MEASUREMENT OF DENSITIES AND DEVELOPMENT OF WORKING CURVES USING A RECORDING AND A NON-RECORDING MICROPHOTOMETER

Thesis for the Degree of M. S.
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This is to certify that the

thesis entitled

Measurement of Densities and Development of Working Curves using a Recording and a Non Recording microphotometer

presented by

Marjorie Jean Lesher

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D.T. Ewing
Major professor

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MEASUREMENT OF DENSITIES AND DEVELOPMENT OF WORKING CURVES USING A RECORDING AND A NON-RECORDING MICROPHOTOMETER

by

Marjorie Jean Lesher

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This investigation was carried out with the eventual analysis of the trace elements in milk ash in mind. The problems considered were primarily photometric and concerned particularly measurements made with a recording and a non-recording microphotometer.

SOLUTIONS. The solutions used in this investigation were prepared to resemble, in the major constituents, a solution of an average sample of milk ash and were made on the assumption that the amount of ash used for analysis would correspond to 1 g. of ash in 5 ml. of solution. The base solution contained in one liter:

40.8 g. of potassium added as KCl
32.8 g. of calcium added as $Ca(NO_3)_2 \cdot 4H_2O$
25.0 g. of phosphorus } added as $NaH_2PO_4 \cdot H_2O$
18.5 g. of sodium }
2.76 g. of magnesium added as $MgCl_2 \cdot 6H_2O$
27.0 g. of ammonium chloride
8.0 g. of copper added as $CuCl_2 \cdot 2H_2O$
.05 g. of bismuth added as $Bi(NO_3)_3 \cdot 5H_2O$

In previous work on solutions of biological ash the addition of ammonium chloride was found to improve arcing conditions.(1) For this reason ammonium chloride was used in these solutions, although no tests were made as to whether it had any advantages in this case.

Copper was added as an internal standard. The concentration of copper used was determined by preliminary experiment and was limited to a relatively high concentration because of the presence of the element in very small amounts in milk ash. Bismuth was also added for an internal standard but was not used.

The solvent for these salts was a solution of equal parts of water and acid, the acid itself being a mixture of equal parts of concentrated nitric acid and concentrated hydrochloric acid. The high concentration of acid used was necessary to keep the salts in solution. All chemicals used were of C.P. grade and the base solution was checked spectrographically to be sure that it contained no aluminum or manganese.

A series of solutions varying only in the amount of aluminum and manganese present was made with the base described above. The concentrations used were (in mg./l.):

Aluminum - 150, 120, 90, 75, 65, 60, 55, 50, 45, 40, 30, 20.

Manganese - 3.75, 3.00, 2.25, 1.88, 1.63, 1.50, 1.38, 1.25, 1.13, 1.00, .75, .50.

The range of concentration of aluminum corresponded to its occurrence in milk ash as reported in the literature. The concentration of manganese was somewhat higher than its natural occurrence.

INSTRUMENTS. The instruments used for this work were: Bausch and Lomb Littrow Spectrograph No. 4392, Bausch and Lomb Density Comparator No. 2108, Eastman Densitometer Model B, and Leeds and Northrup Knorr-Albers Microphotometer for Recording Spectrum Line Densities.

PREPARATION OF ELECTRODES. National Spectroscopic ¼ in. carbons containing traces of titanium, vanadium, iron, magnesium, and possibly calcium were used for electrodes. For the lower electrode the rods of graphite were broken into 5 cm. lengths and both ends were used. During the course of the investigation three types of lower electrodes were used: (1) the crater electrode of 6 mm. depth and prearced twenty seconds at 9 amp.; (2) the crater electrode the same as above, but treated with kerosene; and (3) the crater post electrode made with a Dietert cutting tool, with a depth of 7 mm., and with the center post 2-2½ mm. above the rim after prearcing for ten seconds at 9 amp. The upper electrode used with the crater type of lower electrode was pointed with a hand pencil sharpener used especially for this purpose. One carbon was used several times by removing about 5 mm. of the end and reshaping. With the crater post electrode the upper electrode was 1/8 in. in diameter, was pointed, and was never used twice.

The lower electrode was filled with .1 ml. of solution and was baked for one hour in an oven at 145° C. before arcing. Two methods of filling were used--one with the electrode at room temperature, and one with the electrode warm (i.e., filled immediately after removing from a 145° C. oven). When the electrode was filled warm, liquid appeared on the outside of the electrode about 1-2 cm. from the top. However, this liquid disappeared and seldom left a residue of salt after baking. It was noted at the beginning of the investigation that, if there was much liquid in the electrode at the time it was put in the oven, large amounts of salt collected at points on the inside, outside, and rim of the electrode. For this reason care was taken to evaporate the samples before baking

EXCITATION CONDITIONS. A direct current arc at 200-290 volts, supplied by a General Electric Generator, was used for excitation. The lower electrode was the anode, the electrode gap was 10 mm., and no lens system was used. The slit width was 40 microns, the shutter was opened before the arc was struck, and it was not found necessary to reduce the light with a rotating sector. The No. 3 opening of the Hartmann diaphragm was used to limit the height of the slit. The exposure time varied with the type of plate and current. Iron was run at 55-60 v. and 3.0 amp., while the solutions were run at 30-40 v. and 9-12 amp., the current dropping and the voltage increasing from this when most of the sample was burned out and sputtering began.

CHOICE OF LINES. The following lines were used in this investigation.

Aluminum - 2568.0, 2575.1, 2660.4 A. (Angstrom)

Manganese - 2801.1 A.

Copper - 2882.9, 3036.1 A.

The more sensitive lines of aluminum, 3082.2 A. and 3092.7 A. could not be used because of interferences--magnesium with 3092.7 A. and an impurity in the carbon (probably vanadium) with 3082.2 A.

PROCESSING PLATES. Eastman Spectrum Analysis #1 and Eastman #33 plates were used. All processing took place at 18° C., the developers being Eastman D-11 and D-19. After developing and fixing, the plates were washed half an hour and then rinsed with distilled water and wiped with a cellulose sponge.

