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

Part 2:

**Test methods for three-port directional  
flow-control valves**

*Transmissions hydrauliques — Distributeurs hydrauliques à modulation  
électrique — Partie 2: Méthodes d'essai pour distributeurs de  
commande de débit à trois voies*



Reference number  
ISO 10770-2:2012(E)

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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 10770-2 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 10770-2:1998) 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-port 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 this data can be used for system design, regardless of the data source.

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# Hydraulic fluid power — Electrically modulated hydraulic control valves —

## Part 2: Test methods for three-port directional flow-control valves

### 1 Scope

This part of ISO 10770 describes methods for determining the performance characteristics of electrically modulated hydraulic three-port directional flow-control valves.

This type of electrohydraulic valve controls the direction and amount of hydraulic 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 — Graphical symbols and circuit diagrams — Part 1: Graphical 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 9110-1:1990, *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-12M, *Graphical symbols for 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 and 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 input signal.

**3.1.4  
rated input signal**

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.

The graphical symbols in this document conform to ISO 1219-1 and IEC 60617-DB-12M.

**Table 1 — Symbols and units**

Parameter	Symbol	Unit
Inductance	$L_c$	H
Insulation resistance	$R_i$	$\Omega$
Insulation test current	$I_i$	A
Insulation test voltage	$U_i$	V
Resistance	$R_c$	$\Omega$
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 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)
Load pressure	$p_A$	MPa (bar)
Valve pressure drop	$p_v = p_P - p_A$ or $p_v = p_A - p_T$	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

Table 1 (continued)

Parameter	Symbol	Unit
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 ± 8) cSt at valve inlet
Viscosity grade	Grade VG 32 or VG 46 in accordance with ISO 3448
Pressure drop	Test requirement ± 2,0 %
Return pressure	Shall conform to the manufacturer's recommendations

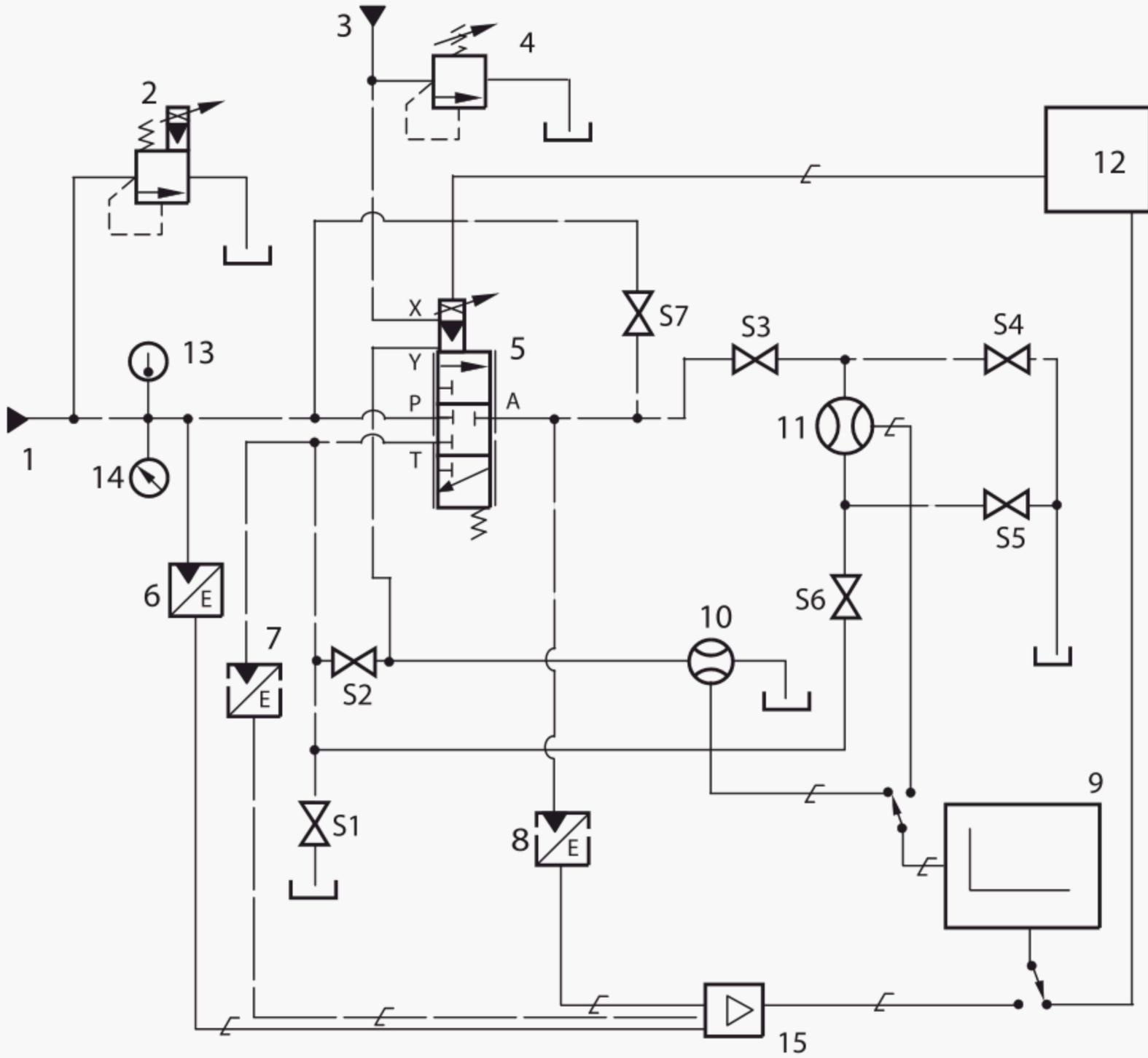
#### 5 Test installation

A test installation conforming to the requirements of either Figure 1, 10 or 11 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, 10 and 11 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 circuits shown in Figures 1, 10 and 11, 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 10 times greater than the maximum test frequency.
- g) Pressure transducers 6 to 8 in Figures 1 and 10 may be replaced by a differential pressure transducer for each flow path under test.



**Key**

- |        |                             |          |                       |
|--------|-----------------------------|----------|-----------------------|
| 1      | main flow source            | 13       | temperature indicator |
| 2      | main relief valve           | 14       | pressure gauge        |
| 3      | external pilot flow source  | 15       | signal conditioner    |
| 4      | external pilot relief valve | S1 to S7 | shut off valves       |
| 5      | unit under test             | A        | working port          |
| 6 to 8 | pressure transducers        | P        | supply port           |
| 9      | data acquisition            | T        | return port           |
| 10, 11 | flow transducer             | X        | pilot supply port     |
| 12     | signal generator            | 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 9110-1:1990:

- a) electrical resistance:  $\pm 2$  % of the actual measurement;
- b) pressure:  $\pm 1$  % of the valve's rated pressure drop to achieve rated flow;
- c) temperature:  $\pm 2$  % of the ambient temperature;
- d) flow:  $\pm 2,5$  % of the valve's rated flow;
- e) input signal:  $\pm 1,5$  % 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 would affect the measured value by more than 1 % of the measured value.

## 7 Electrical tests for valves without integrated electronics

### 7.1 General

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

NOTE Tests 7.2 to 7.4 only apply to current-driven valves.

### 7.2 Coil resistance

#### 7.2.1 Coil resistance (cold)

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 taken to determine a definitive value of Inductance. The value obtained shall be used for comparison purposes only.

