BNL-104173-2014-TECH
AGS.SN300;BNL-104173-2014-IR

Stopband Correction of the AGS Booster Structure Resonances

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July 1993

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U.S. Department of Energy
USDOE Office of Science (SC)

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AGS Complex Machine Studies (AGS Studies Report No. 300) Stopband Correction of the AGS Booster Structure Resonances
Study Period: July 23-25, 1993
Participants: C. Gardner and Y. Shoji
Reported by: Y. Shoji
Machine: User3; MMPS: high intensity 30 G/ms injection, all stopband corrections were turned ON; chromaticities ξx=-0.5, ξy=-0.75 (set value)
Aim: To study a high intensity effect on structure resonances.

We are planning to introduce new stop-band correction strings for the next year's run. Four 9th normal sextupole strings and two 9th skew sextupole strings will correct the 2nd order resonances; 2Qx=9, 2Qy=9 and Qx+Qy=9. But if 4th order structure resonances; 4Qx=18, 3Qx+Qy=18, 2Qx+2Qy=18, Qx+3Qy=18, 4Qy=18 are strong, our effect would not spread the working area. The existence of intensity dependent higher order structure resonances; 5Qx=24 and 5Qy=24 suggested that those 4th order structure resonances could be dangerous [Shoji and Gardner, AGS SR-297].

We decided to see the intensity dependence of the resonance lines at Qy=4.5. If the quadrupole correction parameters changes with the beam current [Machida, SSC Lab., private communication], we would observe the anomaly through this experiment.

I Adjustment of 2Qy=9 Correction

Before we started the measurement, we adjusted the quadrupole and normal sextupole corrections of 2Qy=9. The initial correction functions were calculated functions from the correction parameters. The correction currents were adjusted at two points; just before the changing of dB/dt (27ms from T0, dB/dt=30 G/ms) and just after that (42ms from T0, dB/dt=70 G/ms). By adjusting corrections at these two points, we could decrease the error came from the errors of any correction parameters; off-set term, B term and dB/dt term.

The adjustment procedure for each point was as following:

1. The quadrupole correction currents; N(cos9Y) and N(sin9Y) were measured at dRset=-0.2cm and dRset=1.4cm.
2. Here the time derivatives of correction currents; dN(cos9Y)/dt and dN(sin9Y)/dt were fixed to the calculated value.
3. From two data at the different two dRset we calculated the slopes of correction currents; δN(cos9X)/δdRset and δN(sin9X)/δdRset.
4. Calculate the change of 9th normal sextupole corrections; SH3 and SV3. Here we use the transformation matrix obtained at the other measurements [Shoji and Gardner, AGS SR-293].
5. Change SH3 and SV3 to the re-calculated value. But the time derivatives of correction currents; dSH3/dt and dSV3/dt were fixed to the calculated values.
6. Set the radius to the programmed function for the high intensity operation.
7. Optimize N(sin9Y) and N(cos9Y) again.

This was the procedure we used. But if we had chosen the proper dRset, we could have searched 4 parameters independently. But we were not sure about the proper value of dRset.

The results are summarized in Table I. The initially calculated corrections were correct within the errors. But they were not sufficiently accurate. After the adjustment of 4 correction strings according to the above procedures the beam loss by the resonance crossing had decreased.

III Adjust Bare Tune

A bare tune functions had been not correct. We adjusted the bare tune function to give a constant tune through the measurement (from the injection to 50ms after T0). The measured tunes before and after the adjustment were shown in Fig. 1.

Table I Data of correction adjustment.

SH3	SV3	dRset	N(cos9Y)	N(sin9Y)	loss(%)
T=29ms, B=1.555kG, dB/dt=30G/ms crossing speed = 0.023 /ms; cross one times parameters at 22ms,30ms from T0					
624, 653	56, 75		360, 381	-272,-263	
624, 653	56, 75	-0.2	365, 386	-164,-155	8
		0.8	362, 383	-149,-140	5
		1.4	365, 386	-131,-122	10
624, 653	-233,-214		361, 382	-153,-144	3
T=42 ms, B=2.20kG, dB/dt=70G/ms crossing speed = 0.007 /ms; cross one time parameters at 39ms,77ms from T0					
956, 956	-55, 158		553, 794	-407,-304	
956, 956	-55, 158	-0.2	618, 859	-401,-298	2
		1.4	631, 872	-355,-252	6
904, 956	-307, -94		620, 861	-422,-319	2

IV Intensity Dependence of 2Qy=9

The strength of the resonance was observed with the method of tune survey. Because the expected tune spread was too large to cross the whole resonance line.

The result were shown in Fig. 2. The dip of the beam loss by the resonance became broader and shallower with a intensity (Fig. 3). The strong resonance appeared at lower tune with high beam current is thought to be the coupling resonance; Qx+Qy=9.

The area of the dips presents a strength of the resonance. Except the large loss with 1 turn injection, we could not observe the increase of the dip area. Then we can conclude that the 4th order structure resonance was not dangerous.

There were no evidence of any change of the correction parameters. But the sensitivity was not so good because the correction was not accurate enough to eliminate the beam loss. The residual loss was still larger than that of the corrected third resonances. This residual loss is thought to be come from the imperfection of the half integer resonance correction. Of course the 4th resonance could have contributed to the residual loss. But the beam was lost very fast (see the next section). Then we thought it might be the lower order resonance.

It is not easy to realize enough correction of half integer resonances. We will have to take more time to correct them. And we are still doubtful about the stability of the correction parameters in a long time.

V Intensity Dependence of 5Qx=24

Because the 4th structure resonance was always weak, we decided to see 5Qx=24 again to confirm the previous result; that 5th order structure resonance had a strong intensity dependence [Shoji and Gardner, AGS SR-297]. The results are shown in Fig. 4.

