THERMAL CONTACT CONDUCTANCE AND THERMAL SHIELD DESIGN
FOR SUPERCONDUCTING MAGNET SYSTEMS

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ABSTRACT

The aluminum radiation shields in the SSC quadrupole magnets are conductively cooled from the cryogen flow in the 80 K and 20 K flow circuits. As the shield temperature is very sensitive to the effective heat transfer rate between the shield-piping interface, the method of shield mounting and heat sinking is critical. Cost and reliability concerns also drive the design. Here, we discuss critical issues that can have a limiting effect on the shield thermal performance. The spring-type action of the shield clamps it in place and heat transfer across the interface depends on thermal contact conductance. Thermally induced stresses can be relieved by allowing the shield and piping to slide relative to each other. Test results are presented on stainless steel-aluminum thermal contact conductance and its effect on the shield performance is discussed.

INTRODUCTION

Aluminum radiation shields have many advantages for the cryostat designer. Included among these are: easy fabrication, ready availability, low cost, light weight and high thermal conductivity. However, where stainless steel process lines are used, thermal attachment of the shield to the cryogen supply piping is problematic. Direct welding or soldering are not feasible due to metallurgical incompatibilities. Also, the differences in thermal contraction must be accommodated, else the shield could warp enough to short thermally a section of the cryostat. For the Collider Quadrupole Magnets (CQM) for the Superconducting Super Collider program, Babcock and Wilcox (B&W) has chosen a design wherein the thermal shields physically entrap the stainless steel cryo-pipes. The pipes are clamped into the shield C shaped cross-section, as illustrated in Figure 1. Heat transfer to the cryo-pipes is by thermal conduction through load bearing areas of the shield-pipe interface, commonly referred to as thermal contact conductance. A critical issue for the collider ring operation is
the transient and steady-state thermal performance of the shields, which can be limited by the thermal contact conductance.

Numerous factors influence contact conductance: bulk thermal conductivity, surface finish, oxidation condition, hardness, and load. Theoretical and experimental studies of load versus conductance behavior have indicated a load dependence of \( k_c = a L^{0.9} \) (1)

where \( k_c \) is the thermal contact conductance, \( a \) is a scale factor dependent on the specific contact system, material properties and surface conditions and \( L \) is the applied load. The load behavior is well established and is only of interest for our application to determine the clamping force required to get the overall heat transfer rate within the constraints of our system requirements.

Low temperature effects have been summarized and show a wide variation in both electrical and thermal contact conductance, which can vary over 5 orders of magnitude. At low temperatures, pressed contacts show a temperature variation

\[ k_c = b T^n \] (2)

where \( b \) is a constant, \( T \) is temperature and \( 0.5 \leq n \leq 2.5 \) in the temperature range below 10 K. Note this variation differs appreciably from that exhibited by normal metals, which show a linear temperature behavior in this range. Measuring the electrical contact conductance, a relatively simple experiment, and then calculating an equivalent thermal conductance.

Figure 1. Schematic cross section illustration of the CQM cryostat.