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AGS Sextupole Error Part II

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Abstract

The sextupole magnet error seen at the close of the '03 Polarized Proton run[1] warranted evaluation of AGS sextupole magnets. Three bad ones were found[2]: I13 (horizontal sextupole) G7 (vertical sextupole), and B5 (drive sextupole). They were replaced during the 2003 summer shutdown. Following the replacement, this study was conducted to determine whether a sextupole error still exists in the AGS. The study was not conclusive, as data taken with gold in the AGS on two different occasions gave conflicting results for both sextupole strings; data taken with protons in the AGS shows that no sextupole error exists due to powering either string. During the course of this study, a quick check showed that powering the E20 Siberian snake magnet caused no Sextupole type losses.

Method

The aim of the study was to determine whether a sextupole error still exists following the replacement of the failed AGS sextupole magnets. To this end we used the Optics Control program to bring the horizontal tune from 8 ¾ through 8 2/3 slowly, then return to 8 ¾ (Fig. 1a). We saved the beam current in the oscilloscope memory. Then we set the current in the horizontal sextupole string to 0A. If a sextupole error existed, the beam current transmission through Q_h=8 2/3 would improve when the sextupoles were zeroed. The procedure was repeated with the vertical sextupole string. After taking data with gold ions in the AGS, we repeated the tests with proton beam.

To check of the method described above, we introduced a sextupole error by running the dynamic sextupole with 20A and 30A on the flattop to confirm that there is visible beam loss when the horizontal tune crossed the 8 2/3 resonance and a sextupole error is present.

Results

First, an apology to readers: since the data was taken over the course of several months, between other work in the MCR, the color of the xbar signals was not considered when taking data. Hence there is no continuity in the colors of the traces. The F-15 beam current, and Horizontal Quadrupole current [tune track] scope signal colors are given below the figures, which should ease the confusion. The other traces are not relevant to this paper.

The horizontal tune double crossing of the resonance, as described above, introduced two beam losses, as seen in Fig. 1b. A different loss pattern was intermittent during the course of the study. The horizontal tune was measured to be 8 2/3 with the AGS tunemeter at AT0 plus 2300, which is just before the beam loss begins. The strange

[1] JW Glenn, private communication.
[2] Raymond Zaharatos, email communication 2/12/04

loss pattern seen in Figure 2c as compared with Figure 1b indicates that a different loss mechanism was at work.

Tests of the two sextupoles strings gave different results. The first result of zeroing the horizontal sextupole string can be seen in Fig. 2a. The magenta trace is the difference in the beam current when the sextupoles are zeroed and when they are not. The flat line indicates that zeroing the sextupoles does not improve transmission and therefore there is no sextupole error in the horizontal string for this run. As an aside, when the horizontal sextupoles were set to 0A, an intermittent fast loss at 2100 ms after AT0 became more frequent. This loss is shown in Fig. 2b. This intermittent loss plagued the gold run but this subject is outside the scope of this study, and is being separately investigated.

One data-taking session indicated problems with both sextupole strings. Figures 2c through 2f were taken with gold in the AGS. They show that more serious beam loss (Fig. 2c) could be corrected by zeroing the horizontal sextupole string (Fig. 2d). The loss reappears when the horizontal sextupole current settings are restored to non-zero values (Fig. 2e). Finally, the vertical sextupoles were zeroed, and the losses disappeared again, but with the horizontal string on (Fig. 2f).

In another session with gold in the AGS, when the vertical sextupole string was set to 0A, transmission through Q_h=8 2/3 did not improve. This can be seen in the flat red comparison loss trace in Fig. 3a, which shows the difference between beam loss when the vertical sextupoles were at normal non-zero settings and when the sextupoles were set to 0A. The larger slow loss, as seen in Fig. 3b, appeared when the sextupoles were zeroed, and was the exception. Data taken with protons also indicated that no change in beam current occurred when the vertical sextupoles were zeroed.

A proof of principle test was conducted using the drive sextupole string to substantiate the claim that a sextupole error would cause beam loss with the tune setup as described above, and the beam losses are seen in Fig. 4a and 4b. The losses were visible on every AGS cycle.

