SSC 40mm Coil Insulation Evaluation

J. Carson and R. Bossert 3-27-89

The FNAL SSC short model coil insulation system is being reevaluated. This is being done for two reasons.

1.) Problems related to the coil insulation have been encountered in collaring both F1 and F4. On both magnets (for different reasons) the outer coil collaring shim has been driven farther toward the center of the bore than it should be. This does not occur on other magnets built at Fermilab.

2.) An action item from a cooling/insulation discussion group on February 21, 1989 states:

<u>Action Item 3: Ground Wrap Optimization</u>

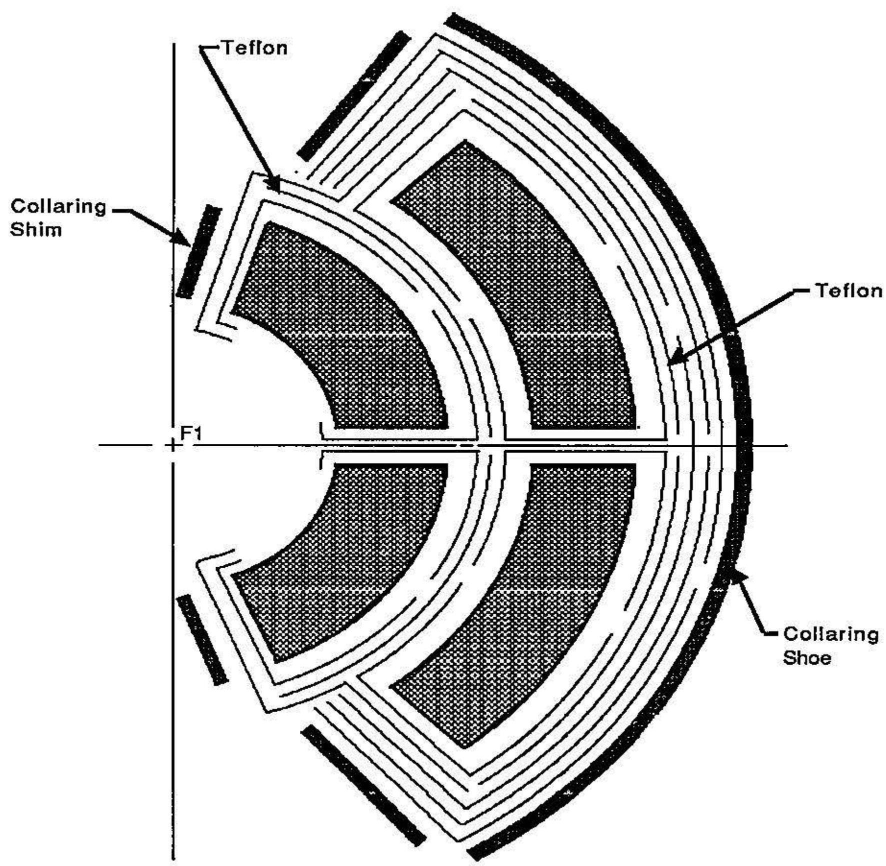
The current Fermilab plan for coil ground wrap incorporates insulation layers that appear to be used only as spacers. There is also, at present, a functional conflict between: (1) use of a kapton (or metal) pole cap designed to mechanically retain a pole face shim; and (2) use of the pole region as part of the Shutt-scheme helium flow path. The goal of this action item is to propose a carefully optimized plan and scheme to provide the minimal needed ground wrap; a mechanically sound scheme to incorporate a pole face (or midplane?) shim; and a method for allowing adequate transverse helium flow to implement the Shutt cooling scheme.

The FNAL insulation plan addresses both these problems. All work in this note is done with NC9 short models.

