BS ISO 19973-4:2014

BSI Standards Publication

Pneumatic fluid power — Assessment of component reliability by testing

Part 4: Pressure regulators

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National foreword

This British Standard is the UK implementation of ISO 19973-4:2014. It supersedes BS ISO 19973-4:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/18, Fluid power systems and components.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Pneumatic fluid power — Assessment of component reliability by testing —

Part 4: **Pressure regulators**

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

Partie 4: Régulateurs de pression

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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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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 19973-4:2007), 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*

The following part is under preparation:

— *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. Within the ISO 19973 series, this part is intended to provide requirements and test conditions that permit the assessment of the inherent reliability of pneumatic pressure regulators.

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 4: Pressure regulators

1 Scope

This part of ISO 19973 provides test procedures for assessing the reliability of pneumatic pressure regulators by testing and the methods of reporting the results of testing. General test conditions and the calculation method are provided in ISO 19973-1. The methods specified in ISO 19973-1 apply to the first failure, as obtained with the three-points moving average (3PMA) method, without repairs, but excluding outliers.

The lifetime of pneumatic pressure regulators is usually given as a number of cycles. Therefore, whenever the term "time" is used in this part of ISO 19973, this variable shall be understood as either cycles or time.

This part of ISO 19973 applies to manually adjustable and remote-piloted pressure regulators, both relieving and non-relieving. This part of ISO 19973 does not apply to pressure regulators that have a permanent bleed.

This part of ISO 19973 also specifies test equipment and failure criteria (threshold levels) for tests to assess the reliability of pneumatic pressure regulators.

The life determined by the method in this part of ISO 19973 and in ISO 19973-1 will be more closely related to applications that have a large variation in flow rate.

NOTE See Annex A for a flow chart illustrating the test procedure specified in this part of ISO 19973.

2 Normative references

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

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

ISO 6953-1, *Pneumatic fluid power — Compressed air pressure regulators and filter-regulators — Part 1: Main characteristics to be included in literature from suppliers and product-marking requirements*

ISO 6953-3, *Pneumatic fluid power — Compressed air pressure regulators and filter-regulators — Part 3: Alternative test methods for measuring the flow-rate characteristics of pressure regulators*

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

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

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

1) To be published. (Revision of ISO 19973-1:2007)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598, ISO 6953-1, ISO 19973-1, and IEC 60050-191 apply.

NOTE Where a conflict of definitions exists for a term in any of these four documents, the following priority order shall apply: first, ISO 19973-1; second, ISO 6953-1; third, ISO 5598; and fourth, IEC 60050-191.

4 Symbols and units

4.1 The units of measurement are in accordance with ISO 80000-1.

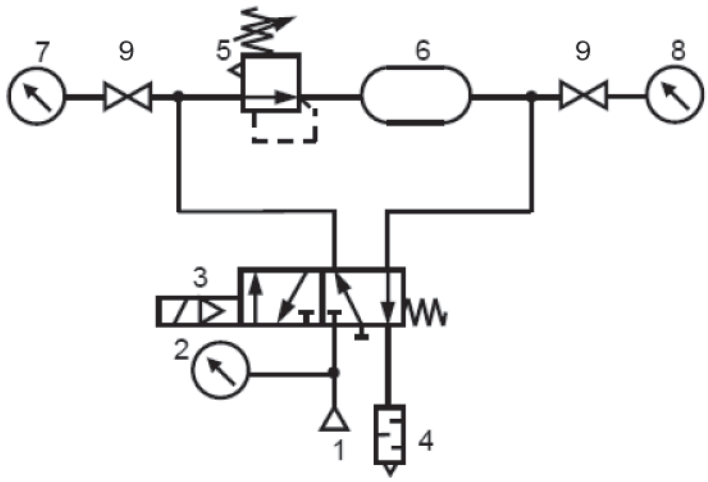
4.2 The graphic symbols used in this part of ISO 19973 conform to the requirements of ISO 1219-1.