EXPERIMENTAL. In the first attempt to make working curves for aluminum and manganese the crater post electrode filled at room temperature and run at a current of 12 amp. for eighty to one hundred seconds was used. The results from these trials gave widely scattered points that did not fall along a smooth curve. Repeated efforts using the same excitation conditions failed to show any improvement and when identical samples were run it was found that the logarithm of the relative exposure ratios for the unknown to the internal standard for these samples varied greatly. Hence, it was decided to make a study of excitation conditions and types of electrodes in order to improve working curves and the reliability of analyses made from them.

Observations were made on the arcing of the different types of electrodes. It was noted that the length of time required to completely burn the sample from a crater or crater post electrode, filled either warm or at room temperature was the same (about 4½ min. at 12 amp.). The sample burned somewhat more rapidly from the kerosene treated electrode.

The crater electrode had a very characteristic manner of burning. For the first twenty seconds or more after arcing wondering of the arc on the rim of the lower electrode took place. After this, a period of "steadiness" began, lasting twenty seconds or more. During this time the arc seemed to cover the entire rim of the lower electrode and did not wonder. After this period the arc again wondered from point to point on the rim of the lower electrode. This "steady" period depended on the current, beginning later and perhaps lasting a little longer for lower currents. On 9 amp. the "steady" period began about forty-five seconds after arcing and was somewhat intermittent, often lasting throughout the entire ninety second exposure time. The average period of steadiness was about thirty seconds, according to the data from 9 plates representing 80 samples.

With the crater post electrode, in the earlier work, the arc burned from the post during the first part of the exposure as it theoretically should. With later work, however, it seemed to burn from the rim in the same manner that the crater electrode did. From 83 samples, during the first one hundred seconds of burning: 43 did not burn from the post at all, 23 were on the post one to three seconds, 4 were on four to seven seconds, 8 were on eight to ten seconds, 1 was on twenty-five seconds, 1 was on forty seconds, and 3 were on seventy seconds. In all cases where it burned seventy seconds and twenty-five seconds, in some cases where it burned eight to ten seconds on the post, and in most cases of the earlier work not recorded here, salt was piled on the post indicating that this may have been an important factor in the manner of burning.

With the kerosene treated electrode the arc wondered rapidly over the rim of the lower electrode and in most cases there was no "steady" period. When there was a "steady" period it began approximately twenty-five seconds after arcing and lasted about fifteen seconds.

It was shown that after a certain amount of burning the arc began to sputter and with this sputtering, heavy background came in. Thus, from the standpoint of holding back background it would be desirable, if possible, to avoid this sputtering. At 12 amp. with the kerosene treated electrode, sputtering began on an average of seventy seconds after arcing, while with the crater post electrode it began eighty-five seconds after arcing. With the crater electrode filled at room temperature the time of sputtering varied with the current as follows: at 11 amp., after eighty seconds; at 10 amp., after one hundred seconds; and at 9 amp., after one hundred and ten seconds.

To find conditions which would give less deviation in the relative exposure ratios for the same sample the excitation conditions listed in Table I were tried. The characteristic curve of each plate was obtained from the step sector pattern of an iron line and plotted as galvanometer deflection versus logarithm of relative exposure (Log E) as described later in the paper. The Log E value for the standard line was subtracted from the Log E value for the unknown line to give the logarithm of the relative exposure ratio, $\mathrm{Log}(E_x/E_{st})$.

The variability of the values of $\mathrm{Log}(E_x/E_{st})$ was then calculated for each series from the equation

$$S = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n - 1}}$$

S = Variability

x = Values of $\mathrm{Log}(E_x/E_{st})$

n = Number of samples

In this calculation any value of $\mathrm{Log}(E_x/E_{st})$ which varied from the mean by an amount greater than 2.6 times the variability was discarded. It was found necessary to omit very few values for this reason. To test to see if the difference in variability from one series to another was significant Snedecor's "F" test was used at the 5% point.(2)

The variability for five pairs of lines is shown in Table II. It was not intended that an exact rating of the different series be made and the data are insufficient for that purpose. However, it would appear that a lowering of the current to 9 amp., using crater

TABLE I

TYPES OF ELECTRODES AND EXCITATION CONDITIONS STUDIED FOR COMPARISON OF REPRODUCIBILITY OF THEIR LOG RELATIVE EXPOSURE RATIOS

Series	Plate No.	Emulsion Type	Exposure Time (sec.)	Type of Electrode	Method of Filling	Current (amp.)	Conc. of Al (mg./l.)	Conc. of Mn (mg./l.)	No. of Samples
A	104	#33	90	Crater	Warm	9	60	1.50	8
B	106	#33	90	Crater	Warm	9	60	1.50	8
C	104	#33	60	Crater	Warm	10	60	1.50	8
D	106	#33	50	Crater	Warm	11.5	60	1.50	8
E	86	SA#1	100	Crater	Warm	12	60	1.50	11
F	107	#33	90	Crater	Room Temp.	9	60	1.50	8
G	102	SA#1	200	Crater	Room Temp.	9	55	1.38	8
H	102	SA#1	160	Crater	Room Temp.	10	55	1.38	8
I	107	#33	50	Crater	Room Temp.	11.5	60	1.50	8
J	90	SA#1	100	Crater	Room Temp.	12	65	1.63	16
K	91	SA#1	100	Crater Post	Room Temp.	12	65	1.63	16
L	96	SA#1	100	Crater Kerosene	Room Temp.	11.8	50	1.25	7
M	96	SA#1	80	Crater Kerosene	Room Temp.	11.8	50	1.25	8

TABLE II

COMPARISON OF VARIABILITY OF LOG(E_x/E_{st}) WITH DIFFERENT EXCITATION CONDITIONS

Series	Variability of Log(E_x/E_{st})				
	Al 2575/Cu 2883	Al 2660/Cu 2883	Mn 2801/Cu 2883	Cu 3036/Cu 2883	Al 2575/Al 2660
A	.012	.018	.011	.011	.016*
B	.012	.019	.011	.009	.018*
C	.023	.021	.016	.007	.012
D	.026*	.025	.016	.014*	.007
E	.028*	.021	.033*	.007	.016*
F	.028*	.025	.014	.018*	.007
G	.032*	.032	.021*	.007	.014*
H	.028*	.018	.005	.007	.009
I	.016	.018	.011	.021*	.011
J	.085*	.051*	.026*	.011	.012
K	.051*	.046*	.014	.012	.009
L	.018	.026	.012	.016*	.011
M	.083*	.078*	.046*	.021*	.026*

* Indicates that Variability is significantly different. In the first three columns comparisons are made with Series A, in the fourth, with series C, and in the fifth, with Series D.

