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Development Standardization "Glossary" and "Strategy" for Reliability Testing as a Component of Trends in Development of ART/ADT

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ABSTRACT

This paper will discuss the first two standards in the six-part series of SAE International reliability testing documents that are being developed by the SAE G11 Reliability Committee. These two documents attempt to standardize the glossary and strategy associated with reliability testing technology.

A new Glossary standard has been drafted that defines the most commonly used words and terms associated with reliability (accelerated reliability/durability) testing. It is intended to serve as a basis for reliability testing definitions and to reduce the possibility of conflicts, duplications, and incorrect interpretations either expressed or implied elsewhere in the technical literature. Terms and definitions included in this standard are important in the acquisition of weapon systems (where there is a need for precise and unambiguous technical definitions), and are expressed clearly (and without mathematical symbols whenever possible). The Strategy document and the remaining other documents in the reliability testing series are to become subdocuments in a revision to JA1009 (Reliability Testing).

The purpose of the Strategy standard is to standardize the strategy for obtaining information needed for accurate prediction during design and manufacturing of reliability, durability, maintainability, supportability, and life cycle cost of machines and their units in real-world conditions.

Real-world conditions consist of integrated full input influences with safety and human factors.

INTRODUCTION

The Strategy standard defines Reliability Testing (Accelerated Reliability/Durability Testing) strategy in a way that crosses disciplines and is useful to contractors and users in the automotive and aerospace industries as well as other areas. This standard contains both general and specific components: the development of an accurate physical simulation of real-world conditions in the laboratory, basic components of simulation strategy implementation, accelerated reliability and durability testing (ART/ADT), analysis and management of degradation, pragmatic strategies in reliability, durability, maintainability, and life cycle cost prediction; and the strategic development of equipment for ART/ADT.

Reliability testing is synonymous with accelerated reliability/durability testing when used to provide accurate reliability and durability prediction during the service life, warranty period, or another part of the life cycle. Therefore, in this standard the term "accelerated reliability/durability testing" is often used instead of "reliability testing".

BACKGROUND

Currently, the primary standards that address reliability testing are either military standards or handbooks in the USA, or are International Electrotechnical Commission (IEC) standards.

Associated military standards and handbooks are:

MIL-STD-690D Failure Rate Sampling Plans and Procedures,

MIL-STD-2074 Failure Classification for Reliability Testing;

MIL-HDBK-108 Sampling Procedures and Tables for Life and Reliability Testing;

MIL-HDBK-217F Reliability Prediction of Electronic Equipment;

MIL-HDBK-781A Handbook for Reliability Test Methods, Plans, and Environments, Engineering, Development, Qualification, and Production;

Military Handbook DoD 3235. 1H Test and Evaluation of Systems Reliability, Availability, and Maintainability: A New Primer.

IEC standards are:

IEC 60300-3-2. Ed.2 Dependability Management - Part 3-2. Application Guide - Collection of Dependability Data from the Field;

IEC 60605 - 2 Reliability of Systems Equipment and Components - Part 10. Guide to Reliability Testing. Section 10.2. Design of Test Cycles; and others.

These standards consider theoretical (statistical) approaches to reliability testing, test plans, tables, etc.

In the new SAE documents, we wish to provide engineers with product reliability/durability testing guidance that allows accurate prediction of product reliability, safety, durability, maintainability, availability, and life cycle costs.

Reliability Testing - Glossary

The Glossary standard defines commonly used words and terms that are associated with reliability testing. This standard is to be used as a basis for reliability testing definitions and to reduce the chance of conflicts, duplications, and incorrect interpretations that may be either expressed or implied elsewhere in the technical literature.

Terms and associated definitions that are included in this standard are:

1. Important in acquisition of weapon systems for describing precise reliability testing (including accelerated reliability testing and durability testing) concepts.

2. Unique in their definitions, allowing no other meaning.

3. Expressed clearly, preferably without mathematical symbols.

The purpose of this standard is to define words and terms used most frequently in the field of Reliability Testing (Accelerated Reliability and Durability Testing) and to give those terms a common meaning for contractors and users in the aerospace and automotive industries as well as in other industries.