5 Test equipment

5.1 Basic test equipment

5.1.1 Each pressure regulator to be tested (test unit) shall be installed in a test circuit that includes the components shown in either Figure 1 or Figure 2. Multiple test circuits can use the same source of compressed air; if this is the case, each test circuit shall be composed of identical components. Annex B describes an optional expanded test circuit that incorporates additional components to isolate measuring instruments.

Figure 1 illustrates a basic circuit that does 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.

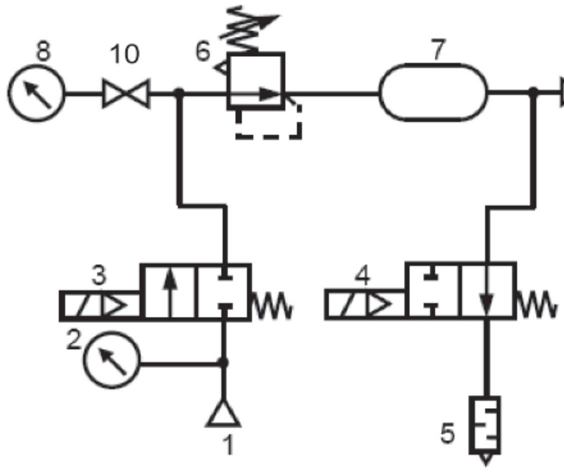


Key

1 supply
2 pressure gauge for measuring pressure, p_1
3 five-port, two-position directional control valve
4 silencer
5 pressure regulator under test (i.e. test unit) (example)
6 volume
7 pressure gauge or transducer for measuring pressure, p_2
8 pressure gauge or transducer for measuring pressure, p_3
9 shut-off valve or quick-action coupling

Figure 1 — Test circuit

5.1.2 An alternative test circuit in accordance with Figure 2 can also be used, if the five-port, two-position directional control valve (key item 3 in Figure 1) is too large. In this circuit, the two-port, two-position directional control valves shall be operated simultaneously.



Key

1 supply
2 pressure gauge for measuring pressure, p_1
3 two-port, two-position directional control valve (NC, normally closed)
4 two-port, two-position directional control valve (NO, normally open)
5 silencer
6 pressure regulator under test (example)
7 volume
8 pressure gauge or transducer for measuring pressure, p_2
9 pressure gauge or transducer for measuring pressure, p_3
10 shut-off valve or quick-action coupling

Figure 2 — Alternative test circuit

5.1.3 If the body of the test unit has ports of two or three different sizes, use the largest port size.

5.1.4 Before installing the test units, perform a forward flow test on them in accordance with ISO 6953-3. Determine the forward sonic conductance, C_f, of each test unit in accordance with ISO 6953-3.

5.1.5 Install pressure measuring instruments (gauges or transducers) into the test circuit as shown in Figure 1 (key items 2, 7, and 8) or Figure 2 (key items 2, 8, and 9), using either quick action couplings or shut-off valves (key item 9 in Figure 1 and key item 10 in Figure 2).

5.2 Directional control valve

An external pilot type or direct-operated type of directional control valve is used in the test circuit. The sonic conductance, C, of the directional control valve used shall be greater than or equal to the C_f value measured for the test unit in 5.1.4. The size of the directional control valve shall also ensure that the requirements of 7.3.1 b) will be fulfilled.

5.3 Volumes

Volumes 6 or 7, in Figures 1 and 2 respectively, shall be sized as described in Table 3 of ISO 19973-1:—.

6 Test conditions

6.1 General test conditions

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

6.2 Inlet and regulated pressures

6.2.1 The inlet pressure to the test unit shall be 800 kPa ± 40 kPa, or the maximum rated inlet pressure, if it is less than this value.

6.2.2 The regulated pressure set point shall be 80 % (±5 %) of the inlet pressure or 80 % (±5 %) of the manufacturer's rated maximum regulated pressure, whichever is lower (see Figure 3). When obtaining this setting, the adjustment shall be made while regulated pressure is increasing. If the pressure exceeds the desired set point during this process, the pressure shall be reduced well below the desired set point and adjusted again while regulated pressure is increasing. The set point shall never be obtained while regulated pressure is decreasing.

