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Stopband Correction of the AGS Booster 9th Normal Sextupole Correction Test

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Stopband Correction of the AGS Booster
9th Normal Sextupole Correction Test

Study Period: April 27 & 28, May 7, 1993

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Reported by: Y. Shoji

Machine: User3; MMPS: with 1.7 kG flat-porch; low intensity (middle 5 turns, 60 degrees)

Aim: Test of 9th normal sextupole correction to reduce the residual loss of the half-integer resonances, 2Qx=9 and 2Qy=9.

On May 5 we newly installed the 9th normal sextupole strings to correct the radial dependence of the correction current of 2Qx=9 and 2Qy=9. This installation was based on a discussion with Y.Y.Lee et al. When the Booster was designed, 9th sextupole corrections were not considered [Booster Design Manual, 1988]. But this 9th normal sextupole error produced the radial dependence of corrections of half integer resonances. Then these half integer resonances could not be corrected perfectly with quadrupole correction strings and there remained a considerable residual loss. That loss was much larger than the loss from any 3rd resonance [Shoji and Gardner, AGS SR-290]. The error source did not necessarily have 9th harmonic sextupole error, but it can be corrected with 9th sextupole correction strings.

I April 28-29 (test strings)

Monitor back-leg windings of the chromaticity control sextupoles were connected to two power supplies; PS1 and PS2. They produced sin9X and cos9X component of normal sextupole fields. The maximum current of these power supplies were ±5A. They were only test strings because we expected much current for a perfect correction [Shoji and Gardner, AGS SR-292].

Chromaticity corrections and sextupole stop-band corrections were turned off. We measured the optimum corrections; N(cos9X), N(sin9X), N(cos9Y) and N(sin9Y) for a various radius; dRset. We observed the change of the slope; Sr = δ[N(sin9X)]/δ[dRset] or δ[N(sin9Y)]/δ[dRset] and Cr = δ[N(cos9X)]/δ[dRset] or δ[N(cos9Y)]/δ[dRset].

The maximum current of the power supplies were far from enough to cancel the slopes. Then the PS1 and PS2 were energized to get the maximum effect. The results were listed in Table I and plotted in Fig.1-3. When we excited PS1 and PS2 the slope and the residual loss changed. It was encouraging that the residual loss decreased as the slope angle decreased.

Table I Half integer correction and 9th sextupole strings. B=1.7kG, dB/dt=0.

reso-nance	PS1 (A)	PS2 (A)	Drset (cm)	N(cos9*)	N(sin9*)	crossing speed	residual loss(%)
2Qx=9				N(cos9X)	N(sin9X)		
	0	0	-0.6	315±10	190±10	0.02	9
			0.4	190±10	140±10		7
			1.2	115±10	105±10		13
	5	-5	-0.6	350±10	205±10		17
			1.2	40±10	100±20		16
2Qy=9				N(cos9Y)	(sin9Y)		
	0	0	-0.6	365±10	-60±10	0.02	8
			-0.1	340±10	-95±10		7
			0.4	300±10	-105±10		7
			0.9	260±10	-100±10		5
			1.4	220±10	-120±10		6
	5	-5	-0.6	390±10	-65±10		8
			1.4	210±15	-130±15		8
	-5	5	-0.6	350±15	-75±10		6
			1.4	240±10	-110±10		4

II May 7 (new windings)

To get enough strength of the 9th sextupole strings, extra windings were added to the chromaticity sextupole magnets. Two strings, SH3 and SV3 excited the cosine and sine harmonic components. The maximum current of each power supply was ±50 A.

First, the change of the slopes by each strings; SH3 and SV3 were measured. The measured data were listed in Table II. The slopes; δN(cos9X)/δDrset, δN(sin9X)/δDrset, δN(cos9Y)/δdRset and δN(sin9Y)/δdRset were calculated and are listed in Table III. The results of the measurement were condensed to the following matrix equations;

$$\begin{pmatrix} \delta N(\cos 9X)/\delta dRset \\ \delta N(\sin 9X)/\delta dRset \end{pmatrix} = \begin{pmatrix} 6.69 \pm 0.33 & 6.31 \pm 0.33 \\ 2.93 \pm 0.29 & -1.45 \pm 0.29 \end{pmatrix} \begin{pmatrix} SH3 \\ SV3 \end{pmatrix}$$

$$\begin{pmatrix} \delta N(\cos 9Y)/\delta dRset \\ \delta N(\sin 9Y)/\delta dRset \end{pmatrix} = \begin{pmatrix} 3.38 \pm 0.29 & 0.68 \pm 0.31 \\ 0.08 \pm 0.29 & 2.28 \pm 0.29 \end{pmatrix} \begin{pmatrix} SH3 \\ SV3 \end{pmatrix}$$

We had decided to measure the elements of these matrices using real machine. But we could have calculated them theoretically with enough reliability. Because uncertainties of the dispersion function and the field strength of the 9th sextupole strings were very small [Shoji and Gardner, AGS SR-292]. With the similar reason we can apply the above equations at any B or dB/dt. The dispersion function does not depend on B nor dB/dt.

