Metal Components for use in the Advanced LIGO Vacuum System

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1 Introduction

All metal components intended for vacuum service shall have quality finishes on all surfaces, suitable for service in an Ultra-High Vacuum (UHV) system. These requirements define the restrictions and practices which must be followed for parts to be used in the LIGO UHV system.

Exceptions, additions or clarifications shall be obtained in writing from the LIGO Contractual Officer or the Contractual Officer's Technical Representative.

2 Scope

These requirements apply to metal components intended for in-vacuum service.
These requirements do not apply to cantilever blade springs and porcelain steel. For these applications see the following references:
LIGO-E0900023, Process for Manufacturing Cantilever Spring Blades and
LIGO-E1000083, Specification for Enameled Steel Sheet to be used in the LIGO Ultra-High Vacuum System.
In addition while reference is made to welds in the sections below, for the complete LIGO welding specification refer to:
LIGO-E0900048, Welding Specification for Weldments used within the Advanced LIGO Vacuum System.

3 Purchase Order Specific Requirements

In addition to the requirements defined in this specification, additional requirements, specific to a particular procurement or part, may be defined in the Statement of Work (SOW) or Request for Quotation (RFQ).

4 General Requirements for Metal parts for use in Vacuum

4.1 Materials

The following requirements apply to all raw materials used for LIGO UHV components. **Substitutions and exceptions to these requirements must be in obtained in writing from LIGO in advance of manufacturing any components.**

- Only materials specified on the drawing may be used.
- Material Certifications are required for all materials. Tooling plate grade materials are not permitted.
- Materials must be of domestic (United States) origin.
- All materials are to be virgin material (i.e. no weld repairs or plugs; see also section 4.7))
- No cast or molded parts are permitted.

4.1.1 Welded (Seamed) Stainless Steel Tubing

Stainless steel seamed tubing, although an option, should not be the first choice if seamless tubing is available. The use of seamed steel tubing requires prior approval from LIGO.

If seamed tubing is utilized, the weld seam and any weld flash must meet the requirements listed below. If the weld flash does not meet the requirements, then it must be removed. Details, including fixtures and/or tooling required to remove this flash and a method for removal should be included in the quotation. The flash removal process must be inspected 100% visually and certified by the vendor and approved by LIGO.

With prior approval from a LIGO Contract Officer stainless steel seamed tubing can be used under the following conditions: -

1. Take a cross-sectional sample of the tube weld for every ~20 ft. of every continuous weld run (batch) and verify that the weld is Class B in Table V of Mil-Std-2219. The verification requires:
   a) Visual inspection for weld discontinuities, porosity and inclusions,
   b) X-ray for complete penetration and fusion and
   c) Weld flash must not extend into the interior of the tube more than .02". The weld flash must not be so rough or porous as to prevent adequate cleaning.
   d) Microstructural examination of weld samples cross-sections. Cross-sections of weld samples, for microstructural examination, shall be prepared by cutting in an orientation perpendicular to the direction of the weld bead so that the size and shape of the weld and the heat-affected zone (HAZ) can be observed. Each weld sample shall be sectioned and polished by standard metallographic procedures (for example, mounted in an epoxy, polished with a 5 micron diamond paste and then be etched with Keller's reagent). The section samples shall be examined and photo-micrographed at approximately 15x. Any weld discontinuities shall be further examined and photographed at 50x to 200x magnification.
2. Supply inspection report for approval to the LIGO contract officer confirming that the as-received seamed welds conform to class B prior to continuing.
3. Note: Prior to welding, all seamed tubing (inside and out) must be electro-polished per ASTM B-912.

As noted above refer to LIGO-E0900048, Welding Specification for Weldments used within the Advanced LIGO Vacuum System.

4.2 Final Surface Finishes

All final surfaces of all parts are to be machined. Machined surfaced must not have smeared metal or galling because these conditions can trap contaminants which could out-gas when the part is in service in the vacuum environment. No as-received or as-rolled rough surfaces will be accepted unless otherwise noted on the drawing or as an exception here:

4.2.1 Exceptions (allowable non-machined surfaces)

4.2.1.1 Extruded Sections (seamless tubes, angles, etc.) and Welded Stainless Steel Tubing

If extruded tubular sections (or angles or other stock shapes) are to be used, then machining the interior surfaces is not practical and machining the outer radius on the corners is prohibitive. In this case either

a) All surfaces of all parts are to be machined, except those not practical to machine. In this case the inner surface and outer radius will be accepted "as extruded" or "as rolled", or
b) The part is electro-polished to remove all surface oxides and potentially embedded contaminants refer to section 5.2.1.2 or 5.2.2.2.
c) (For aluminum) The part is chemically cleaned / etched by acid or caustic process, refer to 5.2.1.
d) As per section 11 of ASTM A554-10 the finished tubes shall be free of injurious defects and have a workmanlike finish. Surface imperfections such as handling marks, shallow pits and scratches shall not be considered as serious defects provided they are within 10% of the specified wall or 0.002 inch, whichever is greater.
e) Each tube shall be individually wrapped and protected from scratches, pitting and digs during transport and handling. Each tube shall be inspected and handled appropriately.

