Designation: E328 – 21

Standard Test Methods for Stress Relaxation for Materials and Structures[1]

This standard is issued under the fixed designation E328; 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.

INTRODUCTION

These test methods cover a broad range of testing activities. To aid in locating the subject matter pertinent to a particular test, the standard is divided into a general section, which applies to all stress-relaxation tests for materials and structures. This general section is followed by letter-designated parts that apply to tests for material characteristics when subjected to specific, simple stresses, such as uniform tension, uniform compression, bending or torsion. To choose from among these types of stress, three factors should be considered:

(1) When the material data are to be applied to the design of a particular class of component, the stress during the stress-relaxation test should be similar to that imposed on the component. For example, tension tests are suitable for bolting applications and bending tests for leaf springs.

(2) Tension and compression stress-relaxation tests have the advantage that the stress can be reported simply and unequivocally. During bending stress-relaxation tests, the state of stress is complex, but can be accurately determined when the initial strains are elastic. If plastic strains occur on application of force, stresses can usually be determined within a bounded range only. Tension stress-relaxation tests, when compared to compression stress-relaxation tests, have the advantage that it is unnecessary to guard against buckling. Therefore, when the test method is not restricted by the type of stress in the component, tension stress-relaxation testing should be used.

(3) Bending stress-relaxation tests, when compared to tension and compression stress-relaxation tests, have the advantage of using lighter and simpler apparatus for specimens of the same cross-sectional area. Strains are usually calculated from deflection or curvature measurements. Since the specimens can usually be designed so that these quantities are much greater than the axial deformation in a direct stress test, strain is more easily measured and more readily used for machine control in bending stress-relaxation tests. Due to the small forces normally required and the simplicity of the apparatus when static fixtures are sufficient, many specimens can be placed in a single oven or furnace when tests are made at elevated temperatures.

1. Scope*

NOTE 1—The method of testing for the stress relaxation of plastics has been withdrawn from this standard, and the responsibility has been transferred to Practice D2991.

1.1 These test methods cover the determination of the time dependence of stress (stress relaxation) in materials and structures under conditions of approximately constant constraint, constant test environment, and negligible vibration. In the procedures, the material or structure is initially constrained by externally applied forces, and the change in the external force necessary to maintain this constraint is determined as a function of time.

1.2 Specific methods for conducting stress-relaxation tests on materials subjected to tension, compression, bending and torsion stresses are described in Parts A, B, C, and D, respectively. These test methods also include recommendations for the necessary testing equipment and for the analysis of the test data.

1.3 Bending stress-relaxation tests to determine relaxation properties by using ring-shaped specimens machined from bulk material have been thoroughly developed and widely used to determine stress-relaxation properties (**1**).[2] These tests are outside the scope of these test methods.

[1] These test methods are under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

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

1.4 The long time periods required for these types of tests are often unsuited for routine testing or for specification in the purchase of material. However, these tests are valuable tools in obtaining practical design information on the stress relaxation of materials subjected to constant constraint, constant test environment, and negligible vibration, and in investigations of the fundamental behavior of materials.

1.5 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D2991 Test Method for Stress-Relaxation of Plastics (Withdrawn 1990)[4]

E4 Practices for Force Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E8/E8M Test Methods for Tension Testing of Metallic Materials

E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature

E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms common to mechanical testing that appear in Terminology E6 apply to this test method, including calibration, eccentricity, gauge length, indicated temperature, modulus of elasticity, Poisson's ratio, proportional limit, reduced parallel section, residual stress, shear modulus, specified temperature, and testing machine.

3.1.2 *stress relaxation, n*—the time-dependent decrease in stress in a solid under given constraint conditions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *initial stress,* σ_0, [FL^{-2}], *n*—the stress introduced into a specimen by imposing the given constraint conditions before stress relaxation begins.

3.2.1.1 *Discussion*—This is sometimes called instantaneous stress.

3.2.2 *relaxed stress* [FL^{-2}], *n*—the initial stress minus the remaining stress at a given time during a stress-relaxation test.

3.2.3 *remaining stress* [FL^{-2}], *n*—the stress remaining at a given time during a stress-relaxation test.

