RGA Test Qualification for the BSC Suspension Structures

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1 Scope

This specification is for the non-volatile residue (NVR) cleanliness qualification by RGA testing of suspension structures which are to be installed into the BSC chambers of the LIGO facility. These structures include the ETM suspension, ITM suspension, FM suspension and BS suspension.
This specification does not address particulate contamination requirements or qualification, nor does it address other components of the suspension assemblies or other equipment which are installed into the LIGO UHV system.

2 Abbreviations and Acronyms

BS Beam Splitter
ETM End Test Mass
FM Folding Mirror
FTIR Fourier Transform Infrared Transmission
ITM Input Test Mass
RGA Residual Gas Analyzer
UHV Ultra-High Vacuum

3 Applicable Documents

For general information on the LIGO project see http://www.ligo.caltech.edu/
For a general description of the advanced LIGO project see M060056-10, Advanced LIGO Reference Design
E960022-B, LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures
T040001-00, Vacuum Hydrocarbon Outgassing Requirements
N.B.: Pending revision. This analysis does not account for the extremely large pumping speed (and essentially infinite capacity) of the beam tubes. The requirements are not as tight as stated in this document and should be comparable to initial LIGO requirements.

It should be noted that "precision cleaning", ultra-high vacuum baking and RGA evaluation requires clean room facilities, clean room handling practices and approved packaging materials and methods. These are described in
G050557-00, UHV Cleanliness Requirements: Cleaning/Baking and Contamination Control
M990034-C, LIGO Contamination Control Plan

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4 Cleaning and Bake-out

The relevant sections of E960022-B for cleaning, vacuum baking and RGA testing are sections 4, 6.1.2, 6.2 and Appendix A. There are several acceptable cleaning methods/procedures and other proposed approaches can be evaluated and approved if/as needed. Appendix A of E960022-B defines two procedures: (1) using ultrasonic cleaning in a detergent (Liquinox) followed by distilled water rinses and ultrasonic cleaning in methanol, or (2) per E970063, repeated hot detergent spray (using an Inpro-Clean 1300 or Mirachem 500 solution with deionized water) washes interspersed with hot deionized water rinses.

For the aluminum suspension structures, the bake is at 120C held for a minimum of 48 hr.

Air baking is mentioned in document E960022-B (section 6.1.2.1.2) as an alternative to vacuum baking. It should be noted that the cleanliness in this case must be verified by an FTIR test to NVR Level A/50 per MIL-STD-1246C or IEST-STDCC1246D.

5 Outgassing Measurement

After cleaning the parts, baking them in vacuum, and allowing the parts to cool to room temperature, an RGA (mass spectrometer) is used to measure the outgassing rate. A suggested equipment arrangement for this measurement is given in section 6.1.2 of E960022-B. A large turbo-pump is used to pump off outgassed contaminants during the bake. Once the chamber and parts have cooled down, a smaller turbo-pump is used in order to raise the background pressure due to outgassing from the parts so that the outgassing rate can be measured. A calibrated leak is used to calibrate the RGA scan.

The base pressure of the chamber when making the RGA measurement should be no higher than 10^{-6} torr and should generally be about 10^{-9} torr.

The chamber should not be significantly larger (in area or volume) than required to fit the parts under test (otherwise deposition to the chamber walls dominates the effective pumping rate and masks a measurement of the outgassing of the parts).

6 RGA Scan Requirements

Our principal concern is high molecular weight hydrocarbons and not the total pressure due to adsorbed water and gasses. When reviewing an RGA scan for approval:

a) Verify that the amplitude of the 43 AMU peak is ≤ 1/10 of the 44 AMU peak
b) Verify that the amplitude of all peaks > 44 AMU are no higher than 1/100 of the 44 AMU peak

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c) Check that the calibrated outgassing rate (torr-liter/sec) of the cracked hydrocarbon signature[1] (sum of AMUs 41, 43, 53, 55, 57) is ≤ 4E-10 torr-liter/sec for a single suspension structure.
d) If a small quantity of material occupies the oven, then it should be background limited at ~2E-12 torr-liter/sec for the hydrocarbon signature
e) Check that there are no "significant" high AMU components above the background or instrument noise floor (even if < 1/100'th of AMU 44) up to AMU 100.

Subtraction of an empty chamber mass spectrum is not permitted when meeting the above requirements.

Every RGA scan must be accompanied by an empty chamber scan (prior to loading the chamber with the parts being evaluated) and a calibrated RGA scan. The empty chamber scan should not have any peaks above the background (instrument noise floor) for AMUs 41, 43 and AMUs > 44. The RGA calibration must be accomplished with a multi-component calibrated leak which includes argon (AMU 40) and krypton (AMUs 85, 86, 87).

[1] High molecular weight hydrocarbons crack into lower AMU components when measured by a mass spectrometer. AMUs 41, 43, 53, 55 and 57 were found to be indicative of all high molecular weight hydrocarbons. See section 6 of the -03 version of E960022, i.e. E960022-03