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Third edition
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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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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 4409:2007), which has been technically revised.

The main changes compared to the previous edition are as follows:

— The normative references in Clause 2 have been updated and revised to reflect the changes made to this document.

— The terms and definitions in Clause 3 were updated and correctly referenced to agree with the existing ISO standards.

— Clause 4 now correctly references the appropriate standard for symbols and units and the corresponding table has been revised to display symbols and units correctly.

— The general description of Clause 5 was revised to include various types of conduits. A table with recommendations for the test fluid to be used is now provided, and the circuit diagrams have been revised for technical accuracy.

— The suggested expression of results has been updated in Clause 6 to include meaningful values obtained from the data gathered with the tests.

— The Bibliography has been updated.

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

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 document 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 document 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 document specifies the requirements for test installations, test procedures 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 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*

ISO 11631, *Measurement of fluid flow — Methods of specifying flowmeter performance*

3 Terms and definitions

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

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

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

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

4 Symbols and units

The symbols and subscripts listed in Table 1 are as specified in ISO 4391. Units as shown in Table 1 are in accordance with ISO 80000-1 and ISO 80000-4.

The letters and figures shall all be 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 shall be used in accordance with ISO 1219-1.

Table 1 — Symbols and units

Description	Symbol	Unit
Volume flow rate	q_V	$m^3\ s^{-1}$
Derived capacity	V_i	$m^3\ r^{-1}$
Rotational frequency	n	s^{-1}
Torque	T	N·m
Pressure	p	Pa[a]
Power	P	W
Mass density	ρ	$kg\ m^{-3}$
Isothermal bulk modulus secant	K_T	Pa[a]
Kinematic viscosity	ν	$m^2\ s^{-1}$[b]
Temperature	θ	K
Volume coefficient of thermal expansion	α	K^{-1}
Overall efficiency [c]	η_τ	—
Volumetric efficiency	η_ς	—
Rotational frequency ratio	Z	—

a 1 Pa = 1 N/m^2.

b 1 cSt = 1 mm^2 s^{-1}.

c Efficiency may also be stated as a percentage.

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.

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 B.

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 the piping, the requirements of ISO 9110-1 and ISO 9110-2 shall be met.

Where flow measurements are made, the requirements of ISO 11631 shall be met.

Where temperature measurements are made within the piping, the temperature tapping point shall be positioned between two and four times the internal diameter of the piping 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 fracture or fragmentation. It is important that those responsible for carrying out the test give due consideration to safeguarding both personnel and equipment.

NOTE A "run in" procedure before testing can have a positive effect on the test results.

5.1.2 Installation of the unit under test

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

5.1.3 Test fluids

The properties of hydraulic fluids affect pump and motor performance. Any fluid can be used for the test, if agreed between the parties concerned, but its characteristics shall be clearly defined, according to the properties listed in Table 2. In order to compare two components, the same fluid shall be used.

Table 2 — Test fluid specification

Property	Standard	Recommended	
Viscosity grade	ISO 3448	ISO VG 32	ISO VG 46
Fluid classification	ISO 6743-4	HM	
Fluid specification	ISO 11158	(Table 3, ISO 11158)	
Additional constraints			
Density, g/cc	ISO 3675	860 to 880	
Viscosity index	ISO 2909	95 to 115	
Viscosity modification	N/A	The use of additional viscosity modifiers is prohibited.	
Friction modification	N/A	The use of additional friction modifiers is prohibited.	

5.1.4 Temperatures

5.1.4.1 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. It is recommended that measurements are made at two temperature levels, 50 °C and 80 °C.

The test fluid temperature shall be maintained within the limits stated in Table 3.

Table 3 — Indicated test fluid temperature tolerance

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

5.1.4.2 Other temperatures

The fluid temperature may be measured 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).

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.

5.1.5 Casing pressure

If the fluid pressure within the casing of the component under test can affect its performance, the fluid-pressure value in the case shall be maintained and shall be recorded.

5.1.6 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 4. If multiple readings of a variable are recorded the mean values shall be documented while the controlled parameter is within the operating limits. The maximum suggested time period to acquire each reading is 10 s at a minimum data acquisition rate of 1 000 Hz. Such readings should include zero displacement and idle operating conditions.

Test parameters are considered stabilized when they are within Table 4 limits.

Table 4 — 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.

