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Water hydraulics — Water-hydraulic pumps — Methods of testing and representing basic steady-state performance

Hydraulique à l'eau — Pompes hydrauliques avec de l'eau — Méthodes d'essai et représentation des performances de base en régime permanent

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Foreword

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Water hydraulics or water-hydraulic systems (hydraulic systems in which water is used as the power-transmitting medium in a fluid power system) have potential market demand as they facilitate maintaining cleanness and permit a reduction in fluid cost, machine size and fire risk. Applications of water hydraulics have been expanding into new fields which require cleanness, most notably the cleaning sector, animals and plants, food, packaging, cosmetics and semiconductors, amongst others. This is due to the environmental cleanliness of water compared with alternative hydraulic fluids, such as oil.

Although water hydraulics is a generally well-known concept, there are currently no International Standards specialized in water hydraulics. As the technology of water hydraulics is an emerging technology, it is considered a relevant topic for international standardization by related countries, including both developing countries as well as developed ones, and in particular by ISO/TC 131 (Fluid power systems), in order to accelerate the development of this technology.

The water-hydraulic pump is one of the key components of water hydraulics. The development of an appropriate International Standard for water-hydraulic pumps, which focuses on methods of testing and representing basic steady state performance, is therefore critical to business trade and/or product acceptance by consumers.

Water hydraulics — Water-hydraulic pumps — Methods of testing and representing basic steady-state performance

1 Scope

This document specifies methods for determining the performance and the efficiency of water-hydraulic positive displacement pumps having continuously rotating shafts. This document provides test equipment, a test procedure under steady-state conditions and the presentation of test results.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 4391, *Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4391 and ISO 5598 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
water-hydraulic pump
positive displacement pump that transforms mechanical energy into water-hydraulic energy with water as the system fluid

3.2
flow rate of the pump under test
flow rate measured at the outlet port of the pump under test

3.3
pump volumetric efficiency
ratio of the effective output flow rate to the derived output flow rate

3.4
hydromechanical pump efficiency
ratio of the derived torque to the effective torque

3.5
inlet gauge pressure of the pump under test
measured gauge pressure at or near the suction port of the pump under test

Note 1 to entry: The value of "inlet gauge pressure of the pump under test" shows either positive or negative.

3.6
outlet gauge pressure of the pump under test
measured gauge pressure at or near the delivery port of the pump under test

3.7
tap water
water supplied through pipes or tubes to taps/faucets

3.8
total dissolved solids
TDS
weight of inorganic and organic matter in true solution per unit volume of water

4 Symbols and units

For the purposes of this document, the symbols and units listed in Table 1 apply. In Table 1, as the unit of derived capacity and shaft speed, m^3 and s^{-1}, as well as m^3/rev and rev/s, may be used.

Table 1 — Symbols and units

Description	Symbols	Unit
Rotational frequency	n	rev/s
Inlet gauge pressure of the pump under test	$p_{e,i}$	Pa
Outlet gauge pressure of the pump under test	$p_{e,o}$	Pa
Flow rate of the pump under test	q_p	m^3/s
Water temperature	T_w	K
Effective torque	t_e	N·m
Derived capacity	V_i	m^3/rev
Pump overall efficiency	η_t	-
Hydromechanical pump efficiency	η_m	-
Pump volumetric efficiency	η_v	-

5 Water

Tap water can be used for the working fluid of water-hydraulic systems including a water-hydraulic pump.

6 Tests

6.1 Requirements

6.1.1 General

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

The tank height level should be designed to be higher than the pump suction port, in order to prevent the reduction of the suction pressure.

Tap water shall be supplied through a filter with the specified filtration performance (10 microns) to a hydraulic tank.

Figure 1 illustrates the basic circuit for the test of a water-hydraulic pump. This figure does not incorporate all the safety devices necessary to protect against damage in the event of any component fracture or fragmentation. Those who are responsible for carrying out the test shall give due consideration to safeguarding both personnel and equipment.

6.1.2 Installation of the unit under test

The test circuit shall be constructed in accordance with Figure 1.

6.1.3 Test fluid

Working fluid of water hydraulics shall be tap water. Additives shall not be added to the test fluid.

6.1.4 Temperature

Tests shall be carried out at a stated test fluid temperature. The test fluid temperature shall be measured in a tank or at the pump inlet. The position of the temperature measurement shall be determined by the manufacturer and user of the pump under test. Water temperature shall be controlled by a heat exchanger within the range recommended by the manufacturer. Measurements shall be made at temperature levels between 20 °C and 40 °C.

