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(R) General Requirements for Powered Drive Units (PDUs) in Aircraft Cargo Systems

RATIONALE

This document is being revised to update requirements.

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1. SCOPE

This SAE Aerospace Information Report (AIR) is intended to assist the user (aircraft manufacturer/airline) in the following areas:

a. In the decision of whether or not to plan for the installation of a powered drive system in the cargo loading system (CLS) during the definition of the aircraft on-board cargo loading system.

b. If a powered drive system is decided upon, to provide general requirements to be considered during the preparation of component specifications for the powered drive units (PDUs) to be used. This provides a selection of criteria in order to obtain an optimum PDU for the application considered.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AS22759 Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy

AS50881 Wiring Aerospace Vehicle

2.1.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/

AC 43.13-1B FAA Advisory Circular; Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair

MIL-STD-810 Environmental Test Methods

2.1.3 RTCA Publications

Available from Radio Technical Commission for Aeronautics Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org

RTCA/DO-160 Radio Technical Commission for Aeronautics

2.1.4 EUROCAE Publications

Available from The European Organization for Civil Aviation Equipment, 17, rue Hamelin, 75116 Paris, France, Tel: +33 1 45 05 71 88, www.eurocae.org

EUROCAE ED-14 European Organization for Civil Aviation Electronics

2.1.5 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org

ISO 2678 Environmental test for aircraft equipment - Insulation resistance and high voltage test for electrical equipment

ISO 6858 Aircraft - Ground support electrical supplies - General requirements

2.2 DEFINITIONS

ULD - Unit Load Device. In this document ULD refers to the devices serving as standardized interfaces between the varied cargo handled by the operator and the systems established by the operator to handle the ground and air transport of the cargo. The ULDs in general have a flat base with either netting or an integral enclosure to contain and retain the cargo on top of the base. The ULD sizes and edge configuration are standardized to simplify operator system configuration and ensure interchange between different operator's systems.

CLS - Cargo Loading System. In this document CLS refers to the system installed into the bare aircraft in order to provide conveyance, guidance, drive, control and restraint of ULDs to be carried in the aircraft.

PDU - Power Drive Unit. Generally a self-contained Line Replaceable Unit attached to supporting structure; interfacing with the electrical system and providing motive force to the ULDs. The PDU may include additional functionality to raise/lower, brake, rotate to various drive directions, etc., depending on requirements established for the unit.

3. SYSTEM LEVEL CONSIDERATIONS AFFECTING PDU REQUIREMENTS

The design policies to be used in the cargo system and the interplay or tradeoffs between interfacing subsystems within the cargo system can have significant effect on the PDU requirements. The following are some significant areas that the prospective creator of a PDU specification should have determined in preparation for generating the detailed PDU specification discussed in later sections of this AIR.

- Main Deck or Lower Deck Cargo System
- Degree of Control of ULDs that is desired or required
- Degree of Automation to be attained via the combined PDU and Control Systems
- ULD Base Sizes, Types and Weights to be carried
- ULD Dynamic and Static Interface Considerations
- Cargo System Conveyance Angles in pitch and roll
- Conveying Resistance
- Cargo System Speed
- Cargo System Braking Rationale, Policy and Resulting Requirements
- Doorway Area Functionality and Resulting Concept and Requirements
- Power Off and Power Loss Functionality

- PDU Commonality
- Weight
- Environment
- Reliability, Availability and Maintainability System Level Requirements and Allocations to the PDU Subsystem
- Logical and Mechanical Integration with the Electrical Control and Wiring Subsystems
- Integration with the Aircraft Drainage Subsystem
- Integration with the Aircraft or CLS Mechanical Mounting Subsystem
- Verification Requirements

4. GUIDELINES FOR THE PREPARATION OF A PDU SPECIFICATION

4.1 General

This part of the document is to outline the technical requirements for PDUs utilized in a powered loading system. These PDUs transport ULDs on a cargo handling system (ball mats, roller tracks, swivel caster area, etc.) during loading and unloading by means of frictional contact between the drive element (transport roller) and the bottoms of the ULDs.

