FITTING OF LIBERATION MODEL PARAMETERS TO DAVIS TUBE TEST DATA

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Fitting of Liberation Model Parameters to Davis Tube Data

After studying the direction work in mineral liberation has taken for the past twenty years, and in particular the more recent five to ten years, it has become apparent to me that at least for the magnetic taconite process, the use of the Davis tube ideal magnetic separator on individual size fractions of process feed can provide useful data on liberation. A study made by the writer[1] of process feed samples to twelve magnetite concentrators indicated a reasonable conformity between Davis tube concentrate magnetite grade and size fraction mean particle size relationships and what was predicted using the idealized "random liberation model" formulation[2] with appropriate specific gravities for magnetite and waste minerals. This then suggests that the magnetic taconite liberation behavior can be characterized by three parameters (given the two specific gravities): (1) magnetite ore feed grade; (2) an average mineral grain size; and (3) an average size fraction particle size.

Of the twelve sample sets noted above, only two indicated significant deviations from the shape of the concentrate grade-particle size relationships displayed by the "random model." A BASIC computer program (LIBFIT.BAS) has therefore been written to obtain the best fit of the two parameters: magnetite feed grade of the ore and average mineral grain size for the "random model," to Davis tube data on size fractions of ground taconite. The program is relatively simple in concept, in that it first seeks a value of average mineral grain size, which minimizes the sum of squares of differences in the measured and calculated Davis tube concentrate grades for an estimated magnetite feed grade of the ore. It then holds the optimum average mineral grain size constant and searches for the optimum magnetite feed grade for that mineral grain size. It continues to switch back and forth, looking at first mineral grain size and then magnetite ore feed grade for some 18 iterations, which then provides a best fit estimate of the two parameters.

A copy of the BASIC program is shown in Table 1, and the results of a trial calculation for the Davis tube data shown in Table 2 are shown in Table 3.

Barren Waste Dilution

It was observed in the work noted above that there could also be a fourth parameter, barren waste dilution, which could play a considerable role in improving the fit of some of these Davis tube concentration data. This result can be rationalized as the combined effect of lean ore dilution in mining and the tendency for some magnetite ore formations to be banded with higher concentrations of magnetite and very lean or barren bands of waste (silica, silicates and other non-magnetic minerals). To allow for this possibility when dealing with the feed of crude ore mixtures to the iron ore concentrator, the previously described LIBFIT.BAS program has been modified to include this dilution parameter, based on the assumption that this "barren waste dilution" contains no magnetite and that its composition and, hence, its specific gravity is the same as the waste mineral in the idealized "random liberation model." The assumption is further made that the occurrence of this "barren waste dilution" has no significant effect on the concentrate grade of magnetite achieved in the Davis tube test on individual size fractions of the broken crude ore.

In the expanded BASIC program, LIBFIT4.BAS, the option has also been added to use weighting factors to obtain a best fit of some weighted combination of Davis tube concentrate magnetite grade, concentrate weight recovery and crude ore magnetite feed grade. In this example, the factors are 0.5, 0.3 and 0.2 respectively. Copies of these programs are available on request. Plots comparing the actual and calculated results of the LIBFIT4.BAS program are included as Figures 1 through 10.

Application of Fitting Program to Existing Davis Tube Data

The extensive Davis tube data contained in the 1975 article referenced above was fit using the LIBFIT4.BAS program, with the 0.5, 0.3 and 0.2 weighting factors and assumed mineral densities of 3.0 for waste and 5.2 for magnetite. The results obtained are shown in Table 7. Unfortunately, the sources for these various samples are lost in antiquity, but they represented virtually all of the magnetite iron formations in the U.S., Canada and Australia being exploited at the time of that article.

REFERENCES

1. R. L. Wiegel, "Liberation in Magnetite Iron Formations," Society of Mining Engineers Transactions, v. 258, pp. 247-256, (1975).

2. R. L. Wiegel, K. Li, "A Random Model for Mineral Liberation by Size Reduction," Transactions SME/AIME, pp. 179-189, (June 1967).

TABLE 1. LIBFIT.BAS PROGRAM

```
100 REM LIBFIT.BAS PROGRAM TO FIT DAVIS TUBE DATA TO RANDOM LIBERATION MODEL PAR
AMETERS ALPHA-AVERAGE PARTICE SIZE OF SIZE FRACTION AND GF-MAGNETITE ORE FEED GR
ADE
105 DIM BETA(20),GCM(20),GC(20),GTN(20),GTM(20),K(20),T(20),EP(20),GM(20),PA(20)
110 OPEN "DTCONC" FOR INPUT AS #1
115 OPEN "LIBFIT" FOR OUTPUT AS #2
120 INPUT "EST GRAIN SIZE (100-5000), EST FEED GRADE (10-65)   " ;ALPHA,GF
125 SSMIN=1111111111#:ROA=3!:ROB=5.2:R=1:SS1=0:EN=1
130 VB=((GF/72.36)/ROB)/((GF/72.36)/ROB+(1-GF/72.36)/ROA)
140 INPUT #1,N: FOR I=1 TO N: INPUT #1,BETA(I),GC(I),GTN(I),GTM(I)
150 GCM(I)=72.36*(GC(I)-(GTN(I)-GTM(I))/(1-GTM(I)/72.36))/(72.36-(GTN(I)-GTM(I))
/(1-GTM(I)/72.36)):NEXT I
155 R=1:RMIN=.1:EN=1:GOSUB 1000
156 R=.1:RMIN=.01:EN=1:GOSUB 2000
157 R=.1:RMIN=.01:EN=1:GOSUB 1000
158 R=.1:RMIN=.01:EN=1:GOSUB 2000
159 R=.1:RMIN=.01:EN=1:GOSUB 1000
160 R=.1:RMIN=.01:EN=1:GOSUB 2000
161 R=.1:RMIN=.01:EN=1:GOSUB 1000
162 R=.01:RMIN=.001:EN=1:GOSUB 2000
163 R=.1:RMIN=.01:EN=1:GOSUB 1000
164 R=.01:RMIN=.001:EN=1:GOSUB 2000
165 R=.1:RMIN=.01:EN=1:GOSUB 1000
166 R=.01:RMIN=.001:EN=1:GOSUB 2000
167 R=.1:RMIN=.01:EN=1:GOSUB 1000
168 R=.01:RMIN=.001:EN=1:GOSUB 2000
169 R=.1:RMIN=.01:EN=1:GOSUB 1000
170 R=.01:RMIN=.001:EN=1:GOSUB 2000
171 R=.1:RMIN=.01:EN=1:GOSUB 1000
172 R=.01:RMIN=.001:EN=1:GOSUB 2000
173 R=.1:RMIN=.01:EN=1:GOSUB 1000
174 R=.01:RMIN=.001:EN=1:GOSUB 2000
175 R=.1:RMIN=.01:EN=1:GOSUB 1000
176 R=.01:RMIN=.001:EN=1:GOSUB 2000
177 R=.1:RMIN=.01:EN=1:GOSUB 1000
178 R=.01:RMIN=.001:EN=1:GOSUB 2000
179 R=.1:RMIN=.01:EN=1:GOSUB 1000
180 R=.01:RMIN=.001:EN=1:GOSUB 2000
181 R=.1:RMIN=.01:EN=1:GOSUB 1000
182 R=.01:RMIN=.001:EN=1:GOSUB 2000
183 R=.1:RMIN=.01:EN=1:GOSUB 1000
184 R=.01:RMIN=.001:EN=1:GOSUB 2000
185 R=.1:RMIN=.001:EN=1:GOSUB 1000
186 R=.01:RMIN=.0001:EN=1:GOSUB 2000
187 R=.1:RMIN=.001:EN=1:GOSUB 1000
188 R=.01:RMIN=.0001:EN=1:GOSUB 2000
189 R=.1:RMIN=.001:EN=1:GOSUB 1000
190 R=.01:RMIN=.0001:EN=1:GOSUB 2000
270 VB=VBMIN:ALPHA=ALPHAMIN:GF=(VB*ROB*72.36)/(VB*ROB+(1-VB)*ROA):PRINT #2, USIN
G " ####.#### ";ALPHA,VB,GF,SSMIN,(SSMIN/(N-2))^.5
275 GF=(VB*ROB*72.36)/(VB*ROB+(1-VB)*ROA):PRINT USING " ####.#### ";ALPHA,VB,GF,
SSMIN,(SSMIN/(N-2))^.5
277 OVER=1:GOSUB 1157
280 FOR I=1 TO N:PRINT #2, USING " ####.#### ";I,BETA(I),GCM(I),GM(I),(GCM(I)-GM
(I)):NEXT I:END
1000 REM SUB FOR MIN OF SS BY ALPHA
1155 SS2=0
1157 FOR I=1 TO N
1160 T(I)=INT(BETA(I)/ALPHA):EP(I)=BETA(I)/ALPHA-T(I)
1170 PA(I)=(1-EP(I))^3*(1-VB)^((T(I)+1)^3)+3*EP(I)*(1-EP(I))^2*(1-VB)^((T(I)+2)*
```

