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Aerospace — Hydraulic, pressure-compensated, variable delivery pumps — General requirements for 35 000 kPa systems

Aéronautique et espace — Pompes hydrauliques à débit variable régulé en fonction de la pression — Exigences générales pour circuits 35 000 kPa

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 12334 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

Aerospace — Hydraulic, pressure-compensated, variable delivery pumps — General requirements for 35 000 kPa systems

1 Scope

This International Standard specifies the general requirements for pressure-compensated, variable delivery hydraulic pumps, suitable for use in aircraft hydraulic systems at 35 000 kPa.

This International Standard shall be used in conjunction with detail specifications concerning each pump model.

2 Normative references

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

ISO 2093:1986, *Electroplated coatings of tin — Specification and test methods*.

ISO 2669:1995, *Environmental tests for aircraft equipment — Steady-state acceleration*.

ISO 2671:1982, *Environmental tests for aircraft equipment — Part 3.4: Acoustic vibration*.

ISO 2685:1998, *Aircraft — Environmental test procedure for airborne equipment — Resistance to fire in designated fire zones*.

ISO 3601-1:1988, *Fluid systems — Sealing devices — O-rings — Part 1: Inside diameters, cross-sections, tolerances and size identification code*.

ISO 6771:1987, *Aerospace — Fluid systems and components — Pressure and temperature classifications*.

ISO 7137:1995, *Aircraft — Environmental conditions and test procedures for airborne equipment*.

ISO 7320:1992, *Aerospace — Couplings, threaded and sealed, for fluid systems — Dimensions*.

ISO 8077:1984, *Aerospace process — Anodic treatment of aluminium alloys — Chromic acid process 20 V DC, undyed coating*.

ISO 8078:1984, *Aerospace process — Anodic treatment of aluminium alloys — Sulfuric acid process, undyed coating*.

ISO 8079:1984, *Aerospace process — Anodic treatment of aluminium alloys — Sulfuric acid process, dyed coating*.

ISO 8081:1985, *Aerospace process — Chemical conversion coating for aluminium alloys — General purpose*.

ISO 8399-1:1998, *Aerospace — Accessory drives and mounting flanges (Metric series) — Part 1: Design criteria*.

ISO 8399-2:1998, *Aerospace — Accessory drives and mounting flanges (Metric series) — Part 2: Dimensions*.

3 Functional requirements

3.1 Hydraulic fluid

The hydraulic fluid on which the pump is intended to be operated shall be defined in the detail specification.

3.2 Rated discharge pressure

The rated discharge pressure of the pump shall be defined as the maximum pressure against which the pump is required to operate continuously at rated temperature, at rated speed and at zero flow (see Figure 1).

The design of the pump shall be such as to maintain rated discharge pressure at the following combination and range of conditions:

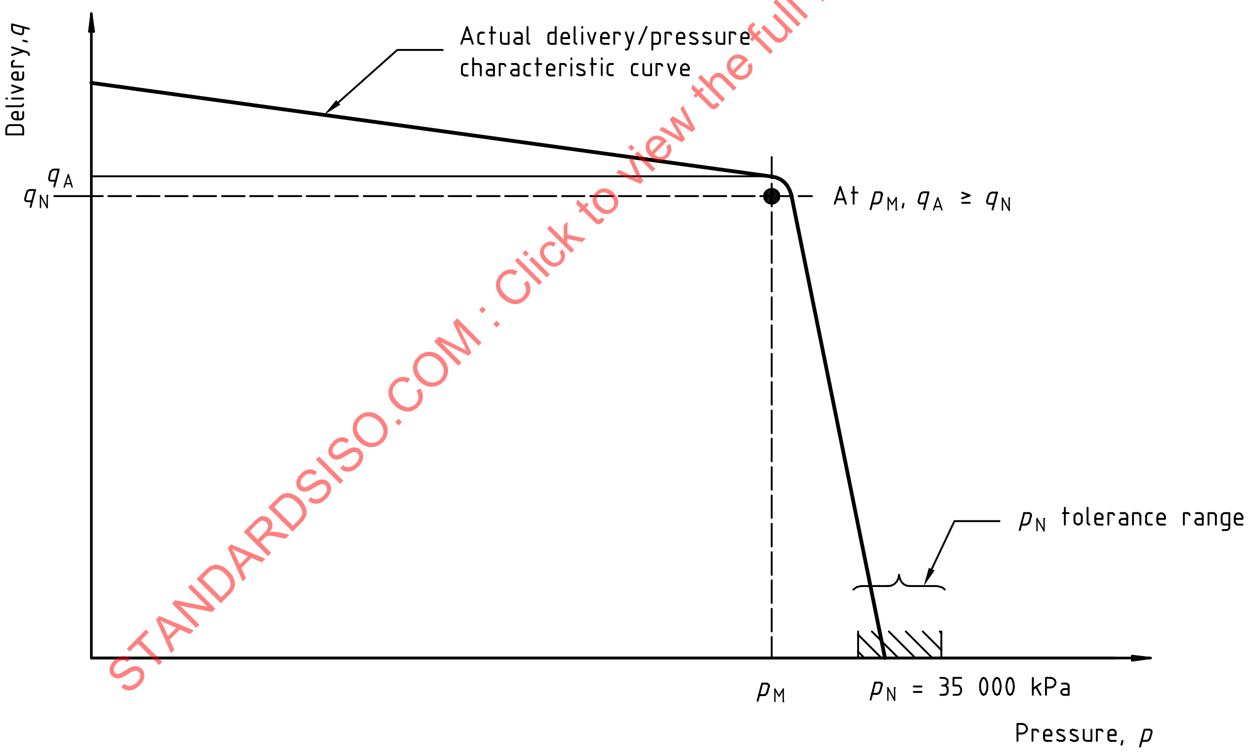
— from 30 °C to rated temperature;

— from 50 % to 115 % of rated speed;

— at rated inlet pressure.

The value of the rated discharge pressure shall be 35 000 kPa. The maximum and minimum tolerance shall be specified in the detail specification:

This permissible tolerance on rated discharge pressure shall be doubled in each direction for fluid temperatures below 30 °C or pump speeds between 25 % and 50 % of rated speed.



Key

q_N = rated delivery (see 3.9)

p_N = rated discharge pressure (see 3.2)

p_M = maximum full-flow pressure (see 3.3)

q_A = actual delivery at maximum full-flow pressure

NOTE — This diagram is given as an indication. It may be presented in a different way, for example, the axes may be reversed.

Figure 1 — Delivery/pressure characteristics of pumps

3.3 Maximum full-flow pressure

The maximum full-flow pressure of the pump shall be defined as the maximum discharge pressure at which the pump control does not react to reduce pump delivery at rated temperature, speed and inlet pressure.

The detail specification shall specify the minimum value of the maximum full-flow pressure (see Figure 1).