References were used from the Publications of SAE, ECSS, IEC, ISO, US Government, and others. This standard provides definitions of terms associated with accelerated testing, accelerated reliability testing, accelerated durability testing, durability testing, accurate prediction, accurate simulation of field input influences, accurate system of reliability prediction, accurate physical simulation, human factors engineering, multi-environmental complex of field input influences, output variables, reliability testing, stress testing, and others.

Based on proceedings of the November 2012 SAE G11 meeting, this document will be integrated into ARP 5638 (RMS Terms and Definitions). However, the Strategy document and those that follow are to become subdocuments in a major revision to JA1009 (Reliability Testing).

Reliability Testing - Strategy

1. General

The strategy standard provides a basis for accurate prediction of quality, reliability, supportability, maintainability and life cycle cost during any part of the life cycle (warranty period, service life, and other) and reduces the possibility of conflicts, duplications, and incorrect interpretations either expressed or implied elsewhere in the technical literature.

General components of reliability testing strategy are given in Figure 1.

2. Quantitative and Qualitative Data Collection

Quantitative data can be counted or measured, and may be assigned numerical values that can be manipulated using statistical methods.

Qualitative data is associated with the quality of real-world conditions. For example, vibration levels of a mobile product vary with environment and use. These include: road composition and profile (surface), speed of the vehicle, wind speed and direction, design and quality of the tires and vehicle shock-absorption system, coupling of the wheels with road surface, etc. As you can see, profile of the road is only one of the many field conditions that have an influence on the vibration. Corrosion is the result of a combination of multi-environmental influences (chemical pollution, mechanical pollution, moisture, temperature, etc.) with mechanical influences (vibration, deformation, friction, etc.), and interconnection factors. Both data types are important and support each other.

The type of data collected will depend on the specific type of test subject and its field conditions.

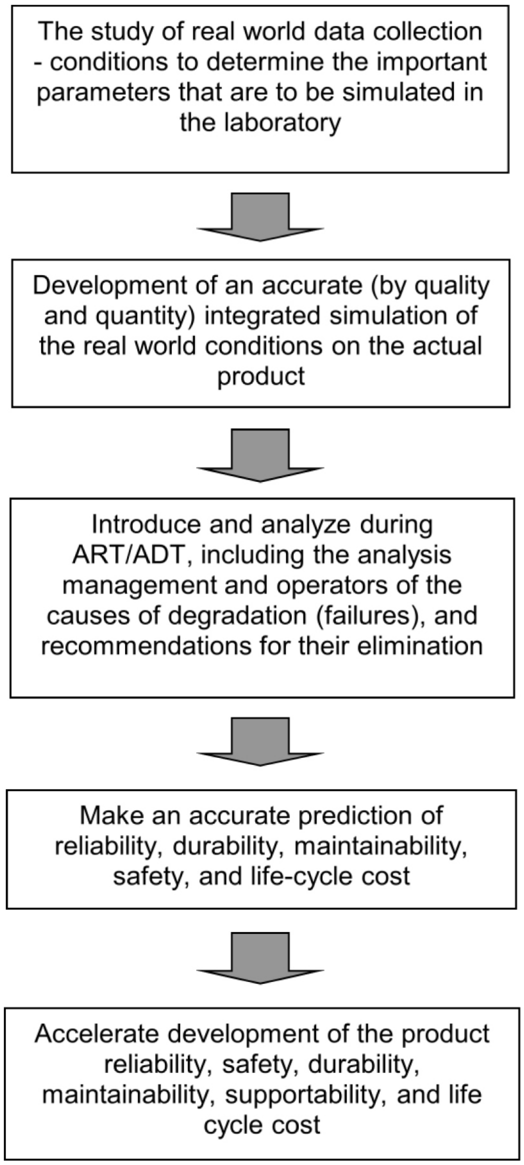

Figure 1. General components of reliability testing strategy.

3. Contents and Methods of Data Collection

Data collection makes accurate simulation of real-world conditions possible when performing reliability testing. These conditions include full field input influences, output variables, safety and human factors, reliability, durability, and maintenance data. The data may be collected over several years and may involve many different users and maintenance personnel. Data collection is a large-scale effort with possible sources of data corruption. Accordingly, the data collection, collation and recording processes have to emphasize ease of use and error proofing.

