Measured Magnetic Forces on
the Tohoku Bubble Chamber Magnet
(from the first run, Spring 1985)

W. Craddock
October 30, 1985

INTRODUCTION

During the first run in the spring of 1985, axial, horizontal, and vertical magnetic forces were measured in the Tohoku Bubble Chamber Magnet. Measurement of these forces was important to verify that all support systems were not overloaded. In addition, new coil and iron geometries for the new larger chamber will certainly increase the axial forces. Unfortunately, good agreement was not found between measured and calculated axial forces.

AXIAL FORCES

Axial forces are by far the most difficult to measure but the easiest to calculate. These forces were measured by two methods. The two top axial posts were instrumented with two quarter bridges mounted on opposite sides near the $300^{o}K$ end but were not wired together. A three lead wire temperature compensation system was used. The second method uses a system of 3 nonmagnetic dial indicators mounted on the vacuum shell at 120^{o} spacings at the center of the coil (r = 29.5").

Axial support system:

Measurement of axial force is complicated by the Inconel 718 pretension rods. These rods were initially tightened with a torque wrench but then further tighten on cooldown. When these rods have tension in them, the axial stiffness of the magnet is the spring constant of the Randolite posts plus the Inconel rods. At some axial force, however, the Randolite posts compress to such a degree that the Inconel rods "break free". At this point the axial stiffness is that only of the Randolite posts.

Randolite (2" diameter) was measured to have the following Young's modulus in the axial direction.

4.48×10^{6} psi	room temperature	(W. Craddock)
4.89×10^{6} psi	$77^{o}K$	(M. Mruzek)

Mike Mruzek also measured the deflection curve of a completed post assembly at LN_2 temperature. See his report dated July 16, 1980. Both a vertical post and one tipped by 1/4" were tested. Posts at the top of the magnet are expected to remain nearly vertical upon cooldown, but those at the bottom may tip as much as ~0.22". His two deflection curves are linear from 50,000 lbs to 300,000 lbs per post. Breaking the curves into two piecewise continuous linear portions, we get the following post assembly spring constants:

1.50×10^6 lbs/inch vertical post; 50,000 to 300,000 lbs

1.67×10^6 lbs/inch 1/4" tipped post; 50,000 to 300,000 lbs

1.06×10^6 lbs/inch both vertical & tipped; 0 to 50,000 lbs

The spring constant of the Randolite supports is eight times the above values since there are 8 posts. The spring constant of the 16 Inconel 718 rods is

$$K = AE/L = 16(\pi/4)(0.3125^2)(29 \times 10^6)/12.625$$

$$= 2.82 \times 10^6 \text{ lbs/inch}$$

For parallel springs,

$$K_{total} = K_{Randolite} + K_{Inconel}$$

It is important to know at what value of magnetic force the Inconel rods loose all their preload. The Inconel rods were initially tightened to a tension of 687 lbs per rod. The rods are further tightened by a difference in thermal contraction.

$$(\Delta L/L) \text{ Randolite} = 0.00127$$

$$(\Delta L/L) \text{ Inconel} = 0.0025$$

For both mechanical and thermal preload; $F_{Randolite} = -2\ F_{Inconel}$ where F is the force in each rod or post.

Preload puts a compressive load of (16 x 687)/8 = -1370 lbs in each Randolite post.

Area of 1 Randolite post = 3.98 in^2

Area of 1 Inconel rod = 0.0767 in^2

For preload the elongation of the Inconel rod is,

$$\Delta L = FL/AE = 687 \times 12.5/(0.0767 \times 29 \times 10^6) = 0.0039''$$

If one assumes that 3/4 of each post and tension rod reaches 77°K, the difference in thermal expansion is

$$\Delta L = 12.5'' \times 3/4\ (0.0025 - 0.00127) = 0.0115''$$

Then for cooldown,

$\Delta L_{Randolite} + \Delta L_{Inconel} = 0.015$ where ΔL is the absolute value of change in length.

$$\frac{2\,F_{Inconel} \times 12.5}{3.98 \times 4.8 \times 10^6} + \frac{F_{Inconel} \times 12.5}{0.0767 \times 29\times10^6} = 0.0115$$

From cooldown, $F_{Inconel}$ = 1660 lbs

Then on cooldown the Inconel rod stretches 0.0093"

Total elongation of the Inconel rod = 0.0039" + 0.0093 = 0.013"

Total preload on the Randolite post = 2(687 + 160) = 4700 lbs

If we take an average spring constant of 1.59 x 10^6 lbs/inch for each Randolite post at loads greater than 50,000 lbs per post, we will get the following overall magnet support spring constant:

11.3 x 10^6 lbs per inch 0 to 147,000 lbs total load

8.48 x 10^6 lbs per inch 147,000 to 400,000 lbs total load

12.7 x 10^6 per inch >400,000 lbs total load

At 147,000 lbs the Inconel rods loose all preload. From 147,000 lbs to 400,000 lbs we are in the range of Randolite post loading where the spring constant per post is only 1.06 x 10^6 lbs/inch.

Strain Gage Measurements of Axial Load:

The appendix gives strain gage type and location as per M. Mruzek. Since only quarter bridges were used, the bridge sensitivity factor is 1.

$$\text{Force in 1 post} = \varepsilon EA = \varepsilon \times 4.5 \times 10^6 \times 3.98$$

$$= 17.9\ \mu\varepsilon$$

where $\mu\varepsilon$ is the microstrain obtained directly from the Strainsert readout.

However, as shown in the previous section, relaxing tension in the Inconel rods will carry part of the axial load up to 147,000 lbs total load. If the post compresses 1 $\mu\varepsilon$, the Inconel rods will relax 1 $\mu\varepsilon$. Thus we get the following relationships

$$\text{Total Force} = \mu\varepsilon\,(8 \times 17.9 + 16 \times 29 \times 0.0767);\ 0 \text{ to } 147{,}000 \text{ lbs}$$

$$= 179\ \mu\varepsilon \text{ up to } 147{,}000 \text{ lbs total load (or } 820\ \mu\varepsilon)$$

$$= 147{,}000 \text{ lbs} + 143\,(\mu\varepsilon - 820) \text{ for } F_z > 147{,}000$$

Strain gage readings were taken on two diferent days. M. Mruzek has taken his set of readings and averaged them all together in Fig. 1. I have plotted the averaged strain from the 3 posts with working instrumentation for both set of measurements in Fig. 2. By averaging the strain readings from the two strain gages on each post, bending in canceled. During the course of reading strain, temperature can be assumed to be a constant and magnet resistivity changes are small for the type of gage selected.

Note the following from Fig. 2.

1. Coil B has an apparent greater load than coil A.

2. The second run has consistently greater strains than the first run.

3. On the second run both posts in Coil A tracked each other nearly perfectly.

4. It is my opinion that the results recorded by P. Kelley in the second run are more reliable. The data was taken on one day over a much shorter period of time and a reading of ~0 με was obtained after discharging the magnet from 700 Amps. No such zero current readings are available from the first run.

In Fig. 3 I have averaged the three curves from the second run together and converted them to an equivalent magnetic load. Comparison to the calculated magnetic field is very good up to 350 Amps. Perhaps early saturation at the top of the yoke, where the instrumented posts are located, might explain the deviation at higher current values.

Dial Indicator Measurements of Axial Load:

At first glance this would appear to be a straightforward and reliable method of measuring axial forces. However, the measurement is made difficult and much less accurate by the following complexities.

1. Inconel 718 pretension members which can break free changing the spring constant of the system.

2. Roll of the cryostat from axial and radial electromagnetic loads resulting in additional apparent deflections.

3. Initial distortion of the vacuum shell at the support post location from vacuum loading and welding.

4. A measured non-linear spring constant for a completed Randolite post assembly in the load range of interest.

As stated previously the Randolite posts are assumed to have two different spring constants depending upon the load value. Use the values previously calculated to obtain force curves from the dial indicator readings. In Fig. 4 M. Mruzek has plotted the three dial indicator readings versus current, and in Fig. 5, he has averaged them together.

Movement of the dial indicator due to cryostat roll was obtained from my 2D cryostat analysis.

At 700 Amps, $\Delta y = + 0.0022"$ due to radial loads

With $F_z = 462{,}000$ lbs, $\Delta y = -0.0128"$

Deflection due to radial loads will be neglected as this is a small value and changes with the current level. Thus, we get from the cryostat deflection, 2.77×10^{-8} inches/lb.

The original 2D axisymmetric vacuum shell ANSYS model was modified to include loading at the axial posts and gap elements along the base plate. The gap elements allow the vacuum shell to pull away from the iron during evacuation. They also provide a stop as the vacuum shell is pushed back down against the iron with increasing axial loading. See the new Appendix 1 to my memo on the Tohoku Vacuum Shell. Results show a maximum deflection of 0.012" away from the iron at the location of the Randolite posts after evacuation. This bow decreases linearly with load up to 55,000 lbs total axial load. At this point the vacuum shell is perfectly flat against the iron. This gives a deflection rate of 2.18×10^{-7} inches/lb.

