Contamination current status.

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1 Introduction

1.1 Purpose

The aim of this report is to present a summary of cleanliness facts and give a general overview of the current contamination of the clean areas of EGO. Thus we will start by giving a short report on the infrastructure, then the cleanliness of the towers and finally of the mirrors.

1.2 Applicable documents

VIR-MAN-CAS-2200-113	Contamination control Plan
VIR-PRO-CAS-2200-114	Procedure for using clean room
VIR-PRO-CAS-2200-115	Procedure for going in a tower
VIR-PRO-CAS-2200-116	Procedure for the mounting of the payload
EGO-PRO-OPE-39-2004	Procedure for the cleaning of EGO clean rooms
EGO-PRO-OPE-1	Users procedure for washing room

2 General consideration

The VIRGO project is a Michelson laser interferometer, made of two orthogonal arms being each 3 kilometers long. A specific optical coating facility has been built in Lyon to produce extremely high quality mirrors combining the highest reflectivity (over 99,999 %), with the highest surface quality (over l/100).

The objective of Virgo is to use optics with a loss by diffusion inferior than 1ppm. The BRDF (bi-directional reflectance distribution function) of an optic can be written as follows:

$$BRDF = C_1\Theta^{-C_2} + \Phi\, C_3 e^{-C_4\Theta}$$

The first term represents the intrinsic contribution of optics, whereas the second term represents the contribution of dust.

Ci = empirical constant

Θ = diffusion angle

Φ = obscuration (fraction of the optical surface covered by the particles**).**

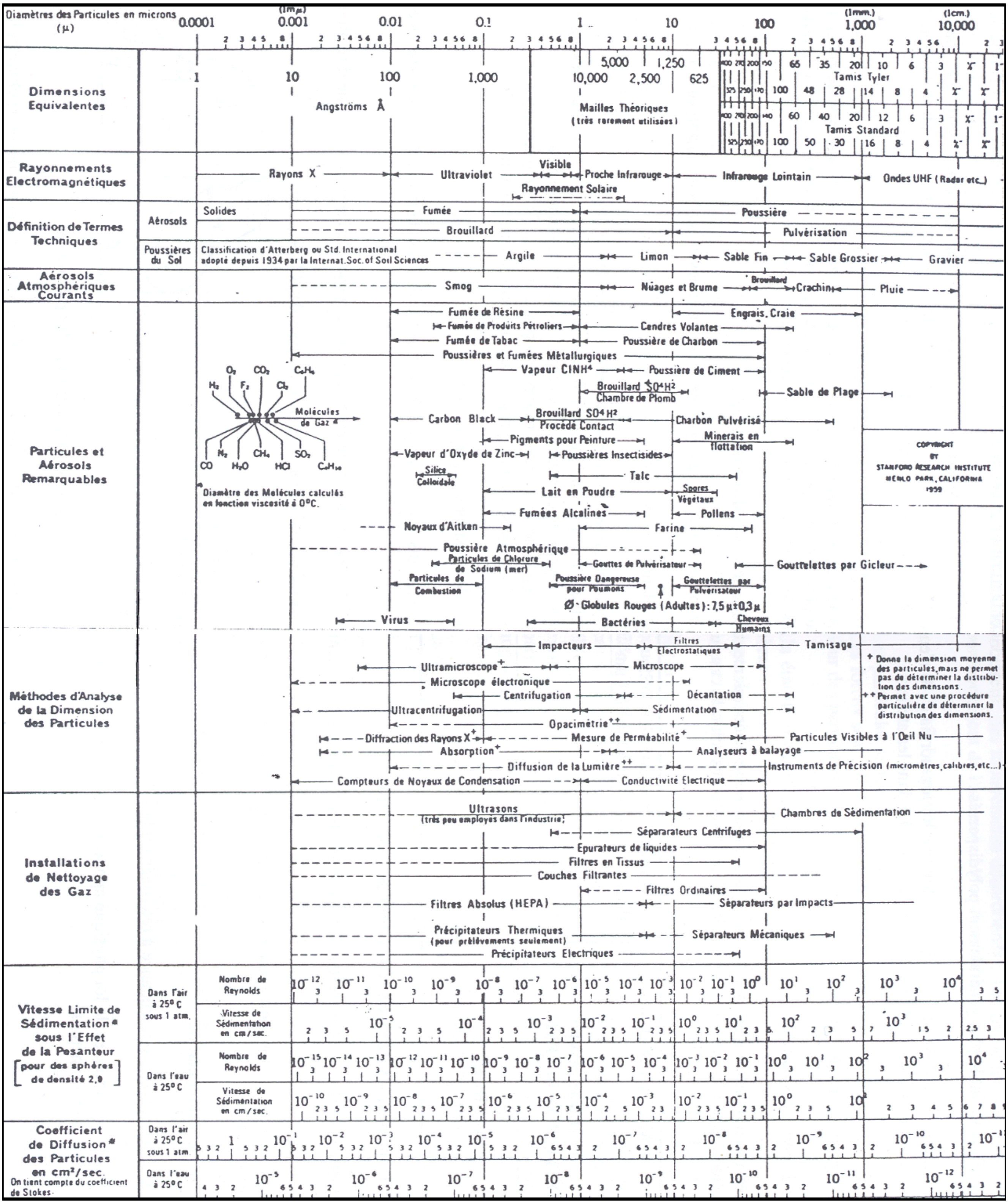
With dust uniformly distributed, $C_3 = 1/\pi$ et $C_4 = 0$, which means that the dust contribution is F/p. Under these conditions a dust contamination leading to an obscuration of 3.5 10-6 to the BRDF qualifies the cleanliness of surface on level 100.

	Exposure Time (Days) for level 100 optics			
	Normal Cln. Rm		Laminar Cln. Rm	
Air Class room	Horizontal Surface	Vertical Surface	Horizontal Surface	Vertical Surface
Class ISO 4	0.65	6.1	3.5	45
Class ISO 5	0.4	2	1	13
Class ISO 6	<<0.1	<<0.1	<<0.1	0.05
Class ISO 7	<<0.1	<<0.1	<<0.1	<<0.1

Exposure times (days) required to generate a level 300 surface

From this, we can say that optics of level 100 can be preserved in vertical position during 6 days in an ISO 4 clean room... time that was unfortunately, systematically exceeded for each mirror of the interferometer.

2.1 General approach of contamination problems.



Characteristics of airborne particles and dusts.

