THE CONSOLIDATED SYSTEM OF ELECTRIC CAR LIGHTING.

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The Consolidated System of Electric Car Lighting.

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Electric Car Lighting has today passed beyond the experimental stage and has established for itself, an important and recognized place in the realm of electrical engineering. The subject of car lighting is one with which every energetic railway manager has to deal and the electrical lighting of railway cars is demanding the attention of most of the railroads throughout the world.

The success of an invention depends upon two things, first upon its capacity for accomplishing the results for which it was designed; and secondly, the demand created for the invention, when it is placed upon the market or put into general service. Electric car lighting fulfills both of these conditions and its success today is proven without a doubt. Electricity is universally admitted to be the best means of supplying light providing it can be produced and regulated successfully. Many systems of regulation and control have been devised and are now in operation on the trains of various railway companies. The success of electric lighted trains may also be attributed to the fact, that the travelling public demand the best service from our railroad companies. The public is no longer content to ride in cars where the furniture is covered with grease and dirt from old oil lamps, nor does any one enjoy inhaling the obnoxious gases, so common to cars lighted with gas, when competitors are offering for the same rate, elegantly furnished cars, free from dirt, grease or odor, and brilliantly and evenly lighted with the modern incadescent lamp.

The electric lighting of cars is accomplished by means of many different systems. Each system must have a source of power, a means of regulating and controlling this power and lastly an efficient means of distribution. In the last few years, marked improvements have been made in various systems of car lighting over some of the earlier types.

It is interesting to go back to the origin of electric car lighting, and review some of the earlier methods and systems by which the various railroads lighted their trains by electricity. Until the year 1890, no attempt was made to use the electric lighting of cars commercially. At this time several of the railroads, becoming interested in the subject, and desiring to investigate its merits as an improvement over the lighting systems at that time, took up the question, and more as an experiment than anything else, equipped several of their best trains with a system of electric lights.

The Inter Colonial R. W. Co. of Canada was among the first to adopt a system of electric car lighting. In 1890, they equipped forty cars for electric lighting, using ten candle power lamps supplied with current from a large storage battery. The battery was designed for a run of five hundred miles, at the terminals of which were located charging stations. The distribution of lights consisted of from eleven to twenty-two lights to the car. Connections were made from car to car, completing the circuit throughout the car and the storage battery. The new system of lighting was a success as far as being an improvement over the old lamps was concerned, but the chances of failure of the battery were many. A storage battery in itself, is a very uncertain piece of apparatus. It may fail at any time without any apparent cause. This would be quite a serious matter, with a train several hundred miles from a charging station.

The combination of the battery and the dynamo as a source of power fromcar lighting, was first adopted by the Pullman Co. Their system consisted of an engine and generator situated in the baggage car. The plan was simply that of a small power station.

The current was here generated for the whole train, a circuit being run throughout. Arrangements were also made so that the exaust steam from the driving engine, could be used for the heating of the cars. This formed a very efficient means of lighting and heating but involved the expense of an engineer for each train so equipped.

About the same time, The Chicago, Milwakee and St. Paul, installed a system very similar to that of the Pullman Company, with the addition of a separate boiler, the function of which was to supply the engine driving the generator, and furnish heat for the entire train. As in other systems the generating was done in the baggage car, a Westinghouse Automatic Engine driving a No. 4 Edison Compound Dynamo.

All of the afore mentioned systems of car lighting, were as an experiment, successful in accomplishing the results for which to they were installed but as a commercial and financial proposition, they could not be accredited as such, on account of the heavy expense of operating. The real commercial problem of car lighting was not solved until a means was devised wherby the motive power for the generator was to be obtained from the axle of the car. This offered a cheap source of power and as a result of which, several of the railroads equipped their best rains for electric lighting with the following system. A generator was placed in the baggage car, attached by means of a belt to the axle of the car. In the same car, a set of twenty-two accumulators were paralleled with the dynamo, for the purpose of supplying the lights when the train was not in motion. In order to regulate the current, a governor was arranged so as to cut down the current when the lamps were cut out of the circuit, and leave the batteries on charge with a normal current. The voltage regulation was obtained by means of a regulator, which allowed no perceptible change in the brilliancy of the lights during the entire run.

The method of getting power from the axle proved to be a success, not only as an experiment, but also as a commercial and financial proposition. Immediately various manufacturing companies commenced work, designing and manufacturing equipments, to be used in the electric lighting of trains, all of the said equipments having the common characteristic of using the car axle as the motive power.

The Consolidated Railway Electric Lighting and Equipment Company is today manufacturing an equipment which, having been installed on the trains of various prominent railroads throughout the United States, is giving excellent results. The proof of this statement is verified by the fact that where the Consolidated has been given a fair trial, it has, upon its own merits, taken the place of other equipments. The chief advantage of the Consolidated over other systems is not only in the fact that it gives almost perfect regulation, but also because of the small amount of care and attention which is required to keep the machinery in working order. This is due largely to the protection that is given to the delicate parts of the machine. The regulator, the sensitive mechanisms of which govern the entire lighting system, is located in the car, which insures it against accidents which might occur, were it located under the car. This position of the regulator admits of a close inspection at any time, by any employee of the company and in case of trouble he can continue his work while the train is in motion and thus prevent a delay of the train.

THE CONSOLIDATED SYSTEM.

The Consolidated System uses as its source of power, the car axle, the function of which is to drive a low voltage generator, suspended from the trucks under the car. This generator is connected in parallel with a storage battery and the lighting circuit of the car With the train in motion, the generator, belted to the axle, furnishes a current of 30 volts pressure, to be used in lighting the car and charging the storage battery. Since the speed of the train, and consequently the voltage of the generator, is very irregular, means are provided to furnish the lamps continuously with a current of constant pressure. This is accomplished by a switch, which automaticly cuts in and out of the circuit, the generator, when it fails to generate the normal voltage required for the lighting of the train. When the car is at rest, the power for the lights is furnished by a storage battery of sixteen cells, installed in a box under the car. This battery is of sufficient capacity to take care of the lights for twenty-four hours continuous run. As soon as the train starts, the battery continues to carry the load until the car axle has attained sufficient speed to cause the generator to build up to normal voltage. When this conditions has been reached, the automatic switch completes the main circuit and the generator furnishes light for the train and at the same time charges the storage battery which is connected in parallel with the lamps.By this means the railway car is lighted continuously at a constant voltage, the regulation of which varies only with the condition of the storage battery at the time at which the generator is thrown in or out of the circuit.

The generator used for the electric lighting of cars by the Consolidated system, is one designed especially for this kind of work. The machine must be strong enough to withstand unusual conditions, on account of its position on the trucks under the car, which in all respects, is the best place possible. But at the same time the generator must be kept at a minimum in order to produce the best possible results. The fields themselves are protected by a heavy iron casing, the field poles being made up of laminated iron. Every detail of the machine is designed for durability. The entire machine is encased in a dust proof enclosure, the pulley shaft protruding from the ends, and the machine terminals being brought up to a terminal block fastened to the encasement.

Electrically, the machine is designed somewhat differently from the ordinary dynamo. Such a quality of iron is used in the manufacture of these machines, that the saturation point is reached at or about 40 volts. This enables the machine to be thrown into the circuit when the speed of the train is sufficienct to cause it to generate the required voltage, and with the aid of a little regulation, the voltage of the lamps can be maintained at a constant pressure of about 30 volts. The dynamo is self excited and builds up very readily from the residual magnetism in the fields.

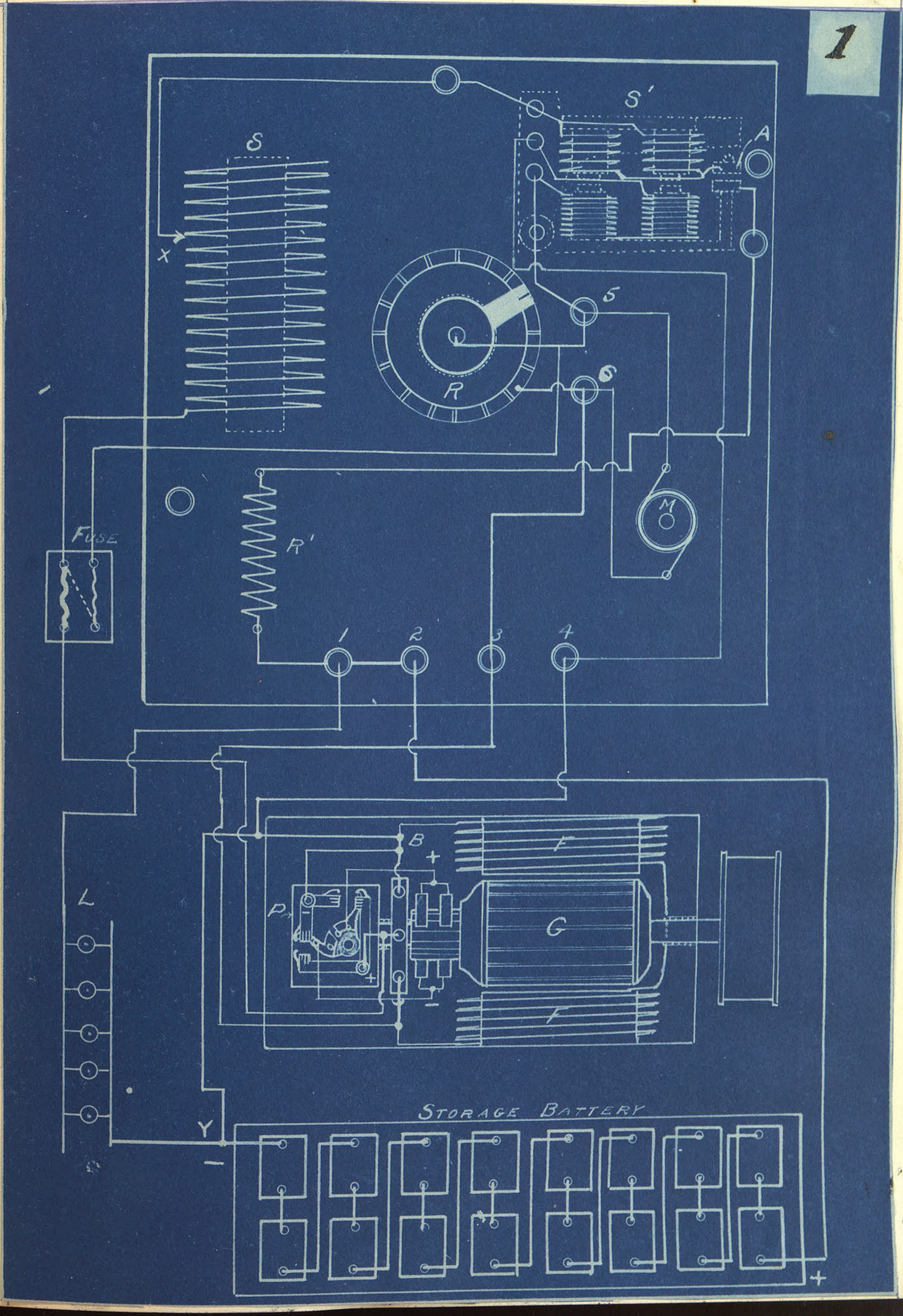
The generator is fitted with a pole changer, which controls the polarity of the machine when the direction of the car is reversed.