The type of PDUs addressed here are individual PDUs acting together by means of an electrical control system, but not by means of any shafts, belts, chains, bars, etc. The PDUs either can be compatible with the cargo handling system height of 38 to 76 mm (1.5 to 3.0 in) or have larger heights requiring mounting provisions which penetrate the floor.

Thus, systems such as shuttle bar, telescopic bins, and belt systems are not covered by this document.

In the event of a decision in favor of a powered drive system using the type of PDU described, a PDU specification must be prepared. The following requirements are addressed to assist in this specification development:

a. Operation

b. Installation, dimensions

c. General technical requirements

d. Weight

e. Power requirements

f. Reliability

g. Maintainability

h. Environmental conditions

i. Testing

The technical requirements for the PDU resulting from these criteria depend on the respective application. In the following, the technical requirements, design possibilities, as well as basic calculations to be considered are explained in detail so that they can be used appropriately in the generation of the component specification.

4.2 Operation

The tractive force for all the types of PDUs addressed in this document is provided by an electric motor and transferred to a drive roller via a gear reduction system. The drive roller transfers the tractive force via friction contact with the bottom of the ULD.

Power supply, which can be switched either directly in the PDU or by external elements, depending on the design of the electric control system, is as follows:

a. Operating power: 115/200 V 400 Hz 3 Ph AC, or other power derived or conditioned from this source, to drive the PDU motor and/or brake-clutch elements has been the standard in the past. Aircraft electrical power is a rapidly developing area and may provide advantages to or require compatibility from the PDU in the future. A potential future power source is 230/400 V 400 Hz 3 Phase AC (reference ISO 6858 developments). Another potential development is variable frequency power.

b. Control power: 28 V DC, or other signal-level lines derived from or conditioned from this or the AC source, to communicate with the PDU as required.

c. Ground: Case ground

The PDUs must be capable of transporting the ULD in any specified direction under any specified condition. After start-up, the PDUs must transport the ULDs at a constant speed within the system. For PDUs currently on the market, this varies between 0.178 to 0.305 m/s (35 and 60 ft/min) and is related to the shock loads which the aircraft structure and the latch and guiding components of the cargo loading system are capable of absorbing. Further, attention should also be directed to the transfer speed of the drive system on the external loaders, which in most cases is 0.305 m/s (60 ft/min). However, speeds of 0.203 to 0.457 m/s (40 to 90 ft/min) are also used. The specified drive speed variation should not exceed a tolerance of ±0.025 m/s (±5 ft/min). Unfavorable environmental conditions, such as moisture and dirt contamination of the ULDs as well as a normally expected pitch and roll angles of the system should not affect the uniform drive process. Recommended pitch and roll angles to be used are 2.5 and 1 degree respectively.

Reversal of direction while transporting a ULD must also be possible, to operate the PDU as a brake for example, without detrimentally affecting the PDU. Any loss of contact between the PDU and ULD should be limited to no more than 0.5 s during drive direction reversal.

The following principles of operation are currently in use:

4.2.1 Principle 1 - Self-Lifting PDU

For this type of drive, the drive roller is lifted automatically when the motor has been switched on and is lowered automatically after switch-off.

In its neutral position, the PDU is below the system transportation level.

The self-lifting PDU permits transportation of ULDs within the doorway loading area of the cargo compartment where the transporting direction is changed from longitudinal to transverse and vice versa.

In the case of power failure, the cargo compartment can be loaded and unloaded manually without PDU contact due to the fact that the PDUs are automatically lowered below the system transportation level.

PDU self-lift mechanisms, which may differ considerably from drive type to drive type, produce a lifting force to enable the PDU roller to act on the bottom of the ULD. Special attention must be paid to driving action sufficient under all possible environmental conditions (dirt, moisture, base deflection) to ensure the required tangential force for transportation of the ULD without slippage of the drive roller.

