9/17/03
TD-03-057

HFDB03 Test Summary

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1. Introduction

HFDB03 is a magnet made from react and wind race track Nb3Sn coils (see construction report). The magnet was completed on April 30th, 2003. After it was installed into the VMTF dewar it was electrically checked out by May 7th , 2003. The VMTF dewar was filled with liquid helium and cold testing begun on May 12th, 2003. This magnet went trough two test cycles. The first one has been completed on May 22, 2003. The second test cycle started on December 9th 2004 and it has been completed on December 11th. The magnet was warmed up and then removed from VMTF dewar.

2. Quench History and Quench Locations

The first quench of the magnet was at relatively low current value (8442 A), about 50% of the critical current value calculated on the basis of short sample critical current measurements. The magnet exhibited erratic quench behavior and practically no training was observed. After quenching the magnet ten times at canonical 20A/sec ramp rates we moved to the next step of the test plan which called for ramp rate dependence studies. The quench program was completed with temperature dependence studies. Ramp rate dependence studies were followed with Heater studies. Being anxious to get to higher current values we tried to quench the magnet many times and try to vary the ramp rates as well. During this exercise we discovered that the magnet quench current has a peek at about 300 A/s ramp rate. So we quenched the magnet many times with even trying to perform pre-cycles before ramping to quench, however we didn't observe any quench current improvements. At the second test cycle we pretty much followed the same quench plan as we did at TCI. There are no significant differences between the two test cycles. The quench summary is shown in Fig 1. and the details are described in Table 1.

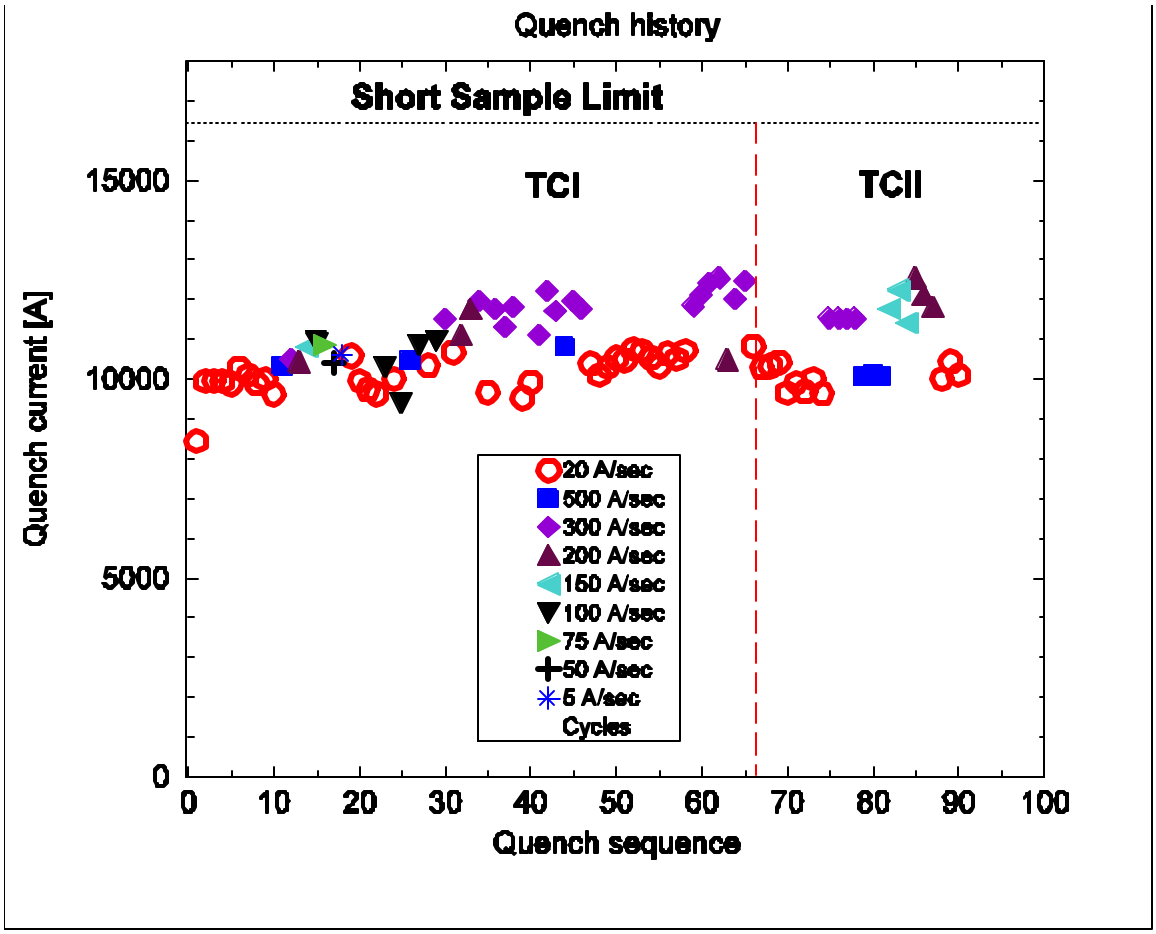

Fig. 1. Quench history of HFDB03 is shown.

Table 1. Quench summary details.

File	Quench No.	Current	dI/dt (Calc.)	Q_{time}	QDC Trigger	Magnet Temp Bot Temp	File Comments
hfdb03.Quench.030512164011.597		2018	0	0.0015	GndRef	4.534	2000A manual trip to check signals
hfdb03.Quench.030512170431.895		3528	0	-0.0613	HcoilHcoil	4.534	3500A heater induced quenchOS_
hfdb03.Quench.030512174735.814	**1**	8442	20	-0.0043	HcoilHcoil	4.532	20 a/s strain gauge run to 10ka
hfdb03.Quench.030512182510.666	**2**	9944	20	-0.0015	HcoilHcoil	4.534	20a/s to quench #2
hfdb03.Quench.030512185313.169	**3**	9964	20	-0.0022	HcoilHcoil	4.533	quench at 9964A ramp was 20 A/s
hfdb03.Quench.030512192458.034	**4**	9941	20	-0.0020	HcoilHcoil	4.537	4th quench 9941A, 20A/sec, 4.3K
hfdb03.Quench.030512200737.080	**5**	9887	20	-0.0017	HcoilHcoil	4.566	5th quench, Iq=9886A, 20A/sec, 4.3K
hfdb03.Quench.030512204442.847	**6**	10260	20	-0.0014	HcoilHcoil	4.588	Iq= 10260 A ramp= 20 A/s
hfdb03.Quench.030512212611.004	**7**	10112	20	-0.0017	HcoilHcoil	4.588	Iq = 10113 A ramp= 20 A/s
hfdb03.Quench.030512220311.192	**8**	9896	20	-0.0020	HcoilHcoil	4.589	Iq = 9896 A Ramp = 20 A/s
hfdb03.Quench.030512223545.236	**9**	9994	20	-0.0020	HcoilHcoil	4.593	Iq = 9994 A Ramp = 20 A/s (waited 2 minutes at 9500 A)
hfdb03.Quench.030513084818.051	**10**	9623	20	-0.0081	HcoilHcoil	4.480	~9800A, 10th quench, 20 A/sec, 4.3K
hfdb03.Quench.030513093913.501	**11**	10342	502	-0.3107	WcoilGnd	4.496	11th quench, 500A/sec, Iq=10342A
hfdb03.Quench.030513101708.236	**12**	10478	301	-0.0013	HcoilHcoil	4.513	Iq=10477A, 300A/sec, 4.3K, q# 12
hfdb03.Quench.030513104814.049	**13**	10430	200	-0.0459	HcoilHcoil	4.525	Iq = 10430 A ramp = 200 A/s Quench #13
hfdb03.Quench.030513112437.997	**14**	10819	150	-0.0042	HcoilHcoil	4.530	Iq = 10819 A Ramp = 150 A/s Quench #14
hfdb03.Quench.030513121724.130	**15**	10937	100	-0.0014	HcoilHcoil	4.531	Quench #15 Iq = 10937 Ramp = 100 A/s
hfdb03.Quench.030513124947.998	**16**	10845	76	-0.0007	HcoilHcoil	4.535	Quench # 16, Iq = 10845 A Ramp = 75 A/s
hfdb03.Quench.030513131837.449	**17**	10412	50	-0.0013	HcoilHcoil	4.538	10411A, 50A/sec, 4.3K, 17th quench
hfdb03.Quench.030513140854.650	**18**	10622	4	-0.0024	HcoilHcoil	4.487	Quench #17 Iq = 10622 A Ramp 20 A/s up to 8000 5 A/s above
hfdb03.Quench.030513144614.368	**19**	10580	20	-0.0027	HcoilHcoil	4.539	Quench #19 Iq = 10580 A, Ramp = 20 A/s
hfdb03.Quench.030513152114.467	**20**	9953	20	-0.0017	HcoilHcoil	4.536	Quench # 20, Iq = 9953 A Ramp = 20 A/s
hfdb03.Quench.030513160326.378	**21**	9739	20	-0.0017	HcoilHcoil	4.536	Quench # 21, Iq = 9739 A, Ramp = 20 A/s
hfdb03.Quench.030513165101.258	**22**	9626	20	-0.0017	HcoilHcoil	4.529	9625.6A, 20A/sec, 4.3K, 22nd quench
hfdb03.Quench.030513165514.816	**23**	10310	100	-0.0004	HcoilHcoil	4.536	10310A, 100A/sec, 4.3K, 23rd quench
hfdb03.Quench.030513192219.154	**24**	10011	20	-0.0319	HcoilHcoil	4.524	Quench #24 Iq = 10010.7 A Ramp = 20 A/s after splice measurement

