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LARP TQC02b Magnet Test Summary

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Content:

1. Introduction

TQC02b magnet is a continuation of the TQC short model series assembled at Fermilab. All coils of this quadrupole were previously tested: coils 10 and 12 as a part of the TQC01a and TQC01b magnets [1], and coils 17 and 19 were tested in TQC02a magnet [2]. Coils 10 and 12 are made of 27-strand Rutherford cable with 0.7-mm Nb_3Sn MJR (54/61) strands, while coils 17 and 19 are made of RRP strands of the same diameter and design. The strands for cable in coils 10 came from billet # 928R, in coil 12 from billet # 932R, and in coils 17 and 19 - from billet # 940R. All coils were wound and cured at Fermilab, but were reacted and impregnated at LBNL.

The magnet was delivered to the Fermilab magnet test facility on July 28th and it was electrically checked by August 1st, 2008. The VMTF dewar was filled with liquid helium on August 4th. First thermal cycle (TC-1) of the magnet test was started on August 5th and was completed on August 29th.

During the cryogenic system maintenance work from September 2nd to 5th the TQC02b magnet was warmed up and temperature in dewar reached ~ 270-290 K (see details in Section 3.2) in the morning of September 5th when cool down was started again. A second thermal cycle (TC-2) was started on September 5th and was finished on September 11th.

The Voltage Spike Detection System (VSDS) was used for detection of small magnetic flux changes in the magnet. Results of the TQC02b spike data analyses, as well as of the magnet mechanical analyses, will be presented in a separate note.

A Residual Resistivity Ratio (RRR) of conductor in TQC02b magnet was not measured, since we already estimated it for all coils in this magnet in previous tests. The measured variations of RRR in coils 10, 12, 17 and 19 were 212±20, 215±26, 206±15 and 186±8 respectively.

2. Instrumentation

The magnet was built with different type of coils and these coils were equipped with different type of protection heaters. Coils 17 and 19 were equipped with 2 strip heaters each, located on the outer surface of the outer layer. These heaters were connected internally in each coil at the lead end. Coils 10 and 12 are equipped with single heater also located on the outer surface of the outer layer covering both transition and non-transition side of coil. Two special heaters were installed at the mid-plane (MP) between coils for temperature margin studies (discussed in Section 6). Strip heater wiring scheme is shown in Fig.1.

Heaters were made of stainless steel with copper cladding in coils 17 and 19, and without the copper cladding in coils 10 and 12. Therefore resistance of heaters in coils 10 and 12 was almost twice as large as resistance of heaters in coils 17 and 19. To have similar resistance of the heater firing circuits, the heaters in coils 10 and 12 were connected to two separate heater firing units (HFU), while heaters in coils 17 and 19 were connected in series to the same HFU. First two HFUs were set in protection mode and 3rd one in testing mode with the heater supply voltage at 300 V and capacitance at 4.8 mF, with 0 ms delay. The HFU3 was triggered by the HFU2 when protecting the magnet.

Spot heaters were mounted on coils 12 and 19, but were not fired during the cold test of this magnet.

The dump resistance was 30 mΩ and dump delay was set to 1 ms.

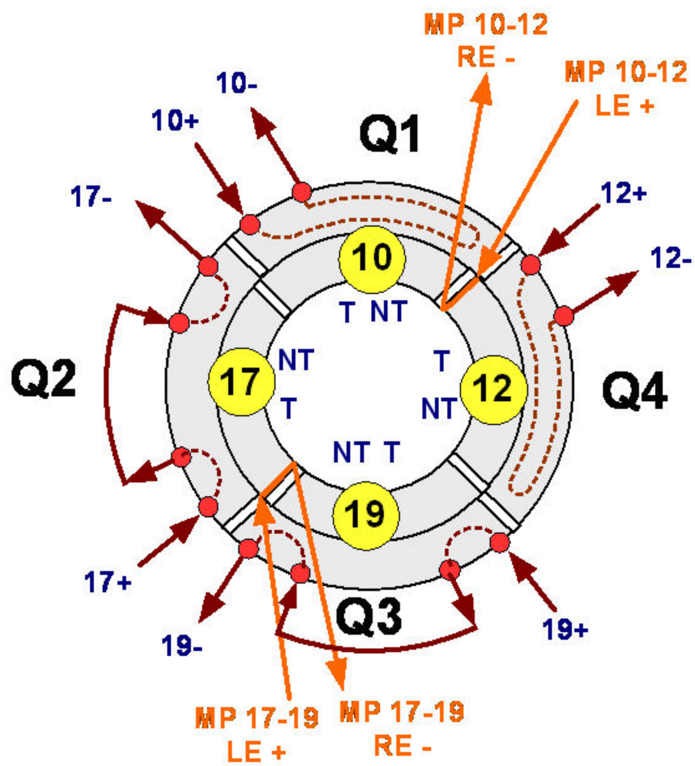

Figure 1. TQC02b strip heater wiring layout (looking from the lead end to the return end).

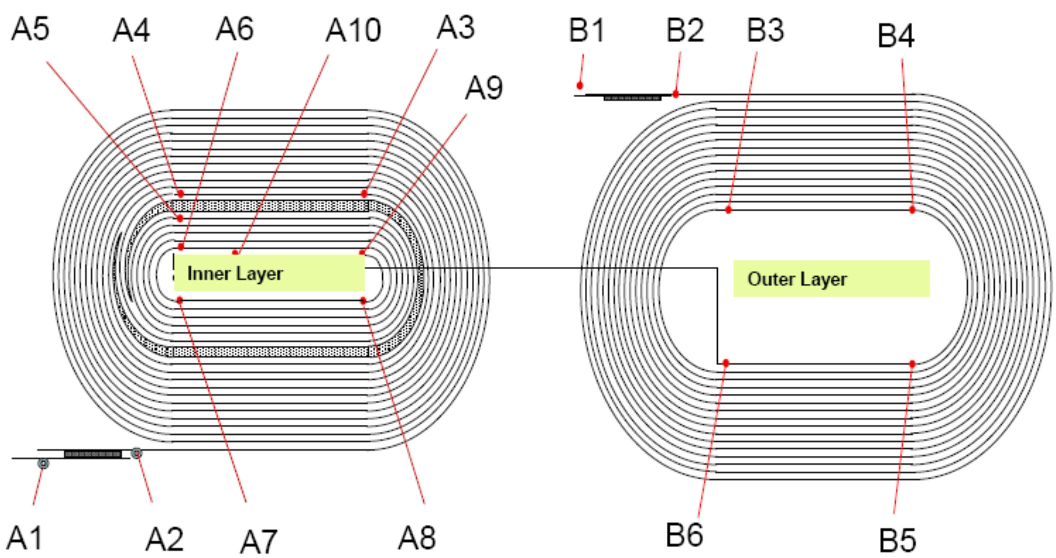

Figure 2. TQC02b voltage tap locations for the inner (left) and outer (right) layers.

Voltage tap system covers the inner and outer coil layers, pole turn, multi-turn and splice sections (see Fig.2). The KEK/HGQ 3-section quench antenna was used during the test to help locate the quench origins.

63 strain gauges were installed at different places (poles, control spacers, skin and bolts) for monitoring mechanical strain and calculating coil stresses during the magnet construction and testing.

In addition to the standard set of the dewar sensors two additional resistive temperature devices (RTD) were mounted on top and bottom of the magnet skin (*Cernox cx43233* and *cx43235* sensors respectively).

Several voltage taps were found open at the beginning of test in coil 10 (***A8, A9, A10, B3, B5***), coil 12 (***B1, A7***) and coil 17 (***B1***b). Voltage signals were found saturated at 10 A current in all ***A3A4*** and ***B3B4*** segments (and in ***B6B4*** segment in coil 10) during the preliminary signal checkout at the room temperature. Isoamplifier gains were generated by the Webtool according to the length of the voltage tap segments.

Initial signal checking at 4.5 K showed that during the cool down we lost two strain gauges: one on the bullets (***Bu57Aq1***) and one on the control spacer (***Cs17-3***) of the magnet.

The quench detection threshold for the half-coil signal was set to 750 mV (signals from the coils 10 and 19 formed the 1st half-coil signal, and signals from the coils 12 and 17 formed the 2nd half-coil signal). After the quench logic failure in quench #69 the half-coil signal threshold for the analog quench detection system was set to 500 mV (see details in Section 11).

3. Quench History

3.1 Test cycle 1

The magnet test program started at 4.5 K with quench training at the 20 A/s ramp rate. From the very beginning coil 12 was limiting the quench performance. This coil exhibited very slow training with quenches developed mostly in the same ***A10A9*** segment of the innermost turn of the inner coil layer (see Fig. 2). After first few quenches to save time training was continued at the 50 A/s ramp rate.

TC-1 started with the first quench at a current of 8400 A and after 29 quenches we reached only 10 kA. Nevertheless it was decided to train the magnet as much as possible in order to perform planned temperature margin measurements in both MJR and RRP coils. After quench #60 magnet reached a quench current of ~ 10.4 kA which was close to the expected maximum quench current of the coil 12 based on the previous tests. Full quench history in 1st test cycle is shown in Fig. 3.

Test at 4.5 K was continued with a ramp rate study. Coil 10 developed quenches only at high ramp rates of 200 A/s and higher. All other quenches occurred in coil 12. Detailed discussion of the ramp rate dependence is presented in Section 4.

Quench logic (QL) failed during the temperature margin measurements when ~28 W power was dissipated in the mid-plane blocks of coils 10 and 12. Estimated MIITs of ~8.86 could cause local conductor degradation resulted in the magnet performance degradation we observed in following two quenches (#70 and #71) at 4.5 K. Details of the QL failure are described in Section 11. Apparently magnet was re-trained at 1.9 K since at the end of TC-1 we reached again the quench currents consistent with the 4.5 K plateau before the incident with high MIITs.

Training at 1.9 K showed some increase of a quench current with increasing the ramp rate up to 175 A/s, but for the same ramp rate the magnet exhibited rather erratic performance (see Fig. 3). We did not any sign of training at any specific ramp rate at 1.9 K. Quenches mostly developed in coil 12 again, with few exceptions when quenches occurred in coils 10 and 17 during the ramp rate or heater studies.

At 1.9 K, only 2 training quenches occurred in coil 17, both after the long magnetic measurements.

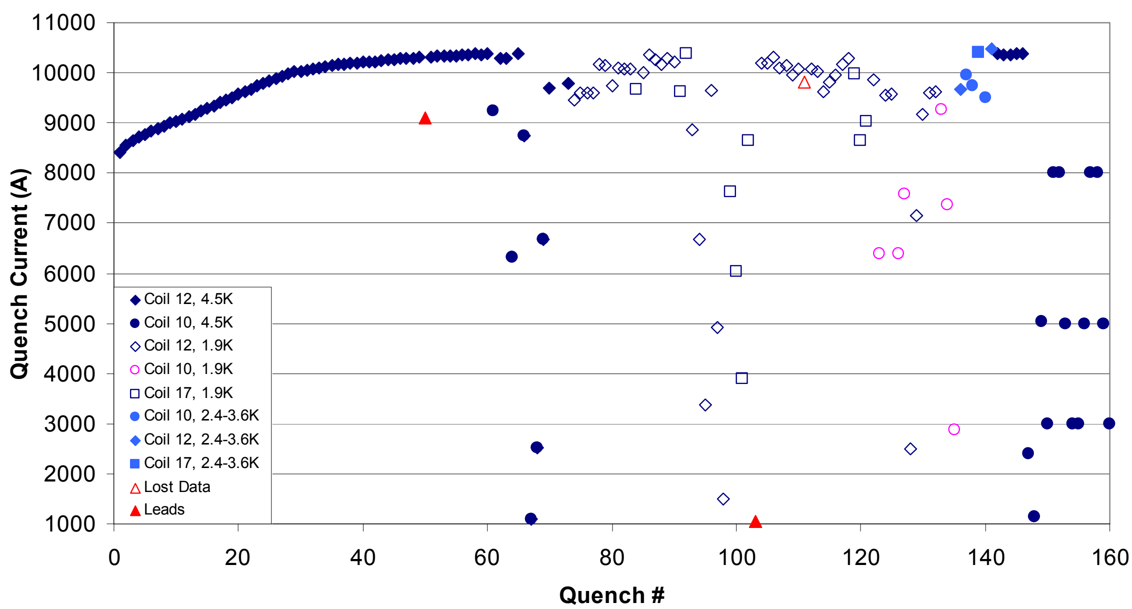

Figure 3. TQC02b quench history in TC-1. Quenches during the protection heater study at the end of TC-1 are also shown.

Some quenches during the temperature margin measurements in RRP coils developed in the superconducting (positive) lead. Apparently the mid-plane strip heater was warming up the leads. These measurements are summarized in Section 6. Protection heater test results are presented in Section 7. In addition, we did a test similar to the stability test of LM02 magnet by locally heating the outer layer protection heater [1]. Although there were no quenches in TQC02b outer layer related to the flux-jump instabilities we performed this test to compare performance of the coils 10 and 12. Results are presented at the end of Section 7.

At the end of the TC-1 we confirmed the quench current plateau at 4.5 K, a quench current of ~10.4 kA was reached again.

The highest quench current in TC-1 was 10469 A at 3.6 K (quench # 141 at a ramp rate of 50 A/s) when the magnet was in process of warming up from 1.9 K to 4.5 K.

3.2 Test cycle 2

Between test cycles the magnet was warmed up to ~ 270 K according to the Carbon Glass temperature sensors in dewar. Cernox sensors mounted on the magnet body showed ~ 290 K. The difference in reading between these two sensors is significant only at around the room temperature, while at 4.5 K this difference is at level of few mK.

In TC-2 the magnet showed re-training at 4.5 K. First training quench occurred at a current of ~9.7 kA in the same coil 12. Quench training in TC-2 looks very similar to the one in TC-1, i.e. very slow and with all quenches developed in coil 12. For comparison training curves in TC-1 and TC-2 are overlaid in Fig. 4. After 20 quenches it was decided not to continue training because of clear re-training trend in TC-2.

All training quenches were located again in the ***A10A9*** segment of the inner layer of the coil 12. All quenches in TC-2 are shown in Fig. 5.

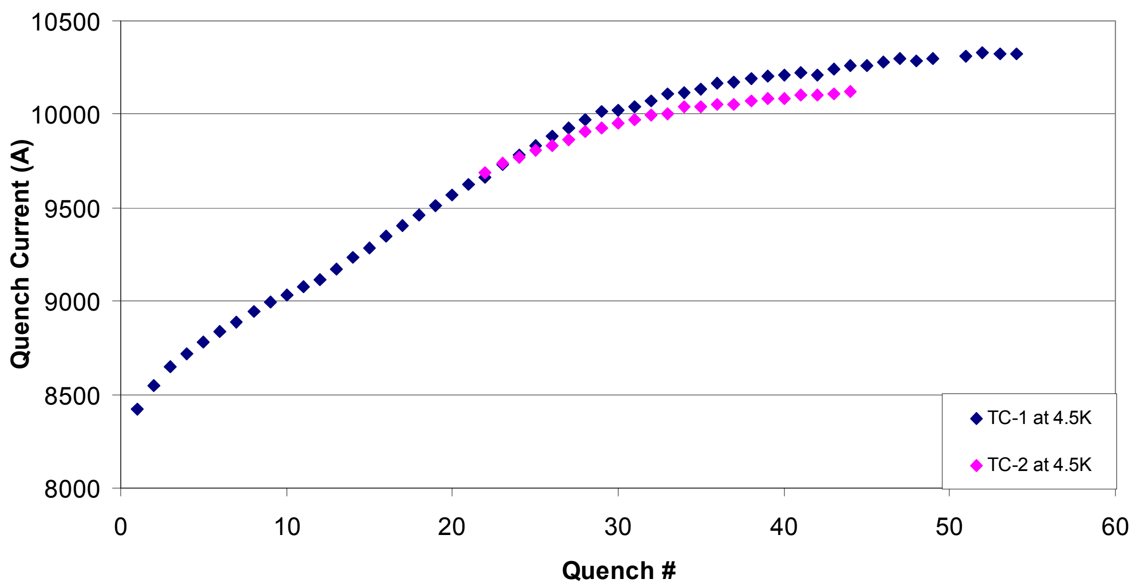

Figure 4. Training quenches in TC-1 and TC-2 at 4.5 K.

TC-2 was completed with the protection heater study and the energy loss measurements.

The field quality magnetic measurements were made at different temperatures in both test cycles. A set of the "warm" magnetic measurements (z-scan) at 300 K was performed on August 1st. Magnetic measurements also were made at 4.5 K on August 5th and on September 8th, as well as at 1.9 K on August 13th and 14th. Results of these measurements are summarized in Section 9.

Quench multiplicity in the TQC02b coils are shown in Fig. 6. 190 quenches were performed in total including the provoked quenches during the protection heater studies. We lost data for quenches #111 and #163. No particular reasons were found for these failures.

The complete quench history is presented in Tables 1 and 2.

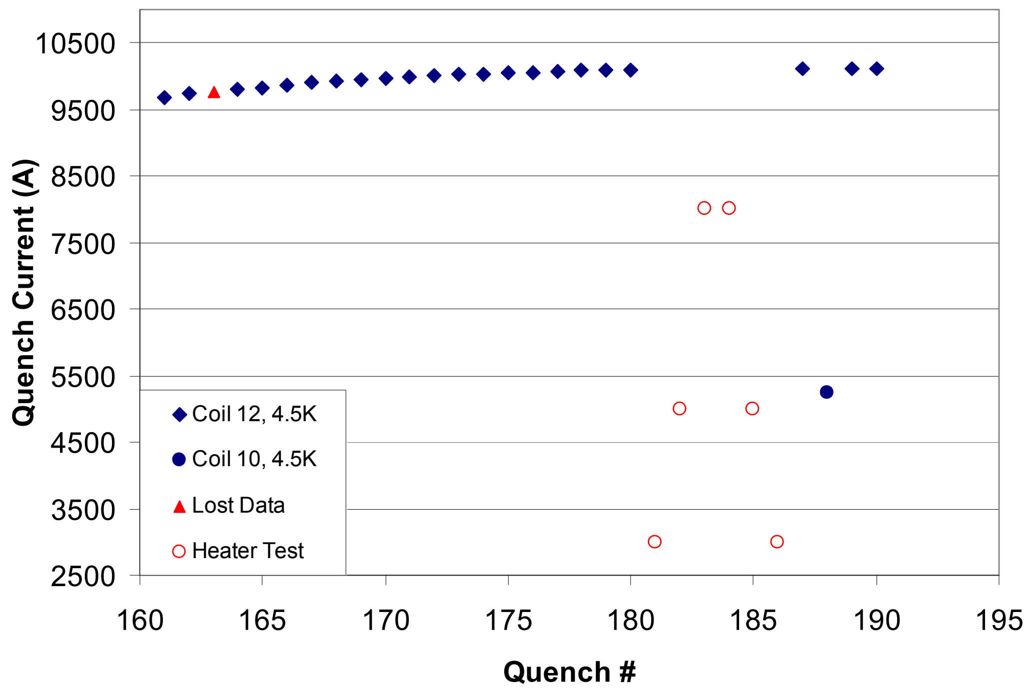

Figure 5. All TC-2 quenches (4.5 K).

