
**Aerospace — Fixed displacement
hydraulic motors — General
specifications**

*Aéronautique et espace — Moteurs hydrauliques à cylindrée fixe —
Spécifications générales*

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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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

This third edition of ISO 9206 cancels and replaces the second edition (ISO 9206:2016) which has been technically revised.

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

- title replaced “Constant displacement” with “Fixed displacement”;
- deletion of requirement for minimum case drain flow ([6.3.2](#));
- update of external leakage requirements ([6.3.4](#));
- correction of requirement for overspeed ([6.4.1.2](#));
- coupling shaft requirements re-written ([10.5](#));
- the test stand requirements have been revised ([13.3](#));
- requirement to leave the case drain port unplugged in the Inlet port proof pressure test ([14.3.4.3](#)) and the Case port proof pressure test ([14.3.4.4](#));
- update of test procedures in Operational tests at rated conditions ([14.3.5](#));
- revision of the Sampling requirements ([14.3.6.1](#));
- correction of flow measurement in Torque and flow rate ([15.3.5.3](#));
- additional detail provided in the stalling torque and internal leakage test ([15.3.5.7](#));
- endurance test representativity text added ([15.3.6.1](#));
- revision of Endurance test alternating loads test requirements ([15.3.6.1](#) and [15.3.6.3](#));

- revision of filter used for endurance testing ([15.3.6.6](#));
- revision of Recalibration requirements ([15.3.6.9](#));
- correction of low-temperature test requirement ([15.3.7.2](#));
- clarification of motor operation during vibration tests ([15.3.8.1.4](#));
- clarification of resonant frequency vibration test ([15.3.8.1.4](#));
- ports identified for the ultimate pressure test ([15.3.8.5](#)); and
- clarification of coupling shear test ([15.3.8.6](#)).

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.

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Aerospace — Fixed displacement hydraulic motors — General specifications

1 Scope

This document establishes the general requirements for constant displacement hydraulic motors, suitable for use in aircraft hydraulic systems at pressures up to 35 000 kPa (5 000 psi).

Primary and secondary function motors (see [Clause 4](#)) are covered in this document; however, actuators with internal rotation angle limits and low-speed motors are not covered.

This document is to be used in conjunction with the detail specification that is particular to each application.

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 2093, *Electroplated coatings of tin — Specification and test methods*

ISO 2669, *Environmental tests for aircraft equipment — Steady-state acceleration*

ISO 2671, *Environmental tests for aircraft equipment — Part 3.4 : Acoustic vibration*

ISO 2685, *Aircraft — Environmental test procedure for airborne equipment — Resistance to fire in designated fire zones*

ISO 3323, *Aircraft — Hydraulic components — Marking to indicate fluid for which component is approved*

ISO 3601-1, *Fluid power systems — O-rings — Part 1: Inside diameters, cross-sections, tolerances and designation codes*

ISO 7137, *Aircraft — Environmental conditions and test procedures for airborne equipment*

ISO 7320, *Aerospace — Couplings, threaded and sealed, for fluid systems — Dimensions*

ISO 8078, *Aerospace process — Anodic treatment of aluminium alloys — Sulfuric acid process, undyed coating*

ISO 8079, *Aerospace process — Anodic treatment of aluminium alloys — Sulfuric acid process, dyed coating*

ISO 8081, *Aerospace process — Chemical conversion coating for aluminium alloys — General purpose*

ISO 8399-1, *Aerospace — Accessory drives and mounting flanges (Metric series) — Part 1: Design criteria*

ISO 8399-2, *Aerospace — Accessory drives and mounting flanges (Metric series) — Part 2: Dimensions*

ISO 8625-1, *Aerospace — Fluid systems — Vocabulary — Part 1: General terms and definitions related to pressure*

ISO 8625-2, *Aerospace — Fluid systems — Vocabulary — Part 2: General terms and definitions relating to flow*

ISO 8625-3, *Aerospace — Fluid systems — Vocabulary — Part 3: General terms and definitions relating to temperature*

ISO 11218, *Aerospace — Cleanliness classification for hydraulic fluids*

ISO 16889, *Hydraulic fluid power — Filters — Multi-pass method for evaluating filtration performance of a filter element*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8625-1, ISO 8625-2, ISO 8625-3, and the following 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 <https://www.iso.org/obp>

3.1 General

3.1.1

fixed displacement hydraulic motor

mechanical actuator that converts hydraulic pressure and flow into torque and angular velocity (rotation)

3.1.2

purchaser

organization that has the engineering responsibility for the hydraulic system that includes the motor

Note 1 to entry: Typically, the purchaser is an aircraft manufacturer, an equipment manufacturer that has the actuation system responsibility or a modification centre.

Note 2 to entry: The purchaser is responsible for the compilation of the detail specification.

3.1.3

detail specification

document compiled by the *purchaser* (3.1.2) that specifies the following:

- a) technical requirements;
- b) acceptance and qualification test requirements;
- c) reliability requirements;
- d) quality requirements;
- e) packaging requirements; and
- f) other requirements

3.1.4

supplier

organization that provides the motor

Note 1 to entry: Typically, the supplier is the manufacturer of the motor who will be responsible for the design, production, and qualification of the motor.

3.2 Ports of the hydraulic motor

A fixed displacement hydraulic motor typically achieves bi-directional operation by reversing the differential pressure across the inlet/outlet ports, thus reversing the output torque. [Table 1](#) below

illustrates the phasing of the motor ports in relation to the motor operation for this application, using the port identification identifiers listed below.

- port A – motor inlet/outlet port
- port B – motor inlet/outlet port
- port C – motor case drain port
- port D – motor shaft seal port

Table 1 — Phasing of the motor ports in relation to the motor operation

Motor drive coupling shaft rotation	Port A	Port B	Port C	Port D
Clockwise	Motor inlet	Motor return outlet	Case drain	Shaft seal
Counter clockwise	Motor return outlet	Motor inlet	Case drain	Shaft seal

3.2.1

motor inlet port

port that receives flow from the hydraulic system to supply the motor

3.2.2

motor outlet port

port that returns flow back to the system

3.2.3

motor case drain port

port that drains internal leakage flow to the reservoir

3.2.4

shaft seal port

port that routes any shaft seal leakage from the motor to an overboard drain, collector tank, etc.

3.3 Temperature terms

All temperatures are expressed in degrees Celsius.

3.3.1

rated temperature

maximum continuous temperature of the fluid to be supplied at the inlet port of the motor

3.3.2

minimum continuous temperature

minimum temperature of the fluid at the inlet port of the motor at which the motor is able to function

Note 1 to entry: This temperature is generally higher than the survival temperature.

3.3.3

normal operating temperature

temperature of the fluid to be supplied at the inlet port of the motor at which full motor performance is required

3.4 Pressure terms

3.4.1

design operating pressure

normal maximum steady pressure

Note 1 to entry: Excluded are reasonable tolerances, transient pressure effects such as may arise from the following:

- pressure ripple;
- reactions to system functioning; and
- demands that may affect fatigue.

