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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Hydraulic fluid power — Determination of characteristics of motors —

Part 2: Startability

Transmissions hydrauliques — Détermination des caractéristiques des moteurs —

Partie 2: Essai de démarrage

Reference number
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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 4392-2 was prepared by Technical Committee ISO/TC 131, *Hydraulic fluid power.*

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Hydraulic fluid power — Determination of characteristics of motors —

Part 2: Startability

0 Introduction

In hydraulic fluid power systems power is transmitted by a fluid under pressure within an enclosed circuit.

Hydraulic motors are units which transform hydraulic energy into mechanical energy, usually with a rotary output. Startability, the ability of a motor to start, is an important property of hydraulic motors, when used for specific applications.

1 Scope and field of application

This part of ISO 4392 specifies two test methods for determining the startability of rotary hydraulic motors. It describes two comparable methods of measurement, namely the constant torque method (see clause 6) and the constant pressure method (see clause 7). Since the results obtained by these two methods are equivalent no preference is given to either.

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

2 References

ISO 1219, *Fluid power systems and components — Graphic symbols.*

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

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

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

3 Definitions

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

3.1 startability: The ability of a hydraulic motor to start against a stated load.

3.2 start at constant torque: That point at which there is an abrupt change in the slope of the angular displacement versus pressure characteristic, when the angular displacement of the motor shaft is measured between the motor and the load.

3.3 start at constant pressure: That point at which there is an abrupt change in the slope of the angular displacement versus pressure torque characteristic, when the angular displacement of the motor shaft is measured between the motor and the load.

4 Symbols

4.1 The physical quantity letter symbols and their suffixes used in this part of ISO 4392 are fully explained either in ISO 4391 or annex A and are given in table 1.

Table 1 — Symbols and units

Quantity	Symbol	Dimension[1)]	SI unit[2)]
Pressure, differential pressure	p, Δp	$ML^{-1}T^{-2}$	Pa
Torque	T	$ML^{2}T^{-2}$	N·m
Instantaneous displacement	v	L^3	m^3
Time	t	T	s
Swept volume	V	L^3	m^3

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

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

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

5 Test installation

5.1 Hydraulic test circuit

5.1.1 An appropriate hydraulic test circuit similar to that shown in the figure shall be used.

NOTES

1 Although the figure illustrates a basic circuit to test a unidirectional motor, a similar, symmetrical, but suitably modified, circuit is acceptable for testing bidirectional motors.

2 An additional booster pump circuit may be necessary when testing piston-type motors.

3 The basic circuit shown in the figure 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 the tests give due consideration to safeguarding both staff and equipment.

5.1.2 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 temperature at the motor inlet at either 50 °C or 80 °C to within ± 2 °C.

5.1.3 The hydraulic ports of the test motor shall be connected to the hydraulic circuit in such a manner that the motor shaft rotation will oppose the torque loading device.

5.1.4 *The maximum test pressure shall not exceed that* recommended by the motor manufacturer.

5.2 Instrumentation

Measuring instruments shall be selected and installed which provide systematic errors which are consistent with the chosen class of measurement accuracy (see annex B).

6 Constant torque method

6.1 Test apparatus

6.1.1 A test rig shall be set up which makes use of the test circuit specified in 5.1.1 *and which provides the equipment shown* in the figure and described in 6.1.2 and 6.1.3.

6.1.2 A suitable torque loading device, either **12** which will allow limited rotation of the test motor shaft at start-up, e.g. a lever arm and adjustable mass at one end, or **17** which allows continuous opposing rotation by a controlled variable speed d.c. electric motor through a high ratio reduction gear (**14** and **15**) shall be provided.

6.1.3 A mechanical stop shall also be provided to prevent the torque loading device rotating the motor shaft in the reverse direction.

