BRITISH STANDARD

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Hydraulic fluid power — Positive displacement pumps and motors — Determination of derived capacity

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British Standards

National foreword

This British Standard is the UK implementation of ISO 8426:2008. It supersedes BS 7250:1989 which is withdrawn.

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A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8426 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 8, *Product testing*.

This second edition cancels and replaces the first edition (ISO 8426:1988), which has been technically revised.

Introduction

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

Two types of components of such systems are the positive displacement pump and motor. One of the key performance parameters of these components is derived capacity, which is the volume of fluid displaced per shaft revolution. This International Standard is intended to unify test methods for determining the derived capacity of hydraulic fluid power positive displacement pumps and motors so as to enable the performance of different components to be compared.

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Hydraulic fluid power — Positive displacement pumps and motors — Determination of derived capacity

1 Scope

This International Standard specifies the methods of determining the derived capacity of hydraulic fluid power positive displacement pumps and motors under steady-state conditions and at defined, continuous shaft rotational frequencies.

Units can be tested as a positive displacement pump, with mechanical energy applied to the shaft and hydraulic energy obtained at the outlet fluid connection, or as a motor, with hydraulic energy supplied to the inlet fluid connection and mechanical energy obtained at the shaft.

NOTE Measurement accuracy is divided into three classes A, B and C, which are explained in Annex A.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols for conventional use and data-processing applications*

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

ISO 4409, *Hydraulic fluid power — Positive-displacement pumps, motors and integral transmissions — Methods of testing and presenting basic steady state performance*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and the following apply.

3.1

direction of rotation

direction of rotation as viewed looking at the shaft end

NOTE In cases where doubt exists, a sketch should be provided.

3.2

volume flow rate

volume of fluid crossing the transverse plane of a flow path per unit of time

3.3
derived capacity
volume of fluid displaced by a pump or motor per shaft revolution, calculated from measurements at different outlet pressures (for pumps) or inlet pressures (for motors) under specified test conditions

4 Symbols and units

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

Table 1 — Symbols and units

Symbol	Description	Unit	Dimension [a]
d	Internal diameter of tube	m	L
n [b]	Rotational frequency (speed)	r/min	t^{-1}
p [b]	Pressure	MPa (bar) [c]	$mL^{-1}t^{-2}$
q_V [b]	Volume flow rate	l/min [d]	L^3t^{-1}
$q_{V,e}$ [b]	Effective flow rate	l/min	L^3t^{-1}
V_i [b]	Derived capacity	l/r	L^3
θ [b]	Temperature	°C	θ
v	Kinematic viscosity	m^2/s	L^2t^{-1}
ρ	Mass density	kg/m^3	mL^{-3}

[a] m = mass; L = length; t = time; θ = temperature.

[b] Letter symbol is used in accordance with ISO 4391.

[c] 1 bar $=$ 10^5 Pa $=$ 0,1 MPa; 1 Pa $=$ 1 N/m^2.

[d] 1 l $=$ 1 dm^3.

The graphic symbols used throughout this standard are in accordance with the requirements of ISO 1219-1.

5 Test installation

5.1 General

5.1.1 Pre-test condition

Before the test begins, the unit under test shall be run-in in accordance with the manufacturer's recommendation.

5.1.2 Installation

The test installation shall be designed to prevent air entrainment and precautions shall be taken to remove all free air from the system before beginning the test.

The unit under test shall be installed and operated in the test circuit (see 5.2) in accordance with the manufacturer's operating instructions. The inlet tube to the unit under test shall be straight, shall have a uniform bore and shall have dimensions consistent with the dimensions of the unit's inlet connection.

5.1.3 Test fluid cleanliness

The cleanliness of the test fluid shall be in accordance with the recommendation of the manufacturer of the unit under test. Filters of sufficient number and of an appropriate type shall be installed in the test circuit to provide the necessary test fluid cleanliness. Details of any filtration used in the test circuit shall be stated in the test report.

5.2 Test circuits

5.2.1 General

Figures 1, 2 and 3 illustrate the basic test circuits. These circuits do not incorporate all of the necessary safety devices. It is important that those responsible for carrying out the tests give consideration to safeguarding personnel and equipment.