3.2.4 *spherometer, n*—an instrument used to measure circular or spherical curvature.

3.2.5 *stress-relaxation curve, n*—a plot of either the remaining time or relaxed stress as a function of time.

3.2.6 *stress-relaxation rate* [FL^{-2} T^{-1}], *n*—the absolute value of the slope of the stress-relaxation curve at a given time.

3.2.6.1 *Discussion*—A stress-relaxation curve is a plot of either the remaining stress or relaxed stress as a function of time.

3.2.7 *zero time,* t_0, *n*—the time when the given stress or constraint conditions are initially obtained in a stress-relaxation test.

4. Summary of Test Methods

4.1 In each of the various methods of stress application described in the applicable specific sections, the specimen is subjected to an increasing force until the specified initial strain is attained (see *zero time,* t_0, in 3.2.7 and in Fig. 1). For the duration of the test, the specimen constraint is maintained constant. The initial stress is calculated from the initial force (moment, torque) as measured at zero time, the specimen geometry, and the appropriate elastic constants, often using simple elastic theory. The remaining stress may be calculated from the force (moment or torque) determined under constraint conditions either continuously (4.1.1), periodically (4.1.2), or by elastic springback at the end of the test period (4.1.3).

4.1.1 Readings are taken continuously from a force indicator while the apparatus adjusts the force to maintain constraint within specified bounds.

4.1.1.1 Most force-, moment-, or torque-measuring devices depend on the elasticity of the device to measure the quantities involved. Therefore, when using such devices, maintain the total strain constant within an upper and lower bound as shown in Fig. 2.

4.1.2 The force required to lift the specimen just free of one or more constraints during the test period is measured.

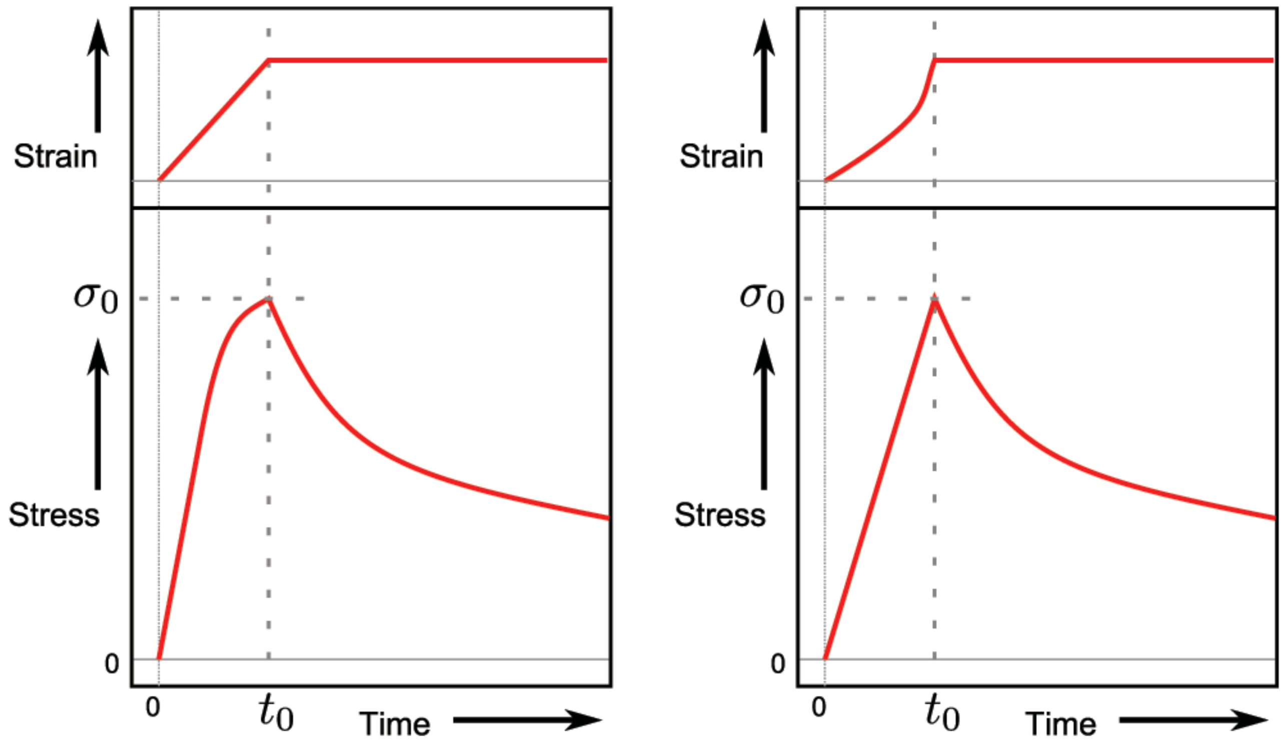
4.1.3 The elastic springback is measured after removing the test stress at the end of the test period.

