INTERNATIONAL STANDARD

ISO 10041-1

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Pneumatic fluid power — Electro-pneumatic continuous flow control valves —

Part 1: Main characteristics to include in the supplier's literature

Transmissions pneumatiques — Distributeurs électropneumatiques à commande continue de débit —

Partie 1: Principales caractéristiques à inclure dans la documentation du fournisseur

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 10041-1 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 5, *Control products and components*.

ISO 10041 consists of the following parts, under the general title *Pneumatic fluid power — Electro-pneumatic continuous flow control valves*:

— *Part 1: Main characteristics to include in the supplier's literature*

— *Part 2: Test methods to determine main characteristics to include in the supplier's literature*

Introduction

In pneumatic fluid power systems, power is transmitted and controlled through a gas under pressure within a circuit.

Electro-pneumatic continuous flow control valves continuously modulate the pneumatic power of a system in response to a continuous electrical control signal and link the electrical control quantity to the effective section of each variable port of the output stage (flow rate stage). The mass flow rate that crosses each restriction depends on the downstream and upstream pressures and the type of gas.

When control of position or force, including position- or force-tracking of a pneumatic cylinder, is required, electro-pneumatic continuous flow control valves can be used to precisely modulate the mass flow rates entering or exiting each cylinder chamber, resulting in a precise positioning. It is, therefore, necessary to know some performance characteristics of these electro-pneumatic continuous flow control valves in order to determine their suitability for a particular application.

Pneumatic fluid power — Electro-pneumatic continuous flow control valves —

Part 1:
Main characteristics to include in the supplier's literature

1 Scope

This part of ISO 10041 specifies the characteristics of electro-pneumatic continuous flow control valves that are to be included in the supplier's literature.

According to ISO 5598, continuous control valves include:

— electrically modulated pneumatic proportional flow control valves,

— pneumatic proportional flow control valves,

— flow control servo-valves.

This part of ISO 10041 is limited to the characterisation of valves that exhaust into the atmosphere except for two-port valves.

NOTE The characteristics of electro-pneumatic continuous pressure control valves are specified in ISO 10094-1.

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 5598, *Fluid power systems and components — Vocabulary*

ISO 10041-2:2010, *Pneumatic fluid power — Electro-pneumatic continuous flow control valves — Part 2: Test methods to determine main characteristics to include in the supplier's literature*

ISO 10094-2:2010, *Pneumatic fluid power — Electro-pneumatic pressure control valves — Part 2: Test methods to determine main characteristics to include in the supplier's literature*

3 Terms and definitions

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

3.1
electro-pneumatic continuous flow control valve
flow control valve that continuously modulates the pneumatic power of a system in response to a continuous electrical control signal and that links the electrical control quantity to the effective section of each variable port of the output stage (flow rate stage)

NOTE The mass flow rate that crosses each restriction depends on the downstream and upstream pressures and the type of gas.

3.2
flow control servo-valve
electrically modulated continuous flow control valve with internal feedback control loop

3.3
inlet pressure
pressure at the inlet port of a component, piping or system

3.4
operating pressure
pressure measured by an external transducer, mounted on a measuring tube or on a volume connected to the working port of the control valve

3.5
exhaust pressure
pressure at the air exhaust port

3.6
electrical control signal
set signal
electrical signal applied to a control device

NOTE The median of the electrical control signal is equal to the mean of the minimum and maximum values, usually noted as 0 %. In this part of ISO 10041, the electrical control signal is a symmetrical signal graduated in percent, varying from −100 % (minimum value) to +100 % (maximum value).

3.7
control signal-flow rate characteristic curve
graphical representation of the global flow rate versus the electrical control signal over its full scale while the operating and inlet pressures are held constant

3.8
pressure-flow rate characteristic curve
graphical representation of the global flow rate versus the pressure ratio while the electrical control signal and the inlet pressure are held constant

3.9
pressure gain characteristic curve at null operating flow rate
graphical representation of the operating pressure versus the electrical control signal over its full scale while the operating flow rate is null and the inlet pressure is held constant

3.10
leakage characteristic curve at null operating flow rate
graphical representation of leakage flow rate measured at the inlet port versus the electrical control signal over its full scale while the operating flow rate is null and the inlet pressure is held constant

4 Symbols and unit

For the purposes of the present document, the symbols and units listed in Table 1 apply.

Table 1 — Symbols and units

Description	Symbol	SI Unit
Critical back-pressure ratio	b	—
Sonic conductance	C	$m^3/(s \cdot Pa)$ (ANR)[a]
Subsonic index	m	—
Atmospheric pressure	p_{atm}	Pa
Stagnation gauge pressure related to the inlet port[b]	p_1	Pa
Stagnation gauge pressure related to the working port[b]	p_2, p_4	Pa
Stagnation gauge pressure related to the air exhaust port[b]	p_3, p_5	Pa
Repeatability	r	%
Electrical control signal	w	V, mA or control signal
Cracking pressure	Δp_c	Pa
Resolution	S	%

[a] Reference atmosphere is defined in ISO 8778[2], i.e.: $T_0 = 293{,}15$ K, $p_0 = 100$ kPa (1 bar) and relative humidity of 65 %.

