BNL-104736-2014-TECH

AGS/AD/Tech Note No. 320;BNL-104736-2014-IR

THE AGS HIGH FIELD VERTICAL BUMP MAGNETS

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May 1989

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USDOE Office of Science (SC)

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Technical Note

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May 15, 1989

Introduction

There are two high field vertical bump magnets in the AGS. This note describes their physical and magnetic properties and shows their effects on the beam.

Description of the Magnets

The magnets are similar to magnets used in the external beam lines where they are called 6.75-D-24. They are made of an epoxy impregnated, laminated steel core, with a water-cooled, window-frame type copper coil. The dimensions and other properties are given in Table I. Note that the magnetic gap is 6.81 inches (horizontal since we are moving the beam vertically). The actual physical gap is somewhat less than this due to the epoxy coating; thus they are called 6.75-D-24 magnets, but to get good agreement between the field measurements and calculations the steel gap of 6.81 inches should be used.

In 1980 these magnets were measured using a Hall probe. Figure 1 shows B/I versus I. The measurements started at 500 Amps, went down in steps to 100 Amps, and then back to 560 Amps. The 200 Ampere point is very low, perhaps because the probe was reversed; the 100 Ampere point is a little low for reasons not understood, otherwise the calculated and measured results give good agreement. Figure 2 shows B versus I and indicates that for our purposes, the agreement between measurement and calculation is good enough; therefore, we can use the formula:

$$B[\text{Gauss}] = \frac{4\pi\ NI}{10\ G}\left[\frac{\text{Ampere-Turns}}{\text{cm}}\right] = 3.487\ I[\text{Amperes}]$$

A recent calibration (J. Funaro, 3/27/89) of the command setting in the Main Control Room and the resulting current in the F-20 magnet is given in Table II and plotted in Figure 3. A good fit to this data is given by:

$$I[\text{Amperes}] = -8.77 + 0.0745*(\text{Command})$$

Effect on the Beam for Fast Extraction

The magnets are located at F-20 and I-10. They are 50 magnets apart which in this case is a phase shift of 663 degrees. Table III shows the effects at the fast beam extraction elements. The calculations in this paper are done by MAD for P = 15 GeV/c, Q_y = 8.772.

Effect on the Beam for Slow Extraction

The slow extraction devices are the F-5 thin septum, where we often center the beam vertically, and the F-10 thick septum, which is the actual vertical aperture. Table IV shows the orbit displacements at these magnets and at H-20, the electrostatic septum. Note also that changing the vertical bumps affects the initial vertical angle of the extracted beam, best given by y' at F-10.

Since the principal use at present for the vertical bumps is to fine tune the position of the beam at F-5, we show in Table V some positions at F-5 as a function of momentum and setting, and we show the calculation below.

$$I[\text{Amps}] = -8.77 + 0.0745*(\text{Command})$$

$$B\ L[\text{T mm}] = 0.266\ I[\text{Amps}]$$

$$\theta[\text{mrad}] = \frac{0.3\ B\ L}{P} \quad \left[\frac{\text{T mm}}{\text{GeV/c}}\right]$$

$$Y(F5)[\text{mm}] = 6.36\ \theta[\text{mrad}]$$

$$Y(F10)[\text{mm}] = 12.24\ \theta[\text{mrad}]$$

$$Y(F5)[\text{mm}] = \frac{0.5\ I}{P}\ [\text{Amps/GeV/c}]$$

These calculations are done by MAD for P = 15 GeV/c, Q_y = 8.772. Figures 4 and 5 show orbits calculated by MAD for P = 29 GeV/c, Q_y = 8.90. The detailed effects are somewhat different, mostly due to the vertical tune change.

Measurements

Figure 6 shows the results of applying a kick to the beam as measured by the PUE system and as calculated by MAD. The absolute agreement is very good, no doubt better than we deserve, probably resulting from some fortuitous estimates. The shape agreement is very good as we would hope. It appears that undertaking a set of careful measurements and calculations will give us a very good calibration of the vertical PUEs.

