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Thesis case

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THESIS for degree of M.S.

A Differential Balancer Set for Search Light Control on a Battleship.

1907

SEARCH LIGHT CONTROL BY MEANS OF A DIFFERENTIAL BALANCER SET.

THE OBJECT:- The object was to determine any changes necessary in the design tested, in order to fulfill the following requirements;

1. When used in connection with a 36" projector, the generator shall give a potential of 60 volts under a load of 130 amperes.

2. For every 5 amperes increase in load, from a range of 95 to 180 amperes, the voltage shall drop one volt, that is, the generator must have a drooping characteristic of about one to five.

3. The motor should be given sufficient compounding to sustain its speed as far as possible under load.

SEARCH LIGHT CONTROL
ORDINARY SYSTEM

The conditions of operation require that while burning, the potential across the arc shall be sufficient to maintain it and at the same time prevent excess of current flowing in order to avoid flaming. It is a difficult matter to satisfy

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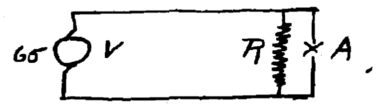
these two claims and it is chiefly done by the special mechanism of the lamps. When the arc breaks, however, we have a problem partly in the province of the lamp mechanism, but chiefly in the province of the characteristic of the supply voltage. This will be best explained by reference to a particular case. Consider that we have an arc taking 65 volts across the carbons. If we had a generator giving 65 volts and the arc broke, there would be no more than 65 volts across the terminals of the feeding coils, and the coils would not energize, for if adjusted to energize at 65 volts, they would keep the arc closed. It is evident that a higher voltage is required; so, let us consider the action with a 70 volt machine using resistance in the line outside the coils, making a drop of 5 volts, to the arc. Now if the arc broke, the small current through the drop coil, due to the current through the operating coils, would cause but a slight drop in voltage, and almost 70 volts would be brought to bear on the operating coils, and on the arc to reestablish it. This is a possible but undesirable solution for the reason that the characteristic would be a straight line changing from 70 to 65 volts when the current went from zero to full, so that with the slightest change in the arc, the voltage would also change slightly with an excessive change in the current, and the effect of this would be that the feeding coils would keep their armatures going one way or the other all the time.

SEARCH LIGHT CONTROL

Therefore, in practice, a large resistance is put in series, and the generator voltage is raised to 125. (Commercial reasons) This makes the resulting efficiency only a little more than 50%, and the lost energy is used up in heating, probably in a closed compartment aboard ship, which is very undesirable. The charateristic is much steeper, and the current changes less for a given change in voltage at the arc. This system requires a special machine for search light circuits.

By the use of a differential balancer set as will be described, it is possible to use a less sloping characteristic, and at the same time keep the supply current well under control. A motor generator set is used, obviating the use of the drop coil, thereby decreasing the heating and the consequent loss with the result that the efficiency is raised to about 75%, besides closer voltage regulation results.

Diagrams of different connections and charateristics.



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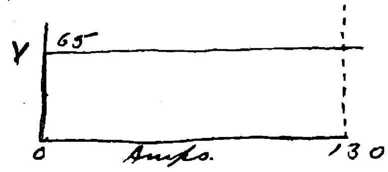

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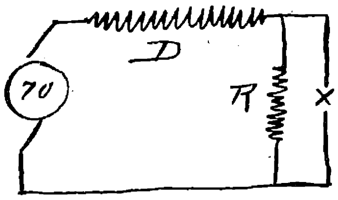

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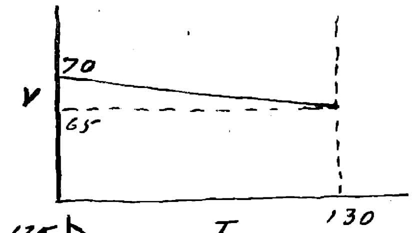
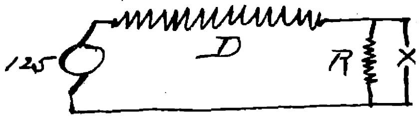


Line resistance for 5V drop.



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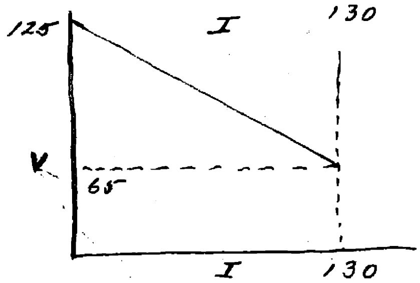


Line resistance for 60V drop

A" arc,   R" regulation coil, D" line drop coil.

The Differential Balancer Set.

Plate 1. This set is a motor generator set of special type. The frame is of the usual G.E.Co,, type, made in two halves, connected by thru bolts, the division being in a horizontal plane thru the axis of the main shaft. The two armatures are mounted on a common shaft having bearings at the ends of the shell. The commutators of the respective armatures are at the bearing ends, and there is a ventilating fan mounted on the shaft between the

two armatures, which draws the air from the ends of the armature and fields and discharges it, thru the ventilating grids at the middle of the shell. The general shape of the frame, is that of a horizontal octagonal cylinder, with lugs cast on for the base fastenings. Each armature revolves inside four laminated pole pieces, bolted to the frame so that their axes are at an angle of 45 degrees with the horizontal, and therefore normal to the faces of the octagon to which they are attached. Each pole piece has a series and a shunt winding. The armatures are series drum wound. The commutators are comparatively large, but as the machine must carry current in excess of its normal output, the area is not excessive. The bearings are lubricated by oil rings riding upon the shaft. The brushes are of the ordinary carbon type, two carbons to each collector and four collectors to each machine. The brushes are kept in contact by springs with adjustable tension. The collectors are mounted on adjustable rocker arms. For accessibility and ventilation, there are hand holes at the ends, and in the middle of the machine, having perforated cover plates. In view of the accompanying sketches and photographs, and tables of demensions etc., further description would be tedious and unprofitable.

Dimensions etc.

	Generator	Motor.	Lengths of Path.
G			
Commutator, Diam.	8"	8"	
Armature, Diam.	10"	10"	
Bars, Length	41/8	4 1/8	
Brush Area,	1 1/4x5/8	1 1/4x5/8	
Field Windings			
Shunt, wire gauge	0.038 (special size)	0.038	
Series, " "	0.070 9x7/8)	0.070	
" turns per pole	5 1/2	5 1/2	
Shunt, " " "	1690	??	
Armature winding	Series drum	series drum	
No. coils	????	35	
Turns per coil	????	12	
Gauge of wire	.134	.109	
Mean air gap	.156	.156	
Permeability			
Teeth	88,500	77,000	3.60"
Pole face	31,500	30,000	
Armature face	41,500	36,800	
" core	51,000	65,700	4.00
Magnet "	65,000	61,500	3.00
" yoke	53,000	50,500	8.00
Depth of slot	.43	.43	

THE SEARCH LIGHT.

Plate 2. The search light used was one designed for a 36" projector. A detailed description of the sketches of the operating mechanism follows. The machine can be operated automatically or by hand feed. The voltage regulation can be adjusted with in the required limits by means of the tension on the spring of the voltage armature as can also the current feed. The latter must be q quite sensitive, when it is considered that the hot arc has less resistance, than the arc first formed, and that to jump the gap requires higher potential than to maintain it, or in other words, the gap must be shorter to make the arc, than proper for the voltage present once the arc is made, the result being that it is necessary to withdraw the carbons to such a distance that the voltage shall not send excessive current thru the arc.

F is a current coil, which withdraws the positive carbon, instantly when the arc strikes, and allows the carbons to approach if the current falls below a definite value, which can be adjusted by means of the tension on the armature spring. This armature 1, acts thru k, l, e, v, and d, which in turn works in a nut on the positive carbon carrier. The feed to allow for the burning away of the carbons, is accomplished by the turning of the feeding screws e and d. These threads are given such a pitch that though the positive carbon wears away twice as fast as the negative carbon, the arc is maintained at the focus of the reflector. As the carbons may not be of just the right length, it is also necessary to provide for moving the mechanism as a whole, and this is done by providing sliding contacts at a and b, by which the current is taken from the casing terminals. G is the voltage regulator, and feeding coil, which can be adjusted to operate at any desired rise in potential. On the 36" projector, it was adjusted to feed at 2 volts rise. The armature has the regular vibrating make and break. The armature P operates the feed mechanism thru the pin M, and the roller Q., moving in a slot in the feeder arm R. The amount of feed is adjusted thru the screw X. A pawl Z engages a ratchet wheel c on the end of the shaft E, thereby thru S and T operating to revolve d. S is broader than T to allow for the travel of d when the current coil operates. A switch C allows of cutting the automatic feed out, when it is desired to operate the feed by hand alone.

CONNECTIONS FOR THE TEST.

These connections will be best understood by reference to the diagrams appended, with the accompanying description. In general the following are the conditions. The motor generator set is to be connected as a balancer across a 220 volt ship's circuit, in connection with a 36" search light projector taking 130 amperes at 60 volts; one leg of the projector circuit to be taken from the negative side of the line, to which one generator terminal is to be connected, the other leg to lead from the other remaining terminal (generator) which is also connected to the negative terminal of the motor, the positive terminal of the motor being connected to the positive side of the 220 volt circuit. (Signs here used are conventions only N). The generator shunt field to be separately excited across the 220 volt mains. The motor shunt field to be connected from the positive line to the negative motor terminal so that the exciting voltage will be the difference between 220 volts and the generator armature voltage. The motor series field is to be connected in series with the load, and accumulative. The generator series field to be in series with the load but differential.

For the purposes of the test a rheostat is to be placed in series with the shunt field of the motor, and an adjustable (German Silver ribbon) shunt is to be placed across the motor Series field so that these will give the necessary compounding for good speed regulation over the range of load.

A rheostat also to be inserted in the generator field (shunt) and a German Silver shunt across the generator series field, so that with the speed of the motor, the necessary compounding can be obtained to give the desired drooping characteristic.

Log of the test.

PROCEDURE.

This test came while working on Government Test at the G.E. plant at Schenectady, New York. The test was conducted by us, but we were not allowed entire fredom as to the line of conduct of the test, owing to directions from the engineer in charge of this experimental design.

Runs #1-8, Preliminary. August 6th-8th, 1906.

The connections were made as in plate 3. with the exception that the generator field connections were crossed, as was later discovered (this was due to an error in the winding depertment.) Also no German Silver shunts were used. With no resistance in the motor shunt field the speed was 1150 rpm with the generator shunt field in and 1400 rpm without the generator shunt field, which was much too low, 1600 rpm being desired. Since the motor field was supposed to be accumulative, and was too strong, to lessen its effect a german silver shunt was fitted in the series field, (see plate 3.) This was adjusted until 1600 rpm was obtained but this gave 100 amps load at 90 volts, which was too high for the load, showing the generator field was too strong.

A run was made under the last conditions, 220 V applied, full shunt fields, and on applying the load, the motor speeded up indicating a differential field, instead of accumulative as supposed. After tracing out all connections, it was found that if they were made according to instructions, the motor would run backward.

The polarity of fields was tested by compass and found alright according to plate 3, as modified to agree with the present connections i.e.: with the shunt field reversed on the generator (this was the only change from the original connections). Now on throwing in the generator field the rpm went from 1300 to 1800, and the motor field voltage to 300 volts, increasing as the load came on, the speed remaining constant but the motor running backwards, thus causing the set to act as a booster, The only trouble now appeared to be that the reversal of direction caused a reversal of conditions on the generator side, which could be corrected if the direction of rotation were made to agree with Plate 3. This was done by rotating the motor brushes through 90 degrees, thus obtaining the effect of reversing the armature current. Results; generator field out, 1280 rpm, and with field in 1080. The reduction being due to the fact, that the motor and generator armatures, being in series, the motor voltage is reduced by the amount of the generator voltage, and besides, the motor armature current has to pass through the generator armature on no load, thus loading the motor and at the same time reducing its potential. With 220v line, got 980 rpm at 130 amps, and 55v load. This voltage is too low and 60 volts can be obtained by increasing the speed of the motor; for the generator fields are full strength, though differential. The latter might be strengthened by shunting the series field.

We now tried the introduction of resistance in the motor shunt field.

PROCEDURE.

Note: The data for the folllwings runs is tabulated and appended, proper reference being made to the runs by the number.

Run #6.

The voltage did not stand up as desired, showing that the generator series field was too strong, so a german silver shunt was put across to hold up the voltage.

Run #7.

This was very successful so far as speed ans slope of characteristic were concerned, but the voltage was not high enough. The instructions were at fault in not stating that the full load ~~sped~~ speed should be 1600rpm instead of maximum speed. To bring the voltage up, the german silver shunt in the generator series field was shortened.

