Turn-to-Turn Short in DCA317

TS-SSC 91-207
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During the installation of the lead end clamp of DCA317, a turn-to-turn short appeared in the upper inner coil. The resistances of the four coils before and after the short appeared are shown in Table 1. These resistances are from 4-wire measurements with Valhalla meter 32-839.

Coil	R before short (mOhms)	R after short (mOhms)
Upper Inner (1007)	1090	1049
Upper Outer	1808	1809
Lower Outer	1808	1808
Lower Inner	1090	1091

Table 1. Quarter Coil Resistances Before and After Short

(Note that the test current of .1 A was flowed through the entire magnet, so that any short between the upper inner and upper outer coils would have been detected.)

Table 2 shows measurements taken with 1 A test current flowing through the upper inner coil, number 1007. The voltage drop between tap 0A (the magnet lead tap) and each of the voltage taps (first column) is given in the second column.

The voltage drops between tap pairs 18A-18C and 18D-17C are not as large as they would be if all of the current were flowing in these sections. Some of the current has been diverted through a resistive short between the sections 18B-18A and 17B-17A as shown in Figure 1.

I would like to acknowledge the assistance of Denis Gaw in these measurements.

Distribution: R. Bossert, J. Carson, S. Gourlay, W. Koska, G. Pewitt, J. Strait, M. Wake, V. Wolf

Voltage Tap Name	Voltage 0A to tap (Volts)	V(A-C) and V(D-B) (Volts)	d(A-C) and d(B-D) (inches)	resistivity (mOhm/ inch)
19B	1.04520 ± .00001			
19A	1.04495	.02804	573.75	**4.887 e-2**
19C	1.01691			
19D	1.01638	.02792	574.50	4.860 e-2
18B	0.98846			
18A	0.98801	**.00692**	575.25	**1.203 e-2**
18C	0.98109			
18D	0.98097	**.00692**	576.00	**1.201 e-2**
17B	0.97405			
17A	0.97381	.02801	576.75	4.857 e-2
17C	0.94582			
17D	0.94542	.02805	577.50	4.857 e-2
16B	0.91737			
16A	0.91692	.02802	578.25	4.846 e-2
16C	0.88890			
16D	0.88850	.02809	579.00	4.851 e-2
15B	0.86041			
15A	0.85998	.02796	576.75	4.848 e-2
15C	0.83202			
15D	0.83140	.02786	574.50	4.849 e-2
14B	0.80354			
14A	0.80286	.02784	575.25	4.840 e-2
14C	0.77502			
14D	0.77446	.02791	576.00	4.845 e-2
13B	0.74655			
13A	0.74594			
				4.850 ±.007 e-2

Table 2. Voltage Tap Measurements from DCA317

Resistance per Unit Length: To help determine the location of the short, let us first consider the resistance per unit length ("resistivity") of the cable as inferred from the voltage tap readings in the properly functioning part of the coil and the known distances between voltage taps. To do this, we obtain the voltage drops for all of the straight section runs between taps, shown in the third column of the table. These are 18A to 18C, 18D to 17B, 17A to 17C, and so on.

Since the current from the Valhalla is 1.000 A, the resistance per unit length between any two taps is the voltage drop divided by the distance between the two taps. The distances are shown in the fourth column; they are from drawing 0102-MC-292211. The resistivities are shown in the fifth column of the table.

At the bottom of the last column, the average resistivity for the coil is given. This is the mean and r.m.s. for all the non-bold values in the last column. The value calculated from the 19A to 19C run seems to be an "outlier" (it is 5.2 r.m.s's away from the mean), and was not included in the average. The 18A-18C and 18D-17B sections do not have 1.000 A, and so are left out of the average. The r.m.s. of the resistivity is probably dominated by uncertainties in the actual voltage tap positions.

The calculated resistivity 4.850±.007 e-2 mOhm/inch is several r.m.s. away from the traveller value 4.888 e-2 mOhm/inch (obtained by dividing the coil resistance after winding by the length of the conductor used. The QC value from the traveller is 4.833 e-2 mOhm/inch, so that the value obtained here is bracketed by the two previous values.

Fraction of Current Through the Short: Now that the resistivity per unit length has been determined, we may infer what fraction of the current flows through the "short" between the 18B-18A and 17B-17A stretches. This is simply unity minus the ratio of the measured resistivity in the 18A-18C and 18D-17B stretches to the actual resistivity. Therefore,

Fraction of current through "short" = 1 - (1.202±.001 e-2)/(4.850±.007e-2)

= 0.752 ± .001

So 75.2% of the current flows through the short, and 24.8% of the current flows through the "normal" path, around to 18A and onward to 18C, 18D, and 17B.