Table I

PROPERTIES OF THE VERTICAL BUMP MAGNETS

	inches		mm
1. Physical Description			
A. Core			
Core Length	24.00		609
Horizontal Steel Aperture	6.81		173
Vertical Steel Aperture	7.56		192
Vertical Clear Aperture	6.30		160
B. Coil			
Type - Window Frame, Water			
Material - Copper			
Total Turns		48	
No. of Pancakes		4	
Turns per Pancake		12	
Dimensions - Square	0.2576		6.54
Cooling Hole Diameter	0.143		3.63
C. Locations F20, I10			
Distance from Magnet Core	9.37		238
2. Electrical Properties			
Resistance, Measured (J. Funaro, 4/18/89)		34.5	milliohms
Resistance, Calculated		47	milliohms
Inductance, Measured (J. Funaro, 4/18/89)		2.035	millihenrys
Inductance, Calculated		2.5	millihenrys
3. Magnetic Properties			
B/I, Calculated		3.487	G/A
L_{eff}, Estimated	30		762
B x L/I, Calculated	105 G-in/A		2,667 G-mm/A
4. Power Supply 40V, 300A			

I = -8.77 + 0.0745*(Command)

Table II

CALIBRATION OF F-20 VERTICAL BUMP MAGNET

Command	Current (Amps)	Fitted Current (Amps)
100	0	- 1.3
500	27	28.5
1000	65	65.7
1500	103	102.9
2000	141	140.2
2500	178	177.4
3000	214	214.6

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Table III

DISPLACEMENTS PRODUCED BY THE VERTICAL BUMPS AT THE FAST EXTRACTION ELEMENTS

A. F-20 Bump

= 0.3 mr

	y_{mm}	y'_{mr}
H-5	- 3.0	0.08
H-10	- 0.8	0.20

B. I-10 Bump

= 0.3 mr

	y_{mm}	y'_{mr}
H-5	- 2.7	- 0.04
H-10	- 1.8	+ 0.04

Table IV

DISPLACEMENT PRODUCED BY THE VERTICAL BUMPS AT THE SLOW EXTRACTION ELEMENTS

			y mm	y' mr
A.	F-20 Bump			
	= 0.3 mr	F-5	2.0	+ 0.24
		F-10	4.0	+ 0.24
		H-20	3.8	- 0.40
B.	I-10 Bump			
	= 0.3 mr	F-5	2.7	- 0.02
		F-10	1.2	- 0.12
		H-20	3.7	- 0.30

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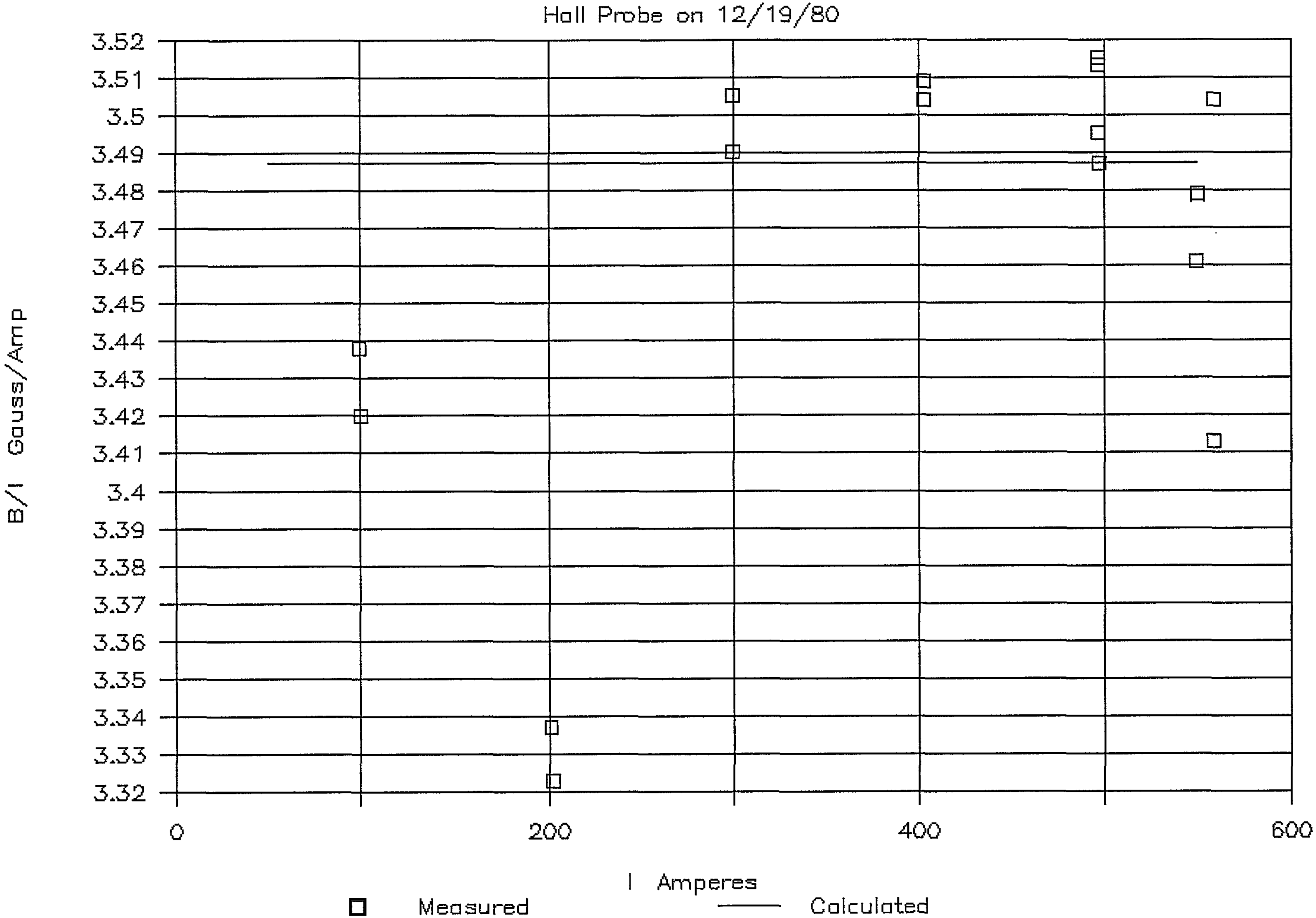
Table V

