



Designation: E 1027 – 92

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Exposure of Polymeric Materials to Ionizing Radiation¹

This standard is issued under the fixed designation E 1027; 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 provides standard procedures for irradiating specimens of polymeric materials under well-defined, controlled conditions. These conditions are to be applied to polymeric specimens during testing for radiation effects on their physical and chemical properties. The specimens of interest may be electrical, structural, or any other components that are required to function in an ionizing radiation environment. Properties to be measured, test methods, and specimen parameters (size, shape, and number) are not specified, but should be considered on the basis of the application or function of the material. However, measurement of properties *during* irradiation is specifically excluded from this practice.

1.2 The response of a polymeric material to ionizing radiation can vary widely from one case to another as a result of *synergistic interplays* between environmental conditions, or stress factors. In conjunction with the principal stress factor of ionizing radiation, other important stress factors identified to date include temperature, oxygen concentration, and radiation absorbed-dose rate. Such synergistic interplays arise because of the complexity of the various reactions possible for the chemical species created by irradiation. Chemical reactions that lead to material damage generally proceed through multiple steps, in which competition exists between the various damaging and restorative reactions. The ultimate result may depend upon a specimen's history, that is, the timing and intensities of the various environmental stress factors. As a result, radiation effects test data for polymeric materials are applicable only to those service situations whose environments, with the exception of dose rate, are closely similar to the test environments. (In most practicable test irradiations, the absorbed dose rate in test materials will be at an accelerated rate as compared to the service situation.)

1.3 This practice prescribes five procedures:

1.3.1 *Procedure A*—Irradiation at ambient room conditions,

1.3.2 *Procedure B*—Irradiation at controlled temperature,

1.3.3 *Procedure C*—Irradiation in non-air media (other gases, liquids, and vacuum),

1.3.4 *Procedure D*—Irradiation under load, and

1.3.5 *Procedure E*—Irradiation under mixed conditions.

1.4 This practice includes four types of radiation environment:

1.4.1 Gamma and x-radiation (photons),

1.4.2 Electrons,

1.4.3 Neutrons, and

1.4.4 Mixtures of the above (for example, reactor radiation).

1.5 The values stated in SI units are to be regarded as the standard.

1.6 *This standard does not purport to address all of the safety problems, 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.* For specific hazard statements, see X1.7 and X1.8.

1.7 **Caution**—Caution shall be exercised in extrapolating from test data to service situations, especially when the test and service environments are not closely similar. This is almost always necessary for interpreting effects that may be sensitive to absorbed dose rate. All test environments shall be controlled carefully, and shall be reported in detail. (For further discussion see Appendix X1.)

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing²

D 1349 Practice for Rubber—Standard Temperatures for Testing³

D 2954 Test Method for Absorbed Gamma and Electron Radiation Dose with the Ferrous Sulfate-Cupric Sulfate Dosimeter⁴

D 3001 Test Method for Absorbed Gamma and Electron Radiation Dose with the Ceric Sulfate Dosimeter⁴

E 170 Terminology Relating to Radiation Measurements and Dosimetry⁵

E 171 Specification for Standard Atmospheres for Conditioning and Testing Materials⁶

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁷

E 261 Test Method for Determining Neutron Fluence Rate, Fluence, and Spectra by Radioactivation Techniques⁵

¹ This practice is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.07 on Radiation Dosimetry for Radiation Effects on Materials and Devices.

Current edition approved May 15, 1992. Published July 1992. Originally published as D 1672 – 59 T. Redesignated E 1027 in 1984. Last previous edition E 1027 – 84.

² *Annual Book of ASTM Standards*, Vols 08.01 and 10.01.

³ *Annual Book of ASTM Standards*, Vol 09.01.

⁴ Discontinued. See 1985 *Annual Book of ASTM Standards*, Vol 12.02.

⁵ *Annual Book of ASTM Standards*, Vol 12.02.

⁶ *Annual Book of ASTM Standards*, Vol 15.09.

⁷ *Annual Book of ASTM Standards*, Vol 14.02.

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E 668 Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices⁵

E 763 Practice for Calculation of Absorbed Dose From Neutron Irradiation by Application of Threshold-Foil Measurement Data⁵

E 844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance⁵

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System⁵

3. Significance and Use

3.1 The irradiation procedures described are intended to specify exposure conditions of polymers for the purpose of studying ionizing radiation effects. They have been made flexible enough to apply to a large variety of conditions that are encountered in service. Because of this flexibility, it is important to have at least a general understanding of both the changes that will occur, and the conditions that will influence them. In some cases, it may be necessary to conduct preliminary exploratory studies in order to determine the most appropriate set of exposure and measurement conditions (see Appendix X1).

