T H E S I S

TESTS OF METERS

For the Degree of

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

Under

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By

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1908

1908

Test of Meters

Meters tested

Meter No. I.

Type - K - Integrating Wattmeter

Single Phase

Amperes 5 Class 2 - 110

Form S.B.A. Cycles 60

No. 306077

Patented April 2, 1901

K = 900

Made by Fort Wayne Electric Works, Fort Wayne, Ind.U.S.A.

Meter No. 2.

Sangamo Integrating Wattmeter

Alternating current Type E.

Volts 110 Amperes 5 Cycles any

K = 2400

Made by Sangamo Electric Company, Springfield, Ill.

It was planned to test the meters Nos. 1 & 2 for the effect of change in load, voltage, frequency, and induction, on their accuracy. However, for the lack of time the meters were only tested for the effect of change in an inductive load, and voltage. A constant frequency of 60 was kept throughout the whole test.

Method. The meters were series connected. See plate No. 26 for details of connections. A current was sent through them and measured by an indicating wattmeter, voltmeter, and ammeter. The meter readings were obtained by counting the turns made by the disc and the time required for the turns observed. Then by the use of the meter constants, time, and number of turns of the disc the watts as indicated by the meters were calculated and compared to the watts as indicated by the wattmeter. See table Nos. 1 to 7 inclusive, pages 1 to 7 inclusive for comparison of true watts and watts by meter, and note the percent error of the meters, reckoned on the meter readings.

Load. The load in this test was lamps and Cos θ was taken = I for this load. Hence it was not necessary to use the voltmeter and ammeter in making the test. The voltmeter and ammeter observations were only used as a check in this work and do not enter into any of the calculations.

Voltage. A series of load tests at different voltage were made, ranging from ninety five volts to one hundred and fifteen volts by steps of five volts each. See tables No. 1 to 5 inclusive and plates No. 1 to 5 inclusive for effect of voltage.

Frequency. The only frequency used was sixty and the generator was kept at the required speed by use of a water tachometer and by the tuning fork method.

Induction. No test for the effect of induction was made.

Instruments used. The instruments used in this work were as follows:

Thomson A.C. Voltmeter No. 145086 Type E.

See page 3 for calibration.

Weston Ammeter Model 151 No. 245.

See page 4 for calibration.

The Westinghouse Ammeter, Style No. 35120

Serial No. 65063

See page 5 for calibration.

Weston Portable Wattmeter No. 407.

See page 6 for calibration.

Calibration of Thomson A.C.Voltmeter No. 145086, Type P.

To calibrate a voltmeter, its readings must be compared to the reading of a standard and the error observed. In this instance the only standard to be had was a direct Weston Laboratory Srandard. It was necessary therefore, to calibrate the electrostatic voltmeter by the Weston Laboratory Standard and then calibrate the Thomson A.C. voltmeter by the electrostatic voltmeter. In this way the readings of the A.C. voltmeter were compared to the readings of the direct weston Laboratory Standard.

The observations for the calibration of the electrostatic voltmeter are given in table No. 8 page 18 and a curve was

plotted between the average deflection of the electrostatic voltmeter and the corrected voltages of the direct Weston Laboratory Standard. See plate No. VII . The observations for the calibration of the Thomson A.C.voltmeter No. 145086, type P, are given in Table No. 9 page 18 . A curve was plotted between the deflections of the electrostatic voltmeter and the A.C. voltmeter, using the same scales and origen as were used for the electrostatic voltmeter and the direct Weston Laboratory Standard. See plate No.

Omit.

By the use of calibration curves (See plate No. VII) the readings of the Thomson A.C. voltmeter No. 145086, type P, were compared to the readings of the direct Weston Laboratory Standard No.—. and the observations recorded in table No.9 page 18 . However it was thought best to plot a curve between the readings of the Thomson A.C. voltmeter and the readings of the Weston Laboratory Standard, see plate No.VIII and then observe the error from curve(See plate No.VIII of the Thomson A.C. voltmeter). See table No.10 page 19 for error and plate No.VIII for correction of the Thomson A.C. voltmeter No. 145086 Type P.

For diagram of connections see plate No. XXVII

Calibration of the Weston A.C.Ammeter Model 151,No.245.

In order to adapt it to the purpose of standardization, the multicellular voltmeter was provided with a mirror on the needle. In front of the instrument is placed a semicircular scale of about 1 1/2 ft. radius divided to millimeters. Deflections are observed by a telescope below the center of the scale.

As deflections are always in the same direction, the mirror at the zero position of the needle stands at about 45° to the line

of the telescope, thus making the whole five feet available for the deflections.

To calibrate an A.C. ammeter, a current is sent through the ammeter and a bank of lamps. The E.M.F. at the lamp terminals is read on the multicellular voltmeter. Then a sufficient D.C. current is sent through the lamps to produce nearly the same E.M.F. and the current is read on the Weston Standard Ammeter.

The weston A.C. ammeter No. 245 was calibrated by the above multicellular voltmeter method. The observations are given in table No. 11 page 20 , and curves plotted with the same scales and origin between the Weston Standard ammeter readings and the multicellular voltmeter deflection and the Weston A.C. ammeter readings and the multicellular voltmeter readings, see plate No. IX From these curves (see plate No. IX) the Weston A.C. ammeter readings were compared to the Weston Standard ammeter readings. See table No. 12 page 21 . A curve was plotted from the data given in table No. 12 page 21 and the error of the Weston A.C. ammeter observed and recorded in table No. 13 page 21.

For correction curve of the Weston A.C. ammeter No. 245 see plate No X .

For diagram of connections see plate No. XXVIII

Calibration of the Westinghouse A.C.Ammeter

Style No. 35120

Serial No. 65063

The same method was used in calibrating this instrument as was used for the Weston A.C. ammeter No. 245. (see page 4)

The multicellular voltmeter gives more accurate reading at a high voltage. For this reason three banks of lamps were used composed of three, nine, and twelve lamps respectively. The observations are given in table No. 14 page 22 . Two curves were plotted for each load, one between Weston Standard ammeter and M. voltmeter, and the other between Westinghouse A.C. ammeter and M. voltmeter. See plate No. XI .

From these sets of curves (see plate No. XI page) the data for calibration was obtained and is given in table No. 15 page 22 . For calibration curve see plate No. XII page . From this cruve (see plate No. XII) the error of the Westinghouse A.C. ammeter was determined and is given in table No. 15 page 22 . For correction curve see plate No. XIII.

Calibration of Weston Portable Wattmeter No. 407.

This wattmeter was calibrated with a non-inductive current. A bank of lamps was used for the load and Cos θ was taken = I for this calibration. The current and voltage applied to the bank of lamps were observed. Then the error of the wattmeter was easily determined by calculation.

Observations were taken from no load to full load at intervals of five volts from eighty to one hundred and twenty volts inclusive. The observations are given in tables (Nos. 16 to 24 inclusive) pages (Nos. 23 to 31 inclusive.) A curve was drawn for each voltage. See plates(Nos. XIV to XXII inclusive). From the curves (see plates Nos. XIV to XXII inclusive) it is easily seen that above two hundred watts, the error of the wattmeter is very small (not more than 1/4 of 1%) and independent of the voltage, and that be-

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low two hundred watts, the error is considerable and is not independent of the voltage.

Method of correction. When the shunt coil for the wattmeter is being used, it is evident the wattmeter will be over-corrected for the current passing through the voltage coil, as only one fifth of this current will pass through the current coil of the wattmeter. Hence to compensate for this over correction, five times the watts used by the voltage coil of the wattmeter must be added to the watts as indicated by the wattmeter. In making the correction of the indicated watts, five times the watts used by the shunt coil plus the watts used by the Thomson A.C. voltmeter No. 145086 type P were added. See plate No. XXIII for correction curve.

As the shunt coil of the wattmeter and voltmeter coil are both non inductive, the current through them is proportional to the voltage applied and us found by the equation $I = E/R$. The watts used by these coils are found by the equation $W = E2 / RI$. The watts consumed by these coils, at any given voltage can easily be found by use of table No. 25 page 32 and by the curves on plate No. XXIV + XXIV a

Correction below 200 watts. The correction for the wattmeter below two hundred watts is divided into two parts, one part depending on the voltage for its value and the other part depending on the watts being measured for its value. The correction for voltage is found by use of curve, see plate No. XXV. The correction for load is found by use of table No. 26 page 33 and curve on plate XXV A. The table No. 26 page 33 was taken from the calibration curves

80 to 120 volts inclusive and is the average corrections at load indicated. See plate No. XXV and table No. 26 page 33. Explanation. To find correction for wattmeter when it indicates, say 120 watts voltage 95. See plate No. XXV for correction curve for voltage and observe the correction at 95 volts. Next see plate No. XXV for load correction and observe the correction at 120 watts. The algebraical sum of these two separate corrections will give the true corcretion for wattmeter.

Correction above 200 watts.

Find the correction for the given voltage from curve on plate No XXIII and add it to the watts as indicated by the wattmeter.

Construction of Shunt Coil for Weston Portable Wattmeter No. 407.

This wattmeter has a capacity of only two amperes. It was necessary to measure as high as five amperes in the test of meters No. 1 and No. 2. Hence a shunt coil for the series coil of the wattmeter was needed. It was decided to make the shunt coil to carry four fifths of the current to be measured, thus making it possible to measure currents up to ten amperes. It was necessary therefore to make the shunt coil with exactly one fourth the resistance and inductance of the series coil of the wattmeter.

Method of Construction. The resistance of the series coil of the wattmeter was determined by an ammeter and a millivoltmeter, and was found to be about 0.284 ohms. Number 16 wire was chosen for making the shunt coil. The length of wire to give the required resistance was first determined roughly by calculation.

The resistance was then adjusted by means of a galvonometer and a resistance box.

Adjusting the Inductance of Shunt Coil.

After the resistance was adjusted, it was then necessary to adjust the inductance of the shunt coil to one fourth of the inductance of the current coil of the wattmeter.

The inductance of the shunt coil was adjusted by coiling the wire, by changing the number of turns of wire, the required inductance was finally found.

Method. A non-inductive slide wire resistance was used in connection with a telephone. The shunt coil for the wattmeter was connected in series with the current coil of the wattmeter. Those two were then shunt connected with the slide wire resistance, see plate No XXIX for details of connections. While sending an alternating current through the circuit, the sliding contact of the telephone was moved along the slide wire till a point of silence was found. The relative inductance was then determined by the position of silent point. Owing to the fact that the slide wire was not likely to be uniform in cross-section, the final test for relative inductance was made as follows. The resistance of the shunt coil was adjusted very closely. A direct current was sent through the circuit, a galvonometer being used instead of the telephone. The point of no deflection was located on the slide wire. Then the galvonometer was disconnected and the telephone placed again in the circuit. An alternating current was passed through the circuit and the inductance of the shunt coil adjusted till the point of silence coincided with the point of no deflection.

By this method the resistance and inductance of the shunt coil were adjusted in the same ratio to the resistance and induction of the current coil of the wattmeter.

For diagram of connections see plate No. XXIX

Test of Meters No. 1 & 2.

60 Cycles. Cos. θ = 1

Table No. 1..

Volts	Ammeter Readings	Wattmeter Readings	Watts	Meter Nº 1				Meter Nº 2			
				Time	Turns	Watts by Meter	Percent Error	Time	Turns	Watts by Meter	Percent Error
95	0.525	46.5	52.0	4'-23"	14	51.3	+1.3	4'-5"	5	49.0	+6.1
"	1.50	22.6	133.0	3'-5"	28	136.2	+2.3	3'-1"	10	132.6	+0.3
"	2.75	44.4	246.2	3'-2"	50	247.2	-0.4	3'-16"	20	244.9	+0.5
"	3.74	61.5	331.7	2'-1"	45	334.7	-0.9	4'-11"	35	344.6	-0.8
"	4.22	70.3	375.7	2'-6"	53	378.6	-0.2	3'-43"	35	413.3	(?)
"	5.16	87.5	451.7	3'-0"	92	460.0	-1.8	2'-38"	30	455.7	-0.9

Remarks: The load was lamps and Cos. θ was taken = 1 for this load. The speed of the alternator in this experiment was kept constant by the water tachometer.

See plate I

Test of Meters No. 1 & 2.

60 Cycle. Cos θ = 1

Table No. 2..

Volts	Ammeter Readings	Wattmeter Readings	Watts	Meter No. 1				Meter No. 2			
				Time	Turns	Watts by Meter	Percent Error	Time	Turns	Watts by Meter	Percent Error
100	0.552	51.5	57.5	4'-14"	16	56.7	+1.4	2'-10"	3	55.4	+3.4
"	1.06	15.8	102.7	2'-3"	14	102.4	+0.3	2'-0"	5	100.0	+2.4
"	1.55	25.0	146.7	3'-2"	30	142.4	+3.0	2'-45"	10	145.4	+0.9
"	2.59	42.8	244.0	3'-5"	50	243.2	+0.3	3'-0"	15	200.0	(?)
"	3.49	59.0	325.0	2'-1"	44	327.2	-0.7	2'-55"	23	315.4	+3.0
"	4.45	77.0	415.0	3'-23"	94	416.8	-0.4	2'-0"	21	420.0	+1.3
"	5.40	95.2	506.0	3'-0"	101	505.	+0.2	2'-0"	25	500.0	+1.0

Remarks: The load was lamps and Cos. θ was taken = 1 for this load. The speed of the alternator in this experiment was kept constant by the water tachometer.

See plate II

Test of Meters No. 1 & 2.

60 Cycles. Cos θ = 1

Table No. 3.

Volts	Ammeter Readings	Wattmeter Readings	Watts	Meter No 1				Meter No 2			
				Time	Turns	Watts by Meter	Percent Error	Time	Turns	Watts by Meter	Percent Error
105	5.86	56.7	60.8	2'-55"	12	61.7	-1.5	2'-0"	3	60.0	+1.3
"	1.10	18.0	116.4	3'-2"	22	108.8	+7.0	3'-37"	10	110.6	+5.2
"	1.66	27.9	165.0	3'-10"	34	161.1	+2.4	3'-41"	15	162.9	+1.3
"	2.62	45.5	263.0	2'-8"	36	253.1	+4.0	3'-9"	20	254.0	+3.5
"	3.17	56.0	315.7	3'-8"	65	311.2	+1.2	3'-12"	25	312.5	+1.0
"	3.74	67.4	372.7	3'-31"	86	366.8	+1.6	3'-16"	30	367.3	+1.5
"	4.57	82.5	448.0	3'-25"	100	439.0	+1.6	3'-39"	40	438.3	+2.2
"	5.05	93.5	50.3	3'-18"	108	491.0	+2.4	3'-15"	40	492.3	2.0

Remarks: The load was lamps and Cos.θ was taken = 1 for this load. The speed of the alternator in this experiment was kept constant by water tachometer.

See plate III

Test of Meters No. 1 & 2.

60 Cycles. Cos. θ = 1

Table No. 4.

Volts	Ammeter Readings	Wattmeter Readings	Watts	Meter No 1				Meter No 2			
				Time	Turns	Watts by Meter	Percent Error	Time	Turns	Watts by Meter	Percent Error
110	0.62	63.0	67.5	3'-30"	16	68.6	-1.6	3'-30"	6	68.6	-1.6
"	1.12	20.0	129.0	3'-25"	28	123.0	+4.8	4'-9"	13	125.3	+3.0
"	1.70	30.5	180.4	3'-17"	40	182.7	-1.2	3'-19"	15	181.0	-0.3
"	2.65	48.3	274.0	3'-17"	61	278.7	-1.7	3'-40"	25	272.7	+0.5
"	3.24	59.8	331.5	3'-11"	70	329.3	+1.0	3'-1"	25	331.5	0.0
"	3.97	74.0	402.5	3'-22"	90	401.0	+0.4	3'-30"	35	390.5	+3.0
"	4.37	83.0	447.5	3'-23"	100	443.3	+0.9	3'-34"	40	448.6	-0.2
"	5.14	99.2	528.5	3'-25"	120	526.8	+0.2	3'-27"	45	521.2	+1.4

Remarks:

The load was lamps and Cos θ was taken = 1 for this load. The speed of the alternator in this experiment was kept constant by the water tachometer.

See plate IV

Test of Meters No. 1 & 2.

60 Cycles. Cos. θ = 1

Table No. 5.

Volts	Ammeter Readings	Wattmeter Readings	Watts	Meter No. 1				Meter No. 2			
				Time	Turns	Watts by Meter	Percent Error	Time	Turns	Watts by Meter	Percent Error
115	0.65	69.0	74.0	3'-35"	18	75.3	-1.7	3'-39"	7	76.7	-3.5
"	1.22	21.5	139.5	3'-9"	28	133.3	+4.6	4'-2"	15	148.7	-6.2
"	1.82	33.3	197.5	3'-2"	40	198.0	-0.2	3'-0"	15	200.0	(?)
"	2.87	54.4	307.7	3'-11"	65	306.3	+0.4	3'-13"	25	311.0	-1.0
"	3.63	70.0	385.7	3'-7"	80	385.0	+0.2	3'-32"	36	407.5	-5.3
"	4.44	89.0	408.7	3'-11"	100	471.2	+1.7	3'-22"	40	475.2	(?)
"	5.50	103.0	550.7	3'-11"	125	589.0	+6.7	3'-0"	44	586.6	-6.0

Remarks: The load was lamps and Cos θ was taken = 1 for this load. The speed of the alternator in this experiment was kept constant by tuning fork.

See plate V

Average Percent Correction for Meter No. I.

Table No. 6...

Watts	Voltage. 95	100	105	110	115	% av. cor.
100	-0.8	+0.3	+5.5	+2.3	+1.0	+1.6
150	-2.1	+2.7	+3.4	+2.1	+3.3	+2.3
200	-1.2	+1.4	+3.1	-1.3	-0.2	+0.4
250	-0.4	+0.2	+4.0	-1.6	+1.0	+0.6
300	-0.7	-0.4	+1.7	-0.5	+0.4	+0.2
350	-0.7	-0.6	+1.5	+0.8	+0.7	+0.3
400	-0.6	-0.5	+1.6	+0.4	+1.1	+0.4
450	-1.6	-0.2	+1.7	+0.8	+1.5	+0.4
500	-2.6	+0.2	+2.5	+0.4	+3.0	+0.7

Remarks: The above table was taken from the correction curves (95 - 115 volts inclusive) of meter No. I.

See Plate No. VI

Average Percent Correction for Meter No. 2.

Table No. 7

Voltage.

Watts.	95	100	105	110	115	% av. cor.
100	+2.6	+2.4	+4.3	+1.0	-4.4	1.2
150	+0.3	+1.0	+2.3	+1.5	-6.1	-0.2
200	+0.4	+1.6	+2.2	-0.2	-4.5	-0.1
250	+0.4	+2.2	+3.4	+0.3	-3.0	+0.6
300	-0.3	+2.8	+1.5	+0.3	-1.4	+0.6
350	-0.8	+2.4	+1.3	+1.0	-2.7	+0.2
400	-0.8	+1.6	+1.8	+2.8	-5.0	+0.1
450	-0.9	+1.2	+2.1	-0.2	-5.5	-0.6
500	-0.9	+1.0	+2.0	+0.9	-5.7	-0.4

Remarks: The above table was taken from the correction curves (95 - 115 volts inclusive) of meter No. 2.

See plate No. VI

Calibration of Thompson A.C.Voltmeter.

No.145086 Type P.

Table No. 8..

Volts by Weston Lab. Standard	Volts	M Voltmeter Deflection	M Voltmeter Deflection Reversed connection	Av. Defl. M Voltmeter
61.50	61.40	23.80	23.85	23.82
72.00	71.60	38.96	38.85	38.90
82.40	82.00	57.70	58.10	57.90
92.60	92.20	76.35	76.10	76.23
103.10	102.70	94.13	94.60	94.36
113.40	113.00	111.50	111.50	111.32
115.60	115.20	114.35	114.70	114.52

See plate VII

Table No. 9..

A.C. Volt-meter Readings	M Volt-meter Deflection	Volts by Weston Lab. Std. from curve No
71.00	36.57	70.00
80.50	54.00	80.00
89.00	69.90	88.90
95.00	80.50	94.40
98.90	86.75	98.20
107.50	102.00	107.30
110.20	106.60	110.10
114.90	114.10	114.80
120.00	121.10	119.90

See plate VIII

Calibration of Thompson A.C.Voltmeter.

No. 145086 Type P.

Table No. 10..

Volts	Correction	Volts	Correction
70	-0.80	115	-0.05
75	-0.70	120	0.00
80	-0.60	125	0.00
85	-0.50		
90	-0.40		
95	-0.35		
100	-0.30		
105	-0.20		
110	-0.10		

See plate VIII

Calibration of Weston A.C.Ammeter.

Model 151. No. 245.

Amp. by Weston Lab. Standard	M.Voltmeter Deflection	M.Voltmeter-Deflection Reversed Connection	Av. Deflection of M. Voltmeter	Amp by A.C. Ammeter	M.Voltmeter Deflection
0.398	8.85	8.85	08.85	0.378	8.89
0.500	10.75	10.75	10.75	0.481	10.75
0.620	13.40	13.40	13.40	0.600	13.50
0.694	16.50	16.50	16.50	0.690	16.48
0.800	21.80	21.80	21.80	0.830	21.85
0.894	28.90	28.90	28.90	0.896	28.90
0.994	39.50	39.50	39.50	0.100	39.50

See Plate (IX)

Table No 11

Calibration of Weston A.C.Ammeter

Model 151 No. 245

Table No. 12

Weston Std. Ammeter	Weston A.C. Ammeter No.245
0.400	0.370
0.500	0.470
0.600	0.580
0.700	0.695
0.800	0.800
0.900	0.905
1.000	1.008

See plate X

Table No. 13

Weston A.C.Ammeter No.245	Error
0.40	+ 0.025
0.50	+0.020
0.60	+0.015
0.70	+0.010
0.80	+0.003
0.90	-0.002
1.00	-0.008

See plate X

Calibration of The Westinghouse A.C.Ammeter.

