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ISO 10770-2

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Hydraulic fluid power — Electrically modulated hydraulic control valves —

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

Transmissions hydrauliques — Distributeurs hydrauliques à modulation électrique —

Partie 2: Méthodes d'essai pour distributeurs à trois voies

Reference number
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Annexes

Foreword

ISO (the International Organisation for Standardisation) 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 organisations, 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 standardisation.

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.

International Standard ISO 10770-2 was prepared by Technical Committee ISO/TC 131, *Fluid power systems,* Subcommittee SC 8, *Product testing.*

This first edition of ISO 10770-2 together with ISO 10770-1 cancel and replace ISO 6404:1985, of which they constitute a technical revision. In particular, ISO 10770 is wider-ranging and more comprehensive, covering both servovalves and proportional valves.

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

— *Part 1: Test methods for four-way directional flow control valves*

— *Part 2: Test methods for three-way directional flow control valves*

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

Annex A forms an integral part of this part of ISO 10770. Annexes B and C are for information only.

Introduction

In hydraulic fluid power systems, power is transmitted by a fluid under pressure from a hydraulic power source to one or several loads through electrically modulated hydraulic control valves.

These control valves are components which receive control signals in the form of an electrical signal, receive hydraulic power from a power source, and then, control the direction and amount of hydraulic flow to the load, depending upon the electrical input signal. There are a number of performance characteristics that must be known in order to successfully apply electrically modulated hydraulic control valves.

Hydraulic fluid power — Electrically modulated hydraulic control valves —

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

1 Scope

This part of ISO 10770 describes methods for production acceptance and type (or qualification) testing of electrically modulated hydraulic three-way directional flow control valves.

2 Normative references

The following standards contain provisions, which, through reference in this text, constitute provisions of this part of ISO 10770. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10770 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1219-1:1991, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols.*

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

ISO 4406:1987, *Hydraulic fluid power — Fluids — Method for coding level of contamination by solid particles.*

ISO 5598:1985, *Fluid power systems and components — Vocabulary.*

ISO 6743-4:1982, *Lubricants, industrial oils and related products (class L) — Classification — Part 4: Family H (Hydraulic systems).*

IEC 617, *Graphical symbols and diagrams.*

3 Definitions

For the purposes of this part of ISO 10770, the definitions given in ISO 5598 and the following definition apply.

3.1 electrically modulated hydraulic flow control valve: Valve that provides a degree of proportional flow control in response to a continuously variable electrical input signal.

4 Symbols and units

The symbols and units for the parameters referred to in this part of ISO 10770 are listed in table 1.

Table 1 — Symbols and units

Parameter	Symbol	Unit
Coil impedance	Z	Ω
Coil inductance	L	H
Coil resistance	R	Ω
Insulation resistance	R_i	Ω
Dither amplitude	—	% of max. input signal
Dither frequency	f_d	Hz
Input signal	I or U	A or V
Rated 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 $\delta q/\delta U)$	l/min/input signal unit
Hysteresis	—	% of max. input 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 $p_A - p_T$	MPa (bar)
Rated valve pressure drop	p_N	MPa (bar)
Pressure gain	$S_v = (\delta p_A/\delta I$ or $\delta p_A/\delta U)$	MPa (bar)/input signal unit
Threshold	—	% of max. input signal
Amplitude	—	dB
Phase lag	—	degree
Temperature	—	°C
Frequency	f	Hz
Time	t	s

NOTE — 1 bar = 10^5 N/m^2 = 0,1 MPa

5 Standard test conditions

Unless otherwise specified, the standard test conditions given in table 2 shall apply to all tests described in this part of ISO 10770.

Table 2 — Standard test conditions

Ambient temperature	(20 ± 5) °C
Filtration	Solid contaminant code number to 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 capable of operating
Fluid temperature	(40 ± 6) °C at valve inlet
Viscosity grade	Grade VG 32 in accordance with ISO 3448
Supply pressure	In accordance with relevant test requirement ± 2,5 %
Return pressure	In accordance with manufacturer's recommendations
NOTE — Where an alternative hydraulic fluid is used, the fluid type and viscosity grade shall be specified.	

6 Test installation

6.1 General

A test installation shall be provided which complies with 6.2 and 6.3 and which is capable of meeting the permissible limits of error stated in annex A. General guidance on conducting the tests is given in annex B.

NOTES

1 Figures 1, 2 and 3 are typical circuits that do not incorporate all the safety devices necessary to protect against damage in the event of component failure. Other circuits which achieve the same purpose may be used. It is important that those responsible for conducting the tests give consideration to safeguarding personnel and equipment.

2 The graphical symbols used in figures 1, 2 and 3 are in accordance with ISO 1219-1 and IEC 617.

6.2 Steady state tests

A typical test circuit is shown in figure 1. This installation allows either point-to-point or continuous plotting methods for

a) recording flow as a function of input signal;

b) recording pressure as a function of input signal;

c) recording flow as a function of valve pressure drop;

d) recording flow as a function of load pressure;

e) recording flow as a function of temperature.

6.3 Dynamic tests

A typical test circuit is shown in figure 2. This installation utilizes much of the circuit shown in figure 1. This installation allows

a) frequency response tests;

b) step response tests.

7 Electrical tests

7.1 General

The tests described in 7.2 to 7.4, as appropriate, shall be carried out on all valves without integrated electronics before proceeding to subsequent tests.

7.2 Coil resistance

The test shall be performed with the coil at the specified ambient temperature. Using an electrical test instrument with an accuracy better than ± 2 % of the measured value, measure the resistance between the two leads of each coil in the valve.

NOTE — The valve under test need not be supplied with pressurized fluid during the measurement of coil resistance.

7.3 Coil inductance

7.3.1 Measure the total coil inductance (corresponding to the series coil connection for a four-lead, two-coil configuration) with the valve operating under the standard test conditions laid down in clause 5.

