INTERNATIONAL STANDARD

ISO 4392-3

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Hydraulic fluid power — Determination of characteristics of motors —

Part 3:
At constant flow and at constant torque

Transmissions hydrauliques — Détermination des caractéristiques des moteurs —

Partie 3: Essai à débit constant et couple constant

Reference number
ISO 4392-3:1993(E)

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.

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.

International Standard ISO 4392-3 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Sub-Committee SC 8, *Product testing and contamination control.*

ISO 4392 consists of the following parts, under the general title *Hydraulic fluid power — Determination of characteristics of motors*:

— *Part 1: At constant low speed and at constant pressure*

— *Part 2: Startability*

— *Part 3: At constant flow and at constant torque*

Annexes A and B form an integral part of this part of ISO 4392.

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Introduction

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

Hydraulic motors are units which transform hydraulic energy into mechanical energy, usually with a rotary output.

Hydraulic fluid power — Determination of characteristics of motors —

Part 3:
At constant flow and at constant torque

1 Scope

This part of ISO 4392 describes a method of determining the low-speed characteristics of positive-displacement rotary fluid power motors under constant flow and constant torque conditions. Motors may be of either the fixed or variable-displacement type.

The method involves testing at slow speeds, which may generate frequencies having a significant influence upon the steady continuous torque output of the motor and affect the system to which the motor would be connected.

The accuracy of measurement is divided into three classes, A, B and C, which are explained in annex A.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 4392. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 4392 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1219-1:1991, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols.*

ISO 3448:1992, *Industrial liquid lubricants — ISO viscosity classification.*

ISO 4391:1983, *Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and letter symbols.*

ISO 4409:1986, *Hydraulic fluid power — Positive displacement pumps, motors and integral transmissions — Determination of steady-state performance.*

ISO 5598:1985, *Fluid power systems and components — Vocabulary.*

ISO 8426:1988, *Hydraulic fluid power — Positive displacement pumps and motors — Determination of derived capacity.*

3 Definitions

For the purposes of this part of ISO 4392, the definitions given in ISO 4391 and ISO 5598 and the following definition apply.

3.1 complete motor cycle: The total angular movement of the motor output shaft needed to achieve a repetitive leakage and/or torque recording. In most motors this will be 360°; however, in some, such as gear motors, it may be several shaft revolutions.

4 Symbols

4.1 The physical quantity letter symbols and their suffixes used in this part of ISO 4392 are in accordance with ISO 4391. Units are given in table 1.

4.2 The graphical symbols used in figure 1 are in accordance with ISO 1219-1.

Table 1 — Symbols and units

Quantity	Symbol	Dimension[1)]	SI unit[2)]
Rotational speed	n	T^{-1}	r/min
Pressure, differential pressure	$p, \Delta p$	$ML^{-1}T^{-2}$	Pa
Flowrate	q	L^3T^{-1}	m^3/min
Torque	T	ML^2T^{-2}	N·m
Time	t	T	s
Swept volume	V	L^3	m^3
Temperature	θ	Θ	°C

1) M = mass; L = length; T = time; Θ = temperature.

2) The practical units which may be used for the presentation of results are given in annex B.