DISPLACEMENTS AT F-5 AND F-10 FOR THE F-20 BUMP

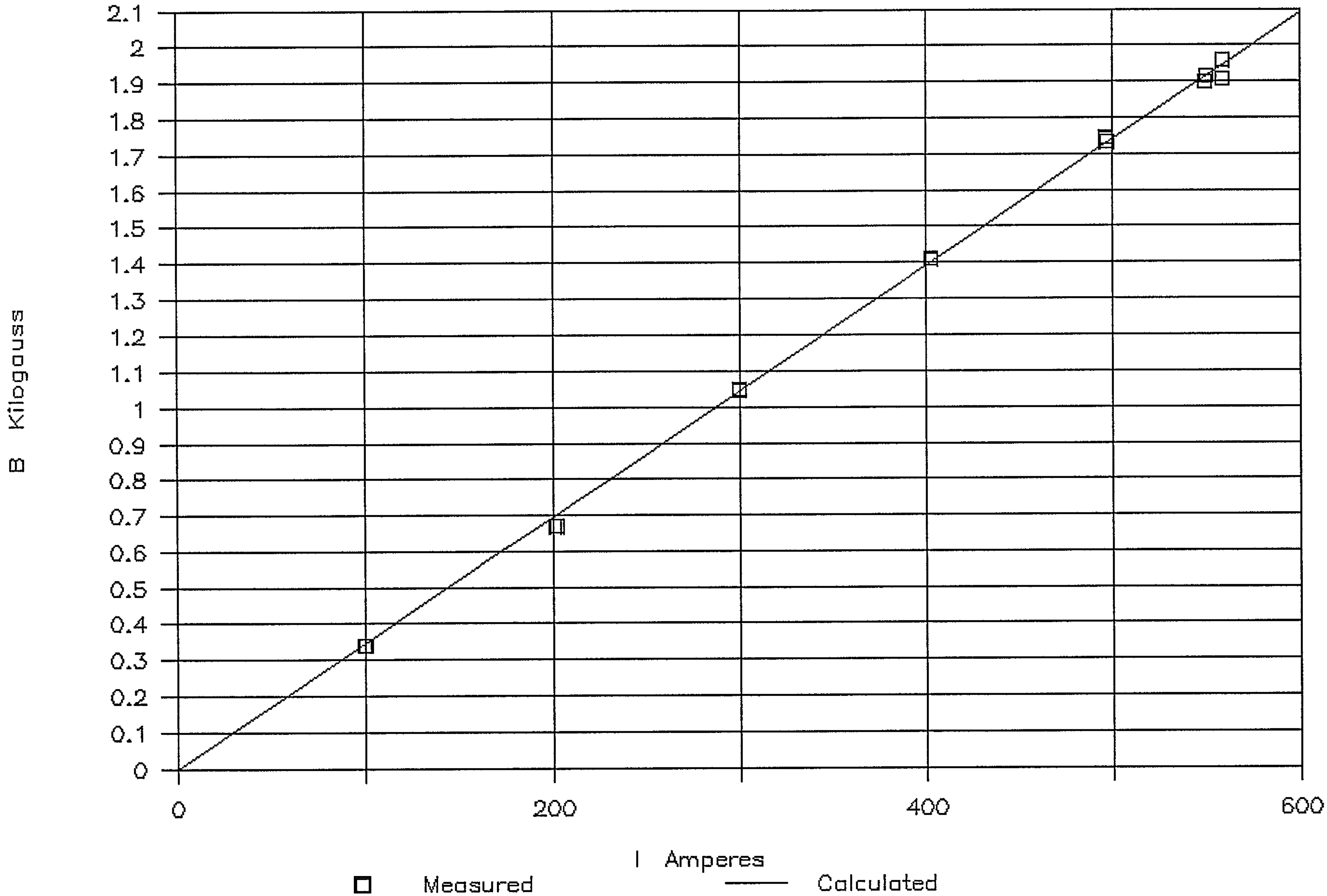
F-20 Command	Current I (Amps)	24 GeV/c Y(F5) mm	24 GeV/c Y(F10) mm	24 GeV/c Y'(F10) mrad	30 GeV/c Y(F5) mm	30 GeV/c Y(F10) mm	30 GeV/c Y'(F10) mrad
100	0.0	0.0	0.1	0.00	0.0	0.0	0.00
500	28.5	0.6	1.2	0.08	0.5	0.9	0.06
1000	65.7	1.4	2.7	0.17	1.1	2.1	0.14
1100	73.1	1.5	3.0	0.19	1.2	2.4	0.16
1500	102.9	2.2	4.2	0.27	1.7	3.3	0.22
2000	140.2	3.0	5.7	0.37	2.4	4.6	0.30
2500	177.4	3.7	7.2	0.47	3.0	5.8	0.38
3000	214.6	4.5	8.7	0.57	3.6	7.0	0.46
3500	251.9	5.3	10.2	0.67	4.3	8.2	0.54
4000	289.1	6.1	11.7	0.77	4.9	9.4	0.61