The dependence on time was much different from that of Qy=4.5. At just after the injection we could not see any resonance. But later (at 2ms or 20ms after the injection) we could observe resonance structures. This tendency had been observed at the previous survey in May. These resonances were 'slow'; they took longer time to blow the beam up and make a beam loss. Probably because they were higher order resonances.

The dependence on the beam current was also much different from that of Qy=4.5. With 5 turn injection there were two resonance dips. One is strong; Qx=4.75 and the other was weak; Qy=4.81. The resonance at Qx=4.75 (with 5 turns injection) behaved like Qy=4.5 resonance. The dip became shallower and broader with beam current. On the other hand the dip by Qx=4.8 became deeper with intensity. The depth of the dips were plotted against the number of injection turns in Fig. 3. The difference was obvious.

With high beam current there was a sharp peak between two dips by Qx=5 and Qx=4.8. That does not look natural. At this point it was possible that a higher order effect affected the beam. This point was much close to the integer resonance. That kind of effect had been observed at the slow extraction of the KEK-PS [Shoji et.al, KEK-PS ASN-323, March 1992].

We have two ideas about the reason why the resonance Qx=4.8 becomes strong.

1. The space charge makes a decapole field.
2. The coherent integer resonance enhanced the effect of the incoherent resonance.

FIGURE CAPTIONS

Fig. 1 Measured tunes before and after the adjustment of bare tunes. The set value of the tune were constant; Qx=4.85 and Qy=4.55.

Fig. 2 Survived beam current to the vertical tune with 1 turn (fixed Qx=4.77), 5 turns (Qx=4.77), 20turns (Qx=4.79), 50 turns (Qx=4.79) and 100 turns (Qx=4.83) injection.

(a) Maximum intensity
(b) 2ms after the injection
(c) 10ms after the injection
(d) 20ms after the injection

Fig. 3 The change of depth of the dip (ratio of the maximum beam loss) and coherent tune of the dip to the number of injection turns.

Fig. 4 Survived beam current to the horizontal tune with 5, 20, 50 and 100 turns injection. The vertical tune was fixed; Qy=4.78.

(a) Maximum intensity
(b) 2ms after the injection
(c) 10ms after the injection
(d) 20ms after the injection

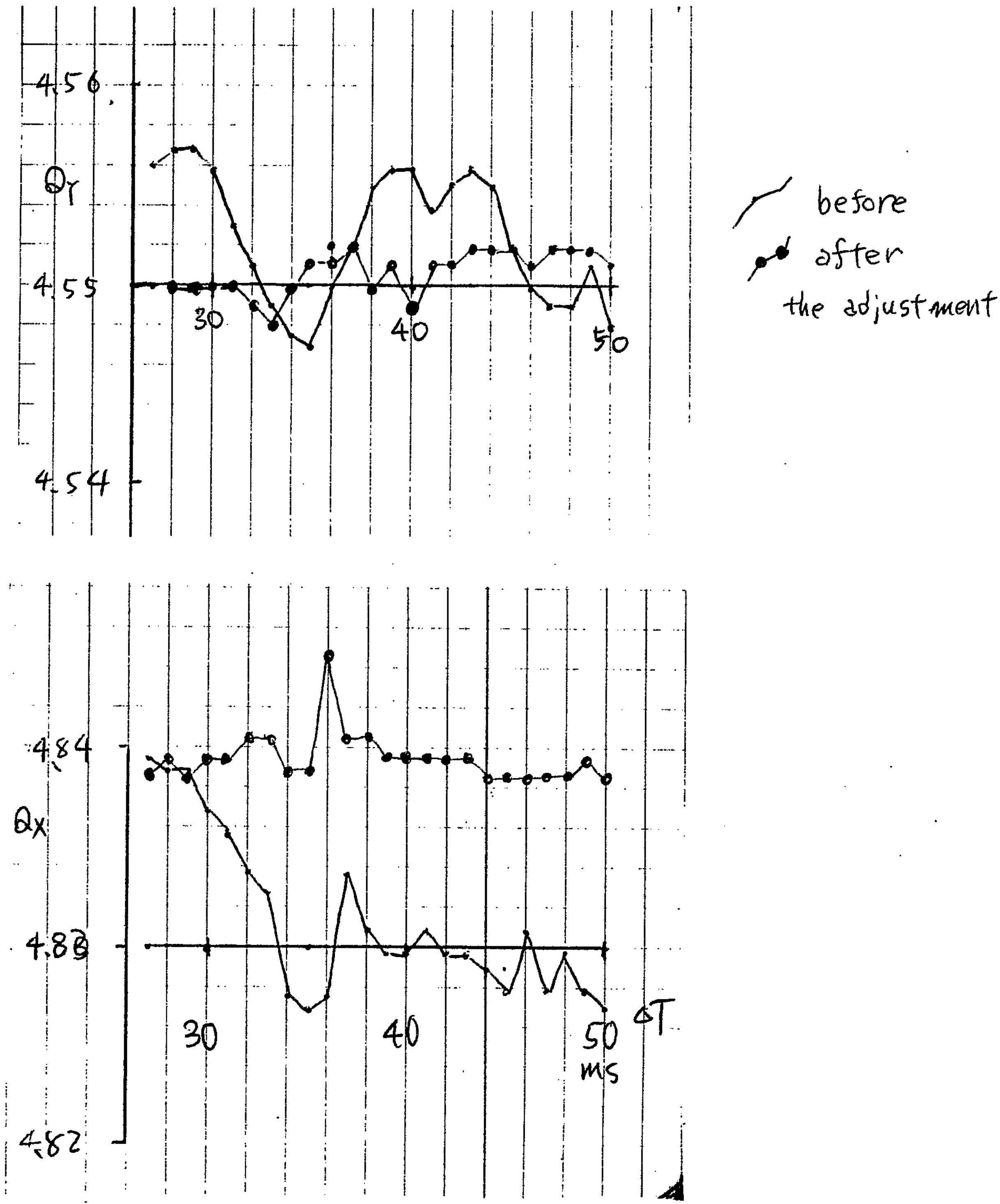
4.56
Qy
4.55
4.54
30
40
50
before
after
the adjustment
4.84
Qx
4.83
4.82
30
40
50
ms
ΔT