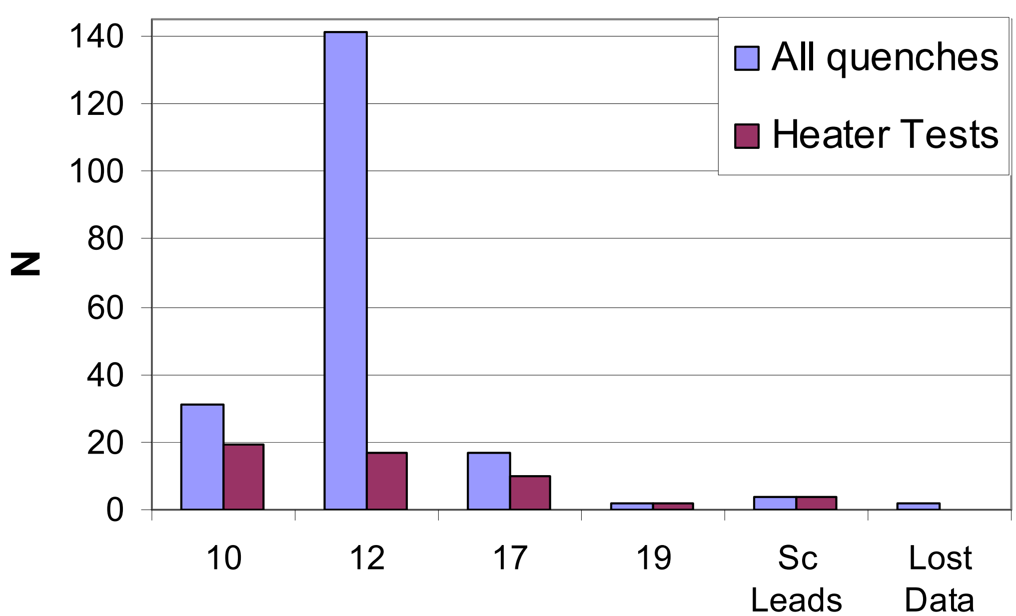

Figure 6. Quench multiplicity in TQC02b coils.

Table 1: TQC02b Quench History with comments

File	#	I (A)	dI/dt (A/sec)	t_{quench}	MIITs	QDC	Mag.Bot Temp	Mag.Top Temp	Comments from File
tqc02b.Quench.080805145418.740		500	20	0.0010	0.06	GndRef	4.485	4.483	manual trip at 500A, all HFU in protection mode
tqc02b.Quench.080805151500.858		5000	20	-0.0339	2.22	HcoilHcoil	4.487	4.491	HFU1 induced quench at 5000A, HFU2-3 in protection mode. dump delay 1ms. All HFU at 300V
tqc02b.Quench.080805153922.344		5000	20	-0.0340	2.69	HcoilHcoil	4.487	4.488	HFU2 induced quench at 5kA, dump delay 25ms, all HFU at 300V
tqc02b.Quench.080805160047.486		5000	20	-0.0452	2.96	HcoilHcoil	4.484	4.480	HFU3 induced quench @ 5kA, dump delay 25ms, all HFUs at 300V. T=4.48K.
tqc02b.Quench.080806103022.743	**1**	8430	20	-0.0141	4.06	HcoilHcoil	4.475	4.474	Quench at 8420A with 20A/s ramp rate.
tqc02b.Quench.080806110458.296	**2**	8550	20	-0.2740	23.08	HcoilHcoil	4.486	4.483	quench at 8550A, 20A/s, 4.5Kato
tqc02b.Quench.080806113125.811	**3**	8657	20	-0.0123	3.99	HcoilHcoil	4.487	4.487	quench at 8647.4A, 20A/s, 4.5K
tqc02b.Quench.080806120216.631	**4**	8725	20	-0.0085	3.74	HcoilHcoil	4.478	4.484	quench at 8716.7A, 20A/, 4.5K
tqc02b.Quench.080806134622.431	**5**	8779	20	-0.5934	48.89	HcoilHcoil	4.446	4.443	quench at 8778A, 20A/s, 4.5K
tqc02b.Quench.080806142020.737	**6**	8841	20	-0.2611	23.57	HcoilHcoil	4.452	4.451	quench at 8838.5A, 20A/s, 4.5Kz
tqc02b.Quench.080806145649.400	**7**	8894	20	-0.0080	3.79	HcoilHcoil	4.461	4.459	quench at 8886.5A, 20A/s (50A/s upto 6kA), 4.5K
tqc02b.Quench.080806153118.993	**8**	8951	20	-0.0077	3.79	HcoilHcoil	4.451	4.451	20A/s ramp rate, 4.45K ramp 8, training quench 8
tqc02b.Quench.080806160757.382	**9**	9003	20	-0.0101	4.03	HcoilHcoil	4.455	4.456	20 A/s ramp9 quench 9 training at 4.5K
tqc02b.Quench.080806163547.417	**10**	9037	20	-0.0097	3.98	HcoilHcoil	4.450	4.446	quench at 9031A, 20A/s (50A/s to 6kA), 4.5K
tqc02b.Quench.080806171403.664	**11**	9083	20	-0.1467	15.33	HcoilHcoil	4.446	4.446	quench at 9075A, 20A/s (50A/s to 6kA), 4.5K
tqc02b.Quench.080806174324.457	**12**	9118	20	-0.0095	4.03	HcoilHcoil	4.455	4.452	quench at 9115A, 20A/s (50A/s upto 6kA), 4.5K
tqc02b.Quench.080806180817.571	**13**	9180	20	-0.0087	3.98	HcoilHcoil	4.459	4.458	quench at 9171.3A with ram rate of 20A/s (50A/s upto 6kA0, 4.5K
tqc02b.Quench.080806183715.154	**14**	9245	20	-0.0078	3.93	HcoilHcoil	4.452	4.450	quench at 9232A, 20A/s (50A/s upto 6kA), 4.5K
tqc02b.Quench.080806190658.424	**15**	9300	20	-0.0076	3.94	HcoilHcoil	4.454	4.449	quench at 9287.1A, 20A/s (50A/s to 6.5kA), 4.5K
tqc02b.Quench.080807085919.993	**16**	9357	20	-0.0069	3.97	HcoilHcoil	4.425	4.430	quench at 9346.4A, 20A/s (50A/s to 6kA), 4.5K58
tqc02b.Quench.080807094319.305	**17**	9411	20	-0.0071	3.95	HcoilHcoil	4.440	4.440	quench at 9403.6A, 20A/s (50A/s to 6kA), 4.5K

tqc02b.Quench.080807101824.408	**18**	9471	20	-0.0066	3.93	HcoilHcoil	4.448	4.451	quench at 9458.8A, 20A/s (50A/s to 6kA), 4.5K
tqc02b.Quench.080807105044.299	**19**	9517	20	-0.0062	3.9	HcoilHcoil	4.459	4.460	quench at 9509.9A, 20A/s (50A/s to 6kA), 4.5K
tqc02b.Quench.080807114051.753	**20**	9555	50	-0.5262	51.55	HcoilHcoil	4.462	4.462	quench at 9570.1A, 50A/s, 4.5K
tqc02b.Quench.080807120827.094	**21**	9634	100	-0.0091	4.19	HcoilHcoil	4.470	4.475	quench at 9623A, 100A/s, 4.5Kto
tqc02b.Quench.080807125144.665	**22**	9666	20	-0.4366	44.2	HcoilHcoil	4.473	4.472	quench at 9663A, 20A/s (50A/s upto 6.5kA), 4.5K
tqc02b.Quench.080807134530.094	**23**	9738	50	-0.0064	4.03	HcoilHcoil	4.462	4.461	quench at 9730A, 50A/s, 4.5K
tqc02b.Quench.080807142319.854	**24**	9764	50	-0.4685	48.21	HcoilHcoil	4.466	4.464	quench at 9780.1A, 50A/s, 4.5K
tqc02b.Quench.080807145159.520	**25**	9821	50	-0.4664	48.47	HcoilHcoil	4.477	4.478	quench at 9830.5A, 50A/s, 4.5K
tqc02b.Quench.080807152720.239	**26**	9892	50	-0.0048	3.92	HcoilHcoil	4.478	4.481	quench at 9883.4A, 50A/s, 4.5K
tqc02b.Quench.080807155432.561	**27**	9914	50	-0.4614	48.87	HcoilHcoil	4.477	4.486	quench at 9924.8A, 50A/s, 4.5K
tqc02b.Quench.080807162531.480	**28**	9985	50	-0.0055	4	HcoilHcoil	4.480	4.475	quench at 9971A, 50A/s, 4.5K
tqc02b.Quench.080807170013.717	**29**	10031	50	-0.0049	3.99	HcoilHcoil	4.473	4.470	quench at 10017.2A, 50A/s, 4.5K
tqc02b.Quench.080807173010.045	**30**	10035	50	-0.0050	3.98	HcoilHcoil	4.478	4.474	Quench at 10024.4A, 50A/s, 4.5K
tqc02b.Quench.080807180944.505	**31**	10045	50	-0.0601	9.55	HcoilHcoil	4.470	4.475	quench at 10040.4A, 50A/s, 4.5K
tqc02b.Quench.080807185302.391	**32**	10082	50	-0.0050	4	HcoilHcoil	4.463	4.468	quench at 10074A, 50A/s, 4.5K
tqc02b.Quench.080807193022.446	**33**	10115	50	-0.0048	3.98	HcoilHcoil	4.472	4.474	quench at 10107.4A, 50A/s, 4.5K
tqc02b.Quench.080808082329.775	**34**	10129	50	-0.0041	4	HcoilHcoil	4.445	4.449	quench at 10115.8A, 50A/s, 4.5K
tqc02b.Quench.080808085749.854	**35**	10144	50	-0.0085	4.37	WcoilGnd	4.457	4.462	quench at 10136.1A, 50A/s, 4.5K
tqc02b.Quench.080808093403.292	**36**	10145	50	-0.5343	58.68	HcoilHcoil	4.468	4.471	quench at 10165.4A, 50A/s, 4.5K
tqc02b.Quench.080808104546.948	**37**	10163	50	-0.4027	45.19	WcoilGnd	4.457	4.454	quench at 10172A, 50A/s, 4.5K
tqc02b.Quench.080808111633.144	**38**	10198	50	-0.0046	3.99	HcoilHcoil	4.484	4.485	quench at 10189.1A, 50A/s, 4.5K
tqc02b.Quench.080808115309.724	**39**	10193	50	-0.4366	48.97	HcoilHcoil	4.483	4.487	quench at 10204A, 50A/s, 4.5K
tqc02b.Quench.080808122345.236	**40**	10223	50	-0.0253	6.16	HcoilHcoil	4.481	4.474	quench at 10213A, 50A/s, 4.5K
tqc02b.Quench.080808134301.013	**41**	10234	10	-0.0035	3.93	HcoilHcoil	4.481	4.479	quench at 10223.4, 10A/s (50A/s to 10kA) 4.5K
tqc02b.Quench.080808141854.904	**42**	10220	50	-0.0032	3.85	HcoilHcoil	4.484	4.480	quench at 10212.8A, 50A/s, 4.5K
tqc02b.Quench.080808145114.431	**43**	10253	50	-0.0045	4	HcoilHcoil	4.503	4.500	quench at 10242A, 50A/s, 4.5K
tqc02b.Quench.080808153426.164	**44**	10262	50	-0.2118	25.88	HcoilHcoil	4.493	4.486	quench at 10262.8A, 50A/s, 4.5K
tqc02b.Quench.080808161505.197	**45**	10275	50	-0.0031	3.86	HcoilHcoil	4.492	4.487	quench at 10263.1A, 50A/s, 4.5K
tqc02b.Quench.080808170219.684	**46**	10283	50	-0.1011	14.25	HcoilHcoil	4.488	4.484	quench at 10277A, 50A/s, 4.5K
tqc02b.Quench.080808174955.979	**47**	10308	50	-0.0032	3.87	HcoilHcoil	4.474	4.467	quench at 10297.7A, 50A/s, 4.5K
tqc02b.Quench.080808182535.943	**48**	10300	50	-0.0043	4.01	HcoilHcoil	4.481	4.476	quench at 10289A, 50A/s, 4.5K
tqc02b.Quench.080808190136.134	**49**	10310	50	-0.0041	4.01	HcoilHcoil	4.476	4.469	quench at 10302A, 50A/s, 4.5K
tqc02b.Quench.080809084726.122	**50**	9093	50	0.0001	3.24	WcoilIdot	4.437	4.431	AQD-leads trip at 9.1kA, 50A/s, 4.5K
tqc02b.Quench.080809091446.760	**51**	10323	50	-0.0031	3.87	HcoilHcoil	4.461	4.457	quench at 10311A, 50A/s, 4.5K
tqc02b.Quench.080809094640.937	**52**	10336	50	-0.0035	3.91	HcoilHcoil	4.463	4.458	quench at 10327A, 50A/s, 4.5K
tqc02b.Quench.080809102802.157	**53**	10333	50	-0.0031	3.86	HcoilHcoil	4.454	4.449	quench at 10324.9A, 50A/s, 4.5K

tqc02b.Quench.080809105308.914	**54**	10330	50	-0.0034	3.9	HcoilHcoil	4.471	4.465	quench at 10323.8A, 50A/s, 4.5K
tqc02b.Quench.080809112045.552	**55**	10336	50	-0.1813	22.93	HcoilHcoil	4.475	4.467	quench at 10335.2A, 50A/s, 4.5K
tqc02b.Quench.080809115333.134	**56**	10359	50	-0.0024	3.78	HcoilHcoil	4.474	4.471	quench at 10350.2A, 50A/s, 4.5K
tqc02b.Quench.080811084633.230	**57**	10369	50	-0.0035	4.02	HcoilHcoil	4.450	4.445	quench at 10361.4A, 50A/s, 4.5K
tqc02b.Quench.080811092619.644	**58**	10393	50	-0.0029	3.85	HcoilHcoil	4.447	4.442	quench at 10376.8A, 50A/s, 4.5K
tqc02b.Quench.080811095853.862	**59**	10367	50	-0.1878	23.77	HcoilHcoil	4.448	4.441	quench at 10368.4A, 50A/s, 4.5K
tqc02b.Quench.080811104431.236	**60**	10379	20	-0.0022	3.77	HcoilHcoil	4.446	4.440	quench at ~10370A, 20A/s, (50A/s to 8kA), 4.5K
tqc02b.Quench.080811110824.499	**61**	9252	200	-0.0036	3.42	HcoilHcoil	4.452	4.451	quench at 9244A, 200A/s, 4.5K
tqc02b.Quench.080811112534.036	**62**	10289	150	-0.0045	3.95	HcoilHcoil	4.444	4.447	quench at ~10282A, 150A/s, 4.5K
tqc02b.Quench.080811121239.187	**63**	10291	100	-0.4821	54.78	HcoilHcoil	4.443	4.438	quench at 10329A, 100A/s, 4.5K
tqc02b.Quench.080811123900.823	**64**	6321	250	-0.0169	2.61	HcoilHcoil	4.444	4.443	quench at 6322A, 250A/s, 4.5K
tqc02b.Quench.080811140641.980	**65**	10396	50	-0.0039	3.99	HcoilHcoil	4.436	4.430	I (heater)=1.434A, ramp rate 50A, T=4.43K, I(quench)=10384.9A
tqc02b.Quench.080811145109.447	**66**	8751	20	-0.0092	3.74	HcoilHcoil	4.442	4.437	I(Heater)=2.3897A, 20A/s (50A/s to 5kA), 4.43K, I(quench)=8734.4A
tqc02b.Quench.080811152033.385	**67**	1094	20	-0.1794	0.31	WcoilGnd	4.438	4.436	I (heater)=3.8927A, 20A/s, 4.43K, I (quench)=1095,3A.
tqc02b.Quench.080811160247.691	**68**	2526	20	-0.4495	3.24	HcoilHcoil	4.435	4.430	I (heater)=3.25A, 20A/s, 4.43K, I(quench)=2520.7A
tqc02b.Quench.080811162820.072	**69**	6676	20	-0.2148	16.27	HcoilHcoil	4.437	4.433	I (heater)=2.82A, 20A/s, 4.43K, I (quench)=6678A.
tqc02b.Quench.080811173723.344	**70**	9706	20	-0.0046	3.86	HcoilHcoil	4.437	4.433	I (heater 17-19)=2.39A, 20A/s (50A/s to 5kA), 4.43K, I (quench)=9704.6A
tqc02b.Quench.080811175619.153	**71**	833	20	-0.6032	0.5	HcoilHcoil	4.433	4.434	quench at 845A, I(heater)=3.89A, 20A/s, 4.43K
tqc02b.Quench.080811181652.483	**72**	807	20	0.0001	0.08	GndRef	4.437	4.435	DQD trip in leads at 845A.
tqc02b.Quench.080811190104.424	**73**	9784	20	-0.0060	3.99	WcoilIdot	4.433	4.426	quench at 9780.9A, no current on heater ph17-19, 20A/s, 4.44K
tqc02b.Quench.080812122908.059	**74**	9467	20	-0.0099	4.41	HcoilHcoil	1.877	1.878	quench at 9460A, 20A/s (50A/s to 6kA), 1.86K
tqc02b.Quench.080812125218.573	**75**	9602	50	-0.1700	19.19	HcoilHcoil	1.907	1.902	quench at 9607.2A, 50A/s, 1.9K
tqc02b.Quench.080812134700.105	**76**	9614	50	-0.0077	4.21	HcoilHcoil	1.882	1.884	quench at 9.6kA, 50A/s, 1.9K
tqc02b.Quench.080812141447.305	**77**	9609	50	-0.0083	4.25	HcoilHcoil	1.871	1.865	quench at 9605.6A, 50A/s, 1.9K
tqc02b.Quench.080812150334.283	**78**	10170	150	-0.0077	4.41	HcoilHcoil	1.900	1.903	quench at 10165A, 150A/s, 1.9K
tqc02b.Quench.080812160146.780	**79**	10144	100	-0.1504	19.13	HcoilHcoil	1.889	1.889	quench at 10153A, 100A/s, 1.9K
tqc02b.Quench.080812164128.644	**80**	9738	75	-0.0084	4.32	HcoilHcoil	1.949	1.952	quench at 9735.6A, 75A/s, 1.95K
tqc02b.Quench.080812170848.658	**81**	10111	100	-0.0066	4.3	HcoilHcoil	1.973	1.968	quench at 10107.5A, 100A/s, 1.96K
tqc02b.Quench.080812172544.625	**82**	10084	100	-0.0066	4.28	HcoilHcoil	1.943	1.939	quench at 10079A, 100A/s, 1.95K
tqc02b.Quench.080812180654.036	**83**	10073	100	-0.0067	4.32	WcoilIdot	1.825	1.834	quench at 10070.2A, 100A/s, 1.9K
tqc02b.Quench.080812184342.102	**84**	9668	200	-0.0190	5.13	HcoilHcoil	1.937	1.939	quench at 9666.2A, 200A/s, 1.94K

