As Built Tech Note for Pole Tip Steering Coils

The pole tip coils were intended as a replacement for the backleg windings steerers placed on quadrupoles where the adjacent multipole was needed as a skew quad element. The other use they had been posited for was in the case of a short straight undulator where, in combination with the multipole steerers, they provided two vertical and horizontal correctors up and downstream of the ID allowing for position and angle correction of the beam through the ID. They could also be used to free a multipole as a compensating optical element for an ID.

Several designs were tried with the constraints being that the coils have as large an amp-turn total with a 22 volt source while still fitting in the tight geometry between the pole tips and not burning up from resistive losses.

The design used is shown in Figure 1. A set of four pieces was fabricated to the drawing in-house to verify the fit to the pole pieces. A Poisson calculation gave a peak on-axis magnetic field of 170 G at 5 amps. A coarse measurement at five on-axis test points using an FW Bell handheld Hall Probe indicated a peak on-axis field of 190 G at 5 amps and an integrated field strength of ~1.0 kG-cm/amp. This corresponds to about 0.4 mrad/amp for an 800 MeV beam.

Once it was verified that those coils fit and met the electrical requirements, bids were solicited from an outside fabrication shop.

Figure 1
While those coils were fabricated outside, a simple, but robust mechanical retaining mechanism, drawing numbers 3004A563 and 3004A564, was designed and fabricated. Figure 2. The retention brackets were glued to the coils using epoxy.

![Figure 2](image)

Once the coils came in-house from fabrication, the rough edges were cleaned up and a final layer of epoxy was put over the turns for mechanical strength and protection. Red and black insulating tubing was installed on the leads to indicate polarity. Each coil was tested to ensure that, with the coil lying flat on the bench and the red lead connected to the positive terminal, the magnetic field produced was positive pointing in the direction that the leads attached to the coil. Final assembled view is shown in Figure 3.

![Figure 3](image)

During assembly onto a quadrupole’s pole tips, it was found that the coils produced by the outside vendor were approximately 0.125 inch too short on the long axis to fit down against the quad coil’s aluminum mounting bracket, see Figure 4. This problem caused the coils to nick their insulation against the sharp corners of the quadrupole’s core during assembly, shorting them out. To solve that problem, double layers of kapton tape were put on all the mating corners of the pole tips and the mounting brackets’ cross bar was re-machined shorter to allow the coils to sit up off the quad coil. This solved the problem in the short term, but it is unclear if it will survive years of temperature and electrical cycles. If more coils are to be procured and installed, it is strongly suggested that the 8.911” dimension be increased by 0.125 or 0.25 inches.
To test the actual performance of the coils after installation, the set of coils on QF02 was connected to a Keithley BOSS bipolar power supply with a Fluke 73 DMM used as a series current meter. A beam was injected and GFB and Tune Tracker were turned on to allow the beam to stabilize. At the start of the test Global Feed Back and Tune Tracker were turned off and the corrector currents and bpm positions were logged. To test the relative strength of the new pole tip coil versus the multipole correctors, HSF02 was used to steer the beam away from the nominal orbit and then the pole tip coil was used to steer the beam back to the original bpm value at QF02.

<table>
<thead>
<tr>
<th>POINT</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPM.QF.02, BPMU</td>
<td>0.00801</td>
<td>-0.1000</td>
<td>-0.1142</td>
<td>0.0077</td>
<td>0.00894</td>
<td>0.00806</td>
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<tr>
<td>HSF02, A</td>
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<td>-0.2802</td>
<td>-0.159</td>
<td>-0.159</td>
<td>0.8481</td>
<td>1.4955</td>
</tr>
<tr>
<td>Pole tip coil, A</td>
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<td>0</td>
<td>0</td>
<td>1.48</td>
<td>3.08</td>
<td>4.00</td>
</tr>
</tbody>
</table>

The first point provides a baseline which could be reproduced by re-optimizing the orbit, the second and third points provide a calibration of bpm offset in BPMU vs amps in HSF02, so that small errors in the final position of the BPM can be accounted for, and points 4, 5 and 6 are actual data points. The calibration of QF.02 vs HSF02 is roughly 8.16 Amps/BPMU, so the correction for point 5’s offset of 0.00093 BPMU from the initial position would be 7.5 mA out of 2.0073 amps in HSF02. Averaging the three data points, 4, 5 and 6, the cross calibration between the pole tip coil and HSF02 is approximately 0.66 amps/amp. This does not take into account the change in the betatron functions between the HSF02 corrector and the QF02 bpm.

If the error caused by the difference in betatron functions is small though, then the relative strengths between the various steersers around the ring are:

Window-frame steerers: 0.98 mrad/amp w/o shielding: VSV1A, 2A, 4A
                        0.85 mrad/amp w DCCT shielding nearby: VSV3A
Sextupole steerers:    0.449 mrad/amp
Quad backleg winding steerers: 0.21 mrad/amp
Pole tip coils:        0.3 mrad/amp

SUMMARY
A new, four coil, pole tip steerer was designed, procured and tested. The Poisson predicted peak on axis field was 170 G at 5 amps. The measurement made with the handheld FW Bell Hall probe was 1000 G-cm/amp with a peak on-axis field of 190 G. This gives a calculated steerer strength of 0.4 mrad/amp at 800 MeV, which is about 30% higher than measured using the electron beam. The beam based relative measurement of the steerers’ strength was 0.3 mrad/amp at 800 MeV.

So, based on the beam based relative measurement, the new coils are about 3/2 stronger than the present backleg winding steerers and about 2/3 as strong as the existing multipole steerers.

There are long term reliability questions for these coils based on the (mis)fit of the coils to the quadrupole core. If more coils
are to be procured, modification of the mechanical dimensions is strongly suggested.

ADDENDA - 19 Feb 2009:
In preparing for the installation of a 1 m undulator in short straight nine, the ring was operated with the Poletip coil on QF09 operating in place of HSF09. Two matrices were taken at 108 MeV and one at 800 MeV. They can be enabled while in Base Lattice under the “BPM” pulldown menu of the Page program. Select “Matrix Control” and then “Horizontal”. Scroll down the list to Feb 19, 2009 and enable the matrices for use. However, the poletip corrector provided sufficient steering to work with the normal matrix at 108 MeV and the beam was ramped to 800 MeV successfully. This will allow the sextupoles to be used as multipole correction magnets or a second set of steerers to generate “doglegs” in the insertion device.