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Aerospace — Hydraulic power transfer units — General specifications

Aéronautique — Unités de transfert de puissance hydraulique — Spécifications générales

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Foreword

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ISO 22089 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

Introduction

Hydraulic power transfer units (PTUs) are designed to transfer hydraulic power, but not hydraulic fluid, between two independent hydraulic systems, or between hydraulic sub-systems.

This International Standard establishes the general requirements for PTUs, including:

— design requirements;

— test requirements.

Aerospace — Hydraulic power transfer units — General specifications

1 Scope

This International Standard establishes the general requirements for hydraulic Power Transfer Units (PTUs).

This International Standard covers uni-directional and bi-directional PTUs.

This International Standard is used in conjunction with the detail specification particular to each application.

2 Normative references

The following referenced documents are indispensable for the application 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, *Fluid power systems — O-rings — Part 1: Inside diameters, cross-sections, tolerances and designation codes*

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

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

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

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

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

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

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

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

ISO 11218, *Aerospace — Cleanliness classification for aeronautical 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.

3.1
Power Transfer Unit (PTU)
hydraulic device that is able to transfer hydraulic power between two independent hydraulic systems (or sub-systems) without transferring hydraulic fluid

NOTE The PTU generally consists of two rotating groups, housed separately and connected by a driveshaft. Hydraulic energy supplied to the hydraulic motor from one system drives the pump, providing hydraulic power to the other system.

3.2
uni-directional PTU
hydraulic pump that transfers hydraulic power between two independent hydraulic systems (or sub-systems), in one direction only, such that the pump and motor cannot reverse their functions

3.3
bi-directional PTU
hydraulic pump that transfers hydraulic power between two independent hydraulic systems (or sub-systems) in either direction

NOTE The PTU acts to provide hydraulic power to the system that is experiencing the greater power demand using hydraulic power from the other (lower demand) system. The pump and motor can reverse their functions such that the pump can function as a motor and vice-versa, depending on the direction of operation.

3.4
purchaser
organization that has the engineering responsibility for the hydraulic system that includes the PTU and who approves the supplier for the design, development and manufacture of aerospace PTUs

NOTE Typically, the purchaser is an aircraft manufacturer, an equipment manufacturer that has hydraulic system responsibility or a modification centre. The purchaser is responsible for the compilation of the detail specification.

3.5
detail specification
document that specifies the following:

a) technical requirements;

b) acceptance and qualification test requirements;

c) reliability requirements;

d) quality requirements;

e) packaging requirements;

f) other requirements.

3.6
supplier
manufacturer of the PTU, responsible for the design, production and qualification of the PTU

3.7
ports of the uni-directional PTU

3.7.1
pump case drain port
(if included) port that drains internal leakage flow to the reservoir

3.7.2
pump inlet port
port that receives flow from the hydraulic reservoir to supply the pump

3.7.3
pump discharge port
port that supplies pressurized flow to the system

3.7.4
motor case drain port
(if included) port that drains motor internal leakage flow to the reservoir

3.7.5
motor supply port
port that receives flow from the hydraulic system to power the motor

3.7.6
motor return port
port that returns flow to the reservoir

3.7.7
shaft seal port
port that routes any shaft seal leakage from the PTU to an overboard drain, collector tank, etc.

3.8
ports of the bi-directional PTU

3.8.1
case drain port
(if included) port that drains internal leakage flow to the reservoir

3.8.2
HP port
port that receives flow from the hydraulic system to power the motor, or supplies pressurized flow to the system

NOTE When the PTU half is acting as a pump, the HP port supplies pressurized flow to the system. When the PTU half is acting as a motor, the HP port receives flow from the hydraulic system.

3.8.3
LP port
port that returns flow to the reservoir or flow from the hydraulic reservoir to supply the pump

NOTE When the PTU half is acting as a pump, the LP port receives flow from the hydraulic reservoir. When the PTU half is acting as a motor, the LP port returns flow to the reservoir.

3.8.4
shaft seal port
port that routes any shaft seal leakage from the PTU to an overboard drain, collector tank, etc.

3.9
design operating pressure
normal maximum steady pressure

NOTE Excluded are reasonable tolerances, transient pressure effects such as may arise from:

— pressure ripple;

— reactions to system functioning;

— demands that may affect fatigue.

3.10
break-out pressure
minimum difference between the pump and motor differential pressures at which the PTU motor will start operating under conditions specified in the detail specification

NOTE Typically, the PTU will not act to provide power until a threshold breakout differential pressure between systems (or sub-systems) has been exceeded.

3.11
rated case-drain pressure
nominal pressure at which the PTU pump and motor cases are required to operate continuously in the system

3.12
maximum transient case pressure
maximum pressure peak that can be imposed by the hydraulic system on the pump or motor case drain port

3.13
maximum transient discharge pressure
pressure recorded during a discrete transient event [normally found whilst cycling from full-flow pressure to rated pressure (zero flow)]

3.14
maximum pump case drain pressure
maximum continuous pressure developed by the PTU pump to enable case drain fluid to return to the reservoir

3.15
maximum inlet pressure
maximum steady state inlet pressure at which the PTU pump might be required to operate during a system failure or during a system high-flow transient condition

3.16
minimum inlet pressure
lowest inlet pressure, specified by the purchaser, for which the supplier ensures that the PTU pump might be required to operate without cavitation during a system failure or during a system high-flow transient condition

NOTE For the purposes of this International Standard, cavitation is assumed to occur when there is a 2 % reduction in discharge flow with reducing inlet pressure.

3.17
rated inlet pressure
minimum pressure measured at the inlet port of the PTU pump at which the PTU is required to provide the performance without any degradation, with all the other parameters at their rated values, except for the fluid temperature, which is the minimum continuous temperature

3.18
maximum full-flow pressure for category C PTUs
maximum discharge pressure at which the pump control will not be acting to reduce pump delivery flow, at rated temperature, rated motor supply and return pressures, pump rated inlet and case drain pressure

NOTE Maximum full-flow pressure is not applicable to categories A and B PTUs.

3.19
rated discharge pressure for categories A and B PTUs
minimum discharge pressure that is met with rated motor differential pressure applied, at the minimum steady state discharge flow just prior to stall and with all other parameters at rated conditions

3.20
rated discharge pressure (or stall pressure) for category C PTUs
nominal pressure that the PTU pump is required to maintain at rated temperature, rated inlet pressure, rated case drain pressure and at zero discharge flow when the PTU is operated continuously with rated motor differential pressure

3.21
pressure pulsations
oscillations of the 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 The amplitude of the oscillations is the difference between the average minimum and the average maximum oscillations recorded during a one-second trace.

NOTE 2 This is a characteristic of the PTU and the system operating together, not solely a PTU characteristic.

3.22
rated motor return pressure
rated return pressure of the system that is supplying the PTU

3.23
rated motor supply pressure
rated pressure of the system that is supplying the PTU

3.24
maximum motor case drain pressure
pressure developed in the PTU motor when the maximum system return pressure is applied to the PTU motor case drain port

3.25
maximum motor supply transient pressure
peak value of the PTU motor supply pressure during the operation of the PTU

3.26
no-load break-out pressure
minimum motor differential pressure required to initiate and sustain rotation of the PTU at zero pump differential pressure with all pump ports at the rated inlet pressure

3.27
rated differential pressure
differential pressure, measured between the PTU motor supply and return ports, required to produce the PTU pump maximum full-flow pressure when the motor is at the rated supply pressure

3.28
stall pressure
minimum opposing differential pressure which stops the rotation of the PTU drive shaft, or reduces the speed to that required to maintain PTU internal leakage, with the pressure at the PTU motor supply port at its rated and the motor operating return and rated case drain pressures

NOTE Some PTUs have a built-in bypass flow (also known as an idle circuit) to ensure that the pump/motor never stops rotating when it is selected to run.

3.29
rated temperature
maximum continuous temperature of the fluid to be supplied at the supply port of the PTU motor and the inlet port of the PTU pump expressed in degrees centigrade

3.30
rated discharge flow
flow rate measured at the PTU pump discharge port under conditions of:

— rated temperature;

— rated motor supply flow rate;

— rated inlet pressure;

— rated case drain pressure;

— maximum full-flow pressure;

— using the hydraulic fluid specified in the detail specification

NOTE The flow is measured in the compressed state.

3.31
rated supply flow
flow rate measured at the PTU motor supply port under conditions of:

— rated temperature;

— rated pump discharge flow rate;

— motor operating differential pressure;

— rated case drain pressure;

— maximum full-flow pressure (category C PTU only);

— using the hydraulic fluid specified in the detail specification

NOTE The flow shall be measured in the expanded state.

3.32
rated displacement
maximum theoretical volume of fluid generated by one revolution of the PTU pump drive shaft and/or as the maximum theoretical volume of fluid consumed by one revolution of the PTU motor drive shaft expressed in millilitres per revolution

3.33
volumetric efficiency
ratio of the PTU pump output flow to the PTU motor input flow when the PTU is operating at rated conditions or any other operating conditions if so specified in the detail specification

NOTE It is derived from the following equation:

$$\text{PTU volumetric efficiency (\%)} = [(Q_p \times D_m)/(Q_m \times D_p)] \times 100$$

where

Q_p is the PTU pump discharge flow in litres per minute;

Q_m is the PTU motor supply flow in litres per minute;

D_p is the PTU pump rated displacement in millilitres per revolution;

D_m is the PTU motor rated displacement in millilitres per revolution.

3.34
overall efficiency
ratio of the PTU pump output fluid power to the PTU motor input fluid power when the PTU is operating at rated conditions or any other operating conditions if so specified in the detail specification

NOTE It is derived from the following equation:

$$\text{PTU overall efficiency (\%)} = [(\Delta P_p \times Q_p)/(\Delta P_m \times Q_m)] \times 100$$

where

ΔP_p is the differential pressure between the PTU pump discharge and inlet ports in kilopascals;

ΔP_m is the differential pressure between the PTU motor supply and return ports in kilopascals;

Q_p is the PTU pump discharge flow in litres per minute;

Q_m is the PTU motor supply flow in litres per minute.