4.2 With 4.1.1 and 4.1.2, a single specimen may be used to obtain data for a curve of stress versus time. With 4.1.3, the same specimen may be used to determine the remaining or relaxed stress after various time intervals, if it can be demonstrated for a given material that identical results are obtained in either using untested or reloaded specimens. Otherwise, an individual specimen shall be used for each point on the curve.

4.3 The stress-relaxation rate of a stress-relaxation curve, Fig. 3, may be determined from slope of either the remaining stress or the relaxed stress as a function of time.

[3] 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.

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



(a) constant strain rate

(b) constant force application rate

FIG. 1 Characteristic Behavior During Force-Application Period in a Stress-Relaxation Test

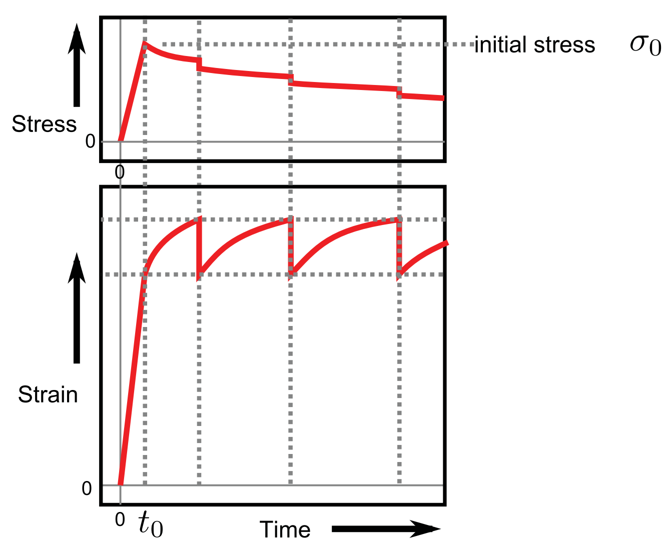


FIG. 2 Derivation of Stress-Relaxation Curve from Continuous Stress-Relaxation Technique

5. Significance and Use

5.1 Stress-relaxation test data are necessary when designing most mechanically fastened joints to ensure the permanent tightness of bolted or riveted assemblies, press or shrink-fit components, rolled-in tubes, etc. Other applications include predicting the decrease in the tightness of gaskets, in the hoop stress of solderless wrapped connections, in the constraining force of springs, and in the stability of wire tendons in prestressed concrete.

5.2 The ability of a material to relax at high-stress concentrations such as are present at notches, inclusions, cracks, holes, and fillets can be predicted from stress-relaxation data. Such test data are also useful to judge the heat-treatment condition necessary for the thermal relief of residual internal stresses in forgings, castings, weldments, machined or cold-worked surfaces, etc. The tests outlined in these methods are limited to conditions of approximately constant constraint and test environment.

