POWER CONSUMPTION TESTS
OF
DOUBLE DECK BASCULE BRIDGE

BY

V. M. CROWN
L. C. BUSH

ARMOUR INSTITUTE OF TECHNOLOGY

1918

POWER CONSUMPTION TESTS OF A DOUBLE DECK BASCULE BRIDGE

A THESIS

PRESENTED BY

V. M. CROWN AND L. C. BUSH

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

MAY 29, 1918

APPROVED:

Alfred E. Phillips
Professor of Civil Engineering

H. M. Raymond
Dean of Engineering Studies

L. C. Monin
Dean of Cultural Studies

POWER CONSUMPTION TEST OF A DOUBLE

DECK BASCULE BRIDGE

Lake Street Double Deck Bascule Bridge

F O R E W O R D

In May 1917 a thesis similar in character to this one was written by two students of Armour Institute pertaining to a power consumption test on the Webster Av. bascule bridge of Chicago. Mention was made therein that under conditions existing at that time a test on the new Lake St. double track bascule bridge would be very difficult to make. However, the bridge department of the City of Chicago was very desirous of having a test made on this bridge. So, through the co-operation of Mr. Chas. Harrington of the electrical department, who personally directed the test, the writers are able to present this thesis.

The authors also wish to express their sincerest thanks to Mr. John C. Bley of the Division of Bridges, Prof. John C. Penn and Mr. Falk of Armour Institute of Technology, for their valuable assistance and co-operation and to A. L.

Schreiber and Stuart N. Miller of the class of 1917 from whose thesis the authors obtained valuable information pertaining to a similar test.

The City of Chicago has in view the erection of several bridges of this type. It is hoped that the results of this investigation will furnish data by which present difficulties in the operation and control of a bridge of this kind may be overcome.

May 1st, 1918.

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INTRODUCTION

The Lake Street bridge is a double leaf, double deck, trunnion bascule bridge spanning the junction of the two branches of the Chicago River, at Lake Street. It replaced a single deck, three truss, swing bridge built in 1888, and in 1893 was strengthened to carry the Chicago and Oak Park Elevated R.R.

On March 31st, 1914, work was begun on the sub-structure. The sub-piers rest on rock at an elevation of 106 to 110 feet, Chicago datum, and were spaced to allow future subway construction. At the anchor piers, the sub-piers are 8 feet in diameter. About 2000 cubic yards of concrete were used in the sub-piers, 5200 cubic yards of mortar were used in waterproofing the main piers and abutments, 392 cubic yards of mortar in waterproofing the tailpits and about 4,112,000 pounds of steel were used in reinforcing the piers.

On Jan. 13th, 1915, work on the super-structure was commenced and on Jan. 1st, 1916, the bridge was practically ready for the initial lowering. The east leaf was the first in place and was lowered on Feb. 28th at 4:10 P. M. The west leaf was lowered March 1st at 8:55 A. M.

The total weight of steel in the bridge is 2025 tons. Each movable leaf weighs about 670 tons and the fixed portion 685 tons. The counterweight in each leaf weighs about 1075 tons, making a total counterweight of 2150 tons.

The length of steel work over all, abutment to abutment, is 355 feet. The distance from center to center of trunnions is 245 feet 3 inches. The width of steel work over all is 70 feet.

The lower deck has a clear roadway

width of 38 feet and two 14 foot sidewalks. The upper deck provides for the elevated railroad tracks.

POWER CONSUMPTION TEST OF A DOUBLE DECK BASCULE BRIDGE

OPERATION OF BRIDGE

Note:- Numbers refer to points on wiring diagram blueprint.

Each leaf is controlled by a bridge operator, who is stationed in an operating house at the East and West ends of the bridge respectively. The power required to operate the bridge may be taken from either the elevated or the street railway source of direct current supply. Both are 600 volt circuits, which are connected to the bridge motor load by means of a single pole double throw switch (1) in the main operating house. The street railway supply is generally used, as other bridges in the city also use this source of energy. Each leaf may be opened independently of the other, but on starting, the bridge operators exchange signals so that succeeding operations may occur as nearly simultaneously as possible.

Then each one rings a large hand operated bell which warns the oncoming traffic that the bridge is about to be opened. Following this, each one throws a switch which starts the warning bell and flasher lights (2). To one approaching the bridge the lights appear and disappear in the form of a wave; even in daylight showing up quite distinctly, and to date, have proven very effective in warning the oncoming traffic of danger.

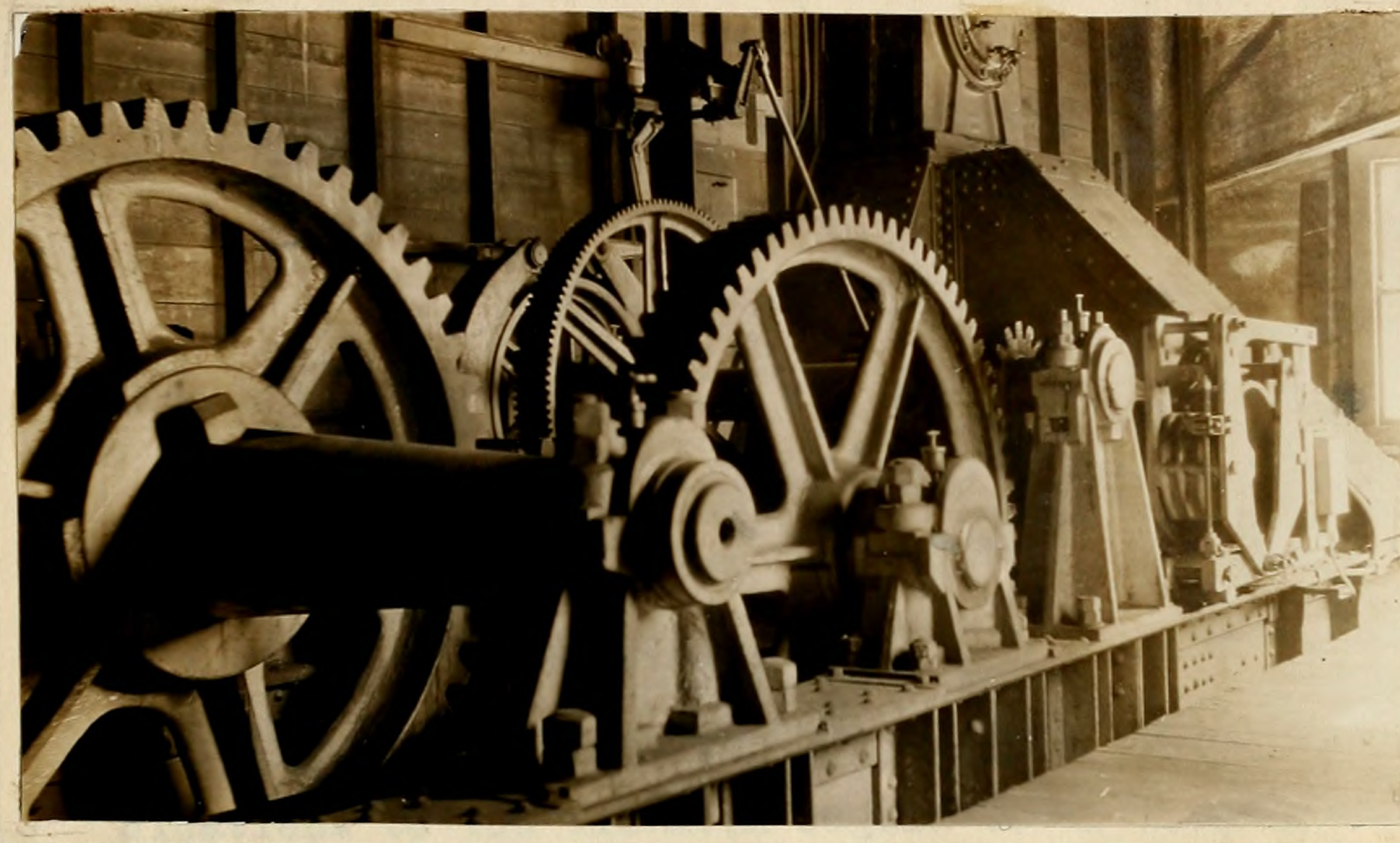
The West side operator now signals the elevated signal tower. Each operator puts down his on-coming roadway gate, sidewalk gates and finally the off-going gate which when shut closes contacts in gate bases which are in series with the car checker switches. The switch in the West house takes care of the West bound trains, and the switch in the east house, the east bound.

A car between barriers, however, would open their respective switches, but when away from these barriers, both switches are closed. This interlocking circuit is completed on both sides by means of a submarine cable across the river.

Now the barriers are lowered which close one contact in the interlocking circuit. The signals on the elevated structure when set at danger, operate a relay and close the 600 volt bridge control circuit after which the center and then the rear locks may be opened. As the barrier and the bridge leaf are interlocked in series, the opening of the bridge leaf is dependent upon the occurence of both the aforementioned events, thereby protecting traffic on both the elevated and the street railway right of way.

Signals are now exchanged between the operators and the two leaves are raised by means of two 100 H. P., 550 V. 530 r.p.m, General

Electric series motors operating in parallel through a train of gears, the current being



admitted to the main motors through controllers which are so arranged that their resistances in circuit are decreased by cutting in additional resistances in parallel (6). Should a heavy wind be blowing against either face when up, it would begin rolling down again, but this is prevented by a magnetic brake (4) which is energized by a circuit not in series with the main lift motors. Should this fail, an emergency hand brake may be used.

In coming down, signals are exchanged between operators so that both leaves may be lowered at the same time for convenience. The brakes are now released (by point 1 on controller) and the bridge is lowered. When the bridge is down the auxiliary leaf switch (5) is closed to permit operation of the rear locks, which when in, permit the center lock to be operated and circuits S and S_2, which give indications to the elevated signal tower that the center locks are in and elevated trains may cross. After this, each operator raises his barrier roadway and sidewalk gates as rapidly as possible. The bell and flasher mechanisms are stopped and the bridge is again ready for traffic.

POWER CONSUMPTION TEST OF A DOUBLE DECK BASCULE BRIDGE

OBJECTS OF TESTS

In studying the conditions and the desired results, six distinct problems presented themselves for solution, namely:

1. The relation of the power consumed at any instant to the angle of the leaf with the horizontal at that instant.

2. The relative power consumed by the two leaves under similar conditions.

3. The features of the parallel operation of the two motors on each leaf.

4. The effect of wind upon the maximum power consumption.

5. The accuracy of the balance of each leaf.

6. The spacing of resistance steps in the controllers.

POWER CONSUMPTION TEST OF A DOUBLE DECK BASCULE BRIDGE

A P P A R A T U S

The apparatus used was:

1. A recording wattmeter and auxiliary equipment.
2. A mechanical device to record the motion of the bridge leaf.
3. An anemometer to measure the velocity of the wind.
4. A Weston Voltmeter (0-600) No.
5. A G. E. Ammeter (0-500) No.

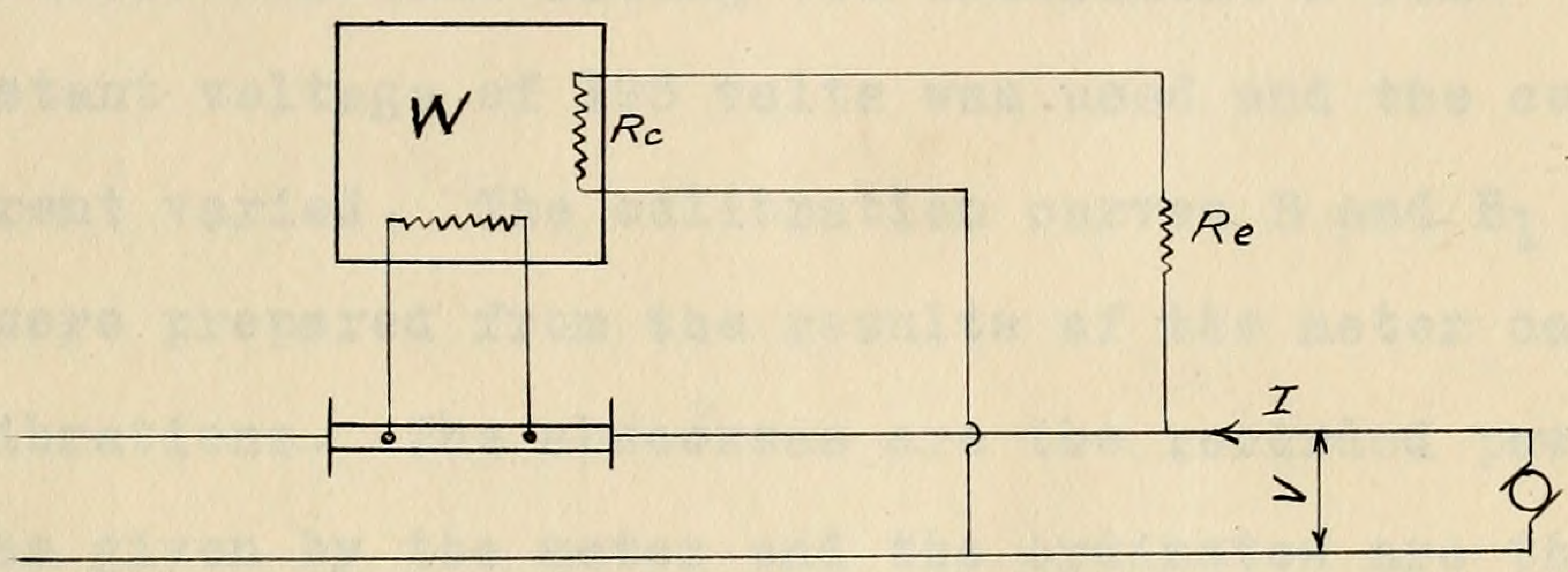
THE WATTMETER AND AUXILIARY EQUIPMENT.

The wattmeter used was a portable type, recording meter, manufactured by the Esterline Company of Indianapolis, Indiana. It was designed to take a maximum current of 5 amperes with a maximum potential of 200 volts through the respective coils, and will operate on either direct or alternating current circuits. The drop over each current coil and its leads was given at 100 milivolts. The recording mechanism consisted of an inking needle swinging over a moving paper operated by clockwork. The paper was ruled with parallel lines so that it would register any power from zero to one kilowatt. The paper movement could be controlled by means of a catch which started or stopped the clockworks.

In order to adapt the meter to working conditions of the test, it was necessary to provide shunts of the proper size to reduce the current over the coils to less than 5 amperes. It was found upon examination that one of the elements of the meter had been burned out and so the one coil was used in recording the power of both motors. In order that the power to each motor could be recorded with the instrument, it was found most convenient to place one shunt in line with the south motor and one in line with the north motor, and the power taken first with one connected to the meter and then the other. In order that both motors could be connected to the meter at one time, it was necessary to provide a single shunt and place it in series with both motors.

From preliminary runs made in the operation of the bridge, an estimate was had as to the probable maximum current at any time, and was found to be 300 amperes for motors operating in parallel. Two 200 ampere, 100 milivolt shunts were provided, and one placed in line with the south motor and the other in line with the north motor. (The meter was calibrated with these shunts before and after installation, and these calibration curves are shown on pages) For both motors operating together, a 300 ampere, 100 milivolt shunt was used. Curve B is the calibration with the 200 ampere shunt and C with the 300 ampere.

It was also necessary to reduce the voltage from 580 to 200 volts, the allowed voltage over the coils. This was done by placing a resistance in series with the coil. The resistance of the coil was given at 4407 ohms. and the external resistance was then computed from the formula:



$$V = ReI_1 + RcI_1 = ReI_1 + Vc$$

$$Re = \frac{V - Vc}{I_1} \qquad I_1 = \frac{Vc}{Rc}$$

$$Re = \frac{V - Vc}{Vc} \times Rc$$

Where Re = required external resistance.

The total voltage was estimated at 600 volts and the necessary resistance to reduce 600 volts to 200 volts is 2 x 4407 = 8814 ohms. The resistance used was measured and found to be 8830 ohms, and when the voltage was checked it was found to be 580 instead of 600. With an external resistance of 8830 ohms. and an impressed voltage of 580 volts, there was impressed upon the coil of the instrument 193 volts. In calibrating the instrument a constant voltage of 193 volts was used and the current varied. The calibration curves B and B_1 were prepared from the results of the meter calibrations. The absci̇ssae are the recorded power as given by the meter and the ordinates are the true power or the product of the currents through the shunts, the voltage over the coils and the ratio of $\frac{580}{193}$.

APPARATUS FOR RECORDING THE ANGULAR POSITION OF BRIDGE.

