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Aerospace series — AC induction electric motor driven, variable delivery, hydraulic pumps — General requirements

Série aérospatiale — Pompes hydrauliques à débit variable, actionnées par des moteurs électriques à induction CA — Exigences générales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

Aerospace series — AC induction electric motor driven, variable delivery, hydraulic pumps — General requirements

1 Scope

This document establishes the general requirements for electric motor driven, variable delivery, hydraulic pumps suitable for use in aircraft hydraulic systems.

This document includes the general requirements for Alternating Current (AC) induction electric motor powered units. The AC power electrical power supply can be either controlled to provide a Constant Frequency (CF) or uncontrolled to provide a Variable Frequency (VF) AC supply to the electric motor.

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

ISO 3601-1:2012, *Fluid power systems — O-rings — Part 1: Inside diameters, cross-sections, tolerances and designation codes*

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

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

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

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

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

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

ISO 8278, *Aerospace series — Hydraulic, pressure compensated, variable delivery pumps — General requirements*

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 11218:1993, *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, and ISO 8625-3 and the following apply.

NOTE See ISO 8278 for terms and definitions that relate to the variable delivery hydraulic pump.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

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

3.1
electric motor driven variable delivery, hydraulic pump
EMP
hydraulic pump driven by an electric motor that is able to supply hydraulic power to the hydraulic system (or sub-system) to meet a variety of functions within the aircraft system

Note 1 to entry: Examples of these functions are listed below:

— as the primary power source for the hydraulic system to supply fluid as demanded by the system, either continuously operating or switched on for particular phases of the aircraft operation e.g. for take-off and landing;

— as a back-up source when the primary source has failed; and

— as a power source to be used when the aircraft is on the ground to operate various utility functions or for ground maintenance purposes.

Note 2 to entry: To operate the EMP, the electrical supply may be derived from various electrical sources, including the main engine driven generators, auxiliary power unit driven generators, or ground cart generators.

3.2
purchaser
organization that has the engineering responsibility for the hydraulic system that includes the pump

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

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

3.3
detail specification
document compiled by the purchaser that specifies:

— technical requirements;

— acceptance and qualification test requirements;

— reliability requirements;

— quality requirements;

— packaging requirements; and

— other requirements.

3.4
supplier
organization that provides the EMP

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

3.5 Ports of the hydraulic pump

3.5.1
pump inlet port
port that receives flow from the hydraulic reservoir to supply the pump

3.5.2
pump discharge port
port that supplies pressurised flow to the system

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

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

3.6 Temperature terms

3.6.1
rated temperature
maximum continuous temperature of the fluid to be supplied at the supply port of the pump

Note 1 to entry: The rated temperature is expressed in degrees centigrade.

3.6.2
minimum continuous temperature
minimum temperature of the fluid at the supply port of the pump at which the pump is able to function

Note 1 to entry: The minimum continuous temperature is expressed in degrees centigrade.

Note 2 to entry: This temperature is generally higher than the survival temperature.

3.7 Pressure terms

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:

— pressure ripple;

— reactions to system functioning; and

— demands that may affect fatigue.

3.7.2 Inlet pressure

3.7.2.1
rated inlet pressure
minimum pressure measured at the inlet port of the EMP at which the pump is required to provide performance without any degradation, with all other parameters at their rated values, except for the fluid temperature, which is the minimum continuous temperature

3.7.2.2
maximum inlet pressure
maximum steady state inlet pressure at which the EMP may be required to operate

3.7.2.3
minimum inlet pressure
lowest pump inlet port pressure, specified by the purchaser, for which the supplier ensures that the EMP might be required to operate without cavitation during a system failure or during a system high-flow transient condition

Note 1 to entry: For the purposes of this document, cavitation is assumed to occur when there is a 2 % reduction in discharge flow with reducing inlet pressure.

3.7.3
discharge pressure
maximum pressure against which the EMP is required to operate continuously at:

— rated supply voltage;

— rated supply frequency;

— rated fluid temperature;

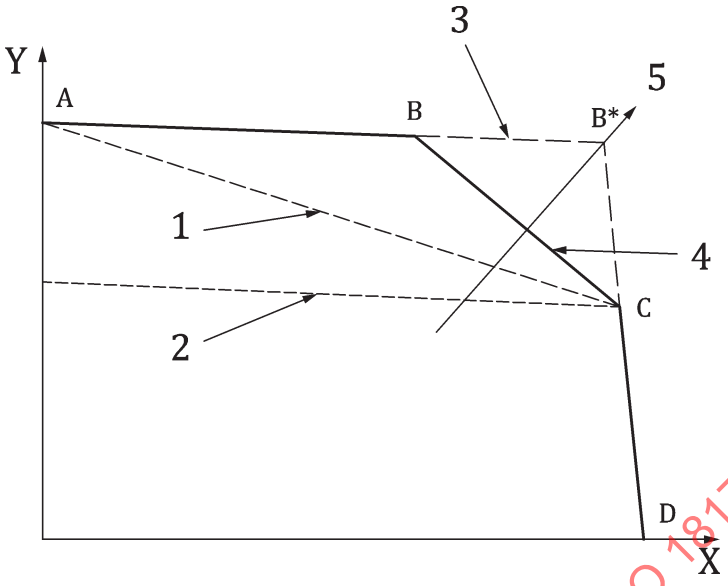
— rated inlet pressure;

— rated case drain pressure;

— zero flow; and

— using the hydraulic fluid specified in the detail specification.

Note 1 to entry: The diagram in Figure 1 is given as an indication. It may be presented in a different way, for example, the axes may be reversed.



Key

1	differential pressure type pump characteristics	A	rated pressure
2	constant pressure type pump characteristics	B	minimum flow at maximum pressure point
3	constant pressure type pump characteristics	B*	cut-off pressure for constant pressure pump
4	constant power type pump characteristics	C	full flow at minimum pressure point
5	increasing power and weight	D	maximum flow point
		X	flow in l/min
		Y	pressure in kPa

Figure 1 — Discharge pressure

3.7.3.1
maximum full-flow pressure
maximum discharge pressure at which the EMP pump control will not be acting to reduce pump discharge, at rated temperature, rated speed, rated inlet and case drain pressure

3.7.3.2
maximum EMP discharge transient pressure
peak value of the discharge pressure recorded during a discrete transient event (normally found whilst cycling from full-flow pressure to rated pressure (zero flow))

3.7.3.3
pressure pulsations
oscillations of the EMP pump discharge pressure, occurring during nominally steady operating conditions, at a frequency equal to the number of pistons times the drive shaft speed, or a multiple thereof

Note 1 to entry: The amplitude of the oscillations is the difference between the average minimum and the average maximum oscillations recorded during a one-second trace.

3.7.4 Case drain pressure

3.7.4.1
maximum case drain pressure
maximum continuous pressure developed by the EMP to enable case drain fluid to return to the reservoir

3.7.4.2
rated case drain pressure
nominal pressure at which the EMP case is required to operate continuously in the system

3.7.4.3
maximum transient case drain pressure
maximum pressure peak that can be imposed by the hydraulic system on the EMP case drain port

3.8
rated discharge flow
flow rate measured at the EMP delivery port under conditions of:

— rated supply voltage;

— rated supply frequency;

— rated fluid temperature;

— rated inlet pressure;

— rated case drain pressure;

— maximum full-flow pressure; and

— using the hydraulic fluid specified in the detail specification.

Note 1 to entry: The flow shall be measured in the compressed state.

3.9
rated displacement
maximum theoretical volume of fluid generated by one revolution of the EMP pump drive shaft at full stroke

Note 1 to entry: The rated displacement shall be calculated from the geometrical configuration of the pump, without allowing for the effects of:

— permissible manufacturing tolerances;

— distortions of the pump structure;

— the compressibility of the hydraulic fluid;

— internal leakage; and

— temperature.

Note 2 to entry: The rated displacement is used to indicate the size of the pump rather than its performance.

3.10
rated speed
maximum speed at which the EMP pump will operate at based on:

— maximum AC supply frequency;

— rated voltage.

Note 1 to entry: The rated speed is expressed as a number of revolutions of the pump drive shaft per minute.

3.11
response time
time interval between the moment when an increase (or decrease) of the EMP delivery pressure begins and the subsequent time when the delivery pressure reaches its first maximum (or minimum) value, when connected to a specified circuit

3.12
stability
freedom from persistent or quasi-persistent oscillation or "hunting" of the EMP (cyclic variations in pressure) at any frequency that can be traced to the delivery control mechanism, within stated limits in the detail specification

3.13 Electrical terms

3.13.1
nominal electric supply condition
nominal system voltage and frequency without consideration of any distribution drop or cable impedance

3.13.2
starting in-rush current
RMS value of the current ignoring any initial half cycle transient effects

3.13.3
voltage drop
reduction in voltage across a given wire length for each phase of an AC electrical supply

3.14
EMP overall efficiency
ratio of the EMP pump output fluid power to the EMP electric motor input electrical power when the EMP is operating at rated conditions or any other operating conditions if so specified in the detail specification. It is derived from the following formula:

$$\text{EMP overall effiency (\%)} = [(\Delta P_p \times Q_p)/(V \times I \cos \phi)] \times 100 \quad (1)$$

where

ΔP_p differential pressure between the EMP pump delivery and inlet ports (kPa);

Q_p EMP pump delivery flow (l/min);

V supply Voltage (volts) for AC volts the Root Mean Square (RMS) value shall be used;

I supply Current (amps) for AC current the Root Mean Square (RMS) value shall be used;

Φ phase angle between voltage and current

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

Note 2 to entry: For a three-phase AC supply, the power should be derived from the summation of the powers for each phase, i.e. $V_A I_A + V_B I_B + V_C I_C$ multiplied by the power factor ($\cos \phi$). For a balanced supply, the input power equates to ($3 \times V_A \times I_A \cos \phi$).