Adding up the deflections of the support system, cryostat roll and vacuum shell deflections we get the following deflection rates.

$$\Delta_z/\Delta F_z = 1/11.3 \times 10^6 + 2.77 \times 10^{-8} + 2.18 \times 10^{-7}$$

$$= 3.34 \times 10^{-7} \text{ inches/lb} \qquad \text{for } F_z = 0 \text{ to } 55{,}000 \text{ lb}$$

$$\Delta_z/\Delta F_z = 1/11.3 \times 10^6 + 2.77 \times 10^{-8} = 1.16 \times 10^{-7} \quad F_z = 55{,}000 \text{ to } 147{,}000 \text{ lbs}$$

$$\Delta_z/\Delta F_z = 1/8.48 \times 10^6 + 2.77 \times 10^{-8} = 1.46 \times 10^{-7} \quad F_z = 147{,}000 \text{ to } 400{,}000 \text{ lbs}$$

$$\Delta_z/\Delta F_z = 1/12.7 \times 10^6 + 2.77 \times 10^{-8} = 1.06 \times 10^{-7} \quad F_z > 400{,}000 \text{ lbs}$$

The overall spring constant is the reciprocal of the deflection rate. Thus, conversion between the dial indicator deflection readings and total magnetic axial force is given below.

$$F_z = \Delta_z \times 2.99 \times 10^6 \text{ lbs/in} \;;\; 0 \text{ to } 55{,}000 \text{ lbs } (z = 0 \text{ to } 0.0184")$$

$$F_z = 55{,}000 + (\Delta_z - 0.0184) \times 8.57 \times 10^6 \;;\; 55{,}000 \text{ to } 147{,}000 \text{ lbs } (z = 0.0184" \text{ to } 0.029")$$

$$F_z = 147{,}000 + (\Delta_z - 0.029) \times 6.85 \times 10^6 \;;\; 147{,}000 \text{ to } 400{,}000 \text{ lbs } (z = 0.029" \text{ to } 0.0659")$$

$$F_z = 400{,}000 + (\Delta_z - 0.0659) \times 9.43 \times 10^6 \;;\; F_z > 400{,}000 \text{ lbs } (z > 0.0659")$$

The averaged dial indicator readings from Fig. 5 are converted to total force using the above formulas and plotted versus current along with TRIM calculations in Fig. 6.

CONCLUSION

Calculated TRIM values fall between those predicted by strain gage readings and those predicted by dial indicator readings. Dial indicator readings should be considered unreliable at the low force (<~200,000 lbs). Simply not enough data is available on complete post assembly deflection rates below the ~25,000 lb per post level. Data does not exist on deflection of post assemblies that have been through several load cycles. Does the deflection become linear at all values once a post assembly has been fully loaded one time?

A bigger uncertainty, however, is the initial gap between iron and vacuum shell. A 0.012" gap was assumed from vacuum considerations, but it is easy to imagine another 0.020" or 0.030". This would not only change the total deflection, it would also be very difficult to subtract out of the data since the vacuum shell would not be totally flat until approximately the calculated load was reached.

If the new chamber is installed, substantially larger forces are expected. Dial indicator readings could then be considered reliable for incremented values of force above the 250,000 to 400,000 lb range. Somewhere in this ballpark, post behavior can be expected to be fully linear and the vacuum shell should have bottomed out against the iron. Dial indicators should definitely be reinstalled when the new coil/iron geometry is tested.

HORIZONTAL FORCE

Horizontal decentering forces are carried by two pairs of Randolite posts. The two posts are preloaded against one another such that a horizontal force adds compression to two of the posts and relaxes compression in the other two posts. Forces (stains) are measured with strain gages mounted at the room temperature end. The preload bolts were strain gaged internally but gave unreliable results when tested. These were not used. Only the top pair of Randolite posts on each coil were instrumented.

Again we probably have the same non-linear deflection characteristics at small load values as was found with the axial posts. For these members we have no test data, however. The strain gages were attached at the room temperature end where the post diameter was 2.25". We, therefore, get the same conversion between measured strain and actual force per post as was found for the axial posts.

$$F = 17.9\ \mu\varepsilon$$

where $\mu\varepsilon$ is the microstrain reading from the Strainsert. Two strain gages were mounted on both of the top horizontal supports of both coils for a total of eight strain gages.

Only 5 gages were read and one of these was not working. For coil A one strain gage on each opposing post was working. For coil B two strain gages on the same post were read. The microstrain readings are plotted in Fig. 7. Note that for coil A compression in one post is almost identical to the relaxation of compression or tension in its opposing member, exactly as expected. Coil B data is confusing. The two strain gages on the same post apparently indicate a large bending stress. It will be assumed that the maximum strain reading is ±600 με. This would then give a maximum horizontal decentering force of

$$\text{Max } F_{horz} = 4 \times 17.9 \times 600 = 43{,}000 \text{ lbs}$$

Each post was designed to carry 37,000 lbs, or the system can carry a maximum force of 2 x 37,500 = 75,000 lbs. Our uncertainty in measuring the horizontal force gives a smaller value than this.

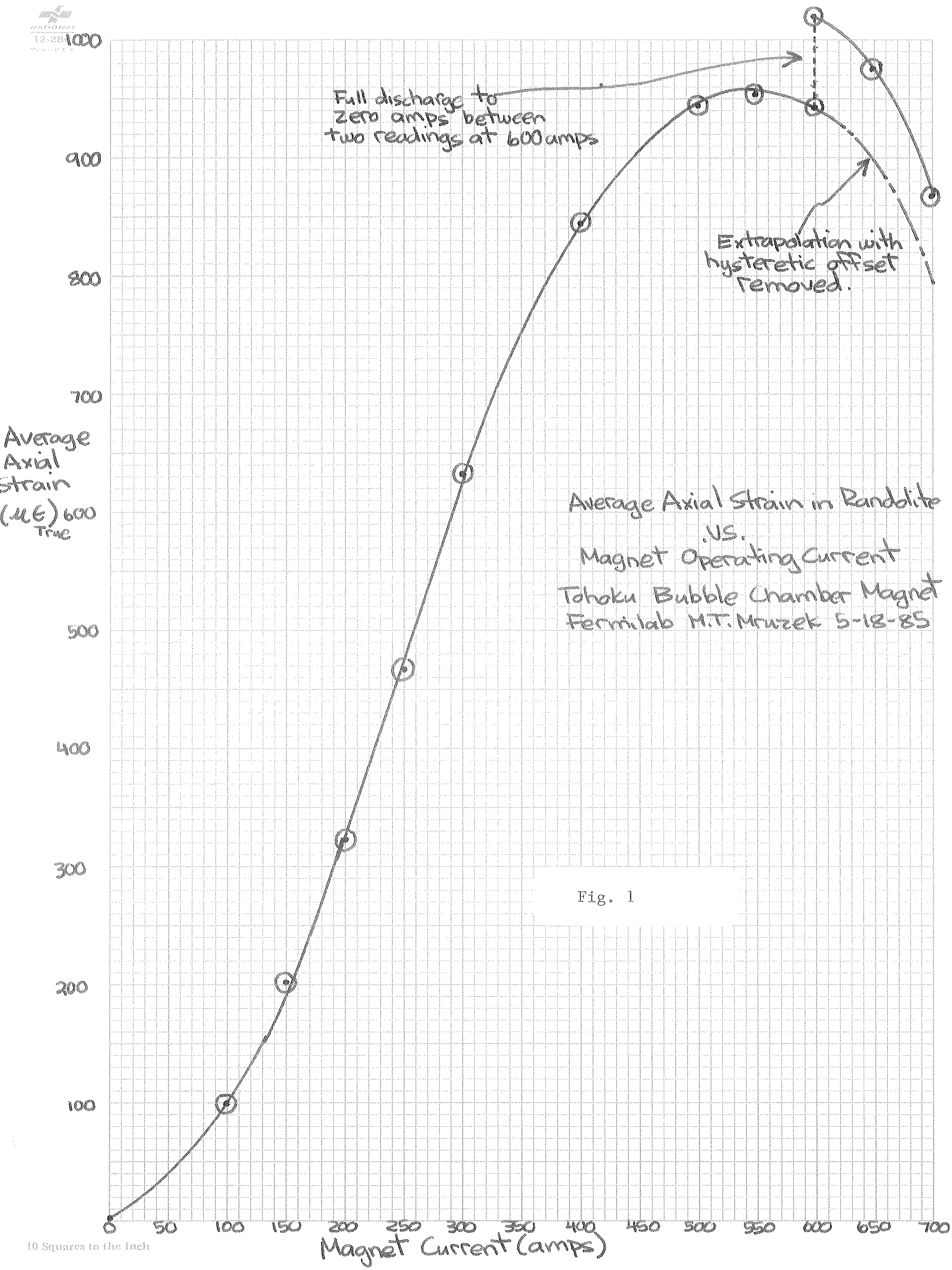
The horizontal post assembly was preloaded by tightening 1-1/2" diameter screws to 1025 ft-lbs. This corresponds to an approximate preload of 40,000 lbs. If we take into account that the horizontal post is slightly shorter and 2/3 of Randolite is smaller (2" diameter) than the axial posts, we can assume a spring constant of 1.3×10^6 lbs/inch per post based on the measured 1.5×10^6 lbs/inch spring rate in the axial post. Preload compresses each post 0.031".

