Disassembly of DSA323 Collared Coil

TS-SSC 91-045
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March 11, 1991

Introduction: A coil to ground short was discovered on March 5, 1991, during a 5 kV hi-pot of collared coil DSA323 while the magnet was in the yoking-skinning press, with iron and shell halves in place, before compression. All previous coil to ground hi-pots had been satisfactory, including those following end clamp installation.

At first the resistance between coil and ground was 250 kΩ. During tests with the collared coil still in the yoking-skinning press, the resistance varied. The initial reading on the morning of March 6, 1991 was 60 ± 5 kΩ. When the lead end plate was removed, with the coil still in the yoking-skinning press, the coil to ground resistance went to 29 kΩ.

Measurements done with the collared coil assembly out of the yoking-skinning press [1] showed that the short (resistance ~25 kΩ) was between the coil and the collar packs (or collaring shoes), *not* the coil and either of the end clamps. (No coil to collar short had ever occurred previously in the Fermilab series of SSC model and 17 m dipole magnets.) It was determined that the short was in the second turn from the pole in the lower outer coil, within the first or second non-lead end collar pack in quadrant III. (See Figure 1.)

Disassemby: On the morning of March 7, 1991, the end clamp caps at the lead and non-lead ends of the collared coil were removed. The initial coil to collar resistance was 13.5 kΩ.

The lead end can was removed, using the fixture designed for 50 mm aperture magnet end clamp removal by Howard Fulton. During the removal of the lead end can, the coil to collar resistance remained close to 13 kΩ.

Next, the return end can was removed. The coil to collar resistance dropped to 11.7 kΩ as the can was being pressed off, and then jumped to 200 ± 5 kΩ when the end can was dislodged.

The non-lead end quadrant III collet insulator was removed, and a visual inspection of the region near the calculated short location was made. (See Figure 2.) We suspected that the problem might be caused by the corner of the brass collaring shoe, which projects about 1/16" beyond the end of the collars. However, there was no obvious damage to the kapton insulator near the corner of the collaring shoe.

Clear impressions of the coils were visible in the outer kapton insulator layers. Axial stress marks in the kapton near the collaring shoe indicated high stress near the end of the collar packs.

By applying pressure at the corner of the collaring shoe with a sharp object, the coil to collar resistance could be made to change. However, this effect was difficult to reproduce, and was easily confused with complicated effects of the observer's body making alternate current paths during the measurement when parts of the metal table were touched.

The other collet insulators were removed from the non-lead end. The layers of kapton insulator were removed from the non-lead end of the coil. When the innermost layer of kapton insulator was removed from the non-lead end, the coil to collar resistance went from 195 kΩ to 135 kΩ.

As reported in reference [1], the short was expected to be located within the first collar pack from the non-lead end. For this reason, this pack was next removed by prying out the bronze keys with a mallet and screw driver. During this operation, the coil to collar resistance went up to 352 kΩ, and then to > 20 MΩ (off-scale on the Fluke DVM being used.)

"Wand" hi-pots [2] at 3 kV and 5 kV were done along the pole turn and second turn of quadrant 3 in the region of the removed collar pack. No current draw was observed, other than a .25 μA DC systematic effect.

Sections of the brass collaring shoe and kapton insulating layers closest to the return end of the coil were cut off to allow closer examination. A small burr could be felt on the corner of the collaring shoe nearest the calculated position of the short. Some creasing of the kapton insulator layers near this burr could be seen. However, there were no obvious holes, cracks, or black marks.

The remaining collar packs were removed from the coil assembly in the 84" collaring/yoking press, and "wand" hi-pots at 5 kV were performed on the quadrant 4 and quadrant 3 regions of the outer coil pole turn and second turn. No breakdown was observed.

Discussion: No obvious cause of the short was discovered, and no effects of arcing such as black deposits on the kapton insulating layers were seen. However, the burr on the collaring shoe is highly suspect, partly because of its close proximity to the calculated location of the short.

It is not clear that the collaring shoes fulfill their intended function of distributing the collaring load smoothly to the outer surface of the outer coil. The collaring shoe is distorted during keying, especially at the ends where the shoe projects beyond the end of the collared section, and at the midplane where the collar laminations don't press directly on the shoe.

Collaring shoes removed from DSA322 show azimuthal creases which match the collar laminations.

