SSC-MAG-105
SSC-N-238

SSC QUAD COIL DESIGN MANUFACTURING CONCEPT

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INTRODUCTION

The purpose of this paper is to discuss the feasibility of manufacturing bifilar coils for the SSC quad magnets. A bifilar winding uses one length of cable for both inner and outer coils in each quadrant. The approximate center of the length of cable is the starting point for both layers. This concept is not new and has been used successfully in many superconducting magnets.

Quad Design Requirements

- o High gradient 220-250 T/m @ 6500 A, 4.3 K, with iron
- o 3 meters in length
- o 1.8 Cu/SC ratio, 30 strand cable as in the SSC dipole outer layer
- o The same pole angle for both layers
- o Cosine Θ cross section, 9 turn inner layer, 13 turn outer layer, and a single wedge in each layer, per octant (See SSC-MAG-87)

Manufacturing Design Concept

The bifilar double layer winding starts in the approximate center of the length of cable required for both inner and outer coils. The outer coil cable is carried piggyback while the inner coil is wound (see Fig. 1.). After winding the inner coil, the cable is clamped to hold tension. A 0.015 steel shim representing the between layer insulation at assembly is placed over the inner coil winding. The shim provides a slip plane during winding, positive register for the coil radii during the curing cycle, and prevents epoxy bonding between layers. The piggyback spool is then placed on the tensioner and the outer coil is wound. Tedlar wrap is applied and the double layer coil is cured in the appropriate baking press. (See Fig. 2.)

Experience

Lawrence Berkeley Laboratory has wound and cured two double layer 12" long model arc quads using the method described above. One coil with glass insulation and one with kapton insulation. In both cases, the fabrication process was easily accomplished although the kapton insulated coil was easier to work with and produced a more uniform coil.

Feasibility

A magnet design with the same cable and same pole angle in both layers ideally suits a bifilar winding. There is approximately 440 ft. of cable required for a 9 and 13 turn bifilar wound 3 meter quad coil. Non-usable length of the outer dipole cable can provide 5 bifilar quad coils. Given the same pole angle for both layers simplifies the transition for the cable from the inner to outer layer. This transition can occur either in the end or the straight section. This also eliminates the center splice between layers and additional parts to accommodate splice leads during winding, baking, and assembly. Without center splices the field distortion produced by splice leads are eliminated. To achieve the high gradient and minimize field harmonics, each layer must have accurate conductor placement and symmetry between quadrants. The manufacturing process described produces highly symmetrical, uniform quadrants and minimize possible conductor variation from layer to layer and quadrant to quadrant. This is accomplished by producing a matched pair of coils and simply reducing the number of curing operations.

A bifilar winding requires only one winding island, mandrel, and curing press. This also reduces the storage and handling of coils throughout the entire fabrication and assembly process.

Cost

In comparison to single coil construction, the estimated cost savings is 40% labor, 40% tooling.

Cost of Coil Winding, Curing, and Assembly
Hourly Estimate at $35.00/Hr.

	4 Double Coils	8 Single Coils
Cable Spooling	2 hrs.	
Winding Set Up	4 hrs.	8 hrs.
Winding	24 hrs.	32 hrs.
Coil Curing	24 hrs.	48 hrs.
Inspection	8 hrs.	16 hrs.
Storage & Inventory	4 hrs.	8 hrs.
Handling	4 hrs.	8 hrs.
Assembly Prep.	16 hrs.	24 hrs.
Assembly	16 hrs.	24 hrs.
Yoke Assembly		8 hrs.
additional splices		
Total hrs.	102 hrs.	180 hrs.
	X $35 per hr.	X $35 per hr.
	$3,570.00	$6,300.00

Percent Savings - 43%

Tooling Estimate in Total % of Ratios

	Double Coil	Single Coil
Winding Mandrel	1	2
Winding Island	1	2
Misc. Winding Tooling	1	1
Curing Form	1	2
Inspection Tooling	1	2
Storage	1	2
Assembly Tooling	1	1
Assembly End Piece	1	1
Splice Parts	1	2
Splices	1	2
Iron Yoke Assembly	1	1
Total %	11	18

Percent Savings - 39%

Conclusion

Based on the preliminary quad design requirement and recent LBL experience, the bifilar manufacturing process described produces a feasible approach to the SSC quadrupole construction. This bifilar process produces highly accurate, uniform coils with minimum random variations. The manufacturing process is accomplished easily and results in a cost savings of approximately 40% when compared to a single coil construction method.

