CONCEPT AND COST ESTIMATE FOR A NEG - PUMPED BEAM LINE

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Recent advances in the field of superconductivity bring forward the possibility of SSC magnets operating at temperatures near 77 K versus the 4.4 K of the present design.

The current beam tube vacuum system depends on the pumping action of beam tube walls at 4.4 K to maintain necessary vacuum. Beam tube walls at 77 K would have little pumping action on H_2, the main component of residual and photodesorbed gases. The pumping action of 77 K beam tube walls on CO, the second most copious gas, is also questionable. Thus if the SSC is to operate at liquid nitrogen temperatures a new method of beam tube vacuum pumping is necessary.

That this pumping will have to be distributed pumping can be inferred from the amount of H_2 photodesorbed by synchrotron light and the conductance of the current beam tube. The formula for the average pressure, <P>, in a tube pumped at intervals of L meters is

$$\langle P \rangle = P_0 + QL\,(S^{-1} + (12C)^{-1}),$$

where P_0 is the pressure at the pumps,
Q is the rate of H_2 desorption per meter,
S is the speed of the pumps,
and C is the conductance of the tube of length L.

We may consider P_0 negligible and S infinite and reduce the above to

$$\langle P \rangle = QL/12C.$$

Photodesorption measurements give Q as 2×10^{-6} Torr•ℓ/s/m for H_2 when the SSC has 70 mA of beam at 20 TeV. The conductance, C, for H_2 at 77 K is given by 1.9 R^3/L ℓ/s where R is the radius of the beam tube in centimeters. Putting the numbers in we have:

$$<P> = 8.8 \times 10^{-8} L^2/R^3 \text{ Torr.}$$

For L = 100 m (a pump every lattice half cell) and R = 1.65 cm (the present radius), we obtain $<P> = 2 \times 10^{-4}$ Torr. Collider operations are impossible at this pressure. In order to achieve a tolerable H_2 partial pressure of 2×10^{-8} Torr, corresponding to a luminosity lifetime of 60 hours, would require pumps every meter, i.e. distributed pumping. The fact that the speed of the pumps has been taken to be infinite and that other gases have not been considered will make matters worse.

Distributed pumping by sputter ion pumps using the magnetic field of the dipoles, as is done in various electron-positron storage rings, is not feasible in the SSC due to the expense of increasing the field volume to accommodate ion pumps. A pumping technique using non-evaporable getter, NEG, in place of sputter ion pumps has been chosen for LEP because of the low magnetic field value in LEP dipoles. NEG consists of a gettering material mounted on metal strips of high electrical resistance. These strips can be made in any width and length and are approximately 0.4 mm thick. The strips take little space themselves; however, they must be electrically insulated from the beam tube as a current is passed through he backing strip to heat the gettering material to activate and recondition it.

A concept for beam tube pumping of a 77 K SSC using NEG is shown in Fig. 1. The scheme shown consists of a beam tube within a beam tube. The inner beam tube is smooth and copper plated for microwave impedance purposes with holes for pumping. The exact placement of the holes must done with some care to preserve good microwave properties. The NEG strips are placed between the inner and outer tubes. The inner tube is oval shaped to give the greatest aperture in the horizontal dimension and to allow use of less critical vertical aperture to place the NEG strips. The inner tube also shields the NEG from synchrotron light, although this may not be a critical concern.

The amount of NEG required to maintain an H_2 pressure of 10^{-8} Torr for 70 MA of SSC beam can be calculated from the measured photodesorption rate of H_2 and the pumping speed of NEG. Taking for the H_2 photodesorption rate the Q of 2×10^{-6} Torr•ℓ/s/m given in the previous calculation, a pumping speed per meter of 2×10^2 ℓ/s is required to maintain a pressure of 10^{-8} Torr. Saes Getters ST707 NEG has a liquid nitrogen temperature H_2 pumping speed of ~0.5 $\ell/s/cm^2$ for H_2. Thus, 400 cm^2 of NEG is required per meter of beam tube. This area can be provided by two 1 cm wide strips of NEG coated on both sides. The pumping speed quoted above is for newly activated NEG. After absorbing 12×10^{-2} Torr•ℓ/cm^2 this speed decreases to 0.15 $\ell/s/cm^2$. However the rate of H_2 photodesorption also decreases in an almost parallel fashion as accumulated synchrotron light dose increases. Hence the two decreasing effects offset each other to maintain a nearly constant H_2 pressure. The total H_2 capacity of NEG is such that a year of continuous operation at 70 mA will not saturate it.

