INTERNATIONAL STANDARD

ISO 19973-2

First edition
2007-08-01

Pneumatic fluid power — Assessment of component reliability by testing —

Part 2: Directional control valves

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

Partie 2: Distributeurs

Reference number
ISO 19973-2:2007(E)

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Published in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 19973-2 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*.

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*

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. Within the ISO 19973 series, this Part 2 is intended to provide requirements and test conditions that permit the assessment of the inherent reliability of pneumatic and electro-pneumatic directional control valves.

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, 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.

Pneumatic fluid power — Assessment of component reliability by testing —

Part 2:
Directional control valves

1 Scope

This part of ISO 19973 provides test procedures for determining the reliability of pneumatic directional control valves by testing and the methods of reporting the results of testing. General test conditions and the calculation method are provided in part 1 of ISO 19973. The methods specified in that part of ISO 19973 apply to the first failure without repairs, but exclude outliers.

The lifetime of pneumatic and electro-pneumatic directional control valves is usually given as a number of cycles. Therefore, whenever the term “time” is used in this part of ISO 19973, this variable is be understood as cycles.

This part of ISO 19973 also specifies test equipment and threshold levels for tests to determine the reliability of pneumatic directional control valves.

2 Normative references

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.

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units*

ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols for conventional use and data-processing applications*

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

ISO 6358, *Pneumatic fluid power — Components using compressible fluids — Determination of flow-rate characteristics*

ISO 8778, *Pneumatic fluid power — Standard reference atmosphere*

ISO 19973-1, *Pneumatic fluid power — Assessment of component reliability by testing — Part 1: General procedures*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598, ISO 19973-1 and IEC 60050-191 apply. Where a conflict of definitions exists for a term in any of these three documents, the following priority order applies: first, ISO 19973-1; second, ISO 5598; and third, IEC 60050-191.

4 Symbols and units

4.1 Units of measurement are in accordance with ISO 1000.

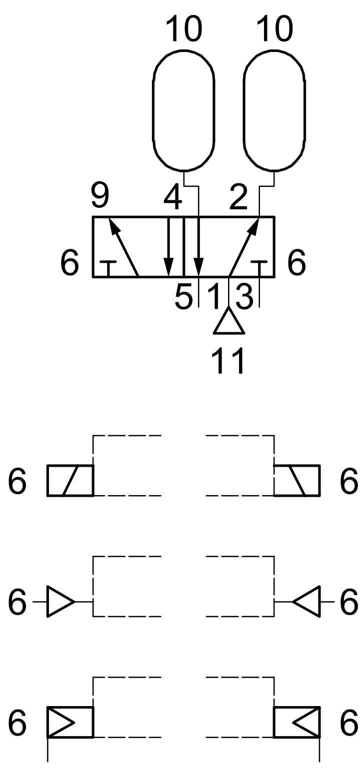
4.2 Graphic symbols used in this part of ISO 19973 conform to the requirements of ISO 1219-1.

5 Test equipment

5.1 Basic test equipment

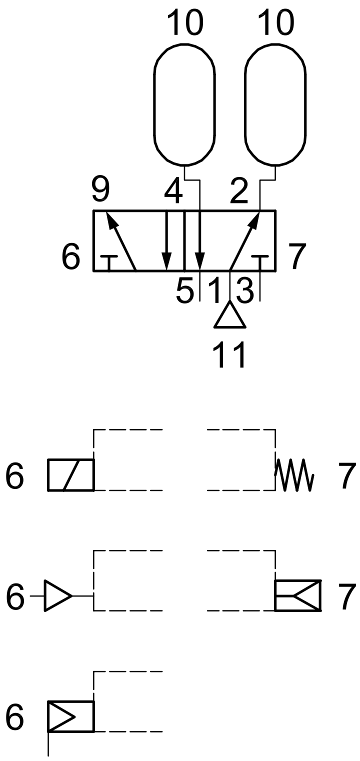
Basic test equipment shall conform to the requirements given in Table 1 and Figure 1. Any silencers fitted to exhaust ports shall not restrict the valve’s flow rate.

The basic circuits in Figure 1 do not incorporate all the safety devices necessary to protect against damage in the event of component failure. It is important that those responsible for carrying out the test give due consideration to safeguarding both personnel and equipment.