Location of Short: Next, consider the diagram in Figure 1. Let L be the distance in inches between the voltage taps 18B and 18A. The distance l_short is the distance from tap 18B to the resistive short. Between 17B and 17A we have L - 1.5", if we neglect the small difference in radii of curvature for the first and second turns. To find L, we assume that it is also the distance between taps 19C and 19D at the return end of the magnet (again ignoring an effect of the radius of curvature.) This latter distance is then obtained from

$$d(19C - 19D) = (V(19C) - V(19D)) / (4.850 \pm .007\text{ e-2})\text{ inches}$$

$$= 10.9 \pm 0.3\text{ inches}$$

So L is 10.9 ± 0.3 inches. Now consider Figure 2. We can obtain values for l_short from consideration of either the 18B-18A or 17B-17A voltage difference. From the 18B-18A difference:

$$(.98846 - 98801) = (1.000 \times Rho \times l\_short) + (.248 \times Rho \times (L - l\_short))$$

Substituting values for Rho and L, we obtain

l_short = 8.7 inches, or about 80% of the way around from 18B to 18A. From the 17B-17A voltage difference:

$$(.97405 - .97381) = (.248 \times Rho \times (l\_short-.75")) + (1.000 \times Rho \times (L - l\_short - .75"))$$

and we obtain

l_short = 6.6 inches.

Taking the average of these two values, the short can be predicted to lie **7.7±1.5 " from voltage tap 18B in the direction of voltage tap 18A.** This puts the short in the lead ramp splice side of the coil in the straight section of the coil but still inside the end clamp. (About 3" of straight section are contained by the end clamp.)

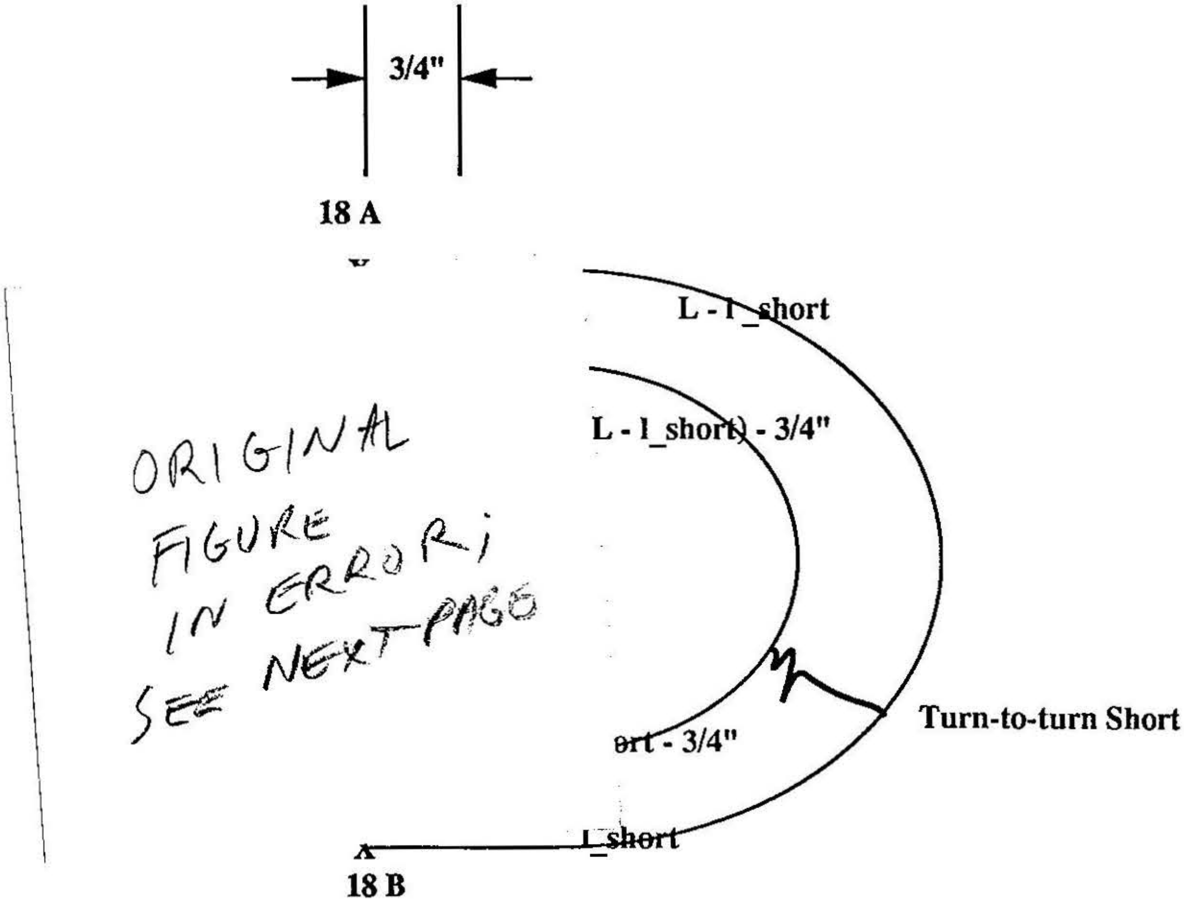
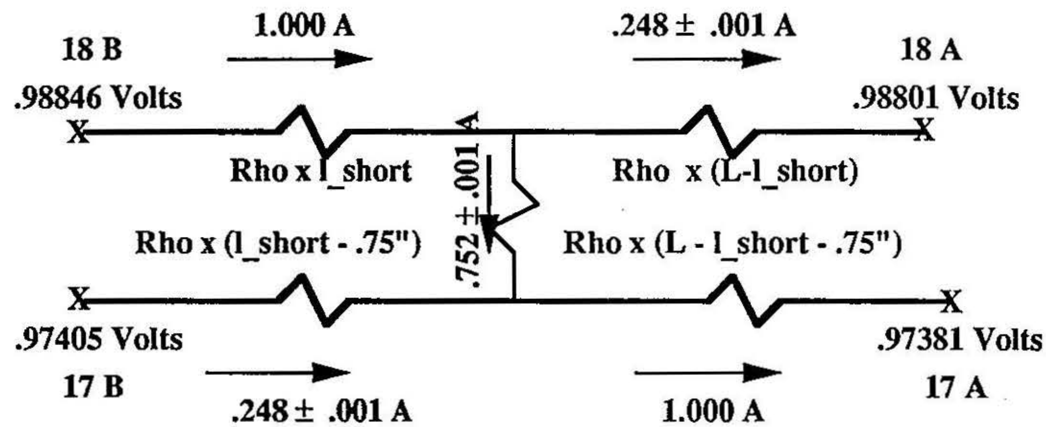
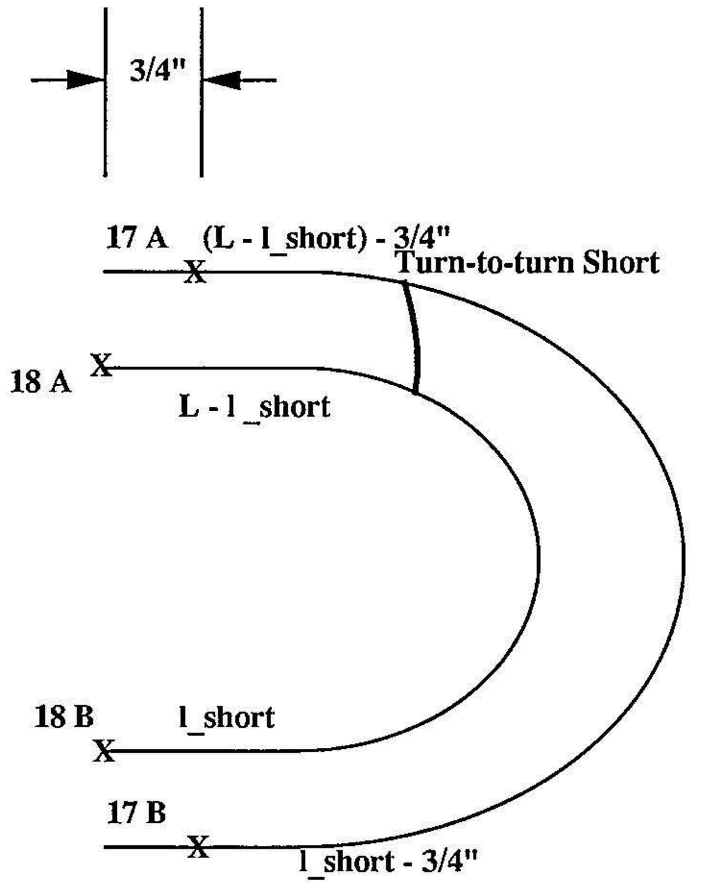