Of the other gases that are photodesorbed only CO presents a problem. It is photodesorbed at a rate that is one third the H_2 rate; however at the same partial pressure it causes a beam lifetime due to nuclear scattering one sixth that of H_2. Also the NEG pumping rate is ~0.4 that of H_2 at liquid nitrogen temperature. Combining the above factors means that CO will have five times the effect on beam lifetime that H_2 does. The luminosity lifetime for H_2 at 10^{-8} Torr is 130 hours. The luminosity lifetime for CO would then be 26 hours. This short lifetime is unacceptable. In order to lower the CO pressure, the amount of NEG surface area per meter of beam tube can be increased above that required for H_2. Figure 1 shows twice the area required for H_2 or two 2 cm wide strips of NEG coated on both sides. This gives a barely acceptable luminosity lifetime due to CO of 52 hours. Developmental work is necessary.

One must also consider the total area of holes necessary in the inner beam tube to not restrict the pumping ability of the NEG. For CO, which needs the largest pumping aperture, an open area of 27 cm^2 is required per meter of beam tube. Care will have to be given to the placement of holes both from the point of view of structural strength and microwave impedance properties.

The NEG must be heated to activate and recondition it. Figure 1 shows electrical insulators supporting the NEG. The insulators are installed one every 2.5 cm to insure that no shorts develop as the NEG expands during heating. The amount of expansion that will occur over the length of one dipole magnet in heating NEG ST707 to 450 C is 11 cm. This expansion must be taken up by spring loading the NEG upon installation. If the NEG has a sight curvature transverse to its length (similar to a venetian blind slat) it will be less prone to bending and shorting out. The amount of power that will be required for one 17 m magnet to active the NEG is approximately 13 kilowatts at 130 volts. What the activation temperature of 450 C will do to magnet structure is an open question at this time.

An estimate of the cost difference between the CDR design and this design is given in Table I. The biggest cost increase comes, of course, from the increase in magnet bore. Table II has a detailed breakdown of the cost of the pumping system in a WBS format.

In summary we have conceptually designed a vacuum system for a liquid nitrogen temperature SSC using NEG as the pumping element. A new vacuum pumping system in necessitated by the loss of beam tube walls at 4.4 K which provided the vacuum pumping for the liquid helium temperature SSC. NEG will work for H_2 desorbed gas but only marginally for CO. Either more research is necessary to produce a NEG that will pump CO more effectively or additional space will have to be provided in the beam tube to accommodate more NEG. All other gases produce negligible effect on the luminosity lifetime. The cost of the design shown in Fig. 1 will add $156M to the CDR cost of the SSC, due mainly to increased magnet bore.

Table I

Outline of Cost Differentials for NEG-Pumped Beam Line

Cost Differential for 5 cm beam tube	$140.0 M
Savings Associated with Larger Magnet Size	(15.0)
Cost Differential for lined beam tube with pump	
Beam tube with getter pumping 10,000 at $2909*	29.1
Beam tube without pumping, 10,000 at $794**	(7.9)
Additional Costs for installation and support equipment	5.0
	$151.2 M
Research, Development and Testing Costs	5.0 M
Total Cost Differential	**$156.2 M**

