International Standard ISO 6404

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Hydraulic fluid power — Servovalves — Test methods

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6404 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit.

A servovalve is a component, within such a circuit, which accepts an electrical or mechanical analogue control signal and provides a correspondingly modulated flow or pressure output.

1 Scope and field of application

This International Standard specifies methods for testing electrohydraulic servovalves, namely production acceptance, and type (or qualification) tests.

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

This International Standard does not specify methods for determining the characteristics associated with external closed-loop control systems.

This International Standard is applicable primarily to electrohydraulic flow control servovalves with current controlled input, but many sections are equally applicable to other types of servovalves, such as pressure-control servovalves and servovalves with interstage feedback.

2 References

ISO 1219, *Fluid power systems and components — Graphical symbols*

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

ISO 4406, *Hydraulic fluid power — Fluids — Solid contaminant code.* 1)

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

IEC Publication 68, *Basic environmental testing procedures.*

IEC Publication 617, *Graphical symbols for diagrams.*

1) At present at the stage of draft.

3 Symbols and units

The symbols and units used throughout this International Standard are as shown in table 1.

Table 1 — Symbols and units

Parameters	Symbol	Unit
Coil impedance	Z	Ω
Coil inductance	L	H
Coil resistance	R	Ω
Dither amplitude	—	mA
Dither frequency	—	Hz
Input current	I	mA
Rated current	I_n	mA
Control flow	q_V	l/min
Flow gain	K_v	l/min·mA
Hysteresis	—	mA
Internal leakage	$q_{V_{in}}$	l/min
Load pressure drop	$p_l = p_a - p_b$	bar or kPa 1)
Supply pressure	p_s	bar or kPa
Rated pressure	$p_n = p_v + p_l = p_s - p_r$	bar or kPa
Return pressure	p_r	bar or kPa
Control pressure	p_a or p_b	bar or kPa
Servovalve pressure drop	$p_v = p_s - p_r - p_l$	bar or kPa
Pressure gain	S_v	bar/mA or kPa/mA
Resolution	—	mA
Threshold	—	mA
Amplitude ratio	—	dB
Phase lag	—	degree

1) 1 bar = 100 kPa = 10^5 Pa = 0,1 MPa; 1 Pa = 1 N/m^2

4 Definitions

For the purposes of this International Standard, the definitions given in ISO 5598 apply.

5 Standard test conditions

Unless otherwise specified, the following standard test conditions apply to all tests specified in this International Standard:

- ambient temperature: 20 ± 5 °C;
- filtration: solid contaminant code to be stated, in accordance with ISO 4406;
- fluid type: commercially available mineral-based hydraulic fluid[1];
- fluid temperature: 40 ± 6 °C servovalve inlet temperature;
- viscosity grade: VG 32, as described in ISO 3448;
- supply pressure: rated pressure + return pressure;
- return pressure: ⩽5 % of rated pressure.

6 Test installation

The suitability of any particular installation will be dependent upon its ability to meet the permissible limits of error stated in the annex.

The circuit of a typical steady-state test installation 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 may be substituted for the two absolute transducers.

The circuits of typical dynamic test installations are shown in figures 2 and 3. These installations utilize much of the circuit shown in figure 1.

7 Electrical tests

7.1 Insulation resistance

7.1.1 The insulation resistance for the servovalve coil and connection shall be measured in accordance with the procedure specified in 7.1.1.1 to 7.1.1.3.

NOTE — Servovalves need not be pressurized for this test. However, if internal electrical components are in contact with the fluid (for example, a wet-coil servovalve), the valve shall be filled with hydraulic fluid.

7.1.1.1 Connect together the coil terminations and apply, between them and the servovalve body, a d.c. voltage of five times the maximum anticipated coil voltage or 500 V, whichever is the greater.

7.1.1.2 Maintain this voltage for a period of 60 s and then, with the voltage still applied, using a suitable commercially available insulation tester, measure the current flowing.

7.1.1.3 From the ratio of the applied voltage to current flowing, calculate the insulation resistance (this should normally exceed 100 MΩ).

NOTE — With a four-lead, two-coil configuration, this test should also be performed between the coils.

7.2 Coil resistance

7.2.1 Since the resistance of a servovalve coil is temperature-dependent, allow time for stabilization to room temperature.

7.2.2 Using an electrical test instrument having an accuracy of ±2 %, measure the resistance of the servovalve coil, or each coil separately, if the servovalve has more than one.