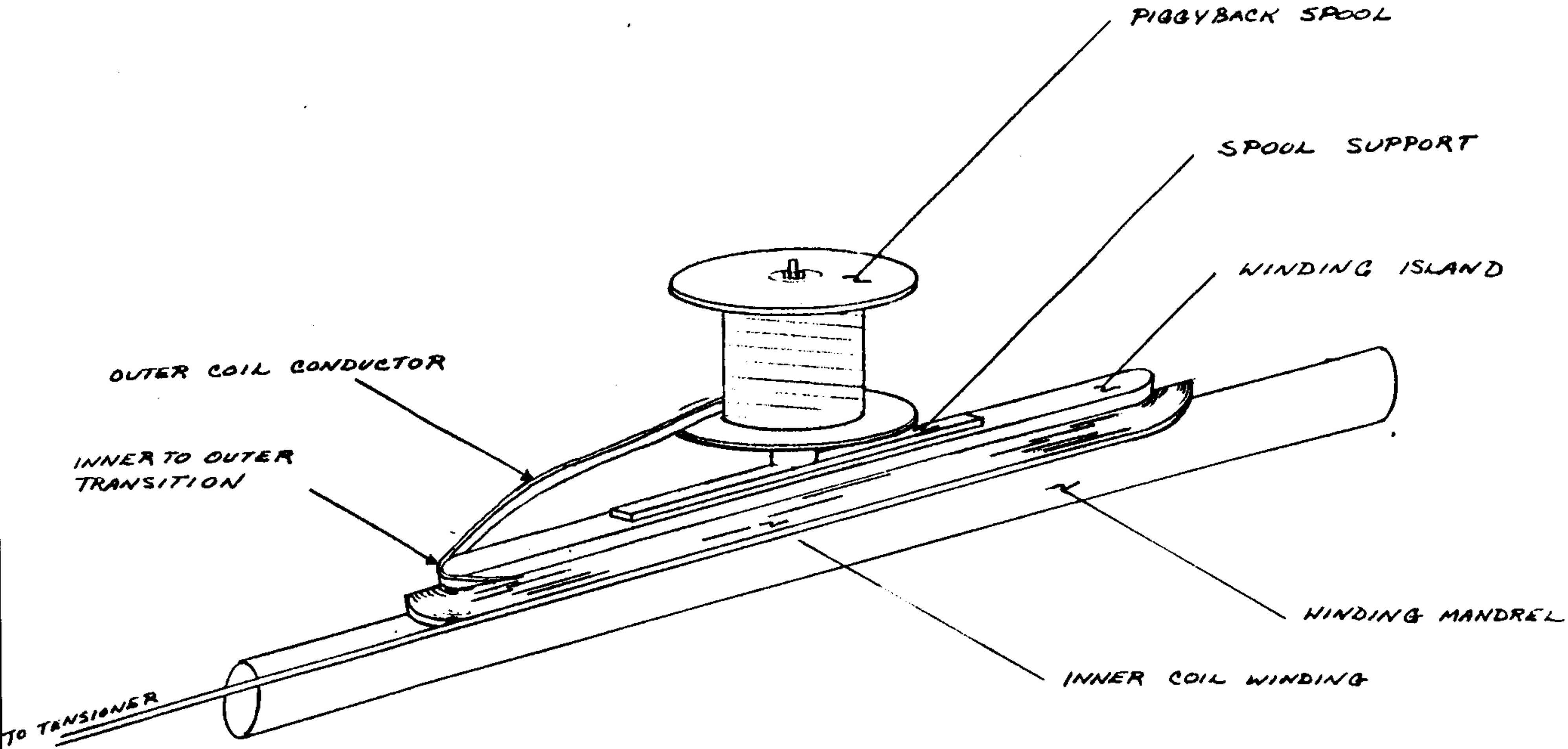

FIG # 1

BIFILER WINDING

