VACUUM LEAK EXERCISES

CAS VACUUM, 6-16 JUNE 2107



 A system at 20°C has to achieve 10⁻⁹ mbar after prolonged pumping with a turbo molecular pump (S_{EFF} = 300 Ls⁻¹, independent of the gas type). What is the maximum allowable leakage?

2.

- A diffusion pump vacuum system with a chamber of 0.75 m³ is isolated from its pumps. The pressure increases from 2·10⁻³ mbar to 5·10⁻¹ mbar in 10 minutes.
- A. What is the leakage rate, assuming no other gas source?
- B. After repairing a significant leak, the system could be evacuated to 5·10⁻⁵ mbar with the diffusion pump (S_{EFF} = 2000 Ls⁻¹). What leakage remains?



The vacuum vessel has a volume of 5 m³. An air leak of 1.05 E-6 mbarl/s is present.

Calculate the response time for 95% of the final signal on the leak detector when it is connected in position 1 with and without valve A open and the position 2 with and without valve B open.

For each case, what is the signal on the detector when the leak is pocketed with helium ?

Which of the 4 configurations is best for the leak test

 $S_{\text{LeakDetector at Inlet}} = 1 \text{ L S}^{-1}$



- A human hair is trapped across an O-ring on a vacuum system where the internal; pressure is 10⁻⁴ mbar and the external pressure is 10³ mbar. The temperature is 20°C. Leakage of air into the vacuum system is occurring:
- A. If the trapped hair is a leak that can be regarded as a uniform tube of 70 um diameter (approximate diameter of a human hair) and length of about 8mm with the above pressure the exit and entrance, respectively, what is the nature of the flow across the leak?
- B. Estimate the leakage (q_L)

GLOBAL HE LEAK DETECTION

global He - flu	ıx de fuite		
Reference leak flow	Q _{f.ref}	mbar l.s ⁻¹	
Signal of the reference leak	S _{f.ref}	-	
Signal of the leak	S _f	-	$Q_f = \frac{Q_{f.ref} \times (S_f - res)}{c} \times \frac{1}{c}$
Residual value	S _{res}	-	$S_{f.ref} - res$ $Conc_{He}$
He concentration	conc	%	
Leak rate	Q _f	mbar.l.s ⁻¹	
Global He – Sensik	ility of the t	test	$0 \cdot \cdot \times m_{\rm H} = 1$
Mini readable value	m _{li}	-	Sensibility = $\frac{Q_{f.ref} \times m_{li}}{C_{conc}} \times \frac{1}{C_{conc}}$
Sensibility of the tests	Sensib.	mbar.ls ⁻¹	$S_{f.ref} - res$ $Conc_{He}$

REFERENCE LEAK

Correction for the	reference leak		
Initial value of the reference leak	Q _{Fref}	mbarls ⁻¹	
Year of the leak	n		X , X , X
Correction for the aging	x	%/an	$Q_{Reff_{cor}} = (Q_{Reff} \times (1 - (\frac{100}{100}))^n)(1 \pm \frac{100}{100})^{\Delta T}$
Difference of temperature	ΔΤ	deg C	
Correction for the temperature	x	%/degC	
Corrected flux for the calibrated leak	Q _{Fref} cor	mbarls ⁻¹	

RESPONSE TIME FOR LEAK DETECTION

Response Time							
Volume	V	0	litre				
Effective Helium pumping speed	S _{eff}	0.00E+00	s ⁻¹				
Response time for 95% of signal	t _{0.95}	#DIV/0!	S				
Response time for lo	ong tube L>100	D					
Length	L	0	m				
Diameter	D	0	m				
Response time for 95% of signal	t _{0.95}	#DIV/0!	S				

$$t_{0.95} = 3 \times \frac{V}{Q_{eff}}$$

$$t_{0.95} = 3 \times 10^{-3} \times \frac{L^2}{D}$$

INTRODUCTION: AIR LEAK IN CASE OF NEG COATED CHAMBER



PROBLEMATICS

- The system is baked and no active pumping is installed
- The installation of a leak detector imply:
 - Connect a turbo molecular pumps on a valves: start the pump down
 - Install the bake out on the valves + transition +TMP in order to do not impact the NEG performance
 - Bake out at least over night
 - After 1 day we could start the leak detection of the vacuum sector

This approach is not convenient for the operation where a fast analysis is necessary and the beam downtime should be minimized

NEG PUMPING MECHANISM

<u>H_2:</u>

Diffuses into the getter bulk even at room temperature,
Small quantities of H₂ do not affect the pumping of other gases.