The storage battery, while a secondary source of power, is the important factor in this system of car lighting. It may be truthfully said that a storage battery in good working condition, is almost perfect in its performance of duty, but a poor battery is absolutely worthless. The storage battery requires more attention and care than any other part of the equipment, yet when this care and attention is given, the battery is the source of very little trouble. The storage battery used with the Type 'A' equipment, consists of sixteen cells, each furnishing a pressure of two or more volts, owing to the condition of the charge. This system gives a working pressure of from 30 to 35 volts to the lamps when the car is not in motion. The battery when it is installed in the car is fully charged and capable of furnishing power for the lights for twenty hours continuous run. However the battery is rarely called upon to furnish power for that length of time without being recharged. Only under the most urgent conditions, should the battery ever be allowed to be come over-discharged. The average train on its run, has no extra layovers, other than the short stop at stations. During the day run the battery is completely charged by the dynamo. At night, the power for the lights is furnished alternately by the battery and the generator, owing to whether the car is in motion or not. It is impossible for the battery to become under-charged, unless for some unexpected reason the car is laid out on the track for a longer time than the battery will hold up under charge. It is quite a common case to have the batterys over-charged, but this is not considered a very serious matter. There are various things that will have injurious effects upon a storage battery. The battery may be injured if too rapidly discharged. There is no danger from this source in the Consolidated system, for the load on the battery is constant. Then the battery may be charged too rapidly, but this is guarded against by the design of the generator, which will not generater more than 35 or 40 volts under the fastest speed. The greatest evil to be guarded against and the one which is most common in the care of storage batteries, is that of neglect. A battery should be cared for and looked after at regular intervals of time. With the proper precautions, a storage battery may be kept in the best of condition, the life of the average cells being from ten to twelve years. The storage battery as used in connection with car lighting, operates under the best conditions. The secret of keeping a storage battery in good condition is to use it. When a set of cells is installed under a car, to be used in lighting a train, it is used continually; charging and discharging in accordance with the throw of the automatic switch. Inspectors who have charge of the battery equipments, report that they have very little trouble with cells sulphating, due undoubtedly to the extra precautions taken to keep the cells in the best condition. The storage battery itself is not an efficient means of furnishing lights for a train, but combined with the axle driven generator, such as is employed by the Consolidated Company, it makes the Axle Light system of car lighting an undoubted success.

REGULATION

The real problem of car lighting is embodied in the one word, regulation. There has been no trouble in finding ways to produce power for train lighting, but a vast amount of time and money has been spent in studying how to regulate this power to give a constant voltage at the lamps. The Consolidated Type 'A' regulator is one of the results. Its regulation is such that it allows no perceptible change in the brilliancy of the lights throughout an entire run, the voltage only varying from one to two volts on either side of the normal value. The electrical circuits and connections of this regulator, with an outline of the generator and battery, are shown on plate (1). To understand the operation of the regulator, let us follow through the complete run from the time the train

1



starts from rest until the next stop is made. As long as the generator fails to furnish the required voltage, say 30 volts, the lamps are burning on the storage battery; the current passing out from the positive terminal, as marked on the plate, up to the regulator terminal No. 2, through No. 1 to the lamps and back to the negative terminal of the battery. As the train comes up to speed and the generator voltage increases, the pull upon the magnet S' becomes stronger and stronger until the pull, which is proportional to the voltage, over-ballances the spring which holds the switch (A), the main circuit through the generator being completed through the switch. Under these conditions, the current from the generator is supplying the lighting circuit and also charging the battery. Tracing the circuit out with the generator in the line, the current leaves the positive brush of the generator and passes through the pole changer up to the dynamo terminal block. From here it goes to the main fuse, the field current dividing, passes through the small fuse to the field rheostat (R). A portion of this field current is used to run the small motor (M) and unites with the main field current at (6), passes through the regulator terminal (3) to the fields of the generator (F) and finally back to the negative brush of the generator through the pole changer. Another circuit in parallel with the last one, furnishes current for charging the storage battery. This circuit branches off from the main at the terminal (2), passes to the positive terminal of the battery, through the battery and united with the main circuit again at (Y). As long as the train can keep up speed so that the generator can furnish the required voltage, this circuit is in use, but as the train slows down, the pull upon the magnets(S') becomes so weak that the switch opens and the lights are again thrown upon the battery circuit alone.

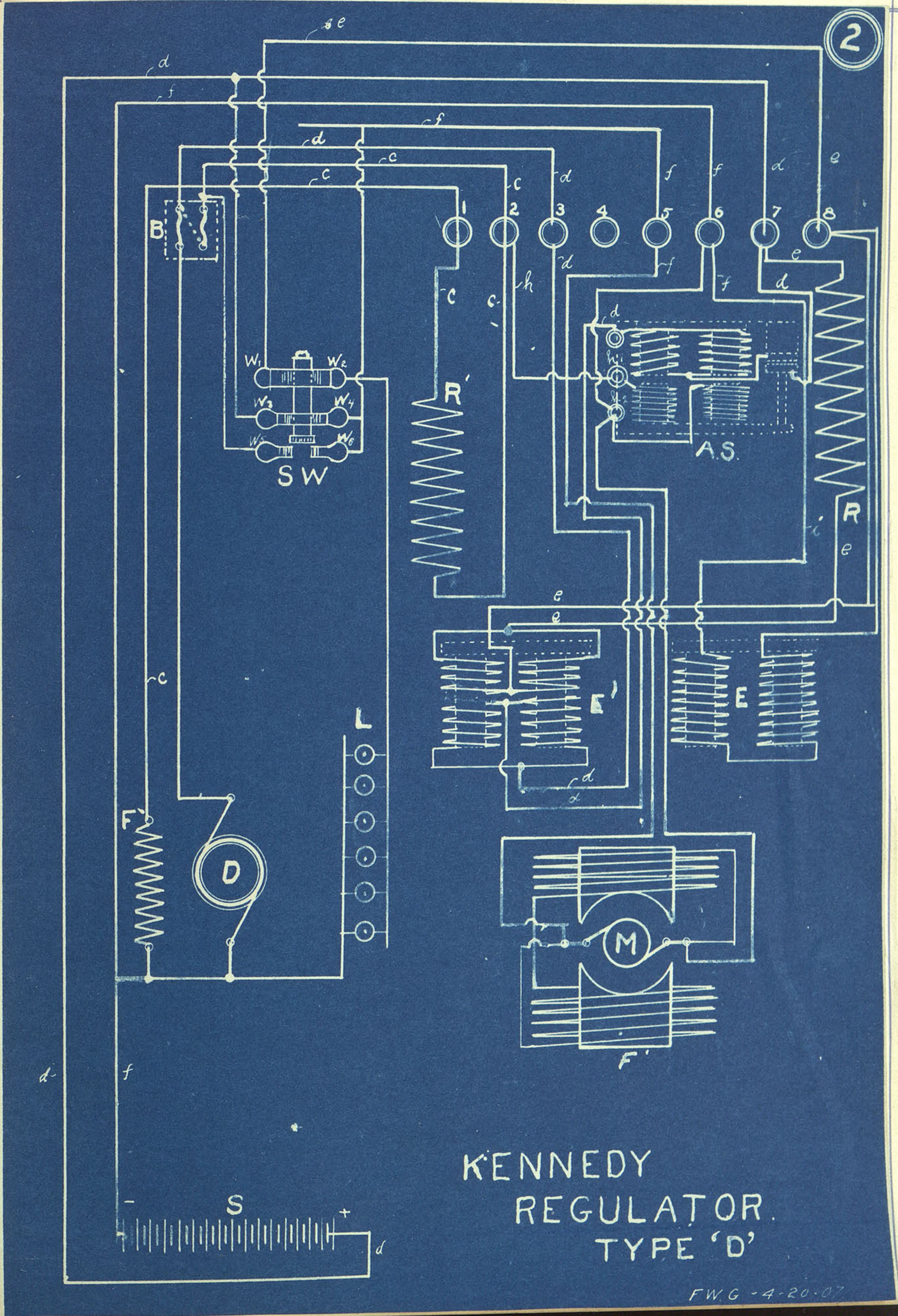
The large solenoid (S) is in the main generator circuit and is affected by any change of voltage from the latter. Attached to the core of the solenoid, is a system of levers and cams which govern the direction and movement of the rheostat (R'). As long as the voltage is constant at its normal value, the core of the solenoid strikes a ballance which allows no movement of the field rheostat. If the train speedsup and the voltage rises, the current through the solenoid is increased and allows the rheostat to be moved, the motor (M) furnishing thenecessary power. The action of the rheostat continues until the resistance cut into the field reduces the voltage to its normal value. The two magnets of the automatic switch (S'), the upper and lower, are differentially wound, so that opposite poles are set up against one another, the repelling force of one being accompanied by an attracting force of the other. The resistance (R') in the main circuit is used to control the lamp voltage. This resistance is also operated by the solenoid (S).