B/I for 6.75-D-24, FIG 1

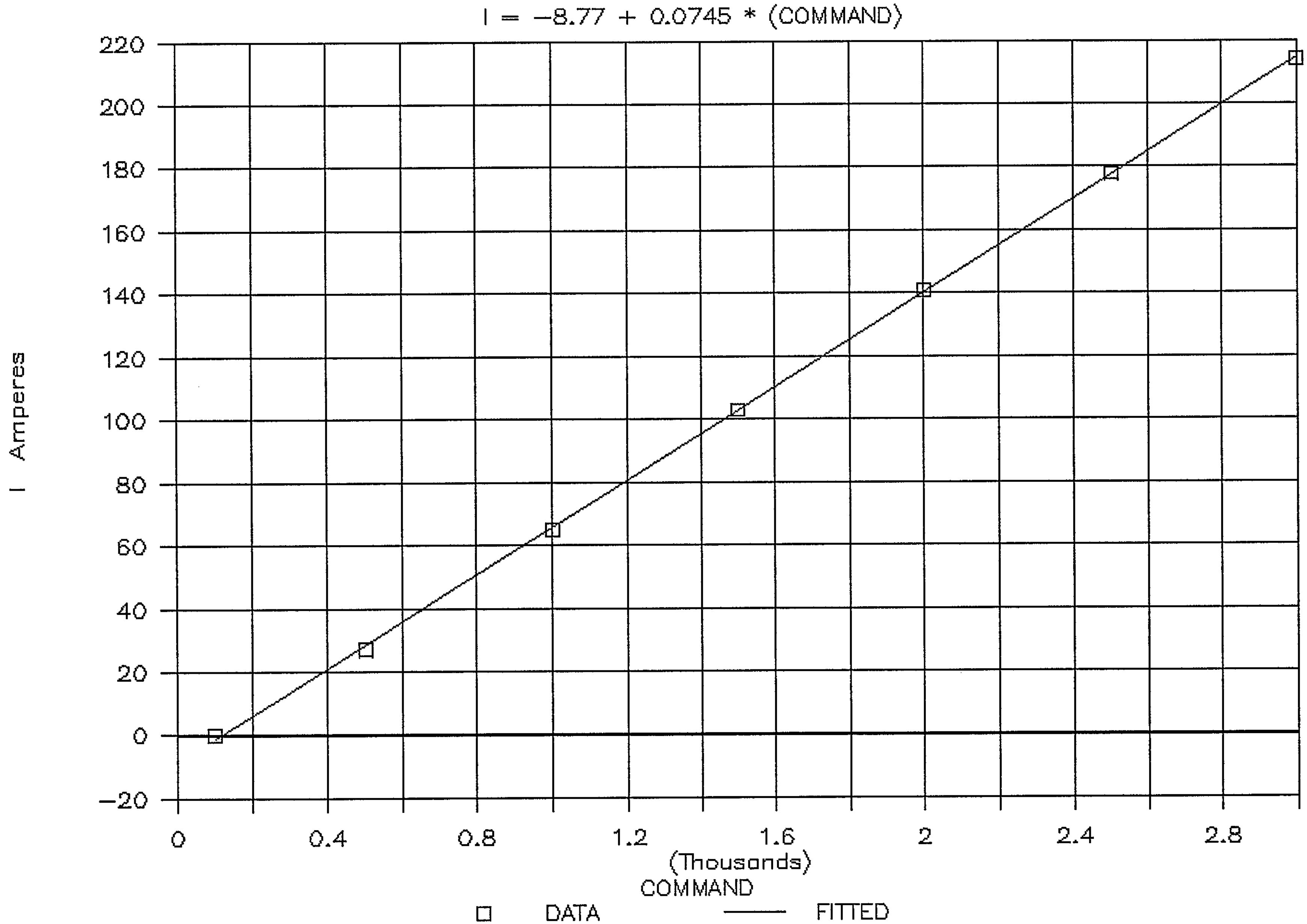


B vs I for 6.75-D-24, FIG 2

Calculated as B = 3.487*I



F-20, CURRENT vs COMMAND, 3/23/89,FIG 3



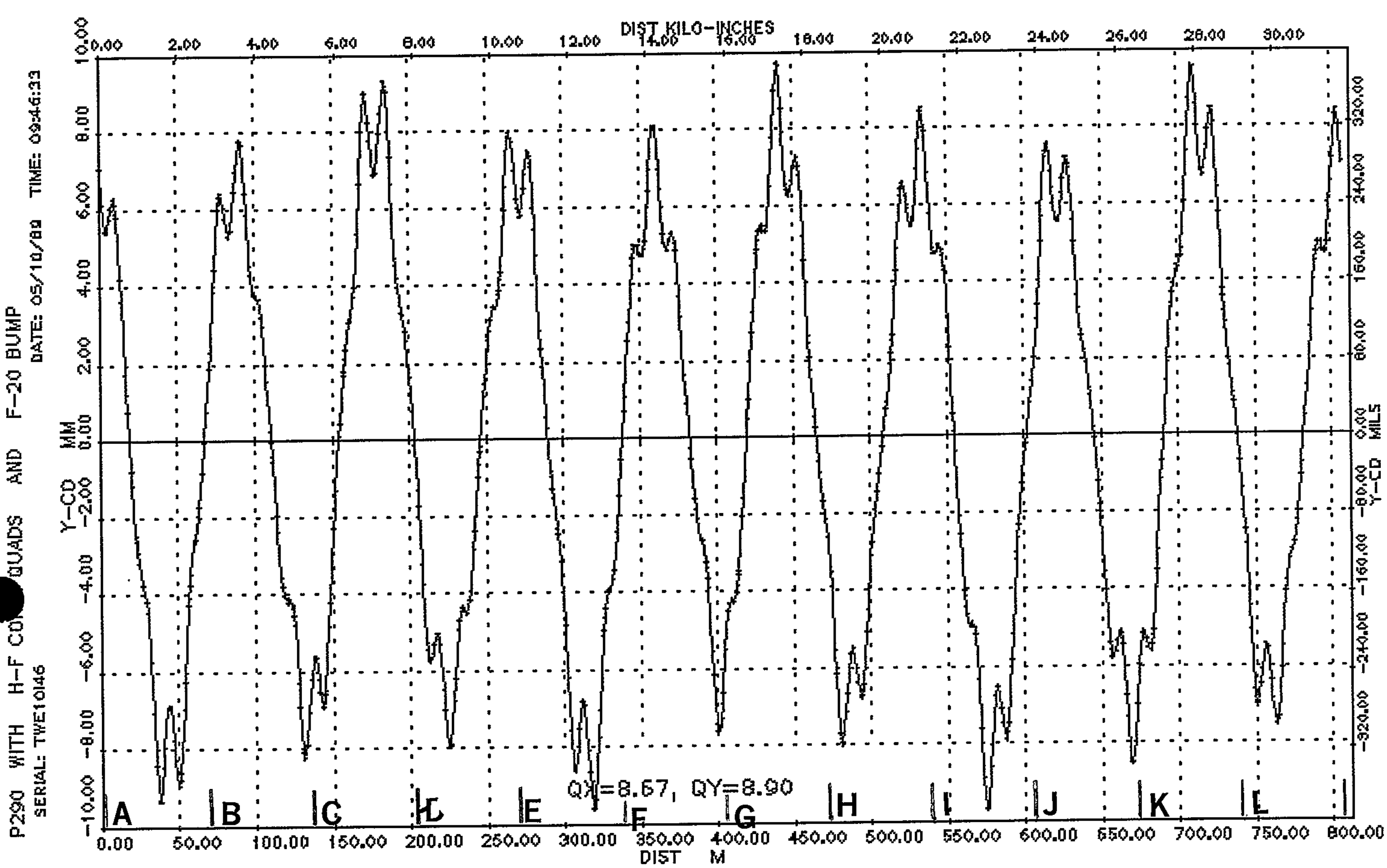

