

STREET RAILWAY EQUIPMENT.

by

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Street Railway Equipment.

Outline.

1. Motors

I. Shunt Motors

- a. Uses
- b. Advantages
- c. Disadvantages

II. Series Motors

- a. Requirements for car service
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2. Test of Motors

I. Data

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I. Uses

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- a. Rheostatic or variable resistance
- b. Series parallel

4. Protective devices

I. Fuses and Fuse Boxes

II. Circuit breakers

III. Blow out coils

IV. Kicking coils and Lightning arresters

Apparatus:-

- 1 Direct current Ammeter (0-150),
- 1 Direct current Voltmeter (0-600),
- 1 Magnetic Tachometer with Voltmeter,

Cars Tested:-

- "Colorado" car fitted with four G. E. #52 motors rated at 26 horse-power each.
- "Georgia" car fitted with four Westinghouse motors rated at 37 1/2 horse-power each.

Date of Test:-

May 27, 1907.

Introduction.

Alternating current will perhaps in time supplant direct current for traction purposes as it did in lighting, with the advent of the long distance high potential transmission, but as yet the direct current plays a very important part in both power and traction. It has however the disadvantage of being difficult to transmit long distances without great loss. This is due to the inherent limitations in the production of high voltages from the direct current generator. Commutation at voltages sufficiently high to warrant economical transmission over long distances, is extremely difficult. Sparking and other difficulties at once arise which place the voltage within the limitations mentioned.

The alternating current generator has not only the advantage of higher voltage, but by means of suitable transformer devices the voltage may be raised to any desired value for economical transmission. It will be readily seen, therefore, that alternating current machinery will supplant the direct current for traction purposes.

In this thesis only direct current is treated. Direct current on a small scale and for local distribution fulfills more nearly the requirements demanded for traction purposes such as is needed on railways. The discussions are confined to the electrical equipment of the car only, the mechanical construction being referred to only as needed in line with the electrical connections.

Railway Motors.

Perhaps no other electrical machine is subjected to so much strain, neglect and abuse as that of the street car motor. The nature of the requirements demand anything but favorable conditions in both construction and operation. The first requirement is reliability

because so much in street car service depends upon continuity of operation. The motors must also be compact at the same time allowing ample means for ventilation. It must be protected from both water and dust, and able to withstand the constant jarring and vibration to which such service subjects it - extreme rigidity must be secured. They must be designed to carry from two to three times the normal loads for short intervals of time. In addition to this they must have a respectable efficiency under the various loads. From these limitations in design and requirements of the service the designing engineer of railway motors has had to build the street car motor. The result is one of the most valuable appliances in electrical traction.

In spite of the constant care necessary for the successful operation of electrical motors, the street car motor is expected to render service with much less care than is accorded the machine at the station or shop where conditions are much more favorable.

But two general types of motors are used in direct current railway work, viz:

1. Shunt Motors
2. Series Motors.

A compound motor consisting of the series motor with a shunt around the field capable of being thrown out or in from the starting device is also used, but not to any considerable extent.

Shunt Motors.

The use of shunt motors for traction purposes, especially on street car work is very limited. The reason for this is that they are not able to give a heavy starting torque. If the full line pressure were impressed over the terminals of a shunt motor, as would be necessary for the motor to give maximum torque, the rush of current through the armature would be disastrous. Before enough speed could be attained for developing sufficient counter electro-motive force to cut down the current due to the impressed electro-motive force the current would probably be excessive. The speed necessary for developing this could not be attained with load on the motor before the enormous rush of current would have damaged the motor.

The facts necessitate apparatus by which the full line pressure may be applied gradually. The apparatus consists of resistance in series, and causes quite a loss due to heating.

Shunt motors however, have the advantage of fairly constant speed under varying load; and they will not race. Where the load may be applied gradually, as with a clutch, and no heavy starting torque essential, they give excellent service. This heavy starting torque is the one essential on street car motors, so that shunt motors are little or rarely used.

Series Motors.

Aside from the general requirements of the shop or station motor, the series motor for streetcar service must have, as before mentioned, several other qualifications which the nature of its work demands as absolutely essential to successful operation. The first of these, reliability, requires not only good mechanical construction but efficiency of operation and protection as well. Situated where it is under the car, it is subjected to much jarring and dust. It is

not easily accessible for repairs when in service, so that all possible precaution is necessary.

The motor must also be moisture proof which is not a requirement of the housed station motor. The brushes need be fastened rigidly to prevent any possible shifting. The iron of the fields should be of sufficient quantity to allow but normal saturation on normal load as motors are frequently required to carry several times their full load capacity. Ventilation must also be provided, which in this case is difficult, protected as it is.

The chief advantage which the series motor has over the shunt type is the powerful torque developed on starting. The fields receive at once, upon closing the circuit, the same current as the armature with the result that the maximum torque of the motor is developed for that impressed electro-motive force. The reason why the starting current is not fatal to the series motor upon starting under heavy load, is that the fields are of sufficient density so that the speed need not be great to create enough counter electro-motive force to cut down the current within safe limits.

Another advantage which the series motor has is in the few turns which are necessary on the field windings. This makes repairing much easier which is quite an item where the service must be continuous. The speed of the series motor may also be changed greatly under varying loads which admits of conforming readily to the various conditions of the track such as grades, curves, etc.

The general construction of the street railway motor is the same as that of any other direct current motor: it must have an armature, field magnets, commutator, brushes, etc.

The armatures are of the drum type and made of sheets of

laminated iron, punched from sheets to fit the armature shaft. Slots for retaining the windings on the armature are made at the same time. Formerly the armature shaft was connected directly to the shaft of the car, but now the motion of the car truck is imparted to it by means of a train of gears. This admits of higher speed motors which increases their efficiency and lessens the jar accompanying the start. They are usually, in addition, mounted upon springs against which the motor acts upon starting. This further decreases the suddenness of the strain.

The field frame is so constructed that it will enclose as much of the motor as possible. In the latest types this is wholly accomplished, but enough opening being left to gain access to the brushes by a small door. By using the entire frame as yoke for the pole pieces, the reluctance is thereby much decreased.

The pole pieces are four in number, usually, and are laminated to prevent heating due to eddy currents. They differ from the pole pieces of the station motor in that they are much shorter from yoke to face and much wider at the faces. On account of the small space allotted to the machine under the car, the armature must be much longer in order to develop the power required. The pole faces not only cover the entire length of the armature but extend out over the brushes as well. This last named feature is for the purpose of creating a magnetic field at the brushes. It is well known that a certain strength of magnetic field is a preventive of sparking; so this field is created here to eliminate sparking that otherwise would occur.

The field coils are wound on forms and covered with a waterproof coating. In this form they can be removed quickly for repairs.

The most delicate mechanism of the street car motor is the

brushes. These are permanently fixed at the neutral point so that they can not be shifted in the least. There are two reasons for this. Firstly, sudden change of load would make brush shifting out of the question. Secondly, a street car motor has to run in either direction. On this account, it will be seen that if the brushes were given a forward lead when the motor was running in one direction, upon reversal the neutral field would be shifted so that the brushes would be in quite a strong magnetic field. Vicious sparking would result. So, to balance this they are placed rigidly at the mechanical neutral, and sparking prevented as much as possible by the magnetic field of the poles. The brushes are set radially and capable of motion toward the center of the axle as wear of the commutator requires. In this position they will work equally well when ~~the~~ motor is running in either direction.

Carbon brushes are used now almost entirely. Aside from the good wearing qualities, they have a resistance of contact which is high enough to favor sparkless commutation.

Test.

The two types of motors tested were the General Electric No. 52 rated at twenty-six horse-power and the Westinghouse No. 44 rated at thirty-seven and one-half horse-power. The circuit was normally 550 volts. There were four motors on each car.

The input was taken for all the motors on each car, and measured by putting the ammeter into the circuit at the circuit breaker and the voltmeter across from the trolley wire to the ground terminal on the motor. Each car was run from Junction City to Ft. Riley and return. The speed was calculated by means of a magnetic tachometer driven by the car axle. From a calibration of the tachometer and the relation between the circumference of the car wheel the constant necessary to reduce the tachometer readings to miles per hour was easily secured.

Curves.

Four curves were plotted for each car, one between input in kilowatts and distance and one between the speed of the car and distance, on each trip out and back.

For convenient representation we assumed that the readings were taken at equal distances apart. This was not exactly true, but for general discussion serves the purpose. In taking the data the amperes, volts, speed and controller points were read simultaneously. The input curve and speed curve are plotted on the same sheet with distance plotted to the same scale. In this way the input corresponding to any speed may be read at a glance. It will be seen that the speed does not vary as the input, due to the varying conditions of the track grades, curves, etc. The point upon which the controller was operated is also noted. By referring to curve #1 it will be observed that as the controller is shifted from "5 point" to "6 point" there

is a great increase in the current, due to the fact that the motors are all thrown in parallel. The entire set of resistances are thrown in series with the motors but the voltage over the motors is so much greater than before that the current is almost as large as the starting current on "1 point".

The very great irregularity of the curves was caused by the different conditions of operation. That is, the different grades; the necessity of slowing down; the use of the hand brake in some cases and the varying line voltage all tend to cause the curves to be very uneven.

The voltage varied greatly at different points along the line, the greatest drop being 170 volts below the normal full load voltage. This was due to the drop over the long transmission line. Feeders were used in four places and thus the drop was not nearly as great as it would otherwise have been.

The largest input at any time was on the car "Georgia" and the input was 72.5 K. W. The car was then running with all the motors in parallel and was going up grade. The maximum speed obtained was also on the car "Georgia" while the car was running on the level track and the controller was on "9 point".

