Tools for the ET Tower Vacuum system: outgassing database and outgassing budget

WP IV.1: Tower Vacuum

Hotel Hermitage (Italy, La Biodola Bay, Isola d'Elba)
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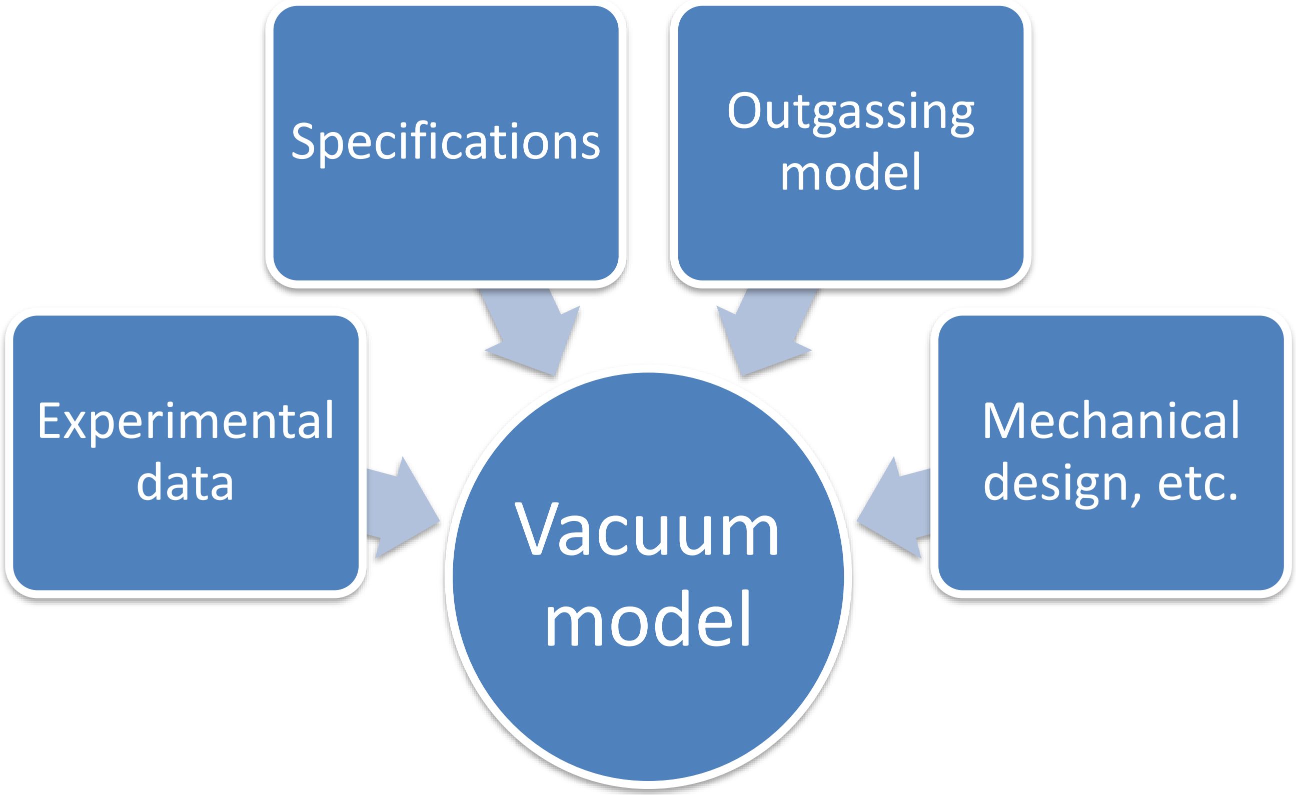
Outgassing of materials



Good vacuum level and estimation of the outgassing budget
→ Essential for the good operation of the interferometer.

Outgassing / optical test

Outgassing of materials

- Order of magnitude for diverse type of materials:

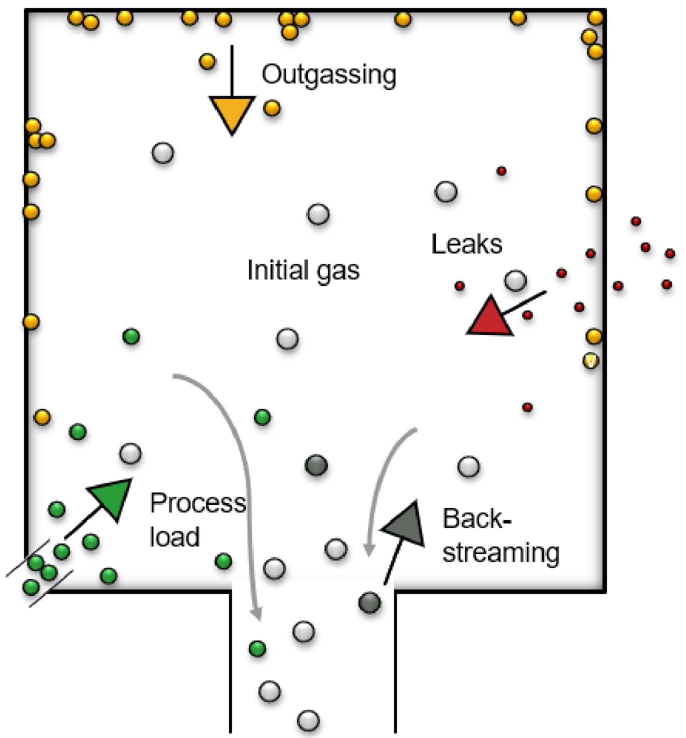
$$from\, 10^{-15}\ to\ 10^{-6}\ mbar.l/s.cm^2$$

$$Pressure\ =\frac{Q}{Pumping\ Speed}+\ P_0$$

- Pumping speed usually varies between 10 to few 1000 l/s.
Except for cryogenics (that need large space + constraints).