Part of this preload is lost on cooldown with 1-1/4" aluminum, 1" stainless steel, and 7" equivalent of Randolite, 0.017" per post is lost upon cooling. Thus 0.031" - 0.017" = 0.014" of compression per post should remain after cooldown. This equals ~21,000 lbs of compressive preload per post. A force of 2 x 2 x 21,000 lbs = 84,000 lbs total decentering load would be required for all preload loss (two of the post come "free"). Note that in loading the preloaded post assemblies only half the applied force compresses one of the posts until its preloading opposite member breaks free. With the measured 43,000 lbs or calculated maximum 75,000 lbs, preload is never expected to be fully lost.

VERTICAL FORCE

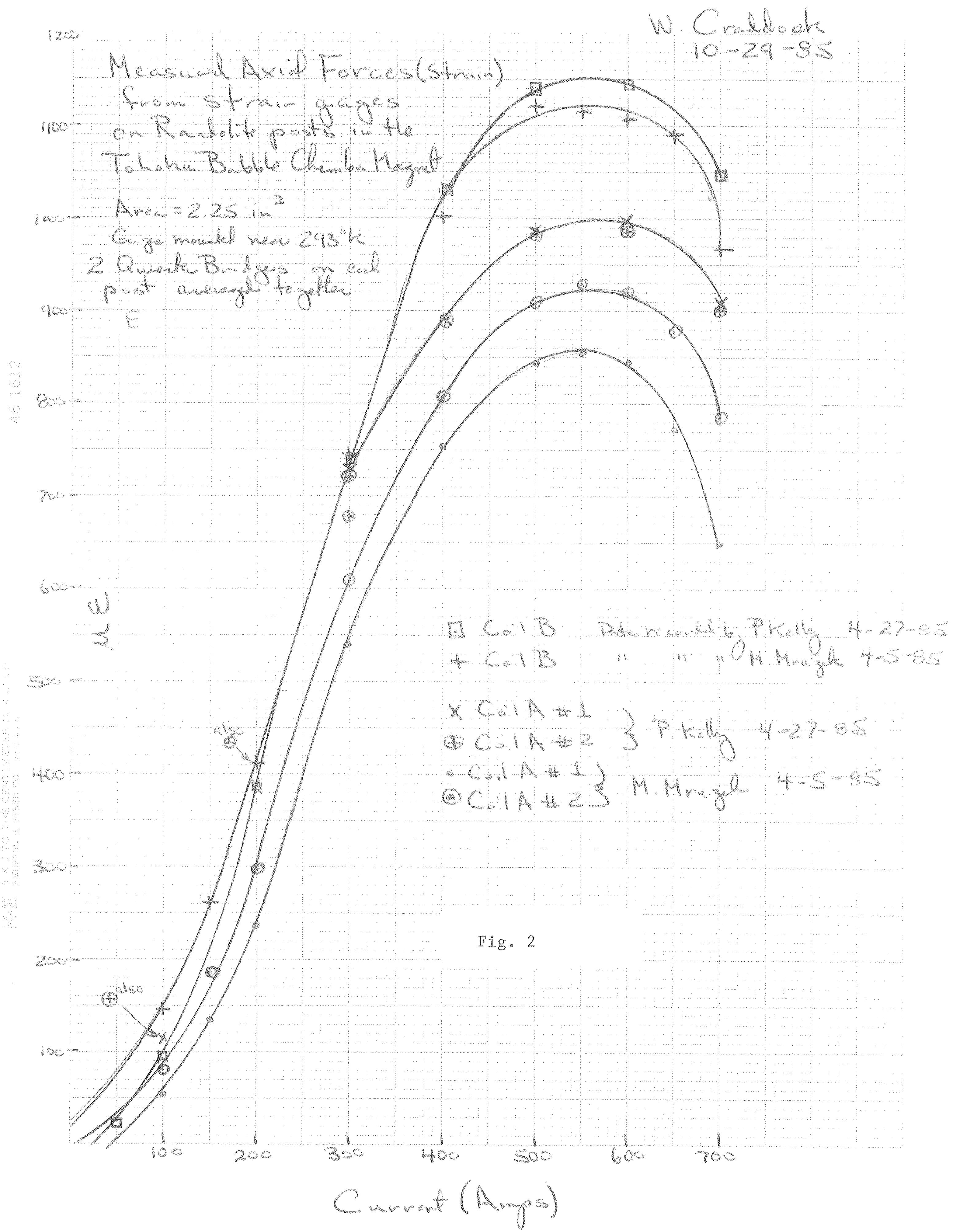
The vertical decentering force is the most reliable and accurately measured electromagnetic force in the entire system. These forces were measured with custom built internally strain gaged 7075-T6 bolts at the top of the tension arms. See the appendix for the calibration sheets on these four bolts. Figure 8 is a plot of strain readings versus magnet current for 3 of the 5 arms. The A coil upstream arm cable had a nick in it and gave either zero or very low readings. Each strain gage bolt has its own calibration but only an average value of 5990 με at 75,000 lbs or 12.5 lbs/με will be used. Figure 9 is M. Mruzek's averaged readings for the run on April 5, 1985.

It is very clear from the two graphs that the downstream arms on both coils have a greater load than the upstream arms. This may be due to iron asymmetries or just "settling" of both coils together. In any event the maximum force in any of the arms is 635 x 12.5 lbs/με = 7900 lbs. This is only ~10% of the of the allowed 75,000 lbs per arm.



1000
900
800
700
600
500
400
300
200
100
Average Axial Strain (με) True
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
Magnet Current (amps)
Full discharge to zero amps between two readings at 600 amps
Extrapolation with hysteretic offset removed.
Average Axial Strain in Randolite
.VS.
Magnet Operating Current
Tohoku Bubble Chamber Magnet
Fermilab M.T. Mruzek 5-18-85

Fig. 1



W. Craddock
10-29-85
Measured Axial Forces (Strain)
from strain gages
on Raddlite posts in the
Tohoku Bubble Chamber Magnet
Area = 2.25 in²
Gages mounted near 293°K
2 Quarter Bridges on each post averaged together
⊡ Coil B Data recorded by P. Kelly 4-27-85
+ Coil B " " " M. Mrazek 4-5-85
x Coil A #1
⊕ Coil A #2 } P. Kelly 4-27-85
• Coil A #1
⊙ Coil A #2 } M. Mrazek 4-5-85
also
Current (Amps)