tqc02b.Quench.080812190536.596	**85**	9992	150	-0.0083	4.37	HcoilHcoil	1.959	1.965	quench at 9991A, 150A/s, 1.9K
tqc02b.Quench.080813091710.707	**86**	10343	150	-0.0591	10.06	HcoilHcoil	1.871	1.874	quench at 10349.2A, 150A/s, 1.87K
tqc02b.Quench.080813094855.584	**87**	10177	150	-0.6214	68.61	HcoilHcoil	1.907	1.898	quench at 10268.7A, 150A/s, 1.87K
tqc02b.Quench.080813103537.500	**88**	10182	150	-0.0078	4.4	HcoilHcoil	1.909	1.902	quench at 10180A, 150A/s, 1.9K
tqc02b.Quench.080813111641.273	**89**	10300	150	-0.0067	4.34	HcoilHcoil	1.888	1.890	quench at 10295A, 150A/s, 1.89K
tqc02b.Quench.080813120537.865	**90**	10214	150	-0.0063	4.29	HcoilHcoil	1.878	1.872	quench at 10206A, 150A/s, 1.9K
tqc02b.Quench.080813181205.532	**91**	9621	150	-0.0028	3.75	HcoilHcoil	1.844	1.844	quench at 9.7kA, 150A/s, 1.9K Ramp started at 9kA after the mag. meas.
tqc02b.Quench.080814123404.108	**92**	10388	150	-0.0039	4.15	HcoilHcoil	1.832	1.841	quench at 10382.2A, 150A/s, 1.9K, ramp after the mag.measurements
tqc02b.Quench.080814140503.483	**93**	8874	20	-0.1714	16.66	HcoilHcoil	1.895	1.895	quench at 8872,9A, 20A/s (50A/s to 5kA), 1.9K, I(MJR Heater)=2.8289A.
tqc02b.Quench.080814143733.934	**94**	6680	20	-0.0384	3.92	HcoilHcoil	1.926	1.947	MJR Heater test, P=37W) quench at 6676.7A, 20A/s, I(Heater)=3.25A, 1.9K
tqc02b.Quench.080814151245.559	**95**	3360	20	-0.4063	5.23	HcoilHcoil	1.937	1.916	MJR Heater test, P=53W, quench at 3367A, 20A/s, 1.9K, I(Heater)=3.89A 0
tqc02b.Quench.080814155255.298	**96**	9645	20	-0.0095	4.42	HcoilHcoil	1.905	1.901	MJR Heater test: P=20W, quench at 9643A, 20A/s (50A/s to 7kA), 1.9K, I(Heater)=2.39A
tqc02b.Quench.080814162838.829	**97**	4911	20	-0.2704	7.81	HcoilHcoil	1.932	1.942	MJR Heater test, P=45W: quench at 4911.8A, 20A/s, 1.9K I(Heater)=3.5857A
tqc02b.Quench.080814165056.818	**98**	1478	20	-0.3671	0.96	HcoilHcoil	1.958	1.946	MJR heater test, P=65W: quench at 1488.7A, 20A/s, 1.9K. I(heater)=4.31A.
tqc02b.Quench.080814170949.568	**99**	7626	20	-0.0370	4.77	HcoilHcoil	1.937	1.951	RRP Heater test, P=45W, quench at 7618.5A, 20A/s, 1.9K, I(Heater)=3.5857A.
tqc02b.Quench.080814173804.089	**100**	6027	20	-0.4474	18.12	HcoilHcoil	1.940	1.951	RRP Heater test, P=53W: quench at 6031.2A, 20A/s, 1.9K, I(Heater)=3.8914
tqc02b.Quench.080814180854.770	**101**	3891	20	-0.1729	3.44	HcoilHcoil	1.925	1.931	RRP Heater test, P=65W, quench at 3889.6A, 20A/s, 1.9K, I(Heater)=4.31A.
tqc02b.Quench.080814183351.114	**102**	8666	20	-0.0235	4.85	HcoilHcoil	1.919	1.921	RRP Heater test, P=40W: quench at 8657A, 20A/s (50A/s to 6kA), 1.9K, I(heater)=3.38A
tqc02b.Quench.080814191732.075	**103**	1045	20	-0.0004	0.1	WcoilGnd	1.900	1.901	RRP Heater test, P=80W, quench at 1044.1A, 20A/s, 1.9K, I(heater)=4.78A.
tqc02b.Quench.080815104724.792	**104**	10197	150	-0.0064	4.34	HcoilHcoil	1.862	1.865	quench at 10194A, 150A/s, 1.9K
tqc02b.Quench.080815111530.493	**105**	10195	150	-0.0067	4.31	HcoilHcoil	1.911	1.894	quench at 10192.3A, 150A/s, 1.9K
tqc02b.Quench.080815114831.016	**106**	10307	150	-0.1012	14.4	HcoilHcoil	1.887	1.890	quench at 10315A, 150A/s, 1.9K
tqc02b.Quench.080815122606.283	**107**	10098	150	-0.0078	4.38	HcoilHcoil	1.911	1.911	quench at 10094A, 150A/s, 1.9K
tqc02b.Quench.080815131146.017	**108**	10140	100	-0.0069	4.35	HcoilHcoil	1.883	1.890	quench at 10135A, 100A/s, 1.9K
tqc02b.Quench.080815135756.911	**109**	9968	100	-0.0076	4.34	HcoilHcoil	1.884	1.911	quench at 9961.1A, 100A/s, 1.89K

tqc02b.Quench.080815145501.456	**110**	10041	100	-0.3500	39.06	HcoilHcoil	1.887	1.879	quench at 10071A, 100A/s, 1.9K
tqc02b.Quench.080815163455.078	**111**	9807	100	0.0000	4.655	AQD_COIL	0.000	0.000	***Data Lost; from eLog:*** I(ph12)=1.25A (20W), quench at 9.8kA, 100A/s, 1.9K
tqc02b.Quench.080815171445.505	**112**	10071	100	-0.0090	4.55	HcoilHcoil	1.843	1.849	quench at 10062.8A, 100A/s, 1.9K
tqc02b.Quench.080815181315.602	**113**	10042	125	-0.0080	4.38	WcoilIdot	1.948	1.953	quench at 10035A, 125A/s, 1.9K
tqc02b.Quench.080815185621.405	**114**	9632	50	-0.0087	4.32	HcoilHcoil	1.812	1.812	quench at 9624A, 50A/s, 1.9K
tqc02b.Quench.080825155659.805	**115**	9813	50	-0.0099	4.62	WcoilIdot	1.864	1.872	quench at 9801 A, 50A/s, 1.9K
tqc02b.Quench.080825162859.187	**116**	9975	100	-0.0073	4.32	HcoilHcoil	1.875	1.879	quench at 9964A, 100A/s, 1.9K
tqc02b.Quench.080825173917.641	**117**	10182	150	-0.0066	4.3	HcoilHcoil	1.856	1.856	quench at 10169.8A, 150A/s, 1.9K
tqc02b.Quench.080825181837.312	**118**	10240	175	-0.3744	43.15	WcoilGnd	1.924	1.928	quench at 10297.4A, 175A/s, 1.9K
tqc02b.Quench.080825185034.923	**119**	9995	190	-0.0027	3.71	HcoilHcoil	1.873	1.878	quench at 9979.3A, 190A/s, 1.9K
tqc02b.Quench.080825191411.306	**120**	8662	250	-0.0029	3.18	HcoilHcoil	1.885	1.891	quench at 8651A, 250A/s, 1.9K
tqc02b.Quench.080825193240.339	**121**	9043	225	-0.0024	3.32	HcoilHcoil	1.879	1.871	quench at 9033.2A, 225A/s, 1.9K
tqc02b.Quench.080826095549.994	**122**	9864	75	-0.0067	4.29	HcoilHcoil	1.885	1.892	quench at 9858.8A, 75 A/s (100A/s to 6kA), 1.9K
tqc02b.Quench.080826103329.982	**123**	6398	300	-0.0039	2.14	WcoilIdot	1.860	1.864	quench at 6.4kA, 300A/s, 1.9K
tqc02b.Quench.080826105346.207	**124**	9556	20	-0.0084	4.25	HcoilHcoil	1.858	1.868	quench at 9548.9A, 20A/s (100A/s to 6kA), 1.9K
tqc02b.Quench.080826113416.803	**125**	9580	5	-0.0179	5.12	HcoilHcoil	1.891	1.884	quench at 9577.3A, 5 A/s (100A/s to 6kA), 1.9K
tqc02b.Quench.080826115501.447	**126**	6232	300	-0.5136	22.42	HcoilHcoil	1.876	1.875	quench at 6.4kA, 300A/s, 1.9K
tqc02b.Quench.080826121403.858	**127**	7538	275	-0.1686	12.16	HcoilHcoil	1.891	1.890	quench at 7581.5A, 275A/s, 1.9K
tqc02b.Quench.080826134839.019	**128**	2475	50	-0.2478	1.88	HcoilHcoil	1.871	1.872	quench at 2486.8A, I(HFU)=2.16A (60W), 50A/s, 1.9K
tqc02b.Quench.080826144532.931	**129**	7165	50	-0.0116	3.07	HcoilHcoil	1.906	1.900	quench at 7160.5A, I(HFU)=1.765A (40W), 50A/s, 1.9K
tqc02b.Quench.080826160945.180	**130**	9160	50	-0.1490	15.84	HcoilHcoil	1.891	1.888	quench at 9167.8A, I(HFU)=1.527A (30W), 50A/s, 1.9K
tqc02b.Quench.080826165155.834	**131**	9598	50	-0.0071	4.16	HcoilHcoil	1.839	1.854	quench at 9595A, I(HFU)=1.25A (20W), 50A/s, 1.9K
tqc02b.Quench.080826174022.364	**132**	9621	50	-0.0097	4.38	HcoilHcoil	1.907	1.913	quench at 9617A, I(HFU-coil 10)=1.25A (20W), 50A/s, 1.9K
tqc02b.Quench.080826180612.586	**133**	9268	50	-0.0139	4.54	HcoilHcoil	1.878	1.880	quench at 9265.3A, I(HFU)=1.527 A (30W), 50A/s, 1.9K
tqc02b.Quench.080826183759.733	**134**	7376	50	-0.0099	3.09	HcoilHcoil	1.848	1.856	quench at 7375A, I(HFU-coil10)=1.76A (40W), 50A/s, 1.9K
tqc02b.Quench.080826190033.398	**135**	2860	50	-0.1666	1.83	HcoilHcoil	1.862	1.862	quench at 2868A, I(HFU-coil10)=2.16A (60W), 50A/s, 1.9K
tqc02b.Quench.080827123227.882	**136**	9681	50	-0.0071	4.25	HcoilHcoil	2.425	2.438	quench at 9677A, 50A/s, 2.42K
tqc02b.Quench.080827130307.058	**137**	9967	200	-0.0024	3.53	HcoilHcoil	2.412	2.445	quench at 9965A, 200A/s, 2.43K
tqc02b.Quench.080827141355.959	**138**	9644	200	-0.4787	48.24	HcoilHcoil	3.054	3.055	quench at 9739.2A, 200A/s, 3K
tqc02b.Quench.080827145016.319	**139**	10408	50	-0.0113	4.94	HcoilHcoil	3.064	3.149	quench at 10402.2A, 50A/s, 3.1K

tqc02b.Quench.080827152954.757	**140**	9515	200	-0.0031	3.46	HcoilHcoil	3.556	3.559	quench at 9511.2A, 200 A/s, 3.56K
tqc02b.Quench.080827161025.377	**141**	10453	50	-0.4170	49.32	HcoilHcoil	3.597	3.616	quench at 10469.4A, 50A/s, 3.56K
tqc02b.Quench.080827170446.786	**142**	10375	50	-0.0230	6.05	HcoilHcoil	4.431	4.437	quench at 10375.5A, 50 A/s, 4.43K
tqc02b.Quench.080827174819.816	**143**	10371	50	-0.0038	3.96	HcoilHcoil	4.443	4.443	quench at 10368A, 50A/s, 4.44K
tqc02b.Quench.080827182142.783	**144**	10378	50	-0.0035	3.93	HcoilHcoil	4.452	4.457	quench at 10370.2A, 50A/s, 4.44Knotch"
tqc02b.Quench.080827184742.598	**145**	10375	50	-0.0038	3.96	HcoilHcoil	4.457	4.454	quench at 10371.7A, 50A/s, 4.44K
tqc02b.Quench.080828095453.035	**146**	10389	50	-0.0036	4.02	HcoilHcoil	4.432	4.437	quench at 10384.9A, 50A/s, 4.44Knotch"
tqc02b.Quench.080828102953.684	**147**	2386	20	-0.4376	2.83	HcoilHcoil	4.438	4.435	quench at 23965A, I(10-12)=3.25A, (37W), 20A/s, 4.43K
tqc02b.Quench.080828110934.788	**148**	1140	20	-0.1652	0.32	WcoilIdot	4.431	4.433	quench at 1147.2A, I(HFU10-12)=3.58A (45W), 20A/s, 4.44KCoef
tqc02b.Quench.080828113120.625	**149**	5028	20	-0.1868	6.07	HcoilHcoil	4.436	4.440	quench at 5030.9A, I(HFU10-12)=3.024A (32W), 20A/s, 4.44K
tqc02b.Quench.080828121354.132	**150**	3004	0	-0.0599	1.05	HcoilHcoil	4.437	4.435	HFU1 induced quench at 3kA (MJR coil 10), 4.44K
tqc02b.Quench.080828123408.665	**151**	8007	0	-0.0182	3.93	HcoilHcoil	4.436	4.438	HFU1 (coil 10) fired at 8kA, 300V (HFU1), 4.44K
tqc02b.Quench.080828140040.709	**152**	8007	0	-0.0154	3.76	HcoilHcoil	4.451	4.451	HFU1 induced quench at 8kA, V(HFU1)=400V, 4.45K
tqc02b.Quench.080828143651.711	**153**	5004	0	-0.0255	1.96	HcoilHcoil	4.454	4.454	HFU1 induced quench at 5kA, V(HFU1)=400V, 4.4K
tqc02b.Quench.080828150203.380	**154**	3003	0	-0.0456	0.92	HcoilHcoil	4.462	4.460	HFU1 (coil 10) induced quench at 3kA, V(HFU)=400V, 4.46K
tqc02b.Quench.080828163708.309	**155**	3002	0	-0.0825	1.25	HcoilHcoil	4.443	4.440	HFU1 (coil 10) fired at 3kA, V(HFU)=200V, C(HFU)=9.6mF, 4.44K
tqc02b.Quench.080828170457.710	**156**	5006	0	-0.0375	2.27	HcoilHcoil	4.437	4.438	HFU1 fired at 5kA, V(HFU)=200V, C(HFU)=9.6mF, 4.44K
tqc02b.Quench.080828171706.655	**157**	8006	0	222.0000	4.02	HcoilHcoil	4.436	4.435	HFU1 fired at 8kA, v(HFU)=200V, C(HFU)=9.6mF, 4.44K
tqc02b.Quench.080828173848.502	**158**	8006	0	-0.0176	3.91	HcoilHcoil	4.439	4.443	HFU1 fired at 8kA, V(HFU)=200V, C=4.8mF, 4.44K
tqc02b.Quench.080828184215.938	**159**	5006	0	-0.0459	2.48	HcoilHcoil	4.427	4.427	HFU1 fired at 5kA, V(HFU)=200V, C=4.8mF, 4.44K
tqc02b.Quench.080828185804.885	**160**	3004	0	-0.0942	1.36	HcoilHcoil	4.425	4.426	HFU1 fired at 3kA, V(HFU)=200V, C=4.8mF, 4.4K
tqc02b.Quench.080905142243.048	**161**	9698	50	-0.0049	3.97	HcoilHcoil	4.4861	4.485	quench at 9688A, 50A/s, 4.5K
tqc02b.Quench.080905144655.690	**162**	9749	50	-0.0053	3.94	HcoilHcoil	4.4731	4.479	quench at 9736A, 50A/s, 4.47K
tqc02b.Quench.080906085447.857	**163**	9771	50	0.0000	4.60	AQD_COIL	0.0000	0.000	***Data Lost; entry based on eLog***
tqc02b.Quench.080906092441.384	**164**	9811	50	-0.0039	3.83	HcoilHcoil	4.4624	4.460	quench at 9804.4A, 50A/s, 4.5K
tqc02b.Quench.080906095743.283	**165**	9843	50	-0.0055	3.99	HcoilHcoil	4.4571	4.462	quench at 9834.2A, 50A/s, 4.45K
tqc02b.Quench.080906101956.921	**166**	9871	50	-0.0053	3.99	HcoilHcoil	4.4755	4.480	50 A/s 4.5K ramp to quench, retraining after thermal cycle
tqc02b.Quench.080906104945.808	**167**	9914	50	-0.0046	3.94	HcoilHcoil	4.4669	4.462	50 A/s 4.5K 7th Training quench 167

									after thermal cycle to 270 K
tqc02b.Quench.080906111545.279	**168**	9941	50	-0.0041	3.90	HcoilHcoil	4.4713	4.469	50 A/s 4.5K 8th training quench at 9928 A after thermal cycle to 270 K
tqc02b.Quench.080906114420.394	**169**	9960	50	-0.0041	3.90	HcoilHcoil	4.4710	4.465	50 A/s 4.5K 9th training quench at 9952.7 A after thermal cycle to 270 K
tqc02b.Quench.080906132137.408	**170**	9984	50	-0.0034	3.87	HcoilHcoil	4.4423	4.445	50 A/s 4.5 K 10th training ramp at 9973.0 A after thermal cycle to 270 K
tqc02b.Quench.080906135254.339	**171**	10006	50	-0.0032	3.82	HcoilHcoil	4.4507	4.455	50 A/s 4.5K 11th training quench at 9999.1 A after thermal cycle to 270 K
tqc02b.Quench.080906142144.313	**172**	10015	50	-0.0043	3.97	HcoilHcoil	4.4675	4.472	50 A/s 4.5 K 12th retraining quench at 10004.6A after thermal cycle to 270 K
tqc02b.Quench.080906145537.891	**173**	10048	50	-0.1649	20.15	WcoilGnd	4.4642	4.461	50 A/s 4.5 K 13th retraining quench at 10039.9 A after thermal cycle to 270 K. Note that magnet current plateaud at 10000 A due to GUI target current limit set at that value. I raised it to 12 kA for future quenches, but this also implies the actual ramp rate for the previous quench was probably very close to zero.@@
tqc02b.Quench.080906152438.888	**174**	10028	50	-0.4100	44.82	HcoilHcoil	4.4681	4.465	50 A/s 4.5 K 14th retraining quench at 10038.7 A after thermal cycle to 270 K. OOPS - Forgot to start the VSDS system for this ramp.
tqc02b.Quench.080906181721.714	**175**	10055	50	-0.0851	12.17	HcoilHcoil	4.4402	4.436	50 A/s 4.5 K 15th retraining quench at 10051.4 A after 270 K thermal cycle
tqc02b.Quench.080906184818.385	**176**	10059	50	-0.0048	4.01	HcoilHcoil	4.4436	4.454	50 A/s 4.5 K 16th retraining quench at 10050.4 A after 270 K thermal cycle
tqc02b.Quench.080906191629.257	**177**	10059	50	-0.3114	35.10	HcoilHcoil	4.4458	4.437	50 A/s 4.5 K 17th retraining quench at 10069.5 A after 270 K thermal cycleterDe
tqc02b.Quench.080906194457.591	**178**	10094	50	-0.0045	3.97	HcoilHcoil	4.4486	4.440	50 A/s 4.5 K retraining quench at 10082.5 A after 270 K thermal cycle
tqc02b.Quench.080906201158.979	**179**	10093	50	-0.0046	4.00	HcoilHcoil	4.4465	4.449	50 A/s 4.5 K 19th retraining quench at 10085.8 after 270 K thermal cycle.248695
tqc02b.Quench.080906204128.161	**180**	10107	50	-0.0048	4.03	HcoilHcoil	4.4449	4.442	Last quench for today: 50 A/s 4.5 K 20th retraining quench at 10100.9 A after 270 K thermal cycle
tqc02b.Quench.080909162015.279	**181**	3000	50	-0.0008	1.43	HcoilHcoil	4.458	4.464	HFU3 (coil 17) fired at 3kA, coils 10 and 12 in parallel to HFU1, coil 19 to HFU2; HFU1 and HFU2: protection mode, 300V, 4.8mF; HFU3 testing mode, 200V, 4.8mF

tqc02b.Quench.080909164032.813	**182**	5000	50	-0.0004	2.33	HcoilHcoil	4.461	4.453	HFU3 fired at 5kA, coils 10 & 12: HFU1 (300V, 4.8mF), coil 19: HFU2 (300V, 4.8mF) coil 17: HFU3 (200V, 4.8mF); 4.5K;
tqc02b.Quench.080909182515.767	**183**	8000	50	-0.0008	3.92	HcoilHcoil	4.446	4.446	HFU3 (coil 17) fired at 8kA; 200V, 4.8mF; HFU1 (coils 10&12): 300V, 4.8mF. same for HFU2 (coil 19).
tqc02b.Quench.080909184738.770	**184**	8000	50	-0.0188	3.97	HcoilHcoil	4.458	4.463	HFU3 (200V, 2.4mF) fired at 8kA; HFU1,2 protection mode (300V, 4.8mF)
tqc02b.Quench.080909190426.642	**185**	5000	50	-0.0445	2.45	HcoilHcoil	4.463	4.469	HFU3 fired at 5kA, 200V, 2.4mF; HFU1,2 in prot.mode: 300V, 4.8mF. 4.5K
tqc02b.Quench.080909191550.865	**186**	3000	50	-0.1383	1.76	HcoilHcoil	4.454	4.457	HFU3 (17) fired at 3kA; HFU1,2: prot.mode (300V, 4.8mF). 4.5K
tqc02b.Quench.080910101138.250	**187**	10113	50	-0.0039	4.00	HcoilHcoil	4.449	4.466	training quench at 10102.8A, 50A/s, 4.5K
tqc02b.Quench.080911085400.010	**188**	5237	300	-0.0088	1.80	WcoilGnd	4.456	4.452	quench at 5237.3A, 300A/s, 4.5K
tqc02b.Quench.080911093622.138	**189**	10111	75	-0.0045	3.94	HcoilHcoil	4.456	4.454	quench at 10111.2A, 75A/s, 4.45K
tqc02b.Quench.080911101046.573	**190**	10120	20	-0.0024	3.74	HcoilHcoil	4.481	4.482	quench at 10119.5A, 20A/s, 4.5K

