Requirement Specification for BepiColombo MPO Propellant Tank

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1 INTRODUCTION AND SCOPE

1.1 Introduction

BepiColombo is an Interdisciplinary Cornerstone Mission to the planet Mercury, in collaboration between ESA and ISAS/JAXA of Japan. It consists of two scientific orbiters, the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO), which are dedicated to the detailed study of the planet and of its magnetosphere.

The mission will commence in 2013 with the launch of the Mercury Composite Spacecraft (MCS) on Soyuz Fregat. Following a long interplanetary cruise, powered by the Mercury Transfer Module (MTM), the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO) will be delivered to their planetary orbits in 2019. The nominal mission will be completed by the end of 2020 with a possible extension of one more year.

The key challenges of the mission are to provide a safe transfer of the spacecraft carrying the scientific instruments to Mercury and to ensure successful science operations of both orbiters under extreme environmental conditions.

This document specifies the performance, design, and test requirements for the Propellant Tank Assembly for use on the BepiColombo Mercury Planetary Orbiter (MPO) Chemical Propulsion System.

This document outlines the unit/equipment/subsystem/system level environment and the test requirements for the BepiColombo satellite.

EMC including EMC test requirements and Magnetic requirements are specified in dedicated BepiColombo EMC Requirement Specification, BC-ASD-SP-00033.

Spacecraft equipment units will be simulated in different test set-up configurations with the necessary level of fidelity which requires a controlled flow of information from the unit subcontractor to test bench engineering who guides/verifies programming of the simulation model of the unit.

The simulation model of an on-board unit will be established according to functional and ICD specification documentation of the unit subcontractor who is responsible for correctness of unit ICD and numerical correctness of functional model.

The information required as input to start the programming of the simulation models as well as the resulting requirements on the unit supplier are identified in a dedicated document, "Guidelines for preparation of equipment and subsystem functional simulation models", BC-ASD-TN-00045.

The mission scenario update as per BC-EST-CC-04073 is not yet implemented (extension of nominal lifetime for extended operational life to 8.6 years). This will affect the radiation requirements defined in Section 6.

1.2 Spacecraft Reference Frame

The MCS co-ordinate system is shown in Figure 1.2-1.

The +Y axis is nominally sun-pointing.
Figure 1.2-1: MCS Co-ordinate System

The MPO co-ordinate system is shown in Figure 1.2-2.
The +Z axis is nominally to nadir.
The identified flight direction in +x and -x is applicable for final operational orbit around Mercury.
1.3 Scope

This document contains the contractually relevant requirements and constraints for the BepiColombo project. This includes:

- The general testing and verification requirements

Requirements within this document are shown in an italic font. Each requirement is preceded by a summary line that contains the following fields, delimited by "/".

- Doors Requirement Number
- Created From
- Verification Method

The Doors Requirement Number has the form ET-xxx where xxx is a unique number assigned consecutively.

The Created From field shows the parent requirement or "Created" if the requirement is created at this level.

The Verification Method codes are as follows:

- R - Review,
- A - Analysis,
- I - Inspection,
- T - Test.

If Tables are considered as part of the requirement they are referenced clearly in the text and inserted after and separated from the requirement Table and are managed as free text attached to the identifier requirement.

The trace to the upper level requirements (Upper Links), shall be managed using the following format:

- AAA-NNN where AAA is a label associated to the upper document and NNN the requirement identifier of this upper level.
- or CREATED keyword if the requirement has no link with upper level.

All document elements not presented in the format explained above are not requirements and will not be verified or tracked.
2 DOCUMENTATION

The following documents form a part of this specification to the extent specified herein. In the event of conflict between this specification and any of the applicable documents referenced below, this conflict shall be notified to the Customer.

2.1 Applicable Documents

Throughout this specification Applicable Documents are referred to in the text as AD(x).

AD(a) Not Used
AD(b) Product Assurance Requirements For Subcontractors BC.ASU.RS.00018
AD(c) General Design and Interface requirements BC.ASD.SP.00001
AD(d) Environmental and Test Requirements BC.ASD.SP.00002

2.2 Reference Documents

Throughout this specification Reference Documents are referred to in the text as RD(x).

None

2.3 Standards

Throughout this specification Standards are referred to in the text as SD(x).

SD(a) Hydrazine MIL-P-26536
SD(b) Nitrogen Tetroxide (MON-1 and 3) MIL-P-27401
SD(c) Helium MIL-PRF-27407B
SD(d) Nitrogen MIL-PRF-27401D
SD(e) Argon Gas MIL-A-18455C
SD(f) HFE7100 Cleaning Fluid MIL-B-81744A
SD(g) Isopropyl Alcohol (Propan-2-ol) TT-I-735A
SD(h) Deionised/Demineralised Water MSC-SPEC-C-20C
SD(i) Dissimilar Metals MIL-STD-889B
SD(j) Space Engineering - Fracture Control ESSS-E-30-01A
SD(k) Standard General Requirements for Safe Design and Operation of Pressurised Missile and Space Systems ESSS-32-02
SD(l) Inspection, Liquid Penetrant MIL-STD-6866
SD(m) Radiographic Inspection MIL-STD-453
SD(n) Titanium and Titanium Alloy bars (rolled or forged) and Reforging Stock, Aircraft Quality MIL-T-9047
SD(o) Product Cleanliness Levels and Contamination Control MIL-STD-1246
SD(p) Design Criteria for Controlling Stress Corrosion Cracking MSFC-SPEC-522
SD(q) Radiographic Standard for Classification of Fusion Weld Discontinuities NAS-1514
SD(r) The Determination of Particulate Contamination in Liquids ARP-598
3 REQUIREMENTS

3.1 Definition

The PTA shall be used to provide gas free propellant (either fuel, N₂H₄, or oxidiser, MON) to a primary thruster set, T₁, and Reaction Control Thruster set, T₂ (also referred to as RCT), on demand commencing from launch vehicle separation to the end of life of the spacecraft, under the demand conditions described in Section 6.

As described in the Appendix, the requirement is for a three axis stabilised transfer orbit.

The PTA shall be a Cassini domed Titanium Tank, with a skirt mounting.

A propellant management device, PMD, shall be placed in this part to manage the propellant for the BepiColombo mission.

3.2 Performance Requirements

OPRP-268/Created/R

The PTA shall be designed to meet the following performance requirements.

3.2.1 Tank Pressure

OPRP-2345/Created/R

The PTA shall be designed to the following pressure requirements.

Note: All pressures specified in this document are pressures above local ambient unless otherwise stated.

The maximum expected operating pressure (MEOP) is 20 bar.
This is the maximum pressure at which the system actually operates.

The regulated operating pressure is 17.5 bar.
This is the pressure delivered by the pressure regulator, including its tolerance.

The maximum collapse pressure (MCP) achievable by the proposed PTA shall be stated by the supplier.
This is the maximum differential pressure between external and internal side of Tank shell.

The minimum internal pressure is then: \( P_{\text{min (inside)}} = P_{\text{outside}} - \text{MCP} \)

The Proof Factor is 1.31 at 20°C.
This is the multiplying factor applied to MEOP to obtain Proof Pressure, for use in acceptance testing.
Note: Must not be less that 1.25 at maximum operating temperature.

The Burst Factor is 1.5 at 20°C.
This is the multiplying factor applied to MEOP to obtain the design Burst Pressure. Burst Factor is synonymous with ultimate pressure factor.

3.2.2 Operating/Test Media

OPRP-292/MPB-4728,Derived/R

The requirements related to operating media included in the following applicable documents shall be complied to:

- Gaseous He SD(c)
- Hydrazine liquid and vapour SD(a)
- MON liquid and vapour SD(b)
OPRP-297/MPB-4728, Derived/R

The requirements related to test media included in the following applicable documents shall be complied to:

- Gaseous Nitrogen SD(d)
- Gaseous Argon SD(e)
- HFE7100 SD(f)
- Isopropyl Alcohol, IPA* SD(g)
- Deionised/demineralised Water SD(h)

*Note: * the pressurisation of IPA in contact with Titanium or Titanium alloys to greater than 6 bar gauge is prohibited in the case of Tanks used for subsequent flight.

OPRP-305/Created/R

The use of any other test media requires the same level of compatibility with the PTA and Customer approval.

3.2.3 Fluid and Gas Temperatures

OPRP-308/Created/T,R

Fluid and gas temperatures shall comply with the following requirements:

(a) Helium and Tank shell **operating** temperatures shall be between -50 °C and 50 °C,
(b) Helium and Tank shell **acceptance** temperatures shall be between -55 °C and 55 °C,
(c) Helium and Tank shell **qualification** temperatures shall be between -60 °C and 60 °C,
(d) Propellant **operating** temperature shall be between 0 °C and 50 °C,
(e) Nitrogen hot gas purge up to 65 °C at a maximum pressure of 10 bars.

3.2.4 Propellant Flow Rates

OPRP-316/Created/R

The PTA shall be compatible with the flow rates detailed in Section 4.4.13.

3.2.5 Expulsion Capability

OPRP-320/MPB-4880/SRD-1874, Derived/T

A gas free liquid volumetric expulsion efficiency greater than 99.5% of total PTA volume shall be achieved under the conditions specified in Section 6.

Additional residuals resulting from vapours or propellant condensation in the pressurant hemisphere are a function of spacecraft operation/thermal management and are to be considered zero for assessment of the expulsion efficiency requirement, however, the value of the total residuals needs to be determined and recorded in the functional analysis report.
3.2.6 Pressure Drop

OPRP-324/Created/T

The PTA pressure drop shall not exceed 30 mbar under any flow up to 20 cc/s of MON at any temperature specified in Section 3.2.3 (b).

3.2.7 External Leakage

OPRP-327/Created/T

The external leak rate shall not exceed $1 \times 10^{-6}$ scc/s with the PTA pressurised to MEOP with helium.

OPRP-329/Created/T

There shall be no propellant leakage from the PTA at any pressure up to and including the Burst Pressure.

3.2.8 Step/Start Pressure Surge

OPRP-332/Created/T

The PTA, pressurised at the regulated operating pressure (contingency case, nominal maximum pressure is 8 bar), shall be compatible with the flow surge resulting from

- a discharge into a 1 litre line initially below 1 Torr,
- through a flow restrictor of an equivalent diameter of 2.77 mm,
- with a discharge coefficient of 1,
- and through a valve having a response time of 20 ms.

This requirement is equivalent (for design calculation purposes) to the PTA being compatible with the flow rates in Table 3.2-1.

<table>
<thead>
<tr>
<th>PRESSURE</th>
<th>MON (cc/s at 0°C)</th>
<th>Hydrazine (cc/s at 0°C)</th>
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<tr>
<td>Regulated Operating pressure</td>
<td>18.8</td>
<td>31.6</td>
</tr>
<tr>
<td>8 bar</td>
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<td>18</td>
</tr>
<tr>
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<td>35.4</td>
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Table 3.2-1: PTA Equivalent Flow Rates for Design Calculation Purposes

3.2.9 Tank Capacity

OPRP-344/Created/T

The Oxidiser Tank minimum usable volume, including ullage shall be 130 litres ± 0.5 litres, unpressurised at ambient conditions.

The Fuel Tank minimum usable volume, including ullage shall be 220 litres ± 0.5 litres, unpressurised at ambient conditions.

OPRP-346/Created/T

Tank growth due to pressure and temperature effects shall be quantified and reported to the Customer.
3.2.9.1 Tank Dimensions

OPRP-2269/Created/T

The propellant Tank shall have a skirt type mounting and shall be a cassini domed, spherical design.
The Oxidiser Tank maximum height shall be 640 mm including outlet stub pipes.
The Fuel Tank maximum height shall be 690 mm including outlet stub pipes.
The Oxidiser and the Fuel Tank maximum diameter shall be 880 mm including skirt.

3.2.10 Propellant Loading

OPRP-351/Created/T

Propellant loading shall comply with the following:
(a) NTO per SD(b): maximum = 162 kg,
(b) Hydrazine per SD(a): maximum = 201 kg.

