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Aerospace fluid systems and components — Variable displacement hydraulic motors — General specifications

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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 of 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 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*.

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.

Introduction

It is noted that, while ISO standards refer to SI units, large segments of the aerospace industry refer to other measurement systems as a matter of common working practice. All dimensions used in this document are in SI units with the non-SI units given in addition for the convenience of those users more familiar with these.

It is further noted that the standard ISO decimal symbol "," (comma) is not used as common working practice for inch dimensions. A decimal point is used in the inch dimensions in this document as in many other aerospace standards.

NOTE The use of non-SI units and the decimal point in this document does not constitute general acceptance of measurement systems other than SI within International Standards.

Aerospace fluid systems and components — Variable displacement hydraulic motors — General specifications

1 Scope

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

These requirements include:

— design requirements;

— test requirements.

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 intended 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 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*

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:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
variable displacement hydraulic motor
mechanical actuator that converts hydraulic pressure and flow into torque and angular velocity (rotation) and whose speed is controlled by varying the displacement of the hydraulic motor

Note 1 to entry: The use of a variable displacement hydraulic motor permits the optimization of hydraulic flow demand.

Note 2 to entry: The motor's output torque, direction of rotation (if bi-directional) and associated operating speed and resultant flow consumption is controlled by a servo valve which varies the motor's displacement which is typically operated in closed loop control.

Note 3 to entry: The specifications, design, manufacture and qualification of the servo valve is outside the scope of this document.

3.1.1
uni-directional hydraulic motor
variable displacement hydraulic motor (3.1) that generates output torque via the drive shaft in only one direction

3.1.2
bi-directional hydraulic motor
variable displacement hydraulic motor (3.1) that generates output torque via the drive shaft to both clockwise and anti-clockwise directions

Note 1 to entry: Except for *bi-directional over-centre hydraulic motors* (3.1.3), bi-directional operation is typically achieved by reversing the differential pressure across the inlet/outlet ports, thus reversing the output torque.

Note 2 to entry: Except for *bi-directional over-centre hydraulic motors* (3.1.3), the position of the swashplate is controlled in each direction by a dedicated controller.

3.1.3
bi-directional over-centre hydraulic motor
bi-directional hydraulic motor (3.1.2) whose direction of rotation of the output drive shaft is controlled by the angle of the motor swashplate which can go over centre

Note 1 to entry: This may be accomplished by controlling the position of the swashplate in each direction by a single controller.

3.2
purchaser
organization that has the engineering responsibility for the system that includes the motor

Note 1 to entry: Typically, the purchaser is a system *supplier* (3.4), an aircraft manufacturer or a contractor.

3.3
detail specification
document compiled by the *purchaser* (3.2) that specifies the following:

a) technical requirements;

b) acceptance and qualification test requirements;

c) reliability, testability and maintainability requirements;

d) quality requirements;

e) packaging requirements;

f) other requirements

Note 1 to entry: Technical requirements include performance requirements and design requirements.

3.4
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.

3.5.1
motor inlet port
port that receives flow from the hydraulic system to supply the motor

3.5.2
motor return port
port that returns flow back to the system reservoir

3.5.3
motor case drain port
port that drains internal leakage flow to the system reservoir

Note 1 to entry: Not all motors have a case drain port; instead the case drain fluid is supplied to the motor outlet port.

3.5.4
shaft seal leakage port
port that routes any shaft seal leakage from the motor to an overboard drain, collector tank, ecology bottle, etc.

3.6.1
rated temperature
maximum continuous temperature of the fluid to be supplied at the inlet port of the motor

3.6.2
normal operating temperature
temperature of the fluid to be supplied at the inlet port of the motor at which full performance of the motor is required

3.6.3
minimum continuous temperature
minimum temperature of the fluid at the supply port of the motor at which the motor is able to function

Note 1 to entry: This temperature is generally higher than the minimum *survival temperature* (3.6.5).

3.6.4
extreme operating temperature
temperature of the fluid to be supplied at the inlet port of the motor at which the motor runs with an agreed degraded performance

3.6.5
survival temperature
ambient temperature at which the motor is not required to run, but runs without degradation at the *normal operating temperature* (3.6.2)

3.7.1
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;

— demands that may affect fatigue.

