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

Transmissions hydrauliques — Pompes, moteurs et variateurs volumétriques — Méthodes d'essai et de présentation des données de base du fonctionnement en régime permanent

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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 4409 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 4409:1986), 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. Pumps are components that convert rotary mechanical power into hydraulic fluid power. Motors are components that convert hydraulic fluid power into rotary mechanical power. Integral transmissions (hydraulic drive units) are a combination of one or more hydraulic pumps and motors and appropriate controls forming a component.

With very few exceptions, all hydraulic fluid power pumps and motors are of the positive-displacement type, i.e. they have internal sealing means that make them capable of maintaining a relatively constant ratio between rotational speed and fluid flow over wide pressure ranges. They generally use gears, vanes or pistons. Non-positive displacement components, such as centrifugal or turbine types, are seldom associated with hydraulic fluid power systems.

Pumps and motors are available either as “fixed-” or “variable-displacement” types. Fixed-displacement units have pre-selected internal geometries that maintain a relatively constant volume of liquid passing through the component per revolution of the component's shaft. Variable-displacement components have means for changing the internal geometries so that the volume of liquid passing through the component per revolution of the component's shaft can be changed.

This International Standard is intended to unify testing methods for hydraulic fluid power positive displacement hydraulic pumps, motors and integral transmissions to enable the performance of the different components to be compared.

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

1 Scope

This International Standard specifies methods for determining the performance and efficiency of hydraulic fluid power positive displacement pumps, motors and integral transmissions. It applies to components having continuously rotating shafts.

This International Standard specifies the requirements for test installations, test procedures under steady-state conditions and the presentation of test results.

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 31, *Quantities and units*

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

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

ISO 9110-1, *Hydraulic fluid power — Measurement techniques — Part 1: General measurement principles*

ISO 9110-2, *Hydraulic fluid power — Measurement techniques — Part 2: Measurement of average steady-state pressure in a closed conduit*

3 Terms and definitions

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

NOTE When there is no risk of ambiguity (i.e. when a test has been carried out on a pump or a motor), the superscripts “P,” “M” and “T” specifying that the quantity concerns, respectively, a pump, a motor or an integral transmission, can be omitted.

3.1
volume flow rate
q_V
volume of fluid crossing the transverse plane of a flow path per unit time

3.2
drainage flow rate
q_{V_d}
volume flow rate from the casing of a component

3.3
pump effective outlet flow rate
$q_{V_{2,\mathrm{e}}}^{\mathrm{P}}$
actual flow rate at temperature $\theta_{2,\mathrm{e}}$ and pressure $p_{2,\mathrm{e}}$ measured at the pump outlet

NOTE If the flow rate is measured anywhere other than at the pump outlet at temperature θ and pressure p, that flow rate is corrected to give the effective outlet flow rate value by using Equation (1).

$$q_{V_{2,\mathrm{e}}}^{\mathrm{P}} = q_V \left[1 - \left(\frac{p_{2,\mathrm{e}} - p}{\bar{K}_\mathrm{T}} \right) + \alpha \left(\theta_{2,\mathrm{e}} - \theta \right) \right] \quad (1)$$

3.4
motor effective inlet flow rate
$q_{V_{1,\mathrm{e}}}^{\mathrm{M}}$
actual flow rate at temperature $\theta_{1,\mathrm{e}}$ and pressure $p_{1,\mathrm{e}}$ measured at the motor inlet

NOTE 1 If the flow rate is measured anywhere other than at the motor inlet at temperature θ and pressure p, that flow rate is corrected to give the effective inlet flow rate value by using Equation (2).

$$q_{V_{1,\mathrm{e}}}^{\mathrm{M}} = q_V \left[1 - \left(\frac{p_{1,\mathrm{e}} - p}{\bar{K}_\mathrm{T}} \right) + \alpha \left(\theta_{1,\mathrm{e}} - \theta \right) \right] \quad (2)$$

NOTE 2 If the flow rate is measured at the motor outlet and the motor has external drainage, the motor flow rate q_v and the drainage flow rate, $q_{V_\mathrm{d}}^{\mathrm{M}}$, shall be corrected to refer to the inlet flow rate temperature θ and pressure p used for computing $q_{V_{1,\mathrm{e}}}^{\mathrm{M}}$ by using Equation (3).

$$q_{V_{1,\mathrm{e}}}^{\mathrm{M}} = q_V \left[1 - \left(\frac{p_{1,\mathrm{e}} - p}{\bar{K}_\mathrm{T}} \right) + \alpha \left(\theta_{1,\mathrm{e}} - \theta \right) \right] + q_{V_\mathrm{d}} \left[1 - \left(\frac{p_{1,\mathrm{e}} - p_\mathrm{d}}{\bar{K}_\mathrm{T}} \right) + \alpha \left(\theta_{1,\mathrm{e}} - \theta_\mathrm{d} \right) \right] \quad (3)$$

3.5
derived capacity
V_i
volume of fluid displaced by a pump or motor per shaft revolution, calculated from measurements at different speeds under test conditions

[ISO 8426]

3.6
rotational frequency
shaft speed
n
number of revolutions of the drive shaft per unit of time.