3.2.11 Filling Rate

OPRP-357/Created/

With the PTA in the vertical attitude, outlet port down, the PTA shall be capable of being filled with either:
- Hydrazine to SD(a),
- MON to SD(b),
- IPA to SD(g),
- Water to SD(h),
at any rate up to 200 cc/s.

OPRP-364/Created/R

The PTA shall be designed for gravity draining to residual level consistent with Section 3.2.5 requirement.

OPRP-366/Created/A

The PTA ullage pressure shall be in the range 1.0 to 2.0 bar absolute for the first 16.5 litres filled.
The ullage pressure shall be in the range 2.5 to 7.5 bar absolute for the remainder of the fill.

OPRP-369/Created/T,A

The PTA shall be capable of ingesting gas, 2000 scc max., released/purged from the propellant loading equipment during the initial stages of filling without subsequent PMD performance degradation.

OPRP-2296/Created/T,A

The PTA shall be compatible with a pressurisation or depressurisation rate of 0.2 bar/minute.
3.2.12 Design Margins

3.2.12.1 Force Margins

OPRP-373/Created/T,R

The PMD shall be designed such that the propellant retention capability essential to successful operation shall have a positive margin over worst case inertial forces resulting from manoeuvres detailed in Section 6.

OPRP-375/Created/R

A minimum force margin of 2 shall be demonstrated under worst case conditions, inclusive of worst case fluid motions, where:  

\[
\text{Force Margin} = \left( \frac{\text{Propellant Retention Force}}{\text{Inertial Force}} \right) - 1.
\]

OPRP-377/Created/R

The worst case analysis shall include consideration of the extent of any database used, i.e. sample size, confidence level, tolerances and finishes in determination of design values.

OPRP-2301/MPB-5054/SYS-2336/Derived/T,A,R

The PMD shall be capable of storing 6 litres of NTO or Hydrazine, when subject to the forces listed in OPRP-1766 and OPRP-2295 below.

3.2.12.2 PTA and PMD Accelerations

OPRP-1765/Created/A

During T1 Thruster set manoeuvres, units shall be able to withstand the following dynamic environments:

- **Linear Acceleration:**
  - in MPO +Z axis: up to 0.18 m/s²,
  - in all other MPO axes: up to ± 0.01 m/s².

- **Angular Velocity:**
  - about all MPO axes: up to ± 0.1 °/s.

- **Angular Acceleration:**
  - about all MPO axes: up to ± 0.07 °/s².

These accelerations can act simultaneously, and are applied at unit CoG.

OPRP-1766/Created/A

During attitude and orbit correction manoeuvres (thrusters only), units shall be able to withstand the following dynamic environments:

- **Linear Acceleration:**
  - in MPO +Z axis: up to 0.13 m/s²,
  - in all other MPO axes: up to ± 0.01 m/s².

- **Rotation Rate**
  - about all axes: up to ± 0.1 °/s.

- **Angular Acceleration:**
  - about all MPO axes: up to ± 0.12 °/s².

These accelerations can act simultaneously, and are applied at unit CoG.
During instrument calibration manoeuvre, units shall be able to withstand the following dynamic environments:

Angular Velocity:
- about MPO X and Y axes: up to ± 0.18°/s.

Angular Acceleration:
- about all MPO axes: up to ± 0.003°/s².

These accelerations can act simultaneously, and are applied at unit CoG.

At least 7 kg of NTO shall remain in a known location, retained within either the PMD and/or held by vanes, etc., when the Tank is exposed to the accelerations defined within this Section.

3.2.12.3 PMD Capacity

Any sponge or trap device contained within the PMD, essential to successful operation, shall have a geometric capacity of at least twice the usable volume of 3 litres.

The worst case analysis should include consideration of the extent of any data base used, i.e. sample size, confidence level, etc. in determination of design values.

The design of the PMD must be consistent with three axis stabilised transfer and operations described in Section 6.

3.3 Life Requirements

There shall be no degradation to the PTA or its performance resulting from any or all of the following:

3.3.1 Storage Life

The PTA shall be capable of being stored for a minimum of 8 years without degradation.

The storage temperature shall be as specified in Section 3.4.1 with relative humidity up to 100%.

Storage shall be in Clean Room conditions, Class 100 000 or better, or under alternative conditions to prior approval by Customer.

3.3.2 Operating Life

20 years following exposure to propellant liquid/vapour.

The functionality or life requirement of the PTA or PMD shall not be impaired by propellant unloading (de-tanking).
3.3.3 Cycle Life

OPRP-442/Created/T,A,R

The PTA shall be designed for the minimum duty cycles in Section 3.3.3.2, Section 3.3.3.3 and Section 3.3.3.4.

3.3.3.1 PTA Load Spectrum

OPRP-445/Created/A

A full Fracture Mechanics Analysis is required for the Tank shell, in order to be compliant with SD(j) and SD(k). Fracture control shall also comply with the definitions of Section 8.2.1 of SD(j).

OPRP-447/Created/T,A

The spectrum for pressure cycles for fracture mechanics analysis are specified in Table 3.3-1

<table>
<thead>
<tr>
<th>Level</th>
<th>Event</th>
<th>Tank Fill</th>
<th>Pressure, bar</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant Tank Assembly Tests (protoflight)</td>
<td>Proof Pressure</td>
<td></td>
<td>26.2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Longitudinal</td>
<td>Wet</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Acceptance Sine: Longitudinal</td>
<td>Wet</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Protoflight Sine: Longitudinal</td>
<td>Wet</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Longitudinal</td>
<td>Wet</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Lateral</td>
<td>Wet</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Acceptance Sine: Lateral</td>
<td>Wet</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Protoflight Sine: Lateral</td>
<td>Wet</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Lateral</td>
<td>Wet</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Leak Test (+ 10 %)</td>
<td></td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Longitudinal</td>
<td>Dry</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Acceptance Sine: Longitudinal</td>
<td>Dry</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Protoflight Sine: Longitudinal</td>
<td>Dry</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Longitudinal</td>
<td>Dry</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Lateral</td>
<td>Dry</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Acceptance Sine: Lateral</td>
<td>Dry</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Protoflight Sine: Lateral</td>
<td>Dry</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Lateral</td>
<td>Dry</td>
<td>3</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Leak Test (+ 10 %)</td>
<td></td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>CPS Tests</td>
<td>Proof Pressure</td>
<td></td>
<td>26.2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>MEOP</td>
<td></td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Spacecraft Level Tests (protoflight)</td>
<td>Leak Test (+ 10 %)</td>
<td></td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Longitudinal</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Acceptance Sine: Longitudinal</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Protoflight Sine: Longitudinal</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Longitudinal</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Lateral</td>
<td>Wet</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Acceptance Sine: Lateral</td>
<td>Wet</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Protoflight Sine: Lateral</td>
<td>Wet</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Low Sine: Lateral</td>
<td>Wet</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Low Acoustic, 8dB</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Acceptance Acoustic</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Protoflight Acoustic</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low Acoustic</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Verification Pressure (+10%)</td>
<td></td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Launch</td>
<td>Tank Pressurisation</td>
<td></td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Flight Sine - Longitudinal</td>
<td>Wet</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Flight Sine - Lateral</td>
<td>Wet</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Flight Acoustic</td>
<td>Wet</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

* Vibration in only one lateral axis is permissible subject to the supplier identifying the critical lateral axis and vibrating along this critical axis.

Table 3.3-1: Load Spectrum of Events
Notes:

All Pressures stated are in bar gauge, i.e. pressure above local ambient pressure.
The vibration and acoustic noise test numbers include all necessary contingencies.
Loads experienced by the PTA after the initial flaw size has been established up to the time of
delivery to the Customer, are additional to the loads presented here and are to be included in the
fracture mechanical analysis.
Contingencies for repeat testing and a safe life factor of 4 must be applied to these pre-delivery loads.
Loads are in Newtons and contain all necessary ‘uncertainty factors’, so are to be used as given and
do not need to be factored together.

3.3.3.2 Non Operating Cycles

OPRP-456/Created/T,A

The PTA will be subjected to a maximum pressure duty cycles, including re-test if any, given in Table
3.3-2.

<table>
<thead>
<tr>
<th>CYCLE DESCRIPTION</th>
<th>PTA LEVEL</th>
<th>CPS LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 bar to MEOP x Proof Factor</td>
<td>1 nominal + 2 retest</td>
<td>1 nominal + 2 retest</td>
</tr>
<tr>
<td>0 bar to MEOP</td>
<td>1 nominal</td>
<td>2 nominal + 5 retest</td>
</tr>
</tbody>
</table>

Table 3.3-2: Pressure Cycles

Notes:
Table 3.3-2 does not include the pressure cycles seen during dynamic and constant acceleration tests.
‘PTA level’ means acceptance testing of the equipment before delivery.
‘CPS level’ means acceptance testing of the CPS with the PTA integrated on the Propulsion Module or the
complete Spacecraft.

3.3.3.3 Operating Cycles

OPRP-465/Created/T,A,R

The PTA shall be designed to be compatible with cycling due to pressure differentials or propellant
sloshing within the PTA.

3.3.3.4 Qualification Test Cycles

OPRP-468/Created/T,A,R

The PTA shall be compatible with the pressure cycles defined in Table 3.3-3, to be compliant with the
requirements of SD(j) and SD(k).

<table>
<thead>
<tr>
<th>CYCLE NUMBER</th>
<th>PRESSURE LEVEL</th>
<th>DURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 cycles</td>
<td>0 bar to Proof</td>
<td>5 minutes at Proof</td>
</tr>
<tr>
<td>50 cycles</td>
<td>0 bar to 22 bar</td>
<td>2 minutes at 22 bar</td>
</tr>
</tbody>
</table>

Table 3.3-3: Qualification Pressure Cycling Test Requirements
3.4 Environmental Conditions

3.4.1 Pre-Launch Storage and Transportation

OPRP-1769/Created/I,R

The equipment shall meet the requirements of this specification after being exposed to the following storage and transportation environmental conditions:

- The surrounding medium will be Air, Nitrogen, or Helium.
- Ambient pressure between sea-level and 15000 m.
- Ambient temperature range from -40°C to 65°C.

3.4.2 Pre-Launch System Assembly Integration and Test

OPRP-1770/Created/I,R

The equipment shall meet the requirements of this specification during exposure to the following AIT conditions:

- The surrounding medium will be Air, Nitrogen, Helium, or Argon.
- Ambient pressure between sea level and vacuum.
- Temperature range in satellite preparation areas (during AIT, fuelling etc.) is +18°C to +25°C.
- Temperature range in satellite fairing after encapsulation is +10°C to +25°C.

3.4.3 Launch

OPRP-1771/ET-36,Derived/T,A,R

The PTA shall perform to the specification after exposure to the following environmental conditions:

a. Relative Humidity
   
   Note: Operating conditions shall be such that condensation (either water or frost) will not take place.

b. Pressure
   
   Atmospheric pressure between sea level and 15 000 m.

c. Temperature
   
   Temperatures in the range between -30°C and 55°C when PTA is empty.

d. Transportation
   
   Transportation in a shipping container which shall be designed in accordance with Section 5.

e. Explosive Atmosphere
   
   The equipment shall be capable of operating in an explosive atmosphere without causing an explosion.

f. Random Vibration
   
   The Flight Limit Loads are given in Section 9.2.1.6 of AD(d).

   No flow is required from the PTA when under this environment. Note that the random vibration environment affects mainly the PMD, hence the loads induced through the mounting of the PMD have to be taken into account for the design of the lower hemisphere.

