Designation: D6112 – 13

Standard Test Methods for Compressive and Flexural Creep and Creep-Rupture of Plastic Lumber and Shapes[1]

This standard is issued under the fixed designation D6112; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the determination of the creep and creep-rupture properties of plastic lumber and shapes, when loaded in compression or flexure under specified environmental conditions. Test specimens in the "as-manufactured" form are employed. As such, these are test methods for evaluating the properties of plastic lumber or shapes as a product and not material property test methods.

1.2 Plastic lumber and plastic shapes are currently made predominantly with recycled plastics. However, this test method would also be applicable to similar manufactured plastic products made from virgin resins where the product is non-homogenous in the cross-section.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D883 Terminology Relating to Plastics
D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D4000 Classification System for Specifying Plastic Materials
D5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics (Withdrawn 2007)[3]
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
E4 Practices for Force Verification of Testing Machines

3. Terminology

3.1 *Definitions:*

3.1.1 *compression—in a compressive creep test,* the decrease in length produced in the gauge length or the total length of a test specimen.

3.1.2 *creep modulus*—the ratio of initial applied stress to creep strain.

3.1.3 *creep strain*—the total strain, at any given time, produced by the applied stress during a creep test.

3.1.3.1 *Discussion*—The term creep, as used in this test method, reflects current plastics engineering usage. In scientific practice, creep is often defined to be the nonelastic portion of strain. However, this definition is not applicable to existing engineering formulas. Plastics have a wide spectrum of retardation times, and elastic portions of strain cannot be separated in practice from nonelastic. Therefore, wherever "strain" is mentioned in these test methods, it refers to the sum of elastic strain plus the additional strain with time.

3.1.4 *deflection—in a flexural creep test,* the change in mid-span position of a test specimen.

3.1.5 *deformation*—a change in shape, size or position of a test specimen as a result of compression, deflection, or extension:

3.1.6 *plastic lumber, n*—a manufactured product made primarily from plastic materials (filled or unfilled), typically used as a building material for purposes similar to those of traditional lumber, which is usually rectangular in cross-section. (Terminology D883)

3.1.6.1 *Discussion*—Plastic lumber is typically supplied in sizes similar to those of traditional lumber board, timber and

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[1] These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and are the direct responsibility of Subcommittee D20.20 on Plastic Lumber (Section D20.20.01).

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

dimension lumber; however the tolerances for plastic lumber and for traditional lumber are not necessarily the same. (Terminology D883)

3.1.7 *plastic shape, n*—a manufactured product composed of more than 50 weight percent resin, and in which the product generally is not rectangular in cross-section, may be filled or unfilled, and may be composed of single or multiple resin blends.

3.1.8 *resin, n*—a solid or pseudo-solid organic material often of high molecular weight, that exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. (Terminology D883)

3.1.8.1 *Discussion*—In a broad sense, the term is used to designate any polymer that is a basic material for plastics.

3.1.9 *stress—for compressive creep,* the ratio of the applied load to the initial cross-sectional area. For flexural creep, maximum fiber stress is calculated according to Eq 1.

3.1.10 Additional definition of terms applying to this test method appear in Terminology D883 and Guide D5033.

4. Summary of Test Method

4.1 These test methods consist of measuring the deflection or compression as a function of time and time-to-rupture, or failure of a specimen subject to constant flexural or compressive load under specified environmental conditions.

4.2 The four-point loading a outlined in this testing standard shall be used for the flexural creep tests.

4.3 Compressive loading as outlined in this testing standard shall be used for the compressive creep tests.

4.4 These test methods represent modifications of the compressive and flexural creep and creep rupture test methods specified in Test Methods D2990.

5. Significance and Use

5.1 Data from creep and creep-rupture tests are necessary to predict the creep modulus and strength of materials under long-term loads and to predict dimensional changes that have the potential to occur as a result of such loads.

5.2 Data from these test methods can be used to characterize plastic lumber: for comparison purposes, for the design of fabricated parts, to determine long-term performance under constant load, and under certain conditions, for specification purposes.

5.3 For many products, it is possible that there will be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that product specification before using this test method. Table 1 in Classification D4000 lists the ASTM materials standards that currently exist.

6. Apparatus

6.1 *General:*

6.1.1 *Loading System:*

6.1.1.1 The loading system must be so designed that the load applied and maintained on the specimen is within ±1 % of the desired load. The loading mechanism must allow reproductively rapid and smooth loading as specified in 11.1.3. In creep-rupture tests, provision must be made to ensure that shock loading, caused by a specimen failure, is not transferred to other specimens undergoing testing. The accuracy of the loading system shall be verified at least once each year in accordance with Practices E4.

6.1.1.2 Loading systems that provide a mechanical advantage require careful design to maintain constant load throughout the test. For example, lever systems must be designed so that the load does not change as the lever arm moves during the test.

6.1.2 *Compression and Deflection Measurements:*

6.1.2.1 The accuracy of the deformation measuring device shall be within ±1 % of the deformation to be measured.

6.1.2.2 Deformation measuring devices shall be calibrated against a precision micrometer screw or other suitable standard under conditions are nearly identical as possible with those encountered in the test. Caution is necessary when using deformation measuring devices whose calibration is subject to drifting with time and is dependent on temperature and humidity.

6.1.2.3 Deformation measuring devices shall be firmly attached to or seated on the specimen so that no slippage occurs. Electrical resistance gauges are suitable only if the material tested will permit perfect adhesion to the specimen and if they are consistent with 6.2.1

6.1.3 *Time Measurement*—The accuracy of the time measuring device shall be ±1 % of the time-to-rupture or failure or the elapsed time of each creep measurement, or both.

6.1.4 *Temperature Control and Measurement:*

6.1.4.1 The temperature of the test space, especially close to the gauge length of the specimen, shall be maintained within ±2°C by a suitable automatic device and shall be stated in reporting the results.

NOTE 2—The thermal contraction and expansion associated with small temperature changes during the test has the potential to produce changes in the apparent creep rate, especially near transition temperatures.

