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Hydraulic fluid power — Electrically modulated hydraulic control valves —

Part 1:
Test methods for four-port directional flow-control valves

Transmissions hydrauliques — Distributeurs hydrauliques à modulation électrique —

Partie 1: Méthodes d'essai pour distributeurs de commande de débit à quatre voies

Reference number
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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 10770-1 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

This second edition cancels and replaces the first edition (ISO 10770-1:1998), which has been technically revised.

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-port 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 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 1: Test methods for four-port directional flow-control valves

1 Scope

This part of ISO 10770 describes methods for determining the performance characteristics of electrically modulated, hydraulic, four-port directional flow-control valves. This type of electrohydraulic valve controls the direction and flow in a hydraulic system.

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, *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, *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 methods*

IEC 60617-DB-12M, *Graphical symbols and diagrams*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

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

3.1.1
electrically modulated, hydraulic directional flow-control valve
valve that provides a degree of proportional flow control in response to a continuously variable electrical input signal

NOTE The flow direction can be changed by the input signal.

3.1.2
input signal deadband
portion of input signal that does not produce a controlled flow

3.1.3
threshold
change of input signal required to produce a reversal in continuous control valve output

NOTE The threshold is expressed as a percentage of rated signal.

3.1.4
rated input signal
that signal defined by the manufacturer to achieve rated output

3.2 Symbols and units

For the purposes of this document, the symbols given in Table 1 apply.

NOTE The graphic symbols in this part of ISO 10770 conform to ISO 1219-1 and IEC 60617-DB-12M.

Table 1 — Symbols and units

Parameter	Symbol	Unit
Inductance	L_c	H
Insulation resistance	R_i	Ω
Insulation test current	I_i	A
Insulation test voltage	U_i	V
Resistance	R_c	Ω
Dither amplitude	—	% (of max. input signal)
Dither frequency	—	Hz
Input signal	I, or U	A, or V
Rated input signal	I_n, or U_n	A, or V
Output flow	q	l/min
Rated flow	q_n	l/min
Flow gain	$K_v = (\Delta q/\Delta I)$, or $K_v = (\Delta q/\Delta U)$	l/min/A, or l/min/V
Hysteresis	—	% (of max. output signal)
Internal leakage	q_l	l/min
Supply pressure	p_P	MPa (bar)
Return pressure	p_T	MPa (bar)

Table 1 (*continued*)

Parameter	Symbol	Unit
Load pressure	p_A or p_B	MPa (bar)
Load pressure difference	$p_L = p_A - p_B$, or $p_L = p_B - p_A$	MPa (bar)
Valve pressure drop	$p_V = p_P - p_T - p_L$	MPa (bar)
Rated valve pressure drop	p_n	MPa (bar)
Pressure gain	$K_p = (\Delta p_L / \Delta I)$, or $K_p = (\Delta p_L / \Delta U)$	MPa (bar)/A MPa (bar)/V
Threshold	—	% (of max. input signal)
Amplitude (ratio)	—	dB
Phase lag	—	°
Temperature	—	°C
Frequency	f	Hz
Time	t	s
Time constant	t_c	s
Linearity error	q_{err}	l/min

4 Standard test conditions

Unless otherwise specified, tests shall be carried out using the standard test conditions given in Table 2.

Table 2 — Standard test conditions

Parameter	Condition
Ambient temperature	20 °C ± 5 °C
Fluid cleanliness	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
Pressure drop	Test requirement ± 2,0 %
Return pressure	Shall conform to the manufacturer's recommendations

5 Test installation

A test installation conforming to the requirements of Figure 1 shall be used for testing all valves.

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

Figure 1 shows 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 circuit shown in Figure 1, the following apply.

a) Guidance on carrying out the tests is given in Annex A.

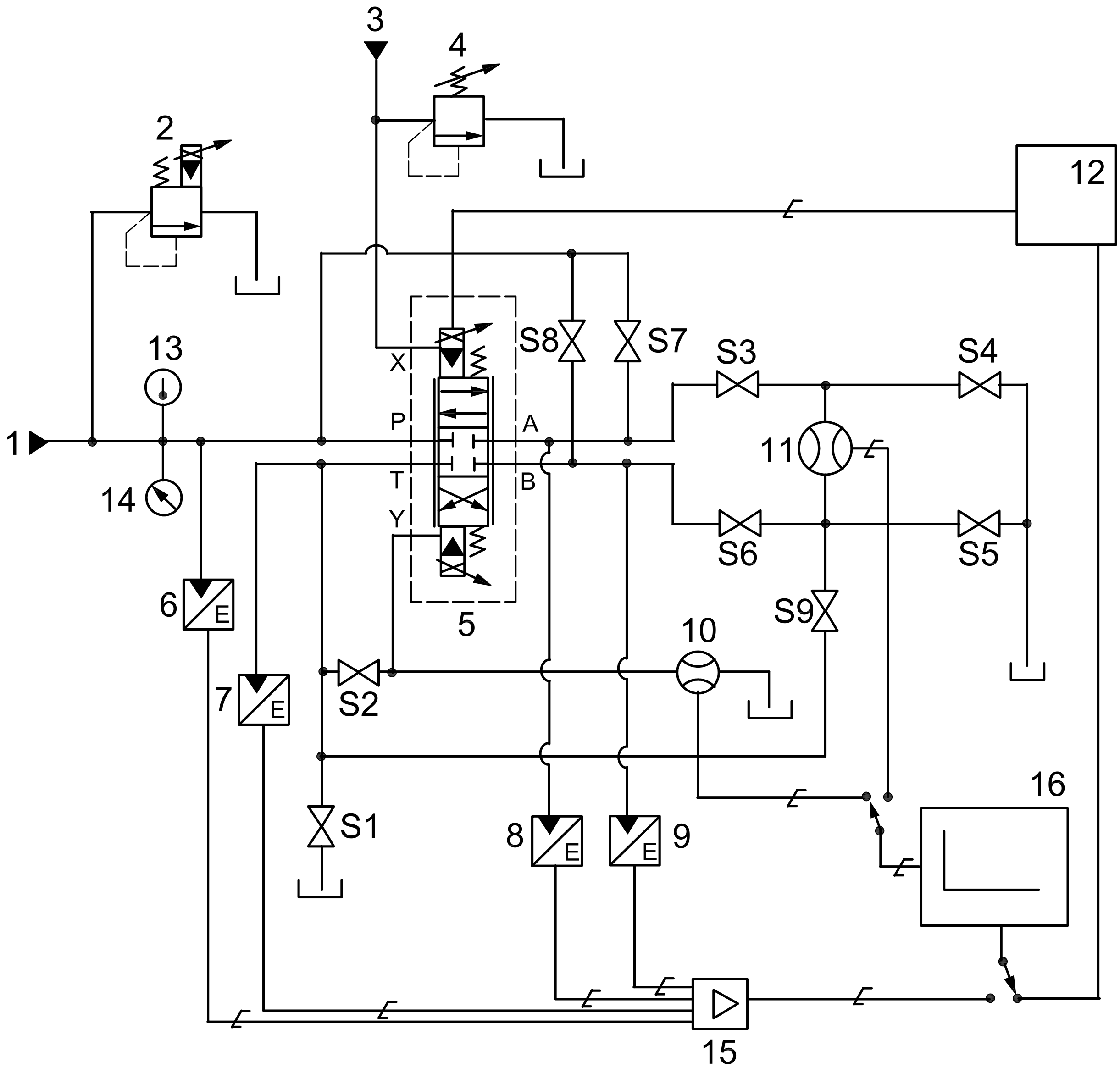
b) A separate circuit may be constructed for each type of test. This can improve the accuracy of test results as it eliminates the possibility of leakage through the shut-off valves.

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.



Key

1	main flow source	10, 11	flow transducer	S1 to S9	shut-off valves
2	main relief valve	12	signal generator	A, B	control ports
3	external pilot flow source	13	temperature indicator	P	supply port
4	external pilot relief valve	14	pressure gauge	T	return port
5	unit under test	15	signal conditioner	X	pilot supply port
6 to 9	pressure transducers	16	data acquisition	Y	pilot drain port

Figure 1 — Test circuit

6 Accuracy

6.1 Instrument accuracy

Instrumentation shall be accurate to within the limits shown in Class B of ISO 9110-1:

a) electrical resistance: ± 2 % of the actual measurement;

b) pressure: ± 1 % of the valve's rated pressure drop to achieve rated flow;

c) temperature: ± 2 % of the ambient temperature;

d) flow: ± 2,5 % of the valve's rated flow;

e) input signal: ± 1,5 % of the electrical input signal required to achieve the rated flow.

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 apply only to current-driven valves.

7.2 Coil resistance

7.2.1 Coil resistance — Cold

Carry out the test as follows.

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

Carry out the test as follows.

a) Soak the complete, energized valve, mounted on a subplate 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 construed to determine a definitive value of inductance. The value obtained shall be used for comparison purposes only.

Carry out 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) The armature shall be held stationary at 50 % of its working stroke during the test.

c) Monitor the coil current on an oscilloscope or similar equipment.

