Mitigation Processes and the resulting Cleanliness Levels

AUTHOR(S)	DATE	Document Change Notice, Release or Approval
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1 Introduction

Once all of the parts or components intended for service within the LIGO Ultra-High Vacuum (UHV) are cleaned, baked and tested to confirm that the surface cleanliness meets requirements it is essential to maintain these levels of cleanliness through the subsequent processes of assembly, testing, transportation, installation and commissioning. This document calls out the required Contamination Control (CC) mitigation processes in place to assure compliance with the LIGO UHV requirements.

2 Scope

This specification covers the Contamination Control mitigation processes required on all parts, components, materials, assemblies that are to be used in the LIGO Ultra-High Vacuum (UHV) system. This document also states the resulting cleanliness levels and compares them to the stated LIGO requirements.

3 Sister document

This document should be read in conjunction with the following sister document, LIGO-E1000088-v1. The specification, E1000088, covers requirements for all parts, components, materials, assemblies that are to be used in the LIGO Ultra-High Vacuum (UHV) system including acceptable materials, surface finishes of materials, manufacturing processes as well as cleaning, baking and testing specifications.

4 Exceptions, Deviations, Clarifications

Exceptions, additions or clarifications should be obtained, by the LIGO Cognizant Engineer, from The Contamination Control Working Group by contacting Calum Torrie ctorrie@ligo.caltech.edu or Kate Gushwa kgushwa@ligo.caltech.edu.

5 Cleanliness Testing

5.1 Cleanliness Requirements

Cleanliness Requirements are defined in section 6.1 of LIGO-E010613, and are repeated here (as they are in LIGO-E1000088-v1) for convenience:

- Achieve a Non-Volatile Residue (NVR) level of A/50 or better (per MIL-STD-1246C or IEST-STD-CC1246D) on piece parts before clean assembly
- Achieve a Particulate Cleanliness Level of 65* or better (per MIL-STD -1246C or IEST-STD-CC1246D) on piece parts before clean assembly

5.2 Testing

For full details of verifying non-volatile residue (NVR) cleanliness using Residual Gas Assay (RGA) testing with a mass spectrometer and FTIR testing (used within LIGO) refer to the sister document LIGO-E1000088-v1.

**LIGO's updated requirement requires a PCL of 65, refer to LIGO-T1300511-v1*

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6 Mitigation Processes

The following mitigation processes are required on all parts, components, materials, assemblies that are to be used in the LIGO Ultra-High Vacuum (UHV) system

6.1 Packaging

The clean parts or assemblies are to be packaged (wrapped, bagged and tagged) per LIGO-E960022. This includes the double wrapping of parts in UHF foil from All Foils Inc. as well as the short term storage of cleaned parts / small assemblies in clean stainless steel containers. All parts are subsequently double bagged in silver anti-static foil/poly barrier bags (#Seco Pack 512) from Seco. *(During purchase one must request zipper type 512 cleaned to class 100.)*

6.2 Clean-rooms

Perform clean assembly in ISO 5 Clean Room (per ISO 14644-1). ISO 5 is equivalent to a Class 100 Clean Room (per retired FED-STD-209). One essential step (often overlooked) in the use of clean-rooms is the cleaning schedule and tools used for cleaning the clean-rooms. For full details refer to Contamination Control Requirements for regular cleaning of Cleanroom and Clean area floors, LIGO-L1300130, and the LIGO Contamination Control Plan, LIGO-E0900047. At all stages during assembly and pre-installation assemblies must be covered with C3 covers within the clean-room when not in use. *(C3 white static-dissipative, cleanroom fabric from Burlington.)*

6.3 Garb

As per the LIGO Contamination Control Plan, LIGO-E0900047, all assemblers must wear scrubs (in place of street clothes) under the “full bunny” clean-room suits. For full details refer to section 4.2 of LIGO-P1300192-v2.

6.4 Cleaning as you go

As per the LIGO Contamination Control Plan, LIGO-E0900047, all assemblers must utilize the following tools during assembly, testing, installation and commissioning: -

- Flashlight arrays (at incident angle) to illuminate the dust
- UV Blacklight
- Ionization gun
- Clean-room vacuum cleaners
- Wipes (Pre-Wetted Wipes) 100% IPA

For full details including part numbers of specific items used refer to section 4.1 of LIGO-P1300192-v2.