3.7.2
rated supply pressure
system rated pressure, which is normally the hydraulic power generation system *design operating pressure* (3.7.1)

3.7.3
rated differential pressure
differential pressure measured between the motor inlet and outlet ports required to produce the *rated torque* (3.11.1)

3.7.4
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* (3.7.6.1) and the return port at the *nominal motor return pressure* (3.7.5.1)

Note 1 to entry: This corresponds to *break-out torque* (3.11.2).

3.7.5.1
nominal motor return pressure
pressure generated at the return port as the motor returns flow back to the system

3.7.5.2
rated motor return pressure
maximum pressure at the return 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 return pressure* (3.7.5.1) is generally considerably less than the rated motor return pressure.

3.7.6.1
rated case drain pressure
nominal pressure at which the motor case is required to operate continuously in the system

3.7.6.2
maximum case pressure
maximum of either

— the maximum pressure peak that may be imposed by the hydraulic system on the *motor case drain port* (3.5.3), or

— the pressure resulting from the internal bypassing of the rated flow towards the return and drain ports in order to take into account the accidental transitory separation of the components

3.8
rated consumption
maximum flow rate measured at the *motor inlet port* (3.5.1) under the following conditions:

— rated fluid temperature;

— *rated differential pressure* (3.7.3);

— *rated speed* (3.10);

— using the hydraulic fluid specified in the *detail specification* (3.3)

3.9
maximum displacement
theoretical volume of fluid consumed by one revolution of the motor drive shaft at full stroke

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

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

— permissible manufacturing tolerances;

— distortions of the motor structure;

— the compressibility of the hydraulic fluid;

— internal leakage;

— temperature.

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

3.10
rated speed
maximum speed at which the motor is required to operate continuously at *rated temperature* (3.6.1) and at *rated differential pressure* (3.7.3)

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

3.11.1
rated torque
minimum torque value at rated operating conditions

3.11.2
break-out torque
minimum torque against which the motor will start at operating conditions specified in the *detail specification* (3.3)

Note 1 to entry: This corresponds to *no-load break-out pressure* (3.7.4)

3.11.3
stalling torque
minimum opposing torque which stops the rotation of the outlet shaft at the *rated supply pressure* (3.7.2) and for the outlet port and case drain port pressures specified in the *detail specification* (3.3)

3.11.4
maximum stalling torque
stalling torque (3.11.3) which can be generated at rated operating conditions

Note 1 to entry: This shall be specified to ensure that the motor's torque capability in a stall (high efficiency) condition does not overload the system's capability (e.g. the shafts and gears, as applicable).

3.12
motor overall efficiency
e
value obtained from the formula

$$e = (o/i) \times 100$$

where

o is the *output shaft power* (3.12.1);

i is the *input fluid power* (3.12.2)

Note 1 to entry: *e* is expressed in per cent.

Note 2 to entry: Calculating hydraulic power and mechanical power can be problematic unless the correct units and associated equations are used:

— Metric units (torque – Nm; flow – L/min)

— Imperial units (torque – lb.in; flow – gpm)

3.12.1
output shaft power
o
value obtained from the formula

$$o = t \times s$$

where

t is the shaft torque;

s is the shaft speed

3.12.2
input fluid power
i
value obtained from the formula

$$i = (p - r) \times f$$

where

p is the inlet pressure;

r is the return pressure;

f is the 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.

3.13
rated endurance
total number of hours and cycles of operation to be included in the endurance phase of its qualification testing

3.14
first article inspection
FAI
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;

— 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, power transfer units, constant speed drives, nosewheel steering.

NOTE ISO 22089 provides the variable displacement motor requirements for power transfer units.

— Category B: Secondary function motors, for example, hoists, guns, radars, doors.

In addition, the motor can be a uni-directional motor or a bi-directional motor.

The motor category and type (uni-directional or bi-directional or bi-directional over-centre) 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 (e.g. +20 °C);

— rated temperature;

— minimum continuous temperature.

