
**Hydraulic fluid power — Electrically
modulated hydraulic control valves —**

**Part 3:
Test methods for pressure control
valves**

*Transmissions hydrauliques — Distributeurs hydrauliques à
modulation électrique —*

*Partie 3: Méthodes d'essai pour distributeurs de commande 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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*, Sub-committee SC 8, *Product testing*.

This second edition cancels and replaces the first edition (ISO 10770-3:2007), which has been technically revised.

A list of all parts in the ISO 10770 series can be found on the ISO website.

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

This document describes methods of testing electro-hydraulic pressure relief and pressure reducing valves. These types of electro-hydraulic valves prevent the pressure in a hydraulic system rising above a level defined or set by an electrical input signal.

Relief valves are used to control the pressure in a closed volume by increasing the flow out of the volume if the pressure exceeds the set pressure level. The excess flow is dumped directly to a tank.

Reducing valves are used to control the pressure in a closed volume by restricting the flow into the volume if the pressure exceeds the set pressure level.

The design of the system and the position of the valve within the system dictates which type of valve is appropriate to use.

This document has been prepared with the intention of improving the uniformity of valve testing and hence the consistency of recorded valve performance data so that these data can be used for system design, regardless of the data source.

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Hydraulic fluid power — Electrically modulated hydraulic control valves —

Part 3: Test methods for pressure control valves

1 Scope

This document describes test methods for determining the performance characteristics of electrically modulated hydraulic pressure control valves.

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 3448:1992, *Industrial liquid lubricants — ISO viscosity classification*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

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

ISO 6743-4, *Lubricants, industrial oils and related products (class L) — Classification — Part 4: Family H (Hydraulic systems)*

ISO 9110-1:1990, *Hydraulic fluid power — Measurement techniques — Part 1: General measurement principles*

ISO 10771-1, *Hydraulic fluid power — Fatigue pressure testing of metal pressure-containing envelopes — Part 1: Test method*

3 Terms, definitions and symbols

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 Terms and definitions

3.1.1

electrically modulated pressure control valve

valve that limits the pressure in a hydraulic system to a level that is continuously variable and proportional to an electrical input signal

3.1.2

electrically modulated relief valve

valve that limits the pressure at the inlet port by dumping excess flow to the tank port

3.1.3

electrically modulated reducing valve

valve that limits the pressure at the outlet port by reducing the flow taken from the inlet port

3.1.4

controlled pressure

pressure difference between inlet and outlet of the relief valve under test or the pressure at the outlet of the reducing valve under test

3.1.5

controlled pressure volume

total volume of fluid in a test rig directly connected to the inlet of the relief valve under test, or the outlet of the reducing valve under test

3.1.6

head loss

minimum pressure drop through a valve

Note 1 to entry: The head loss is plotted as pressure versus flow.

3.1.7

reference pressure

controlled pressure measured at 10 % of rated flow

3.2 Symbols

For the purposes of this document, the symbols given in [Table 1](#) apply:

Table 1 — Symbols

Parameter	Symbol	Unit
Frequency	f	Hz
Input signal	I or U	A or V
Rated signal	I_N or U_N	A or V
Current readout	I_{READ}	A
Pressure gain	$K_p = (\Delta p / \Delta I \text{ or } \Delta p / \Delta U)$	bar (per input signal unit)
Inductance	L_C	H
Supply pressure	p_P	MPa (bar)
Return pressure	p_T	MPa (bar)
Controlled pressure	p_C	MPa (bar)
Valve pressure drop	$p_V = p_P - p_T$	MPa (bar)
Rated pressure	p_N	MPa (bar)
Output flow	q	l/min
Rated flow	q_N	l/min
Internal leakage	q_I	l/min
Insulation resistance	R_i	Ω
Resistance	R_C	Ω
Time	t	s
Time constant	t_C	s
Dither amplitude	—	% (of max. input signal)
Dither frequency	—	Hz
Hysteresis	—	% (of max. output)
Threshold	—	% (of maximum input)

Table 1 (continued)

Parameter	Symbol	Unit
Amplitude (ratio)	—	dB
Phase lag	—	°
Temperature	—	°C

The graphical symbols in this document conform to ISO 1219-1 and IEC 60617-DB.

4 Standard test conditions

Unless otherwise specified, tests shall be carried out using the standard conditions given in [Table 2](#).

Table 2 — Standard test conditions

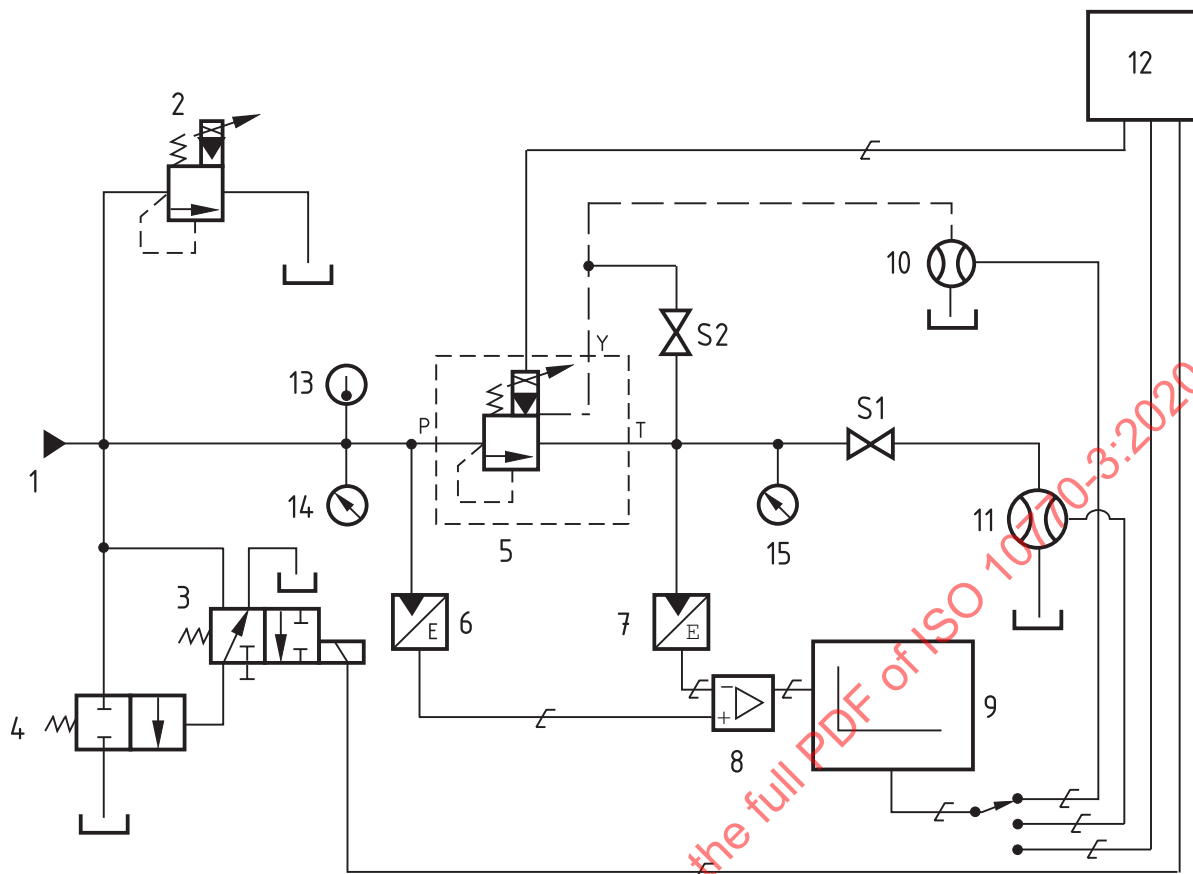
Parameter	Condition
Ambient temperature	20 °C ± 5 °C
Filtration	Solid contaminant code number shall be stated in accordance with ISO 4406.
Fluid type	Commercially available mineral based hydraulic fluid (i.e. L – HL in accordance with ISO 6743-4 or other fluid with which the valve is able to operate).
Fluid viscosity	32 cSt ± 8 cSt at valve inlet
Viscosity grade	Grade VG32 or VG46 in accordance with ISO 3448:1992.
Supply pressure	Test requirement ±2,5 %
Return pressure	Return pressure shall conform to the manufacturer's recommendations.

5 Test installation

SAFETY PRECAUTION — It is essential that consideration is given to the safety of personnel and equipment during the tests.