3.15
rated endurance
total number of hours and cycles of operation to be included in the endurance phase of its qualification testing

3.16
first article inspection
FAI
process that conducts:

— verifies that the parts of a component comply with the drawings;

— verifies that the manufacturing processes have been compiled and are adhered to;

— verifies that the assembly processes have been compiled and are adhered to; and

— verifies that the acceptance test of the component is in accordance with the test procedure, and that the results of the test are in agreement with the test requirements

4 General requirements

4.1 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.

4.2 Electrical system characteristics

The detail specification shall define the range of electrical supply characteristics for normal and abnormal operation. This shall include any of the normal faults such as power interruption. Any deviation from the nominal performance due to variations in the electrical supply shall be agreed between the supplier and the purchaser as early as possible in the design phase. The effect of the aircraft feeder cables shall be considered as part of the electrical supply.

4.3 Hydraulic system characteristics

The detail specification shall include the characteristics of the hydraulic system in which the EMP is to be used in order to assist in the integration of the EMP into the hydraulic system.

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

— normal operating temperature;

— rated temperature; and

— minimum continuous temperature.

4.4 Airworthiness requirements

The EMP shall comply with the applicable airworthiness requirements.

4.5 Qualification

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

5 Functional requirements

5.1 Functional requirements - electrical

5.1.1 AC power requirements

5.1.1.1 General

The power supply should be compliant with the specifications provided in ISO 1540. Any non-compliance should be defined in the detail specification.

5.1.1.2 Rated voltage

The detail specification shall define the rated voltage at the point of regulation (POR), taking into consideration all potential sources of power that will be applied to the EMP. The rated voltage shall be defined at the interface with the EMP, i.e. at the electrical connector. The rated voltage range shall be defined under normal operating conditions and the minimum shall be defined for start-up.

The rated voltage at the POR shall be defined and will typically be a nominal value of either 115 or 230 V AC per phase (single or three phases). The voltage drop between the POR and the electrical motor connector shall be defined in the detail specification to allow for reduction in voltage under all operating conditions. The voltage drop and the phase shift between the rated voltage and the current that is introduced between the POR and motor connector shall be defined in the detail specification. Alternatively, the feeder cable impedance should be defined in the detail specification.

The voltage drop in the return path should be taken into consideration when determining the power available to run the electric motor, particularly for those aircraft that are manufactured from composite materials.

5.1.1.3 Rated AC frequency

5.1.1.3.1 Constant AC frequency supply

The detail specification shall define the rated frequency taking into consideration all potential sources of power that will be applied to the EMP. Typically, a constant frequency supply will maintain the frequency within the range from 385 Hz to 415 Hz with a nominal value of 400 Hz. However, each application should specify the actual application range.

5.1.1.3.2 Variable AC frequency supply

The detail specification shall define the rated frequency taking into consideration all potential sources of power that will be applied to the EMP. The frequency range for engine driven generator derived power sources will be dependent on the engine speed range for each application; the ratio between the minimum and maximum frequencies may exceed 2:1. Typically, the frequency range lies between 360 Hz min to 800 Hz max.

5.1.1.4 Input current

5.1.1.4.1 Rated input current

The electrical current supplied to the motor in steady state when operating at nominal electrical supply conditions and in normal temperature conditions (+20 °C) shall be specified in the detail specification.

For VF systems, a specific frequency or frequency points should be specified.

The maximum electrical current supplied to the equipment in steady state at full output shall be specified in the detail specification at the minimum ambient and fluid operating temperatures.

The maximum electrical current at maximum ambient and fluid temperatures should also be specified; typically, these are 70 °C and 107 °C. A de-rated performance at extreme temperatures should be provided in the detail specification.

The power factor of the EMP shall be specified in the detail specification with the relevant operating conditions, for example, during the EMP start up and when running in steady state conditions at full power.

5.1.1.4.2 Starting (in-rush) current

The starting in-rush current of the EMP, whatever the voltage at the POR and considering the voltage drop between POR and EMP terminals shall be defined in the detail specification.

The starting in-rush current of the EMP should be provided for the extreme ambient and fluid temperatures in addition to the 20 °C condition.

The characteristics of the electrical protection devices, e.g. Remote Controlled Circuit Breaker (RCCB), shall be specified in the detail specification. The EMP shall comply with the electrical protection device characteristics to meet nominal running steady state within a time defined in the detail specification. Any protection device shall not trip under worst case combinations of conditions during start-up of the EMP.

The nominal rating of the protective device should generally exceed the maximum continuous ACMP current by at least 20 %.

5.1.2 Electromagnetic interference

The EMC/EMI requirements shall be specified in the detail specification. Where components are included in the unit to assist with EMC/EMI requirements, consideration shall be given to ensuring that there is sufficient rating/de-rating of the components to ensure their compatibility with the threat level.

5.1.3 Electrical bonding

5.1.3.1 General

The bonding requirements shall be specified in the detail specification. A bonding dedicated area shall be provided on the unit in order to make the connection to the aircraft structure.

A wired connection shall be provided between the EMP case housing and a pin in the electric connector (case bonding) for bench testing. This connection should not be made when the EMP is installed on the aircraft.

The bonding resistance between any point of the EMP and the dedicated bonding area and any point between the EMP case and the connector bonding pin shall be specified by the purchaser.

5.1.3.2 Insulation resistance

The minimum insulation resistance shall be specified in the detail specification. Typically, the insulation resistance shall be at least 100 MΩ measured with a voltage of 500 VDC between each circuit and the EMP case.

The dwell time for the test should be 1 min and the test should be carried out at room temperature (23 ± 5) °C.

5.1.3.3 Dielectric strength

The dielectric strength shall be specified in the detail specification. Typically, the electrical circuit of the electrical unit shall be capable of withstanding an insulation breakdown test without damage at a voltage of:

— [(2 × Phase Voltage) + 1 000 V];

— 1 500 VAC, 50 Hz for a system operating with a nominal supply voltage of 230 VAC per phase; and

— 1 250 VAC, 50 Hz for a system operating with a nominal supply voltage of 115 VAC per phase.

The test should be carried out at room temperature.

The ramp rate for application of these voltages should not exceed 500 V/s and the dwell time at the final voltage should be 1 min. The leakage current observed should be specified by the purchaser (values between 2 mA and 20 mA may be specified depending on size and other considerations).

Any subsequent tests should be carried out at 80 % of the stated voltage.

5.1.4 Protection requirements

5.1.4.1 Self-protection from electrical failures

The EMP motor shall be designed such that means are provided to prevent secondary failures occurring as a result of an internal electrical failure.

Typical examples are:

— limiting motor surface temperature to below 204 °C in the event of a locked rotor self-protection (i.e. is achieved when conducting the locked rotor test); and

— explosion proofness test and any other electrical failure mode tests as may be defined by the detail specification.

This may necessitate devices that can detect failure modes as defined in the detail specification and if the failure modes can result in a fire hazard, then means to isolate the EMP shall be provided. Such equipment shall be considered as a part of the EMP sub-system and shall be subjected to the same acceptance and qualification tests as defined within this document.

Consideration shall be given to the reliability of any safety features/protection to determine whether the EMP is required to protect itself (i.e. without the safety features present) in the event of such faults. The safety features may be part of the EMP itself or as part of a system. The level of inherent safety/protection in the EMP shall be agreed with the purchaser as early as possible in the design phase.

5.1.4.2 Thermal protection

The temperature of cables, pins, crimped connections, etc. shall remain below a safe limit under normal operating conditions. External surfaces shall be below 204 °C. Internal surfaces may be above this temperature if they are within the containment envelope of explosion proof motors.

Protection shall be provided such that when the motor is in the locked rotor condition and at voltage and the frequency (or frequency range) specified in the detail specification is applied continuously, the current of all three phases shall be limited to a specified value without causing a fire hazard. The protective system shall not be automatically reset and both the motor and the protector system are considered expended after one operation.

5.1.4.3 Short circuit protection

Unless stated otherwise in the detail specification, the EMP shall fully contain any arcs/sparks or flames and the external surfaces of the EMP shall not exceed 204 °C in the event of a short circuit occurring within the motor.

The fault current capability of the electrical system shall be stated in the detail specification.

5.1.5 Electric motor cooling methods

Cooling may be achieved by different methods including:

a) Indirect hydraulic fluid cooling whereby both the stator and rotor are cooled using the hydraulic fluid, but the fluid passes through a jacketed housing and through the shaft without coming in direct contact with the rotor or stator windings. This is a totally enclosed design.

b) Direct hydraulic fluid cooling whereby the rotor and stator are immersed in hydraulic fluid to provide the cooling. This is a totally enclosed design.

c) A combination of air and hydraulic fluid cooling whereby the air cools the stator utilizing an integrated fan to force the airflow on the outside of the stator housing and the hydraulic fluid cools the rotor via the shaft. This is a totally enclosed design.

