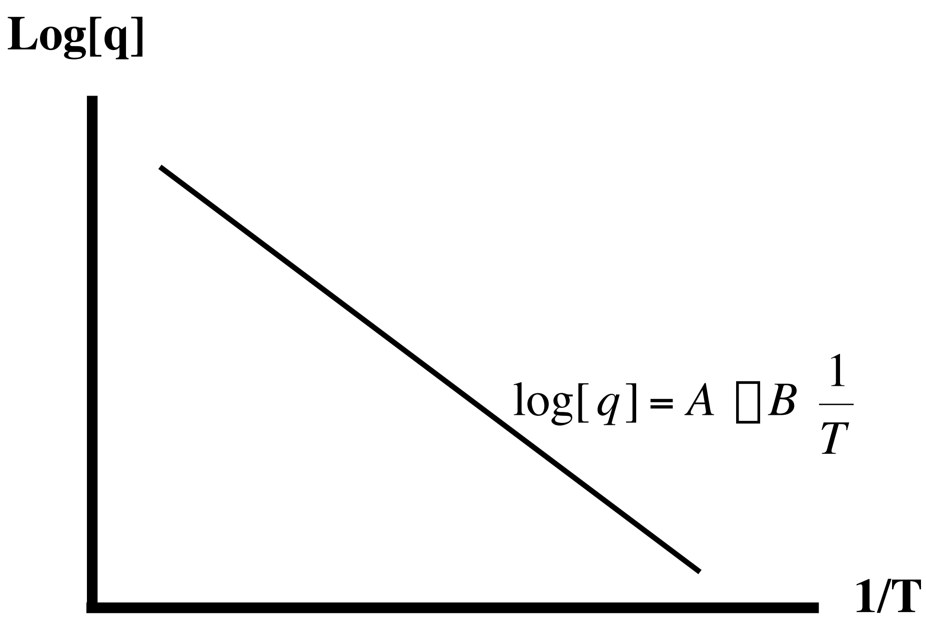
Thermal Desorption

Specific desorption rate : q [Pa m^3 s^{-1} m^{-2}]

$$q = Const \cdot e^{-\frac{E}{kT}}$$

Molecular residence time $\tau = \frac{1}{\nu_o} \cdot e^{\frac{E}{kT}}$

E activation energy for desorption,
$\nu_o \sim 10^{13}$ s^{-1} vibration frequency in the surface potential



Physisorbed molecules E < 40 kJ/mole (0.4 eV)
Chemisorbed molecules E > 80 kJ/mole (0.8 eV)

Bakeout between 150 – 300°C : reduced residence time.
Reduction for H_2O, CO, CO_2 (by factors of 10^{-2} to 10^{-4})
At higher temperature > 400-500°C -> cracking of hydrocarbon molecules (C-H)
Note: Strongly reduced thermal desorption at cryogenic temperatures

Chemical solvent pre-cleaning procedure

1) Removal of gross contamination and machining oils using the appropriate solvents

2) Perchloroethylene (C_2Cl_4) vapour degreasing at (121°C) to day no longer applicable

3) Ultrasonic cleaning in an alkaline detergent (pH =11)

4) Rinsing in cold demineralised water   (electrical conductivity < 5 μS cm^{-1})