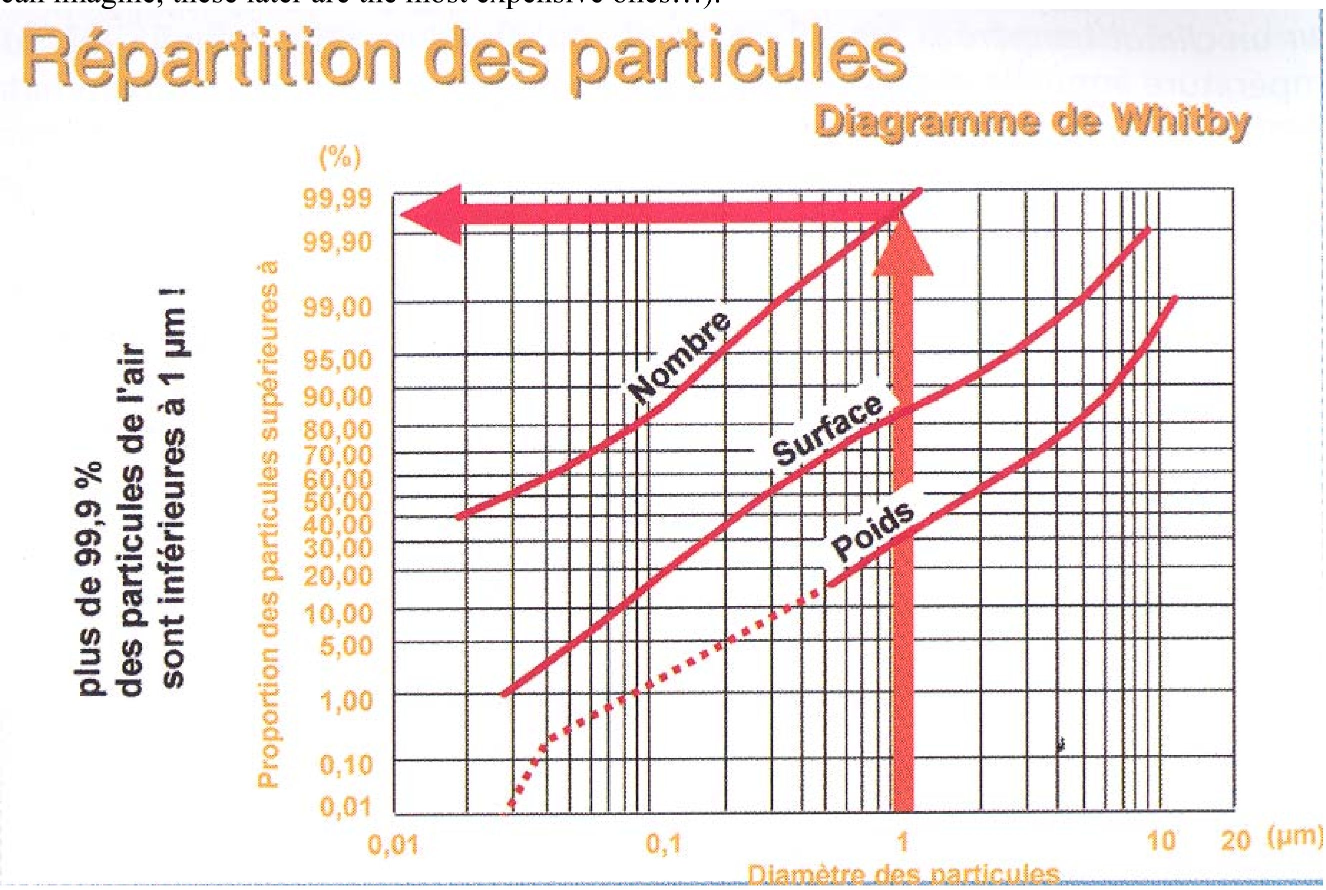
«When 2 surfaces of a different physical and chemical nature are separated again after having been put in contact, they remain charged in electrostatics.»

What is relevant from this chart: a unit cell of skin measures between 4 and 20mm, one hair between 40 and 100 µm, grinding dust approximately 40µm, talc powder 8 µm, cement 20 µm…
The particles come from (by scale of importance): staff, logistics, surface, primary matter, device of process, installation, environment (ambient air).

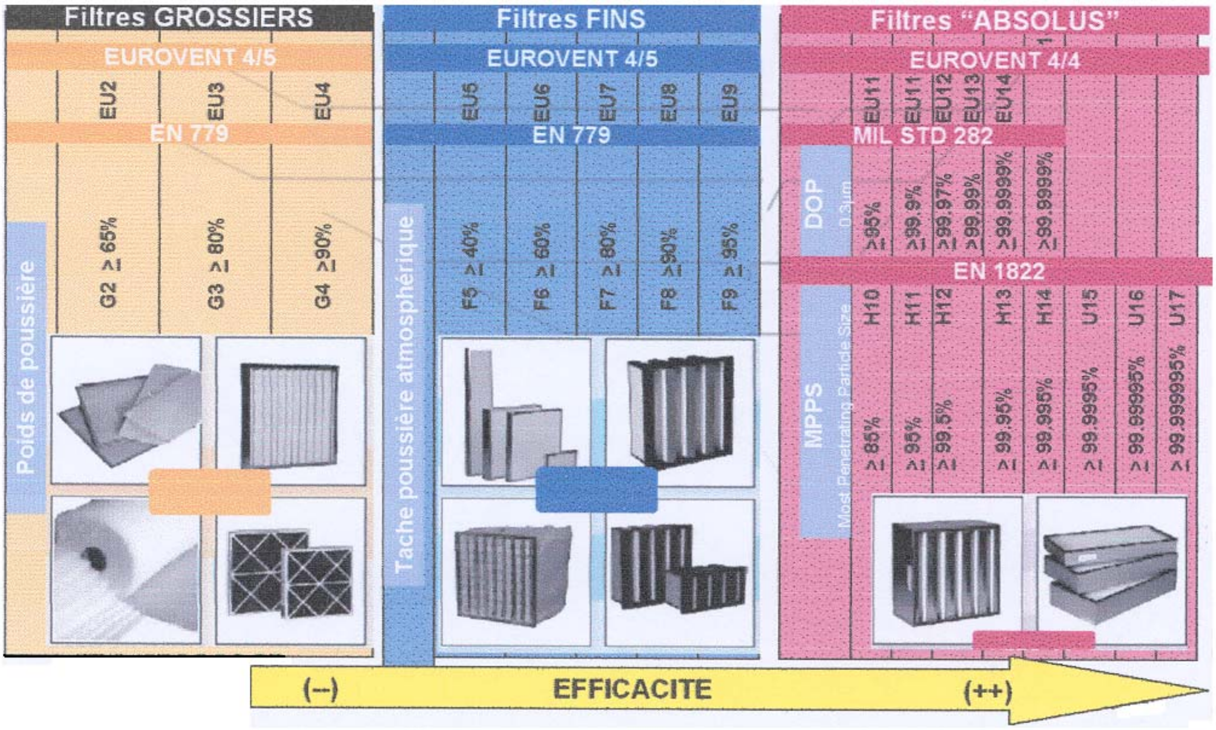
2.2 *Air filtration, air treatments, filter class.*

2.2.1 Filtration

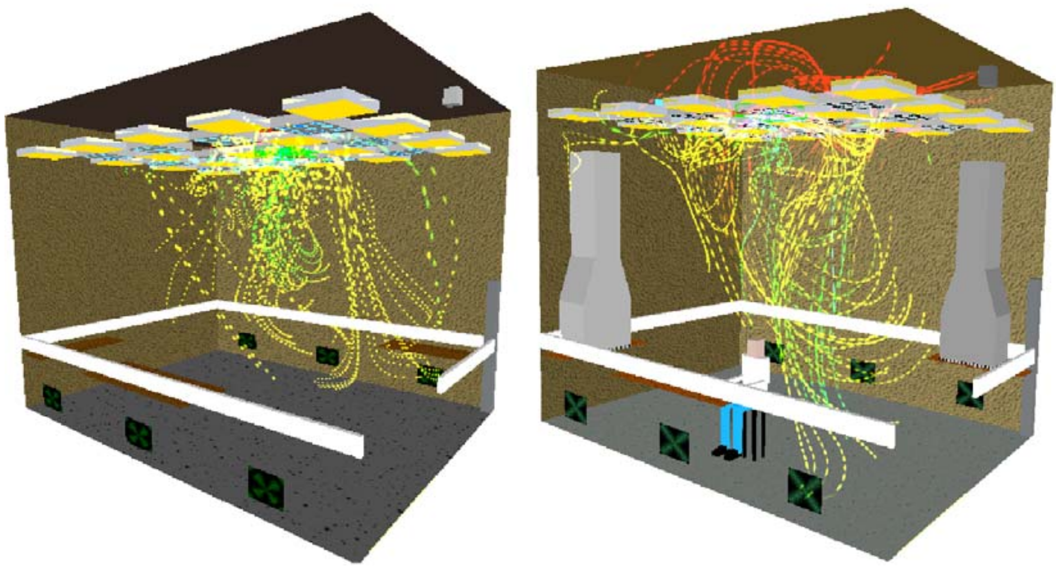
Before all, we must filter the air as "more than 99,9% of particles in air are smaller than 1 µm". A wide variety of filter types and filtration systems are used to remove airborne particles from supply air systems and indoor spaces. Filter panels are inserted into air-handling units (AHUs) upstream of blower fans in HVAC systems and domestic heating and cooling systems. These panels contain an internal fiber, so-called "medium", which varies from a simple metal grid to the more commonly used fibrous mats. These are oriented perpendicular to the direction of the air flow. Filter mats vary in density and depth, with porosities in the range of 70 to 99%. Because of differences in fibber diameters and mat densities, filters also vary in their ability to capture airborne particles. We must maintain and choose with care our collection processes, in order to protect the last stage: the ending filters (as one can imagine, these later are the most expensive ones…).