TABLE 1. (cont'd)

```
(T(I)+1)^2)+3*EP(I)^2*(1-EP(I))*(1-VB)^((T(I)+2)^2*(T(I)+1))+EP(I)^3*(1-VB)^((T(
I)+2)^3)
1180 GM(I)=72.36/(1+(1-VB-PA(I))*ROA/ROB/VB):IF(OVER=1) THEN GOTO 1200
1190 SS2=SS2+(GCM(I)-GM(I))^2:REM PRINT #2, USING " ####.#### ";I,SS2,SS1
1200 NEXT I
1205 IF (OVER=1) THEN RETURN
1210 IF(SS2<=SSMIN) THEN GOTO 1211 ELSE GOTO 1220
1211 SSMIN=SS2:ALPHAMIN=ALPHA:VBMIN=VB
1220 IF(SS2<=SS1) THEN GOTO 1225 ELSE GOTO 1230
1225 EN=EN*1:GOTO 1235
1230 EN=EN*(-1):R=R/2
1235 PRINT #2, USING " ####.#### ";ALPHA,VB,SS2,SS1,SSMIN,ALPHAMIN,VBMIN
1240 ALPHA=ALPHA*(1+R)^EN:SS1=SS2:IF (R<RMIN) THEN GOTO 1250 ELSE GOTO 1155
1250 ALPHA=ALPHAMIN:RETURN
2000 REM SUB FOR MIN OF SS BY VB
2155 SS2=0:FOR I=1 TO N
2160 T(I)=INT(BETA(I)/ALPHA):EP(I)=BETA(I)/ALPHA-T(I)
2170 PA(I)=(1-EP(I))^3*(1-VB)^((T(I)+1)^3)+3*EP(I)*(1-EP(I))^2*(1-VB)^((T(I)+2)*
(T(I)+1)^2)+3*EP(I)^2*(1-EP(I))*(1-VB)^((T(I)+2)^2*(T(I)+1))+EP(I)^3*(1-VB)^((T(
I)+2)^3)
2180 GM(I)=72.36/(1+(1-VB-PA(I))*ROA/ROB/VB)
2190 SS2=SS2+(GCM(I)-GM(I))^2:REM PRINT #2, USING " ####.#### ";I,SS2,SS1
2200 NEXT I
2210 IF(SS2<=SSMIN) THEN GOTO 2211 ELSE GOTO 2220
2211 SSMIN=SS2:ALPHAMIN=ALPHA:VBMIN=VB
2220 IF(SS2<=SS1) THEN GOTO 2225 ELSE GOTO 2230
2225 EN=EN*1:GOTO 2235
2230 EN=EN*(-1):R=R/2
2235 PRINT #2, USING " ####.#### ";ALPHA,VB,SS2,SS1,SSMIN,ALPHAMIN,VBMIN
2240 VB=VB*(1+R)^EN:SS1=SS2:IF (R<RMIN) THEN GOTO 2250 ELSE GOTO 2155
2250 VB=VBMIN:RETURN
```

TABLE 2. DT CONC INPUT FILE FOR LIBFIT.BAS

```
12
1980,48.13,13.09,2.28
1400,48.62,10.93,1.97
0991,51.46,08.25,1.90
0701,52.51,07.48,1.73
0495,55.77,07.32,1.96
0351,58.94,06.83,1.75
0246,62.36,07.64,1.89
0175,65.49,08.53,2.12
0124,67.16,08.70,1.03
0089,68.21,08.13,0.88
0061,69.27,09.43,0.68
0043,69.84,09.35,0.61
```

TABLE 3. LIBFIT OUTPUT FILE FOR LIBFIT.BAS

2965.2430	0.2334	163.0948	163.0948	0.0625	1.0000
2965.2430	0.2702	141.6120	141.6120	0.0063	1.0000
2766.8980	0.2702	136.8449	136.8449	0.0063	1.0000
2766.8980	0.2984	129.2903	129.2903	0.0063	1.0000
2582.2140	0.2984	123.6684	123.6684	0.0063	1.0000
2582.2140	0.3257	116.6893	116.6893	0.0063	1.0000
2381.5230	0.3257	109.8577	109.8577	0.0063	1.0000
2381.5230	0.3546	101.6325	101.6325	0.0006	1.0000
2169.6440	0.3546	93.3349	93.3349	0.0063	1.0000
2169.6440	0.3833	84.1177	84.1177	0.0006	1.0000
1836.5760	0.3833	70.4274	70.4274	0.0063	1.0000
1836.5760	0.4226	49.4510	49.4510	0.0006	1.0000
1593.2620	0.4226	36.1123	36.1123	0.0063	1.0000
1593.2620	0.4488	25.6991	25.6991	0.0006	1.0000
1451.5120	0.4488	20.1387	20.1387	0.0063	1.0000
1451.5120	0.4645	16.1003	16.1003	0.0006	1.0000
1337.9030	0.4645	13.2662	13.2662	0.0063	1.0000
1337.9030	0.4758	10.8324	10.8324	0.0006	1.0000
1279.6210	0.4758	10.2834	10.2834	0.0063	1.0000
1279.6210	0.4821	9.5016	9.5016	0.0006	1.0000
1253.7290	0.4821	9.5396	9.5396	0.0063	1.0000
1253.7290	0.4848	9.3277	9.3277	0.0006	1.0000
1243.7150	0.4848	9.4220	9.4220	0.0063	1.0000
1243.7150	0.4857	9.3340	9.3340	0.0006	1.0000
1233.7810	0.4857	9.5079	9.5079	0.0063	1.0000
1233.7810	0.4866	9.3813	9.3813	0.0006	1.0000
1239.2250	0.4866	9.3957	9.3957	0.0063	1.0000
1239.2250	0.4863	9.3476	9.3476	0.0006	1.0000
1244.6930	0.4863	9.3576	9.3576	0.0063	1.0000
1244.6930	0.4854	9.3363	9.3363	0.0006	1.0000
1249.2480	0.4854	9.3238	9.3238	0.0008	-1.0000
1249.2480	0.4853	9.3232	9.3232	0.0001	-1.0000
1249.9270	0.4853	9.3241	9.3241	0.0008	-1.0000
1249.9270	0.4853	9.3232	9.3232	0.0001	-1.0000
1250.6090	0.4853	9.3247	9.3247	0.0008	-1.0000
1250.6090	0.4851	9.3232	9.3232	0.0001	-1.0000
1250.6090	0.4851	44.8806	0.9323		
1.0000	1980.0000	43.7108	44.8985	-1.1878	
2.0000	1400.0000	45.1574	44.9982	0.1592	
3.0000	991.0000	49.3899	47.0225	2.3674	
4.0000	701.0000	50.7508	50.8779	-0.1271	
5.0000	495.0000	54.4028	54.9655	-0.5627	
6.0000	351.0000	57.8997	58.7016	-0.8019	
7.0000	246.0000	61.4716	62.0046	-0.5331	
8.0000	175.0000	64.8001	64.5724	0.2277	
9.0000	124.0000	66.5335	66.6093	-0.0758	
10.0000	89.0000	67.7416	68.1108	-0.3692	
11.0000	61.0000	68.8404	69.3778	-0.5374	
12.0000	43.0000	69.4905	70.2250	-0.7346	

