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Stopband Correction of the AGS Booster 14th Normal Sextupole Correction

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DISCLAIMER

AGS Complex Machine Studies **(AGS Studies Report No. 286** **Stopband Correction of the AGS Booster** **14th Normal Sextupole Correction**
Study Period: April 30-May 1, 1993: 19:00-02:00 May 2, 1993: 08:00-19:00
Participants: C. Gardner and Y. Shoji
Reported by: Y. Shoji
Machine: Booster User3: flat porch at 1.7 kG Injection: middle 5 turn 60 degrees
Aim: Search correction coefficients of 14th normal sextupole stopbands (3Qx=14 and Qx+2Qy=14)

I B and dB/dt Dependence of 3Qx=14

Correction currents for 3Qx=14 were obtained for different B and dB/dt with dRset=0.4cm, $\xi x=0$, $\xi y=0$, Qy=4.75. Measured points are shown in Fig. 1. We let the working point cross 3Qx=14 in the tune space (cross only once) and observed the beam loss at the crossing point. For each point we measured beam losses for several correction currents and obtained the current which gave the minimum loss. Results are listed in Table I. The curve of beam loss to the correction current was not always parabolic. The listed errors were eye-ball maximum error.

Assuming that the correction N is written as

$$N = No + Nb\,B + Nbt\,(dB/dt) \qquad (1)$$

four data points were fitted with three parameters. The result is

$$N(\cos 14X) = [\ 48\pm31\ ] + [-31\pm15\ ]B + [\ 3.49\pm0.19\ ](dB/dt)$$
$$X^2(\cos 14X \text{ fit}) = 5.1$$

$$N(\sin 14X) = [-129\pm32\ ] + [\ 40\pm15\ ]B + [\ 6.00\pm0.19\ ](dB/dt)$$
$$X^2(\sin 14X \text{ fit}) = 1.1 \qquad (2)$$

B ; kG
dB/dt ; kG/s = G/ms

The fit were not good especially not the cos14X component. We used the listed errors as the standard deviations, which meant that we over estimated the error. So the X^2 should be less than 1 but they are larger than 1. The correction currents with dB/dt=0 are calculated as shown in Table I and plotted on Fig. 2. Of course the fits are not good. We don't know why.

Table I Correction of 3Qx=14

Here the definition of dRmeas is a little bit different from the equation (6). Data from B4 PUE was ignored because the readout of it was looked bad.

	dT (+T0) (ms)	B (kG)	dB/dt (G/ms)	N(cos14X)	N(sin14X)	dRmeas (cm)
A	80	1.70	0	5 ±10	-65 ±11	0.104
B	159	2.24	70	195 ±20	395 ±20	0.156
C	187	4.23	70	210 ±40	440 +40	0.297
D	255	2.48	-70	-290 ±20	-440 ±20	0.068
(B-D)/2			70	243	417	
(B+D)/2		2.36	0	-48	-28	
C-(B-D)/2		4.23	0	-33	23	

Here the dRset was constant through the cycle (dR=0.4cm). The coefficients with constant dRmeas were different but almost the same.

II B and dB/dt Dependence of Qx+2Qy=14

Correction parameters of Qx+2Qy=14 were obtained with the same method used for 3Qx=14 (dRset=0.4cm, ξx=0, ξy=0, Qy=4.75). Data points are listed in Table II, and plotted in Fig. 3. Fitted results are

N(cos14XY) = [5+29] +[14+11]B +[4.74+0.20](dB/dt)
X^2(cos14XY fit) = 0.52

N(sin14XY) = [103+24] +[17+ 9]B +[2.64+0.19](dB/dt)
X^2(sin14XY fit) = 0.005 (3)

The fit were much better and good enough.

Table II Correction of Qx+2Qy=14

	dT (+T0) (ms)	B (kG)	dB/dt (G/ms)	N(cos14XY)	N(sin14XY)
A	80	1.70	0	35 ±20	130 ±20
B	160	2.34	70	360 ±30	330 ±20
C	187	5.80	70	400 ±30	360 ±20
D	257	2.34	-70	-300 ±30	-40 ±30
(B-D)/2			70	330	185
(B+D)/2		2.34	0	30	145
C-(B-D)/2		5.80	0	70	175

We also checked the interference between two resonances. We let the tune cross Qx+2Qy=14 and corrected it (there still existed the residual loss). Then we excited the 3Qx=14 strings to the maximum (900 counts). But the beam loss due to the resonance Qx+2Qy=14 did not change.