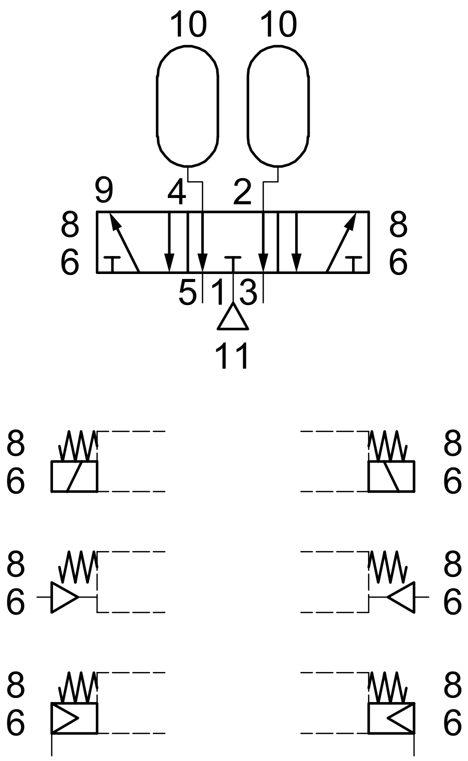


a) Two-position bi-stable valves

Figure 1 — Basic test equipment requirements (*continued*)



b) Two-position monostable valves with spring or air return



c) Three-position valves

Key

1 to 5 ports

6 control signal: electrical, pneumatic, or pilot-operated

7 spring or air-spring return

8 spring return to centre position

9 valve being tested

10 volume at working ports

11 supply pressure to port 1

The pilot supply can be either internal or external as long as it has the capability described in 8.3.

Figure 1 — Basic test equipment requirements

5.2 Volume at working ports

The volume at the working ports depends on the valve's sonic conductance, C, as determined in accordance with ISO 6358. The volumes shall meet or exceed the minimum values given in Table 1.

CAUTION — During testing, the volumes at working ports can become hot. It is necessary to take care to protect personnel.

Table 1 — Minimum volume at the working ports, based on valve's sonic conductance

Sonic conductance C dm³/(s·MPa)	**Minimum volume at working ports** ml
$C \leqslant 4$	2
$4 < C \leqslant 40$	10
$40 < C \leqslant 120$	25
$120 < C \leqslant 200$	50
$200 < C \leqslant 400$	100
$C < 400$	200

5.3 Recommended tube sizes for supply line

5.3.1 Connect the volume to the working ports of the test units either directly or by means of sections of tubes, in a manner that does not restrict flow.

5.3.2 Tubes in the connecting lines shall be kept as short as possible so that the volumes can be charged and vented within the times provided by the control signal.

5.4 Simultaneous operation of multiple pneumatically operated valves

When testing pneumatically operated valves, several test units may be operated simultaneously from one control valve. In doing so, the control pressure described in 6.2.1 shall be applied to all test units.

6 Test conditions

6.1 General test conditions

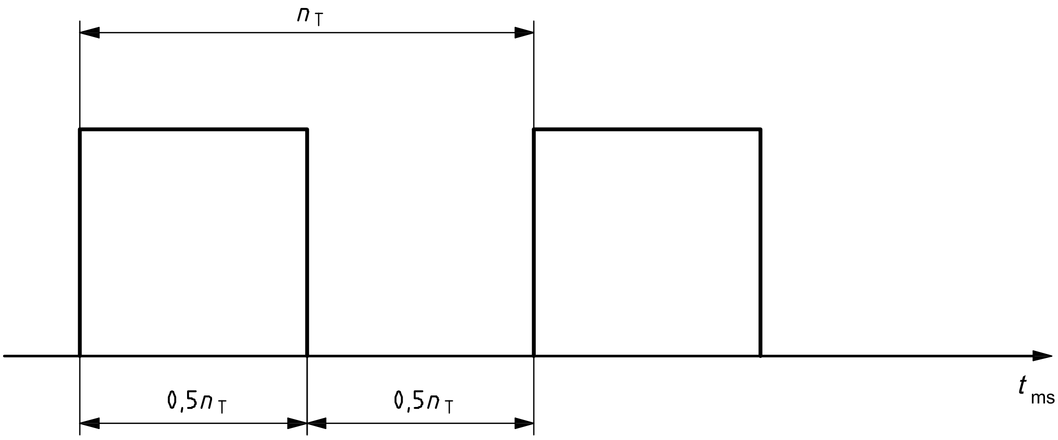
The general test conditions shall be in accordance with ISO 19973-1.

6.2 Cycling frequencies

6.2.1 Actuate the test valves in a manner to ensure that the pressure in the working port volumes drops below 10 %, and rises above 90 %, of the supply pressure during the cycle.

