Fermilab

UPC 135

August 1980

Summary of RT Measurements

TA200-350: June 1980

Section 3.3 - The Amateur Magnet Builder's Handbook

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*Sections without UPC Nos. are in UPC No. 86.

3.3 Summary RT Measurements TA200-350, June 1980

This is a summary of the room temperature measurements of the first 150, 21 ft. dipole coils. During this period, a number of dimensional changes in the coils have been made in order to correct the multipole moments. The analysis here studies the overall distribution of the first four moments, b_1, b_2, b_3, and b_4, and the response to intentional shimming of the magnet dimensions. Since it is implicit in the design of our Magnet Factory that the room temperature measurements supply information to correct the coil dimensions, it is imperative that we check that the room temperature measurements are indeed able to function at a satisfactory level of accuracy to accomplish this goal.

Statistical Distributions

We first examined the normal quadrupole moment b_1. The units used are the magnitude of the quadrupole field at 1 in. divided by the dipole field at the origin times 10^4. The quadrupole moment of a dipole coil is governed by the right-left asymmetry of the coil. It is clear that if the coil is compressed a little bit on the right hand side that the field there will be stronger than it is on the left, and we will generate a positive quadrupole moment. In addition, if a coil is placed within the iron yoke so that it is a little off center, a quadrupole moment will also be generated. This is clear because if the coil is placed a little bit closer to the iron on the right, it will make a field that is a little bit stronger on the right than on the left. In fact, essentially the only moment that is generated by placing the coil off center relative to the axis of the iron is a quadrupole moment. Roughly about .27 units of quadrupole moment are generated per mil of displacement (Table 1.5.14). Thus, there are two sources of quadrupole moment:

right-left dimension asymmetry in the coil and the insertion of the coil off center relative to the iron. The room temperature measurements are made without the iron yoke being placed around the coil, and hence only monitor the asymmetry of the coil as it is produced in the Factory.

The room temperature measurmenets are relative measurements. That is, the probe must be calibrated. This calibration is described in Section 3.2. We will compare later the room temperature measurements with those made with the completed dipole as measured at MTF. The calibration procedure is such that there should be a linear relationship between the RT and MTF measurements. We will examine this relationship shortly.

Fig. 3.3.1 shows the distribution of b_1. Fig. 3.3.1a is the distribution for all 138 coils for which good measurements exist. Some 12 coils which were either experimental or had structural defects are not included. During the period that these coils were made, there were four different arrangements of the asymmetry shims: For coils between 245 and 259, there was a 6 mil shim; between 261 and 299, there was a 4 mil shim; and for coil numbers greater than 300, there was a 2 mil asymmetry. Figs. 3 3.1b, c, d, e show the distribution resulting from these various configurations. Fig. 3.3.2 shows the average value of the quadrupole moment as a function of the asymmetry in mils. A perturbation calculation has been done, and the slope of these lines should be given by 1.04 units per mil. The observed slope is .75 units per mil. Within the statistical errors, the agreement is satisfactory. If the effect is less than that calculated, it could be due to the fact that the shims do not uniformly compress the coil azimuthally.

It is interesting to examine these measurements also in order to find out what the errors are in the manufacturing process. In order to do this Fig. 3.3.3 shows the histogram of the coils that we have been considering, but the systematic shifts due to the asymmetrical shimming have been removed. Repeated measurements of b_1 on the standard Magnet No. 54 show that the rms deviation of a single measurement is $\sim$ 0.3 units. Hence, the spread of b_1 observed in these coils is mainly due to fluctuations of the coil uniformity during manufacture.

As mentioned above, the room temperature probe is calibrated from the measurements made at MTF. Fig. 3.3.4 shows the room temperature measurements of b_1 plotted against those measured at MTF. The line should have a slope of 45^o which depends only in a very nonsensitive way upon the dimensions of the measuring probe, and the intercept of this line with the axis is the main unknown constant that we try to derive from the MTF measurements. The line shown is the least squares fit to the points, and it can be seen that the slope is close to 1, but that the intercept is about -1. This means that the origin of the room temperature histograms shown in Fig. 3.3.1 and 3.3.2 really corresponds to a magnetic moment of about -1 unit. The spread of the points around the line are indicative of the errors in measuring b_1 in both the room temperature measurement and in the MTF measurement and the accuracy with which the coil can be placed on the axis of the yoke. As indicated above, the RT and MTF random errors are small, and so one can attribute the whole spread of these points to the error in yoke centering. The spread is consistant with an error of about 5 mils in Δx. This number is similar to what was observed in the old Type 35 cryostats with magnet numbers below 200 (see Section 3.2).

