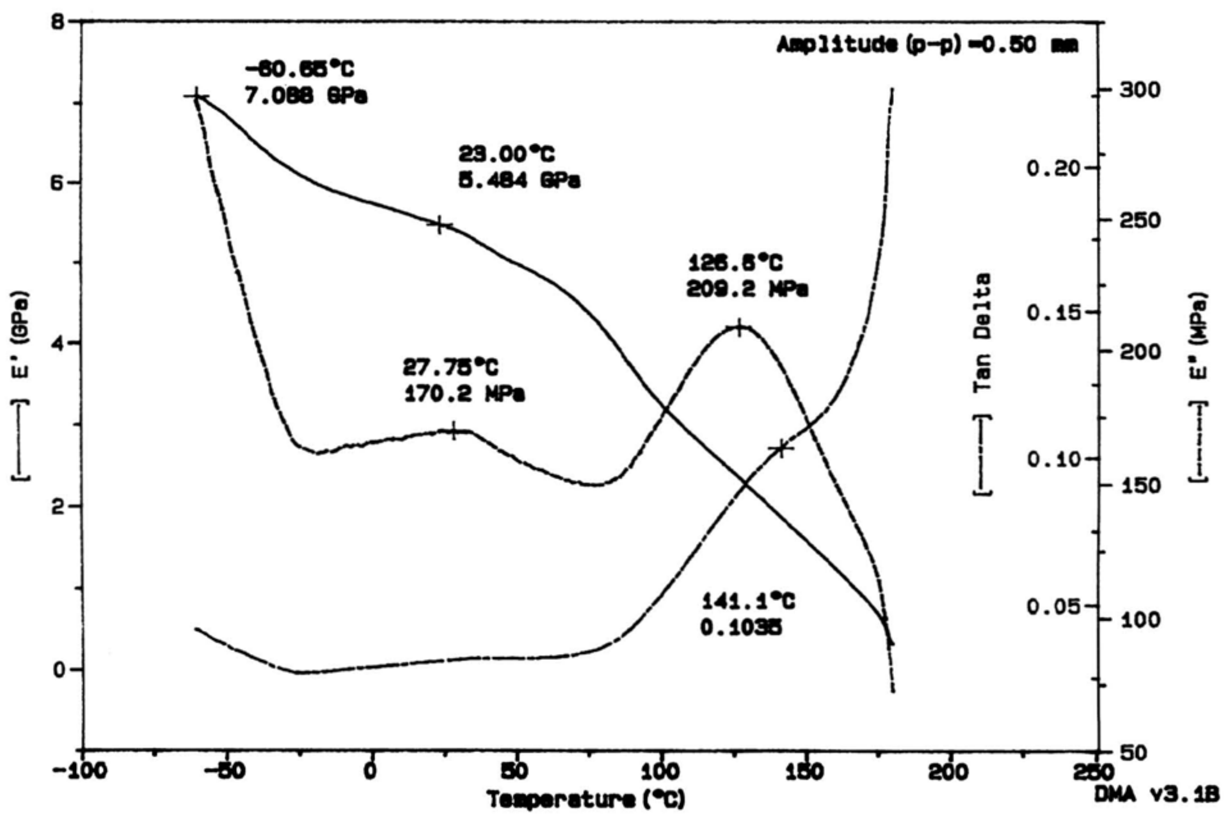


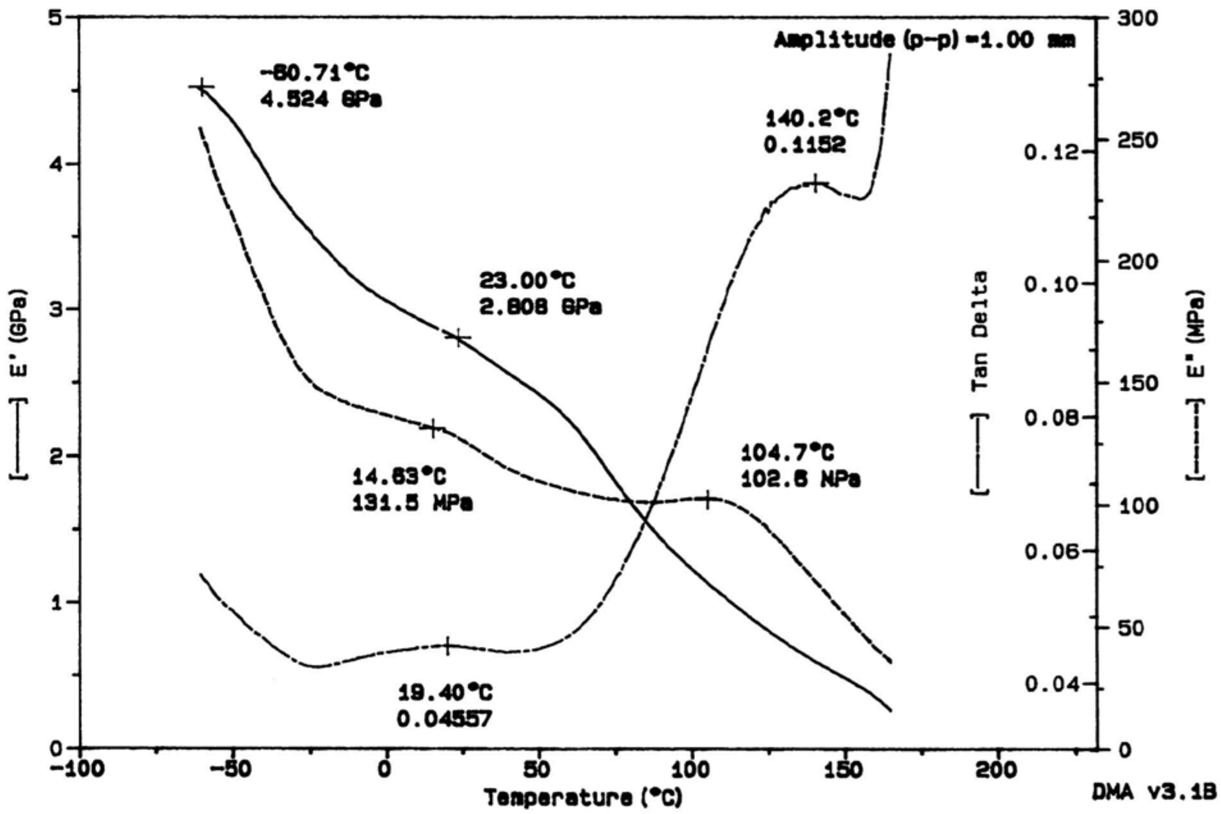
Table 1: Storage and loss properties for DuPont Delrin 500 unfilled acetal homopolymer (POM). (tabular data for Graph 1)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	4.768	245.8	0.05156	70.00	2.635	105.6	0.04009
-55.00	4.674	226.4	0.04845	60.00	2.816	109.5	0.03889
-50.00	4.554	209.7	0.04605	65.00	2.737	107.6	0.03931
-45.00	4.392	190.1	0.04329	70.00	2.635	105.6	0.04009
-40.00	4.227	173.4	0.04101	75.00	2.512	104.0	0.04142
-35.00	4.082	156.3	0.03829	80.00	2.369	102.7	0.04338
-30.00	3.957	141.7	0.03582	85.00	2.201	102.9	0.04676
-25.00	3.855	133.1	0.03454	90.00	2.010	104.2	0.05186
-20.00	3.781	129.9	0.03436	95.00	1.846	106.3	0.05762
-15.00	3.719	128.3	0.03450	100.00	1.698	109.1	0.06427
-10.00	3.659	128.2	0.03504	105.00	1.572	111.7	0.07104
-5.00	3.597	128.7	0.03577	110.00	1.456	114.0	0.07830
0.00	3.535	129.6	0.03668	115.00	1.347	115.1	0.08545
5.00	3.476	130.9	0.03765	120.00	1.249	114.9	0.09196
10.00	3.417	132.0	0.03863	125.00	1.155	113.0	0.09785
15.00	3.368	132.7	0.03939	130.00	1.061	109.3	0.1030
20.00	3.324	132.5	0.03988	135.00	0.9720	104.2	0.1072
25.00	3.276	131.7	0.04021	140.00	0.8773	96.68	0.1102
30.00	3.216	129.3	0.04020	145.00	0.7876	87.98	0.1117
35.00	3.144	125.8	0.04000	150.00	0.7054	78.76	0.1116
40.00	3.073	121.8	0.03964	155.00	0.6304	69.58	0.1104
45.00	3.000	118.0	0.03932	160.00	0.5608	61.58	0.1098
50.00	2.940	114.6	0.03899	165.00	0.4890	54.19	0.1108
55.00	2.881	112.0	0.03886	170.00	0.4129	47.75	0.1156
60.00	2.816	109.5	0.03889	175.00	0.3329	42.56	0.1279
65.00	2.737	107.6	0.03931	180.00	0.1723	33.71	0.1964

Table 2: Storage and loss properties for DuPont Delrin 577 20% glass fiber filled, UV stable acetal homopolymer (POM). (tabular data for Graph 2)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
65.00	4.690	152.6	0.03253	50.00	4.990	159.0	0.03187
70.00	4.551	150.9	0.03316	55.00	4.903	156.6	0.03195
75.00	4.382	150.0	0.03424	60.00	4.806	154.6	0.03218
-60.00	7.082	293.6	0.04145	80.00	4.183	150.2	0.03590
-55.00	6.971	268.1	0.03846	85.00	3.951	152.7	0.03865
-50.00	6.834	246.9	0.03612	90.00	3.697	158.6	0.04290
-45.00	6.664	225.3	0.03381	95.00	3.456	166.8	0.04825
-40.00	6.493	204.8	0.03153	100.00	3.249	175.2	0.05394
-35.00	6.342	186.1	0.02934	105.00	3.068	183.9	0.05994
-30.00	6.213	172.1	0.02770	110.00	2.897	193.1	0.06665
-25.00	6.101	164.0	0.02688	115.00	2.735	200.6	0.07337
-20.00	6.001	162.0	0.02699	120.00	2.575	206.3	0.08011
-15.00	5.920	162.2	0.02740	125.00	2.418	208.9	0.08643
-10.00	5.856	164.1	0.02801	130.00	2.252	208.5	0.09260
-5.00	5.795	164.8	0.02845	135.00	2.086	204.3	0.09796
0.00	5.743	165.7	0.02886	140.00	1.918	196.9	0.1026
5.00	5.690	166.8	0.02932	145.00	1.753	187.0	0.1067
10.00	5.632	166.8	0.02961	150.00	1.589	175.2	0.1103
15.00	5.572	168.7	0.03027	155.00	1.426	163.3	0.1146
20.00	5.518	169.0	0.03062	160.00	1.261	151.5	0.1202
30.00	5.391	169.4	0.03142	165.00	1.083	140.6	0.1298
35.00	5.296	169.0	0.03191	170.00	0.9024	129.3	0.1433
40.00	5.185	165.6	0.03194	175.00	0.6939	115.6	0.1667
45.00	5.080	162.5	0.03199	180.00	0.3255	73.48	0.2263

Graph 3: Storage and loss properties for Ticona Celcon M90 unfilled acetal copolymer (POM copolymer).



Graph 4: Storage and loss properties for Ticona Celcon M90 unfilled acetal copolymer (POM copolymer) showing low temperature behavior.

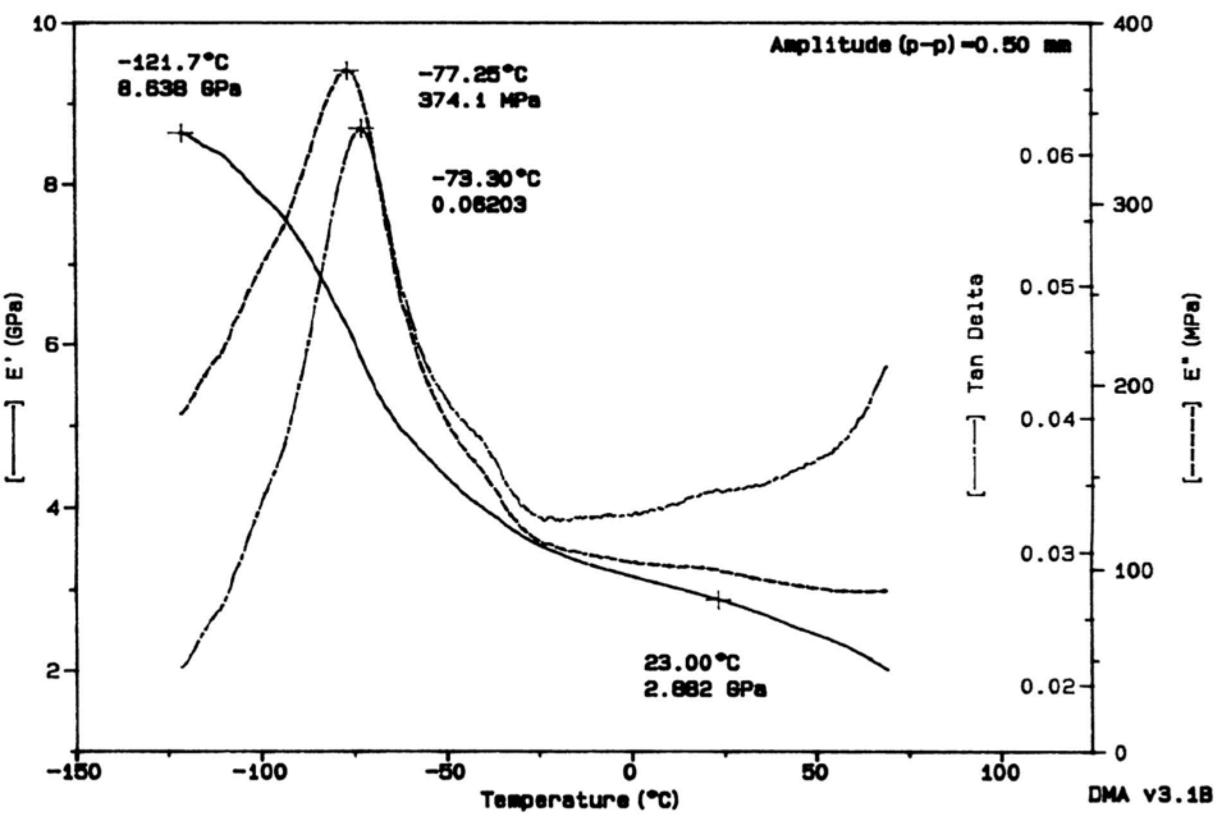


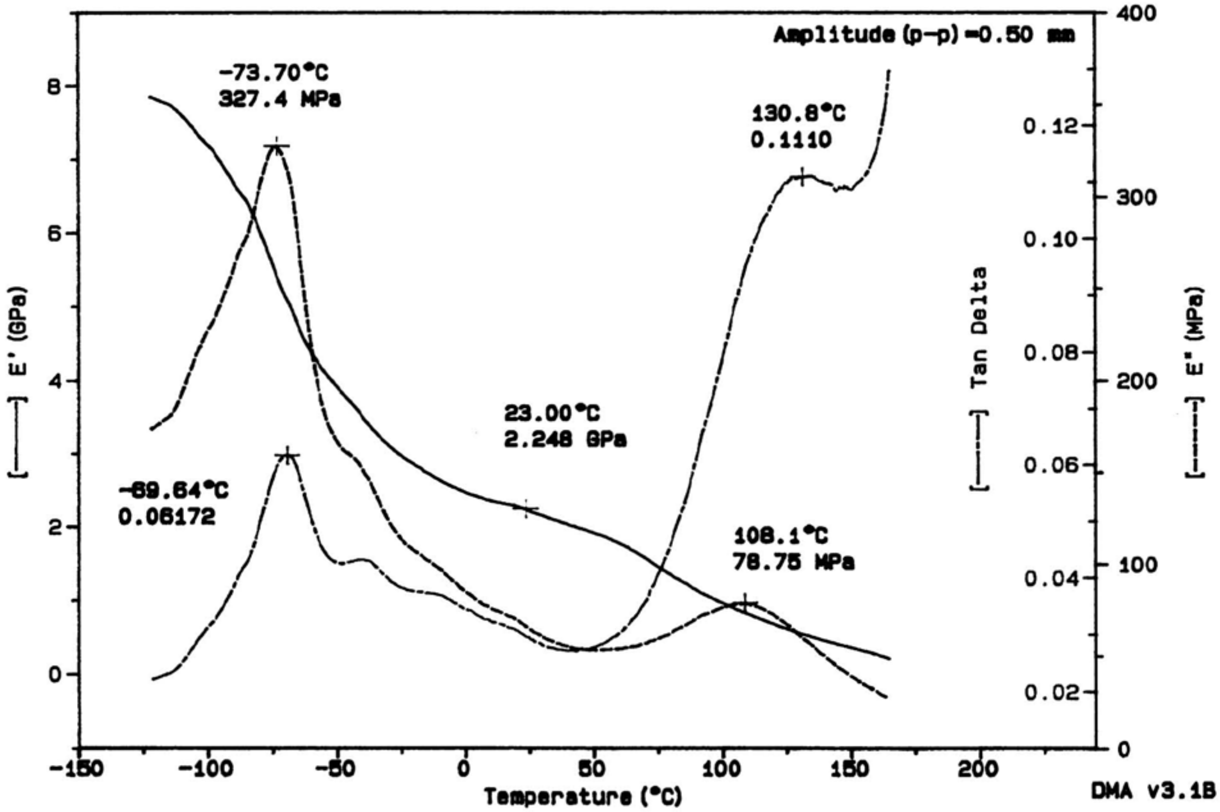
Table 3: Storage and loss properties for Ticona Celcon M90 unfilled acetal copolymer (POM copolymer). (tabular data for Graph 3)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	4.514	252.0	0.05583
-55.00	4.422	233.5	0.05281
-50.00	4.308	218.9	0.05081
-45.00	4.157	201.1	0.04837
-40.00	3.989	186.0	0.04662
-35.00	3.813	170.8	0.04479
-30.00	3.673	159.0	0.04330
-25.00	3.549	150.6	0.04242
-20.00	3.430	145.8	0.04251
-15.00	3.317	142.8	0.04304
-10.00	3.215	140.2	0.04362
-5.00	3.132	138.3	0.04417
0.00	3.065	136.7	0.04461
5.00	3.004	134.9	0.04491
10.00	2.946	133.4	0.04527
15.00	2.890	131.4	0.04548
20.00	2.843	129.5	0.04557
25.00	2.782	126.2	0.04536
30.00	2.712	122.3	0.04508
35.00	2.640	118.2	0.04478
40.00	2.568	114.6	0.04463
45.00	2.498	111.7	0.04474
50.00	2.425	109.5	0.04517
55.00	2.344	107.7	0.04595
60.00	2.245	106.0	0.04719
65.00	2.124	104.5	0.04919
70.00	1.981	103.0	0.05199
75.00	1.832	102.4	0.05586
80.00	1.688	101.4	0.06010
85.00	1.556	101.1	0.06501
90.00	1.436	101.3	0.07051
95.00	1.330	101.9	0.07666
100.00	1.232	102.6	0.08328
105.00	1.138	102.7	0.09018
110.00	1.051	101.8	0.09682
115.00	0.9650	99.17	0.1028
120.00	0.8830	95.19	0.1078
125.00	0.8055	89.30	0.1109
130.00	0.7320	83.23	0.1137
135.00	0.6630	76.10	0.1148
140.00	0.5999	69.11	0.1152
145.00	0.5412	62.01	0.1146
150.00	0.4830	54.78	0.1134
155.00	0.4240	47.83	0.1128
160.00	0.3532	41.24	0.1168

Table 4: Storage and loss properties for Ticona Celcon M90 unfilled acetal copolymer (POM copolymer) showing low temperature behavior. (tabular data for Graph 4)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-120.00	8.613	188.0	0.02182
-115.00	8.464	206.2	0.02437
-110.00	8.340	220.5	0.02644
-105.00	8.113	243.1	0.02996
-100.00	7.862	265.4	0.03376
-95.00	7.644	283.5	0.03708
-90.00	7.317	310.6	0.04245
-85.00	6.927	341.8	0.04935
-80.00	6.483	367.6	0.05670
-75.00	6.026	371.0	0.06156
-70.00	5.512	331.2	0.06009
-65.00	5.119	273.8	0.05349
-60.00	4.844	231.7	0.04784
-55.00	4.592	200.8	0.04371
-50.00	4.359	180.4	0.04139
-45.00	4.147	164.4	0.03963
-40.00	3.980	152.1	0.03820
-35.00	3.818	136.1	0.03566
-30.00	3.660	122.5	0.03345
-25.00	3.538	115.4	0.03261
-20.00	3.444	111.8	0.03246
-15.00	3.358	109.6	0.03263
-10.00	3.287	107.4	0.03266
-5.00	3.225	105.7	0.03277
0.00	3.162	103.7	0.03279
5.00	3.102	103.1	0.03323
10.00	3.043	102.0	0.03352
15.00	2.984	101.7	0.03409
20.00	2.921	100.7	0.03448
25.00	2.854	98.81	0.03462
30.00	2.782	96.79	0.03479
35.00	2.703	94.67	0.03503
40.00	2.612	92.95	0.03559
45.00	2.520	91.42	0.03628
50.00	2.439	90.04	0.03691
55.00	2.353	88.78	0.03773
60.00	2.249	88.33	0.03928
65.00	2.120	88.40	0.04169

Graph 5: Storage and loss properties for Ticona Celcon TX90 unfilled, impact modified acetal copolymer (POM copolymer).



Graph 6: Storage and loss properties for Ticona Celcon GC25A 25% glass fiber filled acetal copolymer (POM copolymer).

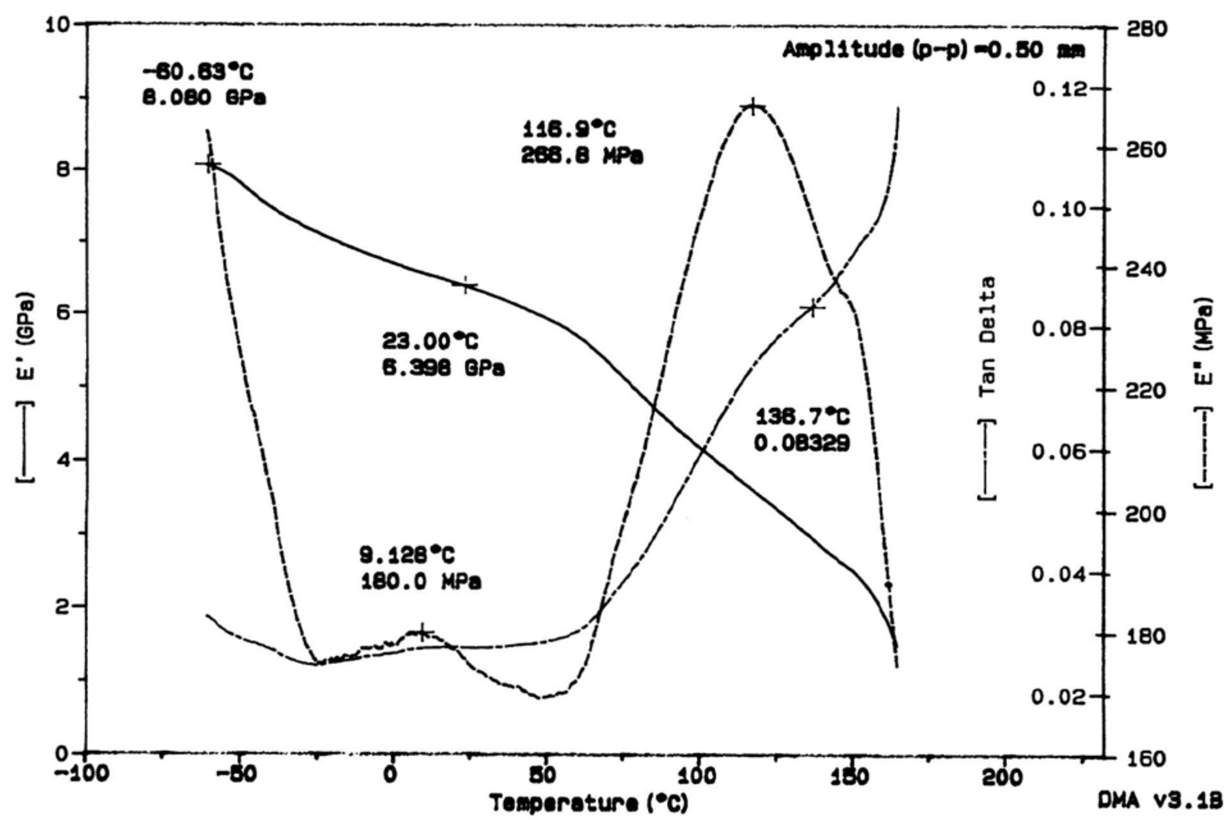


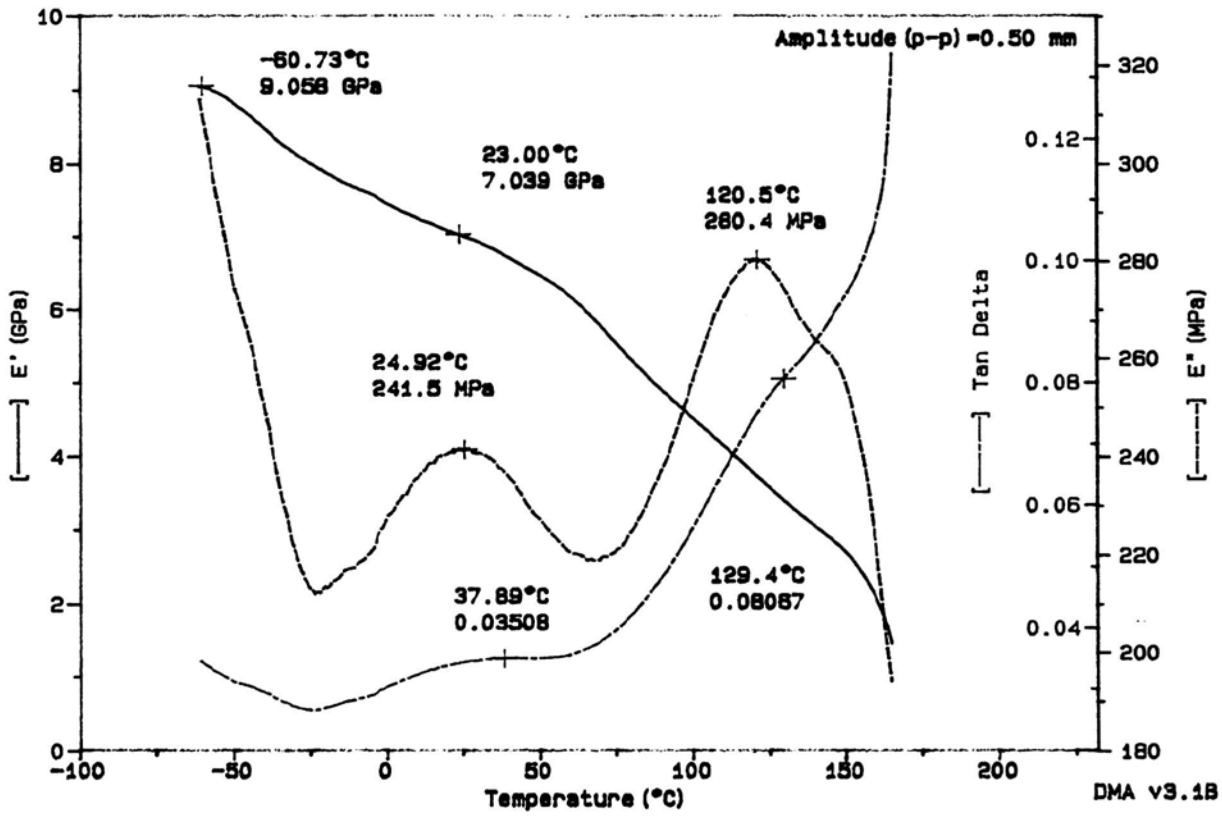
Table 5: Storage and loss properties for Ticona Celcon TX90 unfilled, impact modified acetal copolymer (POM copolymer). (tabular data for Graph 5)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
20.00	2.284	70.04	0.03067
-120.00	7.846	175.0	0.02230
-115.00	7.771	180.2	0.02319
-110.00	7.643	191.5	0.02506
-105.00	7.442	210.6	0.02830
-100.00	7.233	226.6	0.03132
-95.00	7.021	240.3	0.03423
-90.00	6.738	259.6	0.03853
-85.00	6.489	276.7	0.04264
-80.00	6.125	301.8	0.04927
-75.00	5.662	325.4	0.05748
-70.00	5.201	320.8	0.06168
-65.00	4.816	282.9	0.05875
-60.00	4.435	224.0	0.05049
-55.00	4.163	186.2	0.04472
-50.00	3.947	168.1	0.04260
-45.00	3.748	160.5	0.04283
-40.00	3.538	152.7	0.04316
-35.00	3.321	139.3	0.04193
-30.00	3.145	125.1	0.03977
-25.00	2.988	114.1	0.03819
-20.00	2.870	107.8	0.03756
-15.00	2.755	102.8	0.03731
-10.00	2.646	97.59	0.03687
-5.00	2.557	91.30	0.03571
0.00	2.478	85.35	0.03444
5.00	2.412	79.99	0.03316
10.00	2.359	76.08	0.03226
15.00	2.321	73.24	0.03156
25.00	2.223	65.32	0.02939
30.00	2.159	60.61	0.02807
35.00	2.097	57.48	0.02742
40.00	2.037	55.21	0.02711
45.00	1.979	54.02	0.02730
50.00	1.921	53.54	0.02787
55.00	1.858	53.63	0.02887
60.00	1.781	54.07	0.03036
65.00	1.687	55.30	0.03278
70.00	1.578	56.97	0.03610
75.00	1.461	59.75	0.04090
80.00	1.352	62.82	0.04645
85.00	1.247	66.47	0.05332
90.00	1.142	70.39	0.06166
95.00	1.049	73.81	0.07039
100.00	0.9667	76.86	0.07951
105.00	0.8838	78.36	0.08867
110.00	0.8129	78.49	0.09657
115.00	0.7441	76.20	0.1024
120.00	0.6757	72.22	0.1069
125.00	0.6118	67.22	0.1099
130.00	0.5535	61.39	0.1109
135.00	0.5008	55.58	0.1110
140.00	0.4518	49.60	0.1098
145.00	0.4055	44.05	0.1086
150.00	0.3607	39.21	0.1087
155.00	0.3155	34.97	0.1108
160.00	0.2665	30.84	0.1157

Table 6: Storage and loss properties for Ticona Celcon GC25A 25% glass fiber filled acetal copolymer (POM copolymer). (tabular data for Graph 6)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.076	261.9	0.03242
-55.00	7.986	241.4	0.03023
-50.00	7.845	226.5	0.02887
-45.00	7.662	215.0	0.02805
-40.00	7.499	203.5	0.02713
-35.00	7.363	190.0	0.02581
-30.00	7.248	180.4	0.02489
-25.00	7.140	175.3	0.02455
-20.00	7.042	175.7	0.02494
-15.00	6.949	176.2	0.02535
-10.00	6.859	177.5	0.02588
-5.00	6.781	177.5	0.02618
0.00	6.705	178.0	0.02655
5.00	6.627	179.7	0.02712
10.00	6.560	179.8	0.02740
15.00	6.502	178.8	0.02750
20.00	6.436	177.3	0.02755
25.00	6.369	174.8	0.02745
30.00	6.295	173.1	0.02749
35.00	6.216	171.6	0.02760
40.00	6.132	171.1	0.02790
45.00	6.041	169.8	0.02812
50.00	5.949	169.5	0.02849
55.00	5.844	170.1	0.02911
60.00	5.715	172.2	0.03013
65.00	5.554	178.0	0.03204
70.00	5.366	187.8	0.03501
75.00	5.159	197.5	0.03827
80.00	4.951	206.1	0.04163
85.00	4.744	216.2	0.04558
90.00	4.554	227.3	0.04991
95.00	4.372	238.0	0.05444
100.00	4.203	247.8	0.05895
105.00	4.036	256.3	0.06351
110.00	3.870	262.7	0.06788
115.00	3.703	266.4	0.07196
120.00	3.541	266.6	0.07528
125.00	3.378	263.8	0.07810
130.00	3.211	258.2	0.08041
135.00	3.041	251.2	0.08262
140.00	2.861	243.4	0.08509
145.00	2.692	237.6	0.08825
150.00	2.536	233.3	0.09199
155.00	2.318	221.4	0.09552
160.00	1.975	198.3	0.1004

Graph 7: Storage and loss properties for Ticona Celcon CFX-0108 25% glass fiber filled, UV stable acetal copolymer (POM copolymer).



Graph 8: Storage and loss properties for AtoHaas Plexiglas MI-7 unfilled, impact modified acrylic (PMMA).

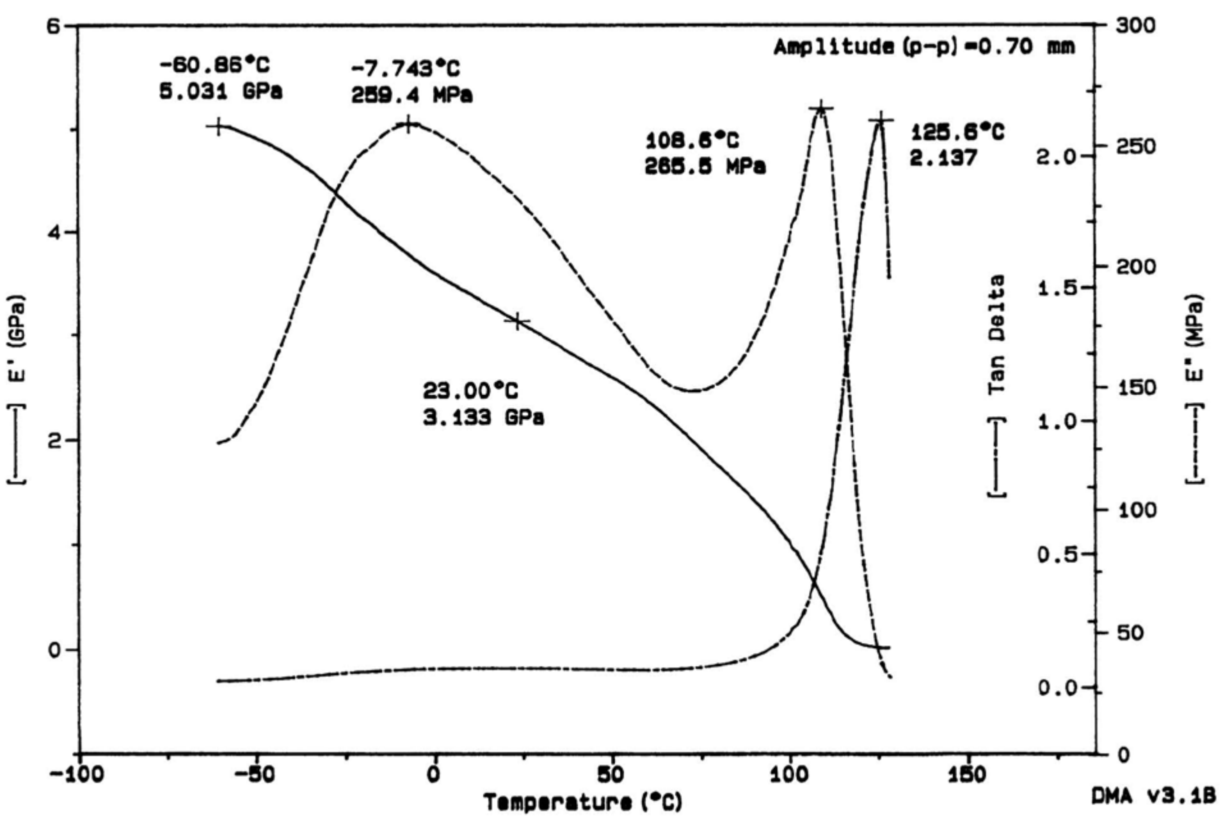


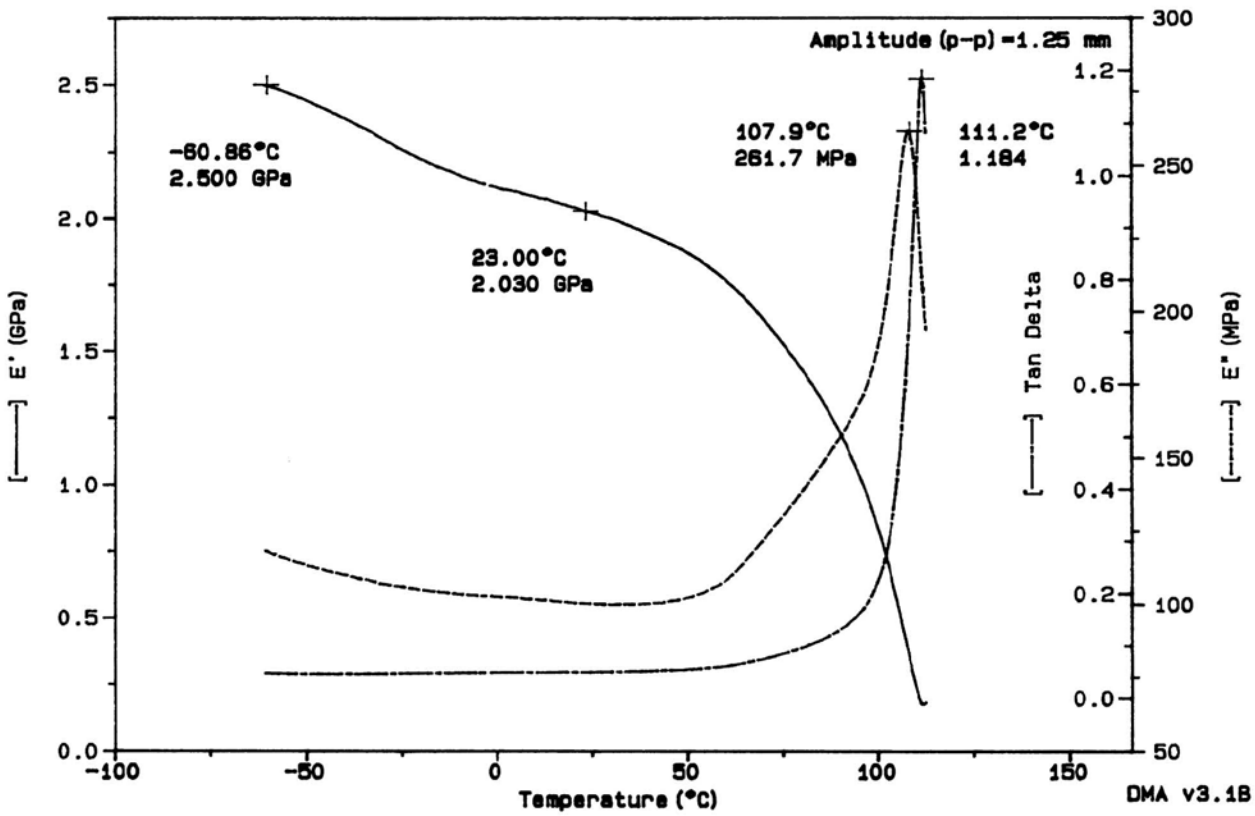
Table 7: Storage and loss properties for Ticona Celcon CFX-0108 25% glass fiber filled, UV stable acetale copolymer (POM copolymer). (tabular data for Graph 7)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.056	310.8	0.03432	55.00	6.349	223.8	0.03526
-55.00	8.981	293.3	0.03266	60.00	6.192	220.7	0.03564
-50.00	8.850	276.5	0.03124	65.00	6.000	219.5	0.03658
-45.00	8.691	265.3	0.03053	70.00	5.779	219.3	0.03795
-40.00	8.509	251.3	0.02953	75.00	5.546	221.0	0.03984
-35.00	8.315	234.5	0.02821	80.00	5.315	224.9	0.04231
-30.00	8.158	221.3	0.02712	85.00	5.100	230.6	0.04522
-25.00	8.020	213.4	0.02661	90.00	4.899	237.6	0.04850
-20.00	7.898	213.7	0.02706	95.00	4.711	245.9	0.05220
-15.00	7.778	215.9	0.02775	100.00	4.525	255.4	0.05645
-10.00	7.680	217.8	0.02836	105.00	4.341	265.0	0.06105
-5.00	7.595	220.8	0.02907	110.00	4.150	272.6	0.06569
0.00	7.468	227.5	0.03046	115.00	3.960	277.5	0.07009
5.00	7.356	231.8	0.03151	120.00	3.768	280.4	0.07441
10.00	7.263	235.8	0.03246	125.00	3.574	278.8	0.07801
15.00	7.180	238.6	0.03323	130.00	3.386	274.3	0.08101
20.00	7.088	240.7	0.03397	135.00	3.214	268.5	0.08354
25.00	7.010	241.5	0.03445	140.00	3.048	264.2	0.08668
30.00	6.931	240.9	0.03476	145.00	2.887	261.0	0.09040
35.00	6.837	239.3	0.03500	150.00	2.701	255.4	0.09454
40.00	6.719	236.2	0.03514	155.00	2.444	242.7	0.09928
45.00	6.596	231.4	0.03509	160.00	2.077	221.9	0.1069
50.00	6.478	227.4	0.03510				

Table 8 Storage and loss properties for AtoHaas Plexiglas MI-7 unfilled, impact modified acrylic (PMMA). (tabular data for Graph 8)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.027	128.3	0.02551	35.00	2.894	208.1	0.07189
-55.00	4.979	133.6	0.02682	40.00	2.789	197.6	0.07086
-50.00	4.906	144.6	0.02948	45.00	2.690	187.8	0.06984
-45.00	4.820	160.9	0.03339	50.00	2.593	178.0	0.06867
-40.00	4.712	181.3	0.03847	55.00	2.487	168.1	0.06760
-35.00	4.590	202.2	0.04406	60.00	2.365	158.6	0.06708
-30.00	4.437	223.6	0.05038	65.00	2.227	152.1	0.06828
-25.00	4.275	238.6	0.05582	70.00	2.073	148.9	0.07180
-20.00	4.124	248.0	0.06013	75.00	1.911	149.0	0.07798
-15.00	3.983	254.4	0.06386	80.00	1.748	152.0	0.08695
-10.00	3.849	258.7	0.06721	85.00	1.588	158.6	0.09991
-5.00	3.712	258.9	0.06974	90.00	1.420	170.5	0.1201
0.00	3.593	256.1	0.07129	95.00	1.232	188.8	0.1533
5.00	3.491	251.7	0.07211	100.00	1.016	212.5	0.2092
10.00	3.394	246.4	0.07261	105.00	0.7573	244.4	0.3229
15.00	3.288	239.5	0.07284	110.00	0.4378	262.2	0.6004
20.00	3.191	233.0	0.07302	115.00	0.1649	183.1	1.113
25.00	3.094	225.8	0.07298	120.00	0.05098	87.92	1.727
30.00	2.995	217.5	0.07261	125.00	0.01980	41.98	2.121

Graph 9: Storage and loss properties for DuPont Zylar ST94-580 unfilled, impact modified acrylic copolymer.



Graph 10: Storage and loss properties for DuPont Zytel ST901 unfilled, impact modified amorphous nylon tested at 0.6% moisture content.

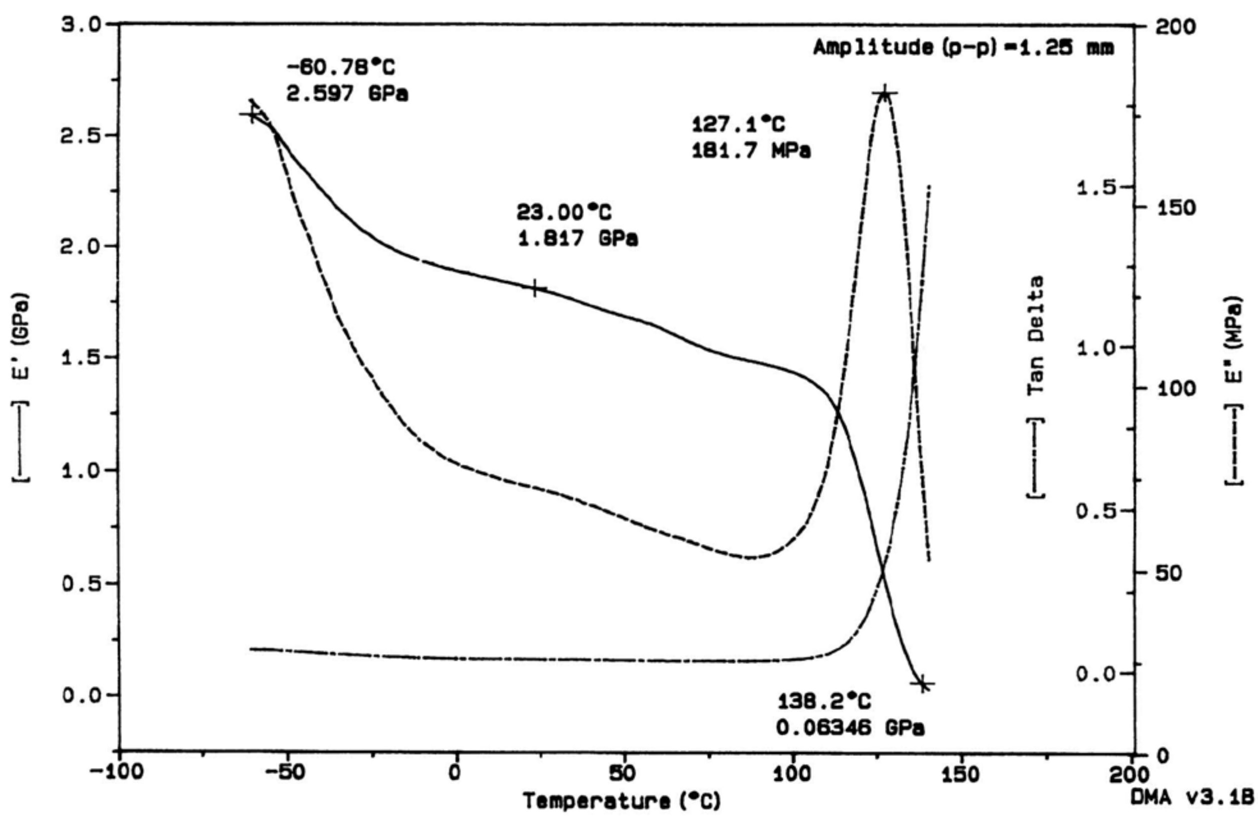


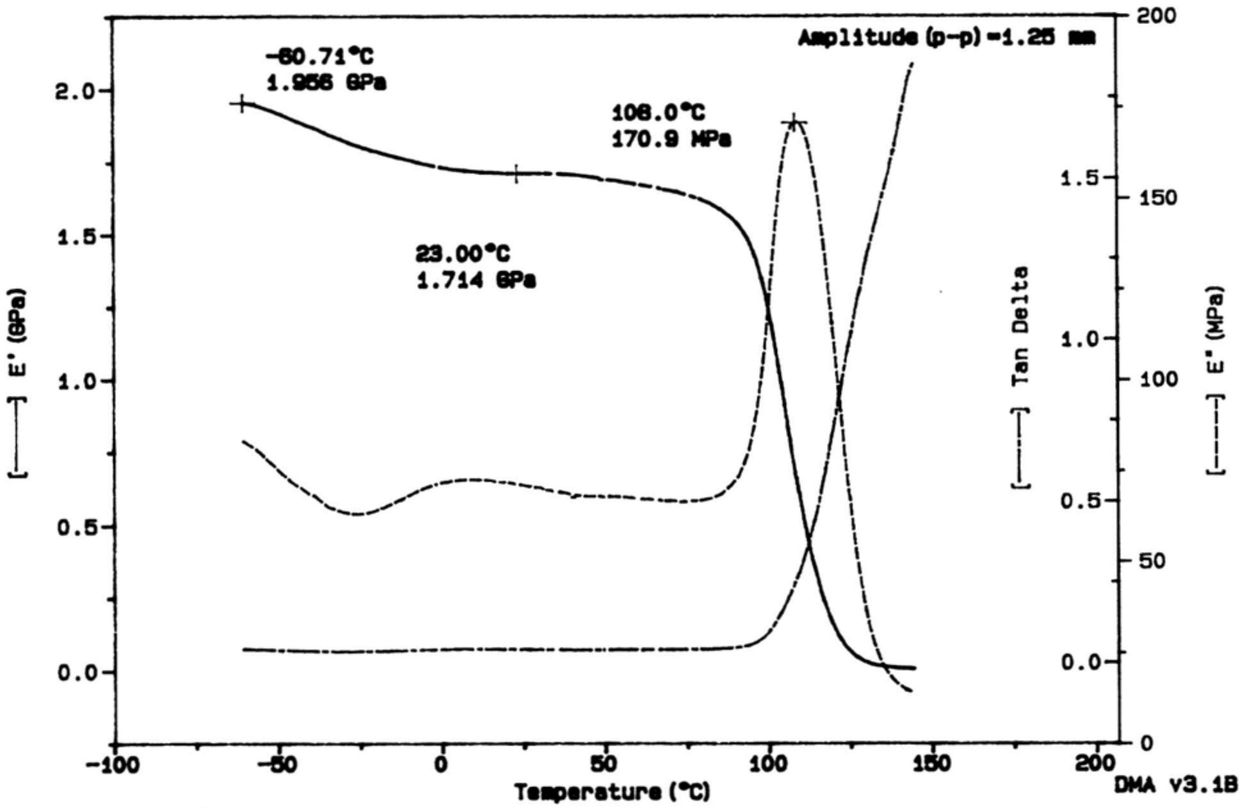
Table 9: Storage and loss properties for DuPont Zylar ST94-580 unfilled, impact modified acryliccopolymer. (tabular data for Graph 9)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.497	117.8	0.04717	30.00	2.001	100.0	0.05000
-55.00	2.472	115.3	0.04662	35.00	1.973	100.1	0.05072
-50.00	2.443	113.3	0.04635	40.00	1.940	100.3	0.05167
-45.00	2.410	111.4	0.04623	45.00	1.908	101.2	0.05303
-40.00	2.377	110.0	0.04627	50.00	1.872	102.5	0.05475
-35.00	2.342	108.5	0.04632	55.00	1.825	104.8	0.05740
-30.00	2.301	106.8	0.04642	60.00	1.768	108.5	0.06135
-25.00	2.262	105.9	0.04680	65.00	1.700	115.1	0.06772
-20.00	2.227	104.9	0.04711	70.00	1.620	122.7	0.07578
-15.00	2.194	104.2	0.04750	75.00	1.529	130.7	0.08546
-10.00	2.166	103.4	0.04774	80.00	1.431	138.9	0.09709
-5.00	2.139	103.0	0.04814	85.00	1.322	147.9	0.1119
0.00	2.119	102.7	0.04845	90.00	1.194	157.5	0.1319
5.00	2.103	102.3	0.04866	95.00	1.037	169.0	0.1630
10.00	2.084	101.7	0.04877	100.00	0.8350	188.9	0.2264
15.00	2.065	101.0	0.04892	105.00	0.5571	237.5	0.4271
20.00	2.043	100.5	0.04919	110.00	0.2363	240.4	1.021
25.00	2.023	100.2	0.04954				

Table 10: Storage and loss properties for DuPont Zytel ST901 unfilled, impact modified amorphous nylon tested at 0.6% moisture content. (tabular data for Graph 10)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.592	178.6	0.06890	45.00	1.714	66.11	0.03857
-55.00	2.544	172.3	0.06770	50.00	1.692	64.31	0.03802
-50.00	2.449	158.2	0.06459	55.00	1.670	62.49	0.03742
-45.00	2.351	144.1	0.06131	60.00	1.643	60.73	0.03697
-40.00	2.262	131.3	0.05802	65.00	1.607	59.32	0.03691
-35.00	2.176	119.0	0.05469	70.00	1.571	57.75	0.03675
-30.00	2.107	110.0	0.05220	75.00	1.541	56.19	0.03646
-25.00	2.048	102.2	0.04987	80.00	1.517	54.89	0.03618
-20.00	2.002	95.03	0.04747	85.00	1.498	53.96	0.03601
-15.00	1.966	89.20	0.04537	90.00	1.482	54.02	0.03645
-5.00	1.916	81.55	0.04257	95.00	1.464	55.49	0.03791
0.00	1.896	79.13	0.04175	100.00	1.441	58.80	0.04080
5.00	1.879	77.41	0.04120	105.00	1.406	65.28	0.04643
10.00	1.862	75.90	0.04077	110.00	1.345	78.51	0.05836
15.00	1.845	74.39	0.04033	115.00	1.217	104.6	0.08603
20.00	1.828	73.26	0.04007	120.00	0.9803	143.7	0.1466
25.00	1.811	72.13	0.03984	125.00	0.6776	177.7	0.2626
30.00	1.790	70.90	0.03960	130.00	0.3683	172.8	0.4701
35.00	1.766	69.62	0.03943	135.00	0.1446	119.8	0.8305
40.00	1.739	67.80	0.03898	140.00	0.03742	55.06	1.475

Graph 11: Storage and loss properties for EMS Grilamid TR55LX unfilled, amorphous, transparent nylon 12 tested dry as molded.



Graph 12: Storage and loss properties for EMS Grilamid TR55LX unfilled, amorphous, transparent nylon 12 tested at 1% moisture content.

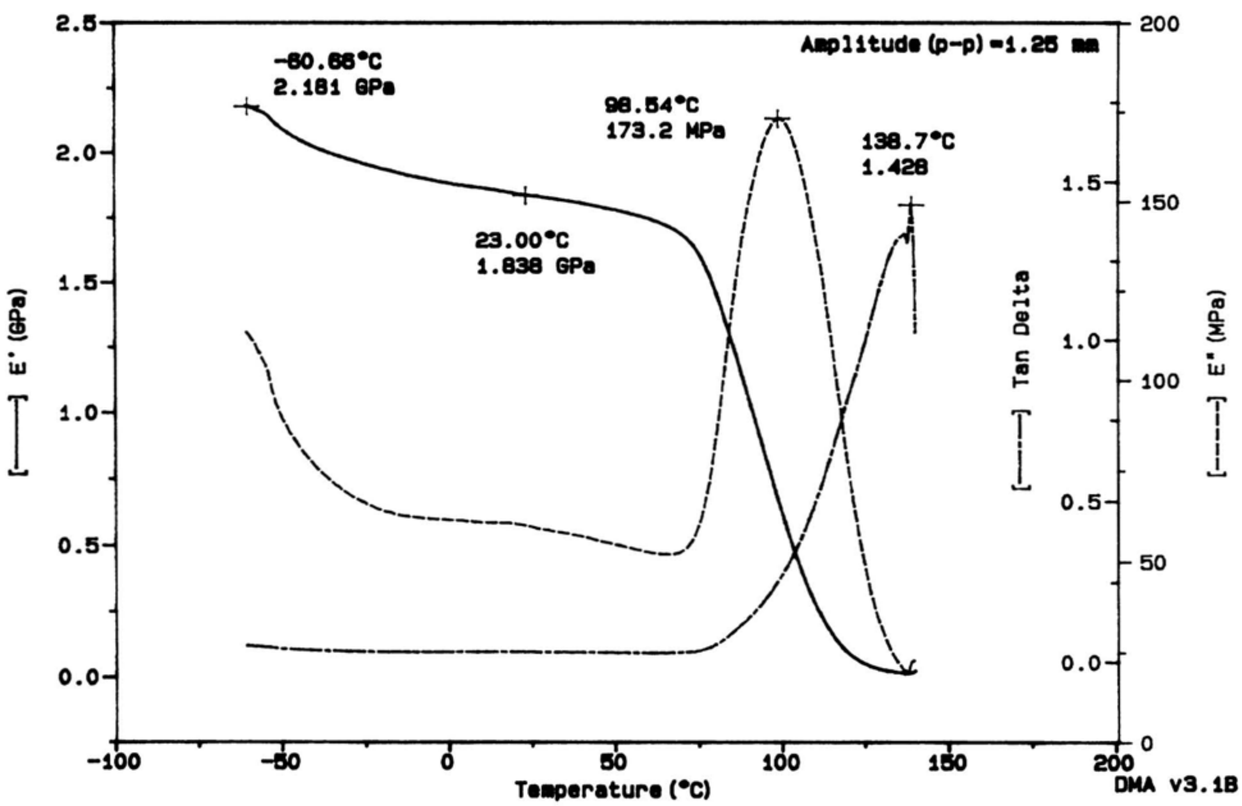


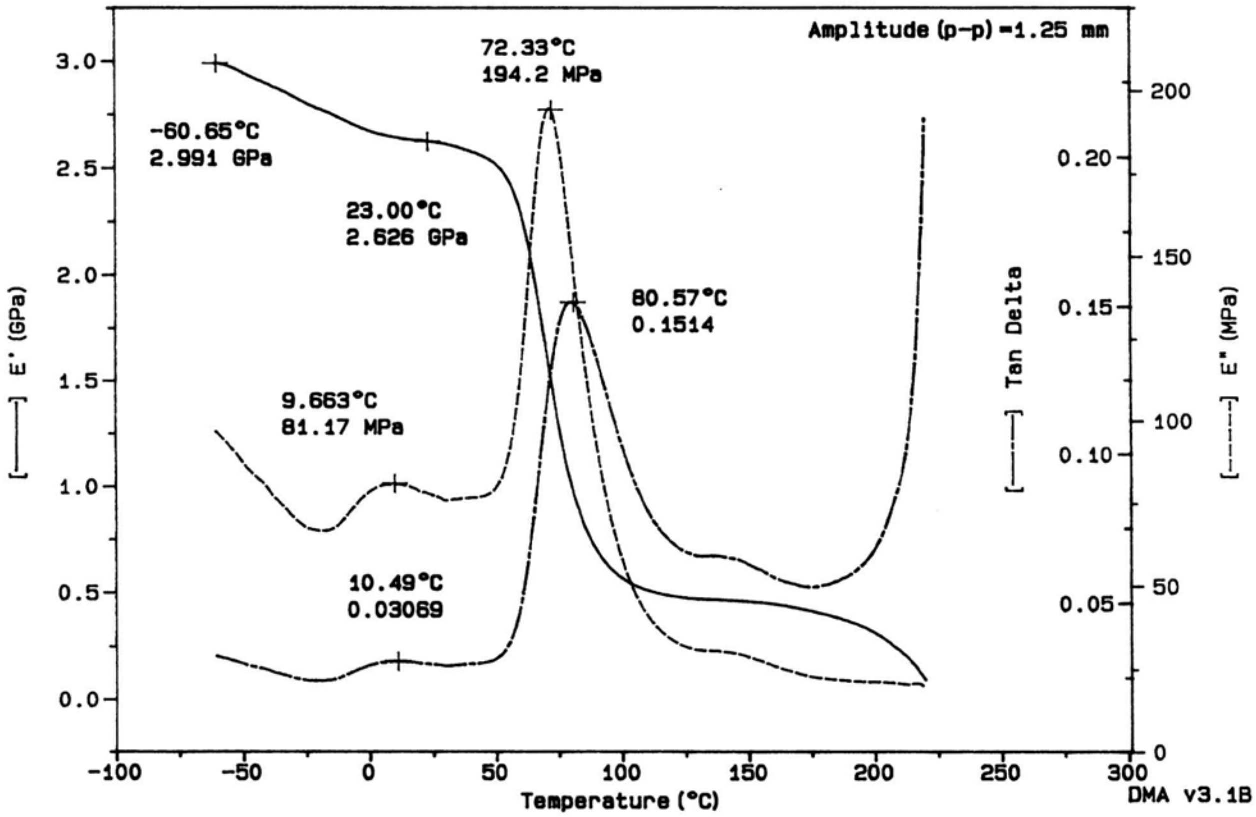
Table 11: Storage and loss properties for EMS Grilamid TR55LX unfilled, amorphous, transparent nylon 12 tested dry as molded. (tabular data for Graph 11)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	1.954	82.85	0.04239	40.00	1.709	67.76	0.03965
-55.00	1.941	79.52	0.04097	45.00	1.703	68.09	0.03999
-50.00	1.920	75.22	0.03917	55.00	1.685	67.93	0.04031
-45.00	1.896	71.34	0.03762	70.00	1.653	66.91	0.04047
-40.00	1.874	68.58	0.03660	80.00	1.621	67.09	0.04139
-35.00	1.849	65.25	0.03529	85.00	1.592	68.56	0.04307
-30.00	1.827	63.69	0.03486	90.00	1.547	72.75	0.04703
-25.00	1.806	63.38	0.03510	95.00	1.455	85.54	0.05881
-20.00	1.789	64.39	0.03599	100.00	1.246	120.9	0.09706
-15.00	1.774	66.26	0.03736	105.00	0.9050	163.4	0.1808
-10.00	1.759	68.53	0.03895	110.00	0.5663	170.1	0.3008
-5.00	1.746	70.54	0.04040	115.00	0.3143	151.7	0.4833
0.00	1.735	71.89	0.04145	120.00	0.1499	110.1	0.7360
5.00	1.725	72.56	0.04205	125.00	0.06545	65.69	1.005
10.00	1.720	72.69	0.04226	130.00	0.02845	35.37	1.244
15.00	1.717	72.41	0.04218	135.00	0.01470	21.27	1.448
25.00	1.714	71.05	0.04145	140.00	0.009631	15.98	1.659
30.00	1.714	70.37	0.04106				

Table 12: Storage and loss properties for EMS Grilamid TR55LX unfilled, amorphous, transparent nylon 12 tested at 1% moisture content. (tabular data for Graph 12)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.180	112.8	0.05176	40.00	1.806	57.01	0.03157
-55.00	2.151	104.3	0.04850	45.00	1.793	55.86	0.03115
-50.00	2.092	89.54	0.04280	50.00	1.780	54.76	0.03076
-45.00	2.051	81.74	0.03986	55.00	1.765	53.68	0.03042
-40.00	2.019	76.02	0.03765	60.00	1.746	52.63	0.03014
-35.00	1.995	71.82	0.03600	65.00	1.722	52.12	0.03027
-30.00	1.975	68.45	0.03466	70.00	1.685	53.06	0.03149
-25.00	1.956	66.02	0.03375	75.00	1.615	60.16	0.03725
-20.00	1.938	64.04	0.03304	80.00	1.474	83.20	0.05645
-15.00	1.922	62.79	0.03267	85.00	1.277	119.9	0.09394
-10.00	1.908	62.24	0.03262	90.00	1.062	149.6	0.1409
-5.00	1.895	61.80	0.03261	95.00	0.8456	167.7	0.1984
0.00	1.884	61.48	0.03264	100.00	0.6342	173.0	0.2730
5.00	1.873	61.18	0.03266	105.00	0.4415	162.5	0.3682
10.00	1.865	60.83	0.03262	110.00	0.2839	140.3	0.4947
15.00	1.855	60.70	0.03272	115.00	0.1693	110.1	0.6512
20.00	1.844	60.41	0.03276	120.00	0.09186	75.71	0.8248
25.00	1.835	59.59	0.03248	125.00	0.04924	48.99	0.9954
30.00	1.826	58.67	0.03213	130.00	0.02668	31.76	1.191
35.00	1.816	57.86	0.03185	135.00	0.01661	21.95	1.322

Graph 13: Storage and loss properties for Allied Signal Capron 8202C unfilled, nucleated nylon 6 tested at 0.15% moisture content.



Graph 14: Storage and loss properties for Allied Signal Capron 8231G 6 - 14% glass fiber filled nylon 6 tested at 0.15% moisture content.

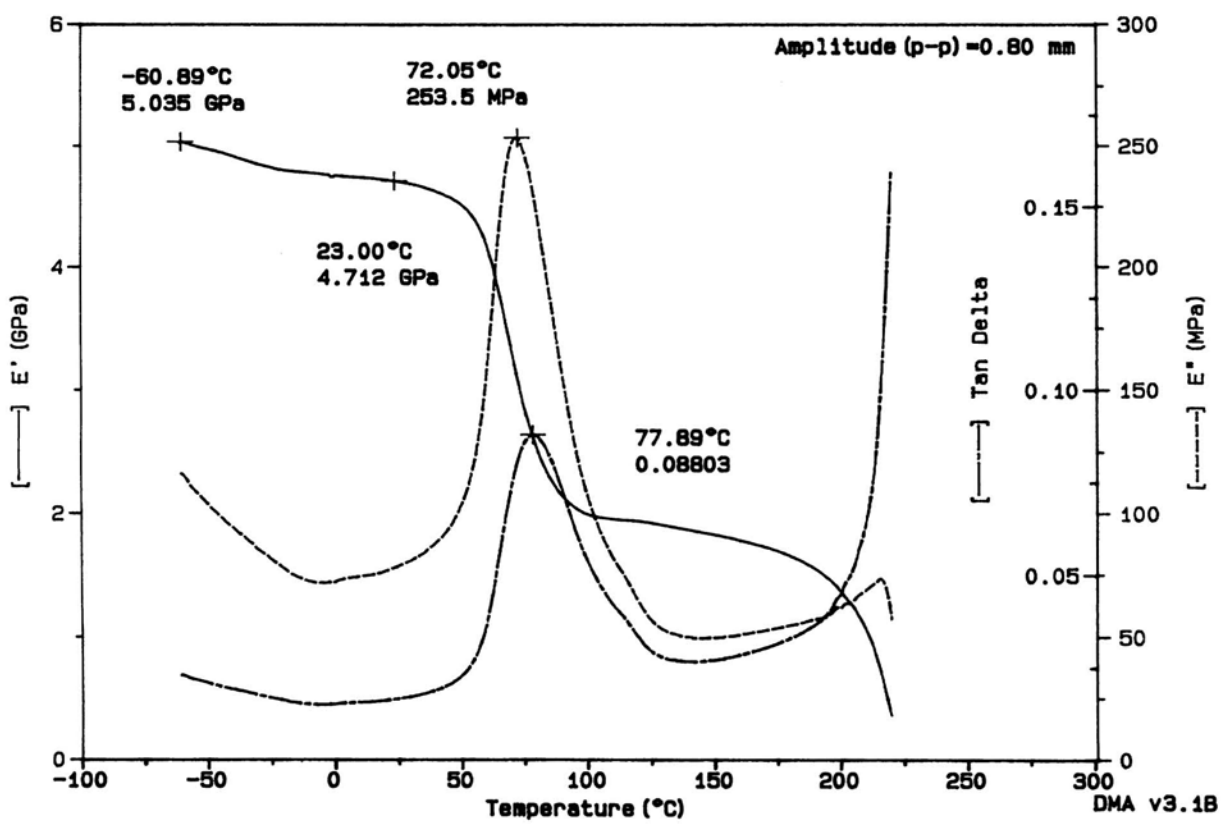


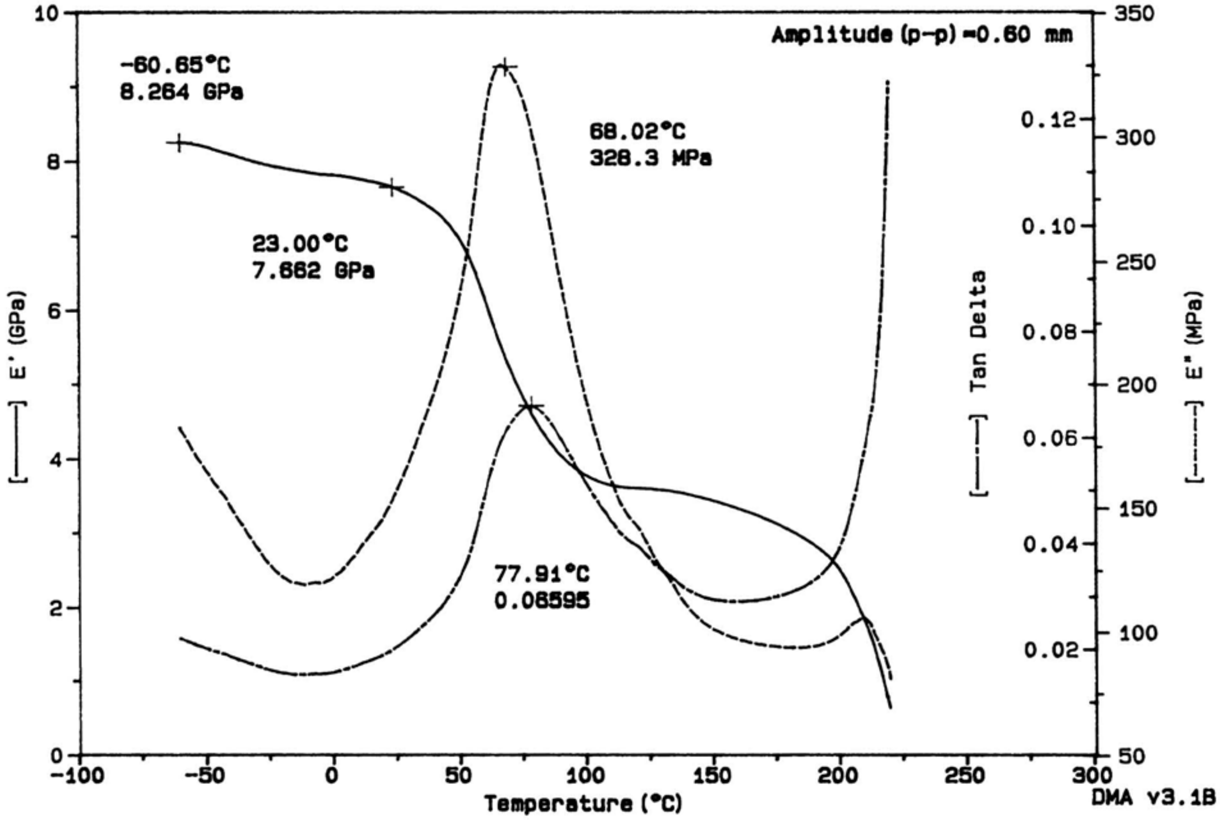
Table 13: Storage and loss properties for Allied Signal Capron 8202C unfilled, nucleated nylon 6 tested at 0.15% moisture content. (tabular data for Graph 13)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.992	96.64	0.03230	80.00	1.015	153.8	0.1516
-55.00	2.977	92.55	0.03109	85.00	0.8253	120.2	0.1456
-50.00	2.948	87.67	0.02974	90.00	0.7014	93.00	0.1326
-45.00	2.919	83.46	0.02860	95.00	0.6209	72.86	0.1173
-40.00	2.893	79.61	0.02752	100.00	0.5685	58.49	0.1029
-35.00	2.866	75.12	0.02621	105.00	0.5336	48.35	0.09061
-30.00	2.836	70.98	0.02503	110.00	0.5104	41.42	0.08114
-25.00	2.804	67.85	0.02419	115.00	0.4945	36.78	0.07438
-20.00	2.778	66.87	0.02407	120.00	0.4835	33.79	0.06989
-15.00	2.754	67.41	0.02447	125.00	0.4757	31.94	0.06715
-10.00	2.726	70.59	0.02589	130.00	0.4711	31.01	0.06581
-5.00	2.699	75.11	0.02783	135.00	0.4681	30.87	0.06595
0.00	2.675	78.73	0.02943	140.00	0.4656	30.49	0.06548
5.00	2.658	80.72	0.03037	145.00	0.4623	29.93	0.06474
10.00	2.645	81.17	0.03068	150.00	0.4583	28.81	0.06286
15.00	2.636	80.53	0.03055	155.00	0.4532	27.61	0.06093
20.00	2.630	78.68	0.02991	160.00	0.4463	26.15	0.05859
25.00	2.623	77.62	0.02959	165.00	0.4372	24.91	0.05698
30.00	2.614	76.02	0.02908	170.00	0.4257	23.79	0.05588
35.00	2.599	76.55	0.02946	175.00	0.4126	22.87	0.05542
40.00	2.580	76.94	0.02983	180.00	0.3983	22.36	0.05614
45.00	2.557	77.38	0.03026	185.00	0.3823	21.98	0.05750
50.00	2.523	79.91	0.03167	190.00	0.3640	21.69	0.05960
55.00	2.454	89.53	0.03648	195.00	0.3419	21.50	0.06288
60.00	2.311	114.7	0.04965	200.00	0.3127	21.36	0.06833
65.00	2.040	160.0	0.07847	205.00	0.2739	21.23	0.07753
70.00	1.673	192.4	0.1151	210.00	0.2289	20.82	0.09098
75.00	1.300	186.0	0.1431				

Table 14: Storage and loss properties for Allied Signal Capron 8231G 6 - 14% glass fiber filled nylon 6 tested at 0.15% moisture content. (tabular data for Graph 14)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.035	115.7	0.02297	80.00	2.531	221.2	0.08740
-55.00	5.006	109.0	0.02177	85.00	2.295	187.8	0.08184
-50.00	4.977	103.6	0.02081	90.00	2.141	154.8	0.07230
-45.00	4.952	98.48	0.01989	95.00	2.044	126.9	0.06206
-40.00	4.918	93.88	0.01909	100.00	1.989	106.5	0.05355
-35.00	4.883	89.70	0.01837	105.00	1.962	92.19	0.04698
-30.00	4.850	85.04	0.01753	110.00	1.949	81.45	0.04179
-25.00	4.825	80.91	0.01677	115.00	1.942	73.42	0.03782
-20.00	4.801	77.33	0.01611	120.00	1.932	63.63	0.03293
-15.00	4.789	74.22	0.01550	125.00	1.917	56.26	0.02935
-10.00	4.780	72.31	0.01513	130.00	1.898	52.49	0.02765
-5.00	4.769	71.76	0.01505	135.00	1.880	50.71	0.02698
0.00	4.746	72.25	0.01522	140.00	1.861	49.84	0.02679
5.00	4.749	73.73	0.01553	145.00	1.842	49.40	0.02682
10.00	4.742	74.51	0.01571	150.00	1.822	49.60	0.02722
15.00	4.733	75.17	0.01588	155.00	1.801	50.30	0.02793
20.00	4.721	76.77	0.01626	160.00	1.777	50.84	0.02861
25.00	4.705	78.79	0.01674	165.00	1.751	51.82	0.02959
30.00	4.688	81.03	0.01729	170.00	1.723	52.72	0.03060
35.00	4.661	84.15	0.01805	175.00	1.690	53.67	0.03176
40.00	4.627	88.61	0.01915	180.00	1.651	54.76	0.03318
45.00	4.583	94.37	0.02059	185.00	1.604	55.84	0.03481
50.00	4.522	104.3	0.02306	190.00	1.547	57.11	0.03692
55.00	4.414	122.2	0.02767	195.00	1.472	58.83	0.03996
60.00	4.206	158.8	0.03778	200.00	1.368	61.67	0.04510
65.00	3.825	215.8	0.05644	205.00	1.244	64.89	0.05218
70.00	3.335	251.0	0.07528	210.00	1.070	69.01	0.06454
75.00	2.868	246.9	0.08611	215.00	0.7880	73.23	0.09318

Graph 15: Storage and loss properties for Bayer Durethan BKV030 30% glass fiber filled nylon 6 tested at 0.47% moisture content.



Graph 16: Storage and loss properties for EMS Grilon PVN-3H 30% glass fiber filled nylon 6 tested at 0.4% moisture content.

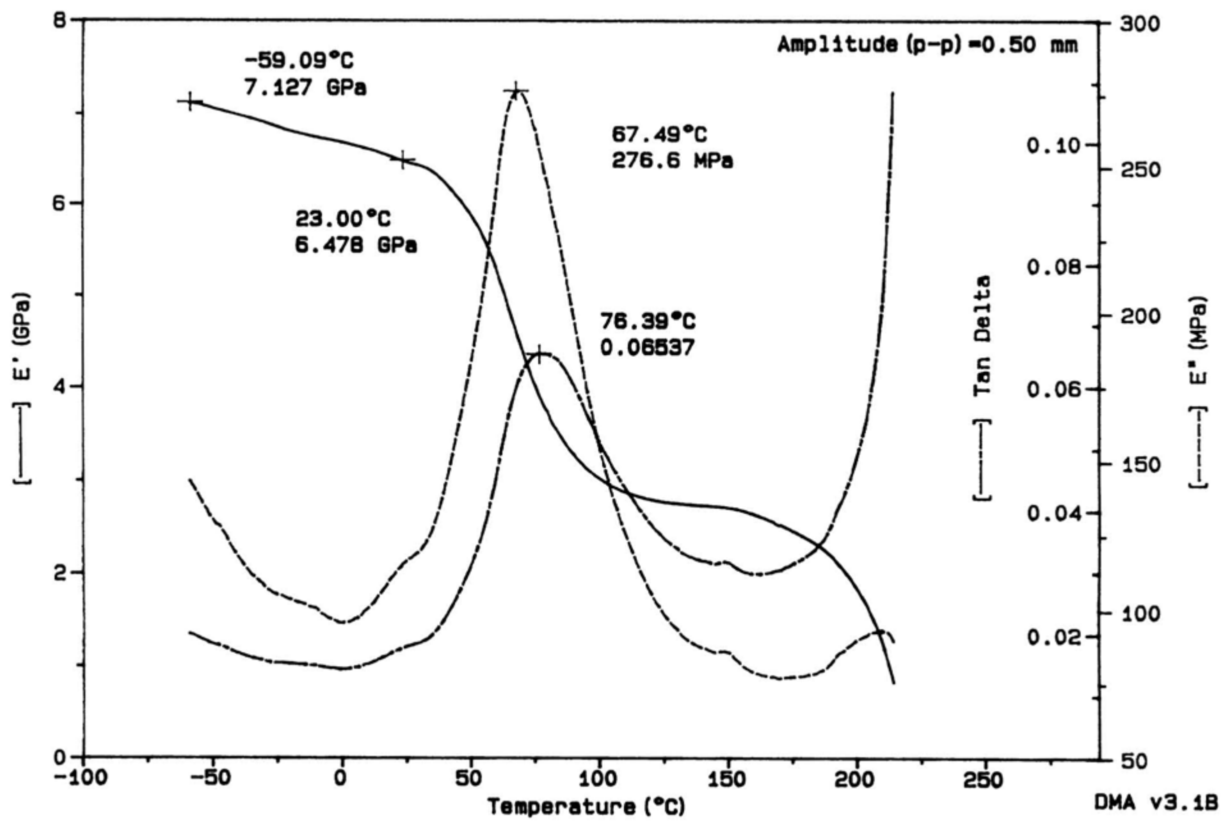


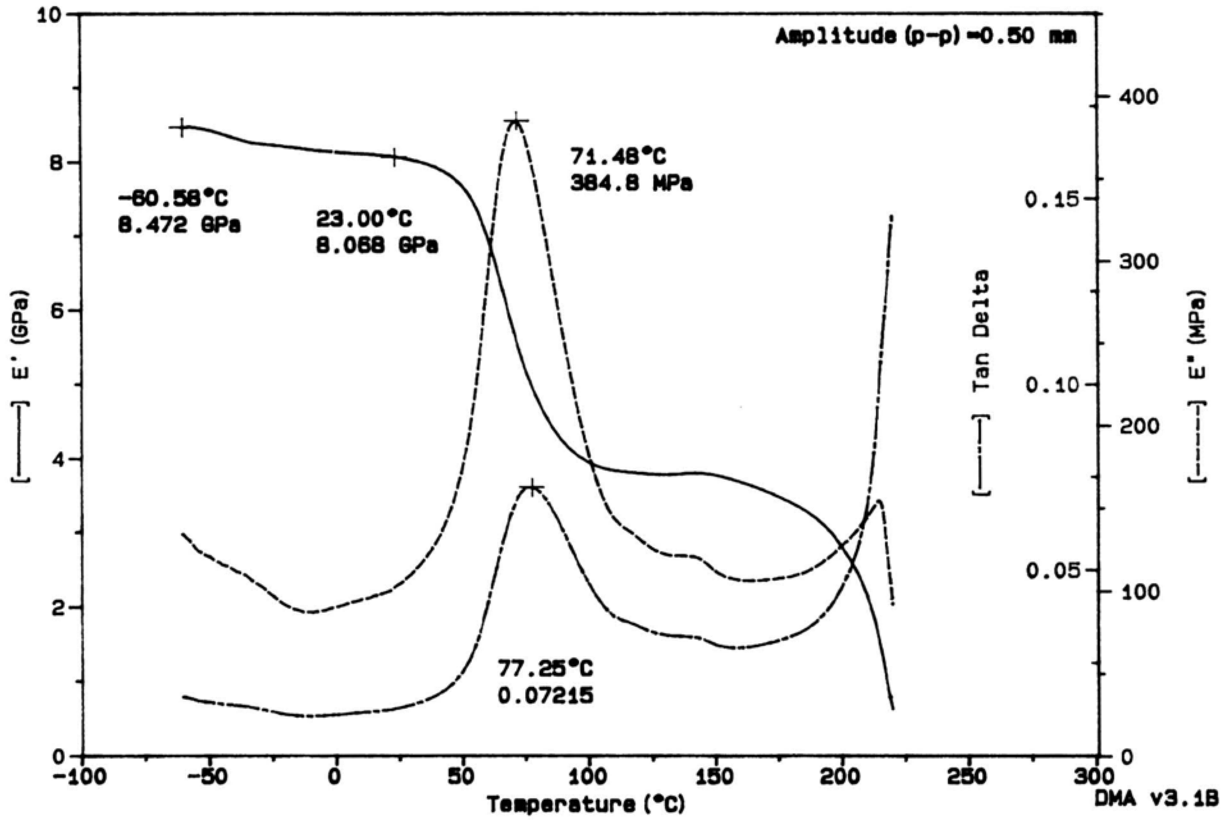
Table 15: Storage and loss properties for Bayer Durethan BKV030 30% glass fiber filled nylon 6 tested at 0.47% moisture content. (tabular data for Graph 15)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.264	181.6	0.02198	80.00	4.515	296.3	0.06562
-55.00	8.240	173.0	0.02099	85.00	4.252	269.6	0.06340
-50.00	8.201	164.9	0.02011	90.00	4.045	241.3	0.05965
-45.00	8.146	157.5	0.01933	95.00	3.889	215.5	0.05540
-40.00	8.096	149.5	0.01847	100.00	3.772	193.1	0.05118
-35.00	8.042	141.8	0.01763	105.00	3.690	174.8	0.04737
-30.00	7.991	134.0	0.01677	110.00	3.638	160.3	0.04406
-25.00	7.948	127.2	0.01601	115.00	3.614	148.9	0.04121
-20.00	7.915	122.6	0.01549	120.00	3.603	142.5	0.03954
-15.00	7.884	120.2	0.01525	125.00	3.593	133.2	0.03708
-10.00	7.855	119.9	0.01527	130.00	3.576	124.9	0.03493
-5.00	7.831	120.2	0.01535	135.00	3.553	117.4	0.03303
0.00	7.818	122.8	0.01570	140.00	3.519	110.0	0.03125
5.00	7.797	127.7	0.01637	145.00	3.477	104.7	0.03012
10.00	7.768	133.9	0.01723	150.00	3.432	101.2	0.02948
15.00	7.733	140.5	0.01817	155.00	3.381	98.82	0.02923
20.00	7.695	147.6	0.01919	160.00	3.324	97.06	0.02920
25.00	7.636	158.1	0.02070	165.00	3.265	95.78	0.02933
30.00	7.560	170.1	0.02250	170.00	3.199	94.82	0.02964
35.00	7.463	183.9	0.02464	175.00	3.125	94.19	0.03014
40.00	7.352	198.2	0.02696	180.00	3.041	93.95	0.03090
45.00	7.199	215.4	0.02992	185.00	2.947	93.91	0.03186
50.00	6.976	237.2	0.03400	190.00	2.839	94.55	0.03331
55.00	6.641	267.8	0.04032	195.00	2.704	96.16	0.03556
60.00	6.170	306.8	0.04972	200.00	2.509	99.21	0.03954
65.00	5.654	327.5	0.05793	205.00	2.194	103.9	0.04737
70.00	5.208	326.6	0.06271	210.00	1.807	105.5	0.05841
75.00	4.835	316.5	0.06546	215.00	1.279	96.08	0.07528

Table 16: Storage and loss properties for EMS Grilon PVN-3H 30% glass fiber filled nylon 6 testedat 0.4% moisture content. (tabular data for Graph 16)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	7.106	137.6	0.01937	80.00	3.729	243.4	0.06527
-50.00	7.064	130.4	0.01846	85.00	3.478	221.9	0.06380
-45.00	7.024	125.0	0.01780	90.00	3.283	197.8	0.06023
-40.00	6.982	117.8	0.01687	95.00	3.131	174.4	0.05570
-35.00	6.939	112.1	0.01615	100.00	3.021	154.3	0.05106
-30.00	6.895	107.9	0.01566	105.00	2.938	138.4	0.04711
-25.00	6.848	105.2	0.01537	110.00	2.875	125.5	0.04367
-20.00	6.803	103.8	0.01526	115.00	2.827	114.5	0.04050
-15.00	6.766	102.2	0.01511	120.00	2.793	105.4	0.03775
-10.00	6.734	100.5	0.01493	125.00	2.768	98.45	0.03557
-5.00	6.706	97.24	0.01450	130.00	2.754	93.55	0.03397
0.00	6.677	96.08	0.01439	135.00	2.741	89.55	0.03267
5.00	6.642	97.34	0.01466	140.00	2.732	87.46	0.03201
10.00	6.605	101.0	0.01530	145.00	2.722	85.87	0.03155
15.00	6.560	106.4	0.01622	150.00	2.706	85.85	0.03172
20.00	6.509	112.4	0.01727	155.00	2.678	81.56	0.03045
25.00	6.459	117.0	0.01811	160.00	2.637	78.89	0.02992
30.00	6.423	120.2	0.01872	165.00	2.584	77.73	0.03007
35.00	6.359	128.0	0.02013	170.00	2.524	77.17	0.03058
40.00	6.237	142.8	0.02290	175.00	2.460	77.68	0.03157
45.00	6.074	162.5	0.02675	180.00	2.386	78.19	0.03277
50.00	5.887	184.6	0.03136	185.00	2.304	79.45	0.03449
55.00	5.648	210.3	0.03723	190.00	2.195	82.80	0.03772
60.00	5.295	244.5	0.04618	195.00	2.041	86.80	0.04254
65.00	4.839	272.1	0.05624	200.00	1.843	90.30	0.04901
70.00	4.407	275.7	0.06255	205.00	1.594	92.62	0.05812
75.00	4.032	262.9	0.06521	210.00	1.241	93.23	0.07524

Graph 17: Storage and loss properties for Allied Signal Capron 8233G 33% glass fiber filled nylon 6 tested at 0.3% moisture content.



Graph 18: Storage and loss properties for BASF Ultramid B3EG6 30% glass fiber filled nylon 6 tested at 0.5% moisture content.

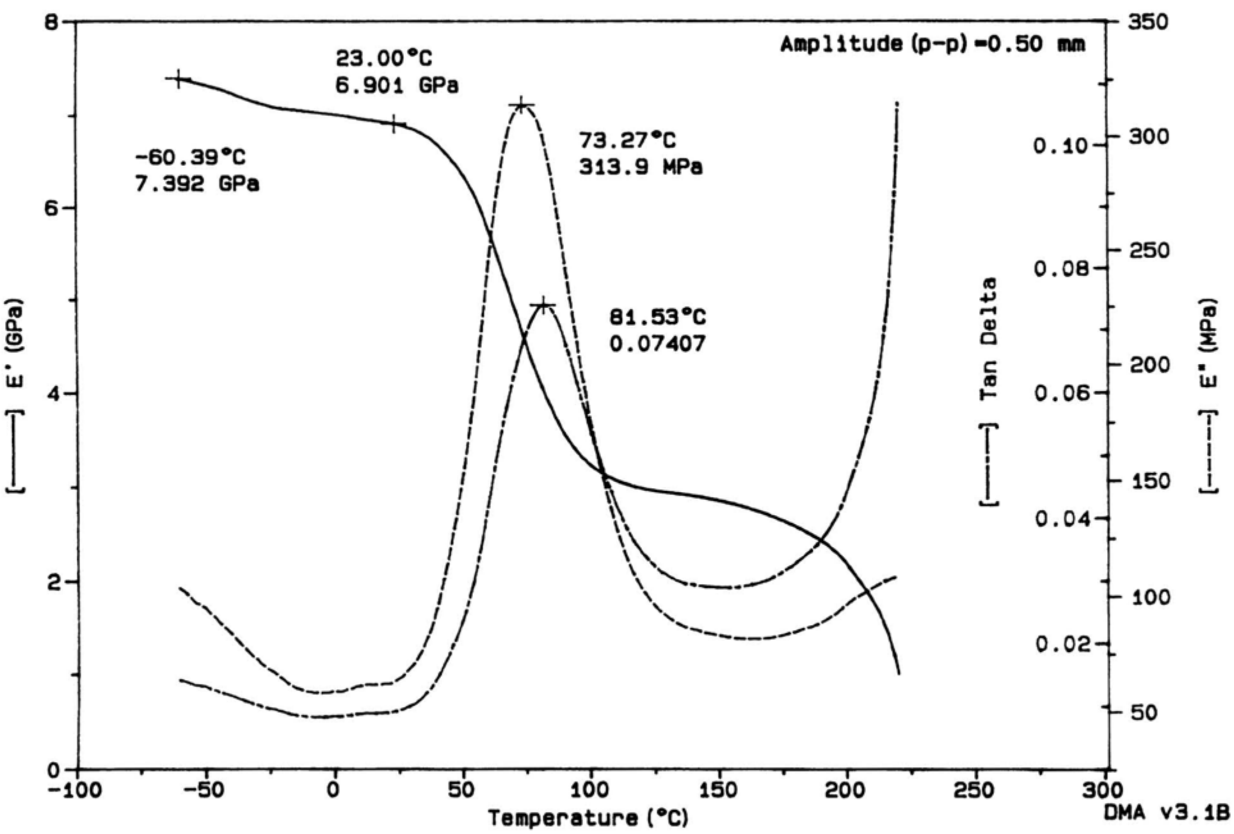


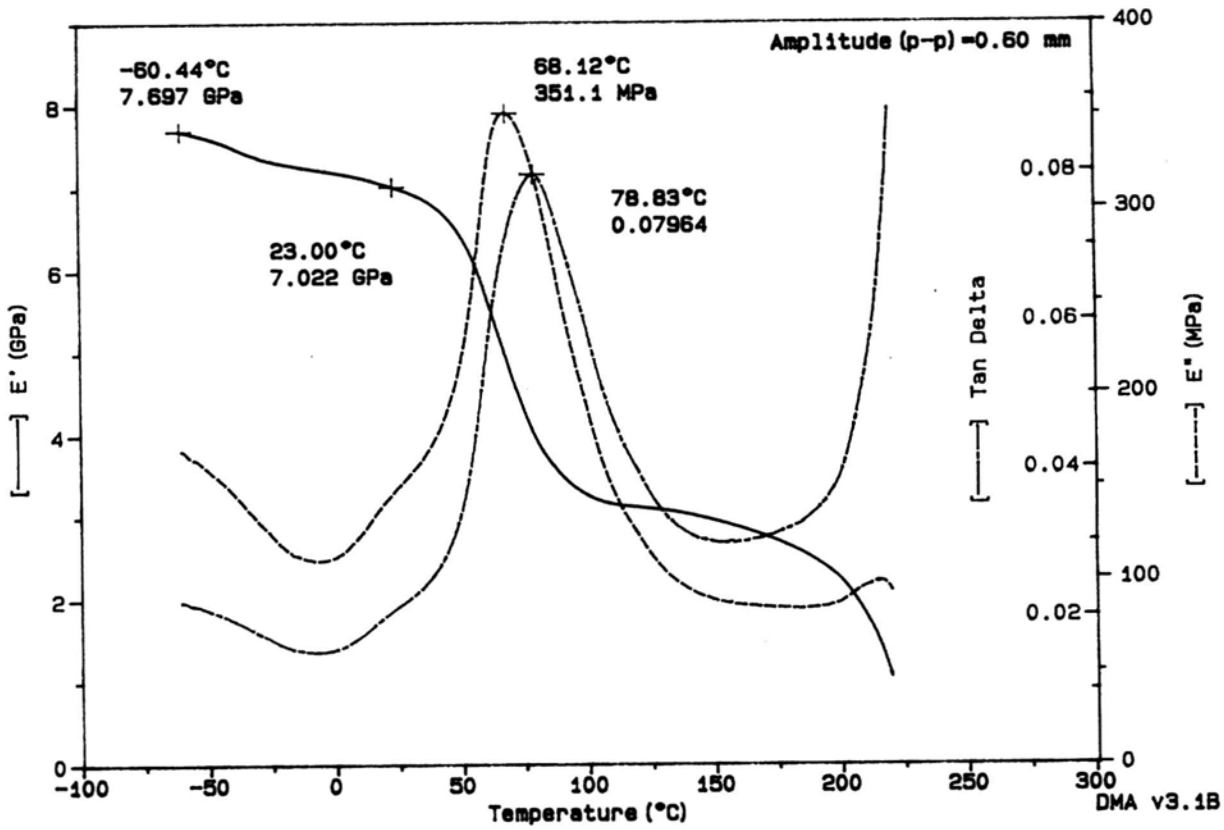
Table 17: Storage and loss properties for Allied Signal Capron 8233G 33% glass fiber filled nylon 6 tested at 0.3% moisture content. (tabular data for Graph 17)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.473	133.6	0.01577
-55.00	8.467	125.2	0.01479
-50.00	8.432	120.8	0.01433
-45.00	8.382	116.0	0.01384
-40.00	8.328	112.5	0.01351
-35.00	8.278	109.0	0.01317
-30.00	8.246	103.5	0.01255
-25.00	8.229	97.24	0.01182
-20.00	8.209	91.54	0.01115
-15.00	8.189	88.42	0.01080
-10.00	8.165	87.40	0.01070
-5.00	8.149	88.38	0.01085
5.00	8.121	93.02	0.01145
10.00	8.109	95.22	0.01174
15.00	8.096	97.36	0.01202
20.00	8.081	99.77	0.01235
25.00	8.058	104.6	0.01298
30.00	8.025	111.2	0.01386
35.00	7.982	119.9	0.01502
40.00	7.921	131.2	0.01656
45.00	7.828	148.5	0.01897
50.00	7.683	175.3	0.02282
55.00	7.435	219.8	0.02956
60.00	7.013	288.2	0.04111
65.00	6.431	353.5	0.05498
70.00	5.782	383.9	0.06639
75.00	5.213	375.1	0.07195
80.00	4.790	341.2	0.07122
85.00	4.462	297.5	0.06667
90.00	4.225	254.0	0.06010
95.00	4.061	214.5	0.05283
100.00	3.949	182.5	0.04622
105.00	3.875	158.3	0.04084
110.00	3.838	143.5	0.03740
115.00	3.816	136.9	0.03588
120.00	3.800	131.0	0.03447
125.00	3.787	125.4	0.03313
130.00	3.781	122.2	0.03233
135.00	3.787	121.6	0.03209
140.00	3.799	121.0	0.03186
145.00	3.796	118.0	0.03110
150.00	3.771	111.9	0.02967
155.00	3.728	108.2	0.02901
160.00	3.676	106.7	0.02901
165.00	3.617	106.6	0.02946
170.00	3.551	107.0	0.03014
175.00	3.479	108.0	0.03104
180.00	3.397	109.3	0.03217
185.00	3.302	111.5	0.03377
190.00	3.183	115.4	0.03626
195.00	3.026	120.8	0.03993
200.00	2.805	127.9	0.04560
205.00	2.537	135.2	0.05331
210.00	2.156	145.0	0.06731
215.00	1.515	154.2	0.1021

Table 18: Storage and loss properties for BASF Ultramid B3EG6 30% glass fiber filled nylon 6 tested at 0.5% moisture content. (tabular data for Graph 18)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	7.390	103.2	0.01396
-55.00	7.361	98.19	0.01334
-50.00	7.323	94.60	0.01292
-45.00	7.289	88.82	0.01219
-40.00	7.242	83.38	0.01151
-35.00	7.188	77.54	0.01079
-30.00	7.140	72.21	0.01011
-25.00	7.100	67.64	0.009527
-20.00	7.071	63.53	0.008985
-15.00	7.056	59.84	0.008481
-10.00	7.040	58.16	0.008261
-5.00	7.022	57.83	0.008235
0.00	7.002	58.61	0.008370
5.00	6.982	59.45	0.008514
10.00	6.956	60.93	0.008760
15.00	6.935	61.48	0.008865
20.00	6.914	62.00	0.008967
25.00	6.892	64.20	0.009315
30.00	6.850	69.67	0.01017
35.00	6.786	79.76	0.01175
40.00	6.689	96.45	0.01442
45.00	6.543	121.2	0.01852
50.00	6.365	152.1	0.02389
60.00	5.783	243.3	0.04208
65.00	5.371	286.2	0.05328
70.00	4.940	308.9	0.06253
75.00	4.513	313.5	0.06946
80.00	4.144	305.2	0.07365
85.00	3.829	280.3	0.07320
90.00	3.566	243.6	0.06830
95.00	3.375	206.9	0.06130
100.00	3.239	175.4	0.05415
110.00	3.072	129.5	0.04215
115.00	3.025	113.7	0.03759
120.00	2.988	103.0	0.03447
125.00	2.962	95.56	0.03227
130.00	2.944	90.69	0.03081
135.00	2.928	87.36	0.02984
140.00	2.908	85.60	0.02944
145.00	2.884	84.03	0.02914
150.00	2.858	83.05	0.02906
155.00	2.828	81.93	0.02897
160.00	2.791	81.64	0.02925
165.00	2.747	81.64	0.02972
170.00	2.700	82.06	0.03039
175.00	2.644	83.36	0.03153
180.00	2.582	84.83	0.03286
185.00	2.511	86.72	0.03453
190.00	2.431	88.88	0.03656
195.00	2.329	92.24	0.03961
200.00	2.186	96.86	0.04431
205.00	2.000	100.6	0.05032
210.00	1.799	104.0	0.05782
215.00	1.509	106.9	0.07091
220.00	1.026	107.9	0.1055

Graph 19: Storage and loss properties for LNP Thermocomp PF1006HI 30% glass fiber filled, impact modified nylon 6 tested at 0.3% moisture content.



Graph 20: Storage and loss properties for DSM Engineering Fiberfil J7-33 33% glass fiber filled, impact modified nylon 6 tested at 0.3% moisture content.