One objection to the Consolidated Type 'A' regulator, is its complexity. With more or less delicate mechanisms, of which the regulator is made up, the chances for disorders to occur, are many. The motor used to furnish power for running the rheostats is especially objectionable. The motor is always in motion so long as there is enough current generated in the field to furnish it with power. A more simple method of furnishing power for the rheostat would, in the authors mind, be a decided advantage in reducing the complexity of the regulator. In some cases where this regulator is used, the lamp resistance (R') is not connected, an equivalent being inserted in the circuit under the car. Results have proven that the regulation is very little affected by this change.

The first equipments which the Consolidated Company put out were of the type just described, the type 'A' regulator and generator. However as soon as a number of the railroads began to equip their cars for electric lighting, there immediately arose a demand for a generator which could furnish more light and closer regulation than those first installed. The type 'A' equipment could hardly be improved on for installations, where from 40 to 50 lights were to be used in the circuit, but the demand for more light, and consequently more lamps, called for a proportional increase in the size and capacity of the generator. The increase in capacity furthermore called for finer and closer regulation and as a result of this demand, the Type 'D' generator and the Kennedy regulator were designed.

The type 'D' generator embodies all the advantages of the type 'A' and in addition is designed for a larger capacity, generating its maximum current at the same speed as the type 'A', without excessive heating. The machine itself is made stronger and more durable than the other type and many of its conducting parts are made larger in order to carry the heavier current. The weight however has been kept at a minimum, the increases over the type 'A' , being comparatively small. The pole changer of the Kennedy regulator is made automatic and with the exception of being larger in order to carry the heavy current, is the same as that used on the type 'A'. The type 'D' generator is designed for both 30 and 60 volts, the capacity of the first being 90 amperes and the second 45. This generator is especially adapted for cars where the number of lights exceed 50.

In connection with the type 'D' generator, the Kennedy regulator should be used. The electric circuits and connections of this regulator are shown on plate (2). In place of the solenoids



KENNEDY REGULATOR. TYPE 'D'

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being used to regulate the voltage and current, electro-magnets are used in the Kennedy regulator. Refering to the details of plate (2), (D) represents the generator and (F) its field magnets; (M) is a motor, supplying power to run the two rheostats (R) and (R') . (S) is the storage battery charged by the generator. The differentially wound electro-magnet (AS) operates, automatically, the switch which opens and closes the main circuit of the genrator. (R) is a rheostat in the lamp circuit and (R') a rheostat in the field magnet circuit of the ~~d~~ dynamo. The switch (SW) controls the lamp circuit. The two electro-magnets (E) and (E') control the movement of the two rheostats, allowing movement only when a change in the current or voltage demands it. The function of the differential winding on the magnet (E') is to govern the generator output. This winding is in series with the lamp circuit, so that all the current supplied to the lamps, passes through it. During the day run, the current generated must not exceed the maximum charging capacity of the battery, and when the lamps are burning, the genrator should supply enough current to run the lamps and charge the storage battery at the same time. When the lamps are turndd on, all the current supplied to the lamps passes through this differential winding and serves to neutralize to a certain extent, the main current from the generator. Under these conditions, a larger current is required to over come the action of the spring of the magnets and hence a closer regulation is obtained.

The type 'D' equipment is especially recomended for use on dining, private, business, sleeping and mail cars, where the service consists of all or nearly all night runs. The most striking feature of this equipment, is its close regulation. The Consolidated Company claims that with the Kennedy regulator, the voltage can be controled within a range of one volt, or in other words, the candle power of the lamps is maintained constant under all conditions, whether the current is supplied from the generator or the battery.

REGULATION TEST ON CONSOLIDATED TYPE 'A' EQUIPMENT.

The following test of a Consolidated Type 'A' equipment, was made on the Santa Fe, the test consisting of an all night run on Train No. 17, from Argentine to Arkansas City, Kansas. Instruments were so connected that at any instant, the speed, current, generator voltage, battery voltage and lamp voltage could be observed. The principle feature of the test being an accurate means of reading the speed of the train at any moment, it may be well to describe the instruments and methods used.

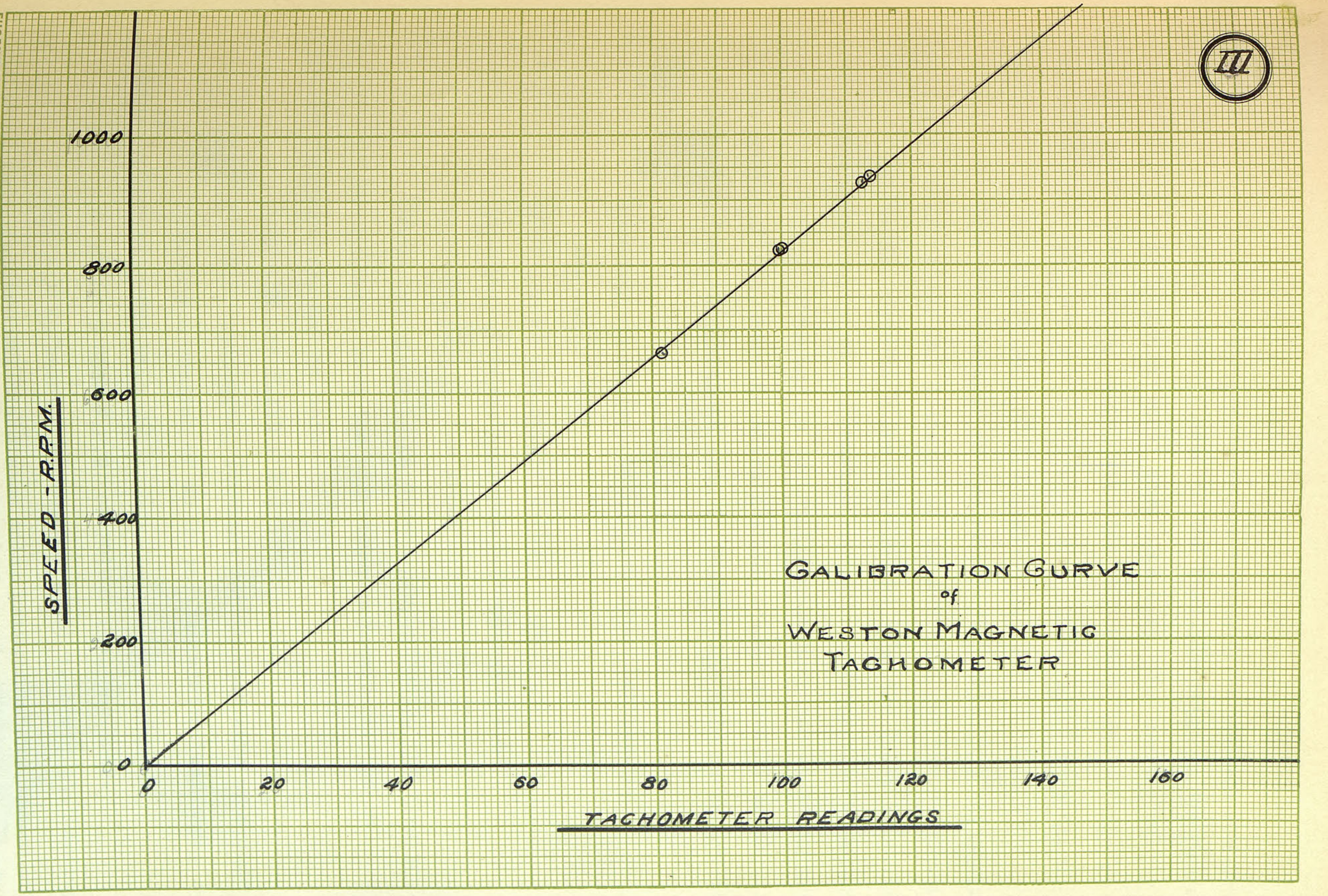
Apparatus:-

Weston Magnetic Tachometer and Milli-voltmeter #38
Weston Voltmeter #15931.
Weston Voltmeter #13520.
Weston Ammeter #20505.

The Weston Magnetic Tachometer, one of the most accurate instruments for obtaining the speed of a shaft or pulley, consists of a small generator, designed especially for use as a speed indicator. Since the output of any dynamo electric machine, is approximately proportional to the speed, it is possible to calibrate a milli-voltmeter, placed across its terminals, to read the speed at which the armature and shaft revolve. The Weston Tachometer is so designed that the hystersis loss of the machine is negligible. With these conditions the voltage output of the tachometer, is directly proportional to the speed at which it revolves.