5) Drying in a hot air oven at 150°C

6) Wrapping in clean Al-foil or paper

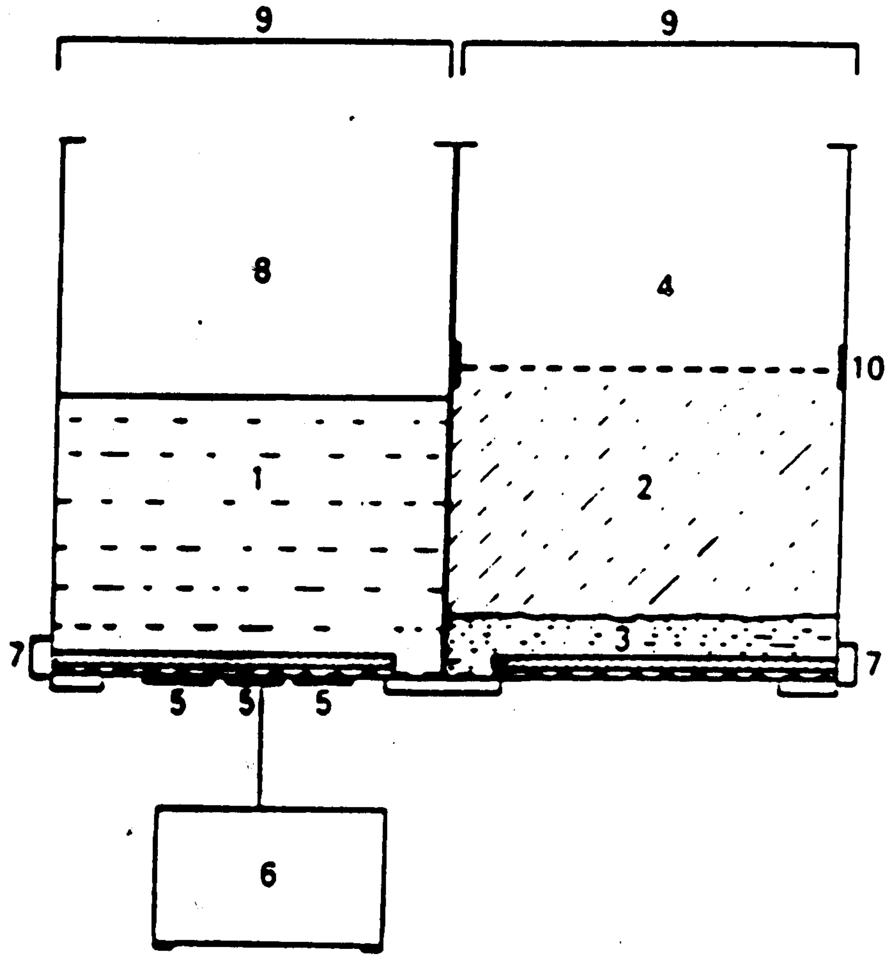
Cleaning method will depend on the material (stainless steel, aluminium, copper)

Important:
Any subsequent handling must be done with clean gloves.
Contamination by any residues in the air must be avoided.

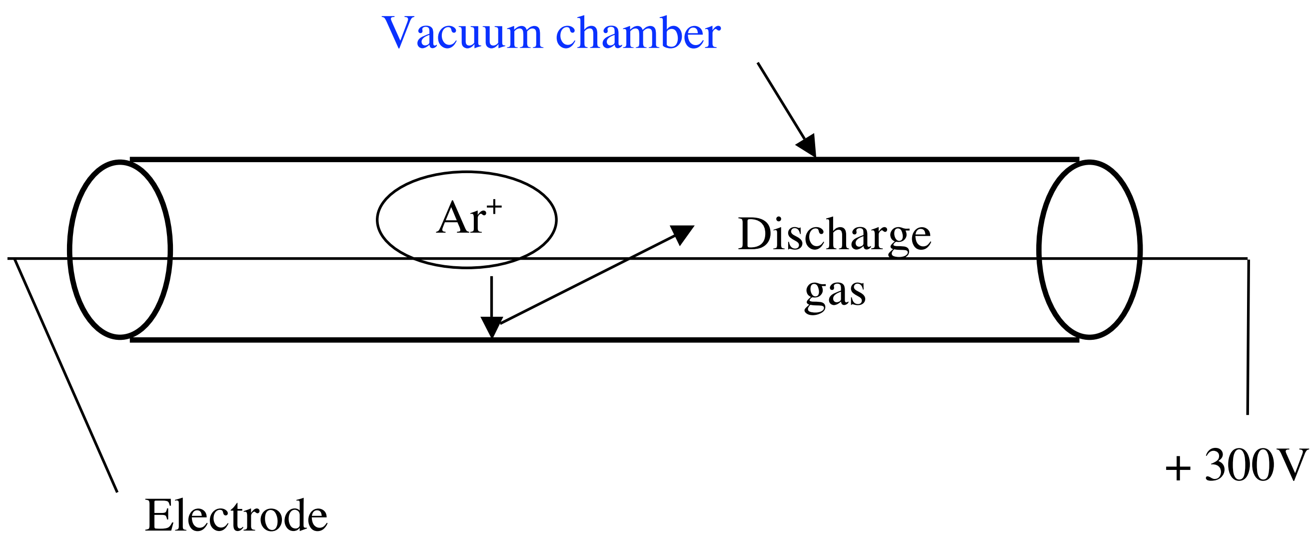
No car exhaust gases, No smoking!!