5 Test installation

5.1 Hydraulic test circuit

5.1.1 A hydraulic test circuit similar to that shown in figure 1 shall be used.

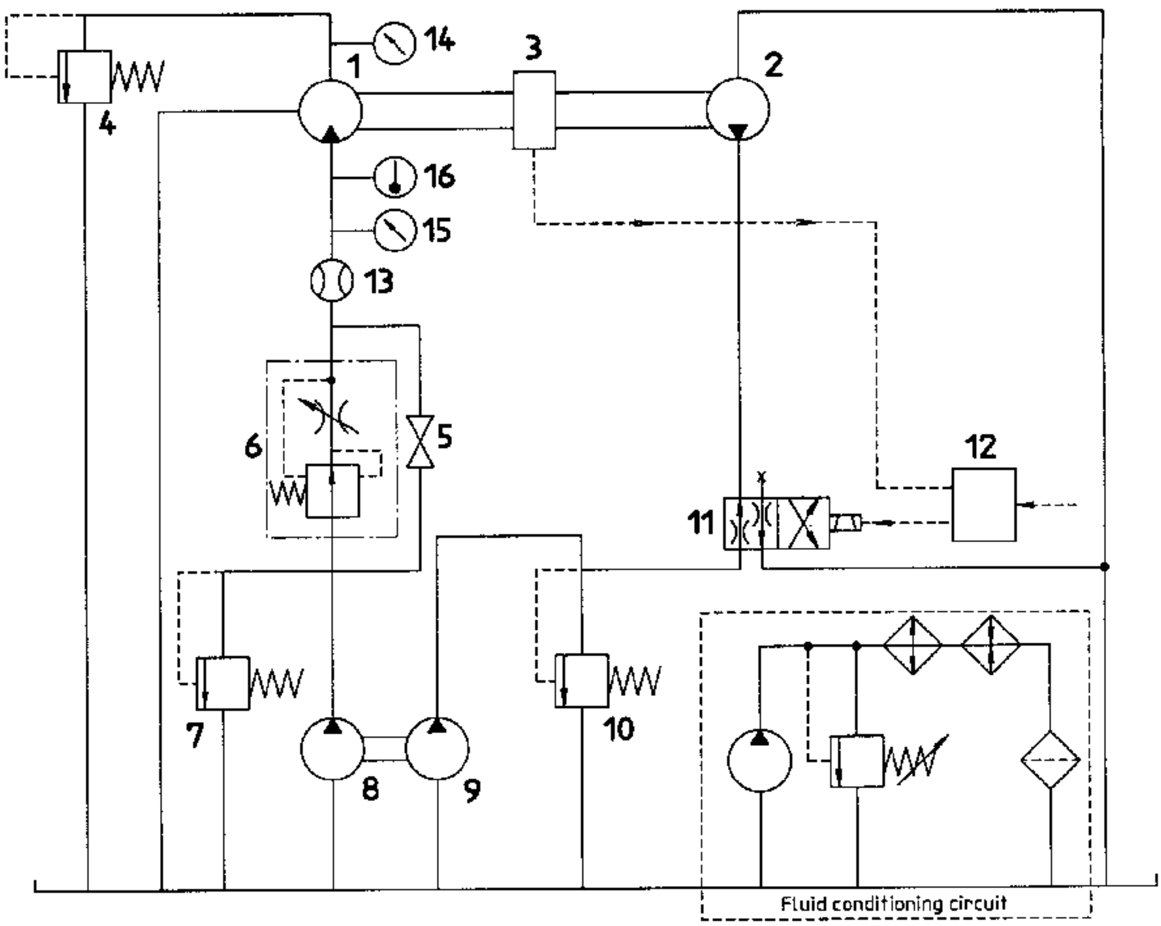
WARNING — The basic circuit shown in figure 1 does not incorporate all the safety devices necessary to protect against damage in the event of component failure. It is important that those responsible for carrying out these tests give due consideration to safeguarding both staff and equipment.

5.1.2 A fluid-conditioning circuit (figure 1) together with shut-off valve **5** and relief valve **7** shall be installed. Valve **5** may be opened to facilitate operation at high speed in order to reach the test operating temperature rapidly (see 8.2). Valve **5** shall be closed during the test.

5.1.3 A fluid-conditioning circuit shall be installed which provides the filtration necessary to protect the test motor and the other circuit components and which will maintain the fluid temperatures specified in clause 7.

5.1.4 A constant motor supply flowrate is obtained by a flow control valve with viscosity and pressure compensation.

5.1.5 Constant torque load can be obtained using a positive-displacement pump and a flow control valve with a torque signal electric feedback (or a magnetic power brake or any other suitable system).



Key

1	Motor under test
2	Constant torque load (positive-displacement pump)
3	Torque, rotational speed and rotational angle meter
4, 7	Relief valves
5	Shut-off valve
6	Constant flow device
8, 9	Displacement pumps
10, 11, 12	Torque control devices
13	Flowmeter
14, 15	Pressure indicators
16	Temperature indicator

Figure 1 — Typical hydraulic test circuit

5.2 Test apparatus

5.2.1 A test rig shall be set up which makes use of the test circuit specified in 5.1 and which provides the equipment shown in figure 1.

5.2.2 A positive-locking device shall be provided on continuously variable displacement motors to prevent the displacement inadvertently changing during the pertinent portion of each test.