The usual method of calibrating the tachometer to read revolutions per minute, is to belt it to the machine, the speed of which is to be determined, and connect its terminals to a milli-voltmeter in series with enough resistance, to give readings on the scale up to the rated speed of the machine. When the machine has attained a constant speed, the R.P.M. is taken with a speed counter and stop watch, the average reading of the milli-voltmeter being noted. By repeating this operation several times, an accurate constant can be determined, by which, if the reading of the milli-voltmeter is multiplied, the speed of the R.P.M. can be determined. Before the test, the tachometer was calibrated in this manner, the machine to which it was belted, being supplied with a current from a 110 volt storage battery, thus insuring constant speed. From the data obtained, a curve was plotted with R.P.M. as ordinates and tachometer readings as abscissas. This curve is shown on plate (III). Throughout the test, the greatest care was taken to insure accurate results. All instruments were accurately tested and calibrated by means of the Potentiometer and Electro-static Voltmeter.

In order that the speed of the train, in miles per hour, could be read on the tachometer, certain dimensions had to be taken into account, vis., the size of car axle and the diameter of the car wheel. The generating element of the tachometer, was completely enclosed, with the exception of the shaft and pulley, in order to keep out the dust and protect it from flying cinders etc. Thus encased, it was securely fastened to the sand board on the trucks between the wheels, and its pulley belted to the car axle, the diameter of which was carefully calipered. Small leads were brought up from its terminals to the milli-voltmeter, placed in the car near the regulator box.



CALIBRATION CURVE
of
WESTON MAGNETIC
TACHOMETER

All other instruments were placed to the best advantage in the car so that the readings could be taken simultaneously. The ammeter was placed in the circuit in series with the fuse block. The voltage of the generator, battery and lamps was taken across their respective terminals at the lower part of the regulator.

With the diameter of the pulley with which the tachometer was first calibrated, the diameter of the car axle and the circumference of the wheel, another curve was platted with the speed in miles per hour as ordinates and tachometer readings as abscissas. By means of this curve, all readings on the milli-voltmeter, can be transposed to the speed of the train in miles pr.hour . This curve is shown on plate(IV). The calculations made in determining this curve are as follows.

Diameter of pulley, with which first calibration was made = 3.5"

Diameter of Car Axle = 5.125"

Constant of Tachometer for 3.5" pulley = 8.22

Circumference of Car Wheel = 117"

Since the speed is in direct proportion to the diameter of the belted pulleys, then the tachometer constant will be in inverse proportion, and we have,

8.22 : X :: 5.125 : 3.5

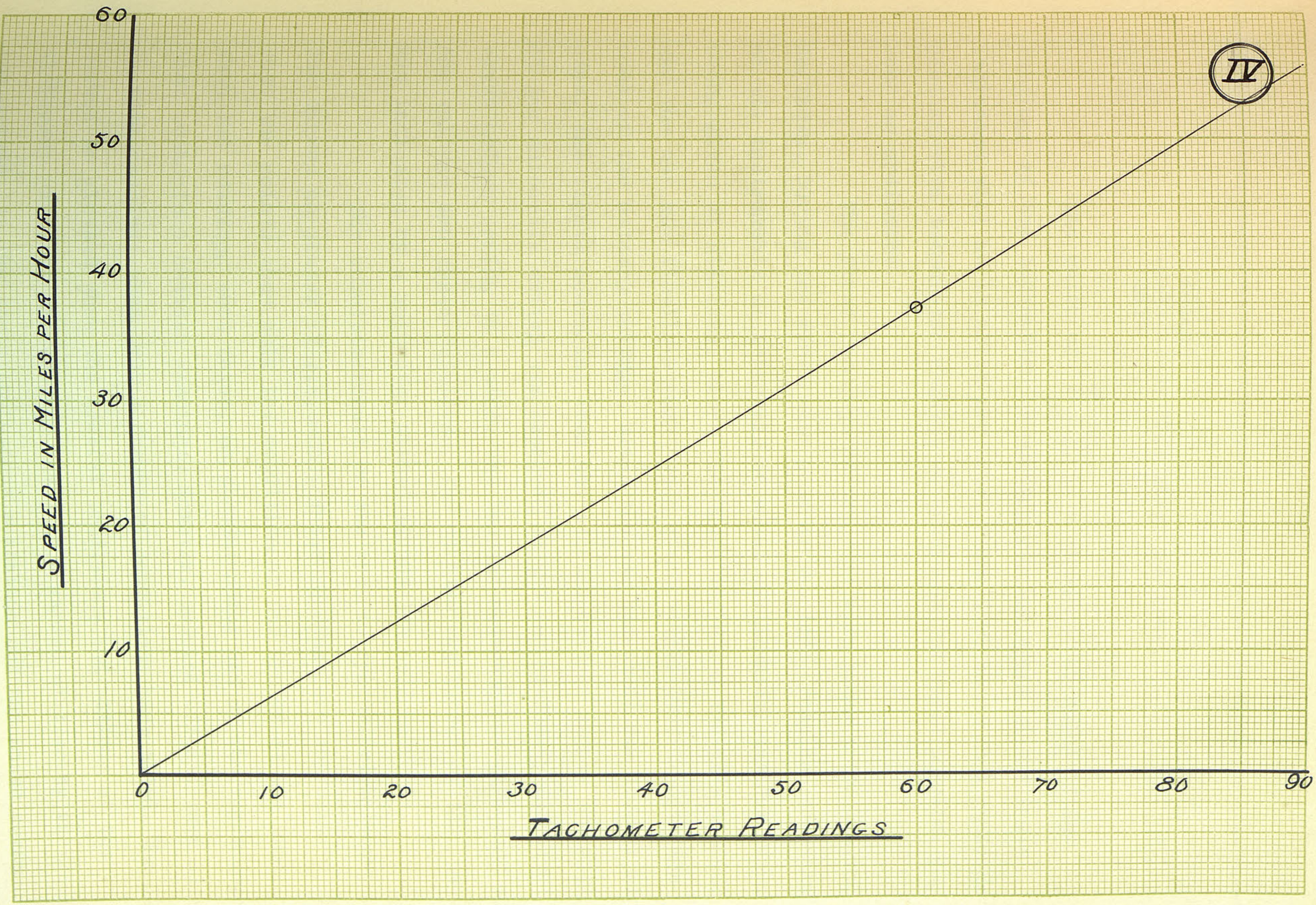
or X = 5.6, tachometer constant for the car axle of 5.125"

Assuming a reading of 60 on the tachometer indicator, the R.P.M. indicated would be,

60 x 5.6 = 3360 R.P.M. or 201600 rev. per hour.

Since the diameter of the car wheel is 117", the car wheel and axle will revolve 441 times each mile, there fore the number of miles per hour indicated by the reading of the tachometer at 60 is

EUGENE DIETZGEN CO., CHICAGO.



$$\frac{201600}{441} = 37.2 \text{ miles per hour.}$$

The ratio of $\frac{37.2}{60}$, is a constant, by which if the readings of the tachometer be multiplied, the speed of the train indicated will be in miles per hour. Plate (IV) shows this ratio as plotted with tachometer readings as abscissas and speed in miles per hour as ordinates.

The first readings of the test were taken after leaving Holliday. During the first half hour of the test, readins were taken on all instruments at intervals of about two minutes, careful attention being given at stations, where the speed variation was at a maximum and the car was finally brought to a stand still. Special note was made of the battery voltage, after the car had stodd for several minutes, the lights operating from the storage battery alone. The action of the automatic switch was observed as the car gradually decreased its speed before coming to a stop, and special observations were made upon the voltage and speed relations. The voltage regulation of the lamps was indicated by a voltmeter placed across the lamp circuit.

The complete result of the test is approximately shown by the curves on plates (V-a,b,andc). These readings are approximate, in that the points show only the condition of the system at the time when the readings were taken, no account being had of the variations that took place between readings. However, special efforts were made to take readings when ever a change of conditions were noted. The five curves as plotted show the general conditions and actions of the different parts of the system. There is a marked similarity in all of the curves. As the train approaches a station and the speed began to

