
**Hydraulic fluid power — Determination of
characteristics of motors —**

**Part 2:
Startability**

*Transmissions hydrauliques — Détermination des caractéristiques des
moteurs —*

Partie 2: Essai de démarrage



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Contents

Page

Foreword.....	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols	2
5 Test installation	2
6 Constant torque method	4
7 Constant pressure method	5
8 Test report	6
Annex A (normative) Additional physical quantities and their letter symbols	8
Annex B (normative) Classes of measurement accuracy	12
Annex C (normative) Use of practical units	13
Bibliography	14

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 3.

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 part of ISO 4392 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4392-2 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 4392-2:1989), of which it constitutes a minor revision.

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 constant pressure*
- *Part 2: Startability*
- *Part 3: At constant flow and at constant torque*

Annexes A, B and C form a normative part of this part of ISO 4392.

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. Startability, the ability of a motor to start, is an important property of hydraulic motors, when used for specific applications.

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Hydraulic fluid power — Determination of characteristics of motors —

Part 2: Startability

1 Scope

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.

Additional physical quantities and their symbols are given in annex A.

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

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 4392. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 4392 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 9110-1:1990, *Hydraulic fluid power — Measurement techniques — Part 1: General measurement principles*

ISO 9110-2:1990, *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 part of ISO 4392, the terms and definitions given in ISO 4391, ISO 5598 and the following apply.

3.1

startability

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 ^a	SI unit ^b
Pressure, differential pressure	$p, \Delta p$	$ML^{-1}T^{-2}$	Pa
Torque	T	ML^2T^{-2}	N·m
Instantaneous displacement	v	L^3	m ³
Time	t	T	s
Swept volume	V	L^3	m ³
^a M = mass; L = length; T = time.			
^b The practical units which may be used for the presentation of results are given in annex C.			

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

5 Test installation

5.1 Hydraulic test circuit

5.1.1 An appropriate hydraulic test circuit similar to that shown in Figure 1 shall be used.

This 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.

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

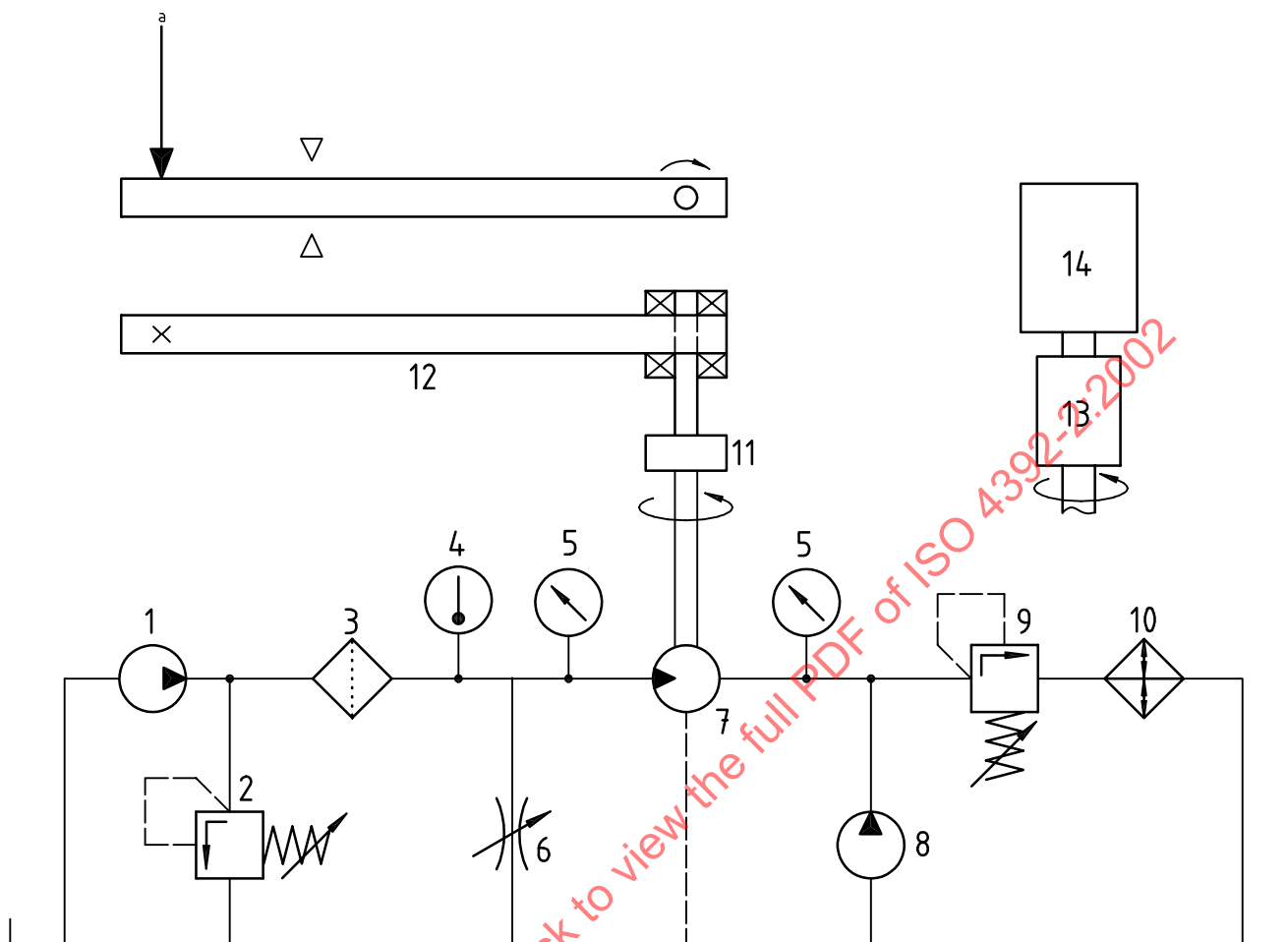
NOTE 2 An additional booster pump circuit may be necessary when testing piston-type motors.