3.35
maximum no-load speed
rotational speed reached by the PTU pump and motor with the motor operating at rated conditions (rated fluid temperature and motor supply flow) and with the PTU pump delivering fluid in a system that is unpressurized

3.36
rated speed
speed at which the PTU will operate continuously at the rated motor flow, at rated temperature and at rated motor differential pressure expressed as a number of revolutions of the PTU drive shaft per minute

3.37
response time
time interval between the moment when an increase (or decrease) of the PTU pump discharge pressure begins and the subsequent time when the discharge pressure reaches its first maximum (or minimum) value, when connected to a specified circuit

NOTE This is only applicable to category C PTUs, and the response time will be different if the PTU is operating continuously or intermittently.

3.38
stability
freedom from persistent or quasi-persistent oscillation or “hunting” of the PTU (cyclic variations in speed) at any frequency which can be traced to the discharge control mechanism, within stated limits in the detail specification

NOTE This is only applicable to category C PTUs, and does not apply to conditions of intermittent rotation.

3.39
first article inspection
process that conducts the following:

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

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

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

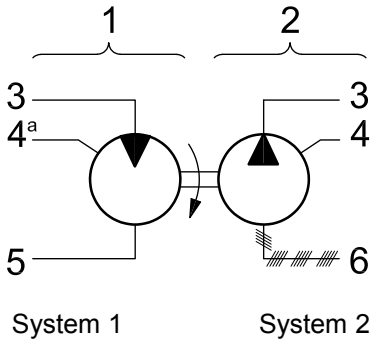
— verifies that the acceptance test of the component is in accordance with the test procedure, and that the results of the test are in agreement with the test requirements

3.40
rated endurance of the PTU
total number of hours and cycles of operation to be included in the endurance phase of its qualification testing

4 Classification

The Power Transfer Units covered by this International Standard are categorized as follows:

— Category A: uni-directional PTU that comprises a fixed displacement hydraulic motor driving a fixed displacement hydraulic pump, as shown in Figure 1.



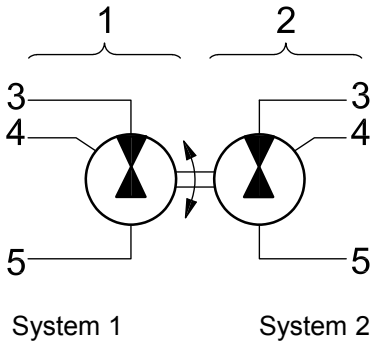
Key

1 system 1
2 system 2
3 pressure
4 case drain
5 return
6 inlet

[a] The case drain can be incorporated into the motor return.

Figure 1 — Uni-directional Power Transfer Unit

— Category B: bi-directional PTU that comprises a fixed displacement hydraulic motor/pump driving a fixed displacement hydraulic motor/pump, as shown in Figure 2.

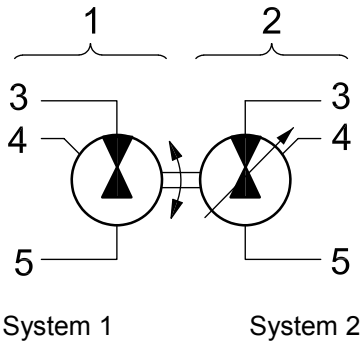


Key

1 system 1
2 system 2
3 pressure
4 case drain
5 return/inlet

Figure 2 — Bi-directional fixed displacement Power Transfer Unit

— Category C: bi-directional PTU that comprises a fixed displacement hydraulic motor/pump driving a variable displacement hydraulic motor/pump, as shown in Figure 3.



Key

1 system 1
2 system 2
3 pressure
4 case drain
5 return/inlet

Figure 3 — Bi-directional variable displacement Power Transfer Unit

The detail specification shall state the PTU category.

5 General requirements

5.1 General

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

5.2 Hydraulic system characteristics

The PTU shall be designed for installation in hydraulic systems as defined in the detail specification. This shall include the characteristics of the hydraulic system in which the PTU is to be used. This should include:

— the volume under pressure on each side of the PTU (category C PTUs only);

— acoustic resonance frequencies of the high pressure side of each system (or sub-system) (category C PTUs only);

— the pump inlet supply characteristics, including the location of the PTU relative to the reservoir;

— pressure drop-flow characteristics for the PTU motor supply and return pipelines over the operating temperature range;

— case drain routing details;

— details of PTU controllers, for example, the shut-off valve, flow control valve;

— the size and pre-charge of accumulators.

This is to enable the supplier to ensure that the PTU is correctly integrated into the hydraulic system by conducting a detailed dynamic analysis of the PTU operation.

5.3 Airworthiness requirements

The PTU shall comply with the applicable airworthiness requirements.

5.4 Qualification

PTUs furnished in accordance with this International Standard shall be products that have passed the qualification tests specified in the detail specification.

6 Functional requirements

6.1 Hydraulic fluid

The detail specification shall state the applicable hydraulic fluid.

6.2 PTU pump/motor displacement

6.2.1 Displacement

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

a) permissible manufacturing tolerances;

b) distortions of the motor/pump structure;

c) the compressibility of the hydraulic fluid;

d) internal leakage;

e) temperature.

The rated displacement is used to indicate the sizes of the motor and pump rather than their performance.

6.2.2 Overall pump/motor displacement relationship

A PTU can supply nominally equal pressure (albeit with a small reduction in pump outlet pressure and pump outlet flow) or supply a reduced flow to have equal system pressures for both the motor and pump sides of the PTU. The supplied flows and pressure from the PTU outlet shall account for the mechanical and volumetric losses from both sides of the PTU.

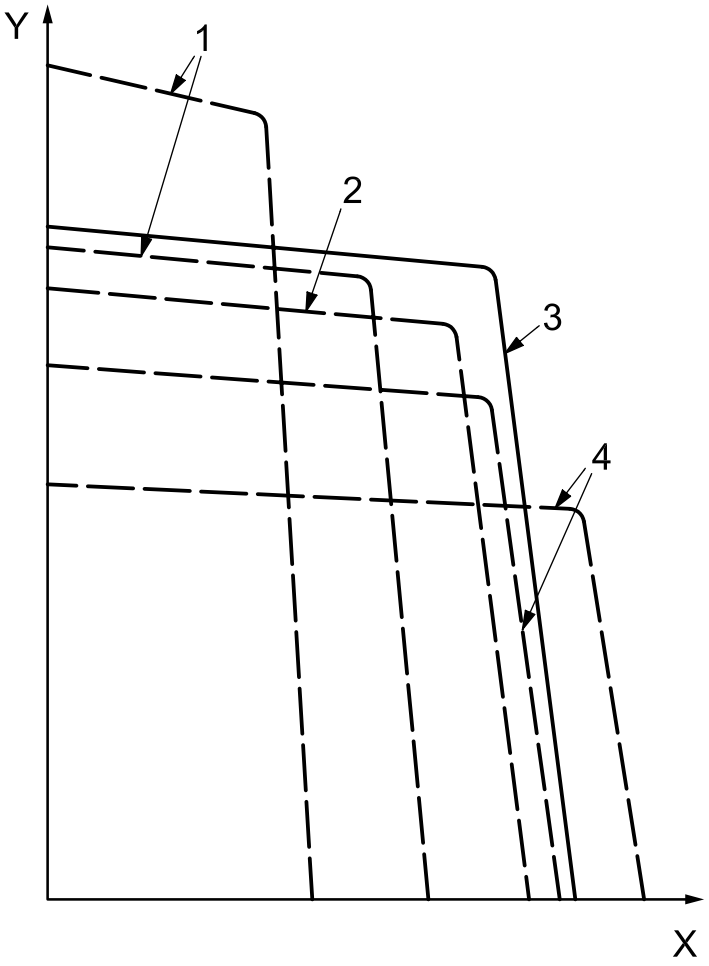
Depending on the relationship between the pump and motor displacements, the PTU can also act as:

— a pressure intensifier

or

— a pressure reducer.

Figure 4 shows the different characteristics of the PTU, depending on the relationship between the pump and motor displacements.



Key

Y pressure, p

X discharge, q

1 PTU pump pressure/discharge characteristics – motor displacement larger than pump displacement

2 PTU pump pressure/discharge characteristics – same size motor and pump displacement

3 PTU motor supply pressure/discharge characteristics

4 PTU pump pressure/discharge characteristics – motor displacement smaller than pump displacement

NOTE 1 This diagram is given as an indication. It may be presented in a different way, for example, the axes may be reversed.

NOTE 2 The PTU motor characteristics are dependent upon the system supply and motor control.

NOTE 3 The PTU motor supply and pump supply characteristics, as shown in this figure, are purely for illustrative purposes.

Figure 4 — Effect of relationship between pump and motor displacements

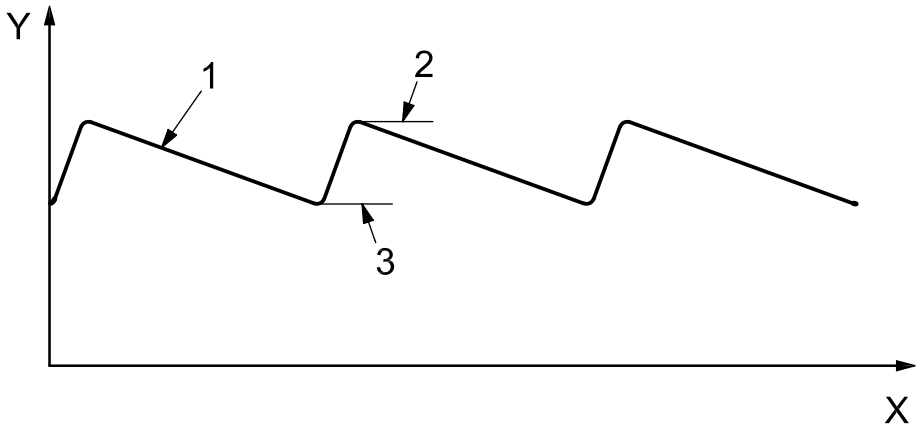
6.3 PTU pressure

6.3.1 Break-out pressure

The detail specification shall state the value of the break-out pressure (see Figure 5). The detail specification should state the minimum/maximum break-out pressure differential characteristics across the PTU versus motor return pressure, if deemed necessary for the specific application.