5.3 Instrumentation

5.3.1 Measuring instruments shall be selected and installed to measure the following test motor data:

a) inlet flow;

b) inlet temperature (see ISO 4409 for guidance on location of the tapping point);

c) inlet and outlet pressures (see ISO 4409 for guidance on location of tapping points);

d) output torque;

e) speed and angular position of the motor shaft.

5.3.2 The systematic errors of the measuring instruments shall be consistent with the chosen class of measurement accuracy (see annex A).

5.3.3 Appropriate recording instruments shall be selected and installed which are capable of resolving signals at frequencies greater than 10 times the highest expected fundamental data frequency.

5.3.4 The test measurements should be taken at equal increments of shaft angle, and their number should be a minimum of ten times the number of displacement pulses per revolution as obtained under 6.1 b).

6 Pretest data

6.1 Using the motor manufacturer's data and other known facts, gather the pretest data as follows.

a) Calculate the rated (geometric or theoretical) torque of the motor ($T_{g,n}$ or $T_{i,n}$) based upon its geometric or theoretical displacement at rated pressure, using the formula

$$T_{g,n} = \frac{\Delta p_n \times V_g}{2\pi}$$

or

$$T_{i,n} = \frac{\Delta p_n \times V_i}{2\pi}$$

where

Δp_n is the rated differential pressure;

V_g is the geometric swept volume;

V_i is the derived swept volume (see ISO 8426).

b) Determine the number of displacement pulses per revolution of the motor shaft, taking into account any gearing which would influence the frequency.

c) Calculate the fundamental data frequency, f_e, in hertz, using the formula

$$f_e = \frac{n_e}{60} \times \text{number of displacement pulses}$$

where n_e is the test speed, in revolutions per minute (r/min). The number of displacement pulses is taken from 6.1 b).

6.2 Using the motor manufacturer's recommended value for rated speed, n_n, calculate the ideal (geometric or theoretical) flow at rated speed, $q_{V_{g,n}}$ or $q_{V_{i,n}}$, using the formula

$$q_{V_{g,n}} = n_n \times V_g$$

or

$$q_{V_{i,n}} = n_n \times V_i$$

6.3 Determine the fluid viscosity in accordance with ISO 3448.

6.4 Estimate the maximum output torque expected to be produced by the motor during the test using the rated torque, $T_{g,n}$ or $T_{i,n}$ [as determined in 6.1 a)].

6.5 The moment of inertia of all the rotating components connected to the motorshaft and the volume between the flow-control valve and the motor inlet port should be kept to a minimum.

7 Test conditions

The following test conditions shall apply:

a) fluid temperature, θ, at motor inlet: either 50 °C or 80 °C;

b) use a hydraulic fluid of a type and viscosity approved by the hydraulic motor manufacturer, appropriate to the test temperature selected;

c) carry out tests at 50 % and 100 % of the motor rated torque;

d) for the two torque conditions given in clause 7 c), establish the minimum inlet flow; the lowest possible flow is that which causes the motor to stop rotating;

e) for variable-displacement motors, select the minimum and maximum displacements recommended by the manufacturer; then test at these minimum and maximum displacements;

f) for reversible motors, carry out the test in both directions of rotation.

8 Test procedure

8.1 Connect the instrumentation and recording apparatus to record the motor test data as listed in 5.3.1 and shown in figure 1.

NOTE 1 Before starting the test, fill the motor case with fluid, if necessary.

8.2 Operate the test circuit before taking measurements, in order to stabilize the system temperature.

8.3 Hold the torque as constant as possible, while peak-to-peak torque variations should be at least within 4 % of the mean value. The requirement specified in 5.3.3 shall be taken into consideration.

8.4 Hold the flow as constant as possible, and record it. Instantaneous flow variation shall be kept to within 4 % of the mean value in accordance with the specifications given in 5.3.3.

8.5 Maintain the measured inlet fluid temperature constant to within ± 2 °C for the duration of a recording.

8.6 Make simultaneous recordings of the variables listed in 5.3.1 for the required test conditions.

8.7 Extend the recording to as many revolutions as are necessary to achieve one complete motor cycle.

8.8 When using digital data acquisition techniques, select a sample interval which provides 95 % confidence that the maximum and minimum values of speed and pressure have been determined by pretesting.