A test installation conforming to the requirements of [Figure 1](#), [Figure 2](#) or [Figure 3](#) shall be used for testing all valves. [Figures 1](#) to [3](#) show the minimum items required to carry out the tests without any safety devices to protect against damage in the event of component failure. For tests using the test circuits shown in [Figures 1](#) to [3](#), the following apply:

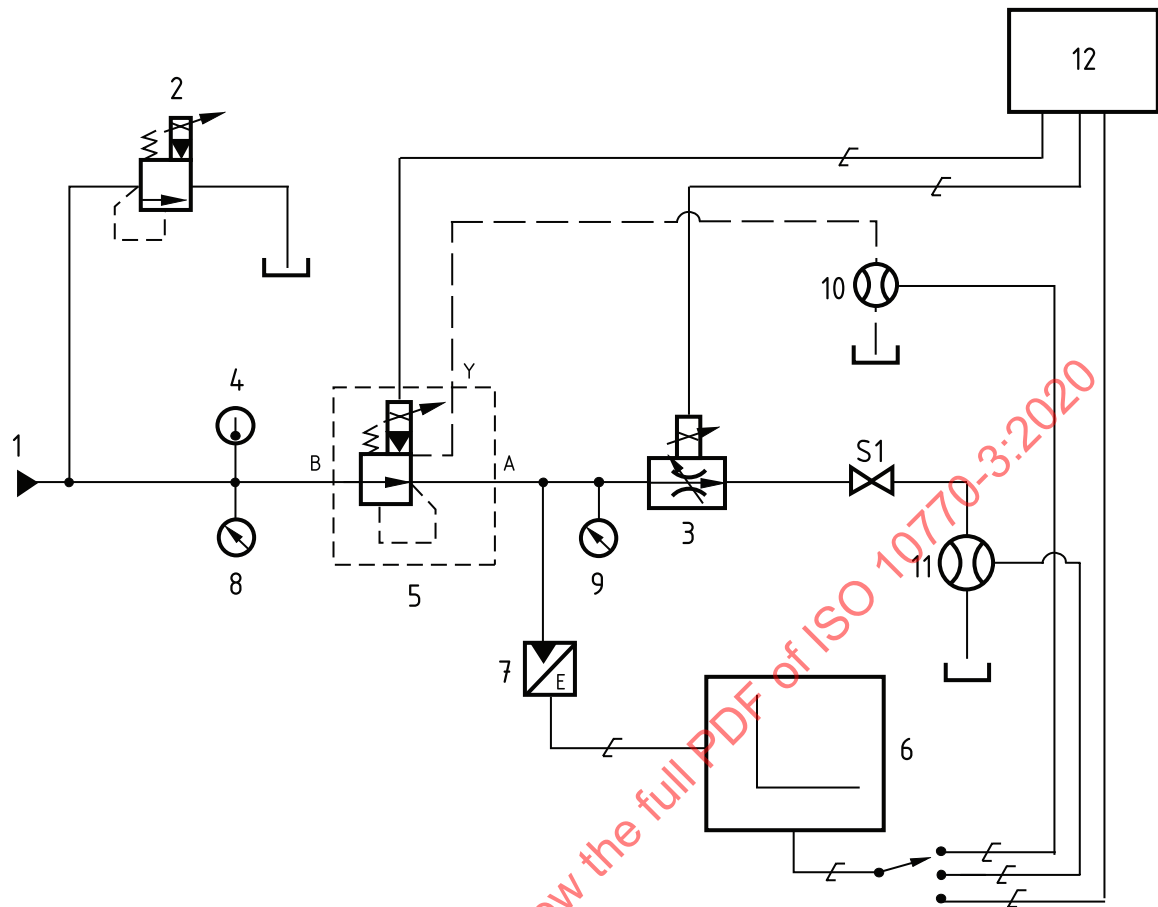
- Guidance on carrying out the tests is given in [Annex A](#).
- A separate circuit may be constructed for each type of test. This can improve the accuracy of test results as it eliminates the possibility of leakage through the shut-off valves.
- Hydraulic performance tests are carried out on a combination of valve and amplifier. Input signals are applied to the amplifier and not directly to the valve. For electrical tests, the signals are applied directly to the valve.
- If possible, hydraulic tests should be conducted using an amplifier, recommended by the valve manufacturer. If not, the type of amplifier used should be recorded, with the operating details (i.e. pulse width modulation frequency, dither frequency and amplitude).
- The amplifier supply voltage and magnitude and sign of the voltage applied to the valve during the on and off periods of the pulse-width modulation should be recorded.
- Electronic test equipment and transducers should have a bandwidth or natural frequency at least ten times greater than the maximum test frequency.
- Flow transducer 10 shall be selected to have negligible effect on the pressure at port Y.



Key

- | | |
|-----------------------------------|--------------------------|
| 1 flow source | 11 flow transducer |
| 2 system relief valve | 12 signal generator |
| 3 pilot valve for unloading valve | 13 temperature indicator |
| 4 unloading valve | 14 pressure gauge |
| 5 unit under test | 15 pressure gauge |
| 6 pressure transducer | S1 shut-off valve |
| 7 pressure transducer | S2 shut-off valve |
| 8 differential amplifier | P supply port |
| 9 data acquisition | T return port |
| 10 flow transducer | Y pilot-drain port |

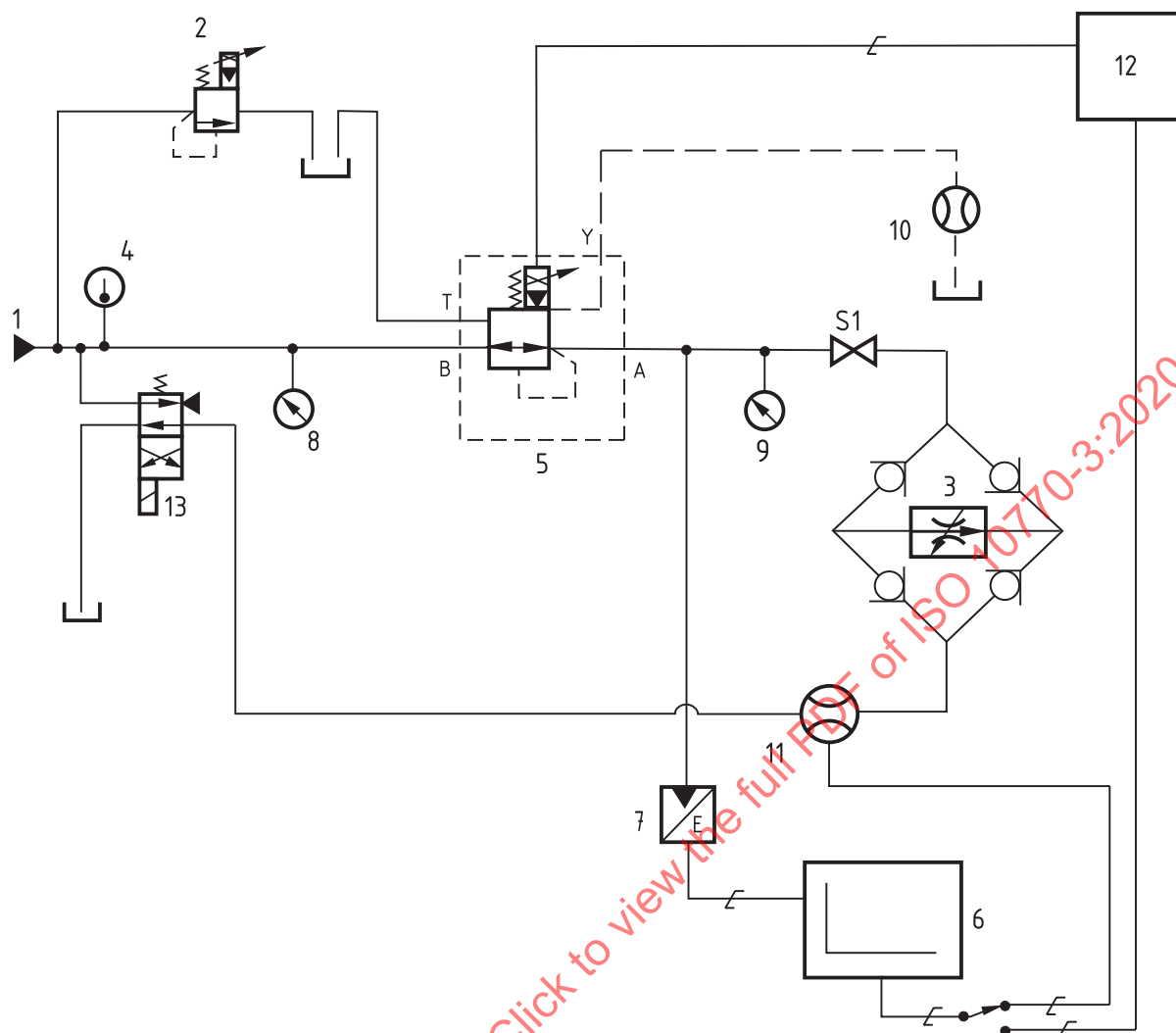
Figure 1 — Relief-valve test circuit



Key

- | | | | |
|---|-----------------------|----|-----------------------|
| 1 | flow source | 9 | pressure gauge |
| 2 | system relief valve | 10 | flow transducer |
| 3 | flow control valve | 11 | flow transducer |
| 4 | temperature indicator | 12 | signal generator |
| 5 | unit under test | A | control-pressure port |
| 6 | data acquisition | B | inlet-pressure port |
| 7 | pressure transducer | S1 | shut-off valve |
| 8 | pressure gauge | Y | pilot-drain port |

Figure 2 — Reducing valve test circuit



Key

1	flow source	10	flow transducer
2	system relief valve	11	flow transducer
3	flow control valve	12	signal generator
4	temperature indicator	13	directional valve
5	unit under test	A	control-pressure port
6	data acquisition	B	inlet-pressure port
7	pressure transducer	S1	shut-off valve
8	pressure gauge	T	return pressure port
9	pressure gauge	Y	pilot-drain port

Figure 3 — Reducing valve with reverse flow test circuit

6 Accuracy

6.1 Instrument accuracy

Instrumentation shall be accurate to within the limits specified in ISO 9110-1:1990, Class B:

- electrical resistance: ± 2 % of the actual measurement;

- b) pressure: ± 1 % of the valve under test rated pressure;
- c) temperature: ± 2 % of the temperature to measure;
- d) flow: $\pm 2,5$ % of the valve under test rated flow;
- e) demand: $\pm 1,5$ % of the electrical demand signal required to achieve the rated pressure.

6.2 Dynamic range

For the dynamic tests, ensure that the measuring equipment, amplifiers and recording devices do not generate any damping, attenuation or phase shift of the output signal being recorded that can affect the measured value by more than 1 % of the measured value.

