SSCL-372
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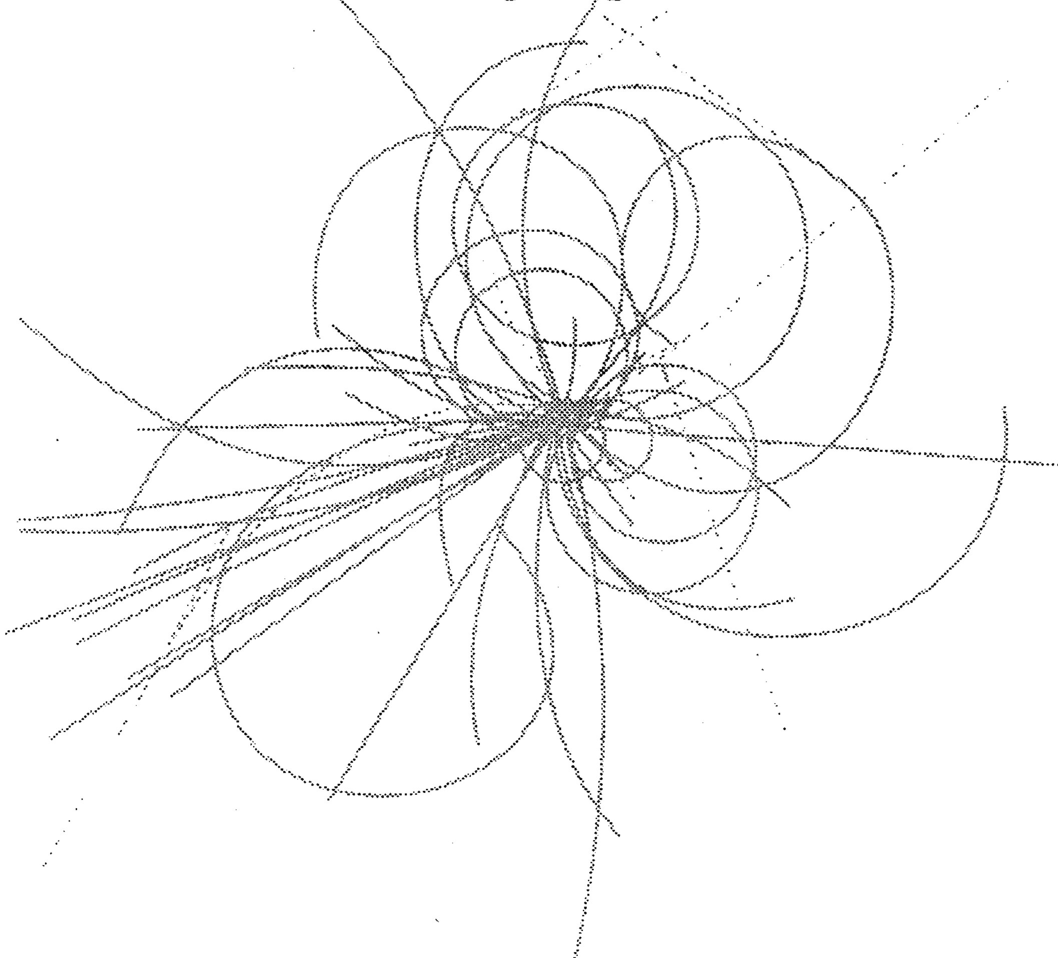

Conceptual Design for the Thermal Shield Bridges and Multilayer Insulation in the Interconnect Region for the SSC

D. Baritchi, T. Nicol and W. Boroski

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Abstract: The interconnect region serves as the connection area between magnets. In order to minimize radiant heat transfer in the interconnect area, we use shield bridges which span the 80K and 20K shield gap between adjacent magnets. A sliding joint between bridge sections on adjacent magnets accommodates contraction during cool-down. An investigation was done to determine which attachment schemes (riveted or bolted versus welded) are better for heat transfer. Each shield bridge is covered with the same multilayer insulation scheme used throughout the body of the magnet. These shield bridges also contain pressure reliefs for each shield in the event of an internal piping failure. The reliefs are located in the upper half of the shield section in order to prevent liquid spills from impinging directly onto the vacuum vessel wall.