The optimum SH3 and SV3 were calculated and applied to 2Qx=9 and 2Qy=9. The results were successful. The residual losses were decreased significantly as listed in the bottom of Table II. Fig.4 shows the improvement of the beam loss by crossing 2Qy=9 resonances with the correction strings. We could have more improvement if we added fine adjustments.

Table II Correction currents of half integer resonances (2Qx=9 and 2Qy=9) for the different momentum displacement (dRset) and 9th sextupole strings (SH3 and SV3).

reso- nance	SH3 (A)	SV3 (A)	dRset (cm)	N(cos9*)	N(sin9*)	crossing speed	residual loss(%)
2Qx=9							
	0	0	-0.6	280±10	155±10	0.01	24
			0.4	185±10	105±10		20
			1.4	65±10	70±10		26
	40	0	-0.6	70±15	40±10		49
			1.4	390±15	190±10		35
	0	40	-0.6	-30±10	280±10		53
			1.4	320±10	80±10		43
2Qy=9							
	0	0	-0.6	350±10	-80±10	0.01	16
			0.4	275±10	-110±10		15
			1.4	180±10	-130±10		19
	40	0	-0.6	255±10	-80±10		19
			1.4	355±10	-125±10		2
	0	40	-0.6	300±15	-137±10		7
			1.4	185±10	-5±10		24
2Qx=9							
	15	-1	0.4	210± 7	110± 7	0.01	4
						0.02	2
2Qy=9							
	25	3	0.4	295±10	-100±10		4

Table III The slopes (radial dependence of the half integer correction quadrupoles) and the 9th harmonic sextupole strings.

resonance	SH3 (A)	SV3 (A)	δN(cos9*) /δdRset	δN(sin9*) /δdRset	mean loss(%)
2Qx=9					
	0	0	-108± 8	-42± 8	25
	40	0	160±10	75± 8	42
	0	40	145±10	-100± 8	48
2Qy=9					
	0	0	-85± 8	-25± 8	17
	40	0	50± 8	-22± 8	10
	0	40	-58± 9	66± 8	15

FIGURE CAPTIONS

Fig. 1 Radial dependence of the 2Qx=9 resonance correction.

Fig. 2 Radial dependence of the 2Qy=9 resonance correction.

Fig. 3 Ninth sextupole (PS1 and PS2) dependence of the residual beam loss of the half integer resonances.

Fig. 4 The decrease of beam loss by the resonance (2Qy=9) crossing. Top trace is the current read back of the vertical tune control quadrupole. The second three traces are beam current in the Booster, without any correction, with only the quadrupole correction, and with quadrupole and sextupole correction.