6.3.2 Stall pressure

The detail specification shall state the value of the stall pressure (see Figure 5). The detail specification should state the minimum/maximum stall pressure versus motor return pressure, if deemed necessary for the specific application.



Key

X time
Y pressure
1 PTU pump discharge pressure
2 stall pressure (6.3.2)
3 break-out pressure (6.3.1)

Figure 5 — PTU pump pressure characteristics (categories A and B PTUs)

6.4 PTU pump pressure

6.4.1 Rated discharge pressure

The following nominal values of rated discharge pressure are commonly used:

a) 10 500 kPa;

b) 21 000 kPa;

c) 28 000 kPa;

d) 35 000 kPa.

6.4.2 Categories A and B PTUs

The detail specification shall state the rated discharge pressure under the following conditions:

a) at the rated motor differential pressure;

b) at the minimum steady state discharge flow just prior to stall;

c) at the rated pump inlet pressure;

d) at the rated fluid temperature.

Care shall be taken when selecting motor and pump displacements to ensure the system relief valve is not activated when the PTU motor is operating at the maximum differential pressure.

6.4.3 Category C PTU

The design of pump shall be such as to maintain the rated discharge pressures within the specified maximum and minimum tolerances for system pressure at the following combination and range of conditions:

a) from 20 °C to rated temperature;

b) from the minimum steady state discharge flow to 115 % of rated flow;

c) at rated inlet pressure;

d) at rated motor differential pressure.

The detail specification shall state the value of the rated discharge pressure and the maximum and minimum tolerances.

This permissible tolerance of rated discharge pressure shall be increased in the detail specification in each direction for fluid temperatures below 10 °C to account for increased viscous losses.

NOTE Temperatures other than 10 °C may be specified, depending, for example, on the hydraulic fluid being used.

6.4.4 Maximum full-flow pressure (category C PTU only)

The detail specification shall state the maximum discharge pressure at which the PTU control will not be acting to reduce pump delivery at rated temperature and rated inlet pressure, when the PTU is operating continuously with rated motor differential pressure.

Unless otherwise specified in the detail specification, the maximum full-flow pressure shall be 0 kPa to 1 500 kPa less than the rated discharge pressure.

6.4.5 Pressure pulsations

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 15.2.10.

6.4.6 Inlet pressure

6.4.6.1 General

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

6.4.6.2 Rated inlet pressure

The detail specification shall state the value of rated inlet pressure, which shall be in kilopascals absolute.

6.4.6.3 Minimum inlet pressure

The detail specification shall state:

— the value of the minimum inlet pressure, which shall be in kilopascals 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;

— any allowable performance degradation when the pump is operating 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 PTU 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.

6.4.6.4 Maximum inlet pressure

The detail specification shall state the value of the maximum steady state inlet pressure, which shall be in kilopascals absolute.

6.5 Motor pressure

6.5.1 Rated motor supply pressure

The detail specification shall state the value of rated motor supply pressure.

6.5.2 Rated motor return pressure

The detail specification shall state the value of rated motor return pressure.

6.6 Case drain pressures

6.6.1 PTU pump/motor rated case drain pressure

The detail specification shall state the value of the rated case drain pressure for both the PTU pump and motor cases.

If the motor case drain line for a category A PTU is incorporated in the motor return, then the motor case has to be designed to cater for the motor return proof, burst and impulse pressure requirements.

A review should be conducted of the possible use of a relief valve in the PTU case drain circuit (which would be bled back to the PTU pump inlet) to prevent over pressurization of the case when PTU idle flow is utilized. The over pressurization could occur when the pump case drain line is restricted due to a blockage or when starting up with a very low ambient temperature (for example below −35 °C).

6.6.2 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 both the PTU pump and motor cases.

6.6.3 Maximum case drain pressure

The detail specification shall state the value of the maximum case drain pressure for both the PTU pump and motor cases.

6.7 Flows

6.7.1 Pump-rated discharge flow

The detail specification shall state the value of the rated pump discharge flow, which shall be expressed in litres per minute. The minimum and maximum rated discharge flow shall be specified.

6.7.2 Zero pump discharge flow

If required by the application, the PTU shall be capable of running for prolonged periods with the PTU pump supplying zero flow to the hydraulic system (for example, when the PTU is isolated from the hydraulic system

by a check valve, and the main system is pressurized by another power source). The detail specification shall define this period.

If required, an internal bleed flow shall be incorporated in the pump (see 6.8.1) to prevent start/stop cycling.

6.7.3 Motor-rated supply flow

The detail specification shall state the value of the rated motor supply flow, which shall be expressed in litres per minute.

6.8 Leakage

6.8.1 Pump case flow

The detail specification shall state that the PTU 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.

If it is required that the PTU runs continuously, that is, the pump/motor does not start/stop rotating, an internal bleed shall be provided between the pump discharge and case drain ports. The detail specification shall state the maximum value of the bleed flow.

The pump case flow rate shall be specified under the following conditions:

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

b) rated temperature;

c) any discharge flow demand from 5 % to 100 % of rated flow;

d) 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.

6.8.2 Motor case flow

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

This shall be under the following conditions:

a) rated motor supply pressure;

b) rated temperature;

c) any motor supply flow from 5 % to 100 % of rated flow;

d) a given maximum differential pressure between case pressure and motor return pressure;

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

The detail specification shall also state if the case drain flow is to be incorporated into the motor return flow, using an integral bypass relief valve.

6.8.3 Shaft seal leakage

The detail specification shall state the value of the maximum dynamic shaft seal leakage at the following conditions:

a) new build:

- the PTU filled with fluid, but unpressurized;
- when subjected to proof pressure at ambient temperature;
- when the PTU is supplying rated discharge flow;

b) qualification testing:

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

6.8.4 External leakage

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

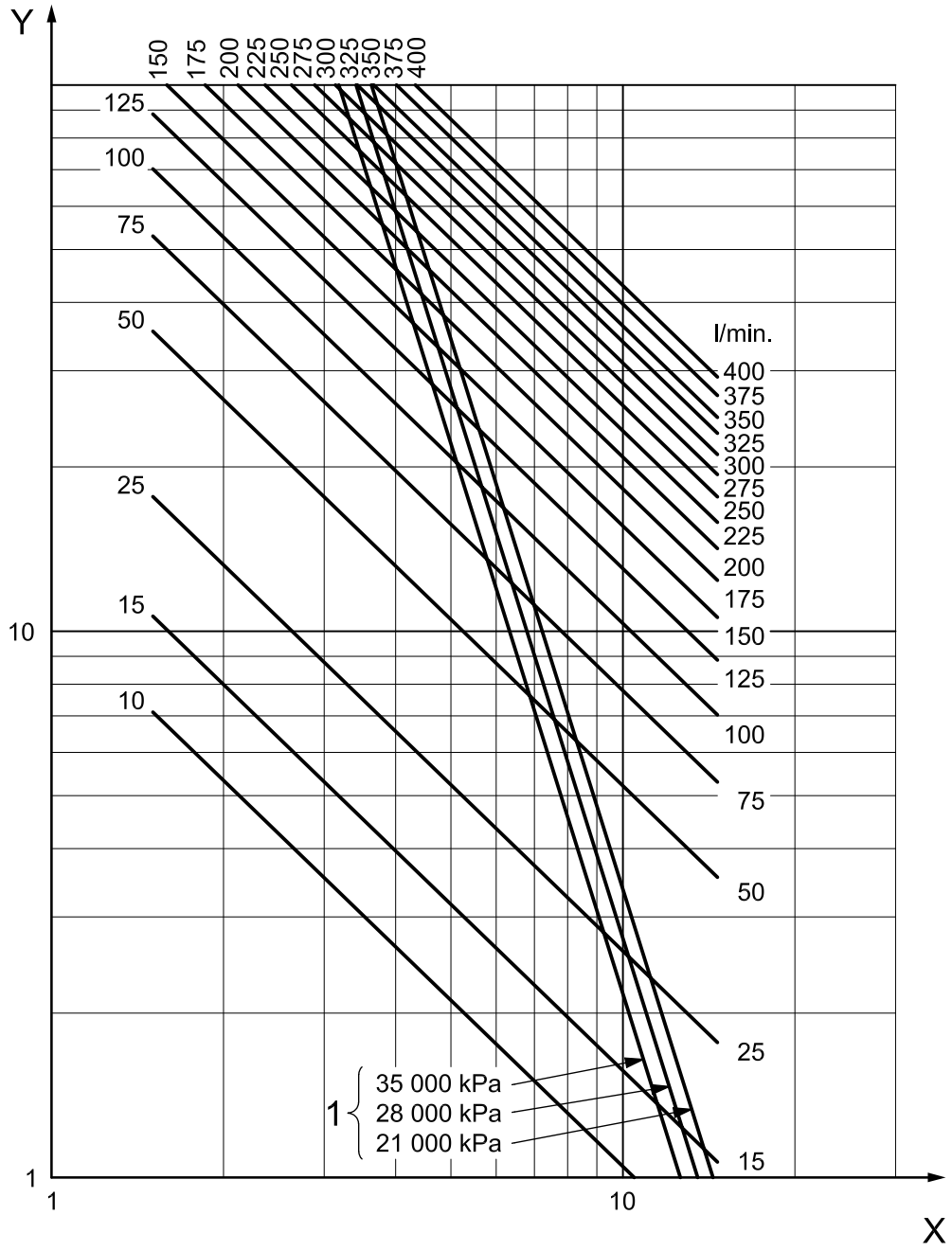
6.9 Speed and direction of rotation

6.9.1 Speed

6.9.1.1 Rated speed

The detail specification may state the rated speed of the PTU if there are other speed related criteria that have to be considered in the PTU application, for example, noise and reliability. The rated speed shall be stated as revolutions per minute (rpm) of the pump drive shaft.

NOTE As an indication, the maximum recommended values are given in the nomograph in Figure 6. If speeds are kept well below those indicated by the curves, the operating life may be improved. However, several system factors such as fluid, temperature, duty cycle, contamination, expected life, etc. will also influence the values.



