

Limitations of Test  
Methods for

# PLASTICS

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EDITOR



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# *Limitations of Test Methods for Plastics*

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# Foreword

This publication, *Limitations of Test Methods for Plastics*, contains papers presented at the symposium of the same name held in Norfolk, Virginia, on 1 November 1998. The symposium was sponsored by ASTM Committee D20 on Plastics. The symposium chairman was James S. Peraro, consultant, Newark, Delaware.

# Overview

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Testing is the means by which information (data) is developed on materials or products, and tests have been used for over 2000 years to provide a wide range of technical information describing a material's properties and characteristics. The first published test standard for plastics was written by ASTM Committee D20 in 1937. The early published test standards were simple in form and composition. Test methods were usually generic and written for the limited number of the then-known polymeric materials. They addressed all material types and were used for the determination of traditional properties such as tensile, flex, impact, and flammability. As polymers evolved into a vast array of polymer types, all different in structure and properties, so have test methods. ASTM standards are no longer those simple documents prepared when plastics were the new curious materials, but have continued to evolve as the technology of plastics has evolved. Test methods range from the very simple to very complex, such as those used to generate property data for engineering applications. Every ASTM committee attempts to provide standards that reflect the latest technology in testing of materials to meet the widening need of the global marketplace. The end result is that today's test methods not only generate more meaningful data but are used for a wide range of applications.

What started out to be simple generic test methods have necessarily become more complicated and difficult to comprehend. As test methods have become more sophisticated and complicated in scope and application, more knowledge about materials and their characteristics is needed by those using ASTM test methods to develop test data and by those who analyze and utilize the data. Generally, the result is a lack of understanding of the variables that contribute to and influence test results. It has been long understood by the testing community that every test method ever written, whether written for metals or non-metals, is composed of variables. There are many sources of variables and all have a direct influence on the accuracy of the generated test data. The sum total of all variables defines test limitations.

Test limitations are a compilation of the variables (1) present within a test method; (2) associated with the material under investigation; and (3) those external to but not related to the test method or material. Test and material variables are the primary source of variability. The external variables are primarily those influenced by an individual's knowledge of the characteristics of the material under investigation or the test method(s) to be used in its evaluation, and the ability to properly analyze the generated test results as related to the intended use or application. Misinterpretation, misuse, or misapplication of the test method or the use of the data generated all contribute to test limitations. Unfortunately these limitations are not fully understood, resulting in inappropriate claims or conclusions pertaining to materials or products made from plastics.

ASTM enjoys an excellent reputation as a leading organization in the development of test methods used worldwide. ASTM technical committees have developed over 10,000 test standards. Unfortunately, there is a general belief that the results obtained from these test standards are absolute, which is not the case since each has its limitations. ASTM standards are living documents and are continually being updated and revised to reflect the latest in testing technology. Limitations are not limited to the ASTM test standards. In the United States there are over 400 standards writing organizations, and when you add all the test standards worldwide (ISO, DIN, BSI etc.) there are an enormous number of test standards all with their own set of limitations.

It has been acknowledged for many years that there was a need for a symposium discussing the limitations inherent in all test methods. ASTM has always encouraged the use of symposia or other formal programs to educate those interested in the proper use and application of ASTM standards or

the principles by which they were developed. In order to promote and educate the business and technical communities about the limitations of test methods of plastics, ASTM D20 on Plastics decided to schedule a symposium on this very important and timely subject. In November 1998 a symposium entitled *Limitations of Testing* was held in Norfolk, Virginia.

In this symposium, 21 papers from both Europe and the United States were grouped into four major categories, namely *General/Design*, *Mechanical*, *Impact/Fracture*, and *Chemical/Rheology*. Some of the papers could have been placed in more than one category. It was a difficult task for the committee to make the final decision on the location of the paper and the order of presentation.

### **General/Design**

In this section papers are presented covering issues facing engineers in the selection of the optimum material candidate and the development of test data for a specific performance criteria. There is a generally accepted protocol that is used by engineers in making a qualified decision based on available facts. The problem is knowing what is required of the product and what is the true functional behavior of the polymer. What is not often completely understood is the correlation of published data and the relevance to design. The various options and concerns are reviewed.