Chemical cleaning facility

1) Hot detergent with ultrasonic agitation
2) Hot vapour zone
3) Hot solvent bath
4) Cooling zone
5) Ultrasonic generators
6) Ultrasonic controls
7) Heaters
8) Drying zone
9) Covers
10) Cooling zone for solvent vapour



Glow-Discharge Cleaning



Cleaning of the surface by energetic ion bombardment (Usually Argon or some other inert gas)
Dose approx. 10^{18} -10^{19} ions/cm^2
Argon pressure between 10^{-1} – 10^{-2} Pa for optimum conditions
Desorption of chemisorbed, strongly bound molecules corresponding to a high activation energy.
Effective cleaning by removing the top layer of the surface by sputtering. -> Tokamak vacuum systems

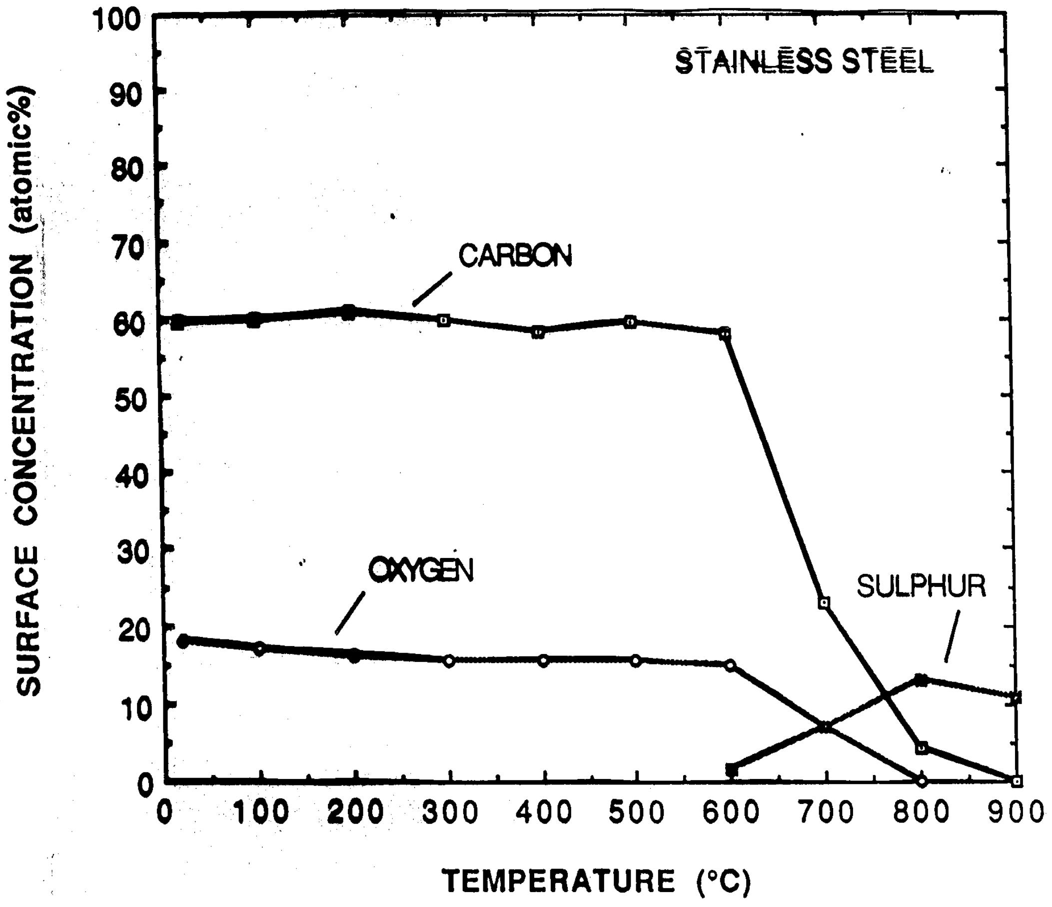
Vacuum firing at high temperature

High temperature baking in a vacuum oven at ~950 deg C

Cracking of hydrocarbons and organic compounds.

