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AGS Studies Report

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Subject Calibration of the HEBT steering dipoles (ND431, ND437) and pitchers (NP435, NP440)

Observations and Conclusion

The purpose of this study was to obtain calibrations of the four final dipole magnets in the High Energy Beam Transport (HEBT) line to the AGS. These four magnets consist of two dipoles, ND430 and ND437, which are used to adjust the horizontal steering, and two pitchers, NP435 and NP440, which adjust the vertical steering of the H^- beam into the AGS.

The basic method of the calibration is illustrated schematically in figure 1. With the two quadrupoles, NQ433 and NQ444, and the AGS magnets turned OFF the dipoles and pitchers were swept through a series of values and the resulting positions of the beam at the A20 SEM were recorded. If we let ΔX be the change in the horizontal position at the A20 SEM due to changes of Δ_{431} and Δ_{437} in the command settings of ND431 and ND437 respectively, then

$$\Delta X = (L_1 + D_1)\, C_{431}\, \Delta_{431} + D_1\, C_{437}\, \Delta_{437} \qquad (1)$$

where L_1 and D_1 are as defined in figure 1 and C_{431}, C_{437} are the desired calibration factors for the two dipoles. Similarly, if we let

ΔZ be the change in the vertical position at the A20 SEM due to changes of Δ_{435} and Δ_{440} in the command settings of NP435 and NP440 respectively, then

$$\Delta Z = (L_2 + D_2)\, C_{435}\, \Delta_{435} + D_2\, C_{440}\, \Delta_{440} \qquad (2)$$

where L_2, D_2 are as defined in figure 1 and C_{435}, C_{440} are the calibration factors for the two pitchers.

Each of the four magnets ND431, ND437, NP435, NP440 were swept in turn through a series of values with the other magnets fixed. Figures 2-5 are plots of the resulting position at the A20 SEM for each of the sweeps. The plots show that the position at the A20 SEM varies linearly with the magnet setting as expected. If we let M_{431}, M_{437}, M_{435}, M_{440} be the slopes of the lines which are fit to the data in figures 2-5 respectively, then the calibration factors defined in (1) and (2) are

$$\begin{aligned}
C_{431} &= M_{431}/(L_1 + D_1) = \frac{.001285}{433.5} = 2.96(16) \times 10^{-6} \text{ radians/command} \\
C_{437} &= M_{437}/D_1 = \frac{.001036}{359.5} = 2.88(14) \times 10^{-6} \text{ radians/command} \\
C_{435} &= M_{435}/(L_2 + D_2) = \frac{.001187}{382.7} = 3.10(08) \times 10^{-6} \text{ radians/command} \qquad (3) \\
C_{440} &= M_{440}/D_2 = \frac{.000620}{327.0} = 1.90(08) \times 10^{-6} \text{ radians/command}
\end{aligned}$$

(Note: The numbers in parentheses are the errors in the last digits of the quoted number.)

Figures 6 and 7 show typical A20 SEM plots from which the horizontal and vertical positions of the beam were determined. Note that with the quads NQ433, NQ444 and the AGS magnets OFF the beam width is broad in the horizontal plane at the A20 SEM and narrow in the vertical plane.

The calibration factors given in equation (3) may be expressed in terms of radians/amp using the 27 March 1985 current vs command calibration done by E. Elliott and J. Addessi for the four magnets. Using C' to denote the calibration factors in terms of radians/amp we find

$$C'_{431} = C_{431}/(1.715 \times 10^{-3} \text{ amps/command}) = 1.728(93) \times 10^{-3} \text{ radians/amp}$$

$$C'_{437} = C_{437}/(1.678 \times 10^{-3} \text{ amps/command}) = 1.717(83) \times 10^{-3} \text{ radians/amp}$$

$$C'_{435} = C_{435}/(0.686 \times 10^{-3} \text{ amps/command}) = 4.52(12) \times 10^{-3} \text{ radians/amp}$$

$$C'_{440} = C_{440}/(0.502 \times 10^{-3} \text{ amps/command}) = 3.78(16) \times 10^{-3} \text{ radians/amp}$$

It would be useful and interesting to compare our results with a calibration of the four magnets in terms of field vs current; however, to our knowledge, no such calibration exists. It would be appreciated if anyone knowing of such a calibration would get in touch with us.