INTRODUCTION

The interconnect region (ICR) is a section that links two magnets of the Superconducting Super Collider (SSC) particle beam accelerator. It consists of eight pipes having stainless steel bellows to accommodate axial motion due to cool-down and warm-up, two aluminum thermal radiation shield bridges operating at 20K and 80K and covered with multilayer insulation (MLI), and a vacuum vessel bridge. A cross-sectional view of the dipole magnet that would be connected to the ICR is shown in Figure 1. An elevation view of the interconnect region, showing the cryogenic pipes, is presented in Figure 2.

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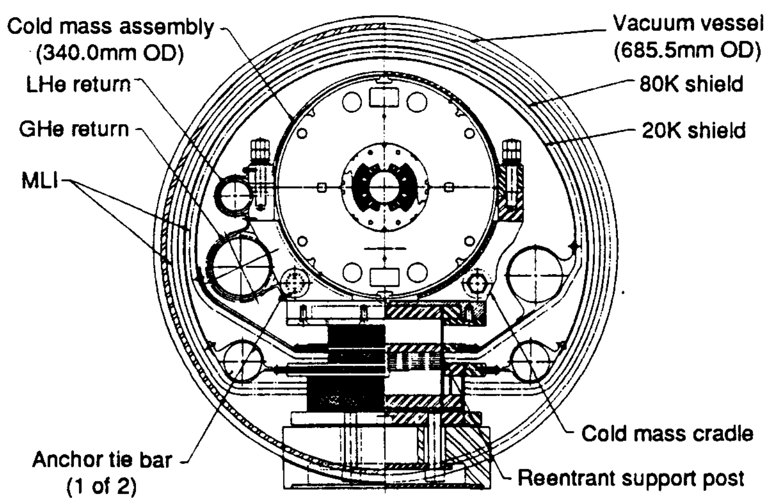

Figure 1. 50 mm Collider Dipole Cryostat Cross Section.

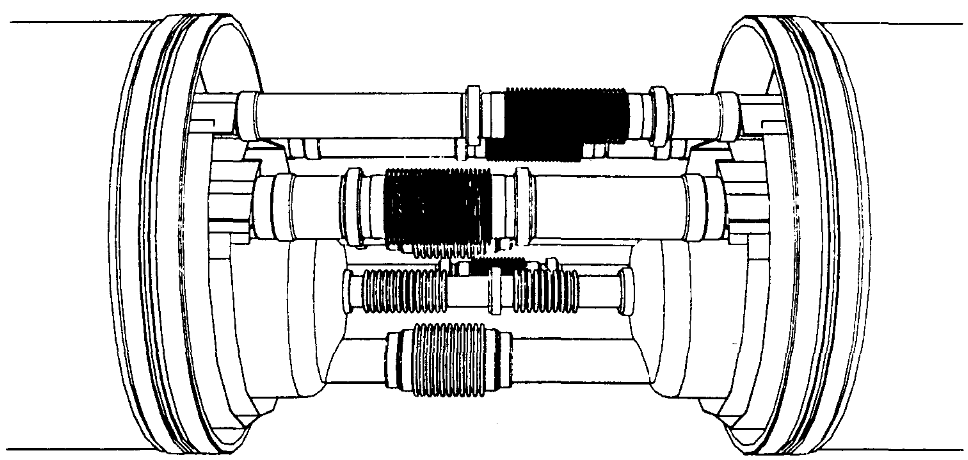

Figure 2. Interconnect Region (elevation view).

