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JLAB-TN-21-025

Tech Note Number:
MEG0002021-R004 REV-

TITLE: THE TEST RESULTS OF THE MQW QUADRUPOLE MAGNET

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-	The initial release	05/21/2021
REV.	DESCRIPTION	DATE
SUMMARY OF CHANGES FROM PREVIOUS REVISION:		

Contents

1 Context

A new MQW type quadrupole corrector magnet (Figure 1) is designed, built, and installed recently in the CEBAF 200 keV injector beamline. The magnet design, functional requirements, manufacturing and assembly details, the quality check of the coils as well as the magnet test plan are discussed elsewhere [1]. This document presents the inspection results of the coils, magnetic measurement results, and a comparison of those data with the results obtained from the electromagnetic simulation of the three-dimensional model based on the as-built MQW magnet parameters.

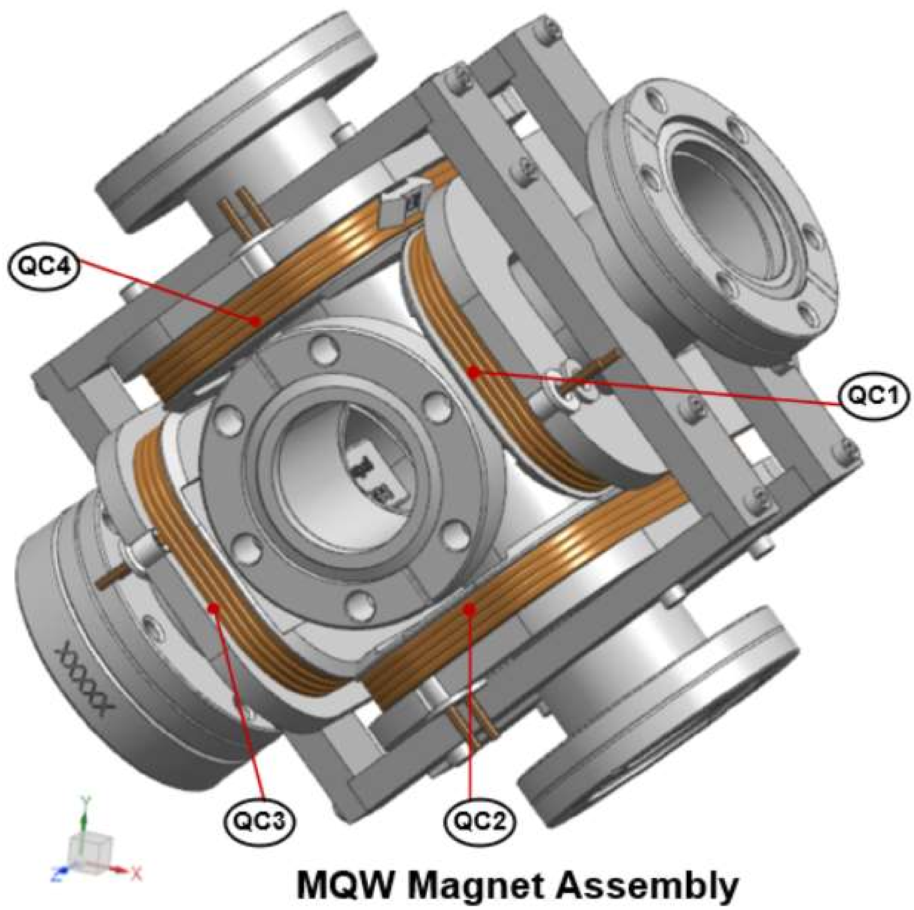

Figure 1: The MQW quadrupole corrector magnet assembled onto the CF six-way cross fitting [2]. The physical orientation of the assembly is such that coordinates x = 0, y = 0, and z = 0 represent the magnet center and the +Z axis point to the direction of the beam. The labels QC1, QC2, QC3, and QC4 denote the four racetrack coils arranged in the normal quadrupole configuration.

2 Results and Discussion

2.1 Quality assurance test results (Tests performed by the manufacturer before shipping the coils to the J Lab; Quantity: 32)

The hipot and surge tests were performed at 1000 V. The leakage current is found to be ≤ 0.015 µA for all coils. The surge tests rule out the presence of any internal electrical shorts in the winding pack. The nominal value of the resistance at 20°C of the coil (including the lead wires) is ~36 mΩ and the coil inductance at 60 Hz is 60 μH.

2.2 The results of quality assurance tests performed at MMF, JLab

All coil (Quantity: 32) passed the visual inspection, and the hipot and surge tests at 500 V. The measured values of room temperature resistance and inductance at 60 Hz of the coils can be found in [3]. The temperature studies were performed on one representative coil. The test results suggest that the coil temperature at 10 A reaches a maximum of ~31°C [4].