Reliability, durability, maintenance, and safety data are the consequence of field conditions acting on the product, and share many common elements. Reliability data collection should be integrated with the maintenance, durability, human factors, and safety systems. The usefulness of data reporting can be increased if additional sources of data are mined for relevant information; examples include economic compensation (spare costs, payment under guarantee, mileage compensation, and time reporting for maintenance). The quality of the reporting is increased if maintenance personnel know how the data will be used. Additionally, incomplete or ambiguous data reporting must be remedied quickly and efficiently.

Data collection can be automated or semi-automated by using electronic data-logging devices. The most complex data collection approach uses built-in electronics to perform the task.

4. Field Conditions

There are three interacted quantitative complexes present in the field conditions: real-world input influences; safety problems; and human factors. For most of them, the full field input influences consist of multi-environmental, mechanical, electrical and electronic groups. Each group is also a complex of subcomponents. A multi-environmental complex of field input influences consists of interacted temperature, humidity, pollution, radiation, wind, snow, fluctuation, air pressure, and rain. Some basic input influences combine to form a multifaceted complex. For example, chemical pollution and mechanical pollution combine in the pollution complex. The electrical group of input influences also contains several simpler influences such as input voltage, electro-static discharge, and others. These factors are interdependent and interconnected, and interact simultaneously. Such interconnections must be accurately accounted for in simulations.

Safety involves two elements. risk analysis and hazard determination. Both of these elements are closely related to reliability. Fault tree analysis may be used to establish a systematic link between the system-level hazard and the contributing hazardous event at the subsystem, equipment or piece-part level.

Each of the two basic safety components is a combination of subcomponents. The solution to the risk problem is found in the following subcomponents:

- Risk assessment
- Risk management
- Risk evaluation.

Solving the safety problem requires the simultaneous study and evaluation of the full complex of these interacting components and subcomponents.

To obtain information for risk assessment one needs to know the following”

- Limits of the machinery
- Accident and incident history
- Requirements for the life phases of the machinery
- Basic design drawings that demonstrate the nature of the machinery
- Statement about damage to health.

For risk analysis one needs:

- Identification of hazards
- Methods of setting limits for the machinery
- Risk estimation.

Human factors engineering is the scientific discipline dedicated to improving the human-machine interface and human performance through the application of knowledge of human capabilities, strengths, weaknesses, and characteristics.

Human factors is closely linked to reliability and safety. The reliability and safety of a product or process are functions of the user's actions and capability.

The term “human factors” is used in the USA, whereas in Europe, it is often called “ergonomics”. This is an umbrella term for several areas of research that include

- Human performance
- Technology
- Human-machine interaction.

Human factors describes the interaction between individuals, facilities, equipment, and management systems. The discipline of human factors seeks to optimize the relationship between technology and humans, and applies information about human characteristics, limitations, perceptions, abilities, and behavior to the design and improvement of objects, processes, and facilities used by people.

We use human factors to analyze how people are likely to use a product or process, and then design the product or process in such a way that it feels intuitive to those using it, thereby facilitating successful operation.

Human factors practitioners come from a variety of backgrounds. They are predominantly psychologists (cognitive, perceptual, and experimental) and engineers. Designers (industrial, interaction, and graphic), anthropologists, technical communication specialists and computer scientists also contribute to the field.

The classification scheme for human factors/ergonomics is much broader than the list above.

The human characteristics include:

- Psychological aspects
- Anatomical aspects
- Group factors
- Individual differences
- Psychophysiological state variables
- Task-related factors.

5. Development of Accurate Integrated Simulation of Real-World Conditions in the Laboratory

The simulation of real-world conditions consists of several subcomponents.

The first subcomponent is selection of a representative region for testing, which extends analysis techniques and establishes characteristics of critical input (or output) processes.

Simulation is a tool that uses a representation or model during testing. Simulation is used to evaluate potential outcomes that are a function of multiple random variables, and may be viewed in a sense as a form of testing.

There are different types of simulations: physical, interactive, computer (software), mathematical, and others. This standard considers the physical simulation of the field circumstances applicable to an actual product or process.

Physical simulation should use as representative a model as possible of those conditions experienced by the actual product or process. For example, the items used in the simulation are typically not smaller or cheaper than those in the real object or system.

