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Preliminary Vacuum Parameters
6 GeV Light Source

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The pressure level in an electron or positron accelerator or storage ring depends on the thermal gas desorption of the vacuum chamber walls, as well as on the photo desorption by synchrotron radiation. The desorbed gas affects the electron beam more than a positron beam so the electron beam is treated here from a conservative view. Photoelectrons produced on the walls by the photons of the synchrotron radiation liberate the gas molecules absorbed on the surface.

Through experiments at PETRA by Uwe Schneekloth[1], it was determined that the specific desorption rate determined for PETRA as a function of the operation dose can be generalized for all electron storage rings, considering the number of photoelectrons produced and the area of the inside chamber surface of the vacuum structure. Determination of the specific desorption rate can be done by the following equation.

$$\frac{dQ}{dt} = 1.55 \cdot 10^{-8} \cdot C \cdot I \left(\frac{C \cdot D}{F}\right)^{-0.63}$$

where $\frac{dQ}{dt}$ = desorption rate in mbar 1/s/m

I = beam current in mA

F = inside surface of vacuum chamber affected by the radiation in cm^2/m

C = photoelectron current in mA per meter and per mA beam current.

D = dosage mAh

For preliminary discussion, C, the photoelectron current in mA per meter and per mA beam current was assumed as being 1.2 mA. This is identical to that determined for PETRA and is assumed as being most representative of the photoelectron current in the 6 GeV Light Source.

In determining the desorption rate, only the surface of the pumping chamber is assumed as being affected by the radiation. This assumption is based on the synchrotron radiation being transferred through a narrow duct to absorbers in the pumping chamber. (See Figure 1)

However, it is probable that some of the gas desorbed by synchrotron radiation will back flow through the narrow duct into the beam chamber. This consideration plus the impedance characteristics of the duct will result in a pressure differential between the pumping chamber and the beam chamber. Furthermore the outgassing of the beam chamber itself becomes an additional factor. If Q is the backflow plus the outgassing load in mbar l/s/m, c is the conductance of the duct in liters/s/m and p_1 is the operating pressure (mbar) in the pumping duct, then,

$$p_2 = p_1 + \frac{Q}{c}$$

where p_2 is the pressure (mbar) in the beam chamber. This small but not insignificant pressure differential between beam chamber and pumping chamber is noted here but not included in the following considerations that pertain only to the pumping chamber.

Applying the assumptions into the above equation results in the curve for the 6 GeV light source plotted among the curves, as derived by Uwe Schneekloth, for PETRA, HERA, and LEP. (See Figure 2) For this comparison of specific desorption rate versus integral dose, the immediate areas featuring the utilization of the light beam crotch absorbers of the 6 GeV light source at extraction points is not included.

A primary pumping source for outgassing and desorption from the 6 GeV light source will be ST 101[2] or ST 107[2], a getter coated strip obtained by deposition of a non-evaporable getter material on to a non-magnetic (constantin) metal support as shown in Figure 1. The getter material forms thermally stable chemical compounds with the majority of the active gasses (O_2, N_2, CO, CO_2, and H_2O) while the absorption of the H_2 is thermally reversible, according to Sieverts law.[3] Another significant design parameter being considered for the 6 GeV light source will be the absorption of synchrotron radiation at defined places (crotches)[4,5]. In these areas, the desorption caused by the synchrotron radiation can be reduced ≈ 85% by installing high speed ion pumps. This will be discussed in later vacuum notes.

Pumping of various combinations of gasses with non-evaporable getter (NEG) strips has shown that pumping of CO and CO_2 is not affected by the presence of H_2. However, the pumping speed for H_2 is reduced by the presence of CO and/or CO_2 on the surface of the getter.[6] The percentage of CO and/or CO_2 determines the rate of decrease in pumping speed and establishes a point at which conditioning of the NEG is required. Conditioning[7] consists of raising the temperature of the NEG strip to 400° C for a few minutes and is different than activation which is carried out at 700° C for 45 minutes (ST 101, ST 107 requires 450° C for 45 minutes) and normally only after exposure to air. For PETRA, the gas composition was established as 70% H_2 and the rest mainly CO. With this composition, three conditionings were required up to 10 Ah to restore larger pumping speeds. Assuming similar gas composition in the 6 GeV light source, the points indicated on the curve (Figure 3) reflects probable conditioning requirements utilizing 1, 2, or 4 NEG strips, each per meter length.