Sextupole Moment

During the period that we are considering here, shim changes to shift the sextupole moment were also made. The effect of shim changes on the sextupole moment has been well studied in the past. In fact, the outer and inner coils were shimmed together in order to adjust the sextupole and decapole moment. Hence, we will only show here the histogram in Fig. 3.3.5 of about 42 magnets past Serial No. 300 in order to indicate the magnitude of the fluctuations that can be expected in b_2 when the shimming is left fixed. The fluctuations in b_2 for a 1 mil change in the key angles is .7 units. Whether or not the wide spread shown in Fig. 3.3.5 of fluctuations in b_2 is due to fluctuations in the key angles is not known at this point. However, since these angles are carefully controlled, it is more likely that the fluctuations in b_2 arise from long range compaction variations in the winding itself. The sextupole moment is the most difficult of all of moments to control accurately.

Again we need to investigate the calibration of the probe, and Fig. 3.3.6 shows a plot of the room temperature values versus the MTF values. It is seen that there is a systematic shift in the curve. The line shown is the least squares fit. The slope should be 1, and again depends only insensitively upon dimensional accuracy of the probe. It is seen that the intercept for b_2 from the room temperature measurements versus MTF is -.93. The spread in the values shown is primarily an indication of the room temperature errors as the assembly of the magnet into the iron yoke does not give rise to systematic errors as is the case for the quadrupole moment.

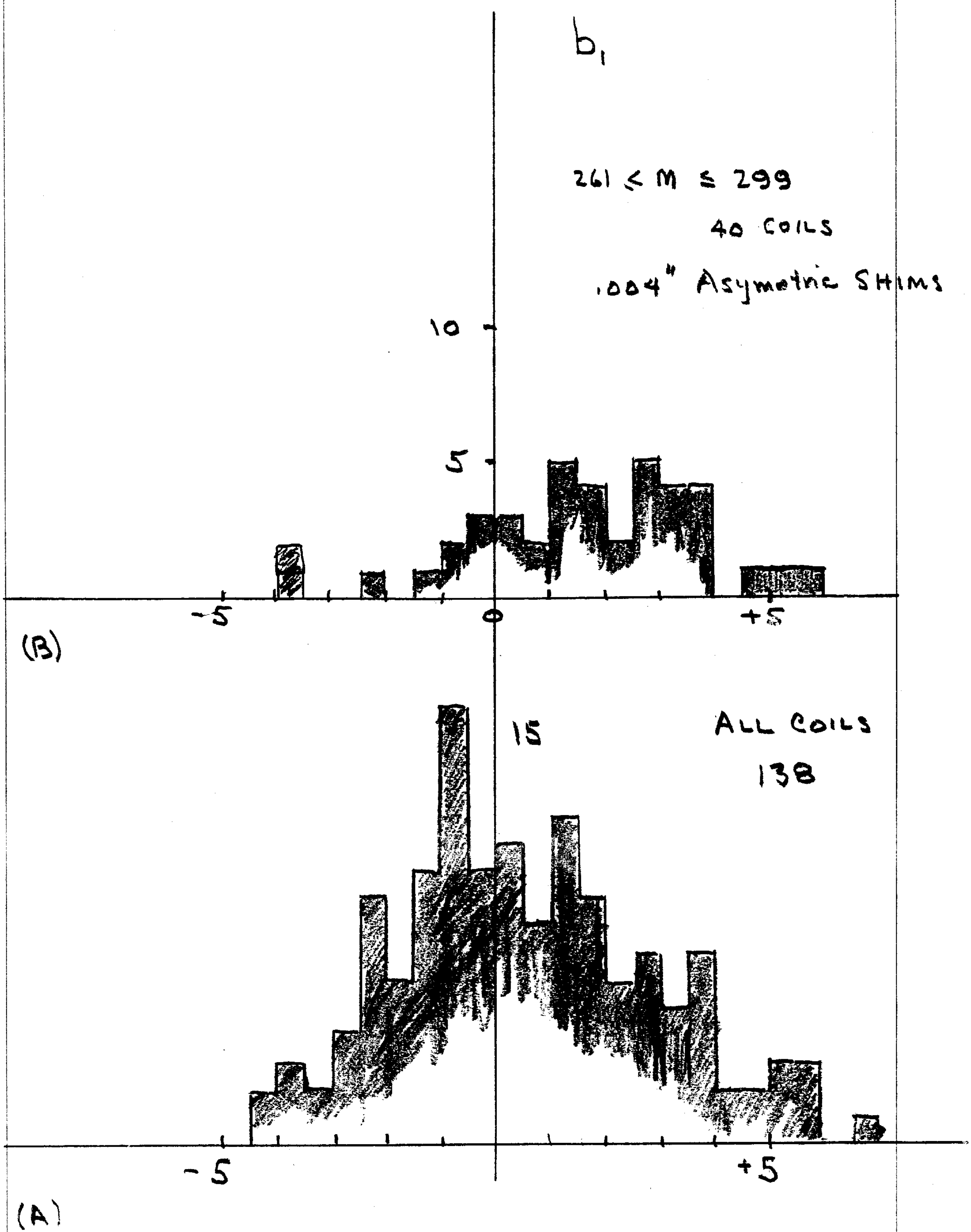

b₁
261 ≤ M ≤ 299
40 COILS
.004" Asymetric SHIMS
10
5
-5
0
+5
(B)
15
ALL COILS
138
-5
+5
(A)

