Hydrocarbon measurements IV: Time dependence of the hydrocarbon pressure in a BSC containing advanced LIGO seismic and suspension components.

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Abstract: Measurements were made on the complex of vacuum enclosures at the y end at LHO containing the full advanced LIGO seismic and suspension system 237 days after the start of pumping. The current measurements are compared with those made 70 days after the start of pumping. Water and several of the hydrocarbons attenuate approximately as ${}^{1}\!/_{t}$ or faster where t is the time since the start of pumping while another smaller group of hydrocarbons attenuates more slowly approximating ${}^{1}\!/_{\sqrt{t}}$ dependence. The current hydrocarbon pressure averaged over the group of amu values between 50 to 70 amu and projected to parent molecules between 100 to 200 amu is 1.3 x 10^{-13} torr at an ETM and approximately 10^{-12} torr at an ITM. The design goal to maintain the mirror loss increase below 1ppm/year is a hydrocarbon pressure less than 10^{-13} torr. The situation is marginal. For example, the first runs with moderate laser power are likely by January 2015, the projected hydrocarbon pressure will be about 1/3 the current values: below the design level at an ETM with a factor of 3 margin but above at an ITM by a factor of 3. However, not all test masses will have had such long pumping times. Advanced LIGO needs to consider whether a low temperature bake, especially, of the ITM is a prudent step.

Results: Prior measurements have been described in LIGO T1100642, T1200021, and T1200395 and are summarized along with the new measurements in **Table 1**

Table 1 Hydrocarbon pressure in ETM BSC with cryo pumping

amu	Initial LIGO BSC	Initial LIGO BSC + cleaned BSC	Initial LIGO BSC +filled BSC	Initial LIGO BSC +filled BSC	${}^{P(237)}\!/_{P(70)}$
	pump time ~4200 days	pump time ~21 days	pump time ~ 70 days	pump time ~ 237 days	
50	8 ± 2 x 10^{-17}torr	1.8 ± 0.1 x 10^{-14}torr	7.3 ± 0.2 x 10^{-14}torr	2.7 ± 0.08 x 10^{-15}torr	0.037
51	10 ± 2 x 10^{-17}	2.0 ± 0.1 x 10^{-14}	3.6 ± 0.2 x 10^{-14}	5.7 ± 0.07 x 10^{-15}	0.16
55	< 6 x 10^{-17}	1.9 ± 0.1 x 10^{-14}	4.3 ± 0.2 x 10^{-14}	3.1 ± 0.06 x 10^{-15}	0.071
57	< 5 x 10^{-17}	1.2 ± 0.1 x 10^{-14}	1.0 ± 0.2 x 10^{-14}	1.4 ± 0.05 x 10^{-15}	0.14
65	< 2 x 10^{-17}	6.3 ± 0.1 x 10^{-15}	5.4 ± 2 x 10^{-15}	6.0 ± 0.4 x 10^{-16}	0.11
67			5.2 ± 2 x 10^{-15}		
69	10 ± 2 x 10^{-17}	1.7 ± 0.1 x 10^{-14}	6.0 ± 2 x 10^{-15}	2.6 ± 0.1 x 10^{-15}	0.43
18			1.7 x 10^{-9}	3.3x10^{-10}	0.19

Amu 18 is not consistent with the formulation in T1100642 by a factor of about 3, needs to be investigated further.

