Document Number: MFG PS-00025/11

Hardware Cleaning Specification

<table>
<thead>
<tr>
<th>Approvers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Manager</td>
</tr>
<tr>
<td>Quality Manager</td>
</tr>
<tr>
<td>Engineering Manager</td>
</tr>
<tr>
<td>Manufacturing Engineer</td>
</tr>
</tbody>
</table>
## Revision History

<table>
<thead>
<tr>
<th>REV</th>
<th>DATE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Aug 31, 2016</td>
<td>Initial release, E. Wernimont incorporated Aug 2, 2016 meeting edits &amp; Johnson email of Aug 30, 2016 (including coin toss agreement to use “type” designations)</td>
</tr>
<tr>
<td>03</td>
<td>Oct 30, 2017</td>
<td>- Added table 5&lt;br&gt;- Added Cleanliness Type to section 1.1</td>
</tr>
<tr>
<td>04</td>
<td>June 29, 2018</td>
<td>- Added Clean Types 6 and 7&lt;br&gt;- Updated to current Virgin Orbit formatting</td>
</tr>
<tr>
<td>05</td>
<td>August 28, 2018</td>
<td>- Removed acetone from clean Type 7</td>
</tr>
<tr>
<td>06</td>
<td>Nov 30, 2018</td>
<td>- Revised language throughout entire document, corrected minor typos&lt;br&gt;- Removed Section 1.2.2&lt;br&gt;- Combined Section 3&lt;br&gt;- Moved Acronyms to Section 2&lt;br&gt;- Added reference to document MFG PS-00128 in Section 4.2.1&lt;br&gt;- Updated Section 4.2.1 to better define Brulin cleaning solution&lt;br&gt;- Defined pH levels of Brulin cleaning solution, changed temperature range to recommended levels, revised max temp. to 145°F from 150°F, revised DI water to Brulin ratio to match recommended 10% concentration&lt;br&gt;- Added instructions to Section 4.2.3.1.1&lt;br&gt;- Added Section 6.1 Cleaning Tubing in Ultrasonic Tank&lt;br&gt;- Updated Section 6 to reference revised Brulin solution&lt;br&gt;- Revised Table 3, 4, and 6 oven dry time to “10 – 120 minutes, as needed” instead of “10 minutes, as needed” for consistency with Table 1&lt;br&gt;- Added “heated oil-free air” in dry steps per Section 4.1.2&lt;br&gt;- Revised Section 7.2.4 to clearly specify to borescope all tubing&lt;br&gt;- Moved Reference Documents section to end of spec</td>
</tr>
<tr>
<td>07</td>
<td>Jan 08, 2019</td>
<td>- Moved ultrasonic tank pH check from MFG PS-00128 to Section 4.2.1&lt;br&gt;- Updated Section 6.1 with part tagging in ultrasonic tank&lt;br&gt;- Added clean type 8 for parts with adhesives</td>
</tr>
<tr>
<td>08</td>
<td>Nov 08, 2019</td>
<td>- Added Clean Types 9 and 10&lt;br&gt;- Updated Title for Type 6 and 7&lt;br&gt;- Updated Section 8.0 with additional requirements&lt;br&gt;- Removed clean level requirement in Section 1.1&lt;br&gt;- Added detailed borescope requirements in Section 7.2.4.&lt;br&gt;- Moved VO resources to the bottom of spec&lt;br&gt;- Updated Section 5.1.1 to a table format for clarity&lt;br&gt;- Added Section 6.1.2&lt;br&gt;- Updated formatting</td>
</tr>
<tr>
<td>09</td>
<td>Feb 10, 2020</td>
<td>- Edited section references&lt;br&gt;- Added acronyms for DI, LOX, and WO&lt;br&gt;- Removed desiccant requirement</td>
</tr>
</tbody>
</table>
- Added oven requirements to Section 8.0
- Added soft goods and tape definitions
- Added black light requirements to Section 5.1.2
- Removed names in approver roles, removed ITAR statement
- Added section 5.1.1

