

3.3 minimum controllable pressure
minimum output pressure when the absolute value of the input pressure command signal is zero and the input flow command signal is maximum (see 7.2.4)

3.4 dead zone
range wherein the output pressure or output flow being controlled by the input signal does not vary when the absolute value of the input signal increases from zero or decreases to zero

3.5 load volume
gross volume of working fluid in the main pipelines from the outlet of the pump to be tested to the inlet of the loading valve

3.6 pressure compensation
condition in which the output flow starts to decrease by the variable displacement control mechanism when the output pressure approaches a set pressure

3.7 deadhead pressure
output pressure without flow

4 Symbols

4.1 The physical quantity letter symbols and their suffixes used in this International Standard (see Table 1), are fully explained in ISO 4391.

Units are given in Table 1 and Annex A.

4.2 Graphical symbols used in Figures 1 and 2, showing test circuit diagrams, conform to ISO 1219-1 and ISO 1219-2.

Table 1 — Symbols and units

Quantity	Symbol	Dimension ^a	SI unit
Power	P	$M L^2 T^{-3}$	W
Pressure, differential pressure	p, Δp	$M L^{-1} T^{-2}$	MPa
Flow rate	q	$L^3 T^{-1}$	dm ³ /min
Rotational speed	n	T^{-1}	min ⁻¹

^a M = mass, L = length, T = time.

5 Test installation — General requirements

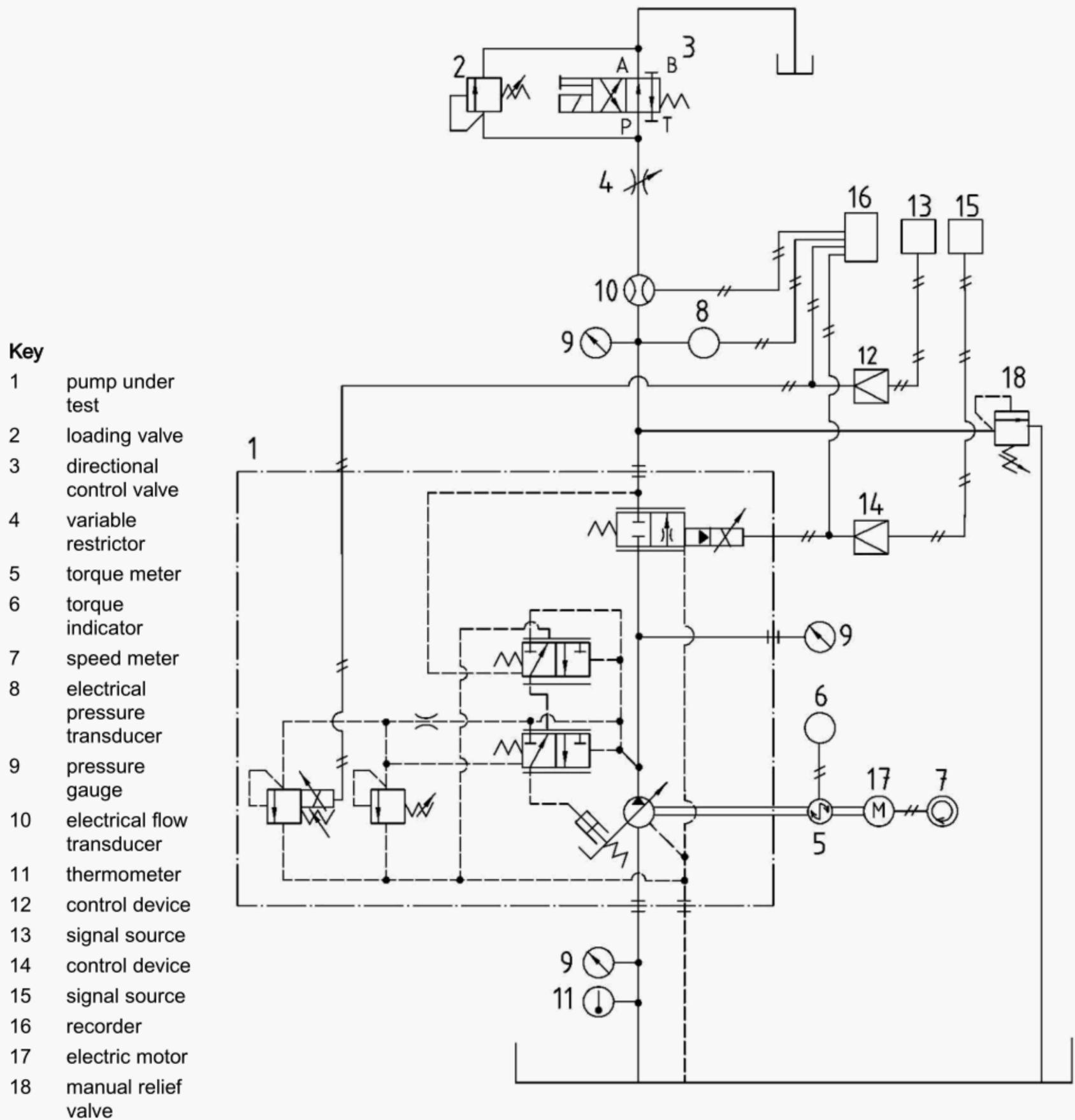
5.1 General

5.1.1 Unless otherwise specified, install the pump with the output shaft horizontal and the drain port facing upwards.

5.1.2 Use a hydraulic test circuit conforming to Figure 1 for test pumps having a pressure control valve to control the pressure in the pressure-compensation state and a flow control valve to control the output flow.