The test fluid temperature shall be maintained within the limits stated in Table 2. The temperature tolerance (either A, B, or C) shall be recorded.

Table 2 — Indicated test fluid temperature tolerance

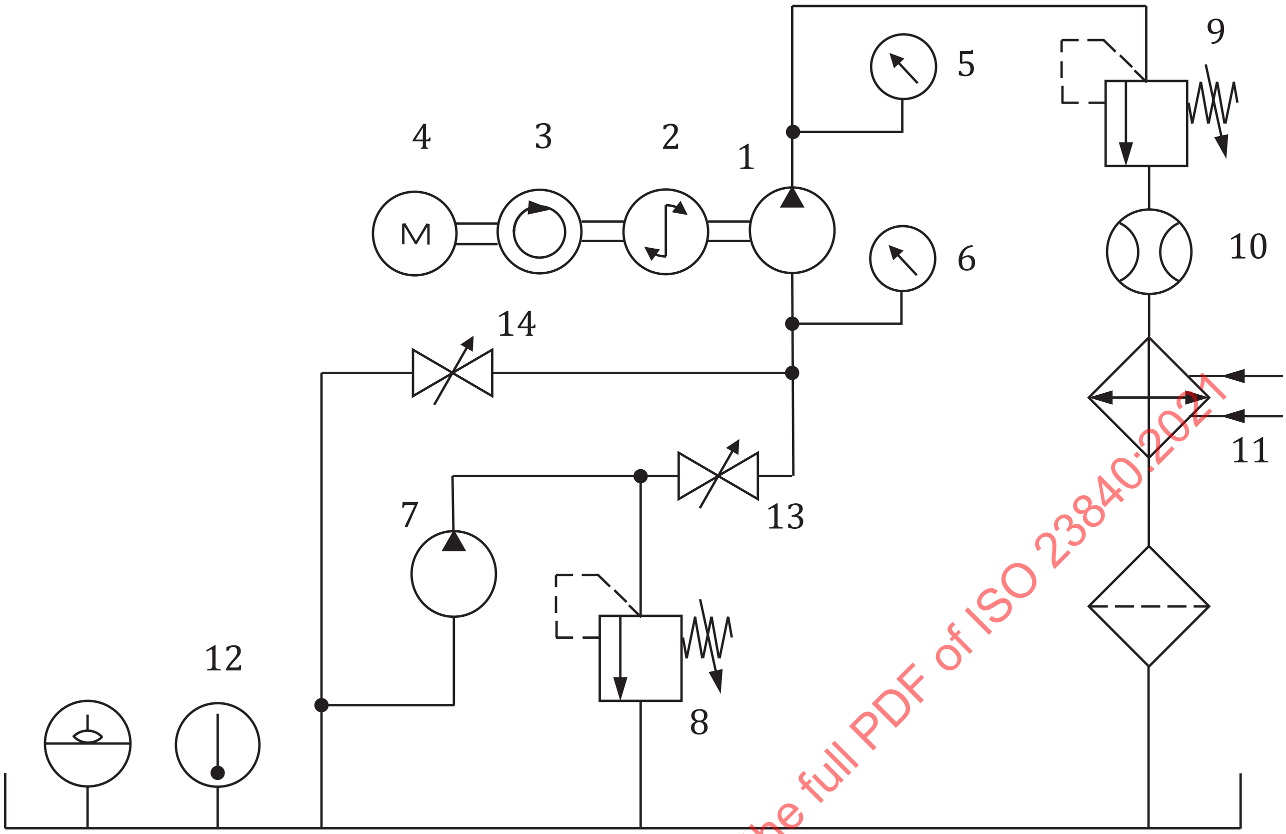
Temperature accuracy class (see Annex A)	**A**	**B**	**C**
Temperature tolerance (°C)	±1,0	±2,0	±4,0

6.2 Test circuit

The test circuit shown in Figure 1 shall be used.

The first shut-off valve (Key 14 of Figure 1) is closed and the second shut-off valve (Key 13) is opened when the inlet port of the pump under test is pressurized by a boost pump (Key 7). The inlet pressure of the pump under test is adjusted by a pressure relief valve (Key 8).

The water level in a tank from the pump inlet port shall be kept up within a given range (e.g. 0,8 m to 1,0 m). A boost pump (Key 7) may be provided to keep the inlet pressure within an acceptable range, which shall be determined by the manufacturer and user of the pump under test, in case there is a demand for pressurized inlet port as a measure to prevent the occurrence of cavitation.