Reduction of the surface oxide layer.

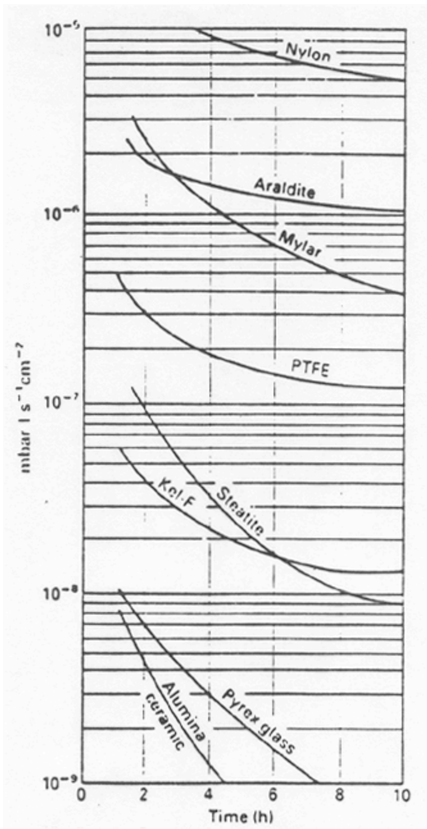
After the high temperature treatment, cool down in a clean gas to generate a controlled oxide layer

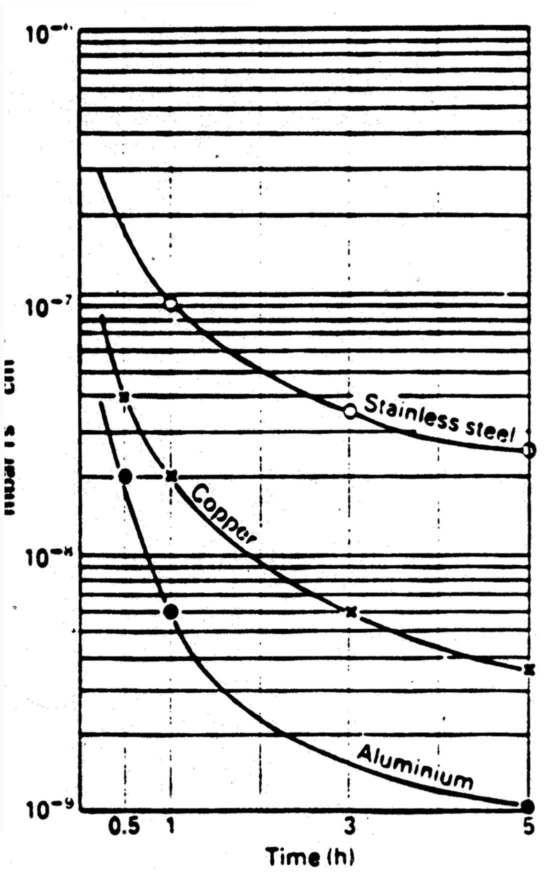


Thermal outgassing Rates of some materials

Comparison of organic materials and of metals

Unbaked samples (usually H_2O dominates)



