# Material Selections For The SSC

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## INTRODUCTION

The Superconducting Super Collider (SSC) represents the next generation of particle accelerators for use in high energy physics research. There are many facets to the complete design of such a machine. This paper, however, will address mainly two; the structural and thermal design of accelerator magnets as that design relates to the particular materials available for consideration.

The material related questions that face the the designer of superconducting accelerator components are unique in many ways. He must be concerned with an operating environment that spans a temperature range of roughly 320 to 4K, a pressure range from atmosphere to high vacuum, and maybe most importantly, is subject to high radiation doses.

The issues driving the overall SSC design are many, but the overwhelming one is cost, not simply the cumulative cost of component pieces, but the operating costs over an anticipated 20 year life. Piece part costs are straightforward. Operating costs, however, are more subtle, an example being the cost of refrigeration. It has turned out that a very low heat load budget has driven many aspects of the cryostat design. The combined heat load to 20 and 4.5K, for example, is budgeted at 0.05 watts per meter. As a point of reference, the comparable heat load in the Tevatron, currently operating at Fermilab, is nearly twenty times this figure. For 80K, the figure for the Tevatron is nearly twelve times that for the SSC.

Attached as an appendix is a cross-section of the dipole (bending) magnet currently being constructed in the model phase of the SSC project. In total, there will be approximately 8000 superconducting dipoles like that shown, each one being 17 meters long with a maximum operating field of 6.6 tesla. The discussions below will address each of the major components depicted in the referenced cross-section.

## VACUUM VESSEL

The outermost vessel shown in the dipole cross-section constitutes the insulating vacuum containment and the attachment for the cold mass suspension system. A variety of materials was considered for the vacuum vessel; low carbon, 9% nickel, and stainless steels, and aluminum. Nickel steel, stainless steel, and aluminum alloys have the advantage that they remain ductile over a broad temperature range. Carbon steel, on the other hand, is susceptible to embrittlement even at relatively high temperatures (relative to the temperatures of the cryogens).

At the moment, however, cost is a very strong factor. Failure analysis has indicated a very low probability of cryogens accumulating in the bottom of the vacuum vessel. Until such time as analysis shows otherwise, low carbon steel will be used.

THERMAL SHIELDS

The next two shells in from the vacuum vessel are thermal shields. Their job is to intercept any heat radiating in toward the 4.5K cold mass from the outside world. The outermost shield operates at 80K, the innermost at 20K. Each shield is cooled by a single supply. In order to maintain a low thermal gradient around the perimeter, the shield material must have very high thermal conductivity. The two materials of choice are aluminum and copper. The structural properties of the shield material are not critical. Again, cost being a critical factor, aluminum was chosen as the shield material. The current alloy is 6061-T6 due to its ready availability, however, production shields may well utilize a different, less expensive, alloy.

COLD MASS

The innermost vessel acutally consists of five separate assemblies. The cold mass containment skin must closely match the thermal expansion properties of the NbTi alloy coil and must be weldable to bellows at the interface between magnets. In addition, it must be capable of withstanding an internal pressure of 20 atm during a magnet quench. For all of these reasons, 304 or 316 stainless steel was the natural material choice.

Directly beneath the cold mass skin is the magnet iron. Unlike previous magnets designed at Fermilab, the SSC dipole is a cold iron design, i.e. the iron operates at 4.5K. By the nature of its function, the magnet iron is low carbon steel.

The collared coil assembly is centered in the magnet iron at a diameter of 11 cm. The collar material in the coil assembly has been the subject of a great deal of debate during the design of the SSC. The forces imposed on the collars during prestressing of the conductors themselves are very high; typically higher than the Lorentz forces that the collars see during magnet operation. These assembly forces tend to distort the as-built coil geometry which complicates cold mass assembly and relaxes the coil prestress. For these reasons, a high strength stainless steel alloy (Nitronic-40) is currently being used as the collar material.

There are advantages, however, to using a material with a high thermal conductivity, particularly during magnet cooldown. This consideration points more toward a high strength aluminum alloy. Although it is conceivable to find an alloy with sufficient yield strength, the lower modulus will result in significantly higher collar deflections upon release from the assembly press.

The battle over these two materials, stainless vs. aluminum, is still raging. Prototype assemblies thus far utilize stainless steel collars. Subsequent models may very well see a change to aluminum.

Inside of the coil collars is the superconducting coil itself. The coil is wound from NbTi superconducting alloy cable similar in cross-section to the Tevatron coils currently operating at Fermilab.

Finally, inside the coil lies the 4 cm diameter bore tube. During a magnet quench, this tube can see enormous external pressures. Like the coil collars, the material selected for the current design is Nitronic-40. In addition to its strength, Nitronic-40 exhibits very low magnetic permeability, minimizing interaction between the tube and beam. The need for beam stability and low beam losses requires that this tube also have very low electrical resistivity. To accomodate this need, the inside diameter of the bore tube is copper plated.

SUSPENSION

The post-type structure connecting the cold mass to the vacuum vessel is the cold mass and shield suspension. The post support was chosen over several other design candidates for several reasons; it is very strong, constitutes a high thermal resistance warm to cold transition, and integrates well with the remainder of the magnet assembly.

In many ways the suspension is the single most critical cryostat system. It must be capable of supporting the cold mass reliably under a variety of load conditions and must represent a very high impedence to heat flow from the outside world.