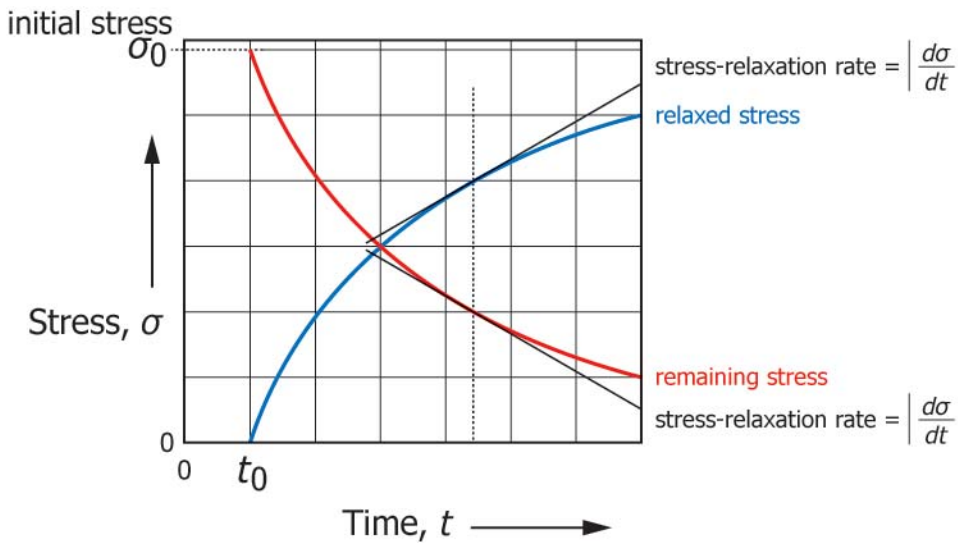


FIG. 3 Typical Stress-relaxation Curve

5.3 The general stress-relaxation test is performed by isothermally applying a force to a specimen with fixed value of constraint. The constraint is maintained constant, and the constraining force is determined as a function of time. The major problem in the stress-relaxation test is that constant constraint can be very difficult to maintain. The effects on test results are very significant, and considerable attention shall be given to minimize the constraint variation. Also, experimenters should determine and report the extent of variation in each stress-relaxation test so that this factor can be taken into consideration.

5.4 There are many methods of performing the stress-relaxation test, each with a different starting procedure. However, the constraint is usually obtained initially by the application of an external force at either a specific force-application rate or a specific strain rate. The two methods will produce the characteristic behavior shown in Fig. 1 when the initial stress, σ_0, exceeds the proportional limit. Some testing machines, while reaching the constraint value, do not produce either a constant force-application rate or constant strain rate, but something in between. However, the general characteristics of the data will be similar to those indicated. The stress-application rate in either case should be reasonably rapid, but without impact or vibration, so that any relaxation during the stress-application period will be small.

5.5 The stress-relaxation test starts at zero time, t_0, in Fig. 1.

NOTE 2—This zero time is the reference time from which the observed reduction in force to maintain constant constraint is based. Selection of this time does not imply that the force-application procedure and period are not significant test parameters which are important in the application of the data.

6. Apparatus

6.1 See the appropriate paragraph under each section.

6.2 The equipment should be located in a draft-free, constant-temperature laboratory, ±5 °F (±3 °C).

7. Temperature Control and Measurement

7.1 Maintain the test environment (controlled-temperature room, furnace, or cold box) at a constant temperature by a suitable automatic device. This is the most important single factor in a stress-relaxation test since the stress-relaxation rate, dimensions, and constraint conditions of the specimen depend upon the temperature. Any type of heating or cooling that permits close temperature control of the test environment may be used.

7.2 The indicated temperature should be recorded, preferably continuously or at least periodically. Indicated temperature variations of the specimens from the specified temperature due to all causes, including cycling of the controller or position along the specimen gauge length, should not exceed ±5 °F (±3 °C) or ±0.5 %, whichever is greater. These limits should apply initially and for the duration of the test.

7.3 The combined strain resulting from differential thermal expansion (associated with normal temperature variation of the test environment) between the test specimen and the constraint and other variations in the constraint (such as elastic follow up) should not exceed ±0.000025 in./in. (mm/mm).

7.4 Temperature measurement should be made in accordance with Practice E139.

8. Vibration Control

8.1 Since stress-relaxation tests are quite sensitive to shock and vibration, the testing machine and mounting should be located so that the specimen is isolated from vibration.

9. Test Specimens

9.1 The test specimens should be of a shape most appropriate for the testing method and end use. Wire may be tested in the "as-received" condition. Metal plate, sheet, strip, bar, or rod may be machined to the desired shape.