Fig. 1

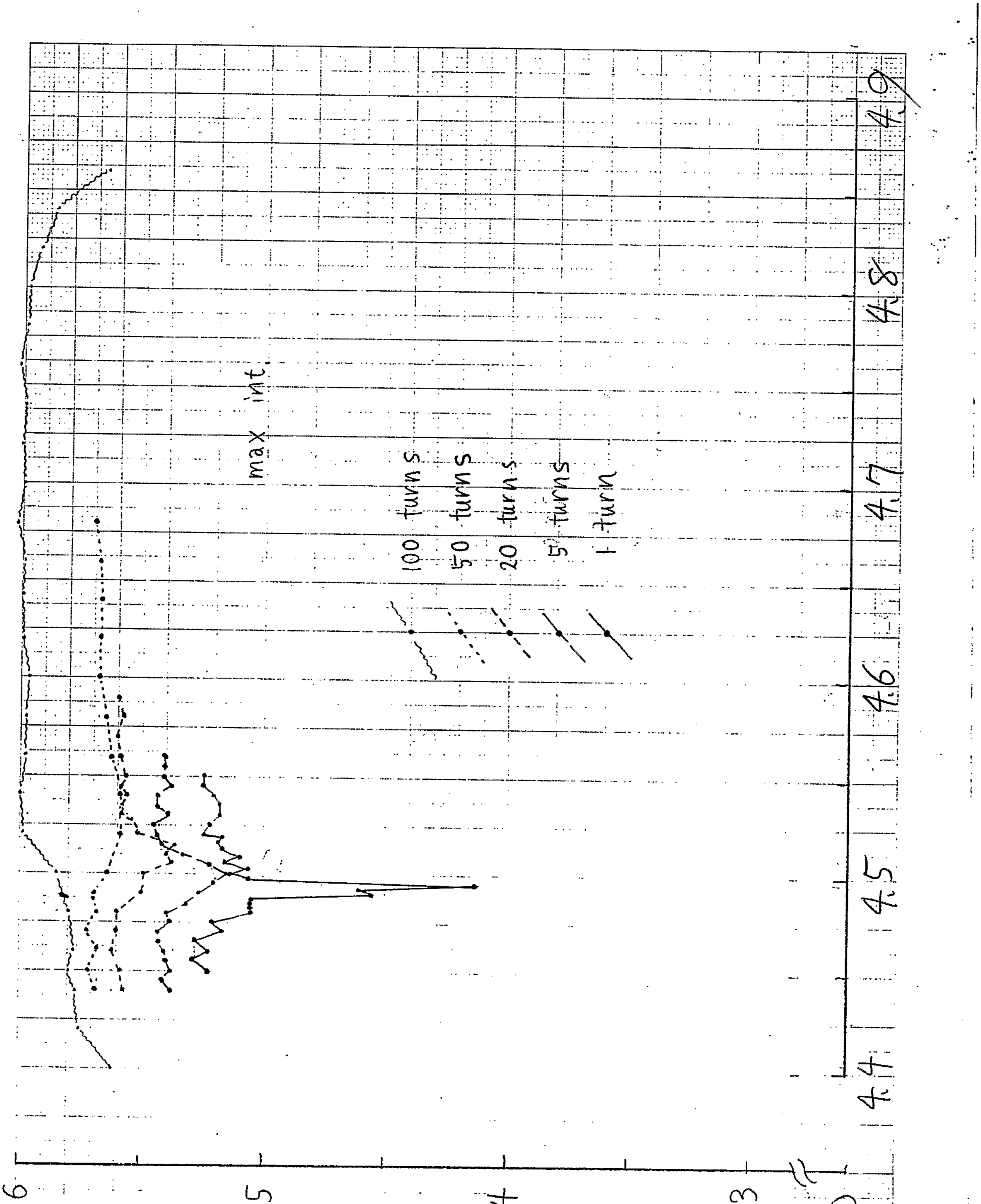
max int.
100 turns
50 turns
20 turns
5 turns
1 turn
4.4
4.5
4.6
4.7
4.8
4.9
6
5
4
3
0

Fig. 2(a)

