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Standard Guide for General Reliability[1]

This standard is issued under the fixed designation E3159; 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 fundamental concepts, applications, and mathematical relationships associated with reliability as used in industrial areas and as applied to simple components, processes, and systems or complex final products.

1.2 The system of units for this guide is not specified. Quantities in the guide are presented only as illustrations of the method or of a calculation. Any examples used are not binding on any particular product or industry.

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]

E456 Terminology Relating to Quality and Statistics

E2334 Practice for Setting an Upper Confidence Bound for a Fraction or Number of Non-Conforming items, or a Rate of Occurrence for Non-Conformities, Using Attribute Data, When There is a Zero Response in the Sample

E2555 Practice for Factors and Procedures for Applying the MIL-STD-105 Plans in Life and Reliability Inspection

E2696 Practice for Life and Reliability Testing Based on the Exponential Distribution

2.2 *ISO Standards:*[3]

ISO 3534-1 Statistics–Vocabulary and Symbols, Part 1: Probability and General Statistical Terms

ISO Guide 73 Risk Management Vocabulary

3. Terminology

3.1 *Definitions:*

3.1.1 Unless otherwise noted, terms relating to quality and statistics are as defined in Terminology E456. Other general statistical terms and terms related to risk are defined in ISO 3534-1 and ISO Guide 73.

3.1.2 B_p *life, n—for continuous variables*, the life at which there is a probability, p, (expressed as a percentage) of failure at or less than this value.

3.1.2.1 *Discussion*—Example: The B_{10} life is a value of life, t, such that cumulative distribution function, $F(t) = 0.1$ or 10 %.

3.1.3 *failure mode, n*—the way in which a device, process or system has failed.

3.1.3.1 *Discussion*—Under some set of conditions, any device, process or system may be vulnerable to several failure modes. For example, a tire may fail in the course of time due to a puncture by a sharp object, from the tire simply wearing out, or from a tire manufacturing anomaly. Each of these describe different failure modes. These three failure modes are said to be competing with respect to the failure event.

3.1.4 *hazard rate, n*—differential fraction of items failing at time t among those surviving up to time t, symbolized by $h(t)$. **E2555**

3.1.4.1 *Discussion—h(t)* is also referred to as the instantaneous failure rate at time t and called a hazard function. It is related to the probability density (*pdf*) and cumulative distribution function (*cdf*) by $h(t) = f(t)/(1 - F(t))$, where $f(t)$ is the *pdf* and $F(t)$ the *cdf*.

3.1.5 *mean time between failures (MTBF), n*—the average time to failure for a repairable item.

3.1.5.1 *Discussion*—A repairable system is one that can be repaired and returned to service following a failure. When an item is repaired, it may not necessarily be returned to service in as good as new condition. There may be a reduction in life in a repaired item making the item not as robust as a new item.

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

Any failure-repair sequence may continue for several cycles, further reducing longevity of service following each repair time. Often the more times the item is repaired, the smaller will be the expected remaining life until the next repair. However, some repairable systems (for example, electronic) may just have some components replaced from time to time rendering the unit as good as new. In those cases, MTBF is the same thing as MTTF.

3.1.6 *mean time to failure (MTTF), θ, n—in life testing*, the average length of life of items in a lot. E2696

3.1.7 *reliability, n*—the probability that a component, device, product, process or system will function or fulfill a function after a specified duration of time or usage under specified conditions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *non-repairable system, n*—a system that is intended for a single use and discarded/replaced following its first failure.

3.2.2 *repairable system, n*—a system that is intended to be used through multiple failure-repair cycles.

4. Significance and Use

4.1 The theory of reliability is used for estimating and demonstrating the probability of survival at specific times or for specific usage cycles for simple components, devices, assemblies, processes, and systems. As reliability is one key dimension of quality, it may be more generally used as a measure of quality over time or over a usage or demand sequence.

4.1.1 Many industries require performance metrics and requirements that are reliability-centered. Reliability assessments may be needed for the determination of maintenance requirements, for spare parts allocation, for life cycle cost analysis and for warranty purposes. This guide summarizes selected concepts, terminology, formulas, and methods associated with reliability and its application to products and processes. Many mathematical relationships and methods are found in the annexes. For general statistical terms not found in Section 3, Terminology E456 and ISO 3534-1 can be used for definitional purposes and ISO Guide 73 for general terminology regarding risk analysis.

4.2 The term "system" implies a configuration of interacting components, sub-assemblies, materials, and possibly processes all acting together to make the system work as a whole. Parts of the system may be linked in combinations of series and parallel configuration and redundancy used in some parts to improve reliability. Additional conditions of complex engineering may have to be considered.

4.3 Process reliability concerns the assessment of any type of well-defined process. This can include manufacturing processes, business processes, and dispatch/demand type processes. Assessment typically measures the extent to which the process can continually perform its intended function without "upset" as well as process robustness.

4.4 A number of reliability metrics are in use. For example, *mean time to failure* (MTTF) is a common measure of average life or average time to the first time a unit fails. For this reason it is said to apply to *non-repairable systems*. Other life percentiles (or quantiles) are in use such as for example a B_p life or that life at which there is p % expected failure. Thus, the B_{50} or median life is the life at which 50 % of items would be expected to fail as well as survive; The $B_{0.1}$ life is the life at which would be expected a 1 in 1000 failure probability 0.1 % failure) and a 99.9 % reliability.

4.4.1 Failure rate and average failure rate are also common metrics in reliability. With failure rates, it is important to understand that a rate may be changing with time and this may be increasing, decreasing or some combination of these over the life of a product or service. The failure rate may also be constant.

4.5 Bench testing of a device is used to obtain early reliability assessment or to demonstrate a specific reliability requirement or a related metric. There are a number of key methodologies that are used for this purpose. Demonstration testing may be dependent on the assumption of a distribution of failure time or may be carried out using nonparametric methods.

4.6 When a system is repaired following failure and placed back into service, we refer to the object as a *repairable system*. A key metric for this is the *mean time between failure* (MTBF); and this is not to be confused with MTTF. When a system is repaired, it may not be the case that its expected remaining life is as good as a new one. There may be a reduction in expected life following a repair and this may continue with continuing repair cycles. The MTBF metric applies to all such sequences of repair and restoration cycles over a service life period. This includes the first time to failure, the 2nd time, the 3rd time, etc.

5. Life Concepts

5.1 Before reliability can be assessed, the measure of life must be selected. Table 1 shows a sample of units that are commonly used as a measure of life.

5.1.1 Variations of these units can be found as for example the difference between an aircraft total engine operating time (EOT) and its time/hours in flight or engine flight hours (EFH). *Cycles* are dependent on ordinary time in that any cycle may last for any length of time. In another case, continued life may be driven more by calendar time.

5.1.2 A dispatch of a product or service can be used to compute the product's *dispatch reliability* (for example, relative frequency of failure free dispatches without a change to a schedule). *Demand cycle* is different than ordinary cycles in that a product may only be demanded infrequently but must be in serviceable condition when called on (for example, fire extinguishers, ambulance vehicles). *Calendar time* may be applicable in situations where a product is exposed to field or

TABLE 1 Common Measures of Product Life

Life Unit	Example
operating time	hrs., minutes, days
cycles of usage	flights, dispatches
calendar time	days since new; shelf life
demand cycles	unit is demanded occasionally