Fig. 2

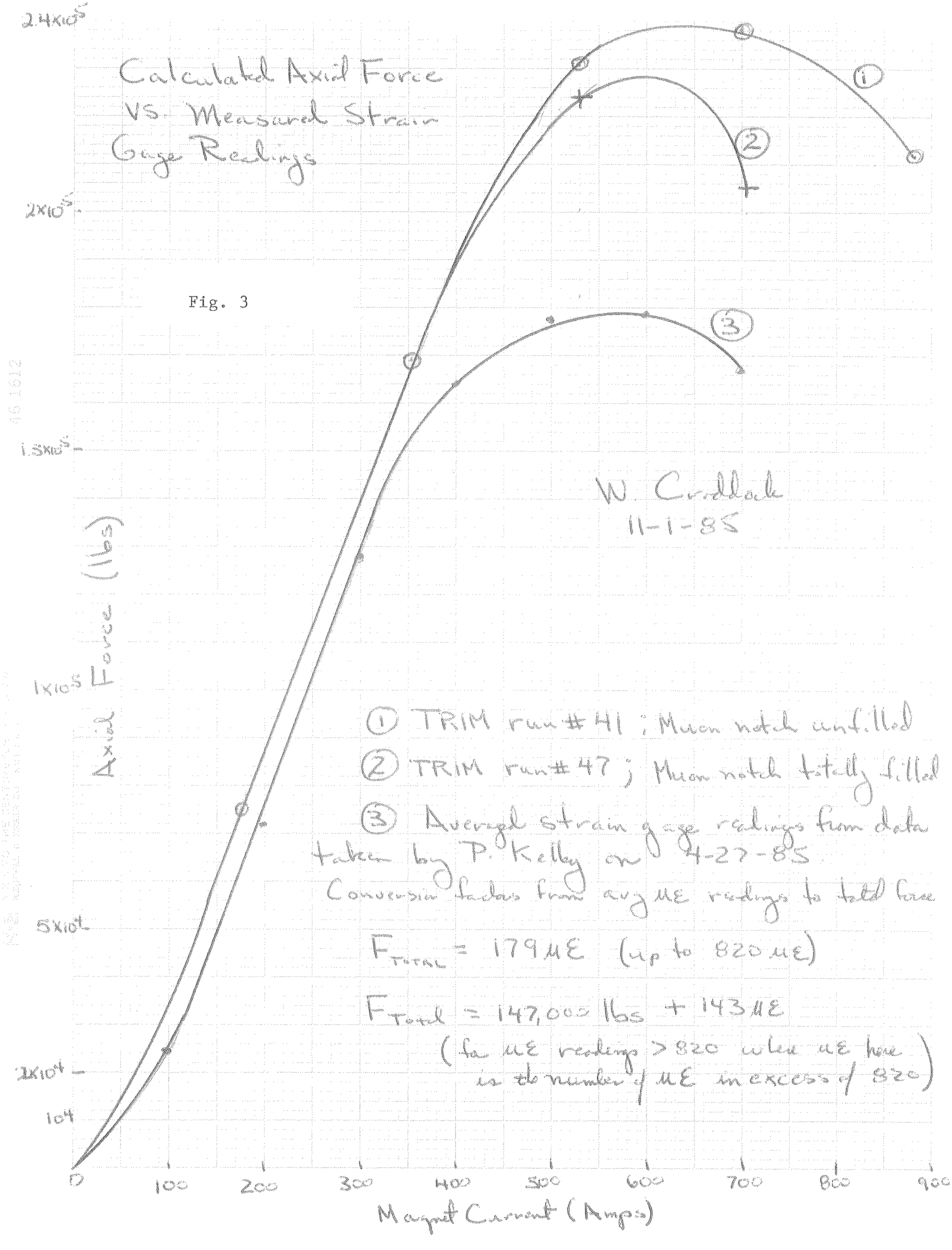
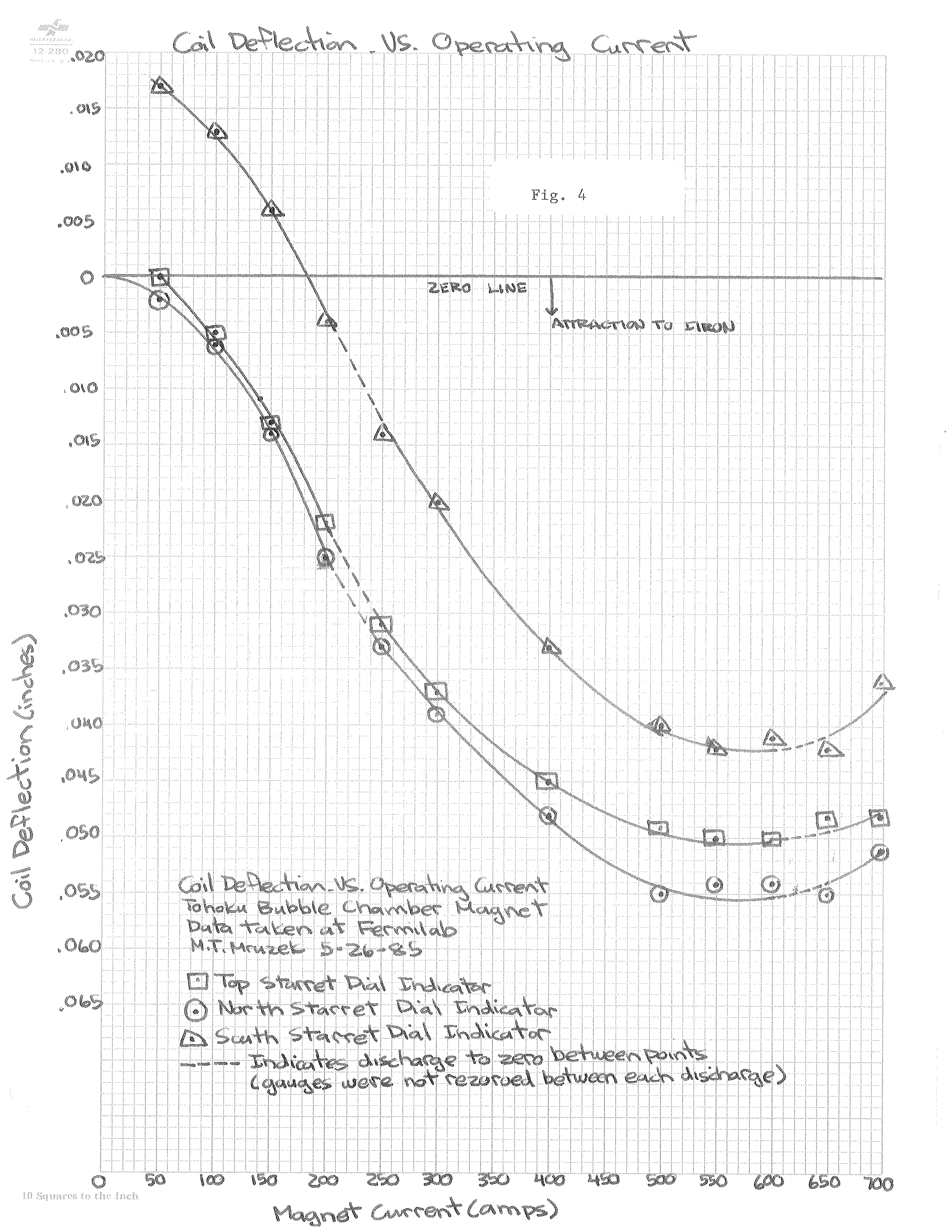

Calculated Axial Force
vs. Measured Strain
Gage Readings
W. Craddock
11-1-85
① TRIM run # 41 ; Muon notch unfilled
② TRIM run # 47 ; Muon notch totally filled
③ Averaged strain gage readings from data
taken by P. Kelly on 4-27-85
Conversion factors from avg με readings to total force
F TOTAL = 179 με (up to 820 με)
F Total = 147,000 lbs + 143 με
(for με readings > 820 where με here
is the number of με in excess of 820)
Axial Force (lbs)
Magnet Current (Amps)
2.4x10^5
2x10^5
1.5x10^5
1x10^5
5x10^4
2x10^4
10^4
0
100
200
300
400
500
600
700
800
900

Fig. 3


Coil Deflection VS. Operating Current
Fig. 4
ZERO LINE
ATTRACTION TO IRON
Coil Deflection VS. Operating Current
Tohoku Bubble Chamber Magnet
Data taken at Fermilab
M.T. Mruzek 5-26-85
Top Starret Dial Indicator
North Starret Dial Indicator
South Starret Dial Indicator
---- Indicates discharge to zero between points
(gauges were not rezeroed between each discharge)
Coil Deflection (inches)
Magnet Current (amps)
10 Squares to the Inch