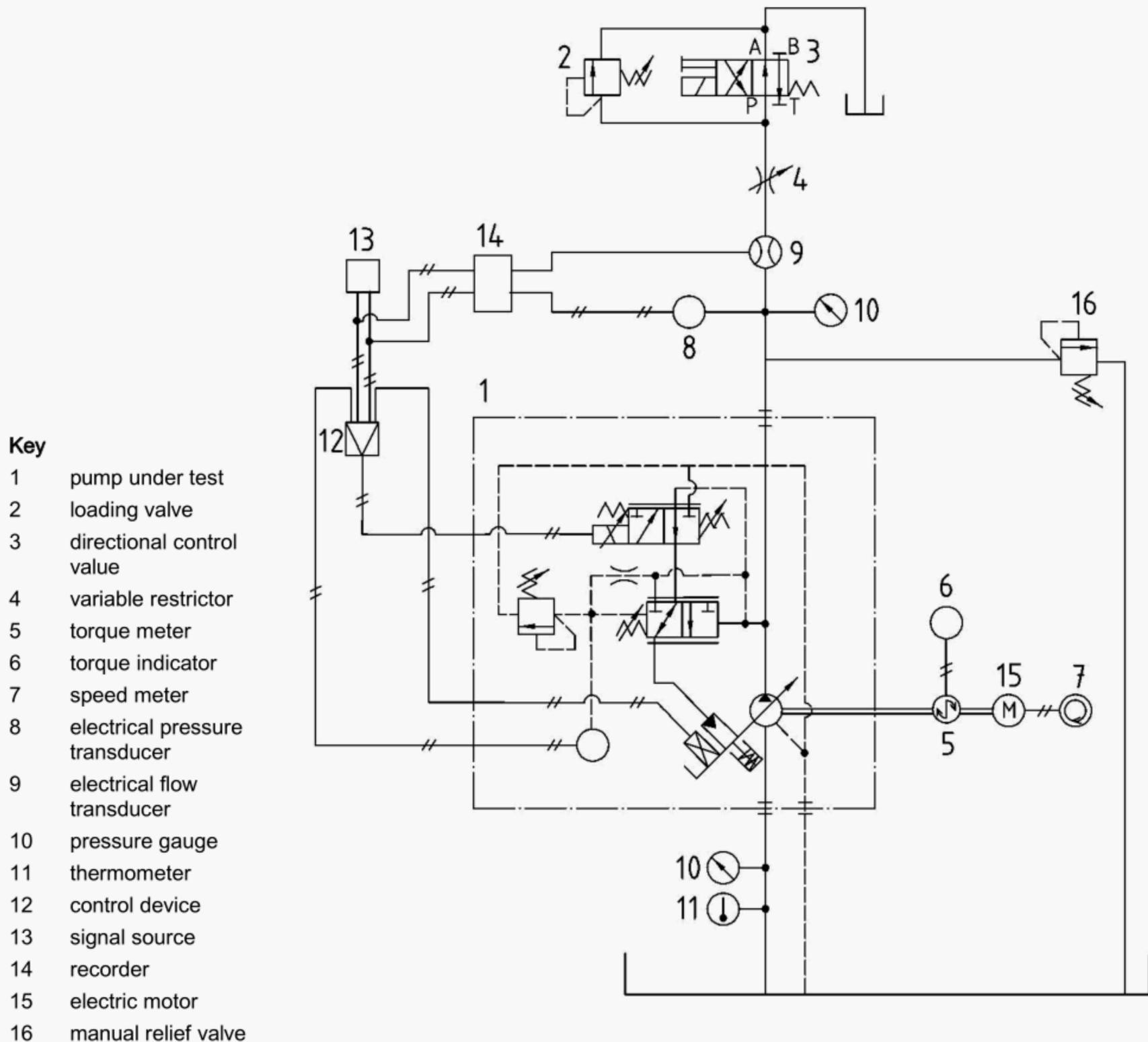
5.1.3 Use a hydraulic test circuit conforming to Figure 2 for test pumps that utilize electrical input signals to control the pressure in the pressure-compensation state and either the position or angle of the mechanism to vary the displacement of the pump.

5.1.4 For applications where the pump will be part of a closed-loop control system it may be necessary to perform a frequency response test. Subclause 8.5 describes a pump test method. The need for the test should be agreed between the customer and manufacturer.



NOTE Details of the pump control valves are for illustration only.

Figure 1 — Pump with pressure-compensation control valve and flow control valve to control output flow



NOTE Details of the pump control valves are for illustration only.

Figure 2 — Pump with electrical input signals to control pressure-compensation and either the position or angle of the mechanism to vary displacement

5.2 General test apparatus

5.2.1 Set up a test rig conforming to 5.1.1 to 5.1.3 and Figures 1 and 2 as applicable.

5.2.2 Maintain the loading valve and variable restrictor in the test circuit at no loading and no restriction except for the conditions specified in the test procedure. If the loading valve is operated, open the variable restrictor completely and adjust the directional control valve so that the P port is closed. If the variable restrictor is operated, adjust the directional control valve so that the P port opens to the A port.

5.2.3 Set the manual relief valve integrated with the pump for safety purposes to limit the maximum steady-state pressure to no less than 125 % of the maximum working pressure setting.

6 General test conditions

6.1 Test fluid

6.1.1 The hydraulic fluid type and viscosity shall conform to ISO VG 32 or ISO VG 46 according to ISO 3448.

6.1.2 Maintain the fluid temperature at the pump inlet in the range of _____ to _____.
45 °C 55 °C

6.1.3 Maintain the fluid contamination class within 19/16 or less according to ISO 4406.

Conditions other than those indicated in this subclause should be agreed between the supplier and purchaser.

6.2 Ambient conditions

The ambient temperature and any variation from still air conditions shall be recorded.