In addition, during the proton run we took the opportunity to check whether the E20 Siberian snake causes beam loss, at extraction energy, when the horizontal 8 2/3 resonance is crossed. . The small losses seen in Fig. 5 are quite similar to those seen in Fig 1b; the same setup without the snake on. That the snake does not increase losses is consistent with the 8.3 TM/M^2 at injection modeled by Tsoupas[3] and the dQ/dX of 9e-3 / mm as measured by Ahrens[4] at injection – implying strength of 12 TM/M^2 – as the strength of a snake drops as 1/cP^2; the equivalent current in the resonance drive string of sextupoles would be about ¼ Amp at extraction energy.

Conclusion

In conclusion, zeroing the sextupole strings often improved transmission through Q_h=8 2/3, but did not always eliminate the loss. This suggests that this simple test to check for errors in the sextupoles was complicated by factors outside the scope of the study and quite possibly the sextupole error was not stable. Data taken with gold in the AGS indicated there was a problem at least in the horizontal string and maybe the vertical

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[3] N Tsoupas, private communication 7/1/04

[4] L Ahrens private communication, 7/8/04

one, although the proton data does not corroborate these findings. A check of the horizontal sextupoles is strongly recommended, and if time permits a check of the vertical string would be prudent.

Fig. 1a Horizontal Tunes Cross 8 2/3 twice

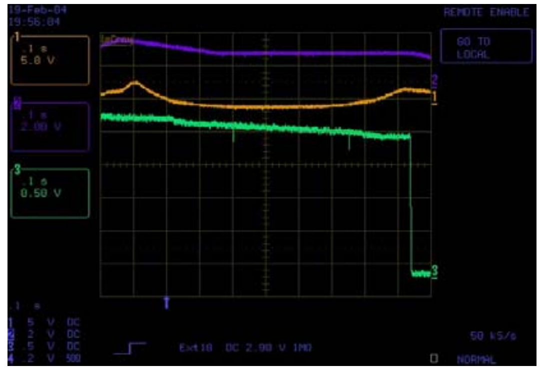

Fig. 1b Two losses appear
(F15=green trace, Hquad = red)

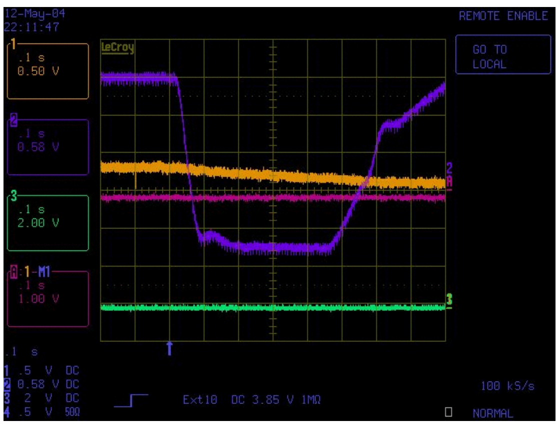

Fig. 2a Horizontal Sextupoles Zeroed
(F15 = Orange, Hquad = blue)

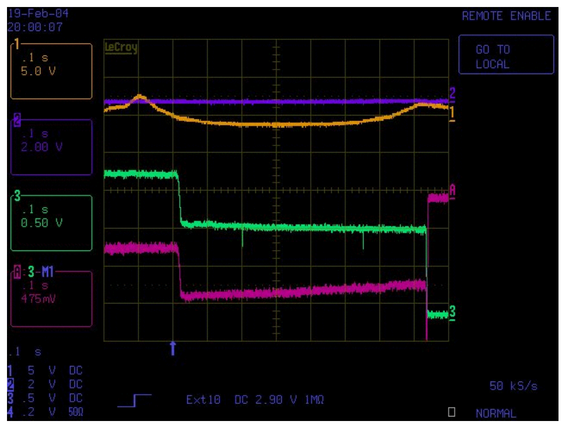

Fig. 2b Horizontal Sextupoles Zeroed – intermittent loss (F15=green, Hquad=orange)

(A) is more common; the fast loss shown in (B) is still unexplained.