TABLE III

SAMPLE DATA USED IN CALCULATING VARIABILITY OF LOG(E_x/E_{st})

INCLUDING CALCULATIONS OF MAXIMUM DEVIATIONS IN TERMS OF CONCENTRATION

Lines	Values for Log(E_x/E_{st})	Variability	Range of Log(E_x/E_{st})			Conc. Corresponding To Range			% Deviation In Conc.	
			Min.	Mean	Max.	Min.	Mean	Max.	Min.	Max.
Series A										
Al 2575/Cu 2883	.055,.074,.040,.049, .062,.040,.028	.012	.028	.055	.074	56.6	60.0	63.1	5.7%	5.2%
Al 2660/Cu 2883	-.231,-.217,-.262,-.229 -.208,-.211,-.229	.018	-.262	-.225	-.208	53.8	60.0	63.1	10.3	5.2
Mn 2801/Cu 2883	-.067,-.093,-.074,-.062 -.083,-.062,-.063,-.078	.011	-.093	-.072	-.062	1.40	1.50	1.55	6.7	3.3
Cu 3036/Cu 2883	.231,.222,.231,.236, .231,.236,.241,.206	.011	.206	.229	.241					
Al 2575/Al 2660	.285,.290,.302,.287 .257,.253,.273,.269	.016	.253	.278	.302					
Series B										
Al 2575/Cu 2883	.062,.076,.078,.065 .048,.062,.083,.081	.012	.048	.069	.083	57.3	60.0	62.1	4.5	3.5
Al 2660/Cu 2883	-.158,-.153,-.153,-.192 -.199,-.171,-.166,-.192	.019	-.199	-.173	-.153	55.2	60.0	63.3	8.0	5.5
Mn 2801/Cu 2883	-.056,-.040,-.053,-.065 -.065,-.063,-.055,-.078	.011	-.078	-.060	-.040	1.42	1.50	1.60	5.3	6.7
Cu 3036/Cu 2883	.190,.187,.190,.185 .204,.183,.171,.187	.009	.171	.187	.204					
Al 2575/Al 2660	.220,.229,.231,.257 .246,.232,.248,.273	.018	.220	.243	.273					

electrodes filled warm should give fairly good results for aluminum and manganese, although perhaps not the best results for manganese. It is interesting to note that, as would be expected, the variability of the ratios from two copper lines or from two aluminum lines is relatively low, but there seems to be little correlation between the variability with two lines from the same element and the variability with two lines from different elements. Thus, while Series A and B have a rather low variability for aluminum to copper or manganese to copper ratios, the variability for copper to copper and aluminum to aluminum is relatively high.

Sample sets of data are shown for Series A and B in Table III. Also in this table are given values for maximum percent deviations in terms of concentration. These were calculated by assuming that the mean value of Log(E_x/E_{st}) was correct and assigning the true concentration of the solution used to this value. Using the working curve for the pair of lines in question, the concentration corresponding to the extreme values of Log(E_x/E_{st}) were found and from this the percent deviation from the true concentration was calculated. The sums of the deviations for the data showed a range of 8.0% to 15.5% which represents the maximum variation for eight samples. According to Pierce and Nachtrieb a mean deviation of 5% in a series of duplicate determinations using graphite electrodes is good and often not better than 10% deviation can be obtained.(3) Hence, satisfactory results could be expected from the excitation conditions used for Series A and B. The conditions finally decided upon were: crater electrode, filled warm, a current of 9 amp., Eastman #33 plates and an exposure time of ninety seconds. This exposure time seemed desirable from the standpoint that the arc was "steady" during much of this period and that no sputtering of the arc occurred.

MEASUREMENT OF LINE BLACKNESS. Measurements of line blackness were made with a Bausch and Lomb density comparator and with a Leeds and Northrup Knorr-Albers microphotometer for recording spectrum line densities. On the Bausch and Lomb instrument the galvanometer scale covered 38 cm. with increasing scale reading indicating increasing blackness. A total balckness reading was made by shutting off the light from the source with an opaque card. The clear plate reading was made on an unexposed portion of the plate and was kept constant, usually at zero, by adjusting the amount of light striking the photocell. The galvanometer deflection for a line was determined by going back and forth over the line slowly until the maximum reading was obtained. For the calculation of the density of a line $\mathrm{Log}(I_0/I)$ was used, where the I_0 measurement was taken as the galvanometer reading for total blackness minus the galvanometer reading for the unexposed portion of the plate and the I measurement was the galvanometer reading for total blackness minus the galvanometer reading for the line.

The Leeds and Northrup microphotometer consisted of two units, the Knorr-Albers microphotometer and the Leeds and Northrup Speedomax Recorder. The plate was scanned on the microphotometer unit and the densities were recorded on logarithmic-scaled paper graduated in densities. The density was defined in this case as $\mathrm{Log}(d_0/d)$ where d_0 was a deflection corresponding to an unexposed portion of the plate and d was a deflection corresponding to an exposed portion. The plate scanning speed used in this work was two millimeters per minute.

The two microphotometers were found to vary somewhat in the measurement of density. A calibrated Eastman step density tablet was read on the two instruments mentioned above and also on the Eastman densitometer, Model B. In order to use the step density tablet with the Bausch and Lomb and the Leeds and Northrup microphotometers it was necessary that it be mounted on a spectrographic plate from which the emulsion had been removed. Zero readings, then, were made on the clear glass plate. The results are given in Table IV and are shown graphically in Fig. 1.