6.2.3 To compensate for initial drift before starting the test, carefully readjust the set point of the test unit to the conditions described in 6.2.2 after 24 h of continuous cycling. Record this reset pressure as the initial set pressure.

7 Test procedure

7.1 Timing of checks and measurements

7.1.1 The following checks and measurements shall be made before the endurance test, at measuring intervals during the endurance test, and after a test unit is removed from the test:

a) functional check in accordance with 7.2.1;

b) set pressure and leakage measurement in accordance with 7.2.2.

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

7.2 Type and scope of checks and measurements

7.2.1 Functional check

Test units shall be checked acoustically, optically, and tactilely and frequently under test conditions to determine whether the test units and the valves controlling them are operating correctly. The objective is to determine whether switching failures or incomplete charging or discharging at the outlet is occurring. Determine if there is audible or detectable leakage. If any of these conditions are observed, perform the tests specified in 7.2.2. Otherwise, any remarkable characteristics shall be documented.

7.2.2 Set pressure and leakage measurements

At each measuring interval (as determined in 7.1.2), energize the directional control valve and allow the temperature to stabilize. Record the set pressure, then record the total leakage measurement (i.e. the sum of internal and external leakage) over a 2 min period with the test pressure as specified in 6.2.1 applied to the inlet port. Leakage shall be measured with a flow meter before the inlet port. The pressure setting of the test unit shall not be adjusted during this step, nor readjusted afterwards.

7.3 Endurance test

7.3.1 Cycle the directional control valve at a rate determined as follows.

a) At the beginning of the test, record the maximum pressure and minimum pressure reached on the outlet side of the test unit (i.e. at the pressure gauge that measures p_3) during the pressure cycle.

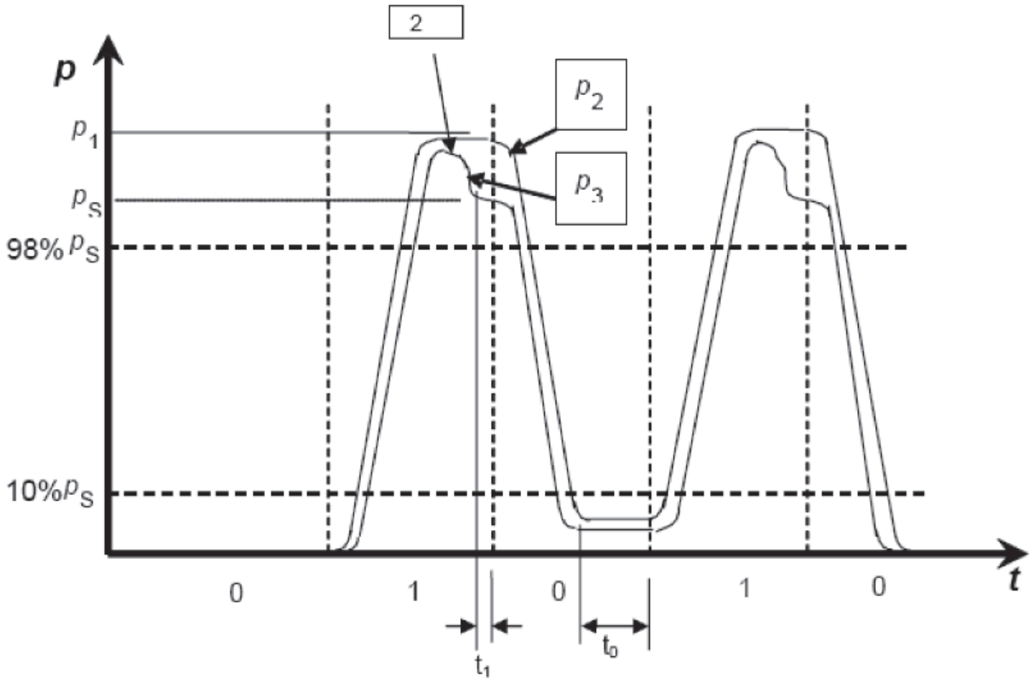
b) Ensure that the maximum pressure reached on the outlet side of the test unit is equal to or greater than 98 % of the initial set pressure, and the minimum pressure reached on the outlet side of the test unit during the exhaust phase is less than 10 % of the initial set pressure (see 6.2.3).

c) Adjust the directional control valve cycle time to achieve these conditions, keeping t_1 and t_0 as small as possible.

d) Maintain a constant cycle rate throughout the test. No adjustments shall be made to this rate or to the set point.

e) Repeat the pressure measurements in step a) occasionally during the test.