5.3 Airworthiness regulations

It is assumed that the hydraulic motor meets the applicable airworthiness requirements, which shall be detailed in the detail specification.

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(s).

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 1 (derived from ISO 6771).

Table 1 — 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 return port pressure

6.2.4.1 Nominal motor return pressure

The nominal motor 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).

The detail specification shall state the return pressure for those over-centre variable displacement motors that have:

— a dedicated high pressure port and a dedicated low pressure port which are not reversed with changes in the direction of rotation.

— a dedicated case drain port with the case drain linked internally with the return port.

NOTE This is because a pressure of 7 000 kPa (1 000 psi) in the return port will otherwise be applied to the case drain cavity, which can be a significant envelope, weight and design driver.

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:

a) the motor turning at rated torque and speed;

b) the motor turning at zero torque;

c) 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

6.3.3.1 Dynamic seal leakage

The detail specification shall state the value of the maximum dynamic shaft seal leakage (which shall be in drops per minute) measured at the shaft seal leakage port at the following conditions:

a) New build:

- when subject to proof pressure at ambient temperature;
- when the motor is operating at rated consumption flow.

b) Qualification testing:

- over the expanded test envelope;
- at the completion of the endurance test;
- when subject to proof pressure at rated temperature;
- when subject to ultimate pressure at rated temperature.

The supplier and the purchaser should agree on the in-service limit for dynamic shaft seal leakage.

6.3.3.2 Static seal leakage

The detail specification shall state the value of the maximum static shaft seal leakage (which shall be in drops per minute) measured at the shaft seal leakage port when the motor filled with fluid, but un-pressurized, at the following conditions:

a) New build.

b) Qualification testing:

- over the expanded test envelope;
- at the completion of the endurance test.

The supplier and the purchaser should agree on the in-service limit for static shaft seal leakage.

6.3.4 External leakage

No leakage sufficient to form a drop from all of the static seals or from the motor case 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.

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 rated motor speed for 30 min.

6.4.1.3 Direction of rotation

Unless otherwise specified in the detail specification, the hydraulic motor shall operate satisfactorily in either direction of rotation.

NOTE 1 For single direction of rotation applications, an improvement of weight and efficiency is obtained by optimizing the timing design parameters for the intended direction of rotation.

NOTE 2 A change from the resistive (motor) to the aiding (pump) modes can result in a change in flow direction, without a change in the direction of rotation.

For uni-directional rotation applications, the direction of rotation shall be clearly marked on the motor case.

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. For bi-directional motors, this shall be in each direction.

6.5.3 Stalling torque

The stalling torque shall be specified in the detail specification. For bi-directional motors, this shall be in each direction.

6.5.4 Maximum stalling torque

The maximum stalling torque shall be specified in the detail specification. For bi-directional motors, this shall be in each direction.

6.5.5 Torque pulsations

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

6.6 Variable output load control

6.6.1 General

The motor shall incorporate means to control the flow consumption to ensure that the motor is able to run at the required constant speed over the range of loads that is specified for its operation.

For bi-directional motors, there shall be two means, one per motor direction of rotation.

The motor shall incorporate means to measure the motor speed to provide a feedback signal to the motor control system. The accuracy of the speed measuring means shall be provided in the detail specification.

NOTE 1 The speed feedback can also be external to the motor, measuring shaft speed elsewhere within the system.

NOTE 2 Variable displacement motors often incorporate a measurement device to provide feedback of the motor's yoke (swash) angle. This feedback can be a useful addition to enhance control, particularly for bi-directional (over centre) motors. This feedback can also be used to assess (and limit) flow consumption to avoid saturation and can also be used to confirm correct control loop function in advance of brake release.

6.6.2 Response time

The real-time plot of motor speed against time shall be used as the criterion of movement of the motor control mechanism. All motors shall have a minimum and a maximum response time in accordance with the detail specification when the load demand is changed, when:

a) operating at rated inlet temperature;

b) from zero to rated output torque;

c) when changing the direction of rotation

6.6.3 Stability

The oscillographic trace of motor speed against time shall be used as the criterion of stability.