Key

Y maximum pump displacement in millilitres per revolution

X pump speed in rpm × 1 000

1 recommended maximum rated speeds

Figure 6 — Nomograph of maximum recommended values for rated speeds against pump displacement

6.9.1.2 Overspeed

Unless otherwise specified in the detail specification, the pump shall be capable of operation at 115 % of rated pump discharge flow for the durations and at the conditions given in Table 4.

6.9.2 Direction of rotation (categories B and C PTUs)

The PTUs shall operate satisfactorily in either direction of rotation. It shall not be necessary to alter the motor to effect a change in the direction of rotation, but it should merely be necessary to reverse the direction of flow.

6.10 Efficiency

6.10.1 General

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

6.10.2 Overall efficiency

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/motor shall be used. The flow rate may be measured downstream of a throttling valve that is used to control the discharge flow of the pump, provided that the efficiency calculations compensate for fluid compressibility.

The detail specification shall state the following efficiency values at a given design temperature:

a) the minimum overall efficiency of the PTU motor and pump when new;

b) the minimum overall efficiency of the PTU motor and pump after endurance testing, this value being considered an objective.

For categories B and C PTUs, the overall efficiency of the PTU shall be specified in both flow directions.

6.10.3 Volumetric efficiency

When calculating the volumetric efficiency, the flow rate may be measured at the low pressure side of the pump discharge or motor return lines, provided that adequate compensation is made for compressibility when calculating volumetric efficiency.

The detail specification shall state the following efficiency values at a given design temperature:

a) the minimum volumetric efficiency of the PTU motor and pump when new;

b) the minimum volumetric efficiency of the PTU motor and pump after endurance testing, this value being considered an objective;

For categories B and C PTUs, the volumetric efficiency of the PTU shall be specified in both flow directions.

6.11 Control

6.11.1 Variable displacement pump/motor pressure control (category C PTU)

All category C PTUs shall incorporate a means of varying the displacement of the motor or pump (depending on which side is being supplied by the PTU) to allow a lower breakout pressure differential to initiate rotation. Once the PTU begins running, the control shall modulate the displacement to a position that satisfies the torque balance and the discharge demand.

If required, the detail specification shall provide the requirements for the control system for a continuously variable sub-assembly with a servo control mechanism and appropriate feedback.

6.11.2 Adjustment (category C PTU)

Means shall be provided of adjusting the discharge control mechanism during PTU acceptance testing to cause the minimum attainable steady state flow just prior to stall, to occur at rated discharge pressure. This adjustment shall preferably be continuous, but it may be in steps of less than 300 kPa of the rated discharge pressure over a minimum range from $\pm$ 2 % of the rated discharge pressure.

The adjustment device shall be capable of being securely locked and it shall be possible to carry out adjustments 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.

6.11.3 Response time (category C PTU)

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

a) operating at rated inlet temperature;

b) at rated flow;

c) in a circuit, with the system impedance as defined in 15.2.9.2.2.

In Figures 7 and 8, the time intervals t_1 and t_2 are the response times of the pump as a function of the system impedance.

The PTU discharge pressure shall be stabilized within $\pm$ 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 PTU pump to decrease the flow from full-flow to zero (t_1), and a separate minimum and maximum response time for the PTU pump to increase the flow from zero to full-flow (t_2).

6.11.4 Stability (category C PTU)

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

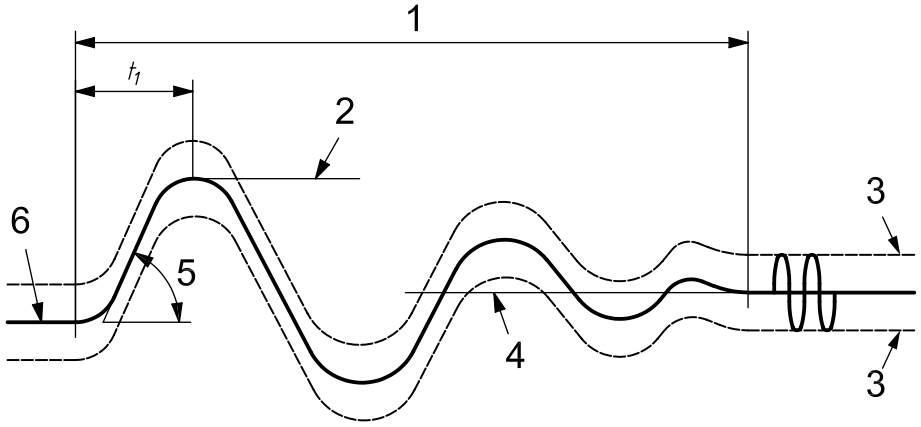
All PTUs shall recover steady-state operation (other than permissible pressure pulsations as specified in 6.4.3) within not more than 1 s of the initial response to that change in flow demand, under the following conditions:

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

b) at any flow rate greater than 50 % of the rated discharge flow rate;

c) after a change in the flow demand.

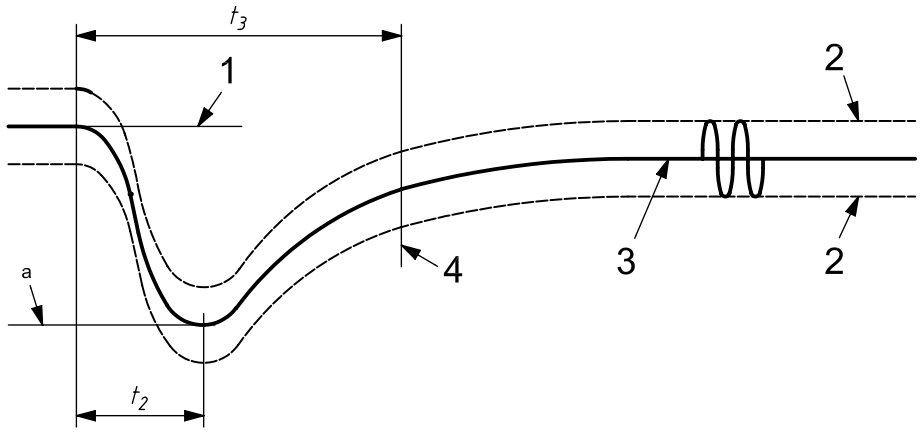
When required by the purchaser, the supplier shall provide adequate PTU pump and motor parameters to permit the system designer to integrate the PTU dynamic performance into the complete PTU/system analysis.



Key

1 maximum 1 s
2 maximum transient pressure (6.11.5)
3 permissible discharge pressure pulsations (6.4.5)
4 rated discharge pressure (6.4.1)
5 pressure rise rate (dP/dT) (Refer to 15.2.9.2.2)
6 maximum full-flow pressure (6.4.4)

Figure 7 — Typical variation of pressure against time — Transient from maximum full-flow pressure to rated discharge pressure (zero flow)



Key

1 rated discharge pressure (6.4.1)
2 permissible pressure pulsations (6.4.5)
3 maximum full-flow pressure (6.4.4)
4 90 % maximum full-flow pressure (15.2.9.4)

[a] Minimum pressure.

Figure 8 — Typical variation of pressure against time — Transient from rated discharge pressure to maximum full-flow pressure (full flow)

6.11.5 Maximum transient pressure

The value of the maximum transient pressure, as determined in the transient pressure test specified in 15.2.9.3, shall not exceed:

a) 7 000 kPa, as determined in the transient pressure test or

b) 125 % of the rated discharge pressure or

c) the maximum pressure as specified in the detail specification.

The maximum transient pressure is dependent upon the hydraulic system characteristics. The purchaser shall provide the circuit impedance for the PTU 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.

6.11.6 Rapid braking

The PTU shall be designed to withstand, at rated conditions, with no operating damage and with no reduction in performance, a change in flow demand from rated flow to zero flow rate in 0,02 s.

6.11.7 Rapid reversals (categories B and C PTUs)

The PTU shall be designed to withstand, at rated conditions, with no operating damage and with no reduction in performance, a reversal in flow demand from:

a) rated flow rate in one direction to rated flow rate in the other direction in 0,05 s;

b) half the rated flow rate in one direction to rated flow rate in the other direction in 0,10 s.

6.12 Rated temperature

ISO 8625-3 provides the requirements for temperature classification (Type I, Type II or Type III) if the PTU 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.

6.13 Acoustic noise level

If required, the PTU shall have a maximum acoustic noise level at rated operating conditions. The detail specification shall state its value together with the measuring procedure, when applicable. When conducting the acoustic noise test, the hydraulic test rig shall have the circuit impedance as specified in 15.2.9.2.1. To the extent possible, acoustic noise contributions from other hydraulic or structural members attached to or in the vicinity of the PTU shall be accounted for separately.

6.14 Endurance

The detail specification should specify the duration and the conditions of the endurance test. However, if they are not specified in the detail specification, then the endurance test shall be in accordance with Table 1 and 15.2.14.

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

Table 1 — Duration of endurance test

Power Transfer Unit application	Duration of endurance test h
Used for military applications	2 000
Used for commercial applications	4 000

6.15 Environmental requirements

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

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

b) humidity (in accordance with ISO 7137);

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

d) vibrations (in accordance with ISO 7137);

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

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

g) resistance to fungus and mould (in accordance with ISO 7137);

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

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

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

k) shock (in accordance with ISO 7137);

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

7 Detail design requirements

7.1 Dimensionally critical components

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

a) they are likely to cause incorrect operation;

b) they can cause damage if the installation direction is reversed;

c) they are incorrectly located on assembly.

7.2 Maintainability features

a) All wear surfaces shall be replaceable or reparable;

b) connections, mounting and wiring provisions shall be designed to prevent incorrect coupling;

c) in addition to the requirements of 7.1, components that are not functionally interchangeable shall not be physically interchangeable;

d) the design shall permit the line replacement of the unit or a module of the unit, using standard tools only;

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

7.3 Seals

Static and dynamic seals shall be in accordance with ISO 3601-1, series A. Non-standard seals, necessary to demonstrate compliance with the requirements of this International Standard, may be used subject to the approval of the purchaser. For pumps for type III systems, back-up rings used shall be subject to the approval of the purchaser.

7.4 Lubrication

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

7.5 Balance

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

7.6 System separation/rip-stop

The PTU construction shall not permit the intermingling or exchange of fluid between hydraulic systems during either normal operation or as a result of a structural failure to any single component.

