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VIRGO

UPDATED ESTIMATION OF THE SUSPENSIONS CONTAMINATION BUDGET

Code:
VIR-TRE-PIS-3400-135

LIGO-T990073-00-D

Date: 23/09/1998

CHANGE RECORD

Issue/Rev	*Date*	*Section affected*	*Reason/ remarks*

Authors:	**Date**	**Signature**
R. Poggiani		Rosa Poggiani
Approved by:		

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In this note the VIRGO suspensions contamination budget is estimated as deduced from the measurements performed in the Virgo Pisa Vacuum Laboratory. Both the projected outgassing flow and the hydrocarbon partial pressures will be presented.

1 - Superattenuator components

A preliminary investigation of the Superattenuator cascade outgassing has been performed in June 1996 (internal note VACPISA 049). It was shown that the outgassing measurements about components available at that moment allowed to build a Superattenuator cascade with an outgassing flow (~10^{-4} mbar l s^{-1}) one order of magnitude below the one quoted in the Virgo Final Design (~10^{-3} mbar l s^{-1}). The table of June 1996 is reported here for completeness.

Item	*flow (mbar l/s)*
filters	no baking: 3.0×10^{-5} moderate baking: 3.0×10^{-6}
blades	1.7×10^{-5}
magnets	unbaked: 4.3×10^{-5} baked: 8.6×10^{-8}
cabling (Kapton)	1.0×10^{-5}
others	$< 2.0\times10^{-6}$

New components have been tested and approved in the last couple of years. A new estimation of the outgassing flow and hydrocarbon pressure will be outlined below.

The main components of the VIRGO suspensions as considered to date (September 1998) are summarised below. Data about motors, cabling, coils, connectors, ferrite magnets, have been supplied by V. Dattilo (VIRGO Pisa); data about marionetta, reference mass and related items have been supplied by P. Rapagnani (VIRGO Roma); data about LVDT and accelerometers have been supplied by R. Stanga (VIRGO Firenze).

- Tower upper part (above conductance plate):
  - Filters: AISI 304 stainless steel
  - Blades: nickel plated steel

- Magnets: Philips ferrite for the antisprings; CIBAS ferrite for the top stage and accelerometers magnets
- Cabling: to date Gore-Tex insulation (by Gore) and Kapton insulation (by Axon) ribbons are being considered
- Connectors: ~100 pieces in each tower; LEMO ones are being considered
- Coils: Pyre-ML insulation is being considered; used for marionetta steering, LVDTs and accelerometers coils
- UHV motors: AML motors are being considered
- Accelerometers: coils and magnets have been included in the above items; electronics consists of peek circuit board plus some resistors/trimmers and capacitors

- Tower upper part (below conductance plate):
  - Marionetta: AISI 304 stainless steel
  - Reference mass: aluminium
  - Mirror magnets: rare-earth magnets from RIAL glued with Vac-Seal to the mirror
  - Cabling
  - Coils for mirror steering: Pyre-ML insulation
  - UHV motors: see above

Data about motors, cabling, coils, ferrite magnets, have been supplied by V. Dattilo (VIRGO Pisa); data about LVDT and accelerometers have been supplied by R. Stanga (VIRGO Firenze); data about marionetta, reference mass and related items have been supplied by P. Rapagnani (VIRGO Roma).

2. Contamination budget

As a first step to ensure good vacuum properties, a good conditioning of components before installation is necessary. The necessary procedures are described in detail in the cleaning note (in preparation) and will only be briefly summarised here. The suggested cleaning procedure is ultrasound bath with a suitable solvent, rinsing and vacuum baking at 150 °C (or the maximum allowable temperature for the component) for a few days. The LIGO experiment has approved a similar procedure for the interferometer components. A peculiar problem of VIRGO as compared to other experiments is the necessity of performing vacuum baking with optical components in situ. Thus a further request for components is the absence of any sizeable contamination during the baking in situ. As much as possible, all components have been tested in typical working conditions and even with strong loads to check the behaviour in the event of malfunctioning. As an example, cabling samples have been supplied with the nominal current values and with huge values during the vacuum test.

The outgassing rate Q and the hydrocarbon partial pressures pp_{HC} for the above mentioned components in various working conditions are summarised below. The reader is referred to the internal notes for the details of each test. We remind that the typical vacuum compatibility test of VIRGO includes raising the temperature up to 50 °C, 100 °C and 150 °C, maintaining each level for a few days. The numbers quoted as the final outgassing rate and hydrocarbon partial pressure are the ones measured after such thermal cycle. We can safely assume that they are the ones to be expected after a several days vacuum baking at 150 °C for component conditioning before installation. The peak values of outgassing rate and hydrocarbon partial pressure measured at some temperature steps are also quoted as an hint to the contamination behaviour during the baking of the lower part of the tower. Some components (mainly inorganic ones) exhibit a final low outgassing rate ($\sim 10^{-10}$ mbar l s^{-1} cm^{-2} or below) together with negligible hydrocarbon contamination at any temperature. In this case no further raising of temperature have been attempted and the values quoted at any temperature above room temperature can be considered as an upper limit to the peak value. Some other components, on the other hand, despite the final low outgassing rate, exhibit sizeable hydrocarbon contamination during some temperature step. It can be reasonably assumed that such components cannot be cleaned completely by the usual procedures, since the contamination problem is more related to the intrinsic material properties than to its history. In this case, an additional raising of temperature is attempted after cooling down to check if the cleaning plus the vacuum baking are effective in assuring a negligible contamination.

