AD/SSC/Tech. No. 82

Accelerator Development Department

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Critical Current Tests on Cable Samples From Magnet DD-16

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Three sets of measurements were made at the request of the autopsy committee. One set of samples (section 2, following) contained a cold weld region which was found by visual inspection of the inner turn. The effects (if any) of bending at the ramp splice (section 1, following) and of dislocated shims (section 3) were also investigated.

1. At and Near the Ramp Splice

Beginning at the ramp splice solder joint, four successive 65" pieces of the inner coil winding were cut. They are labelled, in order from the joint, D16-1, -2, -3, and -4; see Fig. 1. This section of cable, from the joint to the first turn, is a leader which was inadvertently left as part of cable SC376 - the designated inner coil cable. It is a short piece, ~ 50 feet long, of which no prior short sample test was made. The idea of these tests was to compare sample -1, which includes the compound bend associated with the ramp splice, with the other three pieces, -2, -3, and -4. Figure 2 shows results for all 4 pieces, in standard Q.C. report format. There is no significance in the difference in I_c values within the estimated accuracy which is ~ ± 150A. The n-values are probably not significantly different either.

There is a significant difference in the observed quench currents for samples -1 and -2 compared with -3 and -4. This is due to the following. The bend in sample -1 is close to the end. In order to locate the bend region in the uniform field region, it was necessary to solder the return leg, which is sample -2, near the voltage measurement taps, in a relatively high field region, Fig. 3. The presence of this joint is most likely the cause of the reduced quench current. As samples -1 and -2 are measured simultaneously, the same quench current is reported for both.

It is not unlikely that this effect occurs in magnets as well, due to the ramp splice joint, for example. This contributes possibly to observed differences in the ratios of magnet quench currents to short sample I_c values.

2. At and Near the Cold Weld Region

This set consisted of the following 65" pieces. (See Fig. 1)

D16-5: end of the leader cable.
-6: region containing all of the strand cold welds.
-7: first straight length after inner turn, cable SC376.
-8: next piece after -7.

Samples -6 and -8 were paired together while -5 and -7 formed the other pair.

Figure 4 shows the V-I curve for -6, the cold weld region. For comparison, the type of curve observed for an undamaged cable is shown (one of the leader cable samples in this case). The region between voltage taps contained 18 of the 23 splices. Each half of sample -6 was resistive (although not directly proportional to the numbers of splices, as the resistance per splice is not constant).

Sample -6 was able to carry about 7000A at 5T before quenching. This is an extreme example of the fact that for good cables I_c is a good measure of cable performance, while for poor cables considerable current may be carried even though I_c and n are low (~ 0 and 1, respectively, in this case).

Sample -8 was not measured as it was limited by being in series with -6. Sample -7 could be measured. Figure 5 shows the results for this piece, and for a sample which was obtained at the time magnet DD16 was first tested. There is practically no difference. The RRR of the magnet sample is slightly larger, due presumably to some annealing, which occurs during coil manufacture. A third test of cable having the same designation was made a year ago. It gives an I_c which is about 2% lower. This difference is due to a combination of variations in I_c along a cable and to measurement accuracy. Sample -5 itself is in agreement with samples -1 to -4.

3. Outer Coil, First Turn

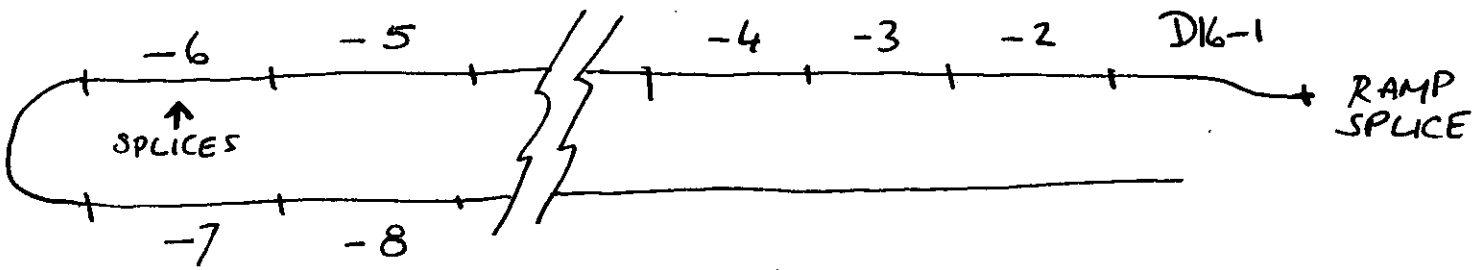
Two samples from the first (inner) turn of the outer coil were submitted for test. These are designated as follows (see A. Greene Memo, March 31, 1989):

Position 1: Overlapped Shims.

