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An American National Standard

Standard Practice for Effects of High-Energy Neutron Radiation on the Mechanical Properties of Metallic Materials, E706 (IB)[1]

This standard is issued under the fixed designation E 184; 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 practice covers special procedures for selecting a material and tests for radiation studies, determining radiation conditions, conducting tests for the mechanical properties of irradiated metallic materials, and reporting of data.

1.2 The purpose of this practice is to achieve better correlation and interpretation of new data in the field of radiation effects testing.

1.3 While primarily intended to apply to ferrite and austenitic steels, this practice may be applied to any appropriate metallic materials. In addition to tests for mechanical properties, these procedures should be helpful in planning other types of radiation effects testing.

1.4 It should be recognized that the effect of high-energy neutron radiation on the mechanical properties of the materials being studied is determined by the change in mechanical properties during radiation. Hence, the post-irradiated mechanical properties must be compared with the pre-irradiation properties of the materials.

2. Referenced Documents

2.1 *ASTM Standards:*

E 8 Test Methods for Tension Testing of Metallic Materials[2]

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials[2]

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[2]

E 45 Test Methods for Determining the Inclusion Content of Steel[2]

E 112 Test Methods for Determining the Average Grain Size[2]

E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials[2]

E 604 Test Method for Dynamic Tear Testing of Metallic Materials[2]

3. Significance and Use

3.1 It is well documented that mechanical properties of steels and other metals are altered by exposure of high-energy neutron radiation. Typical property changes of interest include those in hardness, tensile, notch-impact, and fracture toughness. The magnitude and relationships of these changes are functions of the material composition and its metallurgical condition, the amount, rate, and energy spectrum of the radiation, and the exposure temperature. The influence of these variables, either individually or in combination, is not completely understood, although data are now available to indicate the type and magnitude of effects that may be expected to guide the further study of these effects.

4. Selection of Material

4.1 The following information regarding the chemical composition, properties, and metallurgical structure of the material before radiation shall be obtained and reported as follows:

4.1.1 The material shall be identified and its processing history reported, including such information as metal designation, manufacturer, heat number, fabrication procedures, and heat treatment,

4.1.2 Chemical composition of the material,

4.1.3 Original location and orientation in the parent material of all test specimens,

4.1.4 Appropriate mechanical properties prior to radiation exposure, determined on specimens taken from a location and orientation equivalent to that of the irradiated specimens,

4.1.5 Optical micrographs showing the structure of the material at the test location,

4.1.6 Average grain size of these materials shall be estimated in accordance with the Methods E 112, and for steels, the inclusion content shall be determined in accordance with Practice E 45, and

4.1.7 Other information such as hardenability, the variation in hardness, and other mechanical properties with locations and orientations through the thickness of the material, electron microscopy, etc., should be included if pertinent.

5. Determination of Radiation Conditions

5.1 Available data on the nuclear environment and reactor operating history shall be reported, and neutron dosimetry shall be a part of every irradiation experiment. The procedure described in 5.1.1-5.1.4 is suggested as a minimum guide in measuring the radiation environment.

5.1.1 *Neutron Spectrum and Exposure*—For the particular

[1] This practice is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications.

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

facility utilized, the most complete neutron spectrum description available from reactor data, from pre-experiment surveys, and from monitoring of the experiment shall be obtained and reported. Because the determination of fast-neutron spectra is complex and is important in the evaluation of results, a maximum effort should be expended to obtain and report useful spectral data for radiation effects studies. The method used by the investigator to determine the spectrum shall be described or referenced clearly. The following information shall be reported:

5.1.1.1 Basic dosimetry data for calculating neutron exposure.

5.1.1.2 The neutron spectrum. It may be expressed in terms of fluxes of neutrons with energies above specified levels as determined by the particular detectors used.

5.1.1.3 When the neutron exposure is reported in terms of fluxes of neutrons having energies greater than a specified energy, such as 1 MeV, the detectors as well as the assumptions used in the flux determinations are to be defined clearly.