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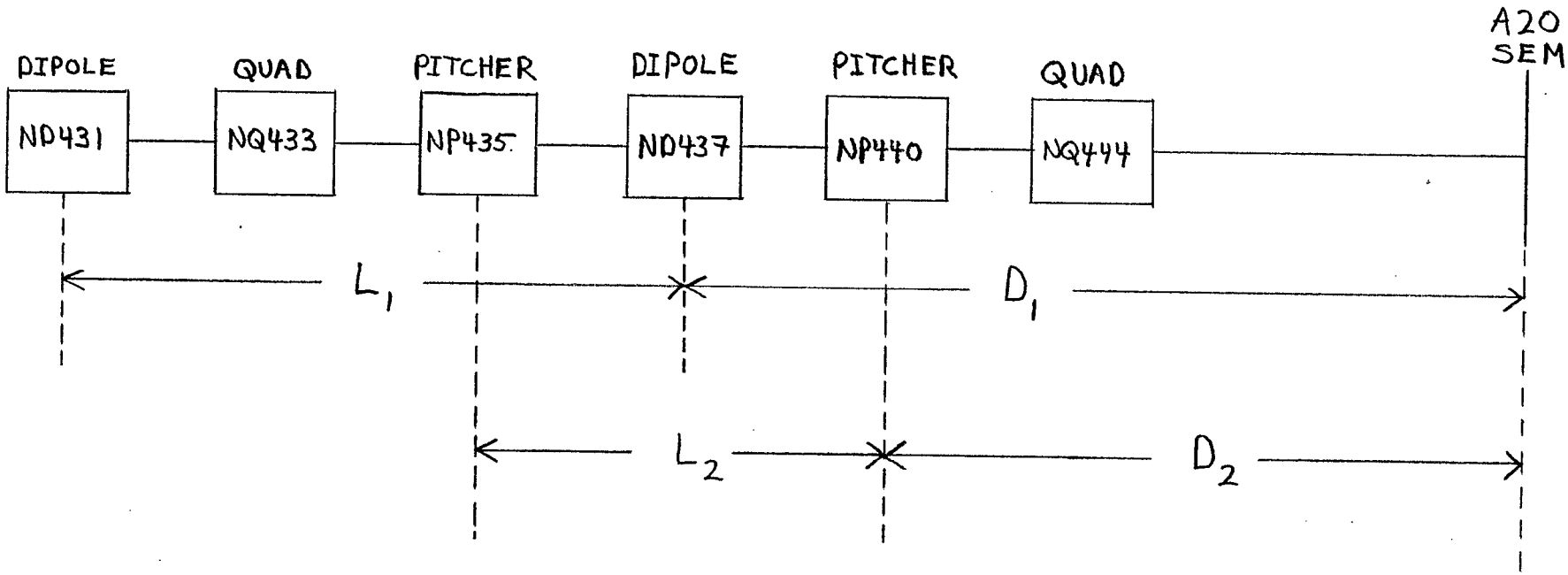
Figure 1. Experimental Setup.



$L_1 = 74.061''$, $D_1 = 359.48''$

$L_2 = 55.632''$, $D_2 = 327.027''$

Quads NQ433, NQ444, and the AGS magnets were <u>OFF</u>.