6.3 Steady-state conditions

Take each set of measurements only when the values of the controlled parameters are within the limits given in Table 2.

Table 2 — Limits of permissible variation in the values of controlled parameters			
Controlled parameter	Limits of permissible variation in the values of controlled parameters for class of measurement accuracy ^a		
	A	B	C
Temperature, °C	± 0,5	± 1	± 2
Rotational speed, %	± 0,5	± 1	± 2
Input signal, %	± 0,5	± 1,5	± 2,5

^a See Annex A.

7 Tests of steady-state performance characteristics

7.1 General

7.1.1 The test circuit and measuring circuit shall conform to Figures 1 or 2 as applicable.

NOTE In addition to the internal control pressure supply as shown in Figure 2, it is possible to use an external control pressure supply.

7.1.2 Adjust the electric motor to the specified rotational speed.

7.1.3 The steady-state performance shall be determined in accordance with ISO 4409.

7.1.4 For pumps in accordance with Figure 2, the swivel angle or stroke in percent of the maximum value may be used as an alternative to the output flow.

7.2 Flow/pressure characteristics

7.2.1 Use the pump having pressure control and flow control functions.

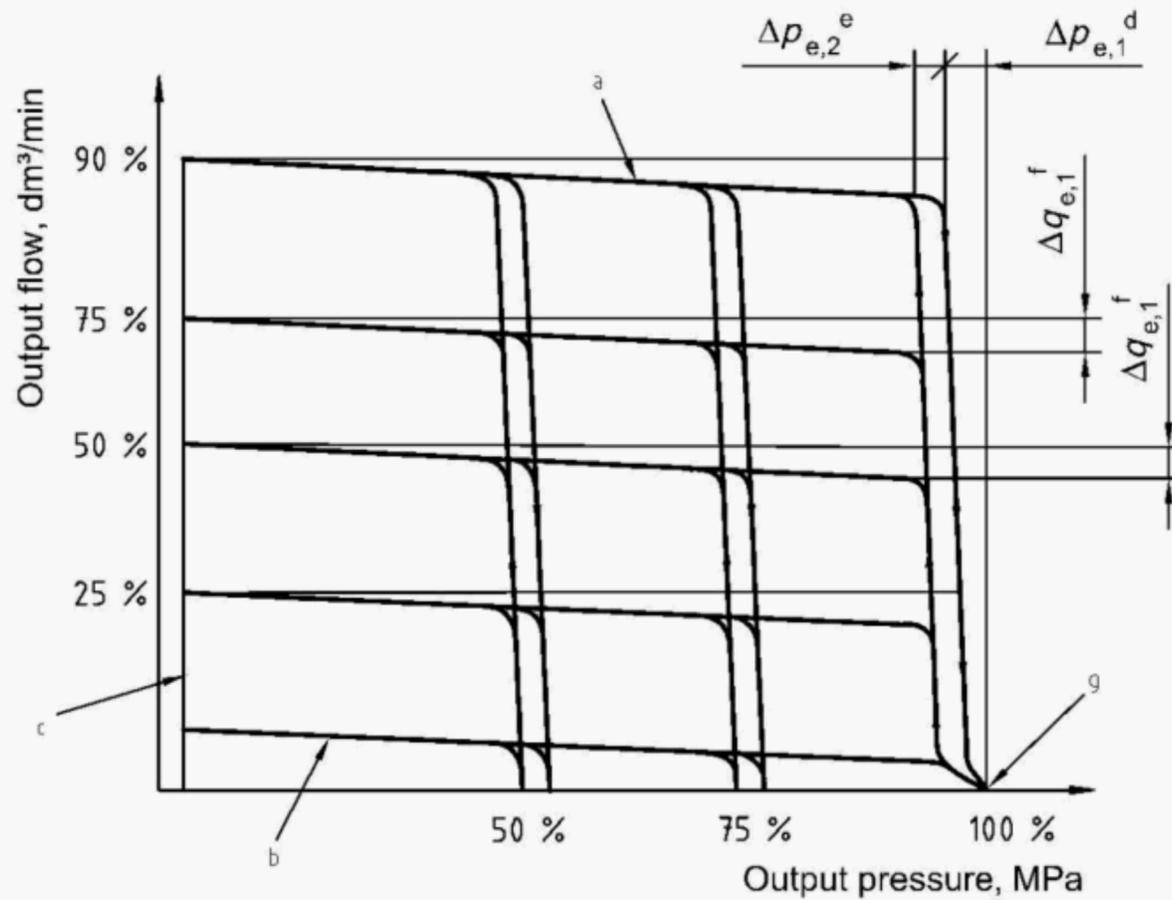
7.2.2 Determine the minimum flow command by the following procedure:

- set the loading valve to shut-off so that there is no output flow;
- slowly decrease the input flow command signal until the deadhead pressure can no longer be maintained;
- record the value of the input flow command signal as the minimum flow set point.

7.2.3 Tests should be performed at 100 %, 75 % and 50 % of the maximum working pressure. Tests should also be performed at 90 %, 75 %, 50 % and 25 % of the maximum output flow, and minimum flow command.

7.2.4 Gradually change the output pressure by adjusting the variable restrictor, cycling the pump from the maximum working pressure, through 75 % and 50 % of the maximum working pressure, to the highest minimum controllable pressure and output pressure when the variable restrictor is opened completely, and back again.

7.2.5 Plot a graph of output flow against output pressure (see Figure 3).



- a Maximum flow command.
- b Minimum flow command.
- c Minimum controllable pressure.
- d Pressure range from starting pressure-compensation state to deadhead pressure.
- e Hysteresis at pressure-compensation.
- f Maximum width of the change of the output flow.
- g Maximum working pressure.