TABLE 4. LIBFIT4.BAS PROGRAM

```
100 REM LIBFIT.BAS PROGRAM TO FIT DAVIS TUBE DATA TO RANDOM LIBERATION MODEL PAR
AMETERS ALPHA-AVERAGE PARTICE SIZE OF SIZE FRACTION, GF-MAGNETITE ORE FEED GRADE
 AND DIL-FRACTIONAL WASTE DILUTION
105 DIM BETA(20),GCM(20),GCT(20),GTT(20),GTM(20),K(20),T(20),EP(20),GM(20),PA(20
),WM(20),WCM(20),GT(20)
110 OPEN "DTCONC" FOR INPUT AS #1
115 OPEN "LIBFIT" FOR OUTPUT AS #2
116 WGC=.5:WWC=.3:WGF=.2:WGC=WGC/(WGC+WWC+WGF):WWC=WWC/(WGC+WWC+WGF):WGF=WGF/(WG
C+WWC+WGF)
120 REM INPUT "EST GRAIN SIZE (100-5000), EST FEED GRADE (10-65), EST DILUTION (
10-50)   " ;ALPHA,GF,DIL
121 ALPHA=500:GF=20:DIL=20/100:SSMIN=999999!
125 ROA=3!:ROB=5.2:R=1:SS1=0:EN=1
130 VB=((GF/72.36)/ROB)/((GF/72.36)/ROB+(1-GF/72.36)/ROA)
132 PRINT #2,CHR$(15):PRINT #2, USING " ####.#### ";SSMIN,ALPHA,VB,DIL
140 INPUT #1,N: FOR I=1 TO N: INPUT #1,BETA(I),GCT(I),GTT(I),GTM(I),WCM(I):NEXT
I
145 SNM=0:WNM=0:FOR I=1 TO N:GNM=(GTT(I)-GTM(I))/(1-GTM(I)/72.36):SNM=SNM+GNM*WC
M(I):WNM=WNM+WCM(I):NEXT I:GNM=SNM/WNM
150 FOR I=1 TO N:GCM(I)=72.36*(GCT(I)-GNM)/(72.36-GNM):NEXT I
155 R=.1:RMIN=.01:EN=1:GOSUB 1000
156 R=.1:RMIN=.01:EN=1:GOSUB 2000
157 R=.1:RMIN=.01:EN=1:GOSUB 3000
158 R=.1:RMIN=.01:EN=1:GOSUB 1000
159 R=.1:RMIN=.01:EN=1:GOSUB 2000
160 R=.1:RMIN=.01:EN=1:GOSUB 3000
161 R=.1:RMIN=.01:EN=1:GOSUB 1000
162 R=.1:RMIN=.01:EN=1:GOSUB 2000
163 R=.1:RMIN=.01:EN=1:GOSUB 3000
164 R=.1:RMIN=.01:EN=1:GOSUB 1000
165 R=.01:RMIN=.001:EN=1:GOSUB 2000
166 R=.01:RMIN=.001:EN=1:GOSUB 3000
167 R=.1:RMIN=.01:EN=1:GOSUB 1000
168 R=.01:RMIN=.001:EN=1:GOSUB 2000
169 R=.01:RMIN=.001:EN=1:GOSUB 3000
170 R=.1:RMIN=.01:EN=1:GOSUB 1000
171 R=.01:RMIN=.001:EN=1:GOSUB 2000
172 R=.01:RMIN=.001:EN=1:GOSUB 3000
173 R=.1:RMIN=.01:EN=1:GOSUB 1000
174 R=.01:RMIN=.001:EN=1:GOSUB 2000
175 R=.01:RMIN=.001:EN=1:GOSUB 3000
176 R=.1:RMIN=.01:EN=1:GOSUB 1000
177 R=.01:RMIN=.001:EN=1:GOSUB 2000
178 R=.01:RMIN=.001:EN=1:GOSUB 3000
179 R=.1:RMIN=.01:EN=1:GOSUB 1000
180 R=.01:RMIN=.001:EN=1:GOSUB 2000
181 R=.01:RMIN=.001:EN=1:GOSUB 3000
182 R=.1:RMIN=.01:EN=1:GOSUB 1000
183 R=.01:RMIN=.001:EN=1:GOSUB 2000
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188 R=.1:RMIN=.01:EN=1:GOSUB 1000
189 R=.01:RMIN=.001:EN=1:GOSUB 2000
190 R=.01:RMIN=.001:EN=1:GOSUB 3000
191 R=.1:RMIN=.01:EN=1:GOSUB 1000
192 R=.01:RMIN=.001:EN=1:GOSUB 2000
193 R=.01:RMIN=.001:EN=1:GOSUB 3000
194 R=.1:RMIN=.01:EN=1:GOSUB 1000
```

```
195 R=.01:RMIN=.001:EN=1:GOSUB 2000
196 R=.01:RMIN=.001:EN=1:GOSUB 3000
197 R=.1:RMIN=.01:EN=1:GOSUB 1000
198 R=.01:RMIN=.001:EN=1:GOSUB 2000
199 R=.01:RMIN=.001:EN=1:GOSUB 3000
200 R=.1:RMIN=.001:EN=1:GOSUB 1000
201 R=.01:RMIN=.0001:EN=1:GOSUB 2000
202 R=.01:RMIN=.0001:EN=1:GOSUB 3000
203 R=.1:RMIN=.001:EN=1:GOSUB 1000
204 R=.01:RMIN=.0001:EN=1:GOSUB 2000
205 R=.01:RMIN=.0001:EN=1:GOSUB 3000
206 R=.1:RMIN=.001:EN=1:GOSUB 1000
207 R=.01:RMIN=.0001:EN=1:GOSUB 2000
208 R=.01:RMIN=.0001:EN=1:GOSUB 3000
270 VB=VBMIN:ALPHA=ALPHAMIN:DIL=DILMIN:GF=(VB*ROB*72.36)/(VB*ROB+(1-VB)*ROA):DIL
WT=100*DIL*ROA/((DIL+1-VB)*ROA+VB*ROB):PRINT #2,:PRINT #2, USING " ####.#### ";S
SMIN,ALPHA,VB,GF,DIL,DILWT,GNM:PRINT #2,
275 GF=(VB*ROB*72.36)/(VB*ROB+(1-VB)*ROA):PRINT USING " ####.#### ";ALPHA,VB,GF,
DIL,DILWT,GNM,SSMIN
277 OVER=1:GOSUB 1157
280 FOR I=1 TO N:PRINT #2, USING " ####.#### ";I,BETA(I),GCT(I),GT(I),GCM(I),GM(
I),WCM(I),WM(I),WCM(I)*GCM(I)/100,WM(I)*GM(I)/100,(WCM(I)*GCT(I)+(100-WCM(I))*GT
T(I))/100,(WM(I)*GT(I)+(100-WM(I))*GNM)/100:NEXT I:END
1000 REM SUB FOR MIN OF SS BY ALPHA
1155 SS2=0
1157 VA=1-VB:FOR I=1 TO N
1160 T(I)=INT(BETA(I)/ALPHA):EP(I)=BETA(I)/ALPHA-T(I)
1170 PA(I)=(1-EP(I))^3*(VA)^((T(I)+1)^3)+3*EP(I)*(1-EP(I))^2*(VA)^((T(I)+2)*(T(I
)+1)^2)+3*EP(I)^2*(1-EP(I))*(VA)^((T(I)+2)^2*(T(I)+1))+EP(I)^3*(VA)^((T(I)+2)^3)
1180 GM(I)=72.36/(1+(1-VB-PA(I))*ROA/ROB/VB):WM(I)=(1*(VB*ROB+(1-VB)*ROA)-PA(I)*
ROA)*100/(VB*ROB+(1-VB)*ROA+DIL*ROA):GT(I)=GM(I)+(1-GM(I)/72.36)*GNM:IF(OVER=1)
THEN GOTO 1200
1190 SS2=SS2+WGC*(GCM(I)-GM(I))^2+WWC*(WCM(I)-WM(I))^2+WGF*(WCM(I)*GCM(I)/100-WM
(I)*GM(I)/100)^2:REM PRINT #2, USING " ####.#### ";I,SS2,SS1
1200 NEXT I
1205 IF (OVER=1) THEN RETURN
1210 IF(SS2<=SSMIN) THEN GOTO 1211 ELSE GOTO 1220
1211 SSMIN=SS2:ALPHAMIN=ALPHA:VBMIN=VB:DILMIN=DIL
1220 IF(SS2<=SS1) THEN GOTO 1225 ELSE GOTO 1230
1225 EN=EN*1:GOTO 1235
1230 EN=EN*(-1):R=R/2
1235 REM PRINT #2, USING " ####.#### ";ALPHA,VB,DIL,SS2,SS1,SSMIN,ALPHAMIN,VBMIN
,DILMIN
1240 ALPHA=ALPHA*(1+R)^EN:SS1=SS2:IF (R<RMIN) THEN GOTO 1250 ELSE GOTO 1155
1250 ALPHA=ALPHAMIN:PRINT #2, USING " ####.#### ";SSMIN,ALPHAMIN,VBMIN,DILMIN:RE
TURN
2000 REM SUB FOR MIN OF SS BY VB
2155 SS2=0:VA=1-VB:FOR I=1 TO N
2160 T(I)=INT(BETA(I)/ALPHA):EP(I)=BETA(I)/ALPHA-T(I)
2170 PA(I)=(1-EP(I))^3*(VA)^((T(I)+1)^3)+3*EP(I)*(1-EP(I))^2*(VA)^((T(I)+2)*(T(I
)+1)^2)+3*EP(I)^2*(1-EP(I))*(VA)^((T(I)+2)^2*(T(I)+1))+EP(I)^3*(VA)^((T(I)+2)^3)
2180 GM(I)=72.36/(1+(1-VB-PA(I))*ROA/ROB/VB):WM(I)=(1*(VB*ROB+(1-VB)*ROA)-PA(I)*
ROA)*100/(VB*ROB+(1-VB)*ROA+DIL*ROA)
2190 SS2=SS2+WGC*(GCM(I)-GM(I))^2+WWC*(WCM(I)-WM(I))^2+WGF*(WCM(I)*GCM(I)/100-WM
(I)*GM(I)/100)^2:REM PRINT #2, USING " ####.#### ";I,SS2,SS1
2200 NEXT I
2210 IF(SS2<=SSMIN) THEN GOTO 2211 ELSE GOTO 2220
2211 SSMIN=SS2:ALPHAMIN=ALPHA:VBMIN=VB:DILMIN=DIL
2220 IF(SS2<=SS1) THEN GOTO 2225 ELSE GOTO 2230
2225 EN=EN*1:GOTO 2235
```

TABLE 4. (cont'd)

```
2230 EN=EN*(-1):R=R/2
2235 REM PRINT #2, USING " ####.#### ";ALPHA,VB,DIL,SS2,SS1,SSMIN,ALPHAMIN,VBMIN
,DILMIN
2240 VB=VB*(1+R)^EN:SS1=SS2:IF (R<RMIN) THEN GOTO 2250 ELSE GOTO 2155
2250 VB=VBMIN:PRINT #2, USING " ####.#### ";SSMIN,ALPHAMIN,VBMIN,DILMIN:RETURN
3000 REM SUB FOR MIN OF SS BY DIL
3155 SS2=0:VA=1-VB:FOR I=1 TO N
3160 T(I)=INT(BETA(I)/ALPHA):EP(I)=BETA(I)/ALPHA-T(I)
3170 PA(I)=(1-EP(I))^3*(VA)^((T(I)+1)^3)+3*EP(I)*(1-EP(I))^2*(VA)^((T(I)+2)*(T(I
)+1)^2)+3*EP(I)^2*(1-EP(I))*(VA)^((T(I)+2)^2*(T(I)+1))+EP(I)^3*(VA)^((T(I)+2)^3)
3180 GM(I)=72.36/(1+(1-VB-PA(I))*ROA/ROB/VB):WM(I)=(1*(VB*ROB+(1-VB)*ROA)-PA(I)*
ROA)*100/(VB*ROB+(1-VB)*ROA+DIL*ROA)
3190 SS2=SS2+WGC*(GCM(I)-GM(I))^2+WWC*(WCM(I)-WM(I))^2+WGF*(WCM(I)*GCM(I)/100-WM
(I)*GM(I)/100)^2:REM PRINT #2, USING " ####.#### ";I,SS2,SS1
3200 NEXT I
3210 IF(SS2<=SSMIN) THEN GOTO 3211 ELSE GOTO 3220
3211 SSMIN=SS2:ALPHAMIN=ALPHA:VBMIN=VB:DILMIN=DIL
3220 IF(SS2<=SS1) THEN GOTO 3225 ELSE GOTO 3230
3225 EN=EN*1:GOTO 3235
3230 EN=EN*(-1):R=R/2
3235 REM PRINT #2, USING " ####.#### ";ALPHA,VB,DIL,SS2,SS1,SSMIN,ALPHAMIN,VBMIN
,DILMIN
3240 DIL=DIL*(1+R)^EN:SS1=SS2:IF (R<RMIN) THEN GOTO 3250 ELSE GOTO 3155
3250 DIL=DILMIN:PRINT #2, USING " ####.#### ";SSMIN,ALPHAMIN,VBMIN,DILMIN:RETURN
```

