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Fermilab

Conventional Main Ring Magnet Quality as a Function of Time

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October 1, 1980

This paper is concerned with the quality of Main Ring conventional magnets as a function of time. The data set contains recent magnets and some of the early magnets, and has been provided by the Magnetic Measurements Group at the Magnet Facility (especially Dean Krause).

The plotting program was set to automatically find the upper and lower boundaries from the data. Only keypunch errors have been weeded out, i.e., errors in transcription from the raw data to the data sheets have not been checked. Since the purpose of this paper is to check the general trend of the magnets with time and not to find any specific bad magnet, the status of the data is adequate for this purpose. A short explanation of this data is contained in the list of figure captions. On several of the figures, lines are drawn which indicate an acceptance criteria which the Main Ring Group uses in deciding to accept or reject a particular magnet. If a figure contains only one line, then the other line is off scale.

Each horizontal step represents one month and the start of the plots is January, 1971.

The measured quantities for the 4' quadrupoles are quite good. Figure 4 indicates that a few of the recent quads have a slight problem for the gradient at high excitation currents, while figure 8 shows a larger spread for the recent magnets as opposed to a small sample of earlier magnets.

The results for the 7' quads are not quite as nice as the 4' quads. Figures 10 and 11 indicate a slight problem with the gradient at the edges of the quadrupoles. Also the Q values (figures 14 & 16) show a wider spread for some of the recent magnets.

For the B1 dipoles we have good results in general. The inductance at 1 KHZ (figure 17) shows a trend for the later magnets which is increasing, but this is not disturbing yet. Figures 21 and 22 are quite interesting, however the most likely explanation for the trend shown in that the measuring procedure simply stabilized and not that there were such gross changes in the magnets.

We see that the B2 results are quite good except for some of the Q values. Figures 31 and 32 show the same trend as figures 21 and 22.

The overall conclusion of this study is that the recent magnets have not deteriorated in quality from the earlier magnets.

FIGURE OPTIONS

Q4 QUADRUPOLES

Figure 1	Percentage difference of the integrated gradient ($\int B'dl$) with respect to a standard reference magnet at an excitation current of 2000 amps.
Figure 2	Percentage difference of the integrated gradient ($\int B'dl$) with respect to a standard reference magnet at an excitation current of 5000 amps.
Figure 3	The percentage difference, of the difference between the reference magnet and the quad, at two different transverse distances: X=0" and X=$\pm$2." The excitation current is 2000 amps.
Figure 4	The same quantity in figure 3 for an excitation current of 5000 amps.
Figure 5	The inductance in millihenrys measured at a frequency of 1 kilohertz.
Figure 6	The quality ratio, Q, measured at 1 kilohertz.
Figure 7	The inductance in millihenrys measured at 50 hertz.
Figure 8	The quality ratio, Q, measured at 50 hertz.

Q7 QUADRUPOLES

Figure 9	Percentage difference of the integrated gradient $(\int B' dl)$ with respect to a standard reference magnet at an excitation current of 2000 amps.
Figure 10	Percentage difference of the integrated gradient $(\int B' dl)$ with respect to a standard reference magnet at an excitation current of 5000 amps.
Figure 11	The percentage difference, of the difference between the reference magnet and the quad, at two different transverse distances: X=0" and X=$\pm$2." The excitation current is 2000 amps.
Figure 12	The same quantity in figure 11 for an excitation current of 5000 amps.
Figure 13	The inductance in millihenrys measured at a frequency of 1 kilohertz.
Figure 14	The quality ratio, Q, measured at 1 kilohertz.
Figure 15	The inductance in millihenrys measured at 50 hertz.
Figure 16	The quality ratio, Q, measured at 50 hertz.

B1 DIPOLES

Figure 17	The inductance in millihenrys measured at 1 kilohertz.
Figure 18	The quality ratio, Q, measured at 1 kilohertz.
Figure 19	The percentage difference of the $\int B dl$, measured with a stretched wire coil, from a standard reference magnet. The value is determine via an interpolation method to obtain the value of this difference at 9 kilogauss as measured by a third coil in the dipole. The value plotted is (A-B)/C where A = $\int B dl$ from the stretched wire B = $\int B dl$ from the reference C = A value determined by the third coil
Figure 20	The same quantity as in figure 19 but at a value of 18 KG.
Figure 21	The average magnitude of the magnetic field, calculated by assuming a magnetic length L of 239," at an excitation current of 2000 amps.
Figure 22	The same quantity as in figure 21 at an excitation current of 5000 amps.
Figure 23	This data is similar to the data in figure 19. The difference is that this is ramped data and no interpolation is done, i.e., the system is set to record the value when a current of 2000 amps is reached. Another difference is that here the quantity is (A-B)/A.
Figure 24	The same quantity as in figure 23 but at a current of 5000 amps.

Figure 25	The maximum percentage difference, of the difference between the reference magnet and the dipole, at two different transverse distances: X=0," and X=+2." The excitation current is 2000 amps.
Figure 26	The same quantity as in figure 25 at an excitation current of 5000 amps.

B2 DIPOLES

Figure 27 — The inductance in millihenrys measured at 1 kilohertz.

Figure 28 — The quality ratio, Q, measured at 1 kilohertz.

Figure 29 — The percentage difference of the $\int B\,dl$, measured with a stretched wire coil, from a standard reference magnet. The value is determined via an interpolation method to obtain the value of this difference at 9 kilogauss as measured by a third coil in the dipole. The value plotted is (A-B)/C where A = $\int B\,dl$ from the stretched wire
B = $\int B\,dl$ from the reference
C = A value determined by the third coil

Figure 30 — The same quantity as in figure 19 but at a value of 18 KG.

Figure 31 — The average magnitude of the magnetic field, calculated by assuming a magnetic length L of 239," at an excitation current of 2000 amps.

Figure 32 — The same quantity as in figure 21 at an excitation current of 5000 amps.

Figure 33 — This data is similar to the data in figure 29. The difference is that this is ramped data and no interpolation is done, i.e., the system is set to record the value when a current of 2000 amps is reached. Another difference is that here the quantity is (A-B)/A.

Figure 34 — The same quantity as in figure 33 but at a current of 5000 amps.

Figure 35	The maximum percentage difference, of the difference between the reference magnet and the dipole, at two different transverse distances: X=0," and X=+2." The excitation current is 2000 amps.
Figure 36	The same quantity as in figure 35 at an excitation current of 5000 amps.

CM:dm

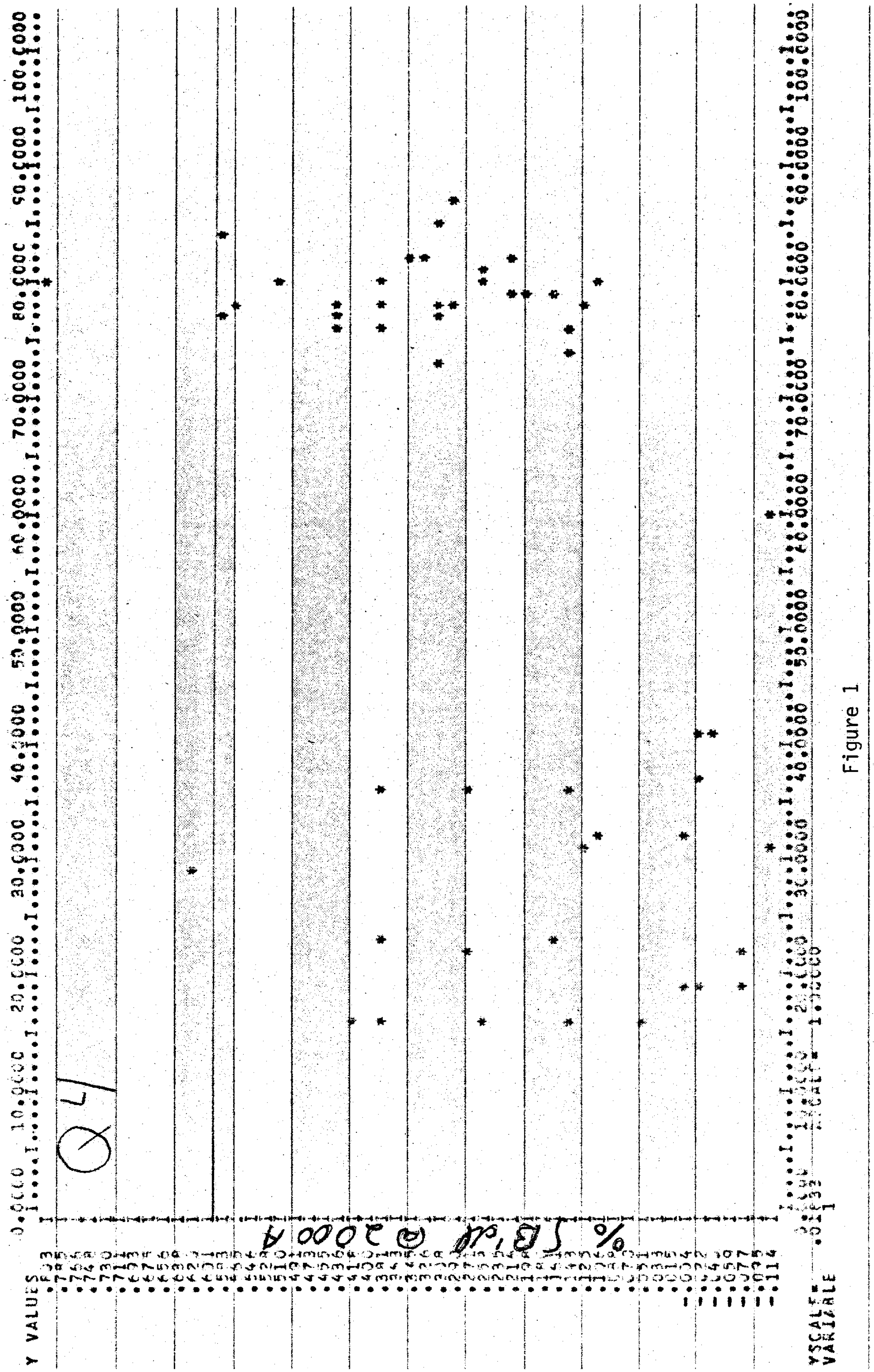

Figure 1

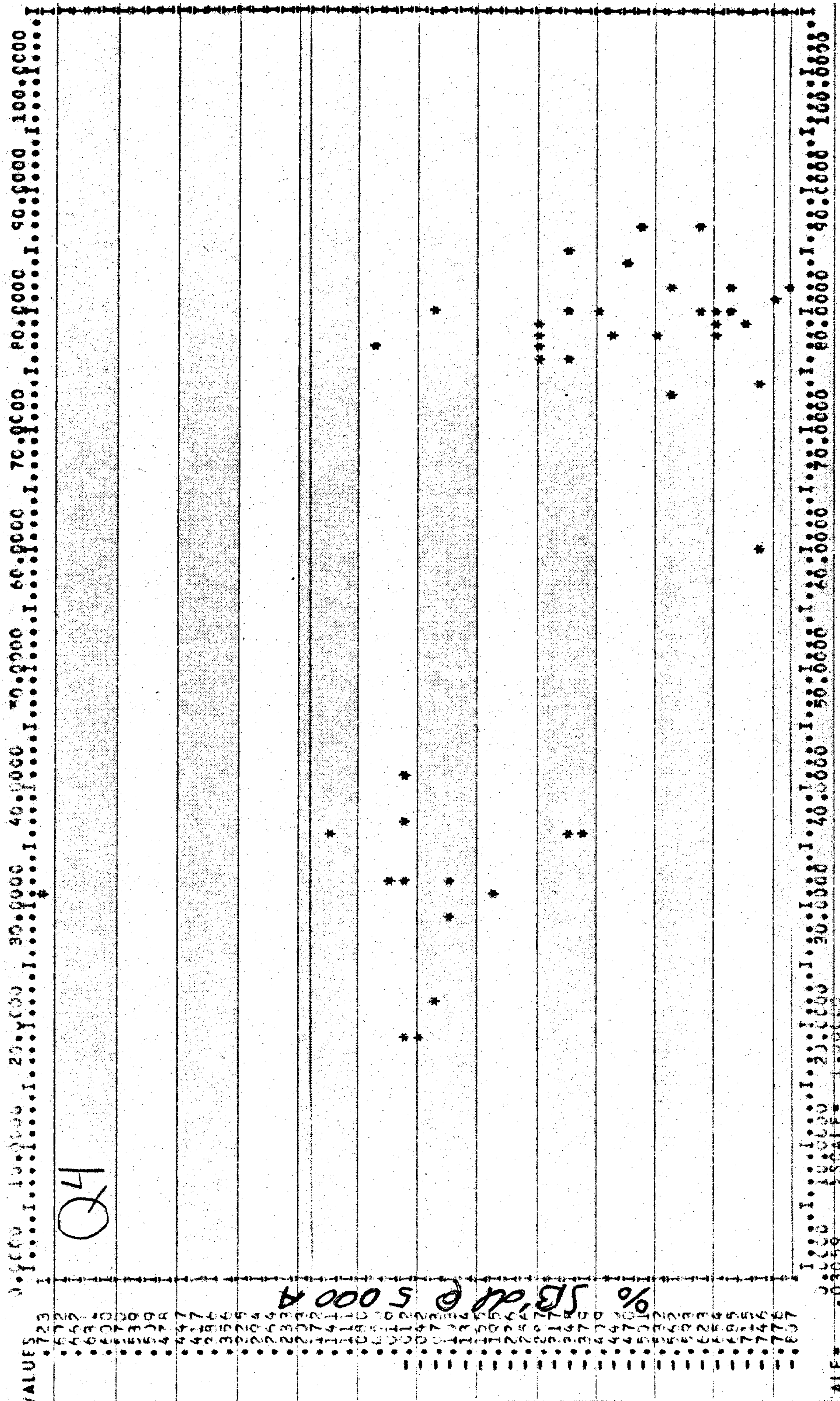
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000