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.

Alternative loading devices (see 7.1.2)

**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 Electrical torque load

a Variable load.

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

5.2 Instrumentation

Instruments shall conform to the requirements of ISO 9110-1 and ISO 9110-2. 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 Figure 1 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, for example a lever arm and adjustable mass at one end, or 14 which allows continuous opposing rotation by a controlled electrical variable torque loading device, 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 the 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 bar¹⁾ (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 the 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.

6.4 Expression of results

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

1) 1 bar = 10⁵ Pa; 1 Pa = 1 N/m².

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

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

or

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

where

$$\Delta p_{\text{i, mi}} = \frac{2\pi}{V_{\text{i}}} \times T'$$

$$\Delta p_{\text{g, mi}} = \frac{2\pi}{V_{\text{g}}} \times T'$$

T' is the applied test torque;

$\Delta p_{\text{e, max}}$ 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 Figure 1 and described in 7.1.2.

7.1.2 A suitable loading device (11 and 12 or 13 and 14) 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.

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

$$T_{i, mi} = \frac{1}{2\pi} \times V_i \times p'$$

$$T_{g, mi} = \frac{1}{2\pi} \times V_g \times p'$$

p' is the 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 measurements 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 (clockwise or anticlockwise).

Annex A (normative)

Additional physical quantities and their letter symbols

A.1 General

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.2 Data at starting conditions on constant torque test

Reference	Description	Symbol	Dimension	Definition or explanation
A.2.1	Differential pressure	$\Delta p_{(\varphi=\dots)}$	$ML^{-1} T^{-2}$	Differential pressure at a given shaft position ($\varphi = \dots$) ^a
A.2.2	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 $\Delta p_{mi} = \frac{1}{2\pi} \int_{\varphi=0}^{\varphi=2\pi} \Delta p_{(\varphi=\dots)} d\varphi$
A.2.3	Minimum differential pressure	$\Delta p_{e,min}$	$ML^{-1} T^{-2}$	Lowest differential pressure over 1 revolution or 2π rad
A.2.4	Maximum differential pressure	$\Delta p_{e,max}$	$ML^{-1} T^{-2}$	Highest differential pressure over 1 revolution or 2π rad
A.2.5	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.2.6	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.2.7	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.2.8	Instantaneous geometric differential pressure	$\Delta p_{g,(\varphi=\dots)}$	$ML^{-1} T^{-2}$	Geometric differential pressure at a given shaft position ($\varphi = \dots$) ^a $\Delta p_{g,(\varphi=\dots)} = \frac{T_{g,(\varphi=\dots)}}{V_{g,(\varphi=\dots)}}$ where $T_{g,(\varphi=\dots)}$ is the instantaneous geometric torque (see A.3.11); $V_{g,(\varphi=\dots)}$ is the geometric swept volume at a given shaft position ($\varphi=\dots$).

