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Pneumatic fluid power — Directional control valves — Measurement of shifting time

Transmissions pneumatiques — Distributeurs de commande directionnels — Mesure du temps de commutation

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Foreword

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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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 5, *Control products and components.*

This second edition cancels and replaces the first edition (ISO 12238:2001), which has been technically revised.

The main changes are as follows:

— the Scope has been extended to include monostable and bistable valves with two or three shifting position functions;

— extensions to the concept of shifting time measurement by addition of specifications for tests when shifting into non-exhausting positions have been added;

— consistency with other International Standards such as the ISO 6358 series has been improved;

— references to state-of-the-art test equipment and procedures have been updated.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In pneumatic fluid power systems, power is transmitted and controlled through a gas under pressure circulating within a circuit. In some applications, the designer of a fluid power system needs to know the time required to cause the valving elements in a pneumatic directional control valve to move and to generate an output signal.

Pneumatic fluid power — Directional control valves — Measurement of shifting time

1 Scope

This document specifies test procedures for measuring the shifting times of electrically or pneumatically operated directional control valves.

It is applicable to monostable and bistable pneumatic directional control valves, with 2 or 3 position functions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 80000-1, *Quantities and units — Part 1: General*

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 6358-1, *Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids — Part 1: General rules and test methods for steady-state flow*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
shifting time (exhaust)
shifting time for shifts into a position where the working port is exhausting, obtained for a change of 10 % in the outlet pressure

3.2
shifting time (fill)
shifting time for shifts into a position where the working port is filling a connected component or system, obtained for a change of 10 % in the outlet pressure

3.3
shifting time (non-exhausting)
shifting time for shifts into a position where the working port is closed.

4 Symbols and abbreviated terms

4.1 The symbols and units for parameters used in this document shall be as given in Table 1 and shall be in accordance with ISO 80000-1.

Table 1 — Symbols and units

Symbol	Parameter	Unit
t_0	base for time measurement	ms
t_E	shifting time (exhaust)	ms
t_F	shifting time (fill)	ms
t_{NE}	shifting time into non-exhausting position (exhaust)	ms

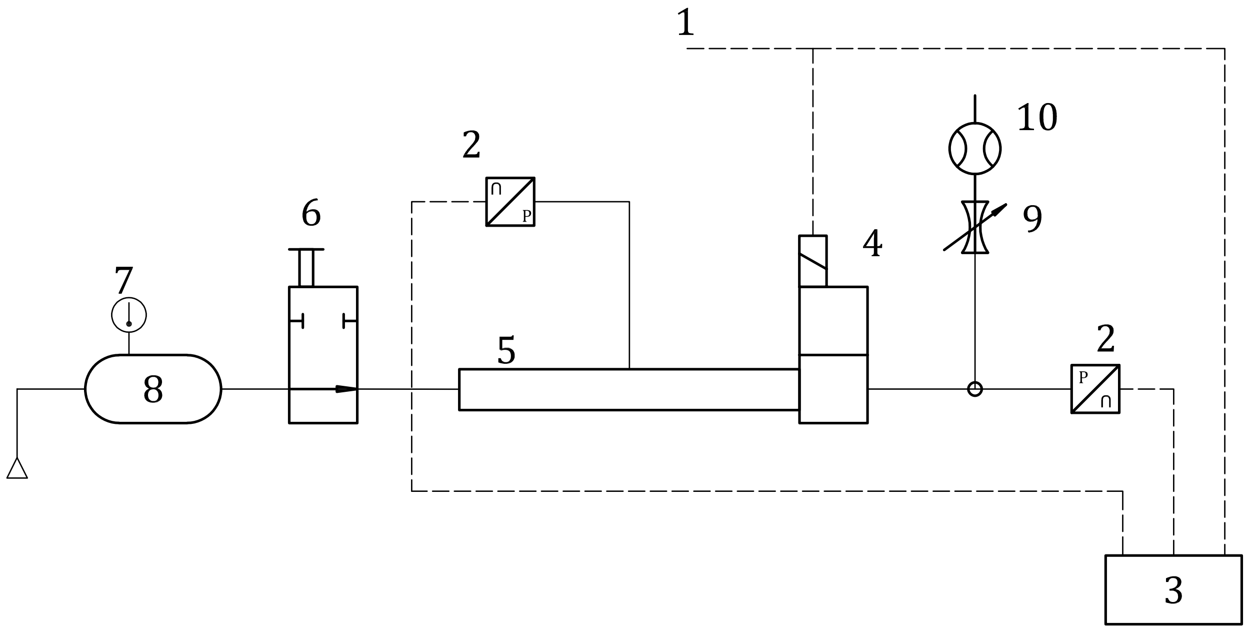
4.2 Graphic symbols used in this document shall conform to the requirements of ISO 1219-1.

5 Test equipment

5.1 Basic test setup

The basic test equipment shall be as shown in Figures 1 and 2.