6.2.2 The ratio between the actuation-impulse on/off times shall be 1:1.

6.2.3 For monostable two-position valves, the control signal shall be applied in accordance with Figure 2.



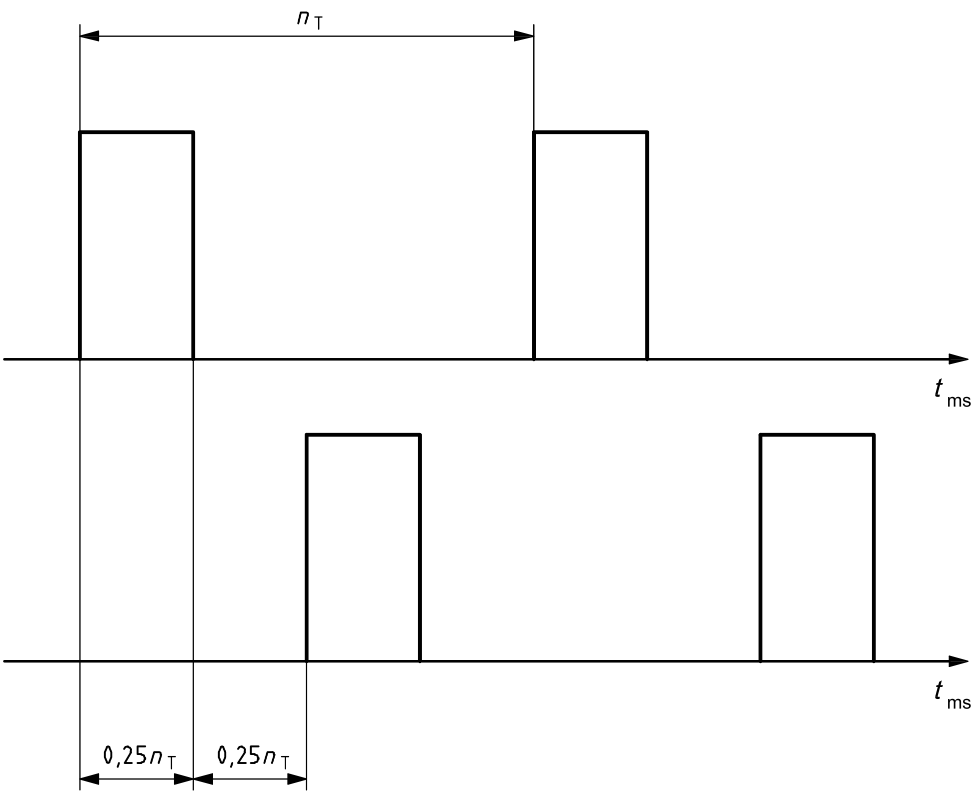
Key

n_T cycle

t_{ms} time, expressed in milliseconds

Figure 2 — Control signal for monostable two-position valves

6.2.4 For bistable and three-position valves, the control signal shall be applied in accordance with Figure 3.



Key

n_T cycle

t_{ms} time, expressed in milliseconds

Figure 3 — Control signal for bistable and three-position valves

7 Test measurement periods

7.1 Timing of checks and measurements

7.1.1 The following checks and measurements shall be made before, during and after the endurance test:

— functional check in accordance with 7.2;

— leakage measurement in accordance with 8.1;

— measurement of pressure characteristics in accordance with 8.2 and 8.3.

7.1.2 Measuring intervals shall be determined in accordance with ISO 19973-1.

7.2 Functional check

Test units shall be checked acoustically, optically and tactilely under test conditions to determine whether the test units and the valves controlling them are operating correctly. The functional check is to see whether switching failures, sticking, incomplete charging of an output or detectable or audible leakage are occurring. Remarkable characteristics shall be documented.

If test units fail between consecutive observations, the termination cycle count shall be determined in accordance with ISO 19973-1.

8 Test measurement requirements

8.1 Leakage measurement

8.1.1 The total leakage (internal and external) shall be measured in each case in all valve positions with working pressure applied to the inlet port.