2.3 Magnetic measurement results

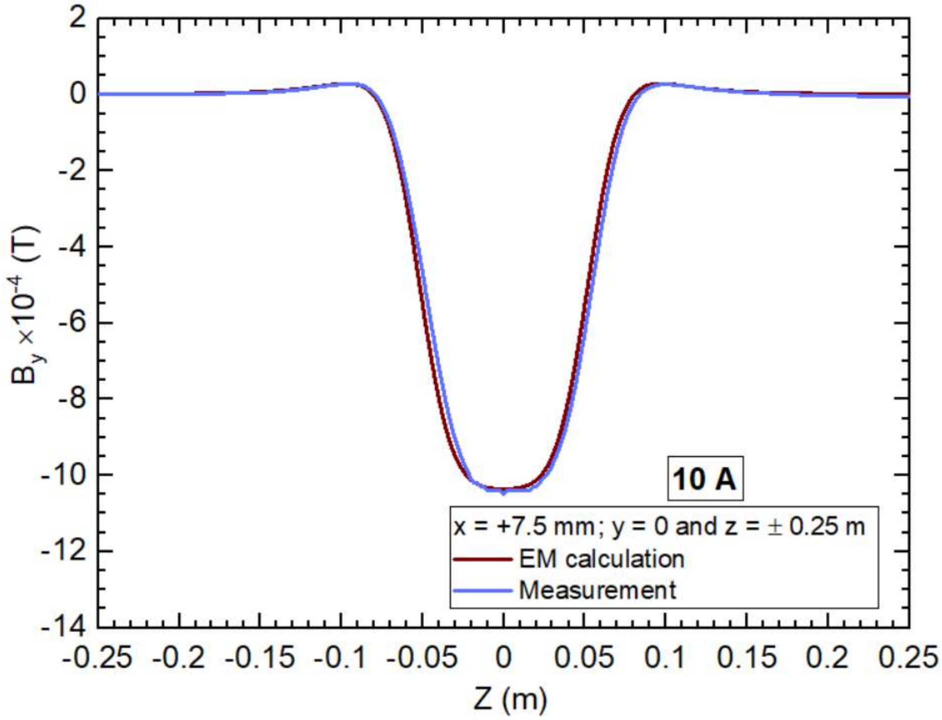

Figure 2: The vertical field (B_y) profile at (x = +7.5 mm, y = 0, z = ± 0.25m) at coil excitation current of 10 A. The brown line shows the data obtained from the three-dimensional electromagnetic simulation whereas the blue line represents the measured data of the as-built MQW magnet.

The magnetic test plan is reported in section 8 of [1]. The magnetic measurement data can be found in [5].

The analysis results indicate that the measured and computed vertical field (B_y) profiles along the longitudinal direction (Z-axis) overlap to a great degree for all excitation currents. For example, Figure 2 shows the $B_y(\mathrm{x} = +7.5\,\mathrm{mm}, \mathrm{y} = 0, \mathrm{z} = \pm 0.25\mathrm{m})$ at 10 A. The center field values obtained from the magnetic measurement and the electromagnetic (EM) calculation agree within 1.3 % (Table 1) and whereas the difference between the measured and the calculated values of the integrated vertical field strengths is about 1.1 % at 10 A.

Table 1 provides a comparison between the parameters extracted from the measured and calculated vertical field characteristics over the range of the interest. As noted in the MQW magnetic design document [1], the field data obtained from the EM simulation of the as-built magnet is used to extract the leading quadrupole field and multipole field components and to provide the relevant parameters (See Table 5 of [1]] to the CEBAF machine control system.

Table 1: Value of the vertical field component (B_y) at x = 0, y = 0, z = 0) and the corresponding integrated field strength over the Z range of ± 0.25 m from the magnetic center of the MQW magnet for coil excitation current ≤ 10 A.

Operating current (A)	Vertical field strength (B_y) at the magnet center (T)			$\int_{Z=-0.25m}^{Z=+0.25m} B_y\,(x=+7.5mm).\partial z$ (T.m)		
	EM simulation	Magnetic measurement	Difference between the values obtained from the magnetic measurement and EM simulation (%)	EM simulation	Magnetic measurement	Difference between the values obtained from the magnetic measurement and EM simulation (%)
0	0	0	-	0	0	-
1	-1.036E-04	-1.053E-04	1.63	-1.017E-05	-1.025E-05	0.75
2	-2.071E-04	-2.091E-04	0.97	-2.035E-05	-2.055E-05	0.97
3	-3.107E-04	-3.144E-04	1.20	-3.052E-05	-3.084E-05	1.05
4	-4.143E-04	-4.178E-04	0.86	-4.070E-05	-4.111E-05	1.01
5	-5.178E-04	-5.233E-04	1.06	-5.087E-05	-5.133E-05	0.89
6	-6.214E-04	-6.271E-04	0.91	-6.104E-05	-6.170E-05	1.08
7	-7.250E-04	-7.318E-04	0.95	-7.122E-05	-7.207E-05	1.19
8	-8.285E-04	-8.361E-04	0.91	-8.139E-05	-8.228E-05	1.09
9	-9.321E-04	-9.406E-04	0.91	-9.157E-05	-9.263E-05	1.16
10	-1.036E-03	-1.049E-03	1.32	-1.017E-04	-1.029E-04	1.12

3 Acknowledgment

The coil tests and magnetic measurements, according to the test plan described in [1], were performed by J. Meyers and M. Beck.

4 References

[1] S-L. Lalitha, "Electromagnetic design report of MQW magnet in the CEBAF 200 keV Injector Beamline", J Lab internal document #MEG0002021-R003 REV-, May 2021, J Lab Tech Note number-JLAB-TN-21-024.

[2] J Lab NX CAD 3D Model JL0091130-0202: Wein filter girder assembly.

[3]M:\MagTest\DataBase\Injector\QW\Coil inspection\MQW coil inspections 02-5-2021.xlsx

[4]M:\MagTest\DataBase\Injector\QW\Temperature Study\QW_Temperature_Study_020221.xlsx

[5]M:\MagTest\DataBase\Injector\QW\Analysis\MQW_Stepper_Measurements-NoShims_210221.xlsx