The motor shall recover its steady-state operation within not more than 0,5 s after the initial response to a change in the change of load demand, under the following conditions:

a) under any operating condition within the limits stated in the detail specification;

b) at any output load greater than 50 % of the rated motor output load;

c) after a change in the motor rotation.

When required by the purchaser, the supplier shall provide adequate motor parameters to permit the system designer to integrate the motor dynamic performance into the complete motor/system analysis.

NOTE 1 The stability of the closed loop control mechanism is vitally important to the longevity of the hydraulic motor. The stability of the motor at system level is influenced by a large number of factors, possibly not all of which are within the motor supplier's scope of responsibility.

The factors that need to be considered are:

— Motor (rotating group, yoke 'swash' control mechanism)

— Servovalve (pressure gain, flow gain, frequency response, hydro-mechanical stability, etc.)

— Controller (feedback signal conditioning, control architecture, gains, iteration rates, etc.)

NOTE 2 It is possible that the supplier of the motor is responsible for the entire system, thus the supplier would typically expect the system integrator to manage and specify interface requirements and any associated interactions between individual components within the combined system.

6.7 Motor overall efficiency

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

— the overall efficiency of the motor when new;

— the overall efficiency of the motor after the endurance test, this value being considered as an objective.

For bi-directional motors, the efficiency shall be determined with the motor running in both clockwise and anti-clockwise rotations.

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.

6.8 Dynamic characteristics

6.8.1 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.

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

6.8.3 Rapid reversals

For bi-directional motors, if required by the application, the motor shall withstand, at conditions specified in the detail specification, rapid reversals of direction of rotation without damage.

6.9 Passive operation

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

6.10 Fluid and ambient temperature

6.10.1 Fluid temperature

6.10.1.1 Rated temperature

The detail specification shall state the 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.

6.10.1.2 Minimum continuous temperature

The detail specification shall state the minimum continuous temperature.

6.10.1.3 Extreme operating temperature

The detail specification shall state the minimum and maximum extreme operating temperatures.

6.10.2 Ambient temperature

6.10.2.1 General

Refer to 6.13.

6.10.2.2 Survival temperature

The detail specification shall state the minimum and maximum survival temperatures.

6.11 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.

The detailed specification should clearly define the pass/fail criteria in the form of sound power level or sound pressure level.

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.

6.12 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 2 and 15.3.6.

The endurance test shall be conducted with filter elements that have a similar micron rating and efficiency to that of the actual hydraulic application.

Table 2 — 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	$0{,}5 \times 10^6$
NOTE Type I, II and III are according to ISO 8625-3 temperature classification.			

6.13 Environmental requirements

If not otherwise specified in the detail specification, it shall state the environmental and operating conditions to which the motor is exposed, as follows:

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 (for the servovalve, speed sensor, etc.) 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, any 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 equipment or the structure that it is installed on. 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 nameplate shall be positioned in a way so that it is readable in the motor's installed position.

The information marked in the spaces provided should be as listed in Figure 1.

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

Figure 1 — Format for nameplate

A NATO Stock Number (NSN) for military parts (or equivalent) shall be added if required by the detail specification.

7.9.2 Modification standard

Information on the modification status shall either be provided on the nameplate or on a separate plate.

7.9.3 Fluid identification

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

7.9.4 Ports

When possible, motor ports 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 of the motor 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 of the motor being impaired.

8.2.3 Motor return 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 of the motor 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 full 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 return port

Unless the detail specification states a different value, the motor return port shall statically withstand a pressure equal to 2,5 times rated pressure for the motor return 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;

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 official 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

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.

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;

— high temperature deterioration.

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

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;

— 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

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

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 the 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.

The centre of gravity shall also be provided on the supplier's installation drawing.

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 3.

Table 3 — 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 supplier and the purchaser.

10.5 Drive shaft

Unless otherwise specified in the detail specification, an easily removable shaft shall be fitted at the interface between the motor rotating group and actuation means that it is driving (e.g. a gearbox).

The drive shaft shall be held in place by means of a positive locking system.