It might be interesting to build a 50 mm aperture model magnet without the collaring shoe, or with the collaring shoe but allowing the shoe to project all the way to the end of the coil assembly, so that there would be no end effect close to the end of the collared section.

Disposition: Since no clear cause of the short was determined by these investigations, it was decided to take a conservative approach; DSA323 will be rebuilt from its component coils, with all new insulation and collaring shoes.

Notes

1. TS-SSC 91-044, "Location of Coil-to-Ground Short," Jim Strait, March 6, 1991.

2. A wand hi-pot is done in the following manner. The high voltage lead of the hi-pot supply is connected to one of the coil leads. The low voltage lead is connected to a metal rod ~ 1" long and ~ 1/4" in diameter, which is attached to a G10 "wand." The rod may then be dragged up and down the surface to be hi-potted. (See Figure 3.) This technique has proved useful for finding areas in kapton insulator susceptible to breakdown.

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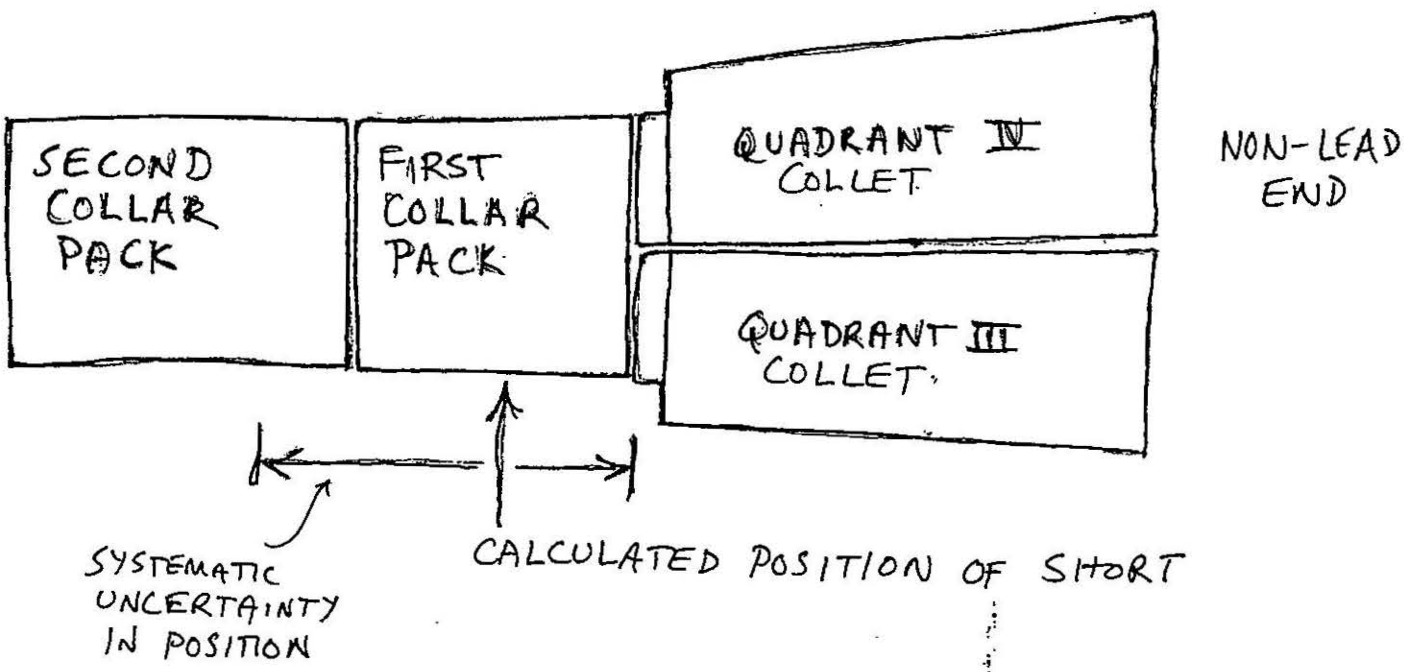
SECOND COLLAR PACK
FIRST COLLAR PACK
QUADRANT IV COLLET
QUADRANT III COLLET
NON-LEAD END
SYSTEMATIC UNCERTAINTY IN POSITION
CALCULATED POSITION OF SHORT