The maximum heat rejection and the means of cooling the electric motor shall be agreed between the purchaser and the supplier.

5.2 Functional requirements — Hydraulic

5.2.1 Hydraulic fluid

The detail specification shall state the applicable hydraulic fluid.

5.2.2 EMP pump pressure

5.2.2.1 Rated discharge pressure

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 125 % of rated speed (pump only);

— within voltage and frequency range specified in the detail specification; and

— at rated inlet pressure.

The value of the rated discharge pressure shall be stated in the detail specification and shall be one of the following values of rated discharge pressure listed in Table 1 (derived from ISO 6771):

Table 1 — Rated discharge 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

The maximum and minimum tolerance of the rated discharge pressure shall be specified in the detail specification: The permissible tolerance range shall be doubled in each direction for fluid temperatures below 30 °C or pump speeds from 25 % to 50 % of rated speed.

5.2.2.2 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 will not be acting 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 — for a "constant power" pump characteristic; this is defined as point B (Figure 1).

5.2.2.3 Pressure pulsations

The detail specification shall state the electrical input frequency range over which the pulsation levels are to be defined.

The detail specification shall state the maximum permitted amplitude of the discharge pressure pulsations.

The amplitude of pressure pulsations shall be determined by the test procedure of 14.2.8.5.

5.2.3 Inlet pressure

5.2.3.1 General

The inlet pressure shall be measured at the inlet port of the EMP pump in a manner that indicates the static head.

5.2.3.2 Rated inlet pressure

The detail specification shall state the value of rated inlet pressure, which shall be in kPa (or psi) absolute.

5.2.3.3 Minimum inlet pressure

The detail specification shall state:

— the value of the minimum inlet pressure, which shall be in kPa (or psi) absolute, and whether it applies during a short-term high flow condition or during a steady state failure case;

— the associated minimum hydraulic fluid temperature; and

— any allowable performance degradation when the pump operation is at the minimum inlet pressure.

The purchaser shall specify the inlet conditions that will exist at the pump inlet including the provision of the circuit impedance for the pump inlet and discharge piping system and/or a complete physical description of the circuit. This is to enable the supplier to conduct a dynamic flow analysis to determine the pump operation at the minimum inlet pressure.

5.2.3.4 Maximum inlet pressure

The detail specification shall state the value of the maximum steady state inlet pressure, which shall be in kPa (or psi) absolute.

5.2.4 Case drain pressures

5.2.4.1 EMP pump rated case drain pressure

The detail specification shall state the value of the rated case drain pressure for the pump case, which shall be in kPa (or psi).

5.2.4.2 Maximum transient case drain pressure

The detail specification shall state the value, duration and frequency of occurrence of the maximum transient case drain pressure for the pump case, which shall be in kPa (or psi).

5.2.4.3 Maximum case drain pressure

The detail specification shall state the value of the maximum case drain pressure for the pump case, which shall be in kPa (or psi).

5.2.5 Flows

5.2.5.1 Pump discharge flow

5.2.5.1.1 Pump rated discharge flow

The detail specification shall state the value of the rated pump discharge flow, which shall be in l/min (or gpm). The minimum and maximum rated discharge flow; this is defined as points C and D (see Figure 1) shall be specified.

5.2.5.1.2 Zero pump delivery flow

If required by the application, the EMP shall be capable of running continuously at zero flow.

5.2.5.2 Pump case flow

The detail specification shall state that the EMP pump shall be capable of producing at least a minimum case drain flow to limit the differential temperature between the inlet port and the case drain port to a stated maximum value.

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

— rated discharge pressure (minimum attainable steady-state flow);

— rated temperature;

— any discharge flow demand between 5 % and 100 % of rated flow; and

— a given maximum differential pressure between case pressure and inlet pressure.

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

If the case drain flow is routed to a system heat exchanger, the detail specification shall state the minimum case flow.

5.2.5.3 Shaft seal leakage flow

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

a) New build:

— the pump filled with fluid, but un-pressurized;

— when subject to proof pressure at ambient temperature; and

— when the pump is supplying rated discharge flow.

b) Qualification testing:

— over the expanded test envelope;

— at the completion of the endurance test;

— when subject to proof pressure at rated temperature; and

— when subject to burst pressure at rated temperature.

5.2.5.4 External leakage

No leakage sufficient to form a drop from the pump case or from any case static seal shall be permitted. The dynamic shaft seal leakage shall not be considered as external leakage.

5.2.6 EMP pump characteristics

5.2.6.1 Displacement

The rated displacement shall be calculated from the nominal theoretical displacement of the pump, without allowing for the effects of:

— permissible manufacturing tolerances;

— distortions of the pump structure;

— the compressibility of the hydraulic fluid;

— internal leakage; and

— temperature.

The rated displacement is used to indicate the size of the pump rather than its performance.

5.2.6.2 Pressure versus flow characteristics

The detail specification shall define the pressure versus flow characteristics, examples of which are shown in Figure 1.

5.2.7 Rated speed

The rated speed is determined by the supplier to achieve rated flow demand. Consideration shall be given to the range of electrical supply in terms of AC frequency and voltage and pump torque requirements that would affect motor speed when determining the rated speed to achieve the rated flow requirement.

The speed is determined by the design of the electric motor (number of poles) and is related to the supply frequency by Formula (2).

$$N = 120 \times F / P \tag{2}$$

where

F frequency (Hz);

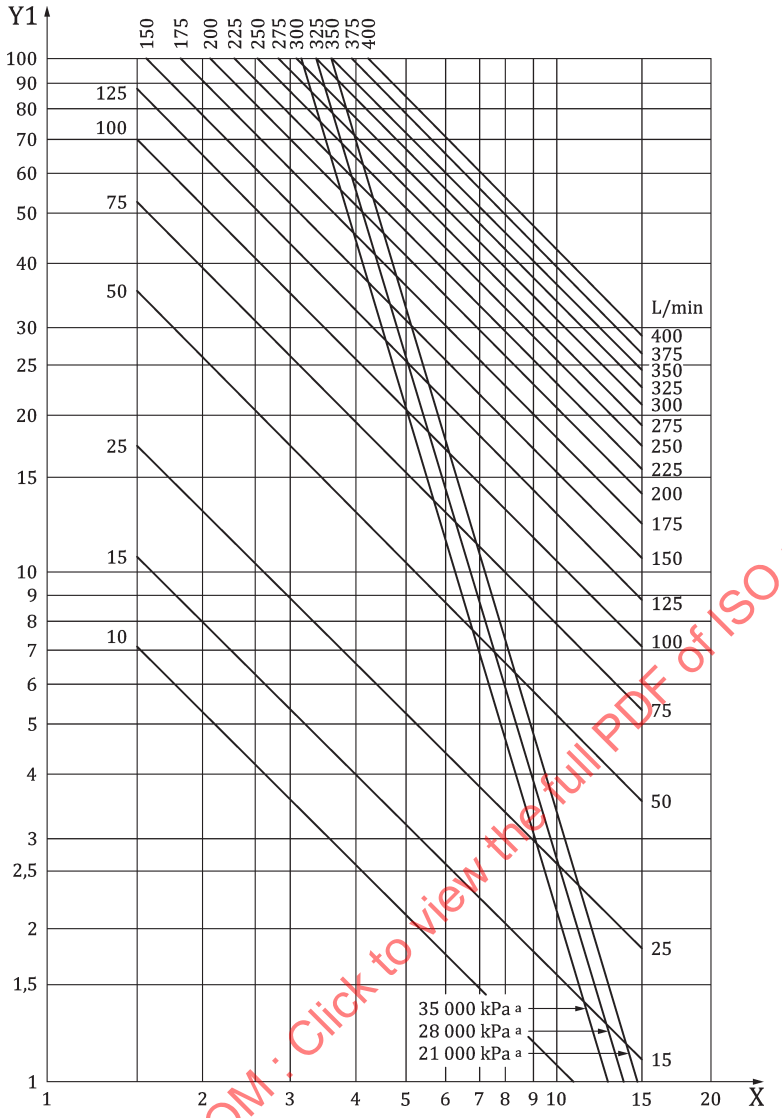
P number of poles;

N synchronous speed (rev per min).

This equation defines the synchronous speed; the actual speed has to take slip into consideration, which is defined as follows:

Slip (%) = [1 – (actual speed / synchronous speed)] × 100

NOTE As an indication, the maximum recommended speeds for the pump design are given in the nomographs in Figure 2 a) and b). If the speeds are kept well below those indicated by the curves, the operating life can be improved. However, several system factors such as case drain pressure, fluid temperature, duty cycle, fluid contamination, expected life, envelope, weight, etc. will also influence the operating life.