- Importance of understanding and control outgassing within the vacuum chamber

→ Outgassing Budget → 1st step: outgassing database



Outgassing – Source: Leybold

Vacuum in ET Towers

Vacuum level: control the residual pressure and identification the gas species present in the tower.

The residual pressure can be estimated according to the pumping system (TMP, getter, cryotraps, etc.).

The residual gas from the tower affects the deposition rate on the mirror (especially for LF interferometer) and on the pressure on the tube arms.

Procedure in collaboration with subsystems that design the assemblies, to allow the selection of materials fitting the vacuum requirements.
Cleaning and baking included.

Interfaces with cryogenic tower (in LF) and cryogenic trap.

Illustration of a possible ET Tower

Vacuum in ET Towers

Large vacuum chambers hosting optical or suspension devices, delicate instruments.

Transient mode after venting, time to pump down before re-starting the experiment.

- *Lower part: 10^{-9} mbar range.*
- *Upper part: 10^{-7} mbar range.*

Fact

- Not baked
- Full of extra sensitive equipment
- Frequent venting

Difficulty

- **Noise effects due to residual pressure (damping, …)**
- **Optical contamination**

Approach method

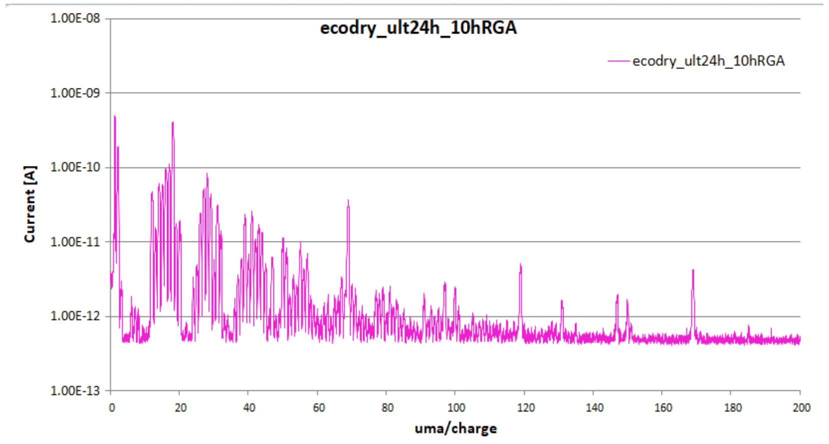
- Outgassing budget table of the tower/area of interest.
- Calculating the outgassing contributions for different gases

Outgassing Database tool

Outgassing of raw materials included – with their respective treatments - AISI 304L, PEEK, Copper, etc.

Main use with assemblies that are inserted into the tower.

One principal treat is the non-volatile compounds… their partial pressure must be calculated.



Outgassing measurement - Pump

Proposed definition for: Low volatile compound «Hydrocarbon» HC:

Sum of fragments > 45

Background subtracted

During blank test the values of fragments > 45 is noted, constant value. Then removed from the outgassing measurement of the test sample.

Considering for each fragment the same sensitivity as Nitrogen.

Outgassing Database tool

Available at (need a gitlab.et-gw.eu account):

https://apps.et-gw.eu/et_outgassing_db/

	Component				Optical measurements		Vacuum measurements															
	Item	Manufacturer	Main material	History	Optical check	Optical losses (ppm)	Test procedure	mbar-l/s							Q_HC (peaks N>44) (m/z)	Preparation (highlight)	Pre-baking			Notes	Installation scenario	Reference
								Q_H2O @24h	Q_H20 @100H	Q_H20 @1000H	Q_H2	Q_N2+OTHERS @24h	Q_N2+OTHERS @100h	Q_HC (level>44)			Done?	Temperature (°C)	Hours			
	Baffle PCB#10-21	IFAE	Pyralux AP		Absolute losses @LMA	0.50	throughtput method	1.03e-8	5.43e-9	1.94e-9			3.31e-11	5.00e-13		IPA cleaning	Yes	70	168	After pre-baking, one day in a clean room ISO5.	Mirror compartment	IMC Instrumented Baffle, Ref. IFAE-PCB#10-21
	Al EN AW-6061	N.A.	Al EN AW-6061		No		throughtput method	4.86e-10	1.17e-10	1.17e-11	5.50e-14					Factory Cleaning	No			Q_H2O : Q=Qo*t^-alpha, with Qo=4.2e-3(Pa L s-1 cm-2) and alpha=1	Lower compartment	NIST: DOI: 10.1116/6.0000657
	AISI 316L Vacuum Fired	N.A.	AISI 316L		No		throughtput method	8.64e-11	2.43e-11	3.21e-12	5.10e-14					Factory Cleaning	No			Vacuum fire process: 950°C for 24h Q_H2O : Q=Qo*t^-alpha, with Qo=3.30e-4(Pa L s-1 cm-2) and alpha=0.91	Lower compartment	NIST: DOI: 10.1116/6.0000657
	AISI 316L	N.A.	AISI 316L		No		throughtput method	1.20e-10	3.09e-11	3.48e-12	1.00e-12					Factory Cleaning	No			Q_H2 : conventional outgassing rate Q_H2O : Q=Qo*t^-alpha, with Qo=7.25e-4(Pa L s-1 cm-2) and alpha=0.95	Lower compartment	NIST: DOI: 10.1116/6.0000657
	AISI 304L	N.A.	AISI 304L		No		throughtput method	2.68e-10	4.19e-11	2.10e-12	1.00e-12					Factory Cleaning	No			Q_H2 : conventional outgassing rate Q_H2O : Q=Qo*t^-alpha, with Qo=7.00e-2(Pa L s-1 cm-2) and alpha=1.3	Lower compartment	NIST: DOI: 10.1116/6.0000657