3.4 Inlet pressure

3.4.1 Rated inlet pressure

The rated inlet pressure of the pump shall be defined as the pressure measured at the inlet port of the pump when it operates at rated speed, maximum full-flow pressure and rated temperature. Rated inlet pressure shall be expressed as an absolute value.

The value of rated inlet pressure shall be specified in the detail specification.

3.4.2 Cavitation pressure

The cavitation pressure of the pump shall be defined as the inlet pressure obtained when, after adjustment of the pump at rated speed, rated temperature and 90 % of maximum full-flow pressure, by reducing inlet pressure, the discharge flow is reduced by 10 %.

3.4.3 Minimum inlet pressure

The minimum inlet pressure of the pump shall be defined as the minimum inlet pressure, stipulated by the supplier, for which the pump meets the rated conditions of operation.

NOTE It is recommended to size the inlet lines so as to prevent any cavitation at the inlet port of the pump, in steady delivery conditions and in sudden demand conditions.

3.5 Case drain pressure

3.5.1 Rated case-drain pressure

Rated case-drain pressure shall be defined as the maximum pressure at which the pump is required to operate continuously in the system.

Rated case-drain pressure shall be stated in the detail specification.

3.5.2 Case proof-pressure

Unless a different value is specified in the detail specification, all pumps shall be designated to withstand a pressure of at least 3 500 kPa (35 bar) at the case-drain port or 150 % of the rated case-drain pressure, whichever is the greater, without permanent damage being done or performance being impaired.

3.6 Case drain flow

The pump shall be capable of producing a minimum case drain flow at a maximum given differential pressure between case pressure and inlet pressure, as specified in the detail specification.

Minimum and maximum case drain flow shall be stated in the detail specification under conditions as specified in the detail specification.

3.7 Rated temperature

The rated temperature of the pump shall be defined as the maximum continuous temperature of the fluid at the inlet port of the pump. It shall be expressed in degrees Celsius.

The rated temperature is related to the maximum temperature (in accordance with ISO 6771) of the hydraulic system in which the pump is to be used and shall be one of the values listed in Table 1. The rated temperature shall be specified in the detail specification.

The minimum continuous temperature of the fluid at the pump inlet port may be specified in the detail specification.

Table 1 — Temperature relationship

Hydraulic system	Maximum system temperature °C	Rated temperature of pump °C
Type I	70	45
Type II	135	110
Type III	200	170

3.8 Maximum displacement

The maximum displacement of the pump shall be defined as the maximum theoretical volume of hydraulic fluid delivered in one revolution of its drive shaft. It shall be expressed in cubic centimetres per revolution.

The maximum displacement of the pump shall be calculated from the geometrical configuration and the dimensions of the pump. The effects of allowable manufacturing tolerances, of deflections of the pump structure, of compressibility of the hydraulic fluid, of internal leakage and temperature shall not be taken into account in the calculation, since the maximum displacement is intended to be an index of the sizes of the pump rather than of its performances.

3.9 Rated delivery

The rated delivery of the pump shall be defined as the measured output of the pump under conditions of rated temperature, rated inlet pressure, rated speed and maximum full-flow pressure.

The rated delivery shall be expressed in cubic decimetres per second and its value shall be specified in the detail specification (with, in parentheses, the corresponding value in cubic decimetres per minute) (see Figure 1).

3.10 Rated speed

The rated speed of the pump shall be defined as the maximum speed at which the detail specification requires the pump to operate continuously at rated temperature and at rated discharge pressure. The rated speed shall be expressed as a number of revolutions of the pump driving shaft per minute.

The rated speed of the pump shall be stated in the detail specification. As an indication, the maximum recommended values are given in the diagram in Figure 2.

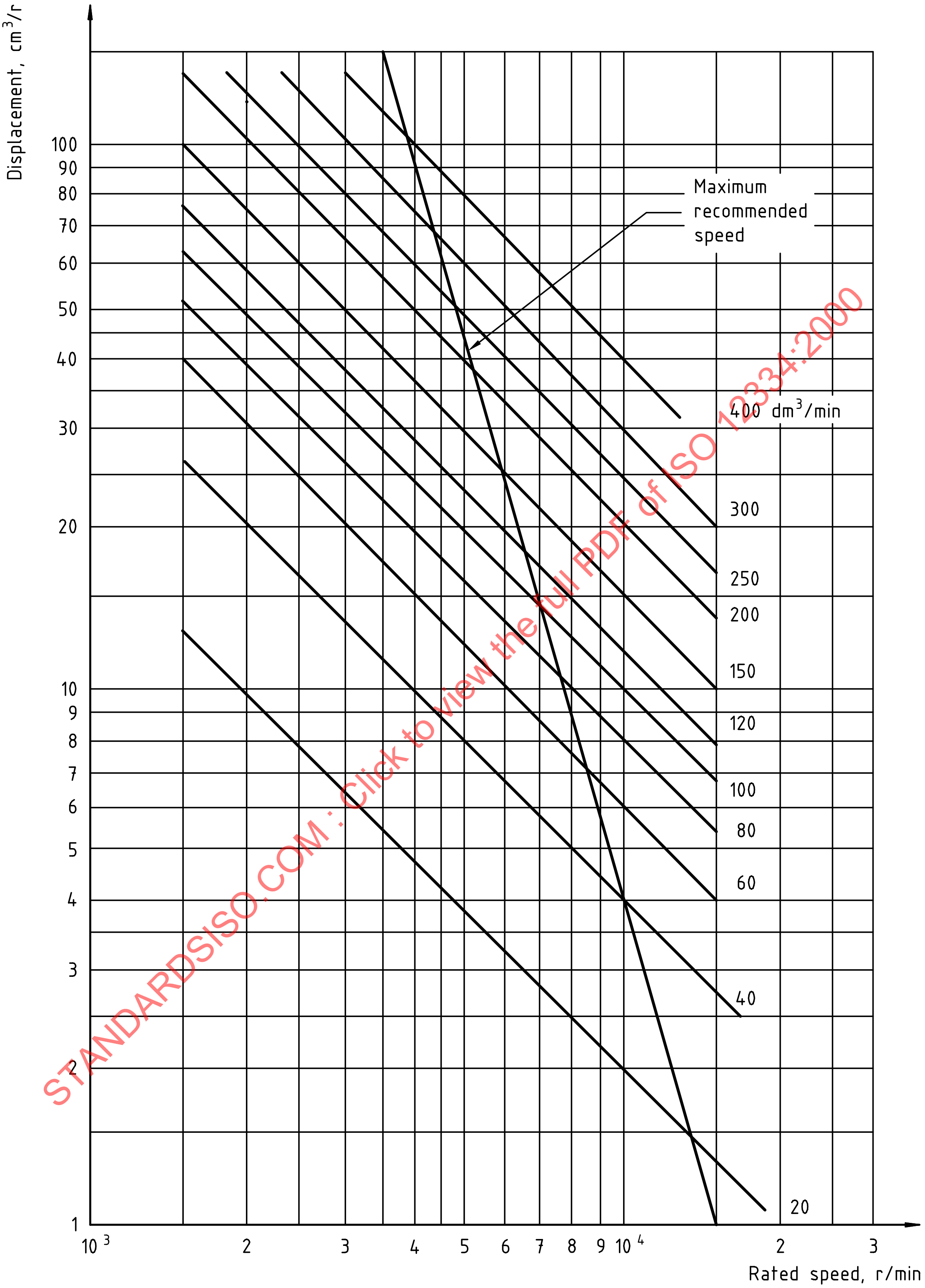


Figure 2 — Nomograph of maximum recommended values for rated speeds against pump displacement

3.11 Endurance

If the duration and the conditions of the endurance test are not specified in the detail specification, they shall be in accordance with Table 2 and 5.13 of this International Standard.