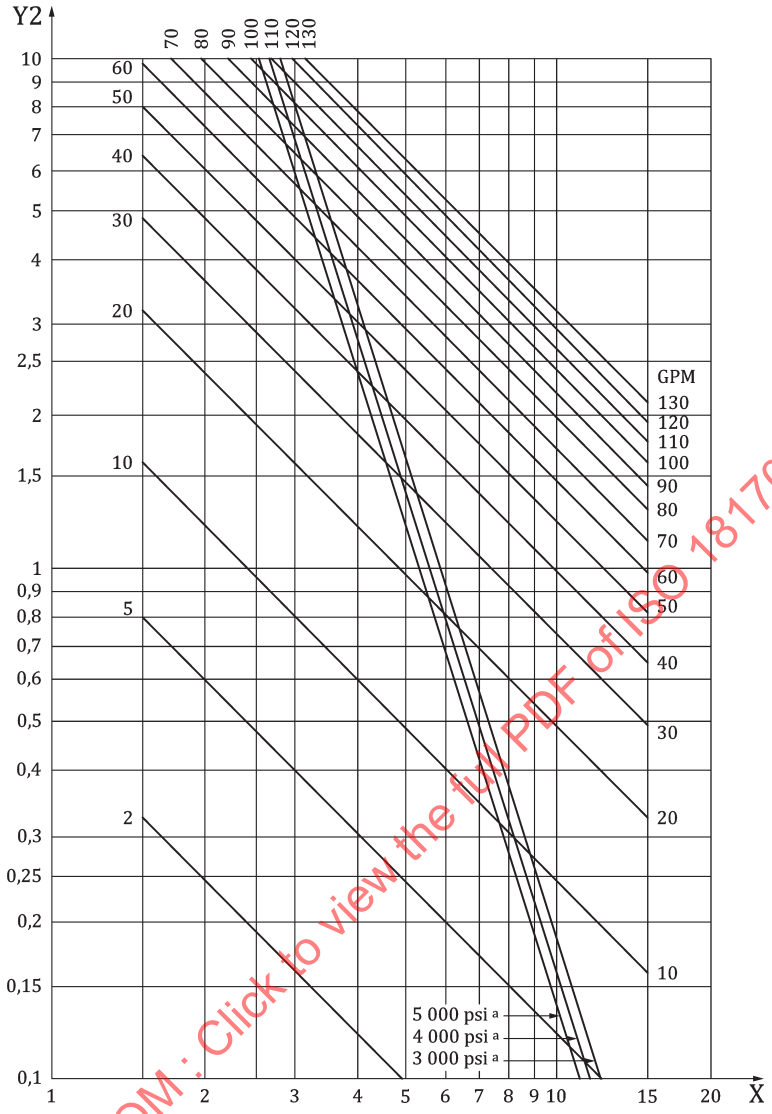
Key

X pump speed (RPM × 1 000)

Y maximum pump displacement in ml/REV

a Recommended maximum rated speeds.

a) Metric units



Key

X pump speed (RPM × 1 000)

Y maximum pump displacement in $inch^3$/REV

a Recommended maximum rated speeds.

b) Imperial units

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

5.2.8 Efficiency

5.2.8.1 General

The efficiency of the EMP is generally expressed as a percentage.

It should be determined at

— normal operating conditions; and

— extreme temperature and power supply conditions.

The latter efficiency requirements should take into account any de-rating factors for operating the EMP under these conditions.

5.2.8.2 Overall efficiency

The detail specification shall state the following efficiency values:

— the minimum overall efficiency of the EMP motor and pump when new; and

— the minimum overall efficiency of the EMP pump after endurance testing, this value being considered in objective.

When calculating the input and output power from the flow rate and pressure change, only the net differential pressure between the inlet and outlet ports of the pump shall be used. The flow rate may be measured downstream of a throttling valve that is used to control the delivery flow of the pump, provided that the efficiency calculations compensate for fluid compressibility.

5.2.9 Heat rejection

Heat rejection is determined by subtracting the power out from the power in. The supplier shall determine what proportion of the heat is rejected to the fluid at the conditions specified in the detail specification. Refer to 5.1.5 for a more detailed explanation of cooling the electric motor pumps.

5.2.10 Variable delivery control

5.2.10.1 General

The pump shall incorporate means to control the delivery which shall act to increase the delivery of the pump from zero to its maximum full-flow value for any given operating speed, as the discharge pressure is reduced from rated discharge pressure to maximum full-flow pressure and vice versa.

5.2.10.2 Adjustment

Means shall be provided to adjust the delivery control mechanism to cause zero flow to occur at rated delivery pressure. This adjustment shall, preferably, be continuous, but it may be in steps of less than 300 kPa (45 psi) of the rated delivery pressure over a minimum range from ±2 % of the rated delivery 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.

For variable speed motor pumps, the adjustment of the delivery control mechanism shall be made at the nominal speed and/or electrical supply conditions, unless otherwise specified in the detail specification.

For motor pumps that have a “constant” power or power limiter characteristic, there is no requirement to make this feature adjustable from the exterior of the unit.

5.2.10.3 Response time

The real-time plot of discharge pressure against time shall be used as the criterion of movement of the discharge control mechanism. All pumps shall have a maximum response time in accordance with the detail specification when changing the flow demand, unless otherwise specified in the detail specification when:

— operating at rated inlet temperature;

— at rated flow; and

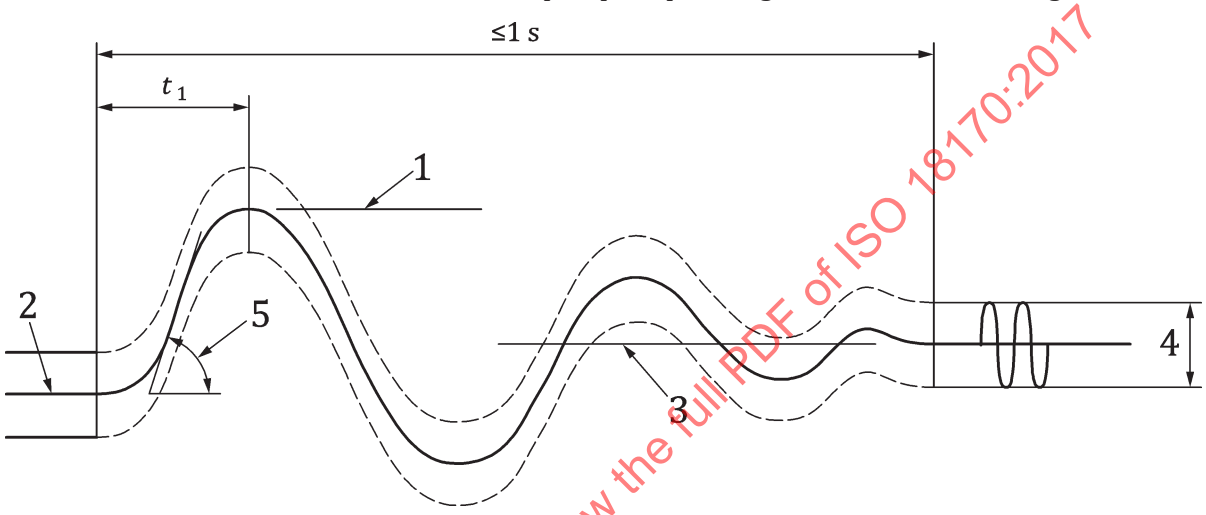
— in a circuit, with the system impedance defined in 14.2.8.2.2.

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 pump discharge pressure shall be stabilized within ±2 % of the rated discharge pressure after a decreasing flow transient (at the end of 1 s after the initiation of the transient flow demand).

The detail specification may state the minimum and maximum response time for the pump to decrease the flow from full-flow to zero (t_1), and a separate minimum and maximum response time for the pump to increase the flow from zero to full-flow (t_2).

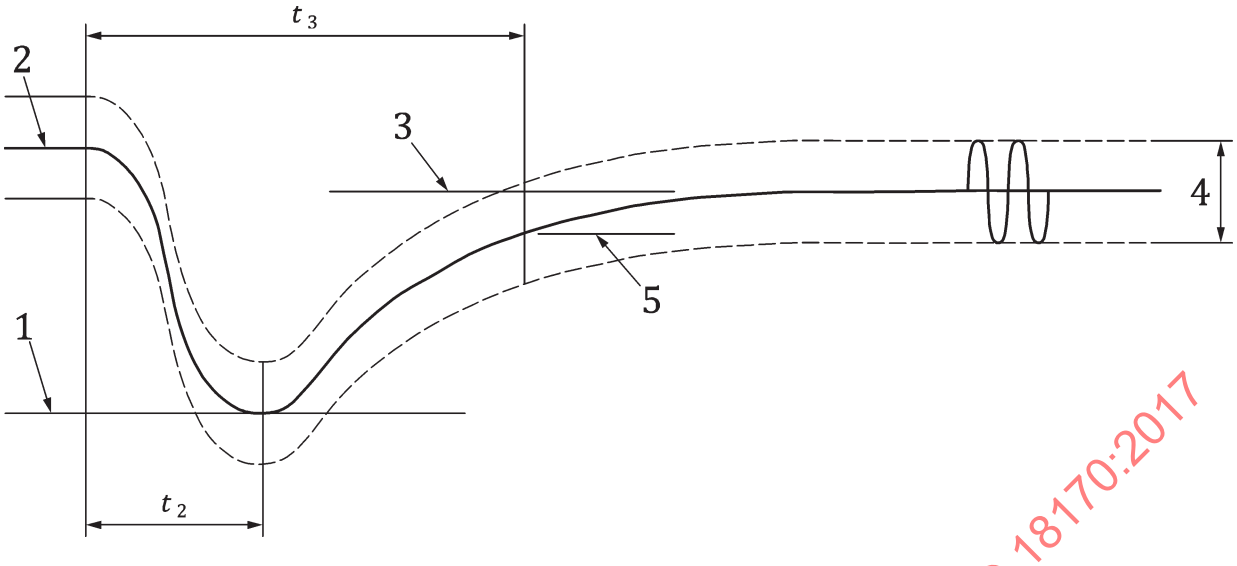
For EMP designs that incorporate a "constant" power control, or similar, the response time shall be performed from the maximum flow where the pump is operating in the "flat cut-off" region.