5.2.2 Circuits for testing positive displacement pumps

Either an open-circuit test circuit in accordance with Figure 1 or a closed-circuit test circuit in accordance with Figure 2 shall be used.

If a pressurized inlet condition is required, a pressure control valve shall be provided in the inlet tube at a point not less than $10d$ from the pressure measuring point.

If it is necessary to increase the inlet pressure to the unit under test, this may be accomplished by providing

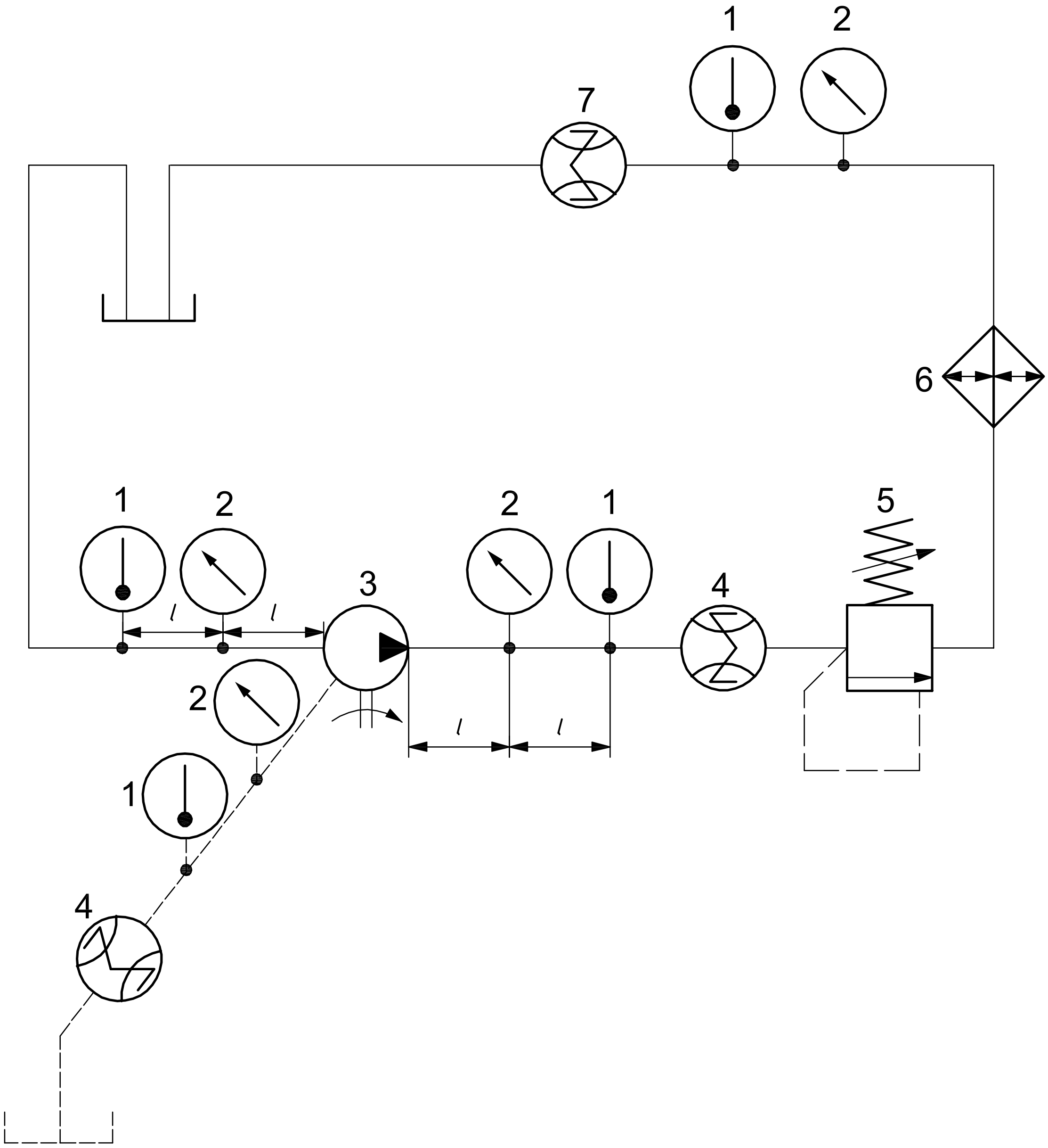
a) a boost pump and a pressure-relief valve capable of maintaining the pressure at the inlet of the unit under test at the desired pressure;