It was necessary to find a means whereby the movement of the leaf could be recorded on the moving paper which, at the same time, was recording the power.

The wattmeter stand was placed in the operating house and at an elevation of about five feet above the end of the trunnion. A braided steel picture wire was wound around the portion of the trunnion protruding from the bearing nearest the operating house, one end was fastened securely and the other end led off to a set of pulleys which were held at the same elevation and in line with the top of the trunnion by means of a bracket fastened on the wall. From this smaller of the two pulleys the wire was led up into the operating house and around the disk, placed horizontally and directly over the wattmeter. A counter weight was hung on the free end of the wire in order to keep the wire taut as the bridge moved. The photographs on page show how the apparatus was arranged. A pencil was dropped through a closely fitted hole in the disk, so that the pencil described an arc on the paper when the disk revolved.

The radius of the arc described by the pencil was made the same as that described by the meter needle. However, the center of this arc was placed about 3/8 of an inch beyond that of the needle to avoid any interference of the two.

By this arrangement, when any movement of the leaf occurred, the wire unwound from the trunnion and in so doing turned the disc through an angle proportional to the angular position of the leaf.

In order to find the instantaneous power corresponding to any angle of leaf, it was necessary to move the leaf-angle curve a distance of 3/8 of an inch to the left, and read the corresponding ordinates of the two curves. In drawing up the final curves, this was taken into account and the whole transformed into rectangular co-ordinates with time as absciessae and power as ordinates.

The necessary diameters of the pulleys to transmit the motion of the leaf were determined as follows:

The diameter of the trunnion equals 25.875 inches. The leaf turns through a maximum angle of 79°, the linear motion of the wire is

$$\frac{25.875 \times 3.1416 \times 79}{360} = 17.83''$$

It was desired to use the same wattmeter stand and disc that had been used in a previous test. The radius of the disc is 6.875 inches and as the swing of the wattmeter needle is 60° and a radius of 4 7/16 inches, the motion of the needle is

$$\frac{4.4375 \times 2 \times 3.1416 \times 60}{360} = 4.64''.$$

This linear motion of the wire must be reduced from 17.83" to 4.64" and this was done by the two pulleys on the same shaft, supported by a bracket.

The second reduction in motion must be equal to $\frac{4.64 \times 6.875}{4.4375} = 7.19''$, and as the smaller of the two pulleys was made 4" diameter, the larger must be

$$\frac{17.83 \times 4}{7.19} = 9.906 = 9\ 29/32''.$$

ANEMOMETER AND DETERMINATION OF TORQUE DUE TO WIND PRESSURE.

The anemometer used was a Tycos instrument # 11431 made by Short and Mason. It is of the vertical plane, revolving vane type. Accompanying this instrument was a correction chart for all possible ranges of wind velocity we might have occasion to determine.

Anemometer Corrections:

Velocity feet per min.	Correction
100	
200	+ 40
300	+ 28
400	+ 16
500	+ 4
600	- 9
700	- 22
800	- 35
900	- 50
1000	- 68
1250	- 86
1500	-104
1750	-122
2000	-140
2250	-158
2500	-176
2750	-186
3000	-210

The pressure of the wind against a flat surface depends upon the velocity and direction of the wind, and upon the inclination of the surface.

Nomenclature:

P = pressure in pounds per square foot on a flat normal surface.

V = velocity in miles per hour as determined by anemometer.

K_1= experimental constant, found by Eiffel the noted expert on aeronautics to be 0.0032 for our conditions.

P_n= normal component of wind pressure.

α = angle of bridge leaf with horizontal in degrees.

M_1= moment due to any uniformly distributed load.

l = half span of bridge.

b = breadth of bridge in feet.

M = total moment due to wind, for any angle of bridge leaf.

The wind is assumed to move horizontally and the pressure against a flat surface, normal to the direction of the wind, may be found from the formula

$$P = K_1V^2 = 0.0032V^2$$

As before mentioned the normal wind pressure varies as the inclination of the surface to the horizontal; and several formulae have been derived for finding the normal component. The formula of Duchemin is based upon carefully conducted experiments, and was selected by the writers to be the most reliable.

$$P_n = P\frac{2\sin\alpha}{1+\sin^2\alpha}$$

also

$$M_1 = (p_n l) \times \frac{l}{2} \quad \text{for a cantilever span.}$$

and

$$M = (p_n l) \times b \times \frac{l}{2} \times \sin\alpha$$

$$= \frac{p2\sin^2\alpha bl^2}{2(1+\sin^2\alpha)} = \frac{K_1V^2\sin^2\alpha bl^2}{1+\sin^2\alpha}$$

The velocity of the wind as determined by the anemometer was 1500 ft. for 30 seconds or 3000 ft. per minute. Applying the correction factor corresponding to this velocity gives

$$3000 - 210 = 2790 \text{ ft. per minute.}$$

This is equivalent to a velocity of

$$V_1 = \frac{2790 \times 60}{5280} = 32 \text{ miles per hour.}$$

As the bridge lies in an east and west direction and the wind was blowing from the northeast, the component parallel to the direction of the bridge leaf would be

$$V = 32 \sin 45^{\circ} = 32 \times 0.707 = 22 \text{ m.p.h.}$$

and

$$M = \frac{0.0032 \times \overline{22}^2 \times \sin\alpha \times 70 \times \overline{105}^2}{1 - \sin^2} =$$

$$1{,}543{,}000 \frac{\sin}{1 + \sin^2\alpha}$$

Curve "C" gives values of this moment in Kip feet plotted against angle of lift with horizontal as absc~~e~~issae.

POWER CONSUMPTION TEST OF A DOUBLE DECK BASCULE BRIDGE

RESULTS

In a test of this kind the results are only relative ones, due not only to the small inaccuracies in the apparatus, but largely to the nature of the problem.

A check was made on the power curves for both motors operating in parallel by placing a calibrated voltmeter and ammeter in the line. This was also done to check the instruments in the operating house. The power recorded varied from two K. W. less than the actual power on one side, to four K. W. greater than that on the other, or a maximum variation of 4 in 174 K. W. This error was probably due to the variation in wind pressure and the small inaccuracies in the apparatus itself, due to temperature changes.

The original curves give the total power at the switch board, and this is greater than the actual power delivered to the motors, because there is power lost in the grid resistances due to the rise in temperature. A thermometer was placed between two grids in order to obtain the rise in temperature during the run. When the first point on the controller is in the resistance, the circuit is 3.6 ohms., for the second it is 1.8, and for the third it is 1.0 ohm. The usual run is made upon these three points, and the power corrections for these resistances were applied. This correction was made by noting what resistance was in and then obtaining the power at that instant from the calibration curve for the wattmeter. The power divided by the total voltage gave the current at that instant from which the IR drop due to the rise in temperature was computed.

The grids have a temperature coefficient of about .004 and using the formula $R = R_t(1+\alpha t)$ where R_t is the resistance at normal temperature, α is the coefficient and t is the rise in temperature, the actual resistance in the circuit was obtained at each point. The loss in power due to the difference in resistance was computed and found to be appreciable for the first two resistance steps. For the other steps, this loss became so small that it was impossible to show it accurately on the scale to which the final curves were plotted.

The maximum rise in temperature for the lift shown by curve 1_c was 38°C. When the first resistance of 3.6 ohms. was in, the actual resistance in circuit as computed by the formula was 4.04 or a difference of 0.44 ohm. The power was 35 K. W. and from this the current was $\frac{35000}{580} = 60.2$ amps. The power lost was $\frac{60.2 \times 0.44 \times 60.2}{1000} =$ 1.57 K. W. The actual power to the motor at this point would be 35-1.57= 33.43 K. W.

In the following paragraphs a discussion is given of each problem as it was encountered.

1. The relation of the power consumed at any instant to the angle of the leaf with the horizontal at that instant.

Curves 1A to 1c inclusive show this relation on the east leaf, and curves 2A to 2c inclusive, show the same relation on the west leaf. These curves have been corrected and transferred to rectangular co-ordinates.

Referring to curve 1c, it is seen that the power jumps from 0 to 0.34 K. W. in one half second, then to 24 in the next half second. During the next second and a half, the power rises to 92 K. W. where it remains constant for one and a half seconds, then gradually drops to 64 at 11 seconds, and then rises to 86 at 24 seconds. The angle curve shows that the bridge does not start to rise until one and one half seconds after the power is applied.

After 11 seconds, the curve has assumed a uniform slope and continues this slope until 27 seconds after the power is applied, when it begins to flatten out. At 30 1/2 seconds, the power rises to 118 K. W. and then falls to 72 K.W. at 35 1/2 seconds and rises to 112 K. W. at 37 seconds. It is at this point where the bridge leaf has come to rest, and it is seen that for only part of the distance, that is, from about 11 seconds to 22 seconds, the leaf had a uniform velocity. When the leaf comes to rest the power drops instantly to 20 K. W. and then gradually to zero.

At 46 seconds the power is again applied and the leaf begins to move downward about 2 seconds later. At 60 seconds the power drops again to 0 and remains there for 13 seconds, when it is again applied to bring the leaf to rest. Just before the leaf comes to rest, there is a large jump in the power curve, that is, during the last few degrees. This large amount of power is applied as a braking action to bring the leaf to rest at the proper point, in order that the central locks may be operated.

Curves 1A and 1B show the relation between power and angle of leaf for each motor and are practically the same. Curves 2A and 2B show this relation for the respective motors on the west leaf, and these two curves also agree very closely.

One of the most notable properties of the angle curve is that the angular velocity of the leaf can be obtained from it. This is done by taking the difference between the two ordinates, between which the velocity is desired, and dividing by the elapse of time between them. This, however, will give only average velocities where the bridge leaf is being accelerated, but along the straight part of the curve, where the velocity is uniform, the actual velocity may be computed.

2. The relative power consumed by the two leaves under similar conditions.

It is very difficult to obtain any satisfactory data upon this relation because the results may be very easily hidden by the effect of the wind. It was impossible to get a lift on each leaf, during the time these tests were made, with the wind velocity down to zero. By comparing the various curves obtained, it is seen that the power for either leaf averages about the same, but the details vary in so many ways that no definite conclusions can be drawn from them.

In order to make a definite comparison of the power consumed by the two leaves, the curves to be compared should be taken at exactly the same time. This would necessitate a duplication of the recording apparatus. On a bridge where there is very little traffic, approximate results may be had, by using the one recording set and making a lift on each side, one immediately after the other and comparing the curves for these runs.

3. Parallel operation of the motors.

Curves 3A and 3B show the action of the motors for the east leaf, and curves 4A and 4B show the same relation for the west leaf.

These curves were obtained by making a lift with only one motor recording at a time. The two lifts for each side were made as near the same time as possible, in order to obtain the action of the two motors, running under like conditions.

The curves for each leaf, in order to prove that the motors take the same power, should enclose equal areas. In either case, however, the curves do not represent exactly identical conditions because lifts were made at least 6 minutes apart, for the west side and 10 minutes apart for the east side. It is seen, however, that in each case the areas are almost exactly equal which proves that the motors operate efficiently in parallel.

If both elements of the wattmeter had been intact, a further test of the action of the two motors under parallel operation, could have been made by connecting both motors to the instrument and then allowing first one and then the other to record the power used. This method is fully described in the results of a series of tests made upon the Webster Avenue bridge by A. L. Schreiber and S. N. Miller.

4. The effect of wind on the maximum power consumption.

It so happened that upon the days the tests were made, the wind blew from a northerly direction. The first day, however, the wind blew from the north-east with a high velocity, and its effect was obtained upon the east leaf only. During the other days the wind blew from the north and its effect was neglected. This, of course, made it impossible to test both leaves under wind pressures constant in volume and direction.

In curve 5, it has been attempted to show the relation of the power consumed at any instant to the overturning moment due to the wind. These curves were obtained for the east leaf with a normal wind velocity of 22 miles per hour.

The values of the overturning moment were obtained from curve "c" which was plotted for the given wind velocity of 22 miles per hour. The values on this curve corresponding to each 10 degree interval of lift were taken and plotted against the time at which the opening of the bridge corresponded to each of these 10 degree intervals.

The overturning moment curve shows a maximum value of 720,000 ft. lbs. at an angle of 69 degrees, and a wind velocity of 22 miles per hour. This is equivalent to a force of 6850 lbs. acting normal to the leaf on the off shore end. The overturning moment curve and the angle of leaf curve show clearly the relation for the effect of wind as the leaf is raised or lowered. These two curves agree very closely except for the smaller angles. The moment curve and the power curve do not show the theoretical relation which they should, but as the wind pressure is only a small per cent of all the forces tending to retard the bridge, this relation would naturally be greatly obscured in such a test.

The data obtained has shown the writers that attempts to measure the effect of the wind give only vague results, where actual values are considered. However, the general effects may be shown and from a set of curves such as curve 5 some very interesting results may be had.

From the angle curve, the time taken to lift the bridge from 18 degrees to 50 degrees is about 12 seconds. This was along the straight part of the curve and hence the bridge leaf was moving with a uniform velocity of:

$$n = \frac{60 \times (50-18)}{12 \times 360} = 0.44 \text{ r.p.m.}$$

From the overturning moment curve the average moment between these two positions of the leaf is:

$$M = \frac{180,000 + 500,000}{2} = 340,000 \text{ ft. lbs.}$$

Then the horse power required to keep the bridge moving, against the wind, with a uniform velocity of 0.44 r.p.m. is

$$\text{H. P.} = \frac{340,000 \times 22 \times 2 \times 0.44}{33,000 \times 7} = 27 \text{ H.P.}$$

The K. W. consumption for this position averages 72 K. W. or 96 H. P. and the power to move the leaf in still air at a uniform velocity of 0.44 r.p.m. would be 98-27 = 71 H.P. However, it is seen that the greatest power is used in accelerating the bridge and braking it down upon closing. At the latter point the maximum instanteous K. W. input is 170, which gives a maximum horse power of 226. This value, however, is only maintained for a small fraction of a second and the point where the greatest steady K. W. input is obtained gives the power as 158 K. W. or 210 horse power.

5. The accuracy of the balance of each leaf.

Due to a lack of accurate data regarding the designers calculated power required to lift the bridge, we were unable to make any comparisons in regard to the balance of the leaf.

6. The spacing of resistance steps in the controllers.

A lift was made on both sides in order to obtain some idea in regard to way the current was admitted to the motors and how it was controlled. The leaves were raised and lowered by throwing in the resistances, which are in parallel, very slowly, thus showing the current jumps distinctly. Curves 6A and 6B give these steps.

On the controller on the east leaf for a high run of 303 amps., the first point gave 96.5 amps., the second 110, and the third 96.5 amps. For the same run, on lowering the bridge, the first point gave 51.8 amps., the second 102.5 and the third 158.7. This shows that resistance steps are just about right. The first point cut in is rather low and is, therefore, about correct.

