SAE International

# Development of Accelerated Reliability/Durability Testing Standardization as a Component of Trends in Development Accelerated Reliability Testing (ART/ADT)

2013-01-0151
Published
04/08/2013

Lev Klyatis
Sohar Inc.


doi:10.4271/2013-01-0151

## ABSTRACT

There are no standards that directly consider practical reliability testing technology (methods and equipment). This void needs to be filled. The SAE G-11 division has approved the development of six new standards to fill this void. This paper discusses these six standards: 1) Reliability Test-Glossary; 2) Reliability Testing-Strategy; 3) Reliability Testing-Procedures; 4) Reliability Testing-Equipment; 5) Reliability Testing-Statistical Criteria for Comparison of Reliability Testing Results and Field Results; 6) Reliability Testing-Collection, Calculation, and Statistical Analysis of Reliability Testing Data, Development Recommendations for Improvement of Test Subject Reliability, Durability, and Maintainability.

These standards are planned as a basis for obtaining the information needed to accurately predict usage, reliability, durability, quality, supportability and maintainability throughout the life-cycle, as well as life-cycle costs in real-world conditions, and to reduce the possibility of conflicts, duplications, and incorrect interpretations either expressed or implied elsewhere in the literature.

## INTRODUCTION

Advances in technology lead to economic development through more complicated products. Such advances require more attention to accurate prediction and successful problems prevention of quality and its components: reliability, safety, maintainability, durability, supportability, and others (see Figure 1).

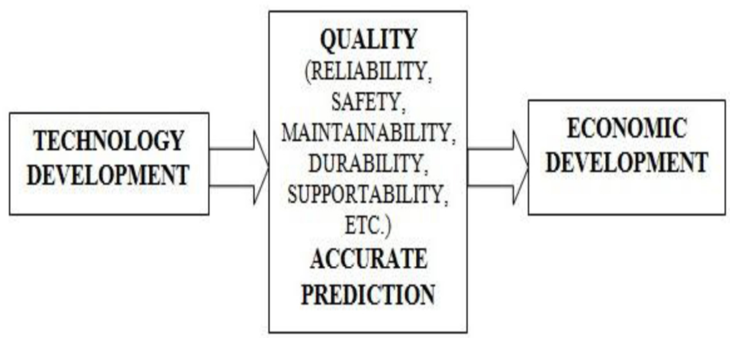


***Figure 1. Quality (and its components) accurate prediction and the economic development.***

On September 19-20, 2012, RMS (Reliability, Maintainability, and Supportability) Partnership organized in Springfield, VA a Department of Defense, Department of Transportation, and industry workshop and symposium, "A Road Map to Readiness at Best Cost for Improving the Reliability and Safety of Ground Vehicles". During this workshop, many presenters and attendees voiced a concern that reliability, durability, and safety are exhibiting decreasing trends. One possible explanation for such observations is that there are not enough strong requirements to industry in these areas.

Current standards that relate to reliability testing: consider mostly theoretical (statistical) aspects; reliability testing equipment is mostly in the title only; leave out interaction reliability, durability, maintainability, safety, human problems, and life cycle cost. Therefore, they cannot help to offer the information for accurate prediction RMS and successful prevention their problems in real world.

Good illustration why Reliability, Durability, and Safety are going down we can see if will analyze the contents of TESTEXPO's over the world (in North America, Germany, China, Korea, India, and others.

These TESTEXPO's demonstrated 5 - 6 years ago complicated test equipment that close to reliability/durability testing (Weiss Technik, Seoul Industry Engineering, ESPEC, and other companies). For Testing Expo 2012 and 2013 these companies demonstrate mostly simple equipment which is far from reliability testing.

Why the market of testing equipment is so changed? Because industrial companies, that use testing equipment, want to save money for testing. Therefore, they buy cheaper and simpler testing equipment. But these equipment cannot offer the information for accurate prediction reliability and durability and, as a result, prevent their problems. Finally, the companies lost much more money than save during use a simpler testing equipment and methodology.