It will be noted that the values from all three instruments vary, but that within the accuracy of the readings there seems to be a linear relationship between the densities above 0.5. The Bausch and Lomb values and Leeds and Northrup values are fairly close together,

TABLE IV

DENSITY OF EASTMAN STEP DENSITY TABLET STRIP #322

AS MEASURED BY THREE INSTRUMENTS

Step	Certified Density	Measured Density		
		Eastman	Bausch & Lomb	Leeds & Northrup
1	.05	.08	.10	.06
2	.19	.23	.32	.22
3	.34	.40	.57	.45
4	.49	.54	.80	.69
5	.64	.71	1.03	.91
6	.79	.84	1.28	1.15
7	.93	1.00	1.50	1.3
8	1.07	1.12	1.68	1.5
9	1.21	1.29	1.92	
10	1.35	1.43	2.12	
11	1.50	1.58	2.35	
12	1.65	1.72		
13	1.80	1.86		
14	1.94	2.01		
15	2.09	2.15		
16	2.24	2.28		
17	2.38	2.41		
18	2.53	2.57		
19	2.68	2.72		

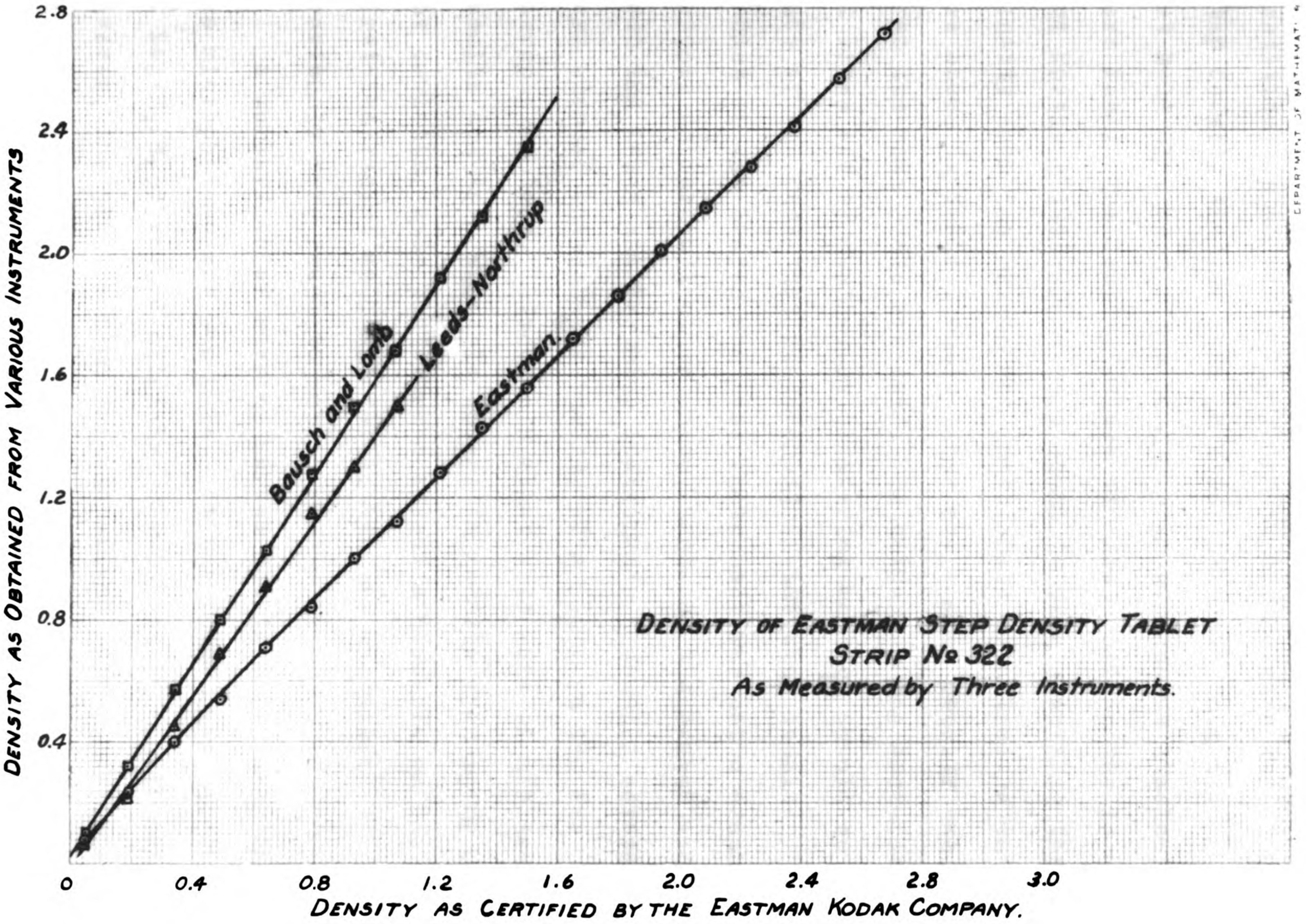
DENSITY OF EASTMAN STEP DENSITY TABLET
STRIP No 322
As Measured by Three Instruments.
Bausch and Lomb
Leeds-Northrup
Eastman.
DENSITY AS OBTAINED FROM VARIOUS INSTRUMENTS
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.0
DENSITY AS CERTIFIED BY THE EASTMAN KODAK COMPANY.

Fig. I

with the Bausch and Lomb being slightly higher. This condition was consistently found to be the case for step density tablets read on other plates. This did not hold true when lines rather than continuous blackening were read. The density values of lines read on the Leeds and Northrup instrument were equal to or higher than the density from the Bausch and Lomb. Data illustrating this are shown in Table V where lines and a step density tablet from the same plate are used. In comparing the measurement of lines and of continuous blackening mention should be made of the fact that measurement of the step density tablet on the Bausch and Lomb instrument was not a scanning process as were all other measurements on the Bausch and Lomb and Leeds and Northrup instruments. Usually several days elapsed between the reading of a plate on the two microphotometers. Since this might give rise to misleading results due to a possible change in density upon aging of the emulsion, some plates were reread afterwards on the first instrument used and the tendencies discussed previously were found to hold.