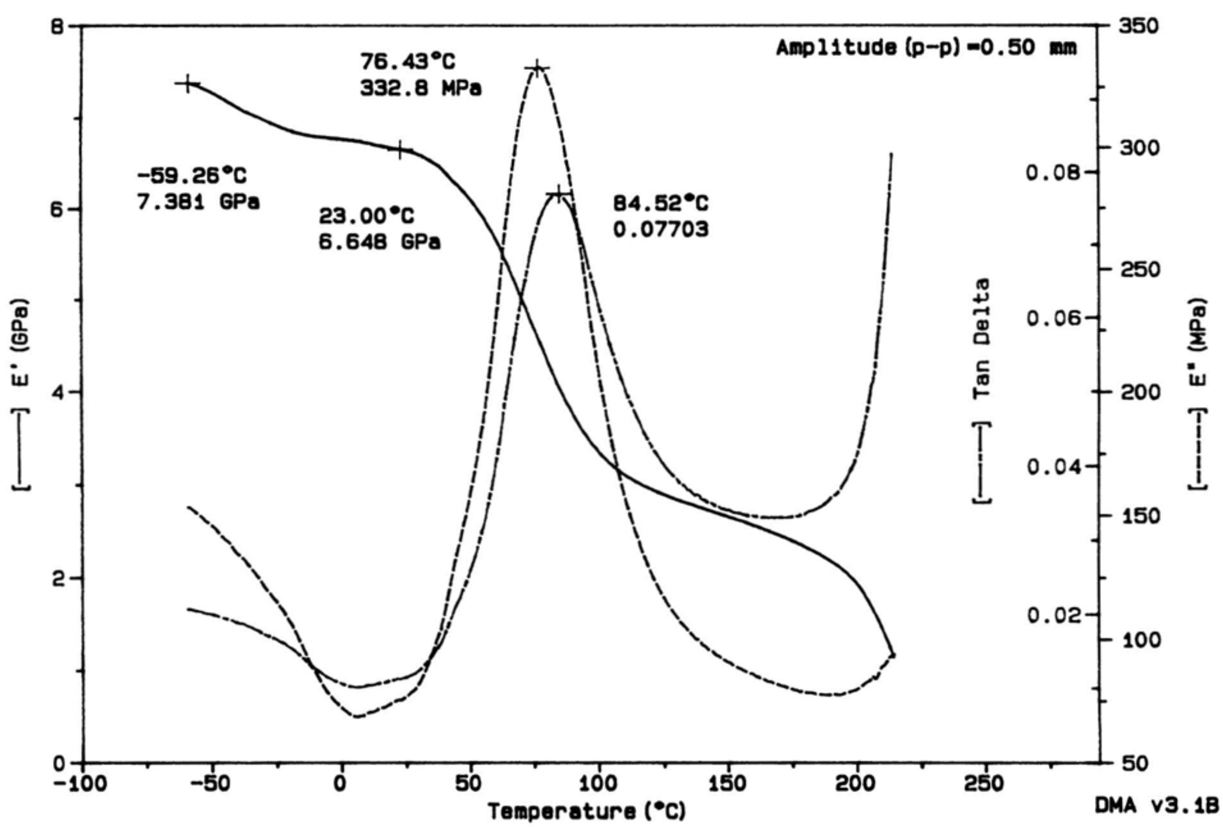


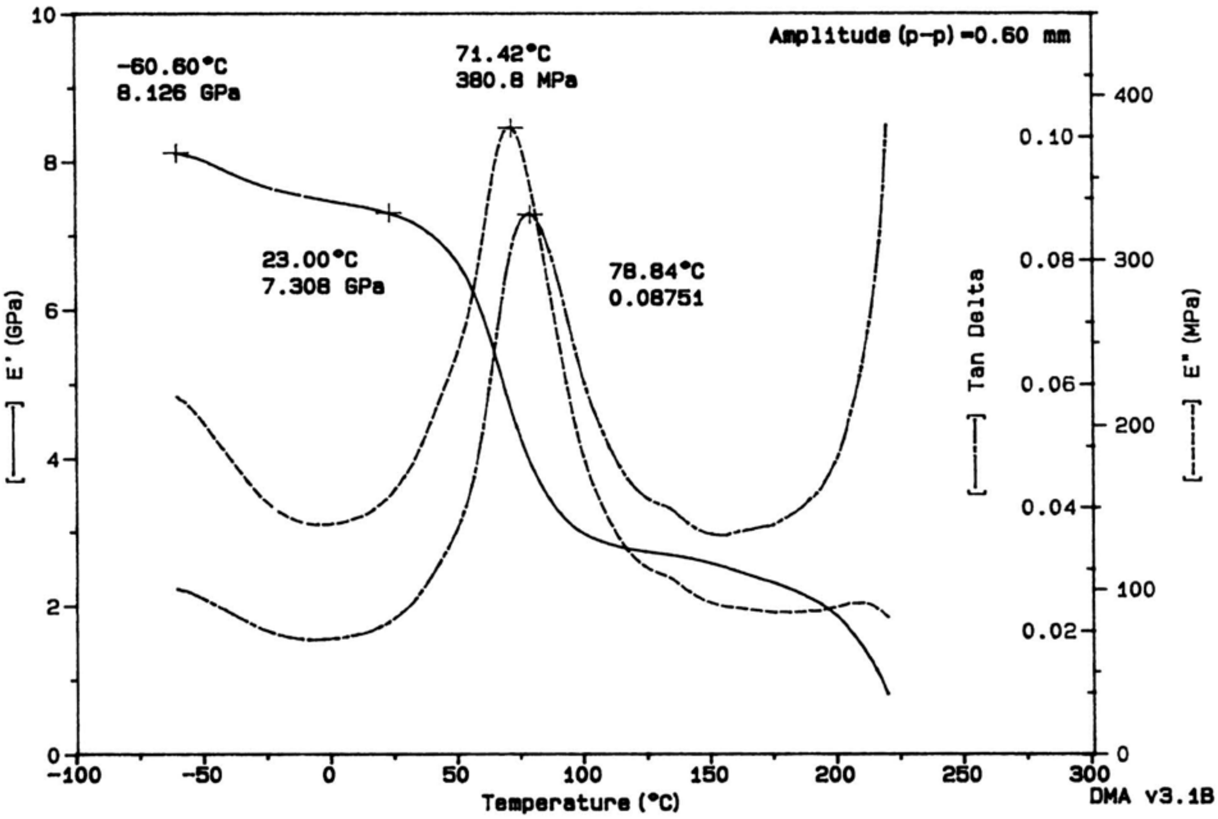
Table 19: Storage and loss properties for LNP Thermocomp PF1006HI 30% glass fiber filled, impact modified nylon 6 tested at 0.3% moisture content. (tabular data for Graph 19)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	7.695	168.6	0.02191	80.00	3.950	314.4	0.07960
-55.00	7.658	163.9	0.02141	85.00	3.694	282.3	0.07643
-50.00	7.616	158.4	0.02080	90.00	3.505	248.1	0.07080
-45.00	7.567	152.4	0.02015	95.00	3.361	218.1	0.06488
-40.00	7.506	145.8	0.01942	100.00	3.264	191.1	0.05856
-35.00	7.439	138.2	0.01857	105.00	3.193	166.0	0.05199
-30.00	7.381	130.0	0.01762	110.00	3.151	147.5	0.04680
-25.00	7.333	123.2	0.01680	115.00	3.128	133.3	0.04260
-20.00	7.300	116.4	0.01595	120.00	3.112	122.5	0.03937
-15.00	7.271	112.4	0.01546	125.00	3.094	112.1	0.03622
-10.00	7.244	110.2	0.01522	130.00	3.075	104.0	0.03383
-5.00	7.220	109.8	0.01521	135.00	3.054	98.01	0.03209
0.00	7.195	111.7	0.01552	140.00	3.024	93.68	0.03098
5.00	7.168	116.4	0.01624	145.00	2.988	90.42	0.03026
10.00	7.136	123.7	0.01733	150.00	2.948	88.14	0.02990
15.00	7.097	132.9	0.01872	155.00	2.906	86.56	0.02979
20.00	7.049	141.9	0.02013	160.00	2.861	85.60	0.02992
25.00	7.001	149.5	0.02135	165.00	2.811	85.09	0.03027
30.00	6.947	156.9	0.02259	170.00	2.758	84.48	0.03063
35.00	6.877	165.3	0.02404	175.00	2.699	84.11	0.03117
40.00	6.780	176.7	0.02607	180.00	2.632	83.72	0.03181
45.00	6.642	193.0	0.02906	185.00	2.558	83.60	0.03268
50.00	6.440	218.7	0.03396	190.00	2.469	84.20	0.03411
55.00	6.144	260.9	0.04247	195.00	2.367	85.22	0.03601
60.00	5.723	315.2	0.05508	200.00	2.237	87.37	0.03906
65.00	5.233	347.4	0.06639	205.00	2.046	92.02	0.04498
70.00	4.747	349.7	0.07367	210.00	1.801	96.12	0.05337
75.00	4.317	337.1	0.07811	215.00	1.489	98.47	0.06618

Table 20: Storage and loss properties for DSM Engineering Fiberfil J7-33 33% glass fiber filled, impact modified nylon 6 tested at 0.3% moisture content. (tabular data for Graph 20)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	7.343	150.2	0.02046	80.00	4.357	329.3	0.07559
-50.00	7.279	146.0	0.02006	85.00	4.031	310.4	0.07700
-45.00	7.202	140.4	0.01949	90.00	3.764	281.0	0.07465
-40.00	7.122	134.4	0.01888	95.00	3.535	244.1	0.06905
-35.00	7.048	128.8	0.01827	100.00	3.352	207.8	0.06198
-30.00	6.983	121.3	0.01738	105.00	3.212	179.2	0.05581
-25.00	6.915	114.9	0.01662	110.00	3.104	157.1	0.05060
-20.00	6.857	106.8	0.01557	115.00	3.019	139.9	0.04634
-15.00	6.816	96.04	0.01409	120.00	2.950	126.6	0.04290
-10.00	6.789	86.01	0.01267	125.00	2.892	116.5	0.04027
-5.00	6.774	77.48	0.01144	130.00	2.838	108.8	0.03832
0.00	6.760	71.97	0.01065	135.00	2.791	102.6	0.03675
5.00	6.744	68.66	0.01018	140.00	2.746	97.64	0.03556
10.00	6.719	70.28	0.01046	145.00	2.700	93.77	0.03473
15.00	6.688	72.40	0.01082	150.00	2.656	90.65	0.03413
20.00	6.661	74.80	0.01123	155.00	2.609	87.69	0.03361
25.00	6.637	77.18	0.01163	160.00	2.560	85.24	0.03329
30.00	6.597	82.88	0.01256	165.00	2.508	82.89	0.03305
35.00	6.523	95.04	0.01457	170.00	2.452	81.22	0.03312
40.00	6.421	112.2	0.01748	175.00	2.394	79.51	0.03321
45.00	6.271	136.6	0.02179	180.00	2.329	78.31	0.03362
50.00	6.118	159.1	0.02600	185.00	2.257	77.65	0.03440
55.00	5.927	187.9	0.03171	190.00	2.172	77.67	0.03576
60.00	5.685	228.3	0.04016	195.00	2.073	78.10	0.03767
65.00	5.372	276.6	0.05150	200.00	1.936	80.01	0.04133
70.00	5.036	313.2	0.06220	205.00	1.718	83.91	0.04885
75.00	4.688	331.4	0.07069	210.00	1.431	89.15	0.06234

Graph 21: Storage and loss properties for Allied Signal Capron 8267G 40% glass fiber/ mineral filled nylon 6 tested at 0.3% moisture content.



Graph 22: Storage and loss properties for Allied Signal Capron 8234G 44% glass fiber filled nylon 6 tested at 0.4% moisture content.

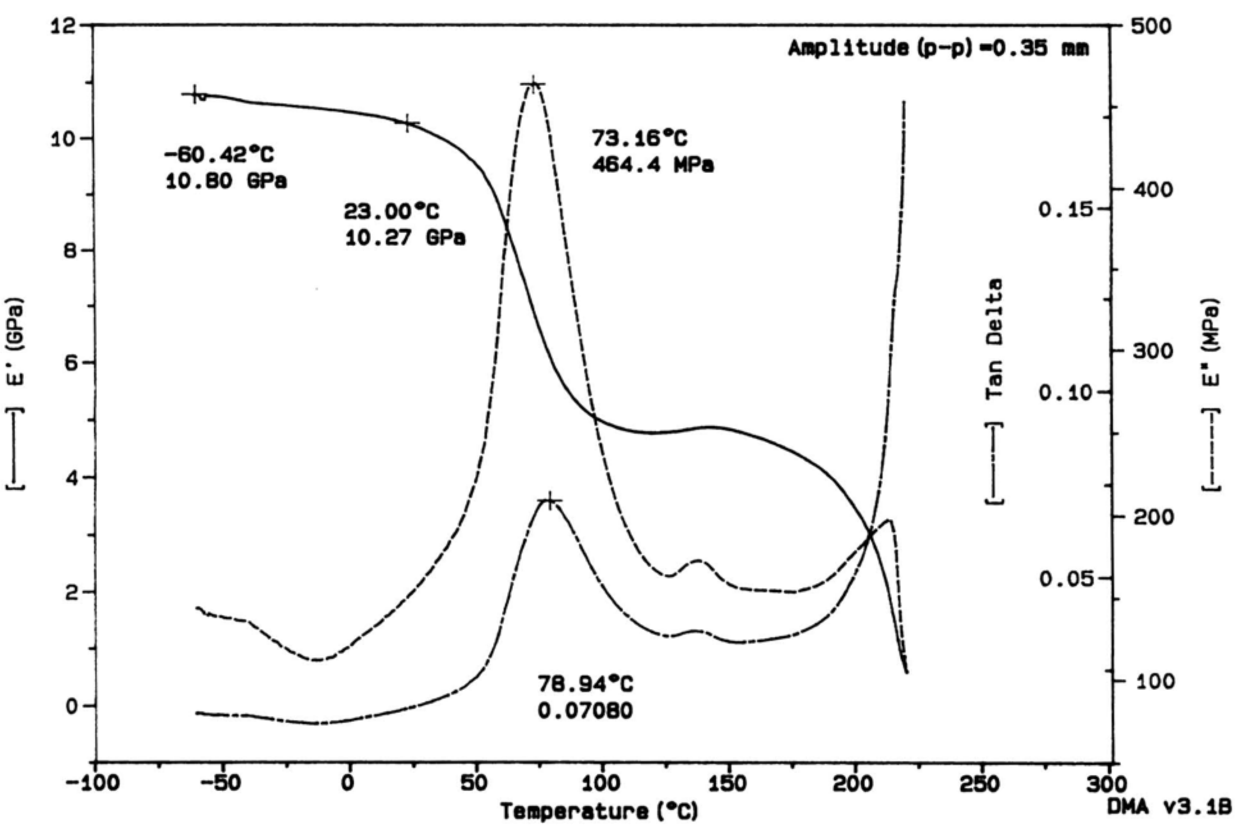


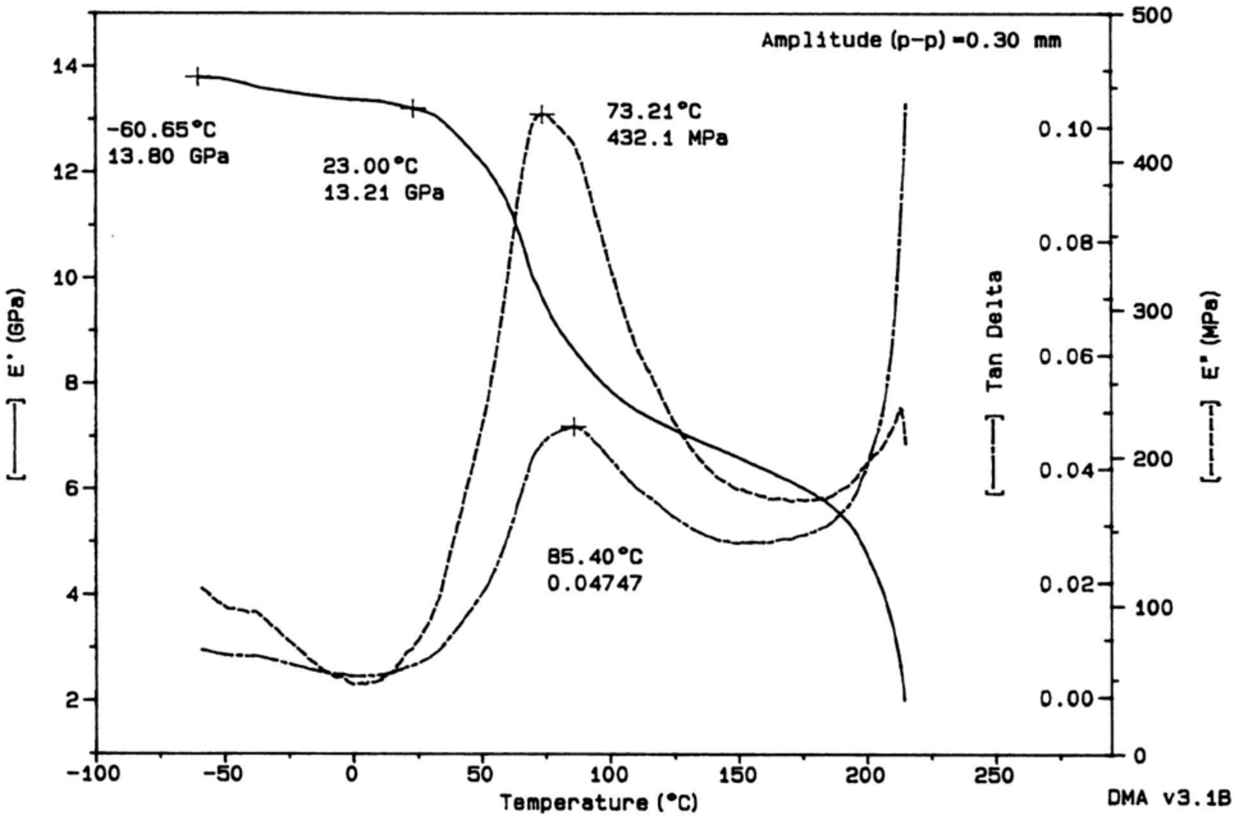
Table 21: Storage and loss properties for Allied Signal Capron 8267G 40% glass fiber/ mineral filled nylon 6 tested at 0.3% moisture content. (tabular data for Graph 21)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.124	216.7	0.02668
-55.00	8.083	210.6	0.02606
-50.00	8.029	201.5	0.02510
-45.00	7.951	191.1	0.02403
-40.00	7.869	180.8	0.02297
-35.00	7.792	170.6	0.02189
-30.00	7.725	160.6	0.02079
-25.00	7.663	152.9	0.01995
-20.00	7.616	146.9	0.01929
-15.00	7.577	142.9	0.01887
-5.00	7.503	139.7	0.01862
0.00	7.470	140.0	0.01874
5.00	7.441	141.3	0.01899
10.00	7.409	143.8	0.01941
15.00	7.377	147.0	0.01992
20.00	7.335	153.0	0.02086
25.00	7.286	160.9	0.02208
30.00	7.225	171.6	0.02375
35.00	7.137	186.3	0.02610
40.00	7.018	204.3	0.02911
45.00	6.866	223.4	0.03253
50.00	6.663	244.1	0.03664
55.00	6.375	271.1	0.04254
60.00	5.968	311.9	0.05227
65.00	5.436	357.8	0.06584
70.00	4.828	380.3	0.07879
75.00	4.310	371.2	0.08614
80.00	3.872	338.1	0.08733
85.00	3.533	294.7	0.08342
90.00	3.283	252.1	0.07679
95.00	3.101	212.0	0.06837
100.00	2.978	180.4	0.06057
105.00	2.897	158.6	0.05476
110.00	2.837	141.8	0.04999
115.00	2.791	128.5	0.04603
120.00	2.756	119.0	0.04318
125.00	2.730	112.9	0.04137
130.00	2.706	109.4	0.04042
135.00	2.682	105.8	0.03945
140.00	2.654	100.0	0.03769
145.00	2.619	95.14	0.03633
150.00	2.577	91.89	0.03566
155.00	2.531	89.76	0.03547
160.00	2.473	88.91	0.03596
165.00	2.417	87.99	0.03641
170.00	2.362	87.06	0.03685
175.00	2.311	86.07	0.03724
180.00	2.246	86.24	0.03839
185.00	2.175	86.35	0.03971
190.00	2.092	86.91	0.04155
195.00	1.994	87.89	0.04407
200.00	1.864	89.53	0.04804
205.00	1.674	91.66	0.05477
210.00	1.452	91.88	0.06331
215.00	1.171	89.20	0.07620

Table 22: Storage and loss properties for Allied Signal Capron 8234G 44% glass fiber filled nylon 6 tested at 0.4% moisture content. (tabular data for Graph 22

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	10.79	144.1	0.01335
-55.00	10.77	139.8	0.01298
-50.00	10.76	138.0	0.01283
-45.00	10.72	136.5	0.01273
-40.00	10.67	135.1	0.01267
-35.00	10.64	129.1	0.01214
-30.00	10.62	123.4	0.01162
-25.00	10.60	118.5	0.01118
-20.00	10.57	114.4	0.01082
-15.00	10.55	112.0	0.01061
-10.00	10.53	112.6	0.01070
-5.00	10.50	116.6	0.01111
0.00	10.47	121.0	0.01155
5.00	10.44	127.6	0.01223
10.00	10.40	133.4	0.01282
15.00	10.36	139.8	0.01350
20.00	10.30	147.7	0.01433
25.00	10.24	154.9	0.01513
30.00	10.15	164.2	0.01618
35.00	10.04	174.5	0.01737
40.00	9.930	186.2	0.01876
45.00	9.782	200.7	0.02052
50.00	9.581	223.0	0.02328
55.00	9.239	263.9	0.02848
60.00	8.798	334.3	0.03801
65.00	8.134	412.6	0.05073
70.00	7.416	456.4	0.06156
75.00	6.683	463.1	0.06931
80.00	6.083	428.8	0.07049
85.00	5.632	374.2	0.06644
90.00	5.322	320.7	0.06026
95.00	5.116	274.1	0.05357
100.00	4.979	237.5	0.04771
105.00	4.886	209.6	0.04290
110.00	4.824	190.5	0.03950
115.00	4.789	176.5	0.03686
120.00	4.775	167.6	0.03510
125.00	4.789	163.6	0.03417
130.00	4.812	166.8	0.03466
135.00	4.846	172.3	0.03555
140.00	4.876	171.8	0.03522
145.00	4.874	164.5	0.03376
150.00	4.842	158.4	0.03270
155.00	4.789	155.9	0.03255
160.00	4.725	155.2	0.03284
165.00	4.652	154.7	0.03326
170.00	4.563	154.4	0.03384
175.00	4.464	153.9	0.03447
180.00	4.344	155.5	0.03580
185.00	4.204	158.2	0.03764
190.00	4.035	163.0	0.04040
195.00	3.800	170.4	0.04484
200.00	3.488	178.5	0.05119
205.00	3.112	186.9	0.06007
210.00	2.557	194.4	0.07609
215.00	1.631	190.8	0.1174

Graph 23: Storage and loss properties for Ticona Celstran N6G50 50% long glass fiber filled nylon 6 tested at 0.4% moisture content.



Graph 24: Storage and loss properties for DuPont Zytel 151 unfilled nylon 612.

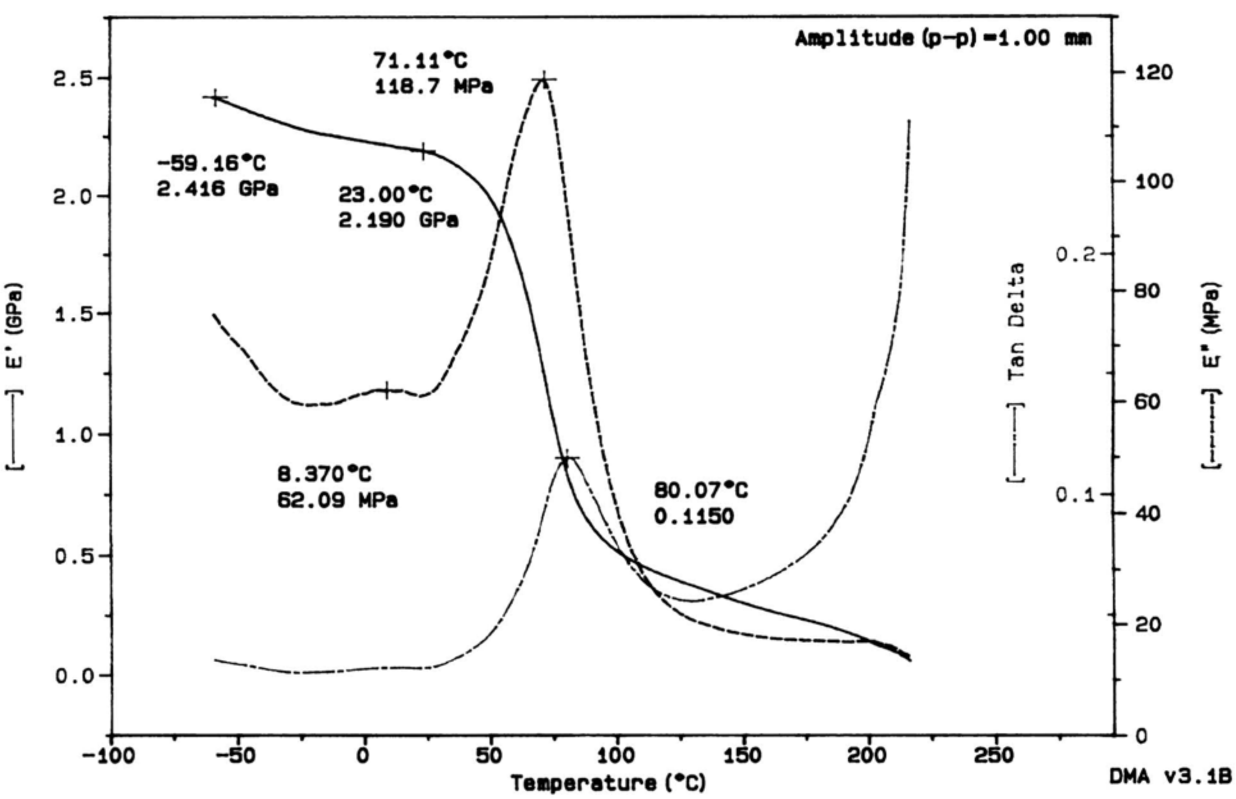


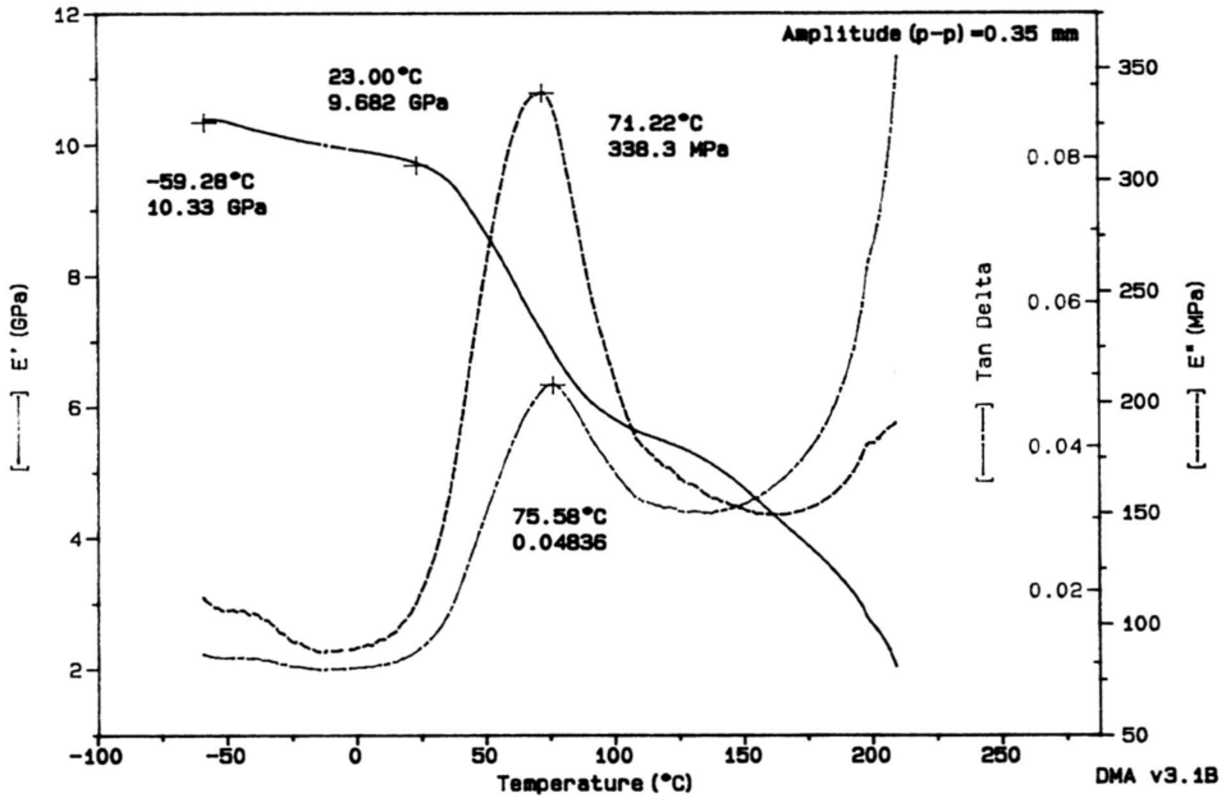
Table 23 Storage and loss properties for Ticona Celstran N6G50 50% long glass fiber filled nylon 6 tested at 0.4% moisture content. (tabular data for Graph 23)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	13.79	105.3	0.007636	80.00	9.061	423.2	0.04671
-50.00	13.77	99.38	0.007218	85.00	8.720	413.7	0.04745
-45.00	13.72	97.06	0.007076	90.00	8.409	391.5	0.04656
-40.00	13.65	94.98	0.006956	95.00	8.127	360.3	0.04433
-35.00	13.59	91.34	0.006723	100.00	7.881	328.3	0.04166
-30.00	13.55	83.77	0.006182	105.00	7.677	299.9	0.03906
-25.00	13.51	75.38	0.005578	110.00	7.501	274.9	0.03665
-20.00	13.48	68.23	0.005063	115.00	7.363	257.2	0.03493
-15.00	13.44	60.76	0.004520	120.00	7.240	239.2	0.03305
-10.00	13.41	54.39	0.004055	125.00	7.117	222.7	0.03130
-5.00	13.39	51.80	0.003869	130.00	7.006	209.1	0.02985
0.00	13.37	46.90	0.003508	135.00	6.901	197.7	0.02864
5.00	13.36	47.41	0.003549	140.00	6.800	188.7	0.02774
10.00	13.34	49.56	0.003716	145.00	6.701	182.7	0.02726
15.00	13.30	55.24	0.004155	150.00	6.597	178.0	0.02699
20.00	13.24	67.52	0.005100	155.00	6.482	175.5	0.02708
25.00	13.19	76.95	0.005836	160.00	6.372	173.0	0.02715
30.00	13.11	92.10	0.007023	165.00	6.256	172.2	0.02752
35.00	12.97	119.1	0.009188	170.00	6.147	170.2	0.02769
40.00	12.74	151.8	0.01192	175.00	6.020	170.6	0.02835
45.00	12.49	186.4	0.01493	180.00	5.878	171.9	0.02924
50.00	12.22	222.0	0.01817	185.00	5.720	173.2	0.03028
55.00	11.89	266.8	0.02243	190.00	5.510	178.4	0.03238
60.00	11.49	321.8	0.02801	195.00	5.237	184.7	0.03527
65.00	10.86	384.9	0.03546	200.00	4.793	196.5	0.04100
70.00	10.06	426.1	0.04236	205.00	4.253	205.2	0.04826
75.00	9.524	431.7	0.04533	210.00	3.455	220.8	0.06397

Table 24: Storage and loss properties for DuPont Zytel 151 unfilled nylon 612. (tabular data for Graph 24)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.402	73.11	0.03044	85.00	0.7083	78.67	0.1110
-50.00	2.379	70.47	0.02962	90.00	0.6206	62.35	0.1005
-45.00	2.358	67.82	0.02876	95.00	0.5602	50.08	0.08938
-40.00	2.338	64.76	0.02770	100.00	0.5163	40.90	0.07921
-35.00	2.319	62.17	0.02681	105.00	0.4819	34.14	0.07083
-30.00	2.301	60.45	0.02627	110.00	0.4539	29.25	0.06444
-25.00	2.284	59.61	0.02609	115.00	0.4304	25.93	0.06024
-20.00	2.270	59.55	0.02624	120.00	0.4095	23.62	0.05769
-15.00	2.259	59.58	0.02638	125.00	0.3899	21.90	0.05618
-10.00	2.250	59.98	0.02666	130.00	0.3716	20.71	0.05574
-5.00	2.241	60.92	0.02719	135.00	0.3523	19.91	0.05653
0.00	2.231	61.52	0.02757	140.00	0.3334	19.17	0.05751
5.00	2.222	62.11	0.02796	145.00	0.3150	18.59	0.05901
10.00	2.213	62.00	0.02802	150.00	0.2976	18.15	0.06099
15.00	2.202	62.04	0.02817	155.00	0.2812	17.74	0.06307
20.00	2.196	61.29	0.02791	160.00	0.2660	17.44	0.06559
25.00	2.185	61.44	0.02812	165.00	0.2515	17.23	0.06850
30.00	2.168	63.38	0.02923	170.00	0.2379	17.10	0.07188
35.00	2.142	67.53	0.03153	175.00	0.2249	16.99	0.07554
40.00	2.106	72.14	0.03426	180.00	0.2108	16.93	0.08030
45.00	2.061	77.84	0.03777	185.00	0.1949	16.88	0.08662
50.00	1.997	85.32	0.04272	190.00	0.1773	16.76	0.09451
55.00	1.900	95.50	0.05027	195.00	0.1584	16.82	0.1062
60.00	1.761	105.7	0.06000	200.00	0.1362	16.89	0.1240
65.00	1.575	113.1	0.07181	205.00	0.1128	16.34	0.1449
70.00	1.331	118.4	0.08904	210.00	0.09335	15.62	0.1675
75.00	1.066	114.0	0.1070	215.00	0.06385	14.35	0.2252
80.00	0.8512	97.88	0.1150				

Graph 25: Storage and loss properties for DuPont Zytel 77G43L 43% glass fiber filled nylon 612 tested at 0.35% moisture content.



Graph 26: Storage and loss properties for LNP Thermocomp IF100-12 60% glass fiber filled nylon 612 tested at 0.4% moisture content.

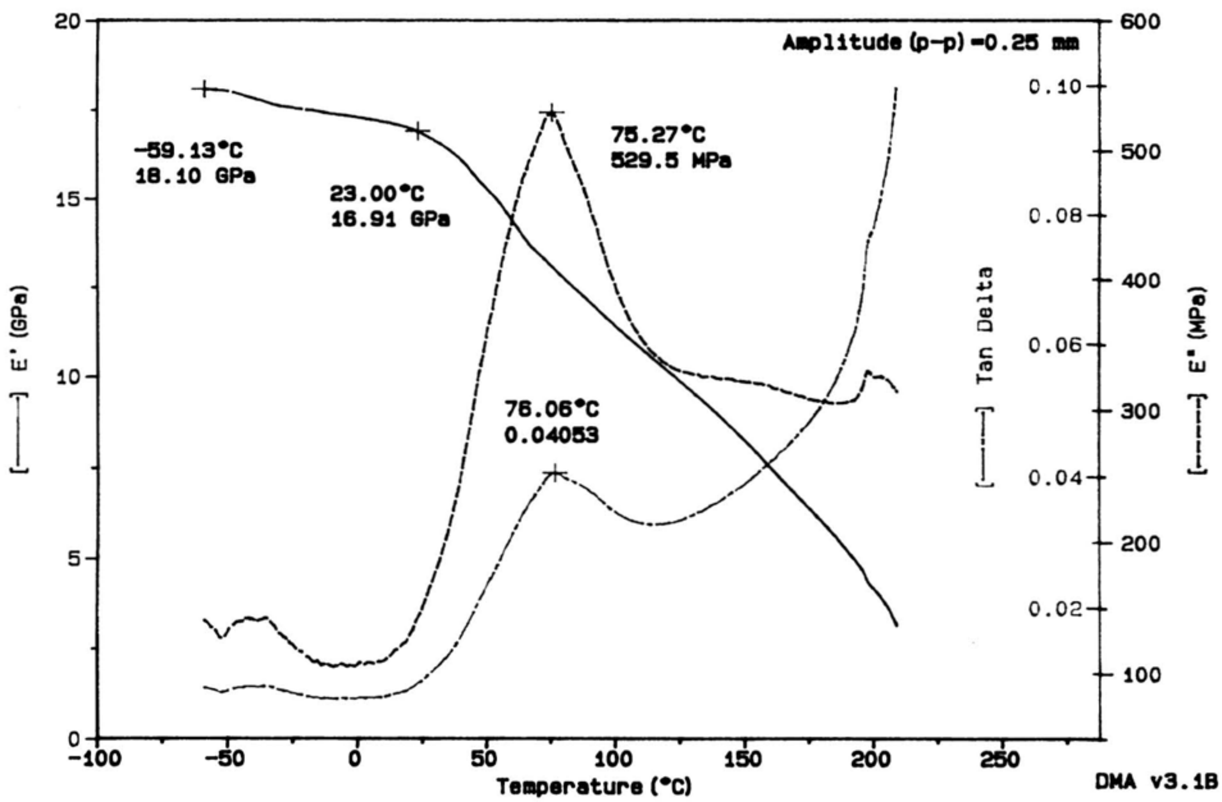


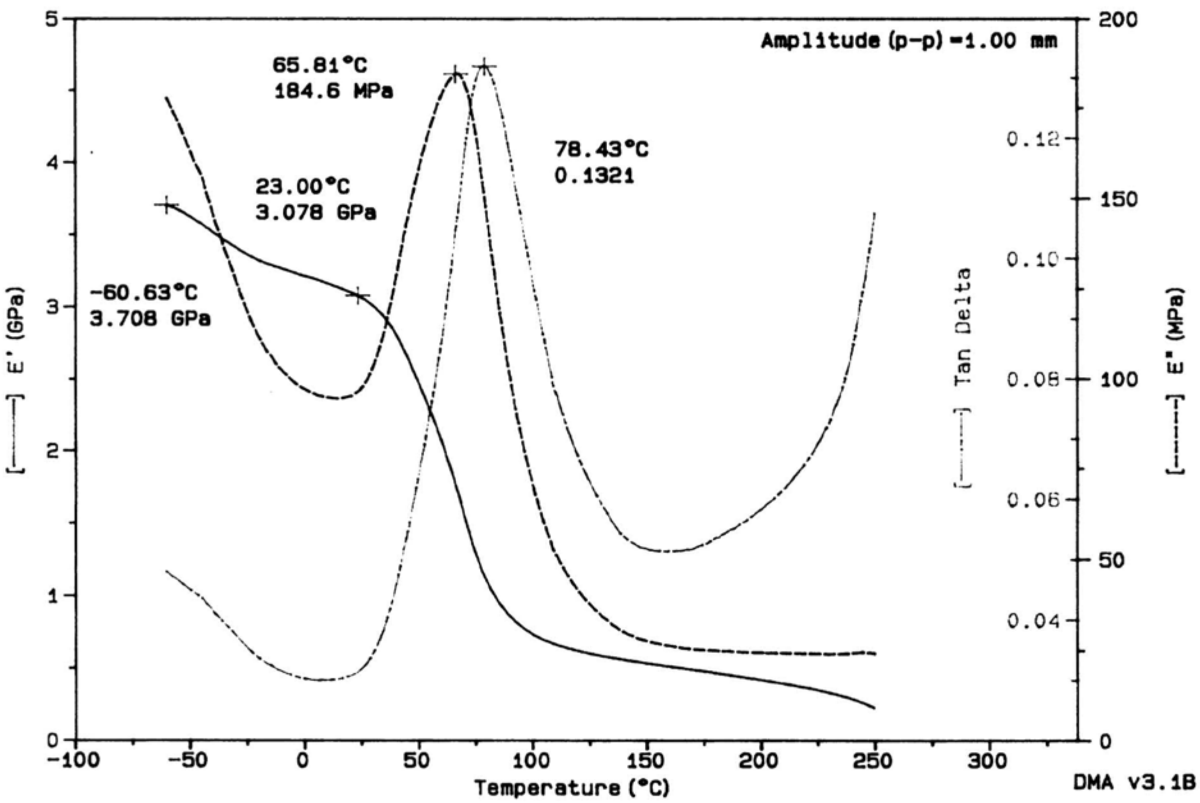
Table 25: Storage and loss properties for DuPont Zytel 77G43L 43% glass fiber filled nylon 612 tested at 0.35% moisture content. (tabular data for Graph 25)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	10.32	106.3	0.01030	80.00	6.570	310.0	0.04717
-50.00	10.29	104.9	0.01020	85.00	6.295	280.7	0.04458
-45.00	10.23	104.9	0.01025	90.00	6.076	251.7	0.04142
-40.00	10.17	103.8	0.01020	95.00	5.916	229.0	0.03871
-35.00	10.13	100.7	0.009942	100.00	5.782	208.9	0.03612
-30.00	10.08	95.31	0.009452	105.00	5.669	192.1	0.03388
-25.00	10.04	90.95	0.009060	110.00	5.581	180.1	0.03227
-20.00	9.996	88.57	0.008860	115.00	5.511	174.5	0.03166
-15.00	9.963	86.41	0.008673	120.00	5.440	169.9	0.03124
-5.00	9.899	87.13	0.008802	125.00	5.363	164.8	0.03073
0.00	9.867	88.41	0.008960	130.00	5.271	162.3	0.03078
5.00	9.840	89.64	0.009110	135.00	5.164	158.0	0.03059
10.00	9.805	92.13	0.009396	140.00	5.039	155.4	0.03085
15.00	9.767	95.50	0.009778	145.00	4.901	152.9	0.03120
20.00	9.718	102.9	0.01059	150.00	4.736	151.1	0.03191
25.00	9.653	114.1	0.01182	155.00	4.566	149.3	0.03270
30.00	9.562	129.3	0.01352	160.00	4.384	148.9	0.03397
35.00	9.424	153.1	0.01625	165.00	4.207	148.9	0.03539
40.00	9.204	186.9	0.02031	170.00	4.034	150.0	0.03719
45.00	8.912	225.9	0.02535	175.00	3.863	151.9	0.03932
50.00	8.604	261.5	0.03040	180.00	3.684	154.6	0.04196
55.00	8.291	293.1	0.03536	185.00	3.486	158.8	0.04555
60.00	7.946	317.6	0.03997	190.00	3.267	164.6	0.05040
65.00	7.571	332.9	0.04398	195.00	3.009	174.0	0.05782
70.00	7.232	337.8	0.04672	200.00	2.672	181.3	0.06786
75.00	6.894	332.9	0.04828	205.00	2.396	187.1	0.07810

Table 26: Storage and loss properties for LNP Thermocomp IF100-12 60% glass fiber filled nylon 612 tested at 0.4% moisture content. (tabular data for Graph 26)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	18.08	133.4	0.007381	80.00	12.77	509.3	0.03990
-50.00	18.04	132.6	0.007350	85.00	12.43	484.6	0.03899
-45.00	17.93	140.0	0.007807	90.00	12.10	457.3	0.03780
-40.00	17.82	141.3	0.007929	95.00	11.75	425.2	0.03618
-35.00	17.71	142.3	0.008035	100.00	11.42	395.9	0.03466
-30.00	17.61	130.4	0.007406	105.00	11.10	372.0	0.03351
-25.00	17.56	121.3	0.006907	110.00	10.78	354.7	0.03289
-15.00	17.45	108.0	0.006185	115.00	10.48	342.9	0.03273
-10.00	17.39	105.8	0.006082	120.00	10.18	335.0	0.03292
-5.00	17.35	106.2	0.006125	125.00	9.880	329.8	0.03339
0.00	17.29	107.3	0.006204	130.00	9.576	327.4	0.03418
5.00	17.23	108.3	0.006283	135.00	9.268	325.7	0.03514
10.00	17.17	109.7	0.006389	140.00	8.948	323.8	0.03619
15.00	17.10	118.6	0.006938	145.00	8.609	323.6	0.03759
20.00	17.00	129.0	0.007590	150.00	8.270	321.5	0.03887
25.00	16.84	151.2	0.008980	155.00	7.908	320.3	0.04050
30.00	16.65	178.2	0.01070	160.00	7.530	318.4	0.04229
35.00	16.42	209.1	0.01273	165.00	7.150	314.7	0.04401
40.00	16.12	251.2	0.01559	170.00	6.775	311.8	0.04603
45.00	15.71	304.6	0.09139	175.00	6.409	308.3	0.04811
50.00	15.30	358.0	0.02340	180.00	6.038	306.8	0.05081
55.00	14.90	404.9	0.02718	185.00	5.644	305.3	0.05410
60.00	14.40	447.9	0.03112	190.00	5.218	306.7	0.05877
65.00	13.87	483.5	0.03485	195.00	4.781	314.4	0.06578
70.00	13.47	509.8	0.03786	200.00	4.187	325.5	0.07774
75.00	13.12	529.2	0.04035	205.00	3.734	323.6	0.08669

Graph 27: Storage and loss properties for DuPont Zytel 101L unfilled nylon 66 tested at 0.5% moisture content.



Graph 28: Storage and loss properties for DuPont Zytel CFE4003 unfilled, impact modified nylon 66 tested at 0.5% moisture content.

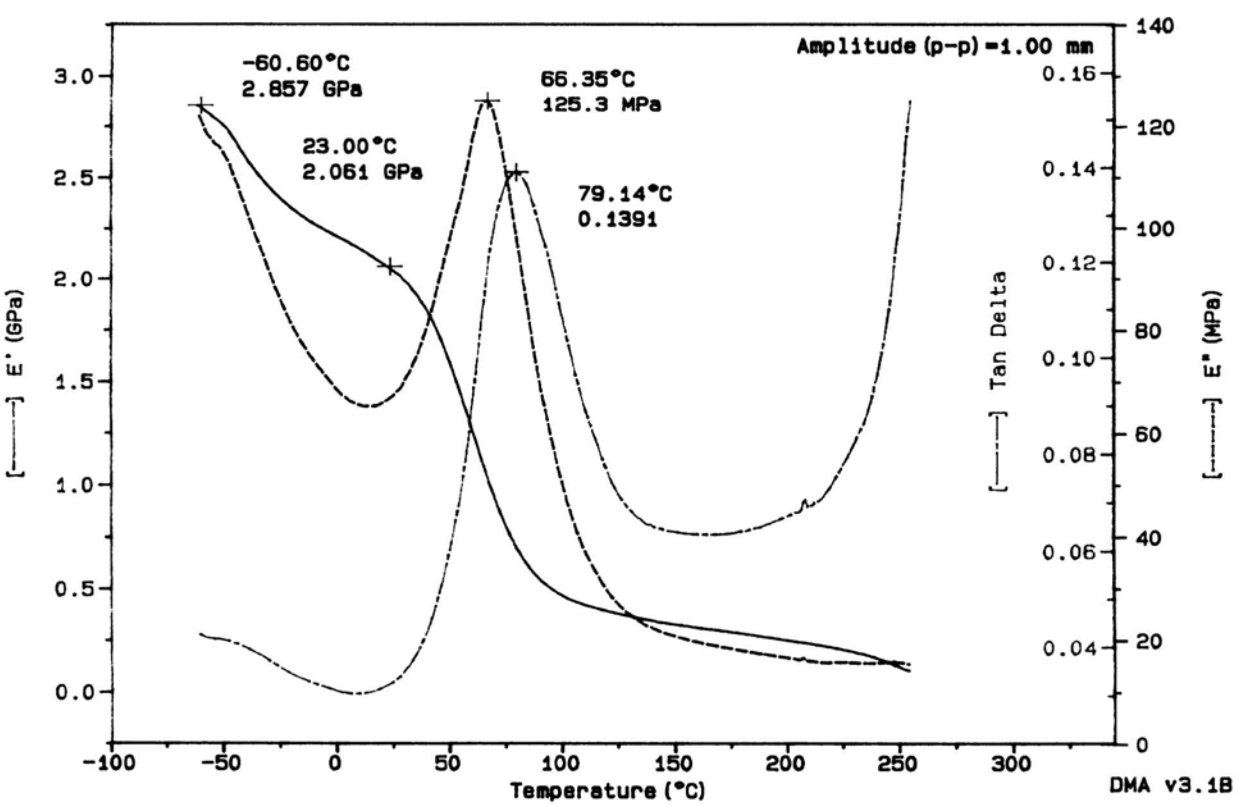


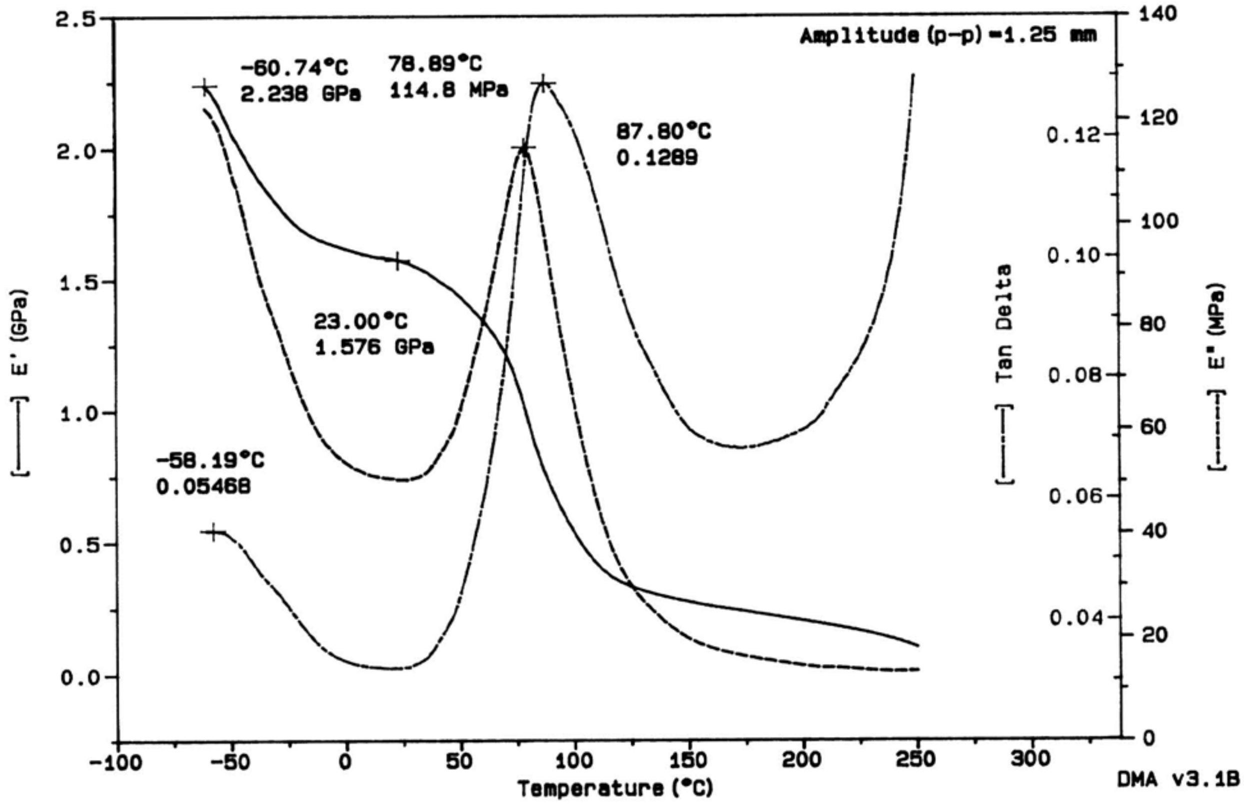
Table 27: Storage and loss properties for DuPont Zytel 101L unfilled nylon 66 tested at 0.5% moisture content. (tabular data for Graph 27)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.705	177.1	0.04780	95.00	0.7836	83.26	0.1063
-55.00	3.671	170.3	0.04639	100.00	0.7302	70.01	0.09587
-50.00	3.624	162.6	0.04487	105.00	0.6909	59.52	0.08614
-45.00	3.572	155.6	0.04354	110.00	0.6616	51.28	0.07751
-40.00	3.514	145.0	0.04126	115.00	0.6376	45.74	0.07173
-35.00	3.459	135.4	0.03915	120.00	0.6179	41.21	0.06668
-30.00	3.408	126.7	0.03718	125.00	0.5989	37.52	0.06266
-25.00	3.360	118.3	0.03521	130.00	0.5831	34.44	0.05907
-20.00	3.320	111.4	0.03356	140.00	0.5562	29.85	0.05367
-15.00	3.288	106.4	0.03237	145.00	0.5437	28.48	0.05238
-10.00	3.263	102.3	0.03136	150.00	0.5317	27.48	0.05167
-5.00	3.236	99.20	0.03065	155.00	0.5206	26.76	0.05140
0.00	3.210	97.00	0.03022	160.00	0.5098	26.20	0.05140
5.00	3.188	95.48	0.02995	165.00	0.4990	25.67	0.05145
10.00	3.160	94.79	0.03000	170.00	0.4882	25.30	0.05183
15.00	3.131	94.57	0.03020	175.00	0.4770	25.08	0.05258
20.00	3.100	95.25	0.03072	180.00	0.4651	24.95	0.05363
25.00	3.060	97.75	0.03194	190.00	0.4419	24.63	0.05573
30.00	3.003	104.1	0.03465	195.00	0.4297	24.51	0.05704
40.00	2.806	128.9	0.04596	200.00	0.4175	24.39	0.05842
45.00	2.649	145.1	0.05477	205.00	0.4050	24.28	0.05996
50.00	2.464	158.9	0.06447	210.00	0.3923	24.23	0.06177
55.00	2.271	170.2	0.07497	215.00	0.3784	24.22	0.06400
60.00	2.059	179.1	0.08702	220.00	0.3641	24.15	0.06633
65.00	1.815	184.2	0.1015	225.00	0.3479	24.12	0.06935
70.00	1.540	181.7	0.1181	230.00	0.3292	23.98	0.07283
75.00	1.286	167.0	0.1299	235.00	0.3088	24.02	0.07780
80.00	1.091	143.6	0.1316	240.00	0.2855	24.28	0.08505
90.00	0.8547	99.68	0.1166	245.00	0.2560	24.50	0.09572

Table 28 Storage and loss properties for DuPont Zytel CFE4003 unfilled, impact modified nylon 66 tested at 0.5% moisture content. (tabular data for Graph 28)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.854	121.6	0.04261	95.00	0.5054	60.04	0.1188
-55.00	2.809	117.6	0.04187	100.00	0.4698	50.74	0.1080
-50.00	2.764	114.9	0.04156	105.00	0.4426	43.45	0.09816
-45.00	2.693	109.9	0.04082	110.00	0.4218	37.71	0.08939
-40.00	2.606	104.0	0.03989	120.00	0.3910	29.82	0.07628
-35.00	2.529	97.76	0.03866	125.00	0.3780	27.07	0.07161
-30.00	2.463	91.70	0.03724	130.00	0.3661	25.07	0.06848
-25.00	2.405	86.10	0.03580	135.00	0.3544	23.54	0.06643
-20.00	2.357	81.31	0.03450	140.00	0.3442	22.45	0.06521
-15.00	2.314	77.34	0.03343	145.00	0.3341	21.53	0.06445
-10.00	2.277	74.04	0.03251	150.00	0.3256	20.85	0.06402
-5.00	2.245	71.31	0.03176	155.00	0.3176	20.24	0.06371
0.00	2.215	68.62	0.03098	160.00	0.3102	19.70	0.06352
5.00	2.185	66.64	0.03050	170.00	0.2958	18.80	0.06358
10.00	2.154	65.57	0.03044	175.00	0.2884	18.40	0.06379
15.00	2.119	65.35	0.03084	180.00	0.2808	18.03	0.06422
20.00	2.082	65.97	0.03168	190.00	0.2645	17.31	0.06547
25.00	2.044	67.44	0.03300	195.00	0.2561	17.00	0.06639
30.00	1.996	70.34	0.03524	200.00	0.2478	16.68	0.06732
40.00	1.855	80.57	0.04344	205.00	0.2396	16.31	0.06809
45.00	1.746	88.84	0.05089	210.00	0.2313	16.04	0.06936
50.00	1.612	97.51	0.06049	215.00	0.2226	15.79	0.07091
55.00	1.458	105.9	0.07265	220.00	0.2131	15.79	0.07408
60.00	1.285	116.7	0.09085	225.00	0.2024	15.81	0.07815
70.00	0.9533	122.5	0.1285	230.00	0.1904	15.73	0.08261
75.00	0.8159	111.7	0.1369	235.00	0.1778	15.64	0.08793
80.00	0.7043	97.95	0.1391	240.00	0.1623	15.67	0.09658
90.00	0.5527	70.46	0.1275	245.00	0.1436	15.82	0.1102

Graph 29: Storage and loss properties for DuPont Zytel ST801 unfilled, impact modified nylon 66 tested dry as molded.



Graph 30: Storage and loss properties for DuPont Zytel ST801 unfilled, impact modified nylon 66 tested at 0.6% moisture content.

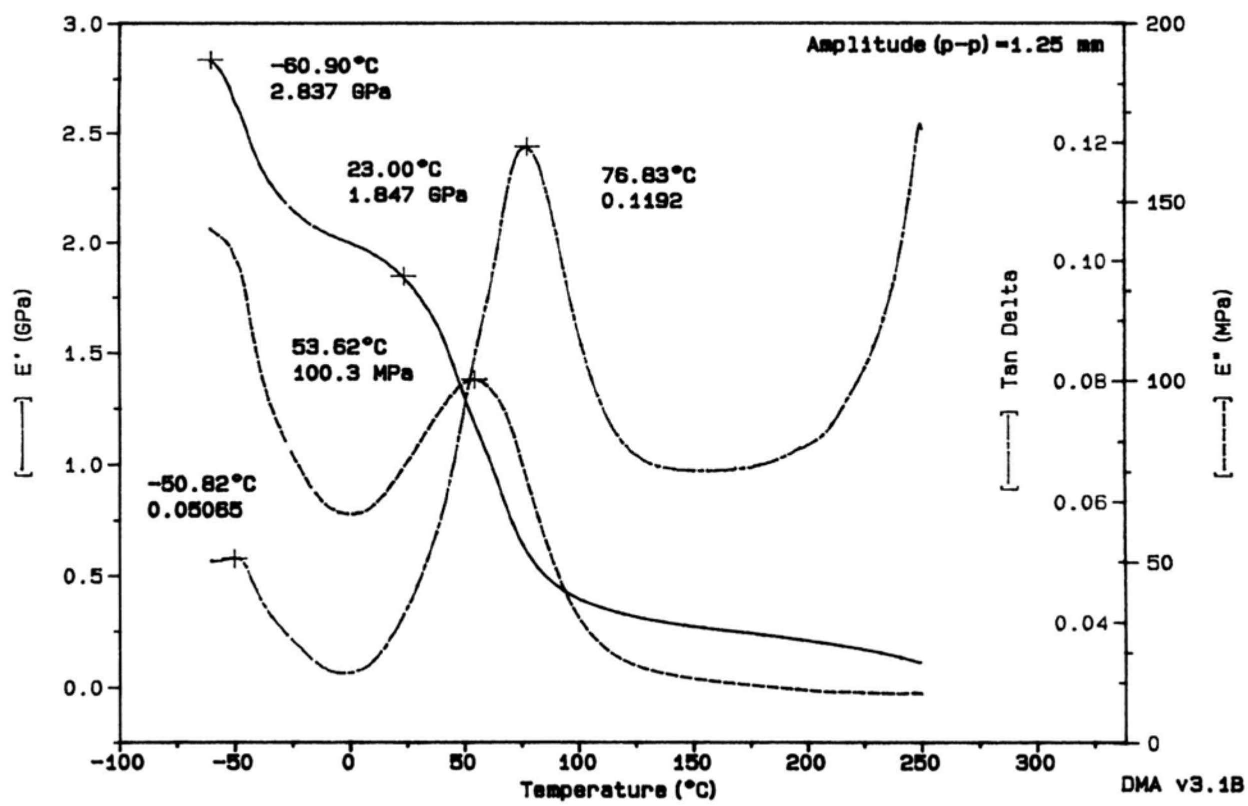


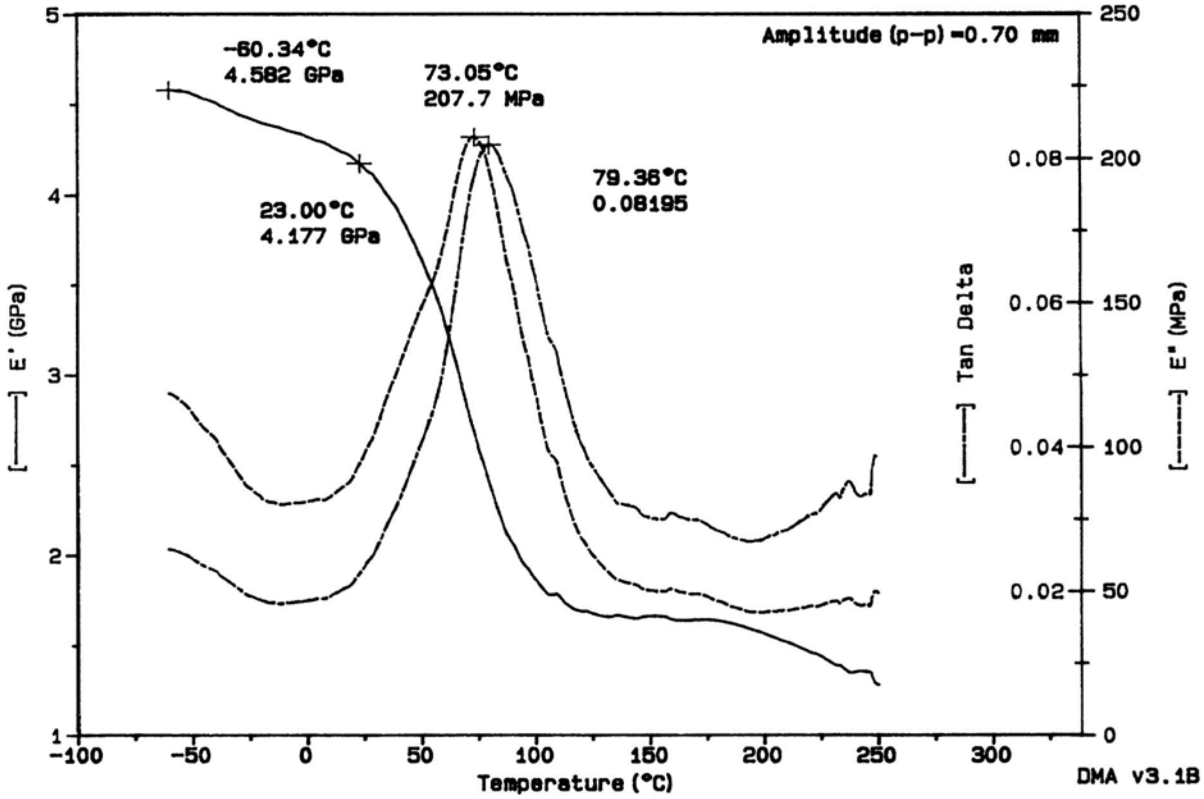
Table 29: Storage and loss properties for DuPont Zytel ST801 unfilled, impact modified nylon 66 tested dry as molded. (tabular data for Graph 29)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.233	122.0	0.05467	100.00	0.5408	65.83	0.1217
-50.00	2.079	111.4	0.05358	105.00	0.4733	55.28	0.1168
-45.00	1.999	103.6	0.05184	110.00	0.4188	46.23	0.1104
-40.00	1.922	94.32	0.04908	115.00	0.3791	39.01	0.1029
-35.00	1.857	86.60	0.04664	120.00	0.3521	33.78	0.09591
-30.00	1.800	80.27	0.04459	125.00	0.3324	29.95	0.09009
-25.00	1.747	73.67	0.04217	130.00	0.3175	27.08	0.08529
-20.00	1.703	67.37	0.03956	140.00	0.2935	22.80	0.07767
-10.00	1.650	58.25	0.03529	145.00	0.2841	21.10	0.07426
-5.00	1.635	55.67	0.03405	150.00	0.2751	19.73	0.07172
0.00	1.620	53.78	0.03319	155.00	0.2661	18.69	0.07023
5.00	1.607	52.42	0.03262	160.00	0.2582	17.89	0.06927
10.00	1.595	51.47	0.03227	165.00	0.2514	17.24	0.06859
15.00	1.587	50.97	0.03212	170.00	0.2449	16.76	0.06845
20.00	1.581	50.68	0.03204	175.00	0.2384	16.31	0.06839
25.00	1.572	50.46	0.03211	180.00	0.2314	15.86	0.06856
30.00	1.555	50.76	0.03264	190.00	0.2178	15.15	0.06959
40.00	1.505	54.47	0.03618	195.00	0.2108	14.84	0.07042
45.00	1.476	58.00	0.03930	200.00	0.2037	14.51	0.07124
50.00	1.442	63.30	0.04391	205.00	0.1964	14.23	0.07244
55.00	1.398	71.20	0.05094	210.00	0.1890	14.10	0.07462
60.00	1.351	80.01	0.05925	215.00	0.1814	14.07	0.07757
65.00	1.295	89.71	0.06927	220.00	0.1733	13.90	0.08021
70.00	1.224	100.6	0.08221	225.00	0.1648	13.74	0.08338
75.00	1.117	111.1	0.09945	230.00	0.1554	13.60	0.08755
80.00	0.9722	114.3	0.1176	240.00	0.1337	13.38	0.1000
90.00	0.7130	91.62	0.1285	245.00	0.1201	13.43	0.1119
95.00	0.6206	77.82	0.1254	250.00	0.1038	13.48	0.1299

Table 30 Storage and loss properties for DuPont Zytel ST801 unfilled, impact modified nylon 66 tested at 0.6% moisture content. (tabular data for Graph 30)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.833	142.0	0.05012	95.00	0.4242	40.35	0.09511
-55.00	2.772	139.6	0.05034	100.00	0.3962	34.56	0.08723
-50.00	2.656	134.4	0.05060	105.00	0.3741	30.26	0.08087
-45.00	2.528	123.6	0.04889	110.00	0.3561	26.98	0.07578
-40.00	2.385	106.1	0.04449	115.00	0.3405	24.52	0.07200
-35.00	2.284	94.01	0.04116	120.00	0.3272	22.72	0.06943
-30.00	2.212	85.97	0.03887	125.00	0.3155	21.37	0.06772
-25.00	2.154	79.35	0.03684	130.00	0.3049	20.28	0.06651
-20.00	2.109	73.85	0.03501	140.00	0.2871	18.81	0.06552
-15.00	2.072	68.97	0.03328	145.00	0.2792	18.23	0.06531
-10.00	2.043	65.48	0.03205	150.00	0.2721	17.76	0.06525
-5.00	2.020	63.84	0.03160	155.00	0.2656	17.33	0.06524
0.00	2.000	63.32	0.03166	160.00	0.2594	16.92	0.06521
5.00	1.977	63.86	0.03229	170.00	0.2479	16.24	0.06551
10.00	1.950	65.82	0.03376	175.00	0.2422	15.92	0.06576
15.00	1.919	68.96	0.03595	180.00	0.2353	15.61	0.06634
20.00	1.877	73.22	0.03902	185.00	0.2290	15.31	0.06686
25.00	1.825	77.96	0.04272	195.00	0.2153	14.79	0.06870
30.00	1.761	82.78	0.04701	200.00	0.2081	14.47	0.06955
40.00	1.589	92.40	0.05817	205.00	0.2007	14.17	0.07061
45.00	1.453	96.49	0.06639	210.00	0.1932	14.02	0.07259
50.00	1.309	99.55	0.07606	215.00	0.1851	13.98	0.07555
55.00	1.174	100.3	0.08548	220.00	0.1766	13.92	0.07882
60.00	1.049	98.50	0.09387	225.00	0.1675	13.80	0.08238
70.00	0.7668	87.65	0.1143	230.00	0.1575	13.70	0.08697
75.00	0.6507	77.43	0.1190	235.00	0.1465	13.60	0.09283
80.00	0.5674	66.98	0.1181	240.00	0.1344	13.57	0.1010
85.00	0.5054	56.98	0.1127	245.00	0.1209	13.65	0.1129

Graph 31: Storage and loss properties for DuPont Zytel 70G13L 13% glass fiber filled nylon 66 tested at 0.2% moisture content.



Graph 32: Storage and loss properties for DuPont Zytel 70G33L 33% glass fiber filled nylon 66 tested at 0.4% moisture content.

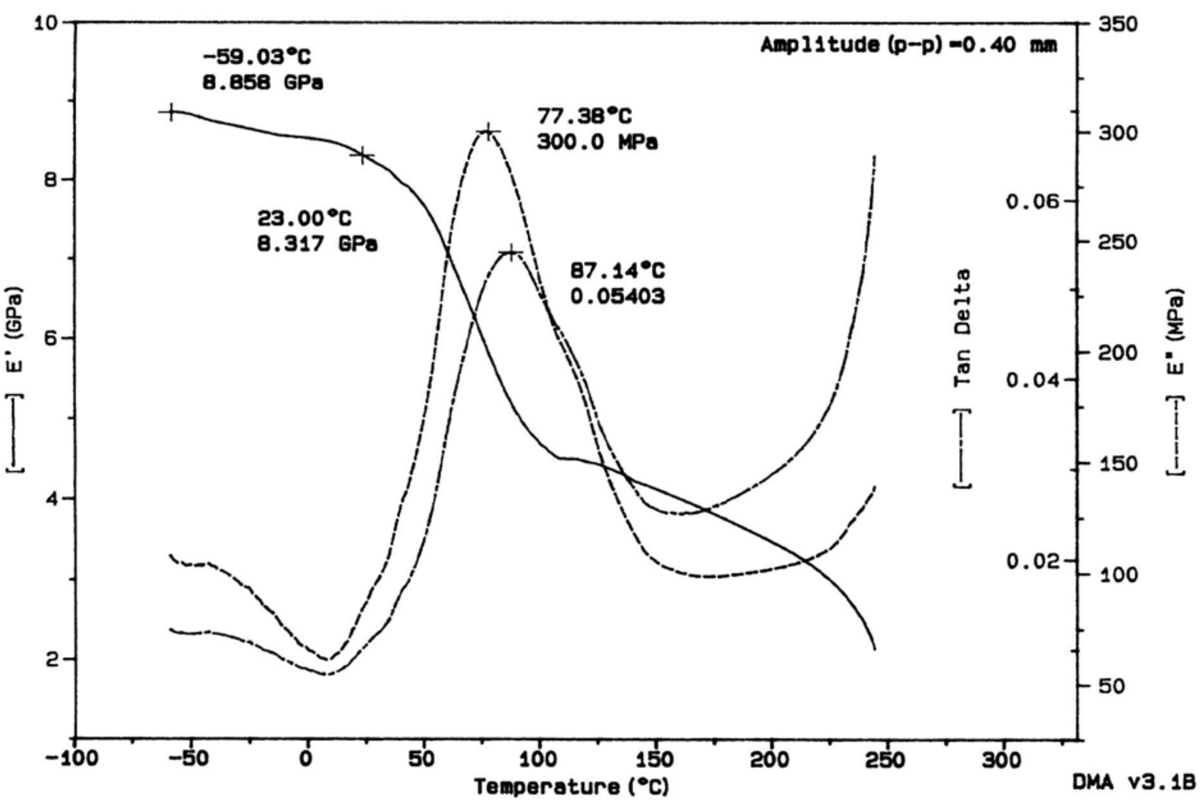


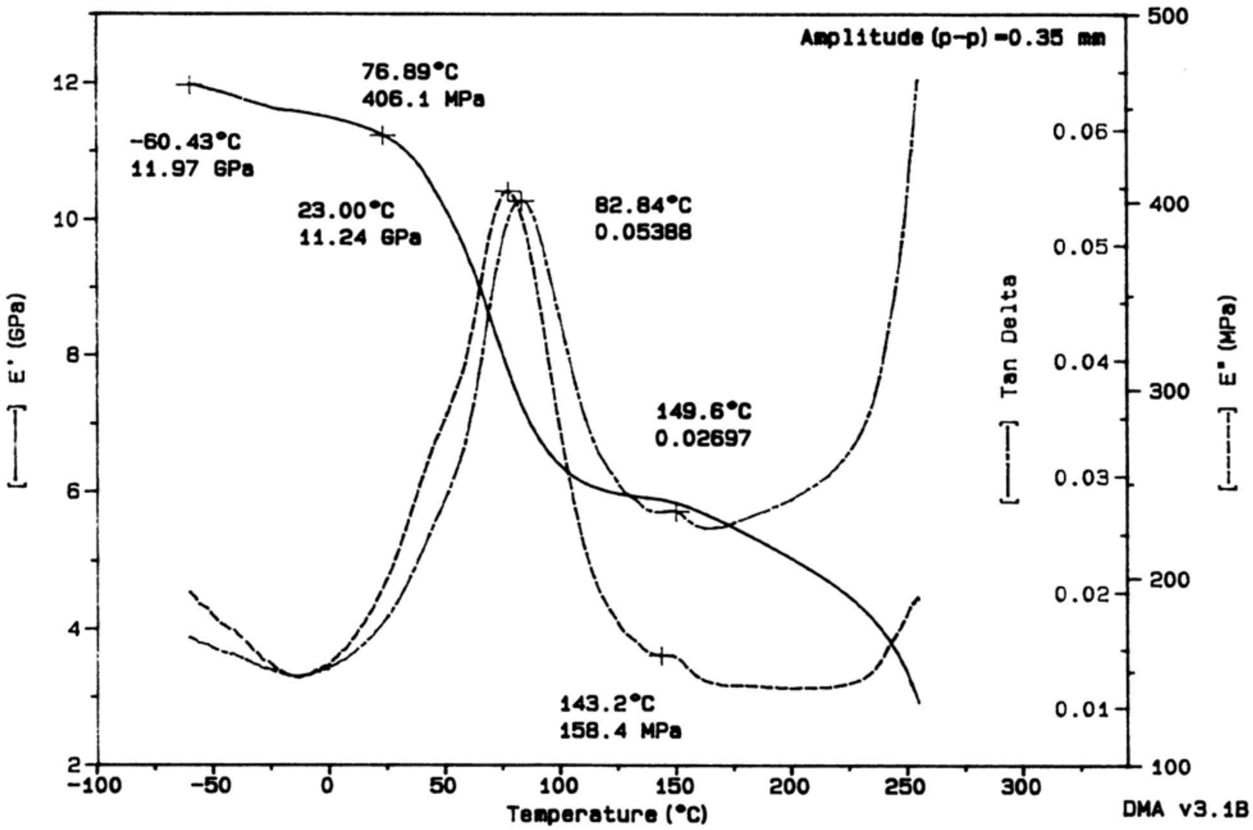
Table 31: Storage and loss properties for DuPont Zytel 70G13L 13% glass fiber filled nylon 66 tested at 0.2% moisture content. (tabular data for Graph 31)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
85.00	2.198	175.8	0.07997	80.00	2.392	196.2	0.08202
90.00	2.064	156.7	0.07593	100.00	1.863	118.5	0.06359
-60.00	4.581	118.6	0.02589	105.00	1.788	100.3	0.05610
-55.00	4.575	115.9	0.02534	110.00	1.777	92.39	0.05198
-50.00	4.559	111.7	0.02449	115.00	1.714	77.87	0.04544
-45.00	4.533	106.6	0.02351	120.00	1.689	68.34	0.04048
-40.00	4.511	102.8	0.02279	125.00	1.676	62.44	0.03725
-35.00	4.478	96.27	0.02150	130.00	1.660	57.77	0.03479
-30.00	4.447	90.35	0.02032	140.00	1.655	52.84	0.03193
-25.00	4.424	85.73	0.01938	145.00	1.653	51.50	0.03115
-20.00	4.399	82.31	0.01871	150.00	1.663	50.22	0.03019
-15.00	4.383	80.98	0.01848	155.00	1.661	49.93	0.03006
-10.00	4.364	80.42	0.01843	160.00	1.642	50.62	0.03083
-5.00	4.345	80.84	0.01860	165.00	1.639	49.36	0.03012
0.00	4.324	81.25	0.01879	170.00	1.641	49.07	0.02991
5.00	4.300	82.02	0.01907	175.00	1.642	47.98	0.02922
10.00	4.276	83.07	0.01943	180.00	1.634	46.39	0.02838
15.00	4.242	86.22	0.02033	190.00	1.604	43.58	0.02717
20.00	4.210	90.30	0.02145	195.00	1.584	42.73	0.02698
30.00	4.099	106.5	0.02599	200.00	1.563	42.85	0.02742
35.00	4.007	118.1	0.02947	205.00	1.537	43.02	0.02798
40.00	3.914	128.0	0.03270	210.00	1.516	43.37	0.02862
45.00	3.787	138.8	0.03664	215.00	1.489	44.12	0.02963
50.00	3.650	148.7	0.04074	220.00	1.461	44.87	0.03072
55.00	3.496	157.8	0.04514	225.00	1.436	45.26	0.03151
60.00	3.312	171.3	0.05173	230.00	1.397	46.50	0.03329
65.00	3.082	190.0	0.06165	240.00	1.353	45.62	0.03371
70.00	2.824	204.9	0.07255	245.00	1.352	45.27	0.03348

Table 32: Storage and loss properties for DuPont Zytel 70G33L 33% glass fiber filled nylon 66 tested at 0.4% moisture content. (tabular data for Graph 32)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	8.850	104.7	0.01183	95.00	4.851	253.2	0.05220
-50.00	8.819	103.6	0.01174	100.00	4.691	231.9	0.04942
-45.00	8.774	103.7	0.01181	105.00	4.565	213.9	0.04686
-40.00	8.733	102.7	0.01176	110.00	4.504	201.6	0.04477
-35.00	8.702	99.83	0.01147	115.00	4.494	190.2	0.04233
-30.00	8.671	96.26	0.01110	120.00	4.463	175.7	0.03936
-25.00	8.638	92.62	0.01072	125.00	4.432	156.7	0.03535
-20.00	8.606	86.17	0.01001	130.00	4.378	141.8	0.03238
-15.00	8.574	81.58	0.009515	135.00	4.315	129.1	0.02992
-10.00	8.551	75.17	0.008791	140.00	4.234	118.4	0.02797
-5.00	8.539	69.51	0.008140	145.00	4.178	110.0	0.02633
0.00	8.522	65.31	0.007663	150.00	4.123	105.2	0.02552
5.00	8.503	61.81	0.007269	155.00	4.065	102.4	0.02519
10.00	8.476	61.67	0.007275	160.00	4.006	100.6	0.02510
15.00	8.431	66.98	0.007945	165.00	3.943	99.20	0.02516
20.00	8.366	76.66	0.009164	170.00	3.881	98.74	0.02544
25.00	8.286	87.32	0.01054	175.00	3.814	98.88	0.02592
35.00	8.111	109.8	0.01354	180.00	3.749	99.11	0.02644
40.00	7.971	130.9	0.01643	190.00	3.613	100.5	0.02782
45.00	7.854	147.4	0.01877	195.00	3.542	101.3	0.02860
50.00	7.673	171.5	0.02235	200.00	3.470	102.3	0.02949
55.00	7.424	203.6	0.02743	205.00	3.396	103.2	0.03039
60.00	7.096	242.8	0.03422	210.00	3.316	104.5	0.03152
65.00	6.747	272.1	0.04033	215.00	3.225	106.3	0.03295
70.00	6.391	290.6	0.04548	220.00	3.122	108.5	0.03474
75.00	6.026	299.5	0.04971	225.00	3.001	111.4	0.03711
85.00	5.343	288.0	0.05390	230.00	2.863	116.7	0.04076
90.00	5.065	272.8	0.05387	240.00	2.459	131.3	0.05338

Graph 33: Storage and loss properties for Ticona Celanese 1603-2 40% glass fiber filled nylon 66 tested at 0.5% moisture content.



Graph 34: Storage and loss properties for Ticona Celanese NFX-0102 40% glass bead filled nylon 66 tested at 0.6% moisture content.

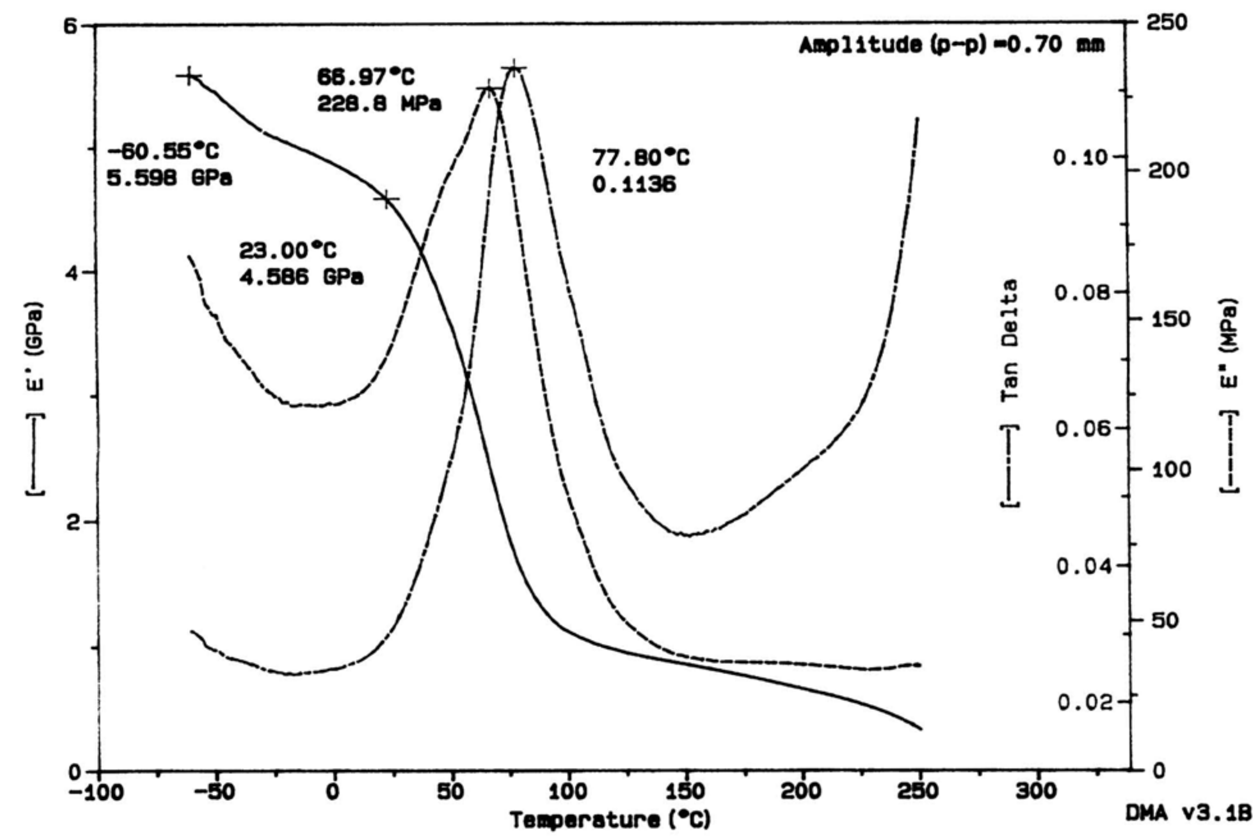


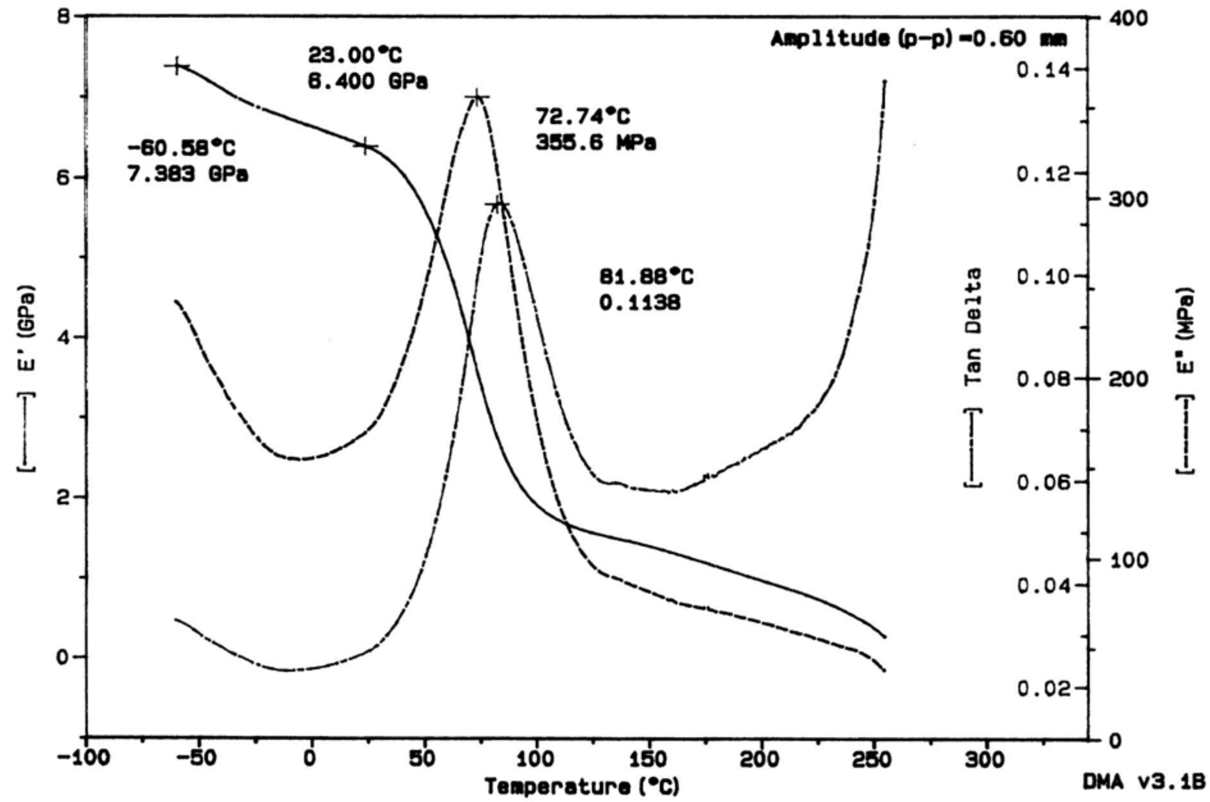
Table 33: Storage and loss properties for Ticona Celanese 1603-2 40% glass fiber filled nylon 66 tested at 0.5% moisture content. (tabular data for Graph 33)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	11.97	191.6	0.01601	100.00	6.379	276.7	0.04337
-50.00	11.89	179.3	0.01508	105.00	6.234	243.6	0.03908
-45.00	11.85	173.7	0.01466	110.00	6.131	217.1	0.03542
-40.00	11.79	169.7	0.01439	115.00	6.060	198.1	0.03269
-35.00	11.73	163.9	0.01397	120.00	6.008	185.1	0.03081
-30.00	11.68	157.4	0.01348	125.00	5.969	174.9	0.02931
-25.00	11.63	153.5	0.01320	130.00	5.943	168.0	0.02827
-20.00	11.60	149.0	0.01285	140.00	5.900	158.9	0.02693
-10.00	11.56	147.5	0.01276	145.00	5.873	158.4	0.02698
-5.00	11.53	150.2	0.01303	150.00	5.831	157.1	0.02695
0.00	11.49	154.3	0.01343	155.00	5.776	151.2	0.02617
5.00	11.45	160.7	0.01403	160.00	5.709	146.4	0.02564
10.00	11.41	167.6	0.01469	165.00	5.635	143.9	0.02554
15.00	11.35	176.7	0.01557	170.00	5.558	142.6	0.02566
20.00	11.29	187.6	0.01663	175.00	5.474	142.6	0.02605
25.00	11.20	200.4	0.01789	180.00	5.388	142.5	0.02644
30.00	11.09	216.0	0.01947	190.00	5.214	141.7	0.02718
40.00	10.73	253.6	0.02363	195.00	5.123	141.3	0.02758
45.00	10.46	270.9	0.02591	200.00	5.030	141.1	0.02805
50.00	10.16	285.5	0.02809	205.00	4.931	141.3	0.02865
55.00	9.833	301.4	0.03066	210.00	4.829	141.2	0.02925
60.00	9.449	322.7	0.03416	215.00	4.721	141.6	0.02999
65.00	9.009	354.6	0.03936	220.00	4.603	142.7	0.03101
70.00	8.499	386.9	0.04552	225.00	4.471	144.0	0.03221
75.00	8.007	404.4	0.05051	230.00	4.320	146.2	0.03384
80.00	7.535	402.8	0.05345	240.00	3.934	159.6	0.04056
90.00	6.819	352.1	0.05164	245.00	3.675	170.1	0.04629
95.00	6.570	313.7	0.04775	250.00	3.336	182.0	0.05457

Table 34: Storage and loss properties for Ticona Celanese NFX-0102 40% glass bead filled nylon 66 tested at 0.6% moisture content. (tabular data for Graph 34)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.595	171.0	0.03056	95.00	1.182	106.8	0.09035
-50.00	5.467	151.8	0.02777	100.00	1.118	91.86	0.08213
-45.00	5.384	143.4	0.02663	105.00	1.069	80.04	0.07490
-40.00	5.296	138.7	0.02618	110.00	1.029	69.34	0.06738
-35.00	5.214	134.0	0.02569	115.00	0.9975	60.55	0.06070
-30.00	5.146	128.5	0.02497	120.00	0.9706	53.83	0.05546
-25.00	5.091	125.1	0.02458	125.00	0.9452	49.22	0.05208
-20.00	5.050	122.8	0.02431	130.00	0.9242	45.68	0.04942
-15.00	5.008	121.9	0.02433	140.00	0.8860	40.62	0.04584
-10.00	4.969	122.0	0.02455	150.00	0.8511	37.90	0.04452
-5.00	4.923	121.7	0.02472	155.00	0.8335	37.19	0.04462
0.00	4.877	122.1	0.02504	160.00	0.8149	36.68	0.04501
5.00	4.827	123.3	0.02554	165.00	0.7966	36.28	0.04554
10.00	4.772	125.0	0.02619	170.00	0.7783	36.20	0.04652
15.00	4.712	128.4	0.02724	175.00	0.7598	36.06	0.04746
20.00	4.637	134.1	0.02892	180.00	0.7405	36.09	0.04874
25.00	4.547	142.0	0.03122	190.00	0.6983	35.88	0.05137
30.00	4.424	153.0	0.03458	195.00	0.6765	35.63	0.05267
40.00	4.067	178.7	0.04394	200.00	0.6550	35.36	0.05398
45.00	3.837	189.9	0.04949	205.00	0.6323	35.11	0.05553
50.00	3.583	199.6	0.05572	210.00	0.6112	34.76	0.05687
55.00	3.289	207.5	0.06309	215.00	0.5874	34.44	0.05863
60.00	2.948	217.0	0.07361	220.00	0.5621	34.08	0.06064
65.00	2.565	227.2	0.08863	225.00	0.5340	33.68	0.06307
70.00	2.187	226.2	0.1034	230.00	0.5038	33.71	0.06691
75.00	1.863	208.7	0.1120	240.00	0.4316	34.46	0.07986
80.00	1.608	182.0	0.1132	245.00	0.3872	35.04	0.09049
90.00	1.281	127.9	0.09983	250.00	0.3334	34.95	0.1049

Graph 35: Storage and loss properties for DuPont Minlon 6122 40% mineral filled nylon 66 tested at 0.5% moisture content.



Graph 36: Storage and loss properties for DuPont Minlon 10B40 40% mineral filled nylon 66 tested at 0.2% moisture content.

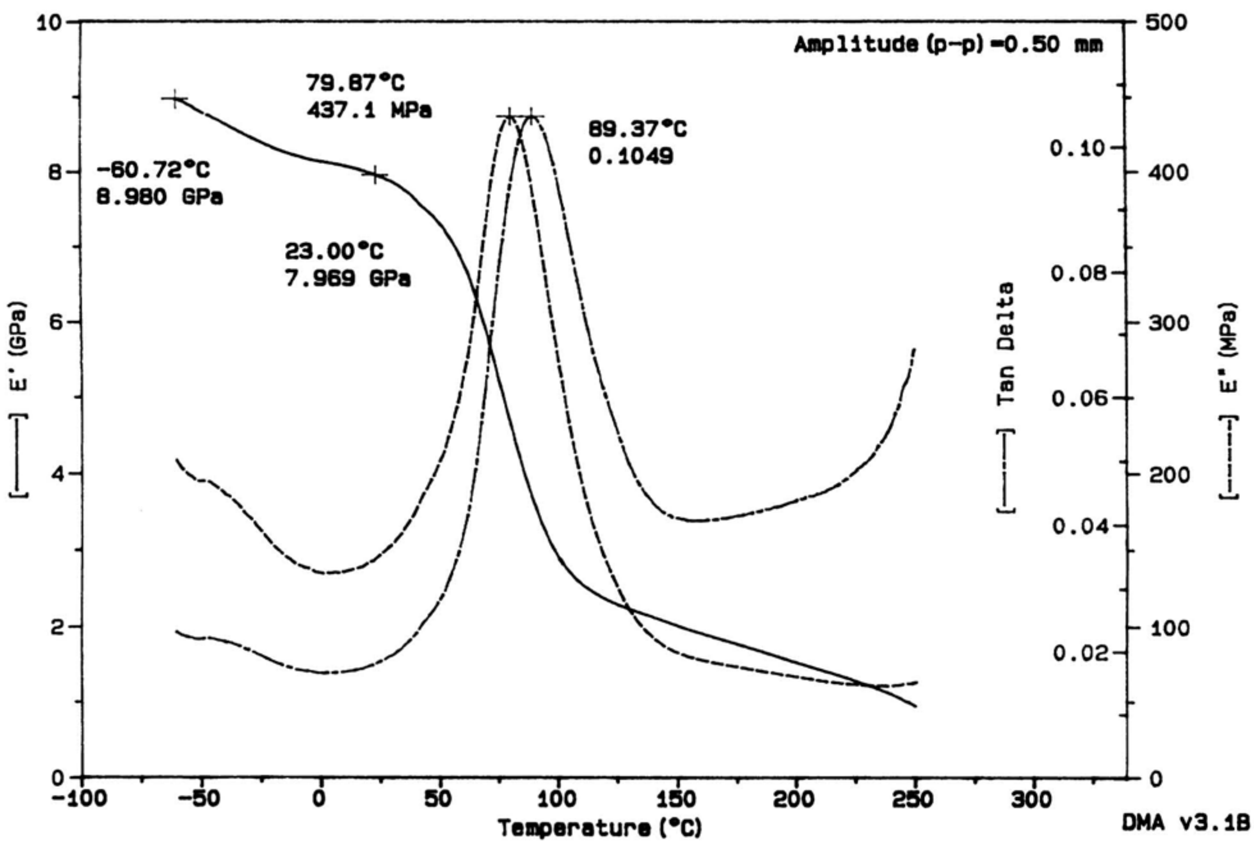


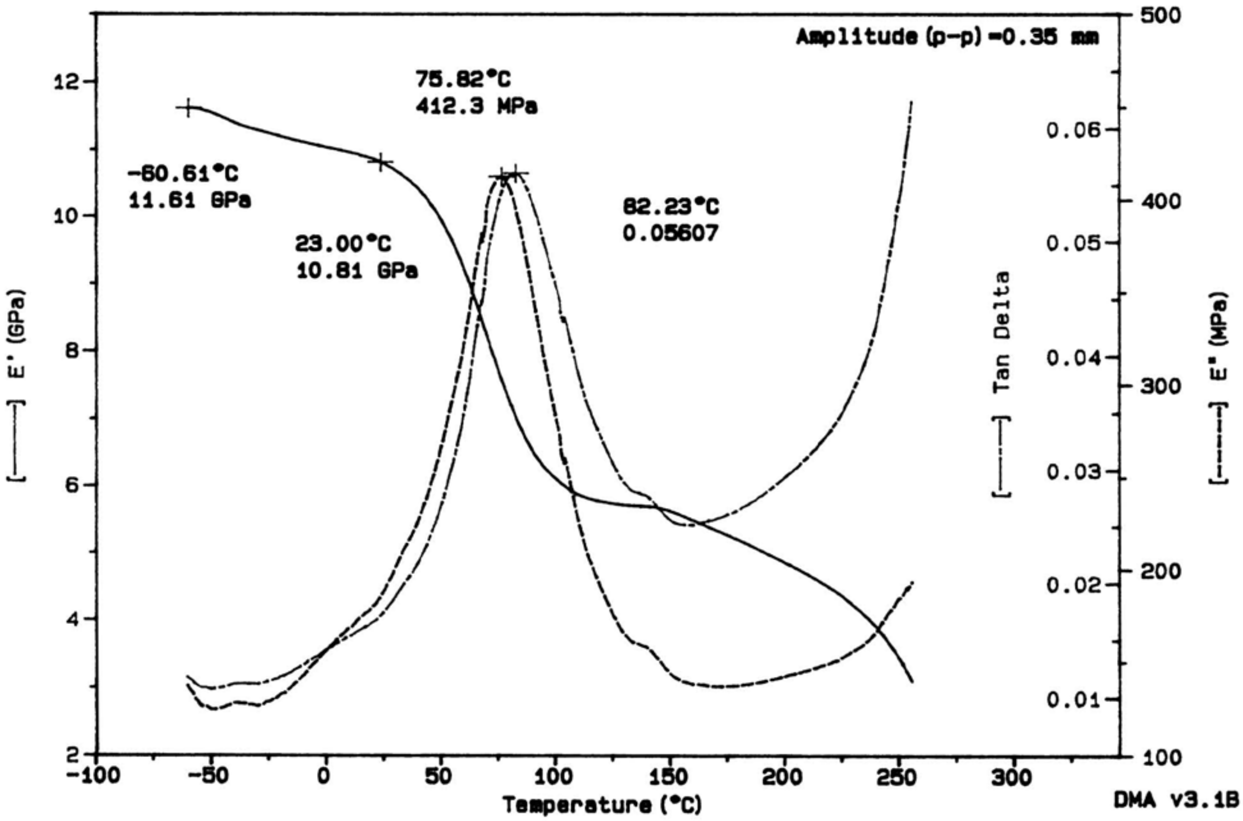
Table 35: Storage and loss properties for DuPont Minlon 6122 40% mineral filled nylon 66 tested at 0.5% moisture content. (tabular data for Graph 35)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	7.380	241.9	0.03277	100.00	1.911	175.9	0.09201
-50.00	7.258	218.5	0.03010	105.00	1.799	149.5	0.08311
-45.00	7.176	205.9	0.02869	110.00	1.716	129.1	0.07523
-40.00	7.093	195.2	0.02752	115.00	1.652	114.1	0.06906
-35.00	7.008	183.9	0.02624	120.00	1.602	103.3	0.06449
-30.00	6.939	175.6	0.02531	125.00	1.563	95.61	0.06118
-20.00	6.828	160.6	0.02352	130.00	1.530	91.19	0.05960
-15.00	6.778	156.5	0.02309	140.00	1.467	86.42	0.05892
-10.00	6.724	154.9	0.02304	145.00	1.434	83.86	0.05848
-5.00	6.677	154.5	0.02314	150.00	1.398	81.28	0.05814
0.00	6.631	155.3	0.02343	155.00	1.359	78.88	0.05805
5.00	6.582	156.7	0.02380	160.00	1.319	76.90	0.05831
10.00	6.532	159.2	0.02438	165.00	1.278	74.53	0.05834
15.00	6.482	162.4	0.02505	170.00	1.236	73.35	0.05936
20.00	6.429	166.5	0.02590	175.00	1.193	73.25	0.06141
25.00	6.376	171.5	0.02689	180.00	1.149	70.76	0.06159
30.00	6.304	179.2	0.02842	190.00	1.060	67.56	0.06371
40.00	6.055	208.2	0.03439	195.00	1.016	66.09	0.06506
45.00	5.859	227.3	0.03879	200.00	0.9722	64.50	0.06634
50.00	5.610	250.6	0.04467	205.00	0.9284	62.76	0.06760
55.00	5.301	277.7	0.05240	210.00	0.8841	60.65	0.06860
60.00	4.931	307.5	0.06238	215.00	0.8389	58.94	0.07026
65.00	4.481	333.0	0.07434	220.00	0.7913	57.45	0.07260
70.00	3.957	350.6	0.08861	225.00	0.7396	55.39	0.07490
75.00	3.415	353.9	0.1037	230.00	0.6819	53.35	0.07824
80.00	2.941	330.8	0.1125	240.00	0.5457	49.76	0.09120
90.00	2.276	247.7	0.1088	245.00	0.4703	47.26	0.1005
95.00	2.063	208.0	0.1008	250.00	0.3785	43.19	0.1142

Table 36: Storage and loss properties for DuPont Minlon 10B40 40% mineral filled nylon 66 tested at 0.2% moisture content. (tabular data for Graph 36)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.976	207.5	0.02311	100.00	2.931	278.4	0.09498
-50.00	8.821	195.3	0.02214	105.00	2.717	231.9	0.08536
-45.00	8.742	192.8	0.02205	110.00	2.562	194.8	0.07601
-40.00	8.651	186.4	0.02155	115.00	2.455	165.6	0.06747
-35.00	8.564	180.3	0.02106	120.00	2.367	143.5	0.06063
-30.00	8.480	171.7	0.02025	125.00	2.294	126.3	0.05504
-25.00	8.404	162.4	0.01932	130.00	2.236	111.2	0.04973
-20.00	8.332	153.4	0.01841	140.00	2.125	92.28	0.04343
-15.00	8.272	146.2	0.01767	145.00	2.068	86.59	0.04186
-10.00	8.223	140.6	0.01710	150.00	2.013	82.90	0.04119
-5.00	8.177	138.1	0.01689	155.00	1.961	79.93	0.04076
0.00	8.147	135.1	0.01658	160.00	1.911	77.81	0.04071
5.00	8.119	135.3	0.01667	170.00	1.817	74.68	0.04111
10.00	8.087	136.1	0.01683	175.00	1.770	73.38	0.04146
15.00	8.049	138.3	0.01718	180.00	1.723	72.08	0.04182
20.00	8.001	142.3	0.01778	185.00	1.674	70.67	0.04220
25.00	7.944	147.3	0.01854	190.00	1.625	69.43	0.04273
30.00	7.878	154.0	0.01954	195.00	1.575	67.97	0.04317
40.00	7.647	176.7	0.02311	200.00	1.525	66.83	0.04383
45.00	7.494	191.9	0.02561	205.00	1.476	65.53	0.04440
50.00	7.329	208.3	0.02842	210.00	1.428	64.22	0.04497
55.00	7.107	231.1	0.03253	215.00	1.381	63.27	0.04581
60.00	6.814	263.0	0.03860	220.00	1.331	62.45	0.04692
70.00	5.887	369.0	0.06270	225.00	1.277	61.75	0.04834
75.00	5.288	418.7	0.07919	230.00	1.222	61.00	0.04993
80.00	4.689	437.2	0.09324	240.00	1.100	60.95	0.05542
90.00	3.642	382.2	0.1050	245.00	1.021	62.27	0.06097
95.00	3.239	330.5	0.1020	250.00	0.9417	63.39	0.06733

Graph 37: Storage and loss properties for DuPont Zytel FE5128 43% glass fiber filled nylon 66 tested at 0.35% moisture content.



