
**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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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 10770-3 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

ISO 10770 consists of the following parts, under the general title *Hydraulic fluid power — Electrically modulated hydraulic control valves*:

- *Part 1: Test methods for four-way directional flow control valves*
- *Part 2: Test methods for three-way directional flow control valves*
- *Part 3: Test methods for pressure control valves*

Introduction

This part of ISO 10770 describes methods of testing electrohydraulic pressure relief and pressure reducing valves. These types of electrohydraulic 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 part of ISO 10770 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.

Hydraulic fluid power — Electrically modulated hydraulic control valves —

Part 3: Test methods for pressure control valves

1 Scope

This part of ISO 10770 describes test methods for determining the performance characteristics of electrically modulated hydraulic pressure control valves.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding 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*

IEC 60617-DB, *Graphical symbols for diagrams*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

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

electrically modulated pressure control 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 to a relief valve under test, or the outlet of the reducing valve under test

3.1.6

headloss

minimum pressure drop through a valve

NOTE The headloss is usually 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
Inductance	L_C	H
Insulation resistance	R_i	Ω
Resistance	R_C	Ω
External test resistance	R	Ω
Dither amplitude	—	% (of max. input signal)
Dither frequency	—	Hz
Input signal	I or U	A or V
Rated signal	I_N or U_N	A or V
Current readout	I_{READ}	A
Output flow	q	l/min
Rated flow	q_N	l/min
Pressure gain	$K_P = (\Delta p/\Delta I$ or $\Delta p/\Delta U)$	bar (per input signal unit)
Hysteresis	—	% (of max. output)
Internal leakage	q_l	l/min
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)
Threshold	—	% (of maximum input)
Amplitude (ratio)	—	dB
Phase lag	—	$^\circ$
Temperature	—	$^\circ\text{C}$
Frequency	f	Hz
Time	t	s
Time constant	t_C	s

3.3 Graphic symbols

The graphic symbols in this part of ISO 10770 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.

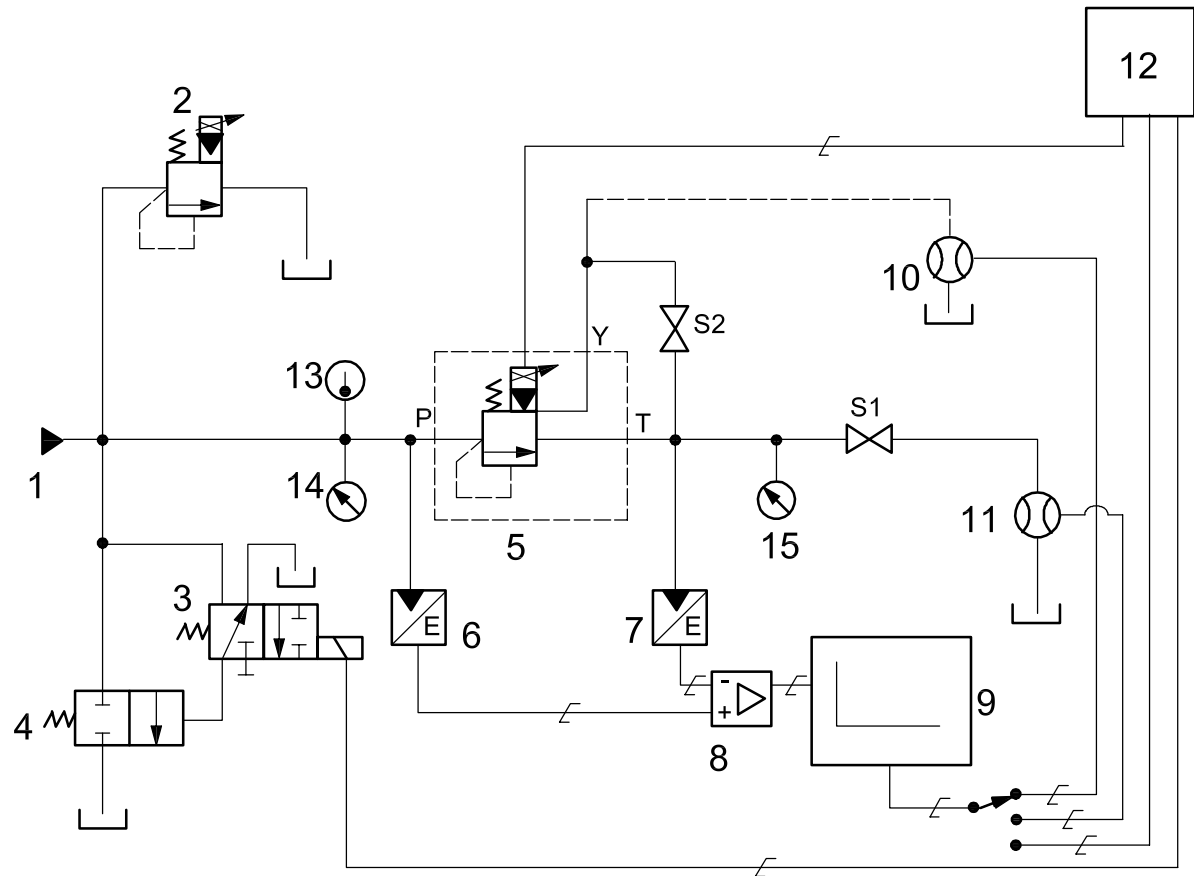
5 Test installation

A test installation conforming to the requirements of Figures 1, 2 or 3 shall be used for testing all valves.

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

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.