[b] In accordance with ISO 11727.

5 Characteristics

5.1 General

Supplier's literature providing information about electro-pneumatic continuous flow control valves shall include the characteristics given in 5.2 to 5.4. Two-port electro-pneumatic continuous flow control valves are not concerned with the static characteristics specified in 5.3.3 and in 5.3.4 (pressure gain characteristic and maximum leakage flow rate at null operating flow rate).

The data provided by the supplier shall assist the user in selecting the electro-pneumatic continuous flow control valve that is best suited for a particular application.

The characterised valve shall be described as having a symmetrical electrical control signal varying from −100 % to +100 % around a median value, noted as 0 %, in accordance with 3.6.

NOTE Even if the electrical control signal is not symmetrical, it is possible to describe it as a symmetrical signal as specified above. For example, in case of electrical control signal of 4 mA-20 mA, the median value corresponds to the value of 12 mA, and the values of –100 % and +100 % correspond respectively to 4 mA and 20 mA.

5.2 Electrical characteristics

The required minimum voltage, the required minimum current and the required minimum power of the power supply shall be given.

5.3 Static characteristics

5.3.1 Control signal-flow rate characteristics

5.3.1.1 Characteristic curves

5.3.1.1.1 Characteristic curves shall be created using data from tests conducted in accordance with ISO 10041-2:2010, 7.2.1 to 7.2.4.

5.3.1.1.2 The actual flow rate at each working port measured at the same conditions as expected in normal use shall be indicated by curves, in accordance with Figure 1. Each curve describes the operating flow rate at the port under consideration, depending on the electrical control signal over its full scale, for given operating and inlet pressures noted in relative value, as shown in Figure 1.

5.3.1.1.3 For each working port, this graph shall have at least three curves that differ in their operating pressure, p_2 or p_4, settings, as referenced in Figure 1, equal to, respectively:

— exhaust pressure (atmospheric pressure, p_{atm}),

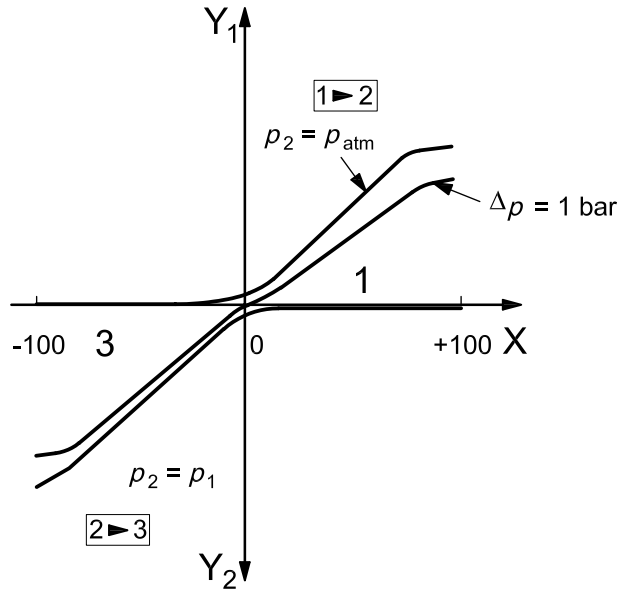
— inlet pressure p_1 minus 100 kPa (1 bar), and

— inlet pressure p_1 (except for two-port valves).

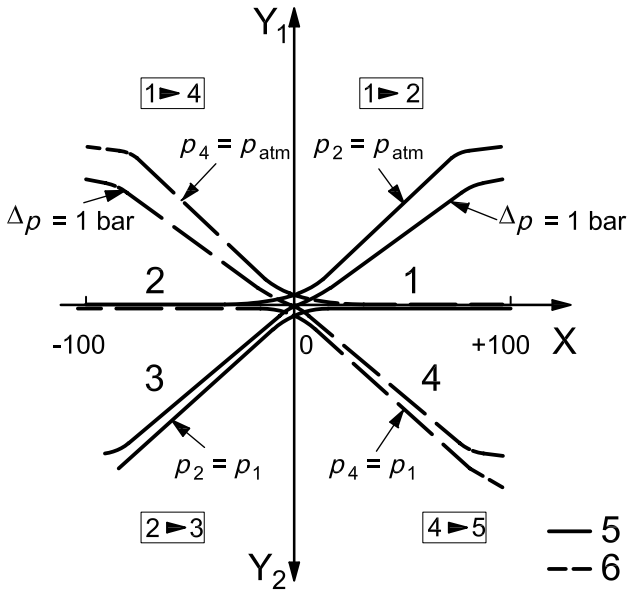
5.3.1.1.4 Each curve shown in Figure 1 shall be plotted in accordance with ISO 10041-2:2010, 7.3.1.2 to 7.3.1.4, taking for each value of electrical control signal the mean value of two measured flow rates with both increasing and decreasing electrical control signals. Positive values of flow rate correspond to forward flow rates whereas negative values correspond to relief flow rates.

