INTERNATIONAL

Designation: ~~D3045 – 92 (Reapproved 2010)~~ D3045 – 18

Standard Practice for Heat Aging of Plastics Without Load[1]

This standard is issued under the fixed designation D3045; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. ~~Scope~~ Scope*

1.1 This practice is intended to define the exposure conditions for ~~testing~~evaluating the ~~resistance~~ thermal endurance of plastics ~~to oxidation or other degradation~~ when exposed solely to hot air for extended periods of time. Only the procedure for heat exposure is ~~specified, not the test method or specimen.~~ specified. The effect of ~~heat~~ elevated temperature on any particular property ~~may be~~ is determined by selection of the appropriate test method and ~~specimen.~~test specimens for that property.

1.2 This practice can be used as a guide to compare thermal aging characteristics of materials as measured by the change in some property of interest. The property of interest is measured at room temperature.

1.3 This practice ~~should be used as a guide to compare thermal aging characteristics of materials as measured by the change in some property of interest. This practice~~ recommends procedures for comparing the thermal aging characteristics of materials at a single temperature. Recommended procedures for determining the thermal aging characteristics of a material ~~at~~using a series of elevated temperatures for the purpose of estimating endurance time to a defined property change at ~~some~~a lower temperature are also ~~described.~~described; the applicability of the Arrhenius relation for making predictions to other temperatures, is assumed in this case.

1.4 This practice does not predict thermal aging characteristics where interactions between stress, environment, temperature, and time control failure ~~occurs.~~occur.

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

NOTE 1—~~ISO-2578 is considered to be technically equivalent to this practice.~~This standard and ISO-2578 address the same subject matter but differ in technical content.

1.6 *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:*[2]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
~~D1870~~D5374 ~~Practice for Elevated Temperature Aging Using a Tubular Oven~~Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation ~~(Withdrawn 1998)~~
~~D1898~~D5423 ~~Practice for Sampling of Plastics~~Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation ~~(Withdrawn 1998)~~
E145 Specification for Gravity-Convection and Forced-Ventilation Ovens
E456 Terminology Relating to Quality and Statistics

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.50 on Durability of Plastics.

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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.

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

2.2 *ISO ~~Standard:~~Standards:*[3]

ISO 2578 ~~(1974)~~(1993) Determination of Time-Temperature Limits After Exposure to Prolonged Action of Heat

ISO 9080 (2012) Plastic Piping and Ducting Systems—Determination of the Long-Term Hydrostatic Strength of Thermoplastic Materials in Pipe Form by Extrapolation

3. Terminology

3.1 *General*—The terminology given in Terminology D883 and Terminology E456 is applicable to this practice. Terminology not in place is defined in 3.2.

3.2 *Definitions:*

3.2.1 *continuous use temperature (CUT)*—the temperature in degrees Celsius corresponding to a given thermal endurance time for a given failure criterion (typically 50 % reduction in property), derived from the Arrhenius relation of endurance time and temperature, determined by heat aging at several elevated temperatures. Several CUT values can exist, one for each property, endurance time and endurance criterion.

3.2.1.1 *Discussion*—

In practice, the continuous use temperature for a plastic, involves other environmental considerations as discussed elsewhere in this standard, than thermal endurance alone. The term, CUT, used here, is intended as an index for thermal endurance alone. The use of this term is found in automotive applications of plastics. The endurance time used for the CUT value reported should be specified as CUT (endurance time).

3.2.2 *temperature index (TI), also referred to as thermal index (TI)*—the temperature in degrees Celsius corresponding to an endurance time of 20,000 hours for a given failure criterion (typically 50% reduction in property), derived from the Arrhenius relation of endurance time and temperature, usually determined by heat aging at several elevated temperatures.

3.2.2.1 *Discussion*—

The TI can thus be seen as a special case of CUT where the endurance time is fixed at 20,000 hours. A given plastic material and property and its retention criterion may be characterized by several CUT times, for example, CUT (1000 hours), CUT (5000 hours), etc. as needed per requirements of different applications. Further, several TI values can exist, one for each property and endurance criterion.

4. Significance and Use

4.1 The use of this practice presupposes that the failure criteria selected to evaluate materials (that is, the property or properties being measured as a function of exposure time) and the duration of the exposure can be shown to relate to the intended use of the materials.

4.2 Plastic materials exposed to heat ~~may be~~ are subject to many types of physical and chemical changes. The severity of the exposures in both time and temperature determines the extent and type of change that takes place. A plastic material is not necessarily degraded by exposure to elevated ~~temperatures, but may be unchanged or improved.~~ temperatures. However, extended periods of exposure of plastics to elevated temperatures will generally cause some degradation, with progressive ~~change~~changes in physical properties. Specific properties and failure (or lifetime) criteria for these properties are typically chosen for the evaluation of thermal endurance.

4.3 Generally, short exposures at elevated temperatures ~~may~~ drive out volatiles such as moisture, solvents, or plasticizers, relieve molding stresses, advance the cure of thermosets, and may cause some change in color of the plastic or coloring agent, or both. Normally, additional shrinkage should be expected with loss of volatiles or advance in polymerization.

4.4 Some plastic materials ~~may~~ become brittle due to loss of plasticizers after exposure at elevated temperatures. Other types of plastics ~~may~~ become soft and sticky, either due to sorption of volatilized plasticizer or due to breakdown of the polymer.