Also, attention should be given to the PDU lift and lowering times with particular attention to retract time in doorway areas. Recommended criteria are as follows:

a. Lifting process: 1 s maximum

b. Lowering process: 1 s maximum

c. Lifting height of drive roller: Typical values range from 8 mm (0.315 in) to 12.7 mm (0.50 in) above system transportation level. It should be noted that empty or lightly loaded ULDs may be lifted by the PDUs and this potential cause of interference with the cargo restraint system should be designed for and/or minimized.

d. Reversal of drive direction: 2 s maximum

e. Electrical Power Loss: Requirements should address PDU behavior in case of electrical power loss.

4.2.2 Principle 2 - Nonretracting PDU

The drive roller of this type of PDU is always above the system transportation level and is constantly engaged with any ULD passing over it.

Therefore, the nonretracting PDU can only be installed in the longitudinal area of the cargo compartment outside of the doorway areas (i.e., cannot be used where transverse as well as longitudinal transportation takes place).

Since the drive roller of this type of PDU is always in contact with the ULD and the design of the PDU is relatively simple it is common to incorporate a brake in these PDUs.

In the event of an electrical power loss or PDU electrical failure, it must be possible to disconnect or lower the drive roller, or the PDU must be back-driveable manually, for manual loading and unloading of the cargo compartment (maximum back-driving force 12 daN (27 lbf) per PDU).

Maximum height of drive roller: Typically from 8 mm (0.315 in) to 12.7 mm (0.50 in) above system transportation level. Note that empty or lightly loaded ULDs may be lifted by the PDUs and this potential cause of interference with the cargo restraint system should be designed for and/or minimized.

Consideration should be given to potential conditions where a mismatch of ULD velocity and PDU drive speed could occur and ensure PDU design addresses this as required.

Consideration should be given to ULD base edge deformation to ensure the PDU design addresses potential damage from this source.

4.2.3 Principle 3 - Self-Lifting PDU with Braking Functions

Lift function is similar to that of the PDU as per principle 1 except that retraction after drive roller power is turned off is separately controlled (such as via a lift-hold clutch or other means) to maintain roller to ULD contact and it also incorporates a braking device to keep the ULDs in position preventing any undesired movement.

The PDU must produce a tangential braking force at the drive roller equal to or larger than that required keeping the ULDs in position.

The tangential braking force must build up automatically and rapidly (<1 s) when the electric drive command is taken away from the PDU. The braking force must be automatically released when: the drive command is given to the PDU, when the lift-hold/brake command is removed or when system power is cut off (due to manual override or system shutdown).

Requirements should address PDU behavior in case of electrical power loss or PDU electrical failure.

4.2.4 Principle 4 - Smart (Steerable) PDU

The drive roller of this type of PDU is capable of operating in different directions. For this purpose, it must have a turning device to rotate it to change to the other direction(s).

These directions could be the in/out and forward/aft directions only, but discrete positions in between these main directions are possible as well, if required.

For turning from one direction to the other, the PDU may be lowered below the transportation level; however, in some circumstances it may be desired that the drive wheel remain raised and in contact with the ULD during the turning cycle to prevent ULD movement.

In the event of a power failure, it must be possible to back-drive, disconnect or lower the drive roller for ease of movement of ULDs by manual means.

Maximum height of drive roller: Typically from 8 mm (0.315 in) to 12.7 mm (0.50 in) above system transportation level. Note that empty or lightly loaded ULDs may be lifted by the PDUs and this potential cause of interference with the cargo restraint system should be designed for and/or minimized.

4.3 Installation

With the PDU in nonpowered, retracted condition adequate clearance should be provided from the conveyor plane to the PDU housings and drive rollers to avoid damage, premature wear or nuisance drag. Features, such as lead-in angles, wear resistant surfaces, and adjacent support elements, may all assist meeting this requirement. A general design goal would be a minimum clearance of 5 mm (0.20 in), but the best approach is to rely on similar successful in-service installations or testing of representative hardware. These aspects of the design are especially important in the doorway area where ULDs may approach the PDU from the lateral direction.

Installations using PDUs designed to fit within the vertical space between the conveyor plane and the floor panels/beams (typically about 50.8 mm (2.00 in) vertical envelope) represent another situation where care is advised, since space is at a premium.