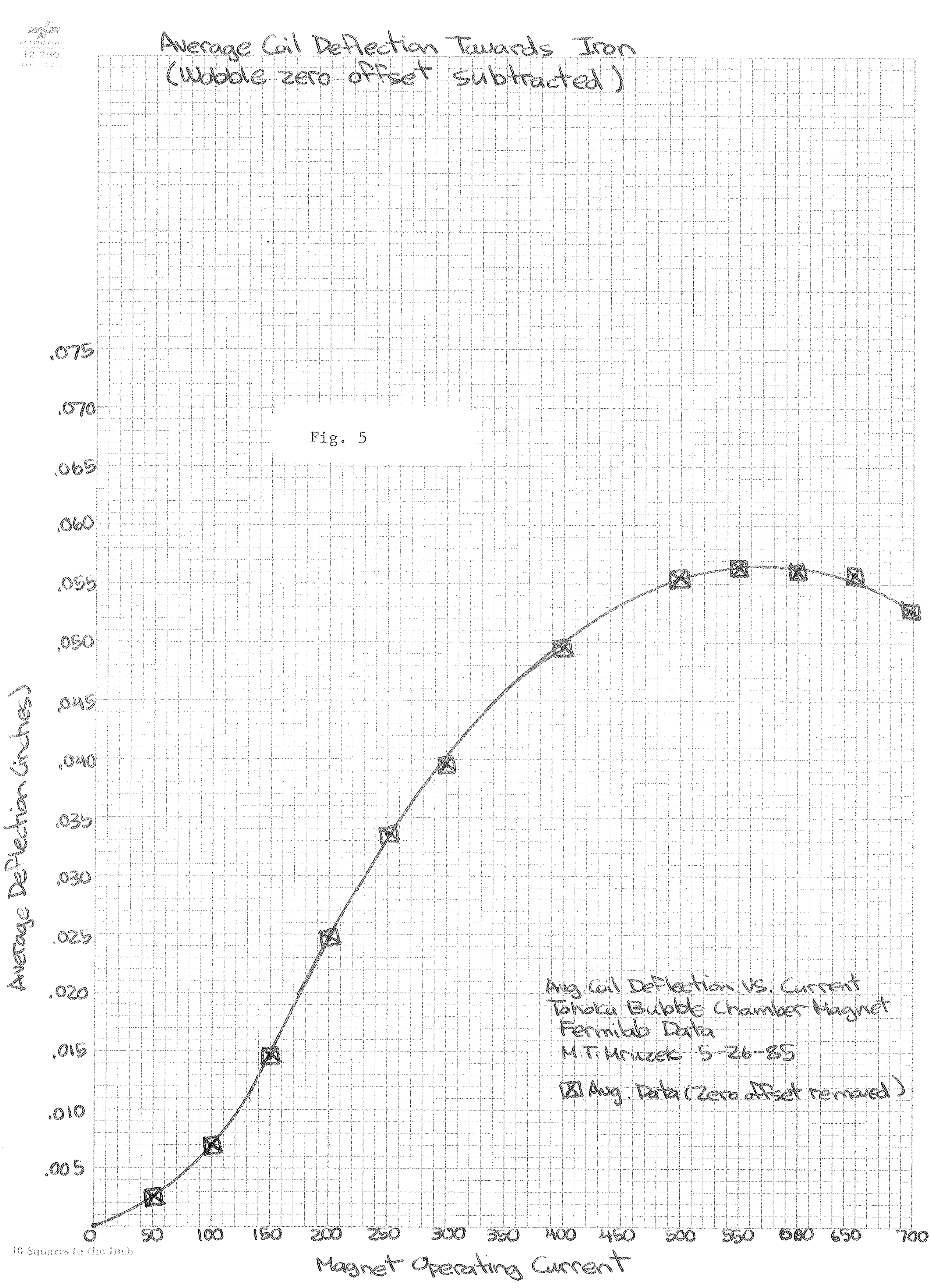

Average Coil Deflection Towards Iron
(Wobble zero offset subtracted)
.075
.070
.065
.060
.055
.050
.045
.040
.035
.030
.025
.020
.015
.010
.005
Average Deflection (inches)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
Magnet Operating Current
Avg. Coil Deflection VS. Current
Tohoku Bubble Chamber Magnet
Fermilab Data
M.T. Mruzek 5-26-85
Avg. Data (Zero offset removed)
10 Squares to the Inch

Fig. 5

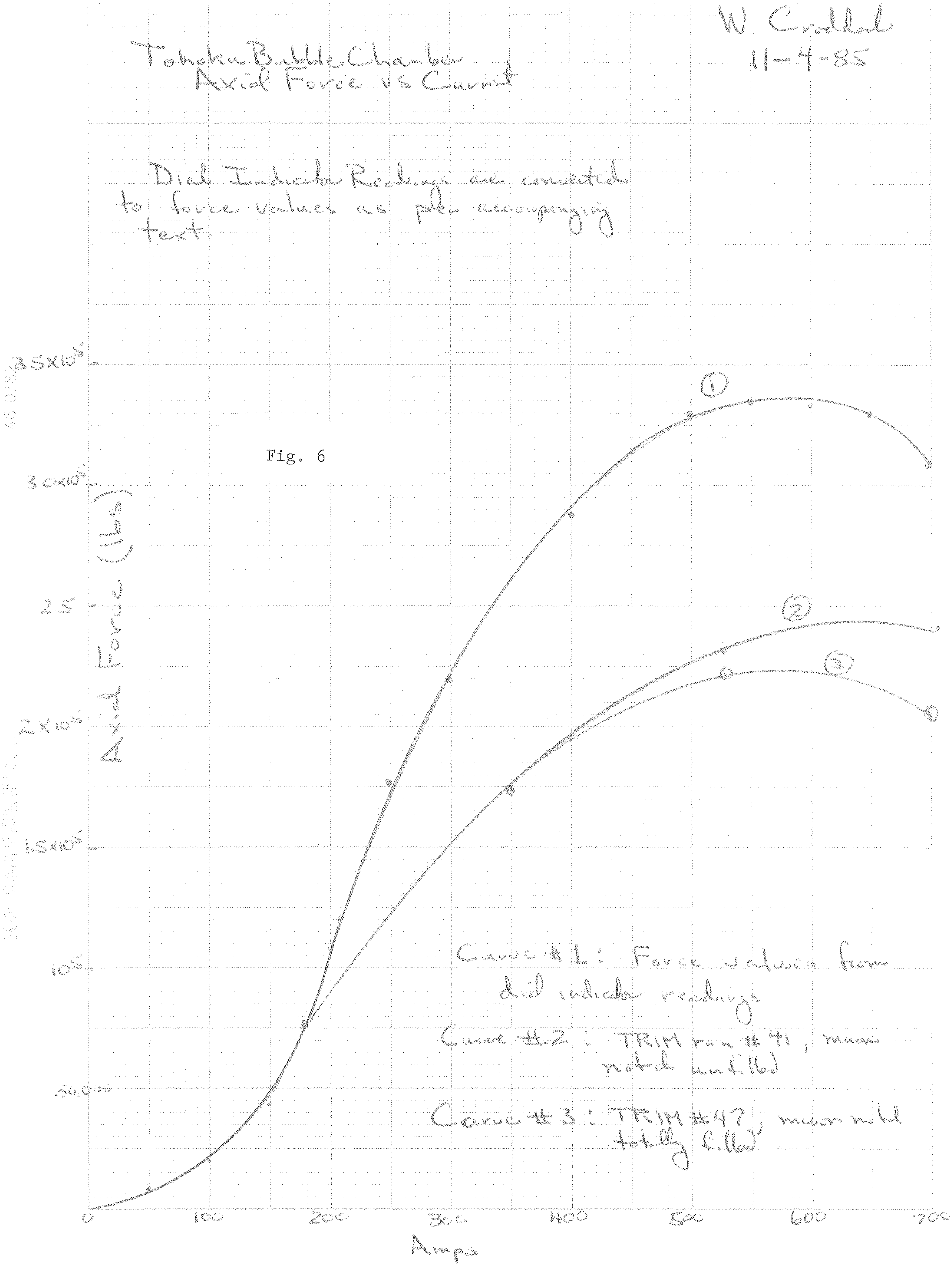

W. Craddock
11-4-85
Tohoku Bubble Chamber
Axial Force vs Current
Dial Indicator Readings are converted to force values as per accompanying text.
Axial Force (lbs)
3.5x10^5
3.0x10^5
2.5
2x10^5
1.5x10^5
10^5
50,000
0
100
200
300
400
500
600
700
Amps
1
2
3
Curve #1: Force values from dial indicator readings
Curve #2: TRIM run #41, muon notch unfilled
Curve #3: TRIM #47, muon notch totally filled