The details of the post design is beyond the scope of this discussion, however, a general description is in order. The post is a 'folded' construction of two composite tubes, connected to the cryostat components at 300, 80, 20 and 4.5K points via stainless steel and aluminum flanges. The composite / metal joints are effected by shrink fitting.

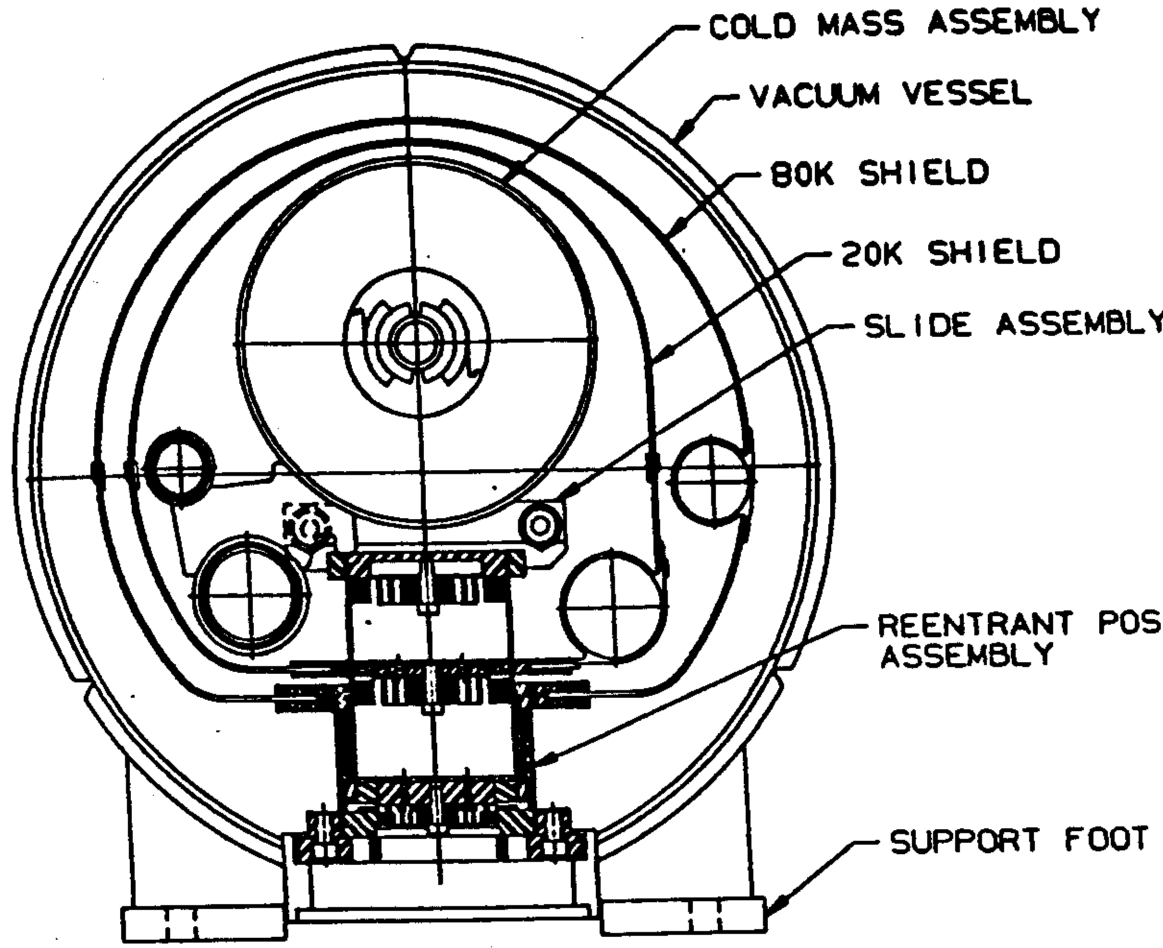
The composite chosen for the prototype assemblies if G-11 CR. This material is an excellent candidate due to its high strength and low thermal conductivity. It has the added advantage of being well characterized by the NBS. That is, the recipe for G-11 has been standardized, and its properties well documented. Work is on-going to investigate additional candidates. Certain aspects of the structural performance could be enhanced by a material with a higher elastic modulus than that of G-11; carbon fiber composites, for example. Unlike G-11, carbon fiber composites are not well standardized and so, are more difficult to evaluate.

BELLOWS

Not shown in the accompanying cross-section are bellows which connect each of the various services from one magnet to the next. Aluminum bellows would be the natural choice for all but the cold mass connection due to the use of aluminum piping through the magnet itself. However, at this time the experience with aluminum bellows is very limited. Stainless steel bellows are certainly the norm. The model magnets use stainless steel bellows throughout. Connections to aluminum pipes are made with an aluminum to stainless steel transition joint where required.

## SUMMARY

The above discussions by no means cover the material related design issues for the SSC completely. Many more issues exist relating to such things as spacer material for multilayer insulation, insulating materials inside the coil assembly, dry lubricants for cold mass slides, and more. However, the design, as it exists today, has certainly been affected by material selection issues. As it matures from the model to production stages, many more materials related questions will arise and be answered.




SSC Magnet Cryostat Cross-Section