

Methods of test for

Electrohydraulic proportional control valves

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- Association of Hydraulic Equipment Manufacturers
- British Compressed Air Society
- British Hydromechanics Research Association
- British Steel Corporation
- British Telecommunications plc
- Department of Trade and Industry (National Engineering Laboratory)
- Electricity Supply Industry in England and Wales
- Federation of Manufacturers of Construction Equipment and Cranes
- Health and Safety Executive
- Institution of Mechanical Engineers
- Machine Tool Industry Research Association
- Ministry of Defence
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- Bath University Library
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Foreword

This British Standard has been prepared under the direction of the Machinery and Components Standards Committee at the request of the Association of Hydraulic Equipment Manufacturers.

This standard describes methods of test for electrohydraulic proportional control valves which are installed to control flow and pressure in hydraulic fluid power circuits.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 18, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard describes methods of testing electrohydraulic proportional control valves which are used for the control of flow or pressure in a hydraulic circuit, namely production acceptance and type (or qualification) tests.

The standard is applicable to two-, three- and four-way flow control valves and to two-way pressure control valves.

Unless otherwise stated, the tests are carried out using commercially available mineral based hydraulic fluids.

The procedures described in this standard do not necessarily apply to electrohydraulic servo-valves or valves controlling flow and pressure, the testing of which are the subject of BS 5995 and BS 4062-2.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 5995 apply, together with the following.

electrohydraulic proportional control valve

a valve that provides a degree of proportional flow or pressure control in response to a continuous electrical input signal

3 Symbols and units

The symbols and units for the parameters referred to in this standard are listed in Table 1.

Table 1 — Symbols and units

Parameter	Symbol	Practical unit
Coil impedance	Z	Ω
Coil inductance	L	H
Coil resistance	R	Ω
Insulation resistance	—	Ω
Dither amplitude	—	mA or V
Dither frequency	—	Hz
Input current	I	A
Rated current	I_n	A
Control flow	Q	L/min
Rated flow	Q_n	L/min
Flow gain	K_v (i.e. $\partial Q/\partial I$)	L/(min A)
Hysteresis	—	mA
Internal leakage	Q_l	L/min
Load pressure drop	$p_L = p_a - p_b$	bar
Supply pressure	p_s	bar
Rated pressure drop	$p_n = p_v + p_L = p_s - p_r$	bar
Return pressure	p_r	bar
Control pressure	p_a or p_b	bar
Valve pressure drop	$p_v = p_s - p_r - p_L$	bar
Pressure gain	S_v (i.e. $\partial p_L/\partial I$)	bar/mA
Bulk modulus (tangent isentropic)	K_s	bar
Resolution	—	mA
Threshold	—	mA
Amplitude	—	dB
Phase lag	—	degree
Temperature	—	°C
NOTE 1 bar = 10^5 N/m ² = 10^5 Pa.		

4 Standard test conditions

Unless otherwise specified, the standard test conditions given in Table 2 shall apply to all tests described in this standard.

Table 2 — Standard test conditions

Ambient temperature	20 ± 5 °C
Filtration	Solid contaminant code number to be stated in accordance with BS 5540-4
Fluid type	Commercially available mineral based hydraulic fluid
Fluid temperature	40 ± 6 °C at valve inlet
Viscosity grade	VG 32 as described in BS 4231
Supply pressure	Rated pressure plus return pressure
Return pressure	In accordance with manufacturer's recommendations

5 Test installation

NOTE 1 Figure 1, Figure 2 and Figure 3 are basic circuits that do not incorporate all the safety devices necessary to protect against damage in the event of component failure. It is important that those responsible for conducting the tests give consideration to safeguarding personnel and equipment.

NOTE 2 The graphical symbols used in Figure 1, Figure 2 and Figure 3 are in accordance with BS 2917 and BS 3939.

NOTE 3 General guidance on conducting the tests is given in Appendix A.

5.1 General

A test installation shall be provided which complies with 5.2 and 5.3 and which is capable of meeting the permissible limits of error stated in Appendix B.

5.2 Flow control valves

5.2.1 Steady-state tests. A typical test circuit is shown in Figure 1. This installation allows:

- either point-to-point or continuous plotting methods for recording the results;
- a single differential pressure transducer to be substituted for the two absolute transducers;
- the controlled flow versus oil temperature to be recorded either automatically on the x-y plotter by connecting
 - the signal from the flow meter 11) to the y-axis, and
 - the signal from the thermocouple 5), located in the pressure line adjacent to the valve, to the x-axis,

or, as an alternative, by a point-by-point method in which readings are recorded when the oil temperature has stabilized.