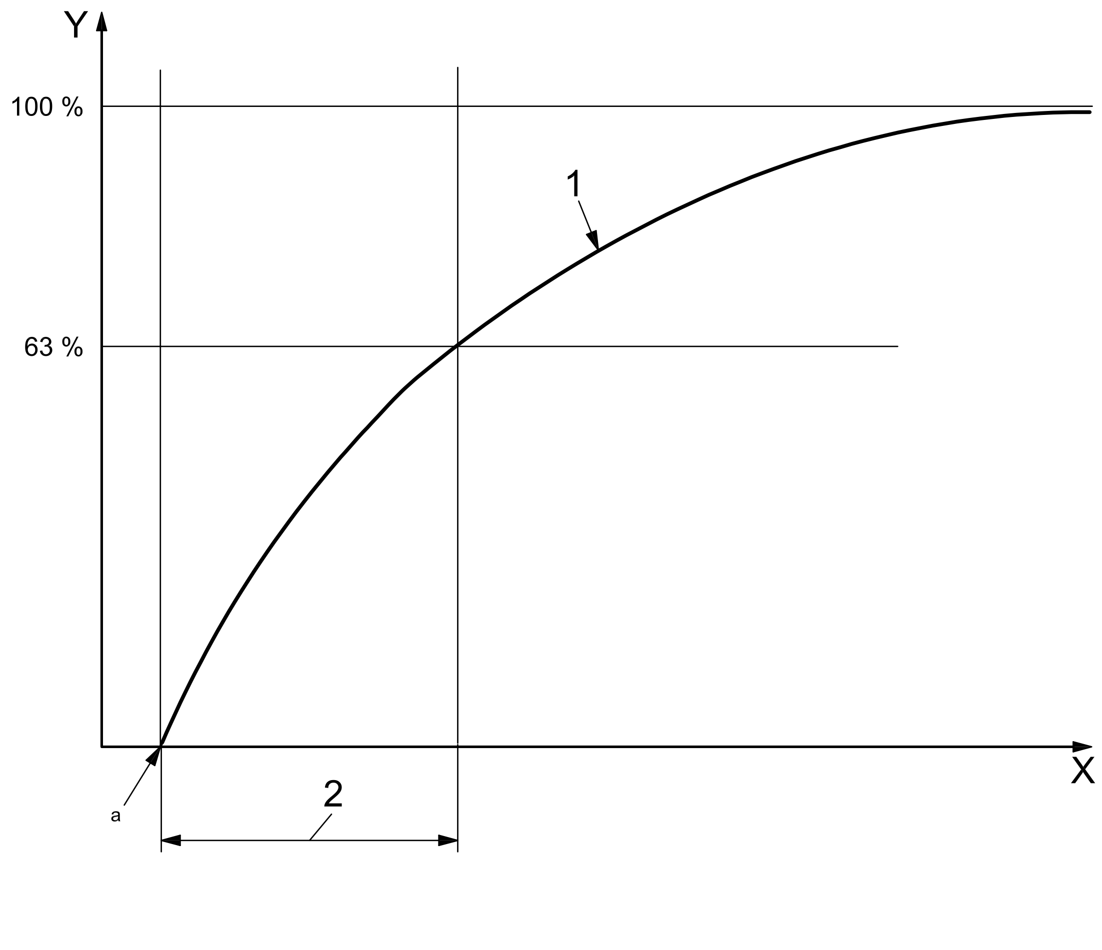
d) Adjust the voltage so that the steady-state current equals the rated current of the coil.

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 2) and calculate the inductance, L_c, using Equation (1):

$$L_c = R_c t_c \quad (1)$$

where R_c is the coil resistance in ohms.



Key

X time

Y current

1 DC current trace

2 time constant, t_c

a Initiation.

Figure 2 — 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 terminals together and apply voltage, U_i, of 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 (ampere, A) readout, I_i, calculate the insulation resistance using Equation (2).

$$R_i = \frac{U_i}{I_i} \tag{2}$$

8 Performance tests

All performance tests should be conducted on a combination of valve and amplifier, as input signals are applied to the amplifier and not directly to the valve.

For multi-stage valves, configure the valve to be an external pilot supply and external pilot drain, where possible.

Before commencing any test, make any mechanical/electrical adjustments that are normally carried out, such as nulling, deadband adjustment and gain adjustment.

8.1 Steady state tests

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

8.1.1 General

Steady-state tests shall be performed in the following order:

a) optional proof pressure tests (8.1.2);

b) internal leakage test (8.1.3);

c) metering output flow versus input signal at constant valve pressure drop (8.1.4 and 8.1.5) to determine

   1) rated flow,

   2) flow gain,

   3) flow linearity,

   4) flow hysteresis,

   5) flow symmetry,

   6) flow polarity,

   7) spool lap condition,

   8) threshold;

d) output flow versus valve pressure drop (8.1.6);

e) limiting output flow versus valve pressure drop (8.1.7);

f) output flow versus fluid temperature (8.1.8);

g) pressure gain versus input signal (8.1.9);

h) pressure null shift (8.1.10);

i) fail-safe function test (8.1.11).

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, A, B and X port test procedure

In the test, a proof pressure is supplied to the pressure and control ports and to the external pilot supply port of the valve, with the return port open. Carry out the test as follows.

a) Apply a proof pressure of 1,3 times the rated pressure to the pressure and control ports and to the X port, for at least 30 s. For approximately half of this period, apply the maximum input signal and for the remainder of the test apply the minimum input signal.

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 Y port

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

8.1.3 Internal leakage and pilot flow test

8.1.3.1 General

The internal leakage and pilot flow test shall be carried out to establish

a) the combined leakage and pilot flow rate, and

b) the pilot flow rate in the case of valves configured for external pilot drain.

8.1.3.2 Test circuit

Perform the internal leakage and pilot flow test with an hydraulic test circuit conforming to the requirements of Figure 1, initially with valves S1, S3 and S6 open and all other valves closed.

8.1.3.3 Set-up

Adjust the valve supply pressure and pilot pressure to 10 MPa (100 bar) above return pressure, or at the manufacturer's rated pressure if this is less than 10 MPa.

8.1.3.4 Procedure

Carry out the test as follows.

a) Immediately before the leakage measurements are taken, operate the valve over its full input signal range several times, ensuring that the oil passing through the valve is within the specified viscosity range.

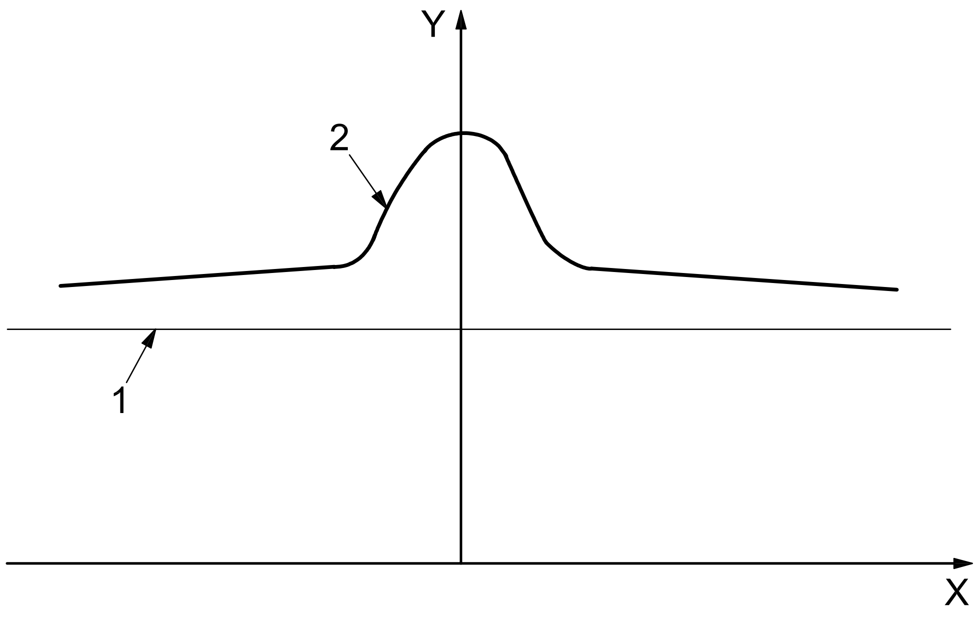
b) Close valves S3 and S6, open valve S2 and then close valve S1.

c) Record the leakage flow from the T port as the input signal is swept slowly over its full range; see Figure 3. The flow recorded by transducer 10 represents mainstage leakage plus pilot leakage. The characteristic shown in Figure 3 is typical for a servo valve. Other valve types have a different characteristic.

d) With a constant input signal, the flow recorded by transducer 10 represents the steady-state mainstage and pilot leakage.

For valves configured for external pilot drain, open valve S1 and close valve S2. Record the leakage flow from the Y port with the input signal set to zero. The flow recorded by transducer 10 represents the pilot flow.

These tests may, if required, be repeated at additional pressures up to the maximum supply pressure of the valve under test.



Key

X input signal

Y flow

1 approximate pilot flow component (pilot-operated valves only)

2 total measured flow including any pilot flow

Figure 3 — Internal leakage measurement

8.1.4 Metering tests

8.1.4.1 General

The objective of this test is to determine the metering characteristics of each metering path of the main spool at a constant pressure drop. Record the flow, using flow transducer 11, in each metering path in turn versus input signal; see Figure 4.

8.1.4.2 Test circuit

8.1.4.2.1 It is necessary that flow transducer 11 be able to measure over a wide flow range, at least 1 % to 100 % rated flow. It can be necessary, especially if the flow metering near zero flow is being measured accurately, to replace transducer 11 by two separate flow transducers that have overlapping working flow ranges: one to measure higher flows, the other to measure low flows.

For multi-stage valves with internal pilot pressure connection, it can be necessary to increase the system pressure by adding a restriction in the main flow circuit in order for the valve to operate correctly.

8.1.4.2.2 Flow from supply port P to control port A

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S1, S3 and S5 open and all other valves closed.

8.1.4.2.3 Flow from control port A to return port T

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S4, S7 and S9 open and all other valves closed.