If required by the detail specification, the drive 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 following shall be specified in the detail specification:

— shear torque;

— the loads other than those self-induced by the motor torque;

— the coupling lubrication mode.

10.6 Ports

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

All of the ports and associated tube unions shall be of different diameters to prevent any cross-connections occurring.

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;

c) the service life limit in operating hours (OH) and/or flight hours (FH).

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 mean time between failure (MTBF) rate;

c) the safety rate (if applicable);

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.

The national authorities reserve the right to carry out any of the inspection operations specified in this document where it is deemed necessary to ensure supplies and services that comply with stipulated specifications.

13.2 Classification of tests

The following test program shall be performed for the purposes of checking whether the motor complies with this document and the detail specification:

a) acceptance tests (see Clause 14);

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 kPad (±30 psid);

e) inlet/temperature:

— −57 °C to +43 °C, within ±3 °C;

— +43 °C to +107 °C, within ±6 °C.

f) flow: within ±2 % of rated flow;

g) shaft speed: ±100 r/m;

h) torque: ±2% of maximum motor input 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 15.3.6.6).

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 under a procurement contract shall be subjected to the examinations and acceptance tests specified in this 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;

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 on, 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 acceptance 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 as 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 dynamic and static shaft seal leakage shall not exceed the values specified for new build conditions (refer to 6.3.3.1 a) and 6.3.3.2 a)).

NOTE When the acceptance test is used for in-service units after repair or overhaul, the limits for in-service units are applicable.

14.3.3 Break-in run

The break-in run shall be made with any nominated pressure in the inlet and return 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 1 If the motor is operated at speeds outside of the normal system requirements, it is sometimes necessary to tailor the run-in speeds to avoid system resonance and associated component damage.

NOTE 2 Alternative operating conditions can be used to optimize the run-in process and to avoid damage, subject to agreement between the supplier and the purchaser.

14.3.4 Proof pressure and overspeed tests

14.3.4.1 Operational test at overpressure

Operate the hydraulic motor for 1 min at its rated speed with an inlet 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.

For bi-directional motors, this shall be conducted for both directions of rotation.

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 the limit specified in the detail specification.

14.3.4.2 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/return ports shall be subjected to an independent proof pressure test.

14.3.4.3 Case port proof pressure test

Pressurize the motor at the pressure determined from 8.2.1 for at least 2 min.

14.3.4.4 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.

For bi-directional motors, this shall be conducted for both directions of rotation.

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 the limit specified in the detail specification.

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 (for bi-directional motors, 15 min in each direction), and rated differential pressure with no opposing torque applied to the output shaft; and;

b) operate for 60 min (for bi-directional motors, 30 min in each direction) 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 per minute.

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

14.3.6 Break-out torque test

Operate the motor smoothly at a speed of 0,5 r/min to 3 r/min. Adjust the inlet 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 min. The break-out torque is defined as the lowest value of the variation in torque that is measured during this test.

For bi-directional motors, this test shall be conducted in both directions of rotation.

NOTE 1 The very low speed (approximately 3 r/min) is achieved with a suitable 'low speed' load mechanism, not through hydraulic or speed control of the unit under test.

NOTE 2 It can sometimes be necessary to verify breakout capability with an alternative method (e.g. using a locked shaft), to avoid the situation where the rotating group's design (notably the loading and pressure-velocity factors) are artificially compromised or biased by the need to complete the 'unrepresentative' 3 r/min test.

14.3.7 Teardown inspection examination

14.3.7.1 Sampling requirements

A teardown inspection shall be conducted on a minimum of 10 motors of a given model of an initial production run or as specified in the detail specification.

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;

b) alternative tooling and production facilities are chosen.

14.3.7.2 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.

14.3.8 Run-in

The run-in after teardown inspection shall be performed at 50 % to 100 % of rated speed for a period of 15 min (for bi-directional motors, 10 min in each direction) with a differential pressure of 80 % to 100 % of the rated differential pressure.

14.3.9 Speed control test

The motor speed shall remain within the limits specified in the detail specification as motor output torque is varied from 50 % to 100 % of rated load or to the load specified in the detail specification.