Run #8.

This brought out the fact, that the motor series field, was too strong, so a german silver shunt was inserted, and adjusted to give 60 v at 130 amps.

Run #9---15. August 9th.

From the preceding runs it became evident that any desired voltage could be obtained by changing the speed or altering the field ofthe generator, and it was further seen that the speed and voltage were intimately related. Also it was seen that any desired slope might be obtained by varying the german silver shunts.

Run #9

This gave too rapid a slope to the characteristic, showing that the generator series field was too strong, so we shortened the german silver shunt.

We now made a series of runs varying the length of german silver shunt until a ratio of 5:1 .03 was obtained, which was practically the ratio desired. See curves 10-15.

In the motor series field one strip 4' 6" long.

In the gen series field, two strips 2' long.

Run #13'. August 10th.

With the same conditions as above, it was desired to observe how the ratio was maintained before the machine was heated up. The ratio had changed to 5:.87.

By direction of the engineer, a four hour heat run was made in which the set behaved satisfactorily, under abnormal conditions, as all openings except the ventilating discharge grids were blocked up.

Run#16.

After preliminary adjustment to get the proper ratio, made this run which made a curve for the voltage characteristic, though closely approximating to the results desired, but insufficient data had been taken.

Run # 17. August 11th.

A preliminary run resulted in the setting of the following lengths of the german silver shunts:

Generator, double strip, 2'--1 3/4" resistance .0104 ohms.

Motor, single strip 3' --6 1/2" resistance .0301 ohms.

By reference to Plate 6 it will be seen that this run gives a straight line for the characteristics within the limits required.

Run # 18. August 14th.

The motor series field was now short circuited outside. As was to be expected, the speed remained nearly constant.

Run # 19.

The german silver shunt was now cut out of the generator series field; motor series field short-circuited as in # 18.

By comparison of #18 and #19 it is seen that though both speed and v curves start at the same point, the speed of #19 rises while it's voltage lowers in reference to #18. To understand that, it is necessary to consider the difference between the two conditions. The generator field being differential, cutting out the german silver shunt to the series field allows full differential action, thus causing the drop in voltage, even though the speed is increased by the increasing potential, and the relatively lighter load. The voltage characteristic shows nearly the proper shape, but the curve lies too low.

Run # 20 August 15th.

On this date a search light was received, and regularly connected. as a load, instead of the waterbarrel load previously used. Conditions as in #18.

The voltages were very low and the currents excessive while the speed rose from 1230 to 1300 rpm. the lamp as received was adjusted to operate at 50 volts and 130 amps. It appeared that the series coil of the lamp did not withdraw the negative carbon sufficiently and it was necessary to withdraw it by hand; the voltage then rising to 35 volts and the current still remaining above 200 amps. We managed to get the voltage to 45, but the lamp flamed badly and would not regulate. We now inserted 42" of german silver shunt in the motor series field, returning to the conditions of the adjustment of run##17, using rheostat in motor shunt field to bring the speed up to 1600 at no load.

At 52 volts and 180 amps, the lamp regulated fairly well, bu still flamed on account of excessive current. For performance see curve # 17. The automatic feed works, but is set for 50 volts and consequently begins to feed too soon, giving excessive current and causing flaming

We now weakened theggenerator shunt field, which dropped the voltage to 56 and the amperes to 140 amps., which was to be expected, speed 1260 and the lamp working fairly well. It appeared that the lamp feeds at 53-54 volts and takes under these conditions about 160 amps. The following run # 20 was taken.

The lamp being adjusted for 50 volts, and the machine having been adjusted for 60 volts at the normal current output of 130 amps; it appeared only reasonable that the lamp should not regulate properly. The trouble appeared that different instructions had been issued to the different departments, probably due to the fact thatthe line drop was to be allowed for, though this fact was not mentionedin the instructions.

PROCEDURE # 4.

This might readily be the case when we consider that the search light may be located in a fighting top or on a bridge, while the set would be located below the protective deck. To show this, the leads from the protective deck to the height of the flying bridge of a battleship would be about 100 feet in length, and with a 00 wire and 130 amps, the drop would be 10 volts.

It was therefore decided to insert a resistance in the line to provide this drop of ten volts, thus giving both the lamp and the machine their normal running conditions, adjusted according to instructions. Run # 21 was made under the conditions of # 17, with the lamp, the lamp being fed at 54 volts.

Run 23-26. August 16th.

A series of four runs were now made by direction of the engineer in charge of design, using water barrel load.

Run # 23.

It was desired to note the performance with the motor field adjusted for 2000 rpm at no load, the generator to give 60 volts at 130 amps under this condition. In the generator series field two strips 2' 1"3/4 long, and in the motor series field, 1 strip 3' 6" were inserted.

Run # 24.

It was desired to note the performance with conditions as above but shunt field of generator adjusted for 70 volts.

Run # 25.

With full shunt field on the generator, the speed was adjusted for 60 volts at 130 amps.

Run 26.

Starting at no load rpm of 2000 the generator shunt field was adjusted to give 60 volts at 130 amps.

Run 27.

This run was the same as #26 except the generator field was adjusted to give 53 volts at 130 amps. The lamp was used as load and performed excellently, but the fluctuations of current and the fact that it was impossible for two observers to make simultaneous observations of all instruments, made it impracticable to obtain data sufficiently accurate to determine the efficiency, though the points observed indicate an efficiency slightly above 80%.

Run 28.

This run was made as a heat run. The behavior is shown on Plate 13 the adjustment being as in #27. From these curves it is seen that the efficiency remains sensibly constant in the neighborhood of 75%. The speed increases, the generator voltage drops., both being clearly due to the effect of the increasing resistance of the respective fields: the load current being maintained constant throughout.

The latter condition combined with the practically constant efficiency and the reducing voltage, also makes the input and output fall in like manner.

CONCLUSION.

As a result of this test, it was the intention of the G-E. company in the final design, to compensate both. G & M fields for the amp. turns equivalent to the G. S. S. shunts inserted in these fields. In allother respects the machine as designed appeared to operate very satisfactorily.

As a general result, it may be stated that the set will show an efficiency in practice of about 80%, the internal loss being 1.9 K.W. The immense advantage from the use of this set, particularly on a 220V circuit is seen at once, for a loss of 20.15 K.W. would be entailed were an ordinary resistance used in rheostat form. The balancer set is very small and compact, as seen by reference to Plate 1.; requires very little attention in operation; does not prove a source of great heat, as do the resistance coils. It should prove of great advantage for shore installations for harbor defence, where the power could be taken from regular mains at a great saving in efficiency and hence operating cost. It may be adapted to use on lightships which are now being fitted with search lights, and floated on lines without necessity for special machines for the searchlight.

The frame of the Balancer Set for a 60" Projector on a 125 volt circuit is of the same size as for the 36". This is important in ship installations, where space is valuable. The 60" arc takes 200 amperes at 65 volts; the efficiency is about the same; the internal losses being 3.15 K.W. A rheostat here would cause a loss of 12 K.W. that is, the saving would be 8.85 K.W., by the use of a Balancer Set. The Smaller relative saving is due to the smaller line voltage in this case. For a 36" projector as used on the U.S.Battleships with 125 volt circuits, there is a loss of 8.45 K.W. in the resistance coil as against 1.95 K.W. loss by the use of this machine, or a saving of 6.5 K.W.As a modern battleship would probably carry from 4 to 6 searchlights, the great saving by the use of these machines is evident.

Holden C. Richardson

James Reed Jr

Line.			Motor.				Generator.				Load.			
V	I	Input.	V_F	I_F	V_A	I_A	V_F	I_F	V_A	RPM	V_{LD}	I	Output	Eff %
							Run #6.							
					84	42			58	1150		130		
					80	35			65.5	1190		95		
							Run #7.							
			83	.82	5			1.8	100	1600		0		
				.85	16			1.75	81.5	1420		30		
				0				1.8	72	1300		60		
				1.06	30			1.8	66	1275		80		
				1.07	34			1.8	61	1240		95		
				1.11				1.8	58.5	1220		110		
									56	1200		120		
									54	1200		130		
							Run #8							
						4.5	0		0	1800		0		
220			119	.80	220	5.0	204	0	104	1600		6		
			62	.82	115	12.5	208	1.95	89	1480		20		
			77	.98	131	20	206	1.90	80	1380		40		
			82	1.03	140	26.5	206	1.87	73	1325		60		
			84	1.06	146	30.5	206	1.88	69.5	1280		80		
			85	1.08	151	33	205	1.87	67	1260		90		
			87	1.16	153	35	206	1.86	64	1255		100		
			88	1.12	157	37	206	1.86	62	1240		110		
			89	1.12	159	39	206	1.84	60	1220		120		
			90	1.14	160	41	206	1.84	58	1210		130		
					164			1.84						
							Run #9.							
220			66	.81	159	44	206	1.80	62.5	1340		130		
			60	.75	47	35.5	206	1.77	73.5	1420		90		
			63	.78	54	40	204	1.76	66.5	1375		110		
			66	.82	59	44		1.74	61.5	1350		130		
			68	.84	63	46.5		1.73	56	1320		150		
			71	.87	72	50		1.74	48.5	1280		180		

#10

Load.

V_{LD}	I_{LD}	RPM
60	130	1290
70	90	1360
50	170	1240

#11

60	130	1265
70.5	90	1350
51.5	170	1220

#12

60	130	1240
69.5	90	1320
60.5	130	1250
52.0	170	1190

#13

68	90	1326
59.5	130	1210
51.5	170	1180
67.2	90	1270
60.	130	1180
53	170	1150

#15

69.5	90	1300
61	130	1240
53	170	1180

#13'

68.5	90	1245
60	130	1190
54.5	170	1150

Run #16.

V_{LD}	I_{LD}	RPM
106	0	1880
99.5	10	1810
93	20	1720
87	30	1650
82	40	1610
80	50	1580
77	60	1550
74	70	1520
72	80	1500
69.5	90	1270
66.5	100	1260
62.5	120	1220
60	130	1190
58.5	140	1190
55	160	1160
51	180	1160
48	200	1140

Run #17.

Line.			Motor.				Generator.				Load.			
V_L	I_L	Input.	V_F	I_F	V_A	I_A	V_F	I_F	V_A	RPM	V_{LD}	I_{LD}	Output.	Eff.%
220	8.24		67	.84	120	5.5	220	1.90	101.5	1590	101.5	0	0	0
	11.77		70	.87	125	9.		1.90	96.5	1520	95.5	10	.965	37.2
	16.80		74	.92	132	14.		1.88	89.	1460	89	20	1.780	48.2
	21.39		80	.99	138	19.5		1.90	83.5	1380	82	30	2.460	52.4
	25.90		81	1.00	140	23.			80.	1350	79	40	3.160	55.5
	26.90		82	1.00	141	24.			78	1340	77.5	50	3.875	65.5
	27.42		83	1.02	143	25.5			76	1320	75	60	4.500	74.5
	30.45		84	1.05	146	28.5			75	1300	72.5	70	5.075	75.8
	32.95		85	1.05	147	31.			73	1270	70	80	5.600	77.3
	36.97		87	1.07	157	34.			69	1260	67.5	90	6.075	75.0
	38.49		88	1.09	153	36.5			67	1250	65.5	100	6.550	77.4
	43.01		90	1.11	156	41.			63	1200	61	120	7.325	77.2
	46.37		91	1.12	158	43.5		1.85	61.5	1190	59.5	130	7.740	75.8
	47.98		92	1.13	160	45.			60	1180	57.5	140	8.050	76.5
	52.00		93	1.15	160	49.			56	1160	53	160	8.475	74.0
	56.02		95	1.17	166	53.			54	1150	50	180	9.000	72.8
	58.05		98	1.20	170	57.			51	1140	47	200	9.400	73.6

Run #18.