III dR Dependence of 3Qx=14 on the Flat Porch

Correction currents of 3Qx=14 were obtained for different dR at the flat porch (B=1.7kG, dB/dt=0, $\xi x = \xi y = 0$, Qy=4.8). Results are shown in Fig. 4. We observed the dR dependence of the correction currents like that observed at 2Qx=9, 2Qy=9 and Qx+Qy=9.

$$\delta N(\cos 14X)/\delta dR = 69 \quad \text{digit/cm}$$
$$\delta N(\sin 14X)/\delta dR = -63 \quad \text{digit/cm} \qquad (4)$$

Here the definition of the dR is the set value of the rf control. The relation of dRset and dRmeas was measured as shown in Fig. 5. That gives the equation:

$$dRmeas = -0.129 + 0.656\, dRset. \qquad (5)$$

The definition of dRmeas is the average of measured dR by PUEs.

$$dRmeas \equiv ((A2+B2+C2+D2+E2+F2)/6 + (A4+B4+C4+D4+E4+F4)/6 + (A6+B6+C6+F6)/4 + (A8+B8+C8+E8+F8)/4)/4 \qquad (6)$$

The average of dispersion function at these points is 2.092m [A. Luccio and M. Blaskiewicz, Booster TN-196]. Then

$$\delta(dP/P)/\delta(dRset) = 0.314 \quad \%/cm \; . \qquad (7)$$

The dependence of correction currents on radius (identical to momentum displacement) produce residual loss. At 1.7 kG flat porch the residual loss was 5% with the crossing speed (if tune ripple did not exist)

$$0.018/98 = 0.0002 \text{ /ms.}$$

The loss was comparable with the improved loss (Fig. 6) because the correction was very small at the flat porch.

The residual loss of Qx+2Qy=14 at the same flat porch was 20% with the faster crossing speed

$$0(.04/98) *2/\sqrt{5} = 0.0004 \text{ /ms.}$$

The crossing speeds and residual losses are listed in Table III.

Table III Residual loss at the 14th normal sextupole resonances.

resonance		3Qx=14		Qx+2Qy=14	
B	dB/dt	crossing speed	residual loss	crossing speed	residual loss
1.7	0	0.0002	5%	0.00036	20%
2.2	70	0.001	0.4%	0.0036	0.2%
4.2	70	0.0002	0.3%	0.0018	<0.1%
2.5	-70	0.001	0.5%	0.0036	<0.1%

IV Chromaticity Dependence of 3Qx=14 on the Flat Porch

Correction currents of 3Qx=14 were obtained for different horizontal chromaticity ξx at the flat porch (dRset=0.4cm, $\xi y=0$). Results are shown in Fig. 7. We observed no meaningful dependence on ξx. The error bars of data points at the non-zero chromaticities are larger than that of zero chromaticity. Because the speed of resonance crossing should be faster due to the tune spread from the chromaticity.

V Consistency with the Old Data

On Table IV the data taken before April 30 are listed up and compared with calculated values using equations (2) and (3).

There are inconsistency of data points of 3Qx=14. On April 8 back-leg winding of C5 was changed. The phase to correct the sextupole field at C5 back-leg winding is

$$N(\sin 14X)/N(\cos 14X) = 0.06$$

Then we cannot explain the change of N(sin14X). The program of stop band correction could have had bugs in March.

The consistency of the data points of Qx+2Qy=14 are better. The difference on April 3 can be explained with C5 change. That corresponds to the bad fit of equations (2) and the good fit of equations (3).