7 Electrical tests for valves without integrated electronics

7.1 General

As appropriate, perform the tests described in [7.2](#) to [7.4](#) on all valves without integrated electronics before proceeding to subsequent tests.

NOTE Tests [7.2](#) to [7.4](#) only apply to current-driven valves.

7.2 Coil resistance

7.2.1 Coil resistance (cold)

- a) Soak the complete un-energized valve at the specified ambient temperature for at least 2 h.
- b) Measure and record the electrical resistance between the two leads or terminals of each coil in the valve.

7.2.2 Coil resistance (hot)

- a) Soak the complete, energized valve, mounted on a sub-plate as recommended by the manufacturer, at its maximum rated temperature and operate the complete valve, fully energised and without flow until the coil temperature stabilizes.
- b) Measure and record the electrical resistance between the two leads or terminals of each coil in the valve. The resistance value shall be measured within 1 s of removing the supply voltage.

7.3 Coil inductance (optional test)

This test method shall not be considered to determine a definitive value of inductance. The value obtained shall be used for comparison purposes only.

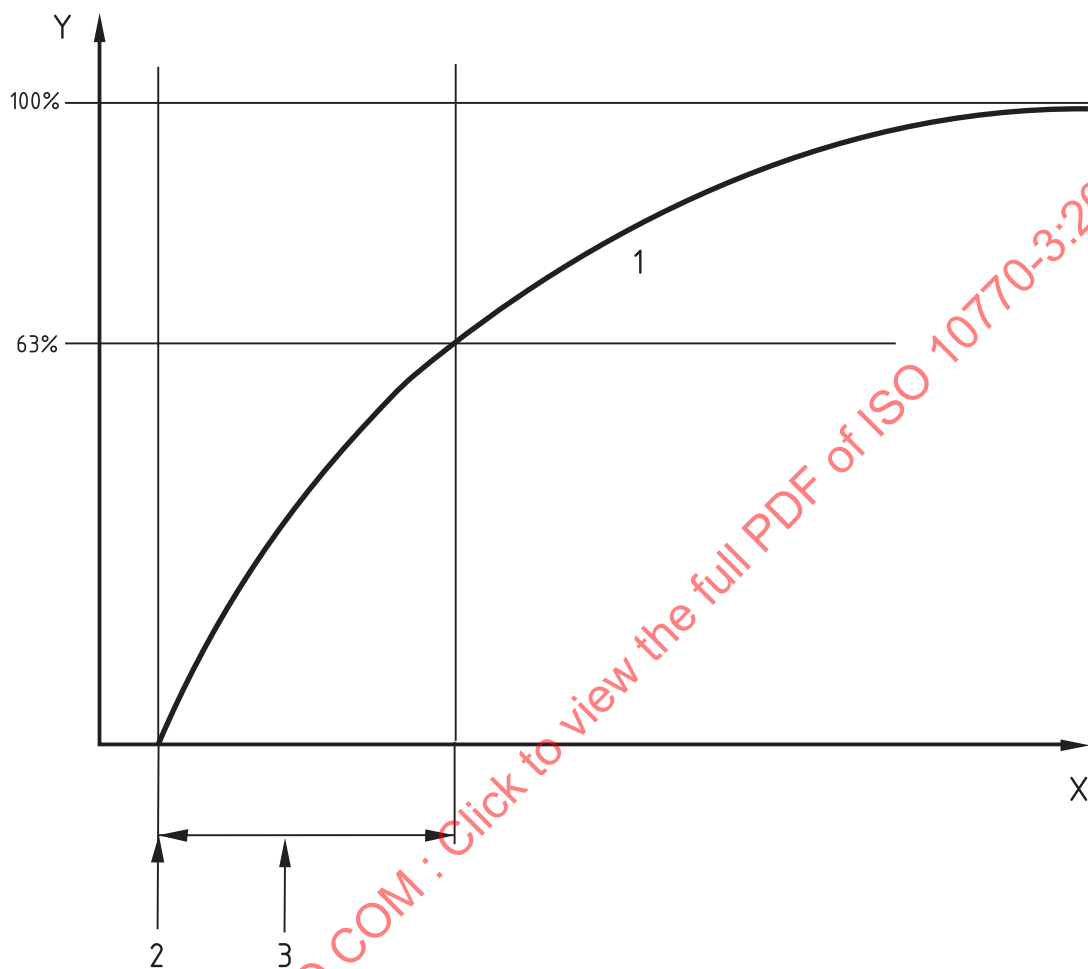
Perform the test as follows:

- a) Connect the coil to a constant voltage supply capable of delivering at least the rated current of the coil;
- b) Hold the armature stationary at 50 % of its working stroke during the test;
- c) Monitor the coil current using an oscilloscope or similar equipment;
- d) Adjust the voltage so that the steady-state current equals the rated current of the coil;
- e) Switch the voltage off then on and record the current transient behaviour;

- f) Determine the time constant, t_c , of the coil (see [Figure 4](#)) and calculate the inductance, L_C , using [Formula \(1\)](#)

$$L_C = R_C t_c \quad (1)$$

where R_C is the coil resistance, expressed in ohms.



Key

- X time
- Y current, in percent
- 1 DC current trace
- 2 initiation
- 3 time constant, t_c

Figure 4 — Coil inductance measurement

7.4 Insulation resistance

Establish the insulation resistance of the coil as follows:

- a) If internal electrical components are in contact with the fluid (i.e. the coil is wet), fill the valve with hydraulic fluid before carrying out the test;
- b) Connect the valve coil termini together with and apply 500 V d.c. between them and the valve body for 15 s;

- c) Using a suitable insulation tester, record the insulation resistance R_i ;
- d) For tester with a current (A) readout, I_{READ} , calculate the insulation resistance using [Formula \(2\)](#).

$$R_i = \frac{500}{I_{\text{READ}}} \quad (2)$$

8 Relief valve

8.1 Steady-state tests

8.1.1 General

Care should be taken to exclude dynamic effects during steady-state tests.

Steady-state tests shall be performed in the order:

- a) optional proof pressure test ([8.1.2](#));
- b) internal leakage test ([8.1.3](#));
- c) test for pressure versus input signal at constant flow ([8.1.4](#) and [8.1.5](#)) to give:
 - 1) the pressure versus signal characteristic,
 - 2) the pressure versus signal linearity,
 - 3) the hysteresis (with respect to input signal changes),
 - 4) the input signal dead band,
 - 5) the threshold;
- d) test for pressure versus flow ([8.1.6](#)) to give:
 - 1) the pressure versus flow characteristic,
 - 2) the hysteresis (with respect to flow changes),
 - 3) the minimum operating pressure,
 - 4) the valve head loss;
- e) pressure versus fluid temperature test ([8.1.7](#)).

8.1.2 Proof pressure tests (optional)

8.1.2.1 General

Proof pressure tests may be carried out to examine the integrity of the valve before conducting further tests.

8.1.2.2 P-port test procedure

Carry out the test as follows:

- a) Apply a proof pressure of 1,0 times the P-port rated pressure to the valve inlet for at least 30 s;
- b) During the test, examine the valve for evidence of external leakage;
- c) After the test, examine the valve for evidence of permanent deformation;

- d) Record the proof pressure used in the test.

8.1.2.3 T-port test procedure

Carry out the test as follows:

- a) Apply a proof pressure of 1,3 times the T-port rated pressure to the valve tank port for at least 30 s;
- b) During the test, examine the valve for evidence of external leakage;
- c) After the test, examine the valve for evidence of permanent deformation;
- d) Record the proof pressure used in the test.

8.1.2.4 Pilot-drain port

Do not apply a proof pressure to any external pilot-drain port.

8.1.3 Internal leakage test

8.1.3.1 General

Internal leakage tests shall be carried out to establish the combined leakage and pilot flow rates at 80 % of the valve reference pressure.

8.1.3.2 Test circuit

Perform the internal leakage test with a hydraulic test circuit conforming to the requirements of [Figure 1](#), with valve S2 open and valve S1 closed.

Measure and record the combined leakage and pilot flow rate using flow transducer 10.

8.1.3.3 Set up

Set the flow source to provide at least 10 % of the test valve rated flow.

Set the maximum input signal to valve 2 so the controlled pressure does not exceed the rated pressure of the test valve.

Set the input signal to the test valve to zero.

8.1.3.4 Procedure

Carry out the test as follows:

- a) Set the input signal to valve 2 to the value defined in [8.1.3.3](#) and the input signal to the test valve to 25 % of the rated pressure of the test valve;
- b) Slowly decrease the setting of valve 2 until the supply pressure to the valve is 80 % of the reference pressure;
- c) Measure and record the total leakage flow;
- d) Decrease the signal to valve 2 to a minimum, then slowly increase the signal until the pressure at the inlet to the test valve is 80 % of the reference pressure;
- e) Measure and record the total leakage flow;
- f) Repeat steps [8.1.3.4](#) a) to e) at 100 % of the rated pressure of the test valve.

8.1.4 Test to establish the valve-controlled pressure versus input signal characteristic with constant flow

8.1.4.1 General

Tests shall be carried out to determine the valve-controlled pressure versus input signal characteristic.

8.1.4.2 Test circuit

Perform the test with a hydraulic test circuit conforming to the requirements of [Figure 1](#), with valve S1 open and valve S2 closed.

Measure the flow through the valve under test using flow transducer 11 and record the result.

8.1.4.3 Set up

Select a suitable plotter or recording apparatus with its X-axis able to record the zero to maximum input signal and its Y-axis able to record the zero to at least the rated pressure (see [Figure 5](#)).