5.3.1.1.5 The curves obtained for the operating pressure, p_2 or p_4, equal to the exhaust pressure (p_{atm}) show the maximum effective forward flow rate of the continuous flow control valve in relation to the electrical control signal. In the same way, the curves obtained for the operating pressure, p_2 or p_4, equal to the supply pressure, p_1 show the maximum effective relief flow rate of the continuous flow control valve in relation to the electrical control signal. These two sets of curves define the network envelope characterising the control signal-flow rate curves for an operating pressure, p_2 or p_4, varying between inlet (p_1) and exhaust (p_{atm}) pressure.

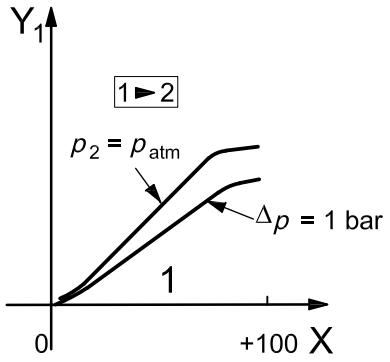
5.3.1.1.6 The curves obtained for the intermediary operating pressure value (p_1 – 100 kPa) enables the illustration of the form of the variation of the effective flow rate in relation to the electrical control signal for an operating pressure value other than the minimum or maximum.



a) Case of three-port control valve



b) Case of five-port control valve



c) Case of two-port control valve

Key

X	electrical control signal, in %	1	1st quadrant
Y_1	forward flows, in dm^3/s (ANR)	2	2nd quadrant
Y_2	relief flows, in dm^3/s (ANR)	3	3rd quadrant
p_1	inlet pressure, $p_1 = 630$ kPa (6,3 bar)	4	4th quadrant
		5	port 2 flow rate
		6	port 4 flow rate

Figure 1 — Control signal-flow rate characteristic curves at inlet pressure of 630 kPa (6,3 bar)

5.3.1.2 Control signal-flow rate hysteresis

5.3.1.2.1 The hysteresis shall be calculated using the control signal-flow rate characteristic data obtained in accordance with the operating methods described in ISO 10041-2:2010, 7.2.2 to 7.2.4, for three different operating pressures (two different operating pressures for a two-port valve).

5.3.1.2.2 The control signal-flow rate hysteresis, expressed as a percentage of the operating flow rate range, shall be calculated according to ISO 10041-2:2010, 7.3.2, Equation (1).

5.3.1.2.3 The calculated value gives the maximum difference between the flow rate measured with both increasing and decreasing electrical control signal.

5.3.1.3 Resolution

5.3.1.3.1 Resolution, S, corresponds to the minimum difference between two electrical control signal values for which there is a difference in the corresponding flow rate values.

5.3.1.3.2 The test shall be performed in accordance with ISO 10041-2:2010, 7.2.5, with the working port connected to the atmosphere.

5.3.1.3.3 Resolution, S, expressed as a percentage of the full scale of the electrical control signal, shall be determined in accordance with ISO 10094-2:2010, 7.3.3.

5.3.1.4 Repeatability

5.3.1.4.1 Repeatability, r, corresponds to the maximum range of resulting flow rate in response to a given electrical control signal.

5.3.1.4.2 The test shall be performed in accordance with ISO 10094-2:2010, 7.2.6, with the working port connected to the atmosphere.

5.3.1.4.3 Repeatability, r, expressed as a percentage of the flow rate range, shall be determined in accordance with ISO 10041-2:2010, 7.3.4.

5.3.2 Flow rate characteristics

5.3.2.1 Characteristic values

5.3.2.1.1 The global flow rate characteristics that is the sonic conductance, C, and the critical back-pressure ratio, b, shall be reported for the maximum and the minimum electrical control signal values, w. When appropriate, the subsonic index, m, and/or the cracking pressure, Δp_c, shall also be reported. In the case of a five-port control valve, these values shall be reported for each of the two working ports.