hfdb03.Quench.030513195225.968	**25**	9403	100	-0.0070	SlWcoil	4.523	Quench #25, Iq = 9400 A, Ramp = 100 A/s
hfdb03.Quench.030513201810.421	**26**	10460	0	-0.6075	WcoilGnd	4.524	Quench # 26, Iq = 10460 A, Ramp = 500 A/s
hfdb03.Quench.030513204718.722	**27**	10846	101	-0.0064	HcoilHcoil	4.525	Quench # 27, Iq = 10845.6 A, Ramp = 100 A/s
hfdb03.Quench.030513212428.838	**28**	10344	20	-0.0013	HcoilHcoil	4.532	Quench # 28 Iq = 10344.3, Ramp = 20 A/s
hfdb03.Quench.030513215426.465	**29**	10975	100	-0.0006	HcoilHcoil	4.533	Quench # 29, Iq = 10975.5 A, Ramp = 100 A/s
hfdb03.Quench.030514112921.375		2020	0	0.0013	GndRef	4.383	Manual trip at 2000 A to look at signals
hfdb03.Quench.030514120721.932		3327	0	-0.0067	HcoilHcoil	4.386	Vmin study at 3300A, SHFU=180V
hfdb03.Quench.030514131226.174		3327	0	-0.1008	HcoilHcoil	4.415	3300A, SHFU=250V, 4.3K
hfdb03.Quench.030514135436.696		6640	0	-0.1049	HcoilHcoil	4.441	SHFU=180V, 6600A, 4.3K
hfdb03.Quench.030514150550.008		6640	0	-0.0015	HcoilHcoil	4.462	Vmin study at 6600A, 4.3K, SHFU=150V
hfdb03.Quench.030514153241.511		6639	0	-0.0321	HcoilHcoil	4.464	6600A, SHFU=400V, 4.3K
hfdb03.Quench.030514155219.462		9048	0	-0.0031	HcoilHcoil	4.457	spot heater study I=9000A, spot heater voltage 20V, 4.3K
hfdb03.Quench.030514162428.867		8391	139	-0.4524	HcoilHcoil	4.450	8412.9 A quench at 300A/sec ramp rate, 4.3K
hfdb03.Quench.030514164135.917		9050	0	-0.0021	HcoilHcoil	4.450	spot heater study at 9000A, spot heater voltage 40V, 4.3K
hfdb03.Quench.030514170208.666		8017	174	-0.0045	HcoilHcoil	4.448	Amother trip or quench at 7980A during ramp with 300A/sec
hfdb03.Quench.030514173958.215		7912	183	-0.0122	WcoilGnd	4.441	another quench during 300A/sec ramp rate at 7876A
hfdb03.Quench.030514180956.013		7043	0	-0.0314	HcoilHcoil	4.442	7000A heater induced quench at SHFU=400V
hfdb03.Quench.030514181718.131	**30**	11510	301	-0.0003	HcoilHcoil	4.449	11500A, 300A/sec, 4.3K
hfdb03.Quench.030514184608.940		9047	0	-0.0028	HcoilHcoil	4.448	9000A spot heater study 4.3K
hfdb03.Quench.030514185745.796		5034	0	-0.0221	HcoilHcoil	4.451	5000A spot heater study at 4.3K, spot heater voltage is 20V
hfdb03.Quench.030514192806.059		7036	0	-0.0305	HcoilHcoil	4.444	7000A, heater induced quench SHFU=400V, 4.3K
hfdb03.Quench.030514194227.210	**31**	10679	19	-0.0008	HcoilHcoil	4.455	36th quench at 10679A
hfdb03.Quench.030514200257.720		6289	149	-0.3887	HcoilHcoil	4.455	Quench # 37, Iq = 6312.1 Ramp = 300 A/s
hfdb03.Quench.030514202325.386		13	0	-0.0001	GndRef	4.443	Snappy at 6312 A61E+00
hfdb03.Quench.030514204101.756		7040	0	-0.0281	HcoilHcoil	4.442	Quec`nch # 38 induced by QH to clean up`
hfdb03.Quench.030514205845.937		6470	201	-0.0013	HcoilHcoil	4.445	Iq = 6440 A , Quench # 39, Ramp = 200 A/s
hfdb03.Quench.030514212314.223		7043	0	-0.0335	HcoilHcoil	4.446	Heater induced quench at 7000 A
hfdb03.Quench.030514214434.026		9050	0	-0.0280	HcoilHcoil	4.473	Heater induced quench at 9000 A
hfdb03.Quench.030514215505.103	**32**	11093	201	-0.0007	HcoilHcoil	4.488	
hfdb03.Quench.030514220752.238	**33**	11762	201	-0.0007	HcoilHcoil	4.511	Quench # 43, Iq = 11761.9 A at 200 A/s after up and down at 200 A/s
hfdb03.Quench.030514222348.873	**34**	11956	301	-0.0004	HcoilHcoil	4.522	Quench # 44, Iq = 11955.6 A, at 300 A/s after up and down to 10000 A