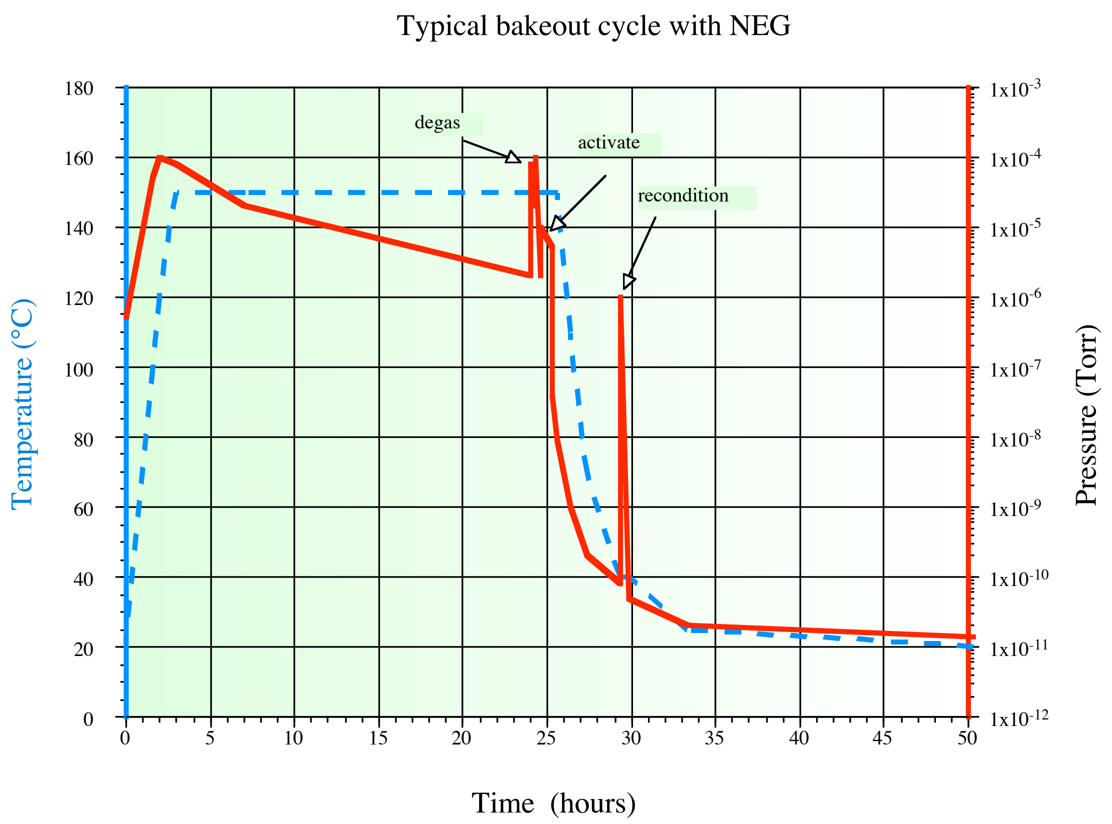


Baked samples
(24 hours at 150°C to 300 °C)

Typical values after 50 hours of pumping :
(units : Torr l s^{-1} cm^{-2})

Gas	Al, Stainless steel
H_2	5 10^{-13}
CH_4	5 10^{-15}
CO	1 10^{-14}
CO_2	1 10^{-14}

Bakeout of the LEP Vacuum System with NEG



Within less than 12 hours after a bakeout uhv conditions can be achieved.

Criteria influencing the Choice of Materials

Low outgassing rate
Low vapour pressure
Temperature resistant -> bakeout
Thermal and electrical conductivity -> beam interaction
Corrosion resistance -> leaks
Low induced radioactivity -> handling
High mechanical strength -> 1dN/cm^2 external pressure!
Machining, welding
Low cost

Common choices:

Stainless steel
Aluminium
Copper
Ceramics for electric insulation
- Low porosity -> leaks
- Brazing to metal -> leaks

For particular applications
Organic materials (e.g. as composite materials (carbon-fibers & epoxy), polymers to be used in small quantities

Synchrotron Radiation Induced Desorption

Radiated power (W)□ $P_{\square} = 88.6 \dfrac{E^{4}\, I}{\square}$ E, beam energy of electrons (GeV)

I, beam current (mA), $\square$, bending radius (m),

Critical energy of the spectrum (eV) $\square_{c} = 2.2 \cdot 10^{3} \dfrac{E^{3}}{\square}$

Photon flux (s^{-1}) $\square = 8.08 \cdot 10^{17}\, I\, E$

Linear photon flux (m^{-1} s^{-1}) $\dfrac{d\square}{ds} = 1.28 \cdot 10^{17} \dfrac{I\, E}{\square}$

Gas desorption occurs in two steps□ 1 -> photons -> produce photo-electrons

2-> photo-electrons -> excite molecules which subsequently will desorb thermally

Gas flow□ $Q = \square\,\square$

$Q = K\, \square\, I\, E + Q_{o}$ with Q_{o}, the thermal desorption rate and $\square$, molecular desorption yield (molecules per photon).