Creep tests can be conducted in either tensile or flexural modes. The time-dependent viscoelastic deformation of polymers and composites is compared and the differences in material compliance is analyzed. The constitutive relationship for creep compliance that takes into account the effect of dilatational stresses is determined. Estimation of lifetime under non-isothermal conditions is also presented. Not only are the thermal and mechanical loading of great importance to estimation of life expectancy, but also the influence of the chemical medium and immersion time. Two possible methods of obtaining this information are discussed: (1) time-temperature extrapolation of the measured aging process, and (2) a functional estimation of time-temperature collectives, the latter being more precise.

### **Mechanical**

In this section, traditional tests such as tensile, and deflection under flexural load (DTUL) are covered. Papers discuss the development of testing procedures for materials and the influence of variables on the generated data. The implications of conversion from ASTM to ISO standards for material characterization for greater opportunity and to compete more effectively in the global market are reviewed. As global interaction increases, it is important that the concerns raised during conversion can be harmonized between the two sets of standards. Also, the comparison of tensile data generated by ASTM and ISO procedures and the results obtained from round-robin tests are discussed for a variety of polymers. Common errors made by laboratories were examined. Data are also presented showing the common variables that affect test results in both ASTM and ISO tensile tests.

Deflection temperature under load (DTUL) measures the temperature at which a specimen of a certain geometry deflects a fixed amount under a very specific set of conditions. However, it is often used in material selection as a measure of the maximum continuous use temperature for that material. The development of dynamic mechanical analysis (DMA) has shown that traditional DTUL test results often give a false measure of the thermal performance of polymeric materials. By measuring the elastic modulus versus temperature by DMA the thermal profile of any polymer can be obtained and a more realistic assessment of the elevated temperature performance can be obtained. New techniques were also presented for testing adhesive bond strength tests for piping systems. The technique developed utilized lap-shear plaques to predict performance in the pipe joint systems. Results indicate extreme sensitivity to minor variations in preparation.

## Impact/Fracture

Papers in this section discuss the variables that have a significant effect on impact resistance. Impact tests measure the response of materials to dynamic loading. Pendulum impact tests such as IZOD and Charpy are used widely to quantify the impact performance of plastic materials. Both tests are used widely to develop impact data and are considered as a primary performance index for impact properties, but cannot be used for design considerations. In these tests there are a large number of variables associated with sample preparation, the test apparatus, and the test procedure. Data are presented comparing instrumented and non-instrumented IZOD and Charpy tests, the effects of the variables, and their influence on the test results. A new approach using fracture mechanics is presented for the determination of the impact fracture resistance  $G_c$ , or impact fracture toughness  $K_{Ic}$ . The fracture mechanics perspective is based on an explanation of impact speed and geometry based on the thermal decohesion model. Analysis leads to a prediction of an apparent impact fracture resistance  $G_{ca}$ . Also, a new standardized test procedure to measure  $K_{Ic}$  and  $G_{Ic}$  for plastics at a moderately high rate of loading, namely 1 m/s, has been proposed. The test procedure is based on previously developed fracture mechanics technology for the determination of  $K_c$  and  $G_c$ . Round robin test data developed over a period of five years are reviewed and show the consistency in the test data, validating the test protocol.

## Chemical/Rheological

Papers on advanced testing techniques primarily in the area of rheological testing were presented. Thermomechanical analysis (TMA) is compared to the coefficient of linear thermal expansion (CLTE) and the measurement of the glass transition temperature ( $T_g$ ). Variables are identified and the effect on temperature measurements is discussed for CLTE and  $T_g$ . In another presentation, capillary and rotational viscometry is compared. The flow curve of the apparent viscosity versus shear rate emphasizes the dangers of using a single viscosity value such as Melt Flow Index. Both orthodox and unorthodox measurements are discussed for viscosity measurements for controlled stress and controlled rate devices. A more direct volumetric method to measure volume swell ratio has been developed for cross-linked polyethylene and compared to the gravimetric method using the deswelling or solvent evaporation techniques. The results show that the direct volumetric technique is more accurate and not subject to the limitations of the other techniques.

This symposium reflects the current work being undertaken within the ASTM D20 subcommittees to insure that all test methods are written in such a way as to be understood and used properly.

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The symposium committee gratefully acknowledges the efforts of the authors, the ASTM D20 technical committee that helped put this symposium in motion, and the 44 individuals who reviewed the presented papers prior to publication of this STP. Finally, for any symposium to be successful, the majority of the individuals involved work behind the scenes, especially Dorothy Fitzpatrick and her staff at ASTM who provided the administrative services. Without their effort this symposium would not have been so successful.

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Symposium Chairman and Editor