NOTE — The servovalve 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 servovalve 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 e.m.f. (electromotive force) generated by the moving armature. The result may be used to select the appropriate design of drive amplifier.

7.3.2 Connect a suitable oscillator to drive the total servovalve coil which is in series with a precision non-inductive resistor, as shown in figure 4.

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

7.3.4 Adjust the servovalve input current to a peak amplitude equal to the servovalve rated current.

7.3.5 Use an oscillator which is capable of supplying undistorted current to the servovalve.

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

7.3.7 Measure the peak a.c. voltages e_R, e_T and e_V.

7.3.8 Construct the diagram shown in figure 5 to show the vectorial relationship of the voltages.

1) In special circumstances, the fluid for which the valve is designed may be substituted.

7.3.9 Determine the coil impedance characteristics from the following expressions:

— phase angle, β

— coil impedance, expressed in ohms

$$Z = R \frac{e_V}{e_R}$$

— apparent inductance, expressed in henry

$$L = \frac{R}{2\pi f} \times \frac{e_L}{e_R}$$

8 Steady-state tests

8.1 General

8.1.1 The following tests shall be carried out:

a) proof pressure, in accordance with 8.2;

b) blocked control ports, in accordance with 8.3, to determine

1) pressure gain (see 8.3.1),
2) resolution and threshold at null (see 8.3.2),
3) null bias and null shift (see 8.3.3),
4) internal leakage (see 8.3.4),
5) null pressure;

c) open control ports, in accordance with 8.4, to determine

1) control flow versus input current at zero load (see 8.4.1),
2) flow gain,
3) linearity,
4) hysteresis,
5) symmetry,
6) polarity,
7) resolution and threshold outside null region,
8) lap conditions (see 8.4.2),
9) flow gain at null;

d) control flow versus load pressure drop, in accordance with 8.5.

8.1.2 The results of the tests shall be presented in graphical or tabular form for convenience (see 13.1).

8.1.3 A signal generator shall be used to provide a continuously variable input signal and an X-Y recorder to show the corresponding pressure and flow detected by suitable pressure and flow transducers.

8.1.4 Alternatively, the response of the servovalve in terms of flow or pressure shall be recorded manually, point by point, against input signal.

NOTES

1 It is important in this context to note that the signal moves in one direction only for one half of the test cycle and in the other direction only in the other half of the cycle. In this way the hysteresis inherent in the servovalve is not obscured. An automatic signal generator is useful in preventing inadvertent reversal of the signal.

2 The type of function (i.e. sinusoidal, ramp, etc.) produced by the signal generator is unimportant provided that the speed is slow in comparison with the response of the recorder.

8.1.5 A recorder incorporating means for adjusting the amplitude of the transducer and servovalve current signals to a convenient scale and means for centralizing the trace on the chart shall be provided.

8.1.6 In addition to the automatic signal generator, a manually controlled input with changeover switch which will allow the servovalve and equipment to be set up shall be provided.

8.1.7 An automatic signal generator and manual controllers capable of providing positive or negative signals without recourse to switching shall be provided.

8.2 Proof pressure

The pressure tests described in 8.2.1 and 8.2.2 shall be carried out to examine the integrity of the servovalve before conducting any further tests.

8.2.1 Supply proof pressure

8.2.1.1 Open the return port valve.

8.2.1.2 Close both control port valves.

8.2.1.3 Adjust the servovalve 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.

8.2.1.4 For approximately half of this period, apply positive rated current, $+I_n$; for the other half, apply negative rated current, $-I_n$.

8.2.1.5 No external leakage or permanent deformation shall occur during the test.

NOTE — Visual examination is required as part of a type test [see 13.2.3 u)].

8.2.2 Return proof pressure

8.2.2.1 Close the return port valve.

8.2.2.2 Close the control port valves and the internal leakage valves.

8.2.2.3 Adjust the servovalve supply pressure to obtain a proof pressure which shall be equal to the servovalve rated pressure or to some specified percentage of it, and maintain this pressure for a minimum of 5 min.

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

8.2.2.4 For approximately half of this period, apply positive rated current, $+I_n$; for the other half apply negative rated current, $-I_n$.

8.2.2.5 No external leakage or permanent deformation shall occur during the test.

NOTE — Visual examination is required as part of a type test [see 13.2.3 u)].

8.3 Blocked control ports

8.3.1 Pressure gain

8.3.1.1 Any necessary mechanical adjustments, such as minimizing the null bias, shall be made before commencing these tests.