6.2 Test conditions

6.2.1 The motor being tested shall be in thermal equilibrium before commencing the test.

6.2.2 The constant outlet pressure shall be maintained at the level recommended by the motor manufacturer.

6.2.3 The rate of increase in inlet pressure per second shall be less than or equal to 20 % of test pressure and shall not significantly influence the starting pressure.

6.2.4 *The differential pressure across the motor shall* be reduced to less than 5 % of the maximum test pressure or 10 bar[1)] (1 MPa), whichever is the smaller, before embarking on every subsequent set of measurements.

NOTE — This requirement is not applicable to motors for special applications, e.g. winch drives.

6.2.5 The number of measurements at different shaft positions shall be greater than the minimum number necessary for the maximum starting pressure over one revolution to be found with a confidence level of 95 %.

6.2.6 The torque levels shall be kept constant to ± 1 %.

6.3 Test procedure

6.3.1 Adjust the back pressure on the motor outlet to a constant value (see 6.2.2).

6.3.2 Gradually increase the inlet pressure until the motor starts to rotate (see 6.2.3). Simultaneously record the angular displacement of the motor shaft against inlet pressure.

6.3.3 Produce a graph of the recordings obtained in 6.3.2 and note the pressure at which the motor starts to rotate, i.e. the point at which there is an abrupt change in the slope of the characteristic (see 3.2).

6.3.4 Repeat the steps described in 6.3.2 and 6.3.3 at a number of different shaft positions (see 6.2.5).

6.3.5 Repeat the steps described in 6.3.2 to 6.3.4 at a number of different torque levels (see 6.2.6) in order that the characteristics over a representative range of starting conditions can be obtained.

6.3.6 For bidirectional motors, repeat the steps described in 6.3.2 to 6.3.5 in the reverse direction.

1) 1 bar = 10^5 Pa; 1 Pa = 1 N/m^2

6.4 Expression of results

NOTE — Refer to clause 4 for a fuller explanation of letter symbols and suffixes.

Calculate the minimum starting efficiency, $\eta_{hm,min}$, for each test torque level, using the following formulae:

$$\eta_{hm,min} = \frac{\Delta p_{i,mi}}{\Delta p_{e,max}}$$

or

$$\eta_{hm,min} = \frac{\Delta p_{g,mi}}{\Delta p_{e,max}}$$

where

$$\Delta p_{i,mi} = \frac{2\pi}{V_i} \times \text{applied test torque};$$

$$\Delta p_{g,mi} = \frac{2\pi}{V_g} \times \text{applied test torque};$$

$\Delta p_{e,max}$ is the highest differential pressure, measured during the test, at a given test torque level.

7 Constant pressure method

7.1 Test apparatus

7.1.1 A test rig shall be set up which makes use of the test circuit in 5.1.1 and which provides the equipment shown in the figure and described in 7.1.2.

7.1.2 A suitable loading device (**11** and **12** or **13** to **17**) complying with the requirements of 6.1.2 shall be provided.

7.2 Test conditions

7.2.1 The motor being tested shall be in thermal equilibrium before commencing the test.

7.2.2 The constant outlet pressure shall be maintained at the level recommended by the motor manufacturer.

7.2.3 The rate of decrease of the test torque per second shall be less than or equal to 20 % of test torque and shall not significantly influence the starting torque.

7.2.4 The differential pressure across the motor shall be reduced by less than 5 % of the maximum test pressure or 10 bar (1 MPa), whichever is the smaller, before embarking on every subsequent set of measurements.

NOTE — This requirement is not applicable to motors for special applications, e.g. winch drives.

7.2.5 The number of measurements at different shaft positions at one torque level shall be sufficient for the minimum starting torque to be found with a confidence level of 95 %.

7.3 Test procedure

7.3.1 Adjust the back pressure on the motor outlet to a constant value (see 7.2.2).

7.3.2 Adjust the test torque of the torque loading device to a value just above the maximum theoretical torque of the motor at the appropriate test pressure.

7.3.3 Gradually increase the inlet pressure to the motor until the required test pressure is reached.

NOTE — If the test pressure is exceeded, decrease the pressure and repeat the step described in 7.3.3.