Figure 2

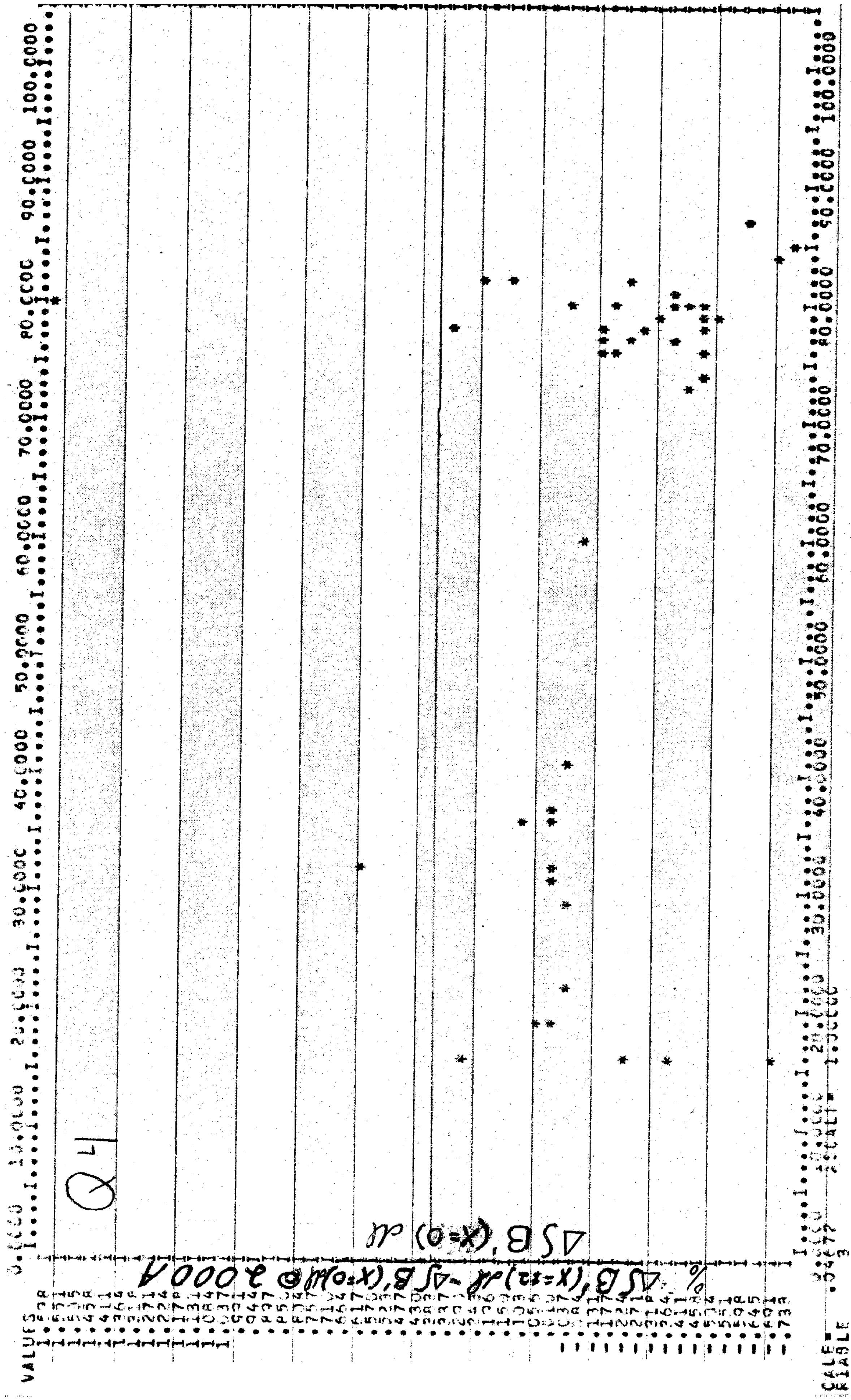

Figure 3

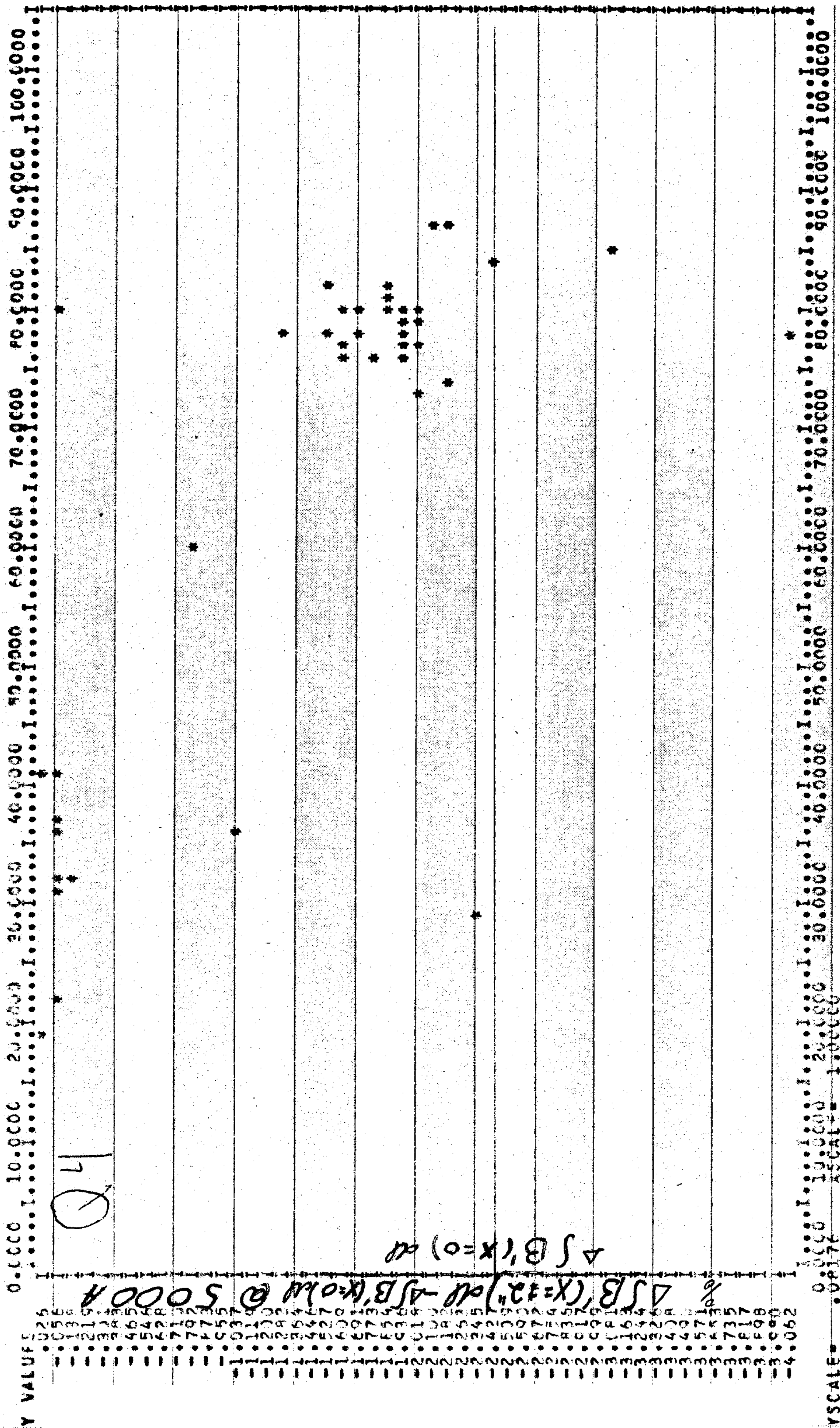

Figure 4

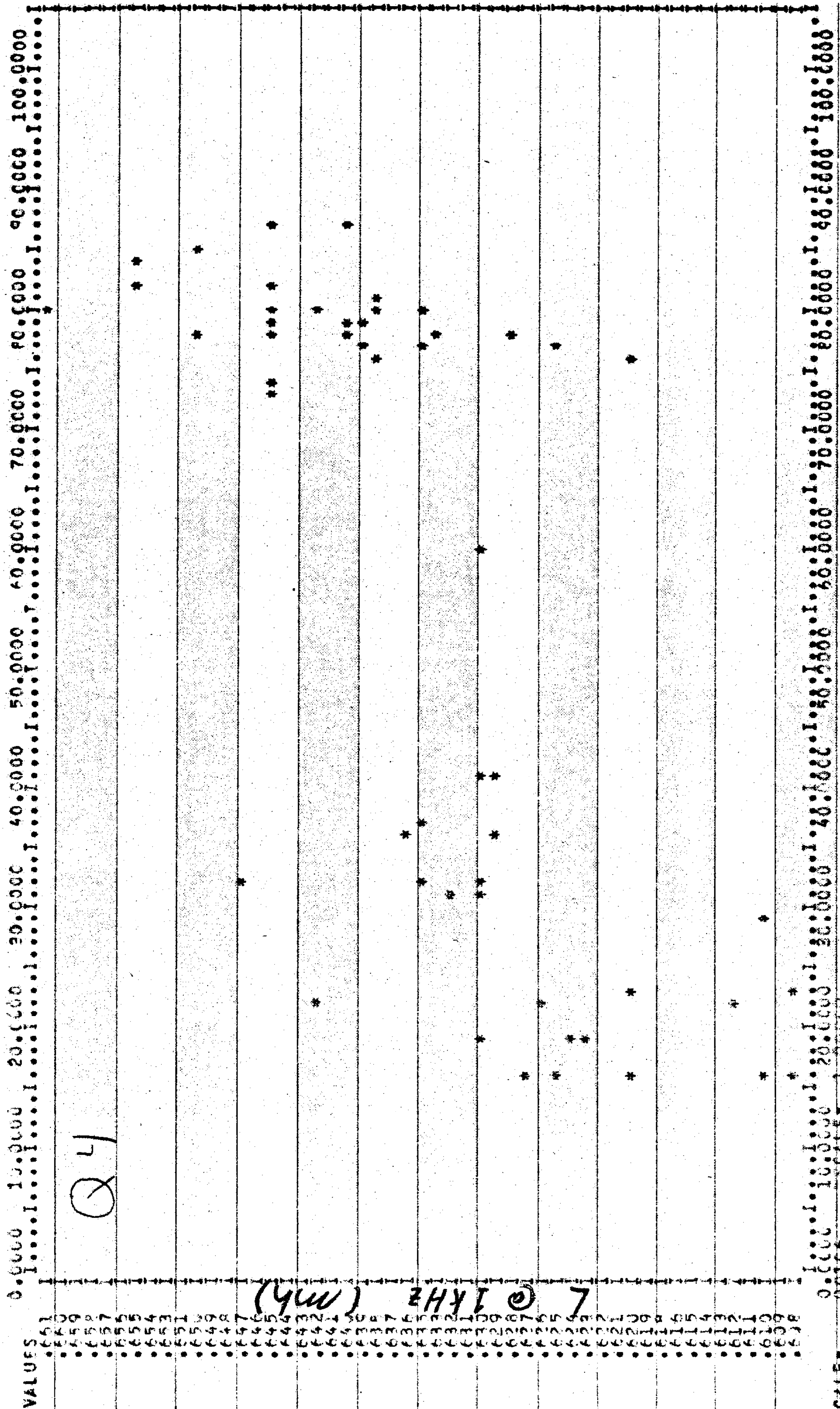
Q_L
L @ 1kHz (mh)
VALUES
SCALE=
XSCALE=
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000

Figure 5

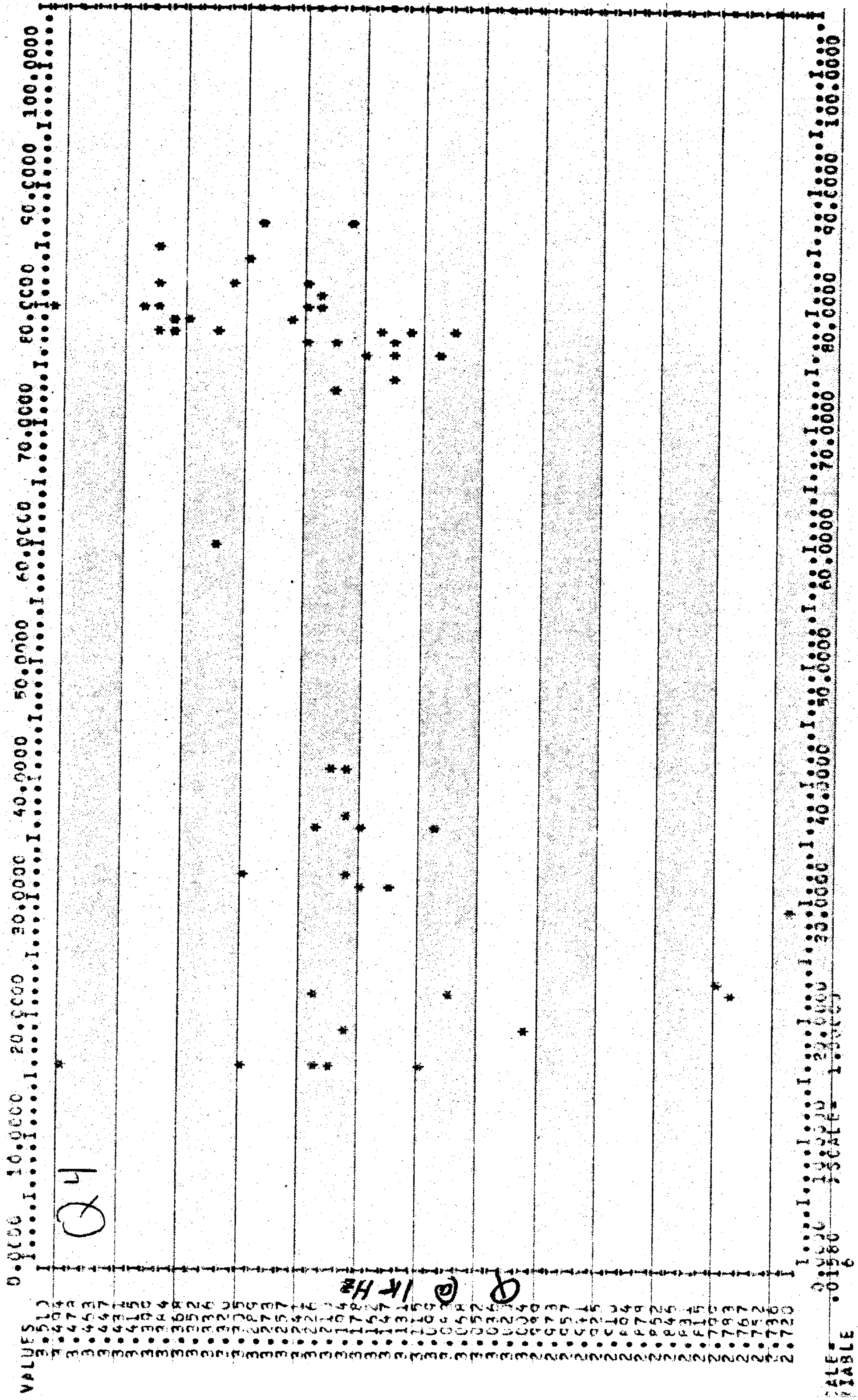
VALUES
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
Q4
Q @ 1k Hz

Figure 6

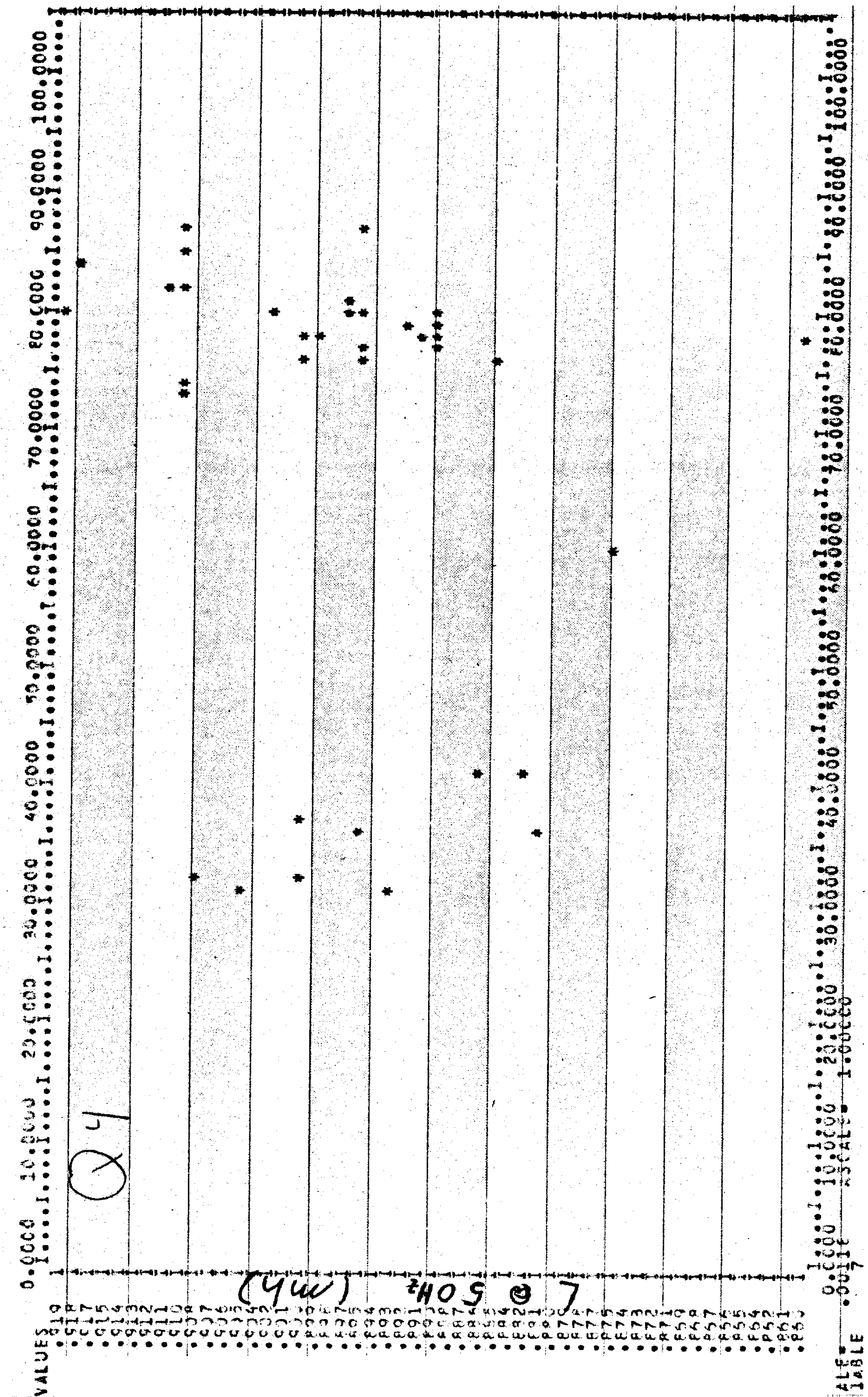

Figure 7

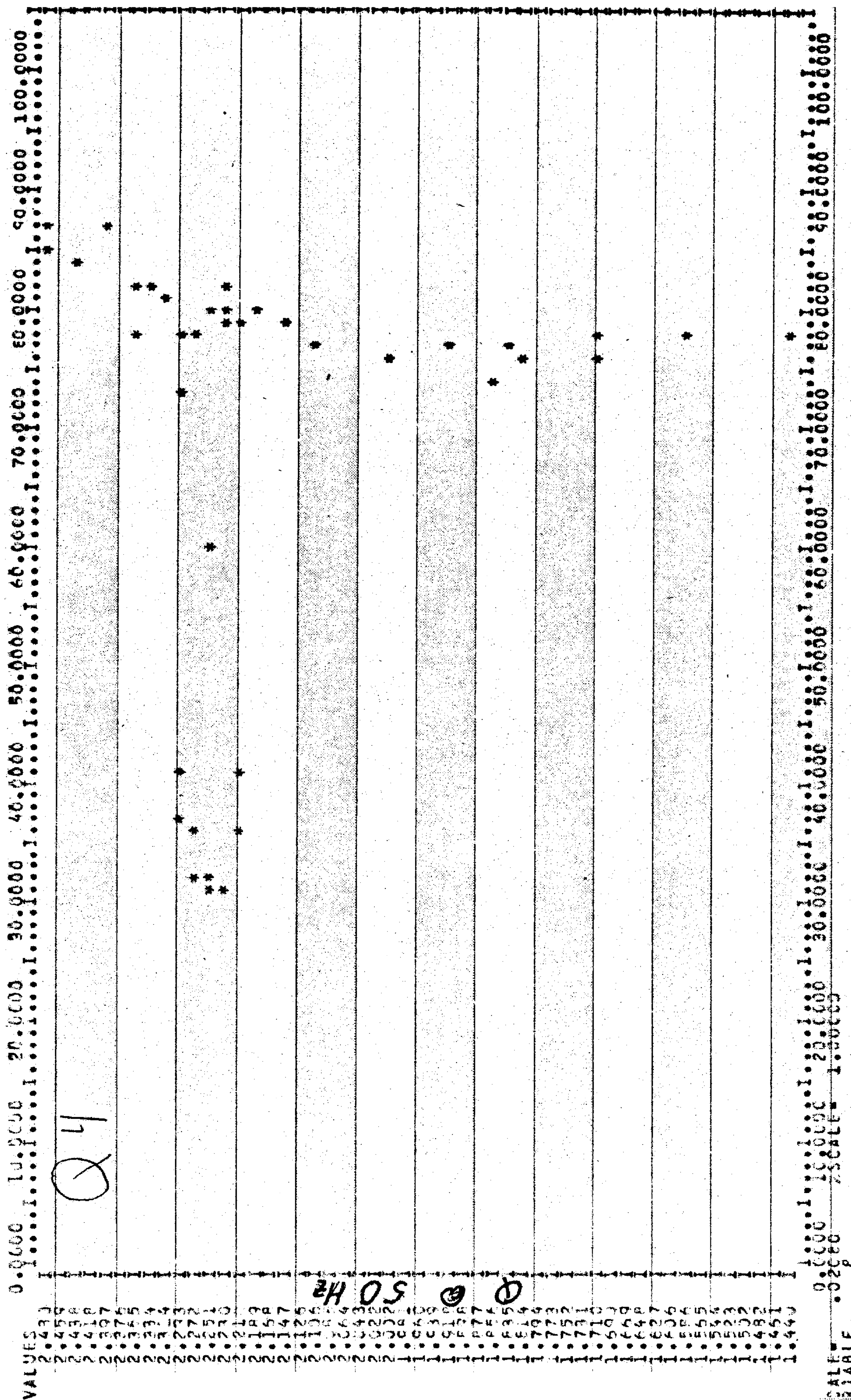
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
VALUES
Q @ 50 Hz