If during the design and manufacturing one tries to save a few pennies in testing, the end results may be a huge loss a thousands of dollars due to faulty products which have to be replaced because of this mistake. This situation relates to many areas of industry.

When reliability/durability test methods and equipment are considered, the interconnection between reliability, durability, maintainability, safety, human factors, and life cycle cost is frequently left out. Therefore, the development of accurate prediction methods based on accurate physical simulation of field conditions and accelerated reliability/ durability testing (ART/ADT) is needed.

These problems may be tackled by accurately modeling field issues in the laboratory for research, design, and testing. This may involve the use of both ART and ADT during research, design, and manufacturing. Also, it may be necessary to establish new requirements for contractors. To accomplish these ends, more effective standardization documents are required.

The author submit that improvement in testing standards, and particularly improvement in ART/ADT (reliability testing) standards, are needed. ART and ADT are extremely important and have uses beyond their obvious applications to reliability, durability, and safety. They also can help to resolve maintainability problems, reduce recalls, minimize life cycle cost, determine levels of safety and risk, and accelerate development [19], [20], [21], [22], [23].

Poor reliability in commercial and defense systems negatively affects the operational readiness rates required by commanders in the field. It leads to larger logistics footprints that detract from mobility, and also increases operating and support costs that divert resources from necessary modernization. Reliability issues continue to cause problems for RMS.

The National Research Council wrote [1]:

“The Department of Defense and the military services should give increased attention to their reliability, availability, and maintainability data collection and analysis procedures because deficiencies continue to be responsible for many of the current field problems and concerns about military readiness.”

The General Accounting Office (GAO) observed that in FY 2003, DoD asked for approximately $185 billion to develop, procure, operate, and maintain its weapon systems-an increase of 18% over FY 2001. A significant portion of these funds cover spare parts and support systems to meet required readiness levels, and the high cost of maintaining systems has limited DoD's ability to modernize and invest in new weapons. This situation is still continuing at the present time.

Military standards and handbooks usually contain current information. But under acquisition reform, many military specifications, standards, and handbooks were cancelled to force the DoD to rely more on the commercial world and thereby accelerate the adoption of commercial best practices and technologies which would improve capability at lower cost.

Unfortunately, in the RAM area, a void formed. The National Research Council (NRC) recognized this situation and recommended [2] new military handbooks and standards. This void has contributed to ineffective execution of RAM tasks on many programs. Recent studies have concluded that defense contractor reliability design practices may be inconsistent with best commercial practices for accelerated testing, simulation- guided testing, and process certification/ control.

The updated RAM guide, DoD Handbook 3235.1-H Test and Evaluation of Systems Reliability, Availability, and Maintainability: A New Primer [6] provides information on reliability, availability, and maintainability throughout the system life cycle.

Here are some military standards associated with reliability testing [3], [4], [5], [6], [7], [8]: MIL-HDBK-108, Sampling Procedures and Tables for Life and Reliability Testing (Based on Exponential Distribution); MIL-HDBK-781A, Handbook for Reliability Test Methods; MIL-HDBK-217F, Reliability Prediction of Electronic Equipment; MIL-STD-690D, Failure

Rate Sampling Plans and Procedures; MIL-STD-882E, System Safety; and MIL-STD-2074, Failure Classification for Reliability Testing.

There are group of IEC standards that relate to reliability testing [9], [10], [11], [12], [13], [14], [15], [16]. This is group of standards with common title Equipment Reliability Testing. But in fact they consider:

• statistical methods for evaluating point estimates, confidence intervals, prediction intervals, and tolerance intervals for the failure rates of items whose time to failure follows an exponential distribution;

• procedures to verify the assumption of a constant failure rate as defined in IEC 60050-191(1990-12) (Terminology).

• compliance testing techniques for availability performance testing of frequently maintained items.

