

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Guide for the statistical analysis of ageing test data –
Part 1: Methods based on mean values of normally distributed test results**

**Guide pour l'analyse statistique de données d'essais de vieillissement –
Partie 1: Méthodes basées sur les valeurs moyennes de résultats d'essais
normalement distribués**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2011 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,...). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00



IEC 60493-1

Edition 2.0 2011-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Guide for the statistical analysis of ageing test data –
Part 1: Methods based on mean values of normally distributed test results**

**Guide pour l'analyse statistique de données d'essais de vieillissement –
Partie 1: Méthodes basées sur les valeurs moyennes de résultats d'essais
normalement distribués**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

ICS 29.035.01

ISBN 978-2-88912-834-1

CONTENTS

| | |
|--|----|
| FOREWORD..... | 3 |
| INTRODUCTION..... | 5 |
| 1 Scope..... | 6 |
| 2 Normative references | 6 |
| 3 Terms, definitions and symbols | 6 |
| 3.1 Terms and definitions | 6 |
| 3.2 Symbols | 8 |
| 4 Calculation procedures..... | 9 |
| 4.1 General considerations..... | 9 |
| 4.2 Single sub-group – Difference of mean and specified value..... | 9 |
| 4.2.1 General | 9 |
| 4.2.2 Complete data sub-group | 9 |
| 4.2.3 Censored data sub-group | 10 |
| 4.3 Two subgroups – Difference of means..... | 10 |
| 4.3.1 General | 10 |
| 4.3.2 Both sub-groups complete | 10 |
| 4.3.3 One or both subgroups censored..... | 11 |
| 4.4 Two or more subgroups – Analysis of variance..... | 11 |
| 4.5 Three or more subgroups – Regression analysis | 13 |
| 4.5.1 Regression analysis – General considerations..... | 13 |
| 4.5.2 Calculations..... | 14 |
| 4.5.3 Test equality of subgroup variances | 15 |
| 4.5.4 Test significance of deviations from linearity..... | 16 |
| 4.5.5 Estimate and confidence limit of y | 16 |
| 4.5.6 Estimate and confidence limit of x | 16 |
| Annex A (informative) Statistical background | 18 |
| Annex B (informative) Statistical tables..... | 22 |
| Bibliography..... | 35 |
| Table B.1 – Coefficients for censored data calculations | 23 |
| Table B.2 – Fractiles of the F -distribution, $F_{0,95}$ | 30 |
| Table B.3 – Fractiles of the F -distribution, $F_{0,995}$ | 32 |
| Table B.4 – Fractiles of the t -distribution, $t_{0,95}$ | 34 |
| Table B.5 – Fractiles of the χ^2 -distribution..... | 34 |

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**GUIDE FOR THE STATISTICAL ANALYSIS
OF AGEING TEST DATA –****Part 1: Methods based on mean values
of normally distributed test results**

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.

International Standard IEC 60493-1 has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

This second edition cancels and replaces the first edition, published in 1974, and constitutes a technical revision.

The main changes with respect to the first edition are that, besides a complete editorial revision, censored data sub-group are considered.

The text of this standard is based on the following documents:

| CDV | Report on voting |
|-------------|------------------|
| 112/172/CDV | 112/192/RVC |

Full information on the voting for the approval of this standard 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.

A list of all the parts in 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.

This document is a preview generated by EVS

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. Also, there may be a linear relationship between time to failure and ageing stress, or mathematical functions of these variables.

The methods described in this part of IEC 60493 apply to such cases of linear relationship. The methods are illustrated by the example of thermal ageing wherein the case of a simple chemical process it may be assumed that the degradation obeys the Arrhenius law, i.e. the logarithm of time to failure is a linear function of the reciprocal thermodynamic temperature. Numerical examples demonstrating the use of the methods in this case are given in IEC 60216-3 [1]¹.

The calculation processes specified in this standard are based on the assumption that the data under examination are normally distributed. No test for normality of the data is specified, since the available tests are unreliable for small sample groups of data. However, the methods have been used for a considerable time without undesirable results and with no check on the normality of the data distributions.

¹ Figures in square brackets refer to the bibliography.

GUIDE FOR THE STATISTICAL ANALYSIS OF AGEING TEST DATA –

Part 1: Methods based on mean values of normally distributed test results

1 Scope

This part of IEC 60493 gives statistical methods which may be applied to the analysis and evaluation of the results of ageing tests.

It covers numerical methods based on mean values of normally distributed test results.

These methods are only valid under specific assumptions regarding the mathematical and physical laws obeyed by the test data. Statistical tests for the validity of some of these assumptions are also given.

This standard deals with data from both complete test sets and censored test sets.

This standard provides data treatment based on the concept of "data sub-group" as defined in Clause 3. The validity of the coefficients used in the calculation processes to derive statistical parameters of the data groups are described in [1].

2 Normative references

None.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms, definitions and symbols apply.

3.1.1

ordered data

set of data arranged in sequence so that in the appropriate direction through the sequence each member is greater than or equal to its predecessor

Note 1 to entry: "Ascending order" in this standard implies that the data is ordered in this way, the first being the smallest.

3.1.2

order-statistic

each individual value in a set of ordered data is referred to as an "order-statistic" identified by its numerical position in the sequence

3.1.3

incomplete data

ordered data, where the values above and/or below defined points are not known

3.1.4

censored data

incomplete data, where the number of unknown values is known