NOTE The direction of rotation (clockwise or counter-clockwise) is specified from the point of view of the observer looking at the end of the shaft. It may also be defined by diagram, if necessary.

3.7
torque
T
measured value of the torque in the shaft of the test component

3.8
effective pressure
p_e
fluid pressure, relative to atmospheric pressure, having a value that is

a) positive, if this pressure is greater than atmospheric pressure, or

b) negative, if this pressure is less than atmospheric pressure.

3.9
drainage pressure
p_d
pressure, relative to atmospheric pressure, measured at the outlet of the component casing drainage connection

3.10
mechanical power
P_m
product of the torque and rotational frequency measured at the shaft of a pump or motor as given by Equation (4):

$$P_m = 2\pi \cdot n \cdot T \quad (4)$$

3.11
hydraulic power
P_h
product of the flow rate and pressure at any point as given by Equation (5):

$$P_h = q_V \cdot p \quad (5)$$

3.12
effective outlet hydraulic power of a pump
$P_{2,h}^P$
total pump hydraulic outlet power given by Equation (6).

$$P_{2,h}^P = q_{V_{2,e}} \cdot p_{2,e} \quad (6)$$

3.13
effective inlet hydraulic power of a motor
$P_{1,h}^M$
total motor inlet hydraulic power as given by Equation (7):

$$P_{1,h}^M = q_{V_{1,e}} \cdot p_{1,e} \quad (7)$$

NOTE The total energy of a hydraulic fluid is the sum of the various energies contained in the fluid. In Equations (6) and (7) the kinetic, positional and strain energies of the fluid are ignored and the power is calculated using the static pressure only. If these other energies have a significant effect on the test results, due account should be taken of them.

3.14
pump overall efficiency
η_t^P
ratio of the power transferred to the liquid, during its passage through the pump, to the mechanical input power as given by Equation (8):

$$\eta_t^P = \frac{\left(q_{V_{2,e}} \cdot p_{2,e}\right) - \left(q_{V_{1,e}} \cdot p_{1,e}\right)}{2\pi \cdot n \cdot T} \qquad (8)$$

3.15
pump volumetric efficiency
η_V^p
ratio of the actual output flow available for work to the product of the pump-derived capacity, V_i, and shaft rotational frequency, n, at defined conditions as given by Equation (9):

$$\eta_V^P = \frac{q_{V_{2,e}}}{V_i^P \cdot n} \qquad (9)$$

3.16
motor overall efficiency
η_t^M
ratio of the mechanical output power at the motor shaft to the hydraulic input power to the motor as given by Equation (10):

$$\eta_t^M = \frac{2\pi \cdot n \cdot T}{\left(q_{V_{1,e}} \cdot p_{1,e}\right) - \left(q_{V_{2,e}} \cdot p_{2,e}\right)} \qquad (10)$$

3.17
motor volumetric efficiency
η_V^M
ratio of the product of motor-derived capacity, V_i, and shaft rotational frequency, n, to the actual input flow required for work at defined conditions as given by Equation (11):

$$\eta_V^M = \frac{V_i^M \cdot n}{q_{V_{1,e}}} \qquad (11)$$

3.18
motor hydro-mechanical efficiency
η_{hm}^M
ratio of the torque in the shaft of the motor to the theoretical torque of the motor as given by Equation (12):

$$\eta_{hm}^M = \frac{T}{T_{th}} = \frac{2\pi \cdot n \cdot T}{\left(p_{1,e} - p_{2,e}\right) V_i^M} \qquad (12)$$

3.19
integral transmission overall efficiency
η_t^T
ratio of the output mechanical power to the input mechanical power as given by Equation (13):

$$\eta_t^T = \frac{n_2 \cdot T_2}{n_1 \cdot T_1} \qquad (13)$$

3.20
integral transmission rotational frequency ratio
r
ratio of output rotational frequency, n_2, to input rotational frequency, n_1, at defined conditions as given by Equation (14):

$$r = \frac{n_2}{n_1} \tag{14}$$

4 Symbols and units

The symbols and units, in accordance with ISO 31 (all parts), used throughout this International Standard are as shown in Table 1.

The letters and figures used as subscripts to the symbols listed in Table 1 are as specified in ISO 4391.

The graphical symbols used in Figures 1, 2, 3 and 4 are in accordance with ISO 1219-1.