8.1.4.2.4 Flow from supply port P to control port B

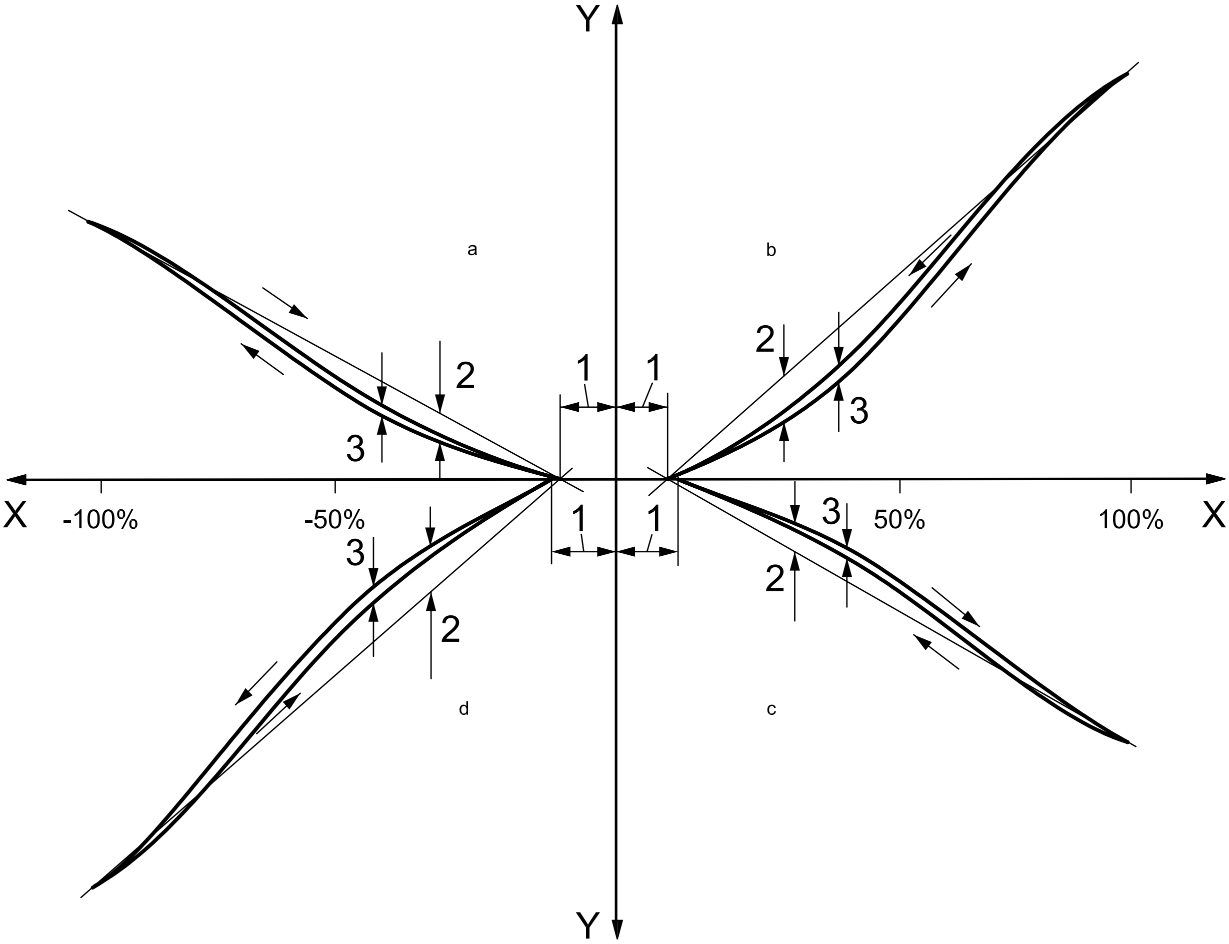
Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S1, S4 and S6 open and all other valves closed.

8.1.4.2.5 Flow from control port B to return port T

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S4, S8 and S9 open and all other valves closed.

8.1.4.2.6 Flow from the supply port P to return port T

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S1, S3 and S6 open and all other valves closed.



Key

X percentage of rated input signal
Y flow
1 deadband
2 Q_{err}
3 hysteresis

[a] P to B flow.
[b] P to A flow.
[c] B to T flow.
[d] A to T flow.

Figure 4 — Metering test

8.1.4.3 Set-up

Select a suitable plotter or recording apparatus with its X-axis able to record the range of input signal and its Y-axis able to record the zero to at least the rated flow; see Figure 4.

Select a signal generator capable of producing a triangular waveform with amplitude of the maximum input signal range. Set the signal generator to produce a triangular waveform 0,02 Hz or lower.

For multi-stage valves with external pilot, adjust the pilot supply to that recommended by the manufacturer.

For multi-stage valves with internal pilot, adjust the P port supply to at least the minimum recommended by the manufacturer.

8.1.4.4 Procedure

8.1.4.4.1 Carry out the test as follows.

a) Control the pressure drop across the metering path to either 0,5 MPa (5 bar) or 3,5 MPa (35 bar) [1,0 MPa (10 bar) or 7,0 MPa (70 bar) in the case of 8.1.4.2.6], measured using pressure transducers 6 to 9 as appropriate. Ensure that the pressure drop across the metering path remains constant to within 2 % over the complete cycle. If the pressure drop across the metering path cannot be continuously controlled, it is necessary to take point readings.

b) Cycle the valve input signal between minimum and maximum several times and check that the controlled flow 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 full cycle.

d) Record the valve input signal and the controlled flow over one complete input signal cycle.

e) Repeat steps 8.1.4.4.1 a) to d) for each flow path.

8.1.4.4.2 Use the data obtained to determine the following:

a) output flow at rated signal;

b) flow gain;

c) linearity of the controlled flow q_{err}/q_n as a percentage;

d) hysteresis of the controlled flow (with respect to changes to the input signal);

e) input signal deadband, if any;

f) symmetry;

g) polarity.

8.1.4.4.3 For cases where it is impracticable to monitor output flow, the spool position can be monitored as an alternative to flow in order to establish the following:

a) spool position at rated signal;

b) hysteresis;

c) polarity.

8.1.5 Threshold

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

Use the hydraulic test circuit described in 8.1.4.2

8.1.5.3 Set-up

Select a suitable plotter or recording apparatus with its X-axis able to record the input signal necessary to achieve 25 % of the rated flow and its Y-axis able to record from zero to about 50 % of the rated flow.

Select a signal generator able to produce a triangular waveform with a d.c. offset. Set the signal generator to produce a triangular waveform 0,1 Hz or lower.

For multi-stage valves with external pilot, adjust the pilot supply to that recommended by the manufacturer.

For multi-stage valves with internal pilot, adjust the P port supply to at least the minimum recommended by the manufacturer.

8.1.5.4 Procedure

Carry out the test as follows.

a) Adjust the d.c. offset and pressures to give a mean flow of approximately 25 % of the rated flow at the rated pressure drop. Adjust the amplitude of the triangular wave form to a minimum and ensure that there is no change in controlled flow.

b) Slowly increase the signal generator output amplitude until a change in controlled flow is observed.

c) Record the controlled flow and input signal over one complete signal cycle.

d) Repeat steps 8.1.5.4 a) to c) for each flow path.

8.1.6 Output flow versus valve pressure drop tests

8.1.6.1 General

Tests shall be carried out to determine the variation of output flow versus valve pressure drop characteristic.