Table 2 — Duration of endurance test

Pump	Hydraulic system (see Table 1)	Duration of endurance test h
Category A (for example, used for military applications)	Type I Type II Type III	2 000 2 000 1 000
Category B (for example, used for commercial applications)	Type I Type II Type III	4 000 4 000 2 000

3.12 Torque

The detail specification shall specify:

— the maximum value of driving torque for rated operating conditions for the pump;

— the torque value when the pump is operated at zero flow, at rated pressure, temperature and rotation speed.

3.13 Efficiency

Efficiency shall be defined as the ratio of output power to input power when the pump is operated under rated conditions and at maximum full-flow pressure. In general, it shall be stated as a percentage.

NOTE The above ratio is commonly referred to as "overall efficiency" and includes volumetric efficiency.

When calculating output power from flow rate and pressure change, only the net pressure difference between inlet and outlet ports of the pump 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.

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

— overall delivery of the pump when new;

— overall delivery of the pump after endurance test, this value being considered an objective.

3.14 Discharge pressure pulsations

Pressure pulsations shall be defined as the oscillations of the discharge pressure, occurring during nominally steady operating conditions, at a frequency equal to or higher than the pump drive shaft speed.

The amplitude of pressure pulsations shall be determined by the test procedure described in 5.9.5. These pulsations shall not exceed ± 2 100 kPa or a pressure band specified in the detail specification, when the pump is tested in the circuit which simulates the actual system in which the pump is to be installed, as defined in the detail specification. The system volume may be simulated using tubing of the discharge line diameter, while being careful to avoid a line length the natural frequency of which is resonant with pulsation frequency.

3.15 Variable delivery control

3.15.1 General

All pump models shall incorporate means to control the delivery with the effect of making the delivery of the pump pass from zero to its maximum full-flow value for any given operating speed, when the discharge pressure is reduced from rated discharge pressure to maximum full-flow pressure and vice versa.

3.15.2 Response time

The response time of the pump shall be defined as the time interval between the moment when an increase (or decrease) in discharge pressure begins and the subsequent moment when the discharge pressure reaches its first maximum (or minimum) value. In Figures 3 and 4, the time intervals t_1 and t_2 are the response times of the pump as a function of the system impedance.

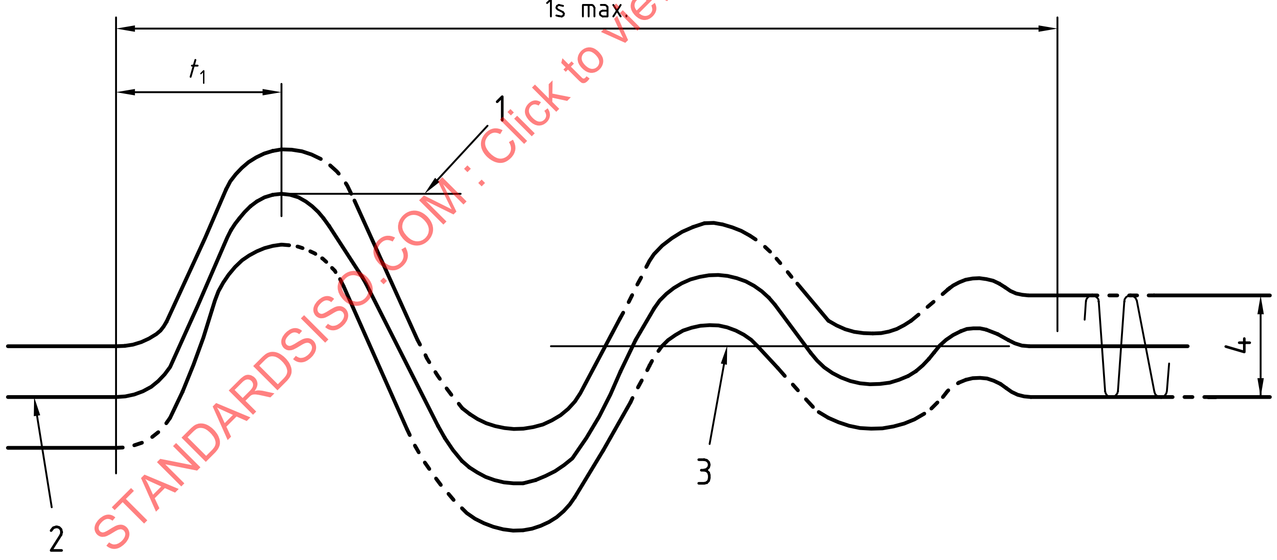
The (oscillographic or computer-aided) plot of discharge pressure against time shall be used as the criterion of movement of the delivery control mechanism. All pump models when operating at rated speed, rated inlet temperature and in a circuit, the system impedance of which is defined in 5.9.2.1 for response times, shall have a response time of, at most, 0,05 s, unless otherwise specified in the detail specification.

3.15.3 Stability

The stability of the pump shall be defined as the freedom from persistent or quasi-persistent oscillation or "hunting" of the delivery control mechanism at any frequency that can be traced to the pump delivery control means. The oscillographic trace of discharge pressure against time shall be used as the criterion of stability.

All pump models, under any operating condition within the limits stated in the detail specification and at any speed greater than 50 % of the rated speed, after a change in flow demand, shall recover steady-state operation (other than permissible pressure pulsations as specified in 3.14) within not more than 1 s after the initial response to that change in flow demand.