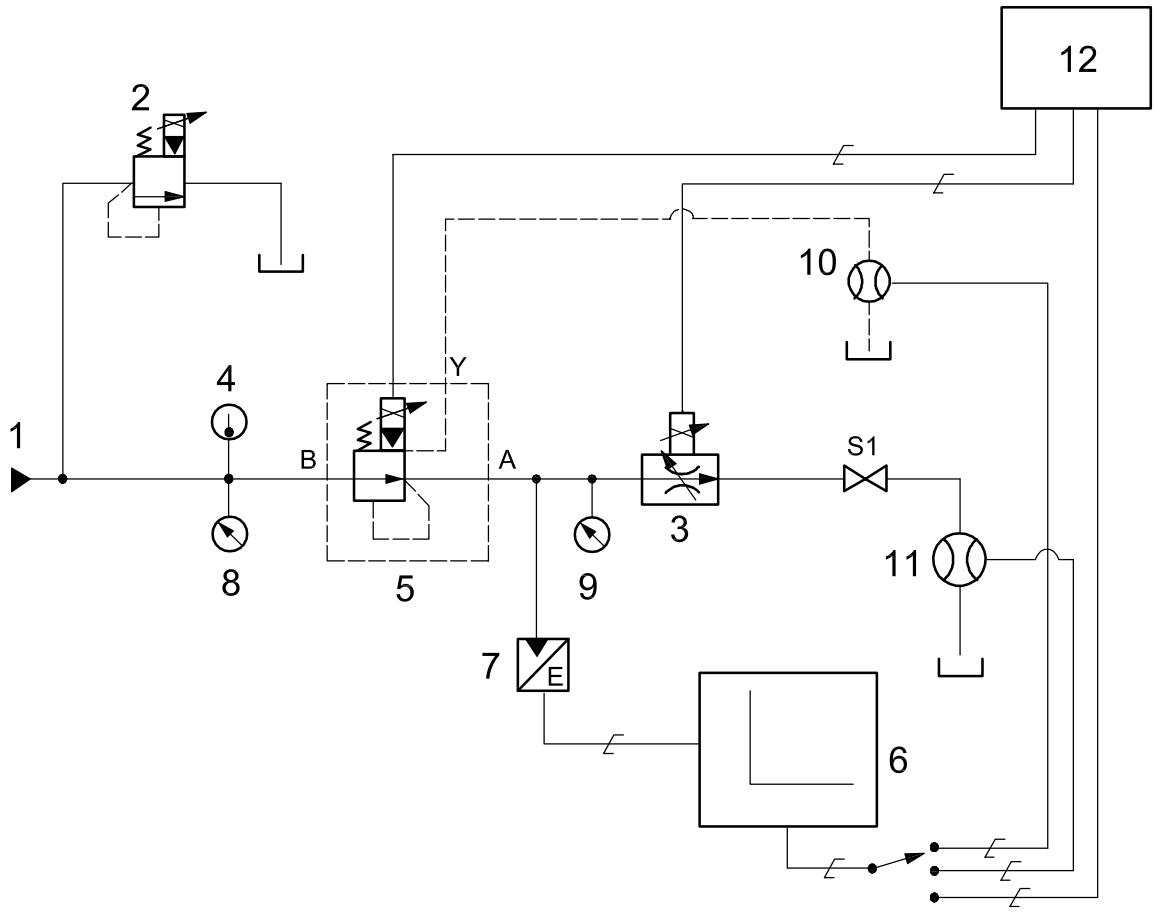
- a) Guidance on carrying out the tests is given in Annex A.
- b) A separate circuit may be constructed for each type of test. This can improve the accuracy of test results as it eliminates the possibility of leakage through the shut-off valves.
- c) Hydraulic performance tests are carried out on a combination 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.
- d) 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).
- e) 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.
- f) Electronic test equipment and transducers should have a bandwidth or natural frequency at least ten times greater than the maximum test frequency.
- g) Flow transducer 10 shall be selected so as to have negligible effect on the pressure at port Y.



Key

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

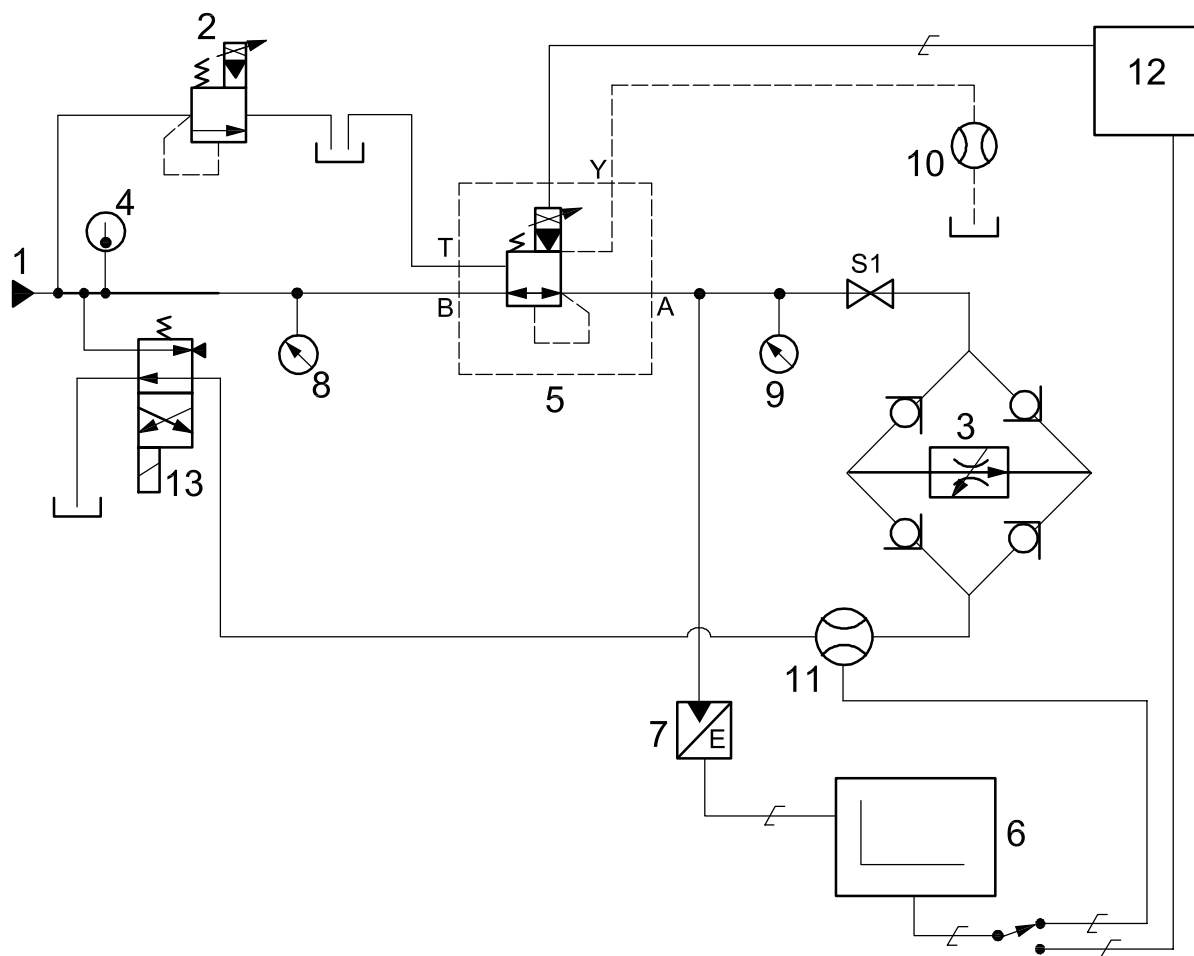
Figure 1 — Relief-valve test circuit



Key

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

Figure 2 — Reducing valve test circuit



Key

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

- a) electrical resistance: $\pm 2\%$ of the actual measurement;
- b) pressure: $\pm 1\%$ of the valve under test rated pressure;
- c) temperature: $\pm 2\%$ of the ambient temperature;
- 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 pressure transducers, amplifiers and recording devices do not generate any damping, attenuation or phase shift of the pressure signal being recorded.