220			144	1.57	144	4.0	220	1.75	72.0	1250	72	0		
			147	1.62	147	8.5			70	1245	70	15		
			148	1.63	148	13.5			67.5	1240	67	30		
			148	1.65	148	16.5			66.5	1240	66	40		
			149	1.66	149	19.0			66	1240	65	50		
			151	1.67	151	22.0			65	1240	64	60		
			152	1.65	152	25.5			64	1235	63	70		
			153	1.70	153	28.5			63	1235	62	80		
			154	1.71	154	31			62	1235	61	90		
			155	1.72	155	33.5			61.5	1230	60	100		
			156	1.73	156	36.5			60.5	1230	59	110		
			157	1.75	157	39.0			59.5	1225	58	120		
			158	1.76	158	41.5			58.5	1225	57	130		
			160	1.67	160	46.5			57	1220	54.5	150		
			161	1.79	161	50.5			54.5	1220	52	170		
			162	1.81	162	52.5			53.5	1220	51	180		
			164	1.81	164	55.5			52	1215	49	200		

Line			Motor			Generator				Load		
V_L	I_L	V_F	I_F	V_A	I_A	V_F	I_F	V_A	RPM	V	I	P
								Run #19.				
220		S	1.60	144	4			72	1250	72	0	
		A	1.61	145	8.5			69	1245	69	15	
		M	1.66	149	13			67.5	1240	66.5	30	
		E	1.65	150	16			65.5	1240	64.5	40	
			1.67	151	19			64.5	1240	63.5	50	
		A	1.69	152	22			63		62	60	
		S	1.72	153	25			62		60.5	70	
			1.71	154	27			60.5		59.5	80	
		V_A	1.74	155	30			59.5	1240	58	90	
			1.75	156	32.5			58.5		56.5	100	
			1.76	157	34			57.		55	110	
			1.77	159	37			56		53.5	120	
			1.78	161	39			54	1260	52	130	
			1.81	162	42			52		49.0	150	
			1.86	164	46			48.5	1260	45.5	170	
			1.82	166	46.5			46.5		44.5	180	
			1.89	172	49			45	1260	41	200	
								Run #20.				
220			1.19		49		1.82	58		55	160	
			1.17		48.7			60		57	150	
			1.15		48			60		58	140	
			1.18		49		1.80	58	1180	52	150	
			1.22		54			54		51	180	
			1.23		55			53		50	190	
			1.17		47			60	1190	58	140	
								Run #21.				
220			1.98		32		1.80	55.5	1080	53	110	
			1.95		30		1.80	57.5		55	95	
			1.92		27		1.79	59.0		56.5	85	
			1.85		25		1.78	57.5		55	90	
			1.95		45		1.78			46.2	162	
			1.89		37.5		1.78	58.5		51.5	130	
			1.95		44.0		1.78	50		47	160	
			1.77		29		1.76			57	90	
			1.85		49.5		1.76			49.5	150	
			1.15				1.76			41.5	240	
								Run #22.				
220		90	1.20	180	42	178	1.60	53		49	160	
			1.20	180	52	178	1.60	56		53	130	

Run #23.

Line.			Motor.				Generator.				Load.		
V	I	Input	V_F	I_F	V_A	I_A	V_F	I_F	V_A	RPM	I	Output	%
220	8.4	1.765	50	.6	104	6	220	1.8	117	2000	0	0	0
	12.75	2.800	52	.65	110	10.5		1.6	110	1900	10	1.000	35.7
	16.48	3.620	56	.68	118	14.0		1.8	102	1800	20	2.040	55.4
	23.05	5.075	60	.75	128	20.5			92	1650	40	3.660	72.2
	32.10	7.060	64	.80	138	29.5			81.5	1500	60	4.830	68.4
	36.10	7.940	66	.83	140	33.5			77.5	1450	80	6.075	76.6
	39.15	8.600	68	.85	145	36.5			75		90	6.525	75.9
	42.16	9.260	69	.86	145	39.5		1.79	72.5	1400	100	7.050	76.0
	44.66	9.825	70	.87	150	42			69		110	7.420	75.5
	46.68	10.290	71	.89	152	44			67.5		120	8.100	78.9
	48.70	10.310	72	.91	154	47			65	1320	130	8.200	79.4
	50.71	11.175	73	.92	155	48			63		140	8.540	82.3
	53.22	11.700	74	.93	157	50.5		1.78	61		150	8.850	75.8
	57.73	12.700	76	.95	160	55			58	1260	170	9.350	73.6
	58.74	12.920	77	.96	162	56			51	1220	180	9.630	74.5
	61.75	13.600	78	.97	164	59			53	1200	200	9.900	72.7

Run #24.

V	I	Input	V_F	I_F	V_A	I_A	V_F	I_F	V_A	RPM	I	Output	%
220	16.42	3.610	34	.47		14		1.95	126	2050	10	1.260	3.490
	23.45	5.160	41	.50	105	21			113	1900	30	3.390	6.570
	26.47	5.825	43	.52	112	24			106	1800	40	4.160	7.140
	34.51	7.600	48	.58	126	32		1.93	94.5	1700	60	5.580	7.460
	40.49	8.875	50	.61	133	38		1.88	86.5	1600	80	6.800	
	42.49	9.340	51	.63	138	40		1.86	84	1525	90	7.380	7.660
	44.50	9.780	52	.64	139	42		1.86	80	1520	100	7.850	7.900
	48.52	10.700	54	.66	144	46		1.86	77	1475	110	8.310	80.40
	50.50	11.120	55	.68	145	48		1.82	73	1450	120	8.760	77.70
	52.51	11.560	55	.69	147	50		1.82	68.5	1400	130	9.160	78.80
	54.50	12.000	56	.70	149	52		1.80	66	1400	140	9.585	79.3
	57.52	12.600	57	.72	151	55			67	1360	150	9.650	79.3
	58.53	12.880	58	.73	153	56			64.5	1340	160	9.930	76.3
	60.53	13.320	59	.73	156	58			62	1300	170	10.120	77.2
	62.54	13.780	60	.74	160	60			60	1280	180	10.250	76.0
	65.55	14.420	61	.75	161	63		1.80	57	1260	200	10.700	74.5

Run #25.

Line.			Motor.				Generator.						Load.		
V_L	I_L	Input	V_F	I_F	V_A	IA	V_F	I_F	V_A	I_L	RPM	V_{LD}	I_{LD}	Output	Eff %
220	7.94	1.735	57	.70	110	5.5	220	1.74	108		1800	108	0	0	0
	17.12	3.770	64	.78	124	14.5			95		1780	95	20	1.900	50.4
	30.09	6.600		.85	135	27.5			85		1520	84	40	3.360	50/9
	35.62	7.840	72	.88	140	33.0			79		1475	78	60	4.680	59.8
	38.16	8.390	74	.92	144	35.5			74		1420	73	80	5.840	69.6
	40.67	8.940	76	.93	146	38.8			71.5		1380	70	90	6.300	75.0
	43.19	9.500	77	.95	148	40.5			69		1370	66.5	100	6.650	70.0
	45.70	10.050	78	.96	150	43.			67		1315	65	110	7.150	71.2
	47.72	10.500	79	.98	152	45			65		1300	63	120	7.560	72.0
	50.73	11.180	80	.99	156	48			63		1270	61	130	7.930	67.2
	51.74	11.400	81	1.00	158	49			62		1250	59	140	8.260	72.5
	54.75	12.050	82	1.01	159	52			59		1230	57	150	8.550	70.8
	55.76	12.290	83	1.02	162	53			60		1215	55	160	8.800	71.7
	57.77	12.710	84	1.03	164	55			56		1200	53	170	9.010	70.8
	60.78	13.380	85	1.04	166	58			55		1180	52	180	9.360	70.0
	63.79	14.040	87	1.05	169	61			52		1220	49	200	9.800	69.8

Run #26.

220	48.54	10.700	73	.90	156	46	220	1.64	62		1400	60	130	7.800	72.8
	8.24	1.810	50	.60	106	6			113		2000	113	0	0	0
	16.34	3.600	56	.70	120	14			98		1800	94	20	1.880	52.2
	23.39	5.140	60	.75	130	21			89		1700	88	40	3.520	68.5
	30.48	6.710	64	.84	138	28			75.0		1580	79.5	60	4.770	71.2
	35.48	7.800	66	.84	144	33			72		1500	74	80	5.920	75.8
	38.49	8.470	68	.85	147	36			69		1475	71	90	6.390	75.2
	40.50	8.910	69	.86	150	38			68		1440	68	100	6.800	76.3
	42.52	9.360	70	.88	152	40			65		1410	66	110	7.360	78.6
	44.53	9.800	71	.89	154	42			63		1390	64	120	7.680	78.4
	47.54	10.480	72	.90	157	45			61		1370	61	130	7.930	75.6
	49.55	10.900	73	.91	159	47			59		1330	59	140	8.260	75.6
	51.56	11.340	74	.92	160	49			57		1310	57	150	8.550	75.3
	53.57	11.800	75	.93	162	51			55		1290	55	160	8.800	74.6
	55.58	12.220	75	.94	163	53			54		1280	53	170	9.010	73.7
	57.59	12.680	76	.95	164	55			54		1270	51	180	9.180	72.4
	59.61	13.140	78	.97	168	57			50		1250	47	200	9.400	71.5

Run #27.

VLD	43	38	50	55	58	54	51
ILD	180	200	150	120	110	120	130

4 Hr. Heat Run.

Line.			Motor.					Generator.							
V_L	I_L	Input.	V_A	I_A	V_F	I_F	RPM	V_A	I_A	V_F	I_F	V_{LD}	I_{LD}	Output	Eff %
220	47.42	10:432	160	44.5	82	1.04	1180	62.5	Load	194	1.88	60	130	7.800	74.77
	45.75	10.065	160	43.0	82	1.04	1220	60.5	130	197	1.71	58		7.541	74.92
	45.22	9.948	160	42.5	83	1.04	1220	59.0		197	1.68	56.8		7.384	74.22
	45.70	10.055	160	42.0	86	1.03	1235	59.0		200	1.67	56.3		7.319	72/74
	44.70	9.834	162	42.0	88	1.05	1230	58.8		198	1.65	55.5		7.216	73.38
	44.20	9.724	161	41.5	87	1.04	1230	58.5		200	1.66	55.5		7.216	73.38
	42.70	9.394	161	41.0	89	1.05	1240	58.5		199	1.65	56.0		7.281	77.49
	43.20	9.504	164	41.5	90	1.06	1240	57.5		199	1.64	55.0		7.150	75.23
	43.18	9.500	164	41.5	90	1.05	1240	57.5		198	1.63	54.5		7.086	74.58

Motor Temperatures.

Air.	Oil.	Frame.	Pole tip L.	Pole tip T.	Spool.	Vent. duct.
26	25	28	28	28	28	
28	26	34	40	39	36	38
26	26	36	44	43	40	40
27	26	40	46	45	43	46
29	27	41	47	47	44	44
27	27	41	48	48	45	42
28	28	41	48	48	45	44
25	28	41	49	48	45	42
25	28	42	50	49	46	42

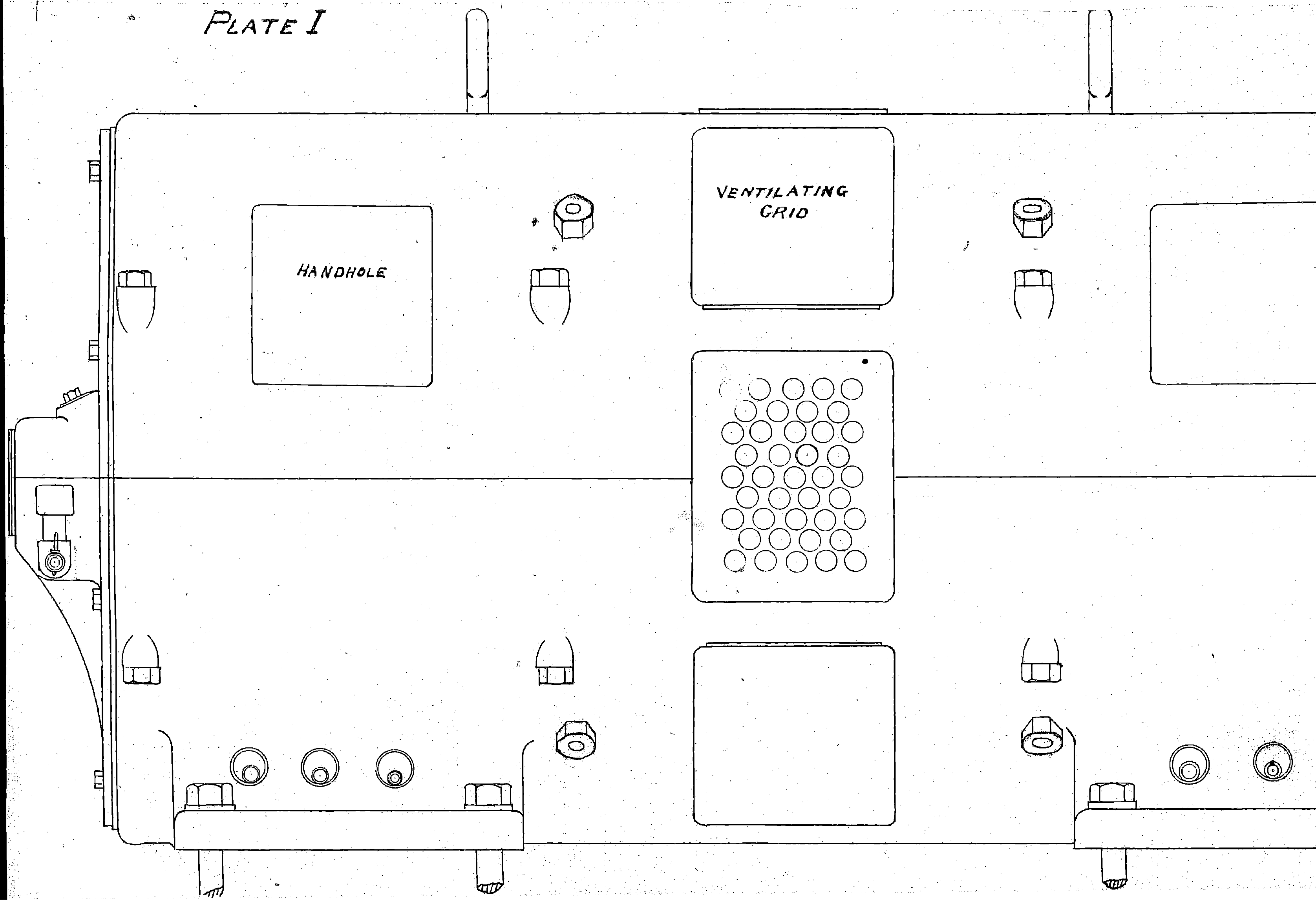
Field Resistances.