Graph 38: Storage and loss properties for DuPont Minlon 11C40 40% mineral filled, impact modified nylon 66 tested at 0.5% moisture content.

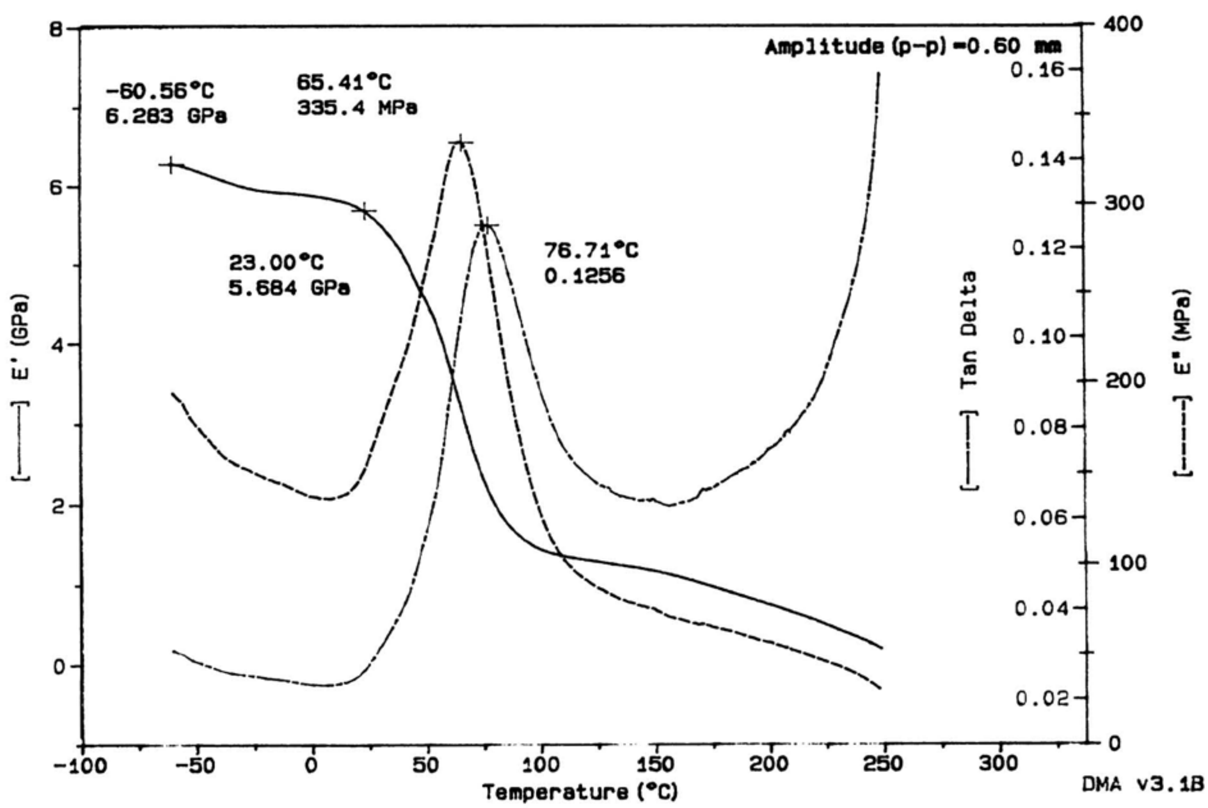


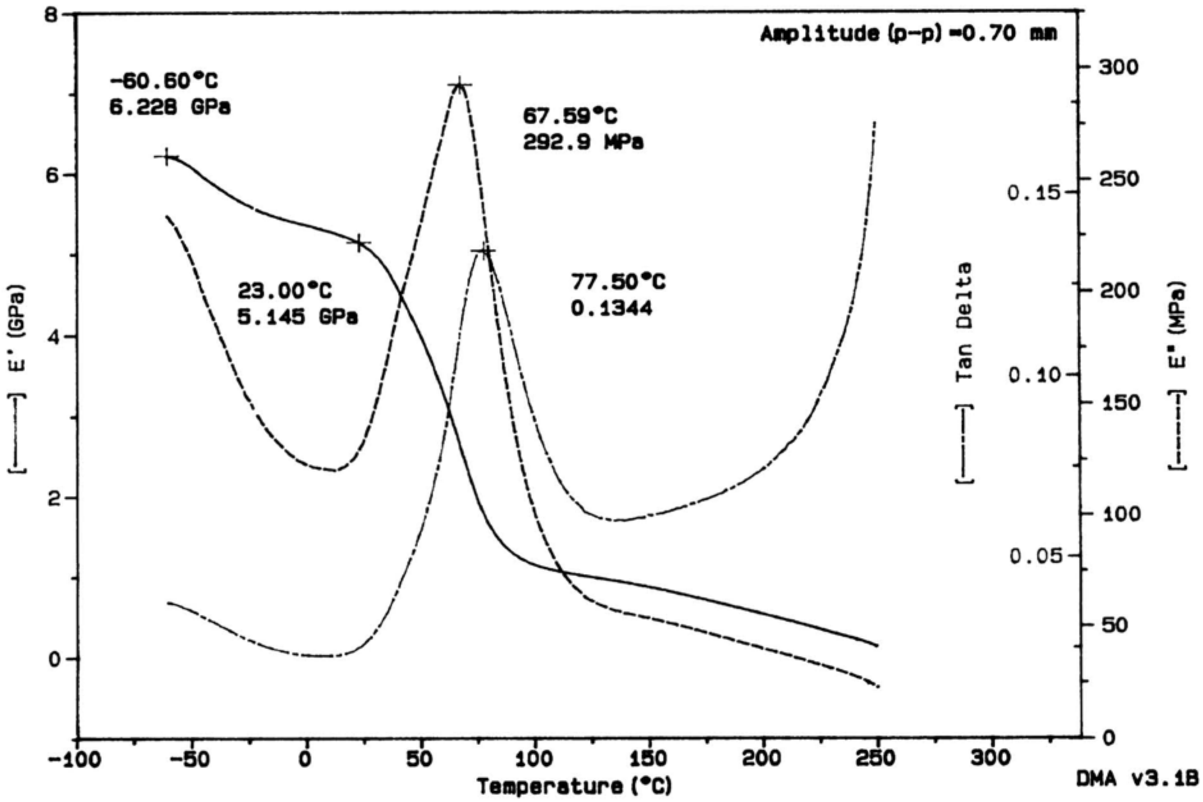
Table 37: Storage and loss properties for DuPont Zytel FE5128 43% glass fiber filled nylon 66 tested at 0.35% moisture content. (tabular data for Graph 37)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	11.62	136.0	0.01171	100.00	6.106	282.3	0.04623
-50.00	11.54	124.4	0.01078	105.00	5.964	254.1	0.04260
-45.00	11.47	125.4	0.01093	110.00	5.863	225.4	0.03844
-40.00	11.39	128.0	0.01124	115.00	5.800	204.3	0.03522
-35.00	11.33	127.4	0.01124	120.00	5.760	189.2	0.03285
-30.00	11.28	126.4	0.01121	125.00	5.732	175.5	0.03061
-25.00	11.23	128.7	0.01146	130.00	5.712	164.9	0.02886
-15.00	11.14	137.3	0.01232	140.00	5.687	157.4	0.02769
-10.00	11.10	142.9	0.01287	145.00	5.661	150.7	0.02662
-5.00	11.06	149.9	0.01355	150.00	5.611	143.4	0.02556
0.00	11.02	156.6	0.01420	155.00	5.546	139.7	0.02518
5.00	10.99	162.9	0.01483	160.00	5.473	138.0	0.02521
10.00	10.95	168.4	0.01538	165.00	5.398	137.5	0.02546
15.00	10.90	174.4	0.01599	170.00	5.323	137.1	0.02575
20.00	10.89	180.0	0.01658	175.00	5.250	137.2	0.02614
25.00	10.78	188.9	0.01752	180.00	5.174	137.8	0.02663
30.00	10.68	201.6	0.01887	190.00	5.013	139.6	0.02785
40.00	10.40	227.6	0.02188	195.00	4.930	141.0	0.02861
45.00	10.20	245.7	0.02409	200.00	4.845	142.6	0.02943
50.00	9.939	267.9	0.02696	205.00	4.758	144.1	0.03028
55.00	9.613	294.6	0.03065	210.00	4.667	145.8	0.03124
60.00	9.215	324.5	0.03522	215.00	4.569	147.9	0.03237
65.00	8.743	364.7	0.04172	220.00	4.466	149.9	0.03357
70.00	8.221	398.7	0.04850	225.00	4.351	152.7	0.03509
75.00	7.708	412.2	0.05349	230.00	4.212	156.4	0.03713
80.00	7.251	405.2	0.05589	240.00	3.893	167.0	0.04290
90.00	6.519	347.6	0.05332	245.00	3.677	176.6	0.04803
95.00	6.275	313.0	0.04988	250.00	3.430	184.8	0.05388

Table 38: Storage and loss properties for DuPont Minlon 11C40 40% mineral filled, impact modified nylon 66 tested at 0.5% moisture content. (tabular data for Graph 38)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.281	193.9	0.03087	95.00	1.514	147.0	0.09714
-55.00	6.252	186.0	0.02976	100.00	1.438	127.0	0.08835
-50.00	6.203	176.3	0.02842	105.00	1.388	112.5	0.08109
-45.00	6.150	169.1	0.02750	110.00	1.354	102.5	0.07569
-40.00	6.095	161.7	0.02654	115.00	1.327	95.70	0.07214
-35.00	6.043	156.8	0.02594	120.00	1.303	91.01	0.06983
-30.00	5.997	153.5	0.02559	125.00	1.282	86.83	0.06771
-25.00	5.960	150.7	0.02528	130.00	1.260	84.12	0.06676
-20.00	5.934	147.5	0.02486	135.00	1.238	80.54	0.06505
-15.00	5.918	145.2	0.02454	140.00	1.216	78.39	0.06447
-10.00	5.906	142.9	0.02419	145.00	1.191	76.52	0.06423
-5.00	5.892	139.9	0.02375	150.00	1.163	74.33	0.06389
0.00	5.874	137.5	0.02341	155.00	1.131	71.19	0.06296
5.00	5.851	136.5	0.02333	160.00	1.094	69.43	0.06346
10.00	5.824	137.0	0.02352	170.00	1.012	67.01	0.06621
15.00	5.788	139.4	0.02409	175.00	0.9692	64.70	0.06676
20.00	5.734	146.2	0.02550	180.00	0.9248	63.25	0.06840
25.00	5.642	160.3	0.02841	190.00	0.8341	59.42	0.07123
30.00	5.518	177.9	0.03224	195.00	0.7886	57.61	0.07306
40.00	5.145	212.9	0.04138	200.00	0.7427	56.11	0.07555
45.00	4.845	235.1	0.04854	205.00	0.6959	53.88	0.07743
50.00	4.556	262.8	0.05769	210.00	0.6472	51.87	0.08016
55.00	4.225	290.3	0.06871	215.00	0.5962	49.74	0.08342
60.00	3.766	321.9	0.08552	220.00	0.5440	47.44	0.08721
70.00	2.732	322.0	0.1179	225.00	0.4867	45.31	0.09309
75.00	2.315	289.3	0.1250	230.00	0.4259	42.88	0.1007
80.00	2.000	248.3	0.1242	240.00	0.3100	36.92	0.1191
90.00	1.622	173.7	0.1071	245.00	0.2426	32.85	0.1355

Graph 39: Storage and loss properties for DuPont Minlon 12T 40% mineral filled, impact modified nylon 66 tested at 0.6% moisture content.



Graph 40: Storage and loss properties for DuPont Zytel 82G33L 33% glass fiber filled, impact modified nylon 6/66 tested at 0.2% moisture content.

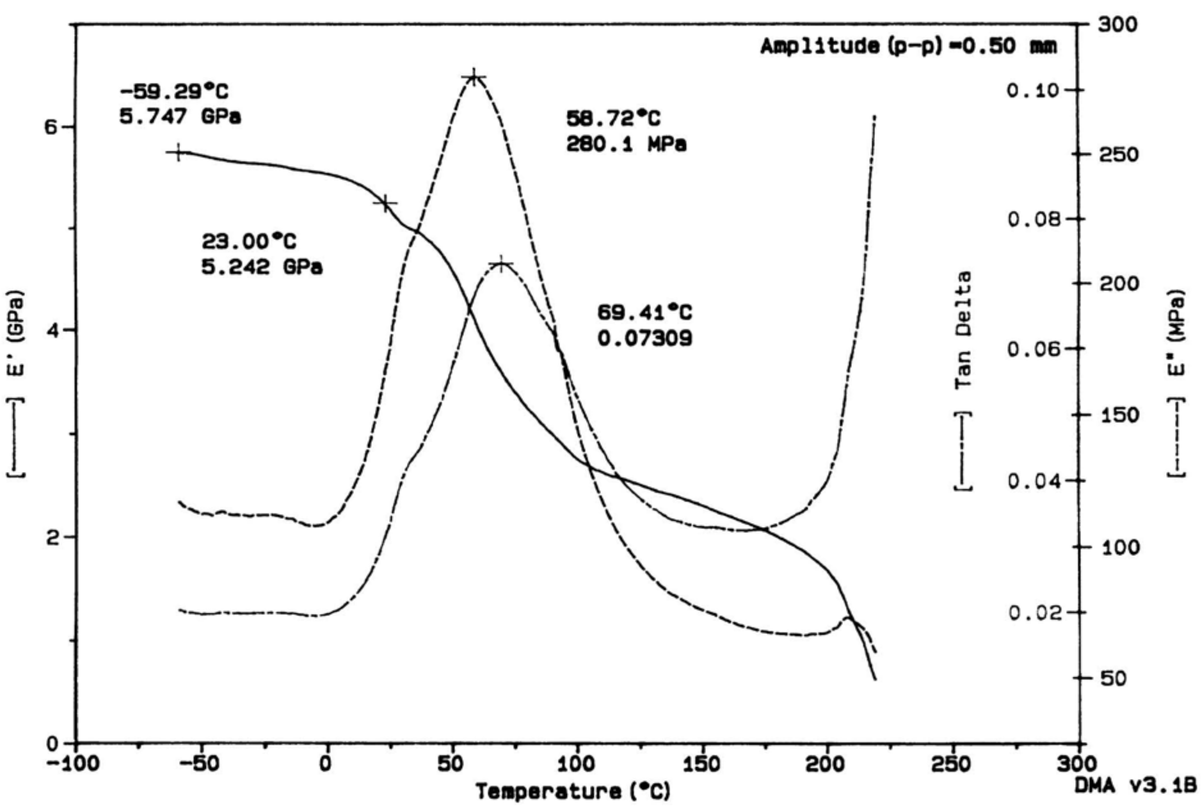


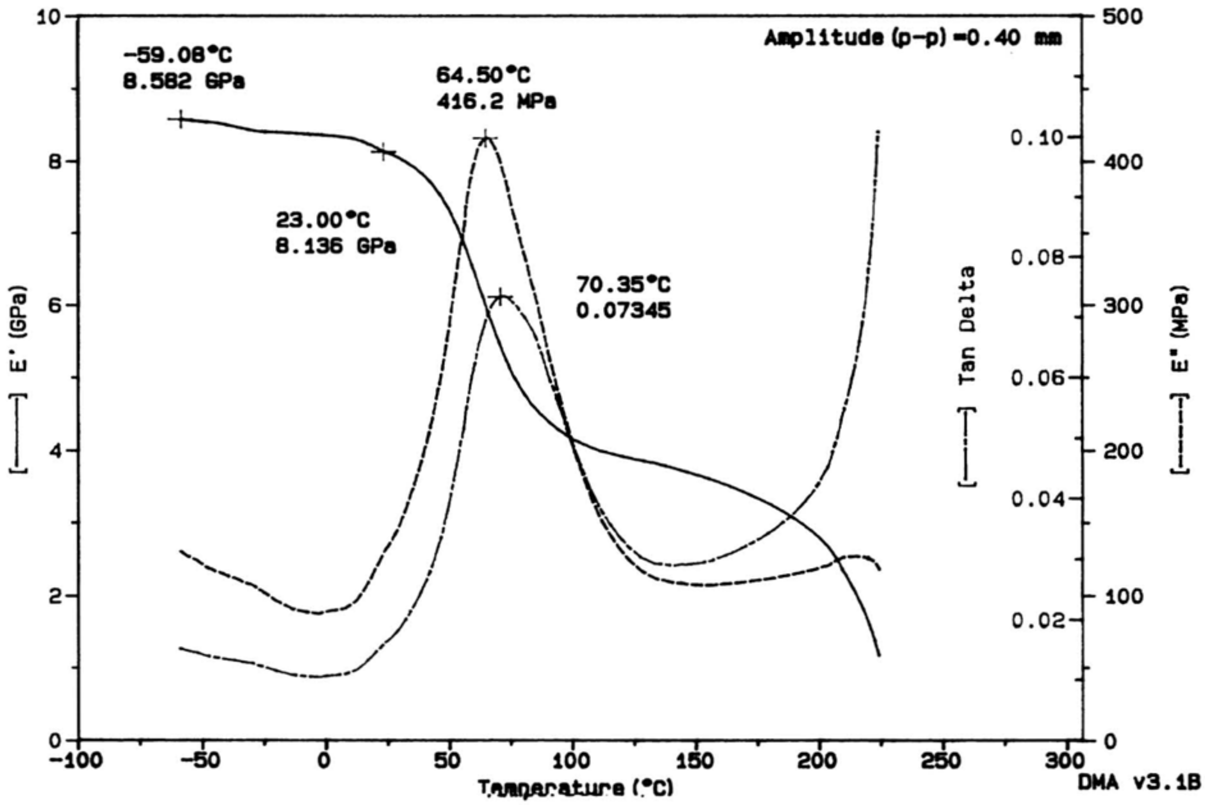
Table 39: Storage and loss properties for DuPont Minlon 12T 40% mineral filled, impact modified nylon 66 tested at 0.6% moisture content. (tabular data for Graph 39)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	6.225	233.5	0.03751	95.00	1.208	119.5	0.9898
-50.00	6.092	214.7	0.03524	100.00	1.146	100.7	0.08785
-45.00	5.976	199.8	0.03344	105.00	1.103	87.35	0.07921
-40.00	5.871	187.0	0.03186	110.00	1.070	77.26	0.07218
-35.00	5.773	174.5	0.03022	115.00	1.043	70.23	0.06731
-30.00	5.682	162.0	0.02852	120.00	1.018	65.18	0.06399
-25.00	5.606	151.8	0.02708	125.00	0.9950	61.31	0.06161
-20.00	5.536	142.8	0.02580	130.00	0.9733	58.97	0.06059
-15.00	5.483	135.7	0.02474	140.00	0.9259	55.60	0.06005
-10.00	5.438	130.3	0.02397	145.00	0.8989	54.66	0.06080
-5.00	5.398	125.8	0.02330	150.00	0.8716	53.67	0.06158
0.00	5.361	123.0	0.02295	155.00	0.8428	52.28	0.06203
5.00	5.322	121.4	0.02282	160.00	0.8107	51.01	0.06293
10.00	5.282	120.8	0.02287	165.00	0.7781	49.76	0.06395
15.00	5.236	121.4	0.02319	170.00	0.7445	48.29	0.06486
20.00	5.185	125.3	0.02416	175.00	0.7099	46.84	0.06598
25.00	5.113	133.7	0.02614	180.00	0.6752	45.42	0.06727
30.00	4.999	148.5	0.02971	190.00	0.6050	42.53	0.07029
40.00	4.581	190.9	0.04167	195.00	0.5698	41.18	0.07227
45.00	4.299	210.1	0.04889	200.00	0.5330	39.66	0.07440
50.00	4.007	229.2	0.05720	205.00	0.4974	38.36	0.07713
55.00	3.669	250.3	0.06822	210.00	0.4613	36.98	0.08017
60.00	3.291	270.5	0.08222	215.00	0.4246	35.52	0.08367
65.00	2.857	289.3	0.1013	220.00	0.3861	34.02	0.08812
70.00	2.387	289.5	0.1213	225.00	0.3454	32.68	0.09462
75.00	1.963	261.1	0.1330	230.00	0.3055	31.04	0.1016
80.00	1.650	219.1	0.1328	240.00	0.2273	27.57	0.1213
90.00	1.298	144.9	0.1116	245.00	0.1835	25.41	0.1385

Table 40: Storage and loss properties for DuPont Zytel 82G33L 33% glass fiber filled, impact modified nylon 6/66 tested at 0.2% moisture content. (tabular data for Graph 40)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	5.736	114.3	0.01992	85.00	3.120	204.5	0.06555
-50.00	5.715	112.5	0.01968	90.00	2.997	187.6	0.06258
-45.00	5.688	112.2	0.01973	95.00	2.873	166.4	0.05793
-40.00	5.665	112.6	0.01988	100.00	2.755	144.7	0.05252
-35.00	5.648	111.7	0.01978	105.00	2.685	129.7	0.04832
-30.00	5.637	111.8	0.01982	110.00	2.627	117.1	0.04459
-25.00	5.628	112.0	0.01990	115.00	2.584	107.0	0.04140
-20.00	5.611	111.6	0.01989	120.00	2.546	99.23	0.03897
-15.00	5.588	110.6	0.01979	125.00	2.503	93.02	0.03716
-10.00	5.564	108.7	0.01954	130.00	2.461	87.93	0.03573
-5.00	5.550	107.7	0.01941	135.00	2.424	83.75	0.03455
0.00	5.531	109.1	0.01973	140.00	2.388	80.70	0.03379
5.00	5.503	113.4	0.02060	145.00	2.348	78.05	0.03324
10.00	5.458	121.9	0.02233	150.00	2.305	75.85	0.03291
15.00	5.399	133.4	0.02471	155.00	2.253	74.02	0.03285
20.00	5.310	151.9	0.02860	160.00	2.207	71.82	0.03254
25.00	5.190	176.0	0.03392	165.00	2.161	70.04	0.03241
30.00	5.043	204.0	0.04045	170.00	2.114	68.68	0.03249
35.00	4.975	218.6	0.04393	175.00	2.065	67.64	0.03275
40.00	4.891	231.6	0.04734	180.00	2.007	67.02	0.03339
45.00	4.773	246.3	0.05161	185.00	1.943	66.65	0.03430
50.00	4.590	262.9	0.05729	190.00	1.874	66.27	0.03536
55.00	4.339	275.9	0.06358	195.00	1.784	66.80	0.03746
60.00	4.042	279.8	0.06924	200.00	1.681	67.49	0.04016
65.00	3.788	273.2	0.07212	205.00	1.509	70.88	0.04699
70.00	3.583	261.9	0.07311	210.00	1.217	72.06	0.05923
75.00	3.406	244.5	0.07180	215.00	0.9421	67.99	0.07224
80.00	3.248	224.8	0.06923				

Graph 41: Storage and loss properties for DuPont Zytel 72G33L 33% glass fiber filled nylon 6/66 tested at 0.4% moisture content.



Graph 42: Storage and loss properties for LNP Verton RF700-10EM 50% long glass fiber filled nylon 6/66 tested at 1% moisture content.

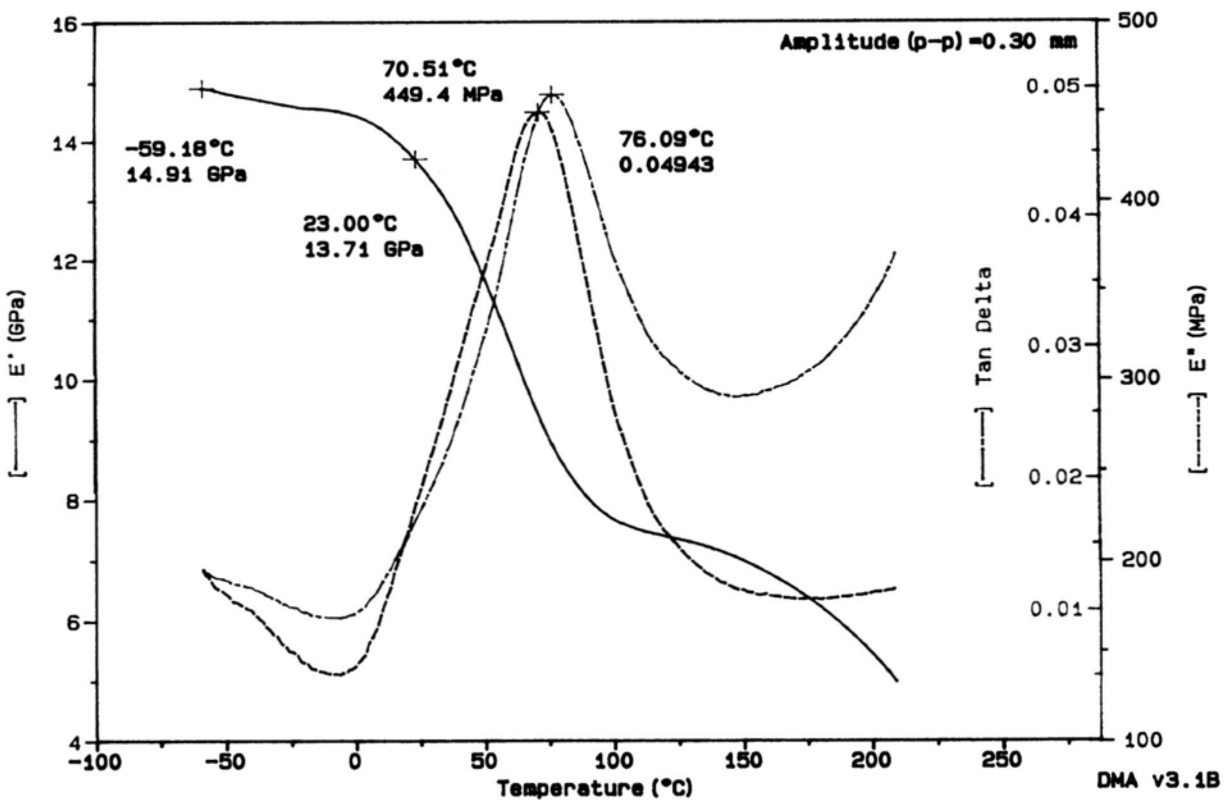


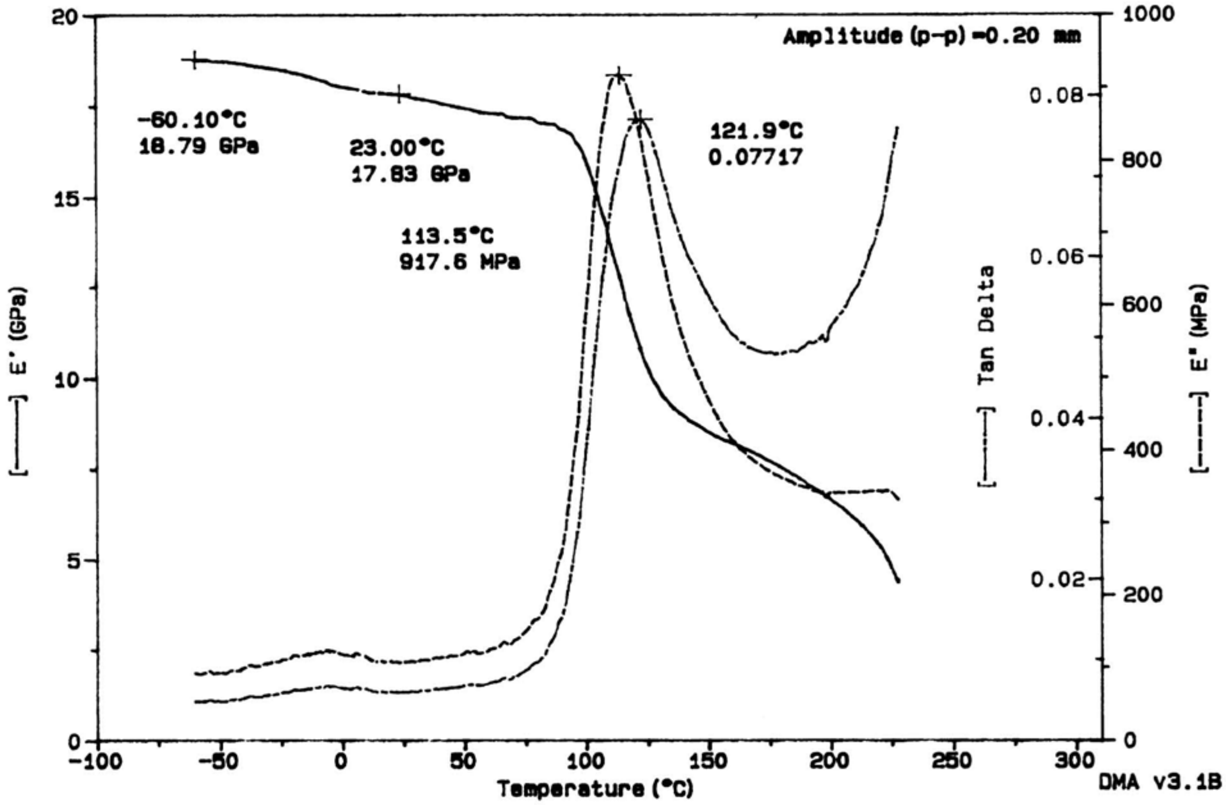
Table 41: Storage and loss properties for DuPont Zytel 72G33L 33% glass fiber filled nylon 6/66 tested at 0.4% moisture content. (tabular data for Graph 41)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	8.565	126.2	0.01474	85.00	4.570	304.7	0.06667
-50.00	8.549	121.3	0.01419	90.00	4.402	266.7	0.06058
-45.00	8.532	116.7	0.01368	95.00	4.266	233.9	0.05483
-40.00	8.500	113.5	0.01335	100.00	4.156	203.2	0.04889
-35.00	8.461	110.4	0.01305	105.00	4.076	178.1	0.04370
-30.00	8.426	107.1	0.01271	110.00	4.006	157.1	0.03921
-25.00	8.406	101.8	0.01211	115.00	3.959	141.4	0.03573
-20.00	8.399	96.00	0.01143	120.00	3.915	129.7	0.03314
-15.00	8.390	91.80	0.01094	125.00	3.876	120.9	0.03119
-10.00	8.380	89.30	0.01066	130.00	3.842	114.8	0.02987
-5.00	8.368	87.99	0.01051	135.00	3.807	111.3	0.02925
0.00	8.354	89.07	0.01066	140.00	3.761	109.3	0.02906
5.00	8.338	90.66	0.01087	145.00	3.711	108.2	0.02916
10.00	8.314	94.08	0.01132	150.00	3.660	107.6	0.02938
15.00	8.266	104.2	0.01260	155.00	3.607	107.3	0.02975
20.00	8.188	119.8	0.01463	160.00	3.547	108.1	0.03046
25.00	8.108	134.8	0.01663	165.00	3.482	108.7	0.03123
30.00	8.030	151.1	0.01882	170.00	3.410	109.9	0.03222
35.00	7.924	174.6	0.02204	175.00	3.332	111.1	0.03334
40.00	7.781	203.0	0.02610	180.00	3.249	112.3	0.03455
45.00	7.586	240.1	0.03165	185.00	3.157	113.8	0.03606
50.00	7.309	289.6	0.03962	190.00	3.053	115.4	0.03781
55.00	6.929	345.5	0.04987	195.00	2.933	117.4	0.04002
60.00	6.463	400.6	0.06199	200.00	2.792	119.6	0.04285
65.00	5.955	416.4	0.06994	205.00	2.607	122.9	0.04713
70.00	5.494	403.0	0.07336	210.00	2.323	126.9	0.05466
75.00	5.081	369.8	0.07278	215.00	2.017	127.4	0.06317
80.00	4.790	336.8	0.07032	220.00	1.623	125.8	0.07756

Table 42: Storage and loss properties for LNP Verton RF700-10EM 50% long glass fiber filled nylon 6/66 tested at 1% moisture content. (tabular data for Graph 42)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	14.88	187.2	0.01258	80.00	8.614	421.9	0.04898
-50.00	14.82	181.7	0.01226	85.00	8.291	388.5	0.04685
-45.00	14.77	176.3	0.01193	90.00	8.025	351.9	0.04385
-40.00	14.73	171.7	0.01166	95.00	7.817	315.9	0.04041
-35.00	14.69	164.2	0.01118	100.00	7.669	283.6	0.03698
-30.00	14.64	156.8	0.01071	105.00	7.573	261.3	0.03450
-25.00	14.60	149.7	0.01025	110.00	7.500	241.4	0.03219
-20.00	14.56	143.6	0.009866	115.00	7.442	225.4	0.03029
-15.00	14.55	138.8	0.009545	120.00	7.397	215.4	0.02912
-10.00	14.52	137.7	0.009481	125.00	7.348	207.3	0.02822
-5.00	14.48	137.7	0.009510	130.00	7.294	200.0	0.02742
0.00	14.43	142.7	0.009892	135.00	7.235	193.8	0.02679
5.00	14.34	155.4	0.01084	140.00	7.166	189.4	0.02642
10.00	14.22	173.7	0.01222	145.00	7.086	186.0	0.02624
15.00	14.04	195.5	0.01392	150.00	6.994	183.9	0.02630
20.00	13.85	216.8	0.01565	155.00	6.894	181.5	0.02632
25.00	13.61	239.9	0.01763	160.00	6.781	180.9	0.02668
30.00	13.33	262.5	0.01969	165.00	6.660	179.9	0.02702
35.00	13.03	286.7	0.02201	170.00	6.529	179.1	0.02743
40.00	12.65	312.2	0.02468	175.00	6.385	179.5	0.02812
45.00	12.19	338.0	0.02773	180.00	6.228	179.0	0.02874
50.00	11.68	361.1	0.03091	185.00	6.053	179.7	0.02969
55.00	11.15	385.1	0.03453	190.00	5.866	180.5	0.03077
60.00	10.60	413.9	0.03904	195.00	5.663	181.3	0.03201
65.00	10.03	438.8	0.04375	200.00	5.441	182.9	0.03361
70.00	9.497	448.8	0.04726	205.00	5.202	183.7	0.03531
75.00	9.015	444.7	0.04933				

Graph 43: Storage and loss properties for Mitsubishi Gas Chemical Reny 1032 60% glass fiber filled nylon MXD6.



Graph 44: Storage and loss properties for EMS Grivory 5H 50% glass fiber filled nylon, aromatic copolymer tested at 0.3% moisture content.

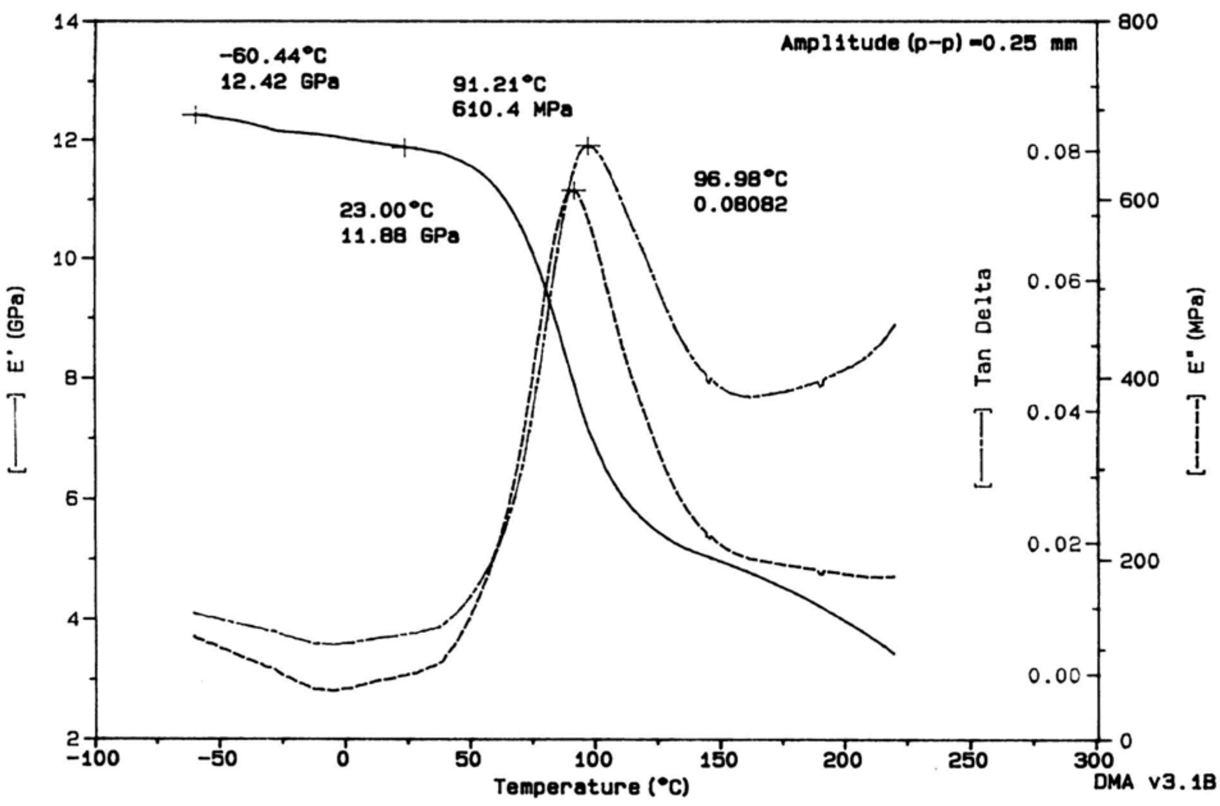


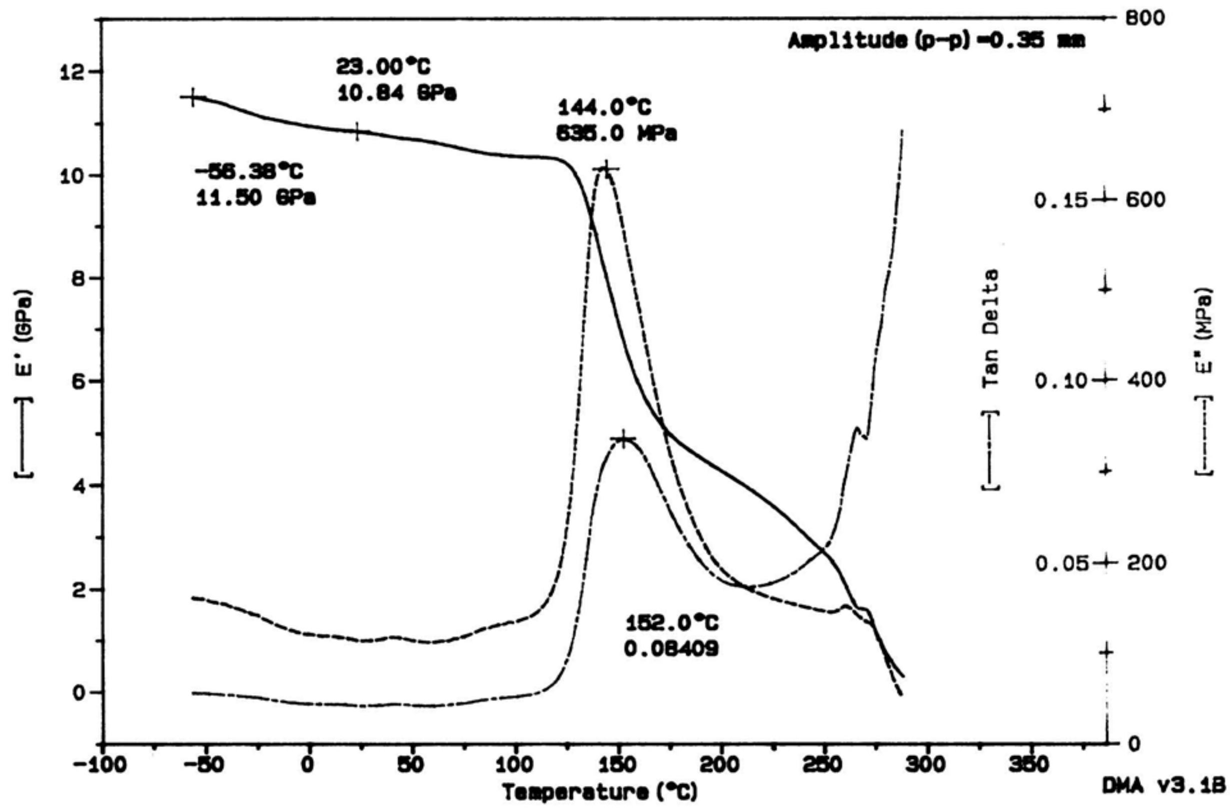
Table 43: Storage and loss properties for Mitsubishi Gas Chemical Reny 1032 60% glass fiber filled nylon MXD6. (tabular data for Graph 43)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
80.00	17.07	167.5	0.009813	90.00	16.87	263.6	0.01562
85.00	17.02	206.2	0.01211	95.00	16.66	395.9	0.02377
-60.00	18.79	92.72	0.004933	100.00	16.04	591.4	0.03687
-55.00	18.77	94.97	0.005059	105.00	15.01	789.7	0.05262
-50.00	18.75	91.77	0.004895	110.00	13.73	901.7	0.06570
-45.00	18.72	96.39	0.005150	115.00	12.45	913.1	0.07332
-40.00	18.67	100.1	0.005363	120.00	11.26	866.4	0.07696
-35.00	18.61	101.9	0.005475	125.00	10.29	783.1	0.07610
-30.00	18.56	106.0	0.005713	130.00	9.658	689.2	0.07135
-25.00	18.50	110.9	0.005996	135.00	9.216	607.2	0.06588
-20.00	18.43	116.2	0.006303	140.00	8.943	549.3	0.06142
-15.00	18.35	118.1	0.006435	145.00	8.719	506.1	0.05804
-10.00	18.25	120.5	0.006603	150.00	8.512	469.3	0.05514
-5.00	18.12	122.7	0.006773	155.00	8.337	436.8	0.05240
0.00	18.03	117.8	0.006532	160.00	8.200	412.9	0.05035
5.00	17.98	119.5	0.006644	165.00	8.049	395.9	0.04918
10.00	17.91	114.6	0.006400	170.00	7.883	381.6	0.04841
20.00	17.85	107.5	0.006020	175.00	7.704	371.1	0.04817
25.00	17.81	107.5	0.006039	180.00	7.525	361.5	0.04803
30.00	17.73	107.6	0.006069	185.00	7.321	354.0	0.04836
35.00	17.67	110.0	0.006222	190.00	7.094	349.1	0.04921
40.00	17.60	113.9	0.006472	195.00	6.893	342.4	0.04967
45.00	17.51	115.9	0.006620	200.00	6.652	341.7	0.05137
50.00	17.45	120.8	0.006921	205.00	6.408	341.7	0.05332
55.00	17.37	119.2	0.006864	210.00	6.116	342.7	0.05603
60.00	17.32	125.1	0.007225	215.00	5.782	343.3	0.05938
65.00	17.30	132.6	0.007663	220.00	5.377	344.4	0.06405
70.00	17.19	137.0	0.007970	225.00	4.739	342.0	0.07217
75.00	17.19	150.1	0.008735				

Table 44: Storage and loss properties for EMS Grivory 5H 50% glass fiber filled nylon, aromatic copolymer tested at 0.3% moisture content. (tabular data for Graph 44)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	12.42	113.0	0.009102	80.00	9.505	496.9	0.05228
-55.00	12.40	107.1	0.008639	85.00	8.827	573.1	0.06493
-50.00	12.35	101.8	0.008238	90.00	8.108	609.4	0.07517
-45.00	12.33	95.97	0.007785	95.00	7.400	594.8	0.08039
-40.00	12.28	90.08	0.007333	100.00	6.883	551.9	0.08018
-35.00	12.23	84.79	0.006931	105.00	6.433	496.6	0.07720
-30.00	12.17	79.79	0.006555	110.00	6.088	442.6	0.07269
-25.00	12.14	70.97	0.005849	115.00	5.832	396.7	0.06802
-20.00	12.12	64.77	0.005344	120.00	5.628	357.9	0.06359
-15.00	12.10	58.46	0.004833	125.00	5.453	320.3	0.05873
-10.00	12.08	55.26	0.004575	130.00	5.314	288.6	0.05431
-5.00	12.05	54.17	0.004494	135.00	5.202	263.2	0.05060
0.00	12.02	56.68	0.004717	140.00	5.120	243.1	0.04748
5.00	11.98	60.03	0.005009	145.00	5.048	224.5	0.04448
10.00	11.95	63.17	0.005284	150.00	4.971	217.0	0.04366
15.00	11.92	66.66	0.005591	155.00	4.890	208.6	0.04265
20.00	11.90	69.25	0.005821	160.00	4.812	203.5	0.04230
25.00	11.87	72.90	0.006143	165.00	4.727	200.2	0.04235
30.00	11.83	76.99	0.006505	170.00	4.634	197.7	0.04266
35.00	11.80	81.43	0.006903	175.00	4.541	194.9	0.04292
40.00	11.74	93.99	0.008003	180.00	4.442	193.0	0.04346
45.00	11.66	112.7	0.009665	185.00	4.334	191.0	0.04407
50.00	11.56	139.1	0.01203	190.00	4.220	184.9	0.04381
55.00	11.42	171.7	0.01504	195.00	4.098	186.5	0.04552
60.00	11.21	208.7	0.01862	200.00	3.975	184.6	0.04645
65.00	10.93	257.1	0.02352	205.00	3.851	182.7	0.04744
70.00	10.56	321.3	0.03043	210.00	3.719	181.5	0.04881
75.00	10.08	407.1	0.04041	215.00	3.579	181.3	0.05065

Graph 45: Storage and loss properties for DuPont Zytel HTN51G35HSL 35% glass fiber filled nylon, partially aromatic.



Graph 46: Storage and loss properties for GE Plastics Lexan 141R unfilled polycarbonate (PC).

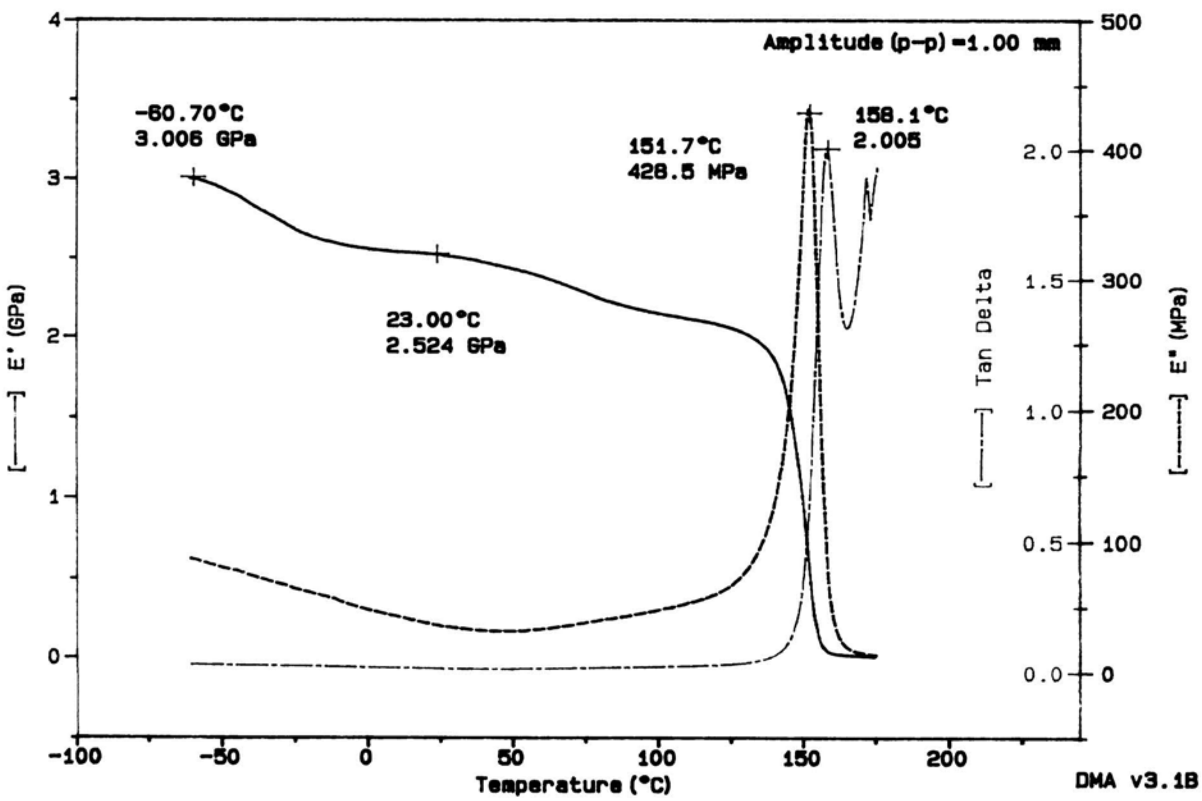


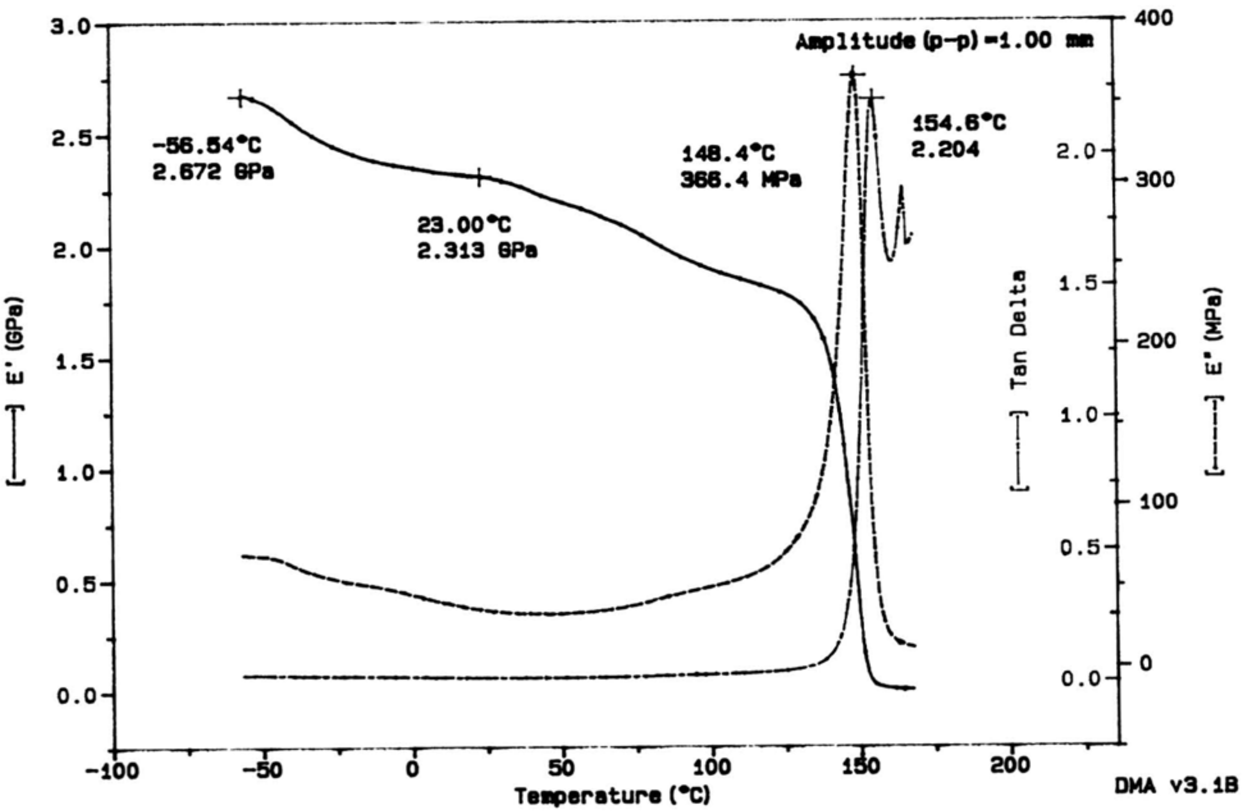
Table 45 Storage and loss properties for DuPont Zytel HTN51G35HSL 35% glass fiber filled nylon, partially aromatic. (tabular data for Graph 45)

Temperature (°C)	E’ (GPa)	E” (MPa)	Tan Delta	Temperature (°C)	E’ (GPa)	E” (MPa)	Tan Delta
-55.00	11.49	160.7	0.01398	120.00	10.31	182.7	0.01773
-50.00	11.46	159.1	0.01389	125.00	10.22	239.2	0.02341
-45.00	11.41	156.1	0.01368	130.00	9.964	352.8	0.03541
-40.00	11.36	11.36	0.01352	140.00	8.714	622.6	0.07146
-30.00	11.21	145.2	0.01295	150.00	7.134	597.8	0.08380
-25.00	11.15	141.5	0.01269	155.00	6.452	539.6	0.08363
-20.00	11.10	135.6	0.01221	160.00	5.920	481.9	0.08141
-15.00	11.06	129.9	0.01175	165.00	5.510	421.5	0.07650
-10.00	11.02	125.2	0.01136	170.00	5.207	366.2	0.07032
-5.00	10.98	122.2	0.01113	180.00	4.799	282.0	0.05877
0.00	10.95	120.2	0.01098	185.00	4.656	252.2	0.05417
5.00	10.92	118.8	0.01088	190.00	4.520	227.2	0.05025
10.00	10.89	118.5	0.01088	195.00	4.391	207.2	0.04718
20.00	10.85	115.5	0.01065	200.00	4.267	192.7	0.04517
25.00	10.84	113.5	0.01048	205.00	4.145	182.6	0.04406
30.00	10.81	113.7	0.01051	210.00	4.018	174.8	0.04351
40.00	10.74	117.5	0.01094	215.00	3.883	169.0	0.04352
50.00	10.69	113.3	0.01060	220.00	3.740	164.4	0.04397
55.00	10.67	111.7	0.01048	225.00	3.589	160.5	0.04474
60.00	10.63	111.9	0.01052	240.00	3.057	151.2	0.04947
65.00	10.59	113.0	0.01067	245.00	2.871	148.6	0.05175
70.00	10.55	115.5	0.01096	250.00	2.694	146.3	0.05430
80.00	10.46	123.2	0.01178	255.00	2.462	145.9	0.05928
90.00	10.40	130.0	0.01251	260.00	2.088	152.6	0.07311
95.00	10.38	132.5	0.01276	270.00	1.601	135.0	0.08432
100.00	10.36	134.7	0.01300	275.00	1.154	122.3	0.1061
110.00	10.34	145.1	0.01403	280.00	0.7355	92.53	0.1259
115.00	10.33	157.5	0.01524	285.00	0.4295	62.67	0.1462

Table 46: Storage and loss properties for GE Plastics Lexan 141R unfilled polycarbonate (PC). (tabular data for Graph 46)

Temperature (°C)	E’ (GPa)	E” (MPa)	Tan Delta	Temperature (°C)	E’ (GPa)	E” (MPa)	Tan Delta
-60.00	3.004	87.18	0.02902	60.00	2.384	33.47	0.01404
-55.00	2.980	83.78	0.02811	65.00	2.353	34.86	0.01482
-50.00	2.943	80.57	0.02738	70.00	2.319	36.47	0.01573
-45.00	2.901	78.27	0.02698	75.00	2.282	38.48	0.01686
-40.00	2.843	74.55	0.02622	80.00	2.245	40.46	0.01802
-35.00	2.791	71.35	0.02557	85.00	2.215	42.02	0.01897
-30.00	2.739	68.23	0.02491	90.00	2.190	43.92	0.02005
-25.00	2.685	64.67	0.02409	95.00	2.168	46.06	0.02125
-20.00	2.643	61.86	0.02340	100.00	2.148	48.35	0.02250
-15.00	2.614	58.84	0.02251	105.00	2.132	50.82	0.02384
-10.00	2.592	55.44	0.02139	110.00	2.116	53.72	0.02539
-5.00	2.573	51.80	0.02014	115.00	2.100	56.78	0.02704
0.00	2.560	48.50	0.01894	120.00	2.082	60.70	0.02916
5.00	2.550	45.75	0.01794	125.00	2.057	66.83	0.03249
10.00	2.541	43.26	0.01702	130.00	2.023	76.96	0.03804
15.00	2.537	40.58	0.01600	135.00	1.970	94.44	0.04795
20.00	2.530	38.07	0.01505	140.00	1.874	125.8	0.06715
25.00	2.519	35.88	0.01424	145.00	1.621	194.1	0.1198
30.00	2.507	34.35	0.01371	150.00	1.035	364.4	0.3547
35.00	2.493	33.02	0.01324	155.00	0.2082	293.3	1.432
40.00	2.474	32.08	0.01297	160.00	0.02897	51.96	1.789
45.00	2.454	31.82	0.01297	165.00	0.01517	19.91	1.312
50.00	2.433	31.88	0.01310	170.00	0.009014	15.04	1.671
55.00	2.411	32.41	0.01344	175.00	0.006980	13.41	1.921

Graph 47: Storage and loss properties for MRC Polymers PC429MMH1-200 unfilled polycarbonate (PC).



Graph 48: Storage and loss properties for Bayer Makrolon T7435 unfilled, impact modified polycarbonate (PC).

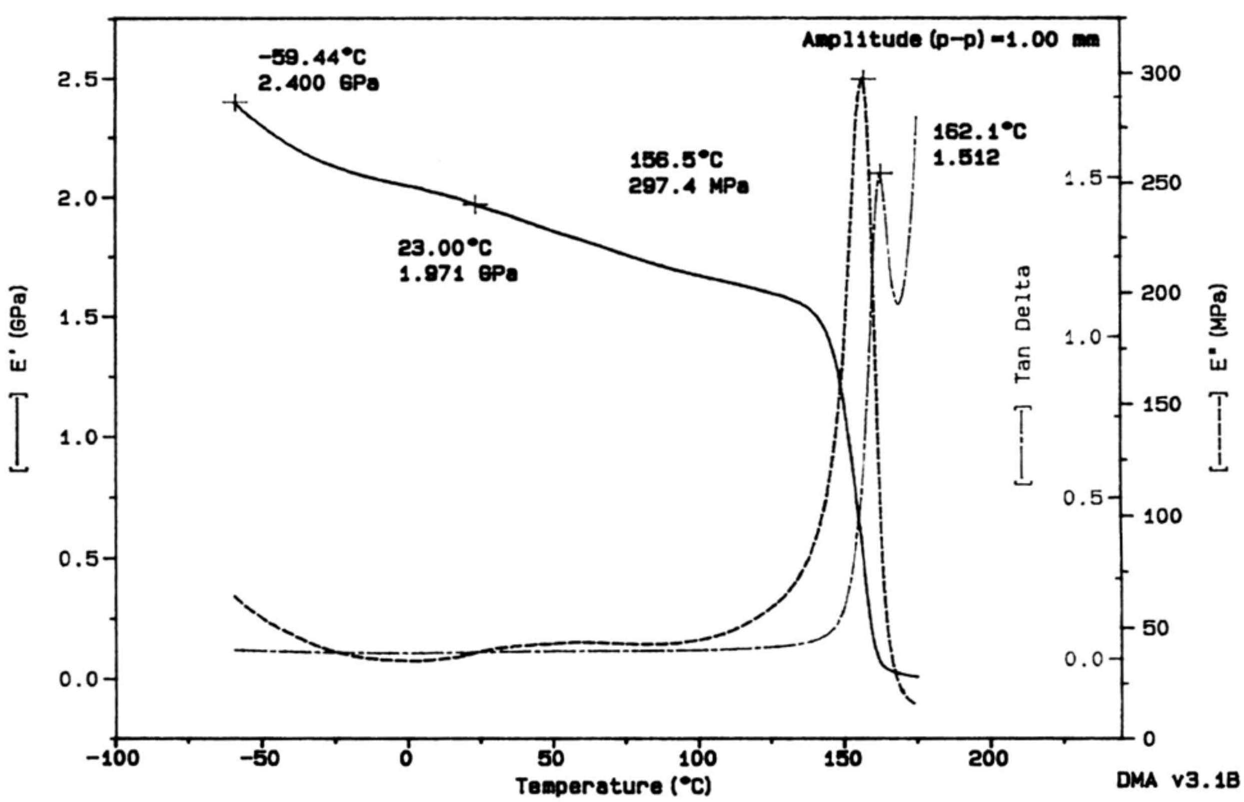


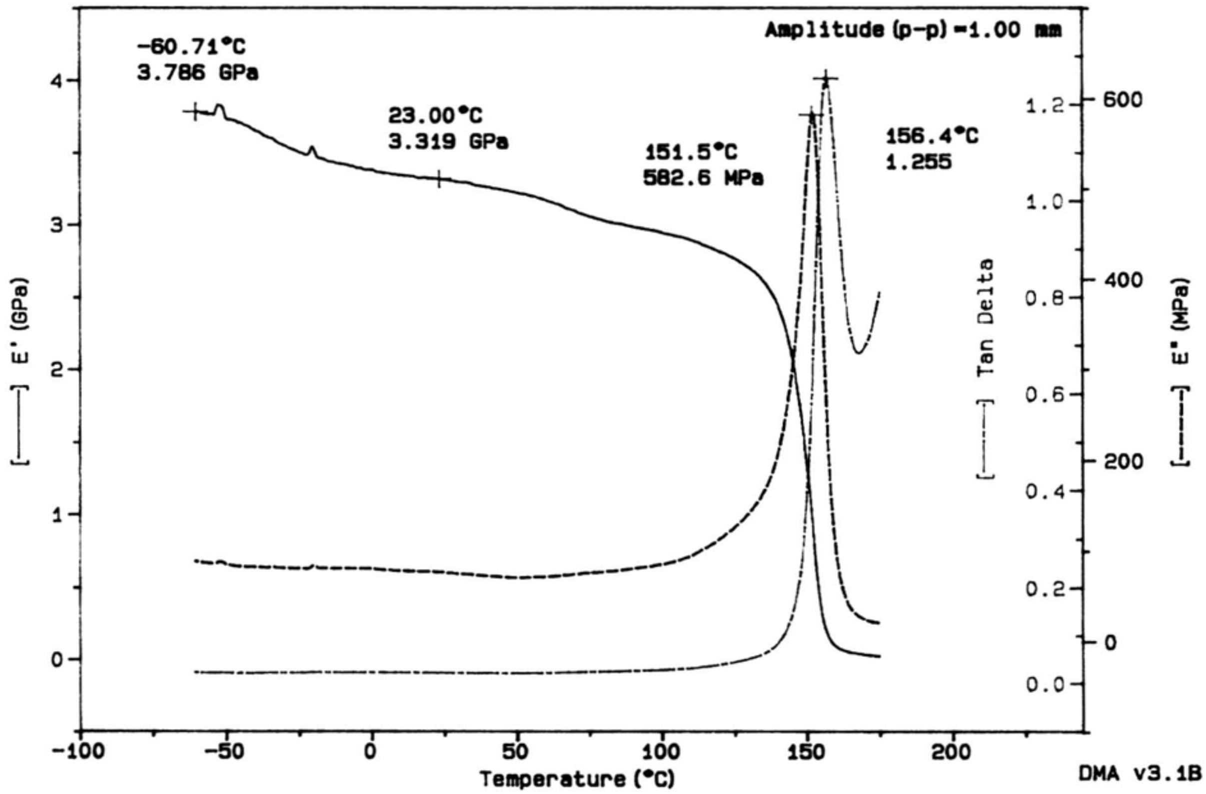
Table 47: Storage and loss properties for MRC Polymers PC429MMH1-200 unfilled polycarbonate (PC). (tabular data for Graph 47)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.673	69.46	0.02599	60.00	2.155	34.25	0.01589
-50.00	2.649	68.83	0.02599	65.00	2.127	35.29	0.01659
-45.00	2.613	67.05	0.02566	70.00	2.100	36.70	0.01748
-40.00	2.564	63.12	0.02491	75.00	2.067	38.53	0.01864
-35.00	2.516	59.28	0.02356	80.00	2.028	40.83	0.02014
-30.00	2.478	56.52	0.02281	85.00	1.989	43.32	0.02178
-25.00	2.445	54.14	0.02215	90.00	1.952	45.46	0.02328
-20.00	2.418	52.34	0.02165	95.00	1.922	47.51	0.02472
-15.00	2.394	50.83	0.02123	100.00	1.894	49.60	0.02620
-10.00	2.377	49.04	0.02063	105.00	1.870	51.73	0.02767
-5.00	2.364	46.98	0.01987	110.00	1.848	54.57	0.02953
0.00	2.353	44.76	0.01902	115.00	1.827	58.03	0.03175
5.00	2.341	42.28	0.01806	120.00	1.806	62.99	0.03489
10.00	2.331	40.07	0.01719	125.00	1.781	71.10	0.03993
15.00	2.323	38.12	0.01641	130.00	1.740	83.02	0.04772
20.00	2.318	36.34	0.01568	135.00	1.667	102.9	0.06175
25.00	2.310	34.99	0.01515	140.00	1.499	150.4	0.1004
30.00	2.295	33.96	0.01480	145.00	1.075	270.0	0.2522
35.00	2.276	33.33	0.01464	150.00	0.3479	338.6	0.9919
40.00	2.252	32.99	0.01465	155.00	0.03086	67.52	2.185
45.00	2.223	32.86	0.01478	160.00	0.01194	19.10	1.599
50.00	2.200	33.04	0.01502	165.00	0.007192	12.99	1.811
55.00	2.179	33.60	0.01542				

Table 48: Storage and loss properties for Bayer Makrolon T7435 unfilled, impact modified polycarbonate (PC). (tabular data for Graph 48)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.348	58.79	0.02504	60.00	1.821	43.35	0.02381
-50.00	2.300	54.16	0.02355	65.00	1.801	43.23	0.02401
-45.00	2.256	50.05	0.02219	70.00	1.780	43.02	0.02417
-40.00	2.216	46.86	0.02114	75.00	1.759	42.77	0.02432
-35.00	2.181	43.63	0.02000	80.00	1.739	42.46	0.02441
-30.00	2.152	40.98	0.01904	85.00	1.720	42.53	0.02473
-25.00	2.129	39.00	0.01832	90.00	1.702	42.89	0.02520
-20.00	2.108	37.31	0.01770	95.00	1.686	43.53	0.02581
-15.00	2.090	36.18	0.01731	100.00	1.672	44.53	0.02664
-10.00	2.075	35.52	0.01712	105.00	1.657	46.10	0.02782
-5.00	2.061	35.11	0.01704	110.00	1.644	48.09	0.02925
0.00	2.048	34.82	0.01700	115.00	1.630	50.95	0.03126
5.00	2.035	35.00	0.01720	120.00	1.614	54.63	0.03385
10.00	2.019	35.73	0.01770	125.00	1.597	59.12	0.03702
15.00	2.003	36.42	0.01818	130.00	1.580	64.96	0.04112
20.00	1.984	37.69	0.01899	135.00	1.555	74.10	0.04766
25.00	1.963	39.25	0.02000	140.00	1.509	89.00	0.05900
30.00	1.943	40.58	0.02089	145.00	1.398	117.1	0.08385
35.00	1.924	41.30	0.02146	150.00	1.114	179.5	0.1614
40.00	1.902	41.91	0.02203	155.00	0.6524	288.3	0.4441
45.00	1.881	42.56	0.02263	160.00	0.1604	201.1	1.266
50.00	1.858	42.79	0.02302	165.00	0.03839	49.45	1.286
55.00	1.839	43.20	0.02349	170.00	0.01865	21.11	1.133

Graph 49: Storage and loss properties for GE Plastics Lexan 500 10% glass fiber filled polycarbonate (PC).



Graph 50: Storage and loss properties for GE Plastics Lexan 3412 20% glass fiber filled polycarbonate (PC).

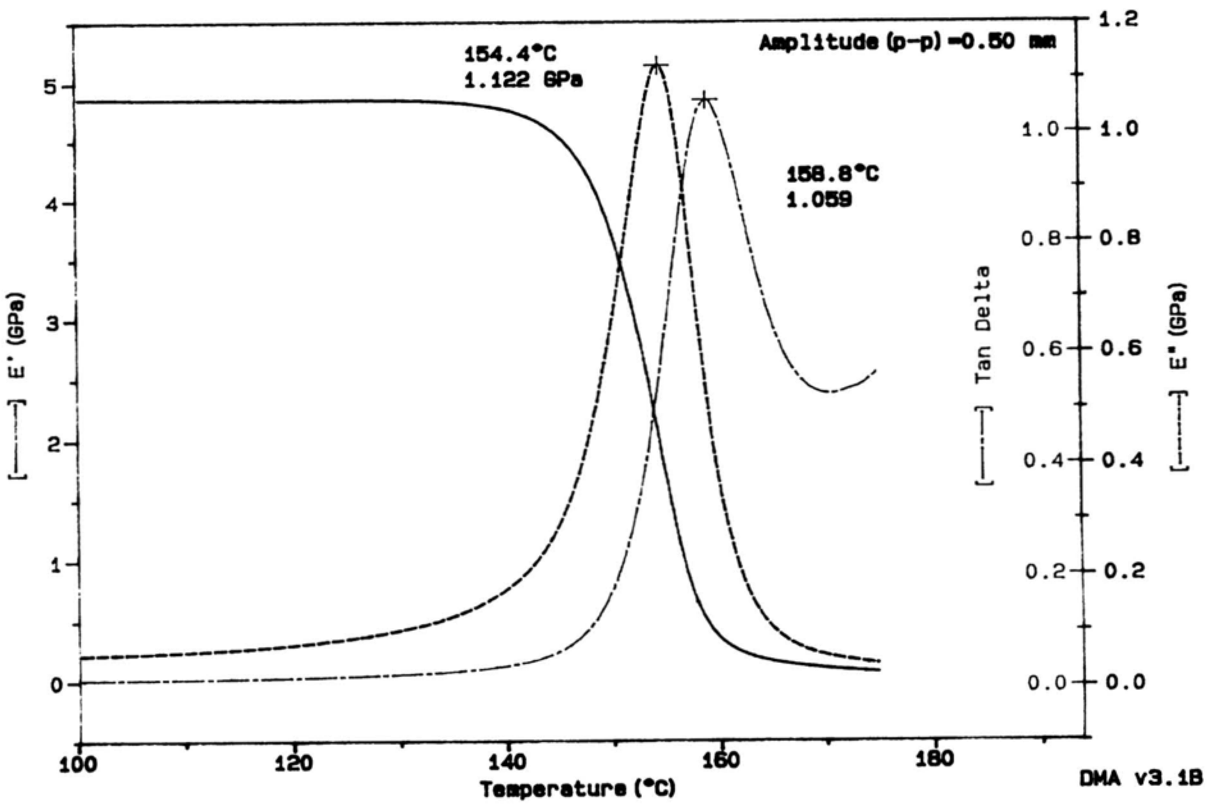


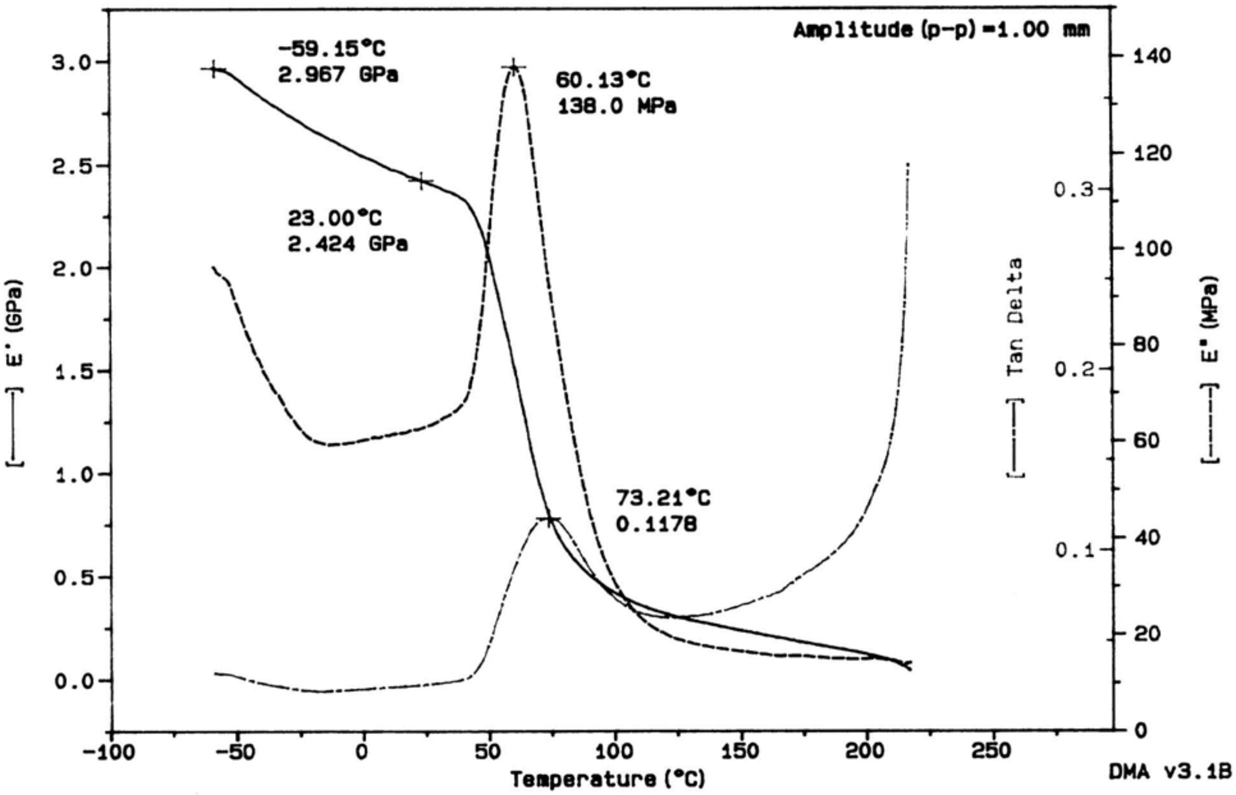
Table 49: Storage and loss properties for GE Plastics Lexan 500 10% glass fiber filled polycarbonate (PC). (tabular data for Graph 49)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.786	88.57	0.02339	60.00	3.170	71.84	0.02266
-55.00	3.771	86.19	0.02286	65.00	3.136	73.21	0.02334
-50.00	3.736	84.56	0.02263	70.00	3.098	74.92	0.02419
-45.00	3.707	82.92	0.02237	75.00	3.058	76.18	0.02491
-40.00	3.654	82.12	0.02247	80.00	3.030	77.56	0.02559
-35.00	3.603	82.04	0.02277	85.00	3.008	78.94	0.02624
-30.00	3.550	81.28	0.02289	90.00	2.987	81.01	0.02712
-25.00	3.504	80.80	0.02306	95.00	2.970	83.23	0.02802
-20.00	3.532	83.94	0.02377	100.00	2.947	85.70	0.02908
-15.00	3.441	80.62	0.02343	105.00	2.924	89.79	0.03071
-10.00	3.422	80.94	0.02365	110.00	2.897	95.32	0.03291
-5.00	3.395	80.66	0.02376	115.00	2.858	104.1	0.03643
0.00	3.382	80.55	0.02382	120.00	2.816	114.3	0.04058
5.00	3.359	79.09	0.02355	125.00	2.770	126.9	0.04580
10.00	3.347	78.42	0.02343	130.00	2.708	142.9	0.05276
15.00	3.331	77.71	0.02333	135.00	2.612	166.3	0.06368
20.00	3.324	77.23	0.02324	140.00	2.444	210.4	0.08611
25.00	3.311	76.20	0.02302	145.00	2.069	306.9	0.1485
30.00	3.296	74.88	0.02272	150.00	1.321	526.4	0.4006
35.00	3.279	73.42	0.02239	155.00	0.3377	390.8	1.164
40.00	3.262	72.33	0.02217	160.00	0.09130	96.08	1.050
45.00	3.244	71.35	0.02199	165.00	0.05103	37.02	0.7251
50.00	3.222	70.84	0.02198	170.00	0.03488	24.38	0.6991
55.00	3.201	71.23	0.02226				

Table 50: Storage and loss properties for GE Plastics Lexan 3412 20% glass fiber filled polycarbonate (PC). (tabular data for Graph 50)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.561	0.07963	0.01432	60.00	5.005	0.03769	0.007531
-55.00	5.537	0.07691	0.01389	65.00	4.978	0.03906	0.007847
-50.00	5.503	0.07416	0.01348	70.00	4.944	0.04163	0.008420
-45.00	5.460	0.07242	0.01327	75.00	4.909	0.04434	0.009032
-40.00	5.409	0.07080	0.01309	80.00	4.879	0.04732	0.009704
-35.00	5.357	0.06889	0.01286	85.00	4.850	0.04960	0.01023
-30.00	5.310	0.06719	0.01265	90.00	4.832	0.05144	0.01065
-25.00	5.273	0.06482	0.01229	95.00	4.822	0.05285	0.01096
-20.00	5.244	0.06216	0.01185	100.00	4.816	0.05457	0.01133
-15.00	5.219	0.05973	0.01144	105.00	4.812	0.05717	0.01188
-10.00	5.196	0.05761	0.01109	110.00	4.809	0.06094	0.01267
-5.00	5.176	0.05558	0.01074	115.00	4.807	0.06612	0.01375
0.00	5.158	0.05428	0.01052	120.00	4.807	0.07358	0.01531
5.00	5.142	0.05330	0.01037	125.00	4.807	0.08434	0.01754
10.00	5.126	0.05234	0.01021	130.00	4.805	0.1002	0.02085
15.00	5.117	0.05080	0.009927	135.00	4.785	0.1257	0.02627
20.00	5.111	0.04906	0.009598	140.00	4.724	0.1733	0.03669
25.00	5.106	0.04719	0.009242	145.00	4.502	0.2903	0.06452
30.00	5.099	0.04570	0.008963	150.00	3.673	0.6614	0.1806
35.00	5.089	0.04411	0.008668	155.00	1.675	1.090	0.6577
40.00	5.073	0.04194	0.008267	160.00	0.3494	0.3571	1.020
45.00	5.056	0.04017	0.007946	165.00	0.1571	0.1019	0.6482
50.00	5.041	0.03822	0.007583	170.00	0.1028	0.05405	0.5257
55.00	5.026	0.03750	0.007461				

Graph 51: Storage and loss properties for GE Plastics Valox 325 unfilled polybutylene terephthalate (polyester PBT).



Graph 52: Storage and loss properties for Ticona Celanex 2016 unfilled polybutylene terephthalate (polyester PBT).

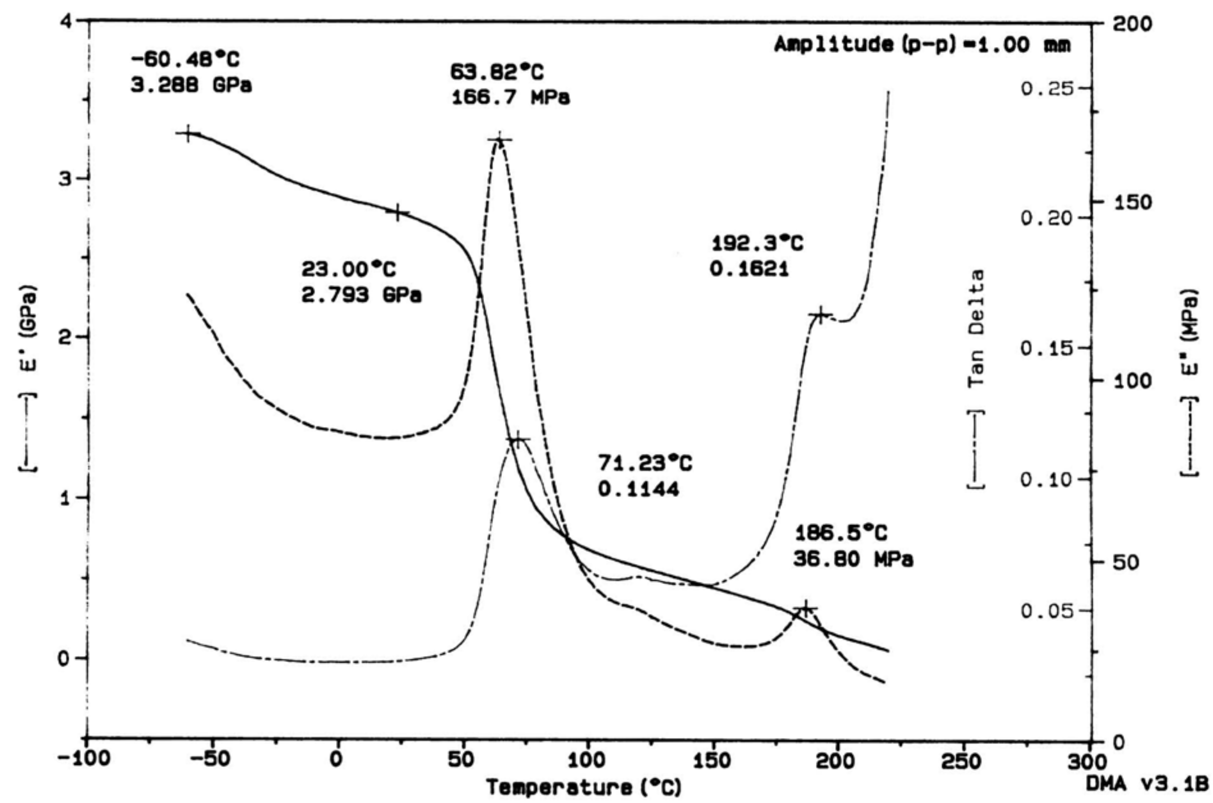


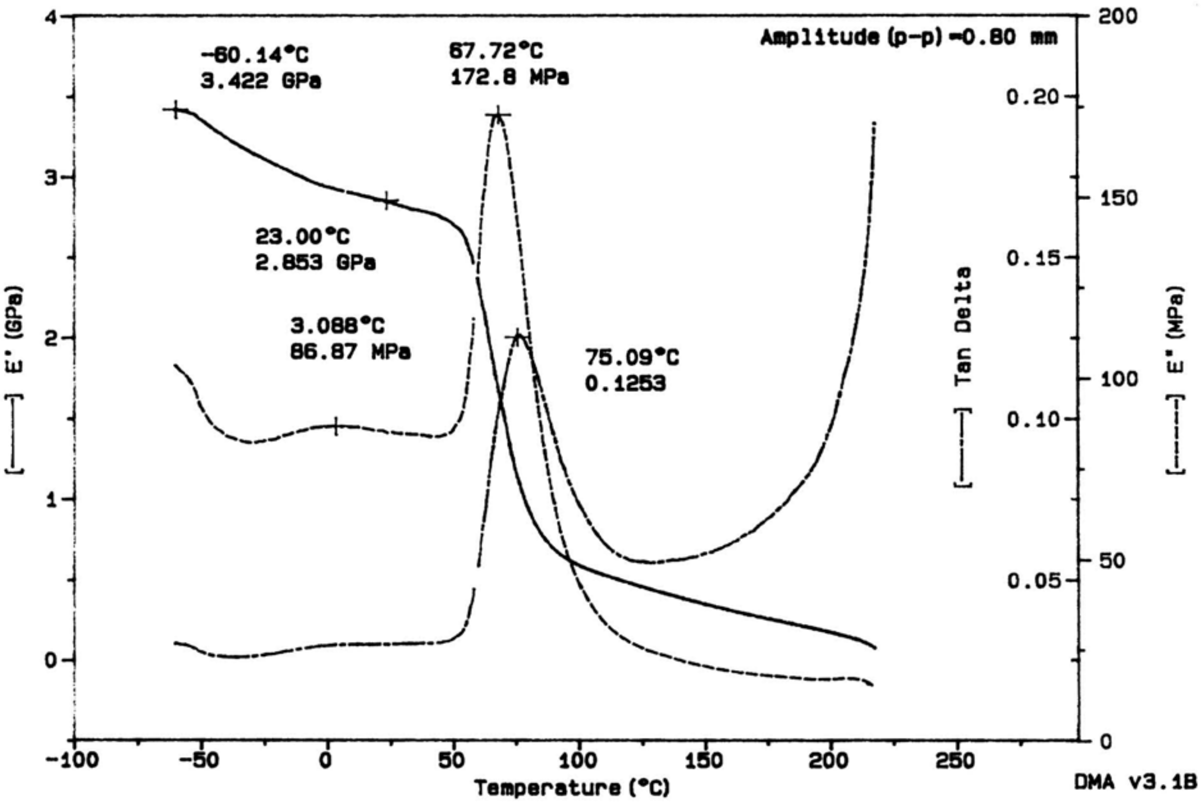
Table 51: Storage and loss properties for GE Plastics Valox 325 unfilled polybutylene terephthalate (polyester PBT). (tabular data for Graph 51)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.954	94.19	0.03189
-50.00	2.919	88.62	0.03037
-45.00	2.870	81.34	0.02834
-40.00	2.825	75.46	0.02671
-35.00	2.783	70.55	0.02534
-30.00	2.744	66.26	0.02415
-25.00	2.707	62.73	0.02317
-20.00	2.667	60.34	0.02262
-15.00	2.636	59.48	0.02256
-10.00	2.605	59.56	0.02286
-5.00	2.572	59.83	0.02326
0.00	2.541	60.39	0.02377
5.00	2.517	60.91	0.02420
10.00	2.485	61.36	0.02463
15.00	2.464	61.85	0.02510
20.00	2.438	62.52	0.02565
25.00	2.415	63.22	0.02618
30.00	2.391	64.32	0.02690
35.00	2.366	65.85	0.02784
40.00	2.331	68.28	0.02929
45.00	2.246	78.03	0.03475
50.00	2.059	102.0	0.04953
55.00	1.791	127.1	0.07097
60.00	1.522	137.9	0.09066
65.00	1.229	131.3	0.1069
70.00	0.9477	110.4	0.1165
75.00	0.7594	89.19	0.1174
80.00	0.6429	72.29	0.1124
85.00	0.5645	57.25	0.1014
90.00	0.5037	45.13	0.08959
95.00	0.4569	36.58	0.08007
100.00	0.4181	30.67	0.07335
105.00	0.3855	26.46	0.06863
110.00	0.3586	23.45	0.06539
115.00	0.3365	21.42	0.06365
120.00	0.3179	20.05	0.06305
125.00	0.3007	18.97	0.06308
130.00	0.2861	18.24	0.06374
135.00	0.2739	17.67	0.06453
140.00	0.2613	17.22	0.06592
145.00	0.2482	16.83	0.06779
150.00	0.2360	16.53	0.07006
155.00	0.2240	16.17	0.07219
160.00	0.2126	15.86	0.07459
165.00	0.2018	15.55	0.07704
170.00	0.1899	15.58	0.08206
175.00	0.1781	15.53	0.08720
180.00	0.1676	15.33	0.09145
185.00	0.1567	15.14	0.09659
190.00	0.1458	15.00	0.1029
195.00	0.1343	14.93	0.1111
200.00	0.1218	14.98	0.1230
205.00	0.1076	14.98	0.1392
210.00	0.08963	14.66	0.1636
215.00	0.06089	13.98	0.2304

Table 52: Storage and loss properties for Ticona Celanex 2016 unfilled polybutylene terephthalate (polyester PBT). (tabular data for Graph 52)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.287	122.5	0.03727
-55.00	3.268	116.9	0.03578
-50.00	3.240	112.0	0.03458
-45.00	3.203	105.6	0.03296
-40.00	3.163	101.0	0.03193
-35.00	3.116	96.82	0.03107
-30.00	3.069	93.75	0.03055
-25.00	3.027	91.42	0.03020
-20.00	2.992	89.38	0.02987
-15.00	2.962	87.66	0.02959
-10.00	2.936	86.27	0.02939
-5.00	2.912	85.66	0.02942
0.00	2.889	85.05	0.02944
5.00	2.867	84.33	0.02942
10.00	2.850	83.86	0.02943
15.00	2.829	83.43	0.02950
20.00	2.808	83.40	0.02971
25.00	2.784	83.77	0.03009
30.00	2.756	84.28	0.03058
35.00	2.724	85.34	0.03133
40.00	2.685	86.89	0.03236
45.00	2.634	89.98	0.03416
50.00	2.558	97.88	0.03827
55.00	2.379	119.9	0.05043
60.00	2.022	155.4	0.07703
65.00	1.615	165.2	0.1025
70.00	1.284	146.2	0.1139
75.00	1.063	119.0	0.1119
80.00	0.9229	92.47	0.1002
85.00	0.8353	73.51	0.08798
90.00	0.7714	59.91	0.07766
95.00	0.7240	50.61	0.06990
100.00	0.6864	44.34	0.06459
105.00	0.6545	40.50	0.06188
110.00	0.6271	38.33	0.06113
115.00	0.6026	37.15	0.06164
120.00	0.5803	36.11	0.06223
125.00	0.5583	34.10	0.06108
130.00	0.5373	32.33	0.06017
135.00	0.5160	30.74	0.05958
140.00	0.4944	29.33	0.05932
145.00	0.4726	28.00	0.05923
150.00	0.4507	26.85	0.05957
155.00	0.4282	26.27	0.06134
160.00	0.4056	26.06	0.06427
165.00	0.3828	26.11	0.06822
170.00	0.3594	26.77	0.07449
175.00	0.3337	28.47	0.08532
180.00	0.3019	32.08	0.1063
185.00	0.2612	36.39	0.1394
190.00	0.2179	34.90	0.1602
195.00	0.1818	29.36	0.1615
200.00	0.1533	24.52	0.1600
205.00	0.1300	20.95	0.1612
210.00	0.1094	18.65	0.1705
215.00	0.08590	17.24	0.2008

Graph 53: Storage and loss properties for GE Plastics Valox 744 10% glass fiber filled, impact modified polybutylene terephthalate (polyester PBT).



Graph 54: Storage and loss properties for LNP Thermocomp PDXW96630 10% glass fiber filled, impact modified polybutylene terephthalate (polyester PBT).

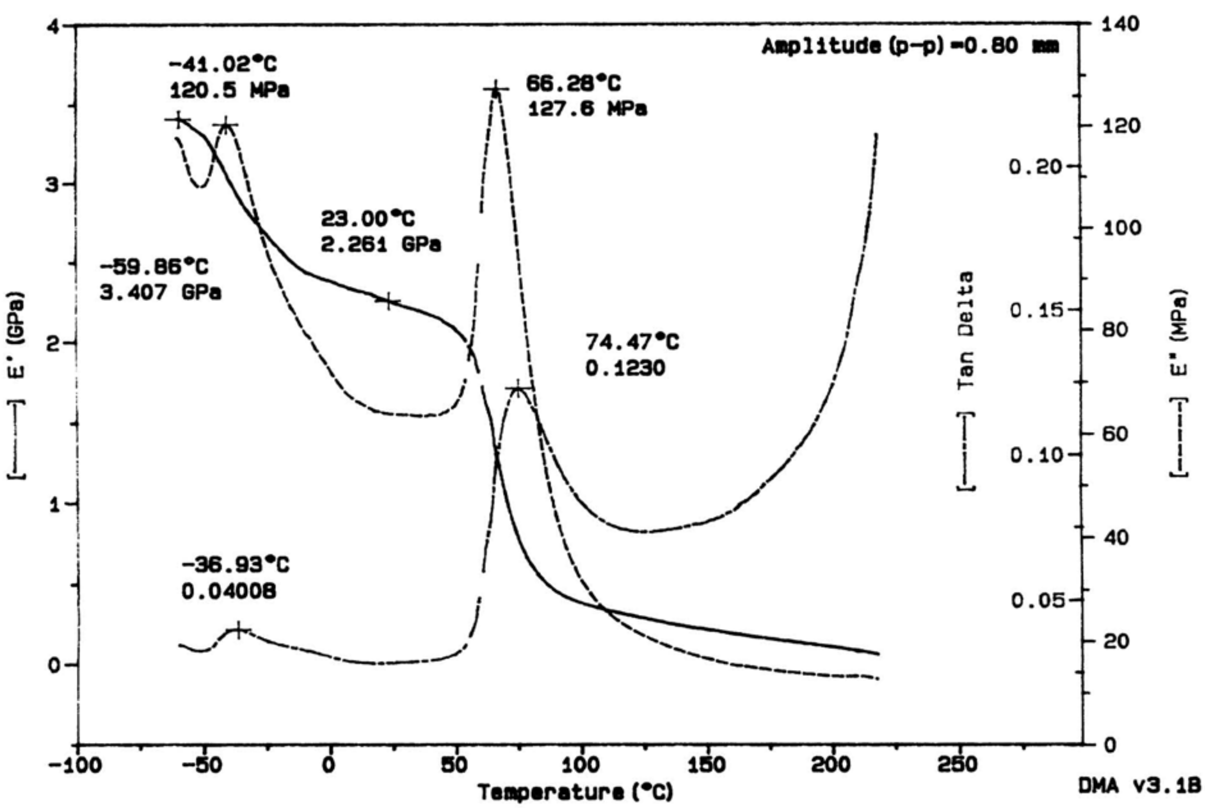


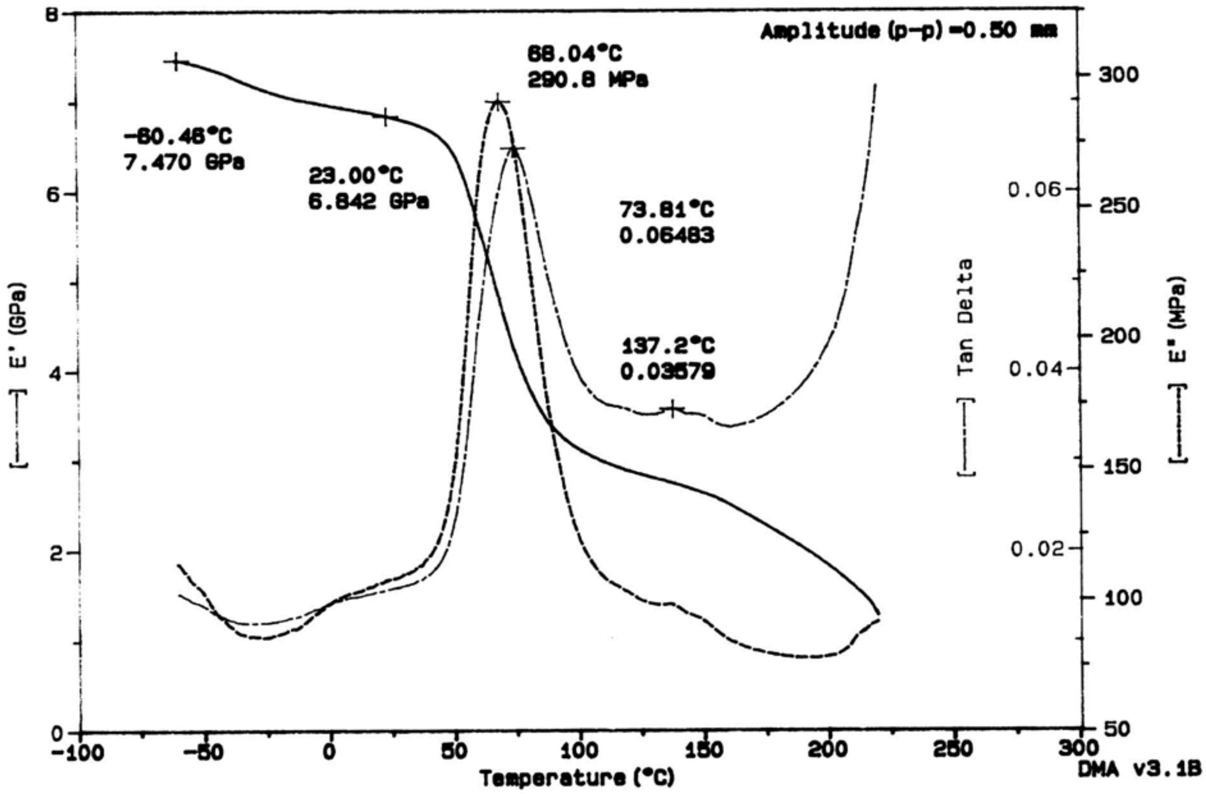
Table 53: Storage and loss properties for GE Plastics Valox 744 10% glass fiber filled, impact modified polybutylene terephthalate (polyester PBT). (tabular data for Graph 53)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.421	103.5	0.03025	80.00	0.9424	114.6	0.1215
-55.00	3.404	100.1	0.02942	85.00	0.7893	86.14	0.1091
-50.00	3.362	92.28	0.02745	90.00	0.6957	66.20	0.09514
-45.00	3.303	87.06	0.02636	95.00	0.6360	52.48	0.08252
-40.00	3.248	84.26	0.02594	100.00	0.5928	43.56	0.07347
-35.00	3.201	83.09	0.02596	105.00	0.5607	37.28	0.06649
-30.00	3.156	82.36	0.02610	110.00	0.5326	32.73	0.06145
-25.00	3.115	82.91	0.02661	115.00	0.5075	29.44	0.05802
-20.00	3.076	83.59	0.02717	120.00	0.4827	27.15	0.05624
-15.00	3.039	84.76	0.02789	125.00	0.4590	25.55	0.05568
-10.00	3.003	85.74	0.02855	130.00	0.4368	24.21	0.05544
-5.00	2.967	86.69	0.02922	135.00	0.4146	23.23	0.05604
0.00	2.940	86.78	0.02952	140.00	0.3938	22.28	0.05657
5.00	2.920	86.91	0.02977	145.00	0.3717	21.26	0.05720
10.00	2.902	86.67	0.02986	150.00	0.3509	20.48	0.05836
15.00	2.883	86.22	0.02991	155.00	0.3319	19.77	0.05958
20.00	2.864	85.73	0.02993	160.00	0.3132	19.19	0.06127
25.00	2.845	85.23	0.02996	165.00	0.2943	18.75	0.06370
30.00	2.821	84.94	0.03011	170.00	0.2774	18.28	0.06591
35.00	2.798	84.61	0.03024	175.00	0.2602	17.98	0.06912
40.00	2.783	84.17	0.03024	180.00	0.2440	17.71	0.07258
45.00	2.757	84.15	0.03052	185.00	0.2267	17.44	0.07694
50.00	2.710	86.10	0.03177	190.00	0.2105	17.14	0.08144
55.00	2.623	95.05	0.03624	195.00	0.1930	16.93	0.08774
60.00	2.363	130.1	0.05509	200.00	0.1749	17.05	0.09751
65.00	1.946	167.4	0.08607	205.00	0.1546	17.29	0.1119
70.00	1.549	170.4	0.1100	210.00	0.1333	17.13	0.1286
75.00	1.178	147.5	0.1252	215.00	0.1011	15.92	0.1575

Table 54: Storage and loss properties for LNP Thermocomp PDXW96630 10% glass fiber filled, impact modified polybutylene terephthalate (polyester PBT). (tabular data for Graph 54)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.407	117.9	0.03460	85.00	0.5185	55.93	0.1078
-55.00	3.366	111.1	0.03299	90.00	0.4549	44.48	0.09777
-50.00	3.307	108.3	0.03275	95.00	0.4123	36.94	0.08957
-45.00	3.186	115.2	0.03618	100.00	0.3824	31.94	0.08352
-40.00	3.032	120.5	0.03973	105.00	0.3584	28.42	0.07928
-35.00	2.888	114.7	0.03973	110.00	0.3380	25.83	0.07644
-30.00	2.775	105.1	0.03789	115.00	0.3196	23.87	0.07469
-25.00	2.677	96.23	0.03595	120.00	0.3030	22.37	0.07385
-20.00	2.587	89.76	0.03470	125.00	0.2867	21.09	0.07356
-15.00	2.505	84.33	0.03367	130.00	0.2707	19.99	0.07385
-10.00	2.444	79.80	0.03265	135.00	0.2550	18.96	0.07438
-5.00	2.410	76.20	0.03162	140.00	0.2413	18.13	0.07514
0.00	2.384	72.48	0.03040	145.00	0.2281	17.37	0.07614
5.00	2.354	68.93	0.02929	150.00	0.2163	16.68	0.07710
10.00	2.327	66.64	0.02864	155.00	0.2045	16.06	0.07855
15.00	2.307	65.32	0.02832	160.00	0.1919	15.50	0.08079
20.00	2.277	64.29	0.02824	165.00	0.1807	15.17	0.08393
25.00	2.249	64.01	0.02846	170.00	0.1701	14.84	0.08728
30.00	2.223	63.85	0.02872	175.00	0.1586	14.52	0.09153
35.00	2.199	63.60	0.02892	180.00	0.1486	14.21	0.09566
40.00	2.170	63.83	0.02941	185.00	0.1380	13.97	0.1012
45.00	2.136	64.21	0.03007	190.00	0.1286	13.73	0.1068
50.00	2.078	65.85	0.03168	195.00	0.1179	13.53	0.1147
65.00	1.422	125.1	0.08802	200.00	0.1072	13.33	0.1244
70.00	1.038	119.7	0.1153	205.00	0.09595	13.21	0.1377
75.00	0.7762	95.56	0.1231	210.00	0.08334	13.33	0.1599
80.00	0.6176	72.51	0.1174	215.00	0.07080	13.05	0.1843

Graph 55: Storage and loss properties for GE Plastics Valox 420 30% glass fiber filled polybutylene terephthalate (polyester PBT).