A comparison of working curves obtained by using the two microphotometers was made. It was found that values of Log(E_x/E_{st}) varied slightly between the two instruments. However, the results from one instrument showed no tendency to be high or low, or to give a different slope to the working curve. All variations could probably be accounted for in errors in the original density measurement and in

TABLE V

DENSITY MEASUREMENTS FROM BAUSCH AND LOMB DENSITY COMPARATOR AND LEEDS AND NORTHRUP MICROPHOTOMETER

PLATE NO. 109

Step Density Tablet		Al 2575		Al 2660	
B & L	L & N	B & L	L & N	B & L	L & N
1.57	1.50	.655	.700	.410	.412
1.35	1.30	.584	.598	.342	.340
1.32	1.05	.410	.440	.225	.230
.870	.820	.407	.430	.223	.240
.619	.590	.314	.350	.152	.185
.435	.400	.391	.418	.207	.226
.258	.230	.354	.365	.193	.193
.134	.130	.324	.345	.173	.178
.061	.055	.312	.330	.170	.180
.021	.018	.263	.267	.130	.144
.009	.005	.173	.194	.093	.097
.000	.000				

TABLE VI

VALUES OF LOG(E_x/E_{st}) AS OBTAINED FROM BAUSCH AND LOMB DENSITY COMPARATOR AND FROM LEEDS AND NORTHRUP MICROPHOTOMETER

PLATE NO. 109

Conc. of Al mg./l.	Al 2575/Cu 2883		Al 2660/Cu 2883	
	B & L	L & N	B & L	L & N
120	.50	.52	.20	.17
90	.41	.44	.12	.11
75	.25	.24	-.02	-.04
65	.22	.23	-.04	-.03
60	.16	.16	-.11	-.08
55	.18	.18	-.09	-.08
50	.13	.14	-.11	-.10
45	.10	.09	-.15	-.15
40	.02	.04	-.21	-.18
30	-.02	-.03	-.27	-.23
20	-.17	-.16	-.36	-.37

Conc. of Mn mg./l.	Mn 2801/Cu 2883		Mn 2801/Cu 3036	
	B & L	L & N	B & L	L & N
3.00	.23	.21	.06	.04
2.25	.11	.10	-.08	-.11
1.88	.07	.04	-.12	-.12
1.63	.03	.01	-.17	-.19
1.50	-.04	-.04	-.19	-.19
1.38	-.02	-.03	-.19	-.21
1.25	-.03	-.03	-.22	-.19
1.13	-.03	-.05	-.22	-.21
1.00	-.10	-.11	-.30	-.30
.75	-.19	-.20	-.36	-.35
.50	-.23	-.23	-.40	-.38

and in plotting and making readings from the characteristic curve. Table VI gives samples of values of Log(E_x/E_{st}) obtained from the Bausch and Lomb and from the Leeds and Northrup microphotometers, while Fig. V shows two working curves plotted with values from both instruments.

CHARACTERISTIC CURVE. In making the characteristic curve of a plate two problems arose. The first was whether there would be a difference in using the step density tablet or the step sector pattern of iron for this purpose. The step density tablet involved light of the visible range whereas the step sector pattern involved a rotating step sector placed in front of the slit and light of any wavelength recorded by the spectrograph could be used. The results of the study are illustrated by Fig. II. It will be noticed that the slope of the curve from the step density tablet is considerably greater than that from the step sector pattern. Thus, the step sector pattern using the same wave length of light as used for analyses is preferable to the step density tablet.

The second problem was whether, with the Bausch and Lomb density comparator, the use of Log(I_0/I) would be better than the use of galvanometer deflection as the ordinate for the characteristic curve. With Log(I_0/I) being a density measurement, the characteristic curve obtained from it would be more like the actual Hurter and Driffield curve. Sets of data were calculated using both types of characteristic curves and the values of Log E as

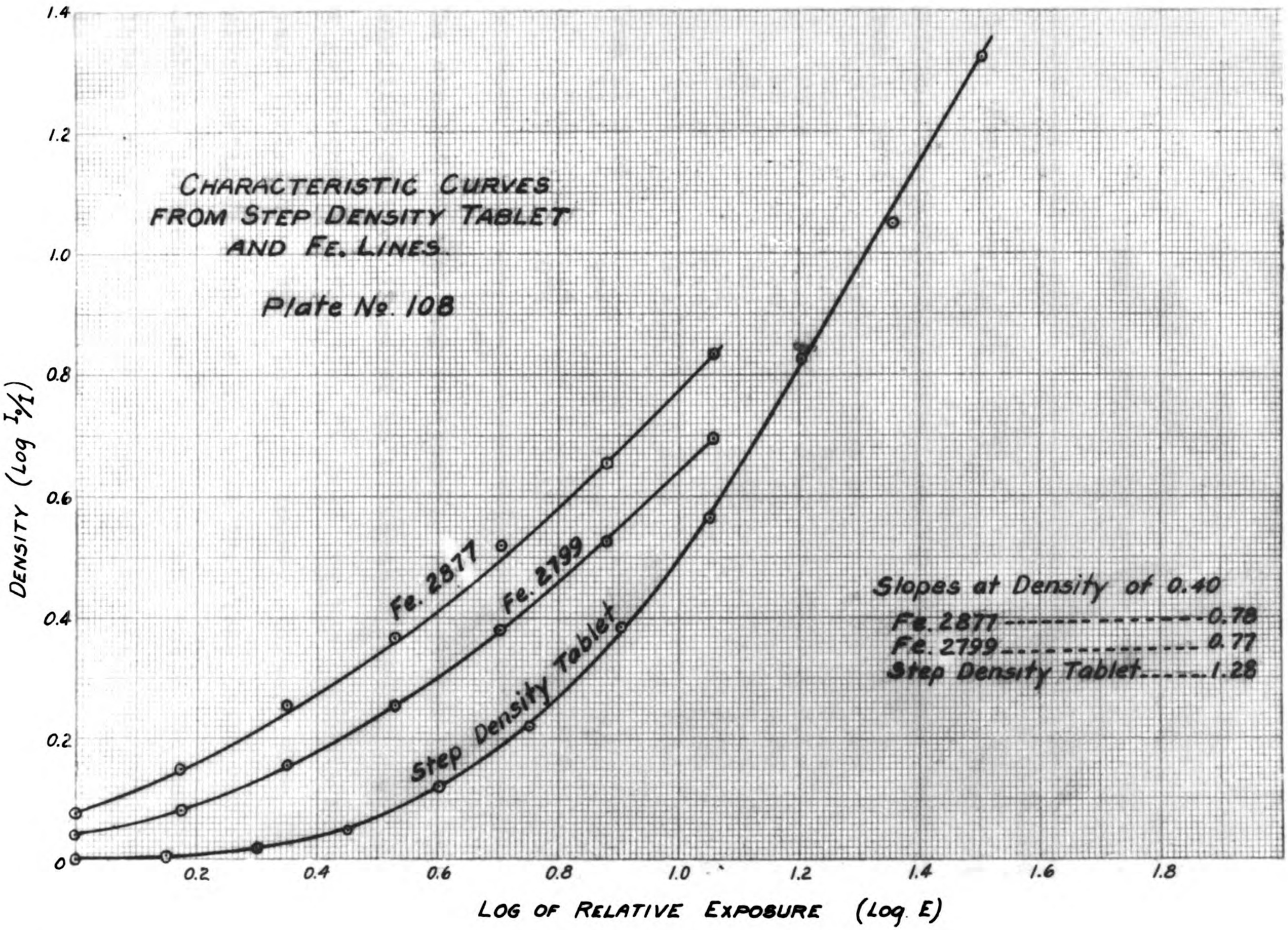
CHARACTERISTIC CURVES
FROM STEP DENSITY TABLET
AND FE. LINES.
Plate No. 108
Fe. 2877
Fe. 2799
Step Density Tablet
Slopes at Density of 0.40
Fe. 2877 ---------------- 0.78
Fe. 2799 ---------------- 0.77
Step Density Tablet ------ 1.28
DENSITY (Log I₀/I)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
LOG OF RELATIVE EXPOSURE (Log. E)