   NOTE When a closed test circuit (see Figure 2) is used, unless a higher flow rate is required for cooling purposes, it is necessary that the boost pump supply a flow rate slightly in excess of the total flow-rate losses of the circuit.

b) a means other than a boost pump (e.g. an air-loaded tank or pressurized reservoir); if these are used, precautions shall be taken to minimize the effects of entrained or dissolved air in the test circuit.

5.2.3 Circuit for testing positive displacement motors

A test circuit incorporating a controlled flow source similar to that shown in Figure 3 shall be used.



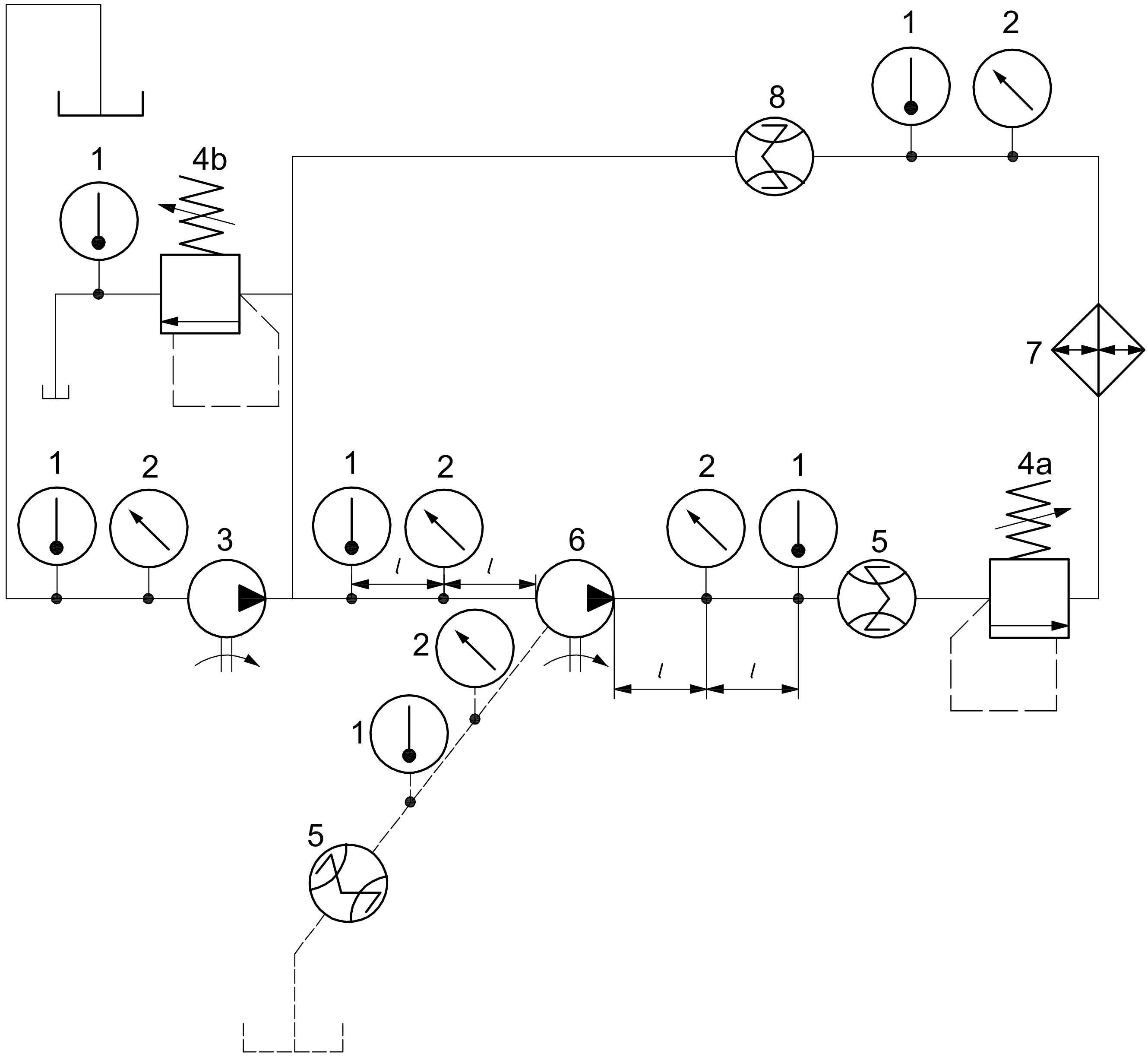
Key

1	temperature-measuring device
2	pressure-measuring device
3	unit under test