2.2.2 Filters efficiency.

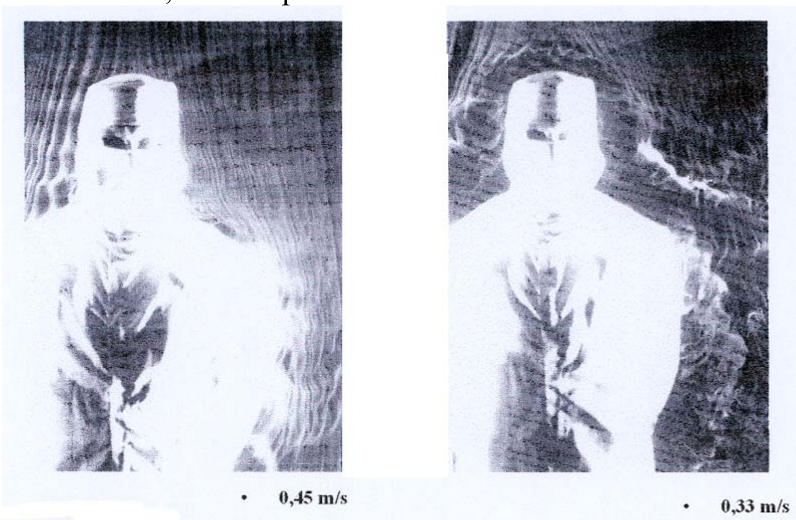


The efficiency or performance of a filter is determined by parameters involving particles, filters, and airflow. These include particle diameter, fiber diameter, filter packing density, filter depth, and airflow rate. The class of very high efficiency is defined according to the measure of local efficiency and the global efficiency of the filter in front of an airborne particle, whose diameter is corresponding to the M.P.P.S. : Most Penetration Particle Size. To use these filters, the most penetrating particle size is between 0,1 et 0,2 µm at a nominal flow. High-efficiency particulate absolute (HEPA) filters are reported to be 99.97% efficient at 0.3 µm. This means that they have a minimum collection efficiency for the most difficult-to-collect particle size.
Recently, various analysis software allowing to analyze airflow, temperature transfer and contaminations have been developed. By example www.flomerics.com



2.3 All clean room parameters must be under control

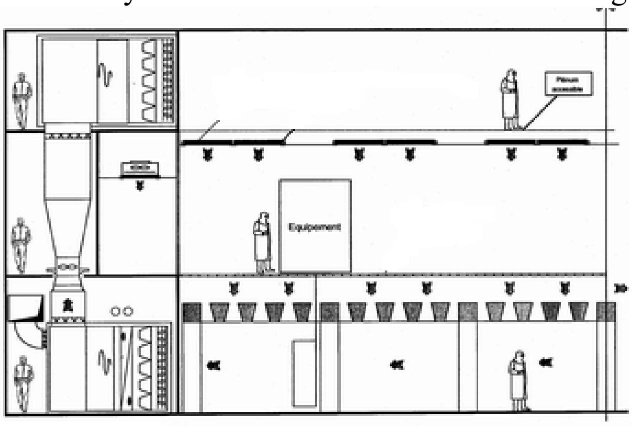
For instance, taking laminar flow, the air speed must be constant 0.45 m/s:



Therefore, the following requirements must be respected:

- Air biological control in clean room
- Air particle monitoring in clean room
- Control of the consumables used in clean room
- Regular cleaning of clean room

The ideal clean room must have every area accessible to enable the cleaning.



We must “think big and flexible”.

3 The central building, terminals building, MC building (blue area)

3.1 Current status

- The measured cleanliness level is on average 400.000 particles of 0.5µm/ft^3 for each area (depending of course on human activities).
  In Ligo - Hanford, the measured cleanliness level is maximum 30 particles of 0.5µm/ft^3, the building design is completely different, the laboratory itself was built like a clean room: from ceiling, the air is flowing and « l'intercapédine » is used as air intake (aspired ventilation aperture).
- In EGO, and in spite of the requirements set for the cleanliness in the towers, the current results cannot be considered satisfactory at all, since the buildings' internals do not invite to respect cleanliness and a visitor has the impression to be in a warehouse rather than in an hospital, as it should look like...
- The wearing of overshoes is not always respected, and most of the people come out and re-enter the restricted blue area without removing and changing them.
- A recurrent problem is that during the rainy season, some mud and dirt, water and even animals are often found inside.
- The tools (vacuum cleaner, scale, trolley…) restrictively dedicated to this zone, are sometime borrowed and used elsewhere on site, where they get dirty.
- The entrance signalization of the clean areas does not differ from the other area (coating of the ground by example), this does not create the "psychological effect" to respect the required precautions in clean areas.

3.2 Suggestions

- A good thing would be to have a linoleum floor, like those used in hospital (puzzled- like), of a clear color.
- It would also be necessary to have all the walls re-painted, in the same color as a standard for internals, and, an obvious but necessary precaution, having all the doors fixed, as some doors even don't close perfectly.
- The garage, which communicates with the clean areas' building, should be perfectly in order (for more than one year, one can see there, laid down on the floor, the same electrical and network material…).
- The data acquisition should also be put in order: close all the racks and find a solution to hide the cabling (wires keep quantity of dust!)
- The cloakroom-infirmary should be in order and the place where the overshoes should be kept.
- The former office area, at the second floor, that the personnel of the collaboration don't use anymore should be reorganized taking into account that all Virgo visitors pass in this area.
- Why not purchasing of sole cleaning machine and oblige its use before every entrance in the restricted blue area: this should limit the multiple in-and-out crossings of a single person, and would certainly enable to keep a better cleanliness.

- For the persons working on the scaffold, only one solution is possible: the wearing of exclusive-shoes for this zone, as clean as possible - as long as it is not possible to find overshoes which do not tear and do not slip.
- Once a year it would be necessary to plan a real thorough cleaning, (much more accurate than what is made daily) as long as many places are difficult to clean and difficult of access: the platform area, the area where lays the air processing machine, the roof of the garage, the walls, the ceiling...
- In general, the major recommendation is that the wearing of overshoes should be extended for all the central building.

4 The clean rooms

Note: Measurement and classification clean aeras (clean rooms and lower part of tower) is made with the new norms : ISO 14644 et 14698 www.afnor.fr.