3.4.2

rated supply pressure

system rated pressure, which is normally the hydraulic power generation system design operating pressure ([3.4.1](#))

3.4.3

rated differential pressure

differential pressure measured between the motor inlet and outlet ports required to produce *rated torque* ([3.8.1](#))

3.4.4

no-load break-out pressure

differential pressure required for starting the output shaft, without interruption, with the case drain port at the rated case drain pressure and the outlet port at the rated return pressure

3.4.5 Motor return pressure

3.4.5.1

nominal motor return pressure

pressure generated at the outlet port as the motor returns flow back to the system

3.4.5.2

rated motor return pressure

maximum pressure at the outlet port

Note 1 to entry: This is applicable to uni-directional motors only.

Note 2 to entry: This is a stressing term only as the nominal motor pressure is generally considerably less than the rated motor return pressure.

3.4.6 Case drain pressure

3.4.6.1

rated case drain pressure

nominal pressure at which the motor case is required to operate continuously in the system

3.4.6.2

maximum case pressure

maximum of either

- the maximum pressure peak that may be imposed by the hydraulic system on the *motor case drain port* ([3.2.3](#)); or
- the pressure resulting from integral bypassing of the rated flow towards the outlet and drain ports in order to take into account the accidental transitory separation of the components

3.5

rated consumption

flow rate measured at the *motor inlet port* (3.2.1) under conditions of the following:

- rated fluid temperature;
- *rated differential pressure* (3.4.3);
- *rated speed* (3.7.1); and
- using the hydraulic fluid specified in the *detail specification* (3.1.3)

Note 1 to entry: This is typically specified as the maximum flow rate.

3.6

rated displacement

maximum theoretical volume of fluid consumed by one revolution of its output shaft

Note 1 to entry: It shall be expressed in cubic centimetres per revolution (cubic inches per revolution).

Note 2 to entry: The rated displacement shall be calculated from the geometrical configuration of the motor, without allowing for the effects of the following:

- permissible manufacturing tolerances;
- distortions of the motor structure;
- the compressibility of the hydraulic fluid;
- internal leakage;
- temperature.

Note 3 to entry: The rated displacement is used to indicate the size of the motor rather than its performance.

3.7 Speed terms

3.7.1

rated speed

maximum speed at which the motor is required to operate continuously at *rated temperature* (3.3.1) and at *rated differential pressure* (3.4.3)

Note 1 to entry: The rated speed shall be expressed as the number of revolutions of the motor output shaft per minute.

3.7.2

maximum no-load speed

speed reached at rated conditions with no opposing torque

3.8 Torque terms

3.8.1

rated torque

minimum torque value at rated operating conditions

3.8.2

break-out torque

minimum torque against which the motor will start at operating conditions specified in the *detail specification* (3.1.3)

Note 1 to entry: The specification shall be met at any angular position of the output shaft.

3.8.3

stalling torque

minimum opposing torque which stops the rotation of the outlet shaft at the *rated supply pressure* (3.4.2) and for the outlet port and case drain port pressures specified in the *detail specification* (3.1.3)

3.9

motor overall efficiency

obtained from the formula:

$$\text{motor overall efficiency (\%)} = (\text{output shaft power} / \text{input fluid power}) \times 100$$

where

output shaft power = shaft torque × shaft speed;

input fluid power = (supply pressure – return pressure) × rated flow

Note 1 to entry: This formula ignores compressibility effects. If this formula is to be used, the flow rate measurement should be made on the compressed flow stream.

3.10

rated endurance

total number of hours and cycles of operation to be included in the endurance phase of its qualification testing

3.11

first article inspection

process that conducts the following:

- verifies that the parts of a component comply with the drawings;
- verifies that the manufacturing processes have been compiled and are adhered to;
- verifies that the assembly processes have been compiled and are adhered to; and
- verifies that the acceptance test of the component is in accordance with the test procedure, and that the results of the test are in agreement with the test requirements

4 Classification

The hydraulic motors covered by this document are classified in two categories.

- Category A: Primary function motors, for example, flight controls, slats, flaps, adjustable planes, transfer units, constant speed drives, etc.
- Category B: Secondary function motors, for example, hoists, guns, radars, doors, etc.

The motor category shall be specified in the detail specification.

5 General requirements

5.1 Order of precedence

The detail specification shall take precedence in the case of a conflict between the requirements of this document and the detail specification.

5.2 Hydraulic system characteristics

The hydraulic motor shall be designed to be operated by the hydraulic system as defined in the detail specification.

The detail specification shall include the characteristics of the hydraulic system in which the motor is to be used. This shall include the flow versus pressure curves for the supply, return, and case drain lines for the following hydraulic fluid temperatures:

- normal operating temperature (for example, +20 °C);
- rated temperature; and
- minimum continuous temperature.

5.3 Airworthiness regulations

The hydraulic motor shall meet the applicable civil aviation requirements. Examples of these general requirements are:

- in the USA: 14 CFR Part 25 § 25.1435;
- in the EU: EASA Certification Specification CS-25 § 25.1435.

5.4 Qualification

Hydraulic motors furnished under this document shall be products that have passed the qualification tests that are specified in the detail specification.

6 Functional requirements

6.1 Hydraulic fluid

The detail specification shall state the applicable hydraulic fluid.

6.2 Pressures

6.2.1 Rated supply pressure

The value of the rated supply pressure shall be stated in the detail specification and shall be one of the following values of rated supply pressures listed in [Table 2](#) (derived from ISO 6771).

Table 2 — Rated supply pressure

Pressure Class	Metric system kPa basic	Imperial system psi basic
A	4 000	600
B	10 500	1 500
C	16 000	2 500
D	21 000	3 000
E	28 000	4 000
J	35 000	5 000

6.2.2 Rated differential pressure

The rated differential pressure shall be specified in the detail specification.

6.2.3 No-load break-out pressure

The no-load break-out pressure shall be specified in the detail specification.

6.2.4 Motor outlet port pressure

6.2.4.1 Nominal return pressure

The nominal return pressure shall be specified in the detail specification.

6.2.4.2 Rated motor return pressure

The rated motor return pressure (where applicable) shall also be specified in the detail specification. Unless otherwise specified in the detail specification, the rated motor return pressure shall be 7 000 kPa (1 000 psi).

6.2.5 Case drain pressure

6.2.5.1 Rated case drain pressure

The rated case drain pressure shall be specified in the detail specification.

Caution should be taken defining the rated case drain pressure. Too high a pressure may cause abnormal shaft seal and shaft bearing loading, affecting their operation and reducing the motor life.

6.2.5.2 Maximum case drain pressure

The maximum case drain pressure shall be specified in the detail specification.

6.3 Flows

6.3.1 Rated consumption

The detail specification shall state the value of the rated consumption, which shall be in l/min (or gpm).

6.3.2 Case drain flow

The motor case flow rate [which shall be in l/min (or gpm)] shall be specified under the following conditions:

- 1) the motor turning at rated torque and speed;
- 2) the motor turning at zero torque; and
- 3) the motor stalled, shaft locked at any position.