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 subplate as recommended by the manufacturer, at its maximum rated temperature and operate the complete valve, fully energized 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.

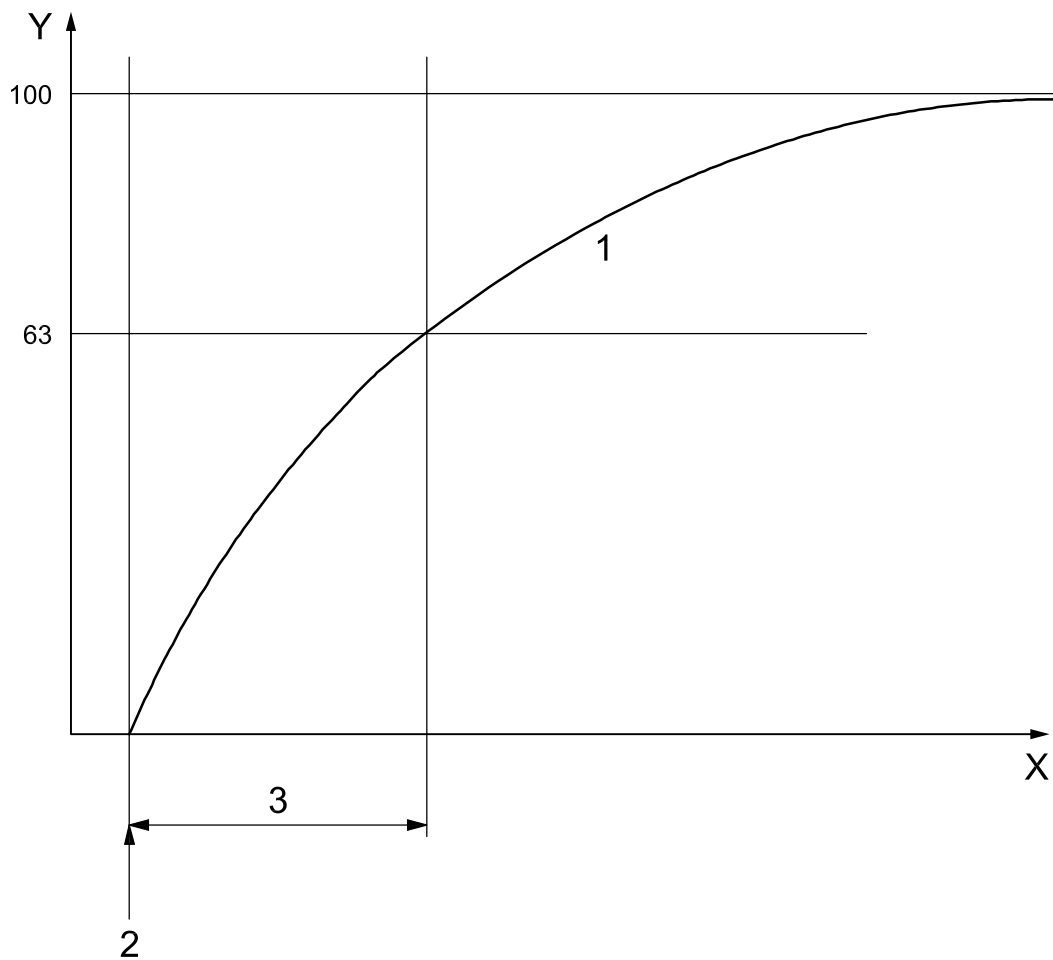
Perform the test as follows.

- 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 Equation (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 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 testers with a current (A) readout, I_{READ} , calculate the insulation resistance using Equation 2

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

8 Relief-valve performance tests

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 headloss;
- 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 setting 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.

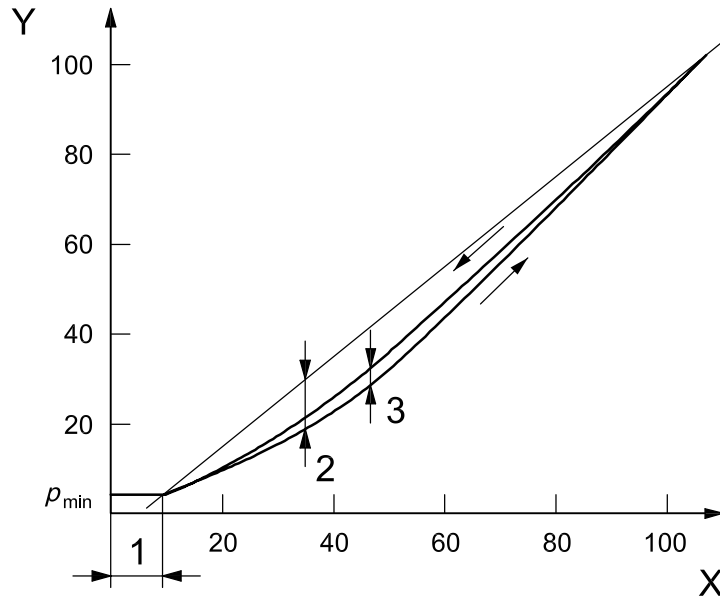
Measure the flow through the valve under test using flow transducer 11 and record the result.

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.



Key

- X input signal, in percent
- Y pressure, in percent
- 1 dead band
- 2 p_{error}
- 3 hysteresis

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 time period 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 output 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 (see 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 25 % of the rated pressure. Adjust the output amplitude of the triangular wave form 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 (see 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 triangular waveform.