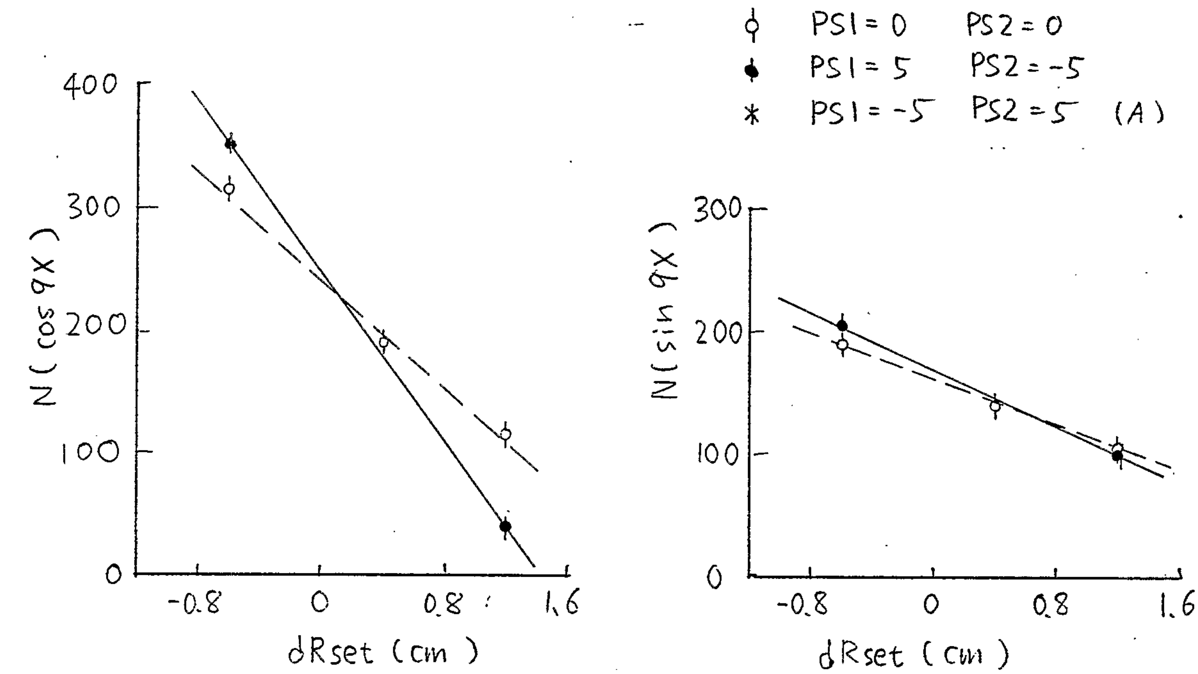
PS1 = 0 PS2 = 0
PS1 = 5 PS2 = -5
PS1 = -5 PS2 = 5 (A)
N(cos 9X)
N(sin 9X)
dRset (cm)
dRset (cm)

Fig. 1

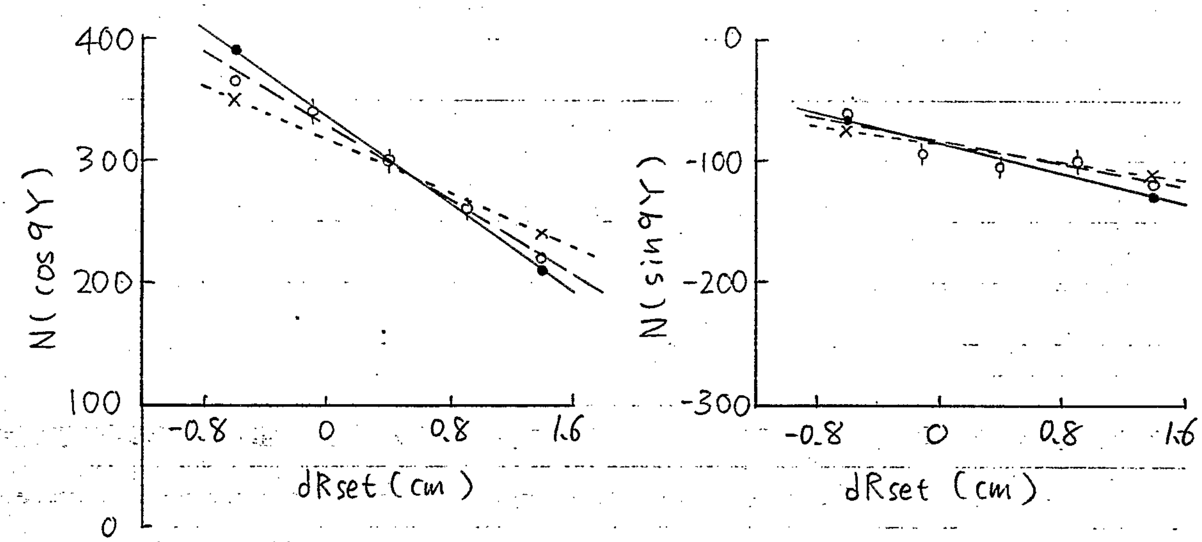
N(cos 9Y)
N(sin 9Y)
dRset (cm)
dRset (cm)