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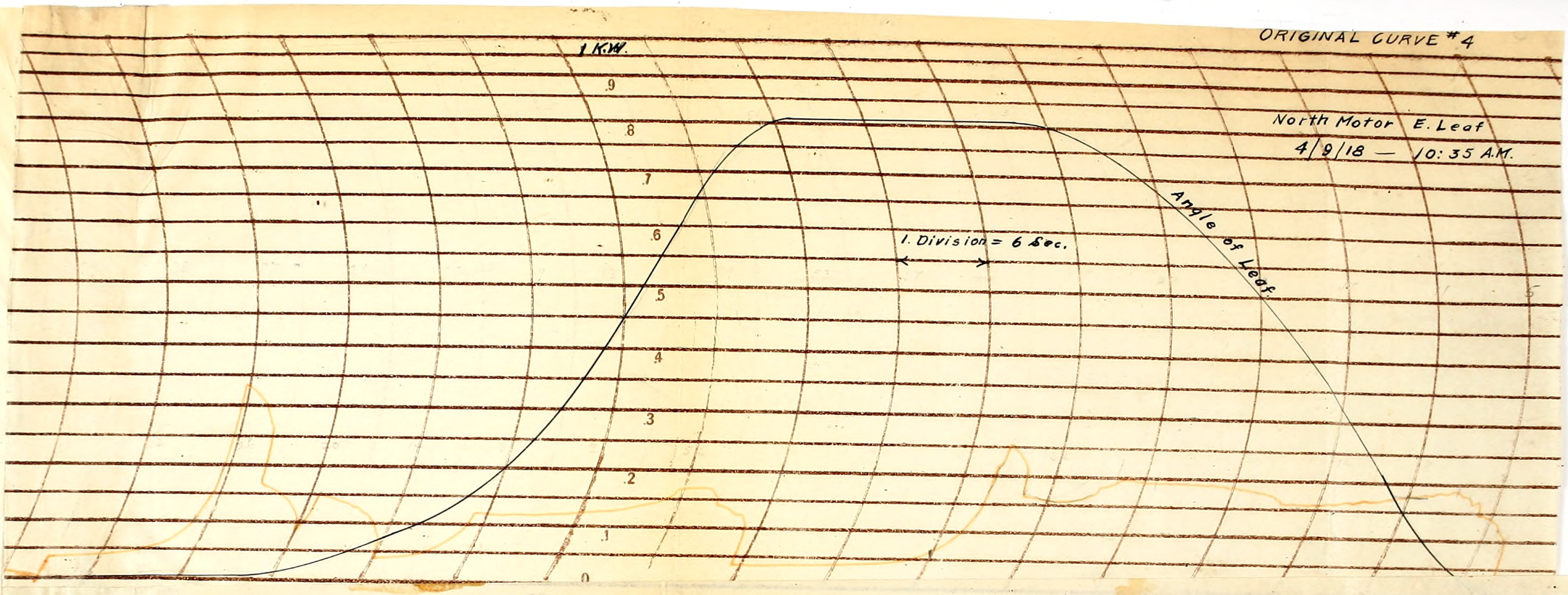
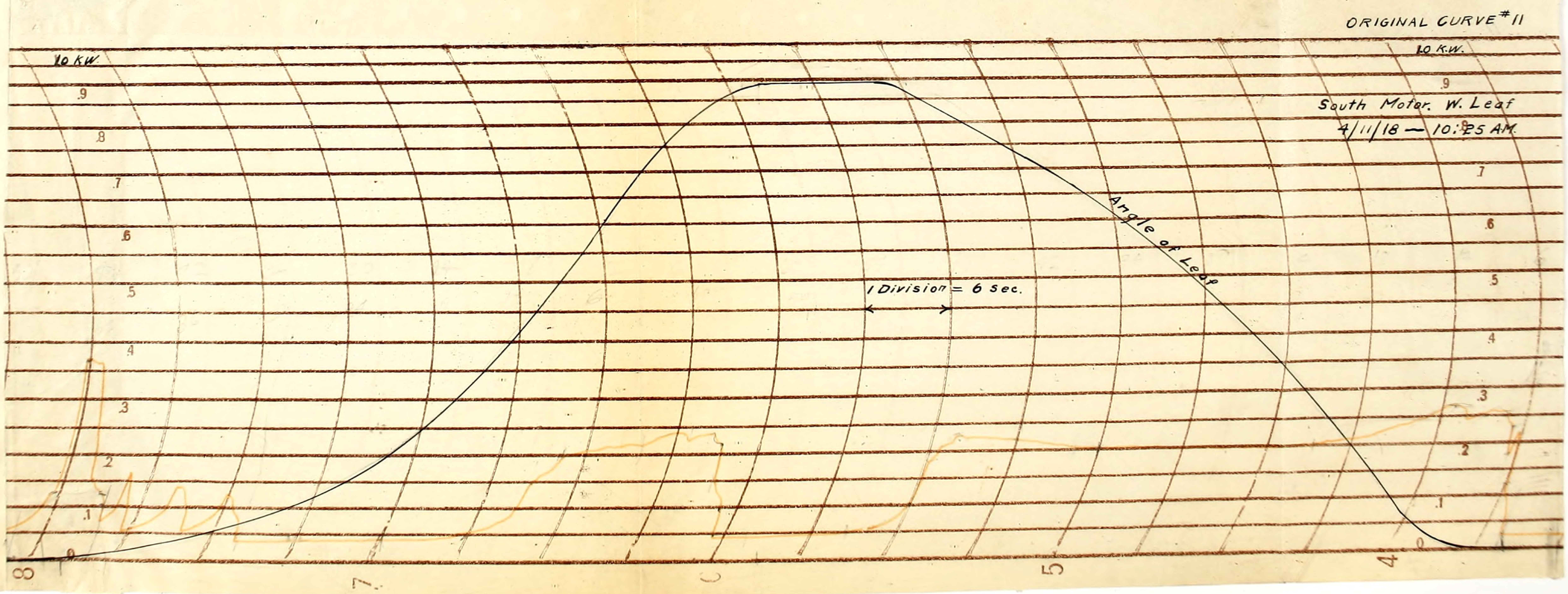
CONCLUSION

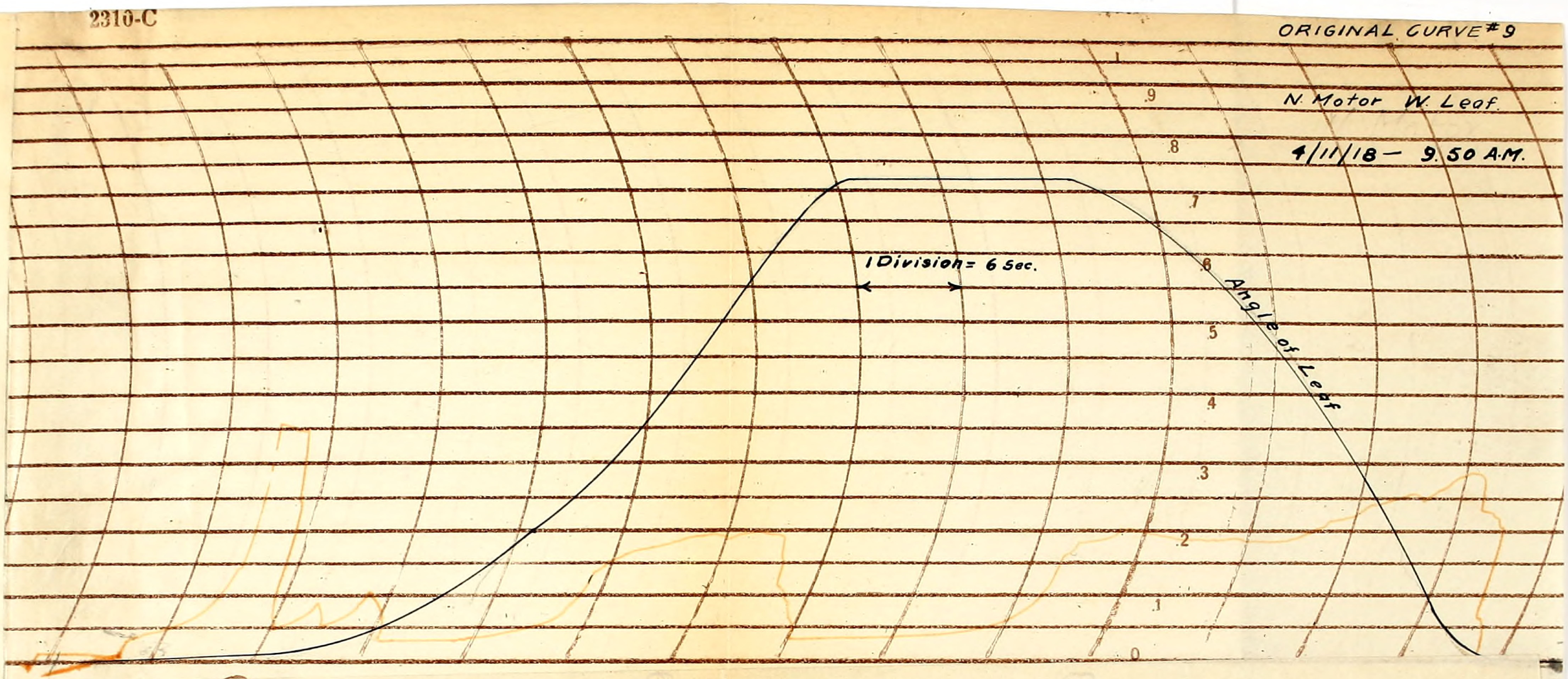
In conclusion the writers wish to state that very reliable information was obtained pertaining to the operation and control of this bridge. Of course, it was not to be expected that very accurate data could be obtained due to many factors over which the writers had no control. However, the tests show that, could a similar test be made on the bridge during erection, better bridge operation would result.

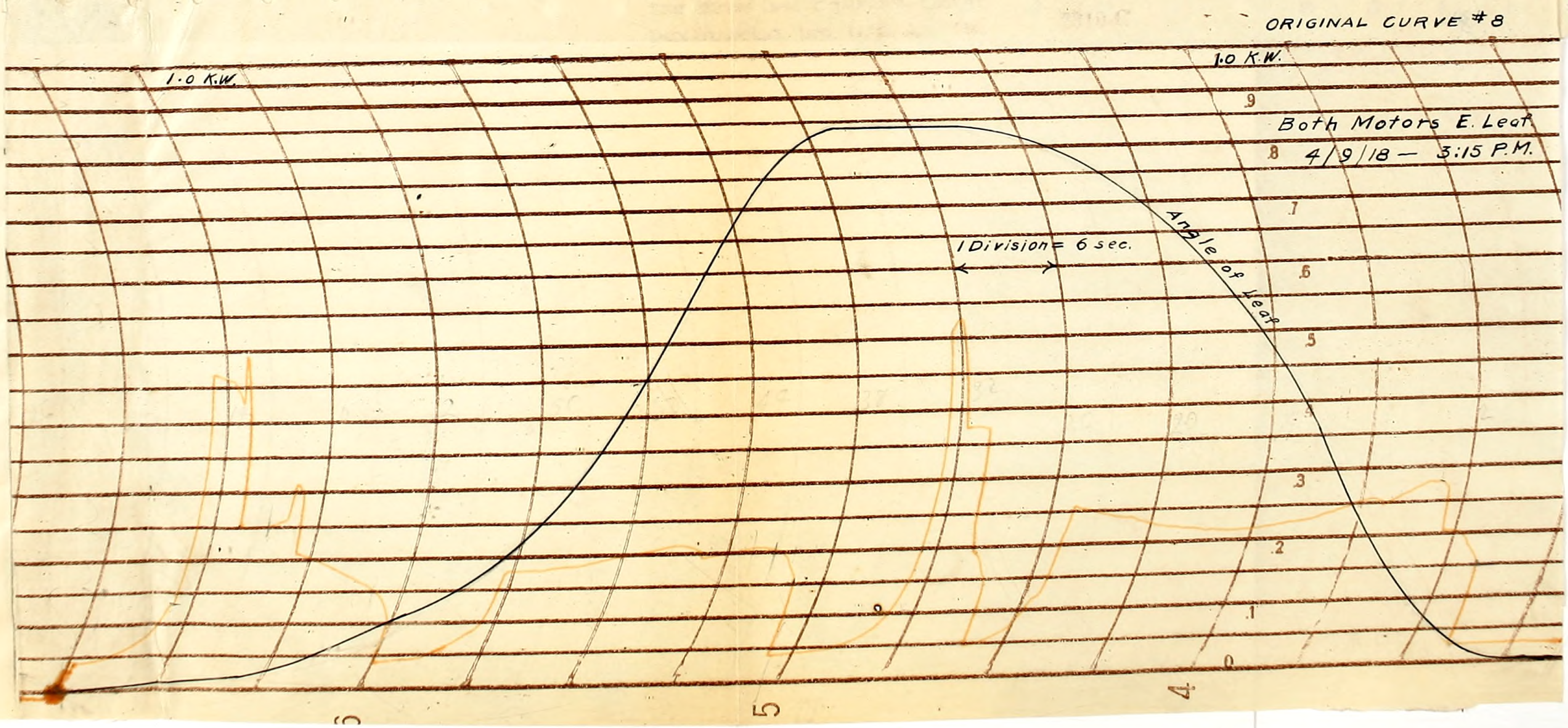
The problems mentioned and discussed herein, are those which will always present themselves in any test of this kind. Each individual bridge will bring forth difficulties which are characteristic of that bridge alone. In a general way, the method of procedure will be the same as that outlined in this thesis.

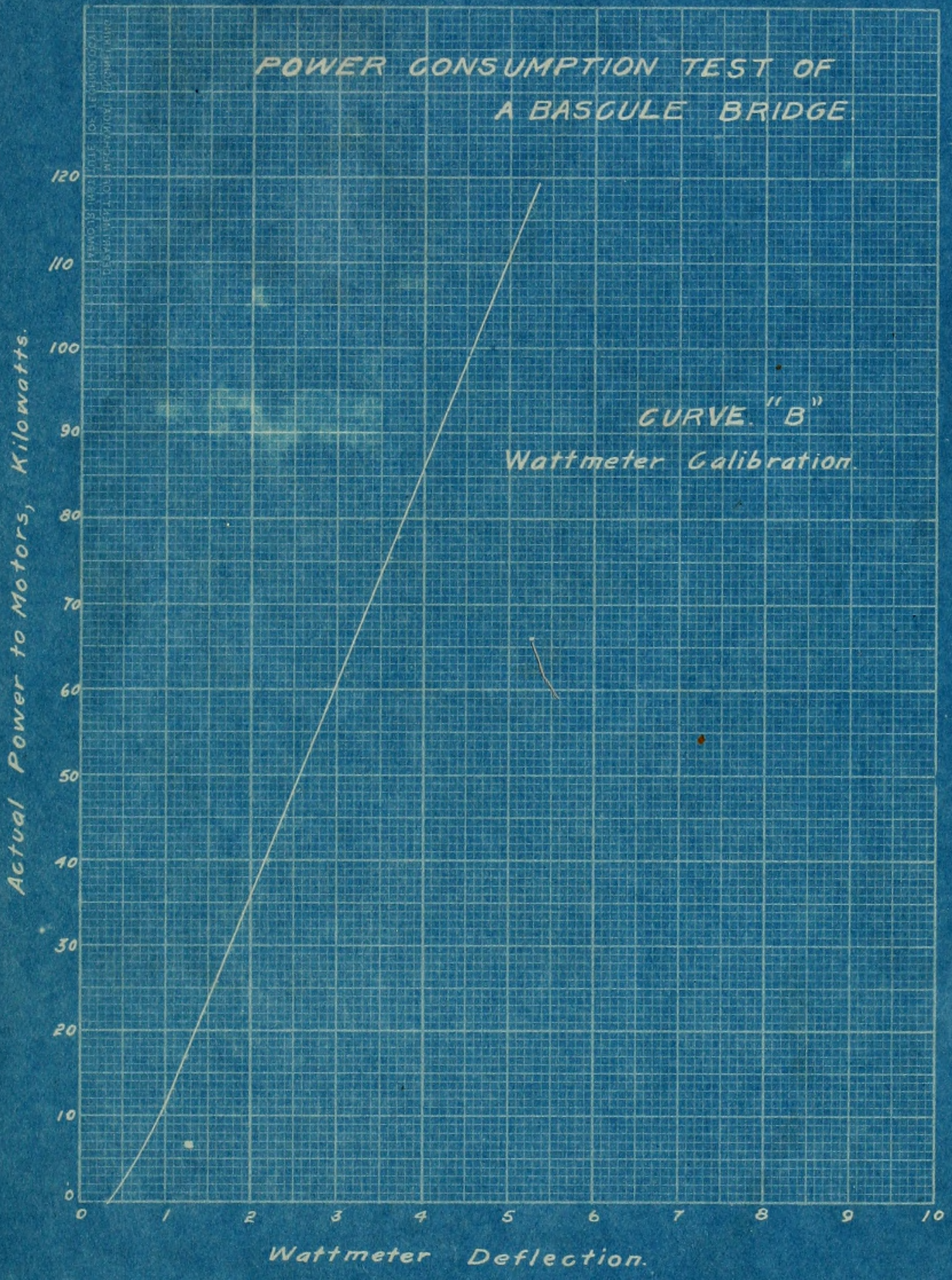
It is hoped that the results of this investigation may contribute their quota to the solution of the problems of bridge operation which will be encountered in the future, and that they will assist in solving the problems which may present themselves in the design and erection of the two similar bridges which the city contemplates building.