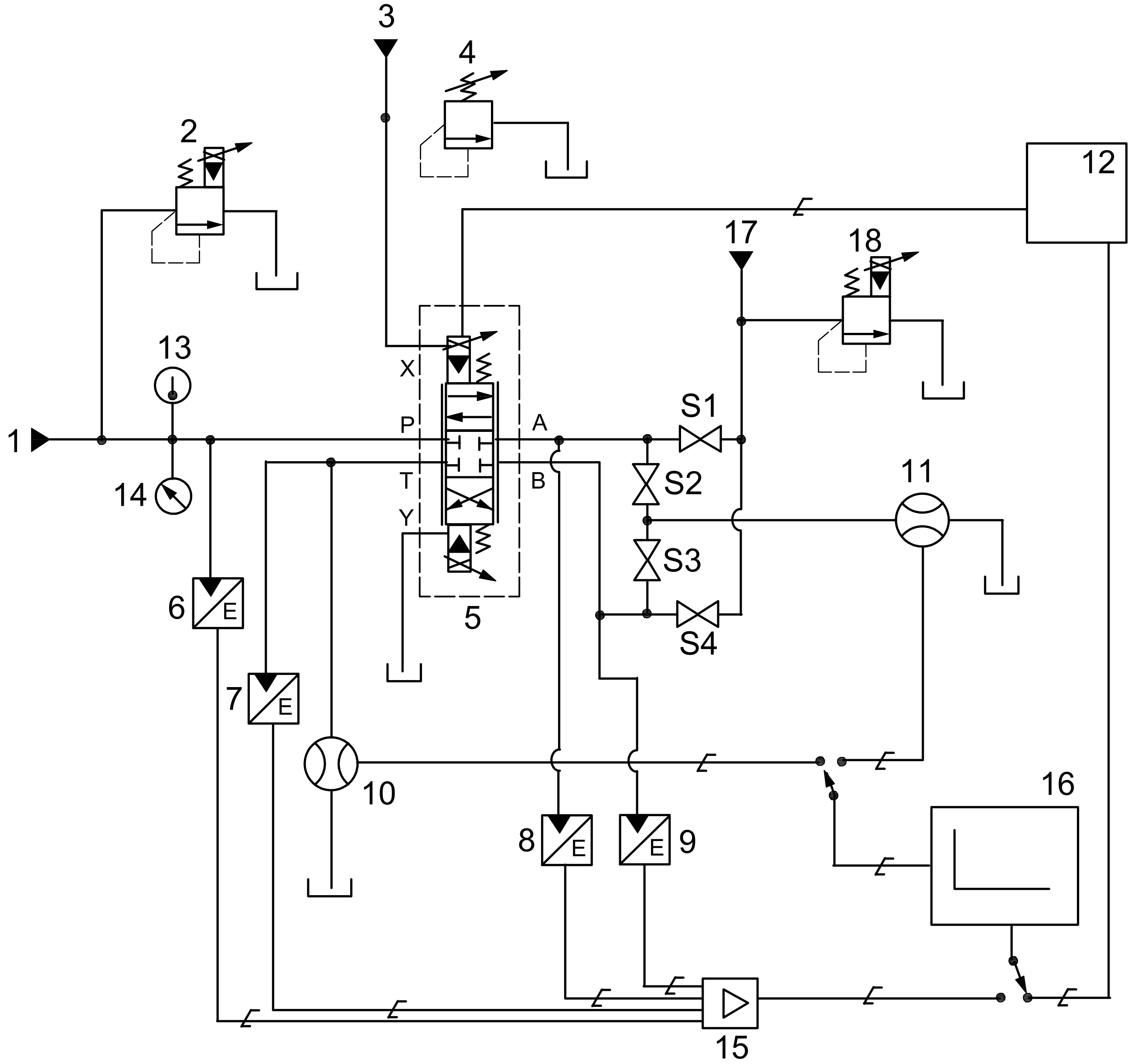
8.1.6.2 Test circuit

8.1.6.2.1 Equal flows to and from the control ports — Symmetric spools

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S1, S3 and S6 open and all other valves closed.

8.1.6.2.2 Unequal flows to and from the control ports — Asymmetric spools

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 5.



Key

1	main flow source	15	signal adaptor
2	relief valve	16	data acquisition
3	external pilot flow source	17	additional flow source
4	external pilot relief valve	18	additional relief valve
5	unit under test	S1 to S4	shut-off valves
6 to 9	pressure transducers	A, B	control ports
10, 11	flow transducers	P	supply port
12	signal generator	T	return port
13	temperature indicator	X	pilot supply port
14	pressure gauge	Y	pilot drain port

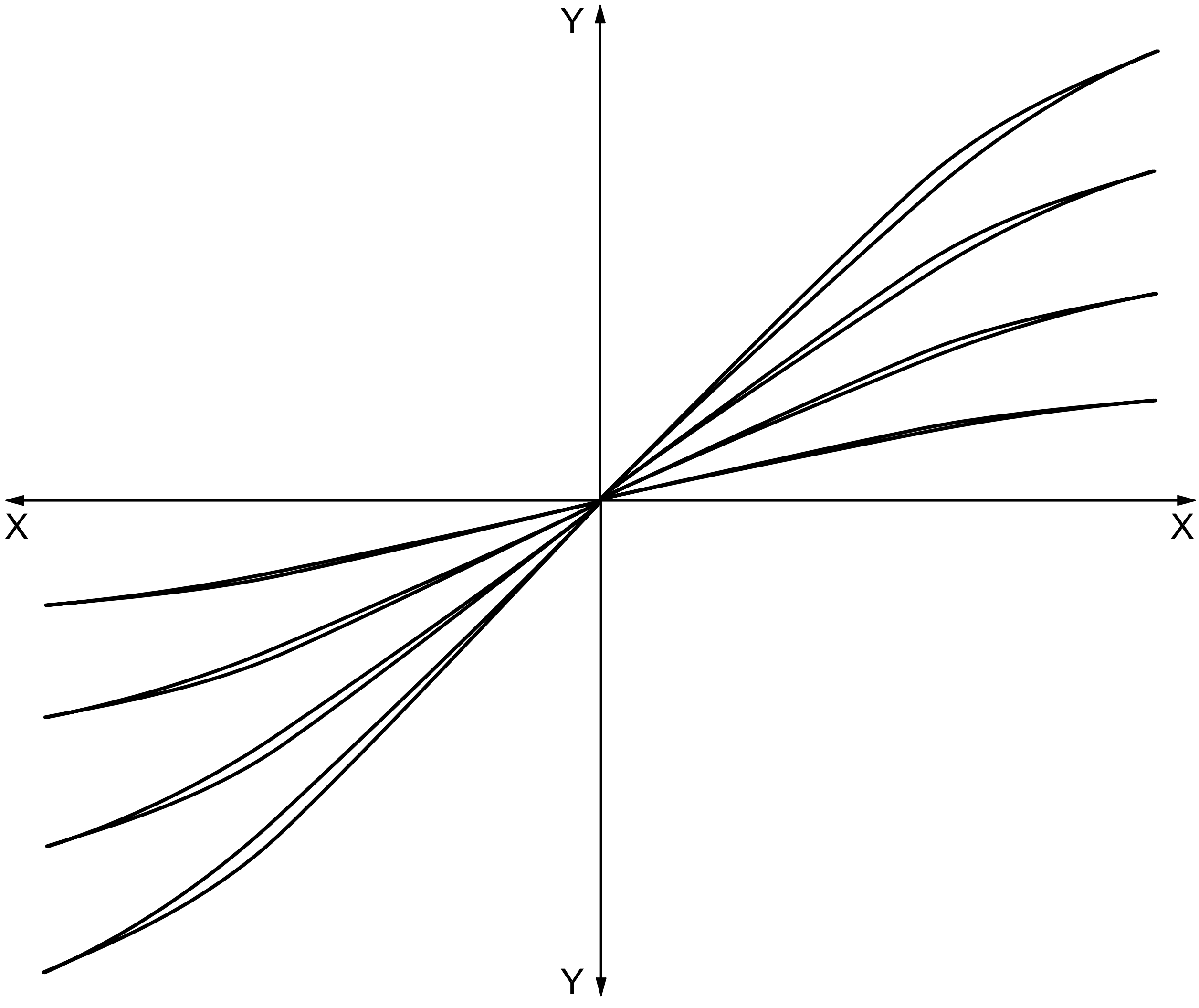
Figure 5 — Test circuit — Asymmetric spools

8.1.6.3 Set-up

Select a suitable plotter or recording apparatus with its X-axis able to record the valve pressure drop, measured using pressure transducers 6 to 9 as appropriate, and its Y-axis able to record the zero to at least three times the rated flow; see Figure 6.

For multi-stage valves with external pilot, adjust the pilot supply to that recommended by the manufacturer.

For multi-stage valves with internal pilot, adjust the P port supply to at least the minimum recommended by the manufacturer.



Key

X valve pressure drop

Y flow

Figure 6 — Output flow without integral pressure compensator

8.1.6.4 Procedure

8.1.6.4.1 Equal flows to and from the control ports — Symmetric spools

Carry out the test as follows.

a) Cycle the input signal gradually several times over its full range.

b) Adjust the valve's pressure drop to the minimum possible.

c) Set the input signal to the rated positive value (100 %).

d) Slowly increase the valve's pressure drop by increasing the P port pressure to its maximum rated pressure by increasing the setting of valve 2, to obtain a continuous plot of flow versus valve pressure drop for a rated positive input signal. Slowly reduce the P port pressure to the minimum possible whilst continuing to plot.

e) Repeat step d) at 75 %, 50 %, and 25 % of the rated input signal; see Figure 6.

f) Repeat the steps outlined in c) to e) for negative input signal; see Figure 6.

g) For valves with an integral pressure compensator, carry out the above tests to determine the effectiveness of the load compensating device; see Figure 7.

8.1.6.4.2 Unequal flows to and from the control ports — Asymmetric spools

Carry out the test as follows.

a) Open valves S2 and S4, with valves S1 and S3 closed.

b) Cycle the input signal gradually several times over its full range.

c) Adjust the valve's pressure drop to the minimum possible.