Select a signal generator able to produce a triangular waveform with amplitude from zero to the maximum input signal. Set the signal generator to produce a 0,05 Hz or lower triangular waveform.

Set the input signal to valve 2 so that it is closed during the test

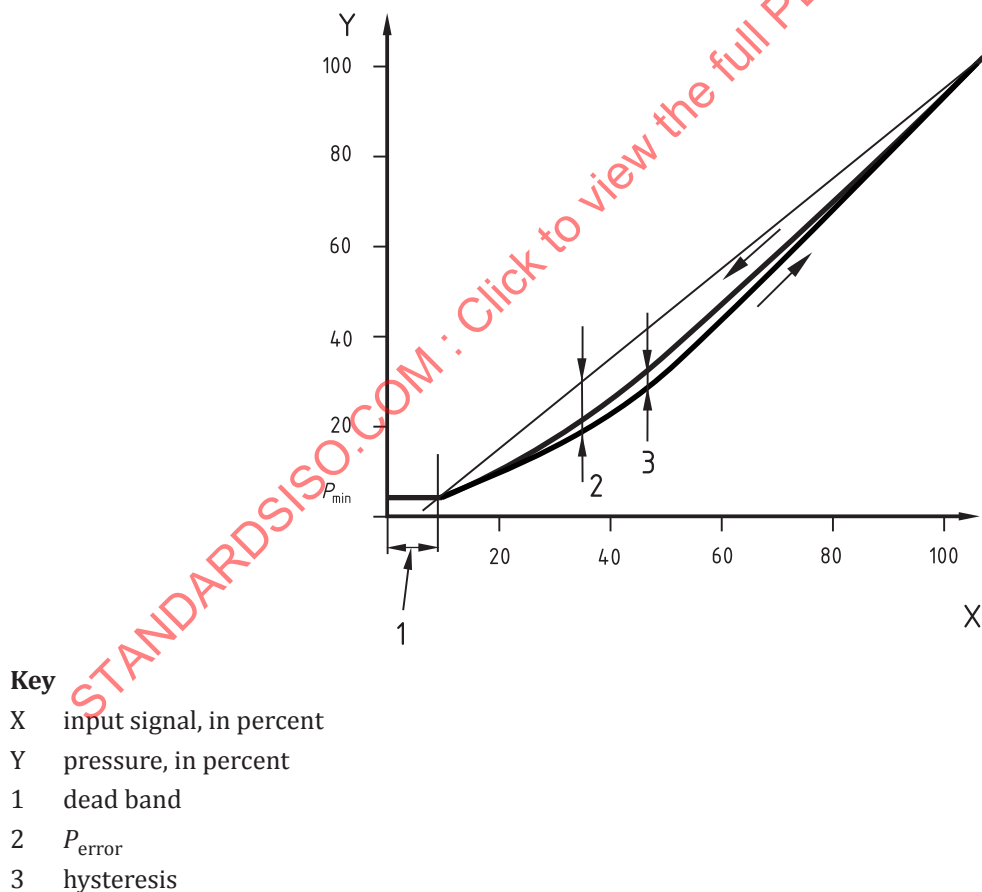


Figure 5 — Pressure versus signal

8.1.4.4 Procedure

Carry out the test as follows:

- a) Set the flow from the flow source to 10 % of the test valve rated flow. During the test, monitor the flow to ensure it does not vary by more than 2 % of the rated flow;

NOTE A means of automatic flow control can be added to the test circuit, if required.

- b) Cycle the valve input signal between minimum and maximum several times and check that the controlled pressure is within the Y-axis range of the recording apparatus;
- c) Ensure that the duration of time of one cycle does not create any dynamic effects that influence the result. Allow the input signal to complete at least one complete cycle;
- d) Record the valve input signal and the controlled pressure over one complete input signal cycle;
- e) Repeat steps 8.1.4.4 a) to d) with the flow source set to 50 % of the test valve rated flow;
- f) Repeat steps 8.1.4.4 a) to d) with the flow source set to 100 % of the test valve rated flow.

For the valve, determine:

- the control pressure at rated signal for each flow source setting used;
- the linearity of the controlled pressure, $p_{\text{error}} / (p_{\text{rated}} - p_{\text{min}})$, expressed as a percentage;
- the hysteresis of the controlled pressure with respect to changes to the input signal;
- the input signal dead band, if any.

8.1.5 Threshold test

8.1.5.1 General

Tests shall be carried out to determine the response of the test valve to a reversal in a ramped input signal.

8.1.5.2 Test circuit

Perform the threshold test with a hydraulic test circuit conforming to the requirements of [Figure 1](#), with valve S1 open and valve S2 closed.

Measure the flow through the test valve using flow transducer 11 and record the result.

8.1.5.3 Set up

Select a suitable plotter or recording apparatus with its X-axis able to record the zero to 10 % input signal and its Y-axis able to record the zero to at least the rated pressure as shown in [Figure 5](#).

Set the signal generator to produce a 0,1 Hz triangular waveform superimposed on a d.c. offset.

Set the input signal to valve 2 so that it is closed during the test.

8.1.5.4 Procedure

Carry out the test as follows:

- a) Adjust the d.c. offset to give a mean pressure of 25 % of the rated pressure. Adjust the output amplitude of the triangular waveform to minimum and ensure there is no change in controlled pressure;

- b) Slowly increase the signal generator output amplitude until a change in controlled pressure is observed;
- c) Record the controlled pressure and input signal over one complete signal cycle;
- d) Repeat steps 8.1.5.4 a) to c) with the mean pressure set to 50 % of the rated pressure;
- e) Repeat steps 8.1.5.4 a) to c) with the mean pressure set to 75 % of the rated pressure.

8.1.6 Pressure versus flow with constant input signal

8.1.6.1 General

Tests shall be carried out to determine the change in controlled pressure with changes in flow through the test valve.

8.1.6.2 Test circuit

Perform the test with a hydraulic test circuit conforming to the requirements of [Figure 1](#), with valve S1 open and valve S2 closed.

Measure the valve flow with flow transducer 11 and record the result.

8.1.6.3 Set up

Select a suitable plotter or recording apparatus with its X-axis able to record the zero to maximum rated flow and its Y-axis able to record the zero to at least the rated pressure as shown in [Figure 6](#).

Select a signal generator able to produce a triangular waveform with amplitude from zero to the rated flow. Set the signal generator to produce a 0,05 Hz or lower triangular waveform.

Set the input signal to valve 2 so that it is closed during the test.

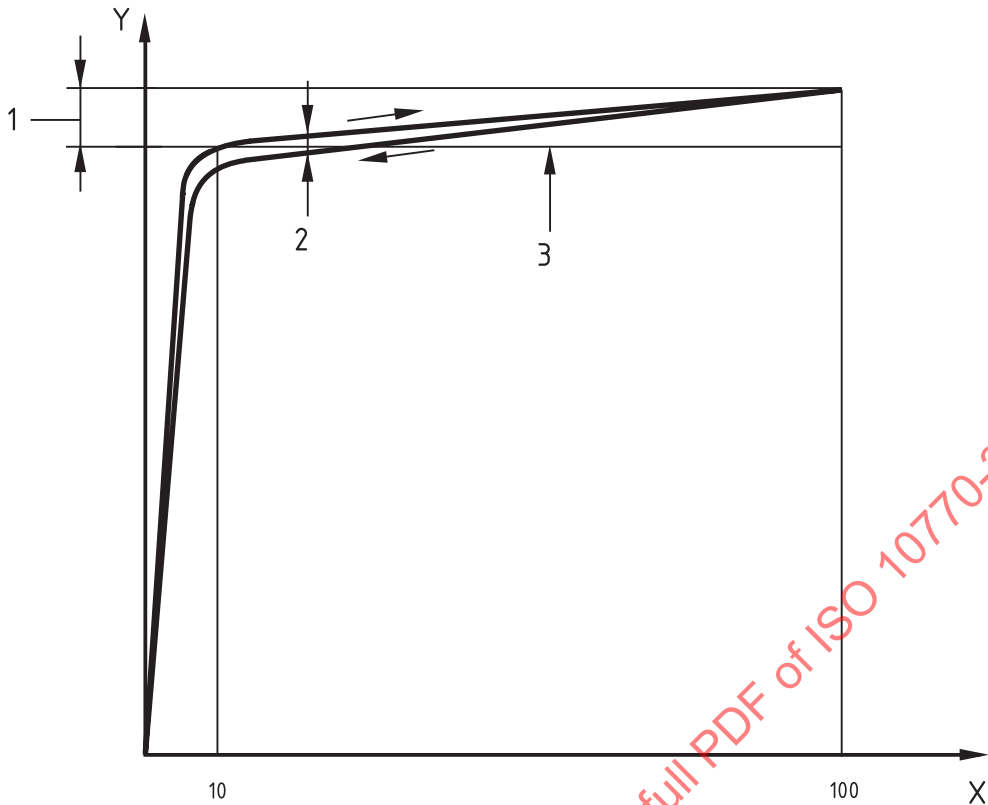
8.1.6.4 Procedure

Carry out the test as follows:

- a) Set the valve flow to 10 % of the rated flow and set the input pressure to the test valve to 25 % of the rated pressure;
- b) Ensure that the duration of time of one cycle does not create dynamic effects that influence the result;
- c) Enable the signal generator for at least one full cycle, recording the valve-controlled pressure and flow for one full cycle;
- d) Repeat steps 8.1.6.4 a) to c) with the input to the test valve set to 50 % of the rated pressure;
- e) Repeat steps 8.1.6.4 a) to c) with the input to the test valve set to 75 % of the rated pressure.
- f) Repeat steps 8.1.6.4 a) to c) with the input to the test valve set to 100 % of the rated pressure;
- g) Repeat steps 8.1.6.4 a) to c) with the input signal set to zero. If the drive amplifier has an enable/disable function, repeat steps 8.1.6.4 a) to c) with the drive amplifier disabled. This gives the minimum pressure (head loss) of the valve.