Figure 3 provides an illustration of a typical pressure cycle trace.



Key

p	pressure
t	time
0	time period during which the directional control valve is de-energised
1	time period during which the directional control valve is energised
2	possible overshoot
t_1, t_0	dwell time between pressure changes
p_1	inlet supply pressure
p_2	trace of pressure at inlet of test unit
p_3	trace of pressure at outlet of test unit
p_s	set pressure of test unit

Figure 3 — Typical pressure-cycle traces for the endurance test

7.3.2 Operate the test units continuously. Test units and directional control valves shall be checked periodically to ensure that they are functioning properly as described in 7.2.1.

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

8 Failure criteria and threshold levels

8.1 General

A test unit shall be considered to have failed if any one of the threshold levels or failure criteria specified in 8.2 through 8.4 is reached. The evaluation method of failures is described in ISO 19973-1.

8.2 Functional failure

A test unit shall be considered to have failed if it does not provide the functionality specified in 7.2.1.

8.3 Failure due to leakage

A test unit shall be considered to have failed if the total leakage rate determined in 7.2.2 exceeds the maximum allowable total leakage rate given in Table 1. (The threshold values for leakage rate are developed as described in Annex B of ISO 19973-1:—[2]).

Table 1 — Threshold values for maximum total leakage rate in relation to the sonic conductance of the test unit

Sonic conductance, C_f $dm^3/(s \cdot bar)$ (ANR)	**Maximum leakage rate** dm^3/h (ANR)[a]
$C_f \leq 1$	8,0
$1 < C_f \leq 1,6$	10
$1,6 < C_f \leq 2,8$	13
$2,8 < C_f \leq 4,6$	17
$4,6 < C_f \leq 8$	22
$8 < C_f \leq 13$	28
$13 < C_f \leq 22$	37
$22 < C_f \leq 36$	47
$36 < C_f \leq 60$	60
$60 < C_f \leq 100$	80
$100 < C_f$	100

[a] In accordance with ISO 8778.

8.4 Failure due to pressure characteristics

A test unit shall be considered to have failed if it does not maintain the set pressure within ±7 % or ±10 kPa, whichever is greater, of its initial value at the start of the test (as measured in 6.2.3).

8.5 Customised agreements

Individual customers and industry segments can use different threshold levels and requirements that do not conform to ISO 19973. Special agreements shall be documented in test reports and in catalogue data.

9 Data analysis

Test data shall be analysed in accordance with ISO 19973-1. An example of a test data sheet is shown in Annex C of this part of ISO 19973.

2) To be published. (Revision of ISO 19973-1:2007)