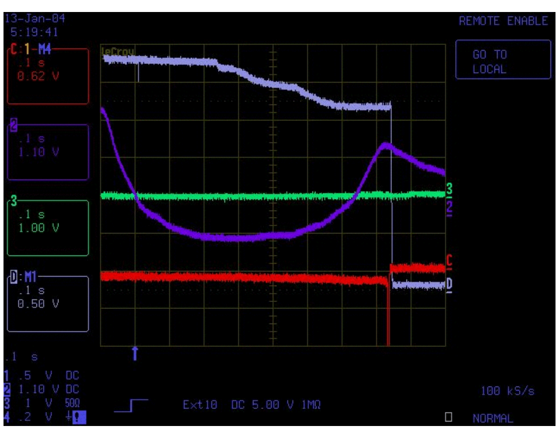

Fig. 2c Losses when $Q_h = 8\ 2/3$

(F15 =Lblu, Hquad=Dk blu)

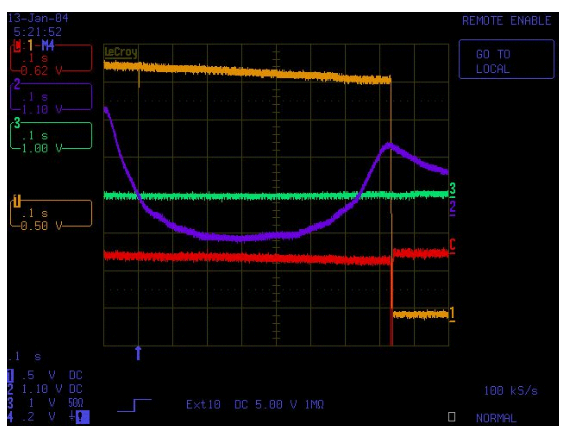

Fig. 2d Zeroing the horizontal sextupoles corrects the loss
(F15 = orange, Hquad=Dk blu)

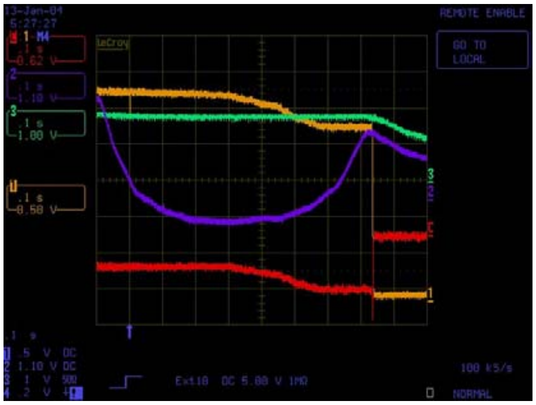

Fig. 2e Revert to horizontal sextupole settings as in Fig. 2c, and the loss reappears (F15 = orange trace, Hquad=Dk blu)

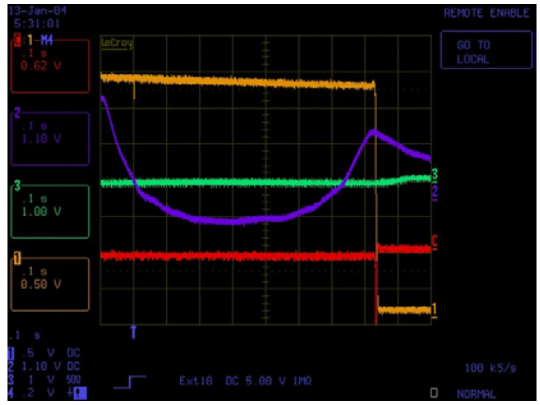

Fig. 2f Zeroing the vertical sextupoles eliminates the loss again (F15 = orange, Hquad=Dk blu)

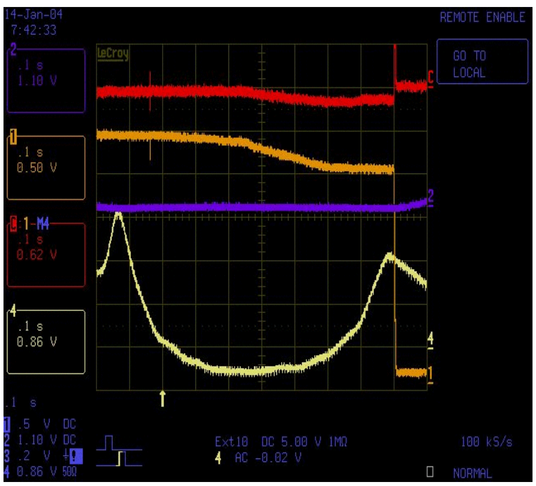

Fig. 3a Vertical sextupoles zeroed (F15 = orange, Hquad=yellow)