7.3.4 Decrease the load torque smoothly (see 7.2.3) until the motor starts to rotate. Simultaneously record the angular displacement of the motor shaft against torque.

7.3.5 Produce a graph of the recordings obtained in 7.3.4 and note the starting torque at which the motor starts to rotate, i.e. the point at which there is an abrupt change in slope of the characteristic (see 3.3).

7.3.6 Repeat the steps described in 7.3.2 to 7.3.5 at a number of different pressure levels and shaft positions (see 7.2.5) in order that the characteristics over a representative range of starting conditions can be obtained.

7.3.7 For bidirectional motors, repeat the steps described in 7.3.2 to 7.3.6 in the reverse direction.

7.4 Expression of results

NOTE — Refer to clause 4 for a fuller explanation of letter symbols and suffixes.

Calculate the minimum starting torque efficiency, $\eta_{hm,min}$ for each test pressure, using the following formulae:

$$\eta_{hm,min} = \frac{T_{e,min}}{T_{i,mi}}$$

or

$$\eta_{hm,min} = \frac{T_{e,min}}{T_{g,mi}}$$

where

$$T_{i,mi} = \frac{1}{2\pi} \times V_i \times \text{applied test pressure};$$

$$T_{g,mi} = \frac{1}{2\pi} \times V_g \times \text{applied test pressure};$$

$T_{e,min}$ is the lowest torque measured during the startability test at the given test pressure level.

8 Test report

8.1 General

All the relevant test data at every test pressure, and the information listed in 8.3, shall be recorded in a test report.

8.2 Presentation of test data

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

8.3 Test data

The following test data shall be included in the test report:

a) a description of the test motor;

b) the test method used, i.e. constant torque method or constant pressure method;

c) the class of measurement accuracy used (see annex B);

d) a description of the hydraulic test circuit and components:

e) a description of the test fluid;

f) the fluid viscosity (determined in accordance with ISO 3448);

g) the fluid temperature (see 5.1.2);

h) the outlet pressure (see 6.2.2 or 7.2.2);