5.2.2 Dynamic tests. A typical test circuit is shown in Figure 2. This installation utilizes much of the circuit shown in Figure 1 and includes a spool position transducer and a flow transducer.

5.3 Pressure control valves

5.3.1 Typical alternative test circuits for testing two-way pressure control valves are shown in Figure 3.

5.3.2 In addition to an input signal source and a u.v. recorder or oscilloscope, provide a mounting manifold which incorporates a pressure transducer located as near to the valve supply port as possible. The volumetric stiffness of the relevant parts of the test valve and the test circuit shall be such that the rate of change of pressure lies within the limits of one agreed range selected from the following.

- 30 000 bar/s to 40 000 bar/s
- 6 000 bar/s to 8 000 bar/s
- 1 200 bar/s to 1 600 bar/s

6 Electrical tests

6.1 General

The tests described in 6.2 to 6.4, as appropriate, shall be carried out on all valves before proceeding to subsequent tests.

6.2 Coil resistance

The test shall be performed with the coil at room temperature. Using an electrical test instrument with an accuracy greater 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.

6.3 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 60 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 Ω) from the following equation:

$$\text{Resistance} = 500 / \text{Current measured}$$

where Current measured is given in A.

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.

6.4 Electronic impedance

NOTE The measurement of electronic impedance relates to those valves with integral electronics where the command signal to the valve is to the input of an amplifier.

The valve under test need not be supplied with pressurized fluid but the amplifier circuit shall be switched on.

Using an ammeter and voltmeter, with accuracies better than 2 % at the measurement point, connected as shown in Figure 4, calculate the electronic input impedance (in Ω) from measurements of current and voltage drop of 100 % of the rated signal using the equation:

$$\text{Electronic input impedance} = \frac{\text{Voltage drop}}{\text{Current}}$$

where

Voltage drop is given in V;

Current is given in A.

Repeat for other input terminals, where appropriate.

7 Flow control tests

7.1 Steady-state tests

NOTE The following test procedures described in 7.1.1 to 7.1.6 are applicable to modulated throttle valves, with and without load pressure compensation, having two, three and four ways.

7.1.1 General. The tests shall be performed in the following order.

- a) Proof pressure test in accordance with 7.1.2.
- b) Internal leakage test in accordance with 7.1.3.
- c) Test for control flow versus input signal characteristics at constant valve pressure drop in accordance with 7.1.4, to determine:
 - 1) rated flow;
 - 2) flow gain (or sensitivity);
 - 3) flow linearity;
 - 4) flow hysteresis;
 - 5) flow symmetry;
 - 6) flow polarity;
 - 7) spool lap condition;
 - 8) repeatability.
- d) Control flow versus toad pressure drop test in accordance with 7.1.5.
- e) Control flow versus fluid temperature test in accordance with 7.1.6.

7.1.2 Proof pressure test

7.1.2.1 General. A proof pressure test shall be carried out to examine the integrity of the valve before conducting any further tests (see Figure 1).

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

- a) Ensure that the appropriate return port valves are open and close all the other valves.
- b) Adjust the valve supply pressure to achieve 1.5 times the rated pressure and maintain this pressure for a minimum of 5 min.

NOTE For production acceptance tests, this duration may be reduced to 1 min.

For approximately half of this period apply the maximum positive input signal and for the remainder of the test, apply the maximum negative input signal.

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

7.1.2.3 Return proof pressure. In the test a proof pressure is applied to the return port of the valve. This pressure shall be equal to the rated valve pressure or to some specified percentage of it. The test shall be carried out as follows.

- a) Close all the valves.
- b) Adjust the valve supply pressure to achieve the required return port proof pressure and maintain this pressure for a minimum of 5 min.

NOTE For production acceptance tests, this duration may be reduced to 1 min.

For approximately half of this period apply the maximum positive input signal and for the remainder of the test apply the maximum negative input signal.

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

7.1.3 Internal leakage test. Before commencing the tests any necessary mechanical/electrical adjustments shall be made, such as nulling the valve, and then the test shall be carried out to determine the internal leakage in the following manner.