Table IV Normal sextupole correction studies before May 1

date	B (kG)	dB/dt (G/ms)	measured		calculated from equations	
3Qx=14			cos14X	sin14X	cos14X	sin14X
April 3	1.60	11	180 ± 40	120 ± 40	37	1
April 7	1.80	70	400 ±100	300 ± 50	236	363
Qx+2Qy=14			cos14XY	sin14XY	cos14XY	sin14XY
April 3	1.59	5	240 ± 20	160 ± 20	51	143
April 11	1.94	70	290 ± 20	310 ± 50	364	321

VI Discussion

Contributions of each terms to the correction is listed on Table V. Parameters near the injection are used because the resonance is most important here. The contribution from dP/P is based on the line in Fig. 4, which is measured at dB/dt=0 porch. Then it can be different at dB/dt≠0. The 14th normal sextupole imperfection is mainly produced from dB/dt.

Table V Contribution to the 14th normal sextupole imperfection. The rows of off-set, B and dB/dt represent the contribution to the optimum correction currents. But the row of dP/P represents the spread of the correction currents.

resonance correction	off-set	B= 1.5kG	dB/dt= 30G/ms	dP/P= 0.3%
3Qx=14				
N(cos14X)	50	50	100	70
N(sin14X)	130	60	180	60
Amplitude	140	80	210	90
Qx+2Qy=14				
N(cos14XY)	0	20	140	?
N(sin14XY)	100	30	80	?
Amplitude	100	30	160	?

FIGURE CAPTIONS

Fig. 1 Four measured points (indicated by A, B, C and D) through the cycle.

Fig. 2 B dependence of the correction current of 3Qx=14.

Fig. 3 B dependence of the correction current of Qx+2Qy=14.

Fig. 4 Radius dependence of the correction current of 3Qx=14.

Fig. 5 Relation between mean radius at H-PUEs (dRmeas) and the set value of the RF control (dRset).

Fig. 6 Beam loss by the 3Qx=14 at the flat porch.

Fig. 7 Chromaticity dependence of the correction current of 3Qx=14.