	Motor.			Generator.		
	E	I	R	E	I	R
	(101	1.36	743)	134	1.43	937)
Cold	(123	1.67	737)	146	1.56	936)
	(140	1.88	745)	160	1.68	952)
	(68	.79	861)	173	1.42	1218)
Hot	(75	.87	862)	190	1.55	1226)
	(85	1.00	850)	198	1.63	1215)

Generator.

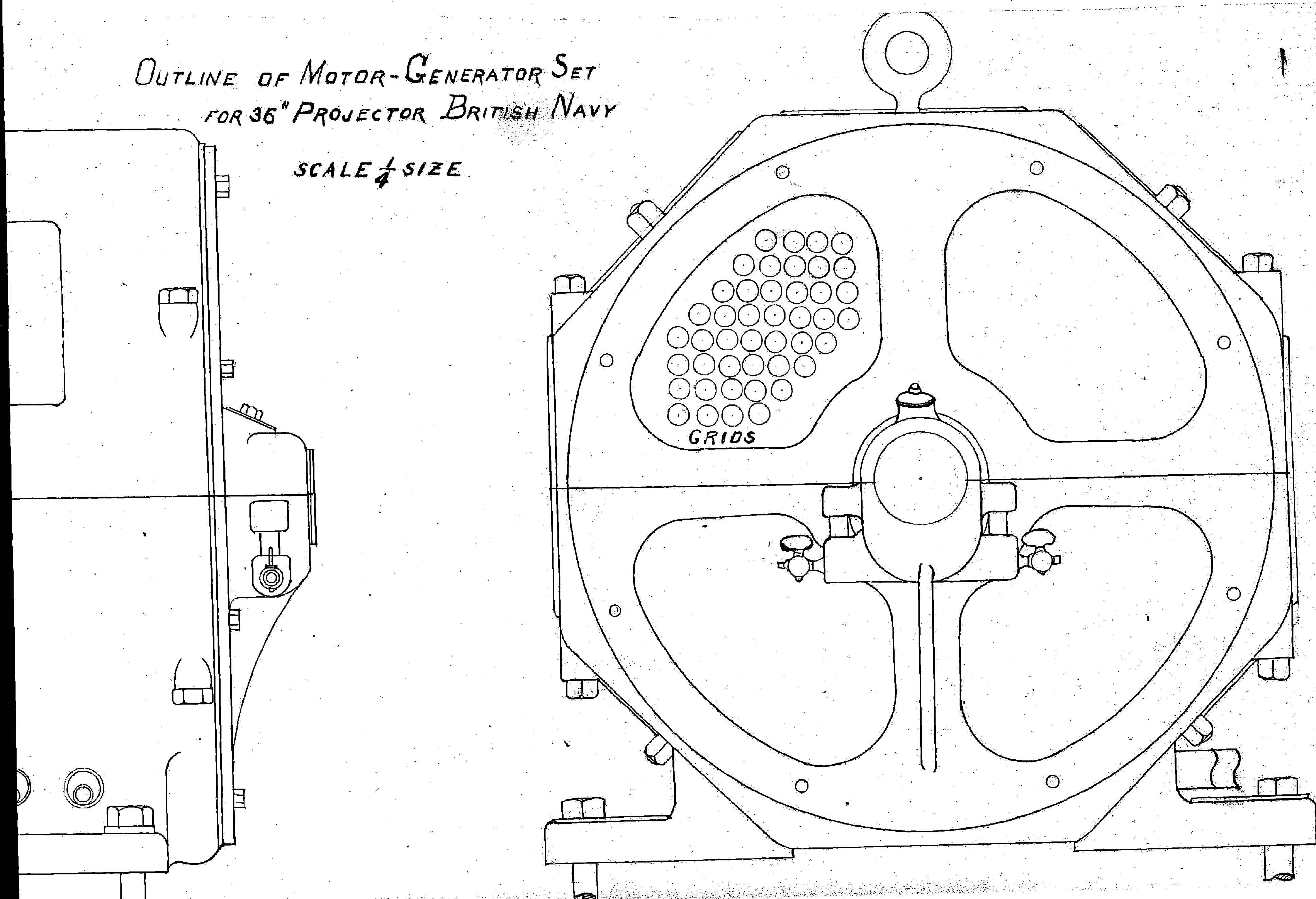
Air.	Oil.	Frame.	Pole tip L.	Pole tip T.	Spool.	Vent. duct.
26	25	28	28	28	28	28
28	26	33	38	34	37	37
26	26	38	45	46	45	40
27	26	41	48	49	46	48
29	27	42	50	50	47	45
27	27	44	51	52	44	44
28	28	44	51	52	45	45
25	28	44	51	52	45	45
25	28	44	51	53	44	44

PLATE I

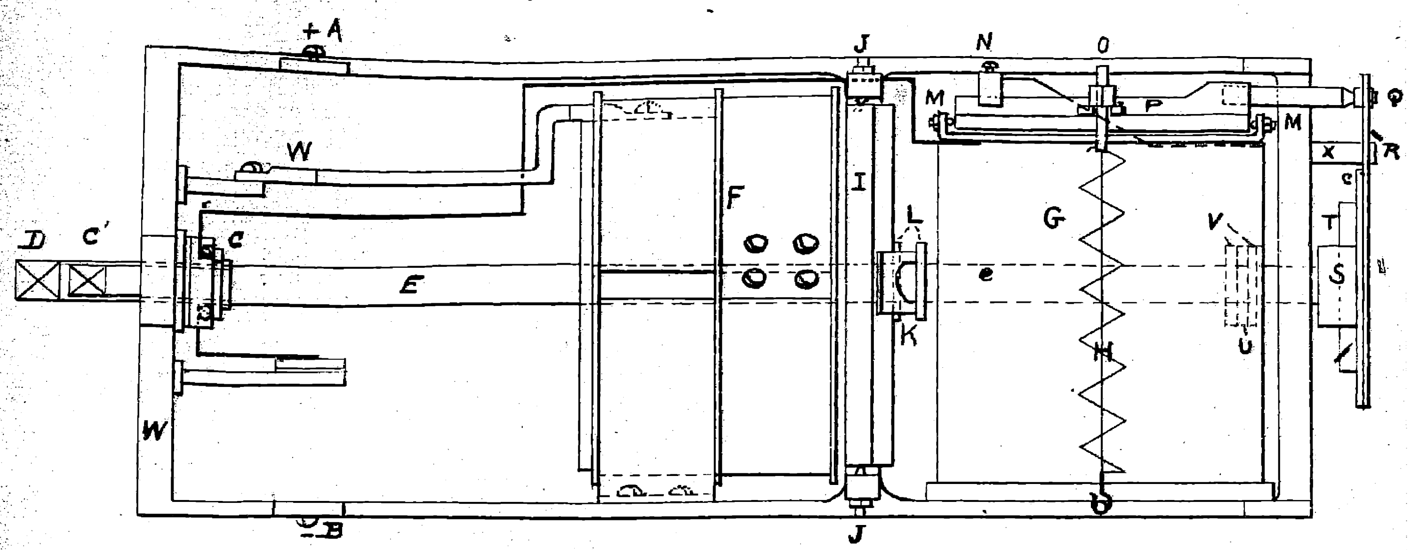


Outline of Motor-Generator Set
for 36" Projector British Navy

Scale 1/4 size



NOTE: THESE SKETCHES ARE NOT TO SCALE.



BOTTOM VIEW OF SEARCH-LIGHT MECHANISM

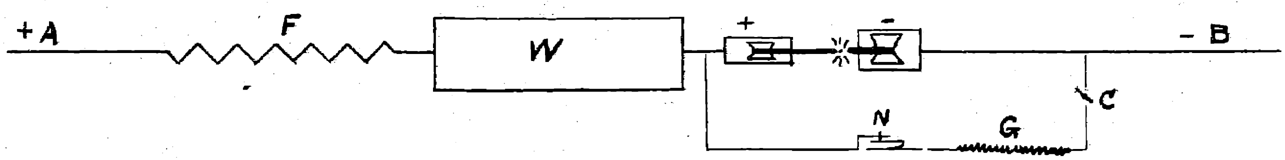
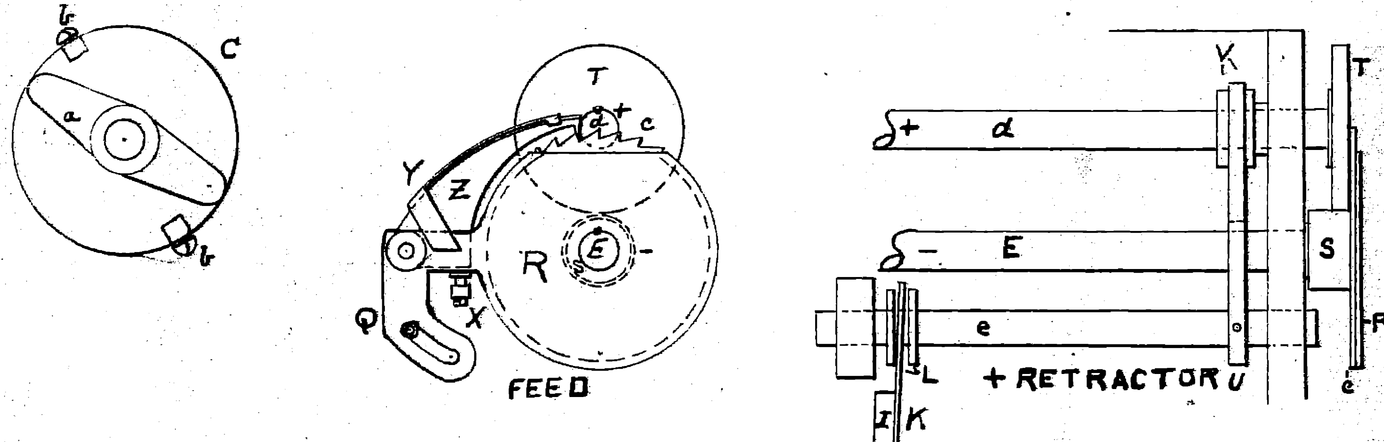
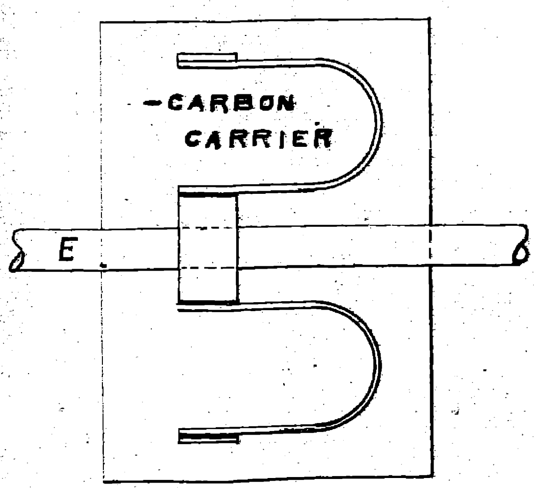