Figure 3 — Output flow versus pressure

7.2.6 Calculate and record the rate of change of adjustable flow rate δq against output pressure using the following formula:

$$\delta q = \frac{\Delta q_{e,1}}{q_0} \times 100$$

where

δq is the rate of change in adjustable flow rate, expressed as a percentage;

$\Delta q_{e,1}$ is the maximum width of the change of output flow (see Figure 3);

q_0 is the output flow at the minimum controllable pressure for each input flow command signal as explained below.

Calculate the values at 75 % and 50 % of the maximum output flow and minimum flow command settings, respectively (these values are the rate of change of adjustable flow rate δq against output pressure). For a pump with pressure-compensation function, $\Delta q_{e,1}$ shall be considered the maximum range of flow rate change immediately before the pump shifts into pressure-compensation mode.

7.2.7 For a pump with pressure-compensation function, calculate and record the following characteristic values for each flow rate setting:

- hysteresis $\Delta p_{e,2}$ of the pressure when controlled by the pressure compensator;
- pressure range $\Delta p_{e,1}$ from commencement of pressure compensation to deadhead condition.

7.3 Characteristic test on output pressure against input pressure command signal: test procedure and presentation of test results

7.3.1 If the pump has pressure control and flow control functions, select input pressure command signal and input flow command signal, and adjust them to their maximum values.

7.3.2 Completely close the loading valve. Increase and decrease input pressure command signal for one cycle, from the minimum controllable pressure of the pump to the maximum working pressure, at a rate that does not subject the pump or measuring equipment to any significant dynamic influence.

7.3.3 Plot a graph of output pressure against input pressure command signal (see Figure 4).

7.3.4 Obtain and record the following characteristic value from the recorded data:

$$\delta p_{hy} = \frac{\Delta p_{max}}{p_{max}} \times 100$$

where

δp_{hy} is the hysteresis of the output pressure, expressed as a percentage;

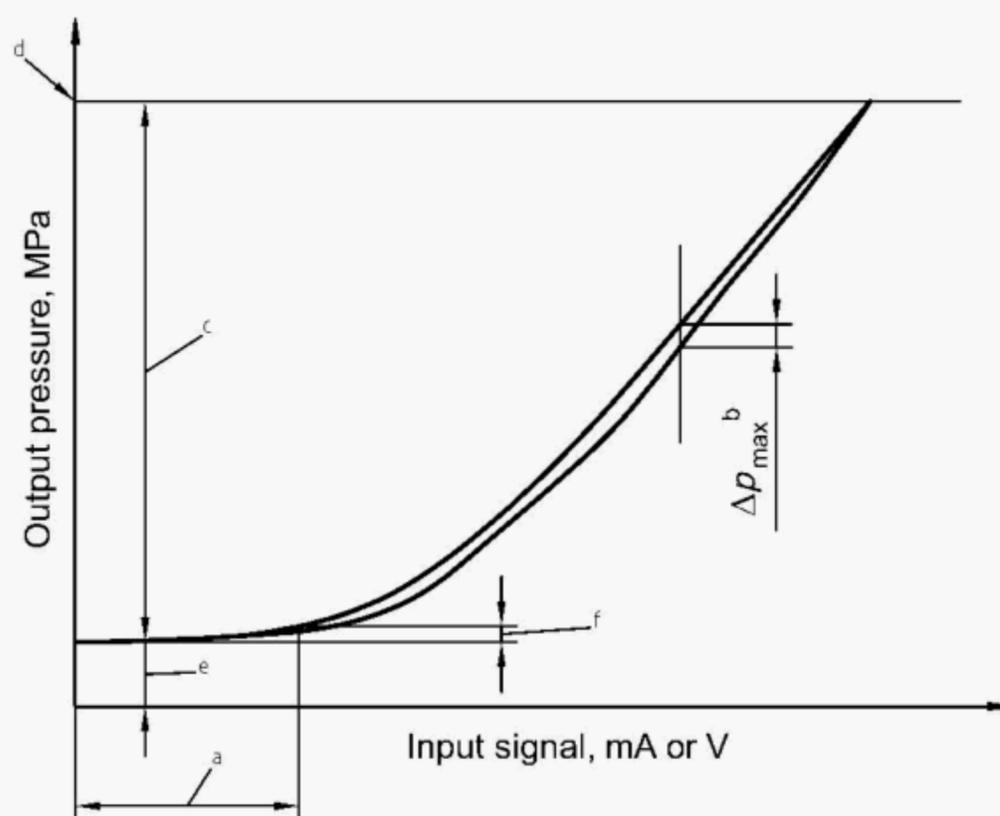
Δp_{max} is the maximum difference in pressure at the same input signal;

p_{max} is the maximum working pressure.

7.3.5 Obtain the adjustable range of output pressure from the recorded data.

7.3.6 Obtain the input signal value at the maximum working pressure from the recorded data.

7.3.7 Determine the dead zone by recording the change in input pressure command signal that causes the dead head output pressure to rise by 10 % above the minimum controllable pressure (see Figure 4). Record the dead zone from the recorded data.



- a Dead zone.
- b Maximum difference in pressure.
- c Adjustable range of pressure.
- d Maximum working pressure.
- e Minimum controllable pressure.
- f 10 % of the minimum controllable pressure.