5.3.2.1.2 The test program shall be performed in accordance with ISO 10041-2:2010, 8.2.

5.3.2.1.3 The calculation of characteristics is performed in accordance with ISO 10041-2:2010, 8.3.1.

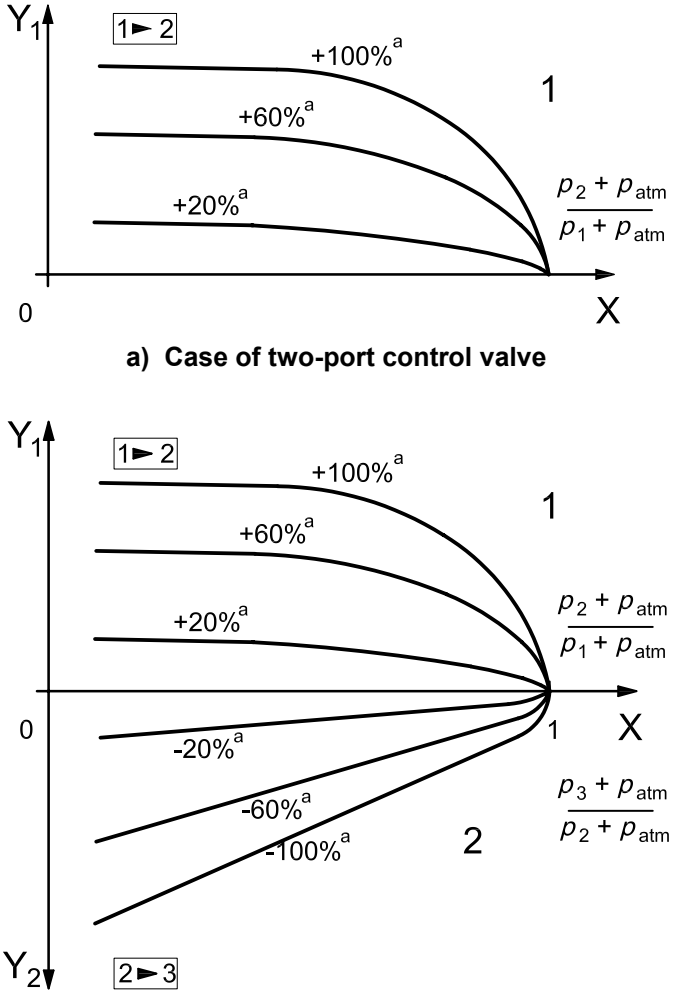
5.3.2.2 Pressure-flow rate global characteristic curves

5.3.2.2.1 In the case of a two-port continuous flow control valve, operating forward flow rate shall be plotted in accordance with Figure 2 a).

5.3.2.2.2 In the case of a three-port continuous flow control valve, operating flow rate shall be plotted in accordance with Figure 2 b).

5.3.2.2.3 In the case of a five-port continuous flow control valve, if the valve is symmetric, only the characteristics of port 2 are given in accordance with Figure 2 b) (they are the same for port 4). Otherwise operating flow rates at each working port shall be plotted on two graphs in accordance with Figure 3.

5.3.2.2.4 Each characteristic curve describes the operating flow rate related to the pressure ratio, for a given inlet pressure noted in relative value as shown in Figure 2 for two-port and three-port flow control valves and in Figure 3 for five-port flow control valves.



a) Case of two-port control valve

b) Case of three-port control valve

Key

X back-pressure ratio

Y_1 forward flows, in dm^3/s (ANR)

Y_2 relief flows, in dm^3/s (ANR)

p_1 inlet pressure, p_1 = 630 kPa (6,3 bar)

1 1st quadrant

2 4th quadrant

a Control signal.

Figure 2 — Pressure-flow rate global characteristics

5.3.2.2.5 Each graph contains several curves that differ in their electrical control signal settings, as shown in Figure 2 a) for two-port flow control valve, in Figure 2 b) for three-port flow control valves and in Figure 3 for five-port flow control valves.

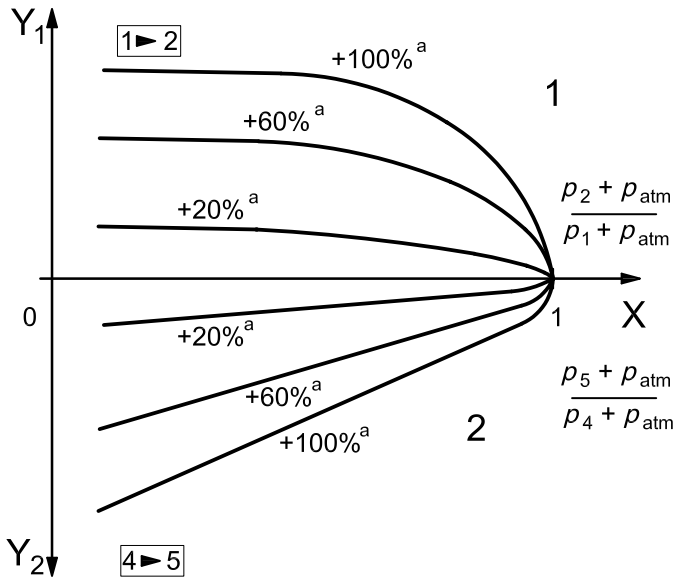
5.3.2.2.6 For a non symmetrical five-port flow control valve, the pressure-flow rate characteristic curves of each of the two working ports are plotted on the same graph:

— curves for electrical control signal values higher than the median value are shown in Figure 3 a);

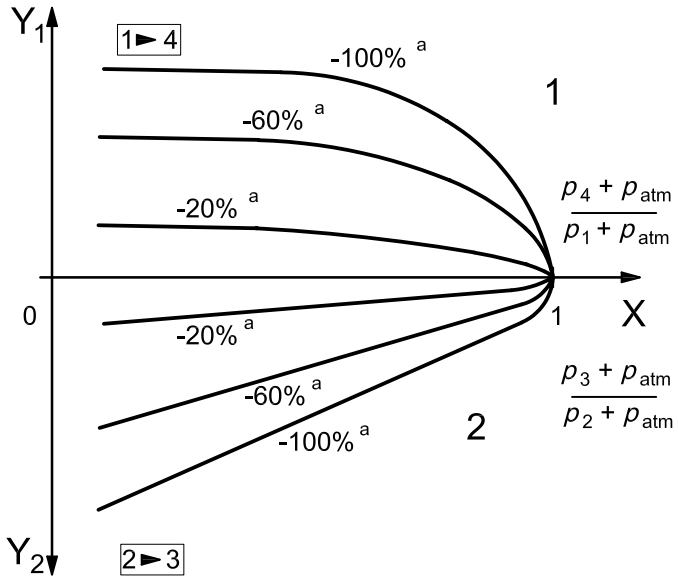
— curves for electrical control signal values lower than the median value are shown in Figure 3 b).

5.3.2.2.7 The selection of control values and test programme shall be in accordance with ISO 10041-2:2010, 8.2.

5.3.2.2.8 Each curve shown in Figure 2 and Figure 3 shall be plotted in accordance with ISO 10041-2:2010, 8.3.2.



a) Control values higher than median value



b) Control values lower than median value

Key

X back-pressure ratio
Y_1 forward flows, in dm^3/s (ANR)
Y_2 relief flows, in dm^3/s (ANR)
p_1 inlet pressure, $p_1 = 630$ kPa (6,3 bar)
1 1st quadrant
2 4th quadrant
a Electrical control signal.

Figure 3 — Pressure-flow rate global characteristics in the case of a five-port control valve

5.3.3 Pressure gain characteristic curve at null operating flow rate

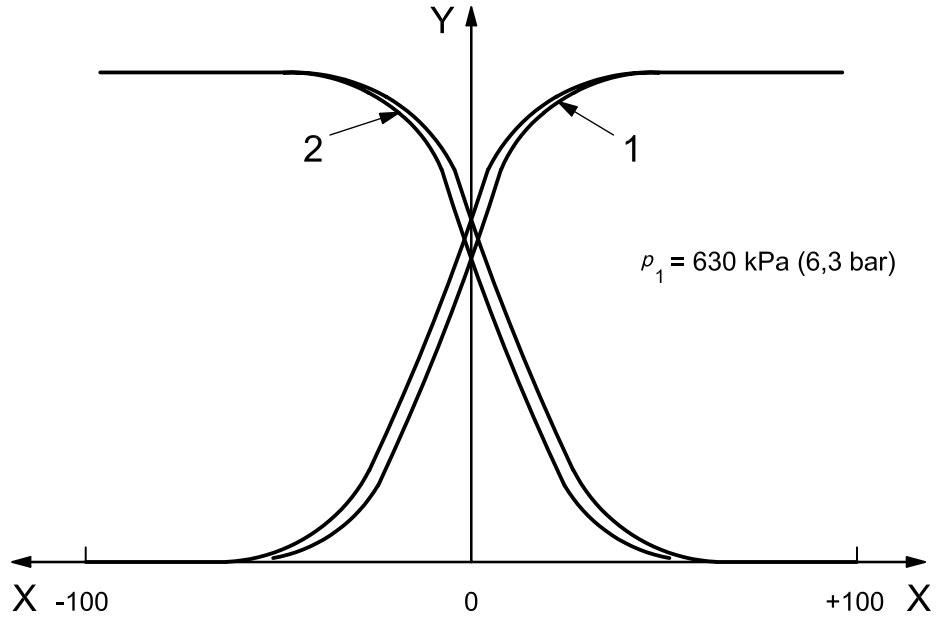
5.3.3.1 In the case of a five-port flow control valve, the variations of the operating pressures, p_2 or p_4, at null operating flow rates shall be indicated by two hysteresis curves in accordance with Figure 4.

5.3.3.2 In the case of a three-port flow control valve, only one hysteresis curve is obtained corresponding to the variation of the operating pressure, p_2, in Figure 4.