6.1.4.2 Care must be taken to ensure accurate temperature measurements over the gauge length of the specimen throughout the test. The temperature measuring devices shall be checked regularly against temperature standards and shall indicate the temperature of the specimen gauge area.

6.1.4.3 Temperature measurements shall be made at frequent intervals, or continuously recorded to ensure an accurate determination of the average test temperature and compliance with 6.1.5.

6.1.5 *Environmental Control and Measurements:*

6.1.5.1 When the test environment is air, the relative humidity shall be controlled to 50 ± 5 % during the test unless otherwise specified, or unless the creep behavior of the material under testing has been shown to be unaffected by humidity. The controlling and measuring instruments shall be stable for long time intervals and accurate to within ±1 %. (The control of relative humidity is known to be difficult at temperatures much outside the range from 50 to 104°F (10 to 40°C).)

6.1.5.2 If, for any reason, the specified relative humidity cannot be achieved or the test is conducted to determine the sensitivity of the product to high humidity, report the actual average value and fluctuation of relative humidity used.

6.1.5.3 The composition of the test environment shall be maintained constant throughout the test. (**Warning—**Take special precautions to avoid personal contact, to eliminate toxic vapors, and to guard against explosion hazards in accordance with any possible hazardous nature of the particular environment being used.)

6.1.6 *Vibration Control*—Creep tests are quite sensitive to shock and vibration. The location of the apparatus, the test equipment, and mounting shall be so designated that the specimen is isolated from vibration. Multiple-station test equipment must be of sufficient rigidity so that no significant deflection occurs in the test equipment during creep or creep-rupture testing. During time-to-rupture or failure, means to prevent jarring of other test specimens by the falling load from a failed test specimen shall be provided by a suitable net or cushion.

6.2 *Compressive Creep:*

6.2.1 *Platens*—Parallel platens shall be used to apply the load to the unconfined-type specimen (see 8.2). One of the platens of the machine shall preferably be self-aligning and shall, so that it is possible to apply the load evenly over the face of the specimen, be arranged so that the specimen is accurately centered and the resultant of the load is through its center.

6.2.2 The compression of specimen gauge length under load shall be measured by means of any device that will not influence the specimen behavior by mechanical (undesirable deformation, notches, etc.) physical (heating of specimen, etc.), or chemical effects. Alternatively, the compression of the specimen can be measured using platen displacement with the entire length of the specimen serving as the gauge length.

6.3 *Flexural Creep:*

6.3.1 *Test Rack*—A rigid test rack shall be used to provide support of the test specimen at both ends with a span equal to 16 (tolerant +4 and −2) times the depth of the specimen. In order to avoid excessive indentation of the specimen, the radius of the support shall be a minimum of 0.5 in. (12.7 mm) and up to 1.5 times the depth of the specimen. Sufficient space must be allowed below the specimen for dead-weight loading.

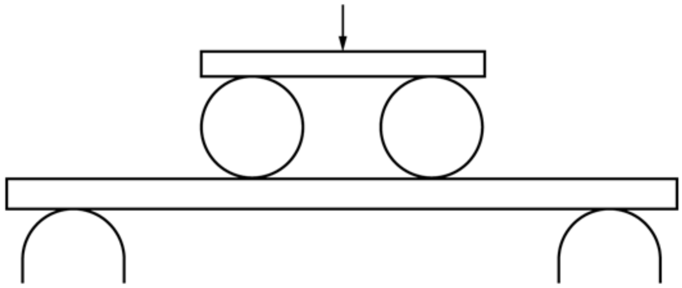
6.3.2 *Loading Beam*—The loading beam shall be configured with loading noses with cylindrical surfaces (see Fig. 1). The radius of noses shall be at least 0.5 in. (12.7 mm) or all specimens. For large specimens it is possible that the radius of the supports will be up to 1.5 times the specimen depth.

6.3.3 A four point loading arrangement shall be used as shown in Fig. 1.

6.3.4 For flexural testing the deflection of the specimen shall be measured at the midpoint of the load span at the bottom face of the specimen.

7. Reagents

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specification are available[4]. It is acceptable to use other grades, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.



NOTE 1—Minimum radius = 0.5 in. (12.7 mm); maximum radius = 1.5 times the specimen depth.

FIG. 1 Four Point Loading and Support Noses at Maximum Radius

7.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

7.3 *Specified Reagents*—If this test method is referenced in a material specification, the specific reagent to be used shall be as stipulated in the specification.

7.4 *Standard Reagents*—A list of standard reagents is also available in Test Method D543.

8. Test Specimen

8.1 *General:*

8.1.1 It is acceptable to make test specimens by any of the techniques normally employed to produce plastic lumber. When the testing objective is to obtain design data, the method of sample fabrication shall be the same as that used in the application.

8.1.2 In the case of materials whose dimensions are known to change significantly due to the specified environment alone (for example, the shrinkage of some thermosetting plastics due to post-curing at elevated temperatures), provision shall be made to test unloaded control specimens alongside the test specimen so as to provide compensation for changes other than creep. A minimum of three control specimens shall be tested at each test temperature.

8.1.3 In creep testing at a single temperature, the minimum number of test specimens at each stress shall be two if four or more levels of stress are used or three if fewer than four levels are used.

8.1.4 In creep-rupture testing, a minimum of two specimens shall be tested at each of the stress levels specified in 10.2.1 at each temperature.

NOTE 3—The scatter of creep-rupture data is considerable, with one half

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[4] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Derner, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

to a full decade of variation in time-to-rupture being typical. Therefore, it is some times necessary to test more than two specimens at each stress level to obtain satisfactory results.

8.2 *Compressive Creep:*

8.2.1 The standard test specimen shall be in the form of a right prism. With the exception that specimen cross sections are the full sections of any manufactured plastic lumber or shape. Surfaces of the test specimens shall be plane and parallel.