Position 4: Missing Shim

The results for these samples and for the original short sample test of SC378 are presented in Fig. 6. There is no significant difference among these three samples. Thus, neither electrical nor visual inspection shows any damage resulting from the shim dislocations. The RRR of the coil samples is increased over that of the original QC cable, SC378, due to annealing during coil fabrication.

INNER COIL, INNER (FIRST) TURN



OUTER COIL, INNER (FIRST) TURN

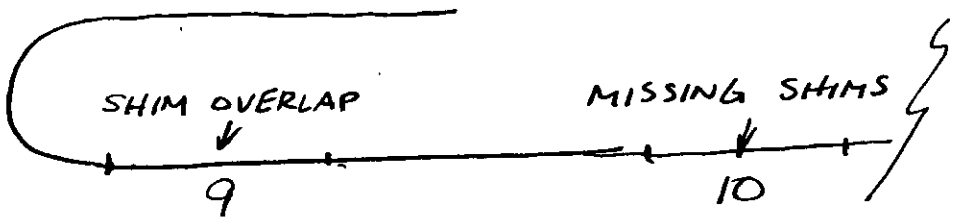


FIGURE 1. LOCATION OF 65" TEST SAMPLES

FIGURE 2. LEADER CABLE RESULTS

D16-1 (INCL. RAMP BEND)

Measurements

B	T	It	Iq	n	Ic
5.38	4.407	11605	11730	26	12433
5.79	4.382	10237	10701	25	10912
6.14	4.486	8875	9480	21	9958

R(295)= 25.6 uohms/cm RRR= 80
R(10) = .32 " C/S= 1.40

Calculated results for T= 4.22

B	Ic	Jc
5	13137	2675
5.6	11561	2354
6	10510	2140
7	7882	1605

D16-2

Measurements

B	T	It	Iq	n	Ic
5.38	4.407	11751	11730	30	12591
5.80	4.382	10361	10701	25	11045
6.14	4.486	8921	9480	25	10010

R(295)= 25.6 uohms/cm RRR= 80
R(10) = .32 " C/S= 1.40

Calculated results for T= 4.22

B	Ic	Jc
5	13288	2706
5.6	11694	2381
6	10631	2165
7	7973	1624

D16-3

Measurements

B	T	It	Iq	n	Ic
5.37	4.451	11430	12150	21	12456
5.81	4.375	10597	11136	28	11265
6.14	4.463	9041	9885	20	10039

R(295)= 25.6 uohms/cm RRR= 80
R(10) = .32 " C/S= 1.40

Calculated results for T= 4.22

B	Ic	Jc
5	13327	2714
5.6	11728	2388
6	10661	2171
7	7996	1628

D16-4

Measurements

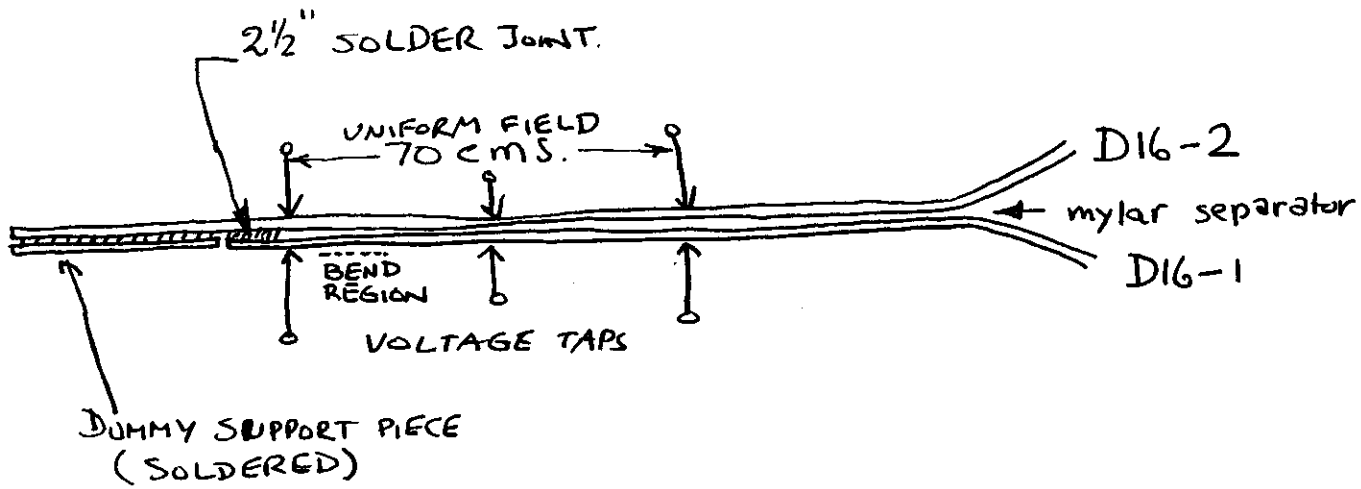
B	T	It	Iq	n	Ic
5.37	4.451	11333	12150	19	12350
5.81	4.375	10608	11136	29	11277
6.14	4.463	8985	9885	19	9977