Key

1 maximum transient pressure (5.2.10.5)
2 maximum full-flow pressure (5.2.2.2)
3 rated discharge pressure (5.2.2.1)
4 allowable discharge pressure pulsations (5.2.2.3)
5 rate of pressure rise (dP/dT)

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



Key

1 minimum transient pressure (5.2.10.5)
2 rated discharge pressure (5.2.2.1)
3 maximum full-flow pressure (5.2.2.2)
4 allowable discharge pressure pulsations (5.2.2.3)
5 90 % maximum full-flow pressure (14.2.8.4)

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

5.2.10.4 Stability

The oscillographic trace of discharge pressure against time shall be used as the criterion of stability.

All EMPs shall recover steady-state operation (other than permissible pressure pulsations as specified in 5.2.2.3) within not more than 1 s after the initial response to that change in flow demand, under the following conditions:

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

— at any flow rate greater than 50 % of the rated discharge flow rate; and

— after a change in the flow demand.

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

5.2.10.5 Maximum transient pressure

The value of the maximum transient pressure, as determined by the transient pressure test specified in 14.2.8.3, shall not exceed:

— 7 000 kPa (1 000 psi), as determined in the transient pressure test, or

— 125 % of the rated discharge pressure, or

— the maximum pressure as specified in the detail specification.

The maximum transient pressure is dependent upon on the hydraulic system characteristics. The purchaser shall provide the circuit impedance for the pump outlet piping system and/or a complete

physical description of the circuit. This is to enable the supplier to conduct a dynamic flow analysis to determine the maximum transient pressure.

For EMP designs that incorporate a constant horsepower control, or similar, the maximum transient pressure test shall be performed from the full flow condition (lower pressure) and from the maximum flow where the pump is operating in the "flat cut-off" region.

5.2.11 Rated temperature

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

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

5.2.12 Dry running

The EMP shall be capable of meeting the ATP requirements after 10 min of continuous operation without inlet flow. The test shall be to operate the pump normally and close a valve on the inlet line. After 10 min, the valve shall be re-opened while the pump is still operating. During the test, the temperature on the exterior surface of the EMP shall not exceed 204 °C. Minor internal damage of the pump or motor is acceptable, e.g. discoloration of mating surfaces or insulation which would indicate operation at excessive temperatures. However, no repair shall be necessary to meet the ATP subsequent to a dry run test.

This requirement is to cater for a single event system failure. The EMP shall not be subjected to this event in normal operation in the aircraft system, even for short periods of time.

5.3 Functional requirements — EMP integrated assembly

5.3.1 Acoustic noise level

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

When conducting the acoustic noise test, the hydraulic test rig shall have the circuit impedance as specified in 14.2.8.2.3. To the extent possible, acoustic noise contributions from other hydraulic or structural members attached to or in the vicinity of the EMP shall be accounted for separately.

5.3.2 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 14.2.12.

5.4 Environmental requirements

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

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

b) Humidity (in accordance with ISO 7137);

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

d) Operational Shocks (in accordance with ISO 7137);

e) Vibration (in accordance with ISO 7137);

f) Acoustic vibration (in accordance with ISO 2671);

g) Steady-state acceleration (in accordance with ISO 2669);

h) Resistance to fungus and mould (in accordance with ISO 7137);

i) Salt spray (in accordance with ISO 7137);

j) Water resistance (in accordance with ISO 7137);

k) Sand and dust (in accordance with ISO 7137);

l) Shock (in accordance with ISO 7137);

m) Ice formation (in accordance with ISO 7137); and

n) Explosion proof (in accordance with ISO 7137).

6 Detailed design requirements

6.1 Dimensionally critical components

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

— they are likely to cause incorrect operation;

— they can cause damage if the installation direction is reversed; and

— they are incorrectly located on assembly.

6.2 Maintainability features

In addition to the requirements of 6.1, components that are not functionally interchangeable shall not be physically interchangeable.

All wear surfaces shall be replaceable or repairable.

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

The design shall permit the line replacement of the EMP or a module of the EMP 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.

6.3 Seals

Static and dynamic seals shall be in accordance with ISO 3601-1:2012, 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 pumps used in commercial aircraft and military type III systems, back-up rings used shall be subject to the approval of the purchaser.

6.4 Lubrication

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

6.5 Balance

The individual rotating parts of the EMP shall be inherently balanced about their own primary operating axis. The EMP 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 over-speed condition.

6.6 Self-contained failure

The EMP 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 EMP shall occur as a result of the failure, other than the external and shaft seal leakages specified in the detail specification.

6.7 Safety wire sealing

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

Lead-type safety wire sealing shall not be used.

6.8 Electro-conductive bonding

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

6.9 Marking

6.9.1 Nameplate

A nameplate shall be securely attached to the EMP. The information marked in the spaces provided shall be as recommended in the format given in Figure 5. Additional information may be required by the customer and shall be defined in the detail specification, for example, modification status.

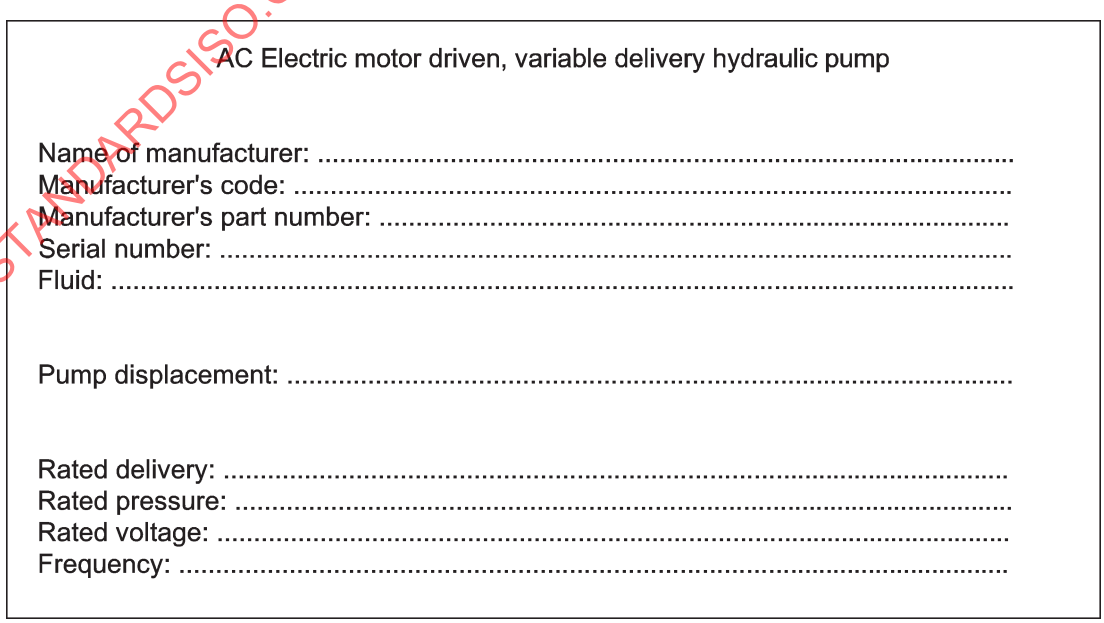


Figure 5 — Nameplate format

If the purchaser requires the nameplate to be readable when the equipment is installed, it is the purchaser's responsibility to indicate the required position of the nameplate as early as possible in the design phase.

6.9.2 Fluid identification

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

6.9.3 Ports

Each port, including the case drain port, and seal drain port shall be clearly and indelibly marked on each EMP.

6.9.4 Direction of rotation

The direction of rotation of the pump shall be clearly and permanently marked on an exposed surface of the EMP, on either the pump or motor housing.

6.9.5 Electrical connection details

Details of the pin connections shall be provided on the EMP adjacent to the electrical connectors to enable the EMP to be correctly connected to the aircraft and test benches, and to assist in troubleshooting

In addition, the electrical connection point shall state the phase identification.

7 Strength requirements

7.1 General

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

7.2 Electric motor

7.2.1 Motor case

7.2.1.1 Internal pressure due to cooling fluid

If the EMP uses the hydraulic system fluid as the cooling medium for the electrical motor, then the detail specification for the EMP shall state the design operating pressure for the motor case. The factors to be applied for the proof and ultimate pressures shall be as defined in 7.3.2 and 7.3.3, respectively. In addition, the pressure impulse requirements as detailed in 7.3.4 shall be considered for the motor case.

7.2.1.2 Mechanical strength

The motor case shall prevent the non-containment of any electric motor parts in the event of faults occurring such as the motor over speeding, which could cause the parts to fail.

7.3 Hydraulic pump requirements

7.3.1 Pressure loads

The detail specification for the EMP shall state the design operating pressure for the inlet, delivery and case drain parts of the EMP pump.

7.3.2 Proof pressure

7.3.2.1 General

During the proof pressure tests, the shaft seal leakage may exceed the maximum allowable leakage for normal operation. If this does occur, it shall not be considered as a test failure. If the shaft seal leakage exceeds the maximum allowable at the rated case pressure after the proof pressure test, then the test shall be considered to have failed.