hfdb03.Quench.030515111305.901		2021	0	-0.0125	GndRef	4.383	2000A anual trip
hfdb03.Quench.030515112959.271	**35**	9663	20	-0.0083	HcoilHcoil	4.387	9600A 45th quench, 4.3K
hfdb03.Quench.030515120146.649		9050	0	-0.0015	HcoilHcoil	4.387	9000A, 4.3K, spot heater temp margin measurment, ~9K it quenched
hfdb03.Quench.030515121211.302		7596	201	-0.3075	HcoilHcoil	4.400	~9000A during temp margin measurement the magnet has quenched
hfdb03.Quench.030515123402.917		9043	0	-0.0017	HcoilHcoil	4.392	Quench # 48, Temp margin measurement at 9000 A SH3
hfdb03.Quench.030515130559.982		7036	0	-0.0048	HcoilHcoil	4.387	Quench #49, SH3 at 7000 A
hfdb03.Quench.030515132002.712		5028	0	-0.0171	HcoilHcoil	4.386	Quench #50, SH3 at 5000 A
hfdb03.Quench.030515134228.862		9043	0	-0.0029	WcoilGnd	4.385	9000A, temp margin study with spot heater #1
hfdb03.Quench.030515140021.695		7035	0	-0.0050	HcoilHcoil	4.393	7000A, temp. margin measurement
hfdb03.Quench.030515142313.130		5028	0	-0.0132	HcoilHcoil	4.395	5000A temp margin study 1st spot heater
hfdb03.Quench.030515144142.923		4932	20	-0.0125	HcoilHcoil	4.402	5000A, 20A/sec, spot heater kept at 10.790K
hfdb03.Quench.030515151905.888		9022	20	-0.0017	HcoilHcoil	4.409	Quench # 54 Iq = 89889 A SH3 at 9.8 K
hfdb03.Quench.030515153558.801	**36**	11760	301	-0.0006	HcoilHcoil	4.422	11760A, 300A/sec, 4.3K
hfdb03.Quench.030515155808.853	**37**	11303	301	-0.0006	HcoilHcoil	4.441	11300A, 300A/sec up and down and up again, 4.3K
hfdb03.Quench.030515162342.970	**38**	11803	301	-0.0007	HcoilHcoil	4.439	11803A, 300A/sec, 4.3K
hfdb03.Quench.030515165123.664		11059	0	-0.0010	WcoilIdot	4.454	11000A, TS1 was used temp margin study
hfdb03.Quench.030515171630.746		11054	0	-0.0010	HcoilHcoil	4.453	11000A, temp margin , spot 1
hfdb03.Quench.030515180419.807		9045	0	-0.0017	HcoilHcoil	4.434	9000A, sph3 was hooked up, temp margin
hfdb03.Quench.030515183029.992	**39**	9521	20	-0.0125	HcoilHcoil	4.431	Quench #61, Iq = 9520.3 A, ramp 20 A/s
hfdb03.Quench.030515184920.600	**40**	923	19	-0.0070	HcoilHcoil	4.441	Quench # 62, Iq = 9923 A. Ramp = 20 A/s
hfdb03.Quench.030515190444.913	**41**	11114	240	-0.0081	WcoilGnd	4.457	Quench # 63, Iq = 11114 A, ramp up 300 A/s, down 500 A/s U D U D U
hfdb03.Quench.030515192547.723	**42**	12223	301	-0.0011	HcoilHcoil	4.467	Quench # 64, Iq = 12223 A, Giorgio's ramp U D U D U D at 500 A/s U at 300 A/s
hfdb03.Quench.030515202501.807	**43**	11716	301	-0.0008	HcoilHcoil	4.451	Quench # 65, Iq = 11716.2 A. Ramp = U D U D U D 500 A/s U 300 A/s
hfdb03.Quench.030515205327.042	**44**	10818	501	-0.0017	HcoilHcoil	4.473	Quench # 66, Iq = 10812 A, U D U at 500 A/s
hfdb03.Quench.030515211750.235	**45**	11953	301	-0.0014	HcoilHcoil	4.490	Quench # 67, Iq = 11952 A, U D U D at 500 A/s U 300 A/s
hfdb03.Quench.030515213214.190	**46**	11780	301	-0.0010	HcoilHcoil	4.520	Quench # 68, Iq = 11780 A, ramp = 300 A/s(
hfdb03.Quench.030516100425.032	**47**	10393	20	-0.0032	HcoilHcoil	3.939	Quench # 69, Iq = 10393 A, Ramp = 20 A/s T = 4 K
hfdb03.Quench.030516103427.460	**48**	10105	20	-0.0028	WcoilIdot	3.912	10105A, 20A/sec, 4.0K
hfdb03.Quench.030516105600.074	**49**	10302	20	-0.0031	HcoilHcoil	3.845	10302A, 20A/sec, 4.0K
hfdb03.Quench.030516114244.618	**50**	10536	20	-0.0050	HcoilHcoil	3.399	10536A, 20A/sec, 3.5K helium bathef

hfdb03.Quench.030516120735.679	**51**	10472	20	-0.0025	HcoilHcoil	3.239	Quench # 64, Iq = 10472 A, Ramp = 20 A/s, T = 3.5 K
hfdb03.Quench.030516123704.442	**52**	10750	20	-0.0046	WcoilGnd	3.160	Quench # 65, Iq = 10750 A, Ramp = 20 A/s, T =3.5-3.3 K
hfdb03.Quench.030516132841.822	**53**	10710	20	-0.0057	HcoilHcoil	2.838	10710A, 20A/sec, 3.0K
hfdb03.Quench.030516140547.582	**54**	10545	20	-0.0032	HcoilHcoil	2.738	10505A, 20A/sec, 3.0K
hfdb03.Quench.030516145113.554	**55**	10331	20	-0.0057	HcoilHcoil	2.737	Quench # 68, Iq = 10330.7 A, Ramp = 20 A/s at T = 2.75 K
hfdb03.Quench.030516163025.009	**56**	10654	20	-0.0049	HcoilHcoil	2.157	Quench # 69, Iq = 10653 A Ramp = 20 A/s T = 4.16 A˜
hfdb03.Quench.030516171220.536	**57**	10513	20	-0.0024	HcoilHcoil	2.156	~10500A, 20A/sec, 2.15
hfdb03.Quench.030516174556.748	**58**	10710	20	-0.0027	HcoilHcoil	2.156	Quench # 71, Iq = 10710.5 A ramp = 20 A/s T = 2.15 K
hfdb03.Quench.030516180725.898	**59**	11843	301	-0.0011	HcoilHcoil	2.157	Quench # 71, Iq = 11843 A, ramp = 300 A/s T = 2.17
hfdb03.Quench.030516182233.268	**60**	12111	306	-0.0007	HcoilHcoil	2.167	Quench # 73, Iq = 12111 A, Ramp = 300 A/s T = 2.165
hfdb03.Quench.030516183934.292	**61**	12401	301	-0.0004	HcoilHcoil	2.174	Quench # 74, Iq = 12401 A, Ramp UD 500 A/s U 300 A/s0
hfdb03.Quench.030516185905.752	**62**	12536	301	-0.0006	HcoilHcoil	2.216	Quench # 75, Iq = 12535.7 Ramp U D at 500 A/s U at 300 A/s
hfdb03.Quench.030516191627.951		5339	501	-0.0028	HcoilHcoil	2.227	trip around 5000A
hfdb03.Quench.030516192322.327		5502	271	-0.0081	WcoilIdot	2.232	5470A, 300A/sec, plus the heater is on as well
hfdb03.Quench.030516193214.518		8039	0	-0.0029	HcoilHcoil	2.246	8000A quench, no change in current but the strip heater is onP
hfdb03.Quench.030516194722.016	**63**	10467	176	-0.0940	HcoilHcoil	2.402	10300A ramping with 300A/sec plus lot of cycle before
hfdb03.Quench.030516195951.131	**64**	12022	302	-0.0134	GndRef	2.604	12020A, 80th quench see logbook
hfdb03.Quench.030516201632.478	**65**	12461	301	-0.0025	GndRef	2.889	ramping up and down for heating and ramping to quench, Iq=12400A
hfdb03.Quench.030516203431.906	**66**	10824	20	-0.0018	HcoilHcoil	3.160	Iq=10824A, 20A/sec, 4.3K