Fig. II

obtained from the two curves were compared. Data from Plate No. 87 are shown below in Table VII

TABLE VII

LOG E VALUES OBTAINED FROM DIFFERENT CHARACTERISTIC CURVES

Galv. Read.	$Log(I_0/I)$	Log E obtained from curve using galv. deflection	Log E obtained from curve using $Log(I_0/I)$
From Al 2575			
31.7	.837	6.56	6.57
30.3	.736	5.93	5.92
28.9	.655	5,42	5.43
25.9	.520	4.53	4.56
25.0	.486	4.30	4.32
21.0	.362	3.49	3.50
16.0	.245	2.69	2.70
12.1	.171	2.11	2.13
From Al 2660			
11.3	.157	1.99	2.03
8.6	.114	1.56	1.62
6.0	.076	1.13	1.15

The conclusion that may be drawn is that in the range of densities covered it makes no difference whether $Log(I_0/I)$ or galvanometer deflection is used for the ordinate of the characteristic curve. This, of course, assumes that if galvanometer deflections are used the clear plate and total blackness deflections are kept constant while the entire plate is read. Since the method of galvanometer deflections did not involve as much calculation as the $Log(I_0/I)$ method, galvanometer deflections were used for the work where density did not have to be calculated for other reasons.

BACKGROUND. A brief study of background was made for the Eastman #33 plate. Background densities were treated the same as line densities, the Log E values being obtained from the characteristic curve in the same manner. The Log E value for the background was subtracted from the Log E value for the line. The difference between the Log E values for the unknown and standard lines, thus "corrected" for background was then taken. When the values of Log(E_x/E_{st}) so obtained were plotted against Log Concentration, the points were found to be rather widely scattered instead of lying along a definite smooth working curve. One explanation of this would be the magnification of errors by working on the toe of the characteristic curve. The density of the background ranged from .02 to .14. Since these values fall on a portion of the characteristic curve which has a very small slope compared with the portion usually worked with, a slight error in background reading would give rise to a relatively large error in the Log E value. The background was irregular and its measurement was difficult and relatively inaccurate, especially with the non-recording microphotometer. Thus, treatment of the small amount of background dealt with in this investigation was not practical with the method used.

Samples of working curves made by using the excitation conditions discussed previously and the method of measurement and treatment of line blackness discussed in this last section are shown in Figs. III, IV, and V. The curves in Figs. III and IV are made from measurements on the Bausch and Lomb density comparator, while those in Fig. V are made with measurements from both Bausch and Lomb and Leeds and Northrup instruments.

SUMMARY. Excitation conditions used in the development of working curves were discussed.

Measurement of densities on a recording and a non-recording microphotometer was treated. It was found that actual density values varied somewhat between the two instruments, but the working curves obtained from each were the same.