Figure 8

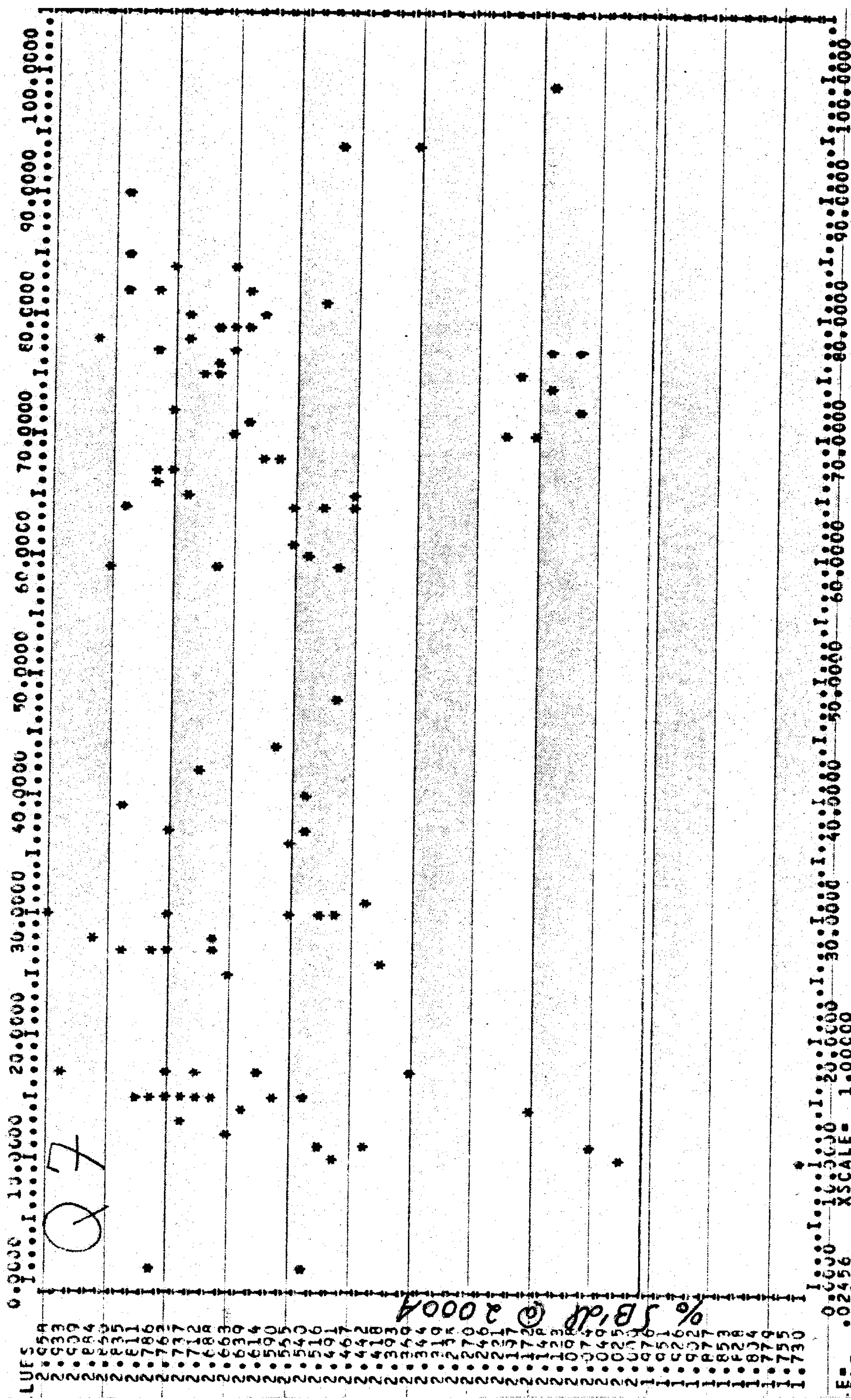
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= 1.00000

Figure 9

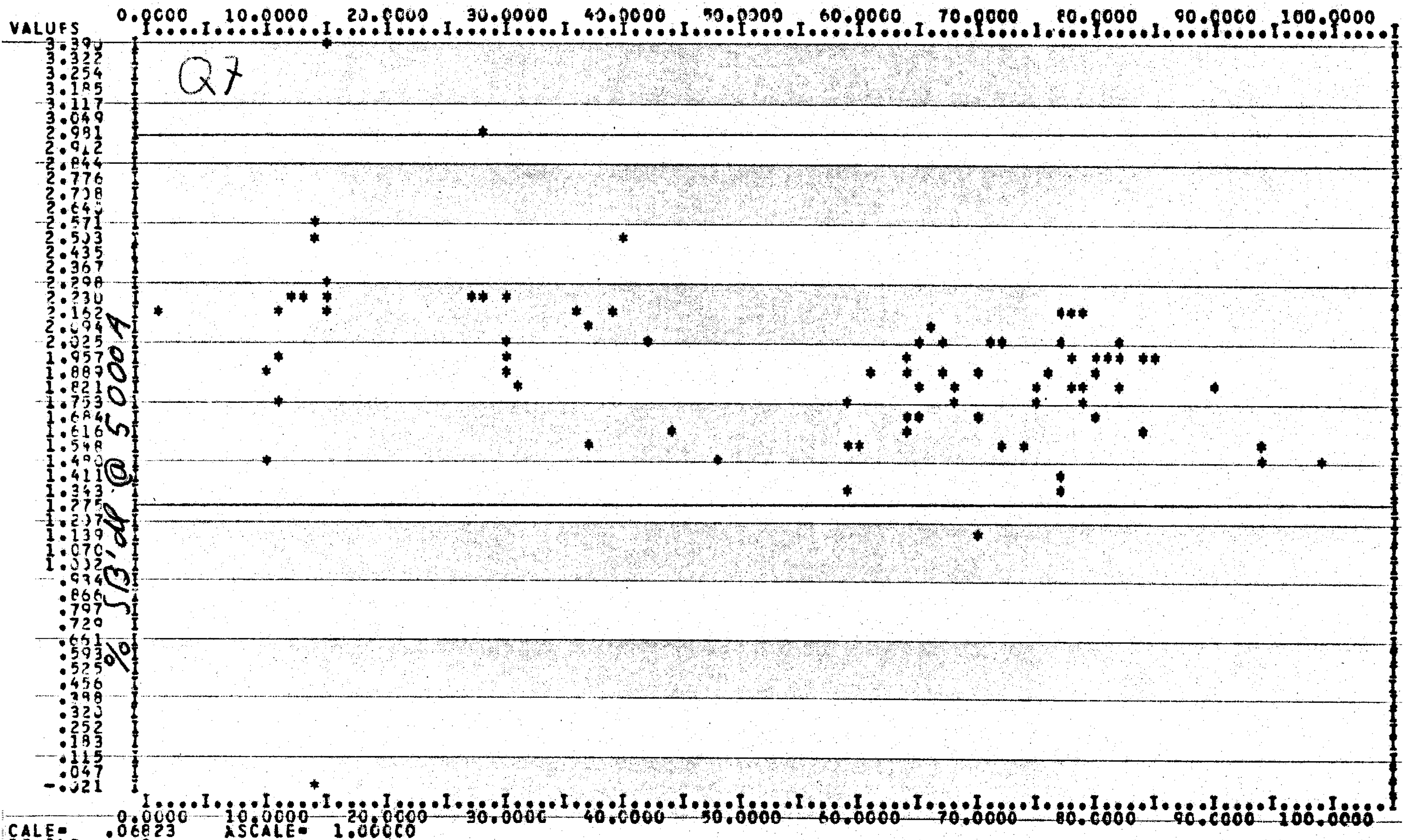
VALUES
0.0000 10.0000 20.0000 30.0000 40.0000 50.0000 60.0000 70.0000 80.0000 90.0000 100.0000
Q7
% SB'dl @ 5000A
CALE= .06823 ASCALE= 1.00000
RIABLE 2

Figure 10

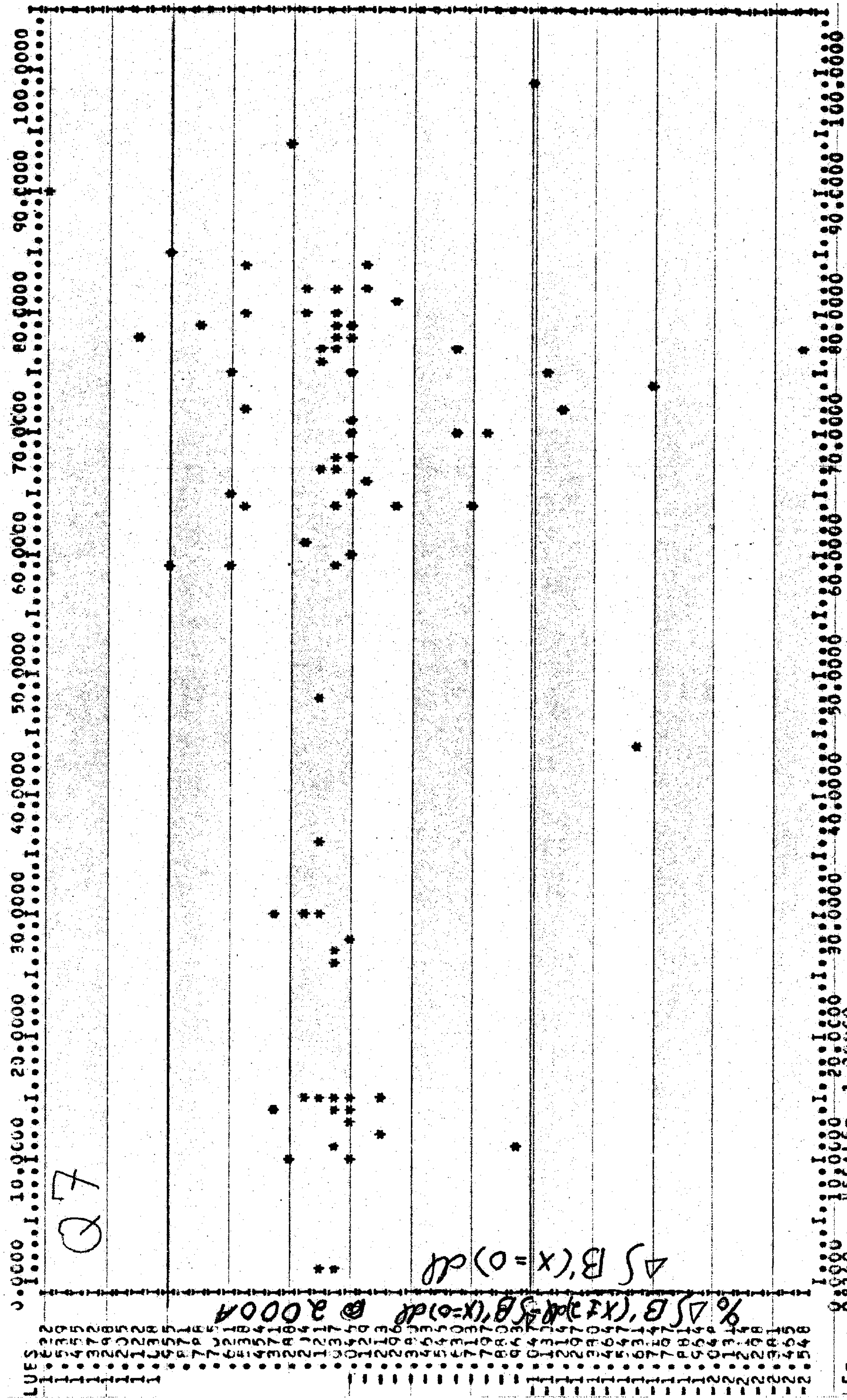

Figure 11

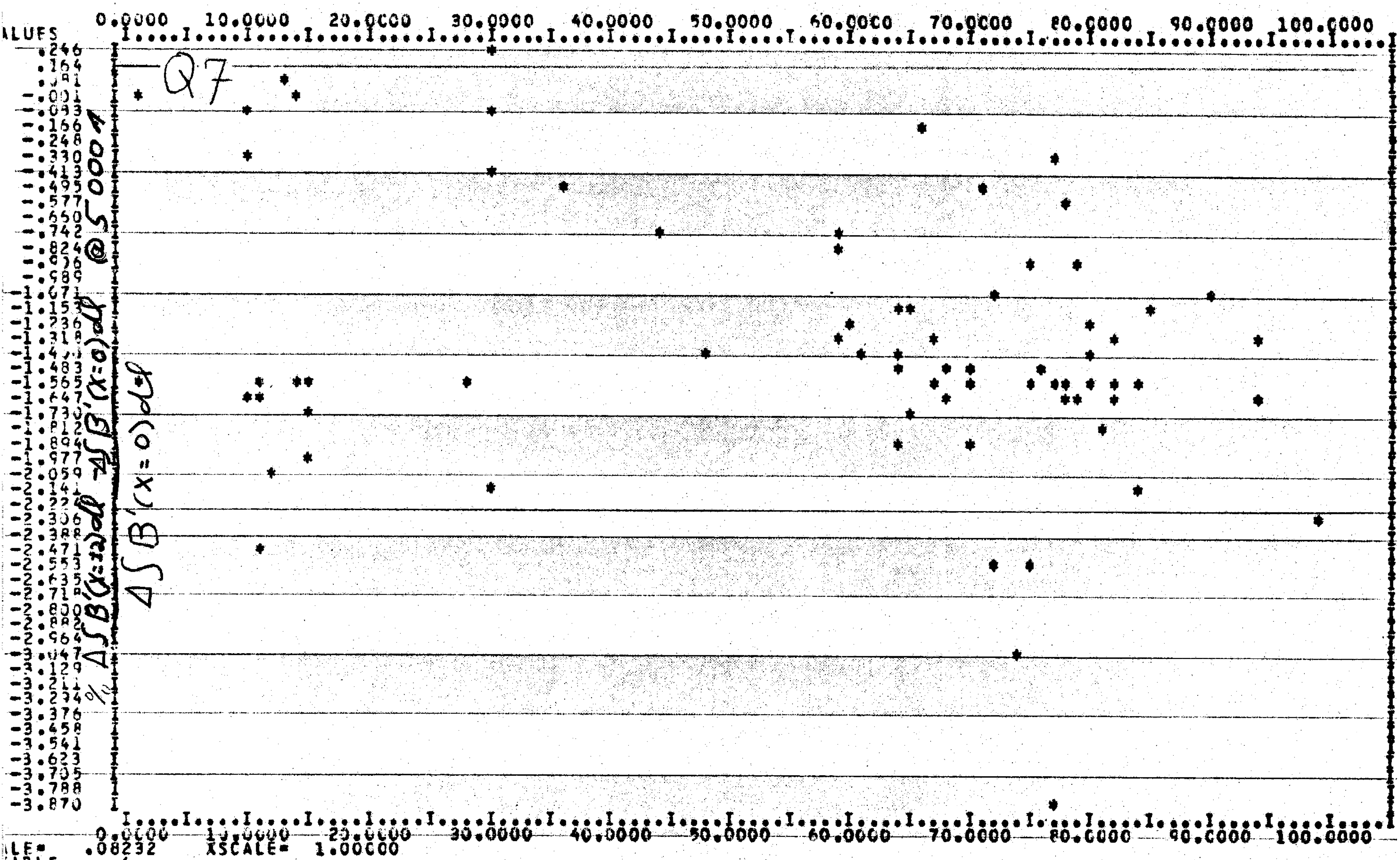
Q7
XSCALE= 1.00000
.08232
0.0000 10.0000 20.0000 30.0000 40.0000 50.0000 60.0000 70.0000 80.0000 90.0000 100.0000