7.3.2.2 Pump case

Unless the detail specification states a different value, the pump case shall statically withstand a pressure of at least equal to or greater than 3 500 kPa (500 psi), or 1,5 times the design operating pressure for the case (whichever is the greater) without permanent damage being done or performance being impaired.

7.3.2.3 Pump inlet port

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

7.3.2.4 Pump outlet supply port

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

7.3.3 Ultimate pressure

7.3.3.1 Pump case

Unless the detail specification states a different value, the pump case shall be designed to withstand a pressure of at least 5 000 kPa (750 psi) at the case drain port or 2,5 times the design operating pressure for the case (whichever is the greater) with no structural failure.

7.3.3.2 Pump inlet port

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

7.3.3.3 Pump discharge port

Unless the detail specification states a different value, the pump discharge port shall statically withstand a pressure equal to 2,5 times the design operating pressure for the pump discharge with no structural failure.

7.3.4 Pressure impulse (fatigue)

The EMP shall withstand the fatigue effects of all cyclic pressures, including transients and externally induced loads.

The detail specification shall state:

— the overall predicted duty cycle for the different parts of the EMP, throughout the lifetime of its application;

— the scatter factor that is to be applied for analysis or fatigue (pressure impulse) testing; and

— any externally induced loads (for example, structural or thermal).

In addition, when defining the duty cycle for the impulse testing, the following should be considered:

— the pressure variations due to the EMP pump pulsation levels; and

— the peak transient pressure generated by the EMP pump as it reacts to changes in flow demands.

7.3.5 Port strength

The structure of the ports and the relevant areas of the pump case shall be such that it withstands a torque 2,5 times the maximum torque resulting from attaching or removing the unions and lines on installation or removing EMPs during maintenance operations.

The detail specification shall state the maximum torque value.

No permanent distortions or alterations in the correct operation shall occur.

8 Construction

8.1 Materials

8.1.1 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 EMP 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.

The use of electrical wires insulated with PVC — polyvinyl chloride or polyamide material — is absolutely prohibited.

8.1.2 Metals

8.1.2.1 General

All metals shall be compatible with any fluids with which it will be in contact, with the service and storage temperatures, and functional requirements to which the components will be subjected. Those metals not in direct contact with the hydraulic fluid shall have the appropriate corrosion-resistant properties or they shall be suitably protected as specified in 8.2.

If the properties or operating safety of the pump 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.

8.1.2.2 Pumps for type I systems

Except for the internal surfaces in constant contact with the hydraulic fluid, ferrous alloys shall have a chromium mass fraction of at least 12 % or shall be suitably protected against corrosion as specified in 8.2.

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

Magnesium alloys shall not be used.

8.1.2.3 Pumps for type II and III systems and for commercial aircraft applications

Ferrous alloys used shall be suitably protected against corrosion as specified in 8.2.

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

Magnesium alloys shall not be used.

8.2 Corrosion protection

8.2.1 General

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

— dissimilar metal combinations;

— moisture;

— salt spray; and

— high temperature deterioration.

8.2.2 Ferrous and copper alloys

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

— electrolytic nickel plating;

— electrolytic silver plating;

— electrolytic tin plating, in accordance with ISO 2093; and

— electroless nickel plating.

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

Exceptions shall be submitted to the purchaser for approval.

8.2.3 Aluminium alloys

Unless otherwise authorized, all aluminium alloys shall be anodized in accordance with ISO 8078 and ISO 8079 except:

— in the absence of abrasive conditions, they may be coated with a chemical film in accordance with ISO 8081).

— aluminium alloys used as part of the motor rotor electrical circuits or the cages need not be anodized.

Other exceptions shall be submitted to the purchaser for approval.

8.3 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.

9 Installation requirements

9.1 Dimensions

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

9.2 Mass

9.2.1 General

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

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

9.2.2 Centre of mass

The position of the centre of mass (or centre of gravity) shall be dimensioned on the supplier's installation drawing.

9.3 Mounting

The detail specification shall state the means of mounting the EMP.

9.4 Orientation

The case drain port(s) of the EMP should be located at or near the top of the unit as it is installed in the aircraft. The shaft seal drain port should be located at or near the base of the EMP as it is installed in the aircraft.

The reorientation of the EMP due to aircraft attitude shall not affect EMP operation.

9.5 Hydraulic ports

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

9.6 Electrical connections

Refer to 6.9.5.

Means shall be provided to ensure that it is only possible to install the electrical connectors in the correct orientation such that the right pins are connected to the right wires.

In addition, means shall be provided to prevent moisture ingress into the electrical connectors.

The wiring and associated connectors for control/fault detection and shut down, etc. shall be independent of the wiring/connector that is used to power the electric motor.

10 Maintenance

10.1 Maintenance concept

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

10.2 Service life limitations and storage specifications

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

a) time between overhauls (if applicable);

b) storage life; and

c) service life limit.

11 Reliability

11.1 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.

11.2 Requirements

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

a) defect rate;

b) failure rate;

c) safety rate (if applicable); and

d) failure mode and effect analysis (FMEA).

12 Quality assurance provisions

12.1 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.

12.2 Classification of tests

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

a) acceptance tests (see Clause 13); and

b) qualification tests (see Clause 14).

12.3 Test stand requirements

12.3.1 General

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:

12.3.2 Hydraulic requirements

Inlet pressure:	±2 % of rated inlet pressure, but not more than ±35 kPa; (±5 psi).
Case pressure:	±2 % of rated case pressure, but not more than ±100 kPa; (±15 psi).
Discharge pressure:	±2 % of rated discharge pressure, but not more than ±200 kPa; (±30 psi).
Inlet fluid temperature:	−57 °C to +43 °C, within ±3 °C;
	+43 °C to +107 °C, within ±6 °C.
Flow:	within ±2 % of rated flow.

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 11218:1993, Class 5, or better, except for the qualification endurance testing (see 14.2.12).

The hydraulic fluid in the test circuit shall be the same as that specified for the application (see 5.2.1).

12.3.3 Electrical requirements

Motor Current:	±0.5 A.
Motor Line Voltage:	±0,6 VAC RMS.
Motor Line Frequency:	±1 Hz.
Digital Voltmeter:	±0,03 % + 2 digits.
Bonding Test Meter:	±2 % of reading + 5 digits.

13 Acceptance tests

13.1 General

Each EMP submitted for delivery under a procurement contract shall be subjected to the examinations and acceptance tests specified in this section. 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:

a) visual examinations; and

b) a test program to determine quality design and check whether the pumps conform to the performance requirements of this document.

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

13.2 Examination of the product

The EMP 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.

13.3 Test program

13.3.1 General

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

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

13.3.2 Electrical checks

13.3.2.1 Insulation resistance

Perform insulation resistance tests between the electrical terminals and the EMP case for at least 1 min each. All insulation resistances recorded shall be at least the value required in the procurement specification.

13.3.2.2 Dielectric strength

Perform dielectric tests between the electrical terminals and the EMP case by progressively raising the voltage, at a uniform rate of between 200 V and 375 V per second, to the required test value and maintaining the test voltage for at least 1 min. All leakage currents recorded shall be at least the value required in the procurement specification.

13.3.2.3 Electrical bonding

Record the resistance between the nominal aircraft bonding location and discrete parts of the EMP motor and pump housings. The resistances that are recorded shall not exceed the value required in the procurement specification.

13.3.3 Hydraulic checks

13.3.3.1 General leakage

No external leakage shall be permitted other than at the shaft seal.

13.3.3.2 Shaft seal leakage

During acceptance and calibration tests, static leakage shall not exceed two drops per minute at rated pressure conditions. Dynamic leakage shall not exceed four drops per minute during a 1 h period.

13.3.4 Break-in run

13.3.4.1 Break-in run — Fixed frequency electric motor

The break-in run may be conducted at any desired operating conditions as deemed appropriate by the supplier, but shall include at least 15 min of operation at rated speed and temperature while operating at maximum full-flow pressure.

13.3.4.2 Break-in run — Variable frequency electric motor

The break-in run may be conducted at any desired operating conditions as deemed appropriate by the supplier, but shall include at least 15 min of operation at rated speed and temperature while operating at maximum full-flow pressure. If the EMP has a variable frequency motor, run the EMP operating at five frequencies between the minimum and maximum values for 3 min at each frequency; for a fixed frequency electric motor, run the EMP at the nominal frequency.

13.3.5 Proof pressure test

This test may be conducted either statically or with the pump in operation. There shall be no evidence of permanent deformation following the test.

The test comprises:

a) pressurizing the discharge port at least 2 min to the proof pressure stated in the detail specification; and

b) pressurizing the case drain and inlet ports for at least 2 min to the proof pressures stated in the detail specification with the outlet port at rated pressure.

During this test, the shaft seal leakage may exceed the requirements as stated in 5.2.5.3. If this does occur, it shall not be considered as a test failure.

13.3.6 Load cycles

13.3.6.1 General

The case drain flow shall be monitored. There shall be no evidence of malfunction.

13.3.6.2 Load cycles — Fixed frequency electric motor

A step-function load shall be imposed, causing the EMP to cycle from rated flow to no flow to rated flow at 10 cycles/min for 5 min, with equal dwells at each load condition.

