DCA317 Coil 1007 Turn-to-Turn Short II

TS-SSC 91-233
December 3, 1991
S. Delchamps

This and TS-SSC 91-207 both deal with the turn-to-turn short in coil 15M-50-1007, the upper inner coil of magnet DCA317, which occurred during the first installation of the DCA317 lead end clamp. The original discrepancy report is DR-267 attached to this report as Appendix 1.

1. Initial Report (TS-SSC 91-207): TS-SSC 91-207 documented the voltage tap data taken at the time the turn-to-turn short occurred. A calculation of the location of the turn-to-turn short based on those data was given. The calculated short location was at the lead end, just inside the end clamp, between the segments 18B-18A and 17B-17A, The calculated position of the short was about 8 inches from tap 18 B in the direction of 18 A. (See Figure 1.)

One of the figures in TS-SSC 91-207 had an error (the turn 18 and turn 17 voltage taps were transposed.) The corrected version of this figure is now filed with 91-207. A more important short-coming was that the voltage tap relative positions had to be estimated from drawing 0102-MC-292211. Furthermore, a fairly cumbersome calculational technique was used to find the short location.

2. Preliminary Investigations: The investigations described in this section were made between October 28 and November 11, 1991. (A detailed chronology is attached to this report as Appendix 2.)

The short dissappeared after the lead end clamp was removed. The magnet was disassembled, and the coil 15M-50-1007 was set up on an inspection table. A Valhalla 4-wire resistance measurement gave 1091 mOhms (within 1 mOhm of nominal) for the coil resistance. A pair of teflon squeezing fixtures was used to squeeze the coil in the region of the lead end key. The short did not return.

The outside of the coil near the lead end was examined visually. No metal chips or popped strands were seen. However, there were three spots near the tightest part of the turns on the outside of the key that appeared to have bare or nearly bare copper conductor. To make it possible to examine the inner side of the coil, the RTV holding down the voltage tap wires on turns 17 and 18 near the lead end key was removed. The lead end key was removed, and the hydraulic sizing fixture was used to squeeze the coil azimuthally. The turn with 19A was separated from the turn with 18A (see Figure 2) along about six inches of length to make it possible to squeeze on both sides of the key. The short did not return in any of these tests.

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A small dark spot was seen underneath the b-stage close to the predicted position of the short. During this time, the location of the short had been recalculated, using measured positions of the 18A,B and 17A,B voltage taps. The calculated values were consistent with the initial calculations, and were consistent with the location of the dark spot. Pressing in the vicinity of the dark spot did not bring back the short.

3. Mock End Clamp Installation: On November 13, a set of coil sections and an end clamp were set up together with 15M-50-1007 to imitate end clamp installation. When this was done, the turn-to-turn short came back. Data were taken with 1 Amp constant current from Valhalla meter 32-839. These data are referred to as Data Set II, and are given in Table 1. A final set of data, Data Set III in Table 1, were taken with 1 Volt constant voltage applied to the coil. The end clamp fixture was then removed, and the short disappeared.

4. Final Inspection and Repair: On November 19, 1991, a final inspection and repair plan was specified. This plan was carried out with the exception of several steps. The plan is attached to this report as Appendix 3.

The 18A turn was parted from the 17A turn along about six inches of its length. No metal flakes, bare conductor, strand misplacement, or any other short-producing features were found. A small piece of material was removed, but this turned out to be non-metallic.

Two layers of 1 mil kapton were placed between the 19A turn and the 18A turn. Three layers of 1 mil kapton were placed between the 18A and 17A turns.

The mock end clamp fixture was installed, and the short did not return. The fixture was then removed, and the repair was made permanent by applying a thin layer of Sicomet adhesive to the inside and outside radius surfaces of the coil over the kapton. The cement and RTV covering of the voltage taps on the inner side of coil were replaced. Figure 2 shows these repairs.

A final electrical checkout of the coil was performed. The resistance and voltage tap readings are in Table 2, and the resistance and inductance values are given on the same page.