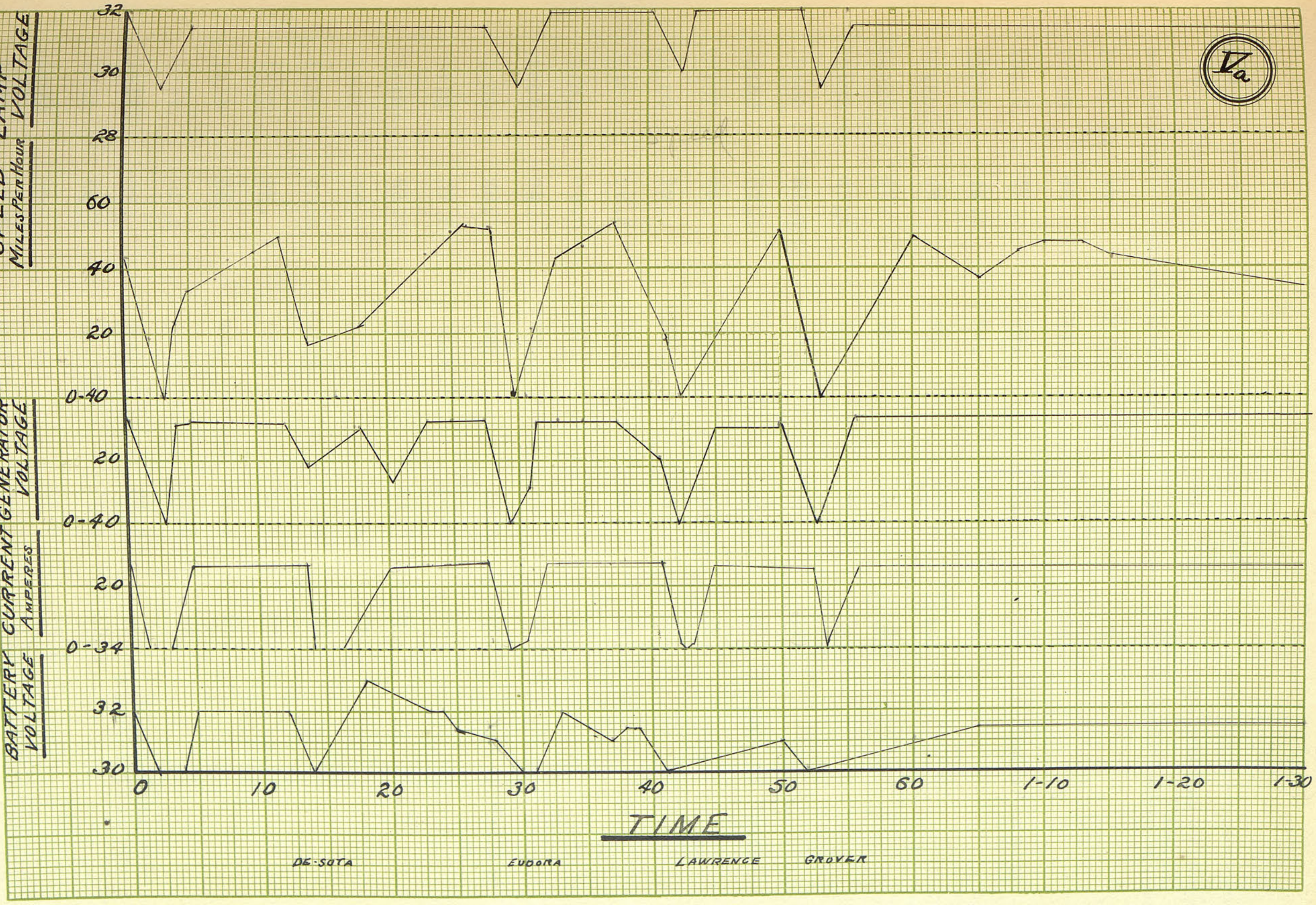
REGULATION TEST

THE CONSOLIDATED EQUIPMENT. TYPE 'A'

Time	Speed	Gen. Volts	Bat. V.	Amperes	Remarks
11.10 P.	43.5	34	32	26.	Out of Holliday.
11.12	18.5	24.5	30	2.5	#
11.14	24.	33.5	30	115.	*
11.15	34.	34.5	32	26.	
11.17	37.5	34.	32	26	
11.18	43.	34.	32	27	
11.20	45.	34.5	32	27	
11.21	48.	34.	32	26.5	
11.22	49.5	34.	32	26.	
11.24	17.5	19.	30	2.	#
11.28	22.	31.	33	2.5	*
11.33	44.	33.5	32	25.	
11.34	45.	34.	32	27.	
11.35	51.	34'5	31.5	25	
11.36	53.5	34.5	31.5	27	
11.38	52.	34.	31	27	
11.40	18.5	20.	30	28	#
11.41	21.5	31.	30	2	*
11.43	43.	34.	32	2.5	
11.45	46.	34.	31.5	27.	
11.47	52.5	34.5	31.	26.	
11.48	53.	34.5	31.5	26.	
11.49	53.5	34.5	31.5	26.	
11.52	18.5	21.	30.	2.	#
12.00	51.	34.	31.	26.5	Out of Lawrence

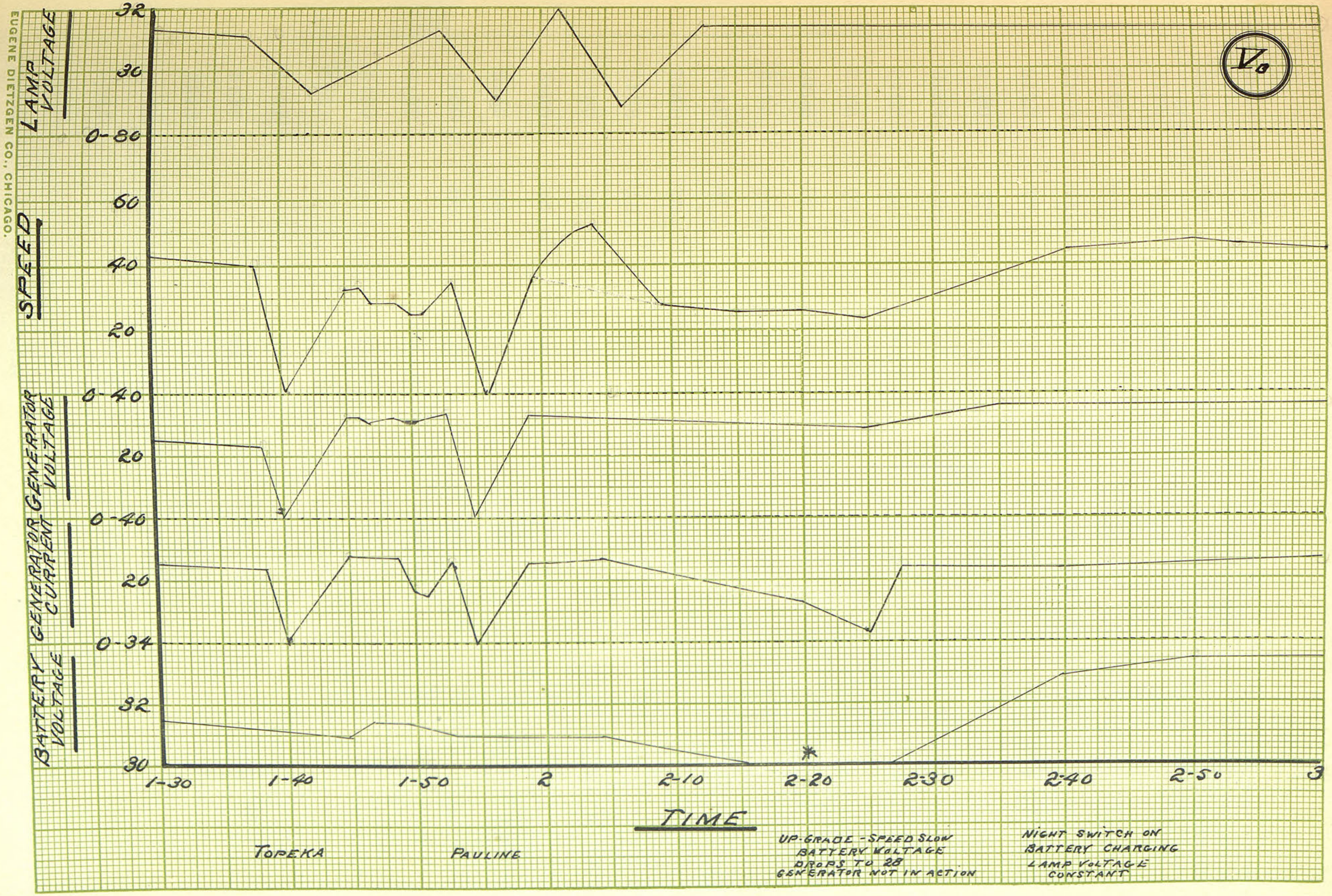
Data taken at the instant the automatic switch went off

* " " " " " " " " " in.



EUGENE DIETZGEN CO., CHICAGO.