The curves show a very large starting current - a condition which is very characteristic of the series motor. At one point, when starting from a standstill, the input was 49 K. W., while the speed was only 1.5 miles per hour. The largest current used at any time was about 160 amperes. This exceeded the capacity of the ammeter used, but a short circuiting switch was used to place a shunt around the ammeter, thus protecting the instrument. The large starting torque available shows the adaptability of series motor for street car service.

"Colorado" Car - Trip Out. Junction City - Ft. Riley.

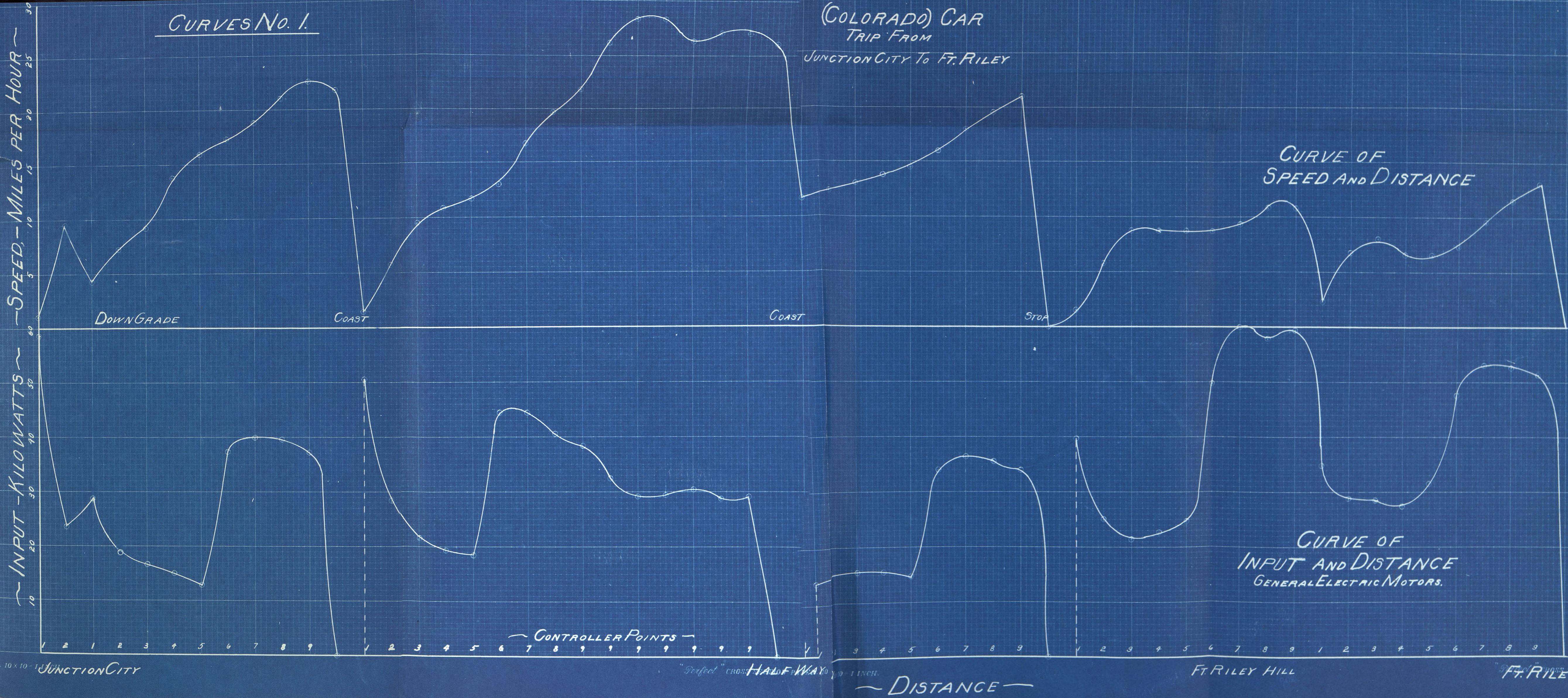
No.	Volts	Amperes	Watts Input	Speed	Controller	Remarks.
1	548	107	58,636	1.5	1 point	Start on level.
2	522	45	23,490	9.5	5 "	
3	524	55	28,820	4.36	1 "	Down grade
4	535	35	18,735	7.3	2 "	
5	536	31	16,618	9.2	3 "	
6	536	28	15,008	13.8	4 "	
7	538	24	12,912	16.	5 "	
8	516	72	37,152	17.4	6 "	
9	518	77	39,886	18.9	7 "	
10	520	76	39,520	21.	8 "	
11	522	71	37,062	22.5	9 "	
12	554			21.8	Open	Coasting.
13	516	98	50,568	1.45	1 "	Stop.
14	524	54	28,296	5.8	2 "	Middle.
15	530	40	21,200	9.5	3 "	Switch.
16	530	36	19,080	10.9	4 "	
17	532	34	18,088	11.6	5 "	
18	490	90	44,100	13.1	6 "	
19	498	89	44,322	16.7	7 "	
20	500	81	40,500	19.6	8 "	Down small grade.
21	510	75	38,250	21.8	9 "	
22	530	59	32,270	26.2	9 "	
23	528	55	29,040	28.3	9 "	
24	530	55	29,150	28.3	9 "	
25	512	59	30,208	26.2	9 "	Up river bank.
26	514	56	28,784	27.	9 "	"
27	510	57	29,070	27.	9 "	
28	556			26.	Open	Coasting

"Colorado" Car - Trip Out. (Continued)

No.	Volts	Amperes	Watts Input	Speed	Controller	Remarks.
29	522	26	13,572	11.6	1 point	Start after coasting.
30	520	29	15,080	12.4	2 "	
31	520	29	15,080	13.08	3 "	
32	520	29	15,080	13.8	4 "	
33	520	28	14,560	14.54	5 "	
34	484	70	33,880	16.	6 "	
35	484	75	36,300	18.	7 "	
36	484	73	35,332	19.6	8 "	
37	485	70	33,950	21.08	9 "	Stop.
38	444	89	39,516	1.45	1 "	Start from Stop.
39	500	50	25,000	5.7	2 "	Big Ft. Riley Hill.
40	510	42	21,420	8.6	3 "	"
41	504	45	22,680	8.6	4 "	"
42	496	50	24,800	8.6	5 "	"
43	436	114	49,704	8.6	6 "	"
44	420	143	60,060	9.3	7 "	"
45	420	138	57,900	10.8	8 "	"
46	410	144	59,400	10.8	9 "	To top of Hill.
47	460	75	34,500	2.9	1 "	
48	490	59	28,910	6.54	2 "	
49	494	58	28,652	8.	3 "	
50	496	55	27,280	6.54	4 "	
51	484	65	31,460	6.54	5 "	Up station hill.
52	444	107	47,508	7.3	6 "	
53	400	133	53,200	9.55	7 "	
54	420	126	52,920	11.6	8 "	
55	430	119	51,170	13.1	9 "	Ft. Riley station.

CURVES No. 1.

(COLORADO) CAR
TRIP FROM
JUNCTION CITY TO FT. RILEY



"Colorado" Car - Trip from Ft. Riley to Junction City.
Data for Curve #2.

No.	Volts	Amperes	Watts Input	Speed	Controller	Remarks
1				9.5	Open	Car started
2				11.6	"	on one point.
3				13.1	"	Then coasted
4				13.8	"	down station
5				14.5	"	hill.
6				15.2	"	"
7	510	31	15,810	9.5	1 point	"
8	504	26	13,104	10.9	1 "	"
9	504	26	13,104	12.4	2 "	"
10	504	27	13,608	13.8	3 "	"
11	502	28	14,056	13.8	4 "	"
12	500	29	14,500	12.4	5 "	"
13	520	28	14,560	13.1	5 "	Small grade.
14	520	26	13,520	13.8	5 "	Level.
15	410	85	34,850	.7	1 "	Start from
16	412	62	25,544	2.9	1 "	stop.
17	480	48	23,040	7.3	2 "	Level.
18	494	39	19,266	10.2	3 "	"
19	496	38	18,488	10.5	4 "	"
20	496	38	18,848	10.2	5 "	"
21	496	81	40,176	11.6	6 "	"
22	524	80	41,920	17.5	7 "	"
23	462	73	33,726	21.8	8 "	"
24	480	79	37,920	24.	9 "	"
25	496	64	31,360	24.7	9 "	"
26	550	27	14,850	11.6	1 "	Down grade.

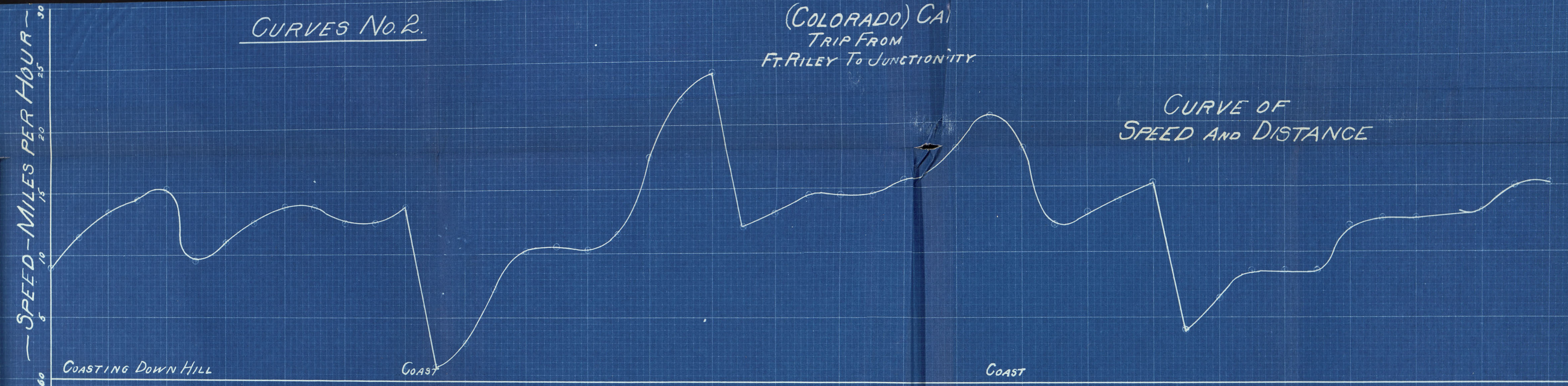
"Colorado" Car - Trip from Ft. Riley to Junction City.
Data for Curve #2. (Continued)