Style No. 35120

Serial No.65063

Table 14

10 Amps. Side

Amp. by Weston Lab. Std.	M. Voltmeter Deflection	Revesed Reading	Av. Deflect. of M. Voltmeter	Amp. by A.C. Amm.	M. Voltmeter Deflection
3 lamps	36.6	36.2	36.4	1.05	36.4
1.00	"	"	"	"	"
1.52	98.05	98.50	98.27	1.60	98.1
9 lamps					
2.00	17.70	17.60	17.65	2.10	17.65
2.50	28.90	28.80	28.85	2.67	28.80
2.98	47.80	47.80	47.80	3.21	47.75
3.50	70.45	70.00	70.22	3.775	70.35
4.08	93.15	93.70	93.42	4.425	94.30
12 lamps					
4.00	57.25	57.15	57.20	4.32	56.90
4.25	65.10	64.90	65.00	4.62	65.05
4.02	57.60	58.00	57.80	4.25	57.65
4.80	82.50	82.50	82.50	5.15	82.70
5.06	91.20	91.20	91.20	5.45	91.20

See plate XI

Table 15.

10 Amp Side

Amp. by Weston Lab. Std.	Amp. by A.C. Amm.	Correction taken from Calibration Curve
0.97	1.00.	-.025
1.43	1.50	-.075
1.90	2.00	-.125
2.33	2.50	-.175
2.78	3.00	-.220
3.22	3.50	-.270
3.70	4.00	-.310
4.17	4.50	-.370
3.79	4.00	-.200
4.21	4.50	-.275
4.67	5.00	-.330
5.10	5.50	-.400

See plates XII + XIII

Calibration of Weston Portable Wattmeter No.407.

Table No 16....

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-correction	Watts in Wattmeter-Shunt Coil	Watts used by Voltmeter	Watts as Corrected	True Watts	Error-Watts
80	0.420	+.025	0.445	32.50	32.5	00.0	2.6	4.1	36.6	35.6	-1.0
"	0.812	+.003	0.815	62.00	62.0	00.0	"	"	66.1	65.2	-0.9
"	1.180	-.040	1.140	15.80	79.0	13.0	"	"	96.1	91.2	-4.9
"	1.575	-.085	1.490	21.75	108.7	"	"	"	125.8	119.2	-6.6
"	1.975	-.125	1.850	27.00	135.0	"	"	"	152.1	148.0	-4.1
"	2.420	-.170	2.250	32.75	163.7	"	"	"	180.8	180.0	- .7
"	2.780	-.200	2.580	38.00	190.0	"	"	"	207.1	206.4	-0.7
"	3.225	-.245	2.980	44.75	223.7	"	"	"	240.8	238.4	-2.4
"	3.600	-.280	3.320	49.75	248.7	"	"	"	265.8	265.6	-0.2
"	4.250	-.345	3.905	59.20	296.0	"	"	"	313.1	312.4	-0.7
"	4.65	-.290	4.36	65.50	327.5	"	"	"	344.6	348.8	+2.2

See plate XIV

Calibration of Weston Portable Wattmeter No.407.

Table No.17.....

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-correction	Watts used by Wattmeter shunt coil	Watts used by Voltmeter	Watts as Corrected	True Watts	Error - Watts
85	.467	+.022	.489	37.50	37.5	00.0	2.9	4.6	42.1	41.6	-0.5
"	.880	-.001	.879	72.40	72.4	00.0	"	"	77.0	74.7	-2.3
"	1.250	-.050	1.200	18.00	90.0	14.7	"	"	109.3	102.0	-7.3
"	1.720	-.100	1.620	24.50	122.5	"	"	"	141.8	137.7	-4.1
"	2.170	-.140	2.030	31.00	155.0	"	"	"	174.3	172.5	-1.8
"	2.620	-.180	2.440	37.50	187.5	"	"	"	206.8	207.4	+0.6
"	2.900	-.210	2.690	42.00	210.0	"	"	"	229.3	228.7	-0.6
"	3.740	-.290	3.450	54.50	272.5	"	"	"	291.8	293.2	+1.4
"	4.150	-.330	3.820	61.00	305.0	"	"	"	324.3	324.7	+0.4
"	4.990	-.330	4.660	74.50	372.5	"	"	"	391.8	396.1	+4.3

See plate XV

Calibration of Weston Portable Wattmeter No. 407.

Table No. 18....

Volts	Ammeter Readings	Error in Amps	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-Correction	Watts used by Wattmeter shunt coil	Watts used by Voltmeter	Watts as Corrected	True Watts	Error-Watts
90	0.496	+.021	0.517	42.00	42.0	00.0	3.3	5.2	47.2	46.5	-0.7
"	0.933	-.004	0.929	80.70	80.7	00.0	"	"	85.9	83.4	-2.5
"	1.350	-.070	1.280	20.20	101.0	16.5	"	"	122.7	113.2	-9.5
"	1.820	-.108	1.712	27.20	136.0	"	"	"	157.7	154.8	-2.9
"	2.300	-.155	2.145	35.00	175.0	"	"	"	196.7	193.5	-3.2
"	2.775	-.200	2.575	42.30	211.5	"	"	"	233.2	231.7	-1.5
"	3.180	-.240	2.940	49.00	245.0	"	"	"	266.7	264.6	-2.1
"	3.680	-.290	3.390	56.30	281.5	"	"	"	303.2	305.1	+1.9
"	4.000	-.320	3.680	61.50	307.5	"	"	"	329.2	331.2	+2.0
"	4.450	-.360	4.090	70.60	353.0	"	"	"	374.7	368.1	-6.6
"	5.200	-.330	4.870	83.75	418.7	"	"	"	440.4	438.3	-2.1

See plate XVI

Calibration of Weston Portable Wattmeter No.407.

Table No.19....

Volts	Ammeter Reading's	Error in Amp.	Amperes	Wattmeter Reading's	Watts by Wattmeter	Watts over-Correction	Watts used by Wattmeter-shunt coil	Watts used by Voltmeter	Watts as corrected	True-Watts	Error-Watts
95	0.530	+.019	0.549	47.00	47.00	00.0	3.7	5.8	52.8	52.2	-0.6
"	1.040	-.030	1.010	14.50	72.5	18.5	"	"	96.3	95.9	-0.4
"	1.470	-.070	1.400	22.70	113.5	"	"	"	137.8	133.0	-4.8
"	1.950	-.120	1.830	31.40	157.0	"	"	"	181.3	173.8	-7.5
"	2.420	-.170	2.250	38.10	190.5	"	"	"	214.8	213.7	-0.9
"	2.860	-.210	2.650	46.20	231.0	"	"	"	225.3	252.7	-2.6
"	3.760	-.300	3.460	61.50	307.5	"	"	"	331.8	328.7	-3.1
"	4.225	-.340	3.885	69.60	348.0	"	"	"	372.3	369.1	-3.2
"	4.600	-.290	4.310	77.00	385.0	"	"	"	409.5	409.5	0.0
"	5.080	-.340	4.740	84.75	423.7	"	"	"	448.0	450.3	+2.3

See plate XVII

Calibration of Weston Portable Wattmeter No.407.

Table No.20.

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-correction	Watts used by Wattmeter shunt coil	Watts used by Voltmeter	Watts as Corrected	True-Watts	Error-Watts
100	0.555	+.017	0.572	51.60	51.6	00.0	4.1	6.4	58.0	57.2	-0.8
"	1.100	-.035	1.065	16.30	81.5	20.5	"	"	108.4	106.5	-1.9
"	1.550	-.080	1.470	25.00	125.0	"	"	"	151.9	147.0	-4.9
"	2.070	-.130	1.940	34.00	170.0	"	"	"	196.9	194.0	-2.9
"	2.520	-.180	2.340	42.00	210.0	"	"	"	236.9	234.0	-2.9
"	3.010	-.220	2.790	50.75	253.7	"	"	"	280.6	279.0	-1.6
"	3.530	-.275	3.250	60.20	301.0	"	"	"	327.9	325.0	-2.9
"	3.970	-.320	3.650	67.50	337.5	"	"	"	264.4	365.0	+0.6
"	4.430	-.360	4.070	76.10	380.5	"	"	"	407.4	407.4	-0.4
"	4.950	-.320	4.630	85.50	427.5	"	"	"	454.4	463.0	+9.0

See plate XVIII

Calibration of Weston Portable Wattmeter No.407.

Table.No.21..

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-correction	Watts used by Wattmeter Shunt coil	Watts used by Voltmeter	Watts as Corrected	True Watts	Error - Watts
105	0.590	+.015	0.605	58.00	58.0	00.0	4.5	7.1	65.1	63.5	-1.6
"	1.100	-.035	1.065	18.00	90.0	22.7	"	"	119.8	111.8	+8.0
"	1.620	-.090	1.530	27.70	138.5	"	"	"	168.3	160.6	-7.7
"	2.200	-.145	2.050	37.60	188.0	"	"	"	217.8	215.3	-2.5
"	2.640	-.190	2.450	45.90	229.5	"	"	"	259.3	257.3	-2.0
"	3.180	-.240	2.940	55.40	227.0	"	"	"	306.8	308.7	+1.9
"	3.710	-.290	3.420	65.75	328.7	"	"	"	358.5	359.1	+0.6
"	4.175	-.335	3.840	74.50	372.5	"	"	"	402.3	403.2	+0.9
"	4.330	-.350	3.980	77.80	389.0	"	"	"	418.8	417.9	-0.9
"	4.650	-.290	4.360	85.40	427.0	"	"	"	456.8	457.8	+1.0
"	5.200	-.360	4.840	96.00	480.0	"	"	"	509.8	508.2	-1.6

See plate ~~XIX~~

Calibration of Weston Portable Wattmeter No. 407.

Table No. 22..

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-Correction	Watts used by Wattmeter shunt coil	Watts used by Voltmeter	Watts as corrected	True Watts	Error - Watts
110	0.623	+.013	0.636	63.60	63.6	00.0	5.0	7.8	71.4	70.0	-1.4
"	1.170	-.040	1.150	20.20	101.0	25.0	"	"	133.8	126.0	-7.8
"	1.700	-.095	1.610	30.60	153.0	"	"	"	185.8	177.1	-8.7
"	2.330	-.160	2.170	42.20	211.0	"	"	"	243.8	238.7	-5.0
"	2.780	-.200	2.580	51.00	255.0	"	"	"	287.8	283.8	-0.7
"	3.370	-.260	3.110	62.00	310.0	"	"	"	342.8	342.1	-0.7
"	3.970	-.320	3.650	73.00	365.0	"	"	"	397.8	401.5	+3.4
"	4.400	-.360	4.040	83.00	415.0	"	"	"	447.8	444.4	-3.4
"	4.900	-.320	4.580	93.50	467.0	"	"	"	499.8	503.8	-4.0
"	5.12	-.340	4.780	98.00	490.0	"	"	"	522.8	525.8	+3.0

See plate XX

Calibration of Weston Portable Wattmeter No.407.

Table No.23.

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-Correction	Watts used by Wattmeter-shunt coil	Watts used by Voltmeter	Watts as Corrected	True Watts	Error - Watts
115	0.650	+.012	0.662	69.50	69.5		5.5	8.5	78.0	76.1	-1.9
"	1.440	-.070	1.370	22.00	110.0	27.4	"	"	145.9	157.5	+11.6
"	1.790	-.100	1.690	33.60	168.0	"	"	"	203.9	194.3	-9.6
"	2.440	-.170	2.270	45.80	229.0	"	"	"	264.9	261.0	-3.9
"	2.950	-.220	2.730	55.80	279.0	"	"	"	314.9	314.0	-0.9
"	3.470	-.270	3.200	67.70	338.5	"	"	"	374.4	368.0	-6.4
"	4.100	-.330	3.770	80.30	401.5	"	"	"	437.4	433.5	-3.9
"	4.570	-.280	4.290	91.00	455.0	"	"	"	490.9	493.3	+2.4
"	5.140	-.350	4.790	102.60	513.0	"	"	"	548.9	550.8	+1.7

See plate XXI

Calibration of Weston Portable Wattmeter No.407.

Table No. 24.

Volts	Ammeter Readings	Error in Amp.	Amperes	Wattmeter Readings	Watts by Wattmeter	Watts over-corrected	Watts used by Wattmeter shunt coil	Watts used by Voltmeter	Watts as Corrected	True Watts	Error-Watts
120	0.680	+.010	0.690	75.40	75.4		5.9	9.2	84.6	82.8	-1.8
"	1.280	-.050	1.230	23.60	118.0	29.5	"	"	156.7	147.6	-9.1
"	1.870	-.110	1.760	31.50	157.5	"	"	"	196.2	211.2	+5.0
"	2.560	-.180	2.380	50.00	250.0	"	"	"	288.7	285.6	-3.1
"	3.080	-.230	2.850	60.60	303.0	"	"	"	341.7	342.0	+0.3
"	3.680	-.290	3.390	73.80	369.0	"	"	"	407.7	406.8	-0.9
"	4.300	-.350	3.950	88.00	440.0	"	"	"	478.7	474.0	-4.7
"	5.200	-.360	4.840	108.90	544.5	"	"	"	583.2	580.8	-2.4

See plate XXII

KNOXVILLE,

Allowance for corrected coil.

Multiply the ~~coil~~ reading by five - add four times the watts used by shunt coil and subtract watts used by voltmeter.

$$\text{Watts} = \frac{E^2}{R} + \frac{1}{R} \text{ of Wattmeter}$$

Shunt = .000411

Correction = $E^2 \times .00164$ for Wattmeter

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Watts used by the shunt coil of the Weston Portable Wattmeter No. 407, also Watts used by the Thomson Voltmeter No. 145086.

By Experiment Table No 25a

Voltmeter Readings	Volts	Ammeter Reading on Lamp	Amp. through Lamp	Amm. Reading Lamp + Watt-meter-shunt coil	Amp through Lamp + W.S.C.	Amm. Reading Lamp + W.S.C + Voltmeter	Amp. through Lamp + W.S.C. + Voltmeter	Amp. through Wattmeter Shunt coil	Amp through Voltmeter	Watts used by Wattmeter-shunt coil	Watts used by Voltmeter
77.4	76.7	.330	.360	.362	.390	.410	.435	.030	.045	2.30	3.45
89.0	88.6	.385	.412	.428	.452	.485	.506	.040	.054	3.54	4.78
100.0	99.7	.445	.469	.487	.508	.560	.577	.039	.069	3.89	6.88
104.4	104.2	.465	.487	.510	.530	.584	.600	.043	.070	4.48	7.29
111.2	111.1	.505	.525	.552	.569	.628	.642	.044	.073	4.89	8.11
115.5	115.5	.525	.544	.575	.591	.650	.662	.047	.071	5.43	8.20
121.0	121.0	.551	.568	.608	.622	.684	.694	.054	.072	6.53	8.71
124.0	124.1	.573	.589	.628	.641	.704	.713	.052	.072	6.45	8.93

See plate XXIV a

Calculation Table No. 25..

Volts	Watts used by Wattmeter Shunt coil	Watts used by Voltmeter	Volts	Watts used by Wattmeter Shunt coil	Watts used by Voltmeter	Volts	Watts used by Wattmeter Shunt coil	Watts used by Voltmeter	Volts	Watts used by Wattmeter shunt coil	Watts used by Voltmeter	
70	2.00	3.15	85	2.95	4.60	100	4.11	6.43	115	5.46	8.50	
75	2.34	3.61	90	3.30	5.20	105	4.54	7.10	120	5.90	9.24	
80	2.60	4.10	95	3.70	5.78	110	4.97	7.78	125	6.36	10.05	

See plate XXIV

Calibration of Weston Portable Wattmeter No.407.

Below 200 Watts.

Table Nº 26

Voltage.

Watts.	80	85	90	95	100	105	110	115	120	Av.Cor.
25	-0.5	-0.0	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	-1.0	-1.0	-0.5	-1.5	+3.0	-1.5	0.0	0.0	0.0	-0.3
75	-2.5	-3.0	-1.5	-0.5	+3.0	-3.5	-1.0	-2.0	-2.0	-1.5
100	-5.0	-5.5	-6.0	-1.0	+3.0	-5.0	-4.0	-3.0	-4.0	-3.4
125	-7.0	-5.0	-8.0	-4.0	-0.0	-5.0	-7.5	-5.0	-6.0	-5.3
150	-4.0	-3.0	-5.0	-6.0	-5.0	-6.0	-8.0	-7.0	-10.0	-5.0
175	-1.0	-2.0	-3.0	-7.5	-5.0	-5.0	-8.0	-8.0	-6.0	-5.0
200	-1.0	-0.0	-3.0	-3.5	-3.5	-2.5	-5.0	-8.0	-1.0	-3.0
2.25	-1.0	-0.0	-3.0	-1.0	-3.5	-2.5	-0.5	-5.0	+1.0	-1.8
2.50	-.8	-0.0	-3.0	-1.0	-3.5	-2.0	-0.0	-0.0	+1.0	-1.2

The above table was taken from the calibration curves. (80-120 volts) and an average taken for the different voltages. This correction is independent of the voltage.

See plate XXV

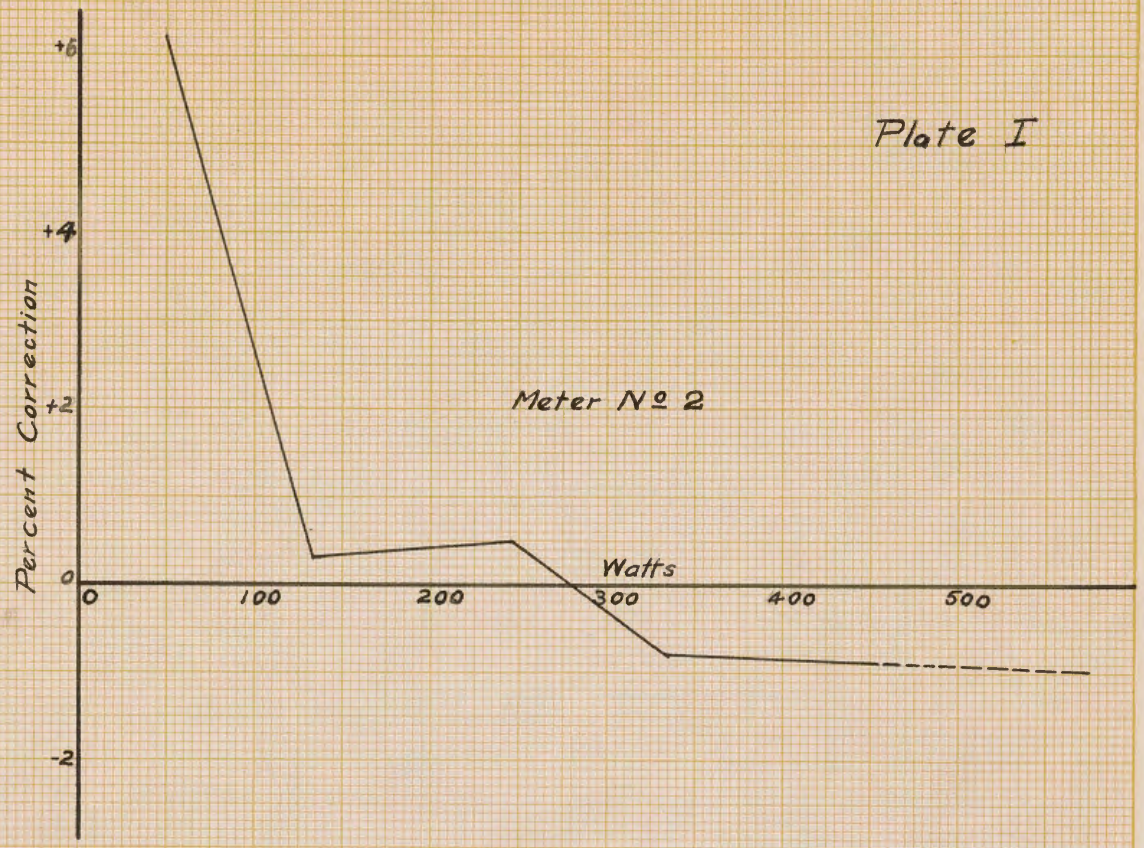
Correction for Weston Portable Wattmeter No.407.
with shunt when the load exceeds 200 watts.

Table No.27.