We briefly mention the problem of contamination from other sources than hydrocarbons, namely silicone compounds and fluorine compounds. Some space missions data suggest evidence of the contamination from silicone compounds such as epoxy adhesives. On the other hand, semiconductor industries have triggered the development of Teflon-like materials with low fluorine outgassing for the same reasons. At the moment, there is no consensus about the levels which could harmful in the context of the laser interferometer gravitational wave detectors. The basic attitude seems to be keeping such types of contamination at the lowest possible levels.

The relevant outgassing data are summarised in Table 1 for the tower upper part and in Table 2 for the tower lower part. The exposed area for each homogeneous component is presented. For composite pieces such as motors or connectors, the total number per tower is quoted and the data in the columns of outgassing rate should be read as outgassing flow data.

Symbol explaination:
- A is the exposed area
- N is the number of pieces for composite items
- Q is the outgassing rate measured in mbar l s^{-1} cm^{-2}
- pp_{HC} is the hydrocarbon partial pressure measured using the above criterion
- Φ is the outgassing flow measured in mbar l s^{-1}
- index 1 labels the values after the vacuum baking described above;
- index 2 labels the peak value attained during vacuum baking
- NG is used for negligible
- NA is used for not available data
- Cabling G means Gore-Tex cabling
- Cabling K means Axon Kapton cabling
- (*) means that the quoted number should be read as outgassing flow and not outgassing rate

Some useful notes for data interpretation:
- Filters: the material is AISI 304 stainless steel; the data are commonly cited values for unbaked and moderately baked material
- Vac-Seal: it has been assumed that each magnet involves ~1 cm^2 of exposed glue surface (on the bottom and on the top)
- Coils: it has been assumed that the exposed surface is the exterior surface plus 10% of the total wiring surface; it is known that is possible to pump out trapped air inside a coil and it seems reasonable to assume that only some part
- EC: electronics components for accelerometers, to be defined

ITEM	A	N	Q_1	pp_{HC1}	Q_2	pp_{HC2}	Φ_1	Φ_2
Filters	7.0+4	unbaked	1.0-10	NG			7.0-6	
		baked	1.0-11	NG			7.0-7	
Blades	1.6+4		4.0-10	2.1-11	4.0-9(2)	2.5-8(2)	6.4-6	6.4-5
					1.8-7(3)	3.4-8(3)	6.4-6	2.9-3
Magnets (Phillips)	1.8+4		7.6-11	1.7-10	4.0-7(2)	3.9-7(2)	1.4-6	7.2-3
Magnets (Cibas)	5.0+2		1.7-11	1.6-13	1.3-5(2)	7.5-5(2)	8.5-9	6.5-3
					3.0-8(3)	1.1-7(3)	8.5-9	1.5-5
					5.4-10(5)	1.3-12(5)	8.5-9	2.7-7
Motors(*)		22	1.0-8	1.0-12	1.7-7(1)	1.0-10(1)	2.2-7	3.7-6
					1.7-6(3)	1.0-9(3)	2.2-7	3.7-5
Cabling G	2.5+5		2.0-12	NG	2.8-8(3)	NG	4.4-7	7.0-3
Cabling K	2.5+5		8.0-12	7.4-12	1.2-8(2)	4.5-7(2)	2.0-6	3.0-3
					1.3-8(3)	8.9-7(3)	2.0-6	3.2-3
					5.8-10(5)	2.3-8(5)	2.0-6	1.4-4
Connectors(*)		100	1.0-9	9.0-12	2.2-5(2)	2.2-7(2)	1.0-7	4.3-7
					1.8-8(4)	6.0-10(4)	1.0-7	1.8-6
					1.2-5(3)	2.2-7(3)	1.0-7	1.2-3
					1.7-7(5)	6.2-9(5)	1.0-7	1.7-5
Coils	2.6+4		8.4-11	2.5-14	1.1-8(2)	1.4-9(2)	2.2-6	2.9-4
Vac-Seal	5.0+2		5.6-10	7.5-11	2.7-5(3)	1.8-6(3)	2.8-7	1.4-2
EC	NA	NA	NA	NA	NA	NA	NA	NA

Table 1 Contamination budget of the tower upper part;
(1) means at 80°C; (2) means at 100°C; (3) means at 150°C;
(4) means at 80°C, second heating; (5) means at 150°C, second heating

ITEM	A	N	Q_1	pp_{HC1}	Q_2	pp_{HC2}	Φ_1	Φ_2
Marionetta	5.0+3	unbaked	1.0-10	NG			5.0-7	
		baked	1.0-11	NG			5.0-8	
Reference mass	6.3+3	unbaked	1.0-10	NG			6.3-7	
		baked	1.0-11	NG			6.3-8	
Magnets (Rial)	13.		NA	NA	NA	NA	NA	NA
Coils	6.5+3		8.4-11	2.5-14	1.1-8[(2)]	1.4-9[(2)]	5.5-7	7.2-5
Motors[(*)]		1	1.0-8	1.0-12	1.7-7[(1)]	1.0-10[(1)]	1.0-8	1.7-7
					1.7-6[(3)]	1.0-9[(3)]	1.0-8	1.7-6
Vac-Seal	4.0		5.6-10	7.5-11	2.7-5[(3)]	1.8-6[(3)]	2.2-9	1.1-4

Table 2 Contamination budget of the tower lower part; for symbols refer to the other caption

3 - Conclusions

As can be deduced from the tables above, it is possible to build a suspension system with a contamination budget with an overall outgassing flow of ~10^{-5} mbar l s^{-1}, two order of magnitudes below the FD constraints, if proper components and proper cleaning and conditioning procedures are selected.