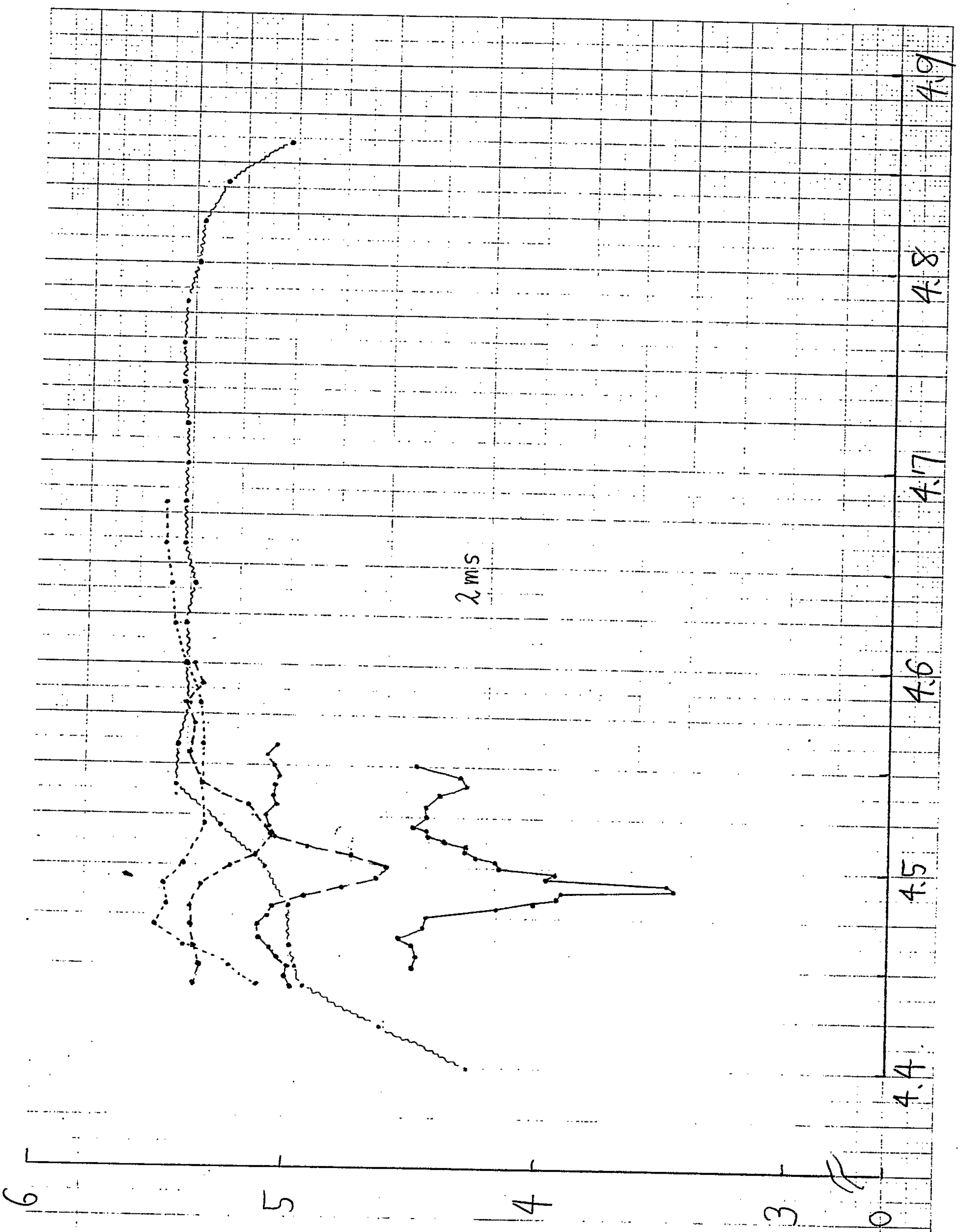

Fig. 2(b)

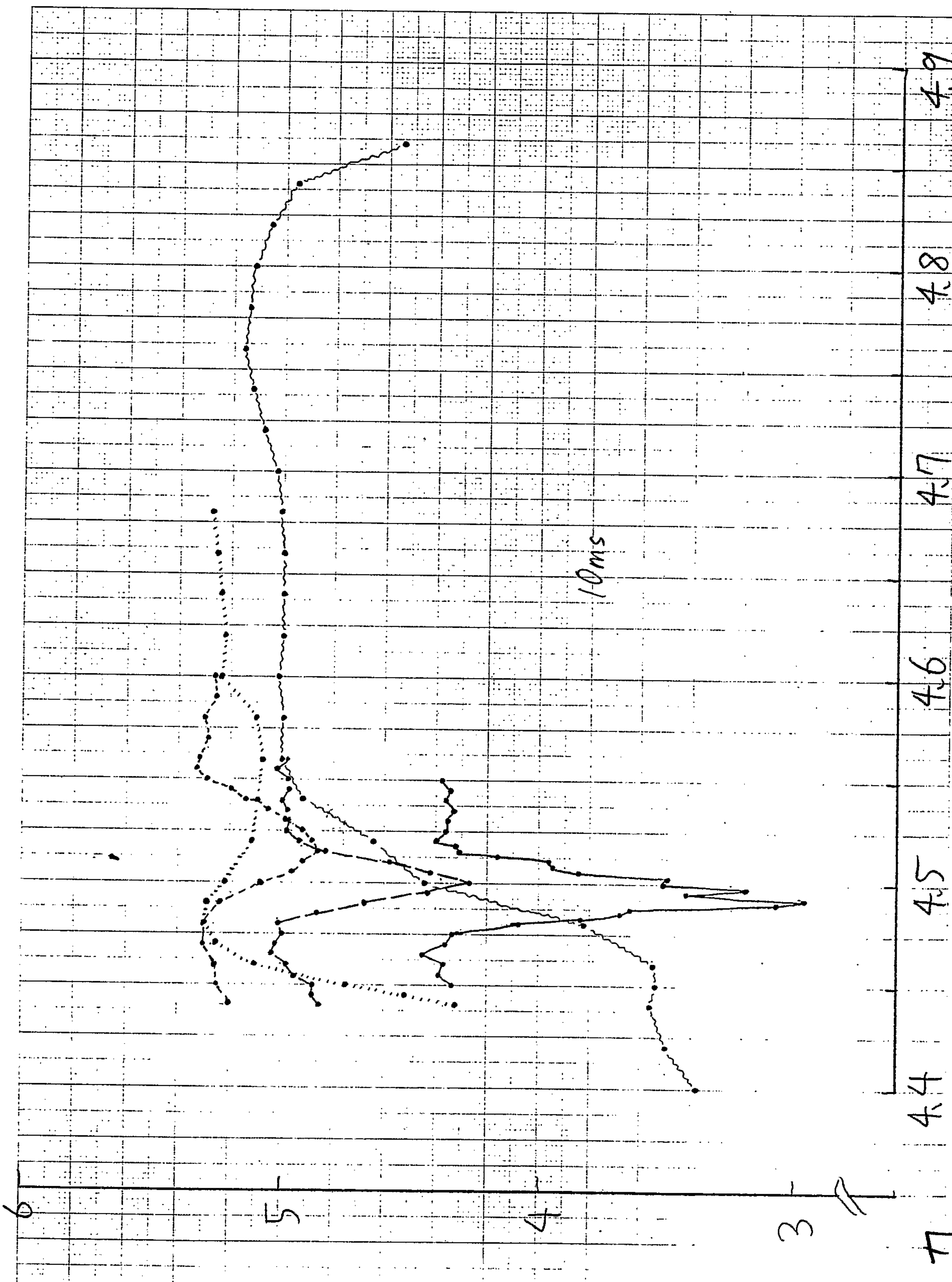

Fig. 2 (c)