Graph 56: Storage and loss properties for DuPont Rynite 530 30% glass fiber filled polyethylene terephthalate (polyester PET).

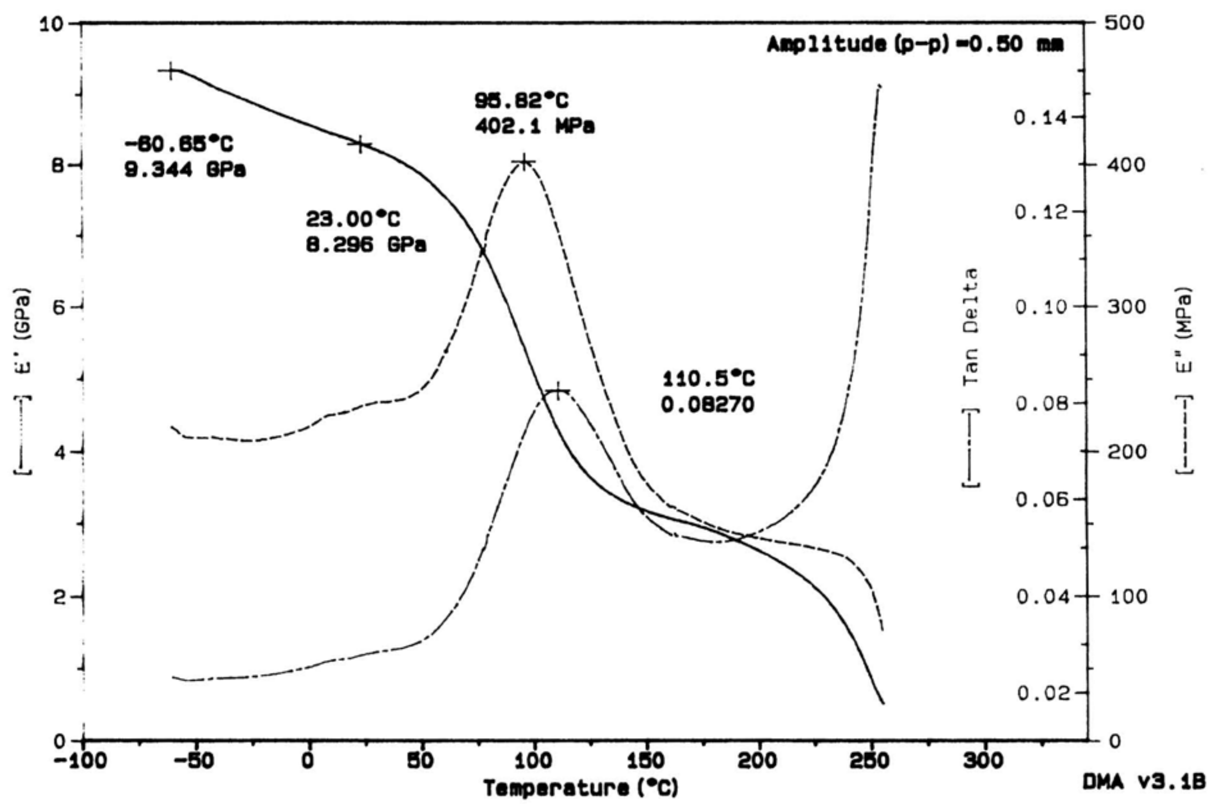


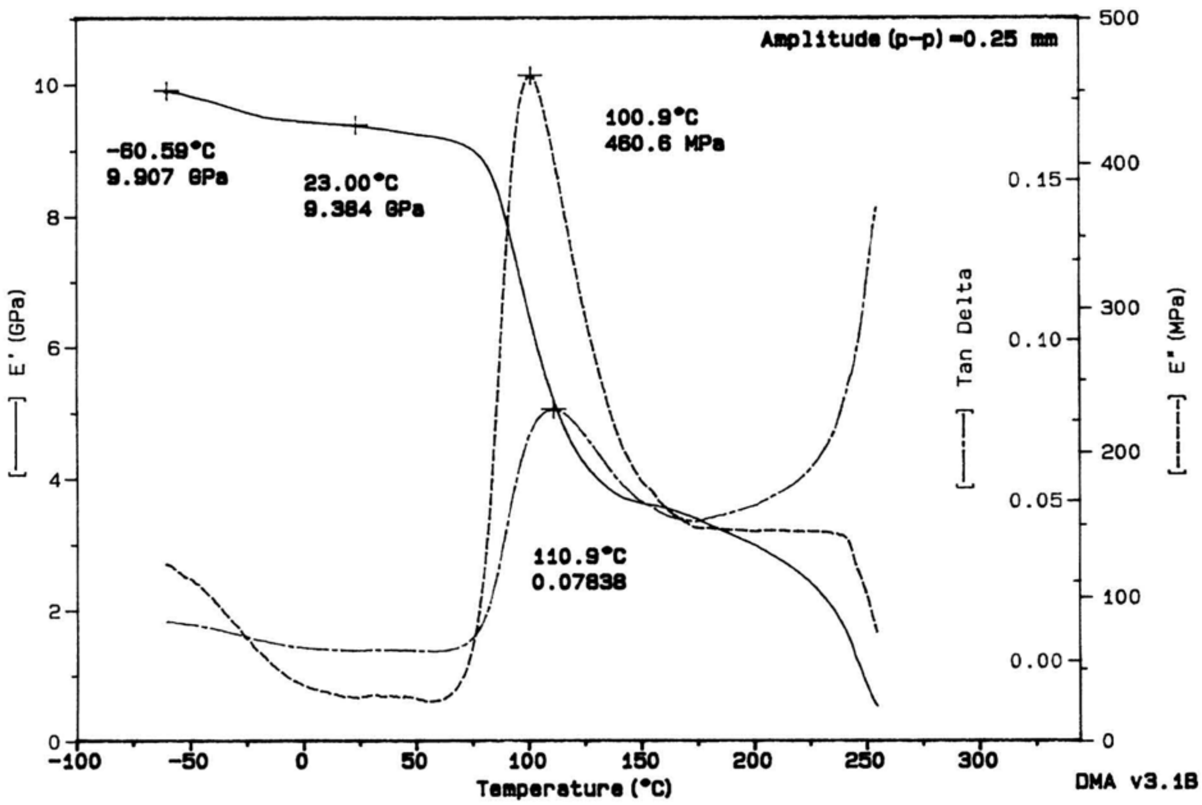
Table 55: Storage and loss properties for GE Plastics Valox 420 30% glass fiber filled polybutylene terephthalate (polyester PBT). (tabular data for Graph 55)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	7.469	113.3	0.01518	80.00	3.836	233.1	0.06078
-55.00	7.440	107.0	0.01438	85.00	3.557	193.0	0.05425
-50.00	7.402	102.1	0.01379	90.00	3.360	161.5	0.04806
-45.00	7.356	94.69	0.01287	95.00	3.224	138.7	0.04303
-40.00	7.305	90.12	0.01234	100.00	3.125	123.6	0.03955
-35.00	7.241	86.94	0.01201	105.00	3.046	114.1	0.03746
-30.00	7.183	86.14	0.01199	110.00	2.980	108.3	0.03635
-25.00	7.132	86.02	0.01206	115.00	2.926	105.4	0.03601
-20.00	7.086	87.37	0.01233	120.00	2.878	102.5	0.03562
-15.00	7.047	89.19	0.01266	125.00	2.837	99.70	0.03514
-10.00	7.014	91.68	0.01307	130.00	2.799	98.28	0.03512
-5.00	6.990	95.37	0.01364	135.00	2.762	98.44	0.03564
0.00	6.963	98.89	0.01420	140.00	2.721	96.70	0.03554
5.00	6.938	101.5	0.01464	145.00	2.675	94.07	0.03517
10.00	6.911	103.1	0.01492	150.00	2.629	91.83	0.03492
15.00	6.887	104.8	0.01522	155.00	2.575	87.76	0.03408
20.00	6.860	106.6	0.01554	160.00	2.506	84.46	0.03370
25.00	6.830	108.3	0.01586	165.00	2.426	82.41	0.03396
30.00	6.794	110.1	0.01621	170.00	2.349	80.68	0.03435
35.00	6.752	112.9	0.01672	175.00	2.269	79.64	0.03511
40.00	6.695	117.2	0.01751	180.00	2.188	78.78	0.03601
45.00	6.606	127.2	0.01926	185.00	2.106	78.14	0.03710
50.00	6.446	151.4	0.02350	190.00	2.019	77.96	0.03860
55.00	6.130	200.4	0.03270	195.00	1.928	77.99	0.04045
60.00	5.662	257.8	0.04555	200.00	1.829	78.58	0.04297
65.00	5.174	285.7	0.05521	205.00	1.719	80.24	0.04669
70.00	4.661	289.6	0.06213	210.00	1.601	85.09	0.05315
75.00	4.194	271.7	0.06476	215.00	1.474	89.04	0.06040

Table 56: Storage and loss properties for DuPont Rynite 530 30% glass fiber filled polyethylene terephthalate (polyester PET). (tabular data for Graph 56)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.344	216.3	0.02315	95.00	5.500	401.6	0.07301
-50.00	9.242	209.5	0.02267	100.00	5.088	397.9	0.07821
-45.00	9.162	209.3	0.02285	105.00	4.702	383.8	0.08162
-40.00	9.082	209.1	0.02303	110.00	4.347	359.4	0.08266
-35.00	9.013	208.5	0.02313	120.00	3.822	303.0	0.07929
-30.00	8.942	207.7	0.02323	125.00	3.639	275.6	0.07571
-25.00	8.873	207.7	0.02340	130.00	3.498	250.6	0.07165
-20.00	8.804	208.5	0.02369	140.00	3.301	207.4	0.06283
-15.00	8.738	210.0	0.02404	145.00	3.229	190.5	0.05898
-10.00	8.677	211.9	0.02442	150.00	3.169	178.5	0.05634
-5.00	8.617	214.4	0.02488	155.00	3.117	170.1	0.05456
0.00	8.558	217.4	0.02540	160.00	3.073	162.5	0.05289
5.00	8.495	222.4	0.02618	165.00	3.032	158.7	0.05232
10.00	8.438	225.7	0.02675	170.00	2.993	155.2	0.05186
15.00	8.388	227.1	0.02708	175.00	2.946	151.3	0.05137
20.00	8.333	229.7	0.02757	180.00	2.892	148.1	0.05120
25.00	8.269	232.2	0.02808	190.00	2.767	143.2	0.05177
30.00	8.204	234.2	0.02855	195.00	2.697	141.8	0.05256
40.00	8.055	235.5	0.02924	200.00	2.624	140.1	0.05340
45.00	7.967	238.1	0.02989	205.00	2.544	138.6	0.05449
50.00	7.861	243.3	0.03095	210.00	2.457	137.3	0.05586
55.00	7.726	251.9	0.03260	215.00	2.361	136.1	0.05765
60.00	7.566	266.4	0.03520	220.00	2.251	134.8	0.05988
65.00	7.396	282.6	0.03822	225.00	2.121	133.2	0.06280
70.00	7.189	303.5	0.04222	230.00	1.963	131.5	0.06698
75.00	6.934	328.5	0.04737	240.00	1.519	125.7	0.08277
80.00	6.633	355.0	0.05352	245.00	1.217	117.8	0.09684
90.00	5.906	393.1	0.06657	250.00	0.8478	105.6	0.1247

Graph 57: Storage and loss properties for Plastics Engineering Plenco 50030 30% glass fiber filled polyethylene terephthalate (polyester PET).



Graph 58: Storage and loss properties for Ticona Impet 330R 30% glass fiber filled polyethylene terephthalate (polyester PET).

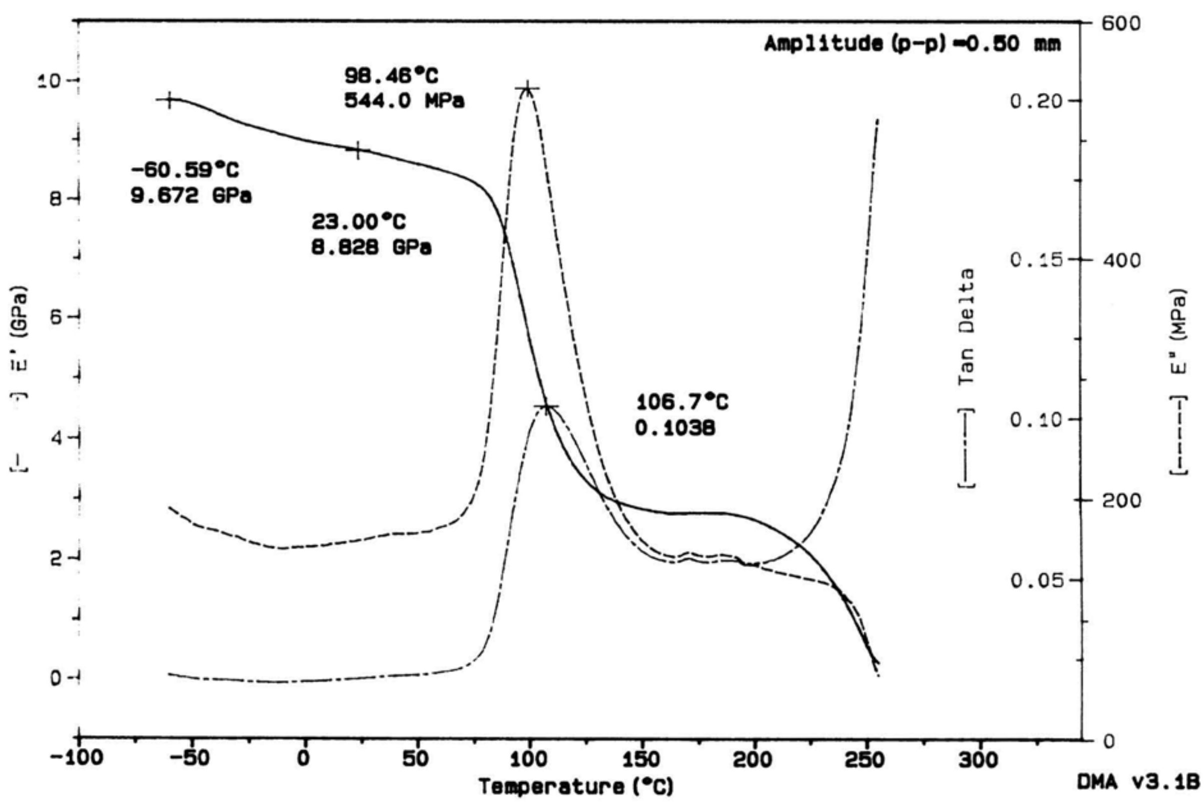


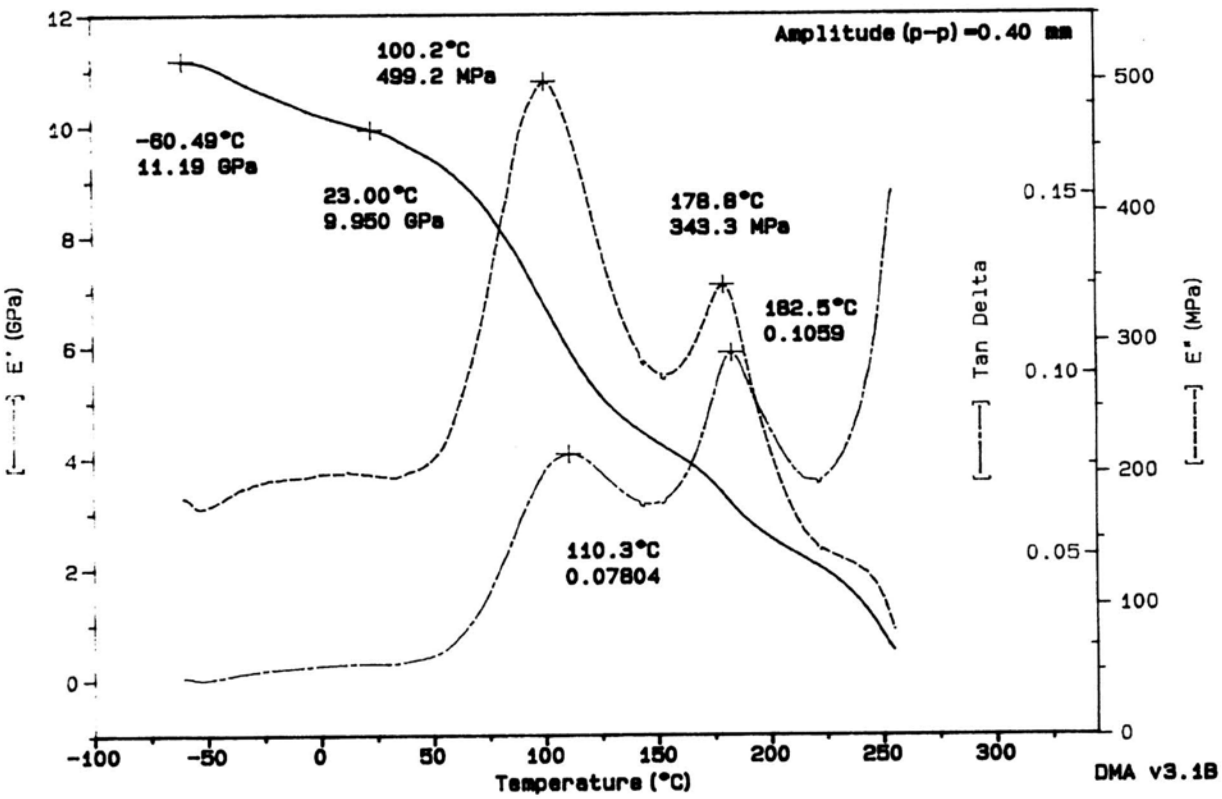
Table 57: Storage and loss properties for Plastics Engineering Plenco 50030 30% glass fiber filled polyethylene terephthalate (polyester PET). (tabular data for Graph 57)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.908	123.1	0.01243	100.00	6.569	459.8	0.07001
-50.00	9.840	113.1	0.01149	105.00	5.896	449.6	0.07626
-45.00	9.796	106.9	0.01091	110.00	5.321	417.0	0.07837
-40.00	9.753	99.00	0.01015	115.00	4.862	376.7	0.07748
-35.00	9.699	89.38	0.009215	120.00	4.503	335.2	0.07444
-30.00	9.644	81.22	0.008421	125.00	4.229	296.5	0.07012
-25.00	9.593	71.29	0.007432	130.00	4.026	263.7	0.06548
-20.00	9.546	62.35	0.006532	140.00	3.744	209.6	0.05598
-15.00	9.506	55.02	0.005788	145.00	3.677	192.9	0.05246
-10.00	9.484	48.05	0.005066	150.00	3.628	179.9	0.04958
-5.00	9.468	42.55	0.004495	155.00	3.598	172.4	0.04791
0.00	9.451	38.89	0.004115	160.00	3.561	162.6	0.04566
5.00	9.435	36.06	0.003821	170.00	3.449	151.4	0.04388
10.00	9.419	34.38	0.003650	175.00	3.387	147.9	0.04367
15.00	9.407	32.06	0.003408	180.00	3.297	147.7	0.04479
20.00	9.393	31.00	0.003300	190.00	3.149	146.4	0.04650
25.00	9.377	30.34	0.003235	195.00	3.071	146.1	0.04756
30.00	9.353	31.95	0.003416	200.00	2.995	145.5	0.04858
40.00	9.308	31.29	0.003362	205.00	2.896	146.1	0.05044
45.00	9.281	31.19	0.003361	210.00	2.796	146.1	0.05224
50.00	9.253	29.63	0.003202	215.00	2.690	145.7	0.05419
55.00	9.232	28.26	0.003061	220.00	2.566	145.6	0.05676
60.00	9.208	28.53	0.003099	225.00	2.419	145.5	0.06016
70.00	9.116	44.06	0.004833	230.00	2.237	145.1	0.06488
75.00	9.028	67.33	0.007458	235.00	2.022	143.7	0.07105
80.00	8.874	116.5	0.01313	240.00	1.728	142.0	0.08215
90.00	8.008	334.6	0.04180	245.00	1.287	122.9	0.09555
95.00	7.292	425.3	0.05835	250.00	0.8435	100.9	0.1198

Table 58: Storage and loss properties for Ticona Impet 330R 30% glass fiber filled polyethylene terephthalate (polyester PET). (tabular data for Graph 58)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.672	191.4	0.01979	95.00	6.484	528.9	0.08159
-50.00	9.596	178.9	0.01865	100.00	5.630	541.7	0.09625
-45.00	9.527	175.7	0.01844	110.00	4.290	442.0	0.1030
-40.00	9.448	173.5	0.01837	120.00	3.523	326.8	0.09276
-35.00	9.369	170.4	0.01818	125.00	3.295	281.5	0.08544
-30.00	9.294	168.2	0.01810	130.00	3.120	243.2	0.07793
-25.00	9.234	164.3	0.01779	135.00	3.004	213.9	0.07121
-20.00	9.179	161.4	0.01759	140.00	2.925	192.0	0.06565
-15.00	9.125	159.5	0.01748	145.00	2.868	176.5	0.06153
-10.00	9.072	159.1	0.01754	150.00	2.826	165.2	0.05848
-5.00	9.021	160.0	0.01773	155.00	2.791	157.9	0.05656
0.00	8.977	160.3	0.01786	160.00	2.765	153.9	0.05565
5.00	8.940	161.0	0.01801	170.00	2.761	156.1	0.05656
10.00	8.906	162.1	0.01820	175.00	2.764	153.6	0.05559
15.00	8.876	163.5	0.01842	180.00	2.763	153.1	0.05540
20.00	8.846	165.0	0.01865	190.00	2.740	153.0	0.05582
30.00	8.775	168.6	0.01921	195.00	2.704	147.6	0.05458
40.00	8.680	171.3	0.01974	200.00	2.646	145.6	0.05503
45.00	8.633	171.7	0.01989	205.00	2.569	142.4	0.05545
50.00	8.588	172.3	0.02006	210.00	2.474	140.1	0.05663
55.00	8.544	173.5	0.02030	215.00	2.362	138.1	0.05847
60.00	8.489	177.1	0.02087	220.00	2.229	136.1	0.06106
65.00	8.432	180.3	0.02138	225.00	2.068	134.0	0.06481
70.00	8.367	187.7	0.02243	230.00	1.864	132.0	0.07079
75.00	8.282	204.2	0.02465	235.00	1.613	128.1	0.07948
80.00	8.138	242.1	0.02976	240.00	1.315	120.8	0.09192
85.00	7.840	329.1	0.04199	245.00	0.9493	108.8	0.1147
90.00	7.277	448.3	0.06163	250.00	0.5422	82.22	0.1520

Graph 59: Storage and loss properties for DuPont Rynite FR530 30% glass fiber filled, flame retardant polyethylene terephthalate (polyester PET).



Graph 60: Storage and loss properties for DuPont Rynite RE5211 30% glass fiber filled, color stable polyethylene terephthalate (polyester PET).

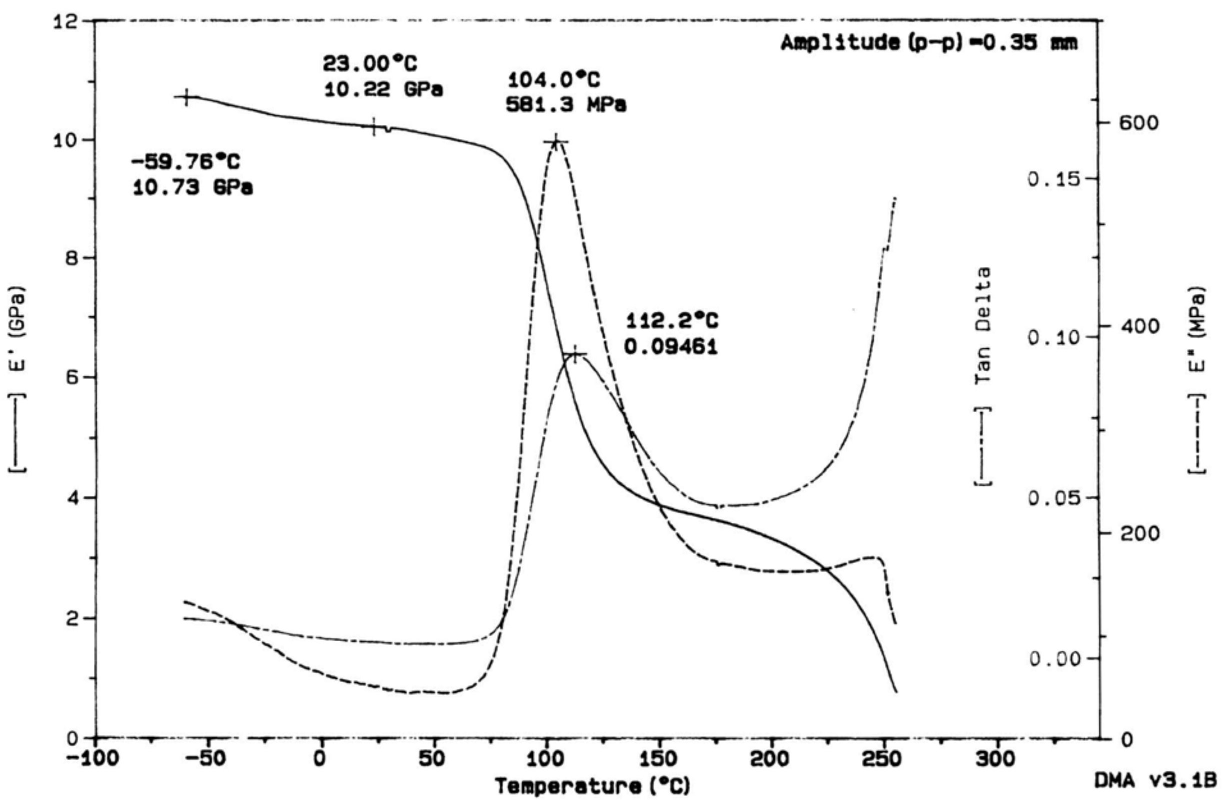


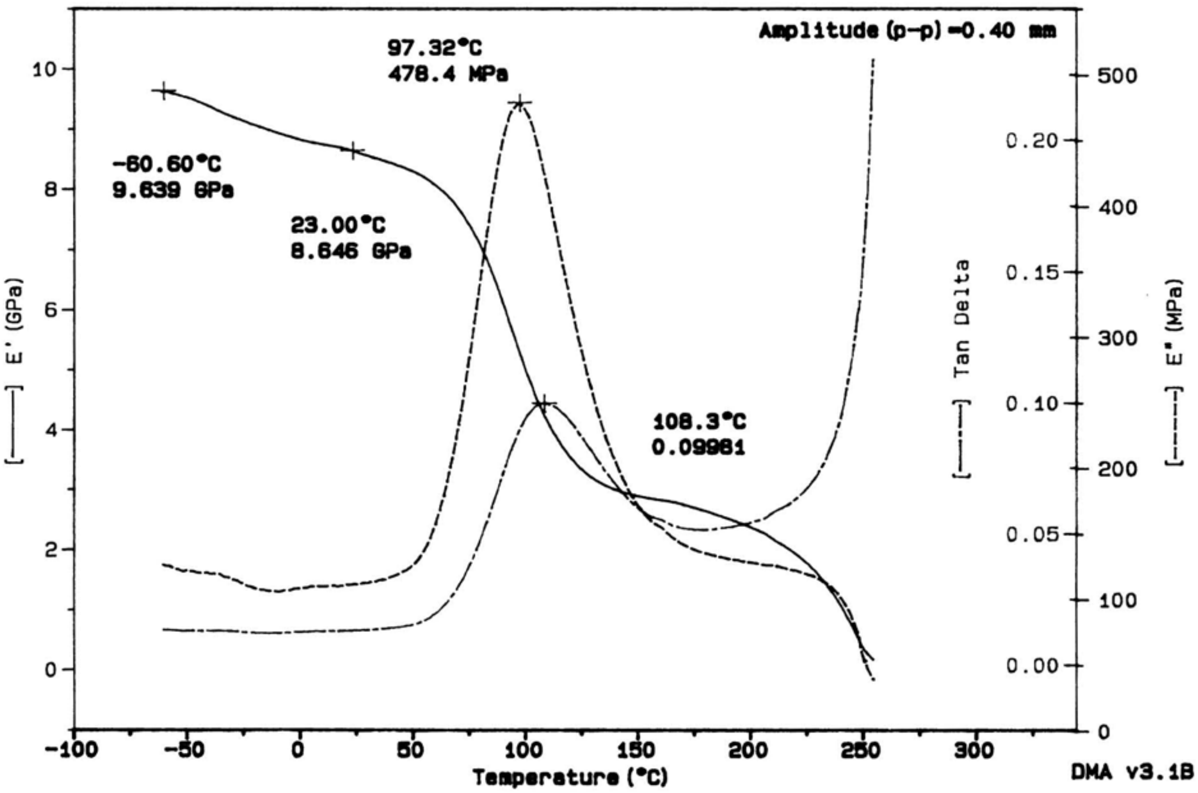
Table 59: Storage and loss properties for DuPont Rynite FR530 30% glass fiber filled, flame retardant polyethylene terephthalate (polyester PET). (tabular data for Graph 59)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	11.19	181.7	0.01624	100.00	6.799	499.1	0.07340
-50.00	11.12	174.8	0.01573	105.00	6.420	492.3	0.07668
-45.00	11.03	178.9	0.01622	110.00	6.042	471.3	0.07800
-40.00	10.93	183.9	0.01682	115.00	5.697	442.1	0.07761
-35.00	10.83	188.6	0.01742	120.00	5.392	408.0	0.07568
-30.00	10.72	191.8	0.01789	125.00	5.127	373.1	0.07277
-25.00	10.63	193.9	0.01824	130.00	4.903	342.0	0.06975
-20.00	10.55	195.3	0.01851	140.00	4.557	296.7	0.06511
-15.00	10.46	196.2	0.01875	145.00	4.414	283.1	0.06414
-10.00	10.38	197.0	0.01898	150.00	4.280	275.8	0.06444
-5.00	10.29	197.9	0.01923	155.00	4.152	274.9	0.06621
0.00	10.22	199.9	0.01957	160.00	4.021	280.3	0.06972
5.00	10.15	200.4	0.01973	165.00	3.882	292.6	0.07538
10.00	10.09	199.9	0.01981	170.00	3.722	311.4	0.08365
20.00	9.980	199.4	0.01998	175.00	3.526	333.4	0.09454
25.00	9.931	198.6	0.02000	180.00	3.297	343.0	0.1040
30.00	9.865	197.6	0.02003	190.00	2.864	280.4	0.09789
40.00	9.653	201.7	0.02089	195.00	2.697	244.8	0.09078
45.00	9.545	204.6	0.02143	200.00	2.552	216.1	0.08470
50.00	9.431	210.9	0.02236	205.00	2.422	191.3	0.07898
55.00	9.304	221.4	0.02380	210.00	2.304	171.0	0.07421
60.00	9.138	242.5	0.02654	215.00	2.190	155.5	0.07101
65.00	8.953	268.9	0.03003	220.00	2.071	146.0	0.07050
70.00	8.745	299.1	0.03420	225.00	1.948	140.3	0.07200
75.00	8.500	337.5	0.03970	230.00	1.799	136.1	0.07566
80.00	8.202	381.7	0.04654	240.00	1.410	127.1	0.09015
90.00	7.565	463.1	0.06123	245.00	1.151	119.5	0.1038
95.00	7.179	486.0	0.06770	250.00	0.8246	104.8	0.1272

Table 60: Storage and loss properties for DuPont Rynite RE5211 30% glass fiber filled, color stable polyethylene terephthalate (polyester PET). (tabular data for Graph 60)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	10.73	132.4	0.01234	90.00	9.047	322.6	0.03567
-55.00	10.71	128.6	0.01201	95.00	8.397	457.5	0.05450
-50.00	10.67	123.8	0.01160	100.00	7.554	553.9	0.07334
-45.00	10.62	119.3	0.01123	105.00	6.708	582.1	0.08679
-40.00	10.58	113.8	0.01076	110.00	5.927	555.9	0.09378
-35.00	10.53	106.1	0.01008	115.00	5.310	501.1	0.09437
-30.00	10.49	98.51	0.009390	120.00	4.872	444.2	0.09116
-25.00	10.45	91.38	0.008748	125.00	4.549	393.1	0.08640
-20.00	10.40	85.28	0.008198	130.00	4.320	349.5	0.08090
-15.00	10.38	76.93	0.007414	140.00	4.036	276.0	0.06839
-10.00	10.35	70.94	0.006854	150.00	3.871	224.8	0.05807
-5.00	10.33	66.38	0.006428	155.00	3.811	207.1	0.05434
0.00	10.30	62.30	0.006049	160.00	3.757	193.2	0.05142
5.00	10.28	58.92	0.005734	165.00	3.714	182.3	0.04909
10.00	10.26	55.66	0.005426	170.00	3.669	176.0	0.04797
15.00	10.24	54.21	0.005293	175.00	3.624	172.7	0.04766
20.00	10.23	51.56	0.005041	180.00	3.575	169.8	0.04748
25.00	10.21	50.54	0.004948	190.00	3.459	165.6	0.04786
30.00	10.13	46.89	0.004625	200.00	3.314	163.0	0.04919
40.00	10.14	44.97	0.004434	205.00	3.232	162.9	0.05042
45.00	10.10	45.43	0.004496	210.00	3.140	162.9	0.05187
50.00	10.07	44.71	0.004441	215.00	3.035	163.1	0.05375
55.00	10.03	44.43	0.004430	220.00	2.917	163.9	0.05619
60.00	9.987	46.25	0.004631	225.00	2.778	166.1	0.05980
65.00	9.945	49.57	0.004985	230.00	2.610	168.8	0.06467
70.00	9.897	57.04	0.005763	235.00	2.398	172.4	0.07193
75.00	9.827	74.27	0.007558	240.00	2.130	175.9	0.08259
80.00	9.703	113.9	0.01174	250.00	1.303	166.3	0.1277

Graph 61: Storage and loss properties for Allied Signal Petra 130 30% glass fiber filled, from recyclate polyethylene terephthalate (polyester PET).



Graph 62: Storage and loss properties for DuPont Rynite 545 45% glass fiber filled polyethylene terephthalate (polyester PET).

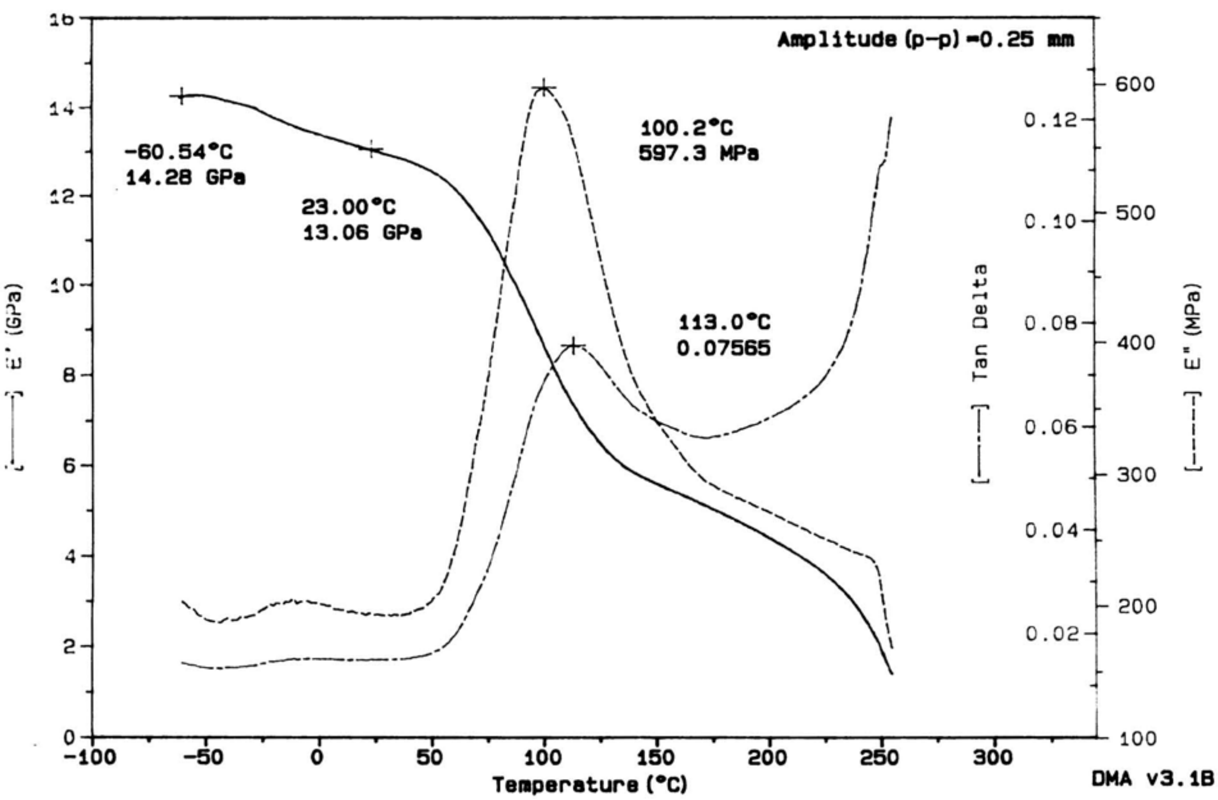


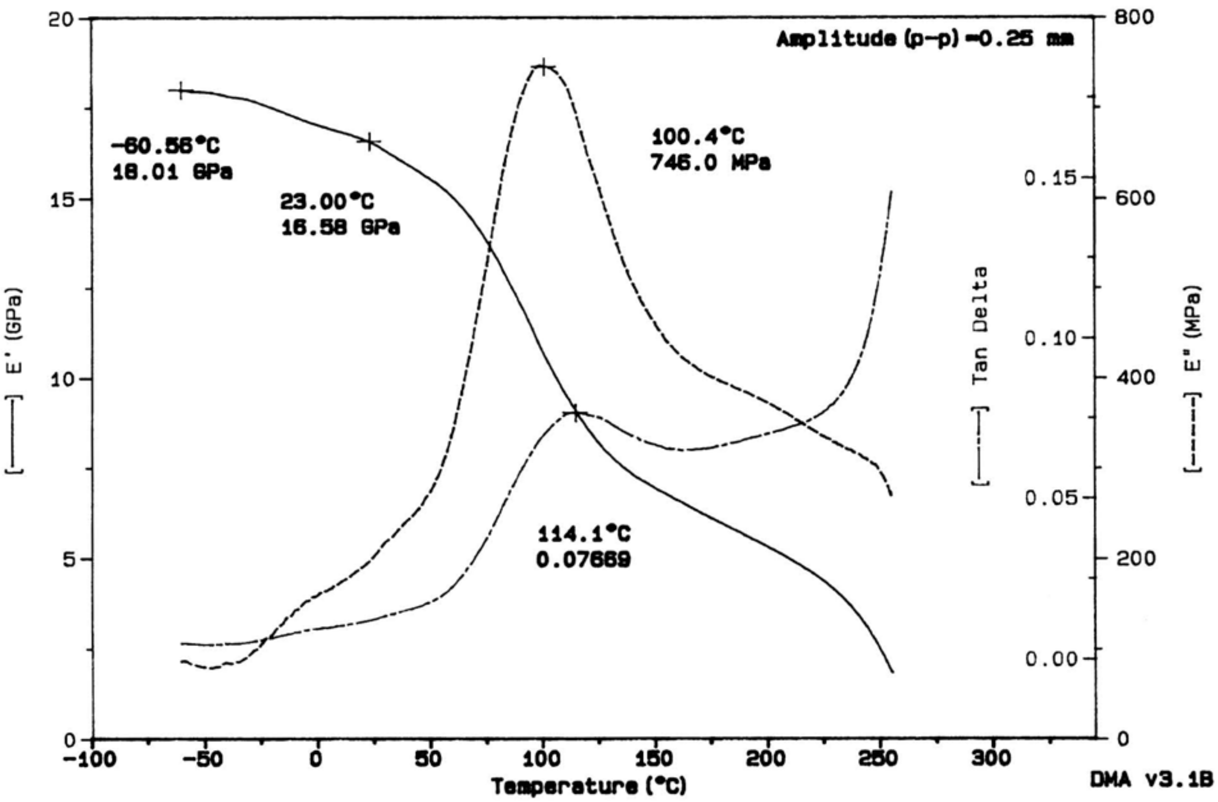
Table 61: Storage and loss properties for Allied Signal Petra 130 30% glass fiber filled, from recyclate polyethylene terephthalate (polyester PET). (tabular data for Graph 61)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.637	126.7	0.01315	100.00	5.066	474.5	0.09367
-50.00	9.543	122.5	0.01283	105.00	4.567	451.6	0.09889
-45.00	9.475	121.1	0.01278	110.00	4.157	414.2	0.09964
-40.00	9.393	120.3	0.01281	115.00	3.823	371.7	0.09724
-35.00	9.301	119.2	0.01282	120.00	3.547	329.4	0.09287
-30.00	9.219	115.6	0.01254	125.00	3.339	289.9	0.08682
-25.00	9.418	112.3	0.01228	130.00	3.186	256.6	0.08052
-20.00	9.075	108.8	0.01198	140.00	2.991	205.0	0.06854
-10.00	8.946	106.1	0.01186	145.00	2.930	186.0	0.06348
-5.00	8.888	107.4	0.01209	150.00	2.883	171.5	0.05948
0.00	8.829	108.7	0.01231	155.00	2.846	161.3	0.05665
5.00	8.784	110.3	0.01255	160.00	2.817	155.2	0.05511
10.00	8.751	110.3	0.01260	165.00	2.786	147.7	0.05300
15.00	8.716	110.9	0.01273	170.00	2.741	142.0	0.05182
20.00	8.679	111.4	0.01283	175.00	2.689	138.1	0.05136
25.00	8.622	111.9	0.01298	180.00	2.631	135.3	0.05142
30.00	8.563	113.0	0.01319	190.00	2.508	131.2	0.05231
40.00	8.446	117.5	0.01391	195.00	2.439	129.8	0.05322
45.00	8.380	121.1	0.01445	200.00	2.367	128.3	0.05421
50.00	8.306	126.8	0.01527	205.00	2.287	126.8	0.05544
55.00	8.213	137.9	0.01679	210.00	2.172	126.1	0.05804
60.00	8.083	157.9	0.01954	215.00	2.060	124.0	0.06019
65.00	7.929	188.2	0.02373	220.00	1.932	122.0	0.06315
70.00	7.721	229.6	0.02974	225.00	1.780	119.4	0.06707
75.00	7.449	281.9	0.03785	230.00	1.592	115.8	0.07278
80.00	7.123	340.9	0.04787	240.00	1.078	101.1	0.09383
90.00	6.188	447.9	0.07240	245.00	0.7375	85.79	0.1164
95.00	5.618	474.6	0.08448	250.00	0.3659	55.79	0.1530

Table 62: Storage and loss properties for DuPont Rynite 545 45% glass fiber filled polyethylene terephthalate (polyester PET). (tabular data for Graph 62)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	14.28	202.7	0.01419	100.00	8.711	597.2	0.06856
-50.00	14.30	190.0	0.01329	105.00	8.155	590.4	0.07240
-45.00	14.26	188.4	0.01321	110.00	7.657	574.9	0.07508
-40.00	14.18	190.8	0.01346	120.00	6.844	507.8	0.07420
-35.00	14.11	191.7	0.01359	125.00	6.516	467.7	0.07177
-30.00	14.04	193.1	0.01375	130.00	6.234	429.6	0.06892
-25.00	13.93	197.7	0.01419	135.00	6.011	397.9	0.06619
-20.00	13.80	200.7	0.01454	140.00	5.845	373.1	0.06384
-15.00	13.69	203.5	0.01486	145.00	5.708	356.4	0.06243
-10.00	13.58	202.3	0.01489	150.00	5.593	341.3	0.06103
-5.00	13.49	204.1	0.01513	155.00	5.482	329.8	0.06016
0.00	13.41	201.5	0.01502	160.00	5.373	318.0	0.05919
5.00	13.33	200.1	0.01501	165.00	5.262	306.4	0.05822
10.00	13.26	197.4	0.01489	170.00	5.146	298.0	0.05791
15.00	13.18	196.1	0.01488	175.00	5.029	291.9	0.05804
20.00	13.10	193.8	0.01479	180.00	4.910	287.1	0.05846
25.00	13.03	193.7	0.01486	190.00	4.662	279.5	0.05996
30.00	12.95	193.6	0.01495	195.00	4.535	275.0	0.06064
40.00	12.80	194.5	0.01520	200.00	4.398	271.4	0.06171
45.00	12.70	198.3	0.01562	205.00	4.258	267.3	0.06278
50.00	12.58	203.9	0.01621	210.00	4.111	263.2	0.06403
60.00	12.21	240.9	0.01973	215.00	3.956	259.0	0.06546
65.00	11.95	278.7	0.02333	220.00	3.790	255.1	0.06729
70.00	11.61	324.5	0.02794	225.00	3.606	251.1	0.06963
75.00	11.26	369.5	0.03281	230.00	3.386	247.3	0.07304
80.00	10.83	424.7	0.03921	240.00	2.818	239.9	0.08515
90.00	9.809	541.0	0.05515	245.00	2.427	236.7	0.09756
95.00	9.257	584.5	0.06315	250.00	1.928	214.1	0.1110

Graph 63: Storage and loss properties for DuPont Rynite 555 55% glass fiber filled polyethylene terephthalate (polyester PET).



Graph 64: Storage and loss properties for GE Plastics Ultem 1000 unfilled polyetherimide (PEI) tested dry as molded.

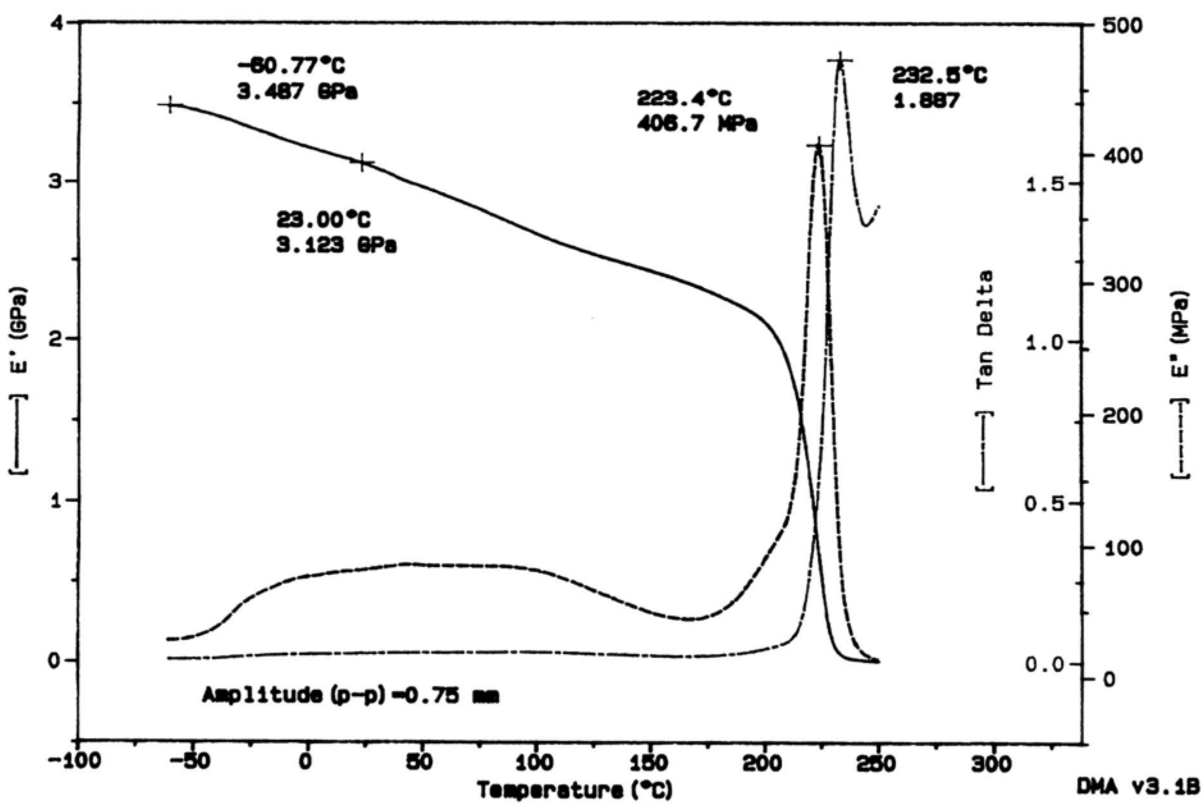


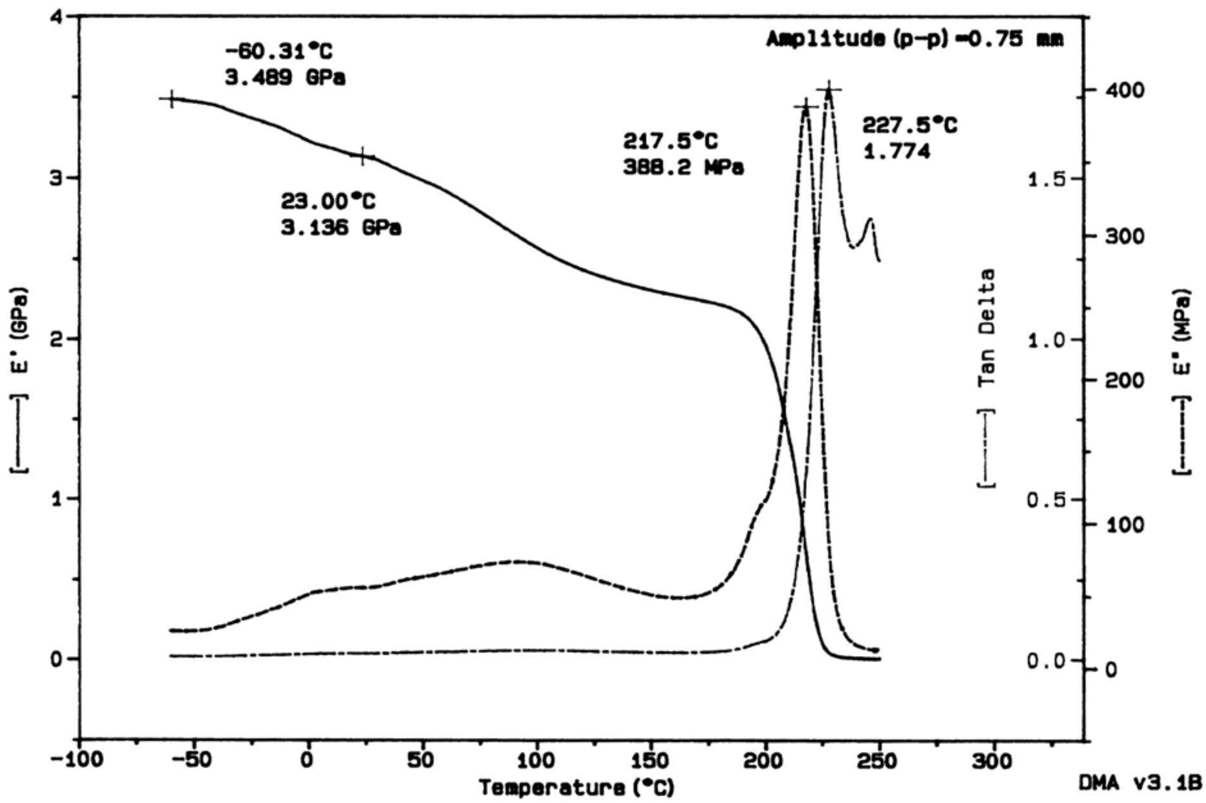
Table 63: Storage and loss properties for DuPont Rynite 555 55% glass fiber filled polyethylene terephthalate (polyester PET). (tabular data for Graph 63)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	18.00	86.75	0.004818	100.00	10.75	746.3	0.06940
-50.00	17.96	79.41	0.004423	110.00	9.572	727.9	0.07605
-45.00	17.91	80.24	0.004480	115.00	9.061	695.2	0.07672
-40.00	17.84	84.71	0.004749	120.00	8.596	652.0	0.07585
-35.00	17.79	85.96	0.004832	125.00	8.183	614.1	0.07504
-30.00	17.73	94.77	0.005345	130.00	7.844	573.0	0.07305
-25.00	17.63	105.5	0.005985	140.00	7.307	505.3	0.06916
-20.00	17.51	117.6	0.006714	145.00	7.116	480.5	0.06752
-15.00	17.39	130.4	0.007496	150.00	6.930	460.2	0.06640
-10.00	17.27	143.1	0.008288	155.00	6.765	441.1	0.06520
-5.00	17.15	153.1	0.008926	160.00	6.592	427.6	0.06488
0.00	17.04	159.9	0.009380	165.00	6.422	416.8	0.06490
5.00	16.95	165.7	0.009778	170.00	6.258	407.9	0.06518
10.00	16.85	173.8	0.01031	175.00	6.099	400.5	0.06566
20.00	16.66	191.1	0.01147	180.00	5.940	394.4	0.06640
25.00	16.52	202.9	0.01228	190.00	5.621	383.9	0.06830
30.00	16.34	218.7	0.01338	195.00	5.464	377.6	0.06910
40.00	15.96	243.0	0.01523	200.00	5.298	371.3	0.07009
45.00	15.76	256.0	0.01624	205.00	5.129	364.2	0.07100
50.00	15.56	273.9	0.01761	210.00	4.947	357.3	0.07224
55.00	15.34	301.2	0.01964	215.00	4.762	349.0	0.07329
60.00	15.06	340.7	0.02263	220.00	4.563	341.8	0.07490
65.00	14.72	394.6	0.02681	225.00	4.340	334.3	0.07704
70.00	14.32	457.2	0.03194	230.00	4.084	327.5	0.08019
75.00	13.85	522.5	0.03773	240.00	3.418	314.4	0.09198
80.00	13.30	593.6	0.04462	245.00	2.983	307.7	0.1032
90.00	12.09	705.5	0.05835	250.00	2.452	295.0	0.1203
95.00	11.44	736.3	0.06434	255.00	1.841	267.4	0.1453

Table 64: Storage and loss properties for GE Plastics Ultem 1000 unfilled polyetherimide (PEI) tested dry as molded. (tabular data for Graph 64)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.486	28.00	0.008030	95.00	2.702	82.77	0.03064
-55.00	3.477	28.44	0.008180	100.00	2.670	81.26	0.03043
-50.00	3.458	30.04	0.008687	105.00	2.639	79.18	0.03000
-45.00	3.437	33.19	0.009657	110.00	2.612	76.25	0.02919
-40.00	3.417	37.45	0.01096	115.00	2.587	73.09	0.02826
-35.00	3.396	44.35	0.01306	120.00	2.562	69.77	0.02723
-30.00	3.369	53.32	0.01583	125.00	2.540	65.79	0.02590
-25.00	3.343	59.79	0.01788	130.00	2.157	62.38	0.02478
-20.00	3.317	64.67	0.01949	140.00	2.475	55.30	0.02234
-15.00	3.292	68.33	0.02075	145.00	2.454	51.98	0.02118
-10.00	3.265	72.13	0.02209	150.00	2.433	49.08	0.02018
-5.00	3.242	74.86	0.02309	155.00	2.411	46.58	0.01932
0.00	3.220	76.47	0.02375	160.00	2.388	45.02	0.01885
5.00	3.198	77.70	0.02429	165.00	2.364	44.13	0.01867
10.00	3.177	79.05	0.02489	170.00	2.337	44.27	0.01894
15.00	3.157	80.30	0.02544	175.00	2.307	46.21	0.02003
20.00	3.137	80.86	0.02578	180.00	2.275	49.55	0.02178
30.00	3.087	82.93	0.02687	190.00	2.208	63.98	0.02898
40.00	3.024	85.29	0.02821	195.00	2.168	75.93	0.03502
45.00	2.995	85.70	0.02861	200.00	2.112	89.55	0.04239
50.00	2.971	85.16	0.02866	205.00	2.023	103.5	0.05119
55.00	2.944	84.89	0.02884	210.00	1.869	121.1	0.06485
60.00	2.916	84.92	0.02912	215.00	1.595	177.4	0.1114
65.00	2.888	84.95	0.02942	220.00	1.136	337.1	0.2980
70.00	2.859	84.66	0.02962	225.00	0.5463	695.5	0.7311
75.00	2.830	84.52	0.02987	230.00	0.1226	203.1	1.669
80.00	2.797	84.55	0.03023	240.00	0.01765	25.54	1.446
90.00	2.733	83.73	0.03063	245.00	0.01205	16.47	1.366

Graph 65: Storage and loss properties for GE Plastics Ultem 1000 unfilled polyetherimide (PEI) tested at 0.5% moisture content.



Graph 66: Storage and loss properties for GE Plastics Ultem 2300 30% glass fiber filled polyetherimide (PEI) tested dry as molded.

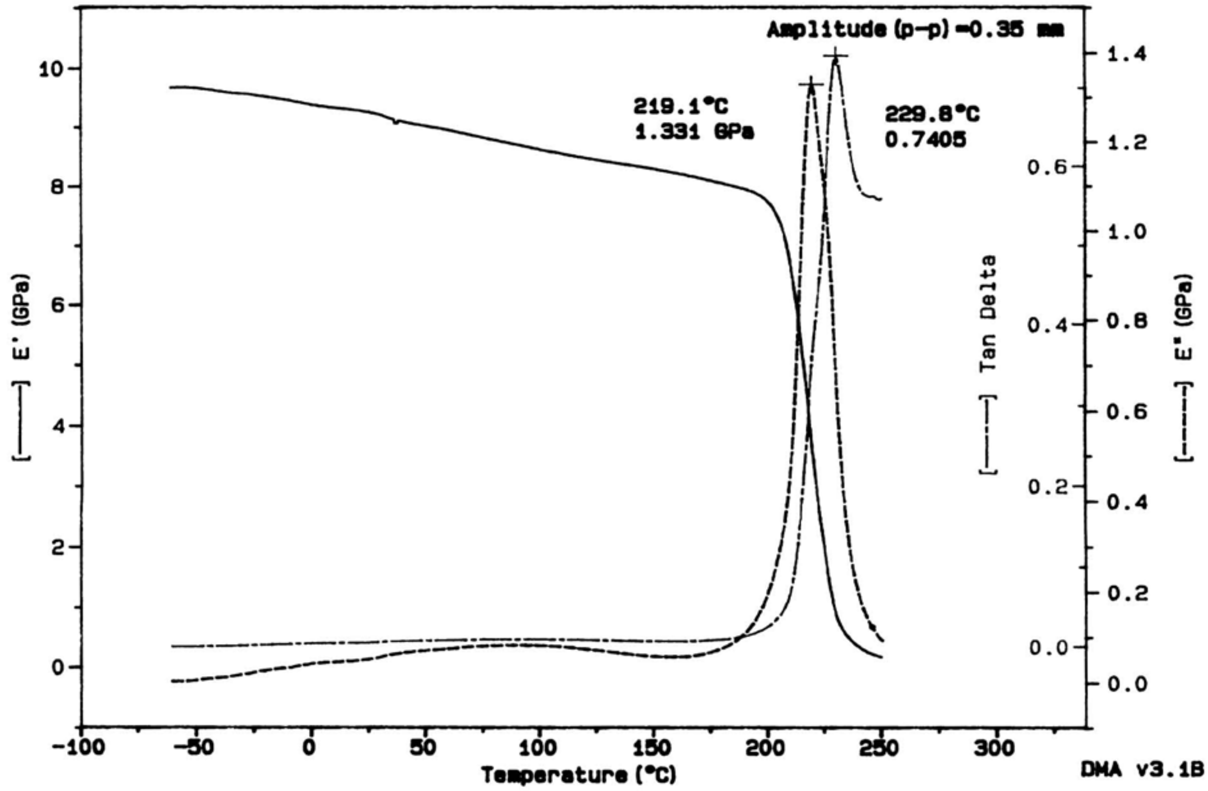


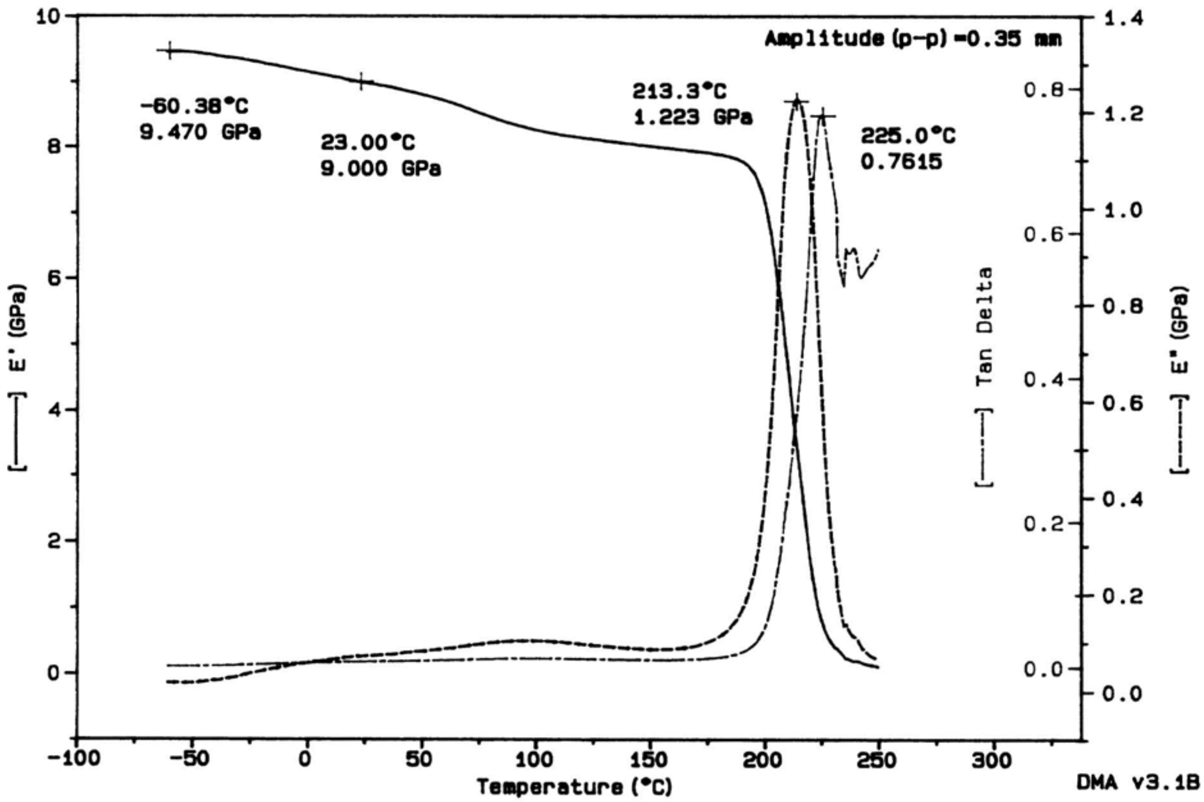
Table 65: Storage and loss properties for GE Plastics Ultem 1000 unfilled polyetherimide (PEI) tested at 0.5% moisture content. (tabular data for Graph 65)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.489	25.41	0.007283	100.00	2.571	72.64	0.02825
-50.00	3.470	25.48	0.007342	105.00	2.532	71.14	0.02810
-45.00	3.460	26.28	0.007595	110.00	2.496	69.01	0.02765
-40.00	3.443	28.02	0.008139	115.00	2.465	66.79	0.02710
-35.00	3.418	30.53	0.008932	120.00	2.436	64.32	0.02641
-30.00	3.393	33.23	0.009794	125.00	2.410	61.70	0.02561
-25.00	3.369	36.15	0.01073	130.00	2.386	59.17	0.02480
-20.00	3.347	38.72	0.01157	140.00	2.344	54.43	0.02322
-15.00	3.322	41.53	0.01250	145.00	2.325	52.48	0.02257
-10.00	3.293	44.72	0.01358	150.00	2.308	50.81	0.02201
-5.00	3.262	48.19	0.01477	155.00	2.292	49.60	0.02164
0.00	3.226	51.57	0.01599	160.00	2.278	49.05	0.02153
5.00	3.203	53.22	0.01662	165.00	2.264	49.17	0.02172
10.00	3.182	54.20	0.01703	170.00	2.250	50.45	0.02243
20.00	3.144	55.62	0.01769	175.00	2.235	53.03	0.02373
25.00	3.130	55.72	0.01780	180.00	2.217	57.91	0.02612
30.00	3.109	56.53	0.01818	190.00	2.158	82.51	0.03824
40.00	3.045	60.46	0.01985	195.00	2.087	104.8	0.05021
45.00	3.014	62.09	0.02060	200.00	1.958	117.1	0.05981
50.00	2.984	63.39	0.02124	205.00	1.741	148.7	0.08542
55.00	2.954	64.86	0.02196	210.00	1.401	227.4	0.1626
60.00	2.919	66.38	0.02274	215.00	0.9731	362.1	0.3737
65.00	2.879	68.04	0.02364	220.00	0.4209	349.7	0.8381
70.00	2.836	69.76	0.02460	225.00	0.1026	161.6	1.583
75.00	2.793	71.09	0.02545	230.00	0.02942	48.94	1.661
80.00	2.748	72.44	0.02636	240.00	0.01233	15.92	1.291
90.00	2.657	73.72	0.02774	245.00	0.009863	13.48	1.367
95.00	2.614	73.44	0.02810	250.00	0.01005	12.52	1.245

Table 66: Storage and loss properties for GE Plastics Ultem 2300 30% glass fiber filled polyetherimide (PEI) tested dry as molded. (tabular data for Graph 66)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.705	0.003558	3.666E-4	100.00	8.636	0.08179	0.009471
-50.00	9.697	0.006396	6.595E-4	105.00	8.596	0.08050	0.009365
-45.00	9.672	0.009891	0.001023	110.00	8.561	0.07877	0.009201
-40.00	9.641	0.01219	0.001264	115.00	8.525	0.07614	0.008932
-35.00	9.611	0.01500	0.001560	120.00	8.489	0.07390	0.008705
-30.00	9.595	0.01926	0.002008	125.00	8.456	0.07112	0.008410
-25.00	9.572	0.02338	0.002443	130.00	8.424	0.06797	0.008068
-20.00	9.540	0.02746	0.002878	140.00	8.364	0.06168	0.007375
-15.00	9.510	0.03132	0.003293	145.00	8.334	0.05926	0.007111
-10.00	9.477	0.03401	0.003589	150.00	8.303	0.05766	0.006945
-5.00	9.438	0.03837	0.004065	155.00	8.266	0.05707	0.006904
0.00	9.400	0.04266	0.004539	160.00	8.231	0.05676	0.006897
5.00	9.368	0.04428	0.004726	165.00	8.192	0.05781	0.007057
10.00	9.347	0.04570	0.004889	170.00	8.151	0.06145	0.007539
20.00	9.301	0.04927	0.005298	175.00	8.105	0.06739	0.008315
25.00	9.271	0.05159	0.005565	180.00	8.060	0.07620	0.009455
30.00	9.231	0.05617	0.006085	190.00	7.963	0.1093	0.01373
40.00	9.112	0.06597	0.007241	195.00	7.892	0.1427	0.01808
45.00	9.068	0.06903	0.007612	200.00	7.764	0.1973	0.02542
50.00	9.035	0.07079	0.007835	205.00	7.479	0.2888	0.03863
55.00	9.001	0.07280	0.008088	210.00	6.769	0.4667	0.06904
60.00	8.967	0.07496	0.008360	215.00	5.414	0.9808	0.1817
65.00	8.922	0.07786	0.008727	220.00	3.545	1.324	0.3749
70.00	8.880	0.07975	0.008981	225.00	2.016	1.101	0.5486
75.00	8.838	0.08094	0.009158	230.00	0.9191	0.6795	0.7393
80.00	8.798	0.08187	0.009305	240.00	0.3382	0.1943	0.5745
90.00	8.719	0.08270	0.009485	245.00	0.2301	0.1292	0.5615
95.00	8.677	0.08269	0.009530	250.00	0.1667	0.09320	0.5592

Graph 67: Storage and loss properties for GE Plastics Ultem 2300 30% glass fiber filled polyetherimide (PEI) tested at 0.5% moisture content.



Graph 68: Storage and loss properties for Victrex PEEK 450G unfilled polyetheretherketone (PEEK).

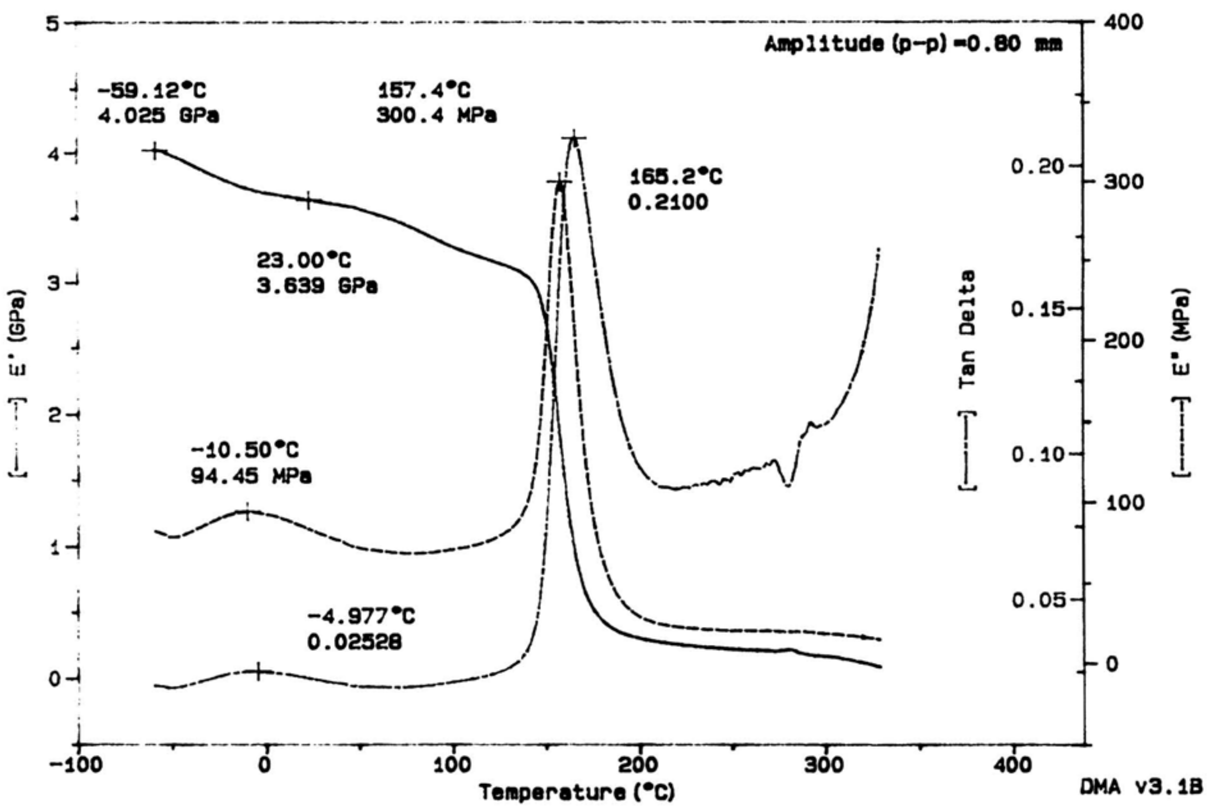


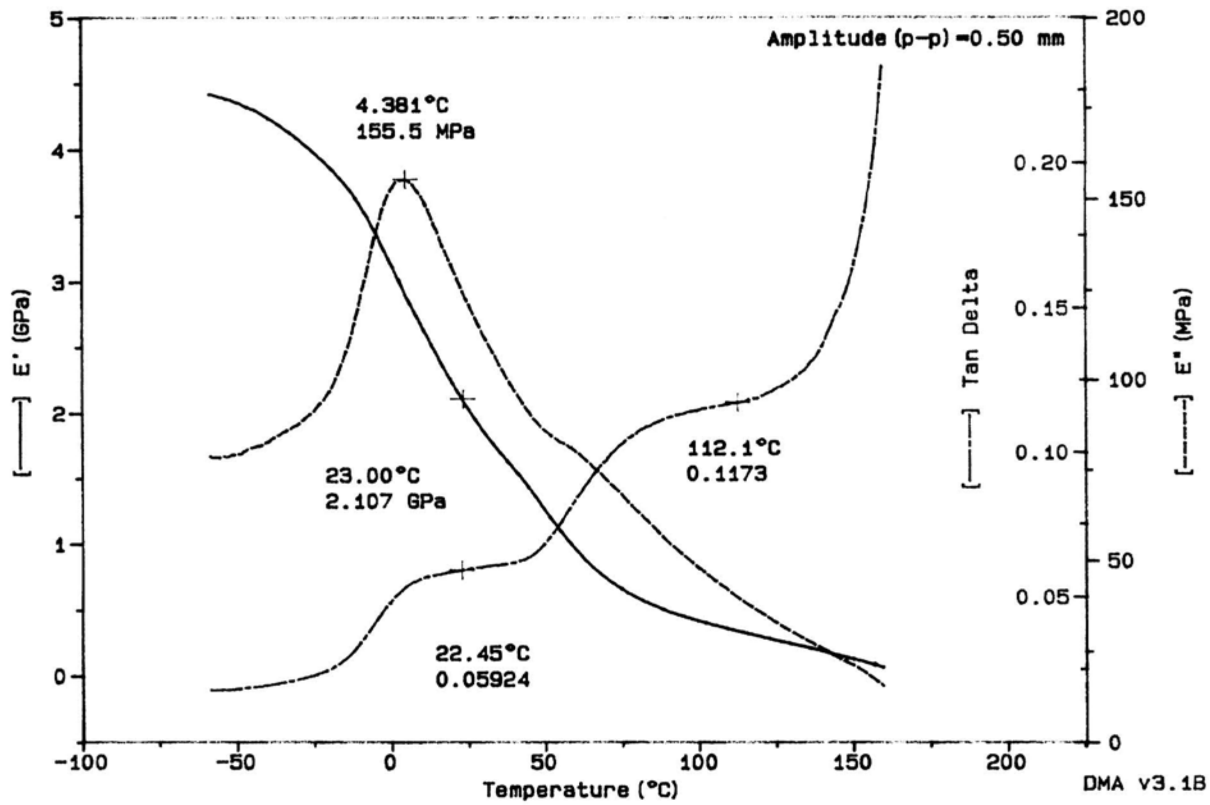
Table 67: Storage and loss properties for GE Plastics Ultem 2300 30% glass fiber filled polyetherimide (PEI) tested at 0.5% moisture content. (tabular data for Graph 67)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.470	0.01868	0.001973	95.00	8.302	0.1040	0.01253
-50.00	9.461	0.01849	0.001954	100.00	8.259	0.1042	0.01262
-45.00	9.437	0.02086	0.002210	105.00	8.222	0.1035	0.01259
-40.00	9.408	0.02408	0.002560	110.00	8.190	0.1017	0.01242
-35.00	9.382	0.02718	0.002897	115.00	8.162	0.09938	0.01218
-30.00	9.361	0.03175	0.003392	120.00	8.139	0.09710	0.01193
-25.00	9.329	0.03809	0.004083	125.00	8.115	0.09498	0.01171
-20.00	9.296	0.04234	0.004554	130.00	8.091	0.09285	0.01148
-15.00	9.261	0.04741	0.005120	140.00	8.048	0.08898	0.01106
-10.00	9.225	0.05194	0.005630	145.00	8.026	0.08776	0.01093
-5.00	9.188	0.05565	0.006057	150.00	8.008	0.08646	0.01080
0.00	9.156	0.05945	0.006493	155.00	7.988	0.08670	0.01085
5.00	9.120	0.06250	0.006852	160.00	7.968	0.08790	0.01103
10.00	9.089	0.06598	0.007260	165.00	7.949	0.09029	0.01136
15.00	9.056	0.06906	0.007627	170.00	7.928	0.09459	0.01193
20.00	9.017	0.07184	0.007967	175.00	7.906	0.1022	0.01293
25.00	8.987	0.07350	0.008179	180.00	7.880	0.1140	0.01446
30.00	8.958	0.07457	0.008325	190.00	7.781	0.1688	0.02170
40.00	8.888	0.07856	0.008839	195.00	7.621	0.2428	0.03186
45.00	8.848	0.08086	0.009139	200.00	7.175	0.4083	0.05694
50.00	8.805	0.08309	0.009436	205.00	6.164	0.7533	0.1224
55.00	8.760	0.08576	0.009791	210.00	4.714	1.131	0.2404
60.00	8.708	0.08815	0.01012	215.00	3.159	1.223	0.3880
65.00	8.652	0.09094	0.01051	220.00	1.720	1.052	0.6134
70.00	8.588	0.09436	0.01099	225.00	0.8035	0.6121	0.7617
75.00	8.522	0.09751	0.01144	230.00	0.4314	0.2846	0.6593
80.00	8.460	0.1000	0.01182	240.00	0.1930	0.1097	0.5685
90.00	8.346	0.1041	0.01247	245.00	0.1409	0.07787	0.5527

Table 68: Storage and loss properties for Victrex PEEK 450G unfilled polyetheretherketone (PEEK). (tabular data for Graph 68)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	4.015	80.64	0.02008	140.00	3.050	100.3	0.03288
-50.00	3.983	78.65	0.01975	145.00	2.963	128.8	0.04350
-45.00	3.951	79.75	0.02019	150.00	2.720	200.1	0.07368
-40.00	3.916	82.26	0.02101	160.00	1.528	286.9	0.1880
-30.00	3.845	87.67	0.02280	170.00	0.7031	139.5	0.1983
-25.00	3.812	90.67	0.02379	175.00	0.5352	92.78	0.1733
-20.00	3.780	92.68	0.02452	180.00	0.4406	65.61	0.1489
-15.00	3.752	93.88	0.02502	190.00	0.3457	39.10	0.1131
-10.00	3.729	94.33	0.02530	195.00	0.3210	32.88	0.1024
-5.00	3.707	93.69	0.02528	200.00	0.3026	28.91	0.09552
0.00	3.692	92.60	0.02508	205.00	0.2882	26.40	0.09158
5.00	3.680	91.36	0.02482	210.00	0.2759	24.58	0.08910
10.00	3.668	89.39	0.02437	220.00	0.2568	22.58	0.08796
15.00	3.657	87.09	0.02381	225.00	0.2491	22.05	0.08852
20.00	3.646	84.88	0.02328	230.00	0.2418	21.63	0.08946
30.00	3.622	80.13	0.02212	235.00	0.2353	21.15	0.08987
40.00	3.600	76.01	0.02111	240.00	0.2310	20.96	0.09072
45.00	3.588	73.24	0.02041	250.00	0.2209	20.29	0.09186
50.00	3.569	71.71	0.02009	255.00	0.2162	20.07	0.09284
55.00	3.546	70.98	0.02001	260.00	0.2144	20.36	0.09495
60.00	3.525	70.17	0.01991	265.00	0.2117	20.13	0.09509
70.00	3.477	68.99	0.01984	270.00	0.2081	20.05	0.09636
75.00	3.448	68.66	0.01991	280.00	0.2181	19.41	0.08899
80.00	3.415	68.67	0.02011	285.00	0.1964	19.73	0.1005
85.00	3.380	69.04	0.02043	290.00	0.1789	19.31	0.1079
90.00	3.344	69.55	0.02080	295.00	0.1720	18.81	0.1093
100.00	3.277	71.23	0.02173	300.00	0.1671	18.45	0.1104
105.00	3.249	72.23	0.02223	305.00	0.1586	18.01	0.1136
110.00	3.223	73.39	0.02277	310.00	0.1468	17.47	0.1190
115.00	3.199	75.03	0.02346	315.00	0.1341	16.92	0.1262
120.00	3.174	76.83	0.02420	320.00	0.1194	16.26	0.1362
130.00	3.123	83.16	0.02663	325.00	0.1017	15.44	0.1519

Graph 69: Storage and loss properties for Exxon Escorene 1032 unfilled, homopolymer polypropylene (PP).



Graph 70: Storage and loss properties for Polypropylene 400121 unfilled, homopolymer polypropylene (PP).

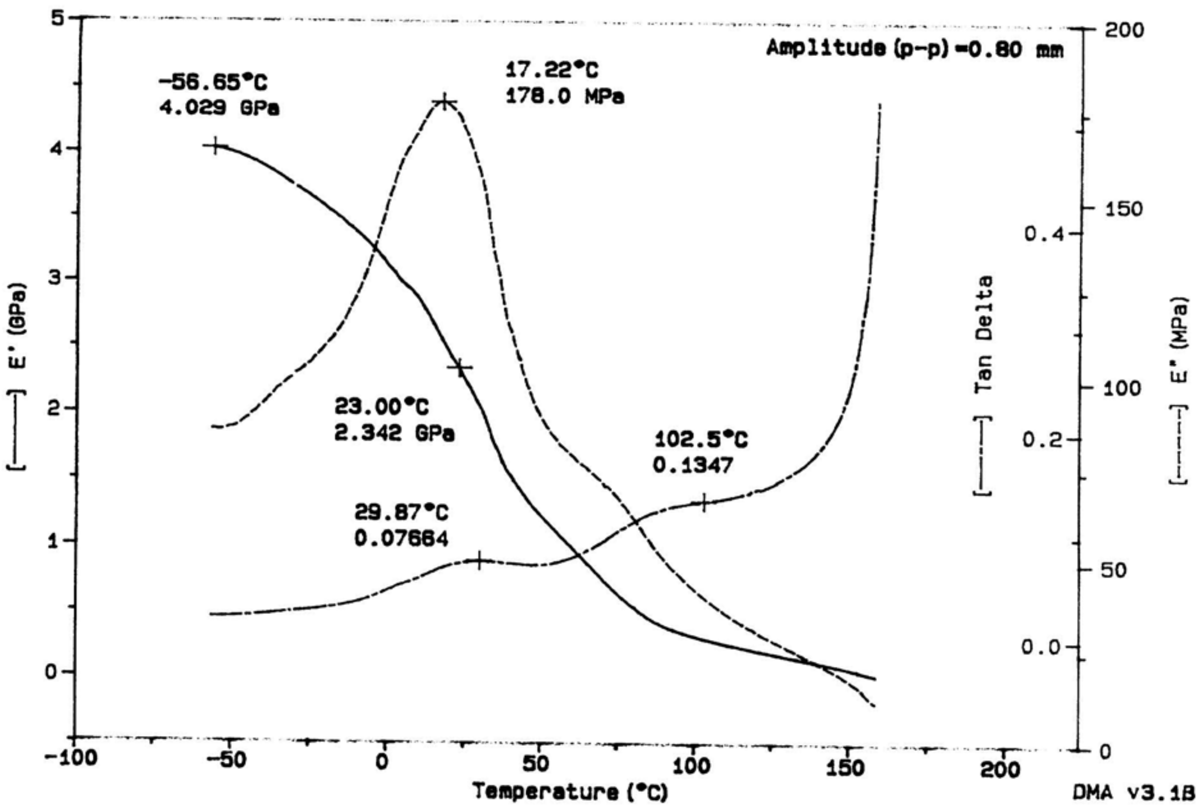


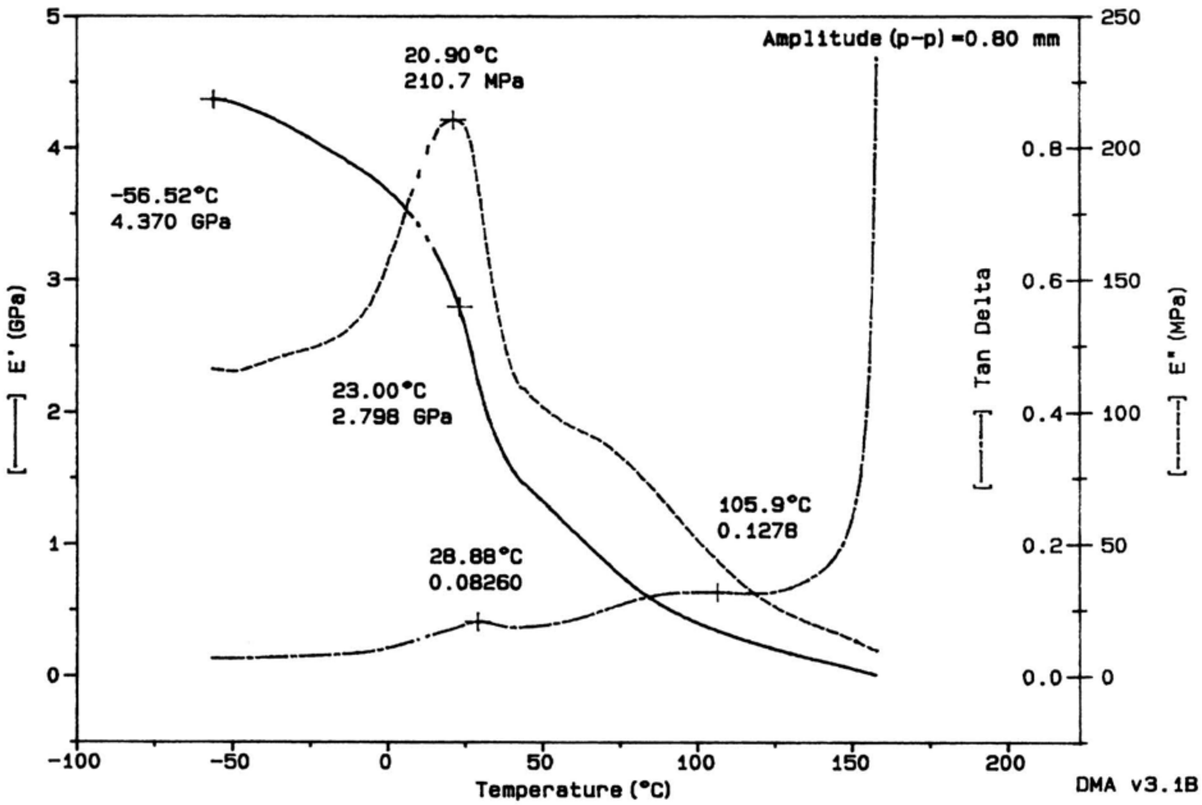
Table 69: Storage and loss properties for Exxon Escorene 1032 unfilled, homopolymer polypropylene (PP). (tabular data for Graph 69)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	4.395	78.71	0.01791	55.00	1.096	82.77	0.07552
-50.00	4.356	79.61	0.01827	60.00	0.9582	80.24	0.08375
-45.00	4.305	81.45	0.01892	65.00	0.8353	76.40	0.09146
-40.00	4.241	82.99	0.01957	70.00	0.7387	72.21	0.09776
-35.00	4.162	85.59	0.02057	75.00	0.6596	68.01	0.1031
-30.00	4.076	88.01	0.02159	80.00	0.5923	63.55	0.1073
-25.00	3.977	91.68	0.02305	85.00	0.5392	59.33	0.1100
-20.00	3.869	97.16	0.02511	90.00	0.4901	55.03	0.1123
-15.00	3.742	107.2	0.02865	95.00	0.4523	51.43	0.1137
-10.00	3.574	123.2	0.03449	100.00	0.4173	47.95	0.1149
-5.00	3.367	140.9	0.04185	105.00	0.3845	44.61	0.1160
0.00	3.130	153.0	0.04887	110.00	0.3547	41.52	0.1171
5.00	2.882	155.3	0.05391	115.00	0.3262	38.49	0.1180
10.00	2.660	150.4	0.05655	120.00	0.2992	35.76	0.1195
15.00	2.436	141.0	0.05789	125.00	0.2701	33.02	0.1223
20.00	2.225	130.9	0.05883	130.00	0.2437	30.48	0.1251
25.00	2.031	121.4	0.05976	135.00	0.2171	28.12	0.1295
30.00	1.857	112.4	0.06053	140.00	0.1892	25.93	0.1371
35.00	1.709	104.5	0.06114	145.00	0.1571	23.45	0.1493
40.00	1.567	97.14	0.06197	150.00	0.1296	21.25	0.1640
45.00	1.418	90.80	0.06402	155.00	0.09789	18.62	0.1903
50.00	1.254	85.97	0.06859				

Table 70: Storage and loss properties for Polypropylene 400121 unfilled, homopolymer polypropylene (PP). (tabular data for Graph 70)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	4.024	86.17	0.02142	55.00	1.104	83.51	0.07564
-50.00	3.992	86.94	0.02178	60.00	0.9885	79.36	0.08029
-45.00	3.946	89.73	0.02274	65.00	0.8666	75.72	0.08737
-40.00	3.885	93.73	0.02413	70.00	0.7485	71.69	0.09578
-35.00	3.815	97.98	0.02569	75.00	0.6349	67.70	0.1066
-25.00	3.658	104.9	0.02868	80.00	0.5393	62.05	0.1151
-20.00	3.569	109.8	0.03078	85.00	0.4572	56.15	0.1228
-15.00	3.482	115.3	0.03312	90.00	0.3963	50.73	0.1280
-10.00	3.377	124.1	0.03675	95.00	0.3536	46.47	0.1314
-5.00	3.265	135.6	0.04153	100.00	0.3183	42.58	0.1338
0.00	3.124	150.5	0.04818	105.00	0.2884	39.18	0.1359
5.00	2.988	162.9	0.05450	110.00	0.2612	36.13	0.1383
10.00	2.867	170.6	0.05953	115.00	0.2361	33.45	0.1417
15.00	2.667	177.2	0.06645	120.00	0.2124	31.22	0.1470
20.00	2.453	176.6	0.07200	125.00	0.1894	28.75	0.1518
25.00	2.253	169.5	0.07523	130.00	0.1663	26.63	0.1602
30.00	2.046	156.8	0.07663	135.00	0.1440	24.52	0.1703
35.00	1.752	132.6	0.07567	140.00	0.1208	22.38	0.1853
40.00	1.527	113.2	0.07415	145.00	0.09692	20.12	0.2077
45.00	1.362	99.26	0.07290	150.00	0.07132	17.56	0.2464
50.00	1.225	89.64	0.07320	155.00	0.04185	13.97	0.3345

Graph 71: Storage and loss properties for Polypropylene 400145 unfilled, homopolymer polypropylene (PP).



Graph 72: Storage and loss properties for Montell PF062-2 20% glass fiber filled polypropylene (PP).

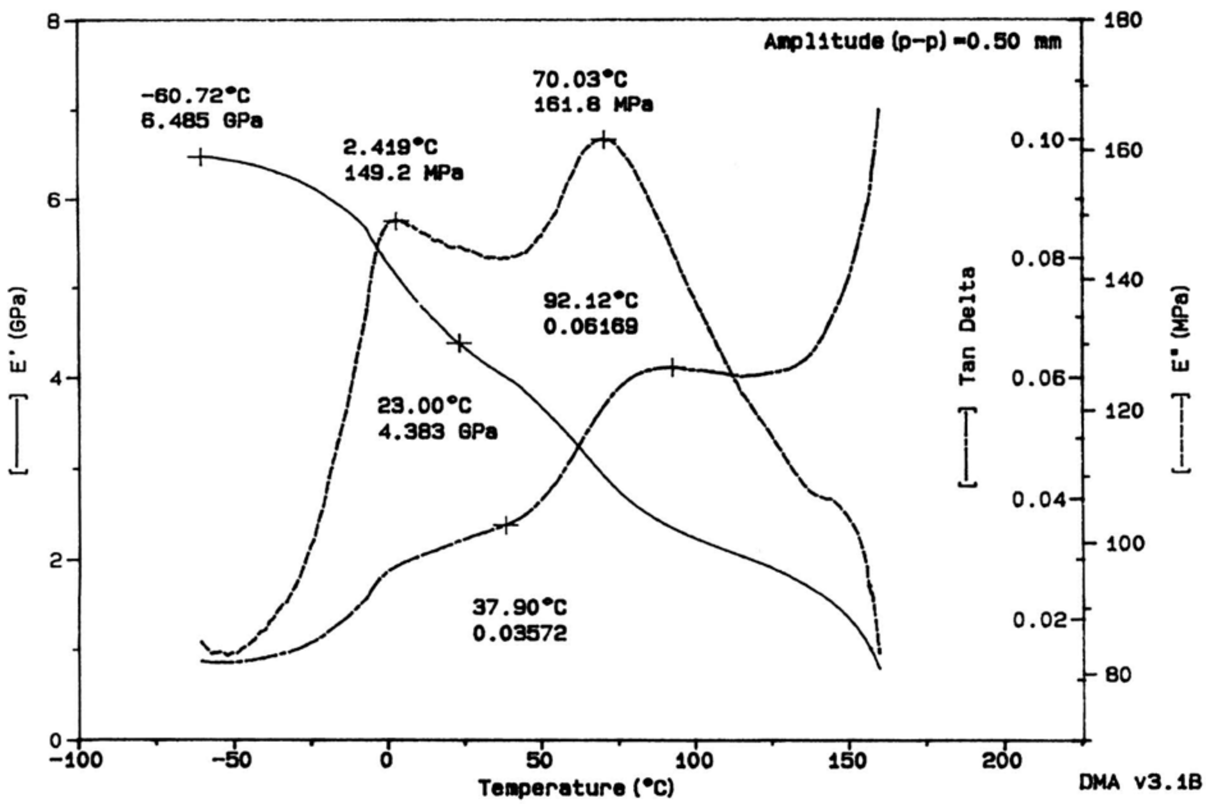


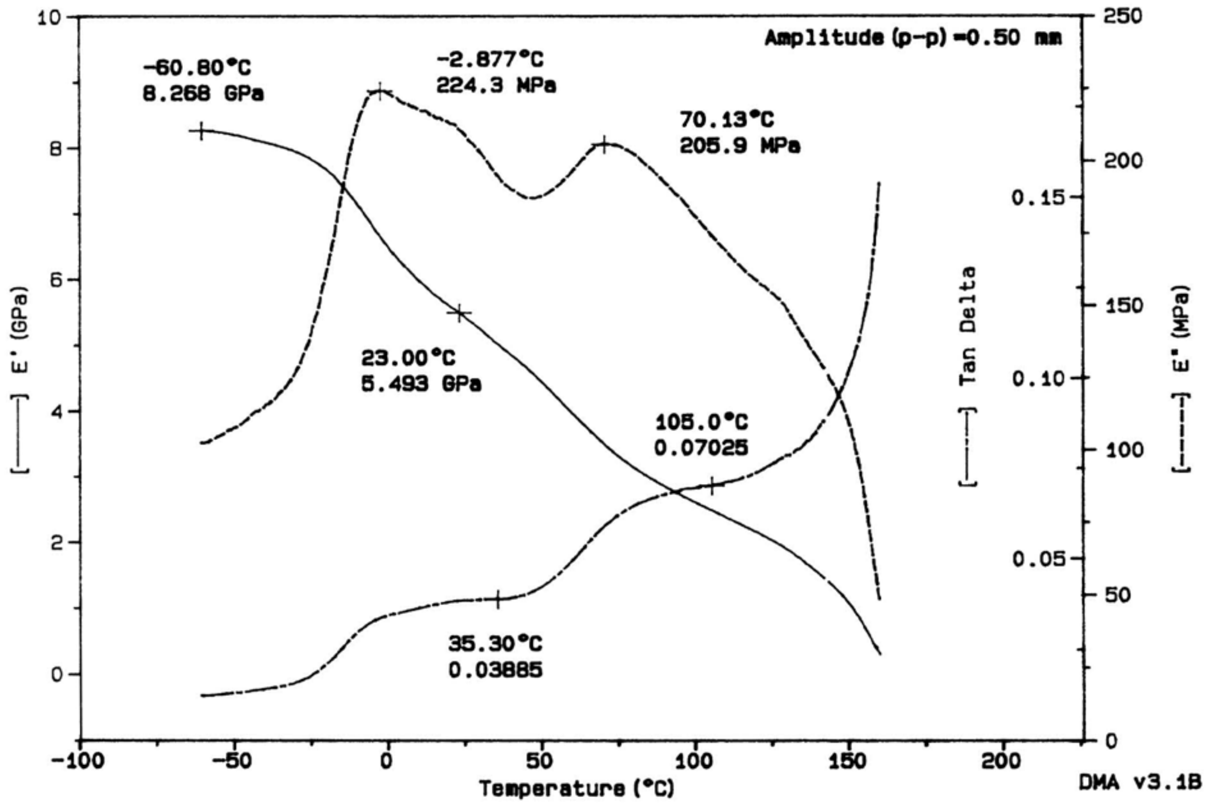
Table 71: Storage and loss properties for Polypropylene 400145 unfilled, homopolymer polypropylene (PP). (tabular data for Graph 71)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	4.367	115.9	0.02654	55.00	1.211	97.61	0.08058
-50.00	4.344	115.3	0.02655	60.00	1.095	94.11	0.08592
-45.00	4.301	116.5	0.02710	65.00	0.9839	91.20	0.09270
-40.00	4.253	118.6	0.02789	70.00	0.8729	87.99	0.1008
-35.00	4.196	120.6	0.02875	75.00	0.7662	83.14	0.1085
-30.00	4.134	122.5	0.02963	80.00	0.6689	77.70	0.1162
-25.00	4.068	124.0	0.03048	85.00	0.5873	71.57	0.1219
-20.00	3.995	126.2	0.03160	90.00	0.5172	64.95	0.1256
-15.00	3.928	129.3	0.03291	95.00	0.4553	57.96	0.1273
-10.00	3.852	134.5	0.03492	100.00	0.4027	51.42	0.1277
-5.00	3.778	142.8	0.03780	105.00	0.3554	45.38	0.1277
0.00	3.676	156.9	0.04268	110.00	0.3121	39.61	0.1269
5.00	3.563	173.2	0.04862	115.00	0.2722	34.29	0.1260
10.00	3.418	190.5	0.05574	120.00	0.2370	29.89	0.1261
15.00	3.228	204.0	0.06321	125.00	0.2031	26.20	0.1290
20.00	2.986	210.3	0.07043	130.00	0.1728	23.30	0.1349
25.00	2.645	207.3	0.07839	135.00	0.1426	20.72	0.1453
30.00	2.165	178.8	0.08257	140.00	0.1152	18.43	0.1600
35.00	1.812	140.9	0.07775	145.00	0.08798	16.28	0.1852
40.00	1.573	116.2	0.07389	150.00	0.05753	13.80	0.2402
45.00	1.439	107.7	0.07480	155.00	0.02596	11.01	0.4270
50.00	1.324	101.7	0.07679				

Table 72: Storage and loss properties for Montell PF062-2 20% glass fiber filled polypropylene (PP). (tabular data for Graph 72)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	6.484	84.53	0.01304	55.00	3.503	150.8	0.04304
-55.00	6.463	83.39	0.01290	60.00	3.322	156.3	0.04705
-50.00	6.433	83.31	0.01295	65.00	3.124	160.5	0.05136
-45.00	6.400	84.74	0.01324	70.00	2.928	161.8	0.05525
-40.00	6.353	86.86	0.01367	75.00	2.751	160.5	0.05835
-35.00	6.294	90.38	0.01436	80.00	2.606	157.2	0.06031
-30.00	6.228	93.75	0.01505	85.00	2.489	152.5	0.06128
-25.00	6.142	99.75	0.01624	90.00	2.390	147.4	0.06168
-20.00	6.036	108.0	0.01790	95.00	2.306	141.9	0.06153
-15.00	5.916	117.6	0.01987	100.00	2.232	136.8	0.06127
-10.00	5.775	128.5	0.02225	105.00	2.164	131.9	0.06096
-5.00	5.537	141.6	0.02558	110.00	2.100	127.2	0.06057
0.00	5.274	148.8	0.02821	115.00	2.038	122.7	0.06019
5.00	5.039	149.0	0.02958	120.00	1.975	119.3	0.06043
15.00	4.640	146.1	0.03149	125.00	1.906	116.0	0.06087
20.00	4.467	145.1	0.03248	130.00	1.828	112.2	0.06142
25.00	4.327	144.7	0.03344	135.00	1.735	108.9	0.06279
30.00	4.192	143.9	0.03433	140.00	1.631	107.1	0.06568
35.00	4.080	143.4	0.03515	145.00	1.505	106.3	0.07063
40.00	3.971	143.6	0.03615	150.00	1.344	103.6	0.07707
45.00	3.835	144.3	0.03763	155.00	1.122	97.98	0.08731
50.00	3.674	146.9	0.04000				

Graph 73: Storage and loss properties for Montell PF072-3C 30% glass fiber filled polypropylene (PP).