The maximum case drain flow shall be stated at conditions specified in the detail specification.

6.3.3 Shaft seal leakage flow

The detail specification shall state the value of the maximum dynamic shaft seal leakage (which shall be in drops/min) at the following conditions.

- a) New build:
 - 1) the motor filled with fluid, but un-pressurized;
 - 2) when subject to proof pressure at ambient temperature; and

- 3) when the motor is operating at rated consumption flow.
- b) Qualification testing:
 - 4) over the expanded test envelope;
 - 5) at the completion of the endurance test;
 - 6) when subject to proof pressure at rated temperature; and
 - 7) when subject to ultimate pressure at rated temperature.

6.3.4 External leakage

No leakage sufficient to form a drop from the motor case or from any static seal shall be permitted. Dynamic and static shaft seal leakage shall not be considered as external leakage.

6.4 Speed and direction of rotation

6.4.1 Speed

6.4.1.1 Rated speed

The rated speed of the motor shall be specified in the detail specification.

NOTE As an indication, the maximum recommended values are given in the Nomograph in [Figures 1](#) and [2](#). If speeds are kept well below those indicated by the curves, the operating life can be improved. However, several system factors such as fluid, temperature, duty cycle, contamination, expected life, etc. will also influence the values.

6.4.1.2 Overspeed

Unless otherwise specified in the detail specification, the motor shall be capable of operating without any failures at 125 % of the rated motor speed for the durations and at the conditions of [Table 7](#) and/or [Table 8](#) for 30 minutes.

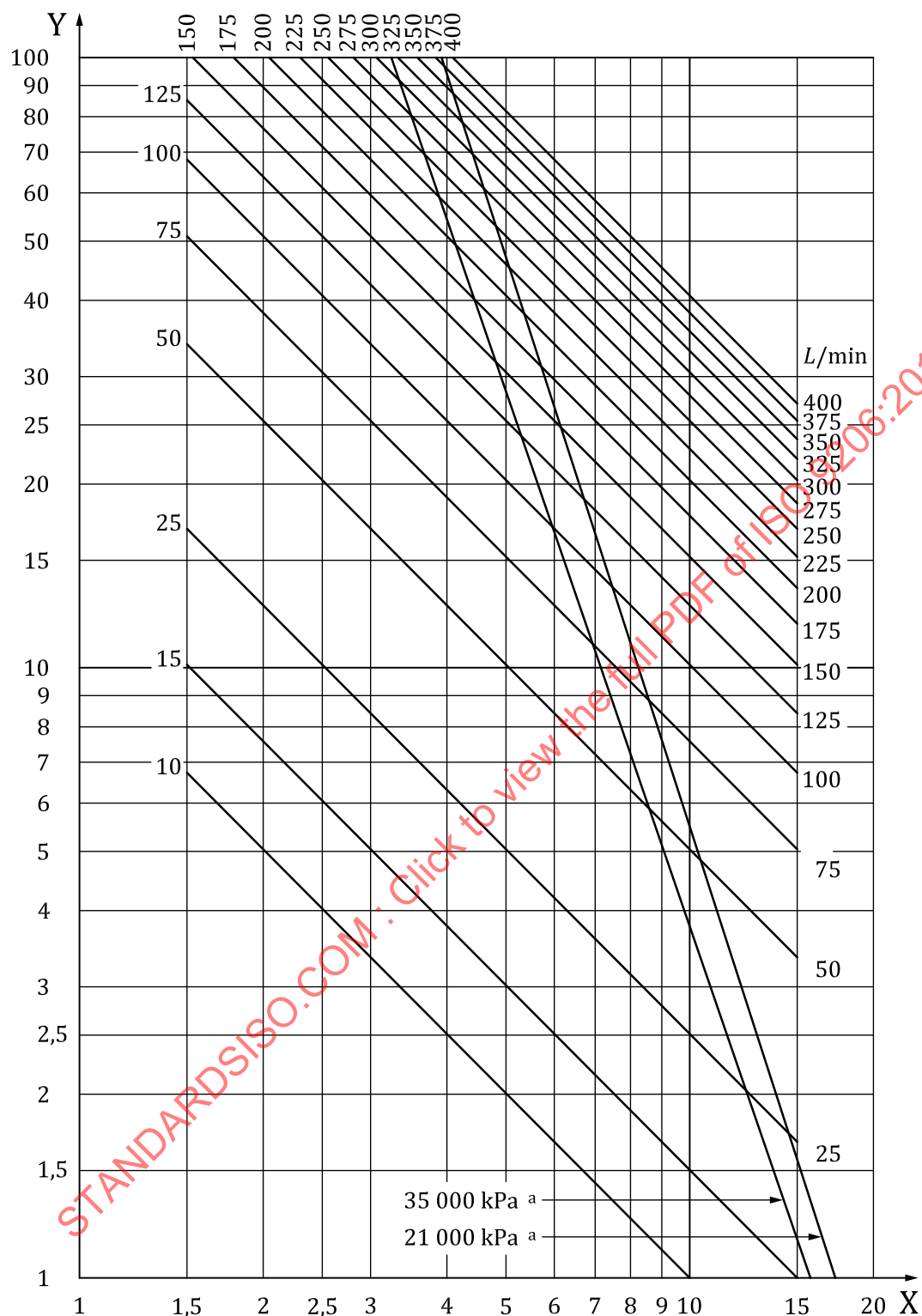
6.4.1.3 Maximum no-load speed

The maximum no-load speed shall be specified in the detail specification.

6.4.1.4 Direction of rotation

Unless otherwise specified in the detail specification, the hydraulic motor shall operate satisfactorily in either direction of rotation. It shall not be necessary to alter the motor to effect a change in the direction of rotation; it should only be necessary to reverse the direction of flow.

NOTE For single direction of rotation applications, an improvement of weight and efficiency can be obtained by optimizing the timing design parameters for the intended direction of rotation.