5. Graphical Determination of Short Location: During the final inspection and repair, accurate measurements of a subset of the voltage tap positions along the coil were made. These measurements are tabulated in the first column of Table 1. Figure 3 shows a plot of the Data Set III voltage tap readings versus position coordinate along the coil relative to tap 19A. The voltage taps are labeled on the drawing. The C and D taps and A and B taps for each turn lie within about 10 inches of each other and so are difficult to distinguish on the graph.

The full current flows in the segment 19A-19C-19D-18B. The change in slope near tap 18B indicates that less than the full current is flowing through segment 18A-18C-18D-17B. (Close examination of the Table 1 data make it clear that the short occurs *after* tap 18B and *before* tap 18A.) The slope becomes normal again after tap 17B, indicating that the current flowing in the segment 17B-17C-17D-16B is the full current.

Linear fits to the data in these three segments were made for Data Sets I, II, and III. The intersections of the "left-center" and "right-center" pairs of lines give two coordinates along the cable where the turn-to-turn short occurs. (Of course, these two coordinates really correspond to the same position in space, where the short is located.) Table 3 gives the positions for Data Sets I, II, and III, as well as the average over the three sets of data. The final row in Table 3 shows the calculated distance of the short in inches from taps 17A and 18A. The difference between these two distances is 1.4 inches, and the actual distance between 17A and 18A on the coil is about 1 inch.

A complete error analysis, complicated somewhat by the presence of non-negligable uncertainties in the positions as well as the voltages, has not been performed for these data.

6. Conclusion: Coil 15M-50-1007 was repaired after suffering a turn-to-turn short, and may be used in DCA317. However, no clear cause of the turn-to-turn short was ever found. Magnet DCA318 has a similar turn-to-turn short [2] in the same region (upper inner coil at the lead end, just inside the end clamp.) This may indicate a problem with lead end clamp installation.

References

1. S. Delchamps, "Turn-to-Turn Short in DCA317", TS-SSC 91-207, October 25, 1991.

2. J. Strait, "Location of turn-to-turn short in DCA318", TS-SSC 91-234, November 27, 1991.

Voltage Tap Names and Positions Relative to 19A (inches)	Voltage from tap 0A (Data Set I) (Volts) [constant 1Amp applied to coil]	Voltage from tap 0A (Data Set II) (Volts) [constant 1Amp applied to coil]	Voltage from tap 0A (Data Set III) (Volts) [constant 1Volt applied to coil]
19B	1.04520	1.05399	0.997??
19A 0	1.04495	1.03718	0.98147
19C 573.079	1.01691	1.00919	0.95485
19D 583.886	1.01638	1.00866	0.95426
18B 1161.287	0.98846	0.98101	0.92821
18A 1173.256	0.98801	0.98050	0.92775
18C 1749.631	0.98109	0.97608	0.92398
18D 1759.080	0.98097	0.97601	0.92391
17B 2335.867	0.97405	0.97173	0.92063
17A 2346.261	0.97381	0.97153	0.92054
17C 2922.497	0.94582	0.94356	0.89363
17D 2930.784	0.94542	0.94315	0.89336
16B 3507.981	0.91737	0.91527	0.86712
16A	0.91692	0.91482	0.86668
16C	0.88890	0.88681	0.84009
16D	0.88850	0.88640	0.83963
15B	0.86041	0.85846	0.81331
15A	0.85998	0.85803	0.81292
15C	0.83202	0.83008	0.78627
15D	0.83140	0.82946	0.78575
14B	0.80354	0.80172	0.75949
14A	0.80286	0.80105	0.75892
14C	0.77502	0.77321	0.73241
14D	0.77446	0.77266	0.73184
13B	0.74655	0.74486	0.70566
13A	0.74594	0.74425	0.70566??