P290 WITH H-F CO[illegible] QUADS AND F-20 BUMP
SERIAL: TWE10146
DATE: 05/10/89 TIME: 09:46:33
DIST KILO-INCHES
Y-CD MM
Y-CD MILS
DIST M
QX=8.67, QY=8.90
A
B
C
D
E
F
G
H
I
J
K
L

Figure 4a

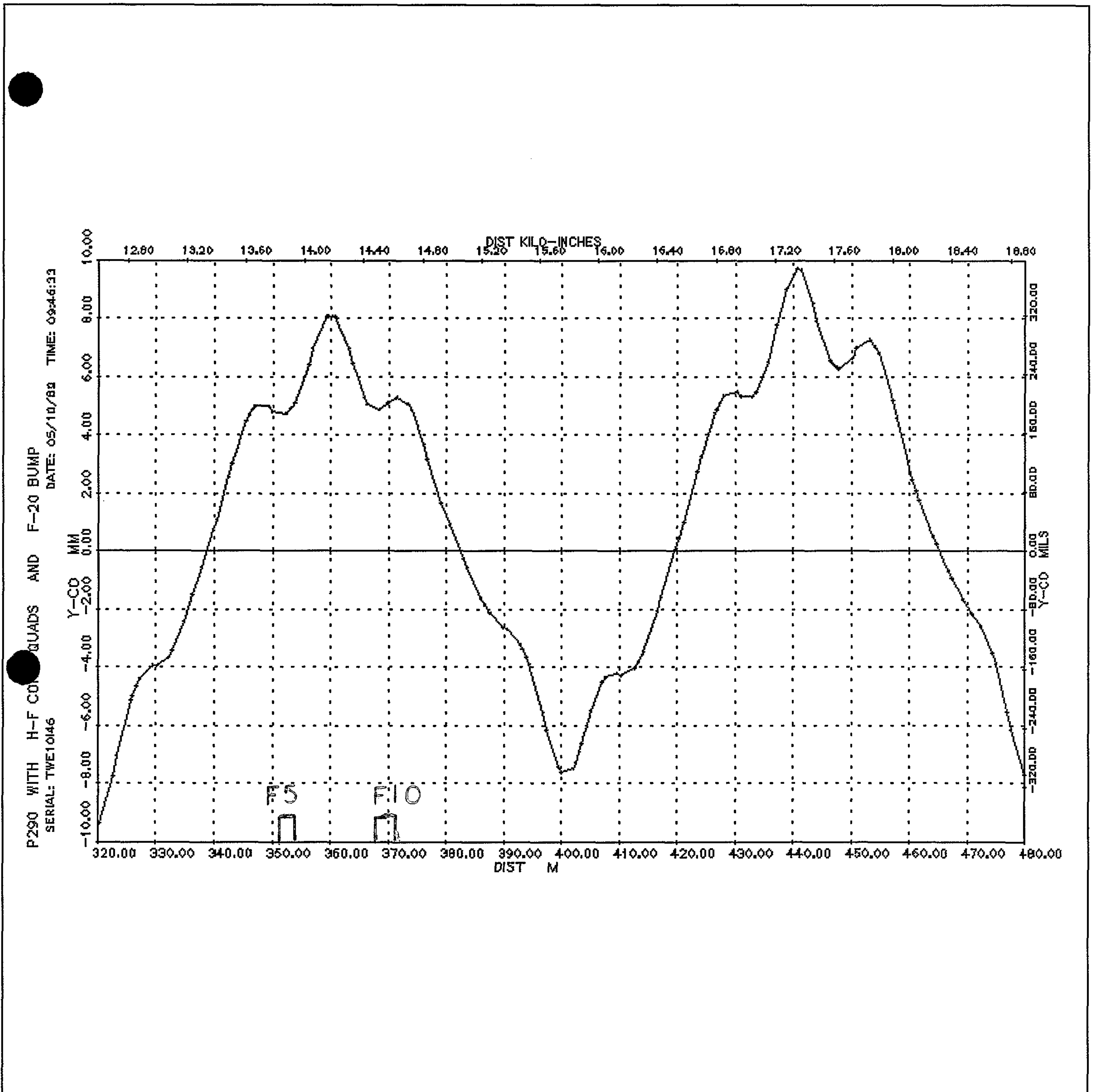

P290 WITH H-F CO QUADS AND F-20 BUMP
SERIAL: TWE10146 DATE: 05/10/82 TIME: 09:46:33
DIST KILO-INCHES
DIST M
Y-CO MM
Y-CO MILS
F5
F10