FIGURE 1

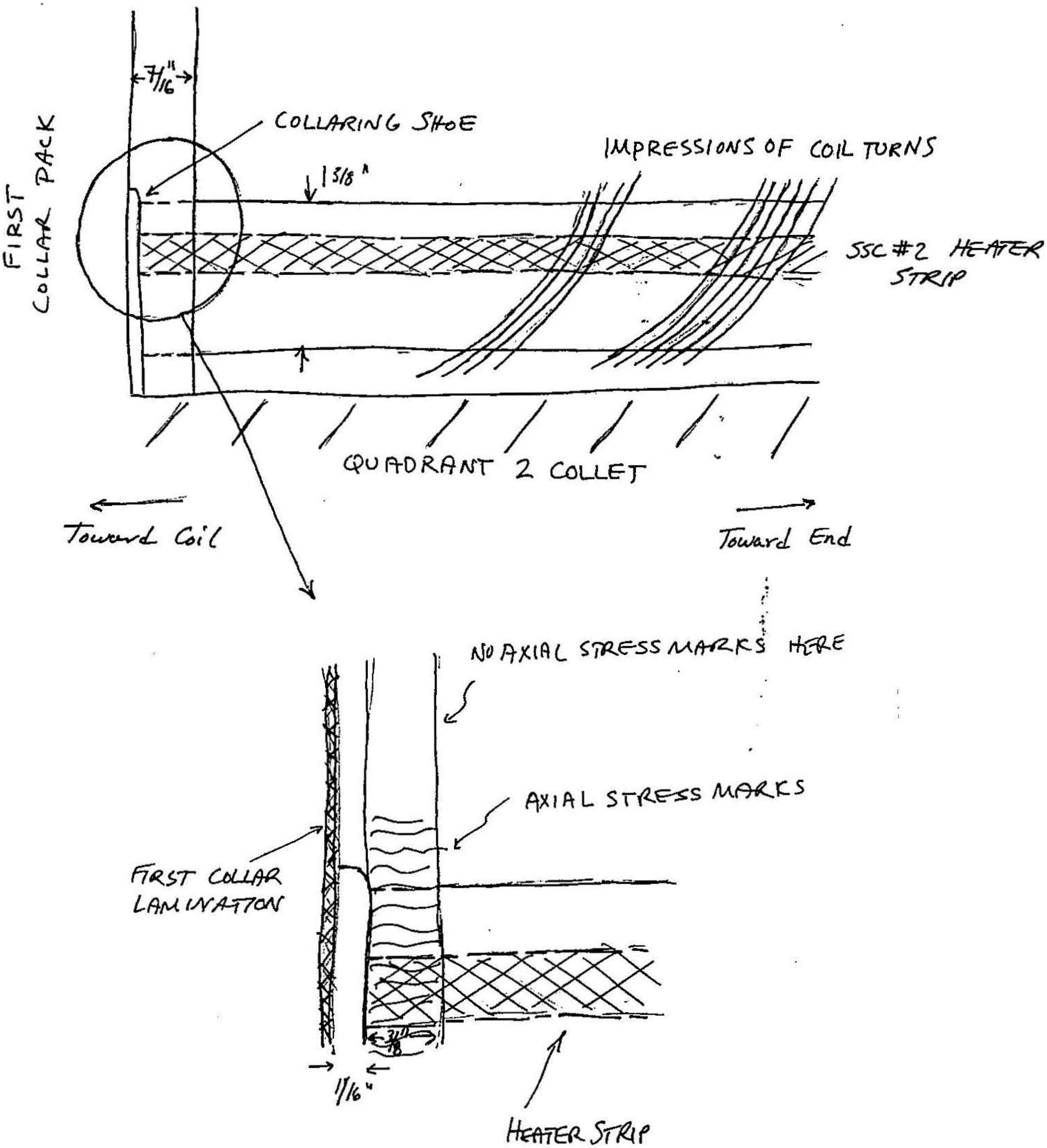
7/16"
COLLARING SHOE
FIRST COLLAR PACK
1 3/8"
IMPRESSIONS OF COIL TURNS
SSC #2 HEATER STRIP
QUADRANT 2 COLLET
Toward Coil
Toward End
NO AXIAL STRESS MARKS HERE
AXIAL STRESS MARKS
FIRST COLLAR LAMINATION
3/8"
1/16"
HEATER STRIP