No.	Volts	Amperes	Watts Input	Speed	Controller	Remarks
27	552	28	15,456	13.1	2 point	Level.
28	550	28	15,400	14.5	3 "	Small grade.
29	552	27	14,904	14.5	4 "	" "
30	552	27	14,904	14.5	5 "	" "
31	518	85	44,030	15.3	6 "	" "
32	516	97	50,052	16.	7 "	" "
33	522	94	47,068	18.2	8 "	" "
34	530	90	47,700	20.3	9 "	Level.
35				18.2	Open	Coasting on level.
36	550	26	14,300	11.6	1 "	Level.
37	552	28	15,456	13.1	2 "	"
38	554	27	15,000	13.8	3 "	"
39	554	26	14,450	14.5	4 "	"
40	555	26	14,475	15.3	5 "	"
41	530	50	26,500	3.6	1 "	Washington Curve.
42	536	50	26,800	6.5	2 "	
43	540	49	26,460	8.7	3 "	
44	540	60	32,400	8.7	4 "	Slight grade
45	550	55	30,250	8.7	5 "	
46	544	47	25,568	11.6	1 "	
47	548	30	16,440	12.4	2 "	
48	548	30	16,440	13.1	3 "	
49	548	30	16,440	15.3	4 "	
50	548	30	16,440	15.3	5 "	Car Barn.

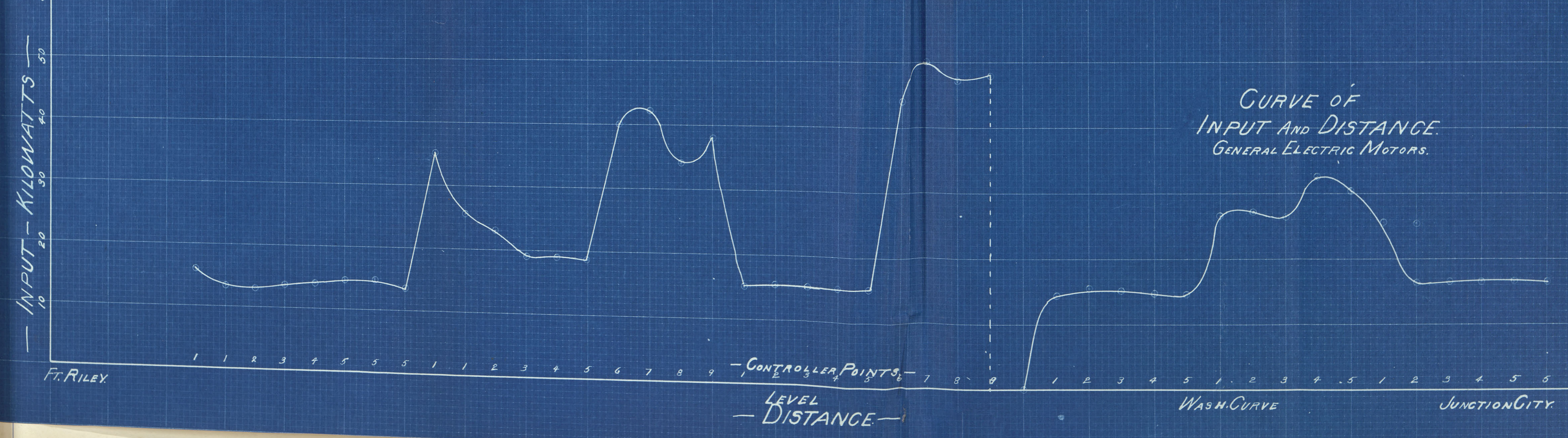
CURVES No. 2.

(COLORADO) CAI
TRIP FROM
FT. RILEY TO JUNCTION CITY.

CURVE OF
SPEED AND DISTANCE



CURVE OF
INPUT AND DISTANCE.
GENERAL ELECTRIC MOTORS.



FT. RILEY 1 1 2 3 4 5 5 5 1 1 2 3 4 5 6 7 8 9 CONTROLLER POINTS 1 2 3 4 5 6 7 8 9 WASH. CURVE 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 5 JUNCTION CITY.

LEVEL DISTANCE

"Georgia" Car.

Data for Curves #3. Trip from Junction City to Ft. Riley.

No.	: Amperes	: Volts	: Watts Input	: Speed	: Controller	: Remarks
1	: 99	: 490	: 48,510	: .645	: 1 point	: Start from
2	: 78	: 485	: 37,830	: 7.1	: 2 "	: barn.
3	: 70	: 496	: 34,720	: 11.	: 3 "	: 7th Street.
4	: 60	: 530	: 31,800	: 7.1	: 1 "	:
5	: 70	: 520	: 36,400	: 9.6	: 2 "	:
6	: 62	: 536	: 33,232	: 12.3	: 3 "	:
7	: 54	: 540	: 29,160	: 14.2	: 4 "	:
8	: 49	: 536	: 26,264	: 15.5	: 5 "	:
9	: 38	: 525	: 19,950	: 19.2	: 5 "	: 6th Street.
10	: 43	: 522	: 22,446	: 16.8	: 5 "	: 17th "
11	: 58	: 512	: 29,696	: 9.	: 5 "	: up grade.
12	: 43	: 520	: 22,360	: 15.5	: 5 "	: 18th Street
13	: 106	: 490	: 51,940	: 20.	: 6 "	: brake on.
14	: 111	: 490	: 54,390	: 23.3	: 7 "	:
15	: 118	: 490	: 57,820	: 22.6	: 8 "	:
16	: 119	: 490	: 58,310	: 20.6	: 9 "	: Red Box Curve.
17	: 55	: 500	: 27,500	: 7.1	: 1 "	:
18	: 44	: 518	: 22,792	: 10.3	: 1 "	:
19	: 51	: 516	: 13,000	: 13.6	: 2 "	: Level.
20	: 50	: 520	: 25,800	: 14.2	: 3 "	: "
21	: 49	: 520	: 25,380	: 15.8	: 4 "	: "
22	: 46	: 490	: 23,920	: 18.	: 5 "	: "
23	: 119	: 496	: 58,310	: 22.6	: 6 "	: "
24	: 126	: 496	: 61,740	: 25.2	: 7 "	: "
25	: 112	: 500	: 55,552	: 27.7	: 8 "	: "
26	: 105	: 484	: 52,080	: 28.3	: 9 "	: "
27	: 98	: 490	: 49,000	: 26.5	: 9 "	: "
28	: 92	: 510	: 44,528	: 3.8	: 1 "	: Start from
29	: 118	: 516	: 57,820	: 7.7	: 2 "	: stop.
30	: 71	: 515	: 36,210	: 11.6	: 3 "	:

"Georgia" Car.

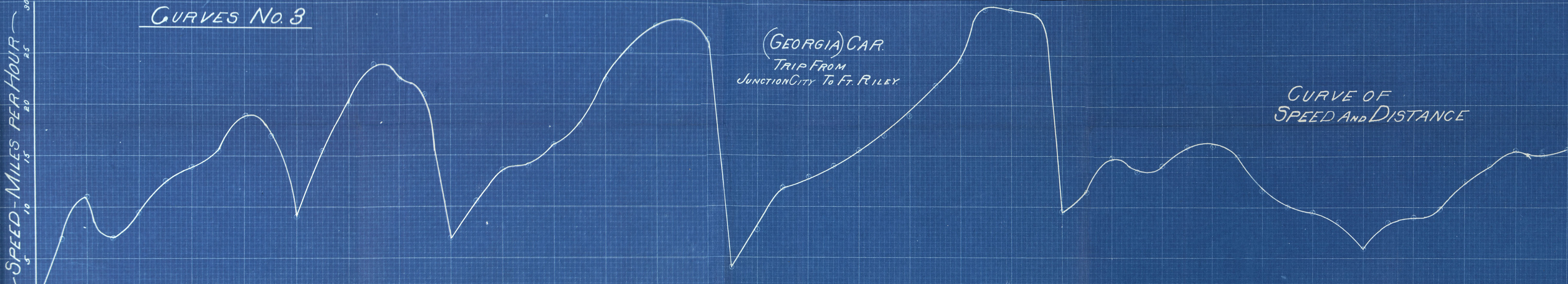
Data for Curves #3. Trip from Junction City to Ft. Riley -(Continued)

No.	Amperes	Volts	Watts Input	Speed	Controller	Remarks
31	60	476	30,960	12.9	4 point	
32	53	470	27,295	14.2	5 "	
33	124	476	59,024	15.5	6 "	
34	135	480	62,450	16.8	7 "	
35	135	484	64,260	19.2	8 "	
36	117	484	56,160	22.	9 "	
37	95	478	45,980	24.6	9 "	
38	93	480	45,012	29.6	9 "	
39	90	485	43,020	29.6	9 "	
40				29.	Open	Coasting.
41	45	496	23,320	9.6	1 "	
42	58	480	26,840	11.6	2 "	
43	55	490	26,950	12.9	3 "	
44	54	496	25,784	13.5	4 "	
45	54	504	27,216	14.2	5 "	Park Switch.
46	44	502	27,208	16.1	5 "	Ft. Riley
47	109	436	47,524	16.1	6 "	Hill.
48	125	390	48,750	14.8	7 "	"
49	150	400	60,000	11.6	8 "	"
50	140	405	56,700	10.	9 "	"
51	50	442	22,100	9.6	1 "	
52	81	445	36,045	8.4	2 "	
53	93	460	42,780	5.8	3 "	
54	85	468	37,780	8.4	4 "	
55	76	476	36,176	9.	5 "	
56	130	416	54,080	9.6	6 "	Station Hill.
57	147	400	58,800	12.3	7 "	" "
58	148	396	58,600	14.2	8 "	" "
59	150	380	57,000	15.5	9 "	" "
60	155	382	59,210	15.5	9 "	" "

CURVES No. 3

(GEORGIA) CAR.
TRIP FROM
JUNCTION CITY TO FT. RILEY.