<u>CO & CO₂:</u>

- Molecules chemically absorbed on the getter surface
- No Diffusion in the bulk and affect the pumping speed of all the other gases,
- CO capacity $\approx 5.10^{14}$ molecules/cm²

<u>N_2</u>:

- No Diffusion in the bulk and the absorption takes place underneath the first monolayer of the surface,
- Six adsorption sites to pump a single N₂ molecule,
- N₂ capacity ≈ about 7 times lower than for CO
- Do not affect the pumping speed of CO

<u>O₂ & H₂O:</u>

• The capacity of NEG for O₂ and H₂O is estimated around 10 times larger than for CO

INTRODUCTION: LEAK IN CASE OF NEG COATED CHAMBERS



EXAMPLE OF A BA GAUGE





Ions are produced in the volume enclosed by the grid.The positive potential on the grid forms a barrier to the ions.

- They are eventually **collected at the central wire**.

THE BA GAUGE SENSITIVITY

The rate of ionization in the grid volume (I⁺/e) depends on:

- the number of molecules in the grid volume (gas density n)
- the ionization cross section for the specific gas at a specific electron energy (σ)
- the number of electrons traversing the grid per unit time (I⁻/e)
- the average path length of the electrons in the grid (L)
- the ion collection efficiency, for 100%:

S is called the gauge sensitivity
[S]=[Torr⁻¹]
It depends on:
-the gas nature and electron energy;
-the geometry and the electrostatic field;
-the absolute temperature.

$$I^{+} = \sigma \cdot L \cdot \frac{P}{k_{B}T} \cdot I^{-}$$
$$S = \frac{\sigma \cdot L}{k_{B}T}$$
$$I^{+} = S \cdot P \cdot I^{-}$$

THE B-A SENSITIVITY: IONIZATION CROSS SECTION



Fig. 3: Generated ions per centimetre electron path length per millibar at 20°C versus kinetic energy of incident electrons for various gases. From A. von Engel, *Ionized Gases*, AVS Classics Series.

The maximum of the cross section is obtained for electron energy in the range **50 to 200 eV**.

Energy variations in this range results in a limited variation of the cross section: less than a factor 2.

For lower energies the variation is much steeper

THE CONDUCTANCE

The quantity of gas which is flowing across a given pressure difference depends on the ease of flow, described by what we call CONDUCTANCE



$$Q = C(p_U - p_D)$$

THE CONDUCTANCE OF A BEAM PIPE

$$C = \frac{1}{6} \sqrt{\frac{2\pi kT}{m}} \frac{D^3}{L}; \quad C_{air, 20^\circ}[l/s] = 12.1 \frac{D[cm]^3}{L[cm]}$$

C_s = 15 l/s.m D = 5 cm

C_s = 121 l/s.m D = 10 cm

L [m]	C, air 20° [l/s]
1	15
5	3
10	1.5

L [m]	C, air 20° [l/s]
1	121
5	23
10	12.1



THE CONDUCTANCE VS TEMPERATURE AND GAS

The conductance depends:

Function of the temperature:





T[K]	4.2	77	150	300	500	600	1300
C [l/s]	20	88	122	100	224	245	361

$C \sim C$	29
$C_{gaz} \sim C_{air}$	M _{gaz}

Function of the molars mass:

Gaz	H ₂	He	CH ₄	H₂O	CO	air	02	Ar	CO ²
Μ	2	4	16	18	28	29	32	40	44

Gaz	H₂	He	CH ₄	H₂O	CO	air	0,	Ar	CO 2
C [l/s]	381	268	135	127	102	100	95	85	81

NOBLE GAS LEAK DETECTION



NEG LEAK DETECTION PROCEDURE

Preparation

- Start LabView pressure logging (1 second)
- Open Variable Leak valve slowly (~50x graduations), monitoring the pressure P₁ until ~1x10⁻⁹ mbar : record P₁ & P₂
 <u>Helium</u>
- Apply low flow helium gas to the VLV, monitor the pressure increase at P₂ and P₁
 - record P₁, P₂ & helium leak detector measurement
- Close VVR and start timer, accumulate for 300 seconds: record P₁ & P₂

<u>Argon</u>

- Apply low flow argon gas to the VLV, monitor the pressure increase at P_2 and P_1
 - record P₁ P₂ & helium leak detector measurement
- Close VVR and start timer : after 300s record P1 & P2





Difference between P1 and P2 during dynamic injection of gases:

	Pressure Helium	Pressure Argon	Effective Pumping Speed TMP Helium	Effective Pumping Speed TMP Argon
Pı	3.1E-9	1.5e-8	43	43
P2	7.5E-10	1.8e-9	11	4.8
Ratio	≈4.1	≈ 8.3	≈ 3.9	≈ 9

Effective pumping speed in the system is the main parameter Sensitivity of the gauges play an important role: Argon higher measured pressure





Difference between P1 and P2 during accumulation of gases:

	ΔP Helium	∆P Argon	
P1 = P2	1.5e-6	1.05e-8	
Time	5'45 `'	5′15″	
Volume [l]	3.3		
Q mabrl/s	≈1.5e-8	≈ 1.05e-9	

Effective leak rate is the main parameter Sensitivity of the gauges play a minor role