   The Tank shall be pressurised to between 4 and 8 bar Helium.
g. Sine Vibration
   The Flight Limit Loads are given in Section 4.4.8.
   No flow is required from the PTA when under this environment. Refer to Section 3.5.2 for Tank support points.
   The Tank shall be pressurised to between 4 and 8 bar Helium.

h. Shock
   The PTA shall demonstrate compatibility with the launcher separation system shock environment as defined in Section 9.2.1.7 of AD(d).

i. Constant Acceleration
   The Flight Limit Loads are given in Section 4.2.2.1 of AD(d).
   No flow is required from the PTA when under this environment. Refer to Section 3.5.2 for Tank support points.

j. For axis definition, the PTA axes are equal to the spacecraft axes. The PTA axes are defined in Section 3.5.2.

k. Acoustic
   The acoustic environment is defined in Section 4.2.2.3 of AD(d). The PTA is pressurised between 4 bar and 8 bar gauge with gaseous Helium.

3.4.4 Post-Launch

OPRP-1772/Created/T,A,R

   The PTA shall perform within specification during exposure to the following environmental conditions:

a. Temperature
   An environmental temperature range of -5°C and 55°C, in conjunction with fluid temperatures specified in Section 3.2.3.

b. Ambient Pressure
   1 bar to 1 x 10^-10 Torr. Pressure gradients of 0.03 bar/s from sea level ambient pressure to vacuum to sea level shall not result in any degradation of the PTA or its performance.

c. Radiation
   The PTA must survive 1.5 x 10^6 Rads per year ionising dose of protons and electrons absorbed in silicon.
   The propellant Tank shell minimum thickness shall not be less than 0.5 mm.

d. Three Axis Stabilised Transfer
   The PTA pressure shall be typically in the range of 12 bar absolute and regulated operating pressure.
   (i) T2 Thruster set shall be required to operate in order to stabilise the spacecraft at any time during transfer orbit. (see Section 6).
   (ii) The spacecraft is transferred under three axis stabilisation and the T1 Thruster set will apply a maximum acceleration along the axis of the PTA given in Section 6.

e. On-Orbit Acceleration
   See Section 6.
3.5 Physical Characteristics

3.5.1 Mass

OPRP-546/Created/T

The Oxidiser Tank and the Fuel Tank mass, including the PMD, shall not exceed 21.5 kg.

3.5.2 Configuration

OPRP-549/Created/A,R

The interior of the unit, including the PMD, shall be designed and manufactured to facilitate cleaning and to prevent the entrapment of contaminants and shall not generate or release particulate or chemical contamination.

OPRP-551/Created/T

The PTA construction shall facilitate draining of fluid from the PTA.

The propellant Tank axes are defined as follows:

- Z axis: this is the central axis between the Tank poles. The PMD is in the -Z axis
- X and Y axes: these are across the circumference of the PTA, perpendicular to the Z axis and 90° from each other.

The Tanks sizing envelope and co-ordinate system is shown schematically in Figure 3.5-1.
Figure 3.5-1: Schematic of the Propellant Tanks Size Envelope and co-ordinate System
OPRP-553/Created/R
PTA shall be cleaned to comply with the requirements of Section 4.4.12, and shall not contain chips, slag, particulate matter, oil, grease, or other foreign material.

OPRP-555/Created/I
Cleanliness requirements for parts, assemblies and the assembly work area shall be established and maintained.

OPRP-557/Created/I
The external physical configuration, e.g. mechanical interface, orientation and all critical dimensions pertaining to the PTA, shall be established and controlled in accordance with the ICD, to be supplied by the tank supplier.

OPRP-559/Created/R
The shell of the Tank shall be constructed of Titanium alloy, solution treated and aged, and compliant with SD(n).

OPRP-563/Created/I
Tank shell forgings shall be 100% ultrasonically inspected.

OPRP-565/Created/I
Only Titanium and Titanium alloys shall be used for the PMD. The Titanium and Titanium alloys shall be compliant with SD(n).

OPRP-576/Created/A
The PTA centre of gravity and moments of inertia shall be determined by analysis and included on the PTA interface drawing delivered with the EIDP.

3.5.3 Compatibility
OPRP-582/Created/R
Exposure of the PTA to:
- Hydrazine liquid or vapour to SD(a)
- MON liquid or vapour to SD(b)
for the period defined in Section 3.3.2 shall not degrade its performance.

OPRP-1774/Created/R
The PTA shall be compatible with:
the propellant decomposition products
- helium to SD(c)
- nitrogen to SD(d)
- argon to SD(e)
- HFE7100 to SD(f)
- IPA to SD(g)
- deionised water to SD(h)
and Section 4.3.6 of this specification.
OPRP-597/Created/R
The equipment shall be compatible with fluids used by the supplier or sub contractors, during manufacture, testing, or cleaning.

OPRP-599/Created/R
The use of halogenated solvents in contact with Titanium alloys requires approval from the Customer. All fluids used shall be agreed by the Customer.

3.5.4 Cleanliness
OPRP-602/Created/I
The unit shall be assembled under Clean Room conditions, Class 100 000 or better.

OPRP-604/Created/I
The particulate and chemical cleanliness of the unit shall be achieved, measured and maintained, in accordance with the manufacturer's specifications, which are to be approved by the Customer. Any chemical contamination of test fluids shall be avoided.

OPRP-606/Created/I
The cleanliness verification fluid sample for HIAC control, filter control and NVR shall be 100 ml of Customer approved fluid per 0.1 m² of internal surface area, including PMD and membrane surfaces.

With Customer written approval the verification fluid sample quantity of 100 ml may be increased to 200 ml per 0.1 m².

OPRP-609/Created/I
The level of particulate contamination shall be determined by a rinse test using the first litre of a fluid approved by the Customer (low flow rate sampling). In addition, the overall PTA particle count shall be determined by sampling all of the liquid used in the rinse test.

OPRP-611/Created/I
The particle count must not exceed the following count or distribution in Table 3.5-1 and Table 3.5-2:

<table>
<thead>
<tr>
<th>SIZE RANGE (s in µm)</th>
<th>MAXIMUM ALLOWABLE NUMBER OF PARTICLES PER 0.1m² SD(0) LEVEL 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 &lt; s</td>
<td>0</td>
</tr>
<tr>
<td>100 &lt; s &lt; 200</td>
<td>1</td>
</tr>
<tr>
<td>50 &lt; s &lt; 100</td>
<td>9</td>
</tr>
<tr>
<td>25 &lt; s &lt; 50</td>
<td>63</td>
</tr>
<tr>
<td>10 &lt; s &lt; 25</td>
<td>484</td>
</tr>
<tr>
<td>5 &lt; s &lt; 10</td>
<td>1101</td>
</tr>
<tr>
<td>1 &lt; s &lt; 5</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3.5-1: Particle Count Cleanliness Levels - HIAC Control
Table 3.5-2: Particle Count Cleanliness Levels - Visual Inspection On Filter

<table>
<thead>
<tr>
<th>SIZE RANGE (s in µm)</th>
<th>MAXIMUM ALLOWABLE NUMBER OF PARTICLES PER COMPARTMENT (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 &lt; s &lt; 500</td>
<td>10</td>
</tr>
</tbody>
</table>

**OPRP-617/Created/I**

The total particulate count requirement for the complete PTA shall be calculated as follows:

Maximum allowable count for the complete PTA = 10 x max. allowable per 0.1 m² (see Table 3.5-1) x PTA internal surface area.

The total particulate count from all the liquid used in the final rinse test shall not exceed this maximum allowable count for the complete PTA.

**NVR**

**OPRP-622/Created/I**

NVR increase in the effluent flushing, shall not exceed 1.0 mg per 0.1 square metres.

A control NVR sample shall be taken on the fluid before entering the PTA to establish a baseline to measure the increase in the effluent rinse.

The control sample NVR shall not exceed 0.5 mg per 100 ml.

**OPRP-626/Created/I**

Prior to flight use the PTA shall not come into contact with any propellant liquid or vapour.

Any other liquids shall be removed by flushing and purging to a procedure approved by Customer.

The unit shall be dried such that all traces of liquid are removed.

**OPRP-1775/Created/I**

After all cleaning procedures have been completed, the level of chemical contaminantns retained in the equipment shall be such that correct functioning shall not be impaired or compromised throughout the operational lifetime. The following limits shall be applied:

- **Liquid Contamination**
  - none
- **Gaseous Contamination**
  - water less than 20 ppm
  - IPA less than 40 ppm by volume

**OPRP-637/Created/I**

After drying to the above levels, the PTA shall be left to stand for at least 12 hours at room temperature with the inlet/outlet ports capped.

The gas inside the PTA after this period shall be verified to be within the above limits.
3.5.5 Maintainability
OPRP-641/Created/R

No field maintenance, servicing or adjustment shall be required during the specified lifetime.

3.5.6 Transportation
OPRP-644/Created/R

The equipment shall be transported by common carrier, including air transporter, with a minimum of protection.

The transportation containers must be capable of providing an environment which meets the shock and transportation requirements of Section 5.

OPRP-647/Created/R

The PTA shall be provided with protective covering to prevent contamination during transportation outside clean areas and to protect against damage in handling.

OPRP-649/Created/I

Inlet and outlet ports shall be individually protected.

3.5.7 Interface and Interchangeability
OPRP-652/Created/R

Each PTA shall be directly interchangeable in form, fit and function with other assemblies of the same part number.

3.5.8 Surface Finish
OPRP-659/Created/I

The surfaces of the PTA shall be adequately finished to prevent deterioration from exposure to the specified environments that might jeopardise fulfilment of the specified performance.

OPRP-661/Created/I

The PTA mounting surfaces shall be unpainted, and any protective coating used shall produce a conductive finish suitable for electrical bonding.

3.5.9 Stiffness Requirements
OPRP-664/Created/R

In launch configuration and when supported as in Section 3.5.2, the PTA shall have an axial natural frequency and a lateral natural frequency greater than those given in the Table below.

OPRP-666/Created/I

This shall be achieved for all combinations of fill level and propellant (see Section 3.2.10).

<table>
<thead>
<tr>
<th></th>
<th>AXIAL (Hz)</th>
<th>LATERAL (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA</td>
<td>&gt;54</td>
<td>&gt;54</td>
</tr>
<tr>
<td>PMD</td>
<td>&gt;100</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

Figure 3.5-2: PTA and PMD Minimum Natural Frequencies

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3.5.10 Thermal Control
OPRP-1776/Created/R
The equipment design shall permit the attachment of the following thermal control and pressure monitoring hardware:
- Heaters
- Velcro strips for MLI attachment
- Temperature sensors
- Low emissivity tape and multilayer insulation blanket

3.5.11 Standard and Commercial Parts
OPRP-678/Created/R
Standard and commercial parts may be used if they do not degrade the reliability of the PTA and are in accordance with the requirements of approved material and parts.

3.5.12 Ceramic Materials
OPRP-681/Created/R
Ceramic materials and coatings that may crack or break under any combination of operating conditions or environments specified herein shall not be used.

3.5.13 Corrosion of Materials
3.5.13.1 Stress Corrosion Sensitivity
OPRP-685/Created/R
Metals and alloys which are susceptible to stress corrosion cracking shall not be used.
Heat treatment of alloys to obtain non-stress-corrosion sensitive conditions is allowed.

3.5.13.2 Corrosive Metals
OPRP-689/Created/I,R
Metals shall be corrosion resistant type or suitably treated to resist corrosive conditions likely to be met in storage and/or normal service.
It shall be a design requirement that metals used comply with Table 1 of SD(p).

3.5.14 Identification and Marking
OPRP-693/Created/R
Permanent identification on the Tank shell shall include, but not be limited to, the following:
(a) Configured Item Master Index
(b) Supplier’s serial number
The identification is given in the Interface Control Drawing, to be supplied by the supplier and approved by the Customer.
OPRP-698/Created/R
No marking of the surface of the PMD shall be allowed for identification purposes. A strict control over the identification of components by labelling and bagging shall be applied to afford full traceability of each part.
3.5.15 Serialisation
OPRP-701/Created/R

Assemblies and higher level equipment shall be assigned a unique serial number.

Serial numbers once assigned shall not be transferred, or used again on other items of the same part number.

Where equipment contains levels of serialised hardware items, the lower level items shall be traceable through the tiers of serialisation to the end items.

3.5.16 Workmanship
OPRP-1777/Created/I

Workmanship should be executed such that the design standard is not degraded or changed.