• procedures for compliance with success ratio or failure ratio test plans where each trial is statistically independent.

• a number of test plans, the corresponding operating characteristic curves, and expected test times. In addition, the algorithms for designing test plans using a spreadsheet program are also given, together with guidance on how to choose test plans. This standard does not cover guidance on how to plan, perform, and report a test as this information can be found in IEC 60300-3-5.

• the design of operating and environmental test cycles referenced in section 8.1 and 8.2 of IEC 60300-3-5.

As one can see, the above current Military and IEC standards that relate to reliability testing cannot be useful for offering information for practical accurate prediction of RMS, safety, and life cycle cost of the product.

## SOLUTION

To remedy this situation, the SAE International G-11 Division decided to develop a group of six standards with the common title “RELIABILITY TESTING”.

This group of six standards is intended to address the basic practical problem of providing step-by-step reliability testing guidance (accelerated reliability/durability testing, durability testing), helping users and contractors accurately predict reliability, durability, maintainability, and availability during the service life (warranty period, and other time. The solution is intended to address both technical and economic aspects of the problem.

These standards are to provide a basis for accurate prediction of quality, reliability, durability, maintainability, and supportability (as well as life-cycle cost) in real-world conditions during any part of the system life-cycle, and to reduce recalls and complaints, the possibility of conflicts, duplications, and incorrect interpretations either expressed or implied elsewhere in the literature.

The purpose of these standards is to define the technology (methods and equipment) of Accelerated Reliability/ Durability Testing - ART/ADT (Reliability Testing, Durability Testing - RT, DT) to give a common practical meaning of this technology for contractors and users in aviation, aerospace, and other areas.

The goal of ART/ADT (durability testing) is to produce results sufficiently close or identical to conventional (un-accelerated) reliability testing. The outcome of these types of testing is normally used for accurate reliability and durability predictions covering service life, warranty period, or other specified periods

Durability testing is different from vibration testing, because durability testing means interaction of multi-environmental, mechanical, electrical, and other necessary testing with correspondence equipment, but vibration testing means mechanical testing only.

The References include applicable documents including: SAE Publications; ASTM Publications; ECSS Publications; IEC Publications; ISO Publications; U.S. Government Publications; and Other Publications.

The basic, planned contents of these standards:

## First Standard. SAE JA 1009/A. Reliability Testing. Glossary.

(Note: per deliberations at the Fall 2012 meeting of the SAE G11 division, this glossary may become integrated into a revision to ARP 5638, “RMS Terms and Definitions”, instead of becoming a new JA 1009 document).

The glossary includes specific terms that relate to reliability testing technology such as accelerated reliability testing, accelerated durability testing, durability testing, reliability testing with appropriate notes, accurate simulation of field input influences, accurate prediction, an accurate physical simulation, classification accuracy, the difference between durability testing and vibration testing, and others.

This glossary includes definitions that improve on versions currently in wide use.

## Second Standard. SAE JA 1009/1. Reliability Testing. Strategy.

The strategy of reliability (accelerated reliability) testing consists of:

• General components of reliability testing strategy;

• Specific components of reliability testing strategy;

• Development of an accurate simulation of the real world conditions in the laboratory;

• Basic components of simulation strategy implementation;

• Introduce accelerated reliability/durability testing (ART/ADT), reliability testing, durability testing, including the analysis, operator's and management of the causes of degradation;

• The ART/ADT methodology;

• Accurate reliability/durability prediction.

One can see the basic methodological aspects of this strategy in Figure 2.