Table 2: TQC02b Quench History with parameters for the first two quenching segments

File	#	I (A)	dI/dt (A/s)	t_{quench}	MIITs	1st VTseg	t_{rise}	2nd VTseg	t_{rise}	Mag. Bot Temp	Mag. Top Temp
tqc02b.Quench.080805145418.740		500	20	0.0010	0.06	V1_TrigCvtB2	-0.0003	V1_TrigFvtB1	-0.0001	4.485	4.483
tqc02b.Quench.080805151500.858		5000	20	-0.0339	2.22	10b4_10b2	-0.0078			4.487	4.491
tqc02b.Quench.080805153922.344		5000	20	-0.0340	2.69	12b2_12b3	-0.0297			4.487	4.488
tqc02b.Quench.080805160047.486		5000	20	-0.0452	2.96	19b4_19b3	-0.0409	19b3_19b2	-0.0407	4.484	4.480
tqc02b.Quench.080806103022.743	**1**	8430	20	-0.0141	4.06	12a10_12a9	-0.016	12a9_12a8	-0.0158	4.475	4.474
tqc02b.Quench.080806110458.296	**2**	8550	20	-0.2740	23.08	12a10_12a9	-0.0155	12a9_12a8	-0.0150	4.486	4.483
tqc02b.Quench.080806113125.811	**3**	8657	20	-0.0123	3.99	12a10_12a9	-0.0142	12a9_12a8	-0.0142	4.487	4.487
tqc02b.Quench.080806120216.631	**4**	8725	20	-0.0085	3.74	12a10_12a9	-0.0102	12a8_12a6	-0.0102	4.478	4.484
tqc02b.Quench.080806134622.431	**5**	8779	20	-0.5934	48.89	12a8_12a6	-0.0132	12a6_12a5	-0.0132	4.446	4.443
tqc02b.Quench.080806142020.737	**6**	8841	20	-0.2611	23.57	12a10_12a9	-0.0138	12a9_12a8	-0.0078	4.452	4.451
tqc02b.Quench.080806145649.400	**7**	8894	20	-0.0080	3.79	12a9_12a8	-0.0101	12a10_12a9	-0.0099	4.461	4.459
tqc02b.Quench.080806153118.993	**8**	8951	20	-0.0077	3.79	12a10_12a9	-0.0091	12a8_12a6	-0.0089	4.451	4.451
tqc02b.Quench.080806160757.382	**9**	9003	20	-0.0101	4.03	12a8_12a6	-0.0118	12a9_12a8	-0.0075	4.455	4.456
tqc02b.Quench.080806163547.417	**10**	9037	20	-0.0097	3.98	12a10_12a9	-0.0111	12a9_12a8	-0.0111	4.450	4.446
tqc02b.Quench.080806171403.664	**11**	9083	20	-0.1467	15.33	12a10_12a9	-0.0098	12a9_12a8	-0.0098	4.446	4.446
tqc02b.Quench.080806174324.457	**12**	9118	20	-0.0095	4.03	12a9_12a8	-0.0106	12a8_12a6	-0.0102	4.455	4.452
tqc02b.Quench.080806180817.571	**13**	9180	20	-0.0087	3.98	12a10_12a9	-0.0095	12a9_12a8	-0.0095	4.459	4.458
tqc02b.Quench.080806183715.154	**14**	9245	20	-0.0078	3.93	12a10_12a9	-0.0092	12a9_12a8	-0.0091	4.452	4.450
tqc02b.Quench.080806190658.424	**15**	9300	20	-0.0076	3.94	12a10_12a9	-0.0087	12a9_12a8	-0.0084	4.454	4.449
tqc02b.Quench.080807085919.993	**16**	9357	20	-0.0069	3.97	12a10_12a9	-0.0082	12a9_12a8	-0.0082	4.425	4.430
tqc02b.Quench.080807094319.305	**17**	9411	20	-0.0071	3.95	12a10_12a9	-0.0083	12a9_12a8	-0.0083	4.440	4.440
tqc02b.Quench.080807101824.408	**18**	9471	20	-0.0066	3.93	12a10_12a9	-0.0075	12a9_12a8	-0.0075	4.448	4.451
tqc02b.Quench.080807105044.299	**19**	9517	20	-0.0062	3.9	12a10_12a9	-0.0077	12a9_12a8	-0.0072	4.459	4.460
tqc02b.Quench.080807114051.753	**20**	9555	50	-0.5262	51.55	12a10_12a9	-0.0090	12a9_12a8	-0.0089	4.462	4.462
tqc02b.Quench.080807120827.094	**21**	9634	100	-0.0091	4.19	12a10_12a9	-0.0104	12a9_12a8	-0.0102	4.470	4.475
tqc02b.Quench.080807125144.665	**22**	9666	20	-0.4366	44.2	12a10_12a9	-0.0069	12a9_12a8	-0.0069	4.473	4.472
tqc02b.Quench.080807134530.094	**23**	9738	50	-0.0064	4.03	12a10_12a9	-0.0079	12a9_12a8	-0.0046	4.462	4.461
tqc02b.Quench.080807142319.854	**24**	9764	50	-0.4685	48.21	12a10_12a9	-0.0078	12a9_12a8	-0.0060	4.466	4.464
tqc02b.Quench.080807145159.520	**25**	9821	50	-0.4664	48.47	12a10_12a9	-0.0075	12a9_12a8	-0.0045	4.477	4.478
tqc02b.Quench.080807152720.239	**26**	9892	50	-0.0048	3.92	12a10_12a9	-0.0070	12a9_12a8	-0.0043	4.478	4.481
tqc02b.Quench.080807155432.561	**27**	9914	50	-0.4614	48.87	12a10_12a9	-0.0068	12a9_12a8	-0.0046	4.477	4.486
tqc02b.Quench.080807162531.480	**28**	9985	50	-0.0055	4	12a10_12a9	-0.0065	12a9_12a8	-0.0039	4.480	4.475

tqc02b.Quench.080807170013.717	**29**	10031	50	-0.0049	3.99	12a10_12a9	-0.0061	12a9_12a8	-0.0036	4.473	4.470
tqc02b.Quench.080807173010.045	**30**	10035	50	-0.0050	3.98	12a10_12a9	-0.0066	12a9_12a8	-0.0044	4.478	4.474
tqc02b.Quench.080807180944.505	**31**	10045	50	-0.0601	9.55	12a10_12a9	-0.0062	12a9_12a8	-0.0036	4.470	4.475
tqc02b.Quench.080807185302.391	**32**	10082	50	-0.0050	4	12a8_12a6	-0.0058	12a9_12a8	-0.0048	4.463	4.468
tqc02b.Quench.080807193022.446	**33**	10115	50	-0.0048	3.98	12a10_12a9	-0.0057	12a9_12a8	-0.0036	4.472	4.474
tqc02b.Quench.080808082329.775	**34**	10129	50	-0.0041	4	12a10_12a9	-0.006	12a9_12a8	-0.0044	4.445	4.449
tqc02b.Quench.080808085749.854	**35**	10144	50	-0.0085	4.37	12a10_12a9	-0.0054	12a9_12a8	-0.0032	4.457	4.462
tqc02b.Quench.080808093403.292	**36**	10145	50	-0.5343	58.68	12a10_12a9	-0.0059	12a9_12a8	-0.0034	4.468	4.471
tqc02b.Quench.080808104546.948	**37**	10163	50	-0.4027	45.19	12a10_12a9	-0.0057	12a9_12a8	-0.0039	4.457	4.454
tqc02b.Quench.080808111633.144	**38**	10198	50	-0.0046	3.99	12a10_12a9	-0.0056	12a9_12a8	-0.0037	4.484	4.485
tqc02b.Quench.080808115309.724	**39**	10193	50	-0.4366	48.97	12a8_12a6	-0.0065	12a9_12a8	-0.0046	4.483	4.487
tqc02b.Quench.080808122345.236	**40**	10223	50	-0.0253	6.16	12a8_12a6	-0.006	12a9_12a8	-0.0048	4.481	4.474
tqc02b.Quench.080808134301.013	**41**	10234	10	-0.0035	3.93	12a10_12a9	-0.0046	12a9_12a8	-0.0046	4.481	4.479
tqc02b.Quench.080808141854.904	**42**	10220	50	-0.0032	3.85	12a10_12a9	-0.0055	12a9_12a8	-0.0031	4.484	4.480
tqc02b.Quench.080808145114.431	**43**	10253	50	-0.0045	4	12a10_12a9	-0.0054	12a9_12a8	-0.0036	4.503	4.500
tqc02b.Quench.080808153426.164	**44**	10262	50	-0.2118	25.88	12a10_12a9	-0.005	12a9_12a8	-0.0029	4.493	4.486
tqc02b.Quench.080808161505.197	**45**	10275	50	-0.0031	3.86	12a10_12a9	-0.0051	12a9_12a8	-0.0028	4.492	4.487
tqc02b.Quench.080808170219.684	**46**	10283	50	-0.1011	14.25	12a10_12a9	-0.0052	12a9_12a8	-0.003	4.488	4.484
tqc02b.Quench.080808174955.979	**47**	10308	50	-0.0032	3.87	12a10_12a9	-0.0044	12a8_12a6	-0.0044	4.474	4.467
tqc02b.Quench.080808182535.943	**48**	10300	50	-0.0043	4.01	12a10_12a9	-0.0052	12a9_12a8	-0.0028	4.481	4.476
tqc02b.Quench.080808190136.134	**49**	10310	50	-0.0041	4.01	12a10_12a9	-0.0051	12a9_12a8	-0.0035	4.476	4.469
tqc02b.Quench.080809084726.122	**50**	9093	50	0.0001	3.24	V1_TrigCvtB1	-0.0004	V1_TrigFvtB1	-0.0003	4.437	4.431
tqc02b.Quench.080809091446.760	**51**	10323	50	-0.0031	3.87	12a10_12a9	-0.0053	12a9_12a8	-0.0031	4.461	4.457
tqc02b.Quench.080809094640.937	**52**	10336	50	-0.0035	3.91	12a10_12a9	-0.005	12a9_12a8	-0.0036	4.463	4.458
tqc02b.Quench.080809102802.157	**53**	10333	50	-0.0031	3.86	12a10_12a9	-0.0044	12a9_12a8	-0.0044	4.454	4.449
tqc02b.Quench.080809105308.914	**54**	10330	50	-0.0034	3.9	12a10_12a9	-0.0055	12a9_12a8	-0.0041	4.471	4.465
tqc02b.Quench.080809112045.552	**55**	10336	50	-0.1813	22.93	12a8_12a6	-0.0055	12a9_12a8	-0.0049	4.475	4.467
tqc02b.Quench.080809115333.134	**56**	10359	50	-0.0024	3.78	12a10_12a9	-0.0059	12a9_12a8	-0.0036	4.474	4.471
tqc02b.Quench.080811084633.230	**57**	10369	50	-0.0035	4.02	12a10_12a9	-0.0052	12a9_12a8	-0.0029	4.450	4.445
tqc02b.Quench.080811092619.644	**58**	10393	50	-0.0029	3.85	12a10_12a9	-0.0043	12a9_12a8	-0.0043	4.447	4.442
tqc02b.Quench.080811095853.862	**59**	10367	50	-0.1878	23.77	12a10_12a9	-0.0054	12a9_12a8	-0.0039	4.448	4.441
tqc02b.Quench.080811104431.236	**60**	10379	20	-0.0022	3.77	12a10_12a9	-0.0044	12a9_12a8	-0.0026	4.446	4.440
tqc02b.Quench.080811110824.499	**61**	9252	200	-0.0036	3.42	10b4_10b2	-0.0042	10a2_10a3	-0.0041	4.452	4.451
tqc02b.Quench.080811112534.036	**62**	10289	150	-0.0045	3.95	12a10_12a9	-0.0066	12b6_12a10	-0.0046	4.444	4.447
tqc02b.Quench.080811121239.187	**63**	10291	100	-0.4821	54.78	12a10_12a9	-0.0058	12a9_12a8	-0.0041	4.443	4.438
tqc02b.Quench.080811123900.823	**64**	6321	250	-0.0169	2.61	10b4_10b2	-0.008	10a2_10a3	-0.008	4.444	4.443
tqc02b.Quench.080811140641.980	**65**	10396	50	-0.0039	3.99	12a10_12a9	-0.0049	12a9_12a8	-0.0027	4.436	4.430
tqc02b.Quench.080811145109.447	**66**	8751	20	-0.0092	3.74	10a2_10a3	-0.0096	12a3_12a2	-0.0094	4.442	4.437
tqc02b.Quench.080811152033.385	**67**	1094	20	-0.1794	0.31	10a2_10a3	-3	12a3_12a2	-3	4.438	4.436

tqc02b.Quench.080811160247.691	**68**	2526	20	-0.4495	3.24	19b1_10a1	-1	10a2_10a3	-0.200	4.435	4.430
tqc02b.Quench.080811162820.072	**69**	6676	20	-0.2148	16.27	19a2_19a3	-0.0141	19b4_19b3	-0.0140	4.437	4.433
tqc02b.Quench.080811173723.344	**70**	9706	20	-0.0046	3.86	12a10_12a9	-0.0061	12a9_12a8	-0.0037	4.437	4.433
tqc02b.Quench.080811175619.153	**71**	833	20	-0.6032	0.5					4.433	4.434
tqc02b.Quench.080811181652.483	**72**	807	20	0.0001	0.08					4.437	4.435
tqc02b.Quench.080811190104.424	**73**	9784	20	-0.0060	3.99	12a10_12a9	-0.0054	12a9_12a8	-0.0032	4.433	4.426
tqc02b.Quench.080812122908.059	**74**	9467	20	-0.0099	4.41	12a10_12a9	-0.0116	12a9_12a8	-0.0113	1.877	1.878
tqc02b.Quench.080812125218.573	**75**	9602	50	-0.1700	19.19	12a10_12a9	-0.0122	12a9_12a8	-0.0122	1.907	1.902
tqc02b.Quench.080812134700.105	**76**	9614	50	-0.0077	4.21	12a10_12a9	-0.0122	12a9_12a8	-0.0117	1.882	1.884
tqc02b.Quench.080812141447.305	**77**	9609	50	-0.0083	4.25	12a10_12a9	-0.0126	12a9_12a8	-0.0123	1.871	1.865
tqc02b.Quench.080812150334.283	**78**	10170	150	-0.0077	4.41	12a10_12a9	-0.0098	12a9_12a8	-0.0094	1.900	1.903
tqc02b.Quench.080812160146.780	**79**	10144	100	-0.1504	19.13	12a10_12a9	-0.0101	12a9_12a8	-0.0097	1.889	1.889
tqc02b.Quench.080812164128.644	**80**	9738	75	-0.0084	4.32	12a10_12a9	-0.0117	12a9_12a8	-0.0111	1.949	1.952
tqc02b.Quench.080812170848.658	**81**	10111	100	-0.0066	4.3	12a10_12a9	-0.0104	12a9_12a8	-0.0103	1.973	1.968
tqc02b.Quench.080812172544.625	**82**	10084	100	-0.0066	4.28	12a10_12a9	-0.0104	12a9_12a8	-0.0097	1.943	1.939
tqc02b.Quench.080812180654.036	**83**	10073	100	-0.0067	4.32	12a10_12a9	-0.0102	12a9_12a8	-0.0102	1.825	1.834
tqc02b.Quench.080812184342.102	**84**	9668	200	-0.0190	5.13	17a3_17a2	-0.0042	17b2_17b3	-0.0042	1.937	1.939
tqc02b.Quench.080812190536.596	**85**	9992	150	-0.0083	4.37	12a9_12a8	-0.0099	12a10_12a9	-0.0081	1.959	1.965
tqc02b.Quench.080813091710.707	**86**	10343	150	-0.0591	10.06	12b5_12b6	-0.0146	12b6_12a10	-0.0146	1.871	1.874
tqc02b.Quench.080813094855.584	**87**	10177	150	-0.6214	68.61	12a10_12a9	-0.009	12a9_12a8	-0.009	1.907	1.898
tqc02b.Quench.080813103537.500	**88**	10182	150	-0.0078	4.4	12a10_12a9	-0.0096	12a9_12a8	-0.0096	1.909	1.902
tqc02b.Quench.080813111641.273	**89**	10300	150	-0.0067	4.34	12a9_12a8	-0.0089	12a10_12a9	-0.0085	1.888	1.890
tqc02b.Quench.080813120537.865	**90**	10214	150	-0.0063	4.29	12a9_12a8	-0.0087	12a10_12a9	-0.0071	1.878	1.872
tqc02b.Quench.080813181205.532	**91**	9621	150	-0.0028	3.75	17a8_17a7	-0.0063			1.844	1.844
tqc02b.Quench.080814123404.108	**92**	10388	150	-0.0039	4.15	17a8_17a7	-0.0066	17a7_17a6	-0.005	1.832	1.841
tqc02b.Quench.080814140503.483	**93**	8874	20	-0.1714	16.66	12a3_12a2	-0.012	12a3_12a4	-0.0115	1.895	1.895
tqc02b.Quench.080814143733.934	**94**	6680	20	-0.0384	3.92	12a3_12a2	-0.0404	12a2_12a1	-0.0385	1.926	1.947
tqc02b.Quench.080814151245.559	**95**	3360	20	-0.4063	5.23	12a3_12a2	-0.252	12a2_12a1	-0.251	1.937	1.916
tqc02b.Quench.080814155255.298	**96**	9645	20	-0.0095	4.42	12a10_12a9	-0.0109	12a9_12a8	-0.0109	1.905	1.901
tqc02b.Quench.080814162838.829	**97**	4911	20	-0.2704	7.81	12a3_12a2	-0.0098	12a2_12a1	-0.0091	1.932	1.942
tqc02b.Quench.080814165056.818	**98**	1478	20	-0.3671	0.96	V1_TrigCvtB2	-0.0031	V1_TrigFvtB1	-0.0028	1.958	1.946
tqc02b.Quench.080814170949.568	**99**	7626	20	-0.0370	4.77	17a3_17a2	-0.0419	17b2_17b3	-0.0419	1.937	1.951
tqc02b.Quench.080814173804.089	**100**	6027	20	-0.4474	18.12	17a3_17a2	-0.0618			1.940	1.951
tqc02b.Quench.080814180854.770	**101**	3891	20	-0.1729	3.44	17a3_17a2	-0.156			1.925	1.931
tqc02b.Quench.080814183351.114	**102**	8666	20	-0.0235	4.85	17a3_17a2	-0.026	19a2_19a3	-0.0206	1.919	1.921
tqc02b.Quench.080814191732.075	**103**	1045	20	-0.0004	0.1					1.900	1.901
tqc02b.Quench.080815104724.792	**104**	10197	150	-0.0064	4.34	12a10_12a9	-0.0096	12a9_12a8	-0.0096	1.862	1.865
tqc02b.Quench.080815111530.493	**105**	10195	150	-0.0067	4.31	12a10_12a9	-0.0095	12a9_12a8	-0.0095	1.911	1.894
tqc02b.Quench.080815114831.016	**106**	10307	150	-0.1012	14.4	12a10_12a9	-0.009	12a9_12a8	-0.009	1.887	1.890

