

Preliminary report NbTi cable measurements December 2012

In response to Purchase Order 13-P0246 issued by Jefferson Lab, the University Twente measured the critical current values of 4 short samples of the SSC outer cable at a temperature of 4.2K in magnetic fields ranging from 5 to 7T.

This document constitutes a preliminary report of the key findings and will be followed by a full report discussing experimental details and analysis methods.

1. As-measured I_c and n-values for the 4 samples.

The tables below give the as-measured critical current- and n-values of the four soldered cable samples, determined with the resistivity criterion $\rho_c = 10^{-14} \Omega\text{m}$. Each cable was fitted with two pairs of voltage contacts, spanning ~ 20 mm and ~ 60 mm, respectively.

Sample 1: 80MPa				
T=4,223				
$\mu_0 H$ [T]	I_{c1} (24 mm) [kA]	n(24 mm) [-]	I_{c2} (60 mm) [kA]	n(60 mm) [-]
7	7,03	18	6,90	27,9
7	6,75	9	6,92	28
6,5	7,94	7,6	8,12	27,3
6	9,28	13,9	9,40	27
6	9,19	7,6	9,35	28,6
5,5	10,54	11,6	10,61	30,3
5,5	10,53	8,9	10,63	29,1
5	11,61	8,1	11,81	30,1

Table 1.1 As-measured critical current and n-value for cable sample marked "80MPa".

Sample 2: 2,59mm				
T=4,230				
$\mu_0 H$ [T]	I_{c1} (20 mm) [kA]	n(20mm) [-]	I_{c2} (59 mm) [kA]	n(59 mm) [-]
7	7,41	72,8	6,92	24,2
7	7,40	64,9	6,93	24,5
6,5	8,72	76,3	8,21	26,1
6	10,00	80,9	9,46	27,5
5,5	11,28	92,7	10,69	28,5
5	12,53	108	11,93	30,1

Table 1.2 As-measured critical current and n-value for cable sample marked "2,59mm".

Sample 3: E002				
T=4,208				
$\mu_0 H$ [T]	$I_{c1}(20 \text{ mm})$ [kA]	$n(20 \text{ mm})$ [-]	$I_{c2}(59 \text{ mm})$ [kA]	$n(59 \text{ mm})$ [-]
7	7,36	43,1	6,96	22,7
6,5	8,61	35,7	8,19	21
6	9,88	40,6	9,42	22,1
5,5	11,06	37,6	10,61	21,8
5	12,33	38,9	11,88	22,9

Table 1.3 As-measured critical current and n-value for cable sample marked “E002”.

Sample 4: 120MPa				
T=4,224				
$\mu_0 H$ [T]	$I_{c1}(22 \text{ mm})$ [kA]	$n(22 \text{ mm})$ [-]	$I_{c2}(58 \text{ mm})$ [kA]	$n(58 \text{ mm})$ [-]
7	7,52	59,1	6,97	23,6
6,5	8,86	76,8	8,31	25,9
6	10,07	59,4	9,51	26,4
5,5	11,39	73,1	10,78	27,9
5	12,61	69,7	11,96	27,1

Table 1.4 As-measured critical current and n-value for cable sample marked “120MPa”.

2. Temperature- and self-field corrected I_c values for the 4 samples.

Following the same procedures as with the original experiments from 2010 (see “*Report 10-P0886.pdf*”), the I_c -values that were measured with the longest voltage pair (60 mm) were corrected for temperature and self-field.

Variations in He bath temperature from sample to sample (due to varying atmospheric pressure) were accounted for by referring all I_c -values to the standard boiling point of He ($P_0 = 1013.3$ hPa; $T_0 = 4.2221$ K). The scaling relation used for this correction is described in section §4.1 of the 2010 report (equation (4.6), p.33).

Instead of the applied field $\mu_0 H$, the peak field on the sample (i.e. the maximum value of superposed applied field and self-field) was worked out for further reference. Also here, the same procedure was used as in 2010 (section §4.2, equation (4.8), p.34 in the 2010 report).

The resulting $I_c(T_0, B_{\text{peak}})$ values for the 4 samples are given below.

Sample 1: 80MPa			
$\Delta T = -0,8$ mK			
$\mu_0 H$ [T]	$I_{c1}(T)$, 60mm [kA]	B_{peak} , 60mm [T]	$I_{c1}(T_0)$, 60 mm [kA]
7	6,90	7,46	6,90
7	6,92	7,46	6,92
6,5	8,12	7,04	8,12
6	9,40	6,63	9,40
6	9,35	6,63	9,35
5,5	10,61	6,21	10,61
5,5	10,63	6,21	10,63
5	11,81	5,79	11,81

Table 2.1 Temperature- and self-field corrected critical current value for cable sample marked “80MPa”.

Sample 2: 2,59mm			
$\Delta T = -7,9$ mK			
$\mu_0 H$ [T]	$I_{c1}(T)$, 59mm [kA]	B_{peak} , 59mm [T]	$I_{c1}(T_0)$, 59mm [kA]
7	6,92	7,46	6,93
7	6,93	7,46	6,94
6,5	8,21	7,05	8,22
6	9,46	6,63	9,47
5,5	10,69	6,22	10,70
5	11,93	5,80	11,94

Table 2.2 Temperature- and self-field corrected critical current value for cable sample marked “2.59mm”.