A step-function load shall be imposed, causing the pump to cycle from maximum delivery pressure at no flow to maximum flow at the minimum practical system backpressure at 10 cycles/min for 1 min.

There shall be no external leakage sufficient to form a drop, except that the shaft seal may leak at a rate not to exceed 5 cm^3/h. Case drain flow shall be monitored. There shall be no evidence of malfunction.

13.3.6.3 Load cycles — Variable frequency electric motor

Conduct the same test as specified in 13.3.6.2, but at three electrical frequencies, minimum, nominal and maximum specified.

13.3.7 Tear-down inspection

13.3.7.1 Sampling requirements

A teardown inspection shall be conducted on a minimum of 10 pumps 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:

— continuity of manufacturing is interrupted — permissible periods of production interruption shall be designated in the detail specification; and

— alternative tooling and production facilities are chosen.

13.3.7.2 Inspection procedure

After the break-in run and proof tests, dismantle and inspect the EMP. If all parts are in acceptable condition, re-assemble and run in the pump in accordance with 13.3.4.

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 13.3.4 may be omitted.

13.3.8 Run-in

The run-in after teardown inspection shall be performed for a period determined by the supplier with the discharge pressure varied between maximum full-flow pressure and rated discharge pressure at a frequency of 6 cycles/min.

13.3.9 Functional tests

Throughout the functional tests, the hydraulic fluid used shall be that specified in the detail specification. Rated inlet pressure shall be maintained within the tolerance specified in this document. The inlet temperature shall be at the rated condition.

The functional test shall comprise the following:

— running at rated speed and maximum full-flow pressure;

— running at rated speed with discharge pressure varied between maximum full-flow pressure and rated discharge pressure at a frequency of 6 cycles/min; and

— running at rated speed and rated discharge pressure; except that at 10 min intervals the discharge pressure shall be reduced to maximum full-flow pressure for 1 min.

The following shall be agreed between the supplier and the purchaser:

— the time spent at each of these conditions; and

— the electrical supply characteristics.

13.3.10 Pressure control test

The rated discharge pressure shall remain within the limits specified in the detail specification, with no indication of pressure control instability, as motor voltage and frequency are varied within the limits specified in the detail specification.

The hysteresis characteristics of the pressure control from zero to rated flow at rated speed shall not exceed the value as specified in the detail specification.

The detail specification shall define the system conditions.

13.3.11 Calibration

13.3.11.1 General

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

a) rated discharge pressure;

b) rated inlet pressure;

c) case pressure of 140 kPa (20 psi) above inlet pressure, or as specified in the detail specification;

d) case drain port flow;

e) rated inlet temperature, or as specified in the detail specification;

f) electrical frequency; and

g) electrical current and power.

The electrical voltage at the electric motor connections shall comply with the limits specified in 12.3.3, unless otherwise stated in the detail specification.

The electrical frequency (minimum, nominal and maximum values) shall be used for calibration for a variable frequency supply. If the EMP supply is at a constant frequency, then conduct these tests at the nominal frequency. The supply frequency shall comply with the limits specified in 12.3.3, unless otherwise stated in the detail specification.

The electrical current shall be measured for the in-rush and the steady state conditions at 20 °C. Any difference between the highest and lowest phase current at each test point shall be agreed between the purchaser and the supplier.

Determine the power factor during the in-rush and the steady state conditions using a power analyser.

The delivery of the pump at the rated speed, rated maximum full-flow pressure, and at the rated inlet pressure shall be measured and recorded.

The measured values for case drain flow and delivery shall be within the limits specified in the detail specification. Flow may be measured in the low pressure side of the discharge line, provided adequate compensation is made for compressibility in stating the delivery

13.3.11.2 Pump pressure settings

Regulate the pump inlet port pressure to the rated inlet pressure.

13.3.11.3 Flow rate

Determine the values of the pump delivery flow rate, the input current (in-rush and steady state) and the corresponding power factor with the electrical supply set to:

a) 90 %;

b) 100 %;

c) 110 % of rated voltage.

If the EMP supply is at a constant frequency, the test shall be conducted with the electrical frequency set to the nominal value specified in the detail specification.

If the EMP supply is at a variable frequency, the test shall be conducted with the electrical frequency set to the minimum, nominal and maximum values as specified in the detail specification.

At each of these voltage and frequency settings, determine the pump outlet flow, the input current (in-rush and steady state) and the corresponding power factor with the pump delivery pressure set to:

— 25 % of pump rated pressure;

— 50 % of pump rated pressure;

— 75 % of pump rated pressure; and

— 100 % of pump rated pressure.

13.3.12 Efficiency check

From the test data, check that the overall efficiency complies with those required in the detail specification.

13.3.13 Wear test

13.3.13.1 General

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

13.3.13.2 Inline particle counters

Inline particle counters should be used to check for an incipient pump failure by continuously monitoring the particle sizes. The EMP 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.

13.3.13.3 Filter patch test

13.3.13.3.1 General

If inline particle counters are not available, then the use of filter patches to check for an incipient pump 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 EMPs.

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.

13.3.13.3.2 Filter sampling method

Install filters in the outlet and case drain or cooling port lines of the test set-up. Check the fluid in the filter bowls by the procedure specified in 13.3.13.3.3 and 13.3.13.3.4 for contamination accumulated during the functional test performed in accordance with 13.3.9.

13.3.13.3.3 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, which will trap contaminants 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.

13.3.13.3.4 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 contaminants than the standard patch to be acceptable. If it does not, up to two additional patch tests may be run to establish the trend. If the patches remain unacceptable, the pump should be disassembled to determine the source of the contamination and corrective action taken.

13.3.14 Electro-conductive bonding

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

13.3.15 Storage and packaging

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

The packaging used for the shipment of the EMP shall consider the normal handling damage that may occur during transportation. Care shall be taken to avoid damage to connectors, electrical conduits, 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 EMP relies on the hydraulic fluid internal to the unit for corrosion protection, then the hydraulic plugs shall form a leak-free seal.

14 Qualification tests

14.1 Purpose

Qualification tests, with the purpose of checking whether the EMP design is in conformity with the requirements of this document, shall consist of the tests specified in 14.2.3.

14.2 Qualification procedure

14.2.1 Qualification by analogy

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

a) the EMP incorporates the same or similar working parts as another EMP that has already been qualified by a controlling authority; and

b) the operating conditions are not more restrictive than those for which the other EMP has already been qualified.

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

14.2.2 EMP 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 EMPs tested comply with the specifications 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. Assembly drawings and installation drawings shall be appended to the test report.

14.2.3 Samples and program of qualification tests

Qualification tests shall be conducted on three sample EMPs (Specimens A, B and C), or as agreed between the supplier and the purchaser. It is essential that these qualification standard EMPs be fully representative of the EMPs to be manufactured.

The qualification tests, to be carried out in the suggested order, are listed in Table 2.

Table 2 — List and sequence of qualification tests

Tests	Specimen			Corresponding subclause
	A	B	C	
Dimensional check	X	X	X	14.2.4
Expanded envelope acceptance	X	X	X	14.2.5
Proof pressure and load cycles	X	X	X	14.2.6
Calibration	X	X	X	14.2.7
Maximum transient pressure		X		14.2.8.3
Determination of response time		X		14.2.8.4
Pressure pulsation		X		14.2.8.5
Heat rejection		X		14.2.9.2
Loss of cooling		X		14.2.10
Electrical		X		14.2.11
Endurance	X			14.2.12
Air ingestion		X		14.2.12.10
Thermal cycles	X			14.2.12.11
Thermal shock	X			14.2.12.12
Minimum inlet pressure		X		14.2.13

[a] An additional test specimen shall be used if a fire resistance test is required.

[b] The low temperature test can be conducted during the endurance tests.

Table 2 *(continued)*

Tests	Specimen			Corresponding subclause
	A	B	C	
Dry run	X	X		14.2.14
Environmental [a]	X			14.2.15
Extreme operating temperature [b]		X		14.2.15.2
Vibration		X		14.2.16.1
Fatigue (pressure impulse)			X	14.2.16.2
Port strength		X		14.2.16.3
Proof pressure at rated temperature		X		14.2.16.4
Ultimate pressure		X		14.2.16.5
Explosion proof	X			14.2.17
Short circuit			X	14.2.18
Drive coupling shear			X	14.2.19
Additional tests	As agreed between purchaser and supplier			Detail specification

[a] An additional test specimen shall be used if a fire resistance test is required.

[b] The low temperature test can be conducted during the endurance tests.

14.2.4 Dimensional check

Prior to the start of the qualification test, conduct the full acceptance test of all test sample EMPs. The run-in specified in 13.3.8 may be carried out, if necessary, after the reset and before the test sequence is continued.

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

14.2.5 Expanded envelope acceptance tests

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

— the fluid temperatures from minimum continuous to rated; and

— flows from zero to rated discharge.

No malfunctions shall be recorded.

14.2.6 Proof pressure and load cycle tests

Carry out the proof pressure test as outlined in 13.3.5 for acceptance tests. After the completion of the proof pressure tests, restore the pump delivery mechanism to its normal adjustment of configuration.

Carry out the load cycle tests as outlined in 13.3.6, except that the tests shall be repeated 10 times.