The curve shown in Figure 3 results from calculation of the gas quantity by the following integration of the 6 GeV light source desorption rate with time[1].

$$\Delta Q = 1.51 \cdot 10^{-4} \cdot C^{0.37} \cdot F^{0.63} \cdot D^{0.37}$$

The NEG strip conditioning points shown in the Figure 3 curve are the No. 1 point at accumulated gas load of 0.21 Tl/m (0.28 mbar l/m), No. 2 point at gas load of 0.71 Tl/m (0.93 mbar l/m), and No. 3 point at gas load of 1.21 Tl/m (1.59 mbar l/m), all as optimum points from previous laboratory measurements.[8] The incremental difference in these gas loadings is 0.5 Tl/m. This value also agrees with the preferred gas load between conditioning points as found in tests on a chamber containing the NEG strip placed and tested in PETRA.[7]

The 6 GeV light source requires a vacuum in the low 10^{-9} Torr range when a beam is circulating. In order to be assured of a beam lifetime of at least 20 hours, the lifetime depends not only on the partial pressure of a given gas but also on its molecular weight and its radiation length. This is demonstrated by the following equation.[9]

$$\tau = 2.82 \times 10^{-8} \frac{X_o}{MP}$$

τ = lifetime in hours

X_o = radiation length in g/cm^2; 62.8 for H_2; 37.9 for CO; 36.6 for CO_2 and 47.0 for CH_4

M = molecular weight; 2 for H_2; 28 for CO; 44 for CO_2; 16 for CH_4

P = pressure in mbar

τ_x = relative lifetime = τ gas/τ_{co}

Figure 4 is a family of curves reflecting the lifetime in hours of hydrogen gas relative to CO for different operating pressures. Indicated on these curves are lifetimes when the composition of the gas is (30% H_2, 20% CO) and (70% H_2, 30% CO)

The lifetime of each component is calculated using its partial pressure in the above equation. For instance, in the operating pressure of 1 x 10^{-8} mbar and 80% H_2, the partial pressure of the H_2 is 8 x 10^{-9} mbar and its lifetime is 110.7 hours. Similarly, the lifetime of the CO at 2 x 10^{-9} mbar is 19.1 hour. The effective lifetime τ_T is found by the following for this mixture:

$$\frac{1}{\tau_T} = \frac{1}{\tau_{H_2}} + \frac{1}{\tau_{co}} \text{ or } \tau_T = 16.3 \text{ hours}$$

This method can be used for the lifetime of many gas mixtures such as 70% H_2, 20% CO, 8% CO_2, and 2% CH_4 which for 5 x 10^{-9} mbar operating pressure results in approximately 21 hours. It is interesting to note that from Figure 4 a mixture of 65.5% H_2 and 34.5% CO will give the same 21 hours lifetime at this same pressure.

The vacuum chambers will be chemically cleaned before installation, then baked for 24 hours, under vacuum, at 150° C after installation. Baking will be done by heating the NEG strips[10] up to a predetermined temperature. Presuming prior cleaning and baking, Figure 5 reflects possible pumpdown scenarios for various pumping combinations.

The pressure for each dose rate and NEG strip pumping speed is from the gas load divided by the pumping speed, in this case per meter of length. For instance, at 100 mAh, the specific desorption rate from Figure 2 is 1.69 x 10^{-7} mbar l/s/m/mA or 16.9 x 10^{-6} mbar l/s/m desorption rate. Dividing this by the pumping rate of 100 l/s/m results in .169 x 10^{-6} mbar or 1.69 x 10^{-7} mbar pressure as shown on Figure 5. Pumping speeds of the NEG strips of course are not constant and in fact decrease as their surfaces become coated with CO and/or CO_2. The speeds indicated are average speeds one might expect between conditioning periods.

Measurements show that approximately 1% of the degassing products is methane. Since NEG does not pump methane nor Argon, small (30 l/s) ion pumps will be mounted approximately every 20 or 30 meters to pump the methane and any Argon drawn into the chamber through minute leaks.