TABLE 5. DTCONC INPUT DATA FILE

```
15
3960,33.3,21.4,1.27,91.9
2790,31.5,14.2,1.22,91.9
1980,34.1,17.0,1.58,87.7
1400,34.3,18.2,1.03,88.4
0991,35.3,15.1,0.81,86.6
0701,35.8,14.1,0.28,81.6
0495,37.3,15.5,1.44,78.3
0351,39.8,15.8,0.33,72.2
0246,42.8,15.7,0.50,62.6
0175,46.7,17.4,0.48,57.8
0124,50.9,16.5,0.40,52.6
0089,57.3,16.4,0.40,48.5
0061,63.6,17.0,0.30,48.0
0048,66.1,17.8,0.68,46.7
0041,67.7,18.6,0.35,46.0
```

TABLE 6. LIBFIT OUTPUT FILE FOR LIBFIT4.BAS

SUM OF SQUARES	MINERAL GRAIN SIZE	VOL FRACT MAGNETITE (W/O DIL)	VOL FRACT DILUTION
%999999	500.0000	0.1806	0.2000
795.0264	303.3475	0.1806	0.2000
276.7749	303.3475	0.2545	0.2000
274.4789	303.3475	0.2545	0.1855
255.5729	337.1850	0.2545	0.1855
255.5147	337.1850	0.2539	0.1855
252.6335	337.1850	0.2539	0.1700
251.4030	362.2327	0.2539	0.1700
251.2899	362.2327	0.2533	0.1700
249.6390	362.2327	0.2533	0.1597
249.6390	362.2327	0.2533	0.1597
248.9843	362.2327	0.2505	0.1597
248.7507	362.2327	0.2505	0.1555
248.6895	366.0910	0.2505	0.1555
248.6772	366.0910	0.2502	0.1555
248.6068	366.0910	0.2502	0.1532
248.5998	365.4226	0.2502	0.1532
248.5750	365.4226	0.2495	0.1532
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5730	365.4226	0.2495	0.1528
248.5729	365.3359	0.2495	0.1528
248.5729	365.3359	0.2495	0.1528
248.5729	365.3359	0.2495	0.1528
248.5729	365.3359	0.2495	0.1528
248.5729	365.3359	0.2495	0.1528
248.5729	365.3359	0.2495	0.1528

TABLE 6. (cont'd)

	PARTICLE SIZE BETA	CONC % TOT FE ACTUAL	CONC % TOT FE CALC	CONC % MAG FE ACTUAL	CONC % MAG FE CALC	CONC % WEIGHT ACTUAL	CONC % WEIGHT CALC	FEED % MAG FE ACTUAL	FEED % MAG FE CALC	FEED % TOT FE ACTUAL	FEED % TOT FE CALC
248.5729	365.3359	0.2495	0.1528								
248.5729	365.3359	0.2495	0.1528								
248.5729	365.3359	0.2495	0.1528								
248.5729	365.3359	0.2495	26.4564	0.1528	11.4419	16.0239					
1.0000	3960.0000	33.3000	36.6216	22.1900	26.4564	91.9000	88.5581	20.3926	23.4293	32.3361	34.2648
2.0000	2790.0000	31.5000	36.6216	19.8781	26.4564	91.9000	88.5581	18.2679	23.4293	30.0987	34.2648
3.0000	1980.0000	34.1000	36.6216	23.2176	26.4564	87.7000	88.5581	20.3618	23.4293	31.9967	34.2648
4.0000	1400.0000	34.3000	36.6216	23.4745	26.4564	88.4000	88.5581	20.7514	23.4293	32.4324	34.2648
5.0000	991.0000	35.3000	36.6218	24.7589	26.4567	86.6000	88.5569	21.4412	23.4293	32.5932	34.2648
6.0000	701.0000	35.8000	36.6589	25.4011	26.5043	81.6000	88.3979	20.7273	23.4293	31.8072	34.2648
7.0000	495.0000	37.3000	37.3902	27.3278	27.4436	78.3000	85.3724	21.3976	23.4293	32.5694	34.2648
8.0000	351.0000	39.8000	39.0821	30.5389	29.6168	72.2000	79.1081	22.0491	23.4293	33.1280	34.2648
9.0000	246.0000	42.8000	44.2329	34.3922	36.2326	62.6000	64.6635	21.5295	23.4293	32.6646	34.2648
10.0000	175.0000	46.7000	49.2947	39.4014	42.7342	57.8000	54.8255	22.7740	23.4293	34.3354	34.2648
11.0000	124.0000	50.9000	54.0934	44.7961	48.8978	52.6000	47.9148	23.5627	23.4293	34.5944	34.2648
12.0000	89.0000	57.3000	58.1395	53.0164	54.0947	48.5000	43.3116	25.7130	23.4293	36.2365	34.2648
13.0000	61.0000	63.6000	61.9270	61.1084	58.9595	48.0000	39.7379	29.3320	23.4293	39.3680	34.2648
14.0000	48.0000	66.1000	63.8789	64.3195	61.4666	46.7000	38.1171	30.0372	23.4293	40.3561	34.2648
15.0000	41.0000	67.7000	64.9858	66.3745	62.8883	46.0000	37.2553	30.5323	23.4293	41.1860	34.2648

TABLE 7. LIBERATION PARAMETERS FOR MAGNETITE IRON FORMATIONS

Sample ID	Effective Mineral Grain Size (μM)	Head Grade* % Mag Fe	Barren Waste Dilution % Wt	Waste % Total Fe	Sum of Squares
1	527	32.19	14.65	10.99	89
2	301	36.01	19.44	5.75	401
3	1175	30.45	20.03	2.97	83
3 repeat	1191	30.55	17.37	3.39	86
4	366	30.15	23.08	3.17	267
5	66.5	25.40	29.77	10.84	117
6	637	53.50	8.79	7.43	317
7	391	57.23	13.54	2.39	150
8	291	32.60	14.43	11.93	347
9	383	31.07	17.15	12.95	450
11	1213	41.06	20.23	3.17	480
12	260	34.08	17.57	13.36	725

* This is head grade excluding the effect of the barren waste dilution.