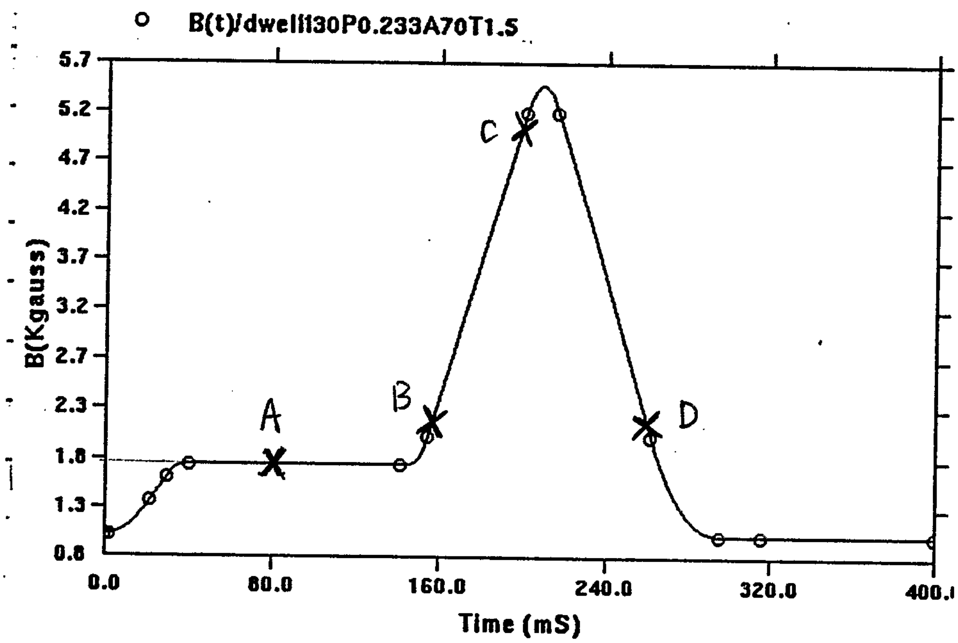
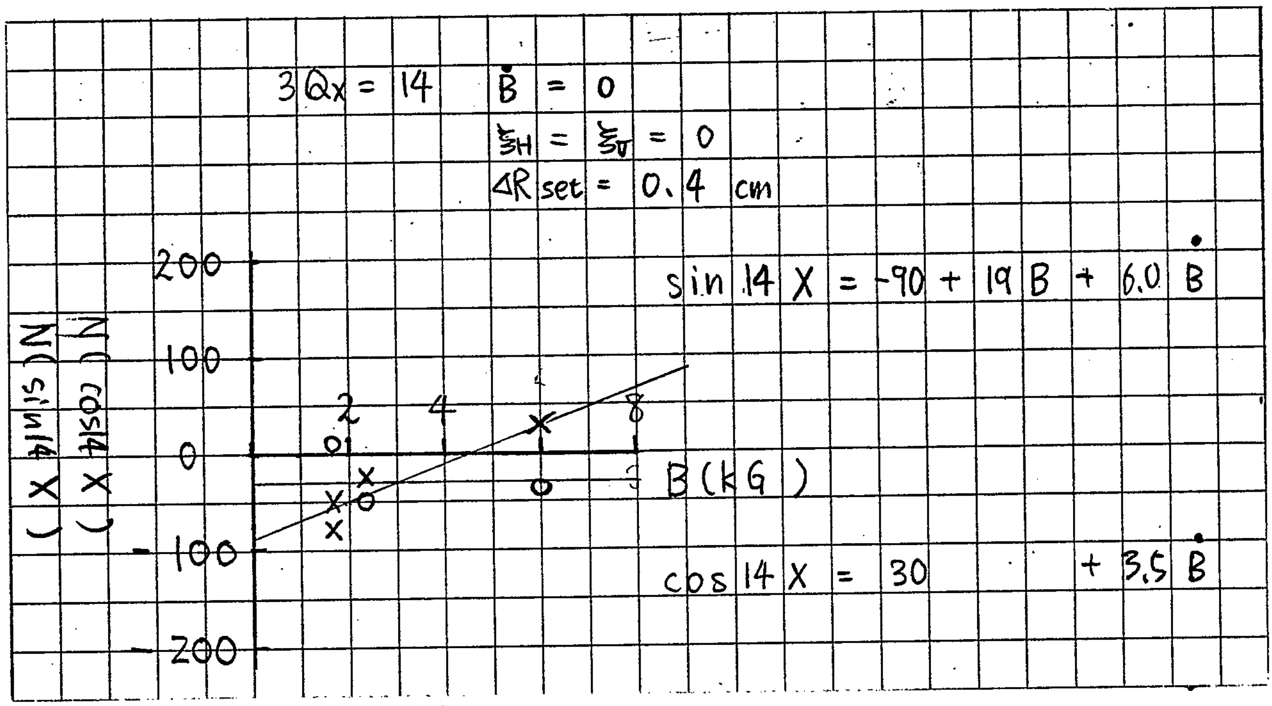