Recent Insulation Developments

The coil insulation scheme used on F1 was the same as that used at LBL on their NC9 magnets. It is shown below in Figure 1:

Figure 1.) F1 Coil Insulation

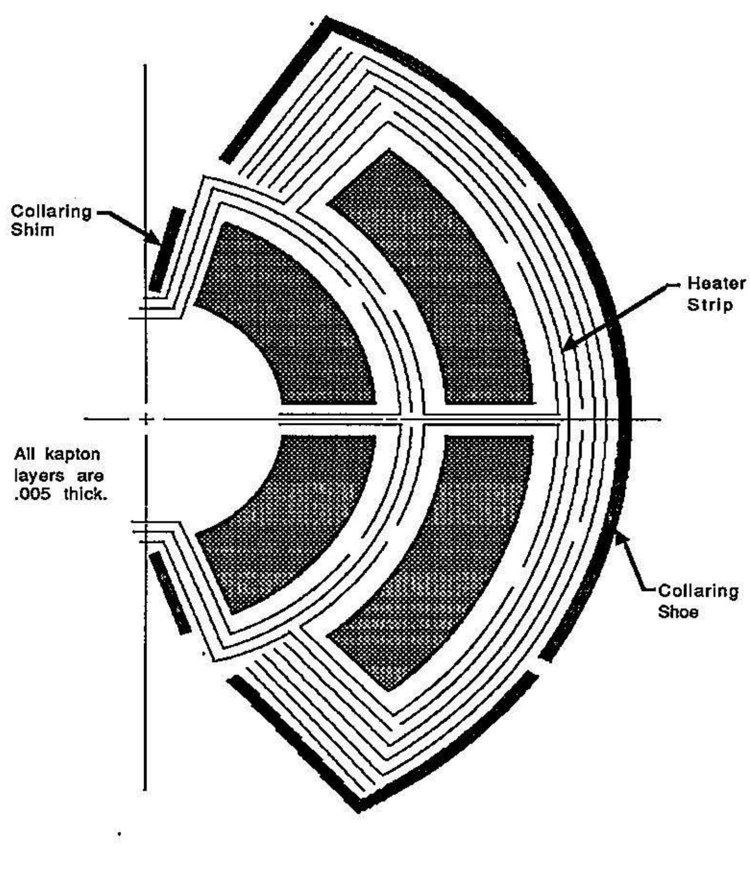


A problem occurred in collaring F1. Both the outer and inner coil collaring shims were displaced from their design positions. Both had moved toward the center of the bore. We attributed this problem on the outer coil to the use of the "collaring shoe" or the .020 thick brass sheet which is positioned on the outer perimeter of the outer coil. Kapton insulation had been caught in the corner between the collaring shoe and the outer coil collaring shim. This drove the outer coil collaring shim downward into the outer perimeter of the inner coil.

The existence of the collaring shoe changes the direction of the forces applied to the kapton ground wrap during collaring. If there is no collaring shoe the collars rub directly on the outer ground wrap layer, causing it to be forced away from the corner. If there is a collaring shoe, the shoe applies the frictional force to the kapton layer. The shoe is one piece and is centered on the outer coil before collaring. During collaring it then moves in a direction opposite the kapton layer, forcing it upward into the corner between the collaring shoe and the collaring shim. Since both the collaring shoe and the collaring shim are rigid, the kapton gets caught between them forcing the collaring shim inward. On both the Tevatron magnets and the design "B" SSC short models, where there is no collaring shoe, this phenomena does not occur.

The inner coil collaring shim was also displaced toward the bore, but for a different reason. The motion of the collars themselves tend to push these shims inward. Since there is nothing to restrain them, they move into the open bore space. The F4 coil insulation scheme (shown below in Figure 2.) attempted to solve these problems.

Figure 2.) F4 Coil Insulation



The inner coil kapton insulation was connected at the pole. This provided a restraint to prevent the inner coil collaring shim from moving inward. The brass collaring shoe and the outer coil collaring shim were connected. They were made of one piece, with a preformed corner to prevent the shim from being driven into the inner coil.