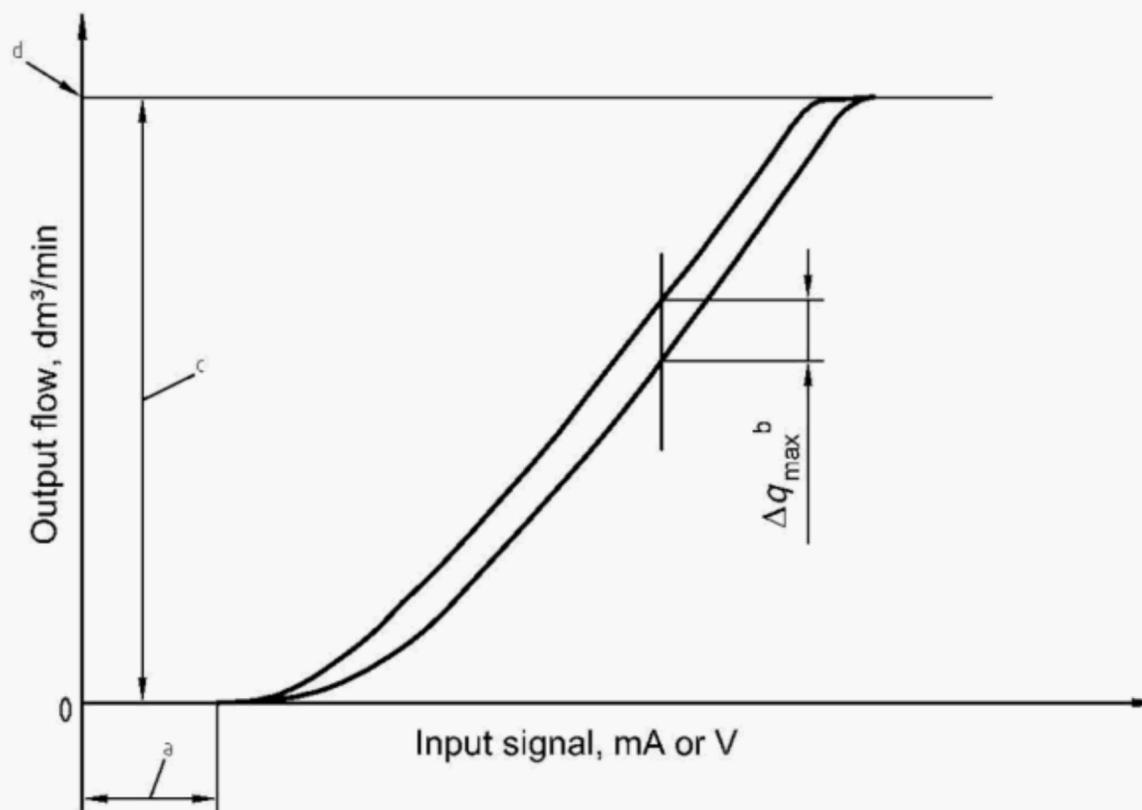
Figure 4 — Output pressure versus input signal

7.4 Characteristic test of output flow against input flow signal — Test procedure and expression of test results

7.4.1 If the pump has pressure control and flow control functions, select the input pressure command signal and input flow command signal and adjust them to their maximum values. Adjust the input pressure command signal to 75 % of the maximum working pressure and the input flow command signal to the maximum, using the loading valve.

7.4.2 Increase and then decrease the flow control input signal for one cycle, from zero output flow to the maximum output flow and back to zero output flow, at a rate that does not subject the pump or measuring equipment to significant dynamic influence.

7.4.3 Plot a graph of output flow against input signal (see Figure 5).



- a Dead zone.
- b Maximum difference in output flow.
- c Adjustable range of output flow.
- d Maximum output flow.

Figure 5 — Output flow versus input signal at 75 % of maximum working pressure

7.4.4 Obtain and record the following characteristic values from the recorded data:

$$\delta q_{hy} = \frac{\Delta q_{max}}{q_{max}} \times 100$$

where

δq_{hy} is the hysteresis of the output flow, expressed as a percentage;

Δq_{max} is the maximum difference in output flow at the same input signal;

q_{max} is the maximum output flow.