FIGURE 1. DT FEED TOTAL FE VS LOG PARTICLE SIZE

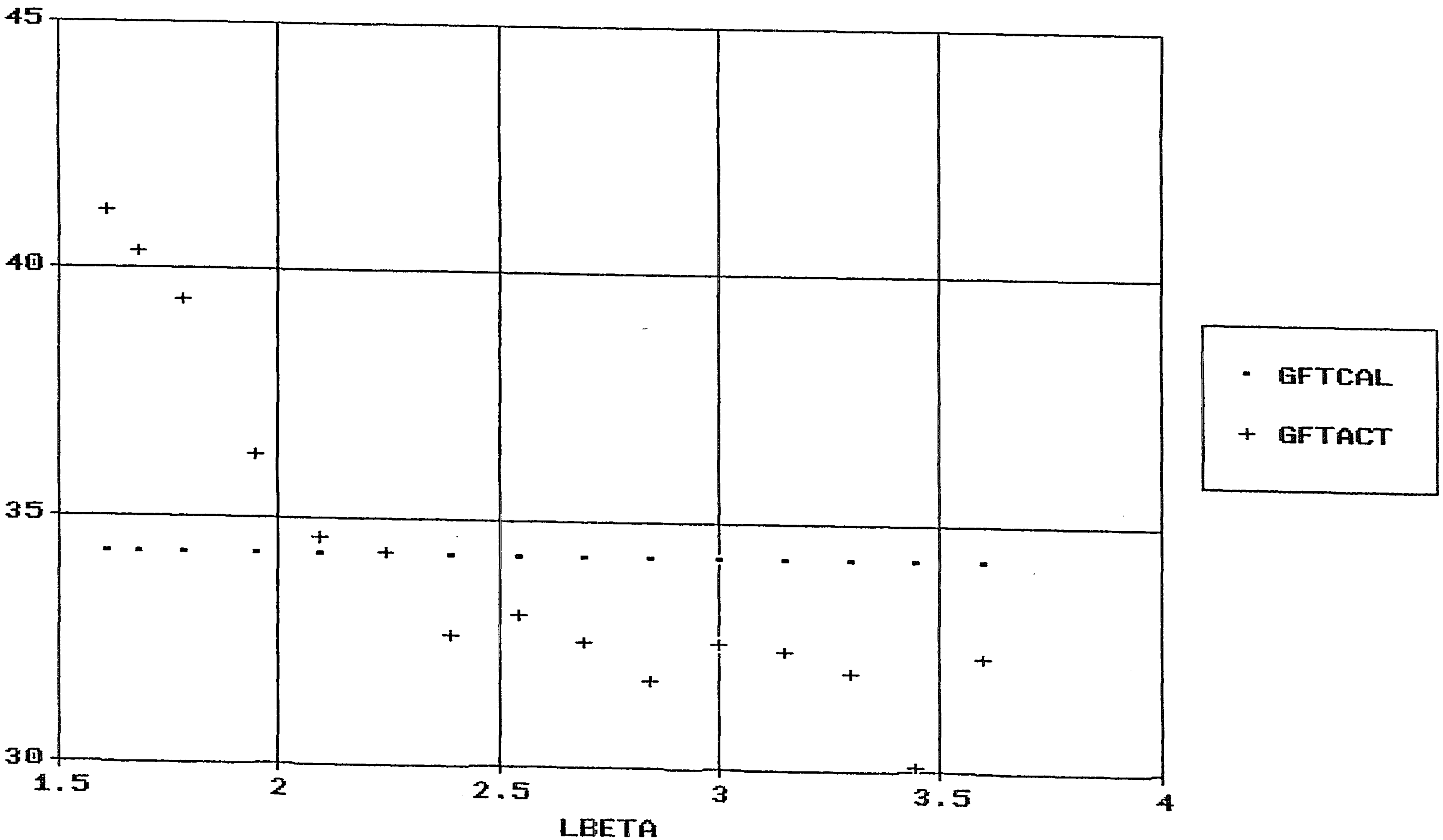


FIGURE 2. DT FEED TOTAL FE CALCULATED VS ACTUAL

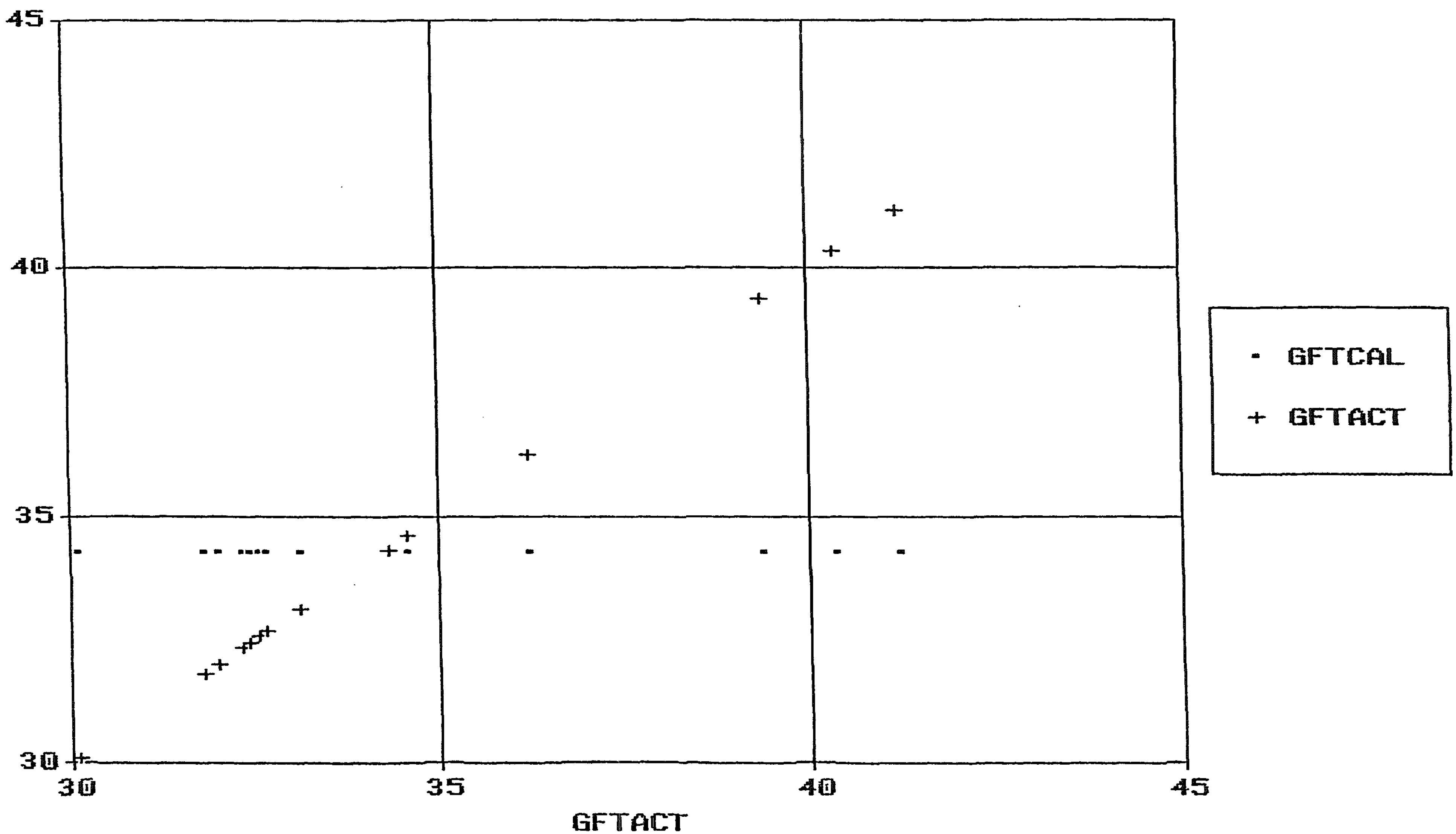


FIGURE 3. DT FEED MAG FE VS LOG PARTICLE SIZE

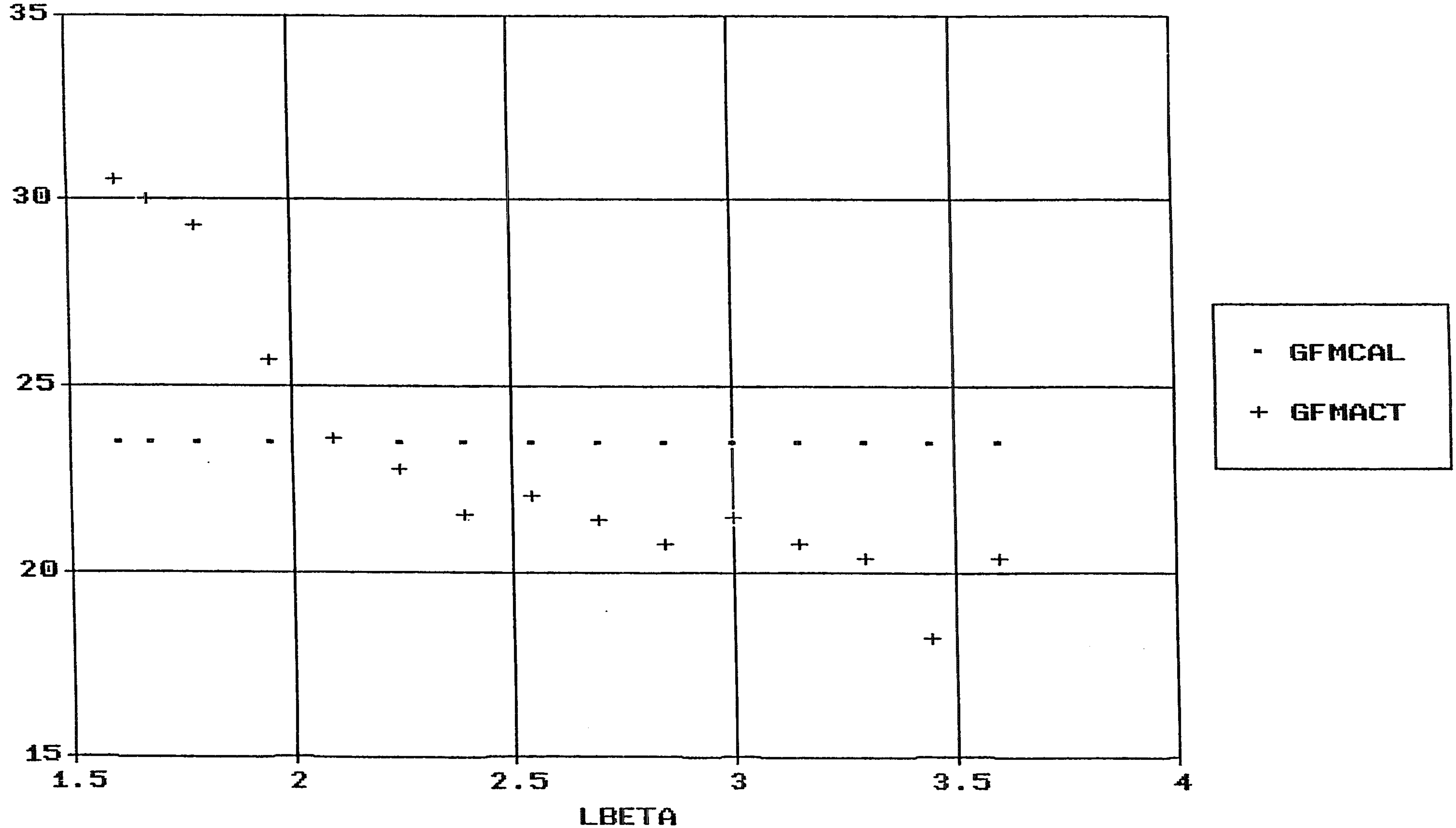