Graph 74: Storage and loss properties for Montell PF072-4C 40% glass fiber filled polypropylene (PP).

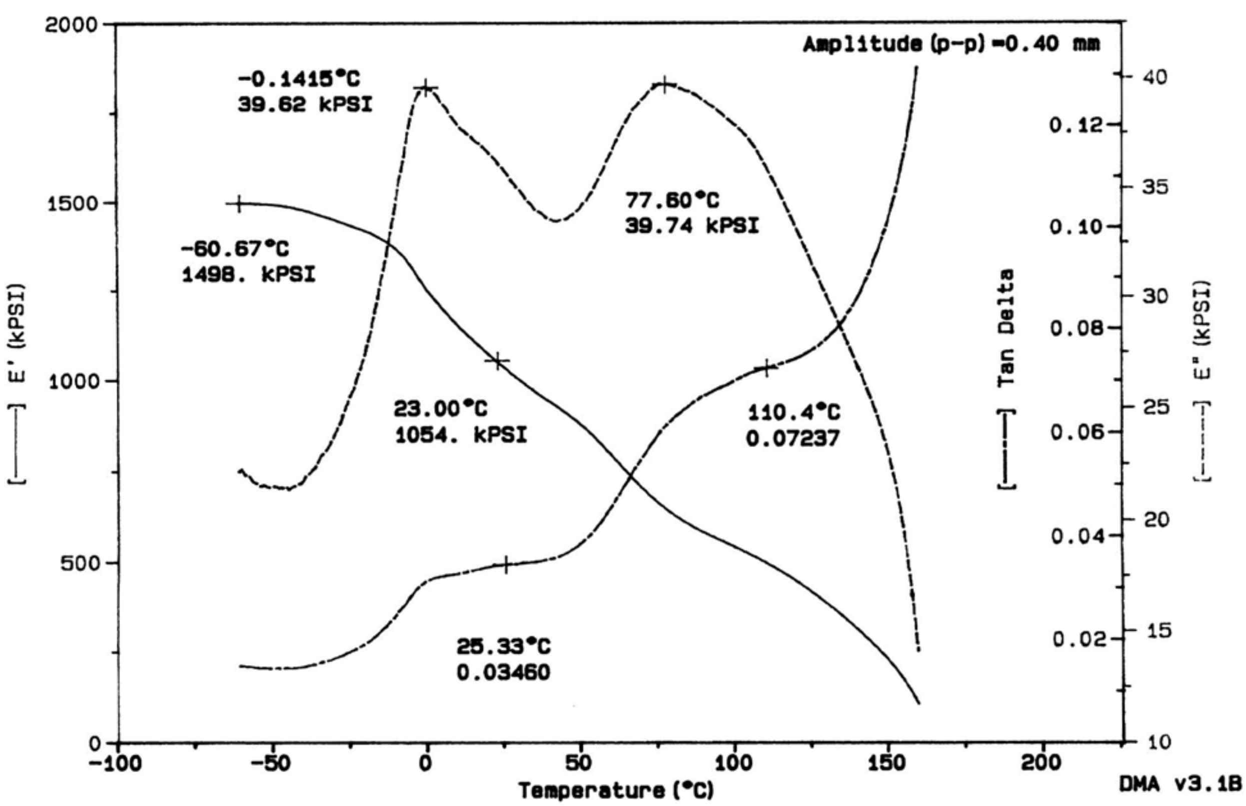


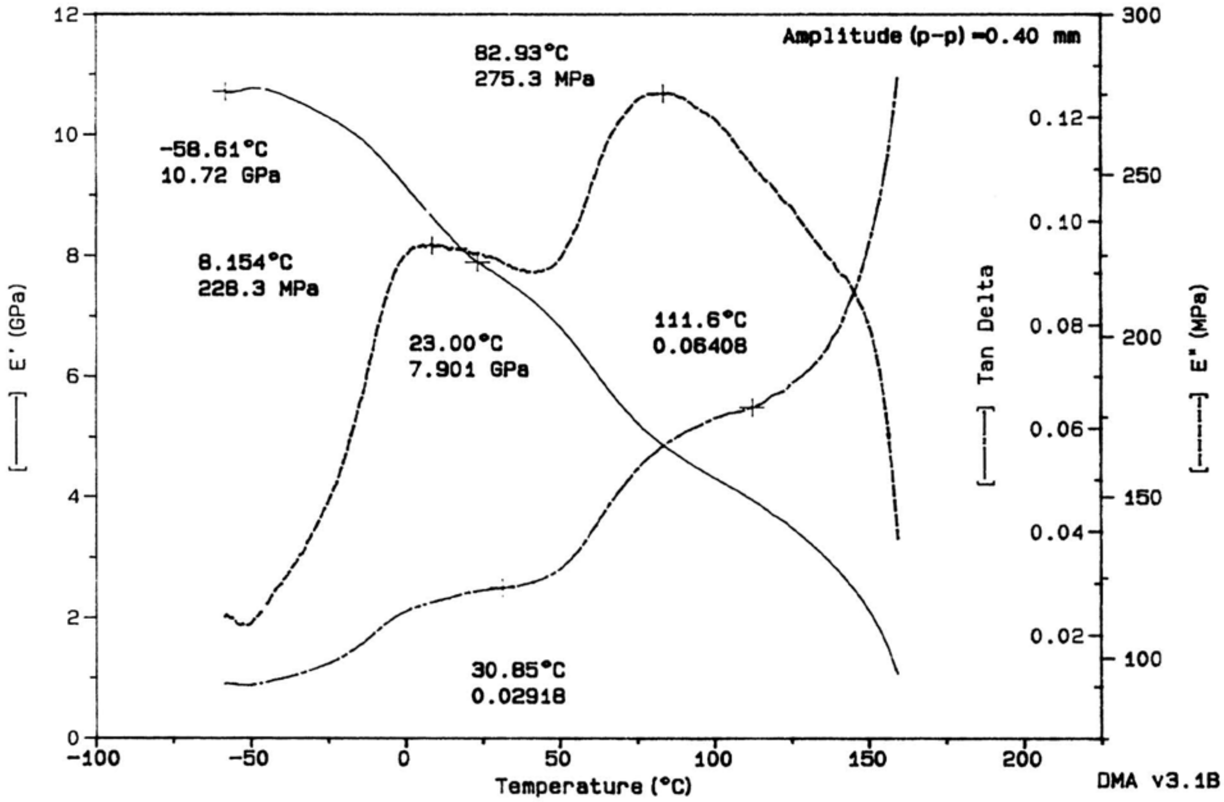
Table 73: Storage and loss properties for Montell PF072-3C 30% glass fiber filled polypropylene (PP). (tabular data for Graph 73)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.265	102.5	0.01240
-55.00	8.237	104.8	0.01272
-50.00	8.196	107.8	0.01315
-45.00	8.142	111.6	0.01371
-40.00	8.081	115.5	0.01430
-35.00	8.019	120.1	0.01498
-30.00	7.939	127.5	0.01606
-25.00	7.824	141.1	0.01804
-20.00	7.665	162.4	0.02118
-15.00	7.432	189.7	0.02552
-10.00	7.136	213.1	0.02986
-5.00	6.804	223.6	0.03286
0.00	6.481	223.3	0.03445
5.00	6.210	219.9	0.03541
10.00	5.975	217.8	0.03645
15.00	5.765	215.5	0.03738
20.00	5.589	212.9	0.03810
25.00	5.418	208.9	0.03855
30.00	5.241	203.0	0.03873
35.00	5.041	195.9	0.03885
40.00	4.850	190.3	0.03924
45.00	4.654	187.2	0.04024
50.00	4.434	187.9	0.04237
55.00	4.198	191.3	0.04558
60.00	3.958	196.6	0.04966
65.00	3.727	202.7	0.05437
70.00	3.502	205.9	0.05881
75.00	3.299	205.2	0.06220
80.00	3.126	202.4	0.06473
85.00	2.976	197.8	0.06648
90.00	2.842	192.6	0.06777
95.00	2.714	187.3	0.06902
100.00	2.596	180.7	0.06962
105.00	2.484	174.5	0.07025
110.00	2.368	168.8	0.07128
115.00	2.255	163.1	0.07234
120.00	2.143	158.5	0.07396
125.00	2.018	154.1	0.07639
130.00	1.880	148.1	0.07875
135.00	1.710	139.3	0.08146
140.00	1.523	131.4	0.08628
145.00	1.319	122.3	0.09272
150.00	1.064	108.9	0.1024
155.00	0.7125	83.44	0.1172

Table 74: Storage and loss properties for Montell PF072-4C 40% glass fiber filled polypropylene (PP). (tabular data for Graph 74)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	1498.	22.26	0.01486
-55.00	1497.	21.68	0.01448
-50.00	1494.	21.49	0.01439
-45.00	1488.	21.47	0.01443
-40.00	1479.	21.73	0.01470
-35.00	1466.	22.62	0.01543
-30.00	1452.	23.72	0.01634
-25.00	1436.	25.41	0.01769
-20.00	1420.	27.29	0.01921
-15.00	1400.	30.33	0.02166
-10.00	1372.	34.00	0.02479
-5.00	1324.	37.97	0.02867
0.00	1260.	39.61	0.03144
5.00	1206.	38.99	0.03233
10.00	1158.	38.00	0.03283
15.00	1116.	37.35	0.03348
20.00	1076.	36.73	0.03412
25.00	1040.	35.96	0.03457
30.00	1005.	34.99	0.03481
35.00	973.4	34.17	0.03510
40.00	943.6	33.62	0.03563
45.00	914.8	33.56	0.03668
50.00	882.4	34.02	0.03855
55.00	844.0	35.02	0.04149
60.00	799.2	36.42	0.04557
65.00	752.9	37.87	0.05030
70.00	708.2	38.94	0.05499
75.00	668.3	39.61	0.05927
80.00	634.9	39.70	0.06253
85.00	607.1	39.43	0.06495
90.00	583.8	39.09	0.06696
95.00	563.2	38.55	0.06845
100.00	543.5	37.96	0.06984
105.00	523.0	37.32	0.07135
110.00	501.0	36.23	0.07232
115.00	476.9	34.90	0.07317
120.00	450.2	33.39	0.07417
125.00	420.1	31.81	0.07572
130.00	387.9	30.22	0.07790
135.00	353.3	28.62	0.08103
140.00	316.0	27.04	0.08557
145.00	275.7	25.36	0.09200
150.00	231.0	23.23	0.1006
155.00	177.5	19.95	0.1124
160.00	107.9	14.16	0.1313

Graph 75: Storage and loss properties for Ferro RPP40EA63UL 40% glass fiber filled, chemically coupled polypropylene (PP).



Graph 76: Storage and loss properties for Ticona Celstran PPG40 40% long glass fiber filled polypropylene (PP).

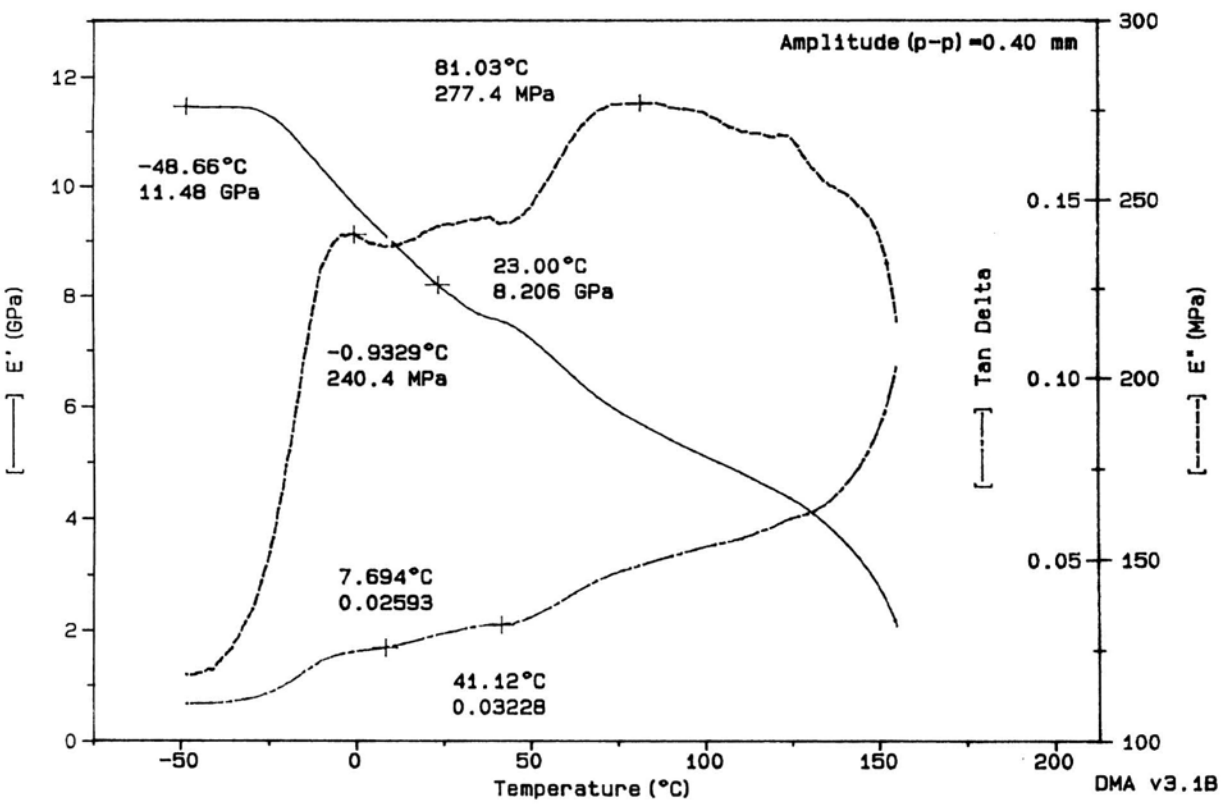


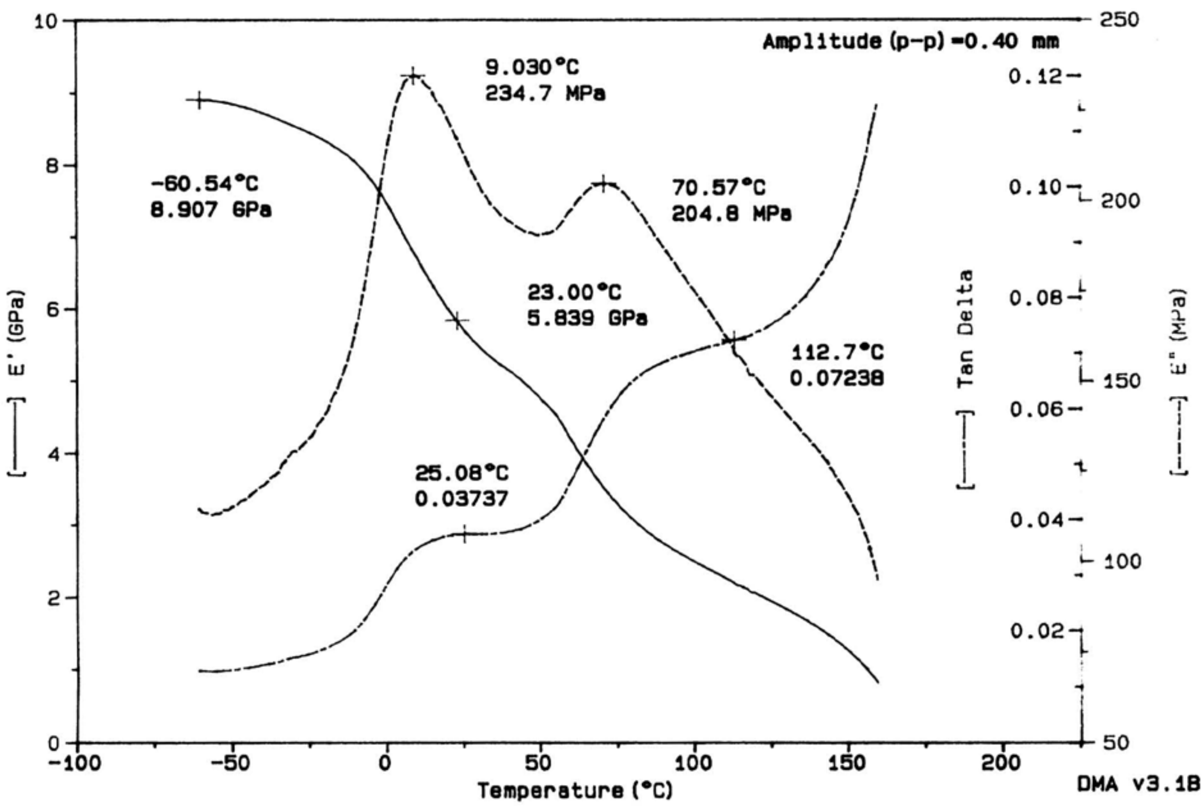
Table 75: Storage and loss properties for Ferro RPP40EA63UL 40% glass fiber filled, chemically coupled polypropylene (PP). (tabular data for Graph 75)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	10.71	111.1	0.01037
-50.00	10.77	110.9	0.01030
-45.00	10.74	116.8	0.01088
-40.00	10.65	123.9	0.01163
-35.00	10.54	131.1	0.01244
-30.00	10.41	139.3	0.01338
-25.00	10.28	149.2	0.01451
-20.00	10.12	162.0	0.01600
-15.00	9.945	179.4	0.01804
-10.00	9.710	199.5	0.02055
-5.00	9.434	216.3	0.02293
0.00	9.138	225.3	0.02465
5.00	8.841	227.9	0.02578
10.00	8.555	227.9	0.02664
15.00	8.281	227.3	0.02745
20.00	8.024	226.6	0.02824
25.00	7.836	225.0	0.02871
30.00	7.674	223.5	0.02913
35.00	7.495	221.1	0.02950
40.00	7.305	220.0	0.03012
45.00	7.078	220.8	0.03119
50.00	6.816	224.3	0.03291
55.00	6.511	233.3	0.03582
60.00	6.171	246.5	0.03995
65.00	5.825	259.5	0.04455
70.00	5.509	267.7	0.04860
75.00	5.223	273.5	0.05237
80.00	4.994	274.9	0.05505
85.00	4.794	275.5	0.05747
90.00	4.618	273.8	0.05928
95.00	4.457	270.4	0.06066
100.00	4.306	267.4	0.03209
105.00	4.159	262.0	0.06300
110.00	4.007	255.5	0.06378
115.00	3.848	249.7	0.06489
120.00	3.665	244.7	0.06678
125.00	3.480	239.8	0.06890
130.00	3.271	232.8	0.07118
135.00	3.041	226.4	0.07445
140.00	2.782	220.2	0.07916
145.00	2.481	214.0	0.08627
150.00	2.115	203.0	0.09597
155.00	1.631	178.5	0.1095

Table 76: Storage and loss properties for Ticona Celstran PPG40 40% long glass fiber filled polypropylene (PP). (tabular data for Graph 76)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-45.00	11.46	118.9	0.01038
-40.00	11.45	121.3	0.01059
-35.00	11.45	127.4	0.01113
-30.00	11.43	136.2	0.01192
-25.00	11.29	151.7	0.01344
-20.00	11.05	177.2	0.01604
-15.00	10.69	206.2	0.01929
-10.00	10.33	231.2	0.02239
-5.00	9.968	239.5	0.02403
0.00	9.614	240.2	0.02498
5.00	9.297	237.7	0.02557
15.00	8.682	238.5	0.02748
20.00	8.379	240.9	0.02875
25.00	8.101	242.9	0.02999
30.00	7.856	243.8	0.03103
35.00	7.658	244.6	0.03194
40.00	7.562	244.1	0.03228
45.00	7.430	244.0	0.03285
50.00	7.200	248.0	0.03444
55.00	6.932	255.8	0.03690
60.00	6.646	264.1	0.03974
65.00	6.365	271.2	0.04261
70.00	6.117	275.4	0.04503
75.00	5.908	277.0	0.04688
80.00	5.727	277.2	0.04840
85.00	5.558	277.4	0.04991
90.00	5.395	276.0	0.05116
95.00	5.242	275.4	0.05255
100.00	5.095	274.2	0.05382
105.00	4.952	271.5	0.05482
110.00	4.809	269.3	0.05599
115.00	4.651	268.8	0.05779
120.00	4.491	267.7	0.05961
125.00	4.325	266.9	0.06171
130.00	4.114	259.8	0.06314
135.00	3.860	254.8	0.06600
140.00	3.557	251.9	0.07083
145.00	3.200	247.5	0.07737
150.00	2.737	239.1	0.08734
155.00	2.020	213.1	0.1056

Graph 77: Storage and loss properties for Ferro HPP40GR09BK 10% glass fiber, 30% talc filled polypropylene (PP).



Graph 78: Storage and loss properties for Ferro TPP40AC45BK 40% talc filled polypropylene (PP).

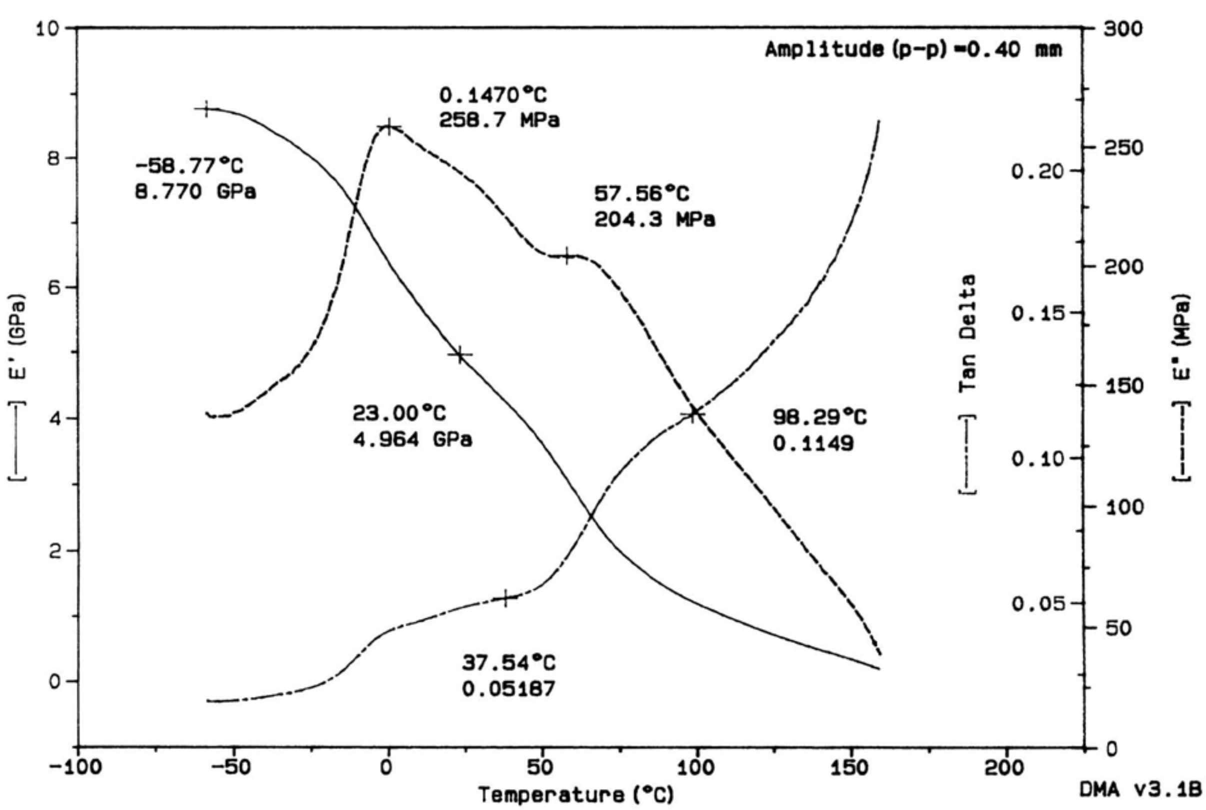


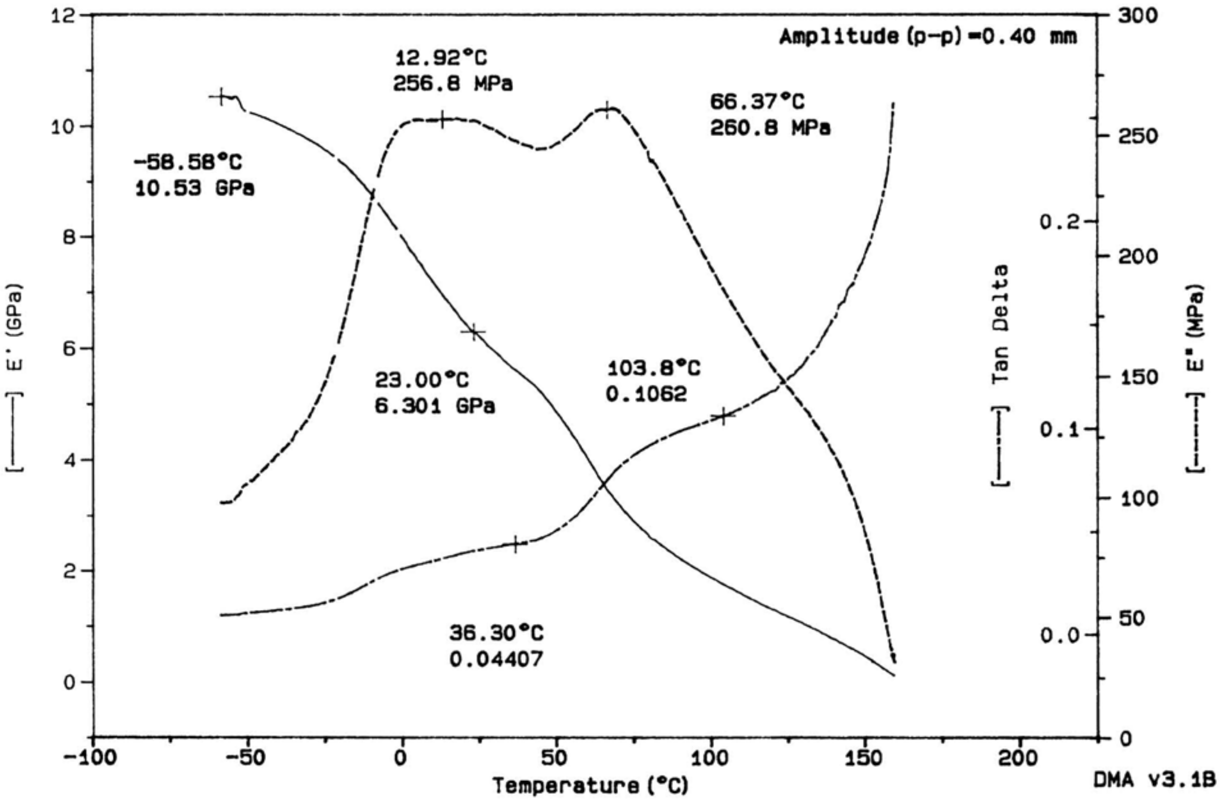
Table 77: Storage and loss properties for Ferro HPP40GR09BK 10% glass fiber, 30% talc filled polypropylene (PP). (tabular data for Graph 77)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	8.906	113.8	0.01278	50.00	4.768	190.8	0.04001
-55.00	8.885	113.2	0.01274	55.00	4.546	192.0	0.04224
-50.00	8.846	115.0	0.01300	60.00	4.203	197.2	0.04694
-45.00	8.790	117.6	0.01338	65.00	3.863	202.2	0.05235
-40.00	8.719	121.0	0.01387	70.00	3.555	204.9	0.05765
-35.00	8.636	124.7	0.01444	75.00	3.291	203.8	0.06195
-30.00	8.543	130.6	0.01528	80.00	3.074	199.8	0.06501
-25.00	8.452	134.0	0.01586	85.00	2.893	193.9	0.06704
-20.00	8.343	140.7	0.01686	90.00	2.742	187.7	0.06844
-15.00	8.209	149.8	0.01825	95.00	2.611	181.5	0.06951
-10.00	8.048	163.2	0.02028	100.00	2.494	175.5	0.07037
-5.00	7.814	185.6	0.02375	105.00	2.380	169.6	0.07124
0.00	7.496	212.2	0.02831	110.00	2.267	163.1	0.07195
5.00	7.106	230.2	0.03240	115.00	2.156	156.8	0.07273
10.00	6.728	234.7	0.03488	120.00	2.050	151.2	0.07374
15.00	6.353	230.9	0.03634	125.00	1.941	146.0	0.07518
20.00	6.016	223.3	0.03713	130.00	1.830	141.0	0.07704
25.00	5.727	214.0	0.03736	135.00	1.712	136.2	0.07958
30.00	5.485	205.2	0.03741	140.00	1.583	131.3	0.08297
35.00	5.295	198.6	0.03751	145.00	1.435	125.2	0.08721
40.00	5.140	194.6	0.03787	150.00	1.263	118.2	0.09353
45.00	4.970	191.8	0.03860	155.00	1.058	109.1	0.1032

Table 78 Storage and loss properties for Ferro TPP40AC45BK 40% talc filled polypropylene (PP). (tabular data for Graph 78)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	8.753	137.4	0.01570	55.00	3.288	204.1	0.06206
-50.00	8.705	138.9	0.01596	60.00	2.935	204.0	0.06952
-45.00	8.626	142.0	0.01646	65.00	2.582	202.9	0.07857
-40.00	8.502	146.8	0.01727	70.00	2.256	197.8	0.08766
-35.00	8.356	152.1	0.01820	75.00	1.996	190.0	0.09518
-30.00	8.203	157.4	0.01918	80.00	1.787	180.1	0.1008
-25.00	8.026	165.3	0.02060	85.00	1.601	169.2	0.1057
-20.00	7.818	178.6	0.02285	90.00	1.446	158.6	0.1097
-15.00	7.562	199.7	0.02641	95.00	1.311	148.0	0.1129
-10.00	7.223	228.0	0.03157	100.00	1.193	138.7	0.1163
-5.00	6.820	251.4	0.03687	105.00	1.085	130.2	0.1200
0.00	6.427	258.8	0.04027	110.00	0.9829	122.3	0.1244
5.00	6.067	256.2	0.04224	115.00	0.8877	114.4	0.1289
10.00	5.738	251.2	0.04378	120.00	0.7942	106.6	0.1343
15.00	5.425	246.9	0.04551	125.00	0.7054	98.95	0.1403
20.00	5.127	242.5	0.04730	130.00	0.6221	90.74	0.1459
25.00	4.858	237.9	0.04897	135.00	0.5424	82.68	0.1524
30.00	4.635	232.7	0.05020	140.00	0.4684	75.45	0.1611
35.00	4.398	225.7	0.05132	145.00	0.3990	67.65	0.1695
40.00	4.164	218.2	0.05239	150.00	0.3271	59.38	0.1815
45.00	3.911	211.0	0.05395	155.00	0.2497	49.19	0.1970
50.00	3.623	205.7	0.05677				

Graph 79: Storage and loss properties for Ferro MPP40FJ15NA 40% mica filled, chemically coupled polypropylene (PP).



Graph 80: Storage and loss properties for Montell SB224-2C 20% glass fiber filled polypropylene copolymer (PP copolymer).

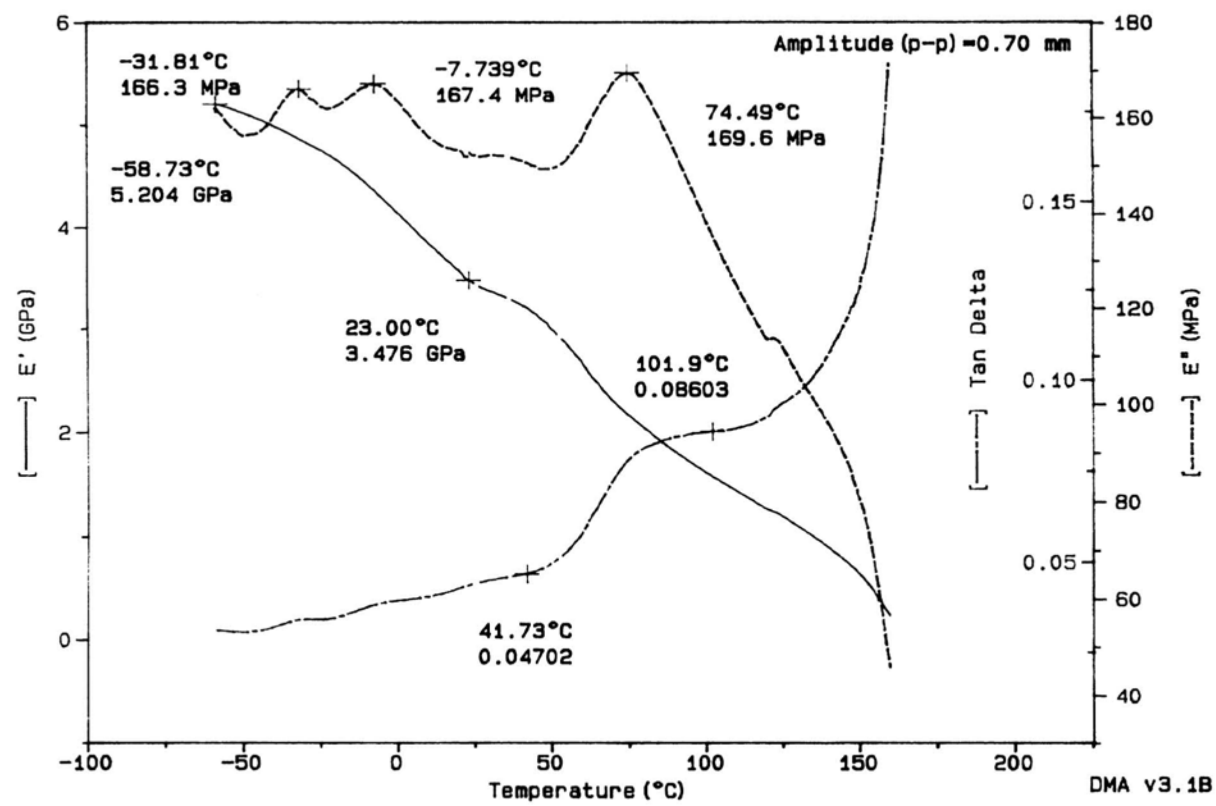


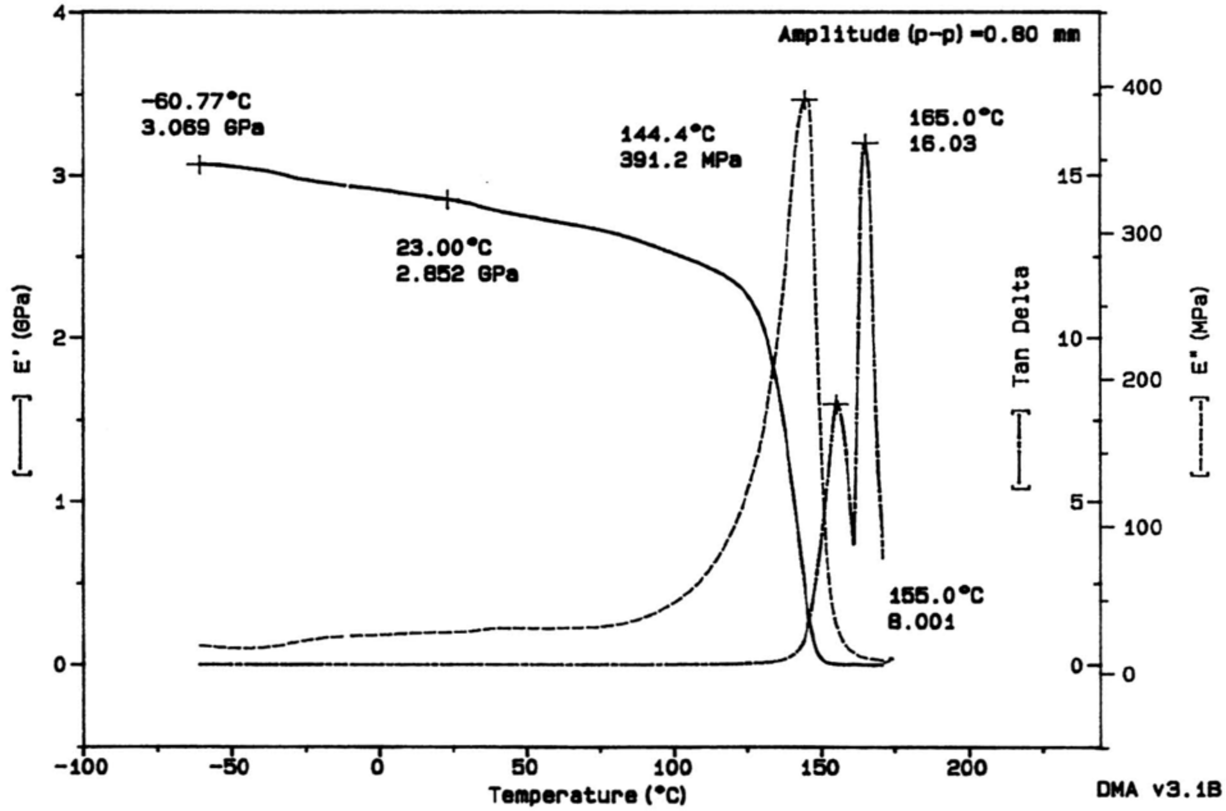
Table 79: Storage and loss properties for Ferro MPP40FJ15NA 40% mica filled, chemically coupled polypropylene (PP). (tabular data for Graph 79)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	10.49	98.59	0.009401	55.00	4.466	251.5	0.05631
-45.00	10.15	111.6	0.01099	60.00	4.036	257.7	0.06385
-40.00	10.03	118.0	0.01176	65.00	3.585	260.8	0.07275
-35.00	9.892	126.0	0.01273	70.00	3.210	260.3	0.08110
-30.00	9.742	134.1	0.01376	75.00	2.894	252.8	0.08734
-25.00	9.566	147.7	0.01544	80.00	2.617	240.7	0.09196
-20.00	9.356	167.7	0.01792	85.00	2.416	231.4	0.09578
-15.00	9.094	194.4	0.02137	90.00	2.218	219.6	0.09899
-10.00	8.766	223.9	0.02554	95.00	2.040	207.2	0.1015
-5.00	8.391	244.6	0.02915	100.00	1.875	195.3	0.1041
0.00	7.981	254.4	0.03188	105.00	1.722	183.9	0.1068
5.00	7.567	256.8	0.03393	110.00	1.575	173.4	0.1101
10.00	7.179	256.4	0.03572	115.00	1.431	163.3	0.1141
15.00	6.815	257.0	0.03771	120.00	1.300	153.8	0.1183
20.00	6.468	256.6	0.03967	125.00	1.169	145.5	0.1244
25.00	6.211	255.6	0.04115	130.00	1.043	137.0	0.1313
30.00	5.944	252.6	0.04249	135.00	0.9076	128.1	0.1412
35.00	5.680	248.7	0.04379	140.00	0.7648	117.4	0.1534
40.00	5.462	246.1	0.04506	145.00	0.6168	103.6	0.1680
45.00	5.205	244.8	0.04702	150.00	0.4625	84.97	0.1838
50.00	4.855	246.7	0.05082	155.00	0.2789	57.88	0.2077

Table 80: Storage and loss properties for Montell SB224-2C 20% glass fiber filled polypropylene copolymer (PP copolymer). (tabular data for Graph 80)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	5.175	159.2	0.03076	55.00	2.849	151.4	0.05314
-50.00	5.115	156.4	0.03058	60.00	2.668	155.8	0.05840
-45.00	5.057	157.0	0.03104	65.00	2.472	162.1	0.06556
-40.00	4.990	160.5	0.03217	70.00	2.298	167.4	0.07287
-35.00	4.915	165.3	0.03363	75.00	2.161	169.6	0.07848
-30.00	4.833	165.6	0.03427	80.00	2.038	166.2	0.08153
-25.00	4.756	162.7	0.03420	85.00	1.919	159.8	0.08326
-20.00	4.665	162.6	0.03485	90.00	1.812	153.1	0.08444
-15.00	4.555	164.9	0.03621	95.00	1.710	145.9	0.08532
-10.00	4.428	166.9	0.03770	100.00	1.614	138.5	0.08581
-5.00	4.285	166.7	0.03891	105.00	1.523	131.4	0.08627
0.00	4.143	163.9	0.03956	110.00	1.436	124.9	0.08697
5.00	3.993	159.8	0.04003	115.00	1.349	118.9	0.08810
10.00	3.843	156.3	0.04068	120.00	1.262	113.6	0.09004
15.00	3.699	154.1	0.04166	125.00	1.191	111.8	0.09386
20.00	3.567	153.4	0.04301	130.00	1.097	106.1	0.09669
25.00	3.441	152.3	0.04426	135.00	0.9967	101.0	0.1013
30.00	3.367	152.4	0.04525	140.00	0.8901	95.73	0.1075
35.00	3.309	152.1	0.04598	145.00	0.7734	89.43	0.1156
40.00	3.233	151.2	0.04677	150.00	0.6356	81.37	0.1280
45.00	3.135	149.9	0.04782	155.00	0.4501	66.02	0.1467
50.00	2.994	149.6	0.04998				

Graph 81: Storage and loss properties for Ticona Topas 5513 unfilled cyclic olefin copolymer.



Graph 82: Storage and loss properties for Ticona Topas 6013 unfilled cyclic olefin copolymer.

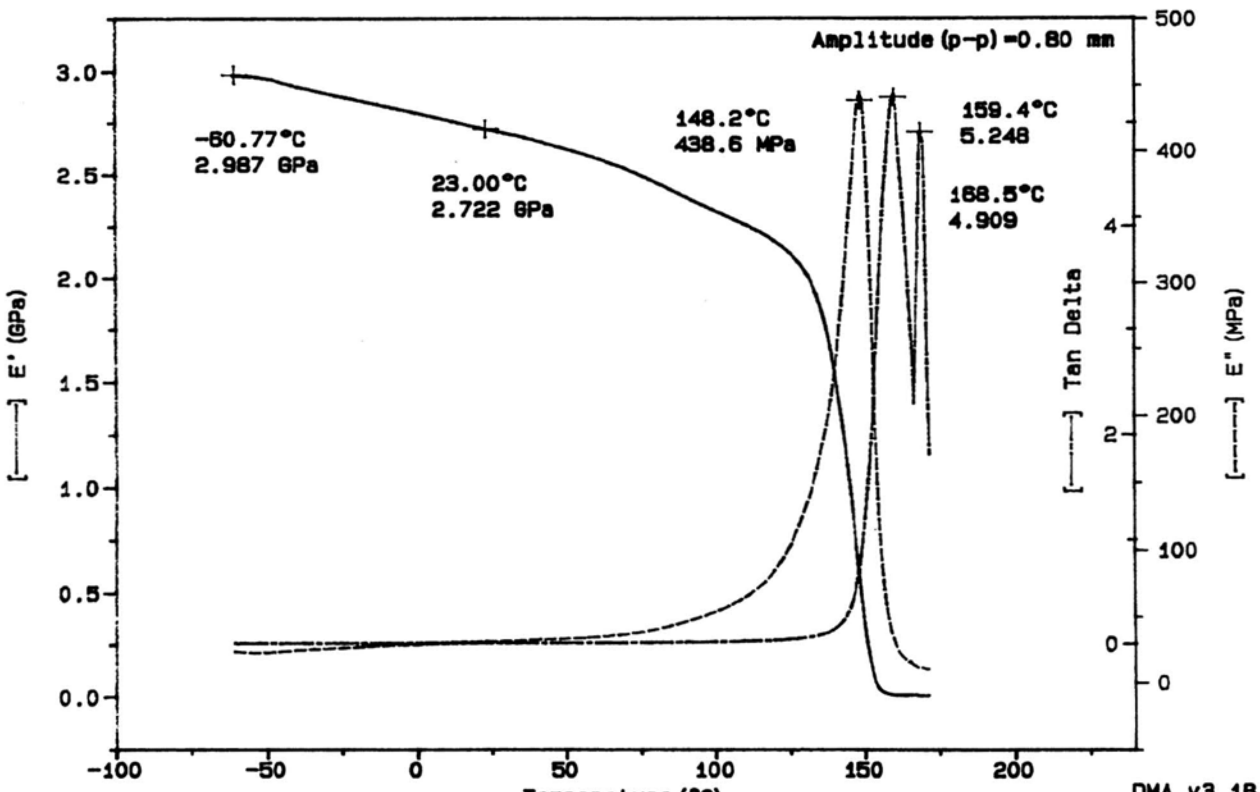


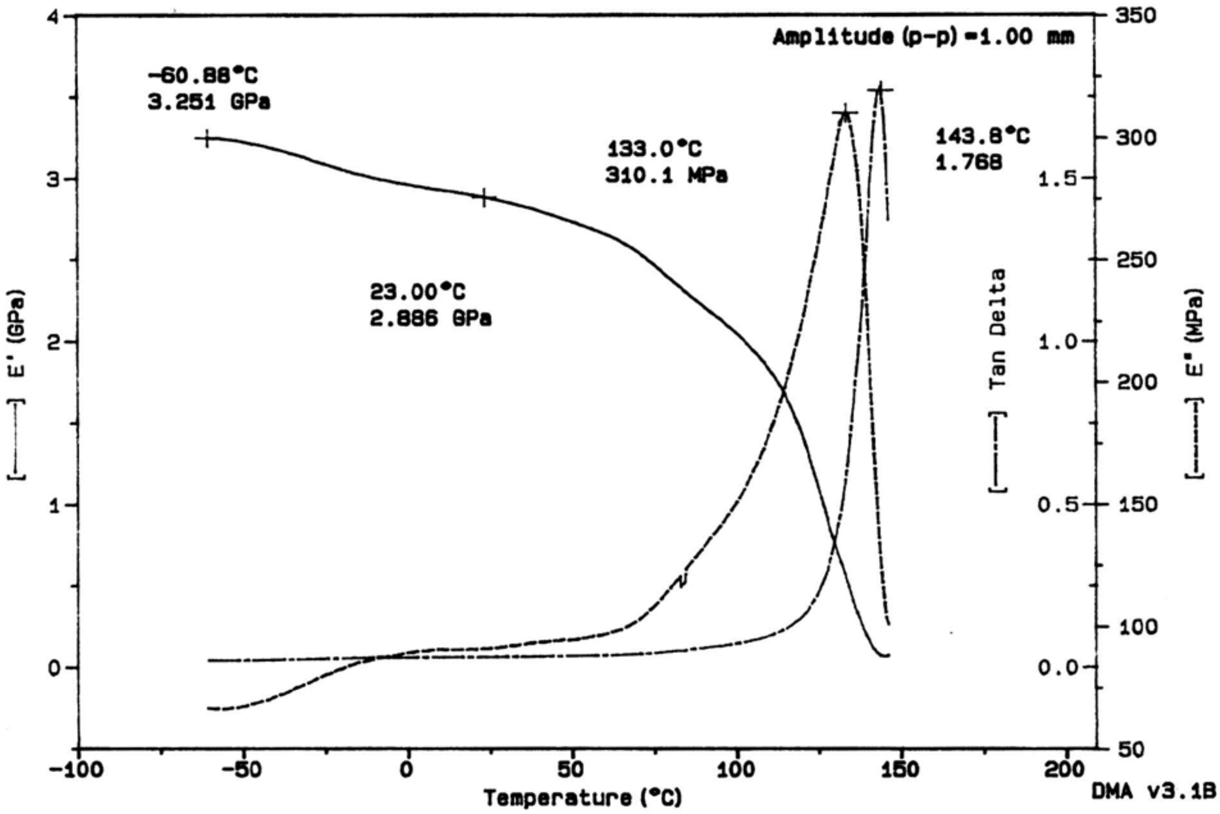
Table 81 Storage and loss properties for Ticona Topas 5513 unfilled cyclic olefin copolymer. (tabular data for Graph 81)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.069	18.75	0.006108
-55.00	3.064	17.77	0.005800
-50.00	3.054	17.32	0.005671
-45.00	3.044	17.09	0.005615
-40.00	3.031	17.57	0.005795
-35.00	3.015	18.71	0.006205
-30.00	2.992	20.83	0.006960
-25.00	2.972	22.43	0.007547
-20.00	2.958	24.08	0.008141
-15.00	2.946	24.90	0.008453
-5.00	2.924	25.88	0.008852
0.00	2.912	26.42	0.009074
5.00	2.899	26.77	0.009234
10.00	2.884	27.35	0.009484
15.00	2.872	27.57	0.009597
20.00	2.860	28.08	0.009819
25.00	2.847	28.17	0.009896
30.00	2.829	28.76	0.01017
35.00	2.804	29.85	0.01065
40.00	2.782	30.81	0.01108
45.00	2.764	30.86	0.01117
50.00	2.748	30.87	0.01123
55.00	2.732	30.76	0.01126
60.00	2.715	30.88	0.01138
65.00	2.699	31.25	0.01158
70.00	2.684	31.46	0.01172
75.00	2.665	32.20	0.01208
80.00	2.644	33.39	0.01263
85.00	2.617	35.57	0.01359
90.00	2.586	38.59	0.01492
95.00	2.554	43.02	0.01685
100.00	2.521	48.77	0.01935
105.00	2.487	55.88	0.02247
110.00	2.449	66.17	0.02702
115.00	2.407	79.81	0.03316
120.00	2.352	98.39	0.04184
125.00	2.264	125.2	0.05532
130.00	2.088	163.4	0.07830
135.00	1.720	225.4	0.1312
140.00	1.116	327.6	0.2947
145.00	0.3843	391.6	1.040
150.00	0.03920	149.3	3.869
155.00	0.004323	34.35	7.974
160.00	0.003208	15.67	4.903
165.00	6.664E-4	10.67	16.01
170.00	0.001904	9.293	4.938

Table 82 Storage and loss properties for Ticona Topas 6013 unfilled cyclic olefin copolymer. (tabular data for Graph 82)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.987	23.69	0.007932
-55.00	2.982	22.96	0.007702
-50.00	2.971	23.14	0.007788
-45.00	2.953	23.91	0.008095
-40.00	2.931	24.94	0.008510
-35.00	2.914	25.51	0.008754
-30.00	2.896	26.01	0.008982
-25.00	2.880	26.61	0.009241
-20.00	2.864	27.27	0.009521
-15.00	2.848	27.86	0.009784
-10.00	2.832	28.48	0.01006
-5.00	2.816	28.74	0.01021
0.00	2.800	29.08	0.01039
5.00	2.783	29.49	0.01060
10.00	2.767	29.96	0.01083
15.00	2.749	30.69	0.01116
20.00	2.732	31.17	0.01141
25.00	2.716	31.65	0.01165
30.00	2.701	31.93	0.01182
35.00	2.686	32.27	0.01201
40.00	2.666	32.91	0.01235
45.00	2.646	33.22	0.01255
50.00	2.626	33.71	0.01284
55.00	2.605	34.24	0.01315
60.00	2.582	34.94	0.01353
65.00	2.557	35.89	0.01403
70.00	2.530	37.04	0.01464
75.00	2.499	38.54	0.01542
80.00	2.466	40.67	0.01649
85.00	2.431	43.36	0.01784
90.00	2.395	46.58	0.01945
95.00	2.360	50.08	0.02122
100.00	2.326	54.24	0.02331
105.00	2.294	59.08	0.02576
110.00	2.261	65.32	0.02889
115.00	2.225	73.57	0.03307
120.00	2.181	85.61	0.03925
125.00	2.125	103.1	0.04854
130.00	2.039	130.0	0.06375
135.00	1.881	169.3	0.09002
140.00	1.558	232.0	0.1490
145.00	1.032	359.8	0.3499
150.00	0.3582	421.2	1.192
155.00	0.03407	121.2	3.602
160.00	0.005770	30.23	5.237
165.00	0.004901	15.14	3.096
170.00	0.002557	10.46	4.222

Graph 83: Storage and loss properties for GE Plastics Noryl N225X flame retardant, moderate heat resistance syrene modified polyphenylene ether (modified PPE).



Graph 84: Storage and loss properties for GE Plastics Noryl SE1X flame retardant, high heat resistance syrene modified polyphenylene ether (modified PPE).

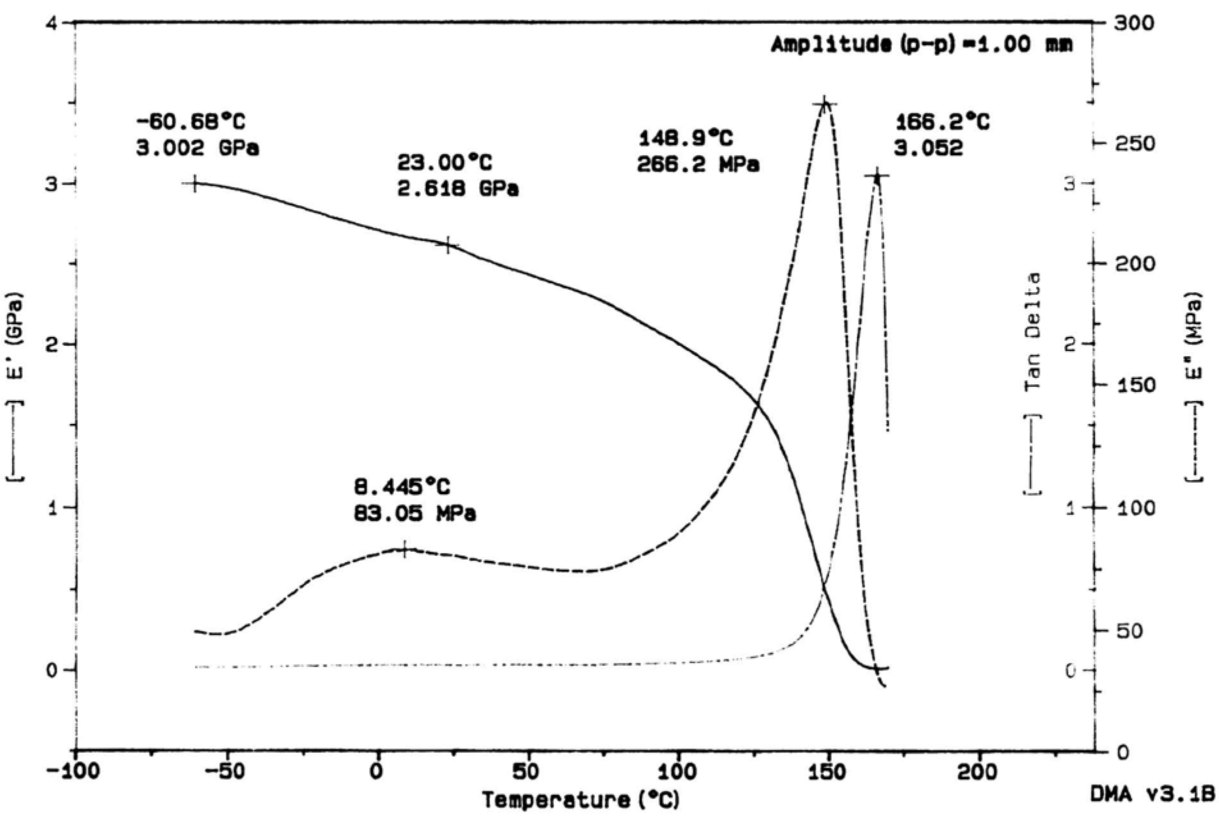


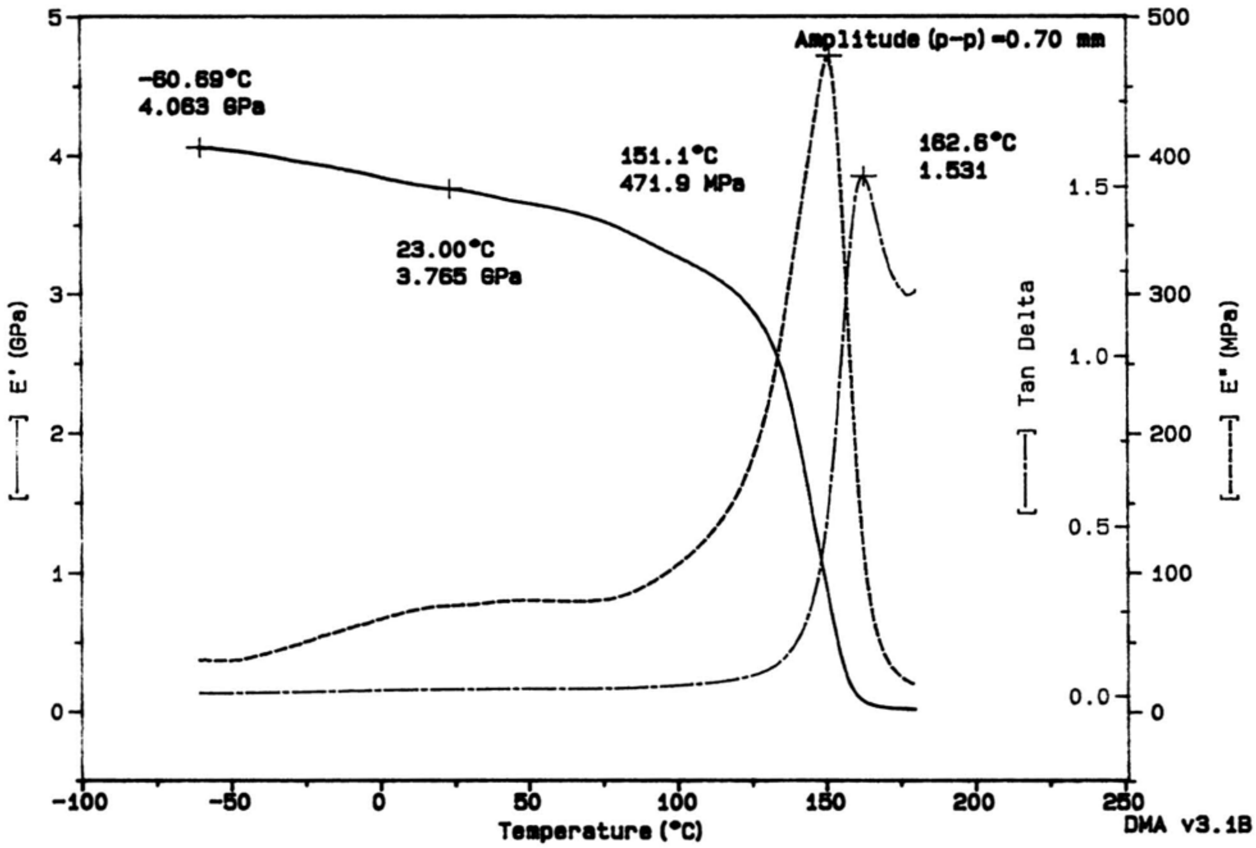
Table 83 Storage and loss properties for GE Plastics Noryl N225X flame retardant, moderate heat resistance syrene modified polyphenylene ether (modified PPE). (tabular data for Graph 83)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.250	66.71	0.02052	45.00	2.768	94.48	0.03414
-55.00	3.240	66.73	0.02059	50.00	2.734	94.88	0.03471
-50.00	3.224	67.67	0.02099	55.00	2.696	96.02	0.03561
-45.00	3.205	69.52	0.02169	60.00	2.658	97.20	0.03657
-40.00	3.180	71.83	0.02259	65.00	2.609	99.09	0.03798
-35.00	3.151	74.68	0.02370	70.00	2.546	103.0	0.04045
-30.00	3.119	77.58	0.02487	75.00	2.468	108.8	0.04409
-25.00	3.086	80.66	0.02614	80.00	2.381	116.3	0.04887
-20.00	3.055	83.20	0.02724	85.00	2.295	124.7	0.05433
-15.00	3.026	85.62	0.02829	90.00	2.214	133.0	0.03007
-10.00	3.001	87.08	0.02902	95.00	2.134	141.7	0.06638
-5.00	2.980	88.34	0.02964	100.00	2.048	151.3	0.07386
0.00	2.962	89.57	0.03023	105.00	1.946	164.1	0.08436
5.00	2.945	90.36	0.03068	110.00	1.823	179.8	0.09864
10.00	2.929	90.86	0.03102	115.00	1.660	199.8	0.1204
15.00	2.914	90.79	0.03115	120.00	1.421	226.0	0.1592
20.00	2.898	90.81	0.03134	125.00	1.096	257.6	0.2360
25.00	2.878	91.33	0.03174	130.00	0.7490	293.6	0.3989
30.00	2.855	92.09	0.03225	135.00	0.4361	303.9	0.7630
35.00	2.830	93.00	0.03287	140.00	0.1705	217.8	1.406
40.00	2.801	93.85	0.03351	145.00	0.06888	107.8	1.593

Table 84: Storage and loss properties for GE Plastics Noryl SE1X flame retardant, high heat resistance syrene modified polyphenylene ether (modified PPE). (tabular data for Graph 84)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.002	49.44	0.01647	55.00	2.401	75.16	0.03130
-55.00	2.992	48.36	0.01616	60.00	2.370	74.68	0.03151
-50.00	2.977	48.71	0.01636	65.00	2.340	74.40	0.03180
-45.00	2.957	50.96	0.01723	70.00	2.307	74.38	0.03225
-40.00	2.932	54.76	0.01868	75.00	2.267	75.04	0.03311
-35.00	2.905	59.17	0.02036	80.00	2.218	76.65	0.03456
-30.00	2.877	63.91	0.02221	85.00	2.165	79.16	0.03657
-25.00	2.849	68.65	0.02409	90.00	2.111	82.21	0.03894
-20.00	2.820	72.43	0.02568	95.00	2.060	85.57	0.04155
-15.00	2.790	75.39	0.02702	100.00	2.006	89.87	0.04480
-10.00	2.764	77.62	0.02808	105.00	1.947	95.54	0.04906
-5.00	2.735	79.73	0.02915	110.00	1.888	102.8	0.05444
0.00	2.710	81.32	0.03001	115.00	1.825	111.1	0.06085
5.00	2.686	82.55	0.03074	120.00	1.752	122.3	0.06982
10.00	2.664	82.84	0.03110	125.00	1.659	137.2	0.08267
15.00	2.649	82.10	0.03100	130.00	1.535	156.7	0.1021
20.00	2.633	81.16	0.03082	135.00	1.349	182.2	0.1350
25.00	2.606	80.63	0.03094	140.00	1.080	212.0	0.1964
30.00	2.566	79.18	0.03086	145.00	0.7539	247.8	0.3293
35.00	2.528	78.24	0.03095	150.00	0.4377	266.6	0.6106
40.00	2.496	77.35	0.03099	155.00	0.1766	201.2	1.144
45.00	2.463	76.79	0.03117	160.00	0.04533	91.35	2.025
50.00	2.433	75.95	0.03122	165.00	0.01317	38.53	2.929

Graph 85: Storage and loss properties for GE Plastics Noryl SE1-GFN1 10% glass fiber filled, flame retardant syrene modified polyphenylene ether (modified PPE).



Graph 86: Storage and loss properties for GE Plastics Noryl GFN2 20% glass fiber filled syrene modified polyphenylene ether (modified PPE).

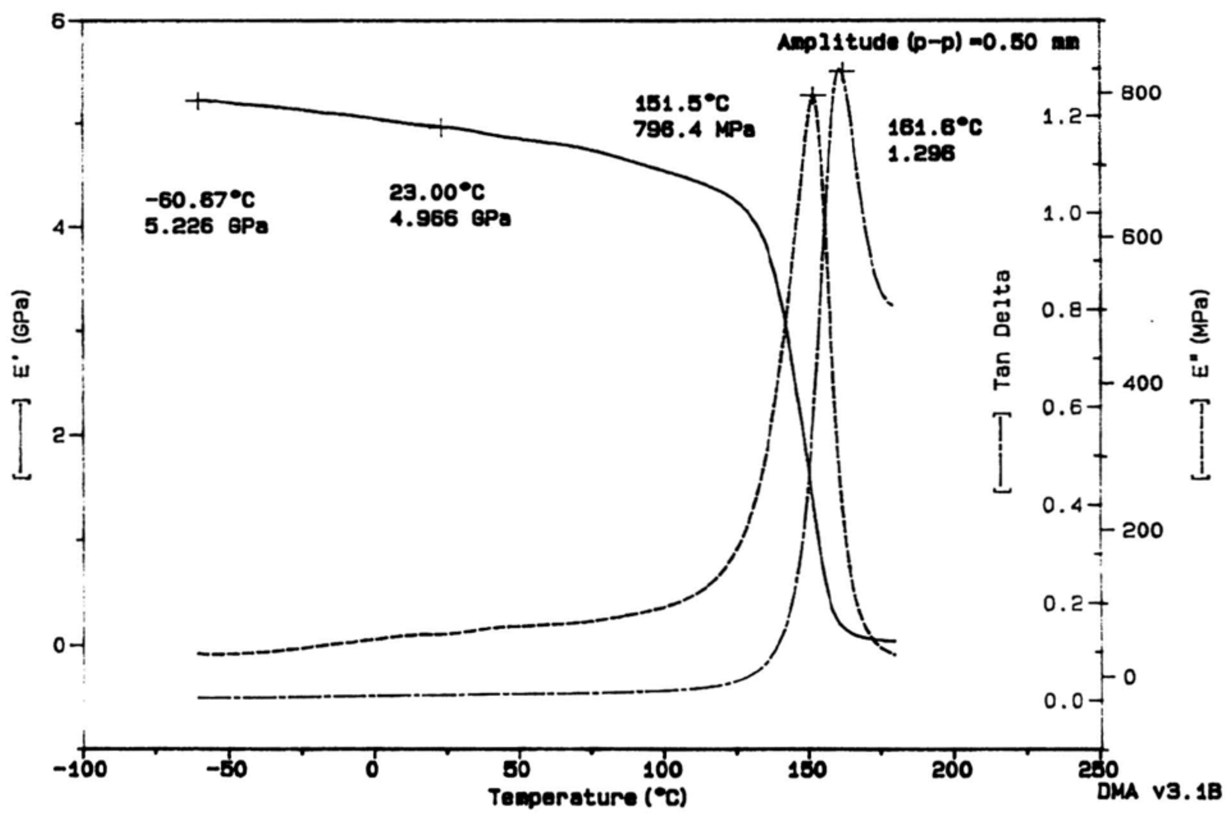


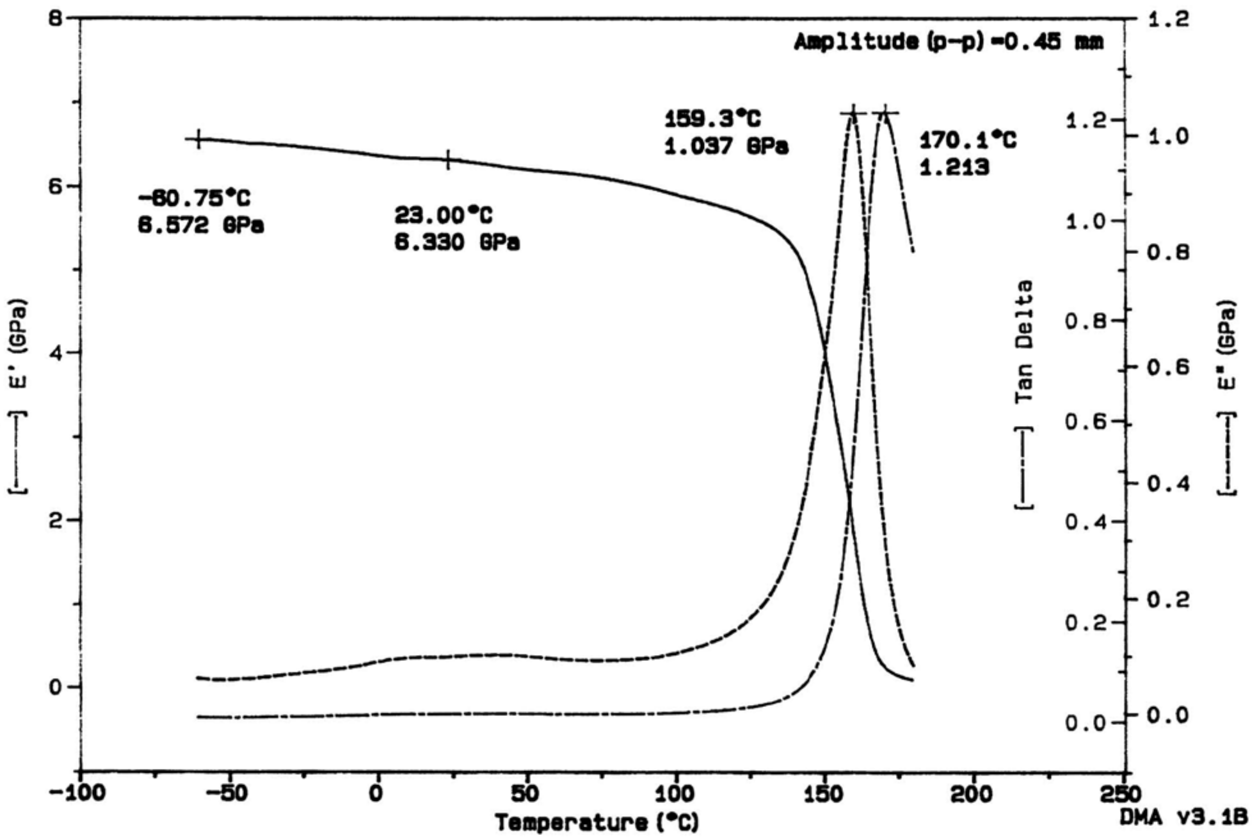
Table 85: Storage and loss properties for GE Plastics Noryl SE1-GFN1 10% glass fiber filled, flame retardant syrene modified polyphenylene ether (modified PPE). (tabular data for Graph 85)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	4.062	37.48	0.009226	60.00	3.618	79.93	0.02209
-55.00	4.053	37.32	0.009208	65.00	3.593	79.75	0.02219
-50.00	4.041	37.29	0.009229	70.00	3.564	80.06	0.02247
-45.00	4.028	38.97	0.009674	75.00	3.530	80.99	0.02294
-40.00	4.011	41.45	0.01034	80.00	3.488	83.14	0.02384
-35.00	3.993	44.33	0.01110	85.00	3.425	86.99	0.02532
-30.00	3.971	47.52	0.01197	90.00	3.381	92.32	0.02731
-25.00	3.952	51.12	0.01293	95.00	3.325	98.82	0.02972
-20.00	3.936	54.91	0.01395	100.00	3.271	106.6	0.03258
-15.00	3.917	57.82	0.01476	105.00	3.217	115.5	0.03590
-10.00	3.895	61.01	0.01566	110.00	3.158	126.4	0.04001
-5.00	3.875	63.69	0.01644	115.00	3.089	139.8	0.04526
0.00	3.849	67.11	0.01744	120.00	3.005	157.1	0.05229
5.00	3.825	70.15	0.01834	125.00	2.890	182.0	0.06299
10.00	3.804	73.01	0.01919	130.00	2.729	217.4	0.07969
15.00	3.785	75.16	0.01986	135.00	2.468	271.4	0.1100
20.00	3.772	76.28	0.02023	140.00	2.031	338.4	0.1668
25.00	3.759	76.99	0.02048	145.00	1.469	406.2	0.2768
30.00	3.744	77.40	0.02067	150.00	0.9070	467.7	0.5169
35.00	3.723	78.44	0.02107	155.00	0.3932	385.9	0.9853
40.00	3.699	79.62	0.02152	160.00	0.1246	182.2	1.464
45.00	3.676	80.48	0.02189	165.00	0.05089	75.52	1.483
50.00	3.658	80.51	0.02201	170.00	0.02978	38.69	1.299
55.00	3.640	80.27	0.02206	175.00	0.02101	25.15	1.197

Table 86: Storage and loss properties for GE Plastics Noryl GFN2 20% glass fiber filled syrene modified polyphenylene ether (modified PPE). (tabular data for Graph 86)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.226	31.54	0.006035	60.00	4.811	71.75	0.01491
-55.00	5.215	30.39	0.005827	65.00	4.793	72.89	0.01521
-50.00	5.199	31.34	0.006027	70.00	4.770	74.66	0.01565
-45.00	5.183	32.36	0.006243	75.00	4.741	76.58	0.01615
-40.00	5.172	33.31	0.006441	80.00	4.706	79.71	0.01694
-35.00	5.160	34.71	0.006728	85.00	4.665	83.06	0.01781
-30.00	5.144	37.21	0.007234	90.00	4.623	86.71	0.01876
-25.00	5.127	39.26	0.007657	95.00	4.582	90.90	0.01984
-20.00	5.109	42.13	0.008247	100.00	4.542	95.81	0.02109
-15.00	5.094	44.58	0.008751	105.00	4.500	102.4	0.02275
-10.00	5.081	46.93	0.009235	110.00	4.454	111.5	0.02504
-5.00	5.064	49.42	0.009759	115.00	4.402	124.5	0.02827
0.00	5.044	51.72	0.01025	120.00	4.339	144.2	0.03323
5.00	5.023	54.38	0.01083	125.00	4.253	173.2	0.04072
10.00	5.003	56.44	0.01128	130.00	4.116	219.3	0.05328
15.00	4.984	57.89	0.01162	135.00	3.868	296.5	0.07666
20.00	4.974	57.97	0.01165	140.00	3.380	419.2	0.1241
25.00	4.960	58.90	0.01187	145.00	2.624	579.8	0.2213
30.00	4.943	61.02	0.01234	150.00	1.710	766.0	0.4490
35.00	4.918	64.11	0.01304	155.00	0.7557	680.6	0.9044
40.00	4.891	66.79	0.01366	160.00	0.2460	317.0	1.290
45.00	4.867	68.33	0.01404	165.00	0.1113	130.9	1.175
50.00	4.849	69.74	0.01438	170.00	0.06758	65.00	0.9614
55.00	4.830	70.61	0.01462	175.00	0.04792	40.28	0.8403

Graph 87: Storage and loss properties for GE Plastics Noryl GFN3 30% glass fiber filled syrene modified polyphenylene ether (modified PPE).



Graph 88: Storage and loss properties for Ticona Fortron 1140 40% glass fiber filled polyphenylene sulfide (PPS).

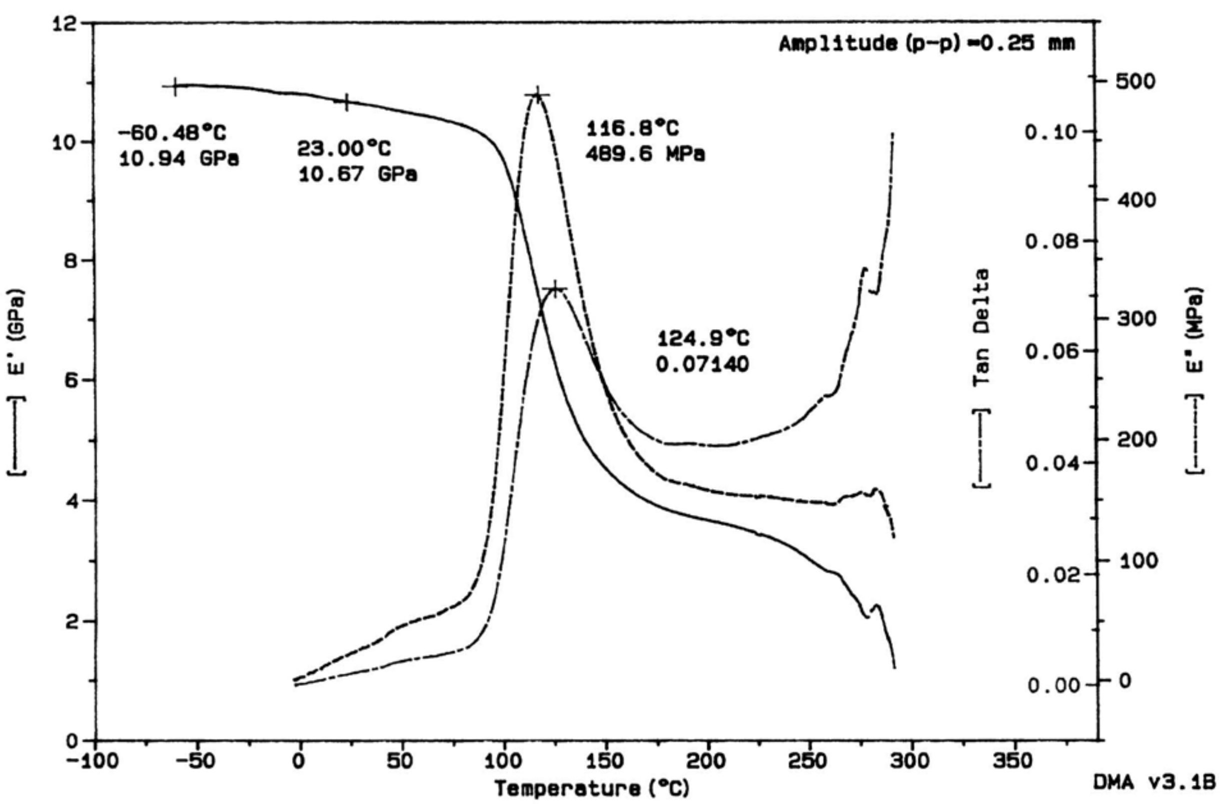


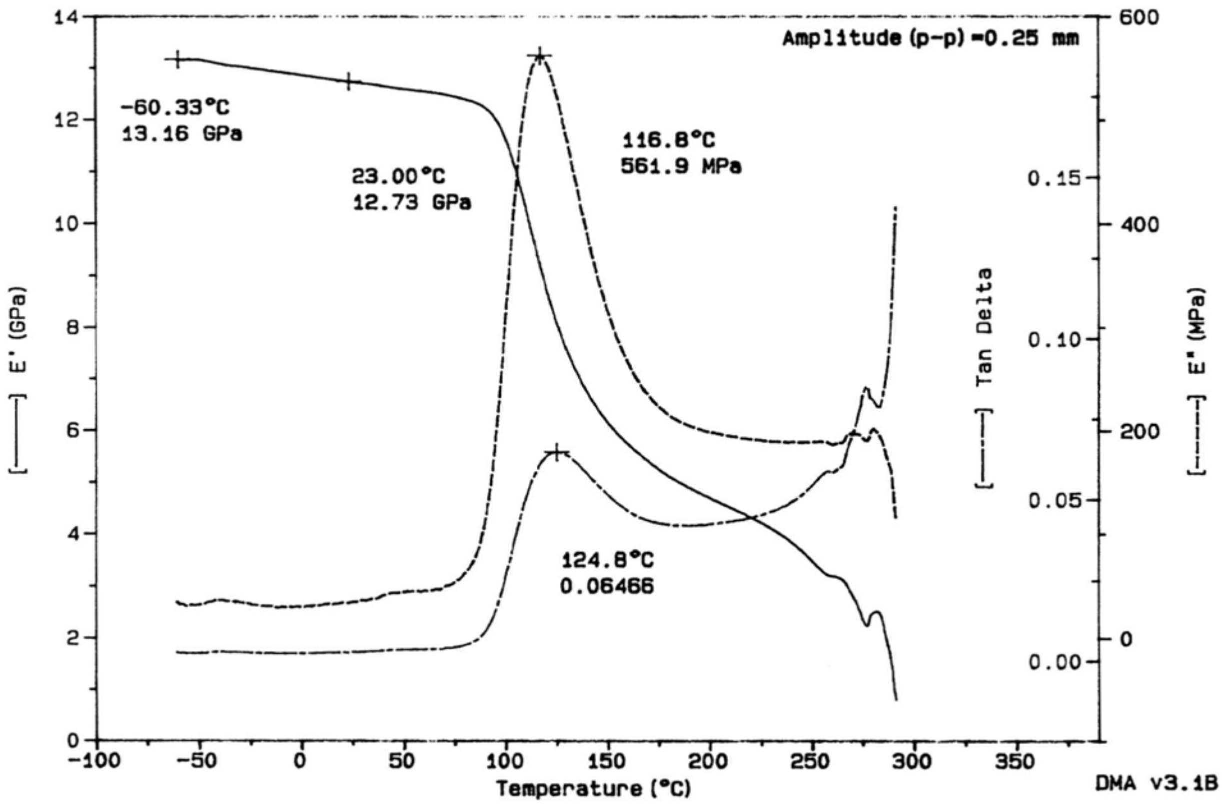
Table 87: Storage and loss properties for GE Plastics Noryl GFN3 30% glass fiber filled syrene modified polyphenylene ether (modified PPE). (tabular data for Graph 87)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	6.573	0.06067	0.009231	60.00	6.179	0.09442	0.01528
-55.00	6.567	0.05807	0.008842	65.00	6.160	0.09290	0.01508
-50.00	6.553	0.05876	0.008967	70.00	6.138	0.09179	0.01496
-45.00	6.533	0.05997	0.009180	75.00	6.111	0.09168	0.01500
-40.00	6.522	0.06196	0.009500	80.00	6.080	0.09214	0.01516
-35.00	6.512	0.06507	0.009991	85.00	6.044	0.09410	0.01557
-30.00	6.497	0.06806	0.01048	90.00	6.004	0.09596	0.01598
-25.00	6.480	0.07062	0.01090	95.00	5.958	0.09974	0.01674
-20.00	6.461	0.07363	0.01140	100.00	5.908	0.1055	0.01786
-15.00	6.443	0.07667	0.01190	105.00	5.863	0.1122	0.01914
-10.00	6.423	0.08015	0.01248	110.00	5.817	0.1207	0.02074
-5.00	6.402	0.08458	0.01321	115.00	5.767	0.1318	0.02286
0.00	6.379	0.08983	0.01408	120.00	5.711	0.1469	0.02572
5.00	6.358	0.09372	0.01474	125.00	5.646	0.1671	0.02960
10.00	6.347	0.09673	0.01524	130.00	5.565	0.1954	0.03510
15.00	6.342	0.09807	0.01546	135.00	5.449	0.2408	0.04419
20.00	6.337	0.09790	0.01545	140.00	5.252	0.3155	0.06007
25.00	6.323	0.09897	0.01565	145.00	4.843	0.4385	0.09057
30.00	6.302	0.1010	0.01603	150.00	4.081	0.6163	0.1511
35.00	6.278	0.1016	0.01618	155.00	3.034	0.8509	0.2808
40.00	6.255	0.1018	0.01627	160.00	1.803	1.034	0.5753
45.00	6.231	0.1014	0.01627	165.00	0.6952	0.6990	1.008
50.00	6.211	0.09924	0.01598	170.00	0.2585	0.3138	1.214
55.00	6.196	0.09670	0.01561	175.00	0.1350	0.1474	1.091

Table 88: Storage and loss properties for Ticona Fortron 1140 40% glass fiber filled polyphenylene sulfide (PPS). (tabular data for Graph 88)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	10.95			115.00	7.748	487.0	0.06286
-55.00	10.96			120.00	6.969	482.4	0.06924
-50.00	10.95			125.00	6.308	450.4	0.07140
-45.00	10.94			130.00	5.759	404.6	0.07025
-40.00	10.93			135.00	5.326	355.5	0.06674
-35.00	10.93			140.00	4.983	310.7	0.06235
-30.00	10.92			145.0	4.724	273.9	0.05797
-25.00	10.90			150.00	4.517	243.6	0.05393
-20.00	10.88			155.00	4.349	220.5	0.05071
-15.00	10.86			160.00	4.204	203.0	0.04829
-10.00	10.82			165.00	4.083	189.5	0.04641
-5.00	10.82			170.00	3.984	179.8	0.04513
0.00	10.81	3.378	3.125E-4	175.00	3.901	172.2	0.04414
5.00	10.79	6.897	6.393E-4	180.00	3.835	167.0	0.04355
10.00	10.76	10.54	9.795E-4	185.00	3.783	164.4	0.04347
15.00	10.72	15.66	0.001461	190.00	3.735	162.9	0.04361
20.00	10.69	19.97	0.001868	200.00	3.660	158.4	0.04327
25.00	10.66	23.65	0.002218	205.00	3.624	156.4	0.04316
30.00	10.63	27.24	0.002562	210.00	3.584	155.0	0.04324
40.00	10.57	35.63	0.003370	215.00	3.540	154.4	0.04363
45.00	10.53	42.18	0.004005	220.00	3.491	153.7	0.04404
50.00	10.50	46.53	0.004433	225.00	3.413	152.3	0.04461
55.00	10.46	50.04	0.004782	230.00	3.381	152.7	0.04516
60.00	10.44	52.71	0.005051	240.00	3.230	150.1	0.04649
65.00	10.40	55.23	0.005310	250.00	3.014	148.5	0.04927
70.00	10.36	59.04	0.005699	255.00	2.895	148.0	0.05111
75.00	10.32	62.71	0.006079	260.00	2.813	146.4	0.05206
80.00	10.27	68.35	0.006659	265.00	2.728	149.5	0.05482
90.00	10.11	105.6	0.01044	270.00	2.471	153.0	0.06191
100.00	9.698	247.5	0.02553	275.00	2.225	156.3	0.07031
105.00	9.207	358.2	0.03892	280.00	2.168	153.8	0.07093
110.00	8.518	447.2	0.05251	290.00	1.504	132.6	0.08864

Graph 89: Storage and loss properties for Phillips 66 Ryton R4 40% glass fiber filled, branched polyphenylene sulfide (PPS).



Graph 90: Storage and loss properties for Phillips 66 Ryton BR90A 40% glass fiber filled, impact modified polyphenylene sulfide (PPS).

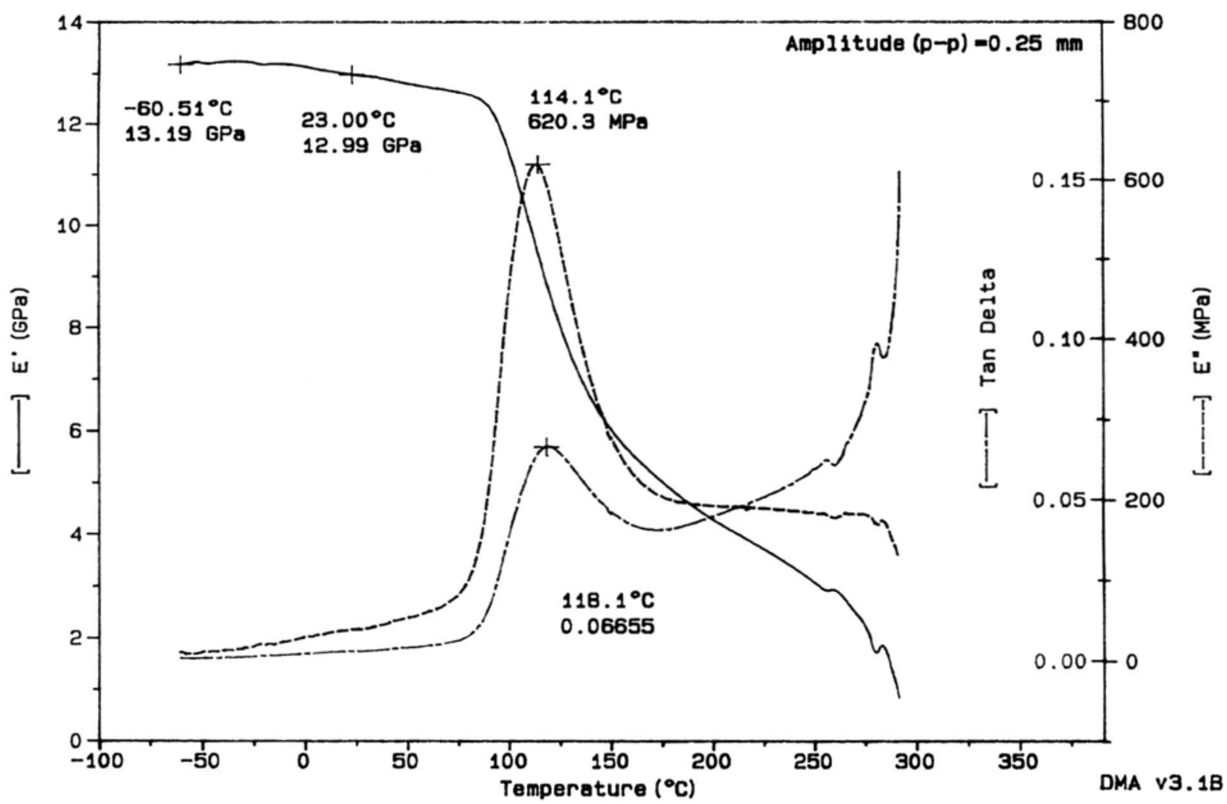


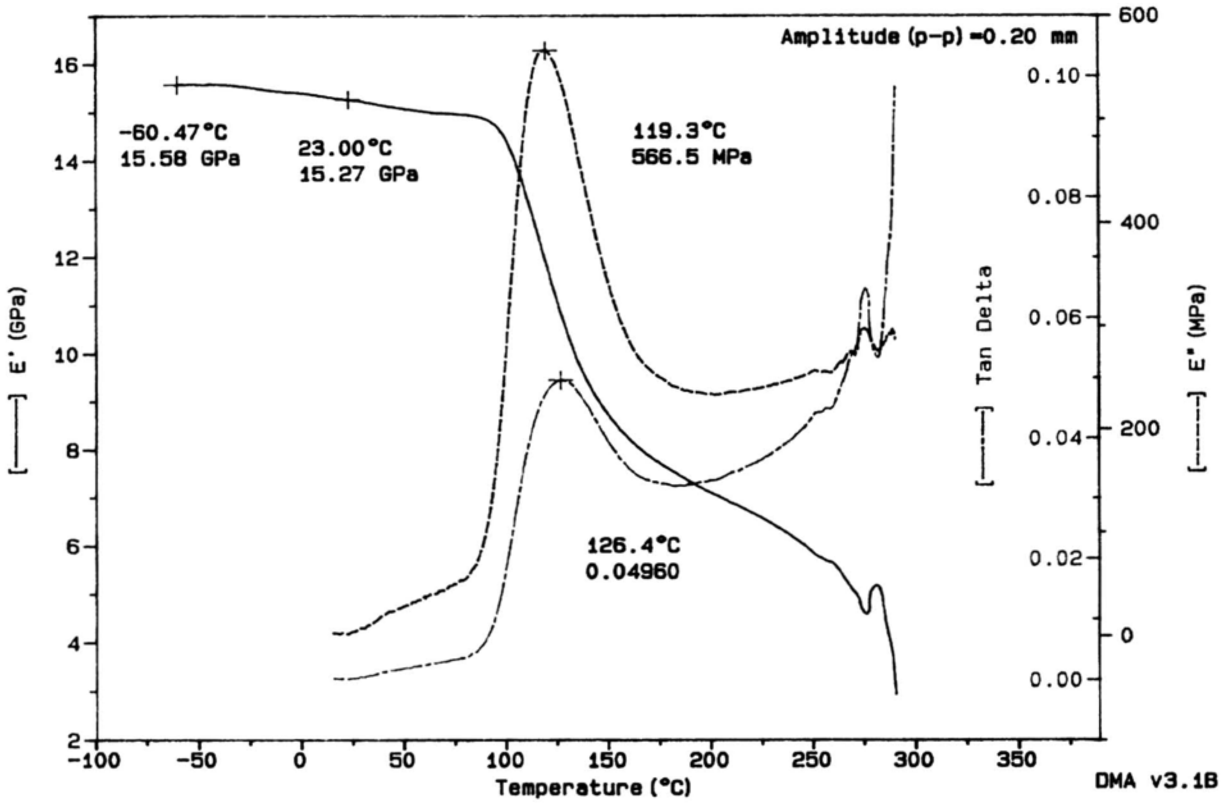
Table 89: Storage and loss properties for Phillips 66 Ryton R4 40% glass fiber filled, branched polyphenylene sulfide (PPS). (tabular data for Graph 89)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	13.16	34.24	0.002602	115.00	9.514	558.1	0.05867
-50.00	13.15	32.23	0.002450	120.00	8.767	555.6	0.06338
-45.00	13.12	35.01	0.002669	130.00	7.569	482.2	0.06371
-40.00	13.08	36.81	0.002815	140.00	6.741	390.7	0.05796
-35.00	13.05	35.95	0.002756	145.00	6.420	350.5	0.05458
-30.00	13.02	34.38	0.002640	150.00	6.150	316.7	0.05149
-20.00	12.97	31.20	0.002406	155.00	5.924	288.5	0.04870
-15.00	12.94	30.58	0.002364	160.00	5.725	266.0	0.04647
-10.00	12.91	30.05	0.002327	165.00	5.549	247.5	0.04461
-5.00	12.88	30.01	0.002329	170.00	5.387	234.0	0.04343
0.00	12.86	29.91	0.002327	180.00	5.105	215.2	0.04214
5.00	12.83	31.03	0.002419	190.00	4.880	204.4	0.04188
10.00	12.80	32.47	0.002537	195.00	4.778	201.1	0.04208
20.00	12.75	34.43	0.002701	200.00	4.682	198.6	0.04243
30.00	12.70	36.54	0.002877	205.00	4.589	196.7	0.04286
40.00	12.64	41.84	0.003310	210.00	4.499	194.6	0.04325
45.00	12.61	43.82	0.003475	215.00	4.408	192.9	0.04375
50.00	12.58	44.31	0.003521	220.00	4.311	191.7	0.04446
55.00	12.56	45.54	0.003626	230.00	4.094	189.6	0.04632
60.00	12.54	45.75	0.003649	240.00	3.829	189.1	0.04940
65.00	12.51	47.08	0.003763	245.00	3.668	188.8	0.05147
70.00	12.48	49.60	0.003974	250.00	3.476	188.9	0.05434
80.00	12.39	63.04	0.005090	255.00	3.286	189.4	0.05765
90.00	12.22	114.5	0.009366	260.00	3.192	186.5	0.05843
95.00	12.03	190.4	0.01584	265.00	3.124	188.2	0.06025
100.00	11.65	308.2	0.02647	270.00	2.820	197.5	0.07007
105.00	11.06	432.6	0.03913	280.00	2.488	201.7	0.08107
110.00	10.31	521.9	0.05065	290.00	1.180	141.0	0.1212

Table 90: Storage and loss properties for Phillips 66 Ryton BR90A 40% glass fiber filled, impact modified polyphenylene sulfide (PPS). (tabular data for Graph 90)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	13.19	11.40	8.641E-4	115.00	9.514	619.1	0.06508
-55.00	13.22	9.376	7.093E-4	120.00	8.816	586.8	0.06656
-50.00	13.23	11.13	8.418E-4	130.00	7.611	463.6	0.06091
-45.00	13.21	12.56	9.511E-4	135.00	7.124	404.4	0.05676
-40.00	13.23	13.65	0.001031	140.00	6.716	354.7	0.05281
-35.00	13.24	13.77	0.001040	145.00	6.371	314.1	0.04929
-30.00	13.24	15.93	0.001203	155.00	5.824	255.7	0.04392
-20.00	13.19	19.94	0.001512	160.00	5.600	236.3	0.04219
-15.00	13.19	21.15	0.001603	165.00	5.398	222.1	0.04115
-10.00	13.19	24.55	0.001861	170.00	5.213	212.0	0.04067
-5.00	13.18	26.67	0.002024	180.00	4.873	200.0	0.04105
0.00	13.14	30.11	0.002291	185.00	4.713	197.1	0.04183
5.00	13.11	32.18	0.002455	190.00	4.563	194.8	0.04268
10.00	13.07	34.07	0.002607	195.00	4.425	193.8	0.04380
15.00	13.04	36.33	0.002787	205.00	4.175	192.0	0.04599
20.00	13.01	38.58	0.002966	210.00	4.057	191.8	0.04727
30.00	12.96	40.79	0.003147	215.00	3.949	191.2	0.04842
40.00	12.90	46.77	0.003625	220.00	3.836	190.5	0.04965
45.00	12.86	51.09	0.003973	230.00	3.608	188.7	0.05230
55.00	12.79	56.64	0.004430	240.00	3.357	186.3	0.05549
60.00	12.75	61.29	0.004807	245.00	3.224	184.9	0.05736
65.00	12.72	65.23	0.005128	250.00	3.082	183.9	0.05968
70.00	12.69	72.77	0.005735	255.00	2.933	182.8	0.06231
80.00	12.61	99.51	0.007893	260.00	2.921	177.4	0.06074
90.0	12.40	208.4	0.01681	265.00	2.767	183.5	0.06634
95.00	12.10	325.4	0.02690	270.00	2.517	182.2	0.07241
105.00	10.96	548.0	0.05003	280.00	1.750	171.2	0.09794
110.00	10.24	604.6	0.05905	290.00	1.194	140.2	0.1180

Graph 91: Storage and loss properties for Ticona Celstran PPSG50 50% long glass fiber filled polyphenylene sulfide (PPS).



Graph 92: Storage and loss properties for Ticona Fortron 4184 50% glass fiber/ mineral filled polyphenylene sulfide (PPS).