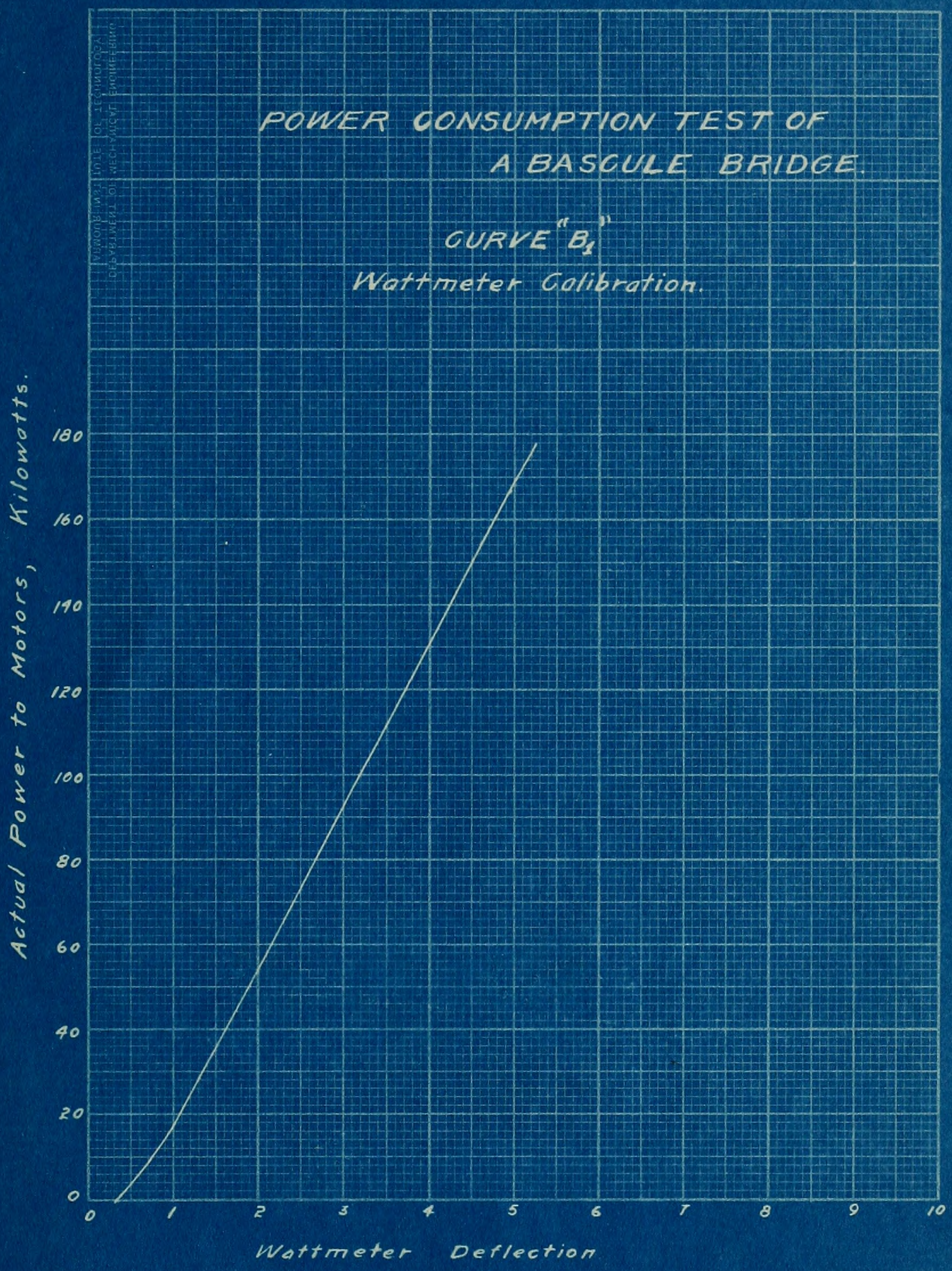

ORIGINAL CURVE #4
1 K.W.
North Motor E. Leaf
4/9/18 — 10:35 A.M.
Angle of Leaf
1. Division = 6 Sec.

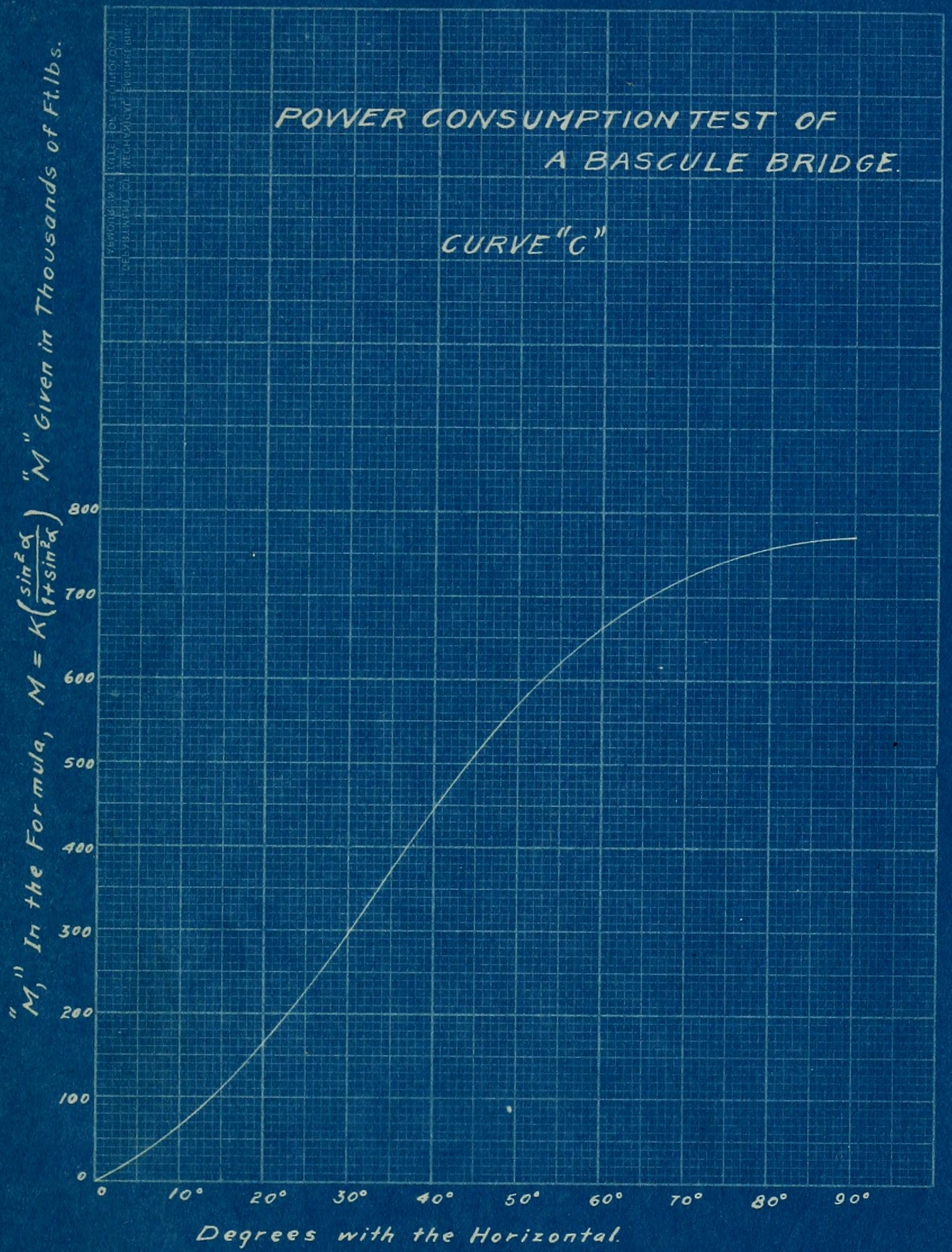

ORIGINAL CURVE #11
10 K.W.
South Motor. W. Leaf
4/11/18 — 10:25 AM.
Angle of Leaf
1 Division = 6 sec.

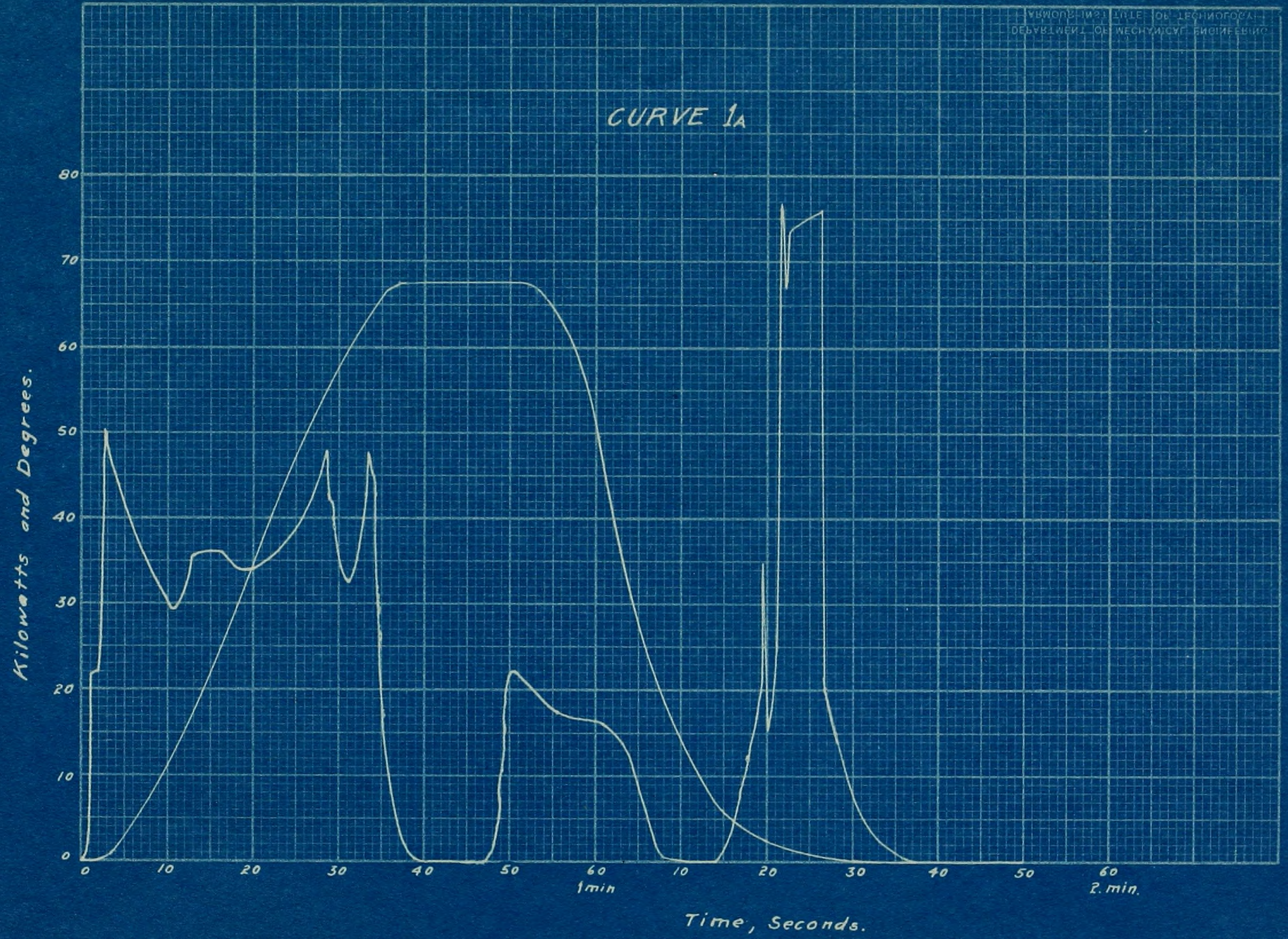

2310-C
ORIGINAL CURVE #9
N. Motor W. Leaf
4/11/18 — 9.50 A.M.
1 Division = 6 Sec.
Angle of Leaf


ORIGINAL CURVE #8
1.0 K.W.
1.0 K.W.
Both Motors E. Leaf
4/9/18 — 3:15 P.M.
1 Division = 6 sec.
Angle of Leaf


POWER CONSUMPTION TEST OF
A BASCULE BRIDGE
CURVE "B"
Wattmeter Calibration
Actual Power to Motors, Kilowatts.
Wattmeter Deflection.
0
10
20
30
40
50
60
70
80
90
100
110
120
0
1
2
3
4
5
6
7
8
9
10

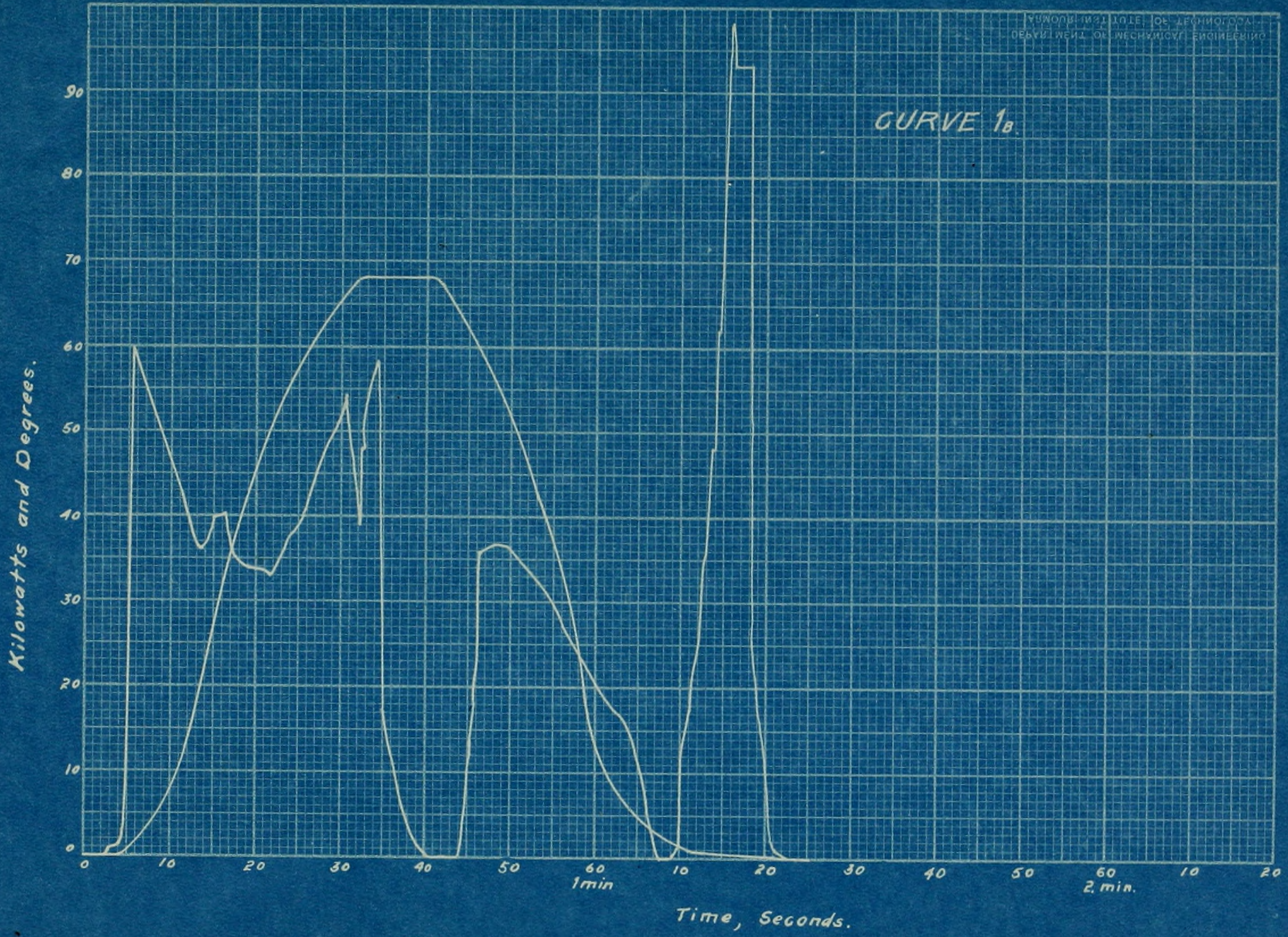

POWER CONSUMPTION TEST OF
A BASCULE BRIDGE.
CURVE "B1"
Wattmeter Calibration.
Actual Power to Motors, Kilowatts.
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
Wattmeter Deflection


POWER CONSUMPTION TEST OF
A BASCULE BRIDGE.
CURVE "C"
"M," In the Formula, M = K(sin²α / 1+sin²α) "M" Given in Thousands of Ft.lbs.
0
100
200
300
400
500
600
700
800
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
Degrees with the Horizontal.