DIAGRAM OF CIRCUITS



DETAILS



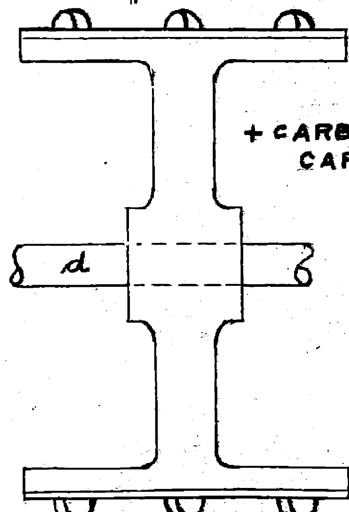
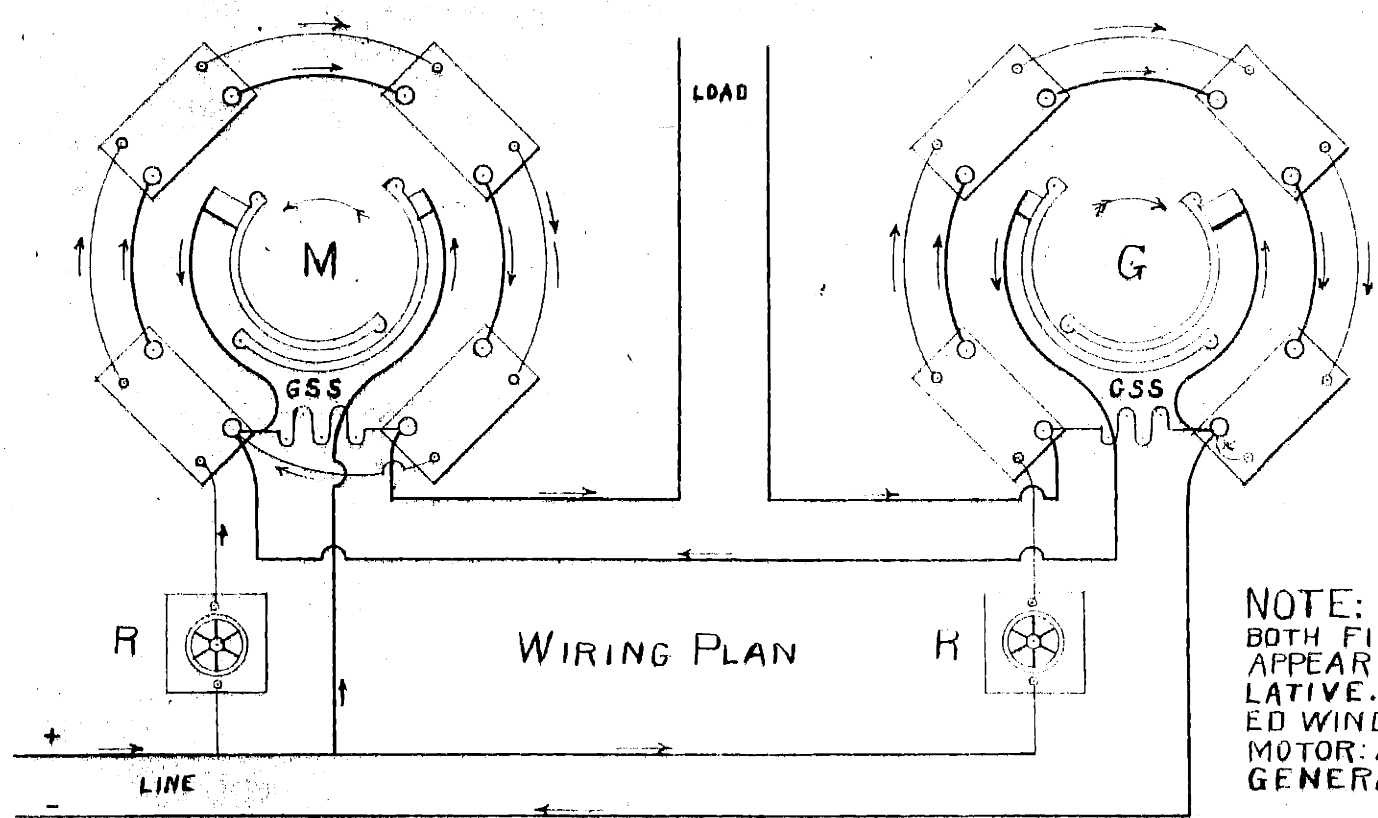


PLATE II



NOTE: As here shown both fields would appear to be accumulative. Open & closed windings correct it. Motor: accumulative Generator: differential.

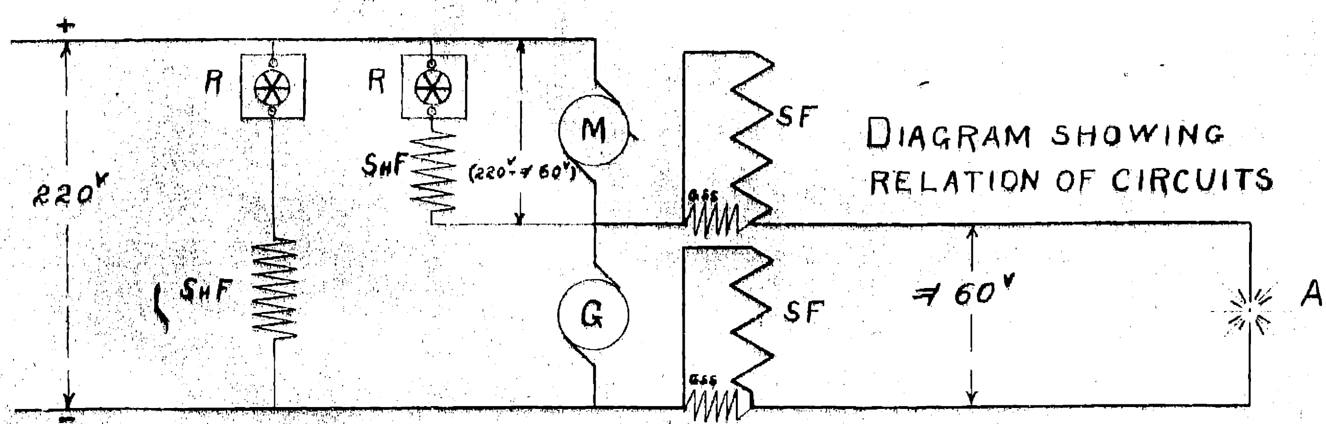
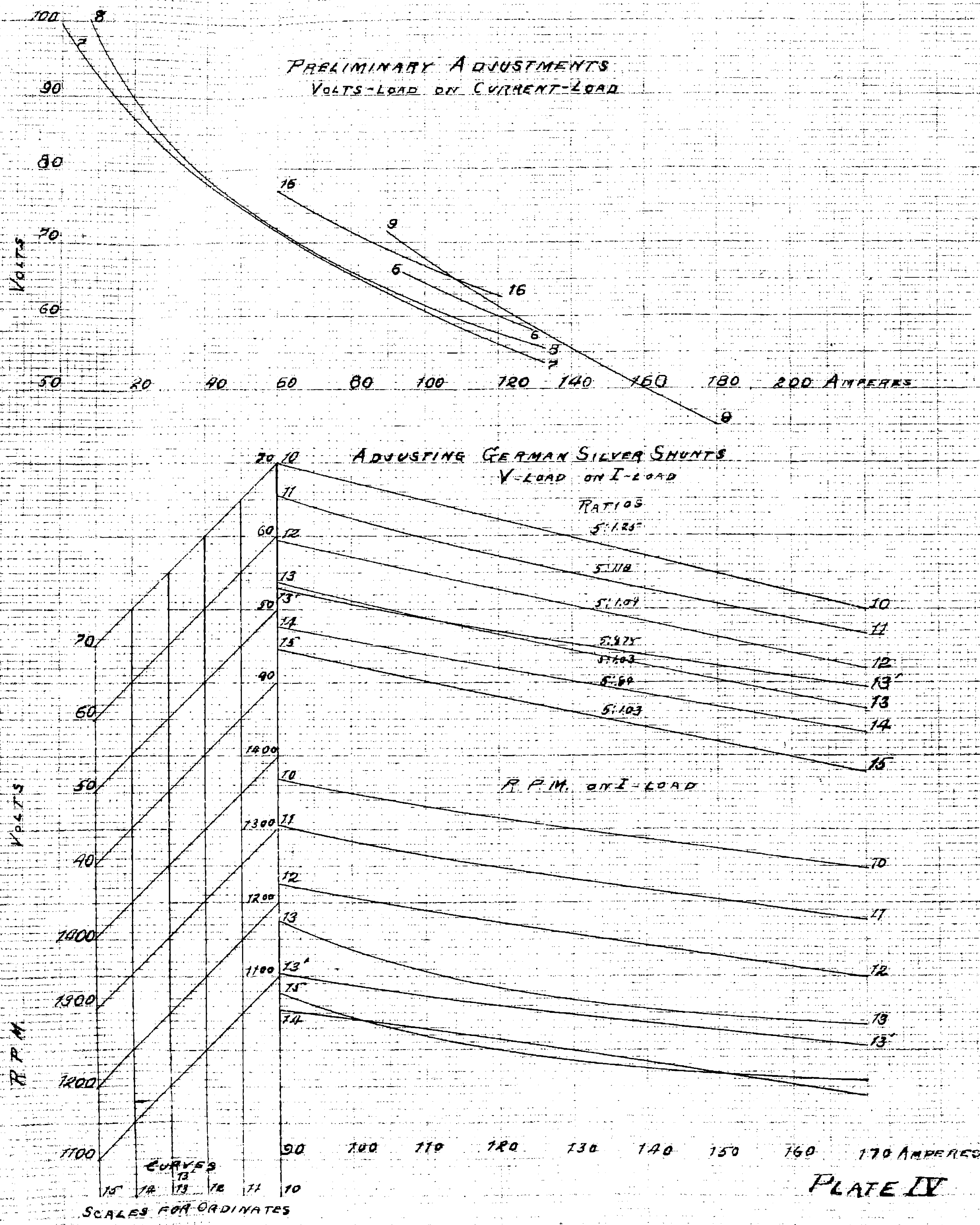


DIAGRAM SHOWING RELATION OF CIRCUITS

PLATE III



PRELIMINARY ADJUSTMENTS
VOLTS-LOAD ON CURRENT-LOAD
VOLTS
AMPERES
ADJUSTING GERMAN SILVER SHUNTS
V-LOAD ON I-LOAD
RATIOS
R.P.M. ON I-LOAD
VOLTS
R P M
170 AMPERES
CURVES
SCALES FOR ORDINATES