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

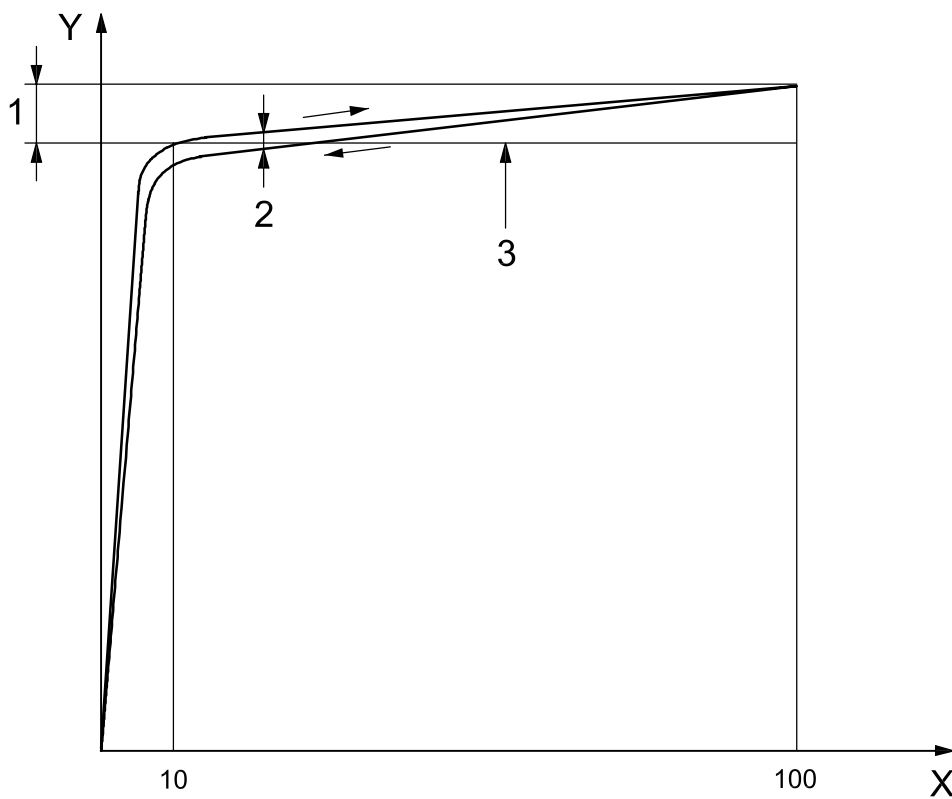
8.1.6.4 Procedure

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 time period 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 (headloss) of the valve.

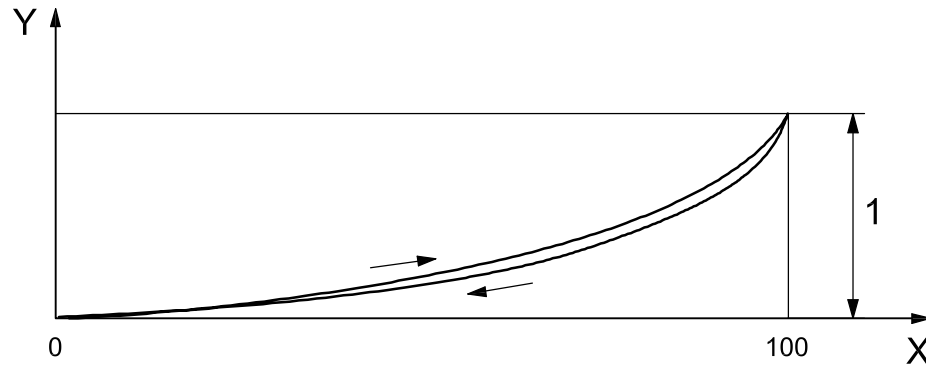
For the valve, determine

- the pressure-override characteristic (see Figure 6),
- the hysteresis with respect to flow changes (see Figure 6),
- the minimum pressure with flow or headloss (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 headloss

Figure 7 — Relief valve headloss

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 (see Figure 8).

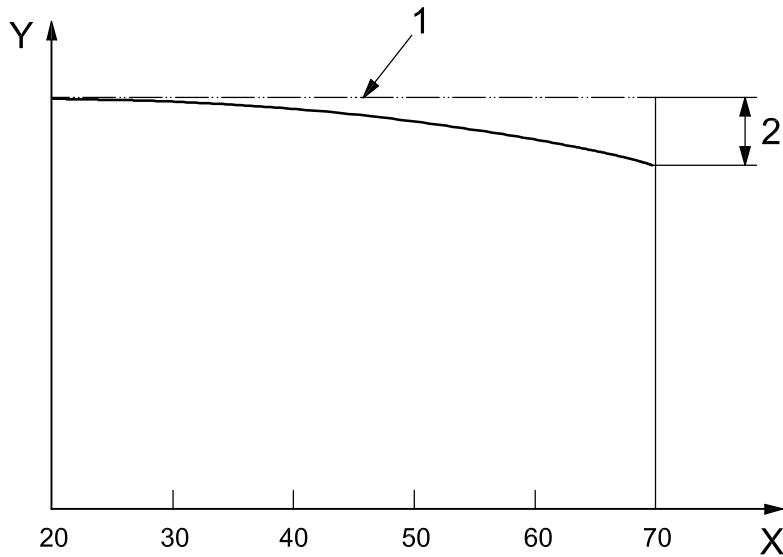
Set the input signal to valve 2 so that it is closed during the test.

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 should be at least 1,5 % of the rated flow. The circuit pipework should conform to Table 3.

NOTE 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 (see Figure 9).

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

8.2.3.3 Procedure

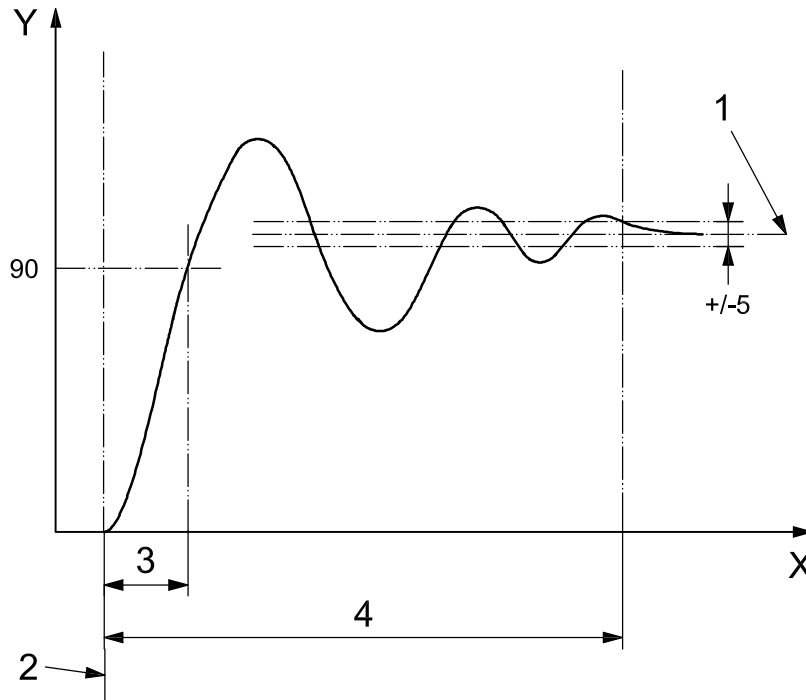
Carry out the test as follows.