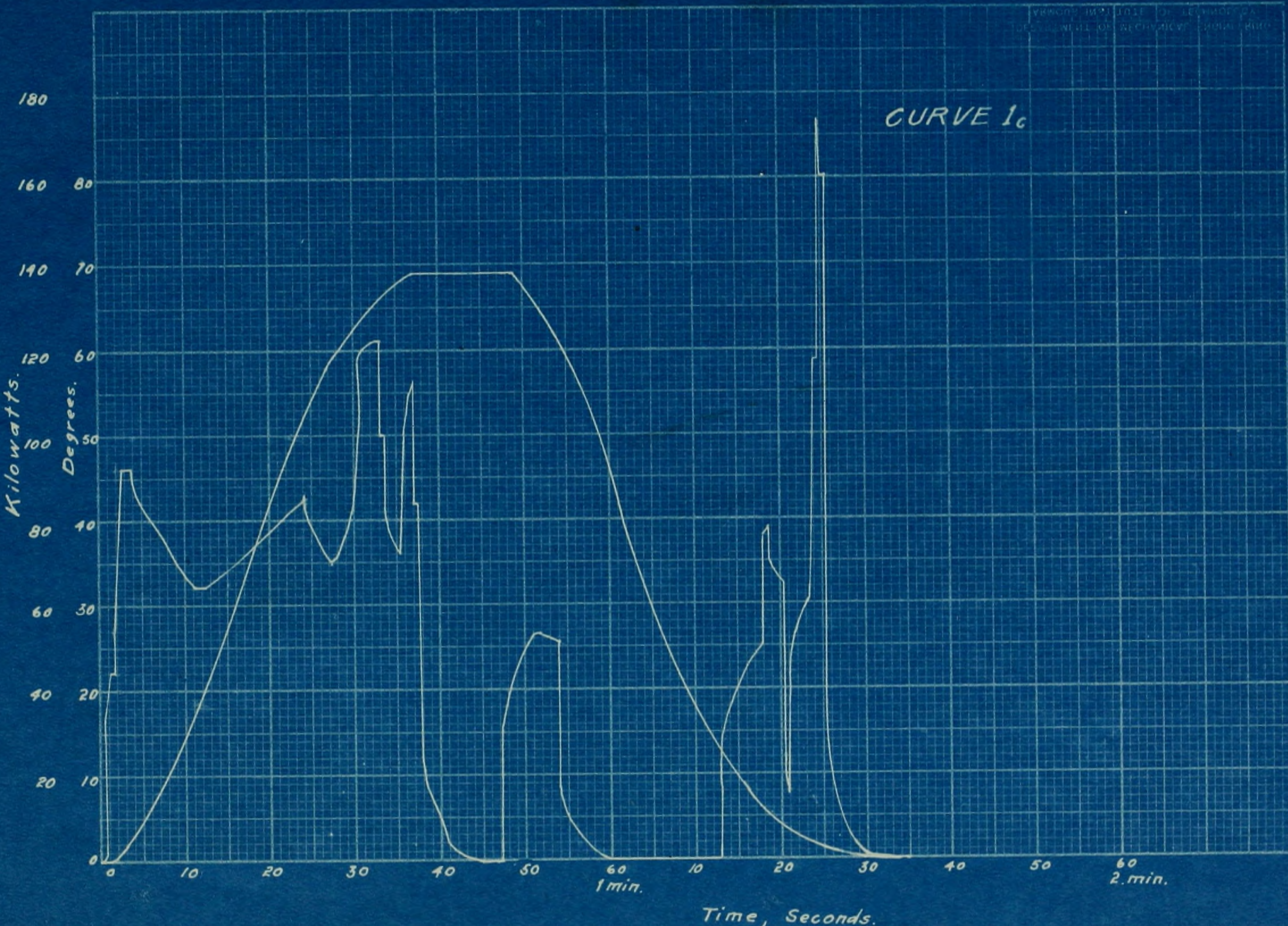
Curve Showing Relation Between Power and Angle of Leaf. 4/9/18 11:00 A.M.

East Leaf. S. Motor.



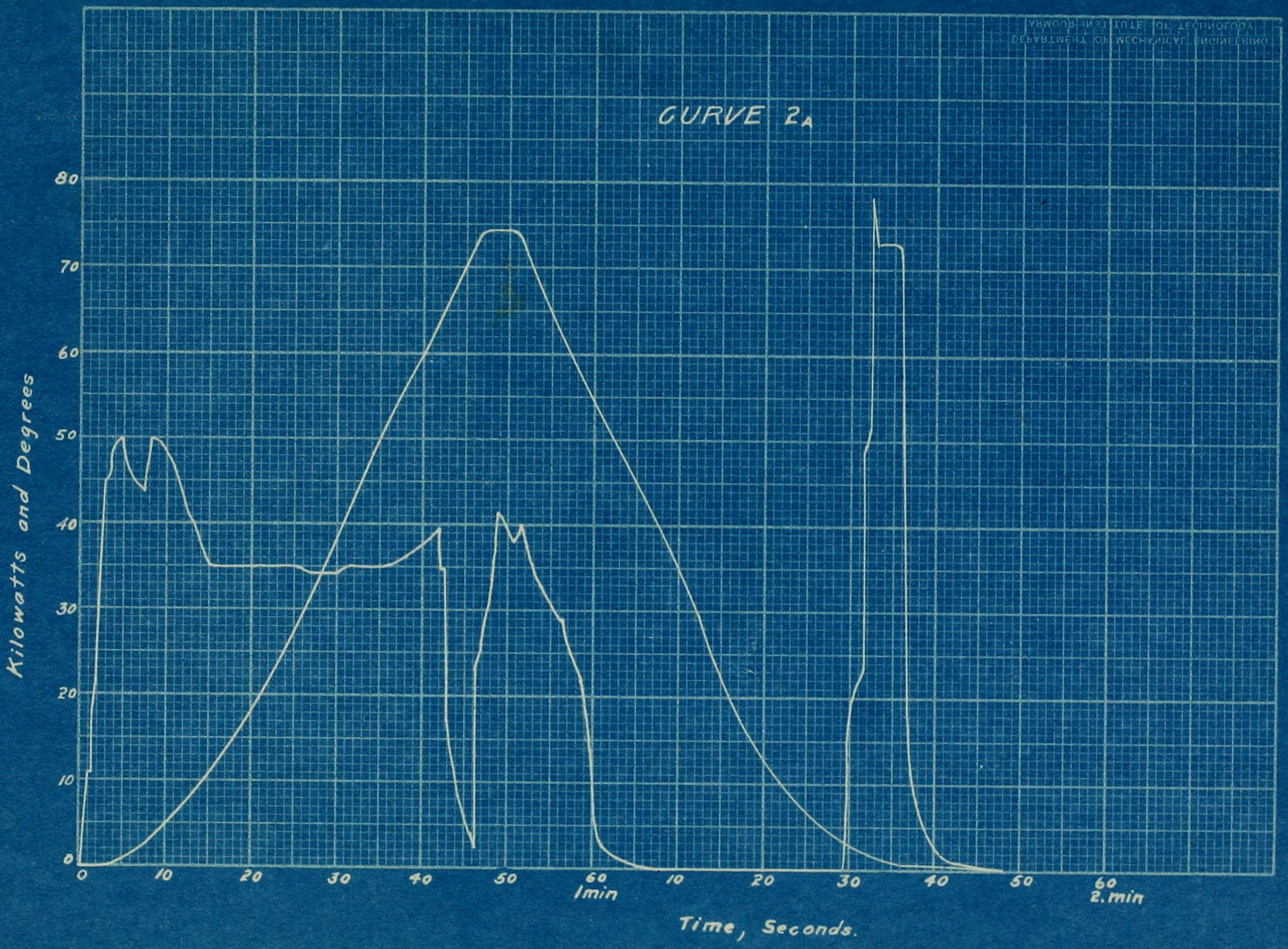
Curves Showing Relation Between Power and Angle of Leaf. 4/9/18. 11:30 AM.

East Leaf. N. Motor.



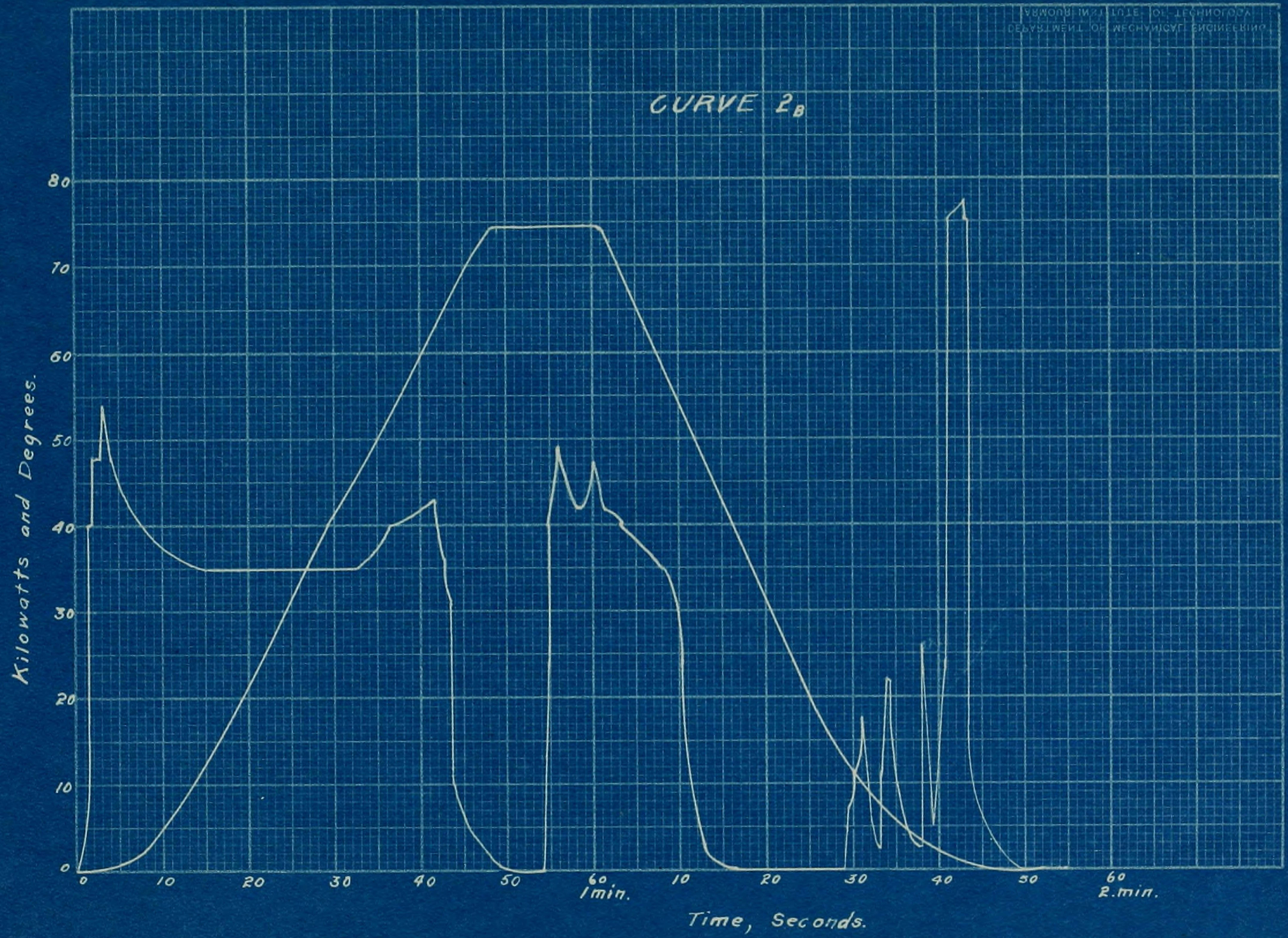
Curves Showing Relation. Between Power and Angle of Leaf. 4/9/18. 11:54 A.M.

East Leaf. Both Motors.



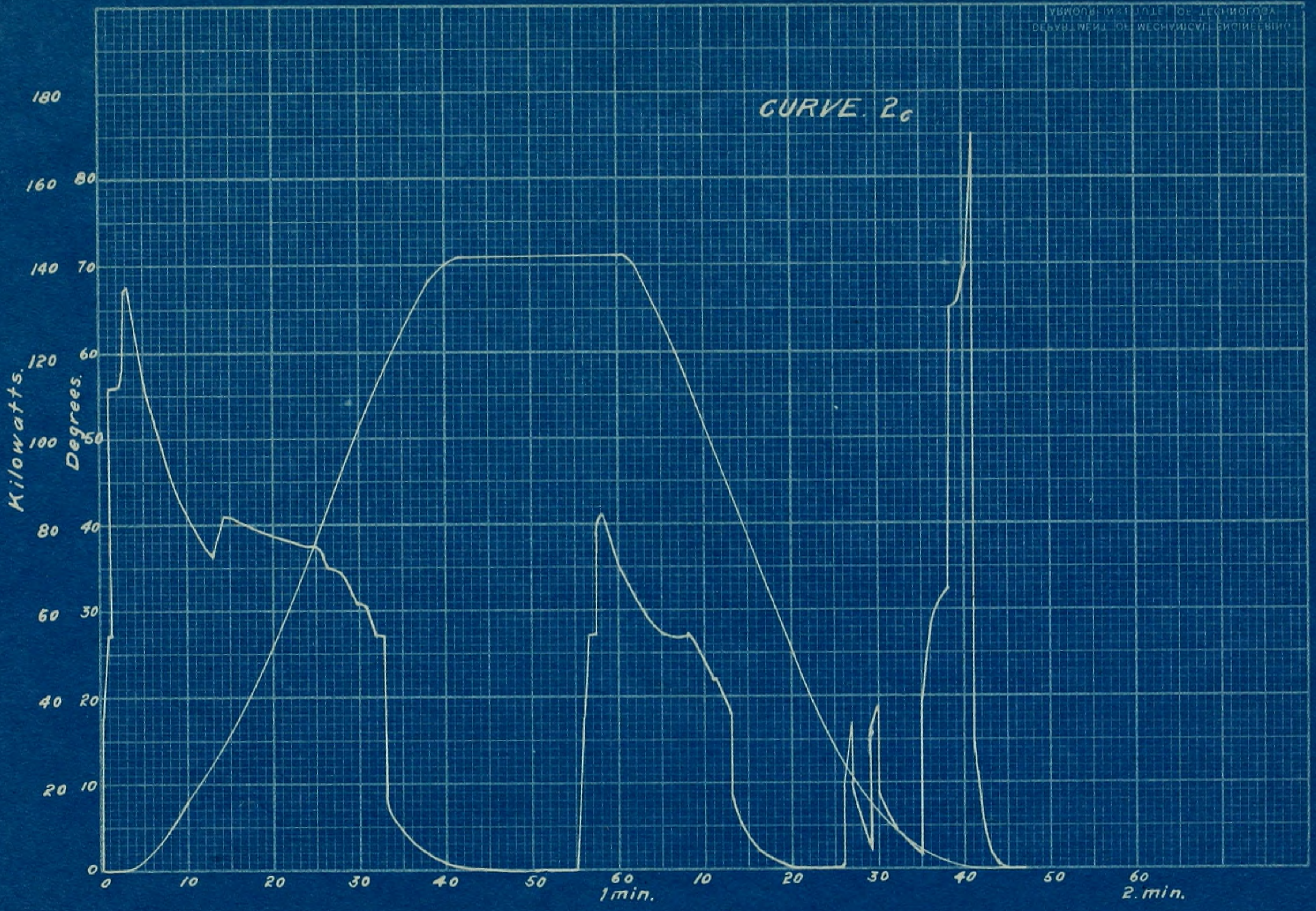
Curves Showing Relation Between Power and Angle of Leaf. 4/11/18 11:20 A.M.

West Leaf N. Motor.



