BERGERT

Review of the Hydro Electric Power Plant at the Rock Island Arsenal

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REVIEW OF THE HYDRO ELECTRIC POWER PLANT AT THE ROCK ISLAND ARSENAL

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HENRY AMOS BERGERT

ENTITLED REVIEW OF HYDRO-ELECTRIC PLANT OF ROCK

ISLAND ARSENAL

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering

Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering

The purpose of this thesis is to present a complete review of the Rock Island Arsenal hydro-electric power plant, which furnishes the power for the largest of the government arsenals. This Arsenal is situated on an island, comprising about(990) nine hundred and ninety acres of land, in the Mississippi river opposite the city of Rock Island, Illinois(see map in the appendix). It is there that the Ordinance Department of the United States Army produces the siege and field gun carriages, caissous artillery harness, and all equipments of the infantry and cavalry soldier, and also the new army rifle.

Besides geographical considerations the selection of this sight for this Arsenal was due to the fact that the rapids of the Mississippi at this point invited the development of a waterpower. Altho the head is low, the large volume of water furnishes power amply sufficient for the needs of a large manufacturing plant. It is well at this point to describe the work of the development.

Development of the Water Power.

Reference must be made to the map in the Appendix. From the map one will see, that there are two power dams, one for the Arsenal plant, and another for the Moline plant owned by the Peoples Power Co., of that city. Both plants have the benefit of the water power development. The rapids between the foot of the Island and the head of the wind dam have a fall of about (11) eleven feet. This is a moderate fall, but the immense volume of water of the Mississippi makes possible a large amount of power. The wing dam, as it was originally, extended only a short distance from the end of the Island, but in the summer and fall of 1899, it was extended about two miles to the Duck creek chain of rapids. An appropriation of $45,000 for this work having been obtained from Congress. This enterprise proved a great success, securing

an increase of head of about (3 ½) three and one-half feet and a volume of water which could not be materially diminished even when all the gates of the two power dams were simultaneously opened.

An appropriation from Congress providing, for a lock for the river-boats to enter the harbor of Moline, makes it possible to increase the head by two feet, providing this wing dam is strengthened and its height increased. This lock is to be situated on the north side at the upper end of the Island; the red lines on the map indicate the position of this lock.

After the wing dam extention had been completed, attention was next directed to the tail races below the power dam, and under an appropriation of $97,000 granted by Congress for this purpose, the channel below the Arsenal dam was excavated, mostly in rock, to a depth of three feet below the low water-mark and a width of (410) four hundred and ten feet at the dam, narrowing farther on to (180) one hundred and eighty feet and extending to the junction with the canal thru the Sylvan island, which forms the tail race from the Moline power dam. A similar piece of work was done on this canal in the fall 1900 and completed the next year, and then the united channel extended, with a width of (350) three hundred and fifty feet thru the slough of the island until it reaches deep water below the viaduct connecting the Arsenal island with the city of Rock Island. For this extention congress made an additional appropriation of $130,500. The completion of this work came this year when the upper end of the coffer dams just below the street car bridge was blown out on New Year's day by a charge of (100) one hundred pounds of dynamite, altho the part of the coffer dam extending parallel to the course and in the middle of the river still remains, it will be taken off this Spring and the part below the line (a b) see map dredged. On the map red lines indicate the location of coffer dams used in connection with the excavations

and a description of these dams will be found in the Appendix. The total cost of this work was $272,000.

About eleven years ago the government dam was reconstructed. The new dam, built of stone provided for (41) forty-one openings for the water wheels. At first only eight turbines of old type were installed, being much inferior to the modern wheel, only (250) two hundred and fifty horse-power from the entire plant.

This was sufficient for the limited operation of the Arsenal at that time, but when the Spanish war was declared steam power was required, greatly increasing the cost of the operating the Arsenal.

The old turbines have now been replaced by modern ones, of the Samson Leffel type. A description of these and their installation will be given later. In order that the dam could be utilized for this new machinery, the upper part had to be reconstructed, the tail race below excavated, and such provisions as were practicable, or advantages were made for future addition of six more turbines, which are now installed, and additional, larger generator also. When increasing the width of the top of the dam between the counterforts when reconstructing the machinery, the work was designed and performed with the idea, that best economy would be secured by installing in the power machinery all improved devices and constructing the harness or frame work for the turbines, the vertical and the horizontal shafts and the gearing also, with strength, rigidity and accuracy. Altho this greatly increased the first cost, this has proven to be a wise plan.

Previously to the electrical transmission of power, rope transmission was used. General Flagler was in charge at that time, and had decided to run a heavy shaft under the South row of buildings as far as shop(c) and to operate this by wire rope transmission from a shaft located at the dam and driven by four (65) sixty-five inch turbines. Five intermediate towers were

erected carrying sheave wheels. Nearly all of this work was done at the Arsenal..The distance from the driving to driven shaft was something like 1,800 feet. General Rodman previous to this,had advocated the use of compressed air but this was never tried. The wire rope transmission was never intended as a final solution and was replaced by the electrical transmission,for not only was this apparatus overtaxed,by the increased number of machines in the shops,but no provision had been made for the North row of shops. Therefore,when the new small arms plant was established,it became at once necessary to provide power for the operation of its machinery. Moreover,the wire rope transmission required frequent repairs.

The replacement of electrical power transmission power transmission power for the wire rope transmission made necessary the installation of an electrical plant and required the removal of the wire rope and its sheave wheels and towers and required also,a considerable expenditure. Its construction,however,was undertaken,including the reconstruction of the power dam and house, and the installation of the new turbines.

General Description of the New Plant.

Before a start could be made on the new work,it was necessary to strip the dam of all old shafting,to take out the old turbines,to remove the penstock floors and to prepare the top surface of the dam for the new machinery,as already has been mentioned. To facilitate the removal of the old turbines and install the new ones,a cofferdam was built reaching from the shore to a point about (300)three hundred feet out on the dam.

On Monday,April 2,1900,the use of the water power was discontinued and the work on the new electrical plant commenced; yet on April,1,1901,a year later,the new plant was in actual

operation.

At first (14)fourteen turbines and two generators of 500 K.W.each,were installed,but about a year and a half later,six more wheels and one more generator larger then the other two,being of 650 K.W.capacity,were installed. This brought the aggregate horse-power up to 2,500.

The power is furnished by (20)twenty turbines,which can be run in groups of seven for the two outside generators,which,for the middle generator,six run with the generator,in conjunction with either end turbines of dam forming the floor of the wheel house,runs the horizontal shaft(see plates 1 and 2)also floor plan,in the Appendix). To this shaft the turbines are connected by a vertical shafts and bevel gears. The cogs of these gears are made of hard maple and thus the gears run almost noiselessly. The length of this shaft is (380) three hundred and eighty feet and is in three main sections,so that any one of the three generators may be operated independently,or three units run in unison. But the generators are,however,operated in parallel, sothat the shafts are not directly coupled,altho they appear to be when all units are in operation since,they all run at the same speeds. The diameter of this horizontal shaft ranges from (7 15/16) seven and fifteen sixteenths,down to (5 7/16) five and seven sixteenths inches at the exciter ends. The two end sections of the shafting to which the exciters are directly connected,are provided with magnetic clutches,by means of which they can be connected with the remainder of the shafts. These have been found to operate satisfactorily except for the rather unpleasant rattling noise that they produce. The generators like the exciters are directly coupled to the shafts.

At the west end or head of the building are located the two switch boards of which a more detailed description will be presented later.

Installation of Turbines.

The following description of the installation of the turbines is an extract from the "Report on the Installation of the New Plant for Generation at Electrical Transmission of Power at the Rock Island Arsenal" by W.S.Pierce,Captain Ordinance Department U.S.A.Commadning officer R.I.A.,May 7,1951. It must be noted that this report was made after two generators and (14) fourteen turbines were in operation,but since then,the other six turbines and generator has been installed,but the turbines being different only in capacity,this extract applies to them with the one exception mentioned.

" The sides of the penstocks in which the turbines are placed are formed by the stone counterforts supporting the wall of the dam which are (13)thirteen feet apart and,at the height of the penstock floor,project to the rear(18)eighteen feet (6)six inches. The rear side of each penstock is closed by a boiler-plate partition riveted to angles bolted to the counterforts and extending from the floor to the spring line of the arches which form the top of the dam. To permit of emptying a penstock for repairs,the tailrace opening below the floor can be closed by means of two iron panels sliding in vertical grooves.

Each of the flume openings has an area of(58) fifty-eight square feet,an amount barely sufficient for the new wheels, but which the construction of the dam did not permit of increasing. They can be closed by sliding panels operated from the front of the dam.

Each of the eight flume openings in previous use was provided with a separate screen or grating to keep out driftwood, which was attached to the face of the dam immediately in front of the opening. These screens materially reduced the area of the openings, and were therefore replaced by a continuous screen extending from the first to the seventeenth penstock. This screen is made in rectangular sections (16) sixteen feet in length, the frames of which consist of (5) five inch steel channels. To the top and bottom channels are riveted the ends of ($1\frac{1}{2}$) one and one-half by (3/8) three-eighths inch iron bars forming the grating, which are placed on edge (2) two inches between centers and are held in line by separator bolts. The end channels of each section are prolonged above the top channel and are fitted at their upper ends with eye lugs, by which they are hinged to eyebolts secured in the wall of the dam just below the corbel at the top. The lower end of the screen rests upon the bottom of the pool about (15) fifteen feet from the dam, making an angle of about 45° with the horizontal. This arrangement carries the grating well out in the front of and away from the flume openings, with the result that, while the requisite protection is secured, the inflowing water is not appreciably obstructed.

The hinge attachment renders the work of putting the screen in place a simple and comparatively inexpensive operation. Each section was brought opposite its position on a scow, and after the hinge connection was made the lower end was let down by a block and tackle until it rested on the bottom. As the sections are not connected, any one of them can similarly be raised when necessary, for repairs.

In order to obtain the area of discharge beneath the

the penstock floors required to utilize the full power of the turbines,the floors were raised (21)twenty-one inches above the old position,bringing them flush with the sills of the flume openings. These floors consist of a framework of timbers (12) twelve inches square,supported by (4)four small cast-iron pillars and covered with (3)three-inch plank,all of yellow pine. The screen and all metal work in the penstocks received two coats of preservative paint,and thw woodwork in like manner was thoroughly covered with tar.

The (14)fourteen water wheels installed are (50)fifty inch horizontal turbines of the Samson-Leffel type,of which (7) seven are right-hand and (7) seven left-hand.

In setting these wheels there were several conditions to be satisfied which were to some extent conflicting. One of these required that the lower ends of the casings be immersed (3) three inches in the lowest standing tail water,while another demanded that the area of discharge below the floor,none too large at the outset,be diminished as little as possible. At the same time,it was of course desirable that the wheels be placed so as to utilize the full head of water.

These conditions were met by setting the wheels so that the casing flanges rest upon wooden curbings (15)fifteen inches above the floor. In this position the bottoms of the casings project only about (3)three inches below the floor timbers and will be immersed the required (3)three inches at the lowest stage of water recordedin the tailrace during the last five years. Fifteen inches of head is thus lost,but it is believed that this does not indicate a loss of power because,were the wheels placed lower,the area of discharge would be correspondingly reduced and the

efficiency of the wheels diminished.

The wheels are connected to the main horizontal shaft above by steel jack shafts,(6)six inches in diameter,which are coupled below to the wheel shafts and on their upper ends carry mortised motor gear wheels meshing into cast-iron pinions mounted on the main horizontal shaft.

Details of Shafting,Upper and Lower Harness,etc.

The main horizontal shaft and the vertical jack shafts run in bearings which are supported by frameworks of steel and iron and shapes called the upper and lower harness. The lower harness is placed in the penstocks and affords a point of support for each vertical shaft between its connection with the turbine shaft and the bearing near its upper end. It consists of two parallel (35) thirty-five -pound steel channels,the ends of which are firmly embedded in the counterforts,connected by a cast-iron bridge tree which supports the bearing. In the lower end of this bearing is screwed a stuffing box to retain the oil that would otherwise ecape too freely.

The upper harness rests upon the top of the dam and supports the bearings of the main horizontal shaft and also the upper bearings of the vertical shafts. It is formed of parallel cast-iron I-beams,partially embedded in concrete,connected by heavy cast-iron bridge trees,to which the upper jack-shaft bearings are attached,and by curved yokes upon which the bearings of the main shaft rest.

The entire weight of each jack shaft and its mortised gear,about 7,000 pounds,is carried on a substantial roller bearing placed just beneath the upper bearing,thus relieving the wheel step of this weight and materially reducing the friction. Oil is fed to the upper bearing through an axial hole leading from an

oil cup in the upper end of the shaft. After leaving that bearing it flows down the shaft, passing through the roller bearing in vertical grooves, and is used again in the lower bearing.

The main horizontal shaft is of forged steel and consists of sections varying in length from (20) twenty to (13) thirteen feet and in diameter from (7 15/16) seven and fifteen sixteenths to (5 7/16) five and seven sixteenths inches. The order in which these sections were placed depended upon the relative arrangement of the generators and water wheels, which is as follows: Starting from the west end, water wheels are installed in penstocks Nos. 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16. Over penstocks Nos. 5 and 12 are placed two generators. As wheels Nos. 1 and 14 are intended chiefly for the use of exciters, it will be seen that this arrangement places each generator in the center of its group of six wheels. To permit, however, the use of any or all wheels with either generator, the main shaft between the two generators is of the maximum diameter throughout, viz, (7 15/16) seven and fifteen sixteenths, but from the generators to the ends of the line the successive lengths are stepped down. The different sections of this shaft are joined by cast-iron flanged and bolted couplings, each provided with a separator plate three-eighths of an inch thick. Ordinarily the center coupling is disconnected, separating the system into two units, but the division can easily and quickly be made at any other point when so desired.

The main shaft rests in (34) thirty-four self-oiling bearings, which are bolted on the tops of the yokes of the upper harness. These bearings have a length of three times the diameter of the shaft and are spaced so as to support the shaft close to

the pinions and couplings. The total length of the shaft is (250)two hundred and fifty feet (6½)six and one-half inches.

In the data supplied by the manufacturers of the water wheels,the speed of the wheels at full gate was given as (90) ninety revolutions per minute. It was decided that the speed of the main shaft should be 200 revolutions per minute,and the bevel gearing was proportioned to obtain this on the assumption that the speed of the water wheels would be as stated. This,the practical operation of the plant,has proved correct,the exacted speed having been easily developed and maintained.

The end thrust of the shaft resulting from the effort of the gearing is reduced to a minimum by balancing the right and left hand turbines. Whenhowever,an odd number of wheels are in use the system will not be balanced,and to provide for this contingency,adjustable ballbearing thrust collars have been placed against bearings on both sides of each generator. These collars also divide the shaft,as concerns the effect of expansion and contractions,into four sections,in each of which the movement proceeds from the center and is consequently much less disturbing than would otherwise be the case. The end sections to which are coupled the exciters are likewise fitted with thrust collars of similar design.

Speed Regulation.