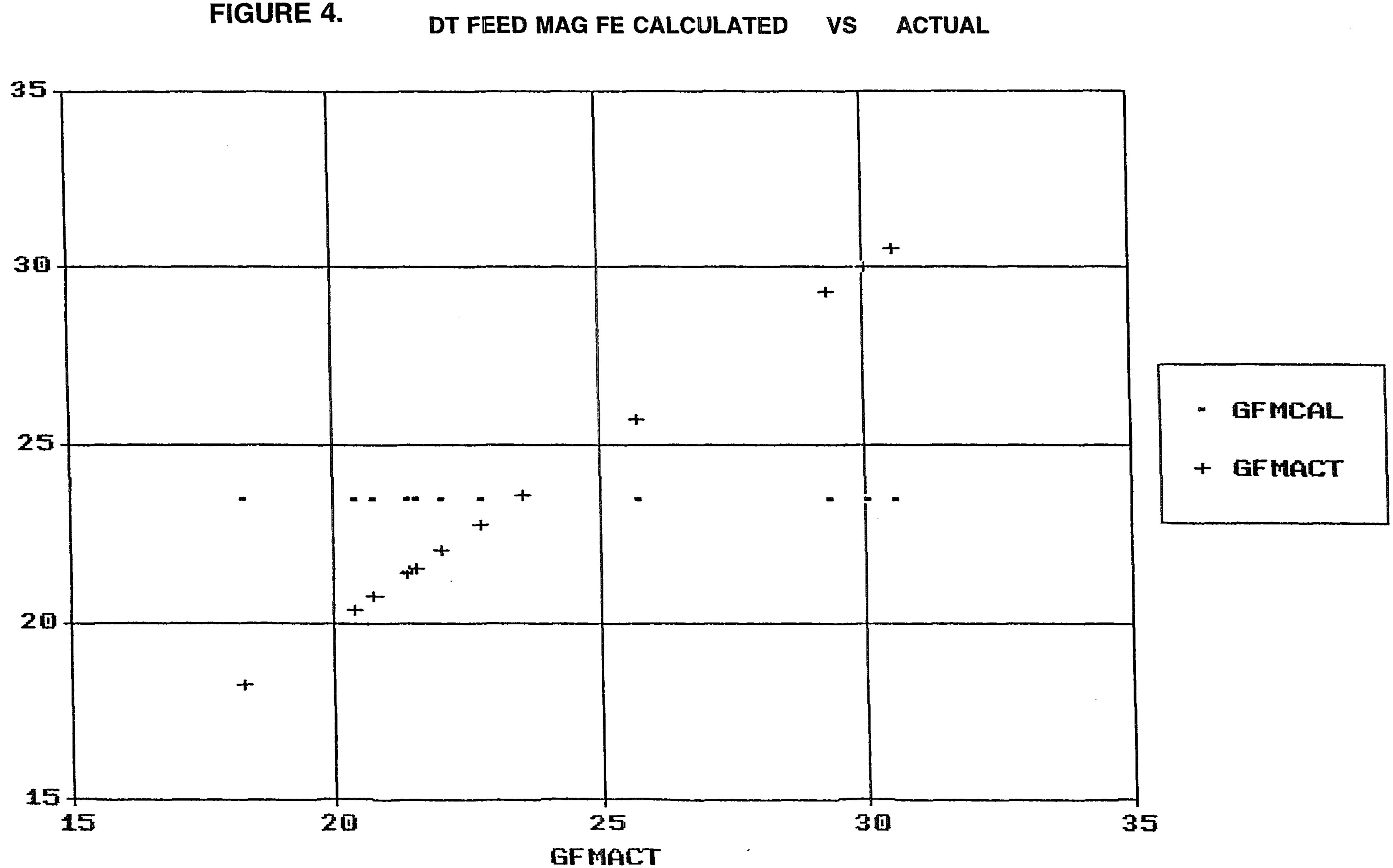


FIGURE 4.



DT FEED MAG FE CALCULATED VS ACTUAL
35
30
25
20
15
15
20
25
30
35
GFMACT
GFMCAL
GFMACT

FIGURE 5. DT CONC TOTAL FE VS LOG PARTICLE SIZE

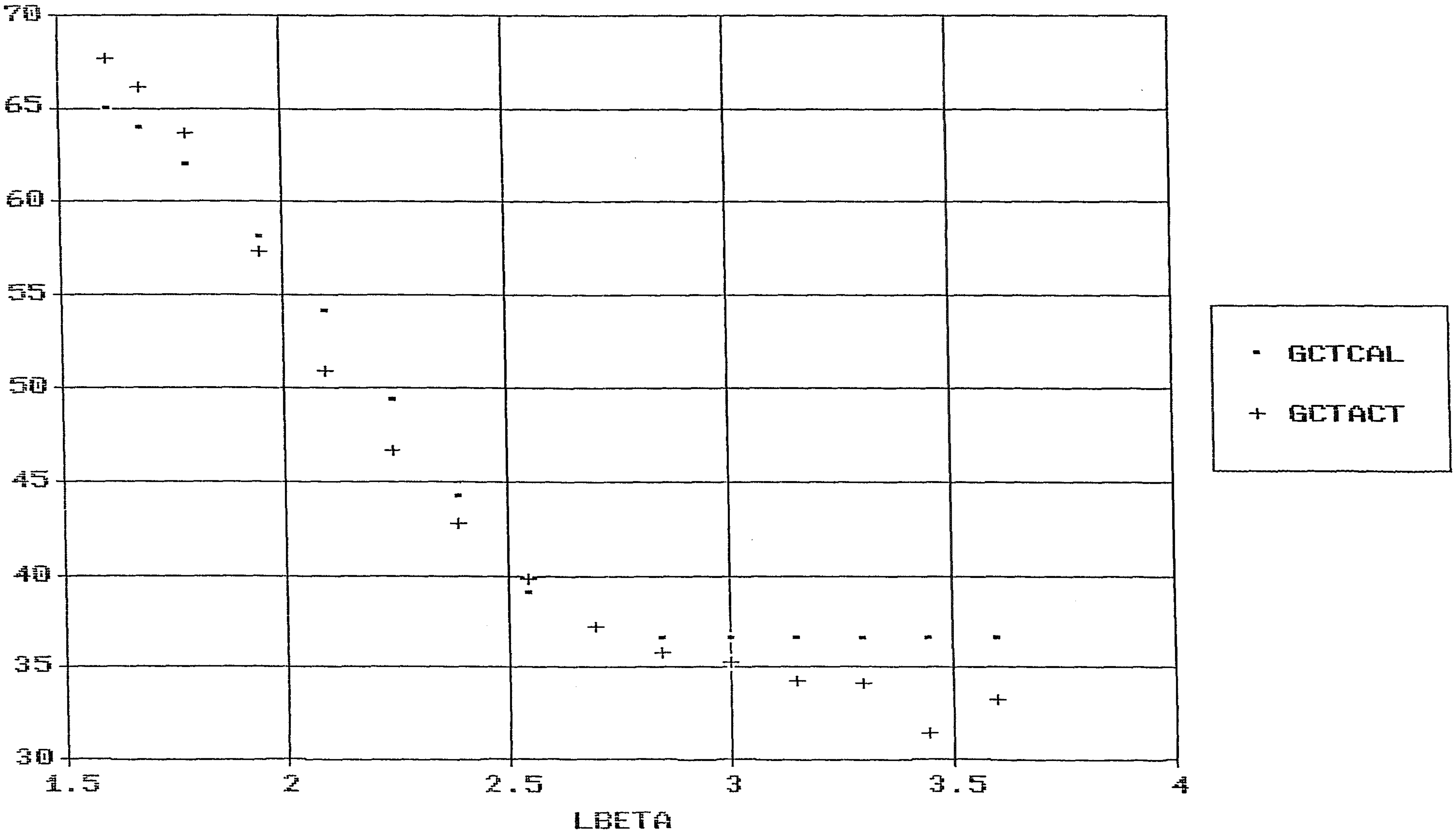


FIGURE 6.