Figure 4b

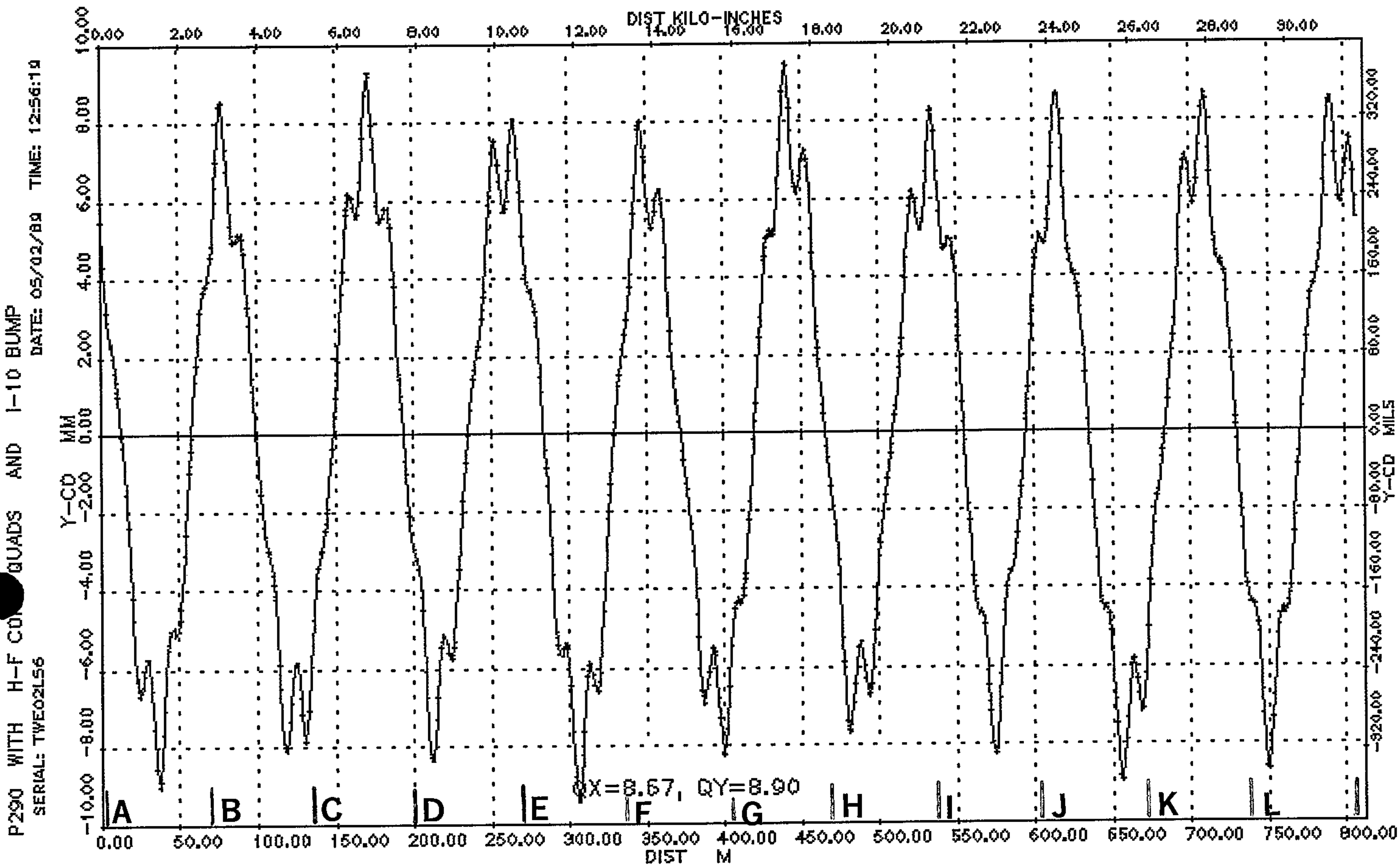

P290 WITH H-F CO QUADS AND I-10 BUMP
SERIAL: TWE02L56 DATE: 05/02/89 TIME: 12:56:19
DIST KILO-INCHES
DIST M
Y-CD MM
Y-CD MILS
QX=8.67, QY=8.90
A
B
C
D
E
F
G
H
I
J
K
L