Figure 3 shows the cryogenic pipes and the beam tube leaving a dipole magnet. The two aluminum thermal shield bridges must intercept radiant heat from the environment and must be cooled by the thermal shields of the magnet. For this reason we must pay close attention to attachment schemes (riveted or bolted versus welded). Inside the magnet the thermal shields are cooled directly by the cryogenic pipes that are welded along their length. In the interconnect region we have no such opportunity to weld between cryogenic pipes and thermal shield bridges, because the former are stainless steel and the latter are aluminum; it is not possible to weld aluminum to stainless steel. In order to make connections between aluminum extruded pipes and stainless steel pipes, transition joints are required. Joints using diffusion bonding or brazing between these two materials have been successfully employed at Fermilab and HERA.[1,6] This paper attempts to summarize the results to date of the design effort on the interconnect region from the thermal shield bridges and multilayer insulation stand point.

DESIGN

Attachment

After much investigation it has been decided that the best attachment scheme between the thermal shields of the magnets and thermal shield bridges in the interconnect region is a welded connection. In order to perform these investigations we analyzed many factors including reliability, cost, heat transfer, and magnet replacement time. One of the most important factors was heat transfer or, more precisely, the task of cooling the thermal shield bridges. In order to understand this problem, let us look at what happens when we use a bolted attachment scheme. In this case the heat leak between the magnet shields and the bridge shields will depend on the thermal contact resistance between the two shields. From Table 1 it is very easy to see that thermal contact resistance depends on the pressure applied between the two shield surfaces.

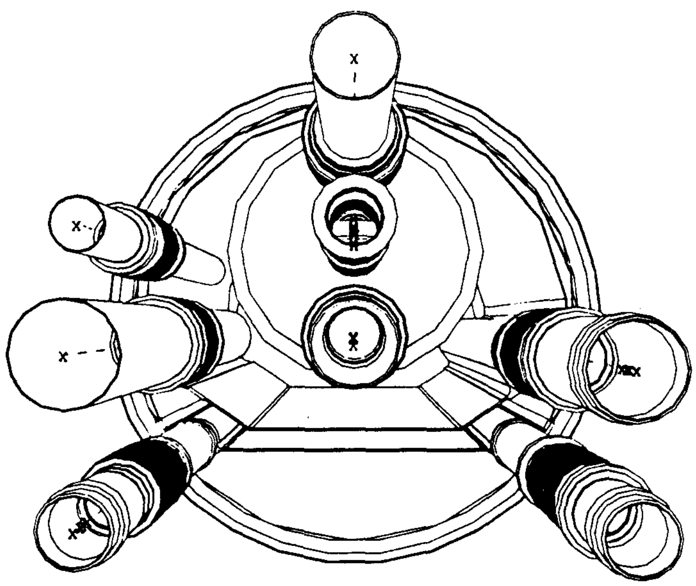

Figure 3. Interconnect Region (end view showing the 8 pipes leaving the dipole).

Table 1. Thermal Contact Resistance Across an Interface.[2]

Typical values	
* R = 5.3 cm^2 × C/W	Aluminum; air gap; 10 psi contact
* R = 0.4 cm^2 × C/W	Aluminum; air gap; 500 psi contact
* R = 10^{-6} cm^2 × C/W	Aluminum; air gap; perfect contact

Let us investigate some of the few ways to minimize the thermal contact resistance. First let us suppose we are using stainless steel bolts for this joint. It is very easy to see that this is not a good idea because during cool-down, the shields are going to shrink more than the stainless steel bolts due to different thermal contraction properties. The gap will be bigger, and the thermal contact resistance will increase in accordance with the above chart. Let us suppose we are using aluminum bolts. In this case we are limited because the yield strength of aluminum is not high enough to realize the required pressure. Another way to minimize thermal contact resistance could be insertion of some indium, copper foil, or thermal grease between thermal shields. We were unable to find a material with very good properties at cryogenic temperature or with good resistance. Another possibility that was investigated is the use of copper braid between the magnet shield and the thermal shield bridge. This seemed to be a very good idea, but there is not enough space between 20K and 80K shields to accommodate this. The idea of using a riveted joint has been investigated, too, but not with good results. Without access from the inside, we can use only pop rivets. With this kind of rivet it is practically impossible to control the pressure between plates (in this case, pressure between shields), and the thermal contact resistance will be very high.