8.2.2 Test specimens for determining compressive properties of plastic lumber and shapes shall be cut from the "as manufactured" profile. Great care shall be taken in cutting and machining the ends so that smooth, flat parallel surfaces and sharp, clean edges to within 1⁄300 (0.0033) of the specimen length perpendicular to the long axis of the specimen results. Plastic lumber is generally nonuniform through the cross-section; no machining operations other than those required to provide flat, parallel ends shall be carried out.

8.2.2.1 The standard test specimen, except as indicated in 8.2.2.2 to 8.2.2.3, shall be in the form of a right cylinder or prism whose height is twice its *minimum* width or diameter.

8.2.2.2 For rod material, the test specimen shall have a diameter equal to the diameter of the rod and whose height is twice its diameter.

8.2.2.3 When testing hollow profiles, the test specimen shall have a minimum length equal to twice its minimum cross sectional dimension.

8.3 *Flexural Creep:*

8.3.1 The specimens shall be full size as manufactured. The original surfaces shall be unaltered.

8.3.2 For flatwise (plank) tests, the depth of the specimen shall be the thickness, or smaller dimension, of the material. For edgewise (joist) tests the width becomes the smaller dimension and depth the larger. For all tests, the support span shall be 16 (tolerance +4 and −2) times the depth of the beam. The specimen shall be long enough to allow for overhanging on each end of at least 10 % of the support span, but in no case less than 0.25 in. (6.4 mm) on each end. Overhand shall be sufficient to prevent the specimen from slipping through the supports.

9. Conditioning

9.1 The specimen shall be preconditioned in the test environment for at least 48 h prior to being tested or for a longer period if needed to establish an equilibrium condition. Those materials whose creep properties are suspected to be affected by moisture content shall be brought to moisture equilibrium appropriate to the test conditions prior to testing.

9.2 If warranted, based on projected usage, submerge the test specimen in water for at least 24 h or until it achieves an equilibrium moisture content prior to conditioning. Tape the ends of the test specimen prior to water immersion.

10. Selection of Test Conditions

10.1 *Test Temperatures*—Selection of temperatures for creep and creep-rupture testing depends on the intended use of the test results and shall be made as follows:

10.1.1 To characterize a material, select two or more test temperatures to cover the useful temperature range usually at elevated temperatures, in suitable increments that reflect the variation of the creep of the material with temperature and transitions of the material. Unless actual conditions warrant otherwise, test temperatures of 50, 73.4, and 104°F (10, 23, and 40°C) are recommended.

10.1.2 To obtain design data, the test temperatures and environment shall be the same as those of the intended end-use application.

10.1.3 To obtain the stress for 1 % strain at 1000 h (see 10.3.2) or for other simple material comparisons such as data sheets, use the recommended test temperatures cited in 10.1.1.

10.2 *Creep-Rupture:*

10.2.1 At each test temperature, make creep-rupture tests at a minimum of seven stress levels selected so as to produce rupture at approximately the following times: 1, 10, 30, 100, 300, 1000, and 3000 h.

10.2.1.1 The objective of these tests is to produce at each test temperature, a curve of stress-at-rupture versus time-to-rupture, often called a "creep-rupture envelope," which indicates a limit of a material's load-bearing capability at the test temperature. For the prediction of long-term performance, for example, in the design of parts that will bear constant loads six months or longer, test times longer than 3000 h are usually necessary, particularly at elevated temperatures where it is possible that heat aging of the material will be occurring, and in aggressive environments, both of which can greatly affect creep-rupture.

10.2.2 For materials that fail catastrophically (that is, with negligible yielding, drawing, or flowing) measure and report the time-to-rupture. For materials that yield, draw, or flow significantly prior to rupture, measure and report the time at the onset of tertiary creep (onset of yielding, flowing, or drawing), which shall be considered the time-to-failure and shall be measured and reported. For materials that yield, draw, or flow, it is possible that creep strain will have to be measured with a recorder or some other method.

10.3 *Creep:*

10.3.1 To obtain design data or to characterize a material, select stress levels as follows:

10.3.1.1 For materials that show linear viscoelasticity, that is, successive creep modulus versus time for different stresses that superimpose upon each other (Boltzman superposition principle,[5] select a minimum of three stress levels for each temperature of interest.

10.3.1.2 For materials that are significantly affected by stress, select at least five stresses (and preferably more) for each temperature of interest.

10.3.1.3 Select stress levels in approximately even increments up to the 1000–h creep-rupture stress: stress levels above 1000 psi (6.9 MPa) to the nearest 500 psi (3.4 MPa); stress levels below 1000 psi (6.9 MPa) to the nearest 100 psi (0.7 MPa).

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[5] Nielsen, L.E., *Mechanical Properties of Polymers*, Reinhold Publishing Corp., New York, NY, 1962.

10.3.1.4 Do not use stress levels that produce failure in less than 1000 h in creep testing.

10.3.2 For simple material comparisons, as for data sheets and the like, determine the stress to produce 1 % strain in 1000 h. Do this by selecting several loads to produce strains in the approximate range of 1 % (both somewhat greater and less than 1 % in 1000 h) and plotting a 1000-h isochronous stress-strain curve from which it will be possible to determine the stress to produce 1 % strain by interpolation.

NOTE 4—Isochronous stress-strain curves are cartesian plots of the applied stress used in the creep test versus the creep strain at a specific time, in this case 1000 h. Since only one point of an isochronous plot is obtained from each creep test, it is usually necessary to run creep tests at least three stress levels (and preferably more) to obtain an isochronous plot (See Fig. 2).

11. Procedure

11.1 *General:*

11.1.1 Mount a properly conditioned and measured specimen in the compressive creep fixture of flexural creep rack. If necessary, mount a properly conditioned and measured control specimen alongside the test specimen in the same manner.

11.1.2 Attach the deformation measuring devices to the specimen (and control specimen) or, if these are optical devices, install ready for measurements. Make the initial or reference measurement for compression or deflection.