5.3.3.3 Each pressure gain characteristic curve shows the operating pressure versus the electrical control signal over its full scale, for a given inlet pressure noted in relative value as shown in Figure 4.

5.3.3.4 The test shall be performed in accordance with ISO 10041-2:2010, 9.3.

5.3.3.5 Each curve shown in Figure 4 corresponding to the pressure at a working port is plotted in accordance with ISO 10041-2:2010, 9.4, taking for each value of electrical control signal the values of pressure measured with both increasing and decreasing electrical control signals.



Key

X electrical control signal, in %
Y operating pressures, in kPa (bar)
p_1 inlet pressure
1 port 2 flow rate
2 port 4 flow rate

Figure 4 — Pressure gain characteristic curves at null operating flow rates

5.3.4 Maximum leakage flow rate at null operating flow rate

5.3.4.1 The maximum leakage flow rate indicates the maximum air consumption when the valve is closed (i.e. leakage at null operating flow rate).

5.3.4.2 The leakage flow rate shall be measured at the inlet port versus the electrical control signal over its full scale, with both increasing and decreasing electrical control signals, for a given inlet pressure.

5.3.4.3 This test shall be performed in accordance with ISO 10041-2:2010, Clause 10 and the maximum value of the leakage rate shall be determined in accordance with ISO 10041-2:2010, 10.2.

5.4 Dynamic characteristics

5.4.1 General

5.4.1.1 The dynamic characterisation of electro-pneumatic continuous flow control valves shall be performed considering the position of the moving element of the valve as the output value. This output value is independent of the number of ports of the valve, so the principle of the dynamic characterisation is the same for two-port, three-port and five-port electro-pneumatic flow control valves.

5.4.1.2 Tests to determine the dynamic characteristics shall be done with the flow control valve connected to the supply circuit and the working port(s) at atmospheric pressure.