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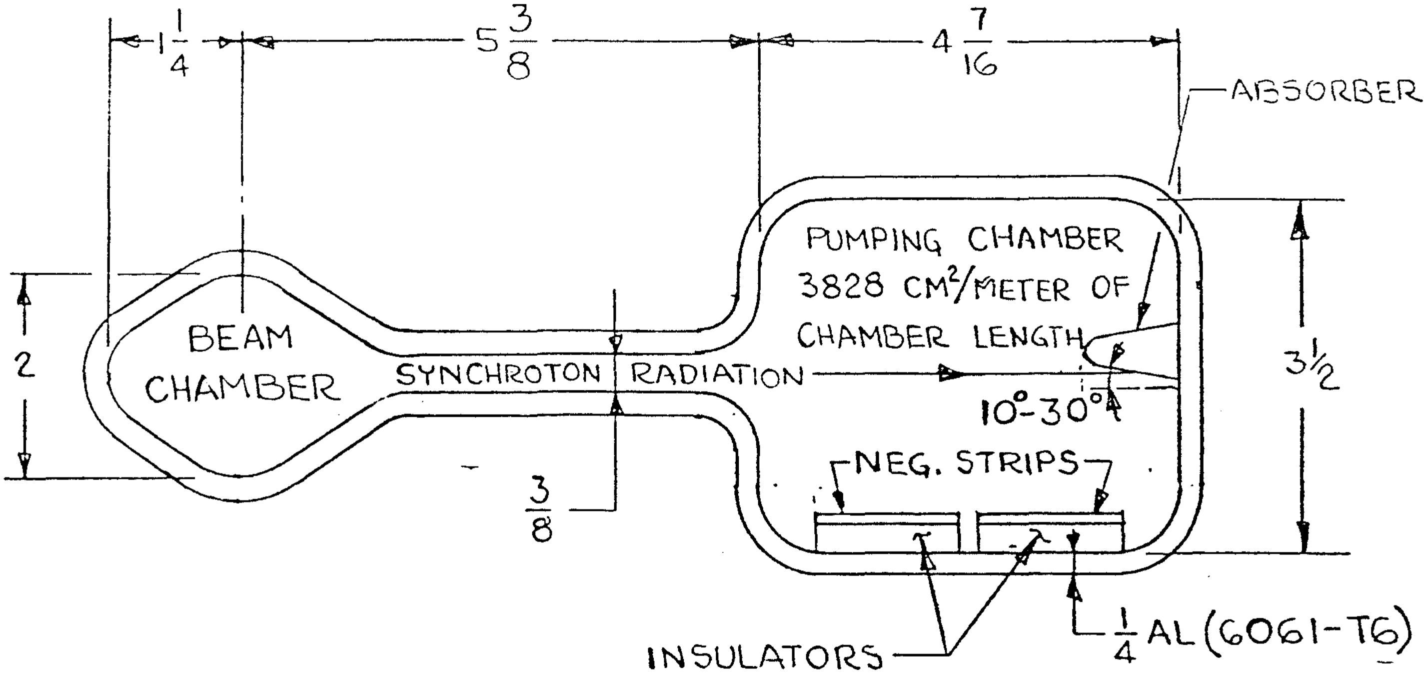


FIG. 1
6 GeV VACUUM CHAMBER
(COOLING PASSAGES TO BE
ADDED LATER)