Outgassing Database tool

https://apps.et-gw.eu/et_outgassing_db/

- H_2O fluxes:
  - short time (about 1 day),
  - Medium time (about 1 week),
  - Long time (about 1 month),
- N_2 and other volatile compounds fluxes at medium term,
- H_2 flux
- HC flux and/or species (hard to measure flux because of the high sticking properties).

Information about preparation and pre-baking added to see the effect on the outgassing.
Help for choosing a manufacturing and cleaning process.

⌛ Vacuum measurements

Test procedure	mbar-l/s							Q_HC (peaks N>44) (m/z)	Preparation (highlight)	Pre-baking		
	Q_H2O @24h	Q_H20 @100H	Q_H20 @1000H	Q_H2	Q_N2+OTHERS @24h	Q_N2+OTHERS @100h	Q_HC (level>44)			Done?	Temperature (°C)	Hours
throughtput method		6.20e-8		2.80e-8		9.30e-9	8.00e-10	69	Factory Cleaning	Yes	150	47

Outgassing Database tool

https://apps.et-gw.eu/et_outgassing_db/

Installation scenario
Mirror compartment

Installation scenario will have an importance on the outgassing budget

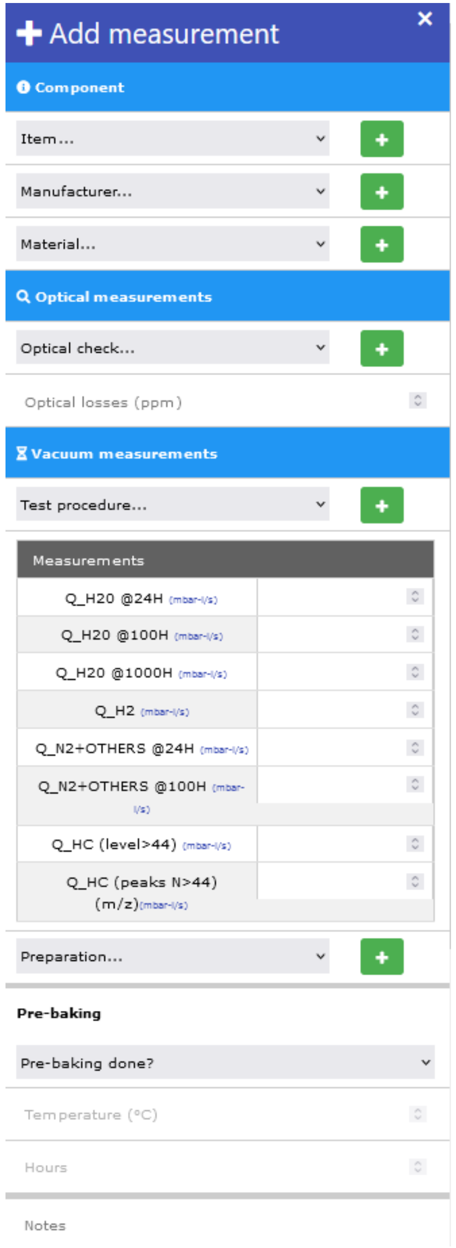
For component installed close to the optics, assessing the contamination level and effect on optical losses is critical!

Optical measurements	
Optical check	Optical losses (ppm)
Absolute losses @LMA	0.02

<u>All components to be inserted in the towers shall be tested on vacuum outgassing test.</u>
<u>The results of the test can then be inserted in the database.</u>

<u>All non-metallic materials shall be tested on thermal outgassing under vacuum.</u>
<u>Temperature and duration will depend on specifications and operating conditions of each component.</u>

Outgassing Database tool



H_2O	N_2 and other gases	H_2

Proposed test activities:

- Water, “air” in thick polymers (> 3mm): ex. PEEK.
- Hydrophobic coatings: behaviour of water or sticky gases during pump-down.
- Hydrogen outgassing in metals.
- Process: Baking, Roughness, etc.
- Correlation between the detected HC level and optical losses.

We need your contribution on expanding the database!

It is a dynamic and shared tool!

- Data taken from literature following the ISO 20177 are accepted.

A template for reporting outgassing test is available : ISB-VC-0039

- Any comments and remarks to improve the database or template are welcomed!

Outgassing Budget

Methodology

The outgassing budget is build for each compartment of the diverse tower types.