PLATE IV

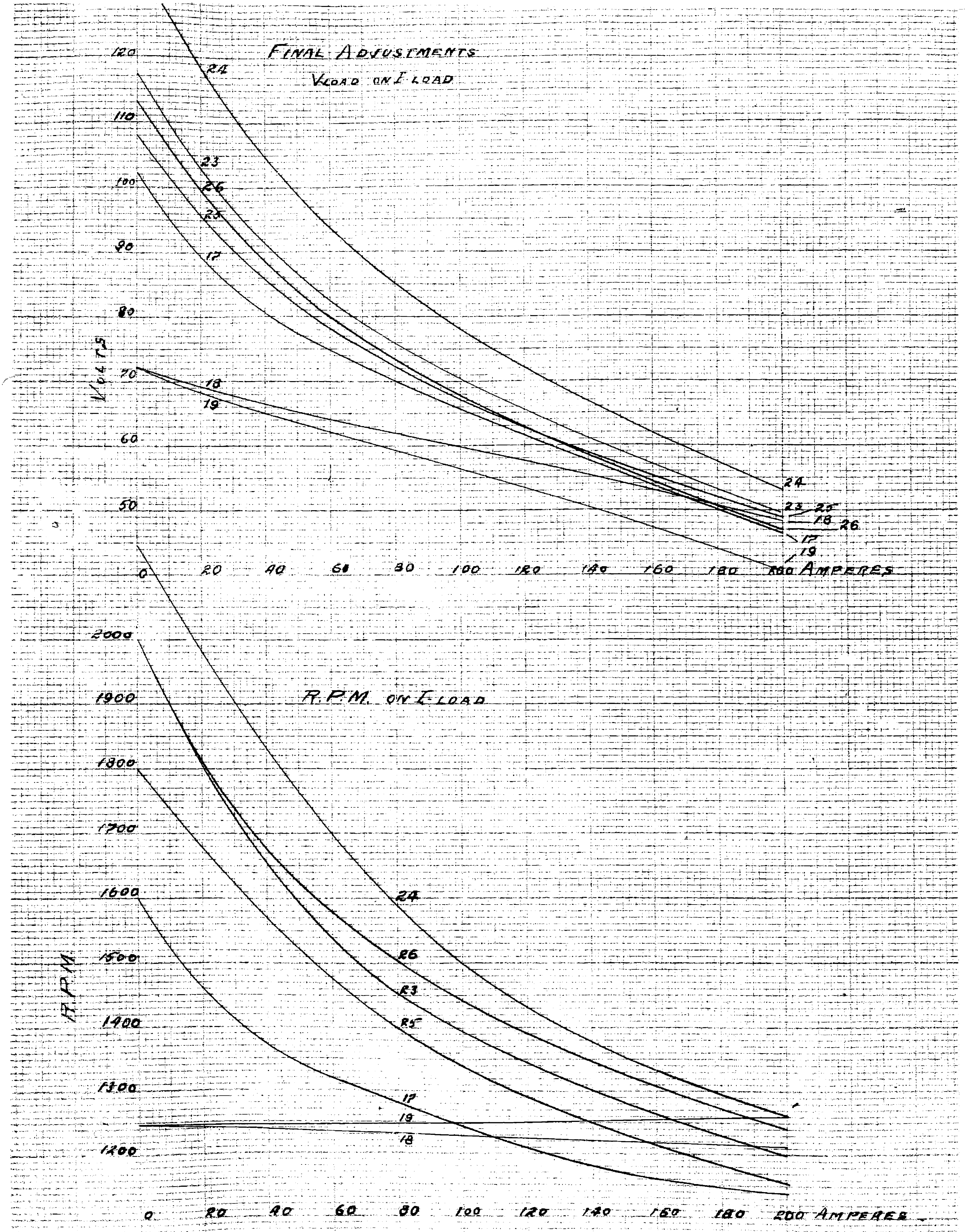
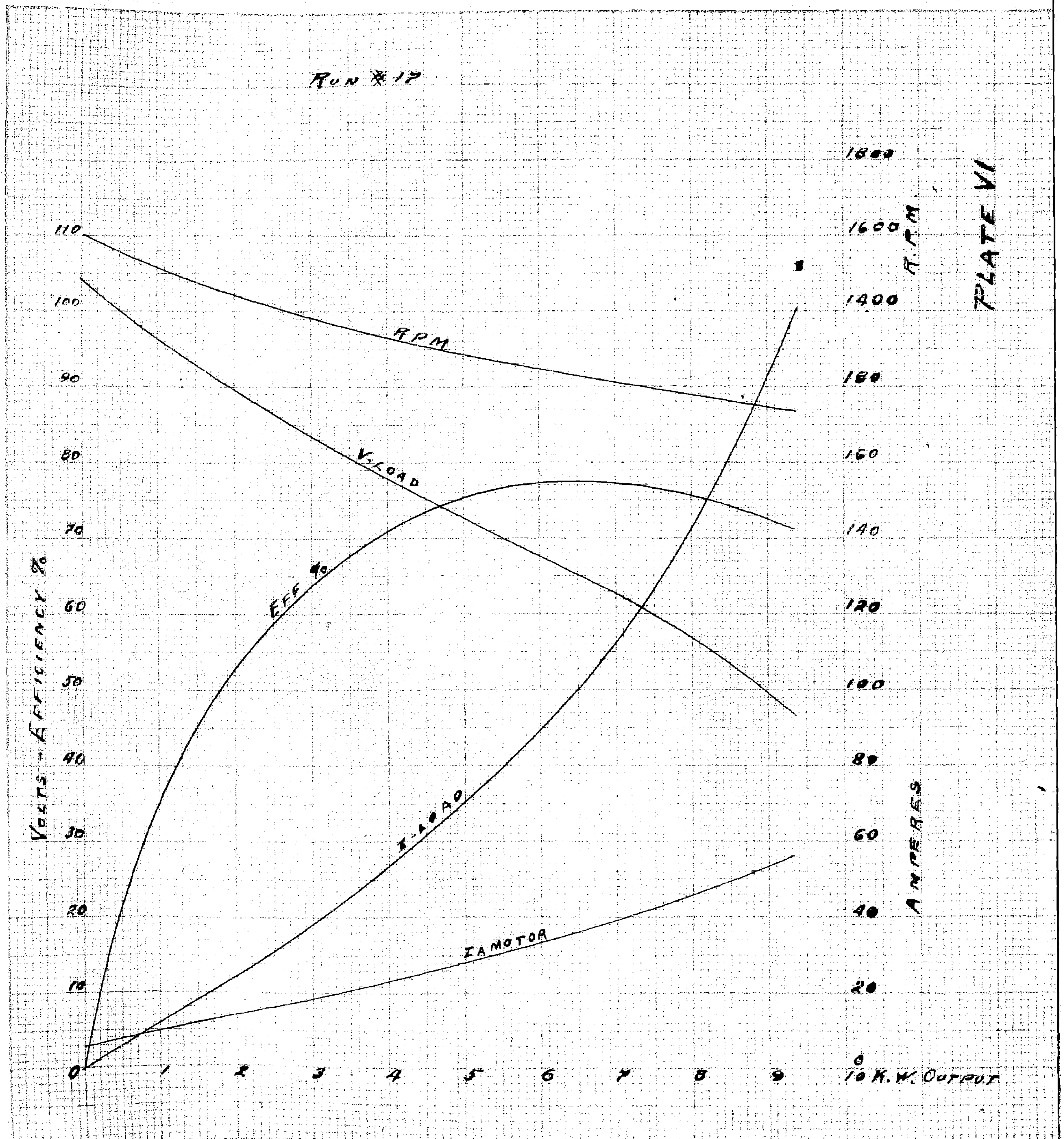
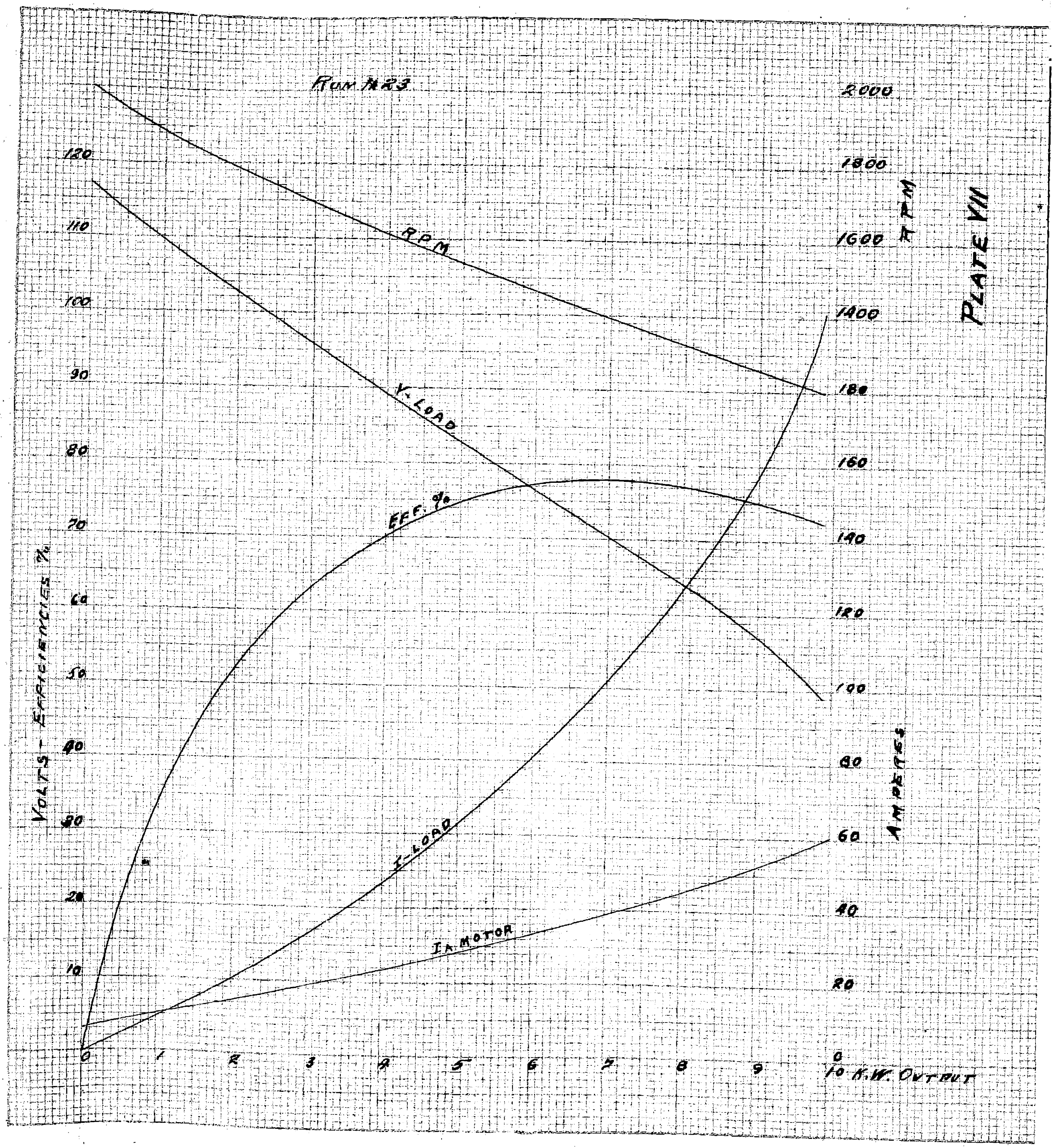
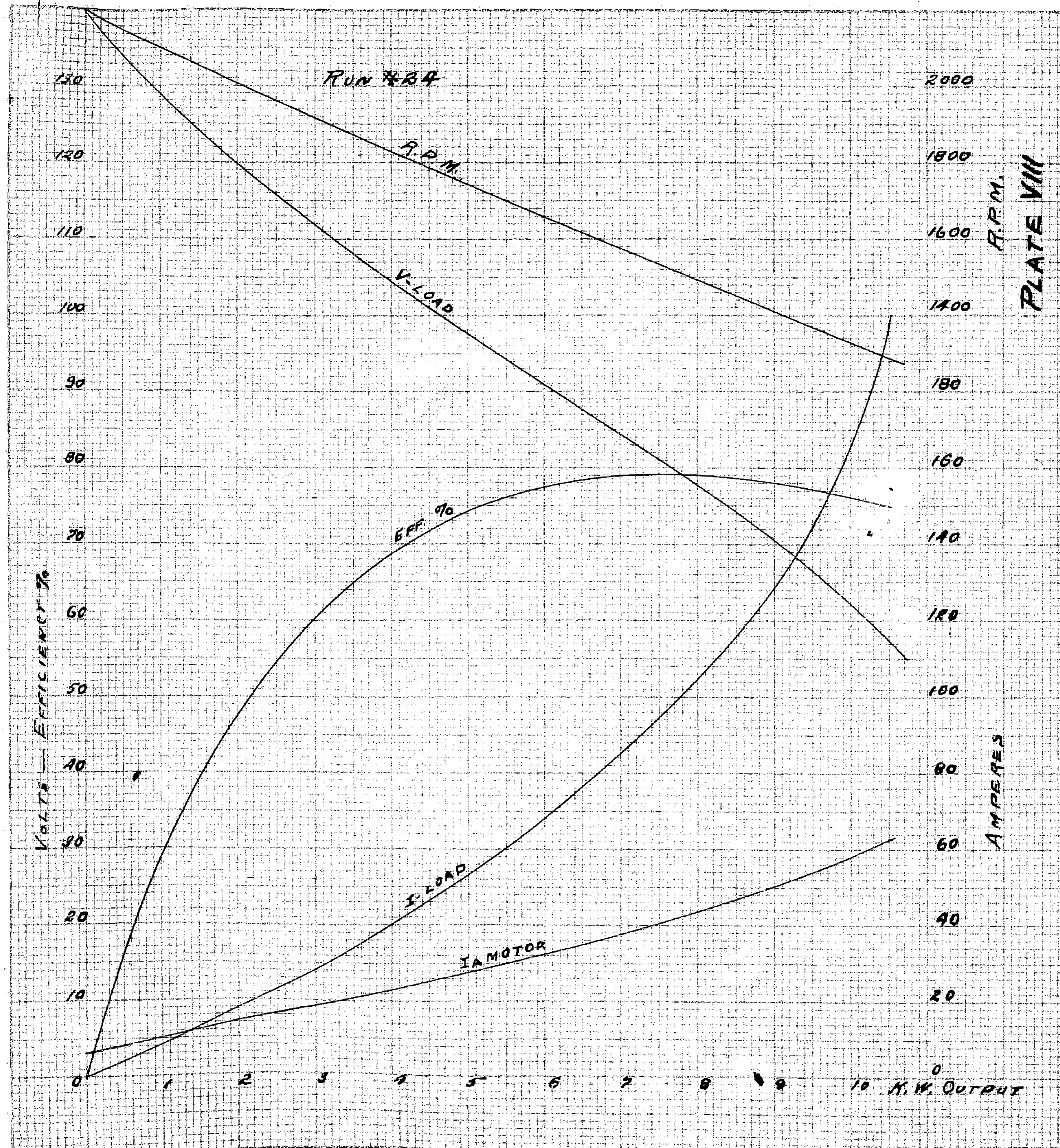