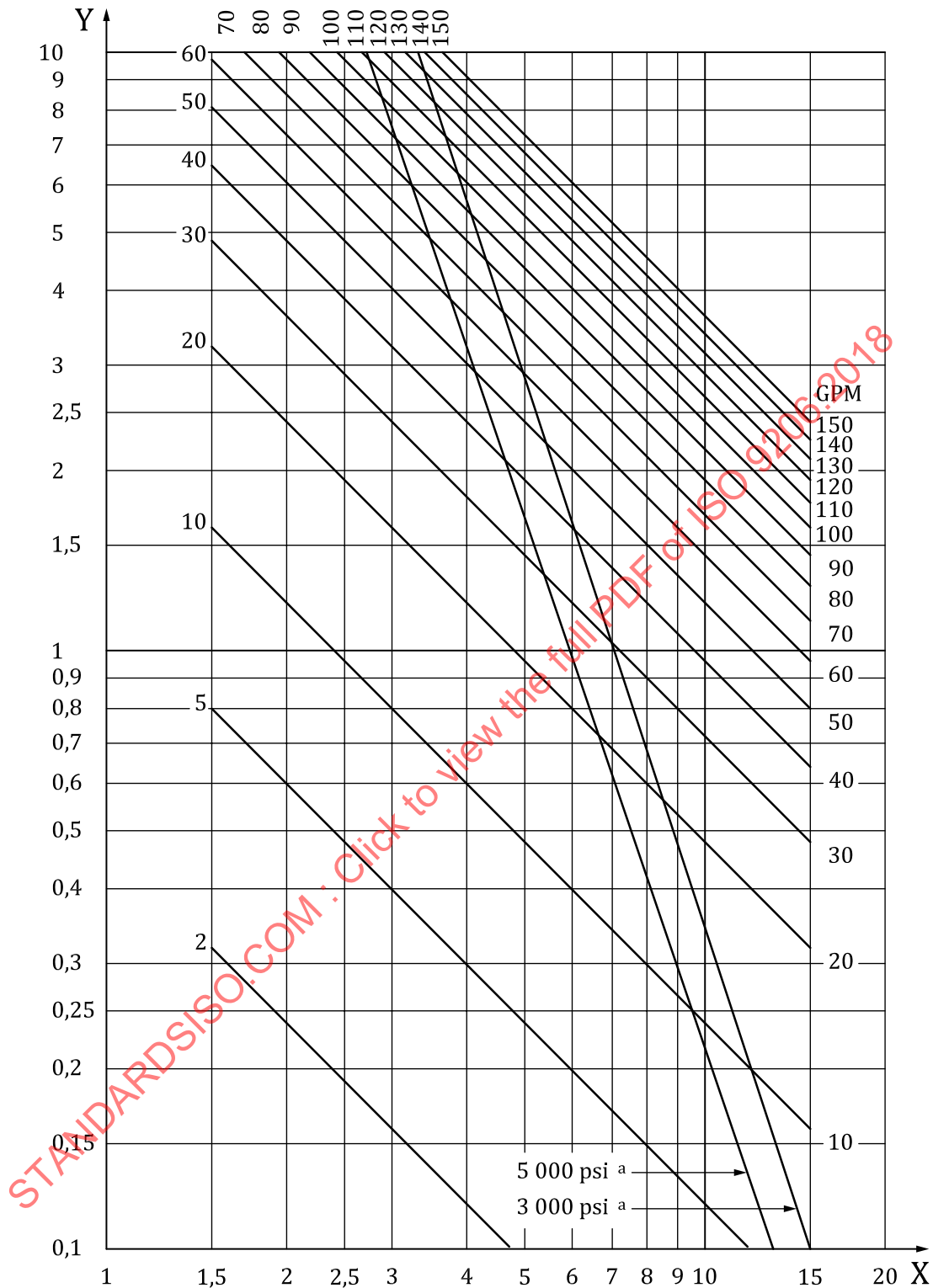
**Key**

Y maximum motor displacement (mL/REV)

X motor speed (RPM × 1 000)

^a Recommended maximum rated speeds.

Figure 1 — Nomograph of maximum recommended values for rated speeds against motor displacement (Metric units)

**Key**

X maximum motor displacement (cubic inch/REV)

Y motor speed (RPM $\times$ 1 000)^a Recommended maximum rated speeds.

Figure 2 — Nomograph of maximum recommended values for rated speeds against motor displacement (American units)

6.5 Torque

6.5.1 Rated torque

The rated torque shall be specified in the detail specification.

6.5.2 Break-out torque

The break-out torque shall be specified in the detail specification.

6.5.3 Stalling torque

The stalling torque shall be specified in the detail specification.

At low speeds (500 to 800 rpm), the mechanical efficiency of hydraulic motors can be up to 99 %. This high efficiency should be considered when stressing the mechanisms that are powered by the hydraulic motor.

6.5.4 Torque pulsations

The motor shall be designed to deliver continuous torque without excessive amplitude ripple (considered as being over ± 10 % of rated torque) when the motor is operated within the rated speed range at any of the conditions specified in [Clause 15](#).

6.6 Motor overall efficiency

The following efficiency values shall be stated in the detail specification:

- the overall efficiency of the motor when new; and
- the overall efficiency of the motor after the endurance test, this value being considered as an objective.

When determining output power by calculation from flow rate and pressure change, only the net pressure difference between inlet and outlet ports of the motor shall be used. The flow rate may be as measured in the low pressure side of the discharge line, provided that adequate compensation is made for compressibility when calculating efficiency.

6.7 Dynamic characteristics

6.7.1 General

If requested by the purchaser, the motor polar moment of inertia and motor impedance shall be supplied to assist in developing system dynamic performance.

6.7.2 Dynamic braking

The motor shall be designed to withstand, at rated conditions, a braking torque which stops it in 0,02 s with no operating damage and with no reduction in performance.

The verification of this requirement may not be achievable for larger displacement motors. It is permissible (subject to the Purchaser's approval) to conduct a static strength test for the rotating group instead using the loads based on the stopping time, the maximum running speeds and the inertia of the rotating group.

In applications where a brake is installed in the actuation system, the actual stopping time can be significantly less than 0,02 s. For these applications, it is recommended that the detail specification details the maximum torque capability of the brake to enable the actual stopping times to be determined.

The detail specification shall identify any circumstances where the pressures in the motor can be reversed (pumping mode) due to an overrunning load. The motor shall be designed to accommodate the pressures and flows that are generated in this mode.

6.7.3 Rapid reversals

If required by the application, the motor shall withstand, at conditions specified in the detail specification, rapid reversals of direction of rotation without damage.

The motor can be subjected to abnormal pressures and torque transient loads. The detail specification should adequately define the system response during these transient events including detailing pressure transients and dynamic responses due to the influence of the actuation system compliance and inertia.

6.8 Passive operation

Passive operation of the motor (for example in redundant systems), without fluid supply, shall be specified in the detail specification.

6.9 Rated temperature

ISO 8625-3 provides the requirements for temperature classification (Type I, Type II, or Type III) if the motor is to be used in a military aircraft or helicopter.

If the application is for a commercial aircraft, the detail specification shall state the rated temperature.

6.10 Acoustic noise level

If required, the motor shall have a maximum acoustic noise level at rated operating conditions. The detail specification shall state its value together with the measuring procedure, when applicable.

When conducting the acoustic noise test, the hydraulic test rig shall have the circuit impedance as specified in 15.3.5.2. To the extent possible, acoustic noise contributions from other hydraulic or structural members attached to or in the vicinity of the motor shall be accounted for separately.

6.11 Rated endurance

The detail specification should specify the duration and the conditions of the endurance test. However, if they are not specified in the detail specification, then the endurance test shall be in accordance with Table 3 and 15.3.6.

The endurance test shall be conducted with the fluid cleanliness of the hydraulic fluid at the maximum class specified for the application.