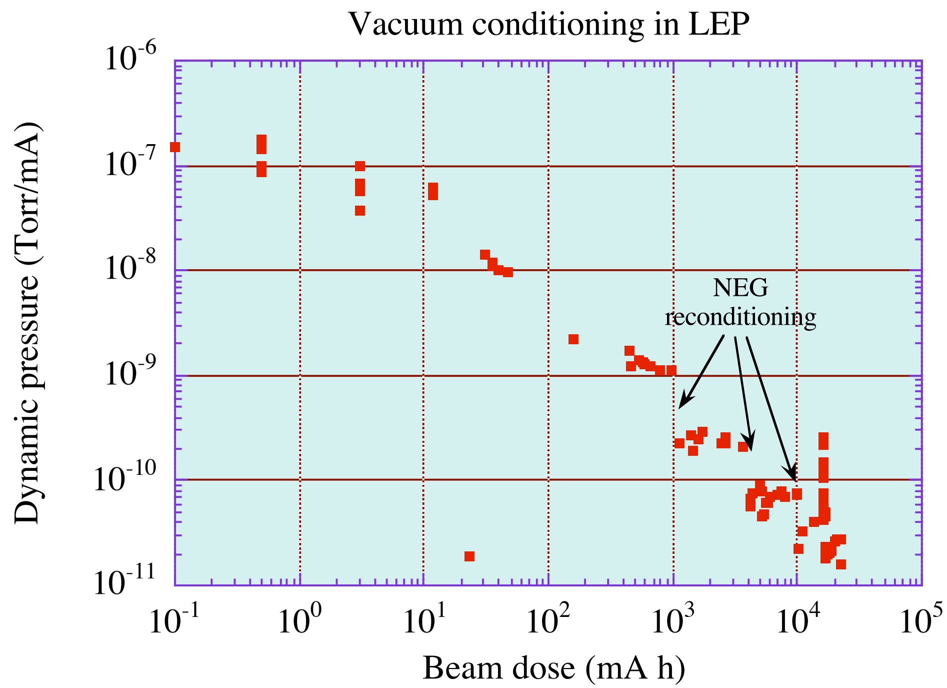
Dynamic pressure□ $P_{dyn} = \dfrac{Q}{S}$.

The dynamic pressure increases proportionally with the beam intensity : $\dfrac{\square P}{I}$ (Pa/mA).

'Beam cleaning' (scrubbing) of the vacuum system is a vital procedure.

Beam cleaning (scrubbing) of the LEP vacuum system

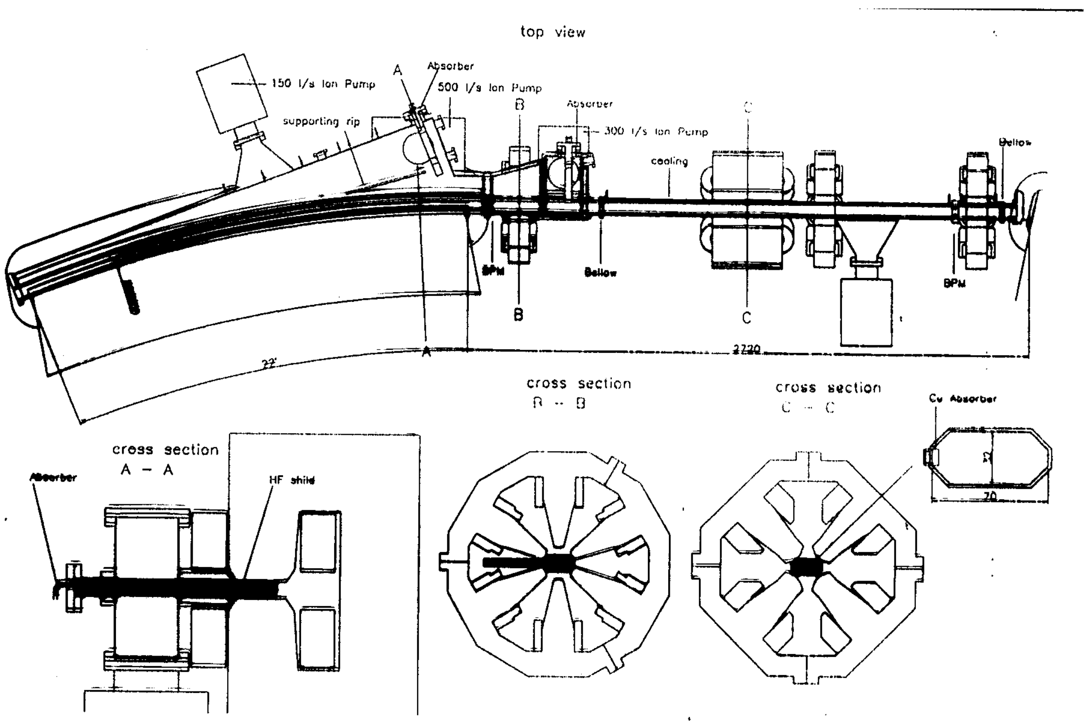
Dose scale may be given in terms of accumulated photons/m or more frequently in mAh.