Fig. 6

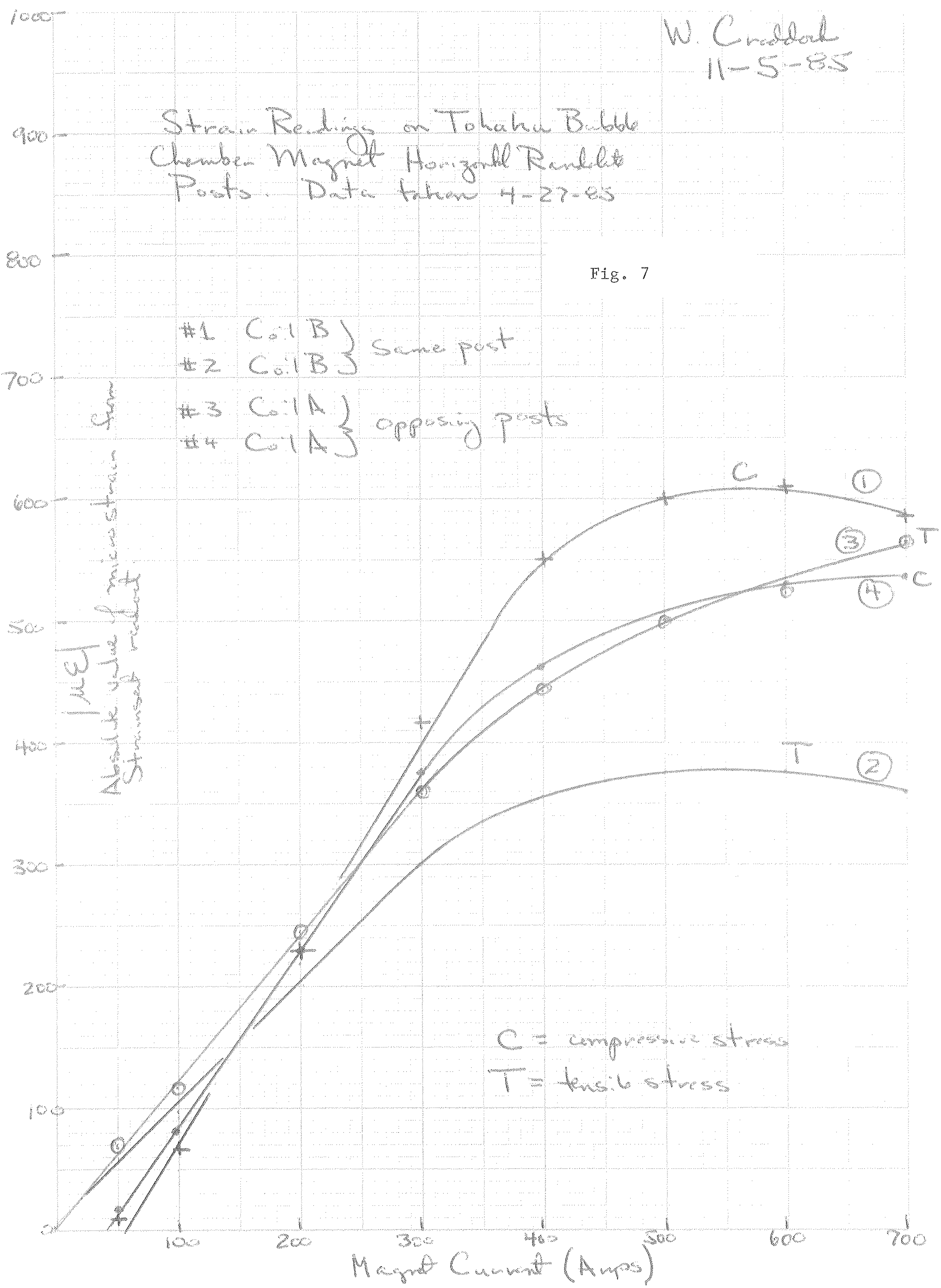
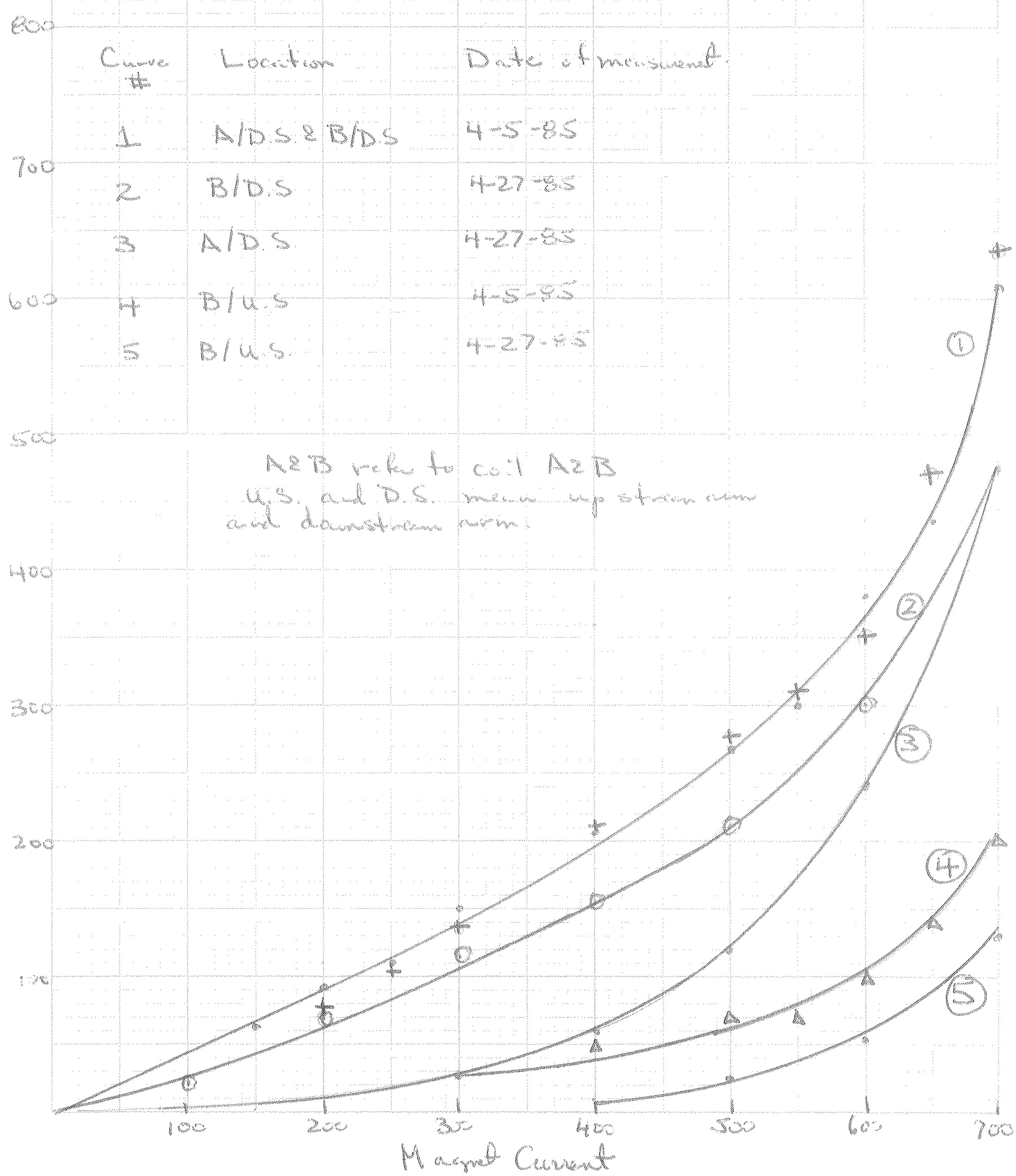

W. Craddock
11-5-85
Strain Readings on Tohoku Bubble Chamber Magnet Horizontal Restraint Posts. Data taken 4-27-85
#1 Coil B
#2 Coil B
Same post
#3 Coil A
#4 Coil A
opposing posts
Absolute value of microstrain from Strain gauge readout |με|
C = compressive stress
T = tensile stress
C
T
C
T
1
2
3
4
0
100
200
300
400
500
600
700
800
900
1000
Magnet Current (Amps)