10 June 25, 2020
- Changed wording of Types 7 and 10 to be "Alodine Coating (With/without Anodized Coating)"
- Section 1.2: Added "or equivalent procedure approved by supplier quality" to application to align spec with new drawing notes
- Added clarity to soft goods definition in Section 2.1. Does NOT include spring energized deals
- Added Approved Cleaning Methods. VO Clean Types are based on hardware and only link specifically to required inspection criteria
- Added Recommended cleaning methods for each VO Clean Type (to align with previous versions of this spec)
- Added language in Section 4 to clarify roles per the new drawing notes: MFG Engineer assigns cleaning method and VO Clean Type as appropriate, drawings specify requirements, and RE is point of contact for any deviations.
- Section 5, clarified that qualified technician is SQuID
- Added example drawing notes to Section 5.1
- Updated any IEST-STD-CC1246 references that were still rev D to rev E
- Added CoC requirement in Section 5.1.1 Documentation for IEST testing if vendors are asked to test cleanliness levels per drawing notes
- Deleted packaging requirements and pointing to SC PROC-10014 for packaging requirements. Leaving Preservation of Cleanliness (6.2) as is
- Moved all documentation language to SM-11006 and now reference SM-11006 in documentation section (5.1.1)
- Changed Section 8 from VO In-House Use Only to apply to Approved Cleaning Methods

11 March 18, 2021
- Added GSE Ground Support Equipment in Acronyms list
- Added statement to define “Flight” vs “GSE” hardware in scope
- Added Type 1 GSE LOX to Scope and Section 4.2
- Changed RP1/General Recommended Cleaning Type to Ultrasonic 2 to match with intent from rev09
- Added “LN2 Liquid Nitrogen” to Section 2.2
- Added Section 4.1.6 Flush Cart
- Added Section 4.1.7 Liquid Nitrogen (LN2) Flush Setup
- Added Section 7.2.1 PPE for working with Cryogenics
- Added Section 8.2.4 Flush Cart Setup
- Added Section 8.2.5 LN2 Flush Setup
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<th>MFG PS-00025/11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document Name</td>
<td>Hardware Cleaning Specification</td>
</tr>
</tbody>
</table>

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1 Introduction

1.1 Scope
This hardware cleaning specification describes the recommended material, safety, methods, and inspection criteria to meet cleanliness requirements specified on drawings and work orders. VO Clean Types drive inspection criteria for applicable hardware are defined in the table below.

<table>
<thead>
<tr>
<th>VO Clean Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LOX</td>
</tr>
<tr>
<td>1 GSE</td>
<td>LOX (GSE Only)</td>
</tr>
<tr>
<td>2</td>
<td>Soft Goods</td>
</tr>
<tr>
<td>3</td>
<td>Pneumatics</td>
</tr>
<tr>
<td>4</td>
<td>RP1 or General</td>
</tr>
<tr>
<td>5</td>
<td>IPA Wipe</td>
</tr>
<tr>
<td>6</td>
<td>Anodized Hardware (No Alodine Coating) (RP1/Pneumatics)</td>
</tr>
<tr>
<td>7</td>
<td>Alodine Coating (With/without Anodized Coating) (RP1/Pneumatics)</td>
</tr>
<tr>
<td>8</td>
<td>Adhesives</td>
</tr>
<tr>
<td>9</td>
<td>Anodized Hardware (No Alodine Coating) (LOX)</td>
</tr>
<tr>
<td>10</td>
<td>Alodine Coating (With/without Anodized Coating) (LOX)</td>
</tr>
</tbody>
</table>

Approved cleaning methods recommended for use for VO Clean Types are included.

This specification does not cover passivation processes.

In this document, “Flight” hardware refers to any hardware to be used on the rocket or plane, while “GSE” hardware refers to any hardware external to the rocket and plane.