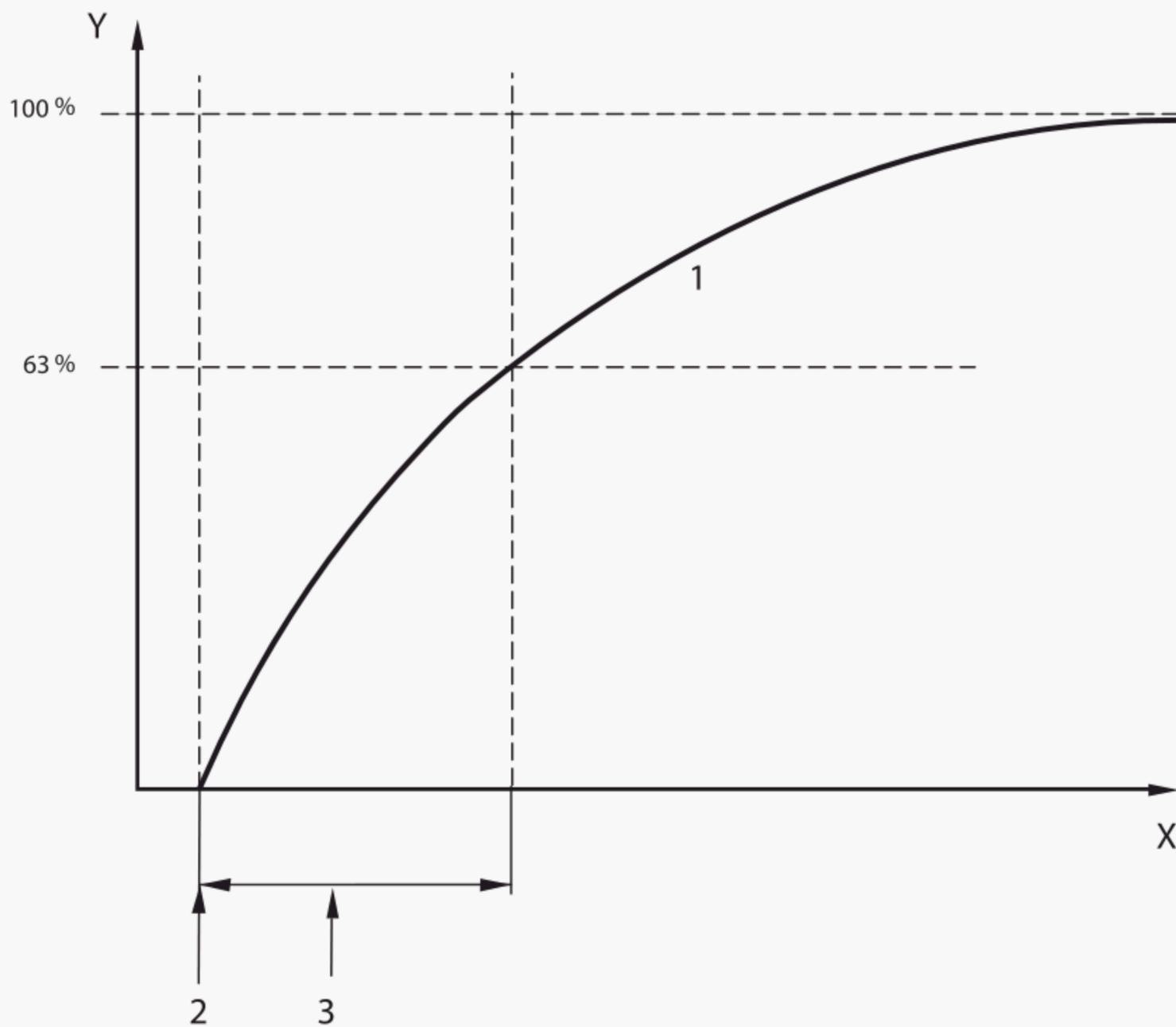
Carry out the test as follows.

- 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 Formula 1.

$$L_c = R_c t_c \tag{1}$$

where

$R_c$  is the coil resistance in ohms.



**Key**

- 1 d.c. current trace
- 2 initiation
- 3 time constant ( $t_c$ )
- X time
- Y current

**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, calculate the insulation resistance using Formula (2).

$$R_i = \frac{U_i}{I_i} \quad (2)$$

## 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 external pilot supply and external pilot drain where possible.

Before commencing any test, any mechanical/electrical adjustments that would normally be carried out, such as nulling, deadband adjustment and gain adjustment, shall be made.

### 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);

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- 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 and X ports test procedure

In the test, a proof pressure is supplied to the pressure and control ports, and 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 port, and 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;
- 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 a 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.

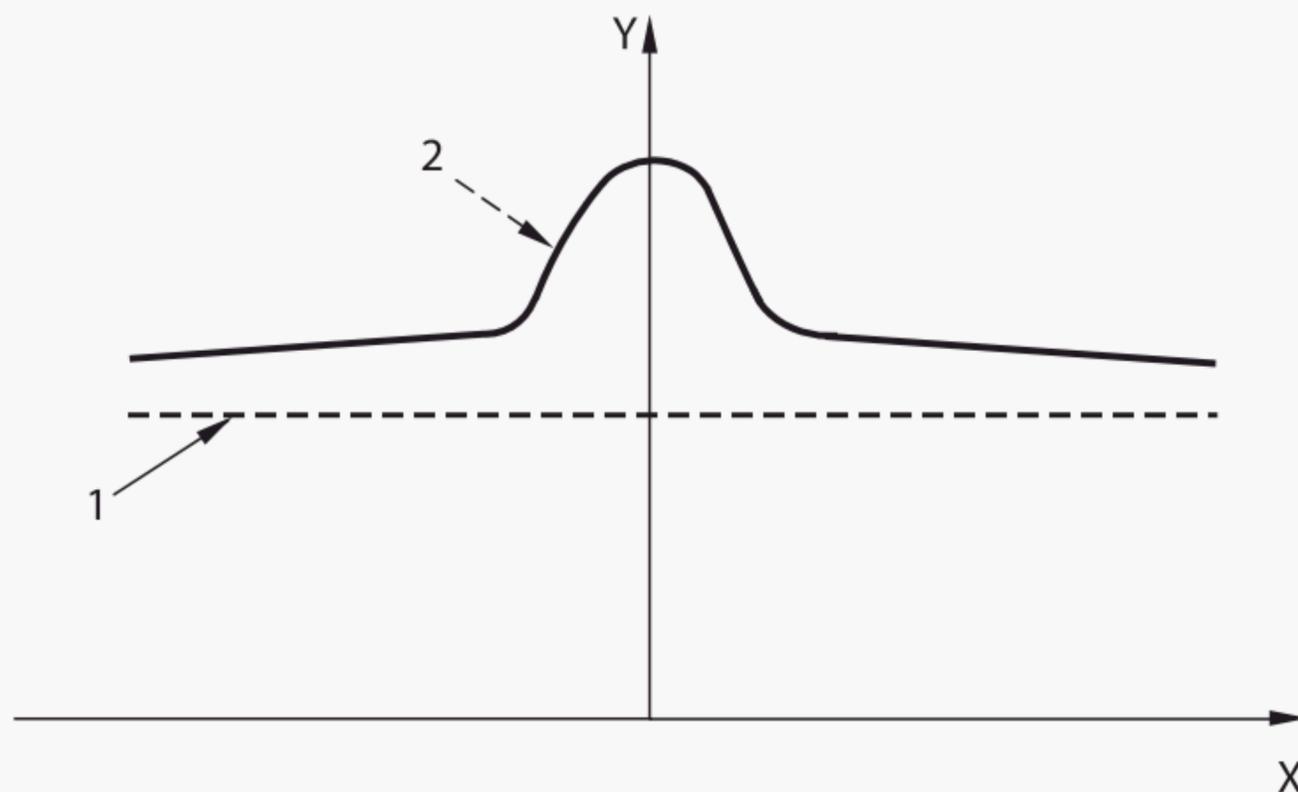
### 8.1.3.4 Procedure

Carry out the test as follows.

- a) Immediately before the leakage measurements are to be 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 will represent mainstage leakage plus pilot leakage. The characteristic shown in Figure 3 is typical for a servo valve. Other valve types would have a different characteristic.
- d) With a constant input signal, the flow recorded by transducer 10 will represent 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 will represent 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

- 1 approximate pilot flow component (pilot operated valves only)
- 2 total measured flow including any pilot flow
- X input signal
- Y 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 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 General