Key

1	pump under test	8	pressure relief valve (boost pump)
2	torque meter	9	pressure relief valve (pump under test)
3	tachometer	10	flowmeter
4	AC servo motor	11	heat exchanger
5	outlet pressure gauge	12	temperature transducer
6	inlet pressure gauge	13	shut-off valve (boost pump)
7	boost pump	14	shut-off valve (pump under test)

Figure 1 — Test circuit for pump

6.3 Test measurement

A test report shall contain at least the following six measured results:

a) effective torque

b) rotational frequency

c) flow rate of the pump under test

d) outlet gauge pressure of the pump under test

e) inlet gauge pressure of the pump under test

f) water temperature

6.4 Preparation of test

The preparation shall be completed in advance, before beginning a test, according to the following procedure using the test circuit shown in Figure 1:

1) Power the test setup.

2) Start the cooling system and set the temperature to a specified value in the range of 20 °C to 40 °C.

3) Set the rotational frequency to the minimum working rotational frequency (e.g. 500 min^{-1}) and verify no leaks of water from the test loop under the condition that the main relief valve (pressure relief valve, Key 9 of Figure 1) is fully released. Increase the rotational frequency gradually (e.g. 900, 1 300, 1 700 min^{-1}) to the maximum working rotational frequency (e.g. 1 800 min^{-1}) after a few minutes of operation (e.g. three minutes) at the minimum working pressure. Verify no leaks of water from the test loop. Verify that no abnormal noise and no abnormal vibration of the pump and other components are observed.

4) Increase the pump outlet pressure to the maximum working pressure (e.g. 16 MPa) with the rotational frequency kept at the maximum working rotational frequency (e.g. 1 800 min^{-1}), by adjusting the main relief valve (pressure relief valve, Key 9).

5) Maintain the condition of 4) for a few minutes (e.g. three minutes).

6) Stop the preparation operation by using the following procedures a) and b) when water temperature and effective torque show steady-state values.

   a) Decrease the outlet gauge pressure of the pump under test by fully releasing the main relief valve (pressure relief valve, Key 9).

   b) Decrease the rotational frequency until the pump is stopped.

6.5 Measurement procedure

Pump basic steady-state performance shall be measured in the rotational frequency range of the minimum to maximum working rotational frequencies (e.g. 500 min^{-1} to 1 800 min^{-1}) and in the outlet gauge pressure range of the minimum to maximum working pressures (e.g. the pressure obtained by fully releasing the main relief valve (Key 9 of Figure 1) to 16 MPa).

Measurements shall be taken according to the following procedure using the test circuit shown in Figure 1.

1) Set the rotational frequency of the pump under test to the minimum working rotational frequency (e.g. 500 min^{-1}).

2) Set the outlet gauge pressure of the pump under test to the pressure obtained by fully releasing the main relief valve (Key 9).

3) Measure the effective torque and rotational frequency by a torque meter (Key 2) and a tachometer (Key 3), respectively, after their values have reached a steady-state.

4) Measure the inlet gauge pressure, outlet gauge pressure and flow rate of the pump under test by an inlet pressure gauge (Key 6), an outlet pressure gauge (Key 5) and by a flowmeter (Key 10), respectively.

5) Set the outlet gauge pressure of the pump under test to a specified value (e.g. 1, 2, 3, ... MPa) by adjusting the main pressure relief valve (Key 9).

6) Repeat the procedures 3) to 5) up to the maximum working pressure (e.g. 16 MPa) with the rotational frequency kept at a constant.

7) Repeat the procedures 2) to 6) at increased rotational frequencies up to the maximum rotational frequency (e.g. 1 800 min^{-1}).

8) Finish the test when measurements at the maximum rotational frequency are taken.

In each case, each set of readings taken for measurement shall be recorded when the indicated value is within the permissible variation of mean indicated values of controlled parameters, in accordance with Annex B).

7 Expression of results

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

For a pump tested, graphs shall contain at least the following three data elements:

a) pump volumetric efficiency, calculated according to Formula (1):

$$\eta_v = \frac{q_p}{V_i n} \tag{1}$$

b) hydromechanical pump efficiency, calculated according to Formula (2):

$$\eta_m = \frac{V_i \left(p_{e,o} - p_{e,i}\right)}{2\pi t_e} \tag{2}$$

c) pump overall efficiency, calculated according to Formula (3):

$$\eta_t = \eta_v \eta_m \tag{3}$$

The parameters shall be recorded (see Table C.1).