- a) Close the appropriate control port valves.
- b) Ensure that the appropriate return port valves are open to direct flow through the leakage flow turbine.
- c) Adjust the valve supply pressure to achieve the rated pressure.
- d) Immediately before the leakage measurements are to be taken, operate the valve over its full range several times.
- e) Record the leakage flow at the zero input signal.
- f) Record the leakage flow at the maximum positive and the maximum negative input signal.

NOTE For spools with special features, it may be necessary to determine the rate of leakage between the ports. This can be accomplished by applying agreed pressures at each port at which these tests are to be made.

7.1.4 Test for control flow versus input signal characteristics at constant valve pressure drop

7.1.4.1 General. The test, described in 7.1.4.2 to 7.1.4.4, shall be carried out to obtain the flow versus input signal curve and to deduce many of the steady-state valve characteristics.

7.1.4.2 Test circuit. Set up the test circuit shown in Figure 1 as follows, in the manner appropriate to the valve configurations.

- a) For two-way valves:
 - 1) for flow from P port to A port, open valves A, B, F and close valves C, D, E, G, H, I;
 - 2) for flow from P port to B port, open valves D, C, E, G and close valves A, B, F, H, I.
- b) For three-way valves:
 - 1) for flow from P port to A port, open valves A, B, F and close valves E, C, G, D, H, I;
 - 2) for flow from A port to T port, open valves I, A, E, F and close valves B, G, C, D;
 - 3) for flow from P port to B port, open valves D, C, E, G and close valves F, A, B, H, I;
 - 4) for flow from B port to T port, open valves H, D, E, F and close valves I, C, G, A, B.
- c) For four-way valves: Open valves A, B, C, D, G and close valves E, F, H, I.

7.1.4.3 Test procedure. Use the following procedure.

- a) Adjust the valve supply pressure to achieve the rated pressure drop (rated pressure drop equals valve pressure drop plus load pressure drop).
- b) Cycle the input signal several times.
- c) Using an x-y plotter, establish a suitable range using the x-axis to record the input signal and the y-axis to record the control flow.
- d) Set the automatic signal generator for plus and minus the maximum input signal.
- e) 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 recorder and flowmeter are negligible. Also ensure that the valve pressure drop remains substantially constant during the complete signal cycle.
- f) With the continuously varying signal still applied, lower the plotter pen and record the characteristics over one complete signal cycle (see Figure 5).
- g) Determine the control flow at rated signal, flow gain, linearity, hysteresis, symmetry, polarity and lap condition from the resulting curve.

- h) If required, compile a family of these curves for various rated pressures.

7.1.4.4 Repeatability. Measure the repeatability as follows.

- a) Apply an input signal of amplitude between 0 % and ± 10 % and record the corresponding flowmeter reading.
- b) Repeat a) at least three times.
- c) Record the difference between the maximum and the minimum flowmeter readings and express this as a percentage of the mean of the flowmeter readings.
- d) Repeat for input signal amplitudes of ± 25 %, ± 50 % and ± 100 %.

7.1.5 Control flow versus load pressure drop test.

The following test shall be carried out to determine the nature of the variation of control flow versus load pressure drop.

- a) Set up the test circuit shown in Figure 1 for the appropriate valve configuration as described in 7.1.4.2.
- b) Adjust the valve supply pressure to achieve the maximum rated pressure drop, compensating for any return pressure if necessary.
- c) Cycle the input signal several times.
- d) Using an x-y plotter, establish a suitable range using the x-axis to record the load pressure drop and the y-axis to record the control flow (see Figure 6).
- e) Set the input signal to a constant positive value.
- f) Lower the plotter pen and slowly close the loading valve to obtain a continuous plot of control flow versus load pressure drop for the positive input signal (see Figure 5).
- g) Apply a constant negative input signal and repeat the procedure to obtain a second continuous plot in the opposite quadrant of the graph (see Figure 5).
- h) If required, repeat steps e) to g) at other values of valve input signal.

7.1.6 Control flow versus fluid temperature test. The following test shall be carried out to determine the nature of the variation of control flow versus fluid temperature.

- a) Set up the test circuit shown in Figure 1 for the appropriate valve configuration as described in 7.1.4.2.
- b) Using an x-y plotter, establish a suitable range using the x-axis to record the oil temperature and the y-axis to record the control flow (see Figure 7).
- c) Apply 50 % of the input signal.