Table 1 — Symbols and units

Quantity	Symbol	Unit [a]
Volume flow rate	q_V	$m^3\ s^{-1}$
Derived capacity	V_i	$m^3\ r^{-1}$
Rotational frequency	n	r^{-1}
Torque	T	N·m
Effective pressure	p_e	Pa
Power	P	W
Mass density	ρ	$kg\ m^{-3}$
Isothermal bulk modulus secant	$\bar{K}_T$	Pa [b]
Kinematic viscosity	ν	$m^2\ s^{-1}$
Temperature	θ	K
Volume coefficient of thermal expansion	α	K^{-1}
Efficiency	η	—
Rotational frequency ratio	R	—

[a] The use of practical units for the presentation of results is described in Annex A.

[b] 1 Pa = 1 N/m^2.

5 Tests

5.1 Requirements

5.1.1 General

Installations shall be designed to prevent air entrainment during operation and measures shall be taken to remove all free air from the system before testing.

The unit under test shall be installed and operated in the test circuit in accordance with the manufacturer's instructions; see also Annex C.

The ambient temperature of the test area shall be recorded.

A filter shall be installed in the test circuit to provide the fluid-cleanliness level specified by the manufacturer of the unit under test. The position, number and specific description of each filter used in the test circuit shall be recorded.

Where pressure measurements are made within a pipe, the requirements of ISO 9110-1 and ISO 9110-2 shall be met.

Where temperature measurements are made within a pipe, the temperature-tapping point shall be positioned between two and four times the pipe diameter from the pressure-tapping point furthest away from the component.

Figures 1, 2, 3 and 4 illustrate basic circuits that do not incorporate all the safety devices necessary to protect against damage in the event of any component failure. It is important that those responsible for carrying out the test give due consideration to safeguarding both personnel and equipment.

5.1.2 Installation of the unit under test

Install the unit to be tested in the test circuit in accordance with the applicable Figure 1, 2, 3 or 4.

5.1.3 Condition of the unit under test

If necessary and before tests are carried out, the unit to be tested shall be "run in" in accordance with the manufacturer's recommendations.

5.1.4 Test fluids

Because the performance of the unit under test can vary considerably with the viscosity of the test fluid used, a fluid approved by the manufacturer of the unit being tested shall be used.

The following fluid parameters shall be recorded:

a) kinematic viscosity;

b) mass density at the test temperature;

c) isothermal secant bulk modulus;

d) volume coefficient of thermal expansion.

5.1.5 Temperatures

5.1.5.1 Controlled temperature

Tests shall be carried out at a stated test fluid temperature. The test-fluid temperature shall be measured at the inlet port of the unit under test and be within the range recommended by the manufacturer.

The test fluid temperature shall be maintained within the limits stated in Table 2.

Table 2 — Indicated test fluid temperature tolerance

Measurement accuracy class (see Annex B)	A	B	C
Temperature tolerance (°C)	± 1,0	± 2,0	± 4,0

5.1.5.2 Other temperatures

The fluid temperature shall be recorded at the following locations:

a) at the outlet port of the unit under test;

b) at the flow measurement point in the test circuit;

c) in the drainage fluid line (if applicable).

The test-area ambient temperature shall be recorded.

For an integral transmission, it might not be possible to measure all the temperatures required. Temperatures not recorded shall be noted in the test report.

5.1.6 Atmospheric pressure

The ambient absolute atmospheric pressure of the test area shall be recorded.

5.1.7 Casing pressure

If the fluid pressure within the casing of the component under test can affect its performance, the fluid-pressure value used for the test shall be recorded.

5.1.8 Steady-state conditions

Each set of readings taken for a controlled value of a selected parameter shall be recorded only where the indicated value of the controlled parameter is within the limits shown in Table 3. If multiple readings of a variable are recorded, all readings shall be noted while the controlled parameter is within the operating limits. The maximum suggested time period to acquire all readings is 10 s.

Table 3 — Permissible variation of mean indicated values of controlled parameters

Parameter	Permissible variation for classes of measurement accuracy[a] (see Annex B)		
	A	B	C
Rotational frequency, %	± 0,5	± 1,0	± 2,0
Torque, %	± 0,5	± 1,0	± 2,0
Volume flow rate, %	± 0,5	± 1,5	± 2,5
Pressure, Pa ($p_e < 2 \times 10^5$ Pa)[b]	$\pm 1 \times 10^3$	$\pm 3 \times 10^3$	$\pm 5 \times 10^3$
Pressure, % ($p_e \geqslant 2 \times 10^5$ Pa)	± 0,5	± 1,5	± 2,5

a The permissible variations listed in this table concern deviation of the indicated instrument reading and do not refer to limits of error of the instrument reading; see Annex B. These variations are used as an indicator of steady state, and are also used where graphical results are presented for a parameter of fixed value. The actual indicated value should be used in any subsequent calculation of power or efficiency.

b 1 Pa = 1 N/m^2.

