Testing to Measure Water and Air Outgassing Rate from Components Exposed to the Atmosphere

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1 Motivation

After an extended period of detector installation or upgrade work (when the vacuum chambers are at atmospheric pressure), the vacuum system must be pumped down to a low pressure before we can open the corner or end-station volumes to the 4 km long beam tube sections. This restriction is to prevent the accumulation of water vapor pressure in the baked beam tube volumes; If the residual gas pressure in the beam tubes is too high it will contribute phase noise due to photon scattering.

The pump-down time after lengthy installation periods in the LIGO chambers is quite long. For example, after a ? month vent period the LHO vacuum system required ? weeks before the system could be opened to the beam tubes. The pressure criteria (in this case 1e-7 torr) is being re-examined to see if this can be relaxed. Even if the opening pressure criteria can be raised, the lengthy time before being able to commission or operate the interferometer is costly; We need to find means to accelerate the pump-down time. This may be difficult if the pump-down is diffusion or desorption rate limited.

In addition, there is a perception that the recent pump-down times have been longer than in the past. This may be due to the longer exposure to atmosphere, or it be sue to recent detector component installations (e.g. black-nickel coated baffles), or it could be a false impression (TBD).

The purpose of this procedure is to measure the water and air outgassing rates of various components of the in-vacuum elements that are suspected of contributing significantly to the pump-down time. The output of this study will be used:

1) to update and improve the residual gas estimate (E0900398) with regard to the water and air components of the spectrum and the total pressure.
2) as input to a pump-down model in order to calculate/predict the time dependence of the pump-down (e.g. using the Li and Dylla formulation[1]).

We will begin by focusing our measurements on the components in the system that we suspect are the leading contributors to water and air outgassing. Once our estimate agrees reasonably well with actual pump-down performance in the observatories we will stop the measurement studies.

In parallel with this study of experimental measurements of water and air outgassing, we are also:

1) Using CAD to make check (or improve) the estimate surface areas of the components for use in updating E0900398.

[1] Minxu Li and H.F. Dylla, "Model for the outgassing of water from metal surfaces", I, II and III, J. Vac. Sci. Technol. A, 11(4), Jul/Aug 1993; 12(4), Jul/Aug 1994; 13(4), Jul/Aug 1995.

2) Using one or more optical contamination cavities to test the possibility of accelerating the desorption of water and air from components with a modest elevation of temperature (40C above ambient). The key question in this case is whether the elevated temperature will cause outgassing of hydrocarbons which condense/plate onto the optics and result in increased optical loss (absorption or scattering).

2 Potential Contributing Components

The following are speculated to be possible significant contributors to the water outgassing load in the LIGO chambers. This is not necessarily an exhaustive list, and not necessarily in a priority order; We may need to update the list as our testing progresses.

1) Stainless steel (304L) walls of the chambers (relatively rough surface). We may be able to get water and air outgas rates from PSI measurements for unbaked chamber walls. Data is also available in the literature.
2) Aluminum surfaces from the many detector components, most notably the Internal Seismic Isolation (ISI) systems. Data is also available in the literature.
3) Cabling. The in-vacuum cabling employed by LIGO are of various types. However the dominant type (by quantity and total length) are cables with D25 connectors with twisted pairs of Kapton insulated wire, with an open braided shield and an overall open braided PEEK braid.
4) Viton. There are a number of instances of the use of Viton (a fluoroelastomer), generally as a vacuum seal on a pumped annulus, or as a damping material (for example in the form of o-rings on optical baffles).
5) PEEK. There are instances of the use of PEEK (other than as a component of a cable, for example the body of the A-OSEMS).
6) Black-Nickel coated stainless steel baffles.

3 Test Considerations

3.1 Atmospheric exposure

Ideally we're testing for the two common observatory installation, or in-chamber work, scenarios:

1) <u>New components</u> are cleaned and vacuum or air baked per our standard procedures, then they are delivered to the observatories in sealed wrapping or containers (often with desiccant inside). These components are then unwrapped and assembled and/or staged for installation. Finally the components are installed into the vacuum volume when the vacuum system is constantly purged with a low-velocity dry air purge (-50C dew point) but with large openings for personnel and equipment that permits moisture diffusion from the nominal lab environment (20% to 70% relative humidity). As a consequence we think that the components have had some exposure to relatively dry air, but are certainly "wet" compared to baked parts. Typically the exposure time for these components in an unwrapped state is

many months. Occasionally a fast vent and installation is accomplished in a few days, but this is less common.

2) Previously installed components (the dominant type) are exposed to purge air (as described above) as well as moisture diffusion through chamber openings. These exposure periods are typically for months between observing runs. Components which are far from openings for egress of personnel and equipment are likely only exposed to relatively dry purge air. Components close to the chamber openings will be ‘dosed’ with moister air.

The tenacity of water adhesion to exposed surfaces increases with exposure time. We have a separate experimental program aimed at determining the water activation temperature for the LIGO beamtubes (E1600073) called VORTEX.

For the purposes of this test program on the water and air outgassing rate of components, we should:

1) Subject the test parts to LIGO standard vacuum preparation (), i.e. clean and bake, as usual,
2) and then ensure that the test components have been exposed to a lab or office atmospheric environment, without desiccant, for a period of at least one week prior to placing the components into the test chamber.

3.2 Contribution from the chamber walls

Since the chamber walls will also outgas air and water, we should strive to place a component test load into the vacuum chamber which has a surface area far greater than the chamber wall surface area. This will not always be possible, but we should strive to test as much surface area of the test component as reasonably possible.

In principle we can subtract the contribution of the chamber walls by first measuring the air and water outgassing from the chamber walls with an empty chamber. However note that the rate of water outgassing from the walls will depend to some extent on how long the chamber was exposed to moist lab air. Best practice is to vent a previously baked chamber with dry nitrogen and then insert the test component(s) quickly with minimal exposure to the lab air. In any case the history of the chamber and up to the time of inserting the test component(s) should be recorded to allow proper interpretation of the outgassing results.

4 Procedure

Since this test is intended to measure the water and air outgassing rate the RGA should be set to log pressure vs time at the following AMUs, with the calibrated leak open:

- AMU 17 (water secondary peak)
- AMU 18 (water primary peak)
- AMU 28 (air, N2 and CO peak)
- AMU 40 (argon peak from calibrated leak)

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Monitoring additional AMUs is OK, but should not be necessary. The sampling rate for these measurements can be quite slow (say 1 per hour), but faster is OK.

While getting a simultaneous total pressure vs time plot/data would be nice, it is not essential.

We are interested in knowing not just the outgassing rate for water, $Q_w(t)$, and air, $Q_a(t)$, at t hours after start of pump-down, but also the rate of decrease in outgassing with time, i.e. the exponent of the time, n:

$$Q(t) = Q_o/t^n$$

The minimum duration of the testing should be 100 hours (~4 days), although longer, up to ~2 weeks may be better or needed; We should evaluate as the Q(t) data is collected before terminating a component/sample test.