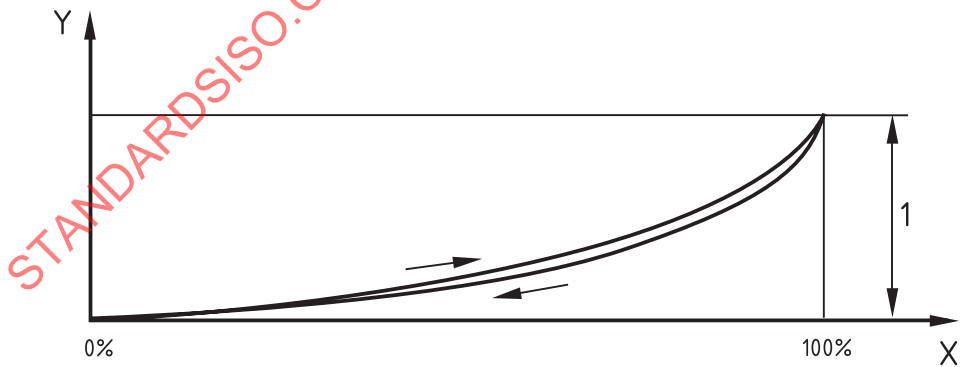
For the valve, determine:

- the pressure-override characteristic (see [Figure 6](#));
- the hysteresis with respect to flow changes (see [Figure 6](#));
- the minimum pressure with flow or head loss (see [Figure 7](#)).



- Key**
- X flow, in percent
 - Y pressure
 - 1 override
 - 2 hysteresis
 - 3 reference pressure

Figure 6 — Pressure versus flow



- Key**
- X flow, in percent
 - Y pressure
 - 1 head loss

Figure 7 — Relief valve head loss

8.1.7 Pressure versus fluid temperature

8.1.7.1 General

Tests shall be carried out to measure the change in controlled pressure with fluid temperature.

8.1.7.2 Test circuit

Perform the test with a hydraulic test circuit conforming to [Figure 1](#), with valve S1 open and valve S2 closed.

8.1.7.3 Set up

Select a suitable plotter or recording apparatus with the X-axis showing the temperature range (20 °C to 70 °C) and the Y-axis showing zero to at least rated pressure as shown in [Figure 8](#).

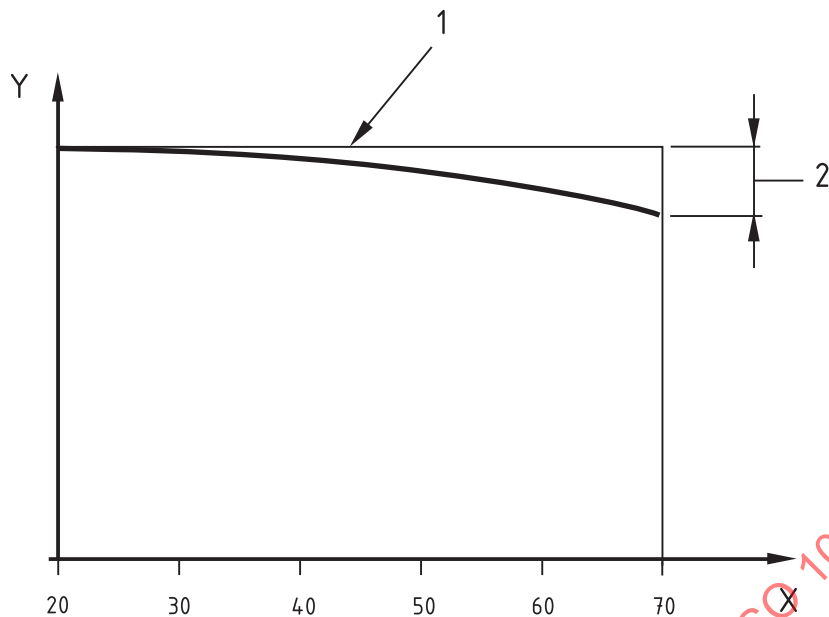
Set the input signal to valve 2 so that it is closed during the test.

Take precautions to avoid air draughts across the valve.

8.1.7.4 Procedure

Carry out the test as follows:

- a) Soak the valve and amplifier at 20 °C for at least 2 h prior to carrying out the test;
- b) Set the flow through the test valve to 50 % of the rated flow and the demand to achieve 50 % of the rated pressure. During the test the flow shall not vary by more than 0,5 % of the rated flow;
- c) Measure and record the controlled pressure, supply fluid temperature and return fluid temperature;
- d) Adjust the heating and/or cooling of the test rig so the fluid temperature rises by approximately 10 °C/h;
- e) Continue recording the parameters shown in [8.1.7.4 c\)](#) until the temperature reaches 70 °C.



Key

- X temperature, °C
- Y pressure
- 1 pressure setting
- 2 pressure change

Figure 8 — Pressure versus temperature

8.2 Dynamic tests

8.2.1 General

The tests shown in [8.2.3](#), [8.2.4](#) and [8.2.5](#) shall be carried out to determine the step response and frequency response of the valve.

8.2.2 Test circuit

Dynamic tests on a pressure relief valve can vary with changes to the controlled pressure volume and diameter of the pipework into and out of the valve under test. The pressure volume shall be less than 1,5 % oil volume of the rated flow. The circuit pipework should conform to [Table 3](#).

Apparent damping of the test valve is increased by any interaction between the pressure and test flow. If possible, the decrease in flow from minimum to maximum test pressure should be less than 2 % of the test flow. The change in flow can result from leakage through valves in the test circuit or leakage within the pump.

Table 3 — Minimum internal diameters of pipes in and out of valve for dynamic tests

Rated flow l/min	Internal diameter mm
25	8
50	10
100	12
200	16
400	24
800	32
1 600	40

8.2.3 Step response (change in input signal)

8.2.3.1 Test circuit

Perform the test with a hydraulic test circuit conforming to the requirements of [Figure 1](#), with valve S1 open and valve S2 closed.

Measure the flow with flow transducer 11 and record the result.

8.2.3.2 Set up

Select a suitable oscilloscope or other electronic equipment to record the controlled pressure and input signal to the valve against time as shown in [Figure 9](#).

Set the signal generator to a square wave output with a duration of time sufficient to ensure that the control pressure has time to stabilize.

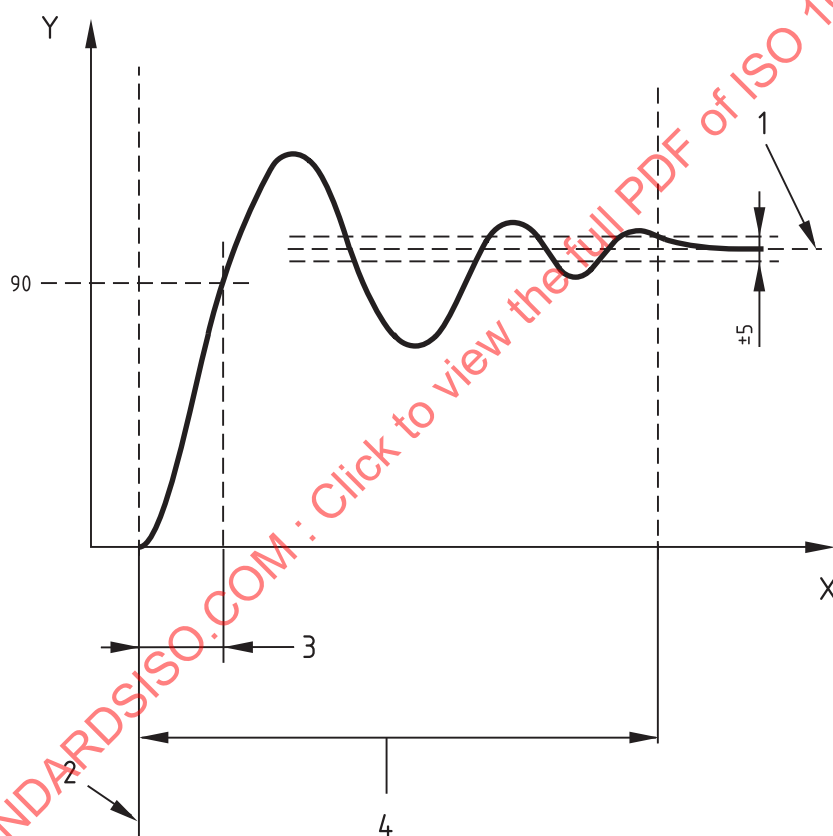
8.2.3.3 Procedure

Carry out the test as follows:

- Set the pump flow through the valve to 50 % of the rated flow;
- Set the signal generator so that the controlled pressure steps between the test 1 pair of start and finish pressures given in [Table 4](#). Enable the output from the signal generator and allow the signal generator to cycle at least once;
- Record the controlled pressure, controlled pressure volume and signal to the valve against time for steps going towards the positive and the negative;
- Ensure that the recording window shows the complete response;
- Repeat steps [8.2.3.3 a\)](#) to [d\)](#) with the controlled pressure set to the pair of pressures given for tests 2 and 3 in [Table 4](#).