Fig. 7

W. Craddock
11-4-85

Fig. 8

Strain Readings from Vertical Support Arms in the Tohoku Bubble Chamber Magnet



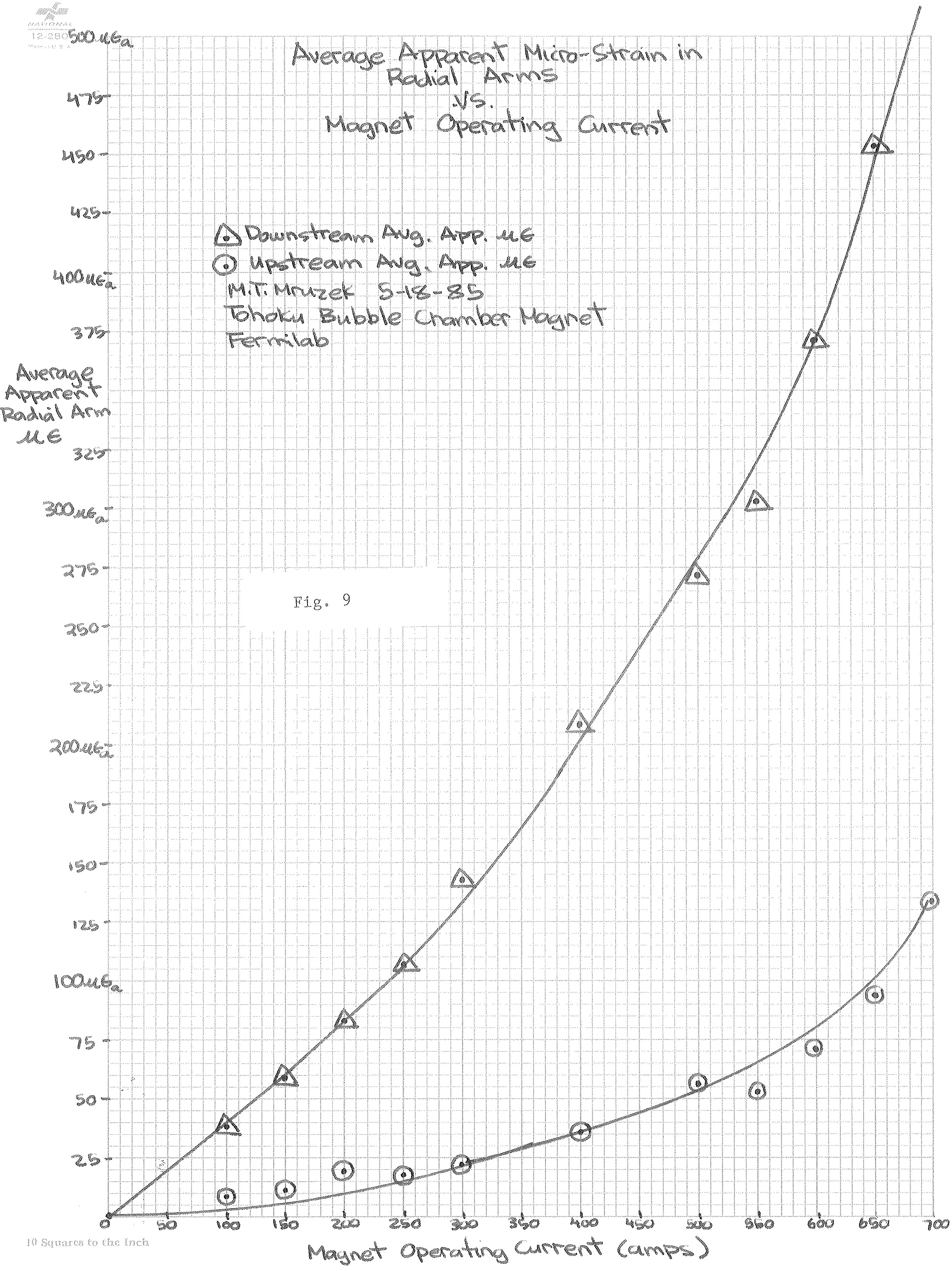


Fig. 9

10 Squares to the Inch

APPENDIX

MAGNET INSTRUMENTATION FOR ENGINEERING TEST RUN

M. Mruzek

The 30" magnet system has been extensively instrumented to provide technical information on its operation during the engineering run. The pertinent data is summarized in Figure 1.

All strain gages have a resistance of 350 Ω ± .3% and a gage factor of 2.07 ± 1%. They are Micro-Measurement type WK-06-125AD-350.

The principal method of measuring the axial load is by using 3 axial deflection probes. The probes are on B coil and use a G-10 "follower" rod to track the movement of the coil in the axial direction. Three nonmagnetic Starrett gauges indicate the amount of deflection. The probes will provide a clear indication of an approaching force reversal.

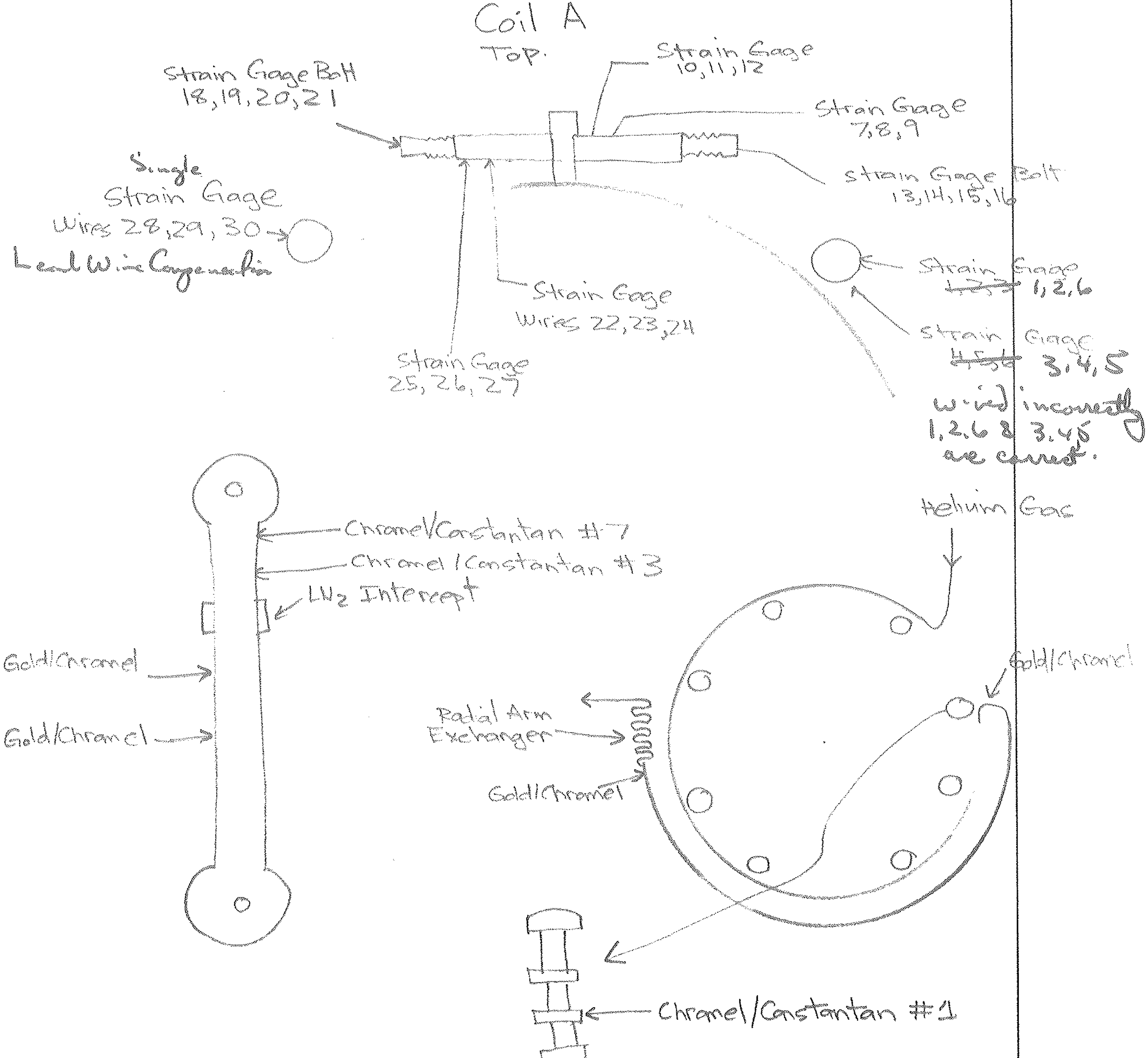
The radial decentering force, expected to be downward, was the most difficult force to estimate. Therefore all four stainless steel supports have been instrumented with strain gage bolts made of 7075-T6 aluminum. The bolts were instrumented for us by Strainsert with a full bridge. The pertinent information about the gages is attached. Note that all bolts have been successfully tested.

The electronic instrumentation for the coil system is summarized elsewhere in this documentation.

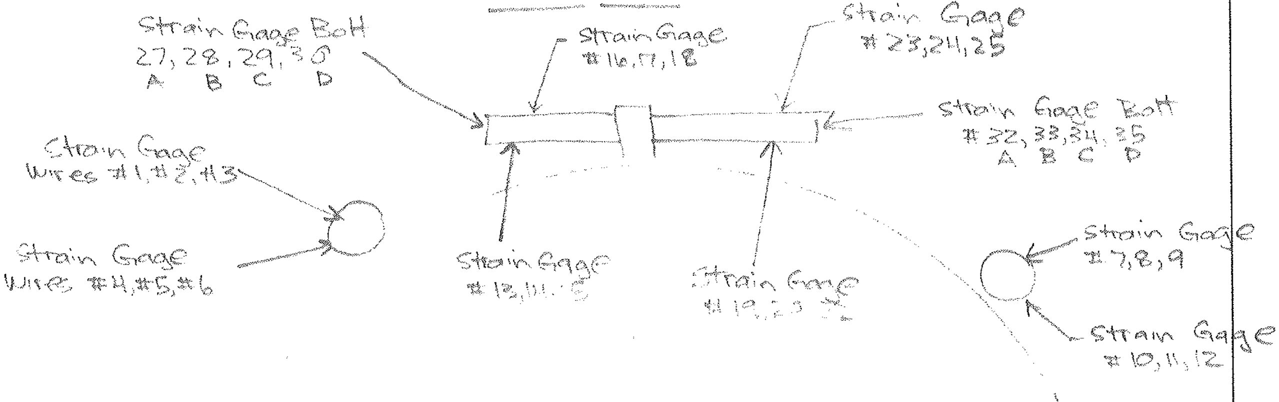
Coil A is on B side 2 V.i.s. Venus

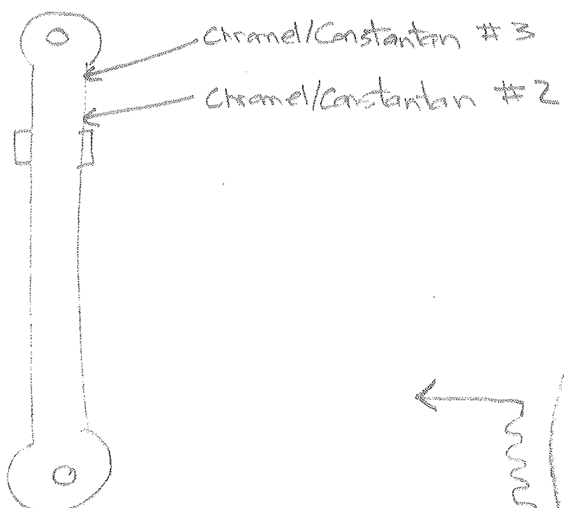
Magnet Instrumentation for Engineering Test, Run I M. Mruzek