NOTE — This test measures the apparent inductance, which varies with signal frequency and amplitude due to the back emf (electro-motive force) generated by the moving armature. The result may be used to select the appropriate design of drive amplifier.

7.3.1.1 Connect a suitable oscillator to drive the total valve coil which is in series with a precision non-inductive resistor, as shown in figure 3 a).

7.3.1.2 Set the oscillator frequency, *f*, at either 50 Hz or 60 Hz, so that it is different from the frequency of the electrical power supply to the test equipment.

7.3.1.3 Adjust the valve input current to a peak amplitude equal to the valve rated current.

7.3.1.4 Use an oscillator which is capable of supplying undistorted current to the valve.

7.3.1.5 Using an oscilloscope, monitor the voltage waveform across the resistor R to check that the waveform is sinusoidal.

7.3.1.6 Measure the peak a.c. voltages U_R, U_T and U_V.

7.3.1.7 Construct the diagram shown in figure 3 b) to show the vectorial relationship of the voltages.

7.3.1.8 Determine the coil impedance characteristics from the following expressions:

— coil impedance, expressed in ohms

$$Z = R \frac{U_V}{U_R} \quad \dots (1)$$

— apparent inductance, expressed in henry

$$L = \frac{R}{2 \pi f} \times \frac{U_L}{U_R} \quad \dots (2)$$

7.3.2 Alternative test method: use step response to full current to give time constant t_c of coil and calculate inductance using:

$$L = R_c \times t_c \quad \text{(as indicated at figure 4)} \quad \dots (3)$$

7.4 Insulation resistance

Connect together the coil terminations and apply between them and the valve body a d.c. voltage of 500 V. Maintain this for 15 s. With this voltage still applied, use a suitable commercially available insulation tester to measure the insulation resistance. On those testers with a current readout, as opposed to a resistance readout, calculate the resistance, in ohms, from the following equation:

$$R_i = \frac{500\ \mathrm{V}}{I} \qquad \ldots (4)$$

where the current measured, I, is expressed in amperes.

This resistance normally exceeds 100 MΩ. In addition, with a four-lead two-coil configuration, similarly determine the resistance between the coils. If internal electrical components are in contact with the fluid (i.e. wet coil), fill the valve with hydraulic fluid before carrying out this test.

8 Performance tests

Conduct all the following tests such that the amplifier specified by the valve manufacturer is included in the test system (when specified).

If an external pulse width modulating amplifier is used, record the modulation frequency.

In all cases record the amplifier supply voltage.

NOTE — All performance tests should be conducted on a combination of valve and amplifier. Input signals are applied to the amplifier and not directly to the valve.

8.1 Steady state tests

8.1.1 General

When conducting these tests, care should be taken to exclude dynamic effects.

Test a) shall be performed prior to carrying out any other test.

a) Proof pressure tests, in accordance with 8.1.2.

b) Internal leakage test, in accordance with 8.1.3.

c) Test for output flow versus input signal at constant valve pressure drop, in accordance with 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 in accordance with 8.1.6.

e) Limiting output flow versus valve pressure drop in accordance with 8.1.7.

f) Output flow versus fluid temperature in accordance with 8.1.8.

g) Load pressure versus input signal in accordance with 8.1.9.

h) Fail-safe function test in accordance with 8.1.10.

8.1.2 Proof pressure tests

8.1.2.1 General

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

A simplified high pressure test rig may be used for these tests in place of that shown in figure 1.

8.1.2.2 Supply proof pressure

In the test, a proof pressure is supplied to the pressure and control port of the valve with the return port open. The test shall be carried out as follows.

8.1.2.2.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves f and i open and all the other valves closed.

8.1.2.2.2 Set up

Adjust the valve supply pressure to achieve 1,3 times the rated supply pressure or 35 MPa (350 bar), whichever is the lower.

8.1.2.2.3 Procedure

Maintain the supply pressure for a minimum of 30 s.

Apply the maximum positive input signal.

Examine the valve for evidence of external leakage or permanent deformation during the test.

8.1.2.3 Return proof pressure

In the test, a proof pressure is supplied to the pressure port, control port and the return port of the valve. The test shall be carried out as follows.

8.1.2.3.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves c, d, and g open and all other valves closed.

8.1.2.3.2 Set up

Adjust the valve supply pressure to achieve 1,3 times the rated return port pressure.

8.1.2.3.3 Procedure

Maintain this pressure for a minimum of 30 s.

Apply the maximum negative input signal.

There shall be no external leakage or permanent deformation during the test.

8.1.3 Internal leakage test (control port blocked)

8.1.3.1 General

Before commencing the test, any mechanical/electrical adjustments necessary shall be made, such as nulling the valve, and then the test shall be carried out to determine the total internal leakage, including any pilot control flow, in the following manner.

8.1.3.2 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valve f open and all other valves closed.

8.1.3.3 Set up

Adjust the valve supply pressures to 10 MPa (100 bar) above return pressure, and pilot pressure where applicable.

8.1.3.4 Procedure

Proceed as follows:

a) Immediately before the leakage measurements are to be taken, operate the valve over its full input signal range several times.

b) Record the leakage flow from the T and y ports over a range from maximum positive to maximum negative input signal (see figure 5).

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

8.1.4 Output flow versus input signal characteristics at constant valve pressure drop (open control port)

8.1.4.1 General

The test shall be carried out to obtain the flow versus input signal curve and to deduce the steady-state valve characteristics.

8.1.4.2 Test circuit

For multi-stage valves with integral pilot supply, use an appropriate modified circuit configuration, for example incorporating either:

a) a pressure compensator inserted between the valve and the test manifold, or

b) using a loading valve as shown in figure 1, to load the valve under test, which operates under open or closed loop conditions, to maintain constant valve pressure drop.

8.1.4.3 Set up

8.1.4.3.1 Set the total valve pressure drop to 1 MPa (10 bar), 7 MPa (70 bar) or 1/3 of the maximum supply pressure, as appropriate.