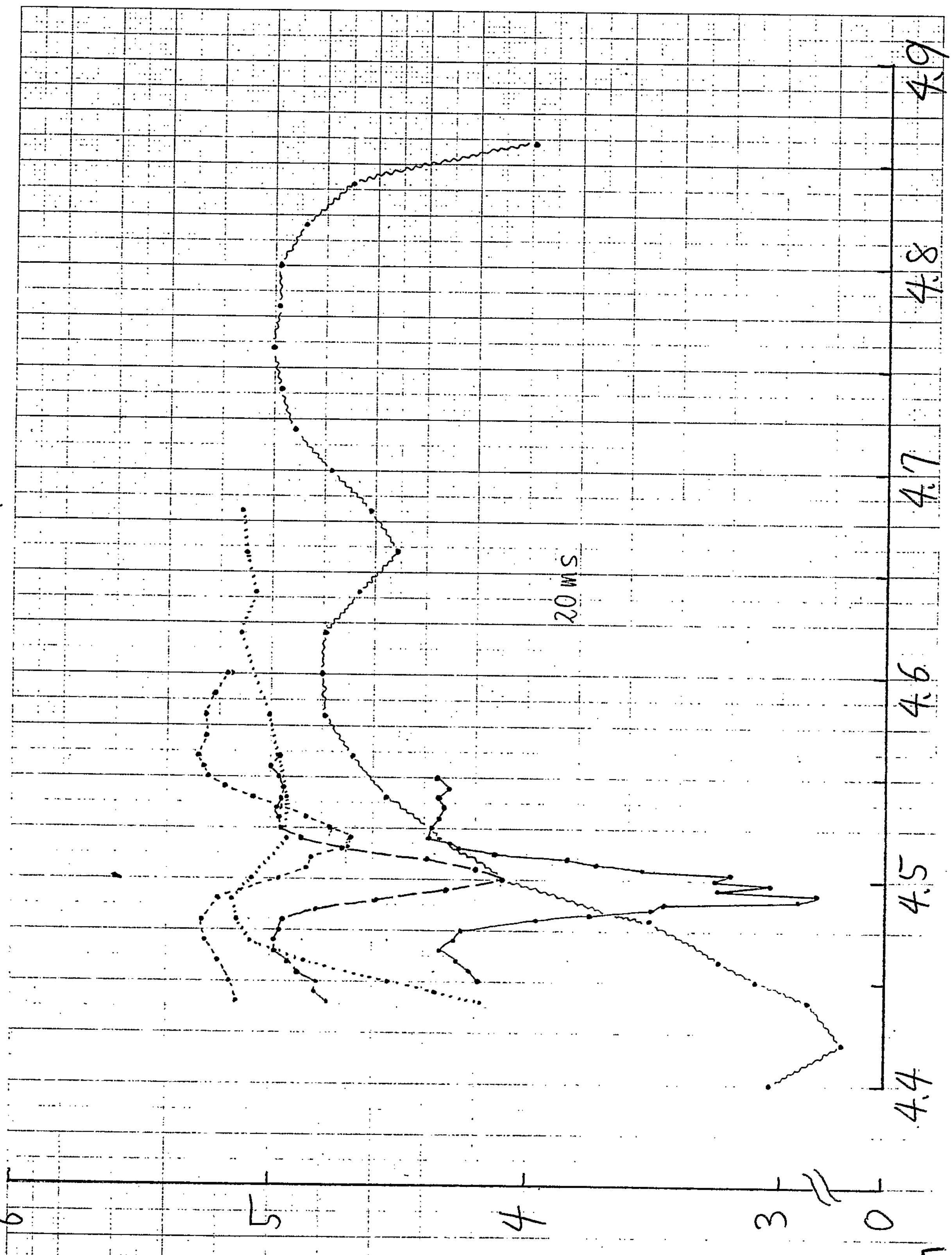

Fig. 2(d)