At all points in the manufacture, production, integration, test, handling, storage and transportation, special steps shall be taken to maintain the design standard.

The skill level of personnel is to be such that all aspects of workmanship shall ensure retention of the high reliability standards, with particular attention to the following:

(a) Absence of blemishes, burrs and sharp edges
(b) Required tolerance on dimensions
(c) Compliance with designed radii of fillets
(d) Adequate and correct marking of parts and assemblies
(e) Thoroughness of cleaning, welding and finishing
(f) Freedom from oxidation, cracks, undercuts, lack of fusion and incomplete penetration of the welds
(g) Freedom from paints, dyes and grease
(h) Alignment of parts and assemblies, in accordance with specified requirements
(i) Interlocking of components and assemblies.

3.5.17 Toxic Materials
OPRP-720/Created/I

Where toxic materials are used in equipment, that equipment shall bear a label that identifies the hazard source. In addition the following hazard reduction criteria shall be implemented:

- the provision of warning notes in manufacturing documents,
- special handling constraints and procedures,
- scrap disposal controls.

3.5.18 Reliability
OPRP-726/Created/A

For the purposes of reliability calculations, each PTA shall be assumed as having a reliability of 1,0.

A mechanical stress analysis shall be performed to ensure that there is no degradation of performance under worst case handling, installation and flight operation over the life duration.

OPRP-729/Created/A

Reliability of operation shall be considered of prime importance in the design and manufacture of the equipment.

A FMECA based on performance and stress analysis is required.
3.5.19 Safety
OPRP-733/Created/R

The equipment shall be designed and fabricated with compatible materials in such a manner that all hazards associated with the equipment are eliminated, or minimised and controlled.

3.5.20 Selection of Specifications and Standards
OPRP-736/Created/R

All specifications and standards intended for use in the design and construction of the equipment shall be in accordance with the requirements defined in AD(b).

3.5.21 Items Subject to Wear-Out/Degradation
OPRP-739/Created/R

Equipment parts, materials and processes, subject to wear-out or deterioration due to environment, including radiation, application stresses, or inherent physical processes, shall be designed, fabricated, selected and used to attain performance life requirements.

3.5.22 Materials, Parts and Processes
OPRP-742/Created/R

Each material, part and process shall be controlled by a detailed specification and shall satisfy the applicable requirements of AD(b).

3.5.23 Dissimilar Metals
OPRP-745/Created/R

Contact of dissimilar metals with each other, as defined in SD(i), shall be avoided.

Protection against electrolytic corrosion which can result from such contact shall be provided by surface treatment of the metals.

3.5.24 Seals
OPRP-749/Created/R

Any seals used shall comply with all the applicable requirements of this specification, in particular Section 3.5.4 and Section 3.5.28.

3.5.25 Lubricants and Sealants
OPRP-752/Created/R

Lubricants and sealants shall be used only if essential for equipment assembly.

Their use shall be minimised and be subject to Customer approval.

3.5.26 Outgassing
OPRP-756/Created/R

Outgassing from PTA materials shall comply with the requirements of AD(b).
3.5.27 Locking
OPRP-759/Created/I

Positive locking of screw type hardware used on the equipment shall be by safety wire.
Alternative methods of locking are to be approved by the Customer.

3.5.28 Magnetic Materials
OPRP-763/Created/R

Materials shall be used that have a minimum susceptibility to induced, transient and permanent magnetic fields, except when it is demonstrated that magnetic metals are essential.

3.6 Design and Safety Criteria
OPRP-766/Created/A

The PTA and PMD shall be designed with a factor of safety of 1.5 or better.

OPRP-2273/Created/A

The PTA shall be designed to withstand the design loads defined in Section 3.2.2.5.1 of AD(c) and shall demonstrate safety margins greater than those given.

OPRP-768/Created/A

In addition, the PTA shall meet the requirements of SD(j) and SD(k) para. 5.1.2.
Any analysis shall use approved initial crack sizes.

OPRP-771/Created/A

Fracture Mechanics analysis shall show ‘Safe Life’ using the Load Spectrum specified in Section 3.3.3.1 and the loads experienced by the PTA after initial flaw size has been established up to the time of delivery to the Customer.

OPRP-773/Created/A

Fracture Mechanics material properties shall be appropriate to the material type and heat treatment condition, the Tank wall thickness, stress levels and to the temperature and the fluid environment.
All Fracture Mechanics properties are subject to Customer reviews and approval.
Stresses shall be determined by an appropriate numerical technique.

OPRP-2272/Created/A

A Finite Element model shall be provided as an input to the spacecraft level analyses. All significant modes with an effective mass of greater or equal to 10% of the PTA mass shall be included in the model.

OPRP-786/GDIR-3624,Derived/R

Loads to be used for design are Flight Limit Loads multiplied by Design Factor as defined in Section 3.2.2.5.1 of AD(c).
4 QUALITY ASSURANCE PROVISIONS

4.1 General Requirements

4.1.1 Responsibility for Inspection and Test

OPRP-793/Created/R

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection and test requirements as specified in herein.

4.1.2 Quality Assurance Programme

OPRP-796/Created/R

The supplier shall have or shall establish and implement a Quality Programme that complies with the requirements of AD(b).

The supplier’s Quality Programme/Plan shall be approved by the Customer.

4.1.3 Surveillance and Witness of Inspection and Test

OPRP-800/Created/I

The Buyer shall be given access to the Supplier’s facilities at all times, given reasonable notice, in order to inspect the Supplier’s quality control system and the records specified to be maintained therein.

The Supplier shall ensure that appropriate arrangements are made for access to lower tier Vendor’s facilities/test houses where critical operations are to be performed.

OPRP-803/Created/R

The Customer and the Customer’s Customer (or their nominated representatives) reserve the right to witness or review the tests or documentation of any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

OPRP-805/Created/R

The Supplier shall notify the Buyer at least 2 weeks and subsequently 48 hours (fax/email) prior to the commencement of the qualification or acceptance test phases to enable representation by the Buyer and witnessing of any or all tests as considered necessary by the Buyer.

4.1.4 Preproduction Sample

OPRP-808/Created/R

Prior to the manufacture of a new equipment batch, the manufacturer shall verify the use of the same materials, techniques and processes as are applicable to the unit referred to in Section 4.1.6.

4.1.5 Classification of Inspection and Test

OPRP-811/Created/R

The examination and testing of the equipment shall be classified as follows:

a. Qualification Inspection and Testing, Section 4.2.3.

b. Acceptance Inspection and Test, Section 4.2.2.

c. Preparation for Delivery, Inspection and Test, Section 5.
4.1.6 Qualification Test Sample

OPRP-817/Created/T

Qualification testing shall be carried out on a PTA identical to the units which will be supplied for flight spacecraft, except that inlet/outlet tube fittings may be retained to facilitate Qualification testing.

OPRP-819/Created/T

The reaction load points for the PTA dynamic response tests shall be as specified in Section 3.5.2.

4.2 Verification of Compliance

OPRP-822/Created/R

Compliance with the requirements of Section 3, shall be verified by acceptance inspections and tests, qualification, or analysis as stated in Section 4.2.1.3.

The method of verification of Section 3 and Section 4 shall be presented in a Design Verification Test Matrix Report to a format to be agreed between the supplier and the Customer

OPRP-825/Created/R

The equipment supplier shall provide positive verification from analysis, trials, or in service experience (and supported by reference data) of the compatibility of the equipment with the operating and test fluids to the requirements of Section 3.5.4.

4.2.1 General

4.2.1.1 Development

OPRP-1779/Created/I,R

In addition to manufacturing development trials, all necessary tests shall be performed at subassembly or Tank level to secure the development.

4.2.1.2 Acceptance

OPRP-835/Created/R

The applicable paragraphs of Section 3 shall be verified by performing acceptance inspections and tests in accordance with Section 4.2.2 on each deliverable item of equipment.

4.2.1.3 Qualification

OPRP-1780/Created/T,A,I,R

Qualification of the equipment to meet the requirements of Section 3 may be demonstrated as specified below:

a. Qualification Inspection and Tests

Design Verification of the equipment shall be established by performing the qualification inspections and tests detailed in Section 4.2.3 on a minimum of one sample unit. This unit shall not subsequently be used on a flight spacecraft.

b. Qualification by Similarity

If the supplier can demonstrate by analysis that the proposed equipment is similar in design, construction and performance to existing space qualified equipment, and that previous qualification covers all or part of the performance and environmental requirements of Section 3, then the supplier may offer "Qualification by Similarity" against the relevant requirements. Qualification testing may be then omitted, subject to Customer approval.
c. Qualification by Analysis

Where analysis is proposed to demonstrate compliance with any of the requirements of this specification it is subject to Customer approval.

d. Protoflight Qualifications

Subject to the Customer agreement, delta qualifications can be performed using a protoflight qualification philosophy. The testing shall occur at protoflight levels as detailed in this specification. Protoflight units are subsequently acceptable for flight use.

4.2.2 Acceptance Inspection and Test

4.2.2.1 Test Sample

OPRP-849/Created/R

Every flight standard PTA produced in accordance with this specification, shall be subjected to the acceptance tests specified in Section 4.2.2.2.

OPRP-851/Created/R

Each unit shall be clean prior to entering acceptance testing.

Note: Protoflight testing shall be the same as acceptance except that sine vibration is carried out at qualification levels.

4.2.2.2 Acceptance Tests Required (Minimum)

4.2.2.2.1 PMD Sub-assembly

OPRP-856/Created/T,I

For each screen before welding in the PMD or on the membrane, the tests defined in Table 4.2-1 and Table 4.2-2 shall be performed.

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bubble Point: Level 1</td>
<td>Section 4.4.9</td>
</tr>
</tbody>
</table>

Table 4.2-1: PMD Screen Acceptance Tests

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bubble Point: Level 2</td>
<td>Section 4.4.9</td>
</tr>
</tbody>
</table>

Table 4.2-2: PMD Sub Assembly Acceptance Tests
4.2.2.2 Propellant Tank Assembly

OPRP-870/Created/T

For each PTA the tests defined in Table 4.2-3 shall be performed.

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Inspection after Tank Assembly</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>2.</td>
<td>Volume and Mass</td>
<td>Section 4.4.6</td>
</tr>
<tr>
<td>3.</td>
<td>Proof Pressure Test</td>
<td>Section 4.4.5</td>
</tr>
<tr>
<td>4.</td>
<td>Volume Measurement</td>
<td>Section 4.4.6</td>
</tr>
<tr>
<td>5.</td>
<td>Pressure Drop Test</td>
<td>Section 4.4.13</td>
</tr>
<tr>
<td>6.</td>
<td>Sine Test</td>
<td>Section 4.4.7</td>
</tr>
<tr>
<td>7.</td>
<td>Leak Test</td>
<td>Section 4.4.11</td>
</tr>
<tr>
<td>8.</td>
<td>Radiographic Inspection</td>
<td>Section 4.4.2</td>
</tr>
<tr>
<td>9.</td>
<td>Penetrant Inspection</td>
<td>Section 4.4.3</td>
</tr>
<tr>
<td>10.</td>
<td>Bubble Point Test: Level 3</td>
<td>Section 4.4.6</td>
</tr>
<tr>
<td>11.</td>
<td>Dimensional Verification</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>12.</td>
<td>Cleanliness Verification</td>
<td>Section 4.4.10</td>
</tr>
<tr>
<td>13.</td>
<td>Inspection</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>14.</td>
<td>Preparation for Data Review</td>
<td>Section 4.4.16</td>
</tr>
</tbody>
</table>

Table 4.2-3: Propellant Tank Assembly Acceptance tests

4.2.2.3 Failure Criteria

OPRP-875/Created/I

The PTA shall exhibit no failure, malfunction, or out of specification performance resulting from the conformance inspections and tests carried out in accordance with Section 4.2.2.3.

Any such occurrence shall be cause for rejection.