- a) Set the pump flow through the valve to 50 % of the rated flow.
- b) Set the signal generator so that the controlled pressure steps between the test 1 pair of start and finish pressures given 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

- c) Enable the output from the signal generator and allow the signal generator to cycle at least once.
- d) Record the controlled pressure, controlled pressure volume and signal to the valve against time for steps going towards the positive and the negative.
- e) Ensure that the recording window shows the complete response.
- f) Repeat steps 8.2.3.3 a) to e) with the controlled pressure set to the pair of pressures given for tests 2 and 3 in Table 4.



- 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

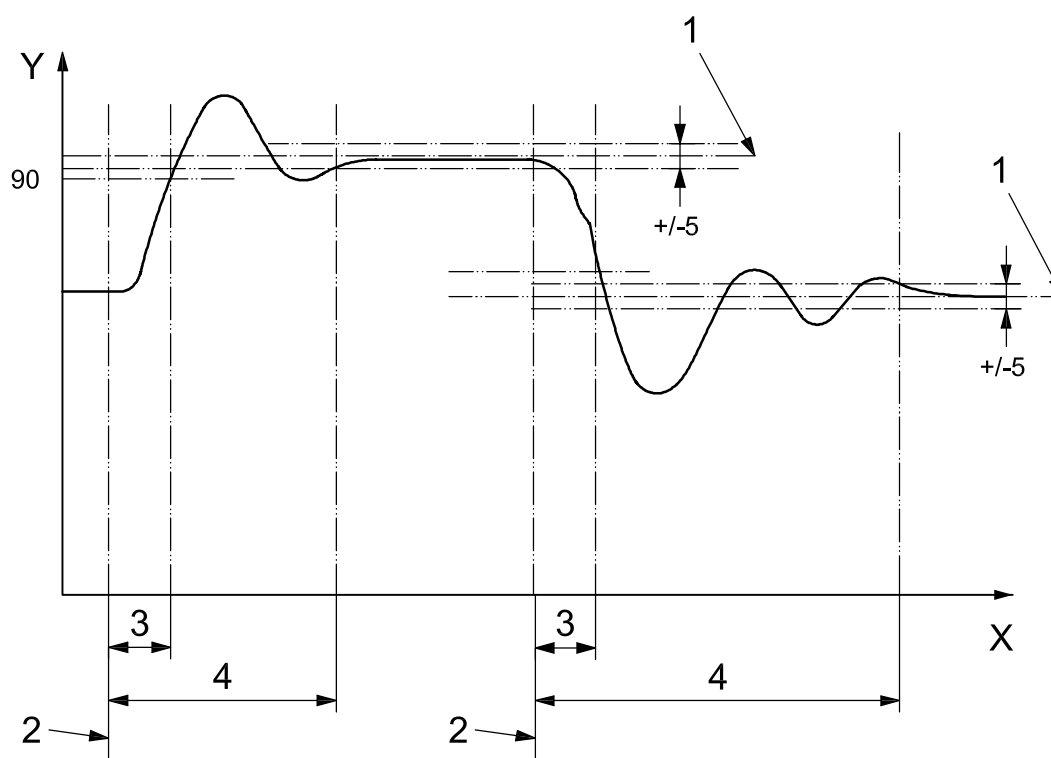
Select a suitable oscilloscope or other electronic equipment to record a signal from the pressure transducer against time (see Figure 10).

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

8.2.4.3 Procedure

Carry out the test as follows.

- Set the flow through the valve to 10 % of the rated flow.
- Adjust the demand to achieve 50 % of the rated pressure.
- 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.
- Ensure that the recording window shows the complete response.
- 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
- 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

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

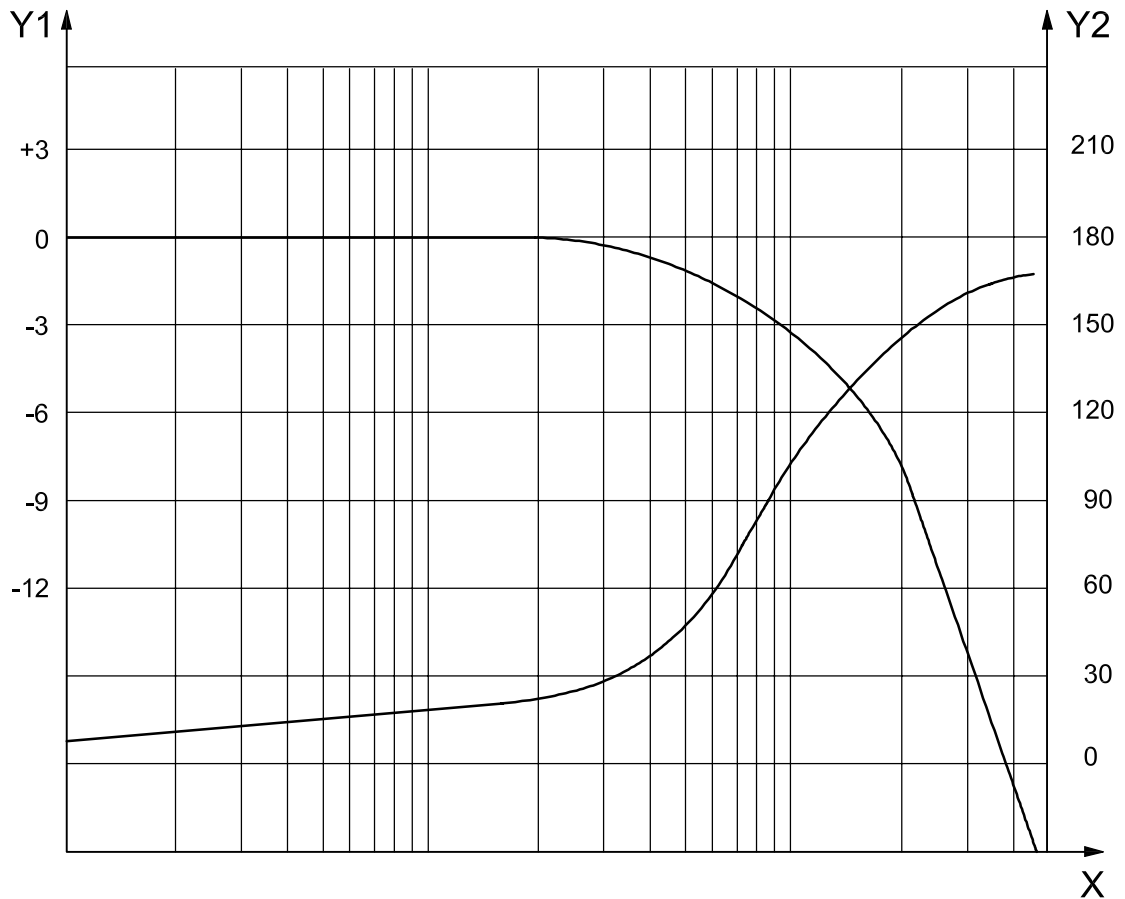
Select a suitable frequency response analyser or other electronic equipment to measure the amplitude ratio and phase shift between two signals using a sinusoidal test signal.

