Vacuum Considerations for an SSC Beam Tube with a 20 K Liner

David Bintinger
SSC Central Design Group
c/o Lawrence Berkeley Laboratory
Berkeley, California 94720

June 1988

If the beam tube of the SSC has a 20 K liner to intercept the heat of the synchrotron radiation, refrigeration requirements for the SSC will be significantly reduced. Furthermore the refrigerator requirements will then be largely independent of increases in sychrotron radiation due to increasing either proton energy or beam current.

From the vacuum point of view there are advantages and disadvantages in having a 20 K liner in the beam tube. The disadvantage is that the 20 K temperature of the liner will no longer cryopump H_2, the gas that will have the greatest effect on the luminosity lifetime. Thus holes will have to be placed in the liner to allow the H_2 to be pumped by the 4 K beam tube walls. The advantage of the liner is that it will shield the cryopumped H_2 on beam tube walls from synchrotron radiation and thus perhaps avoid problems of the H_2 being redesorbed by sychrotron radiation. The main questions to be addressed by this note are what fraction of the liner surface must be hole area to maintain a tolerable pressure of H_2 and other gases, and what effect will the liner have on the H_2 pressure rise that occurs with accumulating photon dose in a beam tube with no liner. The question of how the placement of the holes in the liner will affect RF impedance will not be addressed.

The fraction of the liner surface that should be open to beam tube walls can be estimated from the experimental data of the NSLS and SRC photodesorption experiments. Of the gases photodesorbed, only H_2 will be of concern here as the other two gases, CO and CO_2, have low enough pressures so as to not significantly affect luminosity lifetime. Furthermore, CO and CO_2 would be cryopumped by the 20 K liner.

The NSLS photodesorption experiment predicts an <u>initial</u> room-temperature-equivalent pressure in the SSC beam tube of 3×10^{-9} Torr for a beam current of 70 mA. This pressure corresponds to a luminosity lifetime of 430 hours. If we assume that only a fraction of the beam tube walls are cryopumping, then the pressure in the beam tube will increase in inverse proportion to that fraction. A liner with holes opening to the 4 K beam tube walls approximates this situation. Thus if 10% of the liner is open, the initial pressure will increase by a factor of 10 and the initial luminosity lifetime will decrease to 43 hours. This lifetime is barely tolerable. The pumping speed of the holes will be greater than a cryopumping disk of the same area due to trapping of some of the molecules between the liner and beam tube wall until they stick. Simple Monte Carlo calculations show that this enhancement of pumping speed can be as much as a factor of three, indicating that initial luminosity lifetime could be as much as 120 hours for 10% hole area. The photodesorption measurements at SRC predict an initial SSC beam tube pressure a factor of three less than the NSLS measurement. Thus the SRC measurement would indicate that for initial pressures approximately 3% of liner surface being hole area would be satisfactory.

The above estimates are for initial pressures and lifetimes at a current of 70 mA in the SSC beam tube. The photodesorption experiment at NSLS showed that the H_2 pressure will rise with accumulating photon dose in a beam tube with no liner. This rise most probably comes from cryopumped H_2 on beam tube walls being redesorbed by the action of either synchrotron radiation, photoelectrons, or desorbed molecules impinging on tube walls. If the agents of re-desorption are mainly synchrotron radiation and photoelectrons, then H_2 cryopumped behind a liner will be safe from redesorption and there will be little or no pressure rise with accumulating photon dose. However, if desorbed molecules cause redesorption, then a liner will provide no security for cryopumped H_2. In this latter case the pressure in an SSC beam tube with liner will rise with accumulating photon dose as for a beam tube with no liner.

Assuming that molecules are the agents of H_2 redesorption, then the pressure after significant photon dose with a liner can be estimated from the case without a liner in the following manner. As photon dose increases, the H_2 pressure rises with time slowly enough so that the system within the beam tube can be considered at equilibrium on the scale of time (~ 1 ms) that it takes an H_2 molecule to stick to a cold wall. As many molecules, then, as are photodesorbed per second will enter the volume between liner and cold tube walls through the holes in the liner to be cryopumped by the cold walls. Thus the volume between liner and beam tube walls mimics the beam tube volume in the case of no liner, and the pressure rise in this space with accumulated photon dose should be similar to the pressure rise in the beam tube without liner. The pressure in the volume enclosed by the liner will then be a sum of the pressure created by the photodesorbed molecules that are being pumped through holes in the liner and the pressure created between liner and tube walls by the action of impinging molecules desorbing cryopumped H_2 molecules. Measurements by R. Stulen at Sandia National Laboratory in Livermore show that the H_2 sticking coefficient increases and then plateaus as H_2 coverage increases from zero to one monolayer. This then implies that the pressure created by the photodesorbed molecules will at least decrease with η (the photodesorption efficiency per photon) as photon dose accumulates. Since this pressure is initially ~ 10^{-8} Torr for ~ 10% hole area and the pressure rise with accumulated dose as measured at NSLS is ~ 3×10^{-8} Torr, the resulting pressure at significant photon doses can be of order 5×10^{-8} Torr room-temperature-equivalent.

This is somewhat worse than the case of no liner, but not significantly so. If the SSC with a liner is turned on with design 70 mA then after a few days the bore will have to be warmed to remove cryopumped H_2. This is as in the case with no liner. If, as will probably be the case, the SSC is turned on with a few mA and in the first months of operations the bore temperature is cycled for maintenance or modification of cryogenics, then the temperature cycling at full design current may be very (~ months) infrequent and may not be necessary at all.

In summary, with 5 to 10% of a liner being hole area, the initial (accumulated photon dose < 10^{20} photons/meter) H_2 pressure with a liner will be approximately a factor of five worse than with no liner. With continued operation (accumulated photon dose > 10^{20}

photons/meter) the H_2 pressure with a liner will depend on whether synchrotron radiation and photoelectrons or neutral molecules are the agents of H_2 redesorption. In the former case the H_2 pressure will decline with accumulated dose until the pressure dictated by the isotherm of H_2 at 4 K is reached. In the latter case, where H_2 is redesorbed by neutral molecules, the difference in H_2 pressures for the beam tubes with and without a liner will not be significant as in both cases the H_2 pressures will depend on temperature cycling the beam tube a few times to remove cryopumped H_2.