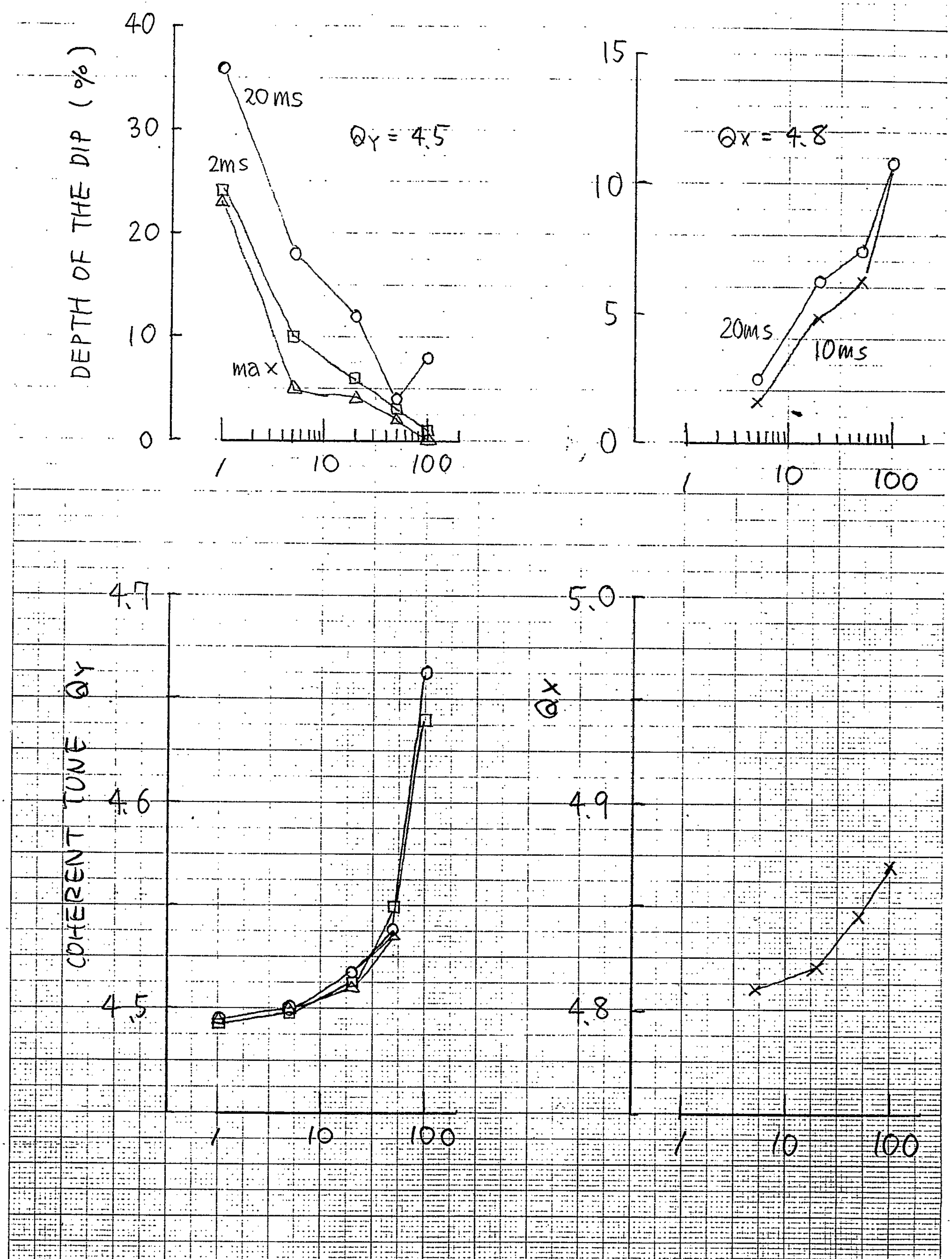
DEPTH OF THE DIP (%)
20ms
2ms
max
QY = 4.5
Qx = 4.8
20ms
10ms
COHERENT TUNE QY
Qx
4.7
4.6
4.5
5.0
4.9
4.8

Fig. 3

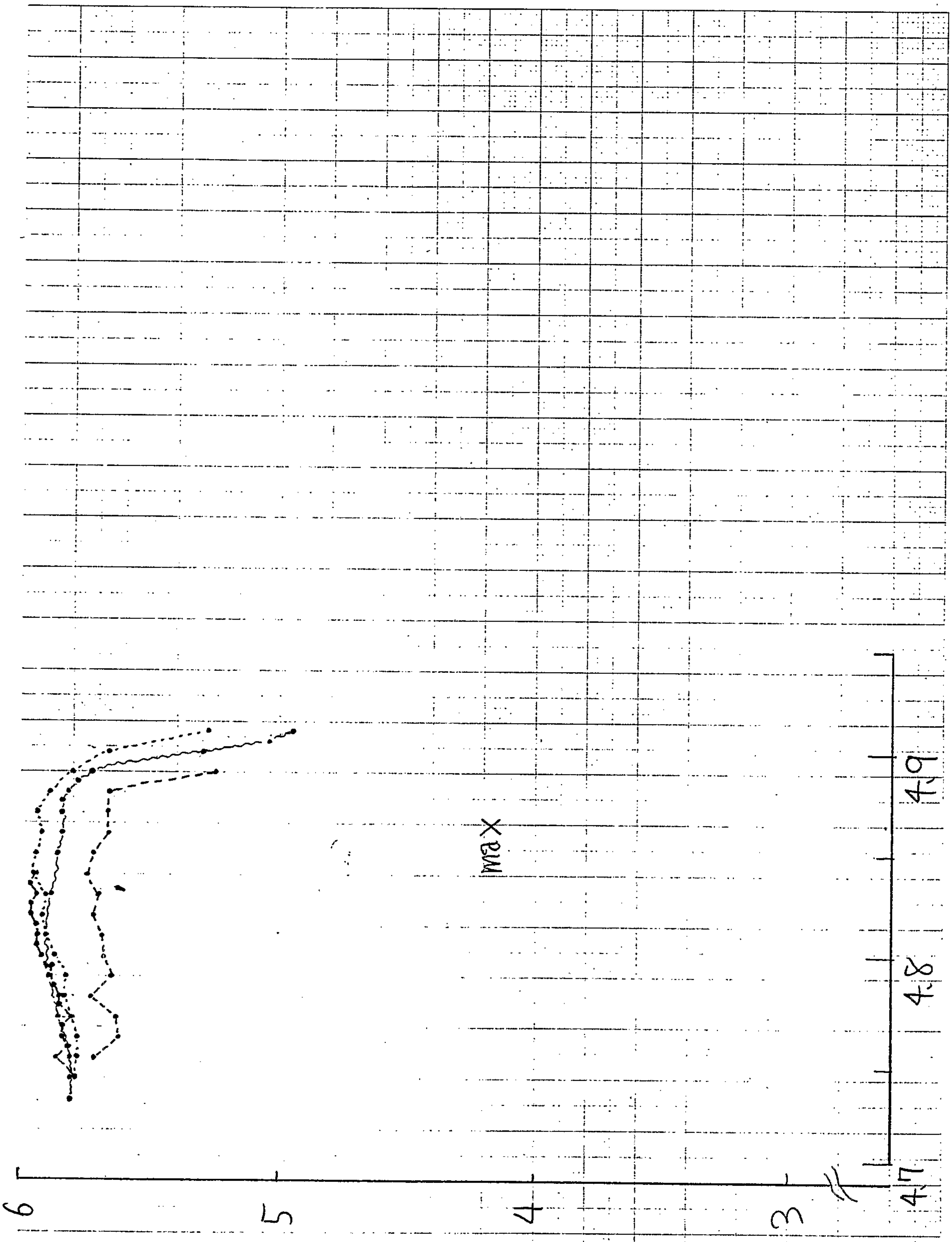

Fig. 4(a)