Connect the equipment so as to be able to measure the response between the valve input signal and the controlled pressure (see 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 (see 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 valves

9.1 Performance tests

9.1.1 General

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

- a) optional proof pressure test (9.1.2);
- b) pilot and 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 (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.

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

9.1.3 Pilot flow

9.1.3.1 General

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 to the valve to zero.

Set the input pressure to 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 steps 9.1.3.4 a) and b) with the signal to the valve at 50 % of the rated pressure.
- d) Repeat steps 9.1.3.4 a) and b) with the signal to the valve at 75 % of the rated pressure.
- e) Repeat steps 9.1.3.4 a) and b) with the signal to the valve at 100 % of the rated pressure.

9.1.4 Test for 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 while 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 (see Figure 5).

Select a signal generator able to produce a triangular wave form with an amplitude from zero to the maximum input signal.

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-energized. Set the flow through load valve 3 to 50 % of the rated flow.
- b) Ensure that the time period of one cycle does not create dynamic effects that influence the result.
- c) Enable the output from the signal generator and allow the signal generator to cycle at least once.
- d) Record the input signal to the test valve and the controlled pressure over one complete cycle of the input signal.
- e) Repeat steps 9.1.4.4 a) to d) with the flow set to 100 % of the rated flow.
- f) Repeat steps 9.1.4.4 a) to d) 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.

- g) Energize 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 d). 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 g), 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 (see 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 flow 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 up to a 10 % of the rated pressure (see 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 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.

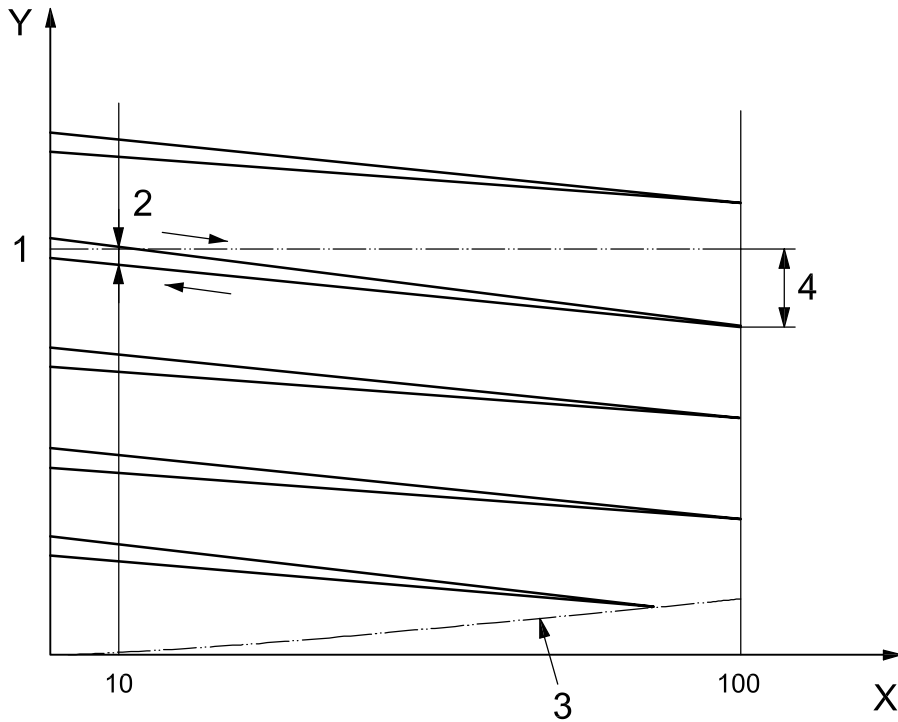
Valve 3 shall be an electrically modulated flow control valve so the flow can be controlled by the signal generator (a pressure-compensated load valve is not required because the flow is measured during the test).

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 (see Figure 12).

Select an automatic signal generator able to produce a triangular waveform with amplitude from zero to rated flow.



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 characteristic

9.1.6.4 Procedure

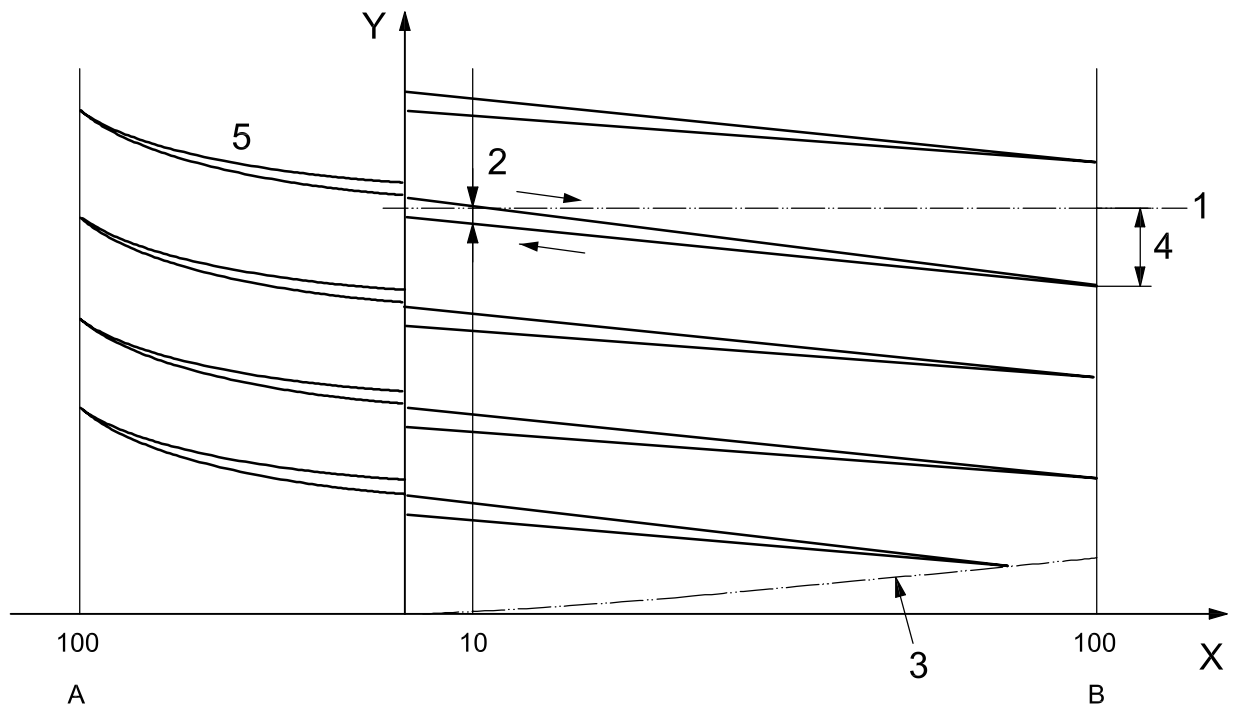
Carry out the test as follows.