80	volts.	17.1	Watts
85	"	19.3	"
90	"	21.7	"
95	"	24.3	"
100	"	26.9	"
105	"	29.8	"
110	"	32.8	"
115	"	35.9	"
120	"	38.7	"
125	"	42.0	"

See Plate No ~~XXIII~~ + ~~XXV~~

Plate I



Correction Curves for Meters Nº 1 & Nº 2
at 95 Volts and 60 Cycles

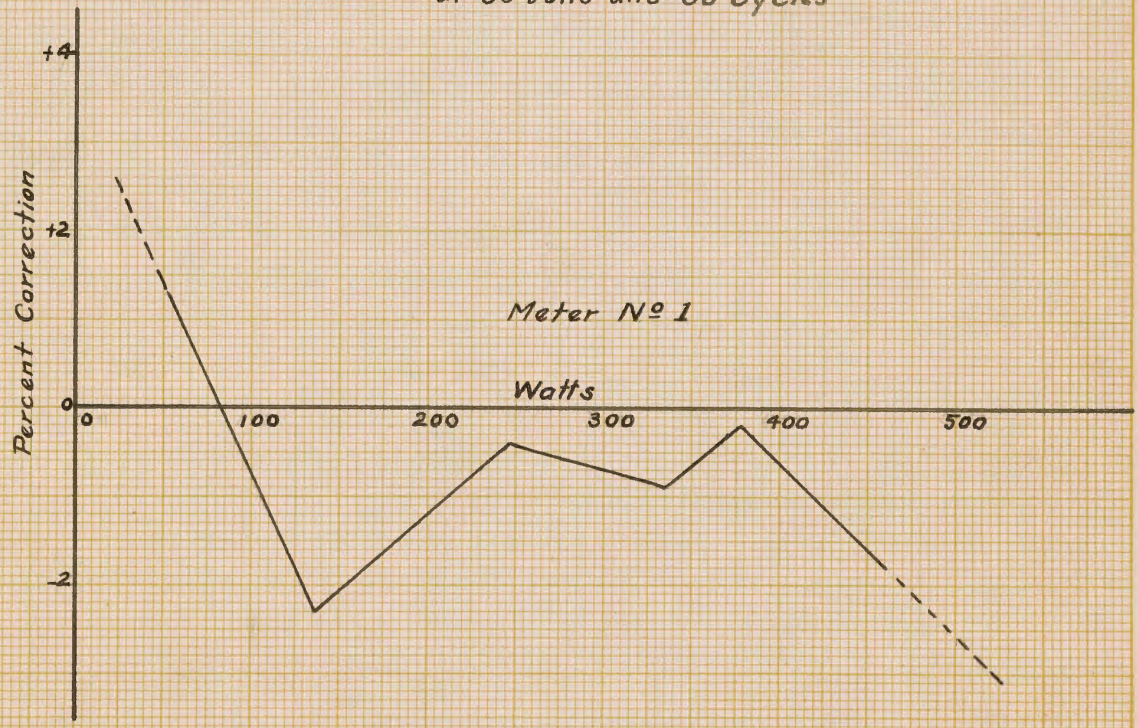
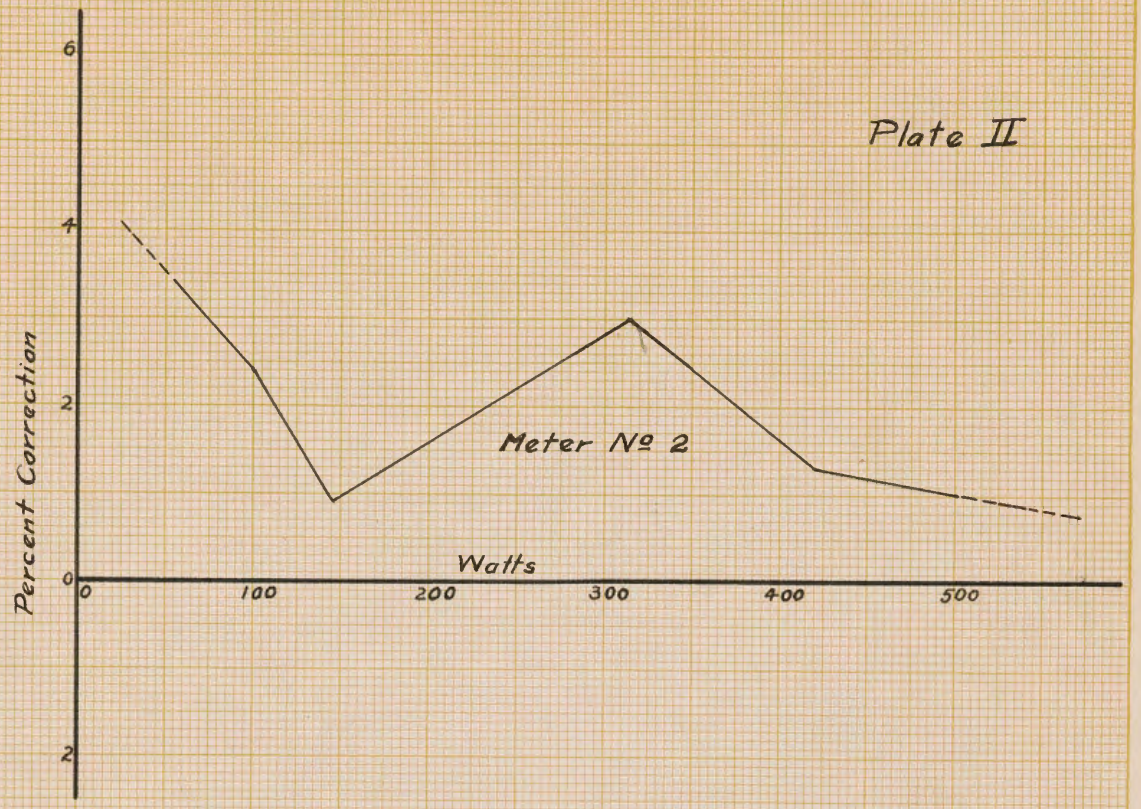


Plate II



Correction Curves for Meters Nº 1 & Nº 2
at 100 Volts and 60 Cycles

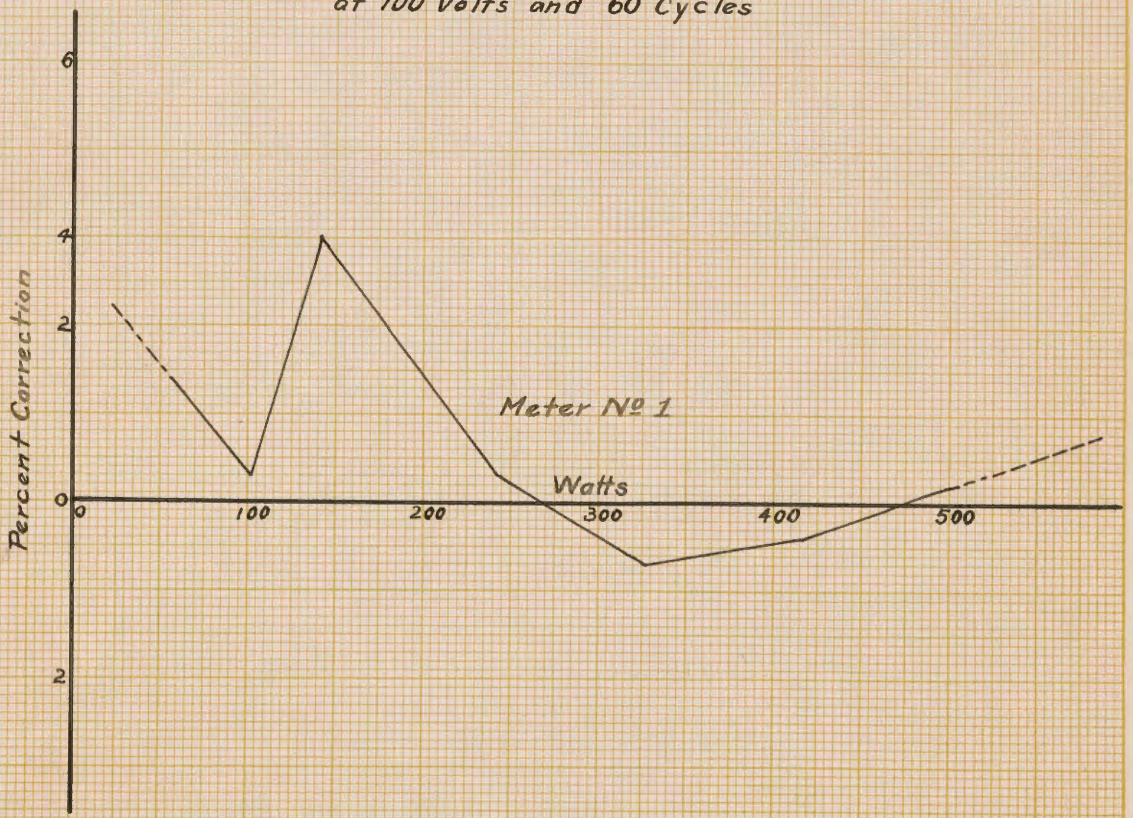
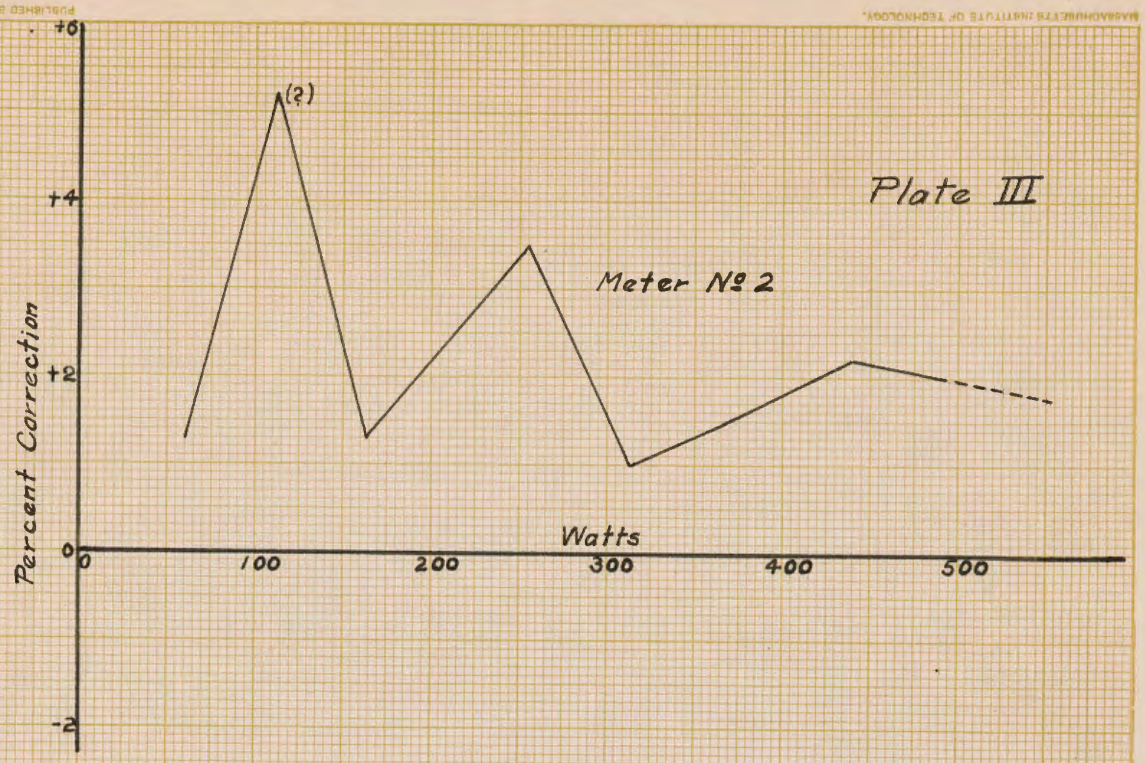


Plate III



Correction Curves for Meters Nº 1 & Nº 2
at 105 Volts - 60 Cycles

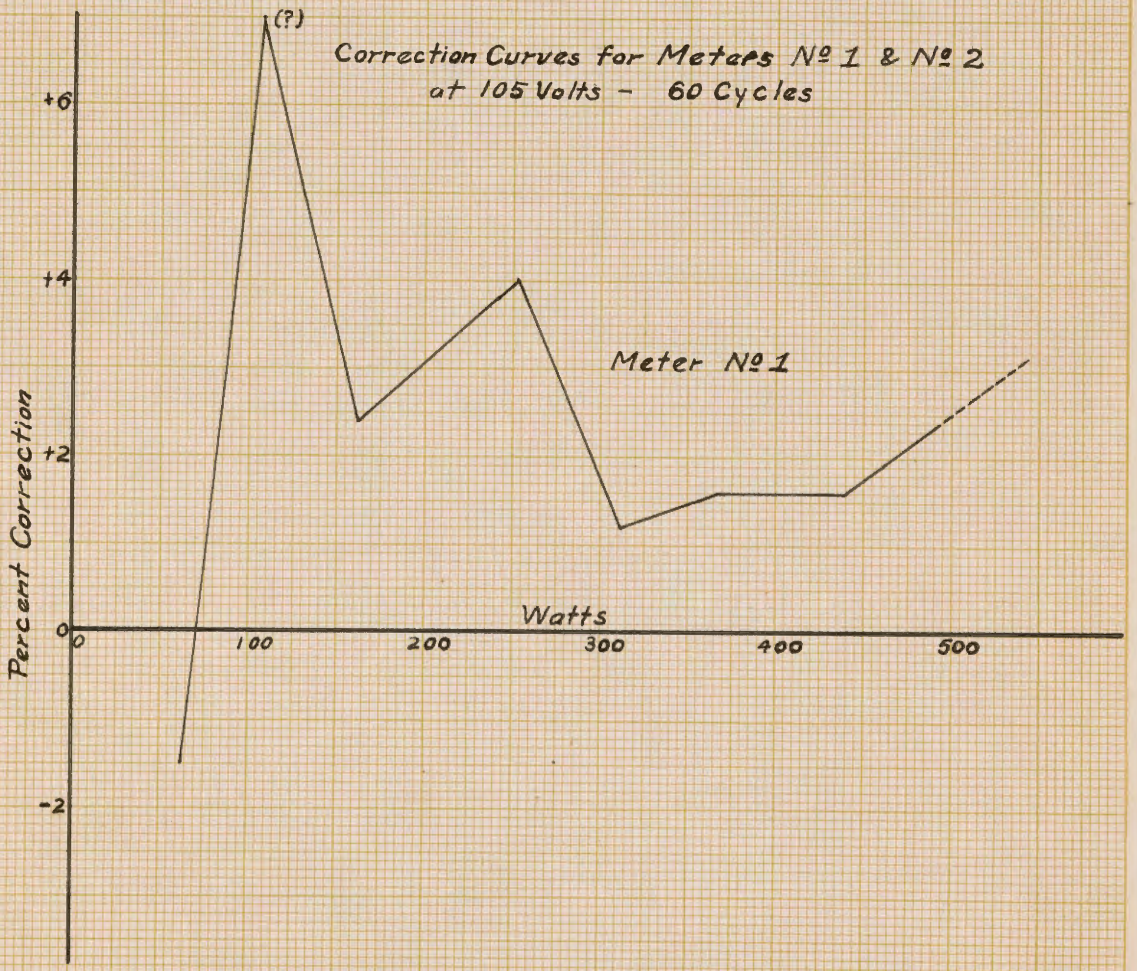
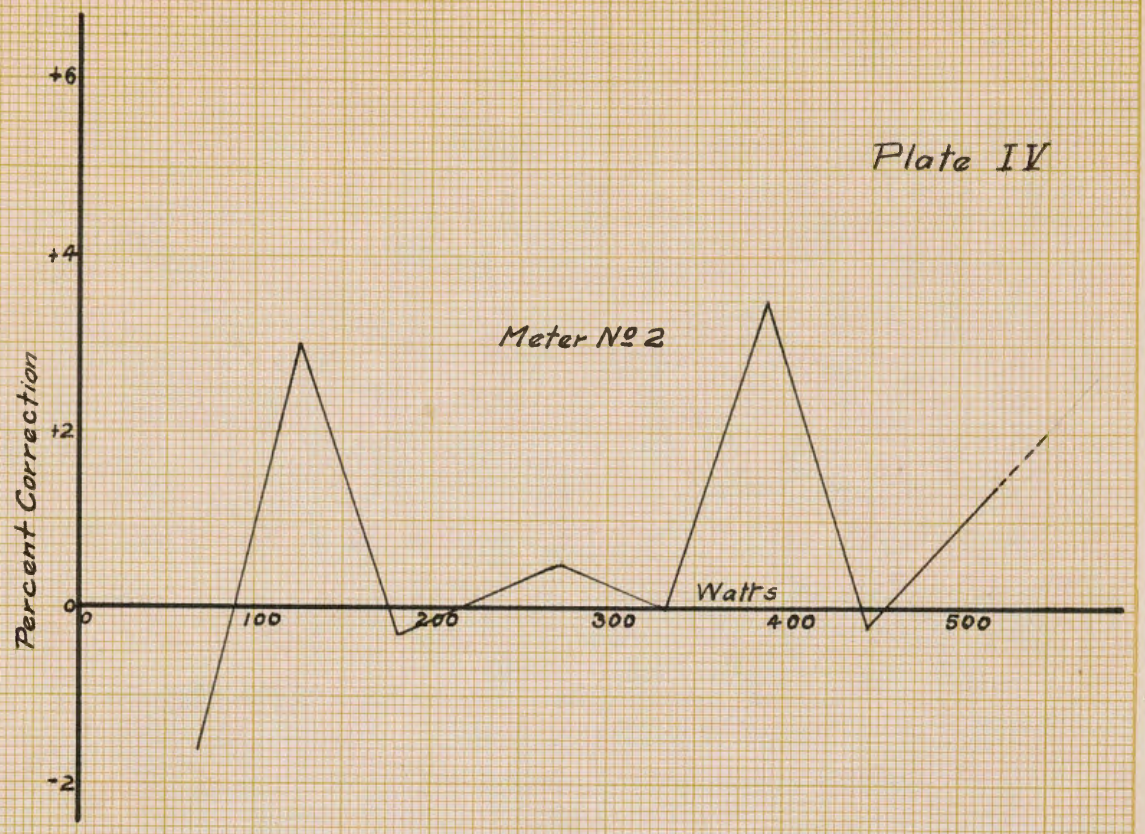
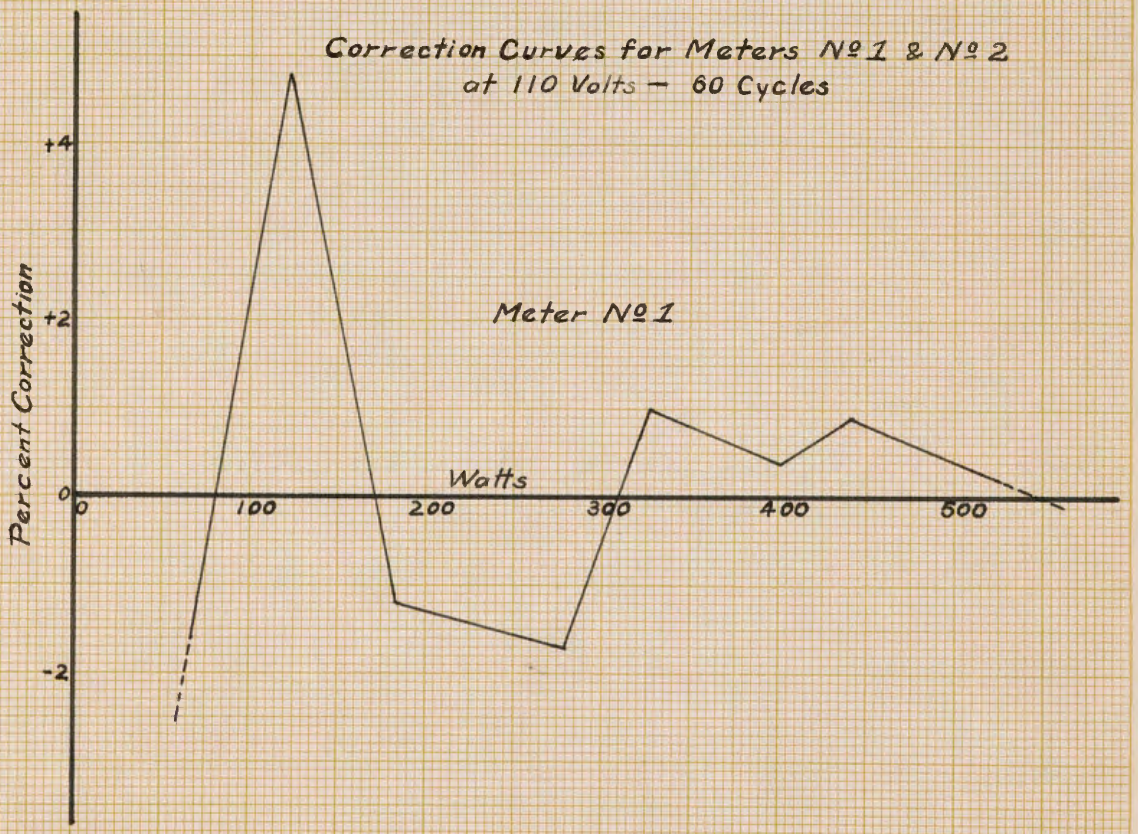