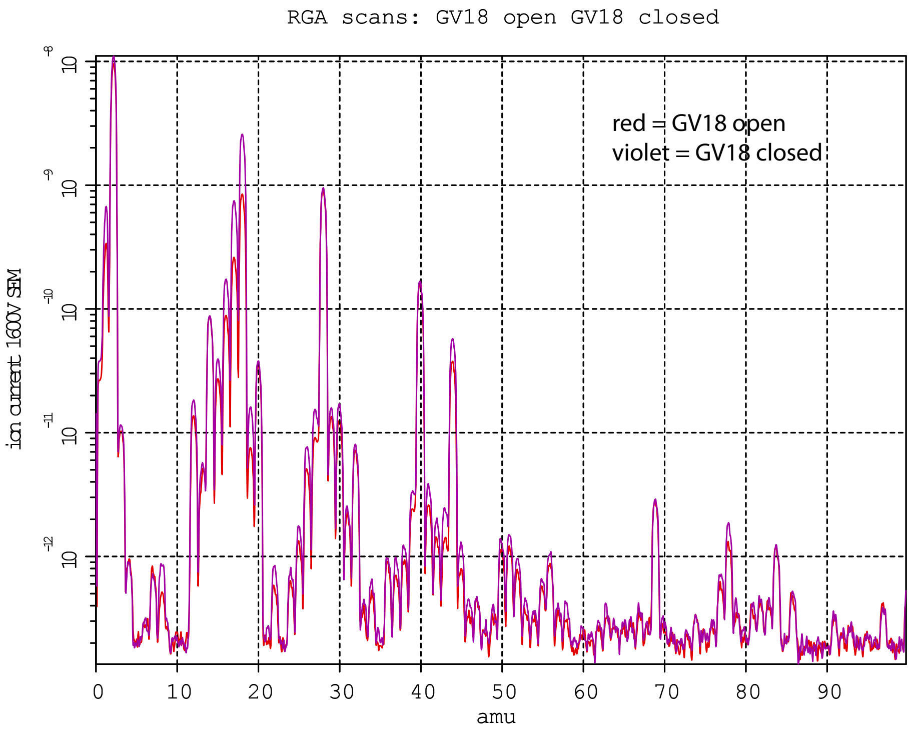

Figure 1: RGA scan with GV18 open (red) and GV18 closed (violet). The current to pressure conversion is 1 torr/amp. The pumping arrangement described in T1100642 gives the pressure in the BSC chamber with the GV18 open as $P_{ch} = 0.022(P(\text{closed}) - P(\text{open}))$

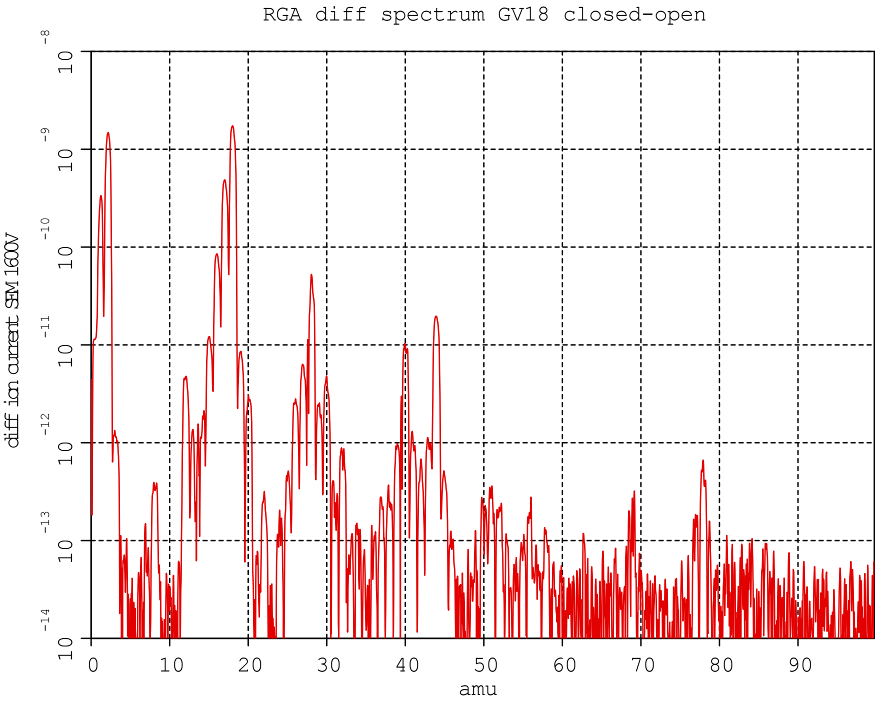

Figure 2: Difference spectrum of **Figure 1**. Negative values are not plotted. The sampled amu values are a good representation of the average hydrocarbon pressures.