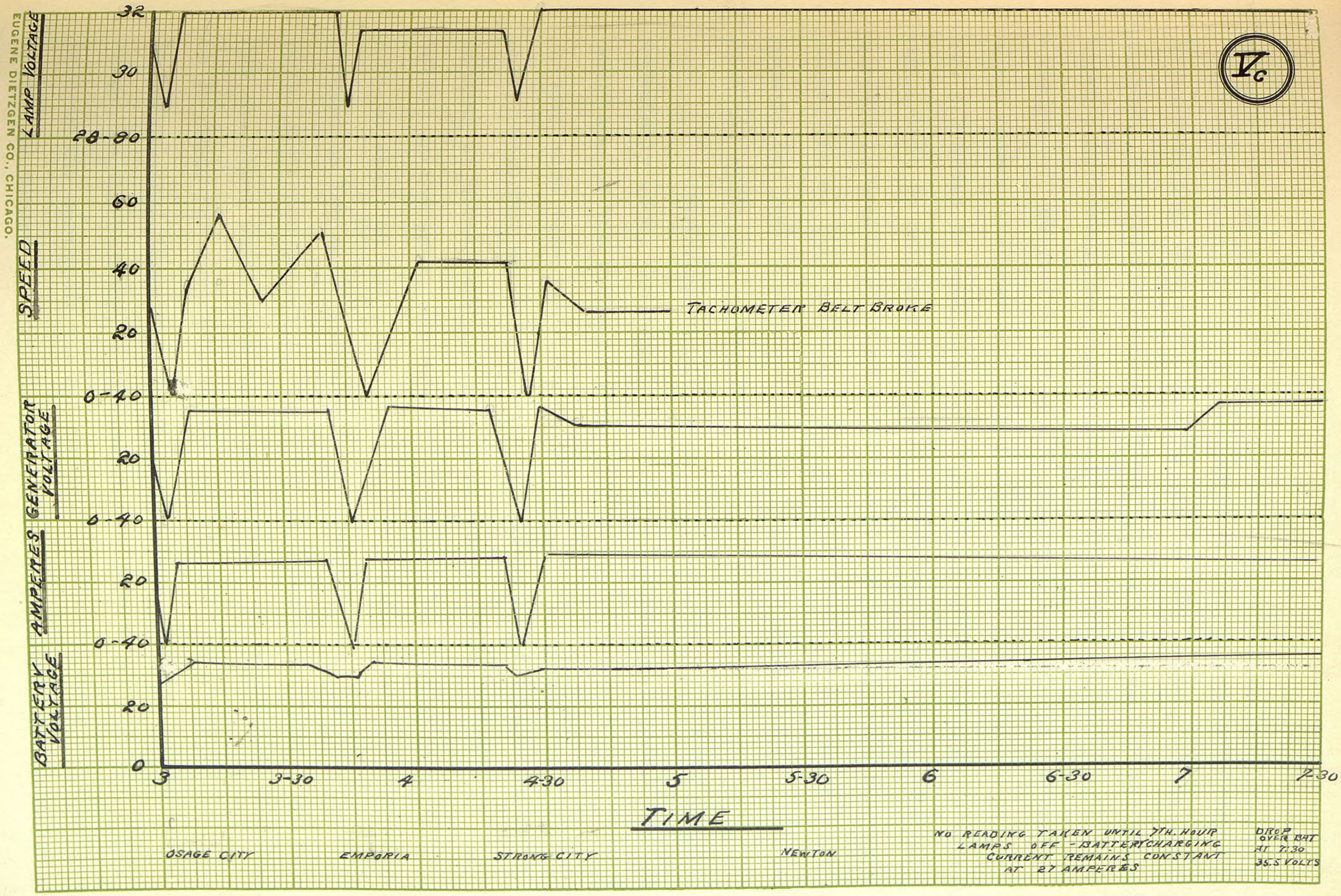
Time	Speed	Gen. Volts	Bat. V.	Amperes	Remarks
12:02 A.	18	20	30	2	
12:10	49	34.5	31	25.2	
12:15	37	34.	31.5	27.	Out of Grover
12:18	44.5	34.	31.5	26.	
12:20	47.	34.	31.5	25.	
12:23	47.	34.	31.5	25.5	
12:25	43.5	34.	31.5	25.5	
12:55	33.5	33.5	31.	28.	
12:56	35.5	33.5	31.5	27.	Out of Topeka.
12:57	29.	32.5	31.5	28.	
12:59	29.	33.5	31.5	28.	
1:00	25.5	31.5	30.	18.	
1:01	25.5	31.	30	16.	
1:03	34.	33.5	31	26.	
1:09	36.	33.	31.5	27.	Out of Pauline
1:10	37.5	33.5	31.5	26.	
1:10	41.5	33.	31.5	27	
1:11	44.5	33.5	31.5	25.	
1:12	48.5	33.5	31.5	25.	
1:13	52.	33.	31.5	26.	
1:13	52	33.	31.5	26.	
1:14	52.5	33.5	31.5	27	
1:19	27.	32.	31.5	22.5	Out of Wakarusa Night Switch On.
1:25	24.5	31.	30.5	17.5	
1:30	24.	30.	29.5	12.5	
1:35	21.5	29.	28.	2.5	


V_b
LAMP VOLTAGE
SPEED
GENERATOR VOLTAGE
GENERATOR CURRENT
BATTERY VOLTAGE
32
30
0-80
60
40
20
0-40
20
0-40
20
0-34
32
30
1-30
1-40
1-50
2
2-10
2-20
2-30
2-40
2-50
3
TIME
TOPEKA
PAULINE
UP-GRADE - SPEED SLOW
BATTERY VOLTAGE
DROPS TO 28
GENERATOR NOT IN ACTION
NIGHT SWITCH ON
BATTERY CHARGING
LAMP VOLTAGE
CONSTANT

Time	Speed	Gen. Volts	Bat. Volts	Amperes	Remarks
1:50	44.5	36	33	26	
2:00	46.5	36	33.5	26	
2:03	44.5	36	34	26	
2:18	37.5	36.5	34	27	Out of Osage C.
2:20	37.	36	34.5	26	
2:23	40.	36	34.5	26.5	
2:25	52.	36.5	34.5	26	
2:26	59.	37.5	34.5	26	
2:28	57.	36.	34.5	26	
2:36	30.5	36.5	34.5	28	
2:45	41.	36.5	34.5	2755	
2:48	50.	36.	34.5	26	
2:55	26.	35.	33.5	28	
2:59	36.	36.5	33.5	26.5	Out of Emporia
3:20	40.5	36.	34	26	
3:40	36.	36	34	26	Out of Strong C.
3:50	28.	36	34	26.5	
5:58		33.5	32	26	Tachometer belt broke. No data for speed taken after this.
5:59		33.5	31	26	
6:01		33.5	32.5	26	
6:08		33	30.5	26	
6:10		36	33	25	Lights off Batteries charging.
6:18		37.5	35.5	26	
6:40		35.5	33.5	26.5	
6:45		37.5	35.5	26	
6:50		37.	35.5	26	
7:00		37.5	35.5	26	Out of Mulvane

Complete time of test 7hours-50 min.

V_c



TACHOMETER BELT BROKE

NO READING TAKEN UNTIL 7TH. HOUR
LAMPS OFF - BATTERY CHARGING
CURRENT REMAINS CONSTANT
AT 27 AMPERES

DROP
OVER BAT
AT 7:30
35.5 VOLTS

to decrease, the generator voltage also lowered proportionally. The battery voltage decreasedslightly, due to the lowering of the charging current. The generator current remains almost constant at its predetermined value until the generator is switched out of the circuit. The strength of the current is kept up by the action of the rheostat which cuts resistance out of the circuit.When the speed of the car has decreased to such an extent that the current generated is no longer sufficient to ballance the spring of the automatic switch, the main circuit is broken and the light circuit is thrown on the battery alone. The battery voltage drops slightly when the lights are thrown upon it but soon attains a constant value at about 30 volts, depending upon the condition of the charge.

The lamp regulation of this equipment was found to be especially good, the regulation however, depending somewhat upon the condition of the battery. At no time was the voltage of the lamps found to vary more than two volts on either side of the normal value and this, producing no visible effects upon the lights. With the train running at normal speed, the voltage would remain constant at 31.5 volts. As the speed commenced to decrease, the voltage would gradually drop to about 30 volts and after a stop of two minutes, the voltage dropped as low as 28 volts. If this drop had been sudden, the effect would have been noticible, but with the gradual decrease, this was not the case. Conditions could prevail when the regulation would not be so good. For instance, if the battery had been discharged to such an extent that there was a drop of 4 or 5 volts when the lights were thrown on the battery, a dimming of the lamps would probably occur; also if the spring of the switch were so adjusted that the generator should be thrown out of the circuit when generating more than the normal voltage, there would be a drop that would probably cause a change in the brilliancy of the lights. However the chance for over- discharge is small, and on the regular trains that are in constant service, the batteries are generally in an over-charged condition. While the overcharging of a battery does it no good, the injury does not seem to warrent the adding of additional equipment to prevent it.

During part of the test run, only a portion of the lights were allowed to burn, resistance being thrown in the circuit by means of a night switch, to compensate for the lights not burning. On plate (Vb), the battery voltage is shown to have run down to 28 volts. At this time the train was some fifteen miles out of Topeka and ascending a steep grade. The speed of the train was not sufficient to generate enough current to supply the lights, and the storage battery was the sole source of power. Immediately upon the increase of speed, the generator went into the circuit at about a speed of 18 miles per hour and the battery charging from the dynamo soon acquirdd its normal voltage.

Throughout the rest of the trip, the train maintained its speed at about 45 miles per hour between stations. Under these conditions the battery voltage remained constant at about 32 volts, a slight drop occuring when the generator was cut out of the circuit at stations.