FINAL ADJUSTMENTS
V LOAD ON I LOAD
VOLTS
120
110
100
90
80
70
60
50
0
20
40
60
80
100
120
140
160
180
200 AMPERES
24
23
26
25
17
18
19
R.P.M. ON I LOAD
R.P.M.
2000
1900
1800
1700
1600
1500
1400
1300
1200
0
20
40
60
80
100
120
140
160
180
200 AMPERES
24
26
23
25
17
19
18

PLATE V

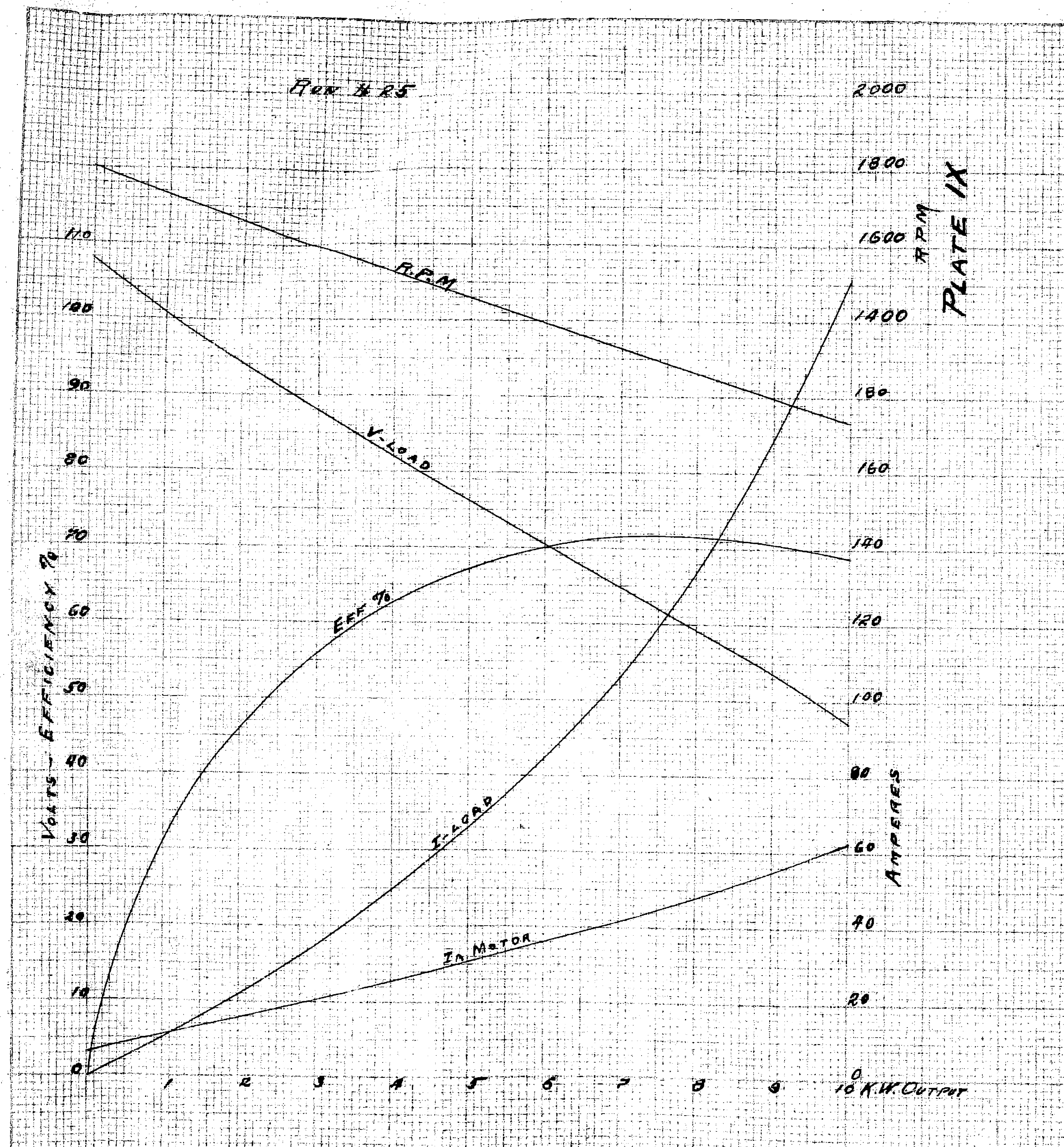

Run # 17
PLATE VI
R.P.M.
RPM
V LOAD
EFF %
I LOAD
I A MOTOR
VOLTS - EFFICIENCY %
AMPERES
K.W. OUTPUT



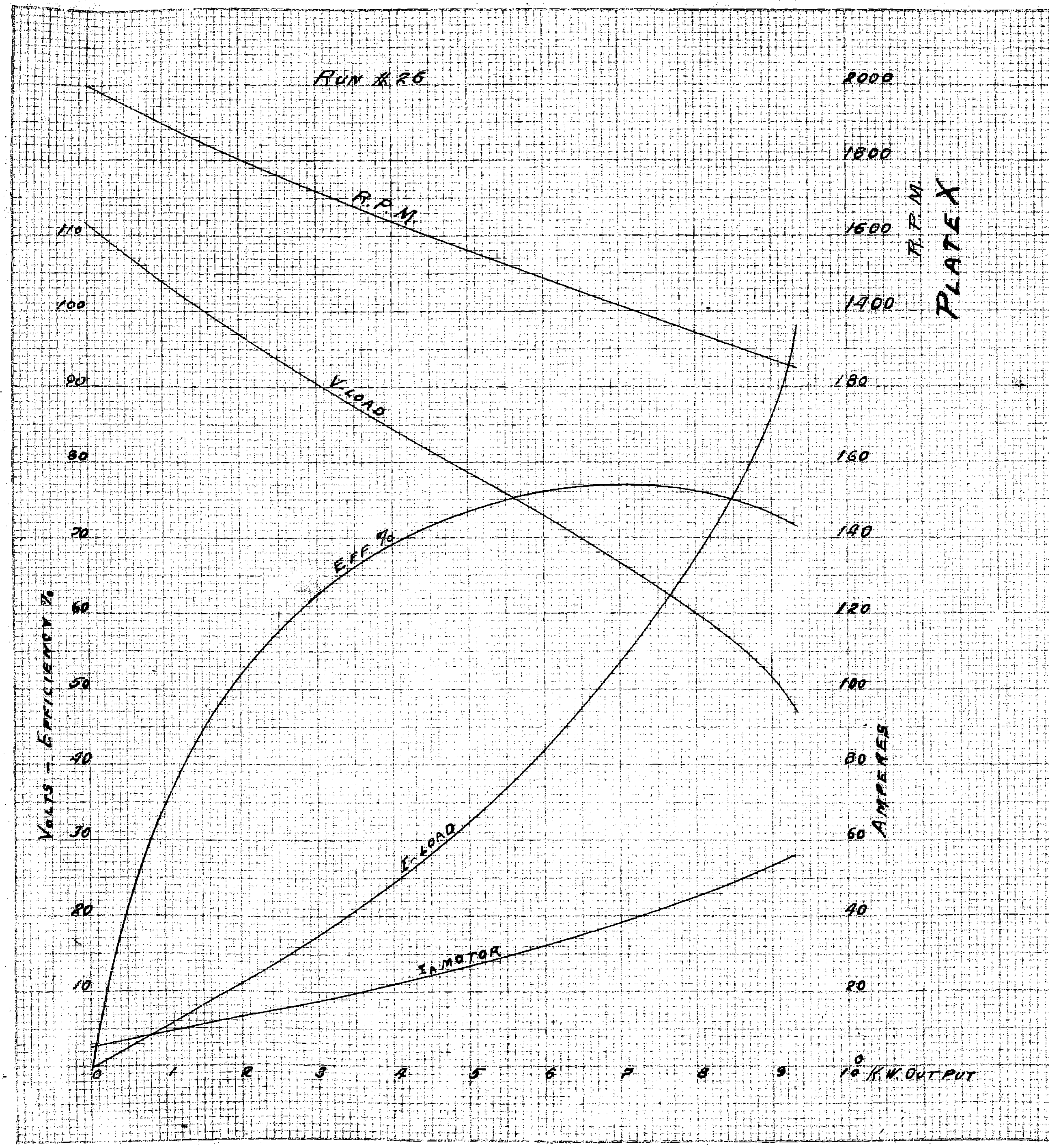
RUN #23
PLATE VII
R.P.M.
V. LOAD
EFF. %
I. LOAD
I A MOTOR
VOLTS - EFFICIENCIES %
AMPERES
R.P.M.
K.W. OUTPUT



RUN #24
PLATE VIII
R.P.M.
V-LOAD
EFF. %
I-LOAD
IA MOTOR
VOLTS — EFFICIENCY %
R.P.M.
AMPERES
K.W. OUTPUT
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2000
1800
1600
1400
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10



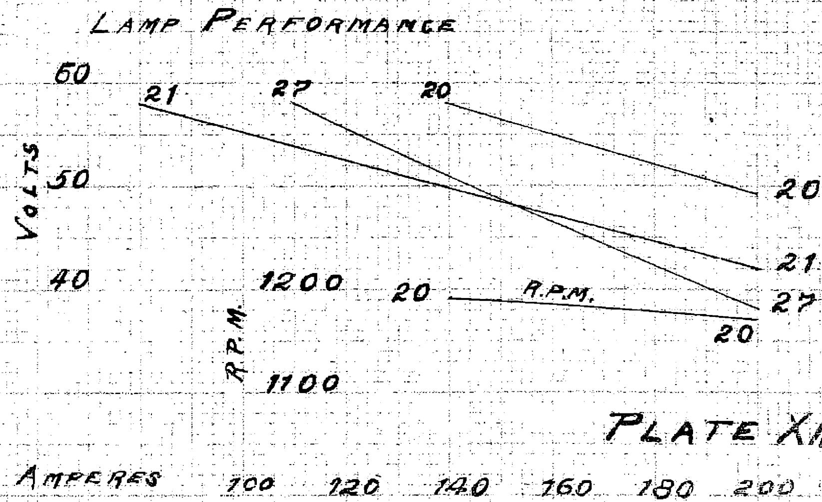
Run # 25
PLATE IX
R.P.M
V-LOAD
EFF %
I-LOAD
In MOTOR
VOLTS - EFFICIENCY %
AMPERES
RPM
K.W. OUTPUT



RUN # 26
R.P.M.
V. LOAD
EFF %
I. LOAD
I. MOTOR
VOLTS - EFFICIENCY %
AMPERES
R.P.M.
K.W. OUTPUT
2000
1800
1600
1400
110
100
90
80
70
60
50
40
30
20
10
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10