- 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 time period 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 set to zero.
- j) If the drive amplifier has an enable/disable function, repeat step 9.1.6.4 i) with the drive amplifier disabled. This gives the minimum pressure (headloss) 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-energizing 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, energize 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 (see Figure 13).



Key

- X flow, in percent
 Y pressure
 1 steady-state pressure
 2 hysteresis
 3 minimum reduced pressure with flow
 4 pressure override
 5 pressure-relieving characteristic (reverse flow)
 A 100 % pressure relieving flow
 B 100 % pressure reducing flow

Figure 13 — Reducing valve — Pressure versus flow characteristic

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

- the pressure underride (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 (see 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.

9.2.2 Test circuit

Dynamic tests on a pressure reducing valve can vary with changes to the controlled pressure volume and diameter of the pipework into and out of the valve under test. In order to take account of this, the reduced pressure volume shall be at least 1,5 % of the rated flow and the pipework to and from the test valve shall conform to the requirements of Table 3.

For dynamic tests on reducing valves, the flow from the source shall be at least 1,5 times the rated flow of the test valve. The volume of oil between the flow source and test valve shall be such that the reduction in inlet pressure during the tests is less than 10 % of the nominal inlet pressure.

9.2.3 Step response (change in input signal)

9.2.3.1 Test circuit

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

During the test, load valve 3 should act as a fixed orifice and so should have a mechanical setting.

9.2.3.2 Set up

Select a suitable oscilloscope or other electronic equipment to record the controlled pressure and input signal to the valve against time.

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

9.2.3.3 Procedure

Carry out the test as follows.

- a) Set the valve input pressure to 2 MPa (20 bar) greater than the valve rated output pressure.
- b) Select a pair of start and finish pressures from Table 4 and set valve 3 so that the flow through the test valve is 25 % of the rated flow at the higher of the two pressure settings.
- c) Adjust the signal generator output amplitude so that the controlled pressure steps between the pressures selected in 9.2.3.3 b).
- d) Enable the output from the signal generator and allow the signal generator to cycle at least once.
- e) Record the valve output pressure and signal to the valve against time for steps going towards the positive and the negative. Ensure that the recorded window shows the complete response.
- f) Repeat steps 9.2.3.3 a) to e) at 50 % of the rated flow.
- g) Repeat steps 9.2.3.3 a) to e) at 100 % of the rated flow.
- h) Repeat steps 9.2.3.3 a) to e) with valve S1 closed.

9.2.4 Step response (change in flow)

9.2.4.1 Test circuit

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

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

9.2.4.2 Set up

Select a suitable oscilloscope or other electronic equipment to record the inlet and outlet pressure signal against time (see Figure 14).

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

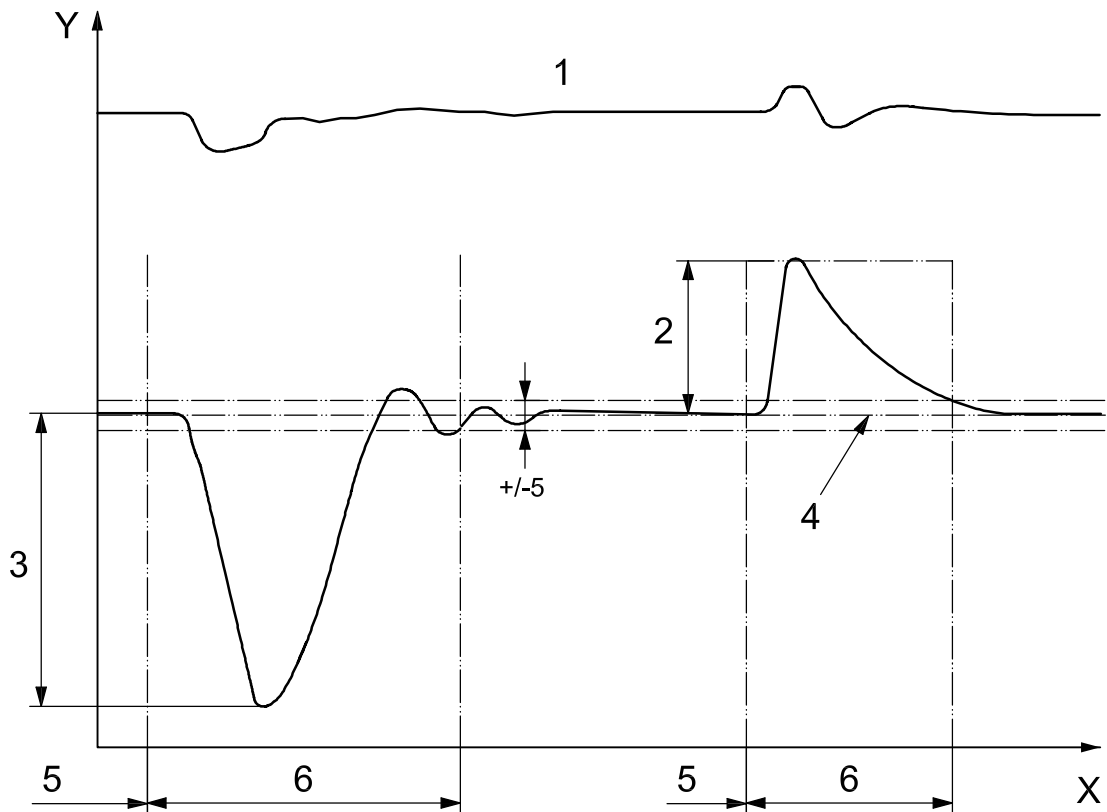
Use the signal generator to open and close valve 3.