1.2 Application
This procedure, or equivalent procedure approved by supplier quality, is applicable to all VO suppliers. This procedure is applicable to all VO facilities.

2 Definitions

2.1 Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Volatile Residue</td>
<td>Material remaining after evaporation of a liquid</td>
</tr>
<tr>
<td>Soft Goods</td>
<td>Examples include seals and O-rings, and backups for T-seals. Does NOT apply to spring-energized seals.</td>
</tr>
<tr>
<td>LOX-compatible tape</td>
<td>Particle free tape, suitable for ISO Class 3 to ISO Class 6 cleanrooms</td>
</tr>
</tbody>
</table>
2.2 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoC</td>
<td>Certificate of Conformance</td>
</tr>
<tr>
<td>FOD</td>
<td>Foreign Object Debris</td>
</tr>
<tr>
<td>GSE</td>
<td>Ground Support Equipment</td>
</tr>
<tr>
<td>IPA</td>
<td>Isopropyl Alcohol</td>
</tr>
<tr>
<td>ME</td>
<td>Manufacturing Engineer</td>
</tr>
<tr>
<td>NVR</td>
<td>Non-Volatile Residue</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>RE</td>
<td>Responsible Engineer</td>
</tr>
<tr>
<td>SDS</td>
<td>Safety Data Sheets</td>
</tr>
<tr>
<td>SQuID</td>
<td>Special Quality Inspection Designation</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>VO</td>
<td>Virgin Orbit</td>
</tr>
<tr>
<td>DI</td>
<td>Deionized</td>
</tr>
<tr>
<td>LOX</td>
<td>Liquid Oxygen</td>
</tr>
<tr>
<td>LN2</td>
<td>Liquid Nitrogen</td>
</tr>
<tr>
<td>WO</td>
<td>Work Order</td>
</tr>
</tbody>
</table>

3 Responsibilities

Quality Engineering and Manufacturing Engineering is responsible for the creation and content of this specification. Any deviation from the specification requires prior approval and shall be clearly documented.

All personnel are required to comply with the guidelines set forth in this specification. All work shall be performed by qualified personnel who possess the skills and knowledge necessary to ensure compliance with this specification.

4 Cleaning Guidelines

This section covers the general guidelines for cleaning hardware based on the approved cleaning methods and VO Clean Type. Manufacturing Engineering is responsible for assigning the cleaning method for hardware. Drawing notes indicate the required level of cleanliness (e.g. per IEST standard) and/or VO Clean Type (outlined in Section 5). Any approved cleaning method may be used for any VO Clean Type as long as the part is not damaged and the part meets the verification requirements outlined...
in Section 5.0. Exceptions to these guidelines should be indicated on the drawing for the specific piece of hardware. Any questions/concerns about exceptions indicated on the drawing should be directed to the RE.

If deviating from approved cleaning methods in Section 4.1, cleaning method must be approved by supplier quality via a deviation request (for out-of-house cleaning) or by ME, RE, and QE via a What To Fix ticket (for in-house cleaning). For out-of-house cleaning, vendors with a deviation request approved by supplier quality are not required to re-submit another deviation request for subsequent Purchase Orders unless changes to the previously approved process are made. For in-house cleaning, a What To Fix ticket should be generated any time a cleaning process deviates from an approved cleaning method in Section 4.1 or the cleaning process specified in the Work Order.

The following tables are for cleaning processes only. Please refer to Section 5.0 (Quality Assurance) for verification processes.