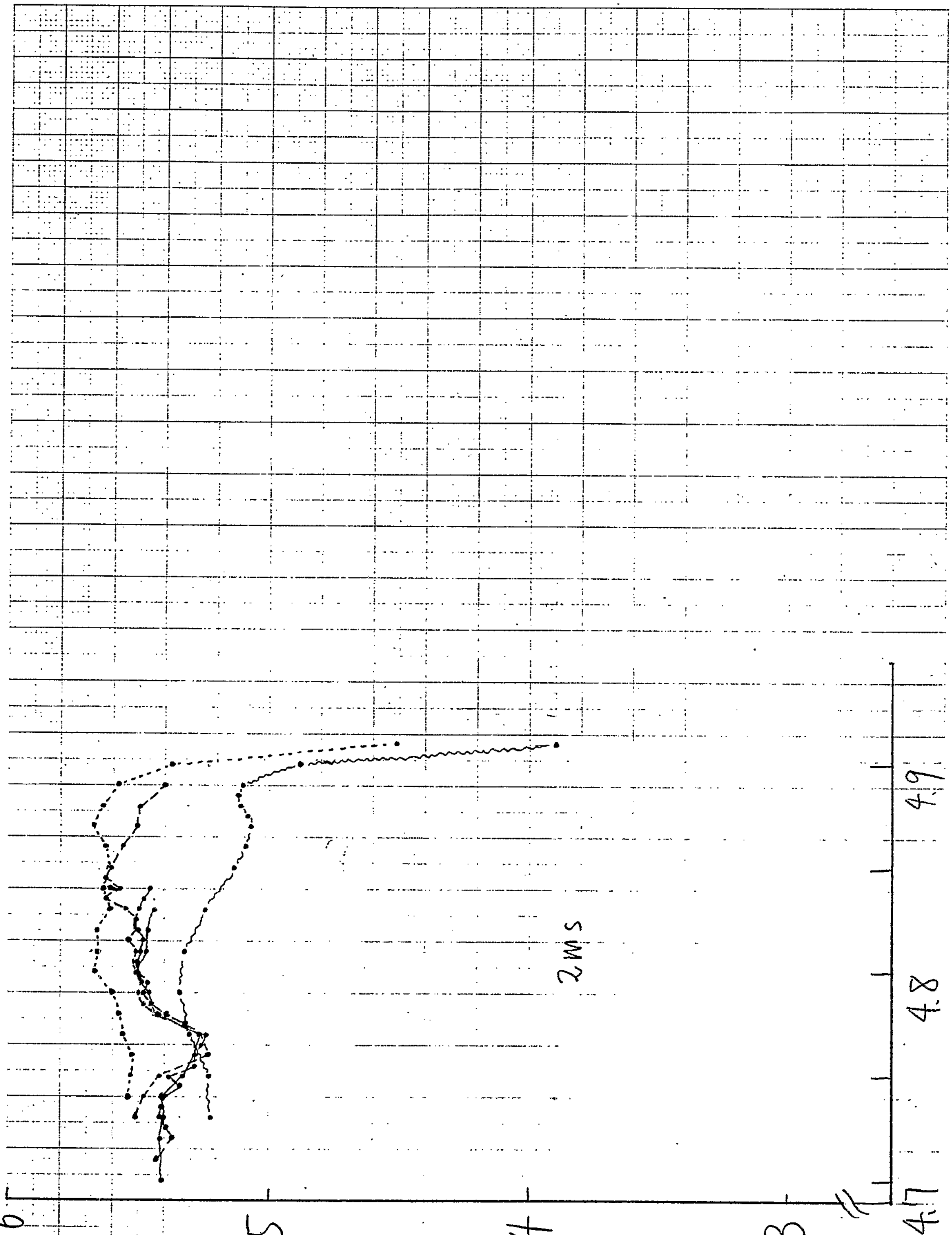

Fig. 4(b)