File Name	Quench No	Current	dI/dt	Quench start	QDC	Quench start location	Magnet Temp Bot Temp	File Comments
hfdb03.Quench.031209145214.608		14	0	0.0087	WcoilGnd	QBHRS_QTHRS	4.540	manual trip to check the heaters
hfdb03.Quench.031209152206.715		1881	20	0.0000	HcoilHcoil	QB28d3_QBHRS	4.543	during the ramp trip at 1866A
hfdb03.Quench.031209153406.174		2019	0	0.0025	WcoilIdot	QB1c_QB2b	4.540	manual trip at 2000A
hfdb03.Quench.031209165700.987		2021	0	0.0014	HcoilHcoil	QB28d1_QB28d2	4.537	2000A manual trip
hfdb03.Quench.031209171638.934		3527	0	-0.0553	WcoilIdot	QB28d2_QB28d3	4.537	3500A, SHFU=300V
hfdb03.Quench.031209175120.320	**67**	10287	20	-0.0025	HcoilHcoil	QT28d1_QT28b	4.537	1st quench at 20A/sec, Iq=10287A, 4.5K
hfdb03.Quench.031209181809.848	**68**	10330	20	-0.0025	WcoilIdot	QT28d1_QT28b	4.545	2nd quench at TC2, 20A/sec, 4.5K, Iq=10330A
hfdb03.Quench.031209184304.570	**69**	10422	20	-0.0154	WcoilGnd	QT28d1_QT28b	4.550	3rd qench at TC2, Iq=10422A, 20A/sec, 4.5K
hfdb03.Quench.031209192528.755	**70**	9653	20	-0.0041	WcoilIdot	QT28d1_QT28b	4.544	4th quench at TC2, Iq=9653A, 4.5K, 20A/sec

hfdb03.Quench.031209195746.860	**71**	9910	20	-0.0032	HcoilHcoil	QT28d1_QT28b	4.541	5th quench, TC2, 20A/sec, 4.5K, Ic=9910A
hfdb03.Quench.031210093021.850		16	0	-0.0004	HcoilHcoil	QB28d1_QB28d2	4.513	trip at 0 current
hfdb03.Quench.031210095014.597	**72**	9691	20	-0.0024	HcoilHcoil	QT28d1_QT28b	4.511	q#77, Iq=9691A, 20A/sec, 4.5K
hfdb03.Quench.031210102446.820	**73**	10004	19	-0.0039	HcoilHcoil	QT28d1_QT28b	4.506	q#78, Iq=10004A. 20A/sec, 4.5K
hfdb03.Quench.031210104836.378	**74**	9641	21	-0.0041	HcoilHcoil	QT28d1_QT28b	4.512	q#79, Iq=9641, 20A/sec, 4.5K00
hfdb03.Quench.031210115737.937	**75**	11526	301	-0.0007	HcoilHcoil	QT28d1_QT28b	4.510	q#80, Iq=11526A, 20A/sec, 4.5K
hfdb03.Quench.031210130959.156	**76**	11529	301	-0.0007	WcoilIdot	QT28d1_QT28b	4.513	q#81, Iq=11529A, 20A/sec, 4.5K
hfdb03.Quench.031210134005.993	**77**	11500	301	-0.0010	HcoilHcoil	QT28d1_QT28b	4.524	q#82, Iq=11500A, 20A/sec, 4.5K
hfdb03.Quench.031210153811.664	**78**	11536	301	-0.0151	WcoilGnd	QT28d1_QT28b	4.501	#83 Iq=11536 A at 300 A/s
hfdb03.Quench.031210155750.251	**79**	10078	501	-0.0150	WcoilGnd	QT28d1_QT28b	4.518	quench #84 Iq=10078 A Ramp=500 A/s
hfdb03.Quench.031210163207.320	**80**	10121	502	-0.0157	WcoilIdot	QT28d1_QT28b	4.537	Quench # 85, Iq=10121 A ramp= 500 A/s
hfdb03.Quench.031210165046.136	**81**	10068	502	-0.0099	WcoilGnd	QT28d1_QT28b	4.548	Quench # 86, Iq=10068 A Ramp=500 A/s
hfdb03.Quench.031210171458.829	**82**	11781	151	-0.0148	WcoilGnd	QT28d1_QT28b	4.548	quench #87 Iq=11781 A ramp= 150 A/s
hfdb03.Quench.031210173414.151	**83**	12232	151	-0.0008	HcoilHcoil	QT28d1_QT28b	4.552	quench #88 Iq=12232 A, ramp=150 A/s
hfdb03.Quench.031210175749.928	**84**	11419	150	-0.0014	HcoilHcoil	QB28d3_QB28a	4.566	q#89, Iq=11419A, 150A/sec, 4.5K
hfdb03.Quench.031210182628.740	**85**	12537	201	-0.0062	HcoilHcoil	QT28d1_QT28b	4.556	q#90, Iq=12537A, 200A/sec, 4.5K
hfdb03.Quench.031210184545.738	**86**	12116	201	-0.0007	HcoilHcoil	QB28d3_QB28a	4.569	quench #91 Iq=12116 A ramp=200 A/s
hfdb03.Quench.031210191003.709	**87**	11801	201	-0.0007	HcoilHcoil	QB28d3_QB28a	4.565	quench #92 Iq=11801 A ramp=200 A/s
hfdb03.Quench.031210193650.664	**88**	10005	24	-0.0073	WcoilGnd	QT28d1_QT28b	4.566	Quench #93 Iq=10005 A ramp=20 A/s
hfdb03.Quench.031210195842.340	**89**	10451	20	-0.0021	HcoilHcoil	QT28d1_QT28b	4.562	Quench #94 Iq=10451 A ramp=20 A/s
hfdb03.Quench.031210201928.021	**90**	10101	20	-0.0020	HcoilHcoil	QT28d1_QT28b	4.560	Quench #95 Iq=10101 A ramp =20 A/s
hfdb03.Quench.031210204358.900	**91**	12167	201	-0.3619	HcoilHcoil	QT28d1_QT28b	4.559	quench # 96 Iq=12167 A ramp UDU at 200 A/s
hfdb03.Quench.031210210536.804	**92**	12482	200	-0.0006	HcoilHcoil	QT28d1_QT28b	4.565	Quench # 97 Iq=12482 A ramp UDU 200 A/s
hfdb03.Quench.031210212641.679	**93**	11148	77	-0.2656	HcoilHcoil	QB16b_QB28b	4.568	Quench #98 Iq=11148 A ramp UW(@11ka)U at 200 A/s
hfdb03.Quench.031211140132.133		1460	0	-0.5631	WcoilIdot	QB15b_QB15c	4.467	Tripped below 2000Amps while ramping down at 100 Amps/sec for eieo.
hfdb03.Quench.031211155156.339		1351	-84	0.0000	HcoilHcoil	QB14c_QB15b	4.466	
hfdb03.Quench.031211160959.917		1394	-87	-0.4576	WcoilIdot	QB14c_QB15b	4.460	RTripped on down rap on precycle for eieo.
hfdb03.Quench.031211175130.766		11065	0	-0.0011	HcoilHcoil	QT28a_QT28d2	4.469	TM (temp Margin) quench 1 at 11000kA TST2 temp 8.35K
hfdb03.Quench.031211184246.712		9051	0	-0.0021	HcoilHcoil	QT28d3_QT28d2	4.469	TM#2 I=9000 A T=8.9K
hfdb03.Quench.031211190736.970		9395	136	-0.0049	HcoilHcoil	QT28d1_QT28b	4.472	TM#3 I= 9353 A temp=8.8 ???

hfdb03.Quench.031211192843.314	6587	200	-0.0097	WcoilGnd	QT28d2_QT28d1	4.470	TM#4 i=6554 temp=???
hfdb03.Quench.031211194546.723	12631	151	-0.0006	HcoilHcoil	QT28d1_QT28b	4.463	TM#5 I=12569 A ramp 150 A/s Temp>7 K
hfdb03.Quench.031211200215.082	9237	150	-0.0020	HcoilHcoil	QT28a_QT28d2	4.477	TM#6 I=9196 A ramp=150 A/s T>8.6 K
hfdb03.Quench.031211201935.885	12611	100	-0.0006	HcoilHcoil	QTLRS1B_QTLqc	4.471	TM#6 I=12555 A ramp=100 A/s T=8.2 K
hfdb03.Quench.031211203618.281	12078	0	-0.6256	WcoilIdot	QT28a_QT28d2	4.478	TM#8 I=12070 A ramp= 75 A/s temp=8.4 K
hfdb03.Quench.031211210049.919	12064	0	-0.0007	HcoilHcoil	QT28d3_QT28d2	4.468	TM#9 I=12000 A increasing temp T=8.5 ??
hfdb03.Quench.031211211725.970	10572	0	-0.5631	HcoilHcoil	QT28a_QT28d2	4.473	TM#10 I=10609 A ramp=150 A/s
hfdb03.Quench.040130150413.224	0	0	0.0000		0		
hfdb03.Quench.040130173048.763	5047	141	0.0001	WcoilIdot	0		

Most of the quenches occurred in the top coil inner turn in segment T28d1_T28b (see example in Figure 2.).

