OVERVIEW OF AN 80 K LINER DESIGN FOR SYNCHROTRON LIGHT INTERCEPTION IN SSCL COLLIDER

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Abstract

The paper reports the efforts that develop a viable design for an SSC 80K Synchrotron Radiation Liner System. The liner is one method under consideration to minimize the presence of photodesorbed gases in the particle beam line vacuum in order to assure an acceptable, operational availability of the SSC Collider. Also the 80K liner is aiming at improving the Collider cryogenic thermal efficiency which would allow a potential luminosity upgrade. The trade studies, engineering analyses, concept evaluation and detailed design are introduced. This paper also briefly discusses the preliminary consideration of lower temperature liners.

I. INTRODUCTION

The Superconducting Super Collider (SSCL) is the first proton superconducting accelerator designed to operate at 20 TeV (each beam) and beam current of 72 mA in which synchrotron radiation is a significant design factor. The Collider will produce a synchrotron power of 0.14 W/m and 18 kW total at 4.2 K. This synchrotron light will produce considerable photodesorbed gases in the beam vacuum. The photodesorbed gases may greatly reduce the beam lifetime and scattered beam power may lead to quenching of superconducting magnets. The Collider availability may be unacceptable without properly addressing this concern. A liner is one method under consideration to minimize the presence of photodesorbed gases. An 80 K liner also replaces the 4 K dynamic heat load of the synchrotron radiation with a static heat load, independent of the beam intensity, and transfers the intercepted heat to the liquid nitrogen system that may improve Collider cryogenic thermal efficiency. It would allow a potential luminosity upgrade.

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The liner operational temperature was required to be 80 K based on photodesorption data available from the CDG and SCDG measurements [1]. Those data showed that liners at lower temperatures 20 K or 4.2 K had either unacceptable impedance margins or excessively long conditioning periods. However, in January of 1993 new photodesorption data also indicated the viability of 4 K and 20 K systems [1].

The Collider Liner System Design addresses photodesorption, particle beam stability, magnetic field quality, beam induced wake fields, RF impedance, cryogenics, magnet quenching (especially quenches induced Lorentz pressure), and many other interdisciplinary technical problems.

II. ASST LINER TUBES CONFIGURATION

As shown in Figure 1, an 80 K liner tube consists of a perforated tube located coaxially inside the 4.2 K magnet bore tube. The ASST Dipole Magnet (CDM) liner temperature is maintained at 80 K by high pressure GHe loops of 0.25 g/s, as (A). The GHe flow is recooled by LN_2 in the cooling pipe of a magnet cryostat. A special end conducting cooling structure is designed to cool the ASST Quadrupole Magnet liner as Figure 1, (B)

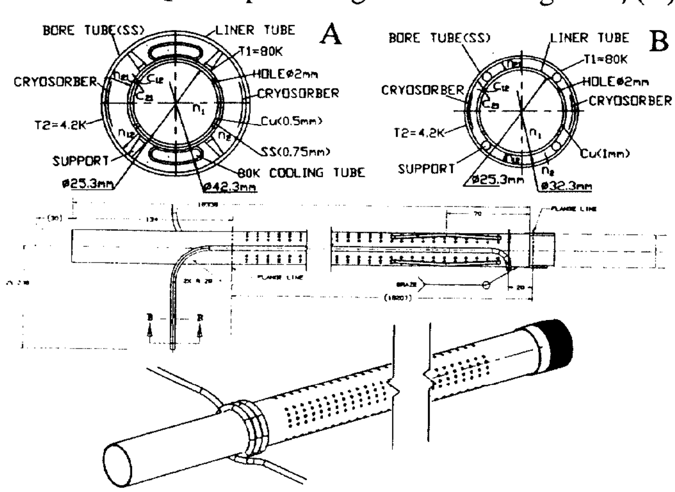

Figure 1. The CDM and CQM liner tubes.

