



SLOVENSKI STANDARD
SIST EN 61649:2009
01-januar-2009

Weibullova analiza (IEC 61649:2008)

Weibull analysis (IEC 61649:2008)

Weibull-Analyse (IEC 61649:2008)

Analyse de Weibull (CEI 61649:2008)

ITEH STANDARD PREVIEW
(standards.iteh.ai)

Ta slovenski standard je istoveten z: EN 61649:2008

[SIST EN 61649:2009](https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009)

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>

ICS:

03.120.30	Wj [a a c a c a } a q ^ q a	Application of statistical methods
29.020	Elektrotehnika na splošno	Electrical engineering in general

SIST EN 61649:2009

en,fr

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN 61649:2009

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 61649

November 2008

ICS 03.120.01; 03.120.30

English version

Weibull analysis
(IEC 61649:2008)

Analyse de Weibull
(CEI 61649:2008)

Weibull-Analyse
(IEC 61649:2008)

This European Standard was approved by CENELEC on 2008-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 56/1269/FDIS, future edition 2 of IEC 61649, prepared by IEC TC 56, Dependability, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61649 on 2008-10-01.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2009-07-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2011-10-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61649:2008 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60300-1	NOTE	Harmonized as EN 60300-1:2003 (not modified).
IEC 60300-2	NOTE	Harmonized as EN 60300-2:2004 (not modified).
IEC 60300-3-1	NOTE	Harmonized as EN 60300-3-1:2004 (not modified).
IEC 60300-3-2	NOTE	Harmonized as EN 60300-3-2:2005 (not modified).
IEC 60300-3-4	NOTE	Harmonized as EN 60300-3-4:2008 (not modified).
IEC 61703	NOTE	Harmonized as EN 61703:2002 (not modified).

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-191	1990	International Electrotechnical Vocabulary (IEV) - Chapter 191: Dependability and quality of service	-	-
IEC 60300-3-5	2001	Dependability management - Part 3-5: Application guide - Reliability test conditions and statistical test principles	-	-
IEC 61810-2	- ¹⁾	Electromechanical elementary relays - Part 2: Reliability	EN 61810-2	2005 ²⁾
ISO 2854	1976	Statistical interpretation of data - Techniques of estimation and tests relating to means and variances	-	-
ISO 3534-1	2006	Statistics - Vocabulary and symbols - Part 1: General statistical terms and terms used in probability	-	-

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>

¹⁾ Undated reference.

²⁾ Valid edition at date of issue.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN 61649:2009

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>



IEC 61649

Edition 2.0 2008-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Weibull analysis iTeh STANDARD PREVIEW
Analyse de Weibull (standards.iteh.ai)

[SIST EN 61649:2009](https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009)

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE **XB**
CODE PRIX

ICS 03.120.01; 03.120.30

ISBN 2-8318-9954-0

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms, definitions, abbreviations and symbols.....	8
3.1 Terms and definitions	8
3.2 Abbreviations	10
3.3 Symbols	10
4 Application of the techniques.....	11
5 The Weibull distribution	11
5.1 The two-parameter Weibull distribution.....	11
5.2 The three-parameter Weibull distribution	13
6 Data considerations.....	13
6.1 Data types.....	13
6.2 Time to first failure	13
6.3 Material characteristics and the Weibull distribution	13
6.4 Sample size.....	13
6.5 Censored and suspended data	14
7 Graphical methods and goodness-of-fit	14
7.1 Overview	14
7.2 How to make the probability plot.....	14
7.2.1 Ranking.....	15
7.2.2 The Weibull probability plot	15
7.2.3 Dealing with suspensions or censored data	15
7.2.4 Probability plotting.....	17
7.2.5 Checking the fit	17
7.3 Hazard plotting.....	18
8 Interpreting the Weibull probability plot.....	19
8.1 The bathtub curve	19
8.1.1 General	19
8.1.2 $\beta < 1$ – Implies early failures.....	19
8.1.3 $\beta = 1$ – Implies constant instantaneous failure rate.....	20
8.1.4 $\beta > 1$ – Implies wear-out.....	20
8.2 Unknown Weibull modes may be "masked".....	20
8.3 Small samples	21
8.4 Outliers	22
8.5 Interpretation of non-linear plots.....	22
8.5.1 Distributions other than the Weibull	25
8.5.2 Data inconsistencies and multimode failures	25
9 Computational methods and goodness-of-fit	25
9.1 Introduction	25
9.2 Assumptions and conditions	26
9.3 Limitations and accuracy.....	26
9.4 Input and output data	26