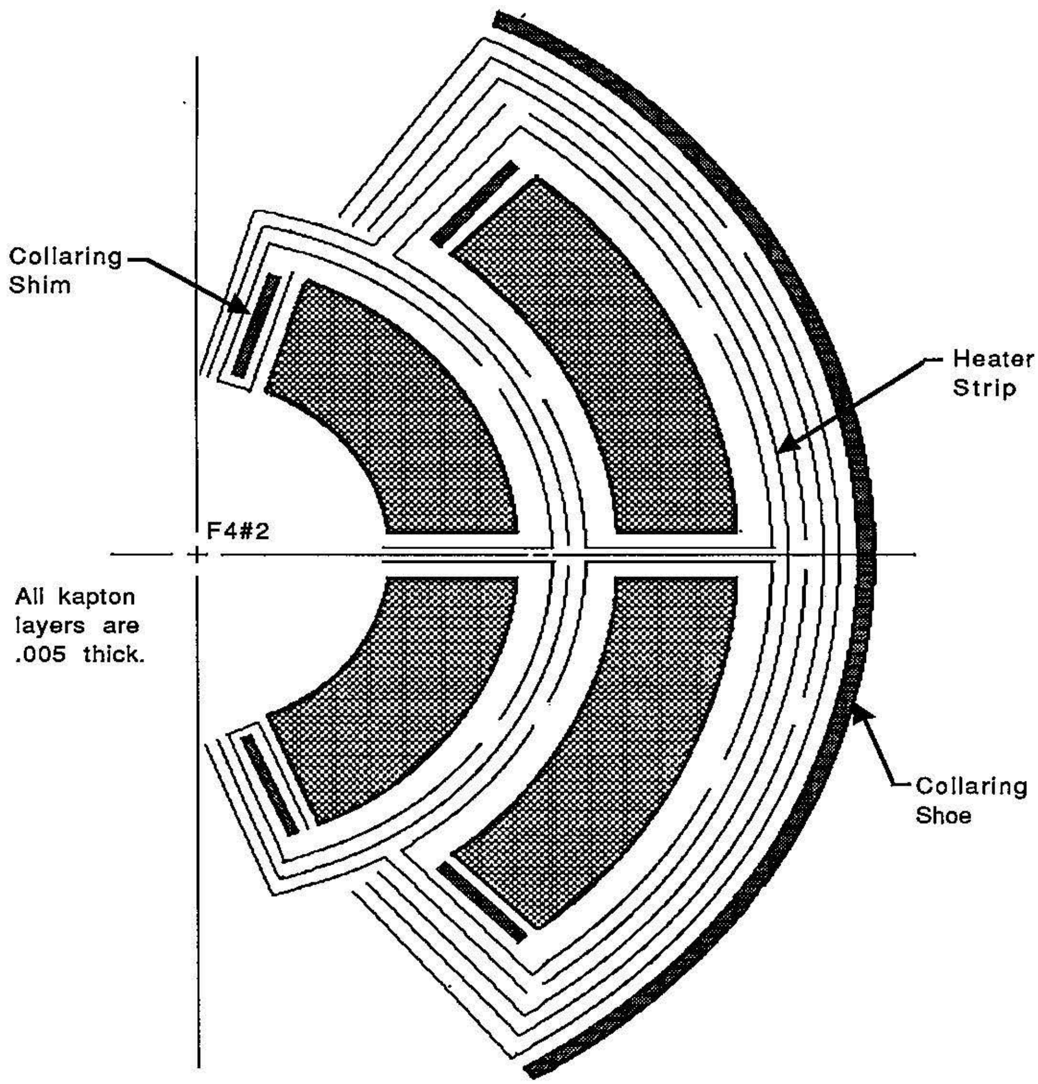
Connecting the inner coil kapton at the pole successfully prevented the inner coil collaring shim from moving inward. It did, however, create new problems. The kapton layers which cross the pole prevent the helium flow path needed to implement the Shutt-scheme for helium flow. They also cover the feature in the collars which is used to attach the beam tube.

On the outer coil, the joining of the collaring shoe and the collaring shim did not prevent the collaring shim from moving inward. The collaring shoe is split on the outer perimeter of the outer coil. The two collaring shoe halves were designed to come together when the magnet was closed. This did not happen. Kapton moved into the gap between the two halves. This caused the collaring shoe to "flow" around the corner at the pole, actually forming a new corner in the brass material. This made the collaring shim longer, driving it into the inner coil. The result; the same problem still existed.

Action to be Taken

F4 was collared with the coil insulation scheme shown in Figure 2. Half of the one meter straight section was potted and made into cookies. The other half will be decollared and cut in half. This will give us two ten inch long sections. Each of these sections will be recollared with different insulation schemes. These are shown in Figures 3 and 4. Both these schemes represent attempts to solve the problems we have encountered. Figure 3 uses a collaring shoe while Figure 4 does not.

Figure 3.) F4 #2 Coil Insulation



The insulation scheme in Figure 3 is an attempt to; 1.) retain the inner coil collaring shim while still allowing helium flow between the bore area and the collars and 2.) retain the outer coil collaring shim without eliminating the collaring shoe.