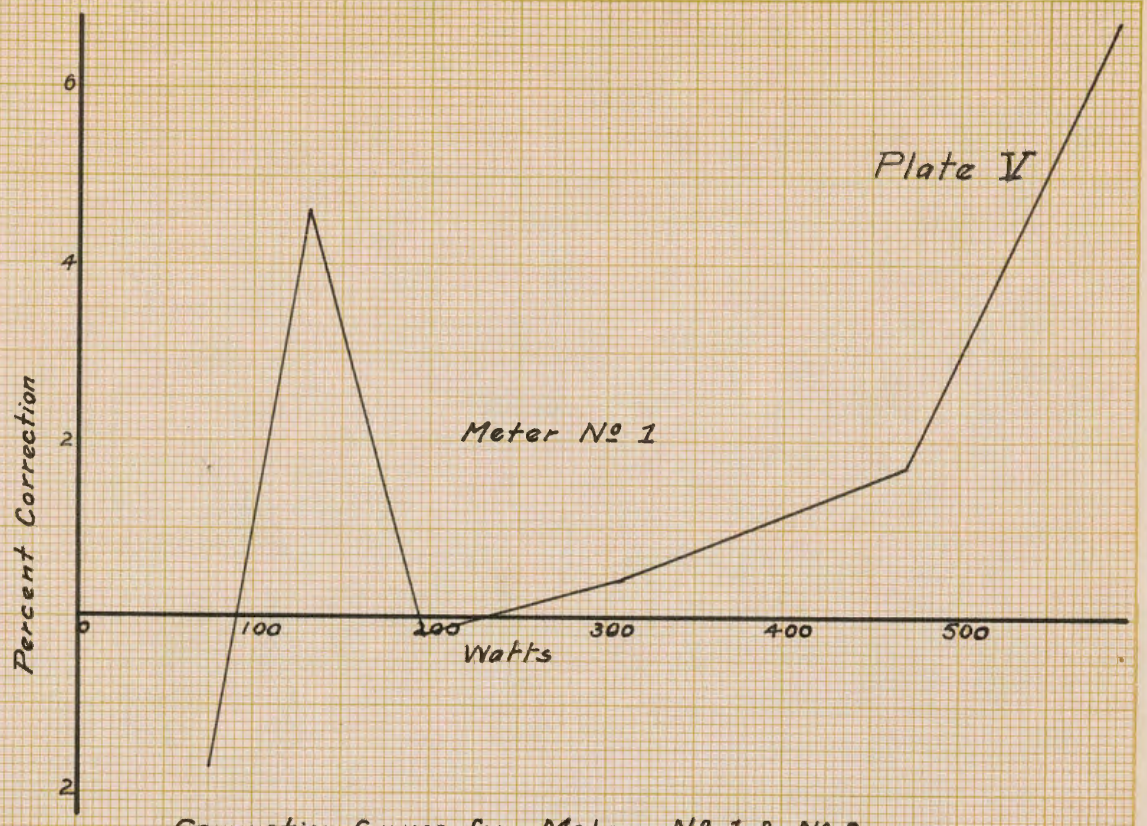
Plate IV





Correction Curves for Meters Nº 1 & Nº 2
at 110 Volts — 60 Cycles

Plate V



Correction Curves for Meters No. 1 & No. 2
at 115 Volts — 60 Cycles

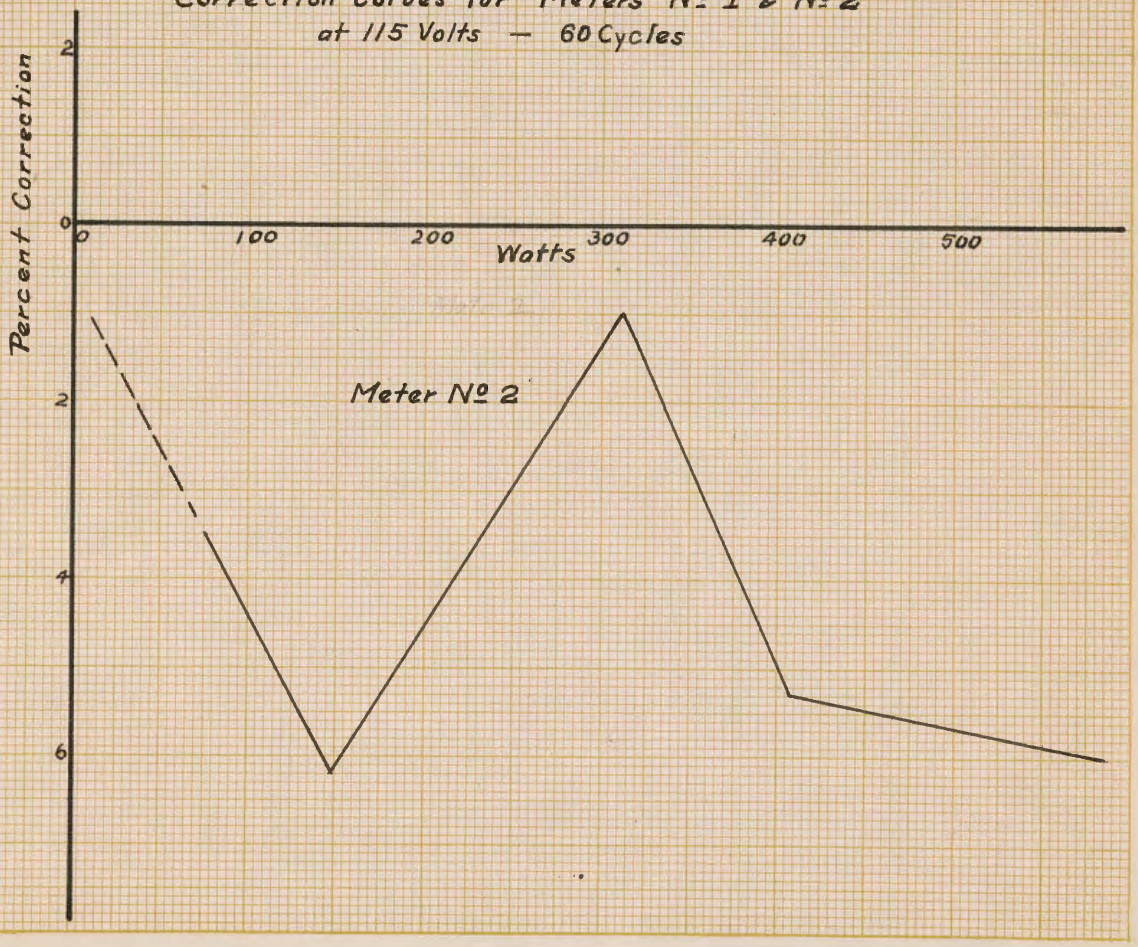
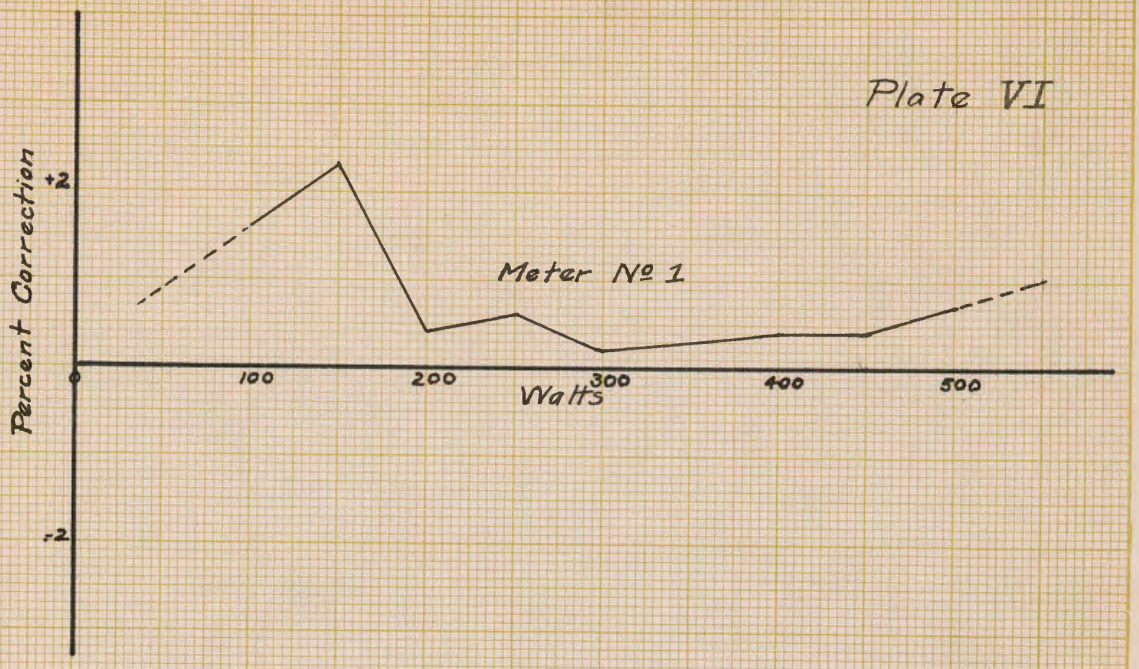
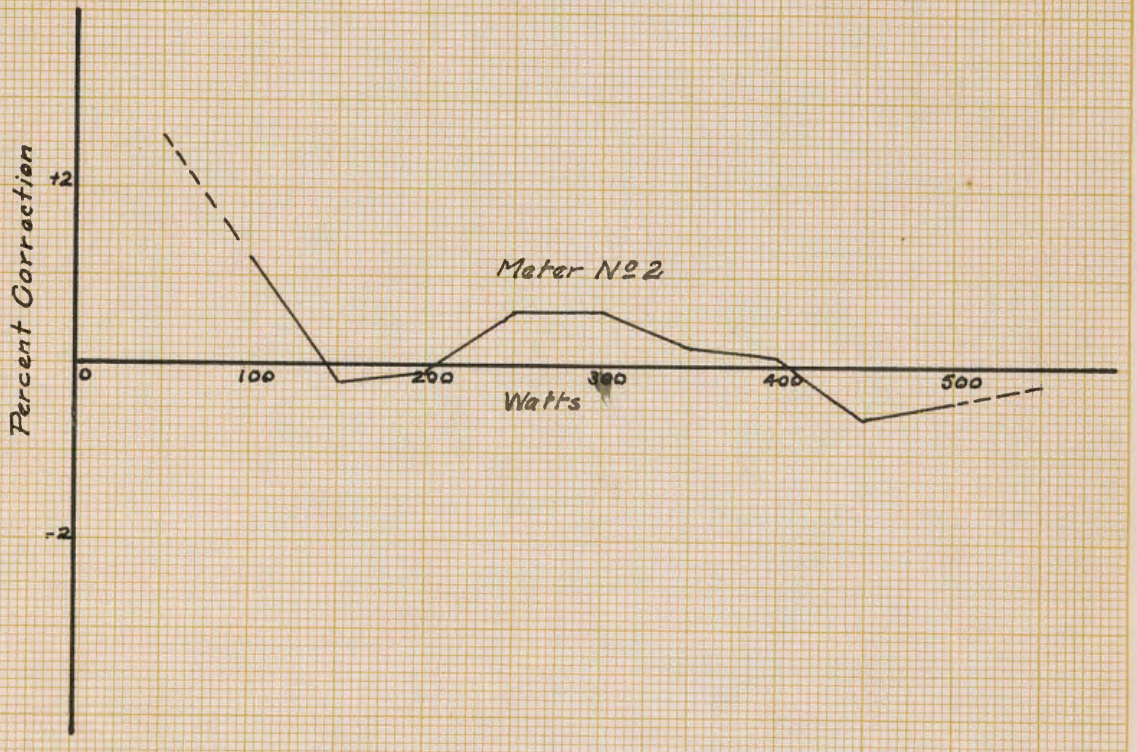


Plate VI



Average Correction for Meters № 1 & № 2
60 Cycles



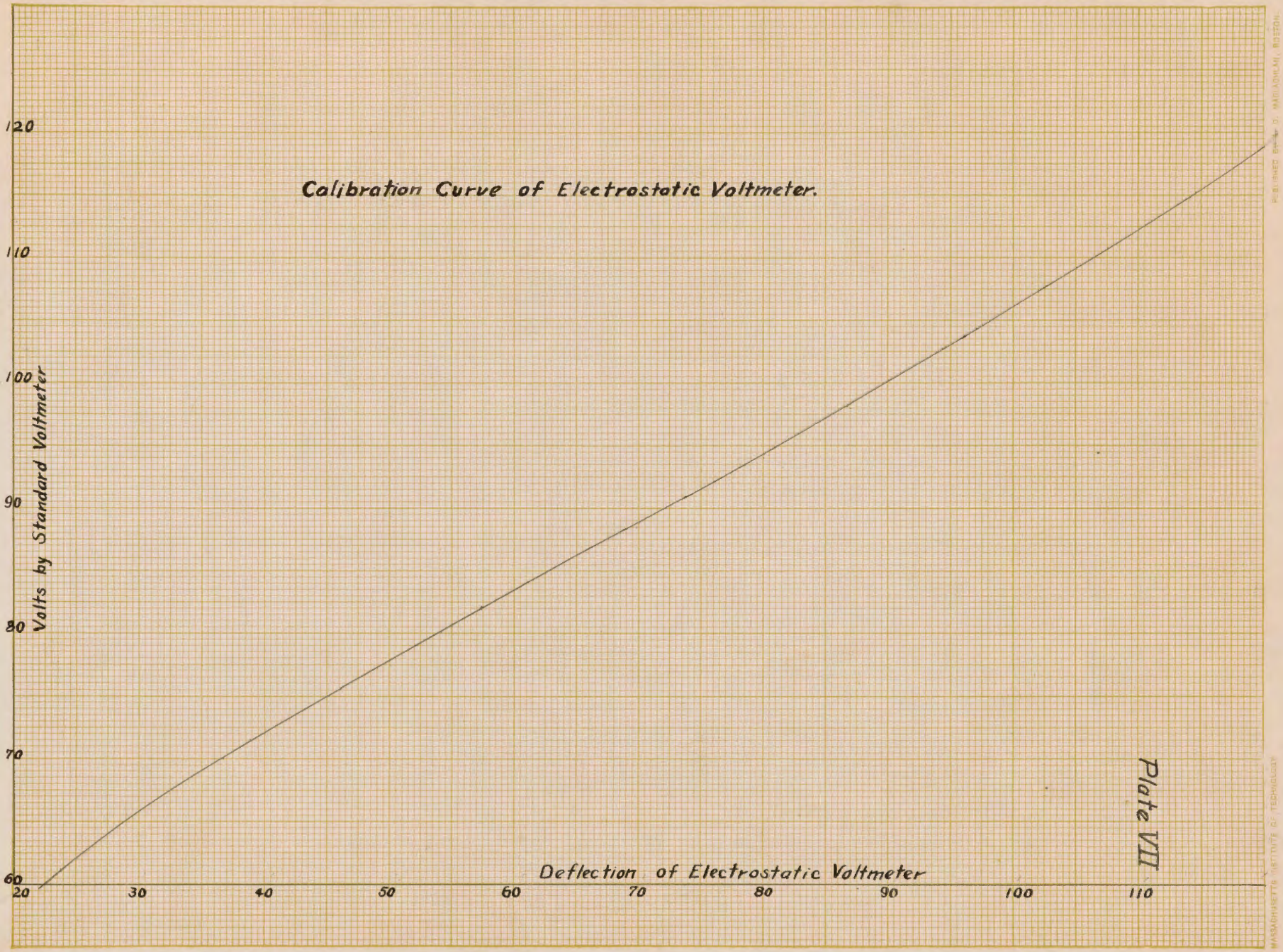
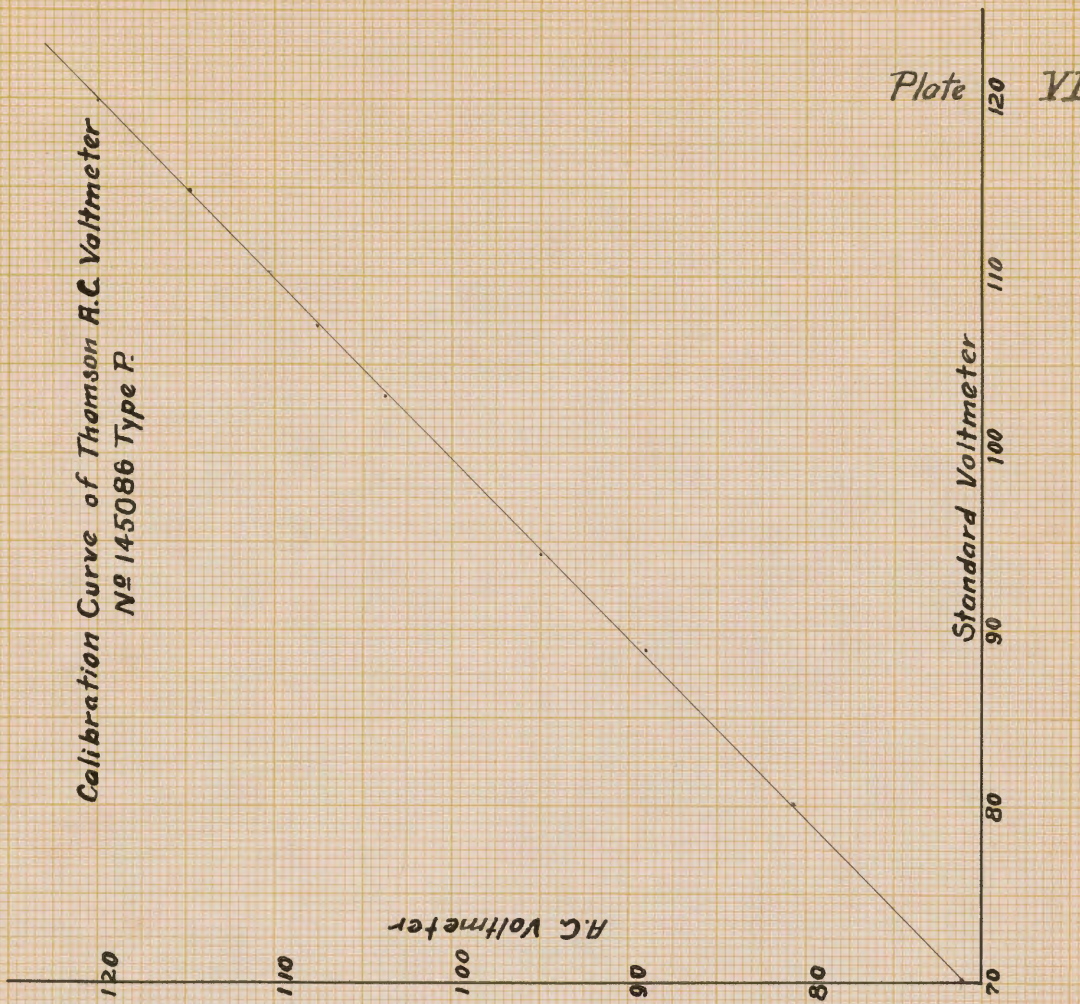
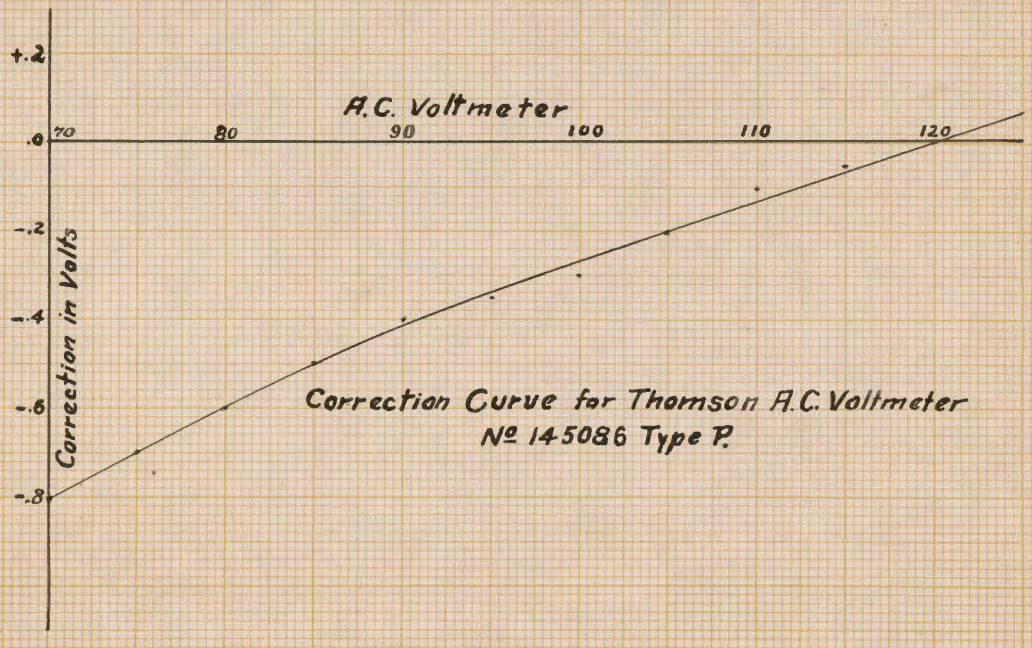

Calibration Curve of Electrostatic Voltmeter.
Volts by Standard Voltmeter
120
110
100
90
80
70
60
Deflection of Electrostatic Voltmeter
20
30
40
50
60
70
80
90
100
110

Plate VII

Plate VIII


Calibration Curve of Thomson A.C. Voltmeter
№ 145086 Type P.
Standard Voltmeter
120
110
100
90
80
70
A.C. Voltmeter
120
110
100
90
80
70


+.2
0
-.2
-.4
-.6
-.8
Correction in Volts
A.C. Voltmeter
70
80
90
100
110
120
Correction Curve for Thomson A.C. Voltmeter
№ 145086 Type P.