9 Expression of results

NOTE 2 Refer to clause 4 for an explanation of symbols and suffixes.

9.1 Determine the speed n_φ for equally distributed positions over one complete motor cycle.

Calculate the mean speed over one complete motorcycle, n_{ma}:

$$n_{ma} = \frac{n_{\varphi 1} + n_{\varphi 2} + n_{\varphi 3} + \ldots + n_{\varphi z}}{z}$$

where

the suffixes $\varphi 1$, $\varphi 2$, $\varphi 3 \ldots \varphi z$, are the respective selected shaft positions;

z is the number of readings per complete motor cycle, in compliance with 5.3.4.

9.2 Calculate the speed irregularity at each selected shaft position Δn_φ, using the following formula:

$$\Delta n_\varphi = |n_{ma} - n_\varphi|$$

9.3 Calculate the mean speed irregularity over one complete motor cycle, Δn_{ma}:

$$\Delta n_{ma} = \frac{\Delta n_{\varphi 1} + \Delta n_{\varphi 2} + \Delta n_{\varphi 3} + \ldots + \Delta n_{\varphi z}}{z}$$

9.4 Determine the speed irregularity index, Ir_n, using the following formula:

$$Ir_n = \frac{\Delta n_{ma}}{n_{ma}}$$

or

$$Ir_n = \frac{|n_{ma} - n_{\varphi 1}| + |n_{ma} - n_{\varphi 2}| + | \ldots | + |n_{ma} - n_{\varphi z}|}{n_{\varphi 1} + n_{\varphi 2} + \ldots + n_{\varphi z}}$$

9.5 Calculate the average volumetric efficiency, $\eta_{v,ma}$, for at least one complete motor cycle using the following formula:

$$\eta_{v,ma} = \frac{V_{i,ma} \cdot n_{ma}}{q_{V_e}}$$

where

$V_{i,ma}$ is the average derived swept volume (see ISO 8426:1988, B.2);

n_{ma} is the mean rotational speed;

q_{V_e} is the volume flowrate.

9.6 Calculate the relative peak-to-peak variation in speed δn, using the following formula:

$$\delta n = \frac{n_{max} - n_{min}}{n_{ma}}$$

9.7 Determine the effective differential pressure, $\Delta p_{e,\varphi}$, for the selected positions over one shaft revolution:

$$\Delta p_{e,\varphi} = p_{1,\varphi} - p_{2,\varphi}$$

where

p_1 is the inlet pressure;

p_2 is the outlet pressure.

9.8 Calculate the mean effective differential pressure, $\Delta p_{e,ma}$, over one complete motor cycle using the following formula:

$$\Delta p_{e,ma} = \frac{\Delta p_{e,\varphi 1} + \Delta p_{e,\varphi 2} + \ldots + \Delta p_{e,\varphi z}}{z}$$

9.9 Calculate the pressure irregularity, $\Delta(\Delta p_e)$, for each selected shaft position using the following formula:

$$\Delta(\Delta p_{e,\varphi}) = |\Delta p_{e,ma} - \Delta p_{e,\varphi}|$$

9.10 Calculate the mean differential pressure irregularity, $\Delta(\Delta p_{e,ma})$, over one complete motor cycle using the following formula:

$$\Delta(\Delta p_{e,ma}) = \frac{\Delta(\Delta p_{e,\varphi 1}) + \Delta(\Delta p_{e,\varphi 2}) + \ldots + \Delta(\Delta p_{e,\varphi z})}{z}$$

9.11 Determine the differential pressure irregularity index, $Ir_{\Delta p}$, using the following formula:

$$Ir_{\Delta p} = \frac{\Delta(\Delta p_{e,ma})}{\Delta p_{e,ma}}$$

or

$$Ir_{\Delta p} = \frac{|\Delta p_{e,ma} - \Delta p_{e,\varphi 1}| + |\Delta p_{e,ma} - \Delta p_{e,\varphi 2}| + | \ldots | + |\Delta p_{e,ma} - \Delta p_{e,\varphi z}|}{\Delta p_{e,\varphi 1} + \Delta p_{e,\varphi 2} + \ldots + \Delta p_{e,\varphi z}}$$

9.12 Calculate the average hydraulic mechanical efficiency, $\eta_{hm,ma}$, using the following formula:

$$\eta_{hm,ma} = \frac{T_e}{\Delta p_{e,ma} \times \frac{V_{i,ma}}{2\pi}}$$

9.13 Calculate the relative peak-to-peak variations of differential pressure, $\delta \Delta p$, using the following formula:

$$\delta \Delta p = \frac{\Delta p_{e,max} - \Delta p_{e,min}}{\Delta p_{e,ma}}$$

10 Test report

10.1 General

The relevant test data using the test torque and flow conditions and the information listed in 10.3 shall be recorded in a test report.