A new potential problem is created by using this configuration. The kapton layers are directly contacting the collar laminations at the pole. The sharp edges of the laminations could conceivably cause breakdown of these kapton layers. This could happen either during long term magnet storage or during magnet operation (over the course of many current cycles). Tests will need to be done to determine if Kapton breakdown will occur over time:

1.) Magnets will have to be built and repeatedly powered. The number of current cycles must equal the number to which an SSC magnet will be subjected times a reasonable safety factor.

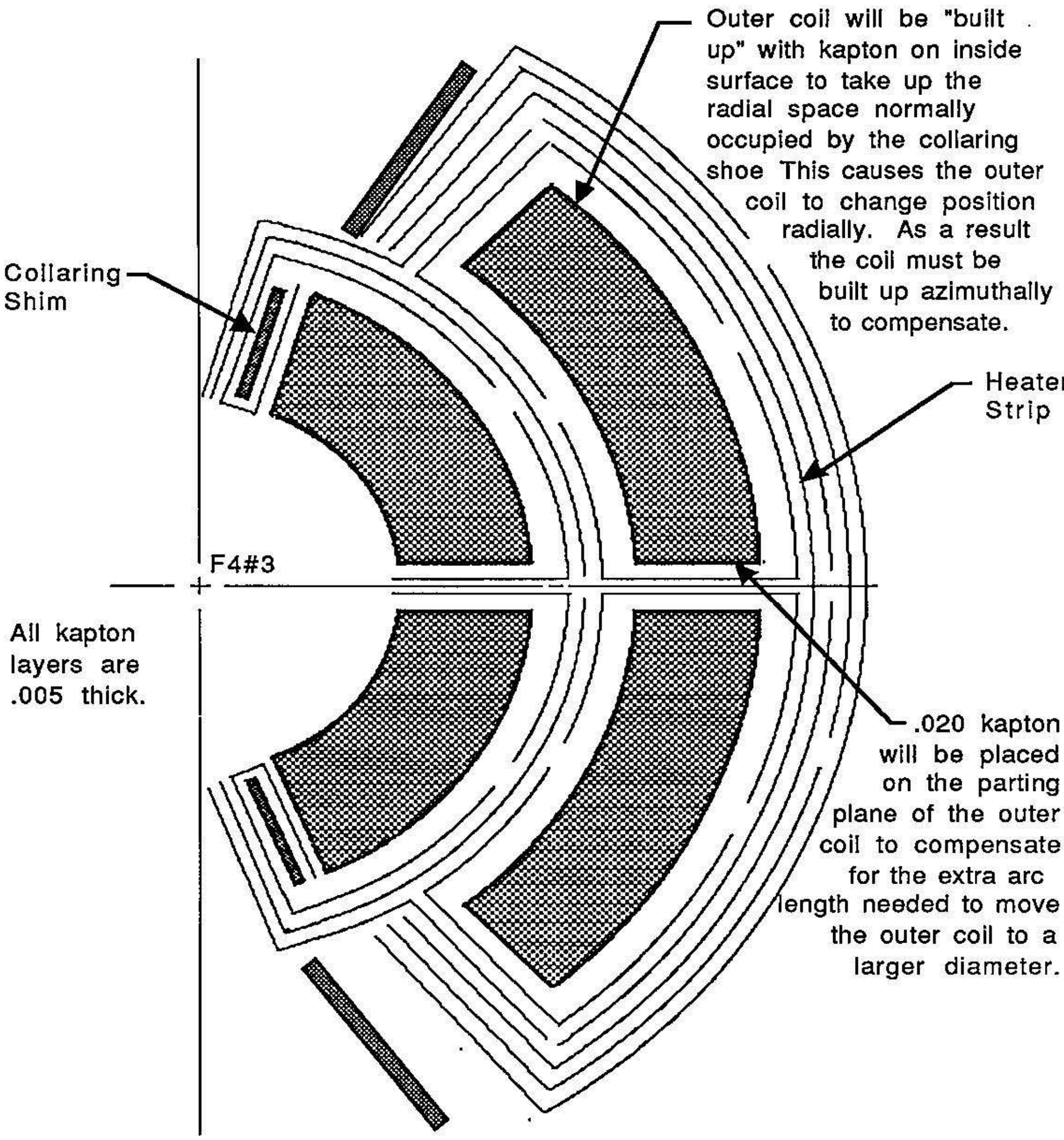
2.) Warm tests need to be done in which insulation is hipotted after being subjected to the maximum tolerable stress over long periods of time.