Another situation to consider is the case of a ULD approaching a running (lifted or nonretracting) PDU which may expose more surfaces to the ULD edge.

System supporting devices such as ball units, transport rollers, swivel casters, etc., should be positioned as near the PDUs as possible to minimize ULDs "sagging" below the system transportation level and dragging in the PDUs. Wear resistant surfaces are also desirable on PDU housing in areas that are vulnerable to ULD sag and drag.

The other dimensions (length/width) differ considerably, depending on the design of the respective cargo loading systems.

The PDUs may be installed in seat or roller track sections or other suitable floor mounted support structure.

4.4 General Technical Requirements

4.4.1 Heat Dissipation

The PDU should be provided with thermal protection to prevent overheating of the PDU. The thermal protection device shall be connected in such a manner to simultaneously disconnect all three powered phases and should automatically reset after reduction of temperature to a safe level.

4.4.2 Wiring

All electrical cables should meet the requirements of the aircraft manufacturer's specification with regard to flammability, smoke, toxicity and durability.

Commonly referenced requirements are contained in AC 43.13-1B Chapter 11, AS50881 and AS22759.

Requirements vary depending on whether the cabling is protected or open (described in the above documents).

Generally, aircraft wiring requires copper conductors coated with tin, silver or nickel and prohibits PVC insulation.

4.4.3 Electrical Connection

The connection can be made directly at the PDU housing or by using a "pigtail". The motor circuit should be electrically isolated from the unit case and motor frame. Care is to be taken to arrange the connectors so that they cannot be damaged by ULDs, loading personnel, or by direct influence of dirt and moisture.

If used, a pigtail connection should consider routing and installation fool proofing as well as potential flexing over the range of motion during the operation and servicing of the unit.

4.4.4 Electrical Bonding

Electrical continuity between the equipment and the structure shall be achieved by applying an appropriate conductive finish at the attachment points. The PDUs case or frame shall be connected to aircraft ground (structure) in a required secondary bonding path.

The primary ground connect conductor shall have an electrical current capacity greater or equal to that of any input power to the PDU.

4.4.5 Dielectric Strength

The PDU must be designed so as to prevent spark over and puncture between the parts insulated from each other, at a voltage of:

a. 500 V DC for 28 V DC circuits

b. 1500 V AC for 115 and 115/200 V AC circuits nominal

The proof voltage is to be applied progressively in about 20 s and maintained for 1 min.

4.4.6 Insulation Resistance

The insulation resistance between any two points of an item of equipment, which are not electrically connected to each other, shall be at least 100 MΩ (ISO 2678). This measurement is to be made on complete item of PDU at a voltage of:

a. 45 V DC for 28 V DC circuits

b. 500 V DC for 115 V AC circuits

4.4.7 Electronic Environment

a. Voltage Spike Susceptibility: RTCA/DO160, Chapter 17, Category A (or equivalent)

b. Audio Frequency Conducted Susceptibility - Power Inputs: RTCA/DO160, Chapter 18, Category A (or equivalent)

c. Inducted Signal Susceptibility: RTCA/DO160, Chapter 19, Category Z (or equivalent)

d. Radio Frequency Susceptibility: RTCA/DO160, Chapter 20, Category U (or equivalent)

e. Emission of Radio Frequency Energy: RTCA/DO160, Chapter 21, Category M (or equivalent)

f. Lightning Indirect Effects: RTCA/DO160, Chapter 22 (as required for aircraft compatibility)

4.5 Tractive Force Requirements

As a basis for calculating the tractive force required to transport the ULDs in the system, the following definitions and criteria are provided:

The maximum tractive force (Fmax) is the force required to ensure a satisfactory transportation of ULDs in the system even under the most unfavorable conditions.

The rated tractive force (Frat) is the average force at which the PDU must comply with the power consumption and transportation speed requirements. (This value shall also be used for tests during the PDU qualification and prior to shipment of the PDUs (quality control)).

The conversion of the specified tractive force to the power (situation between drive roller and bottom of the ULD, contact force, tractive force) to be supplied by the PDUs in consideration of the respective drive function principle, the influences by the different ULDs (materials, floor stiffness) dirt and moisture, must be carried out by the equipment supplier.