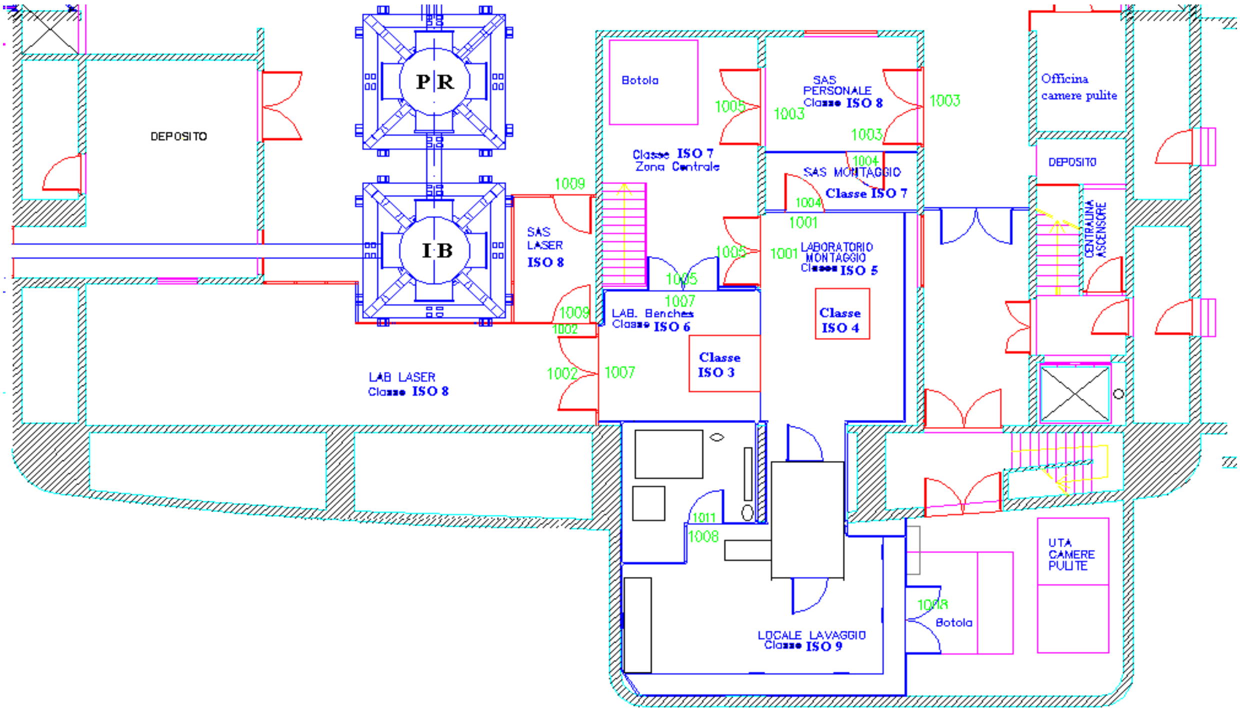
- Particles class ISO

The clean room class defines a higher limit for the pollution and we consider that they may be at 20% of the nominal value without activity and at 70% during the activity.

Number of classification	Concentrations maximal admissible (particles/ m^3 air) in particles of sizes equal or superior which given below.						US FD 209D (Old norm)
ISO (N)	O,1 µm	0,2 µm	0,3 µm	0,5 µm	1 µm	5 µm	
Classe ISO 1	10	2	/	/	/	/	
Classe ISO 2	100	24	10	4	/	/	
Classe ISO 3	1 000	237	12	35	8	/	1
Classe ISO 4	10 000	2 370	1 020	352	83	/	10
Classe ISO 5	100 000	23 700	10 200	3 520	832	29	100
Classe ISO 6	1 000 000	237 000	102 000	35 200	8 320	293	1000
Classe ISO 7	/	/	/	352 000	83 200	2 930	10 000
Classe ISO 8	/	/	/	3 520 000	832 000	29 300	100 000
Classe ISO 9	/	/	/	35 200 000	8 320 000	293 000	
NOTE : Because of uncertainties due to measuring, the concentrations are given with, 3 significant numbers.							

4.1 The first floor

4.1.1 Current status



- The biggest problem is the dust, especially concrete dust (the concrete disintegrates in the plenum (under the false-floor, air recapturing system)), which falls onto the recycling machine and represents certainly a pollution font. The absolute filter pollution cannot be changed because of its substitution costs, so this affects the white room's life duration.
- The operations of cleaning or wrapping all items/materials coming from the exterior is not of common use, since the time dedicated for the operations in the towers (often shortly programmed and quickly prepared) is always too short to allow the technical staff to guarantee the necessary precautions.

4.1.2 Suggestion

- During working periods, the standard cleaning must be done every week, otherwise every month. The important is to allow the easiest cleaning of the clean rooms: with water drainage in each cloakroom.
- The washing room is a strong point for EGO, as much as for its capacity than for its quality, but it would be necessary to be able to control and monitor in continuous the quality of the water and in the next future the result of the cleaning surface.
- EGO must awaken all the users entering in this area and make them feel sensitive and responsible for its cleanliness.
- We must clearly determine the sources of the contamination, dimensions of the contaminant, the classification of the cleanliness, and everybody must feel concerned by the cleaning, how to protect oneself from the contamination, how to behave in the cloakroom and in the clean rooms, the clothing in clean rooms, and also the qualifications of the clean areas, how to measure and control them.

4.2 Lower gallery

4.2.1 Transit area

- This area is not classified but clean. According to the measurements, the average level is 2.000 particles of 0.5µm/ft3.
- A critical problem is that some paving stones come unstuck (although first adjustment works) and seem dirty. Moreover, insects and lizards are still found too often…

4.2.2 Clean tent area

- Once the tower vacuum chamber is opened, it is immediately flushed with clean air and the "clean tent" is then under-pressure with respect to the vacuum chamber and in over-pressure with respect to the transit area. The important is to never forget to let open the door of the lower gallery (otherwise the tower becomes under pressure at the lower gallery).
- The theoretical flushing rate in the tower is 1200 m^3/h.
- The air filtering is 99.999 % DOP and it is expected a class level of 100 (ISO 5). With no human presence, 15 particles of 0.5µm/ft3 at 1.5 m above ground have been measured. Based on experience, we could reasonably assume a class 100 (ISO 5) with two operators present. But in fact during the mounting phase of a M6 mirror (9 September 2004), for example, the measurements show that the area can rather be considered as a class 10000 room. ISO 7! .
- It is not easy to apply the procedure for going in a tower VIR-PRO-CAS-2200-115.
  In practice, the clean tent area is used as a lock chamber to change garments before entering inside the tower. This is done on the Hymo (elevator cart), but this is not easy because the space is very small and a wardrobe is missing. The solution would be to buy a mobile lock chamber with a filtering ceiling- maybe (very expensive)!