4.1 Approved Cleaning Methods

4.1.1 Ultrasonic 1

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-clean hardware with DI water and Brulin.</td>
</tr>
<tr>
<td>2</td>
<td>Clean in ultrasonic tank with Brulin solution for a minimum of 10 minutes. (VO in-house reference Section 8.2.1)</td>
</tr>
<tr>
<td>3</td>
<td>Immediately rinse with DI water.</td>
</tr>
<tr>
<td>4</td>
<td>Flush or wipe with IPA using a lint-free wipe/swab.</td>
</tr>
<tr>
<td>5</td>
<td>Dry in oven. Max oven temperature =250°F for 10 – 120 minutes, as needed. Purge with moisture-free filtered nitrogen, or heated oil-free air, as necessary.</td>
</tr>
</tbody>
</table>

4.1.2 Ultrasonic 2

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-clean hardware with Brulin.</td>
</tr>
<tr>
<td>2</td>
<td>Clean in ultrasonic tank at 30% power with Brulin solution for no more than 5 minutes. (VO in-house reference Section 8.2.1)</td>
</tr>
<tr>
<td>3</td>
<td>Immediately rinse with DI water.</td>
</tr>
<tr>
<td>4</td>
<td>Dry in oven. Max temperature =250°F for 10 – 120 minutes, as needed. Purge with moisture-free filtered nitrogen, or heated oil-free air, as necessary.</td>
</tr>
</tbody>
</table>

4.1.3 IPA Flush

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-clean hardware with IPA only.</td>
</tr>
<tr>
<td>2</td>
<td>Flush with IPA, or hand wipe with IPA, using a lint-free cloth/swab.</td>
</tr>
<tr>
<td>3</td>
<td>Air dry hardware. Purge with moisture-free filtered nitrogen, or heated oil-free air, as necessary.</td>
</tr>
</tbody>
</table>
4.1.4 IPA Wipe

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hand-wipe hardware with IPA to remove contaminants.</td>
</tr>
</tbody>
</table>

4.1.5 DI Water + Brulin

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hand clean with DI water and Brulin solution only to remove contaminants. (VO in-house reference Section 8.2.1)</td>
</tr>
<tr>
<td>2</td>
<td>Rinse with DI water only.</td>
</tr>
<tr>
<td>3</td>
<td>Wipe surface with clean room cloth to dry.</td>
</tr>
</tbody>
</table>

4.1.6 Flush Cart (GSE Only)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-clean hardware with DI water and Brulin.</td>
</tr>
<tr>
<td>2</td>
<td>Flush Item with Brulin solution for a minimum of 10 minutes. (VO in-house reference Section 8.2.1, 8.2.4)</td>
</tr>
<tr>
<td>3</td>
<td>Immediately rinse with DI water.</td>
</tr>
<tr>
<td>4</td>
<td>Purge with moisture-free filtered nitrogen as necessary. (VO in-house reference Section 8.1.2)</td>
</tr>
</tbody>
</table>

4.1.7 Liquid Nitrogen (LN2) Flush (GSE Only)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-clean hardware with IPA only.</td>
</tr>
<tr>
<td>2</td>
<td>Purge with moisture-free filtered nitrogen as necessary. (VO in-house reference Section 8.1.2)</td>
</tr>
<tr>
<td>3</td>
<td>Verify a dewpoint measurement of -40 degC</td>
</tr>
<tr>
<td>4</td>
<td>Flush item with Liquid Nitrogen until components are fully chilled in (~320 degF)</td>
</tr>
<tr>
<td>5</td>
<td>Use dry nitrogen source to purge component and prevent moisture intrusion until component reaches ambient temperatures</td>
</tr>
</tbody>
</table>

4.2 Recommended Cleaning Methods per VO Clean Type

If a VO Clean Type is called out in work instructions but no explicit cleaning method is instructed, the recommended cleaning method per the table below shall be used.