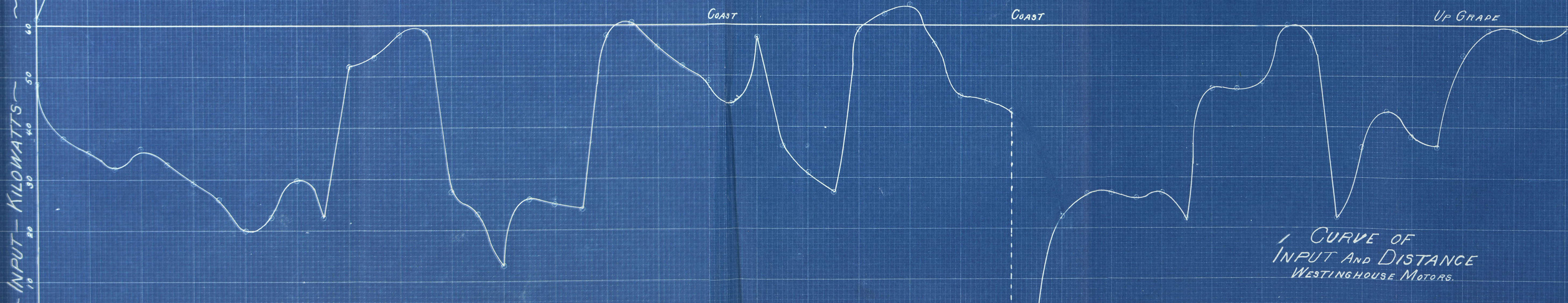
CURVE OF
SPEED AND DISTANCE



COAST

COAST

UP GRADE



CURVE OF
INPUT AND DISTANCE
WESTINGHOUSE MOTORS.

CONTROLLER POINTS. —

FT. RILEY HILL
DISTANCE.

JUNCTION CITY.

FT. RILEY.

"Georgia" Car.

Data for Curves #4. Trip from Ft. Riley to Junction City.

No.	Amperes	Volts	Watts Input	Speed	Controller	Remarks
1	:	:	:	3.	1 point	Start
2	:	:	:	5.8	Open	Coasting.
3	:	:	:	7.7	"	"
4	:	:	:	9.	"	"
5	:	:	:	13.	"	"
6	:	:	:	8.4	"	"
7	:	:	:	5.8	"	"
8	75	470	35,250	2.	1 point	Start after stop.
9	57	420	21,420	5.8	2 "	
10	60	396	23,760	7.7	3 "	
11	63	436	27,468	9.6	4 "	
12	53	450	23,850	12.3	5 "	
13	56	550	30,800	13.5	5 "	
14	80	440	35,200	1.29	1 ")
15	110	420	46,200	4.5	2 ") Time for
16	76	445	33,820	7.74	3 ") this dis-
17	64	460	29,440	10.3	4 ") tance,
18	58	465	25,970	11.6	5 ") 1 min.
19	122	424	51,728	12.9	6 ") 15 sec.
20	142	420	59,640	14.8	7 ")
21	143	424	50,632	18.	8 ")
22	136	430	58,480	19.2	9 ")
23	112	460	51,520	23.3	9 ")
24	90	500	45,000	1.29	1 ") Half way
25	100	500	50,000	6.45	2 ") switch.
26	66	516	34,056	9.6	3 ")
27	58	518	30,440	12.2	4 ")
28	53	518	27,454	13.54	5 ")
29	123	485	59,655	16.12	6 ")
30	138	480	66,240	18.	7 ")

"Georgia" Car.

Data for Curves #4. Trip from Ft. Riley to Junction City - (Continued)

No.	Amperes	Volts	Watts Input	Speed	Controller	Remarks
31	145	484	70,180	22.	8 point)
32	137	492	67,404	24.	9 ") 1 min.
33	122	496	60,512	24.6	9 ") 18 sec.
34	120	498	59,760	24.	9 ")
35	90	480	43,200	1.29	1 "	: Red Box Curve.
36	140	485	67,900	4.5	2 "	:
37	90	516	46,440	7.74	3 "	:
38	75	512	39,000	9.6	4 "	:
39	63	522	32,886	13.54	5 "	:
40	128	485	61,080	16.12	6 "	:
41	146	490	70,540	18.	7 "	:
42	148	490	72,520	20.6	8 "	:
43	139	492	68,068	23.3	9 "	:
44		540		18.	Open	: Coasting.
45	36	520	18,720	13.54	1 "	:
46	48	516	24,768	12.9	2 "	:
47	52	520	27,040	13.54	3 "	:
48	54	520	28,080	13.54	4 "	:
49	55	520	28,600	12.9	5 "	:
50	50	520	26,000	16.12	5 "	:
51	45	530	23,850	16.8	5 "	:
52	41	535	21,935	18.	5 "	:
53	45	536	24,120	16.8	5 "	:
54	46	536	24,650	16.12	5 "	:
55	47	538	25,280	16.12	5 "	:
56	49	540	26,460	15.48	5 "	:
57	54	536	29,244	14.2	5 "	:
58	56	540	30,240	13.5	5 "	:
59	64	530	33,920	12.9	5 "	:
60	61	544	33,184	12.9	5 "	:

CURVES No. 4.

(GEORGIA) CAR
TRIP BACK

SPEED, MILES PER HOUR

COASTING

BRAKE STOP

UP GRADE

COAST

CURVE OF
SPEED AND DISTANCE

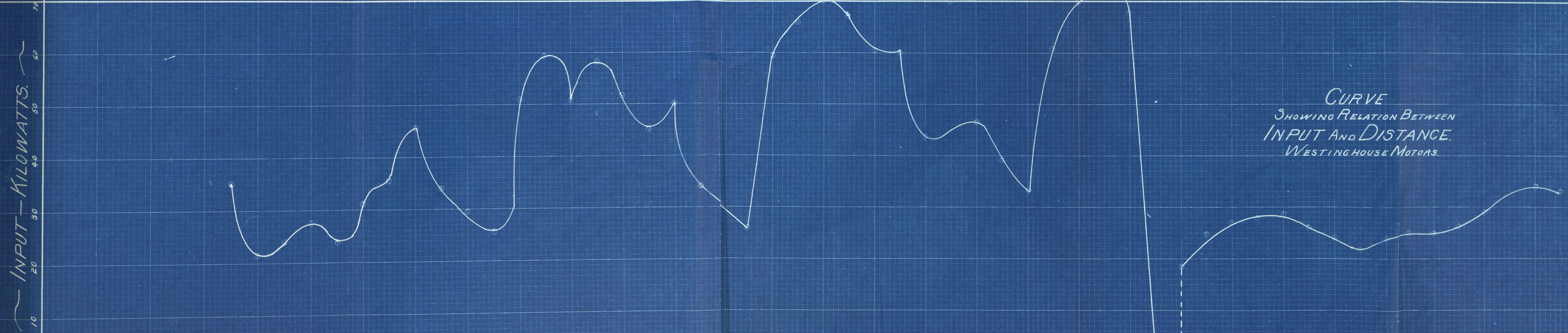
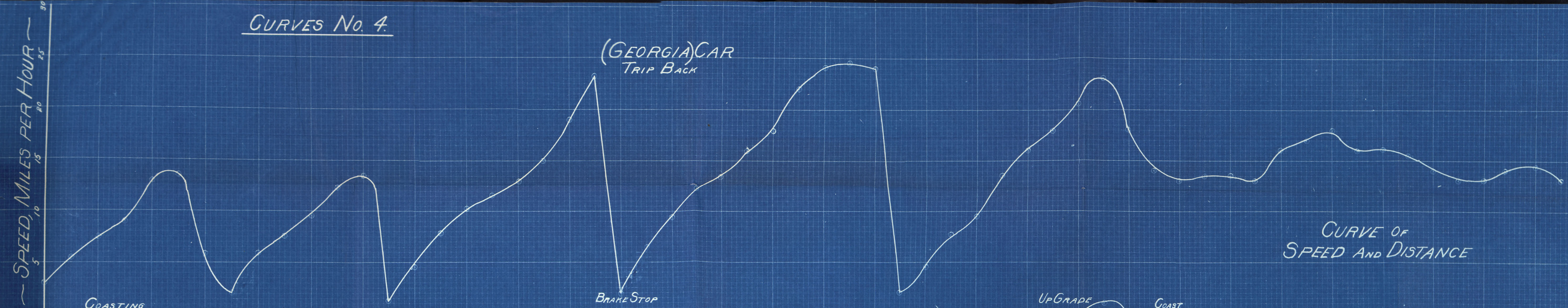
INPUT - KILOWATTS

CURVE
SHOWING RELATION BETWEEN
INPUT AND DISTANCE.
WESTINGHOUSE MOTORS.