Figure 12

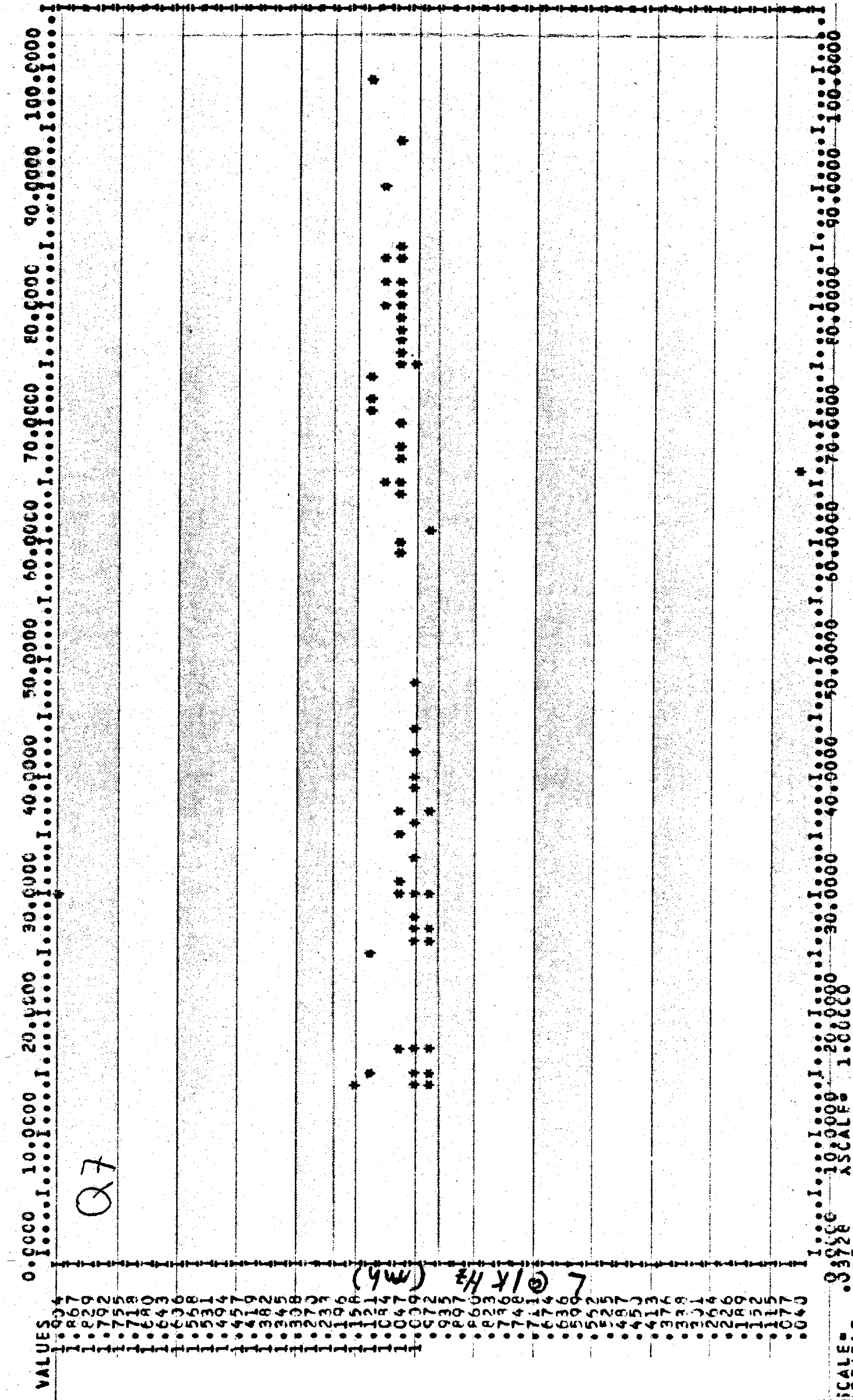

Figure 13

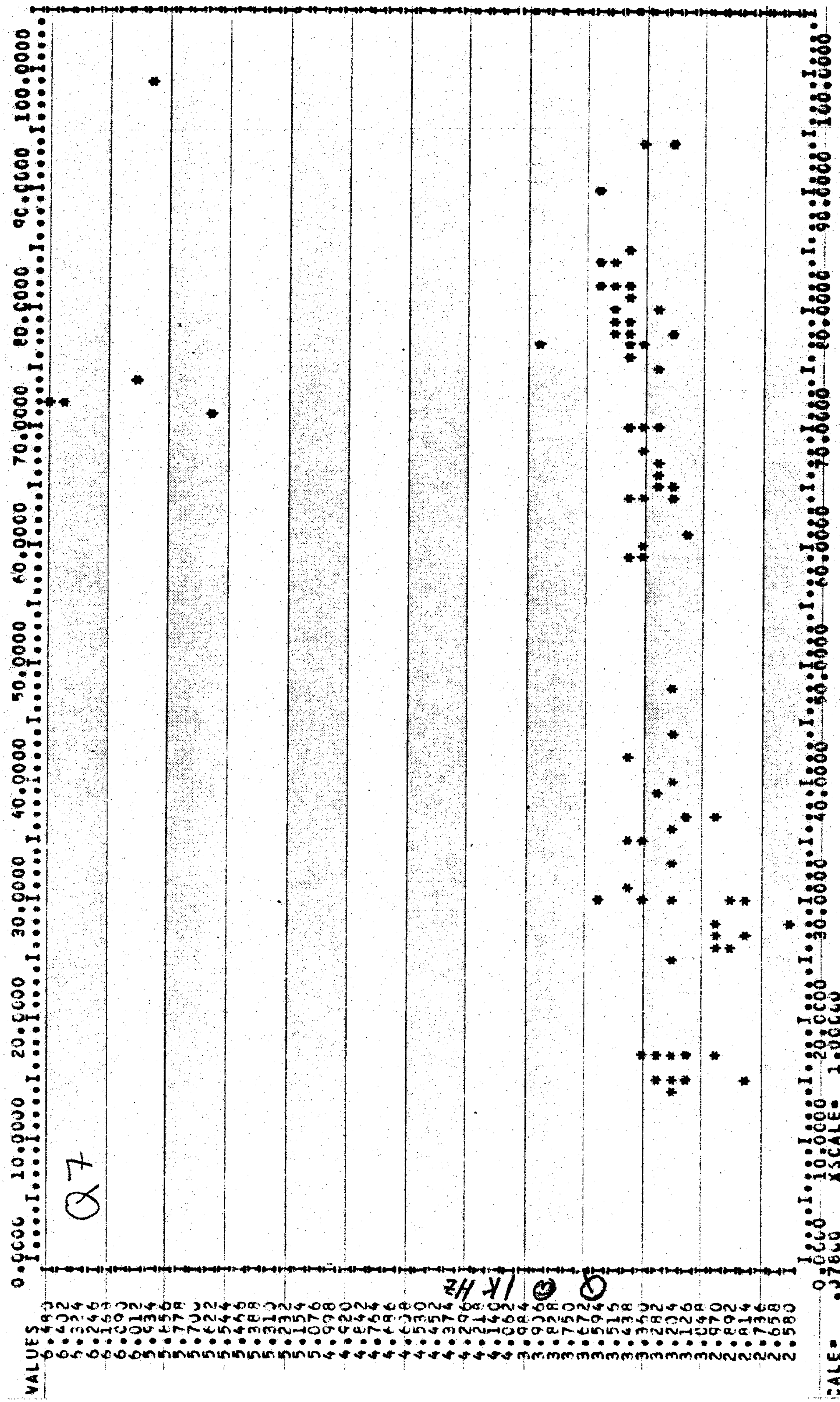
Q7
Q @ 1K Hz
VALUES
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000