The turbine gates are swung by means of vertical gate shafts extending from the wheel casings up through the top of the dam and there connected so that they can be operated either separately by hand or in groups by power automatically controlled by speed governors. For the former method there is provided for each wheel a short hand wheel shaft carrying a pinion which meshes

into a spur gear keyed on the vertical gate shaft. The ratio of the gearing is such that five turns of the hand wheel fully opens or closes the gate. The automatic power control is applied through a horizontal shaft on which are mounted worms which engage in loose worm wheels on the gate shafts. By means of toothed clutches,operated by foot levers,the worm wheels can be locked to the gate shafts when the power control is desired,or released for hand operation.

For power control the wheels are divided into three groups,two of four wheels and one of six wheels,corresponding to the divisions in the line made by the generators. In the center of each group a small motor is placed and connected to the horizontal shaft by a worm and worm wheel,the former coupled direct to the motor shaft."

The governors used for controlling the speed,or what amounts to the same thing,opening of the gates,are the 1902 Horizontal Model Governor of the Compensating Type manufactured by the Woodward Governor Company of Rockford,Illinois. It was the fly ball principle,that is,is the fly balls go apart,the gates are automatically closed,or as they drop again the gates are opened. This governor acts very sensitively keeping the speed fairly constant at 200 R.P.M.

" On the walls,near the wheel,is placed a vertical scale upon which a weighed pointer attached to a wire cord wound around the hand wheel shaft indicates the position of that gate. Each of the two main divisions of the line is provided with a tachometer for recording the speed of the shafting."

Electrical Machinery and Apparatus.

The following specifications were handed to bidders,

for furnishing the required electrical units,switch-boards and other accompanying apparatus.

Specification for generator,motor etc.,for installation of electrical power transmission plant at Rock Island Arsenal Illinois.

"All apparatus and appliance furnished under these specifications are to be delivered f.o.b.cars at Rock Island Arsenal, Rock Island,Ill.

Broken,missing,or defective parts must be replaced free of charge by the contractor.

A careful inspection will be made of all articles delivered,and those not found first-class in every particular will be rejected.

Bidders will bid on each of the following items separately.

1.Generators.

Two(2) multiphase alternating current generators, sixty(60)cycles,direct-connected type,each of 500 K.W.capacity. The voltage at full load must not be less than 440 nor more than 600. The speed must be 200 R.P.M. Each generator will be provided with a suitable base and two bearings for the rotating element. The latter will be mounted on a hollow shaft,or quill,as shown in the accompanying blue print. The bearings must be self-oiling , self-aligning,and provided with sight-feed oil gauge glasses and drain cocks. The quill must be an open-hearth steel forging of ample strength and stiffness. It will be smoothbored to a diameter sufficient to give a proper clearance to the seven and fifteen sixteenths(7 15/16) inch shaft which passes through it. The outside will be finish-turned its entire length concentrically with the bore. The outside diameters are not prescribed,except that the

seat of the hub of the rotating element shall be greater in diameter than the remainder of the quill by twice the depth of one keyway.

The nonrotating element must be designed to permit of a side movement sufficient to allow of easy inspection and repair of the rotating element.

The blue print mentioned above shows the location of the generators and the space available. The dimensions of the quill noted thereon are included simply for convenience and are not prescribed.

2.Exciters.

Two(2) exciters, each of ample capacity to fully excite both generators. It is proposed to connect the exciters to the line shaft, one at each end, either directly as shown in the attached blue print or by gearing. This shaft will run 200 R.P.M. Bidders may, however, in addition, suggest other arrangements if they so desire.

Each exciter will be provided with a wooden sub-base and two bearings, all bearings to be self-oiling, self-aligning, and supplied with sight -feed oil gauge glasses and drain cocks.

It is desired that the generators and exciters be as nearly automatic in regulation as possible. Bidders will therefore explain how this result is secured with the apparatus which they propose to furnish and also any peculiar advantage claimed for such system.

3.Switch Board.

A switch board of suitable size of black enamel, slate or marble, complete with all necessary indicating instruments, switches, and other appliances necessary for the convenient and

and proper manipulation of the generators and exciters,it being understood that the same are to be operated in parallel. The switch board will be mounted in a frame to be built of angle iron, with necessary turn buckles and clevises,and fitted with all connections at back and with rheostats for controlling generators and exciters. The switch board must included a feeder panel,which must be equipped with two 500 K.W.main switches,and the necessary circuit breakers,ammeters,and wattmeters.

4. Motors.

The following 60-cycle induction motors to be run by the generators above mentioned. All motors will be furnished without sub-bases or rails,and fitted for attachment to walls and ceilings.

The bidder to whom the contract for any number of these motors may be awarded must be prepared to furnish them with bearings arranged for attachment to ceilings where so desired.

Instead of a belt pulley each motor will be supplied with a rawhile pinion of the smallest diameter sufficient to transmit 150 per cent of the rated capacity of the motor.

Bidders must specify the price of single motors of each of the different sizes enumerated,both with and without automatic starters for compensators.

List of Motors.

2 3 H.P.motors.	5 20 H.O.motors.
3 5 H.P.motors.	7 25 H.P.motors.
2 8 H.P.motors.	2 30 H.P.motors.
19 1D H.P.motors.	9 40 H.P.motors.
8 15 H.P.motors.	5 50 H.P.motors.

All bearings furnished with the generators,exciters, and motors must be able ,when supplied with proper oil,to run continuously for 24 hours without undue-heating.

The generators, exciters, and motors will be painted with enamel paint of a color to be selected by the commanding officer.

Information Required.

It is essential that the following points be fully covered in each proposal, reference being made to the items by number in the order following (data required concerning generators to be based upon noninductive load):

1st. Speed of generators and motors at full-rated load (slow speed is preferable for motors).

2nd. State whether two-phase or three-phase, and advantages claimed for whicheveryou propose to furnish.

3rd. Rated full load voltage of generators.

4th. Give dimensions of quill and length of quill bearings.

5th. Voltage required at motor terminals.

6th. State whether generators are revolving field, or revolving armature, and the advantage claimed for the kind bid on.

7th. State amperes per phase at rated full load voltage.

8th. State inherent regulation of generators under variations of either inductive or noninductive load, taking power factor for inductive load at 80 per cent.

9th. State maximum rise in temperature above surrounding atmosphere taken at 25 degrees C. of any part of the machine under following conditions: Generators after 24 hours' continuous run at full-rated noninductive load; generators after one hour at 125 per cent noninductive load; motors after 24 hours' continuous run at full-rated load.

10th. State commercial efficiency of generators at full, three-quarters, and half load, noninductive. Figures given are

to include all losses in generators,exciters,and all commutator and brush losses.

11th.State commercial efficiences and power factors of motors at full,three-quarters,and half load.

12th.State kilowatt capacity of exciters,speed and voltage of same,also temperature rise,and the commercial efficiencies,same bases as for generators.

13th.State clearly what you mean by commercial efficiency.

14th.State what kind of marble or slate used on switch board,number of panels,size and dimensions of each,and give full list of equipment and appliances to be furnished therewith, stating make of same.

15th.State whether or not you guarantee the generators to operate successfully in paralle,and under what conditions.

16th.Submit cuts,prints,full descriptions,weights,and complete details of the generators,motors,and switch boards,including diagram of the system proposed ,showing connections of generators,motors,and proposed connections of lighting transformers to the circuits. In case of generators give weights of revolving and stationary parts separately.

17th!Method of construction,workmanship,and materials used in appliances and apparatus must be stated and fully described.

18th.In case the installation proposed is three-phase, state whether such system is capable of being connected with a two-phase system of same number of alternations,so that motors can be run form two-phase generators if required. If such connection is possible,submit diagram of same.

19th. State diameter, width of face, and number of teeth of pinion to be furnished with each motor.

20th. State guaranteed time of delivery of all items bid on.

Test, Acceptance and Payment.

All apparatus and appliances delivered under these specifications will be inspected upon receipt, and if found satisfactory in material and workmanship will be provisionally accepted. Upon such provisional acceptance 80 per cent of the contract price will be paid. After the installation is completed the system will be subjected to a trial run of thirty days.

In case the results of this trial show to the satisfaction of the commanding officer that the apparatus and appliances furnished satisfy the requirements of these specifications and fulfill the claims made in the proposal of the successful bidder, final acceptance and payment will be made, subject to such reductions as may be imposed for delivery beyond the date guaranteed.

The bidder to whom the contract may be awarded must execute the same in quintuplicate within ten days after receiving it, and also execute a bond in one-tenth of the aggregate of the contract on at least two copies of the contract according to the form prescribed.

In case of the failure of the contractor to deliver any of the apparatus or appliances, properly finished, by the date guaranteed in his bid, he will, for each day thereafter, be required to pay a sum equal to one-sixth of one per cent of the total contract price of the article or articles not so delivered, as liquidated damages in consequence of such delay. Penalties imposed

for delay may be deducted from any portion of the aggregate of the contract.

Any questions as to the meaning or intent of those specifications shall be decided by the commanding officer, and such decisions shall be binding on the contractor, the same as if they had been contained herein."

The General Electric Company was awarded this contract applying to the above specifications. The following is their description of the character and performance of the generators and exciters which they agreed to furnish under the accepted bid.

"Classification, alternating current, three phase, revolving field.

Rated capacity, 500 kilowatts.

Revolutions per minute, 200.

Number of poles, 36.

Full load current, 480 amperes.

Voltage, 600.

Voltage of exciter, 125.

Maximum kilowatts required for excitation, $11\frac{1}{4}$ (at over-load).

Each machine to be direct driven and to be furnished with special hollow shaft, base, and two bearings.

The armature frame will be of cast iron and so mounted that it may be moved parallel to the shaft to a position clear of the revolving field, leaving both armature and field open for inspection and cleaning.

The revolving field will consist of a cast-iron spider carrying a steel rim to which the outwardly projecting poles are bolted.

The base and bearings standards will be of cast iron. The standards will be separate castings doweled to the base, thus insuring accurate and permanent alignment.

The bearings will be self-oiling and self-aligning; with ample surface to insure cool running.

The hollow shaft or quill will be of forged steel accurately finished to gauge and of the following dimensions: Length, 117 inches; diameter on spider, $13\frac{1}{2}$ inches; diameter in bearings, 12 inches; interior diameter, $8\frac{1}{4}$ inches.

The temperature of no part of the machine, as measured by thermometer, will be more than 40°C. above that of the surrounding air after twenty-four hours run at rated load and speed, nor more than 50°C. after one hour run at 25 percent overload, provided that the temperature of the surrounding air does not exceed 25°C.

The commercial efficiency will be :

	Per cent.
Full load	94.5
Three-fourths load	93.5
One-half load	91

The friction of the shaft in bearings is included in computing the efficiency.

The inherent regulation, that is, the rise in potential when full noninductive load at rated potential is thrown off the machine, will not exceed 6 per cent, the speed and field excitation remaining constant.

Exciters.

Classification, continuous current generators.
Rated capacity, 25 kilowatts.
Revolutions per minute, 200.
Number of poles, 6.
Full load current, 200 amperes.
Voltage, 125.
Each machine to be direct connected and to be furnished

with base and bearings.

After a run of twenty-four hours at 200 amperes and 125 volts,the temperature of no part of the armature or field coils,as measured by the thermometer,will be more than 40°C.,and the temperature of the commutator more than 45°C.above that of the air surrounding the machine,provided that the temperature of the surrounding air is not above 25°C.and condition of ventilation are normal.

The machine will carry an overload of 25 per cent for one hour without movement of the brushes and without injurious sparking,and 50 per cent overload momentarily without flashing over or injurious sparking."

The commercial efficiency will be:

	Per cent
Full load------ ----------------------------------	87
Three-fourths load---------------------------------	81.5
One-half load---------------------------------------	84 "

Installation of Generators and Exciters.

Extract from Report mentioned previously.

" The foundations for the generators were prepared in the following manner: An excavation(3)three feet (7) seven inches in depth,(13)thirteen feet (10)inches long,and (7)seven feet(6) six inches wide was made in the top of the dam. In this was placed a strong rectangular framework of ths ize of the generator base, composed of steel I-beams,the ends of which porject sufficiently to obtain a firm bearing in the counterforts. This framework is solidly embedded in concrete,the interior space inclosed by it being left open to accommodate the lower part of the generator armature. On top of this frame the concrete is about (4) four inches thick,leaving a space of three-eighths of an inch between the concrete and the bottom of the generator base. After the generator

was put in place it was wedged up into alignment and this space filled by running in melted sulphur. By this means a perfectly firm and stable foundation was secured and, at the same time, the base was thoroughly insulated from the ground. Both exciters were installed in a similar manner, except that no steel framework was used.

The main shaft passes through the quills or hollow shafts of the generators and is secured to them by flanged and bolted couplings similar to those used throughout the main shaft. Instead of a steel separator plate, the halves of these couplings are separated by red sheet fiber one-half inch thick and the bolts are bushed with the same material, thus completely insulating the field from the ground. The same insulation is provided for both exciters.

The two end sections of the shaft to which the exciters are coupled are connected with the remainder of the line by two magnetic clutches of 150 horsepower each. This arrangement possesses several evident advantages. In the event of an unusually heavy load, combined with a low head of water, the aid of the exciter wheel will be required by the generator and can be given by means of the clutch. At all other times the clutch can be left open and the exciter run independently of the main line, a condition under which the changes in speed of the latter, due to variations in load, are not transmitted to the exciter and do not affect its voltage. Also, either exciter can be used with either generator."

The Switch Boards.

At the head of building (see floor plan, also plates 12, 13, 14, 15 Appendix) are placed the switch boards which has been previously cited. At this place the wires from the generators and exciters meet the feeders running from board to shops. Each board, is made

of eight panels,(7)seven feet (6) six inches high (30) thirty inches wide and (2) two inches thick. The panels are supported and joined by steel angles bolted along sides,in the rear and top,and the whole encased with Milwaukee brick work,presenting a beautiful finish. The rear of the boards are accessable by two doors,one at either end of the boards. The boards are placed(5) five feet (8) eight inches from the wall,sothat ample space in rear is provided for all apparatus and connections.

The switch boards are all provided with proper switches and instruments required for operation (see Plate 14-15). Attention is called to the fact,that panels 11,12,13 and 14,have each a power factor.indicator which could be displaced by one ,with proper connection and switches to these panels serving the same purpose, as is now generally done. The generators may be operated separately or in parallel and for throwing in parallel,a Lincoln synchronizer is porvided,although ay first synchrozing lamps were used. According to the switch-board wiring diagram,the switches for the synchronizer are placed on the panels,but this is not the actual case,as they are placed in rear,near the north door a rather inconvenient place. A change in putting these switches on the panels is suggested by the writer. The feeders for the East shops,South West and Armory shops are separate. All three are,however,connected to the bus bars and thus can be supplied with current from either generator.

All main switches are of the oil-break type. In addition to the main switches on each feeder panel there is mounted six single pole knife switches. The feeders,consist each of nine No.0000 stranded conductors through to a phase. Two

conductors of each phase are connected with two of these single pole switches, sothat if one set of feeders happens to be carrying a light load, one third or two thirds of the conductors can be cut out by opening one or both of the switches on each phase. The line loss is thereby increased, but the voltage at the motor terminals, kept down to the proper point.

The Wiring System.

The wires connecting the generators and exciters with the switch boards are led through creosated wood tubing laid in the concrete floor of the power house, into the basement beneath, and up through the floor to the proper panels. From the switch board, the three phase system of transmission is used, and the three sets of feeders pass from the fedder panels down into the basement and thence to the concrete subway or tunnels.