For accelerated laboratory testing of the actual product, the real-world conditions need to be simulated in the laboratory where artificial input influences are used to model the actual influences. The physical simulation of the field input influences has to be accurate by quality and quantity in order to provide accelerated reliability and durability testing.

It is necessary to understand how the various types of input influences that are needed for testing act upon the test subject in the field during its operation and storage (see Figure 2). These influences include temperature, humidity, pollution, radiation, road features, air pressure and fluctuations, input voltage, and many others (X_1, … X_N).

The direct results of their action are output variables [vibration, loading, tension, output voltage, and many others (Y_1,… Y_M)]. The output parameters lead to degradation (deformation, crack, corrosion, overheating) and failures of the product.

Always simulate the full range of input influences ($X_1 \ldots X_N$) in the laboratory when performing reliability testing on the product.

An accurate physical simulation occurs when the physical state of output variables in the laboratory differs from those in the field by no more than the allowable limit of divergence.

There are two requirements that must be met to ensure an accurate simulation.

First, the output variables (vibration, loading, tensions, voltage, amplitude and frequency of vibration) during testing must differ from the same output variables in the real-world by no more than a given limit, for example, 3%.

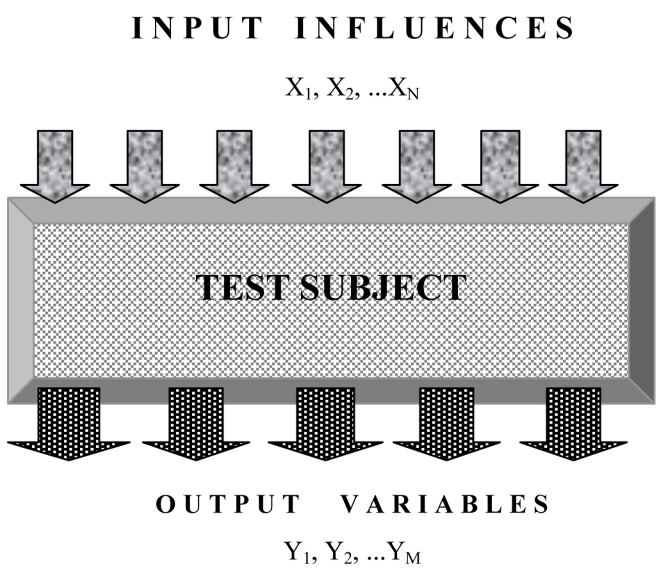

Figure 2. Scheme of input influences and output variables of the actual product.

This means that the output variables

$$Y_{1\ FIELD} - Y_{1\ LAB} \leq \text{given limit (for example, 1\%, 2\%, 3\%, 5\%)}.$$

$$Y_{M\ FIELD} - Y_{M\ LAB} \leq \text{given limit (1\%, 2\%, 3\%, 5\%)}.$$

The output variables comparison typically needs only a short time to complete.

The second and final step is to examine the simulation for accuracy. It is judged to be accurate when the difference between metrics quantifying physics-of-degradation dynamic processes during ART/ ADT and the same metrics measured in real-world operations is not more than a given fixed limit. The degradation mechanism can be estimated during product testing (see Figure 3). In real-world operations, the mechanical, chemical, physical, and other degradation mechanisms often interact with each other. This step typically requires much time.

6. Introduce ART/ADT

Accelerated reliability/durability testing (ART/ADT) consists of laboratory testing and special field testing.

The selection of appropriate methodologies of accelerated laboratory testing and special field-testing depends on the application and the test subject.

The design of equipment employing ART/ADT functionality is becoming more prevalent.

Use special field tests for the evaluation of field influences that are impossible or very expensive to simulate in the laboratory.

Durability testing is different from vibration testing, because it includes interaction of multi-environmental, mechanical, electrical, and other necessary testing with correspondence equipment. Vibration testing only includes mechanical testing.