5.4.2 Frequency responses

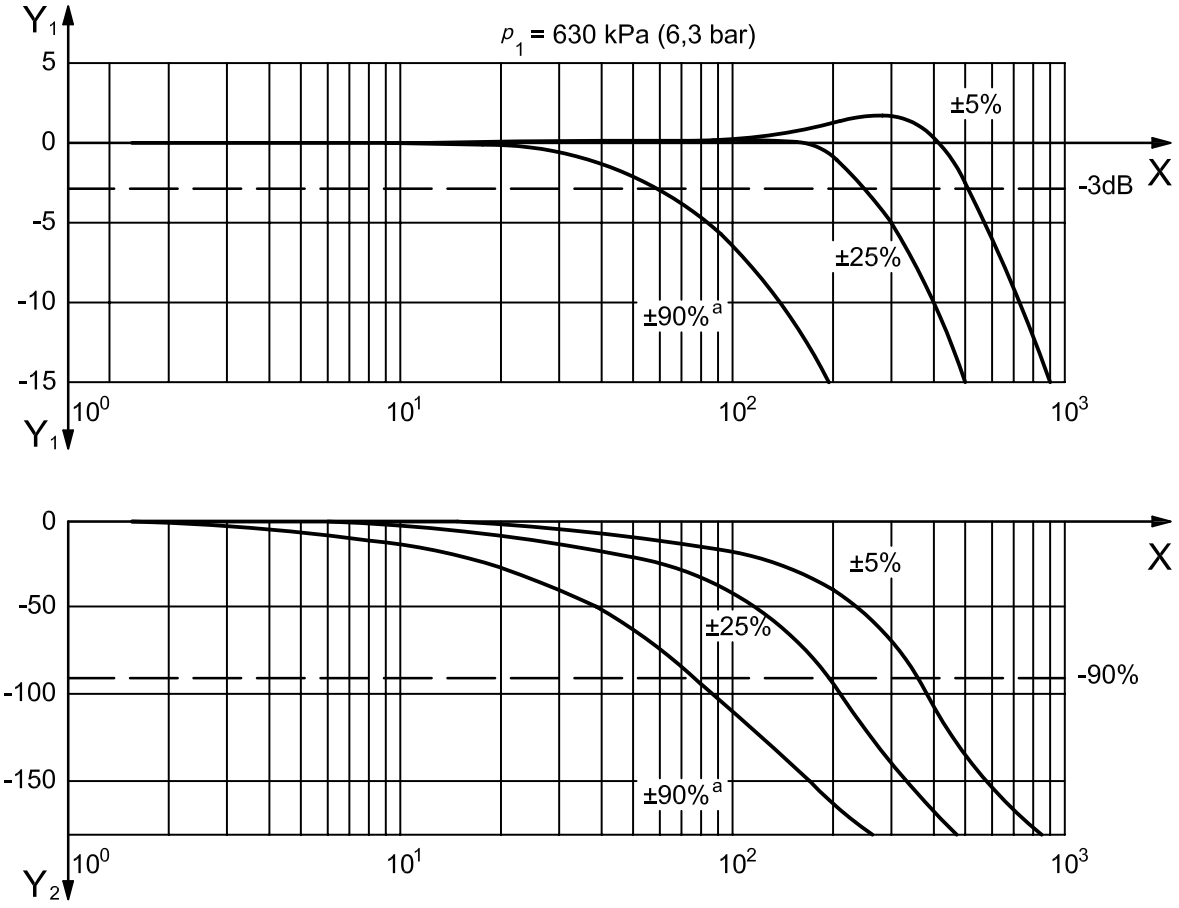
5.4.2.1 Characteristic curve

5.4.2.1.1 The variations of the amplitude and phase-lag of the position signal in relation to the electrical control signal shall be indicated using a Bode diagrams, depending on the frequency, as shown in Figure 5. This graph shall include at least three different electrical control signal amplitudes for a given inlet pressure noted in relative value as shown in Figure 5.

5.4.2.1.2 The selection of amplitudes and the test programme shall be performed in accordance with ISO 10041-2:2010, 11.2.1.

5.4.2.1.3 The values of the amplitudes shall be indicated as shown in Figure 5.

5.4.2.1.4 The curves shown in Figure 5 shall be plotted in accordance with ISO 10041-2:2010, 11.2.2.



Key

X frequency, in Hz

Y_1 amplitude, in dB

Y_2 phase lag (deg)

p_1 inlet pressure

a Input signal.

Figure 5 — Frequency responses

5.4.2.2 Characteristic frequencies

5.4.2.2.1 The frequency values corresponding to, respectively, 3 dB amplitude attenuation and 90° phase lag shall be reported in the format given in Table 3. The table shall include at least three values of electrical control signal amplitude.

5.4.2.2.2 The amplitude values shall be chosen and the test programme performed in accordance with ISO 10041-2:2010, 11.2.1.

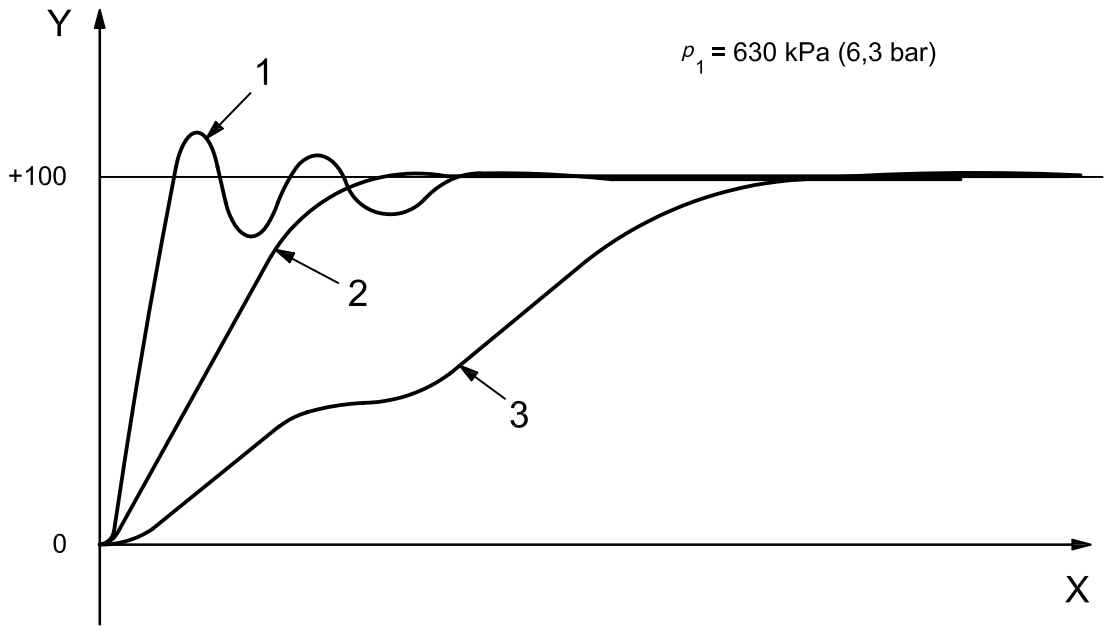
5.4.2.2.3 The frequencies shall be determined in accordance with ISO 10041-2:2010, 11.2.3.