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



Key

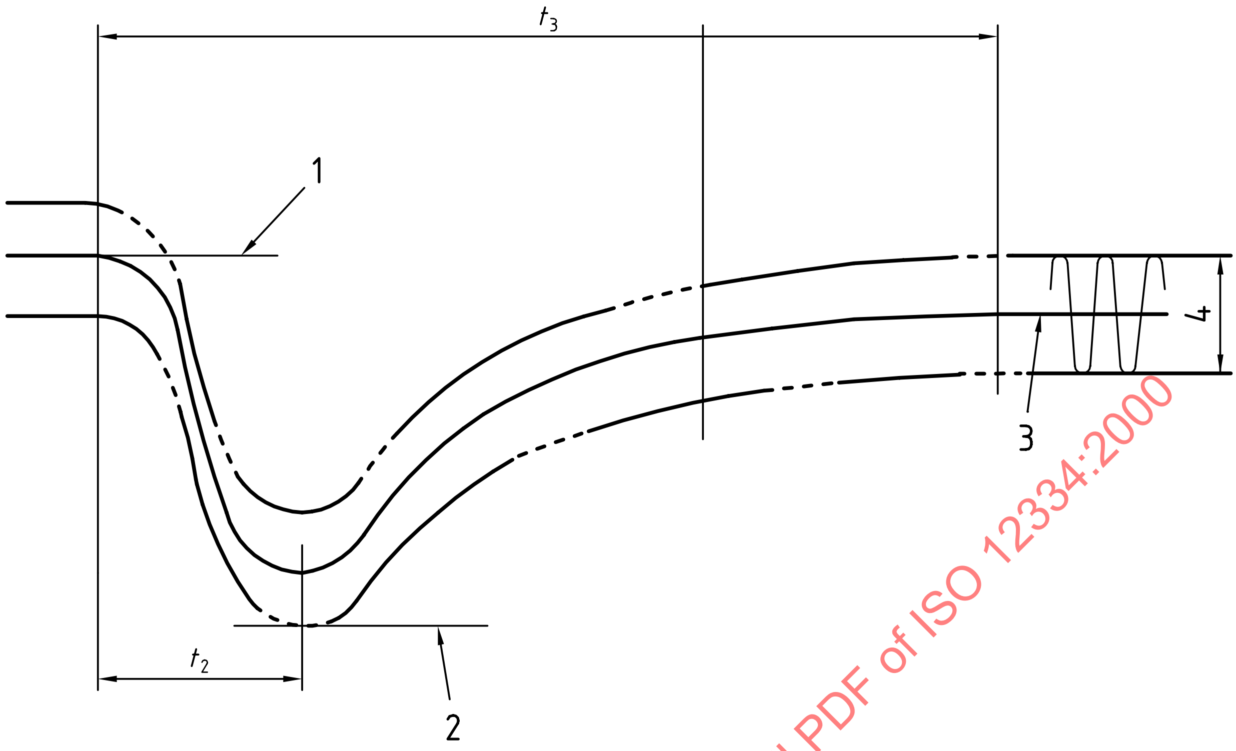
1 Maximum transient pressure (3.16)

2 Maximum full-flow pressure (3.3)

3 Rated discharge pressure (3.2)

4 Allowable discharge pressure pulsations (3.14)

Figure 3 — Typical variation of pressure against time — Transient from maximum full-flow pressure to rated discharge pressure (zero flow)



Key

1 Rated discharge pressure (3.2)
2 Minimal pressure
3 Maximum full-flow pressure (3.3)
4 Allowable discharge pressure pulsations (3.14)

Figure 4 — Typical variation of pressure against time — Transient from rated discharge pressure to maximum full-flow pressure (full flow)

3.16 Maximum transient pressure

The maximum transient pressure shall be defined as the peak value of the oscillographic trace of discharge pressure, made during operation of a pump, as specified in 5.9.3 and measured as shown in Figure 3.

The value of the maximum transient pressure, as determined in the transient pressure test specified in 5.9.3, shall not exceed 45 000 kPa.

3.17 Depressurization

When it is a requirement of the detail specification that the pump be depressurized either automatically or remotely as by an electrical signal the depressurization control shall not, when de-energized, interfere with the normal operation of the variable delivery control. The detail specification shall specify the design integrity and quality assurance tests for the depressurization control.

3.18 Balance

The moving parts of the hydraulic pump shall be inherently balanced and the pump shall not vibrate in such a manner as to cause failure of any part in the pump or drive mechanism at speeds up to and including 115 % of rated speed.

3.19 Adjustment

Means shall be provided to adjust the delivery control mechanism to cause zero flow to occur at rated discharge pressure. This adjustment shall, preferably, be continuous, but it may be in steps of less than 300 kPa of the rated discharge pressure over a minimum range from 33 000 kPa to 42 000 kPa of the rated discharge pressure.

The adjustment device shall be capable of being securely locked and it shall be possible to carry out adjustment and locking using only standard hand tools. Where practicable, the adjustment device shall be fitted in such a way that adjustments can be made while operating under full system pressure with negligible loss of fluid.

3.20 Safety wire sealing

Lead-type safety wire sealing shall not be used.

3.21 Directionally critical components

Wherever practical, internal parts which are subject to malfunction or failure owing to the fact that they have been installed the wrong way round or out of true position shall have mechanical provisions to ensure that they cannot be installed or assembled incorrectly.

3.22 Environmental requirements

The detail specifications shall define environmental conditions to which the pumps will be exposed and in which the pumps shall operate. These detail specifications shall also define how these requirements can be checked by reference to the applicable test methods specified in the relevant International Standards.

The following environmental conditions shall be considered:

a) temperature and altitude (in accordance with ISO 7137);

b) humidity (in accordance with ISO 7137);

c) fluid susceptibility (in accordance with ISO 7137);

d) vibration (in accordance with ISO 7137);

e) acoustic vibration (in accordance with ISO 2671);

f) steady state acceleration (in accordance with ISO 2669);

g) fungus resistance (in accordance with ISO 7137);

h) salt spray (in accordance with ISO 7137);

i) water proofness (in accordance with ISO 7137);

j) sand and dust (in accordance with ISO 7137);

k) shock (in accordance with ISO 7137);

l) fire resistance (in accordance with ISO 2685);

m) ice formation (in accordance with ISO 7137).

3.23 Installation requirements

3.23.1 Dimensions

Dimensions pertinent to the installation of pumps in aircraft shall be specified on the manufacturer's installation drawing.

3.23.2 Mass

The wet and dry mass of the completely assembled pump shall not exceed the value specified in the detail specification. Both wet and dry masses shall be specified on the installation drawing.

3.23.3 Mounting

3.23.3.1 General

Unless otherwise specified in the detail specification, all pumps 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 pump 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	**Flange type** **Spigot reference**
2,5	150
5	200
10	300
15 20 30 40	350

3.23.3.2 Orientation

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

3.23.3.3 Direction of rotation

The direction of rotation of the pump shall be clearly and permanently marked on an exposed surface of the pump housing.

3.23.4 Drive coupling

An easily replaceable part of the pump assembly or a non-metallic coupling muff, incorporating a shear section, shall be interposed between the pump drive shaft and the engine accessory drive shaft by which the pump is to be driven.

This shear coupling part shall be held in place by a positive retainer. The end of the driving shaft shall be in accordance with ISO 8399-1 and ISO 8399-2. The aircraft manufacturer shall specify the coupling lubrication.