4.2.2.4 Acceptance Test Report

OPRP-879/Created/R

Following completion of Acceptance Tests on each unit, a test report shall be prepared evaluating results of tests in accordance with AD(b).

4.2.2.5 Test Limitations

OPRP-882/Created/R

The Acceptance Inspection and Test shall not degrade the PTA performance, or expose the PTA to test levels or conditions which could induce a subsequent failure.

OPRP-884/Created/R

The number of pressure cycles shall not exceed the values given in the Table of Section 3.3.3.
4.2.2.6 Rejection and Re-Submittal
OPRP-887/Created/R

Any failure, malfunction or out-of-specification conditions which occur during the test programmes shall result in immediate stoppage of the test to avoid the possibility of further hazard to equipment or personnel.

Testing shall not be recommended unless the condition has been properly investigated and the proposed recovery and corrective action has been reviewed and approved by the Customer.

In the case of a failure requiring replacement or rework, the test programme will be repeated in its entirety except as mutually agreed between the Supplier and the Customer.

4.2.3 Qualification Inspection and Test
OPRP-892/Created/R

The method of supplier compliance with the requirements specified in Section 4.2.2 and Section 4.2.3 shall be as defined in test plans/procedures to be generated by the supplier.

The test plans and procedures are subject to approval by the Customer.

Subject to Customer approval the sequence of the tests need not necessarily be carried out in the order specified in Section 4.2.3.2 and Section 4.2.2.1.

4.2.3.1 Test Sample
OPRP-897/Created/R

Qualification testing shall be carried out on a unit which has been manufactured in accordance with the requirements of this specification.

The unit shall be identical to the units that will be supplied for flight spacecraft.

4.2.3.2 Qualification Tests Required (Minimum)
4.2.3.2.1 PMD Mechanical Qualification
OPRP-902/Created/R

For each screen before welding in the PMD or on the membrane, the tests defined in Table 4.2-4 shall be performed.

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bubble Point Test: Level 1</td>
<td>Section 4.4.9</td>
</tr>
</tbody>
</table>

Table 4.2-4: PMD Screen Mechanical Qualification Tests
For the complete Development Model PMD Sub-assembly, the tests defined in Table 4.2-5 shall be performed.

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>General and Dimensional Inspection</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>2.</td>
<td>Bubble Point Test: Level 2</td>
<td>Section 4.4.9</td>
</tr>
<tr>
<td>3.</td>
<td>Mass Measurement</td>
<td>Section 4.4.4</td>
</tr>
<tr>
<td>4.</td>
<td>Random Vibration</td>
<td>Section 4.4.7</td>
</tr>
<tr>
<td>5.</td>
<td>Shock</td>
<td>Section 4.4.17</td>
</tr>
<tr>
<td>6.</td>
<td>Bubble Point Test: Level 2</td>
<td>Section 4.4.9</td>
</tr>
</tbody>
</table>

Table 4.2-5: PMD Assembly Mechanical Qualification Tests

4.2.3.2.2 PTA Protoflight Qualification

After the mounting of an acceptance tested PMD (as per Section 4.2.2.2.1), the protoflight/qualification tests defined in Table 4.2-6 shall be performed.

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Inspection</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>2.</td>
<td>Volume Measurement</td>
<td>Section 4.4.6</td>
</tr>
<tr>
<td>3.</td>
<td>Proof Pressure Test</td>
<td>Section 4.4.5</td>
</tr>
<tr>
<td>4.</td>
<td>Volume Measurement</td>
<td>Section 4.4.6</td>
</tr>
<tr>
<td>5.</td>
<td>Pressure Drop Test</td>
<td>Section 4.4.13</td>
</tr>
<tr>
<td>6.</td>
<td>Fill/Drain Cycle Test</td>
<td>Section 4.4.15</td>
</tr>
<tr>
<td>7.</td>
<td>Bubble Point Test: Level 3</td>
<td>Section 4.4.9</td>
</tr>
<tr>
<td>8.</td>
<td>Cleanliness Verification</td>
<td>Section 4.4.10</td>
</tr>
<tr>
<td>9.</td>
<td>Drying</td>
<td>Section 4.4.10</td>
</tr>
<tr>
<td>10.</td>
<td>Sine Vibration (Empty)</td>
<td>Section 4.4.7</td>
</tr>
<tr>
<td>11.</td>
<td>Cleanliness Verification (Status only)</td>
<td>Section 4.4.10</td>
</tr>
<tr>
<td>12.</td>
<td>Leak Test</td>
<td>Section 4.4.11</td>
</tr>
<tr>
<td>13.</td>
<td>Radiographic Inspection</td>
<td>Section 4.4.2</td>
</tr>
<tr>
<td>14.</td>
<td>Penetrant Inspection</td>
<td>Section 4.4.3</td>
</tr>
<tr>
<td>15.</td>
<td>Dimensional Inspection</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>16.</td>
<td>Bubble Point Test: Level 3</td>
<td>Section 4.4.9</td>
</tr>
<tr>
<td>17.</td>
<td>Cleanliness Verification</td>
<td>Section 4.4.10</td>
</tr>
<tr>
<td>18.</td>
<td>Final Inspection</td>
<td>Section 4.4.1</td>
</tr>
<tr>
<td>19.</td>
<td>Preparation for Data Review</td>
<td>Section 4.4.16</td>
</tr>
</tbody>
</table>

Table 4.2-6: PTA Protoflight Tests

NB: Simulant Fill and Drain Cycles (see Section 4.4.15), Step Start Test (see Section 4.4.14), Pressure Cycling (see Section 4.4.18), and Burst Test (see Section 4.4.19) have been removed from Table 4.2-6 on the basis that they shall be demonstrated by similarity as stated in Section 4.2.1.3.
4.2.3.3 Failure Criteria

OPRP-922/Created/I

The unit shall exhibit no failure, malfunction, or out of tolerance performance degradation as a result of Qualification inspections and tests specified in Section 4.2.3.2.

Any such occurrence shall be cause for rejection and refusal to grant qualification.

4.2.3.4 Qualification Test Report

OPRP-926/Created/R

Following the completion of qualification tests, a test report containing the test results, together with an evaluation and comparison with the requirements, shall be delivered.

4.2.3.5 Rejection and Resubmittal

OPRP-929/Created/T,I

Any failure, malfunction, or out of specification conditions which occur during the test programme shall result in immediate stoppage of the test to avoid the possibility of further hazard to equipment or personnel.

Testing shall not be recommenced unless the condition has been correctly investigated and the proposed recovery and corrective action has been reviewed and approved by the Customer.

In the case of a failure requiring a replacement, or rework, the test programme will be repeated in its entirety except as mutually agreed between the supplier and the Customer.

4.3 Test Conditions

4.3.1 Environmental Conditions

OPRP-935/Created/R

Unless otherwise stated, all measurements and tests shall be made within the following ambient conditions:

- Temperature: 23°C ± 15°C
- Relative Humidity: 100% Maximum
- Pressure: 580 to 800 mm of Mercury

OPRP-940/Created/R

Whenever these conditions must be closely controlled in order to obtain reproducible results, a reference temperature of 23°C, a relative humidity of 50% and an atmospheric pressure of 760 mm of Mercury respectively shall be used, together with whatever tolerances are required to obtain the desired precision of measurement.

4.3.2 Test Equipment

OPRP-943/Created/R

The apparatus used in conducting tests shall be capable of producing and maintaining the required test conditions as defined in the applicable test procedures.
4.3.3 Measurement Tolerances

All testing shall observe the tolerances stated in Table 4.3-1.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Max</td>
<td>-0°C, +1°C</td>
</tr>
<tr>
<td>Temperature Min</td>
<td>+0°C, -1°C</td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
</tr>
<tr>
<td>Dynamic Tests</td>
<td>+0.55 / -0 bar</td>
</tr>
<tr>
<td>Pressure Drop Tests</td>
<td>+1.0% actual</td>
</tr>
<tr>
<td>Bubble Point Tests</td>
<td>±10 Pa maximum</td>
</tr>
<tr>
<td>Other Cases</td>
<td>+5% / -0%</td>
</tr>
<tr>
<td>Acceleration</td>
<td>± 10%, -0</td>
</tr>
<tr>
<td>Vibration Frequency</td>
<td>± 2%, ± 0.5 Hz below 20 Hz</td>
</tr>
<tr>
<td>Sinusoidal Vibration</td>
<td>+ 10%, 0 &quot;g&quot; peak</td>
</tr>
<tr>
<td></td>
<td>At low frequencies, the electrodynamic exciter may have an amplitude limitation which prevents achievement of 12.5 mm, zero to peak, and the subsequent &quot;g&quot; level. Such limitations are acceptable down to a minimum amplitude of 5 mm zero to peak for equipment having resonant frequencies greater than 30 Hz.</td>
</tr>
<tr>
<td>Time</td>
<td>+5%, -0</td>
</tr>
<tr>
<td>Random Power Spectral Density</td>
<td></td>
</tr>
<tr>
<td>20 – 500 Hz (25 Hz or narrower)</td>
<td>± 1.5 dB</td>
</tr>
<tr>
<td>500 – 2000 Hz (25 Hz or narrower)</td>
<td>± 3 dB</td>
</tr>
<tr>
<td>Random Overall Acceleration (RMS)</td>
<td>± 1.5 dB</td>
</tr>
<tr>
<td>Sound Pressure Level</td>
<td>See Acoustic Requirements</td>
</tr>
<tr>
<td>Dry Mass</td>
<td>± 20g for the PTA</td>
</tr>
<tr>
<td>Internal Volume</td>
<td>± 200 cc</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>±10%</td>
</tr>
<tr>
<td>Residual Liquid Volume (on ground)</td>
<td>± 65 cc</td>
</tr>
</tbody>
</table>

Table 4.3-1: Test Tolerances
4.3.4  Accuracy of Measurement

OPRP-951/Created/I,R

The accuracy of all instruments and test equipments used to control or monitor the test parameters, whether located at the supplier’s testing laboratory or at a subcontractor’s plant shall be verified periodically by calibration.

Such calibration shall be traceable to National Standards.

4.3.5  Test Data

OPRP-1781/Created/R

The following data shall be included in the End Item Data Pack, EIDP, as a minimum, and supplied with each delivered PTA. Items (c), (d), (e), (f) and (g) can be established by analysis.

(a) Acceptance Test results and reports (control, mechanical and functional tests,...) for the PTA and the PMD

(b) Net internal volume at zero gauge pressure (PTA and PMD)

(c) Net internal volume at regulated operating pressure (Interface Data Sheet)

(d) Residual liquid volume (Interface Data Sheet)

(e) Centre of gravity of dry unit (Interface Data Sheet)

(f) Moments of inertia (Interface Data Sheet)

(g) Variation in PTA dimensions due to pressure and temperature (calculated) (Interface Data Sheet)

OPRP-964/Created/R

An Interface and Control Drawing shall mention items (c), (d), (e), (f) and (g).

Note: The mass of the inlet and outlet tubes and fittings used for testing may be deducted by analysis to obtain the net dry mass of the PTA.

4.3.6  Test Fluids

OPRP-968/Created/R

All fluids for test shall be as per applicable documents as listed in Section 2.3.

OPRP-970/Created/R

For deionised water, the following applicable supplementary requirements must be used for all flight and qualification hardware:

- pH from 5.0 to 7.5
- maximum electrical conductivity of 0.5 mS/m at 25°C.

OPRP-974/Created/R

Immediately before entering any PTA or PMD all test fluid shall be filtered to better than 10 microns nominal.
4.4 Test Methods

4.4.1 Inspection

4.4.1.1 PMD Sub-assembly

OPRP-979/Created/I

The complete PMD shall be inspected in-house, or Subcontractor Quality Assurance for the applicable requirements listed below in accordance with this specification and approved subcontractor standards.

Mechanical inspection criteria shall be specified on the applicable drawings.

4.4.1.2 PTA

OPRP-983/Created/I

The PTA and fittings shall be inspected by in-house, or Subcontractor Quality Assurance for the applicable requirements listed below in accordance with this specification and approved subcontractor standards.