Table 3 — Duration and conditions of the endurance test

Category of motor (see Clause 4)	Hydraulic system	Continuous operation h	Operation with alternating load cycles
A	Commercial applications	1 500	4×10^6
	Types I and II military applications	750	2×10^6
	Type III military applications	250	1×10^6
B	Commercial applications	500	2×10^6
	Types I and II military applications	250	1×10^6
	Type III military applications	125	$0,5 \times 10^6$

6.12 Environmental requirements

The detail specification shall state the environmental and operating conditions to which the motor is exposed, based on the following criteria:

- a) temperature and altitude (in accordance with ISO 7137);
- b) humidity (in accordance with ISO 7137);
- c) fluids susceptibility (in accordance with ISO 7137);
- d) vibrations (in accordance with ISO 7137);
- e) acoustic vibrations (in accordance with ISO 2671);
- f) steady-state acceleration (in accordance with ISO 2669);
- g) resistance to fungus and mould (in accordance with ISO 7137);
- h) salt spray (in accordance with ISO 7137);
- i) water resistance (in accordance with ISO 7137);
- j) sand and dust (in accordance with ISO 7137);
- k) shock (in accordance with ISO 7137);
- l) ice formation (in accordance with ISO 7137);
- m) fire resistance (in accordance with ISO 2685) – motors in fire zones only.

7 Detail design requirements

7.1 Dimensionally critical components

Parts shall include mechanical means to prevent them from being installed incorrectly if:

- a) they are likely to cause incorrect operation;
- b) they can cause damage if the installation direction is reversed; and
- c) they can be incorrectly located on assembly.

7.2 Maintainability features

In addition to the requirements of 7.1, components that are not functionally interchangeable shall not be physically interchangeable.

All wear surfaces shall be replaceable or repairable.

Connections, mounting, and wiring provisions shall be designed to prevent incorrect coupling.

The design shall permit the line replacement of the unit or a module of the unit using standard tools only.

The design shall be such that special or unique equipment is kept to a strict minimum for shop repair, overhaul, and maintenance checks.

7.3 Seals

Static and dynamic seals shall be in accordance with ISO 3601-1 series A. Non-standard seals, necessary to demonstrate compliance with the requirements of this document, may be used subject to the approval of the purchaser.

For motors used in commercial aircraft and military type III systems, back-up rings used shall be subject to the approval of the purchaser.

7.4 Lubrication

The motor shall be self-lubricated with no provision for lubrication apart from the circulating hydraulic fluid.

7.5 Balance

The individual rotating parts of the motor shall be inherently balanced about their own primary operating axis. The motor shall not vibrate due to self-generated accelerations in such a way that any part of it yields or is otherwise structurally compromised throughout the speed range up to the maximum specified overspeed condition.

7.6 Self-contained failure

The motor shall be designed to completely contain all internal parts in the event of a failure due to an overspeed condition. The maximum overspeed conditions shall be specified in the detail specification.

No loss of fluid from the motor shall occur as a result of the failure, other than the external and shaft seal leakages specified in the detail specification.

7.7 Safety wire sealing

A manufacturer's non-metallic seal of guarantee may be used to indicate if the motor has been tampered with internally.

Lead-type safety wire sealing shall not be used.

7.8 Electro-conductive bonding

The motor shall have a facility to enable it to be effectively bonded to the airframe. The detail specification shall state the bonding requirements.

7.9 Marking

7.9.1 Nameplate

A nameplate shall be securely attached to the motor. The information marked in the spaces provided shall be as required in the format given in [Table 4](#).

Table 4 — Format for nameplate

Constant-displacement hydraulic motor	
Name of manufacturer:.....	
Manufacturer's code:.....	
Manufacturer's part number:.....	
Serial number:.....	
Fluid:.....	
Rating:	
Displacement:.....	
Differential pressure:.....	
Speed:.....	
Torque:.....	

7.9.2 Fluid identification

The fluid for which the motor is approved to use shall be identified in accordance with ISO 3323.

7.9.3 Ports

When possible, the inlet port corresponding to each direction of rotation, the case drain port, and the shaft seal port shall be identified on each motor by clear and permanent markings.

8 Strength requirements

8.1 General

The strength requirements shall be maintained over the entire ambient and fluid temperature range.

8.2 Proof pressure

8.2.1 Motor case

Unless the detail specification states a different value, the motor case shall statically withstand a pressure of at least equal to or greater than 5 000 kPa (750 psi), the maximum case pressure or 1,5 times the rated pressure for the case (whichever is the greater) without permanent damage being done or performance being impaired.

8.2.2 Motor inlet port

Unless the detail specification states a different value, the motor inlet port shall statically withstand a pressure equal to 1,5 times the rated supply pressure for the motor inlet without any permanent damage being done or performance being impaired.

8.2.3 Motor outlet port

Unless the detail specification states a different value, the motor return port shall statically withstand a pressure equal to 1,5 times the rated pressure without permanent damage being done or performance being impaired.

8.3 Ultimate pressure

8.3.1 Motor case

Unless the detail specification states a different value, the motor case shall be designed to withstand a pressure of 50 % of system pressure or 2,5 times the rated pressure for the case (whichever is the greater) with no structural failure.

8.3.2 Motor inlet port

Unless the detail specification states a different value, the motor inlet port shall statically withstand a pressure equal to 2,5 times the rated supply pressure for the motor inlet with no structural failure.

8.3.3 Motor outlet port

Unless the detail specification states a different value, the motor outlet port shall statically withstand a pressure equal to 2,5 times rated pressure for the motor outlet with no structural failure.

8.4 Pressure impulse (fatigue)

The motor shall withstand the fatigue effects of all cyclic pressures, including transients and external loads.

The detail specification shall state the following:

- a) the overall predicted duty cycle for the different parts of the motor throughout the lifetime of its application;
- b) the scatter factor that is to be applied for analysis or fatigue (pressure impulse) testing; and
- c) the external loads.

8.5 Port strength

The structure of the ports and the relevant areas of the motor case shall be such that it withstands a torque 2,5 times the maximum torque that is specified for attaching or removing the unions and lines on installation or removing motors during maintenance operations. No permanent distortion or alteration in the correct operation shall occur.

9 Construction requirements

9.1 Materials

9.1.1 General

All materials shall be compatible with the hydraulic fluid that is specified in the detail specification.

Materials and processes used in the manufacture of the motor shall:

- be of aerospace quality;
- be suitable for the purpose; and
- comply with the applicable standards.

Materials that comply with the supplier's material specifications are acceptable provided that these specifications are acceptable to the purchaser and include provisions for adequate testing. The use of the supplier's specifications does not constitute a waiver of other applicable standards.

9.1.2 Metals

9.1.2.1 General

All metals shall be compatible with any fluids with which it will be in contact, with the service and storage temperatures, and functional requirements to which the components will be subjected. Those metals not in direct contact with the hydraulic fluid shall have the appropriate corrosion-resistant properties or they shall be suitably protected as specified in [9.2](#).