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

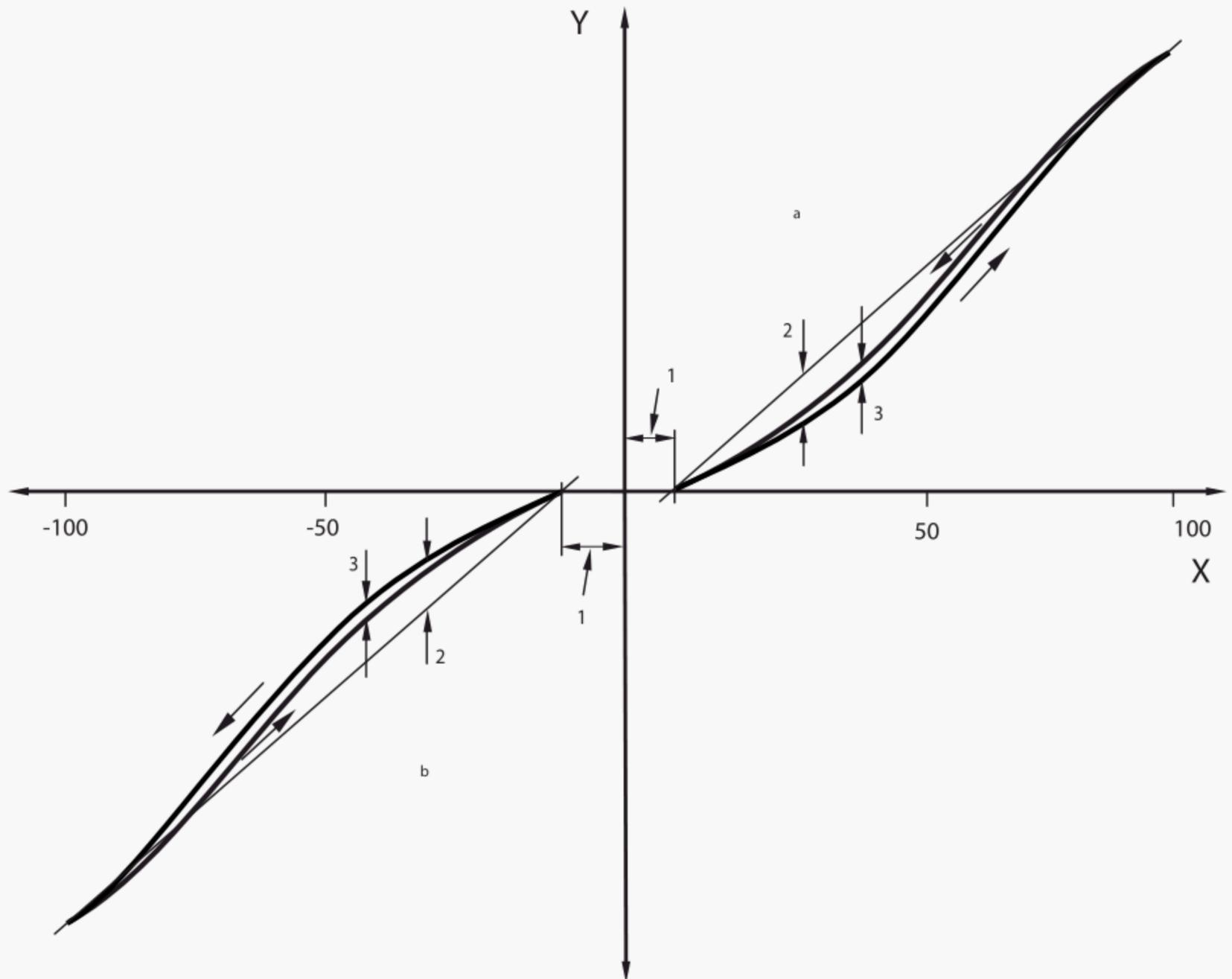
For multi-stage valves with internal pilot pressure connection, it can be necessary to increase the system pressure by adding a restriction in the main flow circuit in order for the valve to operate correctly.

#### 8.1.4.2.2 Flow from supply port P to control port A

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

#### 8.1.4.2.3 Flow from control port A to return port T

Perform the test with a hydraulic test circuit conforming to the requirements of Figure 1, with valves S4, S6 and S7 open and all other valves closed.



### Key

- 1 deadband
- 2 linearity error,  $Q_{err}$
- 3 hysteresis
- X fraction of rated input signal (%)
- Y flow
- a Flow from supply port P to control port A.
- b Flow from control port A to return port T.

**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 from zero to at least the rated flow (see Figure 4).

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

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.

Control the pressure drop across the metering path to either 0,5 MPa (5 bar) or 3,5 MPa (35 bar) measured using pressure transducers 6 to 8 as appropriate. Ensure that the pressure drop across the metering path remains constant within 2 % over the complete cycle. If the pressure drop across the metering path cannot be continuously controlled, it will be necessary to take point readings.

- a) 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.
- b) 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.
- c) Record the valve input signal and the controlled flow over one complete input signal cycle.
- d) Repeat steps 8.1.4.4 a) to c) 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, 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 0,1 Hz or lower triangular waveform.

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 Flow from supply port P to control port A

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

###### 8.1.6.2.2 Flow from control port A to return port T

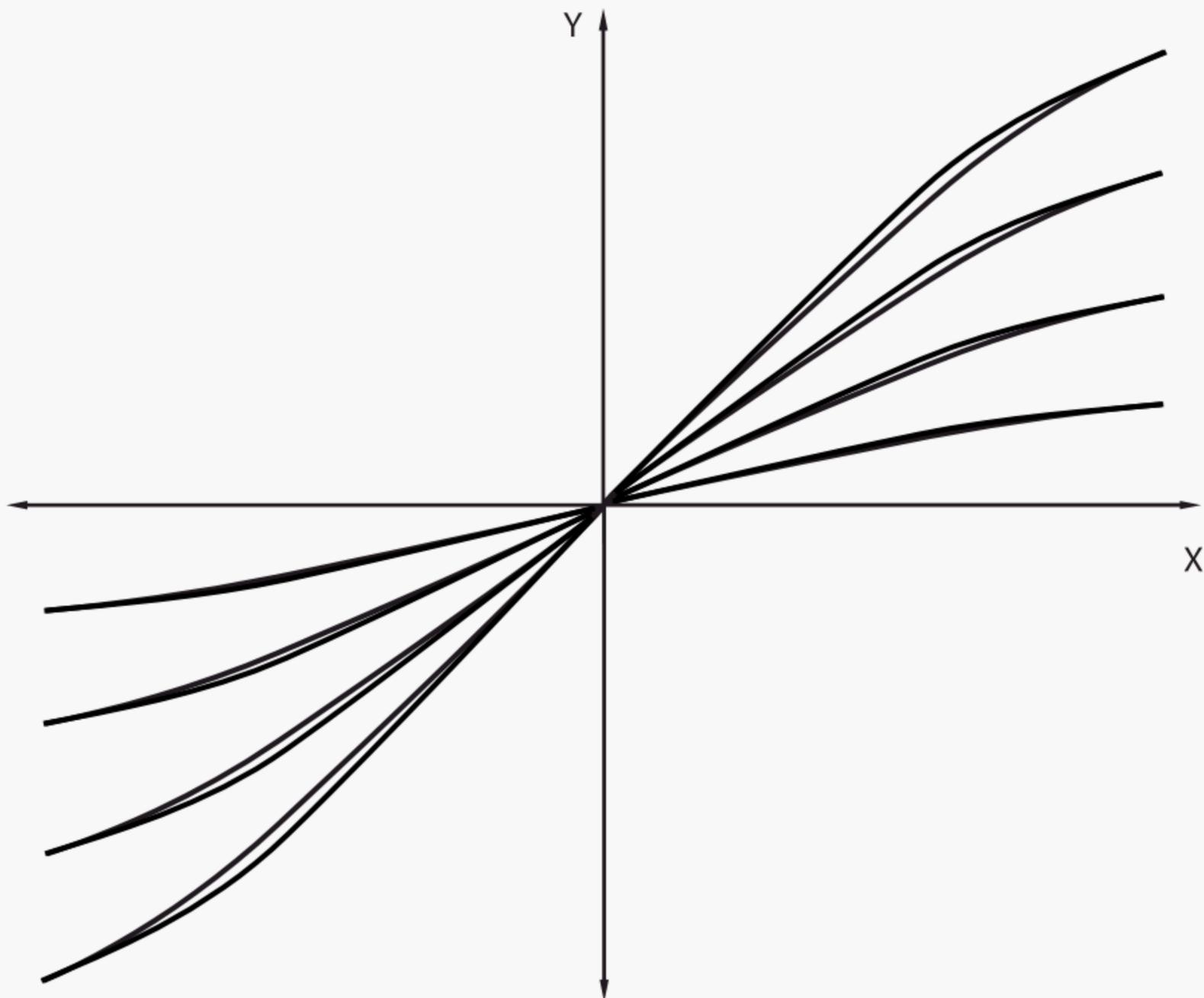
Perform the test with a hydraulic test circuit conforming to the requirements of Figure 1, with valves S4, S6 and S7 open and all other valves closed.

