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An American National Standard

Standard Guide for Measurement Systems Analysis (MSA)[1]

This standard is issued under the fixed designation E2782; 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.

ε1 NOTE—Subsection 3.1 was corrected editorially in July 2022.

1. Scope

1.1 This guide presents terminology, concepts, and selected methods and formulas useful for measurement systems analysis (MSA). Measurement systems analysis may be broadly described as a body of theory and methodology that applies to the non-destructive measurement of the physical properties of manufactured objects.

1.2 *Units*—The system of units for this guide is not specified. Dimensional quantities in the guide are presented only as illustrations of calculation methods and are not binding on products or test methods treated.

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]

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

E456 Terminology Relating to Quality and Statistics

E2586 Practice for Calculating and Using Basic Statistics

E2587 Practice for Use of Control Charts in Statistical Process Control

3. Terminology

3.1 *Definitions*—Unless otherwise noted in this standard, all terms relating to quality and statistics are defined in Terminology E456.

3.1.1 *accepted reference value, n*—a value that serves as an agreed-upon reference for comparison, and which is derived as: *(1)* a theoretical or established value, based on scientific principles, *(2)* an assigned or certified value, based on experimental work of some national or international organization, or *(3)* a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group. **E177**

3.1.2 *calibration, n*—process of establishing a relationship between a measurement device and a known standard value(s).

3.1.3 *gage, n*—device used as part of the measurement process to obtain a measurement result.

3.1.4 *measurement process, n*—process used to assign a number to a property of an object or other physical entity.

3.1.4.1 *Discussion*—The term "measurement system" is sometimes used in place of measurement process. (See 3.1.6.)

3.1.5 *measurement result, n*—number assigned to a property of an object or other physical entity being measured.

3.1.5.1 *Discussion*—The word "measurement" is used in the same sense as measurement result.

3.1.6 *measurement system, n*—the collection of hardware, software, procedures and methods, human effort, environmental conditions, associated devices, and the objects that are measured for the purpose of producing a measurement.

3.1.7 *measurement systems analysis (MSA), n*—any of a number of specialized methods useful for studying a measurement system and its properties.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *appraiser, n*—the person who uses a gage or measurement system.

3.2.2 *discrimination ratio, n*—statistical ratio calculated from the statistics from a gage R&R study that measures the number of 97 % confidence intervals, constructed from gage R&R variation, that fit within six standard deviations of true object variation.

[1] This guide is under the jurisdiction of ASTM Committee E11 on Quality and Statistics and is the direct responsibility of Subcommittee E11.50 on Metrology.

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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.

3.2.3 *distinct product categories, n*—alternate meaning of the discrimination ratio.

3.2.4 *gage consistency, n*—constancy of repeatability variance over a period of time.

3.2.4.1 *Discussion*—Consistency means that the variation within measurements of the same object (or group of objects) under the same conditions by the same appraiser behaves in a state of statistical control as judged, for example, using a control chart. See Practice E2587.

3.2.5 *gage performance curve, n*—curve that shows the probability of gage acceptance of an object given its real value or the probability that an object's real measure meets a requirement given the measurement of the object.

3.2.6 *gage R&R, n*—combined effect of gage repeatability and reproducibility.

3.2.7 *gage resolution, n*—degree to which a gage can discriminate between differing objects.

3.2.7.1 *Discussion*—The smallest difference between two objects that a gage is capable of detecting is referred to as its finite resolution property. For example, a linear scale graduated in tenths of an inch is not capable of discriminating between objects that differ by less than 0.1 in. (0.25 cm).

3.2.8 *gage stability, n*—absence of a change, drift, or erratic behavior in bias over a period of time.

3.2.8.1 *Discussion*—Stability means that repeated measurements of the same object (or average of a set of objects) under the same conditions by the same appraiser behave in a state of statistical control as judged for example by using a control chart technique. See Practice E2587.

3.2.9 *linearity, n*—difference or change in bias throughout the expected operating range of a gage or measurement system.

3.2.10 *measurement error, n*—error incurred in the process of measurement.

3.2.10.1 *Discussion*—As used in this guide, measurement error includes one or both of R&R types of error.

3.2.11 *repeatability conditions, n*—in a gage R&R study, conditions in which independent measurements are obtained on identical objects, or a group of objects, by the same operator using the same measurement system within short intervals of time.

3.2.11.1 *Discussion*—As used in this guide, repeatability is often referred to as equipment variation or EV.

3.2.12 *reproducibility conditions, n— in a gage R&R study*, conditions in which independent test results are obtained with the same method, on identical test items by different operators.

3.2.12.1 *Discussion*—As used in this guide, reproducibility is often referred to as appraiser variation or AV. This term is also used in a broader sense in Practice E177.

4. Significance and Use

4.1 Many types of measurements are made routinely in research organizations, business and industry, and government and academic agencies. Typically, data are generated from experimental effort or as observational studies. From such data, management decisions are made that may have wide-reaching social, economic, and political impact. Data and decision making go hand in hand and that is why the quality of any measurement is important—for data originate from a measurement process. This guide presents selected concepts and methods useful for describing and understanding the measurement process. This guide is not intended to be a comprehensive survey of this topic.

4.2 Any measurement result will be said to originate from a measurement process or system. The measurement process will consist of a number of input variables and general conditions that affect the final value of the measurement. The process variables, hardware and software and their properties, and the human effort required to obtain a measurement constitute the measurement process. A measurement process will have several properties that characterize the effect of the several variables and general conditions on the measurement results. It is the properties of the measurement process that are of primary interest in any such study. The term "measurement systems analysis" or MSA study is used to describe the several methods used to characterize the measurement process.

NOTE 1—Sample statistics discussed in this guide are as described in Practice E2586; control chart methodologies are as described in Practice E2587.

5. Characteristics of a Measurement System (Process)

5.1 Measurement has been defined as "the assignment of numbers to material objects to represent the relations existing among them with respect to particular properties. The number assigned to some particular property serves to represent the relative amount of this property associated with the object concerned." **(1)**[3]

5.2 A measurement system may be described as a collection of hardware, software, procedures and methods, human effort, environmental conditions, associated devices, and the objects that are measured for the purpose of producing a measurement. In the practical working of the measurement system, these factors combine to cause variation among measurements of the same object that would not be present if the system were perfect. A measurement system can have varying degrees of each of these factors, and in some cases, one or more factors may be the dominant contributor to this variation.

5.2.1 A measurement system is like a manufacturing process for which the product is a supply of numbers called measurement results. The measurement system uses input factors and a sequence of steps to produce a result. The inputs are just varying degrees of the several factors described in 5.2 including the objects being measured. The sequence of process steps are that which would be described in a method or procedure for producing the measurement. Taken as a whole, the various factors and the process steps work collectively to form the measurement system/process.

5.3 An important consideration in analyzing any measurement process is its interaction with time. This gives rise to the properties of stability and consistency. A system that is stable and consistent is one that is predictable, within limits, over a period of time. Such a system has properties that do not

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