Unless otherwise indicated in the detail specification, the shear section shall stand 3 times the mechanical torque corresponding to nominal conditions.

3.23.5 Ports

Port configuration shall be in accordance with ISO 7320, unless otherwise specified in the detail specification.

The ports and the affected sections of the pump housing shall be structurally designed so as to withstand, without permanent distortion or impairment of function, the application of a torque 2,5 times the maximum value resulting from the attachment or removal of fittings and hoses when installing or removing pumps during field maintenance.

Inlet, outlet and case drain ports shall be identified on each pump by clear and permanent markings.

3.24 Detail requirements

3.24.1 Material

Materials and processes used in the manufacture of these pumps shall be of high quality, appropriate for the intention of use and in conformity with applicable standards. Materials in conformity with the pump manufacturer's specifications may be used provided that the specifications are approved by the purchaser and contain provisions for appropriate tests. Using the pump manufacturer's specifications does not mean that respect of other applicable specifications shall be waived.

3.24.2 Metals

3.24.2.1 General characteristics

All metals shall be compatible with the fluid, the intended temperature, and the functional, service and storage conditions to which the components will be exposed. The metals shall have adequate corrosion-resisting characteristics or shall be suitably protected in accordance with 3.24.3.

3.24.2.2 Pumps for type I systems

Except for internal surfaces in constant contact with hydraulic fluid, ferrous alloys shall have a mass fraction of chrome of no less than 12 % or shall be suitably protected against corrosion as specified in 3.24.3. In addition, tin, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapours. 0-ring grooves for external seals shall not be considered as internal surfaces in permanent contact with hydraulic fluid. Magnesium alloy shall not be used.

3.24.2.3 Pumps for type II and type III systems

Ferrous alloys shall have a mass fraction of chrome of no less than 12 % or shall be suitably protected against corrosion as specified in 3.24.3. In addition, tin, cadmium, and zinc platings shall not be used for internal parts or internal surfaces in contact with hydraulic fluid or exposed to its vapours. Magnesium alloy shall not be used.

Where performance or reliability of the pump will be jeopardized by the use of materials and processes as specified in 3.24.2 and 3.24.3, alternative materials or processes may be used, subject to the approval of the purchaser. Such materials or processes shall be selected so as to provide the maximum degree of corrosion resistance consistent with the performance requirements.

3.24.3 Corrosion protection

3.24.3.1 General

Metals which do not inherently possess sufficient corrosion-resisting characteristics shall be suitably protected, in accordance with the following subclauses, to resist corrosion which may result from conditions such as dissimilar metal combinations, moisture, salt spray and high temperature deterioration, as applicable.

3.24.3.2 Ferrous and copper alloys

Ferrous alloys requiring corrosion-preventive treatment and all copper alloys, except for parts having bearing surfaces, shall have a suitable electrodeposited metallic coating selected from the following:

a) cadmium plating[1];

b) chromium plating[2];

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1) See ISO/DIS 8921, *Aerospace — Electroplated cadmium coatings on high-strength steels (maximum tensile strength 1 450 to 1 850 MPa)*. This project has been withdrawn. Further information can be obtained from Technical Committee TC 20.

2) This corrosion-preventive treatment is under study and shall be the object of future International Standards which shall come into effect as they are published.

c) nickel plating[2)];

d) silver plating[2)];

e) tin plating (in accordance with ISO 2093);

f) electrodeless nickel[2)].

Tin and cadmium plating shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapours or subject to abrasion. Where there is no indication, class and type of plating are left to the manufacturer and shall be specified in the detail specification.

Other metallic coatings may be used, such as electrodeposited 85 % tin and 15 % cadmium alloy, the use of which has been proved to be satisfactory to the purchaser.

3.24.3.3 Aluminium alloys

Unless otherwise authorized, all aluminium alloys shall be anodized in accordance with ISO 8077, ISO 8078 and ISO 8079, except that, in the absence of abrasive conditions, they may coated with chemical film in accordance with ISO 8081.

The exceptions noted will be subject to the approval of the purchaser.

3.24.4 Castings

Castings shall be of high quality, 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. Inspection and repair of castings shall be checked by quality control techniques and standards satisfactory to the purchaser.

3.24.5 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 International Standard, may be used subject to the approval of the purchaser. For pumps for type III systems, back-up rings used shall be subject to the approval of the purchaser.

3.24.6 Identification marking

A nameplate shall be securely attached to the pump. The information marked in the spaces provided shall be as required in Table 4.

Table 4 — Format for nameplate

Pump, hydraulic, pressure-compensated, variable delivery
Name of manufacturer: ....
Manufacturer's code: ....
Manufacturer's part number: ....
Serial number: ....
Fluid: ....
Displacement: .... cm^3/r
Rated delivery: .... dm^3/s (dm^3/min)
Rated pressure: .... 35 000 kPa
Rated speed: .... r/min

Any additional data required shall be specified in the detail specification.

3.24.7 Design and construction

3.24.7.1 Lubrication

The hydraulic pump shall be self-lubricated with no provisions for lubrication other than the circulating fluid.

3.24.7.2 Leakage

External leakage, significant enough to form a drop, from the pump housing or from any static seal in the housing, shall not be permitted, except at the drive shaft seal, where the rates of leakage under specified operating conditions shall not exceed the values specified in 6.3.6.

3.24.7.3 Maintainability features

3.24.7.3.1 All wear surfaces shall be replaceable or repairable.

3.24.7.3.2 Sockets and connections, mounting and wiring provisions shall be designed to prevent erroneous connections.

3.24.7.3.3 Components which are not functionally interchangeable shall not be physically interchangeable.

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

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

3.25 Maintainability

3.25.1 Maintenance concept

The required maintenance concept shall be specified in the detail specification, for example "on condition".

3.25.2 Useful life and storage conditions

The requirements together with the appropriate definitions shall be specified in the detail specification and shall consist of:

a) time between overhauls (if applicable);

b) storage time;

c) limit life time.

3.26 Reliability

3.26.1 Equipment compliance

All of the reliability requirements shall be met throughout the equipment's lifetime, assuming that all approval maintenance cycles have been performed.

3.26.2 Requirements

The required data together with the appropriate definitions shall be specified in the detail specification and shall consist of:

a) the defect rate;

b) the failure rate;

c) the safety rate (if applicable);

d) a study of the breakdowns and their consequences.

4 Quality assurance provisions

4.1 Responsibility for inspection

Unless otherwise specified in the contract or order, the supplier is responsible for the performance of all inspection requirements as specified in this clause. Except as otherwise specified, the supplier may use his own facilities or the services of any industrial laboratory approved by the national authorities.

These authorities reserve the right to perform any of the inspections specified in this International Standard where such inspections are deemed necessary to ensure that supplies and services conform to the stipulated requirements.