8.3.1.2 Close both control port valves.

8.3.1.3 Open the return port valve.

8.3.1.4 Adjust the servovalve supply pressure to achieve rated pressure.

8.3.1.5 Cycle the input current several times.

8.3.1.6 Establish an X-Y plotter configuration to record load pressure drop (Y-axis) versus input current (X-axis).

8.3.1.7 Check the zero on both scales.

8.3.1.8 Set the automatic signal generator for an input current amplitude ($\pm I_n$) sufficient to obtain maximum load pressure drop ($\pm p_n$).

8.3.1.9 Allow the input signal to be periodically cycled, ensuring that pen motion is unrestricted and that it is moving at such a speed that the recorder dynamic effects are negligible.

8.3.1.10 With the periodically cycled signal still applied, lower the plotter pen and record the characteristics over one complete current cycle.

8.3.1.11 Establish the pressure gain averaged between ±40 % of the maximum load pressure drop from the X-Y plot obtained.

8.3.2 Resolution and threshold at null

8.3.2.1 Repeat steps 8.3.1.2 to 8.3.1.5 of the pressure gain test.

8.3.2.2 Apply a small input current of one polarity until the control port pressures are equal.

8.3.2.3 Note the value of this input current.

8.3.2.4 Apply a further small signal slowly (to avoid dynamic effects) in the same sense of polarity until the control port pressure changes.

8.3.2.5 Note the input current and the control port pressure readings.

8.3.2.6 Measure the servovalve resolution at null by computing the incremental current change from the algebraic difference of the last two values recorded.

8.3.2.7 Slowly reverse the input signal until a reversal in the control port pressures is observed.

8.3.2.8 Record the input current.

8.3.2.9 Measure the servovalve threshold at null by computing the incremental current change from the algebraic difference of the last two values recorded.

8.3.3 Null bias and null shift

The servovalve shall be nulled prior to any test performed to measure the change in null shift with one or more operating conditions.

8.3.3.1 Null bias

8.3.3.1.1 This test shall be carried out before commencing the tests described in 8.3.3.2 to 8.3.3.4.

8.3.3.1.2 Open the return port valve.

8.3.3.1.3 Close both control port valves.

8.3.3.1.4 Adjust the servovalve supply pressure to achieve rated pressure.

8.3.3.1.5 Apply full positive rated current, $+I_n$.

8.3.3.1.6 Decrease the input current slowly to zero then to full negative rated current, $-I_n$.

8.3.3.1.7 To eliminate hysteresis, continue cycling the input current slowly between positive and negative values, while gradually decreasing the maximum current levels.

8.3.3.1.8 When the current has been reduced to zero by this method, note the control port pressures.

8.3.3.1.9 Slowly apply the appropriate input current necessary to bring the servovalve to null, i.e. to make the control pressure equal.

8.3.3.1.10 Note the value of input current.

8.3.3.1.11 Slowly increase the input current in the same direction until the control port pressures change.

8.3.3.1.12 Stop and reverse the direction of application of input current until the control port pressures are again equal.

8.3.3.1.13 Note the value of input current.

NOTE — The null bias current is the average of the two current values noted in the preceding steps, and the procedure outlined above ensures that only null bias is measured, and not the total effect of null bias threshold and hysteresis.

8.3.3.2 Null shift with supply pressure

8.3.3.2.1 Decrease the supply pressure in suitable increments by adjusting the pressure regulator.

8.3.3.2.2 At each value of supply pressure, repeat the steps outlined in 8.3.3.1.9 to 8.3.3.1.13 to obtain the null bias current.

8.3.3.2.3 Plot null bias versus supply pressure.

8.3.3.3 Null shift with return pressure

8.3.3.3.1 Repeat the test described in 8.3.3.1, if necessary.

8.3.3.3.2 Slowly close the return valve to establish suitable increments of return pressure.

8.3.3.3.3 At each value of return pressure, repeat the steps outlined in 8.3.3.1.9 to 8.3.3.1.13 to obtain the null bias current.

8.3.3.3.4 Plot null bias versus return pressure.

8.3.3.4 Null shift with fluid temperature

8.3.3.4.1 Repeat the test described in 8.3.3.1.

8.3.3.4.2 Record the fluid temperature.

8.3.3.4.3 Increase the fluid temperature by a suitable increment, and allow the test circuit temperature to stabilize for at least 1 min.