When shifting into a non-exhausting valve position the shifting time cannot be measured due to a lack of a pressure drop. For measuring the shifting time of shifts into non-exhausting valve positions (e.g. 2/2 or 5/3 closed centre position) a throttle valve and a flow sensor shall be used (also see key 9 and key 10 in Figures 1 and 2).

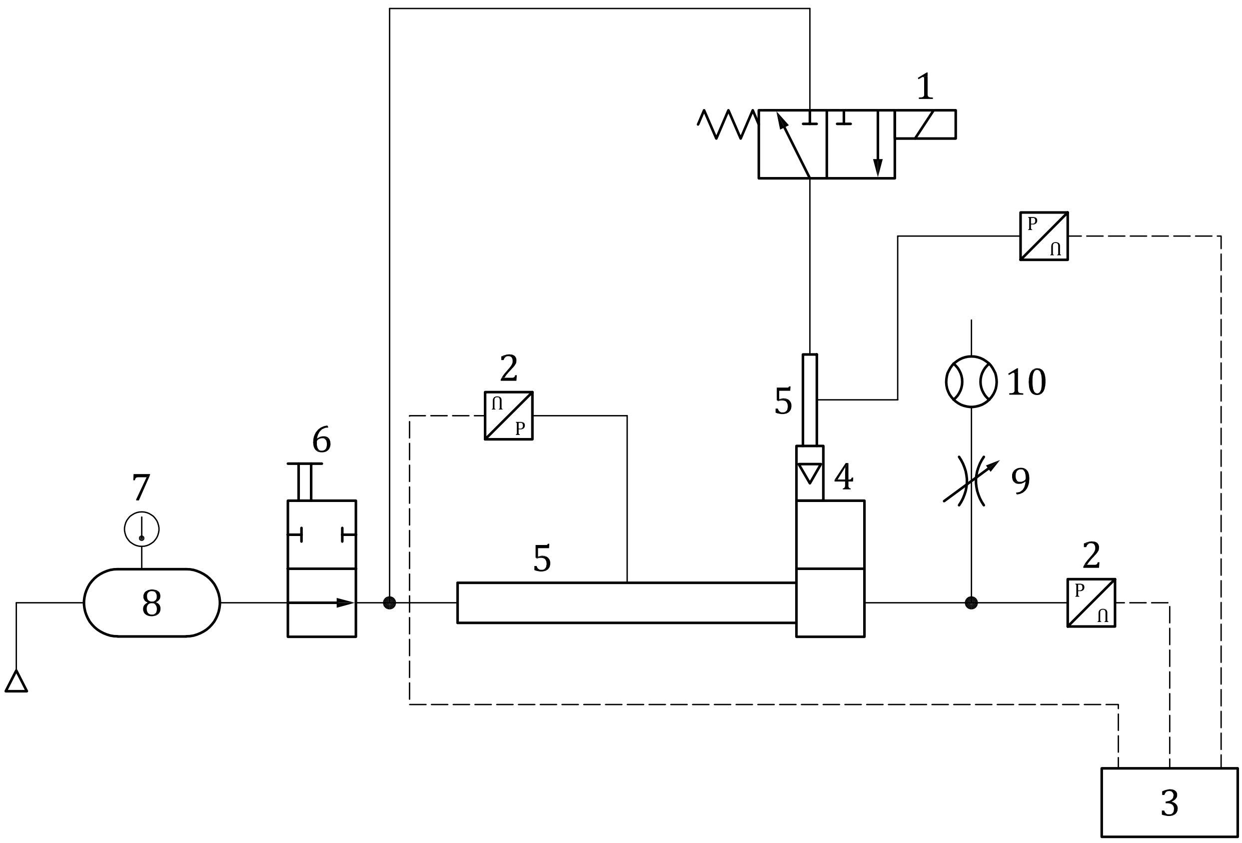


Key

1 control signal
2 pressure transducers
3 output recording device(s)
4 valve under test
5 pressure measuring tube in accordance with ISO 6358-1
6 shut-off valve (optional)
7 thermometer
8 supply reservoir
9 throttle valve (only for non-exhausting valve positions)
10 flow sensor (only for non-exhausting valve positions)

Figure 1 — Test equipment for electrically-operated valves

For pneumatically operated valves (Figure 2) the sonic conductance *C* as defined in ISO 6358-1 of the control valve (key 1) shall be larger than the *C*- value of the pilot port of the valve under test (key 4). The connection between control valve (key 1) and the pressure measuring tube (key 5) at the pilot port of the valve under test should be as short as possible.



Key

1 control valve (to generate control signal)

2 pressure transducers

3 output recording device(s)

4 valve under test

5 pressure measuring tube in accordance with ISO 6358-1

6 shut-off valve (optional)

7 thermometer

8 supply reservoir

9 throttle valve (only for non-exhausting valve positions)

10 flow sensor (only for non-exhausting valve positions)

Figure 2 — Test equipment for pneumatically-operated valves

5.2 Pressure measuring tubes

5.2.1 A straight pressure measuring tube should be threaded into the valve inlet port, as well as into the valve pilot port when applicable, and shall be made in accordance with ISO 6358-1.