##### 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 8 as appropriate, and its *y*-axis able to record from zero to at least three times the rated flow (see Figure 5).

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 5 — Output flow without integral pressure compensator**

**8.1.6.4 Procedure**

**8.1.6.4.1 Flow from supply port P to control port A**

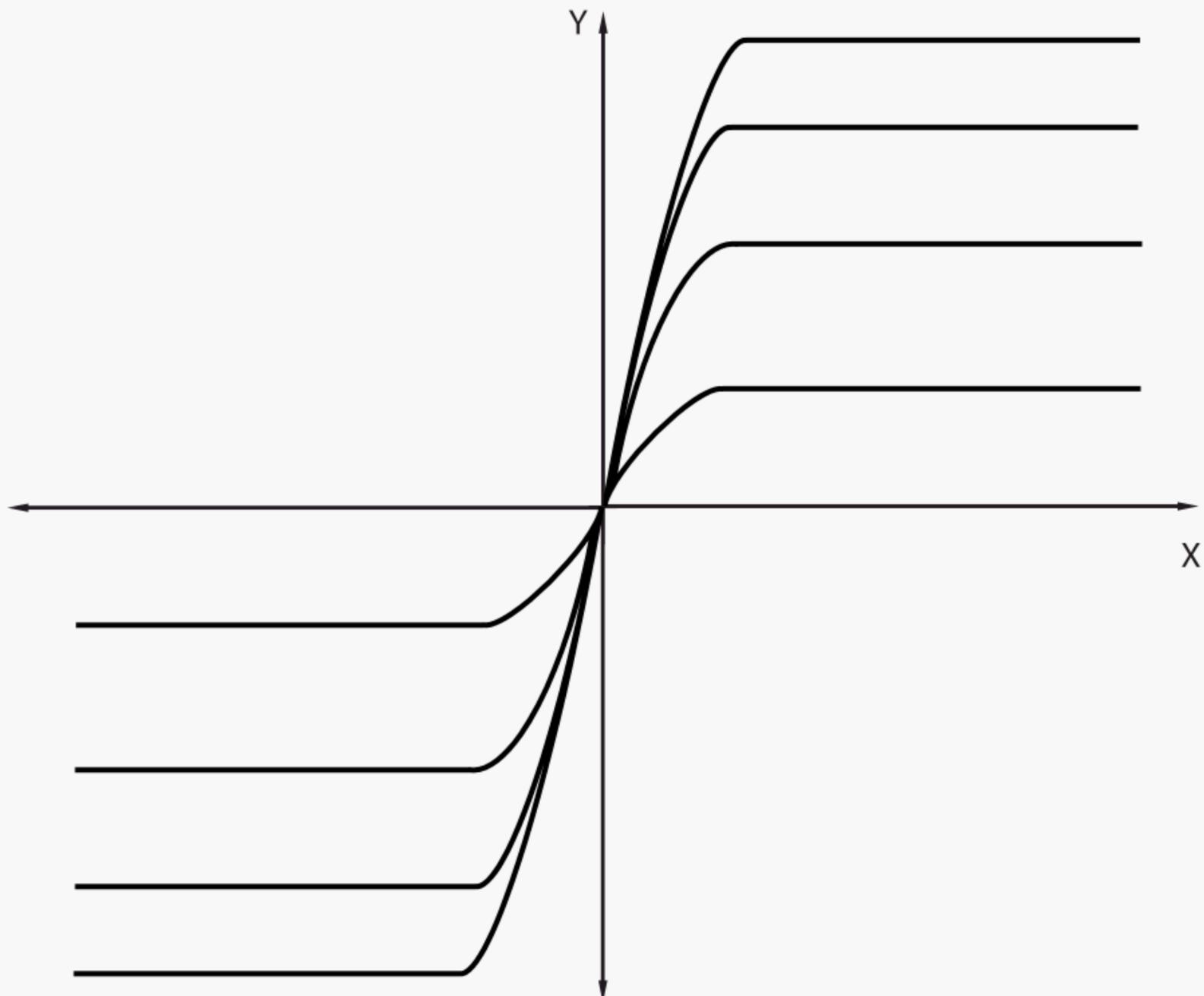
Carry out the test as follows.

- 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 while continuing to plot.
- e) Repeat d) at 75 %, 50 %, and 25 % of the rated input signal (see Figure 5).
- f) For valves with an integral pressure compensator, carry out the above tests to determine the effectiveness of the load compensating device (see Figure 6).

#### 8.1.6.4.2 Flow from control port A to return port T

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 negative value (–100 %) to give A to T flow.
- d) Slowly increase the valve's pressure drop by increasing the A 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 A port pressure to the minimum possible while continuing to plot.
- e) Repeat d) at 75 %, 50 %, and 25 % of the rated input signal (see Figure 5).
- f) For valves with an integral pressure compensator, carry out the above tests to determine the effectiveness of the load compensating device (see Figure 6).



#### Key

- X valve pressure drop  
Y flow

Figure 6 — 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 will be 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 Flow from supply port P to control port A

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

#### 8.1.7.2.2 Flow from control port A to return port T

Perform the test with a hydraulic test circuit conforming to the requirements of Figure 1, with valves S4, S6 and S7 open and all other valves closed.

### 8.1.7.3 Set up

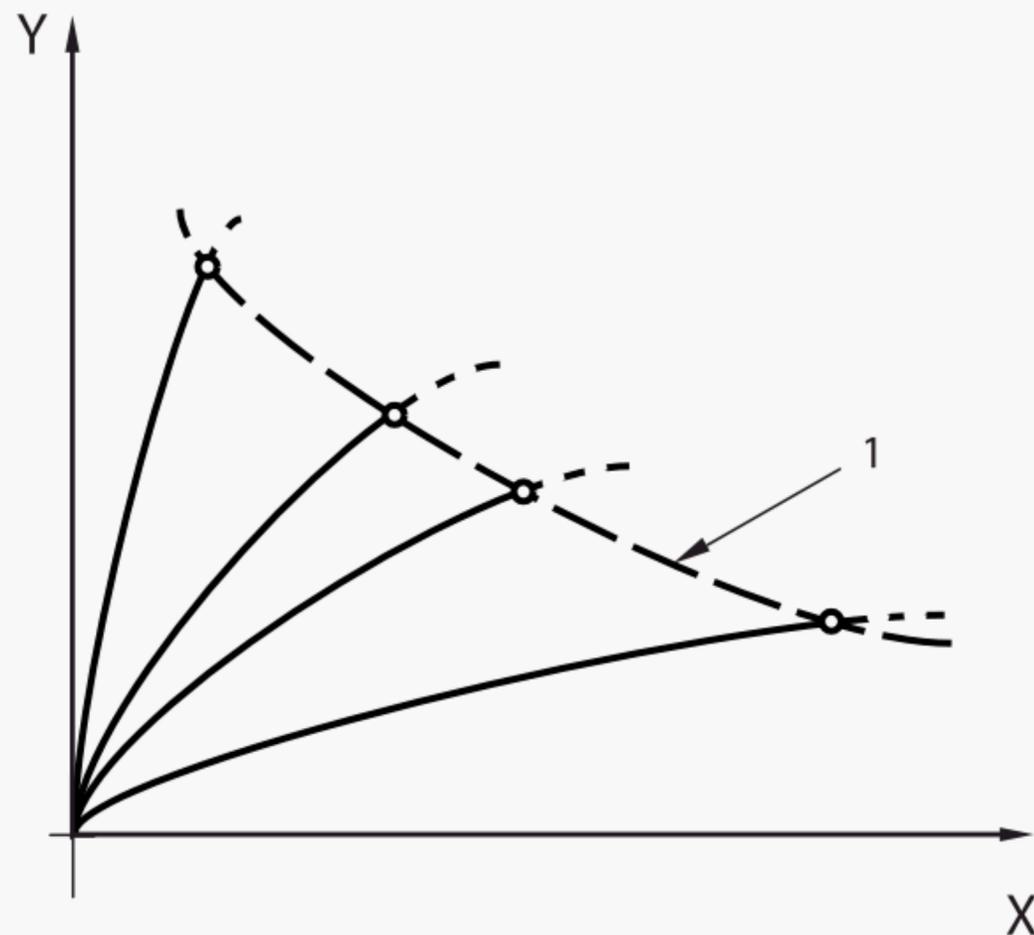
Select a suitable plotter or recording apparatus with its  $x$ -axis able to record the valve pressure drop and its  $y$ -axis able to record the zero to at least three times the rated flow (see Figure 7).