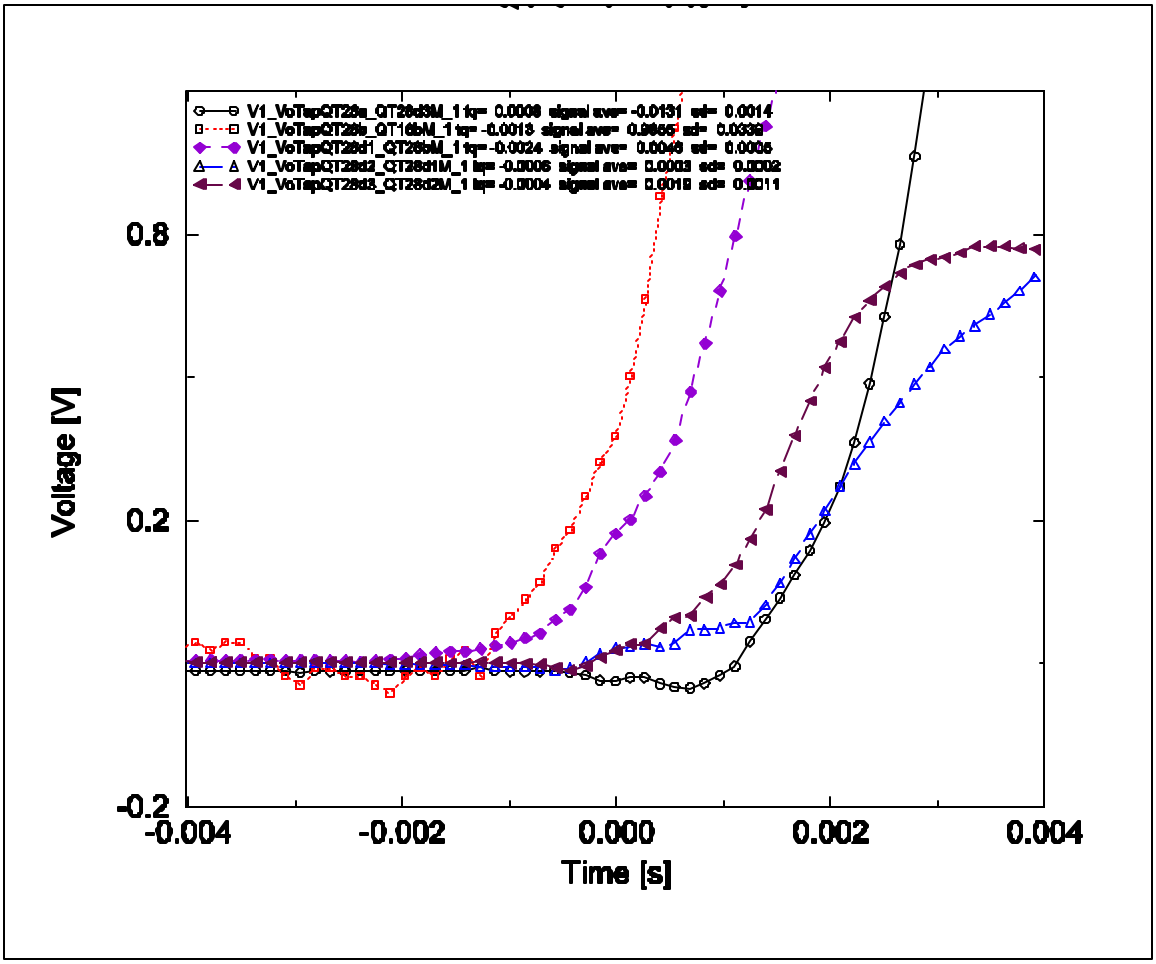

Fig. 2. Quench location example. Most of the quench origins were similar.

3. Quench Ramp Rate Dependence

We took many quenches at different current ramp rates. These quenches are summarized in Figure 3. Since the magnet exhibited erratic behavior it is hard to make conclusions about the quench current ramp rate dependence. It looks like the dependence curve peeks at around 300 A/s. It is hard to understand this phenomena.

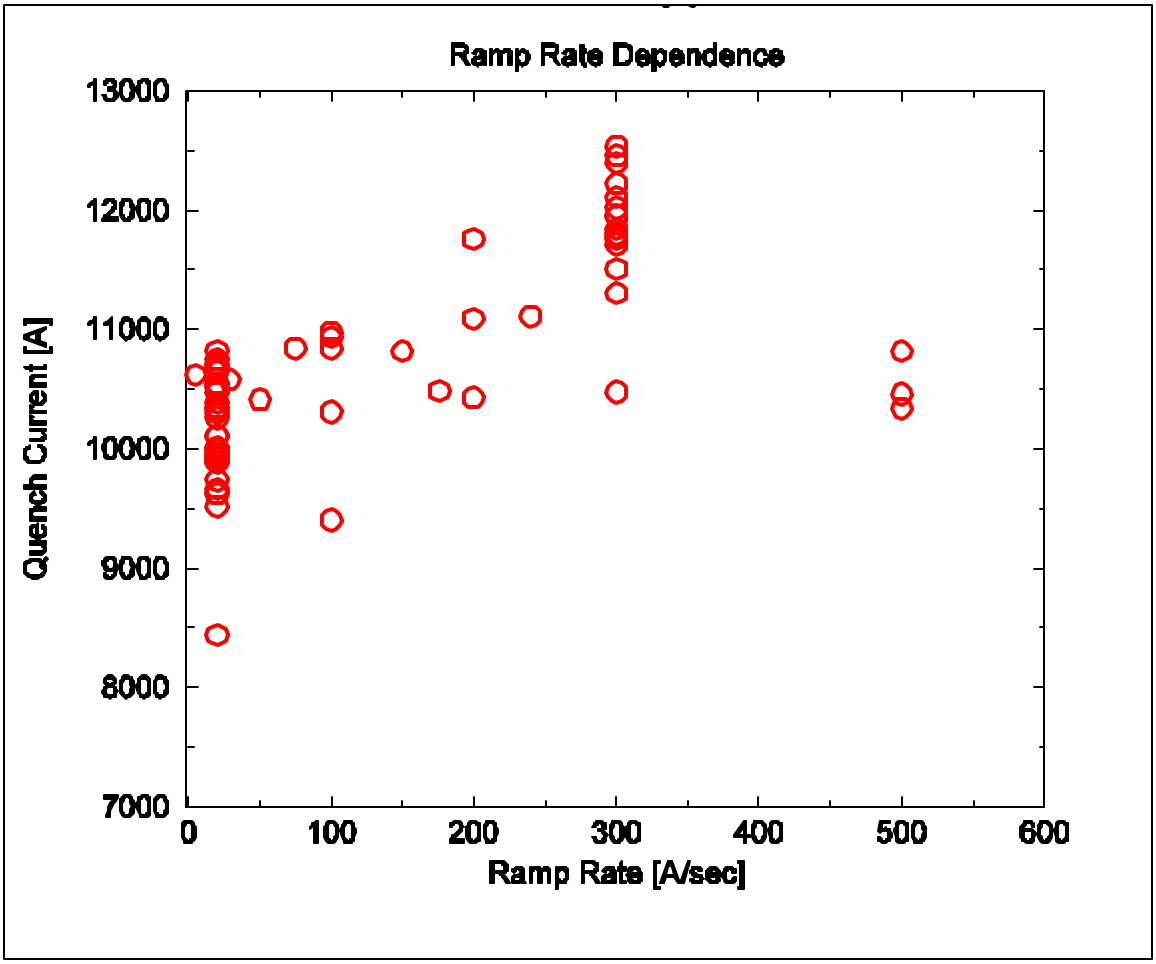

Fig. 3. Magnet quench current ramp rate dependence is shown.

4. Splice Measurements

This magnet was instrumented with many splices. We measured all of them. The results are summarized in table 2 and in Figure 4.