The test setup from ISO 6358-1 requires transition connectors for the flow measurement. These reduce the speed of the flow in the measuring tube. This is not necessary for shifting time measurement and the transition connectors are not required for this test. Nevertheless, the transition connectors from ISO 6358-1 may be used for the tests according to ISO 12238.

5.2.2 Select and attach pressure measuring tubes to the test valve whose threads correspond to each port size of the valve flow path, and to the valve pilot port when applicable.

5.3 Pressure transducers

5.3.1 Install a pressure transducer into the inlet pressure measuring tube. Also install a pressure transducer directly into each outlet port to be tested, to have an outlet volume as small as possible. All untested outlet ports shall be plugged.

5.3.2 When a pneumatically-operated valve is tested, mount an additional control pressure transducer into the pilot pressure measuring tube.

5.4 Supply reservoir

5.4.1 Use a supply reservoir of sufficient capacity so that the pressure drop caused by the piping and measured in the pressure measuring tube at the inlet port during the test does not exceed 3 % of the supply pressure. A larger pressure drop is permissible but will increase the shifting time and result in a less favourable rating for the product under test. Connections from the supply reservoir should be several times larger than the pressure measuring tube and as short as possible, to minimize the pressure drop.

5.4.2 Use a supply reservoir that allows measuring the internal air temperature of the reservoir. Maintain the supply reservoir temperature between 18 °C and 30 °C.

5.4.3 Locate the optional shut-off valve, and the control valve when applicable, as close as possible to the reservoir outlet. Use a valve with a C value larger than that of the pressure measuring tube, because a smaller valve can restrict the flow and increase the shifting time.

5.5 Control signal

5.5.1 For solenoid pilot-operated valves or pneumatically-operated valves, maintain the external pilot supply pressure at either the test pressure supplied to the valve or the maximum permitted pilot supply pressure, whichever is less.

5.5.2 For AC solenoid-operated valves, generate the control signal with a trigger device set to trigger at the zero-voltage crossover point. Maintain voltage to within ±2 % of the rated voltage.

5.5.3 For DC solenoid-operated valves, maintain steady-state voltage to within ±2 % of the rated voltage.

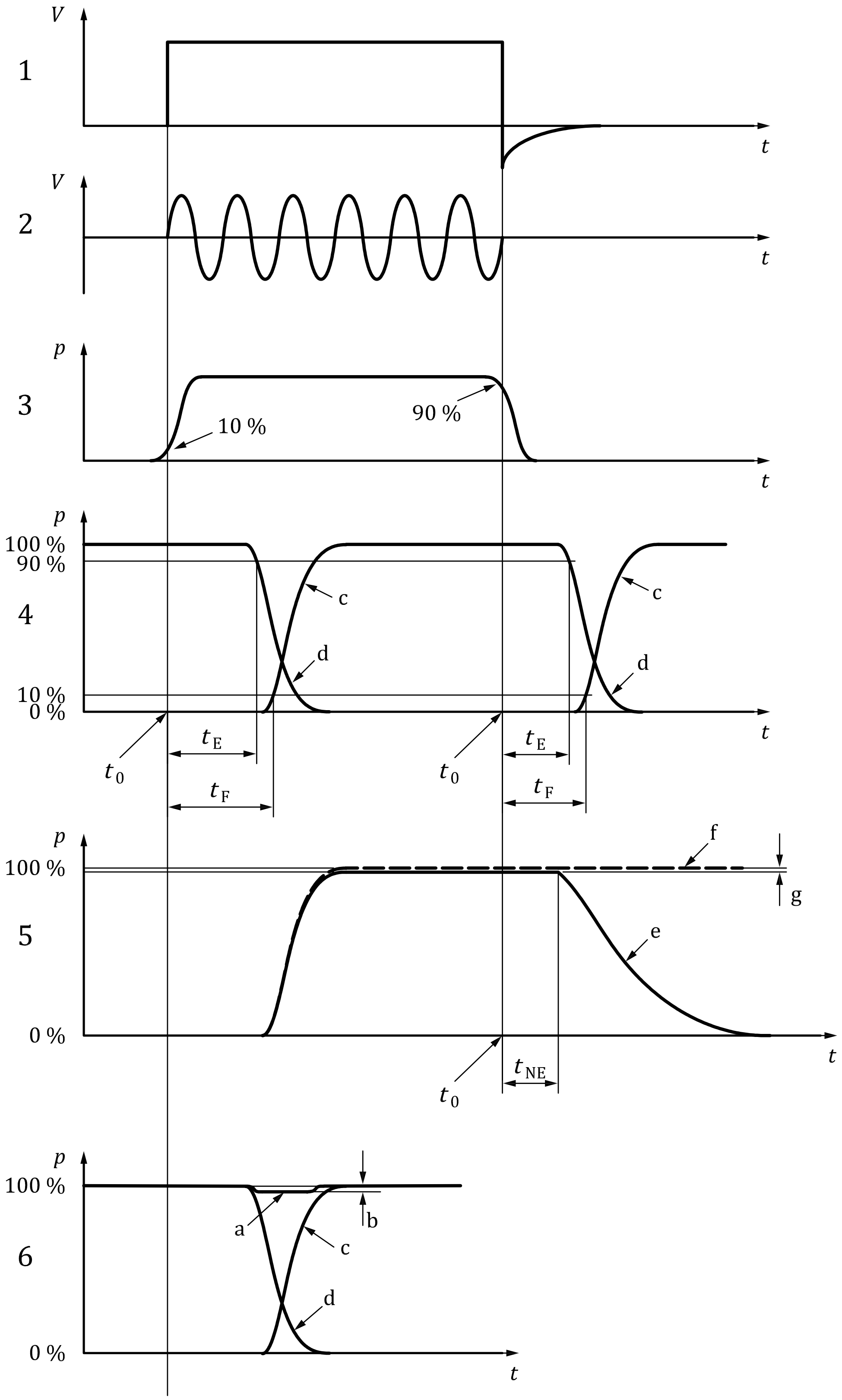
5.5.4 Changes in the shifting time caused by limitation of the negative voltage peaks due to the test equipment should not exceed 0,1 ms.