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.

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**Key**

- 1 power limit
- X valve pressure drop
- Y flow

**Figure 7 — Limiting power curve**

#### 8.1.7.4 Procedure

To carry out the test, repeat 8.1.6.4.1 and 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 7).

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

- a) superimposing on the input signal a small ( $\pm 5\%$ ) sinusoidal signal at a low frequency, typically 0,2 Hz to 0,4 Hz;
- b) slowly increasing the valve supply pressure. Note the point when the sinusoidal motion ceases, or the flow decreases suddenly.

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

**8.1.8.3 Set up**

Select a suitable plotter or recording apparatus with its *x*-axis able to record the temperature range of (20 °C to 70 °C) and its *y*-axis able to record from zero to at least the rated flow (see Figure 8).

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

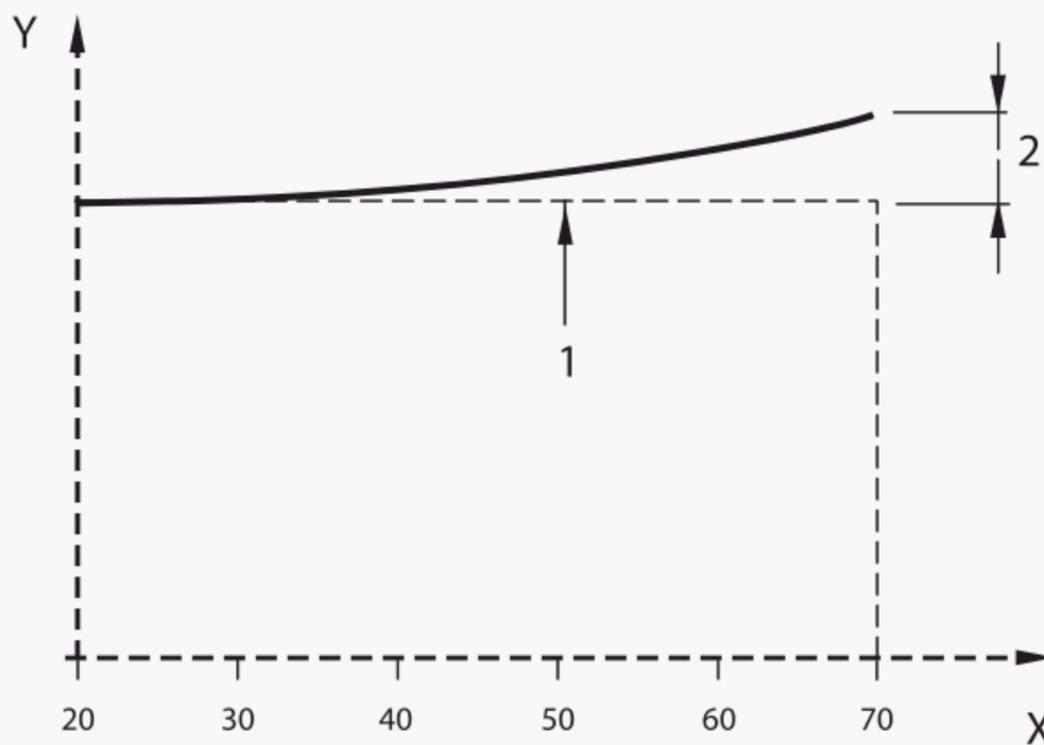
For multi-stage valves with internal pilot, adjust the P port supply to at least the minimum recommended by the manufacturer.

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 the valve pressure drop shall be maintained at its rated value.
- c) Measure and record the controlled flow and the fluid temperature (see Figure 8).
- 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 8.1.8.4 c) until the temperature reaches 70 °C.
- f) Repeat 8.1.8.4 c) to e) with the initial flow set to 50 % of the rated flow.



**Key**

- 1 flow setting
- 2 flow change
- X fluid temperature (°C)
- Y flow

**Figure 8 — 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 port A versus the input signal. This test is not relevant to valves with overlapped spools.

### 8.1.9.2 Test circuit

Perform the test with a 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

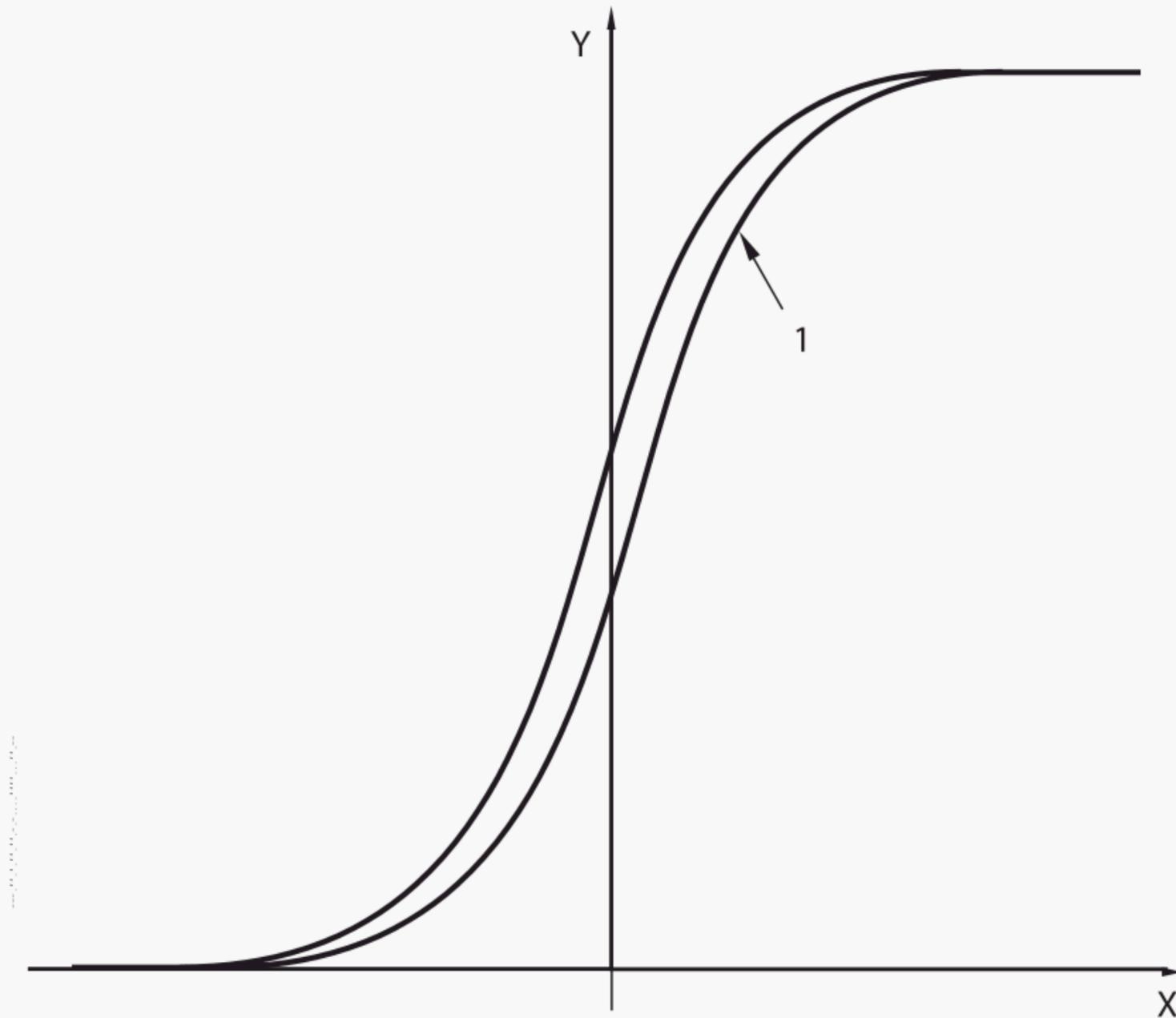
Select a suitable plotter or recording apparatus with its  $x$ -axis able to record up to  $\pm 10\%$  of the maximum input signal and its  $y$ -axis able to record from zero to 10 MPa (100 bar) (see Figure 9).

### 8.1.9.4 Procedure

Select a signal generator able to produce a triangular waveform with amplitude of  $\pm 10\%$  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 can be necessary to ensure that dynamic affects 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 and T port pressure amplitude at the A port (see Figure 9).
- c) Record the blocked port pressures at port A.
- d) Determine the pressure gain as the change in the port A pressure as a percentage of the supply pressure for a 1 % change in the input signal from null.