Mechanical inspection criteria shall be specified on the applicable drawings.

It shall be verified that Bubble Point tests have been performed to levels 1, 2, and 3 of Section 4.4.9.

OPRP-987/Created/I

As part of the Qualification Testing, the emissivity of the internal surfaces of the PTA shall be derived from representative test samples produced using the same alloy and machining conditions.

4.4.1.3 Dimensions

4.4.1.3.1 PMD sub-assembly

OPRP-991/Created/I

The PMD shall be measured for compliance with the overall dimensions and the mounting data requirements defined by the supplier.

4.4.1.3.2 PTA

OPRP-994/Created/I

The PTA shall be measured for compliance with the overall dimensions and mounting which shall be defined in an ICD to be supplier by the supplier.

4.4.1.4 Identification and Marking

OPRP-998/Created/I

The PTA and fittings shall be inspected for compliance with the marking requirements of Section 3.5.14.
4.4.1.5 Inspection after Tank assembly

OPRP-1782/Created/I,R

The unit shall be visually inspected, and manufacturing records and drawings shall be reviewed, to verify that materials and processes used, conform to specified requirements. Inspection shall verify the following as a minimum:

(a) completeness of product,
(b) conformance to drawings or other manufacturing documents,
(c) completeness of all steps in the manufacturing process and correct certification,
(d) workmanship, assembly and fit,
(e) materials, parts and finish,
(f) all tube and girth welds.

OPRP-1009/Created/I

There shall be no evidence of nicks, scratches, burrs or any defect, or physical imperfection, which would adversely affect the performance of the unit, or compromise cleanliness or interface requirements.

4.4.2 Radiographic Inspection

OPRP-1012/Created/I

The unit shall have a radiographic inspection of all girth welds to NASA Special Level, or equivalent. Other defects than flaws are subjected to SD(q) Class I (even for discontinuities).

OPRP-1015/Created/I

The other welds shall have a radiographic inspection to SD(m) and SD(q), Class I, or equivalent, except that Class II shall apply for individual discontinuities.

All defects detected shall be reported to the Customer and shall be within the requirements used for the Fracture Mechanics Analysis.

4.4.3 Penetrant Inspection

OPRP-1020/Created/I

The entire external surface (including girth welds but excluding bosses) of each PTA and all internal surfaces prior to assembly, shall be inspected in accordance with NASA Special Level, or equivalent. The bosses area shall be inspected in accordance with SD(l), Type I, Method A (penetrant), or equivalent, with halogen free solutions. All defects detected shall be reported to the Customer and shall be within the requirements used for the Fracture Mechanics Analysis.

4.4.4 Mass Measurement

OPRP-1025/Created/I

The mass of the unit shall be determined by weighing. The unit mass shall be within the limit specified in Section 3.5.1.
4.4.5 Proof Pressure Test

OPRP-1029/Created/R

The PTA shall be subjected to a Proof Pressure test at the Proof Pressure defined in Section 3.2.1, taking into account the requirements of Section 3.3.3.4.

OPRP-1031/Created/R

This pressure shall be maintained for a minimum of 5 minutes.

OPRP-1033/Created/R

The PTA shall not exhibit permanent set greater than 0.2% after Proof Pressure testing. No failure, degradation, or evidence of physical damage shall be permitted.

OPRP-1036/Created/I,R

The reference dimensions of length and diameter shall be recorded and verified at Proof Pressure for the protoflight model only. Additional instrumentation (e.g. strain gauges) can be requested by the design authority.

OPRP-1039/Created/T,R

As part of the protoflight/acceptance testing, the PTA shall be pressurised to Proof and the volume growth of the PTA determined. The PTA volume growth per bar of pressure shall be recorded and reported with the protoflight/acceptance test results.

OPRP-1042/Created/R

No retest shall be performed unless authorised by the Customer.

4.4.6 Volume Measurement

OPRP-1045/Created/T

PTA volume shall be determined to demonstrate compliance with the requirements of Section 3.2.9 with the tolerance specified in Section 4.3.3.

4.4.7 Random Vibration of the PMD

OPRP-2347/ET-14312&ET-14346,Derived/R

This Section details the Random Vibration requirements for the PMD. The Qualification Random Vibration requirements are given in Table 4.4-1.

<table>
<thead>
<tr>
<th>Axis</th>
<th>Frequency, Hz</th>
<th>PSD, g²/Hz</th>
<th>Composite</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal, z</td>
<td>20 to 100</td>
<td>+3dB/oct</td>
<td>5.0 grms</td>
<td>2 minutes/axis</td>
</tr>
<tr>
<td></td>
<td>100 to 300</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>300 to 2000</td>
<td>-6dB/oct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral, x, y</td>
<td>20 to 100</td>
<td>+3 dB/oct</td>
<td>3.9 grms</td>
<td>2 minutes/axis</td>
</tr>
<tr>
<td></td>
<td>100 to 300</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>300 to 2000</td>
<td>-6dB/oct</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OPRP-2353/Created/T

Notes:
1. The test jig is not pressurised during the test.
2. The levels are to be applied independently in the longitudinal and lateral directions.

Table 4.4-1: PMD Mechanical Qualification Random Vibration Test Levels

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Two tests shall be carried out:

a) with the PMD dry,

b) with the PMD immersed in a MON simulant.

The PMD shall be mounted in a vertical position in a test jig simulating the mechanical interfaces with the lower boss of the PTA.

The test fixture shall be designed to be dynamically decoupled from the PMD, for both the full and empty cases.

When immersed the PMD shall be covered with at least 100 mm of liquid and a free space of gas shall be maintained between the liquid and the cover of the test jig.

Vibration in only one axis is permissible subject to the supplier identifying the critical lateral axis and vibrating along this axis.

A low g sine vibration survey, 10 to 2000 Hz, shall be conducted in each vibration axes, prior to, and after performing the Qualification test specified.

The frequency domain of this test can be modified by the test authority if requested. Survey results should indicate no shift between pre and post vibration surveys attributable to a change in test item, or test fixture characteristics.

After Random Vibration testing, the test fluid shall be flowed out via a filter to verify that no metallic particles have been generated during the test.

### 4.4.8 Sine Vibration (PTA Protoflight and Acceptance)

This Section details the Sine Vibration requirements for the PTA.

The Sine Vibration requirements are given in Table 4.4-2.

<table>
<thead>
<tr>
<th>Axis</th>
<th>Frequency, Hz</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal, z</td>
<td>5 to 50</td>
<td>6.7 g</td>
</tr>
<tr>
<td></td>
<td>50 to 100</td>
<td>4.7 g</td>
</tr>
<tr>
<td>Lateral, x, y</td>
<td>5 to 50</td>
<td>3.3 g</td>
</tr>
<tr>
<td></td>
<td>50 to 100</td>
<td>3.0 g</td>
</tr>
<tr>
<td>Sweep Rate</td>
<td></td>
<td>4 oct/min</td>
</tr>
</tbody>
</table>

Notes:

1. The requirements apply for both empty and full tank testing.
2. The levels are to be applied independently in the longitudinal and lateral directions.
3. For full tank testing the PTA is pressurised to 6 bar gauge with helium.
4. For empty tank testing the PTA is pressurised to 2 bar gauge with helium.

Table 4.4-2: PTA Sine Vibration Test Levels
For Protoflight Sine Vibration testing, the test levels shall be 1.5 times the Acceptance Sine Vibration levels.
Vibration in only one lateral axis is permissible, subject to the supplier identifying the critical lateral axis and vibrating along that axis.

The PTA shall be supported in a configuration representative of flight. The PTA shall be mounted in a vertical position to a test jig simulating the mechanical interfaces with the spacecraft. The test fixture shall have a natural frequency greater than 150 Hz with a solid mass representing the loaded PTA. Prediction of the test fixture stiffness may be performed by finite element analysis. Verification may be achieved by dummy PTA testing prior to qualification PTA testing.

The transmissibility and cross talk of the test fixture shall be determined for each of three mutually perpendicular axes.

For the purpose of controlling vibration applied to the PTA, calibrated control accelerometers shall be attached rigidly to the fixture near the mounting flange, and trued with the axis of the applied vibration. When more than one control accelerometer is used per axis, the arithmetic mean of spectral densities shall be used.

A low g vibration survey, 5 to 600 Hz for an empty Tank, shall be conducted in each vibration axis, prior to, and after performing the protoflight and acceptance tests specified. The frequency domain of this test can be modified by the test authority if requested. Survey results should indicate no shift between pre and post vibration surveys attributable to a change in test item, or test fixture characteristics.

4.4.9 Bubble Point Test

Each screen in the PMD shall be bubble point tested with IPA to ensure its integrity at each stage during manufacturing up to delivery.

<table>
<thead>
<tr>
<th>Level</th>
<th>Screens (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;300</td>
</tr>
<tr>
<td>2 and 3</td>
<td>&gt;300</td>
</tr>
</tbody>
</table>

Table 4.4-3: Minimum Bubble Point Pressure

Temperature of IPA during the test must be as close as possible to 20°C, elsewhere, the corrected values of physical characteristics must be submitted to the Customer for approval.

Note: at 20°C the surface tension of IPA = 21.7 x 10^-3 N/m and density of IPA = 785.5 kg/m^3.
4.4.10 Cleanliness Verification

OPRP-1108/Created/T

The purpose of this test is to verify that the unit meets the cleanliness requirements of Section 3.5.4. The PTA is subjected to a Cleanliness Verification after testing.

The unit shall be flushed with Isopropyl Alcohol, or de-ionised, distilled and filtered, 3 microns absolute, water in the normal and reverse flow direction.

The effluent shall be withdrawn from each port for particle count and NVR analysis.

OPRP-1112/Created/T

The maximum allowable number of particles/0.1m² of surface area, when tested in accordance with SD(o) and SD(r), or an equivalent Customer approved procedure, shall be as specified in Section 3.5.4.

OPRP-1114/Created/T

In the event that the equipment fails to meet the specified requirement on the first cleanliness verification test (except if “Status Only” is required), the supplier shall subject the equipment to additional cleaning until the requirements of Section 3.5.4 are met.

OPRP-1116/Created/T

Following the Cleanliness Verification test the unit shall be gas purged and thoroughly dried to a Customer approved procedure, to remove all traces of residual liquid. (see Section 3.5.4 for levels of contamination).

OPRP-1118/Created/T

After precision cleaning and drying, and while the PTA is still in a controlled Clean Room area, propellant line tube ends are to be capped off, or enclosed using a method to be reviewed and approved by the Customer.

The PTA shall then be bagged, using a 2 mil (0.05 mm) minimum anti static nylon inner bag and outer bagged with 4 mil (0.1 mm) minimum Nylon or polyethylene transparent anti static material.

Bag ends are to be heat sealed closed, the inner bag being evacuated prior to sealing.

An identification, non-shedding tag, shall be placed between the inner and outer bags, and shall display the following caution note as a minimum, “Open in a Contamination Controlled Area Only”.

OPRP-1123/Created/I,R

After all cleaning procedures have been completed, the level of chemical contaminants retained in the PTA, will be such that correct functioning shall not be impaired or compromised throughout the operation lifetime.

4.4.11 External Leak Test

OPRP-1126/Created/T

The dry unit shall be pressurised with gaseous helium and the leakage measured for compliance with Section 3.2.7.

4.4.12 Visual Inspection

OPRP-1129/Created/I

After each environmental test the unit shall be examined for evidence of physical damage.
4.4.13 Pressure Drop Test

**OPRP-1132/Created/l**

The unit shall be subjected to a pressure drop test in the normal flow direction using water SD(h) or appropriate equivalent.

**OPRP-1134/Created/T**

The pressure loss value shall be recorded at representative flows equivalent to 5 cc/s and 10 cc/s of MON during acceptance test and 5 cc/s, 10 cc/s and 20 cc/s of MON during qualification test. The temperature of the outgoing fluid shall be noted as part of the test.