FIG 3.3.1

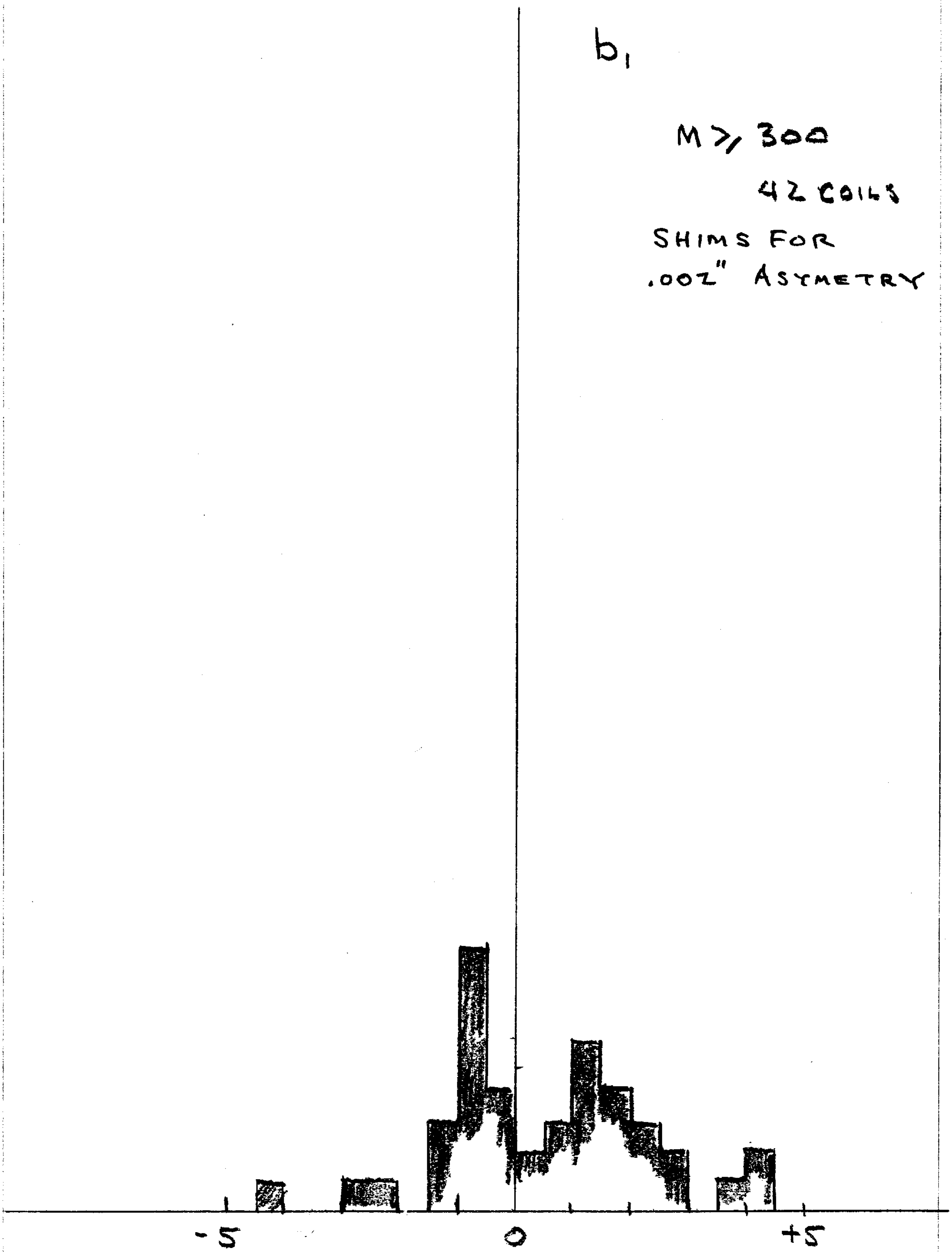


FIG 3.3.1C

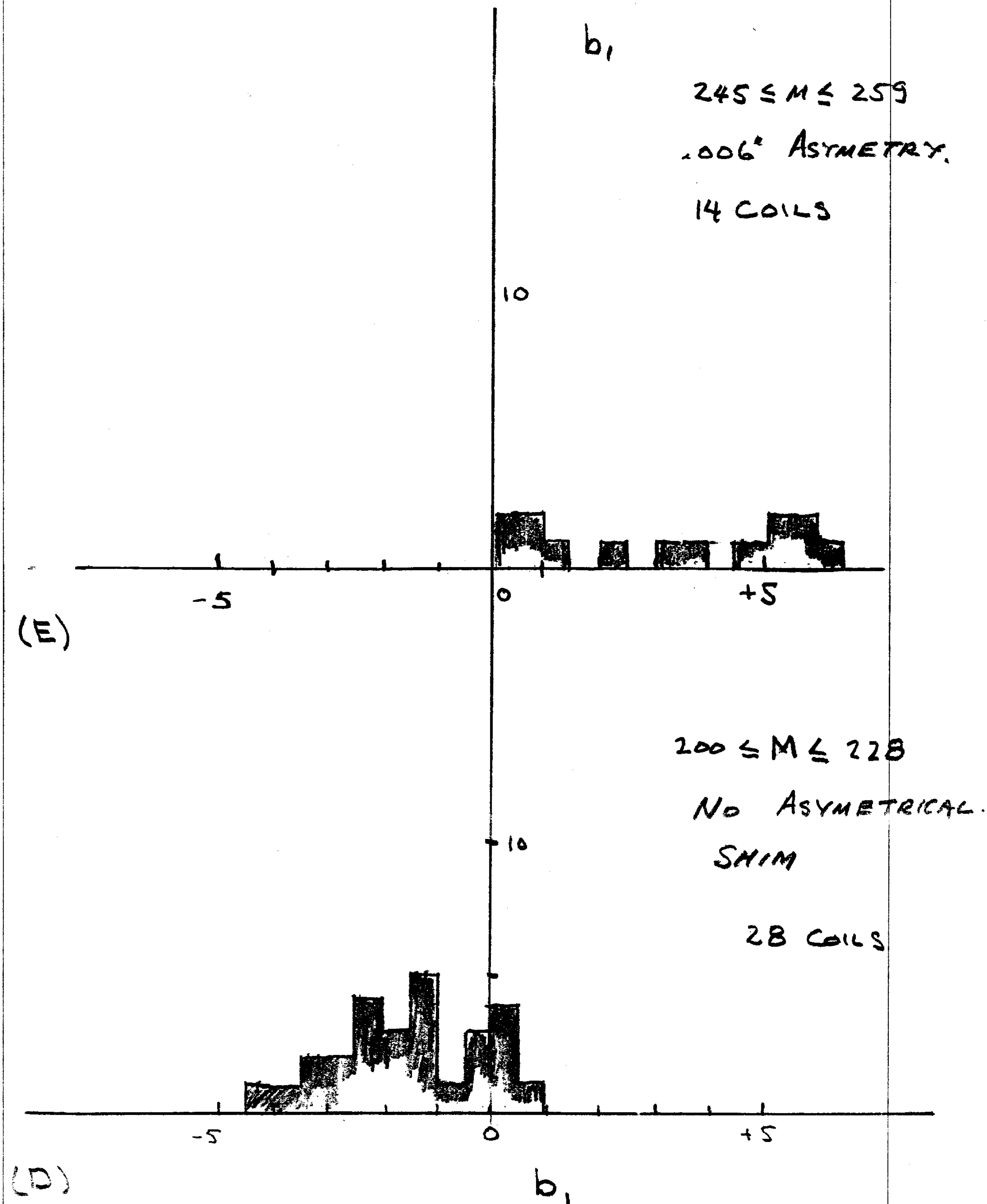

b_1
245 ≤ M ≤ 259
.006" ASYMETRY.
14 COILS
10
-5
0
+5
(E)
200 ≤ M ≤ 228
NO ASYMETRICAL
SHIM
10
28 COILS
-5
0
+5
(D)
b_1

FIG 3.3.1 D, E

EFFECT ON b_1 OF ASYMETRICAL SHIMS.