*See Attached Detailed Listing
**WBS .1.2.1.2.1.1.1 CDR

SSC-N-326

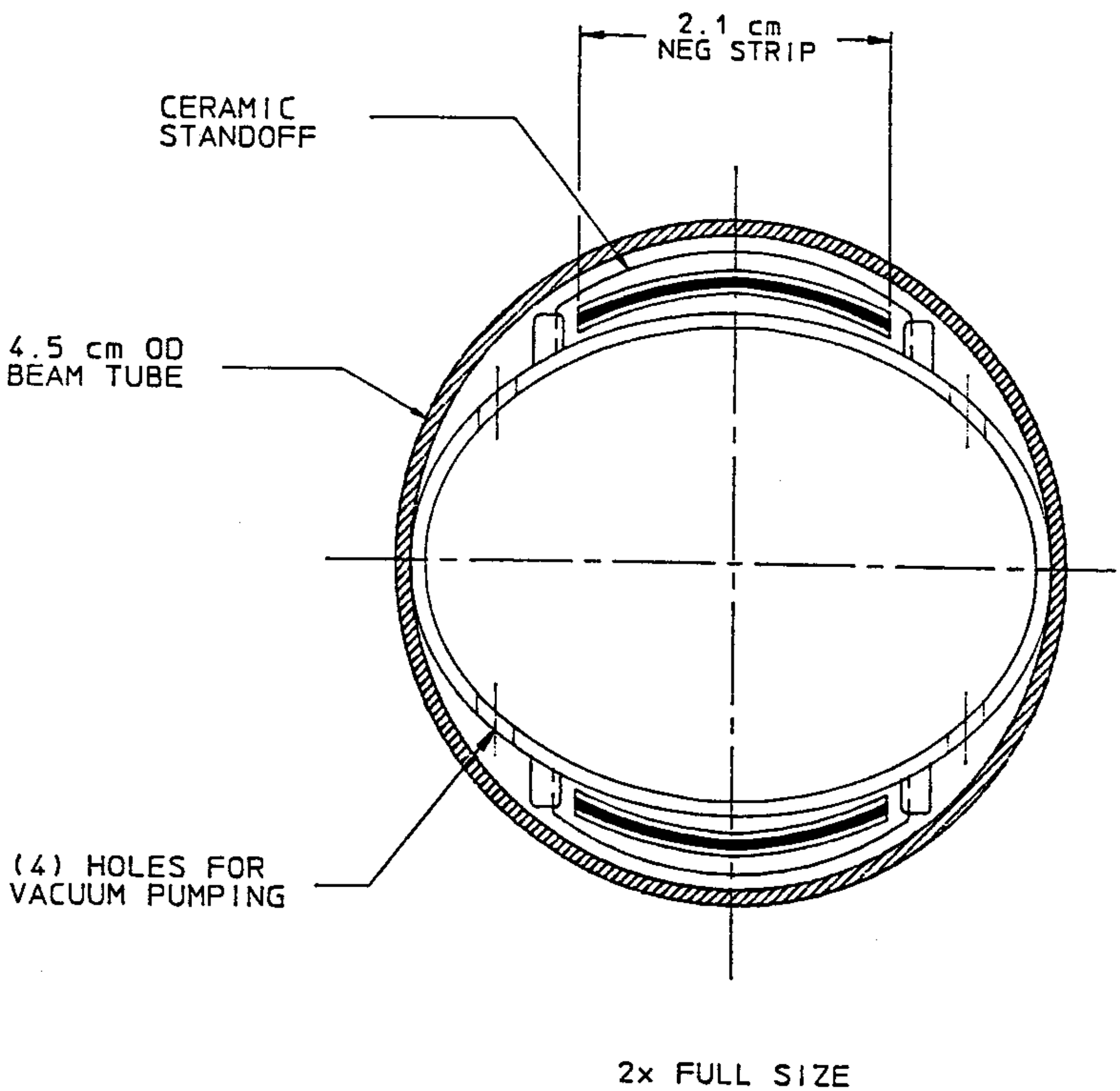
Cost Estimate Detail Listing
Beam Tube Assembly with NEG Pumping

.1.2.1.2.1.1.1 Dipole, Beam Tube with Liner and Getter Pump

		Material Costs					Labor Costs			
Item Nbr.	Item Description	Unit Meas	Nbr. Units	Unit Cost	Cost Basis	Material Total	Total Hour	Craft Code	Labor Rate	Labor Total
.1	Cold Bore Tube	EA	1	557.00	EU	557.00	0	-	-	-
.2	Liner with Holes	EA	1	600.00	EU	600.00	0	-	-	-
.3	Copper Plating	EA	1	300.00	EU	300.00	0	-	-	-
.4	Plating Labor						8	T1	22.00	164.00
.5	Plating Inspection						0.5	T2	33.00	16.50
.6	Ceramic Supports	EA	720	0.10	EU	72.00				
.7	Inst. of Supports	EA	720	.25	EU	180.00				
.8	Getter Material	m	66	8.00	CP*	528.00				
.9	Assembly						4	T1	22.00	88.00
.10	Inspection						0.5	T2	33.00	16.50
.11	Feed-Thrus	EA	2	100.00	EU	200.00				
.12	Clamp, Top	EA	1	29.00	VQ	29.00	1	S1	38.00	38.00
.13	Clamp, Bot.	EA	1	14.00	VQ	19.00	1	S1	38.00	38.00
.14	Flange	EA	2	14.00	EU	28.00	0.6	T1	22.00	13.20
.15	Other Labor						1	T1	22.00	22.00
						2513.00				396.20

<u>Brief Notes / Technical Description:</u>

Beam Tube Assembly for one dipole magnet incorporating distributed getter pumping.
*Saes Getters USA, Inc. Type NEG ST-707: 8 mm wide tape in 10,000 m quantity



CONCEPT FOR
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Fig. 1