Designation: G169 – 01 (Reapproved 2021)

Standard Guide for Application of Basic Statistical Methods to Weathering Tests[1]

This standard is issued under the fixed designation G169; 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 guide covers elementary statistical methods for the analysis of data common to weathering experiments. The methods are for decision making, in which the experiments are designed to test a hypothesis on a single response variable. The methods work for either natural or laboratory weathering.

1.2 Only basic statistical methods are presented. There are many additional methods which may or may not be applicable to weathering tests that are not covered in this guide.

1.3 This guide is not intended to be a manual on statistics, and therefore some general knowledge of basic and intermediate statistics is necessary. The text books referenced at the end of this guide are useful for basic training.

1.4 This guide does not provide a rigorous treatment of the material. It is intended to be a reference tool for the application of practical statistical methods to real-world problems that arise in the field of durability and weathering. The focus is on the interpretation of results. Many books have been written on introductory statistical concepts and statistical formulas and tables. The reader is referred to these for more detailed information. Examples of the various methods are included. The examples show typical weathering data for illustrative purposes, and are not intended to be representative of specific materials or exposures.

1.5 *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]

E41 Terminology Relating to Conditioning (Withdrawn 2019)[3]

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

G141 Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials

2.2 *ISO Documents:*[4]

ISO 3534/1 Vocabulary and Symbols – Part 1: Probability and General Statistical Terms

ISO 3534/3 Vocabulary and Symbols – Part 3: Design of Experiments

3. Terminology

3.1 *Definitions*—See Terminology G113 for terms relating to weathering, Terminology E41 for terms relating to conditioning and handling, ISO 3534/1 for terminology relating to statistics, and ISO 3534/3 for terms relating to design of experiments.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *arithmetic mean; average*—the sum of values divided by the number of values. **ISO 3534/1**

3.2.2 *blocking variable*—a variable that is not under the control of the experimenter, (for example, temperature and precipitation in exterior exposure), and is dealt with by exposing all samples to the same effects

3.2.2.1 *Discussion*—The term “block” originated in agricultural experiments in which a field was divided into sections or

[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.

Current edition approved July 1, 2021. Published July 2021. Originally approved in 2001. Last previous edition approved in 2013 as G169 – 01(2013). DOI: 10.1520/G0169-01R21.

[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.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

blocks having common conditions such as wind, proximity to underground water, or thickness of the cultivatable layer. **ISO 3534/3**

3.2.3 *correlation*—in weathering, the relative agreement of results from one test method to another, or of one test specimen to another.

3.2.4 *median*—the midpoint of ranked sample values. In samples with an odd number of data, this is simply the middle value, otherwise it is the arithmetic average of the two middle values.

3.2.5 *nonparametric method*—a statistical method that does not require a known or assumed sample distribution in order to support or reject a hypothesis.

3.2.6 *normalization*—a mathematical transformation made to data to create a common baseline.

3.2.7 *predictor variable (independent variable)*— a variable contributing to change in a response variable, and essentially under the control of the experimenter. **ISO 3534/3**

3.2.8 *probability distribution (of a random variable)*—a function giving the probability that a random variable takes any given value or belongs to a given set of values. **ISO 3534/1**

3.2.9 *random variable*—a variable that may take any of the values of a specified set of values and with which is associated a probability distribution.

3.2.9.1 *Discussion*—A random variable that may take only isolated values is said to be "discrete." A random variable which may take any value within a finite or infinite interval is said to be "continuous." **ISO 3534/1**

3.2.10 *replicates*—test specimens with nominally identical composition, form, and structure.

3.2.11 *response variable (dependent variable)*— a random variable whose value depends on other variables (factors). Response variables within the context of this guide are usually property measurements (for example, tensile strength, gloss, color, and so forth). **ISO 3534/3**

4. Significance and Use

4.1 The correct use of statistics as part of a weathering program can greatly increase the usefulness of results. A basic understanding of statistics is required for the study of weathering performance data. Proper experimental design and statistical analysis strongly enhances decision-making ability. In weathering, there are many uncertainties brought about by exposure variability, method precision and bias, measurement error, and material variability. Statistical analysis is used to help decide which products are better, which test methods are most appropriate to gauge end use performance, and how reliable the results are.

4.2 Results from weathering exposures can show differences between products or between repeated testing. These results may show differences which are not statistically significant. The correct use of statistics on weathering data can increase the probability that valid conclusions are derived.

5. Test Program Development

5.1 *Hypothesis Formulation:*

5.1.1 All of the statistical methods in this guide are designed to test hypotheses. In order to apply the statistics, it is necessary to formulate a hypothesis. Generally, the testing is designed to compare things, with the customary comparison being:

Do the predictor variables significantly affect the response variable?

Taking this comparison into consideration, it is possible to formulate a default hypothesis that the predictor variables do not have a significant effect on the response variable. This default hypothesis is usually called H_o, or the Null Hypothesis.

5.1.2 The objective of the experimental design and statistical analysis is to test this hypothesis within a desired level of significance, usually an alpha level (α). The alpha level is the probability below which we reject the null hypothesis. It can be thought of as the probability of rejecting the null hypothesis when it is really true (that is, the chance of making such an error). Thus, a very small alpha level reduces the chance in making this kind of an error in judgment. Typical alpha levels are 5 % (0.05) and 1 % (0.01). The *x*-axis value on a plot of the distribution corresponding to the chosen alpha level is generally called the critical value (cv).

5.1.3 The probability that a random variable *X* is greater than the critical value for a given distribution is written $P(X>cv)$. This probability is often called the "*p*-value." In this notation, the null hypothesis can be rejected if

$$P(X>cv) < \alpha$$

5.2 *Experimental Design*—The next step in setting up a weathering test is to design the weathering experiment. The experimental design will depend on the type and number of predictor variables, and the expected variability in the sample population, exposure conditions, and measurements. The experimental design will determine the amount of replication, specimen positioning, and appropriate statistical methods for analyzing the data.

5.2.1 *Response Variable*—The methods covered in this guide work for a single response variable. In weathering and durability testing, the response variable will usually be a quantitative property measurement such as gloss, color, tensile strength, modulus, and others. Sometimes, qualitative data such as a visual rating make up the response variable, in which case nonparametric statistical methods may be more appropriate.

5.2.1.1 If the response variable is "time to failure," or a counting process such as "the number of failures over a time interval," then reliability-based methods should be used.

5.2.1.2 Here are the key considerations regarding the response variable:

(1) **What is the response variable?**

(2) **Will the data represent quantitative or qualitative measurements?**

Qualitative data may be best analyzed with a nonparametric method.

(3) **What is the expected variability in the measurement?**

When there is a high amount of measurement variability, then more replication of test specimens is needed.