If the properties or operating safety of the motor are likely to be jeopardized by the use of the materials and processes specified above, other materials and procedures may be used subject to the purchaser's approval. In this case, materials or processes shall be chosen to provide the maximum corrosion resistance compatible with the operating requirements.

9.1.2.2 Motors for type I systems

Except for the internal surfaces in constant contact with the hydraulic fluid, ferrous alloys shall have a chromium content of at least 120 g/kg or shall be suitably protected against corrosion as specified in [9.2](#).

Tin, cadmium, and zinc platings shall not be used for internal parts or for internal surfaces in contact with the hydraulic fluid or exposed to its vapours. The grooves for external O-rings seals shall not be considered as internal surfaces in constant contact with hydraulic fluid.

Magnesium alloys shall not be used.

9.1.2.3 Motors for type II and III systems and for commercial aircraft applications

Ferrous alloys used shall be suitably protected against corrosion as specified in [9.2](#).

Tin, cadmium, and zinc platings shall not be used for internal parts that are in contact with the hydraulic fluid or exposed to its vapour.

Magnesium alloys shall not be used.

9.2 Corrosion protection

9.2.1 General

Metals that do not inherently possess sufficient corrosion-resisting characteristics shall be suitably protected, in accordance with the following sub-clauses, to resist corrosion that may result from conditions such as the following:

- dissimilar metal combinations;
- moisture;
- salt spray; and
- high temperature deterioration.

9.2.2 Ferrous and copper alloys

Ferrous alloys requiring corrosion-preventive treatment and all copper alloys, except for parts with bearing surfaces, shall receive surface plating selected from the following:

- electrolytic nickel plating;
- electrolytic silver plating;
- electrolytic tin plating, in accordance with ISO 2093; and

— electrodeless nickel plating.

Electrolytic tin shall not be used for internal parts or internal surfaces in contact with the hydraulic fluid or exposed in its vapours, or on surfaces subjected to abrasion. Where not indicated, the class and type of plating are at the supplier's discretion.

Other metal plating, the use of which has been proved to be satisfactory to the purchaser, such as 85 % electrolytic tin plating, shall be protected by anodizing. However, in the absence of abrasive conditions, they may be coated with a chemical film.

Exceptions shall be submitted to the purchaser for approval.

9.2.3 Aluminium alloys

All aluminium alloys shall be anodised in accordance with ISO 8078 and ISO 8079 (except that in the absence of abrasive conditions they shall be coated with chemical film in accordance with ISO 8081), unless otherwise authorised.

Exceptions shall be submitted to the purchaser for approval.

9.3 Castings

Castings shall be clean, sound, and free from cracks, blow holes, excessive porosity, and other defects.

Defects not materially affecting the suitability of the castings may be repaired at the foundry or during machining by peening, impregnation, welding, or other methods acceptable to the purchaser. The inspection and repair of castings shall be checked by quality control techniques and standards that are satisfactory to the purchaser.

10 Installation requirements

10.1 Dimensions

Dimensions pertinent to the installation of the motor in aircraft shall be specified on the supplier's installation drawing and in the detail specification.

10.2 Mass

The dry mass of the completely assembled motor shall be stated on the supplier's installation drawing.

The supplier and the purchaser shall agree on the mass of fluid contained in the motor.

10.3 Mounting

Unless otherwise specified in the detail specification, all motors shall incorporate a standard mounting flange, which shall be in accordance with ISO 8399-1 and ISO 8399-2.

When the mounting flange is in conformity with ISO 8399-1 and ISO 8399-2, the relation between the maximum displacement of the motor and the type of mounting flange shall be in accordance with [Table 5](#).

Table 5 — Relation between displacement and flange type

Maximum displacement cm ³ /r	Maximum displacement in ³ /r	Flange type — Spigot reference
2,5	0,15	150
5	0,31	200
10	0,61	300
15	0,92	350
20	1,22	
30	1,83	
40	2,44	
50	3,05	

10.4 Orientation

The mounting conditions of the motor shall be defined by agreement between the manufacturer and the purchaser.

10.5 Coupling shaft

The detail specification shall state if the motor is provided with a coupling shaft that fitted at the interface between the motor rotating group and actuation means that it is driving (for example, a gearbox).

If a coupling shaft is provided, then the detail specification shall state:

- the coupling shaft shall be easily removable then unless otherwise specified in the detail specification;
- the coupling shaft shall be held in place by means of a positive locking system;
- if required by the detail specification, the coupling shaft shall include a shear section;
- the end of the drive shaft shall comply with ISO 8399-1 and ISO 8399-2 unless otherwise specified in the detail specification;
- the shear torque;
- the loads other than those self-induced by the motor torque; and
- the coupling lubrication mode.

10.6 Ports

Unless otherwise specified in the detail specification, the port configuration shall be in accordance with ISO 7320.

11 Maintenance requirements

11.1 Maintenance concept

The detail specification shall state the specified maintenance concept, for example, “On Condition”.

11.2 Service life limitations and storage specifications

The detail specification shall state the specifications and appropriate definitions and shall include the following:

- a) the time between overhauls (if applicable);
- b) the storage life; and
- c) the service life limit.

12 Reliability requirements

12.1 Equipment compliance

All of the reliability specifications shall be met throughout the service life of the equipment, assuming that all approved maintenance cycles have been carried out.

12.2 Requirements

The detail specification shall state the specifications and the appropriate definitions, which shall include the following:

- a) the defect rate;
- b) the failure rate;
- c) the safety rate (if applicable); and
- d) the failure mode and effect analysis (FMEA).

13 Quality assurance provisions

13.1 Responsibility for inspection

Unless otherwise specified in the contract or order, the supplier:

- is responsible for carrying out all the inspection operations specified in this document; and
- may use his own inspection and testing facilities or the services of any industrial laboratory approved by the national authorities.

13.2 Classification of tests

The following test program shall be performed for the purposes of checking whether the motors comply with this document:

- a) acceptance tests (see [Clause 14](#)); and
- b) qualification tests (see [Clause 15](#)).

13.3 Test stand requirements

The following tolerance limits are set for the required steady state operating conditions for the test stands that are employed for the acceptance tests and the qualification tests, unless otherwise agreed between the supplier and the purchaser:

- a) motor supply pressure: ± 2 % of rated supply pressure, but not more than ± 350 kPa; (± 50 psi);

- b) motor return pressure: ± 2 % of rated supply pressure, but not more than ± 70 kPa; (± 10 psi);
- c) motor case pressure: ± 2 % of rated case pressure, but not more than ± 70 kPa; (± 10 psi);
- d) differential pressure: ± 2 % of maximum differential pressure, but not more than ± 200 kPa; (± 30 psi);
- e) inlet/temperature:
 - -57 to $+43$ °C, within ± 10 °C;
 - $+43$ to $+107$ °C, within ± 15 °C.
- f) flow: within ± 2 % of maximum flow;
- g) shaft speed: ± 100 r/m;
- h) torque: ± 2 % of minimum motor output torque.

The accuracy of the instrumentation shall be consistent with the measurement tolerances required.