4.3 Tower vacuum chamber.

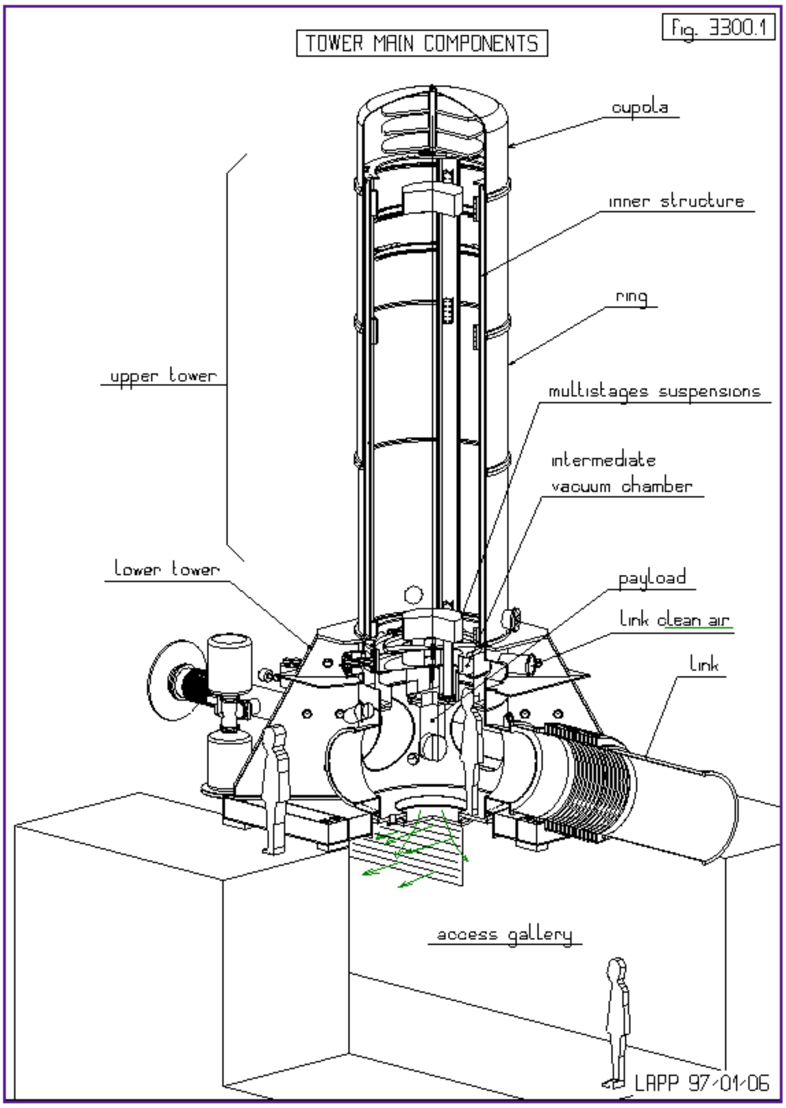


Fig. 1 : Mise en oeuvre díun miroir dans une tour de Virgo

Requirements

- The vacuum chamber shall be a class 1 clean room (ISO 3) at rest and a class 100 (ISO 5) with two operators working inside.
- It shall be in overpressure with respect to the clean tent in the gallery
- The flushing rate shall be 1000 m^3/h. (to be checked).
- Air filtering shall be 99.9995 % DOP (ok)

4.3.1 Status: Cleanliness level average obtained in towers

Without operators.

Towers	BS	MC	IB	NI	NE	WE	WI	PR	OB
DATE	13.09.02	05/06/03	6/25/03	04/07/03	05/01/03	6/27/03	3/9/03	13.11.02	04/03/03
Size µm/ft3									
0,2	63,0	419	7,0	69,0	1,0	2,0	98,0	106,0	69,0
0,3	14,0	93	10,0	43,0	0,0	0,0	31,0	78,0	75,0
0,5	0,0	1	5,0	2,0	0,0	0,0	1,0	15,0	25,0
0,7	0,0	0	0,0	0,0	0,0	0,0	0,0	12,0	21,0
1,0	0,0	0	2,0	0,0	0,0	0,0	0,0	18,0	24,0
2,0	0,0	0	0,0	0,0	0,0	0,0	0,0	4,0	6,0
3,0	0,0	0	0,0	0,0	0,0	0,0	0,0	1,0	2,0
5,0	0,0	0	0,0	0,0	0,0	0,0	0,0	0,0	2,0
ACCUM N/CU-FT	77,0	513,0	24,0	114,0	1,0	2,0	130,0	235,0	224,0

During each mounting, the pollution level has been multiplied by 1000, during in average 1 hour.

Remarks: in the mode cleaner tower, the flushing air seems not to have enough power. Moreover, due to the absence of a HEPA filter under the tower, it is impossible to dress in clean area before entering inside the tower.

4.3.2 Status: Cleanliness level step obtained for the NorthEnd mirror during steps of payload assembling.

Référence		Nb Total	0,3 µm	0,4 µm	0,5 µm	0,6 µm	0,7 µm	1 µm	1,5 µm	2 µm	3 µm	4 µm	5 µm	7 µm	10 µm
SIM 19	Avant	77	21	11	8	10	10	10	3	2	0	0	1	1	0
	Après	**2059 (+ 1982)**	**478**	**244**	**238**	**193**	**222**	**180**	**81**	**107**	**5**	**55**	**80**	**55**	**118**
SIM 20	Avant	120	25	18	17	8	19	20	5	6	0	1	1	0	0
	Après	**1546 (+ 1426)**	**319**	**165**	**165**	**133**	**163**	**152**	**81**	**97**	**4**	**53**	**69**	**51**	**94**
SIM 21	Avant	91	33	15	11	10	12	6	2	1	0	1	0	0	0
	Après	**298 (+ 207)**	**110**	**33**	**43**	**36**	**25**	**12**	**5**	**5**	**0**	**0**	**5**	**8**	**26**
SIM 26 (verticale)	Avant	83	23	11	12	10	14	9	1	2	0	1	0	0	0
	Après	**1006 (+ 923)**	**215**	**115**	**129**	**141**	**109**	**80**	**27**	**33**	**0**	**24**	**31**	**99**	**2**

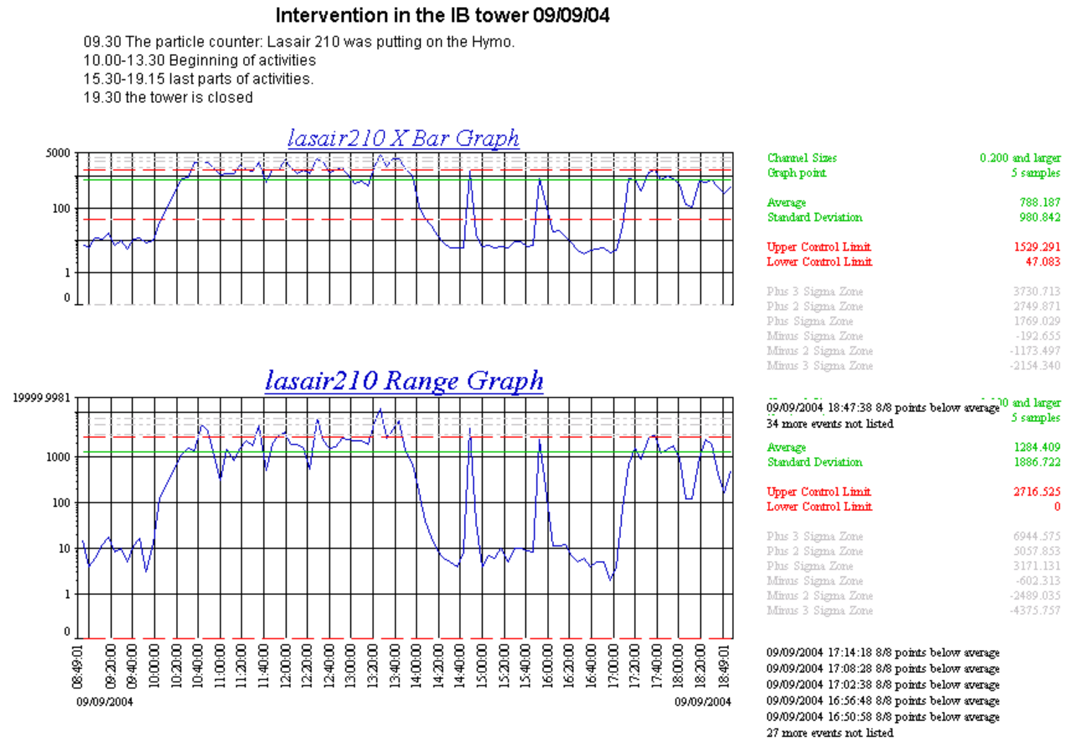
SIM19 Wafer in front of the mirror during the time needed to install the protective mirror (1hour)

SIM 20 Wafer below the mirror (15 cm) in the payload (put the Friday april,25h and kept out the July, 29 under the tower) , during the week-end accidentally the clean room, all the night worked at 30%,