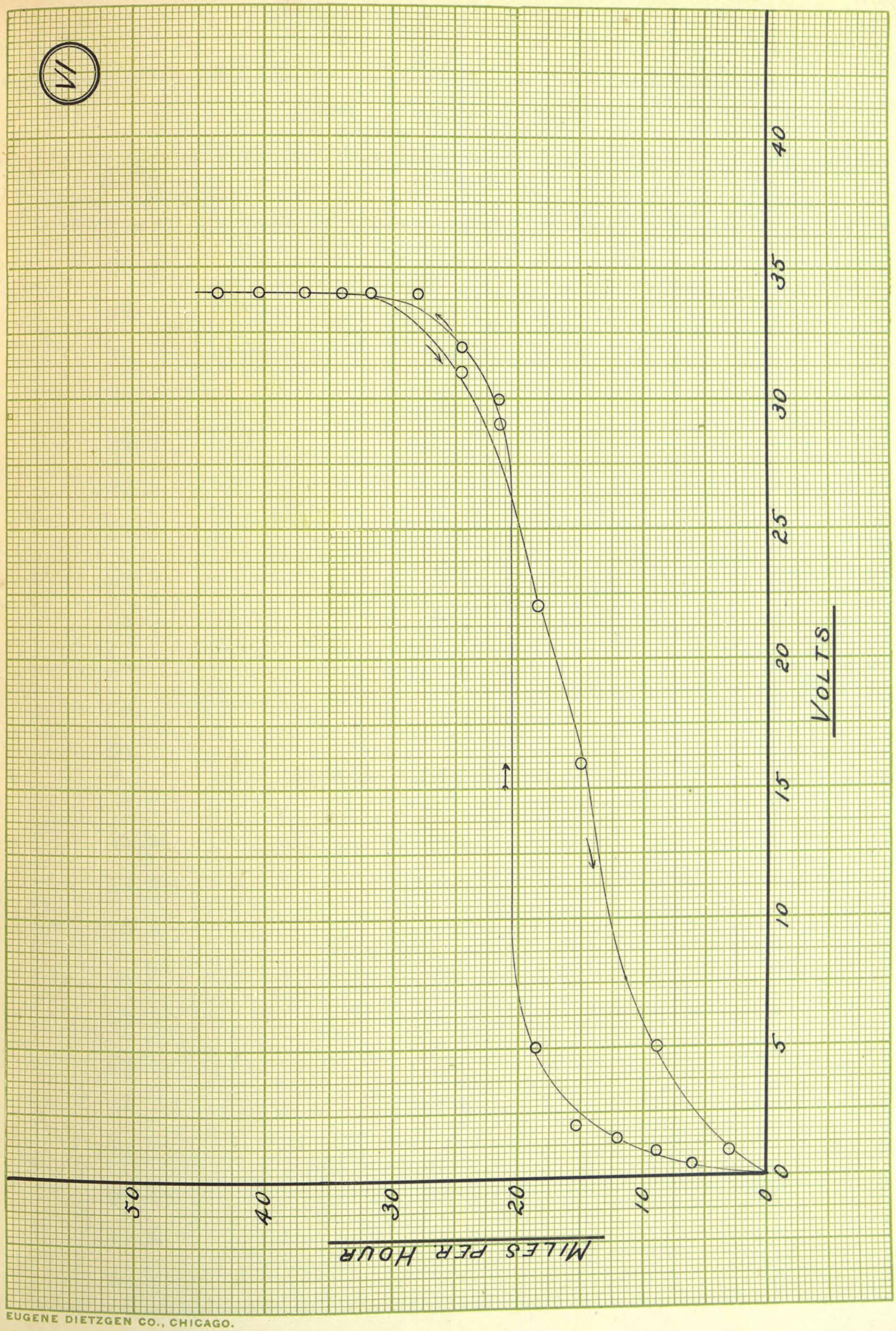
The speed of the train was noted regularly until after leaving Strong City, the belt from the tachometer to the axle, having broken and no chance being had to replace it. Afterleaving Newton, the service of the lamps were no longer needed and were cut out of the circuit. For the next two hours, the voltage of the battery was noted, the entire current from the dynamo being used in charging it. At the end of this time, the drop over the battery was taken and found to be 35.5 volts, a marked increase over the readings taken during the night.

The voltage regulation depends largely upon the adjustment of the spring attached to the automatic switch, such that when the generator voltage is the same as that of the storage battery, the action of the switch will occur. If any other condition exists, there will be a drop in the lamp voltage as the circuit is made or broken. At different times throughout the test, data were taken of the speed and generator voltage, thus showing the magnetizing effect and the relation of the output to the speed of the dynamo. Plates VI, VII, VIII, are the results of the observations, taken at different times as the speed of the train decreased; came to a stop and then regained its speed. The three curves show practically the same results, due allowance being made for the personal errors made in the reading of the instruments.

Taking up a discussion of the curve on plate(VI), we will see the relation between the voltage generated and the corresponding speed. As the car begins to move, the machine builds up very slowly and at a speed of 18 miles per hour is generating about 5 volts. This gradual bending of the curve and small increase of voltage is due to the fact that most of the power generated, is used up in overcoming the losses of the machine or in other words, is used up in magnetization. At a speed of 20 miles per hour, these counter forces have been overcome and the voltage immediately rises to a value of 30 volts From this point, an increase in speed is accompanied by a gradual increase of voltage until a constant value of about 34 volts have been reached. In this condition it is said to be saturated. The density of the iron has become so great that any increase of speed does not

SPEED AND VOLTAGE RELATIONS
PLATE VI

SPEED Miles per Hour.	VOLTAGE	CURRENT Amperes
40.25	34	25
37.	34	25
31.75	34	26
28.	"34	22.5
24.5	31	15.
21.5	28	2.5
18.5	22	2.
15.25	16	0.
9.	5	0.
3.	1	0.
	********************* **	
6.	.5	2.2
9.	1.	.4
12.	1.5	.4
15.25	2.	.5
18.5	5.	1.
21.5	30.	2.5
24.5	32	15.
28.	34	27.
31.75	34	27.5
34	34	27.5
37	34	26.
40.25	34	26.
43.5	34	27.



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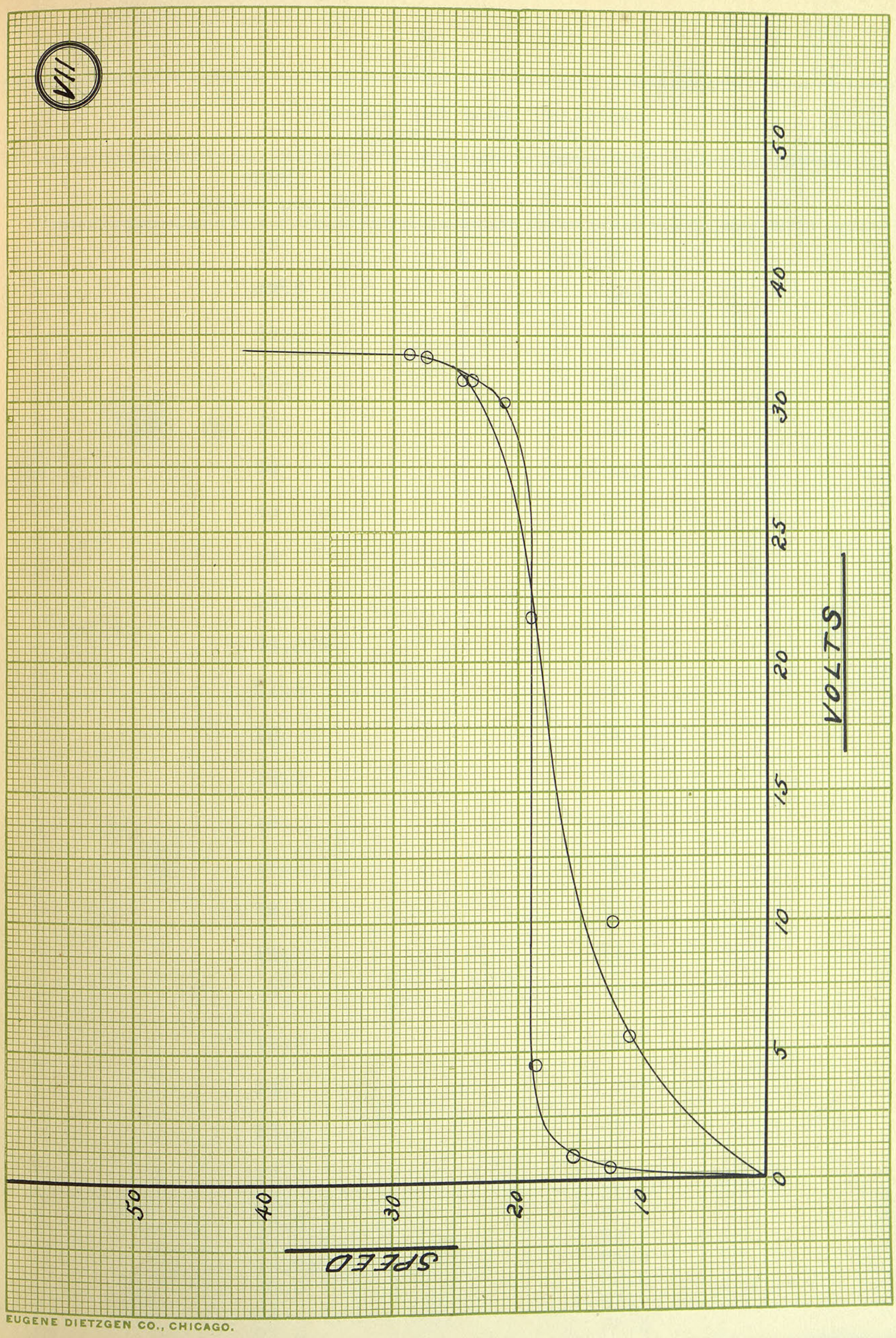
SPEED AND VOLTAGE RELATIONS
PLATE VII

SPEED Miles per Hour	VOLTAGE	CURRENT Amperes
37.5	34	26
34.	34	26
31.	34	25
28.	33.5	24
24.5	31.5	15
21.5	28.5	2.5
18.5	23.5	2.
15.5	17.	1.5
13.5	12.	0.0
12.	10.	0.0
11.	5.5	00.0
10.	5	0.0
	**************************	
6.2	6	2.25
12.255	1.	.5
15.5	2.	.5
18.5	4.5	.75
21.5	30.	2.5
24.5	31.5	14.
28.	34.	25
31	34.	27.5
34	34.	27.5
37.5	34.	26.
40.5	34.	26.
43.5	34	25.5