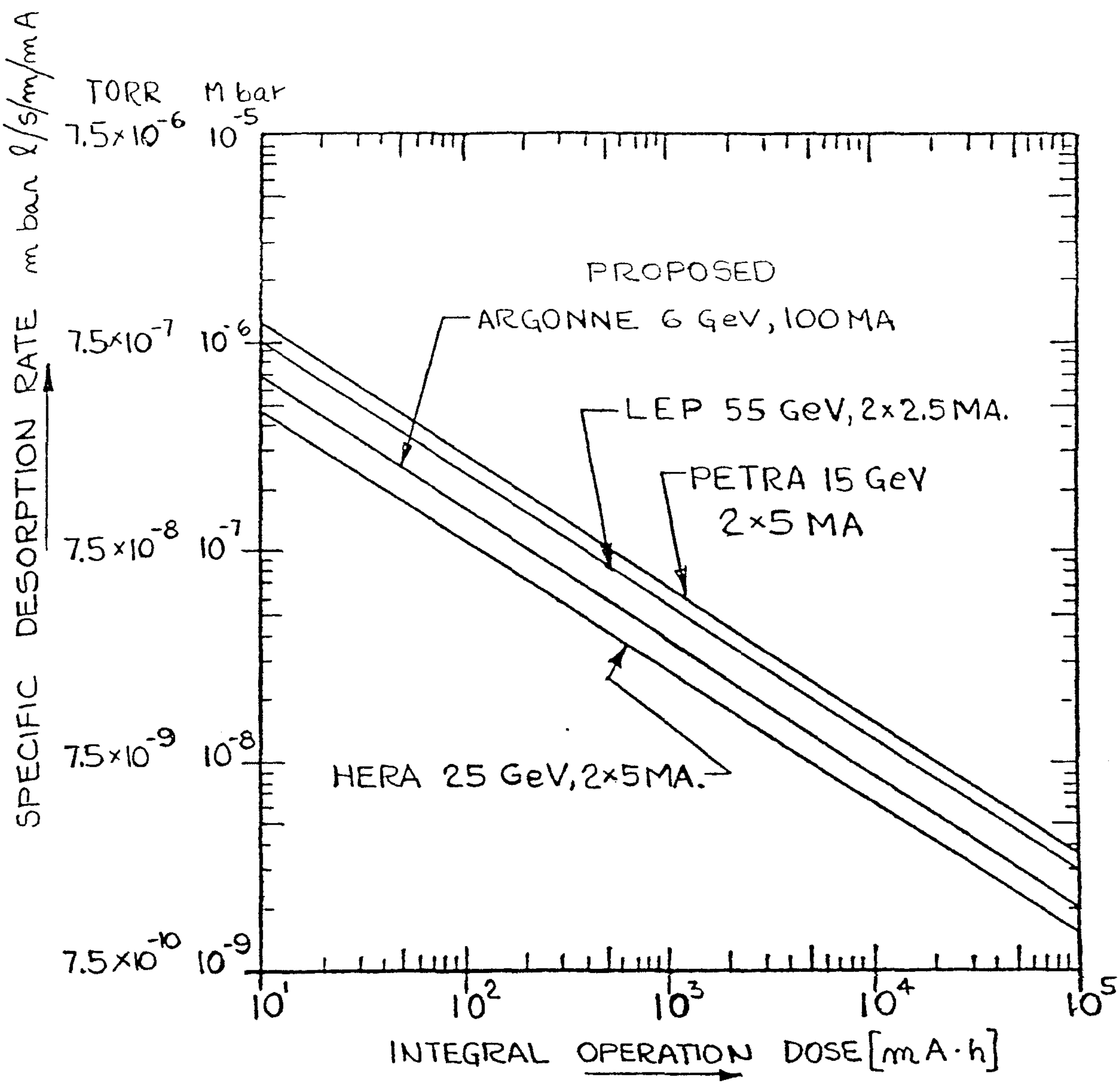