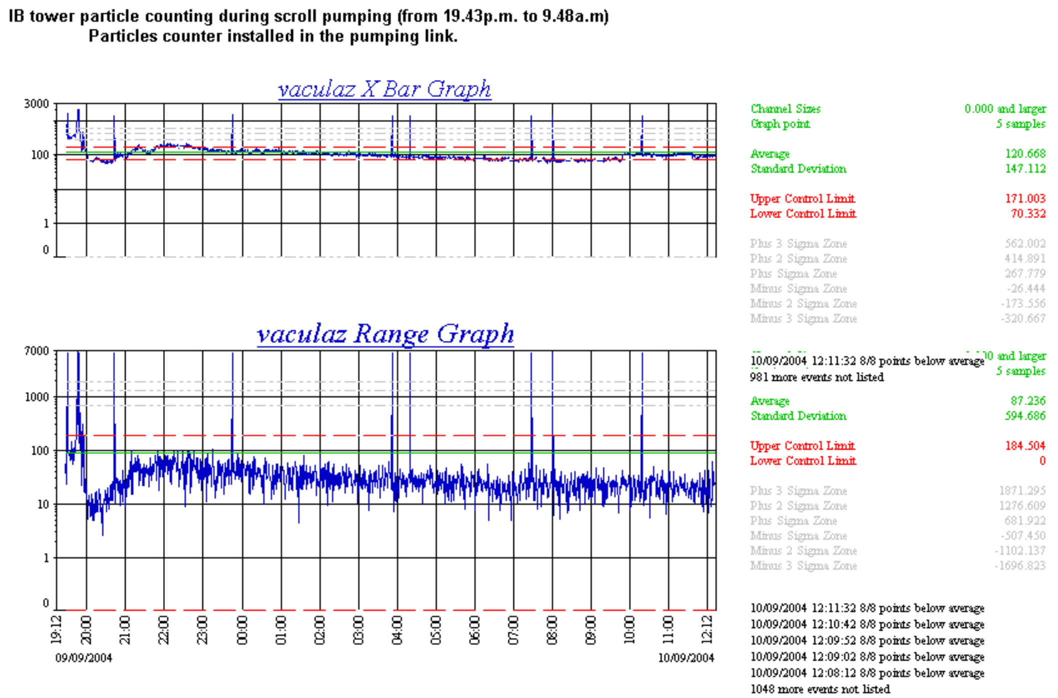
SIM 21 Wafer below the mirror (15 cm) in the payload (put the Tuesday july,29h before to put the plastic layer, and kept out the July, 29 (15,00) under the tower)

SIM 26 Wafer put before the payload, and kept out after the mounting of the payload

4.3.3 The case of the Injection bench Tower: Intervention for the replacement of the mirror M6.



The measurement first gave an average of 1.410 particles of 0.2µm/ft^3 and larger, when the activity is working. During the second part (in the afternoon), the measurement gave an average of 825 particles of 0.2µm/ft and larger.



At the beginning of the pumping, the measurement gave a spike of 2.500 particles of 0.2µm/ft^3 and larger, during the pumping we can see an improvement of the pollution.

4.3.3.1 L.M.A. measurement.

4.3.3.1.1 Wafer staid during 1 year in the IB tower.

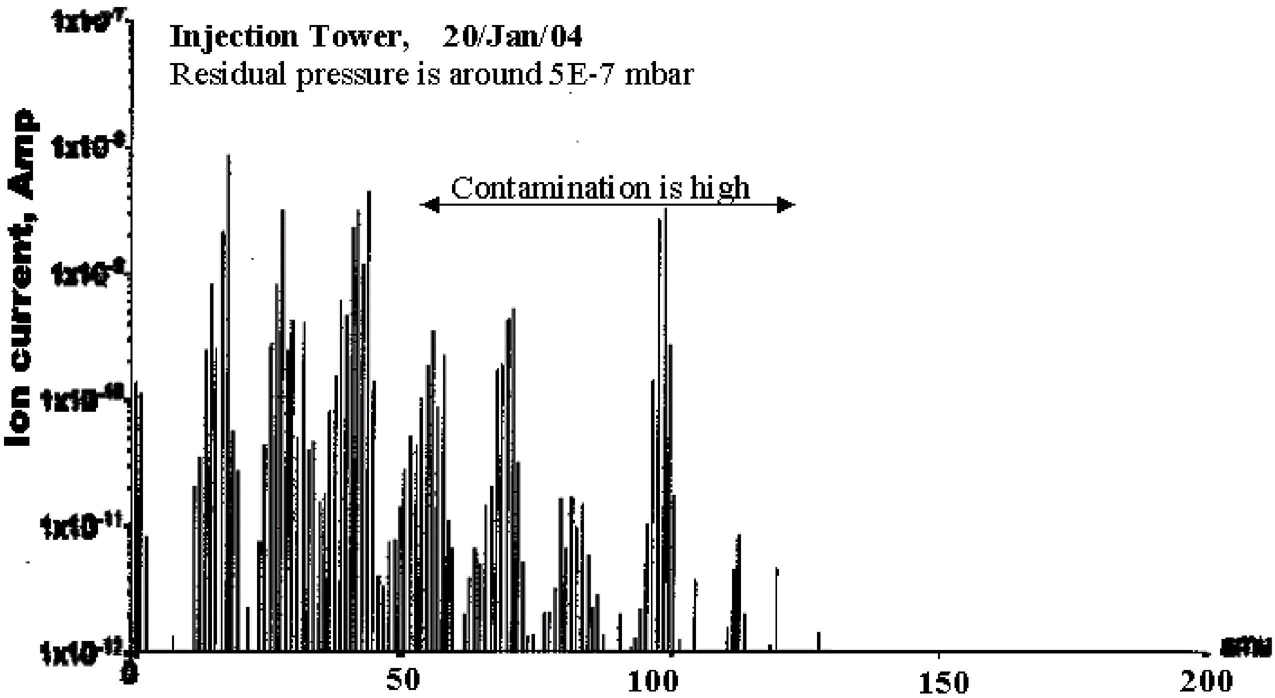
Référence		Nb Total	0,3 µm	0,4 µm	0,5 µm	0,6 µm	0,7 µm	1 µm	1,5 µm	2 µm	3 µm	4 µm	5 µm	7 µm	10 µm
SIMC6	Avant	126	33	17	20	11	12	9	2	0	0	0	0	0	0
	Après	**34706 (+ 34580)**	**3095**	**3000**	**4365**	**5368**	**6753**	**5127**	**1966**	**2074**	**50**	**1094**	**1093**	**473**	**248**

Wafer C6 : wafer placed in the lower part of the IB tower, exited 25/7/2004, entered the 25/06/2003

4.3.3.1.2 Characterization of the particulate contamination by measurement of diffusion of the mirrors used in the bench of injection of the CITF

Référence	Diffusion moyenne après retour Cascina (ppm)		Diffusion moyenne après renettoyage (ppm)		Diffusion d'origine (ppm)	
	Ø 30 mm	Ø 10 mm	Ø 30 mm	Ø 10 mm	Ø 30 mm	Ø 10 mm
Miroir M2 JMM 35	180	180	84	7	-	-
Miroir M3 JMM 32	260	170	45	31	-	-
Miroir M7 JMM 40	190	190	11	7	-	-
Miroir M8 JMM 30	240	250	28	11	-	-
Miroir JMM 27	195	400	32	32	-	-
Miroir M1 98127/1+98139/1	3500	3000	11	10	12	6
Miroir M4 98127/1+98139/1	2100	1400	19	5	9	5

4.3.3.2 Vacuum measurement.



We noticed a too big contamination by hydrocarbon, so each time the vacuum is done, a hydrocarbon layer settles on the Input Bench mirrors.