1. Material of the vacuum chamber itself,
2. Equipment added in the chamber (Payload, Suspensions, Optics, etc.):
   Type and outgassing (raw material or full assembly tested),
   - Restrictions on some high outgassing assemblies or materials.
   - Outgassing test report included into the database.
3. Compilation of outgassing fluxes (H_2, H_2O, N_2, etc.),
4. Screening control when new equipment is added in the tower.

Outgassing Budget

<u>Methodology</u> – Databases are needed:

- Raw material outgassing (from tests or literature)
- Outgassing of assemblies (full objects, in-house tests)
- BOM of inserted components with the exposed surface

For an estimation of pressure in the vacuum chamber, the installed pumping system with speed wrt diverse gas shall be known.

<u>If no budget</u>

- Accepting too many elements,
- Medium / strong outgassing rate

<u>The risk is:</u>

<u>The result is an ultimate pressure elevation and / or longer pumping time to acceptable pressure level.</u>

Acceptable time to start the experiment wrt pressure needs to be defined.

Outgassing Budget - Example

The outgassing table is build by compiling outgassing databases with the BOM.

mbar.l/s	Sum of Outgassing_flow_HC	Sum of Outgassing_flow_H2	Sum of Outgassing_flow_H2O_20h	Sum of Outgassing_flow_H2O_100h	Sum of Outgassing_flow_H2O_1000h	Sum of Outgassing_flow_N2+Other_100h
Cat.1	~1E-08	~3E-08	~4E-04	~1E-04	~5E-05	~1E-04
Cat.2	Negl.	~3E-07	~1E-04	~1E-05	~7E-07	Negl.
Cat.3	Negl.	~2E-08	~9E-05	~1E-05	~2E-06	?
Grand Total	**~1E-08**	**~4E-07**	**~6E-04**	**~2E-04**	**~5E-05**	**?**

Synthesis of an outgassing budget table – Not all categories are shown

At present time: using an excel file for each outgassing table.