The feeders are secured to the brackets fastened to the tunnel walls. This tunnel is lighted by series incandescent lamps along the top of the arch, and is about seven feet high and three feet wide, and 2,200 feet long. Thus the conductors may be easily inspected at any time.

Mains run from the center of distribution to the different shops and storehouses. In the basements of the different shops service wires which lead to the various motors in the wing are connected by means of marble service boards. All mains are properly fused at the centers of distribution and all service wires at the service boards. The mains consist each, of six to nine stranded conductors of smaller size than the feeders, while the service wires vary from No.00 to No.10, depending on the capacity and number of motors on each line and consist of three solid wires.

The following specifications for the wires were

advertised and purchased in accordance with them.

All stranded or solid copper conductors must be 98 per cent pure copper tinned and must have a double coated insulation of best vulcanized Para rubber,covered with substantial braid all well waxed;must not readily carry moisture;and must show an insulation resistance of one megohm per mile,after three weeks submersion in water at (70) seventy degrees F.,and three days submersion in lime water,and after three minutes electrification at 600 volts.

Thickness of insulation(not including braid).

For No.0000 B.&.S.Stranded Conductors	6/64	inches.
" " 000 to 4 " " "	5/64	"
" " 4 to No.10 Solid Conductors	4/64	"

Wire with triple braid weatherproof insulation must have three closely woven cotton braids at least(1/16)one-sixteenth inch in thickness and thoroughly impregnated with a moisture repellant,which must not support combustion;must be of superior finish;smooth braid and not easily abraded.

Motors.

The following is a description of the motors as given by General Electric Company.

"Under the contract made with the General Electrical Company,72 motors of different capacities were delivered. The following list gives the number,power,and speed of each size:

No.	Horse-Power.	Speed	No.	Horse-Power.	Speed	No.	Horse-Power.	Speed	No.	Horse-Power.	Speed
1	1	1,800	2	5	1,800	2	15	600	7	30	900
2	2	900	1	5	900	5	15	1,200	10	40	900
2	3	900	6	10	720	10	20	900	6	50	720
1	3	1,800	15	10	1,200	1	20	450	1	75	720

These are all induction motors of the three-phase ,60 cycle,Form K,or squirrel-cage type,as manufactured by the General Electrical Company,requiring 550 volts at their terminals,and with a commercial efficiency ranging at full load from 79to 84,and a power factor varying from 88 to 81 under the same conditions.

The plan upon which the number of motors was based contemplated the use of a motor for each main-line shaft and for several of the larger exhaust fans and blowers. By such subdivision each line is rendered independent of the others,and in case of an accident it is necessary to shut down only the line immediately affected.

Each motor is provided with a triple-pole circuit breaker of approved design instead of the fuze and switch ordinarily used. Those of 10 horse-power or less are started by simply closing the circuit breaker and holding it in place until the motor attains its speed. With the larger ones,however,this method is not practicable,and they have,therefore,been supplied with starting compensators.

The method of installing the motors was a matter which was thoroughly considered. The desire to economize floor space and to prevent the possibility of accidents from the rapidly running motor belts suggested ceiling or wall suspension,to which method the substantial ceilings of the shops were especially adapted, while the small amount of care required by induction motors could be given them in that position without inconvenience. This arrangement was accordingly decided upon,and all motors except those in shops E and F were suspended from the ceilings. In the excepted shops,which are one-story buildings without ceilings,the motors were attached to the walls.

The orginal intention was to gear the motors to the line shafting, and for that purpose the specifications required rawhide pinions to be supplied with each motor instead of pulleys. Upon further consideration this plan was abandoned and the use of belts and pulleys reverted to as a method more certain of giving satisfactory results. All motors making more than 720 revolutions per minute are belted to countershafts which transmit the power to the line shafting, thus obtaining the necessary reduction in speed with the use of pulleys of moderate diameters. In the case of motors running at 720 or less the countershaft is dispensed with and the motor belted directly to the line shaft."

Additional motors have since been installed bringing the total up to 108. Since the motors are all induction type an excessive inductive load is had, especially because oftne these motors run at light loads, still further increasing the power factor, running as low as .7. There are certain places in the Arsenal were frequent starting and stopping of motors is not necessary, as for instance for pumping apparatus; here synchronous motors with over-excited fields may be used, so as to compensate for the lagging current, and thus bring the power factor nearer to unity. But since the power is cheap little regard is ever paid to the power factor.

Power Plant Building.

The present building for the plant, is one that was built, immediately after a fire destroyed the old wooden one in 1899. An idea of the shape and appearance of this new building may be obtained from the floor plan and plate 10 in the Appendix. The floor is of concrete; the walls are of Milwaukee pressed brick. It is well lighted by the great number of windows, and by the incandescent lamps at night. The roof is of wood and the trusses

for the wheel house also;this is unfortunate,since it renders the building not completely fire-proof thruout. The trusses for the head are of steel. Beneath this room in the basement are located the transformers,regulators and work shop,wash room,etc. A floor plan of this basement is shown in the Appendix,showing location of the transformers,regulators and fan used for cooling the same. An interior view of the wheel house,looking from the switch board room and one from the other end,may be found in the Appendix. It will be noticed that the machinery and framework for the same is all finished in white enamel,giving the whole a beautiful appearance. An exterior view of the south side of the building and dam is also in Appendix. Attention is called to the electric heater located along the walls of the building.

Now this heating system consists of (25)twenty-five radiators of which(18)eighteen are placed along the end of the wheel house and seven in the switch-board room.

Each radiator is three feet wide and three and one-half feet high and consists of three coils entirely covered by a shield. These sections are made of light brass,bent to form a hollow rectangular case,(36)thirty-six inches long,three(3) inches wide and one inch deep,covered by asbestos board and wound with coiled iron wire. These three coils when connected in series with 600 volts A.C.have a resistance,that give a current,which will not injure the coils due to the heating effect. The three coils comsume about three(3) kilowatts at 600 volts or about one kilowatt per coil. A double thru switch at the radiators properly connected with a similar switch in the rear at the switch board, provides for the operation of coils in parallel,for direct current giving less heat for milder weather,and for series operation for

the A.C.circuit,giving a greater amount of heat.

The radiator switches are placed within the shield for proper protection,but may be operated by means of a rod and detachable crank. This heating system has been found to give splendid service.

Operation and Performance of Plant.

Ever since the date, that the plant was put into operation the river has been unusually high,the head averaging only about 7.4 feet. Data was collected by the writer showing variation of head. The average of the daily head reading being used as ordinates and the days of the month as abscissas,(see plate 1,2 and 3 Appendix). Plate 1 shows the average daily variation of head for the months of April and May,1905: this being about the time of the two spring floods. It will be noticed that the head increased slightly toward the end of the month of April and continues to increase until the eleventh,when suddenly it decreases. The low head at the beginning of April is probably due to the high water of the first flood,and the decrease of head in May due to the second flood. As high water comes on a great deal of head is lost because the water flows over the wing dam sothat it fails to serve its purpose then. Plate 2 shows head variations for July and August. July being selected because of the three weeks' vacation period,-during which only one generator is operating and August because of the low water with the low stage: the average head being something like (8½) eight and one-half feet as compared with (6½) six and one-half and (6)six feet for July and May respectively. Plate 3 shows the variation of head for December,a winter month, when the ice is in the river. Attention is desired to the three peaks at about the 4th,25th,and 31st,for December curve. These

peaks are probably due to the fact that the gates for the turbines at the Moline plant were not opened.

It is well to note,that besides floods another factor decreases the head,and sometimes to such an extent that this plant fails to generate enough power for the operation of the Arsenal, sothat recourse must be made to reserve power,which will be touched upon soon. This factor that decreases the head,is the gorging of ice,above the plant,or below;or both may possibly occurr simultaneously. In case it gorges above,the water is prevented from coming down,while if it gorges below,the water "backs up" in the tail,and if both occurr at once the water between the gorges will have little velocity,sothat in any case the head decrease greatly.

Plate 4 shows the comparative kilowatt hours generated by the plant for the year of 1905;the total for this year 3,740,970 K.W.hours. The maximum came in the month of May and the minimum in July,the three weeks vacation coming during this month. Referring to plate 5,we have the daily kilowatt hours generated for the same month. The first part the curve showing that only one generator was in operation until about 19th,when the entire plant was again generating power. Plate 7 shows daily kilowatt hours generated for December and Plate 6 for April. The low points of the curve,indicate the Sunday performance of one generator. These particular months were selected to correspond with those months showing head variation. Plate 8 shows three load curves. One Sunday load curve,while the second,a Saturday load preceding a Monday curve,following this Sunday. Since the Arsenal operates on the eight hour schedule,load comes on just

before eight, dropping somewhat at noon hour, but coming on again at one o'clock and dropping again at four o'clock.

All the above curves, though not of any material value, are interesting and bring out the plant's performance and operating conditions very clearly.

No opportunity for testing the plant on a high head, has yet been realized. Yet, one test has been made with a head of 7.2 feet, and with the tailrace partially obstructed by scows and the presence of the larger part of the cofferdams used in connection with the process of deepening the tailrace. The following results were realized: One unit and exciter driven by seven turbines at full gate developed 536 horsepower non-inductive load. This gives an average of more than 82 horse-power per utrbine, due regard being given to the efficiency of the unit which is 94.5 at full load, and also to the power consumed by the exciter. At ordinary stages of water, and obstruction removed, a head of 8 to 10 feet may be expected. Plates 2 and 3 show that this head can be expected, and such being the case, the turbines may be relied upon to develop from 100 to 130 horse-power each. Since each unit is rated to carry 25 per cent overload, its maximum capacity may be placed at 625 kilowatts or 837 horse-power non-inductive load. To this we must add the 15 horse-power required by the exciter, and taking account of the efficiency again, at full load, then in order to obtain this output each turbine must develop about 128 horse-power, which corresponds closely with the maximum capacity of each turbine, as estimated above.

With the low head as shown by the curves, no difficulty so far has been found in supplying the required power up to the

present time, and besides, heating of the power house all from one generator driven by six turbines, the seventh operating the exciter. Moreover, from one of the operators, it was learned that no shut down has ever been necessary which is not often the case, where new machinery has been installed. If the plant fails to develop the required power owing to low head, recourse is had to the reserve power, which has already been stated and will now be taken up.

Reserve Power.

In order to prevent a complete shut down of the Arsenal in case the plant fails, as may be expected with the gorging of ice, power is obtained from the Moline plant. The current transmitted by this plant is from a 500 kilowatt two-phase 60 cycle unit at 2,200 volts and must be synchromized with the three phase 600 volts circuit of the Arsenal plant. In order to do this the current from the Moline plant is changed by the transformers from two phase 2200 volts to three phase 600 volts. These transformers are the ones previously mentioned in connection with the lighting systems. They are each of 250 kilowatt capacity and are air cooled. In addition to these there are two 500 kilowatt induction potential regulators, which controls the voltage of the current after transformation and conversely when the Arsenal plant only is in use, serves to reduce the primary voltage sothat the secondary voltage may be kept at 2100. These potential regulators are operated by small induction motors whose switches are on panel 10.

An integrating wattmeter on panel 4 south switch board records the kilowatt hours consumed in case the power from Moline plant is required.

In concluding this review it is but fitting that the

writer should acknowledge his grateful appreciation and many thanks, for kindness and courtesy shown to him by Lt.Col.Stanhope Blunt, U.S.A.Commanding Officer,Rock Island Arsenal,for it was thru him the writer was able to collect the necessary data,and besides the various cuts,reports and the map was secured from him. And finally the cost of this great plant was something like 80,000 Dollars.

APPENDIX.

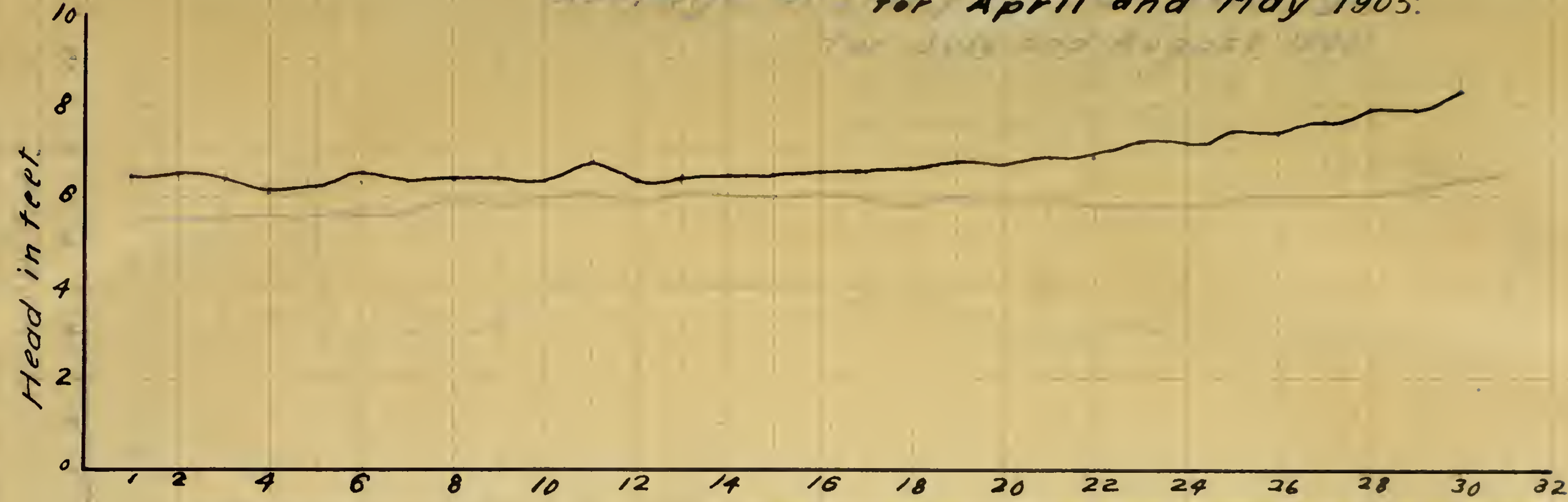
The Construction of the Cofferdams.

The cofferdams were constructed of a heavy framework of timbers and planks, the planks being so placed that they formed a fairly close wall. The planking was placed in each side of the timbers and chains were placed between. This structure formed one wall of the dam. The space between the two walls was filled with sand. The cross section of these dams were nearly square being eighteen feet in height and nearly that in width.

THE GOVERNMENT WATER POWER DAM.