**Key**

- 1 port A pressure
- X input signal
- Y pressure

**Figure 9 — Blocked port A pressure 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 the pressure at port A is 50 % of the supply pressure. Record the value of the input signal.
- b) Repeat a) with supply pressure set at 20 % of the maximum allowable P port pressure.
- c) Repeat 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, loss of feedback signal.
- b) Check the performance of any special fail-safe functions incorporated in the valve by monitoring spool position.
- c) Repeat, if necessary, for various selected input signal conditions.

## 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.

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

- a) Use the output from the flow transducer 11 as the return signal. The flow transducer needs to have a band width which 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. See Figure 11 for a suitable circuit. Use of a linear actuator will not be suitable when running tests with a d.c. biased input signal. Keep the line length from port A to the flow transducer or actuator as short as possible. This method should be avoided when testing valves with significant spool overlap and/or significantly non linear flow gain. For such valves, method b) or c) should be used.
- b) In valves which are equipped with integral spool position transducers and which are not equipped with integral pressure compensated flow controllers, use the spool position signal as the return signal.
- c) In valves which are not equipped with spool position transducers, and which are not equipped with integral pressure compensated flow controllers, it will be necessary for them to be fitted 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) will not yield equivalent results. The data as reported shall therefore identify the test method used.

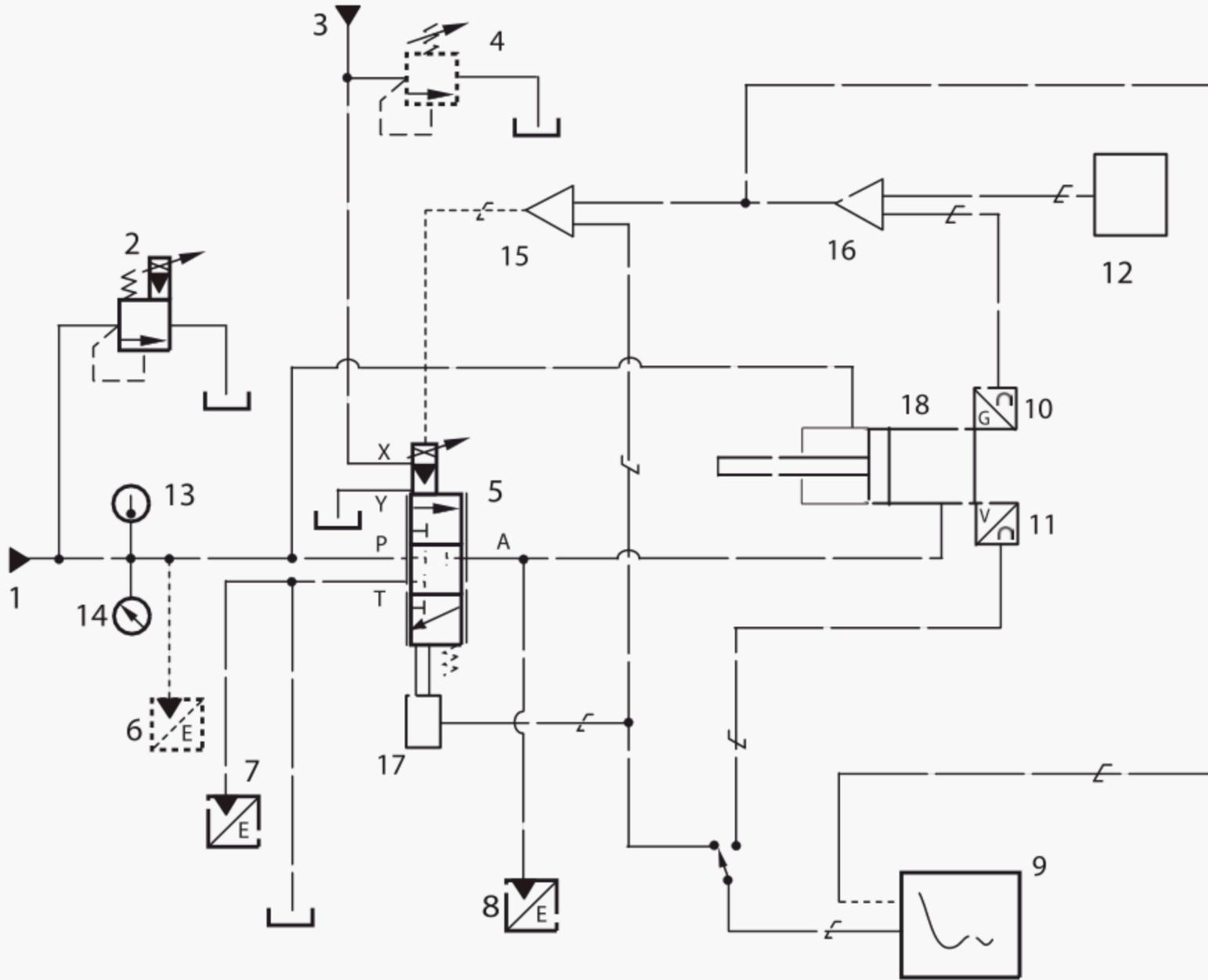
For multi-stage valves it is recommended that these tests are carried out with the valve configured for external pilot supply to obtain the most comparable data.

### 8.2.2 Test circuit

Perform the test with circuit conforming to the requirements of Figure 1 or 10.

For large valves, the requirements of Figures 1 and 10 can become impractical. In such cases, for valves with spool position feedback, close valves S3 and S7 in Figure 1, effectively blocking port A. For large valves that require a pressure at port A to operate and that have spool position feedback, a circuit conforming to the requirements of Figure 11 can be used. In both cases use the spool position signal as the return signal and the data as reported should identify the test method used.

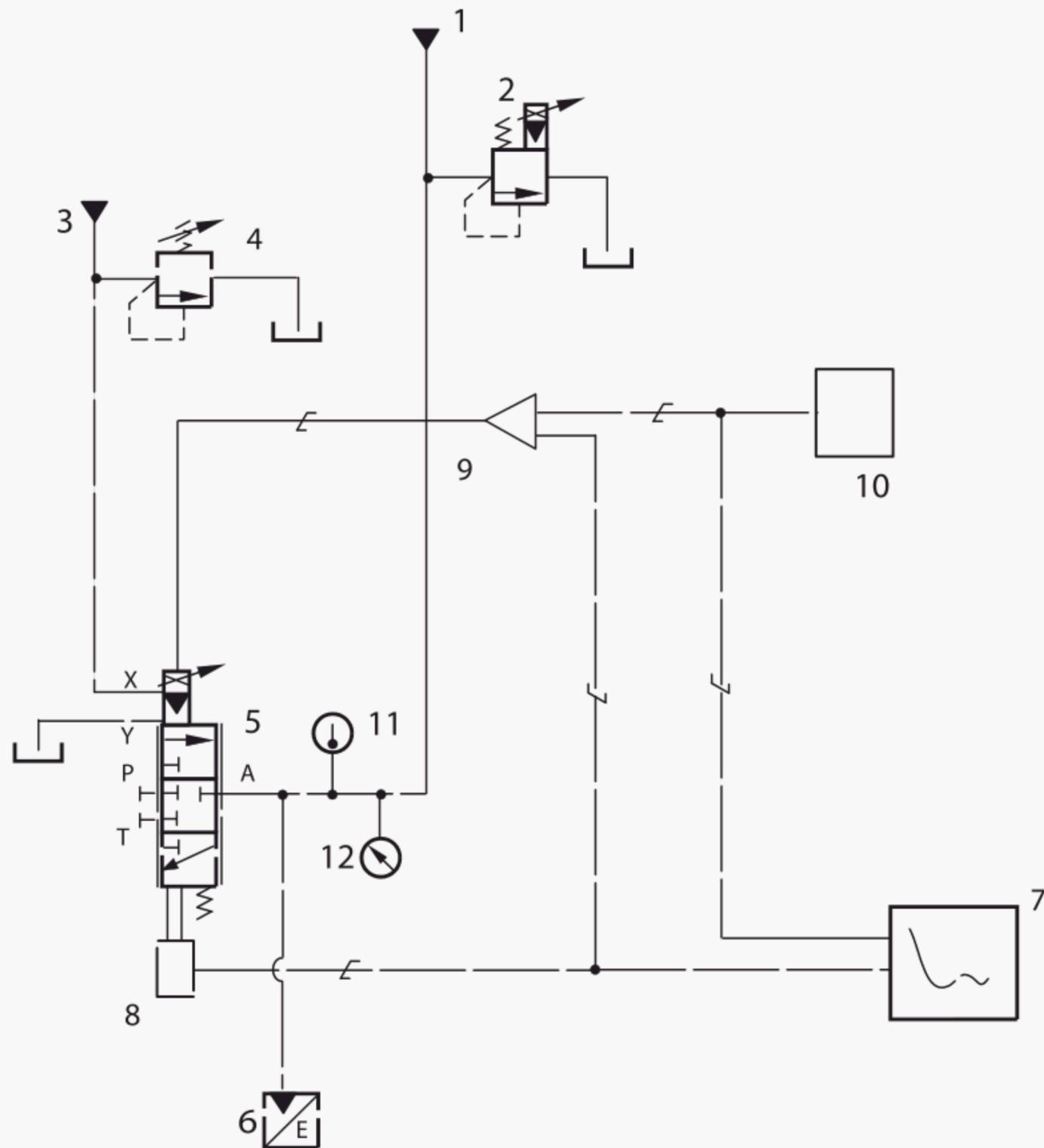
The flow source, and pipework should be sized so as to be able to maintain the valve pressure drop within  $\pm 25\%$  of the nominal setting over the frequency range tested and over the duration of the step response. The flow source can need to include an accumulator.