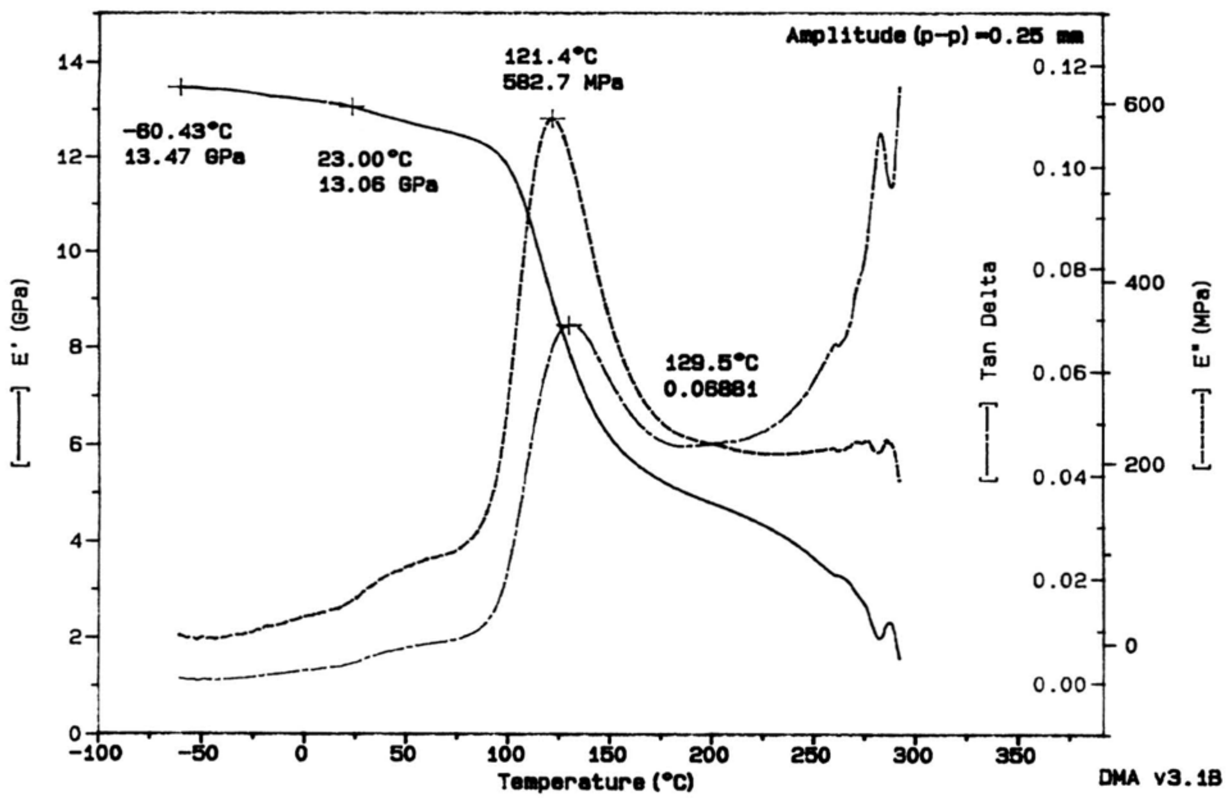


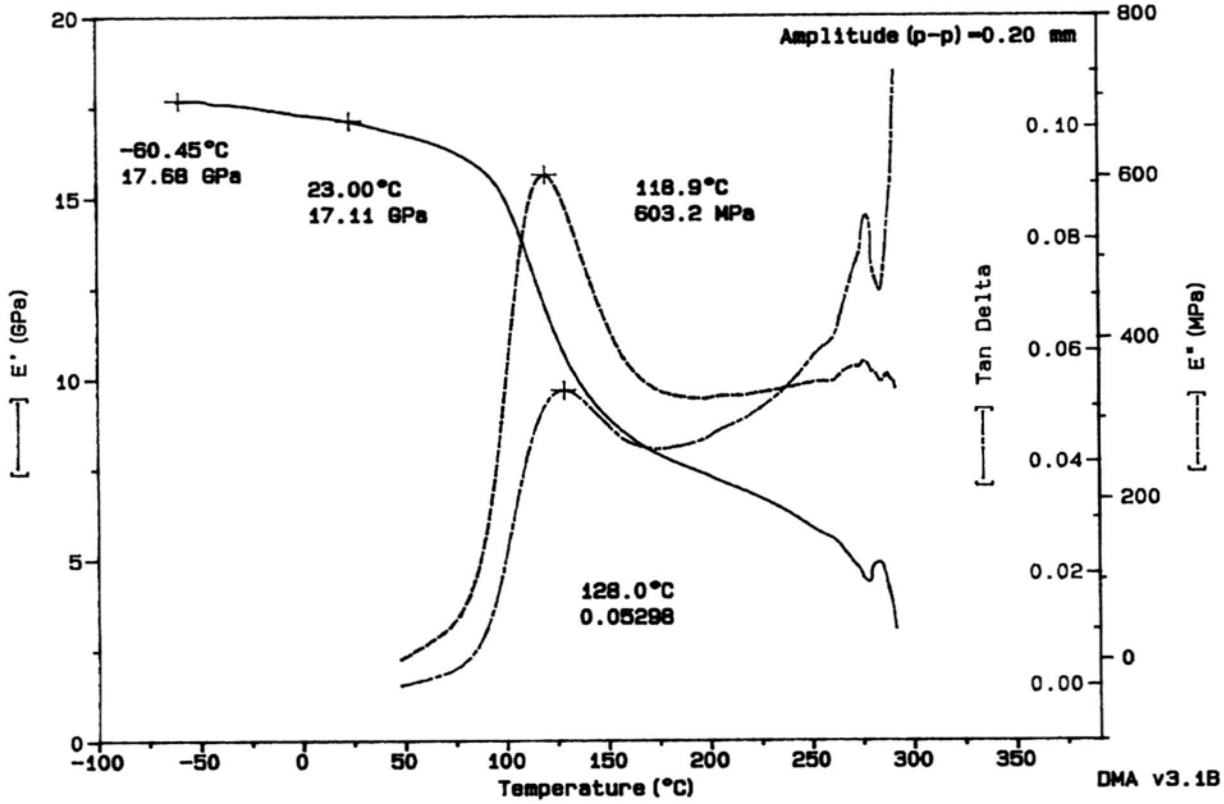
Table 91: Storage and loss properties for Ticona Celstran PPSG50 50% long glass fiber filled polyphenylene sulfide (PPS). (tabular data for Graph 91)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	15.59			120.00	11.87	567.1	0.04777
-50.00	15.59			125.00	11.14	550.6	0.04941
-45.00	15.60			130.00	10.49	518.0	0.04939
-40.00	15.60			140.00	9.433	426.6	0.04523
-30.00	15.56			145.00	9.050	382.2	0.04223
-25.00	15.53			150.00	8.737	343.6	0.03933
-20.00	15.50			160.00	8.231	286.8	0.03484
-10.00	15.44			165.00	8.032	269.0	0.03350
-5.00	15.43			170.00	7.862	258.2	0.03284
0.00	15.41			175.00	7.718	249.8	0.03237
5.00	15.38			180.00	7.586	243.2	0.03206
10.00	15.35			190.00	7.323	235.8	0.03220
15.00	15.31			195.00	7.203	234.6	0.03257
20.00	15.28			200.00	7.095	233.6	0.03292
25.00	15.26	4.484	2.939E-4	205.00	6.996	233.1	0.03332
30.00	15.23	7.613	4.999E-4	210.00	6.882	235.4	0.03421
40.00	15.15	19.92	0.001315	220.00	6.677	238.1	0.03566
50.00	15.08	28.60	0.001896	225.00	6.568	239.7	0.03650
55.00	15.05	32.94	0.002189	230.00	6.444	242.2	0.03758
60.00	15.02	38.36	0.002553	240.00	6.178	246.9	0.03996
65.00	14.99	40.73	0.002716	245.00	6.028	250.9	0.04162
70.00	14.99	43.75	0.002919	250.00	5.844	255.8	0.04377
80.00	14.95	54.95	0.003675	255.00	5.726	255.0	0.04452
90.00	14.87	99.04	0.006661	260.00	5.630	255.6	0.04540
95.00	14.75	161.2	0.01093	265.00	5.351	264.5	0.04944
100.00	14.48	267.3	0.01846	270.00	5.052	275.5	0.05453
105.00	14.00	396.5	0.02832	280.00	5.171	280.5	0.05425
110.00	13.35	499.5	0.03741	290.00	3.073	290.2	0.09529

Table 92: Storage and loss properties for Ticona Fortron 4184 50% glass fiber/ mineral filled polyphenylene sulfide (PPS). (tabular data for Graph 92)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	13.47	8.789	6.524E-4	115.00	10.06	543.7	0.05407
-55.00	13.47	6.484	4.814E-4	120.00	9.302	579.2	0.06228
-50.00	13.45	7.144	5.312E-4	125.00	8.568	577.2	0.06738
-40.00	13.42	6.416	4.780E-4	135.00	7.373	503.4	0.06827
-35.00	13.40	8.586	6.406E-4	140.00	6.889	453.2	0.06579
-30.00	13.38	10.00	7.478E-4	145.00	6.491	402.5	0.06200
-25.00	13.34	12.90	9.673E-4	150.00	6.173	359.7	0.05827
-15.00	13.27	19.94	0.001502	160.00	5.707	296.2	0.05190
-10.00	13.25	22.49	0.001697	165.00	5.533	274.2	0.04956
-5.00	13.23	26.29	0.001987	170.00	5.388	258.0	0.04789
0.00	13.20	29.93	0.002268	175.00	5.260	245.5	0.04668
10.00	13.15	35.04	0.002666	185.00	5.047	230.4	0.04565
15.00	13.12	38.49	0.002935	190.00	4.954	226.6	0.04574
20.00	13.09	43.17	0.003299	195.00	4.868	223.5	0.04592
25.00	13.03	50.05	0.003840	200.00	4.788	220.8	0.04612
30.00	12.97	59.83	0.004613	210.00	4.624	215.9	0.04670
40.00	12.85	75.32	0.005863	215.00	4.536	213.2	0.04700
45.00	12.79	80.35	0.006282	220.00	4.443	211.8	0.04766
50.00	12.74	85.45	0.006709	225.00	4.342	210.7	0.04852
60.00	12.63	93.76	0.007425	240.00	3.980	211.0	0.05302
65.00	12.58	96.02	0.007633	245.00	3.832	211.9	0.05529
70.00	12.53	99.67	0.007954	250.00	3.663	213.6	0.05833
75.00	12.48	104.1	0.008341	260.00	3.316	216.6	0.06531
80.00	12.41	112.0	0.009023	265.00	3.244	215.2	0.06633
90.00	12.23	147.3	0.01205	270.00	3.009	223.1	0.07415
95.00	12.08	188.3	0.01560	275.00	2.722	222.9	0.08191
100.00	11.82	260.5	0.02205	280.00	2.146	214.2	0.09988
110.00	10.79	468.1	0.04339	290.00	2.073	212.7	0.1030

Graph 93: Storage and loss properties for Ticona Fortron 6165 65% glass fiber/ mineral filled polyphenylene sulfide (PPS).



Graph 94: Storage and loss properties for Amoco Performance Polymers Radel AG220 20% glass fiber filled polyethersulfone (PES).

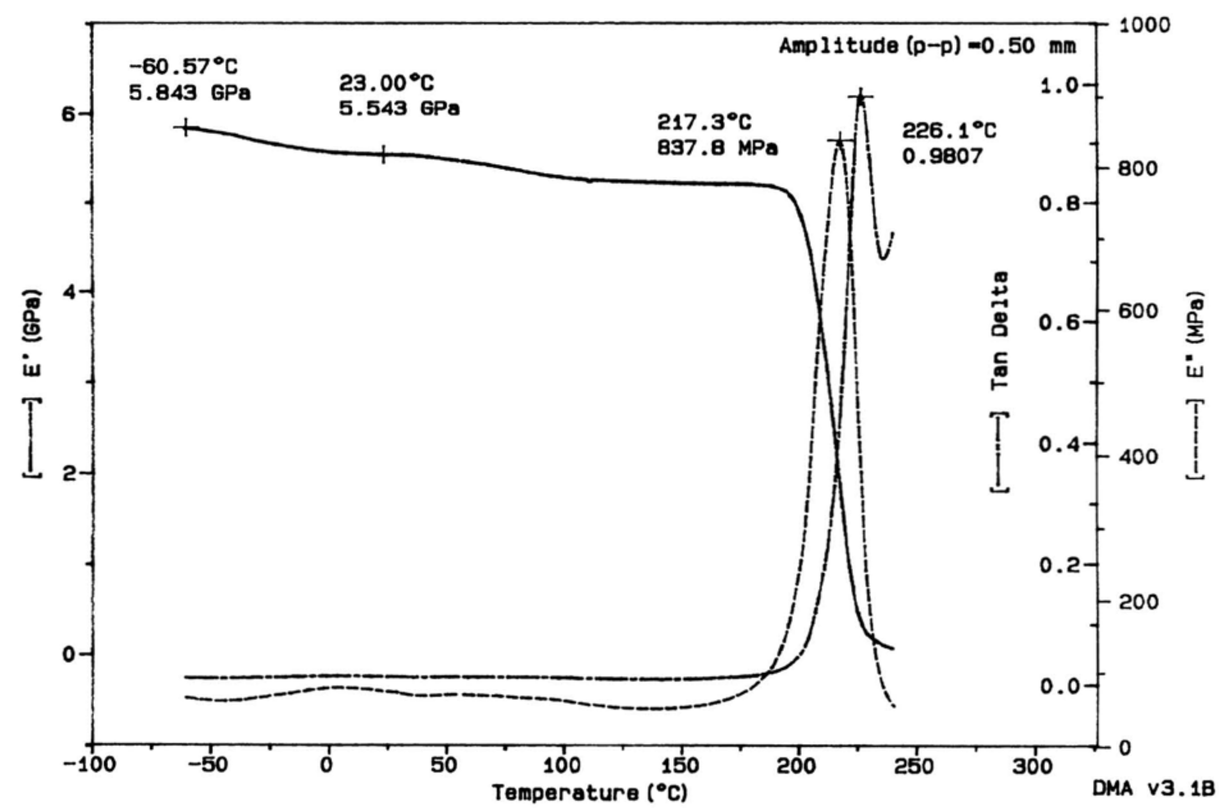


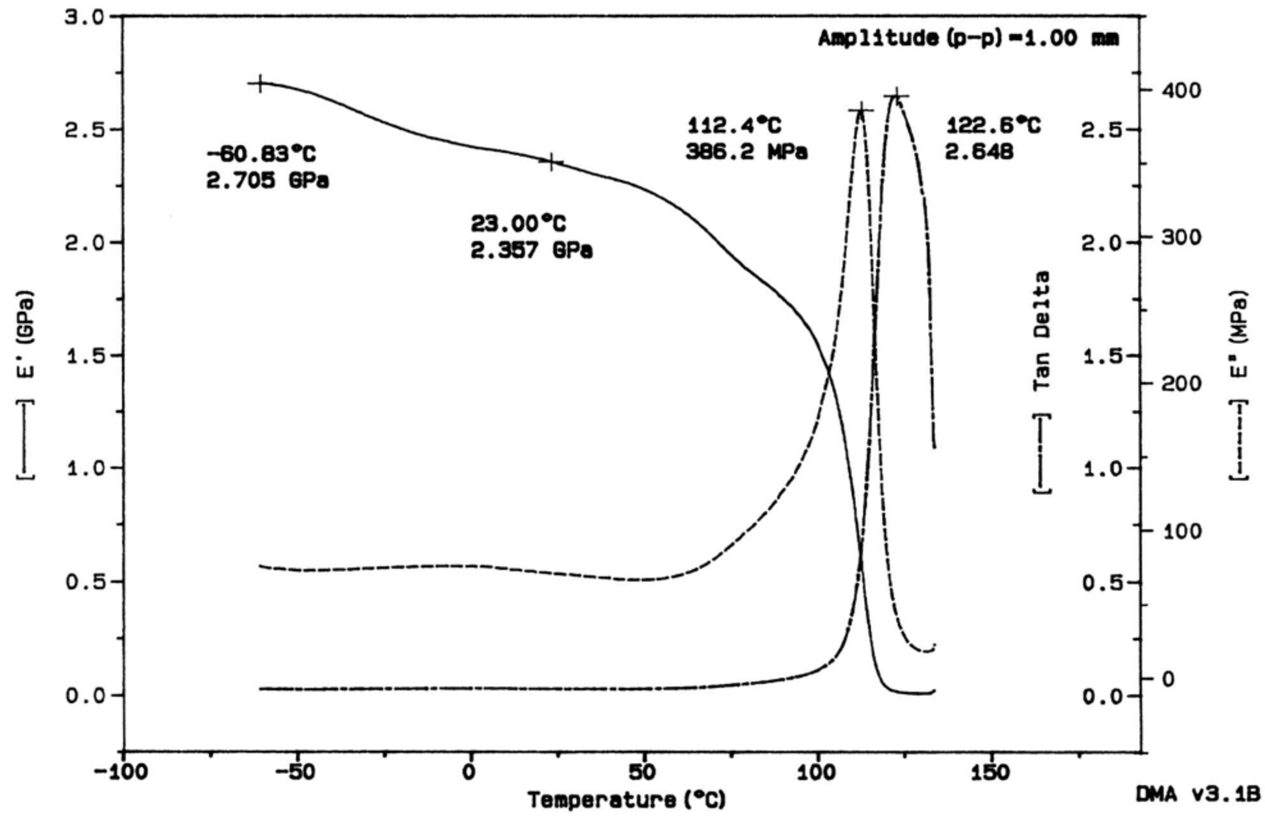
Table 93: Storage and loss properties for Ticona Fortron 6165 65% glass fiber/ mineral filled polyphenylene sulfide (PPS). (tabular data for Graph 93)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	17.69		
-50.00	17.69		
-40.00	17.60		
-35.00	17.59		
-30.00	17.56		
-25.00	17.52		
-20.00	17.47		
-15.00	17.43		
-10.00	17.39		
-5.00	17.35		
0.00	17.29		
10.00	17.24		
20.00	17.14		
25.00	17.10		
30.00	17.04		
40.00	16.89		
45.00	16.82		
50.00	16.75	4.151	2.479E-4
60.00	16.59	19.14	0.001154
65.00	16.50	27.70	0.001679
70.00	16.39	36.96	0.002255
75.00	16.26	50.55	0.003109
80.00	16.11	71.80	0.004456
90.00	15.71	159.1	0.01013
95.00	15.40	210.8	0.01564
100.00	14.93	352.5	0.02361
110.00	13.51	550.0	0.04071
115.00	12.68	594.1	0.04687
120.00	11.87	602.9	0.05079
125.00	11.16	587.2	0.05264
130.00	10.52	557.1	0.05296
140.00	9.582	482.1	0.05031
145.00	9.220	446.5	0.04842
150.00	8.915	415.7	0.04663
160.00	8.428	367.4	0.04360
165.00	8.214	352.6	0.04293
170.00	8.042	341.9	0.04252
175.00	7.891	335.0	0.04245
180.00	7.754	330.3	0.04260
190.00	7.517	325.6	0.04331
195.00	7.406	325.3	0.04392
200.00	7.288	326.2	0.04477
210.00	7.043	328.8	0.04668
215.00	6.927	329.4	0.04756
220.00	6.809	330.8	0.04858
225.00	6.679	332.7	0.04982
230.00	6.540	334.7	0.05117
240.00	6.230	339.8	0.05454
245.00	6.057	342.3	0.05651
250.00	5.875	345.0	0.05874
260.00	5.577	346.8	0.06217
265.00	5.303	358.1	0.06754
270.00	4.944	364.8	0.07381
275.00	4.518	370.8	0.08213
280.00	4.817	358.4	0.07441
290.00	3.455	346.9	0.1010

Table 94: Storage and loss properties for Amoco Performance Polymers Radel AG220 20% glass fiber filled polyether-sulfone (PES). (tabular data for Graph 94)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.842	66.05	0.01131
-50.00	5.805	62.51	0.01077
-45.00	5.784	61.87	0.01070
-40.00	5.761	62.82	0.01091
-35.00	5.728	64.14	0.01120
-30.00	5.696	66.63	0.01170
-25.00	5.669	69.31	0.01223
-20.00	5.647	71.12	0.01260
-15.00	5.624	73.72	0.01311
-10.00	5.604	76.26	0.01361
-5.00	5.586	78.22	0.01400
0.00	5.572	79.71	0.01431
5.00	5.561	80.21	0.01442
10.00	5.553	79.50	0.01432
15.00	5.548	78.23	0.01410
20.00	5.544	76.21	0.01374
25.00	5.542	74.29	0.01341
30.00	5.540	72.47	0.01308
40.00	5.524	68.98	0.01249
45.00	5.509	69.40	0.01260
50.00	5.491	70.40	0.01282
55.00	5.475	70.50	0.01288
60.00	5.457	69.93	0.01281
65.00	5.440	69.37	0.01275
70.00	5.417	68.56	0.01266
75.00	5.396	67.47	0.01250
80.00	5.373	66.38	0.01235
90.00	5.322	65.10	0.01223
95.00	5.302	63.78	0.01203
100.00	5.286	61.96	0.01172
105.00	5.274	59.23	0.01123
110.00	5.263	56.84	0.01080
115.00	5.258	55.44	0.01054
120.00	5.252	53.62	0.01021
125.00	5.246	52.53	0.01001
130.00	5.241	54.63	0.009852
135.00	5.236	51.44	0.009824
140.00	5.232	51.45	0.009834
145.00	5.228	51.85	0.009919
150.00	5.224	53.39	0.01022
155.00	5.221	55.20	0.01057
160.00	5.219	57.58	0.01103
165.00	5.217	60.83	0.01166
170.00	5.216	65.59	0.01258
175.00	5.214	72.29	0.01387
180.00	5.211	81.07	0.01556
190.00	5.177	119.1	0.02300
195.00	5.126	161.9	0.03159
200.00	4.914	241.0	0.04905
205.00	4.443	406.6	0.09163
210.00	3.563	634.7	0.1784
215.00	2.501	807.8	0.3239
220.00	1.305	787.3	0.6065
225.00	0.4851	464.1	0.9586
230.00	0.2134	186.1	0.8706
240.00	0.07436	55.60	0.7481

Graph 95: Storage and loss properties for GE Plastics Cycolac T unfilled, high impact, general purpose acrylonitrile butadiene styrene (ABS).



Graph 96: Storage and loss properties for GE Plastics Cycolac GSM unfilled, high impact acrylonitrile butadiene styrene (ABS).

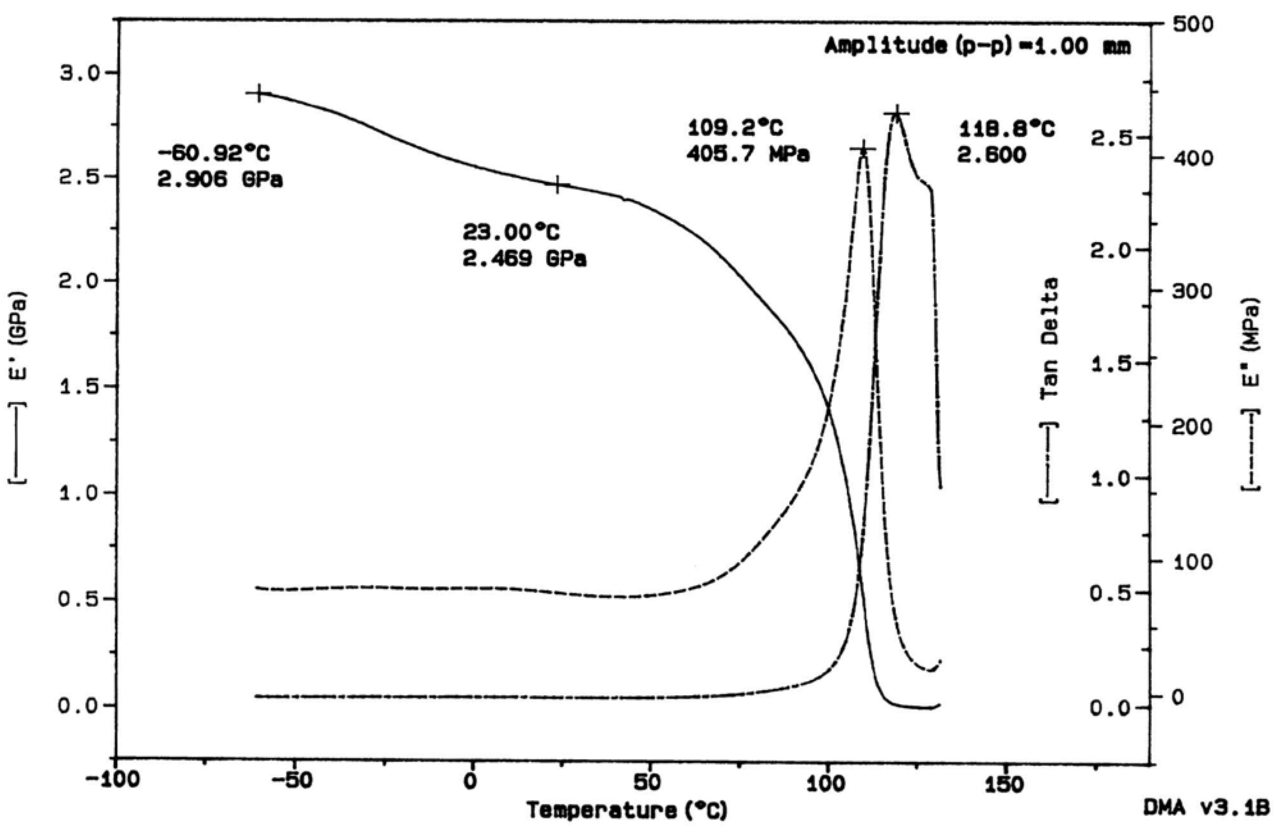


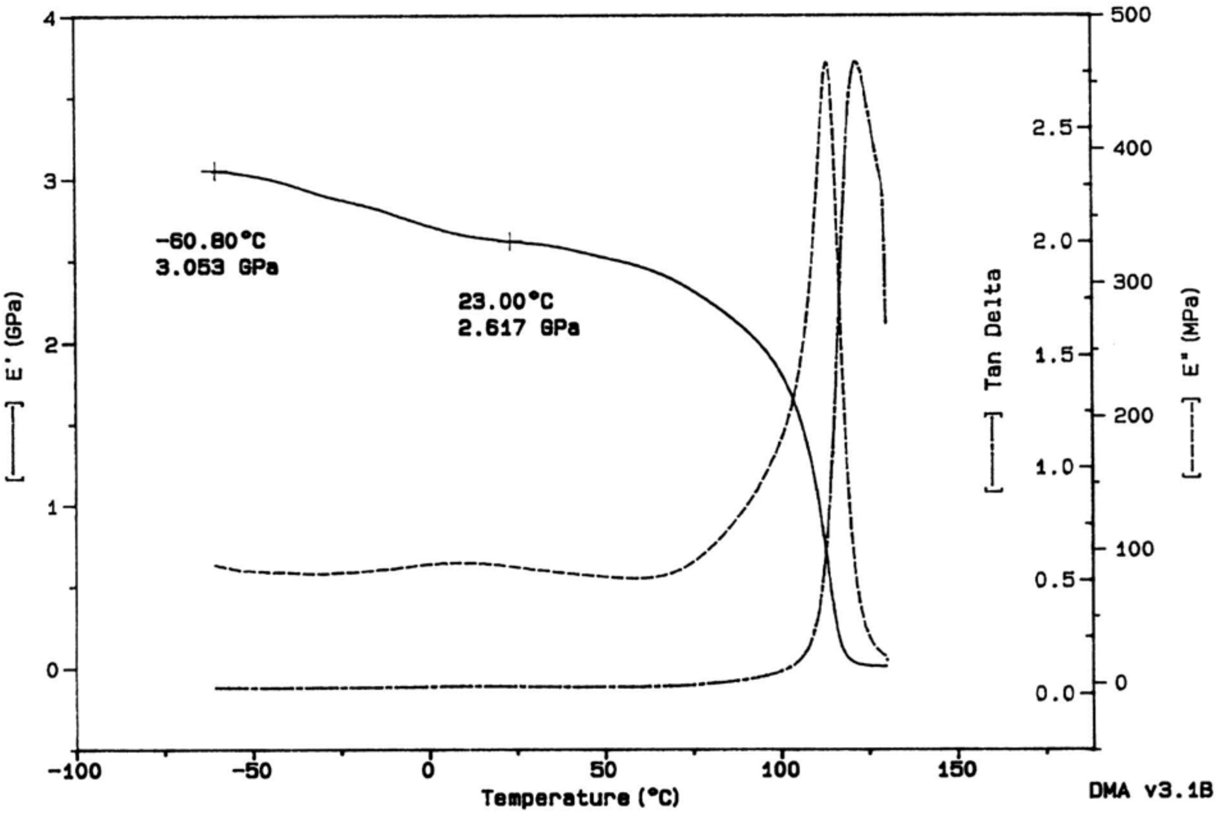
Table 95: Storage and loss properties for GE Plastics Cycolac T unfilled, high impact, general purpose acrylonitrile butadiene styrene (ABS). (tabular data for Graph 95)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.704	75.31	0.02785	40.00	2.284	67.82	0.02970
-55.00	2.693	74.04	0.02749	45.00	2.263	66.94	0.02958
-50.00	2.677	73.03	0.02728	50.00	2.234	66.90	0.02994
-45.00	2.656	72.96	0.02747	55.00	2.197	67.78	0.03085
-40.00	2.627	73.35	0.02792	60.00	2.151	69.97	0.03253
-35.00	2.595	73.77	0.02843	65.00	2.095	74.08	0.03536
-30.00	2.562	74.42	0.02905	70.00	2.025	80.90	0.03996
-25.00	2.531	74.86	0.02957	75.00	1.949	90.17	0.04627
-20.00	2.503	75.35	0.03010	80.00	1.880	100.6	0.05350
-15.00	2.477	75.67	0.03054	85.00	1.821	112.3	0.06164
-10.00	2.458	76.02	0.03093	90.00	1.754	127.5	0.07267
-5.00	2.440	75.99	0.03115	95.00	1.674	146.2	0.08729
0.00	2.423	76.00	0.03136	100.00	1.554	176.3	0.1135
5.00	2.410	75.44	0.03130	105.00	1.340	228.3	0.1705
10.00	2.399	74.35	0.03099	110.00	0.9082	344.3	0.3799
15.00	2.385	72.94	0.03059	115.00	0.2788	321.5	1.162
20.00	2.368	71.75	0.03030	120.00	0.03338	83.65	2.510
25.00	2.349	70.89	0.03018	125.00	0.01104	28.37	2.569
30.00	2.326	69.92	0.03006	130.00	0.008161	18.34	2.247
35.00	2.303	68.82	0.02988				

Table 96: Storage and loss properties for GE Plastics Cycolac GSM unfilled, high impact acrylonitrile butadiene styrene (ABS). (tabular data for Graph 96)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.904	75.98	0.02616	40.00	2.415	71.59	0.02965
-55.00	2.887	75.23	0.02606	45.00	2.390	71.65	0.02999
-50.00	2.866	75.49	0.02634	50.00	2.352	72.70	0.03091
-45.00	2.839	76.21	0.02684	55.00	2.308	74.59	0.03232
-40.00	2.814	76.92	0.02734	60.00	2.258	77.23	0.03421
-35.00	2.782	77.29	0.02778	65.00	2.197	81.23	0.03697
-30.00	2.746	77.30	0.02815	70.00	2.122	87.74	0.04134
-25.00	2.707	77.32	0.02856	75.00	2.035	97.33	0.04783
-20.00	2.672	76.91	0.02879	80.00	1.942	110.5	0.05691
-15.00	2.639	76.77	0.02909	85.00	1.847	126.4	0.06842
-10.00	2.606	76.91	0.02951	90.00	1.743	144.3	0.08280
-5.00	2.580	77.07	0.02988	95.00	1.607	169.6	0.1056
0.00	2.555	77.16	0.03020	100.00	1.406	214.5	0.1527
5.00	2.533	77.50	0.03060	105.00	1.064	303.4	0.2855
10.00	2.513	77.03	0.03065	110.00	0.4964	401.8	0.8137
15.00	2.494	75.93	0.03044	115.00	0.07417	159.6	2.160
20.00	2.478	74.82	0.03019	120.00	0.01721	44.07	2.560
25.00	2.463	73.75	0.02994	125.00	0.009361	21.65	2.313
30.00	2.449	72.50	0.02960	130.00	0.01372	19.85	1.623
35.00	2.433	71.75	0.02949				

Graph 97: Storage and loss properties for Dow Chemical Magnum 9010 unfilled, medium impact acrylonitrile butadiene styrene (ABS).



Graph 98: Storage and loss properties for GE Plastics Cycolac DFA-R unfilled, medium impact acrylonitrile butadiene styrene (ABS).

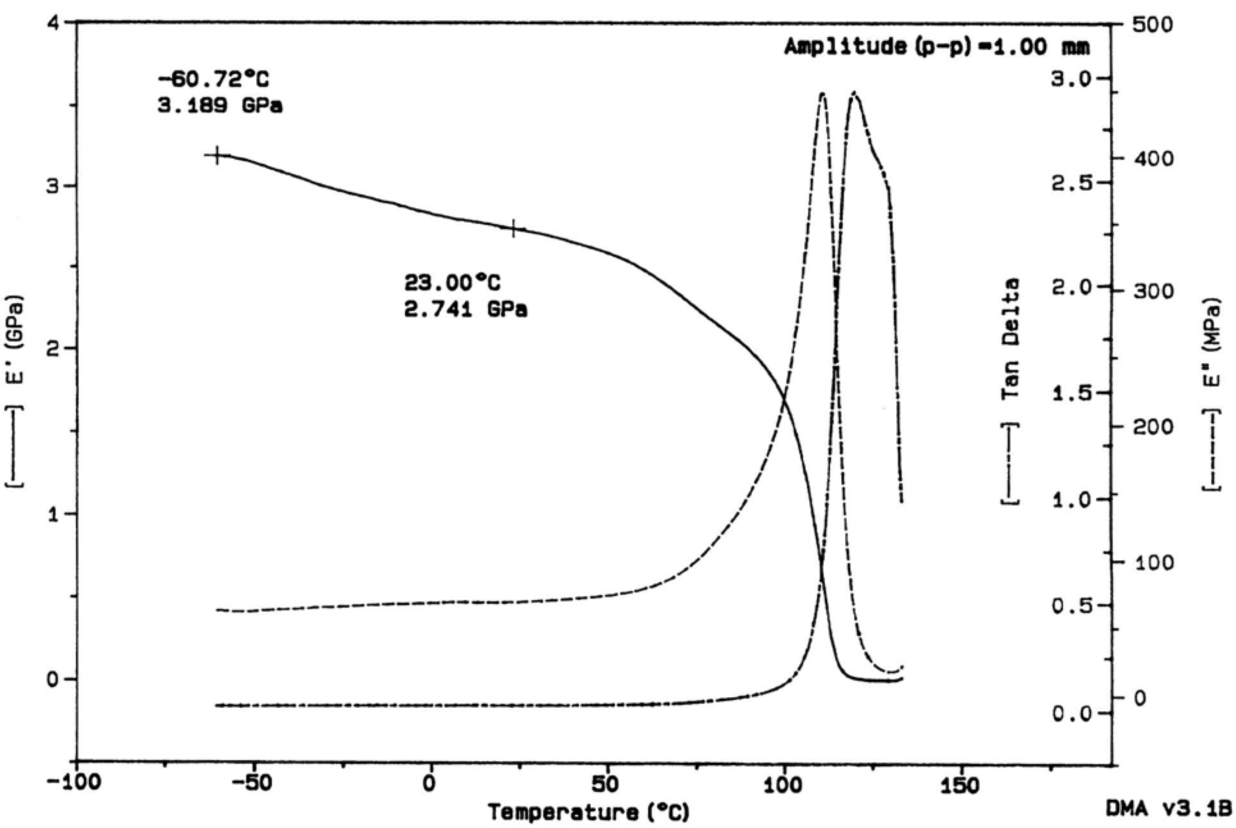


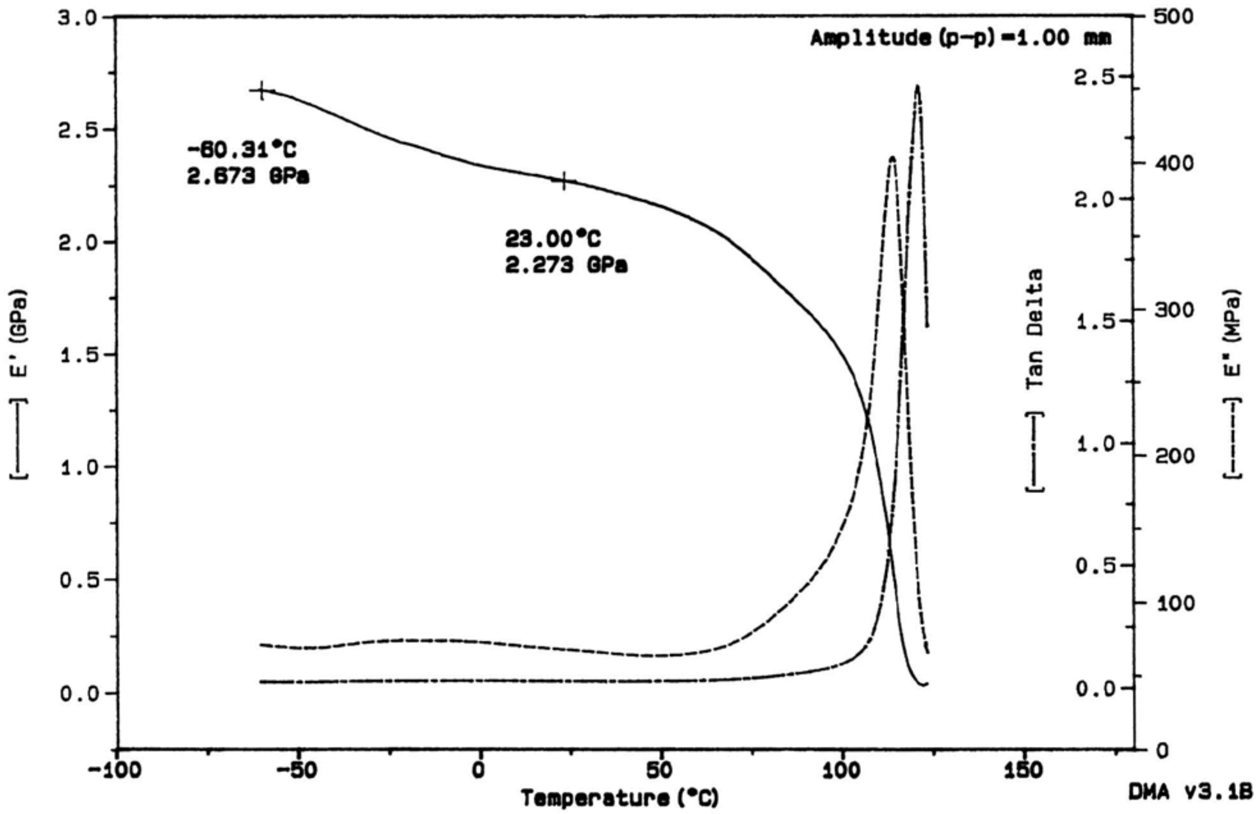
Table 97: Storage and loss properties for Dow Chemical Magnum 9010 unfilled, medium impact acrylonitrile butadiene styrene (ABS). (tabular data for Graph 97)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.054	88.37	0.02894	35.00	2.590	83.53	0.03225
-55.00	3.041	85.40	0.02808	40.00	2.569	82.01	0.03192
-50.00	3.024	84.07	0.02780	45.00	2.545	80.80	0.03175
-45.00	3.002	83.28	0.02774	50.00	2.519	79.62	0.03161
-40.00	2.974	83.04	0.02793	55.00	2.494	78.73	0.03156
-35.00	2.938	82.20	0.02798	60.00	2.464	78.43	0.03183
-30.00	2.903	82.15	0.02830	65.00	2.426	79.92	0.03294
-25.00	2.875	82.94	0.02885	70.00	2.379	83.70	0.03519
-20.00	2.850	83.68	0.02937	75.00	2.318	91.02	0.03926
-15.00	2.821	84.80	0.03006	80.00	2.249	101.8	0.04526
-10.00	2.786	86.03	0.03087	85.00	2.172	115.6	0.05326
-5.00	2.750	87.85	0.03194	90.00	2.084	132.3	0.06349
0.00	2.715	89.39	0.03293	95.00	1.976	153.5	0.07772
5.00	2.682	90.08	0.03359	100.00	1.823	182.1	0.09992
10.00	2.656	90.16	0.03394	105.00	1.574	230.4	0.1464
15.00	2.638	89.83	0.03405	110.00	1.126	354.7	0.3158
20.00	2.625	88.49	0.03371	115.00	0.3726	420.5	1.138
25.00	2.615	86.80	0.03319	120.00	0.04247	113.9	2.688
30.00	2.604	85.16	0.03271	125.00	0.01325	34.23	2.582

Table 98: Storage and loss properties for GE Plastics Cycolac DFA-R unfilled, medium impact acrylonitrile butadiene styrene (ABS). (tabular data for Graph 98)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.188	61.88	0.01941	40.00	2.655	71.48	0.02692
-55.00	3.170	60.88	0.01920	45.00	2.624	72.64	0.02768
-50.00	3.141	61.33	0.01952	50.00	2.588	74.04	0.02861
-45.00	3.105	62.29	0.02006	55.00	2.545	76.06	0.02989
-40.00	3.071	62.93	0.02050	60.00	2.486	79.23	0.03187
-35.00	3.033	63.67	0.02099	65.00	2.415	83.90	0.03474
-30.00	2.997	64.52	0.02153	70.00	2.336	90.55	0.03876
-25.00	2.967	65.07	0.02193	75.00	2.250	100.8	0.04480
-20.00	2.940	66.00	0.02245	80.00	2.168	114.1	0.05262
-15.00	2.913	66.65	0.02288	85.00	2.088	130.2	0.06234
-10.00	2.888	67.03	0.02321	90.00	2.000	149.9	0.07496
-5.00	2.857	67.46	0.02361	95.00	1.882	178.4	0.09479
0.00	2.831	67.92	0.02399	100.00	1.694	223.3	0.1319
5.00	2.807	68.53	0.02442	105.00	1.340	311.5	0.2326
10.00	2.790	68.46	0.02454	110.00	0.7260	445.8	0.6166
15.00	2.772	68.37	0.02466	115.00	0.1189	233.7	1.980
20.00	2.752	68.45	0.02487	120.00	0.01914	55.89	2.920
25.00	2.732	68.99	0.02525	125.00	0.008859	23.48	2.650
30.00	2.712	69.60	0.02566	130.00	0.007652	17.71	2.344
35.00	2.686	70.37	0.02620				

Graph 99: Storage and loss properties for Dow Chemical Magnum 941 unfilled, very high impact acrylonitrile butadiene styrene (ABS).



Graph 100: Storage and loss properties for GE Plastics Cycolac KJW unfilled, flame retardant acrylonitrile butadiene styrene (ABS).

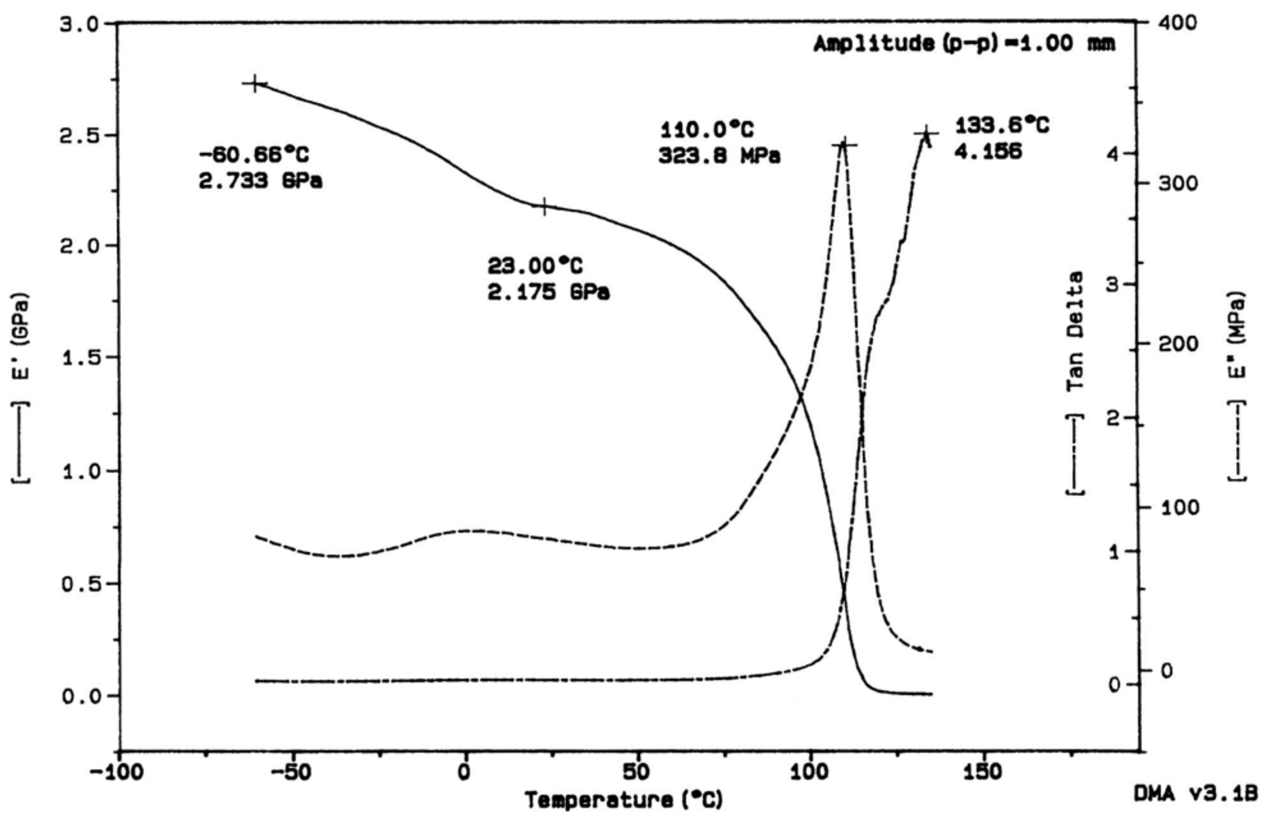


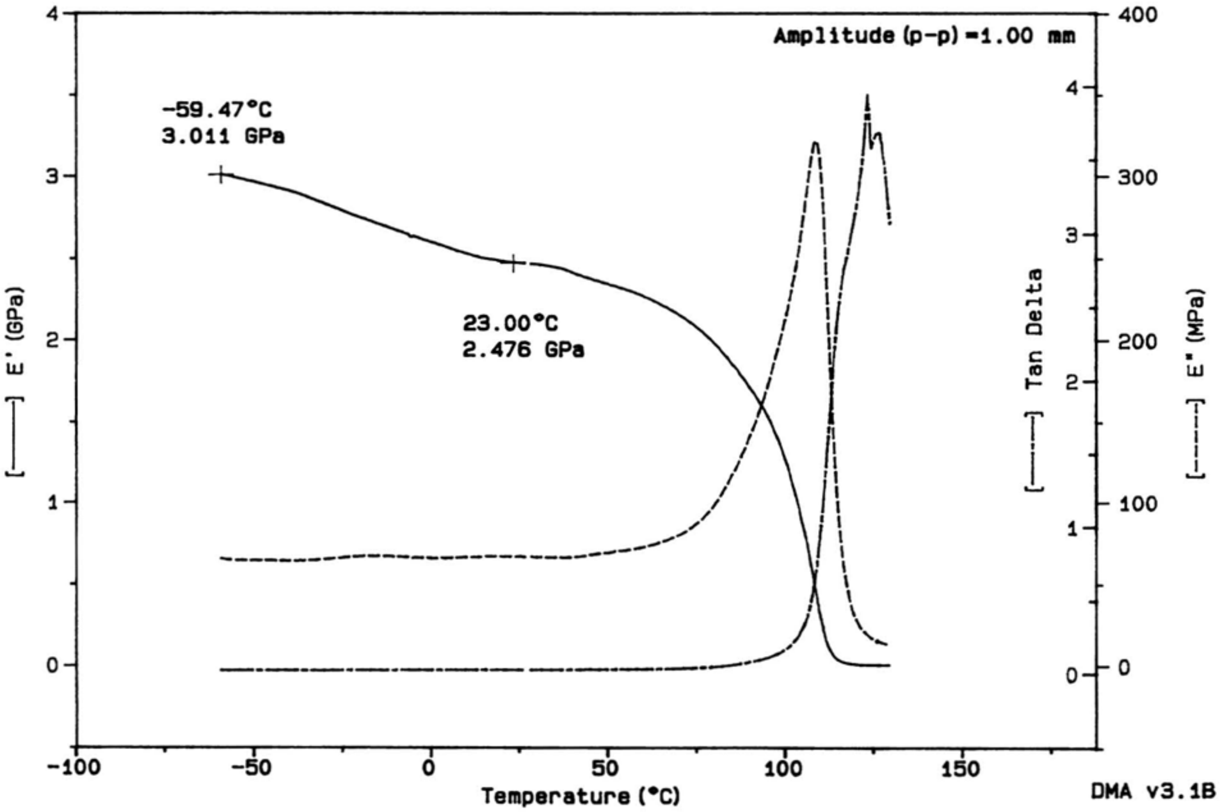
Table 99: Storage and loss properties for Dow Chemical Magnum 941 unfilled, very high impact acrylonitrile butadiene styrene (ABS). (tabular data for Graph 99)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.672	71.14	0.02662	35.00	2.228	65.86	0.02956
-55.00	2.654	70.18	0.02644	40.00	2.206	64.80	0.02937
-50.00	2.629	69.22	0.02633	45.00	2.183	64.15	0.02939
-45.00	2.597	69.45	0.02674	50.00	2.157	64.08	0.02970
-40.00	2.562	70.83	0.02764	55.00	2.126	64.86	0.03051
-35.00	2.526	72.42	0.02866	60.00	2.089	66.39	0.03178
-30.00	2.492	73.61	0.02953	65.00	2.046	69.05	0.03375
-25.00	2.460	74.16	0.03014	70.00	1.989	73.61	0.03700
-20.00	2.435	74.38	0.03055	75.00	1.921	80.62	0.04196
-15.00	2.411	74.33	0.03083	80.00	1.847	89.77	0.04859
-10.00	2.384	74.32	0.03118	85.00	1.771	100.6	0.05682
-5.00	2.361	73.94	0.03132	90.00	1.694	113.0	0.06672
0.00	2.340	73.27	0.03132	95.00	1.606	128.9	0.08024
5.00	2.324	72.09	0.03102	100.00	1.492	153.6	0.1030
10.00	2.310	70.97	0.03072	105.00	1.311	198.7	0.1516
15.00	2.298	69.93	0.03043	110.00	0.9668	309.6	0.3208
20.00	2.283	68.87	0.03017	115.00	0.3797	382.5	1.014
25.00	2.266	67.97	0.03000	120.00	0.05547	131.6	2.377
30.00	2.249	66.90	0.02975				

Table 100: Storage and loss properties for GE Plastics Cycolac KJW unfilled, flame retardant acrylonitrile butadiene styrene (ABS). (tabular data for Graph 100)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.730	81.80	0.02996	40.00	2.121	76.21	0.03593
-55.00	2.704	77.96	0.02883	45.00	2.092	75.44	0.03605
-50.00	2.676	74.56	0.02786	50.00	2.066	75.15	0.03637
-45.00	2.648	71.84	0.02713	55.00	2.035	75.39	0.03704
-40.00	2.623	70.54	0.02690	60.00	1.999	76.40	0.03821
-35.00	2.597	70.55	0.02716	65.00	1.957	78.49	0.04011
-30.00	2.567	71.63	0.02791	70.00	1.903	82.66	0.04345
-25.00	2.534	73.76	0.02911	75.00	1.837	89.54	0.04875
-20.00	2.504	76.23	0.03044	80.00	1.751	101.0	0.05768
-15.00	2.469	79.78	0.03231	85.00	1.651	116.8	0.07076
-10.00	2.427	83.05	0.03421	90.00	1.541	134.7	0.08741
-5.00	2.381	85.23	0.03579	95.00	1.404	156.4	0.1114
0.00	2.331	86.03	0.03690	100.00	1.202	186.0	0.1548
5.00	2.284	85.80	0.03757	105.00	0.8795	246.4	0.2805
10.00	2.242	84.97	0.03791	110.00	0.4207	323.8	0.7738
15.00	2.206	83.34	0.03779	115.00	0.07096	144.2	2.045
20.00	2.180	81.70	0.03747	120.00	0.01494	41.50	2.779
25.00	2.171	80.54	0.03710	125.00	0.006301	19.84	3.153
30.00	2.158	79.00	0.03661	130.00	0.003579	13.68	3.827
35.00	2.145	77.72	0.03623				

Graph 101: Storage and loss properties for GE Plastics Cycolac VW300 unfilled, halogen free flame retardant acrylonitrile butadiene styrene (ABS).



Graph 102: Storage and loss properties for RTP 601 FR 10% glass fiber filled, flame retardant acrylonitrile butadiene styrene (ABS).

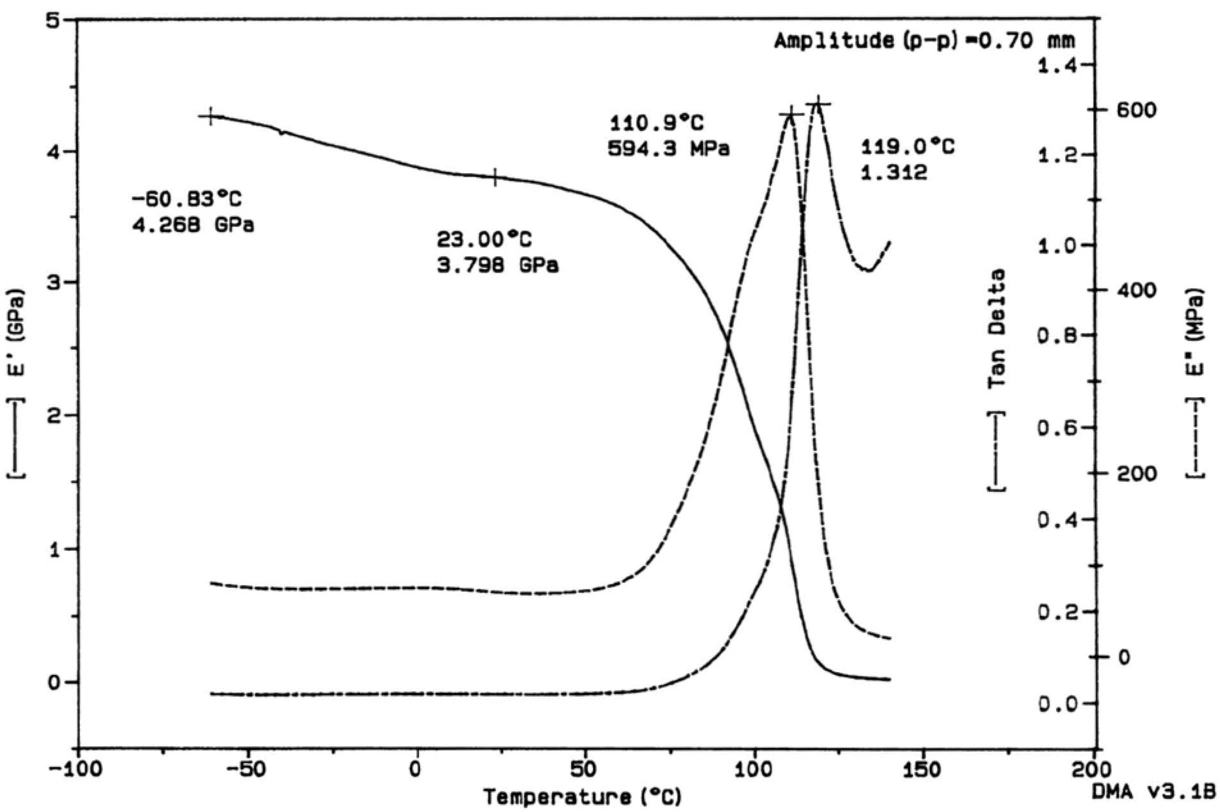


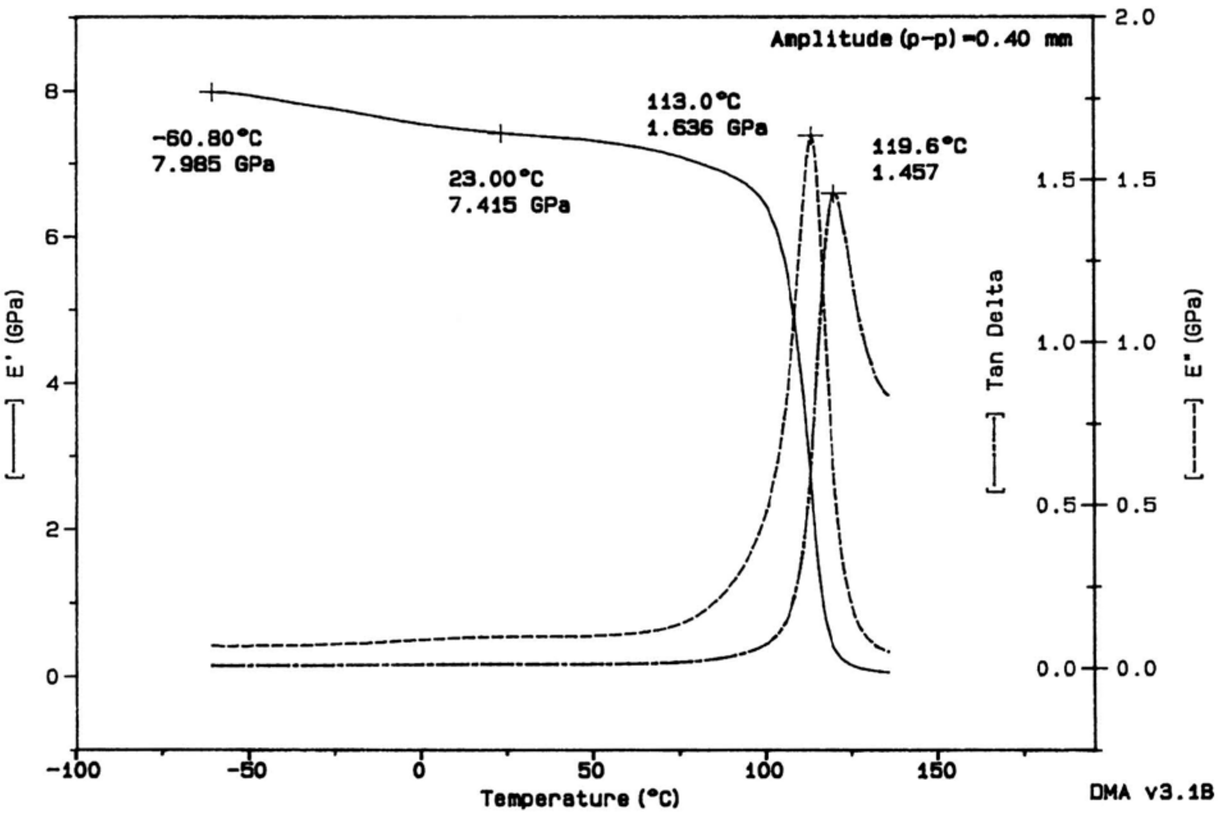
Table 101: Storage and loss properties for GE Plastics Cycolac VW300 unfilled, halogen free flame retardant acrylonitrile butadiene styrene (ABS). (tabular data for Graph 101)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.991	64.73	0.02164	40.00	2.415	66.55	0.02755
-50.00	2.965	64.79	0.02185	45.00	2.378	68.13	0.02865
-45.00	2.938	64.59	0.02199	50.00	2.345	69.47	0.02963
-40.00	2.910	64.36	0.02212	55.00	2.311	70.96	0.03070
-35.00	2.873	64.50	0.02245	60.00	2.270	73.07	0.03220
-30.00	2.831	65.23	0.02304	65.00	2.218	76.16	0.03434
-25.00	2.790	66.33	0.02378	70.00	2.157	80.39	0.03727
-20.00	2.749	67.23	0.02446	75.00	2.080	87.53	0.04208
-15.00	2.710	67.42	0.02488	80.00	1.982	99.35	0.05012
-10.00	2.673	66.82	0.02500	85.00	1.857	118.1	0.06360
-5.00	2.636	66.34	0.02516	90.00	1.714	142.5	0.08313
0.00	2.600	66.01	0.02539	95.00	1.540	173.2	0.1125
5.00	2.565	66.17	0.02580	100.00	1.270	214.7	0.1692
10.00	2.531	66.59	0.02631	105.00	0.8634	276.2	0.3204
15.00	2.502	67.15	0.02684	110.00	0.3097	300.2	0.9769
20.00	2.486	66.96	0.02693	115.00	0.03681	91.30	2.487
25.00	2.474	67.10	0.02712	120.00	0.008901	28.22	3.174
30.00	2.465	66.72	0.02707	125.00	0.004458	16.26	3.647
35.00	2.447	66.56	0.02720				

Table 102: Storage and loss properties for RTP 601 FR 10% glass fiber filled, flame retardant acrylonitrile butadiene styrene (ABS). (tabular data for Graph 102)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	4.266	80.77	0.01893	45.00	3.699	71.16	0.01924
-55.00	4.246	78.31	0.01844	50.00	3.667	72.98	0.01990
-50.00	4.223	76.68	0.01816	55.00	3.627	76.19	0.02100
-45.00	4.196	75.51	0.01800	60.00	3.574	81.80	0.02289
-40.00	4.145	74.82	0.01805	65.00	3.501	91.93	0.02626
-35.00	4.116	75.05	0.01823	70.00	3.403	110.4	0.03246
-30.00	4.078	74.98	0.01839	75.00	3.276	140.7	0.04296
-25.00	4.041	75.27	0.01863	80.00	3.126	181.3	0.05800
-20.00	4.010	75.62	0.01886	85.00	2.940	232.1	0.07896
-15.00	3.978	75.83	0.01906	90.00	2.682	300.5	0.1121
-10.00	3.946	75.95	0.01925	95.00	2.326	390.3	0.1678
-5.00	3.908	76.34	0.01953	100.00	1.919	461.4	0.2404
0.00	3.876	76.21	0.01966	105.00	1.551	518.4	0.3343
5.00	3.848	75.94	0.01973	110.00	1.070	591.0	0.5531
10.00	3.825	75.09	0.01963	115.00	0.3923	430.2	1.099
15.00	3.814	73.74	0.01933	120.00	0.1179	152.5	1.292
20.00	3.806	72.32	0.01900	125.00	0.05652	61.30	1.084
25.00	3.792	70.92	0.01870	130.00	0.03595	34.62	0.9629
30.00	3.775	69.97	0.01854	135.00	0.02591	24.51	0.9459
35.00	3.758	69.82	0.01858	140.00	0.02001	20.09	1.004
40.00	3.734	70.06	0.01877				

Graph 103: Storage and loss properties for RTP 605 30% glass fiber filled acrylonitrile butadiene styrene (ABS).



Graph 104: Storage and loss properties for RTP 607 40% glass fiber filled acrylonitrile butadiene styrene (ABS).

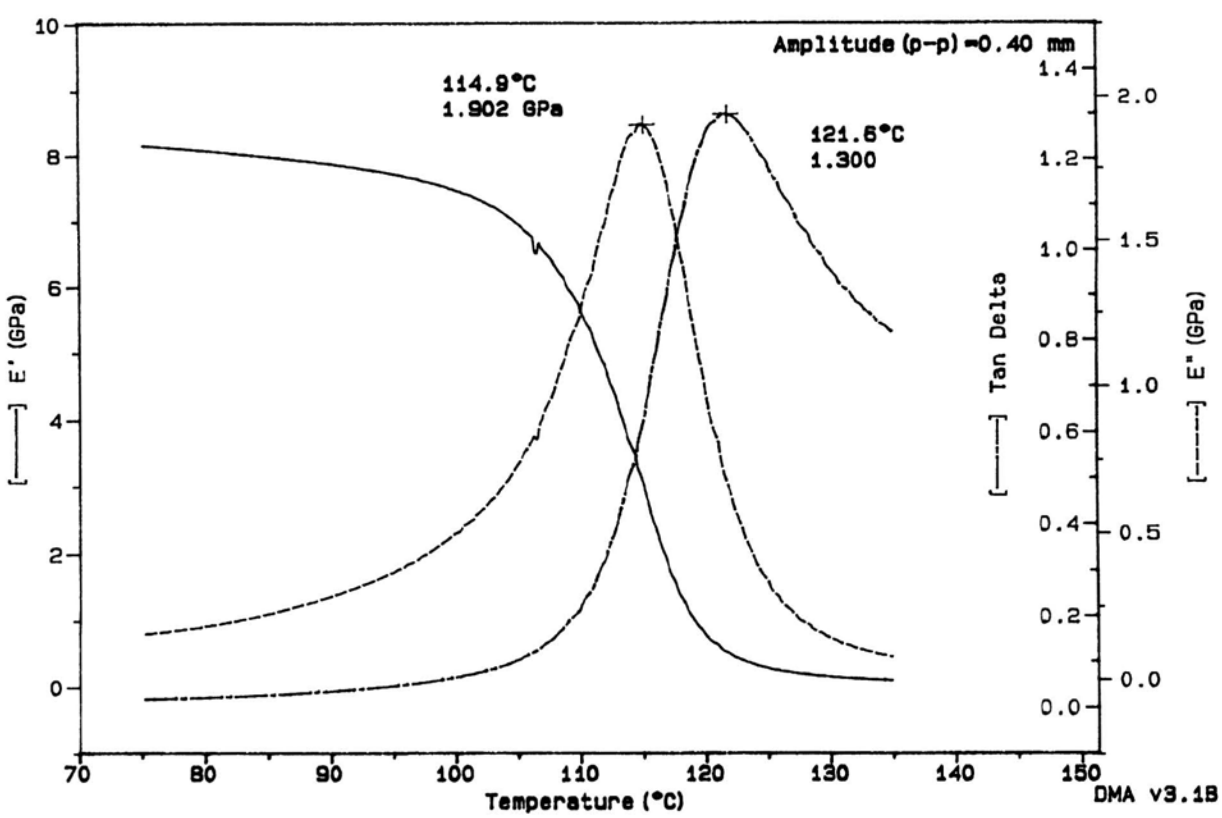


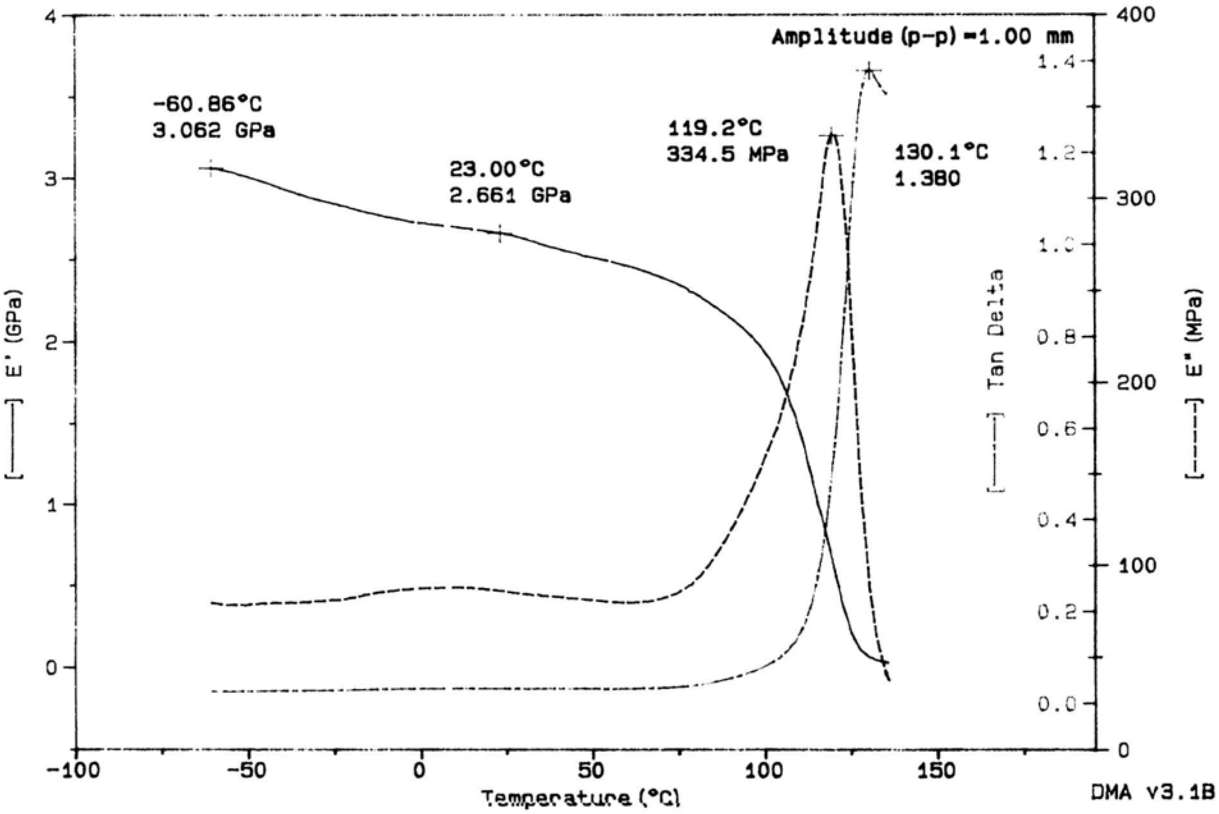
Table 103: Storage and loss properties for RTP 605 30% glass fiber filled acrylonitrile butadiene styrene (ABS). (tabular data for Graph 103)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	7.985	0.06789	0.008502	40.00	7.354	0.09596	0.01305
-55.00	7.965	0.06675	0.008380	45.00	7.337	0.09557	0.01303
-50.00	7.935	0.06708	0.008453	50.00	7.309	0.09833	0.01345
-45.00	7.897	0.06781	0.008587	55.00	7.277	0.1008	0.01386
-40.00	7.855	0.06842	0.008710	60.00	7.242	0.1047	0.01445
-35.00	7.816	0.06853	0.008768	65.00	7.200	0.1108	0.01538
-30.00	7.778	0.07011	0.009013	70.00	7.150	0.1203	0.01683
-25.00	7.743	0.07222	0.009327	75.00	7.085	0.1365	0.01926
-20.00	7.704	0.07459	0.009682	80.00	7.009	0.1618	0.02309
-15.00	7.661	0.07659	0.01000	85.00	6.926	0.2027	0.02927
-10.00	7.616	0.07949	0.01044	90.00	6.828	0.2608	0.03819
-5.00	7.575	0.08245	0.01088	95.00	6.691	0.3456	0.05164
0.00	7.538	0.08546	0.01134	100.00	6.435	0.4841	0.07523
5.00	7.505	0.08838	0.01178	105.00	5.786	0.7541	0.1304
10.00	7.477	0.09111	0.01218	110.00	4.207	1.325	0.3155
15.00	7.451	0.09316	0.01250	115.00	1.613	1.485	0.9255
20.00	7.428	0.09458	0.01273	120.00	0.3670	0.5360	1.460
25.00	7.407	0.09511	0.01284	125.00	0.1513	0.1824	1.205
30.00	7.388	0.09573	0.01296	130.00	0.08729	0.08335	0.9546
35.00	7.370	0.09585	0.01301	135.00	0.06013	0.05062	0.8419

Table 104: Storage and loss properties for RTP 607 40% glass fiber filled acrylonitrile butadiene styrene (ABS). (tabular data for Graph 104)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	9.178	0.08437	0.009192	40.00	8.459	0.1231	0.01455
-55.00	9.198	0.08011	0.008709	45.00	8.423	0.1246	0.01480
-50.00	9.119	0.07907	0.008671	50.00	8.385	0.1264	0.01507
-45.00	9.076	0.07571	0.008342	55.00	8.348	0.1280	0.01533
-40.00	9.048	0.07480	0.008267	60.00	8.311	0.1303	0.01568
-35.00	9.015	0.07594	0.008423	65.00	8.273	0.1347	0.01628
-30.00	8.970	0.07849	0.008751	70.00	8.226	0.1427	0.01735
-25.00	8.927	0.08095	0.009068	75.00	8.162	0.1591	0.01950
-20.00	8.887	0.08344	0.009389	80.00	8.078	0.1875	0.02321
-15.00	8.844	0.08830	0.009985	85.00	7.979	0.2295	0.02876
-10.00	8.804	0.09250	0.01051	90.00	7.867	0.2895	0.03681
-5.00	8.760	0.09760	0.01114	95.00	7.713	0.3722	0.04826
0.00	8.713	0.1039	0.01193	100.00	7.470	0.5030	0.06734
5.00	8.664	0.1106	0.01277	105.00	6.969	0.7381	0.1059
10.00	8.620	0.1155	0.01340	110.00	5.668	1.258	0.2222
15.00	8.582	0.1175	0.01369	115.00	3.025	1.899	0.6304
20.00	8.556	0.1191	0.01392	120.00	0.7770	0.9729	1.254
25.00	8.537	0.1191	0.01395	125.00	0.2791	0.3312	1.186
30.00	8.517	0.1202	0.01411	130.00	0.1486	0.1423	0.957
35.00	8.493	0.1219	0.01435				

Graph 105: Storage and loss properties for Ticona Celstran ABS SS6 6% long stainless steel fiber acrylonitrile butadiene styrene (ABS).



Graph 106: Storage and loss properties for Dow Chemical Styron 484 unfilled high impact polystyrene (HIPS).

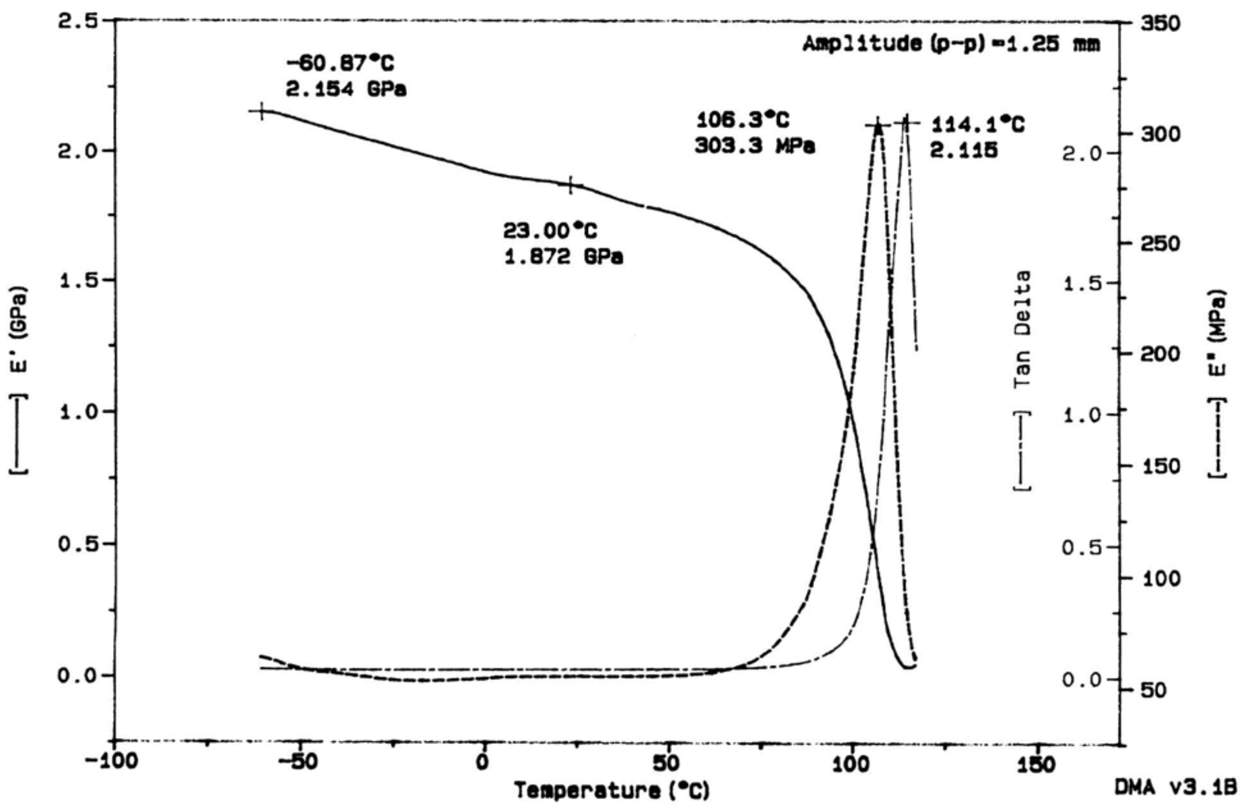


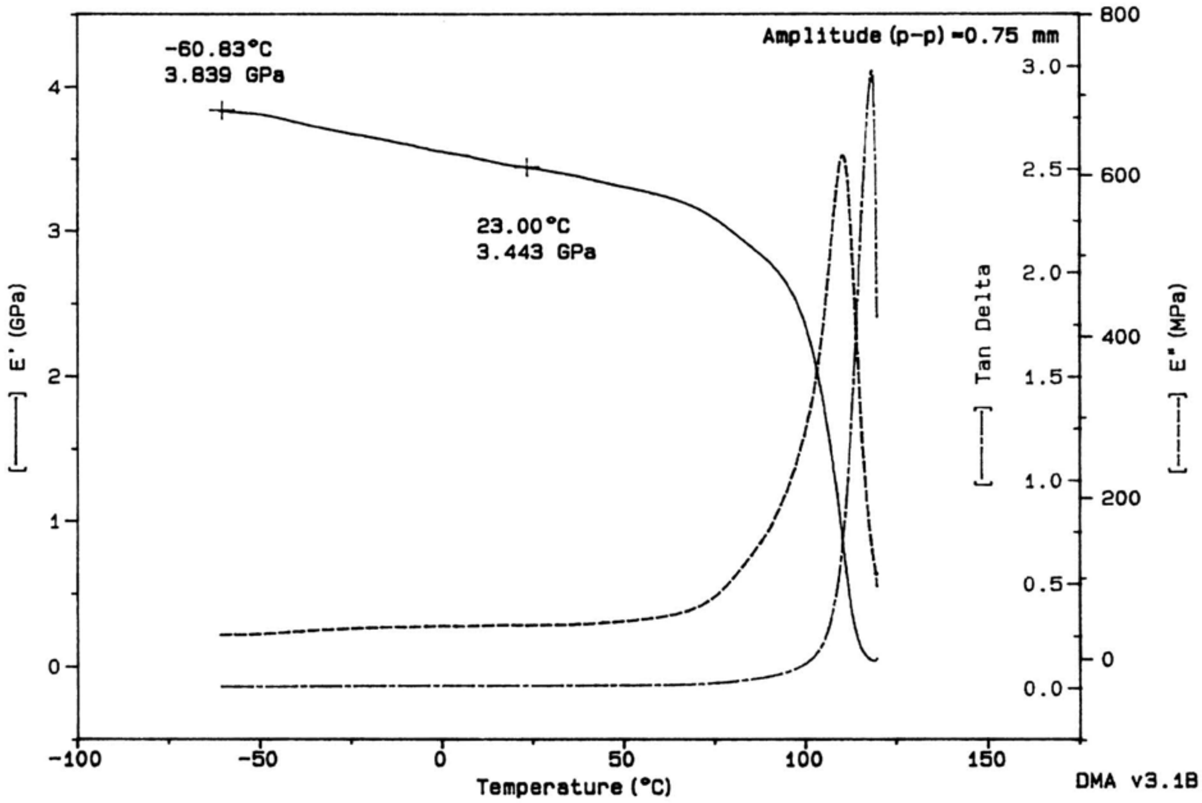
Table 105: Storage and loss properties for Ticona Celstran ABS SS6 6% long stainless steel fiber acrylonitrile butadiene styrene (ABS). (tabular data for Graph 105)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.060	79.02	0.02583	40.00	2.564	82.53	0.03219
-55.00	3.035	78.17	0.02576	45.00	2.539	81.63	0.03216
-50.00	3.005	78.48	0.02611	50.00	2.512	80.77	0.03215
-45.00	2.971	79.04	0.02661	60.00	2.461	79.54	0.03232
-40.00	2.931	79.33	0.02707	65.00	2.429	80.09	0.03297
-35.00	2.897	79.66	0.02750	70.00	2.391	82.05	0.03431
-30.00	2.865	80.23	0.02800	75.00	2.349	85.58	0.03644
-25.00	2.839	80.79	0.02846	80.00	2.292	92.76	0.04048
-20.00	2.810	82.06	0.02920	85.00	2.222	104.4	0.04699
-15.00	2.783	84.13	0.03023	90.00	2.145	119.6	0.05575
-10.00	2.760	85.40	0.03095	95.00	2.055	138.2	0.06723
-5.00	2.739	86.62	0.03162	100.00	1.933	160.5	0.08305
0.00	2.723	87.26	0.03204	105.00	1.749	186.2	0.1065
5.00	2.710	87.51	0.03229	110.00	1.454	224.9	0.1548
10.00	2.696	87.80	0.03256	115.00	1.038	281.3	0.2712
15.00	2.683	87.34	0.03255	120.00	0.6099	335.5	0.5511
20.00	2.670	86.58	0.03243	125.00	0.2157	232.7	1.081
25.00	2.653	85.35	0.03218	130.00	0.06596	90.99	1.380
30.00	2.627	84.16	0.03204	135.00	0.03047	40.54	1.330
35.00	2.593	83.17	0.03207				

Table 106: Storage and loss properties for Dow Chemical Styron 484 unfilled high impact polystyrene (HIPS). (tabular data for Graph 106)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.153	62.97	0.02925	30.00	1.845	54.86	0.02972
-55.00	2.140	60.35	0.02820	35.00	1.821	54.96	0.03017
-50.00	2.118	57.98	0.02737	40.00	1.800	55.05	0.03059
-45.00	2.097	56.80	0.02708	45.00	1.784	55.08	0.03088
-40.00	2.076	55.92	0.02693	50.00	1.767	55.37	0.03134
-35.00	2.057	55.01	0.02675	55.00	1.745	55.69	0.03192
-30.00	2.038	53.84	0.02641	60.00	1.722	56.51	0.03281
-25.00	2.018	53.11	0.02631	65.00	1.693	58.00	0.03426
-20.00	1.999	52.76	0.02639	70.00	1.660	60.22	0.03628
-15.00	1.980	52.84	0.02669	75.00	1.618	64.12	0.03963
-10.00	1.961	52.91	0.02698	80.00	1.565	71.47	0.04566
-5.00	1.941	53.36	0.02750	85.00	1.497	83.17	0.05556
0.00	1.922	53.86	0.02803	90.00	1.395	104.2	0.07467
5.00	1.907	54.46	0.02856	95.00	1.230	138.4	0.1125
10.00	1.896	54.68	0.02884	100.00	0.9723	191.1	0.1967
15.00	1.888	54.75	0.02900	105.00	0.5715	288.5	0.5064
20.00	1.879	54.73	0.02913	110.00	0.1586	224.8	1.424
25.00	1.866	54.82	0.02938	115.00	0.04131	79.31	1.920

Graph 107: Storage and loss properties for Bayer Lustran SAN31 unfilled styrene acrylonitrile copolymer (SAN).



Graph 108: Storage and loss properties for Bayer Triax 1125 unfilled acrylonitrile butadiene styrene/ nylon alloy (ABS/ nylon alloy).

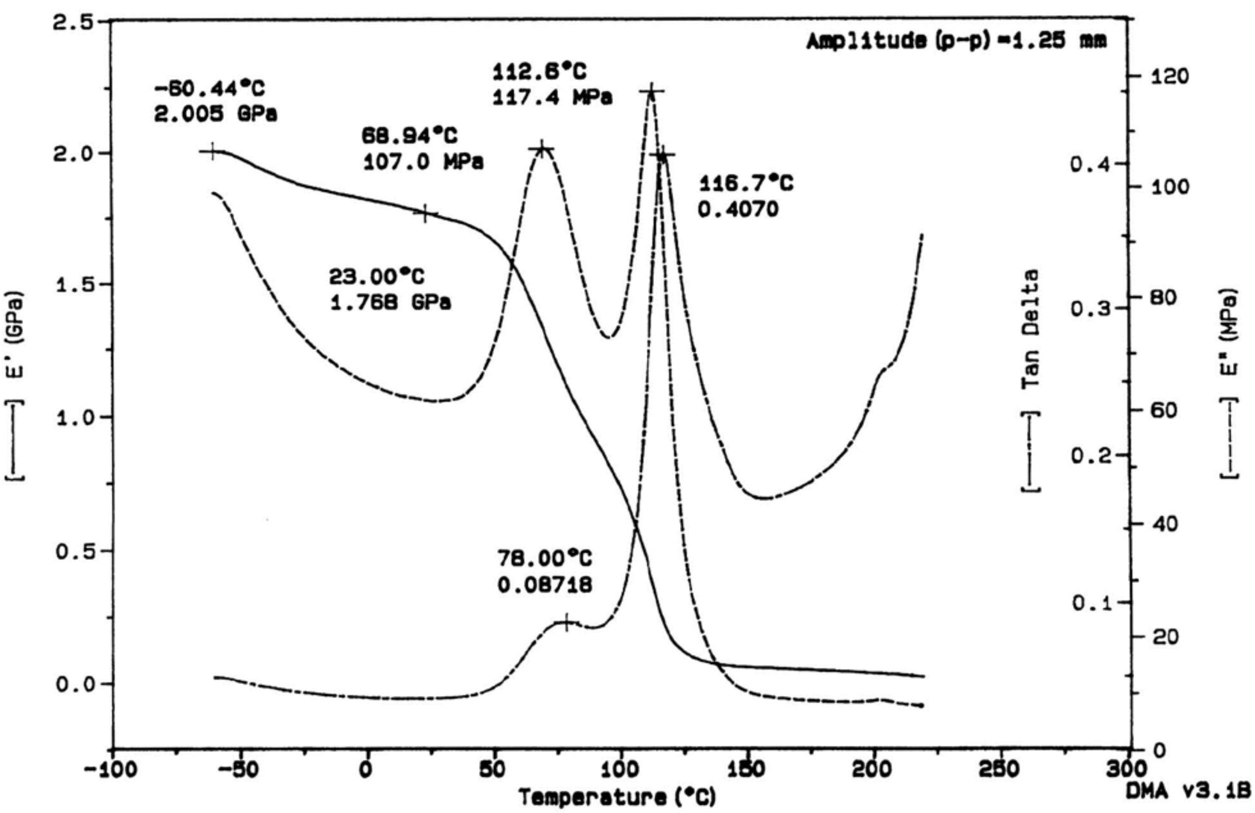


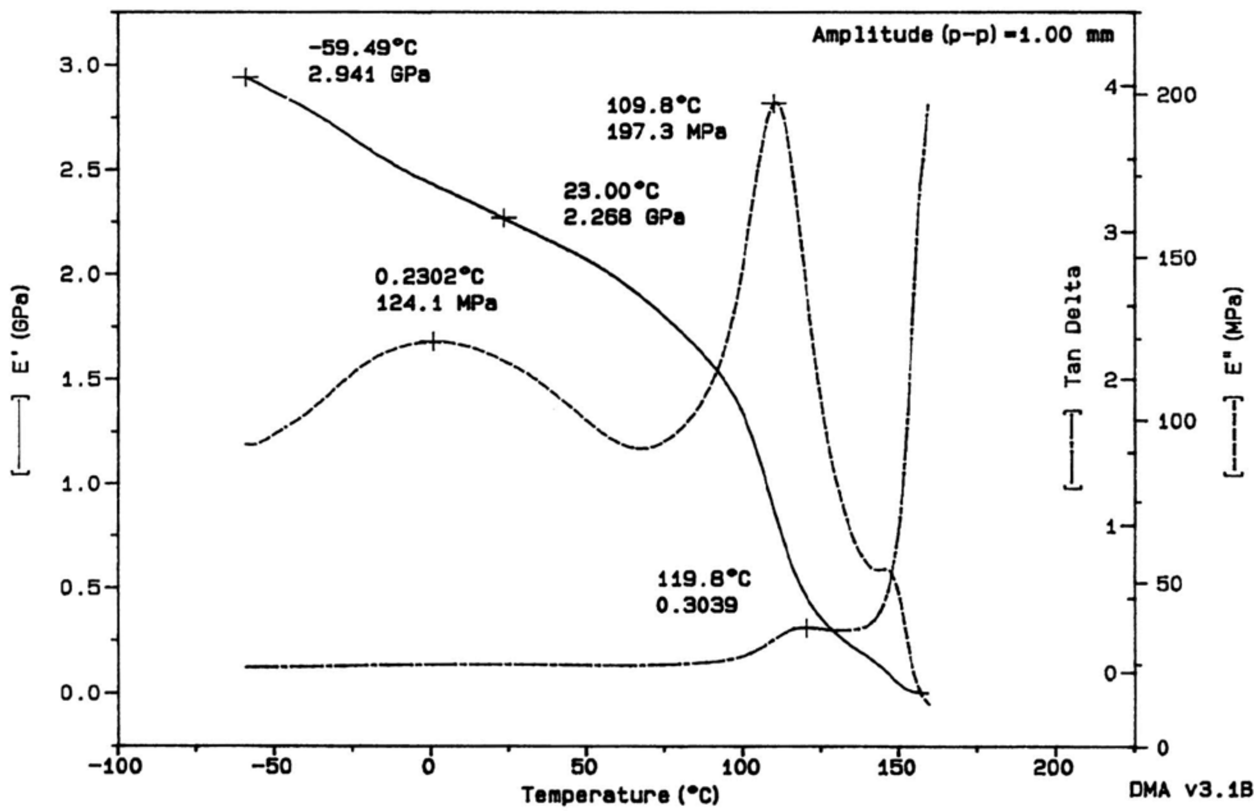
Table 107: Storage and loss properties for Bayer Lustran SAN31 unfilled styrene acrylonitrile copolymer (SAN). (tabular data for Graph 107)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.837	29.93	0.007800	30.00	3.414	42.41	0.01242
-55.00	3.824	30.33	0.007930	35.00	3.392	42.72	0.01260
-50.00	3.812	31.05	0.008146	40.00	3.364	43.59	0.01296
-45.00	3.788	32.37	0.008546	45.00	3.334	45.02	0.01350
-40.00	3.757	34.15	0.009091	50.00	3.306	46.83	0.01417
-35.00	3.728	35.62	0.009556	55.00	3.280	49.13	0.01498
-30.00	3.703	36.79	0.009936	60.00	3.250	52.13	0.01604
-25.00	3.676	37.84	0.01029	65.00	3.212	56.69	0.01765
-20.00	3.654	38.67	0.01058	70.00	3.161	64.22	0.02032
-15.00	3.631	39.35	0.01084	75.00	3.089	77.67	0.02514
-10.00	3.605	39.69	0.01101	80.00	2.998	100.2	0.03342
-5.00	3.577	40.44	0.01131	85.00	2.897	128.9	0.04449
0.00	3.550	40.83	0.01150	90.00	2.791	161.9	0.05800
5.00	3.529	40.61	0.01151	95.00	2.640	210.9	0.07989
10.00	3.503	41.31	0.01179	100.00	2.366	282.9	0.1196
15.00	3.476	41.91	0.01206	105.00	1.832	413.6	0.2260
20.00	3.452	42.04	0.01218	110.00	0.9367	621.7	0.6671
25.00	3.435	42.00	0.01223	115.00	0.1564	328.6	2.113

Table 108: Storage and loss properties for Bayer Triax 1125 unfilled acrylonitrile butadiene styrene/ nylon alloy (ABS/ nylon alloy). (tabular data for Graph 108)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.005	99.12	0.04944	80.00	1.087	94.34	0.08678
-55.00	1.997	96.70	0.04842	85.00	0.9944	83.84	0.08431
-50.00	1.979	91.87	0.04643	90.00	0.9101	76.10	0.08362
-45.00	1.954	87.11	0.04458	95.00	0.8247	72.96	0.08847
-40.00	1.931	82.94	0.04296	100.00	0.7315	75.97	0.1039
-35.00	1.909	79.07	0.04142	105.00	0.6149	87.85	0.1430
-30.00	1.890	75.62	0.04002	110.00	0.4681	110.5	0.2364
-25.00	1.873	73.09	0.03903	115.00	0.2810	108.1	0.3854
-20.00	1.861	70.81	0.03805	120.00	0.1629	62.50	0.3834
-15.00	1.850	69.05	0.03733	125.00	0.1137	35.31	0.3104
-10.00	1.839	67.53	0.03672	130.00	0.08952	23.85	0.2663
-5.00	1.829	66.07	0.03612	135.00	0.07496	17.41	0.2323
0.00	1.819	64.93	0.03569	140.00	0.06678	13.81	0.2068
5.00	1.809	63.99	0.03536	145.00	0.06189	11.49	0.1857
10.00	1.800	63.12	0.03507	150.00	0.05874	10.25	0.1744
15.00	1.788	62.53	0.03498	155.00	0.05633	9.637	0.1711
20.00	1.777	62.15	0.03498	160.00	0.05414	9.286	0.1715
25.00	1.762	61.80	0.03507	165.00	0.05199	9.053	0.1741
30.00	1.748	61.89	0.03540	170.00	0.05001	8.886	0.1777
35.00	1.736	62.25	0.03585	175.00	0.04794	8.747	0.1825
40.00	1.721	63.60	0.03696	180.00	0.04581	8.636	0.1885
45.00	1.696	66.47	0.03918	185.00	0.04359	8.538	0.1959
50.00	1.661	71.90	0.04330	190.00	0.04123	8.499	0.2062
55.00	1.608	80.85	0.05028	195.00	0.03878	8.543	0.2203
60.00	1.530	92.98	0.06077	200.00	0.03611	8.796	0.2436
65.00	1.428	103.4	0.07239	205.00	0.03344	8.669	0.2592
70.00	1.312	107.2	0.08177	210.00	0.03041	8.213	0.2701
75.00	1.193	103.4	0.08668	215.00	0.02658	7.977	0.3002

Graph 109: Storage and loss properties for Cyro Cyrex RDG200 unfilled, impact modified acrylic/ polycarbonate alloy (acrylic/ PC alloy).



Graph 110: Storage and loss properties for Bayer Bayblend FR1441 brominated flame retardant polycarbonate/ acrylonitrile butadiene styrene alloy (PC/ ABS alloy).

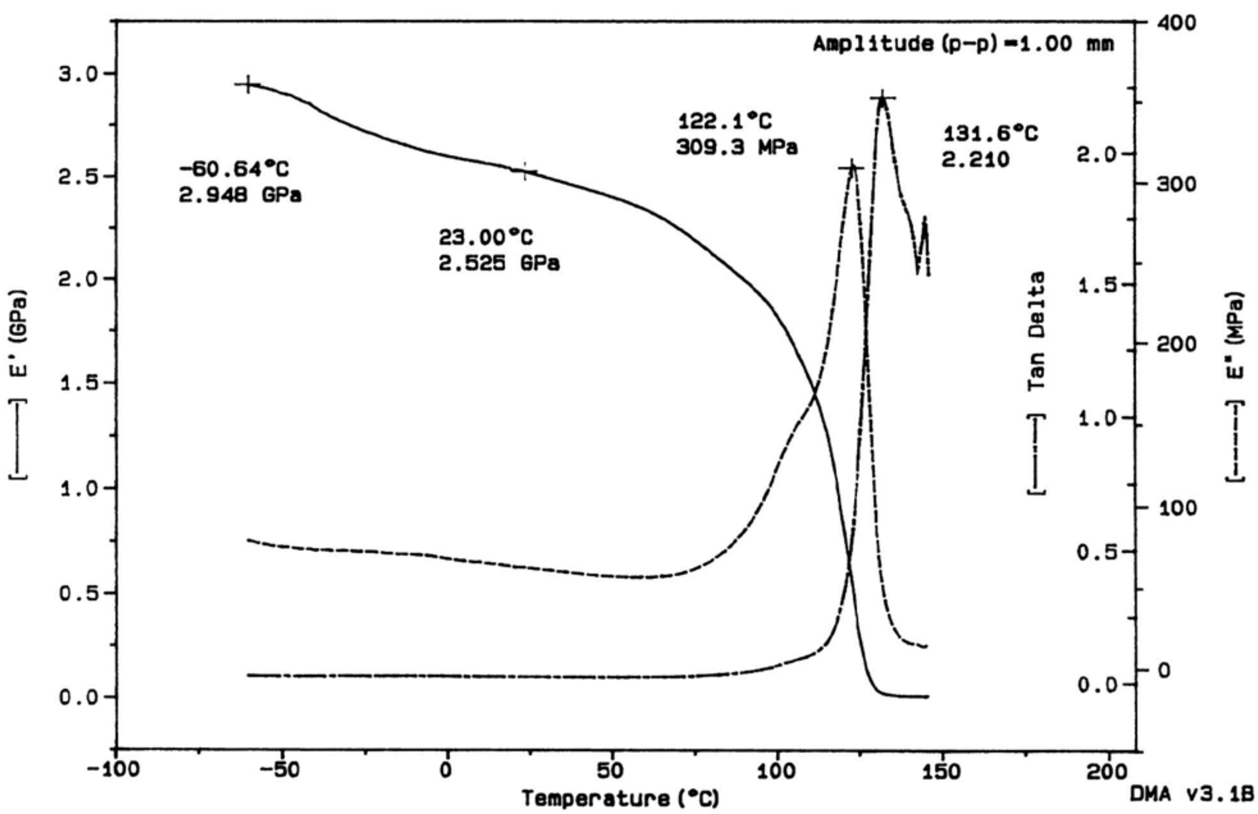


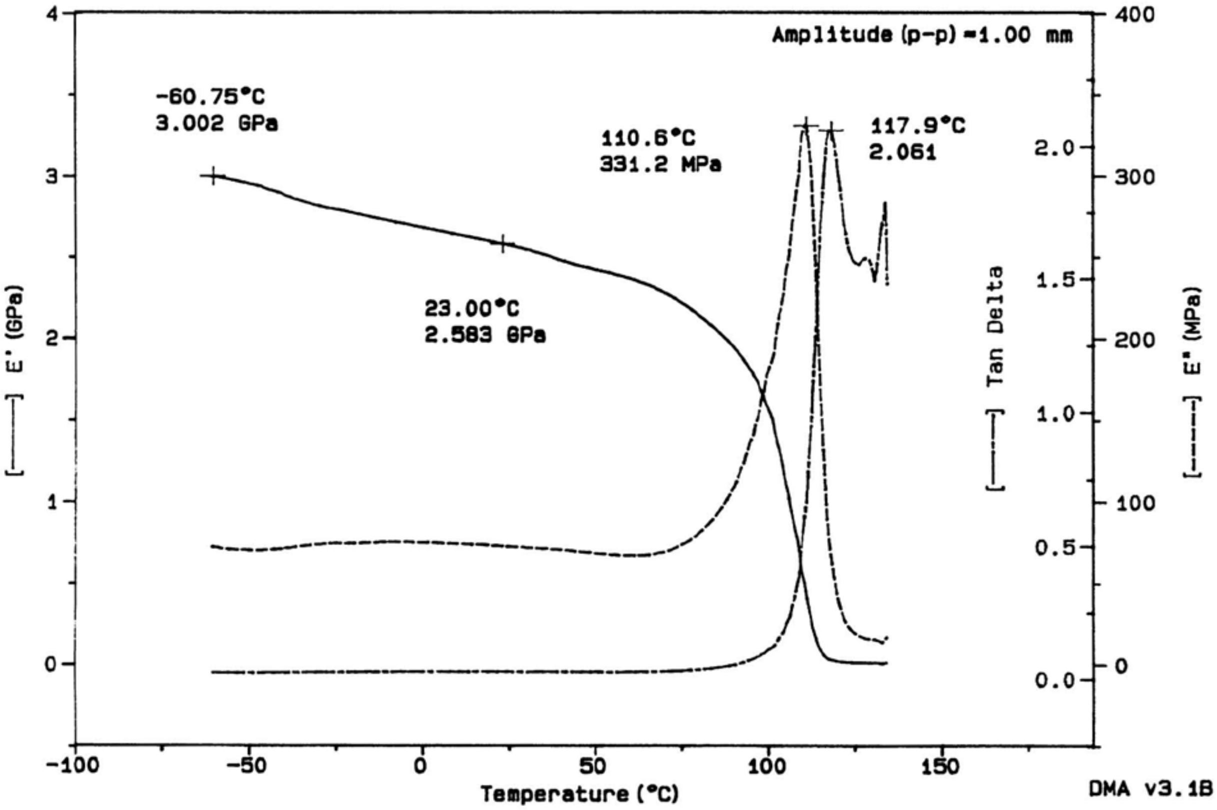
Table 109: Storage and loss properties for Cyro Cyrex RDG200 unfilled, impact modified acrylic/ polycarbonate alloy (acrylic/ PC alloy). (tabular data for Graph 109)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.910	93.13	0.03200	55.00	2.024	96.01	0.04743
-50.00	2.869	95.92	0.03343	60.00	1.976	93.02	0.04708
-45.00	2.834	98.94	0.03491	65.00	1.921	91.53	0.04765
-40.00	2.792	102.1	0.03659	70.00	1.862	91.71	0.04926
-35.00	2.748	106.2	0.03865	75.00	1.797	93.82	0.05222
-30.00	2.699	110.5	0.04093	80.00	1.728	97.62	0.05651
-25.00	2.648	114.5	0.04325	85.00	1.654	103.2	0.06240
-20.00	2.598	118.1	0.04544	90.00	1.572	111.9	0.07121
-15.00	2.551	120.8	0.04733	95.00	1.472	125.6	0.08534
-10.00	2.507	122.5	0.04888	100.00	1.336	148.8	0.1114
-5.00	2.467	123.6	0.05010	105.00	1.127	179.9	0.1597
0.00	2.432	124.1	0.05101	110.00	0.8704	197.4	0.2269
5.00	2.398	123.9	0.05168	115.00	0.6346	181.8	0.2866
10.00	2.363	123.0	0.05204	120.00	0.4647	141.2	0.3038
15.00	2.329	121.7	0.05226	125.00	0.3552	104.4	0.2940
20.00	2.291	119.6	0.05222	130.00	0.2799	80.15	0.2864
25.00	2.252	117.2	0.05205	135.00	0.2218	64.21	0.2895
30.00	2.216	114.6	0.05172	140.00	0.1732	55.49	0.3205
35.00	2.181	111.3	0.05103	145.00	0.1161	54.18	0.4679
40.00	2.144	107.5	0.05014	150.00	0.04564	45.67	1.008
45.00	2.108	103.7	0.04921	155.00	0.007851	21.00	2.692
50.00	2.068	99.73	0.04822				

Table 110: Storage and loss properties for Bayer Bayblend FR1441 brominated flame retardant polycarbonate/ acrylonitrile butadiene styrene alloy (PC/ ABS alloy). (tabular data for Graph 110)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.946	78.87	0.02677	45.00	2.426	57.95	0.02389
-55.00	2.930	76.66	0.02617	50.00	2.401	57.36	0.02389
-50.00	2.903	75.23	0.02592	55.00	2.373	57.05	0.02404
-45.00	2.874	74.30	0.02585	60.00	2.339	56.95	0.02435
-40.00	2.828	73.42	0.02596	65.00	2.298	57.58	0.02506
-35.00	2.785	73.23	0.02630	70.00	2.248	59.27	0.02637
-30.00	2.750	72.94	0.02652	75.00	2.189	62.66	0.02863
-25.00	2.717	72.46	0.02667	80.00	2.126	67.96	0.03197
-20.00	2.689	71.79	0.02670	85.00	2.061	75.80	0.03677
-15.00	2.662	71.14	0.02672	90.00	1.994	86.69	0.04347
-10.00	2.637	70.65	0.02679	95.00	1.917	103.1	0.05377
-5.00	2.616	69.63	0.02661	100.00	1.814	126.4	0.06966
0.00	2.598	68.05	0.02619	105.00	1.675	147.6	0.08813
5.00	2.582	66.75	0.02585	110.00	1.499	164.5	0.1097
10.00	2.569	65.79	0.02561	115.00	1.246	203.4	0.1634
15.00	2.554	64.58	0.02529	120.00	0.8093	282.8	0.3507
20.00	2.530	63.13	0.02495	125.00	0.2716	267.3	0.9939
25.00	2.517	62.35	0.02477	130.00	0.03711	78.32	2.119
30.00	2.495	61.25	0.02455	135.00	0.01259	25.00	1.985
35.00	2.473	60.04	0.02428	140.00	0.009185	15.95	1.737
40.00	2.450	58.92	0.02405	145.00	0.009178	15.29	1.684

Graph 111: Storage and loss properties for Bayer Bayblend FR110 halogen free flame retardant polycarbonate/ acrylonitrile butadiene styrene alloy (PC/ ABS alloy).