<table>
<thead>
<tr>
<th>VO Clean Type</th>
<th>Name</th>
<th>Recommended Cleaning Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight</td>
<td>GSE</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>LOX</td>
<td>Ultrasonic 1</td>
</tr>
<tr>
<td>1 GSE</td>
<td>LOX (GSE Only)</td>
<td>N/A (See VO Clean Type 1 GSE)</td>
</tr>
<tr>
<td>2</td>
<td>Soft Goods</td>
<td>IPA Flush</td>
</tr>
<tr>
<td>3</td>
<td>Pneumatics</td>
<td>Ultrasonic 1</td>
</tr>
<tr>
<td>4</td>
<td>RP1 or General</td>
<td>Ultrasonic 2</td>
</tr>
<tr>
<td>5</td>
<td>IPA Wipe</td>
<td>IPA Wipe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#6 Anodized Hardware (No Alodine) Coating (RP1/Pneumatics)</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Alodine Coating (With/without Anodized Coating) (RP1/Pneumatics)</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>Adhesives</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Anodized Hardware (No Alodine Coating) (LOX)</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Alodine Coating (With/without Anodized Coating) (LOX)</td>
</tr>
</tbody>
</table>

Notable exceptions for choosing a cleaning method for VO Clean Type:

- Alodined hardware (VO Clean Types 7 and 10) should NOT be cleaned with an ultrasonic method (Ultrasonic 1 and Ultrasonic 2) due to their tendency to scratch easily.

5 Quality Assurance

5.1 Cleanliness Verification
All hardware shall be inspected to verify that it has been cleaned properly. Inspection shall be performed by a qualified technician (SQuID) or inspector. Cleanliness verification must meet specified cleanliness levels on drawing notes. If drawing notes specify to clean hardware to a specific VO Clean Type per MFG PS-00025, the cleanliness verification in Section 5.1.2 must be met. If drawing notes specify to clean hardware to a specific IEST-STD-1246 cleanliness level, hardware must be tested to meet the specified cleanliness level and documented per Section 5.1.1. The following are examples of drawing notes that specify cleanliness levels (refer to drawing notes for specific requirements):

1. CLEAN TO IEST-STD-CC1246 CLASS X00 RX IAW MFG PS-00025 TYPE X OR EQUIVALENT
2. CLEAN TO IEST-STD-CC1246 CLASS X00 IAW MFG PS-00025
3. PARTS SHALL BE VISIBLY CLEAN, FREE OF OIL AND DEBRIS, AFTER IPA WIPE OR FLUSH

Where “X” in “X00”, “RX”, and “TYPE X” specify the particle count requirement per IEST-STD-CC1246, the NVR requirement per IEST-STD-CC1246, and the recommended VO Clean Type per MFG PS-00025 respectively.

5.1.1 Documentation
The supplier will provide documentation in accordance with the Supplier Quality Requirements Assurance Manual (SM-11006).

5.1.2 Required Inspection Steps
Required inspection steps based on VO Clean Type are outlined in Table 1 below. Each inspection step is defined in Section 0.
### Table 1: Required Inspection Steps

<table>
<thead>
<tr>
<th>VO Clean Type</th>
<th>Visual Inspection</th>
<th>Wipe Test</th>
<th>Black Light Inspection</th>
<th>Borescope of internal cavities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 1 GSE*</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Type 2</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 3</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 4</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 5</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 6</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 7</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 8</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 9</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>Type 10</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
</tr>
</tbody>
</table>

*For Type 1 GSE, if the wipe test and borescope of internal cavities inspection methods are not performed during component fabrication, the cleanliness of internal cavities must still be measured per IEST STD-CC1246E and pass particle count and NVR requirements for the system as a whole.

#### 5.1.3 Inspection Steps Defined

**5.1.3.1 Visual Inspection**
Visual inspection shall be performed under a strong, white light. Hardware shall be inspected for overall cleanliness. If any oils/greases, FOD, or moisture is found, the hardware being inspected shall be re-cleaned. If oils/greases, FOD, or moisture remains after repeated re-cleaning attempts, a WTF (in-house) or deviation ticket (out-of-house) should be generated and dispositioned appropriately.