ND431 SWEEP; NQ433,444 OFF; AGS OFF; ND437=2040
SLOPE= 0.001285 +/- 0.000069
INTERCEPT= 4.795128 +/- 0.125735

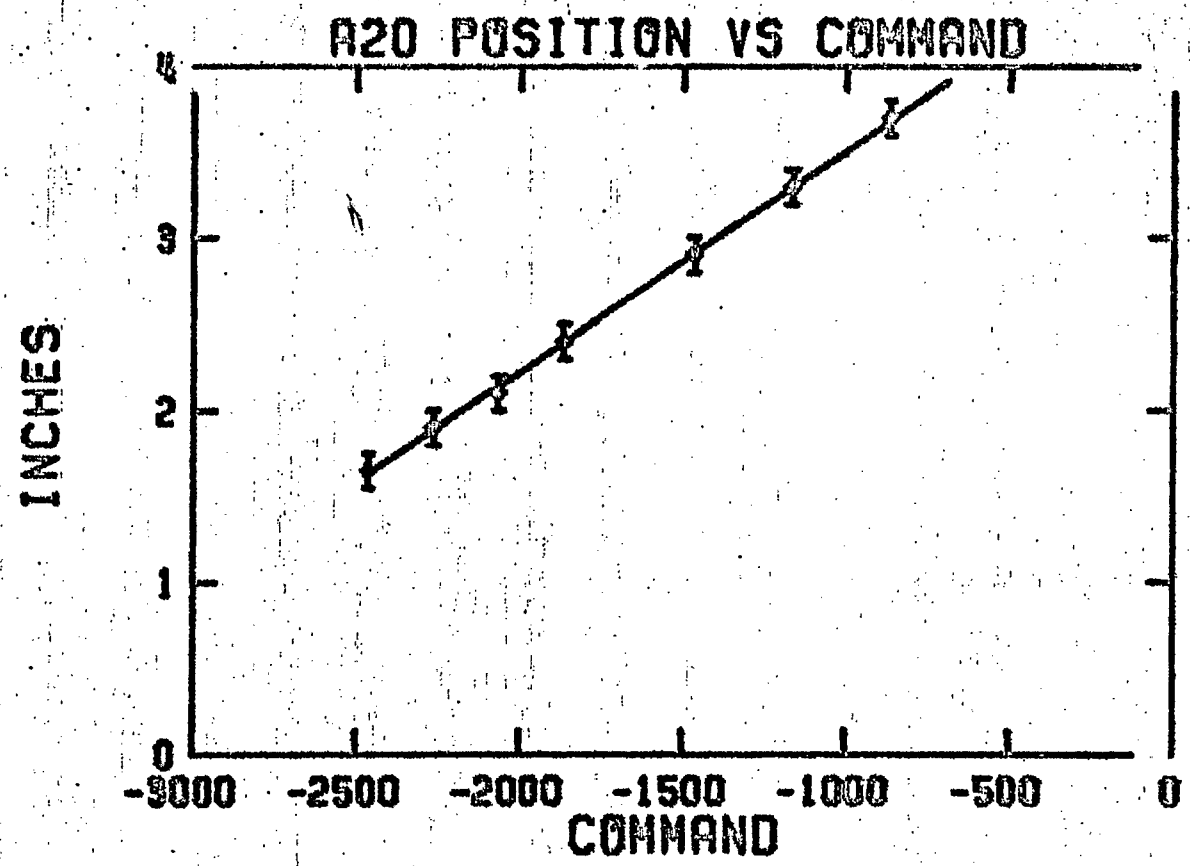


Figure 2.