11.1.2.1 If the test environment would be disturbed during the attachment of the deformation measuring device, mount the device prior to mounting the specimen.

11.1.3 Apply the full load rapidly and smoothly to the specimen, preferably in 1 to 5 s. In no case shall the loading time exceed 5 s. Start the timing at the onset of loading.

11.1.4 If an environmental agent is used, apply it to the entire gauge length of the specimen immediately after loading.

11.1.4.1 If the environmental agent is volatile, cover the specimen to retard evaporation without affecting the applied load. Replenish volatile agents periodically.

NOTE 5—For liquid environmental agents wrap or seal a cotton swab, film, or other device around the gauge length or span of the specimen, and apply the liquid agent to saturate the swab.

11.1.5 Measure the compression or flexure of the specimen in accordance with the following approximate time schedule: 1, 6, 12, and 30 min; 1, 2, 5, 20, 50, 100, 200, 500, 700, and 1000 h. For creep tests longer than 1000 h, measure deformation at least monthly.

11.1.5.1 If discontinuities in the creep strain versus time plot are suspected or encountered, take readings more frequently than scheduled above.

11.1.6 Measure temperature, relative humidity, and other environmental variables and deformation of control specimen in accordance with the same schedule as that for deformation of the test specimen.

11.1.7 Upon completion of the test interval without rupture, remove the load rapidly and smoothly.

NOTE 6—If desired, measurements of the recovery can be initiated on the same schedule as used in 11.1.5 during the load application. Calculate recovery strain as described in 12.2.2.

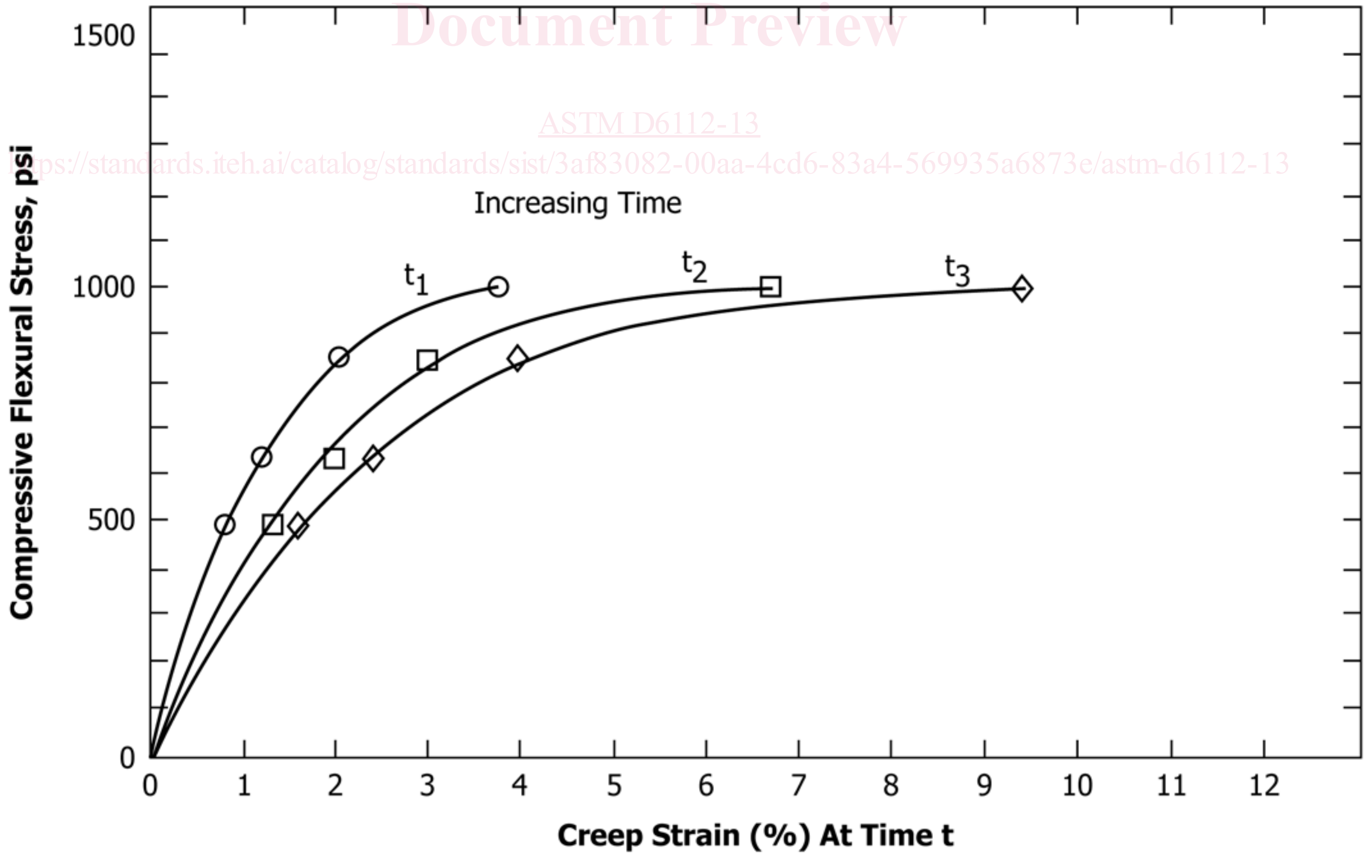


FIG. 2 Cartesian Isochronous Stress Strain Curves at Various Times

11.2 *Flexural Creep:*

11.2.1 Flexural deflection shall be measured at the bottom of the test specimen at the midpoint of the load span.

11.2.2 Measure the width and thickness or diameter of the specimen to a precision of 1 % of the measured dimension at several points along its length. Calculate and record the minimum value of the cross-sectional area (see Test Methods D5947 for additional information).

11.3 *Compressive Creep*—Measure the width and thickness or diameter of the specimen to a precision of 1 % of the measured dimension at several points along its length. Calculate and record the minimum value of the cross-sectional area. Measure the length of the specimen at several points and record the average value (see Test Methods D5947 for additional information).