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

j) either, according to the test method used,

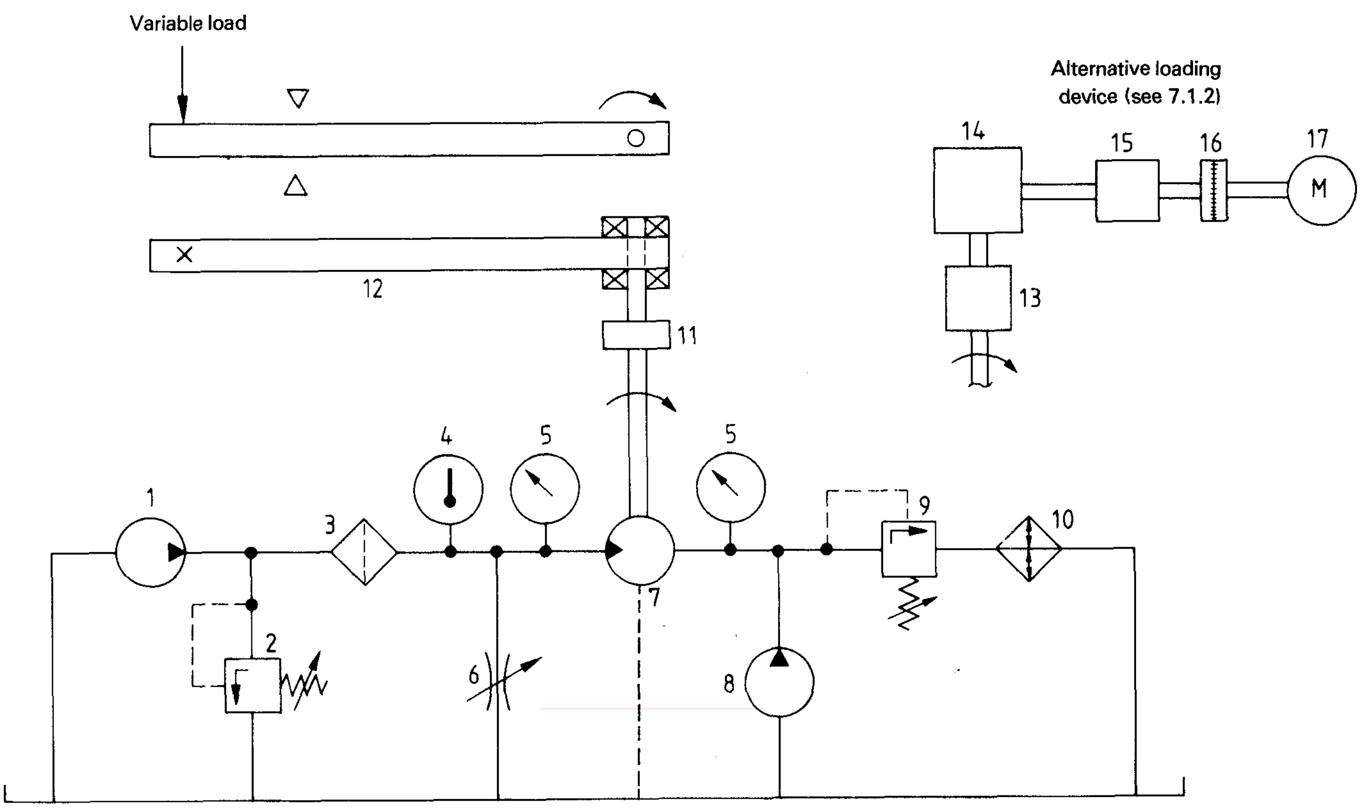
1) the test pressure level and related minimum and maximum starting torque over one shaft revolution at each pressure level,

or

2) the test torque level and related minimum and maximum starting pressures over one shaft revolution at each torque level;

k) the minimum starting efficiency, $\eta_{hm,min}$ (see 6.4 or 7.4);

l) the direction of starting, viewed at end of the shaft (R or L).



Key

1 Supply pump
2 Pressure control valve (manual)
3 Filter
4 Temperature indicator
5 Pressure indicator
6 Variable restrictor
7 Motor under test
8 Back pressure pump
9 Back pressure control valve
10 Heat exchanger
11 Indexing shaft coupling
12 Beam mounted on hydrostatic bearings
13 Torque transducer
14 70: 1 worm gearbox
15 40: 1 worm gearbox
16 Inductive speed pick-up
17 D.C. electric motor

Figure 1 — Typical hydraulic circuit — Constant torque test on unidirectional motor

Annex A

Additional physical quantities and their letter symbols

(This annex forms part of the standard.)

Clauses A.1 and A.2 supplement those given in ISO 4391 with respect to starting conditions of hydraulic motors and shall be used in the preparation of test reports.