Sample 3: E002			
$\Delta T = +14,5$ mK			
$\mu_0 H$ [T]	$I_{c1}(T)$, 59mm [kA]	B_{peak} , 59mm [T]	$I_{c1}(T_0)$, 59mm [kA]
7	6,96	7,46	6,94
6,5	8,19	7,05	8,17
6	9,42	6,63	9,40
5,5	10,61	6,21	10,59
5	11,88	5,79	11,86

Table 2.3 Temperature- and self-field corrected critical current value for cable sample marked “E002”.

Sample 4: 120MPa			
$\Delta T = -2,1$ mK			
$\mu_0 H$ [T]	$I_{c1}(T)$, 58mm [kA]	B_{peak} , 58mm [T]	$I_{c1}(T_0)$, 58mm [kA]
7	6,97	7,47	6,98
6,5	8,31	7,06	8,31
6	9,51	6,64	9,51
5,5	10,78	6,22	10,78
5	11,96	5,80	11,96

Table 2.4 Temperature- and self-field corrected critical current value for cable sample marked “120MPa”.

3. Sample comparison.

In order to compare the samples with each other and with the results from the earlier experiments, once more the same procedure was used as in 2010: using linear interpolation of the $I_c(T_0, B_{peak})$ data, the value $I_c(T_0, B_{peak}=6T)$ was taken as ‘reference value’ for each sample (section §5, equation (5.1), p.38 in the 2010 report).

Sample	$I_c(T_0, B_{peak}=6T)$ [kA]
“80MPa”	11.22
“2.59mm”	11.35
“E002”	11.23
“120MPa”	11.40

Table 3 Reference I_c -values of the four soldered samples.

On average, these 4 soldered cabled samples have an I_c -value (at 4.2221K and a peak field of 6T) of (11.30 ± 0.09) kA, i.e. 4.2% higher than the average value found for the 14 cable samples measured in 2010 ((10.84 ± 0.29) kA, see p.41-42 in the 2010 report).

4. Detailed remarks.

Due to the learning curve involved in finding the optimal soldering procedure for the voltage taps, the taps on the first sample ("80MPa") were established with an excessive amount of solder (Figure 4.1).

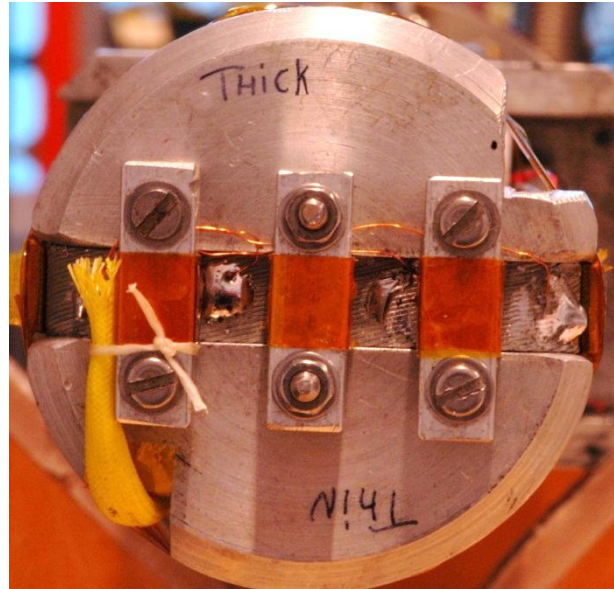


Figure 4.1: Voltage pairs connected to the first sample ("80MPa").

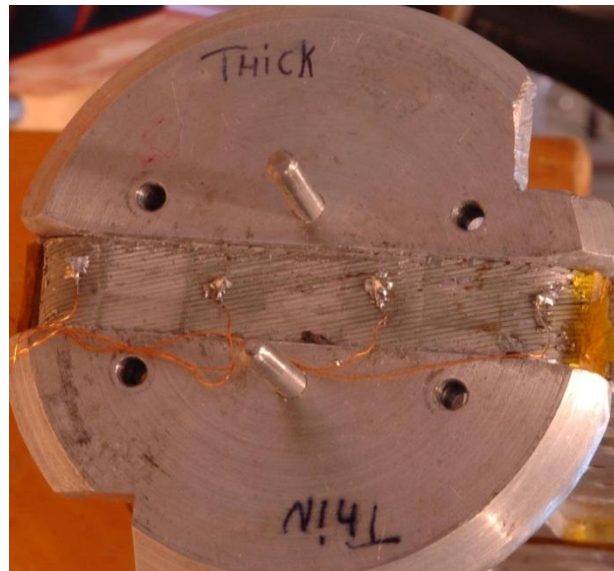


Figure 4.2: Voltage pairs connected to the second sample ("2.59mm"). This picture is also representative for samples 3 and 4 ("E002" and "120MPa").

