INTERNATIONAL STANDARD

ISO 19973-1

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Pneumatic fluid power — Assessment of component reliability by testing —

Part 1: General procedures

Transmissions pneumatiques — Évaluation par essais de la fiabilité des composants —

Partie 1: Procédures générales

Reference number
ISO 19973-1:2015(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 131, *Fluid power systems*.

This second edition cancels and replaces the first edition (ISO 19973-1:2007) which has been technically revised.

ISO 19973 consists of the following parts, under the general title *Pneumatic fluid power — Assessment of component reliability by testing*:

— *Part 1: General procedures*

— *Part 2: Directional control valves*

— *Part 3: Cylinders with piston rod*

— *Part 4: Pressure regulators*

— *Part 5: Non-return valves, shuttle valves, dual pressure valves (AND function), one-way adjustable flow control valves, quick-exhaust valves*

Introduction

In pneumatic fluid power systems, power is transmitted and controlled through a gas under pressure within a circuit. Pneumatic fluid power systems are composed of components and are an integral part of various types of machines and equipment. Efficient and economical production requires highly reliable machines and equipment.

It is necessary that machine producers know the reliability of the components that make up their machine's pneumatic fluid power system. Knowing the reliability characteristic of the component, which can be determined from laboratory testing, the producers can model the system and make decisions on service intervals, spare parts inventory and areas for future improvements.

There are three primary levels in the determination of component reliability:

a) preliminary design analysis: finite element analysis (FEA), failure mode and effect analysis (FMEA);

b) laboratory testing and reliability modelling: physics of failure, reliability prediction, pre-production evaluation;

c) collection of field data: maintenance reports, warranty analysis.

Each level has its application during the life of a component. A preliminary design analysis is useful to identify possible failure modes and eliminate them or reduce their effect on reliability. When prototypes are available, in-house laboratory reliability tests are run and initial reliability can be determined. Reliability testing is often continued into the initial production run and throughout the production lifetime as a continuing evaluation of the component. Collection of field data is possible when products are operating and data on their failures are available.

Specific component test procedures and exclusions are provided in ISO 19973-2, ISO 19973-3, ISO 19973-4 and ISO 19973-5.

Pneumatic fluid power — Assessment of component reliability by testing —

Part 1: General procedures

1 Scope

This part of ISO 19973 provides general procedures, the calculation method for assessing the reliability of pneumatic fluid power components and the methods of reporting. These procedures are independent of the kinds of components and of their design.

This part of ISO 19973 also provides general test conditions and a method for data evaluation.

NOTE Because the service life of any component is subject to variations, a statistical evaluation assists the interpretation of the test results.

The methods specified in this part of ISO 19973 apply to the first failure without repairs (see IEC 60300-3-5), but exclude outliers; however, because outliers can be highly significant, information about how to deal with them is given in Annex F.

2 Normative references

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

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

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 6358 (all parts), *Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids*

ISO 10099, *Pneumatic fluid power — Cylinders — Final examination and acceptance criteria*

ISO 19973-3, *Pneumatic fluid power — Assessment of component reliability by testing — Part 3: Cylinders with piston*

ISO 80000-1, *Quantities and units — Part 1: General*

IEC 60050-191, *International Electrotechnical Vocabulary, chapter 191: Dependability and quality of service*

IEC 61649, *Goodness-of-fit tests, confidence intervals and lower confidence limits for Weibull distributed data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3534-1, ISO 5598 and IEC 60050-191 and the following apply.

3.1
catastrophic failure
failure of an item that results in its complete inability to perform all required functions

3.2
confidence coefficient
confidence level
value $(1 - \alpha)$ of the probability associated with a confidence interval or a statistical coverage interval

Note 1 to entry: See also 3.6.

Note 2 to entry: See ISO 3534-1 for notes related to this term and definition.

3.3
confidence limit
either of the limits, T_1 or T_2, of the two-sided confidence interval, or the limit, T, of the one-sided confidence interval

Note 1 to entry: See ISO 3534-1 for notes related to this term and definition.

3.4
failure
termination of the ability of an item to perform a required function

Note 1 to entry: In the ISO 19973 (all parts), the reaching of a threshold level for statistical calculation is also considered a statistical failure (see Annex A).

[SOURCE: IEC 60050-191]

3.5
one-sided confidence interval
T
interval estimator for a parameter, Θ, comprised of the interval from the smallest possible value of the parameter, Θ, up to T or the interval from T up to the largest possible value of Θ, where the probability $p(T \geq \Theta)$ or $p(T \leq \Theta)$ is at least equal to $(1 - \alpha)$, where $(1 - \alpha)$ is a fixed number, positive and less than 1

Note 1 to entry: See ISO 3534-1 for notes related to this term and definition.