5.5.5 For bistable valves, add a pause of non-operation between control signals to ensure that the pilot control volumes are completely exhausted, before measuring the shifting time in the opposite condition.

5.6 Data recording system

5.6.1 Use pressure transducers, amplifiers and recording devices that together have a system frequency response of within –3,0 dB at minimum 2 000 Hz and a resolution of less than 0,1 ms. For shifting times smaller than 5 ms, a system frequency response of within –3,0 dB at minimum 5 000 Hz shall be used.

5.6.2 During a test run, record the control signal (AC, DC or pilot pressure) and pressure-time diagram for all transducers in the system. Figure 3 gives examples of how data can look.



Key

1 control signal — DC solenoid (V)

2 control signal — AC solenoid (V)

3 control signal — pressure pilot (kPa (bar))

4 pressure-time diagram (example, 5/2 monostable valve)

5 pressure-time diagram (example, 2/2 normally closed valve, non-exhausting)

6 typical inlet pressure
a inlet pressure p_1
b 3 % maximum recommended drop
c fill test
d exhaust test
e exhaust test with small leakage
f exhaust test without small leakage
g pressure drop caused by small leakage
t_0 time base (start of shifting time measurement)
t_F shifting time (fill)
t_{NE} shifting time (non-exhausting)

Figure 3 — Typical data-time recordings

6 Test accuracy

Test conditions shall be maintained and data obtained within the accuracy limits given in Table 2.

Table 2 — Test accuracy parameters

Parameter of measuring instrument	Permissible systematic error
Pressure	±10 kPa (±0,1 bar)
Temperature	±2 °C
Time	±5 %

7 Test procedure

7.1 An overview of test procedures is given in tables 3 and 4

Table 3 — Test procedures for shifting on-test

Valve	Type		Shifting on (control signal is applied)				Test procedure
			Fill		Exhaust		
			Port 2	Port 4	Port 2	Port 4	Clause
2/2	NC (normally closed)	Monostable	12	—	—	—	7.5
	NO (normally open)	Monostable	—	—	(10)[a]	—	7.7
	- - -	Bistable	12	—	(10) [a]	—	7.5, 7.7
3/2	NC (normally closed)	Monostable	12	—	—	—	7.5
	NO (normally open)	Monostable	—	—	10	—	7.6
	- - -	Bistable	12	—	10	—	7.5, 7.6
4/2 5/2		Monostable	—	14	14	—	7.5, 7.6
		Bistable	12	14	14	12	7.5, 7.6
5/3	Pressurized center position	Monostable	12	14	14	12	7.5, 7.6
	Exhausted center position	Monostable	12	14	14	12	7.5, 7.6
	Closed center position	Monostable	12	14	14	12	7.5, 7.6

[a] Control mechanism values in parentheses show shifting positions where exhaust is not possible (closed position).

NOTE Designation of valve types and control mechanisms in accordance with ISO 11727 and ISO 5598

Table 4 — Test procedures for shifting off-test

Valve	Type		Shifting off (control signal is removed)				Test procedure
			Fill		Exhaust		
			Port 2	Port 4	Port 2	Port 4	Clause
2/2	NC (normally closed)	Monostable	—	—	(12) [a]	—	7.7
	NO (normally open)	Monostable	10	—	—	—	7.5
	- - -	Bistable	—	—	—	—	---[b]
3/2	NC (normally closed)	Monostable	—	—	12	—	7.6
	NO (normally open)	Monostable	10	—	—	—	7.5
	- - -	Bistable	—	—	—	—	---[b]
4/2 5/2		Monostable	14	—	—	14	7.5, 7.6
		Bistable	—	—	—	—	---[b]
5/3	Pressurized center position	Monostable	14	12	—	—	7.5
	Exhausted center position	Monostable	—	—	12	14	7.6
	Closed center position	Monostable	—	—	(12) [a]	(14) [a]	7.7

[a] Control mechanism values in parentheses show shifting positions where exhaust is not possible (closed position).