10 Test report

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

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

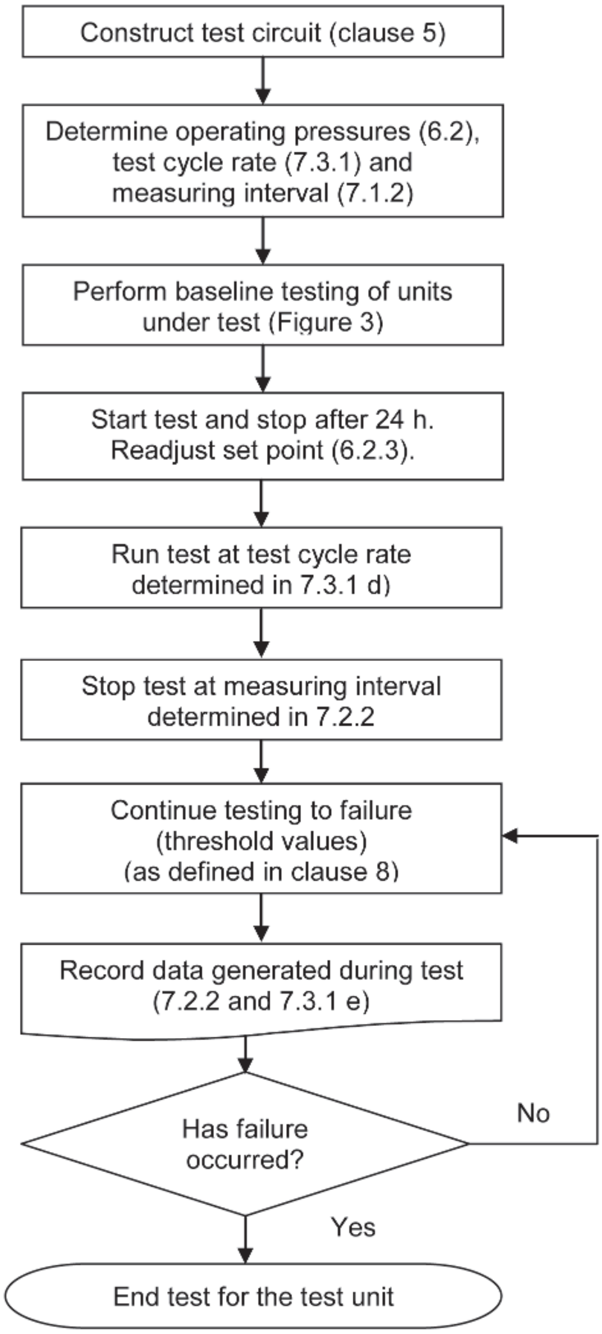
Use the following statement in test reports, catalogues, and sales literature when electing to comply with this part of ISO 19973:

"Reliability and lifetime of pneumatic pressure regulators assessed in accordance with ISO 19973-4, *Pneumatic fluid power — Assessment of component reliability by testing — Part 4: Pressure regulators*."

Annex A
(informative)

Flow chart illustrating the test procedure specified in this part of ISO 19973

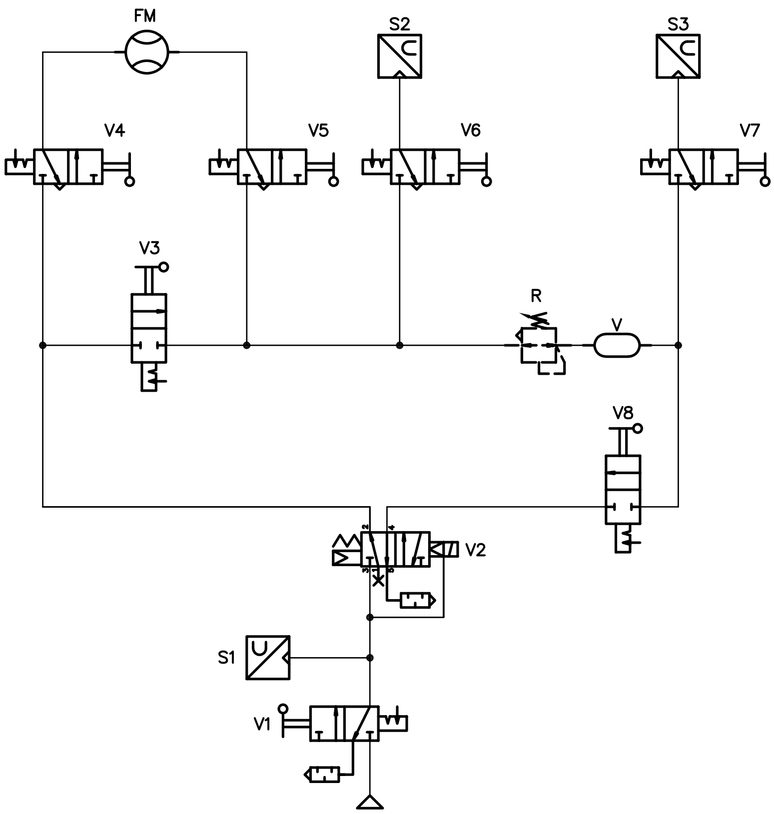
NOTE This flow chart applies to each test unit individually.