The test stands shall use sufficient filtration so as to maintain the cleanliness of the fluid to ISO 11218 Class 5, or better, except for the qualification endurance testing (see [15.3.6](#)).

The hydraulic fluid in the test circuit shall be the same as that specified for the application (see [6.1](#)).

14 Acceptance tests

14.1 General

Each motor submitted for delivery shall be subjected to the examinations and acceptance tests specified in this sub-clause. The acceptance or approval of material during manufacture shall, in no case, be construed as a guarantee of the acceptance of the finished product.

Acceptance tests, for the purposes of this document, shall consist of the following:

- a) visual examinations; and
- b) a test program to determine quality design and check whether the motors conform to the performance requirements of this document.

The first production motor shall undergo a First Article Inspection (FAI) in the presence of the purchaser's representatives. Any deviations recorded in the FAI shall be corrected, or agreed, prior to the delivery of the first motor.

14.2 Examination of the product

The motor shall be examined to determine conformance with the applicable standards and all requirements of this document and the detail specification, for which there are no specific tests.

14.3 Test programme

14.3.1 General

Filters shall be installed in all the lines to and from the motor, as applicable.

The supplier shall repeat the applicable parts of the conformance test procedure if, at any phase of testing, working parts require replacement. The break-in run portion may be omitted if the rotating group assembly was not affected.

Throughout the test programme, the hydraulic fluid used shall be that specified in the detail specification.

14.3.2 External leakage requirements

14.3.2.1 General leakage

Other than at the shaft seal, no external leakage of sufficient magnitude to form a drop shall be permitted.

14.3.2.2 Shaft seal leakage

During acceptance and calibration tests, the shaft seal leakage shall not exceed the values specified for new build conditions [refer to [6.3.3 a\)](#)].

14.3.3 Break-in run

The break-in run shall be made with any nominated pressure in the inlet and return outlet lines and shall consist of at least 30 min at 30 % to 75 % of rated speed and at least 30 min at 80 % to 100 % of rated speed with a differential pressure of 80 % to 100 % of the rated differential pressure.

NOTE Alternative operating conditions to optimize the run-in process and avoid damage can be used, subject to agreement between the supplier and the purchaser.

14.3.4 Proof pressure and overspeed tests

14.3.4.1 Overspeed test

Operate the hydraulic motor for 2 min at a speed equal to 125 % of the rated speed with a differential pressure as specified in the detail specification.

The motor shall withstand the test without any alteration to its correct operation, and there shall be no external leakage apart from that from the shaft which shall not exceed 5 cm³/h.

14.3.4.2 Operational test at overpressure

Operate the hydraulic motor for 1 min at its rated speed with an supply pressure equal to 125 % of the rated pressure and, unless otherwise specified in the detail specification, with a pressure of 3 500 kPa (500 psi) at the outlet and case drain ports.

The motor shall withstand the test without any alteration to its correct operation and there shall be no external leakage apart from that from the shaft which shall not exceed 5 cm³/h.

14.3.4.3 Inlet port proof pressure test

With the motor shaft locked and the case drain port unplugged, pressurize the motor for 5 min to 1,5 times the rated supply pressure.

In the case of a bi-directional motor, both inlet/outlet ports shall be subjected to an independent proof pressure test.

14.3.4.4 Case port proof pressure test

With the inlet and outlet ports blanked, pressurize the motor at the pressure determined from [8.2.1](#) for 5 min.

14.3.5 Operational tests at rated conditions

Unless otherwise specified in the detail specification, the operational tests in rated conditions shall include the following:

- a) operate for 30 min at the rated speed; and rated differential pressure with no opposing torque applied to the output shaft; and
- b) operate for 60 min with the rated supply pressure while the opposing torque on the output shaft is varied between 50 % of the rated value and the rated value at a frequency of 6 cycles/min.

There shall be no external leakage sufficient to form a drop. Case drain flow shall be monitored. There shall be no evidence of malfunction.

Operate the motor smoothly at a speed of 0,5 rpm to 3 rpm. Adjust the supply and return pressures to establish the pressure differential defined in the detail specification. Make a continuous record of the motor output torque of the motor over at least 2 minutes. The break-out torque is defined as the lowest value of the variation in torque that is measured during this test.

The test shall be conducted in both directions of rotation if the motor is a bi-directional type.

NOTE The test is only one method of verifying torsional capability at breakout. Alternative methods of verifying breakout capability can be used, subject to agreement between the purchaser and the supplier.

14.3.6 Teardown inspection examination

14.3.6.1 Sampling requirements

A teardown inspection shall be conducted on a number of motors of a given model of an initial production run. The quantity of motors to be subjected to the teardown inspection shall be agreed between the supplier and the purchaser.

The teardown inspection shall be repeated whenever either of the following changes in a production programme occurs:

- a) continuity of manufacturing is interrupted — permissible periods of production interruption shall be designated in the detail specification; and
- b) alternative tooling and production facilities are chosen.

14.3.6.2 Inspection procedure

After the break-in run and proof tests, dismantle and inspect the motor. If all parts are in acceptable condition, re-assemble and run in the motor in accordance with [14.3.8](#).

If, at any phase in the testing, working parts require replacement, the entire conformance test procedure shall be repeated.

When the teardown inspection is no longer required, the run-in in accordance with [14.3.8](#) may be deleted.

14.3.7 Run-in

The run-in after teardown inspection shall be performed at 50 % to 100 % of rated speed for a period of 15 min with a differential pressure of 80 % to 100 % of the rated differential pressure.

14.3.8 Performance data

Once the acceptance tests have been completed, measure and record the following parameters at rated conditions:

- a) supply pressure;
- b) inlet port flow;
- c) case drain port flow; and
- d) rated torque.

14.3.9 Fluid contamination test

14.3.9.1 General

This test shall be conducted to prevent shipment of a functionally acceptable but materially deteriorating motor (incipient failure). The fluid from the motor case drain and/or discharge of the motor shall be checked for contamination as agreed to between the supplier and the purchaser.

14.3.9.2 Inline particle counters

Inline particle counters should be used to check for an incipient motor failure by continuously monitoring the particle sizes. The motor shall be stopped and removed for a tear down inspection if there is a noticeable increase in the number of particles in the case drain line after the break-in run has been completed.

14.3.9.3 Filter patch test

14.3.9.3.1 General

If inline particle counters are not available, then the use of filter patches to check for an incipient motor failure is an acceptable alternative means. The definition of a patch standard is either initially established by the manufacturer and, in that case, shall be specified in the detail specification, or may possibly be established during the functional tests of the first 25 motors.

Unless otherwise specified in the detail specification, all the filters used during the test shall be able to filter to a value less than or equal to 5 µm absolute.

14.3.9.3.2 Filter sampling method

Install filters in the outlet and case drain or cooling port lines of the test setup. Check the fluid in the filter bowls by the procedure specified in [14.3.9.3.3](#) for contamination accumulated during the functional test performed in accordance with [14.3.5](#).