FT. RILEY

CONTROLLER POINTS
5 6 8 9 9 1 2 3 4 5 6 7 8 9
HALF WAY
DISTANCE

JUNCTION CITY

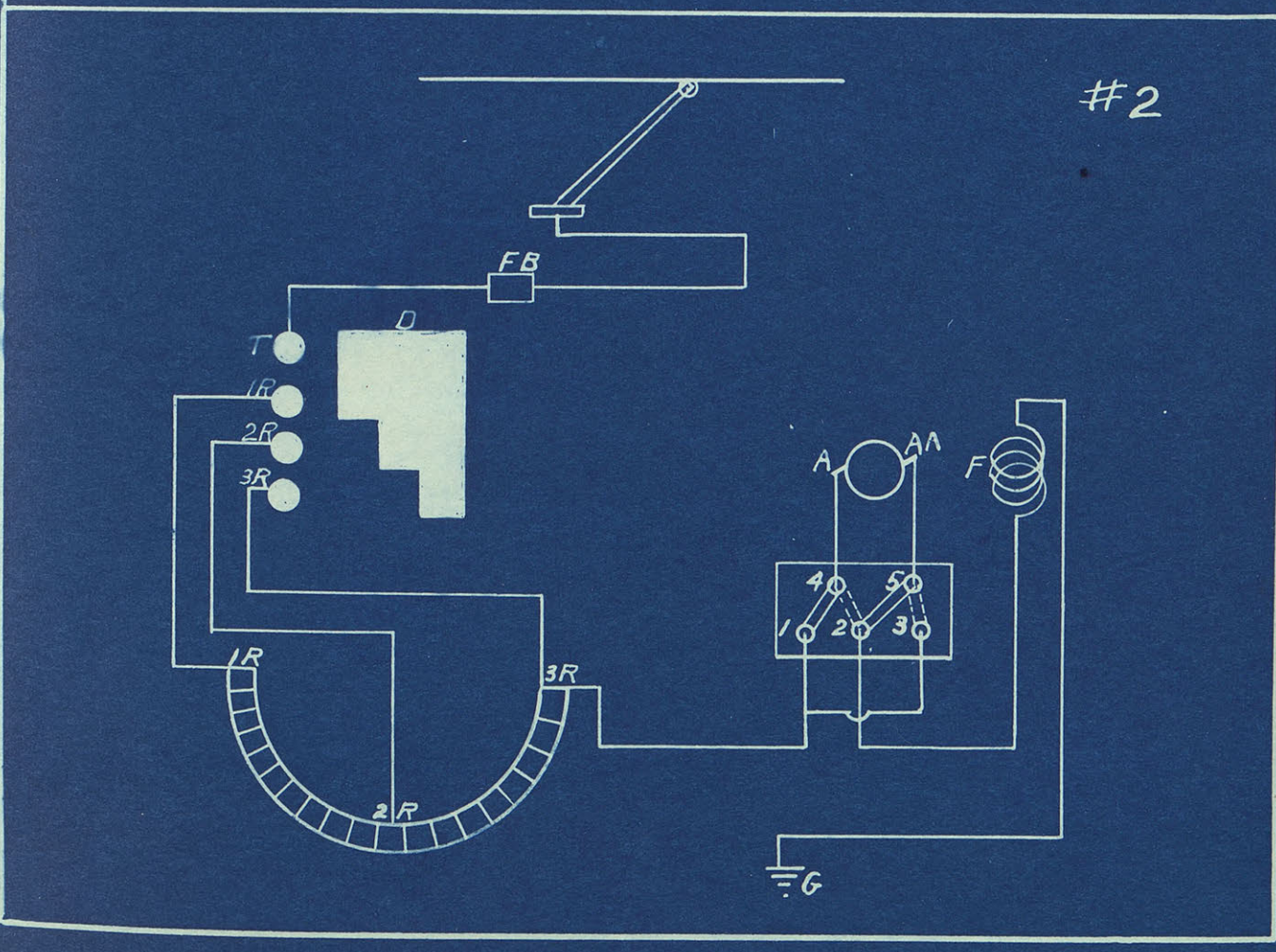
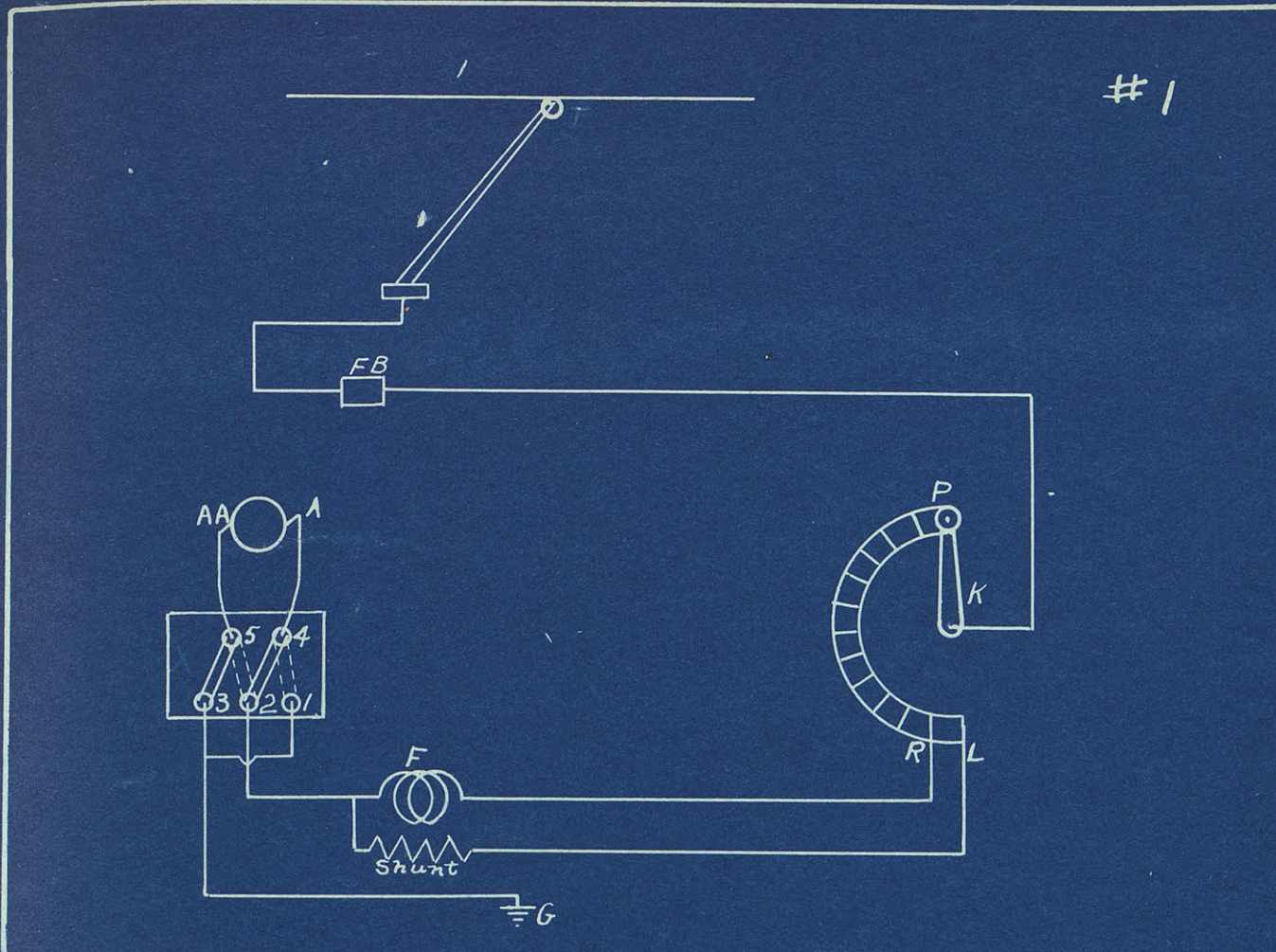


I. For the purpose of obtaining different speeds and to prevent excessive starting currents, motor controllers of some kind are necessary on every street car. These controllers are placed at the end of each car, usually two to the car although in some modern cars intended for use on a "loop" track only one controller is necessary.

II. The controllers used for street car work are of two distinct types - the rheostatic or variable resistance and the series parallel.

(a) The first of these, while rapidly being replaced by the second kind, is still in use on many of the older cars and on cars having only one motor. The principle upon which they work is that of changing the voltage over the motor terminals by means of cutting in or out resistances which are in series with the motors. There is no doubt but that with this system a large number of speeds can be obtained, but it has the disadvantage of being inefficient, especially at low speeds, because of the excessive C^2R losses.