8.1.2 In addition, the following types of leakage may be measured for the valve type indicated:

— for pneumatically controlled valves: leakage rate in all internal pneumatic pilot lines and control chambers without working pressure applied to the inlet port, but with pilot pressure applied;

— for valves with auxiliary pilot air: leakage rate in all internal pneumatic pilot lines in all valve positions without working pressure applied to the inlet port, but with pilot pressure applied;

— for three-position valves with closed centre position: leakage rate in the closed centre position at the open outlet ports with inlet pressure applied to the inlet port; then leakage at the exhaust ports after applying working pressure to the outlet ports;

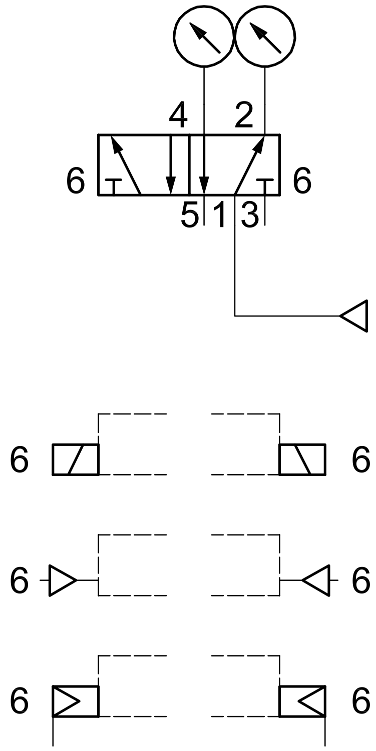
— for three-position valves with other types of centre positions: leakage rate at the exhaust ports with the valve in the centre position and with working pressure applied to the inlet port;

— for electrically controlled bistable valves: leakage rate in each valve position with the solenoid energized and de-energized.

8.2 Measurement of immediate shifting pressures

8.2.1 Determination of correct shifting

To determine if the test unit is shifting correctly, that is, whether the pressure at the outlet ports of a test unit increases and decreases fully without leakage, a pressure gauge shall be connected to the outlet ports of the test unit (see Figure 4).



Key

1 to 5 ports

6 control signal: electrical, pneumatic or pilot-operated

Figure 4 — Measuring circuit

8.2.2 Measurement for monostable two-position valves

8.2.2.1 Shifting pressure for electrically operated valves

For valves with internal pilot supply, apply the electrical control signal (with nominal voltage) alternately ON-OFF and increase the pressure continuously on port 1 until correct shifting is observed.

For valves with an external pilot supply, apply working pressure to port 1. Apply the electrical control signal (with nominal voltage) alternately ON-OFF and increase the pressure continuously on the pilot port until correct shifting is observed.

8.2.2.2 Shifting pressure for pneumatically operated valves

Apply working pressure to port 1. Activate the control valve alternately ON-OFF and increase the pressure on the pilot until correct shifting is observed.

8.2.3 Measurement for bistable valves and three-position valves

8.2.3.1 Shifting pressure for electrically operated valves

For valves with an internal pilot supply, apply the electrical control signal (with nominal voltage) at each side alternately and increase the working pressure continuously on port 1 until the valve shifts in all valve positions.

For valves with an external pilot supply, apply the working pressure to port 1. Apply the electrical control signal (with nominal voltage) at each side alternately and increase the pilot pressure continuously until the valve shifts in all valve positions.

8.2.3.2 Shifting pressure for pneumatically operated valves

Apply the working pressure to port 1, apply control signal at control valves alternately and increase the pilot pressure at the control valves continuously until the valve shifts in all valve positions.

8.2.4 Data to report

The pressure at which correct shifting occurs shall be recorded and reported as the shifting pressure.

8.3 Measurement of shifting pressures after rest period

Every time a function test is conducted, perform the test specified in 8.2 after the test units have remained motionless for 24 h in the pressurized condition. Monostable valves shall remain in the position from which the next shift requires the higher shifting force. With supply pressure continuously applied to the inlet port, increase or decrease the pilot pressure until the valve shifts. Record the pilot pressure at which the valve first shifts.

If the test valves are internal pilot types, use the external pilot exhaust port to either apply or reduce a supplementary pilot pressure for this test. If necessary, the pilot flow path in the test valve may be modified to permit control of this supplementary pilot pressure.

9 Threshold levels

9.1 General

The test unit shall be considered to fail if any one of the threshold levels or failure criteria specified in 9.2 through 9.4 is reached.

9.2 Functional failure

The test unit shall be considered to fail if it does not provide the functionality specified in 7.2.

9.3 Failure due to leakage

9.3.1 The leakage of new test units shall not exceed the manufacturer’s specifications for this characteristic.

9.3.2 The test unit shall be considered to fail if the total leakage at any position, measured in accordance with 8.1, exceeds the values in Table 2.

