Fermilab

TS-SSC 91-010
1/18/91

To: J. Carson, W. Koska

From: Jim Strait

Subject: Location of DC0303 upper-lower coil short by resistance measurements

To determine the location of the internal short a series of resistance measurements were made using the Valhalla temperature compensated ohmmeter. Current was passed through the whole coil and the voltages across the whole coil and each of the quarter coils was recorded. To minimize the power dissipated in the short the meter was set to 0.1 Amp output. The apparent of that required to make a complete measurement set, so data were recorded only to the nearest mΩ (0.1 mV). To check the internal consistency of the measurement the whole coil voltages was recorded immediately before and after the quarter coils and compared with the sum of the quarter coil voltages. The data are displayed in Table I.

Table I
Coil Voltages at 0.1 A

Coil	Voltage
Whole Coil	81.0 mV
Upper Inner	15.5 mV
Upper Outer	21.2 mV
Lower Outer	21.2 mV
Lower Inner	23.3 mV
Whole Coil	81.1 mV
Σ(Quarter Coils)	81.2 mV

The apparent outer coil resistances are identical to each other but the apparent inner coil resistance differ significantly from each other. This, together with the small total coil resistance (0.81 Ohms versus 6.59 Ohms before the short occurred) strongly suggests that the short is at the mid-plane of the inner coil.

To determine the short location the coil and short were modeled as the resistor array shown in Figure 1. The values of the quarter coil resistances are known from measurements recorded in the traveller[1] and are displayed in Table II. The values of the unknown resistances R_A and R_B is determined by solving the following equations:

$$V_{UO} + V_{LO} = I_C(R_{UO} + R_{LO})$$

$$V_{UI} = IR_A + I_C(R_{UI} - R_A)$$

$$V_{LI} = IR_B + I_C(R_{LI} - R_B)$$

These have the solutions:

$$I_C = (V_{UO} + V_{LO}) \;/\; (R_{UO} + R_{LO}) = 11.13 \text{ mA}$$

$$R_A = (V_{UI} - I_C R_{UI}) \;/\; (I - I_C) = 0.9 \text{ m}\Omega$$

$$R_B = (V_{LI} - I_C R_{LI}) \;/\; (I - I_C) = 88.1 \text{ m}\Omega$$

Table II
Quarter Coil Resistances.

Upper Inner	1.386 Ω
Upper Outer	1.902 Ω
Lower Outer	1.908 Ω
Lower Inner	1.390 Ω

The cable used in the two inner coils has a resistance of 0.803 mΩ/ft. This places the short approximately 1 foot from the upper inner lead and 110 feet from lower inner lead. The roughly ±0.1 mV uncertainty in the voltage measurements translates into an uncertainty of roughly ±1 mΩ R_A and R_B and of ±1 foot in the distances to the short. Therefore the sum of the two distances is, within the measurement uncertainty, equal to the 109 foot length of the mid-plane turn, suggesting that the one short model in Figure 1 is correct.

Between the point where the ohmmeter clip leads were attached and the coil itself is about 1.5 feet of double cable, which presumably has 0.4 mΩ/ft. resistance. This means that the short is 0.3±1 mΩ into the coil proper. Otherwise stated, the short is on the side with the upper coil lead < 2 feet from the lead end. The short can be located with greater precision after the upper-lower splice is broken. In this case electrical measurements can be made in which no current passes through the short and the voltages are expected to be much more stable with time.

Footnote

[1] The resistances quoted here are those taken on the individual coils after they were molded. Two other useful measurements exist in the traveller which agree within a few mΩ. The measurements taken after the coils were assembled into the collars are not useful since they were made using a 2-wire measurement method through voltage tap leads. The procedures in the Traveller need to be improved to specify the proper 4-wire resistance measurements in all places.

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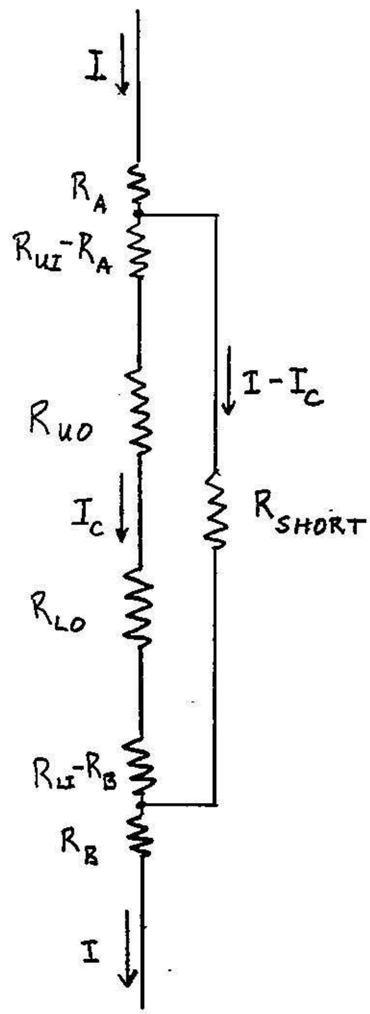