[b] For bistable valves in general the removal of the control signal does not lead to a change of the valve position. Therefore, a determination of a shifting off-time is not possible for these kinds of valves.

NOTE Designation of valve types and control mechanisms in accordance with ISO 11727 and ISO 5598

7.2 Set up the test circuit as shown in Figure 1 or, when appropriate, Figure 2, with components as specified in Clause 5.

7.3 The fill and exhaust shifting times for each outlet port shall be measured based on the operation capabilities of the valve, either by a shifting on-time test or a shifting off-time test. The following data shall be recorded:

— fill time from inlet to each outlet port and

— exhaust time from each outlet to exhaust port.

Tests to measure exhaust and fill times may be combined to run in sequence.

7.4 A test shall always include three single test runs, which shall be done individually for each flow path.

7.4.1 A single test run shall consist out of several preliminary shifts, directly followed by the operation of the valve according to the type of test (see 7.5.3, 7.6.2 or 7.7.3 and also Figure 3).

7.4.2 The preliminary valve shifts shall be conducted by energizing and de-energizing the solenoid on electrically-operated valves, or by operating the control valve to pressurize and de-pressurize the pilot control mechanism of a pneumatically-operated valve. They shall be done with a frequency that ensures the complete exhausting and pressurizing of the flow path under test.

7.4.3 Each test run shall be conducted after a waiting time of at least 1 min, to ensure temperature stabilization. Maintain the supply reservoir temperature between 18 °C and 30 °C.

7.5 For shifting into filling positions, the shifting time (fill) shall be determined as follows:

7.5.1 Maintain supply reservoir pressure at a pressure of 630 kPa (6,3 bar[1)]) or at the maximum working pressure at the inlet pressure transducer, whichever is less.

7.5.2 Vent the outlet port under test to atmosphere.

7.5.3 Perform a test according to 7.4, venting the outlet port each time and then shifting into the filling position.

7.6 For shifting into exhausting positions, the shifting time (non-exhausting) shall be determined as follows:

7.6.1 Charge the outlet port under test to a pressure of 630 kPa (6,3 bar) or to the maximum working pressure at the outlet pressure transducer, whichever is less.

7.6.2 Perform a test according to 7.4, pressurizing the outlet port each time and then shifting into the exhausting position.

7.7 For shifting into non-exhausting positions (e.g. 2/2 closed position and 5/3 closed centre position), the shifting time (non-exhausting) shall be determined as follows:

NOTE Although it is actually shifted into a non-exhausting position, from a technical point of view, the shifting time is regarded as shifting time (exhaust).

7.7.1 Maintain supply reservoir pressure at a pressure of 630 kPa (6,3 bar) or at the maximum rated pressure at the inlet pressure transducer, whichever is less. Shift the valve into the pressurized position. Set the throttle valve so that a small leakage in the range of 1,0 l/min to 1,5 l/min (ANR) is present and measured with the flow sensor while the outlet port is pressurized. A pressure decrease shall be detectable when the valve is shifted into the non-exhausting position.

NOTE Small leakage in the range of 1,0 l/min to 1,5 l/min (ANR) ensures that the measurement is conducted close to the reference test pressure of 6,3 bar so that the shifting characteristic is not influenced.

7.7.2 With the throttle valve set as described in 7.7.1, perform several preliminary shifts according to. 7.4.2. During the waiting time according to 7.4.3, the inlet ports shall be pressurized to allow determination of the fluctuation band of pressure and electrical signal noise.

7.7.3 Perform a test according to 7.4, pressurizing the outlet port each time and then shifting into the non-exhausting position.

8 Data calculations

8.1 For electrically-operated valves, establish the time base, t_0, as the point at which a definite change in the voltage is noted (see Figure 3).

8.2 For pneumatically-operated valves, establish the time base, t_0, as the point at which a 10 % change in pilot pressure is noted (see Figure 3).

8.3 For shifting into filling positions, measure the time to fill from t_0 to the point at which the pressure reaches 10 % of its supply reservoir pressure value for each test run of an outlet port. Determine the

1) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2

average of the data from the test runs defined in 7.5 for each outlet port; this is the shifting time (fill) for each outlet port (see Table A.1 for an example of test data).

8.4 For shifting into exhausting positions, measure the time to exhaust from t_0 to the point at which the pressure reaches 90 % of its supply reservoir pressure value for each test run of an outlet port. Determine the average of the data from the test runs defined in 7.6 for each outlet port; this is the shifting time (exhaust) for each outlet port (see Table A.1 for an example of test data).