tqc02b.Quench.080815122606.283	**107**	10098	150	-0.0078	4.38	12a10_12a9	-0.0098	12a9_12a8	-0.0098	1.911	1.911
tqc02b.Quench.080815131146.017	**108**	10140	100	-0.0069	4.35	12a10_12a9	-0.0095	12a9_12a8	-0.0095	1.883	1.890
tqc02b.Quench.080815135756.911	**109**	9968	100	-0.0076	4.34	12a10_12a9	-0.0101	12a9_12a8	-0.0101	1.884	1.911
tqc02b.Quench.080815145501.456	**110**	10041	100	-0.3500	39.06	12a10_12a9	-0.0108	12a9_12a8	-0.0108	1.887	1.879
tqc02b.Quench.080815163455.078	**111**	9807	100	0.0000	4.655	------------	----	------------	----	0.000	0.000
tqc02b.Quench.080815171445.505	**112**	10071	100	-0.0090	4.55	12a10_12a9	-0.0107	12a9_12a8	-0.0107	1.843	1.849
tqc02b.Quench.080815181315.602	**113**	10042	125	-0.0080	4.38	12a9_12a8	-0.0097			1.948	1.953
tqc02b.Quench.080815185621.405	**114**	9632	50	-0.0087	4.32	12a10_12a9	-0.0124	12a9_12a8	-0.0124	1.812	1.812
tqc02b.Quench.080825155659.805	**115**	9813	50	-0.0099	4.62	12a10_12a9	-0.012	12a9_12a8	-0.0116	1.864	1.872
tqc02b.Quench.080825162859.187	**116**	9975	100	-0.0073	4.32	12a10_12a9	-0.0109	12a9_12a8	-0.0107	1.875	1.879
tqc02b.Quench.080825173917.641	**117**	10182	150	-0.0066	4.3	12a10_12a9	-0.0103	12a9_12a8	-0.0103	1.856	1.856
tqc02b.Quench.080825181837.312	**118**	10240	175	-0.3744	43.15	12a10_12a9	-0.009	12a9_12a8	-0.0088	1.924	1.928
tqc02b.Quench.080825185034.923	**119**	9995	190	-0.0027	3.71	17a3_17a2	-0.0042	17b2_17b3	-0.0042	1.873	1.878
tqc02b.Quench.080825191411.306	**120**	8662	250	-0.0029	3.18	17a3_17a2	-0.0048	17b2_17b3	-0.0048	1.885	1.891
tqc02b.Quench.080825193240.339	**121**	9043	225	-0.0024	3.32	17a3_17a2	-0.004	17b2_17b3	-0.004	1.879	1.871
tqc02b.Quench.080826095549.994	**122**	9864	75	-0.0067	4.29	12a10_12a9	-0.0108	12a9_12a8	-0.0108	1.885	1.892
tqc02b.Quench.080826103329.982	**123**	6398	300	-0.0039	2.14	10b4_10b2	-0.0056	10a2_10a3	-0.0056	1.860	1.864
tqc02b.Quench.080826105346.207	**124**	9556	20	-0.0084	4.25	12a10_12a9	-0.0118	12a9_12a8	-0.0114	1.858	1.868
tqc02b.Quench.080826113416.803	**125**	9580	5	-0.0179	5.12	12a10_12a9	-0.0085	12a9_12a8	-0.0084	1.891	1.884
tqc02b.Quench.080826115501.447	**126**	6232	300	-0.5136	22.42	10b4_10b2	-0.0055	10a2_10a3	-0.0055	1.876	1.875
tqc02b.Quench.080826121403.858	**127**	7538	275	-0.1686	12.16	10b4_10b2	-0.0043	10a2_10a3	-0.0043	1.891	1.890
tqc02b.Quench.080826134839.019	**128**	2475	50	-0.2478	1.88	12b2_12b3	-0.25	12b3_12b4	-0.25	1.871	1.872
tqc02b.Quench.080826144532.931	**129**	7165	50	-0.0116	3.07	12b2_12b3	-0.0163	12b6_12a10	-0.0163	1.906	1.900
tqc02b.Quench.080826160945.180	**130**	9160	50	-0.1490	15.84	12b2_12b3	-0.0063	12b6_12a10	-0.0063	1.891	1.888
tqc02b.Quench.080826165155.834	**131**	9598	50	-0.0071	4.16	12a10_12a9	-0.011	12a9_12a8	-0.011	1.839	1.854
tqc02b.Quench.080826174022.364	**132**	9621	50	-0.0097	4.38	12a10_12a9	-0.0117	12a9_12a8	-0.0114	1.907	1.913
tqc02b.Quench.080826180612.586	**133**	9268	50	-0.0139	4.54	10b4_10b2	-0.0042			1.878	1.880
tqc02b.Quench.080826183759.733	**134**	7376	50	-0.0099	3.09	10b4_10b2	-0.0128	10b2_10b1	-0.0128	1.848	1.856
tqc02b.Quench.080826190033.398	**135**	2860	50	-0.1666	1.83	10b4_10b2	-0.12	10b2_10b1	-0.12	1.862	1.862
tqc02b.Quench.080827123227.882	**136**	9681	50	-0.0071	4.25	12a10_12a9	-0.0115	12a9_12a8	-0.0113	2.425	2.438
tqc02b.Quench.080827130307.058	**137**	9967	200	-0.0024	3.53	10b4_10b2	-0.0025	10a2_10a3	-0.002	2.412	2.445
tqc02b.Quench.080827141355.959	**138**	9644	200	-0.4787	48.24	10b4_10b2	-0.0033	10a2_10a3	-0.0033	3.054	3.055
tqc02b.Quench.080827145016.319	**139**	10408	50	-0.0113	4.94	17b6_17a10	-0.0099	17a6_17a5	-0.0097	3.064	3.149
tqc02b.Quench.080827152954.757	**140**	9515	200	-0.0031	3.46	10b4_10b2	-0.0033	10a2_10a3	-0.0033	3.556	3.559
tqc02b.Quench.080827161025.377	**141**	10453	50	-0.4170	49.32	12b6_12a10	-0.0055	12a8_12a6	-0.0046	3.597	3.616
tqc02b.Quench.080827170446.786	**142**	10375	50	-0.0230	6.05	12a10_12a9	-0.0049	12a9_12a8	-0.0026	4.431	4.437
tqc02b.Quench.080827174819.816	**143**	10371	50	-0.0038	3.96	12a10_12a9	-0.0049	12a9_12a8	-0.0025	4.443	4.443
tqc02b.Quench.080827182142.783	**144**	10378	50	-0.0035	3.93	12a10_12a9	-0.0048	12a9_12a8	-0.0028	4.452	4.457
tqc02b.Quench.080827184742.598	**145**	10375	50	-0.0038	3.96	12a10_12a9	-0.0031	12a9_12a8	-0.0029	4.457	4.454

tqc02b.Quench.080828095453.035	**146**	10389	50	-0.0036	4.02	12a10_12a9	-0.0048	12a9_12a8	-0.0027	4.432	4.437
tqc02b.Quench.080828102953.684	**147**	2386	20	-0.4376	2.83	19b1_10a1	-1	10a2_10a3	-0.5	4.438	4.435
tqc02b.Quench.080828110934.788	**148**	1140	20	-0.1652	0.32	19b1_10a1	-1	10a2_10a3	-0.5	4.431	4.433
tqc02b.Quench.080828113120.625	**149**	5028	20	-0.1868	6.07	19b1_10a1	-0.16	10a1_10a2	-0.010	4.436	4.440
tqc02b.Quench.080828121354.132	**150**	3004	0	-0.0599	1.05	10b4_10b2	-0.0202			4.437	4.435
tqc02b.Quench.080828123408.665	**151**	8007	0	-0.0182	3.93	10b4_10b2	-0.0047			4.436	4.438
tqc02b.Quench.080828140040.709	**152**	8007	0	-0.0154	3.76	10b4_10b2	-0.0041			4.451	4.451
tqc02b.Quench.080828143651.711	**153**	5004	0	-0.0255	1.96	10b4_10b2	-0.0065			4.454	4.454
tqc02b.Quench.080828150203.380	**154**	3003	0	-0.0456	0.92	10b4_10b2	-0.0192			4.462	4.460
tqc02b.Quench.080828163708.309	**155**	3002	0	-0.0825	1.25	10b4_10b2	-0.0289			4.443	4.440
tqc02b.Quench.080828170457.710	**156**	5006	0	-0.0375	2.27	10b4_10b2	-0.0084			4.437	4.438
tqc02b.Quench.080828171706.655	**157**	8006	0	222.0000	4.02	10b4_10b2	-0.0044			4.436	4.435
tqc02b.Quench.080828173848.502	**158**	8006	0	-0.0176	3.91	10b4_10b2	-0.0051			4.439	4.443
tqc02b.Quench.080828184215.938	**159**	5006	0	-0.0459	2.48	10b4_10b2	-0.0072			4.427	4.427
tqc02b.Quench.080828185804.885	**160**	3004	0	-0.0942	1.36	10b4_10b2	-0.0346			4.425	4.426
tqc02b.Quench.080905142243.048	**161**	9698	50	-0.0049	3.97	12a10_12a9	-0.008	12a9_12a8	-0.0045	4.4861	4.485
tqc02b.Quench.080905144655.690	**162**	9749	50	-0.0053	3.94	12a10_12a9	-0.0076	12a9_12a8	-0.0042	4.4731	4.479
tqc02b.Quench.080906085447.857	**163**	9771	50	0.0000	4.60	------------	----	------------	----	0.0000	0.000
tqc02b.Quench.080906092441.384	**164**	9811	50	-0.0039	3.83	12a10_12a9	-0.0074	12a9_12a8	-0.0047	4.4624	4.460
tqc02b.Quench.080906095743.283	**165**	9843	50	-0.0055	3.99	12a10_12a9	-0.0073	12a9_12a8	-0.0039	4.4571	4.462
tqc02b.Quench.080906101956.921	**166**	9871	50	-0.0053	3.99	12a8_12a6	-0.0077	12a9_12a8	-0.0054	4.4755	4.480
tqc02b.Quench.080906104945.808	**167**	9914	50	-0.0046	3.94	12a10_12a9	-0.0067	12a9_12a8	-0.0039	4.4669	4.462
tqc02b.Quench.080906111545.279	**168**	9941	50	-0.0041	3.90	12a10_12a9	-0.0066	12a9_12a8	-0.0038	4.4713	4.469
tqc02b.Quench.080906114420.394	**169**	9960	50	-0.0041	3.90	12a10_12a9	-0.0066	12a9_12a8	-0.0037	4.4710	4.465
tqc02b.Quench.080906132137.408	**170**	9984	50	-0.0034	3.87	12a10_12a9	-0.0065	12a9_12a8	-0.0037	4.4423	4.445
tqc02b.Quench.080906135254.339	**171**	10006	50	-0.0032	3.82	12a10_12a9	-0.0065	12a9_12a8	-0.0043	4.4507	4.455
tqc02b.Quench.080906142144.313	**172**	10015	50	-0.0043	3.97	12b6_12a10	-0.0057	12a8_12a6	-0.005	4.4675	4.472
tqc02b.Quench.080906145537.891	**173**	10048	50	-0.1649	20.15	12a10_12a9	-0.0049	12a9_12a8	-0.0037	4.4642	4.461
tqc02b.Quench.080906152438.888	**174**	10028	50	-0.4100	44.82	12a10_12a9	-0.0061	12a9_12a8	-0.0033	4.4681	4.465
tqc02b.Quench.080906181721.714	**175**	10055	50	-0.0851	12.17	12a10_12a9	-0.0055	12a9_12a8	-0.0028	4.4402	4.436
tqc02b.Quench.080906184818.385	**176**	10059	50	-0.0048	4.01	12a10_12a9	-0.0057	12a9_12a8	-0.0032	4.4436	4.454

tqc02b.Quench.080906191629.257	**177**	10059	50	-0.3114	35.10	12a10_12a9	-0.0051	12a9_12a8	-0.0027	4.4458	4.437
tqc02b.Quench.080906194457.591	**178**	10094	50	-0.0045	3.97	12a10_12a9	-0.0054	12a9_12a8	-0.0038	4.4486	4.440
tqc02b.Quench.080906201158.979	**179**	10093	50	-0.0046	4.00	12a10_12a9	-0.0054	12a9_12a8	-0.0028	4.4465	4.449
tqc02b.Quench.080906204128.161	**180**	10107	50	-0.0048	4.03	12a10_12a9	-0.0051	12a9_12a8	-0.0034	4.4449	4.442
tqc02b.Quench.080909162015.279	**181**	3000	50	-0.0008	1.43	17b2_17b3	-0.0553	17b1_17b2	-0.0553	4.458	4.464
tqc02b.Quench.080909164032.813	**182**	5000	50	-0.0004	2.33	17b2_17b3	-0.0119			4.461	4.453
tqc02b.Quench.080909182515.767	**183**	8000	50	-0.0008	3.92	17b2_17b3	-0.0064			4.446	4.446
tqc02b.Quench.080909184738.770	**184**	8000	50	-0.0188	3.97	17b2_17b3	-0.0063			4.458	4.463
tqc02b.Quench.080909190426.642	**185**	5000	50	-0.0445	2.45	17b2_17b3	-0.0136			4.463	4.469
tqc02b.Quench.080909191550.865	**186**	3000	50	-0.1383	1.76	17b2_17b3	-0.066			4.454	4.457
tqc02b.Quench.080910101138.250	**187**	10113	50	-0.0039	4.00	12a10_12a9	-0.0057	12a9_12a8	-0.0031	4.449	4.466
tqc02b.Quench.080911085400.010	**188**	5237	300	-0.0088	1.80	10a2_10a3	-0.0092	12b4_10b2	-0.0092	4.456	4.452
tqc02b.Quench.080911093622.138	**189**	10111	75	-0.0045	3.94	12a10_12a9	-0.0063	12a9_12a8	-0.0037	4.456	4.454
tqc02b.Quench.080911101046.573	**190**	10120	20	-0.0024	3.74	12a10_12a9	-0.0061	12a9_12a8	-0.0044	4.481	4.482

4. Ramp Rate Dependence

Several quenches were performed for the ramp rate dependence study at 4.5 K and 1.9 K. A plot summarizing all ramp rate quenches is shown in Fig. 7.

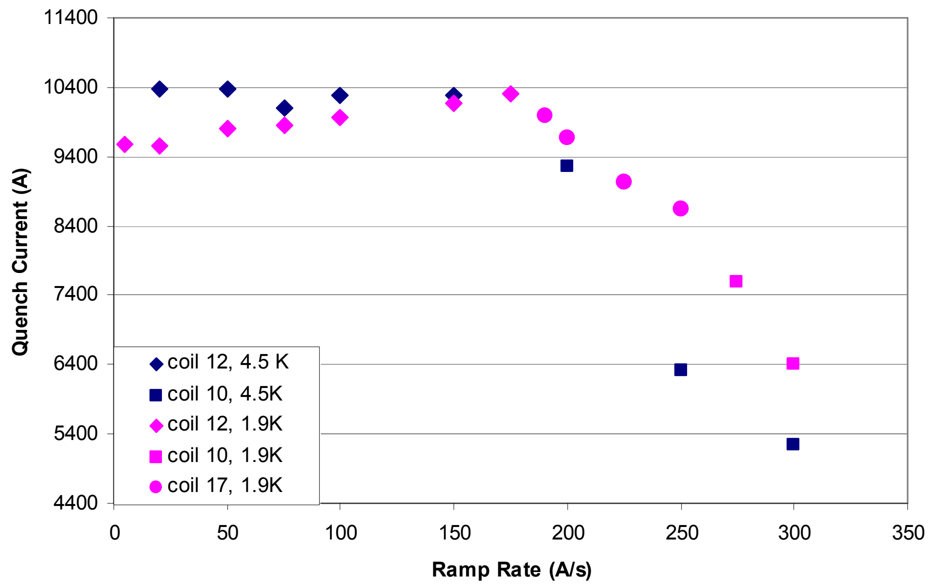

Figure 7. Ramp rate study at 4.5 K and 1.9 K.

At both 4.5 K and 1.9 K temperatures we do not see expected smooth decrease of quench current with increasing the ramp rate up to 150-175 A/s. This dependence is flat at 4.5 K and even inverted at 1.9 K (i.e. quench current increases with increasing the ramp rate). At ramp rates of 150-175 A/s and higher the ramp rate dependence exhibits a sharp decline and quench location moves from coil 12 to 10 at 4.5 K and to 17 or 10 at 1.9 K (see Fig. 7). This seems indicate significant mechanical or other limitation in coil 12, which limited the magnet quench performance.

5. Temperature Dependence Study

Quench current temperature dependence was studied during the warm-up to 4.5 K after the 1.9 K test in TC-1, using ramp rates of 50 and 200 A/s. Results at a 50 A/s ramp rate are shown in Fig. 8. We see noticeable drop in the quench current at temperatures below ~ 3 K. For comparison temperature dependence for TQC02a and TQC02e magnets obtained at a ramp rate of 20 A/s are also shown in Fig. 8.

TQC02b temperature dependence for a ramp rate of 200 A/s is shown in Fig. 9. We see smooth temperature dependence, only at 1.9 K quench current is not consistent with other data. Quench at 1.9 K developed in coil 17, while all others occurred in coil 10. Similar temperature dependence exhibited TQC02a magnet at a ramp rate of 100 A/s (see Fig. 9). This is very suggestive of instability in the Nb_3Sn conductor, which arises due to increased Jc at lower temperature.

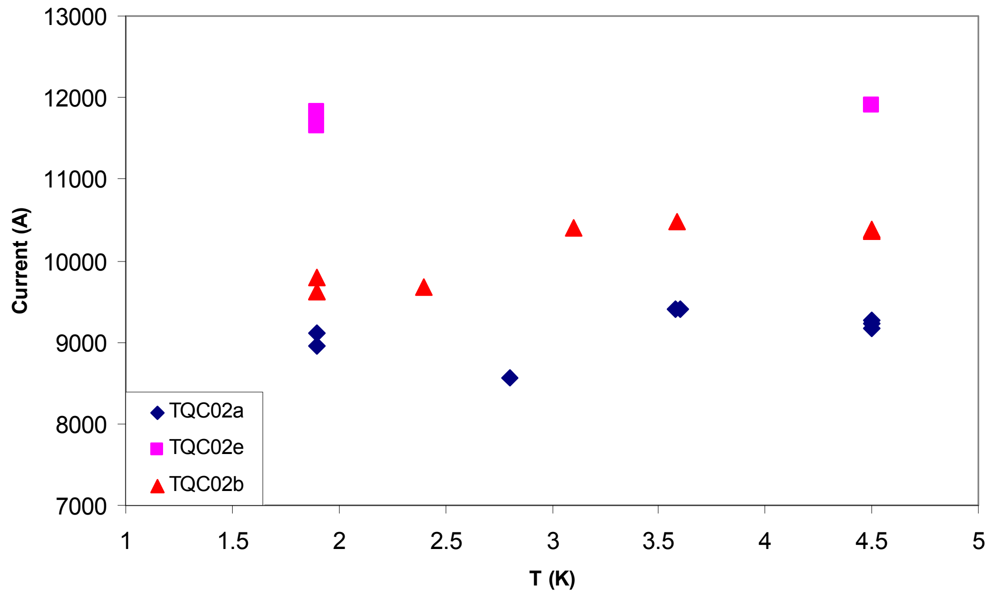

Figure 8. Quench current temperature dependence for TQC02 magnets at a ramp rate of 20 A/s (at 50 A/s for TQC02b magnet).