7.7 Drive shaft

Unless otherwise specified in the detail specification, an easily removable shaft shall be fitted between the two sets of rotating groups. The drive shaft shall be held in place by means of a positive locking system.

7.8 Self-contained failure

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

7.9 Safety wire sealing

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

Lead-type safety wire sealing shall not be used.

7.10 Electro-conductive bonding

If required, the PTU shall have a facility to enable it to be effectively bonded to the airframe. The detail specification shall state the bonding requirements.

7.11 Marking

7.11.1 Nameplate

A nameplate shall be securely attached to the PTU. The information marked in the spaces provided shall be as specified in the format given in Figure 9, unless otherwise stated by the detail specification.

7.11.2 Fluid identification

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

7.11.3 Ports

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

Power Transfer Unit
Name of manufacturer: .....
Manufacturer's code:.....
Manufacturer's part number:.....
Serial number: .....
Fluid:.....
Rated consumption: ..... l/min
Rated discharge: ..... l/min
Rated pressure:.....kPa

Figure 9 — Nameplate format

The nameplate as shown in Figure 9 is for a category A Power Transfer Unit. The detail specification shall state the additional requirements for categories B and C PTUs and/or any additional data.

8 Strength requirements

8.1 Pressure loads

8.1.1 General

The detail specification for the PTU shall state the design operating pressure for the inlet, discharge and case drain parts of the PTU pump, and the supply, return and case drain parts of the PTU motor. In addition, the detail specification for the PTU shall state the limit structural load, if applicable.

8.1.2 PTU motor bypass pressure

The PTU motor case shall also be designed to withstand, without damage, the pressure resulting from integral bypassing of the flow from the case drain to the return port.

8.2 Proof pressures

8.2.1 Pump/motor case

Unless the detail specification states a different value, the pump/motor cases shall statically withstand a pressure of at least equal to or greater than 5 000 kPa or 1,5 × the design operating pressure for the case (whichever is the greater) without permanent damage being done or performance being impaired.

8.2.2 Pump inlet port (category A PTU)

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

8.2.3 Motor return port (category A PTU)

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

8.2.4 Pump outlet/motor supply port (category A PTU)

Unless the detail specification states a different value, the pump outlet/motor supply ports shall statically withstand a pressure equal to 1,5 × the design operating pressure for the pump outlet or the motor supply (whichever is the greater) without permanent damage being done or performance being impaired.

8.2.5 Inlet and outlet ports (categories B and C PTUs)

Unless the detail specification states a different value, the fluid inlet and outlet ports shall statically withstand a pressure equal to 1,5 × the design operating pressure for the pump inlet and discharge or the motor supply and return (whichever is the greater) without permanent damage being done or performance being impaired.

8.3 Burst pressure

8.3.1 Pump/motor case

Unless the detail specification states a different value, the pump/motor cases shall be designed to withstand a pressure of at least 6 000 kPa at the case drain port or 2,5 × the design operating pressure for the case (whichever is the greater) with no structural failure.

8.3.2 Pump inlet port (category A PTU)

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

8.3.3 Motor return port (category A PTU)

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

8.3.4 Pump outlet/motor inlet port (category A PTU)

Unless the detail specification states a different value, the pump outlet/motor supply ports shall statically withstand a pressure equal to 2,5 × the design operating pressure for the pump discharge or the motor supply (whichever is the greater) with no structural failure.

8.3.5 Inlet and outlet ports (categories B and C PTUs)

Unless the detail specification states a different value, the pump and motor fluid inlet/outlet ports shall statically withstand a pressure equal to 2,5 × design operating pressure for the pump inlet and discharge or the motor supply and return (whichever is the greater) with no structural failure.

8.4 Pressure impulse (fatigue)

The PTU 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 PTU, throughout the lifetime of its application;

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

— 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:

a) the pressure variations due to the pump pulsation levels;

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

8.5 Pressure and structural load

The PTU shall be designed to withstand 1,5 × the design operating pressure on the various parts of the PTU in combination with limit structural loads that can reasonably simultaneously occur. No structural failure is permitted.

8.6 Port strength

The structure of the ports and the relevant areas of the pump/motor case shall be such that it withstands a torque 2,5 × the maximum torque resulting from attaching or removing the unions and lines on installation or removing PTUs during maintenance operations. The detail specification shall state the maximum torque value. No permanent distortions or alterations in the correct operation shall occur.

9 Construction

9.1 Materials

9.1.1 General

All materials shall be compatible with the hydraulic fluid that is specified in the detail specification. Materials and processes used in the manufacture of these PTUs shall be of aerospace quality, suitable for the purpose and shall comply with the applicable official standards. Materials that comply with the supplier's material specifications are acceptable provided that these specifications are acceptable to the purchaser and include provisions for adequate testing. The use of the supplier's specifications does not constitute a waiver of other applicable standards.

9.1.2 Metals

9.1.2.1 General

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

If the properties or operating safety of the PTU are likely to be jeopardised by the use of the materials and processes specified above, other materials and procedures may be used subject to the purchaser's approval.

In this case, materials or processes shall be chosen to provide the maximum corrosion resistance compatible with the operating requirements.

9.1.3 Pumps/motors 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 9.2. In addition, tin and zinc plating shall not be used for internal parts or for internal surfaces in contact with the hydraulic fluid or exposed to its vapours. The grooves for external O-ring seals shall not be considered as internal surfaces in constant contact with hydraulic fluid. Magnesium alloys shall not be used.

9.1.4 Pumps/motors for type II and III systems

Ferrous alloys used shall be suitably protected against corrosion as specified in 9.2. In addition, tin plating shall not be used for internal parts that are in contact with the hydraulic fluid or exposed to its vapour. Magnesium alloys shall not be used.

9.2 Corrosion protection

9.2.1 General

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

— dissimilar metal combinations;

— moisture;

— salt spray;

— high temperature deterioration.

9.2.2 Ferrous and copper alloys

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

a) electrolytic nickel plating;

b) electrolytic silver plating;

c) electrolytic tin plating, in accordance with ISO 2093;

d) electrodeless nickel plating.

Electrolytic tin shall not be used for internal parts or internal surfaces in contact with the hydraulic fluid or exposed to its vapours, 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.

9.2.3 Aluminium alloys

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

Exceptions shall be submitted to the purchaser for approval.

9.3 Castings

Castings shall be of high quality, clean, sound and free from cracks, blow holes, excessive porosity and other defects. Defects not materially affecting the suitability of the castings may be repaired at the foundry or during machining by peening, impregnation, welding or other methods acceptable to the purchaser. The inspection and repair of castings shall be checked by quality control techniques and standards that are satisfactory to the purchaser.

10 Installation requirements

10.1 Dimensions

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

10.2 Mass

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

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

10.3 Mounting

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

10.4 Ports

10.4.1

Unless otherwise specified in the detail specification, the ports shall comply with ISO 7320.

10.4.2 Orientation

The case drain port(s) of the PTU 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 PTU as it is installed in the aircraft. The reorientation of the PTU due to aircraft attitude shall not affect PTU operation.

11 Maintenance

11.1 Maintenance concept

The detail specification shall state the specified maintenance concept; for example "On Condition".

11.2 Service life limitations and storage specifications

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

a) the time between overhauls (if applicable);

b) the storage life;

c) the service life limit.

12 Reliability

12.1 Equipment compliance

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

12.2 Requirements

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

a) the defect rate;

b) the failure rate;

c) the safety rate (if applicable);

d) the failure mode and effect analysis (FMEA).

13 Quality assurance provisions

13.1 Responsibility for inspection

The supplier is responsible for carrying out all the inspection operations specified in this International Standard, unless otherwise specified in the contract or order. The supplier may use his own inspection and testing facilities or the services of any industrial laboratory approved by the national authorities, unless otherwise specified in the contract or order.

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

13.2 Classification of tests

The following test programme shall be performed for the purposes of checking whether the PTUs comply with this International Standard:

a) acceptance tests (see Clause 14);

b) qualification tests (see Clause 15).

13.3 Test stand requirements

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

a) inlet pressure: ± 2 % of rated inlet pressure, but not more than ± 34 kPa;

b) case pressure: ± 2 % of rated case pressure, but not more than ± 103 kPa;

c) discharge pressure: ± 2 % of rated discharge pressure, but not more than ± 207 kPa;

d) inlet/temperature: − 57 °C to + 43 °C, within ± 3 °C,
+ 43 °C to + 107 °C, within ± 6 °C;

e) 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 Class 5, or better, except for the qualification endurance testing (See 15.2.14).

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

14 Acceptance tests

14.1 General

Each PTU 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 International Standard, shall consist of:

a) visual examinations;

b) a test programme to determine quality design and check whether the PTUs conform to the performance requirements of this International Standard.

The test programme is specified in 14.3.

The first production PTU shall undergo a first article inspection (FAI) in the presence of the supplier's representatives. Any deviations recorded in the FAI shall be corrected, or agreed, prior to the delivery of the first PTU.

14.2 Examination of the product

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

14.3 Test programme and inspection methods

14.3.1 General

Filters shall be installed in all the lines to and from the PTU motor and 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.

14.3.2 External leakage

14.3.2.1 General leakage

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

14.3.2.2 Shaft seal leakage

During acceptance and calibration tests, the shaft seal leakage shall not exceed the values specified for new build conditions (see 6.8.3).

14.3.3 Proof pressure test

14.3.3.1 General

These tests may be conducted at normal operating temperature, either statically or with the PTU in operation. There shall be no evidence of damage, permanent deformation, or external leakage (apart from shaft seal leakage) during the tests.

14.3.3.2 Low pressure proof test

Except for the case drain ports, blank the high pressure ports and the low pressure ports. Pressurize the case drain ports to the proof pressures stated in 8.2.1. Maintain this pressure for 10 min.

14.3.3.3 High pressure proof test

14.3.3.3.1 Category A PTU

With the pump inlet, motor return, and pump/motor case drain ports unrestricted, simultaneously apply the pressure as stated in 8.2.4 to the PTU pump discharge port and the motor supply port. Maintain the pressure for 3 min.