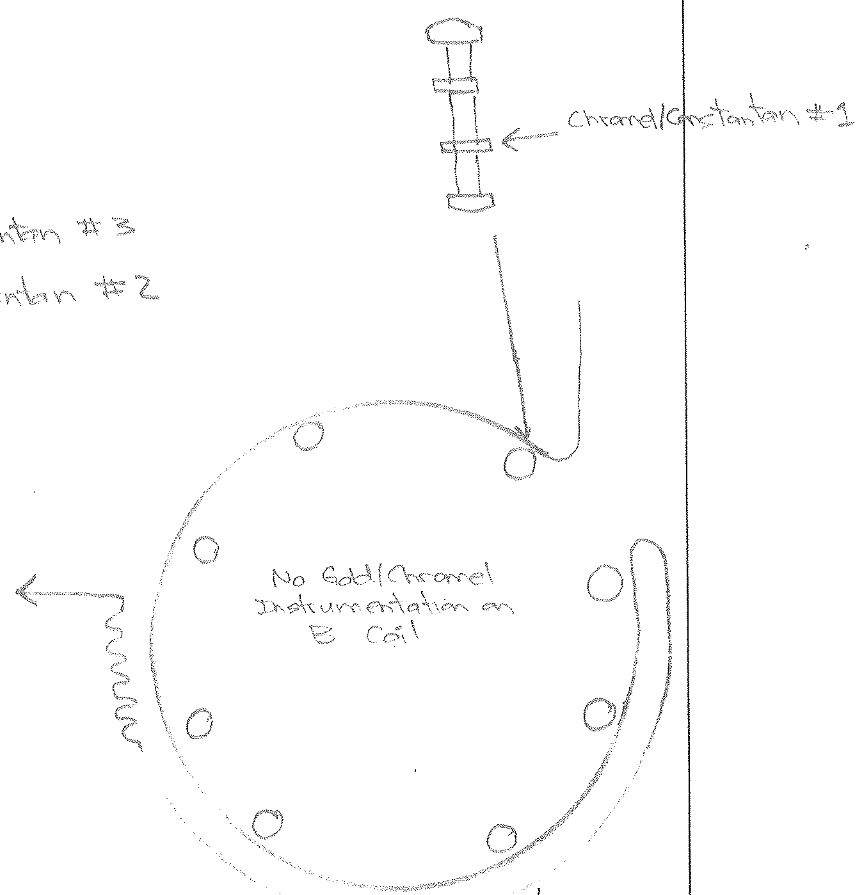
The 30" magnet system has been extensively instrumented to provide technical information on its operation during the engineering run. The pertinent data is summarized in Figure #1.



Coil B

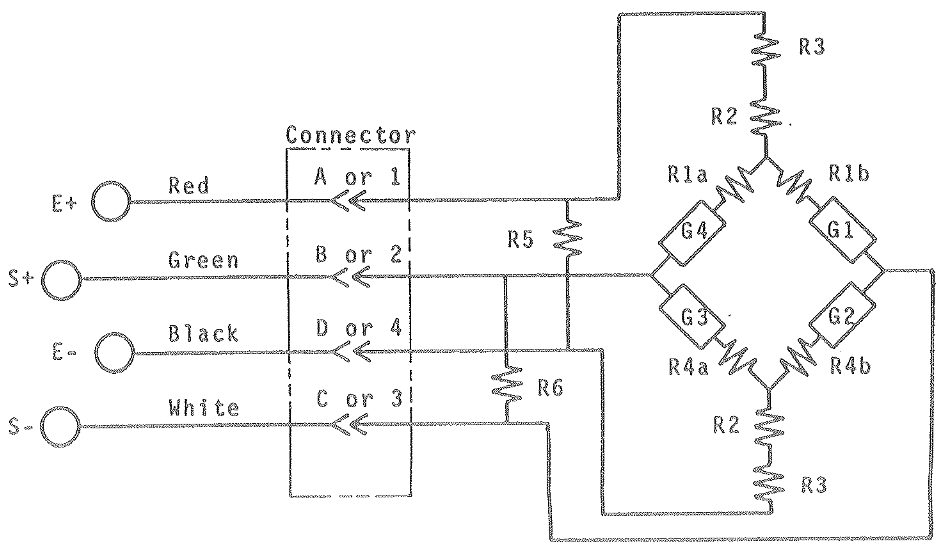

Strain Gage Bolt
27, 28, 29, 30
A B C D
Strain Gage
#16,17,18
Strain Gage
#23,24,25
Strain Gage Bolt
#32, 33, 34, 35
A B C D
Strain Gage
Wires #1,#2,#3
Strain Gage
Wires #4,#5,#6
Strain Gage
Strain Gage
Strain Gage
#7,8,9
Strain Gage
#10,11,12


Chromel/Constantan #3
Chromel/Constantan #2


Chromel/Constantan #1
No Gold/Chromel
Instrumentation on
B Coil

STRAINSERT

Full Bridge
Trim & Compensation Resistance
Connector Pin Identification
&
Cable Color Code



Legend:

Strain Gages: G1, G2, G3, and G4
Excitation : E+, and E-
Signal : S+, and S-

Bridge Trim & Compensation Resistors when required, as follows:

Initial Bridge Balance	: R1a or R1b	Temperature Compensation:	R4a or R4b
Signal Trim	: R2	Modulus Trim	: R3
Excitation Res. Trim	: R5	Signal Res. Trim	: R6

(Applicable notations and codes conform to Western Regional Strain Gage Committee's recommendations.)

Note: Increasing tension strain in gages G1 and G3, and compression in gages G2 and G4, induces increasing signal of positive polarity.

Form S-113A

PROOF LOADING DATA

Fermi Lab Batavia, IL Customer P.O. No. 99349	Q-6167 Strainsert Job No. Date: 6/3/82 Sign: CGH

Transducer		Gaging		Proof Loading		
S/N	Description	Type	Ohms	°F	Load LBS.	Signal με
-1	Threaded Stud, as supplied Aluminum Alloy 7075-T6 (SA-F) 2½-4NC x 7-3/4 (350Ω/150°F) C To KoSo	C	350	76	75,000	6278
-2	Same	C	350	76	75,000	5828
-3	Same	C	350	76	75,000	6026
-4	Same	C	350	76	75,000	5836

Notes:

1 - Loading on ☒ Strainsert Dead Weight Calibration Device
☐
Last Calibration Date: 7/6/81

2 - Readings on ☒ Model HW1-D ☐ Model TN8C ☐ Model TN20C
☐
Last Calibration Date: 6/1/82 Gage Factor Setting: 2.0

3 - To convert mv/v to με, use 1-mv/v = 2000με

08A

CALIBRATION DATA

Fermi Lab Batavia, IL	Q-6167 Strainsert Job No.
	Date: 6/3/82
Customer P.O. No. 99349	Sign: CGH

Transducer: Threaded Stud, as supplied by Fermi
Aluminum 7075-T6
(SA-F) 2½-4NC x 7-3/4
(350Ω/150°F) C To K So

Gages: EA-13-100ZF-350
Service Temp.: 150°F Max.
Calib. Temp.: 76°F

Type: C (Bendix PT02H-8-4P)
Ins. Res.: Over 10,000 megohms
S/N: Q6167-1

Load LBS.	Straight Line Signal με	Deviation, με			Rep. με
		Run 1	Run 2	Run 3	
0	0	0	0	0	0
15,000	1,253	-15	-13	-14	2
30,000	2,506	- 2	0	- 1	2
45,000	3,759	+ 9	+ 9	+ 9	0
60,000	5,012	+14	+16	+15	2
75,000	6,265	+13	+15	+14	2
60,000	5,012	+19	+21	+20	2
45,000	3,759	+21	+23	+22	2
30,000	2,506	+11	+10	+11	1
15,000	1,253	- 5	- 6	- 5	1
0	0	0	0	0	0
	Hysteresis	12	14	13	

Calibration Analysis:

Non-Linearity:	16	parts in	6,265	=	0.26%
Repetition					
Loading :	2	parts in	"	=	0.03%
Unloading:	2	parts in	"	=	0.03%
Zero Load:	0	parts in	-	=	-
Max. Load:	2	parts in	"	=	0.03%
End Point :	15	parts in	"	=	0.24%
Hysteresis :	14	parts in	"	=	0.22%

1. All με readings are with gage factor setting of 2.0.
2. To convert to mV/V, divide με values by 2000.