Vacuum vessel of a synchrotron radiation light source

Bending magnet vessel with ‘ante chamber’ and light port.

Synchrotron radiation absorbers protect critical elements of the machine.



Water cooled absorber with integrated vacuum pumps

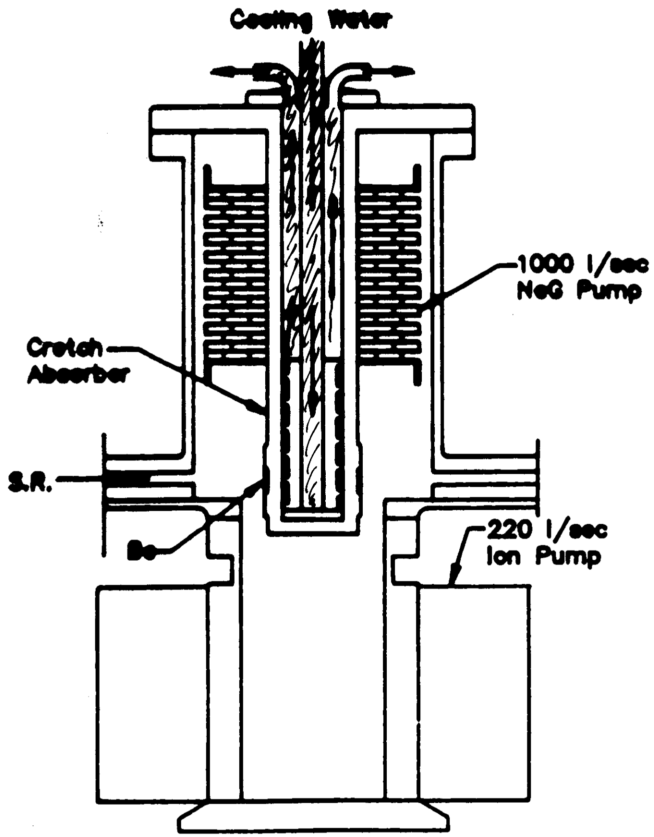
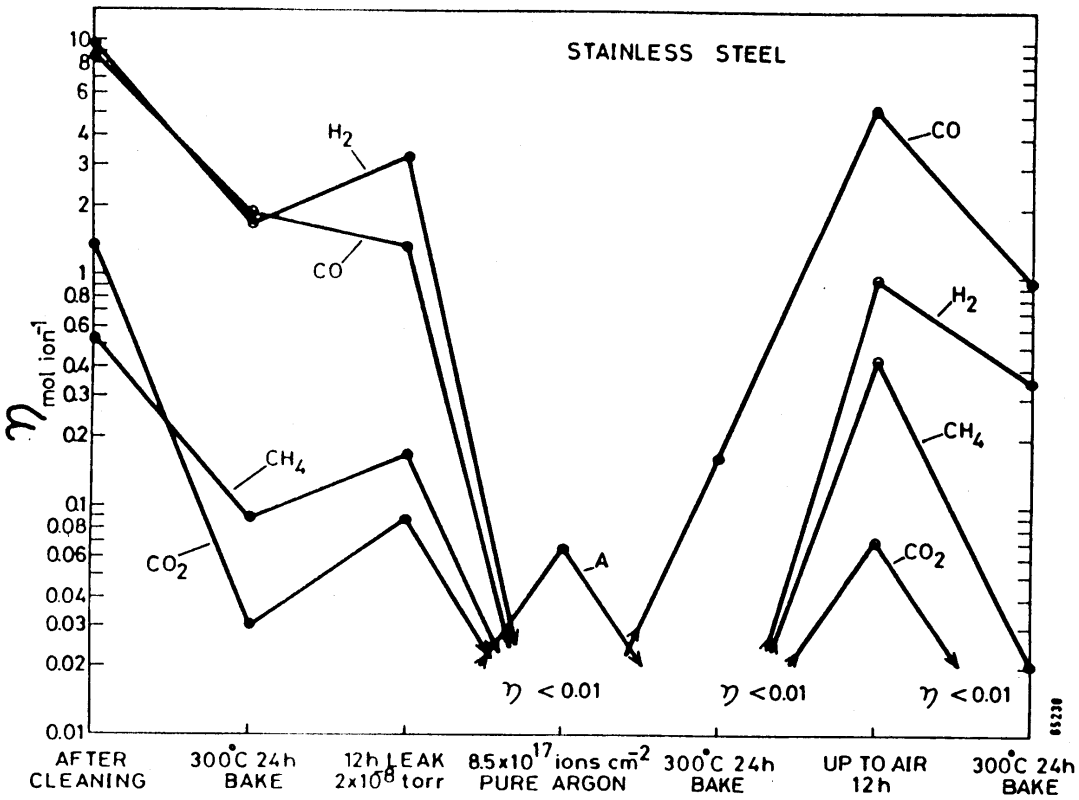