3.6
relevant failure
failure that should be included in interpreting test or operational results or in calculating the value of a reliability performance measure

[SOURCE: IEC 60050-191]

3.7
reliability
probability that an item can perform a required function under given conditions for a given time interval

[SOURCE: IEC 60050-191]

3.8
sample
one or more test units taken from a population and intended to provide information on the population

Note 1 to entry: A sample can serve as a basis for a decision on the population or on the process that produced it.

3.9
sample size
number of test units in the sample

Note 1 to entry: In a multi-stage sample, the sample size is the total number of test units at the conclusion of the final stage of sampling.

3.10
three-point moving average
3PMA
arithmetic average of three consecutive measured component's test data

3.11
threshold level
value of a performance characteristic (for example, leakage, shifting pressure, stroke time, etc.) against which the component's test data is compared

Note 1 to entry: This is an arbitrary value defined by the experts as the critical value for performance comparisons, but is not necessarily indicative of a component failure.

4 Symbols and units of measurement

4.1 The symbols used in this part of ISO 19973 are given in Table 1.

Table 1 — Symbol list

Symbol[a]	Definition
B_{10}	Expected time at which 10 % of the population is predicted to fail (10 % of the lifetime distribution)
$(B_{10})_{95\,\%}$	B_{10} life at the one-sided 95 % confidence level
η	Scale parameter (characteristic life) of the Weibull distribution
$F(t)$	Probability of failure, expressed in percent.
β	Shape parameter (slope) of the Weibull distribution
$R(t)$	Reliability of a component at time t ; $1\text{-}F(t)$
t	Life time expressed in time, cycles, or distance

[a] Other symbols can be used in other documents and software.

4.2 Units of measurement are in accordance with ISO 80000-1.

5 Concept of reliability

For the purposes of this part of ISO 19973, reliability is the probability that a component does not have a relevant failure for a specified interval of time, number of cycles or distance when it operates under stated conditions.

A relevant failure occurs when

— component data, determined using the three-points moving average (*3PMA*), exceeds a threshold level for the first time (see 10.2), or

— a component experiences a catastrophic failure (burst, fatigue or functional failure, etc.).

Threshold levels of the components covered by ISO 19973 (all parts) are specified in the component-specific parts of this International Standard.

This probability can be determined by analysing the results of a series of tests and describing the population failure by statistical methods. There are many different statistical distributions that describe the population of failures that result from testing.

It is also possible to verify the minimum life of a component by the one-sided confidence estimation at a specified reliability level. Examples are given in Annex E.

6 Strategies for conducting testing

6.1 Assumptions

The reliability of pneumatic components in an application depends on many environmental factors, including pressure, temperature, dew point and contamination level of the compressed air, externally imposed loads, duty cycle, etc. Any prediction of the reliability of an individual component, therefore, shall take all of these environmental factors into consideration.

This part of ISO 19973 is based on a prescribed level of stress, test conditions and duty cycle that reflects the best judgement of its developers to represent typical industrial conditions. It also includes conditions that provide consistency in the test method. Thus, the results can be used as a reference that a user can apply to judge against any other set of conditions.

In particular applications, the requirements of this part of ISO 19973 may be modified to suit a specific stress level, test condition or duty cycle. However, such testing shall follow all of the other requirements for test methods and data analysis specified in this part of ISO 19973.

6.2 Test stand and measurement of parameters

Two other important factors are the test stand and measurement of parameters. The test stand shall be designed to operate reliably within the planned environmental conditions. Its configuration shall not affect the results of the test being run on the component. Evaluation and maintenance of the test stand during the reliability test program is critical. The accuracy of parameter measurement and control of parameter values shall be within the specified tolerances to ensure accurate and repeatable test results.

6.3 Test planning

Proper test planning is essential in order to produce results that accurately predict the component's reliability under specified conditions. The goals and objectives of the test program shall be clearly defined if a supplier and user agree to apply ISO 19973 (all parts).

7 Statistical analysis

The resulting test data shall be evaluated for assessing the reliability. One of the most commonly used methods is the Weibull analysis because of its versatility in modelling various statistical distributions. This method shall be used for the analysis of the test data to ensure comparability of the results. Examples of applying Weibull analysis are given in the Annex C and Annex D.

NOTE Commercial software can be helpful for this purpose.

8 Test conditions

8.1 Testing shall be carried out in accordance with the provisions defined in the part of ISO 19973 that relates to the component tested, including the test parameters that are measured and threshold levels specified for each test parameter.