Figure 1. Location of Voltage Taps Near Resisistive Short



(Rho = 4.850 ± .007 e-2 mOhms / inch)

Figure 2. Network in Neighborhood of Resistive Short



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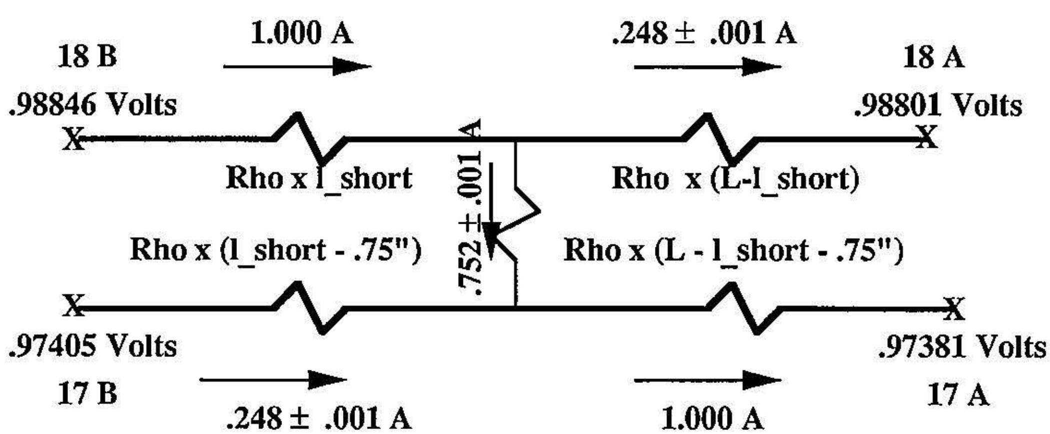

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