Figure 14

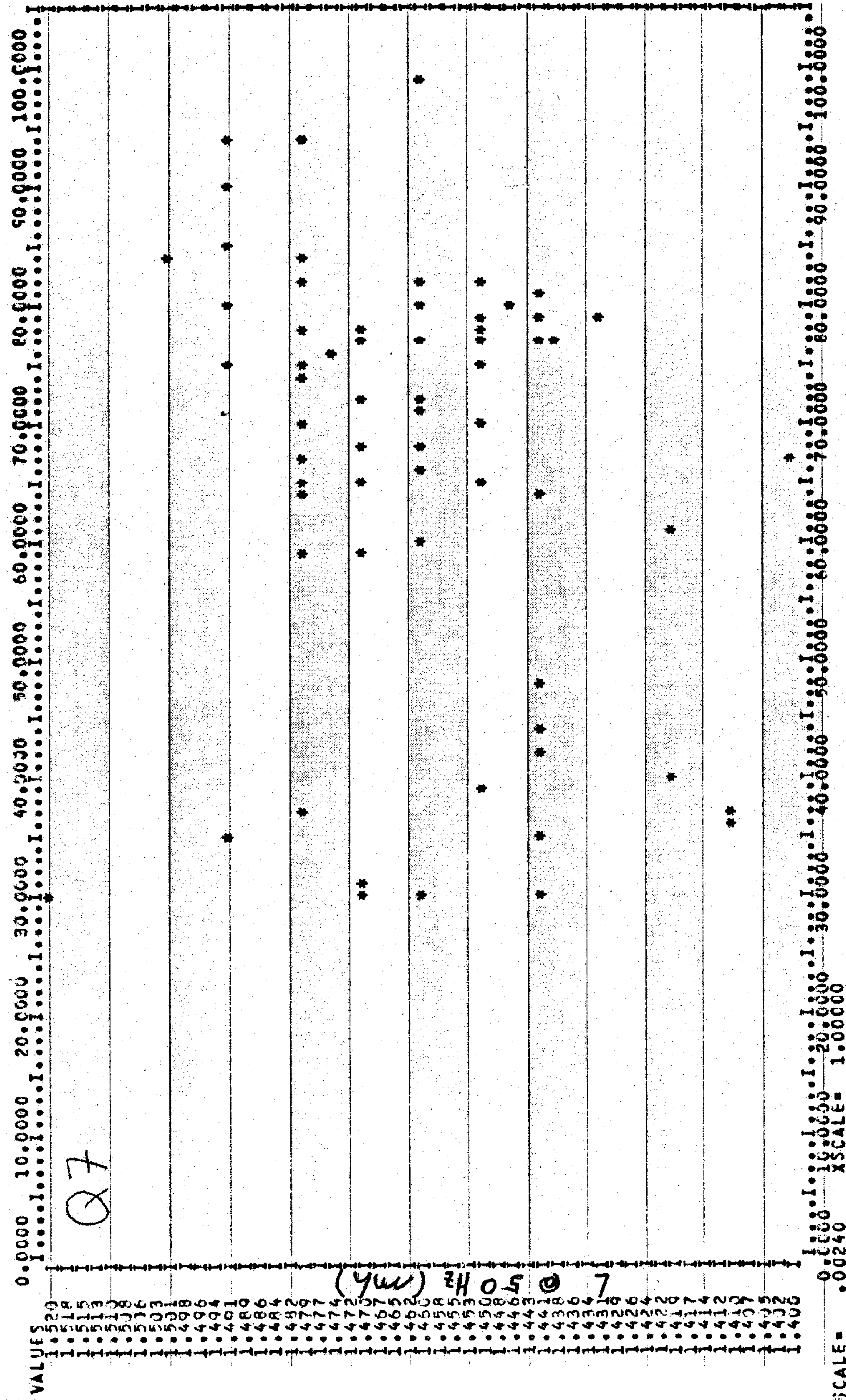

Figure 15

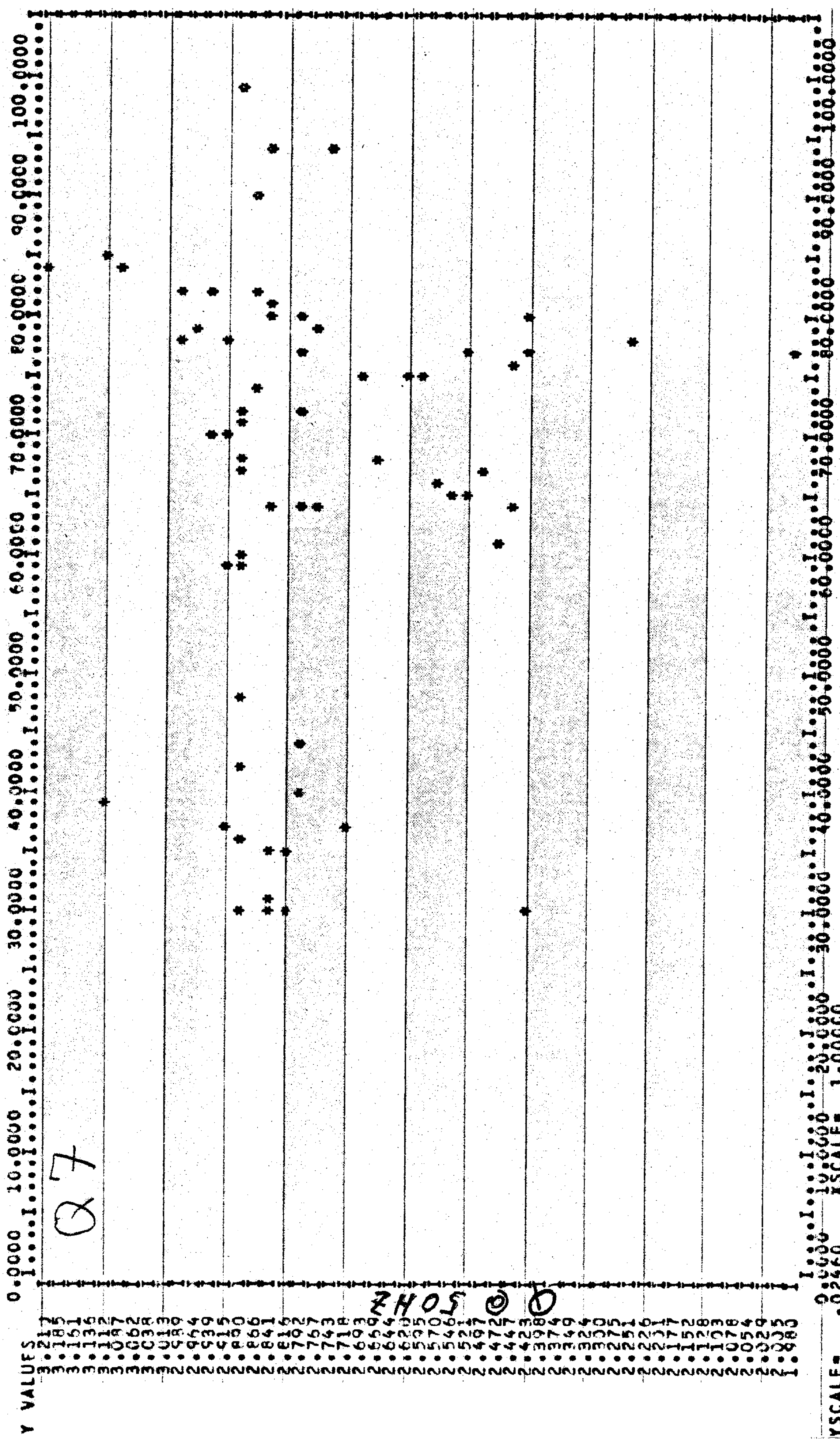

Figure 16

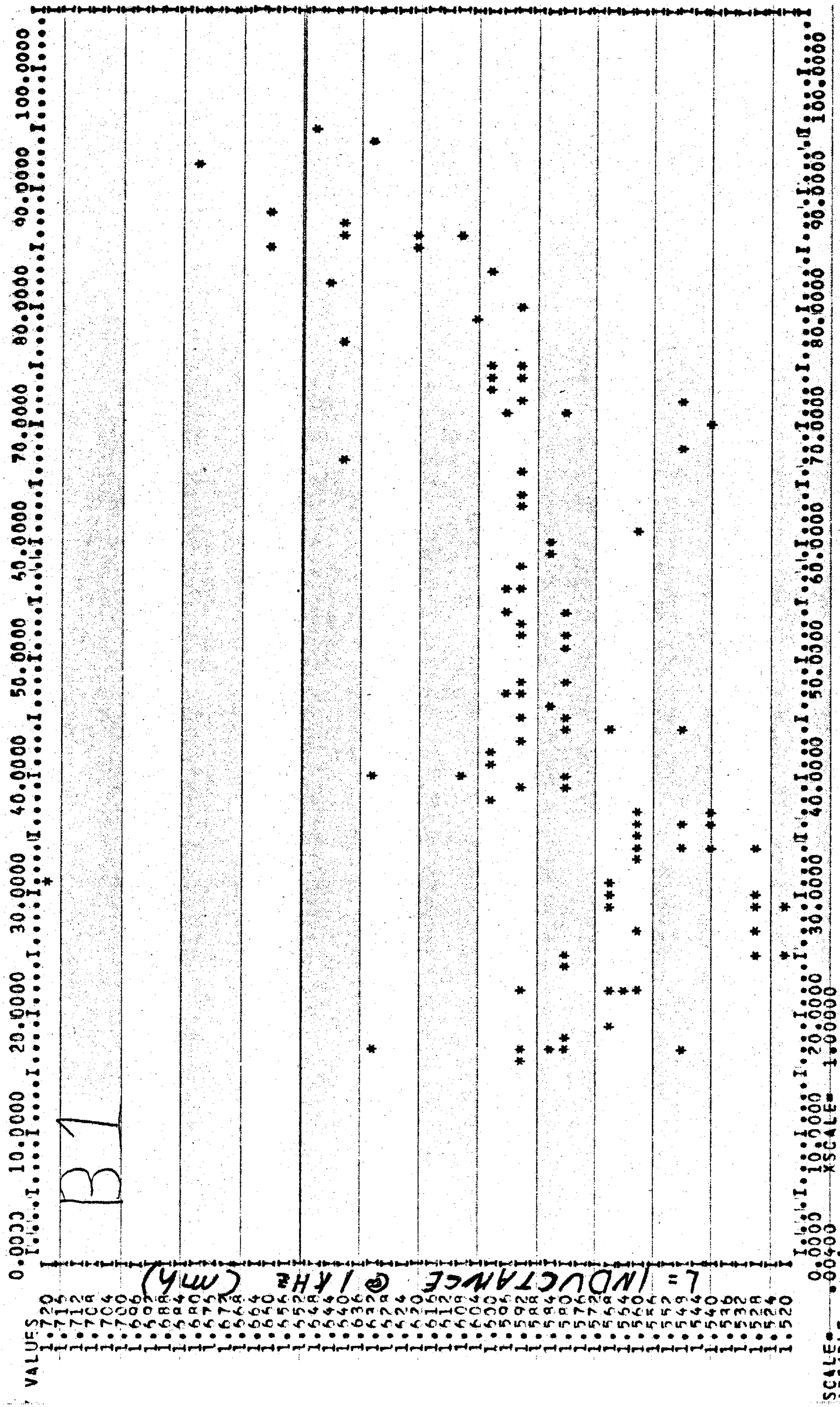

Figure 17

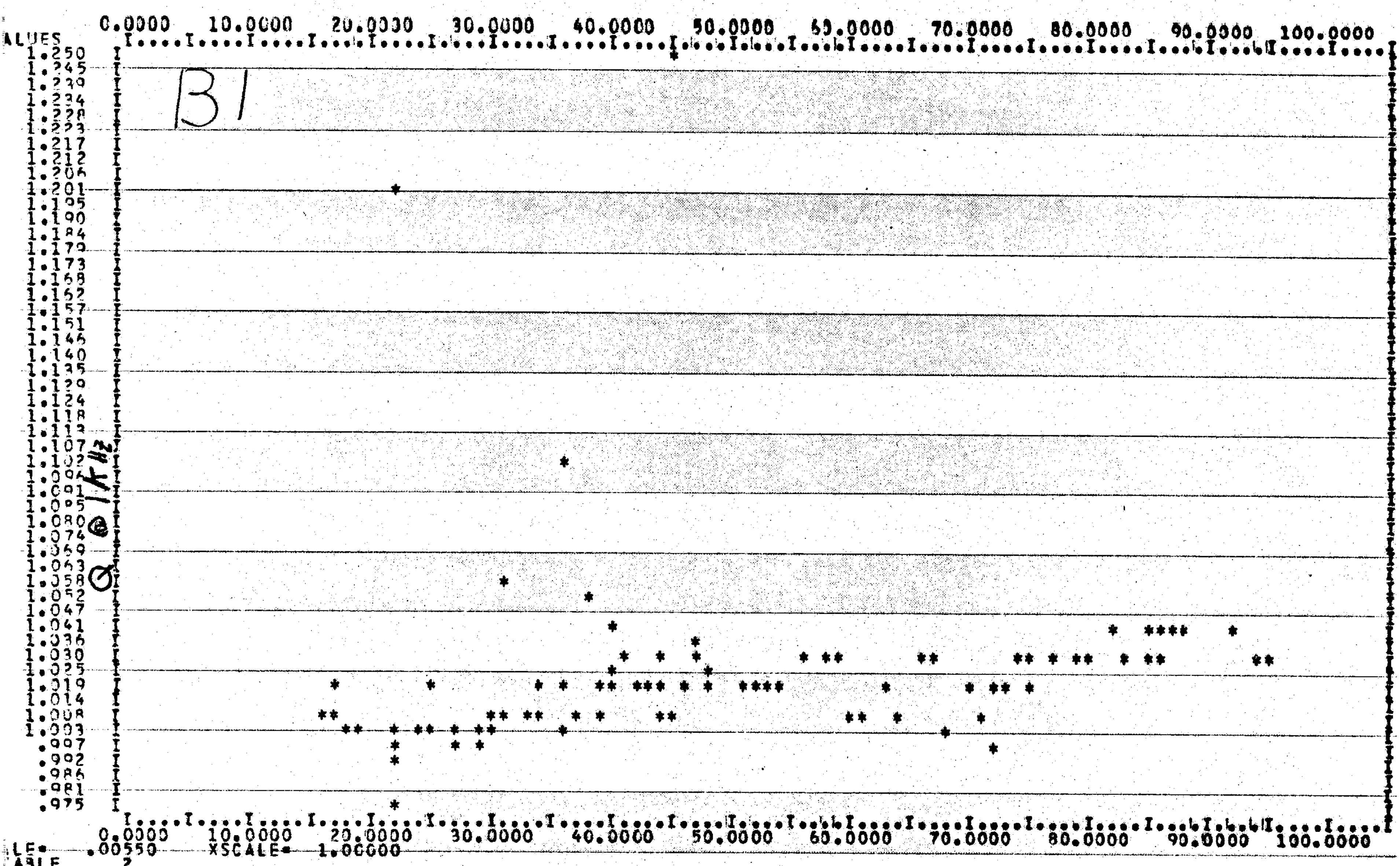
B1
Q @ 1 kHz
VALUES
0.0000 10.0000 20.0000 30.0000 40.0000 50.0000 60.0000 70.0000 80.0000 90.0000 100.0000
1.250 1.245 1.239 1.234 1.228 1.223 1.217 1.212 1.206 1.201 1.195 1.190 1.184 1.179 1.173 1.168 1.162 1.157 1.151 1.146 1.140 1.135 1.129 1.124 1.118 1.113 1.107 1.102 1.096 1.091 1.085 1.080 1.074 1.069 1.063 1.058 1.052 1.047 1.041 1.036 1.030 1.025 1.019 1.014 1.008 1.003 .997 .992 .986 .981 .975
.00550 XSCALE= 1.00000
2

Figure 18

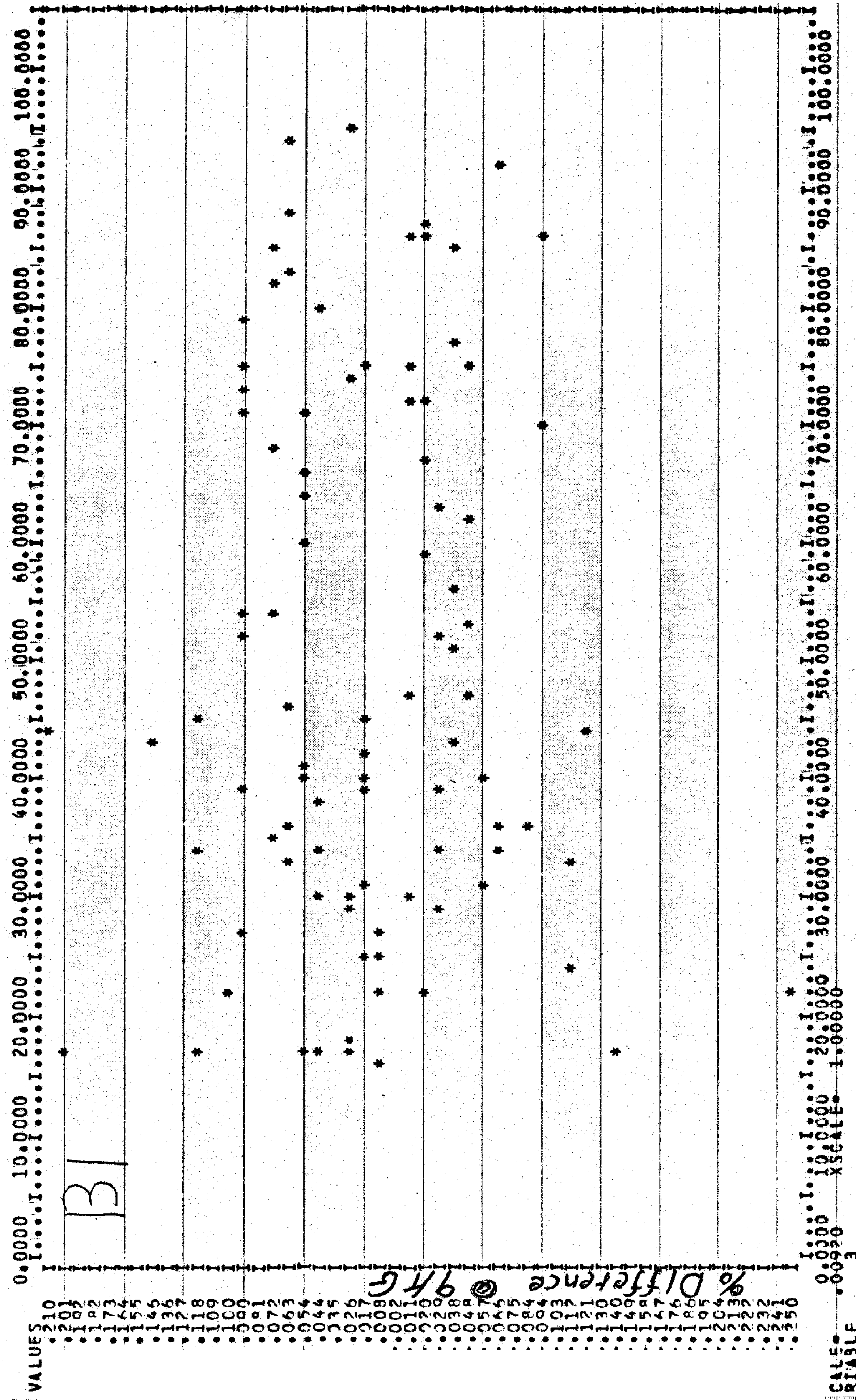

Figure 19

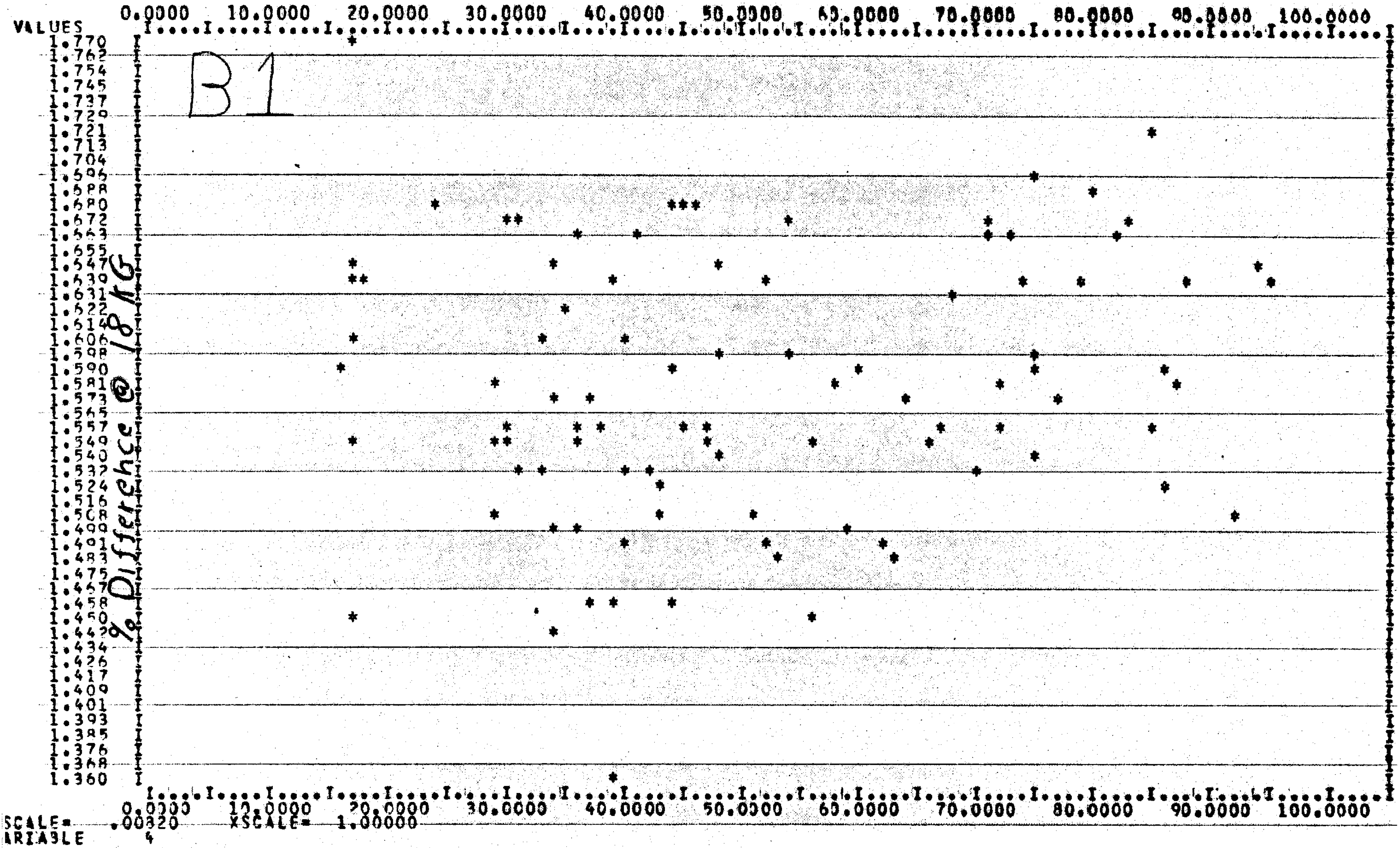
B1
% Difference @ 18 kG
VALUES
0.0000 10.0000 20.0000 30.0000 40.0000 50.0000 60.0000 70.0000 80.0000 90.0000 100.0000
SCALE= .00820 XSCALE= 1.00000
VARIABLE 4

Figure 20

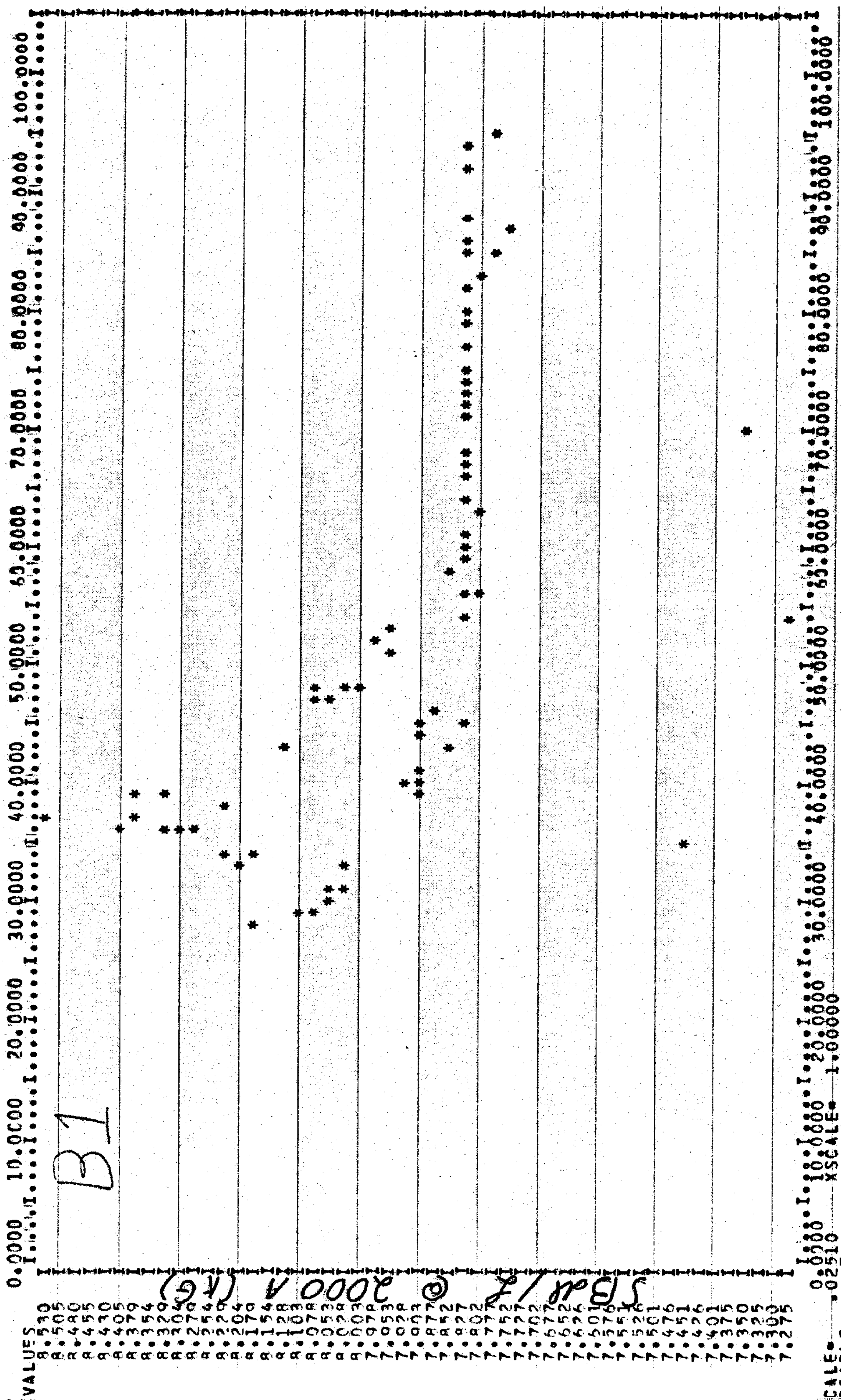
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
B1