FIGURE 2

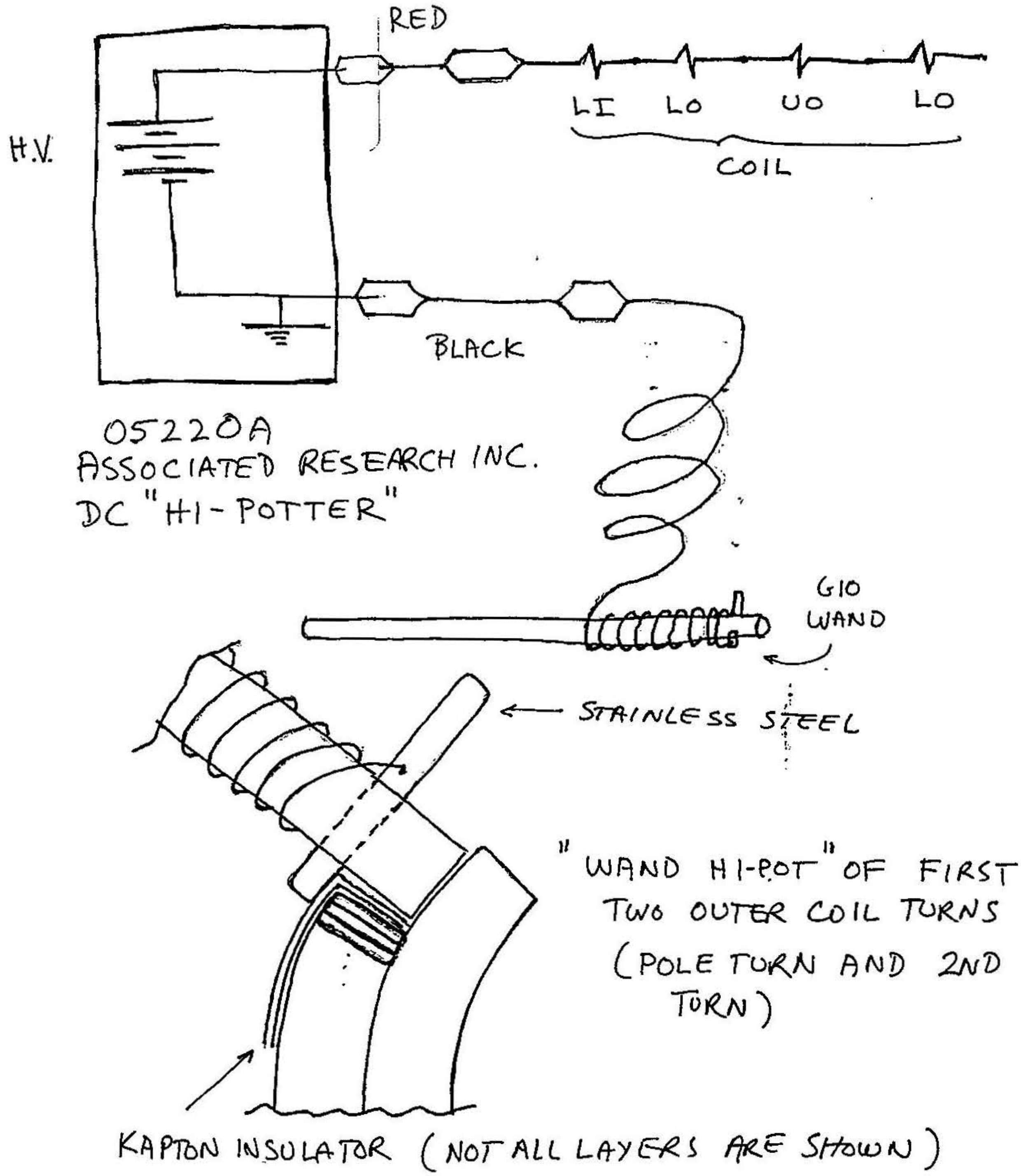
RED
LI
LO
UO
LO
COIL
H.V.
BLACK
05220A
ASSOCIATED RESEARCH INC.
DC "HI-POTTER"
G10
WAND
STAINLESS STEEL
"WAND HI-POT" OF FIRST TWO OUTER COIL TURNS (POLE TURN AND 2ND TURN)
KAPTON INSULATOR (NOT ALL LAYERS ARE SHOWN)

FIGURE 3