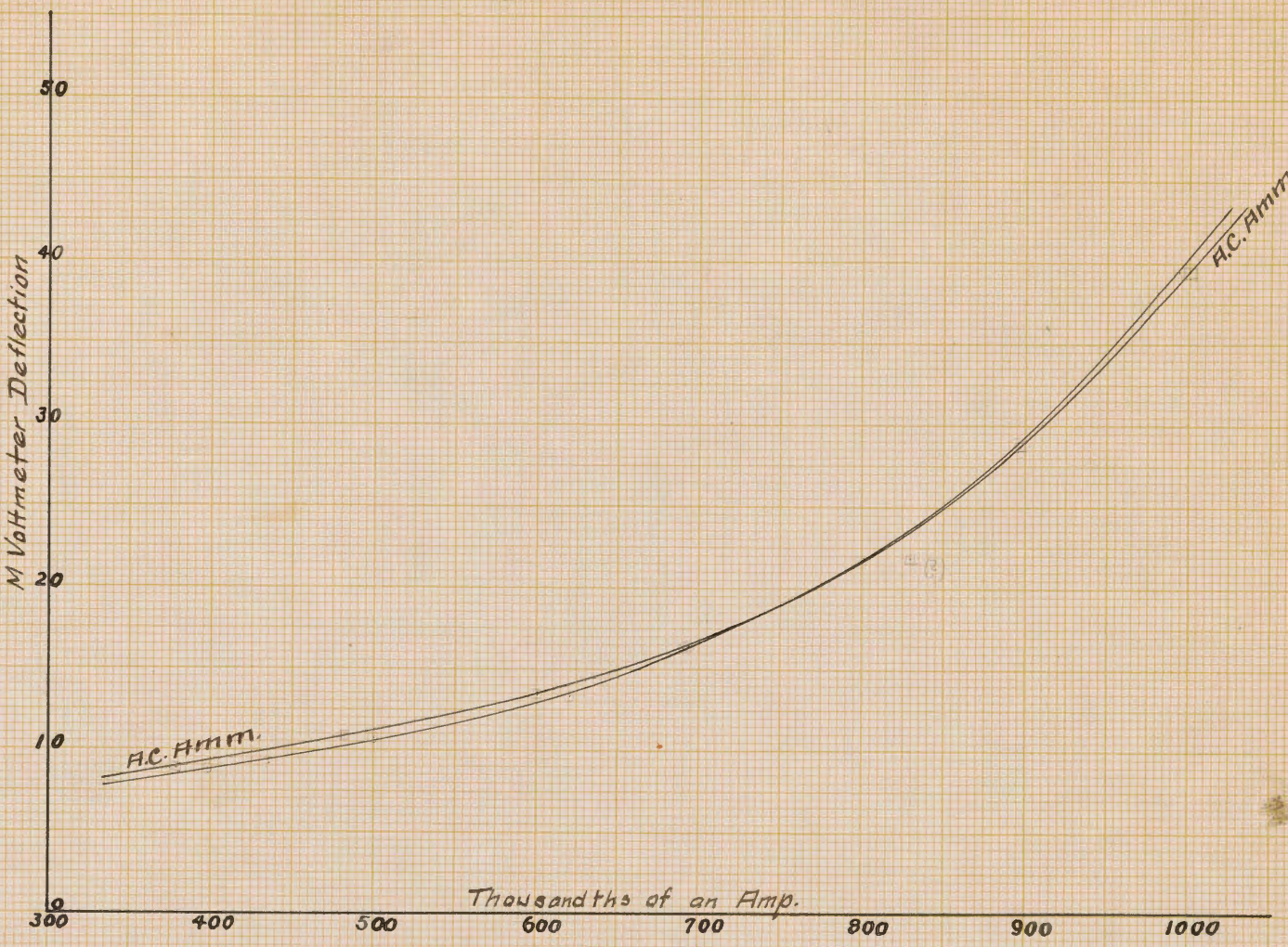
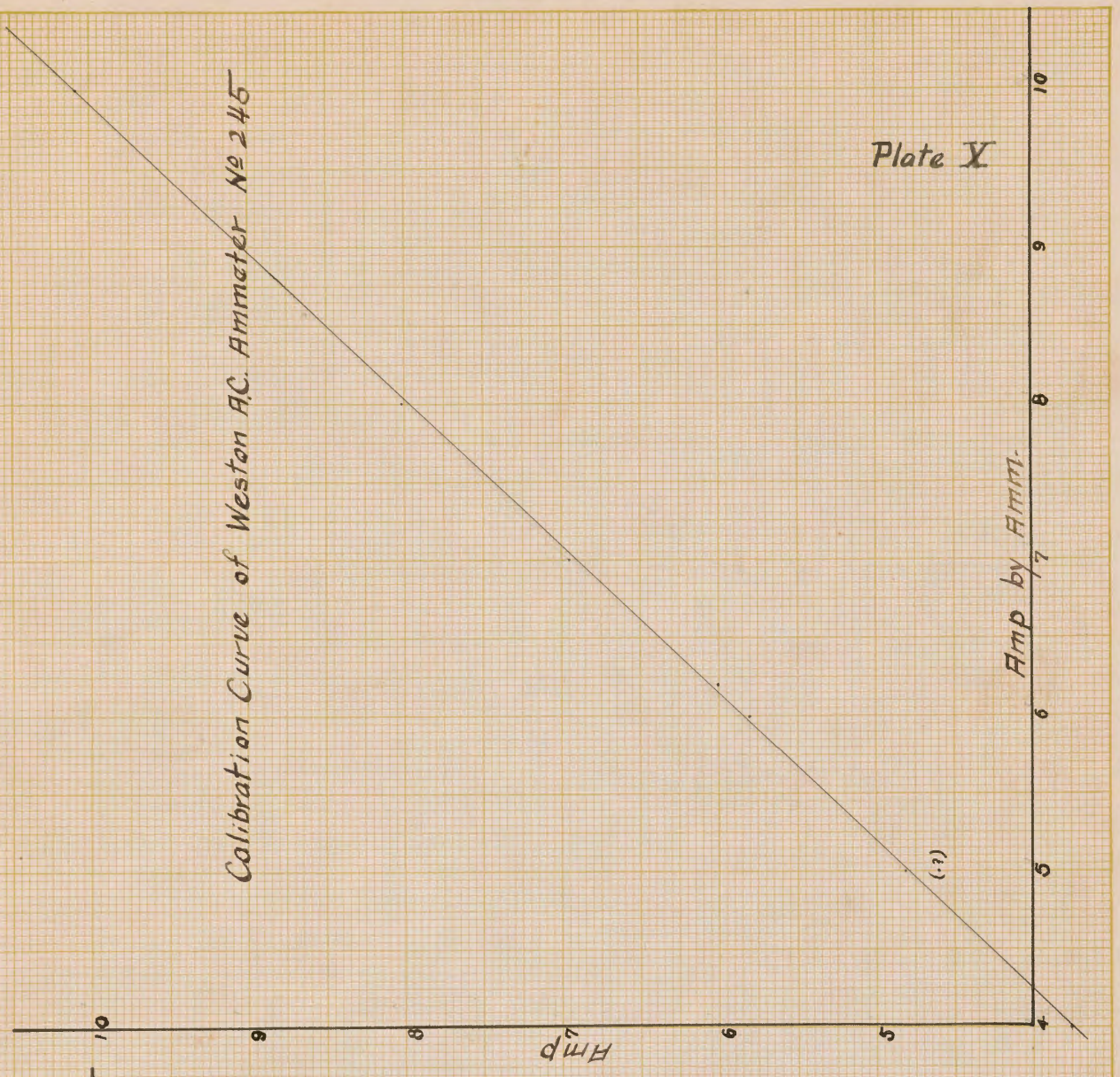
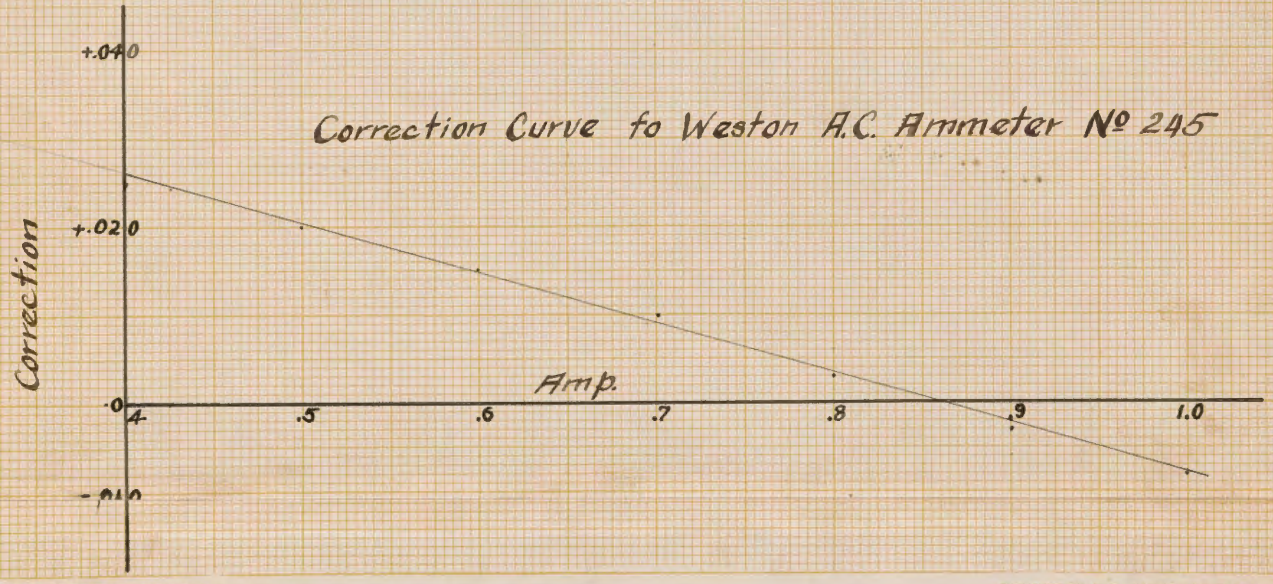

M Voltmeter Deflection
50
40
30
20
10
0
300
400
500
600
700
800
900
1000
Thousandths of an Amp.
A.C. Amm.
A.C. Amm.

Plate IX.

Plate X





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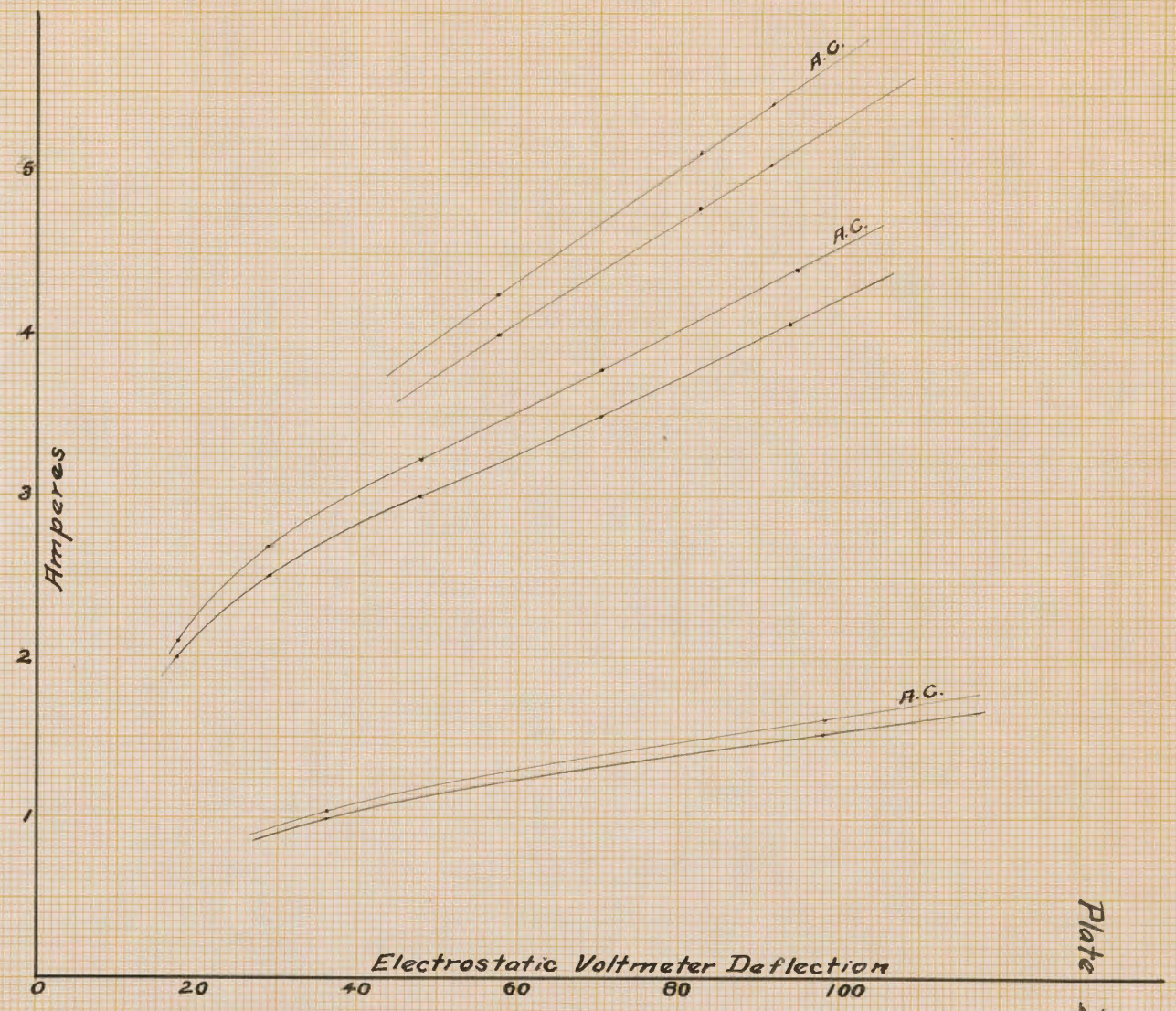

A.C.
A.C.
A.C.
5
4
3
2
1
Amperes
0
20
40
60
80
100
Electrostatic Voltmeter Deflection

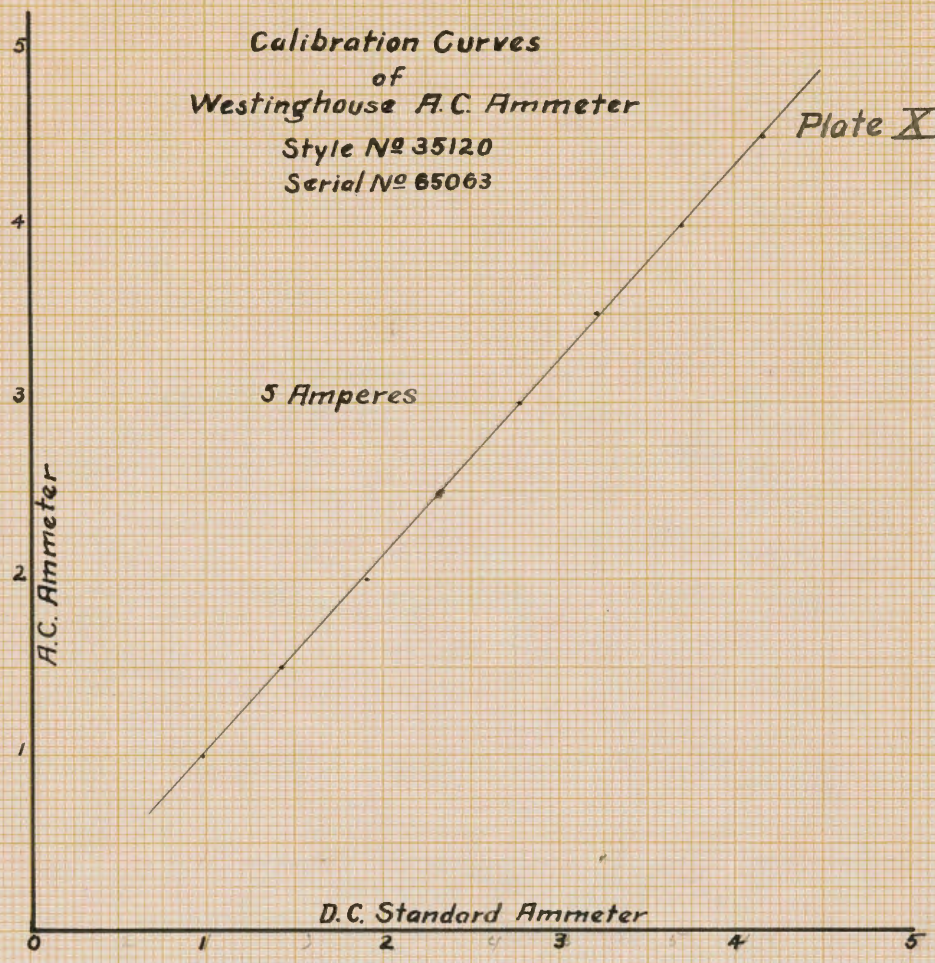
Plate XI

Calibration Curves of Westinghouse A.C. Ammeter

Style No 35120

Serial No 65063

Plate XII



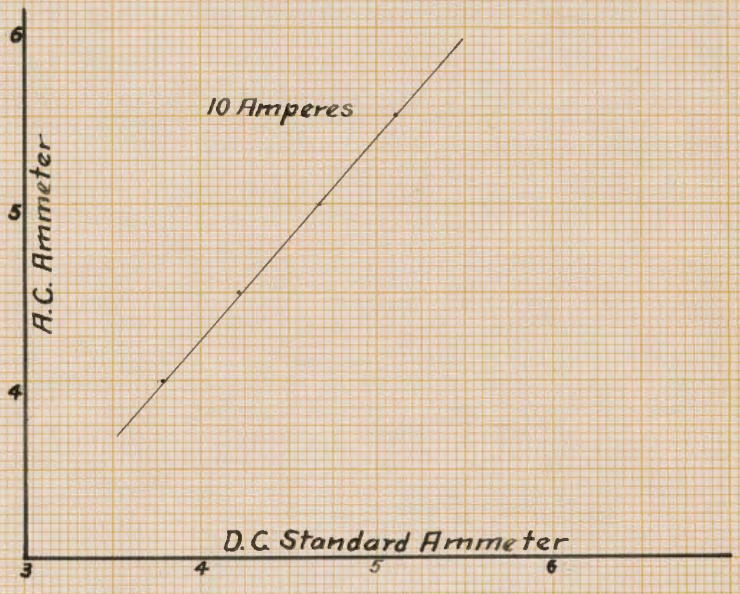
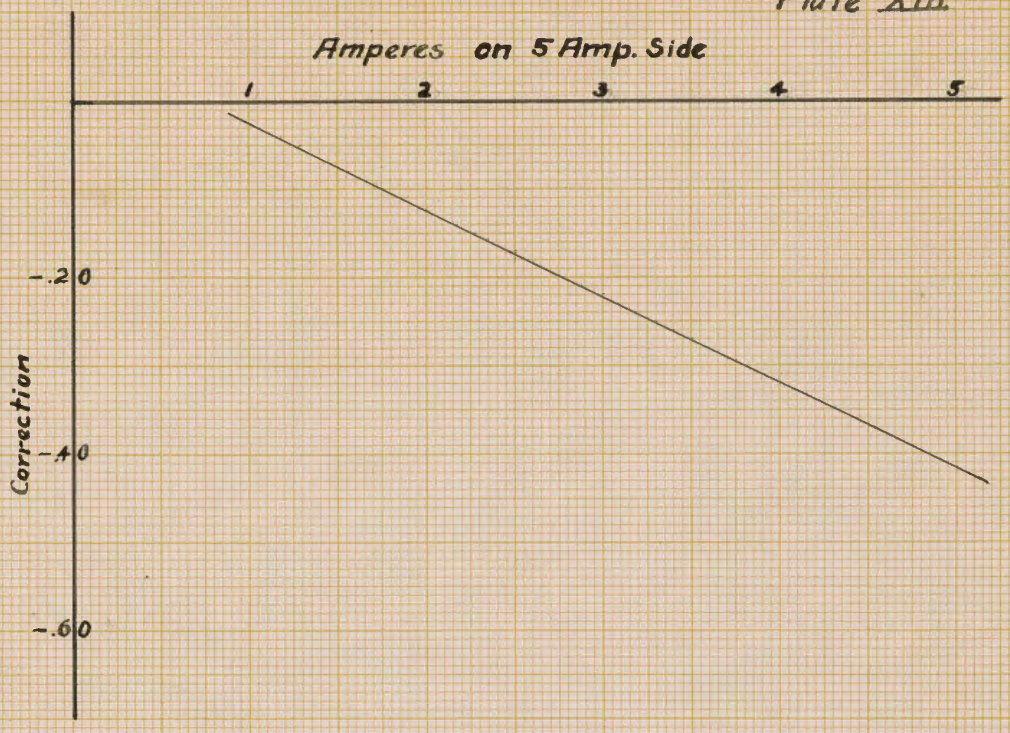
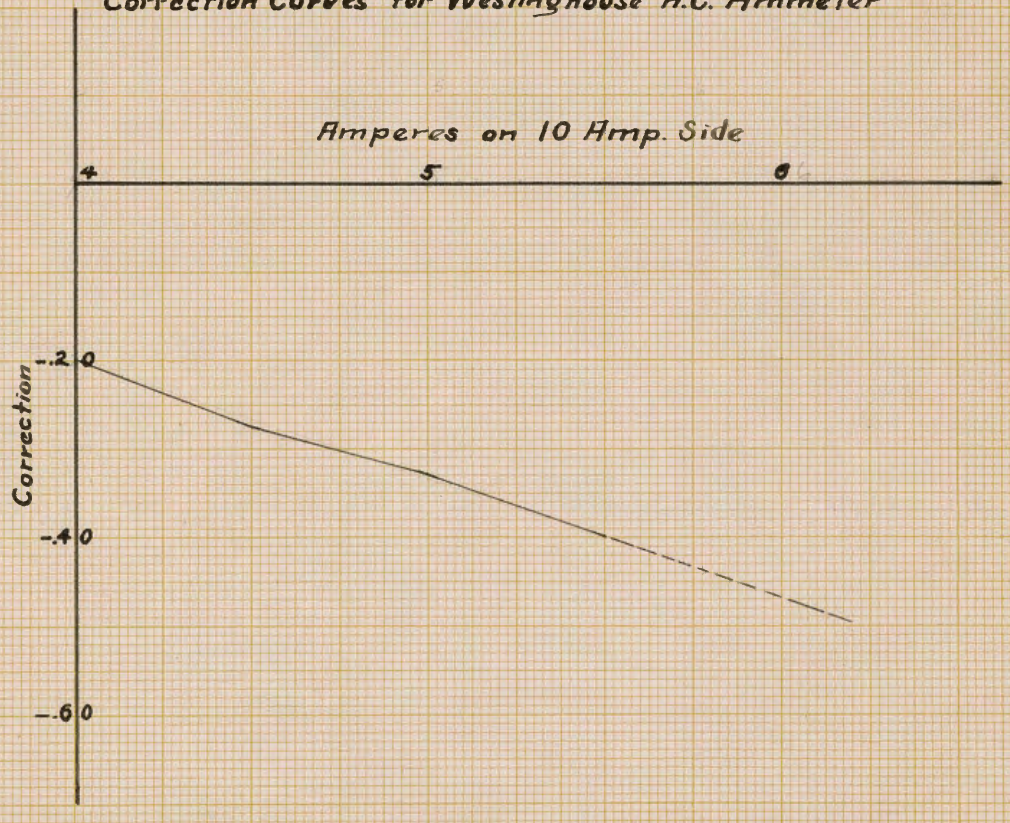


Plate XIII.