Figure 21

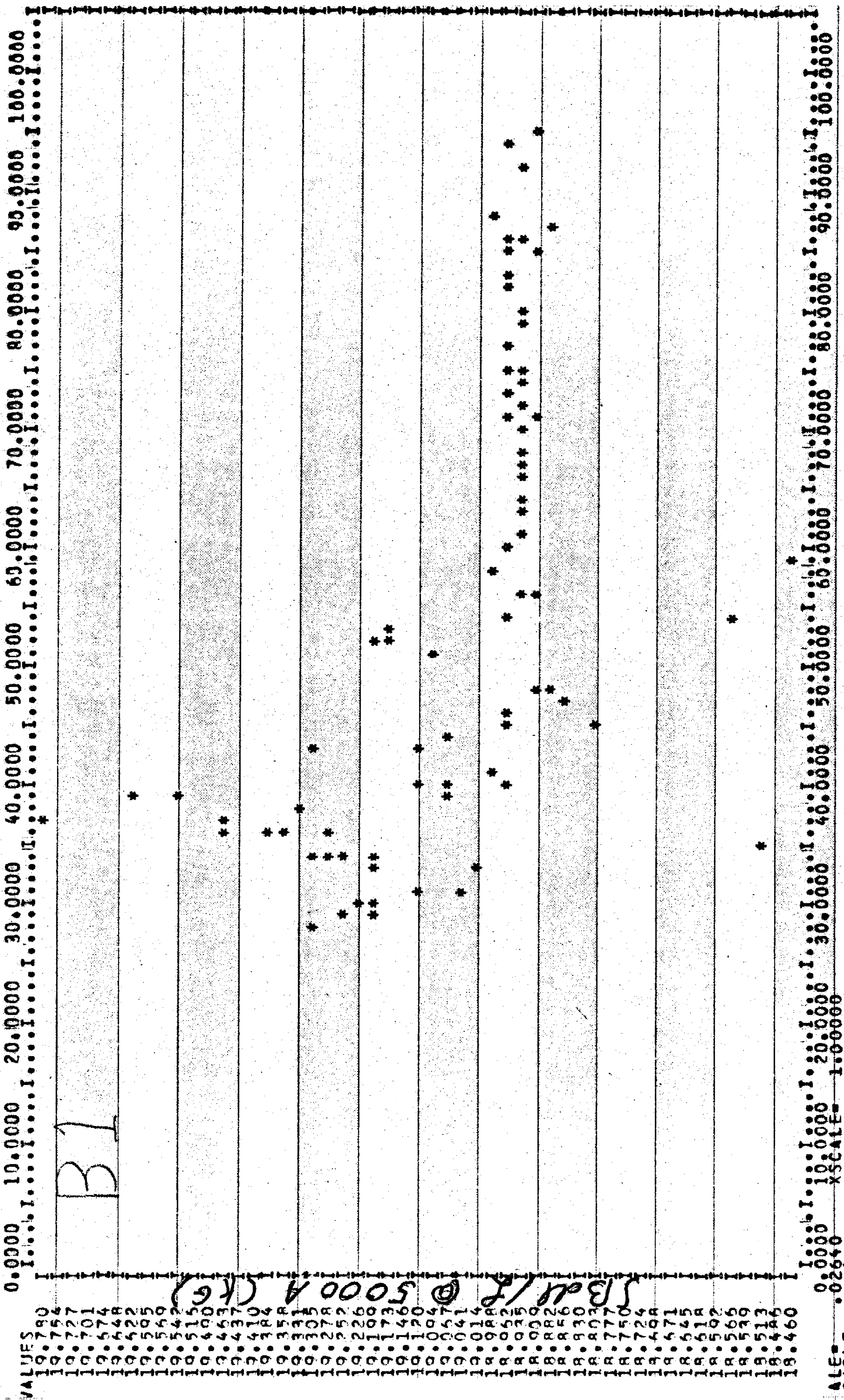

Figure 22

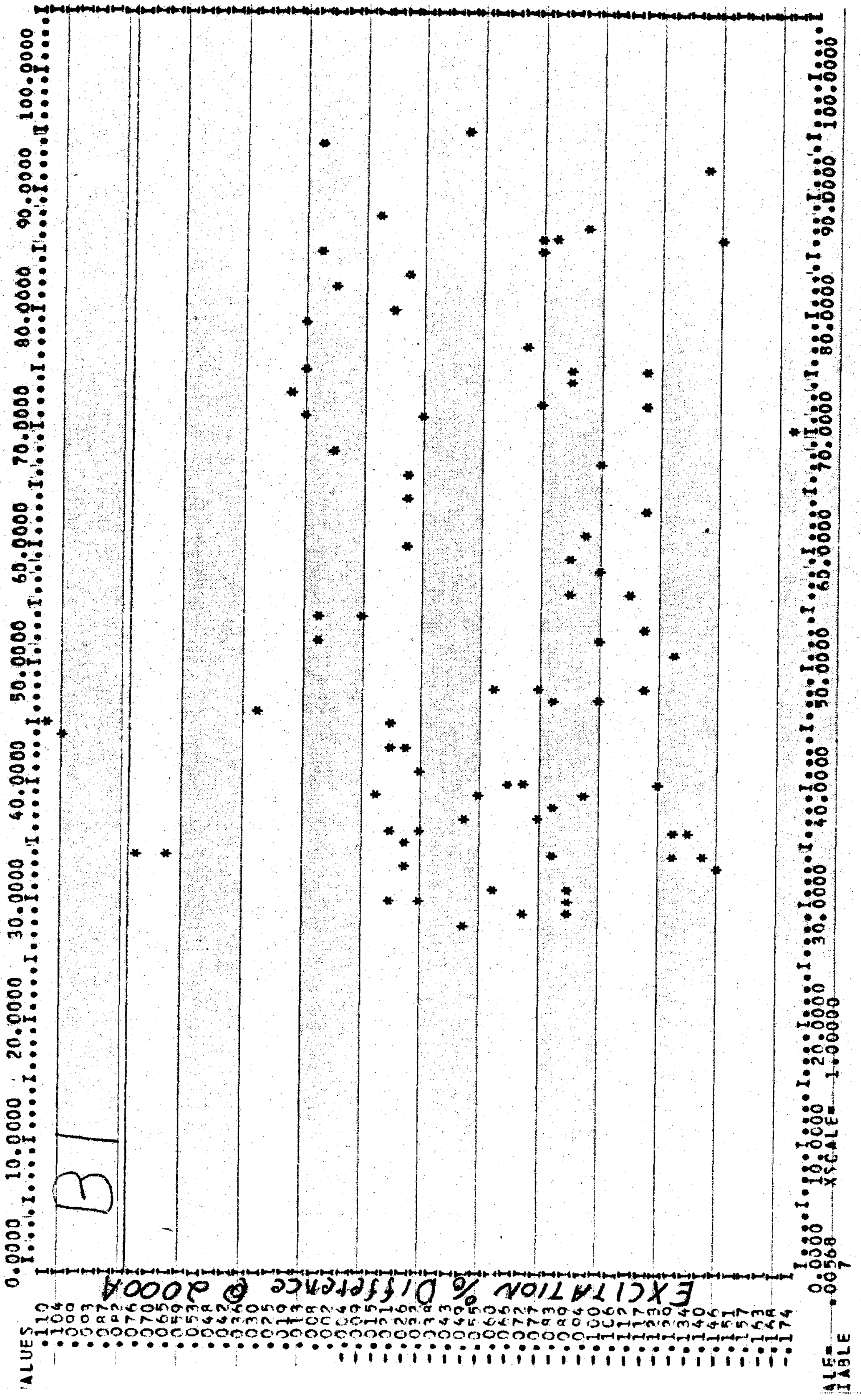

Figure 23

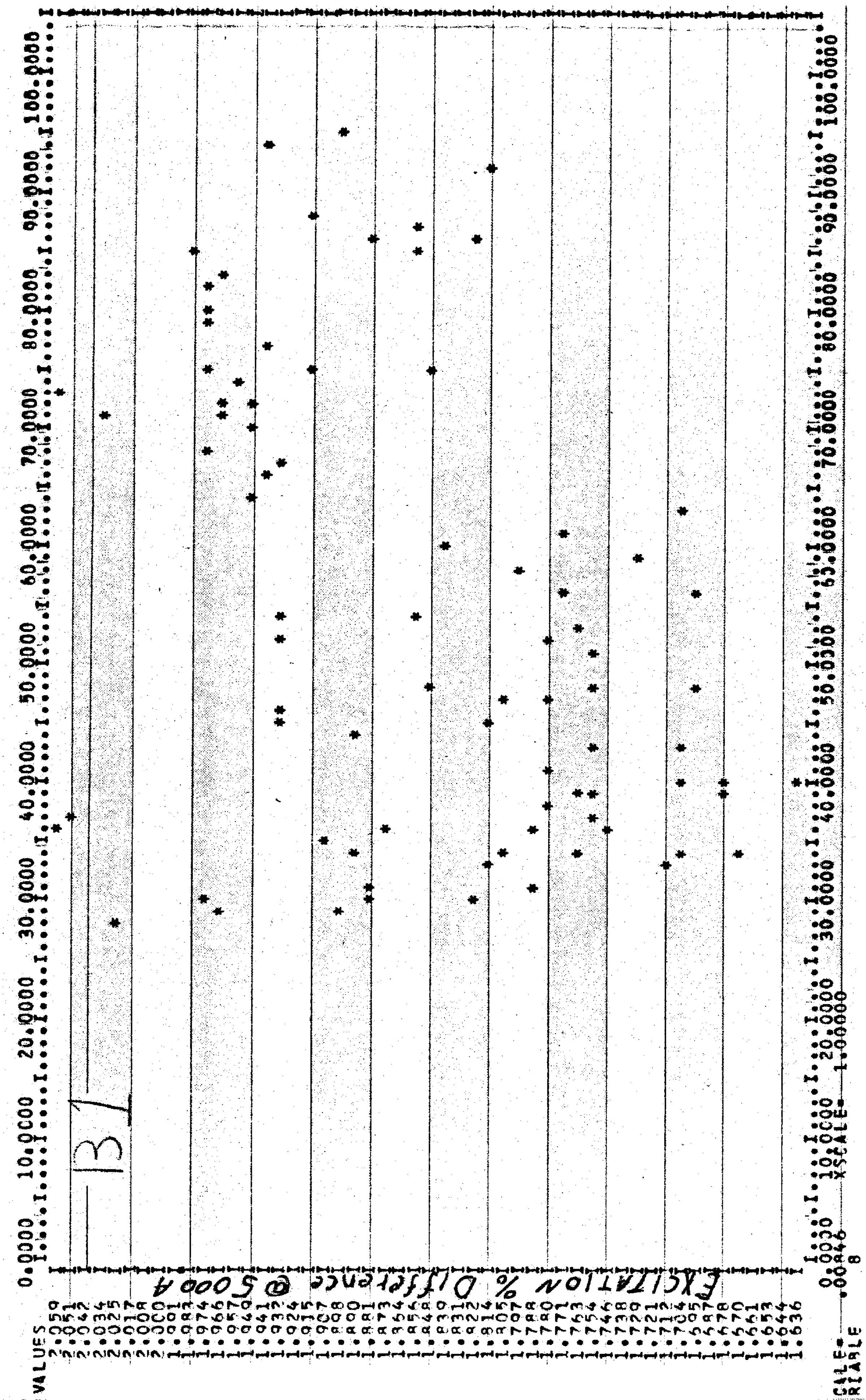

Figure 24

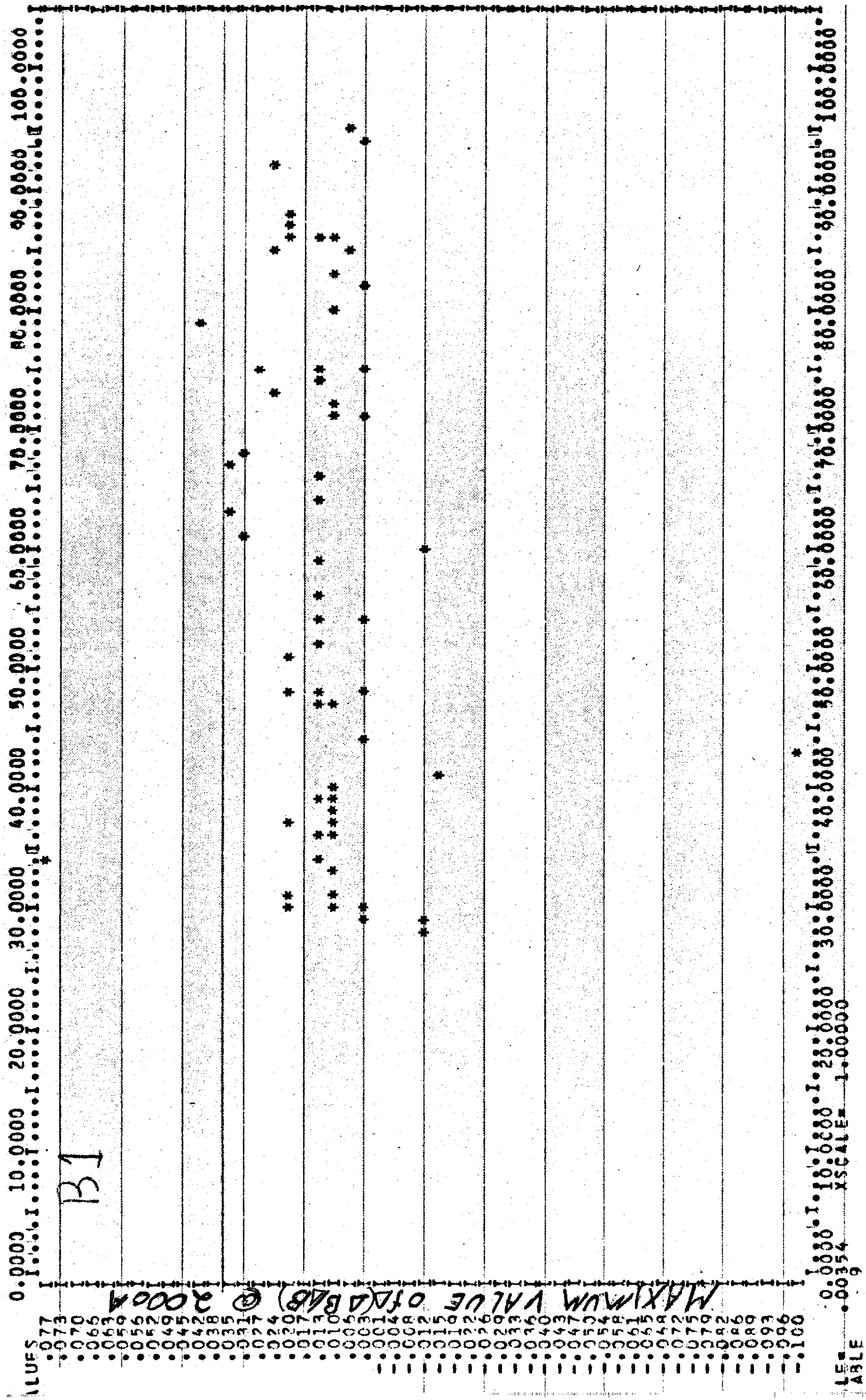
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
B1
XSCALE= 1.00000

Figure 25

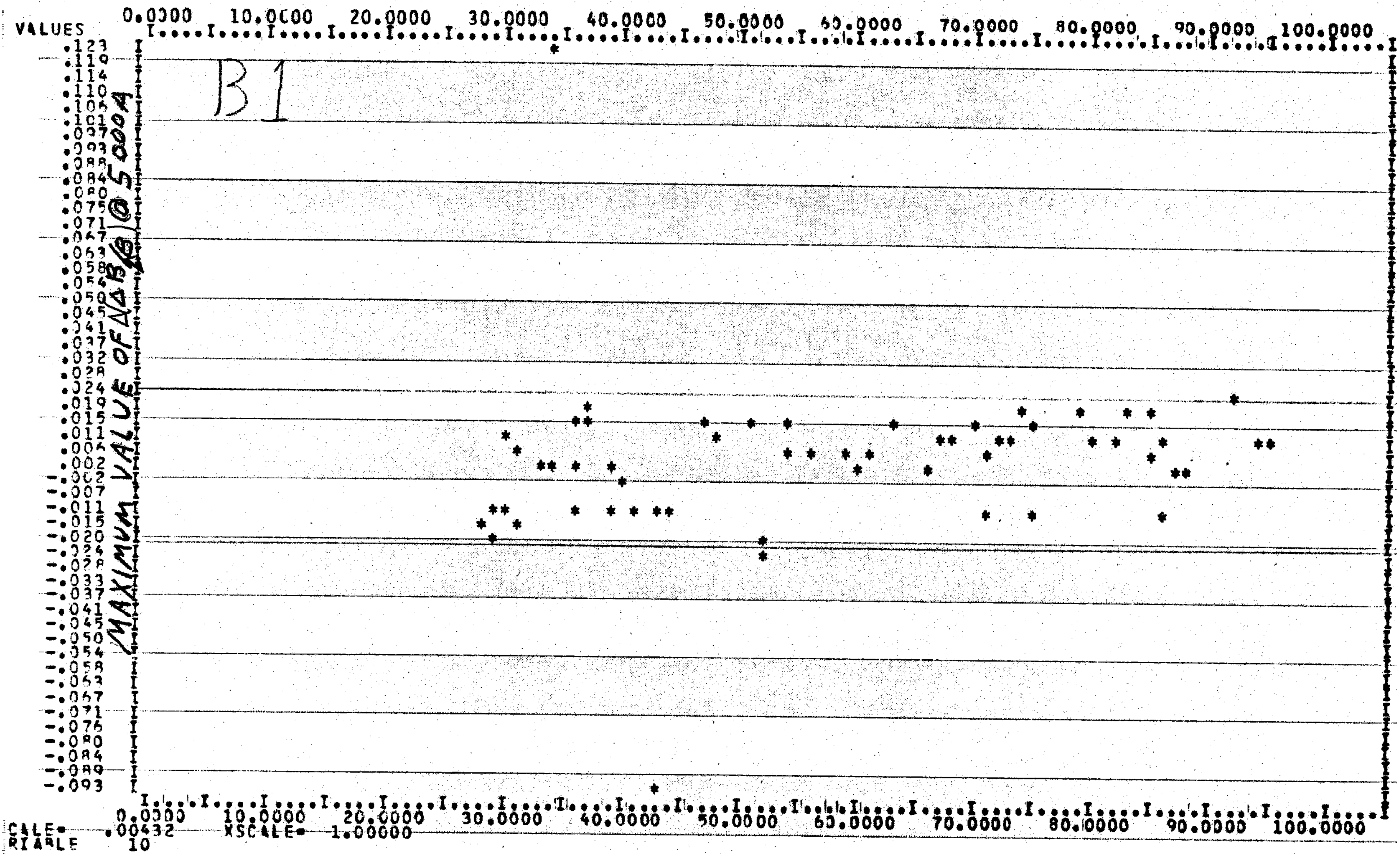
VALUES
0.0000 10.0000 20.0000 30.0000 40.0000 50.0000 60.0000 70.0000 80.0000 90.0000 100.0000
.123 .119 .114 .110 .106 .101 .097 .093 .088 .084 .080 .075 .071 .067 .063 .058 .054 .050 .045 .041 .037 .032 .028 .024 .019 .015 .011 .006 .002
-.002 -.007 -.011 -.015 -.020 -.024 -.028 -.033 -.037 -.041 -.045 -.050 -.054 -.058 -.063 -.067 -.071 -.076 -.080 -.084 -.089 -.093
B1
MAXIMUM VALUE OF ΔB/B @ 5000A
CALE= .00432 XSCALE= 1.00000
RIABLE 10