8.3.3.4.4 At each stable temperature, repeat the steps outlined in 8.3.3.1.9 to 8.3.3.1.13 to obtain the null bias current.

8.3.3.4.5 The test shall be carried out over the range of operating temperatures for which the servovalve is designed.

8.3.3.4.6 Take further readings with the fluid temperature decreased by increments so as to minimize experimental errors.

8.3.3.4.7 Plot null bias versus fluid temperature.

8.3.4 Internal leakage

8.3.4.1 Close both control port valves.

8.3.4.2 Open the internal leakage valves.

8.3.4.3 Close the return port valve.

8.3.4.4 Adjust the servovalve supply pressure to achieve rated pressure.

8.3.4.5 Establish an X-Y plotter configuration to record return line flow (Y-axis) versus input current (X-axis).

8.3.4.6 Check the zero on both scales.

8.3.4.7 Set the automatic signal generator for a maximum amplitude of $\pm I_n$.

8.3.4.8 Allow the input signal to be periodically cycled, ensuring that pen motion is unrestricted and that it is moving at such a speed that

a) recorder dynamic effects are negligible;

b) the change in internal leakage near servovalve null is fully and accurately recorded.

8.3.4.9 With the periodically cycled signal still applied, lower the plotter pen and record the characteristics over half a complete cycle, commencing at either $+I_n$ or $-I_n$.

NOTE — If a flowmeter is fitted in the return line, as shown in figure 1, the internal leakage may be measured by a method similar to that described above, but with the control valves set to divert return port flow directly through this flowmeter instead of to the positive displacement flowmeter. Depending on the nature of the flowmeter, either a continuous plot of internal leakage versus input current, or point-by-point checks can be performed.

8.4 Open control ports

The tests described in 8.4.1 to 8.4.4 shall be carried out.

8.4.1 Control flow versus input current characteristics at zero load

NOTE — This test obtains the no-load flow versus input current curve and is used to deduce many of the steady-state valve characteristics.

8.4.1.1 Open the return port valve.

8.4.1.2 Open both control port valves and close internal leakage valves.

8.4.1.3 Adjust the servovalve supply pressure to achieve rated pressure.

8.4.1.4 Cycle the input current several times.

8.4.1.5 Establish X-Y plotter configuration to record control flow (Y-axis) versus input current (X-axis).

8.4.1.6 Set the automatic signal generator for a maximum amplitude of $\pm I_n$.

8.4.1.7 Allow the input signal to be periodically cycled, ensuring that pen motion is unrestricted and that it is moving at such speed that the dynamic effects of the recorder and flowmeter are negligible.

8.4.1.8 The servovalve pressure drop shall remain substantially constant during the complete current cycle.

8.4.1.9 With the periodically cycled signal still applied, lower the plotter pen and record the characteristics over one complete current cycle.

8.4.1.10 Determine the control flow at rated current, flow gain, linearity, hysteresis, symmetry and polarity from the resulting curve.

8.4.2 Lap conditions

8.4.2.1 Following the test described in 8.4.1, obtain a curve which indicates lap conditions by increasing the sensitivity of the X-Y plotter on both axes from the values required for a full flow curve, and recording only that part of the flow curve in the null region.

8.4.2.2 For this particular test, the accuracy and null characteristics of the flow measurement device shall be such that they do not significantly affect the accuracy of the test results.

8.4.3 Flow saturation

Following the test described in 8.4.1, obtain a curve which gives an indication of flow saturation by increasing the current sufficiently to produce flow saturation effects.

8.4.4 Resolution and threshold outside null region

8.4.4.1 Following the test described in 8.4.1, cycle the input current.

8.4.4.2 Apply a small biasing current.

8.4.4.3 Note the current and the corresponding flowmeter reading.

8.4.4.4 Slowly apply a further small signal (to avoid dynamic effects) in the same sense of polarity until there is a change in the flowmeter reading.

8.4.4.5 Note the new input current.

8.4.4.6 Measure the servovalve resolution by computing the incremental current change from the algebraic difference of the two values recorded.

8.4.4.7 Slowly reverse the input signal until a corresponding change in the flowmeter reading is noted.

8.4.4.8 Record the input current.

8.4.4.9 Measure the servovalve threshold by computing the incremental signal change from the algebraic difference of the last two values recorded.

8.4.4.10 Repeat the above steps at other signal levels of both polarities and record the maximum values of resolution and threshold.