9.5	Goodness-of-fit test.....	27
9.6	MLE – point estimates of the distribution parameters β and η	27
9.7	Point estimate of the mean time to failure.....	28
9.8	Point estimate of the fractile (10 %) of the time to failure.....	28
9.9	Point estimate of the reliability at time t ($t \leq T$).....	28
9.10	Software programs	28
10	Confidence intervals.....	28
10.1	Interval estimation of β	28
10.2	Interval estimation of η	29
10.3	MRR Beta-binomial bounds	30
10.4	Fisher's Matrix bounds	30
10.5	Lower confidence limit for B_{10}	31
10.6	Lower confidence limit for R	31
11	Comparison of median rank regression (MRR) and maximum likelihood (MLE) estimation methods	31
11.1	Graphical display.....	31
11.2	B life estimates sometimes known as B or L percentiles	31
11.3	Small samples.....	32
11.4	Shape parameter β	32
11.5	Confidence intervals.....	32
11.6	Single failure.....	32
11.7	Mathematical rigor.....	32
11.8	Presentation of results	32
12	WeiBayes approach.....	33
12.1	Description.....	33
12.2	Method.....	33
12.3	WeiBayes without failures	33
12.4	WeiBayes with failures	33
12.5	WeiBayes case study	34
13	Sudden death method	35
14	Other distributions	37
	Annex A (informative) Examples and case studies	38
	Annex B (informative) Example of computations	40
	Annex C (informative) Median rank tables.....	42
	Annex D (normative) Statistical Tables	47
	Annex E (informative) Spreadsheet example.....	48
	Annex F (informative) Example of Weibull probability paper.....	55
	Annex G (informative) Mixtures of several failure modes.....	56
	Annex H (informative) Three-parameter Weibull example.....	59
	Annex I (informative) Constructing Weibull paper.....	61
	Annex J (informative) Technical background and references.....	64
	Bibliography.....	67
	Figure 1 – The PDF shapes of the Weibull family for $\eta = 1,0$	12
	Figure 2 – Total test time (in minutes).....	16
	Figure 3 – Typical bathtub curve for an item	19

Figure 4 – Weibull failure modes may be “masked”	21
Figure 5 – Sample size: 10	21
Figure 6 – Sample size: 100	22
Figure 7 – An example showing lack of fit with a two-parameter Weibull distribution	23
Figure 8 – The same data plotted with a three-parameter Weibull distribution shows a good fit with 3 months offset (location – 2,99 months).....	24
Figure 9 – Example of estimating t_0 by eye	25
Figure 10 – New compressor design WeiBayes versus old design	35
Figure A.1 – Main oil pump low times.....	38
Figure A.2 – Augmenter pump bearing failure	39
Figure A.3 – Steep β values hide problems	39
Figure B.1 – Plot of computations	41
Figure E.1 – Weibull plot for graphical analysis.....	49
Figure E.2 – Weibull plot of censored data.....	51
Figure E.3 – Cumulative hazard plot for data of Table E.4	52
Figure E.4 – Cumulative hazard plots for Table E.6	54
Figure H.1 – Steel-fracture toughness – Curved data.....	59
Figure H.2 – t_0 improves the fit of Figure H.1 data	60
iTeh STANDARD PREVIEW	
(standards.iteh.ai)	
Table 1 – Guidance for using this International Standard.....	11
Table 2 – Ranked flare failure rivet data	15
Table 3 – Adjusted ranks for suspended or censored data	16
Table 4 – Subgroup size to estimate time to X % failures using the sudden death method	36
Table 5 – Chain data: cycles to failure	36
Table B.1 – Times to failure	40
Table B.2 – Summary of results	41
Table D.1 – Values of the gamma function.....	47
Table D.2 – Fractiles of the normal distribution	47
Table E.1 – Practical analysis example.....	48
Table E.2 – Spreadsheet set-up for analysis of censored data.....	50
Table E.3 – Example of Weibull analysis for suspended data.....	50
Table E.4 – Example of Spreadsheet application for censored data	51
Table E.5 – Example spreadsheet.....	52
Table E.6 – A relay data provided by ISO/TC94 and Hazard analysis for failure mode 1	53
Table I.1 – Construction of ordinate (Y).....	62
Table I.2 – Construction of abscissa (t).....	62
Table I.3 – Content of data entered into a spreadsheet.....	62

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WEIBULL ANALYSIS

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, 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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 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 61649 has been prepared by IEC technical committee 56: Dependability.

This second edition cancels and replaces the first edition, published in 1997, and constitutes a technical revision.

The main changes with respect to the previous edition are as follows:

- the title has been shortened and simplified to read "Weibull analysis";
- provision of methods for both analytical and graphical solutions have been added.