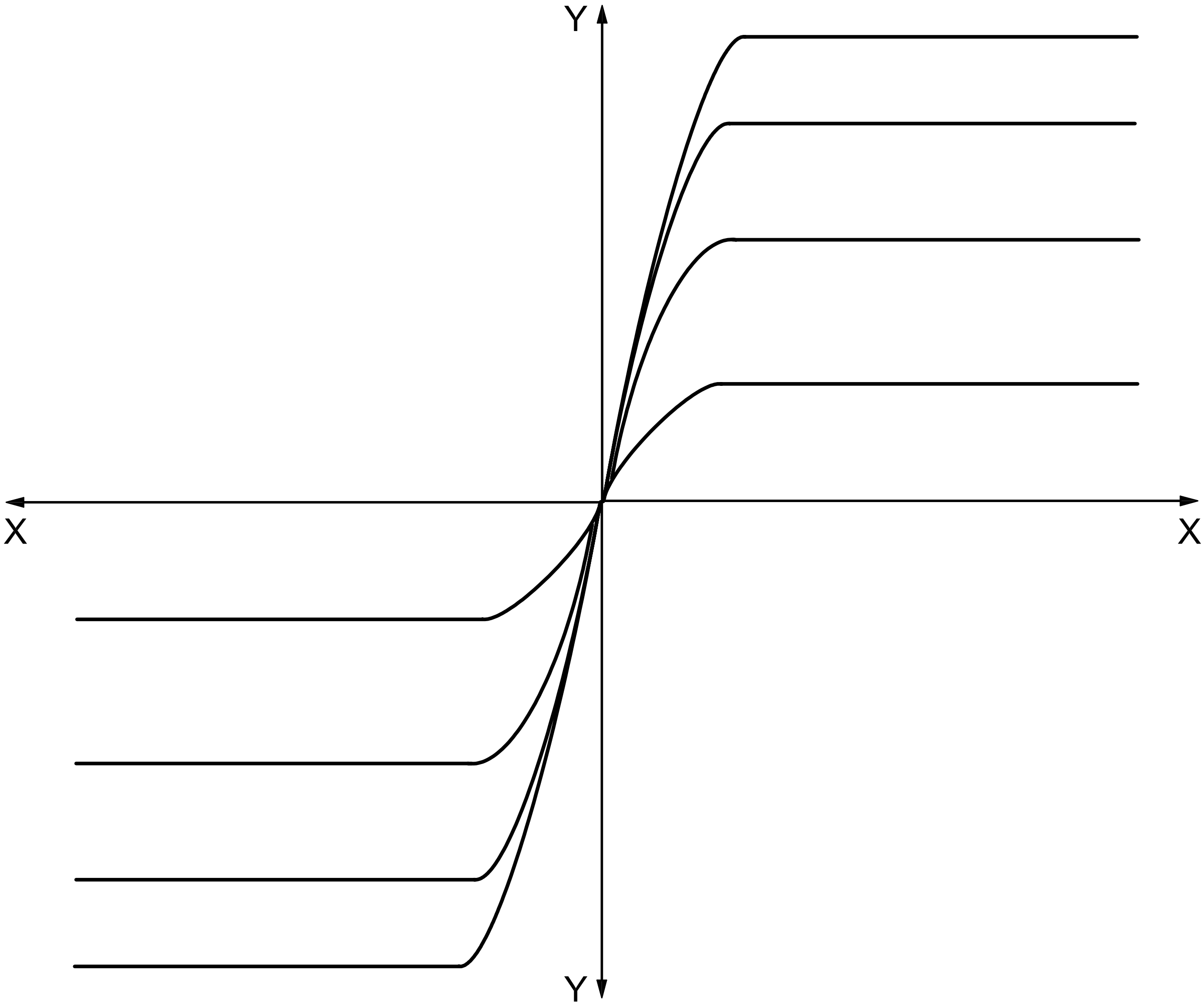
d) Set the input signal to the rated value (100 %) to give P to A flow.

e) Slowly increase the valve's pressure drop by increasing the P port pressure to its maximum rated pressure by increasing the setting of valve 2 in small discreet steps. At each step, adjust the pressure setting of the additional flow source by means of adjusting relief valve 18 to maintain the appropriate ratio of flows measured by transducers 10 and 11. If the target flow ratio is unknown, use a ratio of 1,7:1. Plot a graph of flow P to control port (measured by transducer 11) against total valve pressure drop.

f) Repeat step d) at 75 %, 50 %, and 25 % of the rated input signal; see Figure 6.

g) Open valves S1 and S3 and close valves S2 and S4. Repeat the steps outlined in d) to f) for negative input signal and the reversed flow ratio; see Figure 6.

h) For valves with an integral pressure compensator, carry out the above tests to determine the effectiveness of the load compensating device; see Figure 7.



Key

X valve pressure drop

Y flow

Figure 7 — Output flow with integral pressure compensator

8.1.7 Limiting power test

8.1.7.1 General

Tests shall be carried out to determine the hydraulic power limit of valves with spool position feedback. For valves without spool position feedback, this limit is represented by the curve obtained in 8.1.6.4 at 100 % rated signal.

The purpose of the limiting power test is to determine the flow and pressure levels beyond which the valve is unable to maintain spool position due to the action of flow forces. To determine this limit for valves with spool position feedback, the following test should be carried out.

8.1.7.2 Test circuit

8.1.7.2.1 Equal flows to and from the control ports — Symmetric spools

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S1, S3 and S6 open and all other valves closed.

8.1.7.2.2 Unequal flows to and from the control ports — Asymmetric spools

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 5. If such a circuit is not available, then use a test circuit conforming to the requirements of Figure 1 and use the alternative procedure described in 8.1.7.4.3 below. However, for this alternative test it is necessary to monitor either the current to the solenoid (for direct-operated valves) or pilot pressure applied to the mainstage (for pilot-operated valves).

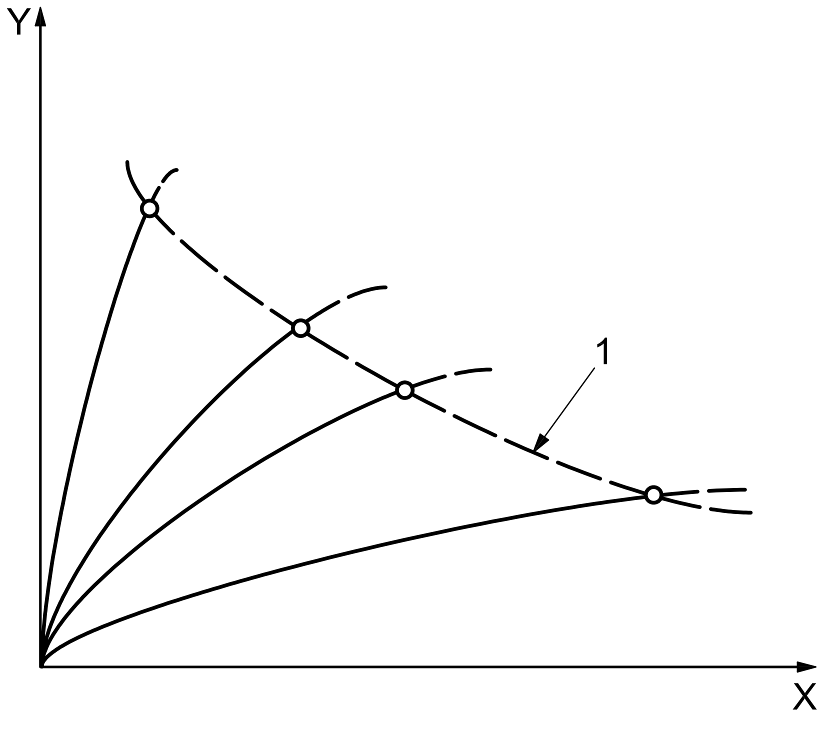
8.1.7.3 Set-up

Select a suitable plotter or recording apparatus with its X-axis able to record the valve pressure drop and its Y-axis able to record the zero to at least three times the rated flow; see Figure 8.

For multi-stage valves with external pilot, adjust the pilot supply to that recommended by the manufacturer.

For multi-stage valves with internal pilot, adjust the P port supply to at least the minimum recommended by the manufacturer.

Ideally monitor the valve main spool position.



Key

X valve pressure drop

Y flow

1 power limit

Figure 8 — Limiting power curve

8.1.7.4 Procedure

8.1.7.4.1 Equal flows to and from the control ports — Symmetric spools

To carry out the test, repeat 8.1.6.4.1. At each signal input level, establish the point at which the valve is unable to maintain the closed loop position control and the spool starts to move position. Connect together the marked points to give the limiting power capacity; see Figure 8.

If it is not possible to monitor the spool position, determine the limiting point by

a) superimposing on the input signal a small (± 5 %) sinusoidal signal at a low frequency, typically 0,2 Hz to 0,4 Hz, and

b) slowly increasing the valve supply pressure; note the point when the sinusoidal motion ceases, or the flow decreases suddenly.

8.1.7.4.2 Unequal flows to and from the control ports — Asymmetric spools

Carry out the test as follows.

Repeat 8.1.6.4.2. At each signal input level, establish the point at which the valve is unable to maintain the closed loop position control and the spool starts to move position. Connect together the marked points to give the limiting power capacity; see Figure 8.

If it is not possible to monitor the spool position, determine the limiting point by

a) superimposing on the input signal a small (± 5 %) sinusoidal signal at a low frequency, typically 0,2 Hz to 0,4 Hz, and

b) slowly increasing the valve supply pressure; note the point when the sinusoidal motion ceases, or the flow decreases suddenly.

8.1.7.4.3 Alternative method using single flow source — Asymmetric spools

Carry out the test as follows.

a) Open valves S3 and S5 and maintain all other valves closed; see Figure 1.

b) Apply 100 % input signal to give P to A flow.

c) Slowly increase the valve's pressure drop by increasing the P port pressure to its maximum rated pressure by increasing the setting of valve 2 in discreet small steps. Monitor the following:

    1) valve pressure drop (P to A);

    2) valve flow;

    3) either the current to the solenoid (direct-operated valves) or the pilot pressure applied to the mainstage (pilot-operated valves).

d) Using a spreadsheet or similar, record the above valves at about 7 to 10 points over the pressure range.

e) For each point, determine the B to T flow for the spool's design flow ratio. If the target flow ratio is unknown, use a ratio of 1,7:1.

f) Open valves S4, S8, S9 with all other valves closed. For each point in step e), measure the valve pressure drop B to T and the solenoid current or pilot pressure to achieve the calculated B to T flow.

g) With the hydraulic supply turned off, measure the solenoid current or pilot pressure. Subtract this value from the value measured in step f) to obtain a net value.

h) Add together the pressure drops recorded in steps c) and f) to obtain a total valve pressure drop. Produce a graph of total valve pressure drop against P to A flow.

i) Add together the solenoid current or pilot pressures recorded in steps c) and g) to obtain a total solenoid current or total pilot pressure. Produce a graph of total solenoid current or total pilot pressure against P to A flow. Use this graph to determine the maximum possible P to A flow not exceeding the maximum current rating of the solenoid or the current output limit of the amplifier, whichever is the lower, or the manufacturer's minimum recommended pilot pressure.

j) Determine the total valve pressure at the flow determined in step i) using the graph created in step h).

k) Repeat steps b) to j) for a range of input signals. This thus generates a series of pairs of values determined in step j). An XY graph of these values represents the hydraulic power capacity of the valve.

l) Repeat steps a) to k) for flows P to B and A to T, but in step a) open valves S4 and S6 and maintain all other valves closed, and in step f) open valve S7 instead of S9.