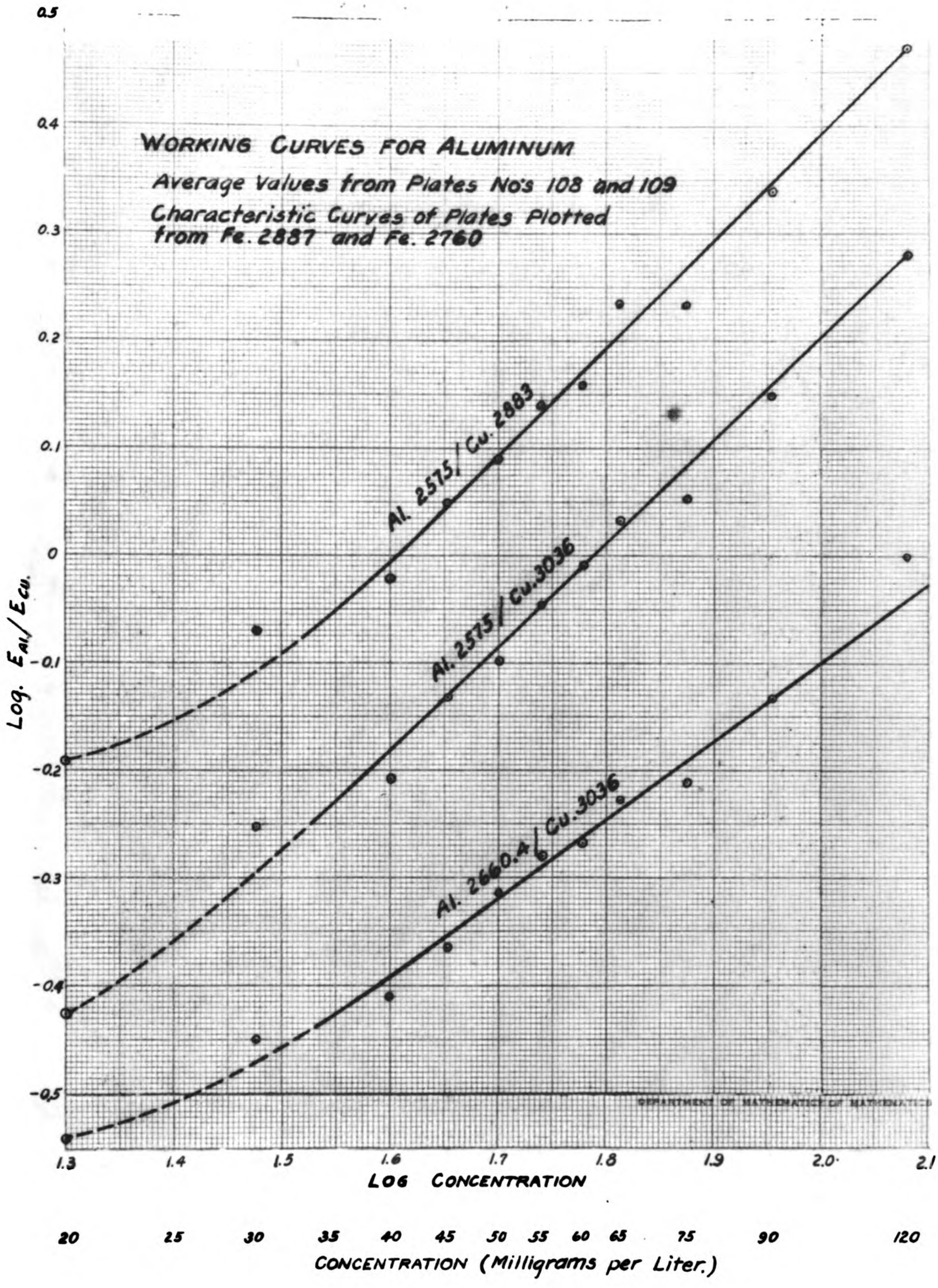
WORKING CURVES FOR ALUMINUM
Average Values from Plates No's 108 and 109
Characteristic Curves of Plates Plotted from Fe. 2887 and Fe. 2760
Al. 2575 / Cu. 2883
Al. 2575 / Cu. 3036
Al. 2660.4 / Cu. 3036
Log. E_{Al}/E_{Cu}
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
LOG CONCENTRATION
20
25
30
35
40
45
50
55
60
65
75
90
120
CONCENTRATION (Milligrams per Liter.)

Fig. III

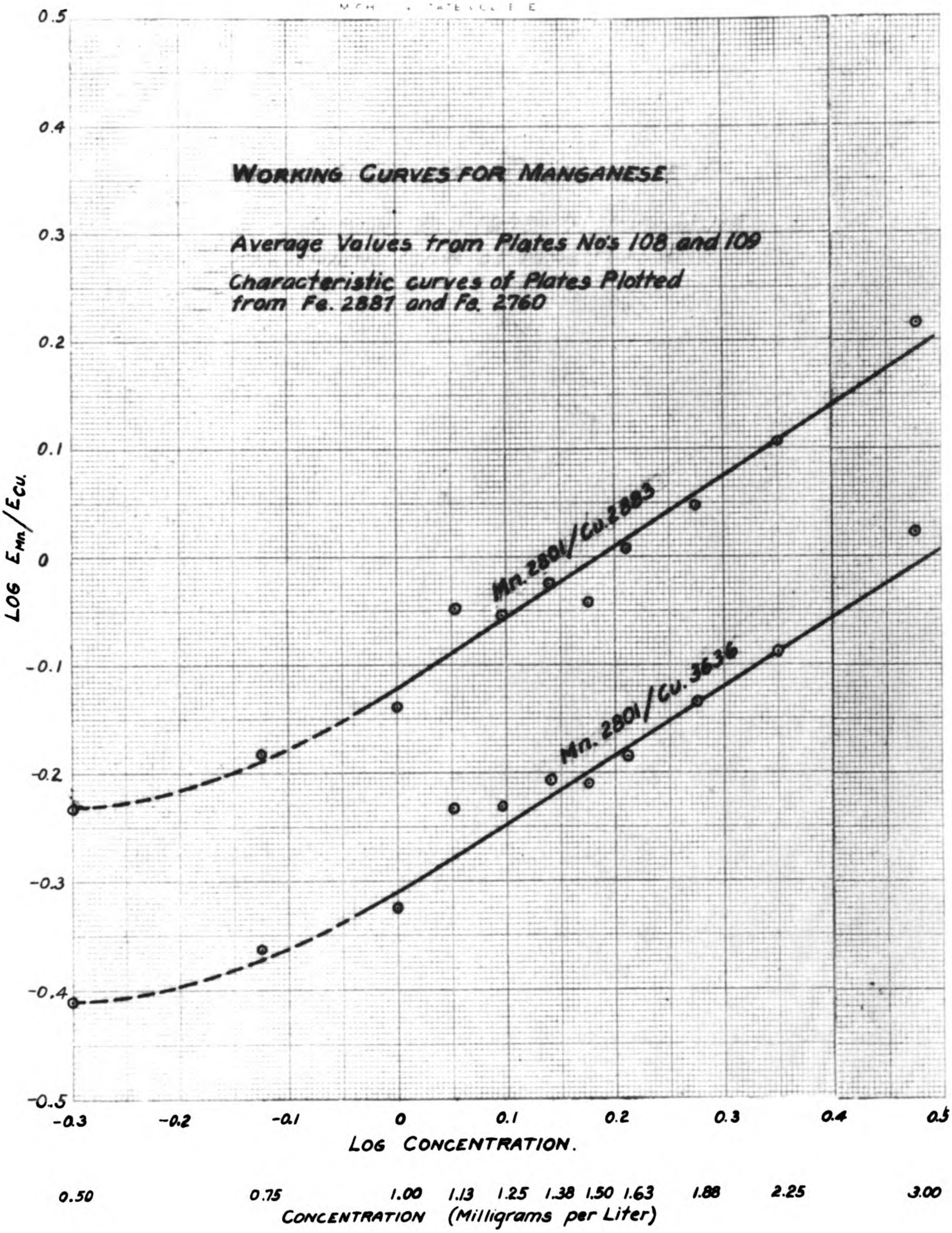
WORKING CURVES FOR MANGANESE
Average Values from Plates No's 108 and 109
Characteristic curves of Plates Plotted from Fe. 2887 and Fe. 2760
Mn. 2801/Cu. 2883
Mn. 2801/Cu. 3636
LOG E_{Mn}/E_{Cu}
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
LOG CONCENTRATION.
0.50
0.75
1.00
1.13
1.25
1.38
1.50
1.63
1.88
2.25
3.00
CONCENTRATION (Milligrams per Liter)