Fig. 2

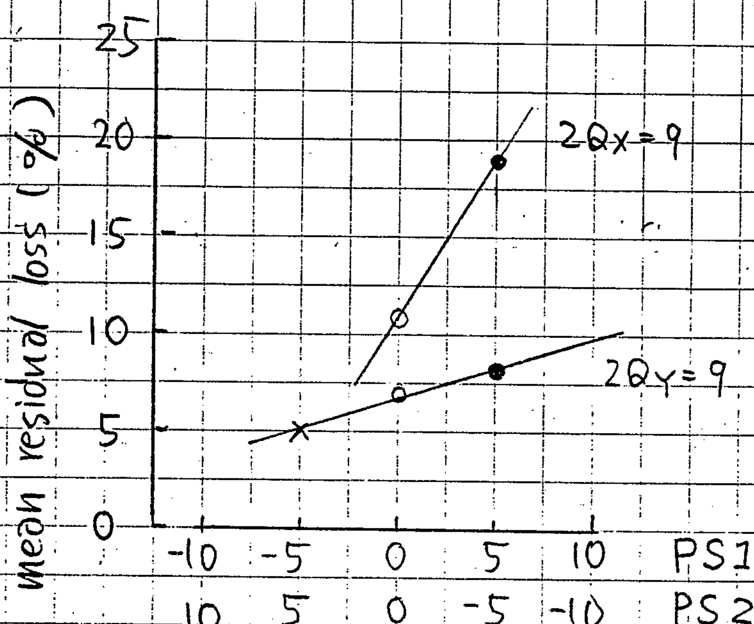
mean residual loss (%)
25
20
15
10
5
0
2Qx = 9
2Qy = 9
-10 -5 0 5 10 PS1
10 5 0 -5 -10 PS2

Fig. 3

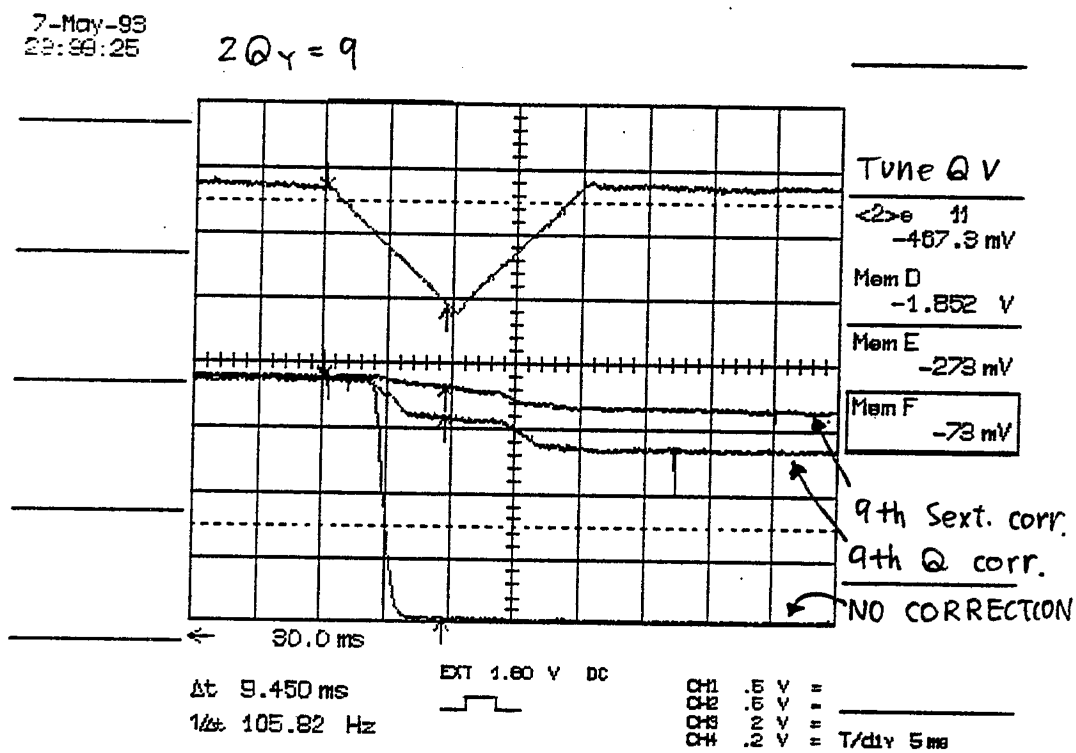
7-May-93
22:38:25
2Q_Y = 9
Tune Q V
<2>e 11
-467.3 mV
Mem D
-1.852 V
Mem E
-273 mV
Mem F
-73 mV
9th Sext. corr.
9th Q corr.
NO CORRECTION
30.0 ms
Δt 9.450 ms
1/Δt 105.82 Hz
EXT 1.60 V DC
CH1 .5 V =
CH2 .5 V =
CH3 2 V =
CH4 .2 V =
T/div 5 ms

Fig. 4