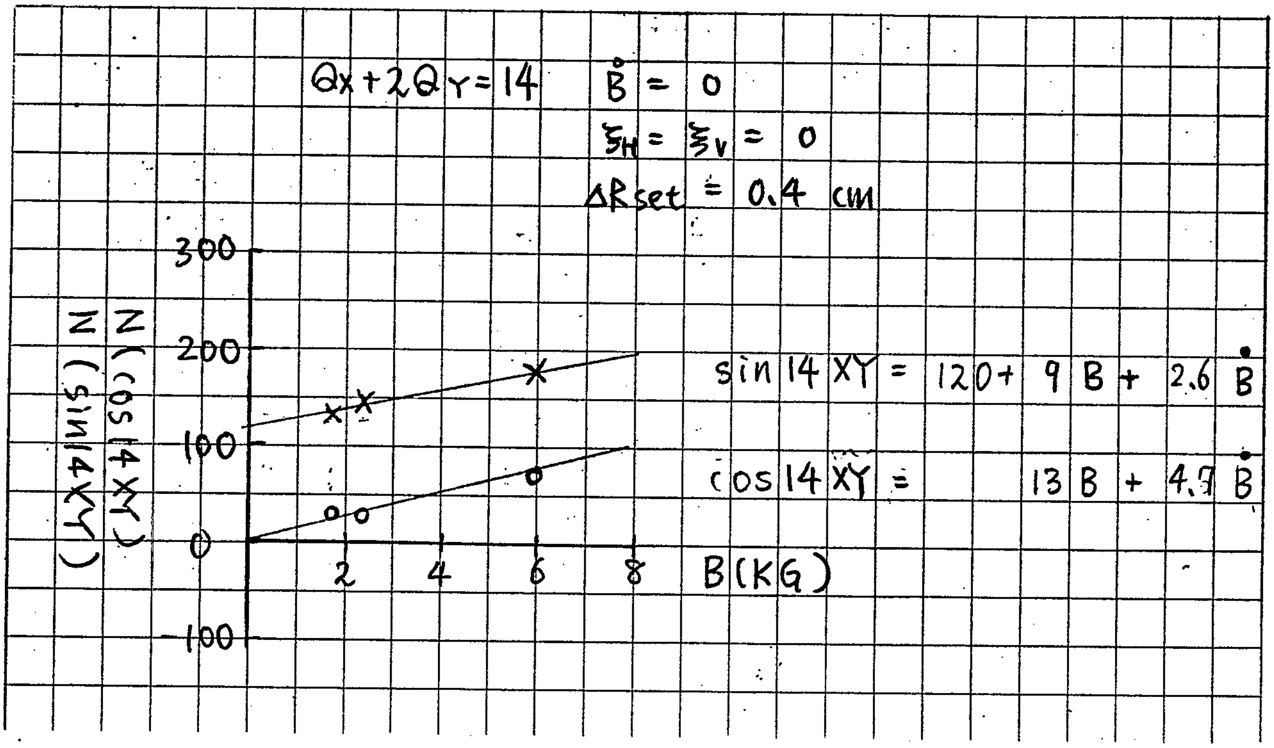