8.5 For shifting into non-exhausting positions, measure the time to exhaust by throttle for non-exhausting shifting positions from t_0 to the point at the start of the pressure decrease for each test run of an outlet port. This shall be the point at which the pressure changes and remains below the initial value, also taking into consideration the fluctuation band of pressure and electric signal noise (for an example of the determination of the fluctuation band also see Annex B). Determine the average of the data from the test runs defined in 7.7 for each outlet port; this is the shifting time into non-exhausting position (exhaust) for each outlet port.

NOTE For the data calculations the rate of the pressure drop caused by the small leakage is not relevant. Only the time at the beginning of the pressure drop is relevant.

9 Reporting of test data

9.1 Report the average shifting time for each flow path in the valve; see the column titled "Each flow path" in Table A.1 for an example of this type of reporting.

9.2 As an alternative to 9.1, report the average of shifting time for all flow paths in a valve; see the column titled "Valve as a whole" in Table A.1 for an example of this type of reporting.

10 Identification statement (reference to this document)

It is strongly recommended that manufacturers use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard:

"Shifting time of pneumatic directional control valves or moving part logic devices was measured in accordance with ISO 12238:2022, *Pneumatic fluid power — Directional control valves — Measurement of shifting time.*"

Annex A
(informative)

Example of generated test data and values to be reported

Table A.1 — Example of shifting time test data generated from testing a 5/2 monostable valve and values to be reported

Shifting time	**Description of flow path** in accordance with ISO 11727	**Shifting time data from each test run** ms	**Average shifting times to be reported** ms	
			each flow path	valve as a whole
Shifting-on (energized)	Fill with ports 1 to 4	17	18	17
		18		
		19		
	Exhaust with ports 2 to 3	15	16	
		16		
		17		
Shifting-off (de-energized)	Fill with ports 1 to 2	35	36	35
		36		
		37		
	Exhaust with ports 4 to 5	33	34	
		34		
		35		

Annex B
(informative)

Measurement of shifting time into non-exhausting positions

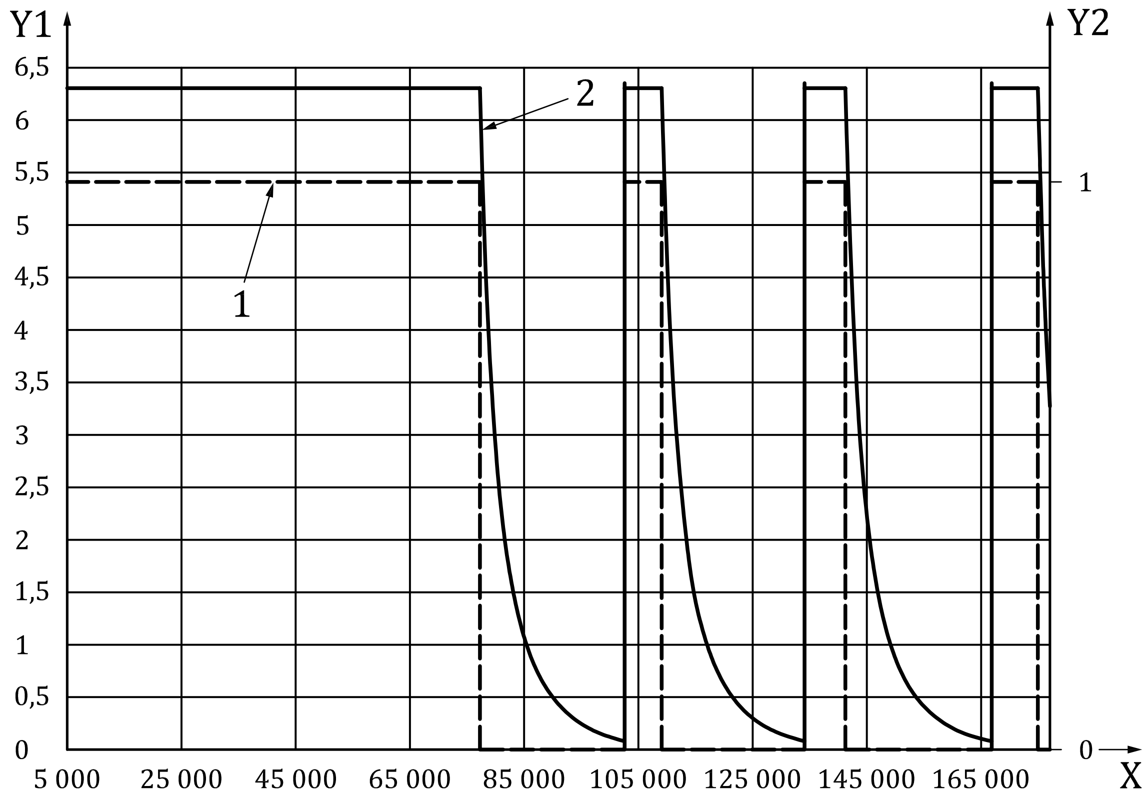
B.1 General

The purpose of this annex is to help users in understanding the measurement of the shifting time of a valve with a non-exhausting position (e.g. 2/2 closed position and 5/3 closed centre position) which differs from the other measuring procedures due to the construction of this type of valves.