Table 4 — Test pressures for step response tests

Test number	Percentage of rated pressure	
	Start %	Finish %
1	0	100
	100	0
2	10	90
	90	10
3	25	75
	75	25

**Key**

- X time
- Y pressure, in percent
- 1 steady-state pressure
- 2 initiation
- 3 response time
- 4 settling time

Figure 9 — Step response — Change in input signal

8.2.4 Step response (change in flow)

8.2.4.1 Test circuit

Perform the test with a hydraulic test circuit conforming to [Figure 1](#), with valve S1 open and valve S2 closed.

Measure the flow with flow transducer 11 and record the result.

The known response time of valve 4 must be less than 30 % of the measured response time of the valve under test.

8.2.4.2 Set up

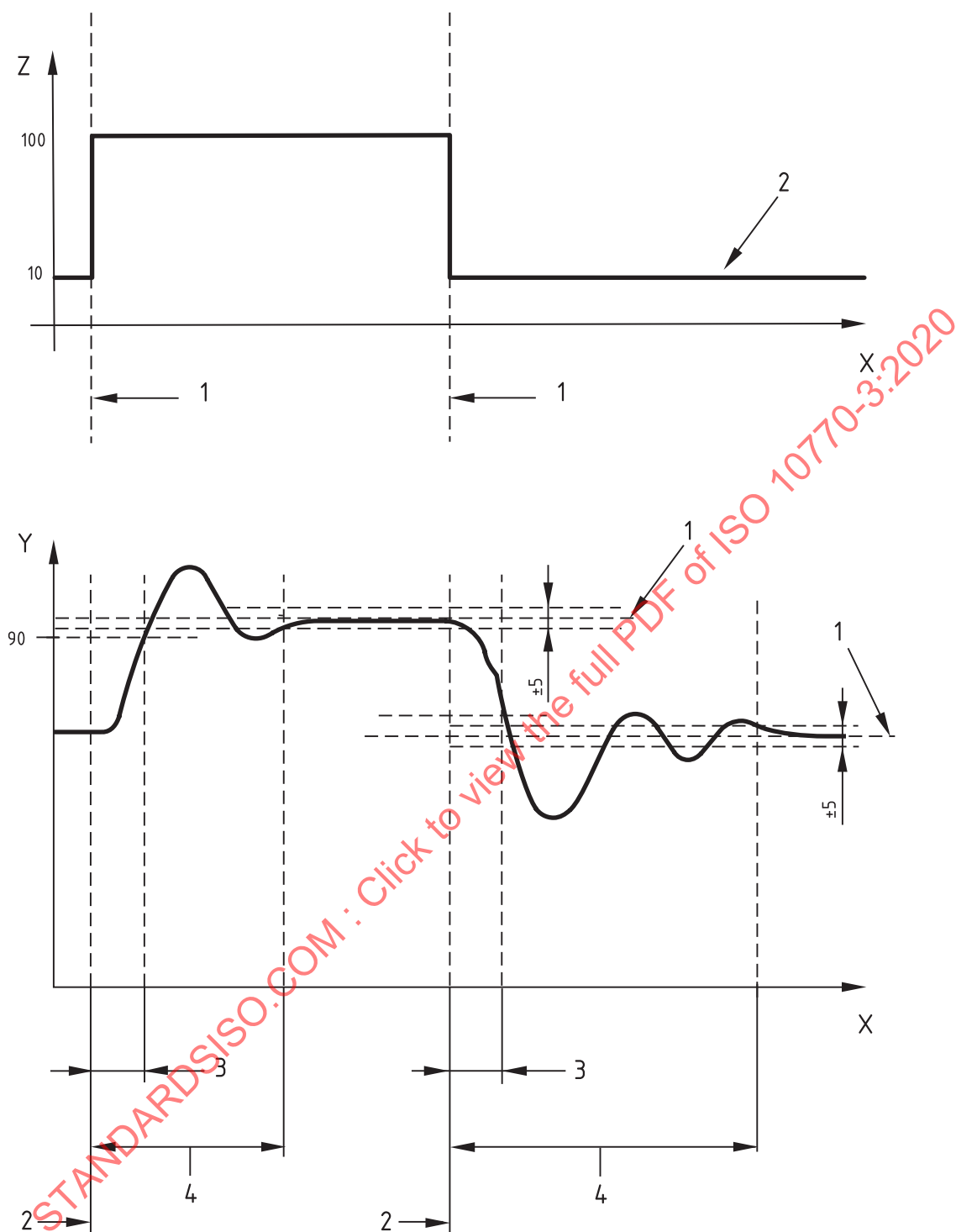
Select a suitable oscilloscope or other electronic equipment to record a signal from the pressure transducer against time as shown in [Figure 10](#).

Set the signal generator to a square wave output with a duration of time sufficient to ensure that the control pressure has time to stabilize.

8.2.4.3 Procedure

Carry out the test as follows:

- a) Set the flow through the valve to 10 % of the rated flow;
- b) Adjust the demand to achieve 50 % of the rated pressure;
- c) Step the flow through the valve between 10 % and 100 % rated flow by means of valve 4 and record the controlled pressure against time for steps going towards the positive and the negative;
- d) Ensure that the recording window shows the complete response;
- e) Repeat steps [8.2.4.3 a\) to d\)](#) with the signal to the valve at 100 % of the rated pressure.



Key

- X time
- Y pressure, in percent
- Z flow, in percent
- 1 steady-state pressure
- 2 initiation
- 3 response time
- 4 settling time

Figure 10 — Relief-valve step response

8.2.5 Frequency response

8.2.5.1 General

The test shall be carried out to determine the frequency response between the electrical input to the valve and the controlled pressure.

8.2.5.2 Test circuit

Perform the test with a hydraulic test circuit conforming to the requirements of [Figure 1](#) and [Table 3](#), with valve S1 open and valve S2 closed.

8.2.5.3 Set up

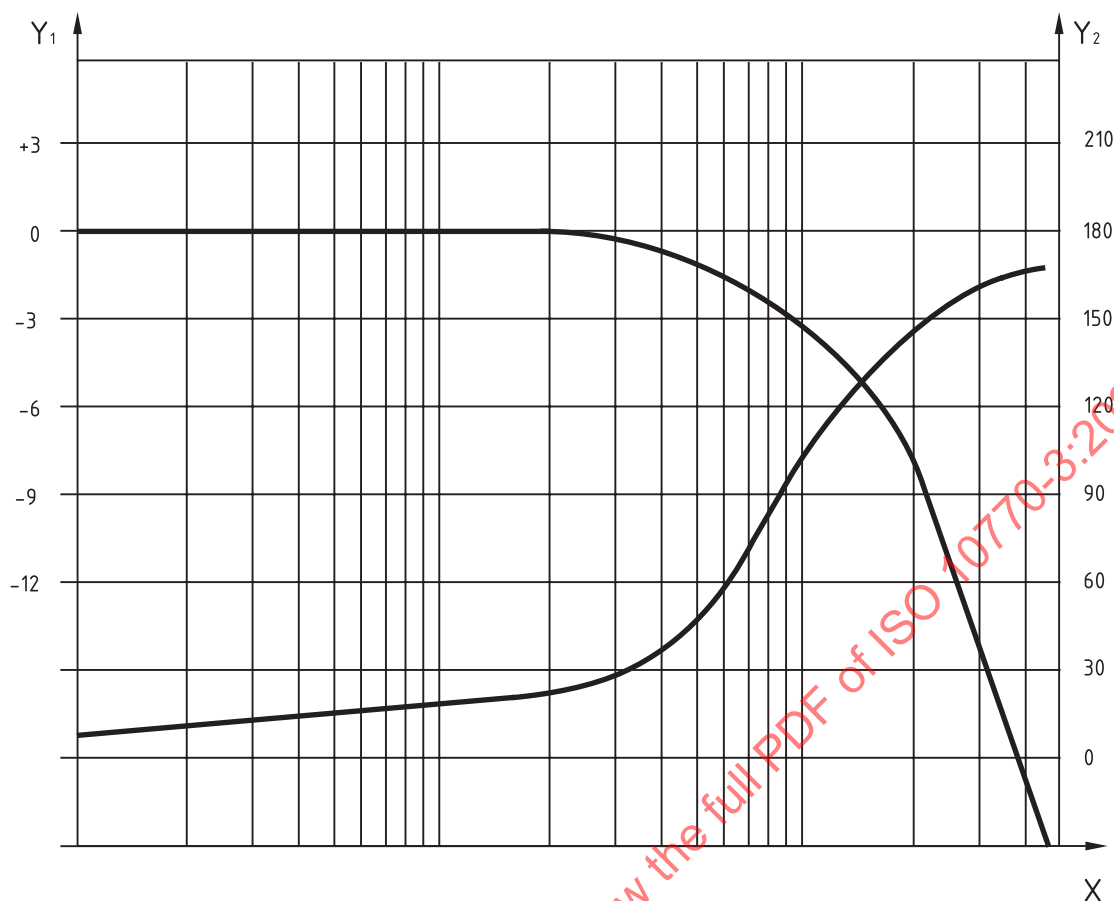
Select a suitable frequency response analyser or other electronic equipment to measure the amplitude ratio and phase shift between two signals using a sinusoidal test signal.

Connect the equipment so as to be able to measure the response between the valve input signal and the controlled pressure as shown in [Figure 11](#).