Fig. 5 Water cooled crotch absorber

Comparison of successive vacuum treatments

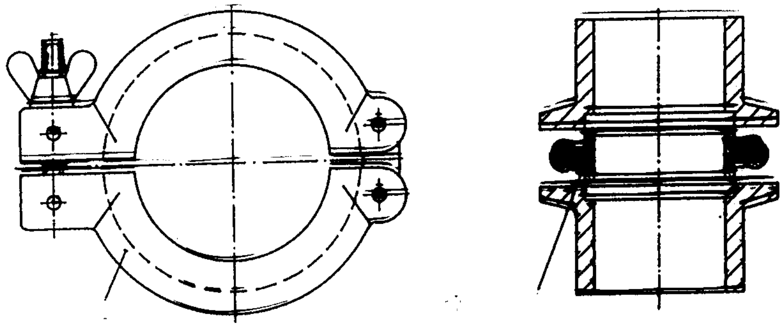
Effect of various surface treatments including exposure to atmospheric air on the ion stimulated desorption yield.

This result illustrates the importance to avoid exposure to ambient air to maintain a clean uhv system.

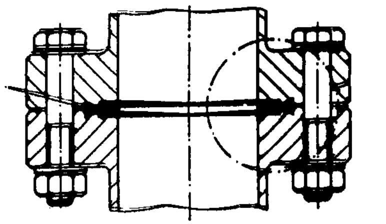


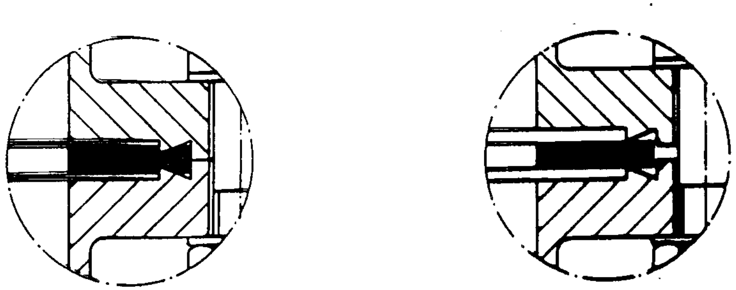
Flanges and gaskets for primary vacuum and for uhv applications

Flange with clamp and elastomer seal for
high vacuum systems



'ConFlat' flange for uhv systems
Copper gasket for 'all metal' vacuum system





Valves for high and ultrahigh vacuum

UHV valves use all metal construction (copper seals)

Manual valve with Viton seal for high vacuum applications (>10^{-4} Pa)

Manual Valves, Viton Main Seal