Designation: E 151 – 64 (Reapproved 1981)

Standard Practice for

TENSION TESTS OF METALLIC MATERIALS AT ELEVATED TEMPERATURES WITH RAPID HEATING AND CONVENTIONAL OR RAPID STRAIN RATES[1]

This standard is issued under the fixed designation E 151; 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 This recommended practice covers procedures, and equipment requirements for conducting tension tests on metallic materials under conditions of (*1*) rapid rates of heating and normal rates of straining, and (*2*) rapid rates of heating and straining.

1.2 This recommended practice covers tension tests using faster heating rates or faster heating rates in combination with faster straining rates than those covered by ASTM Recommended Practice E 21, for Elevated Temperature Tension Tests of Metallic Materials.[2]

1.3 Preferred conditions of testing are recommended for the purpose of promoting directly comparable data from laboratories conducting the tests.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

2. Tension Test Apparatus

2.1 The type of testing machine to be used for the loading of the specimen is not specified but should be made part of the report of the test results. The accuracy of the testing machine should be within the permissible variations specified in ASTM Methods E 4, Verification of Testing Machines.[3]

2.2 The testing machine must be capable of smoothly applying the load to the specimen at the strain rates specified in Section 7. The speed of response of the load indicator shall be higher than the maximum rate of load increase in the test. The calibration of the testing machine should take into account the accurate measurement of loads under the dynamic conditions existing for tests requiring rapid strain rates.

2.3 Precautions shall be taken to assure that the load on the specimen is applied as nearly axial as possible. It is difficult to obtain axial alignment. Nonaxiality shall not exceed that which will produce a difference of 15 percent in elastic strain readings on opposite sides of the specimen when an extensometer is positioned to measure the maximum effect of nonaxiality as described in 2.4. Brittle materials may require considerably better alignment than that which would produce a 15 percent variation in elastic strain.

2.4 Eccentricity of loading can often be detected by elastic extension measurements taken at room temperature. Apparatus provided with extensometers affording separate measurements on opposite sides will reveal unsatisfactory alignment in respect to one plane when unequal strain is shown by the readings on opposite sides. Repeating this procedure with the points of attachment to the specimen at 90 deg to the first eccentricity test will help define the extent and orientation of any eccentricity. Such eccentricity

[1] This practice is under the jurisdiction of the ASTM-ASME Joint Committee on Effect of Temperature on Properties of Metals.

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[2] *Annual Book of ASTM Standards*, Part 10.

[3] *Annual Book of ASTM Standards*, Parts 10, 14, 32, 35, and 41.

measurements shall be taken periodically at room temperature to check axial alignment. Devices which measure extension on only one side of the specimen will not detect eccentric loading.

3. Heating Apparatus

3.1 The apparatus for and method of heating the specimen are not specified. Present practice mainly uses:

3.1.1 The resistance of the specimen gage length to the passage of an electric current,

3.1.2 Resistance heating supplemented by radiant heating,

3.1.3 Radiant heating, and

3.1.4 Induction heating to maintain the specimen gage length at temperature.

3.1.5 The apparatus must be suitable for heating the specimen under the conditions specified in Section 5.

4. Test Specimens

4.1 The size and shape of the test specimen shall be based on two requirements:

4.1.1 The specimen shall be representative of the material being investigated and shall be taken from the material produced in the form and condition in which it will be used, and

4.1.2 The specimen should be adapted to meet the requirements on temperature control and rates of heating and straining.

4.1.3 The use of small specimens is discouraged because of the difficulties of machining and testing. When subsize specimens are used, they should be as large as is practical.

4.2 Method of manufacture, type and size of product, and other pertinent processing information as well as heat treatment, microstructure, and chemical composition of the material being tested shall be reported. It has been found that all these factors can have pronounced influence on tensile properties of materials.

4.3 Test specimens with the dimensions of the gage section shown by Figs. 1 and 2 are preferred when these specimens meet the requirements of 4.1. When the dimensions of the material permit, except for sheet, strip, and plate, the gage length of the specimens shall have a circular cross section. The largest diameter specimen consistent with the requirements of 4.1 shall be used except that the diameter need not be larger than 0.500 in. (12.7 mm).

4.4 The minimum diameter of round specimens or the minimum width of strip specimens shall be at the center of the gage length. A taper facilitates control of the test. For such tapered specimens the variation at the ends shall be not more than +0.5 percent of the minimum diameter or width of the specimen. In those cases where a taper is not desirable, the variation in diameter of the gage length of round specimens or the width of the gage length of strip specimens shall not be more than ±0.001 in. (0.025 mm).