B(t)/dwell130P0.233A70T1.5
5.7
5.2
4.7
4.2
3.7
3.2
2.7
2.3
1.8
1.3
0.8
B(Kgauss)
0.0
80.0
160.0
240.0
320.0
400.
Time (mS)
A
B
C
D

Fig. 1



3Qx = 14
B = 0
ξH = ξV = 0
ΔR set = 0.4 cm
sin 14 X = -90 + 19 B + 6.0 B
cos 14 X = 30 + 3.5 B
200
100
0
-100
-200
2
4
8
B (kG)
N (sin14 X)
N (cos14 X)

Fig. 2



Qx + 2Qy = 14
B̊ = 0
ξH = ξv = 0
ΔRset = 0.4 cm
300
200
100
0
-100
N (cos 14 XY)
N (sin 14 XY)
2
4
6
8
B (KG)
sin 14 XY = 120 + 9 B + 2.6 Ḃ
cos 14 XY = 13 B + 4.9 Ḃ

Fig. 3

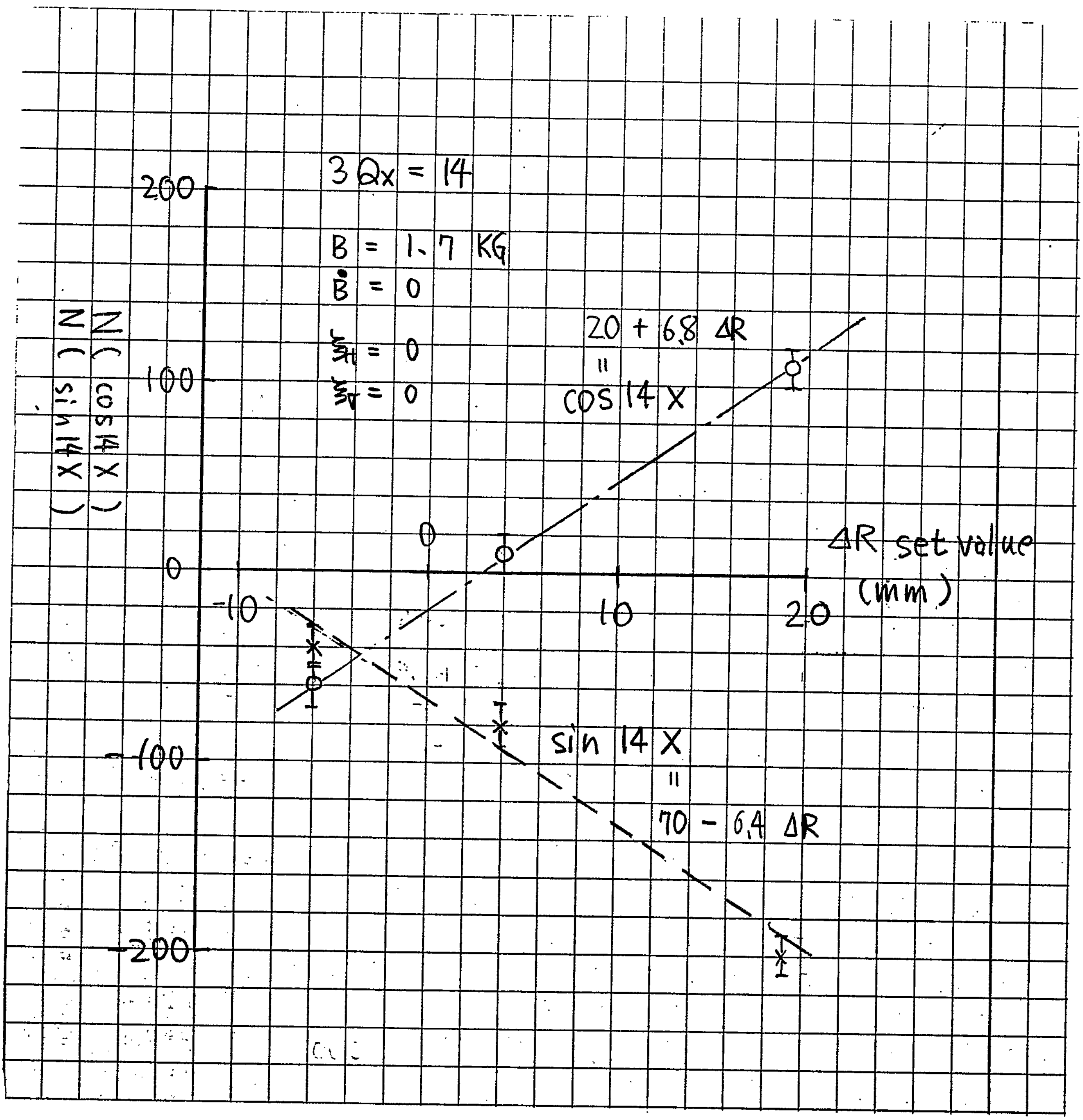

3 Qx = 14
B = 1.7 KG
Ḃ = 0
ξ_H = 0
ξ_V = 0
20 + 6.8 ΔR
=
cos 14 X
sin 14 X
=
70 - 6.4 ΔR
ΔR set value
(mm)
N (cos 14 X)
N (sin 14 X)
200
100
0
-100
-200
-10
0
10
20