4.2 Classification of tests

For the purpose of checking whether the pumps comply with this International Standard, the following test programme shall be performed:

a) qualification tests (in accordance with clause 5);

b) acceptance tests (in accordance with clause 6).

5 Qualification tests

5.1 General

Qualification tests, with the purpose of checking whether pump design is in conformity with the requirements of this International Standard, shall consist of the tests specified in this clause.

5.2 Qualification procedure

5.2.1 Detail specification

The airframe contractor or pump manufacturer shall prepare a detail specification for each pump for which design approval is desired. This specification shall specify conformance with the requirements of this International Standard, including satisfactory completion of the specified design approval tests. Furthermore, it shall include any additional requirements and the detail test methods necessary to ensure satisfactory operation and service life in the particular installation concerned. This detail specification shall be submitted to the applicable purchaser for approval and acceptance.

5.2.2 Qualification by analogy

If the following conditions are met:

a) the pump incorporates the same or operationally similar working parts as a pump which has previously received design approval by a purchaser, and

b) the service requirements for the previous utilisation for which the pump was qualified were equivalent to or greater than the service requirements for the intended utilisation of the pumps,

all or some of the design approval tests may be waived and a report substantiated by drawings showing the similarity with the approved pump shall be submitted instead of carrying out actual tests.

5.2.3 Pump qualification test report

A report of the tests performed and the test results shall be compiled. This report shall include full assessment of the extent to which the tested pumps comply with the specified requirements as well as the thorough way in which testing was carried out. The description of the instruments used, schematic diagrams and photographs, as appropriate, shall be attached and the report shall give a complete summary of the test results in the form of a table. Hydraulic test circuits shall be described in detail for each test. A full set of detail and assembly drawings of the pump shall be attached to the test report.

5.3 Samples and programme of qualification tests

Qualification tests shall be conducted on one or two sample pumps (A and B). It is essential that these sample pumps be representative of the pumps to be manufactured.

The qualification tests, to be carried out in the suggested order, are given in Table 5.

Table 5 — List and sequence of qualification tests

Tests	Specimen		Corresponding subclause
	A	B	
Acceptance	×	×	5.5
Dimensional control	×		5.6
Proof pressure	×	×	5.7
Calibration	×	×	5.8
Maximum pressure		×	5.9
Determination of response time		×	5.9
Pressure pulsations		×	5.9
Heat rejected		×	5.10
Vibrations		×	5.11
Low temperature		×	5.12
Endurance	×		5.13
Cavitation		×	5.14
Shear of drive shaft	× or	×	5.15
Additional tests	× or	×	Detail specification

5.4 General conditions for qualification tests

The hydraulic fluid used in all these tests shall be as specified in the detail specification. Unless otherwise specified, required test operating conditions shall be maintained within the following limits:

a) inlet pressure within ± 2 %;

b) inlet temperature:

from – 55 °C to + 45 °C, within (0, + 5) °C

from + 45 °C to + 170 °C, within ± 10 °C

c) pump shaft speed within ± 2 %;

d) discharge pressure within ± 2 %;

e) flow within ± 2 %.

5.5 Acceptance tests

Acceptance tests, as part of the design approval test programme, shall be performed exactly as specified in 6.3, except that pressure control tests shall be extended to check the discharge pressure at cut-off and pump stability for the fluid's whole range of temperatures and speeds as specified in 3.2.

5.6 Dimensional check

Prior to the start of the qualification test, check the critical wear dimensions and record the dimensions. Check these dimensions again for comparison purposes once qualification tests have been completed. The run-in specified in 6.3.5 may be carried out, if necessary, after reset and before the test sequence is continued.

5.7 Proof-pressure and overspeed test

Carry out the proof-pressure and overspeed tests as outlined in 6.3.2 for acceptance tests, except that the tests shall be repeated 10 times. On completion of the proof-pressure tests, restore the pump delivery mechanism to its normal adjustment configuration.

5.8 Calibration

5.8.1 Pump inlet pressurized

Regulate the pressure at the pump inlet port to the rated inlet pressure at full flow and rated speed conditions.

5.8.2 Flow rate and driving torque values

Determine values of flow rate and driving torque at minimum operating speed, at 25 %, 50 %, 75 %, 100 % and 110 % of rated speed. At each of these speeds, make four series of flow and torque recordings at 25 %, 50 %, 75 % and 100 % of maximum full-flow pressure and at five equally spaced increments of flow between maximum full-flow pressure and rated discharge pressure. Unless otherwise specified in the detail specification, perform calibrations at the inlet condition specified in 3.4 and flow measurements may be made in the line downstream of the load valve, but shall be corrected for fluid compressibility.

5.8.3 Minimum operating speed

Reduce the speed to below 25 % of the rated speed to determine the speed at which the discharge flow or pressure become erratic. Record this point and designate it as the "minimum operating speed" for that condition.

5.9 Maximum pressure, response time and pressure pulsation tests

5.9.1 General

Pressure pick-up and recording equipment shall be used to provide an oscillographic record, or its equivalent, of the pressure/time function or the pump and its hydraulic circuit through the transient and steady-state periods described in the following three tests.

The pressure pick-up and recording equipment shall be capable of static calibration accurate to within 5 % of rated pressure and readability of 3 % of rated pressure. A consideration is that static calibrations of the pick-up and recording equipment are valid for dynamic conditions.

The pressure pick-up shall be located in the pump discharge line as close to the pump outlet fitting as is physically possible.

5.9.2 System impedance

5.9.2.1 Determination of response time

The system impedance used by determining response time is 340 000 kPa/s (3 400 bar/s).

This impedance:

— refers to a sudden no-flow of the pump operating at rated speed, at rated temperature and at rated delivery;

— is calculated from the system volume, the pump rated delivery and the fluid bulk modulus at rated temperature and rated discharge pressure.

5.9.2.2 All other tests

The system impedance of the test circuit when determining maximum pressure, pressure pulsations, stability and the remaining qualification tests shall be specified in the detail specification. Both the inlet circuit and the high-pressure circuit shall be representative of aircraft circuits.

5.9.3 Maximum pressure test

The test circuit specified in 5.9.2.2 shall be used. For this test, all gases shall be evacuated from the pump. Flow changes shall be initiated by means of a solenoid-operated valve with a response time of 0,02 s or less, or a response time as specified in the detail specification.

Operate the test pump between steady-state maximum full-flow pressure and steady-state rated discharge pressure in both directions and make an oscillographic record of the pressure/time function through the transient period. Run the test at 50 % and 100 % of rated pump speed. Take all precautions to keep the proportion of air in the hydraulic fluid to a minimum. Unless otherwise specified in the detail specification, the peak pressure transient as measured on the above record shall not exceed 45 000 kPa.