4	integrating flow meter
5	pressure control valve
6	temperature controller
7	integrating flow meter (alternative position)

NOTE 1 See 6.6 for the location of pressure and temperature measuring points.

NOTE 2 The part of the circuit shown with dashed lines is used only if the unit under test requires a casing drain.

Figure 1 — Open-circuit test circuit for pumps



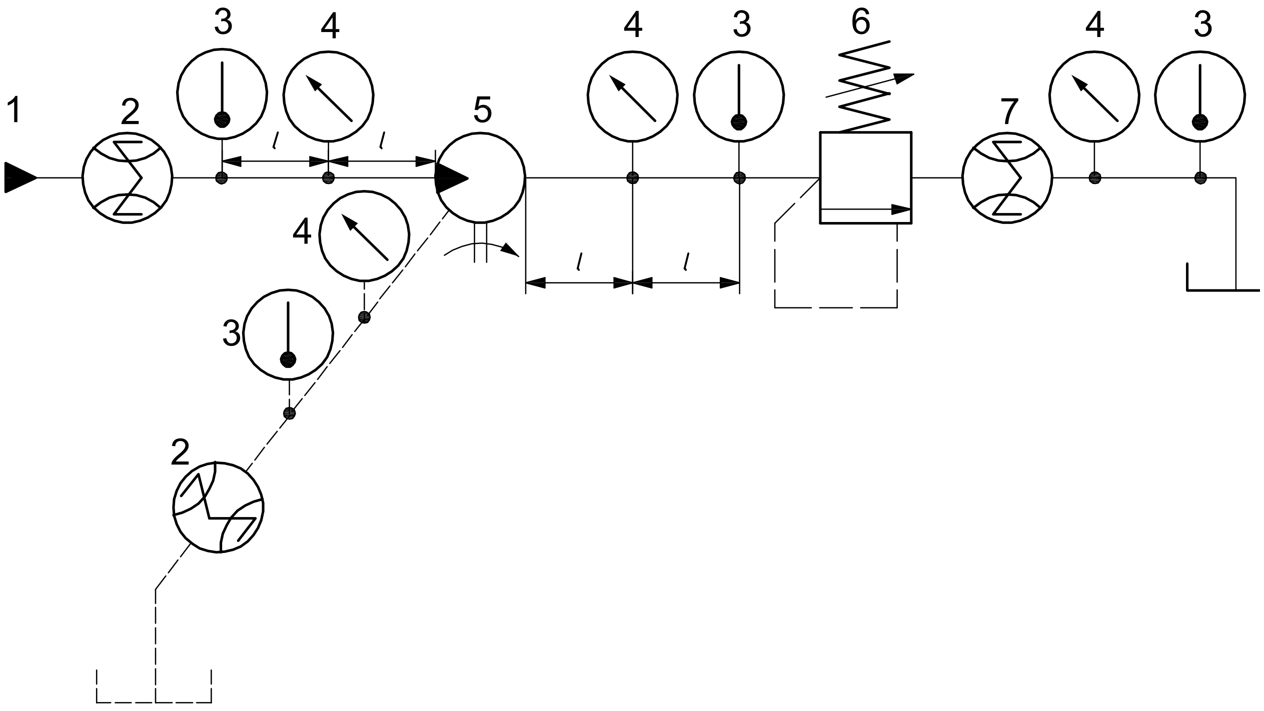
Key

1 temperature-measuring device
2 pressure-measuring device
3 boost pump
4 pressure control valve (4a and 4b)
5 integrating flow meter
6 unit under test
7 temperature controller
8 integrating flow meter (alternative position)

NOTE 1 See 6.6 for the location of pressure and temperature measuring points.