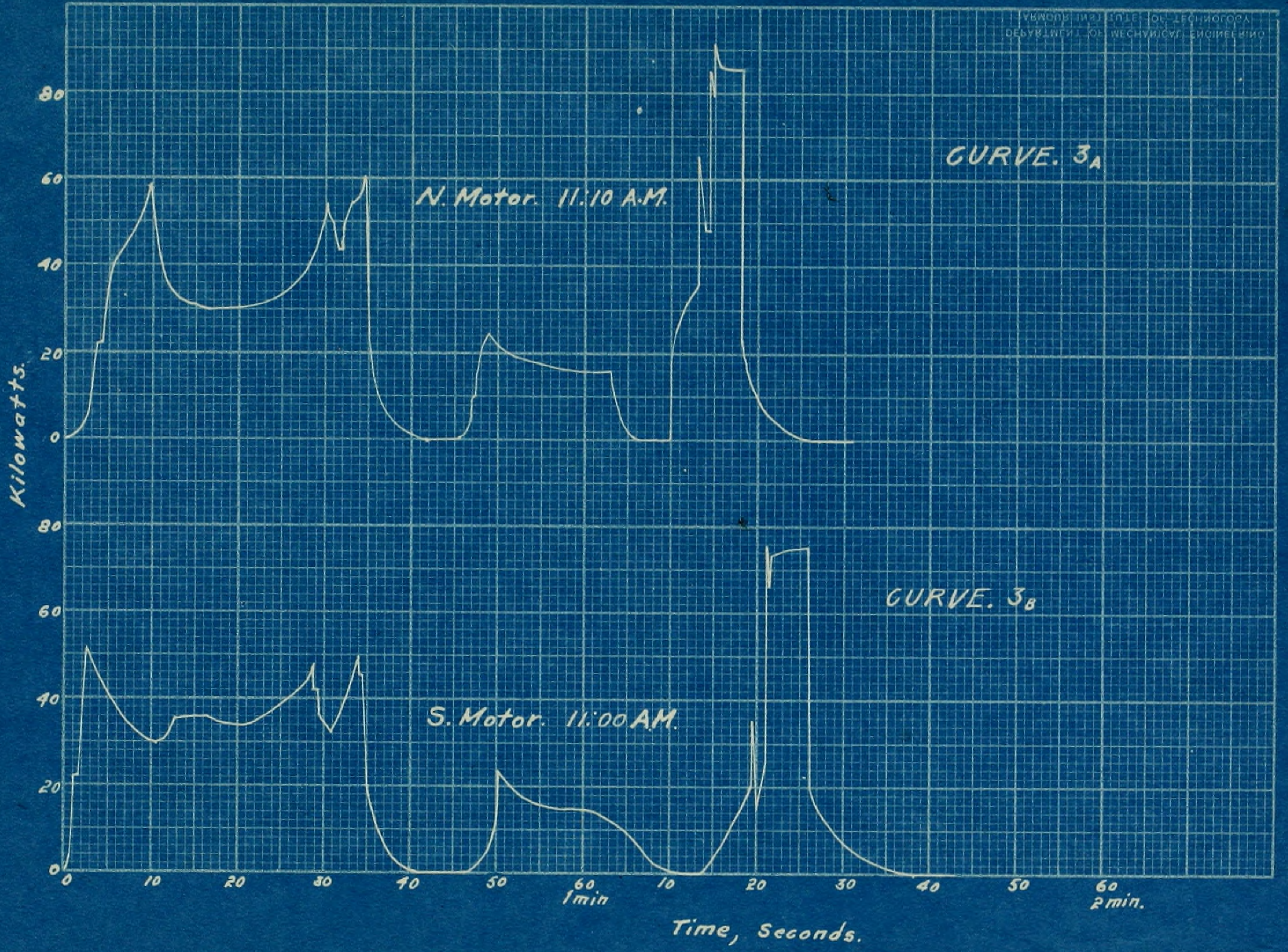
Curves Showing Relation Between Power and Angle of Leaf. 4/11/18 11:50 A.M.

West Leaf. S. Motor.

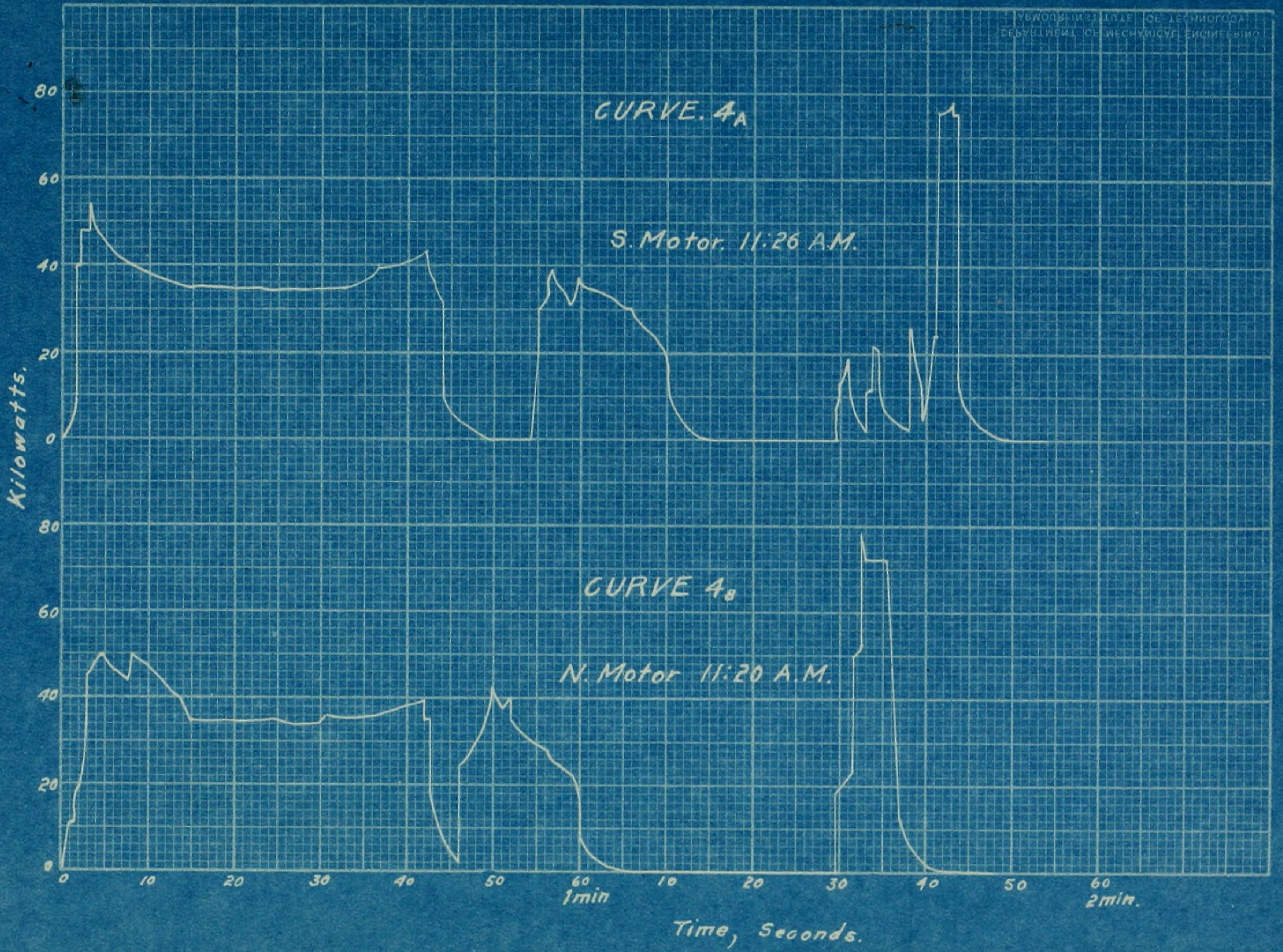


Curves Showing Relation, Between Power and Angle of Leaf. 4/11/18 4:10 P.M.

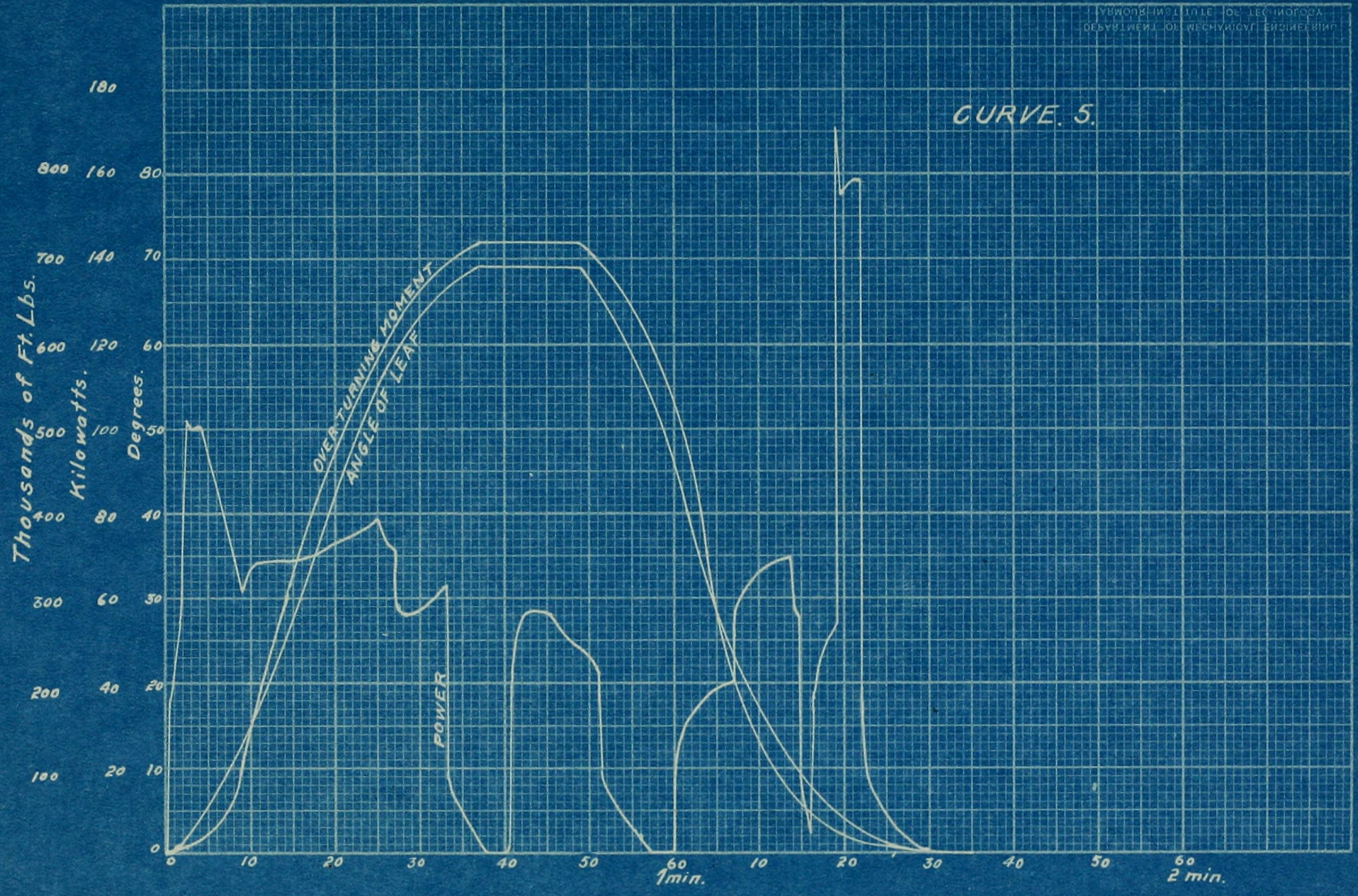
West Leaf. Both Motors.



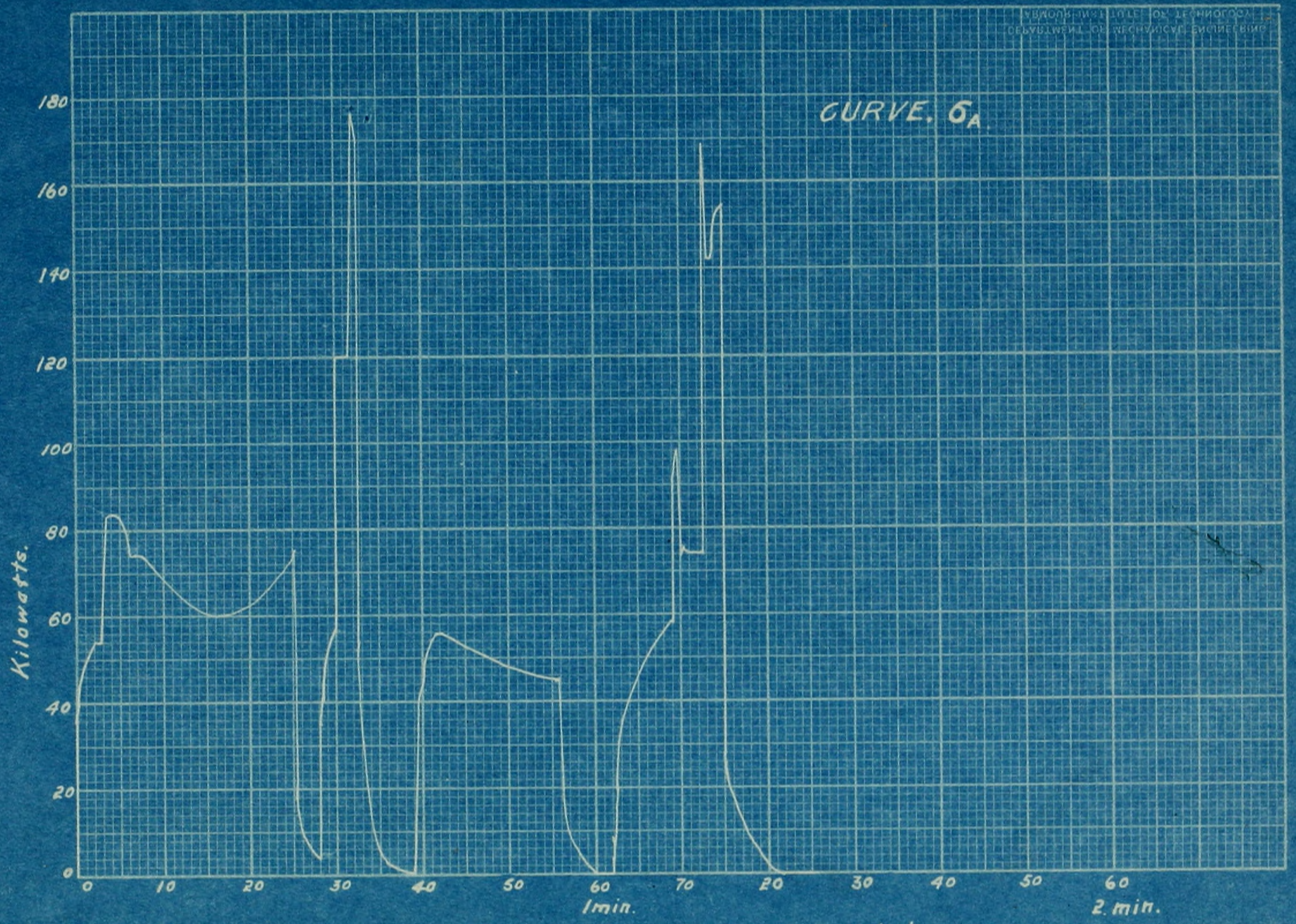
Curves Showing Parallel Operation of Motors. East Leaf. 4/9/18.



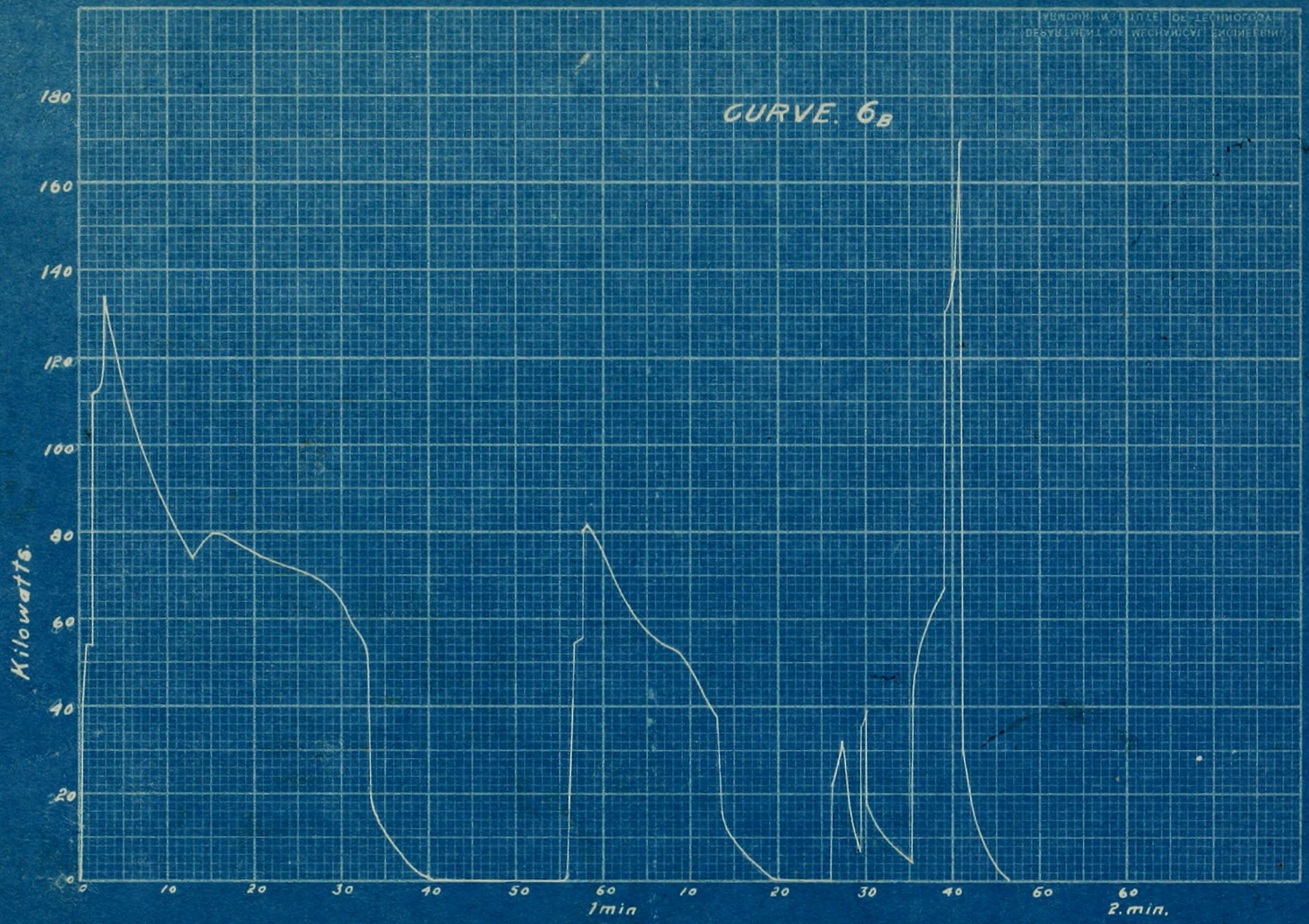
Curves Showing Parallel Operation of Motors. West Leaf. 4/11/18.