7.4.5 Obtain the adjustable range of the output flow from the recorded data.

7.4.6 Obtain the input signal value at the maximum output flow from the recorded data.

7.4.7 Record the dead zone from the recorded data (see Figure 5).

7.5 Repeatability test

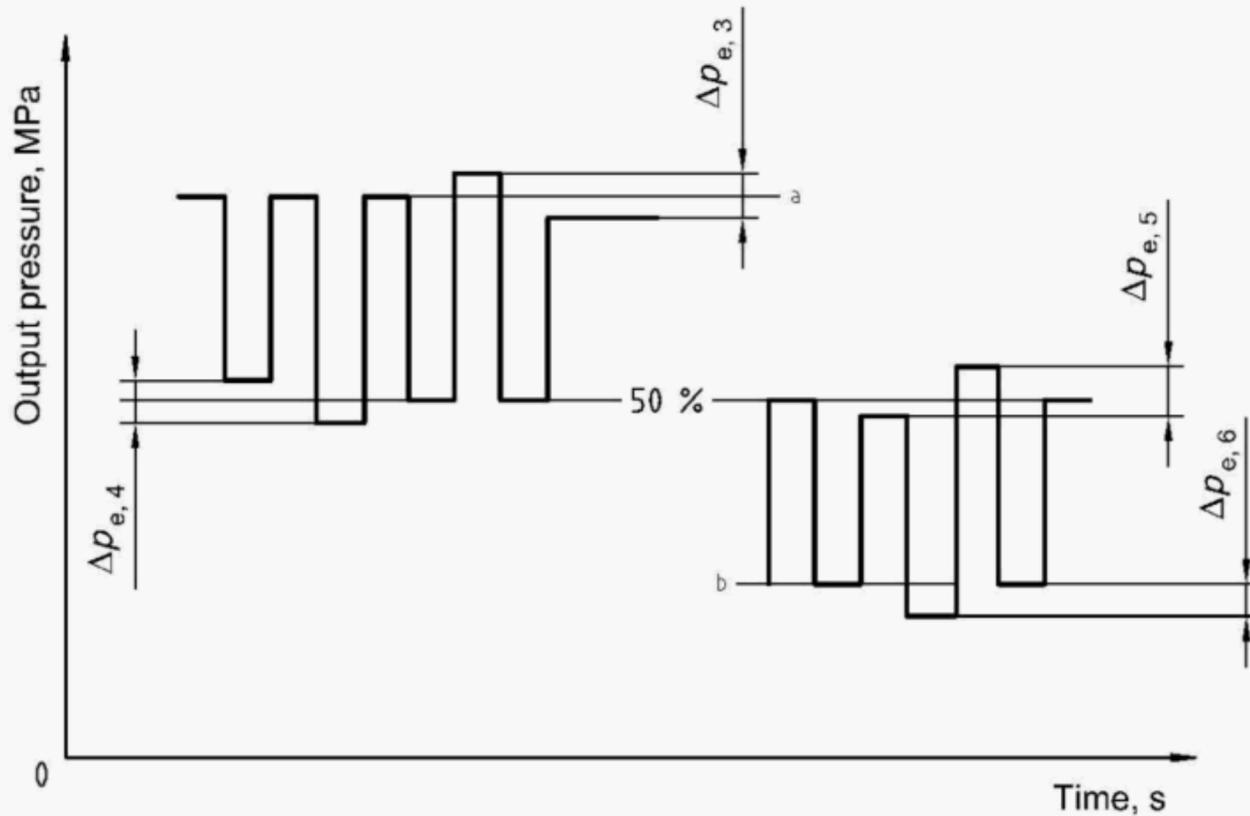
7.5.1 Repeatability of output pressure — Test procedure and presentation of test results

7.5.1.1 If the pump has pressure control and flow control functions, select the input pressure command signal and input flow command signal, and adjust them to their maximum values.

7.5.1.2 Vary the input pressure command signal in accordance with 7.3.2, stepwise for 20 cycles, to attain the maximum working pressure and 50 % of the maximum working pressure.

7.5.1.3 Vary the input pressure command signal in accordance with 7.3.2, stepwise for 20 cycles, to attain 50 % of the maximum working pressure and the minimum controllable pressure.

7.5.1.4 Record graphically the results of the tests in 7.5.1.2 and 7.5.1.3, plotting output pressure against time (see Figure 6).



- a Signal 100 %.
- b Signal 0 % minimum adjustable pressure.

Figure 6 — Repeatability of output pressure

7.5.1.5 Obtain and record the ratio of dispersion relative to each pressure setting (see Figure 6), using the following formula:

$$\delta p_{re} = \frac{\overline{\Delta p_{e,max}}}{p_{max}} \times 100$$

where

δp_{re} is the repeatability of the output pressure, expressed as a percentage;

$\Delta p_{e,max}$ is the maximum value ($\Delta p_{e,3}$ to $\Delta p_{e,6}$);

p_{max} is the maximum working pressure (see Figure 6).

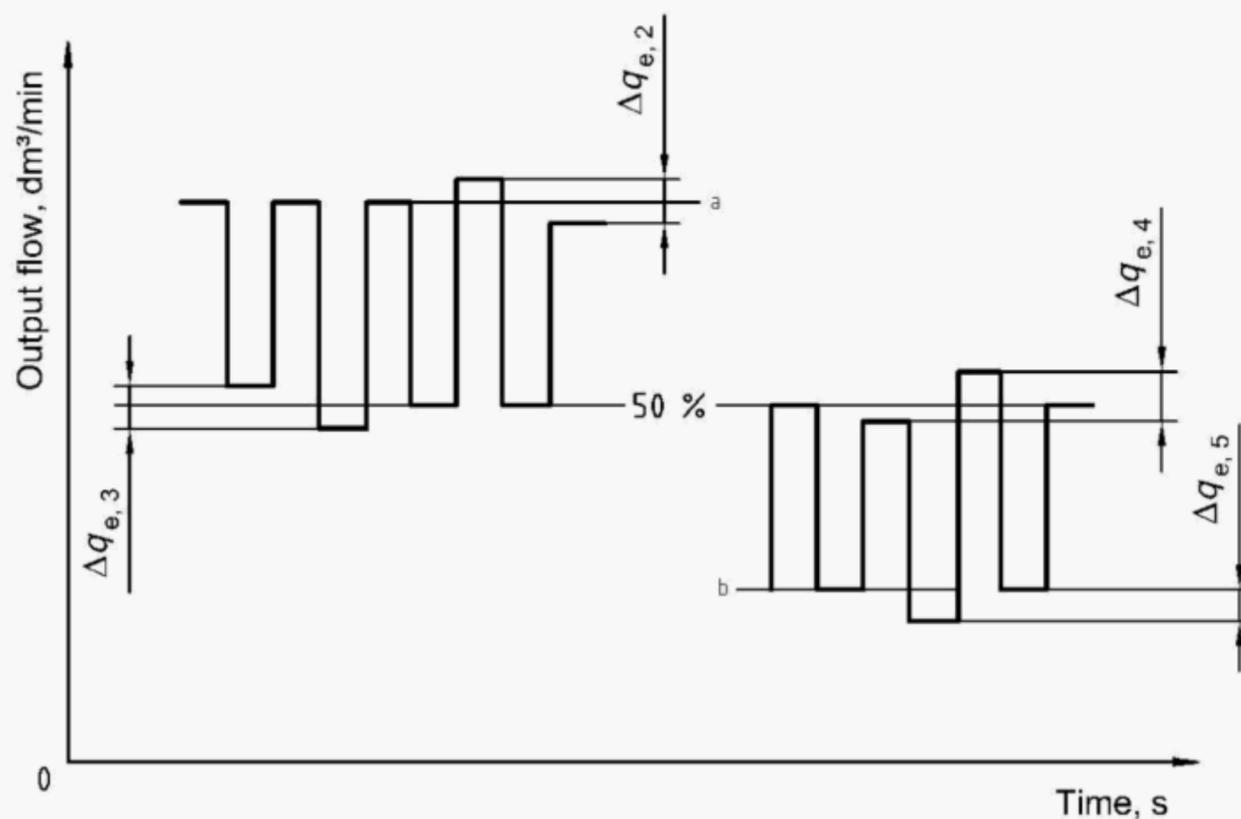
7.5.2 Repeatability of output flow — Test procedure and presentation of test results