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Outgassing Budget - Example

Component_name	Category	Material	Exposed_Area_cm	Outg_flow_HC	Outg_flow_H2O_10h	Outg_flow_H2O_20h	Outg_flow_H2O_100h	Outg_flow_H2O_200h	Outg_flow_H2O_800h	Outg_flow_N2_O2_200h	Outg_flow_H2	Outgassing rate - total 20h mbar.l.s-1.cm-2	Outgassing rate - total 200h mbar.l.s-1.cm-2	Outgassing rate - total 800h mbar.l.s-1.cm-2	Notes
anello-500-3		Alluminio EN AW-6082	2615.49	0.00E+00	7.85E-07	3.92E-07	7.85E-08	3.92E-08	9.81E-09	0.00E+00	1.05E-10	1.50E-10	1.50E-11	3.79E-12	
0820-D-1MovePlate M3 WI		Alluminio 6061	718.70	0.00E+00	8.41E-07	4.19E-07	8.41E-08	4.19E-08	1.05E-08	0.00E+00	3.95E-11	5.83E-10	5.84E-11	1.47E-11	
0825-D-1MovePlate M2_WI		Alluminio 6061	724.88	0.00E+00	8.48E-07	4.23E-07	8.48E-08	4.23E-08	1.06E-08	0.00E+00	3.99E-11	5.83E-10	5.84E-11	1.47E-11	
Baffle-CITF-side -284		AISI 316 L	2679.80	0.00E+00	7.41E-07	3.83E-07	8.27E-08	4.29E-08	1.16E-08	0.00E+00	2.68E-09	1.44E-10	1.70E-11	5.32E-12	
schermo-B		Alluminio EN AW-6082	3139.82	0.00E+00	9.42E-07	4.71E-07	9.42E-08	4.71E-08	1.18E-08	0.00E+00	1.26E-10	1.50E-10	1.50E-11	3.79E-12	
schermo-B_MIR1		Alluminio EN AW-6082	3139.82	0.00E+00	9.42E-07	4.71E-07	9.42E-08	4.71E-08	1.18E-08	0.00E+00	1.26E-10	1.50E-10	1.50E-11	3.79E-12	
anello-bobine-new		Alluminio EN AW-6082	4232.68	0.00E+00	1.27E-06	6.35E-07	1.27E-07	6.35E-08	1.59E-08	0.00E+00	1.69E-10	1.50E-10	1.50E-11	3.79E-12	
0814-D-1BasePlate M3 WI		Alluminio 6061	1215.33	0.00E+00	1.42E-06	7.09E-07	1.42E-07	7.09E-08	1.77E-08	0.00E+00	6.68E-11	5.83E-10	5.84E-11	1.47E-11	
0826-D-1BasePlate M1_WI		Alluminio 6061	1216.43	0.00E+00	1.42E-06	7.09E-07	1.42E-07	7.09E-08	1.78E-08	0.00E+00	6.69E-11	5.83E-10	5.84E-11	1.47E-11	
0822-D-1Base Plate M2_WI		Alluminio 6061	1230.49	0.00E+00	1.44E-06	7.17E-07	1.44E-07	7.17E-08	1.80E-08	0.00E+00	6.77E-11	5.83E-10	5.84E-11	1.47E-11	
orecchia_2014		Vetro	80.66	0.00E+00	1.61E-06	8.07E-07	1.61E-07	8.07E-08	8.07E-09	0.00E+00	0.00E+00	1.00E-08	1.00E-09	1.00E-10	
orecchia_2014_MIR1		Vetro	80.66	0.00E+00	1.61E-06	8.07E-07	1.61E-07	8.07E-08	8.07E-09	0.00E+00	0.00E+00	1.00E-08	1.00E-09	1.00E-10	
0815-D-1Pedestal M3		Alluminio 6061	2011.72	0.00E+00	2.35E-06	1.17E-06	2.35E-07	1.17E-07	2.94E-08	0.00E+00	1.11E-10	5.83E-10	5.84E-11	1.47E-11	
Mirror Safety 2015 Roma 1		AISI 316 L	7349.15	0.00E+00	2.03E-06	1.05E-06	2.27E-07	1.18E-07	3.17E-08	0.00E+00	7.35E-09	1.44E-10	1.70E-11	5.32E-12	
0823-D-1Pedestal M2_WI		Alluminio 6061	2042.02	0.00E+00	2.39E-06	1.19E-06	2.39E-07	1.19E-07	2.98E-08	0.00E+00	1.12E-10	5.83E-10	5.84E-11	1.47E-11	
Det-1		PEEK	1.59	3.18E-13	1.95E-07	1.38E-07	6.16E-08	4.36E-08	2.18E-08	4.13E-08	0.00E+00	1.13E-07	5.34E-08	1.37E-08	
marionetta-input-new		AISI 316 L	8413.52	0.00E+00	2.33E-06	1.20E-06	2.60E-07	1.35E-07	3.63E-08	0.00E+00	8.41E-09	1.44E-10	1.70E-11	5.32E-12	
Det_DN1000_DN400		AISI 304 L	9725.55	0.00E+00	8.12E-06	3.30E-06	4.08E-07	1.65E-07	2.72E-08	0.00E+00	9.73E-09	3.40E-10	1.80E-11	3.80E-12	
culla-titanio5		Titanio	9648.42	0.00E+00	3.48E-06	1.14E-06	3.48E-07	1.75E-07	4.35E-08	0.00E+00	2.41E-10	1.18E-10	1.81E-11	4.54E-12	
DISCO-BOBINE-INPUT		Alluminio EN AW-6082	13420.01	0.00E+00	4.03E-06	2.01E-06									
spingi-orecchia		PEEK	2.69	5.38E-13	3.30E-07	2.33E-07									
spingi-orecchia_MIR		PEEK	2.69	5.38E-13	3.30E-07	2.33E-07									
Tank-Flangia-2100		AISI 304 L	14573.41	0.00E+00	1.22E-05	4.94E-06									
RHring		Vetro	260.46	0.00E+00	5.21E-06	2.60E-06									
GAMBONI-NORD		Alluminio EN AW-6082	17406.91	0.00E+00	5.22E-06	2.61E-06									
VAC-LNK-1265-2		AISI 304 L	26272.25	0.00E+00	2.19E-05	8.91E-06									
Ass_support		PEEK	7.21	1.44E-12	8.83E-07	6.24E-07									
PUNTE-PEEK		PEEK	7.46	1.49E-12	9.14E-07	6.46E-07									
Part-24-window glass		Vetro	749.91	0.00E+00	1.50E-05	7.50E-06									
punta-peek-specchio		PEEK	9.61	1.92E-12	1.18E-06	8.33E-07									
Assi-blocca-fili		PEEK	9.97	1.99E-12	1.22E-06	8.64E-07									
BaffleTCS_Post		Vetro	1001.60	0.00E+00	2.00E-05	1.00E-05									
Piastra-2400		AISI 304 L	10984.00	0.00E+00	9.17E-06	3.72E-06									
VAC-LNK-1262-2		AISI 304 L	68374.79	0.00E+00	5.71E-05	2.32E-05									
Tank-Flangia-Inferiore		AISI 304 L	29397.00	0.00E+00	2.45E-05	9.97E-06									
OTTICA		BK7	1217.37	0.00E+00	2.43E-05	1.22E-05									
antiribaltamento		PEEK	28.20	5.64E-12	3.46E-06	2.44E-06									
antiribaltamento_MIR		PEEK	28.20	5.64E-12	3.46E-06	2.44E-06									
antiribaltamento_MIR1		PEEK	28.20	5.64E-12	3.46E-06	2.44E-06									
CP-Mirror		Vetro	2306.55	0.00E+00	4.61E-05	2.31E-05									
staffa-rotante - motore		PEEK	38.84	7.77E-12	4.76E-06	3.37E-06									
staffa-rotante		PEEK	40.86	8.17E-12	5.01E-06	3.54E-06									
staffa-rotante-RH		PEEK	41.57	8.31E-12	5.09E-06	3.60E-06	1.61E-06	1.14E-06	5.70E-07	1.08E-06	0.00E+00	1.13E-07	5.34E-08	1.37E-08	
ASS-Mirror-Fibers		Vetro	4352.01	0.00E+00	8.70E-05	4.35E-05	8.70E-06	4.35E-06	4.35E-07	0.00E+00	0.00E+00	1.00E-08	1.00E-09	1.00E-10	
guida01_MIR2		PEEK	54.58	1.09E-11	6.69E-06	4.73E-06	2.11E-06	1.50E-06	7.48E-07	1.42E-06	0.00E+00	1.13E-07	5.34E-08	1.37E-08	
guida01		PEEK	54.58	1.09E-11	6.69E-06	4.73E-06	2.12E-06	1.50E-06	7.48E-07	1.42E-06	0.00E+00	1.13E-07	5.34E-08	1.37E-08	
Piattina1		PEEK	61.05	1.22E-11	7.48E-06	5.29E-06	2.37E-06	1.67E-06	8.36E-07	1.59E-06	0.00E+00	1.13E-07	5.34E-08	1.37E-08	

