

ROGOWSKI COIL MEASUREMENTS OF PQP003 AND PQP004

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The 8 GeV transfer line from the Booster to the Main Injector requires nine permanent magnet quadrupoles which can be considered as prototypes of the ones needed for the Recycler Ring.¹ In the course of developing this magnet, two prototypes were constructed with slightly different amounts of temperature compensating material and measured at MTF. They were found to require more temperature compensating material, to require that the gradient be reduced and to require that the field shape (i.e. multipole content) be improved. This note reports on our attempt to use a modified Rogowski coil² as a quick measure of the relative effect of small modifications of these quadrupoles.

The Rogowski measurement procedure used for this work included the flux measurement and drift compensation procedure³. Repeated measurements gave an rms. relative variation of .0001, consistent with predictions from ref. 2. The probe described in Ref. 2 was used. Both magnets were measured in early October before being shipped to MTF to be measured there. When they were returned to MP9 in early November, they were remeasured with the Rogowski probe to recheck reproducibility. PQP003-3 appeared stronger in November by $5e-4$, while PQP004-3 appeared stronger by $1e-4$, neglecting any temperature effects. In the table below the MTF strength measurement is compared with the Rogowski strength measurement. Note that PQP004-4 has 2 rows of 4 of 1.9" x 4" x 1" bricks/pole while the other three versions all have 2" x 4" x 1" bricks. The behavior of the MTF to Rogowski strength ratio suggests that once the number of temperature compensation strips is fixed, then the strength can be trimmed using the Rogowski coil to better than 0.5%.

Magnet Version	MTF Strength (T)	Rogowski Strength (V-s)	MTF/Rogowski	Total Trim Iron(in.)	Compensator Strips/Pack	MTF Strength/Desired
PQP003-3	1.4496	1.1597e-03	1249.98	0.00	10	1.172
PQP004-3	1.42155	1.1380e-03	1249.17	0.00	12	1.150
PQP003-4	1.30145	1.0461e-03	1244.10	68.00	16	1.053
PQP004-4	1.33775	1.0749e-03	1244.53	5.71	16	1.082
PQP003-4		1.1095e-03		0.00	16	
PQP004-4		1.0825e-03		0.00	16	

After balancing the Rogowski strength of each of the four poles of these two quads, the MTF field quality measurements indicate that these magnets are within tolerance, so that was successful. The Rogowski coil strength measurements indicated that PQP003-4 had a temperature dependence of $+7e-4$ per degree C. It may be that the Rogowski measurement is misled by the presence of temperature compensating strips at the ends of the magnets. This will be investigated further. In summary, this tool appears to be capable of allowing the overall strength of the magnet and the relative strength of the four poles to be balanced during assembly at MP9 before shipment to MTF for final measurement.

¹ W. Foster, "Recycler and 8 GeV Line Permanent Magnets Reference Design & Performance Requirements," FERMILAB Main Injector Note 150.

² K. Bertsche, "A Modified Rogowski Coil for Measurements of Hybrid Permanent Magnets," FERMILAB-Conf-96/190.

³ B. Brown et. al., "The MTF Permanent Magnet Brick Tester", FERMILAB-MTF-96-0004 version 1.2, Oct 24, 1996.