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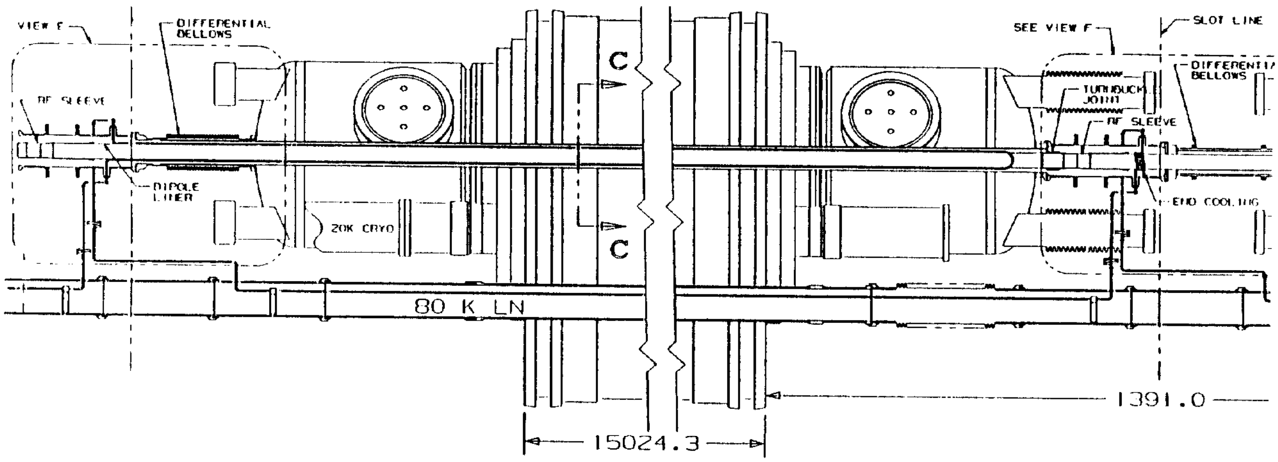

Figure 2. A CDM liner assembly in a CDM magnet.

since the (CQM) beam tube ID (32.3 mm) is much smaller than an ASST dipole ID (42.3 mm). Low heat leak supports hold the liner in the center of the beam tube. A thin layer of cryosorber (0.5 mm) on the inner surface of the 4.2 K beam tube pumps the photodesorbed gases through the holes on the liner tube (1300 holes/m, D=2 mm for CDM liner; 2400 holes/ m, D=1.5 mm for CQM liner). The CQM liner tube is made of 1 mm thickness copper. The CDM liner is 1.25 mm bimetallic tube of an inner 0.5 mm copper and outer 0.75 mm stainless steel.

III. ASST LINER STRUCTURE

A liner system prototype has been developed for testing at the Accelerator System String Test (ASST) facility since the half cell (five dipoles, one quadrupole and one spool piece with a beam position monitor) is an existing basic unit of the Collider.

An extensive trade study has been performed to develop a retrofit 80 K liner structure and flow return cooling loop, Figure 2. If an 80 K liner is chosen for collider upgrade, the structure will help its insertion into magnets to be retrofitted in the tunnel. Figure 3 shows that a CQM liner is refrigerated through thermal conduction by 80 K GHe in a compact heat exchanger at the end of the liner tube outside the CQD cold mass. The maximum temperature increase ΔT could be less than 5 K for a Spool Piece liner, and 10 K for a CQM. The total heat load from a liner system in a half cell to 4K is 5 - 6 W that is much smaller than a Collider baseline design.

The RF joint and a good thermal contact joint assure the continuity of the image current and aid assembly and maintenance. The magnet interconnect with these joints, and a compact heat exchanger are included in a cryogenic box. The cryogenic box also allows each liner to have up to a 54-mm thermal contraction during cooldown and warmup, as Figure 4. However, the liner is discontinuous when routed through the Beam Position Monitor (BPM). Two options of BPM designs have been carried out. One is an 80K BPM which is easy to connect with an 80K liner, but not to a Spool Piece. Another option is a 4K BPM, which is easy to connect to the Spool Piece, but not easy to a liner. Figure 5 shows a 4 K BPM.

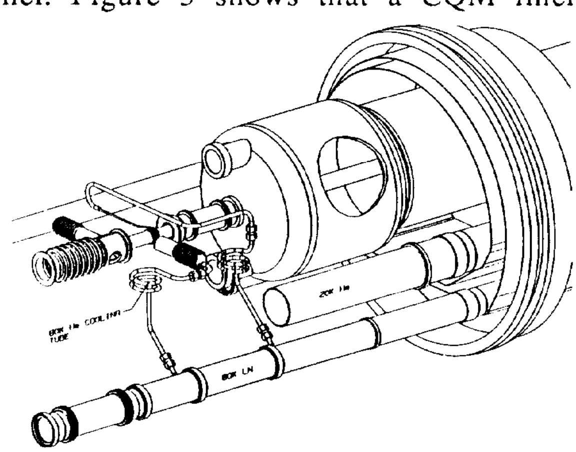

Figure 3. The end structure of a CQM liner.

IV. ANALYSES AND TRADE STUDY

A uniform and maximum possible liner inner diameter (ID) is needed due to: (1) particle beam commissioning, (2) particle beam dynamic stability, and (3) safety margin. However, the maximum liner ID is constrained by: (1) the available magnet beam tube inner diameter (ID), and (2) the minimum liner radial space. Using cooling, the minimum liner radial space is 6 mm and using end conducting cooling, the radial space needs to be 3.5 mm. Tables 1 and 2 show the maximum liner ID and the liner impedances in various options, respectively.