Figure 1

	0.1A	1.0A	
	10x V	V	
whole	.810	.790	
uI	.155		
uO	.212		
LO	.212		
LI	.233		
whole	.811		
Equarters	.812		

post cure R's

$I_c = (V_{uO} + V_{LO}) / (R_{uO} + R_{LO})$

$= .424 / 3.810 = 0.1113$

$R_{uO} = 1.902$
$R_{LO} = 1.908$

$R_A = 0.0009 \Omega$

$R_{uI} = 1.386$

$R_B = 0.0881 \Omega$

$R_{LI} = 1.390$

$R_A + R_B = 0.0890$

$R_I / 16 = 1.388/16 = 0.0868$

$\Delta = 2.2 m\Omega = 2.8 ft$

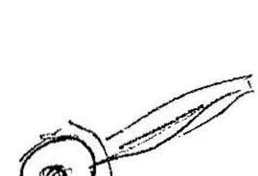
$I_c = .1114 A$

Pre collar assy R's

$R_A = 0.0009 \Omega = 1.1\ ft$

$R_B = 0.0887 \Omega = 109.7 ft$

$R_A + R_B = 0.0896$



$R_{uO} = 1.901$
$R_{LO} = 1.905$
$R_{uI} = 1.384$
$R_{LO} = 1.384$

let $\delta V_{uI} =$ ~~.034~~ .001, use ~~post cure~~ pre-collar R's

$\delta R_A = .0011 \Omega$

let $\delta V_{uO} = .001$

Then $\delta I_c = .0003A \Rightarrow \delta R_A = .4 m\Omega$

$R_A =$ ~~0.9~~ $1 \pm 1 m\Omega = 1 \pm 1 ft$

$R_B = 89 \pm 1 m\Omega$

(1) $V_{UI} = IR_A + (I - I_S)(R_I - R_A)$

(2) $V_{UO} = V_{LO} = (I - I_S) R_O$

(3) $V_{LI} = IR_B + (I - I_S)(R_I - R_B)$

$R_O = 2.221\ \Omega$

$R_I = 1.554\ \Omega = 16 \times 0.0971\Omega$

from (2)

$I_C \equiv (I - I_S) = V_{LO}/R_O = 0.216/2.221 = 0.0973\ A$

(1) $V_{UI} = \cancel{IR_A\ II}\ R_A(I - I_C) + I_C R_I$

$R_A = (V_{UI} - I_C R_I)/(I - I_C) = 0.0087\ \Omega$

(2) $R_B = (V_{LI} - I_C R_I)/(I - I_C) = 0.0940\Omega$

for mid plane inner short expect $R_A + R_B \cong R_I/16$

$R_A + R_B = 0.103\Omega$

$R_I/16 = 0.097\Omega$

Redo with $R_O = 1.905$
$R_I = 1.388$

$I_C = 0.1134A$

$R_A = 0.0018 \rightarrow 2.2\ ft$ –

$R_B = 0.0887 \rightarrow 110.4\ ft$ –

$$\left.\begin{array}{l} R_A + R_B = 0.0905 \\ R_I/16 = 0.0868 \end{array}\right\} 0.0038\Omega \cong 4.7\ ft$$

~11:15 11:35

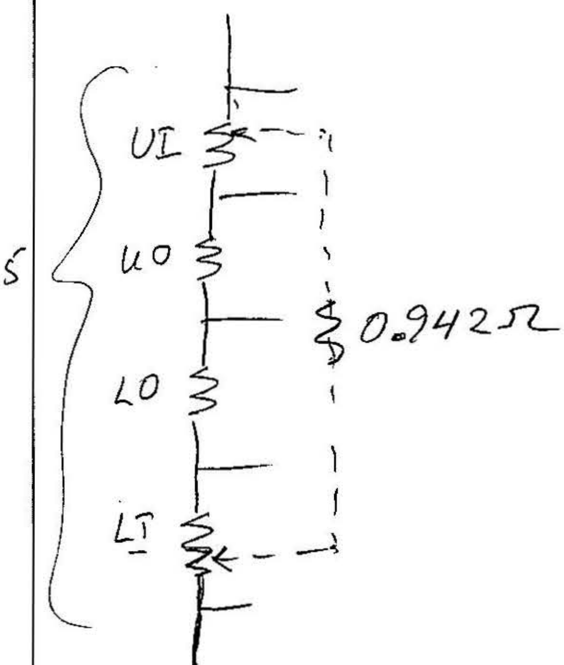
~~0.1 A thru coil~~

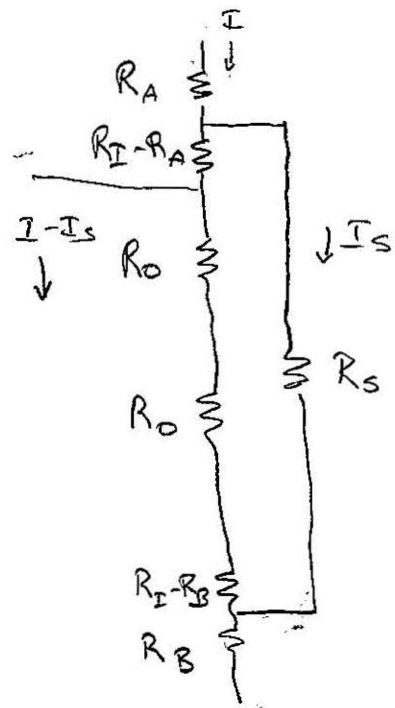
	Vx10	
Whole coil	0.825	.830

UI 0.159 } 0.375
UO 0.216
LO 0.216 } 0.452
LI 0.236

0.827

LI − UI = .077





Whole	811.1
UI	155.6
UO	211.8
LO	212.5
LI	232.5
Whole	812.8
Σq's	812.4

$1.5 \times .4\,m\Omega/ft \cong 0.6\,m\Omega$

$0.9 \pm 1.1\,m\Omega$

$0.3 \pm 1.1\,m\Omega$

$0 \sim 1.4\,m\Omega$

$0 \sim 2\,ft$