Annex B
(informative)

Optional expanded test circuit

The test circuit in Figure 1 is a basic type that includes the minimum required components. The expanded circuit shown in Figure B.1 is optional and includes components that help to isolate measuring instrumentation. The isolation valves prevent pressure from being imposed on the instruments during the cycling operation but can be actuated to allow recording during the measurement periods. Table B.1 lists the measurement steps for the optional expanded test circuit shown in Figure B.1.



Key

FM	Flow meter
S1 to S3	Pressure sensors
R	Regulator under test
V	Volume
V1	Inlet shut-off valve
V2	Cycling valve
V3 & V8	Isolation valves
V4 to V7	Sensor shut-off valves

Figure B.1 — Optional expanded test circuit

Table B.1 — Measurement steps

Step	Cycling operation
1	Close valves V4 and V5
2	Open valves V1, V3, V6, V7, and V8
3	Energize valve V2 but do not cycle it
4	Set pressures to required values
5	Cycle valve V2 and observe pressures
6	Close valves V6 and V7 and continue cycling data recording operation
7	Open valves V6 and V7 and record pressures cycling
8	Stop cycling V2 and leave it in an energized state
9	Close valve V3 and V8
10	Open valves V1, V4, V5, V6, and V7
11	Perform set point and leakage measurements
12	Close valves 4, V5, V6, V7; open valves V1, V3, and V8
13	Resume cycling operation of valve V2

Annex C
(informative)

Test data sheet

An example of a test data sheet is shown on the next three pages.

Use one sheet for four test units.													
Test laboratory:			Test number:						Sheet:		of		
Regulator manufacturer:			Model number:			Port size:							
						Test unit identification number							
Total circuit volume on upstream side of test unit, cm^3													
Total circuit volume on downstream side of test unit, cm^3													
Bench test at start	Forward sonic conductance, C_f, of test unit, $dm^3/(s \cdot bar)$(ANR)												
Bench test at start	Sonic conductance, *C*, of directional control valve, $dm^3/(s \cdot bar)$(ANR)												
Bench test at start	Regulated pressure set point, bar (see note regarding 24 h in 6.2.3)												
Bench test at start	Total leakage – 2 min, dm^3/h (ANR)												
Cycle test data →						Set point	Leakage (2 min)	Set point	Leakage (2 min)	Set point	Leakage (2 min)	Set point	Leakage (2 min)
			Temperature	Inlet p_0	Dew point								
			°C	bar	°C	bar	dm^3/h (ANR)	bar	dm^3/h (ANR)	bar	dm^3/h (ANR)	bar	dm^3/h (ANR)
Threshold value:													
Date	Counter	Cycles											

Test laboratory:			**Test number:**							**Sheet:**		**of**	
						Test unit identification number							
				Cycle test data →		**Set point**	**Total leakage** (2 min)	**Set point**	**Total leakage** (2 min)	**Set point**	**Total leakage** (2 min)	**Set point**	**Total leakage** (2 min)
			Temperature	**Inlet p_0**	**Dew point**								
			°C	bar	°C	bar	dm^3/h(ANR)	bar	dm^3/h(ANR)	bar	dm^3/h(ANR)	bar	dm^3/h(ANR)
Threshold value:													
Date	**Counter**	**Cycles**											

Use this sheet to record observations.

Test laboratory:			**Test number:**		**Sheet:**		**of**	
Date	**Counter**	**Cycles**	**Test unit number**	**Observations**				

Copy pressure traces for each test unit on this sheet, at the beginning of the endurance cycling and whenever a pressure trace is made.

Bibliography

[1] ISO 6953-2, *Pneumatic fluid power — Compressed air pressure regulators and filter-regulators — Part 2: Test methods to determine the main characteristics to be included in literature from suppliers*

[2] ISO 8778, *Pneumatic fluid power — Standard reference atmosphere*

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