8.1.4.3.2 For multi-stage valves with separate pilot supply adjust the pilot supply pressure to 10 MPa (100 bar).

8.1.4.3.3 For multi-stage valves with integral pilot supply, adjust the supply pressure to 10 MPa (100 bar), unless otherwise specified by the manufacturer.

8.1.4.4 Flow from supply port P to control port A

8.1.4.4.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, b, d, f, i open and all other valves closed.

8.1.4.4.2 Procedure

Proceed as follows:

a) Cycle the input signal several times.

b) Using a continuous plotting/recording method, establish a suitable range using the X-axis to record the input signal and the Y-axis to record the output flow.

c) Set the automatic signal generator to produce a triangular waveform with an amplitude to reach null and maximum positive input signal.

d) Allow the input signal to be continuously cycled, ensuring that the pen motion is unrestricted and that it is moving at such speed that the dynamic effects of the flow transducer and its output signal and recorder are negligible. When an X-Y plotter or recorder is used, automatic control of valve pressure drop will be necessary. Also ensure that the valve pressure drop remains constant within 5 % during the complete signal cycle.

e) With the continuously varying signal still applied, continuously record the characteristics over one complete signal cycle (see figure 6) to determine the following characteristics for the flow direction from supply port P to control port A:

   1) output flow at rated positive signal;

   2) flow gain;

   3) linearity;

   4) hysteresis;

   5) null zone characteristics (i.e. spool lap condition).

The above tests may, if required, be repeated at additional pressures up to the rated pressure of the valve under test.

8.1.4.5 Flow from control port A to return port T

8.1.4.5.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, d, e, h, and i, open and all other valves closed.

8.1.4.5.2 Procedure

Proceed as follows:

a) Cycle the input signal several times.

b) Using a continuous plotting/recording method, establish a suitable range using the X-axis to record the input signal and the Y-axis to record the output flow.

c) Set the automatic signal generator to produce a triangular waveform with an amplitude to reach null and maximum negative input signal.

d) Allow the input signal to be continuously cycled, ensuring that the pen motion is unrestricted and that it is moving at such speed that the dynamic effects of the flow transducer and its output signal and recorder are negligible. When an X-Y plotter or recorder is used automatic control of valve pressure drop will be necessary. Also ensure that the valve pressure drop remains constant within 5 % during the complete signal cycle.

e) With the continuously varying signal still applied, continuously record the characteristics over one complete signal cycle (see figure 6) to determine the following characteristics for the flow direction from control port A to return port T:

   1) output flow at rated negative signal;

   2) flow gain;

   3) linearity;

   4) hysteresis;

   5) null zone characteristics (i.e. spool lap condition);

   6) symmetry in reference to 8.1.4.4.2 e) 1).

The above tests may, if required, be repeated at additional pressures up to the rated pressure of the valve under test.

In cases where it is impracticable to monitor output flow, spool position can be monitored as an alternative to flow in order to establish

— spool position at rated signal;

— hysteresis;

— polarity.

8.1.5 Threshold

8.1.5.1 General

The test shall be carried out to obtain the response of the valve versus a reverse input signal.

8.1.5.2 Set up

Repeat the set up described in 8.1.4.3.1, 8.1.4.3.2 and 8.1.4.3.3.

8.1.5.3 Flow from supply port P to control port A

8.1.5.3.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, b, d, f and i open and all other valves closed.

8.1.5.3.2 Procedure

Repeat the procedure 8.1.4.4.2 a) and b) and then proceed as follows:

a) apply a positive signal causing 25 % of the rated flow (P to A) and then reduce the applied signal to cause a reduction of flow. Reduce the signal slowly to eliminate dynamic effects;

b) record the input signal at which the flow starts to decrease;

c) measure the threshold by computing the incremental signal change from the algebraic difference of the two signal values recorded;

d) repeat steps a) to c) at 75 % of the rated flow;

f) repeat a similar test about null when testing zero and under-lapped valves.

NOTE — When conducting these tests, the sensitivity of the recorder may require adjusting. See figure 7 for a representative recording plot, an alternative signal level may be used for a production acceptance test.

8.1.5.4 Flow from control port A to return port T

8.1.5.4.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, d, e, h and i open and all other valves closed.

8.1.5.4.2 Procedure

Repeat the procedure 8.1.4.4.2 a) and b) and then proceed as follows:

a) apply a negative signal causing 25 % of the rated flow (A to T) and then reduce the applied signal to cause a reduction of flow. Reduce the signal slowly to eliminate dynamic effects;

b) record the input signal at which the flow starts to decrease;

c) measure the threshold by computing the incremental signal change from the algebraic difference of the two signal values recorded;

d) repeat steps a) to c) at 75 % of the rated flow;

e) repeat a similar test about null when testing zero and under-lapped valves.

NOTE — When conducting these tests the sensitivity of the recorder may require adjusting. See figure 7 for a representative recording plot, an alternative signal level may be used for a production acceptance test.

8.1.6 Output flow versus valve pressure drop tests (open control port)

8.1.6.1 General

Carry out the following steps to determine the nature of the variation of output flow versus valve pressure drop.

8.1.6.2 Set up

Adjust the valve supply pressure to achieve rated pressure, compensating for any return pressure, if necessary. Ensure that the set supply pressure remains constant throughout the test. A drop of supply pressure indicates insufficient flow capacity of the hydraulic power source.

8.1.6.3 Flow from supply port P to control port A

8.1.6.3.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, b, d, f and i and loading valve 13 open and all other valves closed.

8.1.6.3.2 Procedure

Proceed as follows:

a) Cycle the input signal gradually several times over the range null to maximum positive.

b) Establish an X-Y plotter configuration to record output flow on the Y-axis and valve pressure drop ($p_P - p_A$) on the X-axis (see figure 8).

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

d) Close the loading valve 13, lower the plotter pen and slowly open the loading valve 13 (see figure 1) to obtain a continuous plot of output flow versus valve pressure drop for a rated positive input signal.

e) Repeat steps c) and d) over the range of 75 %, 50 %, and 25 % of rated input signal (see figure 8).

f) For valves with integral pressure compensation, carry out the above tests to determine the effectiveness of the load compensating device and record the results in the manner shown in figure 9.