Figure 5a

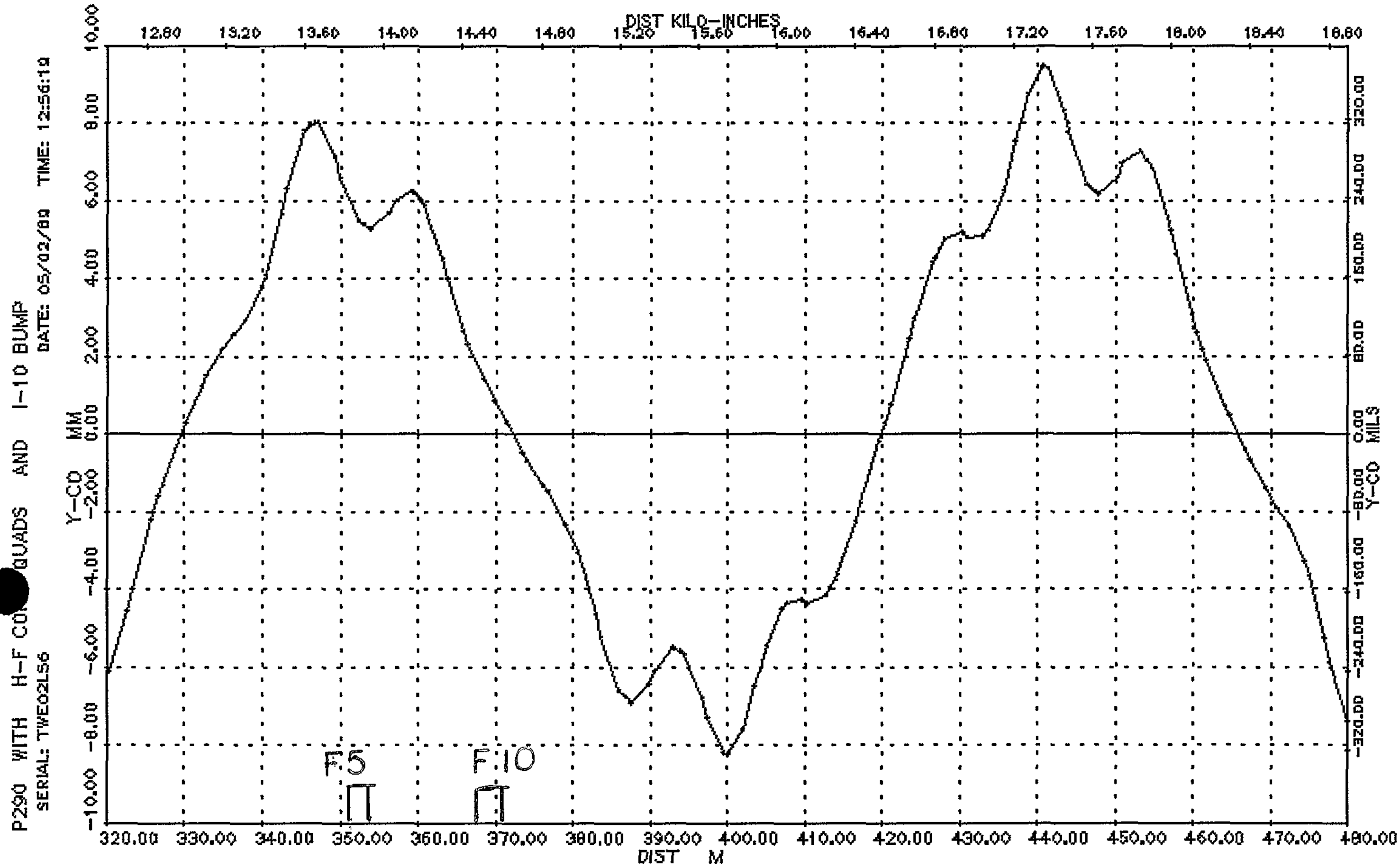

P290 WITH H-F CO QUADS AND I-10 BUMP
SERIAL: TWE02L56
DATE: 05/02/89 TIME: 12:56:19
DIST KILO-INCHES
DIST M
Y-CO MM
Y-CO MILS
F5
F10

Figure 5b

MEASURED VERTICAL BUMP FIG. 6