5.9.4 Determination of response time

Using the test circuit specified in 5.9.2.1 and with load valves set at a flow condition equivalent to maximum full-flow pressure at each of the test speeds, use the solenoid valve which changes the discharge line from fully open to fully closed, or vice versa, to conduct the test. Carry out runs at 50 %, 75 % and 100 % of rated speed or as specified in the detail specification. With the solenoid valve open and the test pump operating at steady-state maximum full-flow pressure, make a record of the pressure/time function through the transient period associated with the closing of the solenoid valve and the establishing of steady-state rated discharge pressure. This record shall be similar to the typical variation shown in Figure 3, and the response time, t_1, as indicated in Figure 3, shall not exceed 0,050 s at 100 % of rated speed. At 50 % and 75 % of rated speed, t_1 shall not exceed the value specified in the detail specification.

Record the response time t_2, for the change from rated discharge pressure to minimal pressure and, as indicated in Figure 4, t_2 shall not exceed 0,05 s at 100 % rated speed. At 50 % and 75 % of rated speed, t_2 shall not exceed the value specified in the detail specification.

Record the response time t_3 for the change from rated discharge pressure to minimal full-flow pressure and, as indicated in Figure 4, t_3 shall not exceed 1 s at 100 % rated speed.

Check the response time for small incremental changes of flow as follows:

a) introduce a parallel flowpath which includes an orifice and a downstream solenoid valve with a 0,02 s response time or a response time as specified in the detail specifications;

b) adjust this orifice to pass 5 % of maximum full-flow and adjust the main load throttling valve to pass 90 % of maximum full flow for each of the three pump speed settings;

c) check the response time at each speed setting when the small flowpath solenoid is opened and closed with the main flowpath solenoid valve both opened and closed.

   The response time at rated speed should not exceed 0,05 s;

d) check the response time at rated speed, rated pressure, minimum inlet pressure and fluid temperature as specified in the detail specification.

5.9.5 Pressure pulsation test

Equip the test circuit specified in 5.9.2.2 with a pressure transducer of zero volume and sensitive to 20 kHz to 100 kHz.

With the pump at rated discharge pressure:

a) vary the speed from 50 % to 100 % of rated speed at a rate of change not exceeding 100 r/min/s at 0 %, 25 % and 50 % of rated flow;

b) vary the flow from 0 % to 100 % at 25 %, 50 %, 75 % and 100 % of rated speed.

Make an oscillographic record of the pulsation pattern. The values of pressure pulsations shall not exceed the limits specified in 3.14.

5.10 Heat rejection test

5.10.1 Principle

The principle of this test is to measure the rate of heat rejection of the pump over the expected normal range of operating conditions. The rate of heat rejection at specified conditions shall be considered to be equal to the difference between the input and output power of the pump in those conditions. Output power may be calculated on the basis of flow measurements in the low-pressure side of the discharge line, provided that adequate compensation is made for fluid compressibility when calculating output power.

5.10.2 Determination of heat rejection

In order to determine the rate of heat rejection, run the pump at rated speed and rated inlet temperature and measure the input and output power at rated discharge pressure, maximum full-flow pressure and at least two additional flow points between those values. Should it be necessary to determine the rate of heat rejection at operating conditions other than these, the additional requirements shall be defined in the detail specification. The maximum acceptable value of heat rejection rate, in kilowatts, at specified operating conditions shall be specified in the detail specification.

5.11 Vibration tests

See ISO 7137.

5.11.1 Mounting of the test pump

Mount the test pump successively on a vibration-generating mechanism in each of at least three positions. Carry out all of the testing specified in each of the mounting positions. One of these mounting positions shall be chosen so that the direction of vibratory motion shall be parallel to the shaft axis of the pump. Another mounting position, if and when practicable, shall be chosen so that the direction of vibratory motion shall be parallel to the axis of the compensating mechanism.

If the pump is equipped with an electrical depressurization device, an additional mounting position shall be chosen so that the direction of vibratory motion shall be parallel to the electrical depressurization valve.

5.11.2 Pump operating during vibration tests

Throughout the vibration tests specified in 5.11.3, 5.11.4 and 5.11.5, the pump shall be operated in the test circuit given in 5.9.2.2. Fluid inlet temperature shall be maintained at 60 °C, regardless of the rated temperature of the pump being tested, and ambient temperatures shall be maintained at room ambient conditions. The pump discharge pressure shall fluctuate in continuous cycles from rated discharge pressure (zero flow) to a discharge pressure corresponding to approximately 50 % of rated delivery. These pressure cycles shall be abruptly accomplished by solenoid valves at a rate of 5 cycles per minute. Transition from one condition of flow to the other condition of flow shall be accomplished in a valve time of less than 0,5 s.

If the pump is equipped with a depressurization device, the cycles between the different modes shall be as required by the detail specification.

5.11.3 Resonant frequency vibration test

Search for resonant frequencies in accordance with the double amplitude and frequency charts in ISO 7137. Applicable procedures and test values shall be specified in the detail specification.

5.11.4 Cyclic frequency vibration test

On completion of the resonant frequency vibration test, apply a cycling vibration in accordance with ISO 7137. Applicable procedures and test values shall be specified in the detail specification.

5.11.5 Other vibration tests

The detail specification shall require other vibration tests to be performed if a particular installation imposes severe environmental conditions peculiar to its system requirements.

5.12 Low temperature test

The test circuit for the low temperature test shall be as specified in 5.9.2.2. All temperature requirements apply equally to the pump body, hydraulic fluid and ambient environment. After at least 18 h at the minimum inlet temperature specified in the detail specification [or at –55 °C $\left(^{+5}_{0}\right)$ °C, in the absence of such stipulation in the detail specification], start up the pump and uniformly accelerate to 50 % of rated speed in not more than 10 s, unless otherwise specified in the detail specification.

Carry out 20 runs with the outlet pressure at low as practicable and the inlet pressure as specified in the detail specification. Rated speed should be reached within 20 s after start-up. When rated speed has been reached, maintain it for at least 10 s; observations shall indicate whether the pump displaces fluid through the hydraulic system.

Then carry out five start-ups and runs, with the pump discharge line terminating in a relief valve set to pass fluid at maximum full-flow pressure. In addition, carry out five starts with the pump discharge line completely closed so that the pump will operate at rated discharge pressure.

Throughout the tests, after each run, allow the pump and fluid to stand idle long enough for them to be restored to the above soaking temperature before starting the next run.

If the pump includes a depressurization device that is used as an engine starting aid, activate the device during starts and deactivate it when the pump reaches 50 % of rated speed.

Throughout the tests, the test circuit shall contain a volume simulating operating conditions in the aircraft system or as specified in the detail specification.

5.13 Endurance testing

5.13.1 Test programme

See Table 2.