10.2 Presentation of test data

All test measurements and the results of the calculations derived from the measurements shall be presented in tabular form and, where appropriate, graphically.

10.3 Test data

10.3.1 General

The following data shall be included in the test report:

a) a description of the motor;

b) the class of measurement accuracy used (see annex A);

c) a description of the hydraulic test circuit and components;

d) a description of the test fluid;

e) the fluid viscosity (see 6.3).

10.3.2 Test results

The target values of torque and flow under which the tests were performed shall be recorded, together with the following information:

a) the fluid temperature, θ [see clause 7 a)];

b) the speed as a function of rotational angle at constant flow, constant torque and constant temperature;

c) the differential pressure as a function of the rotational angle at constant flow, constant torque and constant temperature;

d) the geometric swept volume, V_g, or derived swept volume, V_i;

e) the mean rotational speed over one complete motor cycle, n_{ma} (see 9.1);

f) the mean speed irregularity over one complete motor cycle, Δn_{ma} (see 9.3);

g) the speed irregularity index, Ir_n (see 9.4);

h) the average volumetric efficiency, $\eta_{v,ma}$ (see 9.5);

i) the relative peak-to-peak value of speed, δn (see 9.6);

j) the mean effective differential pressure over one complete motor cycle, $\Delta p_{e,ma}$ (see 9.8);

k) the mean differential pressure irregularity over one complete motor cycle, $\Delta(\Delta p_{e,ma})$ (see 9.10);

l) the differential pressure irregularity index, $Ir_{\Delta p}$ (see 9.11);

m) the average hydraulic mechanical efficiency, $\eta_{hm,ma}$ (see 9.12);

n) the relative peak-to-peak value of differential pressure, $\delta\Delta p$ (see 9.13).

Annex A
(normative)

Classes of measurement accuracy

NOTE 3 The contents of this annex are under review and may be subject to amendment in the future.

A.1 Classes of measurement accuracy

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

NOTES

4 Classes A and B are intended for special cases when there is a need to have the performance more precisely defined.

5 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 shall be used which by calibration or comparison with International Standards has been demonstrated to be capable of measuring with systematic errors not exceeding the limits given in table A.1.

NOTE 6 The limits given in table A.1 are percentage limits for speed, output torque, total input flow and inlet/output pressure and are based on the value of the quantity being measured and not on the maximum scale reading of the instrument. The limits for temperature are in degrees Celsius and are not percentage limits.

Table A.1 — Permissible systematic errors of measuring instruments as determined during calibration

Parameter of measuring instrument	Permissible systematic errors for classes of measurement accuracy		
	A	B	C
Speed, n_e, %	± 0,5	± 1	± 2
Output torque, $T_{2,e}$, %	± 1,5	± 3	± 5
Total input flow, $q_{V_{1,t,e}}$, %	± 2	± 4	± 6
Inlet/outlet pressure, $p_{1,e}$ and $p_{2,e}$, %	± 0,8	± 1,5	± 3
Inlet temperature, $\theta_{1,e}$, °C	± 0,5	± 1	± 2

Annex B
(normative)

Use of practical units

The results of tests, given either in tabular or graphical form, may be presented using the practical units given in table B.1.

Table B.1 — Practical units

Quantity	Symbol	SI unit	Practical units
Rotational speed	n	r/min	r/min
Pressure, differential pressure	p, Δp	Pa	bar[1)]
Flowrate	q	m^3/s	dm^3/s [2)]
Torque	T	N·m	N·m
Time	t	s	s, ms
Swept volume	V	m^3	dm^3
Temperature	θ	°C	°C

1) 1 bar = 10^5 Pa = 10 N/m² = 0,1 MPa

2) 1 dm^3 = 1 litre

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