14.3.9.3.3 Patch preparation

Collect the fluid in each filter bowl in clean containers. Rinse both the filter bowl and element with the appropriate volume of a suitable fluid solvent and add to the applicable container. The total resulting fluid shall be passed through a membrane having a diameter of approximately 47 mm (1,85 in), which will trap contaminant in each filter bowl. The detail specification shall state the membrane material. Wash the membrane free of fluid with the appropriate volume of fluid solvent. After drying, the resultant filter patch shall be coated with clear lacquer and permanently attached to the log sheet of the test.

All fluid solvent shall be filtered through a 0,45 µm pore size membrane prior to use in all stages of the patch preparation procedure.

14.3.9.3.4 Patch comparison

Each filter patch specified in the acceptance test procedure shall be compared with the standard patch then in effect and any discrepancy noted in the test log.

If the contamination level exceeds that of the standard, the filter patch test may be repeated. The second patch shall show equal or less contaminant than the standard patch to be acceptable. If it does not, up to 2 additional patch tests may be run to establish the trend. If the patches remain unacceptable, the motor should be disassembled to determine the source of the contamination and corrective action taken.

14.3.10 Electro-conductive bonding

If required, measure the electrical resistance between any point on the mounting flange face and specified points on the motor (for example, at the pipe connections). It shall not be greater than the value specified in the detail specification.

14.4 Storage and packaging

The detail specification shall state the procedures for preservation and packing.

The packaging used for the shipment of the motor shall consider the normal handling damage that may occur during transportation. Care shall be taken to avoid damage to any electrical connectors, thin metal parts, etc.

The packaging shall be suitable for storage according to the shelf life requirements specified in the detail specification, considering that adequate care shall be taken by the storage agency. If the motor relies on the hydraulic fluid internal to the unit for corrosion protection, then the hydraulic plugs shall form a leak-free seal.

15 Qualification procedures

15.1 General

Qualification tests, with the purpose of checking whether the motor design is in conformity with the requirements of this document, shall comprise the tests specified in [15.2.3](#).

15.2 Qualification procedure

15.2.1 Qualification by analogy

All or some of the qualification tests may be waived if the following requirements are met:

- a) the motor incorporates the same or similar working parts as another motor that has already been qualified by a controlling authority;
- b) the operating conditions are not more restrictive than those for which the other motor has already been qualified.

A report, substantiated by drawings showing the similarity with the already qualified motor, shall be submitted instead of carrying out the tests.

15.2.2 Motor qualification test report

A report of the tests carried out and the test results shall be compiled. This report shall include a full assessment of the extent to which the motors tested comply with the detail specification and a detailed account of the way in which the tests were carried out. The report shall also include a description of the instruments used, schematic diagrams, and photographs, as appropriate. The complete test results shall

be given in the report in table form. The hydraulic test systems shall be described with all the details for each test. The assembly drawings and installation drawings shall be appended to the test report.

15.2.3 Samples and program of qualification tests

The qualification tests should be conducted on a minimum of two sample motors (A and B). It is essential that these sample motors are representative of the motors to be manufactured.

The qualification tests, together with the suggested order that they are conducted, are given in [Table 6](#).

NOTE Additional samples can be employed, for example, to conduct impulse fatigue and vibration on different units.

Table 6 — List and sequence of qualification tests

Tests	Sample		Clause, subclause, etc. to be referred to
	A	B	
Acceptance	X	X	Clause 14
Dimensional check	X		15.3.1
Expanded envelope acceptance	X	X	15.3.2
Overspeed	X	X	15.3.3
Operation at overpressure	X	X	15.3.4
Calibration			15.3.5
— Torque and flow rate	X	X	15.3.5.3
— Dynamic braking	X	X	15.3.5.4
— Rapid reversals	X	X	15.3.5.5
— Passive operation	X	X	15.3.5.6
— Stalling torque and internal leakage	X	X	15.3.5.7
Endurance ^a	X		15.3.6
Environmental	X	or X	15.3.7.1
Low temperature		X	15.3.7.2
Thermal shock		X	15.3.7.3
Fire Resistance ^b			15.3.7.4
Vibration		X	15.3.8.1
Fatigue (pressure impulse)		X	15.3.8.2
Port strength		X	15.3.8.3
Proof pressure at rated fluid temperature		X	15.3.8.4
Ultimate pressure		X	15.3.8.5
Coupling shear	X	or X	15.3.8.6
Supplementary tests	X	or X	15.3.9
^a The shaft seal leakage is permitted to degrade to the limit specified in the detail specification (refer to 6.3.3).			
^b An additional test specimen shall be used if a fire resistance test is required.			

15.3 Qualification testing

15.3.1 Dimensional check

Prior to the start of the qualification test, conduct the full acceptance test of both test sample motors. The run-in specified in [14.3.8](#) may be carried out, if necessary, after reset and before the test sequence is continued.

Check the critical wear dimensions and record the dimensions of each test sample motor. Check these dimensions again for comparison purposes once the qualification tests have been completed.

15.3.2 Expanded envelope acceptance tests

The acceptance tests shall be repeated, but the motor shall be run with the following:

- a) the fluid temperatures from minimum continuous to rated;
- b) pressures from zero to rated differential pressure; and
- c) loads from zero to rated torque.

No malfunctions shall be recorded.

15.3.3 Overspeed test

The performance of the hydraulic motor shall show no evidence of deterioration after it has been running for 2 min at a speed of up to 125 % of the rated speed with a differential pressure as specified in the detail specification.

15.3.4 Operational test at overpressure

The performance of the hydraulic motor shall show no evidence of deterioration after it has been running for 1 min at its rated speed with a supply pressure equal to 125 % of the rated pressure and with a pressure of 3 500 kPa (500 psi) at the outlet and case drain ports, unless otherwise specified in the detail specification. In the case of a bi-directional motor, the test shall be repeated on the second inlet port.

15.3.5 Calibration

15.3.5.1 General

The calibration test is carried out before and after the endurance test, and comprises the tests described in [15.3.5.3](#) to [15.3.5.7](#).

15.3.5.2 Dynamic characteristics

The hydraulic system impedance, the inertia and the stiffness of the opposing load applied to the motor shaft should be the same as those of the operating conditions specified in the detail specification.

NOTE If the system specific parameters such as compliance and inertia cannot be readily reproduced at the supplier's facility, the supplier can utilize alternative loading mechanisms and hydraulic systems to conduct the tests, subject to agreement by the purchaser.

15.3.5.3 Torque and flow rate

Measure the torque produced by the motor and the inlet and case drain flow rates, at a fluid inlet temperature as specified in the detail specification, after operating for at least 5 min at motor rotation speeds of 25 %, 50 %, 75 %, and 100 % of rated speed in the following conditions:

- motor return and case drain pressures of 200 kPa to 1 400 kPa (30 psi to 200 psi, relative); and
- rated motor differential pressure.

The output torque at any of the motor rotation speeds at the above conditions shall not be less than the rated torque. The drain flow rate shall be less than the values specified in the detail specification. The efficiency shall be calculated from the results obtained.