Tower_ID	Tower_Subdiv	Component_ID	Nb_Component	Category	Outgassing_flow_HC	Outgassing_flow_H 10h
NI	PAY+F7	braccio-pilota-INPUT	8		5.47E-10	3.3
NI	PAY+F7	bobine-specchio-bs-IN	4		7.18E-11	4.4
NI	PAY+F7	guida01_MIR2	2		2.18E-11	1.3
NI	Walls	Tin	1		0.00E+00	1.3
NI	PAY+F7	staffa-rotante	2		1.63E-11	1.0
NI	PAY+F7	Piattina2	1		1.61E-11	9.8
NI	PAY+F7	punta-peek-specchio	8		1.54E-11	9.4
NI	PAY+F7	Piattina1	1		1.22E-11	7.4
NI	PAY+F7	antiribaltamento	2		1.13E-11	6.9
NI	PAY+F7	guida01	1		1.09E-11	6.6
NI	PAY+F7	ASS-Mirror-Fibers	1		0.00E+00	8.7
NI	TCS	OTTICA	3		0.00E+00	7.3
NI	PAY+F7	PUNTE-PEEK	6		8.95E-12	5.4
NI	PAY+F7	Ass_support	6		8.65E-12	5.3
NI	PAY+F7	staffa-rotante-RH	1		8.31E-12	5.0
NI	PAY+F7	Assi-blocca-fili	4		7.98E-12	4.8
NI	PAY+F7	staffa-rotante - motore	1		7.77E-12	4.7

Part of the outgassing budget table – Example lower compartment Virgo Tower WI

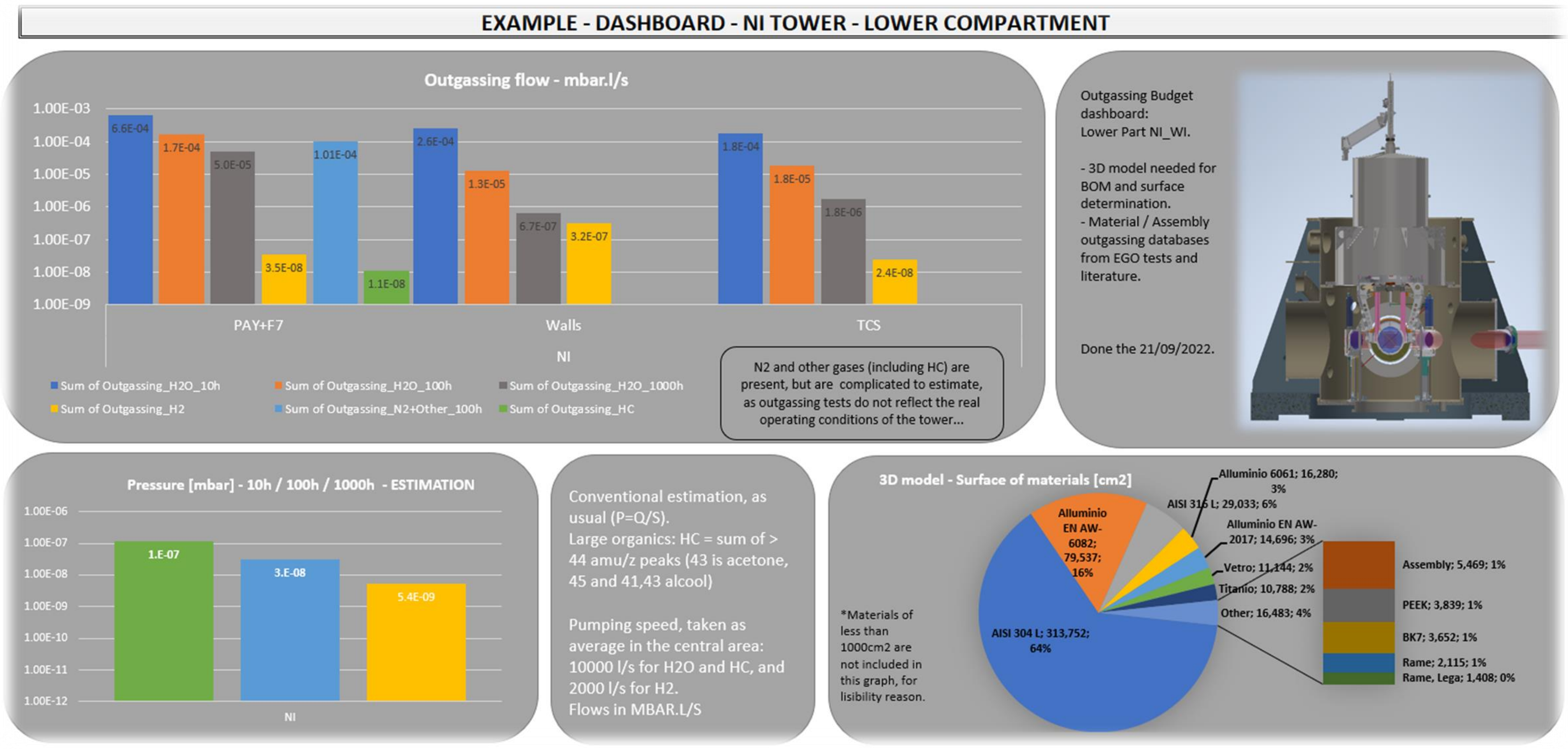
For one compartment, EXAMPLE:

