INTERNATIONAL STANDARD

ISO 4409

Second edition
2007-04-01

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

Reference number
ISO 4409:2007(E)

Contents

Page

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).

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

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).

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

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).

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

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):

$$P_m = 2\pi \cdot n \cdot T \tag{4}$$

3.11
hydraulic power
P_h

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

$$P_h = q_V \cdot p \tag{5}$$

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

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

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

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

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):

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

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):

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

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):

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

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):

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

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):

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

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):

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

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.