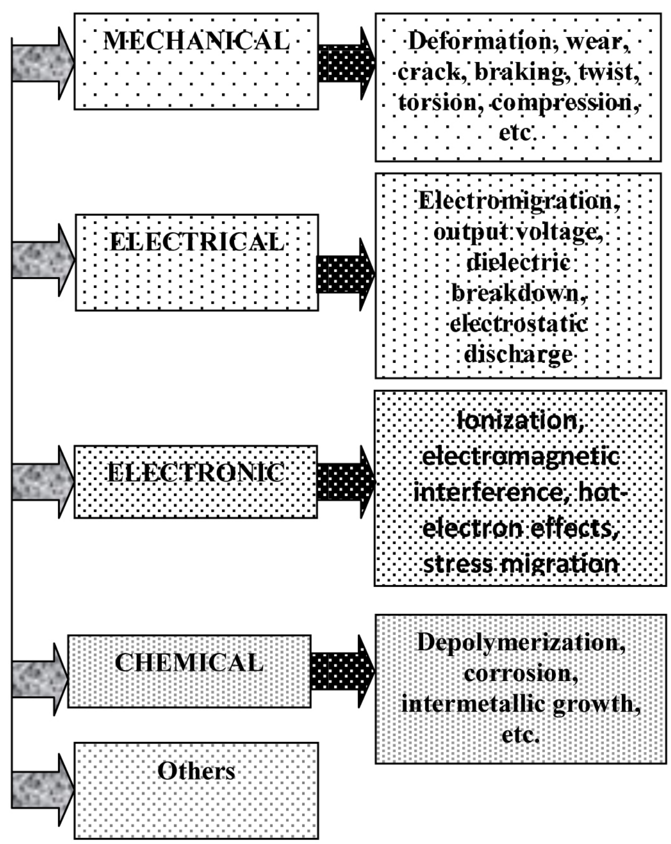

Figure 3. Types of physics-of-degradation mechanisms and their parameters.

7. Basic Components of Accurate Simulation Strategy Implementation

The following basic components of the simulation strategy must be implemented to conduct accelerated reliability and accelerated durability testing (ART/ADT) in the laboratory to aid in the accurate prediction of reliability, durability, safety, maintainability, and life cycle cost:

- Obtain accurate data from actual operations.
- Conduct an accurate physical simulation of the integrated field conditions.
- Conduct testing 24 hours a day, every day, but not including
    - Idle time (breaks, interruptions) or
    - Time operating at minimum loading that does not cause failure.
- Accurately conduct simulation of each group of field input influences (multi-environmental, electrical, mechanical) in simultaneous combinations.
- Consider these input influences to be random processes.
- Use a complex integrated system to model each interacting type of field influences, as well as human factors and safety.
- Simulate the whole range of field influences, human factors, safety considerations, and their interactions.
- Use the physics-of-degradation process as a final criterion for accurate simulation of the field conditions.
- Treat the system as interconnected using a system of systems approach.
- Consider the interaction of components (of the test subject) within the system.
- Conduct laboratory testing in combination with special field-testing, as components of ART/ADT.
- Reproduce the complete range of field schedules and maintenance or repair actions.
- Maintain a proper balance between real-world and laboratory conditions.
- Correct the simulation system after an analysis of degradation and failures in real-world operations and during ART/ADT.
- Simulation must address the full range of values that may be taken by each input influence.
- Accurate simulation of the input processes is attained when the random statistical characteristics computed during the simulation (such as mean, variance, normalizing correlation and power spectrum) lie sufficiently close to the actual measurements (a requirement that is usually expressed as a maximum allowable percentage).
- Simulation accuracy can be determined after comparing the physics-of-degradation (failure) processes during ART/ADT to those experienced during real-world operations.

SUMMARY

1. Current standardization terms, definitions, and strategy associated with reliability testing practice need improvement.

2. To address this need, the SAE G-11 Division is developing a group of six documents providing reliability testing guidelines of practical use to allow accurate prediction of product reliability, durability, maintainability, life cycle cost, etc. But the first of these (the Glossary) will be integrated with ARP 5638 per recent SAE G11 guidance. However, the Strategy document and those that follow are to become subdocuments in a major revision to JA1009 (Reliability Testing).

3. These new documents, after successfully passing through the SAE adjudication process, will make a worthwhile contribution toward improving the standardization of reliability testing processes.

*This paper is based on the draft of SAE G-11 standards that were prepared by Lev Klyatis together with James Bartlett and Jennifer McGill.

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