5.1.9 Test measurements

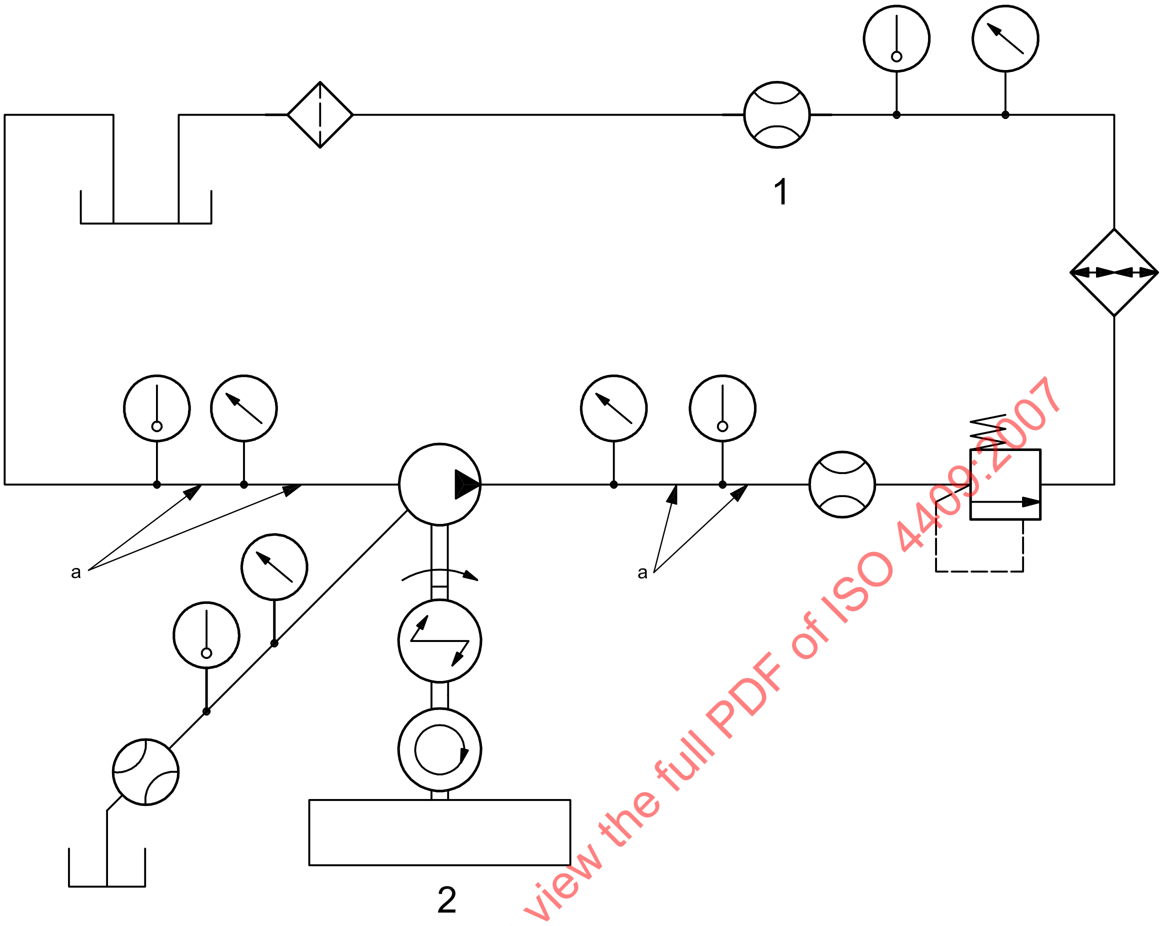
The number of sets of readings to be taken and their disposition over the range shall be selected in order to give a representative indication of the performance of the unit under test over the full range of the quantity being varied.

5.2 Pump tests

5.2.1 Test circuits

5.2.1.1 Open-circuit tests

A test circuit configured in accordance with and containing at least the components shown in Figure 1 shall be used. Where a pressurized inlet condition is required, a suitable means shall be provided to maintain the inlet pressure within the specified limits (see 5.2.2).