A.1 Data at starting conditions on constant torque test

Reference	Description	Symbol	Dimension	Definition or explanation
A.1.1	Differential pressure	$\Delta p_{(\varphi=\ldots)}$	$ML^{-1}T^{-2}$	Differential pressure at a given shaft position ($\varphi=\ldots$)[1]
A.1.2	Integrated differential pressure over 1 revolution or 2π rad	Δp_{mi}	$ML^{-1}T^{-2}$	The mean value obtained by integration of the pressure over 1 revolution $\Delta p_{mi} = \frac{1}{2\pi}\int_{\varphi=0}^{\varphi=2\pi} \Delta p_{(\varphi=\ldots)}\, d\varphi$
A.1.3	Minimum differential pressure	$\Delta p_{e,min}$	$ML^{-1}T^{-2}$	Lowest differential pressure over 1 revolution or 2π rad
A.1.4	Maximum differential pressure	$\Delta p_{e,max}$	$ML^{-1}T^{-2}$	Highest differential pressure over 1 revolution or 2π rad
A.1.5	Deviation of minimum pressure from integrated differential pressure	$\delta\Delta p_{e,min}$	1	$\delta\Delta p_{e,min} = \frac{\Delta p_{e,mi} - \Delta p_{e,min}}{\Delta p_{e,mi}}$
A.1.6	Deviation of maximum pressure from integrated differential pressure	$\delta\Delta p_{e,max}$	1	$\delta\Delta p_{e,max} = \frac{\Delta p_{e,max} - \Delta p_{e,mi}}{\Delta p_{e,mi}}$
A.1.7	Overall deviation from integrated differential pressure	$\delta\Delta p_{e,t}$	1	$\delta\Delta p_{e,t} = \delta\Delta p_{e,min} + \delta\Delta p_{e,max} = \frac{\Delta p_{e,max} - \Delta p_{e,min}}{\Delta p_{e,mi}}$
A.1.8	Instantaneous geometric differential pressure	$\Delta p_{g,(\varphi=\ldots)}$	$ML^{-1}T^{-2}$	Geometric differential pressure at a given shaft position ($\varphi=\ldots$)[1] $\Delta p_{g,(\varphi=\ldots)} = \frac{T_{g,(\varphi=\ldots)}}{V_{g,(\varphi=\ldots)}}$ where $T_{g,(\varphi\ldots)}$ is the instantaneous geometric torque (see A.2.11 in table 2); $V_{g,(\varphi\ldots)}$ is the geometric swept volume at a given shaft position ($\varphi\ldots$).
A.1.9	Integrated theoretical differential pressure over 1 revolution	$\Delta p_{i,mi}$	$ML^{-1}T^{-2}$	$\Delta p_{i,mi} = \frac{2\pi T_{i,mi}}{V_i}$ where $T_{i,mi}$ is the integrated theoretical torque over 1 revolution (see A.2.13 in table 2); V_i is the derived swept volume (see A.2.10 in table 2).
A.1.10	Integrated geometrical differential pressure over 1 revolution	$\Delta p_{g,mi}$	$ML^{-1}T^{-2}$	$\Delta p_{g,mi} = \frac{2\pi T_{g,mi}}{V_g}$ where $T_{g,mi}$ is the integrated geometric torque over 1 revolution (see A.2.12 in table 2); V_g is the geometric swept volume (see A.2.9 in table 2).
A.1.11	Integrated mean hydraulic mechanical efficiency	$\eta_{hm,mi}$	1	$\eta_{hm,mi} = \frac{\Delta p_{g,mi}}{\Delta p_{e,mi}}$

1) φ is the rotational angle.

Reference	Description	Symbol	Dimension	Definition or explanation
A.1.12	Maximum hydraulic mechanical efficiency[1)]	$\eta_{hm,max}$	1	$\eta_{hm,max} = \frac{\Delta p_{g,(\varphi ...)}}{\Delta p_{e,min}}$
A.1.13	Minimum hydraulic mechanical efficiency[1)]	$\eta_{hm,min}$	1	$\eta_{hm,min} = \frac{\Delta p_{g,(\varphi ...)}}{\Delta p_{e,max}}$

1) In cases where $\Delta p_{g,(\varphi = ...)}$ is not available, the use of $\Delta p_{i,mi}$ or $\Delta p_{g,mi}$ is allowed.