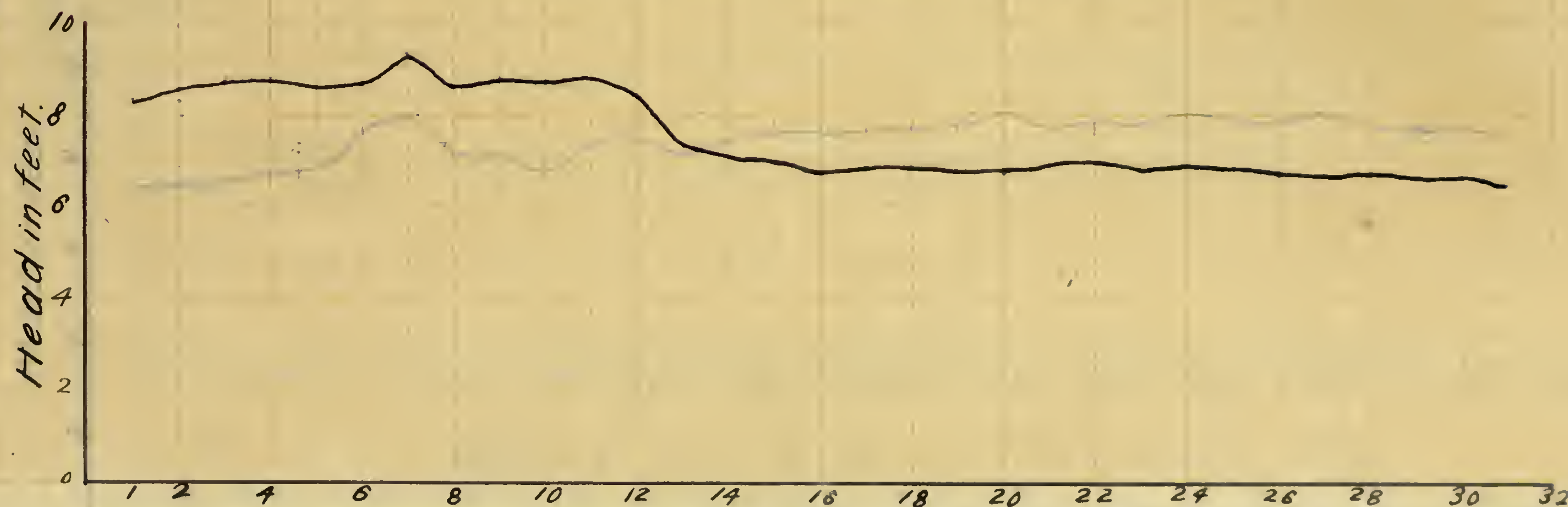
Old power house destroyed by fire in 1899.

Curves Showing Varition of the Average of Daily Head Readings, for April and May 1905.



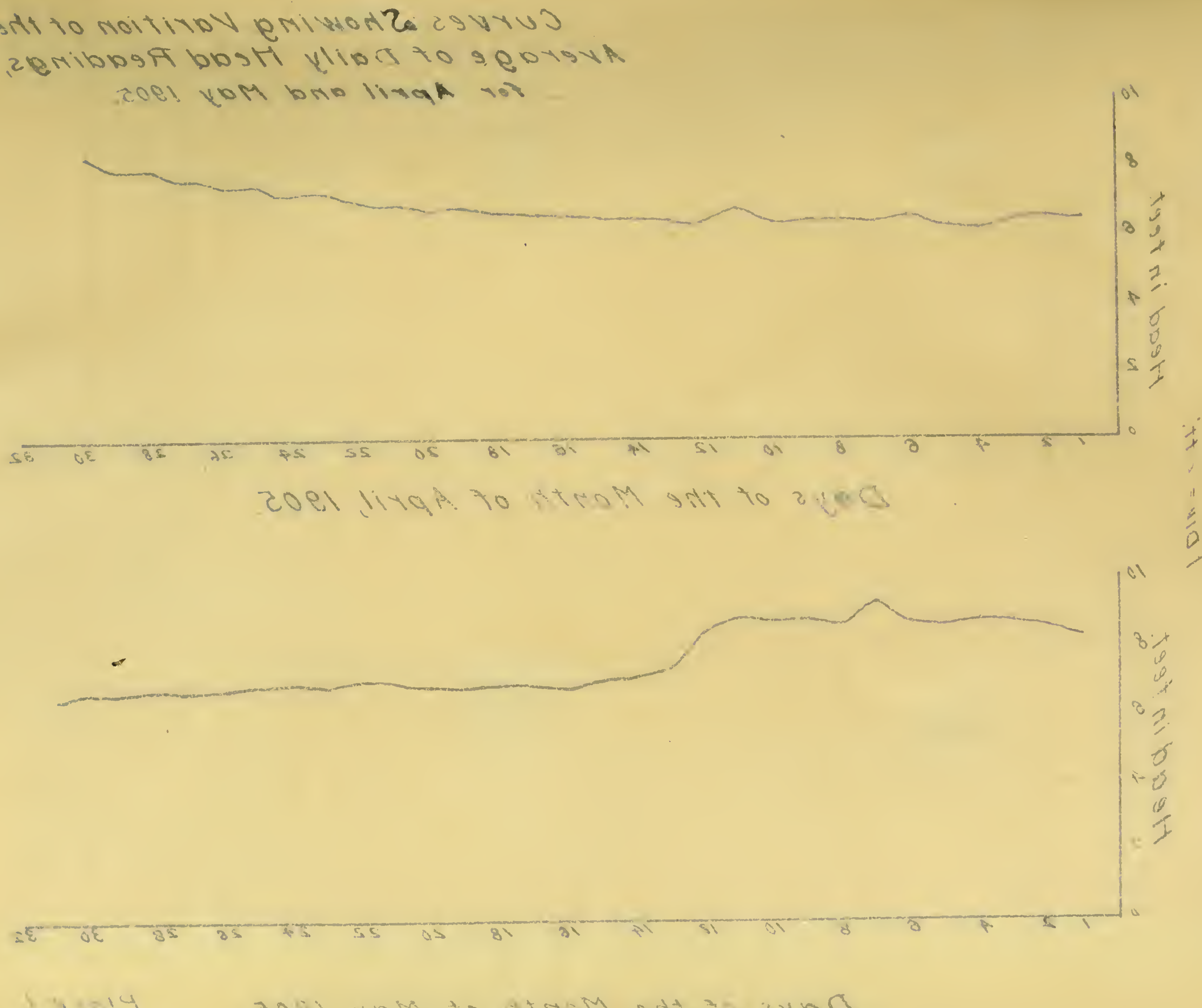
Days of the Month of April, 1905.

1 Div. = 2 ft.



Days of the Month of May, 1905.

Plate I.



Curves Showing Varition of the
Average of Daily Head Readings,
for April and May 1905.
Head in feet
Days of the Month of April 1905
Head in feet
Days of the Month of May 1905

Curves Showing the Variation of the Average of Daily Head Readings, for July and August, 1905.

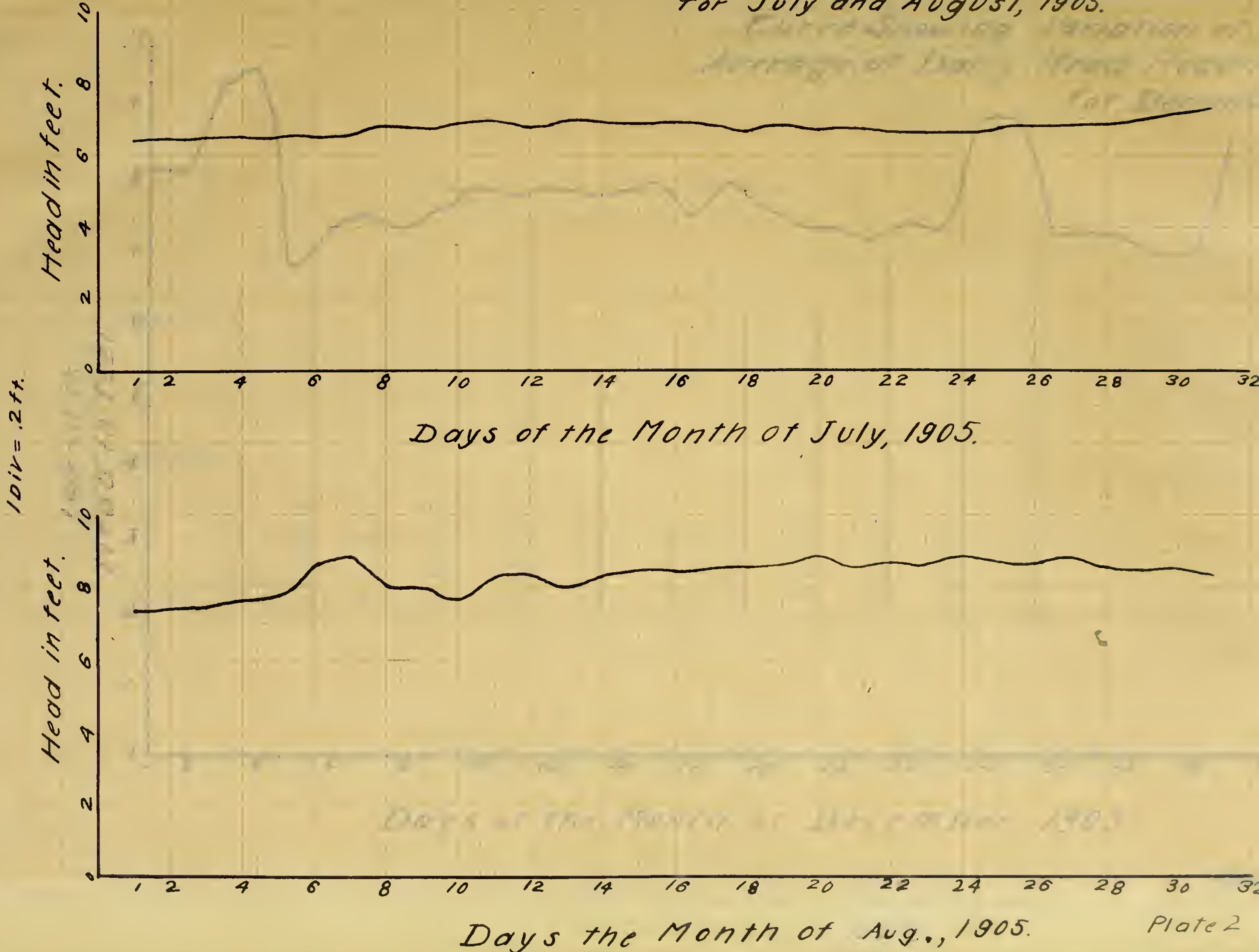
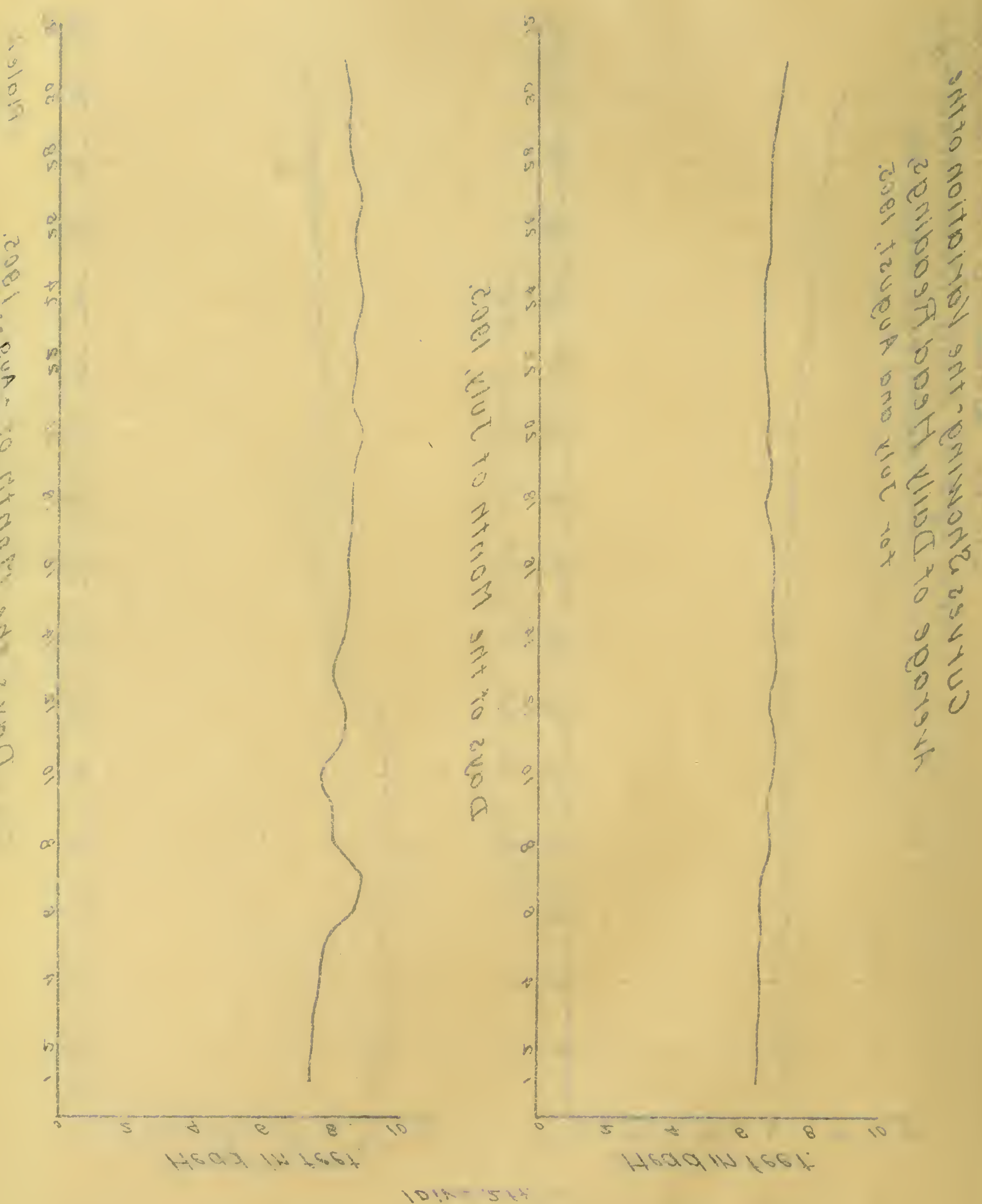


Plate 2


Curves Showing the Variation of the
Average of Daily Head Readings
for July and August 1905.
Head in feet
Days of the Month of July, 1905.
Head in feet
Days of the Month of Aug., 1905.