Key

1 alternative position

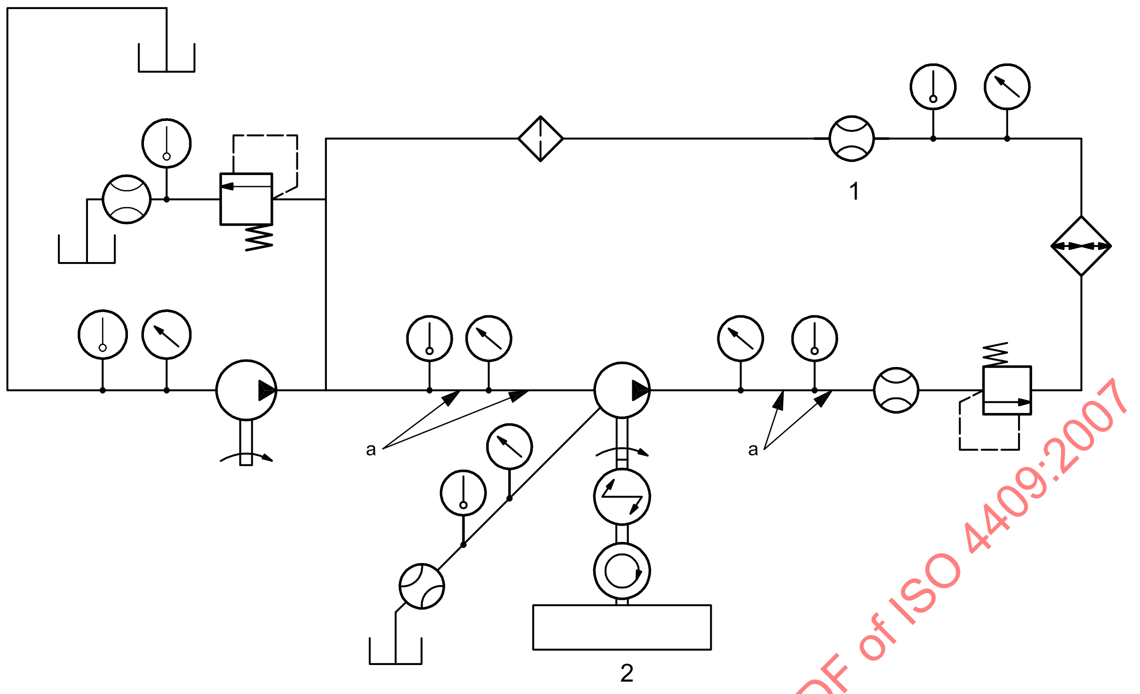
2 driver

a For pipe lengths see 5.1.1.

Figure 1 — Test circuit for pump unit (open circuit)

5.2.1.2 Closed-circuit tests

A test circuit configured in accordance with and containing at least the components shown in Figure 2 shall be used. In this circuit, the boost pump provides a flow slightly in excess of the total circuit losses. A greater flow may be provided for cooling purposes.



Key

1 alternative position

2 driver

[a] For pipe lengths, see 5.1.1.

Figure 2 — Test circuit for pump unit (closed circuit)

5.2.2 Inlet pressure

During each test, maintain the inlet pressure constant (see Table 3) at a stated value within the permissible range of inlet pressures specified by the manufacturer.

If required, carry out the tests at different inlet pressures.

5.2.3 Test measurements

Record measurements of

a) input torque;

b) outlet flow rate;

c) drainage flow rate (where applicable);

d) fluid temperature.

Test at a constant rotational frequency (see Table 3) and at a number of outlet pressures so as to give a representative indication of the pump performance over the full range of outlet pressures.

Repeat measurements 5.2.3 a) to d) at other rotational frequencies to give a representative indication of the pump performance over the full range of rotational frequencies.

5.2.4 Variable capacity

If the pump is of the variable capacity type, carry out complete tests at its maximum capacity setting and any other settings as required (e.g. 75 %, 50 % and 25 % of the maximum capacity setting). Each of these settings shall give the required percentage of the flow rate at the minimum outlet pressure at the minimum rotational frequency specified for the test.

5.2.5 Reverse flow

If the direction of flow through the pump can be reversed (e.g. by means of a capacity control), carry out tests in both directions of flow.

5.2.6 Non-integral boost pumps

If the pump under test is associated with a separate boost pump and the power inputs can be measured separately, the pumps shall be tested and the results presented independently.

5.2.7 Full-flow, integral boost pump

If the boost pump is integral with the pump under test, which results in the power inputs being inseparable, and the boost pump delivers the full flow of the main pump, the two pumps shall be treated as one integral unit and the results presented accordingly.

NOTE The inlet pressure being measured is boost pump inlet pressure.

Any excess flow from the boost pump shall be measured and recorded.