For pumps for type I and II systems, the sample pump shall undergo the following endurance tests:

a) Normal test

1 920 h for pumps of category A and 3 840 h for pumps of category B, consisting of the nine phases specified in Table 6 in the order listed, plus two calibrations, the start-stop cycles, filter checks and air ingestion cycles as specified in the following subclauses.

b) Overload test

80 h for pumps of category A and 160 h for pumps of category B consisting of the four phases specified in Table 7 in the order listed, plus two calibrations, the start-stop cycles, thermal cycles and thermal shock test.

The test circuit for the endurance tests shall be as specified in 5.9.2.2. Modification of any of the test conditions given in Tables 6 and 7, or additional endurance testing, in the form of additional cycles in any of the phases, may be required by specifying such modifications or additions in the detail specification.

For type III pumps, the schedule for normal and overload endurance testing shall be defined in the detail specification.

5.13.2 Filtration for normal endurance tests

Pass the hydraulic fluid to be charged into the endurance test system through a 5 µm absolute filter before entering the test system. Install filters of 15 µm absolute rating in the pump inlet, outlet, and case-drain or cooling port lines throughout the endurance test. For type III systems, the filters shall in general be suitable for the temperature specified in the detail specification.

5.13.3 Filter check

At intervals of (100 ± 20) h, during the endurance test, install clean filter elements in all three filters. Resume the endurance test schedule for 2 h at the end of which these filter elements shall be removed and replaced with clean filter elements. The filter elements removed after 2 h of operation shall be checked in accordance with 6.3.9.

5.13.4 Calibration

Before starting phase 1 of both the normal and overload endurance tests and also on completion of the full test schedule, calibrate the pump, using the procedure specified in 5.8, plot the results of these three calibrations on one chart to show the effect of the endurance test on the performance of the pump.

5.13.5 Start-stop cycles

Start-stop cycles shall be performed after the normal endurance test and after the overload endurance test. The system impedance of the test circuit shall be as specified in 5.9.2.2. Fluid temperatures may range from ambient to rated, but actual values shall be recorded.

For those cycles run following the overload test, the compensator shall be left adjusted at its maximum pressure.

5.13.5.1 Full-flow cycles

Unless otherwise specified in the detail specification, accelerate the pump to rated speed within 2 s, with the load orifice adjusted to 33 000 kPa. Allow the pump to coast to a stop immediately after reaching rated speed. Record the deceleration time.

Perform one full-load start-stop cycle for each 5 h of endurance testing performed.

Table 6 — Endurance testing — Normal test

Phase[a]	Percentage of the test[b]	Percentage of rated speed	Duration	Percentage of nominal inlet pressure	Drain port pressure	Cycle 1			Cycle 2			Cycle 3			Cycle 4			Cycle 5		
						Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration
	%	%	min			%	%	s	%		s	%		s	%		s	%		s
1	1,57	70	5	c		70						52,5			14			35		
2	3,12	70	10	100		70						52,5			14			35		
3	1,57	70	5	200		70						52,5			14			35		
4	3,12	100	10	c		100						75			20			50		
5	68,75	100	260	100	d	100	e	120	0	35 000 kPa	30	75	f	30	20	f	90	50	f	30
6	3,12	100	15	200		100						75			20			50		
7	3,12	115	5	c		110						82,5			22			55		
8	10,94	115	5	100		110						82,5			22			55		
9	4,69	115	5	200		110						82,5			22			55		

a Test temperature

For each range of 160 h or 30 series of the 9 phases above

1) If the rated temperature (see 3.7) is equal to 45 °C (type I systems), all phases shall be run at this temperature.

2) If the rated temperature is equal to 110 °C (type II systems),

— 6 series of 9 phases shall be run with inlet temperature equal to 70 °C;

— 14 series of 9 phases shall be run with inlet temperature equal to 90 °C;

— 10 series of 9 phase shall be run with inlet temperature equal to 110 °C.

3) If the rated temperature is equal to 170 °C (type III systems),

— 6 series of 9 phases shall be run with inlet temperature equal to 70 °C;

— 14 series of 9 phases shall be run with inlet temperature equal to 150 °C;

— 10 series of 9 phases shall be run with inlet temperature equal to 170 °C.

For type III systems, the full schedule for the normal endurance test shall be as specified in the detail specification.

b A time tolerance of ± 1 % is permissible on the duration of each phase. The total test duration shall be as specified in 5.13.1 as a minimum.

c The inlet pressure for this phase shall be equal to 100 kPa (1 bar) absolute, or to 1,1 times the absolute pressure at cavitation onset (defined in 5.14), whichever is the greater.

d The drain port pressure shall be as specified in the detail specification. It shall be set by means of a fixed restriction at maximum drain flow condition.

e The discharge pressure shall be equal to 95 % of maximum full-flow pressure.

f Pressure shall be adjusted to provide the flow stipulated.

Table 7 — Endurance testing — Over-pressure test

Phase[a]	Percentage of the test[b]	Percentage of rated speed	Duration	Percentage of nominal inlet pressure	Drain port pressure	Cycle 1			Cycle 2			Cycle 3			Cycle 4			Cycle 5		
						Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration	Flow as percentage of rated delivery	Discharge pressure	Duration
	%	%	min			%	%	s	%		s	%		s	%		s	%		s
1	40	100	240	100	c	100	d	120	75	e	30	50	e	30	20	e	90	0	41 000	30
2	10	100	60	200		100			75			50			20					
3	40	115[f]	240	100		115			84,5			55			22					
4	10	115[f]	60	200		115			84,5			55			22					

a Test temperature

For each range of 8 series of the 4 phases above

1) If the rated temperature (see 3.7) is equal to 45 °C (type I systems), all phases shall be run at this temperature.

2) If the rated temperature is equal to 110 °C (type II systems),

— 2 series shall be run with inlet temperature equal to 70 °C;

— 4 series shall be run with inlet temperature equal to 90 °C;

— 2 series shall be run with inlet temperature equal to 110 °C.

3) If the rated temperature is equal to 170 °C (type III systems),

— 2 series shall be run with inlet temperature equal to 70 °C;

— 4 series shall be run with inlet temperature equal to 150 °C;

— 2 series shall be run with inlet temperature equal to 170 °C.

For type III systems, the full schedule for the normal endurance test shall be as specified in the detail specification.

b A time tolerance of ± 1 % is permissible on the duration of each phase. The total test duration shall be as specified in 5.13.1 as a minimum.

c The drain port pressure shall be as specified in the detail specification. It shall be set by means of a fixed restriction at maximum drain flow condition.

d The discharge pressure shall be equal to 95 % of maximum full-flow pressure.

e Pressure shall be adjusted to provide the flow stipulated.

f The overspeed of phases 3 and 4 shall apply to all pumps the rated speed of which corresponds to the specifications in 3.10. If the rated speed indicated in the detail specification exceeds the values indicated here, deduct 20 % of the overspeed percentage for each 10 % of the pump's excess speed compared to the indications in 3.10; whatever the case, overspeed shall not be less than 110 % of rated speed for phases 3 and 4.