NOTE 2 The part of the circuit shown with dashed lines is used only if the unit under test requires a casing drain.

Figure 2 — Closed-circuit test circuit for pumps



Key

1	controlled flow source
2	integrating flow meter
3	temperature-measuring device
4	pressure-measuring device
5	unit under test
6	pressure control valve
7	integrating flow meter (alternative position)

NOTE See 6.6 for the location of pressure and temperature measuring points.

Figure 3 — Test circuit for motors

6 General test conditions

6.1 Test fluid

Only a fluid approved by the manufacturer of the unit under test shall be used during testing and the test fluid used shall be stated in the test report.

The kinematic viscosity, υ, and the mass density, ρ, of the test fluid shall be recorded for the controlled temperature used during the test.

6.2 Test temperatures

Tests shall be carried out at fluid temperatures within the range recommended by the manufacturer of the unit under test. The temperature of the test fluid and the ambient temperature shall be maintained within the limits specified in Table 2.

Table 2 — Limits of permissible variation in the value of controlled parameters during a specified test condition

Controlled parameter	Limits of permissible variation in the value of controlled parameters for each class of measurement accuracy		
	A	B	C
Rotational frequency (%)	± 0,5	± 1	± 2
Flow rate (%)	± 0,5	± 1,5	± 2,5
Pressure, MPa (bar) gauge where $p < 0{,}15$ (1,5)	± 0,001 (± 0,01)	± 0,003 (± 0,03)	± 0,005 (± 0,05)
Pressure, MPa (bar) gauge where $p \geqslant 0{,}15$ (1,5)	± 0,05 (± 0,5)	± 0,15 (± 1,5)	± 0,25 (± 2,5)
Test fluid temperature (°C)	± 0,5	± 1	± 2
Ambient temperature (°C)	± 2,5	± 2,5	± 2,5

[a] See Annex A.

As a minimum, the following shall be recorded for each test condition:

a) test fluid temperature at the inlet of the unit under test;

b) test fluid temperature at the outlet of the unit under test;

c) test fluid temperature at the flow rate measurement point;

d) ambient test area temperature.

6.3 Casing pressure

If the casing pressure (i.e. the fluid pressure within the casing of the unit under test) affects its performance, the casing pressure used during testing shall be maintained at a value recommended by the manufacturer and that value shall be recorded in the test report.

6.4 Steady-state conditions

Each set of measurements shall be taken only when the values of the controlled parameters are within the limits given in Table 2.

6.5 Volume flow rate

The volume flow rate of the test unit shall be measured adjacent to the motor inlet port, $q_{V1,\mathrm{e,m}}$, or pump outlet port, $q_{V2,\mathrm{e,p}}$, as appropriate, and the corresponding test fluid temperature and pressure shall be recorded.

6.6 Pressure and temperature measuring point locations

Pressure measuring points shall be located in the tubes adjacent to the unit under test and no less than $2d$ and no more than $4d$ from the port face of the unit.

Temperature measuring points shall be located in the tubes adjacent to the pressure measuring points, no less than $2d$ and no more than $4d$ from the corresponding pressure measuring point and further removed from the unit under test.

Greater distances may be used provided consideration is given to the effect of pressure losses in the tube.

7 Test and evaluation procedures

7.1 General

7.1.1 This International Standard applies to units that can be used either as hydraulic positive-displacement pumps or hydraulic positive-displacement motors. Units intended to be used as motors shall be tested as motors and units intended to be used as pumps shall be tested as pumps. The derived capacity determined when a given unit is tested as a motor can differ from that determined when the unit is tested as a pump.

7.1.2 The number of readings taken and their disposition over the measurement range shall be selected so as to give a representative indication of the unit's performance over its full operating range.