Table 2 — Threshold values for leakage rate measured during the test

Sonic conductance C dm³/(s·MPa)	Maximum leakage rate dm³/h (ANR) [a]	
	Valves with soft sealing (class 1.5 [b])	**Valves with metal-to-metal sealing (class 2.5 [b])**
$C \leqslant 10$	6,0	60
$10 < C \leqslant 16$	8,0	80
$16 < C \leqslant 28$	11,0	110
$28 < C \leqslant 46$	14,0	140
$46 < C \leqslant 80$	18,0	180
$80 < C \leqslant 130$	23,0	230
$130 < C \leqslant 220$	30,0	300
$220 < C \leqslant 360$	38,0	380
$360 < C \leqslant 600$	50,0	500
$600 < C \leqslant 1000$	63,0	630

[a] In accordance with ISO 8778.

[b] See Annex A.

9.4 Failure due to pressure characteristics

The test unit shall be considered to have failed if the pressure characteristics for solenoid valves or pneumatically operated valves measured in accordance with 8.2 and 8.3 exceed the minimum working pressure given in the manufacturer's datasheet or product specification.

10 Data analysis

Test data shall be analysed in accordance with ISO 19973-1.

11 Test report

Data shall be reported in accordance with ISO 19973-1.

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

It is strongly recommended to manufacturers who have chosen to conform to this part of ISO 19973 that the following statement be used in test reports, catalogues and sales literature:

"Reliability and lifetime of pneumatic valves assessed in accordance with ISO 19973-2, *Pneumatic fluid power — Assessment of component reliability by testing — Part 2: Directional control valves*."

Annex A
(informative)

Determination of threshold values for leakage rates

A.1 Introduction

The threshold values listed in Table 2 were determined according to the method described in this annex. This method allows a systematic determination of threshold values for pneumatic components. The equations in this annex do not describe physical correlations or physical laws but are used only for the calculation of the threshold values.

A.2 Symbols

The symbols listed in Table A.1 are used in this annex.

Table A.1 — Symbol list

Symbol [a]	Description	SI unit
C	Sonic conductance	$dm^3/(s \cdot MPa)$
c	Subscript for critical values, e.g. for threshold or size	—
S	Component size Representative dimensions or performance data, such as piston diameter or nominal diameter	millimetres raised to the nth power
K	Leakage level coefficient	$\frac{dm^3/h \text{ (ANR)}}{mm^n}$
m	Threshold class (superscript) Groups of pneumatic components can be allocated to different threshold levels by using a threshold class factor. This may be necessary to concern different quality classes or design principles.	—
n	Slope index (superscript) The physical correlation between leakage and its cause is described by the slope index. The value of n is limited to $n = 1$ or $n = 2$. For linear correlations, such as diameter of a piston or length of a sealing device, the slope index is $n = 1$. For squared correlations, such as area of orifices or related energy, the slope index is $n = 2$.	—
p_{abs}	Absolute working pressure	megapascals
q	Threshold value	dm^3/h (ANR)

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

A.3 Principle of modelling threshold values for leakage rates

A.3.1 The threshold value, q, expressed in dm^3/h (ANR), can be calculated by using Equations (A.1) and (A.2):

$$q = K \cdot S^n \tag{A.1}$$

where $S \geqslant S_c$.

The threshold value for a small component (below a critical size) can be limited to a certain value:

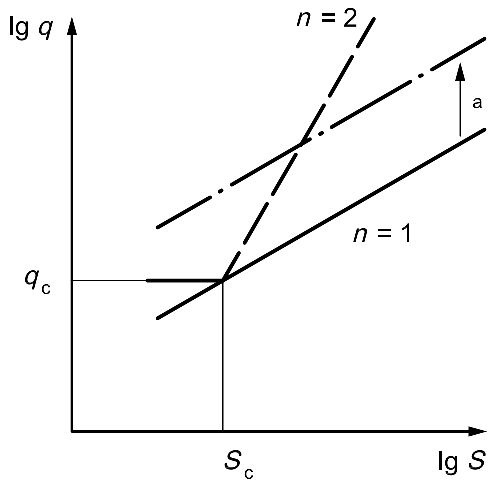
$$q = q_c = K \cdot S_c^n \tag{A.2}$$

where

$S < S_c$;

$$K = 0{,}06 \cdot 10^m \cdot p_{abs}. \tag{A.3}$$

A.3.2 Figure A.1 shows a graph that illustrates threshold values and the influences of different parameters.



