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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

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

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

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## 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.

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# 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

$\Delta P_p$  is the differential pressure between the PTU pump discharge and inlet ports in kilopascals;

$\Delta P_m$  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

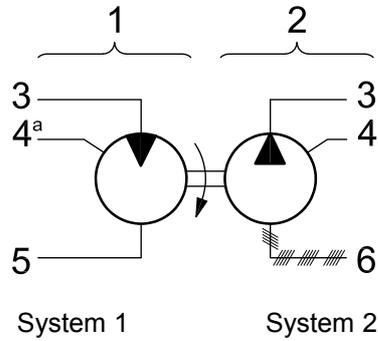
**3.40****rated endurance of the PTU**

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.



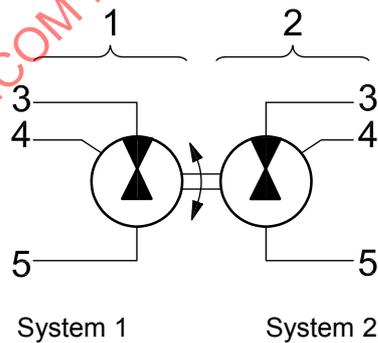
**Key**

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

<sup>a</sup> 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.

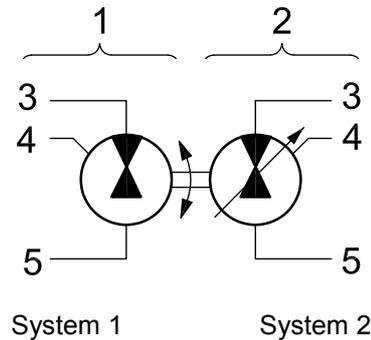


**Key**

- 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.

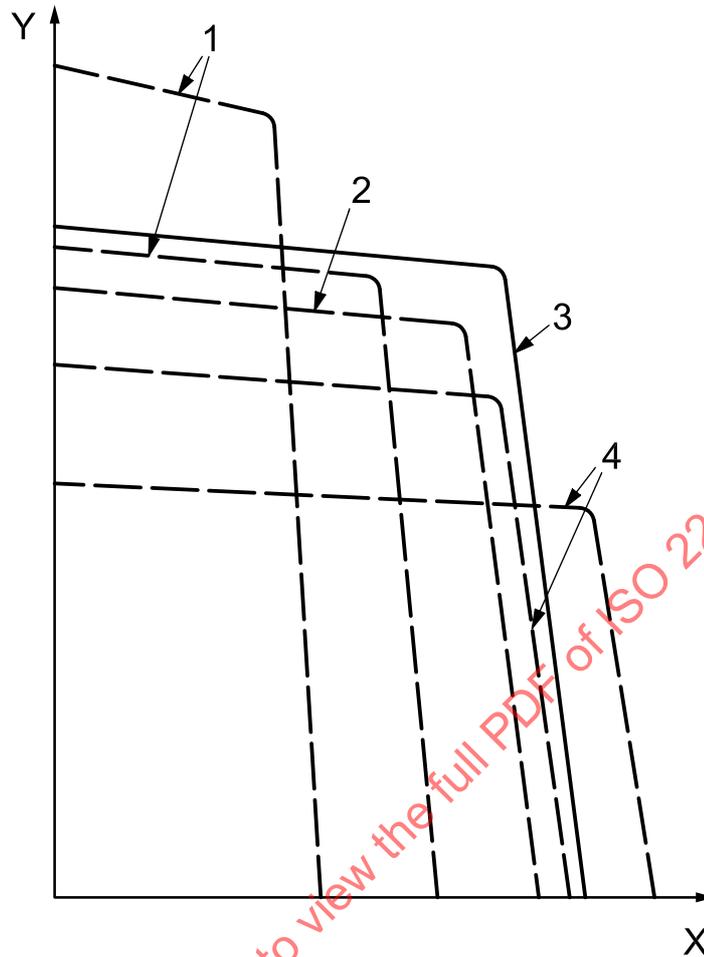
Depending on the relationship between the pump and motor displacements, the PTU can also act as:

— 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**

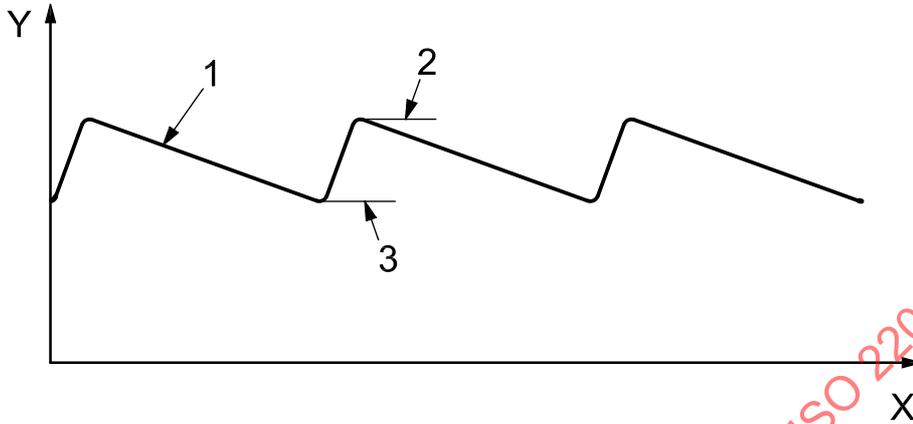
## 6.3 PTU pressure

### 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  $-35^{\circ}\text{C}$ ).

#### 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.

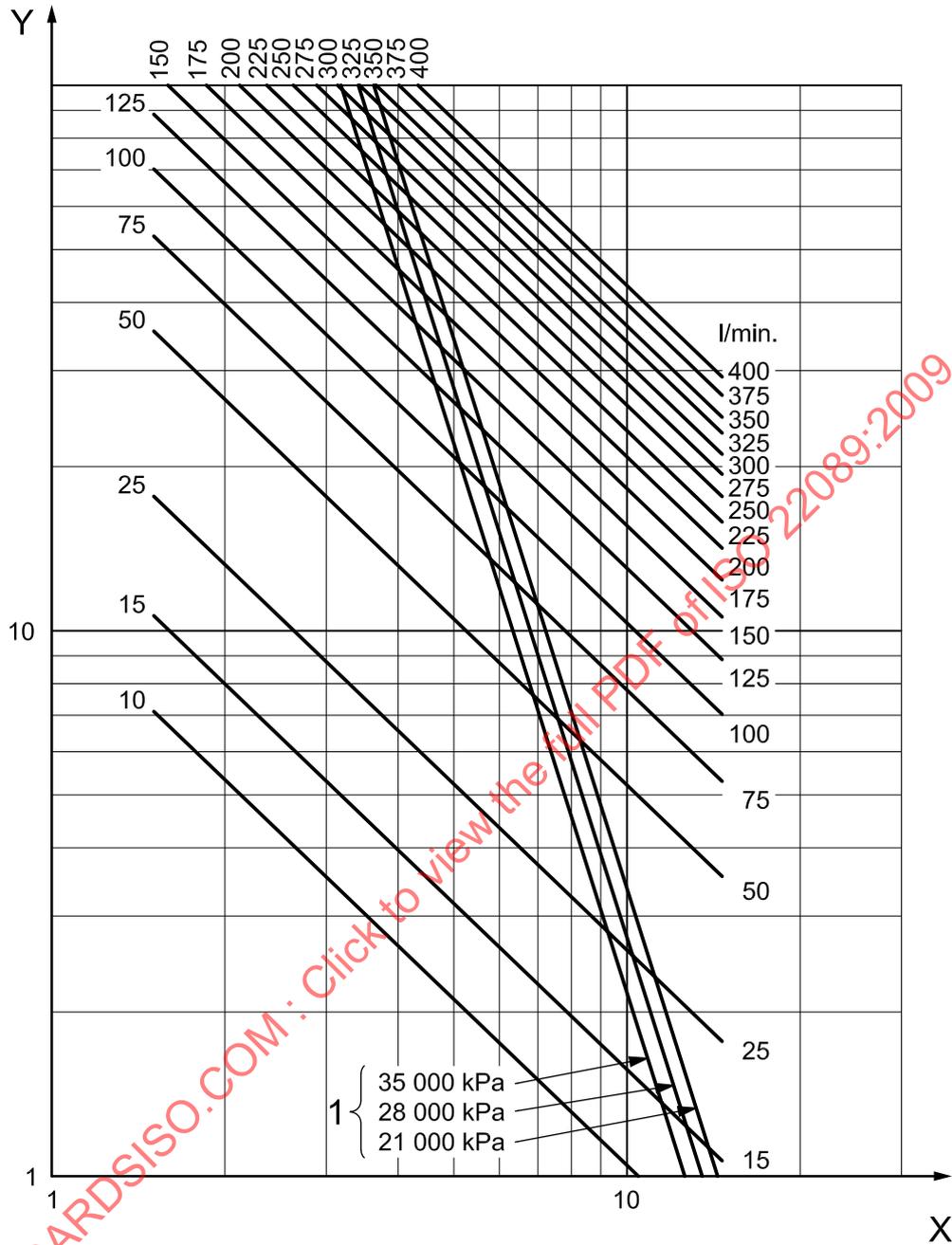
## 6.9 Speed and direction of rotation

### 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 ( $t_2$ ).

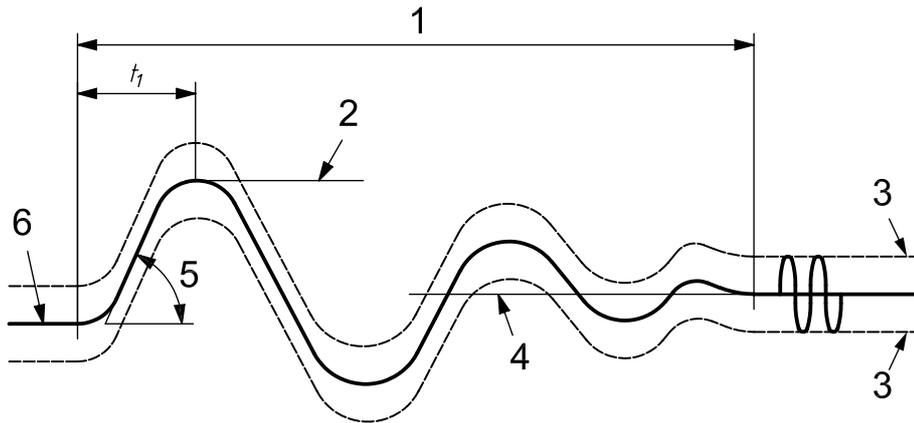
### 6.11.4 Stability (category C PTU)

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.

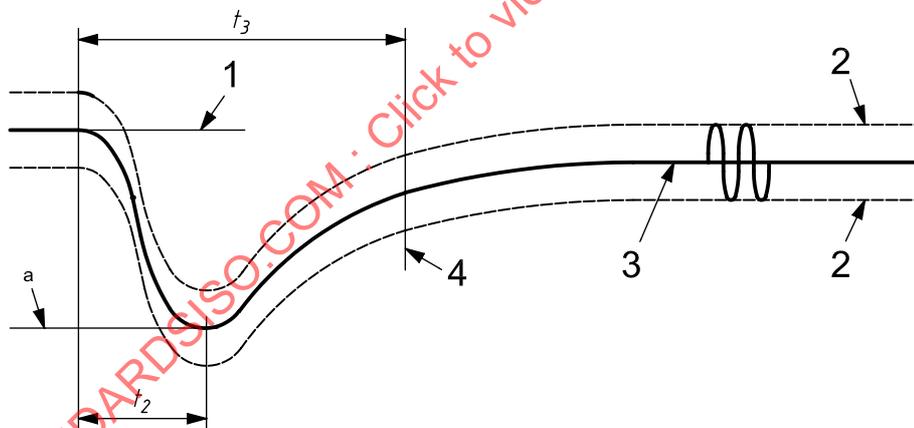
When required by the purchaser, the supplier shall provide adequate PTU pump and motor parameters to permit the system designer to integrate the PTU dynamic performance into the complete PTU/system analysis.



**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  $1,5 \times$  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  $1,5 \times$  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  $1,5 \times$  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  $1,5 \times$  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  $2,5 \times$  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  $2,5 \times$  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  $2,5 \times$  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  $2,5 \times$  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  $2,5 \times$  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  $1,5 \times$  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  $2,5 \times$  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:  $\pm 2\%$  of rated inlet pressure, but not more than  $\pm 34$  kPa;
- b) case pressure:  $\pm 2\%$  of rated case pressure, but not more than  $\pm 103$  kPa;
- c) discharge pressure:  $\pm 2\%$  of rated discharge pressure, but not more than  $\pm 207$  kPa;
- d) inlet/temperature:  $-57\text{ }^{\circ}\text{C}$  to  $+43\text{ }^{\circ}\text{C}$ , within  $\pm 3\text{ }^{\circ}\text{C}$ ,  
 $+43\text{ }^{\circ}\text{C}$  to  $+107\text{ }^{\circ}\text{C}$ , within  $\pm 6\text{ }^{\circ}\text{C}$ ;
- e) flow: within  $\pm 2\%$  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  $\leq 5 \mu\text{m}$  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  $\mu\text{m}$  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  $dP/dT$  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.