**OPRP-1136/Created/I,R**

The test result shall be corrected to an equivalent pressure loss with MON and shall show compliance with the requirements of Section 3.2.6.

4.4.14 Step Start Test

**OPRP-1139/Created/T**

The PTA shall be loaded with an appropriate simulant to a level ensuring that the critical elements are properly immersed and wetted and then pressurised to a pressure which will produce a flow rate of 310 cc/s of the Freon substitute at 20°C (equivalent to the pressure drop produced by Hydrazine pressurised at regulated operating pressure).

The PTA shall be subjected to a flow surge into a downstream evacuated volume of not less than 1 litre. The actuation time of the valve initiating the surge shall not exceed 20 msec. There shall be no evidence of degradation of the PMD elements, or PTA functional capability.

4.4.15 Fill/Drain Cycling Test

**OPRP-1143/Created/T**

The PTA shall be subjected to fluid flows simulating fill and drain maximum flow conditions in order to verify the structural and functional integrity of PMD elements.

The PTA shall be filled and drained, 9 times with either water to SD(h) or equivalent, or Freon substitute to maximum capacity.

The flow rate shall be representative to the pressure drop equivalent to MON, flow rate of 20 cc/sec. After test there shall be no evidence of degradation of PMD elements, or of PTA functional capability.

**OPRP-1147/Created/T**

During this test, the volume of the residuals on ground shall be recorded.

4.4.16 Preparation for Data Review

**OPRP-1150/Created/l**

The PTA shall be inspected by In-house or Subcontractor Quality Assurance for physical damage.

Data taken during the test shall be completed, required analyses and computations shall be performed, and all test data shall be reviewed and certified by In-house, or Subcontractor Quality Assurance.

The data shall then be submitted to the designated Customer representative for review as defined in the Statement of Work.
4.4.17 Shock (PMD Qualification)
OPRP-1178/Created/T

The PTA and PMD shall conform to the shock requirements given in Table 4.4-4.

<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>SRS, g (Q = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>12.5</td>
</tr>
<tr>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>1000</td>
<td>400</td>
</tr>
<tr>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td>10000</td>
<td>1000</td>
</tr>
</tbody>
</table>

Table 4.4-4: PMD Qualification Shock Test Requirements

4.4.18 Pressure Cycling
OPRP-3061/Created/T

The PTA shall be subjected to Pressure Cycling as defined in Section 3.3.3.4, unless it can be shown that the requirement can be verified by similarity.

4.4.19 Burst Pressure Test
OPRP-1181/Created/T

The PTA shall be subjected to a Burst Pressure test at the Burst Pressure defined in Section 3.2.1, unless it can be shown that the requirement can be verified by similarity.

OPRP-1183/Created/I

The PTA shall not rupture, or leak externally at, or below this pressure test.

OPRP-1185/Created/R

After demonstrating no burst at the Burst Pressure defined in Section 3.2.1, increase pressure to actual burst of vessel. Record actual Burst Pressure.
5 PREPARATION FOR DELIVERY

5.1 Preservation and Packaging

OPRP-1189/Created/R

Preservation and packaging of the PTA shall be accomplished in a manner which will ensure protection against mechanical damage, deterioration and contamination.

Double bagged units shall be packaged within each shipping container with cellulose cushioning material, pads, fillers, or other acceptable packaging aids which will centralise and provide protection to unit propellant lines and prevent contact, shifting, or rotation of the PTA within the container.

OPRP-1192/Created/R

The equipment container shall be usable for storage of the package material.

OPRP-1194/Created/R

The shipping container shall be designed and constructed to provide sufficient strength and protection of the PTA, during the handling and environmental hazards which may be encountered when transported by common carrier.

The inside dimensions of the container shall permit a minimum of 50 mm spacing between any surface of the PTA and the inside surface of the container.

OPRP-1197/Created/R

The shipping container shall contain a shock recorder capable of recording the g levels which the PTA and its container was subjected to during the transportation.

OPRP-1199/Created/R

A copy of the suppliers' handling/transportation and safety procedures shall be included with the equipment in an obvious and readily accessible position to facilitate reference before final stages of unpacking.

5.2 Marking for Shipment and Storage

All markings on containers shall be clearly legible from a distance of 1 metre and may be applied by stencil, rubber stamp, or lacquer over coated gummed labels.

"ITEMS FOR SPACE FLIGHT USE"

"OPEN ONLY WITH QA/QC SUPERVISION"

In addition all interior packages and exterior shipping containers shall be marked as follows:

(a) Part Numbers
(b) Nomenclature
(c) Quantity
(d) Contract Numbers, prime and subcontract
(e) Serial Number
(f) Gross weight of packaged PTA marked on the outside of package only.
5.3 PTA Shipping Container Requirements

5.3.1 Steady State and Sine Acceleration and Shock

OPRP-1216/ET-36,Derived/R

Transportation containers and their method of transportation shall be such as to ensure that levels experienced by the propellant Tanks are less severe than those specified in Section 4.2 of AD(d).

5.3.2 Other Environments

OPRP-1228/Created/

Equipment in the container may suffer extremes of temperature, pressure, etc. during transportation and shall be designed to withstand the environments as specified in Section 3.4.3 of the main part of this document.
6 APPENDIX - PROPELLANT OPERATIONAL REQUIREMENTS

6.1 Horizontal Transportation Requirements
Not applicable.

6.2 Launch
No performance requirements during this phase.

6.3 Pressurisation
Refer to step start pressure surge Section 3.2.8.

6.4 Attitude Control and Trajectory Correction Manoeuvres
OPRP-1238/Created/A

*The PMD shall have the capability to refill 3.0 litres within 45 minutes in orbit, assuming a failure of one of the vanes and the following conditions:
- PTA fill ratio: from full to empty,
- No flow to the thrusters.*

6.5 T1 Thruster set Manoeuvres
OPRP-1251/Created/A

*Up to four thrusters are fired for T1 Thruster set firings of up to 13 minutes, assuming the following conditions:
- PTA fill ratio: from full to empty
- nominal flow rate: 10 cc/s Oxidiser/16 cc/s Fuel per PTA, contingency case flow rate: 20 cc/s Oxidiser/32 cc/s Fuel per PTA
- linear accelerations, rotation rates and angular accelerations are as defined in Section 3.2.12.2.*
7 GDIR APPLICABILITY MATRIX

The following Table lists the applicable requirements of the GDIR.

It contains, in the first column, the **Local ID** for each applicable GDIR requirement number.

The second column contains the GDIR Requirement number and the opening text of the requirement.

The third column defines the Applicability **Y/N**

The final column shows the intended verification method. If no method is shown it shall be assumed that verification is required, but is to be confirmed.

<table>
<thead>
<tr>
<th>Req No.</th>
<th>Reference</th>
<th>Applicability</th>
<th>Verif. Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Applicable Documents</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2357</td>
<td>GDI-3994: The following documents, of the latest issue, or o ...</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><strong>2.2 Applicable Standards</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2359</td>
<td>GDI-3993: The following documents, of the latest issue, or o ...</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><strong>2.2.1 ECSS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.2.2 Military/Industrial</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3.1.1 Lifetime</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2363</td>
<td>GDI-35: The equipment/subsystem shall meet the requirement ...</td>
<td>Y</td>
<td>TBD</td>
</tr>
<tr>
<td>OPRP-2364</td>
<td>GDI-38: Maintenance during storage shall be as limited as ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2365</td>
<td>GDI-53: The MTM equipment/subsystems shall be designed wit ...</td>
<td>Y</td>
<td>T,A</td>
</tr>
<tr>
<td>OPRP-2366</td>
<td>GDI-48: Where the design margin on nominal lifetime is not ...</td>
<td>Y</td>
<td>R,TBC</td>
</tr>
<tr>
<td>OPRP-2367</td>
<td>GDI-49: The lifetime of items which degrade shall be desig ...</td>
<td>Y</td>
<td>R,TBC</td>
</tr>
<tr>
<td><strong>3.1.2 Safety and Product Liability</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2369</td>
<td>GDI-55: The subcontractor shall comply to the applicable s ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td><strong>3.1.4 Venting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2371</td>
<td>GDI-59: The equipment/subsystem shall be able to operate w ...</td>
<td>Y</td>
<td>A,R</td>
</tr>
<tr>
<td><strong>3.1.5 Interchangeability</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2374</td>
<td>GDI-70: All spacecraft equipment/subsystems of the same pa ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td><strong>3.1.6 Identification and Marking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2376</td>
<td>GDI-72: The equipment hardware shall be identified with a ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td>OPRP-2377</td>
<td>GDI-73: The equipment/subsystem identification nameplate s ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td><strong>3.1.7 Accessibility/Maintainability, and Ground Testing Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2379</td>
<td>GDI-82: The design of the equipment/subsystem, the positio ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2380</td>
<td>GDI-83: The equipment shall be designed to require a minim ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2381</td>
<td>GDI-84: No field maintenance, servicing or adjustment shal ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td><strong>3.1.8 Transportation, Handling and Storage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Req No.</td>
<td>Reference</td>
<td>Applicability</td>
<td>Verif. Method</td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>OPRP-2384</td>
<td>GDI-77: The equipment/subsystems shall be transported using ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2385</td>
<td>GDI-78: The equipment/subsystem containers, covers (for op ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2386</td>
<td>GDI-79: The equipment/subsystem transport container shall ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2387</td>
<td>GDI-80: The equipment/subsystem storage container shall be ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td><strong>3.1.8.1 Transport</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2389</td>
<td>GDI-90: Where applicable blanking caps shall be fitted to ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td>OPRP-2390</td>
<td>GDI-91: All equipment shall be packaged to ensure that it ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td>OPRP-2391</td>
<td>GDI-93: The specified item GSE shall follow as far as appr ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td><strong>3.1.8.2 Equipment/Subsystem Packing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2393</td>
<td>GDI-95: Each container shall be labelled, tagged or marked ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td>OPRP-2394</td>
<td>GDI-96: In addition to the above, the container shall also ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td>OPRP-2395</td>
<td>GDI-2267: Size of company labels on containers shall be agre ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td><strong>3.1.8.3 Container Identification</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2397</td>
<td>GDI-98: Equipment/subsystem weighing more than 10 kg shall ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td><strong>3.1.10 Lubricants and Sealants</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2399</td>
<td>GDI-103: No lubricants or sealants shall be used without th ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2400</td>
<td>GDI-3289: The spacecraft equipments/subsystems shall be able ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2401</td>
<td>GDI-3292: The equipment/subsystem shall be able to safely wi ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2402</td>
<td>GDI-3594: SEE in terms of transients are depending on applic ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2403</td>
<td>GDI-3595: The subcontractor shall perform a displacement ana ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2404</td>
<td>GDI-3596: With respect to radiation impact, the unit shall b ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2405</td>
<td>GDI-105: All drawings, specifications and engineering data ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2406</td>
<td>GDI-106: Equipment/subsystem shall be compatible with mecha ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2407</td>
<td>GDI-2137: Material selection shall be in accordance with ECS ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2408</td>
<td>GDI-2139: Mechanical parts selection shall be in accordance ...</td>
<td>Y</td>
<td>R</td>
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<td>OPRP-2409</td>
<td>GDI-3980: All reference frames shall be right-handed orthogo ...</td>
<td>Y</td>
<td>R</td>
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<tr>
<td><strong>3.2.2 Structural Design</strong></td>
<td></td>
<td></td>
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<tr>
<td>OPRP-2412</td>
<td>GDI-117: The following failure modes, for equipment/subsyst ...</td>
<td>Y</td>
<td>A</td>
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<tr>
<td><strong>3.2.2.1 General Requirements</strong></td>
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<td>Req No.</td>
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<tr>
<td>OPRP-2413</td>
<td>GDI-118:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>For all structural items the following analyses ar ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2414</td>
<td>GDI-119: Dynamic Analysis:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>The dynamic analysis shall show ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2415</td>
<td>GDI-121: Stress Analysis:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>For each item a complete stress/s ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2416</td>
<td>GDI-122:</td>
<td>Y</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>No yielding is allowed at proof load/proof pressur ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2417</td>
<td>GDI-2053: The structure shall be of adequate strength to wit ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>OPRP-2418</td>
<td>GDI-2054:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Local buckling shall be tolerated only if it is re ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2419</td>
<td>GDI-2055:</td>
<td>Y</td>
<td>A</td>
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<tr>
<td></td>
<td>For composite materials, microbuckling of fibers s ...</td>
<td></td>
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<tr>
<td>OPRP-2420</td>
<td>GDI-123:</td>
<td>Y</td>
<td>A</td>
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<tr>
<td></td>
<td>The equipment/subsystem shall be designed to withs ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2421</td>
<td>GDI-124:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>For sine and random vibrations, the mechanical siz ...</td>
<td></td>
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</tr>
<tr>
<td>OPRP-2422</td>
<td>GDI-125:</td>
<td>Y</td>
<td>A</td>
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<tr>
<td></td>
<td>Wherever practical in the design of the primary st ...</td>
<td></td>
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<tr>
<td>OPRP-2423</td>
<td>GDI-126:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Redundancy concepts (fail-safe) shall be considere ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2424</td>
<td>GDI-127:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Fracture control principles shall be applied where ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2425</td>
<td>GDI-128:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>In cases where a fail-safe design cannot be implem ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2426</td>
<td>GDI-129:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Pressure vessels shall be potential fracture criti ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2427</td>
<td>GDI-131:</td>
<td>Y</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Pressure lines, fittings and components shall subj ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2428</td>
<td>GDI-133:</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>All fusion joints shall be 100 %inspected accordin ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2429</td>
<td>GDI-134:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Fasteners used in safe life applications, items fa ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2430</td>
<td>GDI-135: Fasteners</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>a. Fasteners shall be classified and ana ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2431</td>
<td>GDI-136:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>PFCIs shall comply with ECSS-E-30-01A in full. ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2432</td>
<td>GDI-137:</td>
<td>Y</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Non-metallic flight structural items (composite, g ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2433</td>
<td>GDI-138:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>For load cases involving thermal and/or moisture d ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2434</td>
<td>GDI-139:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Where pressure and/or temperature and/or moisture ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2435</td>
<td>GDI-140:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>The Flight equipment shall be able to survive 4 ti ...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.2.2 Mass Properies