Annex A
(informative)

Errors and classes of measurement accuracy

A.1 Classes of measurement accuracy

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

NOTE Classes A and B are intended for special cases when it is necessary to have the performance precisely defined.

Attention is drawn to the fact that classes A and B require the use of more accurate apparatus and methods, which increases the test cost.

A.2 Errors

Any device or method used shall, by calibration or comparison with international standards, have been proven to be capable of measuring the given values with systematic errors not exceeding the limits given in Table A.1.

Table A.1 — Measuring instrument permissible systematic calibration errors

Measuring instrument parameter	Permissible systematic error for classes of measurement accuracy		
	A	B	C
Rotational frequency (%)	±0,5	±1,0	±2,0
Torque (%)	±0,5	±1,0	±2,0
Volume flow rate (%)	±0,5	±1,0	±2,0
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 $p \geq 0,15$ (1,5)	±0,05 (±0,5)	±0,15 (±1,5)	±0,25 (±2,5)
Temperature (K)	±0,5	±1,0	±2,0
Mechanical power (%)	—	—	±4,0

NOTE 1 The percentage limits apply to the value of the measured quantity and not to the maximum test value 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”.

A.3 Combination of errors

When calculations of power or efficiency are made, the combination of errors involved in the calculation may be determined by the root mean square method including all errors measured and used in calculation parameters. See Formula (A.1):

EXAMPLE $$\frac{\partial \eta_{\mathrm{v}}}{\eta_{\mathrm{v}}} = \sqrt{\left(\frac{\partial q_{\mathrm{p}}}{q_{\mathrm{p}}}\right)^2 + \left(\frac{\partial V_{\mathrm{i}}}{V_{\mathrm{i}}}\right)^2 + \left(\frac{\partial n}{n}\right)^2} \quad \text{(A.1)}$$

The systematic errors used above, ∂q_{p}, ∂V_{i}, and ∂n, are the systematic instrument errors and not the maximum values given in Table A.1. For a more precise summation of errors, see ISO/IEC Guide 98-3.

Annex B
(normative)

Permissible variation of mean indicated values of controlled parameters

Table B.1 shows permissible variation of mean indicated values of controlled parameters.

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 B.1. If multiple readings of a variable are recorded the mean values shall be documented while the controlled parameter is within the operating limits.

Table B.1 — Permissible variation of mean indicated values of controlled parameters

Parameter	Permissible variation for classes of measurement accuracy [a] (see Annex A)		
	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, % ($p_e \geqq 2 \times 10^5$ 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 A. 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, efficiency or power losses.

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

Annex C
(informative)

Example of graphs presenting test results

C.1 General

This annex shows examples of graphs representing test results of a water-hydraulic pump.

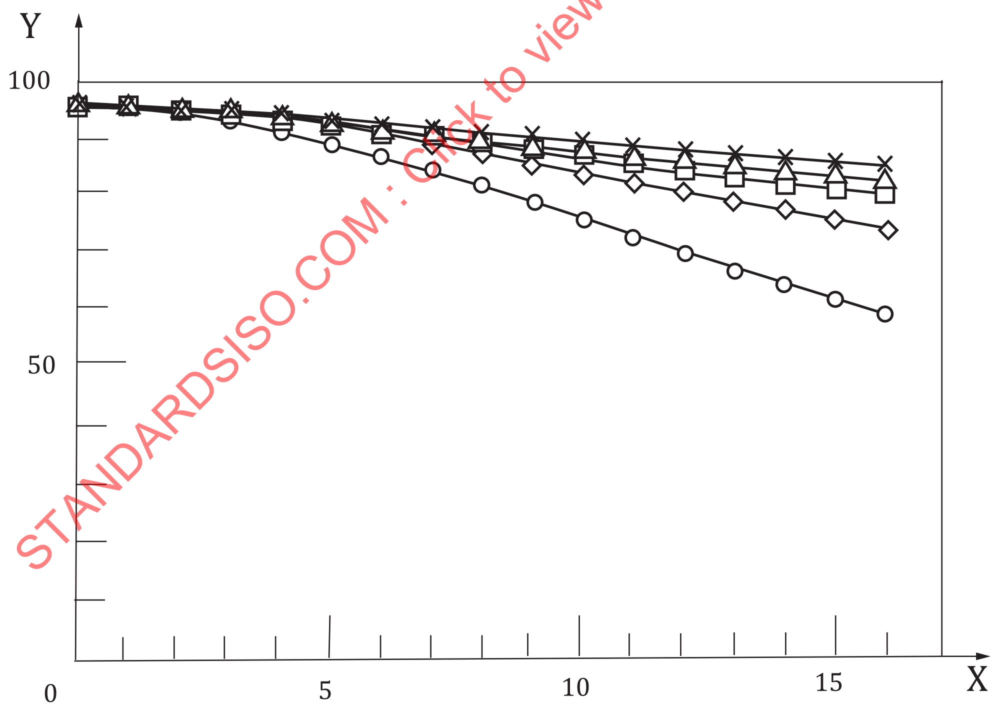
Figures C.1, C.2, and C.3 represent examples of pump volumetric efficiency, hydromechanical pump efficiency, and pump overall efficiency, respectively. In Figures C.1, C.2, and C.3, the open circle (○), open diamond (◇), open square (☐), open triangle (Δ), and cross mark (x) show pump efficiency data in a condition of 500 min^{-1}, 900 min^{-1}, 1 300 min^{-1}, 1 700 min^{-1}, and 1 800 min^{-1}, respectively.