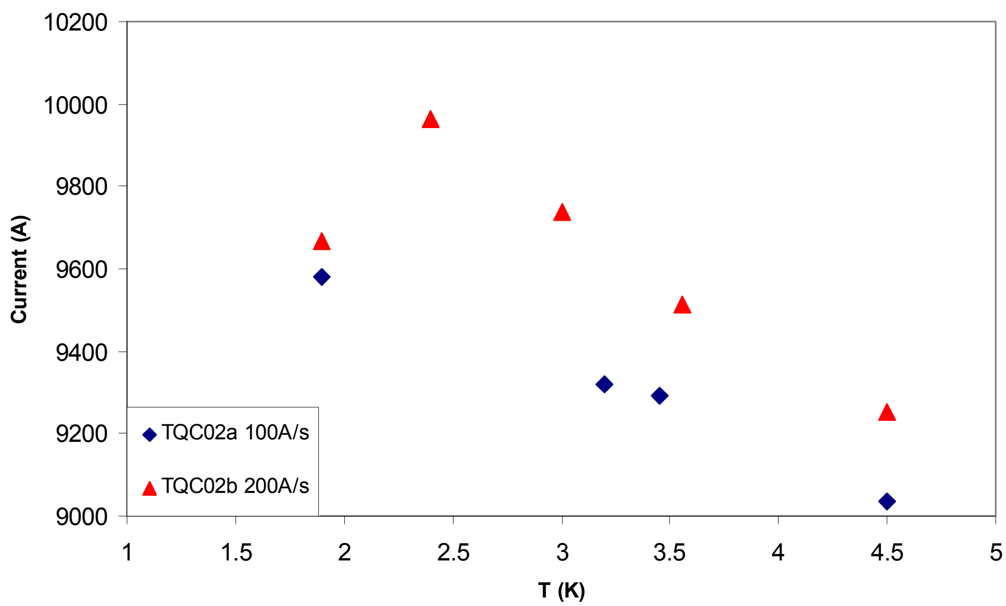

Figure 9. Temperature dependence at a high ramp rate.

6. Temperature Margin Measurements

TQC02b magnet was equipped with a strip heater for the temperature margin measurements in coils. The heaters were placed in the mid-plane section between the MJR coils 10 and 12, as well as between the RRP coils 17 and 19 (see Fig. 1).

Each measurement involved setting the heater current to a specific value and then ramp to quench. *Kepco* power supply was used to provide the heater power in the range of 28-65 W. A low ramp rate of 20 A/s was used to avoid additional cable heating by eddy currents.

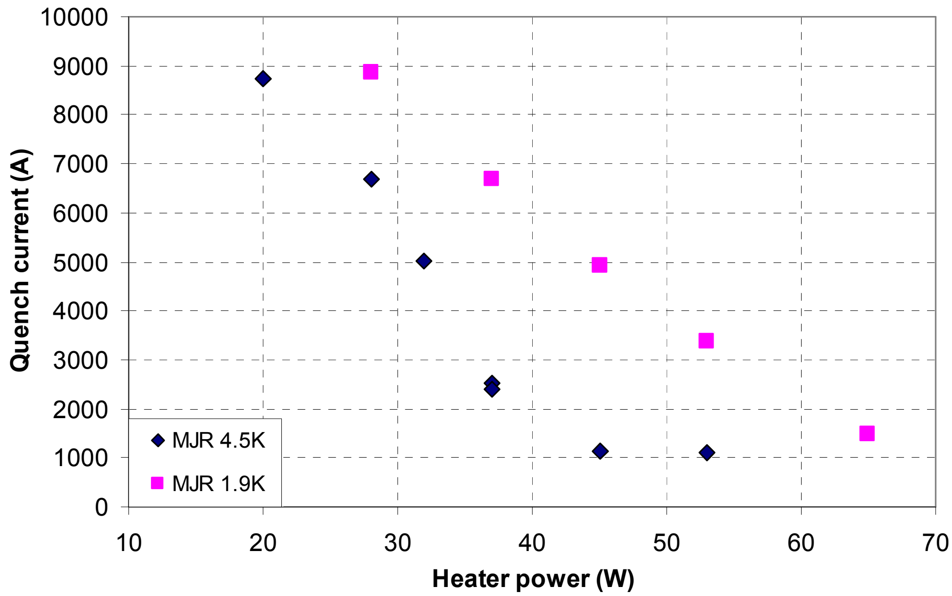

Figure 10. Quench current as a function of the heater power in the mid-plane section of MJR coils.

Measured quench current as a function of the heater power in the MJR coils is presented in Fig.10. For a heater power of 32 W and higher quenches at 4.5 K developed in the ramp section between coils 10 and 19 (***19B1_10A1*** segment) instead of the mid-plane segments in coils 10 and 12 as one could expect based on the heater location. Therefore these measurements are not useful for the temperature margin estimation at 4.5 K.

The results of measurements in the MJR and RRP coils at 1.9 K are compared in Fig.11. Unfortunately measurements in RRP coils at 4.5 K also failed due to the quenches developed in the NbTi-NbTi splice between the magnet and the positive power lead. Magnet checkout after the test will help to understand reasons of the failures during the temperature margin measurements.

7. Protection Heater Study

Coils 10 and 12 in TQC02b magnet were equipped with the stainless steel (SS) protection heater with a resistance of ~12.8 Ohm at 4.5 K. In coils 17 and 19 modified version of heater was used – the SS heater with the copper cladding. Resistance of the latter was ~5.7 Ohm at 4.5 K. All protection heaters were mounted on the outer surface of the outer coil layer.

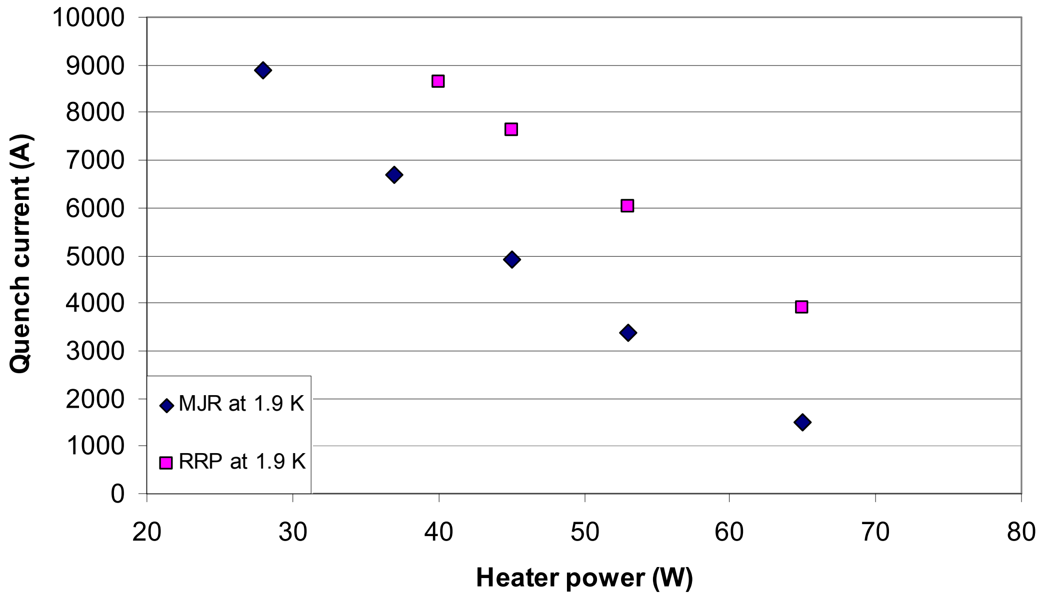

Figure 11. Quench current as a function of the heater power in the mid-plane section of MJR and RRP coils at 1.9 K

Protection heater study was done at 4.5 K. The SS heater in the MJR coil 10 was tested at the end of the TC-1, and the SS heater with the copper cladding in the RRP coil 17 – at the end of the TC-2. During the test one HFU was manually fired with the magnet at a fixed current (3 kA, 5 kA and 8 kA) to initiate a quench, while remaining two HFUs were discharged as protection heaters by the quench detection system. HFU delay was set to 0 ms.

Heater studies were performed at different voltages of the HFU (200 V, 300 V and 400 V) and for different capacitance of the HFU capacitor bank (2.4 mF, 4.8 mF and 9.6 mF).

Protection heater delay time as a function of the magnet current for the HFU capacitance of 4.8 mF is shown in Fig. 12. Full markers show the delay to quench detection (i.e. HFU firing time) and open markers show the delay to quench start (i.e. time delay from the firing time to the quench onset time). The delay to quench detection depends on the detection threshold, which was set to 0.5 V for the half-coil signal during the TQC02b test.

Protection heater delays in coil 10 for the HFU capacitances 4.8 mF and 9.6 mF and at 200 V are shown in Fig. 13. One can see that at 8 kA (~ 64% of the short sample limit at 4.5 K) we practically do not see difference in delay time for these two HFU capacitances.

Heater in the RRP coil 17 was tested at low voltage only (200 V) in order to avoid overheating of the protection heater. High temperatures in heater could cause degradation of the isolation material, especially for a large time constant (RC).

Results of the protection heater study in the RRP coil 17 is shown in Fig. 14. Comparison of the heater delay in coils 10 and 17 for the same capacitance (4.8 mF) and voltage (200 V) is shown in Fig. 15.

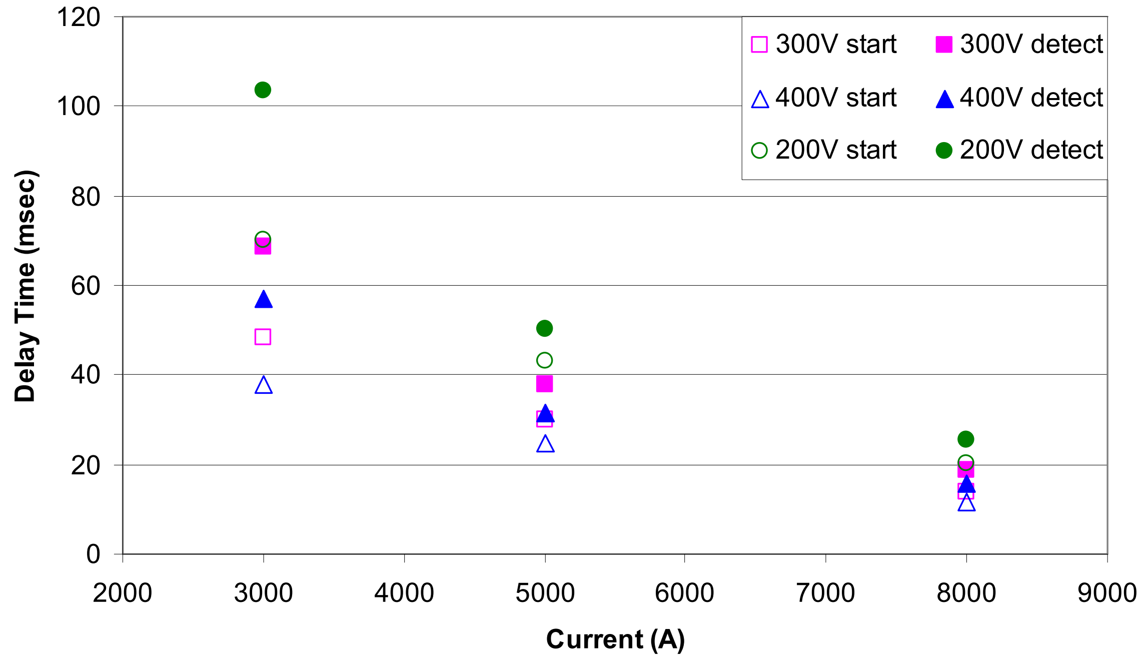

Figure 12. Protection heater delays in the MJR coil 10 at different HFU voltage

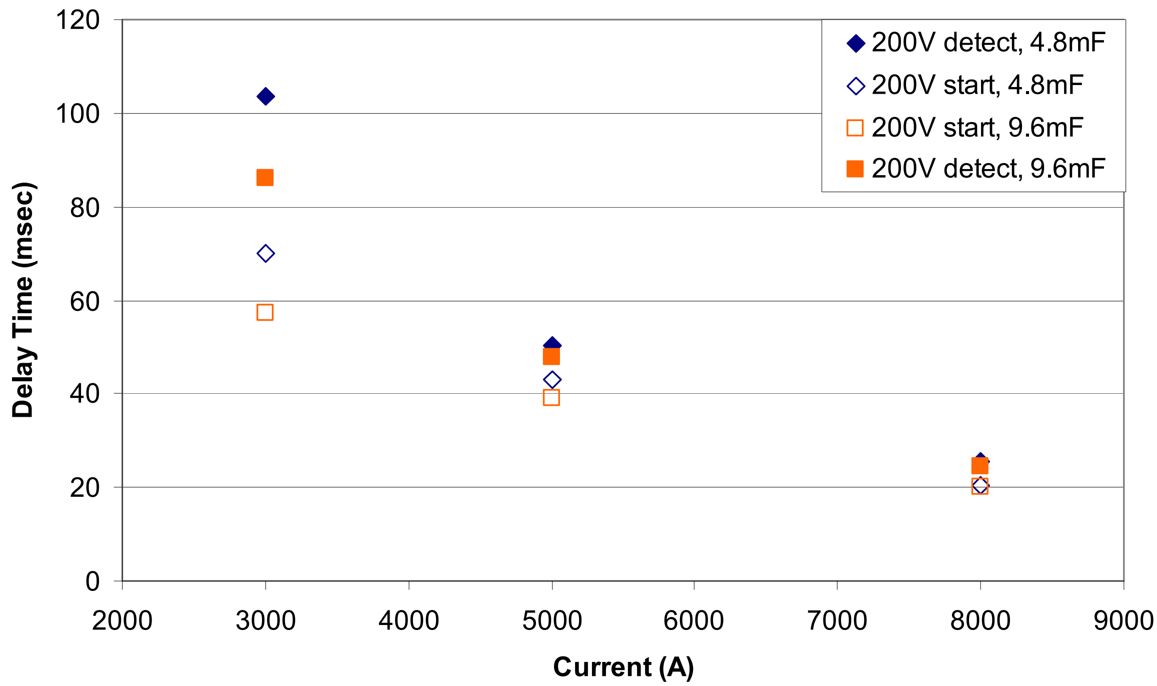

Figure 13. Protection heater delay in the MJR coil 10 at different HFU capacitance

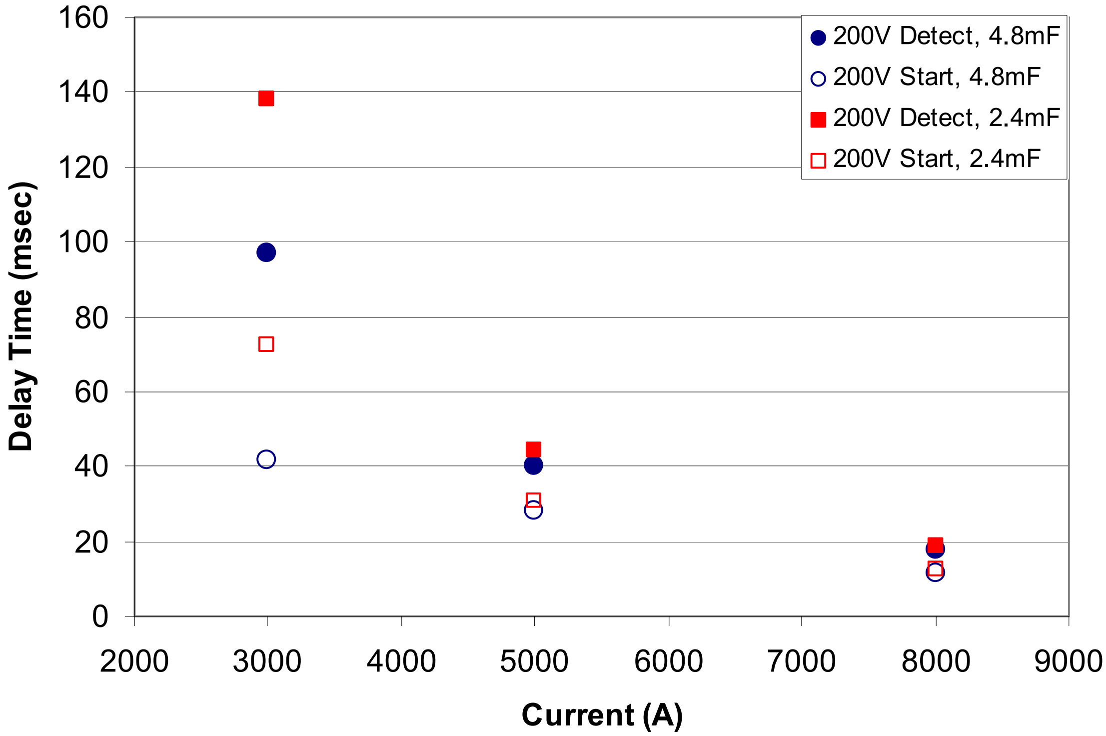

Figure 14. Protection heater delay in the RRP coil 17 at different HFU capacitance

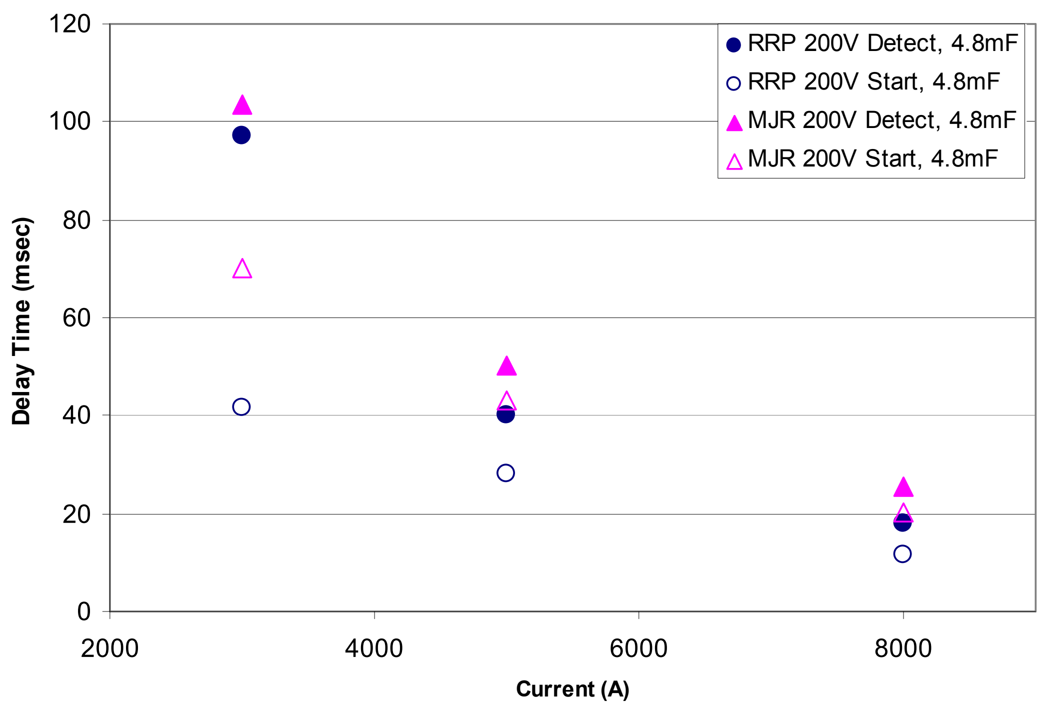

Figure 15. Comparison of the protection heater delay in the coils 10 and 17

Additional test, similar to the stability test of LM02 magnet [3], was performed with the protection heater in coils 10 and 12. During this test the heater current varied within the 1.2 – 2.1 A range corresponding to the total dissipated power from 20 to 60 W. Quench current as a function of the dissipated power is shown in Fig. 16.