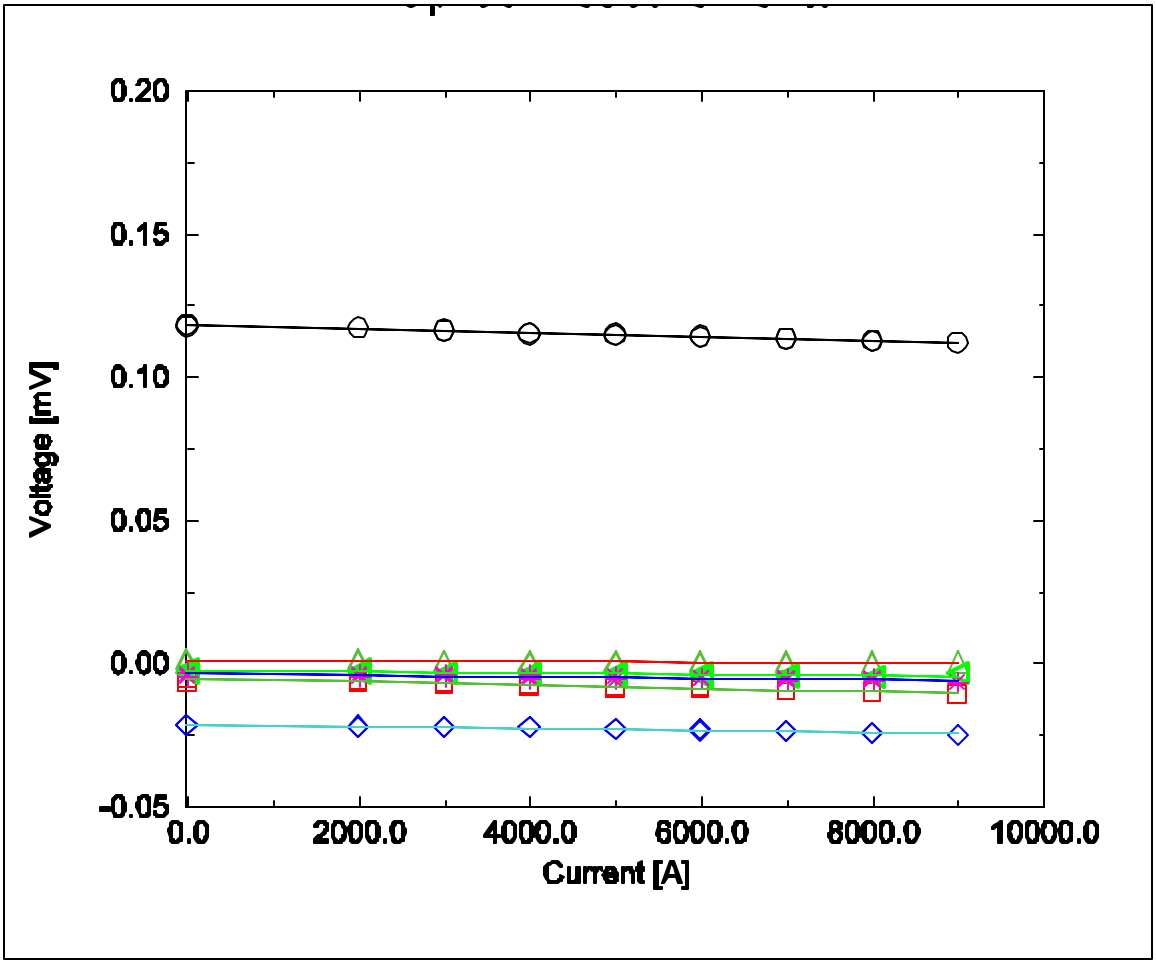

Fig. 4. Splice measurement. Current voltage dependence was directly measured and the splice was obtained by fitting a straight line to the data.

Table 2. Splice measurement results

Splice number	Splice resistance [n?]
1	0.33 ± 0.08
2	0.58 ± 0.04
3	0.68 ± 0.03
4	0.09 ± 0.03
5	0.25 ± 0.05
6	0.43 ± 0.04

5. RRR Measurements

The RRR measurement was performed on 5/17-5/21. The racetrack coil was gradually warming up and meanwhile we recorded the whole coil voltage value generated by ?10 A across the magnet. The temperature plot and the corresponding magnet voltage is shown in Figure 5 and 6. The measured RRR value is 5.3.

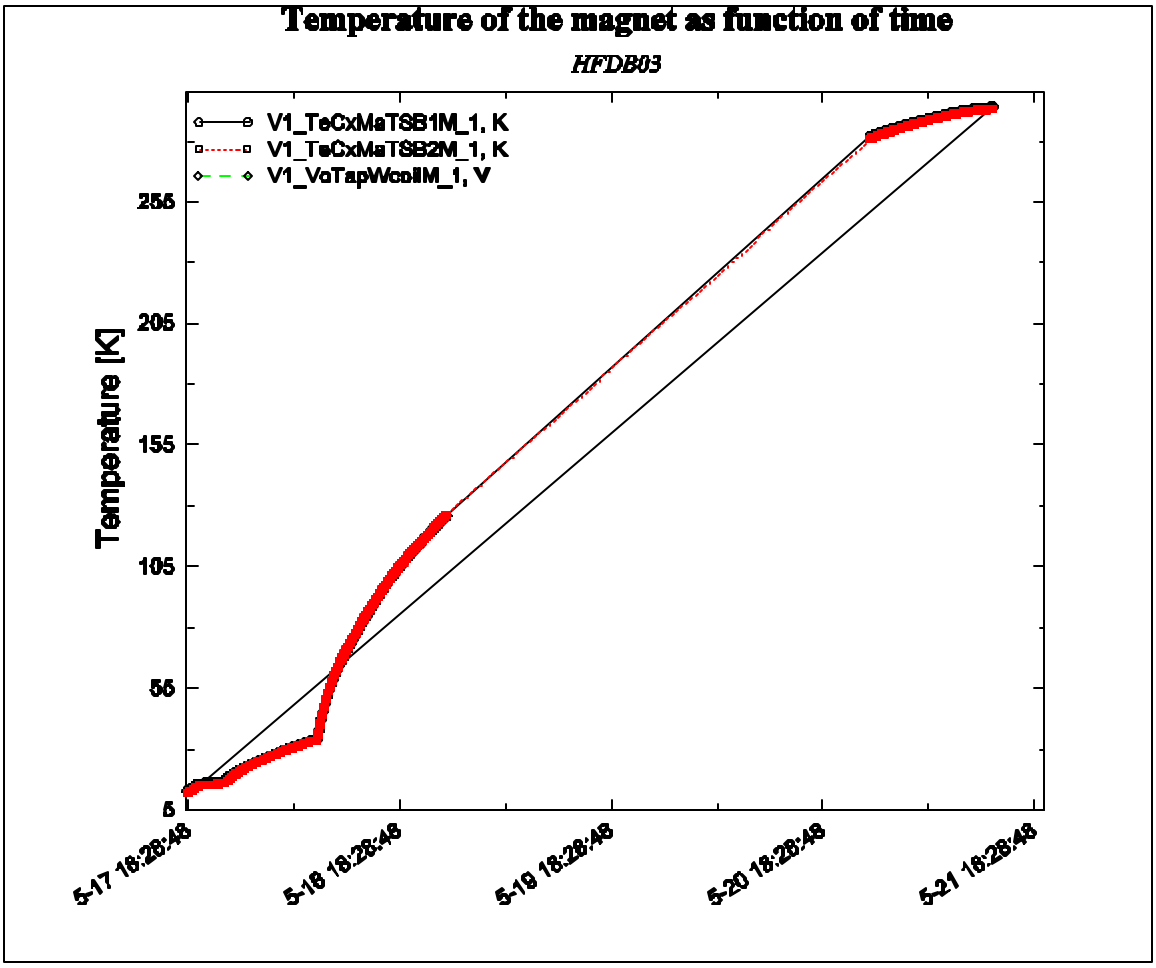

Fig. 5. The magnet was gradually warmed up while we took voltage measurement.