**Key**

- |        |                             |    |  |
|--------|-----------------------------|----|--|
| 1      | main flow source            | 14 | pressure gauge                           |
| 2      | main relief valve           | 15 | signal conditioner                       |
| 3      | external pilot flow source  | 16 | low gain cylinder position feedback      |
| 4      | external pilot relief valve | 17 | optional valve spool position transducer |
| 5      | unit under test             | 18 | low inertia cylinder                     |
| 6 to 8 | pressure transducer         | A  | working port                             |
| 9      | data acquisition            | P  | supply port                              |
| 10     | position transducer         | T  | return port                              |
| 11     | velocity transducer         | X  | pilot supply port                        |
| 12     | signal generator            | Y  | pilot drain port                         |
| 13     | temperature indicator       |    |  |

**Figure 10 — Test circuit - dynamic tests**



**Key**

- |   |                             |    |                       |
|---|-----------------------------|----|-----------------------|
| 1 | main flow source            | 10 | signal generator      |
| 2 | main relief valve           | 11 | temperature indicator |
| 3 | external pilot flow source  | 12 | pressure gauge        |
| 4 | external pilot relief valve | A  | working port          |
| 5 | unit under test             | P  | supply port           |
| 6 | pressure transducer         | T  | return port           |
| 7 | data acquisition            | X  | pilot supply port     |
| 8 | spool position transducer   | Y  | pilot drain port      |
| 9 | valve control amplifier     |    |                       |

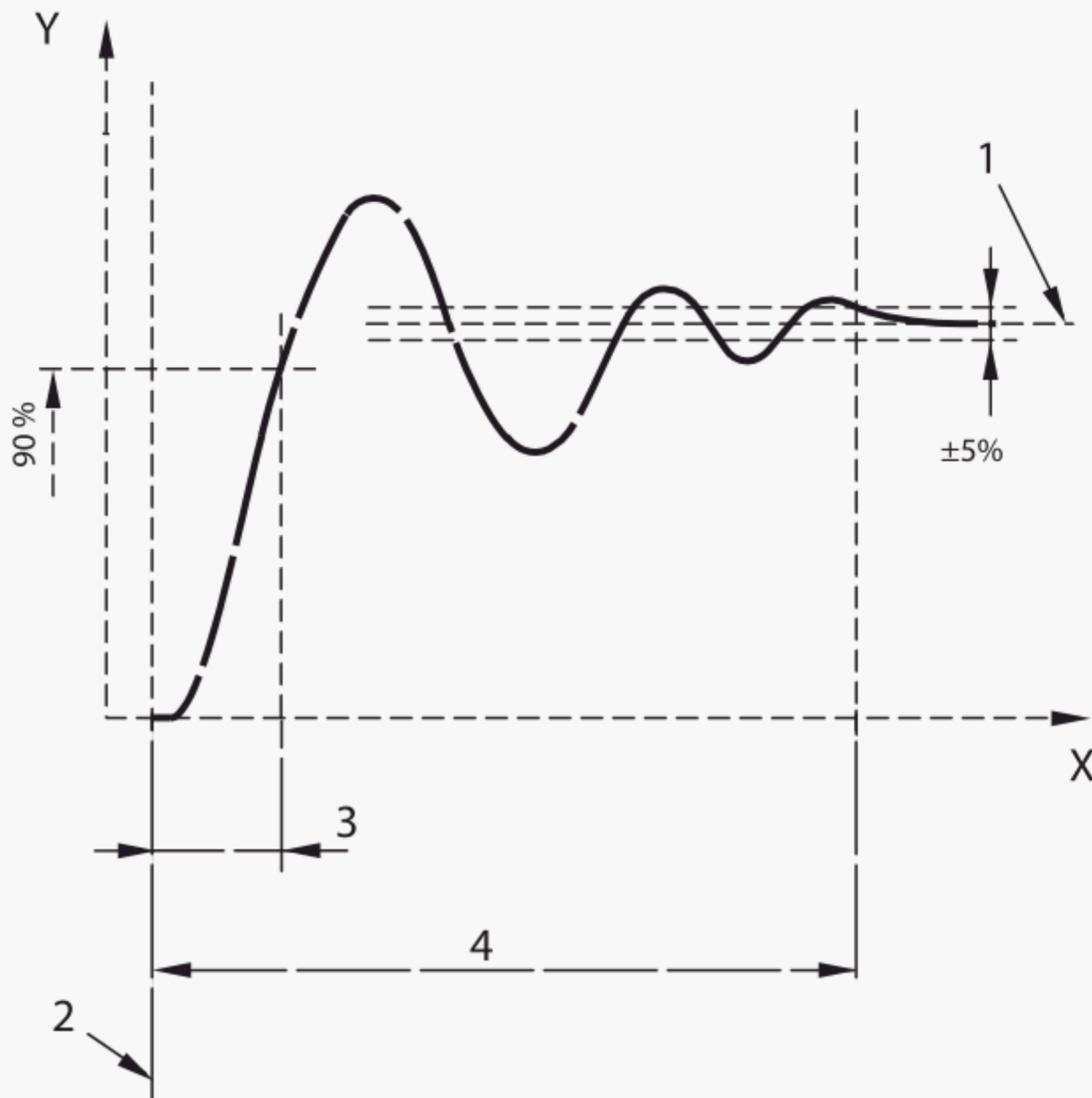
**Figure 11 — Alternative test circuit - dynamic tests**

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 return signal 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

- 1 steady-state return signal
- 2 initiation
- 3 response time
- 4 settling time
- X time
- Y return signal

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 rated pressure drop at 50 % rated flow.
- c) Set the signal generator so that the controlled flow steps between the test number 1 pair of start and finish flows given in Table 3.

Table 3 — Input step functions

Test number	Fraction 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 positive- and negative-going steps.
- 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 pair 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 the flow meter 11. The known response time of this additional valve shall be less than 30 % of the measured response time of the valve under test.