8.1.6.4 Flow from control port A to return port T

8.1.6.4.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, d, e, h and i and loading valve 13 open and all other valves closed.

8.1.6.4.2 Procedure

Proceed as follows:

a) Cycle the input signal gradually several times over the range null to maximum negative.

b) Establish an X-Y plotter configuration to record output flow on the Y-axis and valve pressure drop ($p_A - p_T$) on the X-axis (see figure 8).

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

d) Close the loading valve 13, lower the plotter pen and slowly open the loading valve 13 (see figure 1) to obtain a continuous plot of output flow versus valve pressure drop for a rated negative input signal.

e) Repeat c) and d) over the range of 75 %, 50 % and 25 % of the rated input signal (see figure 8).

f) For valves with integral pressure compensation, carry out the above tests to determine the effectiveness of the load compensating device and record the results in the manner shown in figure 9.

8.1.7 Limiting power test (open control port)

8.1.7.1 General

Single stage valve performance is extremely limited by flow forces. To determine these effects the following test shall be carried out.

8.1.7.2 Set up

Adjust the supply pressure to achieve, for example, 10 % of the rated pressure.

8.1.7.3 Flow from supply port P to control port A

8.1.7.3.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, b, d, f and i open and all other valves closed.

8.1.7.3.2 Procedure

Establish an X-Y plotter configuration to record output flow on the Y-axis and valve pressure drop ($p_P - p_A$) on the X-axis to get a continuous plot of output flow versus valve pressure drop.

a) Set the input signal to its positive 95 % value plus a superimposed small (± 5 %) sinusoidal signal at a low frequency, typically 0,2 Hz to 0,4 Hz.

b) Lower the plotter pen.

c) Increase the supply pressure slowly to get a flow versus pressure drop curve see figure 10. Stop increasing supply pressure when the sinusoidal motion ceases or flow decreases suddenly. Mark this point.

d) Repeat this procedure for other positive input signal amplitudes, e.g. 75 %, 50 % and 25 % of the rated flow.

e) Connect the zero slope points of the curves by a line to obtain the limiting power curve (see figure 10).

8.1.7.4 Flow from control port A to return port T

8.1.7.4.1 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, e, f, i, j open and all other valves closed.

8.1.7.4.2 Procedure

Establish an X-Y plotter configuration to record output flow on the Y-axis and valve pressure drop ($p_A - p_T$) on the X-axis to get a continuous plot of output flow versus valve pressure drop.

a) Set the input signal to its negative 95 % value plus a superimposed small (± 5 %) sinusoidal signal at a low frequency, typically 0,2 Hz to 0,4 Hz.

b) Lower the plotter pen.

c) Increase the supply pressure slowly to get a flow versus pressure drop curve see figure 10. Stop increasing supply pressure when the sinusoidal motion ceases or flow decreases suddenly. Mark this point.

d) Repeat this procedure for other negative input signal amplitudes, e.g. 75 %, 50 % and 25 % of the rated flow.

e) Connect the zero slope points of the curves by a line to obtain the limiting power curve (see figure 10).

8.1.8 Output flow or spool position versus fluid temperature test (open control port)

8.1.8.1 General

The following test shall be carried out to determine the nature of the variation of output flow versus fluid temperature. The valve and amplifier should be exposed to a constant ambient temperature of 20 °C.

8.1.8.2 Test circuit

Set up the hydraulic test circuit shown in figure 1, with valves a, b, d, f and i open and all other valves closed.

8.1.8.3 Set up

Repeat the set up described in 8.1.4.3.

8.1.8.4 Procedure

Proceed as follows:

a) Using a continuous plotting/recording method, establish a suitable range using the X-axis to record the oil temperature and the Y-axis to record the output flow and/or spool position (see figure 11).

b) Apply a positive input signal corresponding to 10 % of the rated output flow.

c) Record output flow or spool position versus fluid temperature (see figure 11).

d) The above tests may, if required, be repeated for different input signals and valve pressure drops.

e) Compile a family of curves for various input signals and valve pressure drops over the selected temperature range.

8.1.9 Pressure gain versus input signal test (blocked control port)

8.1.9.1 General

The objective of this test is to determine the pressure gain of the control port A versus the input signal.

8.1.9.2 Test circuit

Set up the hydraulic test circuit shown in figure 1 with valves f and i open and all other valves closed.

8.1.9.3 Set up

Adjust the supply pressure to the valve rated pressure.

8.1.9.4 Procedure

Proceed as follows:

a) Select the input signal so that the spool passes through the valve centre with sufficient travel to effectively reach supply pressure amplitude at the control port.

b) Using a continuous plotting/recording method to establish suitable ranges and deflections.

c) Slowly vary the input signal over the range established in a) while recording the blocked port pressure at port A.

NOTE — Since this test is affected by the valve leakage characteristics and the volume of fluid under pressure it may require several minutes to make one sweep.

d) Produce a graph of the pressure at port A versus input signal (see figure 12).

8.1.10 Fail-safe function test

Proceed 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 (open control port)

8.2.1 Test circuit and set up

8.2.1.1 Set up the test circuit similar to that shown in figure 2.

8.2.1.2 Keep line length from port A to the actuator as short as possible.

8.2.1.3 Keep the accumulator as close to the valve P port as possible.

8.2.1.4 Provide constant hydraulic pressure at 10 MPa (100 bar), or rated pressure whichever is the lower and measure the maximum output flow.

8.2.1.5 For frequency response tests, use a frequency response analyzer, oscilloscope or other suitable electronic equipment that will measure the amplitude of the output signal as well as its phase shift relative to the input signal. For step response tests, use an oscilloscope or other suitable electronic equipment to record output signal versus time.