7.1.3 If flow rate measurements are made at an alternative location and not at the port face of the unit under test (i.e. the pump outlet or motor inlet), the corresponding test fluid temperature and pressure at the alternative location shall be recorded and the flow rate at the alternative location corrected to reflect the flow rate at the port face of the unit under test. These corrections shall be made in accordance with procedures specified in ISO 4409.

NOTE Flow rate corrections are necessary to compensate for differences in temperature and pressure between the port face of the unit under test and the alternative flow rate measurement location.

7.2 Positive displacement pumps

7.2.1 During each test, the input shaft rotational frequency and outlet test fluid temperature shall be maintained within the limits specified in Table 2.

7.2.2 If the unit under test is of the variable-capacity type, carry out the tests at the maximum capacity setting and at any other settings as are considered necessary (e.g. 75 %, 50 % and 25 %).

7.2.3 If the unit under test is to be operated in an overcentre (i.e. reverse flow) or reverse direction of rotation mode, a modification to the test circuit as shown in Figures 1 and 2 is required. The circuit as shown is appropriate only for testing in a single direction of fluid flow.

7.2.4 Determine, by measurement, the outlet flow rate, $q_{V2,\mathrm{e}}$, for outlet pressure, p_2, for the increments specified in Table 3.

Table 3 — Positive-displacement pump- and motor-test pressures

Measurement accuracy class	Number of outlet pressures measured	Outlet test pressure over full continuous rated pressure range
A	10 or more	In equal increments
B	5 or more	In equal increments
C	3 or more	At 20 %, 50 % and 100 % of maximum rated pressure of the unit under test

7.2.5 Calculate the derived capacity, V_i, for each set of input shaft rotational frequency, fluid inlet temperature and capacity test conditions, using the method specified in Annex B.

7.3 Positive displacement motors

7.3.1 During each test, the output shaft rotational frequency and inlet fluid temperature shall be maintained within the limits specified in Table 2.

7.3.2 If the unit under test is of the variable-capacity type, carry out the tests at the maximum capacity setting and at any other settings as considered necessary (e.g. 75 %, 50 % and 25 %).

7.3.3 If the unit under test is to be operated in an overcentre (i.e. reverse flow) or reverse direction of rotation mode, a modification to the test circuit as shown in Figure 3 is required. The circuit as shown is appropriate for testing in a single direction of fluid flow.

7.3.4 Determine, by measurement, the inlet flow rate, $q_{V1,\mathrm{e}}$, for inlet pressure, p_1, for the increments specified in Table 3.

7.3.5 If an alternative flow rate measurement location is selected on the motor outlet, and the unit under test is of the type with an external drain that is returned to the reservoir, flow from the motor outlet and the case outlet shall be corrected for pressure and temperature as specified in 7.1 and summed to obtain the equivalent value for the motor input flow rate.

7.3.6 Calculate the derived capacity, V_i, for each set of output shaft rotational frequency, fluid inlet temperature and capacity test conditions, using the method specified in Annex B.

8 Test report

8.1 General

A test report shall be drawn up and shall, at a minimum, include the following:

a) time and location of the test;

b) name of test operator and/or responsible engineer;

c) description of the unit under test, including model and serial number, if available;

d) measurement accuracy class (see Annex A);

e) ambient temperature of the test area (see 5.1.2);

f) test circuit filtration details (see 5.1.3);

g) description of the test circuit, including location of flow-meters (see 5.2);

h) details of test fluid (i.e. its classification in accordance with ISO 6743-4, its kinematic viscosity in accordance with ISO 3448, and its mass density) (see 6.1);

i) inlet test temperatures (see 6.2);

j) casing fluid pressure, if appropriate (see 6.3).

8.2 Presentation of test results

8.2.1 The derived capacity of a positive displacement pump or motor forms the basis for the determination of the volumetric and mechanical efficiency of the unit under test in accordance with ISO 4409. It is, therefore, a most important value and shall be determined by using the most accurate means that are economically possible to apply. Because of the importance of derived capacity, the test data shall be presented in numeric form and the final value determined by calculation. Graphical presentation shall be considered acceptable only when the scale for the displacement per revolution is large enough to meet the standard of accuracy required.

