



# 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 2-8318-1086-2

## 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 $\chi^2$ function.....	13
4.2.5 Student's <i>t</i> function.....	13
4.2.6 Student's <i>t</i> 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” <i>t</i> function .....	23
8.5.3	Bartlett’s $\chi^2$ (variance equality) function .....	24
8.6	Generation of uniformly distributed random numbers .....	24
8.7	Values of the <i>t</i> -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*