4. Test Specimens

4.1 Wherever possible, the types of specimens employed shall be in accordance with ASTM test methods for the specific properties of interest to be measured.

4.2 In all cases, irradiated and non-irradiated (control) specimens shall be of the same size and shape.

5. Conditioning

5.1 Condition specimens to be irradiated in air in accordance with the procedures of Practices D 618 and D 1349, and Specification E 171.

5.2 Condition specimens to be irradiated in a gas other than air at the temperature of irradiation in an appropriate container at a pressure of 0.13 Pa (10^{-3} torr) or less, under continuous pumping, for at least 8 h, followed by three flushes with the gas to be present during irradiation. After the final flush, fill the container with the exposure gas and seal it.

5.3 Condition specimens to be irradiated in vacuum in an appropriate container at a pressure of 0.13 Pa (10^{-3} torr) or less, under continuous pumping, for at least 48 h. Then seal the container.

5.4 Condition specimens to be irradiated in a liquid medium in accordance with 5.1 before being placed in the liquid medium. Completely immerse the specimens in the liquid during the entire irradiation period.

6. Procedure A—Irradiation at Ambient Room Conditions

6.1 After conditioning in accordance with 5.1, arrange the specimens to be irradiated on suitable racks or in containers such that free access by air on all sides is assured.

6.2 When the nature of the radiation source requires that the specimens be enclosed in a container (for example, as in a nuclear reactor), package the specimens in the standard laboratory atmosphere referenced in 5.1. Under such conditions, the composition of the air in the container likely will be changed by radiation-induced reactions. Therefore, the

report shall state clearly that the irradiation was made in a closed container and shall give an adequate description of the container.

6.3 Irradiate the specimens to one (and only one) absorbed dose level. For each new absorbed dose level, irradiate additional, properly conditioned specimens. Each specimen shall be irradiated as uniformly as possible.

NOTE 1—For example, if the irradiation is performed using an electron accelerator having a beam size that is small compared to specimen dimensions, either a diffusing plate should be used, or the beam should be deflected in a scanning raster (alternatively, the specimens should be moved about so that they traverse the beam); the ratio of irradiation time to non-irradiation time should be constant for any point in the specimen. Such scanning or deflection procedures are unnecessary for irradiation in nuclear reactors or other sources having uniform radiation fields over volumes that are large compared to specimen dimensions.

6.4 After the required period of irradiation time, remove the specimens from the radiation field. Condition them prior to post-irradiation measurements in the standard laboratory atmosphere referenced in 5.1 for no less than 16 h and no more than 32 h, unless it is necessary to store the specimens for longer times because of induced radioactivity or other reasons. Report the time and conditions of storage in detail.

6.5 Condition nonirradiated control specimens in the standard laboratory atmosphere, in accordance with 6.4, prior to making the post-irradiation set of measurements.

7. Procedure B—Irradiation at Controlled Temperature

7.1 Follow the procedure specified in 6.1 and 6.2.

7.2 Construct a dummy specimen that is identical to the regular specimens in all respects, except that it contains at its middle a grounded thermocouple. Irradiate the specimens, including the dummy, as specified in 6.3, while maintaining the atmospheric temperature around the specimens at the desired control level. If irradiation causes the thermocouple temperature to vary from the control level by more than $\pm 2^{\circ}\text{C}$, report the variation in detail.

7.3 After irradiation, condition the specimens in accordance with 6.4.

7.4 Except for irradiation, expose the control specimens to the same environments as that of the irradiated specimens. For pre- and post-irradiation conditioning, the controls and the irradiated specimens may be treated together, in one group. During the period of irradiation, expose the controls to the same temperature and other non-irradiation conditions as the irradiated specimens.

8. Procedure C—Irradiation in Non-Air Media (Other Gases, Liquids, and Vacuum)

8.1 After conditioning in accordance with 5.2, 5.3, or 5.4, irradiate the specimens as described in 6.3.

8.2 After irradiation, remove the specimens from the medium and condition as described in 6.4.

8.3 Condition the nonirradiated, control specimens in accordance with 5.2, 5.3, or 5.4 and keep them in the selected medium for the same period of time as the irradiated specimens.

8.4 After irradiation, condition the control specimens and the irradiated specimens in accordance with 6.4, prior to making post-irradiation measurements.