The first controllers of this type were the Thompson-Houston Controllers which consisted of a rheostat, capable of carrying a heavy current, placed in series with the motors. The rheostat was regulated by means of a controller rod passing through the floor of the car and terminating in a handle. Blue print #1 shows the connections for a one-motor car equipped with one of the Thompson-Houston controllers. The current enters at the trolley T, passes through the fuse box FB and then follows this path: K-P-R-F-2-4-A-AA-5-3-G. If the car is to move in the opposite direction the reversing lever on the switch-board x is thrown and the path is from 2 to 5 then AA-A-4-1-G. In this way the direction of the current through the field is kept the same, but the direction through the armature is reversed. As the arm



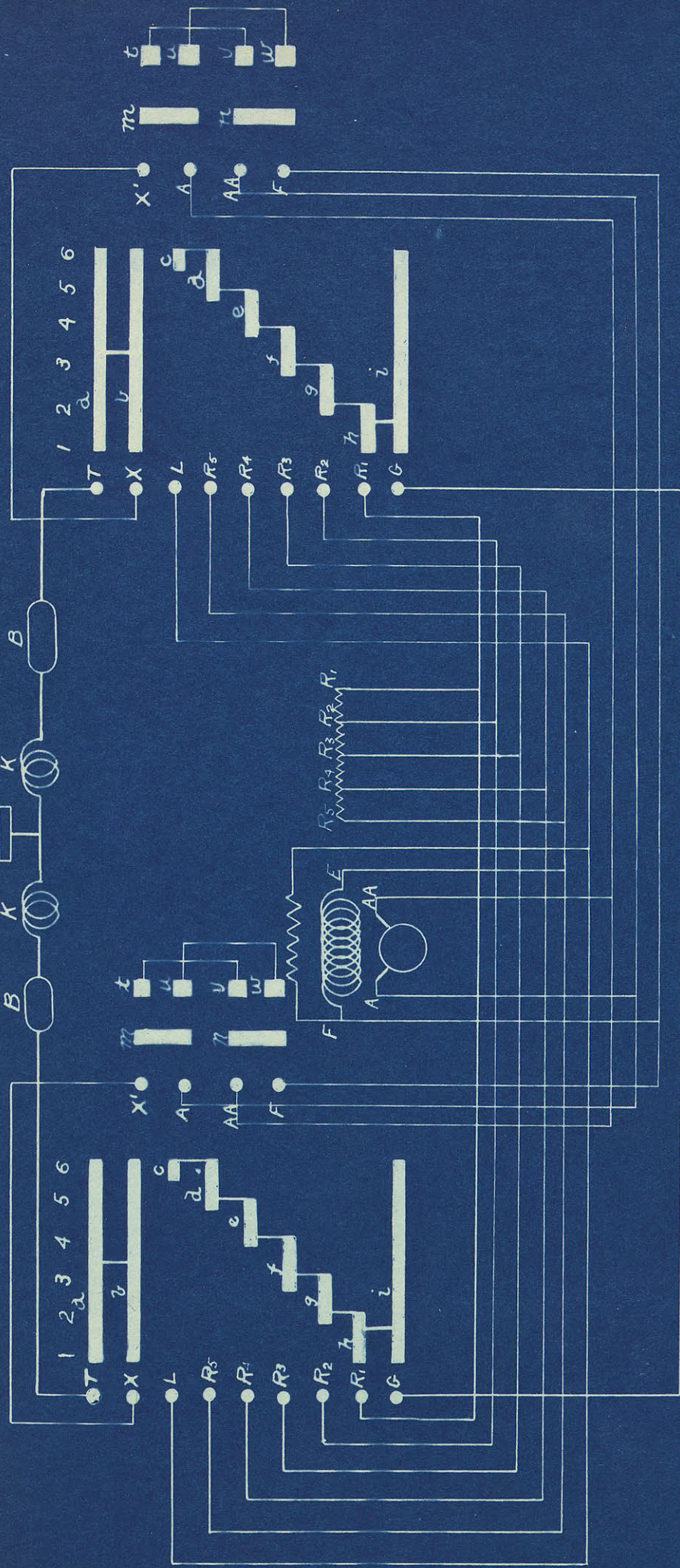
K is moved toward the left, the resistance of the rheostat is gradually cut out until when position R is reached the motor is running on the full line voltage with no resistance in the circuit. The same controller was often arranged with a field shunt so that when the arm K reached R, it would also touch point L, which completed a shunt around the field. This weakened the motor field and increased the speed of the motor.

This method of control was used for a short time only, as the rheostat was heavy and cumbersome, the chances of short circuit were great and the apparatus easily damaged. It was replaced by the first of the platform drum controllers. The principle in this type was the same as in the rheostat controllers, but the resistances were placed under the center of the car and wires were run from them to the controller drum. They could be more easily insulated and could be made in a more convenient shape, hence they were much better. The drum consisted of a wooden cylinder, on which was fastened a circular strip of copper of a shape shown in the blue print. As the drum was turned, by means of a handle, this plate came in contact with a number of contact fingers to which the connecting wires were fastened. Blue print #2 shows the connections for a one-motor car equipped with a controller of this type. The device for reversing the direction of the current through the armature was just the same as in #1. The path of the current in this case, when the controller handle is on the first resistance position, is as follows: T-D-1R-1R-2R-3R-1-4-A-AA-5-2-F-G. On the second resistance position the circuit is the same except that the rheostat resistance from 1R to 2R is cut out. On the third position all the resistance is cut out and the motor is running on the line voltage.