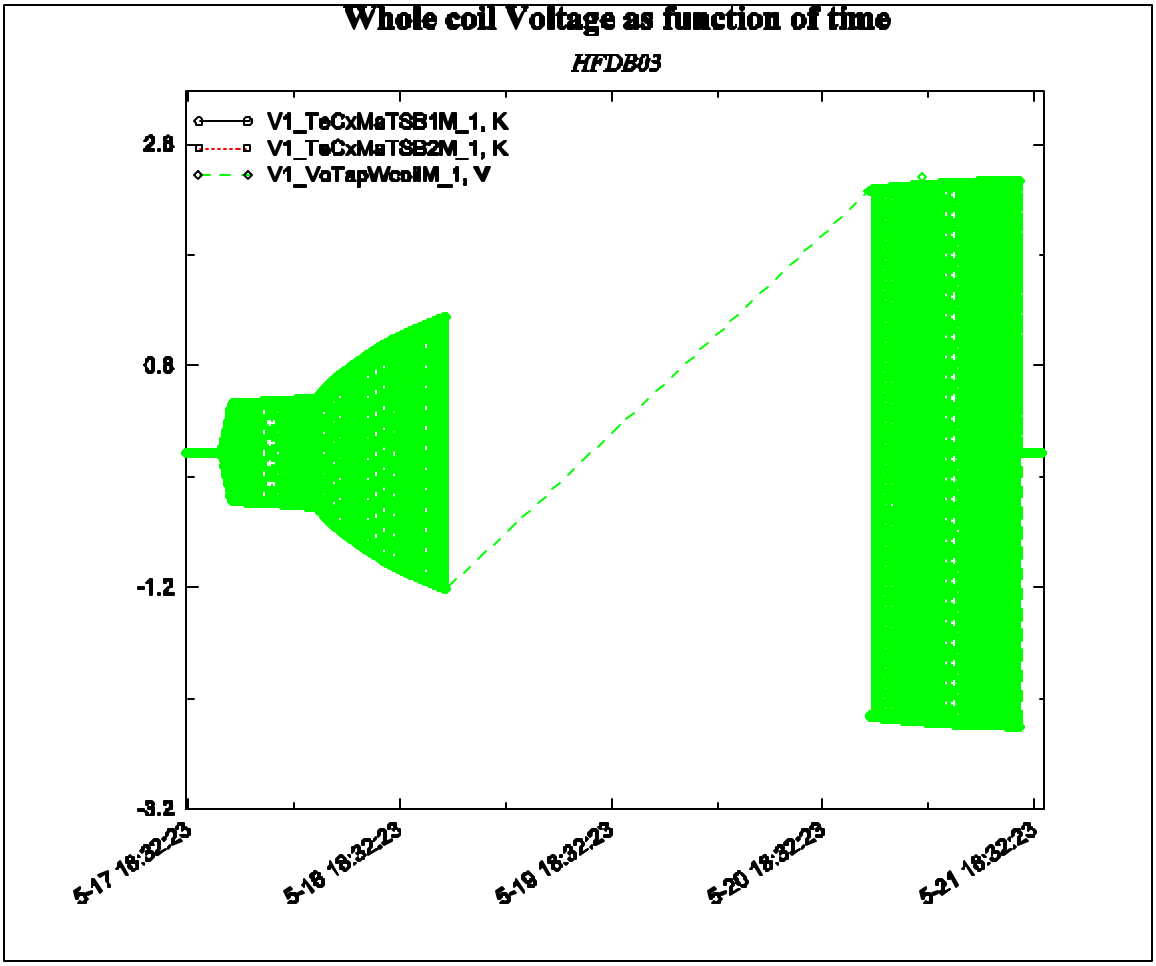

Fig. 6. The magnet voltage is plotted. The applied current was ± 10A.

6. Temperature Margin Measurements

The temperature margin was measured where the coils were instrumented with spot heaters and temperature sensors (i.e. the innermost turns of both coils). Measurements were performed at constant current (using the same procedure adopted for HFDB02 and describe in TD-02-024), and at constant temperature (i.e. with a constant current in the spot heater while ramping the current in the magnet).

The temperature margin was measured in both coils during the first cold test, only in the top coil during the second cold test.

The measurements performed at constant current gave larger margin than those performed at constant temperature, but were not reproducible. They showed a scattering as large as 0.5 K. Part of this scattering depended on the temperature steps (i.e. the larger the temperature steps the lower the quench temperature). The temperature steps used were in the range 90 – 180 mK. There was also a difference between the temperatures measured before and after the quench, with the same power generation at the spot heater (i.e. with the same current in the spot heater). The temperature measured after the quench

(after equilibrium was re-established) was higher than before the quench by 200 – 300 mK. The magnetic field should cause a very small error (|? T| < 20 mK) on these sensors (Cernox 1050) at fields below 6 T. This difference could be the effect of different cooling conditions with or without current in the magnet. In the straight section the magnetic forces push the turns toward the block center. So, when the magnet is excited, small displacements could leave some room for helium close to the sensor.

During measurements at constant temperature some quenches started outside of the voltage taps enclosing the spot heater. The lowest current at which this happened was 9350 A, the highest current was 12555 A (shown in Figure 7).

Figure 7 shows the quench temperature as a function of the magnet current. The results of the same measurement performed on HFDB-02 are presented for comparison (open marks). In the legend "top" and "bottom" refer to the position of the coils during fabrication. The bottom coil is wound first and the top coil is wound on the top of the first one. They have the same position also during impregnation. They should be identical, still temperature margin measurements have shown higher margins in the bottom coil.

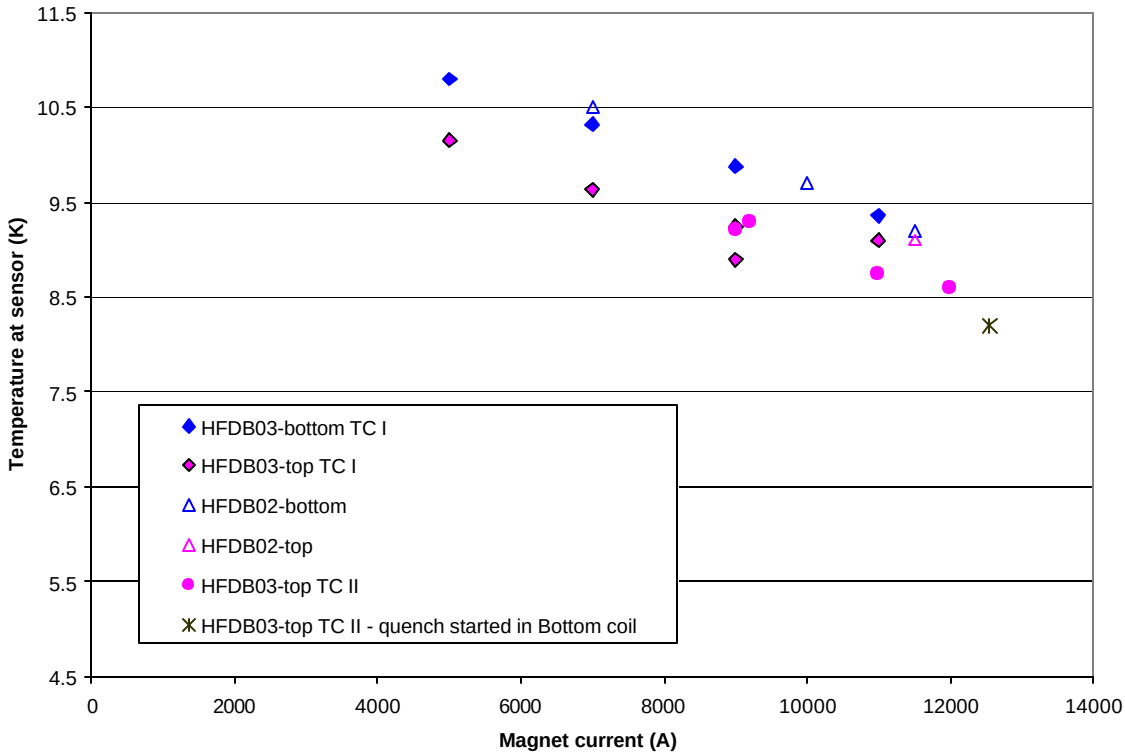

Figure 7: Temperature margin measurements in HFDB-03 (first and second thermal cycle) and in HFDB.