12. Calculation

12.1 *General:*

12.1.1 When a material shows a significant dimensional change due to the environment alone, use either of the following approaches, depending on the intended use of the results:

12.1.2 Correct each measurement of deformation under load by the algebraic addition to it of the average deformation measured on three nonloaded control specimens at the same time and at the same temperature. Contraction of the control specimens used for compressive measurements shall be considered negative (−), expansion positive (+). Upward deflection of the control specimens used for flexural measurements shall be considered positive (+); downward shall be considered negative (−). Calculate corrected strain using the deformation corrected for or dimensional change due to the environment. Multiply corrected strain by 100 to obtain percent corrected strain.

12.1.3 If, because of the intended use of the results, it is desired not to correct the deformation under load for significant dimensional change due to the environment alone, then the strain calculated in accordance with 12.2.2 or 12.3.1 shall be called uncorrected strain. Calculate the strain change due to the environment in accordance with 12.2.2 or 12.3.1 by using the average deformation in the control specimen. Multiply by 100 to obtain percent strain change due to the environment. Contraction of the control specimens used for compressive measurements shall be considered negative (−), expansion positive (+). Upward deflection of the control specimens used for flexural measurements shall be considered positive (+), downward negative (−).

12.1.4 Calculate creep modulus in megapascals by dividing the initial stress by the strain at the times specified in 11.1.5.

NOTE 7—For purposes of comparing materials, the plot of creep modulus versus time not only realistically ranks materials but also provides modulus values for use in many design equations (see Fig. 3).

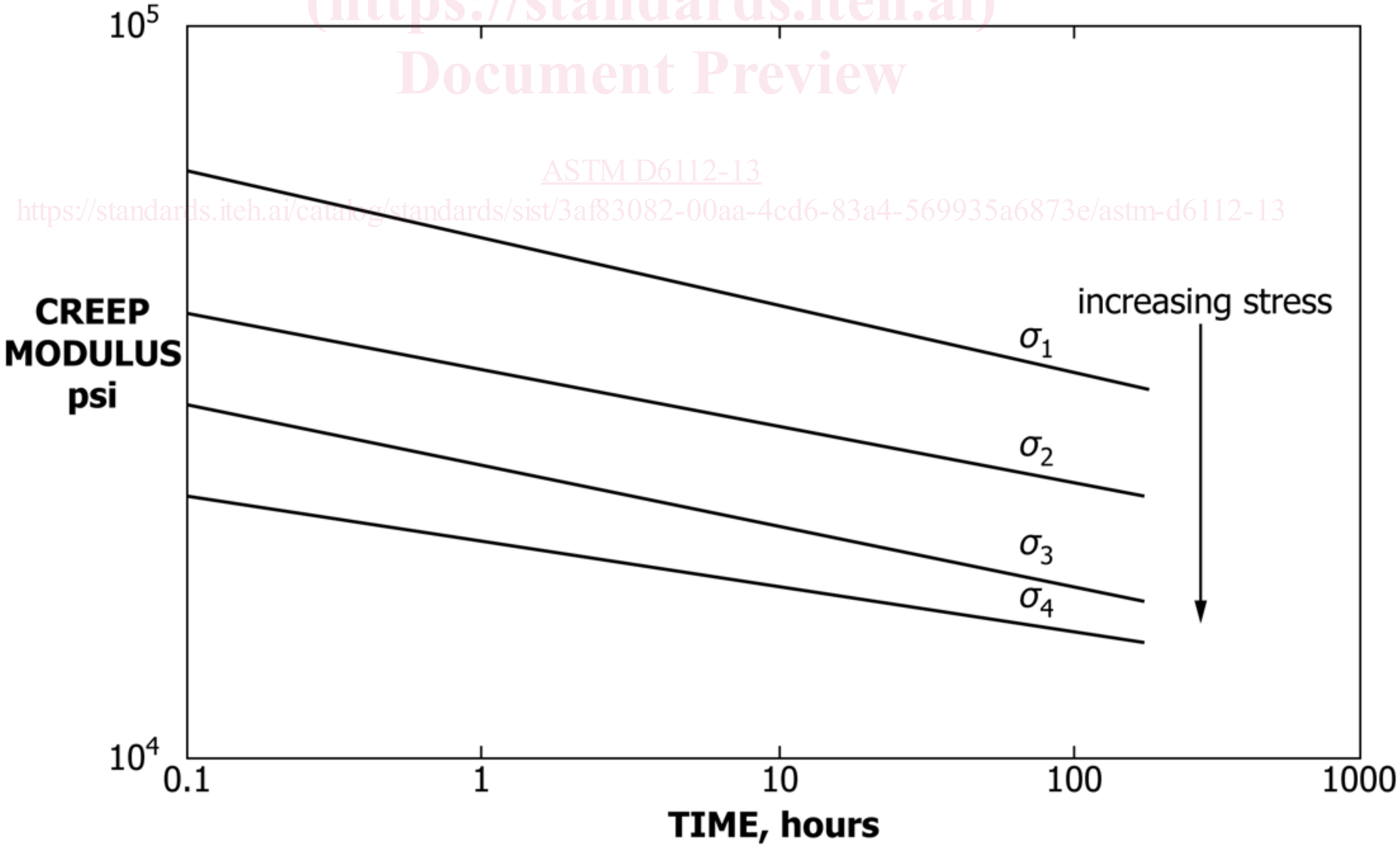


FIG. 3 Logarithmic Creep Modulus Versus Time Curves at Various Stress Levels

12.1.5 At each test temperature, calculate a statistical least squares regression equation of log stress versus log time-to-rupture or failure. From the regression equation calculate the stress-to-rupture failure in megapascals at 1000 h (see Fig. 4).

12.1.6 To calculate the stress to produce 1 % strain at 1000 h, plot at each test temperature the 1000–h isochronous stress-strain curve (see Fig. 2) and interpolate for the stress at 1 % strain. The isochronous stress-strain curve at 1000 h is obtained from several (at least three, and preferably more) creep curves at different stresses by plotting stress versus strain calculated from deformation measurements at 1000 h.