8.1.8 Output flow or spool position versus fluid temperature test

8.1.8.1 General

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

8.1.8.2 Test circuit

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valves S1, S3 and S6 open and all other valves closed.

8.1.8.3 Set-up

Select a suitable plotter or recording apparatus with its X-axis capable of recording the temperature range of 20 °C to 70 °C and its Y-axis able to record the zero to at least the rated flow; see Figure 9.

For multi-stage valves with external pilot, adjust the pilot supply to that recommended by the manufacturer.

For multi-stage valves with internal pilot, adjust the P port supply to at least the minimum recommended by the manufacturer.

Take precautions to avoid forced air draughts across the valve.

8.1.8.4 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.

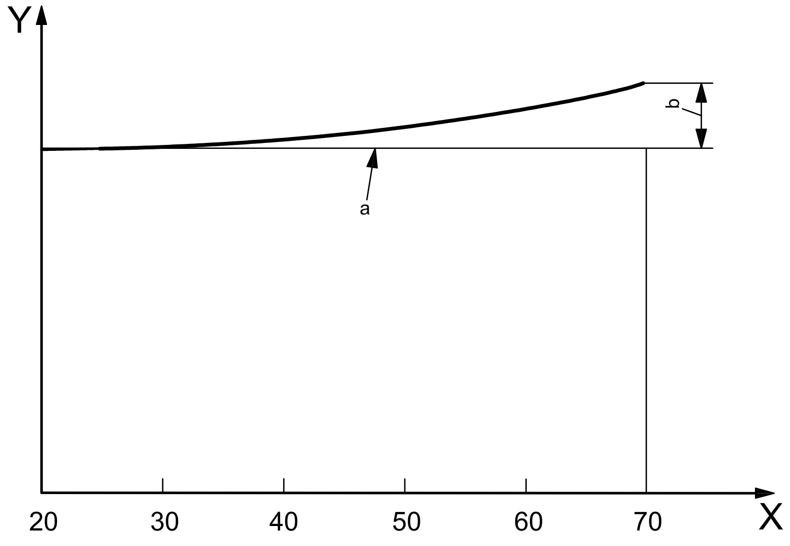
b) Apply an input signal to achieve 10 % of the rated output flow at the valve rated pressure drop. During the test, maintain the valve pressure drop at its rated value.

c) Measure and record the controlled flow and the fluid temperature; see Figure 9.

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 specified in 8.1.8.4 c) until the temperature reaches 70 °C.

f) Repeat steps 8.1.8.4 c) to e) with the initial flow set to 50 % of the rated flow.



Key

X fluid temperature

Y flow

a Flow setting.

b Flow change.

Figure 9 — Flow versus fluid temperature

8.1.9 Pressure gain test (optional for proportional control valves)

8.1.9.1 General

Tests shall be carried out to determine the pressure gain of the control ports A and B versus the input signal. This test is not relevant to valves with overlapped spools.

8.1.9.2 Test circuit

Perform the test with an hydraulic test circuit conforming to the requirements of Figure 1, with valve S1 open and all other valves closed.

8.1.9.3 Set-up

Select a suitable plotter or recording apparatus with its X-axis able to record up to ± 10 % of the maximum input signal and its Y-axis able to record 0 MPa to 10 MPa (100 bar); see Figure 10.

8.1.9.4 Procedure

Select a signal generator able to produce a triangular waveform with an amplitude of ± 10 % of the maximum input signal range. Set the signal generator to produce a 0,01 Hz or lower triangular waveform. This test is affected by the valve's internal leakage and the volume of fluid under pressure, and therefore an even lower frequency waveform may be necessary to ensure that dynamic effects do not affect the measured data.

Carry out the test as follows.

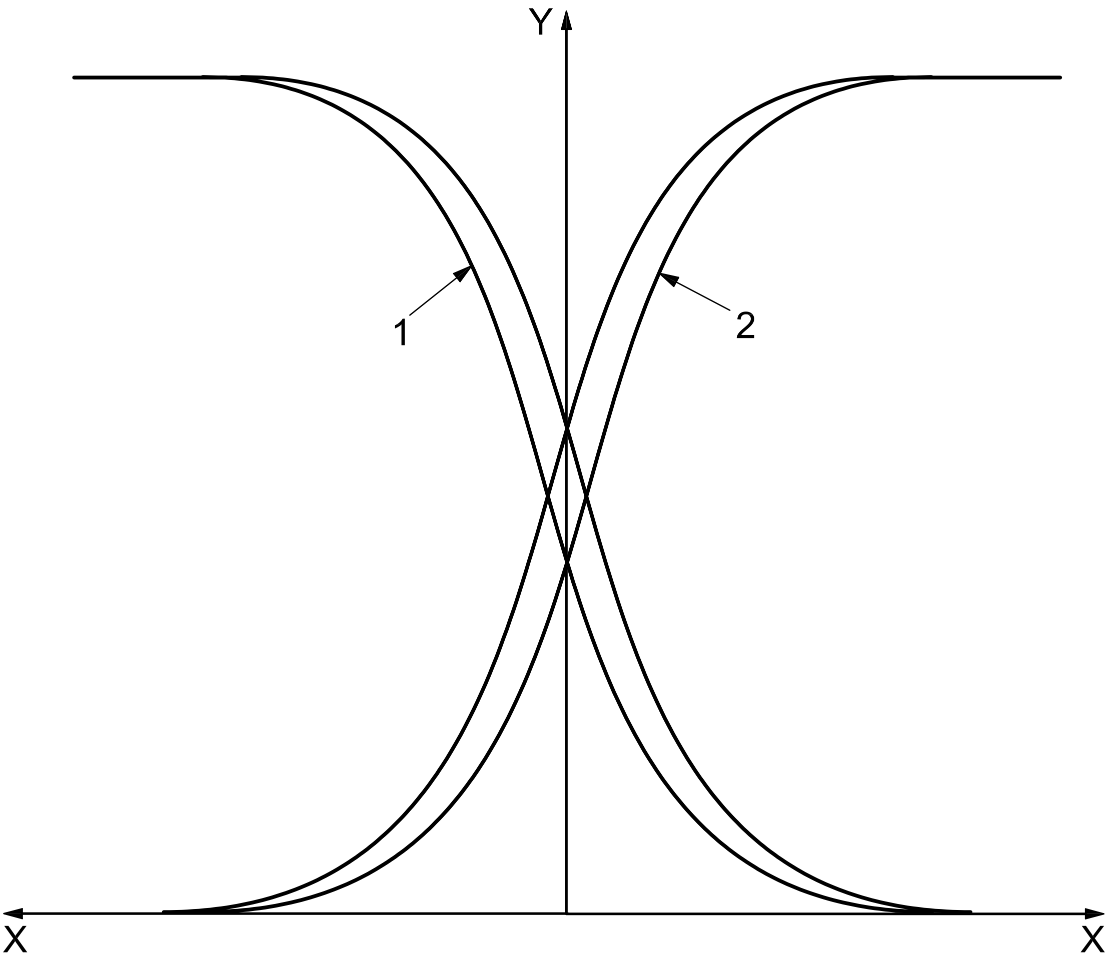
a) Adjust the supply pressure to 10 MPa (100 bar).

b) Adjust the amplitude of the input signal so that the spool passes through the valve centre with sufficient travel to effectively reach supply pressure amplitude at both control ports; see Figure 10.

c) Record the blocked port pressures at ports A and B. Label each trace as to its associated port.

d) Produce a plot of load pressure difference versus input signal; see Figure 11.

e) Determine the pressure gain as the change in the load pressure difference as a percentage of the supply pressure for a 1 % change in the input signal from null.