At a heater current of 1.2 A (or a 20 W dissipated power) in coil 12 or coil 10 quench still occurred in the inner layer of coil 12. But with increasing the heater current quench location moved to the outer layer mid-plane block of the coil where the protection heater was fired.

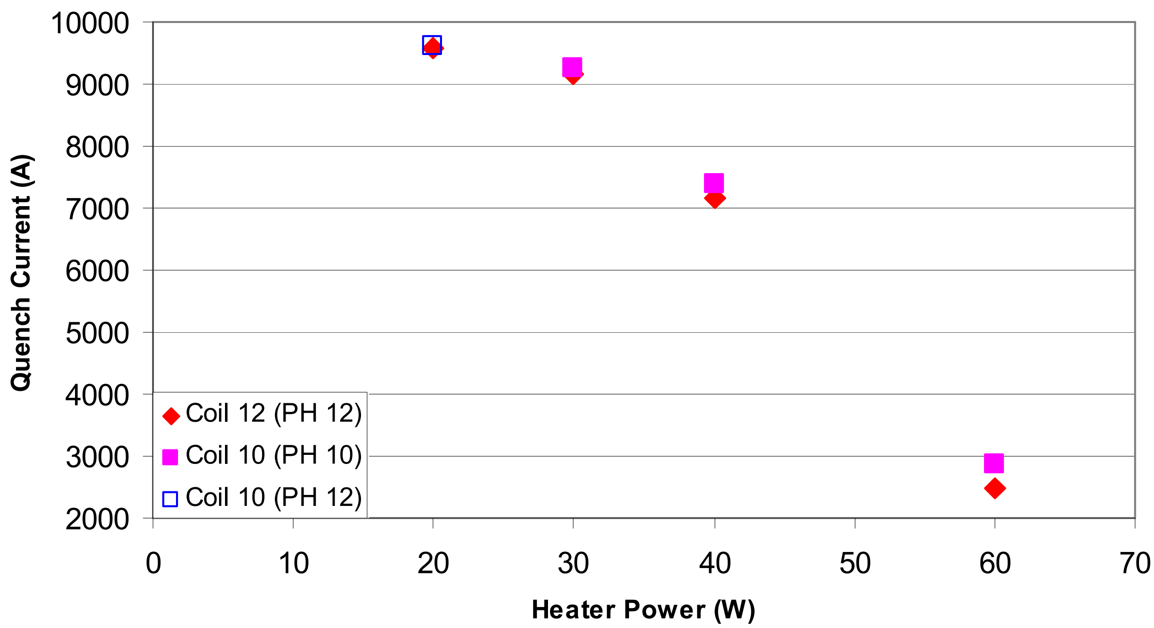

Figure 16. Quench current vs heater power in the outer layer of coils 10 and 12, fired protection heater is shown in parentheses.

8. Quench Locations

Time-of-flight based quench-origins were calculated from resistive signal growth in voltage tap segments for several quenches during the TQC02b magnet training, using the following three times: quench-onset, 1st exit and 2nd exit (when available). The time-of-flight distance assumed the known voltage-tap locations and equal quench-propagation speeds for both quench-fronts. In our estimations we use the voltage tap locations and segment length shown in Table 3. Voltage tap locations and corresponding CVT segments were already shown in Section 2.

Almost all training quenches developed in coil 12 in the inner layer. High ramp rate quenches in coils 10 and 17 were located in the mid-plane multi-turn segments and are not considered in this study.

Table 3. TQC02b configurable voltage tap locations and calculated segment lengths (z = 0 mm for the *A10* voltage tap)

Vtap (ID)	Y (mm)	Z (mm)	Segment	L.calc (mm)
A6	-11.08	-230.04	**A3A4**	564
A7	9.08	-230.04	**A6A7**	168
A8	9.08	314.58	**A7A8**	545
A9	-9.08	314.58	**A8A9**	184
A10	-9.08	0.00	**A9A10**	315
B6	26.51	-230.00	**A10B6**	352
B5	26.51	326.58	**B6B5**	557
B4	-26.51	326.58	**B5B4**	135
B3	-26.51	-230.00	**B4B3**	557

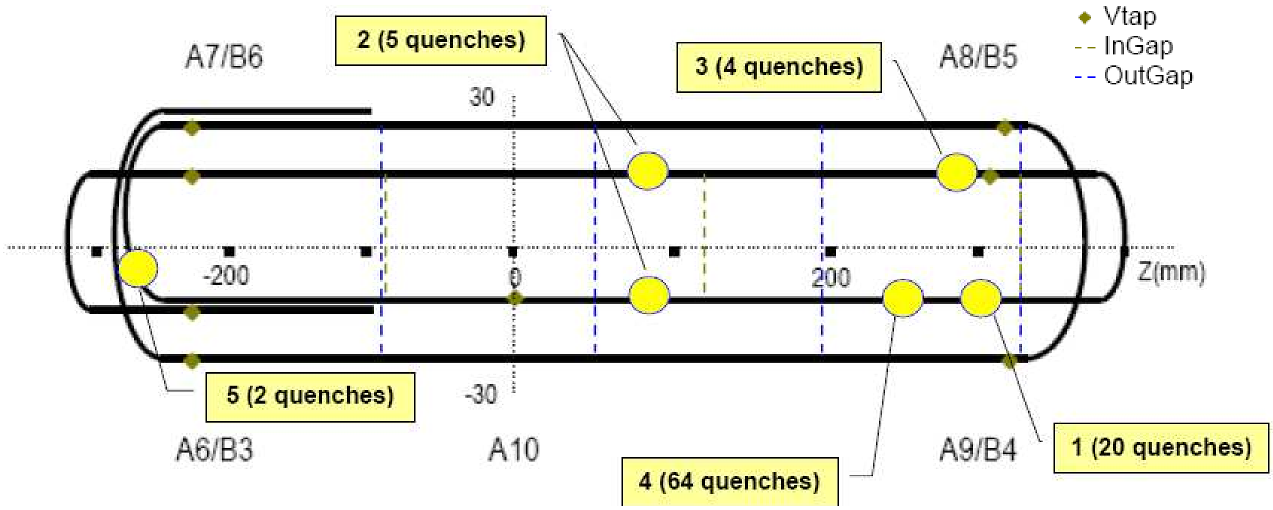

Figure 17. Location of quenches in coil 12 at 4.5 K. Number of quenches of each type is shown in parentheses.

Estimated quench locations in coil 12 at 4.5 K and 1.9 K are shown in Fig.17 and 18 respectively (figure is shown looking at the inside surface of the coil). All TQC02b quenches were divided into 5 different groups according to development location. These groups are listed below:

1. Quench developed in the **A10A9** and **A9A8** segments almost at the same time, next is the **A8A6** segment. Quench Antenna (QA) signal location in C3 group of coils (at the return end of magnet).

2. Quench starting in both **A10A9** and **A8A6** segments at the same time. First QA signal in C2; large spike detected by the Voltage Spike Detection System (VSDS) in the beginning of quench.
3. **A8A6** is the first quenching segment, next is **A9A8** in 0.2-1 ms; QA signals in both C2 and C3.
4. **A10A9** is the first quenching segment, then quench propagates in the **A9A8** and **A8A6** segments; QA signal location in C2.
5. Quench in the ramp segment (**B6A10**). QA signal location in both C1 and C2.

We see most quenches are located at the return end of the coil (quench type 1, 3 and 4). Few quenches of type 2 may indicate mechanical motion of the conductor at the beginning of training. In these quenches spikes were found in the half-coil voltage signal at the very beginning of quench (see Fig.19).

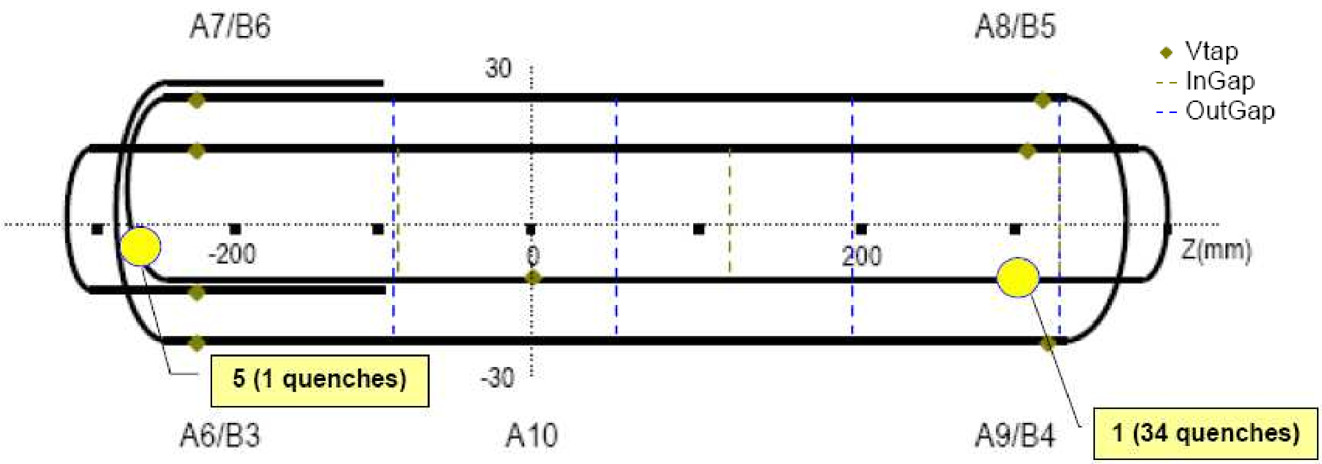

Figure 18. Location of quenches in coil 12 at 1.9 K. Number of quenches of each type is shown in parentheses.

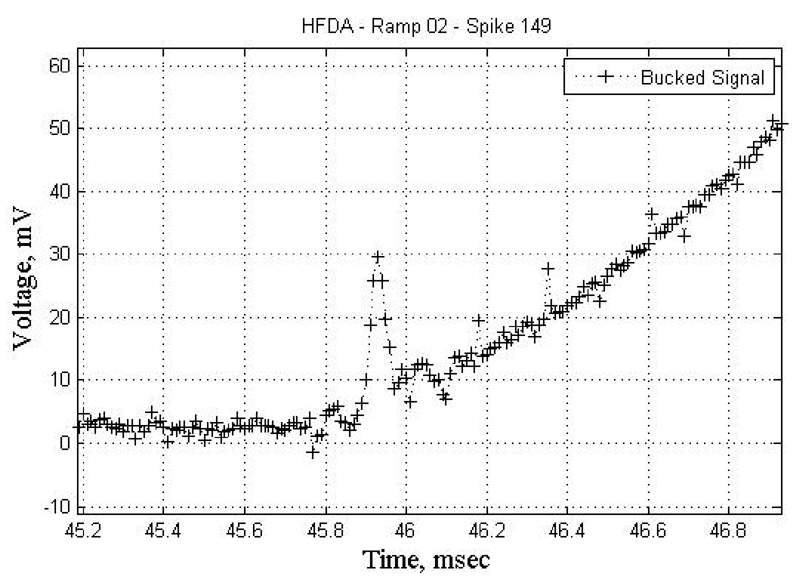

Figure 19. Spike in the half-coil voltage signal in the beginning of quench 8

Two only training quenches in coil 17 are located in the innermost turn of the inner layer (segment ***A7A8***). Coil 19 never quenched during the training or ramp rate studies. All quenches in this coil developed during the heater tests in the mid-plane section.

9. Magnetic Measurements

Field quality magnetic measurements were made with the VMTF vertical drive system and DSP rotating harmonic coil readout cart. Measurements at the room temperature (warm measurements) were not done just to save time for long run plan of testing the magnet.

The full cold measurement program is described below. A 10 cm long tangential probe, with 2 dipole, 2 quadrupole and 1 tangential windings, was utilized. This probe was specially built for LARP magnet measurements with a radius of 2.17 cm, optimized to the warm finger inner diameter.

The positive direction of the z-axis for the scans is pointing from the magnet center to the lead end, from which the probe was inserted. Each measurement (e.g., at one z-position) contains data from at least 120 full rotations of the probe, and z-scans steps were equal to the length of the probe.

The cold magnetic measurement program at 4.5 K and 1.9 K consisted of the following measurements:

a. Z-scans at 6.5 kA (4.5 K),
b. Z-scans at 12.3 Tm/m (LHC injection, estimated to be 0.720 kA), 100 Tm/m (estimated to be 5.8 kA) and 9.0 kA (1.9 K)
c. Eddy current loops with the ramp rates 20 A/s, 40 A/s and 80 A/s up to 9.0 kA with the probe positioned in the center of the magnet (1.9 K)
d. Dynamic effects measurement, which included a current accelerator profile, similar to the one used in LHC MQXB quads (15 min. duration of the injection plateau and the probe positioned in the center of the magnet).

All magnetic measurement results are presented at 22.5 mm reference radius, which corresponds to the official radius adopted for LHC (17 mm) corrected for the expected increase in the magnet aperture from 70 mm to 90 mm.

Table 4 summarizes the geometrical harmonics at 45 T/m field gradient for the TQC and TQS magnets. Unallowed harmonics of several units are observed almost in all magnets.

Table 5 summarizes the harmonics at injection (0.72 kA) and maximum measured current (9 kA), averaged over the magnet (left) and for the center body position (right). In general, the field harmonics are on the order of several units. The b_4 and b_6 at injection are observed to be relatively large, ~ 30 - 40 units at reference radius 22.5 cm.

Fig. 20 shows the transfer function (TF) versus z coordinate profiles at 0.72, 5.8 and 9.0 kA. The effective length of the magnet is calculated to be 0.745 m, 0.749 m and 0.750 m at these currents.

Fig. 21 shows the dodecapole versus time. The current profile used in this measurement was derived from the profile of production inner triplet LHC quadrupole (LQXB) measurements. The duration of the injection porch was set to 15 min at 12.8 T, accordingly to the LHC specifications. One can observe that the b6 *decay* and *snapback*, which are commonly observed in NbTi magnets, are not present (see the time interval from ~700 to ~1700 s).

Table 4. TQC and TQS geometrical harmonics at 45 T/m field gradient

n	TQC					TQS		
	calc	measured				calc	measured	
		01	02E	02A	02B		01	02
b_3	0.00	2.01	1.07	-3.42	0.00	0.00	-1.46	2.98
b_4	0.00	-1.9	-2.92	1.98	-1.02	0.00	-0.52	1.31
b_5	0.00	0.58	-2.11	2.15	0.48	0.00	3.06	-1.45
b_6	0.90	1.71	2.72	0.71	-0.38	5.00	5.4	6.23
b_7	0.00	0.07	-0.37	0.14	0.08	0.00	0.07	0.05
b_8	0.00	0.01	0.12	0.19	0.09	0.00	-0.11	-0.13
b_9	0.00	0.04	0.08	0.00	0.04	0.00	0.02	0.1
b_{10}	0.00	-0.06	-0.02	-0.06	-0.09	-0.04	0.02	-0.05
a_3	0.00	-1.72	1.17	-4.38	3.94	0.00	4.41	0.66
a_4	0.00	0.62	1.47	-0.68	-3.22	0.00	-1.99	0.82
a_5	0.00	-1.33	-3.31	-0.55	-0.64	0.00	0.71	-1.5
a_6	0.00	-0.1	0.59	-1.64	0.17	0.00	-0.37	0.12
a_7	0.00	0.1	-0.09	0.05	0.17	0.00	-0.11	-0.01
a_8	0.00	-0.03	-0.19	-0.10	0.02	0.00	-0.18	-0.1
a_9	0.00	0.08	0.11	-0.11	0.07	0.00	-0.02	0.02
a_{10}	0.00	0	-0.08	0.04	0.03	0.00	0	-0.08

Table 5 TQC02b body and average harmonics at different currents

Multipole (units)	Average		Body only	
	720A	9kA	720A	9kA
b_3	-2.86	0.025	-6.38	-1.41
b_4	30.3	2.32	30.6	0.366
b_5	-5.54	3.04	-6.74	3.02
b_6	-40.3	-0.195	-41.8	-1.31
b_7	0.81	-0.754	0.897	-0.263
b_8	-1.99	0.761	-2.24	0.379
b_9	0.189	0.406	0.356	0.189
b_10	0.112	-0.122	0.376	-0.035

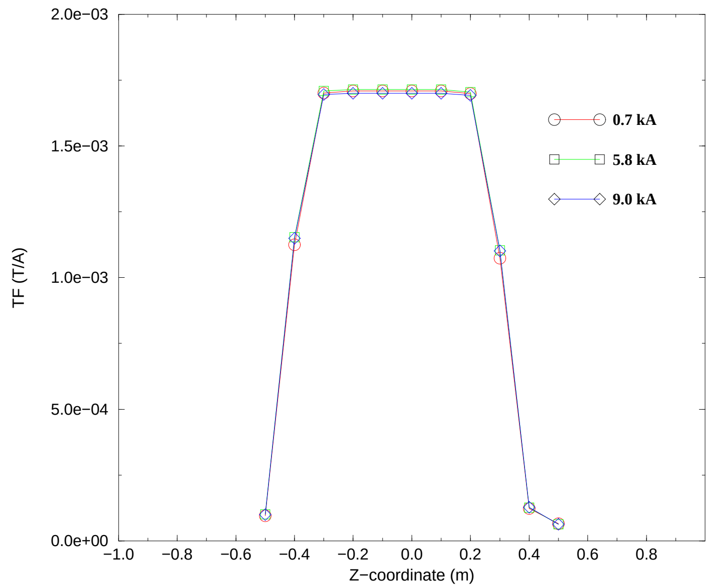

Figure 20. The magnet TF vs z-coordinate at 0.72 kA, 5.8 kA and 9 kA.

Current loops at 20, 40 and 80 A/s for TQC02a quadrupole have been executed. The b_6 difference between the ramp rate loops is small, indicating small or negligible eddy current effect on the hysteresis loop, similar to what was observed in TQS01c measurements. The b_6 hysteresis loops are shown in Fig. 22.

Ramp rate dependence of the ΔTF at different field gradients is shown in Fig. 23. Strand characteristics, like the interstrand resistance in coils, may explain different slope for the different magnets.