Graph 112: Storage and loss properties for GE Plastics Xenoy 6123 unfilled, impact modified polycarbonate polybutylene terephthalate alloy (PC/ polyester PBT alloy).

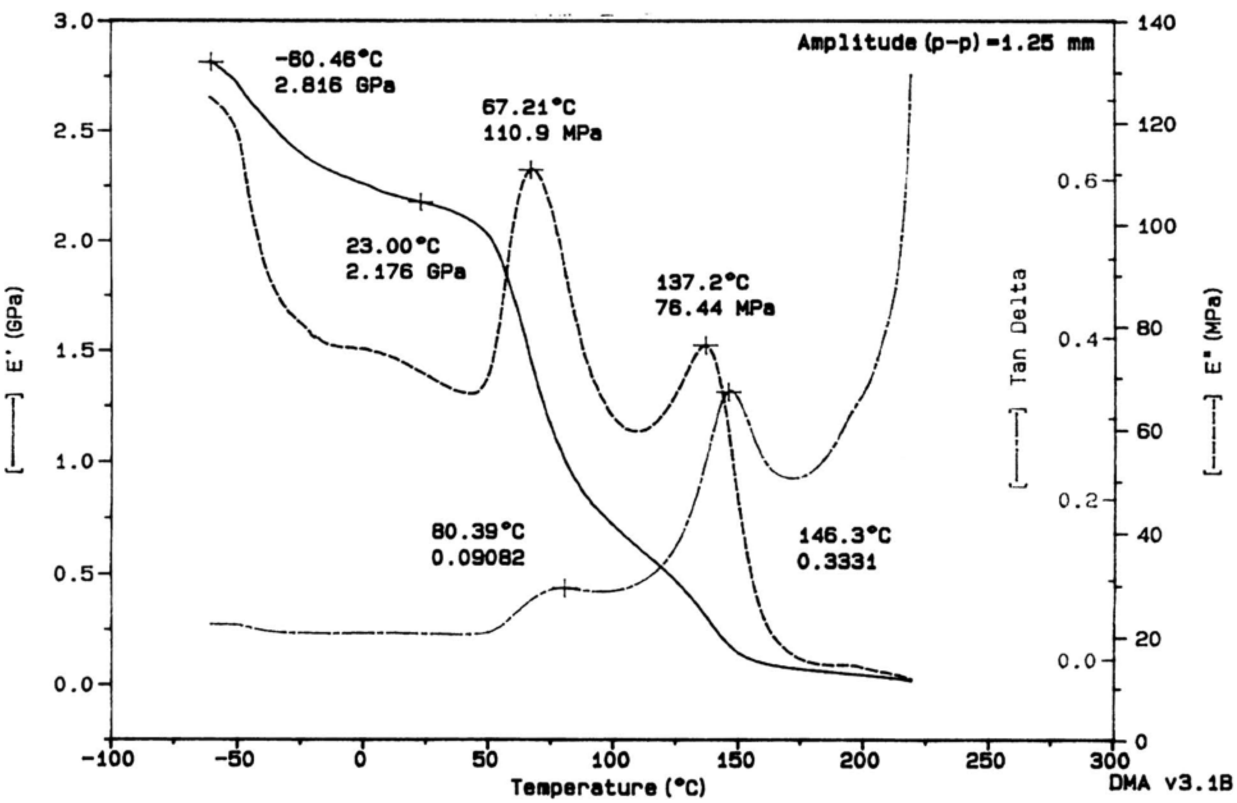


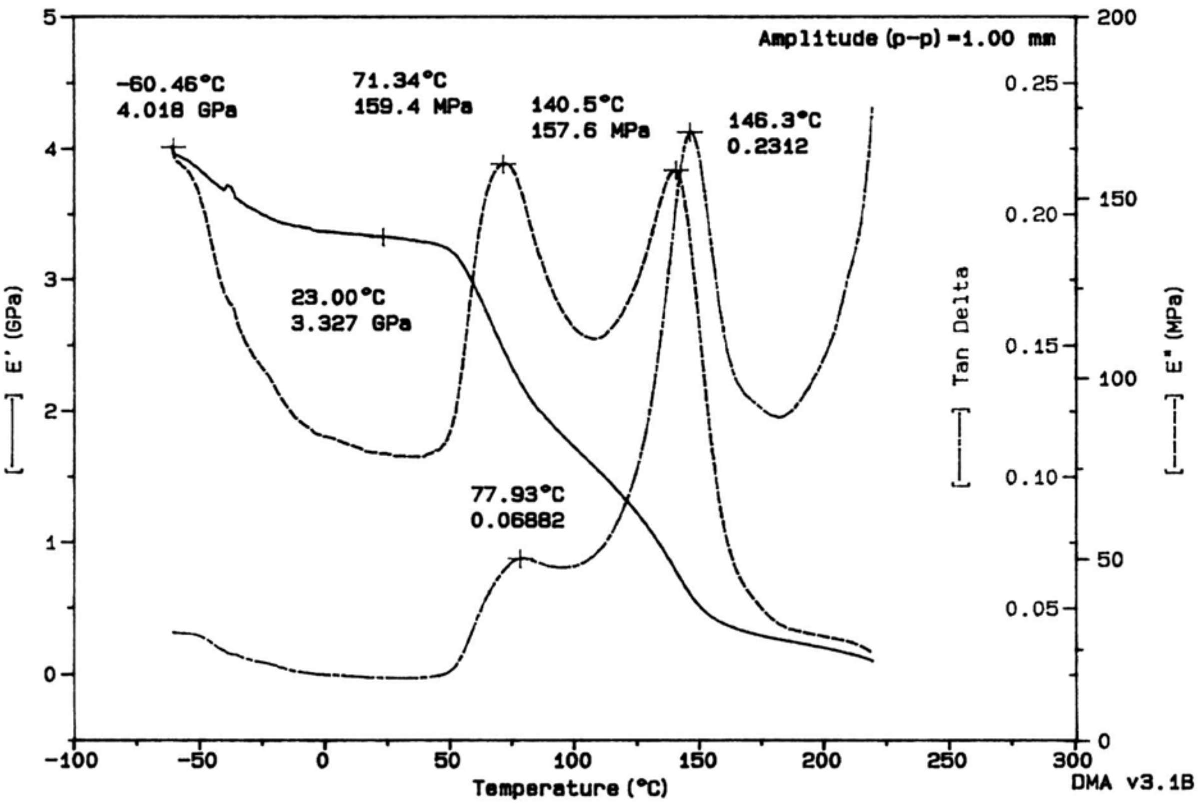
Table 111: Storage and loss properties for Bayer Bayblend FR110 halogen free flame retardant polycarbonate/ acrylonitrile butadiene styrene alloy (PC/ ABS alloy). (tabular data for Graph 111)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.001	72.50	0.02416	40.00	2.483	70.63	0.02844
-55.00	2.980	70.99	0.02382	45.00	2.451	69.65	0.02841
-50.00	2.957	70.43	0.02382	50.00	2.425	68.56	0.02827
-45.00	2.925	70.75	0.02419	55.00	2.399	67.60	0.02817
-40.00	2.888	71.70	0.02482	60.00	2.370	67.43	0.02845
-35.00	2.850	73.10	0.02565	65.00	2.333	67.70	0.02901
-30.00	2.818	74.20	0.02633	70.00	2.285	69.77	0.03053
-25.00	2.795	75.04	0.02684	75.00	2.223	74.22	0.03339
-20.00	2.774	74.96	0.02702	80.00	2.148	81.27	0.03784
-15.00	2.750	75.28	0.02738	85.00	2.058	92.67	0.04502
-10.00	2.728	75.74	0.02777	90.00	1.955	109.7	0.05608
-5.00	2.705	75.67	0.02797	95.00	1.811	138.5	0.07644
0.00	2.683	75.26	0.02805	100.00	1.583	180.9	0.1143
5.00	2.662	74.91	0.02814	105.00	1.159	238.2	0.2059
10.00	2.641	74.50	0.02821	110.00	0.5818	326.9	0.5646
15.00	2.620	74.07	0.02828	115.00	0.1005	170.5	1.705
20.00	2.598	73.35	0.02824	120.00	0.02169	41.24	1.900
25.00	2.574	72.84	0.02830	125.00	0.01234	19.26	1.561
30.00	2.549	71.87	0.02819	130.00	0.01018	15.66	1.539
35.00	2.519	71.46	0.02837				

Table 112: Storage and loss properties for GE Plastics Xenoy 6123 unfilled, impact modified polycarbonate polybutylene terephthalate alloy (PC/ polyester PBT alloy). (tabular data for Graph 112)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.814	125.0	0.04442	80.00	1.038	94.27	0.09086
-55.00	2.773	122.7	0.04426	85.00	0.9232	82.26	0.08910
-50.00	2.723	118.5	0.04353	90.00	0.8390	73.02	0.08703
-45.00	2.639	105.4	0.03992	95.00	0.7765	67.08	0.08638
-40.00	2.574	94.29	0.03663	100.00	0.7204	62.76	0.08712
-35.00	2.510	87.52	0.03486	105.00	0.6678	60.41	0.09047
-30.00	2.452	83.40	0.03401	110.00	0.6206	59.82	0.09639
-25.00	2.403	80.86	0.03364	115.00	0.5737	60.57	0.1056
-20.00	2.362	78.23	0.03312	120.00	0.5255	62.93	0.1198
-15.00	2.331	76.93	0.03301	125.00	0.4731	66.50	0.1406
-10.00	2.305	76.12	0.03302	130.00	0.4135	71.25	0.1724
-5.00	2.283	75.97	0.03327	135.00	0.3449	75.78	0.2199
0.00	2.261	75.68	0.03347	140.00	0.2679	75.05	0.2803
5.00	2.238	75.14	0.03357	145.00	0.1979	64.93	0.3282
10.00	2.215	74.42	0.03360	150.00	0.1453	47.46	0.3267
15.00	2.200	73.41	0.03337	155.00	0.1153	33.37	0.2893
20.00	2.185	72.07	0.03298	160.00	0.09708	24.50	0.2523
25.00	2.171	70.76	0.03259	165.00	0.08533	19.90	0.2332
30.00	2.156	69.28	0.03213	170.00	0.07673	17.39	0.2266
35.00	2.138	68.09	0.03185	175.00	0.06988	15.87	0.2272
40.00	2.113	67.24	0.03182	180.00	0.06410	15.06	0.2350
45.00	2.081	67.15	0.03228	185.00	0.05883	14.73	0.2504
50.00	2.032	70.12	0.03452	190.00	0.05361	14.67	0.2736
55.00	1.930	81.42	0.04220	195.00	0.04843	14.67	0.3029
60.00	1.762	98.78	0.05607	200.00	0.04332	14.19	0.3276
65.00	1.570	109.4	0.06968	205.00	0.03762	13.60	0.3616
70.00	1.356	110.3	0.08139	210.00	0.03158	13.14	0.4161
75.00	1.177	104.4	0.08867	215.00	0.02525	12.60	0.4992

Graph 113: Storage and loss properties for GE Plastics Xenoy 6240 10% glass fiber filled, impact modified polycarbonate polybutylene terephthalate alloy (PC/ polyester PBT alloy).



Graph 114: Storage and loss properties for Bayer Makroblend UT1018 unfilled, impact modified polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy).

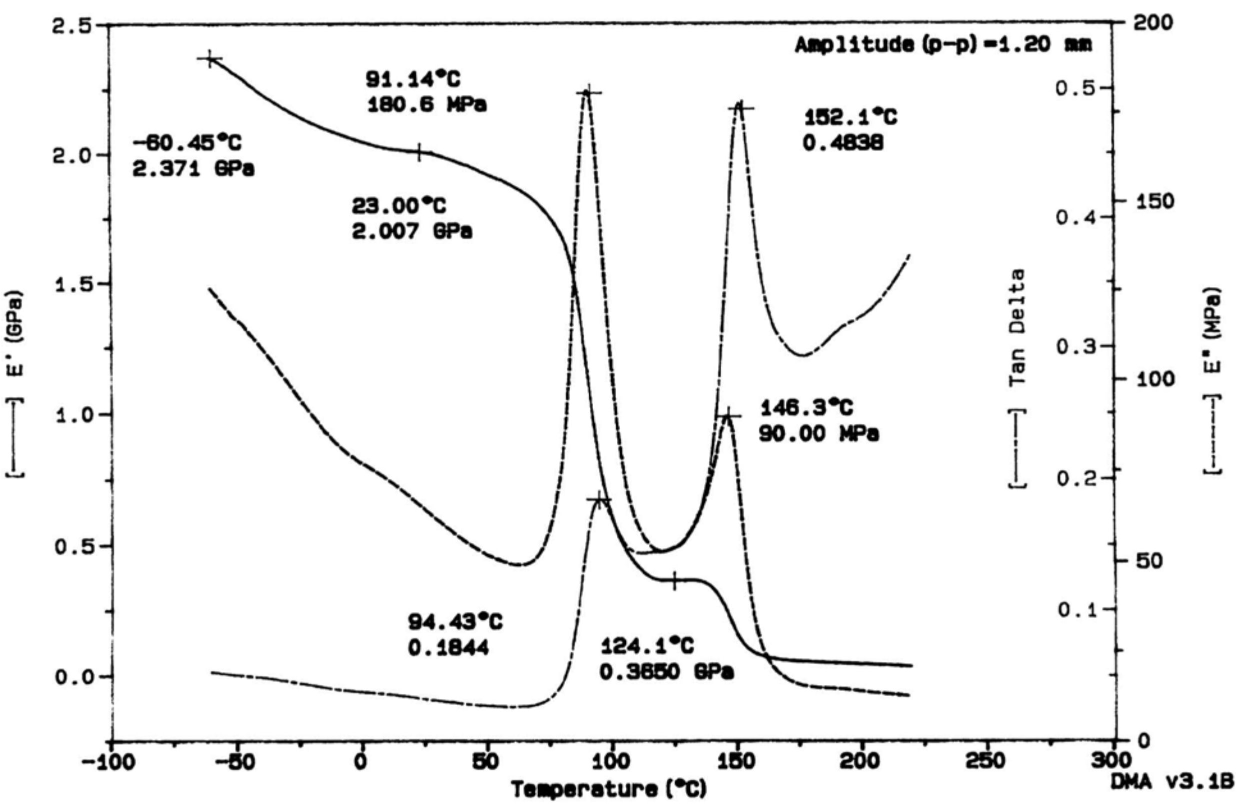


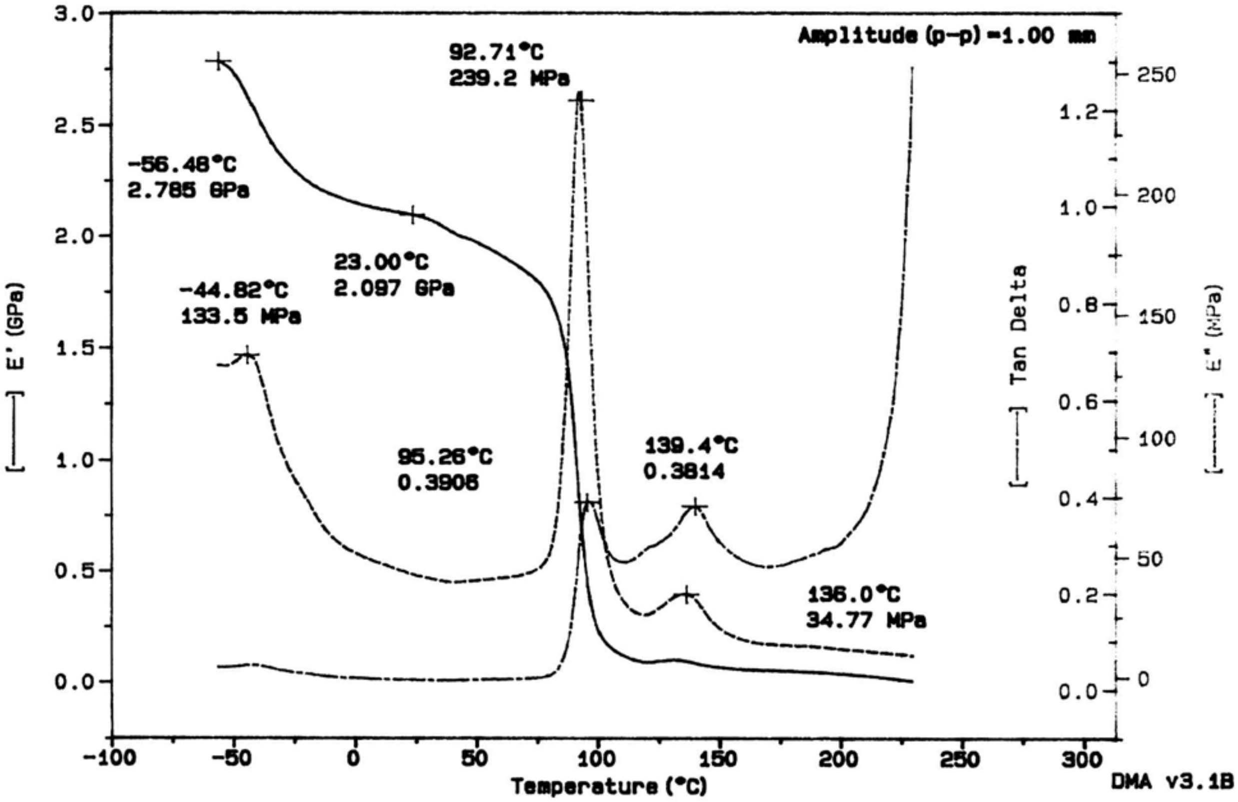
Table 113: Storage and loss properties for GE Plastics Xenoy 6240 10% glass fiber filled, impact modified polycarbonate polybutylene terephthalate alloy (PC/ polyester PBT alloy). (tabular data for Graph 113)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.992	162.4	0.04068	80.00	2.177	150.0	0.06890
-55.00	3.921	158.2	0.04033	85.00	2.032	136.8	0.06735
-50.00	3.852	151.8	0.03940	90.00	1.927	126.8	0.06581
-45.00	3.764	137.9	0.03663	95.00	1.826	119.3	0.06533
-40.00	3.690	124.0	0.03361	100.00	1.732	114.1	0.06587
-35.00	3.626	116.6	0.03216	105.00	1.639	111.4	0.06800
-30.00	3.559	108.4	0.03045	110.00	1.544	111.1	0.07194
-25.00	3.505	103.1	0.02943	115.00	1.446	113.8	0.07872
-20.00	3.459	97.94	0.02831	120.00	1.340	118.8	0.08868
-15.00	3.427	92.15	0.02689	125.00	1.229	126.3	0.1028
-10.00	3.407	88.17	0.02588	130.00	1.105	136.7	0.1237
-5.00	3.386	85.66	0.02530	135.00	0.9633	149.4	0.1552
0.00	3.367	83.85	0.02490	140.00	0.8041	157.5	0.1960
5.00	3.359	82.83	0.02466	145.00	0.6433	146.9	0.2284
10.00	3.348	81.56	0.02436	150.00	0.5160	115.0	0.2227
15.00	3.342	80.36	0.02404	155.00	0.4313	81.07	0.1879
20.00	3.332	79.46	0.02385	160.00	0.3781	58.33	0.1543
25.00	3.325	79.00	0.02376	165.00	0.3407	46.56	0.1366
30.00	3.313	78.46	0.02368	170.00	0.3111	40.39	0.1298
35.00	3.300	78.22	0.02371	175.00	0.2870	36.12	0.1258
40.00	3.284	78.42	0.02388	180.00	0.2669	32.83	0.1230
45.00	3.268	80.06	0.02450	185.00	0.2494	30.84	0.1236
50.00	3.230	84.68	0.02621	190.00	0.2326	29.85	0.1283
55.00	3.134	101.6	0.03241	195.00	0.2150	29.15	0.1356
60.00	2.966	129.8	0.04375	200.00	0.1966	28.47	0.1448
65.00	2.769	150.5	0.05436	205.00	0.1764	27.75	0.1573
70.00	2.554	158.7	0.06214	210.00	0.1530	27.01	0.1765
75.00	2.350	158.6	0.06750	215.00	0.1308	25.74	0.1969

Table 114: Storage and loss properties for Bayer Makroblend UT1018 unfilled, impact modified polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy). (tabular data for Graph 114)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.369	125.3	0.05288	80.00	1.685	76.84	0.04562
-55.00	2.343	120.8	0.05156	85.00	1.522	127.4	0.08381
-50.00	2.308	117.0	0.05067	90.00	1.171	180.8	0.1546
-45.00	2.273	113.3	0.04984	95.00	0.8187	151.2	0.1847
-40.00	2.235	108.9	0.04876	100.00	0.6072	103.3	0.1701
-35.00	2.201	104.6	0.04751	105.00	0.4894	73.86	0.1509
-30.00	2.171	99.86	0.04600	110.00	0.4194	60.47	0.1442
-25.00	2.143	94.97	0.04431	115.00	0.3780	54.62	0.1445
-20.00	2.119	90.38	0.04266	120.00	0.3650	52.89	0.1449
-15.00	2.098	85.97	0.04098	125.00	0.3649	54.08	0.1482
-10.00	2.080	82.42	0.03963	130.00	0.3657	57.15	0.1563
-5.00	2.062	79.42	0.03851	135.00	0.3612	63.45	0.1757
0.00	2.046	77.12	0.03769	140.00	0.3347	74.06	0.2214
5.00	2.032	75.09	0.03695	145.00	0.2630	88.81	0.3383
10.00	2.021	72.83	0.03604	150.00	0.1574	75.95	0.4829
15.00	2.014	70.27	0.03489	155.00	0.09708	42.29	0.4352
20.00	2.010	67.40	0.03353	160.00	0.07438	26.21	0.3522
25.00	2.004	64.46	0.03216	165.00	0.06364	20.05	0.3151
30.00	1.995	61.61	0.03089	170.00	0.05749	17.26	0.3003
35.00	1.979	58.89	0.02976	175.00	0.05370	15.76	0.2935
40.00	1.961	56.24	0.02868	180.00	0.05116	15.11	0.2954
45.00	1.944	53.93	0.02775	185.00	0.04918	14.87	0.3024
50.00	1.922	51.93	0.02703	190.00	0.04718	14.70	0.3116
55.00	1.901	50.47	0.02655	195.00	0.04516	14.37	0.3182
60.00	1.879	49.38	0.02628	200.00	0.04306	13.93	0.3234
65.00	1.851	49.40	0.02669	205.00	0.04091	13.54	0.3310
70.00	1.814	51.53	0.02841	210.00	0.03871	13.24	0.3421
75.00	1.759	59.09	0.03359	215.00	0.03637	12.95	0.3561

Graph 115: Storage and loss properties for MRC Polymers Stanuloy ST125 unfilled, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy).



Graph 116: Storage and loss properties for MRC Polymers Stanuloy ST110WCS impact modified, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy).

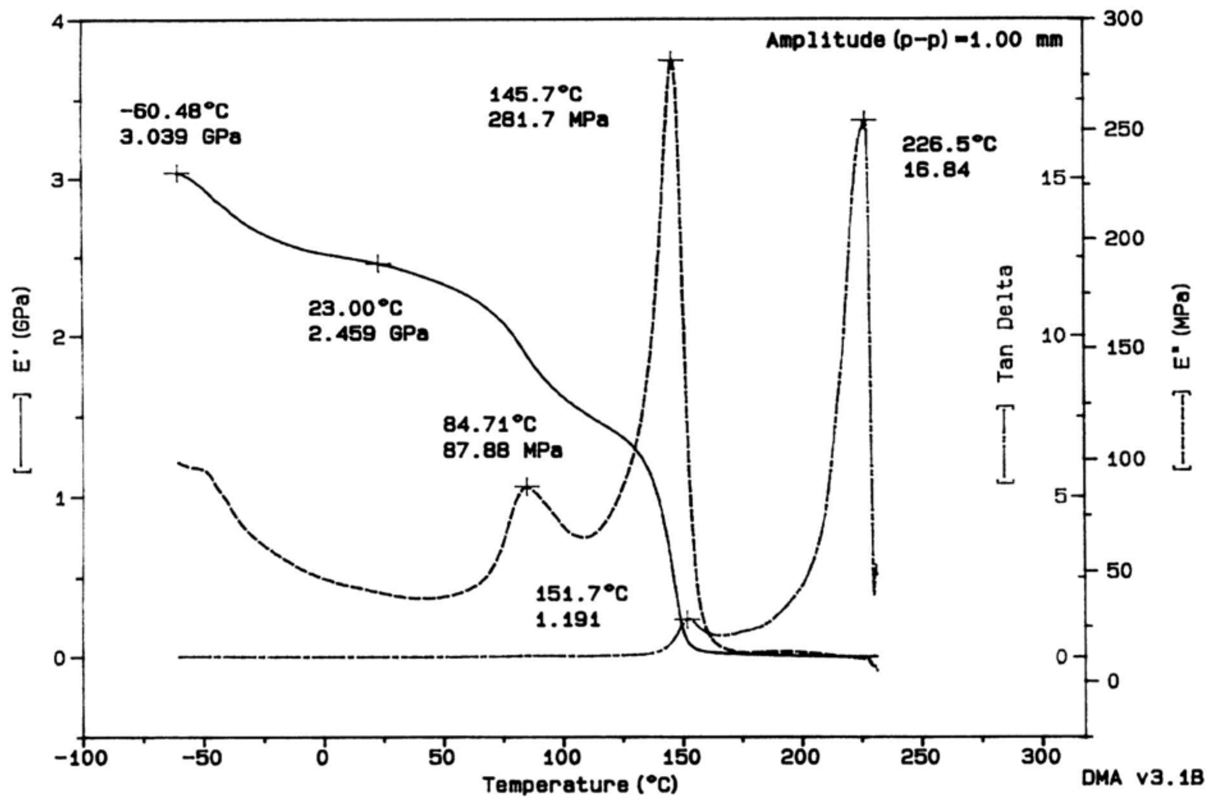


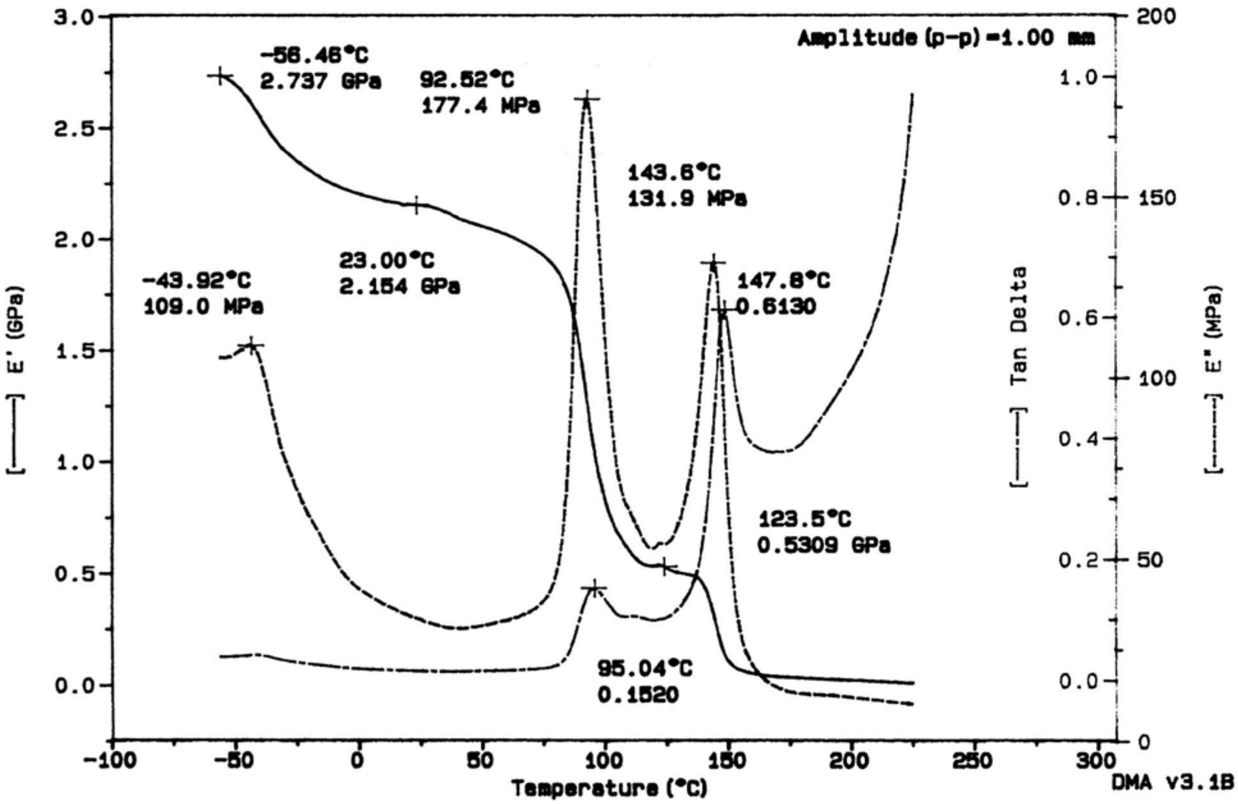
Table 115: Storage and loss properties for MRC Polymers Stanuloy ST125 unfilled, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy). (tabular data for Graph 115)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.778	129.0	0.04644	90.00	1.145	210.3	0.1848
-50.00	2.730	130.3	0.04772	95.00	0.4963	192.1	0.3875
-45.00	2.638	133.5	0.05061	100.00	0.2365	82.86	0.3500
-40.00	2.533	127.2	0.05022	105.00	0.1581	44.35	0.2804
-35.00	2.432	109.0	0.04481	110.00	0.1219	32.36	0.2654
-30.00	2.355	93.01	0.03950	115.00	0.1001	27.34	0.2732
-25.00	2.295	82.16	0.03581	120.00	0.08941	26.27	0.2938
-20.00	2.248	73.69	0.03278	125.00	0.09499	29.14	0.3067
-15.00	2.213	65.08	0.02941	130.00	0.1012	33.01	0.3262
-10.00	2.187	58.59	0.02679	135.00	0.09639	34.86	0.3617
-5.00	2.166	54.37	0.02510	140.00	0.08481	32.34	0.3813
0.00	2.148	51.48	0.02396	145.00	0.07414	25.51	0.3440
5.00	2.134	49.19	0.02305	150.00	0.06646	20.38	0.3066
10.00	2.122	47.36	0.02232	155.00	0.06124	17.36	0.2835
15.00	2.111	45.51	0.02156	160.00	0.05790	15.49	0.2675
20.00	2.103	43.94	0.02089	165.00	0.05555	14.35	0.2584
25.00	2.092	42.34	0.02024	170.00	0.05400	13.84	0.2564
30.00	2.076	41.23	0.01986	175.00	0.05224	13.55	0.2593
40.00	2.016	39.48	0.01958	180.00	0.04987	13.34	0.2675
45.00	1.993	39.94	0.02004	190.00	0.04501	12.75	0.2832
50.00	1.972	40.44	0.02051	195.00	0.04183	12.31	0.2944
55.00	1.944	40.89	0.02104	200.00	0.03851	11.80	0.3065
60.00	1.914	41.49	0.02168	205.00	0.03419	11.40	0.3336
65.00	1.881	42.11	0.02239	210.00	0.02982	11.01	0.3693
70.00	1.844	43.20	0.02342	215.00	0.02425	10.56	0.4358
75.00	1.799	45.28	0.02517	220.00	0.01840	10.09	0.5489
80.00	1.727	52.44	0.03037	225.00	0.01214	9.601	0.7924

Table 116: Storage and loss properties for MRC Polymers Stanuloy ST110WCS impact modified, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy). (tabular data for Graph 116)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	3.038	98.88	0.03254	90.00	1.777	83.79	0.04714
-55.00	3.004	96.87	0.03225	95.00	1.693	77.32	0.04568
-50.00	2.945	95.73	0.03250	100.00	1.622	70.40	0.04341
-45.00	2.870	89.02	0.03102	105.00	1.565	66.16	0.04227
-40.00	2.811	81.16	0.02888	110.00	1.515	65.46	0.04321
-35.00	2.746	72.30	0.02633	115.00	1.467	68.61	0.04678
-30.00	2.693	66.33	0.02463	120.00	1.421	76.12	0.05357
-25.00	2.651	61.79	0.02330	125.00	1.371	87.61	0.06390
-20.00	2.615	58.00	0.02218	130.00	1.303	104.0	0.07985
-15.00	2.586	54.68	0.02114	135.00	1.193	133.0	0.1115
-10.00	2.560	51.64	0.02017	140.00	0.9880	189.2	0.1919
-5.00	2.539	49.09	0.01933	145.00	0.6213	276.1	0.4476
0.00	2.524	46.96	0.01861	150.00	0.1804	188.7	1.056
5.00	2.511	45.18	0.01799	155.00	0.05256	56.69	1.076
10.00	2.497	43.85	0.01756	160.00	0.03133	24.03	0.7662
15.00	2.484	42.75	0.01721	165.00	0.02407	16.36	0.6798
20.00	2.470	41.44	0.01678	170.00	0.01990	14.11	0.7092
25.00	2.452	40.34	0.01645	175.00	0.01641	13.22	0.8060
30.00	2.435	39.16	0.01608	180.00	0.01478	13.23	0.8955
40.00	2.386	38.24	0.01603	190.00	0.01008	13.68	1.358
45.00	2.360	38.22	0.01620	195.00	0.007842	13.65	1.741
50.00	2.331	38.88	0.01668	200.00	0.005975	13.28	2.225
55.00	2.299	40.11	0.01745	205.00	0.004180	12.82	3.071
60.00	2.262	42.04	0.01859	210.00	0.002693	12.23	4.554
65.00	2.216	45.01	0.02031	215.00	0.001451	11.58	7.999
70.00	2.158	50.99	0.02362	220.00	8.644E-4	11.08	12.84
75.00	2.090	62.60	0.02996	225.00	6.301E-4	10.41	16.52
80.00	1.996	80.31	0.04023	230.00	0.003972	6.852	1.986

Graph 117: Storage and loss properties for MRC Polymers Stanuloy ST150 unfilled, impact modified, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy).



Graph 118: Storage and loss properties for Bayer Makroblend UT403 unfilled, impact modified, UV stabilized, low viscosity polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy).

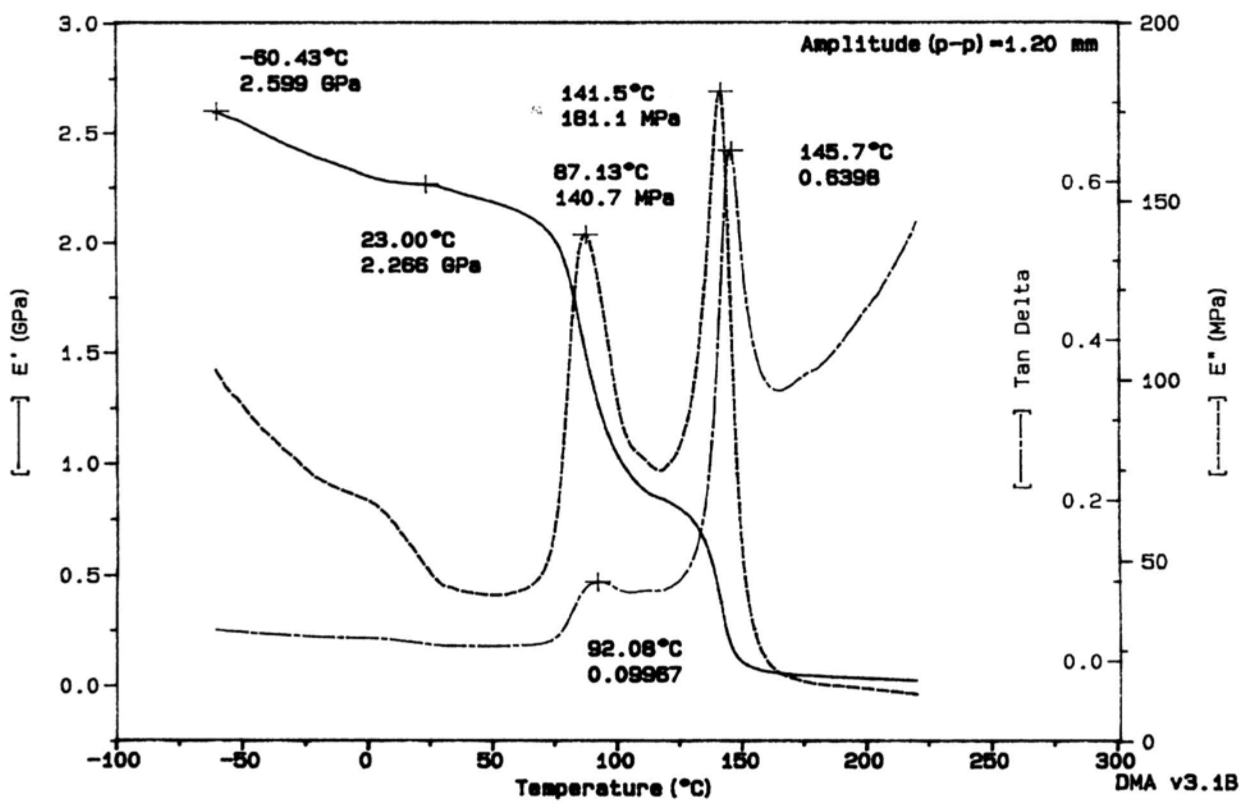


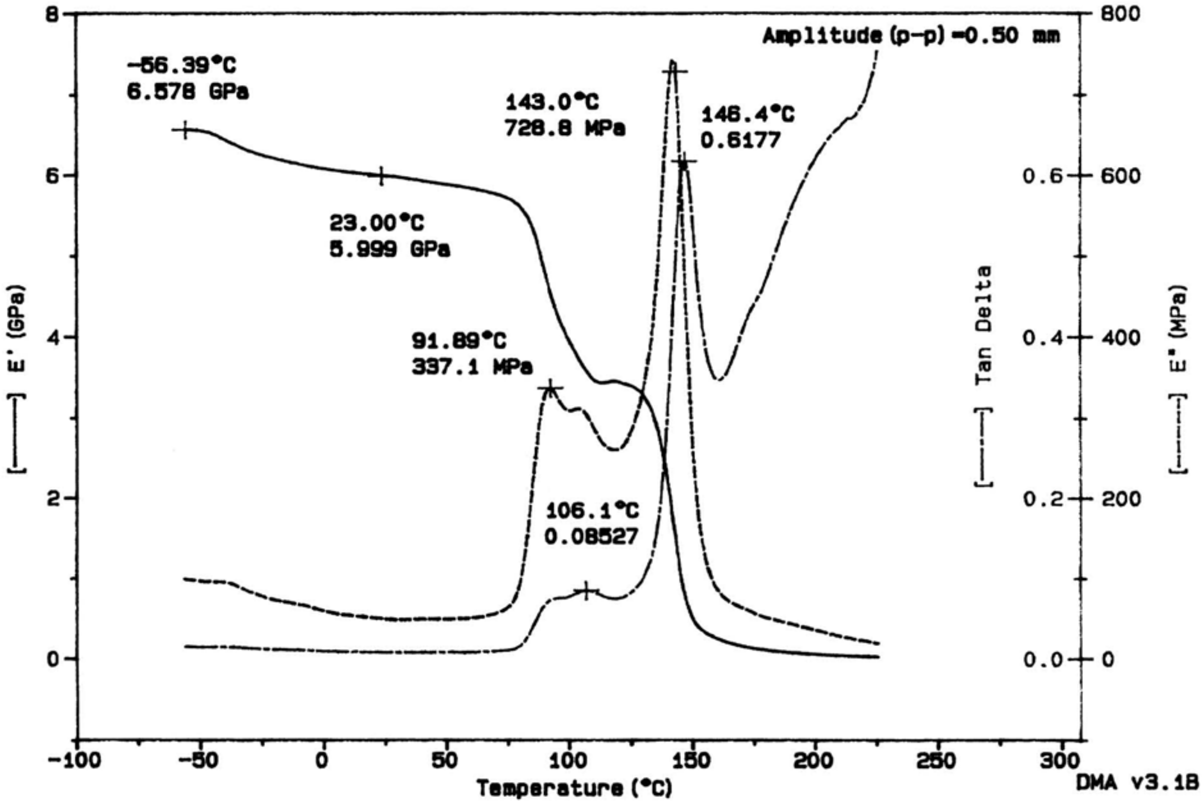
Table 117: Storage and loss properties for MRC Polymers Stanuloy ST150 unfilled, impact modified, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy). (tabular data for Graph 117)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	2.731	105.6	0.03865	85.00	1.748	80.30	0.04597
-50.00	2.694	106.8	0.03966	90.00	1.475	161.8	0.1099
-45.00	2.633	109.0	0.04139	95.00	1.076	163.6	0.1520
-40.00	2.545	104.1	0.04091	100.00	0.8231	108.7	0.1321
-35.00	2.460	89.85	0.03652	105.00	0.6805	73.45	0.1079
-30.00	2.396	77.12	0.03219	110.00	0.5960	62.88	0.1055
-25.00	2.349	68.47	0.02914	115.00	0.5425	55.58	0.1024
-20.00	2.308	61.29	0.02655	120.00	0.5375	53.41	0.09935
-15.00	2.272	55.24	0.02431	125.00	0.5223	54.58	0.1045
-10.00	2.243	49.36	0.02200	130.00	0.5028	61.11	0.1215
-5.00	2.221	44.75	0.02015	135.00	0.4926	76.67	0.1557
0.00	2.203	41.65	0.01891	140.00	0.4417	110.0	0.2494
5.00	2.187	39.43	0.01803	145.00	0.2584	128.4	0.4995
10.00	2.173	37.41	0.01722	150.00	0.1046	60.22	0.5749
15.00	2.164	35.67	0.01649	155.00	0.06659	28.58	0.4289
20.00	2.157	34.27	0.01589	160.00	0.05235	20.35	0.3887
25.00	2.152	33.06	0.01536	165.00	0.04383	16.60	0.3787
30.00	2.141	32.00	0.01494	170.00	0.03891	14.72	0.3782
35.00	2.122	31.11	0.01466	175.00	0.03571	13.58	0.3803
40.00	2.095	30.84	0.01472	180.00	0.03323	13.08	0.3937
45.00	2.074	31.08	0.01499	185.00	0.03081	12.91	0.4191
50.00	2.057	31.71	0.01542	190.00	0.02843	12.75	0.4484
55.00	2.039	32.41	0.01590	195.00	0.02604	12.49	0.4795
60.00	2.018	33.18	0.01644	200.00	0.02365	12.14	0.5132
65.00	1.993	34.24	0.01718	205.00	0.02129	11.76	0.5523
70.00	1.963	35.86	0.01827	210.00	0.01884	11.39	0.6043
75.00	1.924	38.77	0.02015	215.00	0.01619	10.99	0.6792
80.00	1.865	46.48	0.02492	220.00	0.01351	10.60	0.7850

Table 118: Storage and loss properties for Bayer Makroblend UT403 unfilled, impact modified, UV stabilized, low viscosity polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy). (tabular data for Graph 118)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	2.598	102.3	0.03937	80.00	1.905	93.63	0.04917
-55.00	2.576	97.09	0.03768	85.00	1.659	135.4	0.08166
-50.00	2.555	93.35	0.03654	90.00	1.398	137.0	0.09802
-45.00	2.525	89.04	0.03526	95.00	1.194	118.1	0.09888
-40.00	2.495	85.48	0.03424	100.00	1.051	95.28	0.09064
-35.00	2.467	82.13	0.03328	105.00	0.9580	82.78	0.08642
-30.00	2.440	79.01	0.03238	110.00	0.8915	78.80	0.08840
-25.00	2.416	75.78	0.03136	115.00	0.8537	75.54	0.08848
-20.00	2.392	72.99	0.03052	120.00	0.8320	76.31	0.09172
-15.00	2.372	71.10	0.02998	125.00	0.7991	81.42	0.1019
-10.00	2.352	69.60	0.02959	130.00	0.7529	94.29	0.1253
-5.00	2.331	68.27	0.02929	135.00	0.6615	124.0	0.1877
0.00	2.308	66.93	0.02900	140.00	0.4765	174.8	0.3684
5.00	2.290	64.42	0.02813	145.00	0.2104	133.8	0.6368
10.00	2.279	60.92	0.02674	150.00	0.1080	54.55	0.5043
15.00	2.272	56.40	0.02482	155.00	0.07880	30.69	0.3893
20.00	2.269	51.73	0.02280	160.00	0.06442	22.33	0.3466
25.00	2.265	46.87	0.02070	165.00	0.05606	18.88	0.3369
30.00	2.255	43.48	0.01928	170.00	0.05074	17.47	0.3444
35.00	2.236	42.29	0.01891	175.00	0.04645	16.53	0.3558
40.00	2.219	41.46	0.01868	180.00	0.04358	15.87	0.3642
45.00	2.204	40.95	0.01858	185.00	0.04101	15.52	0.3784
50.00	2.189	40.67	0.01858	190.00	0.03851	15.28	0.3967
55.00	2.171	40.87	0.01883	195.00	0.03584	14.95	0.4173
60.00	2.150	41.72	0.01941	200.00	0.03323	14.58	0.4389
65.00	2.123	43.22	0.02036	205.00	0.03098	14.23	0.4595
70.00	2.086	46.81	0.02244	210.00	0.02845	13.85	0.4868
75.00	2.025	58.43	0.02886	215.00	0.02610	13.47	0.5161

Graph 119: Storage and loss properties for MRC Polymers Stanuloy ST170-30G 30% glass fiber filled, impact modified, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy).



Graph 120: Storage and loss properties for Montell Hivalloy GXPA064 35% glass fiber filled, impact modified polypropylene/ polystyrene alloy (PP/ PS alloy).

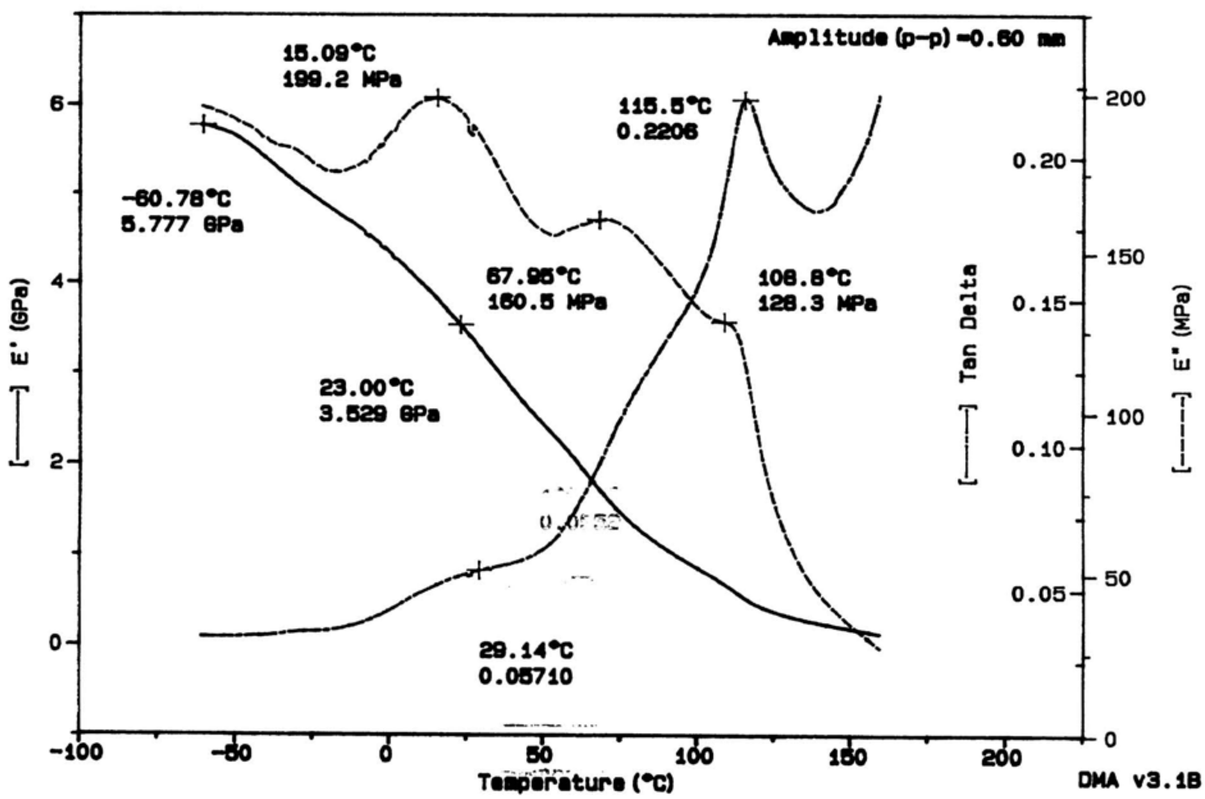


Table 119: Storage and loss properties for MRC Polymers Stanuloy ST170-30G 30% glass fiber filled, impact modified, from recyclate polycarbonate polyethylene terephthalate alloy (PC/ polyester PET alloy). (tabular data for Graph 119)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-55.00	6.575	98.75	0.01502	90.00	4.804	329.0	0.06850
-50.00	6.558	96.84	0.01477	95.00	4.284	325.9	0.07607
-45.00	6.519	96.03	0.01473	100.00	3.947	309.8	0.07850
-40.00	6.443	95.16	0.01477	105.00	3.665	310.7	0.08479
-35.00	6.369	90.50	0.01421	110.00	3.467	287.5	0.08292
-30.00	6.303	83.14	0.01319	115.00	3.443	264.3	0.07676
-25.00	6.249	77.49	0.01240	120.00	3.444	261.9	0.07605
-20.00	6.210	72.87	0.01173	125.00	3.395	285.3	0.08404
-15.00	6.171	70.02	0.01135	130.00	3.274	337.7	0.1032
-10.00	6.138	67.12	0.01093	135.00	2.938	453.7	0.1546
-5.00	6.107	63.41	0.01038	140.00	2.158	694.2	0.3229
0.00	6.081	59.37	0.009765	145.00	1.039	613.7	0.5920
5.00	6.058	56.03	0.009249	150.00	0.4889	264.0	0.5389
10.00	6.038	54.03	0.008948	155.00	0.3261	126.9	0.3890
15.00	6.022	52.44	0.008708	160.00	0.2479	86.11	0.3474
20.00	6.008	50.77	0.008450	165.00	0.1945	70.95	0.3648
25.00	5.994	49.33	0.008231	170.00	0.1565	63.51	0.4060
30.00	5.979	48.54	0.008119	175.00	0.1281	56.53	0.4414
35.00	5.956	48.89	0.008209	180.00	0.1080	51.05	0.4729
40.00	5.931	49.46	0.008340	185.00	0.09148	47.22	0.5162
45.00	5.906	49.52	0.008384	190.00	0.07779	43.40	0.5581
50.00	5.885	49.58	0.008425	195.00	0.06653	39.42	0.5926
55.00	5.862	50.10	0.008546	200.00	0.05705	35.45	0.6214
60.00	5.836	50.98	0.008735	205.00	0.04909	31.64	0.6445
65.00	5.805	53.04	0.009136	210.00	0.04247	28.08	0.6611
70.00	5.768	56.84	0.009856	215.00	0.03693	24.81	0.6719
75.00	5.714	64.63	0.01131	220.00	0.03157	21.90	0.6936
80.00	5.607	99.03	0.01767	225.00	0.02551	19.15	0.7508
85.00	5.352	218.5	0.04085				

Table 120: Storage and loss properties for Montell Hivalloy GXPA064 35% glass fiber filled, impact modified polypropylene/ polystyrene alloy (PP/ PS alloy). (tabular data for Graph 120)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.773	196.1	0.03397	50.00	2.443	157.1	0.06429
-55.00	5.723	194.5	0.03398	55.00	2.265	156.2	0.06893
-50.00	5.654	192.3	0.03401	60.00	2.072	158.3	0.07642
-45.00	5.535	189.8	0.03428	65.00	1.860	159.9	0.08600
-40.00	5.396	186.4	0.03455	70.00	1.653	160.8	0.09732
-35.00	5.247	183.9	0.03505	75.00	1.466	159.4	0.1088
-30.00	5.103	182.3	0.03572	80.00	1.312	155.7	0.1187
-25.00	4.975	178.5	0.03587	85.00	1.180	150.5	0.1276
-20.00	4.856	175.9	0.03623	90.00	1.065	145.0	0.1361
-15.00	4.737	176.1	0.03717	95.00	0.9609	138.9	0.1446
-10.00	4.625	178.0	0.03849	100.00	0.8618	133.1	0.1544
-5.00	4.491	182.2	0.04058	105.00	0.7662	129.4	0.1689
0.00	4.343	187.9	0.04328	110.00	0.6586	127.9	0.1943
5.00	4.181	193.6	0.04631	115.00	0.5397	118.6	0.2198
10.00	4.011	197.8	0.04931	120.00	0.4415	93.15	0.2110
15.00	3.837	199.2	0.05191	125.00	0.3741	73.29	0.1959
20.00	3.644	197.3	0.05413	130.00	0.3220	60.54	0.1880
25.00	3.451	192.9	0.05591	135.00	0.2789	51.11	0.1832
30.00	3.248	186.3	0.05737	140.00	0.2434	44.24	0.1818
35.00	3.036	177.5	0.05847	145.00	0.2111	39.10	0.1853
40.00	2.826	168.5	0.05963	150.00	0.1786	34.61	0.1937
45.00	2.627	161.2	0.06137	155.00	0.1492	30.70	0.2058

Graph 121: Storage and loss properties for Montell Hivalloy GXPA065 35% glass fiber filled, impact modified polypropylene/ polystyrene alloy (PP/ PS alloy).

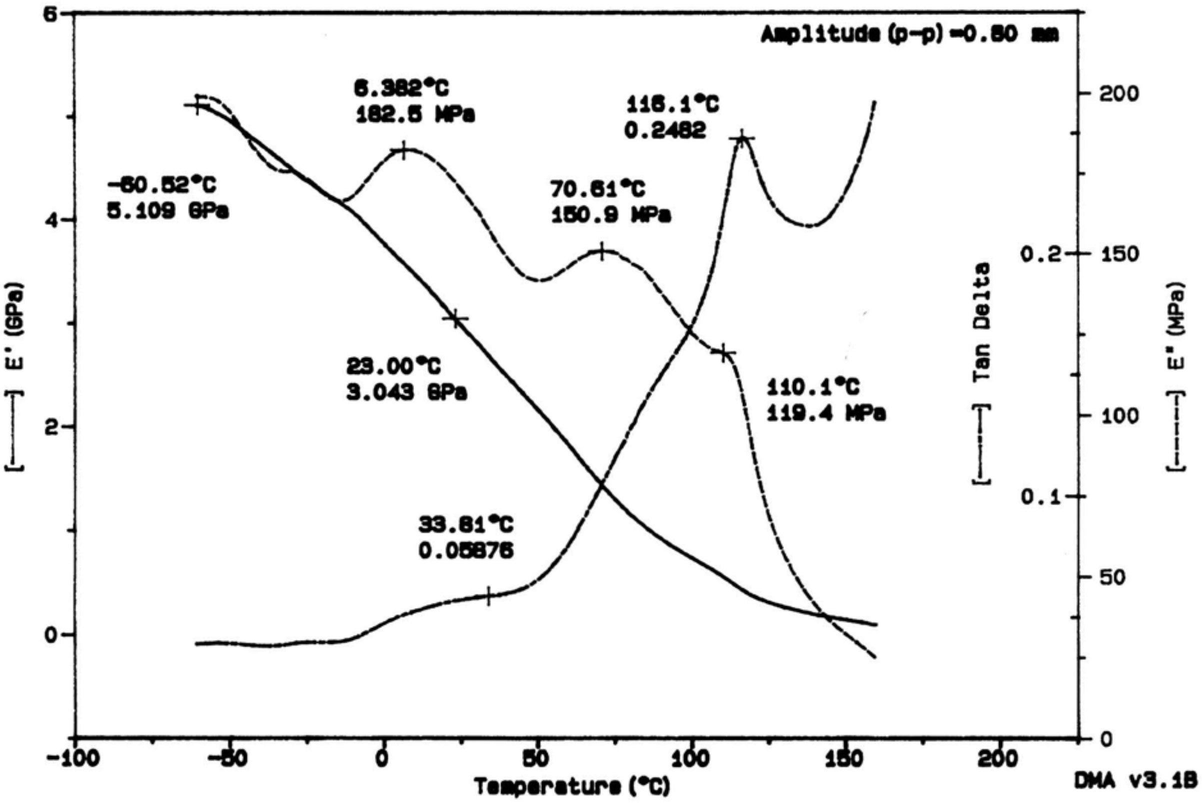


Table 121: Storage and loss properties for Montell Hivalloy GXPA065 35% glass fiber filled, impact modified polypropylene/ polystyrene alloy (PP/ PS alloy). (tabular data for Graph 121)

Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta	Temperature (°C)	E' (GPa)	E" (MPa)	Tan Delta
-60.00	5.106	199.2	0.03902	50.00	2.165	141.7	0.06543
-55.00	5.047	198.4	0.03931	55.00	1.999	142.8	0.07147
-50.00	4.964	194.6	0.03620	60.00	1.829	145.8	0.07973
-45.00	4.848	187.5	0.03868	65.00	1.644	149.2	0.09073
-40.00	4.733	180.8	0.03819	70.00	1.467	150.8	0.1028
-35.00	4.615	176.5	0.03824	75.00	1.302	150.2	0.1154
-30.00	4.496	175.8	0.03910	80.00	1.155	147.4	0.1276
-25.00	4.374	173.5	0.03966	85.00	1.034	144.1	0.1393
-20.00	4.274	169.3	0.03961	90.00	0.9226	138.0	0.1496
-15.00	4.180	166.6	0.03986	95.00	0.8254	131.7	0.1595
-10.00	4.070	168.1	0.04130	100.00	0.7379	125.6	0.1702
-5.00	3.923	173.5	0.04423	105.00	0.6517	121.4	0.1863
0.00	3.767	179.0	0.04753	110.00	0.5590	119.5	0.2137
5.00	3.615	182.2	0.05040	115.00	0.4557	112.0	0.2458
10.00	3.472	182.4	0.05252	120.00	0.3680	88.60	0.2407
15.00	3.314	180.2	0.05436	125.00	0.3091	69.16	0.2237
20.00	3.146	176.2	0.05601	130.00	0.2642	56.90	0.2154
25.00	2.977	170.4	0.05724	135.00	0.2272	48.18	0.2121
30.00	2.822	164.1	0.05817	140.00	0.1959	41.47	0.2117
35.00	2.653	156.4	0.05894	145.00	0.1687	36.36	0.2156
40.00	2.487	148.9	0.05990	150.00	0.1433	32.32	0.2255
45.00	2.327	143.5	0.06168	155.00	0.1190	28.63	0.2407

					Graph 1	Graph 2	Graph 3 & 4	Graph 5	Graph 6	Graph 7	Graph 8	Graph 9
Material Family					acetal homopolymer (POM)	acetal homopolymer (POM)	acetal copolymer (POM copolymer)	acetal copolymer (POM copolymer)	acetal copolymer (POM copolymer)	acetal copolymer (POM copolymer)	acrylic (PMMA)	acrylic copolymer
Description					unfilled	20% glass fiber filled, UV stable	unfilled	unfilled, impact modified	25% glass fiber filled	25% glass fiber filled, UV stable	unfilled, impact modified	unfilled, impact modified
Supplier					DuPont	DuPont	Ticona	Ticona	Ticona	Ticona	AtoHaas	Novacor
Material Trade Name					Delrin 500	Delrin 577	Celcon M90	Celcon TX90	Celcon GC25A	Celcon CFX-0108	Plexiglas MI-7	Zylar ST94-580
Test Notes	**Test condition**	**Test Specimen**	**Test Method**	**(Unit)**								

PHYSICAL PROPERTIES

Test Notes	Test condition	Test Specimen	Test Method	(Unit)	Graph 1	Graph 2	Graph 3 & 4	Graph 5	Graph 6	Graph 7	Graph 8	Graph 9
melt volume rate			ISO 1133, DIN 53735, CAMPUS	ml/10min	12 (190°C, 2.16 kg)							
melt flow rate			ASTM D1238	g/10min		6 (1.05 kg, 190°C)						
water absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%	0.9		0.8 (ASTM D 570)		0.27 (at 24 h, ASTM D 570)		0.3 (at 24 h, ASTM D 570)	0.1 (at 24 h, ASTM D 570)
moisture absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%	0.22							
density	test temperature: 21-25°C	>=10 x >=10 x 4 mm	ISO 1183, CAMPUS	g/m^3	1420							
specific gravity			ASTM D792				1.41	1.39	1.58		1.17	1.05
flammability UL94 at 1.6 mm		125 x 13 mm	UL 94, CAMPUS		HB		HB	HB	HB			

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

Test Notes	Test condition	Test Specimen	Test Method	(Unit)	Graph 1	Graph 2	Graph 3 & 4	Graph 5	Graph 6	Graph 7	Graph 8	Graph 9
tensile modulus (secant, 1 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 1 mm/min; elongation: 0.05-0.25%; atmosphere according to ISO 291	ISO 3167 multipurpose test specimen	ISO 527-1, ISO 527-2, CAMPUS, DIN 53457	MPa	3200	5700 (ASTM D638)						1900 (ASTM D638)
stress at yield (50 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 50 mm/min; atmosphere according to ISO 291	-	ISO 527-1, ISO 527-2, CAMPUS, DIN 53455	-	72							
strain at yield (50 mm/min)	-	-	-	%	15							
tensile strength at break (5 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 5 mm/min; atmosphere according to ISO 291	-	-	MPa		57 (ASTM D638)					48 (ASTM D638)	26.9 (ASTM D638)
strain at break (5 mm/min)	-	-	-	%	30 (50 mm/min)	10 (ASTM D638)	60 (ASTM D638)	100 (ASTM D638)	3.5 (ASTM D638)			80 (ASTM D638)
Charpy impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm	ISO 179/1eU, CAMPUS	kJ/m2	NB							
Charpy impact strength (-30°C)	test temperature: -30°C	-	-	-								
Charpy notched impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm, V notch, r = 0.25 mm	ISO 179/1eA, CAMPUS	-	9							
Charpy notched impact strength (-30°C)	test temperature: -30°C	-	-	-	7							
notched Izod impact strength (23°C)		3.2 mm thick	ASTM D256	J/m		31	69	96	59		32	235
flexural modulus			ASTM D790	MPa		5000	2584	1929	7579		2618	2100
flexural strength			ASTM D790	MPa		74	90	65	158		99	57.2

THERMAL PROPERTIES

Test Notes	Test condition	Test Specimen	Test Method	(Unit)	Graph 1	Graph 2	Graph 3 & 4	Graph 5	Graph 6	Graph 7	Graph 8	Graph 9
melting temperature				°C	177	178 (ASTM D3418)						
heat deflection temperature at 0.45 MPa		80 x 10 x 4 mm	ISO 75-1, ISO 75-2, CAMPUS	-	170	174 (ASTM D648)	158 (ASTM D648)	150 (ASTM D648)	166 (ASTM D648)			
heat deflection temperature at 1.8 MPa		-	-	-	115	147 (ASTM D648)	110 (ASTM D648)	101 (ASTM D648)	163 (ASTM D648)		85 (ASTM D648)	69 (ASTM D648)
Vicat B softening temperature	load: 50N; note: 50°C/h	>=10 x >=10 x 4 mm	ISO/DIN 306, CAMPUS	-	160						97 (ASTM D1525)	97 (ASTM D1525)
coefficient of linear thermal expansion (flow direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C	1.2	0.81 (ASTM D696)						
coefficient of linear thermal expansion (normal direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C								

Graph 10	Graph 11 & 12	Graph 13	Graph 14	Graph 15	Graph 16	Graph 17	Graph 18	Graph 19	Graph 20	Graph 21	Graph 22	Graph 23	
amorphous nylon	nylon 12	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	nylon 6	**Material Family**
unfilled, impact modified, super tough	unfilled, amorphous, transparent	unfilled, nucleated, low viscosity	14% glass fiber filled,	30% glass fiber filled	30% glass fiber filled	33% glass fiber filled	30% glass fiber filled	30% glass fiber filled, impact modified	33% glass fiber filled, impact modified	40% glass fiber/ mineral filled	44% glass fiber filled	50% long glass fiber filled	**Description**
DuPont	EMS	Allied Signal	Allied Signal	Bayer	EMS	Allied Signal	BASF	LNP	DSM Engineering	Allied Signal	Allied Signal	Ticona	**Supplier**
Zytel ST901	Grilamid TR55LX	Capron 8202C	Capron 8231G	Durethan BKV030	Grilon PVN-3H	Capron 8233G	Ultramid B3EG6	Thermocomp PF1006HI	Fiberfil J7-33	Capron 8267G	Capron 8234G	Celstran N6G50	**Material Trade Name**
(dry as molded)	(conditioned)	(dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)		(dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)	**Test Notes**

PHYSICAL PROPERTIES

Graph 10	Graph 11 & 12	Graph 13	Graph 14	Graph 15	Graph 16	Graph 17	Graph 18	Graph 19	Graph 20	Graph 21	Graph 22	Graph 23	
	50 (275°C, 5 kg)				70 (275°C, 5 kg)		50 (275°C, 5 kg)						**melt volume rate**
													melt flow rate
	2.5	9.3	8.2	7	7	6.7	6.6	1.1 (at 24 h, ASTM D 570)	0.8 (at 24 h, ASTM D 570)	4	5.6		**water absorption at saturation**
	1	2.6	2.3	2.1	2	1.9	2.1			1.5	1.6		**moisture absorption at saturation**
	1040	1130	1230	1360	1350	1390	1360			1480	1490		**density**
1.11								1.37	1.33			1.56	**specific gravity**
HB (0.86 mm)	HB (0.8 mm)	V-2 (0.7 mm)	HB (3 mm)	HB	HB (0.8 mm)	HB (3 mm)	HB (0.8 mm)			HB (3 mm)	HB (3 mm)		**flammability UL94 at 1.6 mm**

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

Graph 10	Graph 11 & 12	Graph 13	Graph 14	Graph 15	Graph 16	Graph 17	Graph 18	Graph 19	Graph 20	Graph 21	Graph 22	Graph 23	
	1900	3760	5960	9700	9500	10300	9500			8970	13500	15640 (ASTM D638)	**tensile modulus (secant, 1 mm/min)**
	70	90			195								**stress at yield (50 mm/min)**
	6	4			3								**strain at yield (50 mm/min)**
62 (ASTM D638)			140	180		195	185	151 (ASTM D638)	138 (ASTM D638)	132	230	249 (ASTM D638)	**tensile strength at break (5 mm/min)**
120 (ASTM D638)	>50 (50 mm/min)	12 (50 mm/min)	3.5	3	4 (50 mm/min)	3.5	3.5	4 (ASTM D638)	4 (ASTM D638)	3.6	2	2.1 (ASTM D638)	**strain at break (5 mm/min)**
	NB				75		95						**Charpy impact strength (23°C)**
	NB				65		80						**Charpy impact strength (-30°C)**
	9				11	14	15			8			**Charpy notched impact strength (23°C)**
	8				8		11						**Charpy notched impact strength (-30°C)**
1026 (6.4 mm thick)								171	267			459	**notched Izod impact strength (23°C)**
2000								6890	7579			13298	**flexural modulus**
86								220	207			372	**flexural strength**

THERMAL PROPERTIES

Graph 10	Graph 11 & 12	Graph 13	Graph 14	Graph 15	Graph 16	Graph 17	Graph 18	Graph 19	Graph 20	Graph 21	Graph 22	Graph 23	
	(Tg: 120°C)	220	220	222	222	220	220			220	220		**melting temperature**
120 (ASTM D648)	90	190	217	215		218	220		171 (ASTM D648)	217	219		**heat deflection temperature at 0.45 MPa**
115 (ASTM D648)	80	75	195	200	205 (105°C @ 8 MPa)	207	210	210 (ASTM D648)	60 (ASTM D648)	200	212	213 (ASTM D648)	**heat deflection temperature at 1.8 MPa**
	103				212		220						**Vicat B softening temperature**
0.7 (ASTM D696)	0.9		0.39		0.2	0.21	0.23			0.3	0.32		**coefficient of linear thermal expansion (flow direction)**
	0.9		0.78		1.1	0.7	0.65			0.67	0.79		**coefficient of linear thermal expansion (normal direction)**

					Graph 24	Graph 25	Graph 26	Graph 27	Graph 28	Graph 29 & 30	Graph 29 & 30	Graph 31
Material Family					nylon 612	nylon 612	nylon 612	nylon 66	nylon 66	nylon 66	nylon 66	nylon 66
Description					unfilled	43% glass fiber filled	60% glass fiber filled	unfilled	unfilled, impact modified	unfilled, impact modified	unfilled, impact modified	13% glass fiber filled
Supplier					DuPont	DuPont	LNP	DuPont	DuPont	DuPont	DuPont	DuPont
Material Trade Name					Zytel 151	Zytel 77G43L	Thermocomp IF100-12	Zytel 101L	Zytel CFE4003	Zytel ST801	Zytel ST801	Zytel 70G13L, general purpose
Test Notes	**Test condition**	**Test Specimen**	**Test Method**	**(Unit)**	(tested dry as molded)	{dry as molded}	{dry as molded}	(tested dry as molded)	{dry as molded}	(tested dry as molded)	{conditioned}	{dry as molded}

PHYSICAL PROPERTIES

melt volume rate			ISO 1133, DIN 53735, CAMPUS	ml/10min								
melt flow rate			ASTM D1238	g/10min								
water absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%	3	1.7 {ASTM D 570}		8.5		6.7		7.1 {ASTM D 570}
moisture absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%	1.3			2.8		2.2		
density	test temperature: 21-25°C	>=10 x >=10 x 4 mm	ISO 1183, CAMPUS	g/m^3	1060			1140		1080	1080	
specific gravity			ASTM D792			1.42	1.49					1.22
flammability UL94 at 1.6 mm		125 x 13 mm	UL 94, CAMPUS		V-2 {0.8 mm}	HB {0.7 mm}		V-2 {0.8 mm}		HB {0.8 mm}	HB {0.8 mm}	HB {0.7 mm}

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

tensile modulus (secant, 1 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 1 mm/min; elongation: 0.05-0.25%; atmosphere according to ISO 291	ISO 3167 multipurpose test specimen	ISO 527-1, ISO 527-2, CAMPUS, DIN 53457	MPa	2700			3300		2000	1200	
stress at yield (50 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 50 mm/min; atmosphere according to ISO 291	-	ISO 527-1, ISO 527-2, CAMPUS, DIN 53455	-	61			85		50	43	
strain at yield (50 mm/min)	-	-	-	%	7			4.4		6	38	
tensile strength at break (5 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 5 mm/min; atmosphere according to ISO 291	-	-	MPa		193 {ASTM D638}	214 {ASTM D638}		51.4 {ASTM D638}			121 {ASTM D638}
strain at break (5 mm/min)	-	-	-	%	17 {50 mm/min}	3 {ASTM D638}	1 {ASTM D638}	17 {50 mm/min}	33 {ASTM D638}	41 {50 mm/min}	>50 {50 mm/min}	3 {ASTM D638}
Charpy impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm	ISO 179/1eU, CAMPUS	kJ/m2	NB			NB		NB	NB	
Charpy impact strength (-30°C)	test temperature: -30°C	-	-	-	NB			NB		NB	NB	
Charpy notched impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm, V notch, r = 0.25 mm	ISO 179/1eA, CAMPUS	-	5			6		85	110	
Charpy notched impact strength (-30°C)	test temperature: -30°C	-	-	-	5			4		18	18	
notched Izod impact strength (23°C)		3.2 mm thick	ASTM D256	J/m		155	171		160			48
flexural modulus			ASTM D790	MPa		10340	15847		1973			4830
flexural strength			ASTM D790	MPa		269	317					165

THERMAL PROPERTIES

melting temperature				°C	218	217 {ASTM D3418}		263	260 {ASTM D3418}	263		262 {ASTM D3418}
heat deflection temperature at 0.45 MPa		80 x 10 x 4 mm	ISO 75-1, ISO 75-2, CAMPUS	-	180	215 {ASTM D648}	223 {ASTM D648}	235		219		
heat deflection temperature at 1.8 MPa		-	-	-	90	210 {ASTM D648}	218 {ASTM D648}	80	54 {ASTM D648}	66		243 {ASTM D648}
Vicat B softening temperature	load: 50N; note: 50°C/h	>=10 x >=10 x 4 mm	ISO/DIN 306, CAMPUS	-	181			238		213		
coefficient of linear thermal expansion (flow direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C	1.31	0.22 {ASTM D696}		1.2		1.7		0.27 {ASTM D696}
coefficient of linear thermal expansion (normal direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C	1.31			1.2		1.5		

Graph 32	Graph 33	Graph 34	Graph 35	Graph 36	Graph 37	Graph 38	Graph 39	Graph 40	Graph 41	Graph 42	Graph 43	Graph 44	
nylon 66	nylon 66	nylon 66	nylon 66	nylon 66	nylon 66	nylon 6/66	nylon 66	nylon 6/66	nylon 6/66	nylon 6/66	nylon MXD6	nylon, aromatic copolymer	**Material Family**
33% glass fiber filled	40% glass fiber filled	40% glass bead filled	40% mineral filled	40% mineral filled	43% glass fiber filled	40% mineral filled, impact modified	40% mineral filled, impact modified	33% glass fiber filled, impact modified	33% glass fiber filled	50% long glass fiber filled	60% glass fiber filled	50% glass fiber filled, food contact	**Description**
DuPont	Ticona	Ticona	DuPont	DuPont	DuPont	DuPont	DuPont	DuPont	DuPont	LNP	Mitsubishi Gas Chemical	EMS	**Supplier**
Zytel 70G33L	Celanese 1603-2	Celanese NFX-0102	Minlon 6122	Minlon 10B40	Zytel FE5128	Minlon 11C40	Minlon 12T	Zytel 82G33L	Zytel 72G33L	Verton RF700-10EM	Reny 1032	Grivory 5H	**Material Trade Name**
(tested dry as molded)	(dry as molded)			(tested dry as molded)		(tested dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)	(dry as molded)	(conditioned)	**Test Notes**

PHYSICAL PROPERTIES

												80 (275°C, 21.6 kg)	melt volume rate
													melt flow rate
6	0.9 (at 24 h, ASTM D 570)			5		5.7					1.3 (ASTM D 570)	4.5	water absorption at saturation
1.9				1.6		1.8						1.3	moisture absorption at saturation
1400				1500		1460						1560	density
	1.47							1.34	1.38	1.57	1.77		specific gravity
HB (0.8 mm)	HB			HB (0.8 mm)		HB (0.8 mm)		HB (0.8 mm)	HB (0.8 mm)		HB	HB (0.8 mm)	flammability UL94 at 1.6 mm

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

				5800		6000					23324 (ASTM D638)	17000	tensile modulus (secant, 1 mm/min)
													stress at yield (50 mm/min)
													strain at yield (50 mm/min)
195	221 (ASTM D638)			89		87	79 (ASTM D638)	153 (ASTM D638)	186 (ASTM D638)	255 (ASTM D638)	274 (ASTM D638)	210	tensile strength at break (5 mm/min)
3	3 (ASTM D638)			3.7		10	20 (ASTM D638)	4 (ASTM D638)	4 (ASTM D638)	3 (ASTM D638)	1.8 (ASTM D638)	3	strain at break (5 mm/min)
90				36		120						85	Charpy impact strength (23°C)
75				26		80						80	Charpy impact strength (-30°C)
12				3		6						14	Charpy notched impact strength (23°C)
10				3		5						13	Charpy notched impact strength (-30°C)
	139						129	225	123	320			notched Izod impact strength (23°C)
	10400						4585	7585	8965	15847	20874		flexural modulus
	338							230	290	400	376		flexural strength

THERMAL PROPERTIES

260	257			260		255	259 (ASTM D3418)	233 (ASTM D3418)	233 (ASTM D3418)			260	melting temperature
	257 (ASTM D648)			240		220	225 (ASTM D648)						heat deflection temperature at 0.45 MPa
254	253 (ASTM D648)			210		147	75 (ASTM D648)	220 (ASTM D648)	220 (ASTM D648)	243 (ASTM D648)	226 (ASTM D648)	235 (165°C @ 8 MPa)	heat deflection temperature at 1.8 MPa
				247		235						245	Vicat B softening temperature
				0.67		0.86	0.54 (ASTM D696					0.15	coefficient of linear thermal expansion (flow direction)
				0.88		0.86						0.9	coefficient of linear thermal expansion (normal direction)

					Graph 45	Graph 46	Graph 47	Graph 48	Graph 49	Graph 50	Graph 51	Graph 52
Material Family					nylon, partially aromatic	polycarbonate (PC)	polycarbonate (PC)	polycarbonate (PC)	polycarbonate (PC)	polycarbonate (PC)	polybutylene terephthalate (polyester PBT)	polybutylene terephthalate (polyester PBT)
Description					35% glass fiber filled, heat stabilized	unfilled, medium viscosity, release agent	unfilled, recycled content	unfilled, impact modified	10% glass fiber filled, medium viscosity	20% glass fiber filled, high viscosity	unfilled, general purpose	unfilled, non blooming flame retardant
Supplier					DuPont	GE Plastics	MRC Polymers	Bayer	GE Plastics	GE Plastics	GE Plastics	Ticona
Material Trade Name					Zytel HTN51G35HSL	Lexan 141R	PC429MMH1-200	Makrolon T7435	Lexan 500	Lexan 3412	Valox 325	Celanex 2016
Test Notes	**Test condition**	**Test Specimen**	**Test Method**	**(Unit)**	{dry as molded}							

PHYSICAL PROPERTIES

melt volume rate			ISO 1133, DIN 53735, CAMPUS	ml/10min		12 {300°C, 1.2 kg}			8 {300°C, 1.2 kg}	6 {300°C, 1.2 kg}	14 {250°C, 2.16 kg}	
melt flow rate			ASTM D1238	g/10min		0.35		0.15 {at 24 h, ASTM D 570}	0.31	0.29	0.34	
water absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%							0.08	
moisture absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%		1200			1250	1350	1310	
density	test temperature: 21-25°C	>=10 x >=10 x 4 mm	ISO 1183, CAMPUS	g/m^3	1.09			1.2			1.44	
specific gravity			ASTM D792			V-2 {1.14 mm}			V-0 {1.5 mm}		HB {1.47}	
flammability UL94 at 1.6 mm		125 x 13 mm	UL 94, CAMPUS		12100 {ASTM D638}	2350		2067 {ASTM D638}	3300	6000	2400	

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

tensile modulus (secant, 1 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 1 mm/min; elongation: 0.05-0.25%; atmosphere according to ISO 291	ISO 3167 multipurpose test specimen	ISO 527-1, ISO 527-2, CAMPUS, DIN 53457	MPa		63					55	
stress at yield (50 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 50 mm/min; atmosphere according to ISO 291	"	ISO 527-1, ISO 527-2, CAMPUS, DIN 53455	"		6					3.5	
strain at yield (50 mm/min)	"	"	"	%	214 {ASTM D638}		57 {ASTM D638}	56 {ASTM D638}	45	90		
tensile strength at break (5 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 5 mm/min; atmosphere according to ISO 291	"	"	MPa	2.4 {ASTM D638}	>50 {50 mm/min}	90 {ASTM D638}	110 {ASTM D638}	7	2	>50 {50 mm/min}	20 {ASTM D638}
strain at break (5 mm/min)	"	"	"	%					NB	30		
Charpy impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm	ISO 179/1eU, CAMPUS	kJ/m2								
Charpy impact strength (-30°C)	test temperature: -30°C	"	"	"					9		4	
Charpy notched impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm, V notch, r = 0.25 mm	ISO 179/1eA, CAMPUS	"							4	
Charpy notched impact strength (-30°C)	test temperature: -30°C	"	"	"			748	742				32
notched Izod impact strength (23°C)		3.2 mm thick	ASTM D256	J/m	10300		2136	2101				3286
flexural modulus			ASTM D790	MPa			90	83				106
flexural strength			ASTM D790	MPa								

THERMAL PROPERTIES

melting temperature				°C								
heat deflection temperature at 0.45 MPa		80 x 10 x 4 mm	ISO 75-1, ISO 75-2, CAMPUS	"		136	132 {ASTM D648}	130 {ASTM D648}	140	144	110	70 {ASTM D648}
heat deflection temperature at 1.8 MPa		"	"	"		125	121 {ASTM D648}	121 {ASTM D648}	132	139	50	
Vicat B softening temperature	load: 50N; note: 50°C/h	>=10 x >=10 x 4 mm	ISO/DIN 306, CAMPUS	"		141		145 {ASTM D1525}	141	147	175	
coefficient of linear thermal expansion (flow direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C		0.7			0.4	0.3	0.13	
coefficient of linear thermal expansion (normal direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C							0.13	

Graph 53	Graph 54	Graph 55	Graph 56	Graph 57	Graph 58	Graph 59	Graph 60	Graph 61	Graph 62	Graph 63	Graph 64 & 65	Graph 66 & 67	
polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polybutylene terephthalate	polyetherimide (PEI)	polyetherimide (PEI)	**Material Family**
10% mineral filled, impact modified	10% glass fiber filled, impact modified	30% glass fiber filled	30% glass fiber filled	30% glass fiber filled	30% glass fiber filled	30% glass fiber filled, flame retardant	30% glass fiber filled, color stable	30% glass fiber filled, from recyclate	45% glass fiber filled	55% glass fiber filled	unfilled, general purpose*	30% glass fiber filled	**Description**
GE Plastics	LNP	GE Plastics	DuPont	Plastics Eng	Ticona	DuPont	DuPont	Allied Signal	DuPont	DuPont	GE Plastics	GE Plastics	**Supplier**
Valox 744	Thermocomp PDXW96630	Valox 420	Rynite 530	Plenco 50030	Impet 330R	Rynite FR530	Rynite RE5211	Petra 130	Rynite 545	Rynite 555	Ultem 1000	Ultem 2300	**Material Trade Name**
													Test Notes

PHYSICAL PROPERTIES

		12 (250°C, 2.16 kg)	5 (280°C, 2.16 kg)			6 (280°C, 2.16 kg				5 (280°C, 5 kg	13 (360°C, 5 kg)	6 (360°C, 5 kg)	melt volume rate
													melt flow rate
		0.26		0.07 (at 24 h, ASTM D 570)		0.77	0.6				1.25	0.9	water absorption at saturation
		0.06	0.2			0.17	0.16				0.7	0.5	moisture absorption at saturation
		1530	1560			1670	1590			1800	1270	1510	density
1.36				1.58	1.58		1.8						specific gravity
HB		HB (0.8 mm)	HB (0.8 mm)		HB	V-0 (0.8 mm)		HB (0.75 mm		HB (0.8 mm)	V-0 (0.41 mm	V-0 (0.25 mm)	flammability UL94 at 1.6 mm

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

		9300	11000			12000		10200	15500 (ASTM D638)	19500	3200	9500	tensile modulus (secant, 1 mm/min)
											105		stress at yield (50 mm/min)
											6		strain at yield (50 mm/min)
		115	158	168 (ASTM D638)	168 (ASTM D638)	135	173	155	186 (ASTM D638)	196		165	tensile strength at break (5 mm/min)
		2	2.5		2 (ASTM D638)	2	2	3.5	2.1 (ASTM D638)	2	>50 (50 mm/min)	2	strain at break (5 mm/min)
			65			40	48			50			Charpy impact strength (23°C)
			45			33	42			45			Charpy impact strength (-30°C)
		45	11			8.5	9.5			12	4		Charpy notched impact strength (23°C)
		45	11			8.5	9			12			Charpy notched impact strength (-30°C)
53.4				80	80		90						notched Izod impact strength (23°C)
2687				8957	9646		12700		17900				flexural modulus
				245	245		225		283				flexural strength

THERMAL PROPERTIES

			254			254	255	245		255			melting temperature
163 (ASTM D648)		225	245			246	245	240			200	215	heat deflection temperature at 0.45 MPa
65 (ASTM D648)		205	224	224 (ASTM D648)	224 (ASTM D648)	224	224	210		229 (190°C @ 8 MPa)	190	210	heat deflection temperature at 1.8 MPa
		215	228			218	230			230	211	213	Vicat B softening temperature
		0.25	0.3			0.25	0.21			0.11			coefficient of linear thermal expansion (flow direction)
			1.22				0.74						coefficient of linear thermal expansion (normal direction)

					Graph 68	Graph 69	Graph 70	Graph 71	Graph 72	Graph 73	Graph 74	Graph 75
Material Family					polyetheretherketone (PEEK)	polypropylene (PP)	polypropylene (PP)	polypropylene (PP)	polypropylene (PP)	polypropylene (PP)	polypropylene (PP)	polypropylene (PP)
Description					unfilled	unfilled, homopolymer	unfilled, homopolymer	unfilled, homopolymer	20% glass fiber filled, low viscosity	30% glass fiber filled	40% glass fiber filled	40% glass fiber filled, chemically coupled
Supplier					Victrex	Exxon			Montell	Montell	Montell	Ferro
Material Trade Name					PEEK 450G	Escorene 1032	Polypropylene 400121	Polypropylene 400145	PF062-2	PF072-3C	PF072-4C	RPP40EA63UL
Test Notes	**Test condition**	**Test Specimen**	**Test Method**	**(Unit)**								

PHYSICAL PROPERTIES

Test Notes	Test condition	Test Specimen	Test Method	(Unit)	Graph 68	Graph 69	Graph 70	Graph 71	Graph 72	Graph 73	Graph 74	Graph 75
melt volume rate			ISO 1133, DIN 53735, CAMPUS	ml/10min								
melt flow rate			ASTM D1238	g/10min		5 {230°C, 2.16 kg}			18 {230°C, 2.16 kg}	2 {230°C, 2.16 kg}	1.8 {230°C, 2.16 kg}	
water absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%								
moisture absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%								
density	test temperature: 21-25°C	>=10 x >=10 x 4 mm	ISO 1183, CAMPUS	g/m^3								
specific gravity			ASTM D792		1.3	0.9			1.04	1.13	1.22	
flammability UL94 at 1.6 mm		125 x 13 mm	UL 94, CAMPUS		V-0 {3.2 mm}							

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

Test Notes	Test condition	Test Specimen	Test Method	(Unit)	Graph 68	Graph 69	Graph 70	Graph 71	Graph 72	Graph 73	Graph 74	Graph 75
tensile modulus (secant, 1 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 1 mm/min; elongation: 0.05-0.25%; atmosphere according to ISO 291	ISO 3167 multipurpose test specimen	ISO 527-1, ISO 527-2, CAMPUS, DIN 53457	MPa								
stress at yield (50 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 50 mm/min; atmosphere according to ISO 291	"	ISO 527-1, ISO 527-2, CAMPUS, DIN 53455	"								
strain at yield (50 mm/min)	"	"	"	%								
tensile strength at break (5 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 5 mm/min; atmosphere according to ISO 291	"	"	MPa	92 {ASTM D638}				79 {ASTM D638}	97 {ASTM D638}	103 {ASTM D638}	
strain at break (5 mm/min)	"	"	"	%	4.9 {ASTM D638}				2.9 {ASTM D638}	2.7 {ASTM D638}	2.2 {ASTM D638}	
Charpy impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm	ISO 179/1eU, CAMPUS	kJ/m2								
Charpy impact strength (-30°C)	test temperature: -30°C	"	"	"								
Charpy notched impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm, V notch, r = 0.25 mm	ISO 179/1eA, CAMPUS	"								
Charpy notched impact strength (-30°C)	test temperature: -30°C	"	"	"								
notched Izod impact strength (23°C)		3.2 mm thick	ASTM D256	J/m	83	37			79	151	112	
flexural modulus			ASTM D790	MPa	3660	1309			4100	6300	7030	
flexural strength			ASTM D790	MPa					117	155	169	

THERMAL PROPERTIES

Test Notes	Test condition	Test Specimen	Test Method	(Unit)	Graph 68	Graph 69	Graph 70	Graph 71	Graph 72	Graph 73	Graph 74	Graph 75
melting temperature				°C								
heat deflection temperature at 0.45 MPa		80 x 10 x 4 mm	ISO 75-1, ISO 75-2, CAMPUS	"		100 {ASTM D648}			160 {ASTM D648}	160 {ASTM D648}	160 {ASTM D648}	
heat deflection temperature at 1.8 MPa		"	"	"	160 {ASTM D648}	54 {ASTM D648}			149 {ASTM D648}	151 {ASTM D648}	151 {ASTM D648}	
Vicat B softening temperature	load: 50N; note: 50°C/h	>=10 x >=10 x 4 mm	ISO/DIN 306, CAMPUS	"								
coefficient of linear thermal expansion (flow direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C	0.47							
coefficient of linear thermal expansion (normal direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C								

Graph 76	Graph 77	Graph 78	Graph 79	Graph 80	Graph 81	Graph 82	Graph 83	Graph 84	Graph 85	Graph 86	Graph 87	Graph 88	
polypropylene (PP)	polypropylene (PP)	polypropylene (PP)	polypropylene (PP)	polypropylene copolymer	cyclic olefin copolymer	cyclic olefin copolymer	syrene modified polyphenylene ether	syrene modified polyphenylene ether	syrene modified polyphenylene ether	syrene modified polyphenylene ether	syrene modified polyphenylene ether	polyphenylene sulfide (PPS)	**Material Family**
40% long glass fiber filled	10% glass fiber, 30% talc filled	40% talc filled	40% mica filled, chemically coupled	20% glass fiber filled	unfilled	unfilled	flame retardant, moderate heat resistance	flame retardant, high heat resistance, unfilled	10% glass fiber filled, halogen free flame retardant	20% glass fiber filled	30% glass fiber filled	40% glass fiber filled	**Description**
Ticona	Ferro	Ferro	Ferro	Montell	Ticona	Ticona	GE Plastics	GE Plastics	GE Plastics	GE Plastics	GE Plastics	Ticona	**Supplier**
Celstran PPG40	HPP40GR09BK	PP40AC45BK	MPP40FJ15NA	SB224-2C	Topas 5513	Topas 6013	Noryl N225X	Noryl SE1X	Noryl SE1-GFN1	Noryl GFN2	Noryl GFN3	Fortron 1140	**Material Trade Name**
													Test Notes

PHYSICAL PROPERTIES

Graph 76	Graph 77	Graph 78	Graph 79	Graph 80	Graph 81	Graph 82	Graph 83	Graph 84	Graph 85	Graph 86	Graph 87	Graph 88	
								9 (280°C, 5 kg)					melt volume rate
	3.2 (230°C, 2.16 kg)	5.5 (230°C, 2.16 kg)	10.4 (230°C, 2.16 kg)	1.5 (230°C, 2.16 kg)									melt flow rate
							0.07 (at 24 h, ASTM D 570)	0.23	0.22	0.14	0.2		water absorption at saturation
								0.1			0.1		moisture absorption at saturation
1220								1110	1160	1210	1280	1640	density
	1.26	1.26	1.22	1.05			1.09						specific gravity
							V-0	V-1 (1.5 mm)	V-1 (1.5 mm)	HB (1.5 mm)	HB (1.5 mm)	V-0 (0.4 mm)	flammability UL94 at 1.6 mm

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

Graph 76	Graph 77	Graph 78	Graph 79	Graph 80	Graph 81	Graph 82	Graph 83	Graph 84	Graph 85	Graph 86	Graph 87	Graph 88	
9100								2500	4000	6000	8000	14500	tensile modulus (secant, 1 mm/min)
								55					stress at yield (50 mm/min)
								5					strain at yield (50 mm/min)
115				61 (ASTM D638)			55 (ASTM D638)		70	90	105	160	tensile strength at break (5 mm/min)
2	4 (ASTM D638)	8 (ASTM D638)	2 (ASTM D638)	3.7 (ASTM D638)				10 (50 mm/min)	5	2.5	2	1.6	strain at break (5 mm/min)
53									30	25		35	Charpy impact strength (23°C)
62									30	25			Charpy impact strength (-30°C)
23								15				9	Charpy notched impact strength (23°C)
24								7					Charpy notched impact strength (-30°C)
	52.9	24	16.6	150			320						notched Izod impact strength (23°C)
	4065	3445	6890	3480			2377						flexural modulus
				86			76						flexural strength

THERMAL PROPERTIES

Graph 76	Graph 77	Graph 78	Graph 79	Graph 80	Graph 81	Graph 82	Graph 83	Graph 84	Graph 85	Graph 86	Graph 87	Graph 88	
162 (Tg: -5°C												285 (Tg: 100°C)	melting temperature
	155 (ASTM D648)	129 (ASTM D648)	143 (ASTM D648)	157 (ASTM D648)			118 (ASTM D648)		135	145			heat deflection temperature at 0.45 MPa
154 (132°C @ 8 MPa)	133 (ASTM D648)	75 (ASTM D648)	109 (ASTM D648)	127 (ASTM D648)			107 (ASTM D648)		130	132	140	260 (196°C @ 8 MPa)	heat deflection temperature at 1.8 MPa
								130	140	135	145		Vicat B softening temperature
								0.7	0.5	0.4	0.25		coefficient of linear thermal expansion (flow direction)
								0.9		0.1	0.7		coefficient of linear thermal expansion (normal direction)

					Graph 89	Graph 90	Graph 91	Graph 92	Graph 93	Graph 94	Graph 95	Graph 96
Material Family					polyphenylene sulfide (PPS)	polyphenylene sulfide (PPS)	polyphenylene sulfide (PPS)	polyphenylene sulfide (PPS)	polyphenylene sulfide (PPS)	polyethersulfone(PES)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)
Description					40% glass fiber filled, branched	40% glass fiber filled, impact modified	50% long glass fiber filled	50% glass fiber/ mineral filled	65% glass fiber/ mineral filled	20% glass fiber filled	unfilled, high impact, general purpose	unfilled, high impact
Supplier					Phillips 66	Phillips 66	Ticona	Ticona	Ticona	Amoco Perfor.	GE Plastics	GE Plastics
Material Trade Name					Ryton R4	Ryton BR90A	Celstran PPSG50	Fortron 4184	Fortron 6165	Radel AG220	Cycolac T	Cycolac GSM
Test Notes	**Test condition**	**Test Specimen**	**Test Method**	**(Unit)**								

PHYSICAL PROPERTIES

melt volume rate			ISO 1133, DIN 53735, CAMPUS	ml/10min							26 (220°C, 10 kg)	8 (220°C, 10 kg)
melt flow rate			ASTM D1238	g/10min								
water absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%						0.45 (at 24 h, ASTM D 570)	1	1
moisture absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%							0.2	0.2
density	test temperature: 21-25°C	>=10 x >=10 x 4 mm	ISO 1183, CAMPUS	g/m^3				1800	1970		1040	1050
specific gravity			ASTM D792		1.65					1.51		
flammability UL94 at 1.6 mm		125 x 13 mm	UL 94, CAMPUS		V-0			V-0 (0.8 mm)	V-0 (0.8 mm)	V-0 (0.8 mm)	HB (1.4 mm)	HB (1.47 mm)

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

tensile modulus (secant, 1 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 1 mm/min; elongation: 0.05-0.25%; atmosphere according to ISO 291	ISO 3167 multipurpose test specimen	ISO 527-1, ISO 527-2, CAMPUS, DIN 53457	MPa				16600	19000	5690 (ASTM D638)	2100	2100
stress at yield (50 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 50 mm/min; atmosphere according to ISO 291	"	ISO 527-1, ISO 527-2, CAMPUS, DIN 53455	"							44	45
strain at yield (50 mm/min)	"	"	"	%								
tensile strength at break (5 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 5 mm/min; atmosphere according to ISO 291	"	"	MPa	121 (ASTM D638)			155	120	109 (ASTM D638)		
strain at break (5 mm/min)	"	"	"	%	0.9 (ASTM D638)			1.4	1.2	3.2 (ASTM D638)	15 (50 mm/min)	
Charpy impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm	ISO 179/1eU, CAMPUS	kJ/m2				29	20			
Charpy impact strength (-30°C)	test temperature: -30°C	"	"	"				29	20			
Charpy notched impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm, V notch, r = 0.25 mm	ISO 179/1eA, CAMPUS	"				7	7		15	20
Charpy notched impact strength (-30°C)	test temperature: -30°C	"	"	"				7	7			
notched Izod impact strength (23°C)		3.2 mm thick	ASTM D256	J/m	69					59		
flexural modulus			ASTM D790	MPa	11000					6550		
flexural strength			ASTM D790	MPa	179					162		

THERMAL PROPERTIES

melting temperature				°C				285 (Tg: 100°C)	285 (Tg: 100°C)			
heat deflection temperature at 0.45 MPa		80 x 10 x 4 mm	ISO 75-1, ISO 75-2, CAMPUS	"							87	89
heat deflection temperature at 1.8 MPa		"	"	"	>260 (ASTM D648)			260 (217°C @ 8 MPa)	260 (218°C @ 8 MPa)	204 (ASTM D648)	74	75
Vicat B softening temperature	load: 50N; note: 50°C/h	>=10 x >=10 x 4 mm	ISO/DIN 306, CAMPUS	"							94	96
coefficient of linear thermal expansion (flow direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C						3.1 (ASTM D696)	0.85	0.8
coefficient of linear thermal expansion (normal direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C								