8.2 No repairs are permitted on the test units during the reliability test.

8.3 Unless otherwise specified in the relevant part of ISO 19973 that relates to the component being tested, or when agreed between the user and supplier, all tests shall be carried out under the conditions specified in Table 2.

Table 2 — General test conditions

Parameter	Value
Test pressure	630 kPa ± 30 kPa (6,3 bar ± 0,3 bar)
Ambient temperature	23 °C ± 10 °C
Temperature of the medium	23 °C ± 10 °C
Filtration: nominal filtration rating	5 µm
Dryer: maximum inlet or test pressure dew point[a]	+7 °C
Lubrication	None

[a] Testing at dew points of less than −20 °C could result in shorter lifetimes.

8.4 Temperature changes due to thermodynamic processes while pressurizing and depressurizing test units should be considered during the setup and initial running period of the first day. If the temperature change of the test unit's body exceeds ±20 °C during the initial running period, the test frequency should be adjusted. Later adjustments of the test frequencies are not permitted.

8.5 During the endurance test, test units shall be operated continuously, and the measuring intervals for recording data shall be determined taking into account the experience and judgement of the people conducting the test. A measuring interval of one week is recommended.

8.6 Except for cylinders, the volume at outlet ports depends on the component's sonic conductance, *C*, as determined in accordance with ISO 6358 (all parts). The volumes shall meet or exceed the minimum values given in Table 3.

NOTE During testing, the volumes at the outlet ports can become hot. It is necessary to take care to protect personnel.

Table 3 — Minimum volume at the outlet ports, based on component's sonic conductance

Sonic conductance *C* dm³/(s·kPa)(ANR)	Minimum volume at the outlet ports cm³
$C \leq 0{,}004$	2
$0{,}004 < C \leq 0{,}04$	10
$0{,}04 < C \leq 0{,}12$	25
$0{,}12 < C \leq 0{,}2$	50
$0{,}2 < C \leq 0{,}4$	100
$C > 0{,}4$	200

9 Sample size and selection criteria

9.1 The samples shall be representative of the population and shall be selected randomly.

9.2 The minimum sample size shall be seven test units.

NOTE It is important that the sample has at least seven test units in order that the first data point on the Weibull graph is below the 10 % cumulative-failure point. This allows a more accurate projection of the lower confidence limit lines to intersect the 10 % cumulative-failure point and determine a B_{10} life.

9.3 For a product series with the same design principle, it is not necessary to test all types or sizes. However, the test program shall include the type with the most critical conditions, for example, highest stress caused by velocity or load.

10 End of test

10.1 Minimum number of failures required

The minimum number of test units that are required to fail (e.g. reach a threshold level) is described in Table 4. This number does not include suspensions, which are not considered failures.

NOTE It is desirable to achieve at least 10 failures in accordance with IEC 61649. Fewer failures result in a wider confidence interval and a shorter $(B_{10})_{95\ \%}$ life at the lower confidence limit.

Table 4 — Minimum number of failures for evaluation of the characteristic life

Sample size	7	8	9	10	>10
Minimum numbers of failures	5	6	7	7	70 % of the sample size

10.2 Termination time of a test unit

A test unit shall be terminated from testing when its life reaches the first failure, calculated as follows: First, determine a three-point moving average of the test data on a continuous basis (an example is shown in Annex A). When the three-point moving average exceeds the threshold value, the test unit shall have reached a first failure and shall be terminated from testing.

10.3 Termination life

The termination life shall be the last time at which the three-point moving average did not exceed the threshold, or the time preceding a catastrophic failure. If a more precise determination of the termination life is desired, performance of a test unit can be monitored with limit switches or other suitable means to detect failures.

10.4 Suspended test unit

Testing on an individual test unit may be stopped before a relevant failure occurs. This is known as a suspension. Some examples of suspensions include

— a unit which has been disassembled for inspection, or

— a unit which has been accidentally crushed.

Suspensions have an influence on the result of calculating the statistical parameters and should therefore be considered. See Annex D.

10.5 Censored test

If the test is stopped after the minimum number of failures specified in Table 4 is reached but the remaining test units are still operating, the test shall be considered censored. If the censored test does not include any suspensions, the method specified in Annex C should be used to calculate the statistical parameters. If the censored test includes one or more suspensions, the method specified in Annex D should be used to calculate the statistical parameters.

11 Evaluation of reliability characteristics from the test data

11.1 To improve the interpretation of the calculation results, the failure mode shall be specified and recorded.

11.2 The Maximum Likelihood Estimation or Median Rank Regression shall be used to determine the best fit of the Weibull curve to the test data, and the Fisher Matrix shall be used to determine the confidence bounds.