Δ	
0	−1.38
2	.48
4	1.59
6	3.24

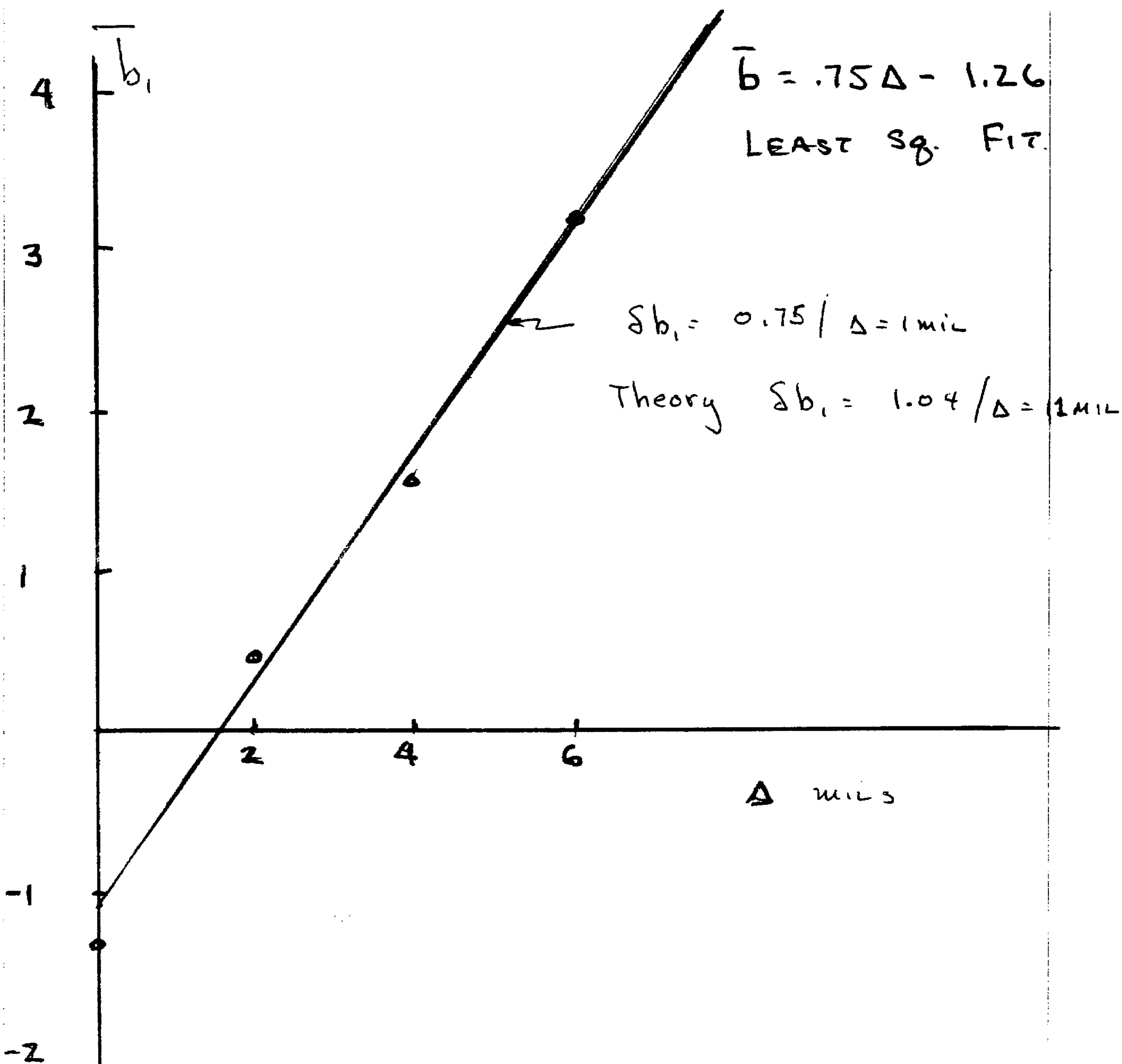