- More than 250 components (including 30 assemblies)
- 20 materials

Components can be classified into categories such as:

Blades, Magnets, Coils, Filters, etc.

Outgassing Budget - Example



Outgassing Budget

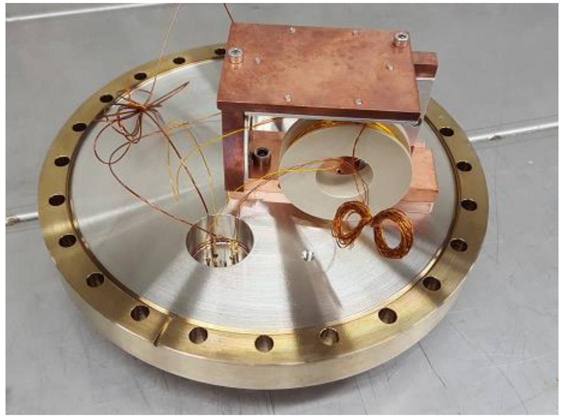
The outgassing budget table depends entirely on the quality of the inputs: Outgassing database and BOM.

- The Bill of Material shall be updated when maintenances are done.
- Outgassing flows on sticky gases, such as H_2O and HC are complicated to estimate.

Nevertheless it is a powerful tool to manage the vacuum quality on the system.

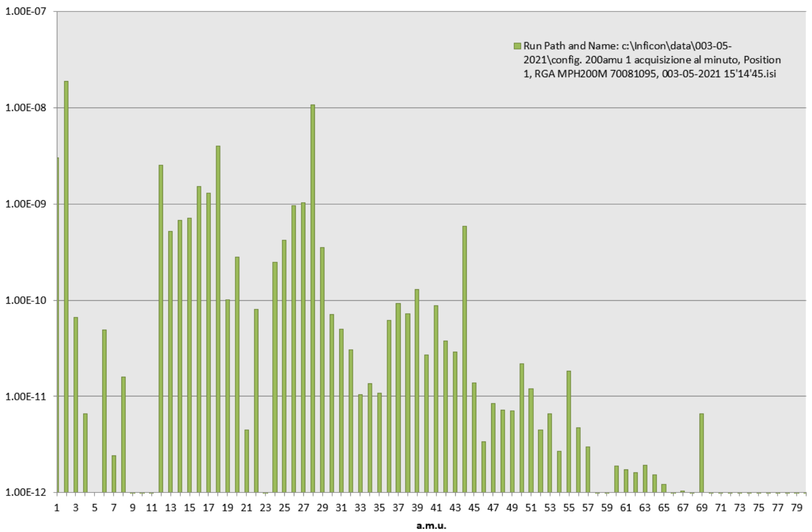
Outgassing Tests

- New bench for measuring H_2 outgassing by accumulation
  - H_2O and other gases by the throughput method.