8.2.1.6 Obtain the output signal by one of the following methods:

a) Use the output from a velocity transducer driven by a low friction [having a pressure drop not exceeding 0,3 MPa (3 bar)] low inertia actuator (having a band width which is at least three times greater than the maximum test frequency including the effects of trapped fluid volume) as the output signal. When this method is not practicable, use method b) or c).

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 output 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 an external spool position transducer and appropriate signal conditioning electronics. Use that signal as the output 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.

8.2.2 Frequency response — Test procedure

8.2.2.1 Apply the input signal at a frequency of 5 Hz or 5 % of the frequency at which the phase lag is 90°, whichever is the lower, and then plot amplitude and phase lag over a range of frequencies wide enough to cover 15 dB attenuation (see figure 13). Include frequencies corresponding to 45°, 90° and higher phase lags, as required.

8.2.2.2 Test the valve under all of the following sinusoidal input conditions:

a) Use a centred input signal, such that the output flow alternates about zero through port A, of amplitude sufficient to cause a peak output flow of approximately ± 5 % of the maximum steady state output. For overlapped valves, conduct this test with the dead-band eliminator activated.

b) For overlapped valves without dead-band eliminator, use a biased input signal, in which the d.c. bias and input signal are adjusted so that the flow output is always in one direction only, i.e., the spool cycles totally on one side of centre. Replace the linear actuator with a flow sensor of adequate bandwidth. Use a small signal, i.e. an input signal amplitude which, at or sufficiently near 0 Hz, causes a change in output signal from approximately 5 % to 15 % of maximum steady output signal at that supply pressure. Repeat in the opposite direction.

c) Repeat the tests in a) or b) under the conditions shown in table 3.

Table 3 — Sinusoidal signal function

Test procedure	**d.c. bias signal** % of flow	**Superimposed sinusoidal input** % of rated flow or maximum spool displacement
8.2.2.2 a)	0 0 0 0 0	± 5 ± 10 ± 25 ± 50 ± 75
8.2.2.2 b)	+ 50	± 5 ± 10 ± 25
	– 50	± 5 ± 10 ± 25

Maintain the amplitude of the sinusoidal input signal constant throughout each complete sweep.

8.2.3 Step response — Test procedures

8.2.3.1 Transient response to step input signal demand

Test the valve in response to a step input signal demand under the following conditions:

Trigger the step function generator and the recording instrument to provide dynamic traces of the input and monitored valve output signal for each of the step conditions selected from table 4. See figure 14 a). Clearly identify each trace with the appropriate data.

Table 4 — Input step functions

Starting condition % of rated flow	**Ending condition** % of rated flow
0	+ 10
0	– 10
0	+ 25
0	– 25
0	+ 50
0	– 50
0	+ 75
0	– 75
0	+ 90
0	– 90
+ 10	0
– 10	0
+ 25	0
– 25	0
+ 50	0
– 50	0
+ 75	0
– 75	0
+ 90	0
– 90	0
– 10	+ 10
– 25	+ 25
– 50	+ 50
– 90	+ 90
+ 25	+ 75
+ 75	+ 25

8.2.3.2 Response to load changes (valves with load pressure compensation)

Record the flow response for step changes of load pressure of 0 % to 50 % and 50 % to 90 % of the specified maximum load pressure at a signal amplitude of 50 % rated input [and other signal amplitudes if required; see figure 14 b)].

9 Endurance test

9.1 General

Endurance tests shall be carried out at a supply pressure equal to the maximum supply pressure of the valve and with the control port blocked.

9.2 Test procedure

9.2.1 Apply the supply pressure to the valve and cycle the electrical input signal sinusoidally from one polarity maximum to the reverse polarity maximum. Select the frequency of the electrical input signal such that the pressure in the blocked port rises to at least 90 % of the supply pressure at the crest of each cycle. Continue the test for a duration of not less than 10×10^6 cycles.

9.2.2 After completion of the endurance test, subject the valve to a production acceptance test to ascertain the degree of performance degradation.

9.2.3 Record the total number of cycles and the degree of performance degradation.

10 Pressure impulse test

10.1 For a minimum duration of 10×10^6 cycles, apply pressure impulses to the supply port of the valve according to its intended fatigue pressure rating with the control port blocked using the following test conditions.

a) Range the amplitude of the pressure impulse between the return pressure [but not more than 0,35 MPa (3,5 bar)] and (100 ± 5) % of the supply pressure, taking care to limit the rate of pressure rise to avoid overshoots and cavitation. Maintain the supply pressure for at least 50 % of each cycle time.

b) Apply the rated input at the positive polarity required for half of the test duration and at a negative polarity for the remainder of the test.

10.2 After completion of the pressure impulse test, subject the valve to the steady state test (see 8.1) to ascertain the degree of performance degradation.

10.3 Record the number of cycles and the degree of performance degradation.

11 Environmental tests

This part of ISO 10770 specifies that testing shall be carried out under the standard test conditions specified in clause 5. However, due to the increasing use of hydraulic equipment in applications operating under severe environmental conditions it may be necessary to conduct other tests to establish behaviour under various environmental conditions. In such cases the requirements for environmental testing should be agreed on between the supplier and the purchaser.

Environmental testing may take account of

a) the range of ambient temperature;

b) the range of fluid temperature;

c) vibration;

d) shock;

e) acceleration;

f) explosion resistance;

g) fire resistance;

h) corrosion resistance;

i) vacuum;

j) environmental pressure;

k) tropical exposure;

l) water immersion;

m) humidity;

n) electrical susceptibility;

o) airborne dust and dirt;

p) EMC (electromagnetic compatibility);

q) contamination sensitivity.

12 Presentation of results

12.1 General

The results obtained from testing a valve shall be presented either

a) in tabular form; or

b) for convenience in graphical form, where applicable.

NOTE — Since the scope of testing, particularly with regard to different system pressures and input signal levels, will depend on whether the testing is for development work, production or specific customer information, not all of the parameters which describe valve performance will necessarily be provided with each valve.