Key

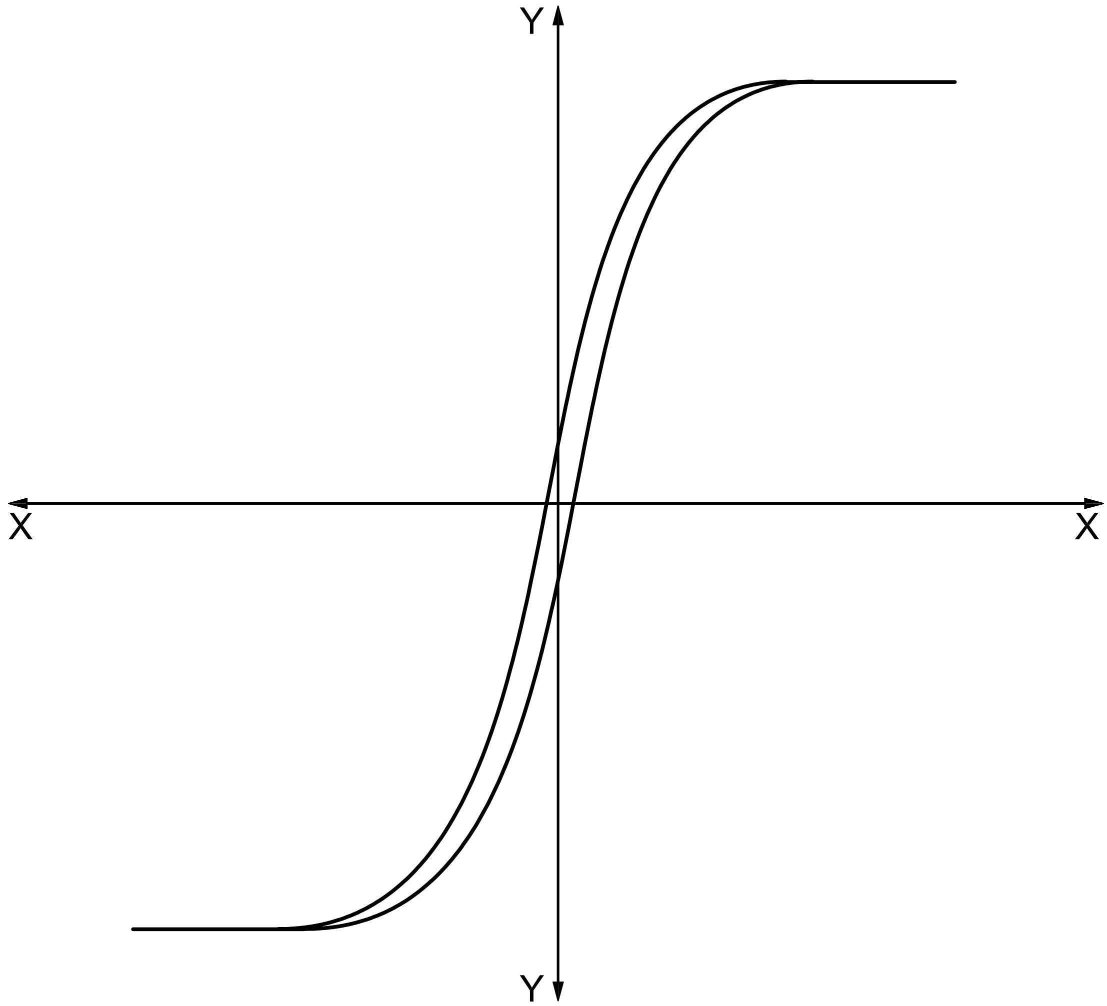
X input signal

Y pressure

1 port B pressure

2 port A pressure

Figure 10 — Blocked port load pressure versus input signal



Key

X input signal

Y load pressure difference

Figure 11 — Load pressure difference versus input signal

8.1.10 Pressure null shift — Servo valves only

8.1.10.1 Test circuit

Use the hydraulic test circuit described in 8.1.9.2.

8.1.10.2 Procedure

Carry out the test as follows.

a) With the supply pressure at 40 % of the maximum allowable P port pressure, adjust the input signal such that pressures at ports A and B are equal. Record the value of the input signal.

b) Repeat step a) with supply pressure set at 20 % of the maximum allowable P port pressure.

c) Repeat step a) with supply pressure set at 60 % of the maximum allowable P port pressure.

8.1.10.3 Conclusion

The variation in input signal, expressed as a percentage of the maximum input signal, constitutes the pressure null shift applicable to the change in supply pressure. This can be expressed as a percentage per megapascal of supply pressure.

8.1.11 Fail-safe function test

Carry out the test as follows.

a) Check the inherent fail-safe characteristics of the valve, e.g. at loss of input signal, loss or reduction of electric power, loss or reduction of hydraulic power, or loss of feedback signal.

b) Check the performance of any special fail-safe functions incorporated in the valve by monitoring the spool position.

c) Repeat, if necessary, for various selected input signal conditions.

8.2 Dynamic tests

8.2.1 General

The tests described in 8.2.3 to 8.2.5 shall be carried out to determine the step response and frequency response of the valve.

Obtain the return signal by one of methods 8.2.1 a), b) or c).

a) Use the output from flow transducer 10 as the return signal. It is necessary that the flow transducer have a band width that is at least three times greater than the maximum test frequency including the effects of trapped fluid volume. Alternatively, replace the flow transducer with a low friction [having a pressure drop not exceeding 0,3 MPa (3 bar)], low inertia actuator, together with a velocity transducer having the above-required bandwidth. Use of a linear actuator is not suitable when running tests with a d.c. biased input signal. Keep line lengths from ports A and B to the flow transducer or actuator as short as possible.

b) In valves that are equipped with integral spool position transducers and that are not equipped with integral pressure compensated flow controllers, use the spool position signal as the return signal.

c) In valves that are not equipped with spool position transducers and that are not equipped with integral pressure compensated flow controllers, it is necessary to fit them with a spool position transducer and appropriate signal conditioning electronics. Use that signal as the return signal, provided the addition of the transducer does not alter the frequency response of the valve.

Methods a), b) and c) do not yield equivalent results. The data as reported shall therefore identify the test method used.

For multi-stage valves, it is recommended that these tests be carried out with the valve configured for external pilot supply to obtain the most comparable data.

8.2.2 Test circuit

Perform the test with a circuit conforming to the requirements of Figure 1, with valves S1, S3 and S6 open and all other valves closed, possibly with flow transducer 10 replaced by a linear actuator as described in 8.2.1 a).

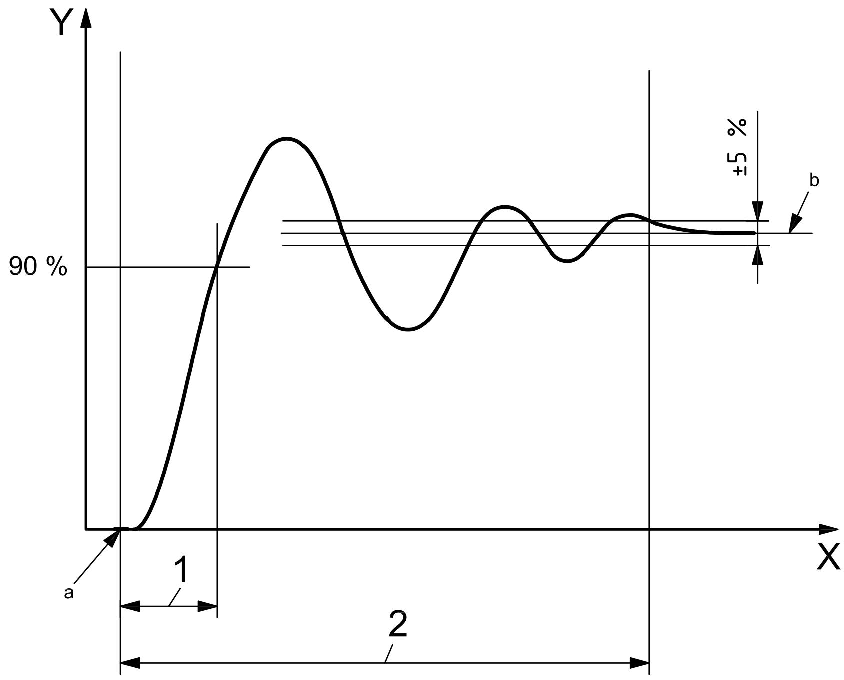
The flow source and pipework should be sized so as to be able to maintain the valve pressure drop within ± 25 % of the nominal setting over the frequency range tested and over the duration of the step response. It can be necessary for the flow source to include an accumulator.

8.2.3 Step response — Change in input signal

8.2.3.1 Set-up

Select a suitable oscilloscope or other electronic equipment to record the controlled flow and input signal to the valve against time; see Figure 12.

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



Key

X time

Y flow or spool position

1 response time

2 settling time

a Initiation.

b Steady-state flow.

Figure 12 — Step response — Change in input signal

8.2.3.2 Procedure

Carry out the test as follows.

a) For multi-stage valves without integral pilot pressure control, set the pilot pressure to 20 % of rated maximum pilot pressure. Repeat the dynamic tests at 50 % and 100 % of rated maximum pilot pressure.

b) Adjust the inlet pressure to achieve the rated pressure drop at 50 % of rated flow.

c) Set the signal generator so that the controlled flow steps between the pair of start and finish flows for test 1 as given in Table 3.

Table 3 — Input step functions

Test number	Percentage of rated flow	
	Start %	Finish %
1	0	+10
	+10	0
2	0	+50
	+50	0
3	0	+100
	+100	0
4	+10	+90
	+90	+10
5	+25	+75
	+75	+25
6	0	–10
	–10	0
7	0	–50
	–50	0
8	0	–100
	–100	0
9	–10	–90
	–90	–10
10	–25	–75
	–75	–25
11	–10	+10
	+10	–10
12	–90	+90
	+90	–90

d) Enable the output from the signal generator and allow the signal generator to cycle at least once.

e) Record the controlled flow and signal to the valve against time for steps in the positive and negative directions.

f) Ensure that the recording window shows the complete response.

g) Repeat steps 8.2.3.2 a) to e) with the controlled flow set to the pairs of pressures given for tests 2 through to 12 in Table 3.

8.2.4 Step response — Change in load

This test is only applicable to valves with an integral pressure compensator.

8.2.4.1 Test circuit

Perform the test with a circuit as described in 8.2.2 but with the addition of an electrically operated loading valve added in series with flow meter 10. The known response time of this additional valve shall 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 the controlled flow and input signal to the loading valve against time; see Figure 13.

8.2.4.3 Procedure

Carry out the test as follows.