Figure 26

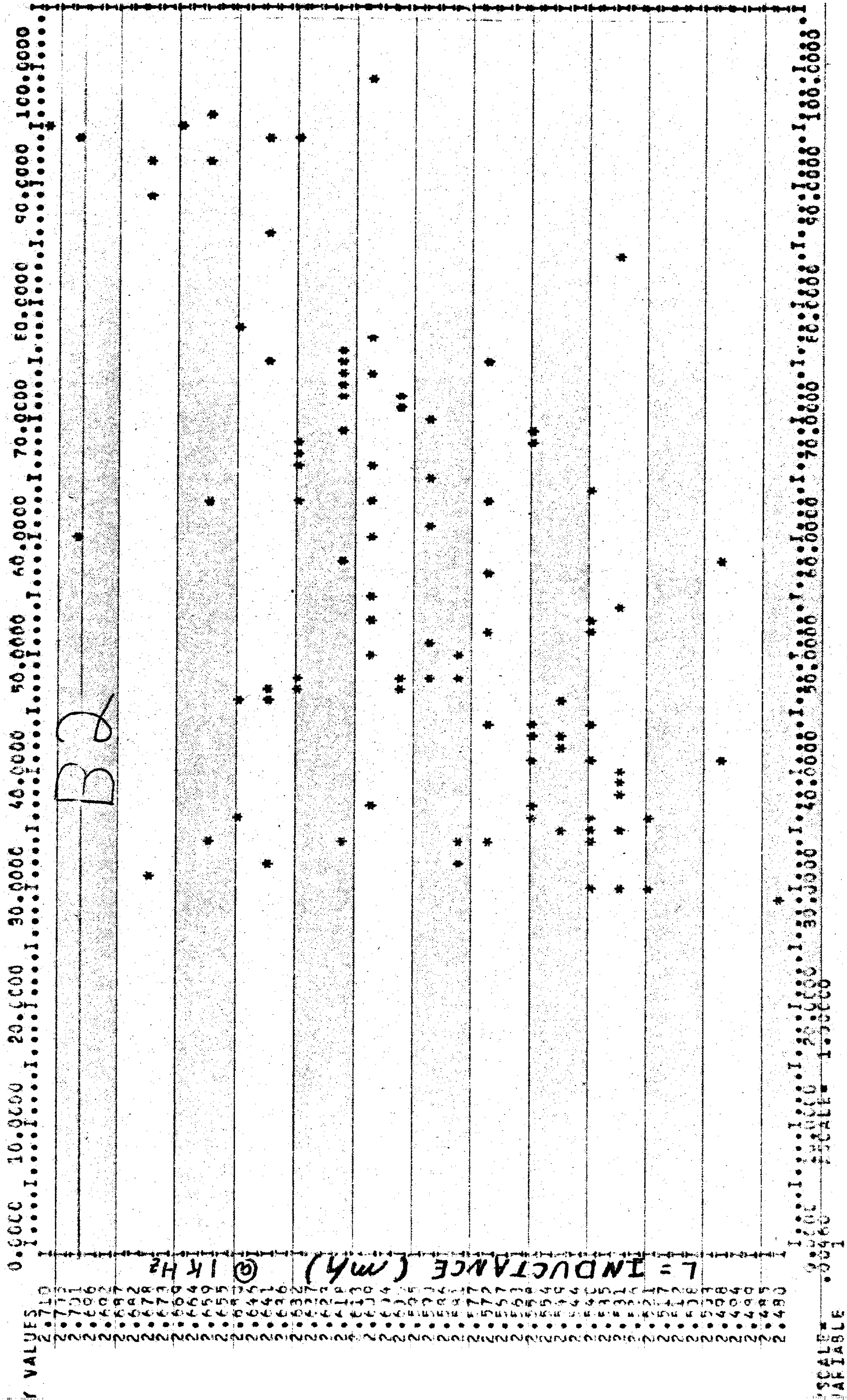

Figure 27

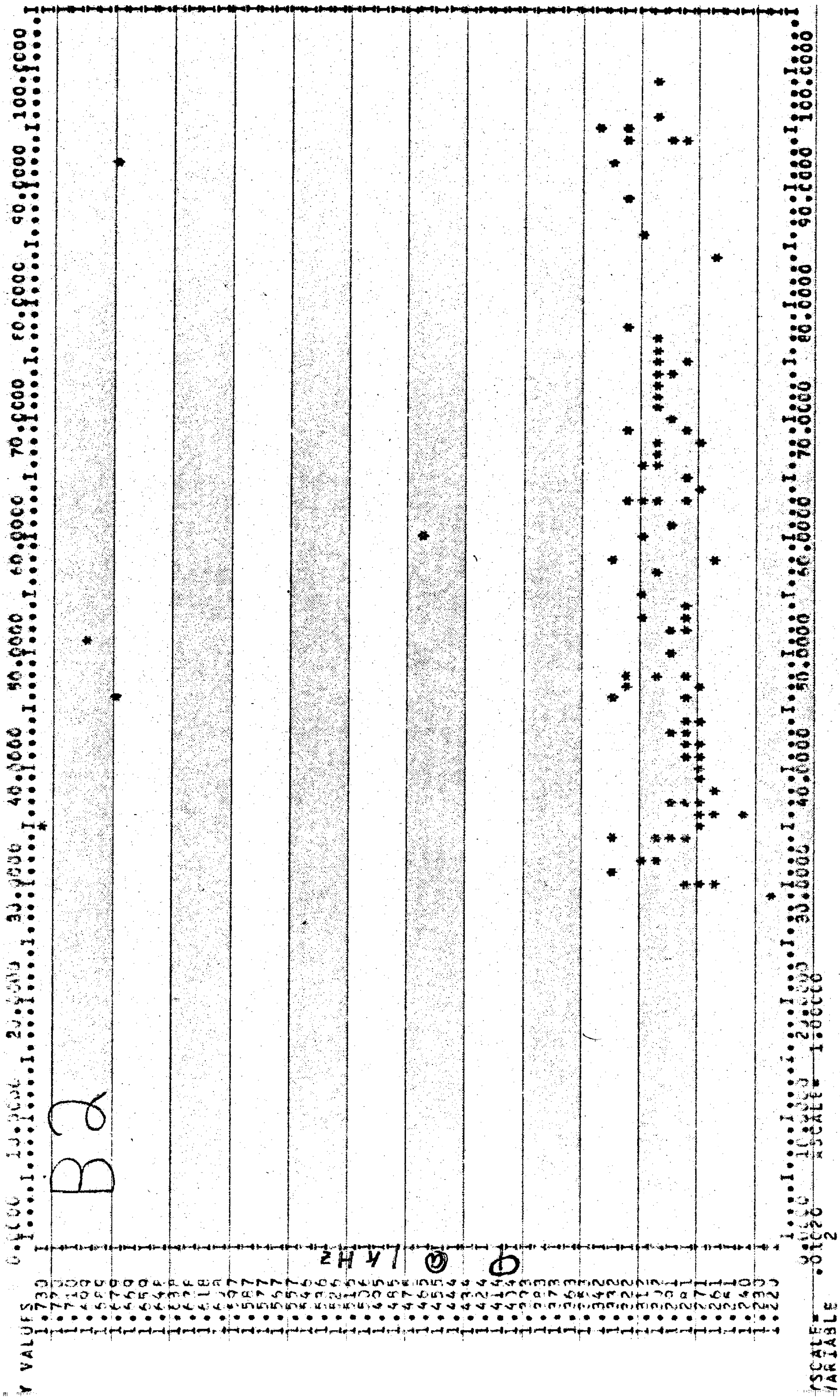

Figure 28

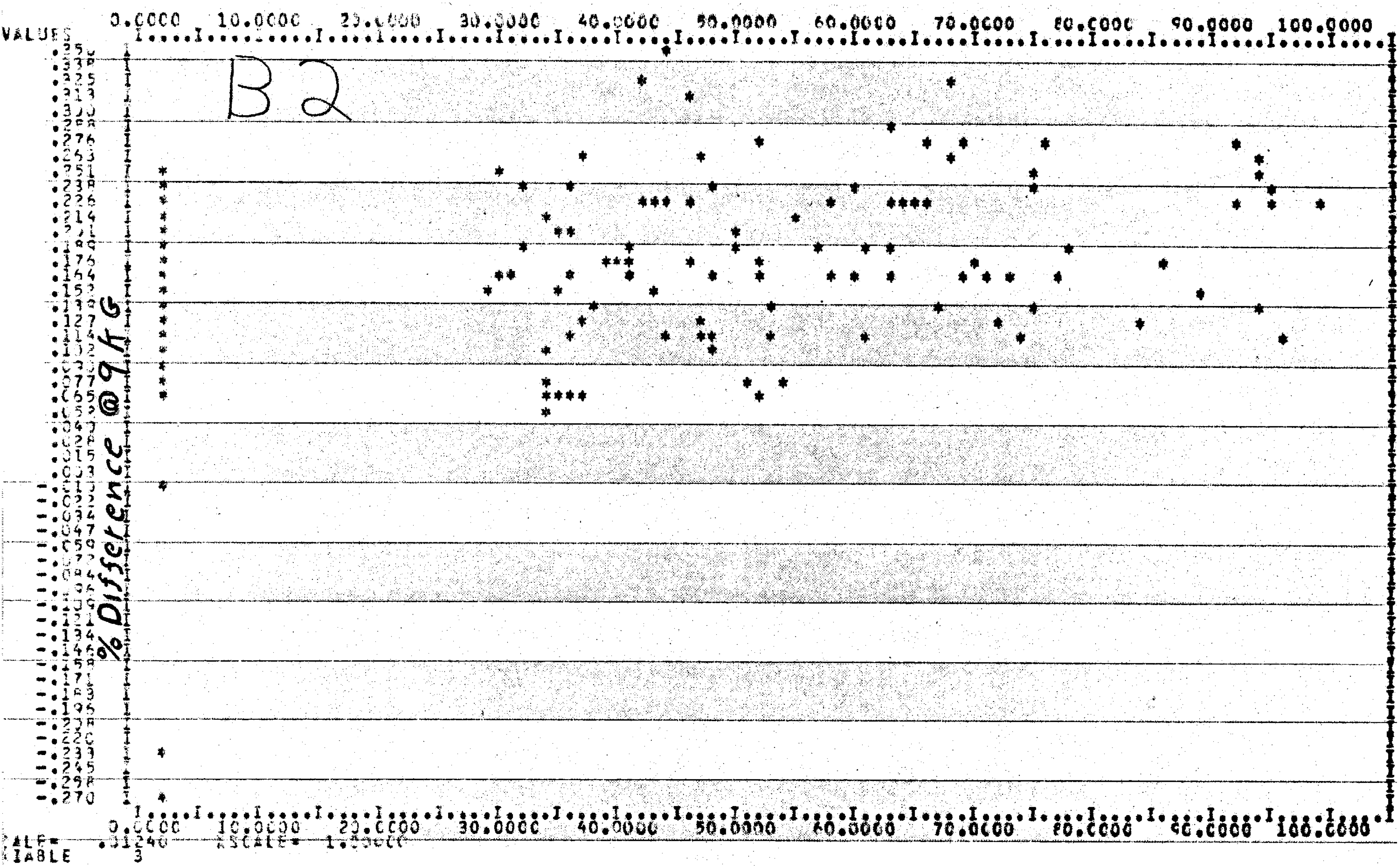
B2
% Difference @9KG
VALUES
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000