Fig. 4

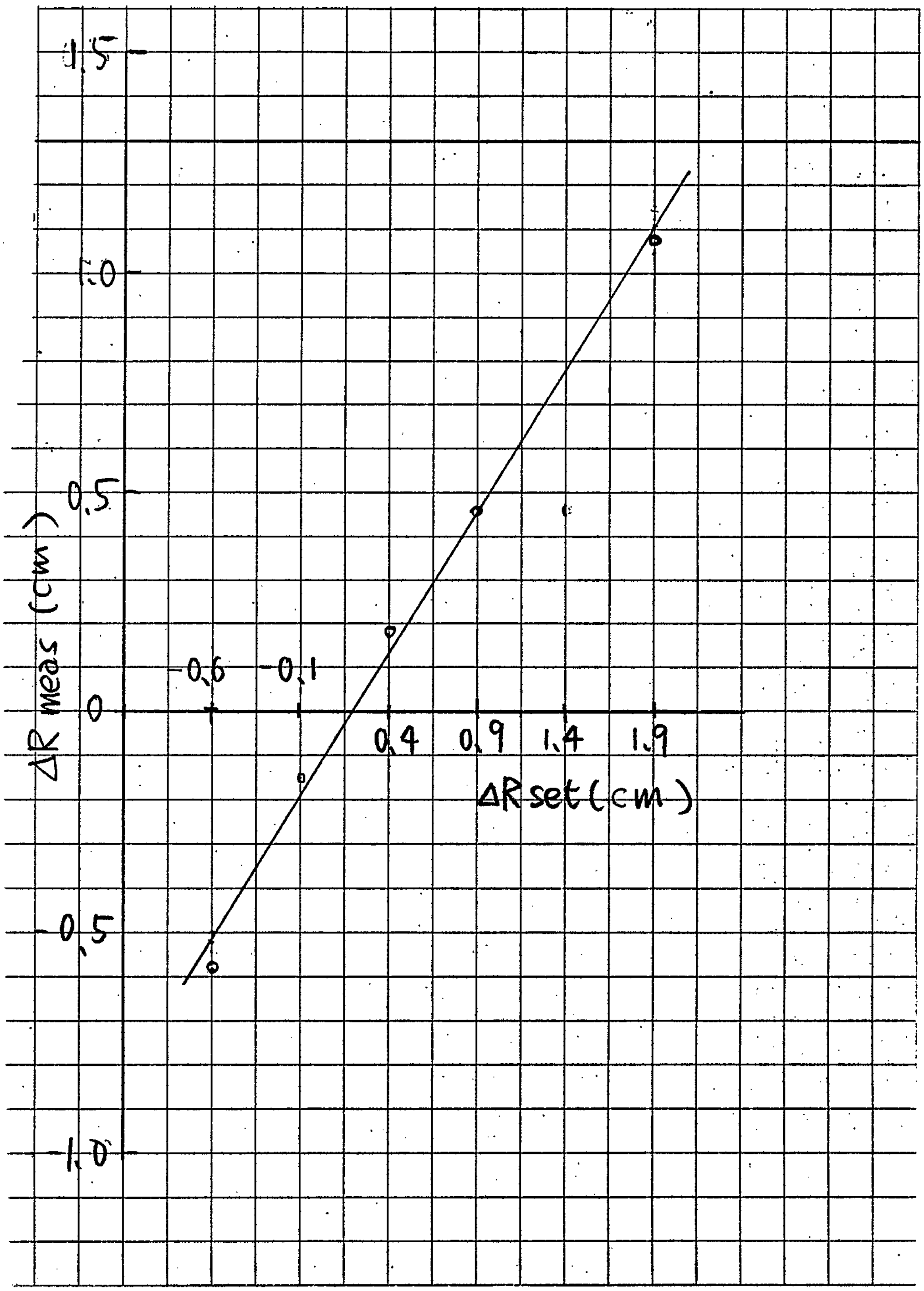


Fig. 5

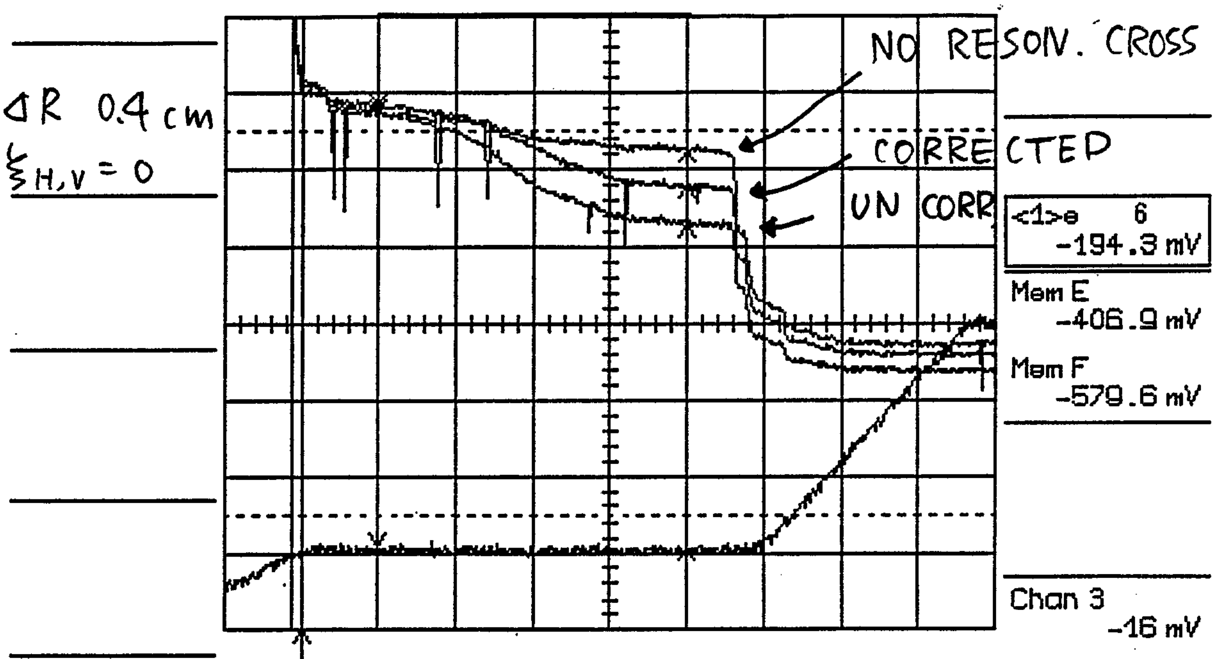

ΔR 0.4 cm
$\xi_{H,V} = 0$
NO RESON. CROSS
CORRECTED
UN CORR
<1>e 6
-194.3 mV
Mem E
-406.9 mV
Mem F