Table 1. Voltage Tap Readings with Turn-to-Turn Short Present in coil 15M-50-1007

Voltage Tap Name	Voltage from tap 19B (Volts) [constant 1Volt applied to coil]
19A	.000423
19C	.025990
19D	.026468
18B	0.52072
18A	.052597
18C	.078195
18D	.078614
17B	.104301
17A	.104762
17C	.130405
17D	.130775
16B	.156514
16A	.156920
16C	.182573
16D	.182971
15B	.208768
15A	.209144
15C	.234780
15D	.235363
14B	.260950
14A	.261601
14C	.286625
14D	.287064
13B	.31316
13A	.31373

Table 2. Voltage Tap Readings after Repair in coil 15M-50-1007

Final coil readings: R = 1090.3 mOhms
Ls = 3.029 mH
Q = 2.10

	left - center intersection (inches)	right - center intersection (inches)
Data Set I	1168.2	2343.1
Data Set II	1168.1	2342.9
Data Set III	1169.4	2343.0
Average ± RMS	1168.6 ± 0.7	2343.0 ± 0.1
Distance from 18A and 17A taps	4.7 inches	3.3 inches

Table 3. Predicted Short Locations from Data Sets I, II, and III
(Refer to Section 5 of the text and Figure 3.)

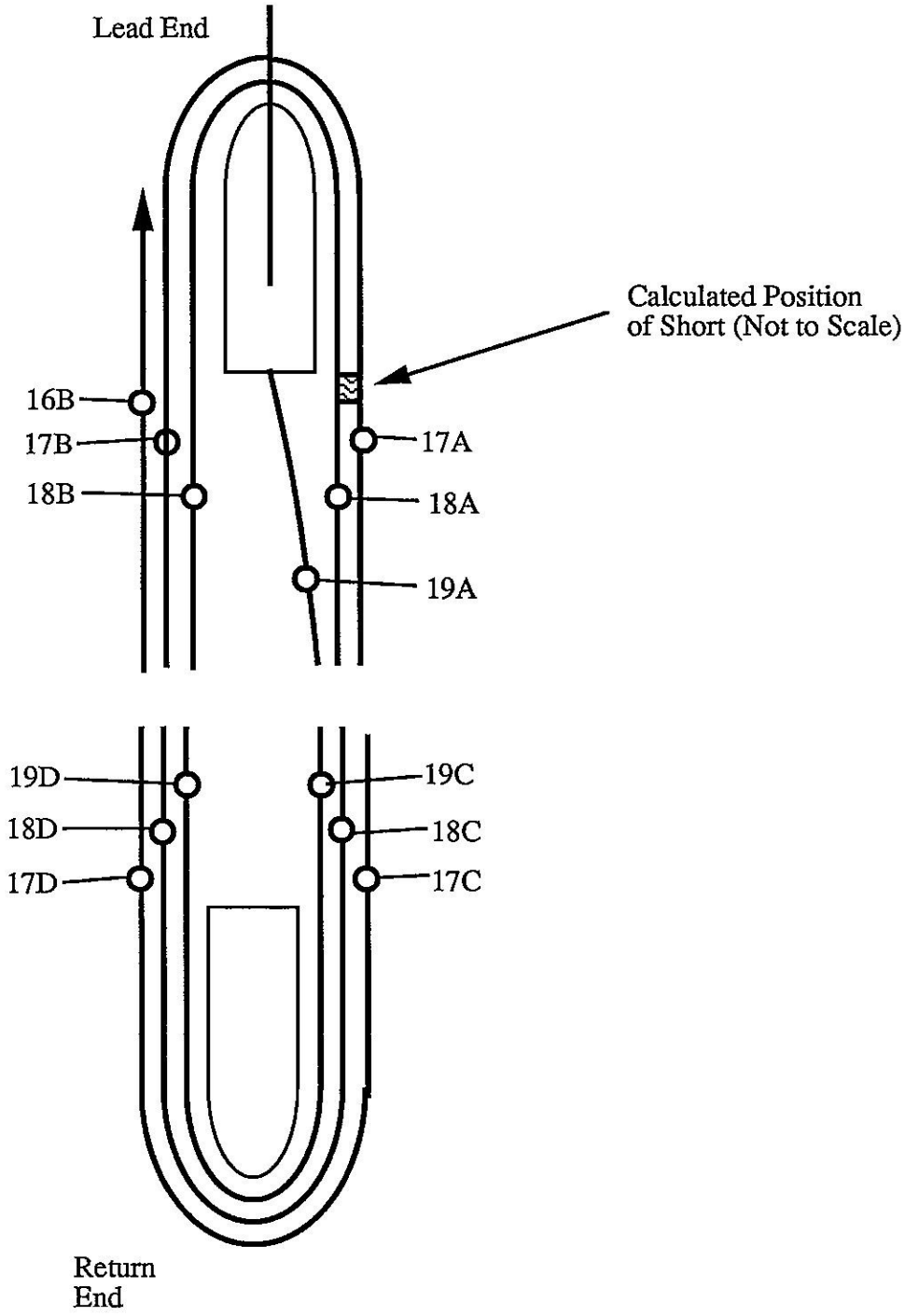

Lead End
Calculated Position
of Short (Not to Scale)
16B
17B
18B
17A
18A
19A
19D
18D
17D
19C
18C
17C
Return
End

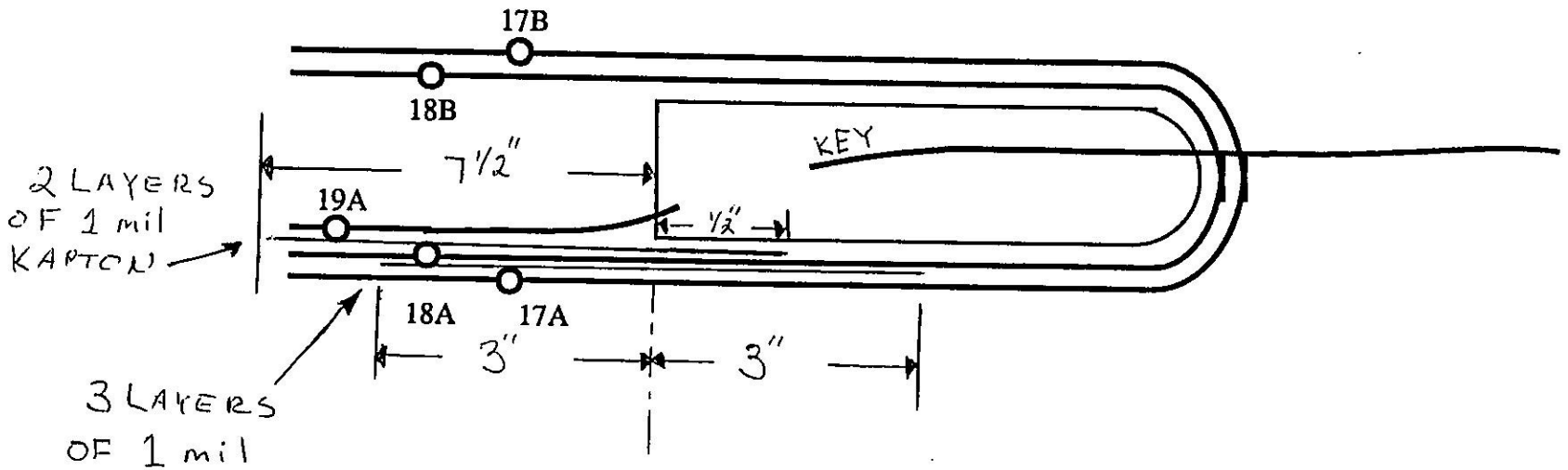
FIGURE 1

11/27/91

Andrew Wendt / Scott Lockwood

Coil # 15M-50-1007

FIGURE 2



A THIN LAYER OF SICOMET ADHESIVE WAS APPLIED TO THE INSIDE AND OUTSIDE RADIUS SURFACES OF THE COIL OVER THE KAPTON TO HELP BOND THE COIL BACK TOGETHER AND TO HOLD THE KAPTON IN PLACE.