Correction Curves for Westinghouse A.C. Ammeter



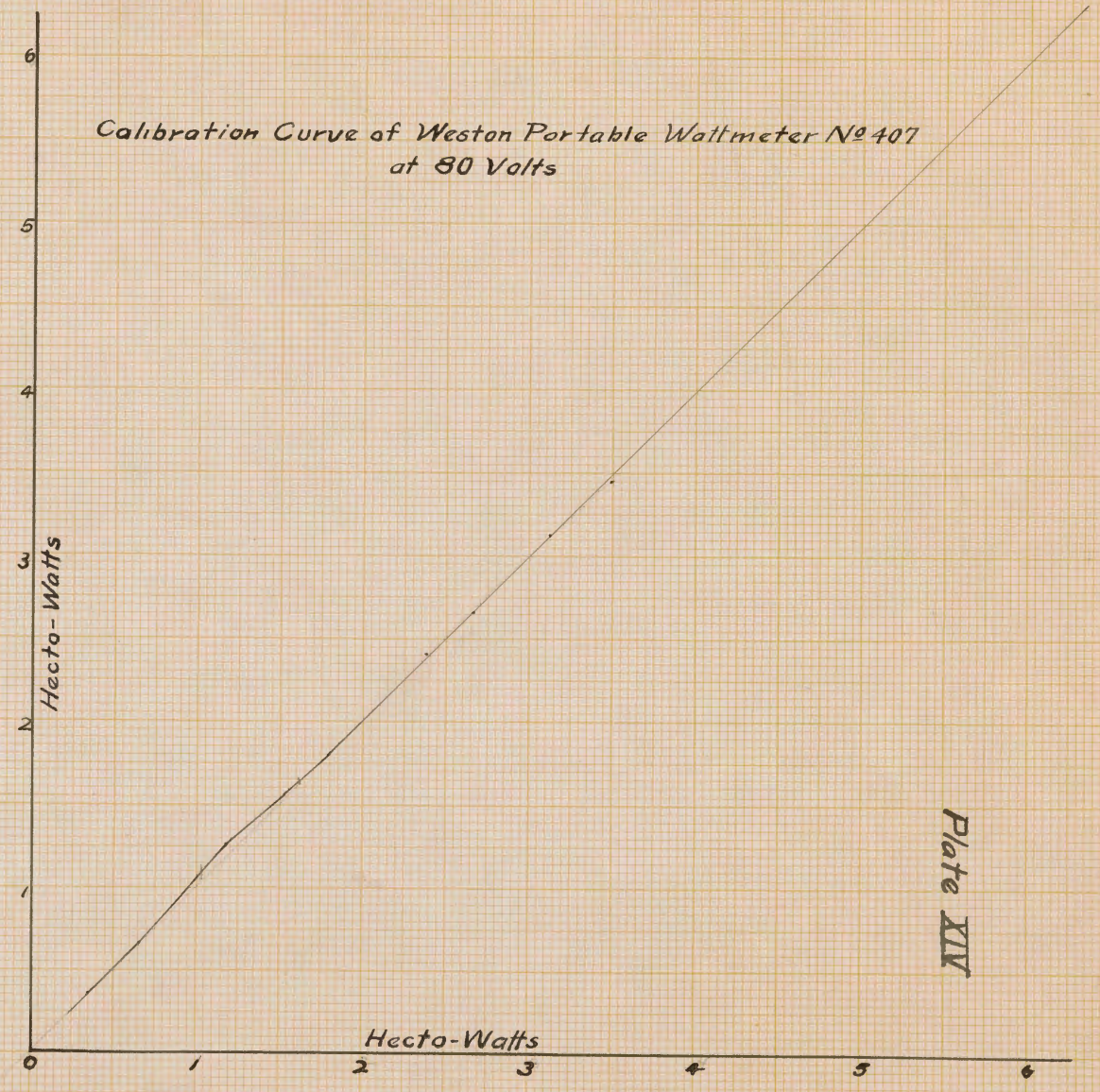

Calibration Curve of Weston Portable Wattmeter No 407
at 80 Volts
Hecto-Watts
Hecto-Watts
0
1
2
3
4
5
6

Plate XIV

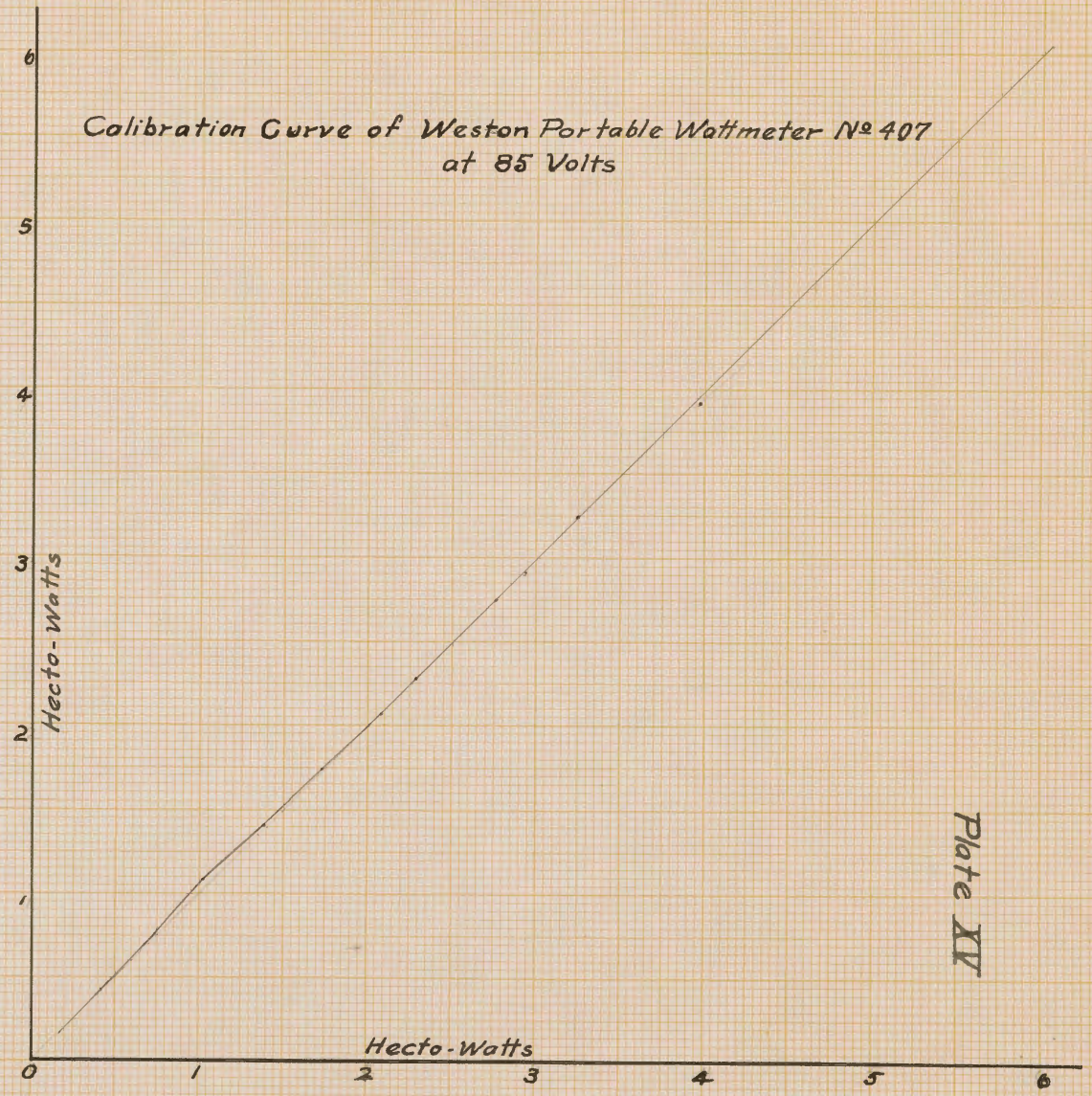

Calibration Curve of Weston Portable Wattmeter No 407
at 85 Volts
Hecto-Watts
Hecto-Watts
0
1
2
3
4
5
6

Plate XV

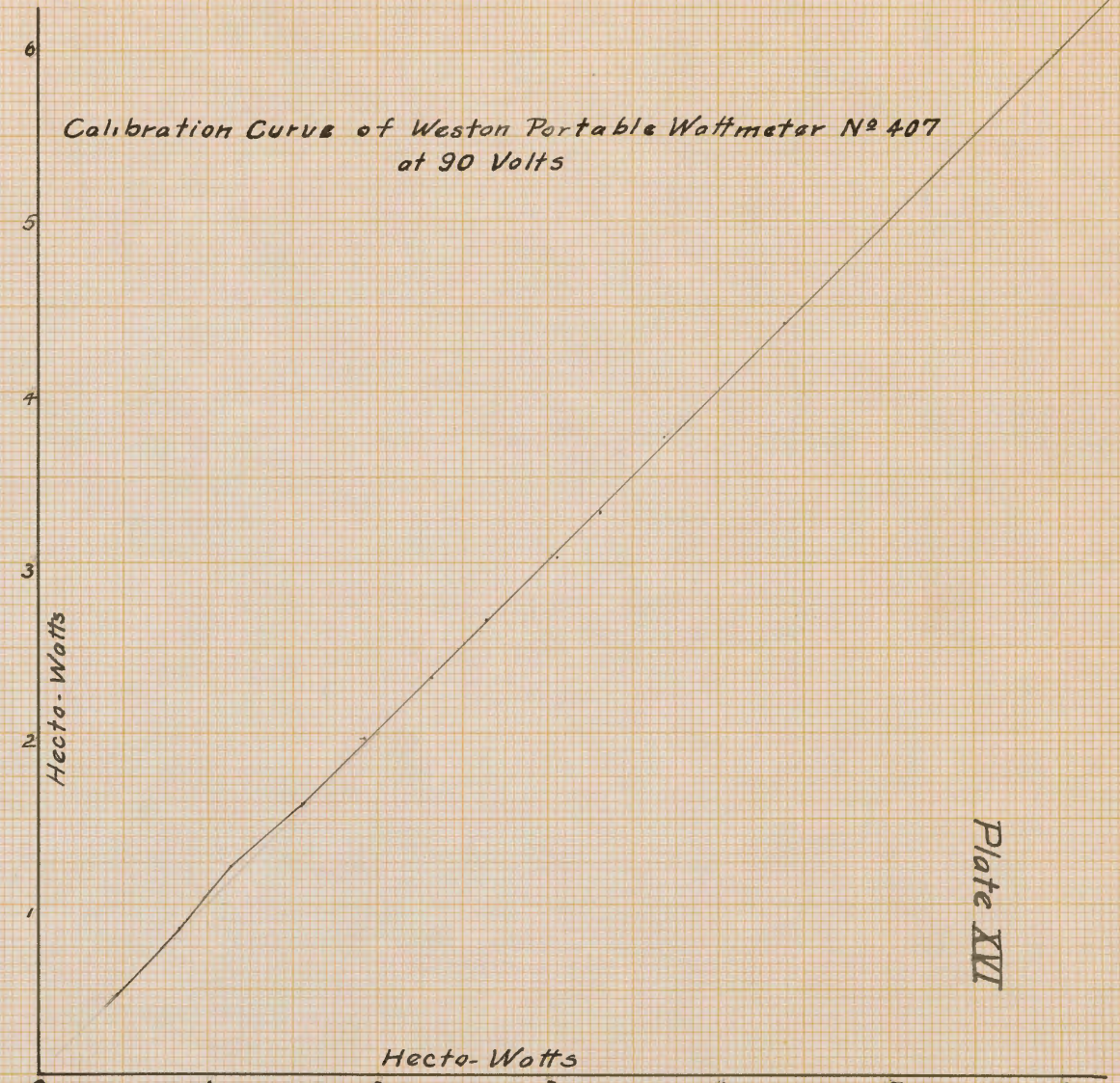


Plate XVI

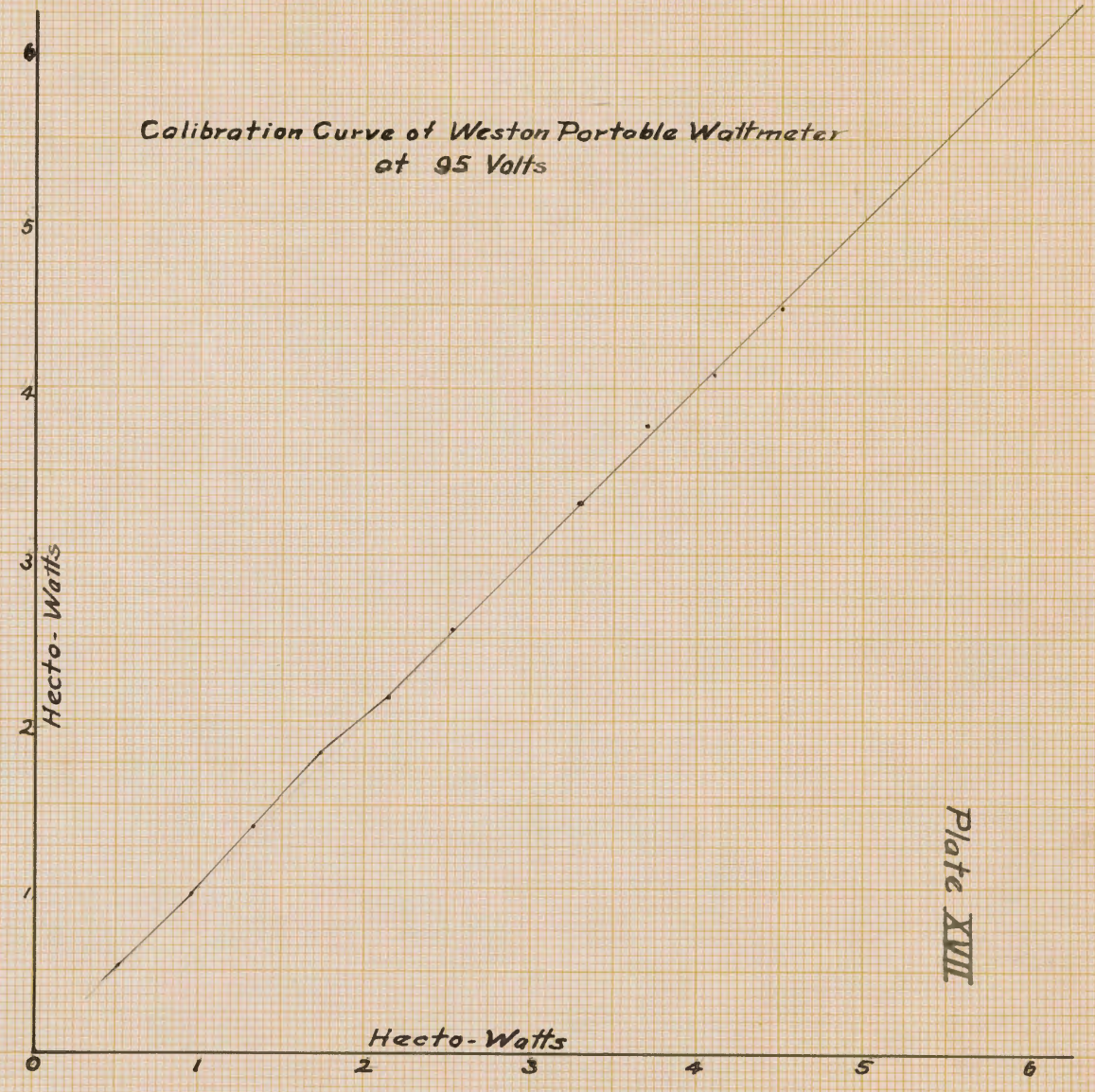

Calibration Curve of Weston Portable Wattmeter
at 95 Volts
Hecto-Watts
Hecto-Watts
0
1
2
3
4
5
6

Plate XVIII

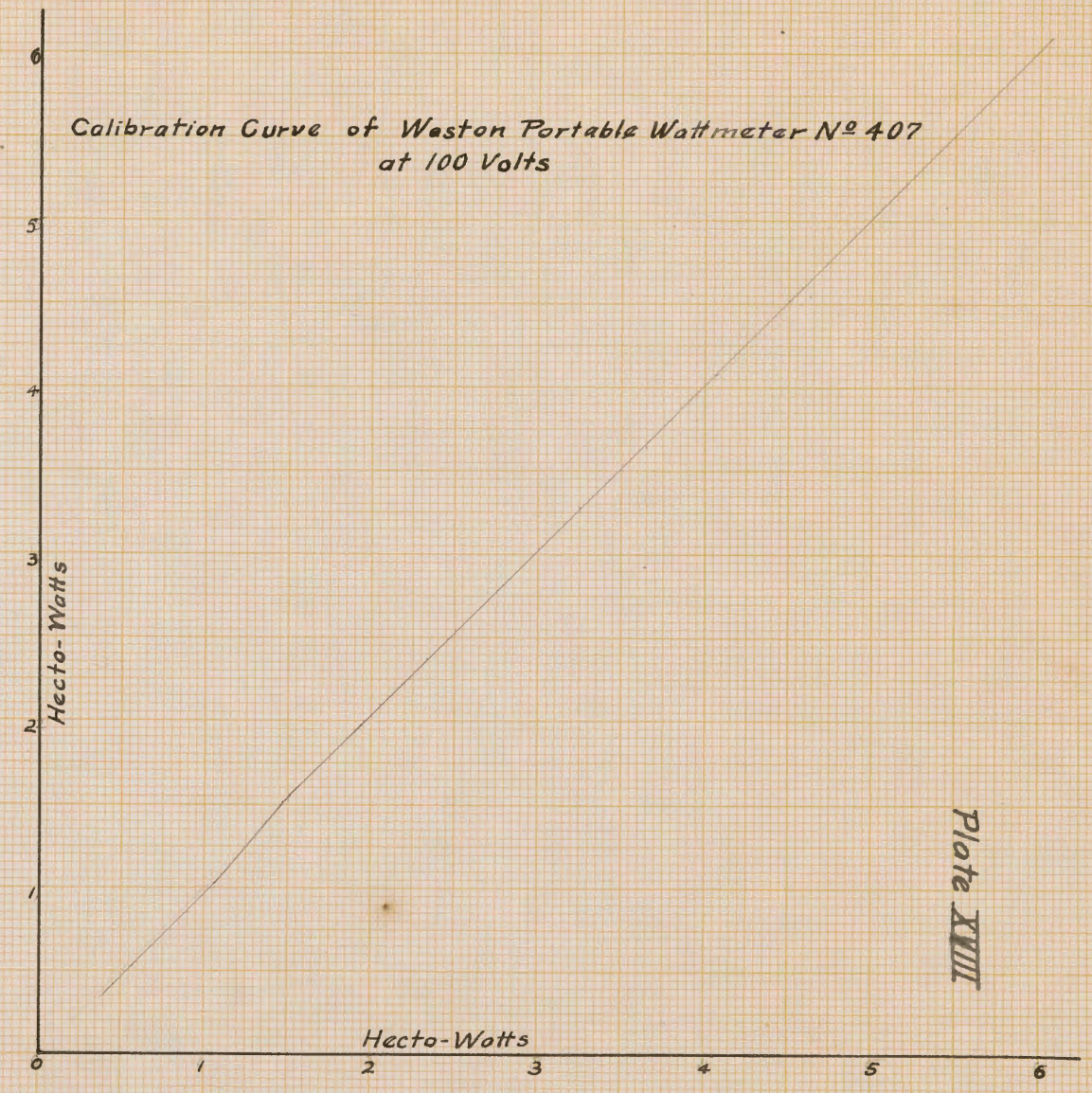

Calibration Curve of Weston Portable Wattmeter No 407
at 100 Volts
Hecto-Watts
0
1
2
3
4
5
6
Hecto-Watts
0
1
2
3
4
5
6