-579.6 mV
Chan 3
-16 mV

Fig. 6

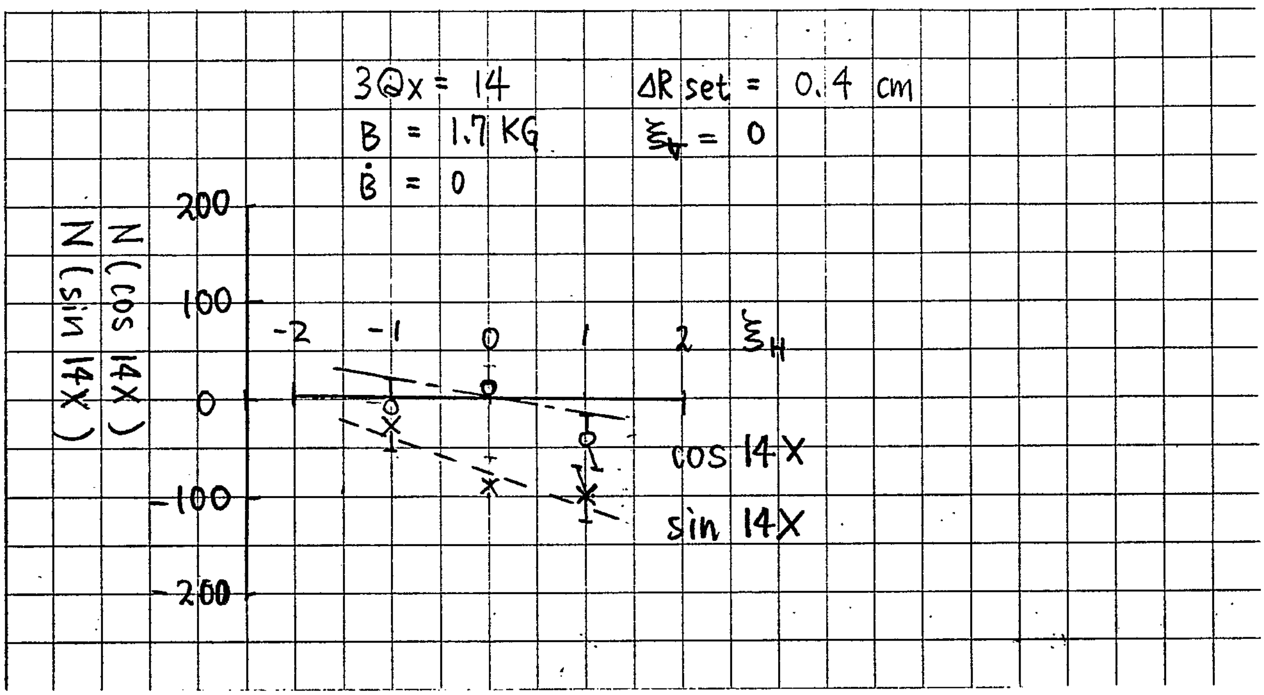

3Qx = 14
B = 1.7 KG
Ḃ = 0
ΔR set = 0.4 cm
ξv = 0
200
100
0
-100
-200
N (cos 14X)
N (sin 14X)
-2
-1
0
1
2
ξH
cos 14X
sin 14X

Fig. 7