There shall be no indication of motor speed control instability as motor operating load is varied over the range specified in the detail specification (which would normally include aiding and opposing load).

For bi-directional motors, the test shall be conducted with both directions of rotation. If required by the detail specification, the speed control shall be checked with changes of direction of rotation; the detail specification providing the rate of the rotation change.

The system conditions for this test shall be defined in the detail specification.

The hysteresis characteristics of the motor speed control over the operating load range shall not exceed the value as specified in the detail specification.

14.3.10 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;

d) rated torque.

14.3.11 Fluid contamination test

14.3.11.1 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 between the supplier and the purchaser.

14.3.11.2 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.

14.3.11.3 Filter patch test

14.3.11.3.1 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.

14.3.11.3.2 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 14.3.11.3.3 for contamination accumulated during the functional test performed in accordance with 14.3.5.

14.3.11.3.3 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.

14.3.11.3.4 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.

14.3.11.4 Electro-conductive bonding

If required, measure the electrical resistance between any point on the mounting flange face and specified points on the motor (e.g. 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 and the detail specification, 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 shall be conducted on 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 4.

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 the minimum to run the motor at its rated speed to rated differential pressure;

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 subjected to the test in 14.3.4.4, but running for 30 min instead of 2 min.

Table 4 — List and sequence of qualification tests

Tests	Sample		Clause, subclause, etc. to be referred to
	A	B	
Acceptance	X	X	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
— Determination of motor speed control response time	X	X	15.3.5.4
— Dynamic braking	X	X	15.3.5.5
— Rapid reversals	X	X	15.3.5.6
— Passive operation	X	X	15.3.5.7
— Stalling torque and internal leakage	X	X	15.3.5.8
Endurance[a]	X		15.3.6
Environmental			15.3.7
— General	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
Structural tests			15.3.8
— 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
— Drive coupling shear	X	or X	15.3.8.6
Combination	X	or X	15.3.9
Supplementary tests	X	or X	15.3.10

[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.

15.3.4 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 an inlet 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 and is not an over-centre type, 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 15.3.6.8.

15.3.5.2 Dynamic characteristics

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

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 output loads of 25 %, 50 %, 75 %, and 100 % of rated load in the following conditions:

— motor outlet and case drain pressures of 200 kPa to 1 400 kPa (30 psi to 200 psi, relative);

— rated motor differential pressure.

The output torque at any of the test loads at the above conditions shall not be greater than the rated torque. The case drain flow rate shall be less than the values specified in the detail specification.

The motor efficiency shall be calculated from the results obtained from this test.

For bi-directional motors, conduct the test in both directions.

15.3.5.4 Determination of motor speed control response time

This test shall be conducted at the rated fluid temperature. The test set up shall incorporate means to change the motor output load over the opposing and aiding load range at rates specified in the detail specification.

With the motor operating against zero load, apply 25 % of the rated opposing load. Make a record of the motor speed/time function as the load is applied. The motor speed response time shall not exceed the value specified in the detail specification. Check for any evidence of motor speed instability.

Repeat the test reducing the load back to zero and check the motor speed/time function and evidence of speed instability.

Repeat these tests for 50 %, 75 % and 100 % of the rated load (opposing and then aiding loads) or as specified in the detail specification.

Carry out runs with 25 %, 50 %, 75 % and 100 % of the rated load (opposing and aiding (as applicable)) or as specified in the detail specification. Make a record of the motor speed/time function as the load over the range of opposing and aiding loads. The motor speed response time shall not exceed the value specified in the detail specification. Check for any evidence of motor speed instability.

Check the response time for small incremental changes of the output load (e.g. 5 %), and check for any evidence of motor speed instability

For bi-directional motors, this test shall be conducted with both directions of rotation.

If required by the detail specification, repeat these tests with different fluid temperatures.

15.3.5.5 Dynamic braking

Install a relief valve set at 125 % of the rated pressure, adapted to the test conditions, in the supply line.

With the motor at rated supply pressure and load conditions, apply a braking torque to the shaft in order to decelerate continuously from the rated speed to zero within 0,02 s.

The motor shall not be damaged in any way which would jeopardize its subsequent operation.