6.5 Training

As part of the mitigation processes for maintaining cleanliness levels LIGO has introduced a suite of training material. The training is split into two levels with sub-categories. Level 1 is required for all workers (from engineers to cleaners and custodians) and level II has a number of sub-categories for specialty workers including those operating in the vacuum chambers. There is also training material and approved buy lists for the business office. All of the details, including the training material, can be found at LIGO-E1400029-x0.

6.6 Protection of key surfaces

At all times during assembly, testing, installation and commissioning the key surfaces (in our case the optical surfaces) should be protected when possible. This is achieved using a protective layer of First Contact Polymer, utilizing lens caps and metal shields (dust barriers) around the key optical surfaces.

7 Resulting Cleanliness Levels

By utilizing all of the items laid out in section 6 above we have so far achieved Particulate Cleanliness Levels (PCL's) of ~ 100. This cleanliness level was obtained from a 4" silicon wafer (witness plate) which was placed in a vacuum chamber just before pump-down (in a vertical orientation adjacent to a core optic) and removed shortly after the next vent. Refer to LIGO-G1400142-v1 for full details and the latest results obtained per location (vacuum chamber) within LIGO. *(While further work is required to match our requirement. We believe this is achievable.)*

8 Last lick cleaning

A last lick cleaning of the key optical surfaces is performed with First Contact Polymer, from photonic cleaning. The polymer is used in conjunction with a non-contact spray device to provide last lick cleaning of the key optical surfaces prior to closing the vacuum chambers. For full details refer to section 5 of LIGO-P1300192-v2. *(At present we are working on quantitative measurements of the effect of the first contact. Contact the authors for more details.)*

9 Testing cleanliness level

9.1 Witness plates and witness optic

In LIGO we use two types of witness plates (4" silicon wafers and 1" coated silica optics) that get placed in our assembly areas and ultimately in our vacuum chambers. For full details on how to place, receive, use, send, buy and store these samples refer to LIGO-E1201096-v5 and LIGO-T1300014-v5.

9.2 Particle Evaluation Tool

The LIGO Particulate Evaluation Tool (PET), based on a similar system designed by the National Ignition Facility (NIF), has been developed to quantify contamination on mechanical surfaces during assembly, testing, installation and commissioning. The idea is to obtain "live" or as close to "live" results as is possible so additional mitigation steps can be introduced as required. The PET has three main components:

1. A dry swipe technique and particulate collection tool, aka swipe tool,
2. Sample analysis using a stereomicroscope and ToupView software to count particle area,
3. And an Excel spreadsheet to calculate the Particle Cleanliness Level (PCL).

Refer to LIGO-T1300665-v9 for full details.

10 Abbreviations and Acronyms

FTIR Fourier Transform Infrared Transmission

LIGO Laser Interferometer Gravitational-wave Observatory

RGA Residual Gas Analyzer or Assay

UHV Ultra-High Vacuum

PCL Particulate Cleanliness Level

PET Particle Evaluation Tool

CC Contamination Control

11 References

Please note the reference list below is not complete. If there is a link below or in the document above that is not currently a public link please contact one of the authors of this document for a copy. The authors are working on getting all of these links public.

1. LIGO-E960050 LIGO Vacuum Compatible Materials List
2. LIGO-E960022 LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures
3. Li, D., Coyne, D., and Camp, J., "Optical Contamination Screening of Materials with a High-finesse Fabry-Perot Cavity Resonated Continuously at 1.06-um Wavelength in Vacuum, Appl. Optics, 38, 5378-5383 (1999)
4. LIGO-E010613 Generic Requirements & Standards for Detector Subsystems
5. E0900364 Metal components intended for use in the Adv LIGO Vacuum System
6. E0900048 Welding Specification for Weldments used within the Adv. LIGO Vacuum System
7. FED-STD-209
8. E0900047 LIGO Contamination Control Plan
9. IEST-CC1246D Product Cleanliness Levels and Contamination Control Program (replaces MIL-STD-1246C)
10. LIGO-E080177 Specification: RGA Test Qualification
11. LIGO-E0900480 FTIR Testing to Qualify Parts for LIGO UHV Service
12. LIGO-E0900479 Instructions for taking Low Volatility Residue (LVR) Wipe Samples
13. J.J. Herrick, et. al., "Analysis of Semi-Volatile Residues Using Diffuse Reflectance Infrared Fourier Transform Spectroscopy" in Optical System Contamination: Effects, Measurements, and Control VII; July 2002, edited by Phillip T. C. Chen and O. Manuel Lee; Proceedings of the SPIE, Vol. 4774, pp. 251-261, (2002).