4.5 The degree of change observed will depend on the property measured. Different properties, mechanical or electrical, may not change at the same rate. For instance, the arc resistance of thermosetting compounds improves up to the carbonization point of the material. Mechanical properties, such as flexural properties, are sensitive to heat degradation and may change at a more rapid rate. Ultimate properties such as strength or elongation are more sensitive to degradation than bulk properties such as modulus, in most cases.

4.6 The material studied can change inherent behavior with change in temperature as for example when crossing α, β, and γ transitions. These transitions should be avoided both in the range of aging temperatures used, as well as in extrapolation of the

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

lifeline. Arrhenius principles may only be used to accelerate a chemical mechanism if there are no fundamental changes in the material properties. With semi-crystalline and highly crystalline polymers, elevated temperatures may cause significant changes to the morphology of the material, invalidating or compromising that assumption.

NOTE 2—Caution should be exercised in using the Arrhenius relation and knowledge of physical changes in the material at elevated temperatures is important. Guidance given in ISO 9080 for characterizing lifetime of plastic materials in pipe form by extrapolation suggests that the highest oven aging temperature should be at least 15°C lower than the Vicat softening temperature for glassy amorphous polymers, and at least 15°C lower than the melting point for semi-crystalline polymers.

4.7 Effects of exposure ~~may~~can be quite variable, especially when specimens are exposed for long intervals of time. Factors that affect the reproducibility of data are the degree of temperature control of the enclosure, humidity of the oven, air velocity over the specimen, and period of exposure. Errors in exposure are cumulative with time. Certain materials are susceptible to ~~degradation due to~~ the influence of ~~humidity in long-term heat resistance tests. Materials susceptible to hydrolysis may undergo degradation when subjected to long-term heat resistance tests.~~humidity.

4.8 It is not to be inferred that comparative material ranking is undesirable or unworkable. On the contrary, this practice is designed to provide data which can be used for such comparative purposes. However, the data obtained from this practice, since it does not account for the influence of stress or environment that is involved in most real life applications, must be used cautiously by the designer, who must inevitably make material choices using additional data such as creep and creep rupture that are consistent with the requirements of ~~his~~the specific application.

4.9 It is possible for many ~~temperature indexes to exist, in fact, one for each failure criterion.~~ CUT and TI values to exist. Therefore, for any application of the ~~temperature index~~ CUT or the TI (temperature index) to be valid, either the thermal aging program must duplicate the intended thermal exposure conditions of the end ~~product. If the material is stressed in the end product in a manner not evaluated in the aging program, the temperature index thus derived is not applicable to the use of the material in that product.~~product, or the Arrhenius relation must apply.

4.10 There can be very large errors when Arrhenius plots or equations based on data from experiments at a series of temperatures are used to estimate time to produce a defined property change at some lower temperature. This estimate of time to produce the property change or "failure" at the lower temperature is often called the "service ~~life."~~ life;" however, using this term should be avoided as this implies the tester has information on specific failure criteria in end-use, while numerous factors are not under the scope of this test. It is preferable to use terms such as "end point," "thermal endurance time," and such. Because of the errors associated with these calculations, this endurance time should be considered as "maximum expected" rather than "typical."

5. Apparatus

5.1 Provisions for conditioning at specified standard conditions.

5.2 *Oven*—A controlled horizontal or vertical air flow oven, employing forced-draft circulation with substantial constant fresh air intake is recommended. ~~When it is necessary to avoid contamination among specimens or materials, a tubular oven method such~~ To harmonize with ISO 2578 and IEC standards, it is preferable to use ovens that comply with the set temperature, temperature variation and air change requirements of Specification D5423 as ~~Practice~~evaluated ~~D1870 may be desirable. Oven apparatus shall~~by the test methods of Test Methods D5374~~be in accordance~~. Alternatively, Specification E145~~with Specifications~~ may be used, with Specification E145, Type IIB ovens for ~~temperature~~ aging temperatures up to ~~70°C. For higher~~70°C, and Specification E145~~temperature,~~, Type IIA ~~is required. Provision should be made for suspending specimens without touching each other or the side of the chamber. Recording instrumentation to monitor the temperature of exposure is recommended.~~ovens for higher temperatures. Indicate the specific oven standard used in the test report.

5.3 *Test Equipment* to determine the selected property or properties, in accordance with appropriate ASTM procedures.

6. Sampling

6.1 ~~The~~ Use the number and type of test specimens required ~~shall be in accordance with the ASTM test method for~~ by the applicable test method each time the specific property ~~to be determined; this requirement should be met at each time and temperature selected.~~is determined.

~~6.2 Sampling should also be in accordance with the pertinent considerations outlined in Practice D1898.~~

7. Test Specimens

7.1 ~~The~~ Use the number and type of test specimens required ~~shall be in accordance with the ASTM test method for~~ by the applicable test method each time the specific property ~~to be determined; this requirement should be met at each time and temperature selected. Unless otherwise specified or agreed upon by all interested parties, expose a minimum of three replicates of each material at each time and temperature selected.~~is determined.

7.2 The specimen thickness should be comparable to but no greater than the minimum thickness of the intended application.

7.3 ~~The method of specimen fabrication should be the same as that of~~If possible, fabricate test specimens by the same method as used in the intended application.