Plate XIIII

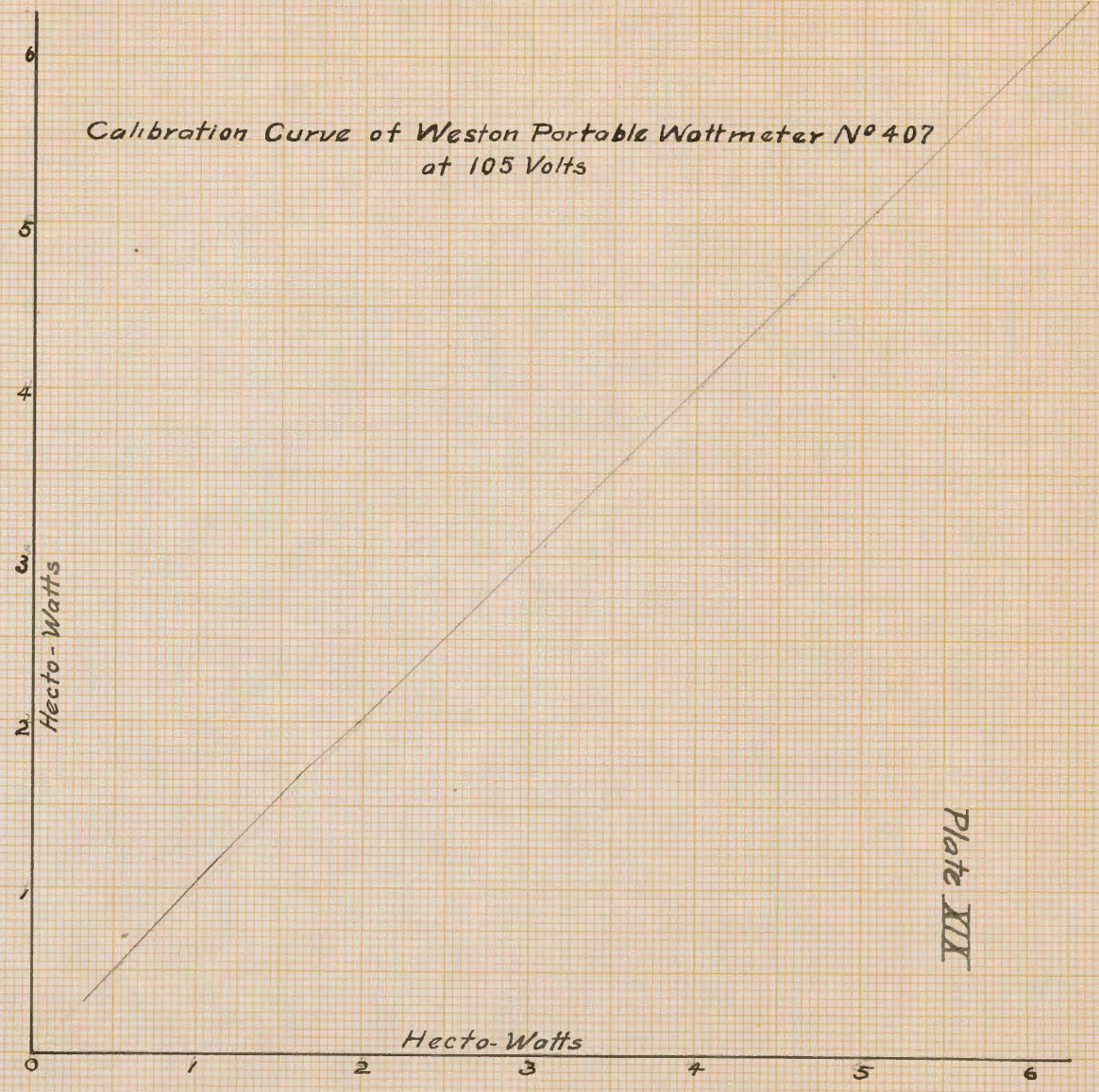

Calibration Curve of Weston Portable Wattmeter No 407
at 105 Volts
Hecto-Watts
Hecto-Watts
0
1
2
3
4
5
6

Plate XIX

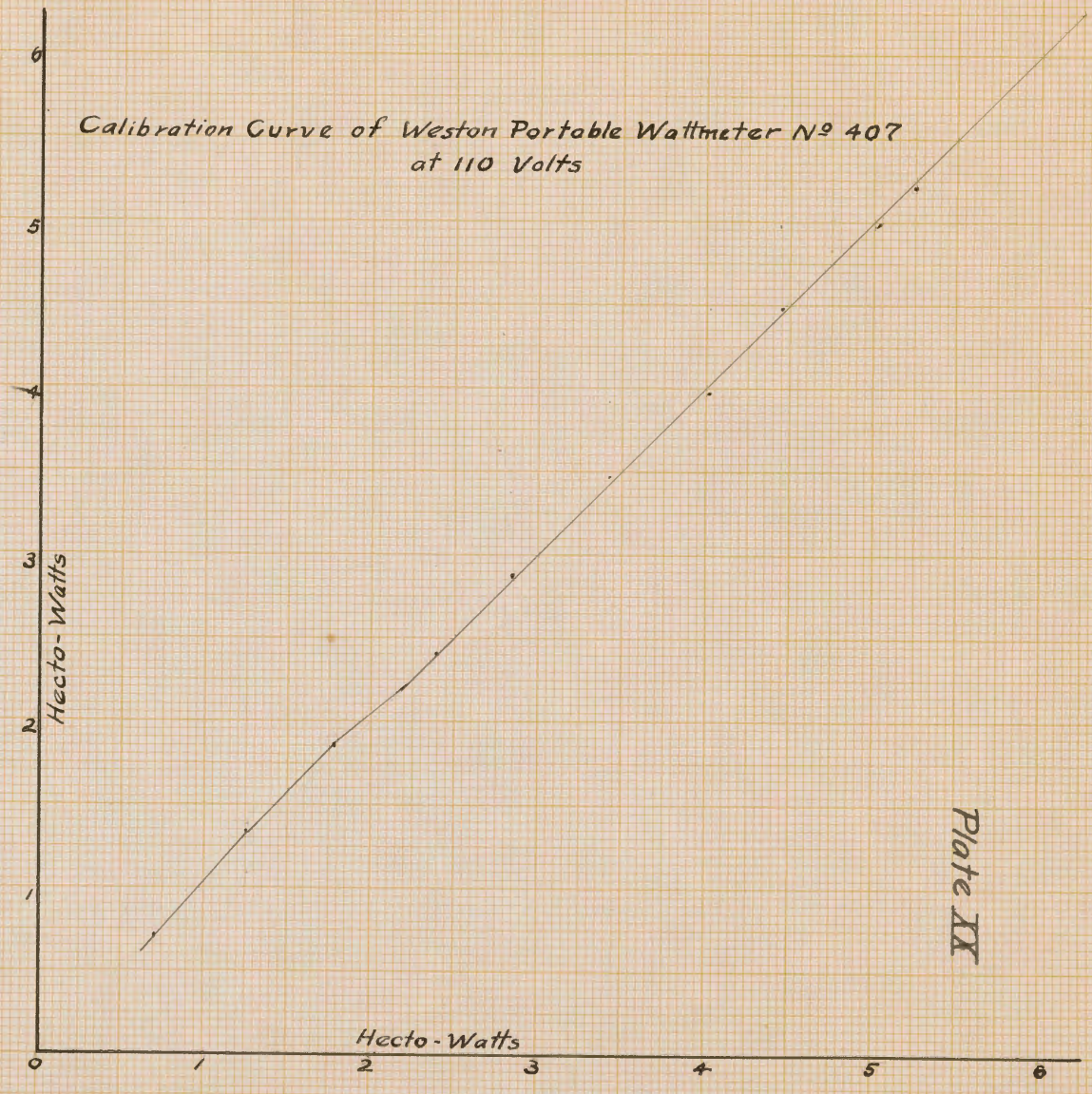

Calibration Curve of Weston Portable Wattmeter No 407
at 110 Volts
Hecto-Watts
Hecto-Watts
0
1
2
3
4
5
6

Plate XX

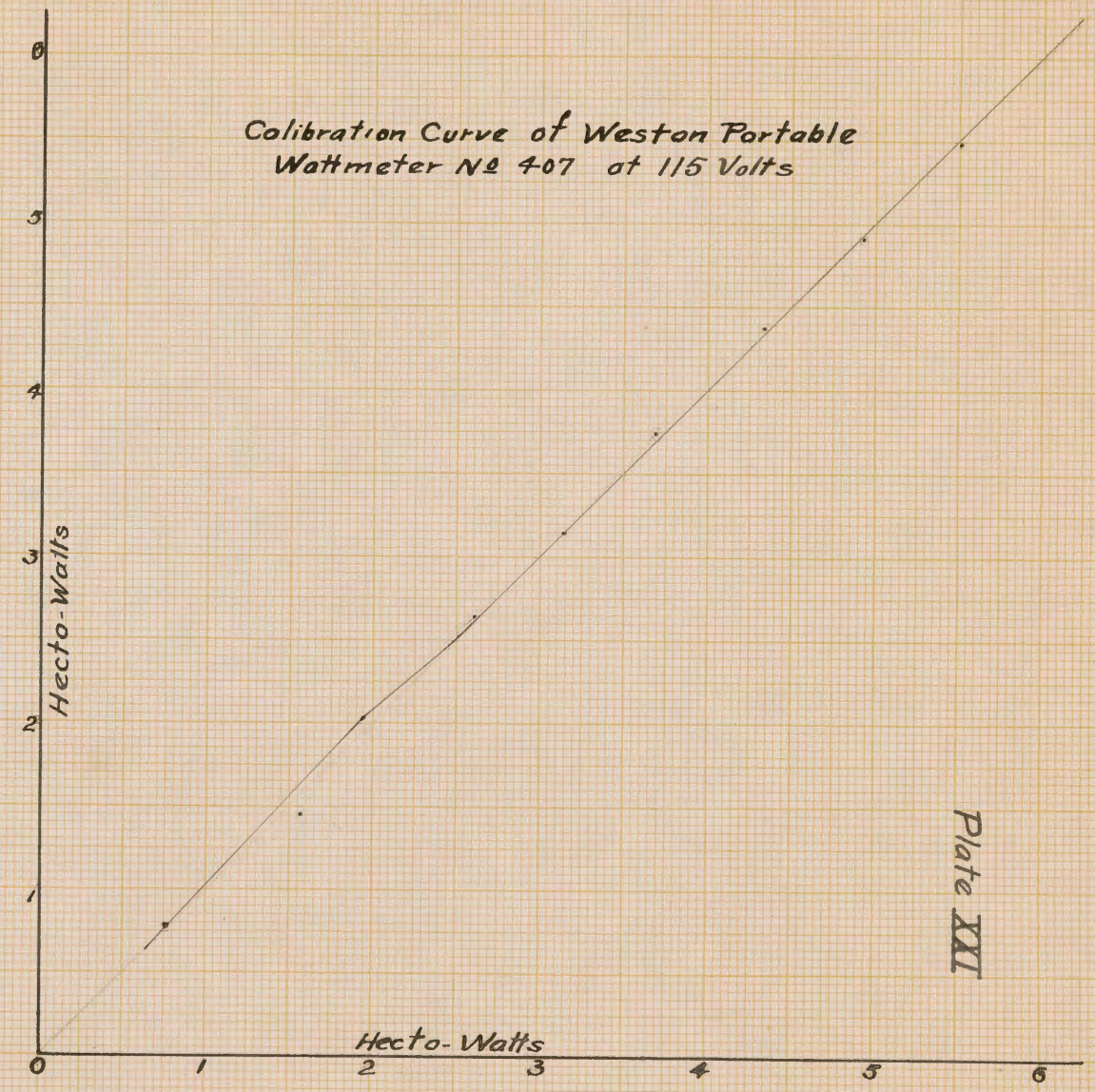

Calibration Curve of Weston Portable
Wattmeter No 407 at 115 Volts
Hecto-Watts
Hecto-Watts
0
1
2
3
4
5
6

Plate XXI

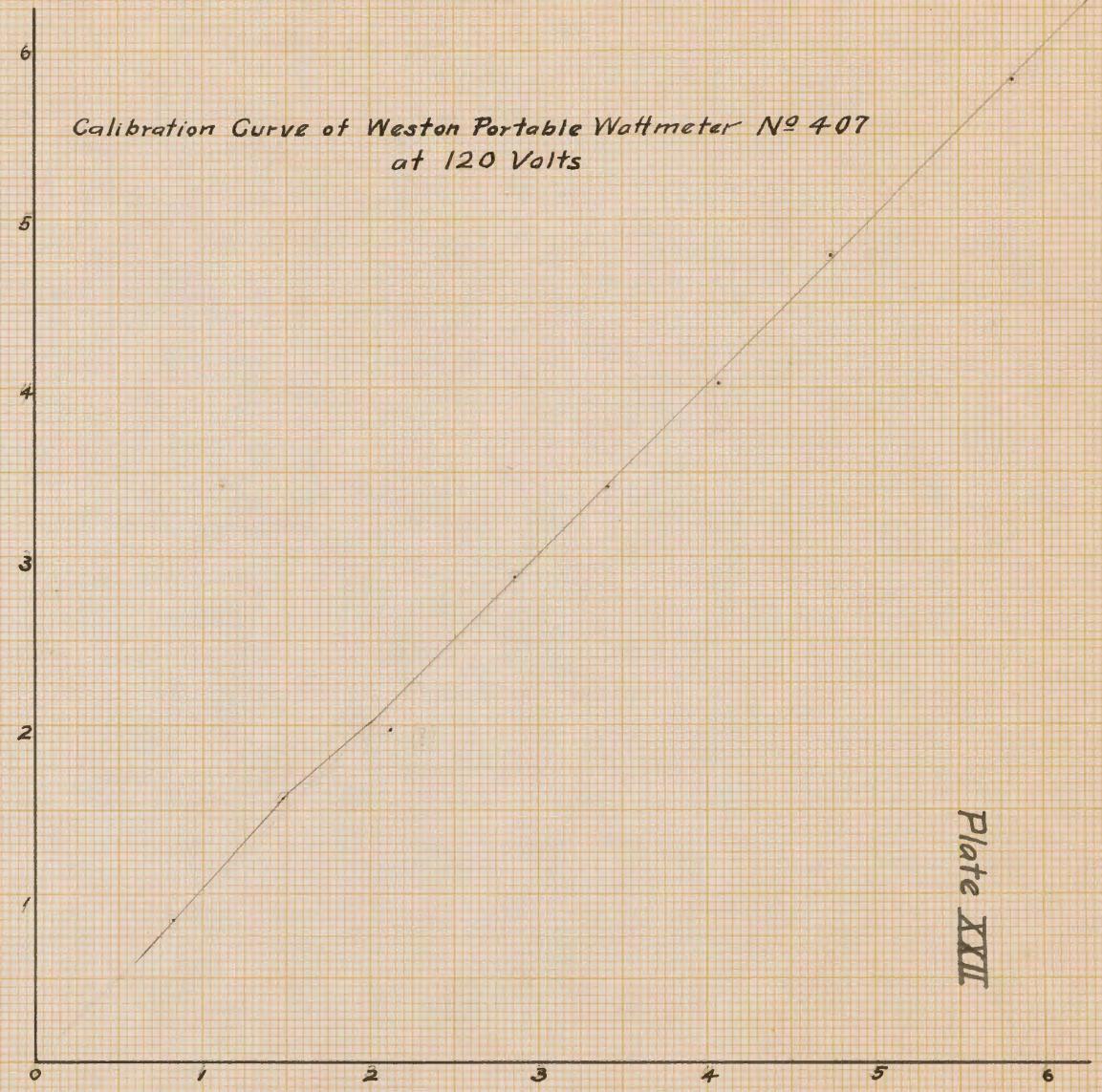


Plate XXII

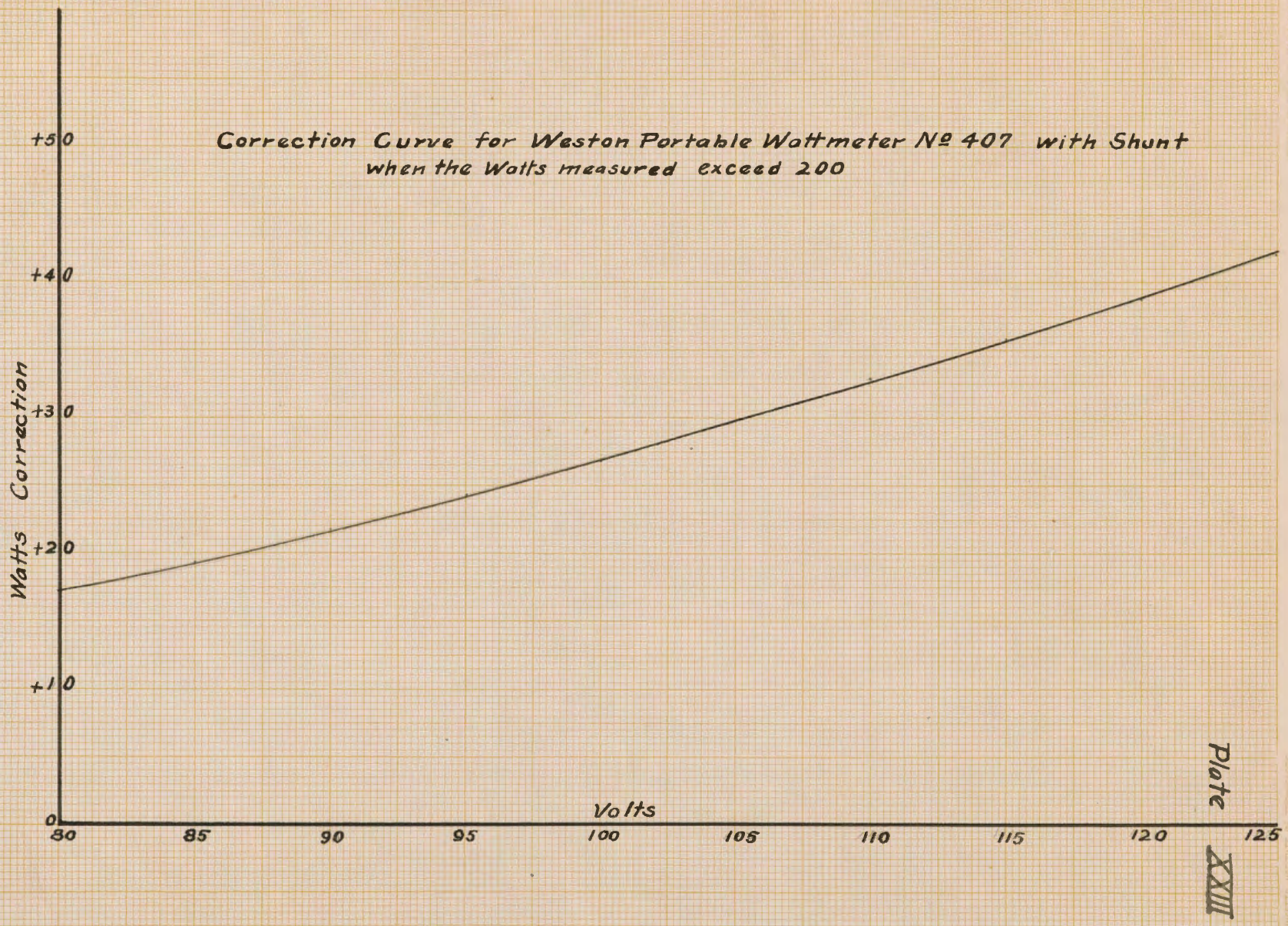

Correction Curve for Weston Portable Wattmeter No 407 with Shunt
when the Watts measured exceed 200
+50
+40
+30
+20
+10
0
Watts Correction
80
85
90
95
100
105
110
115
120
125
Volts

Plate XXIII

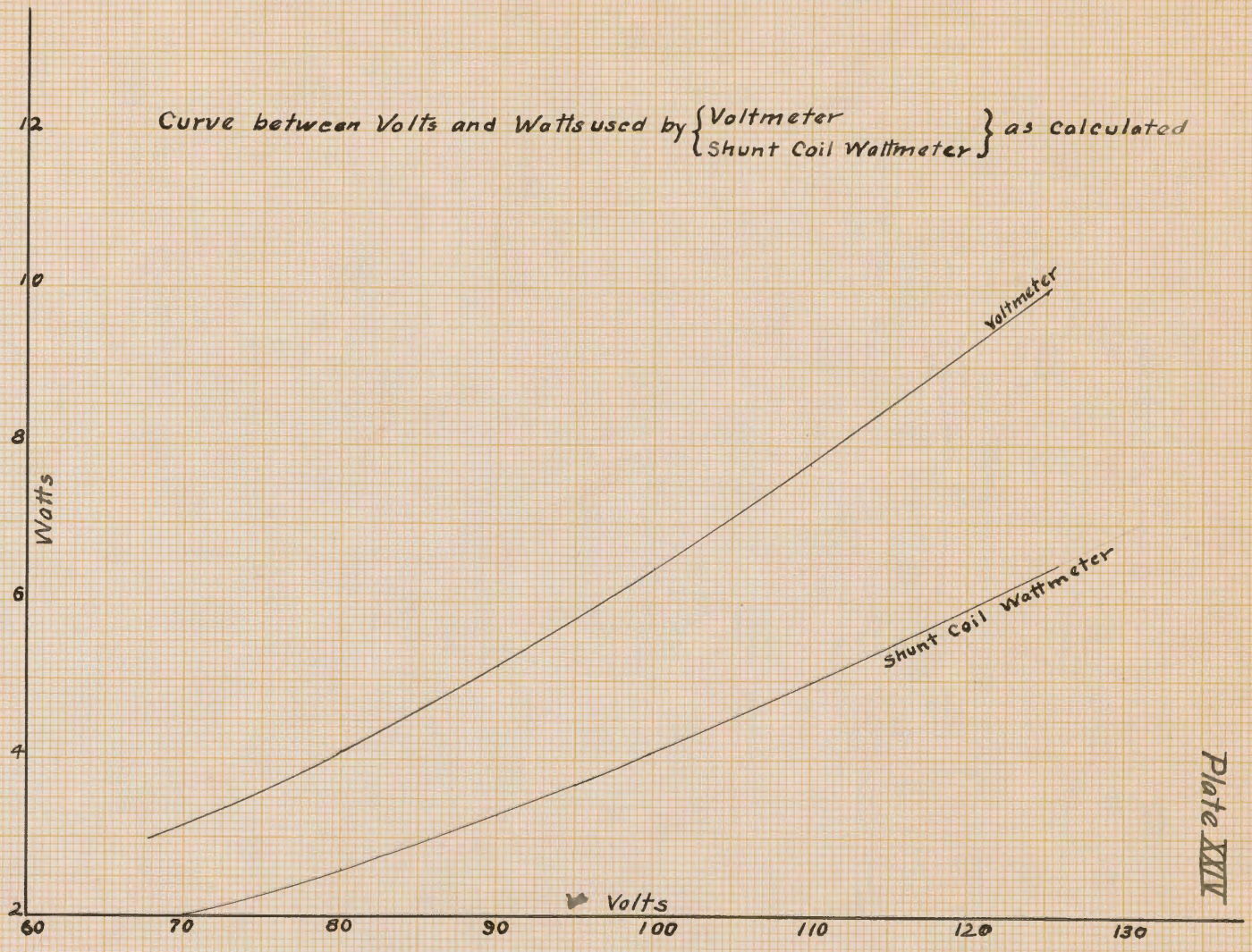

Curve between Volts and Watts used by {Voltmeter / Shunt Coil Wattmeter} as calculated
12
10
8
6
4
2
Watts
Voltmeter
Shunt Coil Wattmeter
Volts
60
70
80
90
100
110
120
130