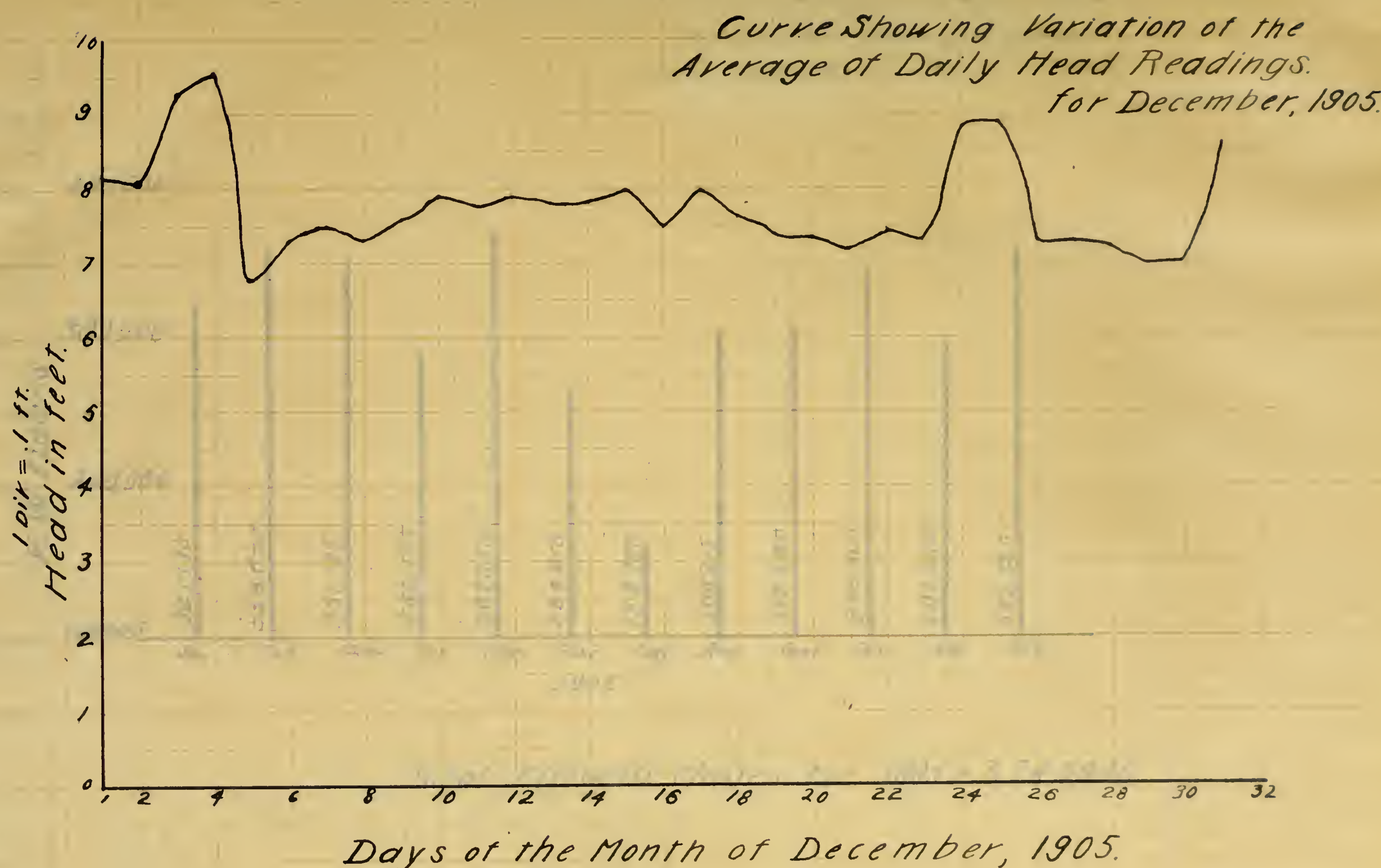
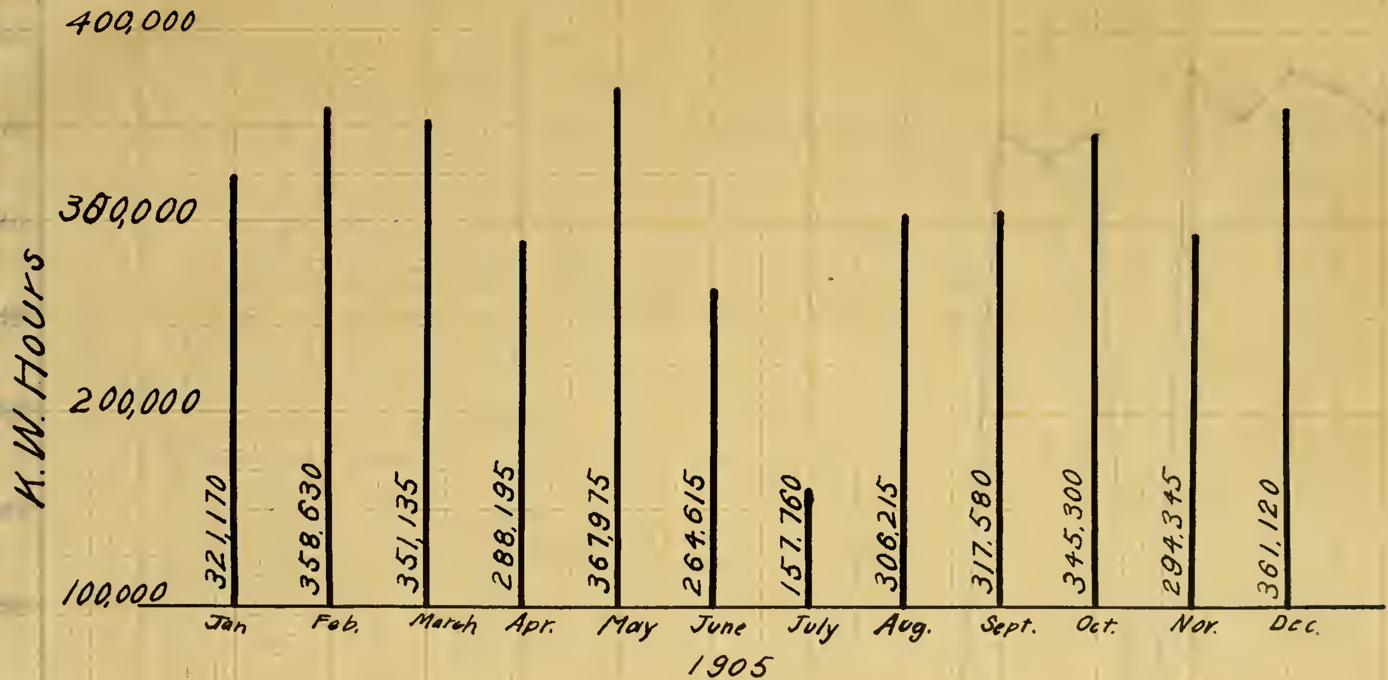

Curve Showing Variation of the
Average of Daily Head Readings.
for December, 1905.
Head in feet.
1 div = .1 ft.
0
1
2
3
4
5
6
7
8
9
10
1
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Days of the Month of December, 1905.

Plate 3



Total Kilowatt Hours for 1905 = 3,740,970.

Plate 4

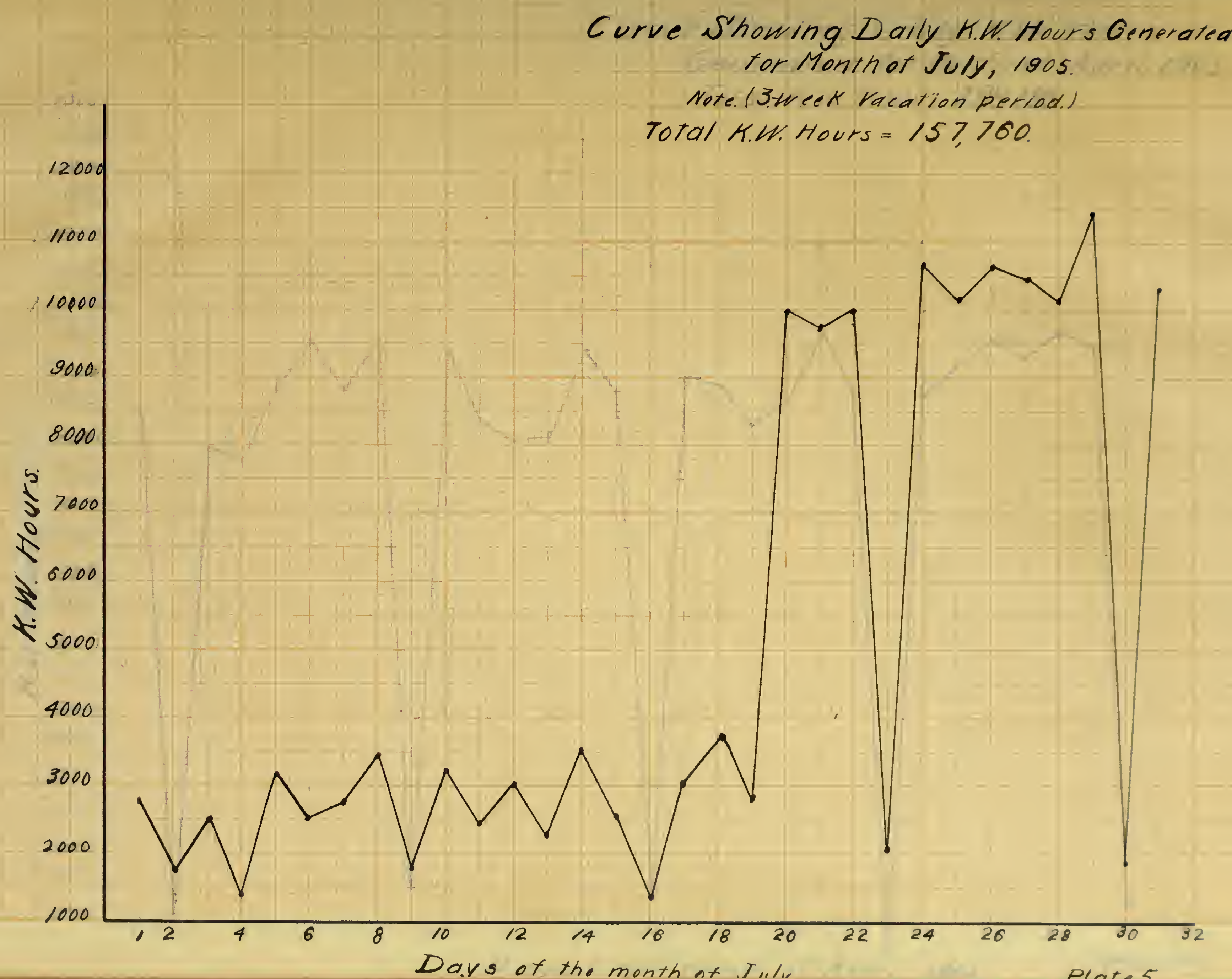
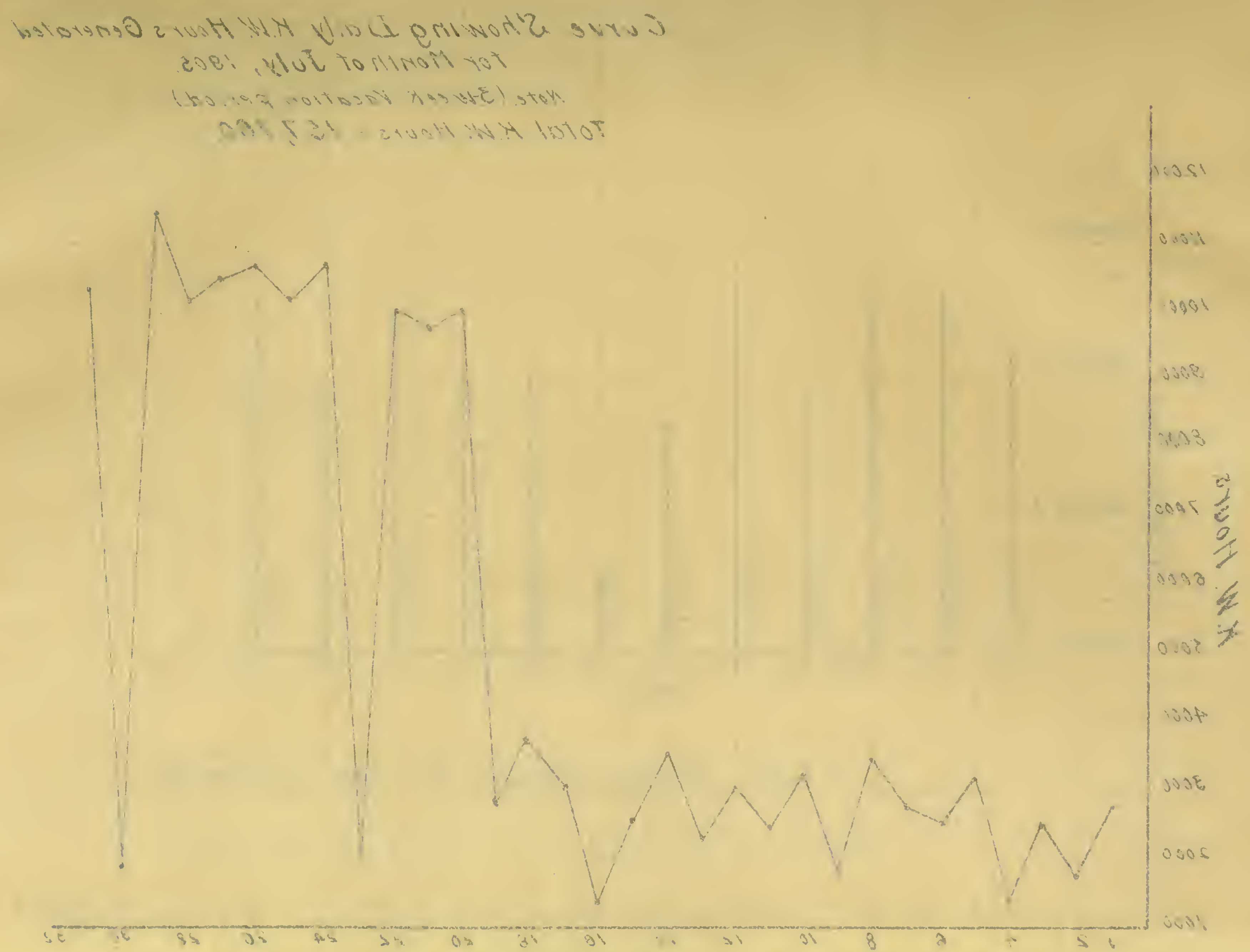

Curve Showing Daily K.W. Hours Generated
for Month of July, 1905.
Note. (3 week Vacation period.)
Total K.W. Hours = 157,760.
K.W. Hours
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Days of the month of July

Plate 5


Curve Showing Daily K.W. Hours Generated
for Month of July, 1905.
Note (3 Week Vacation Period)
Total K.W. Hours
K.W. Hours

Curve Showing Daily K.W. Hours
Generated for Month of April, 1905.
Total K.W. Hours 288,195