DT CONC TOTAL FE CALCULATED VS ACTUAL

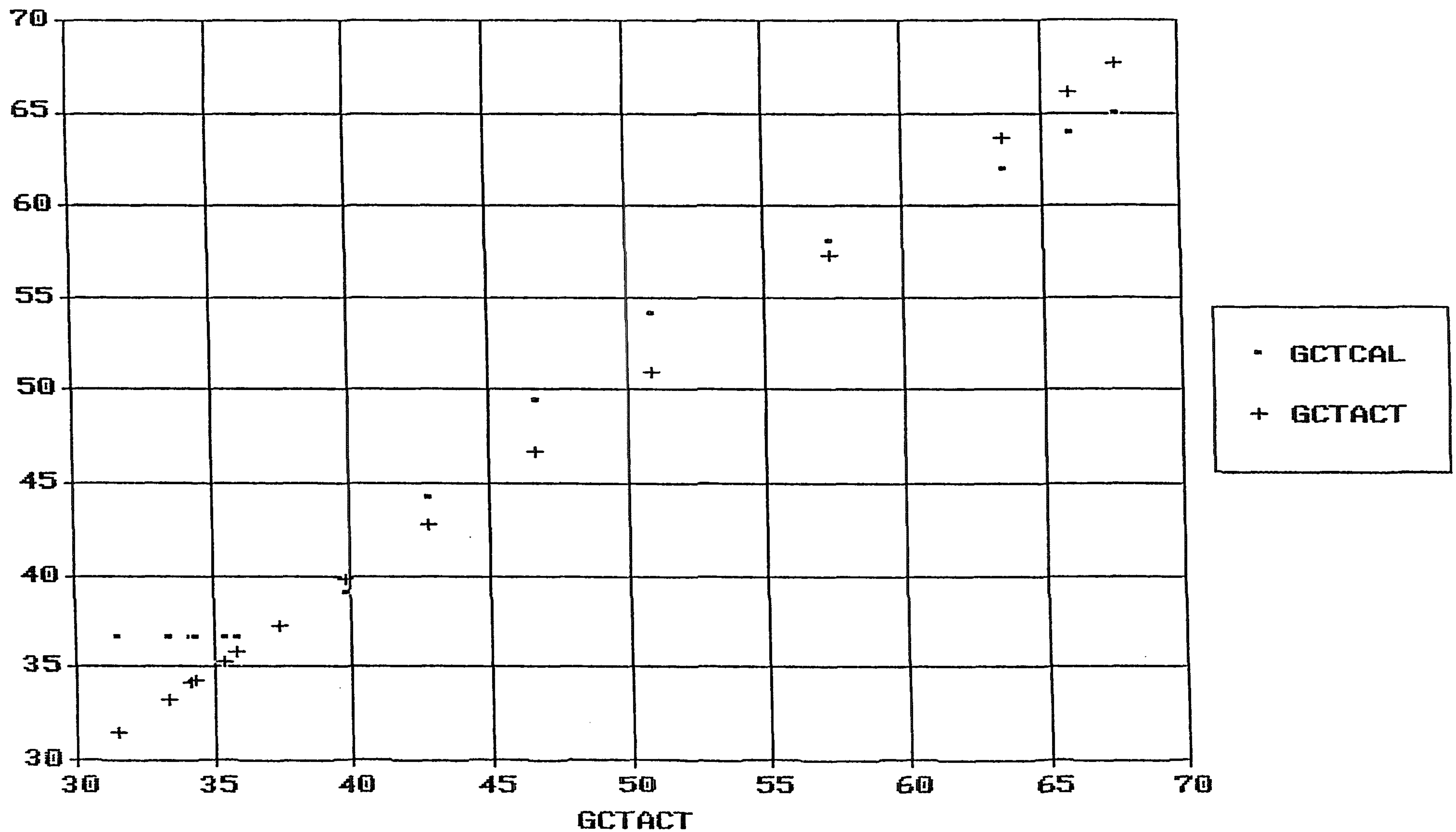


FIGURE 7.