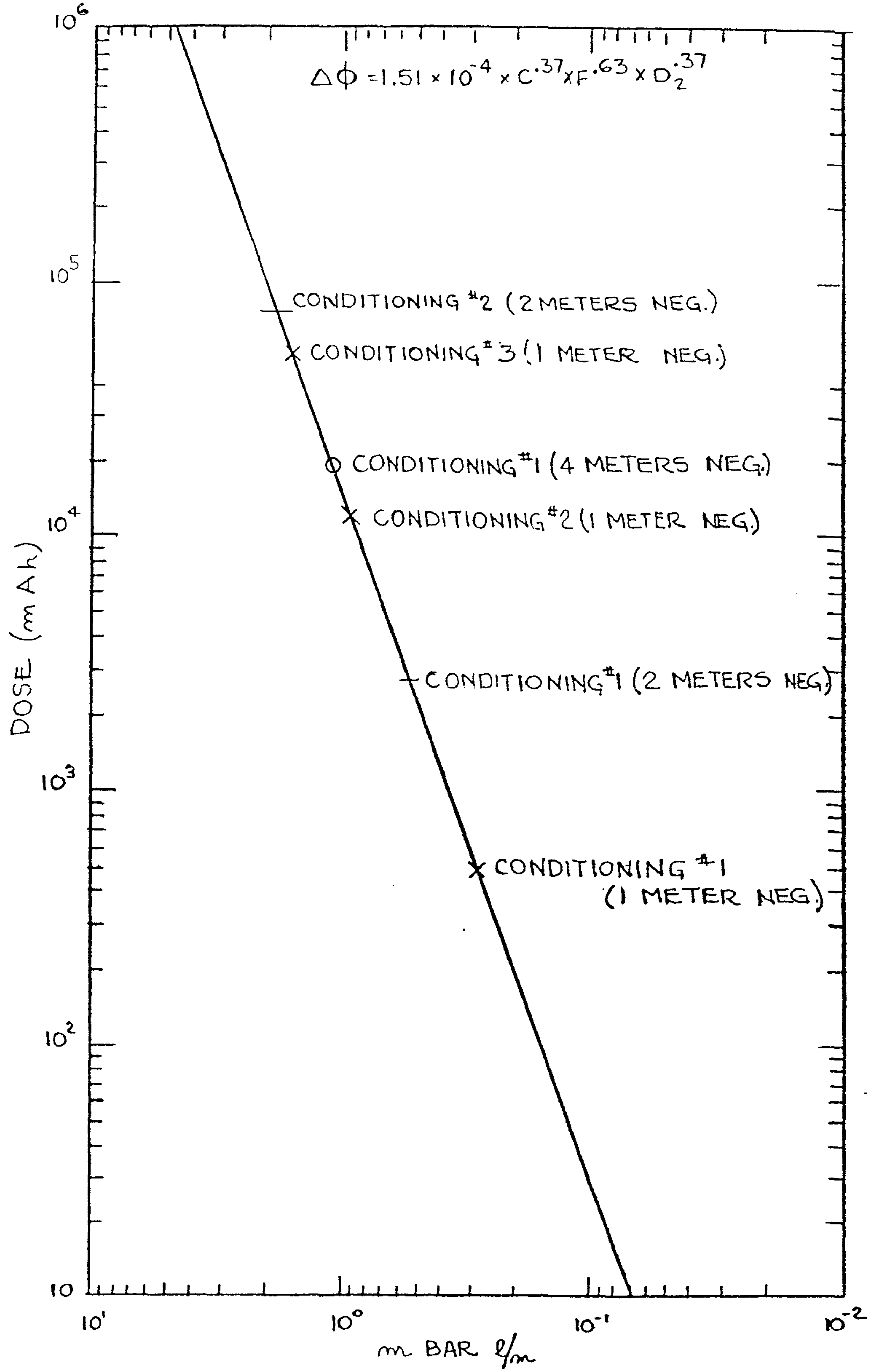