Table C.1 denotes a suggested table for data-recording (example).

Table C.2 shows contents of tap water used in water hydraulics (example).

C.2 Pump volumetric efficiency

Figure C.1 shows an example of a plot representing test results of pump volumetric efficiency of a water-hydraulic pump.



Key

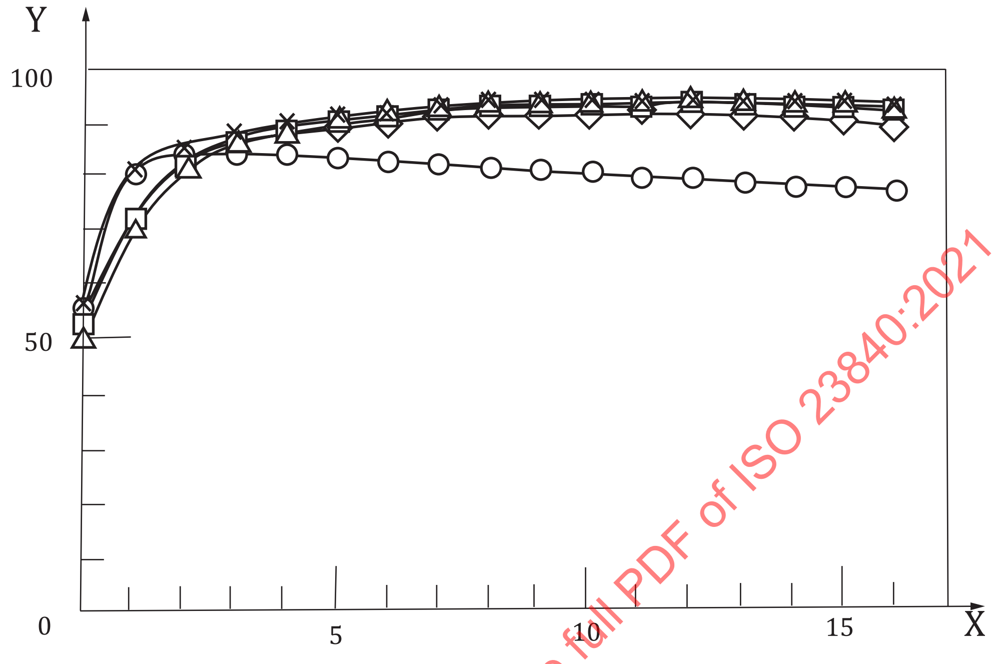
X pressure difference ($p_{e,o}$-$p_{e,i}$) (MPa)

Y pump volumetric efficiency (%)

Figure C.1 — Example of a plot representing test results of pump volumetric efficiency of a water-hydraulic pump

C.3 Hydromechanical pump efficiency

Figure C.2 shows an example of a plot representing test results of hydromechanical pump efficiency of a water-hydraulic pump.



Key

X pressure difference ($p_{e,o}$-$p_{e,i}$) (MPa)

Y hydromechanical pump efficiency (%)

Figure C.2 — Example of a plot representing test results of hydromechanical pump efficiency of a water-hydraulic pump

C.4 Pump overall efficiency

Figure C.3 shows an example of a plot representing test results of pump overall efficiency.