ND437 SWEEP; NQ433,444 OFF, AGS OFF; ND431=-2064
SLOPE= 0.001036 +/- 0.000049
INTERCEPT= 0.092500 +/- 0.120981

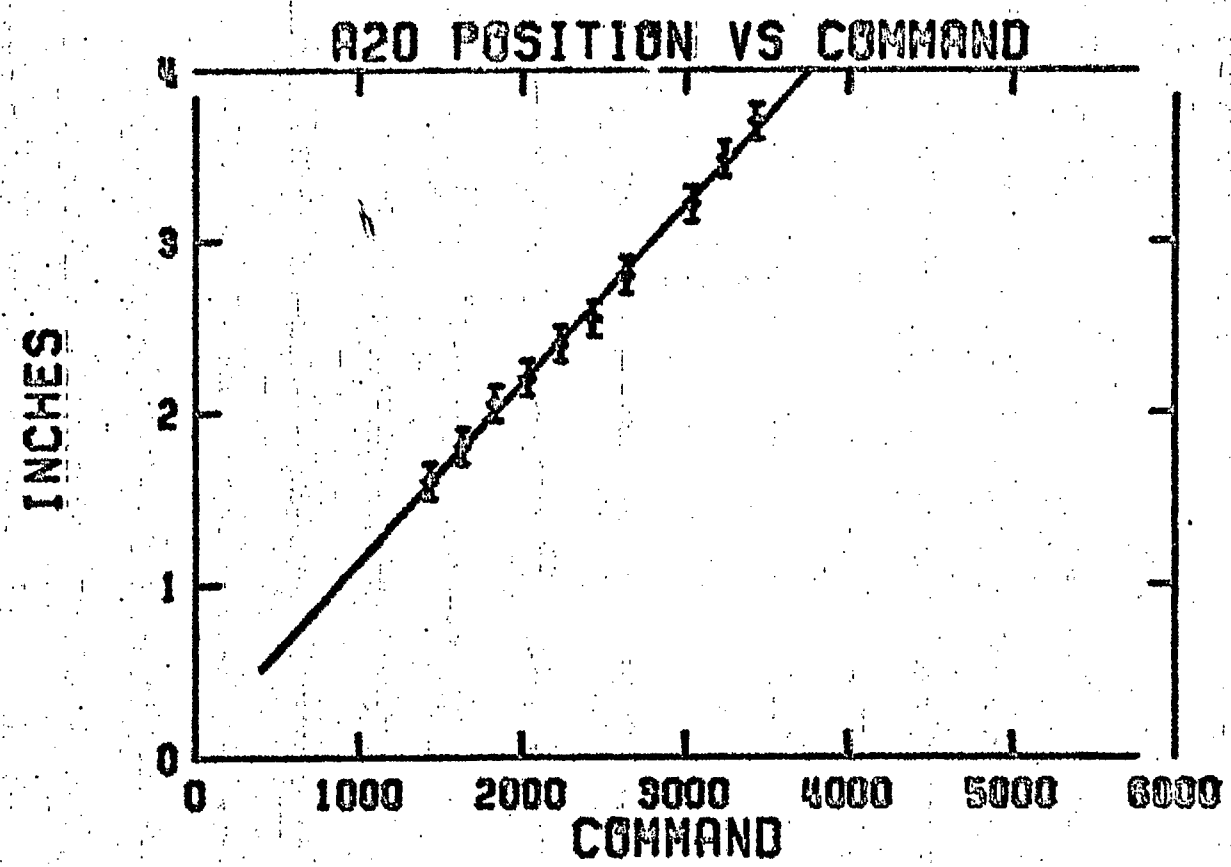


Figure 3.

