IEC/TR 60493-2

Edition 1.0 2010-03

TECHNICAL REPORT

Guide for the statistical analysis of ageing test data – Part 2: Validation of procedures for statistical analysis of censored normally distributed data

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRICE CODE XG

ICS 29.035.01

ISBN 978-2-88910-198-6

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms, symbols and definitions 7
3.1 Definitions 7
3.2 Symbols 10
4 Statistical calculations 11
4.1 General 11
4.1.1 Objectives of the analysis 11
4.1.2 Outline of work program 11
4.1.3 Computer programs 12
4.2 Calculations for complete (uncensored) data 12
4.2.1 Sub-group 12
4.2.2 Group (several sub-groups) 12
4.2.3 The F-function 13
4.2.4 Bartlett's χ^2 function 13
4.2.5 Student's *t* function 13
4.2.6 Student's *t* function for the difference of two means 14
4.3 Censored data groups 14
4.3.1 Sub-groups 15
4.3.2 Group (several sub-groups) – Analysis of variance 15
4.3.3 Group (several sub-groups) – Analysis of covariance (regression analysis) 16
4.3.4 Difference of means of 2 sub-groups 18
4.4 Complete (uncensored) data 19
5 Random number generation 19
5.1 General 19
5.2 Uniform variates 19
5.3 Normal variates 20
6 Validation procedures 20
6.1 Size of samples 20
6.2 Validation of random number generation 21
7 Outline of tasks 21
7.1 Optimum size of samples 21
7.2 Uniformly and normally distributed random number generation 22
7.3 Examine properties of single sub-groups 22
7.3.1 Correlation of mean and standard deviation (SD) 22
7.3.2 Distribution and possible bias of mean and SD estimates 22
7.4 Examine properties of compound groups 22
7.5 Procedure for testing difference of two means 22
8 Discussion of results and conclusions 22
8.1 Optimum size of samples 22
8.2 Correlation coefficients of mean and standard deviation of sub-groups 22
8.3 Values of mean, variance and SD of mean of censored data sub-groups 22
8.4 Distribution functions of mean and variance of censored data sub-groups 23

8.5 Properties of compound data groups 23
8.5.1 F (variance ratio) function 23
8.5.2 “Student’s” *t* function 23
8.5.3 Bartlett’s χ^2 (variance equality) function 24
8.6 Generation of uniformly distributed random numbers 24
8.7 Values of the *t*-ratio for the difference of two means 24
9 Conclusions 25
9.1 Random number generation 25
9.1.1 Uniform distribution 25
9.1.2 Normal distribution 25
9.2 Statistical functions of censored data groups 25
9.2.1 Simple sub-groups 25
9.2.2 Compound groups – Analysis of variance 25
9.2.3 Compound groups – Regression analysis 26
9.2.4 Difference of means of 2 sub-groups 26
10 Summary of conclusions and recommendations 27
10.1 Summary of conclusions 27
10.2 Recommendations 27
Annex A (informative) Results 28
Annex B (informative) Key to graph features 43
Annex C (informative) Graphical displays for the group statistical functions 47
Annex D (informative) Computer programs 148
Annex E (informative) Worked example 150
Bibliography 151

Figure A.1 – Confidence limits for value counts 29

Table A.1 – Confidence limits for value counts 28

INTERNATIONAL ELECTROTECHNICAL COMMISSION

GUIDE FOR THE STATISTICAL ANALYSIS OF AGEING TEST DATA –

Part 2: Validation of procedures for statistical analysis of censored normally distributed data

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 60493-2 which is a technical report, has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
112/140/DTR	112/145/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This publication contains attached files in the form of a CD-ROM. These files are intended to be used as a complement and do not form an integral part of the standard.

A list of all parts of the IEC 60493 series, published under the general title *Guide for the statistical analysis of ageing test data,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Procedures for estimating ageing properties are described in specific test procedures, or are covered by the general documents on test procedures for ageing tests with a specific environmental stress (e.g. temperature, radiation, partial discharges).

In many cases, a certain property is determined as a function of time at different ageing stresses, and a time to failure based on a chosen end-point criterion is found at each ageing stress. A plot of time to failure versus ageing stress may be used to obtain an estimate of the time to failure for similar specimens exposed to a specified stress, or to obtain an estimate of the value of stress which will cause failure in a specified time.

The physical and chemical laws governing the ageing phenomena may often lead to the assumption that a linear relationship exists between the property examined and the ageing time at fixed ageing stresses, or between certain mathematical functions of property and ageing time, e.g. square root or logarithm.

The relationships between property values, ageing time, ageing and ageing exposure temperature are determined by mathematical procedures known as analysis of variance, analysis of covariance and regression analysis. In some cases, the property values cannot be determined because of time or property measurement limitations. Such data are referred to as “censored data”.

The mathematical procedures are well known and accepted as valid for complete (uncensored) data. This technical report describes the work done to validate the procedures for censored data.

GUIDE FOR THE STATISTICAL ANALYSIS OF AGEING TEST DATA –

Part 2: Validation of procedures for statistical analysis of censored normally distributed data

1 Scope

This part of IEC 60493 provides an account of the work done in designing and validating the statistical procedures for operations on censored groups of normally distributed data.

The relationship to similar operations on complete (uncensored) data is examined, and it is shown that “mixed” or wholly uncensored data groups may be analysed in the same way as wholly censored ones.

Attention is drawn to the effect of some variation of group size and extent of censoring, as well as the effect of non-uniform data group sizes.

2 Normative references

IEC 60216-3, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60216-6, *Electrical insulating materials – Thermal endurance properties – Part 6: Determination of thermal endurance indices (TI and RTE) of an insulating material using the fixed time frame method*

IEC 60493-1, *Guide for the statistical analysis of ageing test data. Part 1: Methods based on mean values of normally distributed test results*