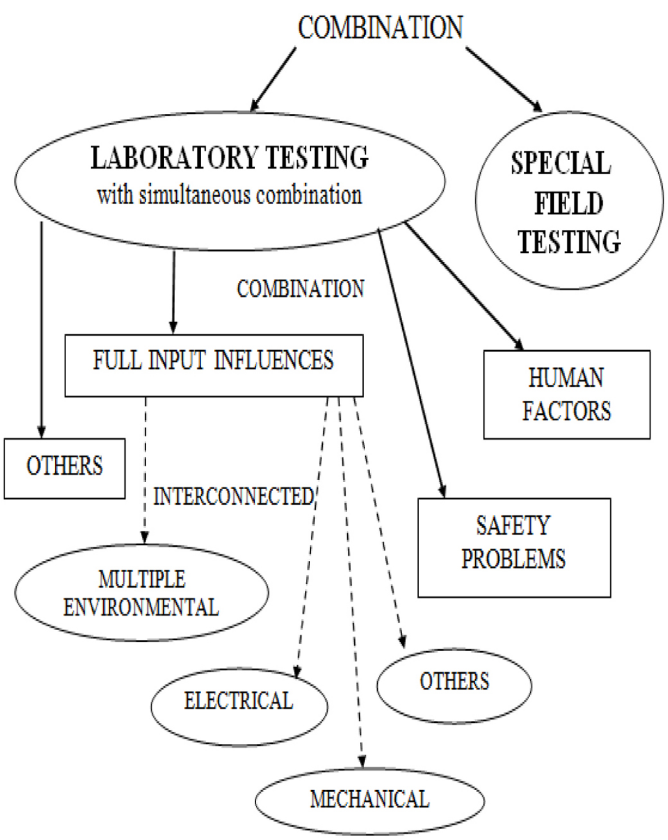


***Figure 2. Basic methodological specific of accelerated reliability/durability testing strategy***

Special field testing takes into account factors which cannot be accurately simulated in the laboratory, such as the stability of the product's intended function over the life cycle, and how human factors associated with operators, managers, etc., influence the product's reliability and durability. Accurate simulation of actual service conditions requires comprehensive simulation of the influencing factors integrated with safety and human factors.

This standard also demonstrates that currently used strategies of durability testing, as well as strategies of accelerated reliability testing frequently do not help to predict accurately reliability, durability, maintainability, and life cycle cost. As a result, for example, time and cost of maintenances by users 3 ÷ 5 times more than were predicted during design and manufacturing, final profit of companies - producers 4 - 5 times less than was predicted [22]. A good example of this situation is Nissan's practice. In [27] is described that vibration testing results can be used for durability evaluation. The authors wrote in the paper, "The results of this study proved that a road-load durability test can be performed on the rear bed of a pickup truck independent of the rest of the vehicle. As a result of this study, the number of full-vehicle durability tests can be reduced for future vehicle development programs while the quality of testing is maintained." [28]

## Third Standard. SAE JA 1009/2. Reliability Testing. Procedures.

Consists of applicable documents and the following eleven procedures:

• Procedure 1: Collection of the Accurate Initial Information from the Field;

• Procedure 2: Analysis of the Initial Field Information as a Random Process;

• Procedure 3: Establishing Concepts for the Physical Simulation of the Input Influences on the Product;

• Procedure 4: The Development and Use of Test Equipment that Simulates the Field Input Influences on the Actual Product;

• Procedure 5: Determining the Number and Types of Test Parameters for Degradation and Failures Analysis during Accelerated Reliability/Durability Testing;

• Procedure 6: Selecting a Representative Input Region for Accelerated Reliability/Durability Testing;

• Procedure 7: Accelerated Reliability/Durability Testing Preparation;

• Procedure 8: Use of Statistical Criteria for Comparison of Accelerated Reliability/ Durability Testing Results and Field Results;

• Procedure 9. Collection, Calculation, and Statistical Analysis of Accelerated Reliability/Durability Testing Data;

• Procedure 10: About Accurate Prediction of the Dynamics of the Test Subject's Reliability, Durability, and Maintainability During its Service Life

• Procedure 11: Use Accelerated Reliability/Durability Testing Results for Rapid and Cost-Effective Test Subject and Test Technology Development and Improvement.

This standard considers each of the above procedures with examples.