NP435 SWEEP; NQ433,444 OFF, AGS OFF; NP440=943
SLOPE= 0.001187 +/- 0.000029
INTERCEPT= 0.513304 +/- 0.018226

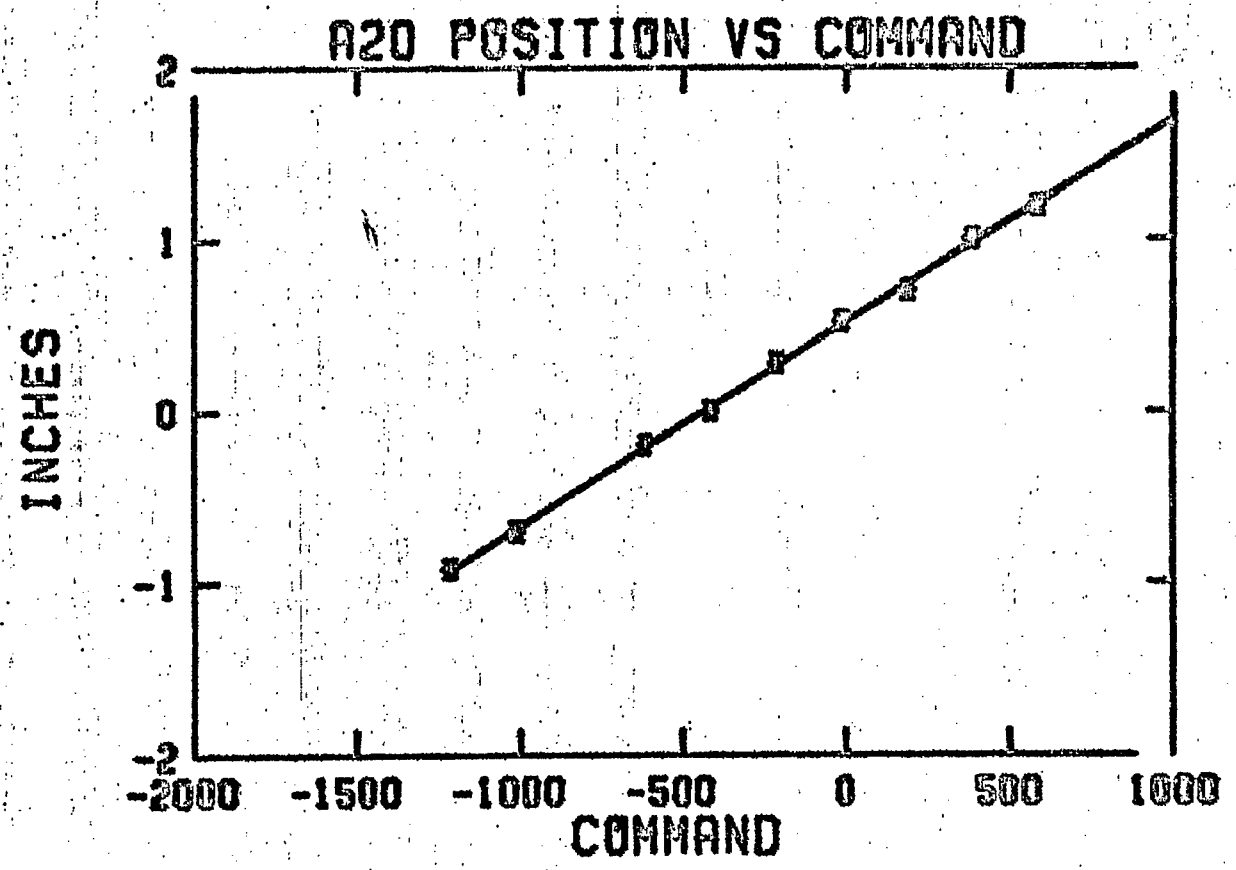


Figure 4.

NP440 SWEEP; NQ433,444 OFF; AGS OFF; NP435=-412
SLOPE= 0.000620 +/- 0.000026
INTERCEPT= -0.530778 +/- 0.034158

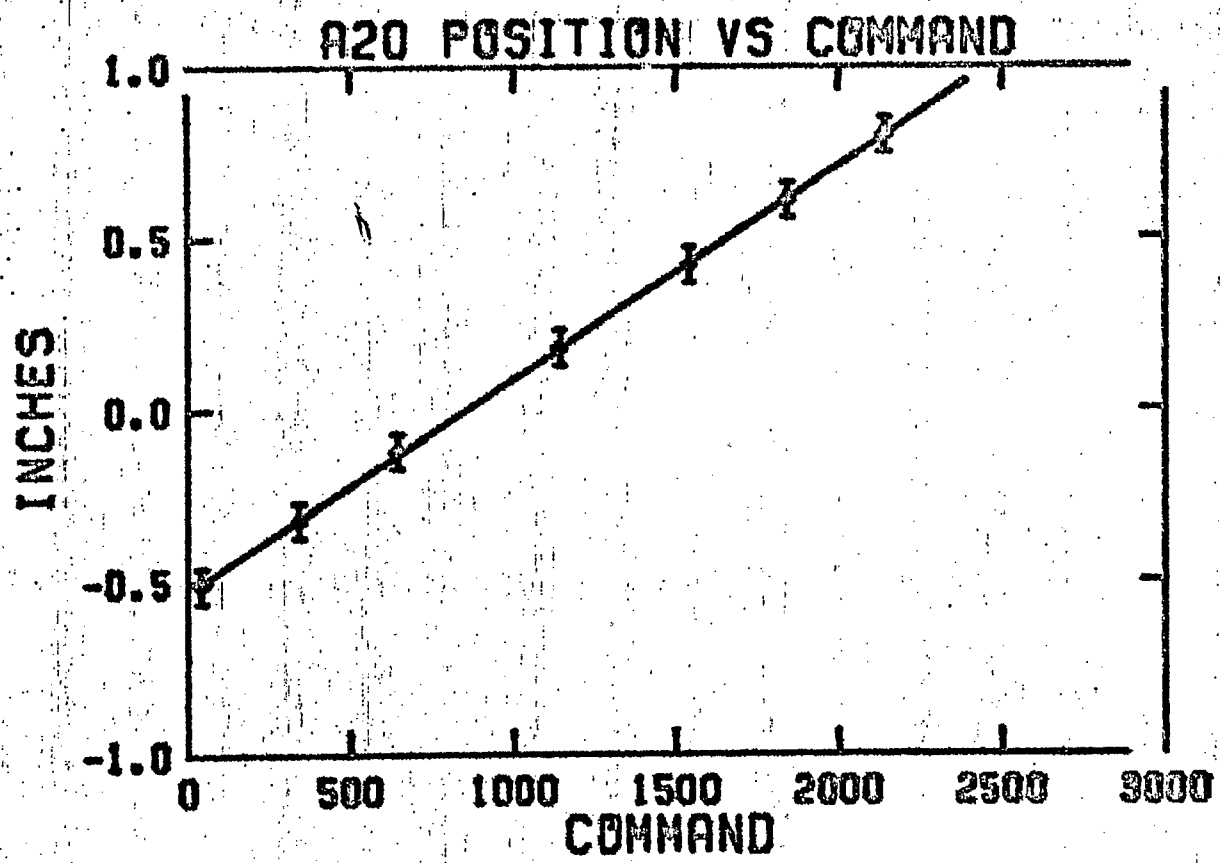


Figure 5.