Valve 3 shall open and close in less than 50 % of the time required to pressurize the controlled volume.

9.2.4.3 Procedure

Carry out the test as follows.

- a) Close valve 3 and adjust the signal to the valve to give 25 % of the rated pressure.
- b) Set the signal generator output to valve 3 so that when open, the flow through the test valve is 50 % of the rated flow.
- c) Enable the output from the signal generator and allow to cycle at least once.
- d) Record the inlet and reduced pressures against time when valve 3 is opened and closed. Ensure that the recorded window shows the complete response.
- e) Repeat steps 9.2.4.3 a) to d) at 50 % of the rated pressure.
- f) Repeat steps 9.2.4.3 a) to d) at 75 % of the rated pressure.
- g) Repeat steps 9.2.4.3 a) to d) at 100 % of the rated pressure.



Key

- X time
- Y pressure, in percent
- 1 input pressure
- 2 pressure overshoot
- 3 pressure undershoot
- 4 steady-state pressure
- 5 initiation
- 6 settling time

Figure 14 — Reducing valve step response — Change in flow

9.2.5 Frequency response

9.2.5.1 General

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

For valves without a relieving feature that are not normally used in high dynamic applications, this test may not be appropriate, and as such should be considered optional.

9.2.5.2 Test circuit

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

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

9.2.5.3 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 pressure at the test valve outlet (see Figure 11).

9.2.5.4 Procedure

Carry out the test as follows.

- a) Set the flow source to more than 50 % of the rated flow, close valve 3 and adjust valve 2 so the input pressure is the rated input pressure.
- b) Apply a d.c. offset to the valve input to obtain 50 % of the rated pressure.
- c) 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 9.1.4. 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.
- d) Check that the reduction in pressure signal amplitude is at least 10 dB over the same frequency range.
- e) 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 (see Figure 11).
- f) Repeat steps 9.2.5.4 a) to e) with the signal amplitude set to give a pressure amplitude of ± 25 % of the rated pressure at the lowest frequency.
- g) If results with flow are required, an optional test is to repeat steps 9.2.5.4 a) to f) with the flow source set to 100 % of the rated flow and valve 3 adjusted to give 50 % of the rated flow.

10 Pressure impulse test

Refer to ISO 10771-1.

11 Presentation of results

11.1 General

Test results shall be presented either

- a) in tabular form, or, if convenient,
- b) in graphical form.

11.2 Test reports

11.2.1 General

All test reports shall contain at least

- a) the name of the valve manufacturer,
- b) the valve type and serial number, if applicable,

- c) the amplifier type and serial number, if an external amplifier is used,
- d) the valve rated flow at its rated pressure drop,
- e) the valve pressure drop,
- f) the supply pressure,
- g) the return pressure,
- h) the test circuit fluid type,
- i) the test circuit fluid temperature,
- j) the test circuit fluid viscosity (as specified in ISO 3448),
- k) the rated input signal,
- l) the coil connection type (e.g. series, parallel),
- m) the dither waveform, amplitude and frequency (if used),
- n) the allowable test limits for each test parameter,
- o) the date of the test,
- p) the name of the test operator.

11.2.2 Test reports for production acceptance tests

Test reports for valve production acceptance tests shall contain at least

- a) the insulation resistance (7.4),
- b) the proof pressure (8.1.2 and 9.1.2),
- c) the maximum internal leakage (8.1.3 and 9.1.3),
- d) the pressure versus input signal characteristics and the flow used in the test (see 8.1.4 and 9.1.4),
- e) the hysteresis from the pressure versus input signal curve (8.1.4.4 and 9.1.4.4),
- f) the pressure/flow characteristics (8.1.4.4 and 9.1.4.4),
- g) the threshold (8.1.5 and 9.1.5),
- h) the pressure flow characteristic (8.1.6 and 9.1.6),
- i) the linearity of the pressure flow characteristic (8.1.4 and 9.1.4).

11.2.3 Test reports for type test

Test reports for valve type tests shall contain at least

- a) production acceptance test information (11.2.2),
- b) the coil resistance (7.2),

- c) the coil inductance (7.3),
- d) the supply proof pressure (8.1.2 and 9.1.2),
- e) the pressure versus fluid temperature characteristics (8.1.7 and 9.1.7),
- f) the pressure signal linearity (8.1.4.4 and 9.1.4.4),
- g) the pressure flow linearity (8.1.4.4 and 9.1.4.4),
- h) the pressure dead band (8.1.4.4 and 9.1.4.4),
- i) the dynamic characteristics (8.2 and 9.2),
- j) the pressure impulse test results (Clause 10),
- k) details of any physical degradation following disassembly and visual inspection.

12 Identification statement

It is strongly recommended to manufacturers who have chosen to conform to this part of ISO 10770 that the following statement be used in test reports, catalogues and sales literature:

“Tested in accordance with the methods described in ISO 10770-3, *Hydraulic fluid power — Electrically modulated hydraulic control valves — Part 3: Test methods for pressure control valves.*”

Annex A (informative)

Testing guidance

Prior to testing, any amplifier used to drive the test valve should be set up in accordance with the manufacturer's instructions.

A signal generator should be used to provide a continuously variable input signal and a recorder to show the corresponding pressure and flow detected by suitable pressure and flow transducers.

NOTE 1 Alternatively, the valve response in terms of flow or pressure against input signal can be recorded manually with a point-to-point method.

NOTE 2 The signal moves in one direction for only half of the test cycle and in the other direction only in the other half, and the hysteresis inherent in the valve is not obscured. An automatic signal generator is useful in preventing inadvertent reversal of the signal.

For steady-state tests, the type of function (e.g. sinusoidal, ramp) produced by the signal generator is not important, provided the ratio of change of output is slow in comparison with the response of the recorder. The recorder should incorporate means for adjusting the amplitude of the transducer and valve input signals to a convenient scale and a means for centring the trace on the chart.

In addition to the automatic signal generator, a manually controlled input with changeover switch should be provided. This allows the valve and equipment to be set up.

Electronic adjustments should be recorded.

Bibliography

- [1] ISO 10770-1, *Hydraulic fluid power — Electrically modulated hydraulic control valves — Part 1: Test methods for four-way directional flow control valves*
- [2] ISO 10770-2, *Hydraulic fluid power — Electrically modulated hydraulic control valves — Part 2: Test methods for three-way directional flow control valves*