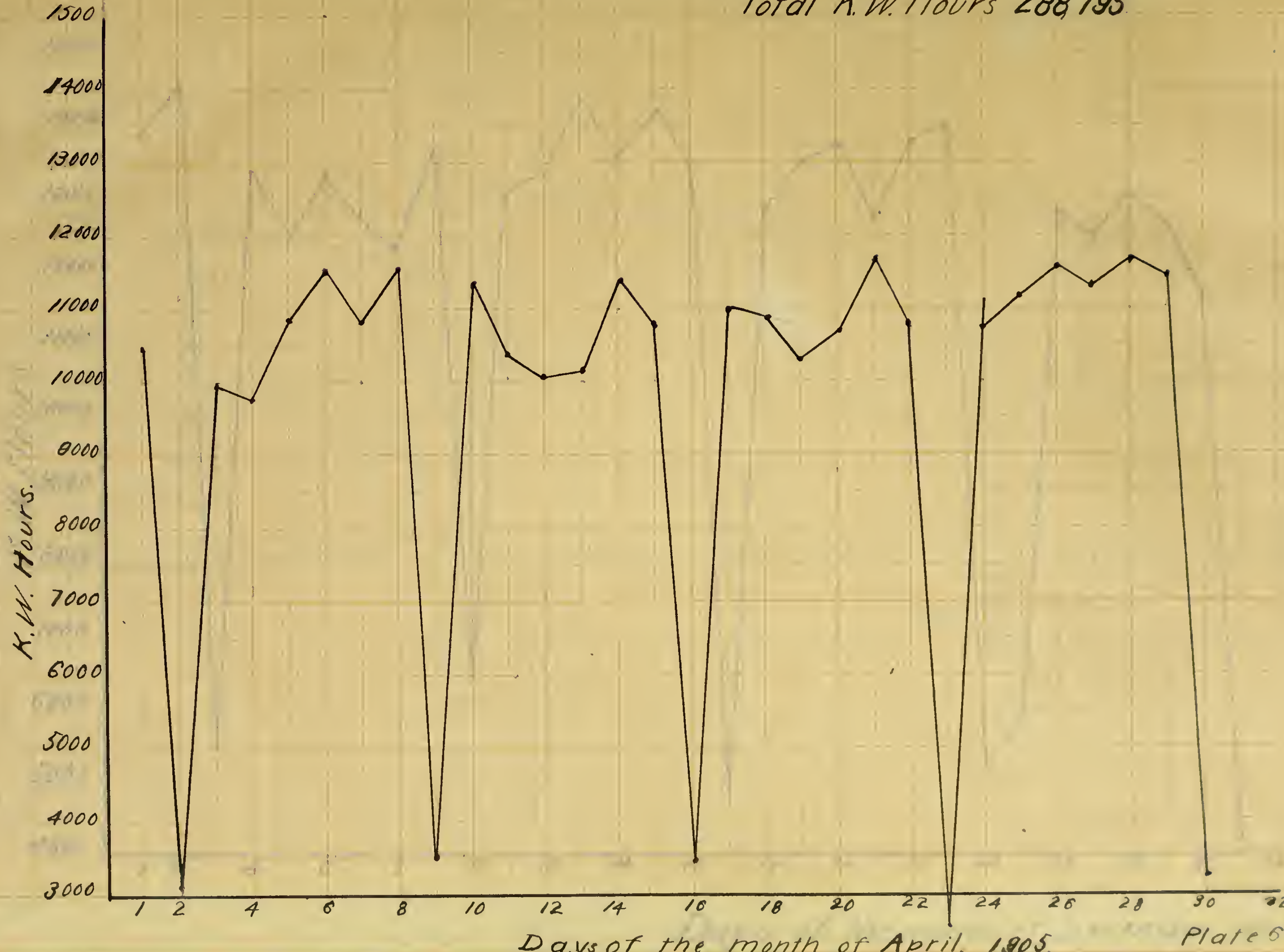
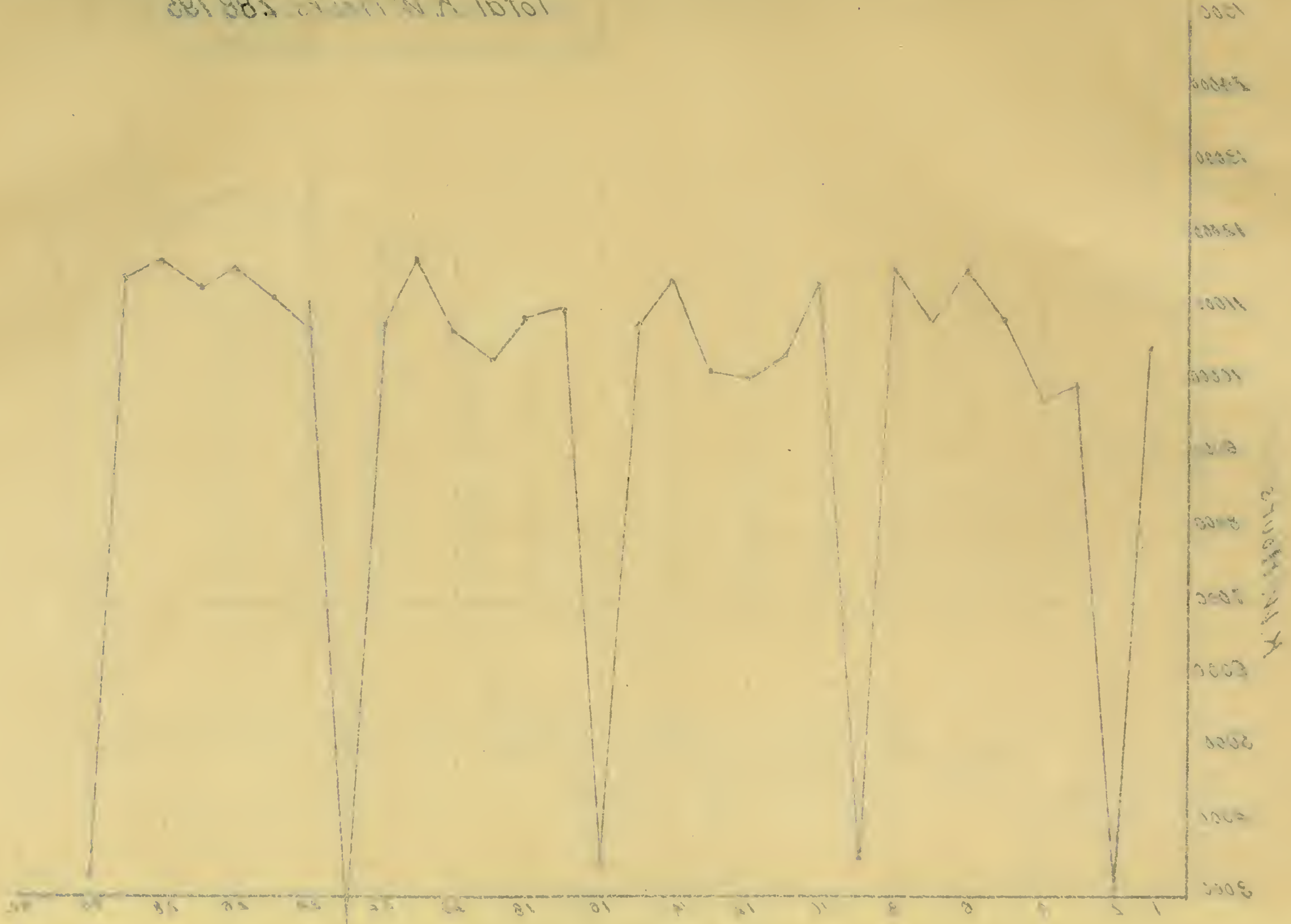


Plate 6

Curve Showing Daily KW Hours Generated for Month of April 1905

Total K.W. Hours 288185



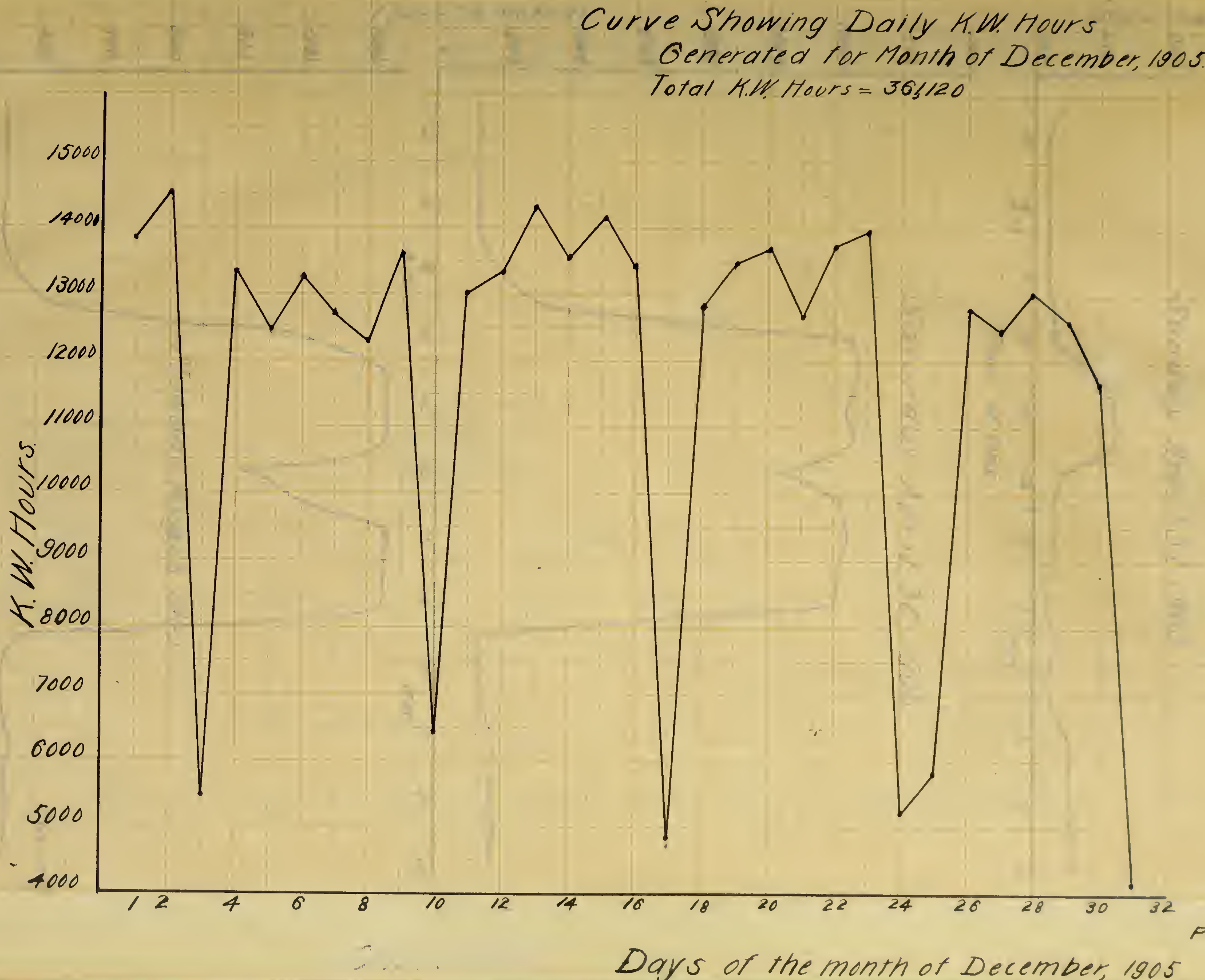
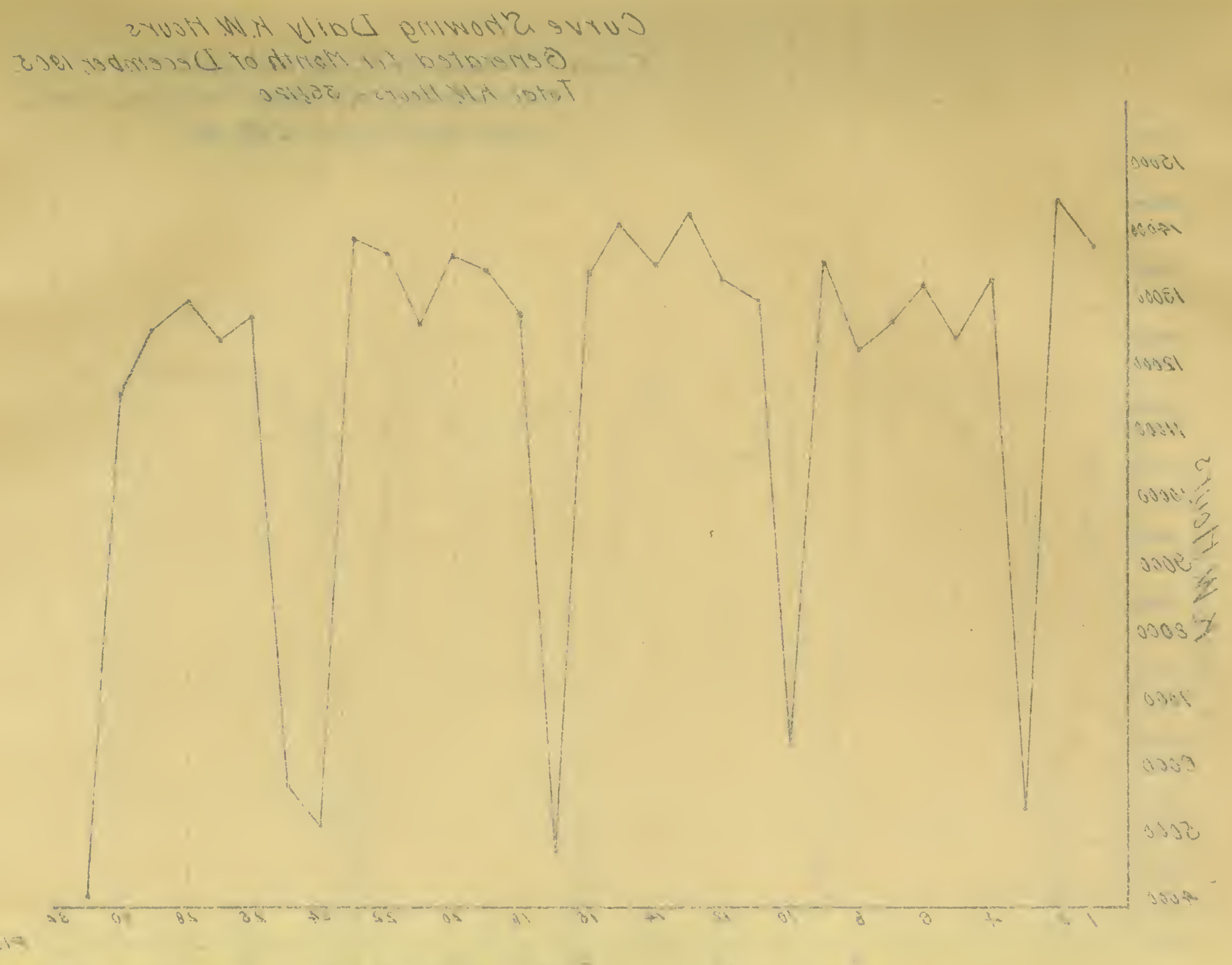

Curve Showing Daily K.W. Hours
Generated for Month of December, 1905.
Total K.W. Hours = 361,120
K. W. Hours
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
1
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Days of the month of December, 1905

Plate 7


Curve Showing Daily K.W Hours
Generated for Month of December
K.W Hours

LOAD-CURVES.