OPRP-2437 GDI-143: All equipment/subsystem suppliers shall provide eq ... | Y | R |

OPRP-2438 GDI-146: The mass of an item must be measured with the foll ... | Y | T |
### 3.2.2.3 Centre of Gravity and Moment of Inertia

<table>
<thead>
<tr>
<th>Req No.</th>
<th>Reference</th>
<th>Applicability</th>
<th>Verif. Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPRP-2440</td>
<td>GDI-148:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>All COG and MOI estimates shall be accompanied by ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2441</td>
<td>GDI-149:</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>The Center of Gravity (CoG) shall be given. w.r.t. ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2442</td>
<td>GDI-150:</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>The Moments of Inertia (MoI) shall be given about ...</td>
<td></td>
<td></td>
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</tbody>
</table>

### 3.2.2.4 Stiffness requirements

<table>
<thead>
<tr>
<th>Req No.</th>
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<th>Applicability</th>
<th>Verif. Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPRP-2444</td>
<td>GDI-2140:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Minimum natural frequency requirements are imposed ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2445</td>
<td>GDI-154:</td>
<td>Y</td>
<td>T,A</td>
</tr>
<tr>
<td></td>
<td>Except otherwise specified, when equipment/subsyst ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2446</td>
<td>GDI-155:</td>
<td>Y</td>
<td>T,A</td>
</tr>
<tr>
<td></td>
<td>Modal analysis shall be performed to verify the fr ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2447</td>
<td>GDI-2188:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>The units and associated transport containers shall ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2448</td>
<td>GDI-2189:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Vertical and horizontal loads shall be considered ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2449</td>
<td>GDI-2199:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>The transportation containers shall be designed to ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2450</td>
<td>GDI-2200:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>The MGSE design and analysis shall consider a desi ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2451</td>
<td>GDI-3629:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>During ground transportation the units shall withs ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2452</td>
<td>GDI-3664:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>All MGSE, containers, transportation and handling ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2453</td>
<td>GDI-3665:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Sine and random vibrations: the unit transport con ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2454</td>
<td>GDI-3666:</td>
<td>Y</td>
<td>T,R</td>
</tr>
<tr>
<td></td>
<td>For containers, the shock requirement is a drop of ...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.2.6 Strength requirements

#### 3.2.2.6.1 Definitions and General Requirements

#### 3.2.2.6.2 Margins of Safety and Factors of Safety

<table>
<thead>
<tr>
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<th>Reference</th>
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<th>Verif. Method</th>
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<tr>
<td>OPRP-2458</td>
<td>GDI-186:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>An uncertainty factor Jf shall be defined to provi ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2459</td>
<td>GDI-187:</td>
<td>Y</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>A Qualification Factor of 1.5 shall be used for KQ ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2460</td>
<td>GDI-188:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>An Acceptance Factor of 1.0 shall be used for KA t ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2461</td>
<td>GDI-189:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>A Design Factor of 1.5 shall be used for DF to det ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2462</td>
<td>GDI-194:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>The unit shall be able to withstand, without failu ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2463</td>
<td>GDI-195:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Margin of safety (MOS) a. Margins of safety (MOS) ...</td>
<td></td>
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</tr>
<tr>
<td>OPRP-2464</td>
<td>GDI-197:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Minimum Factors of Safety against ultimate for pre ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2465</td>
<td>GDI-198:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>For combined loads where L(P) is the load due to m ...</td>
<td></td>
<td></td>
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<tr>
<td>OPRP-2466</td>
<td>GDI-207:</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Conservative friction coefficients regarding minim ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPRP-2467</td>
<td>GDI-208:</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Wherever applicable, for general design of bolts, ...</td>
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<td></td>
</tr>
</tbody>
</table>
### Req No. | Reference | Applicability | Verif. Method |
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>OPRP-2468</td>
<td>GDI-209: In addition, in case of combined loads due to ther ...</td>
<td>Y</td>
<td>A</td>
</tr>
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#### 3.2.3 Design Requirements

#### 3.2.3.1 Mounting Requirements

<table>
<thead>
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<th>Reference</th>
<th>Applicability</th>
<th>Verif. Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPRP-2471</td>
<td>GDI-219: The attachment points of the equipment/subsystem s ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2472</td>
<td>GDI-3996: The mechanical mounting interface shall be consist ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2473</td>
<td>GDI-220: The number of attachment bolts for a equipment sh ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2474</td>
<td>GDI-221: The interface plane flatness of a equipment/subsys ...</td>
<td>Y</td>
<td>I</td>
</tr>
<tr>
<td>OPRP-2475</td>
<td>GDI-222: The equipment/subsystem bolts type and number shal ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2476</td>
<td>GDI-223: Except otherwise specified, all equipment/subsystem ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2477</td>
<td>GDI-228: Unless special conditions override, the thickness ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2478</td>
<td>GDI-229: Minimum clearance between mechanical parts shall c ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2479</td>
<td>GDI-230: All equipment/subsystems shall be designed allowin ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2480</td>
<td>GDI-2550: The minimum load carrying capability of the insert ...</td>
<td>Y</td>
<td>A,R</td>
</tr>
<tr>
<td>OPRP-2481</td>
<td>GDI-2551: The following typical insert distances along the m ...</td>
<td>Y</td>
<td>A,R</td>
</tr>
</tbody>
</table>

#### 3.2.4 Mechanical / Optical Interface Control Documents

<table>
<thead>
<tr>
<th>Req No.</th>
<th>Reference</th>
<th>Applicability</th>
<th>Verif. Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPRP-2483</td>
<td>GDI-239: The mechanical and optical configuration and its i ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2484</td>
<td>GDI-240: Interfaces will be subjected to a formal inspectio ...</td>
<td>Y</td>
<td>T,I</td>
</tr>
<tr>
<td>OPRP-2485</td>
<td>GDI-241: The issues of ICDs have to be released as defined ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2486</td>
<td>GDI-242: One of the attachment holes on a equipment/subsyst ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2487</td>
<td>GDI-243: The equipment/subsystem reference frame shall have ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>OPRP-2488</td>
<td>GDI-246: The dimensioning of the attachment hole pattern sh ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2489</td>
<td>GDI-247: Interface Control Drawings shall be provided to AS ...</td>
<td>Y</td>
<td>R</td>
</tr>
</tbody>
</table>

#### 3.2.5 Mechanical Mathematical Model Requirements

<table>
<thead>
<tr>
<th>Req No.</th>
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<th>Applicability</th>
<th>Verif. Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPRP-2491</td>
<td>GDI-253: Detailed Finite Element Models (FEM) shall be prov ...</td>
<td>Y</td>
<td>A</td>
</tr>
<tr>
<td>OPRP-2492</td>
<td>GDI-254: All FE model requirements, checks and formats are ...</td>
<td>Y</td>
<td>T</td>
</tr>
<tr>
<td>OPRP-2493</td>
<td>GDI-2256: Mechanisms shall conform to the spacecraft system ...</td>
<td>Y</td>
<td>A,R</td>
</tr>
</tbody>
</table>

#### 3.4 Thermal Design and Interface Requirements

#### 3.4.2 Definition of Temperatures and Terms

#### 3.4.2.3 Isothermal Equipment/Subsystem

<table>
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<tr>
<td>OPRP-2497</td>
<td>GDI-302: As far as possible thermal gradients across the ba ...</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>Req No.</td>
<td>Reference</td>
<td>Applicability</td>
<td>Verif. Method</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>OPRP-2498</td>
<td>GDI-303: For radiative equipment/subsystems the temperature ...</td>
<td>Y</td>
<td>T,A</td>
</tr>
<tr>
<td>OPRP-2499</td>
<td>GDI-304: For conductive equipment/subsystems the temperature ...</td>
<td>Y</td>
<td>T,A</td>
</tr>
<tr>
<td>OPRP-2500</td>
<td>GDI-305: For non-isothermal equipment/subsystems a reference ...</td>
<td>Y</td>
<td>R</td>
</tr>
</tbody>
</table>

3.4.2.4 Temperature Reference Point (TRP)

3.4.3 Thermal Interface Requirements

3.4.3.1 Conductive Interface

OPRP-2505 | GDI-316: The mounting interface shall comply with the mechanical interface ... | Y | A |

3.4.3.2 Radiative Interface

OPRP-2508 | GDI-322: Equipment/subsystems shall be designed with an emissivity factor ... | Y | R |

3.4.3.3 Internal Temperature Monitoring

OPRP-2510 | GDI-325: The location, type and electrical interface of all temperature sensors ... | Y | R |

3.4.5 Thermal Control

OPRP-2512 | GDI-331: All thermal hardware mounted on the equipment/subsystem ... | Y | R |

3.4.6 Thermal Interface Control Documents

OPRP-2514 | GDI-333: All equipment/subsystem thermal interfaces shall be described ... | Y | R |

3.4.7 Thermal Mathematical Model Requirements

3.4.7.2 Thermal Interface Modeling

OPRP-2517 | GDI-336: The Thermal mathematical model shall be provided ... | Y | A |

OPRP-2518 | GDI-337: SI units: All units used in thermal models (geometry ... | Y | A |

3.4.7.3 Thermal Model Correlation

OPRP-2520 | GDI-339: The detailed thermal model of a equipment/subsystem ... | Y | T,A |

3.4.7.4 Reduced Thermal Model

OPRP-2522 | GDI-341: The consistency between reduced and detailed thermal models ... | Y | A |

OPRP-2523 | GDI-342: The convergence of the thermal models shall be demonstrated ... | Y | A |

5.1 Mechanical Interface Datasheet

OPRP-2525 | GDI-2760: The mechanical and optical configuration and its interface ... | Y | R |

6.1 Thermal Interface Control Document

OPRP-2527 | GDI-2892: All unit thermal interfaces shall be described ... | Y | R |
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