5.2.8 Secondary-flow, integral boost pump

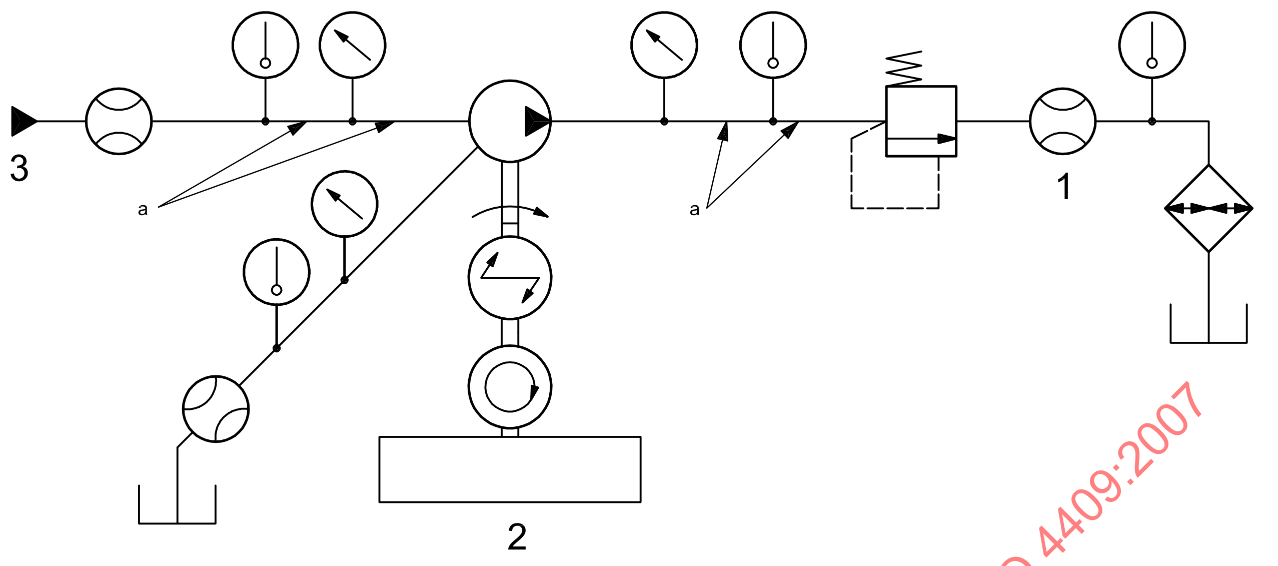
If the boost pump is integral with the main pump, which results in the power inputs being inseparable, but the boost pump supplies only a secondary flow to the hydraulic circuit of the main pump and the remainder is by-passed or used for an auxiliary service (e.g. cooling circulation), then, where practicable, the flows from the boost pump shall be measured and recorded.

5.3 Motor tests

5.3.1 Test circuit

A test circuit configured in accordance with and containing at least the components shown in Figure 3 shall be used.

If the flow rate is measured downstream of the motor outlet (alternative position), the motor-case flow rate shall also be included in the calculation for the corrected flow rate.



Key

1 alternative position

2 load

3 controlled fluid supply

a For pipe lengths, see 5.1.1.

Figure 3 — Test circuit for motor unit

5.3.2 Outlet pressure

The outlet pressure from the motor shall be controlled (e.g. using a pressure control valve) so that a constant outlet pressure is maintained throughout the test, within the limits given in Table 3.

This outlet pressure shall meet the requirements of the envisaged motor application and the manufacturer's recommendations.

5.3.3 Test measurements

Measurements shall be taken of

a) inlet flow rate;

b) drainage flow rate (where applicable);

c) output torque;

d) test fluid temperature.

Test over the full rotational frequency range of the motor and at a number of different input pressures so as to give a representative indication of the motor performance over the full range of input pressures.

5.3.4 Variable capacity

If the motor is of the variable-capacity type, carry out complete tests at its minimum and maximum capacity settings and such other settings, as required (e.g. 75 %, 50 % and 25 % of the maximum capacity setting).

Obtain the percentage capacity by setting the adjustment to give the required proportional rotational frequency for the same inlet flow rate with zero output torque. The flow rate shall be chosen so that at minimum capacity the motor runs at its maximum rotational frequency.