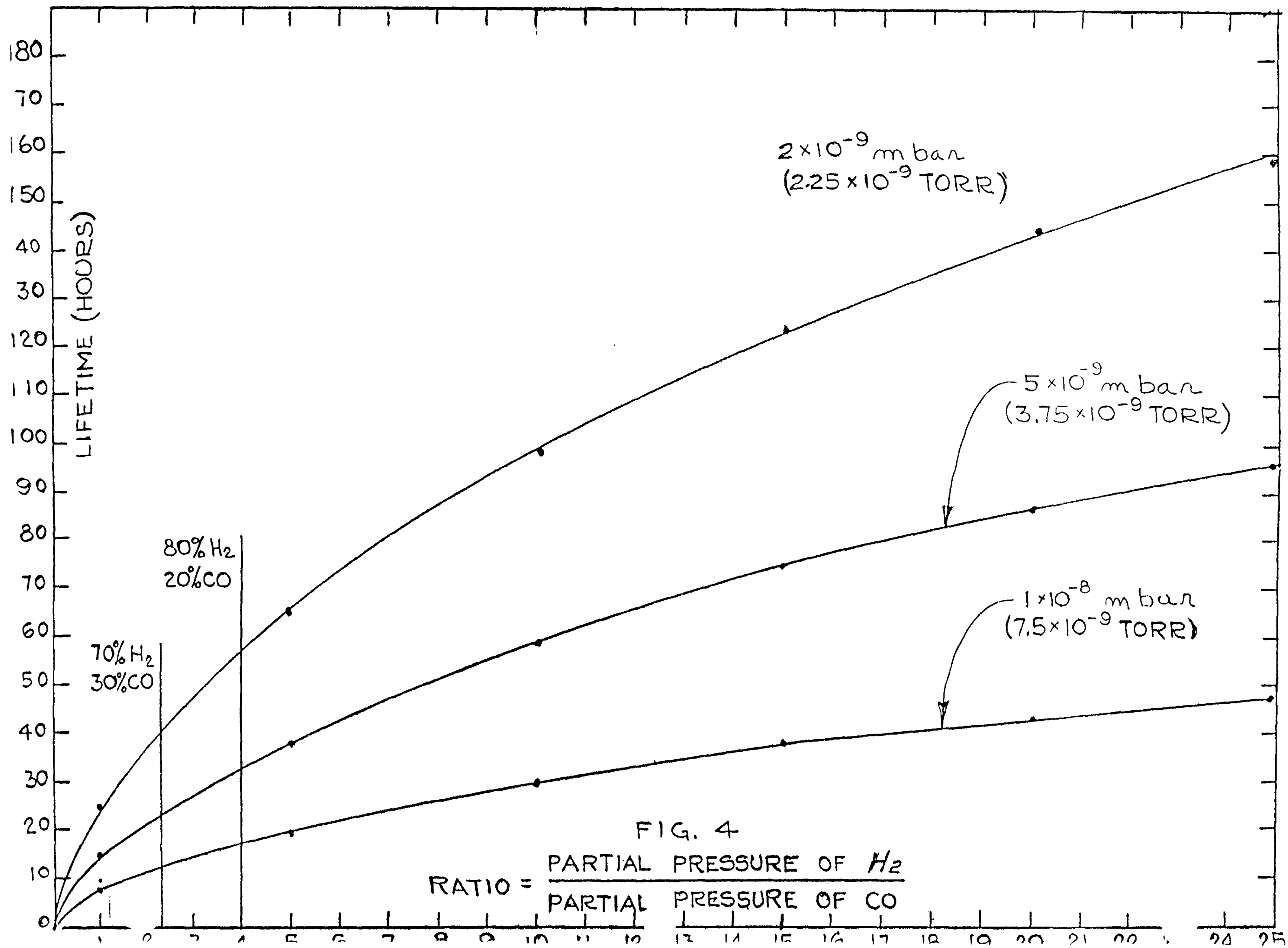
FIG. 2

SYNCHROTRON RADIATION DESORPTION AS A FUNCTION OF THE INTEGRAL OPERATION DOSE (BEAM CURRENT × OPERATION TIME) FOR PETRA, HERA, LEP AND 6 GeV LIGHT SOURCE.