Coil being tested

<u>No correlation between the detected HC level and optical losses</u>



Contaminated chamber

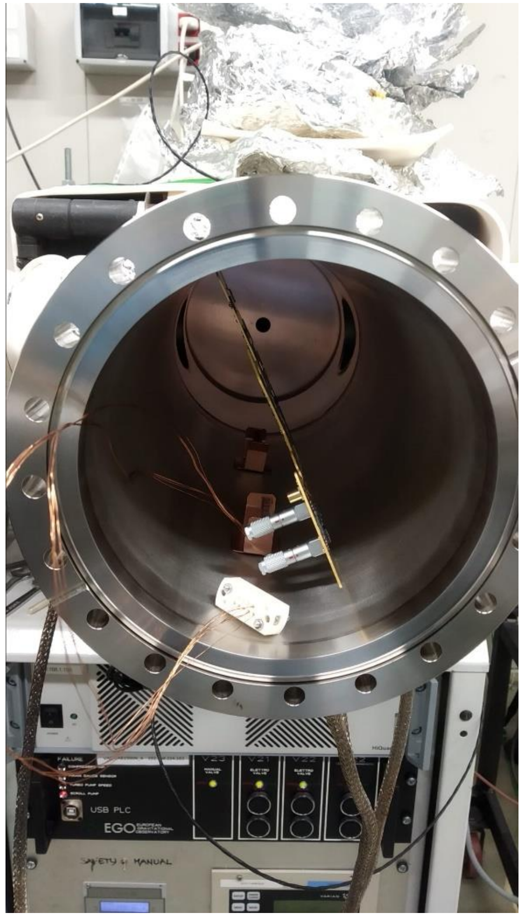
Vacuum laboratory section

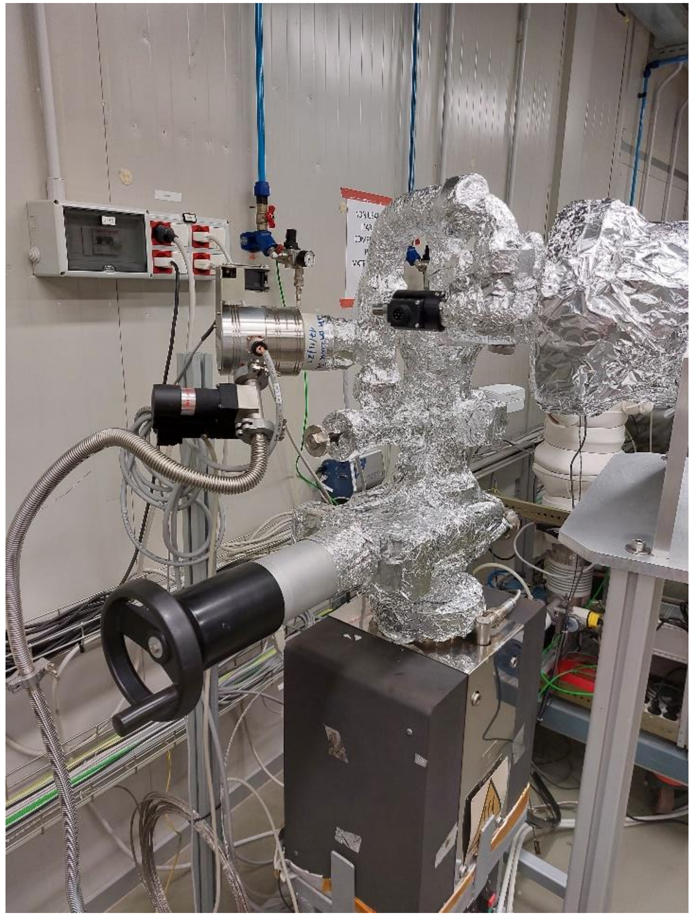
Outgassing Tests

'Throughput method'

$$Q = C * (P_1 - P_2)$$

Thermal degassing cycles,
HC level measurments
(at different temperatures)





"Accumulation" method (rate-of-rise)

Use of RGA to analyse accumulated gases

$$q_{acc} = S_{eff} \int_{t_1}^{t_2} \frac{I}{s} \, dt$$

s: sensitivity factor for the considered gas

Optical / Contamination Aspects

The contamination is measured in the traditional way: Usual Absorption bench using photothermal deflection technique @1064 nm.

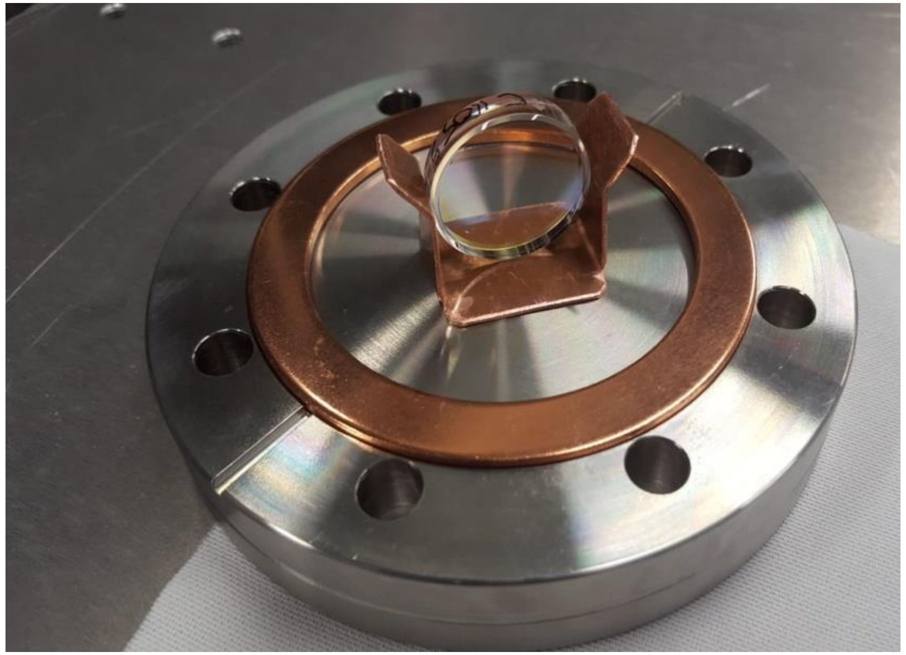
This method is very effective but takes time and skilled people to perform it.

Goal: Investigating new ways to analyse contamination, understand the condensate nature on the surface.

A quantitative estimate of the acceptable deposit (now done conventionally) needs to be defined.

- Optical measurement:

Information about degradation of the optical performances due to exposition under vacuum.



Viewing factor between test mirror and material under test may be relevant.

Collaborative Aspects

- The database is a shared tool
  - Contributions can drive the choice of materials
  - Link with subsystems for the heat treatment and cleaning processes
- Outgassing tests
  - Diverse raw materials, treated materials, chambers and assemblies to test…
  - Long tests and little availability: mutualisation of the tests.

Arm pipe module test - Virgo