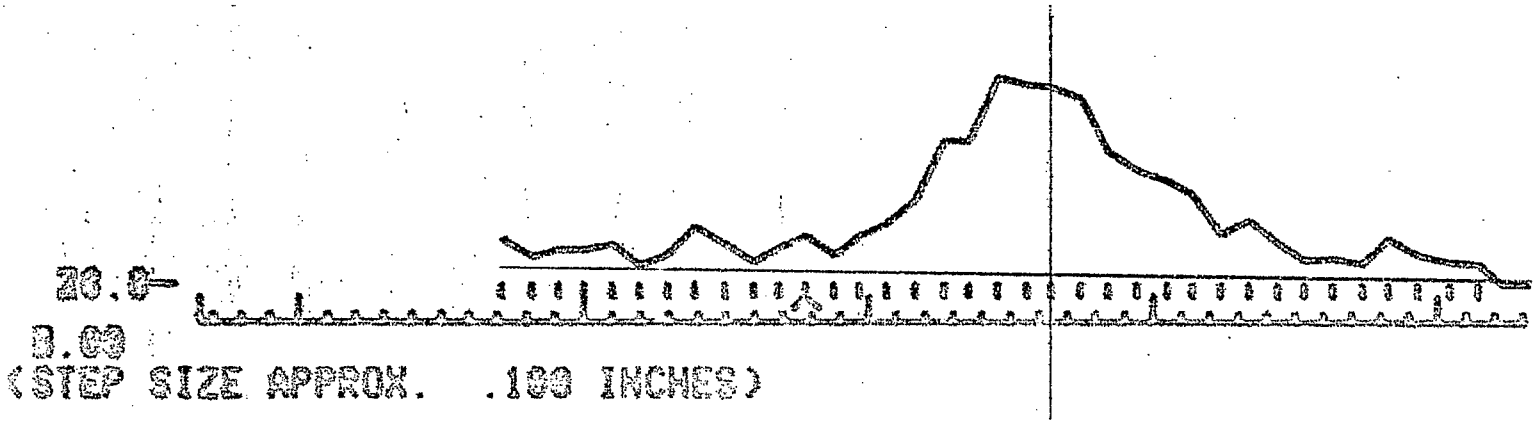


Fig. 6. Horizontal A20 SEM plot.

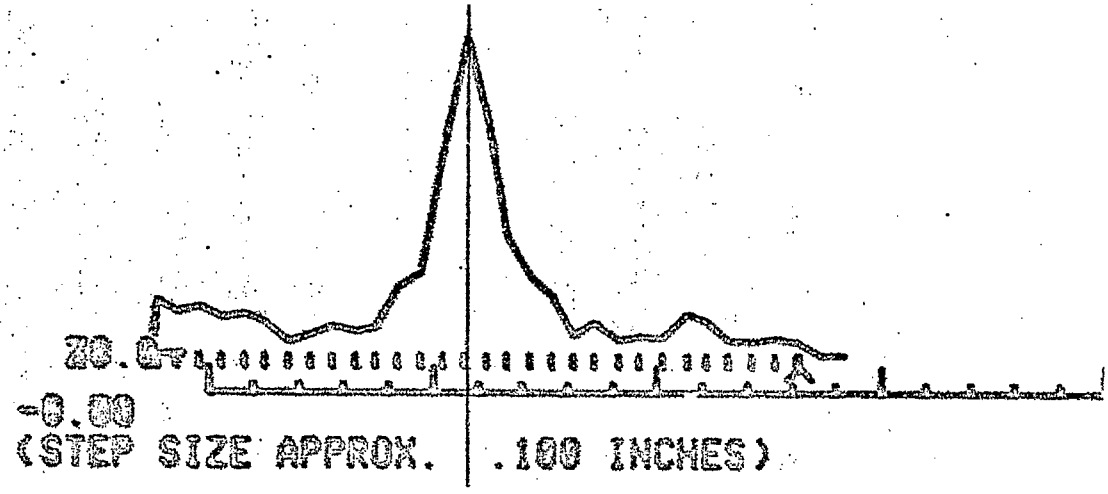


Fig. 7. Vertical A20 SEM plot.