In determining the tractive force required, the following factors and criteria should be used:

a. Type of the mechanical cargo loading system with the conveying elements used in it (ball mats, roller tracks, swivel caster, guiding elements)

b. Maximum gross weight of the ULD to be transported

c. Type and size of the ULD to be transported

d. Pitch and roll attitudes of the aircraft system (statically) and as influenced by the loading/ unloading sequencing

e. Number of PDUs which are to be engaged under a ULD at the same time

f. Inertial force of the ULD to be accelerated

g. Environmental influences (moisture, dirt)

The maximum tractive force Fmax, is:

$$\text{Fmax} = \frac{F(fr) + F(in) + F(incl)}{n} \qquad \text{(Eq. 1)}$$

where:

Fmax = Maximum tractive force (N)

F(fr) = Frictional resistance (N)

F(in) = Inertial force (N)

F(incl) = Inclination force (N)

n = Number of PDUs

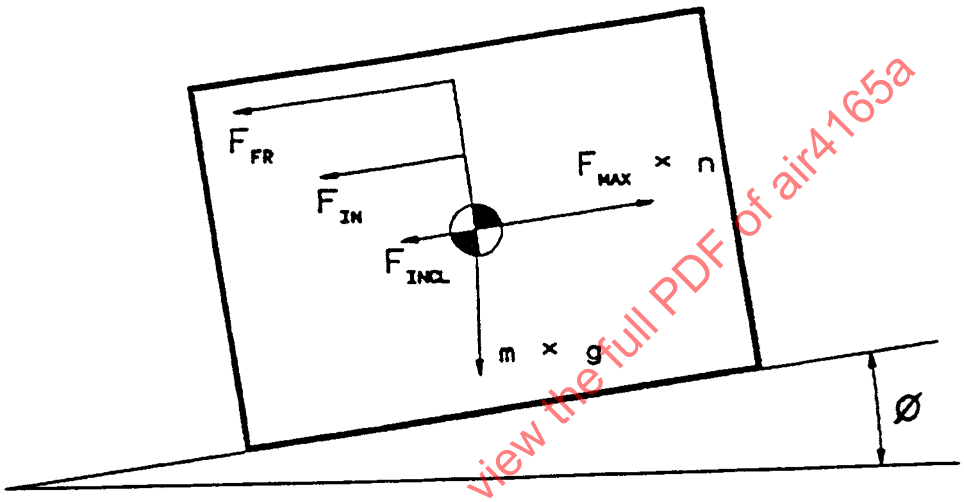

FIGURE 1

The friction force F(fr) is calculated according to the following formula:

$$F(fr) = m \times g \times \cos\phi \times \mu R \quad \text{(Eq. 2)}$$

where:

m = Maximum gross mass of ULD (kg)

g = Gravity acceleration (9.81 m/s^2)

ϕ = Maximum cargo loading system inclination

μR = Friction coefficient

In this formula the maximum gross mass of the ULD and the gravity acceleration are specified values. The value cosϕ approximates 1 due to the small cargo compartment inclination (<5 degrees). Therefore, the value cosϕ can be neglected.

Only the determination of the friction coefficient causes problems. This depends on the configuration and condition of the mechanical cargo loading system and also varies with the conveying elements used in it (ball mats, swivel casters, roller track, etc.) type, size, condition of the ULDs to be transported, and the environmental conditions (moisture, dirt, etc.).

Unfortunately, comprehensive investigations have not yet been carried out in this field so that reference cannot be made to a specific document with the appropriate data. However, a few companies have carried out investigations for certain applications and although the data varies somewhat, the following values are generally accepted as conservative approximations:

a. Ball mat area: $\mu R = 0.02$

b. Roller track area: $\mu R = 0.01$

c. Swivel caster area (rollers aligned): $\mu R = 0.01$

d. Swivel caster area (rollers not aligned, ULD unguided): $\mu R = 0.03$

e. Swivel caster area (rollers not aligned, ULD guided): $\mu R = 0.05$

The values apply to all metal pallets.