8.5 Control flow versus load pressure drop

The test described in 8.5.1 to 8.5.9 shall be carried out to determine the nature of the variation of control flow versus load pressure drop.

8.5.1 Open the return port valve.

8.5.2 Open both control port valves.

8.5.3 Adjust the servovalve supply pressure to achieve rated pressure, compensating for any return pressure, if necessary.

8.5.4 Cycle the input current gradually several times over the range $-I_n$ to $+I_n$.

8.5.5 Establish an X-Y plotter configuration to record control flow on the Y-axis and load pressure drop on the X-axis.

8.5.6 Set the input current to a constant value of $+I_n$.

8.5.7 Lower the plotter pen and slowly close one control port valve to obtain a continuous plot of control flow versus load pressure drop for the input current $+I_n$.

8.5.8 Apply a constant current of $-I_n$, and repeat the procedure to obtain a second continuous plot in the opposite quadrant of the graph.

8.5.9 If required, repeat the steps outlined in 8.5.6 to 8.5.8 at other values of servovalve input current.

9 Dynamic tests

The dynamic performance of the servovalve shall be determined in accordance with the two distinct tests described in 9.1 and 9.2.

9.1 Frequency response

9.1.1 Test equipment

9.1.1.1 The test equipment shall comply with the circuit shown in figure 2 and include the following items:

a) signal oscillator (sine wave generator);

b) drive amplifier incorporating current feedback;

c) symmetrical hydraulic cylinder (actuator);

d) velocity and positional transducers;

e) oscilloscope, transfer function analyser (TFA) or other suitable recorder.

9.1.1.2 The drive amplifier and transducers shall have a bandwidth which is high in relation to the bandwidth of the servovalve and capable of supplying an undistorted output signal.

9.1.1.3 The hydraulic cylinder (which is used to monitor the output flow) and the associated test equipment shall have low frictional characteristics and a natural frequency which is high in relation to the frequency bandwidth of the servovalve, i.e. of one order higher, so as to have a negligible effect on servovalve dynamic performance.

9.1.1.4 The linear velocity transducer shall be used to monitor the flow.

9.1.1.5 The positional transducer shall be used to provide a low gain feedback signal to prevent actuator drift.

9.1.1.6 The amplitude and phase relationship shall be obtained from an oscilloscope Lissajous pattern, a suitable recorder plot or from a suitable transfer function analyser.

9.1.2 Test conditions

In addition to the conditions specified in clause 5, the following test conditions shall apply:

a) external actuator load: essentially zero;

b) input signal amplitude: ± 100 %, ± 25 % and ± 5% of the specified rated current;

c) the input waveform: sinusoidal.

9.1.3 Test procedure

9.1.3.1 Adjust the equipment so that the piston is near the mid-point of total stroke.

9.1.3.2 Apply the input signal at a frequency of 5 Hz or 5 % of the frequency at which phase lag is 90°, whichever is the lower.

9.1.3.3 Record this frequency and also the amplitude of the velocity signal measured at the oscilloscope or TFA.

9.1.3.4 Measure the phase lag between the input signal to the servovalve and the output (velocity) signal at the oscilloscope.

9.1.3.5 Record this value.

9.1.3.6 Adjust the input signal frequency to a higher value.

NOTE — If necessary, the amplitude of the oscillator output signal should be adjusted to maintain the servovalve input current amplitude at a constant value.

9.1.3.7 Record the new values of frequency, amplitude and phase lag.

9.1.3.8 Compute the ratio of the amplitude at this frequency to the amplitude at the initial frequency.

9.1.3.9 Convert this ratio to decibels.

9.1.3.10 Measure amplitude and phase lag over a range of frequencies wide enough to cover 15 dB attenuation and including frequencies corresponding to 45°, 90° and higher phase lags as required.

9.1.3.11 Compute the corresponding values of amplitude ratio.

9.2 Transient response

9.2.1 Test equipment

9.2.1.1 The test equipment shall comply with the circuit shown in figure 3 and include the following items:

a) input signal source circuit;

b) drive amplifier (optional);

c) symmetrical hydraulic cylinder;

d) velocity and positional transducers;

e) oscilloscope.

9.2.1.2 The hydraulic cylinder (which is used to monitor the output flow) and the associated test equipment shall have low frictional characteristics and a natural frequency which is high in relation to the frequency bandwidth of the servovalve, i.e. of one order higher, so as to have a negligible effect on servovalve dynamic performance.

9.2.1.3 The linear velocity transducer shall be used to monitor the flow.