8.2.2 As a minimum, the following shall be presented:

a) inlet pressure;

b) outlet pressure;

c) shaft rotational frequency;

d) flow rate, either

   1) pump outlet flow rate, or

   2) motor inlet flow rate;

e) time interval for flow rate measurements;

f) test fluid temperature.

8.2.3 From the data obtained by test, at least the following shall be determined and presented:

a) pressure differential across the test unit, expressed in megapascals (bar);

b) flow rate, expressed in litres per minute;

c) actual shaft rotational frequency, expressed in revolutions per minute or revolutions per unit time;

d) kinematic viscosity of the test fluid, expressed in square millimetres per second;

e) mass density of the test fluid;

f) calculated derived capacity (fluid displacement per revolution), expressed in litres per revolution.

9 Identification statement (reference to this International Standard)

It is strongly recommended to manufacturers who have chosen to conform to this International Standard that the following statement be used in test reports, catalogues and sales literature:

"Derived capacity determined in accordance with ISO 8426:2008, *Hydraulic fluid power — Positive displacement pumps and motors — Determination of derived capacity*".

Annex A
(normative)

Measurement accuracy classes

A.1 Measurement accuracy classes

Depending on the accuracy required, the tests shall be carried out in accordance with one of the three classes A, B or C, as agreed by the parties concerned.

NOTE 1 Classes A and B are intended for special cases when there is a requirement to have performance more precisely defined.

NOTE 2 Attention is drawn to the fact that Class A and B tests require more accurate apparatus and methods, which increase the costs of such tests.

A.2 Errors

Any device or method used shall, by calibration or comparison with International Standards, be capable of measuring with systematic errors not exceeding the limits given in Table A.1.

Table A.1 — Permissible systematic measuring instrument errors

Parameter	Permissible systematic measuring instrument errors for each class of measurement accuracy		
	A	B	C
Rotational frequency (%)	± 0,5	± 1	± 2
Flow rate (%)	± 0,5	± 1,5	± 2,5
Pressure, MPa (bar) gauge where $p <$ 0,15 (1,5)	± 0,001 (± 0,01)	± 0,003 (± 0,03)	± 0,005 (± 0,05)
Pressure, MPa (bar) gauge where $p \geqslant$ 0,15 (1,5)	± 0,05 (± 0,5)	± 0,15 (± 1,5)	± 0,25 (± 2,5)
Test fluid temperature (°C)	± 0,5	± 1	± 2

NOTE 1 The percentage limits given in Table A.1 relate to the value of the quantity being measured and not to the maximum values of the test or the maximum reading of the instrument.

NOTE 2 The mean indicated value of an instrument reading can differ from the true mean absolute value of the quantity being measured because of inherent and constructional limitations of the instrument and because of the limitations of its calibrations; this source of uncertainty is called “systematic error”.

Annex B
(normative)

Calculation of derived capacity using the zero-pressure intercept method

B.1 General

Flow rate shall be recorded for a pressure range over which the capacity (i.e. displacement per shaft revolution) is nominally constant. If the results of initial calculations for derived capacity do not conform to a nominally constant value over the continuously rated pressure range specified by the manufacturer, the tests should be repeated at increased inlet pressure when testing a pump, or at increased outlet pressure when testing a motor.

It shall be confirmed that deviations of the derived capacity are not attributable to errors in test fluid temperature control or to errors in the measurement or control of any other parameter. Suspect values shall be re-evaluated at the appropriate conditions to determine if the data were in error or an anomaly in expected performance actually exists at the specific test conditions. If a test results in suspect values, a re-test shall be carried out at the appropriate conditions.

B.2 Principle of calculating derived capacity, V_i

The derived capacity of a positive-displacement hydraulic pump or motor is determined from the measured pump outlet flow rate or motor inlet flow rate, q, at a number of pump outlet or motor inlet pressures, p (see Figure B.1).

Using the least squares approximation and establishing the best linear relationship between q and p for the specified pressure range, after first discarding any obvious random errors, the derived capacity, V_i, is established as the zero-pressure intercept of the characteristic curve of q versus Δp for a pressure range over which the displacement is nominally constant (see Figure B.1).