Table 2 — Format for reporting characteristic frequencies

Inlet pressure: __ kPa (bar)		
Amplitude of electrical control signal %	**Frequency corresponding to**	
	3 dB **amplitude attenuation**	90° **phase lag**
±5		
±25		
±90		

5.4.3 Step responses

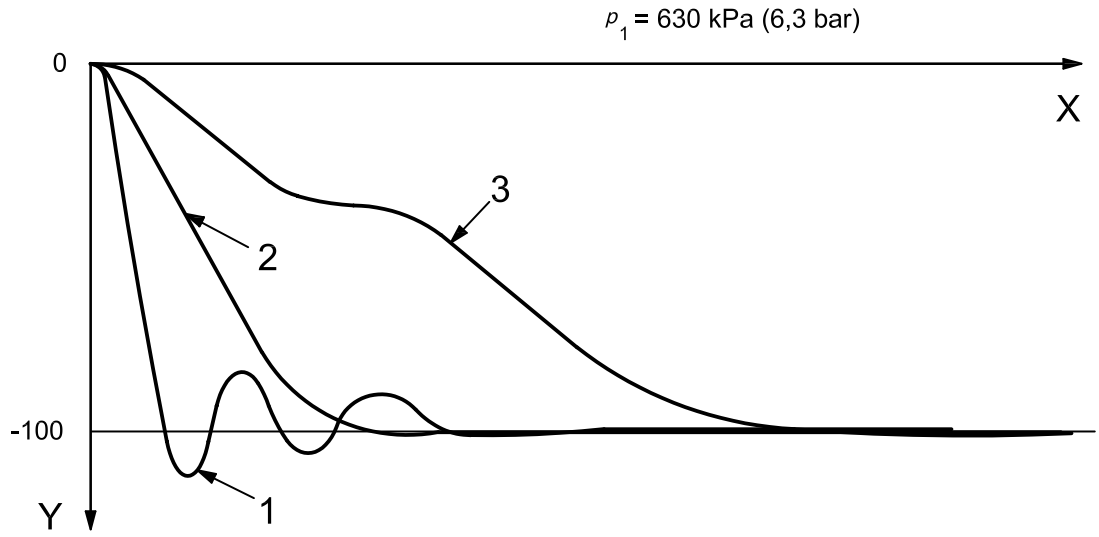
5.4.3.1 The variations over time of the valving element position in response to electrical control signal steps shall be shown in accordance with Figures 6 and 7.



Key

X	time, in s	1	step 1
Y	position, in % of amplitude	2	step 2
p_1	inlet pressure	3	step 3

Figure 6 — Step responses to positive control signal steps



Key

X	time, in s	1	step 1
Y	position, in % of amplitude	2	step 2
p_1	inlet pressure	3	step 3

Figure 7 — Step responses to negative control signal steps

5.4.3.2 For each of the six types of control steps specified in Table 3, a graph shall indicate at least three different step electrical control signal amplitude curves. The amplitude values shall be selected and the test shall be performed in accordance with ISO 10041-2:2010, 11.3.1.

5.4.3.3 Initial and final electrical control signal values shall be indicated in accordance with Figures 6 and 7 and Table 3.

5.4.3.4 Step responses represented in Figures 6 and 7 shall be plotted in accordance with ISO 10041-2:2010, 11.3.2.

5.4.3.5 The shifting time, the response time, the settling time and the overshoot or undershoot shall be determined for each control step in accordance with ISO 10041-2:2010, 11.3.3, and shall be reported in the format given in Table 3.

Table 3 — Format for reporting dynamic characteristic values for each type of control step

Electrical control signal values	Type of control steps					
	On both sides of the median value of the electrical control signal		From the median value of the electrical control signal		Towards the median value of the electrical control signal	
	Positive steps %	Negative steps %	Positive steps %	Negative steps %	Positive steps %	Negative steps %
Step 1	–5 to +5	+5 to –5	0 to +5	0 to –5	–5 to 0	+5 to 0
Shifting time (s)						
Response time (s)						
Settling time (s)						
Overshoot or undershoot (%)						
Step 2	–25 to +25	+25 to –25	0 to +25	0 to –25	–25 to 0	+25 to 0
Shifting time (s)						
Response time (s)						
Settling time (s)						
Overshoot or undershoot (%)						
Step 3	–90 to +90	+90 to –90	0 to +90	0 to –90	–90 to 0	+90 to 0
Shifting time (s)						
Response time (s)						
Settling time (s)						
Overshoot or undershoot (%)						

6 Identification statement (reference to this part of ISO 10041)

It is highly recommended that the following statement be used in test reports, catalogues and sales literature when electing to comply with this part of ISO 10041:

"Characteristics and requirements for electro-pneumatic continuous flow control valves are in accordance with ISO 10041-1:2010, *Pneumatic fluid power — Electro-pneumatic continuous flow control valves — Part 1: Main characteristics to include in the supplier's literature.*"

Bibliography

[1] ISO 6358-1[1)], *Pneumatic fluid power — Determination of flow-rate characteristics of components — Part 1: General rules and test methods for steady-state flow*

[2] ISO 8778:2003, *Pneumatic fluid power — Standard reference atmosphere*

[3] ISO 10094-1, *Pneumatic fluid power — Electro-pneumatic pressure control valves — Part 1: Main characteristics to include in the supplier's literature*

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

1) To be published. (Revision of ISO 6358:1989)

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