**5.1.3.2 Wipe Test**
The wipe test shall be used to inspect areas or surfaces that are not easily accessible. The wipe test shall be performed using a clean, lint-free wipe/swab. A sample of the inaccessible surface area should be tested, it is not required to wipe the entirety of the inaccessible surface area. The wipe/swab used to hand wipe the hardware shall be inspected using a strong, white light. If any oils/greases, FOD, or moisture is found, the hardware being inspected shall be re-cleaned. Note: Ensure that the hardware is wiped/swabbed such that FOD is not caused by the wipe/swab, and the surface finish of the hardware is not altered.

**5.1.3.3 Black Light Inspection**
The black light (UV) inspection is used to detect non-volatile residue (NVR). A UV light source shall be used in a dark room. This better facilitates the discovery of any lint, oil, grease or NVR on the
hardware. Any fluorescence found on the hardware shall be removed using a lint-free wipe/swab and IPA, as applicable. Use black light on a clean wipe for areas that cannot be inspected directly. If any fluorescence is discovered, the hardware in question shall be re-cleaned. Acceptable black lights shall meet the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>365 – 395nm</td>
</tr>
<tr>
<td>UV Intensity</td>
<td>8000 – 9000 µW/cm² *</td>
</tr>
</tbody>
</table>

* At a distance of 15cm

5.1.3.4 Borescope
Borescope inspection is available for use in any VO cleanliness type verifications. However, it is only required for internal cavities that cannot be inspected using any of the visual inspection methods outlined above. It is also required for all tubing. The inner diameter of all tubing shall be borescope inspected to ensure zero FOD present after the cleaning process. Reference QA WI-30226 for acceptance criteria. The entire length of the tube shall be inspected if possible, including welded areas.

6 Packaging and Preservation of Cleanliness
6.1 Packaging
All hardware must be packaged per SC PROC-10014. All packaging materials shall meet or exceed the VO cleanliness type.

6.2 Preservation of Cleanliness
6.2.1 Opening Packaging
Packaging shall not be opened unless the surrounding environment allows the cleanliness level of the part to be maintained. Additionally, if hardware is removed from packaging, it must be repackaged to meet design requirements.

6.2.2 Proper Handling
Gloves must be worn at all times when handling hardware. Do not touch hardware with bare hands at any time. Ensure all tooling is free of FOD and wiped with IPA before use on hardware. Do not place hardware on unclean surfaces, verify surfaces are clean using an IPA wipe.

7 Precautionary Information
This section of the specification covers general safety guidelines.
7.1 Safety Data Sheets (SDS)  
This specification stipulates the use of solvents that are regulated by federal and/or state agencies. All personnel implementing the procedures outlined in this specification shall be familiar with all appropriate SDS, including the use of appropriate personal protective equipment, and the disposal of cleaning solutions and solvents.

7.2 Personal Protective Equipment (PPE)  
When working with solutions and solvents, employees are required to wear the appropriate PPE per the SDS. In addition to PPE stipulated by the appropriate SDS, the following are mandatory at all times during cleaning operations:

- Working in a well-ventilated area
- Wearing approved, powder-free gloves
- Wearing eye protection in the form of a face shield or safety goggles/glasses

7.2.1 PPE for working with Cryogenics  
When working cryogenics, additional precautions must be taken. Appropriate PPE must be rated for cryogenic conditions (environments as low as -425 degF). In addition to PPE stipulated by the appropriate SDS, the following are mandatory at all times during cryogenic operations:

- Working in a well-ventilated area
- Wearing approved, cryogenic gloves
- Wearing eye protection in the form of a face shield or safety goggles/glasses
- Wearing a cryogenic rated apron
- Wearing the appropriate footwear for hazardous spills.

8 Resources Applicable for Approved Cleaning Methods  
This section is for use if utilizing any of the approved cleaning methods in Section 4.1 for VO Clean Types 1-10.