## Fourth Standard. SAE JA 1009/3. Reliability Testing. Equipment.

Consists of basic requirements to advanced equipment for reliability (accelerated reliability, accelerated durability) testing and its components (multi-environmental, mechanical, electrical, and others), as well as their subcomponents (vibration, dynamometer, solar radiation, chemical pollution, mechanical pollution, input voltage, and others).

Includes examples of these types of equipment.

## Fifth Standard. SAE JA 1009/4. Reliability Testing. Statistical criteria for a comparison of a reliability testing results and field results.

Consists of criteria for a comparison during reliability/ **durability** testing of the output variables and physics-of-degradation processes with those in the actual service conditions. There are criteria for reliability testing (mean time to failure, mean time between failures, failure intensity, dynamics of degradation, and others) and examples of how these criteria are used. ART/ADT is performed over some time interval of interest. Typical examples include the warranty period, the service life period, or other specified time period. For Accelerated Reliability Testing (Durability Testing) these criteria may be expressed in terms of operating hours, years, miles, etc.

## Sixth Standard. SAE JA 1009/5. Collection, calculation, statistical analysis, of reliability testing data, development recommendations for improvement of test subject reliability, durability, and maintainability.

Consists of methodology: data collection during the test time, statistical analysis of these test data, methods for analysis of the causes of degradation and failures, preparation recommendations for eliminations of these causes, counting the acceleration coefficient, development recommendations for improving the reliability, durability, and maintainability of test subject, as well as improving testing technology.

## CONCLUSIONS

**1.** Current reliability testing standards do not offer the information needed for accurate prediction of reliability, safety, durability, maintainability, and life-cycle cost, or that needed to successfully prevent associated problems.

**2.** Current standards in reliability testing do not include enough strong requirements for reliability, durability, safety, maintainability, and life-cycle cost.

**3.** Therefore, the SAE G-11 division (which includes the reliability committee) decided to solve new problem: begin developing a group of six standards to help eliminate this situation and stop negative trends in the development of reliability, durability, and safety standards. This paper outlines the basic contents planned for the above standards, with their advantages for practical engineering.

**4.** The basic advantages of these planned standards are summarized as follows:

• Reliability testing is based on accurate physical simulation of field conditions for accurate prediction of interacted reliability, durability, maintainability, safety, and life cycle cost;

• Combines practical reliability testing (ART/ADT) techniques and equipment.

• Considers data needed for accurate prediction and successful prevention of problems during design, manufacturing, and usage, and the interaction of reliability, safety, human factors, and economic problems.

• Eliminates wrong approaches that would separate consideration of factors that are interacted in the field (full input influences, safety, and human factors).

## REFERENCES

**1.** National Research Council, Statistics, Testing, and Defense Acquisition: New Approaches and Methodological Improvements, Panel on Statistical Methods for Testing and Evaluating Defense Systems, Cohen Michael L., Rolph John B., and Steffey Duane L., Editors, Committee on National Statistics; Washington D.C., National Academy Press, 1998.

**2.** National Research Council; Reliability Issues for DoD Systems, Report of a Workshop; Francisco Samaniego and Michael Cohen, Editors.; Committee on National Statistics; Washington D.C., National Academy Press; 2002.

**3.** MIL-HDBK-108. Sampling Procedures and Tables for Life and Reliability Testing (Based on Exponential Distribution.

**4.** MIL-HDBK-217F. Reliability Prediction of Electronic Equipment.

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

**6.** MIL-HDBK-3235. 1H. Test and Evaluation of Systems Reliability, Availability, Availability, and Maintainability: A New Primer.

**7.** MIL-STD-690D. Failure Rate Sampling Plans and Procedures.

**8.** MIL-STD-2074. Failure Classification for Reliability Testing.

**9.** IEC 60300-3-2, Ed.2. Dependability Management - Part 3-2: Application Guide - Collection of Dependability Data from the Field.