Fig. IV

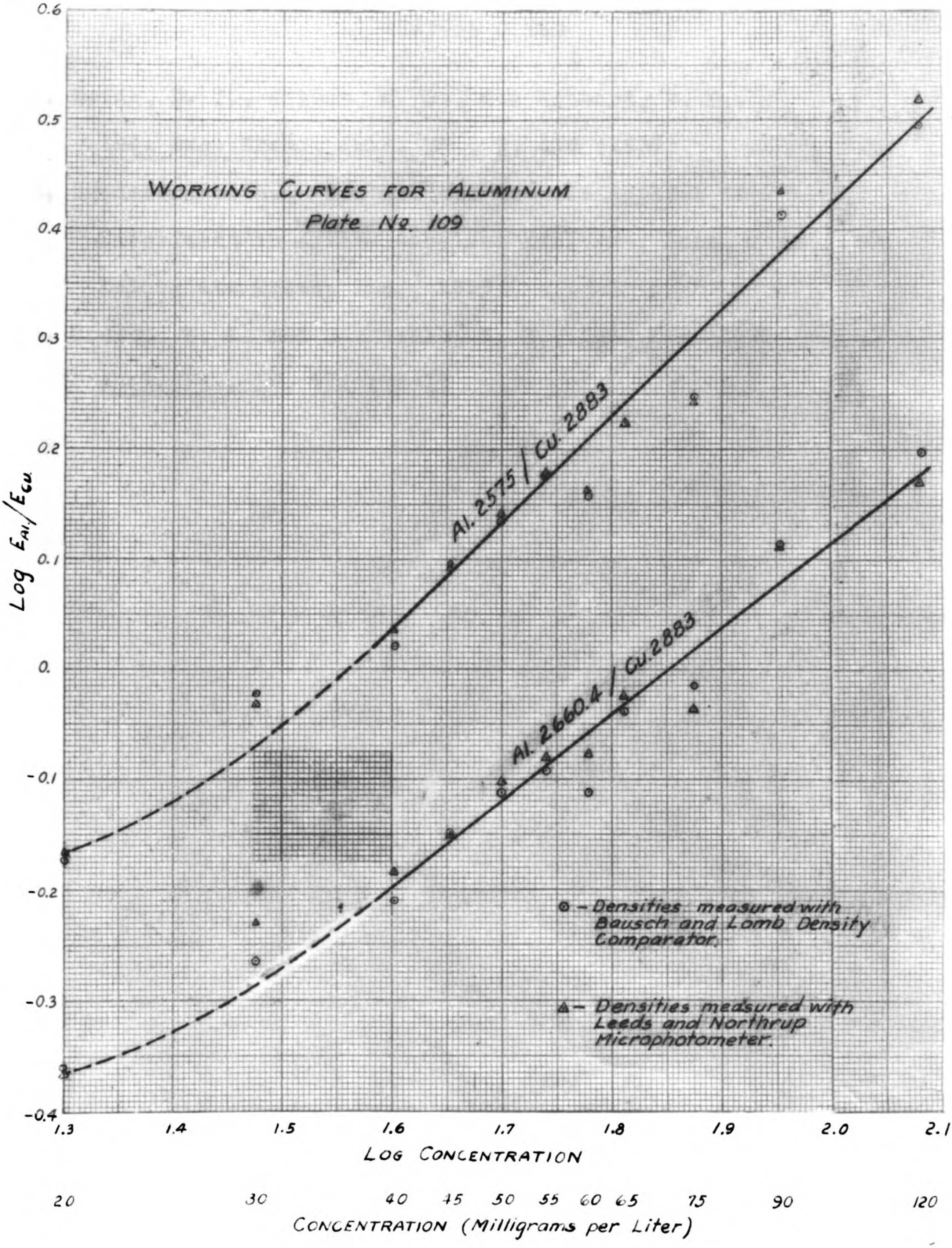
WORKING CURVES FOR ALUMINUM
Plate No. 109
Al. 2575 / Cu. 2883
Al. 2660.4 / Cu. 2883
⊙ – Densities measured with Bausch and Lomb Density Comparator.
△ – Densities measured with Leeds and Northrup Microphotometer.
Log $E_{Al.}/E_{Cu.}$
0.6
0.5
0.4
0.3
0.2
0.1
0.
-0.1
-0.2
-0.3
-0.4
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
LOG CONCENTRATION
20
30
40
45
50
55
60
65
75
90
120
CONCENTRATION (Milligrams per Liter)

Fig. V

LITERATURE CITED

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3. Pierce, W. C. and Nachtrieb, N. H., *Ind. Eng. Chem., Anal. Ed.*, *13*, 774 (1941)