8.1 Materials  
8.1.1 Cleaning Solutions and Solvents  
Only the approved cleaning solutions and solvents listed below may be used in the cleaning process. If a cleaning solution or solvent that is not listed in this section is going to be used during a cleaning operation, obtain prior RE approval.

a) Brulin 815 GD, chemical characteristics listed below:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Form</td>
<td>Liquid</td>
</tr>
<tr>
<td>Color</td>
<td>Blue</td>
</tr>
<tr>
<td>Odor/Fragrance</td>
<td>Mild</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Water-thin</td>
</tr>
<tr>
<td>Weight</td>
<td>8.96 lbs/gal</td>
</tr>
<tr>
<td>pH of Concentrate</td>
<td>12.0</td>
</tr>
<tr>
<td>pH of Working Solution</td>
<td>11.5</td>
</tr>
<tr>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Flash Point (PMCC)</td>
<td>None to boiling</td>
</tr>
<tr>
<td>Foaming Tendency</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Calculated V.O.C</td>
<td>None</td>
</tr>
<tr>
<td>Freeze/Thaw</td>
<td>Reusable after thawing and remixing</td>
</tr>
</tbody>
</table>

b) IPA, 99.8% min
c) Deionized (DI) Water

8.1.2 Gases
Moisture-free, filtered gaseous nitrogen shall be used to dry and purge all hardware. All purge lines shall be filtered with a 5µ in-line filter. When drying with nitrogen isn’t practical, heated, oil-free air in an oven may be used.

8.1.3 Cleaning Materials
Shop rags are approved for general degreasing and pre-cleaning processes, only. However, only lint-free rags/swabs shall be used for final cleaning operations.

Acceptable examples:
- P/N: TC1PS2-99, Polyester Knit Wiper, 9”x9”, 150/bag
- P/N: P3135-case, Puritan Knitted Polyester Swab, Small Rigid Tip, 1000/case
- P/N: P3605-case, Puritan Knitted Polyester Swab, Symmetrical Round head, 6” 1000/Case

8.2 Tools
8.2.1 Ultrasonic Tanks

![Figure 1: Ultrasonic Tank](image)

8.2.1.1 Tank Solution Maintenance
Clean room personnel shall perform the following solution maintenance procedure once per week:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Measure pH level of tank with pH measuring kit or equivalent.</td>
</tr>
<tr>
<td>2</td>
<td>Verify that measured pH is within the acceptable pH range described in Section 8.2.1.2.</td>
</tr>
<tr>
<td>3</td>
<td>If pH is within acceptable pH range, the maintenance operation is complete.</td>
</tr>
</tbody>
</table>
If measured pH is not within acceptable pH range, notify ME or production supervisor and perform either step 4a or 4b.

4a Add Brulin until pH level is within acceptable range.

4b Drain ultrasonic tank until empty. Refill tank with solution outlined in Section 8.2.1.2.

5 Measure pH level of tank and verify that it is within the acceptable pH range described in Section 8.2.1.2.

8.2.1.2 Solution Requirements
Ultrasonic tank Brulin 815 GD solution must meet the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Temperature</td>
<td>140 – 145°F (60 – 66°C)</td>
</tr>
<tr>
<td>Acceptable Temperature</td>
<td>130 – 145°F (54 – 77°C)</td>
</tr>
<tr>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>Target Concentration</td>
<td>10% Concentration with DI Water (1:9 ratio Brulin:DI Water)</td>
</tr>
<tr>
<td>Acceptable Concentration</td>
<td>5 – 15% Concentration with DI Water (1:19 – 3:17 ratio Brulin:DI Water)</td>
</tr>
<tr>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>Target pH</td>
<td>11.5</td>
</tr>
<tr>
<td>Acceptable pH Range</td>
<td>9.5 – 14</td>
</tr>
</tbody>
</table>