A.2 Data at starting conditions on constant pressure test

Reference	Description	Symbol	Dimension	Definition or explanation
A.2.1	Torque	$T_{(\varphi = ...)}$	$ML^2 T^{-2}$	Torque at a given shaft position ($\varphi = ...$)[1)]
A.2.2	Integrated torque over 1 revolution or 2π rad	T_{mi}	$ML^2 T^{-2}$	The mean value obtained by integration of the torque over 1 revolution $T_{mi} = \frac{1}{2\pi} \int_{\varphi = 0}^{\varphi = 2\pi} T_{(\varphi = ...)} \, d\varphi$
A.2.3	Maximum torque	$T_{e,max}$	$ML^2 T^{-2}$	Highest torque measured over 1 revolution or 2π rad
A.2.4	Minimum torque	$T_{e,min}$	$ML^2 T^{-2}$	Lowest torque measured over 1 revolution or 2π rad
A.2.5	Deviation of maximum torque from integrated torque	$\delta T_{e,max}$	1	$\delta T_{e,max} = \frac{T_{e,max} - T_{e,mi}}{T_{e,mi}}$
A.2.6	Deviation of minimum torque from integrated torque	$\delta T_{e,min}$	1	$\delta T_{e,min} = \frac{T_{e,mi} - T_{e,min}}{T_{e,mi}}$
A.2.7	Overall deviation from integrated torque	$\delta T_{e,t}$	1	$\delta T_{e,t} = \delta T_{e,max} + \delta T_{e,min} = \frac{T_{e,max} - T_{e,min}}{T_{e,mi}}$
A.2.8	Instantaneous geometric displacement	$V_{g,(\varphi = ...)}$	L^3	Swept volume at a given shaft position, calculated geometrically
A.2.9	Geometric swept volume	V_g	L^3	Swept volume, calculated geometrically without reference to tolerances, clearances or deformations
A.2.10	Derived swept volume	V_i	L^3	Swept volume obtained from flow measurements
A.2.11	Instantaneous geometric torque	$T_{g,(\varphi = ...)}$	$ML^2 T^{-2}$	Geometric torque at given shaft position ($\varphi = ...$)[1)]
A.2.12	Integrated geometric torque over 1 revolution	$T_{g,mi}$	$ML^2 T^{-2}$	$T_{g,mi} = \frac{1}{2\pi} \int_{\varphi = 0}^{\varphi = 2\pi} T_{g,(\varphi = ...)} \, d\varphi$
A.2.13	Integrated theoretical torque over 1 revolution	$T_{i,mi}$	$ML^2 T^{-2}$	$T_{i,mi} = \frac{V_i \cdot \Delta p}{2\pi}$ where Δp is the differential pressure (see A.1.1 table 1).
A.2.14	Average hydraulic mechanical efficiency	η_{hm}	1	$\eta_{hm} = \frac{T_{e,mi}}{T_{g,mi}}$
A.2.15	Maximum hydraulic mechanical efficiency[2)]	$\eta_{hm,max}$	1	$\eta_{hm,max} = \frac{T_{e,max}}{T_{g,(\varphi = ...)}}$
A.2.16	Minimum hydraulic mechanical efficiency[2)]	$\eta_{hm,min}$	1	$\eta_{hm,min} = \frac{T_{e,min}}{T_{g,(\varphi = ...)}}$

1) φ is the rotational angle.

2) In cases where $T_{g,(\varphi = ...)}$ is not available, the use of $T_{i,mi}$ or $T_{g,mi}$ is allowed.

Annex B

Classes of measurement accuracy

(This annex forms part of the standard.)

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

B.1 Classes of measurement accuracy

B.1.1 Depending on the accuracy required, the tests shall be carried out to one of three classes of measurement accuracy, A, B or C, as agreed by the parties concerned.

NOTES

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

2 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.

B.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 2.

NOTE — The limits given in table 2 are of the value of the quantity being measured and not a percentage of the maximum scale reading of the instrument.

Table 2 — Permissible systematic errors of measuring instruments as determined during calibration

Parameter of measuring instrument	Permissible systematic errors for class of measurement accuracy		
	A	B	C
Torque, %	± 0,5	± 1	± 2
Pressure below 2 bar gauge, bar	± 0,01	± 0,03	± 0,05
Pressure greater than or equal to 2 bar gauge, %	± 0,5	± 1,5	± 2,5
Fluid temperature, °C	± 0,5	± 1	± 2