4.5 The ratio of gage length to diameter for round specimens shall be 4. For sheet, strip, or plate specimens the preferred gage length is 2 in. (25.4 mm). When the dimensions of the material being tested require the use of specimens of sheet, strip, or plate with a gage length of less than 2 in., the ratio of gage length to width should be maintained at 4 to 1.

NOTE 2—In conducting the tests the attainment of specified temperature variation and distribution may be facilitated by short gage lengths. When it is necessary to use a gage length less than 2 in. (25.4 mm) (for either round or flat specimens), due to temperature gradients or other problems, preferred gage lengths are ½ (12.7 mm) or 1 in. (25.4 mm). The use of short gage length specimens which do not have a ratio of gage length to width of 4 to 1 should be limited to tests, such as those using electrical-resistance heating, where it is known that temperature distribution cannot be maintained after the maximum load is attained during the test. Such conditions make the ductility values questionable and eliminate the necessity for maintaining standard gage lengths to provide comparable ductility values.

4.6 The form and dimensions of the ends of the specimens beyond the gage length are not specified. Making the reduced section three times the gage length, or prolongation of the ends with only slightly larger dimensions than the gage section is recommended to facilitate the attainment of satisfactory temperature uniformity when using the resistance-heating method. Any method of gripping the specimen that meets the requirements of Section 2 for alignment of the specimen may be used.

4.7 Caution should be exercised in preparing the surface of the test specimens since many materials may exhibit properties which are sensitive to the conditions of machining. Machining methods or conditions which lead to high residual stresses and cold-worked surface layers can influence properties as much or more than surface roughness. A surface finish of 16 to 32 μin. rms is recommended when testing materials whose properties are known to be significantly affected by variations in surface finish. When this recommended practice is used in conjunction with a product specification, the specimens shall meet the surface finish requirements of the product specification.

4.8 Specimen dimensions above 0.100 in. (2.54 mm) shall be measured to the nearest 0.001 in., dimensions under 0.100 in. shall be measured at least to the nearest 1 percent. In testing material under 0.010 in. (0.254 mm), measurement to within 1 percent may be impossible with available instruments, in which case the closest practical measurement should be made and so stated in the report. The minimum cross-sectional area shall be used for the calculation of stress.

5. Temperature Control

5.1 The preferred conditions for heating the gage length of the specimen are as follows: 60 s or less to heat to the indicated nominal test temperature, and holding time at the indicated nominal test temperature, before applying the load, equal to the heating time.

5.2 The indicated control temperature of the specimen shall not vary more than ±10 F (5.5 C) from the nominal test temperature up to and including 1000 F (538 C) and not more than ±1.0 percent of the nominal test temperature above 1000 F. The uniformity of temperature within the specimen gage length shall be within +10 F and −20 F (−11 C) of the nominal test temperature up to and including 1000 F and within +1.0 and −2.0 percent of the nominal test temperature above 1000 F.

5.3 The maximum permissible overshoot in indicated temperature during the heating and holding period is 10 F, or 2 percent of the nominal test temperature, whichever is greater, for a time not exceeding 5 s. Higher temperatures or longer periods of over temperature shall require a retest. The overshoot requirement permits a larger temperature variation for a 5-s period than is permitted under 5.2.

5.4 The conditions of heating to and holding at the nominal test temperature specified in 5.1 are preferred to facilitate comparison of data between laboratories. Any deviation from the requirements of this paragraph should be permitted only for the purpose of simulating special service requirements with the test. Such deviation when used shall be clearly reported with the test results.

5.5 The "indicated nominal temperature" designated in 5.1 and the "indicated temperature" of 5.2 are the temperatures indicated by the temperature measuring instrument using good pyrometric practice.

NOTE 4—It is recognized that actual specimen temperatures may vary more than the indicated temperatures. The permissible indicated temperature variations specified in 5.1 and 5.2 are not to be construed as minimizing the importance of good pyrometric practices and precise temperature control in tests covered by this practice. All laboratories are obligated to keep both indicated and actual specimen temperature variations as small as practicable. It is recognized that close temperature control is necessary in view of the extreme dependency of strength of materials on temperature. The limits prescribed represent ranges which are common practice.

6. Temperature Measurement

6.1 The method of temperature measurement must be sufficiently sensitive and reliable to ensure that the temperature of the specimen is within the limits specified in Section 5.

6.2 The usual methods of measuring temperatures utilize thermocouples. Care must be exercised to prevent conduction of heat along the thermocouple wires from cooling the specimen at the point of attaching the thermocouple thereby resulting in low indicated temperature. Small diameter thermocouple wires should be used. Wires larger than 28-gage should not be used and 36-gage is preferred. Fastening the thermocouple wires parallel to the heated gage section reduces the cooling effect of conduction at the bead.

6.3 Other methods of temperature meas-