5.1.7 Pump inlet pressure

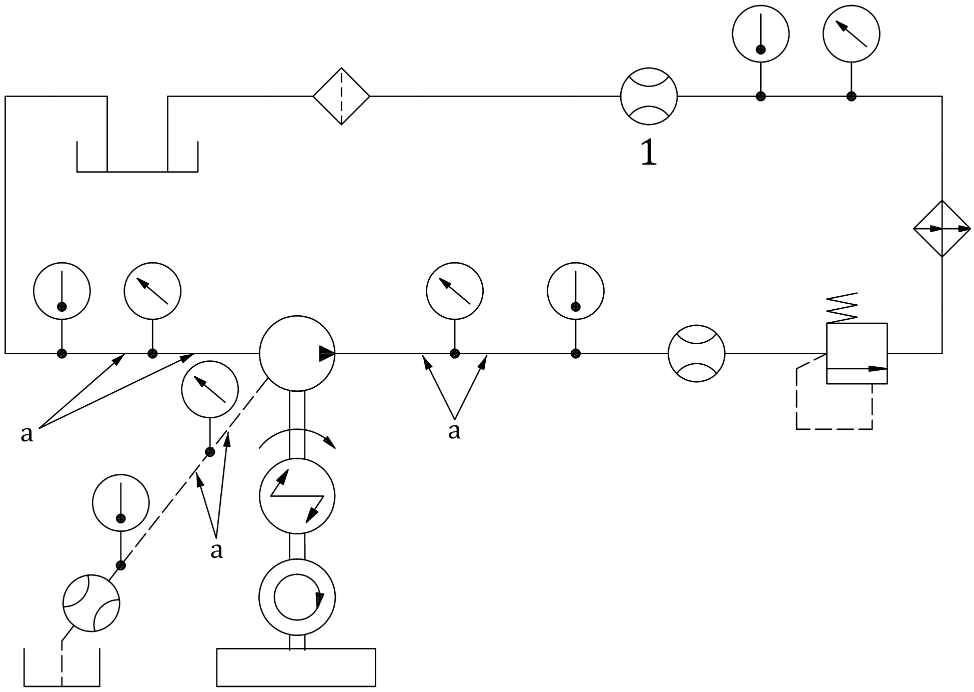
The pump inlet line should not exceed 25 000 Pa (0,25 bar or 3,6 psi). Unless otherwise required, the pump inlet pressure at the inlet fitting shall be maintained within 3 386 Pa (0,034 bar or 0,49 psi) of atmospheric pressure at pump maximum displacement and rated speed. This can be controlled by reservoir fluid level and/or reservoir pressure. The inlet pressure will be permitted to rise as variable pump displacement is reduced. A shutoff valve may be installed at least 20 internal diameters upstream from the pump in the inlet line.

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). If an alternative position for the flow sensor is used, use pressure p and temperature θ measured at point 1 to calculate using the corresponding formula and symbols listed in ISO 4391:1983, Reference 10.18. Flow, pressure and temperature measured in drainage are not used in the formula.



Key

1 alternative position

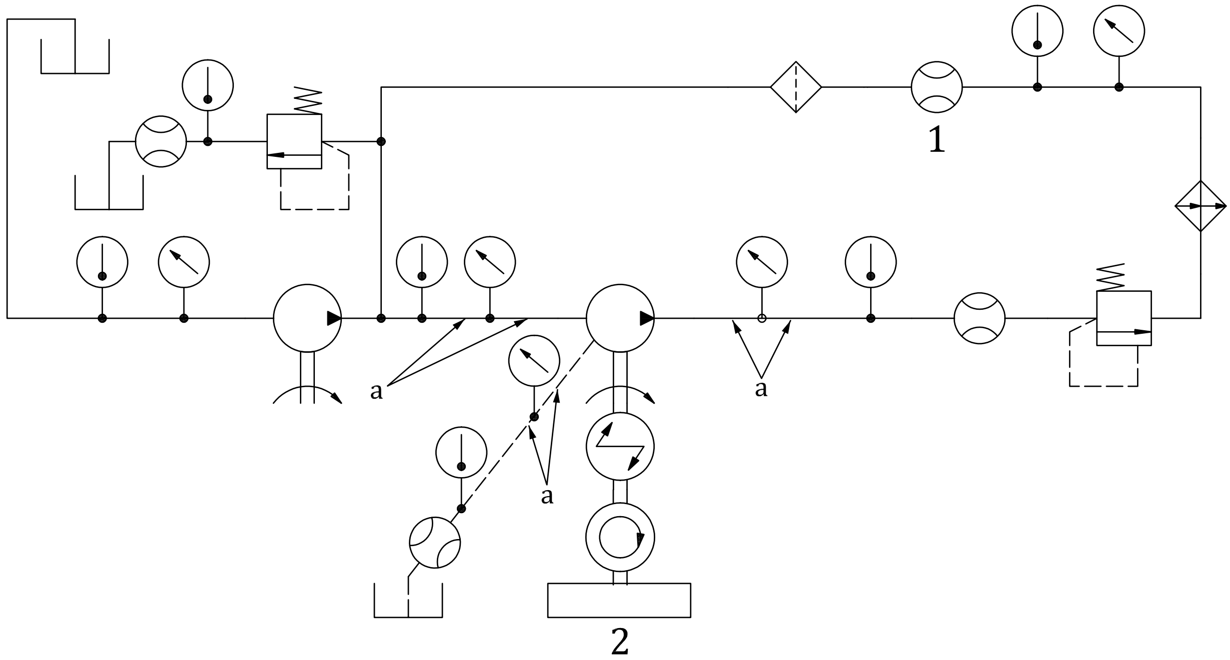
2 driver

[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. If an alternative position for the flow sensor is used, use pressure p and temperature θ measured at point 1 to calculate using the corresponding formula in ISO 4391:1983, Ref.10.18. Flow, pressure and temperature measured in drainage are not used in the formula.



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 4) 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 4) 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). For variable displacement units, this test requires monitoring and recording the position of the displacement actuator to ensure it does not change during testing. If a swash plate type unit is used, the swivel angle