Both of the preceding controllers are now obsolete, but

#3

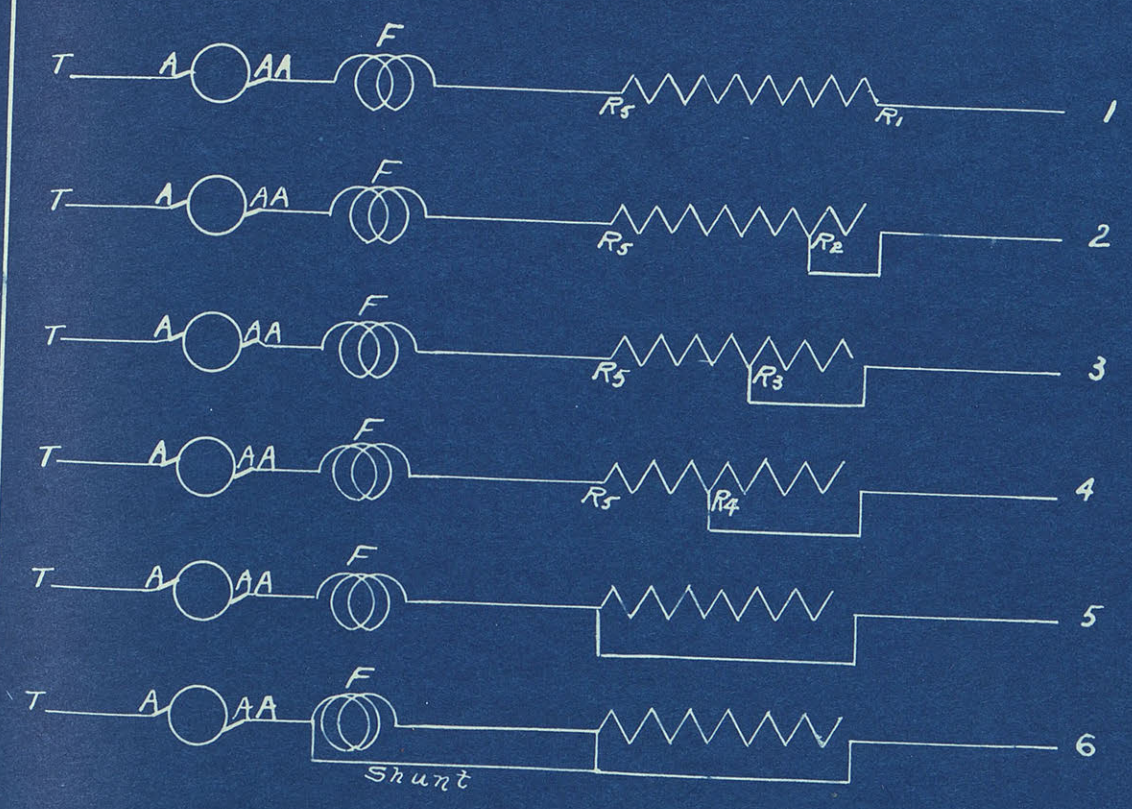
TROLLEY WIRE

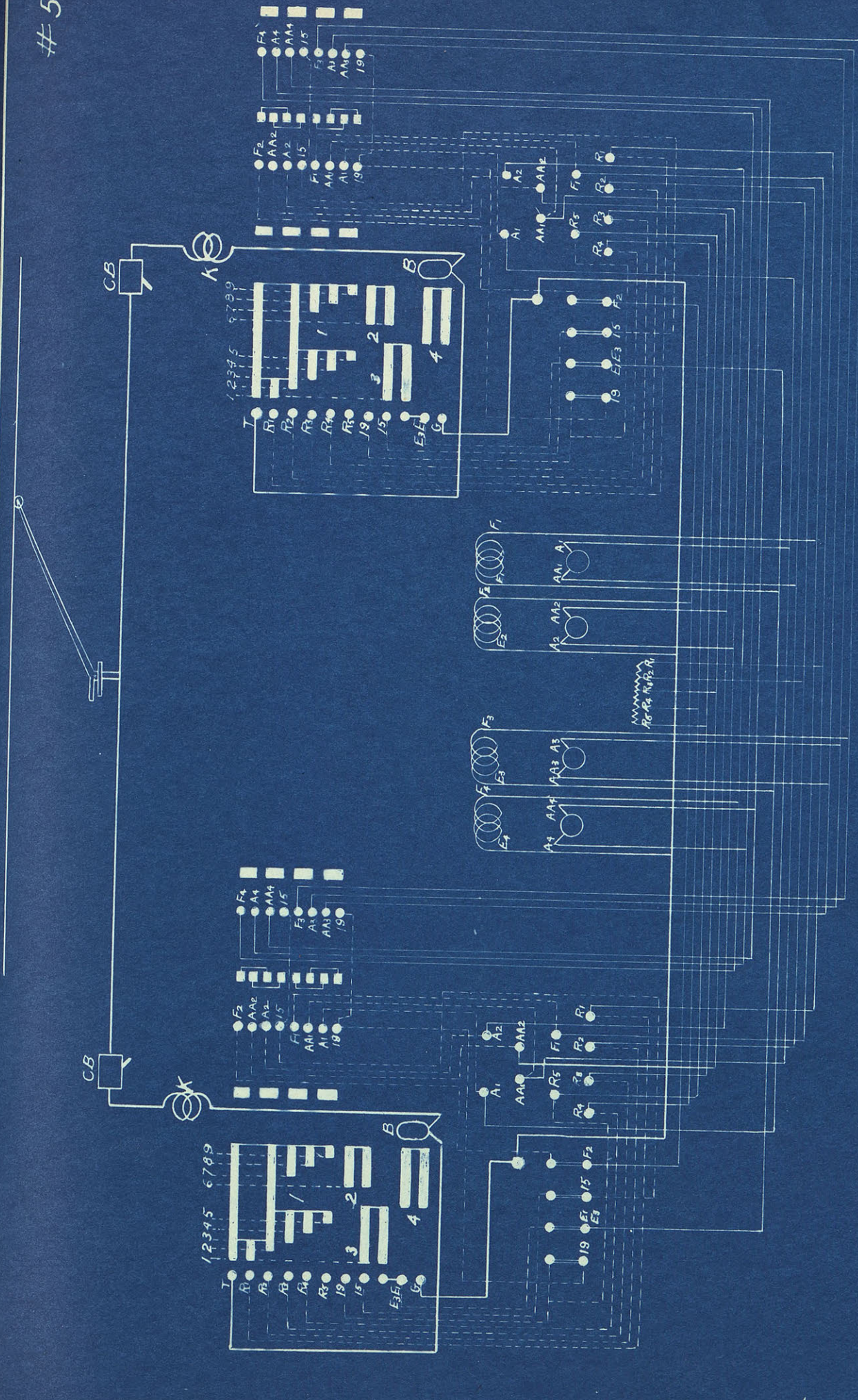


there is one type of variable resistance that is still used to some extent. The General Electric Co. manufactures it for use under the name "Type R Rheostatic Controller." Blue print #3 shows the wiring of a car equipped with one motor and two controllers of this type. There are six notches, or positions for the controller handle, and the car may be run on any position. In most controllers of this kind however only the last position is used for continuous running. In the blue print the white bands a, b, c, d, e, f, g, h and i are the developments of the contact strips on the controller drum. As an example of the working of this controller let us suppose the power or reversing lever to be in the forward position and the controller handle on the first position. The current enters through the trolley, passes through the kicking coil K, the blow-out coil B and enters the controller through contact finger T. Its path then is: a-b-x-x'-m-A-A-AA-AA, n, F, F, E, R₅-R₁-h-i-G. This completes the circuit. If the direction of the car is to be reversed the reverse lever is thrown in the backward position and the current path is as follows: Trolley, K₁-B-T-a-b-x-x'-t-v-AA-AA-A-A-u-w-F-F-E-R₅-R₁-R₁-h-i-G. This reverses the direction of the current in the armature without changing the direction through the field. For the next four points the path is exactly the same except that a part of the resistance is cut out at each forward step. Thus on point 5, the motor is running on the full line voltage. This controller is also supplied with a field shunt and it is thrown into the circuit when the controller is on point 6. Blue print #4 shows the conditions which exist for each position of the controller handle.

In this controller the reversing device is also made in drum form. The point x', A, AA and F are movable and when the lever is thrown into the "ahead" position x' and A are connected together

#4





while AA and F are together. When the controller is thrown into the "Back" position the point x' is connected to AA while A is connected to F. This reverses the direction of the current through the armature but not through the field.

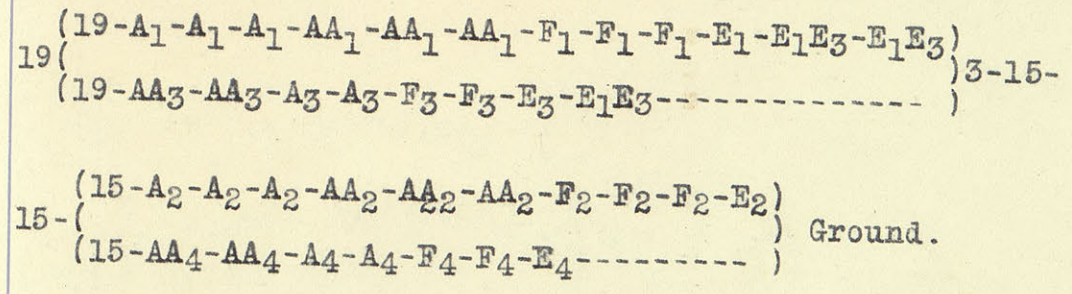
(b) The system of control used in practically every street car put out by the leading companies today is the series parallel type. It can be used only on cars having at least two motors, but as very few modern cars are equipped with only one motor, this is no disadvantage. This system of control allows the use of a low voltage over the motors without the use of series resistances. Because of this fact, cars can be run at low speed and the C^2R loss is not excessive as it would be, were series resistances used. For low speeds the motors of a car are connected in series thus giving a low voltage over the terminals of each, while for high speeds the motors are placed in parallel and the full line voltage is used. For starting, the controllers are so arranged that resistances can be thrown in series until the car comes up to speed and then they can be cut out. These resistances are not to be used for continuous running so the C^2R loss is very small.

There are a great many series - parallel controllers on the market but the type used to the greatest extent is the K type, put out by both the Westinghouse and General Electric companies. The K-12 controller, used for four-motor cars, contains all the characteristics of the controllers for two-motor cars and has a few additional features, hence a description of it will be given.

The motors in this system, are connected in pairs, each pair having two motors in parallel. It is customary to have a motor on one truck connected in parallel with the corresponding motor on the other truck. That is motor #1 is connected to motor #3 and #2 to #4. In this way if one pair or one motor becomes damaged the pair can be

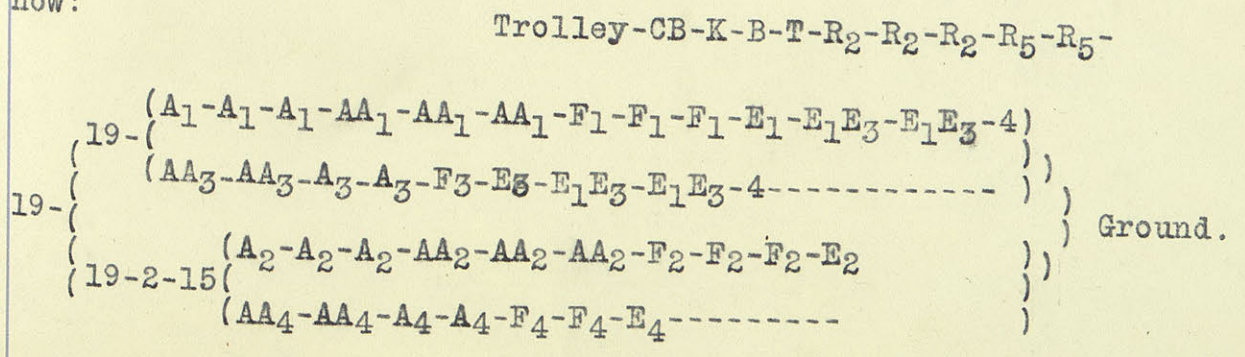
cut out and there will still be one good motor on each truck.

There are nine positions or points on the controller, but only two of them - "5 point" and "9 point" - are to be used for continuous running. Blue print #5 shows the connections and wiring for a car equipped with two K-12 controllers and four motors. The current path is as follows, when the controller handle is on "1 point" and the power lever on the "Ahead" position: Trolley-CB-K-B-T-R₁-R₁-R₅-R₅-



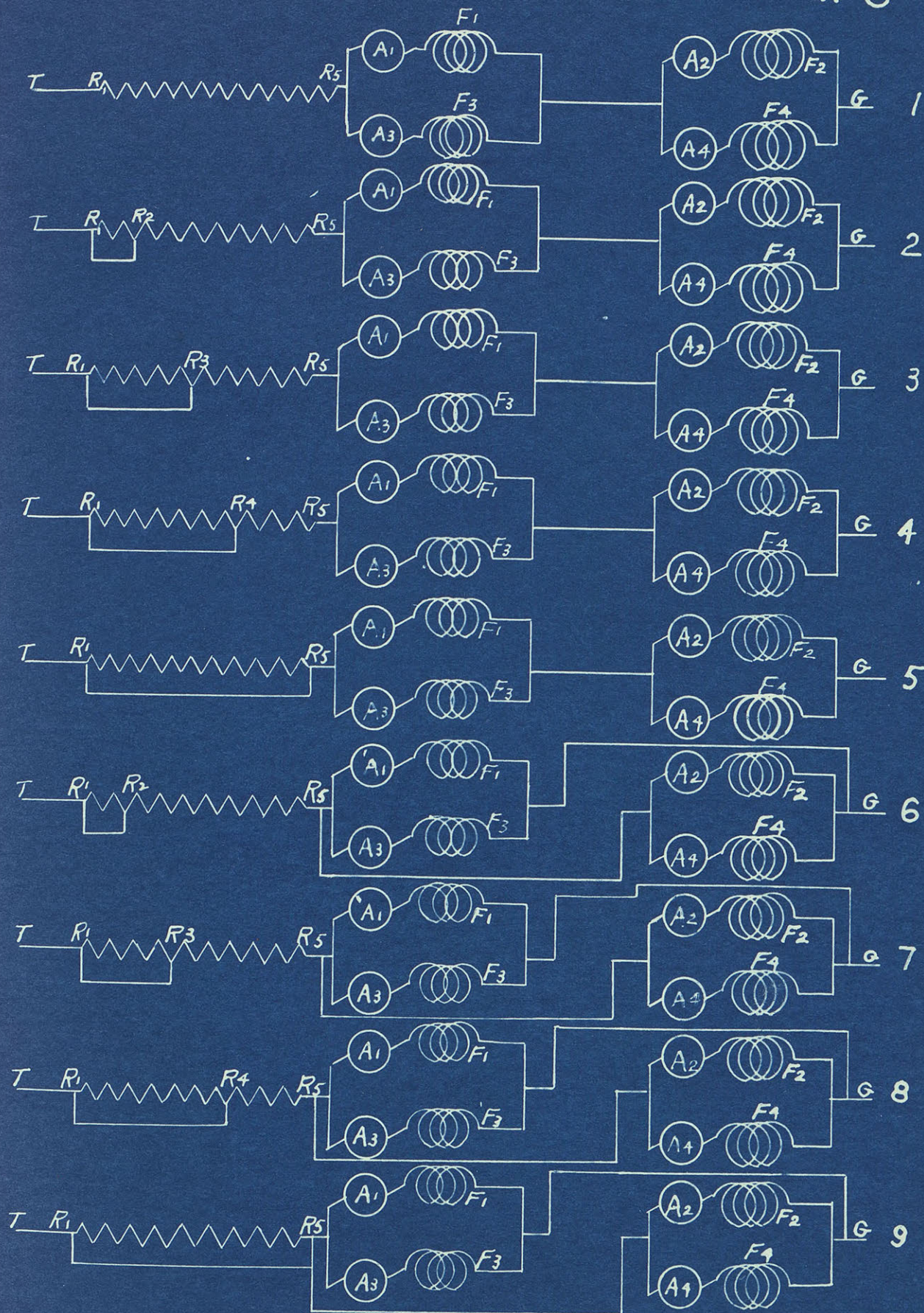
For "2 point" the circuit is exactly the same except that the part R₁R₂ of the starting resistance is cut out. For 3, 4 and 5 "points" the operation is just the same - a part of the resistance being cut out at each step until at "5 point" the motors are running with no resistance in the circuit. No. 1 and #3 are in parallel and #2 and #4 are in parallel, the two pairs being in series. They can be run continuously on this position, but as each of the motors are receiving only one-half of the line voltage the speed is low.