12.2 Test reports

12.2.1 All test reports

All test reports shall contain the following data:

a) the manufacturer;

b) the valve type and serial number where applicable;

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

d) the rated flow at rated valve pressure drop;

e) the valve pressure drop;

f) the supply pressure;

g) the return pressure;

h) the fluid type;

i) the fluid temperature;

j) the fluid viscosity according to ISO 3448;

k) the rated input signal;

l) the coil connection where applicable (i.e. series, parallel, etc.);

m) the dither waveform, amplitude and frequency, if used;

n) the relevant polarity;

o) the allowable test limits for each test parameter;

p) the date of test;

q) the name of test operator.

12.2.2 Test reports for production acceptance tests

These reports shall include the following information:

a) the insulation test (see 7.4);

b) the supply proof pressure (see 8.1.2.2);

c) the return proof pressure (see 8.1.2.3);

d) the maximum internal leakage (see 8.1.3);

e) the output flow versus input signal (see 8.1.4);

f) the polarity from the output flow versus input signal curve (see 8.1.4.5);

g) the hysteresis from the output flow versus input signal curve (see 8.1.4.5);

h) the flow gain K_V and the pressure used in determining the gain (see 8.1.4.5);

i) the flow linearity (see 8.1.4.5);

j) the null zone characteristics (see 8.1.4.5);

k) the pressure gain (see 8.1.9);

l) the threshold (see 8.1.5);

m) fail-safe function test where applicable (see 8.1.10).

NOTE — Additional tests can include: null shift with supply pressure (two or more datum points), and symmetry.

12.2.3 Test reports for type test

These reports shall include the following information:

a) the production acceptance test data (see 12.2.2);

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) the output flow versus pressure drop data (see 8.1.6);

g) the endurance test results (see clause 9);

h) the pressure impulse test results (see clause 10);

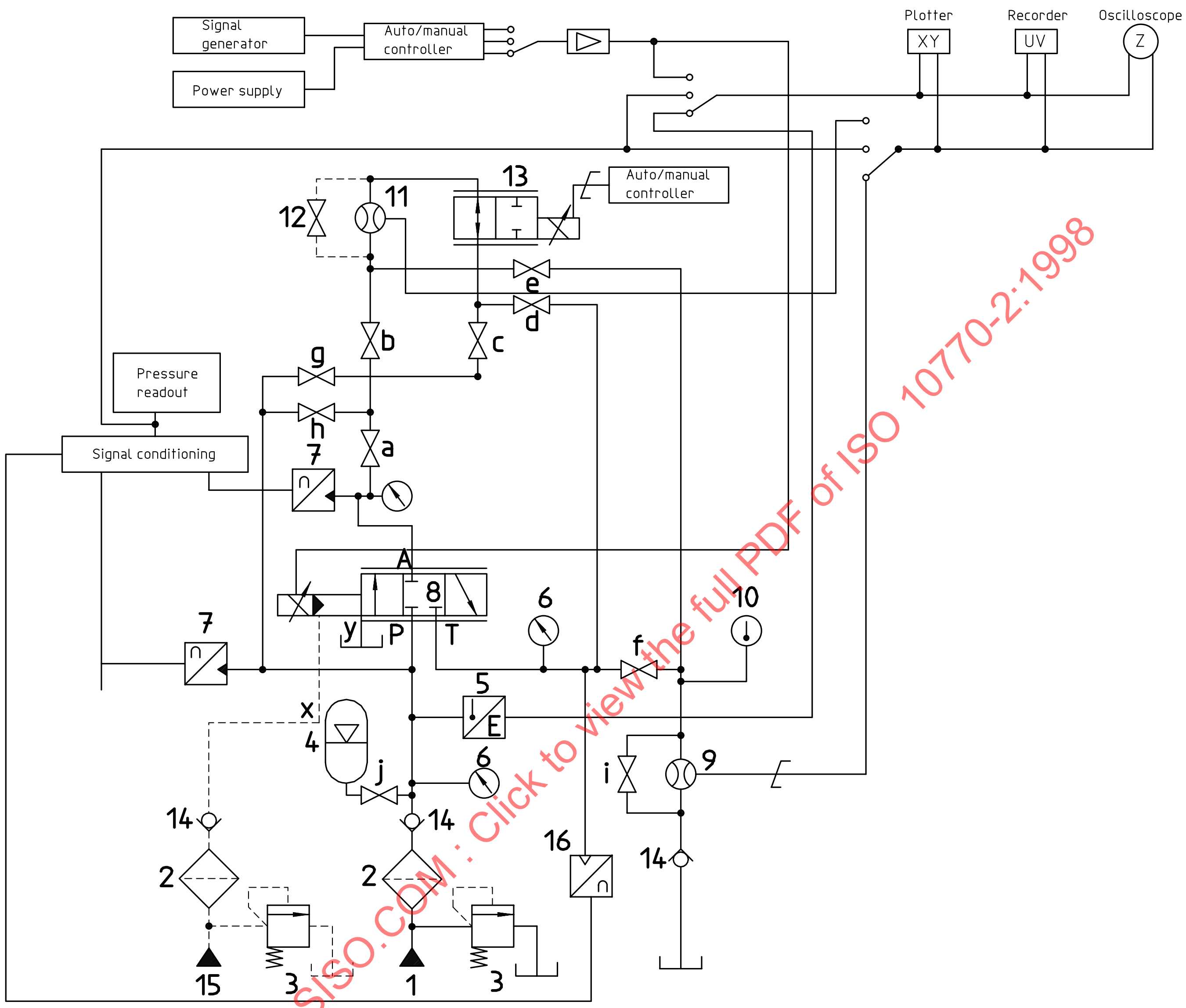
i) the environmental test results (see clause 11);

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

13 Identification statement

It is strongly recommended that manufacturers use the following statement in test reports, catalogues and sales literature when electing to comply with this part of ISO 10770.

"Tested in accordance with the methods described in IS0 10770-2:1998, *Hydraulic fluid power — Electrically modulated hydraulic control valves — Part 2: Test methods for three-way directional flow control valves*."