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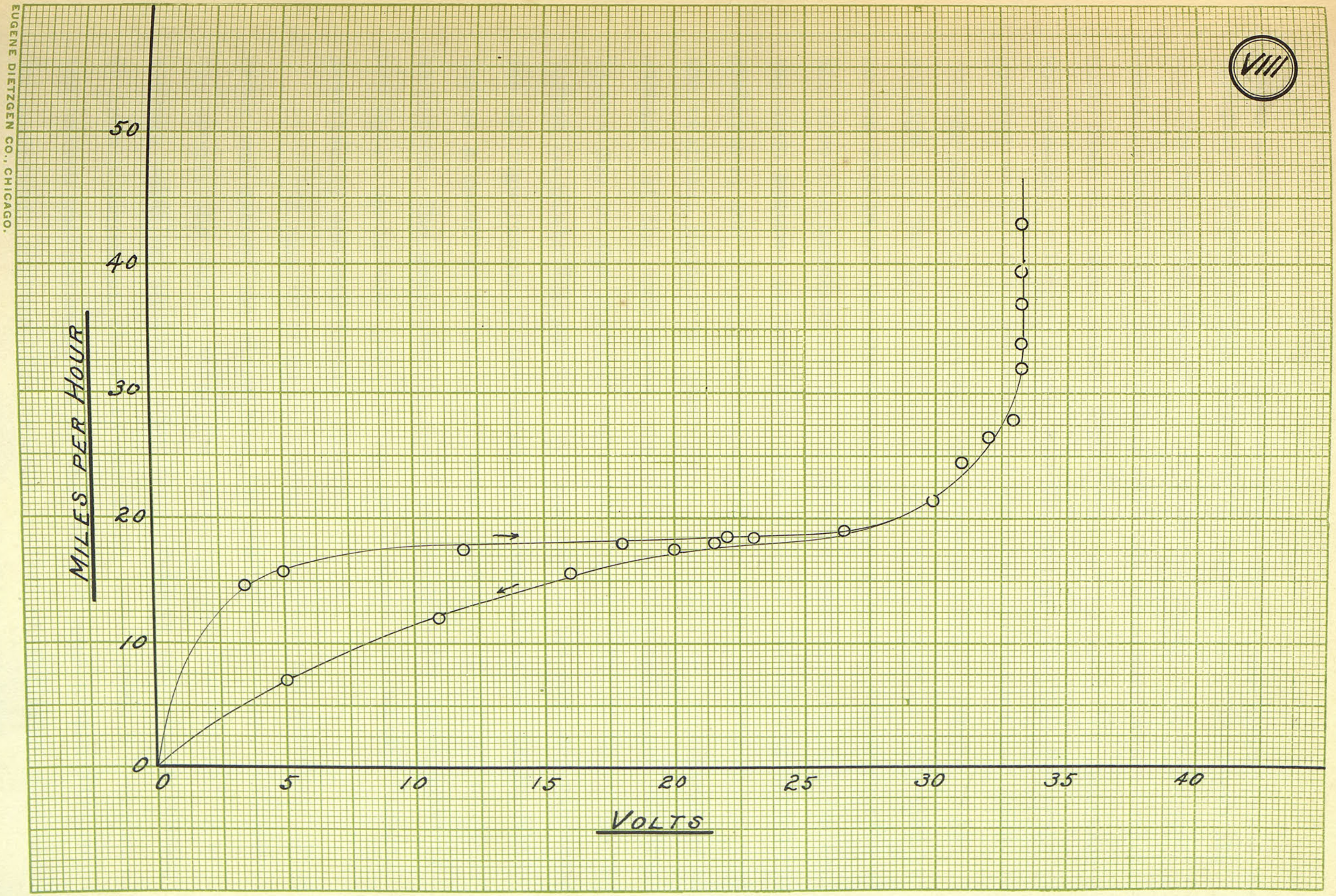
Voltage and Speed Relations
PLATE VIII

SPEED Miles per Hour	VOLTAGE
43.	34
42.5	34
39.5	34
40.5	34
37.	34
34	33.5
32	34
28	33.5
26.5	32.
24.5	31.
21.5	30
19	26.5
18.5	23.
18.	21.5
17.5	20
15.5	16.
12.	11
7.	5
12.5	2.5
14.	3.5
15.5	5.
17.5	12
18.	18.
18.5	22
19.	23
19.75	24.5
20.5	25.5
21.	27.
21.5	28.5

VIII



EUGENE DIETZGEN CO., CHICAGO.

produce a corresponding increase in the voltage. This shows the peculuarity in the design of the machine. Thses conditions must exist in order that the battery will not be injured with a charge of more than its rated value. During the entire test, the generator did not reached a voltage higher than 38. and at this time the train was running at 59 miles per hour. As the train decreased its speed, the voltage gradually decreased. There was no abrupt changes in the voltage as the speed decreased, due to the residual magnetism left in the fields of the generator. This is a common characteristic of all electric machines. With the machine running under full voltage, the iron becomes so saturated that when the magnetizing current is diminished and finally no longer exists, there remains in the iron the residual magnetism, which for a timeholds up the voltage of the machine. At the same speed, where the voltage was five, upon building up,now due to the residual magnetism, has a value of 25 volts. The curves on plate VII and VIII are similar to the one just discussed, the voltage rising almost immediately upon the start to 15 volts and at a speed of 18 miles per hour, rising to a voltage of 30 volts as before. The generator is never called upon for power until it has built up to that part of the curve where the voltage remains practically constnt for all speeds.

A number of readingswere taken when the automatic switch broke and opened the circuit of the generator. As the train increased its speed, the switch threw the generator into the circuit at an average value of 22.3 miles per hour. This is the average reading taken from a number of tials. As the train slowed down, the action of the switch was retarded due to the residual magnetism holding up the generator voltage. The average reading of the speed at which the switch broke the circuit, was about 18 miles per hour.

The following data shows the condition of the storage battery at different intervals of the test. The readings were taken after the car had come to rest and the generator was out of the circuit.

Time	Voltage
11:24 P.M.	29.5
11:40	29.5
11:51	29.5
12:55 A.M.	29.
3:40	32.5
4:15	33.
4:45	32.
5:10	30
5:35	29.5
6:50	29
7:30	32.5

* * *

The low voltage of the battery at the start, is due to lights having been burning on the battery alone for some time before leaving the Union Depot at Kansas City. Up until 1 P.M., the battery had no chance to regain its voltage by charging, on account of the several stops between Kansas City and Topeka. After leaving Topeka, no long stops were made until Osage City was reached at 2:15. The battery voltage by that time had raised a little and between Osage City and Emporia, the battery charged up to its normal value of 32 volts. It reached its maximum of 33 volts at 4:15 after a long stretch of continuous running at good speed. With a number of stops, including thirty minutes at Newton, the battery agained dropped to 29 volts. When the lights were switched off in the morning, the full current of the generator was used in charging the battery and the voltage again came up to 32.5.

This test shows the complete cycle of the battery in its night run. Unless for some unexpected reason, the car makes a long stop, there is no danger of the battery becoming over-discharged, for as soon as the car attains sufficient speed, the battery is recharged from the generator. On the average run, this operation of charging and discharging goes on continually, and the battery is thus kept in good condition, and at all times supplying when necessary, a current of constant voltage.

DOUBLE EQUIPMENT.

A double or combined equipment, consisting of the type 'A' and type 'D' generators and regulators, is found to be advantageous on some cars, where continuous service is called for while the car is not in motion. At times, mail and dining cars are side tracked for as long as six hours during the night, and during this time the storage battery is called upon to furnish the required current. An equipment of this kind insures against any posibility of light failure and eliminates the use of an auxillary light. In equipments of this kind, the two types of generators are used with their respective regulators. The type 'A' regulator simply controls the current of its generator, while the Kennedy regulator regulates both the current output and the voltage of the lights. Each generator is driven by a separate axle and their regulators placed at opposite ends of the cars. In case one of the equipments fails, either of the machines are so designed that they can carry the full load for a limited time.

LIGHT DISTRIBUTION.

The electric lighting of railway cars affords a means of distribution which excell that of any other lighting system. With the one exception, that of thorough insulation of the circuit wire from wood and other inflamable material, no precautions need be taken in the distribution of the light. In the chair cars, the lamps are placed on each side of the car above the seats and in this way the entire car is evenly lighted. In the parlor, dining and other special cars, the lamps are clustered, the number depending upon the brilliancy of the light required. No other light in use today is so adapted to the use in railway cars as the incadescent. It may be placed anywhere that wires can be run, and the entire current controlled by a single switch. The circuit wires are all concealed in the moulding of the cars, the terminals being brought to a switchboard installed in a suitable and convenient place. The lights are divided into two circuits. One circuit includes all the lights in the car and is controlled by the main switch. A second circuit is completed through a night switch and resistance, this circuit including only a part of the lights, the resistance being placed in the circuit to compensate for the lamps not burning. Where it is desired there is practically no limit to which the lighting system may be elaborated.

EFFICIENCY OF SYSTEM

The efficiency of the system or the cost of operating electrically lighted cars is a question still under discussion among car lighting officials. The first cost and the extra expense due to inspection and depreciation can be accounted for but as to the actual data in regard to the cost of power, necessary to light a railway car, no definite results have been obtained. The power output of the generator may be calculated, and knowing the efficiency of the generator, the axle power necessary to drive it could be obtained. But this does not necessarily involve an extra expense in the operation of the train. Train operators have acknowledged that they can detect no increased consumption in the amount of coal, where axle light equipments have been installed. This apparent absurdity is explained when it is remembered that the average locomotive has a capacity of about 1000 horse-power. Tests show that the average lighting equipment for each car uses about two horse-power, the total power consumed by the lights, being about one-tenth of one per-cent of the total power generated by the locomotive. Taking into account the enormous loss with which every train operates, it is readily seen why the additional loss used in car lighting, cannot be detected. The results obtained by companies using the Consolidated system, show that the expense is limited to interest, depreciation, renewals and inspection, and that the total cost of operating is less than that of any oil or gas system, furnishing one half the candle-power.