8.2.5.4 Procedure

Carry out the test as follows:

- a) Set the flow source to 10 % of the rated flow and apply a d.c. offset to the input of the valve to obtain 50 % of the rated pressure;
- b) Add a sinusoidal signal onto the d.c. offset. Set the amplitude of the signal to give a pressure amplitude of ± 5 % of the rated pressure under steady-state conditions. This can be established from the test in [8.1.4](#). Adjust the frequency measurement range so that the phase lag between the input signal and the pressure is less than 10° at the lowest frequency and more than 90° at the highest frequency;
- c) Check that the reduction in pressure signal amplitude is at least 10 dB over the same frequency range;
- d) Sweep the sinusoidal input signal from the lowest to the highest test frequency at a rate of between 20 s and 30 s per decade. Maintain the signal amplitude constant throughout each complete sweep as shown in [Figure 11](#);
- e) Repeat steps [8.2.5.4 a\)](#) to d) with the signal amplitude set to give a pressure amplitude of ± 25 % of the rated pressure at the lowest frequency.



Key

- X frequency, expressed as the logarithm of the degrees
 Y1 amplitude ratio, expressed in decibels
 Y2 phase lag, expressed in degrees

Figure 11 — Frequency response

9 Reducing valve

9.1 Steady-state tests

9.1.1 General

Care should be taken to exclude dynamic effects during steady-state tests.

Reducing valve performance tests shall be performed in the following order:

- a) optional proof pressure test (9.1.2);
- b) pilot and internal leakage flow test (9.1.3);
- c) test for pressure versus input signal at constant flow (9.1.4 and 9.1.5) to give:
 - 1) pressure versus input signal gain,
 - 2) pressure versus signal linearity,
 - 3) hysteresis (with respect to input signal changes),

- 4) input signal dead band,
- 5) threshold;
- d) test for pressure versus flow at constant input signal (9.1.6) to give:
 - 1) pressure versus flow characteristic,
 - 2) pressure versus flow: linearity,
 - 3) hysteresis (with respect to flow changes),
 - 4) minimum operating pressure;
- e) pressure versus fluid temperature test (9.1.7).

9.1.2 Proof pressure test (optional)

9.1.2.1 General

Proof pressure tests may be carried out to examine the integrity of the valve before conducting further tests.

9.1.2.2 Inlet port test procedure

Carry out the test as follows:

- a) Apply a proof pressure of 1,3 times the B port rated pressure to the valve inlet for at least 30 s;
- b) During the test, examine the valve for evidence of external leakage;
- c) After the test, examine the valve for evidence of permanent deformation;
- d) Record the proof pressure used in the test.

9.1.2.3 Outlet port test procedure

Carry out the test as follows:

- a) Apply a proof pressure of 1,0 times the outlet port rated pressure to the valve outlet for at least 30 s;
- b) During the test, examine the valve for evidence of external leakage;
- c) After the test, examine the valve for evidence of permanent deformation;
- d) Record the proof pressure used in the test.

9.1.2.4 Pilot-drain port

Do not apply a proof pressure to any external pilot-drain port.

If required, the pressure at the drain port may be increased to its rated pressure to force the outlet pressure to the test. The signal to the valve may be adjusted also, if required.

9.1.3 Pilot flow test

9.1.3.1 Test circuit

Pilot flow tests shall be carried out to establish the pilot flow required during valve operation. This flow includes leakage within the valve.

9.1.3.2 Test circuit

Perform the pilot flow test with a hydraulic test circuit conforming to the requirements of [Figure 2](#) with valve S1 closed.

Measure the pilot flow with flow transducer 10 and record the result.

9.1.3.3 Set up

Set the input signal of the valve to zero.

Set the input pressure of the valve to the rated input pressure with valve 2.

9.1.3.4 Procedure

Carry out the test as follows:

- a) Measure and record the pilot flow using the flow transducer;
- b) Increase the signal to the valve to 25 % of the rated pressure and re-measure, and record the pilot flow;
- c) Repeat [9.1.3.4 b\)](#) with the signal to the valve at 50 % of the rated pressure;
- d) Repeat [9.1.3.4 b\)](#) with the signal to the valve at 75 % of the rated pressure;
- e) Repeat steps [9.1.3.4 b\)](#) with the signal to the valve at 100 % of the rated pressure.

9.1.4 Test to establish the valve-controlled pressure versus input signal characteristics with constant flow

9.1.4.1 General

Tests shall be carried out to determine the controlled pressure, versus input signal characteristic.

9.1.4.2 Test circuit

For valves without reverse flow relieving capability, perform the test with a hydraulic test circuit conforming to the requirements of [Figure 2](#) with valve S1 open.

For valves with reverse flow relieving capability, perform the test with a hydraulic test circuit conforming to the requirements of [Figure 3](#), with valve S1 open.

Load valve 3 shall be a pressure compensated flow control valve capable of maintaining the flow to within 2 % of the set value whilst the characteristic is plotted.

Select load valve 3 to have a low resistance to flow when fully open.

Measure the flow with flow transducer 11 and record the value.

9.1.4.3 Set up

Select a suitable plotter or recording apparatus with the X-axis able to record the zero to maximum input signal and the Y-axis able to record zero to rated pressure as shown in [Figure 5](#).

Select a signal generator able to produce a triangular waveform with an amplitude from zero to the maximum input signal. Set the signal generator to produce a 0,05 Hz or lower triangular waveform.

9.1.4.4 Procedure

Carry out the test as follows:

- a) For valves with reverse flow capability (using a circuit conforming to [Figure 3](#)), set valve 13 de-energised. Set the flow through load valve 3 % to 50 % of the rated flow;
- b) Cycle the valve input signal between minimum and maximum several times and check that the controlled pressure is within the Y-axis range of the recording apparatus;
- c) Ensure that the duration of time of one cycle does not create dynamic effects that influence the result;
- d) Enable the output from the signal generator and allow the signal generator to cycle at least once;
- e) Record the input signal to the test valve and the controlled pressure over one complete cycle of the input signal;
- f) Repeat steps [9.1.4.4 b\) to e\)](#) with the flow set to 100 % of the rated flow;
- g) Repeat steps [9.1.4.4 b\) to e\)](#) with the flow set to 0 % of the rated flow.

If the valve operates with reverse flow (from A to T), carry out the following additional test:

- h) Energise valve 13 and set valve S1 open. With 50 % of the rated reverse flow into port A, repeat steps [9.1.4.4 b\) to e\)](#). Repeat the test again with 100 % of the rated reverse flow into port A.

For the valve, and using the procedure shown in [9.1.4.4 a\) to h\)](#), determine:

- the controlled pressure at rated signal for each flow;
- the linearity of the controlled pressure $P_{\text{error}} / (P_{\text{rated}} - P_{\text{min}})$ expressed as a percentage;
- the hysteresis of the controlled pressure with respect to changes in the input signal as shown in [Figure 5](#);
- the input signal dead band.

9.1.5 Threshold

9.1.5.1 General

Tests shall be carried out to determine the response of the test valve to a reversal in a ramped input signal.

9.1.5.2 Test circuit

Perform the threshold test with a hydraulic test circuit conforming to the requirements of [Figure 2](#), with valve S1 open.

Measure the flow with transducer 11 and record the value.

9.1.5.3 Set up

Select a suitable plotter or recording apparatus with the X-axis able to record up to a 10 % change in input signal and the Y-axis able to record a 10 % of the rated pressure as shown in [Figure 5](#).

Set the signal generator to produce a 0,1 Hz triangular waveform super imposed on a d.c. offset.

Set the input signal to valve 2 so that the pressure at the valve input is the rated input pressure.

9.1.5.4 Procedure

Carry out the test as follows:

- a) Set the flow through load valve 3 % to 50 % of rated flow. Adjust the d.c. offset of the signal generator to give a mean controlled pressure 25 % of the rated pressure. Adjust the output amplitude of the triangular waveform to minimum and ensure there is no change in controlled pressure;
- b) Slowly increase the amplitude of the signal generator output until a change in controlled pressure is observed using transducer 7;
- c) Record the controlled pressure and input signal over one complete signal cycle;
- d) Stop the flow with valve S1;
- e) Repeat steps 9.1.5.4 a) to d) with the mean pressure set to 50 % of the rated pressure;
- f) Repeat steps 9.1.5.4 a) to d) with the mean pressure set to 75 % of the rated pressure;
- g) Repeat steps 9.1.5.4 a) to d) with the mean pressure set to 100 % of the rated pressure.

9.1.6 Valve pressure versus flow characteristic with constant input signal

9.1.6.1 General

Tests shall be carried out to determine the valve pressure versus flow characteristic.

9.1.6.2 Test circuit

For valves without reverse flow relieving capability, perform the test with a hydraulic test circuit conforming to the requirements of [Figure 2](#) with valve S1 open.

For valves with reverse flow relieving capability, perform the test with a hydraulic test circuit conforming to the requirements of [Figure 3](#), with valve S1 open.