For each set of test conditions (i.e. shaft rotational frequency, test fluid temperature and capacity of the unit under test), the derived capacity, V_i, expressed in litres per revolution, shall be determined by the least squares method as shown in Equations (B.1) and (B.2):

$$V_i = \frac{q_i}{n} \text{ where } \Delta p = 0 \qquad \text{(B.1)}$$

$$V_i = \left\{ \left(\frac{1}{k} \cdot \sum_{i=1}^{k} q_i \right) - \left[\frac{\frac{1}{k} \cdot \sum_{i=1}^{k} (\Delta p_i . q_i) - \frac{1}{k^2} \cdot \left(\sum_{i=1}^{k} \Delta p_i \right) \left(\sum_{i=1}^{k} q_i \right)}{\left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i^2 \right) - \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i \right)^2} \right] \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i \right) \right\} \frac{1}{n} \qquad \text{(B.2)}$$

where

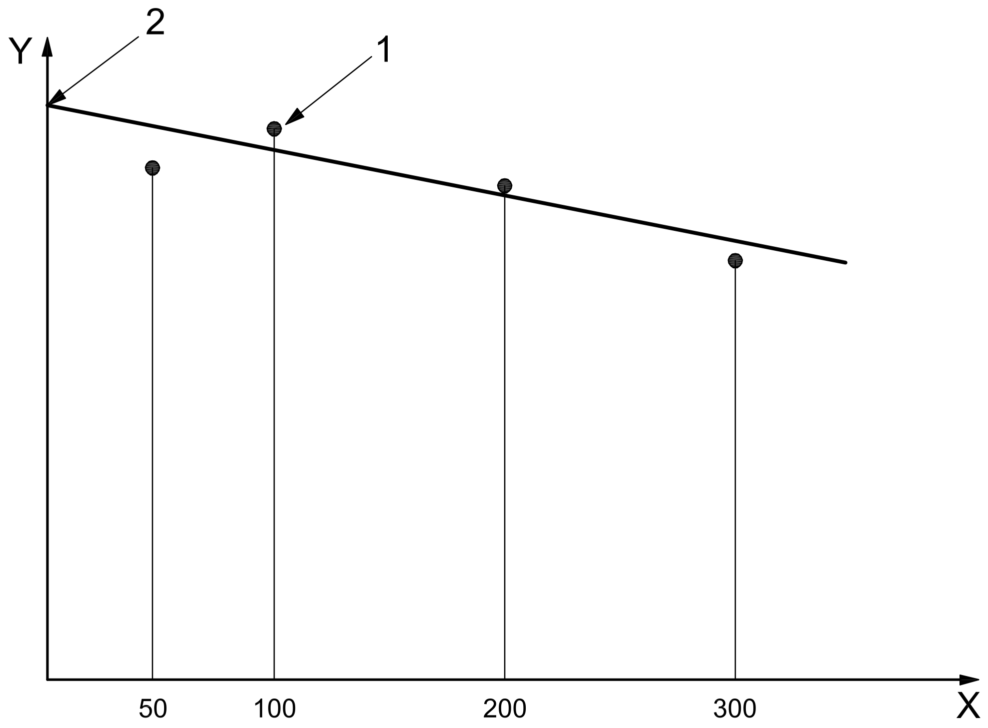
q_i is the flow rate at $\Delta p = 0$, expressed in litres per minute;

n is the shaft rotational frequency, expressed in revolutions per minute;

Δp is the differential pressure, that is, the difference between the outlet and inlet pressures, expressed in megapascals (bar);

Δp_i is the differential pressure at a particular pump outlet or motor inlet pressure level, expressed in megapascals (bar);

k is the number of pump outlet or motor input pressures used during the test.



Key

X	pump outlet or motor inlet differential pressure, Δp
Y	flow rate, q
1	measured flow rate at Δp_k, q_k
2	extrapolated flow rate when $\Delta p = 0$

Figure B.1 — Example of the determination of derived capacity using the zero-pressure intercept method

Bibliography

[1] ISO 4391, *Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols*

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