5.1.1.4 Information on the time of exposure and the operating history of the reactor during the experiment shall be documented.

NOTE 1—It is recommended that the procedures established by ASTM Subcommittee E10.05 on the use of threshold detectors be followed.

5.1.2 *Correlation Monitors*—In addition to the neutron detectors described in 5.1, 5.1.1.2, and 5.1.1.3, it is suggested that metal specimens from a standard reference material[3] be considered to correlate one irradiation experiment with another, in order that the mechanical property changes of the reference material may serve as a relative standard for estimating exposure. Such correlation monitors shall be irradiated and tested and the data reported in accordance with the recommendations given in other sections of this practice.

5.1.3 *Temperature Knowledge and Control*—For irradiation experiments, a continuous temperature record is desirable. Sufficient sensors should be used in large assemblies to provide a complete knowledge of the temperature pattern throughout the assembly, since temperatures usually vary locally because of radiation heating. Thermal gradients also occur between the center and surface of individual specimens due to the flow of radiation-induced heat through the specimens regardless of the method used to cool the specimens. These gradients can be severe in large specimens or in high-radiation fields.

5.1.4 *Irradiation Atmosphere or Medium*—The composition and impurities of the medium surrounding the specimens during irradiation shall be reported in as much detail as possible.

6. Control Specimens

6.1 Duplicate specimens subjected to a thermal history and surrounding medium similar to that experienced by the irradiation specimens shall be tested for control and the results reported.

7. Mechanical Property Tests

7.1 One or more of the following test methods may be used for radiation effects testing. It is recommended that, as a minimum, tension and notched-bar impact tests be used in each radiation study.

7.1.1 *Tension Tests*:

7.1.1.1 *Test Specimens*—The type of specimen employed shall conform to the requirements of Methods E 8. Where it is not possible to use standard test specimens, irradiated and nonirradiated specimens shall be of the same size and shape, and every effort shall be made to establish the correlation between the type of specimen used and a standard specimen.

7.1.1.2 *Procedure*—Conduct tension tests in accordance with Test Methods E 8 and Practice E 21, except for the following modifications:

(1) Measure and control the speed of testing by a suitable pacing device.

(2) If the test is interrupted for removal of the extensometer, do not decrease the load during the interruption.

(3) Record the stress-strain curve until approximately maximum load. Beyond this point, record stress and cross-head movement.

(4) Record the load at fracture.

(5) Determine uniform elongation, which is the increase in length of the gage length prior to the onset of necking, expressed as a percentage of the original gage length, from the elongation (elastic plus plastic extension) recorded by autographic or extensometer methods at maximum load or when visible necking deformation begins. The uniform elongation may also be determined from the change in cross-sectional area of the unnecked portion of the broken tension test specimen.

(6) Photomacrographs of the fractures are desirable.

7.1.1.3 *Report*—The report shall include the following:

(1) Description of the material tested in accordance with Section 4,

(2) Description of the test specimen, size, shape, etc., and if other than a standard specimen is used, include the data correlating the specimen used with a standard specimen,

(3) Location and orientation of the test specimen in the parent material,

(4) Data on radiation environment in accordance with Section 5,

(5) Trade name and model of testing machine, gripping devices, extensometer, and recording devices used in the test, methods and results of calibrations of the apparatus,

(6) Speed of testing and method of measuring and controlling the speed,

(7) Stress-strain curves (if a group of specimens exhibits similar stress-strain curves, a typical curve may be reported for the group).

(8) Yield strength or yield point and method of measurement,

(9) Tensile strength,

(10) Fracture strength and fracture stress. (Fracture strength is the load at fracture divided by the initial cross-sectional area. Fracture stress is the load at fracture divided by the cross-sectional area at time of fracture.)

(11) Uniform elongation and method of measurement.

[3] Standard material samples of reactor pressure vessel steels may be obtained through Subcommittee E10.02 of ASTM Committee E-10 on Nuclear Technology and Applications or by contacting ASTM Headquarters.