14.2.7 Calibration

14.2.7.1 Pump inlet pressurized

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

14.2.7.2 Pump flow rate and pressure values

This test should be conducted with the voltage set to the minimum, nominal and maximum values as specified in the detail specification.

If the EMP electrical supply is a variable frequency type, the test shall be conducted with the electrical frequency set to the minimum, nominal and maximum values as specified in the detail specification.

Determine the values of EMP pump flow rate at 5 %, 10 %, 25 %, 50 %, 75 %, and 100 % of rated pump flow rate. At each of these flow rates, record the pressure at the pump outlet port and the electrical supply characteristics, voltage, current, frequency.

Calculate the overall efficiency.

Unless otherwise specified in the detail specification, perform calibrations at the inlet condition specified in 5.2.3.2 and the flow measurements may be made in the line downstream of the load valve, but shall be corrected for fluid compressibility.

14.2.8 Maximum pressure and response time tests

14.2.8.1 General

Pressure transducers and recording equipment shall be used to provide a permanent record of the dynamic pressure/time history of the pressure/time function of the EMP and its hydraulic circuit throughout the transient and steady-state periods described in the following two tests.

The pressure transducers and recording equipment shall be capable of meeting the repeated accuracy requirements as stated in 12.3 over a frequency range of 0 times to 5 times the EMP pump piston fundamental frequency. An essential consideration is that the dynamic calibration of the pick-up and recording equipment is valid for the dynamic conditions. The pressure transducers shall be located in the EMP discharge line as close to the pump outlet fitting as is physically possible. The pressure pulsations shall be measured with a pressure transducer with a minimum additional volume, and shall have a frequency range from 20 Hz to 100 kHz.

Tests shall be conducted at the rated conditions, unless otherwise noted below or in the detail specification.

14.2.8.2 System impedance

14.2.8.2.1 General

The impedance is calculated from the system configuration, the pump rated delivery and the fluid bulk modulus at rated temperature and rated discharge pressure.

14.2.8.2.2 System impedance for determination of response time

The system impedance of the test circuit when determining the EMP response shall meet the following requirements:

— the pump is operating over the specified flow range, and at rated inlet temperature; and

— the rate of EMP pump discharge pressure rise when the flow in the system is suddenly stopped shall be 350 000 kPa/s (50 000 psi/s) minimum.

The EMP pump discharge pressure rise rate is defined as the average value of the slope of dP/dT during the initial pressure transient increase, prior to the peak value (see Figure 3).

14.2.8.2.3 System impedance for all other tests

The detail specification shall provide sufficient characteristics of the aircraft hydraulic system to enable a representative test circuit to be achieved when determining maximum pressure, pressure pulsations, stability and the remaining qualification tests. The system volume may be simulated using tubing of the discharge line diameter, while being careful to avoid a line length whose natural frequency is resonant with pulsation frequency.

The high-pressure circuit shall be representative of the EMP pump application.

The system impedance can get very small due to circuit isolation or degraded modes. If it is considered to be appropriate, the test circuit shall replicate the different system impedances to check for potential pump instability.

14.2.8.3 Maximum transient pressure test

The test circuit specified in 14.2.8.2.3 shall be used. For this test, all gases shall be evacuated from the EMP inlet and discharge lines. 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 EMP between steady-state maximum full-flow pressure and steady-state rated discharge pressure and make an oscillographic record of the pressure/time function through the transient period. Run the test at 50 %, 60 %, 70 %, 80 %, 90 % and 100 % of rated EMP flow. Keep the air entrainment in the hydraulic fluid to a minimum. The peak pressure transient as measured on the above record shall not exceed the requirements of 5.2.10.5, at rated fluid temperature.

14.2.8.4 Determination of response time

This test shall be conducted at the rated fluid temperature. The test set up shall be as follows:

— the test circuit specified in 14.2.8.2.2; and

— load valves set at a flow condition equivalent to maximum full-flow pressure at each of the test speeds.

Use the solenoid valve that 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 flow, 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 0,05 s at 100 % of rated flow. 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 flow. 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 90 % maximum 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:

— 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 specification;

— 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;

— 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; and

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

14.2.8.5 Pressure pulsation test

Equip the test circuit specified in 14.2.8.2.3 with a pressure transducer of zero volume and sensitive to 20 kHz to 100 kHz, installed in the pump delivery line.

During this test, the following conditions shall be maintained:

— the pump at rated discharge pressure;

— pump inlet pressure to be at the rated inlet pressure;

— pump case pressure to be at the nominal case pressure; and

— fluid temperature to be 50 °C ± 10 °C.

Run the EMP to deliver 25 % of rated flow. Make an oscillographic record of the pulsation pattern. Repeat the test with the pump supplying 50 %, 75 % and 100 % of rated flow. The values of pressure pulsations shall not exceed the limits specified in 5.2.2.3.

14.2.9 Heat rejection test

14.2.9.1 Principle

The principle of this test is to demonstrate the ability of the EMP to reject the heat that it generates. When the pump is running at the rated fluid temperature, the fluid temperature in the EMP case drain ports should not exceed a specified maximum temperature.

14.2.9.2 Determination of heat rejection

Run the EMP at zero pump discharge flow rate and with rated inlet temperature. Measure the pump inlet and pump case drain temperatures when the temperatures have stabilized. Repeat the test with the EMP running at rated flow and at least two additional flow points between these values.

Check that the fluid temperatures in the EMP case drain port does not exceed the specified maximum temperatures.

14.2.10 Loss of cooling

This is applicable to EMPs that use air as the cooling medium.

Run the EMP with the ambient air and hydraulic fluid at their maximum operating temperatures. With the pump supplying fluid with a duty cycle that is application representative, block off the EMP cooling air supply.

Continue to operate the EMP until the electric motor body temperature has stabilized. If the EMP has not been fitted with any thermal cutout devices/measures, check that unit surface temperature does not exceed 204 °C. If the EMP has been fitted with thermal cutout devices/measures, these should be seen to take effect and shut down the EMP before the housing temperature exceeds 204 °C.

14.2.11 Electrical tests

14.2.11.1 Magnetic effect

The EMP shall be subjected to an electromagnetic interference test in accordance with ISO 7137 or equivalent, as applicable if the EMP includes components that could potentially have a magnetic interference effect.

14.2.11.2 Power input tests

The EMP shall be subjected to the applicable AC electric power input tests in accordance with ISO 7137 or equivalent.

14.2.11.3 Voltage spike test

The EMP shall be subjected to the AC electric voltage spike test in accordance with ISO 7137 or equivalent.

14.2.11.4 Audio frequency conducted susceptibility – power inputs test

The EMP shall be subjected to the AC electrical audio frequency conducted susceptibility test in accordance with ISO 7137 or equivalent.

14.2.11.5 Induced signal susceptibility

The EMP shall be subjected to the AC electrical induced signal susceptibility test in accordance with ISO 7137 or equivalent.

14.2.11.6 Radio frequency susceptibility (radiated and conducted) test

The EMP shall be subjected to a radio frequency susceptibility (radiated and conducted) test in accordance with ISO 7137 or equivalent.

14.2.11.7 Emission of radio frequency energy test

The EMP shall be subjected to a radio frequency energy test in accordance with ISO 7137 or equivalent, as applicable, if: the EMP includes components that have a radio frequency interference effect.

14.2.11.8 Lightning induced transient susceptibility

The EMP shall be subjected to the lightning induced transient susceptibility test in accordance with ISO 7137 or equivalent.

14.2.11.9 Insulation resistance and high voltage

The EMP shall be subjected to the insulation resistance and high voltage test in accordance with ISO 7137 or equivalent.

14.2.11.10 Lightning direct effects

If required by the purchaser, the EMP shall be subjected to the lightning direct effects test in accordance with ISO 7137 or equivalent.

14.2.12 Endurance test

14.2.12.1 General

The sample EMP shall undergo an accelerated endurance test, as outlined in Table 3.

The detail specification shall state any modification of any of the test conditions.

The EMP under test shall satisfactorily complete the test with no failure of parts or excessive wear.

The test circuit for the endurance tests shall be as specified in 14.2.8.2.3. Modification of any of the test conditions given in Table 3, 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.

14.2.12.2 Hydraulic fluid

The test system shall be filled at the start of the endurance test, and no fluid shall be added before the endurance tests are completed, except in the following cases:

a) the amount of fluid unavoidably lost from the system when filters are checked may be replaced;

b) in the event of damage to the test system away from the EMP, resulting in loss or contamination of the fluid not related to the endurance qualities of the EMP the system fluid may be completely replaced; and

c) in order to maintain the fluid within the physical and chemical property limits drawn up by the purchaser.

A record shall be made of when and how much fluid is added.

14.2.12.3 External leakage permissible during endurance testing

14.2.12.3.1 Case tightness

There shall be no external leakage throughout the endurance test (including the re-calibration time).

14.2.12.3.2 Shaft seal

The leakage shall not exceed one drop every 4 min when the EMP is stopped. The leakage shall not exceed eight drops per minute when the EMP is running.

14.2.12.4 Filtration for endurance tests

14.2.12.4.1 General

Pass the hydraulic fluid used for the endurance tests through a 5 µm absolute filter before entering the test system.

Unless the detail specification states the filter capability, install 15 µm absolute filters on the fluid inlet, outlet and drain lines during the endurance tests.

For the type III systems, the detail specification shall state the temperature that the filters shall be adapted to.