Curves Showing Effect of Wind Pressure. V = 22 M.P.H. East Leaf. 4/9/18. 1:10 P.M.



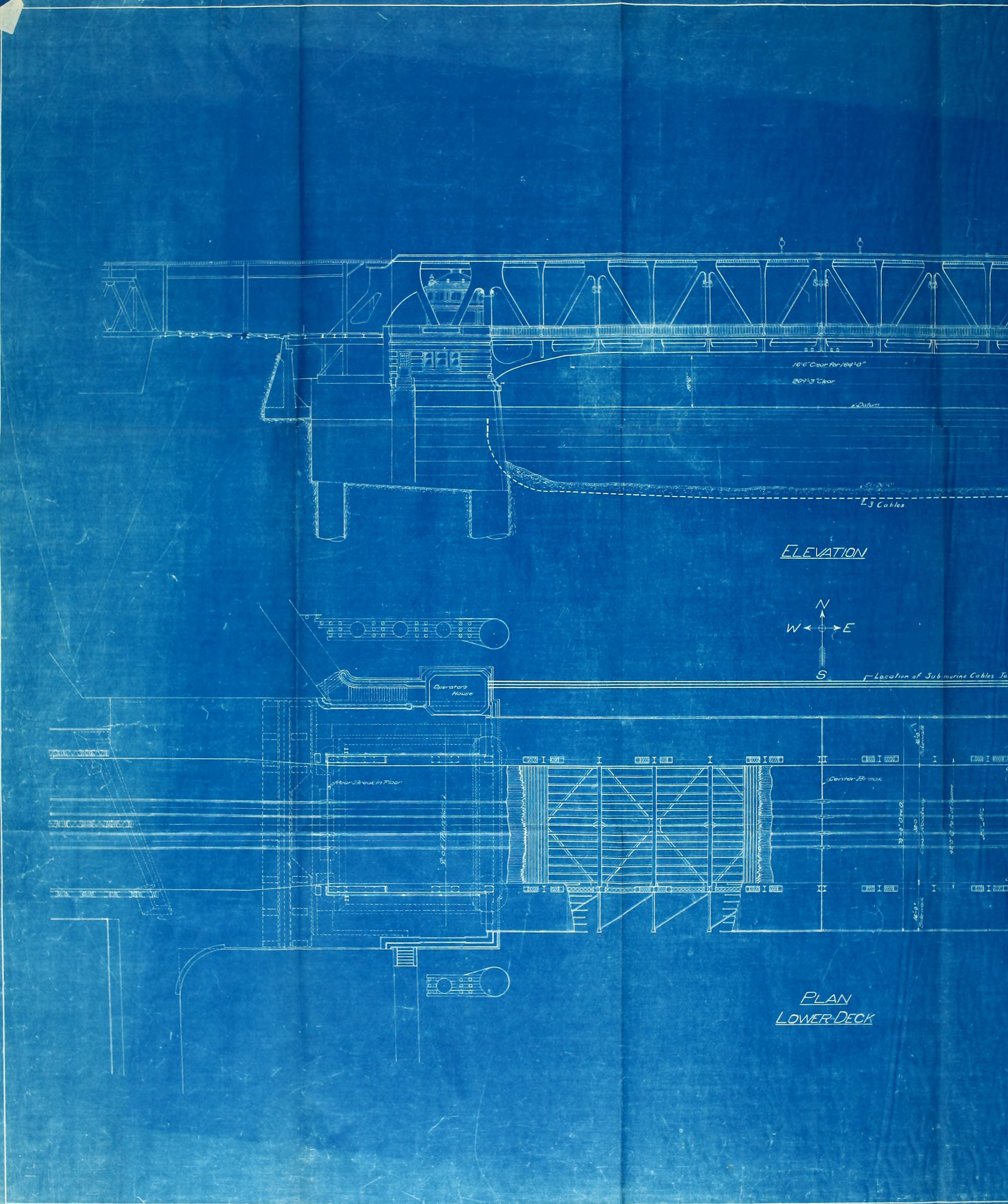
Curve Showing Resistance Steps. East Leaf. 4/9/18. 3:15 P.M.



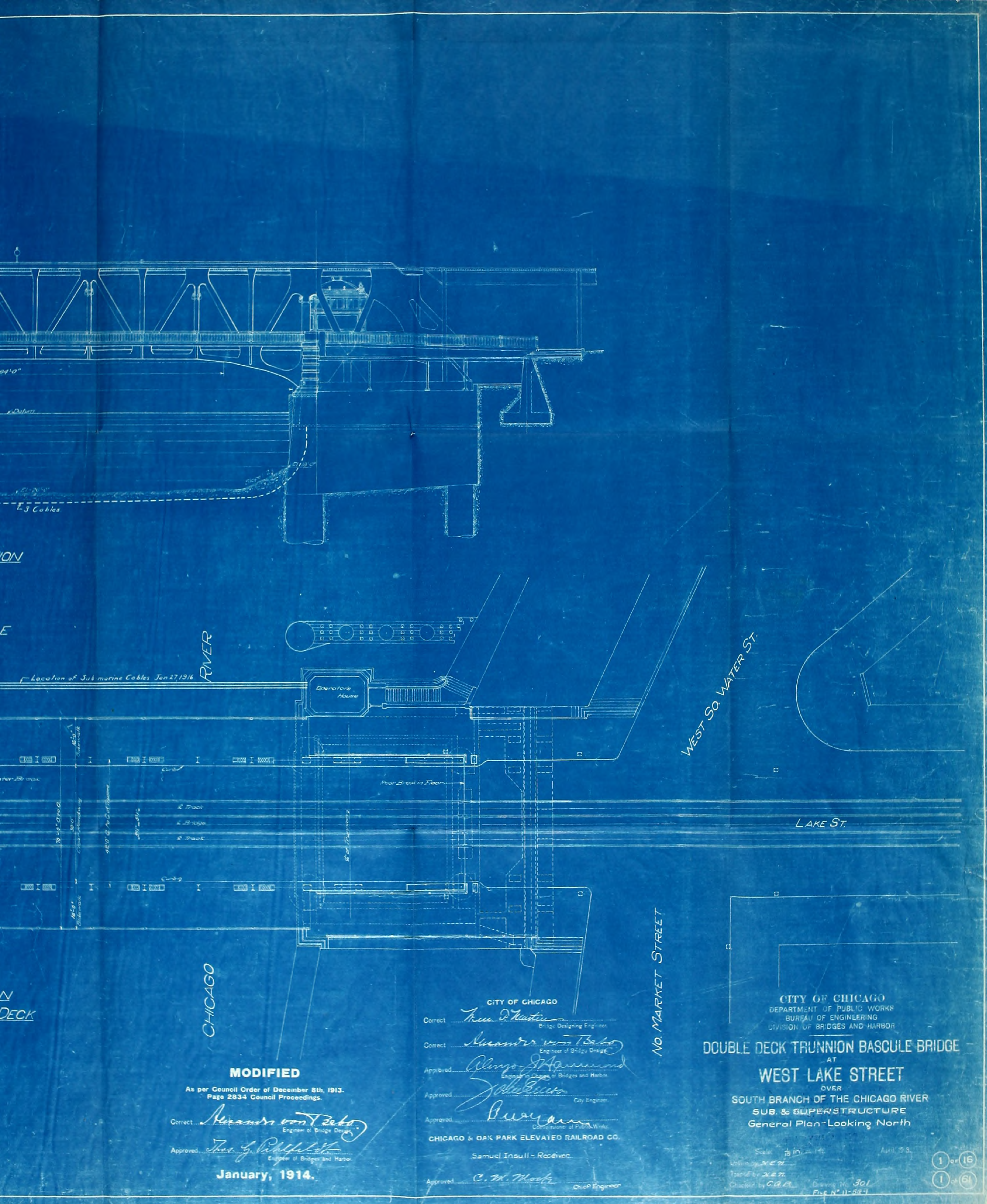
Curve Showing Resistance Steps. West Leaf. 4/11/18. 4:20 P.M.

System of interlocking patented July 29, 1908, by R. M. Gaston
Circuit giving back indication to signal system that bridge is safe for trains. Train signals should be locked at danger while bridge is open and released only after this circuit has been closed.
This switch only to be closed only after signals have been set at danger.
Signals Clear.
Signals Danger.
Main or Leaf Operating G.E. 108 MD, 550V, 100 HP. 530 R.P.M. Series Motors with Electric Controlled Shoe Brakes
South Motor
North Motor
Resistance by Steps
Reversing Contactors
Resistance Contactors
Mech. Interlock
Contactor Controlling Rr.
Brake Contactor
Motor Overload Relays
Main Overload Relay
Red indicator lamps indicate Ry. signals have been set at danger
To East Side Thru Submarine Cable
Emergency Interlock Release Switches
#1 Signal Machine = #18 on Drg. 9961
#2 Leaf Motors = #19
#3 Rear Lock Motors = #20
#4 Center Lock Motors = #21
From Switch 28 See Diagram 9961
From Switch 34 See Diagram 9961
G.P.N. Controllers #25
Left Hand Roadway Gate
Right Hand Roadway Gate
Raised
Lowered
Gate limit Sw.
West. Master #284556
Leaf Operating Motors Controller
Interlock contacts are closed only when contactors are open
Interlock contacts are closed only when contactors are closed.
Raise
Lower
Foot Switch
Coasting
Elev. Ry. Supply 550V.
Street Ry. Supply 550V.
West. 184247 Lightning arrester
Sol. brakes
Pit Pump
7½ H.P. West S.K. 975 R.P.M. Vertical Shunt
West. 3 Pt. Master Signal Ball Controller
Red Ball Signal
2 H.P. 550V. West 1K series Motor
Overload Relay
Aux. Leaf Switch
Leaf Down
All other positions
Rear Lock Controller
Center Lock Controller
West. Master #284445
Lock
Unlock
Reversing Contactors
Overload Relays 20 to 40 Amp Range
Over Load Relays 10 to 20 Amp.
7½ H.P. 550V. 500 r.p.m. West K4 Series Motors
Rear Locks
3 H.P. 550V. 600 r.p.m. West. 2K Series Motor
Center Locks
Neg. Return. To Surface Lines Cable
Unlocked
Rear Lock Limit Switch
Locked
Front Lock Limit Switch
To Submarine Cable
All #14
Note:
All Contactors are Westinghouse Elec. & Mfg. Co. Type "C"
"West" designates Apparatus mfd. by Westinghouse Elec. & Mfg. Co.
"C.H." " " " The Cutler Hammer Mfg. Co.
"G.E." " " " General Electric Co.
"G.P.N." " " " Geo. P. Nichols & Bro.
Approved Hugh E. Young Engineer of Bridge Design
Approved Thos. G. Pihlfeldt Engineer of Bridges
Approved City Engineer
Approved Frank I. Bennett Commissioner of Public Works.
Lake St. Bridge
Ketler Elliott Erect. Co. Contractors
Geo. P. Nichols & Bro. Chicago
245'-3" Double Deck - Double Leaf Bascule Bridge Wiring Diagram
W. Lake St. West Side Chicago
Scale
Date Aug. 11 - 1915
Contract 653
9960
Drawing No. 4852. File No. 15-1-5