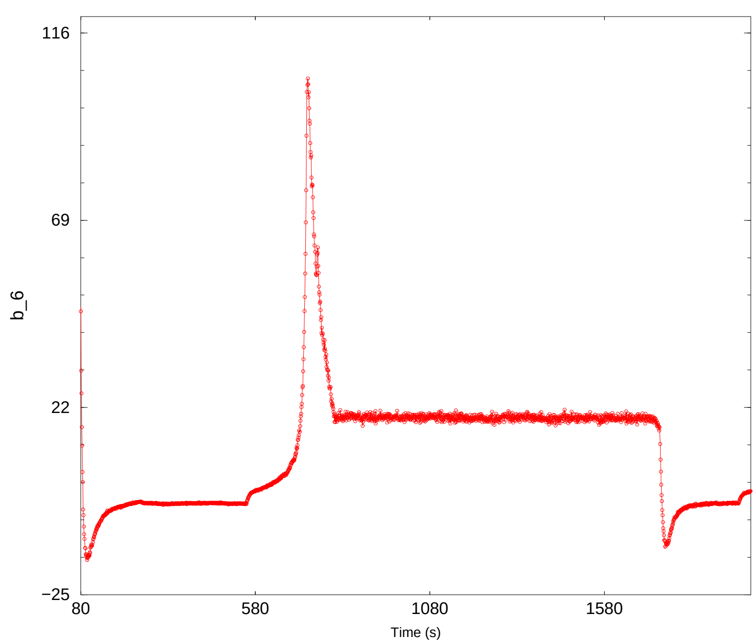

Figure 21. Dodecapole (b6, in units) vs time (s) in a modified LHC accelerator current profile.

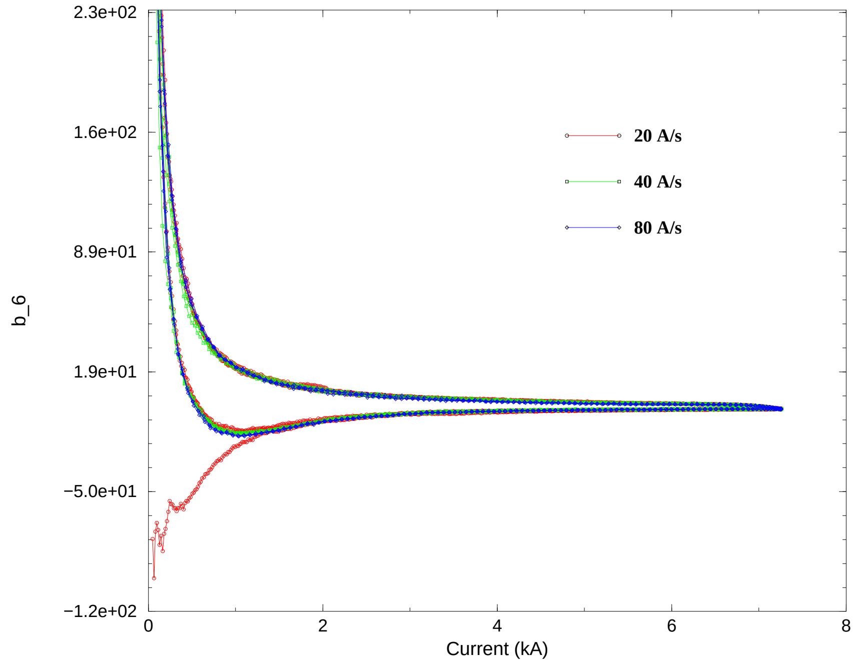

Figure 22. Dodecapole (b6) vs excitation current at different ramp rates.

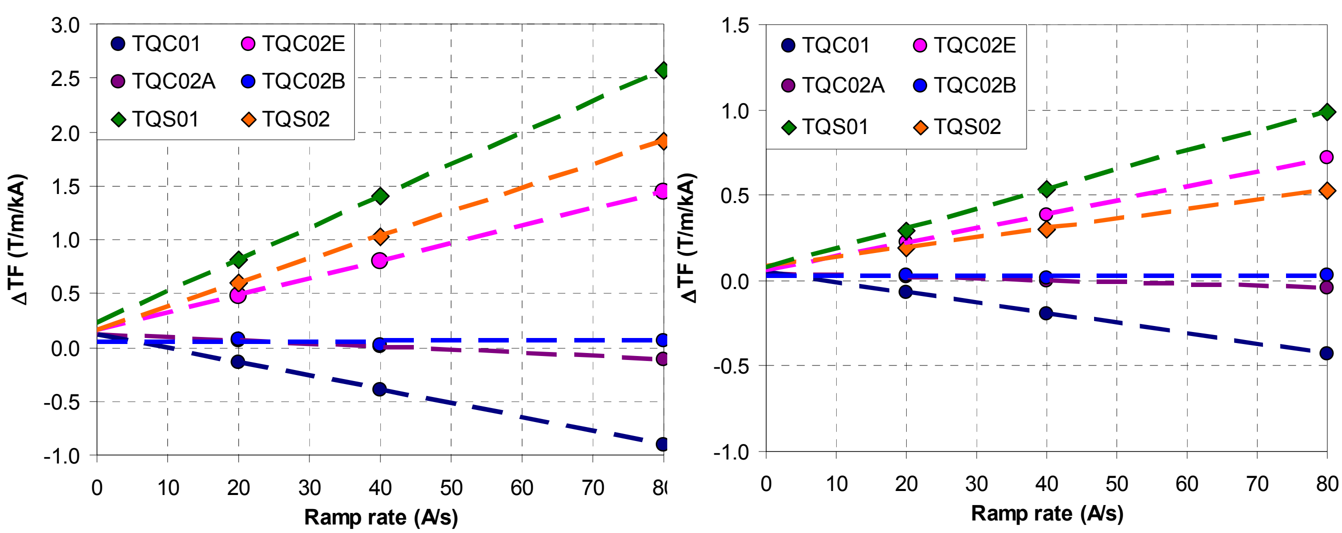

Figure 23. ΔTF ramp rate dependence at 45 T/m and 90 T/m field gradients.

10. Energy Loss Measurements

Energy loss measurements were made as a function of ramp rate to study AC losses from eddy currents and iron/conductor magnetization. One of the goals of these measurements also was commissioning the new measurement system using the PXI modules and the *Labview* based software. The reference and more comprehensive measurements were done using the existing system utilizing VME modules in the *VxWorks* real-time operating system to communicate with a 3458 DVM. Therefore, in the text or figures we refer to the "old" measurement system as a *VxWorks* system and to the new system as a *Labview* system.

The energy loss measurements were performed on July 28th, September 8th and 9th at 4.5 K temperature. Sawtooth ramps from 500 A to 6500 A were used to measure energy losses as a function of ramp rate in the range 75-225 A/s (in 25 A/s steps). 5 measurements were taken for each ramp rate. Results and the linear fit to the data obtained with the *VxWorks* system are shown in Fig. 24. The fit intercept, corresponding to the hysteresis energy loss, is ~ 1.8 kJ. The fit slope, measuring losses from eddy currents, is 3.95 J/A/s.

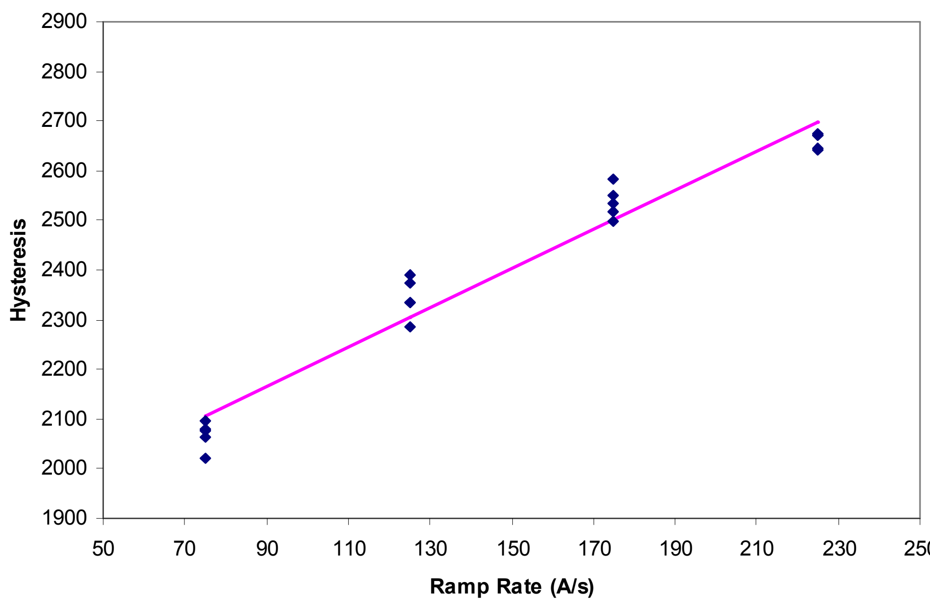

Figure 24. Energy loss measurements at 4.5 K using the *VxWorks* system

Energy losses were also measured in the individual coils using the *VxWorks* system in order to check if the results are consistent with each other, and to study whether they could explain the high ramp rate quenches in coils 17 and 10. These measurements were performed at 75 A/s, 150 A/s and 200 A/s ramp rates (see Fig. 25).

The slope and intercept of the linear fit to data for each coil are listed below:

Coil #:	17	10	19	12
Slope	1.2	1.2	1.2	1.1
Intercept	538.3	419.0	395.9	301.1

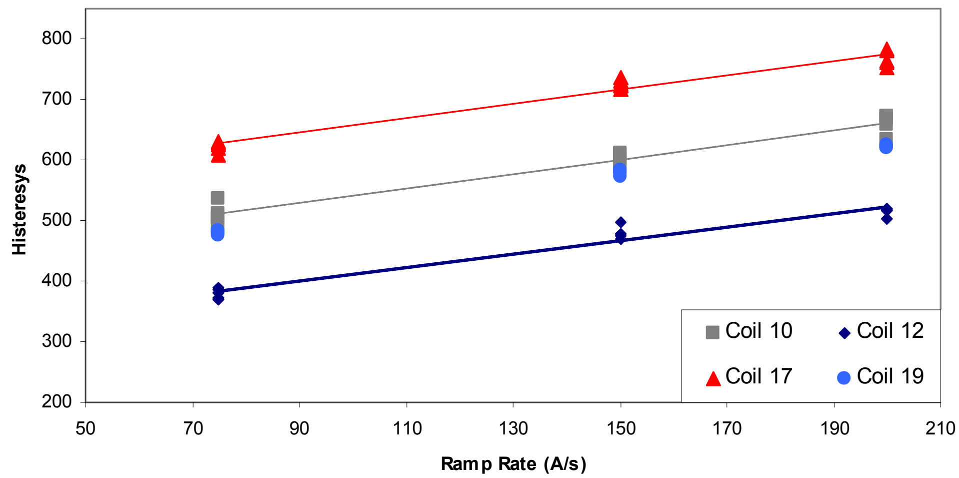

Figure 25. Energy Loss measurements in the individual coils at 4.5 K using the *VxWorks* system.

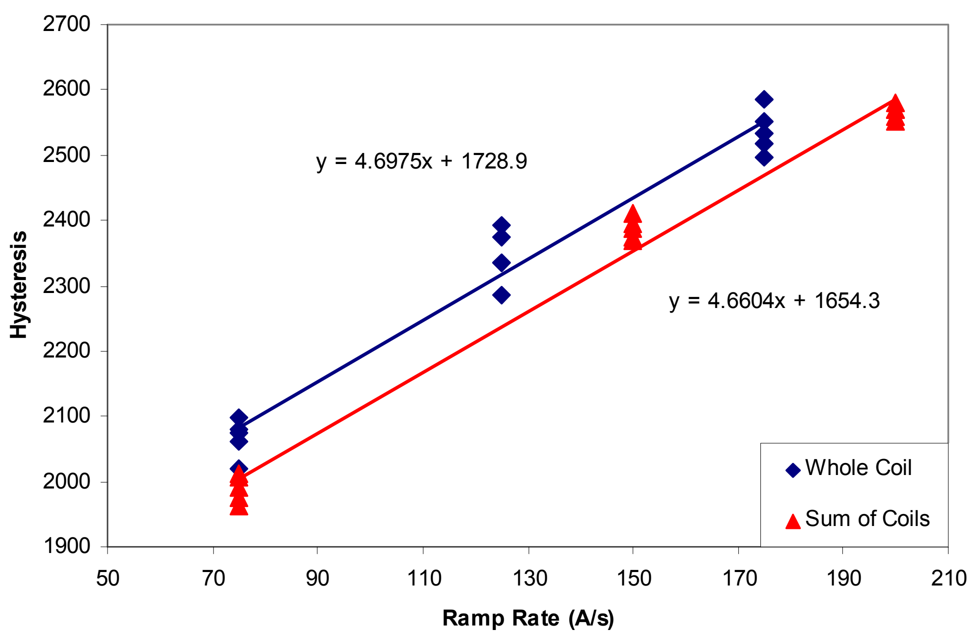

Figure 26. Energy loss measurements in the whole coil and in the individual coils at 4.5 K using the *VxWorks* system.

Combining the individual coil measurements, the summed intercept and slope are 1.65 kJ and 4.66 J/A/s respectively. These numbers are in good agreement with the whole coil measurements for the same 75 A/s, 125 A/s and 175 A/s ramp rates: 1.73 kJ and 4.70 J/A/s (see Fig. 26).

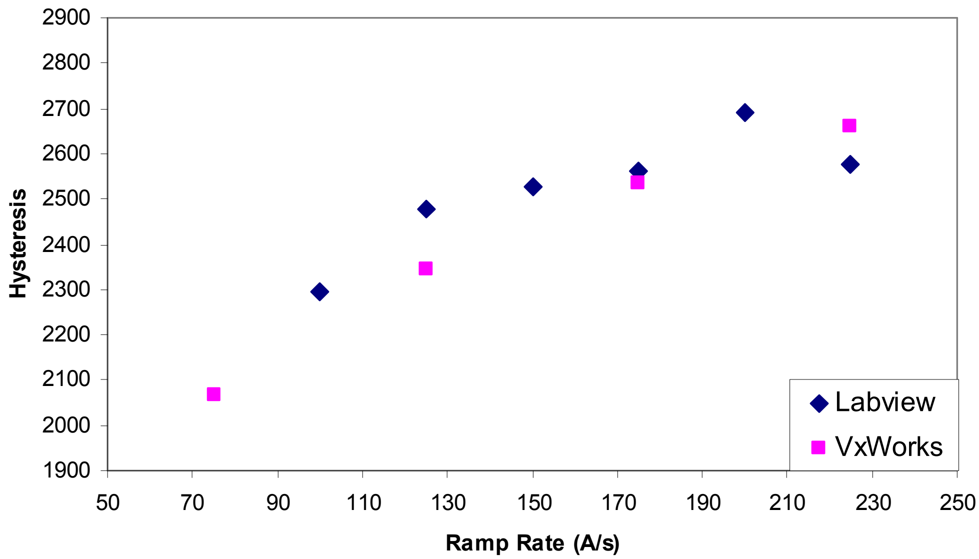

Figure 27. Averaged energy losses measured with the *VxWorks* and *Labview* systems.

Comparison of results from the measurements made with the use of the *VxWorks* and the *Labview* systems is shown in Fig. 27. Results of the *Labview* system measurements, the linear fit intercept (2.14 kJ) and slope (2.36 J/A/s) both seem quite different from the results obtained with the VxWorks system (1.8 kJ and 3.95 J/A/s respectively). But the test results are more consistent if we ignore the data at the highest ramp rate of 225 A/s. We need to improve the algorithm of calculations in order to avoid the observed energy loss drop at high ramp rates.

The *Labview* system also has a caveat that we can not do measurements at ramp rates below 75 A/s due to limitations on digitizing time of the PXI module. We need to understand and fix the above mentioned problems with the energy loss measurements.

11. Quench Logic Failure

A slow ramp down occurred on August 11th when the mid-plane strip heater between the MJR coils 10 and 12 was tested. The quench logic analysis showed that the ground fault AQD tripped first, followed by the half-coil signal (see Fig. 28). The logic associated with a ground fault AQD trip is to disable the power supply phase-back, disable the dump fire and disable the heater fire. The heater "charge status" and "load status" never changed state for the above mentioned quench # 69, which means that the load status did not initiate the slow ramp down and the heaters did not fire. All this is consistent with the QLM logic for ground fault detection, and the logger trigger occurred at the time of the ground fault trip, which is correct.

The ground fault trip in quench #69 occurred due to the fact that quench developed in both half-coils simultaneously and the AQD ground fault threshold was set very low ~ 4 mA. The asymmetrical grounding configuration and filter capacitor grounding scheme generated ground current from the simultaneous coil resistive growth. There was no real magnet ground fault but the ground current in this case exceeded the threshold before the coil quench detection thresholds were crossed resulting in a ground fault AQD trip. Since a ground fault trip initiates a slow ramp down and disables the power supply phase-back, dump fire, and heater fire, the resistive growth of the coils generated significant MIITS (~8.9) as a result.

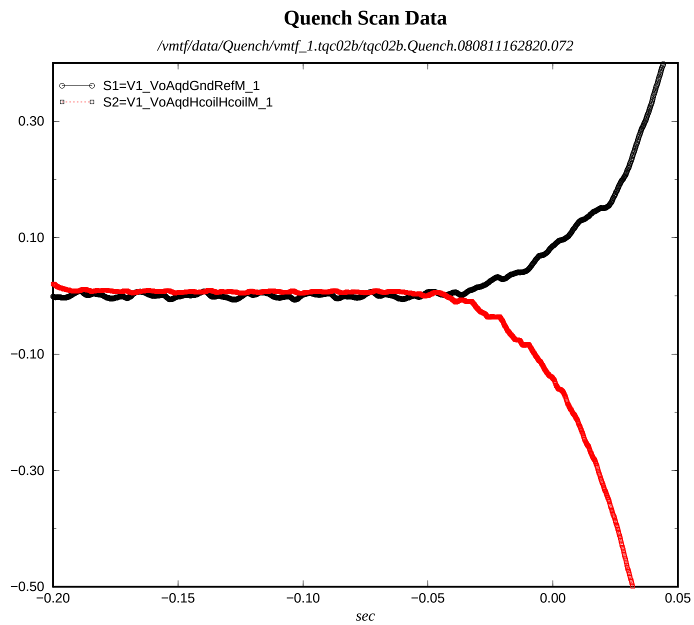

Figure 28. The AQD half-coil and ground fault signals in quench # 69.

As a short term solution, the ground fault AQD threshold was increased from 4 to 8 mA. The long term solution is to implement symmetric grounding, which has been developed and is nearly ready to implement in VMTF. This configuration will eliminate this problem.

Nevertheless, it is still possible to get high MIITS from a symmetric quench in both half-coils (at very high ramp rates for example), and in this case we need to be able to reduce threshold on the Whole-Coil minus Idot signal.

12. Conclusions

TQC02b magnet is a 1-m long quadrupole fabricated as a part of the LARP program at Fermilab. The coils of this magnet were made of 0.7-mm Nb_3Sn strands based on the MJR (coils 10 and 12) and RRP (coils 17 and 19) of 54/61 sub-element design. All coils of this magnet were previously tested at 4.5 K and 1.9 K.

TQC02b magnet exhibited very slow training at 4.5 K with quenches mostly developed in coil 12 (only 2 training quenches occurred in coil 17 at 1.9 K). Quench current at the plateau (~ 10.4 kA) is consistent with the test results from the TQC01b magnet.

Similar to other TQ magnets of 2nd series, in TQC02b test we observed erratic quench performance at 1.9 K, with noticeable increase of quench current with increasing the ramp rate up to 175 A/s. Temperature dependence of the quench performance is negligible at a ramp rate of 50 A/s, with the quench current drop at temperatures below ~3 K. At a ramp rate of 200 A/s we see smooth temperature dependence of the quench current.

Quench locations in TQC02b are concentrated at the return end, near the junction between the pole pieces, which also may indicate some mechanical damage during the assembly process.

References:

1. LARP TQC01b Test Summary, TD-07-026, 2007

2. LARP TQC02a Test Summary, TD-08-022, 2008

3. LM02 Mirror Magnet Test Summary, TD-08-003, 2008