7.5.2.1 If the pump has pressure control and flow control functions, select the input pressure command signal and input flow command signal and adjust them to their maximum values. Adjust the input pressure command signal to 75 % of the maximum working pressure and the input flow command signal to the maximum, using the loading valve.

7.5.2.2 With the pump output flow at 90 % of the maximum, adjust the loading valve so that the pressure becomes 75 % of the maximum working pressure. Vary the flow control input signal stepwise for 20 cycles to attain 90 % and 50 % of the maximum output flow at a rate that does not subject the pump or measuring equipment to any dynamic influence.

7.5.2.3 With the pump output flow at 50 % of the maximum, adjust the loading valve so that the pressure becomes 75 % of the maximum working pressure. Vary the input signal in accordance with 7.5.2.2, stepwise for 20 cycles, to attain 50 % of the maximum output flow and the minimum flow command at a rate that does not subject the pump or measuring equipment to any dynamic influence.

7.5.2.4 Record graphically the results of tests in 7.5.2.2 and 7.5.2.3, plotting output flow against time (see Figure 7).



- a Signal 90 %.
- b Signal 0 % minimum flow command.

Figure 7 — Repeatability of output flow

7.5.2.5 Obtain and record the ratio of dispersion relative to each flow rate setting (Figure 7), using the following formula:

$$\delta q_{re} = \frac{\Delta q_{e,max}}{q_{max}} \times 100$$

where

δq_{re} is the repeatability of the output flow, expressed as a percentage;

$\Delta q_{e,max}$ is the maximum value ($\Delta q_{e,2}$ to $\Delta q_{e,5}$);

q_{max} is the maximum output flow (see Figure 5).

7.6 Test for change in characteristics against oil temperature

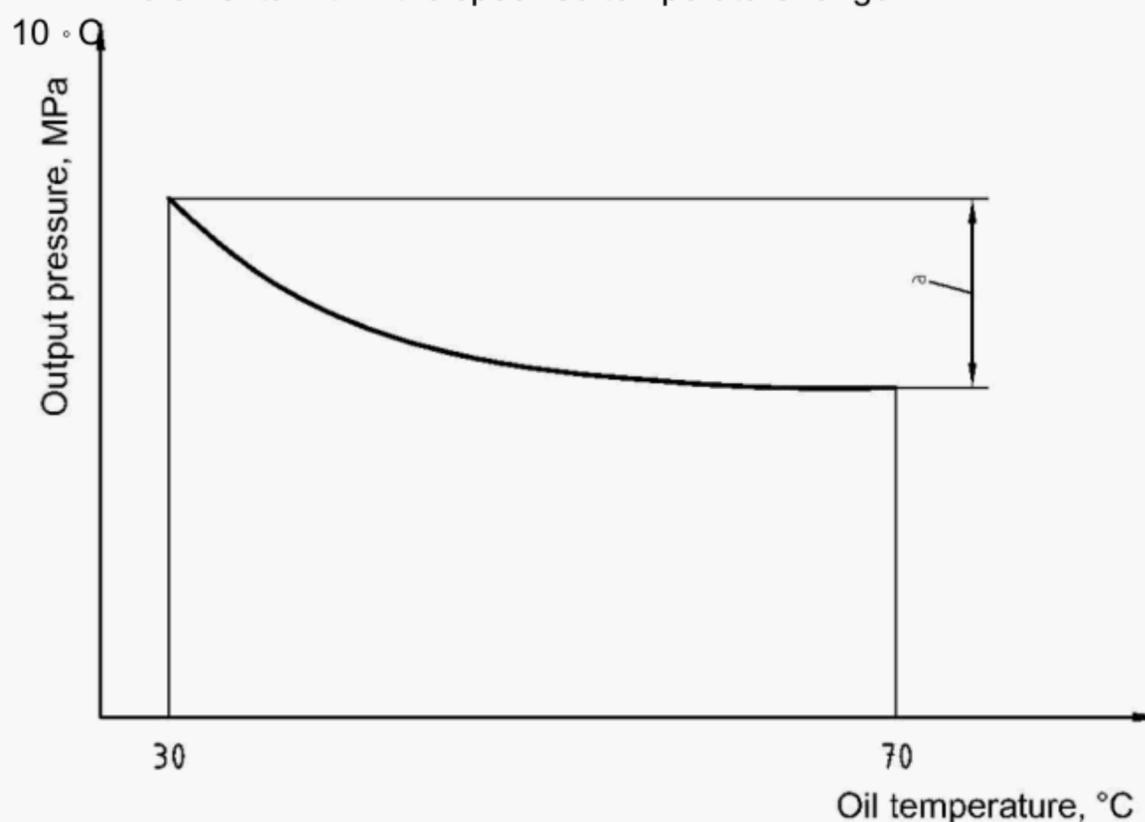
7.6.1 Change in characteristics with respect to pressure — Test procedure and presentation of test results

7.6.1.1 If the pump has a pressure control function, completely close the loading valve and maintain the input pressure command signal to attain the maximum working pressure.