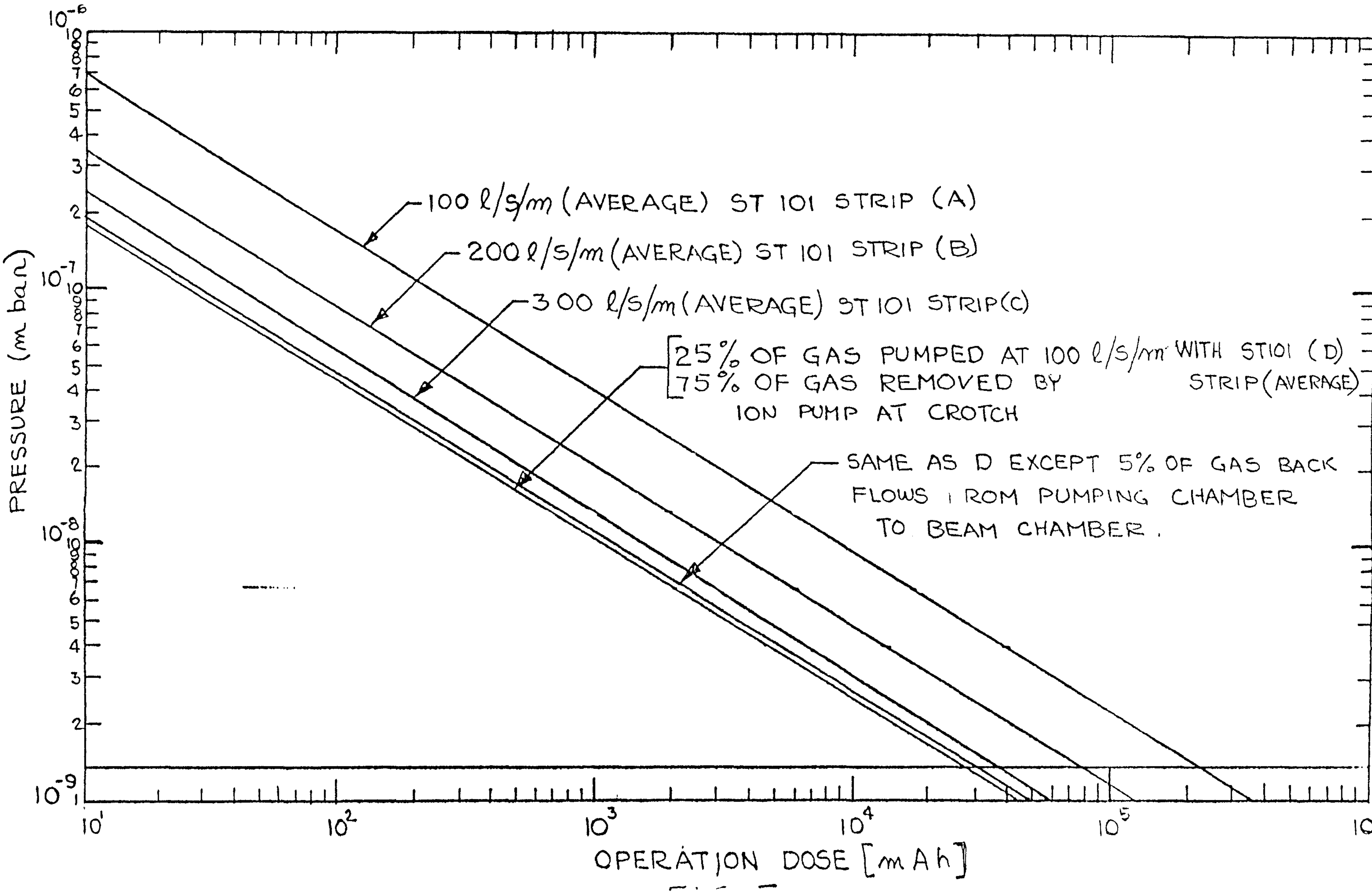
$\Delta\Phi = 1.51 \times 10^{-4} \times C^{.37} \times F^{.63} \times D_2^{.37}$
CONDITIONING #2 (2 METERS NEG.)
CONDITIONING #3 (1 METER NEG.)
CONDITIONING #1 (4 METERS NEG.)
CONDITIONING #2 (1 METER NEG.)
CONDITIONING #1 (2 METERS NEG.)
CONDITIONING #1 (1 METER NEG.)
DOSE (mAh)
10^6
10^5
10^4
10^3
10^2
10
10^1
10^0
10^{-1}
10^{-2}
m BAR l/m

FIG. 3



LIFETIME (HOURS)
0
10
20
30
40
50
60
70
80
90
100
110
120
30
40
150
160
70
180
2×10^{-9} m bar
(2.25×10^{-9} TORR)
5×10^{-9} m bar
(3.75×10^{-9} TORR)
1×10^{-8} m bar
(7.5×10^{-9} TORR)
80% H_2
20% CO
70% H_2
30% CO
$\text{RATIO} = \frac{\text{PARTIAL PRESSURE OF } H_2}{\text{PARTIAL PRESSURE OF CO}}$

FIG. 4



100 l/s/m (AVERAGE) ST 101 STRIP (A)
200 l/s/m (AVERAGE) ST 101 STRIP (B)
300 l/s/m (AVERAGE) ST 101 STRIP (C)
25% OF GAS PUMPED AT 100 l/s/m WITH ST101 STRIP (AVERAGE) (D)
75% OF GAS REMOVED BY ION PUMP AT CROTCH
SAME AS D EXCEPT 5% OF GAS BACK FLOWS FROM PUMPING CHAMBER TO BEAM CHAMBER.
PRESSURE (m bar)
OPERATION DOSE [mAh]

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