The example from the annex was chosen from a test series conducted by two laboratories out of two different countries.

B.2 Test procedure

Test equipment and test procedure are according to Clauses 5 and 7 of this document.



Key

X Time (ms)

Y1 pressure (bar)

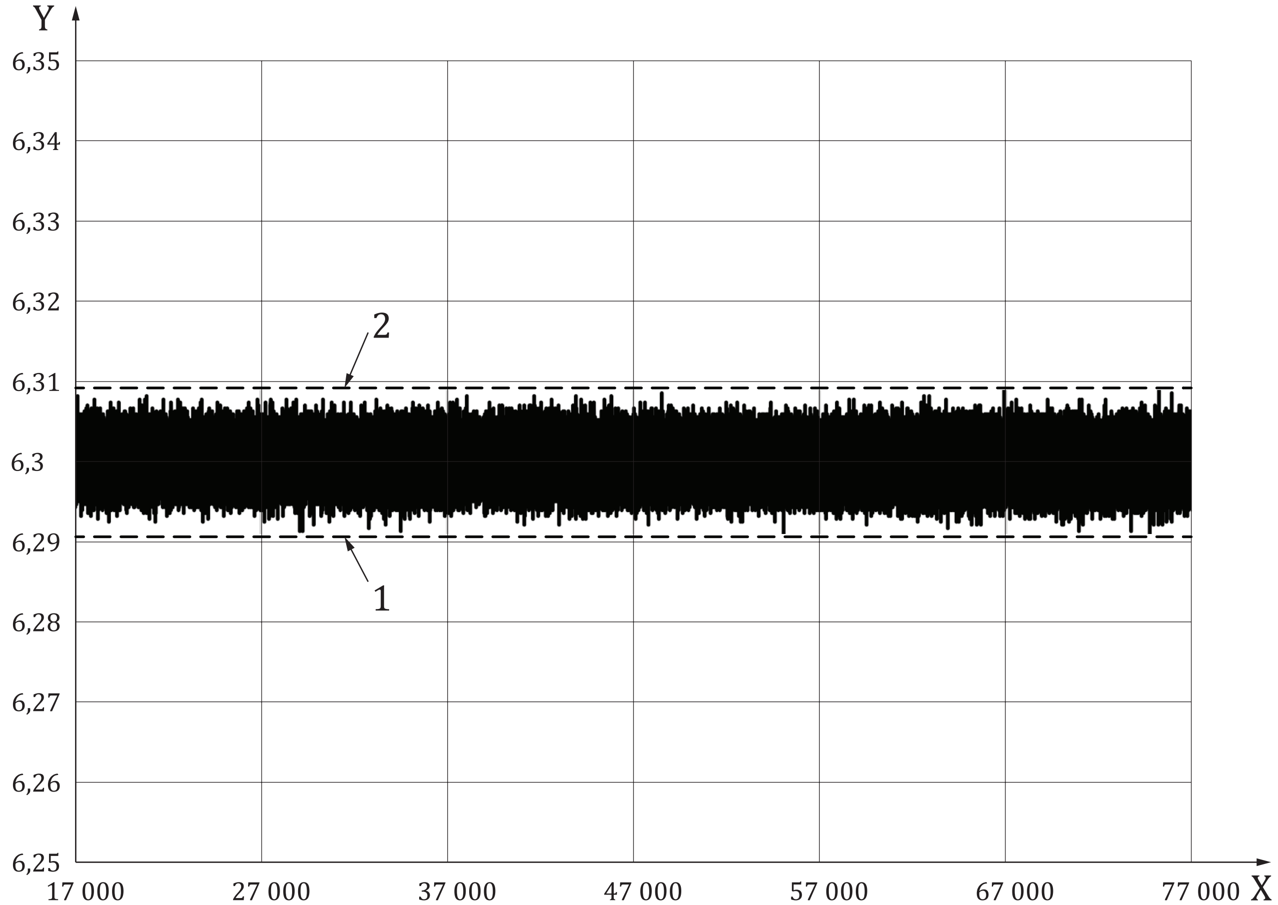
Y2 control signal (digital)

1 control signal

2 outlet pressure (bar)

Figure B.1 — Shifting time into non-exhausting position (exhaust) test procedure for shifting into non-exhausting positions

During the waiting time the inlet ports are pressurized to allow a determination of the minimum and the maximum measured value of the fluctuation band of the pressure and the electric signal noise as shown in Figure B.2. Then the valve is shifted into the non-exhausting position and the shifting time into non-exhausting position (exhaust) is measured as shown in Figure B.3.