7.6.1.2 Raise the oil temperature from 30 °C to 70 °C at a rate that ensures stable temperatures of the test equipment.

If this range is considered to be too small to have any influence on the control, a temperature range other than that indicated above should be agreed between the parties concerned.

7.6.1.3 Record the results graphically by plotting output pressure against oil temperature (see Figure 8). Record the open-air temperature. If the temperature cannot be recorded continuously, plot at least five points over the range in 10 °C increments within the specified temperature range.



^a Change in output pressure.

Figure 8 — Output pressure versus oil temperature

7.6.2 Change in characteristics with respect to flow rate — Test procedure and expression of results

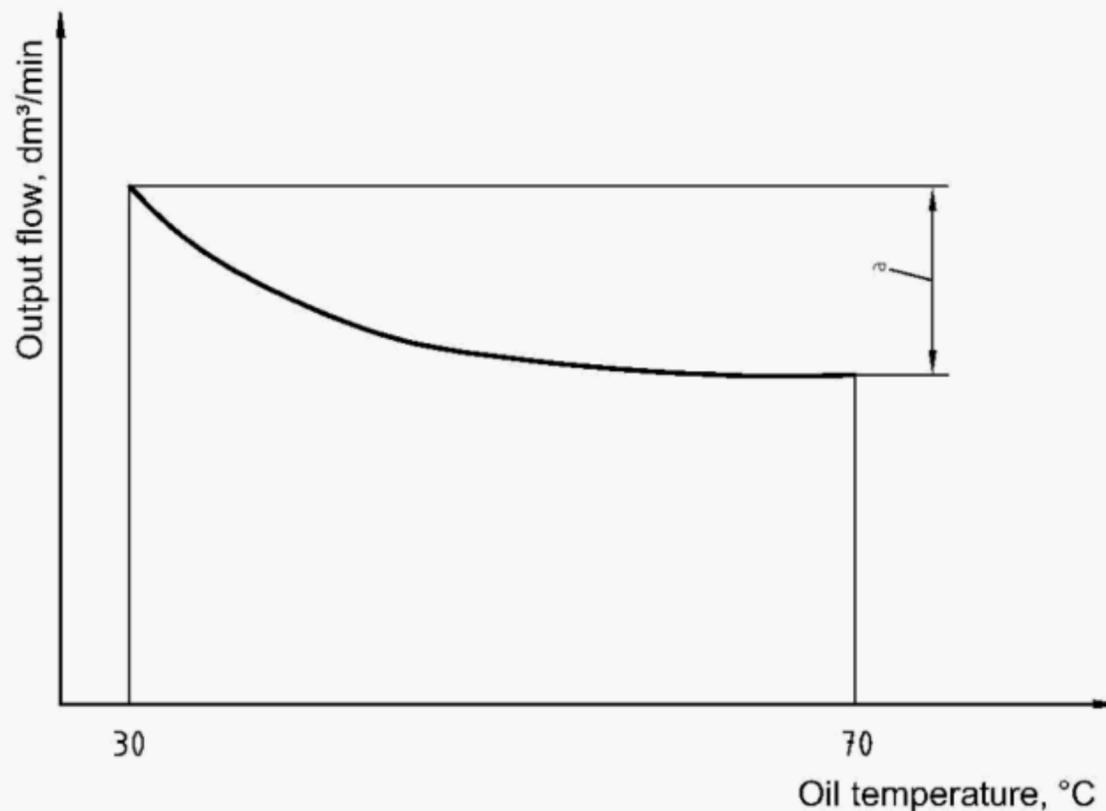
7.6.2.1 If the pump has pressure control and flow control functions, adjust the input flow command signal to 75 % of the maximum, and adjust the loading valve to a pressure of 5 MPa.

7.6.2.2 Raise the oil temperature from 30 °C to 70 °C at a rate that ensures stable temperatures of the test equipment.

If this range is considered to be too small to have any influence on the control, a temperature range other than that indicated above should be agreed between the parties concerned.

7.6.2.3 Record the results graphically by plotting output flow against oil temperature (see Figure 9). Record the open-air temperature. If the temperature cannot be recorded continuously, plot at least five points over the range in $10\text{ }^{\circ}\text{C}$ increments within the specified temperature range.

NOTE Pressure ripple measurement should be carried out in accordance with ISO 10767-1 and ISO 10767-2.



^a Change in output flow.

Figure 9 — Output flow versus oil temperature

8 Tests of dynamic performance characteristics

8.1 General

8.1.1 The test circuit and measuring circuit shall conform to Figures 1 or 2 as applicable.

NOTE In addition to the internal control pressure supply as shown in Figure 2, it is possible to use an external control pressure supply.

8.1.2 Adjust the electric motor to the specified rotational speed.

8.1.3 For pumps in accordance with Figure 2, the swivel angle or stroke in percent of the maximum value may be used as an alternative to the output flow.

8.2 Pressure compensator response and recovery

8.2.1 If the pump has pressure and flow rate control functions, select the input pressure command signal and input flow command signal, and adjust them to their maximum values.

8.2.2 Use a directional control valve for rapid shut-off and a pressure transducer in the pump outlet line so that the instantaneous pressure can be recorded against time on an oscilloscope (or oscillograph).

8.2.3 Condition the circuit such that the rate of pressure rise is between 680 MPa/s and 920 MPa/s when the directional control valve is closed. Use 800 MPa/s as the target pressure rise rate [5].

800 MPa/s