5 The mirror cleaning in situ.

5.1 Preliminaries

On one hand, L.M.A. advises to use the mirrors like they are, even if they are dirtied by the phenomena of condensation, i.e. - act as less as possible on the mirrors.
If a micro dust or a small trace is detected, one can blow delicately with an ionizing gun or possibly use Q tip with isopropanol.

On the other hand, according to its experience L.M.A. is not favorable at all to the use of CO2 gun to clean VIRGO optics, even if LIGO does it.
This being said, we have found convenient to use it to clean mechanic components and the Van-Tran system (CO2 cleaning system) was bought for this use.

According to the technical literature, the criteria of success for the process validation of cleaning optical surfaces by jet of dry ice are the quasi-elimination of the particles of sizes higher than 10 microns without any damage on the optical treatments, but without any knowledge about the smallest particles, but with strong probabilities of a growth up of their number.

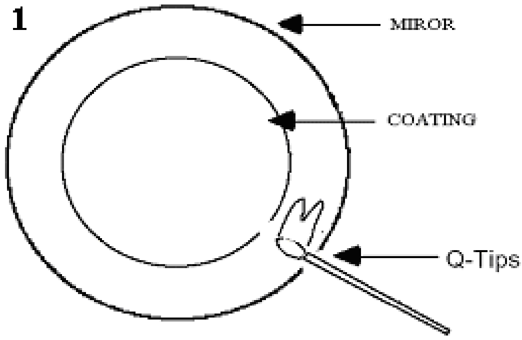
5.2 Procedures

5.2.1 Classic method

Gloves without powder +clean room suits
Q-Tips (in wood)
Pure isopropanol alcohol, 99,99% or ultra-pure water 18 MΩ
Absorbent cotton wipe
Nitrogen ionising gun (Simco gun)
Lighting with intense focused lamp

Humidify Q-Tip with solvent (alcohol). Shake Q-Tip to remove alcohol excess.
With a light pressure, move Q-Tip on the dirty trace. Turn it slowly on itself at each passage.
Throw away Q-Tips after a passage or a 360-degree cleaning. Start again the operation, if necessary.
With an ionizing gun, blow to move all the particles.

1



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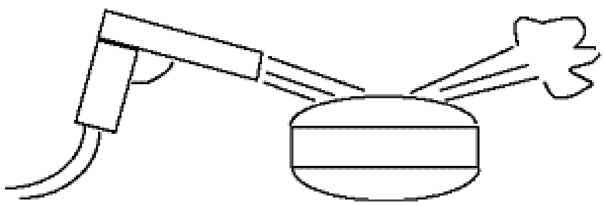
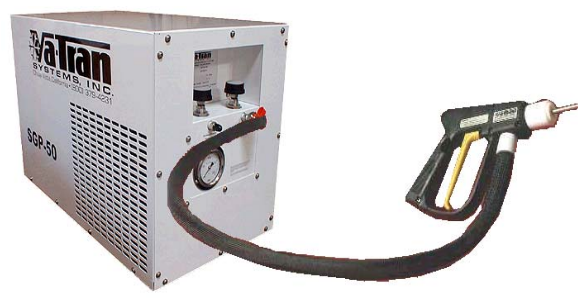
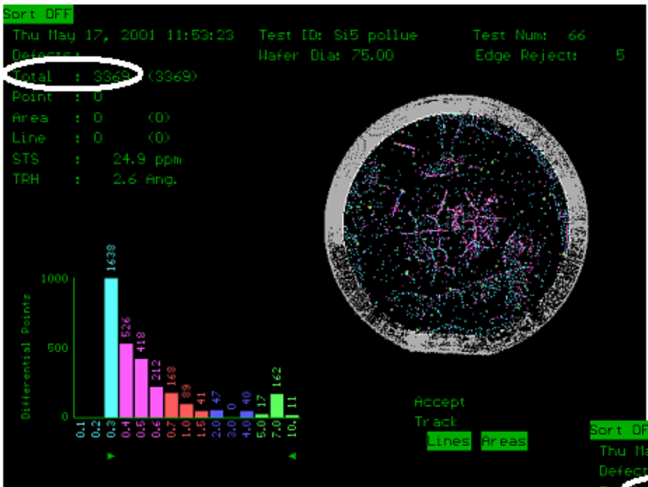


5.2.2 CO2 cleaning procedures.

PROCESS SPECIFICATION **E990316-00-D** **DRWG NO. REV. GID** TITLE CO2 Cleaning Procedures APPROVALS: DATE REV DCN NO BY CHK DCC DATE DRAWN: H. Armandula 08-10-99 CHECKED: APPROVED: DCC RELEASE: LIGO Form CS-01 (4/96) CALIFORNIA INSTITUTE OF TECHNOLOGY MASSACHUSETTS INSTITUTE OF TECHNOLOGY	

Here are results presented by the L.M.A. team.