Plate XXIV

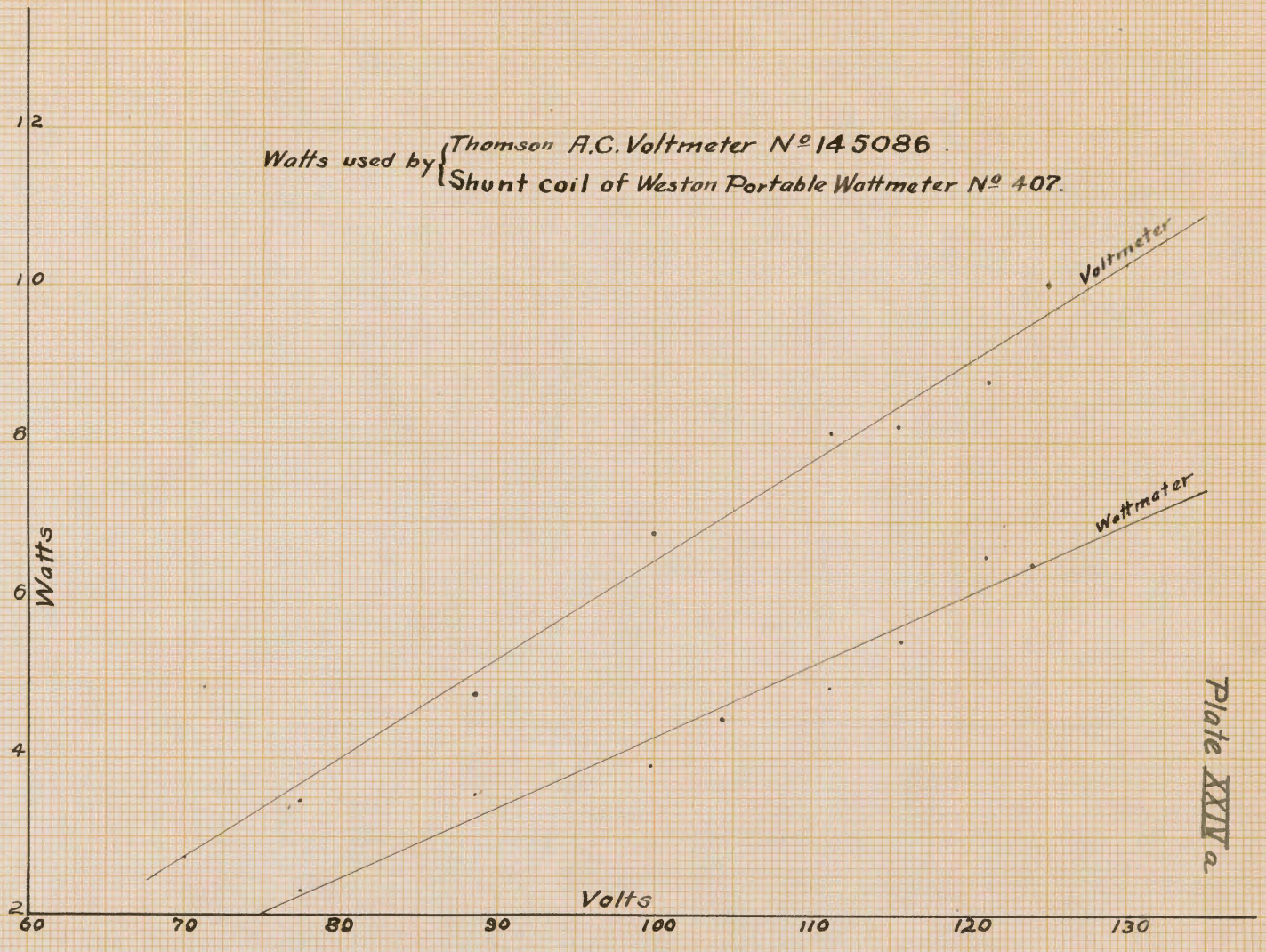
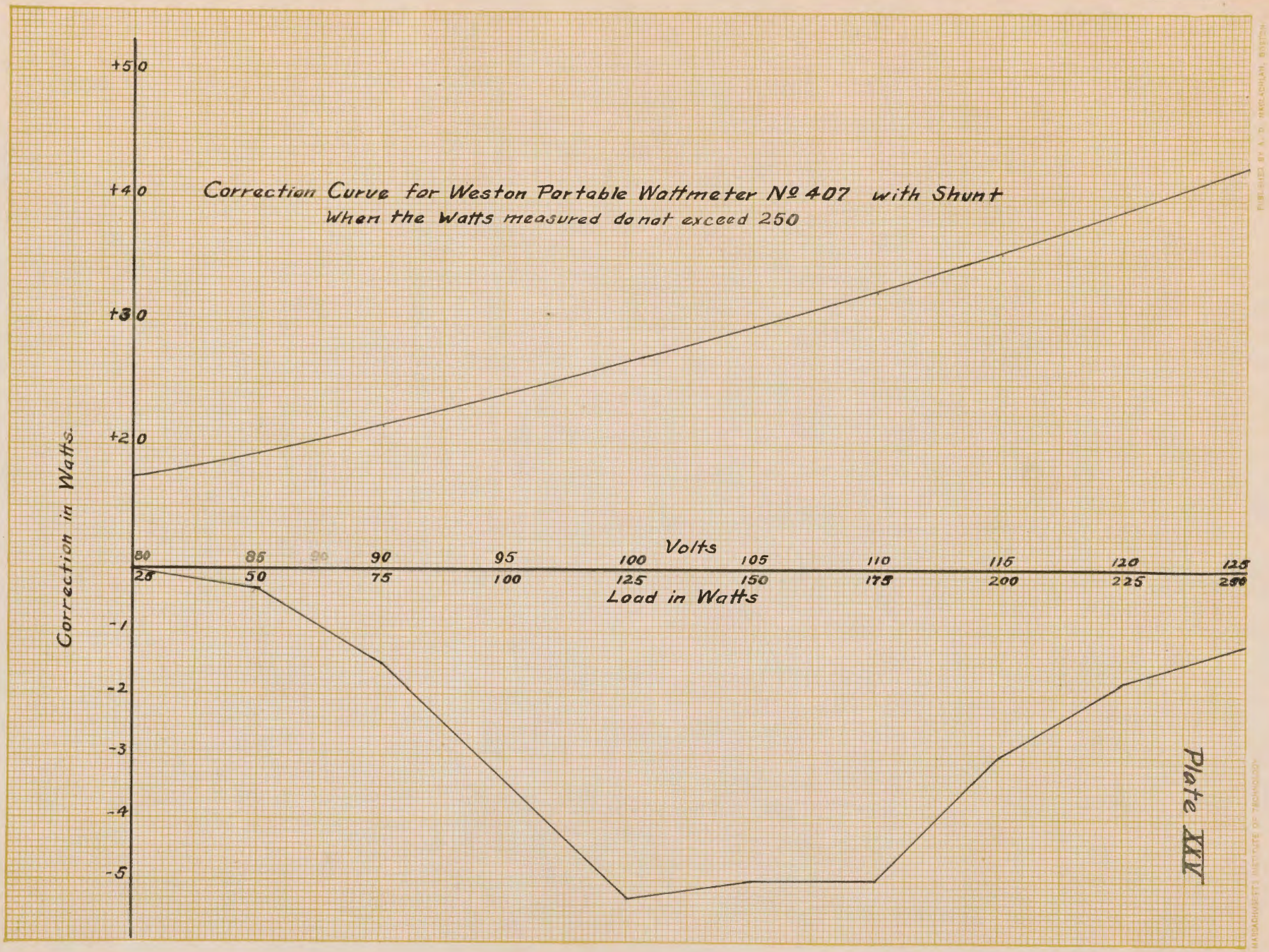

Watts used by {Thomson A.C. Voltmeter No 145086.
Shunt coil of Weston Portable Wattmeter No 407.
Voltmeter
Wattmeter
Watts
Volts
2
4
6
8
10
12
60
70
80
90
100
110
120
130

Plate XXIV a.


Correction Curve for Weston Portable Wattmeter No 407 with Shunt
When the Watts measured do not exceed 250
Correction in Watts.
+5 0
+4 0
+3 0
+2 0
-1
-2
-3
-4
-5
Volts
80 85 90 95 100 105 110 115 120 125
25 50 75 100 125 150 175 200 225 250
Load in Watts
Plate XXV

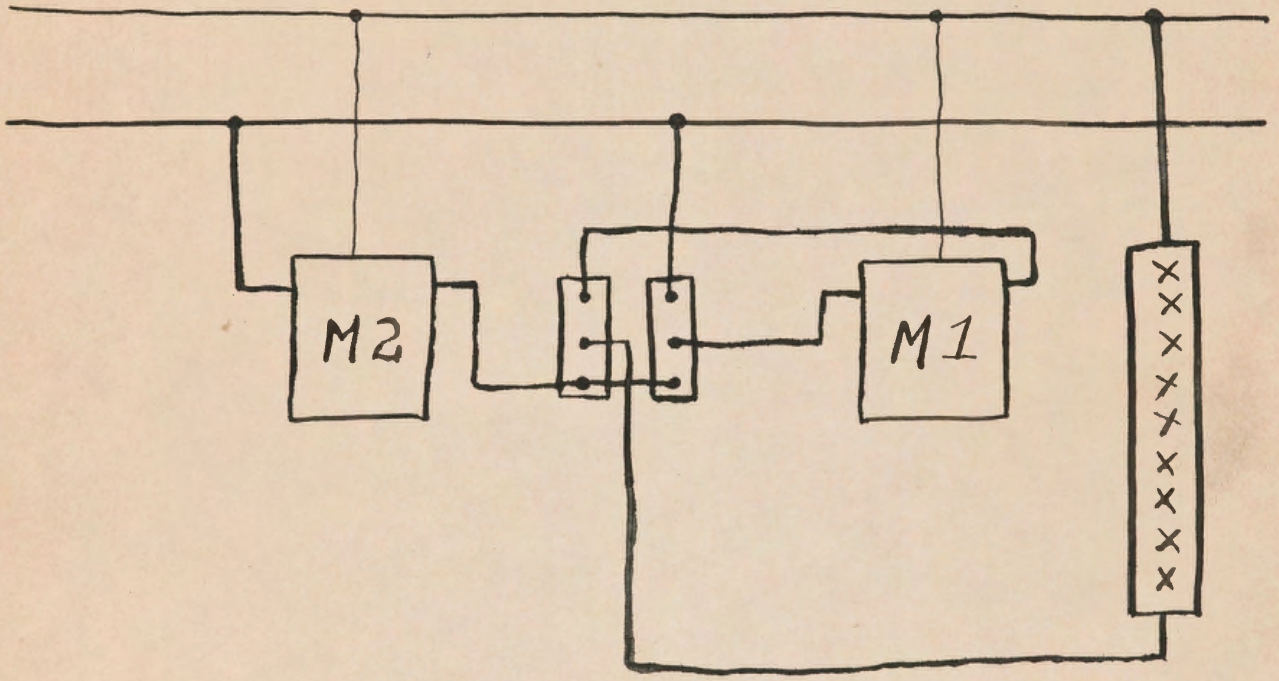

M2
M1

Plate XXVII

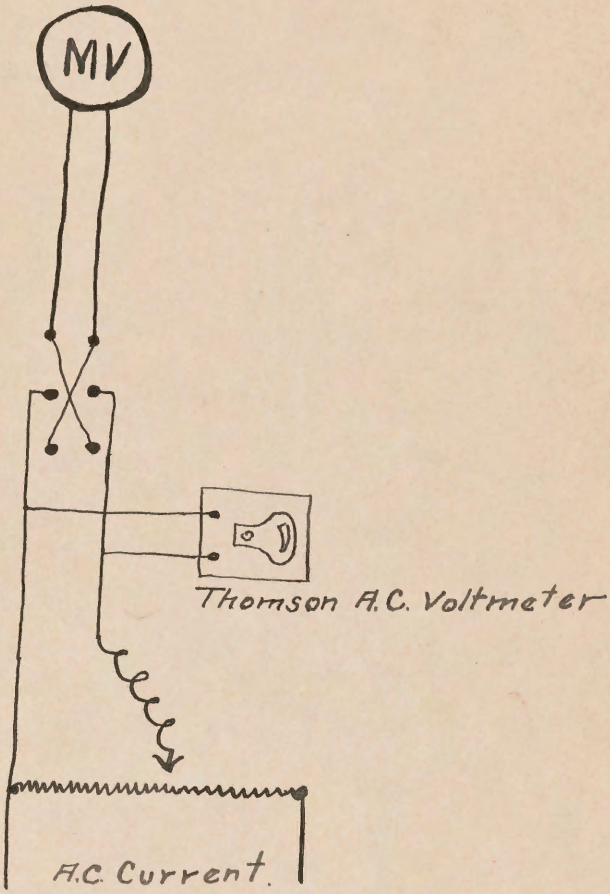


Plate XXVIII

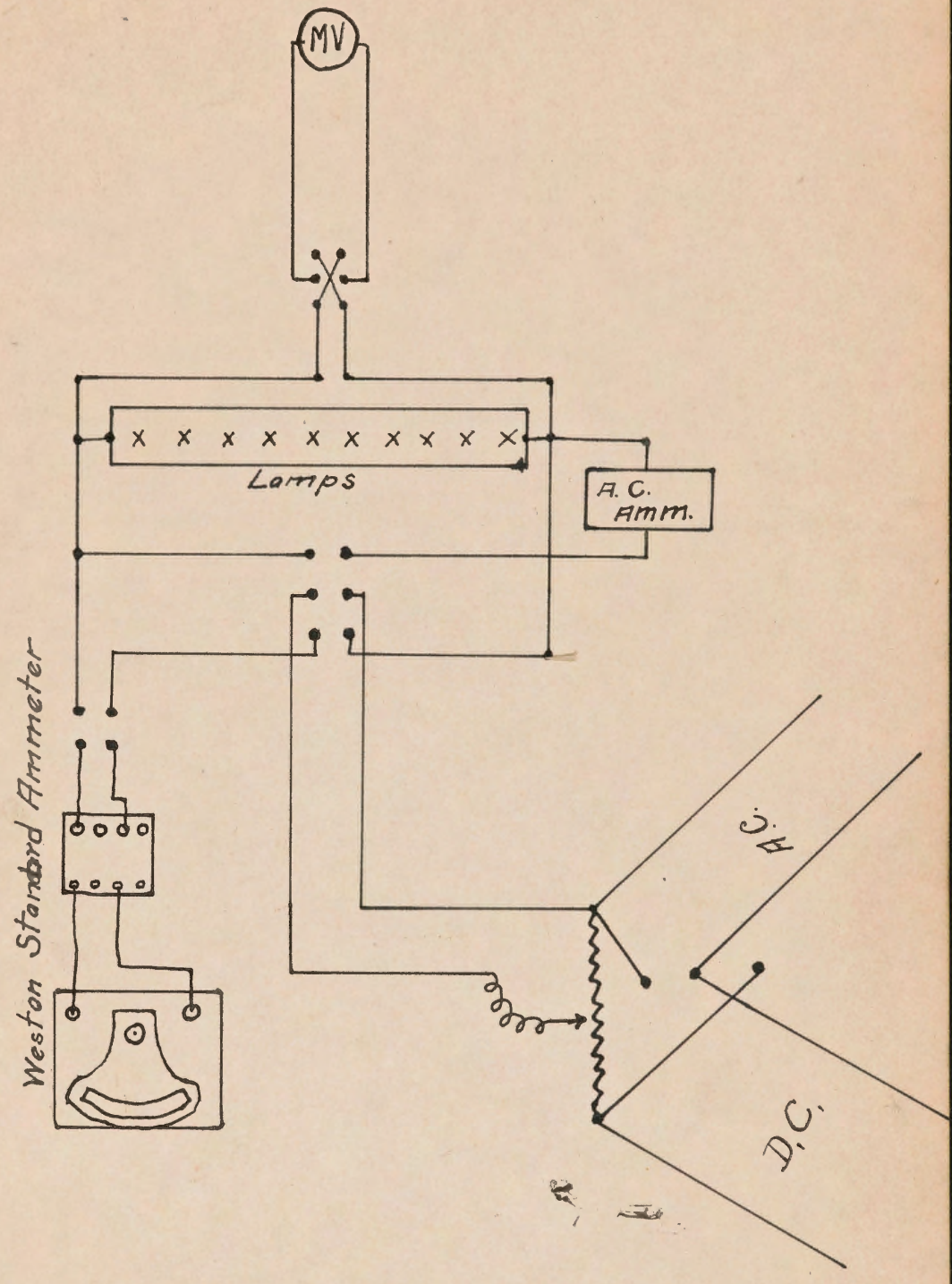
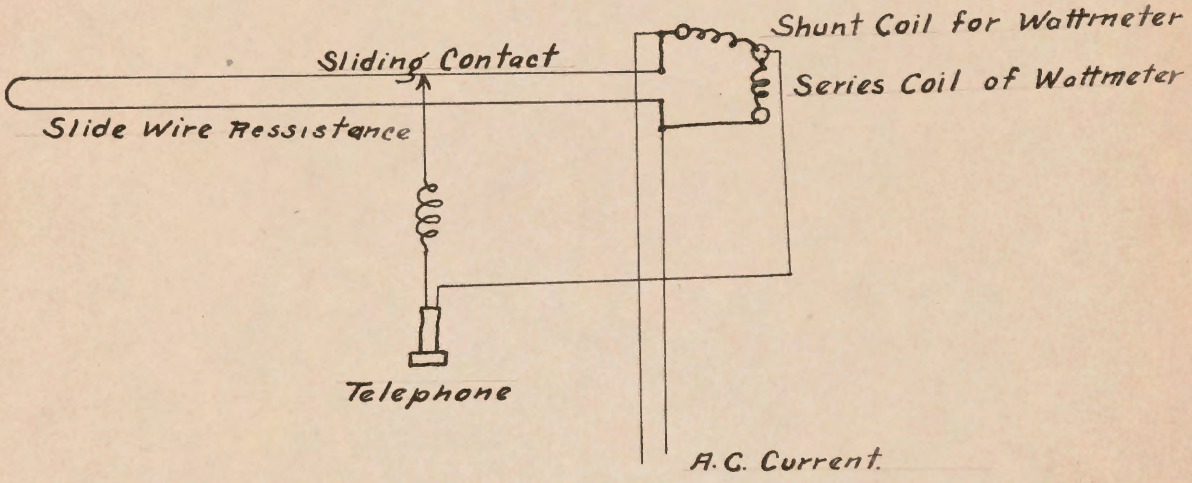
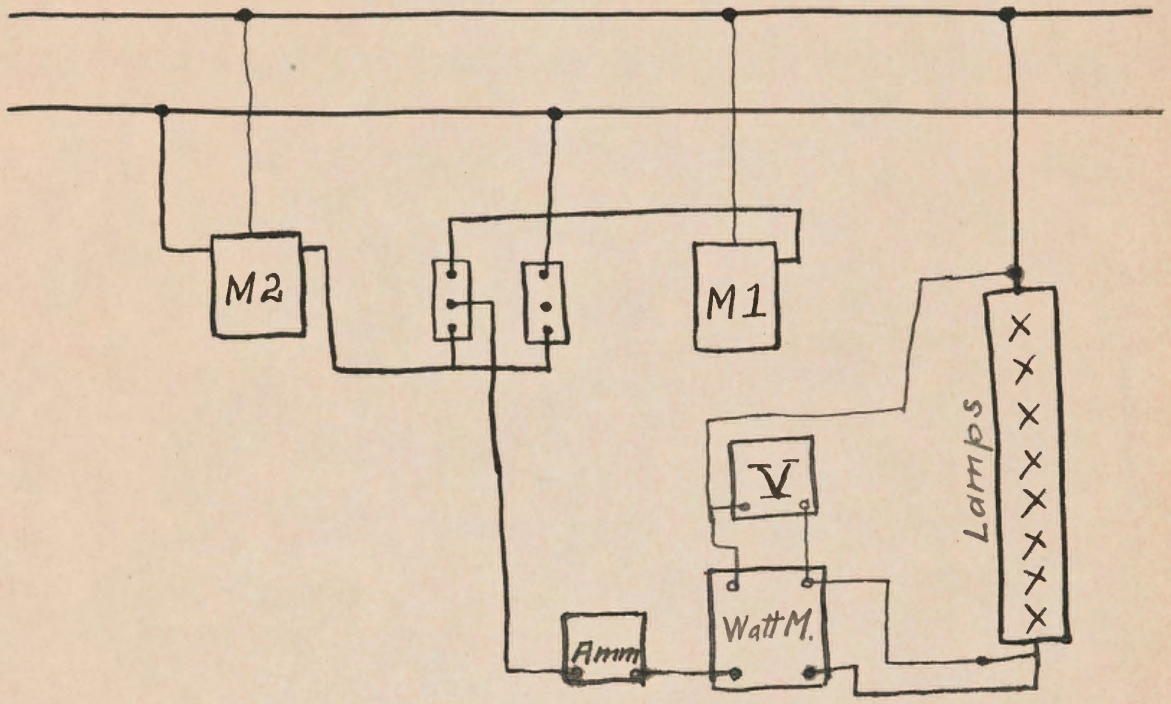


Plate XXIX


Shunt Coil for Wattmeter
Sliding Contact
Series Coil of Wattmeter
Slide Wire Resistance
Telephone
A.C. Current.



Connection of Instruments

as used in

Tests of Meters.