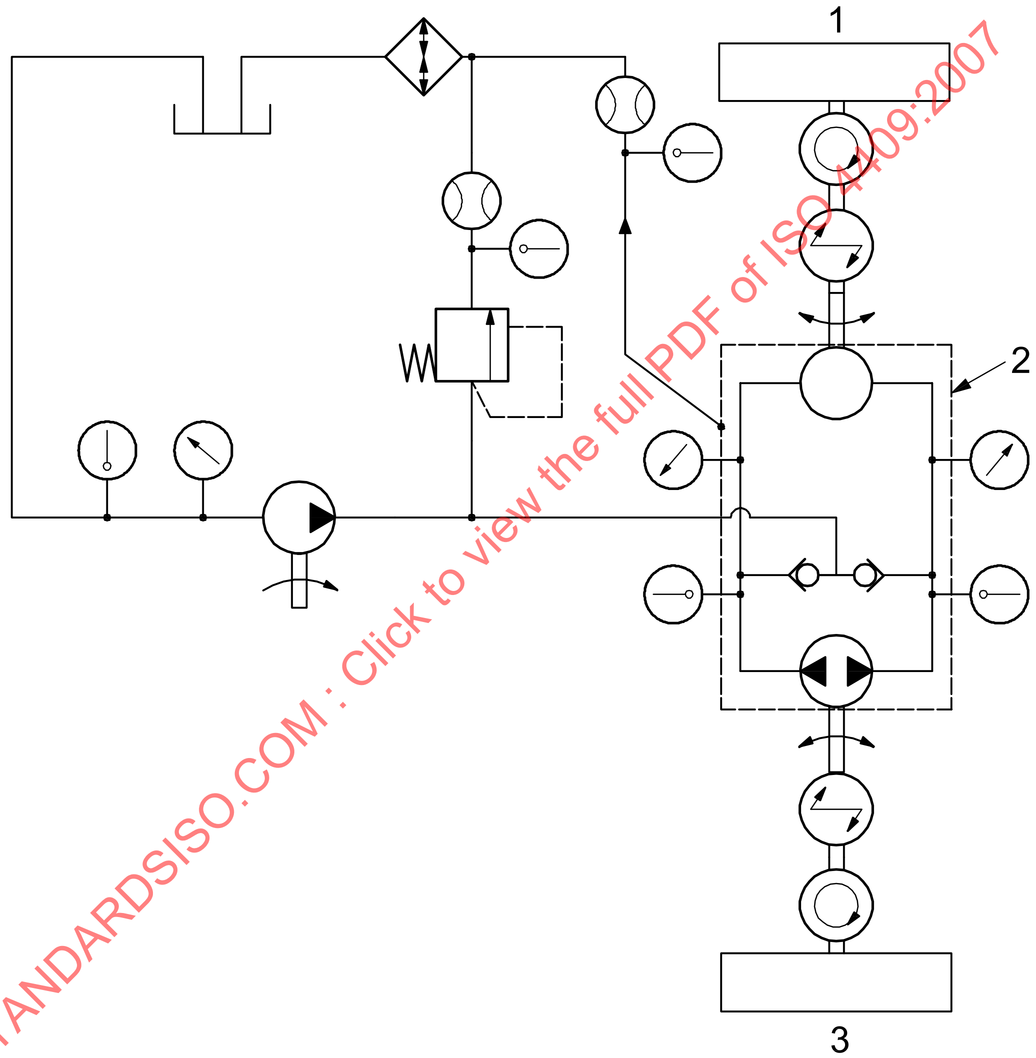
5.3.5 Reverse rotation

For motors that are required to operate in both directions of rotation, carry out tests in both directions.

5.4 Integral transmission tests

5.4.1 Test circuit

A test circuit configured in accordance with and containing at least the components shown in Figure 4 shall be used.



Key

1 load

2 integral transmission case

3 driver

Figure 4 — Integral transmission test circuit

5.4.2 Test measurements

The following test measurements shall be made with the integral transmission running at its maximum flow rate capacity for a specified input rotational frequency:

a) input torque;

b) output torque;

c) output rotational frequency

d) test fluid pressure;

e) test fluid temperature, where appropriate.

Test over a power range as recommended by the manufacturer for a specified input rotational frequency.

Repeat the measurements given in 5.4.2 a) to e) for several different input rotational frequencies within the limits specified in Table 3.

If the pump unit is of the variable-capacity type, repeat the measurements given in 5.4.2 a) to e) at flow rates equal to 75 %, 50 % and 25 % of the pump maximum flow rate capacity, with the motor set at its maximum flow rate capacity.

The pump flow-rate capacity shall be determined as the ratio of the output shaft frequency at reduced pump flow-rate capacity to the output shaft frequency at maximum pump flow rate capacity, with no load applied to the output shaft and with the motor set at its maximum flow rate capacity.

If the motor unit is of the variable-capacity type, repeat the measurements given in 5.4.2 a) to e) with the motor set at its minimum flow rate capacity.

5.4.3 Boost pumps

If boost pumps or other auxiliaries are integral with the transmission pump and driven by the same input shaft, the pumps shall be treated as one integral unit and this information shall be recorded in the test results.

If boost pumps or other auxiliaries are driven separately, their power requirements shall be excluded from the transmission performance and this information shall be recorded in the test results.

5.4.4 Reverse rotation

If the output shaft is required to operate in both directions of rotation, tests shall be performed in both directions.

6 Expression of results

6.1 General

All test measurements and the calculation results derived from them shall be tabulated by the testing agency and presented graphically.