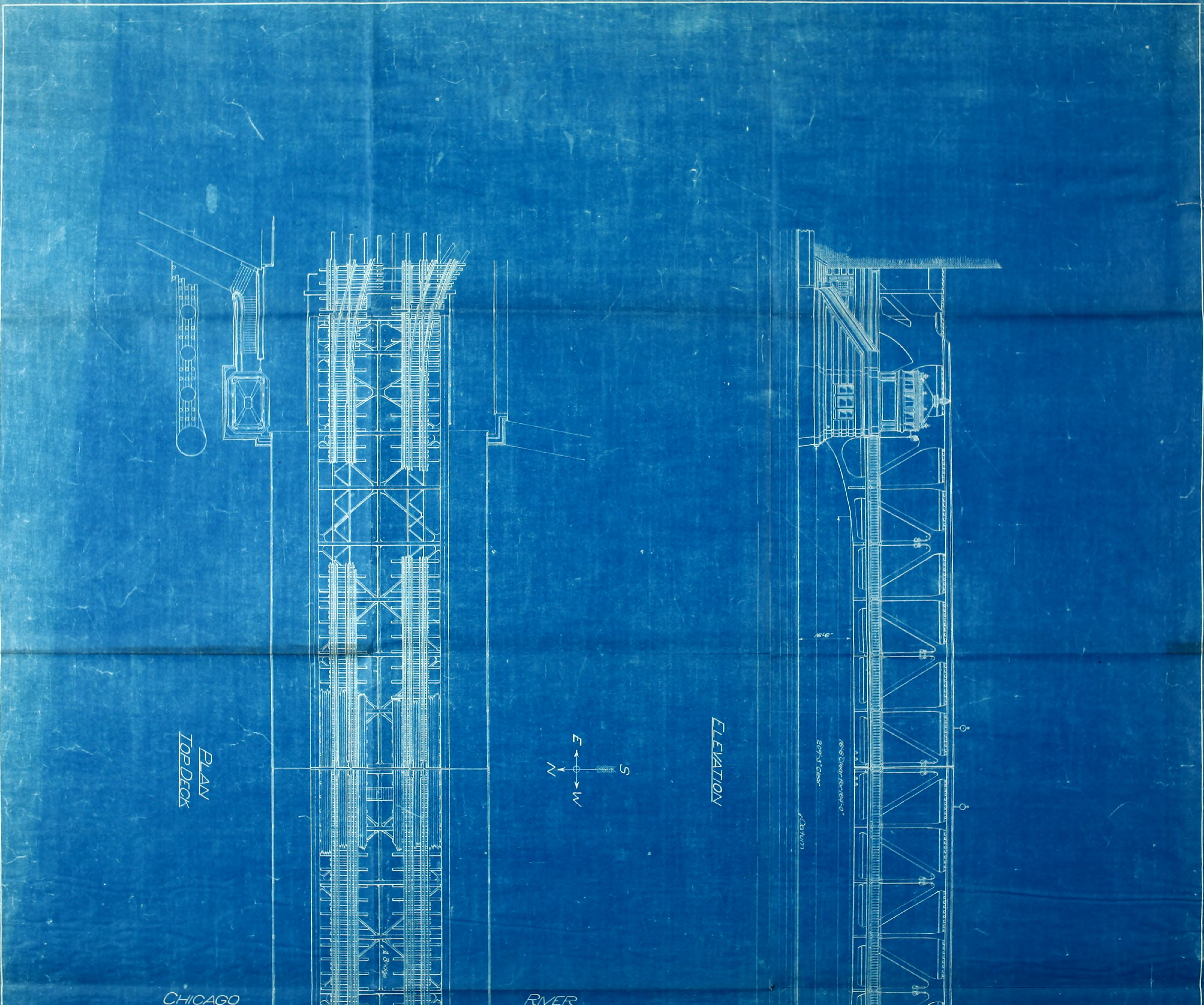

System of interlocking patented July 28, 1908 by R. M. Gaston
Main or Leaf Operating G.E. 108 MD, 550V, 100HP, 530 R.P.M. Series Motors with Electric Controlled Shoe Brakes
South Motor
North Motor
Reversing Contactors
Resistance Contactors
Mech. Interlock
For details of resistance see Drawing (= Wiring Diagram for West side)
10 Frames of West. 8" Grid Resistance - See West. Dwg. 326936
Contactor Controlling R1
Brake Contactor
Motor Overload Relays
Main Overload Relay
750V Weston
600A Weston
West. Master #284356
Raise
Lower
Interlock contacts are closed only when contactors are open
Interlock contacts are closed only when contactors are closed.
Leaf Operating Motors Controller
Foot Switch
Elev Ry Supply 550V
Street Ry Supply 550V
West. 164247 Lightning arresters
Choke Coils
Sol brakes
80A West.
100Amp 600V
Emergency Interlock Release Switches
#1 Signal Machine #18 on Drg. 9961
#2 Leaf Motors #19
#3 Rear Lock Motors #20
From Switch #28 See Diagram 9961
G.P.N. Controllers #25
From Switch 34 See Diagram 9961
Raised
Gate limit Sw.
Lowered
Left Hand Roadway Gate
Right Hand Roadway Gate
2 HP Electric Motors 550V. 1800 R.P.M.
To Light Sw. #33
Raise
Lower
Master #284445
West. 3 Pt. Master Signal Ball Controller
Overload Relay Shunted
West. C-804
2 HP 550V. West. 1K Series Motor
Red Ball Signal
Down Ball Limit Switch Up
7½ HP West SK #30 975 R.P.M. Vertical Shunt
CH 2170
Pit Pump
Rear Locks.
7½ HP 550V 500 r.p.m. West K4-Series Motors
Reversing Contactors
West. C-250 Amp
Lock
Unlock
West. Master #284445
Rear Lock Controller
Overload Relays 20 to 40 Amp Range
Aux. Leaf Switch
Leaf Down
All other positions
Unlocked Rear Lock Limit Switch Locked
Red Indicator Lamps - 1 for House, 1 for Span - indicate Rx Signals have been set at danger.
Red Light Indicators to West Side
To Submarine Cable
Neg. Return To Surface Lines Cable
Note:
All Contactors are Westinghouse Elec. & Mfg. Co. Type "C".
"West." designates Apparatus mfd by Westinghouse Elec. & Mfg. Co.
"C.H." " " " The Cutler Hammer Mfg. Co.
"G.E." " " " General Electric Co.
"G.P.N." " " " Geo. P. Nichols & Bro.
Approved Engineer of Bridge Design
Approved Engineer of Bridges
Approved City Engineer
Approved Commissioner of Public Works
Lake St. Bridge
Ketler Elliott Erect. Co. Contractors
Geo. P. Nichols & Bro.
Chicago
245'-3" Double Deck - Double Leaf Bascule Bridge
Wiring Diagram
W Lake St East Side Chicago
Scale
Date Apr. 29-1916
Contract 853
Drawing No. 4860
REV. Feb. 1-1917

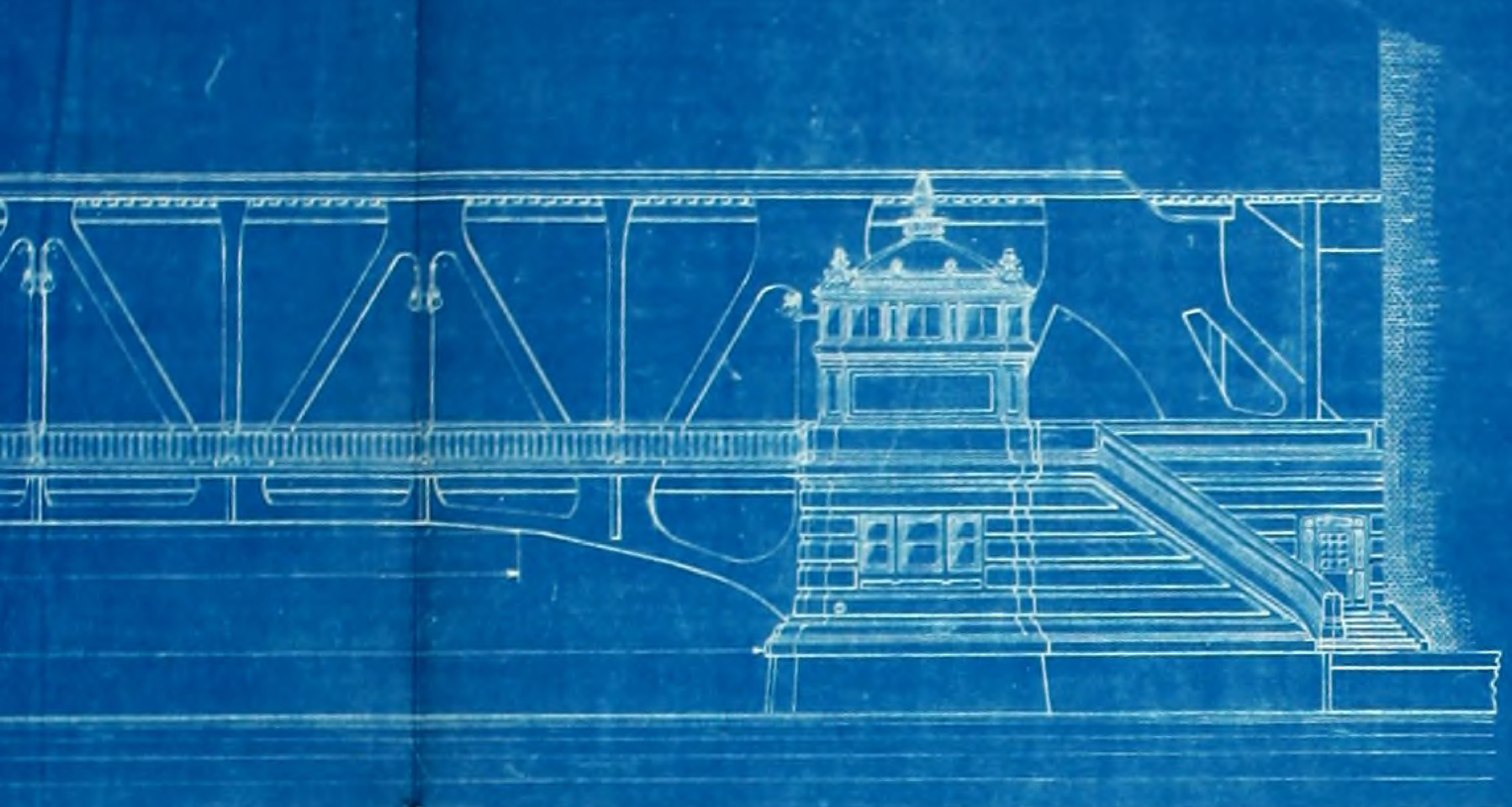


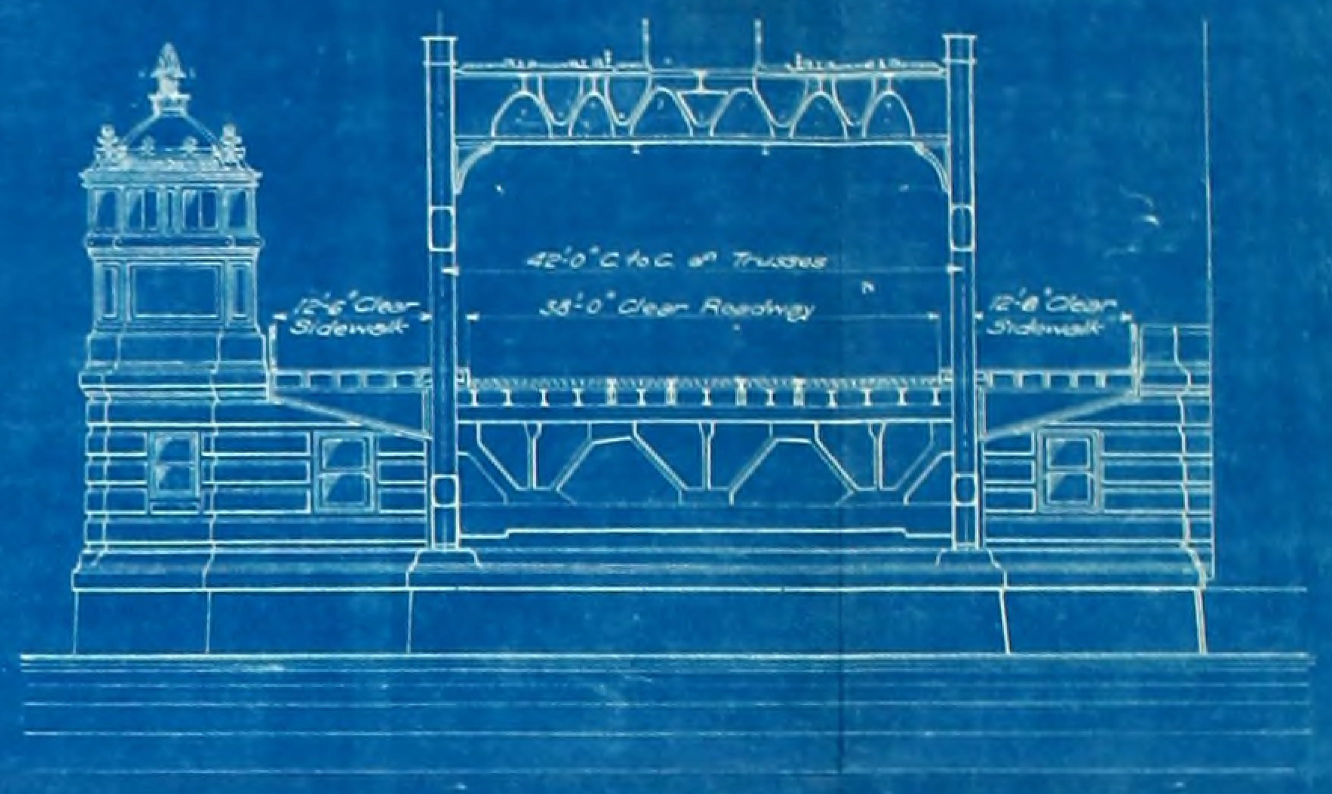
16'-6" Clear for 184'-0"
Datum
3 Cables
ELEVATION
N
W
E
S
Location of Submarine Cables
Operator's House
Center Break
Main Break in Floor
PLAN
LOWER-DECK



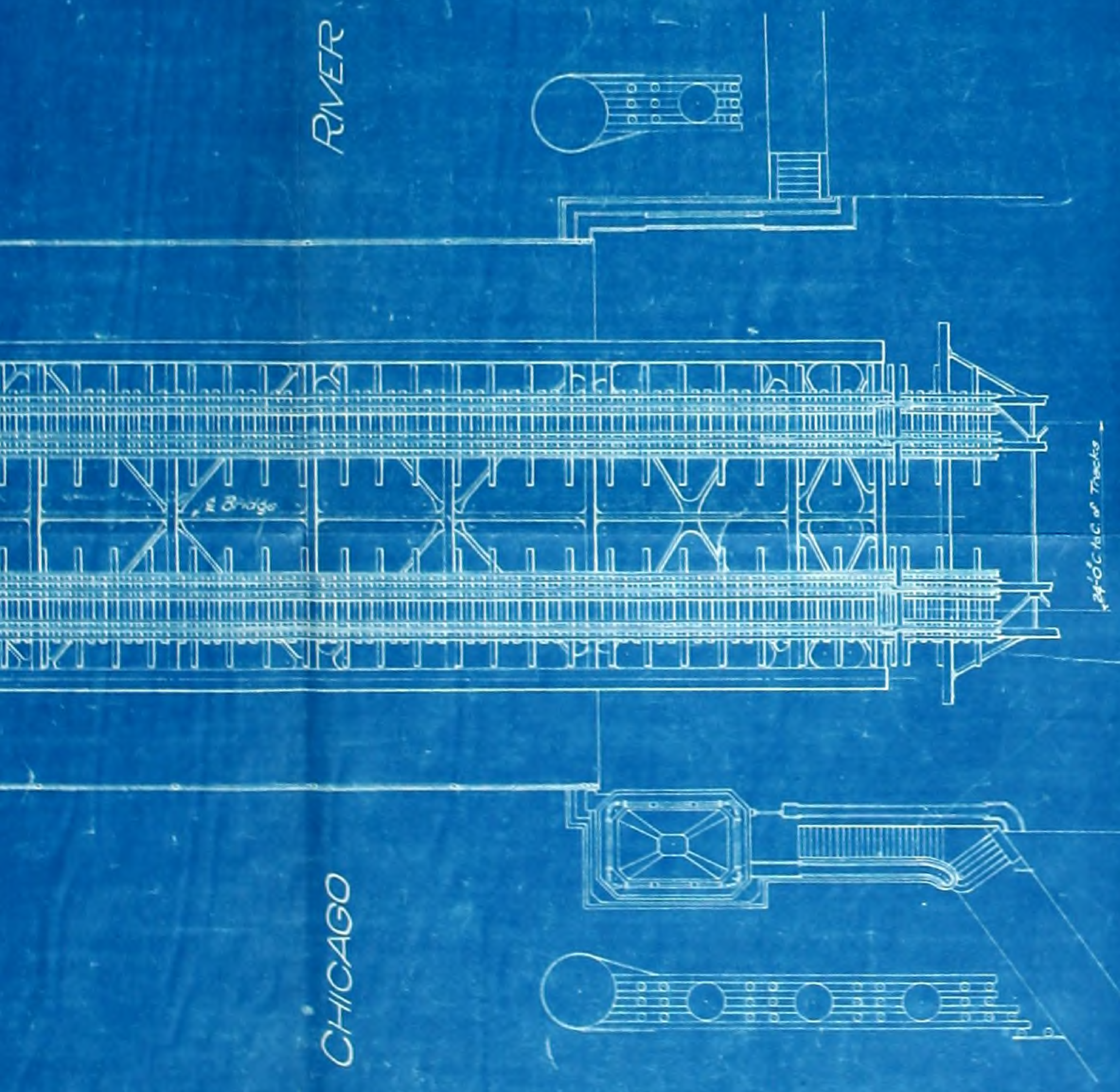
Location of Submarine Cables Jan 27, 1916
RIVER
CHICAGO
Operator's House
Rear Break in Floor
Lake St.
West So. Water St.
No. Market Street
Curb
Track
Bridge
Sidewalk
Clear Roadway
Cables
Datum
MODIFIED
As per Council Order of December 8th, 1913.
Page 2834 Council Proceedings.
Correct
Engineer of Bridge Design
Approved
Engineer of Bridges and Harbor
January, 1914.
CITY OF CHICAGO
Correct
Bridge Designing Engineer
Correct
Engineer of Bridge Design
Approved
Engineer in Charge of Bridges and Harbor
Approved
City Engineer
Approved
Commissioner of Public Works
CHICAGO & OAK PARK ELEVATED RAILROAD CO.
Samuel Insull - Receiver
Approved C. M. Moats
Chief Engineer
CITY OF CHICAGO
DEPARTMENT OF PUBLIC WORKS
BUREAU OF ENGINEERING
DIVISION OF BRIDGES AND HARBOR
DOUBLE DECK TRUNNION BASCULE BRIDGE
AT
WEST LAKE STREET
OVER
SOUTH BRANCH OF THE CHICAGO RIVER
SUB. & SUPERSTRUCTURE
General Plan-Looking North
April 1913
Traced by K.E.M.
Checked by C.G.B.
Drawing No. 301
File No 11-58-1
1 of 16
1 of 61


PLAN
TOP DECK
ELEVATION
E
S
N
W
16'-8"
Datum
CHICAGO
RIVER





SECTION



MODIFIED

As per Council Order of December 8th, 1913.
Page 2834 Council Proceedings.

Correct ______ Engineer of Bridge Design

Approved ______ Engineer of Bridges and Harbor

January, 1914.

CITY OF CHICAGO

Correct ______ Bridge Designing Engineer.

Correct ______ Engineer of Bridge Design

Approved ______ Engineer in Charge of Bridges and Harbor.

Approved ______ City Engineer.

Approved ______ Commissioner of Public Works.

CHICAGO & OAK PARK ELEVATED RAILROAD CO.

Samuel Insull - Receiver

Approved ______ Chief Engineer

CITY OF CHICAGO.
DEPARTMENT OF PUBLIC WORKS
BUREAU OF ENGINEERING
DIVISION OF BRIDGES AND HARBOR

DOUBLE DECK TRUNNION BASCULE BRIDGE
AT
WEST LAKE STREET
OVER
SOUTH BRANCH OF THE CHICAGO RIVER
SUB. & SUPERSTRUCTURE
General Plan-Looking-South

Scale: ⅛ in = 1 ft. April, 1913

Drawn by H.E.M.

Traced by H.E.M.

Checked by C.O.B.

Drawing No. 302

File No. 11-56-2

2 of 16

2 of 61