Table 1. Possible maximum liner ID in various cases.

Object	Dipole Beam tube ID, mm	Magnet Liner ID, mm	Quad Beam tube ID, mm	Magnet Liner ID, mm	Spool Beam tube ID, mm	Piece Liner ID, mm
ASST	42.3	25.3	32.3	25.3	32.3	25.3
GD, B & W	32.3	20.2	32.3	20.2	32.3	20.2
Desired	42.3	31	42.3	31	42.3	31

Table 2. Comparison of impedances.

Case	Liner ID, mm	Hole/Slots Coverage	Z (liner) M ohm/m	Z (other) M ohm/m	Z (total) M ohm/m	Safety margin
Baseline	32.3			40	40	6.7
With liner	25.3	2 mm, 2%	22	112	133	2
With liner	25.3	2 mm, 4%	44	112	156	1.7
With liner	25.3	2 × 6, 2%	8	112	120	2.2
With liner	33	2 mm, 4%	15	40	55	4.9

Besides, the liner tube design also must meet the following requirements:

1.	Inner wall conductivity and thickness	$\sigma*\delta > 2 \times 10^5$ Ohms^{-1}
2.	Liner impedance	Z L/n < 0.34 Ohm, Z T < 20 M Ohm/m
3.	Inner wall photodesorption coefficient	$\eta = 0.02$, $\alpha = 0.3$ for H_2
4.	Liner pump speed	600 l/m/s for H_2
5.	Total liner heat leak to 4 K	< 1 W for dipole
6.	Cryosorber pump speed	1200-3000 l/m/s for H_2
7.	Cryosorber pumping capacity	30 Torr l/m at 294K
8.	Cryosorber activation temperature	294 K; regeneration < 80 K H_2, <294 K all Gases; recovery fraction > 98%
9.	Liner quench survivability and ASME code	100 quenches in 25 yrs
10.	Radiation dose tolerance	1400 MRad in 25 yrs

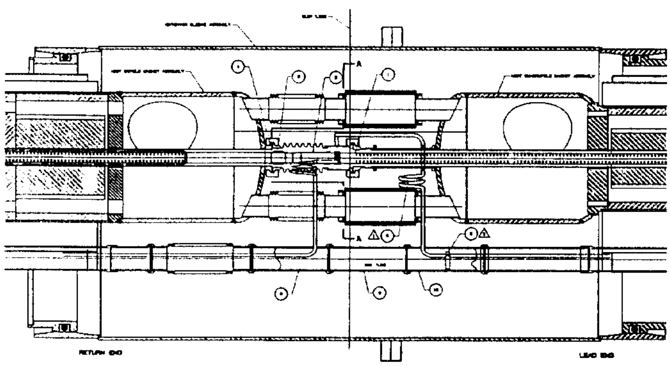

Figure 4. The liner interconnects.

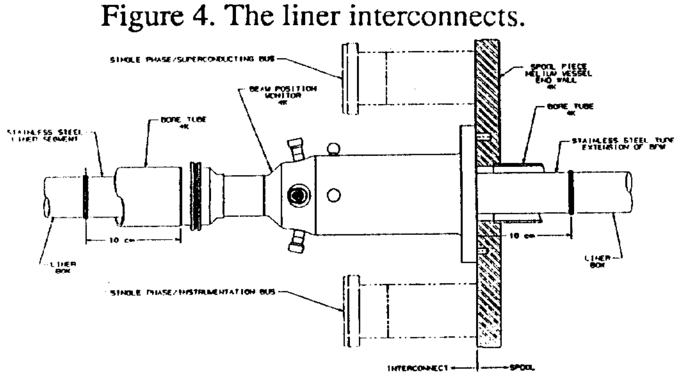

Figure 5. A schematic of a 4K BPM

V. LOWER TEMPERATURE LINERS

Several concepts of 4.2 K and 20 K Liners have been studied as a result of the new photodesorption tests. Concept A had a complex extruded shape with three supports integral to the liner tube. Concept B showed a circular beam tube with three brazed hat shaped supports running the full length of the tube (to ensure even thermal distribution between liner and bore tube). Concept C showed the same support system as proposed for 80 K liner, i.e., discrete supports located every 1 m. All three concepts would be optimized for good thermal contact between the liner and beam tube. In the three concepts, the cryosorber is located on the liner outer surface. Concept D considered addition of a 4.2 K channel on the liner tube to boost cooling capacity. The 20 K liner system concept is very similar to the 80 K system, but with the option of cryosorber on liner outer surface.

REFERENCES

1. 80 K ASST Liner Design Report, edited by Q. S. Shu, in preparation.