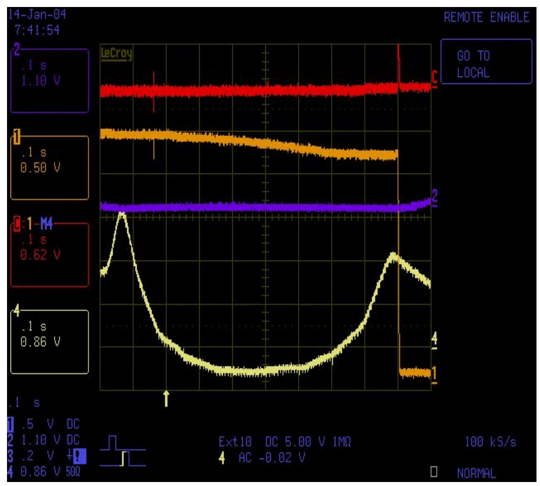

Fig. 3b Vertical sextupoles zeroed (F15 = orange, Hquad=yellow)

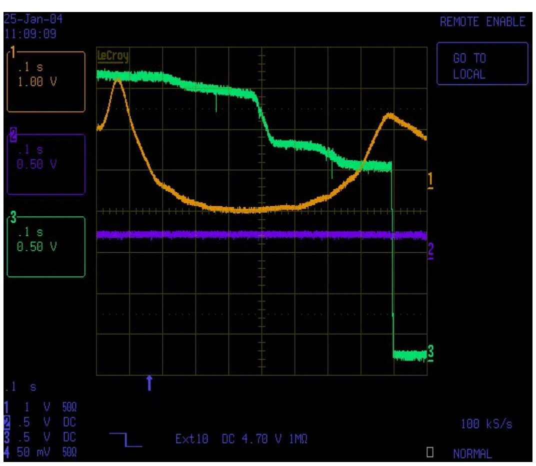

Fig. 4a Dynamic sextupole at 20A (F15 = green, Hquad=orange)

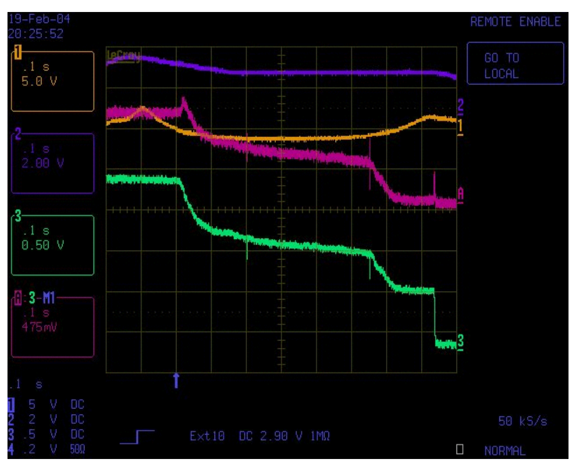

Fig.4c Dynamic sextupole at 30A (F15 = green, Hquad=orange)

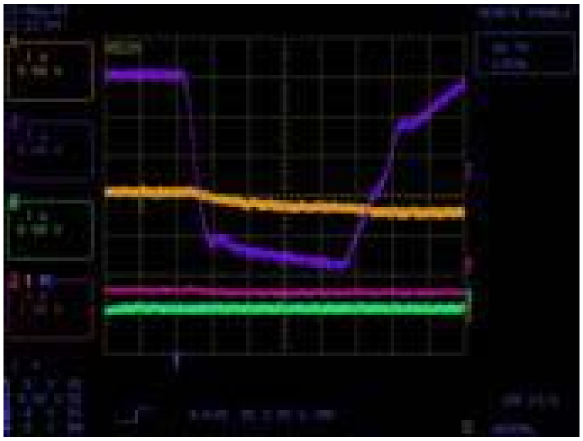

Fig. 5 Siberian snake on
(F15 = orange, Hquad=blue)