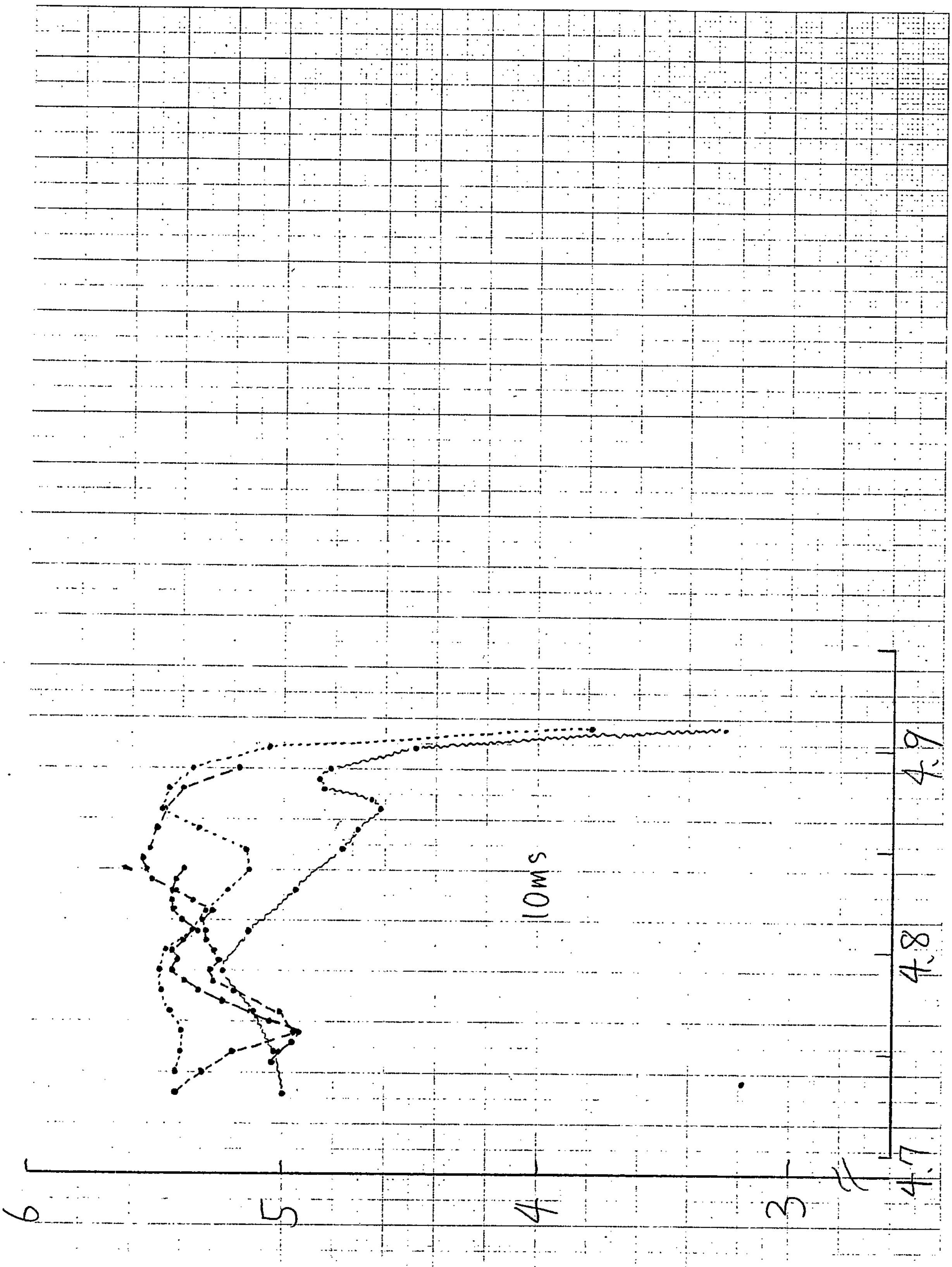

Fig. 4(c)

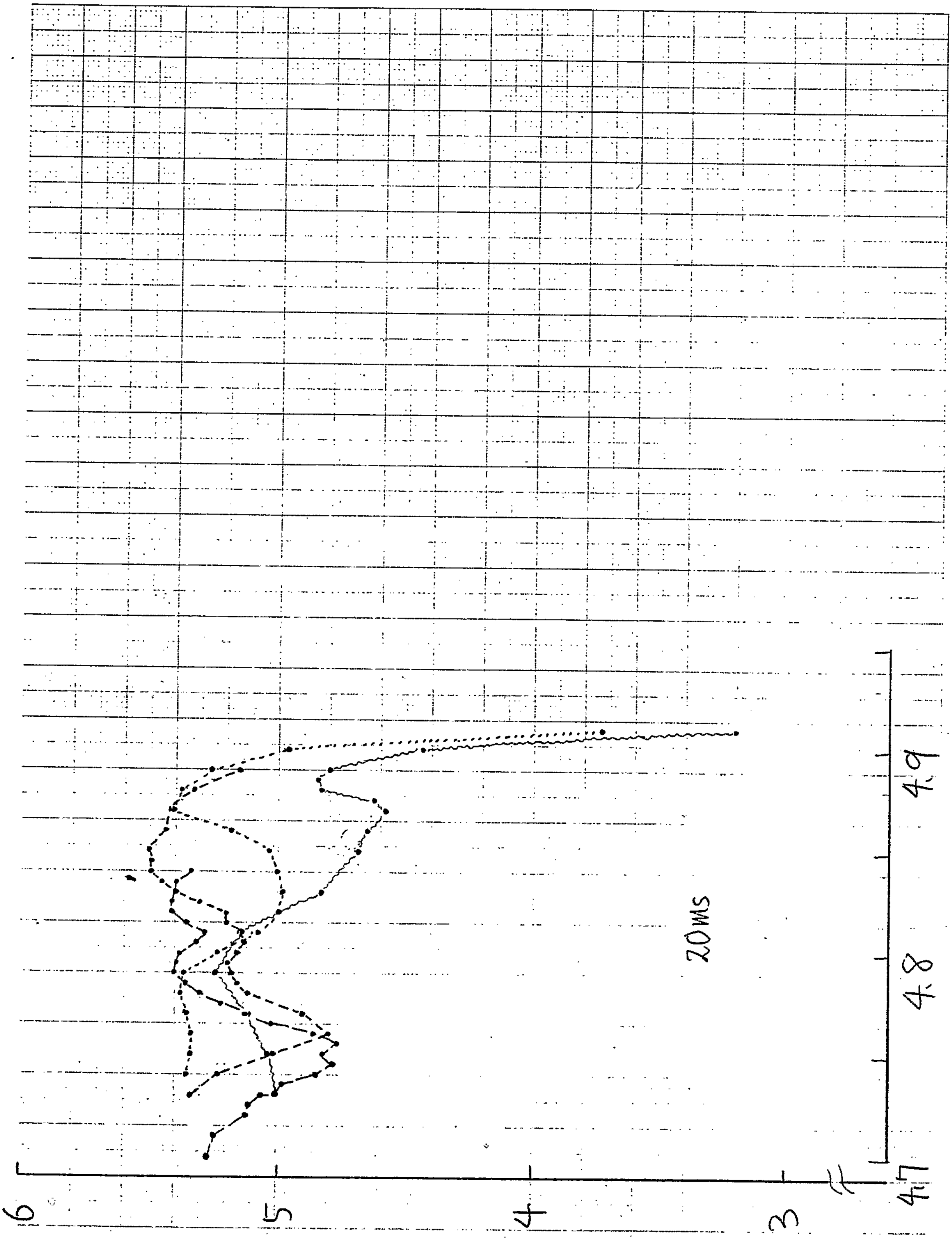

Fig. 4(d)