The inertial force F(in) of the ULDs is calculated as follows:

$$F(in) = m \times a \quad \text{(Eq. 3)}$$

where:

m = Maximum gross mass of ULD (kg)

a = Acceleration of the ULD (m/s^2)

As an approximation, an acceleration of 0.1 m/s^2 can be assumed. The maximum tractive force to be determined is only insignificantly influenced by the inertial force.

The inclination force F(incl) due to the system inclination is calculated according to the following formula:

$$F(incl) = m \times g \times \sin \phi \quad \text{(Eq. 4)}$$

where:

m = Maximum gross mass of ULD (kg)

g = Gravity acceleration (9.81 m/s^2)

ϕ = Maximum cargo loading system inclination

The value determined according to Equation 1 represents the maximum tractive force theoretically required. To ensure safe transportation of the ULDs and account for such additional friction resistance on latches or guiding elements, sluggishness of transportation elements resulting from damage or contamination, damaged or different types of ULDs, the value determined should be increased by the safety factor of k = 1.25.

This results in the following formula for calculating the maximum tractive force:

$$\text{Fmax} = \frac{(m \times g \times \mu R) + (m \times a) + (m \times g \times \sin\phi)}{n} \times k \tag{Eq. 5}$$

$$\text{Fmax} = \frac{k \times m}{n} \times (g \times \mu R + a + g \times \sin\phi) \tag{Eq. 6}$$

where:

k = Safety factor (1.25)

m = Maximum gross mass ULD (kg)

n = Number of PDUs

g = Gravity acceleration (9.81 m/s^2)

μR = Friction coefficient

a = Acceleration of the ULD (0.1 m/s^2)

ϕ = Maximum cargo loading system inclination

The rated tractive force F(rat) is calculated according to the following formula:

$$F(\text{rat}) = \frac{F(\text{fr}) + F(\text{incl})}{n} \tag{Eq. 7}$$

where:

F(rat) = Rated tractive force (N)

F(fr) = Friction resistance (see form. 2) (N)

F(incl) = Inclination force (see form. 4) (N)

n = Number of PDUs

$$F(\text{rat}) = \frac{(m \times g \times \mu R) + (m \times g \times \sin\phi)}{n} \tag{Eq. 8}$$

$$F(\text{rat}) = \frac{m \times g}{n}(\mu R + \sin\phi) \tag{Eq. 9}$$

where:

m = Maximum gross mass of ULD (kg)

n = Number of PDUs

g = Gravity acceleration (9.81 m/s^2)

μR = Friction coefficient

ϕ = Maximum (normally expected) cargo loading system inclination

4.6 Reliability

4.6.1 Reliability Requirements

An important criteria in the design of the PDU is the reliability during its operation in the aircraft. The PDU reliability should meet industry standards and the requirements of the airlines for safe and dependable in service operation.

When establishing the reliability requirements the following points are to be considered:

4.6.1.1 Useful Life

Useful life is the period with a constant PDU failure rate and during which the characteristic values and requirements defined in the specification are complied with, if the PDUs are properly handled and the maintenance provisions are observed.

To avoid expensive replacement actions the useful life required for the PDU should correspond to the specified service life of the total aircraft.

4.6.1.2 Mean Cycle Between Failure (MCBF)

MCBF is a measure of performance and calculated by dividing the sum of the duty cycles of all the units by the number of unit failures that occurred during the same period. Duty cycle is defined as one complete loading and unloading of a cargo compartment.

Typical PDU MCBFs range from 20 000 to 50 000 aircraft load/unload cycles or as specified for the particular aircraft.

MCBF values for failure modes which result in failure of the PDU in the extended position should be two (2) to three (3) times higher than the above.

4.6.2 Reliability Data

Early in the preliminary design stage, PDU reliability predictions should be calculated to determine if reliability requirements will be achieved.

This information is normally provided in the form of a failure analysis as defined in 4.6.3. A justification document such as failure mode effects analysis (FMEA) should also be generated.