R(295)= 25.6 uohms/cm RRR= 80
R(10) = .32 " C/S= 1.40

Calculated results for T= 4.22

B	Ic	Jc
5	13257	2700
5.6	11666	2376
6	10606	2160
7	7954	1620

FIGURE 3. MOUNTING OF LEADER SAMPLES 1 AND 2



4-3-89

CABLE TEST GROUP
DD-16 DATA

LEFT
V-I curve for 28" section containing most of the cold welds in DD-16.
Quench current = 7200 (no insulation)

RIGHT
V-I curve for normal inner type cable

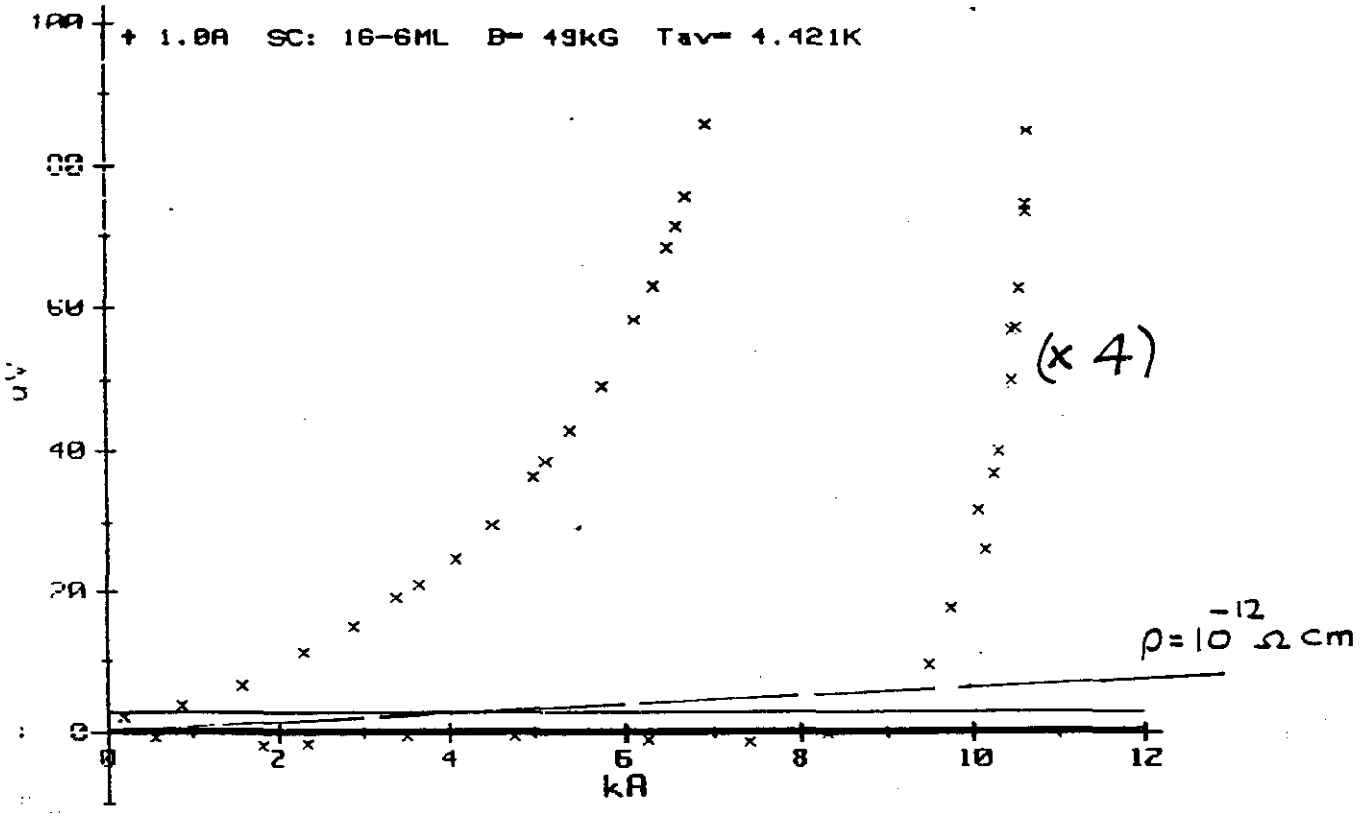


FIGURE 4.

FIGURE 5. SC 376 BEFORE & AFTER COIL FABRICATION

R 2225 SC 376 L* 2/17/89

Measurements

B	T	It	Iq	n
5.37	4.415	11328	12035	21
5.37	4.415	11318	12035	21
5.79	4.424	10106	10765	20
5.79	4.424	10157	10765	22
6.14	4.458	9009	9642	23
6.14	4.458	9023	9642	24

R(295)= 25.7 uohms/cm RRR= 66
R(10) = .39 " C/S= 1.39

Calculated results for T= 4.22

B	Ic	Jc
5	13052	2645
6	10442	2116
7	7831	1587

CF.403 1.25 1.67

* SAMPLE TAKEN FROM REMNANT AFTER FABRICATION OF D16 INNER COIL

R 2297 D16-7 4/4/89

Measurements

B	T	It	Iq	n	Ic
5.38	4.379	11617	11975	31	12313
5.81	4.332	10569	10973	24	11039
6.16	4.334	9550	10158	21	10015

R(295)= 25.6 uohms/cm RRR= 78
R(10) = .33 " C/S= 1.40

Calculated results for T= 4.22

B	Ic	Jc
5	13196	2682
5.6	11612	2360