8.2.1.3 Cleaning Tubing in Ultrasonic Tank
8.2.1.3.1 Cleaning Long Tubes
Use Ultrasonic 1 per Section 4.1.1 for tubing that can be fully submerged in ultrasonic tank. Use the following procedure for tubing that is unable to be fully submerged:

1) Clean portion of component that is fully submerged in ultrasonic tank with Brulin solution per Section 8.2.1.2 for a minimum of 10 minutes.
2) Remove component from ultrasonic tank and immediately rinse with DI water to remove cleaning solution.
3) Clean opposite portion of component in ultrasonic tank with Brulin solution per Section 8.2.1.2 for a minimum of 10 minutes.
4) Continue with baseline cleaning operation per Section 4.0, starting with immediate DI water rinse to remove cleaning solution.

8.2.1.3.2 Cleaning Multiple Tubes
When cleaning multiple tubes in the ultrasonic tank, the cleaning technician shall differentiate between similar tubes using a non-corrosive metal tag that shall be placed next to the tube in the ultrasonic tank. The tag shall be stamped with a number or any character that can then be connected to the tube’s corresponding WO when the tube is removed from the ultrasonic tank. Figure 2 illustrates an acceptable tag.

![Figure 2: Example Ultrasonic Tank Tag](image)

8.2.2 Local Sinks with DI Water
Brulin is the only solvent approved for use in sinks that drain to the sewer, such as the one in Figure 3 below in the VO cleaning area.

![Figure 3: Cleaning Sink](image)

8.2.3 Ovens
Do not exceed max oven temperature of 500 °F.
8.2.3.1 Oven Operation Procedure – for VO Internal Use Only
8.2.3.1.1 Large Oven in Clean Department

- Turn on using “Oven On” switch located on the right of the oven
- Set temperature as needed
- Turn on “Heat On” switch located on the right of the oven
- Turn off after use

Figure 2: Large Oven in Propulsion Area

8.2.4 Flush Cart Setup
Provide flushing setup as described in Figure 3. Ensure pump is able to provide fluid velocity capable of turbulent flow inside cleaned components. Ensure heating device is able to maintain solution temperature described in Section 8.2.1.2. Provide filter with ≤50 micron absolute rating. Confirm wetted components of pump are oil free. During and between flushes visually inspect cleaning solution in container for signs of gross contamination. Storage tank bath shall be maintained per Section 8.2.1.1

Figure 3: Flush Cart Schematic

8.2.5 LN2 Flush Setup
Provide flushing setup as described in Figure 4. Verify all equipment used from Dewar or LN2 source to catch container are appropriately rated to cryogenic conditions (<-320 degF). Reference Section 7.2.1 for appropriate PPE. Connect cryogenic flex line to the Liquid OUTLET port of the LN2 source. Connect the test article to the LN2 supply line. Connect the outlet of the test article to the base of a metal
container, preferably made of stainless steel. Connect a diffuser to the hose outlet. Activate the self-pressurization circuit of the LN2 source. Verify LN2 source has adequate head pressure to flow liquid. OPEN the LIQUID valve to allow the flow of liquid nitrogen to flow through. Deactivate the internal pressurization circuit to stop the flow of LN2.

![Figure 4: LN2 Flush Setup Schematic](image)

8.3 Personnel
All personnel shall be trained prior to cleaning flight hardware. Training shall be provided by a lead Propulsion Assembly technician, production supervisor/manager, or trained delegate. All training shall be documented and submitted to the Propulsion Assembly supervisor and the training director within the People team.

9 Reference Documents
- ISO14644-1 – Cleanrooms and associated controlled environments
- IEST-STD-CC1246E – Product Cleanliness levels and contamination control program
- SC PROC-10014 – Materials Packaging Requirements
- QA WI-30226 – Tube Acceptance Criteria
- QA PROC-20038 – Foreign Object Damage (FOD) Prevention Program
- QA WI-30100 - Surface Finish Visual Inspection for All Machined and Metallic Components