Key

X time (ms)

Y pressure (bar)

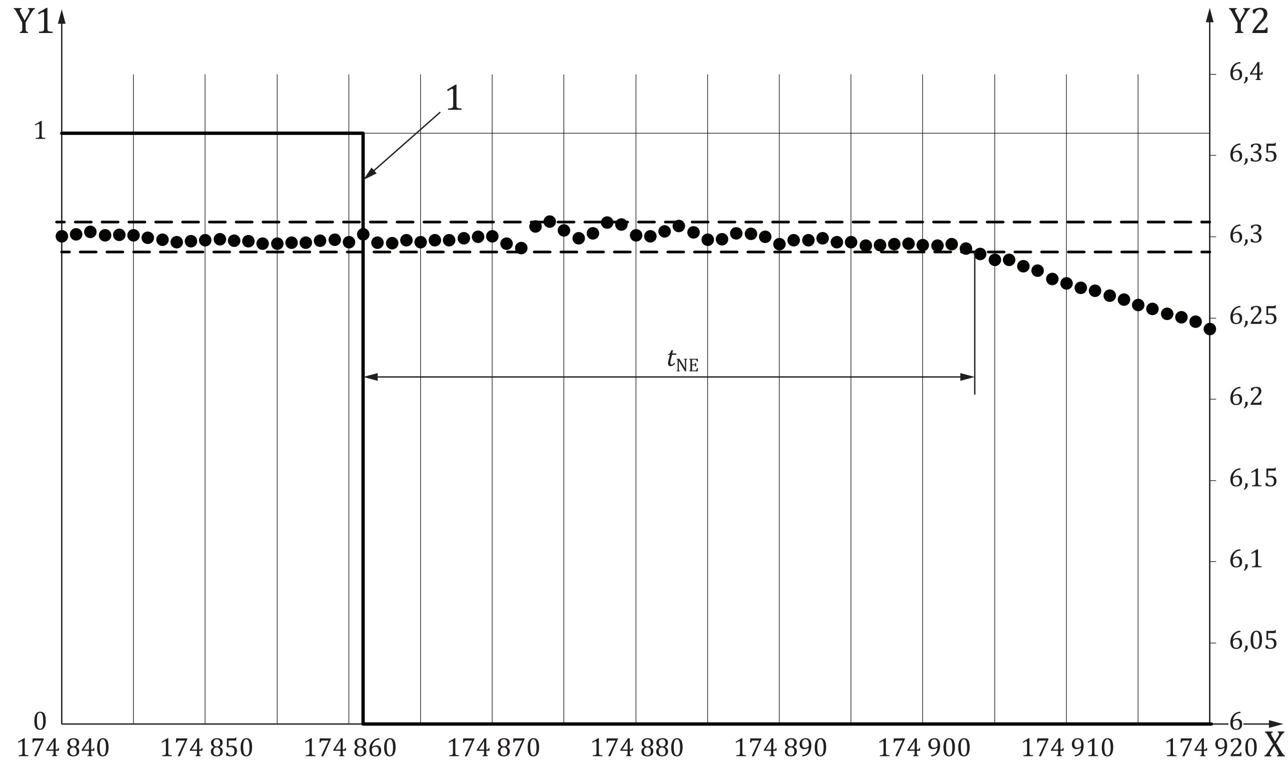
1 minimum of the fluctuation band (bar)

2 maximum of the fluctuation band (bar)

Figure B.2 — Determination of the fluctuation band

B.3 Data calculations

Data calculations are made according to Clause 8 of this document. The shifting time into non-exhausting position (exhaust) is the elapsed time from t_0 to the first time-measurement from which the pressure is always below the minimum of the fluctuation band, as shown in Figure B.3.



Key

X time (ms)

Y1 pressure (bar)

Y2 control signal (digital)

1 control signal

2 outlet pressure (bar)

t_{NE} shifting time into non-exhausting position (exhaust)

Figure B.3 — Determination of the shifting time into non-exhausting position (exhaust)

B.4 Test results

Repeatability and reproducibility were tested in different laboratories and the results were cross-checked. The characteristics are not affected by the size of the valve under test and of the throttle valve used to set the small leakage on outport.

Table B.1 — Example of calculated shifting times (non-exhaust)

Shifting time	Description of flow path in accordance with ISO 11727	Laboratory	Valve	Nominal flow-rate l/min ANR	Average shifting time ms	Standard deviation ms
Shifting time into non-exhausting position (exhaust)	Exhaust with port 4 to throttle valve	A	1	700	39	0,7
			2	1 600	68,4	0,5
			3	3 480	93,5	0,7
		B	4	148	19,5	0,4
			5	2 048	33,5	0,3
			6	4 690	59,1	0,7

Bibliography

[1] ISO 11727:1999, *Pneumatic fluid power — Identification of ports and control mechanisms of control valves and other components*

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