Expansion

It has been decided to vertically split the thermal bridges perpendicular to the magnet axis, and to provide a sliding joint (shown in Figure 4) between two portions of the thermal shield bridge. The length of the sliding joint has been calculated in accordance with thermal contraction of aluminum from 310K to 80K and to 20K. The length of the sliding joint will be 88.9 mm (3.5 in.). The shields are segmented along their length for installation purposes; they will also be skip-welded along their length.

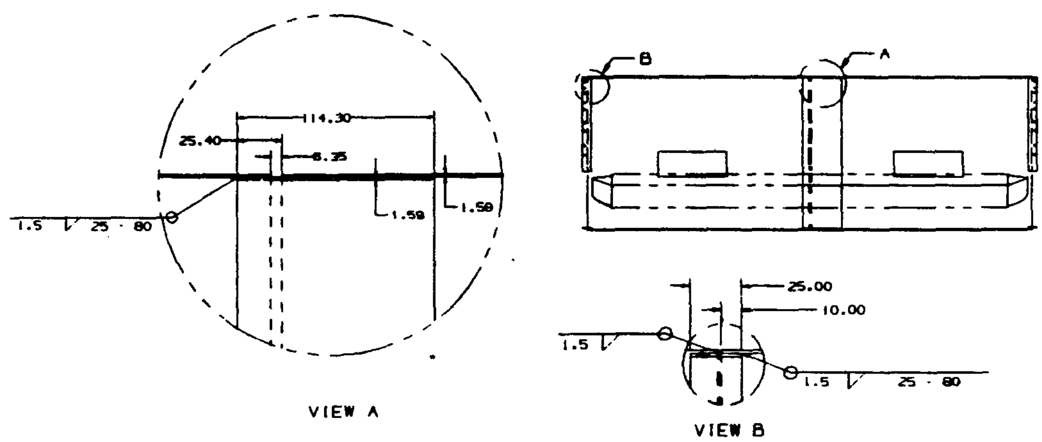

Figure 4. Sliding Joint.

Pressure Reliefs

Contained by the thermal shield, bridges are designed to prevent buildup within either shield in the event of an internal bellow or piping failure. The reliefs for the 20K thermal shield bridges will be located in the upper half of the shield sections in order to prevent cryogenic liquid spills from impinging directly onto the vacuum vessel wall. The reliefs for 80K will be located in the lower half of the shield sections (as shown in Figure 5), as high as possible, for the same purpose.

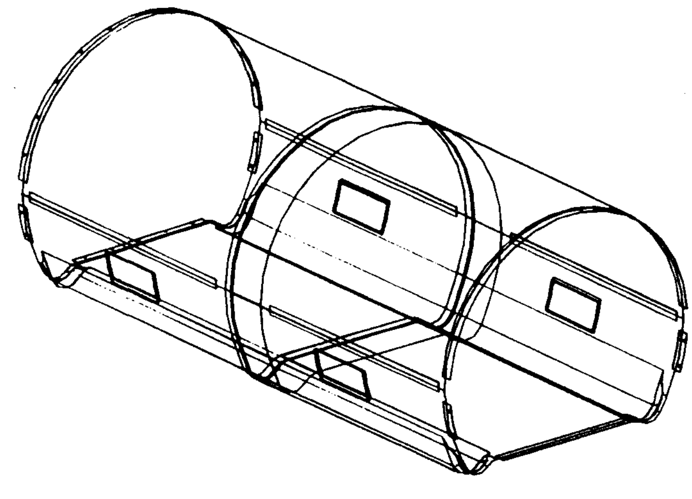

Figure 5. Interconnect Region (80K shield bridge with pressure reliefs).