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

**11.** IEC 60605-4 (2001-2008). Equipment reliability testing, Part 4: Statistical procedures for exponential distribution - Point estimates, confidence intervals, prediction intervals and tolerance intervals.

**12.** IEC 60605-6 Corr. 1 (2000-2012). Equipment reliability testing - Part 6: Tests for the validity of the constant failure rate or constant failure intensity assumptions.

**13.** IEC 61070 (1991-2011) Compliance test procedures for steady-state availability.

**14.** IEC 61123 (1991-2012). Reliability testing. - Compliance test plans for success ratio.

**15.** IEC 61124 (2006-030 Reliability testing - Compliance tests for constant failure rate and constant failure intensity.

**16.** IEC 60605-2 (1994-2010) Equipment Reliability Testing. Part 2: Design of test cycles.

**17.** Chan, H. Antony, Parker T. Paul, Felkin Charles, Oates Antony. 2000, Accelerated Stress Testing. IEEE Press.

**18.** Wayne Nelson. 1990. Accelerated Testing. John Wiley & Sons, Inc. New York, NY.

**19.** Klyatis Lev M. 2012. Accelerated Reliability and Durability Testing Technology. John Wiley & Sons, Inc.

**20.** Klyatis Lev and Klyatis Evgeny. 2006. Accelerated Quality and Reliability Solutions. Elsevier. Oxford, UK.

**21.** Klyatis, L. and Verbitsky, D., "Accelerated Reliability/ Durability Testing as a Key Factor for Accelerated Development and Improvement of Product/Process Reliability, Durability, and Maintainability," SAE Technical Paper 2010-01-0203, 2010, doi: 10.4271/2010-01-0203.

**22.** Klyatis, L., "Why Current Types of Accelerated Stress Testing Cannot Help to Accurately Predict Reliability and Durability?," SAE Technical Paper 2011-01-0800, 2011, doi: 10.4271/2011-01-0800.

**23.** Klyatis, Lev, Aysik Vaysman. "Accurate Simulation of Human Factors and Reliability, Maintainability, and Supportability Solutions". The Journal of RMS (Reliability, Maintainability, Supportability) in Systems Engineering. Winter 2007/2008.

**24.** Hybrid Electric Vehicle End-of-Life Testing on Honda Insights. Honda Insight Hybrid Electric Vehicle. Fleet and Accelerated Reliability Testing - September 2006. Report. U.S. Department of Energy.

**25.** Honda Civic Fleet and Reliability Testing - July 2005. U.S. Department of Energy. Energy Efficiency and Renewable Energy. FreedomCAR & Vehicle Technologies Program.

**26.** Schwab, Harry L. and Dodson, Bryan L., "Accelerated Testing A Practitioner's Guide to Accelerated and Reliability Testing," Society of Automotive Engineers, Inc., Warrendale, PA, ISBN 978-0-7680-0690-2, 2006, doi: 104271/R-304.

**27.** Karbassian, A., Bonathan, D., and Katakami, T., "Accelerated Vibration Durability Testing of a Pickup Truck Rear Bed," SAE Technical Paper 2009-01-1406, 2009, doi: 10.4271/2009-01-1406.

**28.** "Nissan Speeds up Truck Bed Durability Testing," SAE Automotive Engineering International, Aug. 2009.

## CONTACT INFORMATION

**Lev Klyatis**
klyatislm@gmail.com

The Engineering Meetings Board has approved this paper for publication. It has successfully completed SAE's peer review process under the supervision of the session organizer. This process requires a minimum of three (3) reviews by industry experts.



ISSN 0148-7191

Positions and opinions advanced in this paper are those of the author(s) and not necessarily those of SAE. The author is solely responsible for the content of the paper.

**SAE Customer Service:**
Tel: 877-606-7323 (inside USA and Canada)
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
**SAE Web Address:** http://www.sae.org
**Printed in USA**

SAE International®