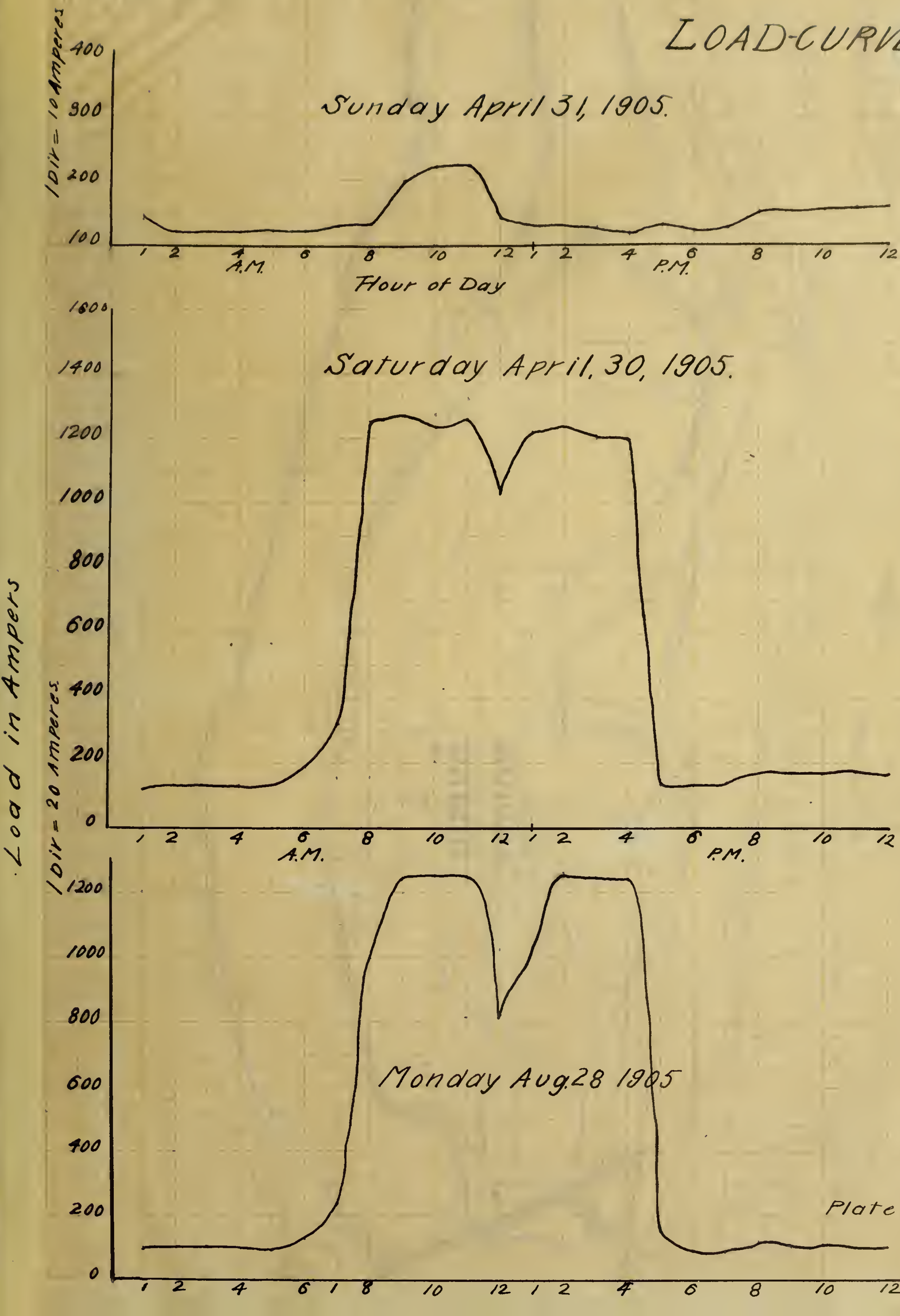
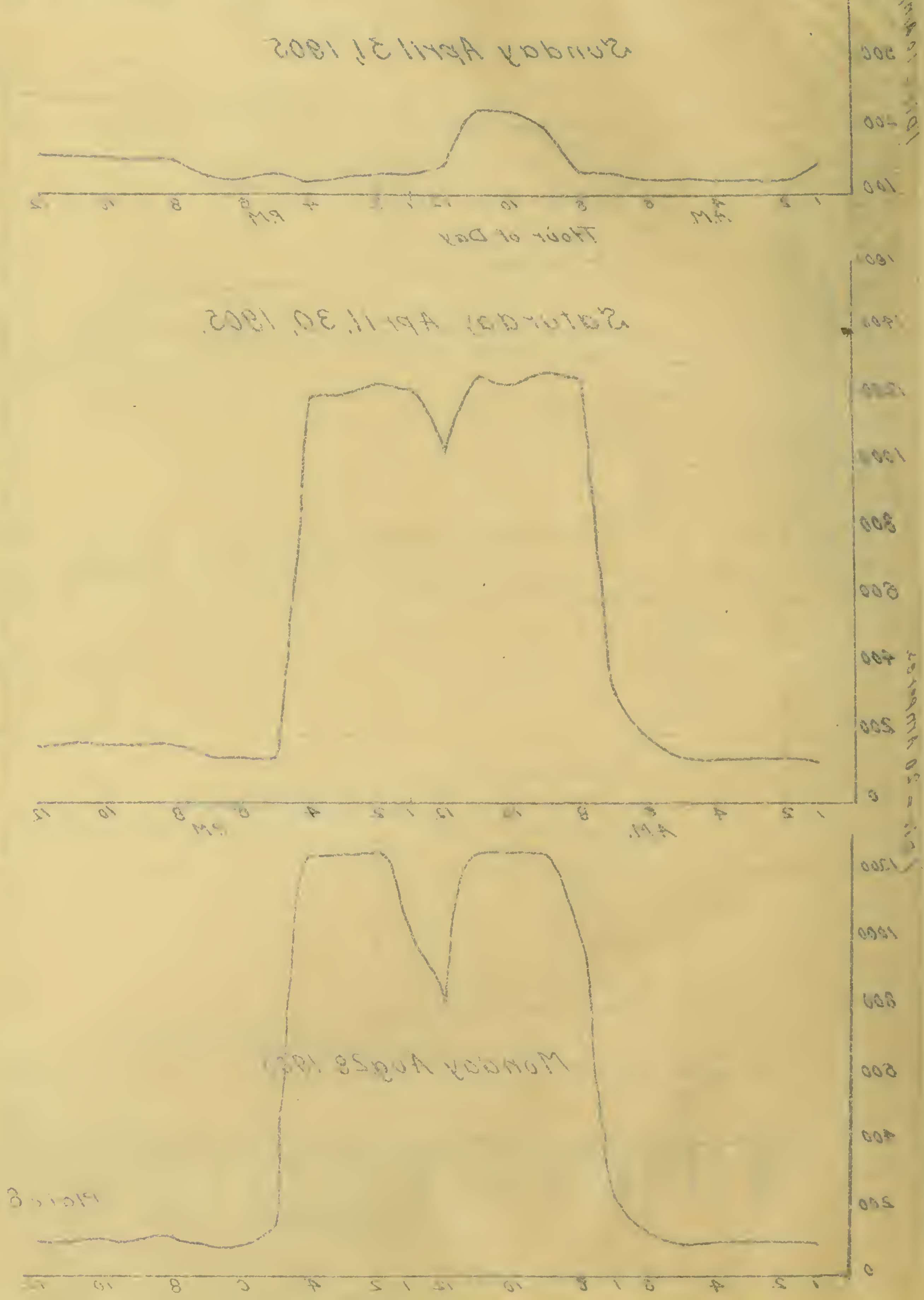


Plate 8

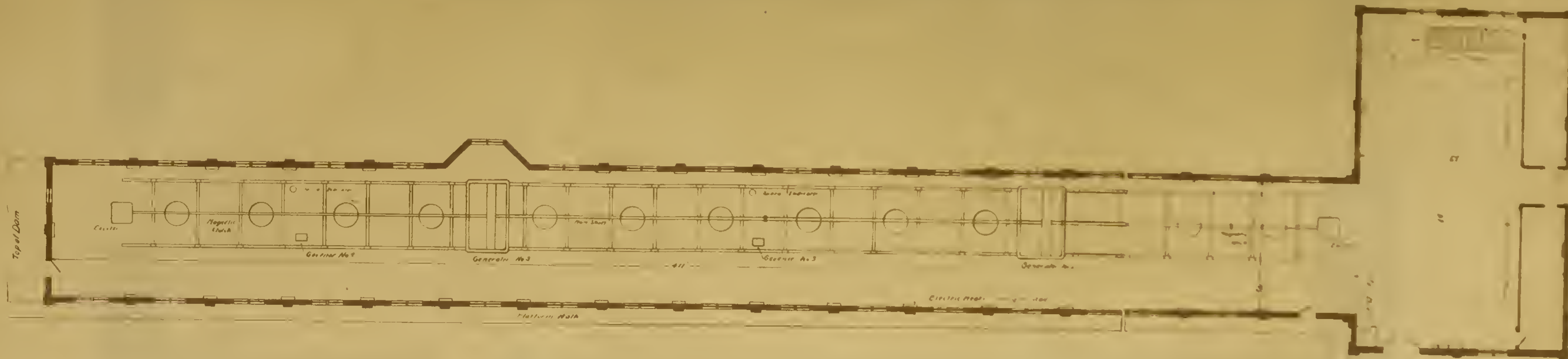
LOAD-CURVES



Sunday April 31, 1905
Hour of Day
A.M.
P.M.
Saturday April 30, 1905.
Amperes
Monday Aug 28 1905
Plate 6

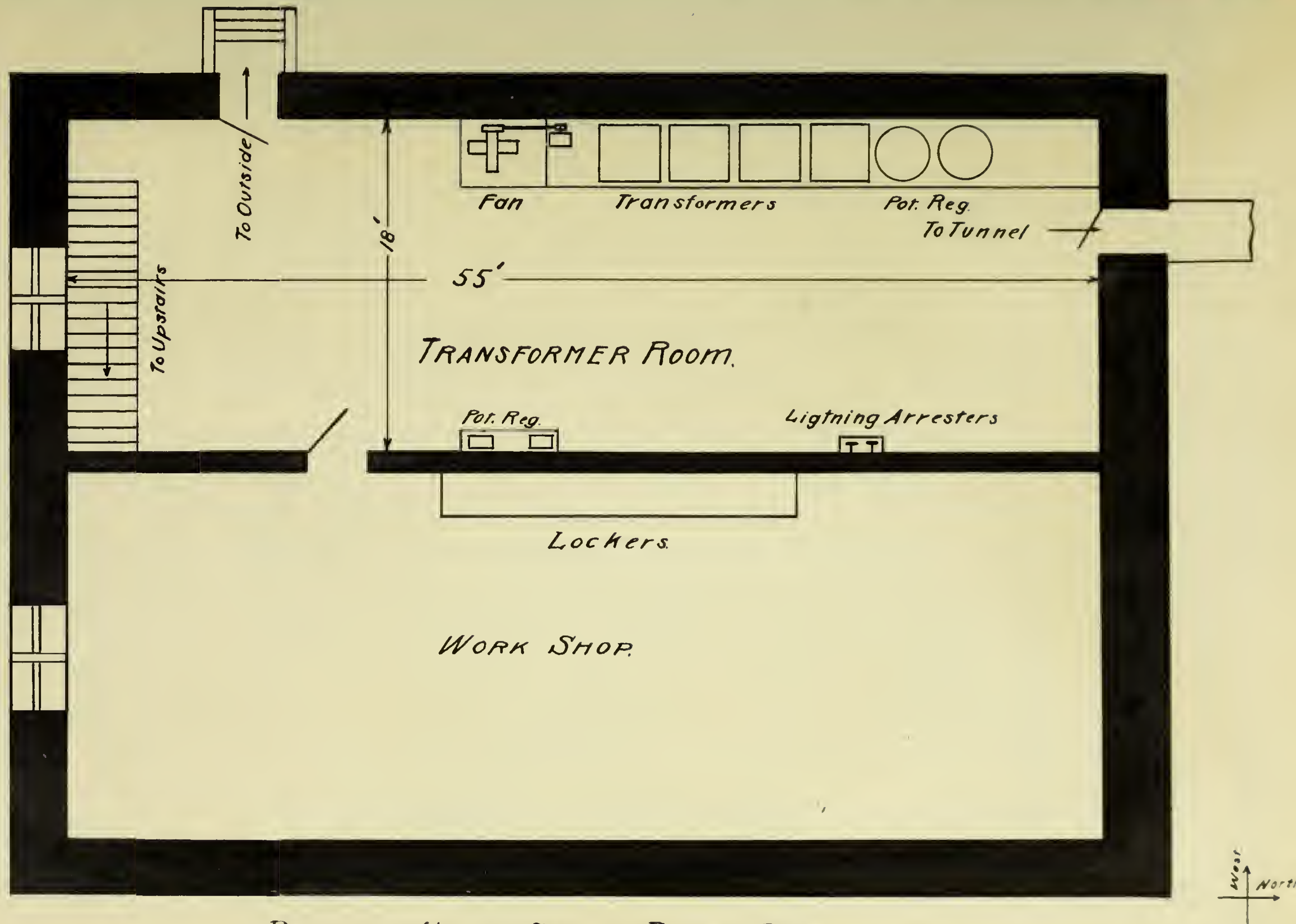

DAVENPORT
MISSISSIPPI RIVER
WATER POWER
WATER POWER POOL
WATER POWER TAIL RACE
U.S. WATER POWER DAM
CANAL
WING DAM
MOLINE
ROCK ISLAND
ROCK ISLAND ARSENAL AND VICINITY
X Streetcar Bridge
LEGEND
SCALE OF FEET
DWG PERTAINS TO
REVISIONS
CLASS
DRAWING
FILE

PLATE 9



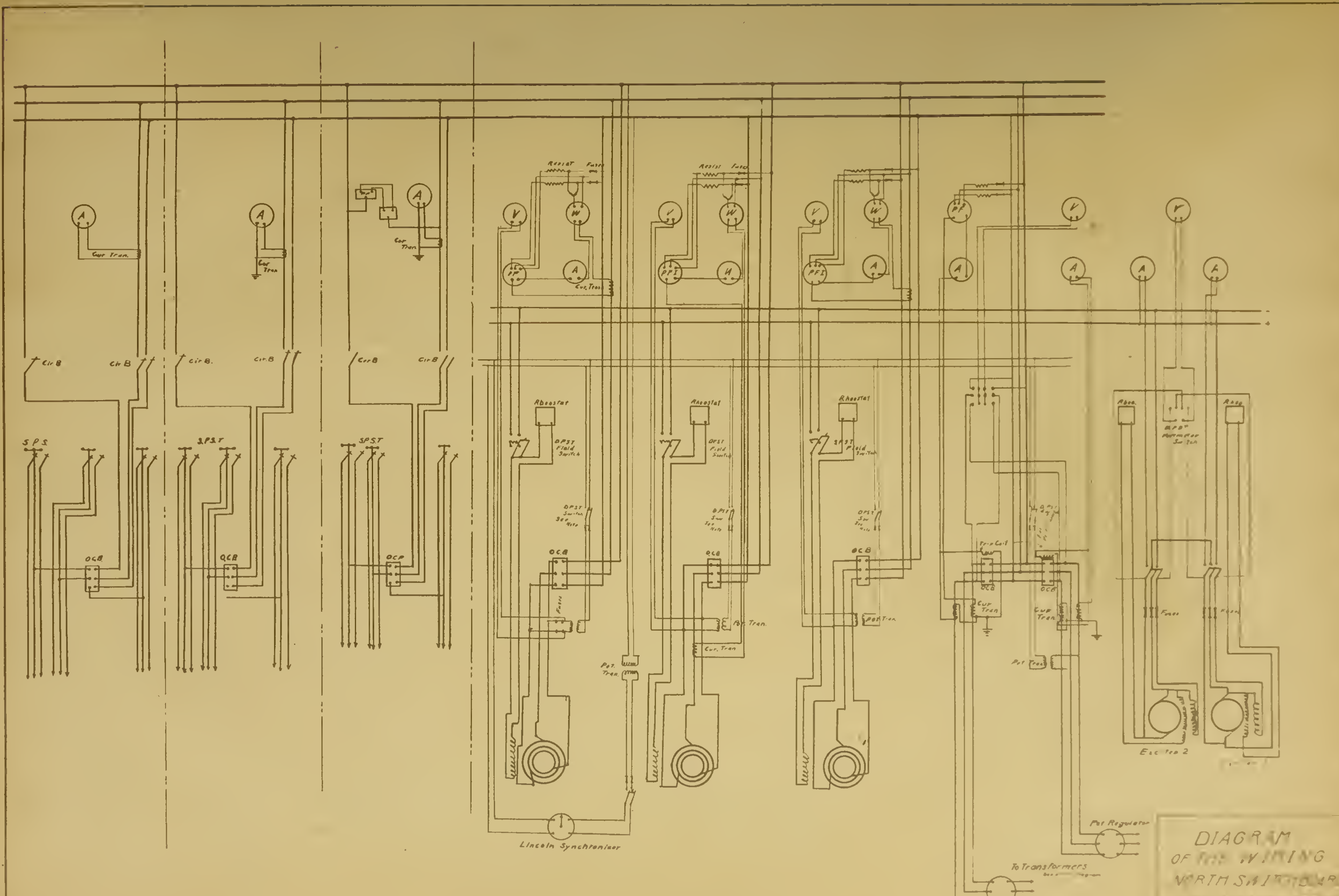
Floor Plan Hydro-Electric Plant.
Rock Island Arsenal
Rock Island Ill.