Insulation

The design requirements for the thermal insulation in the interconnect region imply that the heat load from thermal radiation and residual gas conduction will be limited to the values listed in Table 2. The mean apparent thermal conductivity of the insulation system must be 0.76 $\times 10^{-6}$ W/cm-K in order to meet the design heat load budget. In order to realize that value, a multilayer insulation (MLI) system composed of reflective layers of aluminized polyester separated by spunbonded polyester spacer layers is used. The reflective layers consist of flat polyester film aluminized on both sides to a nominal thickness not less than 350 angstroms. The spacer layers consist of randomly oriented spunbonded polyester fiber mats.The mean apparent thermal conductivity of the MLI blanket has been measured to be 0.52 $\times 10^{-6}$ W/cm-K to 80K. Polyethylene terephtalate (PET) has been selected as the material of choice for each of the MLI blanket components. The material selection was formulated after consideration of such design parameters as mechanical strength, nuclear irradiation dosages, irradiated gas evolution, hygroscopicity, vacuum outgassing rates, interstitial gas pressure, crack geometry measurements, and thermal performance measurements.[3]

Table 2. SSC Dipole Interconnect Heat Leak Budget.[4]

T (K)	Q (Watts)
4	.150
20	.320
80	2.100

The 80K interconnect region will have the same two blankets of MLI as the magnets, with a total thickness of 17.78 mm. Stepped joints will be used to minimize heat leak through the MLI connection. In order to obtain a solid connection between the two MLI blankets it has been decided to make an ultrasonic weld between cover layers made of spunbonded polyester 0.23 mm thick. For the 20K interconnect region, Fermilab is testing a scheme using 10 reflective layers with spacers having a total thickness of 3.96 mm.[5] The connection scheme will be the same as the 80K: stepped joints with ultrasonic weld. In the interconnect region we need not provide any reserve of material for thermal contraction because it is provided in the dipole magnet.

ANALYSIS

The General Dynamic Thermal Analyzer[7] was used to perform heat flow calculations through the heat shields and MLI insulations. These results were compared with the heat leak budget shown in Table 2.

Total Thermal Flux through 80K = 0.6664 W/m^2. Multiplying by the surface area of the 80 K shield.

6664 $W/m^2 \times 1.48\ m^2$ = 0.986 W. From Table 2, see the heat leak budget is 2.1 W.

Total Thermal Flux through 20K = 0.1845 W/m^2. Multiplying by the surface area of the 20 K shield.

1845 $W/m^2 \times 1.28\ m^2$ = 0.236 W. From Table 2, see the heat leak budget is 0.320 W.

The calculated values of heat flow were well within the heat leak budget.

A steady-state heat transfer of the interconnect region (ICR) was carried out using ANSYS, a commercial finite element program. An ANSYS plot of the ICR insulation system is shown in Figure 6. The model accounts for radiation and conduction heat transfer between the different components in the ICR. The results of the analysis are the heat flow rates across the different sections of the ICR insulation system, as shown in Figure 7. The heat flow rate across the 80 K heat shield was determined as 1.23 W and across the 20 K heat shield as 0.250 W.