PLATE X

PLATE XI DOES NOT EXIST



LAMP PERFORMANCE
VOLTS
60
50
40
21
27
20
20
21
27
R.P.M.
1200
1100
20
R.P.M.
20
AMPERES
100
120
140
160
180
200

PLATE XII

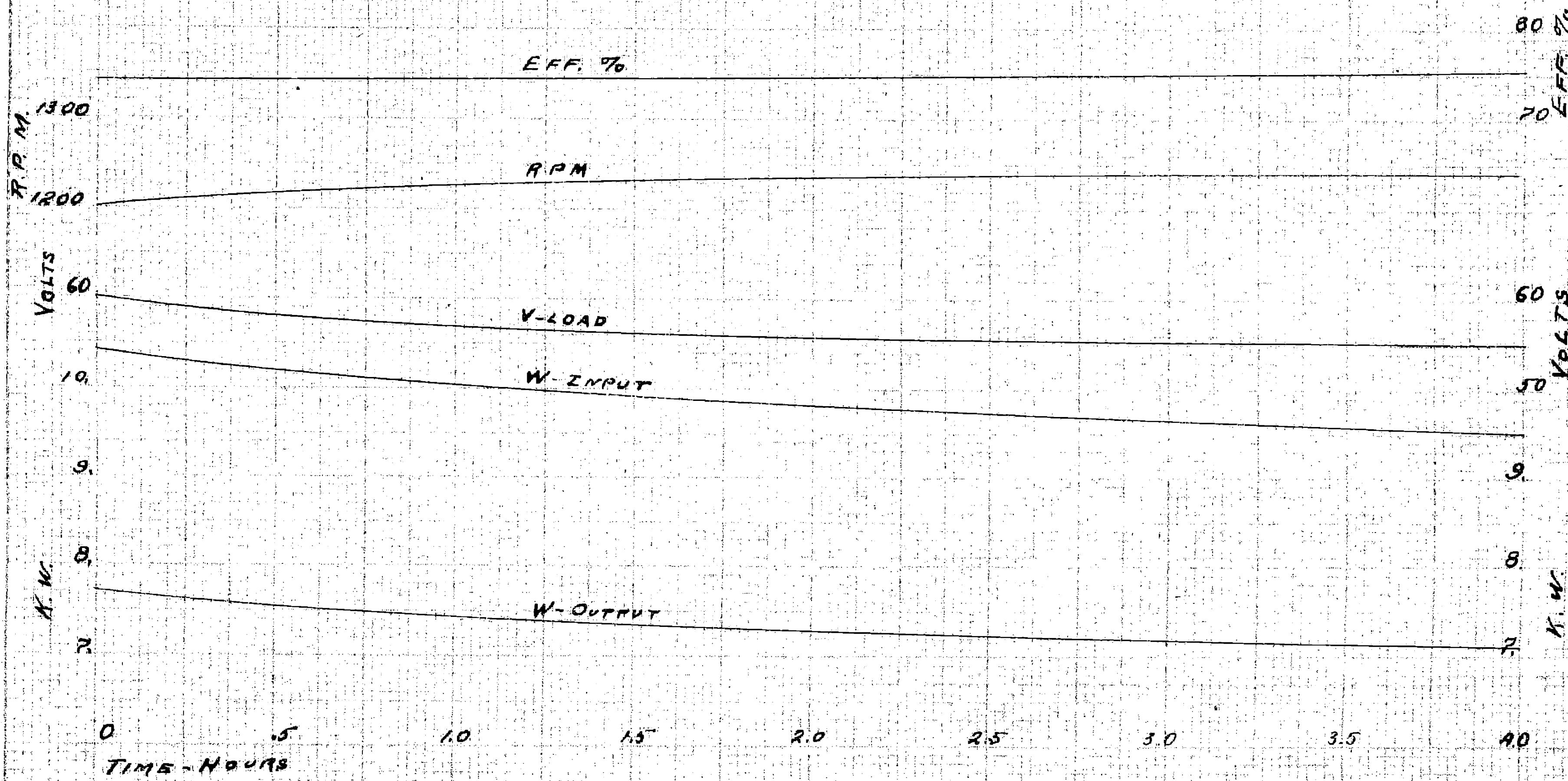
PLATE XIII

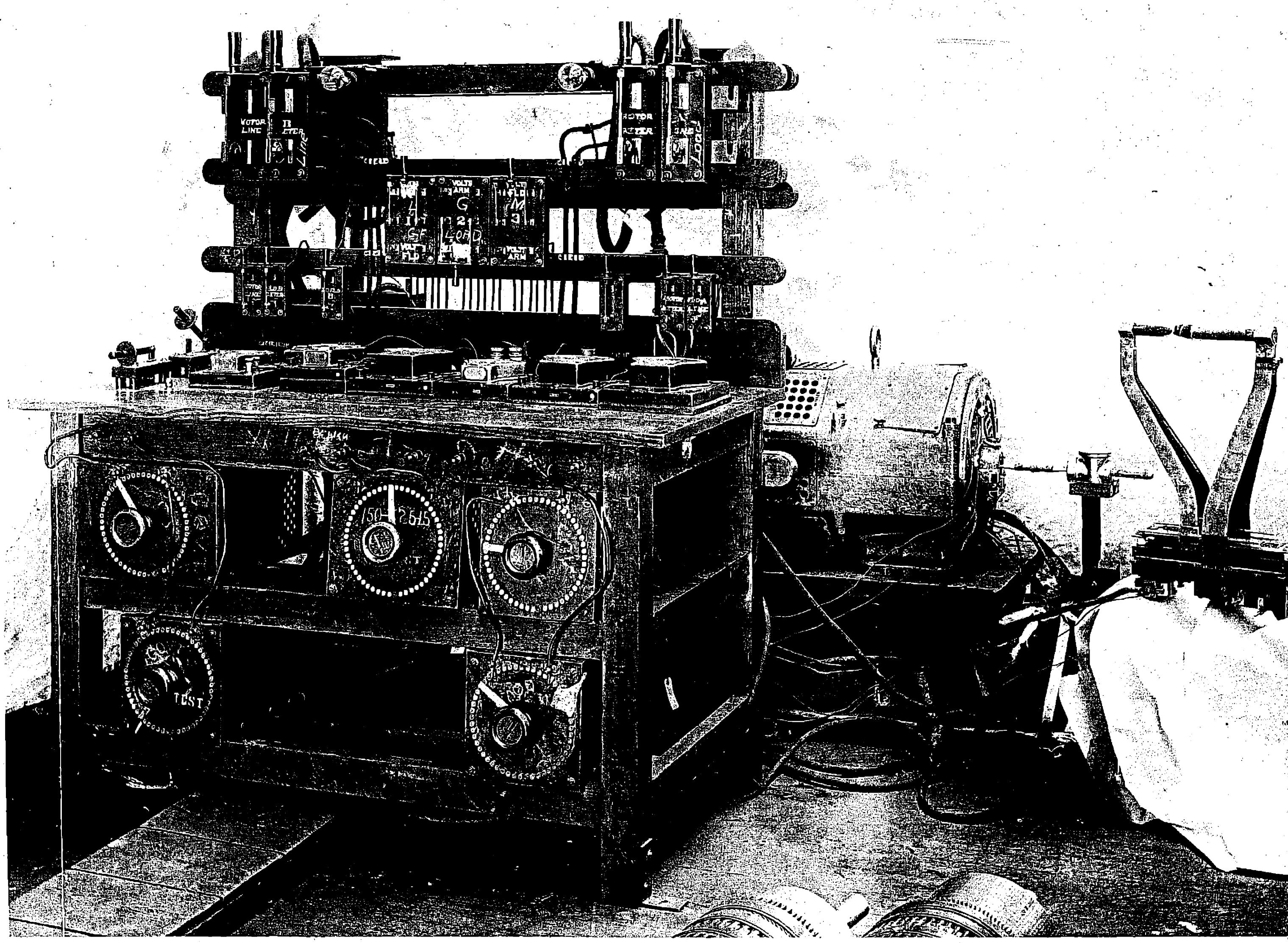
CURVES-OF-PERFORMANCE-ON-FOUR-HOUR-HEAT-RUN.

130-AMPERES-LOAD-THRUOUT

60-VOLTS-INITIAL

1200-RPM- "





101791 TEST ON BALANCER SET, FOR 36" PROJECTOR

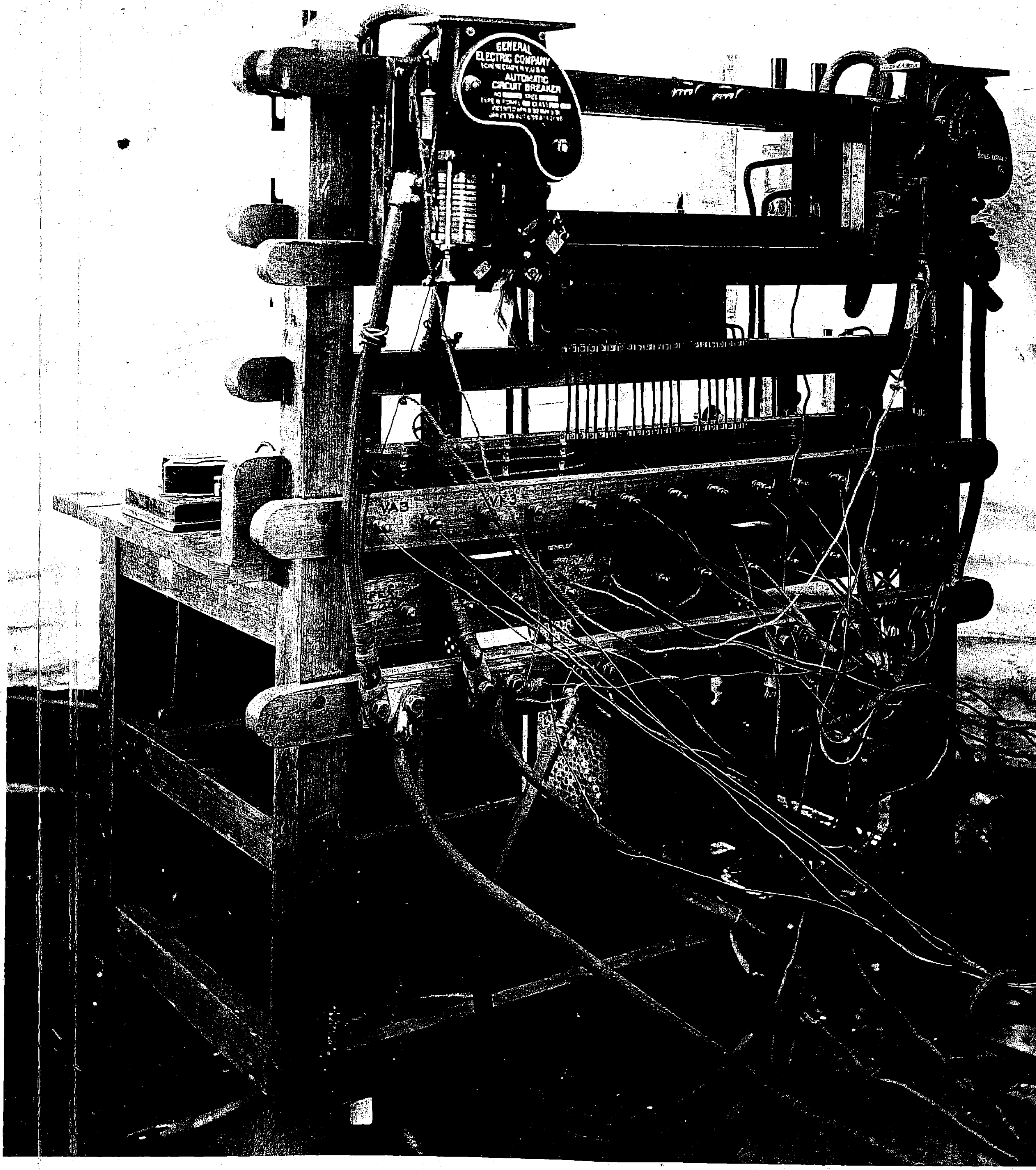
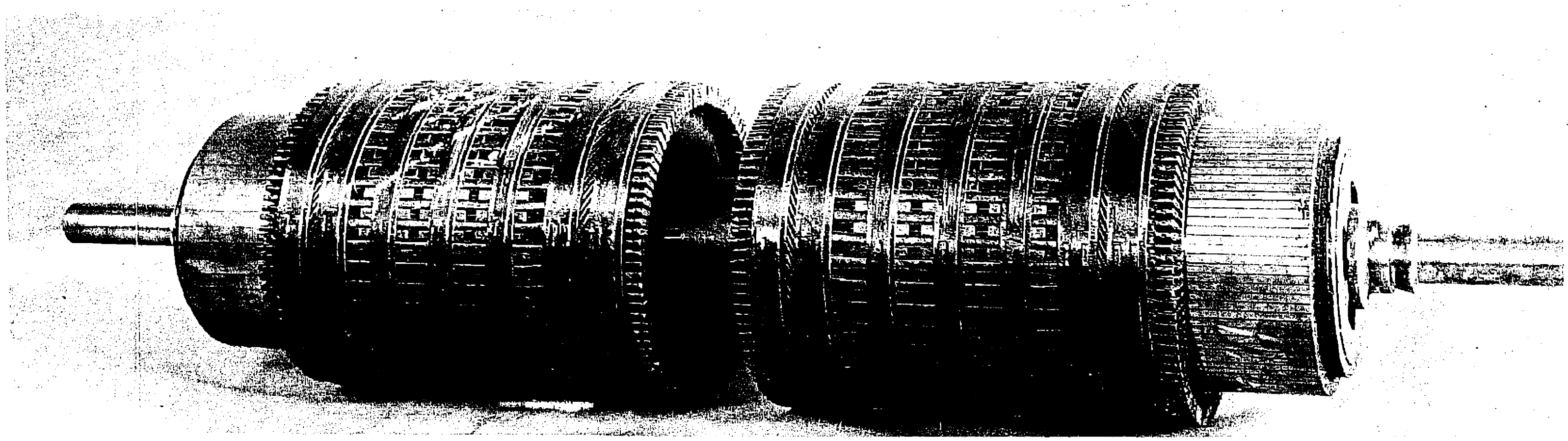


PLATE XV

101792 TEST ON BALANCER SET FOR 36" PROJECTOR, BACK OF TESTING BOARD.



101793 TEST ON BALANCER SET FOR 36" PROJECTOR, ARMATURE BALANCER.

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