11.3 Calculations shall be made from the test data to determine the following:

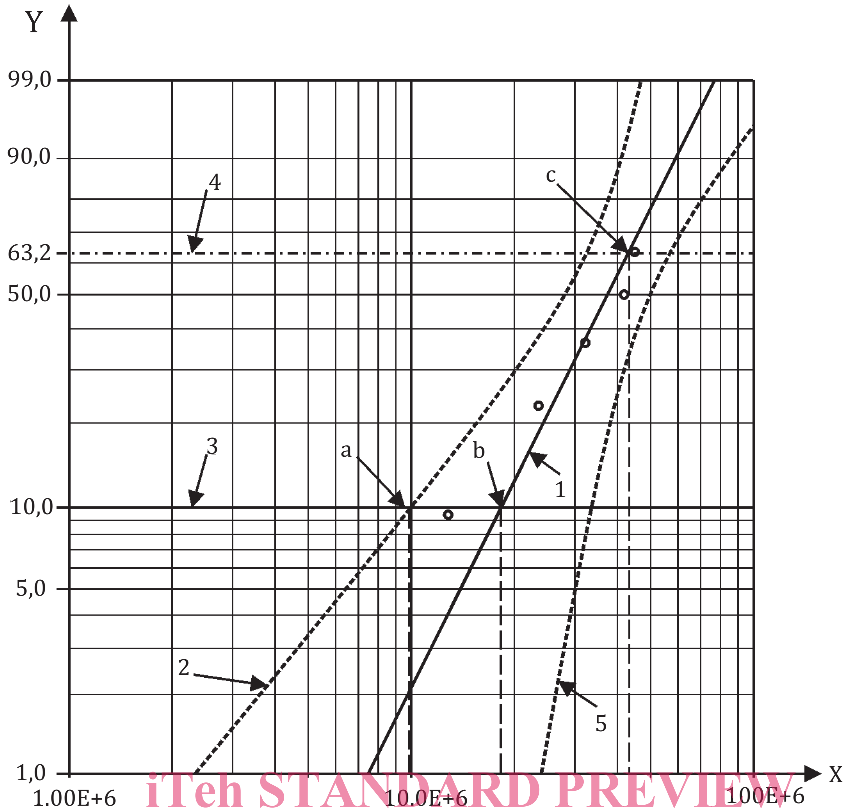
— characteristic life, η: relative location of the straight line in the Weibull plot relative to the x-axis (time or scale parameter);

— Weibull shape parameter, β: slope of the straight line in the Weibull plot.

11.4 Calculate the B_{10} life at the best fit line (see Figure 1, key b).

NOTE See Annex D for information on how to deal with censored data with suspensions.

11.5 Calculate the confidence limit of the $(B_{10})_{95\ \%}$ life at the lower 95 % confidence level (see Figure 1, key a).



Key

X number of cycles to failure, *t*

Y probability of failure, expressed as a percentage

1 best fit line, determined by the Maximum Likelihood Estimation

2 lower confidence limit at 95 %, obtained by Fisher Matrix

3 10 % failure probability line

4 63,2 % failure probability line

5 upper confidence limit at 5 %

[a] $(B_{10})_{95\ \%}$ life at the lower, one-sided 95 % confidence level.

[b] B_{10} life.

[c] Characteristic life, η.

NOTE Commercial software can be useful in constructing the graphs.

Figure 1 — Example of how a B_{10} life value is determined from a Weibull curve

12 Test report

The test report shall include at least the following data:

a) number of the relevant part of ISO 19973, including the component-specific part number (for example, ISO 19973-2 for valves);

b) date of the test report;

c) component description (manufacturer, type designation, series number);

d) sample size;

e) test conditions (test pressure, temperature, air quality, frequency, load, etc.);

f) threshold levels;

g) type of failure for each test unit;

h) B_{10} life at the median rank, and confidence limit of $(B_{10})_{95\ \%}$ life at one-sided 95 % confidence level;

i) characteristic life, η, and shape parameter, β;

j) number of failures considered and test interval used;

k) method used to calculate the Weibull data (for example, maximum-likelihood, median rank regression, Fisher Matrix);

l) Weibull plot;

m) other remarks, as necessary.

13 Identification statement (reference to this part of ISO 19973)

It is recommended that manufacturers use the following statement in test reports, catalogues and sales literature when electing to comply with this part of ISO 19973:

"General procedures for assessing pneumatic component reliability by testing performed in accordance with ISO 19973-1, *Pneumatic fluid power — Assessment of component reliability by testing — Part 1: General procedures*."