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Standard Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials[1]

This standard is issued under the fixed designation G141; 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

No experimental procedure is exactly repeatable or reproducible. Exposure testing is susceptible to poor test reproducibility because of many contributing factors. These include the type of material and its homogeneity, the complexity and variability of the outdoor environment, difficulty in precisely controlling the laboratory testing environment, and the variability in the measurement of performance. It is extremely difficult to compare "absolute data," that is, color shift, gloss, tensile, and elongation, and so forth, from different exposure tests. This is true for natural and accelerated exposures conducted outdoors or for accelerated exposure tests conducted at different times in one laboratory or comparing results between laboratories. The purpose of this guide is to provide the user with background information on test variability and guidance to conduct an exposure test that will provide valid and useful durability information.

1. Scope*

1.1 This guide covers information on sources of variability and strategies for its reduction in exposure testing, and for taking variability into consideration in the design, execution, and data analysis of both exterior and laboratory accelerated exposure tests.

1.2 The values stated in SI units are to be regarded separately as the standard. The inch-pound values given in parentheses are for information only.

1.3 *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.*

1.4 *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]

D4853 Guide for Reducing Test Variability (Withdrawn 2008)[3]

D6631 Guide for Committee D01 for Conducting an Interlaboratory Study for the Purpose of Determining the Precision of a Test Method

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials

G24 Practice for Conducting Exposures to Daylight Filtered Through Glass

G90 Practice for Performing Accelerated Outdoor Weathering of Materials Using Concentrated Natural Sunlight

G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

G147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

[1] This guide is under the jurisdiction of ASTM Committee G03 on Weathering and Durability and is the direct responsibility of Subcommittee G03.93 on Statistics.

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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.

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

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

G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
G152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
G153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials
G166 Guide for Statistical Analysis of Service Life Data
G169 Guide for Application of Basic Statistical Methods to Weathering Tests
G172 Guide for Statistical Analysis of Accelerated Service Life Data
G183 Practice for Field Use of Pyranometers, Pyrheliometers and UV Radiometers

3. Terminology

3.1 *Definitions:*

3.1.1 Terminology G113 is generally applicable to this guide.

4. Significance and Use

4.1 Many standards and specifications reference exposure tests performed according to standards that are the responsibility of Committee G03 on Durability of Nonmetallic Materials. In many cases, use of the data generated in these tests fails to consider the ramifications of variability in the exposure test practices. This variability can have a profound effect on the interpretation of results from the exposure tests, and if not taken into consideration in test design and data analysis, can lead to erroneous or misleading conclusions. This guide lists some of the sources for test variability and recommends strategies for executing successful weathering studies. Not all sources of variability in weathering testing are addressed in this guide. Specific materials, sampling procedures, specimen preparation, specimen conditioning, and material property measurements can contribute significantly to variability in weathering test results. Many of these concerns are addressed in Guide G147. To reduce the contribution of an instrumental method to test variability, it is essential to follow appropriate calibration procedures and ASTM standards associated with the particular property measurement. Additional sources of variability in test results are listed in Guide D4853, along with methods for identifying probable causes.

5. Variability in Outdoor Exposure Tests

5.1 *Variability Due to Climate*—Climate at the test site location can significantly affect the material failure rates and modes. Typical climatological categories are; arctic, temperate, subtropical, and tropical (that are primarily functions of latitude). Subcategories may be of more importance as being dictated by geographic, meteorological, terrain, ecological, and land-use factors, and include such categories as desert, forested, (numerous classifications), open, marine, industrial, and so forth. Because different climates, or even different locations or orientation in the same climate, produce different rates of degradation or different degradation mechanisms, it is extremely important to know the characteristics of the exposure sites used and to evaluate materials at sites that produce intensification of important climate stresses. Typically, exposures are conducted in “hot/wet” and “hot/dry” climates to provide intensification of important factors such as solar radiation and temperature, and to determine possible effects of moisture. Different exposure sites in one climate (even those in close proximity) can cause significantly different results, depending on material.

NOTE 1—Exposures in a tropical summer rain climate (for example, Miami, Florida) and in a hot desert climate (for example, Phoenix, AZ) are recognized as benchmarks for evaluating the durability of many different materials.

5.2 *Variability Due to Time of Year*—Solar-ultraviolet radiation, temperature, and time of wetness vary considerably with time of year. This can cause significant differences in the rate of degradation in many materials. Therefore, comparison of results between short-term exposure studies (less than one full year) will be subject to greater variability. If exposures of less than a full year are required, consider using times when climatological stress is maximized so a worst case test result is obtained. It may also be valuable to make several exposure tests with varying start dates in order to provide more representative data. This is especially true when the material’s response to the environment cannot be predetermined, or when materials with different environmental responses are to be compared. Often exposure periods are timed by total solar or solar-ultraviolet dose, or both. This approach may reduce variability in certain instances. However, an inherent limitation in solar-radiation measurements is that they do not reflect the effects of variation in temperature and moisture, which are often as important as solar radiation. Temperature and time of wetness are highly dependent on time of year, especially in temperate climates. With materials that are sensitive to heat or moisture, or both, the same solar-ultraviolet radiation dose may not give the same degree of change unless the heat and moisture levels are also identical.

5.2.1 Another problem related to timing exposures by broad-band radiation measurements is that solar radiation in the 290 to 310-nm band pass exhibits the most seasonal variability. Some polymer systems are extremely sensitive to radiation in this band pass. Variations in irradiance in this critical region (because of their relatively small magnitude) are not adequately reflected in total solar radiation or broad-band solar ultraviolet (UV) measurements.

5.2.2 The time of year (season) that an exposure test is initiated has, in certain instances, led to different failure rates for identical materials (**1**).[4]

5.3 *Variability Due to Year-to-Year Climatological Variations*—Even the comparison of test results of full-year exposure increments may show variability. Average temperature, hours of sunshine, and precipitation can vary considerably from year to year at any given location. The microclimate for the test specimens can be affected by yearly

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