3.) Creep vs. time, temperature and pressure should be measured.

The insulation scheme in Figure 4 eliminates the collaring shoe. Many magnets have been successfully built at Fermilab (Tevatron, Low Beta Quad and others) without collaring shoes. No degradation of kapton in the areas where it contacts the collars has been observed.

This configuration has the smallest number of parts. It is therefore the most desirable alternative provided it accomplishes the objectives without causing any new problems. It would also have to be subjected to all the aforementioned warm and cold testing before being approved.

Figure 4.) F4 #3 Coil Insulation



After these sections have been collared they will be potted and cut into cookies. They will be examined to determine what the coil insulation scheme will be for the rest of the F series magnets.

Long Term Action

It is always desirable to eliminate as many non-essential parts as possible. We will build a magnet (time unspecified) without collaring shims. It will have to be subjected to all the warm and cold tests and autopsied to observe if there is any kapton degradation. This magnet will provide some insight into whether collaring shims are necessary at all.

Other Misc. Points

The action item refers to "insulation layers that appear to be used only as spacers". This statement refers to the F4 coil insulation scheme shown in Figure 2. There are kapton layers at the outer coil pole used only as spacers in this configuration. This was done because the collar laminations used were the only ones available. There are extra spaces due to the incompatibility between these laminations and our insulation scheme. These kapton layers exist only to fill these spaces and would not be part of a long term design.

It is possible that there are more kapton layers than necessary between the outer coil and the collars. All current designs use five layers. We must continue to use all five layers because we must fill the space within the present collar laminations. Eliminating these layers can be considered only if a new lamination is stamped.

The question of whether or not to extend the inner coil cap around the coil at the parting plane and pole tip has not yet been addressed. Tevatron magnets do not use this cap technique at the parting plane. The pole tip was effectively isolated from the coil by wrapping the ground insulation (multilayers of kapton) around the collar pole tip (although it was split in the middle to allow helium flow). Coil cap extensions of this type can easily be added later if necessary.

Collaring shims should be made full length (or as long as is practical). Difficulty in keeping the individual collaring shims in place on F2 and F3 has shown that the short collaring shims can cause serious problems.

Results and conclusions from the F4 insulation schemes

(This section was written on 5-24-89 after F4#2 and F4#3 were recollared, potted and sectioned.)

Results:

F4 :
- Solved inner coil shim problem while creating a new helium flow problem (see p.4).
- Did not solve outer coil collaring shim problem. Brass shoe/shim was pushed around the corner, driving itself into the inner coil.

F4#2
- Solved part of inner coil shim problem. Shims can no longer fall completely into the bore, but they still slip toward the bore during collaring. To use this scheme, however, it must be proven that direct contact with the collars does not cause long term deterioration in the kapton insulation and consequently ground shorts (see p.6).
- Seems to have solved the outer coil collaring shim problem. This scheme is subject to the same qualification about kapton deterioration described on p.6.

F4#3
- Solved part of the inner coil shim problem by a method identical to that of F4#2.
- Did not solve the outer coil shim problem.

Conclusions:

There are no apparent solutions that do not have drawbacks. The primary drawback to most solutions is the risk of ground shorts from direct contact between the kapton insulation and the collars.

An appealing solution to all these problems is the elimination of all collaring shims and shoes. This would not only eliminate all problems related to the shims and shoes but would also result in a cross section with less total parts.

There are two drawbacks to eliminating these parts:

1.) The shims can no longer be used for adjusting the azimuthal coil preload.

2.) Tests must be performed to insure that there is no significant ground short risk associated with the direct contact between the kapton insulation and the laminated surface.

All collaring shims and shoes will be eliminated from FNAL SSC short and long models. We can use these models to perform the testing necessary to prove or disprove the existence of the ground short risk. The preload adjustment, if it is necessary, can be done by adding kapton at the pole. Preload adjustment in any case is not an option for long term SSC magnet production. The coil must be made uniform enough to make preload adjustment unnecessary.