Figure 29

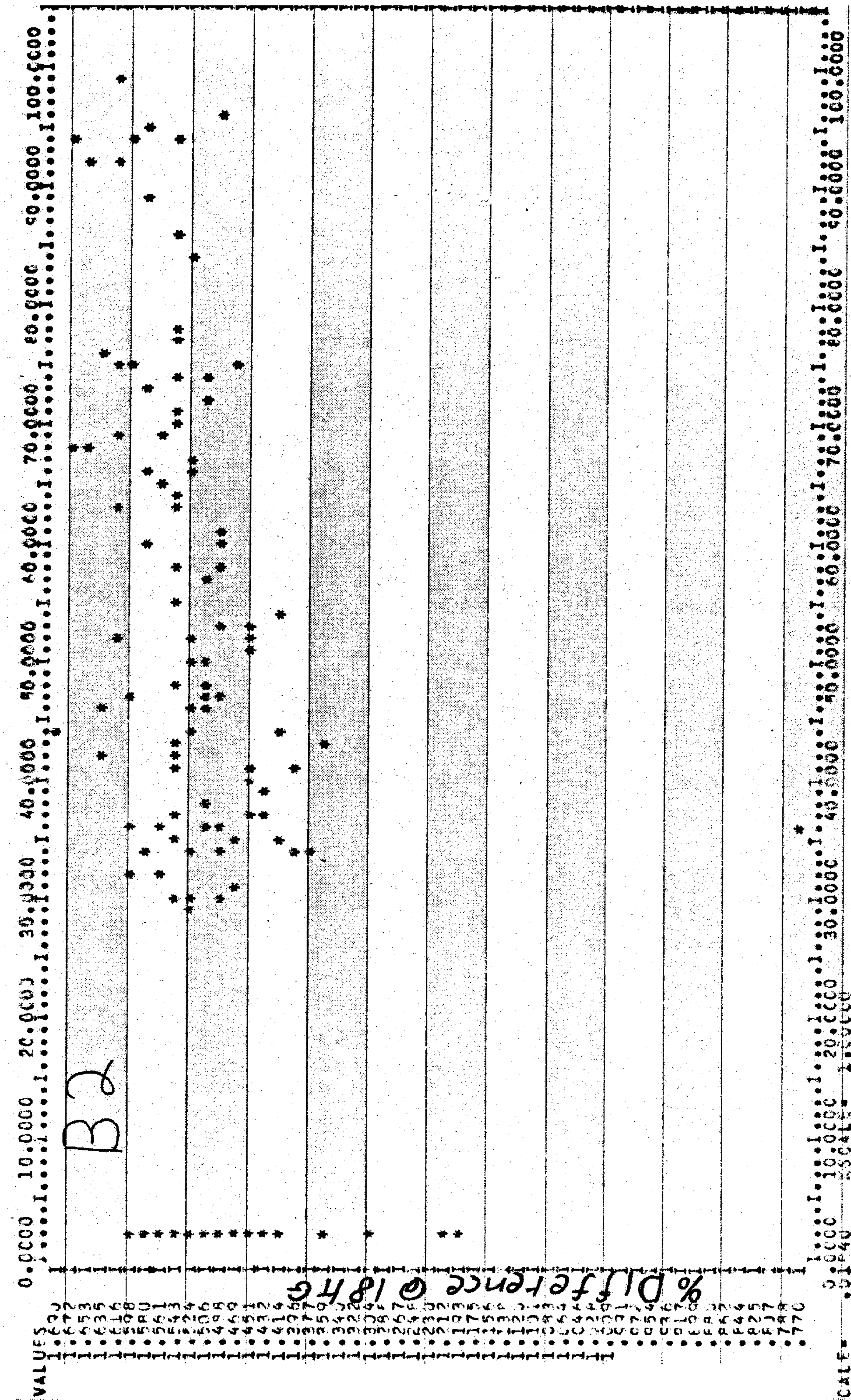

Figure 30

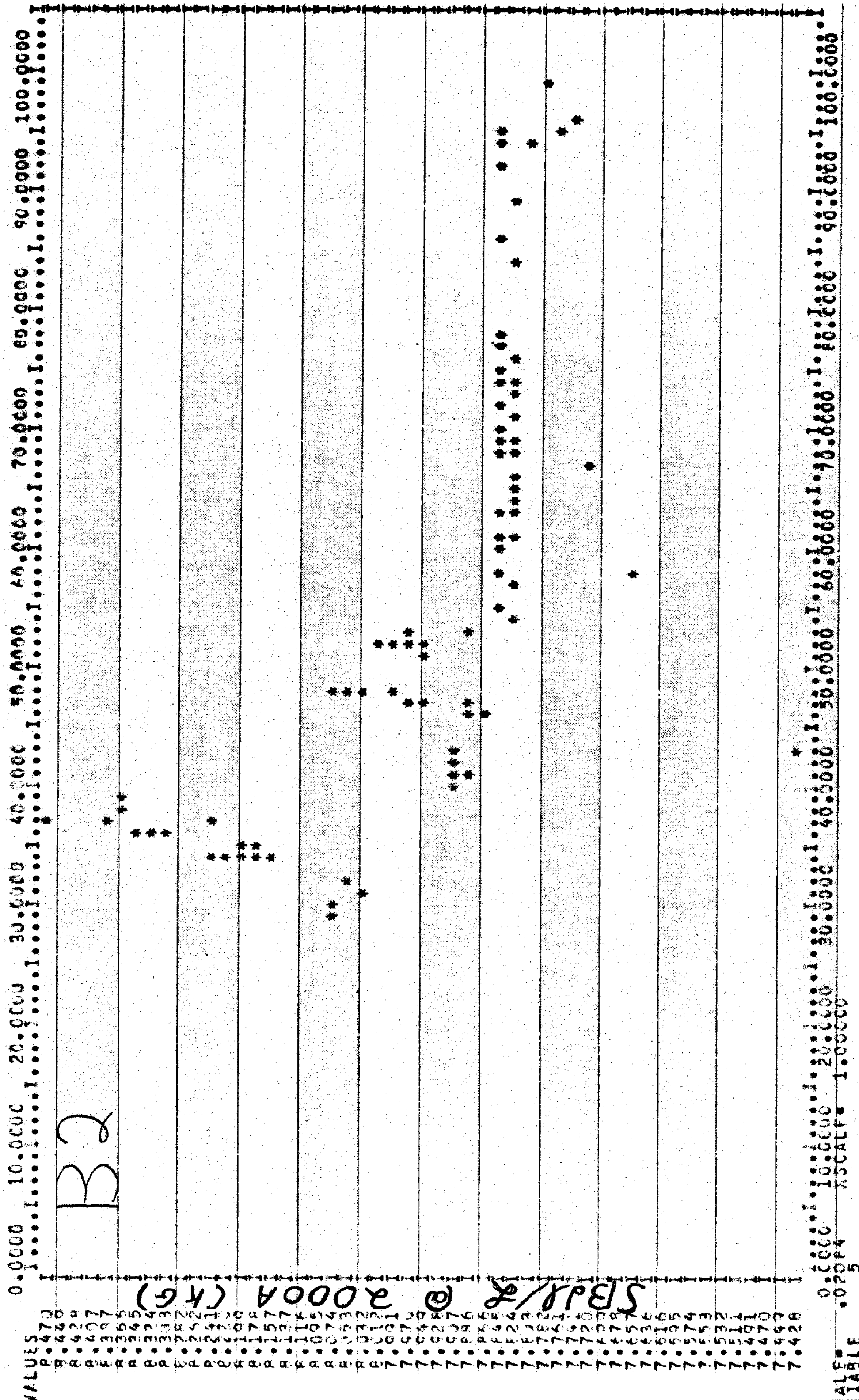

Figure 31

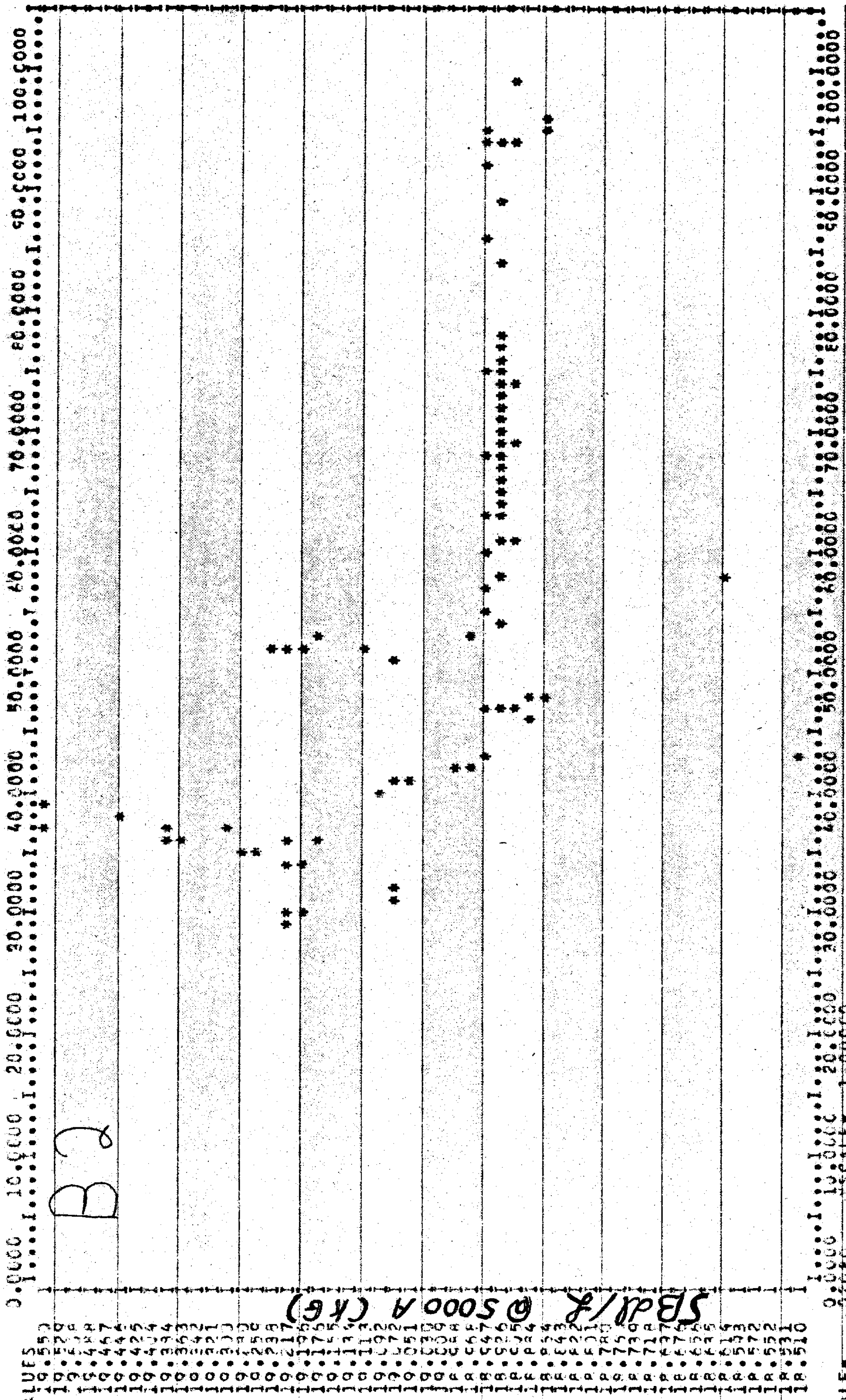
0.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000

Figure 32

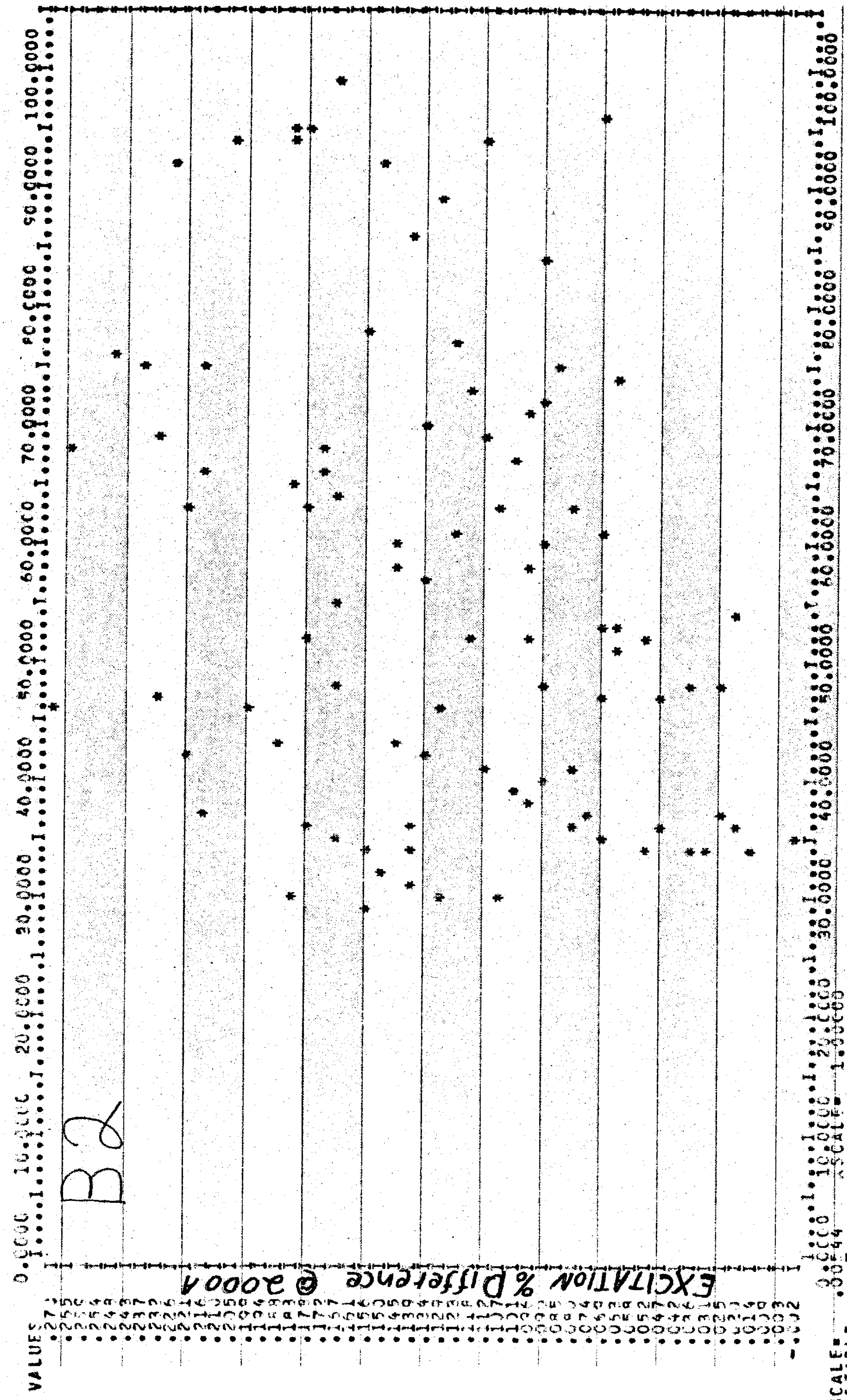

Figure 33

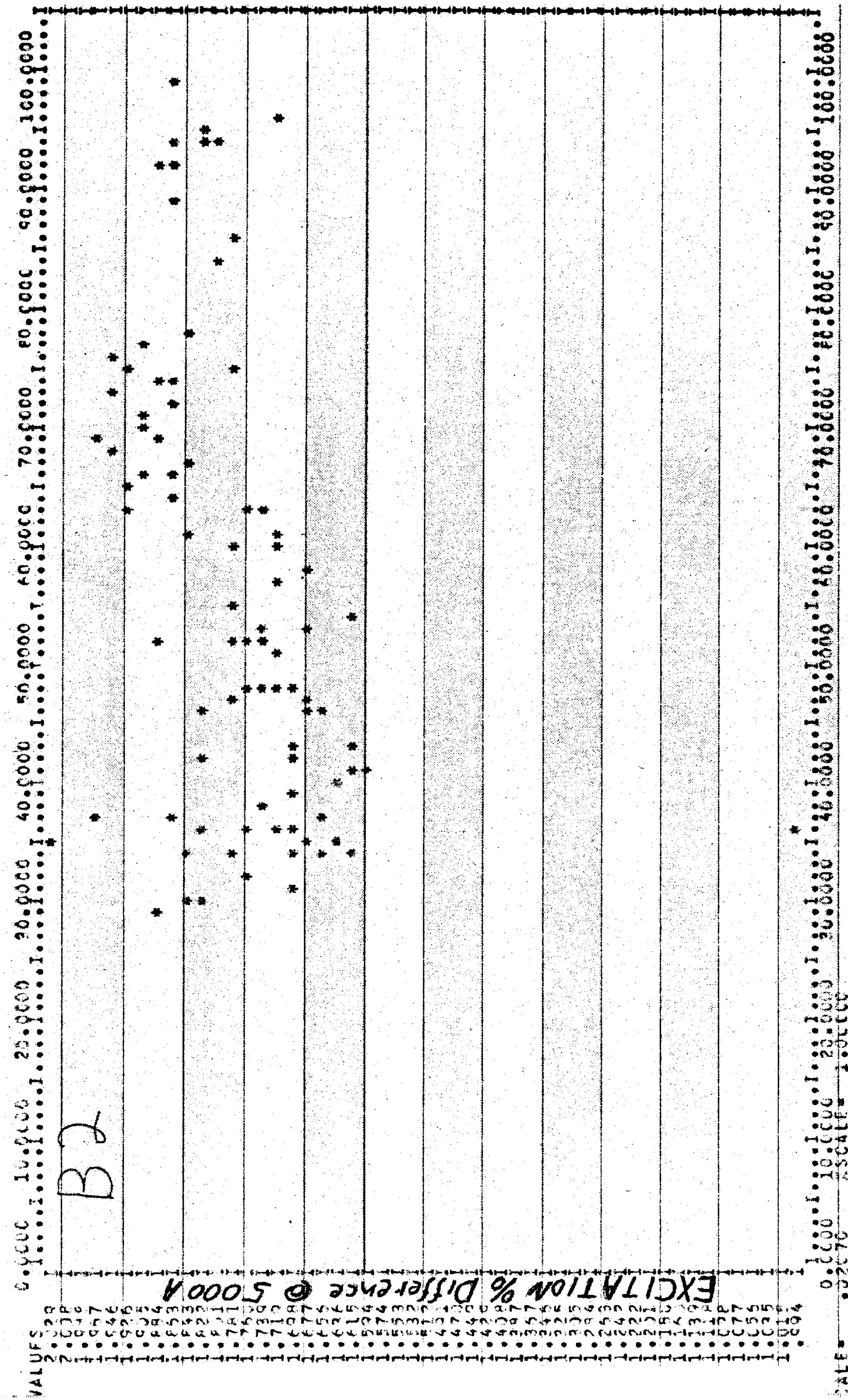

Figure 34

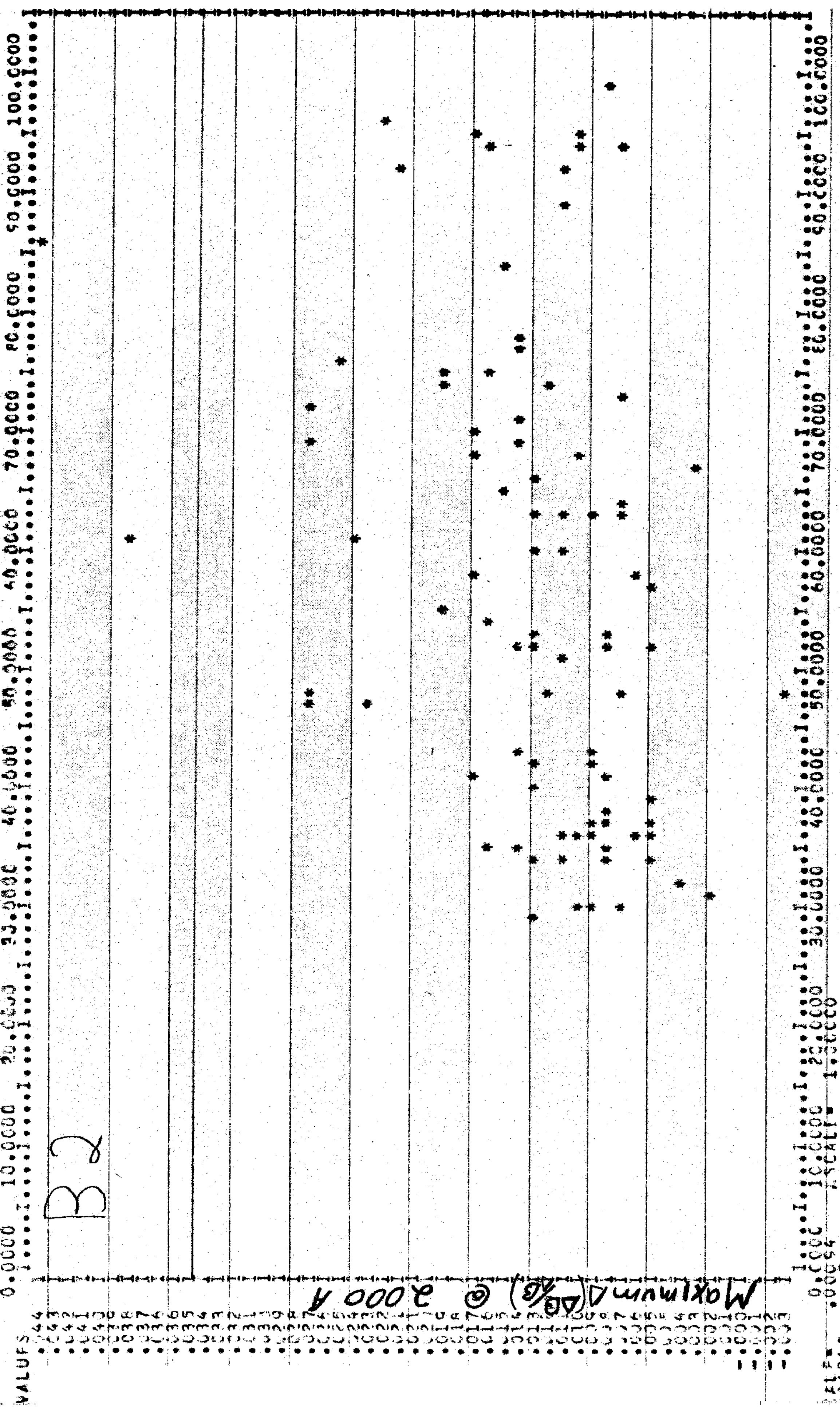

Figure 35

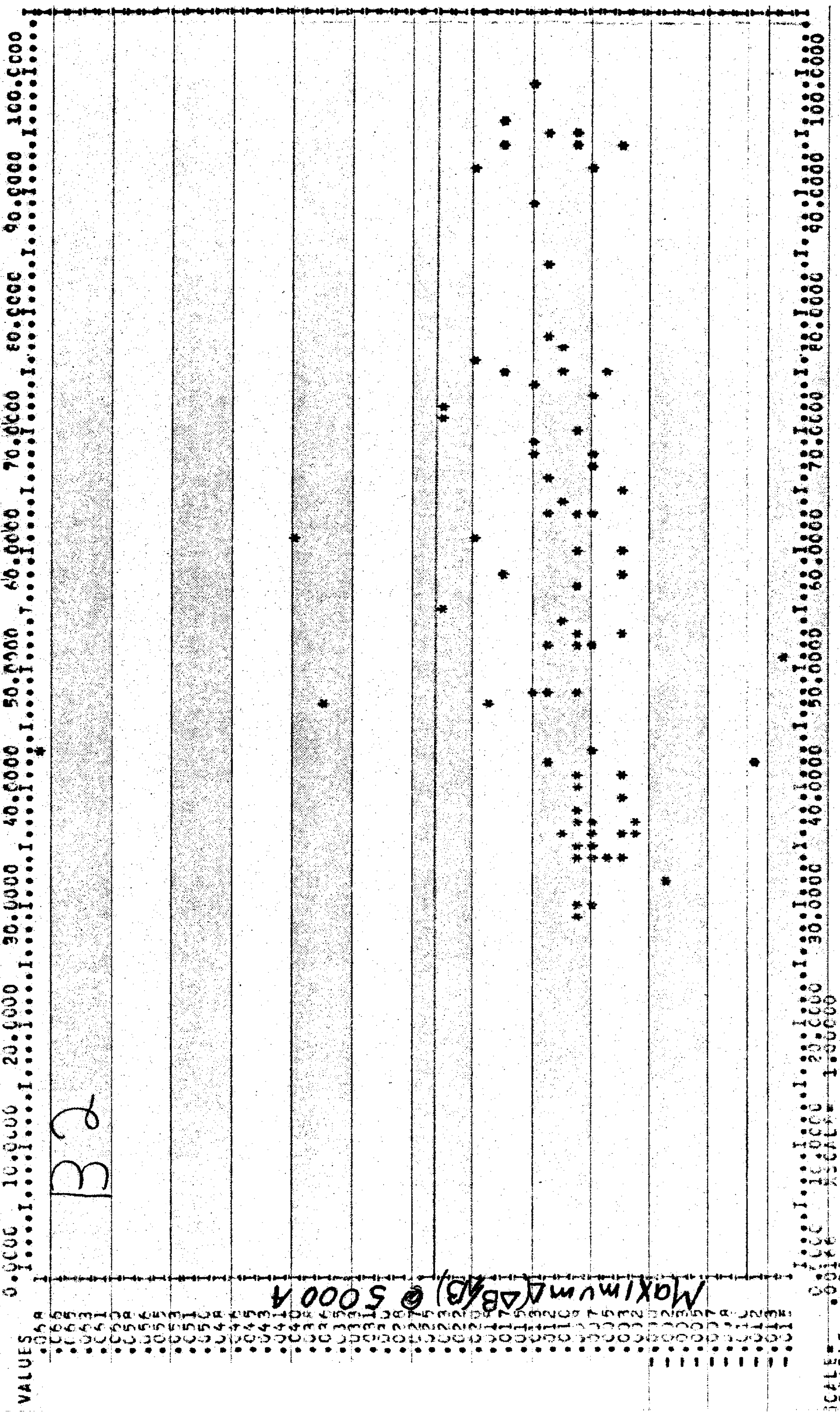
B2
Maximum(ΔB/B) @ 5000 A
0.0000 10.0000 20.0000 30.0000 40.0000 50.0000 60.0000 70.0000 80.0000 90.0000 100.0000

Figure 36