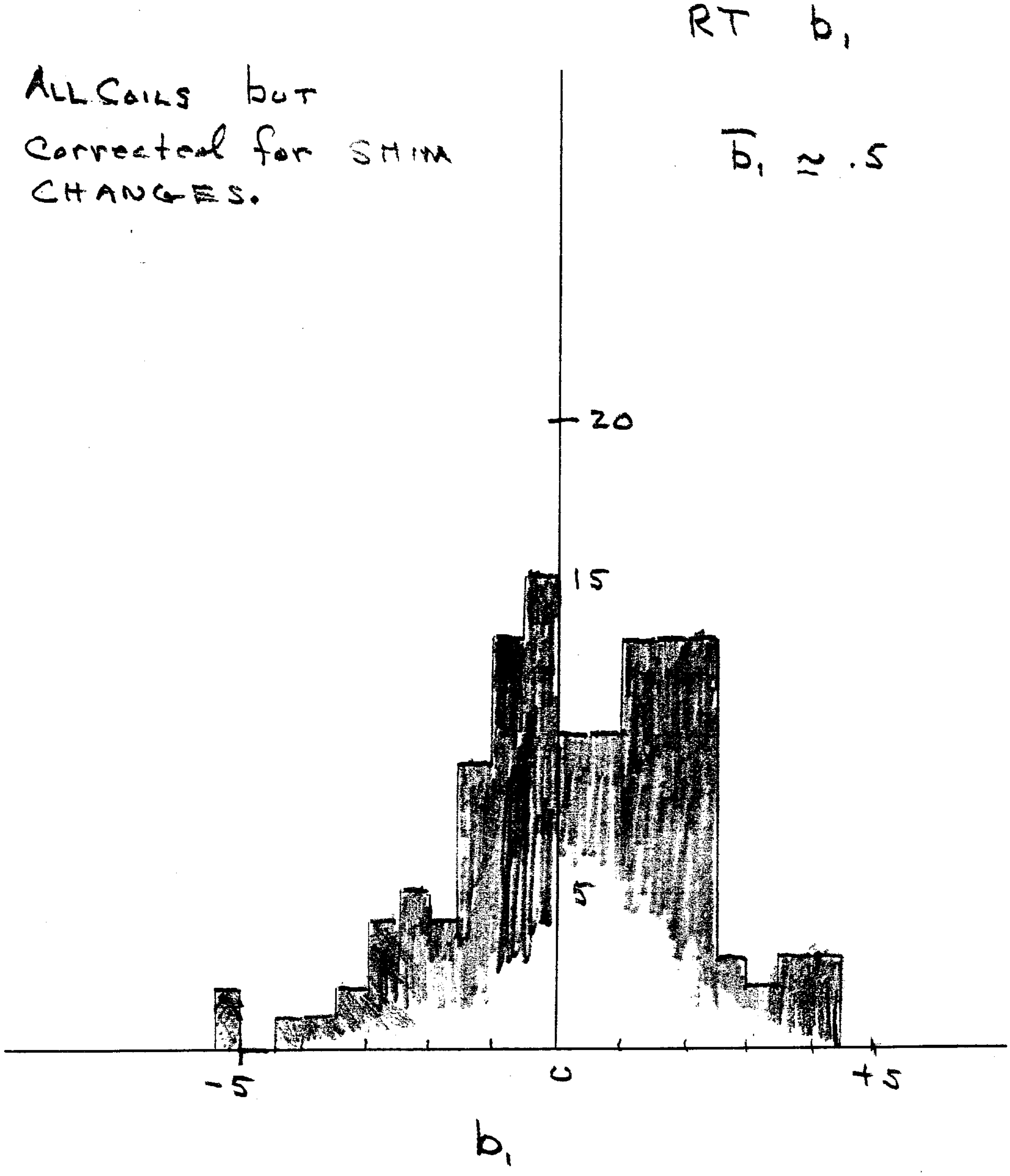