As shown in figure 4.3, this lead to anomalous but reproducible features in the current-electric field $E(I)$ curves measured with the 20mm voltage pair for this sample (presumably due to current-redistribution effects in the immediate vicinity of these contacts). In an attempt to remedy this, care

was taken to minimize the contact size for the voltage taps in the subsequent 3 cable samples (figure 4.2).

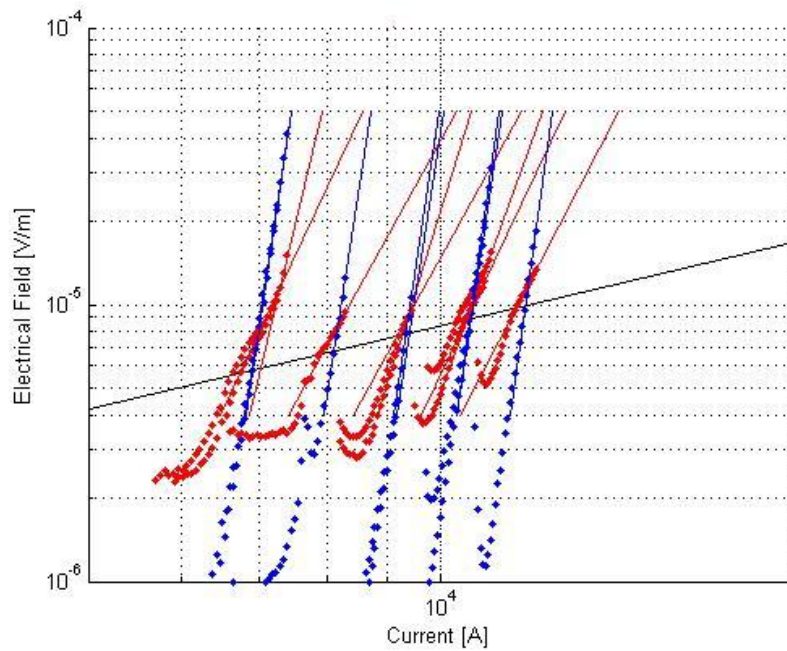


Figure 4.3: Electric field versus current curves for the first sample (“80MPa”) measured at $T = 4.223\text{K}$ and $\mu_0H = 5, 5.5, 6, 6.5$ and 7 T . The data represented with red symbols are recorded with the voltage pair spanning 24 mm , the blue points correspond to the 60 mm pair. The black line indicates the resistive I_c criterion.

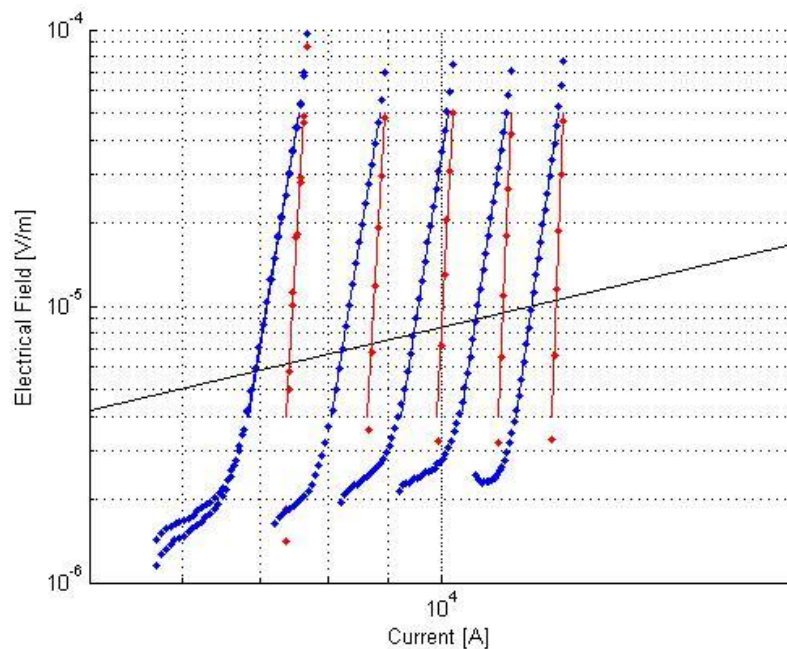


Figure 4.4: Electric field versus current curves for the second sample (“2.59mm”) measured at $T = 4.230\text{K}$ and $\mu_0H = 5, 5.5, 6, 6.5$ and 7 T . The red data correspond to the 20 mm voltage pair, the blue ones to the 59 mm pair. The black line indicates the resistive I_c criterion. These curves are qualitatively also representative for the third and fourth sample (“E002” and “120MPa”).

As seen by comparing figures 4.3 and 4.4, the elimination of excess solder not only lead to the disappearance of the low-current 'shoulder' feature in the voltage traces recorded with the shorter voltage pair, but also systematically allowed to reach higher quench currents for the second to fourth sample.

Note that the processed data discussed in sections 2 and 3 of this document were all recorded with the longer 60 mm voltage pairs, in accordance with the measurement and analysis protocol followed in 2010.