14.3.3.3.2 Categories B and C PTUs

With the pump and motor case drain ports unrestricted, simultaneously apply the pressure as stated in 8.2.5 to the PTU high-pressure inlet and outlet ports. Maintain the pressure for 3 min.

14.3.4 Break-in run

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

14.3.5 Load cycles

A step-function load shall be imposed, causing the PTU 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 discharge pressure at no flow to maximum flow (115 % of rated flow) at minimum practical system back pressure at 10 cycles/min for 1 min. For categories B and C PTUs, the PTU shall supply fluid in both directions.

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

14.3.6 Tear-down inspection

14.3.6.1 Sampling requirements

A tear-down inspection shall be conducted on a minimum of three PTUs of a given model of an initial production run or as specified in the detail specification. The PTUs shall be disassembled and inspected; if all parts are in acceptable condition, the PTU shall be re-assembled and the test programme continued. The requirements of this subclause may be omitted after the last PTU has successfully passed the inspection.

The tear-down inspection shall be reinstated whenever the following changes in a production programme occur:

a) continuity of manufacturing is interrupted — the detail specification shall designate the permissible periods of production interruption;

b) alternative tooling and production facilities are chosen.

The tear-down inspection shall also be re-instated if a failure occurs during conformance testing, which:

— upon inspection reveals visible damage to the PTU and

— may not, in all cases, be detected by measurable test parameters.

14.3.6.2 Inspection procedure

The PTU shall be dismantled and inspected after the break-in run and proof tests. If all parts are in acceptable condition, re-assemble and run in the pump in accordance with 14.3.4.

When the tear-down inspection is no longer required, the run-in, in accordance with 14.3.4, may be omitted.

14.3.7 Break-in run after tear-down inspection

The run-in after tear-down inspection shall be performed at 30 % to 100 % of rated flow for a period of 15 min at a frequency of 6 cycles/min.

For categories B and C PTUs, the PTU shall supply fluid in both directions. The time spent supplying fluid in each direction shall be the same.

14.3.8 Functional tests

The rated inlet and motor return pressures shall be maintained within the tolerance specified in this International Standard. The pump inlet and motor return temperatures shall be at the rated condition.

The functional test shall comprise the following:

a) 15 min at rated PTU pump discharge flow rate and maximum pump discharge and motor differential pressures;

b) 15 min at rated PTU pump discharge flow rate with the PTU pump discharge pressure ranging from maximum full-flow pressure to rated discharge pressure at a frequency of 6 cycles/min;

c) 30 min at rated PTU pump discharge flow rate and rated discharge pressure; except that at 10 min intervals the discharge pressure shall be reduced to maximum full-flow pressure for 1 min.

For categories B and C PTUs, this test shall be conducted twice, one in each flow direction.

14.3.9 Pressure control test (category C PTU)

The rated discharge pressure shall remain within the limits specified in the detail specification, with no indication of pressure control instability, as motor inlet flow rate is made to vary from 20 % to 100 % of rated flow rate or to the motor inlet flow rate specified in the detail specification.

This test shall be conducted with the PTU:

a) supplying fluid in one direction;

b) supplying fluid in the other direction;

c) cycling the fluid supply between both systems.

The detail specification shall define the system conditions.

The detail specification shall specify the value of the hysteretic characteristics of the pressure control from zero to rated flow at rated speed/motor inlet flow rate, which shall not be exceeded.

14.3.10 Calibration

14.3.10.1 General

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

a) motor supply pressure;

b) motor return pressure;

c) motor inlet port flow;

d) motor case drain port flow;

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

f) motor case pressure of 140 kPa, or as specified in the detail specification, above inlet pressure;

g) pump discharge pressure;

h) pump inlet pressure;

i) pump outlet port flow;

j) pump case drain port flow;

k) pump inlet temperature at rated conditions, or as specified in the detail specification;

l) pump case pressure of 140 kPa, or as specified in the detail specification, above inlet pressure.

For categories B and C PTUs, measure and record these parameters in both flow directions.

14.3.10.2 Pump and motor pressure settings

Regulate the pump inlet port pressure to the rated inlet pressure and the motor return pressure to the rated return pressure.

14.3.10.3 Flow rate

Determine the values of the motor supply flow rate with the pump discharge flow rate set to:

a) 0 % — for this flow setting, check that the behaviour of the PTU is as expected (for example, if there is an integral bleed, check that the PTU runs slowly and smoothly with the correct inlet flow);

b) 25 %;

c) 50 %;

d) 75 %;

e) 100 %;

f) 110 % of pump rated flow.

Confirm that the motor supply flow rate at each of these flow settings meets the specified requirements with the pump discharge pressure set to:

— 25 %;

— 50 %;

— 75 %;

— 100 % of pump rated pressure.

14.3.10.4 Efficiency check

From the test data, check that the following efficiencies comply with those required in the detail specification:

a) overall efficiency;

b) volumetric efficiency.

14.3.10.5 Break-out/stall pressure test

If required by the detail specification, a test to determine the minimum/maximum break-out pressure differential characteristic across the PTU and the stall pressure versus motor return pressure shall be conducted.

14.3.11 Filter patch test

14.3.11.1 General

This test shall be conducted to prevent shipment of a functionally acceptable but materially deteriorating pump (incipient failure). The fluid from the PTU case drain of the motor/pump shall be checked for contamination as agreed to between the supplier and the purchaser. The operating time and duty shall be chosen such as to yield the most significant patch information for the particular PTU model, and shall be a permanent part of the acceptance test procedure along with the filter membrane specifics.

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 PTUs.

14.3.11.2 Filter sampling method

Unless otherwise specified in the detail specification, all the filters used during the test shall be able to filter to a value $\leqslant$ 5 µm absolute.

Install an identified and suitable filter in the case drain port lines of the test set-up. Check the fluid in these filter bowls using the procedure specified in 14.3.11.3 for contamination accumulated during the functional test performed in accordance with 14.3.8.

For a category A PTU only, if the PTU motor case drain is incorporated in the motor return, then a filter shall be installed in the motor return line, and the motor contamination shall be checked from this filter.

14.3.11.3 Patch preparation

Collect the fluid from 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 contaminant in each filter bowl. The detail specification shall state the membrane material. Wash the membrane free of fluid with the appropriate volume of fluid solvent. After drying, the resultant filter patch shall be coated with clear lacquer and permanently attached to the log sheet of the test.

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

14.3.11.4 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. To be acceptable, the second patch shall show equal or less contaminant than the standard patch. 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.

14.3.12 Electro-conductive bonding

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

14.3.13 Storage and packaging

The pump shall be 90 % filled with fresh hydraulic fluid to a cleanliness standard of ISO 11218 Class 5 or better.

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

15 Qualification tests

15.1 Purpose

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

15.2 Qualification procedure

15.2.1 Qualification by analogy

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

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

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

NOTE Qualification by analogy might also be possible by utilizing other hydraulic components (that is, pumps and motors).

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

15.2.2 PTU 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 PTUs 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. 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.

15.2.3 Samples and programme of qualification tests

It is recommended that qualification tests be conducted on three sample PTUs (specimens 1, 2 and 3). It is essential that the PTUs that are tested are identical to those that are manufactured using a serial process, and that any deviations be approved by the purchaser prior to the commencement of testing.

NOTE The shaft seal leakage is permitted to degrade to the limit specified in the detail specification (see 6.8.3).

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 sub-clause
	1	2	3	
Acceptance	X	X	X	15.2.4
Dimensional check	X	X	X	15.2.5
Expanded envelope acceptance	X			15.2.6
Load cycle	X			15.2.7
Calibration	X			15.2.8
Maximum pressure	X			15.2.9.3
Response	X			15.2.9.4
Rapid reversal	X			15.2.9.5
Pressure pulsations	X			15.2.10
Heat rejection	X			15.2.11
Vibration		X		15.2.12
Low temperature		X		15.2.13
Endurance	X			15.2.14
Minimum inlet pressure	X			15.2.15
Environmental		X		15.2.16
Fatigue			X	15.2.17.1
Port strength			X	15.2.17.2
Burst			X	15.2.17.3
Pressure and structural load			X	15.2.17.4
Supplementary	X as applicable			15.2.18

15.2.4 Acceptance tests

Acceptance tests, as part of the design approval test programme, shall be performed exactly as specified in 14.3.

15.2.5 Dimensional check

Prior to the start of the qualification test, check the critical wear dimensions and record the dimensions. Check these dimensions again for comparison purposes once the qualification tests have been completed. The run-in specified in 14.3.4 may be carried out, if necessary, after reset and before the test sequence is continued.

15.2.6 Expanded envelope acceptance tests

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

a) the fluid temperatures from minimum continuous to rated;

b) flows from zero to rated discharge.

No malfunctions shall be recorded.

15.2.7 Load cycle test

Carry out the load cycle tests as outlined in 14.3.5, except that the tests shall be repeated ten times.

15.2.8 Calibration

15.2.8.1 Motor supply pressure and pump inlet pressure

Regulate the pressure at full flow and rated speed conditions as follows:

a) at the pump inlet port to the rated inlet pressure;

b) between the motor supply and return ports to the rated supply differential pressure.

15.2.8.2 Pump/motor flow rate and pressure values

Determine the values of the PTU discharge pump and motor supply flow rate at 5 %, 10 %, 25 %, 50 %, 75 %, 100 % and 110 % of rated pump flow rate. At each of these flow rates:

a) make four series of pressure recordings at 25 %, 50 %, 75 % and 100 % of pump inlet pressure, recording the pump discharge pressure, motor supply pressure and motor return pressure;

b) calculate the overall and volumetric efficiencies.

Unless otherwise specified in the detail specification, perform calibrations at the inlet condition specified in 6.4.6.2 and the flow measurements may be made in the line downstream of the load valve, but shall be corrected for fluid compressibility.

15.2.9 Maximum pressure, response time and rapid reversal tests

15.2.9.1 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 PTU and its hydraulic circuit throughout the transient and steady-state periods described in the following three tests.

The pressure transducers and recording equipment shall be capable of meeting the repeated accuracy requirements as stated in 13.3 over a frequency range of 0 to 5 $\times$ the PTU 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 pump discharge line as close to the PTU 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 kHz to 100 kHz. Tests shall be conducted at the rated conditions, unless otherwise noted below or in the detail specification.