Graph 97	Graph 98	Graph 99	Graph 100	Graph 101	Graph 102	Graph 103	Graph 104	Graph 105	Graph 106	Graph 107	Graph 108	Graph 109	
acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	acrylonitrile butadiene styrene (ABS)	high impact polystyrene (HIPS)	tyrene acrylonitrile copolymer (SAN)	acrylonitrile butadiene styrene/ nylon alloy	acrylic/ poly-carbonate alloy (acrylic/ PC alloy)	**Material Family**
unfilled medium impact	unfilled medium impact	unfilled, very high impact	unfilled, flame retardant	unfilled, halogen free flame retardant, indoor UV	10% glass fiber filled, flame retardant	30% glass fiber filled	40% glass fiber filled	6% long stainless steel fiber	unfilled	unfilled, general purpose	unfilled, easy flow, high impact	unfilled, impact modified	**Description**
Dow Chemical	GE Plastics	Dow Chemical	GE Plastics	GE Plastics	RTP	RTP	RTP	Ticona	Dow Chemical	Bayer	Bayer	Cyro	**Supplier**
Magnum 9010	Cycolac DFA-R	Magnum 941	Cycolac KJW	Cycolac VW300	601 FR	605	607	Celstran ABS SS6	Styron 484	Lustran SAN31	Triax 1125	Cyrex RDG200	**Material Trade Name**
											{dry as molded}		**Test Notes**

PHYSICAL PROPERTIES

Graph 97	Graph 98	Graph 99	Graph 100	Graph 101	Graph 102	Graph 103	Graph 104	Graph 105	Graph 106	Graph 107	Graph 108	Graph 109	
				"22 {220°C, 10 kg}"									melt volume rate
"7.0 {230°C, 3.8 kg}"		"2.2 {230°C, 3.8 kg}"											melt flow rate
				1	0.20 {at 24 h, ASTM D 570}	0.16 {at 24 h, ASTM D 570	0.12 {at 24 h, ASTM D 570}	0 {at 24 h, ASTM D 570}		0.25 {ASTM D 570}	4.2 {ASTM D 570}		water absorption at saturation
				0.2							1.6 {ASTM D 570}		moisture absorption at saturation
				1200									density
1.04	1.04	1.04	1.23		1.29	1.28	1.38	1.11	1.04	1.07	1.06	1.15	specific gravity
HB	HB	HB	V-0	V-0					HB {3.1 mm}		HB		flammability UL94 at 1.6 mm

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

Graph 97	Graph 98	Graph 99	Graph 100	Graph 101	Graph 102	Graph 103	Graph 104	Graph 105	Graph 106	Graph 107	Graph 108	Graph 109	
2415 {ASTM D638}	2300 {ASTM D638}	2000 {ASTM D638}	2100 {ASTM D638}	2500					1648 {ASTM D638}	3280 {ASTM D638	1890 {ASTM D638}	2250 {ASTM D638}	tensile modulus (secant, 1 mm/min)
				36									stress at yield (50 mm/min)
													strain at yield (50 mm/min)
36 {ASTM D638}								43.4 {ASTM D638}	24 {ASTM D638}	72 {ASTM D638	47 {ASTM D638}	55 {ASTM D638}	tensile strength at break (5 mm/min)
45 {ASTM D638}					2 {ASTM D638}	1 {ASTM D638}	1 {ASTM D638}	0 {ASTM D638}	52 {ASTM D638}	3.0 {ASTM D638}	70 {ASTM D638}	56 {ASTM D638}	strain at break (5 mm/min)
				NB									Charpy impact strength (23°C)
													Charpy impact strength (-30°C)
				8									Charpy notched impact strength (23°C)
													Charpy notched impact strength (-30°C)
210	210	641	210		64	69.4	64	64.1	112	32	850	1388	notched Izod impact strength (23°C)
2480	2500	2030	2300		4134	6890	8957	2825	1910	3450	2140	2250	flexural modulus
72	80	62	70		86	131	138	78.6	43	75.9			flexural strength

THERMAL PROPERTIES

Graph 97	Graph 98	Graph 99	Graph 100	Graph 101	Graph 102	Graph 103	Graph 104	Graph 105	Graph 106	Graph 107	Graph 108	Graph 109	
													melting temperature
94 {ASTM D648}	94 {ASTM D648}	93 {ASTM D648}			104 {ASTM D648}	115 {ASTM D648}	118 {ASTM D648}		87 {ASTM D648}		94 {ASTM D648}	123 {ASTM D648}	heat deflection temperature at 0.45 MPa
79 {ASTM D648}	84 {ASTM D648}	79 {ASTM D648}	88 {ASTM D648}		101 {ASTM D648}	110 {ASTM D648}	115 {ASTM D648}	87 {ASTM D648}	74 {ASTM D648}	96.1 {ASTM D648}		101 {ASTM D648}	heat deflection temperature at 1.8 MPa
108 {ASTM D1525}		107 {ASTM D1525}		91					101 {ASTM D1525}	110 {ASTM D1525}			Vicat B softening temperature
										0.68 {ASTM D696}			coefficient of linear thermal expansion (flow direction)
													coefficient of linear thermal expansion (normal direction)

					Graph 110	Graph 111	Graph 112	Graph 113	Graph 114	Graph 115	Graph 116	Graph 117
Material Family					polycarbonate/ acrylonitrile butadiene	polycarbonate/ acrylonitrile butadiene	polycarbonate polybutylene	polycarbonate polybutylene	polycarbonate polyethylene	polycarbonate polyethylene	polycarbonate polyethylene	polycarbonate polyethylene
Description					brominated flame retardant	halogen free flame retardant	unfilled, impact modified	10% glass fiber filled, impact modified	unfilled, impact modified	unfilled, from recyclate	"impact modified, from recyclate	unfilled, impact modified, from recyclate
Supplier					Bayer	Bayer	GE Plastics	GE Plastics	Bayer	MRC Polymers	MRC Polymers	MRC Polymers
Material Trade Name					Bayblend FR1441	Bayblend FR110	Xenoy 6123	Xenoy 6240	Makroblend UT1018	Stanuloy ST125	Stanuloy ST110WCS	Stanuloy ST150
Test Notes	**Test condition**	**Test Specimen**	**Test Method**	**(Unit)**								

PHYSICAL PROPERTIES

melt volume rate			ISO 1133, DIN 53735, CAMPUS	ml/10min		20 (240°C, 5 kg)						
melt flow rate			ASTM D1238	g/10min								
water absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%		0.7						
moisture absorption at saturation	test temperature: 21-25°C; relative humidity: 50%	50 x 50 x 1 mm	ISO 62, CAMPUS	%		0.2						
density	test temperature: 21-25°C	>=10 x >=10 x 4 mm	ISO 1183, CAMPUS	g/m^3		1190						
specific gravity			ASTM D792		1.18		1.24	1.3	1.22			
flammability UL94 at 1.6 mm		125 x 13 mm	UL 94, CAMPUS		V-0	V-0	HB		HB			

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

tensile modulus (secant, 1 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 1 mm/min; elongation: 0.05-0.25%; atmosphere according to ISO 291	ISO 3167 multipurpose test specimen	ISO 527-1, ISO 527-2, CAMPUS, DIN 53457	MPa	2700 {ASTM D638}	2600						
stress at yield (50 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 50 mm/min; atmosphere according to ISO 291	"	ISO 527-1, ISO 527-2, CAMPUS, DIN 53455	"		60						
strain at yield (50 mm/min)	"	"	"	%		4						
tensile strength at break (5 mm/min)	test temperature: 21-25°C; relative humidity: 50%; strain rate: 5 mm/min; atmosphere according to ISO 291	"	"	MPa	50 {ASTM D638}			62 {ASTM D638}	52 {ASTM D638}		57 {ASTM D638}	
strain at break (5 mm/min)	"	"	"	%	60 {ASTM D638}	>50 {50 mm/min}	130 {ASTM D638}	4.0 {ASTM D638}	165 {ASTM D638}		80 {ASTM D638}	
Charpy impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm	ISO 179/1eU, CAMPUS	kJ/m2								
Charpy impact strength (-30°C)	test temperature: -30°C	"	"	"								
Charpy notched impact strength (23°C)	test temperature: 23°C; relative humidity: 50%; atmosphere according to ISO 291	80 x 10 x 4 mm, V notch, r = 0.25 mm	ISO 179/1eA, CAMPUS	"								
Charpy notched impact strength (-30°C)	test temperature: -30°C	"	"	"								
notched Izod impact strength (23°C)		3.2 mm thick	ASTM D256	J/m	500		801	187	961		801	
flexural modulus			ASTM D790	MPa	2600		2000	2755	2070		2139	
flexural strength			ASTM D790	MPa	96		76	96	75		83	

THERMAL PROPERTIES

melting temperature				°C								
heat deflection temperature at 0.45 MPa		80 x 10 x 4 mm	ISO 75-1, ISO 75-2, CAMPUS	"	110 {ASTM D648}	100	116 {ASTM D648}	177 {ASTM D648}	115 {ASTM D648}		135 {ASTM D648}	
heat deflection temperature at 1.8 MPa		"	"	"	100 {ASTM D648}	90	87 {ASTM D648}	121 {ASTM D648}	88 {ASTM D648}		115 {ASTM D648}	
Vicat B softening temperature	load: 50N; note: 50°C/h	>=10 x >=10 x 4 mm	ISO/DIN 306, CAMPUS	"	110 {ASTM D1525}	108						
coefficient of linear thermal expansion (flow direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C		0.76	0.5	0.52				
coefficient of linear thermal expansion (normal direction)	test temperature: 23-55°C	>=10 x >=10 x 4 mm	ASTM E831, CAMPUS	E-4/°C		0.8	0.5	0.52				

Graph 118	Graph 119	Graph 120	Graph 121										
polycarbonate polyethylene	polycarbonate polyethylene	polypropylene/ polystyrene alloy (PP/ PS alloy)	polypropylene/ polystyrene alloy (PP/ PS alloy)										**Material Family**
unfilled, impact modified, UV stabilized, low viscosity	30% glass fiber filled, impact modified, from recyclate	35% glass fiber filled, impact modified	35% glass fiber filled, impact modified										**Description**
Bayer	MRC Polymers	Montell	Montell										**Supplier**
Makroblend UT403	Stanuloy ST170-30G	Hivalloy GXPA064	Hivalloy GXPA065										**Material Trade Name**
													Test Notes

PHYSICAL PROPERTIES

													melt volume rate
													melt flow rate
													water absorption at saturation
													moisture absorption at saturation
													density
1.22													specific gravity
HB													flammability UL94 at 1.6 mm

MECHANICAL PROPERTIES (AT 23°C /50% R.H.)

													tensile modulus (secant, 1 mm/min)
													stress at yield (50 mm/min)
													strain at yield (50 mm/min)
55 (ASTM D638)													tensile strength at break (5 mm/min)
151 (ASTM D638)													strain at break (5 mm/min)
													Charpy impact strength (23°C)
													Charpy impact strength (-30°C)
													Charpy notched impact strength (23°C)
													Charpy notched impact strength (-30°C)
800													notched Izod impact strength (23°C)
2330													flexural modulus
88													flexural strength

THERMAL PROPERTIES

													melting temperature
134 (ASTM D648)													heat deflection temperature at 0.45 MPa
120 (ASTM D648)													heat deflection temperature at 1.8 MPa
													Vicat B softening temperature
													coefficient of linear thermal expansion (flow direction)
													coefficient of linear thermal expansion (normal direction)

Glossary of Terms

ABS See *acrylonitrile butadiene styrene polymer.*

ABS nylon alloy See *acrylonitrile butadiene styrene polymer nylon alloy.*

ABS PC alloy See *acrylonitrile butadiene styrene polymer polycarbonate alloy.*

ABS resin See *acrylonitrile butadiene styrene polymer.*

absorption Taking up of matter in bulk by other matter, as in desolving a gas by a liquid.

acetal resins Thermoplastics prepared by polymerization of formaldehyde or its trioxane trimer. Acetals have high impact strength and stiffness, low friction coefficient and permeability, good dimensional stability and dielectric properties, and high fatigue strength and thermal stability. Acetals have poor acid and UV resistance and are flammable. Processed by injection and blow molding and extrusion. Used in mechanical parts such as gears and bearings, automotive components, appliances, and plumbing and electronic applications. Also called acetals.

acetals *See acetal resins.*

acrylate styrene acrylonitrile polymer Acrylic rubber-modified thermoplastic with high weatherability. ASA has good heat and chemical resistance, toughness, rigidity, and antistatic properties. Processed by extrusion, thermoforming, and molding. Used in construction, leisure, and automotive applications such as siding, exterior auto trim, and outdoor furniture. Also called ASA.

acrylic resins Thermoplastic polymers of alkyl acrylates such as methyl methacrylates. Acrylic resins have good optical clarity, weatherability, surface hardness, chemical resistance, rigidity, impact strength, and dimensional stability. They have poor solvent resistance, resistance to stress cracking, flexibility, and thermal stability. Processed by casting, extrusion, injection molding, and thermoforming. Used in transparent parts, auto trim, household items, light fixtures, and medical devices. Also called polyacrylates.

acrylonitrile butadiene styrene polymer ABS resins are thermoplastics comprised of a mixture of styrene-acrylonitrile copolymer (SAN) and SAN-grafted butadiene rubber. They have high impact resistance, toughness, rigidity and processability, but low dielectric strength, continuous service temperature, and elongation. Outdoor use requires protective coatings in some cases. Plating grades provide excellent adhesion to metals. Processed by extrusion, blow molding, thermoforming, calendaring and injection molding. Used in household appliances, tools, nonfood packaging, business machinery, interior automotive parts, extruded sheet, pipe and pipe fittings. Also called ABS, ABS resin, acrylonitrile-butadiene-styrene polymer.

acrylonitrile butadiene styrene polymer nylon alloy A thermoplastic processed by injection molding, with properties similar to ABS but higher elongation at yield. Also called ABS nylon alloy.

acrylonitrile butadiene styrene polymer polycarbonate alloy A thermoplastic processed by injection molding and extrusion, with properties similar to ABS. Used in automotive applications. Also called ABS PC alloy.

acrylonitrile copolymer A thermoplastic prepared by copolymerization of acrylonitrile with small amounts of other unsaturated monomers. Has good gas barrier properties and chemical resistance. Processed by extrusion, injection molding, and thermoforming. Used in food packaging.

acrylonitrile-butadiene-styrene polymer See *acrylonitrile butadiene styrene polymer.*

adsorption Retention of a substance molecule on the surface of a solid or liquid.

amorphous nylon Transparent aromatic polyamide thermoplastics. Produced by condensation of hexamethylene diamine, isophthalic and terephthalic acid.

amorphous polymer Amorphous polymers are polymers having noncrystalline or amorphous supramolecular structure or morphology. Amorphous polymers may have some molecular order but usually are substantially less ordered than crystalline polymers and subsequently have inferior mechanical properties. Materials in this class do not have a detectable melting point. Examples are PVC, acrylic, and polycarbonate.

aromatic polyester estercarbonate A thermoplastic block copolymer of an aromatic polyester with polycarbonate. Has higher heat distortion temperature than regular polycarbonate.

aromatic polyesters Engineering thermoplastics prepared by polymerization of aromatic polyol with aromatic dicarboxylic anhydride. They are tough with somewhat low chemical resistance. Processed by injection and blow molding, extrusion, and thermoforming. Drying is required. Used in automotive housings and trim, electrical wire jacketing, printed circuit boards, and appliance enclosures.

aromatic polymer Aromatic polymers are polymers, the backbone of which consist of repeating aromatic ring units. Aromatic rings in a unit may be single, fused, or joined by a chemical bond, bridging atom, or a group of atoms. Aromatic rings are 6 carbon rings containing three double bonds and are typified by benzene. Some hydrogen atoms in these rings may be substituted by other atoms or atom groups.

ASA *See acrylate styrene acrylonitrile polymer.*

ASTM D256 An American Society for Testing of Materials (ASTM) standard method for determination of the resistance to breakage by flexural shock of plastics and electrical insulating materials, as indicated by the energy extracted from standard pendulum-type hammers in breaking standard specimens with one pendulum swing. The hammers are mounted on standard machines of either Izod or Charpy type. **Note:** Impact properties determined include Izod or Charpy impact energy normalized per width of the specimen. Also called ASTM method D256-84. See also *impact energy.*

ASTM method D256-84 See *ASTM D256.*

ASTM D412 An American Society for Testing of Materials (ASTM) standard methods for determining tensile strength, tensile stress, ultimate elongation, tensile set and set after break of rubber at low, ambient and elevated temperatures using straight, dumbbell and cut-ring specimens.

ASTM D638 An American Society for Testing of Materials (ASTM) standard method for determining tensile strength, elongation and modulus of elasticity of reinforced or unreinforced plastics in the form of sheet, plate, moldings, rigid tubes and rods. Five (I-V) types, depending on dimensions, of dumbbell-shaped specimens with thickness not exceeding 14 mm are specified. Specified speed of testing varies depending on the specimen type and plastic rigidity. **Note:** Tensile properties determined include tensile stress (strength) at yield and at break, percentage elongation at yield or at break and modulus of elasticity. Also called ASTM method D638-84. See also *tensile strength*.

ASTM D638, type IV See *ASTM D638*.

ASTM method D638-84 See *ASTM D638*.

ASTM method D648 See *ISO 75*.

ASTM D671 An American Society for Testing of Materials (ASTM) standard test method for determination of the flexural fatigue strength of rigid plastics subjected to repeated flexural stress of the same magnitude in a fixed-cantilever type testing machine, designed to produce a constant-amplitude-of-force on the test specimen each cycle. The test results are presented as a plot (S-N curve) of applied stress vs. number of stress cycles required to produce specimen failure by fracture, softening, or reduction in stiffness by heating caused by internal friction (damping). The stress corresponding to the point when the plot becomes clearly asymptotic to a horizontal (constant-stress) line is reported as fatigue strength in pascals, along with corresponding number of cycles. Also called ASTM D671-71B.

ASTM D671-71B See *ASTM D671*.

ASTM D696 An American Society for Testing of Materials (ASTM) standard test method for the measurement of the coefficient of linear thermal expansion of plastics by using a vitreous silica dilatometer. The test is carried out under conditions excluding any significant creep or elastic strain rate and effects of moisture, curing, loss of plasticizer, etc. The specimen is placed at the bottom of the outer dilatometer tube and the tube is immersed in a liquid bath at a desired temperature.

ASTM D746 An American Society for Testing of Materials (ASTM) standard method for determining brittleness temperature of plastics and elastomers by impact. The brittleness temperature is the temperature at which 50% of cantilever beam specimens fail on impact of a striking edge moving at a linear speed of 1.8-2.1 m/s and striking the specimen at a specified distance from the clamp. The temperature of the specimen is controlled by placing it in a heat-transfer medium, the temperature of which (usually subfreezing) is controlled by a thermocouple.

ASTM D785 An American Society for Testing of Materials (ASTM) standard test method for determination of indentation hardness of plastics by a Rockwell tester. The hardness number is derived from the net increase in the depth of impression as the load on a ball indenter is increased from a fixed minor load (10 kgf) to a major load and then returned to the minor load. This number consists of the number of scale divisions (each corresponding to 0.002 mm vertical movement of the indentor) and scale symbol. Rockwell scales, designated by a single capital letter of English alphabet, vary depending on the diameter of the indentor and the major load.

ASTM D1708 An American Society for Testing of Materials (ASTM) standard method for determining tensile properties of plastics using microtensile specimens with maximum thickness 3.2 mm and minimum length 38.1 mm, including thin films. Tensile properties include yield strength, tensile strength, tensile strength at break, elongation at break, etc. determined per ASTM D638.

ASTM D2240 An American Society for Testing of Materials (ASTM) standard method for determining the hardness of materials ranging from soft rubbers to some rigid plastics by measuring the penetration of a blunt (type A) or sharp (type D) indenter of a durometer at a specified force. The blunt indenter is used for softer materials and the sharp indenter - for more rigid materials.

ASTM D3763 An American Society for Testing of Materials (ASTM) standard method for determination of the resistance of plastics, including films, to high-speed puncture over a broad range of test velocities using load and displacement sensors. **Note:** Puncture properties determined include maximum load, deflection to maximum load point, energy to maximum load point and total energy. Also called ASTM method D3763-86. See also *impact energy*.

ASTM method D3763-86 See *ASTM D3763*.

B

bending properties See *flexural properties*.

bending strength See *flexural strength*.

bending stress See *flexural stress*.

bisphenol A polyester A thermoset unsaturated polyester based on bisphenol A and fumaric acid.

breaking elongation See *elongation*.

brittle temperature Temperature at which a material transforms from being ductile to being brittle, i.e., the critical normal stress for fracture is reached before the critical shear stress for plastic deformation.

bursting strength Bursting strength of a material, such as plastic film, is the minimum force per unit area or pressure required to produce rupture. The pressure is applied with a ram or a diaphragm at a controlled rate to a specified area of the material held rigidly and initially flat but free to bulge under the increasing pressure.

C

CA See *cellulose acetate*.

CAB See *cellulose acetate butyrate*.

carbon black A black colloidal carbon filler made by the partial combustion or thermal cracking of natural gas, oil, or another hydrocarbon. There are several types of carbon black depending on the starting material and the method of manufacture. Each type of carbon black comes in several grades. Carbon black is widely used as a filler and pigment in rubbers and plastics. It reinforces, increases the resistance to UV light and reduces static charging.

cellulose acetate Thermoplastic esters of cellulose with acetic acid. Have good toughness, gloss, clarity, processability, stiffness, hardness, and dielectric properties, but poor chemical, fire and water resistance and compressive strength. Processed by injection and blow molding and extrusion. Used for appliance cases, steering wheels, pens, handles, containers, eyeglass frames, brushes, and sheeting. Also called CA.

cellulose acetate butyrate Thermoplastic mixed esters of cellulose with acetic and butyric acids. Have good toughness, gloss, clarity, processability, dimensional stability, weatherability, and dielectric properties, but poor chemical, fire and water resistance and compressive strength. Processed by injection and blow molding and extrusion. Used for appliance cases, steering wheels, pens, handles, containers, eyeglass frames, brushes, and sheeting. Also called CAB.

cellulose propionate Thermoplastic esters of cellulose with propionic acid. Have good toughness, gloss, clarity, processability, dimensional stability, weatherability, and dielectric properties, but poor chemical, fire and water resistance and compressive strength. Processed by injection and blow molding and extrusion. Used for appliance cases, steering wheels, pens, handles, containers, eyeglass frames, brushes, and sheeting. Also called CP.

cellulosic plastics Thermoplastic cellulose esters and ethers. Have good toughness, gloss, clarity, processability, and dielectric properties, but poor chemical, fire and water resistance and compressive strength. Processed by injection and blow molding and extrusion. Used for appliance cases, steering wheels, pens, handles, containers, eyeglass frames, brushes, and sheeting.

chain scission Breaking of the chainlike molecule of a polymer as a result of chemical, photochemical, etc. reaction such as thermal degradation or photolysis.

Charpy impact energy The energy required to break a notched specimen, for metals in accordance with ASTM E23, equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact with the specimen and the energy remaining after complete fracture of the specimen.

chemical saturation Absence of double or triple bonds in a chain organic molecule such as that of most polymers, usually between carbon atoms. Saturation makes the molecule less reactive and polymers less susceptible to degradation and crosslinking. Also called chemically saturated structure.

chemical unsaturation Presence of double or triple bonds in a chain organic molecule such as that of some polymers, usually between carbon atoms. Unsaturation makes the molecule more reactive, especially in free-radical addition reactions such as addition polymerization, and polymers more susceptible to degradation, crosslinking and chemical modification. Also called polymer chain unsaturation.

chemically saturated structure See *chemical saturation*.

chlorendic polyester A chlorendic anhydride-based unsaturated polyester.

chlorinated polyvinyl chloride Thermoplastic produced by chlorination of polyvinyl chloride. Has increased glass transition temperature, chemical and fire resistance, rigidity, tensile strength, and weatherability as compared to PVC. Processed by extrusion, injection molding, casting, and calendering. Used for pipes, auto parts, waste disposal devices, and outdoor applications. Also called CPVC.

chlorosulfonated polyethylene rubber Thermosetting elastomers containing 20- 40% chlorine. Have good weatherability and heat and chemical resistance. Used for hoses, tubes, sheets, footwear soles, and inflatable boats.

coefficient of friction See *kinetic coefficient of friction*.

coefficient of friction, kinetic See *kinetic coefficient of friction*.

coefficient of friction, static See *static coefficient of friction*.

compatibilizer A chemical compound used to increase the compatibility or miscibility and to prevent the separation of the components in a plastic composition, such as the compatibility of a resin and a plasticizer or of two polymers in a blend. Block copolymers bearing blocks similar to the polymers in the blend are often used as compatibilizers in the latter case.

concentration units The units for measuring the content of a distinct material or substance in a medium other than this material or substance, such as solvent. **Note:** The concentration units are usually expressed in the units of mass or volume of substance per one unit of mass or volume of medium. When the units of substance and medium are the same, the percentage is often used.

conditioning Process of bringing the material or apparatus to a certain condition, e.g., moisture content or temperature, prior to further processing, treatment, etc. Also called conditioning cycle.

conditioning cycle See *conditioning*.

continuous maximum service temperature Maximum temperature at which a material can perform reliably in a long-term application.

copolymer Copolymers are polymers prepared by polymerization of two or sometimes more monomers. Copolymers are called random when different repeating units are in random order, block when they are arranged in blocks consisting of different repeating units, alternating when they alternate, and graft when some monomers are polymerized and grafted to the existing polymer.

covulcanization Simultaneous vulcanization of a blend of two or more different rubbers to enhance their individual properties such as ozone resistance. Rubbers are often modified to improve covulcanization.

CP See *cellulose propionate*.

CPVC See *chlorinated polyvinyl chloride*.

cracking Appearance of external and/or internal cracks in the material as a result of stress that exceeds the strength of the material. The stress can be external and/or internal and can be caused by a variety of adverse conditions: structural defects, impact, aging, corrosion, etc. or a combination of thereof. Also called cracks. See also *processing defects*.

cracks See *cracking*.

crazes See *crazing*.

crazing Appearance of thin cracks on the surface of the material or, sometimes, minute frost-like internal cracks, as a result of stress that exceeds the strength of the material, impact, terperature changes, degredation, ect. Also called crazes.

creep Time-dependent increase in strain in material, occuring under stress.

crosslinked polyethylene Polyethylene thermoplastics partially photochemically or chemically crosslinked. Have improved tensile strength, dielectric properties, and impact strength at low and elevated temperatures.

crosslinking Reaction of formation of covalent bonds between chain-like polymer molecules or between polymer molecules and low-molecular compounds such as carbon black fillers. As a result of crosslinking polymers, such as thermosetting resins, may become hard and infusible. Crosslinking is induced by heat, UV or electron-beam radiation, oxidation, etc. Crosslinking can be achieved ether between polymer molecules alone as in unsaturated polyesters or with the help of multifunctional crosslinking agents such as diamines that react with functional side groups of the polymers. Crosslinking can be catalysed by the presence of transition metal complexes, thiols and other compounds.

crystal polystyrene See *general purpose polystyrene*.

crystalline melting point The temperature of melting of the crystallite phase of a crystalline polymer. It is higher than the temperature of melting of the surrounding amorphous phase.

crystallinity Content of crystalline phase, usually as percentage.

CTFE See *polychlorotrifluoroethylene*.

cycle time See *processing time*.

cyclic compounds A broad class of organic compounds consisting of carbon rings that are saturated, partially unsaturated or aromatic, in which some carbon atoms may be replaced by other atoms such as oxygen, sulfur and nitrogen.

D

DAP See *diallyl phthalate resins*.

dart impact energy The mean energy of a free-falling dart that will cause 50% failures after 50 tests to a specimen directly stricken by the dart. The energy is calculated by multiplying dart mass, gravitational acceleration and drop height. Also called falling dart impact energy, dart impact strength, falling dart impact strength.

dart impact strength See *dart impact energy*.

deflection temperature under load See *heat deflection temperature*.

deformation under load The dimensional change of a material under load for a specified time following the instantaneous elastic deformation caused by the initial application of the load.

degradation Loss or undesirable change in the properties, such as color, of a material as a result of aging, chemical reaction, wear, exposure, etc. See also *stability*.

diallyl phthalate resins Thermosets supplied as diallyl phthalate prepolymer or monomer. Have high chemical, heat and water resistance, dimensional stability, and strength. Shrink during peroxide curing. Processed by injection, compression and transfer molding. Used in glass-reinforced tubing, auto parts, and electrical components. Also called DAP.

diffusion Spontaneous slow mixing of different substances in contact without influence of external forces.

DIN 53453 A German Standards Institute (DIN) standard specifying conditions for the flexural impact testing of molded or laminated plastics. The bar specimens are either unnotched or notched on one side, mounted on two-point support and struck in the middle (on the unnotched side for notched specimens) by a hammer of the pendulum impact machine. Impact strength of the specimen is calculated relative to the cross-sectional area of the specimen as the energy required to break the specimen equal to the difference between the energy in the pendulum at the instant of impact and the energy remaining after complete fracture of the specimen. Also called DIN 53453 impact test.

DIN 53453 impact test See *DIN 53453*.

DIN 53456 A German Standards Institute (Deutsches Institut fuer Normen, DIN) standard test method for determining ball indentation hardness of plastics. The indentor is forced into the specimen under the action of the major load, the position of the indentor having been fixed beforehand as a zero point by the application of a minor load. The hardness is calculated as the ratio of the major load to the area of indentation.

DIN 53461 See *ISO 75*.

DMA See dynamic mechanical analysis.

drop dart impact See f*alling weight impact energy*.

drop dart impact energy See *falling weight impact energy*.

drop dart impact strength See *falling weight impact energy*.

drop weight impact See *falling weight impact energy*.

drop weight impact energy See *falling weight impact energy*.

drop weight impact strength See *falling weight impact energy*.

durometer A hardness See *Shore hardness*.

DTUL See *heat deflection temperature*.

durometer hardness Indentation hardness of a material as determined by either the depth of an indentation made with an indentor under specified load or the indentor load required to produced specified indentation depth. The tool used to measure indentation hardness of polymeric materials is called durometer, e.g., Shore-type durometer.

dynamic mechanical analysis A technique that employs a low-strain, oscillatory stress in order to quantify the viscoelastic behavior of materials. Commonly referred to as DMA.

E

ECTFE See *ethylene chlorotrifluoroethylene copolymer.*

elasticity Property whereby a solid material changes its shape and size under action of opposing forces, but recovers its original configuration when the forces are removed.

elastomer A large class of polymers that can be stretched at room temperature to at least twice their original length and, after having been stretched and the stress removed, return with force to approximately their original length in a short time. This class includes natural and synthetic rubbers, i.e., elastomers that can be vulcanized, and thermoplastic elastomers. They are characterized by a combination of low modulus and good elastic recovery. Polymeric materials of this type are above the glass transition in the temperature range at which they are useful.

elongation The increase in gauge length of a specimen in tension, measured at or after the fracture, depending on the viscoelastic properties of the material. **Note:** Elongation is usually expressed as a percentage of the original gauge length. Also called tensile elongation, elongation at break, ultimate elongation, breaking elongation, elongation at rupture. See also *tensile strain.*

elongation at break The increase in distance between two gauge marks, resulting from stressing the specimen in tension, at the exact point of break. See also *elongation.*

elongation at rupture See *elongation, elongation at break.*

elongation at yield The increase in distance between two gauge marks resulting from stressing the specimen in tension to the yield point. See also *elongation.*

EMAC See *ethylene methyl acrylate copolymer.*

embrittlement A reduction or loss of ductility or toughness in materials such as plastics resulting from chemical or physical damage.

endurance limit The maximum stress below which a material can endure an infinite number of loading-unloading cycles of specified type without failure or, in practice, a very large number of cycles. Also called fatigue endurance limit.

EPDM See *EPDM rubber.*

EPDM rubber Sulfur-vulcanizable thermosetting elastomers produced from ethylene, propylene, and a small amount of nonconjugated diene such as hexadiene. Have good weatherability and chemical and heat resistance. Used as impact modifiers and for weather stripping, auto parts, cable insulation, conveyor belts, hoses, and tubing. Also called EPDM.

epoxides Organic compounds containing three-membered cyclic group(s) in which two carbon atoms are linked with an oxygen atom as in an ether. This group is called an epoxy group and is quite reactive, allowing the use of epoxides as intermediates in preparation of certain fluorocarbons and cellulose derivatives and as monomers in preparation of epoxy resins. Also called epoxy compounds.

epoxies See *epoxy resins.*

epoxy compounds See *epoxides.*

epoxy resins Thermosetting polyethers containing crosslinkable glycidyl groups. Usually prepared by polymerization of bisphenol A and epichlorohydrin or reacting phenolic novolaks with epichlorohydrin. Can be made unsaturated by acrylation. Unmodified varieties are cured at room or elevated temperatures with polyamines or anhydrides. Bisphenol A epoxy resins have excellent adhesion and very low shrinkage during curing. Cured novolak epoxies have good UV stability and dielectric properties. Cured acrylated epoxies have high strength and chemical resistance. Processed by molding, casting, coating, and lamination. Used as protective coatings, adhesives, potting compounds, and binders in laminates and composites. Also called epoxies.

EPR See *ethylene propene rubber.*

ETFE See *ethylene tetrafluoroethylene copolymer.*

ethylene An alkene (unsaturated aliphatic hydrocarbon) with two carbon atoms, $CH_2{=}CH_2$. A colorless, highly flammable gas with sweet odor. Autoignition point 543°C. Derived by thermal cracking of hydrocarbon gases or from synthesis gas. Used as monomer in polymer synthesis, refrigerant, and anesthetic. Also called ethene.

ethylene acrylic rubber Copolymers of ethylene and acrylic esters. Have good toughness, low temperature properties, and resistance to heat, oil, and water. Used in auto and heavy equipment parts.

ethylene copolymers See *ethylene polymers.*

ethylene methyl acrylate copolymer Thermoplastic copolymers of ethylene with <40% methyl acrylate. Have good dielectric properties, toughness, thermal stability, stress crack resistance, and compatibility with other polyolefins. Transparency decreases with increasing content of acrylate. Processed by blown film extrusion and blow and injection molding. Used in heat-sealable films, disposable gloves, and packaging. Some grades are FDA-approved for food packaging. Also called EMAC.

ethylene polymers Ethylene polymers include ethylene homopolymers and copolymers with other unsaturated monomers, most importantly olefins such as propylene and polar substances such as vinyl acetate. The properties and uses of ethylene polymers depend on the molecular structure and weight. Also called ethylene copolymers.

ethylene propene rubber Stereospecific copolymers of ethylene with propylene. Used as impact modifiers for plastics. Also called EPR.

ethylene tetrafluoroethylene copolymer Thermoplastic alternating copolymer of ethylene and tetrafluoroethylene. Has good impact strength, abrasion and chemical resistance, weatherability, and dielectric properties. Processed by molding, extrusion, and powder coating. Used in tubing, cables, pump parts, and tower packing in a wide temperature range. Also called ETFE.

ethylene vinyl alcohol copolymer Thermoplastics prepared by hydrolysis of ethylene-vinyl acetate polymers. Have good barrier properties, mechanical strength, gloss, elasticity, weatherability, clarity, and abrasion resistance. Barrier properties and processibility improve with increasing content of ethylene due to lower absorption of moisture. Ethylene content of high barrier grades range from 32 to 44 mole %. Processed by extrusion, coating, blow and blow film molding, and thermoforming. Used as packaging films and container liners. Also called EVOH.

ethylene-acrylic acid copolymer A flexible thermoplastic with water and chemical resistance and barrier properties similar to those of low-density polyethylene and enhanced adhesion, optics, toughness, and hot tack properties, compared to the latter. Contains 3-20% acrylic acid, with density and adhesion to polar substrates increasing with increasing acrylic acid content. FDA-approved for direct contact with food. Processed by extrusion, blow and film methods and extrusion molding, and extrusion coating. Used in rubberlike small parts like pipe caps, hoses, gaskets, gloves, hospital sheeting, diaper liners, and packaging film.

EVOH See *ethylene vinyl alcohol copolymer*.

extenders Relatively inexpensive resin, plasticizer or filler such as carbonate used to reduce cost and/or to improve processing of plastics, rubbers or nonmetallic coatings.

F

falling dart impact See *falling weight impact energy*.

falling dart impact energy See *dart impact energy*.

falling dart impact strength See *falling weight impact energy*.

falling weight impact See *falling weight impact energy*.

falling weight impact energy The mean energy of a free-falling dart or weight (tup) that will cause 50% failures after 50 tests to a directly or indirectly stricken specimen. The energy is calculated by multiplying dart mass, gravitational acceleration and drop height. Also called falling weight impact strength, falling weight impact, falling dart impact energy, falling dart impact strength, falling dart impact, drop dart impact energy, drop dart impact strength.

falling weight impact strength See *falling weight impact energy*.

fatigue endurance limit See *endurance limit*.

fatigue life Number of loading-unloading cycles of a specified type that material specimen can endure before failing in a fatigue test. Also called cycles to failure.

FEP See *fluorinated ethylene propylene copolymer*.

filler A relatively inert substance added to plastics to reduce their cost and/or improve physical properties such as impact strength. In contrast to reinforcement, filler particles are usually nonfibrous, small, and do not improve the tensile strength. The fillers are added to the plastics at fairly high percentages (>5 vol.%). The most important fillers are mineral and glass fillers. Based on their use, the fillers are also classified as extenders and reinforcing fillers.

fireproofing agent See *flame retardant*.

flame retardant A substance that reduce the flammability of materials such as plastics or textiles in which it is incorporated. There are inorganic flame retardants such as antimony trioxide (Sb_2O_3) and organic flame retardants such as brominated polyols. The mechanisms of flame retardation vary depending on the nature of material and flame retardant. For example, some flame retardants yield a substantial volume of coke on burning, which prevents oxygen from reaching inside the material and blocks further combustion. Also called fireproofing agent, flame retardant chemical additives, ignition resistant chemical additives.

flame retardant chemical additives See *flame retardant*.

flammability UL rating A vertically oriented sample with a thickness of 0.125 inches is exposed to a Bunsen burner flame for 10 s. If burning ceases within 30 s, a second 10 s application of flame is required. Cotton is placed under the sample to catch flame drippings. If the average burning time is lower than 5 s and drips do not ignite the cotton, the material is self- extinguishing, rating V-0. If the time is lower than 25 s and drips do not ignite the cotton, the material is self- extinguishing, rating V-1; and if the cotton is ignited, the material is self-extinguishing, rating V-2. If the sample burns slower than 1.5 in/min than the rating is HB.

flaw See *processing defects*.

flexural fatigue Progressive localized permanent structural change occurring in a material subjected to cyclic flexural stress that may culminate in cracks or complete fracture after a sufficient number of cycles.

flexural modulus of elasticity The ratio, within the elastic limit, of the applied stress on a test specimen in flexure to the corresponding strain in the outermost fibers of the specimen.

flexural properties Properties describing the reaction of physical systems to flexural stress and strain. Also called bending properties.

flexural strength The maximum stress in the extreme fiber of a specimen loaded to failure in bending. **Note:** Flexural strength is calculated as a function of load, support span and specimen geometry. Also called modulus of rupture in bending, modulus of rupture, bending strength.

flexural stress The maximum stress in the extreme fiber of a specimen in bending. **Note:** Flexural stress is calculated as a function of load at a given strain or at failure, support span and specimen geometry. Also called bending stress.

flexural yield strength The maximum stress in the bended specimen at the yield point, i.e., when the deflection increases without an increase in the load. For metals, it is measured according to ASTM E290 and related standards. **Note:** Flexural yield strength is calculated if the specimen does not break.

flexure Condition of a specimen under bending loading in which the points originally lying on any straight line are displaced to form a plane curve.

fluorinated ethylene propylene copolymer Thermoplastic copolymer of tetrafluoroethylene and hexafluoropropylene. Has decreased tensile strength and wear and creep resistance, but good weatherability, dielectric properties, fire and chemical resistance, and friction. Decomposes above 204°C (400°F), releasing toxic products. Processed by molding, extrusion, and powder coating. Used in chemical apparatus liners, pipes, containers, bearings, films, coatings, and cables. Also called FEP.

fluoro rubber See *fluoroelastomers*.

fluoroelastomers Fluorine-containing synthetic rubber with good chemical and heat resistance. Used in underhood applications such as fuel lines, oil and coolant seals, and fuel pumps, and as a flow additive for polyolefins. Also called fluoro rubber.

fluoroplastics See *fluoropolymers.*

fluoropolymers Polymers prepared from unsaturated fluorine-containing hydrocarbons. Have good chemical resistance, weatherability, thermal stability, antiadhesive properties and low friction and flammability, but low creep resistance and strength and poor processibility. The properties vary with the fluorine content. Processed by extrusion and molding. Used as liners in chemical apparatus, in bearings, films, coatings, and containers. Also called fluoroplastics.

fluorosilicones Polymers with chains of alternating silicon and oxygen atoms and trifluoropropyl pendant groups. Most are rubbers.

FMQ See *methylfluorosilicones.*

fracture mechanics A method of fracture analysis that can determine the stress required to induce fracture instability in a structure containing a crack of known size and shape. Also called linear elastic fracture mechanics.

furnace black The most common type of carbon black made by burning vaporized heavy oil fractions in a furnace with 50% of the air required for complete combustion. It comes in high abrasion, fast extrusion, high modulus, general purpose, semireinforcing, conducting, high elongation, reinforcing and fast-extruding grades among others. Furnace black is widely used as a filler and pigment in rubbers and plastics. It reinforces, increases the resistance to UV light and reduces static charging.

G

gas black See *channel black.*

general purpose polystyrene General purpose polystyrene is an amorphous thermoplastic prepared by homopolymerization of styrene. It has good tensile and flexural strengths, high light transmission and adequate resistance to water, detergents and inorganic chemicals. It is attached by hydrocarbons and has a relatively low impact resistance. Processed by injection molding and foam extrusion. Used to manufacture containers, health care items such as pipettes, kitchen and bathroom housewares, stereo and camera parts and foam sheets for food packaging. Also called crystal polystyrene.

glass bead Glass beads range in size from 5 to 5000 um, but normally are about 30 um in diameter. They improve the flexural modulus, abrasion resistance, compressive strength, mold flow, and corrosion resistance of plastics; reduce mold shrinkage and cycle time. The beads are made from various kinds of glass including A type and borosilicate and can be surface modified with silane coupling agents to improve adhesion to the polymer matrix. Used in housewares, machine parts, bearings, molds, and auto parts.

glass filler Glass fillers are a widely used family of fillers in the form of beads, hollow spheres, flakes, or milled particles. They increase dimensional stability, chemical resistance, moisture resistance, and thermal stability of plastics.

glass transition temperature (T_g) The temperature at which an amorphous polymer (or the amorphous regions in a partially crystalline polymer) changes from a hard and relatively brittle condition to a viscous or rubbery condition. In this temperature region, many physical properties, such as hardness, brittleness, thermal expansion, and specific heat, undergo significant, rapid changes. **Note:** In dynamic mechanical analysis (DMA), the peak of the loss modulus is conventionally identified as the glass transition temperature, even though the DMA plot clearly shows that the transition is a process that spans a temperature range.

H

hard clays Sedimentary rocks composed mainly of fine clay mineral material without natural plasticity, or any compacted or indurated clay.

HDPE See *high density polyethylene.*

HDT See *heat deflection temperature.*

heat deflection point See *heat deflection temperature.*

heat deflection temperature The temperature at which a material specimen (standard bar) is deflected by a certain degree under specified load. At this temperature, a material achieves a specific modulus which is defined by the applied stress and the sample geometry. Also called heat distortion temperature, heat distortion point, heat deflection point, deflection temperature under load, DTUL, tensile heat distortion temperature, HDT. See also *ISO 75.*

heat distortion point See *heat deflection temperature.*

heat distortion temperature See *heat deflection temperature.*

high density polyethylene A linear polyethylene with density 0.94-0.97 g/cm^3. Has good toughness at low temperatures, chemical resistance, and dielectric properties and high softening temperature, but poor weatherability. Processed by extrusion, blow and injection molding, and powder coating. Used in houseware, containers, food packaging, liners, cable insulation, pipes, bottles, and toys. Also called HDPE.

high impact polystyrene See *impact polystyrene.*

high molecular weight low density polyethylene Thermoplastic with improved abrasion and stress crack resistance and impact strength, but poor processibility and reduced tensile strength. Also called HMWLDPE.

HIPS See *impact polystyrene.*

HMWLDPE See *high molecular weight low density polyethylene.*

I

ignition resistant chemical additives See *flame retardant.*

impact energy The energy required to break a specimen, equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact and the energy remaining after complete fracture of the specimen. Also called impact strength. See also *ASTM D256, ASTM D3763.*

impact polystyrene Impact polystyrene is a thermoplastic produced by polymerizing styrene dissolved in butadiene rubber. Impact polystyrene has good dimensional stability, high rigidity and good low temperature impact strength, but poor barrier properties, grease resistance and heat resistance. Processed by extrusion, injection molding, thermoforming and structural foam molding. Used in food packaging, kitchen housewares, toys, small appliances, personal care items and audio products. Also called IPS, high impact polystyrene, HIPS, impact PS.

impact property tests Names and designations of the methods for impact testing of materials. Also called impact tests. See also impact toughness.

impact PS See *impact polystyrene.*

impact strength See *impact energy.*

impact tests See *impact property tests.*

impact toughness Property of a material indicating its ability to absorb energy of a high-speed impact by plastic deformation rather than crack or fracture. See also *impact property tests.*

intermittent maximum service temperature Maximum temperature at which a material can perform reliably in a short-term application.

ionomers Thermoplastics containing a relatively small amount of pendant ionized acid groups. Have good flexibility and impact strength in a wide temperature range, puncture and chemical resistance, adhesion, and dielectric properties, but poor weatherability, fire resistance, and thermal stability. Processed by injection, blow and rotational molding, blown film extrusion, and extrusion coating. Used in food packaging, auto bumpers, sporting goods, and foam sheets.

IPS See *impact polystyrene.*

ISO 2039-2 An International Organization for Standardization (ISO) standard test method for determination of indentation hardness of plastics by Rockwell tester using Rockwell M, L, and R hardness scales. The hardness number is derived from the net increase in the depth of impression as the load on a ball indenter is increased from a fixed minor load (98.07 N) to a major load and then returned to the minor load. This number consists of the number of scale divisions (each corresponding to 0.002 mm vertical movement of the indentor) and scale symbol. Rockwell scale vary depending on the diameter of the indentor and the major load. For example, scale R corresponds to the ball diameter 12.7 mm and major load 588.4 N. Also called *ISO 2039-B.*

ISO 2039-B See *ISO 2039-2.*

ISO 75 An International Organization for Standardization (ISO) standard test method for determination of heat deflection temperature (HDT) and deflection temperature under load (DTUL). HDT is a relative measure of a material's ability to perform for a short time at elevated temperatures while supporting a load. The test measures the effect of temperature on stiffness: a standard test specimen is given a defined surface stress and the temperature is raised at a uniform rate. Alternate test methods for HDT and DTUL are DIN 53461 and ASTM D648.

In both ISO and ASTM standards, a loaded test bar is placed in a silicone oil filled heating bath. The surface stress on the specimen is either: low - for ASTM and ISO both 0.45 MPa; high - for ASTM 1.82 MPa and for ISO 1.80 MPa. The force is allowed to act for 5 minutes; this waiting period may be omitted when testing materials that show no appreciable creep during the inital 5 minutes. After 5 minutes the original bath temperature of 23°C is raised at a uniform rate of 2°C/minute.

The deflection of the test bar is continuously observed: the temperature at which the deflection reaches 0.32 mm (ISO) or 0.25 mm (ASTM), is reproted as 'deflection temperature under load' or 'heat deflection temperature. Although not mentioned in either test standard, it has become common practice to use the acronym DTUL for ASTM values and HDT for ISO values. Depending upon the applied surface stress, the letters A or B are added to HDT: HDT/A for a load of 1.80 MPa; HDT/B for a load of 0.45 MPa.

isophthalate polyester An unsaturated polyester based on isophthalic acid.

Izod See *Izod impact energy.*

Izod impact See *Izod impact energy.*

Izod impact energy The energy required to break a specimen equal to the difference between the energy in the striking member of the Izod-type impact apparatus at the instant of impact and the energy remaining after complete fracture of the specimen. Also called Izod impact, Izod impact strength, Izod.

Izod impact strength See *Izod impact energy.*

J

J See *joule.*

joule A unit of energy in SI system that is equal to the work done when the point of application of a force of one newton (N) is displaced through distance of one meter (m) in the direction of the force. The dimension of joule is N m. Also called J.

K

kinetic coefficient of friction The ratio of tangential force, which is required to sustain motion without acceleration of one surface with respect to another, to the normal force, which presses the two surfaces together. Also called coefficient of friction, coefficient of friction, kinetic.

L

LCP See *liquid crystal polymers.*

LDPE See *low density polyethylene.*

linear expansion coefficient The change in specimen length resulting from a specified change in temperature per specimen length at a reference temperature per said change in temperature.

linear low density polyethylene Linear polyethylenes with density 0.91-0.94 g/cm^3. Has better tensile, tear, and impact strength and crack resistance properties, but poorer haze and gloss than branched low-density polyethylene. Processed by extrusion at increased pressure and higher melt temperatures compared to branched low-density polyethylene, and by molding. Used to manufacture film, sheet, pipe, electrical insulation, liners, bags and food wraps. Also called LLDPE, LLDPE resin.

linear polyethylenes Linear polyethylenes are polyolefins with linear carbon chains. They are prepared by copolymerization of ethylene with small amounts of higher alfa-olefins such as 1-butene. Linear polyethylenes are stiff, tough and have good resistance to environmental cracking and low temperatures. Processed by extrusion and molding. Used to manufacture film, bags, containers, liners, profiles and pipe.

liquid crystal polymers Thermoplastic aromatic copolyesters with highly ordered structure. Have good tensile and flexural properties at high temperatures, chemical, radiation and fire resistance, and weatherability. Processed by sintering and injection molding. Used to substitute ceramics and metals in electrical components, electronics, chemical apparatus, and aerospace and auto parts. Also called LCP.

LLDPE See *linear low density polyethylene*.

LLDPE resin See *linear low density polyethylene*.

loss modulus In a dynamic experiment, that portion of the stress-strain response which is out of phase with the applies stress. The loss modulus is related to that portion of the polymer structure that undergoes viscous flow when a load is applied. **Note:** Loss modulus versus temperature curves are commonly reported in dynamic mechanical analysis (DMA) tests.

low density polyethylene A branched-chain thermoplastic with density 0.91-0.94 g/cm^3. Has good impact strength, flexibility, transparency, chemical resistance, dielectric properties, and low water permeability and brittleness temperature, but poor heat, stress cracking and fire resistance and weatherability. Processed by extrusion coating, injection and blow molding, and film extrusion. Can be crosslinked. Used in packaging and shrink films, toys, bottle caps, cable insulation, and coatings. Also called LDPE.

M

macroscopic properties See *thermodynamic properties*.

mechanical loss Loss in energy, dissipated as heat, that result when a material is subjected to an oscillatory load or displacement.

mechanical properties Properties describing the reaction of physical systems to stress and strain.

melamine resins Thermosetting resins prepared by condensation of formaldehyde with melamine. Have good hardness, scratch and fire resistance, clarity, colorability, rigidity, dielectric properties, and tensile strength, but poor impact strength. Molding grades are filled. Processed by compression, transfer, and injection molding, impregnation, and coating. Used in cosmetic containers, appliances, tableware, electrical insulators, furniture laminates, adhesives, and coatings.

melt index The amount, in grams, of a thermoplastic polymer which can be forced through an orifice of 0.0825 in. diameter when subjected to a force of 2160 gf in 10 min at 190 C.

melt strength Denotes the viscous flow of a polymer melt under tensile stress.

melt viscosity Intrinsic viscosity of a molten plastic material as determined in a capillary rheometer.

melt volume index The volume of plastic extruded in 10 min at a given load on a specified die.

methylfluorosilicones Silicone rubbers containing pendant fluorine and methyl groups. Have good chemical and heat resistance. Used in gasoline lines, gaskets, and seals. Also called FMQ.

methylphenylsilicones Silicone rubbers containing pendant phenyl and methyl groups. Have good resistance to heat, oxidation, and radiation, and compatibility with plastics.

methylsilicone Silicone rubbers containing pendant methyl groups. Have good heat and oxidation resistance. Used in electrical insulation and coatings. Also called MQ.

methylvinylfluorosilicone Silicone rubbers containing pendant vinyl, methyl, and fluorine groups. Can be additionally crosslinked via vinyl groups. Have good resistance to petroleum products at elevated temperatures.

methylvinylsilicone Silicone rubbers containing pendant methyl and vinyl groups. Can be additionally crosslinked via vinyl groups. Vulcanized to high degrees of crosslinking. Used in sealants, adhesives, coatings, cables, gaskets, tubing, and electrical tape.

mica Mica is a crystalline platy filler made by wet or dry grinding of muscovite or phlogopite, minerals consisting mainly of aluminum and potassium orthosilicates, or by chemical reaction between potassium fluorosilicate and alumina. Used as a filler in thermosetting resins to impart good dielectric properties and heat resistance, and in thermoplastics such as polyolefins to improve dimensional stability, heat resistance, and mechanical strength. Mica fillers also reduce vapor permeability and increase wear resistance. Mica fillers having increased flake size or platiness increase flexural modulus, strength, heat deflection temperature, and moisture resistance. Surface modified grades of mica are available for specialty applications.

micron A unit of length equal to 1E-06 meter. Its symbol is Greek small letter mu(μ) or mum.

microtensile specimen A small specimen as specified in ASTM D1708 for determining tensile properties of plastics. It has maximum thickness 3.2 mm and minimum length 38.1 mm. Tensile properties determined with this specimen include yield strength, tensile strength, tensile strength at break and elongation at break.

migration A mass-transfer process in which the matter moves from one place to another usually in a slow and spontaneous fashion. In plastics and coatings, migration of pigments, fillers, plasticizers and other ingredients via diffusion or floating to the surface or through interface to other materials results in various defects called blooming, chalking, bronzing, flooding, bleeding, etc.

mineral filler Mineral fillers are a large subclass of inorganic fillers comprised of ground rocks or natural or refined minerals. Some fillers, so-called commodity minerals, are relatively inexpensive and are used mostly as extenders. A good example of these is ground limestone. Other fillers, so-called specialty minerals, are usually reinforcing fillers. These are inherently small particle size fillers, such as talc, and surface chemically modified fillers.

miscibility Miscibility is the ability of a liquid or gas to dissolve uniformly in another liquid or gas. In polymers, miscibility is the compatibility of different polymers in a polymer blend. In miscible blends, the different polymers behave as a single material, in immiscible blends, the different polymers maintain their distinct identities and require additional ingredients to maintain the integrity of the blend.

modified polyphenylene ether Thermoplastic polyphenylene ether alloys with impact polystyrene. Have good impact strength, resistance to heat and fire, but poor resistance to solvents. Processed by injection and structural foam molding and extrusion. Used in auto parts, appliances, and telecommunication devices. Also called MPE, MPO, modified polyphenylene oxide.

modified polyphenylene oxide See *modified polyphenylene ether*.

modulus The ratio of stress to corresponding strain below the elastic limit of a material.

modulus of elasticity The ratio of unit stress to the unit if deformation of an elastic material below the proportional limit.

modulus of rupture in bending See *flexural strength*.

molding defects Structural and other defects in material caused inadvertently during molding by using wrong tooling, process parameters or ingredients. Also called molding flaw. See also *design, etc. Usually preventable*.

molding flaw See *molding defects*.

molecular weight The sum of the atomic weights of all atoms in a molecule. Also called MW.

molecular weight distribution The relative amounts of polymeric molecules of different weights in a specimen. **Note:** The molecular weight distribution can be expressed in terms of the ratio between weight- and number-average molecular weights. Also called polydispersity, MWD, molecular weight ratio.

molecular weight ratio See *molecular weight distribution*.

MPE See *modified polyphenylene ether*.

MPO See *modified polyphenylene ether*.

MQ See *methylsilicone*.

MW See *molecular weight*.

MWD See *molecular weight distribution*.

N

neoprene rubber Polychloroprene rubbers with good resistance to petroleum products, heat, and ozone, weatherability, and toughness.

nitrile rubber Rubbers prepared by free-radical polymerization of acrylonitrile with butadiene. Have good resistance to petroleum products, heat, and abrasion. Used in fuel hoses, shoe soles, gaskets, oil seals, and adhesives.

no-flow point The temperature at which gelation (crosslinking) of a plastic material reaches a degree of no flow in a capillary rheometer.

nonelastomeric thermoplastic polyurethanes See *rigid thermoplastic polyurethanes*.

nonelastomeric thermosetting polyurethane Curable mixtures of isocyanate prepolymers or monomers. Have good abrasion resistance and low-temperature stability, but poor heat, fire, and solvent resistance and weatherability. Processed by reaction injection and structural foam molding, casting, potting, encapsulation, and coating. Used in heat insulation, auto panels and trim, and housings for electronic devices.

notch effect The effect of the presence of specimen notch or its geometry on the outcome of a test such as an impact strength test of plastics. Notching results in local stresses and accelerates failure in both static and cycling testing (mechanical, ozone cracking, etc.).

notched Izod See *notched Izod impact energy*.

notched Izod impact See *notched Izod impact energy*.

notched Izod impact energy The energy required to break a notched specimen equal to the difference between the energy in the striking member of the Izod-type impact apparatus at the instant of impact and the energy remaining after complete fracture of the specimen. **Note:** Energy depends on geometry (e.g., width, depth, shape) of the notch, on the cross-sectional area of the specimen and on the place of impact (on the side of the notch or on the opposite side). In some tests notch is made on both sides of the specimen Also called notched Izod impact strength, notched Izod impact, notched Izod.

notched Izod impact strength See *notched Izod impact energy*.

nylon Thermoplastic polyamides often prepared by ring-opening polymerization of lactam. Have good resistance to most chemicals, abrasion, and creep, good impact and tensile strengths, barrier properties, and low friction, but poor resistance to moisture and light. Have high mold shrinkage. Processed by injection, blow, and rotational molding, extrusion, and powder coating. Used in fibers, auto parts, electrical devices, gears, pumps, appliance housings, cable jacketing, pipes, and films.

nylon 11 Thermoplastic polymer of 11-aminoundecanoic acid having good impact strength, hardness, abrasion resistance, processability, and dimensional stability. Processed by powder coating, rotational molding, extrusion, and injection molding. Used in electric insulation, tubing, profiles, bearings, and coatings.

nylon 12 Thermoplastic polymer of lauric lactam having good impact strength, hardness, abrasion resistance, and dimensional stability. Processed by powder coating, rotational molding, extrusion, and injection molding. Used in sporting goods and auto parts.

nylon 46 Thermoplastic copolymer of 2-pyrrolidone and caprolactam.

nylon 6 Thermoplastic polymer of caprolactam. Has good weldability and mechanical properties but rapidly picks up moisture which results in strength losses. Processed by injection, blow, and rotational molding and extrusion. Used in fibers, tire cord, and machine parts.

nylon 610 Thermoplastic polymer of hexamethylenediamine and sebacic acid having decreased melting point and water absorption and good retention of mechanical properties. Processed by injection molding and extrusion. Used in fibers and machine parts.

nylon 612 Thermoplastic polymer of 1,12-dodecanedioic acid and hexamethylenediamine having good dimensional stability, low moisture absorption, and good retention of mechanical properties. Processed by injection molding and extrusion. Used in wire jackets, cable sheath, packaging film, fibers, bushings, and housings.

nylon 66 Thermoplastic polymer of adipic acid and hexamethylenediamine having good tensile strength, elasticity, toughness, heat resistance, abrasion resistance, and solvent resistance but low weatherability and color resistance. Processed by injection molding and extrusion. Used in fibers, bearings, gears, rollers, and wire jackets.

nylon 6/66 Thermoplastic polymer of adipic acid, caprolactam, and hexamethylenediamine having good strength, toughness, abrasion and fatigue resistance, and low friction but high moisture absorption and low dimensional stability. Processed by injection molding and extrusion. Used in electrical devices and auto and mechanical parts.

nylon MXD6 Thermoplastic polymer of m-xylyleneadipamide having good flexural strength and chemical resistance but decreased tensile strength.

O

olefin resins See *polyolefins.*

olefinic resins See *polyolefins.*

olefinic thermoplastic elastomers Blends of EPDM or EP rubbers with polypropylene or polyethylene, optionally crosslinked. Have low density, good dielectric and mechanical properties, and processibility but low oil resistance and high flammability. Processed by extrusion, injection and blow molding, thermoforming, and calendering. Used in auto parts, construction, wire jackets, and sporting goods. Also called TPO.

OPP See *oriented polypropylene.*

oriented polypropylene A grade of polypropylene film hot stretched uniaxially or biaxially (usually longitudinally or longitudinally and transversely, respectively) to orient polymer molecules in the direction of stretching. Oriented films have enhanced mechanical properties. They will shrink in the direction of stretching when reheated, e.g., during heat sealing. Also called OPP.

P

Pa See **pascal**.

PABM See *polyaminobismaleimide resins.*

paraffinic plasticizer Plasticizers for plastics comprising liquid or solid long-chain alkanes or paraffins (saturated linear or branched hydrocarbons).

pascal An SI unit of measurement of pressure equal to the pressure resulting from a force of one newton acting uniformly over an area of one square meter. Used to denote the pressure of gases, vapors or liquids and the strength of solids. Also called Pa.

PBI See *polybenzimidazoles.*

PBT See *polybutylene terephthalate.*

PC See *polycarbonates.*

PCT See *polycyclohexylenedimethylene terephthalate.*

PCTG See *glycol modified polycyclohexylenedimethylene terephthalate.*

PE copolymer See *polyethylene copolymer.*

PEEK See *polyetheretherketone.*

PEI See *polyetherimides.*

PEK See *polyetherketone.*

perfluoroalkoxy resins Thermoplastic polymers of perfluoroalkoxyethylenes having good creep, heat, and chemical resistance and processibility but low compressive and tensile strengths. Processed by molding, extrusion, rotational molding, and powder coating. Used in films, coatings, pipes, containers, and chemical apparatus linings. Also called PFA.

PES See *polyethersulfone.*

PET See *polyethylene terephthalate.*

PETG See *polycyclohexylenedimethylene ethylene terephthalate.*

PFA See *perfluoroalkoxy resins.*

phase transition See *phase transition properties.*

phase transition point The temperature at which a phase transition occurs in a physical system such as material. **Note:** An example of phase transition is glass transition. Also called phase transition temperature, transition point, transition temperature.

phase transition properties Properties of physical systems such as materials associated with their transition from one phase to another, e.g., from liquid to solid phase. Also called phase transition.

phase transition temperature See *phase transition point.*

phenolic resins Thermoset polymers of phenols with excess or deficiency of aldehydes, mainly formaldehyde, to give resole or novolak resins, respectively. Heat-cured resins have good dielectric properties, hardness, thermal stability, rigidity, and compressive strength but poor chemical resistance and dark color. Processed by coating, potting, compression, transfer, or injection molding and extrusion. Used in coatings, adhesives, potting compounds, handles, electrical devices, and auto parts.

PI See *polyimides.*

plasticizer A substance incorporated into a material such as plastic or rubber to increase its softness, processability and flexibility via solvent or lubricating action or by lowering its molecular weight. Plasticizers can lower melt viscosity, improve flow and increase low-temperature resilience of material. Most plasticizers are nonvolatile organic liquids or low-melting-point solids, such as dioctyl phthalate or stearic acid. They have to be non-bleeding, nontoxic and compatible with material. Sometimes plasticizers play a dual role as stabilizers or crosslinkers.

plastics See *polymers.*

PMMA See *polymethyl methacrylate.*

PMP See *polymethylpentene.*

polyacrylates See *acrylic resins.*

polyallomer Crystalline thermoplastic block copolymers of ethylene, propylene, and other olefins. Have good impact strength and flex life and low density.

polyamide thermoplastic elastomers Copolymers containing soft polyether and hard polyamide blocks having good chemical, abrasion, and heat resistance, impact strength, and tensile properties. Processed by extrusion and injection and blow molding. Used in sporting goods, auto parts, and electrical devices. Also called polyamide TPE.

polyamide TPE See *polyamide thermoplastic elastomers.*

polyamides Thermoplastic aromatic or aliphatic polymers of dicarboxylic acids and diamines, of amino acids, or of lactams. Have good mechanical properties, chemical resistance, and antifriction properties. Processed by extrusion and molding. Used in fibers and molded parts. Also called PA.

polyaminobismaleimide resins Thermoset polymers of aromatic diamines and bismaleimides having good flow and thermochemical properties and flame and radiation resistance. Processed by casting and compression molding. Used in aircraft parts and electrical devices. Also called PABM.

polyarylamides Thermoplastic crystalline polymers of aromatic diamines and aromatic dicarboxylic anhydrides having good heat, fire, and chemical resistance, property retention at high temperatures, dielectric and mechanical properties, and stiffness but poor light resistance and processibility. Processed by solution casting, molding, and extrusion. Used in films, fibers, and molded parts.

polyarylsulfone Thermoplastic aromatic polyether-polysulfone having good heat, fire, and chemical resistance, impact strength, resistance to environmental stress cracking, dielectric properties, and rigidity. Processed by injection and compression molding and extrusion. Used in circuit boards, lamp housings, piping, and auto parts.

polybenzimidazoles Mainly polymers of 3,3',4,4'-tetraminonbiphenyl (diaminobenzidine) and diphenyl isophthalate. Have good heat, fire, and chemical resistance. Used as coatings and fibers in aerospace and other high-temperature applications. Also called PBI.

polybutylene terephthalate Thermoplastic polymer of dimethyl terephthalate and butanediol having good tensile strength, dielectric properties, and chemical and water resistance, but poor impact strength and heat resistance. Processed by injection and blow molding, extrusion, and thermoforming. Used in auto body parts, electrical devices, appliances, and housings. Also called PBT.

polycarbodiimide Polymers containing -N=C=N- linkages in the main chain, typically formed by catalyzed polycondensation of polyisocyanates. They are used to prepare open-celled foams with superior thermal stability. Sterically hindered polycarbodiimides are used as hydrolytic stabilizers for polyester-based urethane elastomers.

polycarbonate See *polycarbonates.*

polycarbonate polyester alloys High-performance thermoplastics processed by injection and blow molding. Used in auto parts.

polycarbonate resins See *polycarbonates.*

polycarbonates Polycarbonates are thermoplastics prepared by either phosgenation of dihydric aromatic alcohols such as bisphenol A or by transesterification of these alcohols with carbonates, e.g., diphenyl carbonate. Polycarbonates consist of chains with repeating carbonyldioxy groups and can be aliphatic or aromatic. They have very good mechanical properties, especially impact strength, low moisture absorption and good thermal and oxidative stability. They are self-extinguishing and some grades are transparent. Polycarbonates have relatively low chemical resistance and resistance to stress cracking. Processed by injection and blow molding, extrusion, thermoforming at relatively high processing temperatures. Used in telephone parts, dentures, business machine housings, safety equipment, nonstaining dinnerware, food packaging, etc. Also called polycarbonate, PC, polycarbonate resins.

polychlorotrifluoroethylene Thermoplastic polymer of chlorotrifluoroethylene having good transparency, barrier properties, tensile strength, and creep resistance, modest dielectric properties and solvent resistance, and poor processibility. Processed by extrusion, injection and compression molding, and coating. Used in chemical apparatus, low-temperature seals, films, and internal lubricants. Also called CTFE.

polycyclohexylenedimethylene ethylene terephthalate

Thermoplastic polymer of cyclohexylenedimethylenediol, ethylene glycol, and terephthalic acid. Has good clarity, stiffness, hardness, and low-temperature toughness. Processed by injection and blow molding and extrusion. Used in containers for cosmetics and foods, packaging film, medical devices, machine guards, and toys. Also called PETG.

polycyclohexylenedimethylene terephthalate Thermoplastic polymer of cyclohexylenedimethylenediol and terephthalic acid having good heat resistance. Processed by molding and extrusion. Also called PCT.

polydispersity See *molecular weight distribution.*

polyester resins See *polyesters.*

polyester thermoplastic elastomers Copolymers containing soft polyether and hard polyester blocks having good dielectric strength, chemical and creep resistance, dynamic performance, appearance, and retention of properties in a wide temperature range but poor light resistance. Processed by injection, blow, and rotational molding, extrusion casting, and film blowing. Used in electrical insulation, medical products, auto parts, and business equipment. Also called polyester TPE.

polyester TPE See *polyester thermoplastic elastomers.*

polyesters A broad class of polymers usually made by condensation of a diol with dicarboxylic acid or anhydride. Polyesters consist of chains with repeating carbonyloxy group and can be aliphatic or aromatic. There are thermosetting polyesters, such as alkyd resins and unsaturated polyesters, and thermoplastic polyesters such as PET. The properties, processing methods and applications of polyesters vary widely. Also called polyester resins.

polyetheretherketone Semi-crystalline thermoplastic aromatic polymer having good chemical, heat, fire, and radiation resistance, toughness, rigidity, bearing strength, and processibility. Processed by injection molding, spinning, cold forming, and extrusion. Used in fibers, films, auto engine parts, aerospace composites, and electrical insulation. Also called PEEK.

polyetherimides Thermoplastic cyclized polymers of aromatic diether dianhydrides and aromatic diamine. Have good chemical, creep, and heat resistance and dielectric properties. Processed by extrusion, thermoforming, and compression, injection, and blow molding. Used in auto parts, jet engines, surgical instruments, industrial apparatus, food packaging, cookware, and computer disks. Also called PEI.

polyetherketone Thermoplastic having good heat and chemical resistance. Thermal stability. Used in advanced composites, wire coating, filters, integrated circuit boards, and bearings. Also called PEK.

polyethersulfone Thermoplastic aromatic polymer having good heat and fire resistance, transparency, dielectric properties, dimensional stability, rigidity, and toughness, but poor solvent and stress cracking resistance, processibility, and weatherability. Processed by injection, blow, and compression molding and extrusion. Used in high temperature applications electrical devices, medical devices, housings, and aircraft and auto parts. Also called PES.

polyethylene copolymer Thermoplastics polymers of ethylene with other olefins such as propylene. Processed by molding and extrusion. Also called PE copolymer.

polyethylene terephthalate Thermoplastic polymer of ethylene glycol with terephthalic acid. Has good hardness, wear and chemical resistance, dimensional stability, and dielectric properties. High-crystallinity grades have good tensile strength and heat resistance. Processed by extrusion and injection and blow molding. Used in fibers, food packaging (films, bottles, trays), magnetic tapes, and photo films. Also called PET.

polyimides Thermoplastic aromatic cyclized polymers of trimellitic anhydride and aromatic diamine. Have good tensile strength, dimensional stability, dielectric and barrier properties, and creep, impact, heat, and fire resistance, but poor processibility. Processed by compression and injection molding, powder sintering, film casting, and solution coating. Thermoset uncyclized polymers are heat curable and have good processability. Processed by transfer and injection molding, lamination, and coating. Used in jet engines, compressors, sealing coatings, auto parts, and business machines. Also called PI.

polymer chain unsaturation See *chemical unsaturation.*

polymers Polymers are high-molecular-weight organic or inorganic compounds the molecules of which comprise linear, branched, crosslinked or otherwise shaped chains of repeating molecular groups. Synthetic polymers are prepared by polymerization of one or more monomers. The monomers are low-molecular-weight substances with one or more reactive bonds or functional groups. Also called resins, plastics.

polymethyl methacrylate Thermoplastic polymer of methyl methacrylate having good transparency, weatherability, impact strength, and dielectric properties. Processed by compression and injection molding, casting, and extrusion. Used in lenses, sheets, airplane canopies, signs, and lighting fixtures. Also called PMMA.

polymethylpentene Thermoplastic stereoregular polyolefin obtained by polymerizing 4-methyl-1-pentene based on dimerization of propylene; having low density, good transparency, rigidity, dielectric and tensile properties, and heat and chemical resistance. Processed by injection and blow molding and extrusion. Used in laboratory ware, coated paper, light fixtures, auto parts, and electrical insulation. Also called PMP.

polyolefin resins See *polyolefins.*

polyolefins Polyolefins are a broad class of hydrocarbon-chain elastomers or thermoplastics usually prepared by addition (co)polymerization of alkenes such as ethylene. There are branched and linear polyolefins and some are chemically or physically modified. Unmodified polyolefins have relatively low thermal stability and a nonporous, nonpolar surface with poor adhesive properties. Processed by extrusion, injection molding, blow molding and rotational molding. Polyolefins are used more and have more applications than any other polymers. Also called olefinic resins, olefin resins, polyolefin resins.

polyphenylene ether nylon alloys Thermoplastics having improved heat and chemical resistance and toughness. Processed by molding and extrusion. Used in auto body parts.

polyphenylene sulfide High-performance engineering thermoplastic having good chemical, water, fire, and radiation resistance, dimensional stability, and dielectric properties, but decreased impact strength and poor processibility. Processed by injection, compression, and transfer molding and extrusion. Used in hydraulic components, bearings, electronic parts, appliances, and auto parts. Also called PPS.

polyphenylene sulfide sulfone Thermoplastic having good heat, fire, creep, and chemical resistance and dielectric properties. Processed by injection molding. Used in electrical devices. Also called PPSS.

polyphthalamide Thermoplastic polymer of aromatic diamine and phthalic anhydride. Has good heat, chemical, and fire resistance, impact strength, retention of properties at high temperatures, dielectric properties, and stiffness, but decreased light resistance and poor processibility. Processed by solution casting, molding, and extrusion. Used in films, fibers, and molded parts. Also called PPA.

polypropylene Thermoplastic polymer of propylene having low density and good flexibility and resistance to chemicals, abrasion, moisture, and stress cracking, but decreased dimensional stability, mechanical strength, and light, fire, and heat resistance. Processed by injection molding, spinning, and extrusion. Used in fibers and films for adhesive tapes and packaging. Also called PP.

polypyrrole A polymer of pyrrole, a five-membered heterocyclic substance with one nitrogen and four carbon atoms and with two double bonds. The polymer can be prepared via electrochemical polymerization. Polymers thus prepared are doped by electrolyte anion and are electrically conductive. Polypyrrole is used in lightweight secondary batteries, as electromagnetic interference shielding, anodic coatings, photoconductors, solar cells, and transistors.

polystyrene Polystyrenes are thermoplastics produced by polymerization of styrene with or without modification (e.g., by copolymerization or blending) to make impact resistant or expandable grades. They have good rigidity, high dimensional stability, low moisture absorption, optical clarity, high gloss and good dielectric properties. Unmodified polystyrenes have poor impact strength and resistance to solvents, heat and UV radiation. Processed by injection molding, extrusion, compression molding, and foam molding. Used widely in medical devices, housewares, food packaging, electronics and foam insulation. Also called polystyrenes, PS, polystyrol.

polystyrenes See *polystyrene.*

polystyrol See *polystyrene.*

polysulfones Thermoplastics, often aromatic and with ether linkages, having good heat, fire, and creep resistance, dielectric properties, transparency, but poor weatherability, processibility, and stress cracking resistance. Processed by injection, compression, and blow molding and extrusion. Used in appliances, electronic devices, auto parts, and electric insulators. Also called PSO.

polytetrafluoroethylene Thermoplastic polymer of tetrafluoroethylene having good dielectric properties, chemical, heat, abrasion, and fire resistance, antiadhesive properties, impact strength, and weatherability, but decreased strength, processibility, barrier properties, and creep resistance. Processed by sinter molding and powder coating. Used in nonstick coatings, chemical apparatus, electrical devices, bearings, and containers. Also called PTFE.

polyurethane resins See *polyurethanes.*

polyurethanes Polyurethanes (PUs) are a broad class of polymers consisting of chains with a repeating urethane group, prepared by condensation of polyisocyanates with polyols, e.g., polyester or polyether diols. PUs may be thermoplastic or thermosetting, elastomeric or rigid, cellular or solid, and offer a wide range of properties depending on composition and molecular structure. Many PUs have high abrasion resistance, good retention of properties at low temperatures and good foamability. Some have poor heat resistance, weatherability and resistance to solvents. PUs are flammable and can release toxic substances. Thermoplastic PUs are not crosslinked and are processed by injection molding and extrusion. Thermosetting PUs can be cured at relatively low temperatures and give foams with good heat insulating properties. They are processed by reaction injection molding, rigid and flexible foam methods, casting and coating. PUs are used in load bearing rollers and wheels, acoustic clamping materials, sporting goods, seals and gaskets, heat insulation, potting and encapsulation. Also called PUR, PU, urethane polymers, urethane resins, urethanes, polyurethane resins.

polyvinyl chloride Thermoplastic polymer of vinyl chloride, available in rigid and flexible forms. Has good dimensional stability, fire resistance, and weatherability, but decreased heat and solvent resistance and high density. Processed by injection and blow molding, calendering, extrusion, and powder coating. Used in films, fabric coatings, wire insulation, toys, bottles, and pipes. Also called PVC.

polyvinyl fluoride Crystalline thermoplastic polymer of vinyl fluoride having good toughness, flexibility, weatherability, and low-temperature and abrasion resistance. Processed by film techniques. Used in packaging, glazing, and electrical devices. Also called PVF.

polyvinylidene chloride Stereoregular thermoplastic polymer of vinylidene chloride having good abrasion and chemical resistance and barrier properties. Vinylidene chloride (VDC) content always exceeds 50%. Processed by molding and extrusion. Used in food packaging films, bag liners, pipes, upholstery, fibers, and coatings. Also called PVDC.

polyvinylidene fluoride Thermoplastic polymer of vinylidene fluoride having good strength, processibility, wear, fire, solvent, and creep resistance, and weatherability, but decreased dielectric properties and heat resistance. Processed by extrusion, injection and transfer molding, and powder coating. Used in electrical insulation, pipes, chemical apparatus, coatings, films, containers, and fibers. Also called PVDF.

PP See *polypropylene.*

PPA See *polyphthalamide.*

PPS See *polyphenylene sulfide.*

PPSS See *polyphenylene sulfide sulfone.*

pressure Stress exerted equally in all directions., processing pressure

process characteristics See *processing parameters.*

process conditions See *processing parameters.*

process media See *processing agents.*

process parameters See *processing parameters.*

process pressure See *processing pressure.*

process rate See *processing rate.*

process speed See *processing rate.*

process time See *processing time.*

process velocity See *processing rate.*

processing additives See *processing agents.*

processing agents Agents or media used in the manufacture, preparation and treatment of a material or article to improve its processing or properties. The agents often become a part of the material. Also called process media, processing aids, processing additives.

processing aids See *processing agents.*

processing defects Structural and other defects in material or article caused inadvertently during manufacturing, preparation and treatment processes by using wrong tooling, process parameters, ingredients, part design, etc. Usually preventable. Also called processing flaw, defects, flaw. See also cracking.

processing flaw See *processing defects.*

processing methods Method names and designations for material or article manufacturing, preparation and treatment processes. **Note:** Both common and standardized names are used. Also called processing procedures.

processing parameters Measurable parameters such as temperature prescribed or maintained during material or article manufacture, preparation and treatment processes. Also called process characteristics, process conditions, process parameters.

processing pressure Pressure maintained in an apparatus during material or article manufacture, preparation and treatment processes. Also called process pressure. See also *pressure.*

processing procedures See *processing methods.*

processing rate Speed of the process in manufacture, preparation and treatment of a material or article. It usually denotes the change in a process parameter per unit of time or the throughput speed of material in a unit of weight, volume, etc. per unit of time. Also called process speed, process velocity, process rate.

processing time Time required for the completion of a process in the manufacture, preparation and treatment of a material or article. Also called process time, cycle time. See also *time.*

propylene An alkene (unsaturated aliphatic hydrocarbon) with three carbon atoms, CH_2=$CHCH_3$. A colorless, highly flammable gas. Autoignition temperature 497°C. Derived by thermal cracking of ethylene or from naphtha. Used as monomer in polymer and organic synthesis. Also called propene.

PS See *polystyrene.*

PSO See *polysulfones.*

PTFE *See polytetrafluoroethylene.*

PU See *polyurethanes.*

PUR See *polyurethanes.*

PVC See *polyvinyl chloride.*

PVDC See *polyvinylidene chloride.*

PVDF See *polyvinylidene fluoride.*

PVF See *polyvinyl fluoride.*

PVT relationship Pressure-(P) volume-(V) temperature-(T) relationship of Boyle's law stating that the product of the volume of a gas times its pressure is a constant at a given temperature, PV/T=R, where R is Boltzmann constant.

R

relative humidity The ratio of the actual vapor pressure of the air to the saturation vapor pressure. Also called RH.

resins See *polymers.*

resorcinol modified phenolic resins Thermosetting polymers of phenol, formaldehyde, and resorcinol having good heat and creep resistance and dimensional stability.

RH See *relative humidity.*

rigid thermoplastic polyurethanes Rigid thermoplastic polyurethanes are not chemically crosslinked. They have high abrasion resistance, good retention of properties at low temperatures, but poor heat resistance, weatherability and resistance to solvents. Rigid thermoplastic polyurethanes are flammable and can release toxic substances. Processed by injection molding and extrusion. Also called rigid thermoplastic urethanes, nonelastomeric thermoplastic polyurethanes.

rigid thermoplastic urethanes See *rigid thermoplastic polyurethanes.*

Rockwell A See *Rockwell hardness.*

Rockwell E See *Rockwell hardness.*

Rockwell hardness A number derived from the net increase in the depth of impression as the load on an indenter is increased from a fixed minor load (10 kgf) to a major load and then returned to the minor load. This number consists of the number of scale divisions (each corresponding to 0.002 mm vertical movement of the indentor) and scale symbol. Rockwell scales, designated by a single capital letter of English alphabet, vary depending on the diameter of the indentor and the major load. For example, scale A indicates the use of a diamond indentor and major load 60 kgf, E - 1/8" ball indentor and 100 kgf, K - same ball and 150 kgf, M - 1/4" ball and 100 kgf, R - 1/2" ball and 60 kgf. The hardness increases in the order of R, M, K, E, and A scales. Also called Rockwell A, Rockwell E, Rockwell K, Rockwell M, Rockwell R.

Rockwell K See *Rockwell hardness.*

Rockwell M See *Rockwell hardness.*

Rockwell R See *Rockwell hardness.*

S

SAN See *styrene acrylonitrile copolymer.*

SAN copolymer See *styrene acrylonitrile copolymer.*

SAN resin See *styrene acrylonitrile copolymer.*

semi-crystalline polymers Polymers in which a portion of the structure is organized into crystals. These materials have useful load-bearing properties above the glass transition temperature and exhibit a well-defined melting point. Examples are polyethylene, nylon 6/6, and acetal.

service life The period of time required for the specified properties of the material to deteriorate under normal use conditions to the minimum allowable level with material retaining its overall usability.

shelf life Time during which a physical system, such as a material, retains its storage stability under specified conditions. Also called storage life.

Shore A See *Shore hardness.*

Shore D See *Shore hardness.*

Shore hardness Indentation hardness of a material as determined by the depth of an indentation made with an indentor of the Shore-type durometer. The scale reading on this durometer is from 0, corresponding to 0.100" depth, to 100 for zero depth. The Shore A indenter has a sharp point, is spring-loaded to 822 gf, and is used for softer plastics. The Shore B indenter has a blunt point, is spring-loaded to 10 lbf, and is used for harder plastics. Also called Shore D, Shore A, durometer A hardness.

silicone There are rigid thermoplastic and liquid silicones and silicone rubbers consisting of alternating silicone and oxygen atom chains with organic pendant groups, prepared by hydrolytic polymcondensation of chlorosilanes, followed by crosslinking. Silicone rubbers have good adhesion, flexibility, dielectric properties, weatherability, barrier properties, and heat and fire resistance, but decreased strength. Rigid silicones have good flexibility, weatherability, soil repelling properties, dimensional stability, but poor solvent resistance. Processed by coating, casting, and injection compression, and transfer molding. Used in coatings, electronic devises, diaphragms, medical products, adhesives, and sealants. Also called siloxane.

siloxane See *silicone.*

SMA See *styrene maleic anhydride copolymer.*

SMA PTB alloy See *styrene maleic anhydride copolymer PBT alloy.*

softening point Temperature at which the material changes from rigid to soft or exhibits a sudden and substantial decrease in hardness. Also called softening temperature, softening range.

softening range See *softening point.*

softening temperature See *softening point.*

solubility A capacity of one substance to be fully dissolved in another without any phase separation, e.g., precipitation. Usually expressed as a percentage of dissolved substance.

solubility coefficient The volume of a gas that can be dissolved by a unit volume of solvent at a fixed pressure and temperature.

stability The ability of a physical system, such as a material, to resist a change or degradation under exposure to outside forces, including mechanical force, heat and weather. See also *degradation.*

static coefficient of friction The ratio of the force that is required to start the friction motion of one surface against another to the force, usually gravitational, acting perpendicular to the two surfaces in contact. Also called coefficient of friction, static.

storage modulus In a dynamic experiment, that portion of the stress-strain response which is in phase with the applied stress. The storage modulus is related to that portion of the polymer structure that fully recovers when an applied stress is removed. **Note:** Storage modulus versus temperature curves are commonly reported in dynamic mechanical analysis (DMA) tests.

strain The per unit change, due to force, in the size or shape of a body referred to its original size or shape. **Note:** Strain is nondimensional but is often expressed in unit of length per unit of length or percent.

stress The intensity at a point in a body of the forces or components of force that act on a given plane through the point. The ratio of an applied load to the original cross sectional area of a sample. **Note:** Stress is expressed in terms of a force per unit area such as pounds per square inch (psi) or newtons per square meter.

stress cracking Appearance of external and/or internal cracks in the material as a result of stress that is lower than its short-term strength.

stress pattern Distribution of applied or residual stress in a specimen, usually throughout its bulk. Applied stress is a stress induced by an outside force, e.g., by loading. Residual stress or stress memory may be a result of processing or exposure. The stress pattern can be made visible in transparent materials by polarized light.

stress relaxation Time-dependent decrease in stress in a solid material under a constant strain as a result of changes in internal or external conditions.

styrene acrylonitrile copolymer SAN resins are thermoplastic copolymers of about 70% styrene and 30% acrylonitrile with higher strength, rigidity and chemical resistance than polystyrene. Characterized by transparency, high heat deflection properties, excellent gloss, hardness and dimensional stability. Have low continuous service temperature and impact strength. Processed by injection molding, extrusion, injection-blow molding and compression molding. Used in appliances, housewares, instrument lenses for automobiles, medical devices, and electronics. Also called styrene-acrylonitrile copolymer, SAN, SAN resin, SAN copolymer.

styrene butadiene block copolymer Thermoplastic amorphous block polymer of butadiene and styrene having good impact strength, rigidity, gloss, compatibility with other styrenic resins, water resistance, and processibility. Used in food and display containers, toys, and shrink wrap.

styrene butadiene copolymer Thermoplastic polymers of butadiene and >50% styrene having good transparency, toughness, and processibility. Processed by extrusion, injection and blow molding, and thermoforming. Used in film wraps, disposable packaging, medical devices, toys, display racks, and office supplies.

styrene maleic anhydride copolymer Thermoplastic copolymer of styrene with maleic anhydride having good thermal stability and adhesion, but decreased chemical and light resistance. Processed by injection and foam molding and extrusion. Used in auto parts, appliances, door panels, pumps, and business machines. Also called SMA.

styrene maleic anhydride copolymer PBT alloy Thermoplastic alloy of styrene maleic anhydride copolymer and polybutylene terephthalate having improved dimensional stability and tensile strength. Processed by injection molding. Also called SMA PTB alloy.

styrene plastics See *styrenic resins.*

styrene polymers See *styrenic resins.*

styrene resins See *styrenic resins.*

styrene-acrylonitrile copolymer See *styrene acrylonitrile copolymer.*

styrenic resins Styrenic resins are thermoplastics prepared by free-radical polymerization of styrene alone or with other unsaturated monomers. The properties of styrenic resins vary widely with molecular structure, attaining the high performance level of engineering plastics. Processed by blow and injection molding, extrusion, thermoforming, film techniques and structural foam molding. Used heavily for the manufacture of automotive parts, household goods, packaging, films, tools, containers and pipes. Also called styrene resins, styrene polymers, styrene plastics.

styrenic thermoplastic elastomers Linear or branched copolymers containing polystyrene end blocks and elastomer (e.g., isoprene rubber) middle blocks. Have a wide range of hardnesses, tensile strength, and elongation, and good low-temperature flexibility, dielectric properties, and hydrolytic stability. Processed by injection and blow molding and extrusion. Used in coatings, sealants, impact modifiers, shoe soles, medical devices, tubing, electrical insulation, and auto parts. Also called TES.

syndiotactic A polymer molecule in which pendant groups and atoms attached to the main chain are arranged in a symmetrical and recurring fashion relative to it in a single plane.

T

talc Talc is a filler made by dry or wet grinding of mineral magnesium silicate. Talc improves stiffness, dimensional stability, flexural modulus, creep resistance, flow, surface smoothness, moisture resistance, tensile strength, and wear resistance of plastics. It also increases heat deflection temperature and decreases vapor permeability. Can be used as a film antiblock agent. Used mainly in polypropylene but also in thermoplastic and unsaturated polyesters and epoxy resins at low levels. Surface-modified grades are available.

tan delta Mathematically expressed as the loss modulus divided by the storage modulus, the tangent of the phase angle between an applied stress and the strain response in a dynamic experiment. **Note:** Tan delta versus temperature curves are commonly reported in dynamic mechanical analysis (DMA) tests.

temperature Property which determines the direction of heat flow between objects. **Note:** The heat flows from the object with higher temperature to that with lower.

tensile elongation The increase in distance between 2 gage marks that result from stressing the specimen in tension to fracture. Usually elongation is expressed as a percentage of the original gage length. **Note:** Elongation is affected by specimen geometry (length, width, thickness of gage section and adjacent regions) and test procedure, such as alignment and speed of pulling. See also *elongation.*

tensile heat distortion temperature See *heat deflection temperature.*

tensile impact energy Kinetic energy dissipated on break of a specimen in a tensile impact test. In the test, one end of the specimen is attached to a swinging pendulum while another is gripped in a crosshead that travels with pendulum. The specimen is ruptured by tensile stress as the crosshead strikes an anvil and is arrested.

tensile properties Properties describing the reaction of physical systems to tensile stress and strain. See also *tensile property tests.*

tensile property tests Names and designations of the methods for tensile testing of materials. Also called tensile tests. See also *tensile properties.*

tensile strain The relative length deformation exhibited by a specimen in tension. See also *elongation.*

tensile strength The maximum tensile stress that a specimen can sustain in a test carried to failure. **Note:** The maximum stress can be measured at or after the failure or reached before the fracture, depending on the viscoelastic behavior of the material. Also called tensile ultimate strength, ultimate tensile strength, UTS, tensile strength at break, ultimate tensile stress. See also *ASTM D638.*

tensile strength at break The maximum load per original minimum cross-sectional area of the plastic specimen in tension within the gage length when the maximum load corresponds to the break point. **Note:** For plastics- when the maximum load corresponds to the yield point, this property is called tensile strength at yield. See also *tensile strength.*

tensile stress The stress is perpendicular and directed to the opposite plane on which the forces act.

tensile strength at yield The maximum load per original minimum cross-sectional area of the plastic specimen in tension within the gage length, when the maximum load corresponds to the yield point. **Note:** When maximum load corresponds to the break point, this property is called tensile strength at break.

tensile tests See *tensile property tests.*

tensile ultimate strength The maximum tensile stress subjected to the test specimen during the tensile test. The value can be identical with the tensile stress at break.

tensile yield point The first engineering stress in a tensile test, in which stresses and strains are determined for a material that exhibits the phenomenon of discontinuous yielding, at which an increase in strain occurs without an increase in stress. For materials that do not exhibit a yield point, yield strength serves the same purpose as yield point.

tensile yield strength The engineering stress determined at the intersection of the tensile stress-strain curve with a line drawn in the diagram with a slope equal to the modulus of elasticity, and offset by the specified strain. The percent offset (0.2% is the most common in USA) must be stated for values to be meaningful.

terephthalate polyester Thermoset unsaturated polymer of terephthalic anhydride.

TES See *styrenic thermoplastic elastomers.*

test methods Names and designations of material test methods. Also called testing methods

test variables Terms related to the testing of materials such as test method names.

testing methods See *test methods.*

tetrafluoroethylene propylene copolymer Thermosetting elastomeric polymer of tetrafluoroethylene and propylene having good chemical and heat resistance and flexibility. Used in auto parts.

thermal expansion Expanding of physical matter (solid body, liquid, gas) as a result of heating.

thermal expansion coefficient The change in volume per unit volume resulting from a change in temperature of the material. The mean coefficient of thermal expansion is commonly referenced to room temperature.

thermal properties Properties related to the effects of heat on physical systems such as materials and heat transport. The effects of heat include the effects on structure, geometry, performance, aging, stress-strain behavior, etc.

thermal stability The resistance of a physical system, such as a material, to decomposition, deterioration of properties or any type of degradation in storage under specified conditions.

thermodynamic properties A quantity that is either an attribute of the entire system or is a function of position, which is continuous and does not vary rapidly over microscopic distances, except possibility for abrupt changes at boundaries between phases of the system. Also called macroscopic properties.

thermoplastic Thermoplastics are resin or plastic compounds which, after final processing, are capable of being repeatedly softened by heating and hardened by cooling by means of physical changes. There is a large number of thermoplastic polymers belonging to various classes such as polyolefins and polyamides.

thermoplastic polyesters A class of polyesters that can be repeatedly made soft and pliable on heating and hard (flexible or rigid) on subsequent cooling.

thermoplastic polyurethanes A class of polyurethanes including rigid and elastomeric polymers that can be repeatedly made soft and pliable on heating and hard (flexible or rigid) on subsequent cooling. Also called thermoplastic urethanes, TPUR, TPU.

thermoplastic urethanes See thermoplastic polyurethanes.

thermoset Thermosets are resin and plastic compounds which, after final processing, are substantially infusible and insoluble. During processing, thermosets undergo a chemical reaction that results in the formation of a three dimensional covalent bond. Thermosets are often liquids at some stage in their manufacture or processing and are cured by heat, oxidation, radiation, or other means often in the presence of curing agents and catalysts. Curing proceeds via polymerization and/or cross- linking. Cured thermosets cannot be resoftened by heat. There is a large number of thermosetting polymers belonging to various classes such as alkyd, epoxy and phenolic resins.

thermosetting elastomer A large class of polymers that can be stretched at room temperature to at least twice their original length and, after having been stretched and the stress removed, return with force to approximately their original length in a short time. To attain this elastic property the rubbers must be crosslinked or vulcanized, usually by heating in the presence of various crosslinking agents and catalysts. There are natural and synthetic rubbers. The most important synthetic rubber families are olefinic rubbers, dienic rubbers (nitrile, butadiene, neoprene), silicone rubbers, and urethane rubbers. Used often as impact modifiers/fillers in plastics.

toughness Property of a material indicating its ability to absorb energy by plastic deformation rather than crack or fracture.

TPO See *olefinic thermoplastic elastomers.*

TPU See *thermoplastic polyurethanes.*

TPUR See *thermoplastic polyurethanes.*

transition A structural relaxation in a material brought on by the onset of molecular motion. It is accompanied by a sudden decline in the elastic properties of the material and a momentary increase in the loss properties. The most important of these transitions is the glass transition.

transition point See *phase transition point.*

transition temperature See *phase transition point.*

U

UHMWPE See *ultrahigh molecular weight polyethylene.*

ultimate elongation See *elongation.*

ultimate tensile strength See *tensile strength.*

ultimate tensile stress See *tensile strength.*

ultrahigh molecular weight polyethylene Thermoplastic linear polymer of ethylene with molecular weight in the millions. Has good wear and chemical resistance, toughness, and antifriction properties, but poor processibility. Processed by compression molding and ram extrusion. Used in bearings, gears, and sliding surfaces. Also called UHMWPE.

units See *units of measurement.*

units of measurement Systematic and non-systematic units for measuring physical quantities, including metric and US pound-inch systems. Also called units.

urea resins Thermosetting polymers of formaldehyde and urea having good clarity, colorability, scratch, fire, and solvent resistance, rigidity, dielectric properties, and tensile strength, but decreased impact strength and chemical, heat, and moisture resistance. Must be filled for molding. Processed by compression and injection molding, impregnation, and coating. Used in cosmetic containers, housings, tableware, electrical insulators, countertop laminates, adhesives, and coatings.

urethane polymers See *polyurethanes.*

urethane resins See *polyurethanes.*

urethane thermoplastic elastomers Block polyether or polyester polyurethanes containing soft and hard segments. Have good tensile strength, elongation, adhesion, and a broad hardness and service temperature ranges, but decreased moisture resistance and processibility. Processed by extrusion, injection molding, film blowing, and coating. Used in tubing, packaging film, adhesives, medical devices, conveyor belts, auto parts, and cable jackets. Also called TPU.

urethanes See *polyurethanes*.

UTS See *tensile strength*.

V

Vicat softening point The temperature at which a flat-ended needle of prescribed geometry (typically with a cross sectional area of 1 square millimeter) will penetrate a thermoplastic specimen to a certain depth (usually 1 mm) under a specified load using a uniform rate of temperature rise. **Note:** Vicat softening point is determined according to ASTM D1525 test for thermoplastics such as polyethylene which have no definite melting point. Also called Vicat softening temperature.

Vicat softening temperature See *Vicat softening point*.

vinyl ester resins Thermosetting acrylated epoxy resins containing styrene reactive diluent. Cured by catalyzed polymerization of vinyl groups and crosslinking of hydroxy groups at room or elevated temperatures. Have good chemical, solvent, and heat resistance, toughness, and flexibility, but shrink during cure. Processed by filament winding, transfer molding, pultrusion, coating, and lamination. Used in structural composites, coatings, sheet molding compounds, and chemical apparatus.

vinyl resins Thermoplastics polymers of vinyl compounds such as vinyl chloride or vinyl acetate. Have good weatherability, barrier properties, and flexibility, but decreased solvent and heat resistance. Processed by molding, extrusion, and coating. Used in films and packaging.

vinyl thermoplastic elastomers Vinyl resin alloys having good fire and aging resistance, flexibility, dielectric properties, and toughness. Processed by extrusion. Used in cable jackets and wire insulation.

vinylidene fluoride hexafluoropropylene copolymer Thermoplastic polymer of vinylidene fluoride and hexafluoropropylene having good antistick, dielectric, and antifriction properties and chemical and heat resistance, but decreased mechanical strength and creep resistance and poor processibility. Processed by molding, extrusion, and coating. Used in chemical apparatus, containers, films, and coatings.

vinylidene fluoride hexafluoropropylene tetrafluoroethylene terpolymer Thermosetting elastomeric polymer of vinylidene fluoride, hexafluoropropylene, and tetrafluoroethylene having good chemical and heat resistance and flexibility. Used in auto parts.

viscoelasticity The dual response of a material under an applied load where part of the material returns to its original shape when the load is removed while the other part undergoes permanent deformation.

viscosity The internal resistance to flow exhibited by a fluid, the ratio of shearing stress to rate of shear. A viscosity of one poise is equal to a force of one dyne/square centimeter that causes two parallel liquid surfaces one square centimeter in area and one centimeter apart to move past one another at a velocity of one cm/second.

vulcanizate Rubber that had been irreversibly transformed from predominantly plastic to predominantly elastic material by vulcanization (chemical curing or crosslinking) using heat, vulcanization agents, accelerants, etc.

vulcanizate crosslinks Chemical bonds formed between polymeric chains in rubber as a result of vulcanization.

W

warpage See *warping*.

warping Dimensional distortion or deviation from the intended shape of a plastic or rubber article as a result of nonuniform internal stress, e.g., caused by uneven heat shrinkage. Also called warpage.

water swell Expansion of material volume as a result of water absorption.