On "6 point" the motors are all thrown in parallel and nearly all the resistances are placed in the circuit. The current path is now:



6

3



For 7, 8 and "9 points" the operation is the same except that a part of the resistance is cut out at each step and on "9 point" the motors are all running in parallel with the full voltage over their terminals.

Blue print #6 shows the conditions of operation for each position of the controller handle. The controller point is indicated by the number.

Protective Devices.

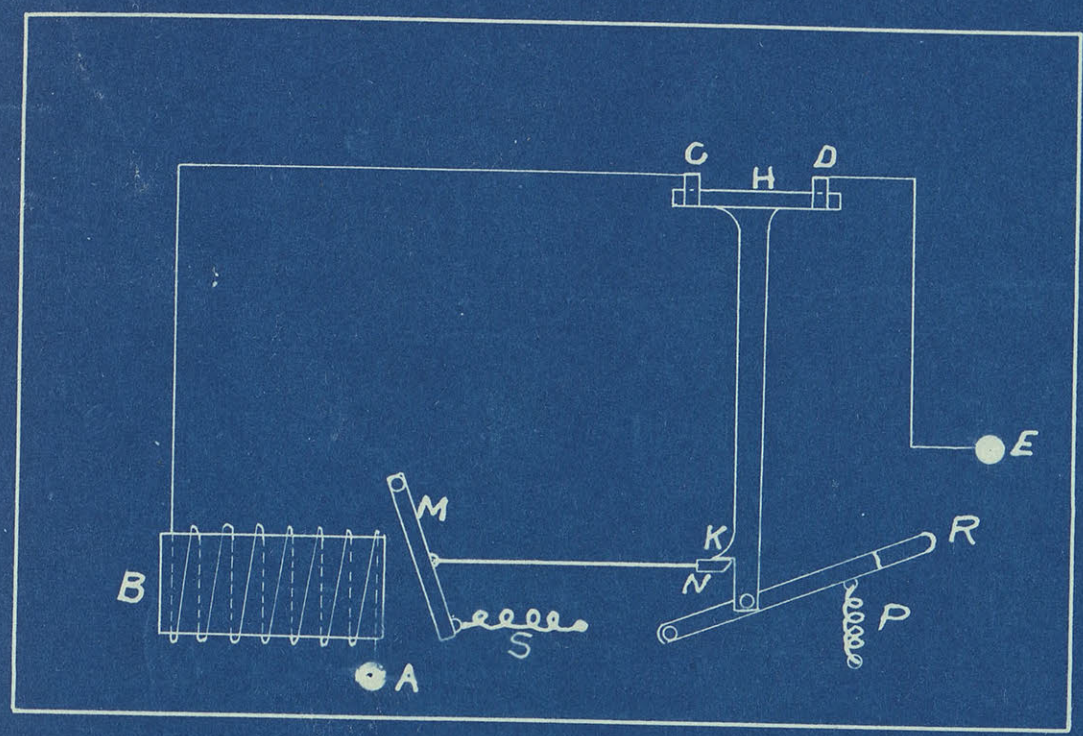
(a) To protect the armature coils against the effect of an excessive armature current, fuses are placed in the main circuit of each car. The fuses are usually made of copper wire, somewhat smaller than the wire used for the armature, and they are usually placed in a more or less unprotected place. In the cars tested at Junction City, #12 copper wire was used and it was held in place by two strong springs. These springs were so arranged that they could be pulled back, the fuse slipped in and then the springs released. There was thus no danger of a short circuit by the person putting in the fuse. Some cars are equipped with fuse boxes of different types which cover the fuse and protect it from injury. They are also arranged so that a blown out fuse may be replaced easily and without danger. Most modern cars are equipped with circuit breakers and upon them, rather than the fuses, the manufacturers depend for protection from heavy currents.

(b) Circuit breakers have been in use for some time on switchboards and in various places in power houses, but their use on street cars is of comparatively recent date. They are placed under the hood of the platform just above the controller. The circuit breaker depends for its working upon the action of an electro-magnet which operates a switch in the line circuit.

Blue print #1 shows the working principle of a circuit breaker. It is not the actual plan of any one, but it illustrates the principle. A and E are the binding posts to which the connecting wires are carried; B is an electro-magnet whose coils carry the full current. From B the current passes to C and C'. The circuit through the circuit breaker is completed when the switch blade H makes contact with C and D. This blade H is placed in position by the handle R and is held in position by the catch N which presses against the notch K.

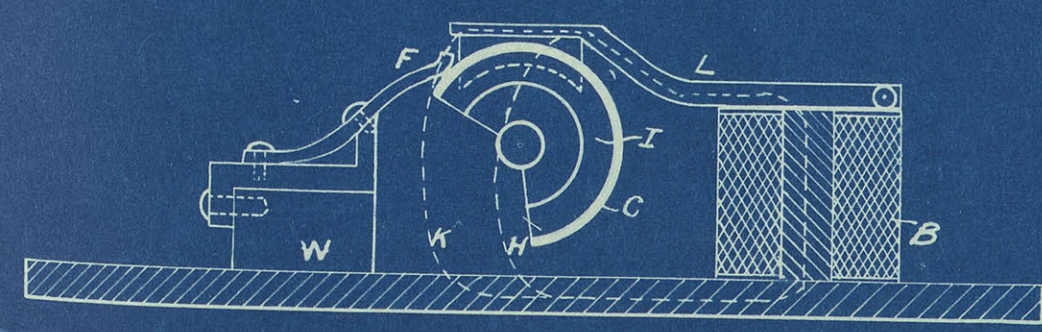
#7

CIRCUIT BREAKER



#8

SECTIONAL VIEW OF CONTROLLER



The spring P pulls downward on this handle so that when the catch N is released the switch knife H is pulled down breaking the circuit. If the current through B gets strong enough to overcome the pull of the spring S, the catch N is released, the knife H pulled down and the circuit is broken. The spring S can be regulated to balance the pull exerted by the magnet for any required current strength.

(c) In the controllers there is a liability of considerable damage being done by arcs formed on breaking a circuit, unless some protective device is used. To prevent this arcing, which would in a short time destroy the contact strips of the controller, a device known as the "magnetic blow out" is used. The construction of this coil is shown in blue print #8. The current passes through the coil B, (shown in blue print #5) thus making a magnet. This magnet does not have a continuous iron circuit however as may be seen by the print. The back of the controller forms a part of the circuit, and the movable iron plate L (which extends the full length of the controller) forms another part of the circuit, leaving an air gap through the part of the circuit occupied by the controller drum. Now an electric arc is acted upon by a magnetic field in just the same way as a conductor carrying a current - i.e. it is pulled aside and in this way blown out or extinguished. This serves to prevent the destructive action of the arc as the action of the "blow out" is practically instantaneous.

(d) Since the line of a trolley system is grounded at nearly all times, it offers an excellent path for a lightning discharge. The passage of the current of such a discharge would probably not injure the motors of a car, but because of the high induction which would result because of the high frequency of the discharge, the high voltage would probably puncture the insulation of the windings and in this

way greatly injure the motors. The tendency of any rapidly alternating current of high voltage is to take a non-inductive path of comparatively high ohmic resistance, rather than an inductive path of low ohmic resistance. This tendency is taken advantage of, in the lightning arresters which are now used in practically every street car. A tap is placed on the trolley wire at some place before it enters the controller. It is then led to one terminal of the lightning arrester, while the other terminal is grounded. The arrester is nothing but two well insulated conductors separated by a short air gap. In some cases the conductors are almost connected by charcoal points. The air gap between the two points is always great enough to prevent the passage of a current with the 550 volts pressure, but not large enough to prevent the formation of an arc when a very high voltage is impressed. The arc which is set up when the discharge takes place would, if allowed to exist, act practically as a short circuit on the line, for a current from the line would then flow. To prevent this several simple devices are used. The Westinghouse Company have two lignum vitae blocks placed close together, one on each side of the points of the arrester. When the arc occurs these blocks being so close together tend to smother it. The General Electric Co. have a blow out coil which serves the same purpose. The current which flows across the air gap sets up a flux which pulls the arc aside until it dies out.

To assist in increasing the inductance in the circuit a kicking coil is placed in the main line of the car at some point just below the tap wire for the lightning arrester. This kicking coil also serves as a protective device in another way, in that it helps to cut down the starting current at the instant of starting and thus allows the motor to get started before the full current flows.