15.2.9.2 System impedance

15.2.9.2.1 General

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

15.2.9.2.2 System impedance for determination of response time

The system impedance of the test circuit when determining the category C PTU response shall meet the following requirements:

a) the PTU is operating over the specified flow range, and at rated inlet temperature;

b) the rate of PTU pump discharge pressure rise when the flow in the system is suddenly stopped shall be 340 000 kPa/s (3 400 bar/s) minimum.

NOTE The PTU pump discharge pressure rise rate is defined as the average value of the slope of $\mathrm{d}P/\mathrm{d}T$ during the initial pressure transient increase, prior to the peak value (see Figure 7).

15.2.9.2.3 All other tests

The detail specification shall state the system impedance of the test circuit when determining maximum pressure, pressure pulsations, stability and the remaining qualification tests. The PTU shall be installed in a hydraulic circuit that simulates the aircraft system, details of which shall be provided in the detail specification. The system volume may be simulated using tubing of the discharge line diameter, while being careful to avoid a line length whose natural frequency is resonant with pulsation frequency.

The high-pressure circuit shall be representative of the PTU pump application and motor supply.

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

15.2.9.3 Maximum pressure test

This test is strictly only applicable for category C PTUs. This test should only be conducted for categories A and B PTUs if required for system integration purposes.

The test circuit specified in 15.2.9.2.2 shall be used. For this test, all gases shall be evacuated from the PTU pump inlet and discharge lines. Flow changes shall be initiated by means of a solenoid-operated valve with a response time, from full closed to full open and vice versa, of 0,02 s or less, or a response time as specified in the detail specification.

Operate the test PTU between steady-state maximum full-flow pressure and steady-state rated discharge pressure (in both directions for categories B and C PTUs) 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 PTU flow. Keep 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 6.11.5, at rated fluid temperature.

15.2.9.4 Determination of response time

This test is strictly only applicable for category C PTUs. This test should only be conducted for categories A and B PTUs if required for system integration purposes.

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

a) the test circuit as specified in 15.2.9.2.2;

b) 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 7, and the response time, t_1, as indicated in Figure 7, shall not exceed the specified time 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 8, 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 minimal full-flow pressure and, as indicated in Figure 8, t_3 shall not exceed 1 s at 100 % rated speed.

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

Conduct this test in both flow directions for categories B and C PTUs.

15.2.9.5 Rapid reversal test (categories B and C PTUs)

Modify the test circuit specified in 15.2.9.2.3 such that there are two separate test circuits, each capable of supplying and receiving fluid from the Power Transfer Unit. In each circuit, (known as circuit A and circuit B) install load valves that are set at a flow condition equivalent to maximum full-flow pressure, and use the solenoid valve that changes the discharge line from fully open to fully closed, or vice versa. Install solenoid valves in circuit A and circuit B test pump discharge lines to isolate the pump supply from the test circuit.

Run the test pumps in circuit A and circuit B, and select the circuit B test pump valve to close. Select the PTU to run, supplying 50 % of rated flow to circuit B. Operate the test valves such that the PTU supplies 100 % of rated flow to circuit A within 0,20 s.

Repeat the above test but with the PTU initially supplying 100 % of rated flow to circuit B. Operate the test valves such that the PTU supplies 100 % of rated flow to circuit A within 0,50 s.

Repeat the above tests but with the PTU initially supplying fluid to circuit A.

15.2.10 Pressure pulsation test

Equip the test circuit specified in 15.2.9.2.3 with a pressure transducer of zero volume and sensitive to 20 kHz to 100 kHz, installed in the pump discharge line.

During this test, the following conditions shall be maintained:

— motor differential pressure to be at the rated differential pressure;

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

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

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

Run the PTU 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 6.4.5.

Conduct this test in both directions for categories B and C PTUs.

15.2.11 Heat rejection test

15.2.11.1 Principle

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

15.2.11.2 Determination of heat rejection

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

Conduct this test in both flow directions for categories B and C PTUs.

Check that the fluid temperatures in the PTU pump and motor case drain ports do not exceed the specified maximum temperatures.

15.2.12 Vibration tests

See ISO 7137.

15.2.12.1 Mounting of test unit

Mount the test PTU successively on a vibration-generating mechanism in each of at least three axes that shall be representative of the PTU installation in terms of the application. Carry out all of the testing specified in each of the mounting positions. One of these mounting positions shall be chosen so that the direction of vibratory motion shall be parallel to the shaft axis of the PTUs.

15.2.12.2 PTU operating during vibration tests

If it is determined that more potential damage to the PTU will be incurred as a result of it being non-operational during the vibration tests, then it is permissible to conduct the vibration tests with the PTU in a static unpressurized condition.

However, if it is determined that the PTU will incur more damage with it being run during the vibration tests, then the following applies.

Throughout the vibration tests specified in 15.2.12.3, 15.2.12.4 and 15.2.12.5, the PTU shall be operated in the test circuit given in 15.2.9.2.3. Fluid temperature at the pump inlet and the motor supply shall be maintained at 60 °C, regardless of the rated temperature of the pump being tested, and ambient temperatures shall be maintained at room ambient conditions. The pump discharge flow shall fluctuate in continuous cycles from zero flow to approximately 50 % of rated discharge. These flow cycles shall be abruptly accomplished by operating solenoid valves at a rate of 5 cycles/min. Transition from one condition of flow to the other condition of flow shall be accomplished in a valve time of less than 0,5 s.

If the PTU is equipped with a system/PTU control device (shut-off valve, flow control valve, etc.), the detail specification shall state the cycles between the different modes.

15.2.12.3 Resonant frequency vibration test

Search for resonant frequencies in accordance with the double amplitude and frequency charts in ISO 7137. The detail specification shall state the applicable procedures and test values.

15.2.12.4 Cyclic frequency vibration test

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

15.2.12.5 Other vibration tests

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

15.2.13 Low temperature test

The test circuit for the low temperature test shall be as specified in 15.2.9.2.3. All temperature requirements apply equally to the PTU body, hydraulic fluid and ambient environment. The ambient environment may vary by ± 10 °C. Start up the PTU and uniformly accelerate to 50 % of rated flow rate in not more than 10 s, unless otherwise specified in the detail specification, after:

— at least 18 h at the minimum inlet temperature specified in the detail specification

or

— between − 50 °C and − 55 °C in the absence of such stipulation in the detail specification.

Carry out five runs with the outlet pressure as low as practicable and the inlet pressure as specified in the detail specification. Rated flow rate should be reached within 20 s of start-up; when it has been reached, maintain it for at least 10 s. Observations shall indicate whether the PTU pump displaces fluid through the hydraulic system.

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

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

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

15.2.14 Endurance test

15.2.14.1 Accelerated endurance test

The sample pump shall undergo an accelerated endurance test, as outlined in Tables 3 and 4.

The total endurance time for the PTU applications is specified in Table 1. The detail specification shall state any modification of any of the test conditions.

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

The purchaser shall state if the normal endurance test is to be conducted with the flow/pressure limiting device that is used in the PTU application.

15.2.14.2 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 PTU, resulting in loss or contamination of the fluid not related to the endurance qualities of the PTU system, fluid may be completely replaced;

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.

15.2.14.3 Leakage permissible during endurance testing

15.2.14.3.1 Case tightness

There shall be no external leakage sufficient to form a drop throughout the endurance test (including the re-calibration time).

15.2.14.3.2 Shaft seal

See 6.8.3.

15.2.14.4 Test programme

15.2.14.4.1 General

The test circuit for the endurance tests shall be as specified in 15.2.9.2.3. Modification of any of the test conditions given in Tables 3 and 4, 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.

The sample PTU shall undergo the following endurance tests:

a) Normal test.

   1 920 h for PTUs used for military applications and 3 840 h for PTUs used for commercial applications, consisting of the five phases specified in Table 3 in the order listed, plus two calibrations, the start-stop cycles, filter checks and air ingestion cycles as specified in the following subclauses.

b) Overload test.

   80 h for PTUs used for military applications and 160 h for PTUs used for commercial applications consisting of the four phases specified in Table 4 in the order listed, plus two calibrations, the start-stop cycles, thermal cycles and thermal shock test.

15.2.14.4.2 Reverse direction cycles (categories B and C PTUs)

The endurance test for bi-directional PTUs shall be in two parts.

a) Continuous flow in one direction only.

   Conduct 60 % of the test as detailed in 15.2.14.4.1, with 30 % of the flow in one direction, and 30 % of the flow in the other direction. There shall be an equal amount of time spent with the PTU supplying flow in each direction; the quantity of fluid pumped in each flow direction shall be the same, unless otherwise agreed between the purchaser and the supplier.

b) Alternating flow direction.

Conduct 40 % of the test as detailed in 15.2.14.4.1, with direction of flow alternating at a frequency of 0,2 cycles/s.

15.2.14.5 Filtration for endurance tests

15.2.14.5.1 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 contamination class or filter capability, install 15 µm absolute filters on the fluid inlet, outlet and drain lines during the endurance tests. If the detail specification states the contamination class, install the required filters to achieve the required level of fluid contamination.

15.2.14.5.2 Filter check

Unless otherwise specified in the detail specification, install clean filter elements in all three filters at intervals of (100 ± 20) h, during the endurance tests. Resume the endurance test schedule for 2 h, at the end of which remove these filter elements and replace with clean filter elements. Check the filter elements removed after 2 h operation in accordance with 14.3.11.

15.2.14.6 Calibration

Calibrate the PTU using the procedure specified in 14.3.9 before starting phase 1 of both the normal and the overload endurance tests for each test series and also on completion of the full test schedule. Plot the results of these three calibrations on one chart to show the effect of the endurance test on the performance of the PTU.

NOTE The calibration tests can be conducted more frequently if required in the procurement specification.

15.2.14.7 Start-stop cycles

15.2.14.7.1 General

Start-stop cycles shall be conducted at the beginning and at the end of the endurance test. The test circuit system impedance shall be as specified in 15.2.9.2.2. Fluid temperatures may range from ambient to rated temperature, but the actual values shall be recorded.

For category C PTUs, the compensator shall be adjusted at its maximum pressure for the tests conducted at the end of the endurance tests.