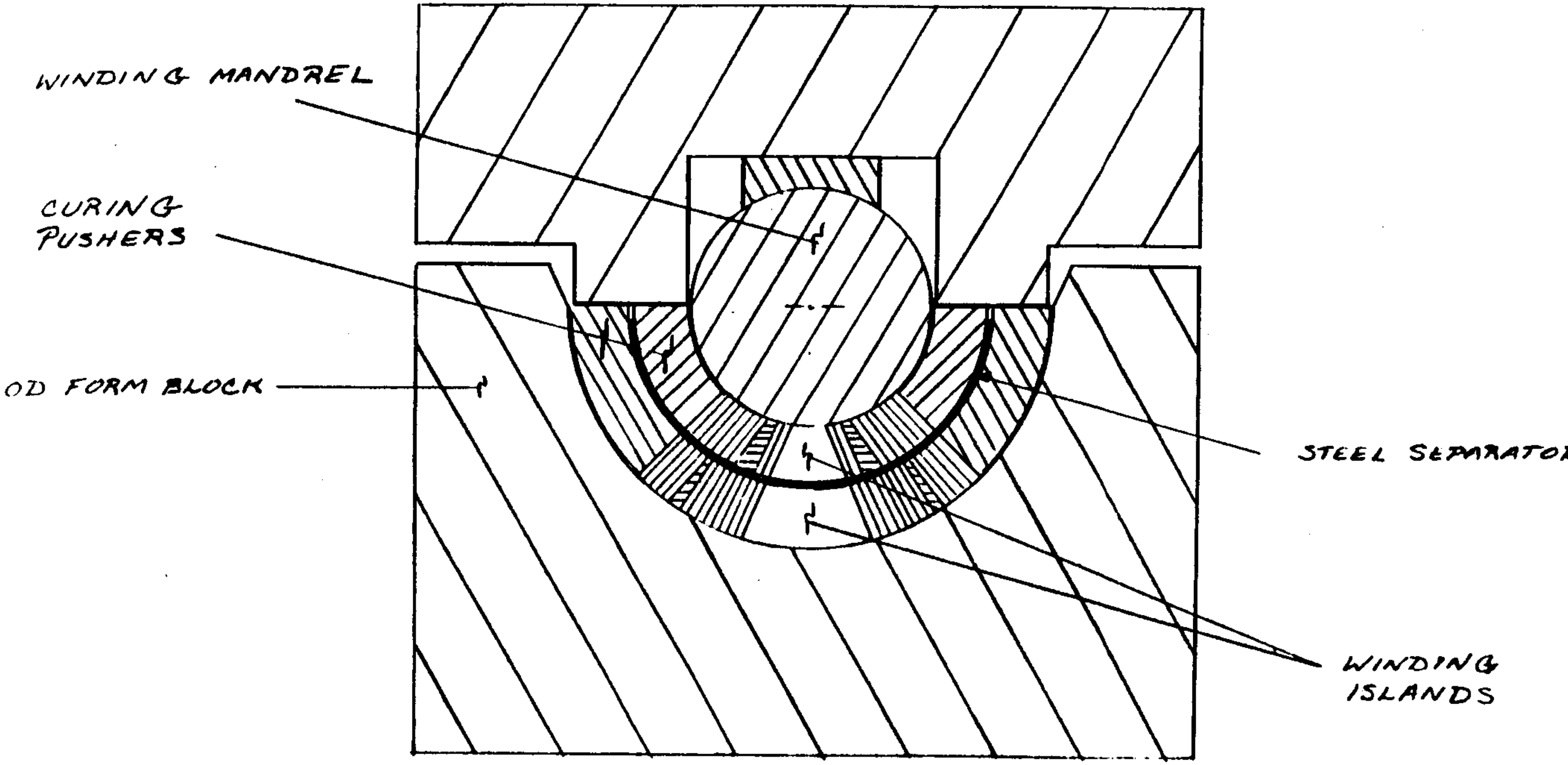

FIG # 2

COIL CURING FORM