Plate 10



BASEMENT UNDER SWITCH BOARD ROOM.

Plate 11



Cir B
Cur Tran.
SPS
SPST
OCB
Resist
Fuse
Rheostat
DPST Field Switch
Pot. Tran.
Cur. Tran
Lincoln Synchronizer
Trip Coil
Pot Regulator
To Transformers
Fuses
DIAGRAM

Plate 12

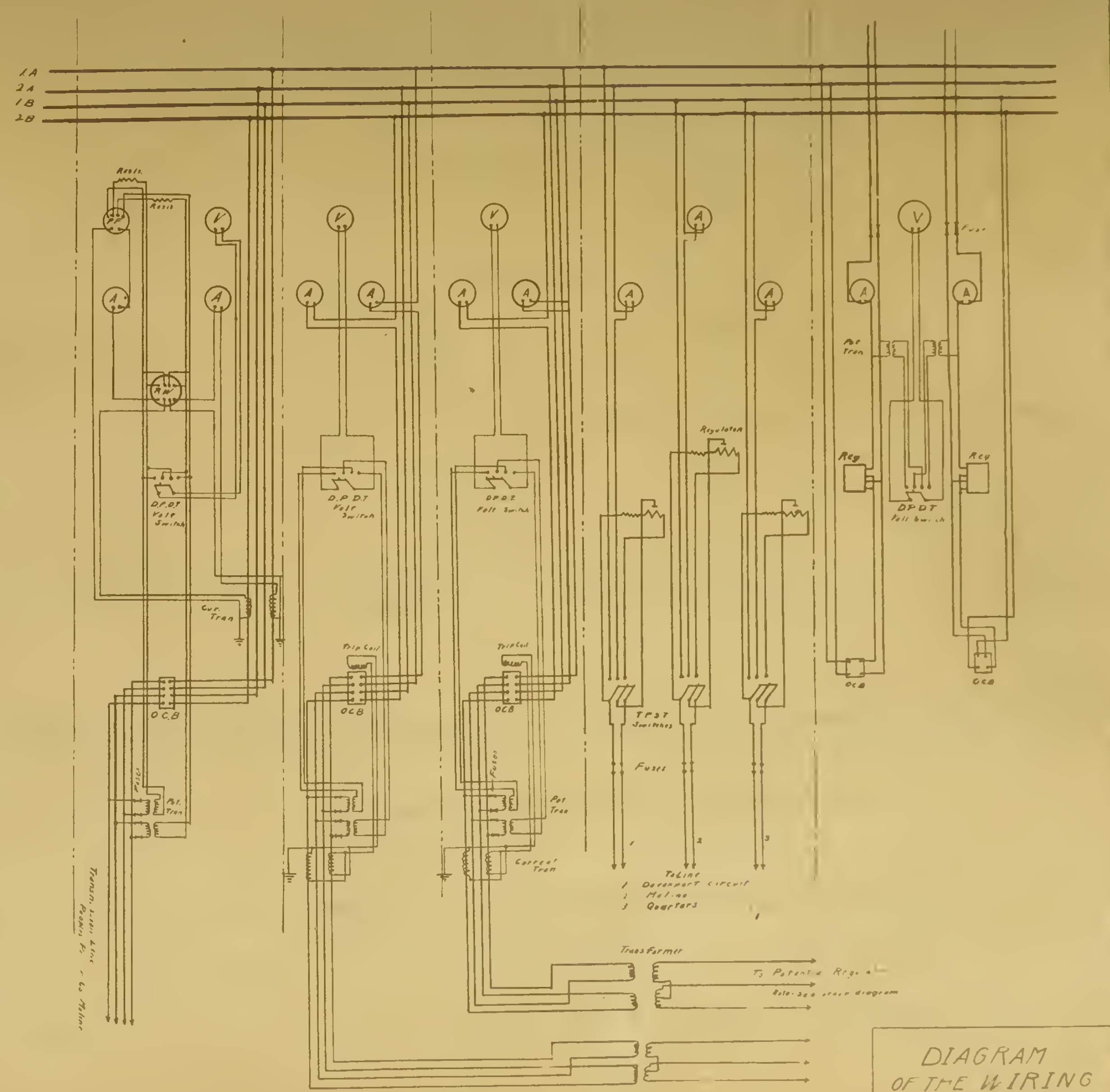


DIAGRAM
OF THE WIRING
SOUTH SWIT[illegible]BOA[illegible]
ROCK ISLAND ARS[illegible]

Plate 13

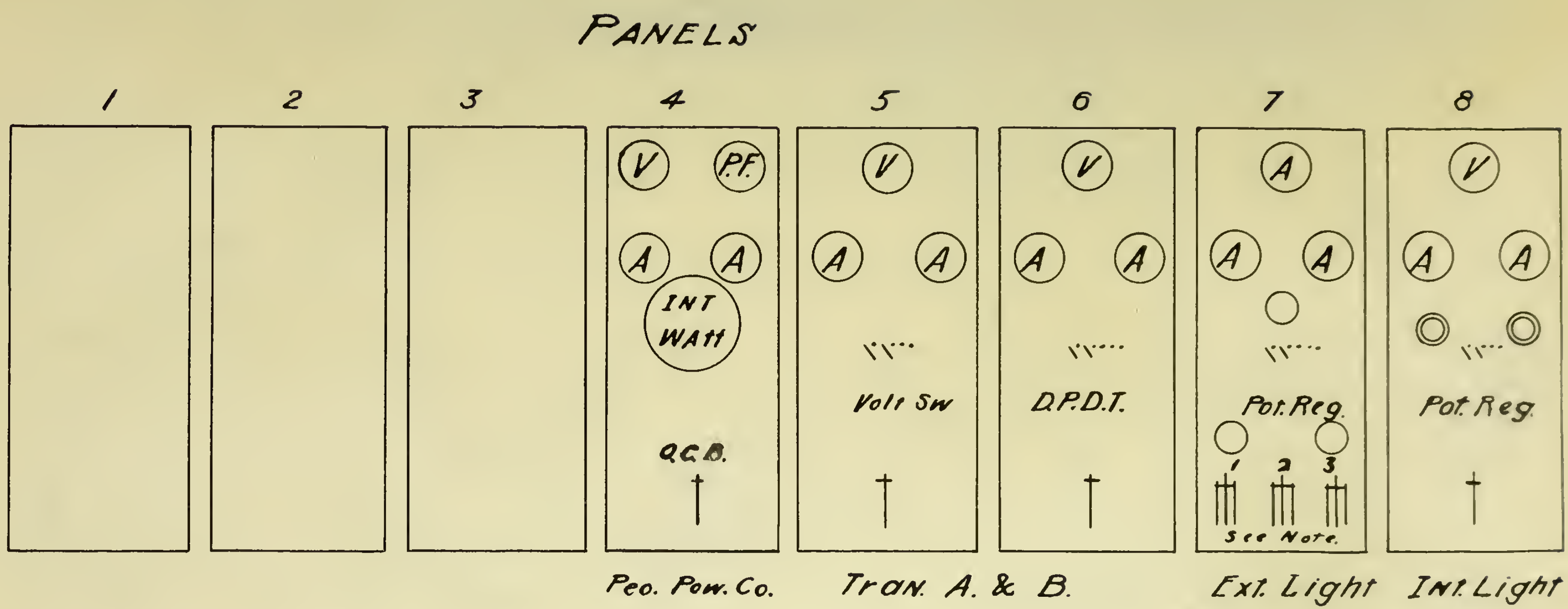


Chart Showing Location of Instruments Switches etc.

South Switch Board

Note.
1. Davenport Circuit.
2. Moline Circuit.
3 Quarsters Circuit.

Plate 14

PANELS.

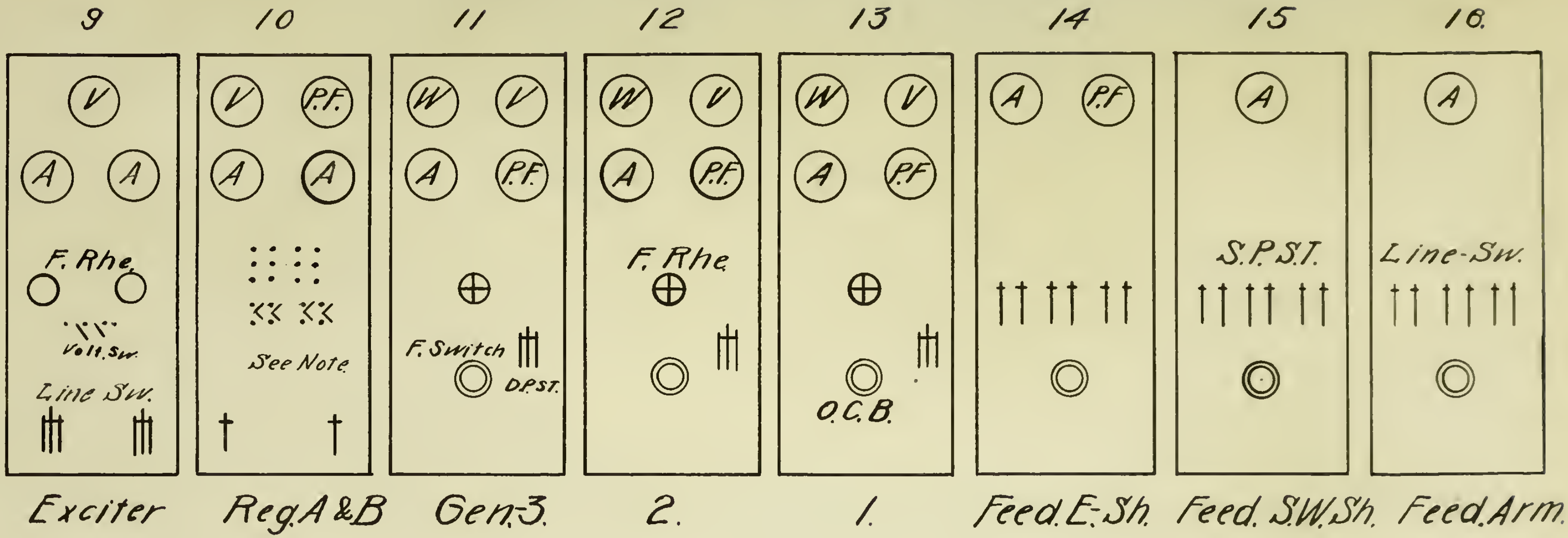


Chart Showing Location of Instruments, Switches, etc.

North Switch-Board.

Note { Switch controls, Motors for Reg.
Switch D.T. To Lower throw up.
To Raise " down.

Plate 15

Plate 16

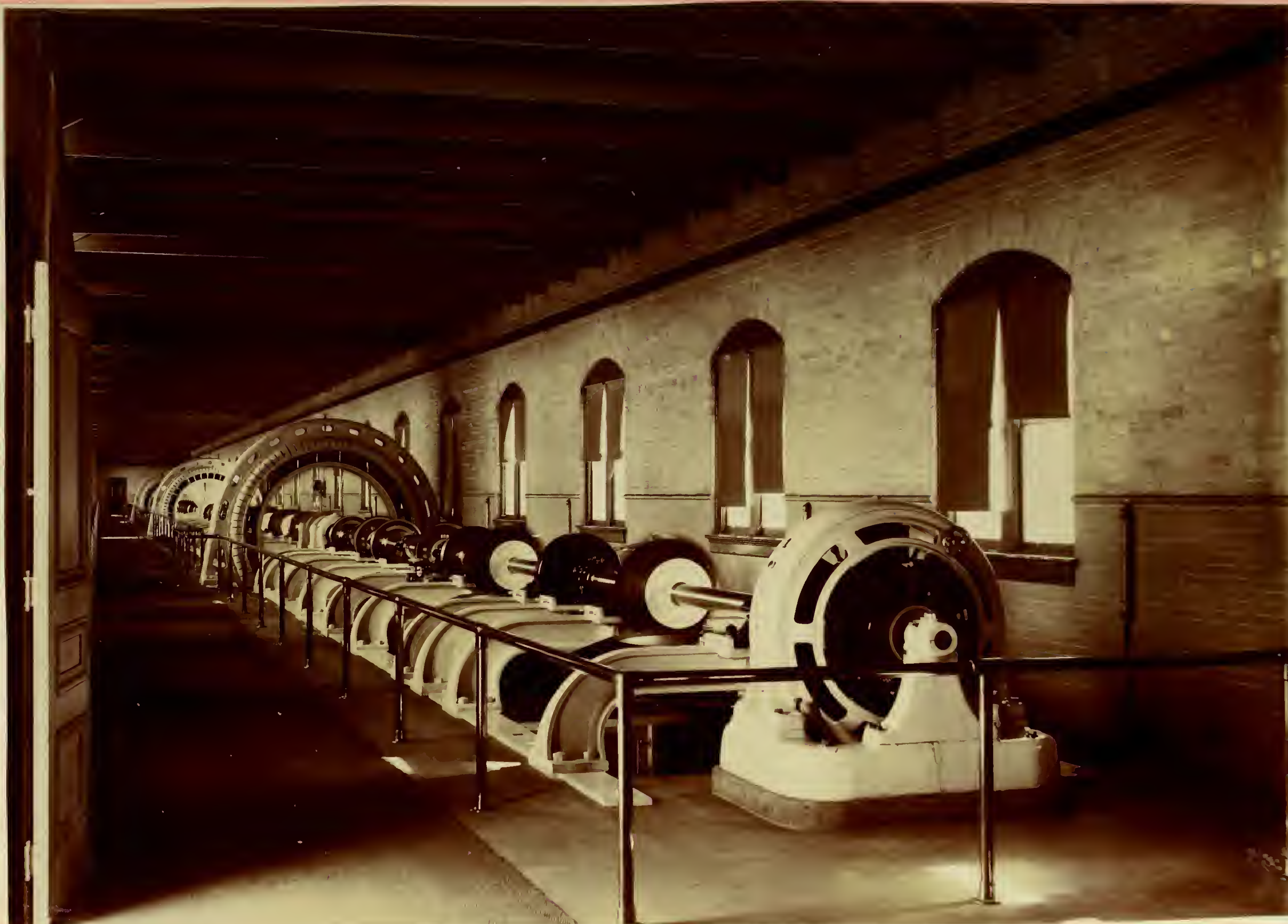


Plate 17

Plate 18

Plate 19