6	10557	2146
7	7917	1609

Comments: Cable from magnet 16 cf. SC 376

CF.403 1.25 1.67

FIGURE 6. OUTER COIL SAMPLES BEFORE AND AFTER COIL FABRICATION

R 1658 SC 378 (= SO 122)

Measurements

B	T	It	Iq	n
5.24	4.343	8479	9070	27
5.24	4.343	8462	9070	26
5.68	4.348	7524	8135	26
5.68	4.348	7537	8135	25
6.05	4.342	6763	7485	21
6.05	4.342	6753	7485	21

R(295)= 28.7 uohms/cm RRR= 74
R(10) = .39 " C/S= 1.65

Calculated results for T= 4.22

B	Ic	Jc
5	9164	2453
6	7331	1963
7	5499	1472

Comments: S/C 378 IGC 5152-1001 Nominal C/S = 1.78

R 2300 D16-9 (POSITION 1 - SHIM OVERLAP)

Measurements

B	T	It	Iq	n	Ic
5.24	4.376	8404	8793	20	8886
5.67	4.351	7455	7913	19	7838
6.05	4.348	6806	7157	20	7172

R(295)= 28.5 uohms/cm RRR= 92
R(10) = .31 " C/S= 1.73

Calculated results for T= 4.22

B	Ic	Jc
5	9175	2534
5.6	8074	2230
6	7340	2027
7	5505	1520

R 2299 D16-10 (POSITION 4 - MISSING SHIMS)

Measurements

B	T	It	Iq	n	Ic
5.25	4.334	8715	9120	27	9074
5.68	4.334	7713	8148	24	8055
6.06	4.317	7035	7467	26	7317

R(295)= 28.5 uohms/cm RRR= 95
R(10) = .30 " C/S= 1.73

Calculated results for T= 4.22

B	Ic	Jc
5	9409	2597
5.6	8280	2285
6	7527	2077
7	5645	1558

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