4.6.3 Failure Mode Effect Analysis (FMEA)

This is essentially based on a breakdown of the PDUs into functional components. This breakdown must be continued to the level of independent failures and detail components, as required to demonstrate that the reliability objectives are met. The links between the different functional components must be clearly defined.

It is the PDU supplier's responsibility to justify the component failure rates that are assumed in the calculations.

The following must be included in this FMEA or related document(s):

a. Failures rates of every component in the functional PDU breakdown

b. Failures connected with the location of the various components within the PDU.

c. The analysis of the effects of various component failures on the performance of the PDU.

4.6.4 In-Service Experience

If a nearly identical PDU has accumulated sufficient in-service experience in a similar environment, a report of the PDU failures and cycles showing compliance with the MCBF requirement may be used to substitute for some of the analyses of the FMEA. All differences between the proposed and baseline PDU, and their effect on reliability shall be analyzed and reported in the FMEA.

4.7 Maintenance/Maintainability

Maintainability is defined as the characteristics of material, design and installation that determine the extent of maintenance expenditures. This includes time, personnel skill, test equipment, technical data, and facilities to accomplish operation objectives in the operational environment.

Quantitatively, maintainability is expressed as the period of time within which the maintenance action can be performed with a specified probability using defined resources and prescribed procedures.

The design of the PDU shall allow on-line maintenance (as a line replaceable unit (LRU)). No scheduled maintenance (inspection, overhaul, lubrication, etc.) shall be required.

The PDU design shall allow repair, calibration and operational testing without the use of special tools and with a minimum of test equipment and facilities.

It shall be possible to carry out normal maintenance with standard commercial tools and quick interchangeability of defective transport rollers shall be ensured without PDU removal from the aircraft.

4.8 Environmental Conditions

4.8.1 General

To establish appropriate environmental categories for the equipment type, aircraft type, and location as well as for test requirements, documents presently available and used by the equipment procuring agencies or equipment manufacturers are:

a. MIL-STD-810

b. RTCA/DO-160

c. EUROCAE ED-14

Since the special requirements for equipment may vary according to aircraft type or location, only the general environmental conditions to be considered are described in the following paragraphs (with reference to the corresponding chapter in the RTCA).

4.8.2 Temperature

The PDU shall be designed to ensure dependable operation in ambient compartment temperatures ranging from -40 to +70 °C (-40 to +158 °F).

It shall not be damaged at survival temperatures ranging from -55 to +85 °C (-67 to +185 °F).

See RTCA/DO-160, Chapter 4.

4.8.3 Altitude/Pressure

The PDU must operate at altitudes ranging from -1000 ft below sea level to 10 000 ft above sea level.

The PDU shall be designed to withstand without damage pressures from 189 mbar up to 1823 mbar abs with a pressure change from 752 mbar (8000 ft) to 189 mbar (40 000 ft) being effected within 15 s. At this pressure, however, the PDU is in the nonoperating mode.

See RTCA/DO-160, Chapter 4.

4.8.4 Humidity, Waterproofness, Sand, Dust

The PDU operates in locations which may be subjected to water mixed with sand and dust, brought into the cargo compartments together with the ULDs or blown through the cargo door by the wind.

These impingements shall not cause any deterioration of the performance and function or cause corrosion of the PDU. Refer to:

a. RTCA/DO-160: Chapter 4, Humidity

b. RTCA/DO-160: Chapter 10, Waterproofness

c. RTCA/DO-160: Chapter 12, Sand and Dust

Since no test procedure is given in the RTCA/DO-160 for this combination of environmental conditions, it is necessary to define a special test procedure, which will consider all requirements of above chapters.

4.8.5 Fungus Resistance

The equipment materials used shall be capable of withstanding any exposure to fungus.

See RTCA/DO-160, Chapter 13.

4.8.6 Shocks

The PDU shall be designed to withstand without damage all impact forces generated during loading and unloading procedures.

See RTCA/DO-160, Chapter 7.

4.8.7 Vibrations

The PDU shall be designed to withstand the vibration levels and frequency compositions as encountered in flight and in ground operations.