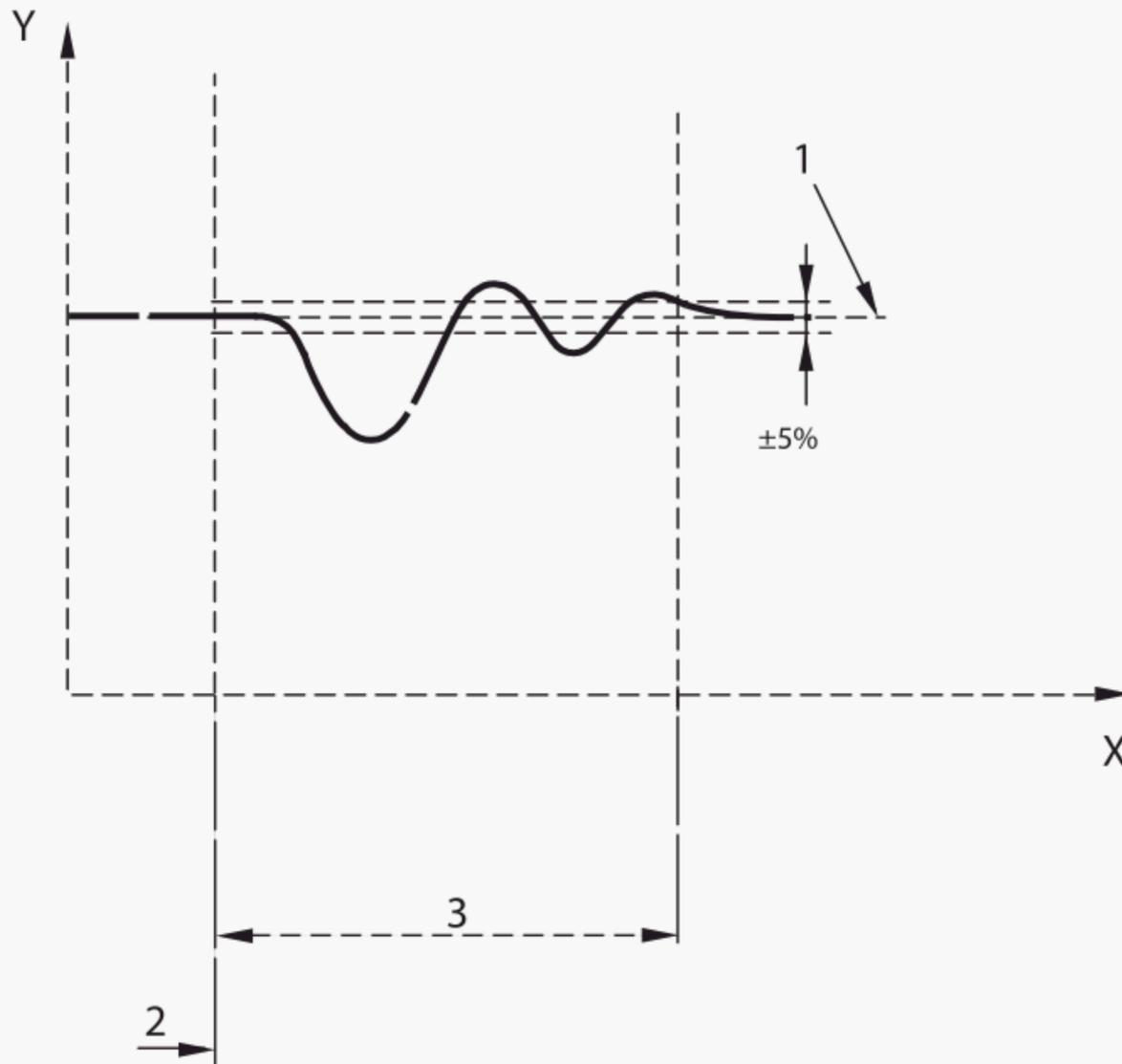
##### 8.2.4.2 Set up

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 % 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 % 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

- 1 steady-state flow
- 2 initiation
- 3 settling time
- X time
- Y flow

Figure 13 — Step response – Change in load

## 8.2.5 Frequency response

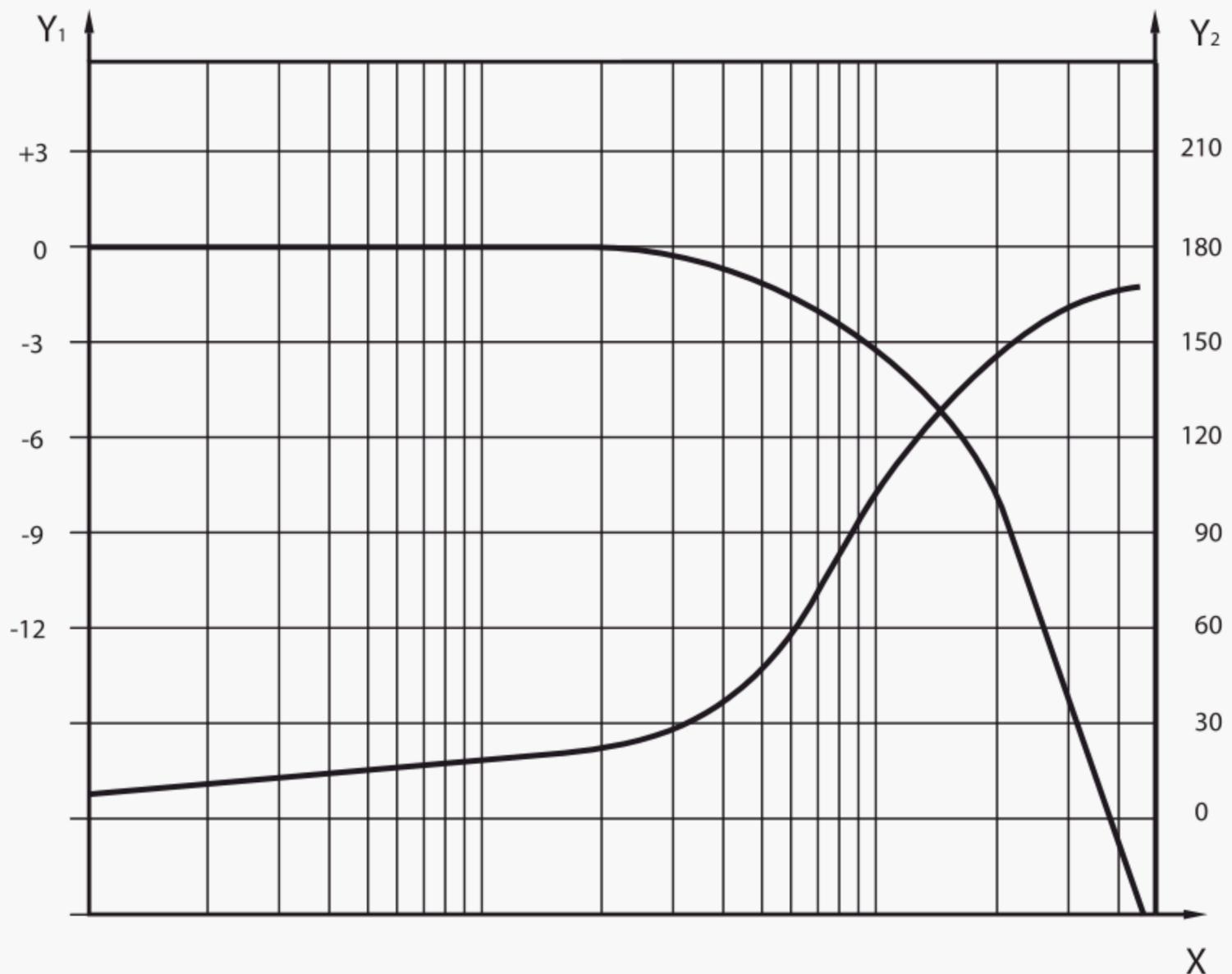
### 8.2.5.1 General

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<sub>1</sub> amplitude ratio
- Y<sub>2</sub> phase lag (degrees)

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 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  $\pm 5\%$  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 to be no more than 5 % of the frequency that results in a 90 degree phase lag; the maximum frequency to be at least that which results in a 180 degree 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 d) with 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	$\pm 50$
		$\pm 10$
		$\pm 25$
		$\pm 100$
	+50	$\pm 50$
		$\pm 10$
-50	$\pm 25$	
	$\pm 50$	
Overlapped valves	+50	$\pm 10$
		$\pm 25$
		$\pm 50$
	-50	$\pm 50$
		$\pm 10$
		$\pm 25$

## 9 Pressure impulse test

ISO 10771-1 applies.

## 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 (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.

### 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 input signal deadband characteristics (see 8.1.4.4);
- i) the pressure gain (see 8.1.9);
- j) the threshold (see 8.1.5);
- k) fail-safe function test, where applicable (see 8.1.11).

NOTE Additional tests can 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)

The following statement shall be used in test reports, catalogues and sales literature for products that conform to this part of ISO 10770:

“Tested in accordance with the methods described in ISO 10770-2, *Hydraulic fluid power — Electrically modulated hydraulic control valves — Part 2: Test methods for three-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 obscured. An automatic signal generator is useful in preventing inadvertent reversal of the signal.

For steady-state tests, the type of function (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.

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