12.1.6.1 It is acceptable to plot isochronous stress-strain curves at times other than 1000 h for purposes of analysis or for specialized design situations involving relatively short-time loads and materials that show pronounced creep at such times. For long-term loading and in general, however, creep modulus curves are more useful.

12.2 *Compressive Creep:*

12.2.1 For compressive measurements, calculate the stresses for each specimen in megapascals (or pounds-force per square inch) by dividing the load by the average initial or effective cross-sectional area.

12.2.2 Calculate strain by dividing the extension or compression at the times specified in 11.1.5 by the initial gauge length of the conditioned specimen; multiply strain by 100 to obtain percent strain.

12.3 *Flexural Creep:*

12.3.1 For flexural measurements, calculate the maximum fiber stress for each specimen in megapascals as follows:

$$S = PL/bd^2 \tag{1}$$

where:

S = stress in outer fiber throughout load span, psi (MPa),
P = load at a given point on the load-deflection curve, lb (N)
L = support span, in. (mm),
b = width of beam, in. (mm), and
d = depth of beam, in. (mm).

NOTE 8—Eq 1 represents only a first-order approximation to the actual flexural stress because the distribution of stress across the section becomes increasingly nonlinear as creep occurs. Its use is consistent with Test Methods D2990.

12.3.2 Calculate the maximum strain in the outer fiber at the mid-span as follows:

$$r = 4.70\, Dd/L^2 \tag{2}$$

where:

r = maximum strain, in./in. (mm/mm),
D = maximum deflection at mid-span, in. (mm),
d = depth of beam, in. (mm), and
L = support span, in. (mm).

Multiply strain by 100 to obtain percent strain.

13. Report

13.1 Report the following information:

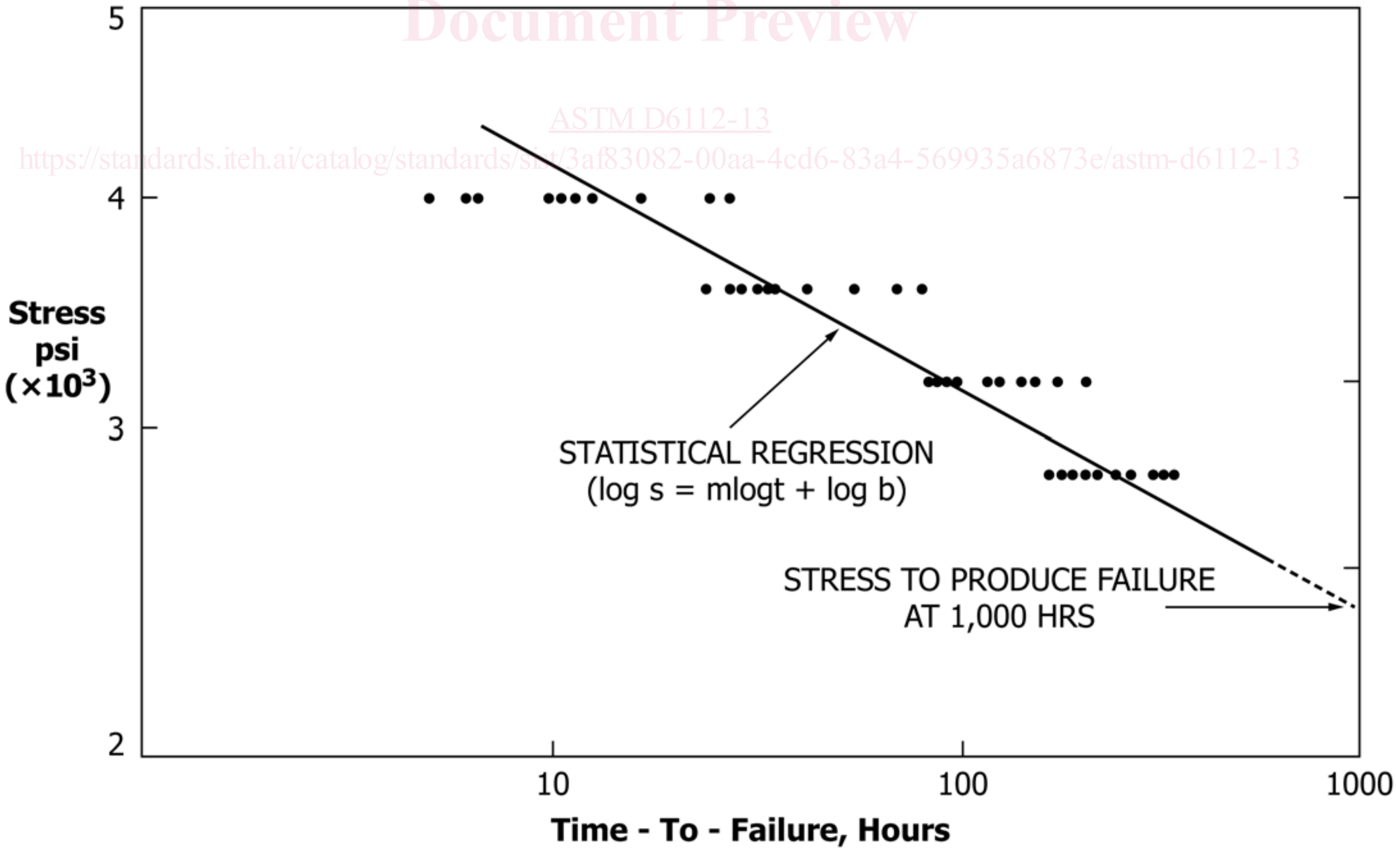


FIG. 4 Logarithmic Time-to-Failure (Stress Rupture) Curve

13.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, and previous history,

13.1.2 Laboratory name,

13.1.3 Date of test,

13.1.4 Dimensions of the test specimen,

13.1.5 All pertinent information on composition, preparation, date of manufacture, type of molding, annealing, etc.,

13.1.6 Preconditioning used and description of test conditions, including the relative humidity, temperatures, as well as concentration and composition of the environment other than air, loads used, type loading, etc.,