See RTCA/DO-160, Chapter 8.

4.8.8 Salt

Influences of salt or humid salt air shall not cause the PDU to corrode or its function to deteriorate.

See RTCA/DO-160, Chapter 14.

4.8.9 Pollution

The PDU shall not be adversely affected when exposed to hydraulic fluids, oils, solvents, detergents and materials that may spill from ULDs (including animal urine) such as may normally be encountered in the cargo compartment during worldwide operation.

See RTCA/DO-160, Chapter 11.

5. QUALIFICATION TESTS

5.1 General

Qualification tests shall be performed to verify capability and compliance of the PDU with the specified requirements as follows:

a. The supplier shall prepare a "Qualification Test Procedure" (QTP) for all tests mentioned. The QTP has to be submitted to the purchaser for approval at least 6 weeks prior to the beginning of the tests. Any change of the procedure shall be reviewed and approved by the purchaser.

b. The tests shall be conducted by the supplier in accordance with the QTP.

   At the beginning of the tests, conformance of the test PDU with the future series PDUs shall be justified by the supplier.

   Every deviation of the test PDU from the future series PDUs shall be listed by the supplier with a written statement of the effects such deviations have on the test results. Validity of the test PDU should then be agreed by the purchaser.

   If in the course of performance testing important deviations are disclosed on individual PDUs, the supplier shall prove by repeat qualification tests that the modifications, necessary to exclude such deviations in future, are sufficient to meet the requirements.

c. The test results shall be recorded in a "Qualification Test Report" (QTR).

d. Within the complete QTP the supplier shall define the areas which are intended to be demonstrated by similarity.

   The supplier shall submit to the purchaser all technical documents necessary to demonstrate the actual state of similarity as part of the QTP.

e. The purchaser reserves the right at any time to witness tests to be performed at PDU supplier's or their subcontractor's sources.

5.2 Function Tests

Function tests shall be carried out before and after each required test. Unless otherwise specified, these tests shall be made within the following ambient conditions:

a. Temperature: +15 to +35 °C (+59 to +95 °F)

b. Relative humidity: Not greater than 85%

c. Ambient pressure: 84 to 107 kPa (equivalent to +5000 to -1500 ft/+1525 to -460 m)

As a minimum, these function tests shall involve the examination and measurement of the following parameters:

a. Visual inspection of the PDU

b. Insulation resistance test

c. Function tests without loads

d. Function tests with required rated tractive force

e. Transportation speed at rated tractive force

f. Determination of maximum tractive force

5.3 Environmental Condition Tests

It shall be justified that the PDU and its function will not be negatively influenced by the environmental conditions mentioned under 4.8 of this document.

5.4 Performance and Endurance Tests

To justify the required performance data of the PDU, tests on a supplier mock-up, representing a part of the relevant cargo loading system, shall be carried out.

At least four PDUs shall be subjected to a useful life test and to overload tests that show the performance limits of the PDU.

The tests shall be performed with ULDs in a serviceable but used, rather than new, condition exhibiting the maximum allowable base deformation and maximum allowable uneven load distribution per relevant ULD specifications.

The following tests shall be carried out:

a. Endurance test for demonstration of the PDU useful life. Since the required useful life very much depends on the respective application, the load cycles which have to be justified must be defined in each case.

   For the definition of the load cycles it may be considered that ULDs will only be loaded up to 66.7% of the maximum allowable gross mass in 95% of all loading processes. These values are based on service experience.

b. Determination of tractive force on wet and dry ULD bottoms.

   The load applied to the PDU shall be increased in steps up to stall or scrubbing of the PDU.

c. Continuous operation of a PDU under a latched ULD.

d. Determination of PDU behavior on transportation of ULDs with uneven bottoms.

e. Operation of a PDU under a ULD with the direction of rotation constantly being reversed.

f. If a PDU frequently goes into stall or scrub under normal procedure (for instance during transportation of loaded ULDs against latches or guides), it must be demonstrated by suitable tests that such PDU behavior does not reduce the MTBF.

6. NOTES

6.1 A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.