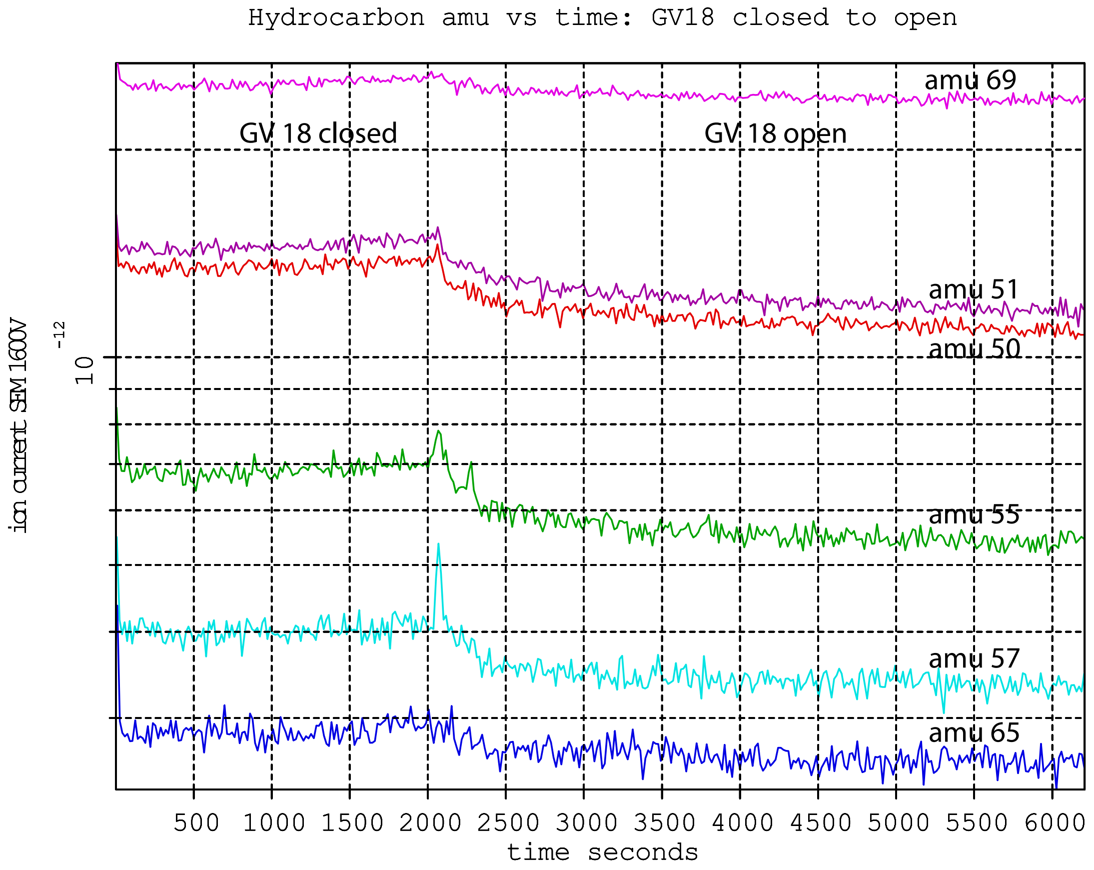

Figure 3: The sampled hydrocarbon amu ion currents vs time. GV18 is closed t< 2000 seconds and opened for t>2000 seconds. The entries in **Table 1** were calculated from these curves. The conversion of ion current to pressure is 1 torr/amp.

Discussion: Assuming 15% of the hydrocarbon amu vary as $1/\sqrt{t}$ with the rest as $1/t$ and that the parent hydrocarbon has a mass between 100 and 200 amu, the average total hydrocarbon pressure at the ETM is 1.3 x 10^{-13} torr. At an ITM, where the pumping speed is 1/10 that at an ETM, the average pressure would be about 10^{-12} torr. If extended runs at moderate optical power begin in January 2015, the average hydrocarbon pressure will be about 1/3 of these values. The goal values are to achieve a hydrocarbon pressure less than 10^{-13} torr at the test masses. At such a pressure the estimated increase in optical loss is 1ppm/year. The pressure at an ETM will then be about factor of 3 smaller than the goal while at an ITM it will be about 3 times larger than the goal. The situation is marginal. Not all test masses will have had the pumping time of this test mass. It seems worthwhile to contemplate low temperature bakeouts at least for the ITMs.