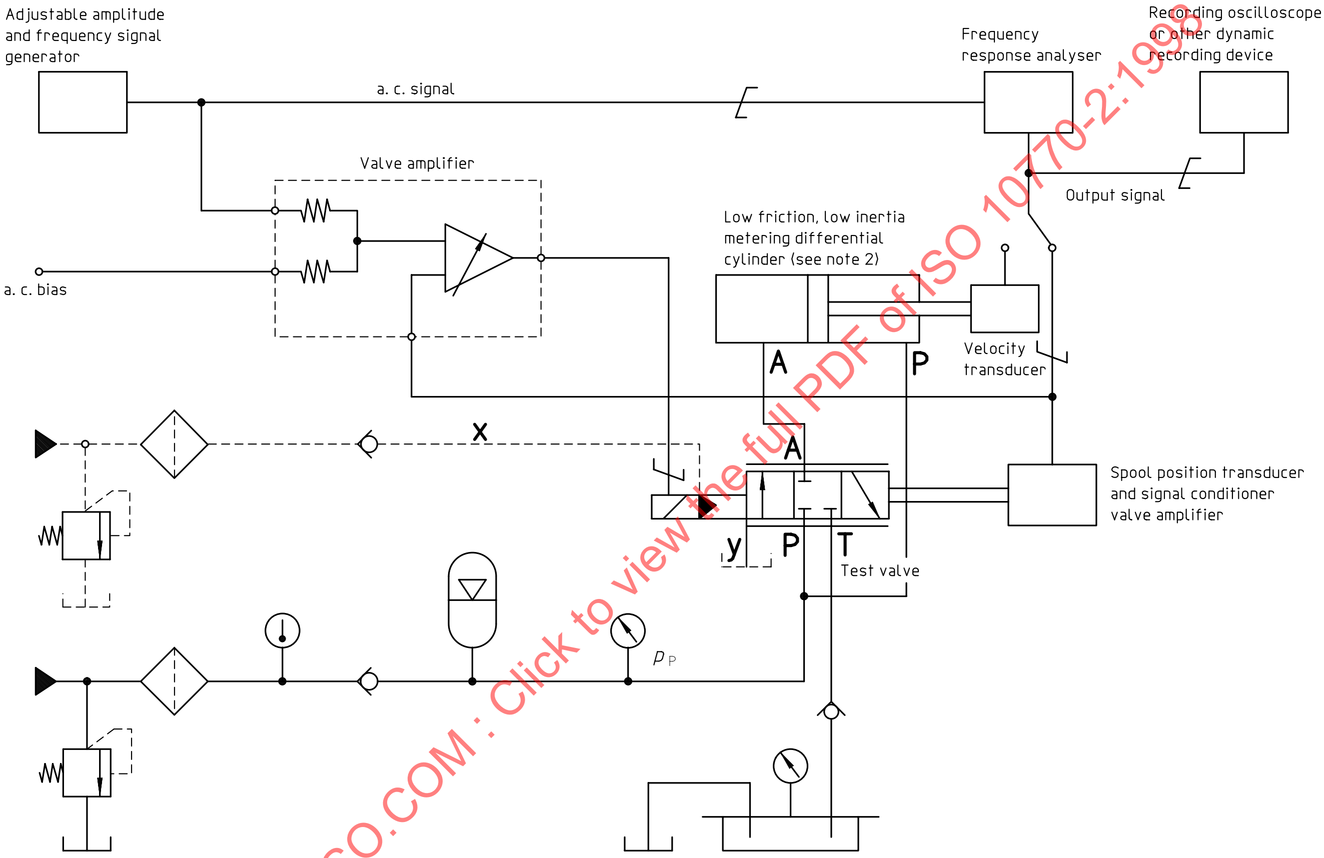


Key

1 Hydraulic power source
2 Filter
3 Pressure relief valve
4 Accumulator
5 Temperature sensor
6 Pressure gauge
7 Pressure transducer or differential pressure transducer
8 Valve under test
  P: Supply port
  T: Return port
  A: Control port
  x and y: Pilot ports
9 Leakage flow transducer
10 Temperature indicator
11 Flow transducer
12 Optional by pass
13 Loading valve
14 Non-return valve
15 Hydraulic pilot power source
16 Electrical pressure transducer