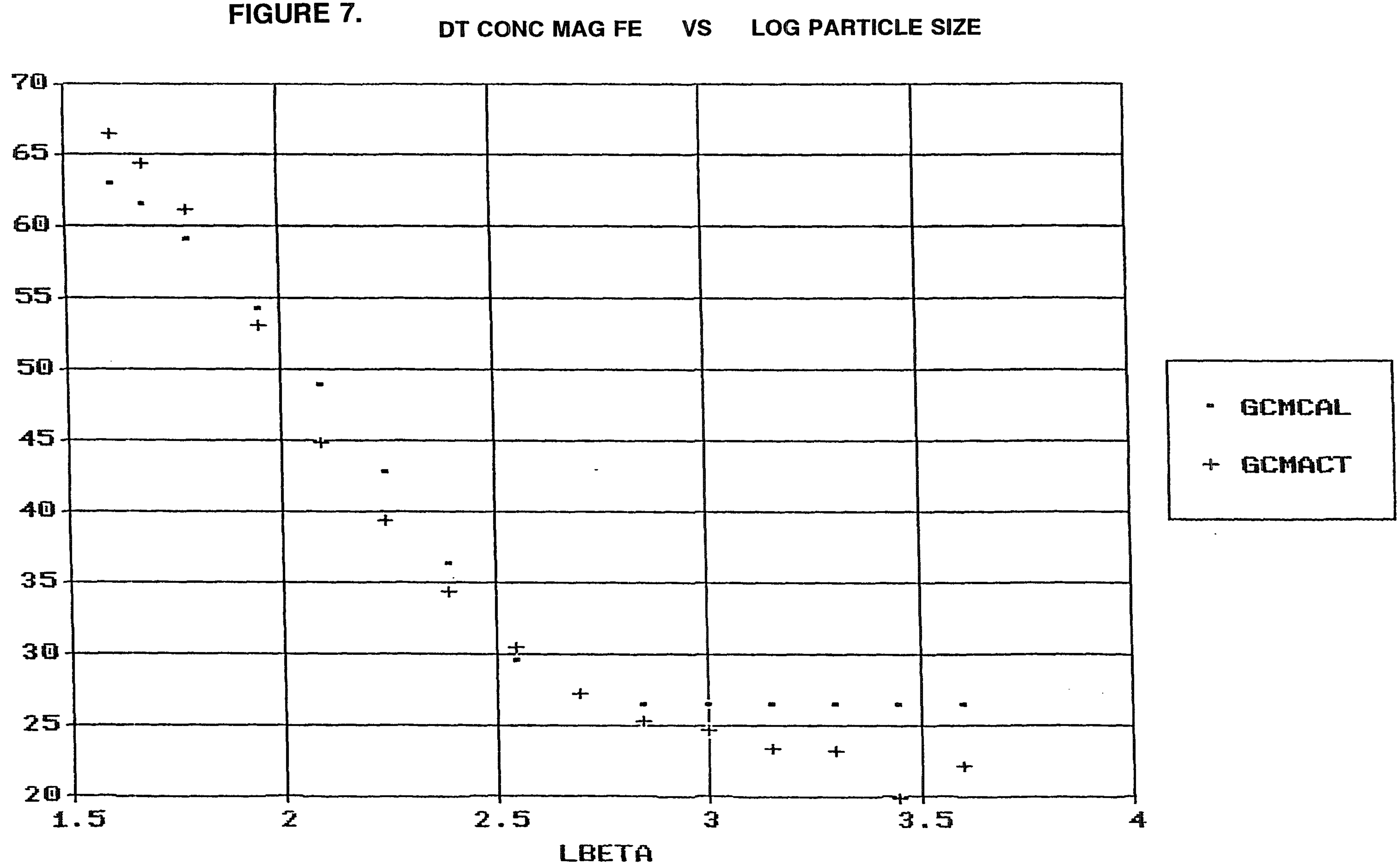

DT CONC MAG FE VS LOG PARTICLE SIZE
70
65
60
55
50
45
40
35
30
25
20
1.5
2
2.5
3
3.5
4
LBETA
GCMCAL
GCMACT

FIGURE 8. DT CONC MAG FE CALCULATED VS ACTUAL

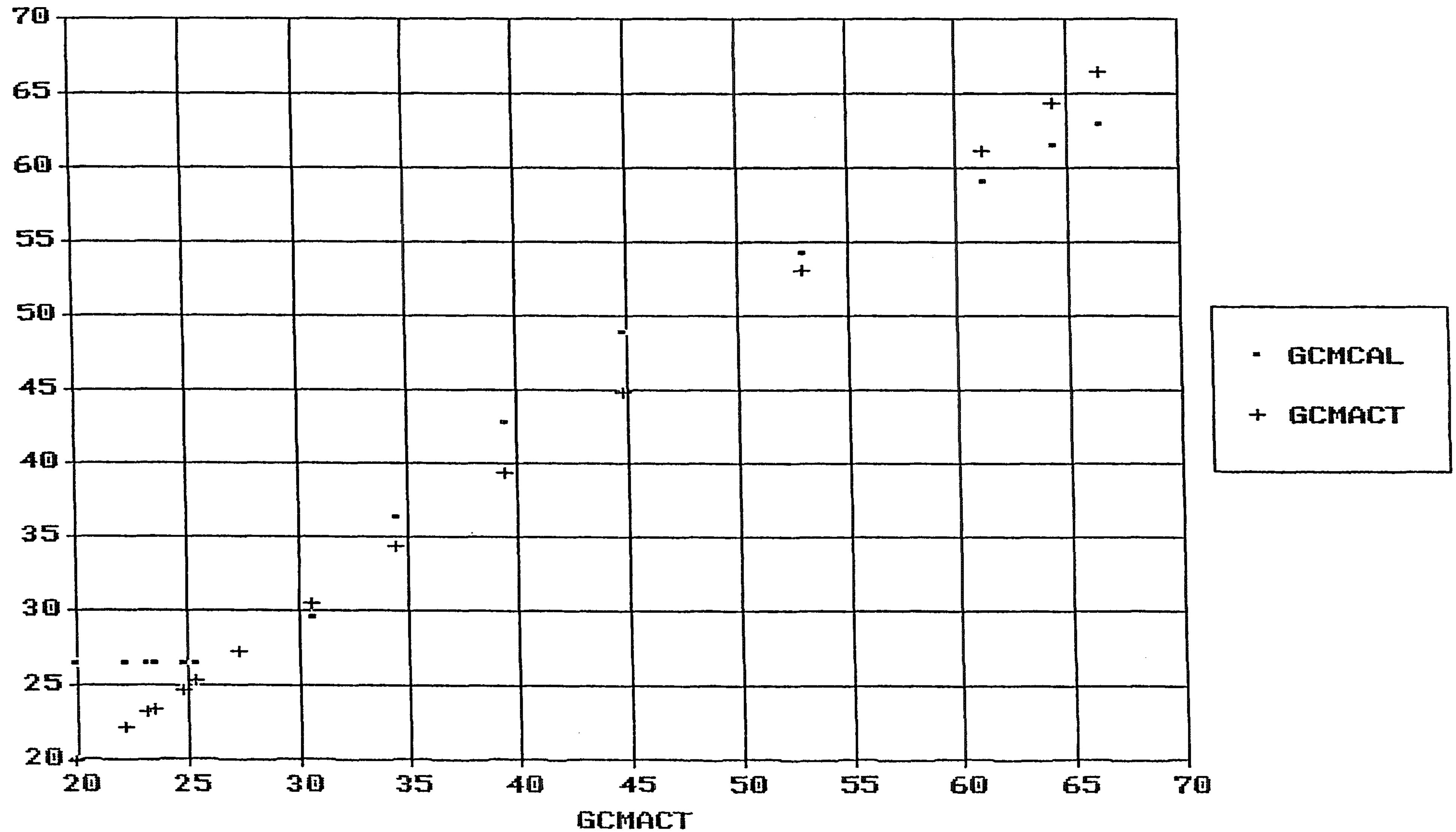


FIGURE 9. DT CONC % WEIGHT VS LOG PARTICLE SIZE

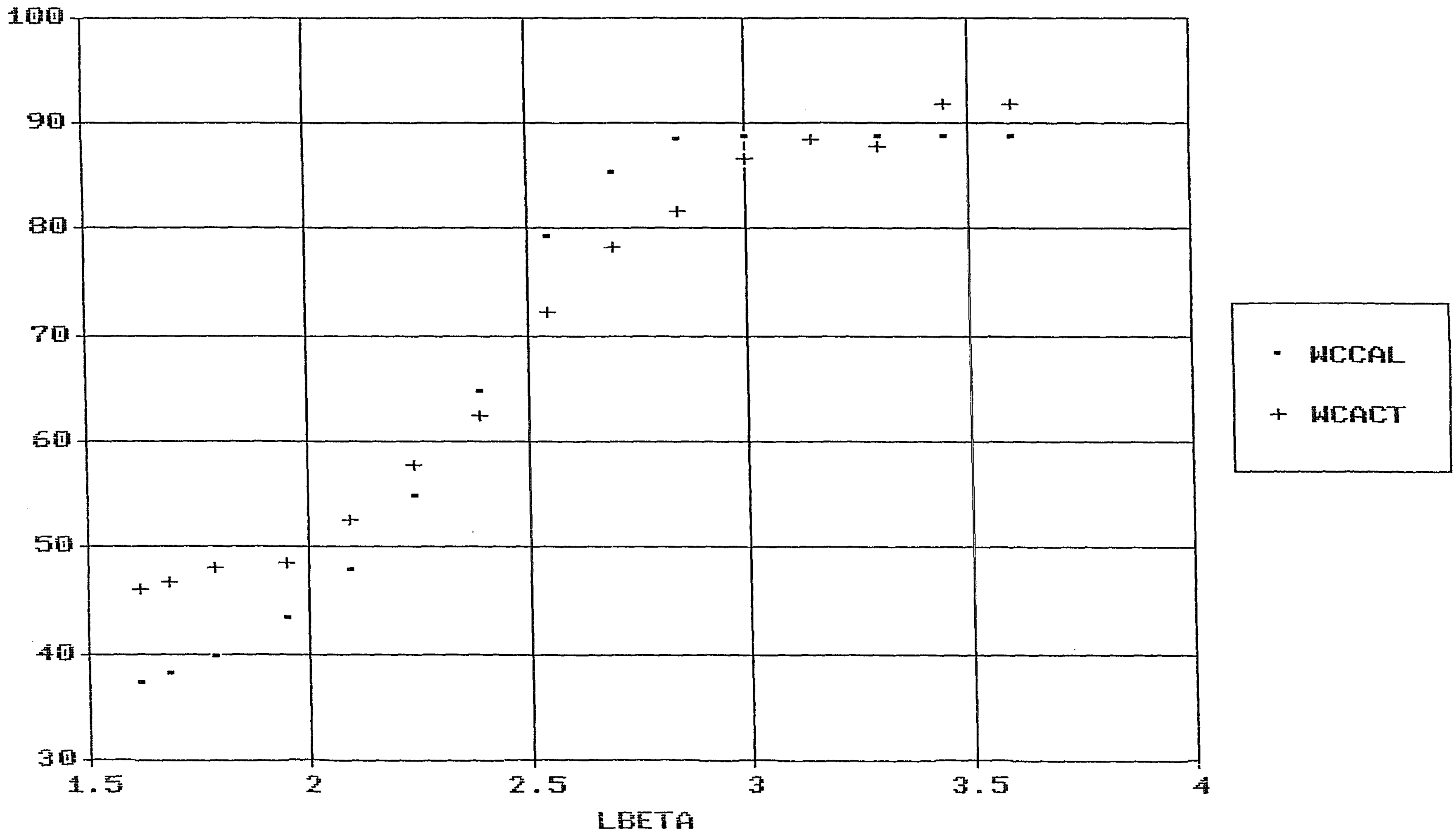
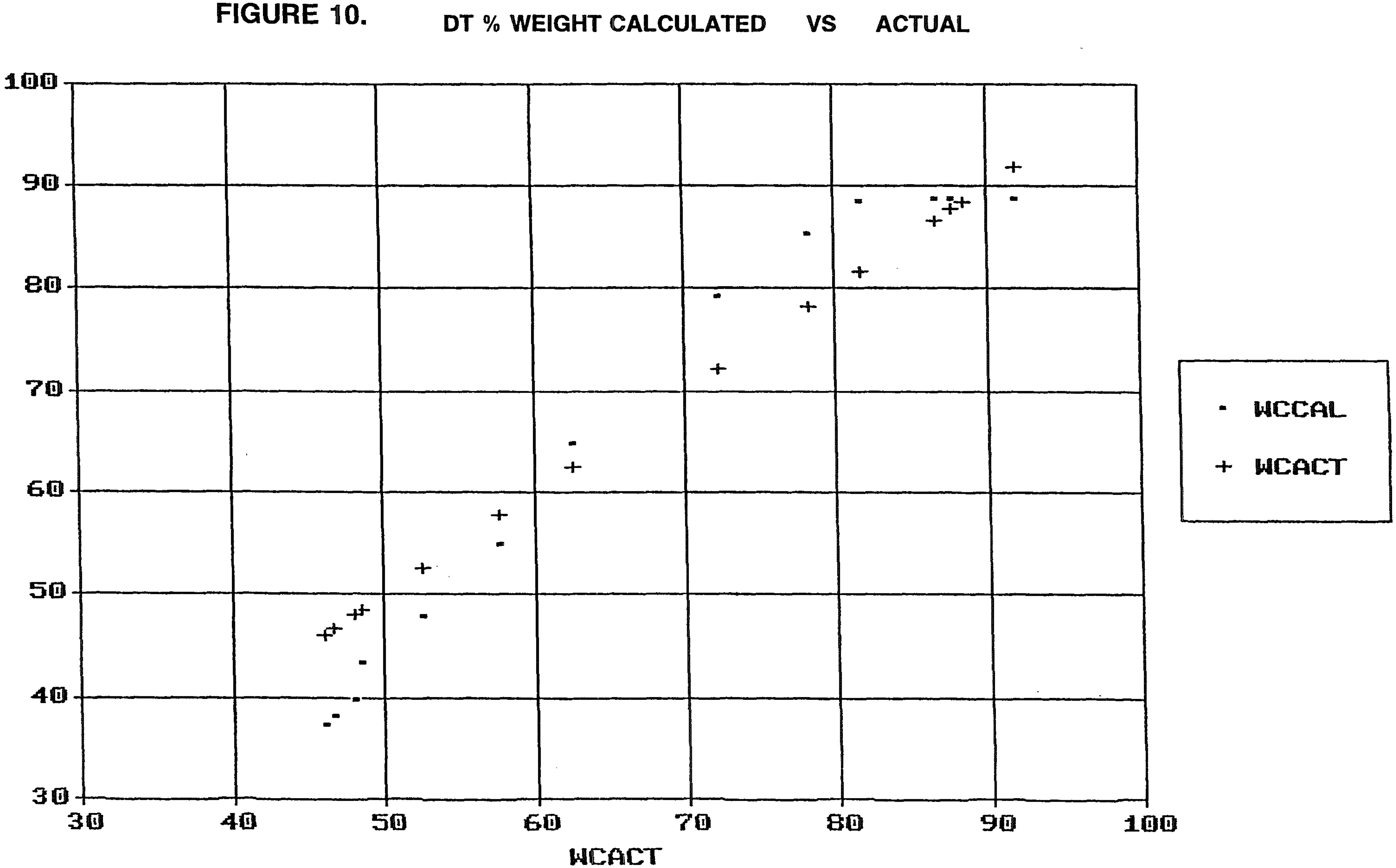


FIGURE 10.


DT % WEIGHT CALCULATED VS ACTUAL
100
90
80
70
60
50
40
30
30
40
50
60
70
80
90
100
WCACT
WCCAL
WCACT