15M-50-1007 Coil Voltage Tap Data

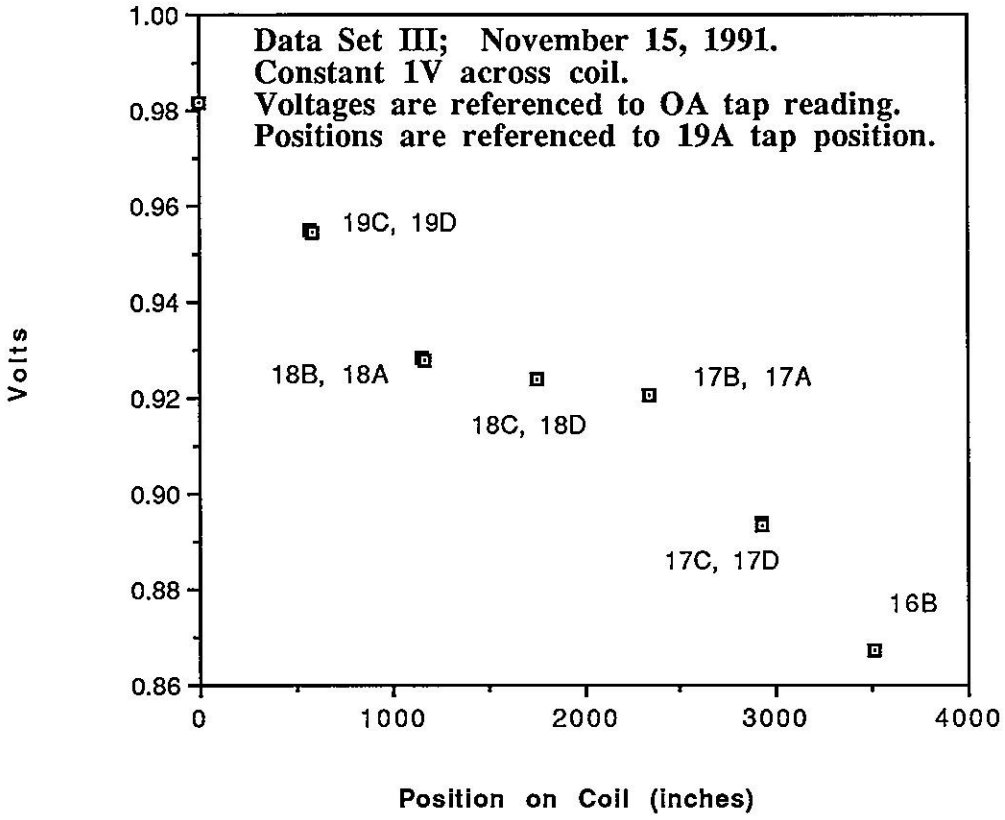


FIGURE 3

APPENDIX 1

FNAL/SSC DISCREPANCY REPORT

Traveler Title:	2) Traveler No.:	3) Rev. No.:	4) DR No.:
End Clamp Assembly	ES-298290	E	267

5) Step No.:	6) Drawing/Revision No.:	7) Magnet/Coil Serial No.:	QA Assigned: Class: (I) or II
4.14	MD-292161	DCA-317	

8) Nonconformance Description by First Hand Observer:

While installing the End Clamp, the mΩ dropped from 5796 mΩ to 5758 mΩ. The reading for each coil is: Lower Outter 1807 mΩ, Upper Outter 1807 mΩ, Lower Inner 1090 mΩ, and Upper Inner 1051 mΩ.

9) Name Doug Lipsey Title: QA Tech Date: 10/24/91

10) Cause of Nonconformance:

COPY

Steve,
You need to look into this DR. It appears to be a turn to turn short. They are work stopage now, till you give a Disposition. Doug

11) Responsible Authority/Physicist Date:

12) Disposition:

Original in Traveler.