13.2 For each test temperature, plot log strain in percent versus log time in hours under load with stress as a parameter (see Fig. 5),

13.2.1 Where deformation measurements of loaded specimens have been corrected from unloaded control specimens, plot log corrected strain (in percent) versus log time (in hours) under load, and on the same graph also plot the log average dimensional change (in percent) due to the environment alone versus log time,

13.2.2 Where significant changes in deformation due to the environment alone have occurred, but because of the intended use of the results it is desired not to correct the deformation under load, then plot log uncorrected strain, in percent, versus log time in hours under load, and on the same graph plot the log average strain change (in percent) of the control specimen versus log time, and

13.2.3 When a material shows a significant dimensional change due to the environment alone, any properties calculated from the creep data (such as creep modulus or isochronous stress-strain curves) shall be labeled corrected or uncorrected, depending on which approach is used.

14. Precision and Bias

14.1 These are new test methods for which precision and bias have not been determined. Interlaboratory studies will be initiated to define the reproducibility of test specimens prepared using this practice.

14.2 It is the intent of Subcommittee D20.20 to investigate the precision and bias of these test methods in the near future.

15. Keywords

15.1 creep; creep-rupture; plastic lumber; recycled plastic

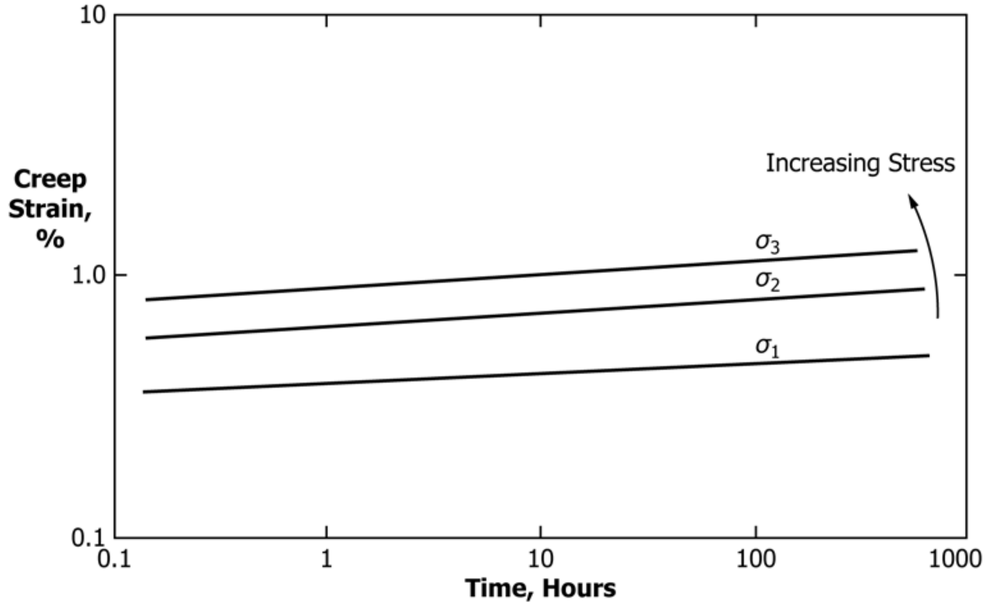


FIG. 5 Logarithmic Creep Strain Versus Time Curves at Various Stress Levels

APPENDIXES

(Nonmandatory Information)

X1. INTRODUCTION

X1.1 Since the properties of viscoelastic materials are dependent on time-, temperature-, and rate-of-loading, an instantaneous test result cannot be expected to show how a material will behave when subjected to stress or deformation for an extended period of time. Therefore, values of modulus and strength should be obtained under conditions (stress, time, and so forth) that simulate the end-use application, and be used in engineering design.

X2. CREEP CURVE

X2.1 The creep test measures the dimensional changes that occur during time under a constant static load, while the creep rupture test measures the time to break under a constant load. Creep is the progressive deformation of a material at constant load (stress). A constant load is applied to a specimen in selected loading configurations, (such as, tension, flexure, or compression) at constant temperature and the deformation is measured as a function of time.

X2.2 Following an initial rapid elongation (ε_o) upon application of the load (ε_o may be considered to consist of the elastic (ε_o) and the plastic (ε_o)), the following occurs:

X2.2.1 The creep rate decreases rapidly with time, (primary creep, Stage I), then

X2.2.2 It reaches a steady-state value (secondary creep, Stage II), followed by

X2.2.3 A rapid increase and fracture (tertiary creep, Stage III).

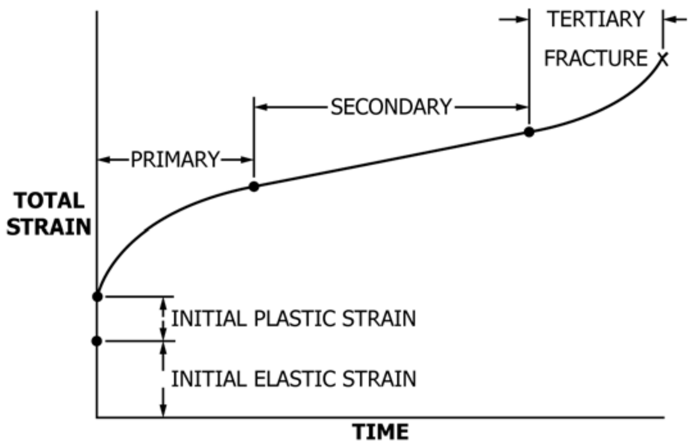
NOTE X2.1—This is an idealized curve. Some materials do not have a secondary stage, while tertiary creep usually occurs at high stresses and for ductile materials.