a to j: Positive shut-off valves

Figure 1 — Typical steady-state test circuit

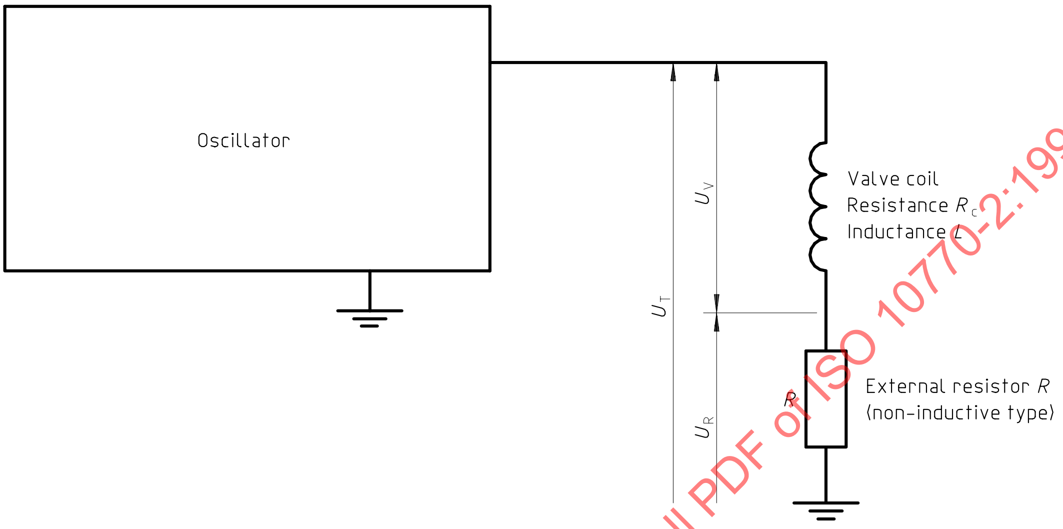


NOTES

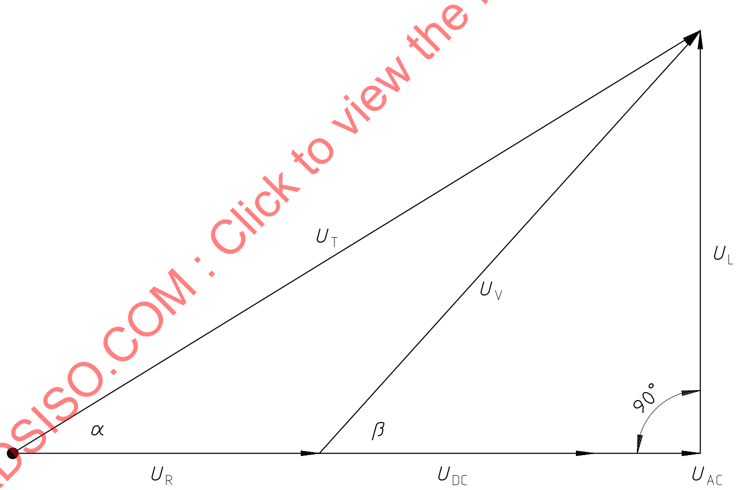
1 Shut-off valves are not shown on this circuit diagram.

2 It may be necessary to incorporate a low gain position feedback loop to correct for drift of the metering cylinder.

Figure 2 — Typical dynamic test circuit



a) Inductance test



Where
U_L is the voltage drop due to valve apparent coil inductance;
U_{DC} is the voltage drop due to coil resistance;
U_{AC} is the additional in phase voltage drop associated with back e.m.f. effects.

b) Voltage vector diagram

Figure 3 — Valve coil inductance

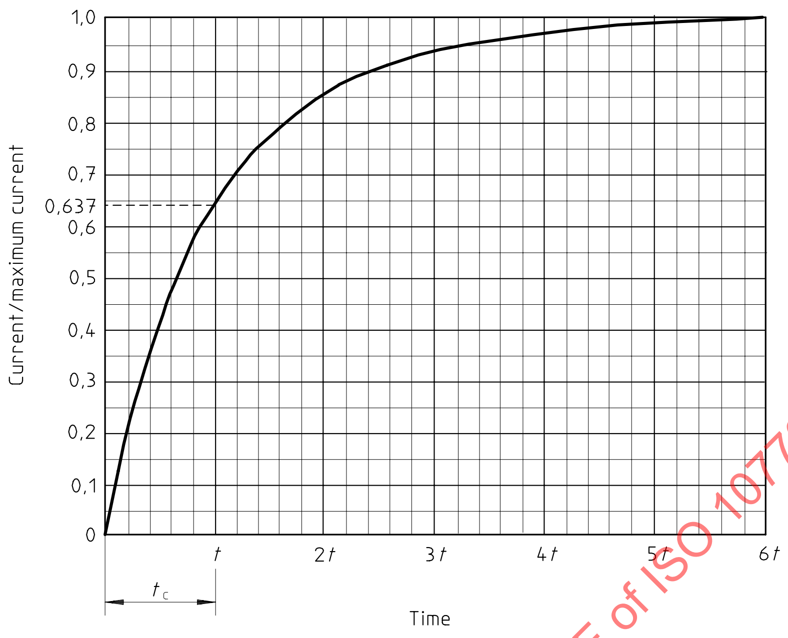


Figure 4 — Valve coil step response

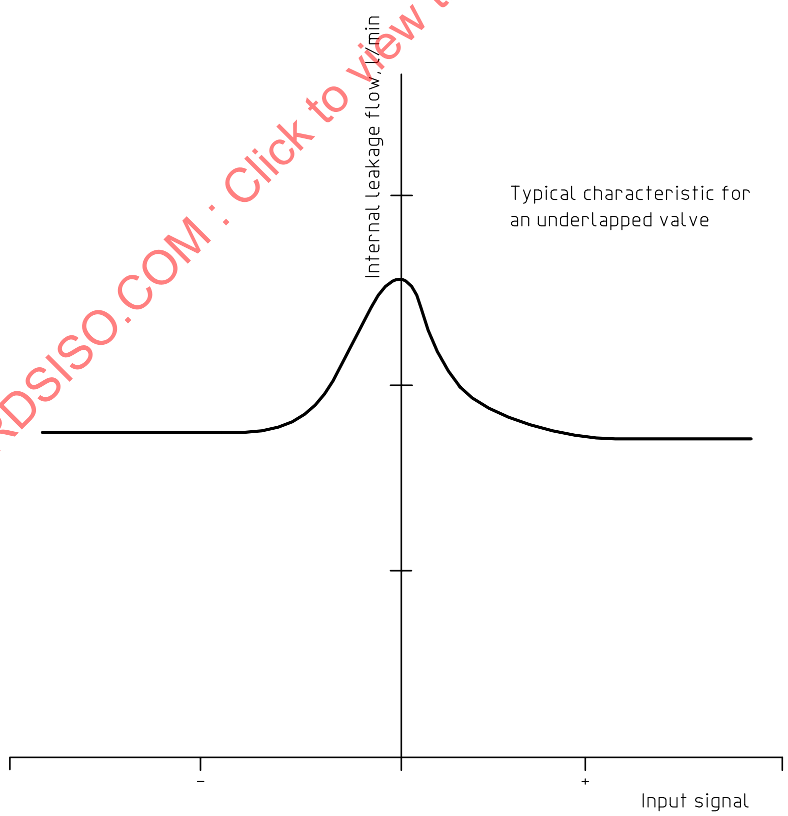


Figure 5 — Internal leakage versus input signal