Key

n slope index; examples for $n = 1$ and $n = 2$ are shown in the graph

S_c critical component size

q_c critical threshold value

a Influence of leakage level, K, and threshold class m [see also Equation (A.3)].

Figure A.1 — Graph illustrating threshold values and influences of parameters

A.4 Leakage-rate threshold values for valves

A.4.1 The leakage-rate threshold values listed in Table 2 were calculated using Equations (A.1), (A.2) and (A.3).

a) Component size, S, was related to the valve's sonic conductance using Equation (E.4):

$$S = 1{,}45 \cdot \sqrt{C} \qquad \text{(A.4)}$$

NOTE The factor 1,45 was chosen to meet threshold values that are based on experiences of the experts of the Technical Committee ISO/TC 131, Working Group WG 4.

b) Two threshold classes were defined for valves:

1) class 1.5, to be used for valves with soft sealing;

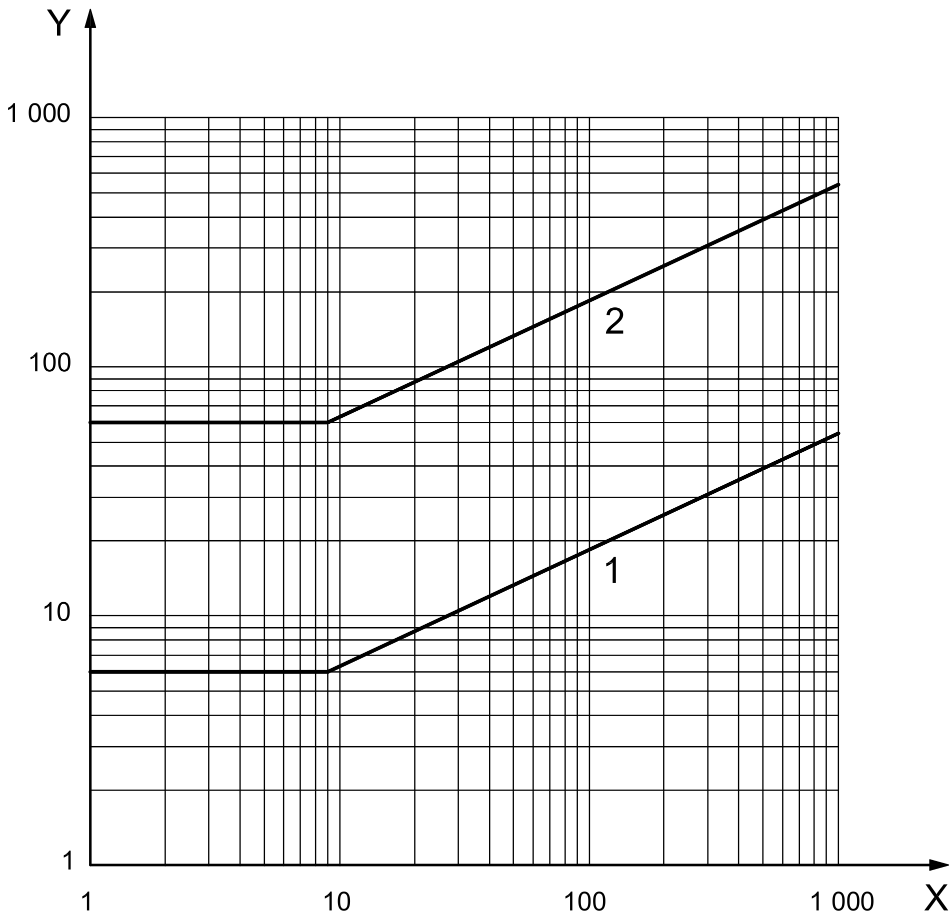
2) class 2.5, to be used for valves with metal-to-metal sealing.

c) The slope index, n, was set to equal to 1, because the leakage of a valve is related to the length of the internal sealing devices.

d) An absolute working pressure, p_{abs}, of 0,73 MPa was used.

e) The critical threshold value, q_c, was defined as 6 dm^3/h for class 1.5 (valves with soft sealing) and as 60 dm^3/h for class 2.5 (valves with metal-to-metal sealing).

The results are shown in Figure A.2.



Key

X sonic conductance, C, expressed in $dm^3/(s \cdot MPa)$

Y leakage rate, q, expressed in dm^3/h (ANR)

1 threshold level for class 1.5

2 threshold level for class 2.5

Figure A.2 — Leakage-rate threshold values for valves

A.4.2 The leakage rate threshold values in Table 2 are in accordance with Figure A.2 (rounded values).

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