4.2.1.2 Thin Sheet

Sheet metal shall be purchased in the 2B finish condition which should normally have a surface finish of 12-20 Ra. However, if the surface finish exceeds 32 Ra then:

a) the surface finish should be discussed with LIGO Contractual office prior to acceptance, or
b) the sheet shall be electro-polished as per section 5.2.2.2

c) the sheet shall be chemically cleaned / etched by acid and / or caustic process, refer to section 5.2.1

Further questions related to machining all surfaces can be discussed with the LIGO Contractual officer or the Contracting Officer's Technical Representative. Under no circumstances shall the parts be anodized.

4.2.2 Surface Roughness

The required surface roughness is defined in the drawing block entitled "finish". Please note if finish is called out on the drawing it is in Ra. If no call-out is included in this block, then the maximum surface finish shall default to:

- 63 micro-inch (Ra) for stainless all surfaces
- 63 micro-inch (Ra) for aluminum all surfaces
- 32 micro-inch (Ra) for sheet metal. See section 4.2.1.2.

Localized scratches, digs and blemishes should be minimized and addressed though visual inspection and QA. If such blemishes compromise the function or performance of the part (e.g. a stray light control baffle), then limits on acceptable scratches and digs should be defined in the drawing or associated process specification.

4.3 Machining Fluids / Coolant

All machining, and tapping, fluids must be fully synthetic, water soluble (not simply water miscible) and free of sulfur, chlorine, and silicone. Reference LIGO document LIGO-E0900237-v5 for a list of approved coolants. If this is difficult or expensive please talk to LIGO staff about an exemption.

4.4 Abrasive Removal Techniques

4.4.1 Grinding

No grinding or lapping with abrasive wheels, cloth or stones is permitted for the final surface, unless otherwise noted on the drawing. Grinding (e.g. Blanchard grinding) is acceptable if all ground surfaces are machined afterwards.

4.4.2 Sanding

No parts are to be sanded with abrasive techniques e.g. sanding, grinding. Stainless steel wool can be used.

4.4.3 Scotch-Brite™

The use of Scotch-Brite™ or similar products is not permitted at any time.

4.4.4 Water Jet Cutting

The use Water Jet Cutting is permitted on sheet metal parts which will later be porcelain coated. For all other parts, the Water Jet Cut surface must be removed by traditional machining methods. Electro-polishing may be used to remove the Water Jet Cut surface if a written exemption is granted by LIGO.

4.5 Electrical Discharge Machining (EDM)

The use of EDM is not permitted unless the porous re-cast layer is removed by conventional machining techniques. Removal of the re-cast layer by electro-polishing may be used if a written exemption is granted by LIGO.

4.6 De-burring

All sharp edges and corners shall be rounded or chamfered per the drawing. De-burring should be done on the lathe or mill as much as possible or with de-burring tools, filing and / or stainless steel wire brushes. Tumbling or use of standard steel wool is not acceptable for de-burring, however clean stainless steel wool is okay. All de-burring tools, files and stainless wire brushes must be clean and free of oils and contaminants.

4.7 Repairs

No repairs shall be made unless approved in advance, and in writing, by LIGO Laboratory. In general weld repairs and press fit insert repairs are never acceptable. The material shall be virgin material. Special circumstances can be reviewed if/when brought to the attention of LIGO. Complete LIGO form Q110001 Request for Deviation and email to quality@ligo.org.

4.8 Tapped Holes

To prevent cold welding or galling, LIGO uses stainless fasteners into aluminum, and uses silver coated stainless fasteners into stainless. In addition, for all in-vacuum fasteners LIGO uses oversize tapped threads or heli-coil® inserts. Accuracy (and usability) of the finished thread when the insert is installed is dependent upon the accuracy of the tapped hole. Therefore (as below) LIGO requires gaging of all tapped holes.

4.8.1 Oversized taps

All Oversized tapped holes are to be machined according to the steps specified in the drawing example linked below or as per the specific drawings included. These steps include drilling, countersinking, tapping, and gaging the holes to sizes specified on the LIGO part drawings. All Oversized tapped holes shall be 100% gaged with appropriate Go/No Go gage tools. Oversized tap drawing call-out example: https://dcc.ligo.org/LIGO-D1600227/public. The associated Go/No Go Gages can be obtained essentially using the call-out from the associated hole e.g. for a ¼-20 UNC H11 threaded hole a ¼-20 UNC, H11 Go-No Go

4.8.2 Heli-Coil® Holes

All Heli-Coil holes are to be machined according to the call-outs on the associated drawings as per steps specified in this Heli-Coil® Catalog. These steps include drilling, countersinking, tapping, and gaging the holes to sizes specified on the LIGO part drawings. All Heli-Coil threaded holes shall be 100% gaged with appropriate gage tools according to the Catalog. Heli-coil® drawing call-out example: https://dcc.ligo.org/LIGO-D1600227/public. The Catalog has all of the part numbers and details for the STI Taps, Helicoils, Helicoil tools, UNC 2B Go/No Go Working Gage etc …

4.8.3 Vendors (internal use only)

LIGO staff can find further information via the following internal link, which is a pathway to additional information https://dcc.ligo.org/LIGO-G1600801. The additional information including vendor's information for taps, Gages etc … If this is required, please contact LIGO.