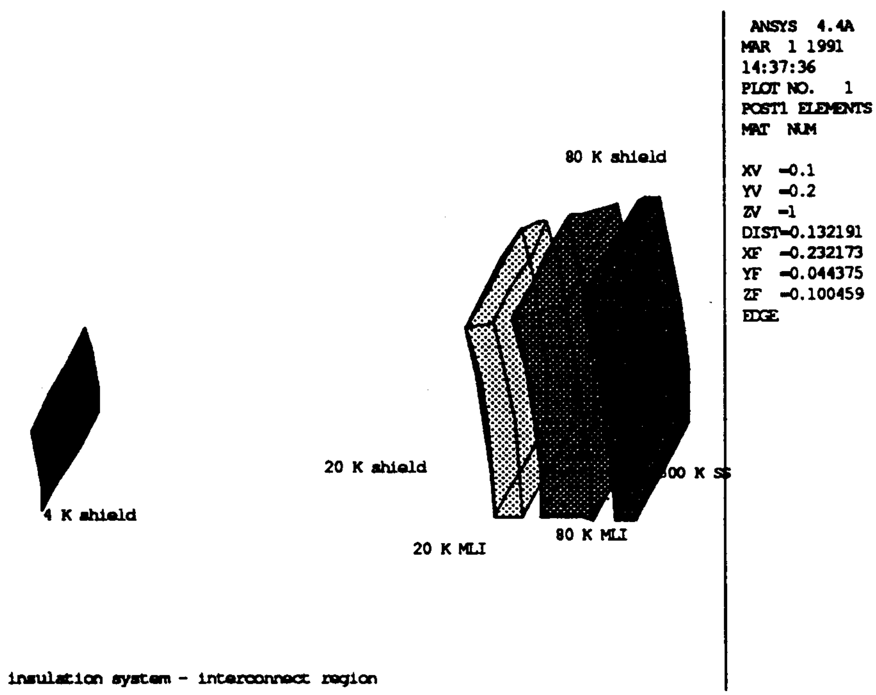

Figure 6. ICR Insulation System Model.

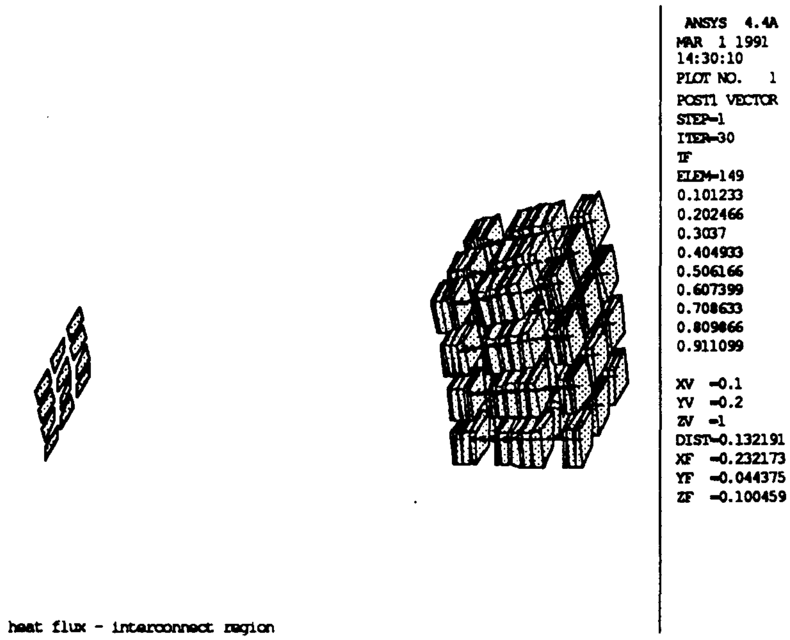

Figure 7. ICR Heat Flux

A comparison of the heat leak budget and the calculated values of the heat flow across the 20K and 80K thermal shield shows that the designed insulation system meets the design requirements.

Table 3. SSC Dipole Interconnect Region Heat Leak Budget and Values Calculated in ANSYS and General Dynamic Thermal Analyser.[7]

	20K	80K
Heat Leak Budget	0.320 (W)	2.100 (W)
Thermal Convair Analyser	0.236 (W)	0.986 (W)
ANSYS	0.250 (W)	1.230 (W)

SUMMARY

We are in the process of finishing detailed drawings for the thermal shield bridges. Fermilab is going to provide drawings for the MLI and will procure the MLI parts. Heat leak tests will begin in July 1991.

ACKNOWLEDGEMENTS

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