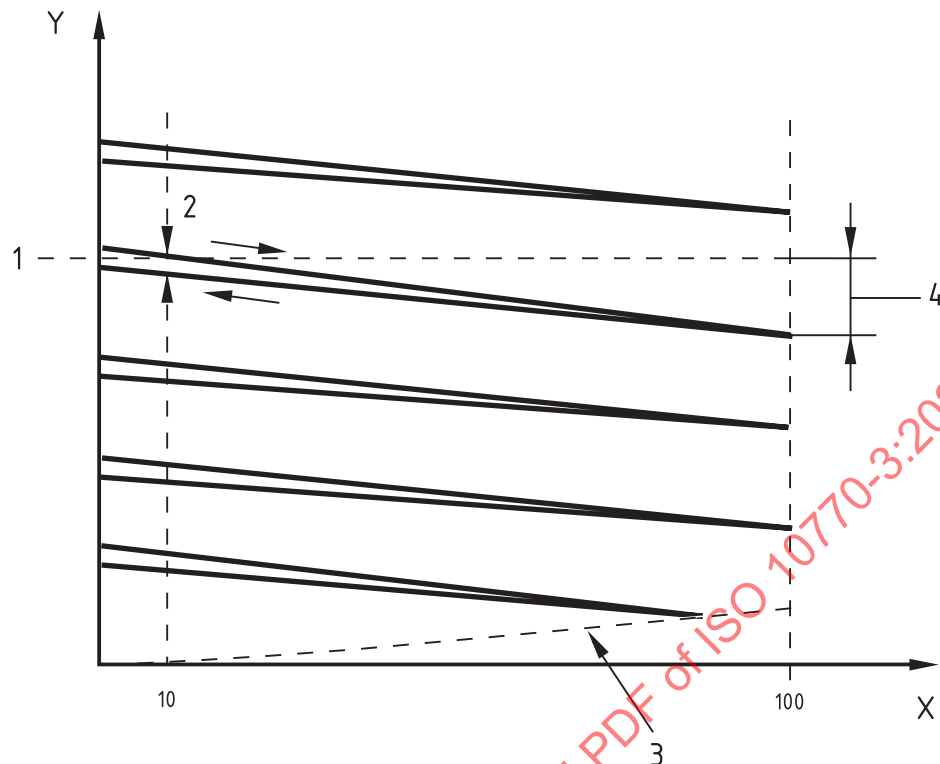
Valve 3 shall be an electrically modulated flow control valve so the flow can be controlled by the signal generator (a pressure-compensated load valve is not required because the flow is measured during the test).

Measure the flow with flow transducer 11 and record the value.

9.1.6.3 Set up

Select a suitable plotter or recording apparatus with the X-axis able to record from zero to the rated flow and the Y-axis able to record from zero to the rated pressure as shown in [Figure 12](#).

Select a signal generator able to produce a triangular waveform with an amplitude from zero to rated flow. Set the signal generator to produce a 0,05 Hz or lower triangular waveform.

**Key**

- X flow, in percent
- Y pressure
- 1 steady-state pressure
- 2 hysteresis
- 3 minimum reduced pressure with flow
- 4 pressure override

Figure 12 — Reducing valve — Pressure versus flow characteristics

9.1.6.4 Procedure

Carry out the test as follows:

- a) Set the reducing flow to 10 % of the rated flow and set the inlet pressure to the test valve to 50 % of the rated pressure;
- b) Set the controlled pressure to 25 % of the rated pressure;
- c) Ensure that the duration of time of one cycle does not create dynamic effects that influence the result;
- d) Enable the output from the signal generator and allow the signal generator to cycle at least once;
- e) Record the controlled pressure and flow for one full cycle starting at zero flow. Ensure that the cycle ends at zero flow by closing valve S1. Hold for 30 s and record the output pressure;
- f) Repeat steps 9.1.6.4 a) to e) with the inlet pressure set to 100 % of the rated pressure and the controlled pressure set to 25 % of rated pressure;
- g) Repeat steps 9.1.6.4 a) to e) with the inlet pressure set to 100 % of the rated pressure and the controlled pressure set to 50 % of rated pressure;

- h) Repeat steps 9.1.6.4 a) to e) with the inlet pressure set to 100 % of the rated pressure and the controlled pressure set to 75 % of rated pressure;
- i) Repeat steps 9.1.6.4 a) to e) with the inlet pressure set to 100 % of the rated pressure and the input signal to zero;
- j) If the drive amplifier has an enable/disable function, repeat step 9.1.6.4 i) with the amplifier disabled. This gives the minimum pressure (head loss) of the valve.

If the valve operates with reverse flow (from A to T) steps 9.1.6.4 a) to j) shall be modified by:

- k) De-energising valve 13 and setting the reducing flow to 10 % and recording the controlled reducing pressure and flow for one full cycle ending at zero flow. Once valve S1 is closed, energise valve 13. Without adjusting the demand to the test valve, open valve S1 and record the controlled relieving pressure up to the rated reverse flow and back down to zero flow as shown in Figure 13.

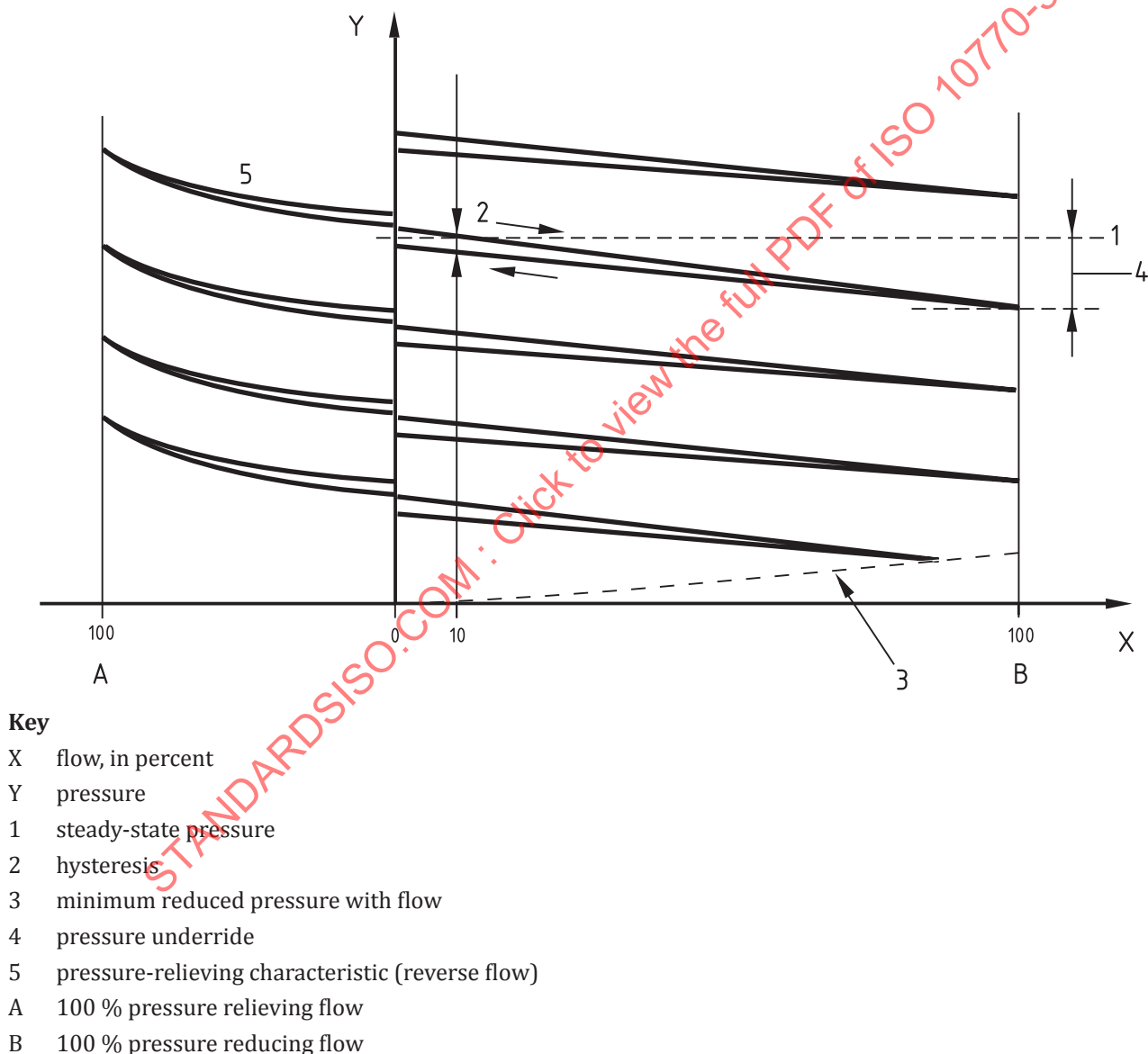


Figure 13 — Reducing valve — Pressure versus flow characteristic

For the valve and using steps 9.1.6.4 a) to k) determine:

- the pressure under-ride (see Figure 12);
- the hysteresis with respect to flow changes (see Figure 12);
- the minimum pressure with flow at zero demand signal (see Figure 12);
- the minimum differential pressure between the valve inlet and outlet ports required to maintain operation at the rated flow;
- the maximum flow with respect to differential pressures between the inlet and outlet of the valve.

9.1.7 Controlled pressure versus fluid temperature

9.1.7.1 General

Tests shall be carried out to measure the change in controlled pressure with fluid temperature.

9.1.7.2 Test circuit

Perform the test with a hydraulic test circuit conforming to the requirements of Figure 2, with valve S1 open.

9.1.7.3 Set up

Select a suitable plotter or recording apparatus with the X-axis showing the temperature range (20 °C to 70 °C) and the Y-axis showing zero to at least rated pressure as shown in Figure 8.

Take precautions to avoid air draughts across the valve.

9.1.7.4 Procedure

Carry out the test as follows:

- a) Soak the valve and amplifier at 20 °C for at least 2 h prior to carrying out the test;
- b) Set the flow through the test valve to 50 % of the rated flow and the input pressure to the rated input pressure. Set the signal to the valve to give a pressure of 50 % of the rated pressure. During the test, the flow shall not vary by more than 0,5 % of the rated flow;
- c) Measure and record the reduced pressure, supply fluid temperature and return fluid temperature;
- d) Adjust the heating and/or cooling of the test rig so the fluid temperature rises by approximately 10 °C/h;
- e) Continue recording the parameters listed in 9.1.7.4 c) until the temperature reaches the specified maximum.

9.2 Dynamic tests

9.2.1 General

The tests shown in 9.2.3, 9.2.4 and 9.2.5 shall be carried out to determine the step response and frequency response of the valve.