NOTE X2.2—Since the specimen elongates and decreases in cross-sectional area, the axial stress increases. Therefore, in a constant-load creep test the onset of Stage III shows up earlier than in a constant-stress test (see dotted line in Fig. X2.1)

NOTE X2.3—In some terminologies the instantaneous strain (ε_o) is often called the first stage, in which case we have four stages of creep.

X2.3 The strain, shown as ε_o occurs instantaneously upon application of the load. Even though the applied stress is below the yield stress, some of this strain is not totally recoverable. Although this strain is not really creep it is very important since it constitutes a considerable fraction of the allowable total strain in designing. Therefore, it should be included in all calculations, especially of the creep modulus.

NOTE X2.4—In cases where this instantaneous strain is subtracted from the total strain, the creep curve must start at the origin of the time/strain coordinates.



NOTE 1—The segregation of creep data into instantaneous, primary, and secondary stages is dependent upon the time scale of the plot.

NOTE 2—The parameters, ε_e, ε_p, and ε_o are not obtainable using these test methods (see Note 3). However, such factors may be separately defined for the sake of stress analysis. Any such definitions can be more or less arbitrary with respect to the time-dependent material behavior.

FIG. X2.1 Creep Curve

X2.4 Due to the long times involved, creep curves are usually plotted on logarithmic scales where the data is generally linear. The three curves shown in Figs. X2.2-X2.4 are an example.

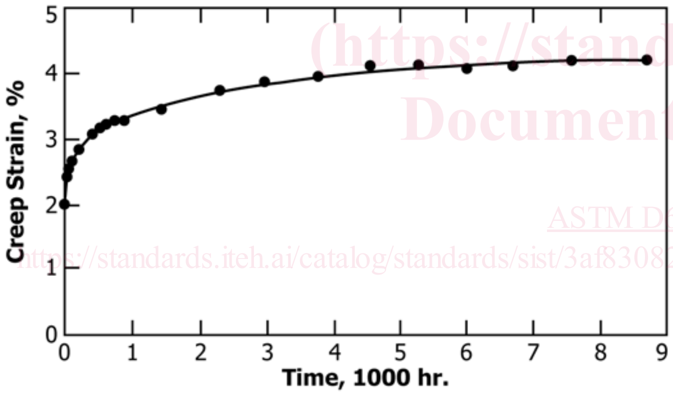
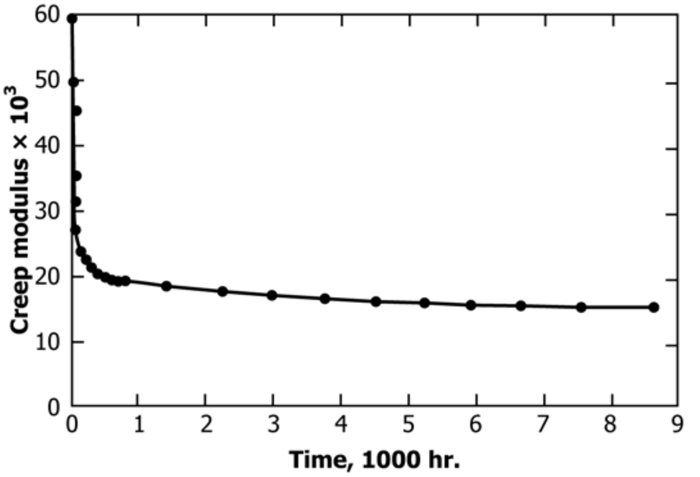


FIG. X2.2 Tensile-Creep Curve of PTFE at 650 psi, 23°C Creep Strain Versus Time



NOTE 1—Modulus = Applied Stress/Total Creep Strain.

FIG. X2.3 Creep Modulus Versus Time

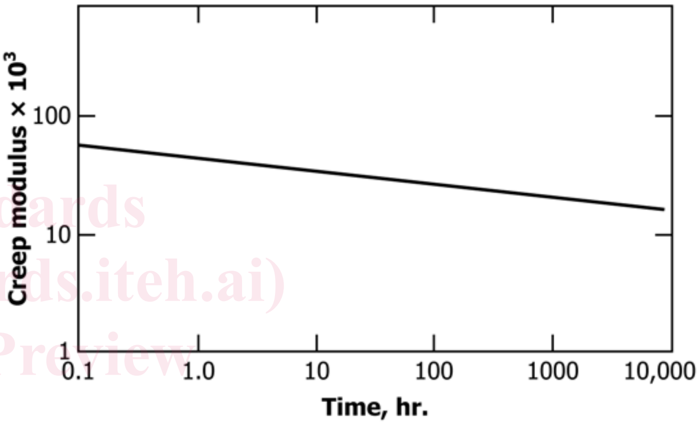


FIG. X2.4 Creep Modulus Versus Time on Logarithmic Coordinates

X2.5 As the stress levels increase the creep modulus will be lowered.

X3. CREEP STRENGTH AND CREEP RUPTURE

X3.1 In reporting strength data, creep strength and rupture strength (creep rupture), is often spoke of.

X3.2 The minimum creep rate (slope d_E/d_t) is one of the important parameters. A condition (for example, for jet-engine material) is the stress needed to produce a creep rate of 0.0001 % *E*/*h* or 1 % *E*/10 000 h. Fig. X3.1 illustrates the importance of the creep rate.

X3.3 *Creep Strength* is defined as the stress at a given temperature that produces a steady creep rate of a fixed amount in percent per hour. (See Fig. X3.2)

X3.4 *Rupture Strength* is defined as the stress at a given temperature to produce rupture in a fixed amount of time in hours. (See Fig. X3.3)

X3.5 The stress-rupture test is basically similar to a creep test with the exception that it is continued until the material fails. Since higher loads are used, creep rates are higher and the material fails in a shorter time (usually terminated in 1000 h). This test is useful in establishing a safe envelope inside which a creep test can be conducted. The basic information obtained from the stress-rupture test is the time-to-failure at a given stress. Based on this data, a safe stress can be determined