6.2 Pump tests

6.2.1 Pumps tested at one constant, rotational frequency

For a pump tested at one constant rotational frequency, graphs shall be plotted of the effective outlet pressure ($p_{2,e}$) versus

a) volumetric efficiency,

b) overall efficiency,

c) effective outlet flow rate, and

d) effective inlet mechanical power.

In addition, the following parameters shall be recorded:

Parameter	Result	Units
Test fluid used		—
Temperature of the test fluid at the pump inlet		K
Kinematic viscosity of the test fluid used		$m^2 s^{-1}$
Density of the test fluid		$kg m^{-3}$
Effective pump inlet pressure		Pa
Percentage of pump full capacity at which the test was conducted		%
Rotational frequency of the pump at which the test was conducted		s^{-1}

6.2.2 Pumps tested at several different, constant rotational frequencies

For a pump tested at a number of constant rotational frequencies, the results for each different effective outlet pressure value, $p_{2,e}$, used in the test shall be presented as described in 6.2.1 or graphs shall be plotted of the rotational frequency versus

a) volumetric efficiency;

b) overall efficiency;

c) effective outlet flow rate; and

d) effective inlet mechanical power.

In addition, the following parameters shall be recorded:

Parameter	Result	Units
Test fluid used		—
Temperature of the test fluid at the pump inlet		K
Kinematic viscosity of the test fluid used		$m^2 s^{-1}$
Density of the test fluid		$kg m^{-3}$
Effective pump inlet pressure		Pa
Percentage of pump full capacity at which the test was conducted		%
Effective pump outlet pressure		Pa

6.3 Motor tests

For motors, graphs shall be plotted of the rotational frequency, n, versus the following for each different effective inlet pressure value, $p_{1,e}$, used in the test:

a) volumetric efficiency;

b) overall efficiency;

c) effective inlet flow rate;

d) output torque;

e) hydro-mechanical efficiency.

In addition the following parameters shall be recorded:

Parameter	Result	Units
Test fluid used		
Temperature of the test fluid at the pump inlet		K
Kinematic viscosity of the test fluid used		$m^2\ s^{-1}$
Density of test fluid		$kg\ m^{-3}$
Percentage of pump full capacity at which the test was conducted		%
Pump effective outlet pressure		Pa

6.4 Integral transmission tests

For testing an integral transmission, the transmission shall be tested at one constant input rotational frequency (constant input power) and a graph shall be plotted of the overall efficiency, η_t, versus the output rotational frequency, n_2.

The test shall be repeated for three different effective outlet powers, $P_{2,e}$.

In addition, the following parameters shall be recorded:

Parameter	Result	Units
Test fluid used		
Temperature of the test fluid at the pump inlet		K
Kinematic viscosity of the test fluid used		$m^2\ s^{-1}$
Density of test fluid		$kg\ m^{-3}$
Input rotational frequency		s^{-1}
Effective outlet power		W

In addition, a graph shall be plotted of the rotational frequency ratio, r, versus the effective pump outlet pressure, p_2.

In addition, the following parameters shall be recorded:

Parameter	Result	Units
Test fluid used		
Temperature of the test fluid at the pump inlet		K
Input rotational frequency		s^{-1}
Percentage of pump full capacity at which the test was conducted		%
Percentage of motor full capacity at which the test was conducted		%

7 Identification statement

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:

"Basic steady state performance data determined and presented in accordance with ISO 4409, *Hydraulic fluid power — Positive-displacement pumps, motors and integral transmissions — Methods of testing and presenting basic steady state performance*."

Annex A
(informative)

Use of practical units

A.1 Practical units

The test results may be presented in either tabular or graphical form using the practical units shown in Table A.1.

Table A.1 — Practical units

Quantity	Symbol	Practical unit
Volume flow rate	q_V	l min^{-1}
Rotational frequency	n	min^{-1}
Torque	T	N·m
Pressure	p	bar
Power	P	kW
Mass density	ρ	kg l^{-1}
Isothermal secant bulk modulus	$\overline{K}_T$	Pa (bar) [b]
Kinematic viscosity	ν	mm^2 s^{-1} [c]
Temperature	θ	°C
Total efficiency [a]	η	—

[a] Efficiency may also be stated as a percentage.

[b] 1 bar = 10^5 Pa.

[c] 1 cSt = 1 mm^2 s^{-1}.

A.2 Calculation

A.2.1 General

In order to present results in practical units (see Table A.1), Equations (4) to (8), and (10), (12) and (13) may be modified as shown in A.2.2 to A.2.7.

A.2.2 Mechanical power

$$P_m = \frac{2\pi \cdot n \cdot T}{60\,000}, \text{ expressed in kW} \qquad \text{(A.1)}$$

A.2.3 Hydraulic power

$$P_h = \frac{q_V \cdot p}{600}, \text{ expressed in kW} \qquad \text{(A.2)}$$