11) Responsible Authority/Physicist Date:

13) Corrective Action to Prevent Recurrence:

14) Responsible Authority/ Physicist Title: Date:

15) Corrective Action/Disposition Verified By:

11) Responsible Authority/Physicist Date:
Class: I or II
Will Configuration be effected? [ ] Yes [ ] No

16) Approved By:
QA/QC Project Manager Date:

17) Reviewed By:
SSCL Q.A. Engineer Date:

Appendix 2. History of DCA317 Turn to Turn Short (Mondays are shown in bold print.)

Oct 24: Short appears during lead end clamp installation
Oct 25: Complete voltage tap readings taken (**DATA SET I**) with 1A from Valhalla meter.**TS-SSC 91-207** published.

Oct 28 - Nov 1: End clamp removed; short disappears. DCA317 coil 1007 gets set up on aluminum table. Little formal work done on finding the short.

Nov 4: Squeeze end of coil with various fixtures; visual inspection.
Nov 5: More visual inspection. Short has still not reappeared.
Nov 7: Small "dark spot" on inside surface of coil discovered.
Nov 8: Careful measurement of 18A, 18B, 17A, 17B voltage tap positions relative to each other and black spot

Nov 11: still trying to make short reoccur with fixtures
Nov 13: Mock end clamp fixture installed; short reappears; data taken with 1A constant current from Valhalla meter (**DATA SET II**)
Nov 14: Various unsuccessful attempts at voltage tap measurements with higher currents
Nov 15: 1V constant voltage data set taken (**DATA SET III**); end clamp fixture removed (short disappeared)

Nov 18: physicist unavailable; end clamp fixture being removed, coil being prepared for inspection
Nov 19: Further coil test plan specified (Appendix 3 of this report) Accurate position measurements of voltage taps made
Nov 20: Turns parted; foreign matter found; insulator installed between parted turns; foreign matter was non-metallic, probably just a b-stage flake
Nov 21: Mock end clamp fixture installed again; short does not come back; Mock end clamp fixture removed
Nov 22: Continuation of making repair permanent

Nov 26: continue repairs; Thursday - Sunday holiday.

Dec 2: Repairs now complete, including an electrical check. Impulse testing is planned before installation in DCA317.

Appendix 3. Coil 1007 Test Plan for November 19, 1991

(Remarks are shown in bold print.)

1) Examine outside of coil with microscope in shorted region. Record any strange looking locations below. **Dan Smith led this inspection. Actually, the inside of the coil was inspected first since that was the way the coil was turned. While there were several small dark spots, they turned out to be merely discolorations of the b-stage.**

2) Turn coil over.

3) a- Examine inside of coil w/ microscope. Record strange locations below.
b- Measure positions of voltage taps 19B, 19C, 19D, 18B, 18A, 18C, 18D, 17B, 17A, 17C, 17D, 16B. **This was done on November 19.**

4) Recalculate short location. **When this was done, the calculated short location was still about 8 inches from 18B in the direction of 18A.**

5) Squeeze radially in any suspected regions. **This was not done because it would have meant squeezing the voltage tap solder points.**

6) Squeeze axially in turn-around section. **This was not done.**

7) Part turns in suspected region, with white tape to catch any debris. **When the sections between 18A and 17A were parted, several small dark pieces of material were found, but none of these were obvious causes of the short. The one small chip-like piece that was saved (by Wally Zimmerman) didn't even look like metal on close examination.**

8) Insert two 1 mil kapton sheets. **This was revised to the following: Two layers of 1 mil were placed between the preform turn and the turn with 18A. Three layers of 1 mil were placed between the 18A turn and the 17A turn. The kapton pieces were about 6 inches long.**

9) Re-install end clamp to see whether short comes back. **This was done on November 21. The short did not come back. The technicians were instructed to remove the mock end clamp assembly.**