15.2.14.7.2 Full-flow cycles

The PTU shall be accelerated to rated speed within 2 s, or as specified in the detail specification, at rated motor differential pressure, and the pump load orifice adjusted to permit full-flow. Allow the PTU to coast to a stop immediately after reaching rated speed. Record the deceleration time.

For categories B and C PTUs, conduct the test in both flow directions.

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

NOTE The full-load start-stop test can be performed for a specified number of times with no sequential cycles during the endurance testing. This will allow the supplier to optimize the testing time.

Table 3 — Endurance test — Normal test

Phase [a]	Duration	% of Nominal inlet pressure	Cycle 1 [b]			Cycle 2 [b]			Cycle 3 [b]			Cycle 4 [b]		
	min.		Flow [c] %	Motor differential pressure	Time s	Flow [c] %	Motor differential pressure	Time s	Flow [c] %	Motor differential pressure	Time s	Flow [c] %	Motor differential pressure	Time s
1	10	100	70			52,5			14			35		
2	5	[d]	70			52,5			14			35		
3	20	100	100	[e]	115	75	[e]	25	20	[e]	75	50	[e]	25
4	10	[d]	100			75			20			50		
5	15	100	110			82,5			22			55		

[a] Test Temperature

1) If the rated temperature (see 3.28) is equal to 45 °C (type I systems), all phases shall be run at this temperature.
2) If the rated temperature is equal to 110 °C (type II systems),
   - 6 series of 5 phases shall be run with inlet temperature equal to 70 °C;
   - 16 series of 5 phases shall be run with inlet temperature equal to 90 °C;
   - 10 series of 5 phases shall be run with inlet temperature equal to 110 °C.
3) If the rated temperature is equal to 170 °C (type III systems),
   - 6 series of 5 phases shall be run with inlet temperature equal to 70 °C;
   - 16 series of 5 phases shall be run with inlet temperature equal to 150 °C;
   - 10 series of 5 phases shall be run with inlet temperature equal to 170 °C.

For type III systems, the detail specification shall state the full schedule for the normal endurance test.

[b] There shall be a dwell cycle of 15 s prior to the next cycle.

[c] The flow is expressed as a percentage of the rated pump discharge.

[d] The inlet pressure for this phase shall be the minimum possible inlet pressure that could be achieved for the PTU application.

[e] The motor differential pressure shall be equal to 95 % of motor rated pressure.

Table 4 — Endurance test – Over-pressure test

Phase [a]	Duration	Nominal inlet pressure	Motor rated flow	Cycle 1			Cycle 2			Cycle 3			Cycle 4			Cycle 5		
				Pump flow [b]	Discharge pressure	Time	Pump flow [b]	Discharge pressure	Time	Pump flow [b]	Discharge pressure	Time	Pump flow [b]	Discharge pressure	Time	Pump flow [b]	Discharge pressure	Time
	min.	%	%	%	%	s	%	%	s	%	%	s	%	%	s	%	%	s
1	240	100	100	100	c	120	75	d	30	50	e	30	20	e	90	0	Rated	30
2	60	100	100	100			75			50			20					
3	240	200	115	115			82,5			55			22					
4	60	200	115	115			82,5			55			22					

[a] Test Temperature

For each range of 8 series of the 4 phases above,

1) If the rated temperature (see 3.28) is equal to 45 °C (type I systems), all phases shall be run at this temperature.
2) If the rated temperature is equal to 110 °C (type II systems),
   - 10 series of 5 phases shall be run with inlet temperature equal to 70 °C;
   - 25 series of 5 phases shall be run with inlet temperature equal to 90 °C;
   - 15 series of 5 phases shall be run with inlet temperature equal to 110 °C.
3) If the rated temperature is equal to 170 °C (type III systems),
   - 10 series of 5 phases shall be run with inlet temperature equal to 70 °C;
   - 25 series of 5 phases shall be run with inlet temperature equal to 150 °C;
   - 15 series of 5 phases shall be run with inlet temperature equal to 170 °C.

For type III systems, the detail specification shall state the full schedule for the normal endurance test.

[b] The variation in pump flow and discharge pressure is only applicable to category C PTUs.

[c] The flow is expressed as a percentage of the rated pump discharge.

[d] The inlet pressure for this phase shall be equal to 100 kPa (1 bar) absolute, or to 1,1 × the absolute pressure at minimum inlet pressure (defined in 6.4.6.3), whichever is greater.

[e] The motor differential pressure shall be equal to 95 % of motor rated pressure.

15.2.14.8 Air ingestion

A test shall be carried out simulating the ingestion of air by the hydraulic circuit as a result of the replacement of elements during maintenance operations, after the completion of the overload test. For the air ingestion test, use the aircraft's reservoir, or an agreed equivalent, and use the aircraft suction line size, length and configuration together with rated inlet pressure of the applicable aircraft in question.

Unless otherwise required in the detail specification, this test shall also be performed during endurance testing according to the periodicity defined below.

Arrange the line supplying fluid to the PTU pump so that a 1,20 m length of line immediately adjacent to the pump can be disconnected, vented, drained and reconnected without draining the rest of the test system. Stop the test while the pump is operating at full flow whenever the test rig is shut down to install the filter elements for the 2 h patch run (see 14.3.11) (or alternatively, to remove these elements at the end of the 2 h patch run). Depressurize the reservoir, disconnect, vent, drain and reconnect the 1,20 m length of inlet line. During these operations, replace the filter elements. Then restart the pump with the test system set to develop maximum full flow. Thirty seconds after the restart, record the discharge pressure, then pressurize the reservoir and resume the endurance test schedule.

If the PTU is a category B or C type, then this test shall be conducted for both sets of rotating groups.

15.2.14.9 Thermal cycles

After completion of the overload test, eight thermal cycles of the pump from − 30 °C to rated temperature shall be carried out.

With the PTU delivering no flow, stabilize the PTU and test system at − 30 °C for 1 h. Then start and operate the PTU at maximum rated pressure, flow and rated inlet pressure until the fluid reaches rated temperature. This operation shall comprise one cycle. The detail specification shall state the heating rate.

15.2.14.10 Thermal shock

After completion of the overload test, a thermal shock cycle shall be completed.

Cool the PTU and fluid in the PTU to a temperature of − 55 °C or the temperature specified in the detail specification. Maintain the hydraulic reservoir temperature at rated temperature. The reservoir shall contain a volume of fluid equal to that in the aircraft system or as specified in the detail specification. Start the PTU and bring up to rated speed in a time interval specified in the detail specification. Set the PTU motor differential pressure and inlet flow to cause the PTU to deliver rated flow as specified in the detail specification. The PTU shall not malfunction.

15.2.14.11 Failure of parts

Should the endurance test programme be interrupted because of a part failure, the PTU shall be replaced or repaired using a part or parts of modified design. In the event of a material defect or manufacturing error, it may be possible to fit a part of the same design as the broken part, without the defect.

The programme shall be considered to be complete if all the PTU parts have fulfilled the programme requirements, specified in the detail specification, without failure. Should the PTU tests be continued, after failure of one or more parts, with repaired or replaced parts, subsequent failure of parts that have fully met the endurance requirements shall not be considered as a reason for rejection.

15.2.14.12 Tear-down inspection

15.2.14.12.1 PTU inspection

After the completion of the endurance tests, dismantle the PTU, inspect all parts visually and prepare a dimensional statement of the working parts, to enable an analysis of the wear effects to be conducted.

The general condition of the parts shall be reported.

15.2.14.12.2 Filter inspection

At the completion of the endurance tests, remove the filter elements and check for evidence of abnormal wear particles.

15.2.14.13 Additional endurance test

The detail specification may also specify a dedicated endurance test that closely resembles the aircraft duty cycle. If this is required, the detail specification shall state the total endurance test time, and provide sufficient details to enable a representative test to be conducted.

15.2.15 Minimum inlet pressure test

Operate the PTU pump at rated flow rate, rated inlet temperature and 90 % of maximum discharge pressure. Adjust the fluid pressure at the pump inlet port to 120 % of rated inlet pressure. Measure the rate of flow and discharge pressure as inlet pressure is reduced down to a minimum. Confirm that there is no degradation in performance with the PTU pump running at the minimum inlet pressure.

Continue reducing the inlet pressure until cavitation occurs (i.e. 2 % reduction in the pump discharge flow).

Confirm that the margin between the critical inlet pressure (i.e. when cavitation occurs) and the minimum inlet pressure is appropriate for the PTU application.

15.2.16 Environmental tests

Tests shall be conducted on the PTU, or relevant parts of the PTU, if it cannot be demonstrated by analogy or analysis that the PTU complies with the environmental requirements of 6.15.

15.2.17 Structural tests

15.2.17.1 Fatigue (pressure impulse) tests

The PTU shall be subjected to a pressure impulse test to demonstrate that it complies with the requirements of 8.4. The detail specification shall state:

— the method of testing;

— the frequency of the application of the pressure impulse;

— the shape of the pressure impulse wave form.

A permanent record of the dynamic pressure/time history of the pressure impulse test shall be made. Unless otherwise agreed between the purchaser and the supplier, this shall be repeated at every 15 000 cycles to ensure that the pressure/time history of the impulse is maintained.

No evidence of cracks in any part of the component shall occur.

15.2.17.2 Port strength

The structure of the ports and the relevant areas of the pump/motor case shall be subjected to a torque of 2,5 × the maximum torque resulting from attaching or removing the unions and lines on installation or removing PTUs during maintenance operations. The detail specification shall state the maximum torque value. No permanent distortions or alterations in the ports and the relevant areas of the pump/motor case shall occur.

15.2.17.3 Burst test

The static burst test to show compliance with the requirements of 8.3 shall be applied once for 15 min. This test should be conducted last on one specimen, since no further operations on that PTU are specified.

The shaft seal leakage shall not exceed that specified for the burst test (see 6.8.3).

15.2.17.4 Pressure and structural load test

The pressure and structural load test to show compliance with the requirements of 8.5 shall be applied once for 15 min. This test should be conducted last on the other specimen, since no further operations on that PTU are specified.

15.2.18 Supplementary tests

The detail specification shall state any supplementary tests including any special demanding cases that will contribute to the robustness of the equipment.

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