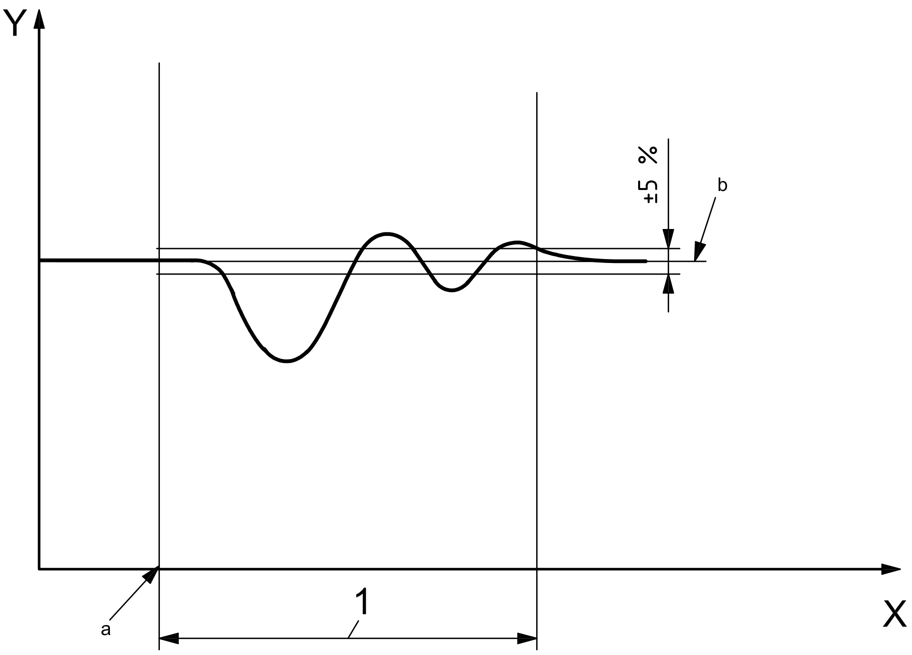
a) For multi-stage valves without integral pilot pressure control, set the pilot pressure to 20 % of the rated maximum pilot pressure. Repeat the dynamic tests at 50 % and 100 % of rated maximum pilot pressure.

b) Set the inlet pressure to the test valve to its maximum rated value.

c) Adjust the input signal to the test valve and the signal to the loading valve to achieve 50 % of the rated flow with a load pressure differential of 50 % of the specified maximum load pressure.

d) Adjust the signal levels to the loading valve so that the load pressure difference steps between 50 % and 100 % of the specified maximum load pressure. Record the transient characteristic of the control flow; see Figure 13.

e) Repeat the test, switching the load pressure drop between 50 % of the specified maximum load pressure and the minimum possible value.



Key

X time

Y flow

1 settling time

a Initiation.

b Steady-state flow.

Figure 13 — Step response — Change in load

8.2.5 Frequency response

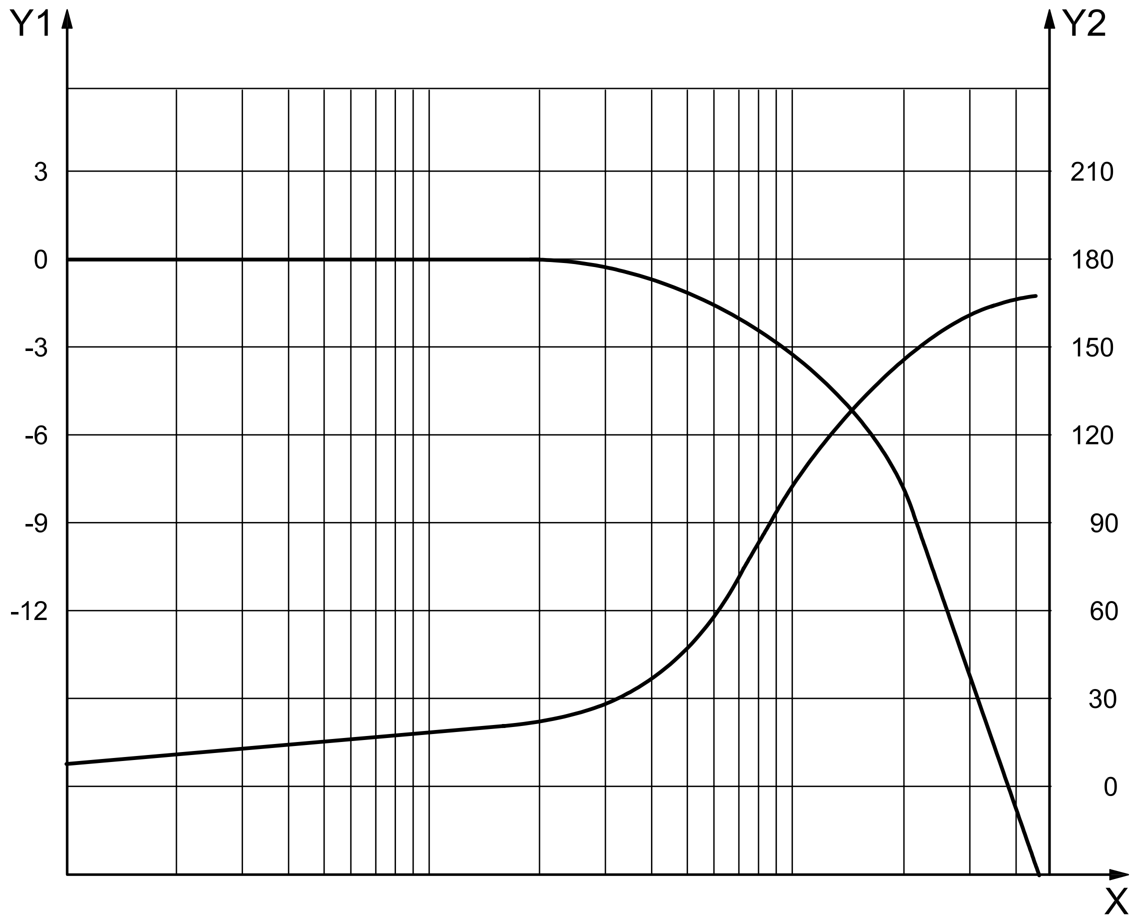
8.2.5.1 General

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

8.2.5.2 Set-up

Select a suitable frequency response analyser or other electronic equipment to measure the amplitude ratio and phase shift between the 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 return signal (see Figure 14).



Key

X frequency of input signal

Y_1 amplitude ratio

Y_2 phase lag

Figure 14 — Frequency response

8.2.5.3 Procedure

Carry out the test as follows.

a) For multi-stage valves without integral pilot pressure control, set the pilot pressure to 20 % of rated maximum pilot pressure. Repeat the dynamic tests at 50 % and 100 % of rated maximum pilot pressure.

b) Adjust the inlet pressure and d.c. offset to the input of the valve to achieve the rated pressure drop at 50 % of rated flow.

c) Add a sinusoidal signal onto the d.c. offset. Set the amplitude of the signal to give a flow amplitude of ± 5 % of the rated flow under steady-state conditions. This can be established from the metering tests of 8.1.4. Choose the frequency measurement range to satisfy the following: the minimum frequency shall be no more than 5 % of the frequency that results in a 90° phase lag; the maximum frequency shall be at least that which results in a 180° phase lag, or until such point that it is not possible to reliably measure the return signal amplitude.

d) Check that the reduction in return 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 amplitude of the sinusoidal input signal constant throughout each complete sweep.

f) Repeat steps 8.2.5.3 a) to e) with the other conditions listed in Table 4.

Table 4 — Frequency response tests

Valve type	**Flow bias** % of rated flow	**Flow amplitude** % of rated flow
Zero lap valves	0	± 5 ± 10 ± 25 ± 100
	+50	± 5 ± 10 ± 25
	–50	± 5 ± 10 ± 25
Overlapped valves	+50	± 5 ± 10 ± 25
	–50	± 5 ± 10 ± 25

9 Pressure impulse test

Refer to ISO 10771-1.

10 Presentation of results

10.1 General

Test results shall be presented either

a) in tabular form; or, if convenient,

b) in graphical form.

10.2 Test reports

10.2.1 General

All test reports shall contain at least the following:

a) the name of the valve manufacturer;

b) the valve type and serial number, if applicable;

c) the amplifier type and serial number, where applicable (if an external amplifier is used);

d) the valve rated flow at rated valve 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 in accordance with 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 test operator.

10.2.2 Test reports for production acceptance tests

Test reports for valve production acceptance tests shall contain at least the following:

a) the insulation resistance (see 7.4);

b) the maximum internal leakage (see 8.1.3);

c) the output flow versus input signal metering (see 8.1.4);

d) the phasing of the output flow versus input signal curve (see 8.1.4.4);

e) the hysteresis from the output flow versus input signal curve (see 8.1.4.4);

f) the flow gain, K_V, and the pressure used in determining the gain (see 8.1.4.4);

g) the flow linearity (see 8.1.4.4);

h) the null zone characteristics (see 8.1.4.4);

i) the pressure gain, K_p (see 8.1.9);

j) the threshold (see 8.1.5);

k) fail-safe function test, where applicable (see 8.1.11).

Additional tests may include: null shift with supply pressure (two or more datum points) and symmetry (see 8.1.10).

10.2.3 Test reports for type test

Test reports for valve type tests shall contain at least the following:

a) the production acceptance test information (see 10.2.2);

b) the coil resistance (see 7.2);

c) the coil inductance (see 7.3);

d) the output flow versus fluid temperature (see 8.1.8);

e) the limiting power test data (see 8.1.7);

f) output flow versus valve pressure drop (see 8.1.6);

g) the pressure null shift (see 8.1.10.3);

h) the dynamic characteristics (see 8.2);

i) the pressure impulse test results (see Clause 9);

j) the details of any physical degradation following disassembly and visual inspection of piece parts.

11 Identification statement (Reference to this part of ISO 10770)

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 10770-1:2009, *Hydraulic fluid power — Electrically modulated hydraulic control valves — Part 1: Test methods for four-port directional flow-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 by a point-to-point method.

NOTE 2 The signal moves in one direction only for one half of the test cycle and in the other direction only in the other half, and the hysteresis inherent in the valve is not hidden. 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, etc.) produced by the signal generator is not important provided the ratio of change of the 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 centralizing the trace on the chart.

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

Electronic adjustments should be recorded.

ICS 23.100.50

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