Reference	Description	Symbol	Dimension	Definition or explanation
A.2.9	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.3.13); V_i is the derived swept volume (see A.3.10).
A.2.10	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.3.12); V_g is the geometric swept volume (see A.3.9).
A.2.11	Integrated mean hydraulic mechanical efficiency	$\eta_{hm, mi}$	1	$\eta_{hm, mi} = \frac{\Delta p_{g, mi}}{\Delta p_{e, mi}}$
A.2.12	Maximum hydraulic mechanical efficiency ^b	$\eta_{hm, max}$	1	$\eta_{hm, max} = \frac{\Delta p_{g, (\varphi \dots)}}{\Delta p_{e, min}}$
A.2.13	Minimum hydraulic mechanical efficiency ^b	$\eta_{hm, min}$	1	$\eta_{hm, min} = \frac{\Delta p_{g, (\varphi \dots)}}{\Delta p_{e, max}}$
^a φ is the rotational angle. ^b In cases where $\Delta p_{g, (\varphi \dots)}$ is not available, the use of $\Delta p_{i, mi}$ or $\Delta p_{g, mi}$ is allowed.				

A.3 Data at starting conditions on constant pressure test

Reference	Description	Symbol	Dimension	Definition or explanation
A.3.1	Torque	$T_{(\varphi = \dots)}$	ML ² T ⁻²	Torque at a given shaft position ($\varphi = \dots$) ^a
A.3.2	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 $T_{mi} = \frac{1}{2\pi} \int_{\varphi=0}^{\varphi=2\pi} T_{(\varphi=\dots)} d\varphi$
A.3.3	Maximum torque	$T_{e, \max}$	ML ² T ⁻²	Highest torque measured over 1 revolution or 2π rad
A.3.4	Minimum torque	$T_{e, \min}$	ML ² T ⁻²	Lowest torque measured over 1 revolution or 2π rad
A.3.5	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.3.6	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.3.7	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.3.8	Instantaneous geometric swept volume	$v_g, (\varphi = \dots)$	L ³	Swept volume at a given shaft position, calculated geometrically
A.3.9	Geometric swept volume	V_g	L ³	Swept volume, calculated geometrically without reference to tolerances, clearances or deformations
A.3.10	Derived swept volume	V_i	L ³	Swept volume obtained from flow measurements
A.3.11	Instantaneous geometric torque	$T_{g, (\varphi = \dots)}$	ML ² T ⁻²	Geometric torque at given shaft position ($\varphi = \dots$) ^a
A.3.12	Integrated geometric torque over 1 revolution	$T_{g, mi}$	ML ² T ⁻²	$T_{g, mi} = \frac{1}{2\pi} \int_{\varphi=0}^{\varphi=2\pi} T_{g(\varphi=\dots)} d\varphi$
A.3.13	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.2.1).
A.3.14	Average hydraulic mechanical efficiency	η_{hm}	1	$\eta_{hm} = \frac{T_{e, mi}}{T_{g, mi}}$
A.3.15	Maximum hydraulic mechanical efficiency ^b	$\eta_{hm, \max}$	1	$\eta_{hm, \max} = \frac{T_{e, \max}}{T_{g, (\varphi = \dots)}}$

Reference	Description	Symbol	Dimension	Definition or explanation
A.3.16	Minimum hydraulic mechanical efficiency ^b	$\eta_{hm, \min}$	1	$\eta_{hm, \min} = \frac{T_{e, \min}}{T_{g, (\varphi = \dots)}}$
^a φ is the rotational angle. ^b In cases where $T_{g, (\varphi = \dots)}$ is not available, the use of $T_{i, \min}$ or $T_{g, \min}$ is allowed.				

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