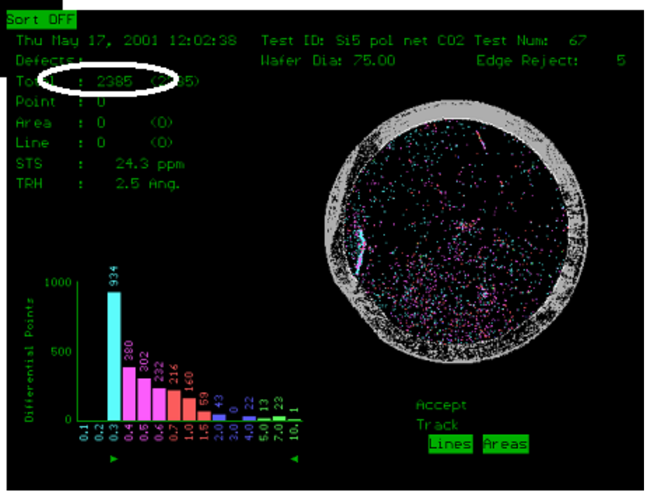


CO2 Cleaning

Extract of J-M. Mackowski presentation – June 2th, 2001

Si 5 with pollution

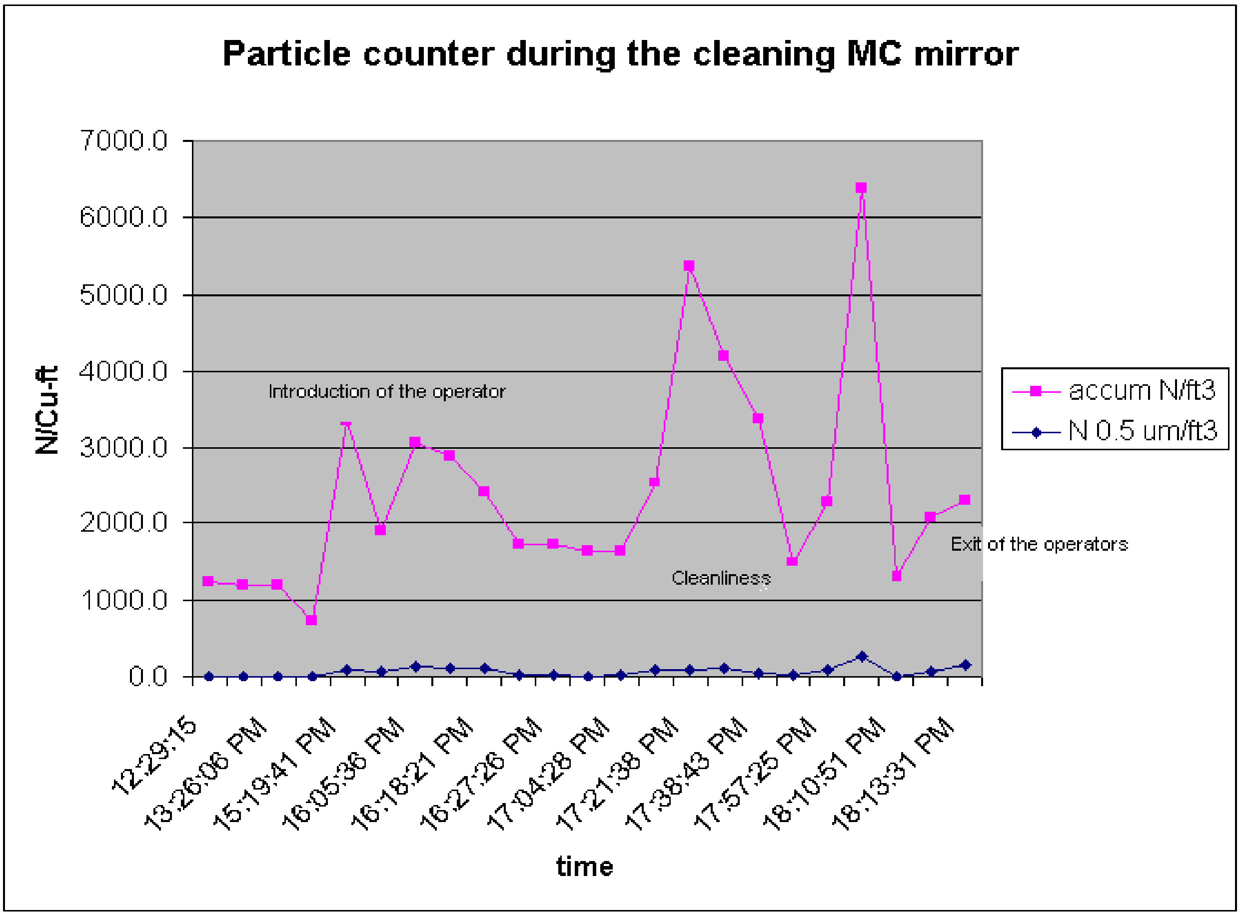
Tot:3369 particles

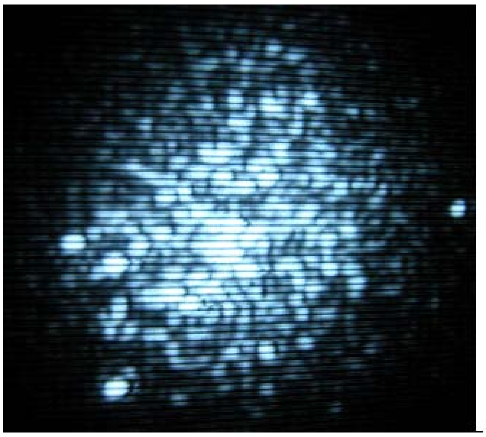


Si 5 with pollution after CO2 Cleaning

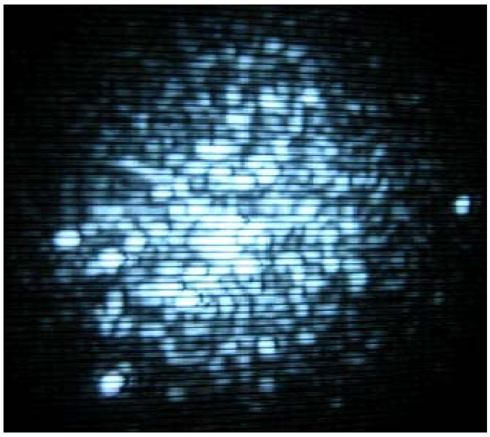
Tot:2385 particles

Our intervention on June 30th, 2004 to clean the mirror in the MC tower did not give the expected results. The Isys performance was the same after the intervention.





Before cleaning

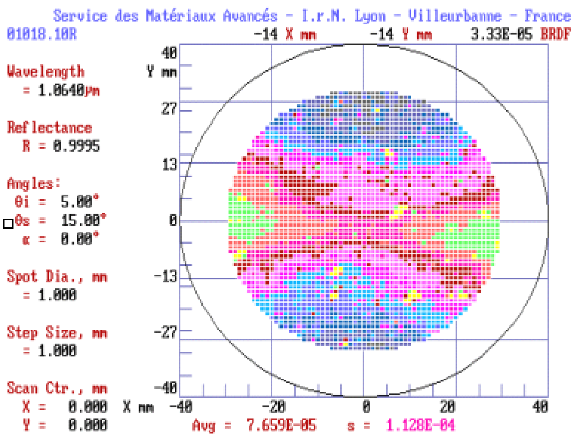


After...

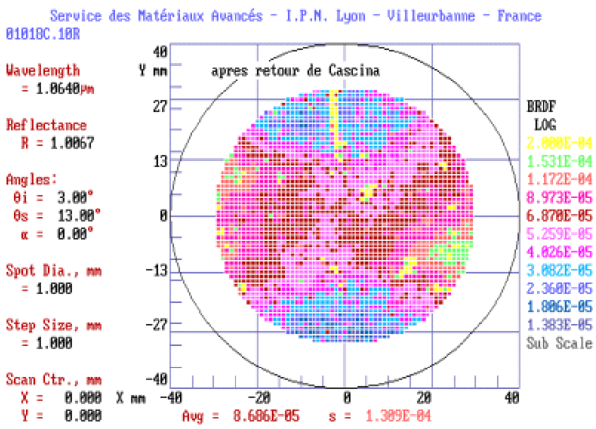
Remark: The pictures have been taken with a video camera, in front of which optical filters had been displayed. The optical cavity was locked. It seems that what is seen are not particles, nor organic traces. During the cleaning intervention, we tried to remove a trace on the edge of the mirror with a Q-Tip humidified with Isopropanol but this did not give positive results. We suppose that either the coating itself, or the substrate be at the origin of the defects.

CITF results:

Before use in the CITF



After use in the CITF



5.2.3 N2 liquid cleaning

Developing a method on Cascina site, which would work with liquid nitrogen, is a new idea, on which, although it is difficult to find support literature presents attractive points, but the risk that it does not function exists! Risk that under the thermal shock, the substrate breaks.

This being said, in that case, we would observe the substrate (standard wafer) beforehand with a monocular microscope coupled with a camera (cost study required with support of the optics group).
Afterwards, we would project a liquid nitrogen using a dermatology gun (2000 Euro), then make the same observation as at the beginning....
But clearly, some questions remain open to perform this trial operation: we don't have a tool, here, to do any measurement or observation, and stocking liquid nitrogen is complex…

6 CONCLUSION

- To obtain a "clean environment", Virgo staff must be made aware of the cleanliness problems.
- In the future, we could envisage the systematical acquisition of the particle counting from the exhaust line during the scroll pumping.
  This means that the installation of a PMS viewing module would be necessary for each tower, in order to use the vaculaz counter for each pumping performed.
- It is essential to reinforce the links with Lyon to list/define the different problems met at the time of the assembly of the 1st generation mirrors and include/understand the pollution measured on the CITF mirrors, in order to foresee/adapt our future operations.
- In order to make in situ tests of mirror cleaning, the return on Cascina site of the CITF mirrors, presently in Rome and in Nice, would be necessary.
- In the same prospect, then it could be interesting to develop, in collaboration with L.M.A and the optical group of EGO, an on-site "measuring tool", to measure the pollution of the mirrors in situ.
- All technicians who must intervene on the apparatus: mechanics, suspensions, vacuum or optics, must be sensitized with cleanliness.
- The whole central building should be put in "clean" area, overshoes obligatory.
  A decent floor covering (linoleum white) should be installed, the walls re-painted, generally the entire building must be kept as clean as possible, i.e. cleaner than now.

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