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

FDIS	Report on voting
56/1269/FDIS	56/1281/RVD

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.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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.

iTeh STANDARD PREVIEW (standards.iteh.ai)

[SIST EN 61649:2009](#)

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>

INTRODUCTION

The Weibull distribution is used to model data regardless of whether the failure rate is increasing, decreasing or constant. The Weibull distribution is flexible and adaptable to a wide range of data. The time to failure, cycles to failure, mileage to failure, mechanical stress or similar continuous parameters need to be recorded for all items. A life distribution can be modelled even if not all the items have failed.

Guidance is given on how to perform an analysis using a spreadsheet program. Guidance is also given on how to analyse different failure modes separately and identify a possible weak population. Using the three-parameter Weibull distribution can give information on time to first failure or minimum endurance in the sample.

iTeh STANDARD PREVIEW **(standards.iteh.ai)**

[SIST EN 61649:2009](https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009)

<https://standards.iteh.ai/catalog/standards/sist/d4a4d715-af94-4efc-ac02-ac1816998680/sist-en-61649-2009>

WEIBULL ANALYSIS

1 Scope

This International Standard provides methods for analysing data from a Weibull distribution using continuous parameters such as time to failure, cycles to failure, mechanical stress, etc.

This standard is applicable whenever data on strength parameters, e.g. times to failure, cycles, stress, etc. are available for a random sample of items operating under test conditions or in-service, for the purpose of estimating measures of reliability performance of the population from which these items were drawn.

This standard is applicable when the data being analysed are independently, identically distributed. This should either be tested or assumed to be true (see IEC 60300-3-5).

In this standard, numerical methods and graphical methods are described to plot data, to make a goodness-of-fit test, to estimate the parameters of the two- or three-parameter Weibull distribution and to plot confidence limits. Guidance is given on how to interpret the plot in terms of risk as a function of time, failure modes and possible weak population and time to first failure or minimum endurance.

iTeh STANDARD PREVIEW

2 Normative references (standards.iteh.ai)

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-191:1990, *International Electrotechnical Vocabulary – Part 191: Dependability and quality of service*

IEC 60300-3-5:2001, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

IEC 61810-2, *Electromechanical elementary relays – Part 2: Reliability*

ISO 2854:1976, *Statistical interpretation of data – Techniques of estimations and tests relating to means and variances*

ISO 3534-1:2006, *Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms in probability*

3 Terms, definitions, abbreviations and symbols

For the purposes of this document, the definitions, abbreviations and symbols given in IEC 60050-191 and ISO 3534-1 apply, together with the following.

3.1 Terms and definitions

3.1.1

censoring

terminating a test after either a given duration or a given number of failures

NOTE A test terminated when there are still unfailed items may be called a “censored test”, and test time data from such tests may be referred to as “censored data”.

3.1.2

suspended item

item upon which testing has been curtailed without relevant failure

NOTE 1 The item may not have failed, or it may have failed in a mode other than that under investigation.

NOTE 2 An “early suspension” is one that was suspended before the first failure. A “late suspension” is suspended after the last failure.

3.1.3

life test

test conducted to estimate or verify the durability of a product

NOTE The end of the useful life will often be defined as the time when a certain percentage of the items have failed for non-repairable items and as the time when the failure intensity has increased to a specified level for repairable items.

3.1.4

non-repairable item

item that cannot, under given conditions, after a failure, be returned to a state in which it can perform as required

NOTE The given conditions may be technical, economic, ecological and/or others.

3.1.5

operating time

time interval for which the item is in an operating state

NOTE “Operating time” is generic, and should be expressed in units appropriate to the item concerned, e.g. calendar time, operating cycles, distance run, etc. and the units should always be clearly stated.

3.1.6

relevant failure

failure that should be included in interpreting test or operational results or in calculating the value of a reliability performance measure

NOTE The criteria for inclusion should be stated.

3.1.7

reliability test

experiment carried out in order to measure, quantify or classify a reliability measure or property of an item

NOTE 1 Reliability testing is different from environmental testing where the aim is to prove that the items under test can survive extreme conditions of storage, transportation and use.

NOTE 2 Reliability tests may include environmental testing.

3.1.8

repairable item

item that can, under given conditions, after a failure, be returned to a state in which it can perform as required

NOTE The given conditions may be technical, economic, ecological and/or others.

3.1.9

time to failure

operating time accumulated from the first use, or from restoration, until failure

NOTE In applications where the time in storage or on standby is significantly greater than “operating time”, the time to failure may be based on the time in the specified service.