FIG 3.3.2



RT b_1
ALL COILS but
Corrected for SHIM
CHANGES.
$\bar{b}_1 \simeq .5$
20
15
5
-5
0
+5
b_1

FIG 3.3.3

RT vs MTF b_1

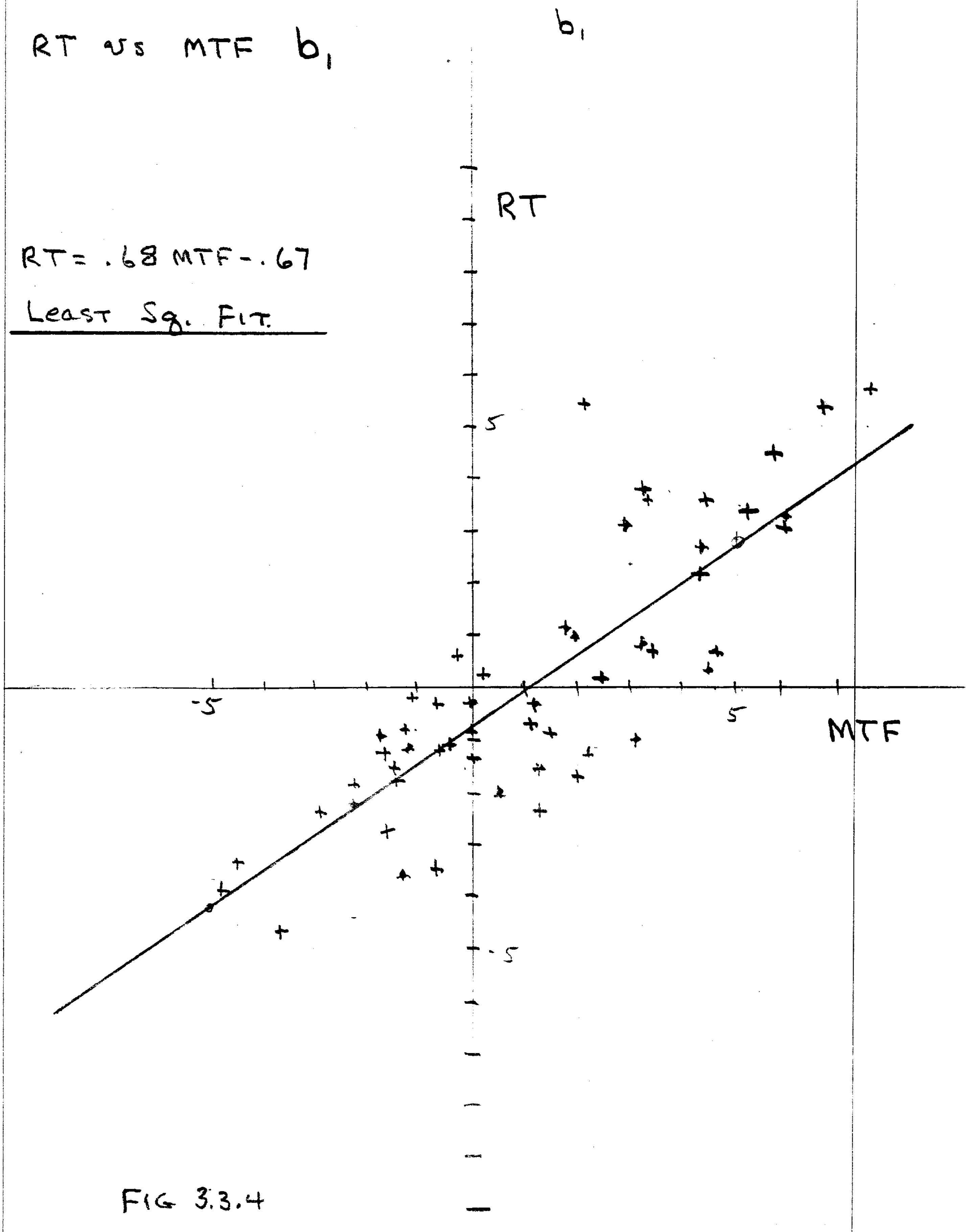


FIG 3.3.4

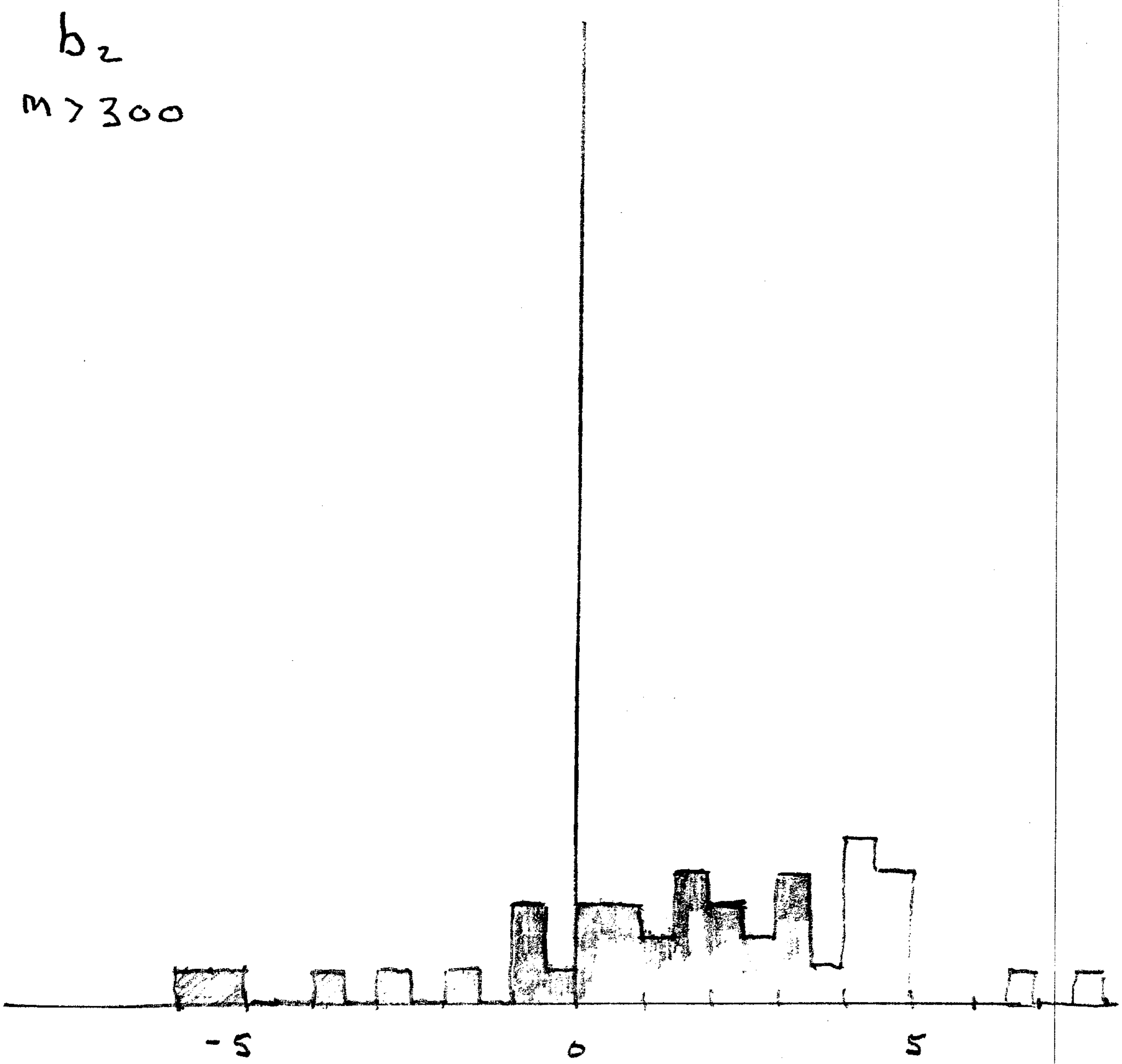


FIG 3.3.5

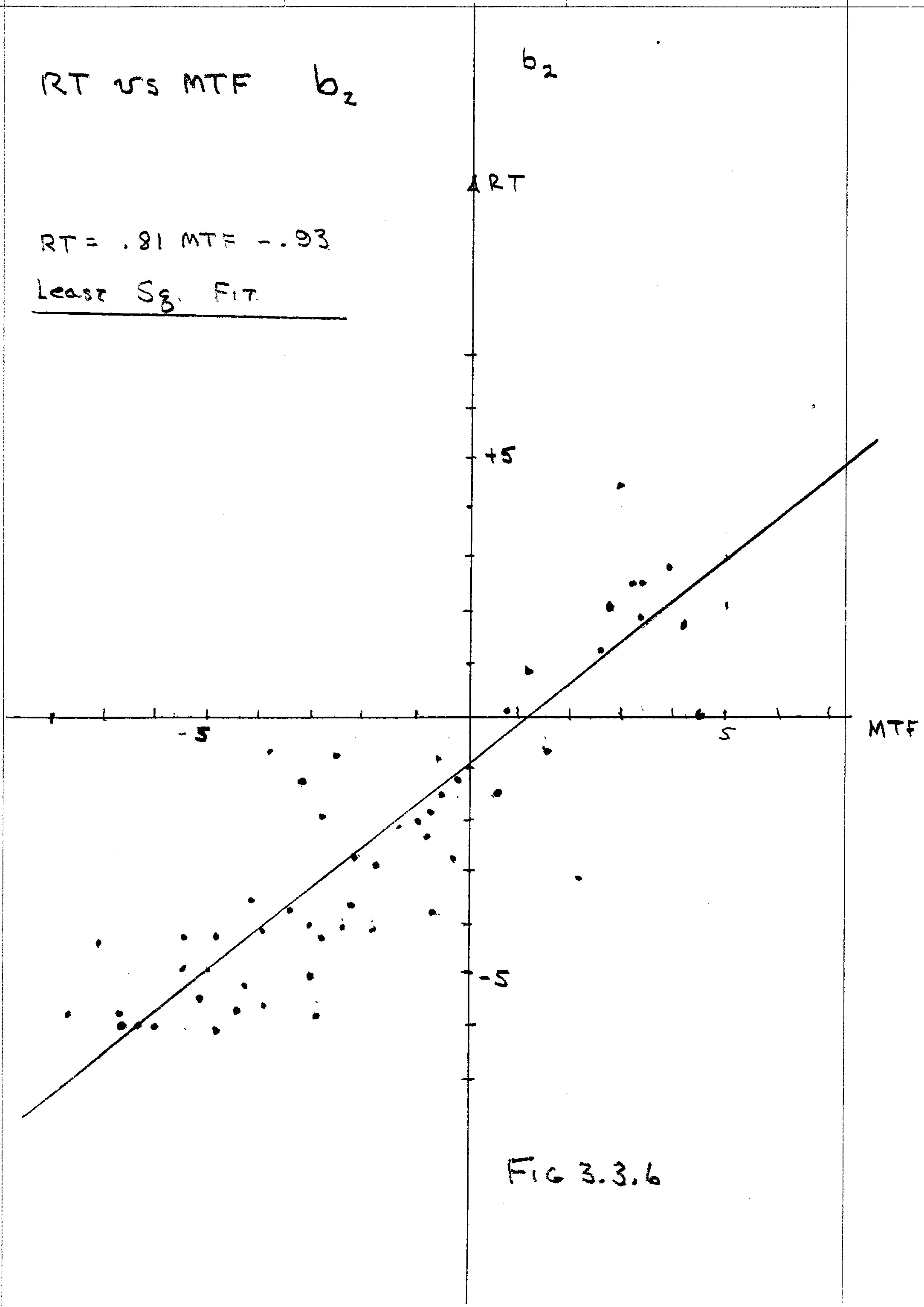


FIG 3.3.6