7. Temperature dependence studies

The magnet was cooled down to 2.2K temperature to see its quench behavior at low temperatures. We expected to see quench current improvements. Apparently it didn't happen. Flat temperature dependence doesn't allow us to distinguish which degradation mechanism plays major role in its quench behavior.

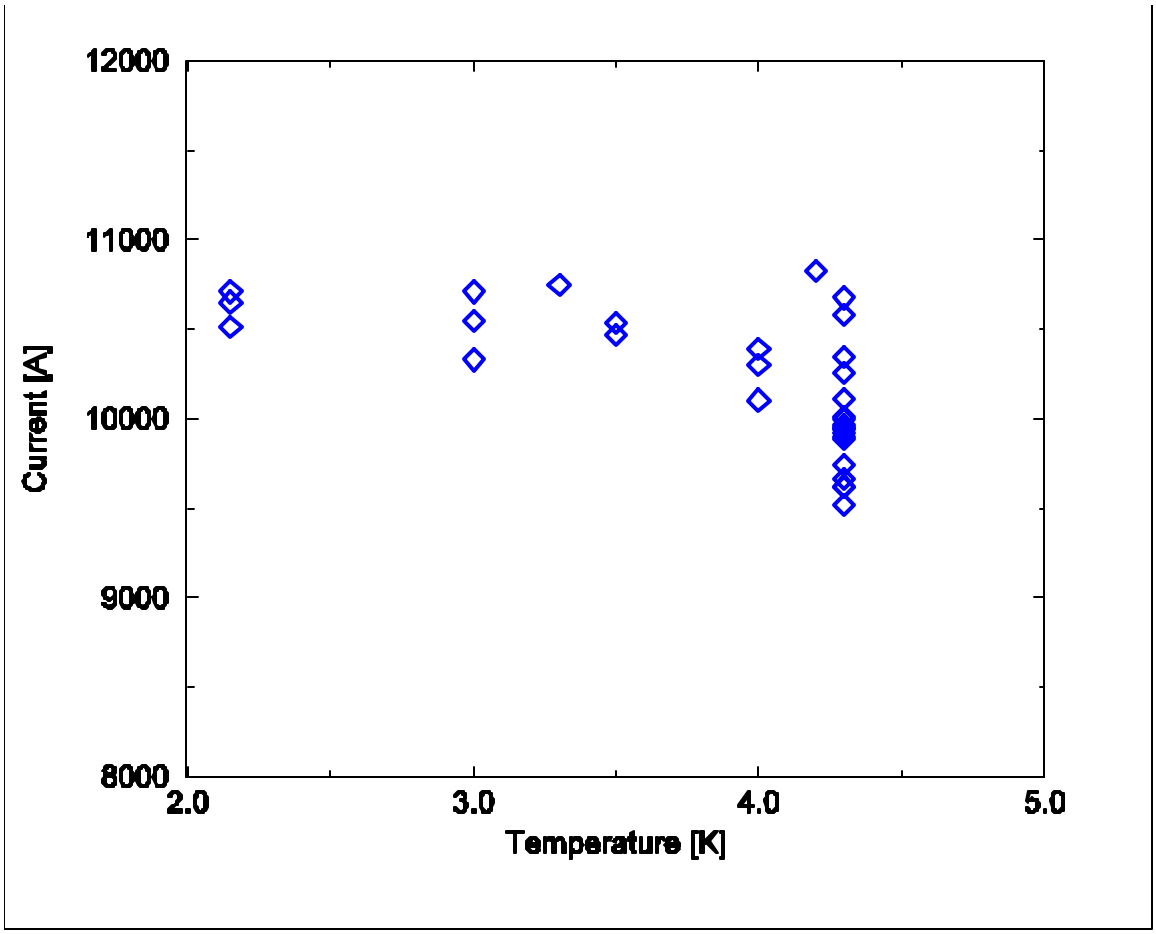

Figure 8. Quench current temperature dependence plot.

8. AC loss measurements

Energy Loss measurements were performed on HFDB03 at 4.5K using two HP3458A Digital Multimeters (dmm) setup to integrate over 1 power line cycle and sample at 60Hz. One dmm measured the magnet voltage and the second dmm measured the magnet current via the sum of four Holec Transductors with a combined transfer function of 3KA/Volt. The magnet was ramped between 500A and 6500A for all measurements. Several measurements were performed at each ramp rate of 50A/s, 100A/s, 150A/s, 200A/s, 250A/s and 300A/s., and three pre-ramp cycles were performed before each new ramp rate.

The measured **Hysteresis = 931 Joules**
And the measured **Slope = -0.262 J/A/s**

The following is a plot of the data (see next page):

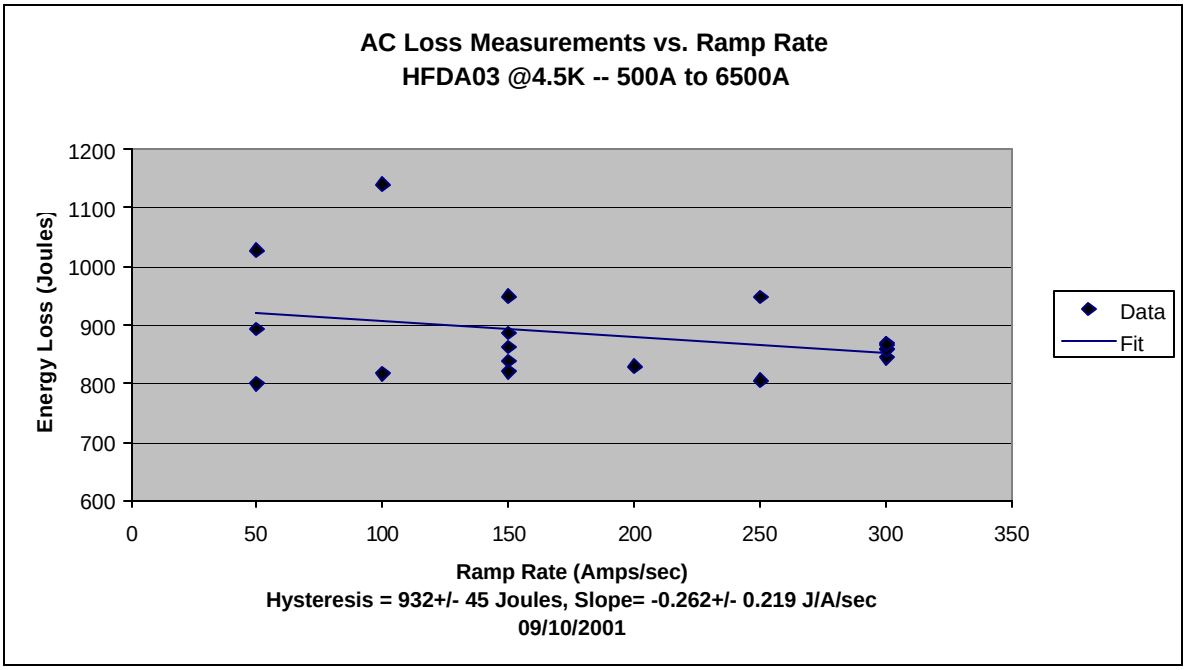

Figure 9. AC loss measurement plot as a function of current ramp rate.

Table 3

HFDA03 Energy Loss Measurement Summery @4.5K -- 500Amps to 6500Amps

Ramp Rate(Amps/sec)	*Energy Loss(Joules)*	*Integral Volts*
50	1027	0.009
50	800	0.016
50	893	0.004
100	1140	0.024
100	817	0.007
150	886	0.002
150	862	0.008
150	949	0.0015
150	838	0.011
150	820	0.013
200	829	0.011
250	805	0.017
250	948	0.009
300	857	0.001
300	868	0.001
300	844	0.007
300	857	0.007
300	867	0.011