5 Cleaning

5.1 Standard Cleaning of Metal Components before delivery to LIGO

a) Unless otherwise specified on the drawing, SOW, or RFQ the standard requirement is for all components to be thoroughly cleaned to remove all ink, oil, grease, dirt, and chips.
b) All inks (stamping, Sharpie, etc) should be removed with solvent such as acetone or isopropanol.
c) Use Soap (such as Simple Green) and water to remove machining fluids.
d) Thoroughly rinse soap with clean water (DI or distilled preferred).
e) Parts should be dried thoroughly with clean air, nitrogen, or lint-free cloth.
f) Wrap parts to protect from damage and to maintain cleanliness during shipment. Avoid the use of materials that shed particulates such as newspaper. Bubble wrap is recommended for many parts.

5.2 Further Cleaning (only if specified)

These cleaning steps only apply if called out in the individual SOW and/or RFQ and/or drawing or other LIGO Specification. Additional questions related to this section on further cleaning can be discussed with the LIGO Contractual officer or the Contracting Officer's Technical Representative.

5.2.1 Aluminum

5.2.1.1 Chemical cleaning of Aluminum

a) Standard clean parts per 5.1 above.
b) Wash parts with Alkaline Soak Cleaner and inspected for cleanliness using the water break test (refer to ASTM A380-06 and ASTM F22).
c) Acid etch the parts to achieve less than 0.0005 material removal. Under no circumstances should the parts be anodized. Section 10 of LIGO document E960022 can be referred to for additional information.
d) Thoroughly rinse parts with DI or distilled water and inspect all surfaces for cleanliness.
e) Thoroughly dry parts with clean air, nitrogen, or lint-free cloth.
f) Wrap parts to protect from damage and to maintain cleanliness during shipment. Avoid the use of materials that shed particulate such as newspaper. Bubble wrap is recommended for many parts.

5.2.1.2 Electro-polishing of Aluminum

Aluminum may be electro-polished to achieve a material removal of .001 inch per surface. Due to the lack of commonly recognized industry standards, please talk to LIGO about proposed suppliers and processes before proceeding.

5.2.2 Stainless Steel

5.2.2.1 Pickling & Passivation of Stainless Steel

1. Clean parts per section 5.1 above, inspect for cleanliness using the water break test (refer to ASTM A380-06 and ASTM F22).
2. Stainless steel parts shall be pickled and passivated (citric acid preferred) at room temperature, with special attention paid to sufficiently agitate the solution or flush the inside of the box section. The pickling and passivation process formulation, time and temperature should be chosen to achieve slight chemical etching (<0.0005 inch). (Ref. ASTM A380 for pickling and ASTM A967 for passivation)
3. Rinse parts with DI or distilled clean water. After rinsing, visually inspect the surfaces for cleanliness.
4. Dry Parts using dry nitrogen blow-off or bake at approximately 130°F. Re-inspect for cleanliness.

5. Wrap parts to protect from damage and to maintain cleanliness during shipment. Avoid the use of materials that shed particulate such as newspaper. Bubble wrap is recommended for many parts.

5.2.2.2 Electro-polishing of Stainless Steel

Electro-polishing of Stainless Steel parts is allowed. If using electro-polishing on a part, follow similar steps to those outlined in section 5.2.2.1 Pickling and Passivation of Stainless Steels. The use of Scotch-Brite™ or similar products is never permitted.

6 Coatings

- No coatings are to be applied unless specified on the drawing or associated process specification. In particular, no aluminum parts are to be anodized.
- The Statement of Work should define if the machining vendor is responsible to apply coatings specified on the drawing. If in doubt, ask.
- As applicable, refer to the process specification for coatings as defined on drawings (for example, LIGO E1000083 Specification for Enameled Steel to be used in the LIGO Ultra High Vacuum System).
- Autocatalytic (Electroless) Nickel Plating, when required, should be applied per ASTM B733-97 Type III (2-4 wt% Phosphorus). Due to the outgassing concerns for UHVV service, the specific cleaning/etching and plating process steps proposed by the plating company shall be submitted to LIGO for approval. Refer to section 2.5 of LIGO-E0900023-v10 for suggested process steps.