(*Paper No. 3936.*)

"Alternating-Current Dynamo Tests."

By Horace Field Parshall, M. Inst. C.E.

The object of the following investigation was to measure the efficiency of a large alternating-current dynamo at different loads; to obtain definite quantitative results regarding armature reaction and its effect upon the field-magnets, and upon the form of the electromotive-force curve; to subdivide and locate the elements of the total losses in the machine; and to establish an economical, accurate and comprehensive method of testing. The efficiency of large machines has hitherto been only indirectly measured, by determining the efficiency of the engine or other prime mover, and comparing this with the combined efficiency of the prime mover and the dynamo. It is generally understood that the efficiency of an alternating-current dynamo under load cannot be predicted from no-load trials, as in the case of continuous-current machines; for, whereas in a continuous-current dynamo the reaction of the armature on the field-magnets may be expressed in the same terms as the effect of the field-magnets on the armature, as is shown by Drs. John and Edward Hopkinson,[1] in an alternating-current machine, when the current is in phase with the electromotive force induced by the magnetism of the field-magnets, there is no corresponding armature reaction, as in a continuous-current machine when the brushes are set symmetrically with respect to the polar projections. When, however, the current is displaced in phase from the electromotive force, it reacts on the field-magnets, and, in the case of lagging current, tends to diminish the magnetization of the field; or, in the case of a leading current, such as would occur in a dynamo acting on a system of sensible capacity, it tends to act with the field-magnets, such effect being proportional to the angular displacement of the current with respect to electromotive force. This, in a general way, corresponds to the angular lead of the collecting

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[1] Philosophical Transactions of the Royal Society, vol. clxxvii. p. 331.

brushes in a commutating dynamo. Owing, however, to the effect of alternating currents and self-induction of the armature coils, currents are set up in the mass of the field-magnets, of double the frequency of the generated current. These local currents tend to demagnetize an alternating-current dynamo in the case of lagging current, or to increase the magnetism in the case of a leading current. Further, owing to the mutual induction between the armature and magnet coils, and the self-induction of the armature, the current in the field-magnet coils is to some extent reduced. The nature and theory of these phenomena have been set forth by Dr. John Hopkinson and Mr. E. Wilson.[1]

The method of test followed was that devised by Dr. John Hopkinson.[2] Two similar machines were rigidly connected by a coupling which admitted of the angular position of one armature varied relatively to the other, the power for driving being supplied by shafting through a specially-designed dynamometer. When two alternating-current dynamos are connected in parallel, whether or not current passes between them, the work required to drive them from an independent source, depends simply on the frictional and other losses in each, the amount of current that passes between them, and, consequently, the load on each, depending on the angular displacement in phase of the one in respect to the other. The coupling was graduated in degrees, so that the phase difference between the machines was known. The amount of phase difference necessary for a given current, and, consequently, a given load, was first determined mathematically by coplanar vectors, which have been found generally useful and reliable in this work, and agree with the results obtained. When two machines are rigidly coupled together and are displaced one with respect to the other in phase, one acts as a motor and the other as a dynamo; and to maintain them at a given speed and load it is only necessary to supply from external sources the work lost between the two machines. This being done, the machines can be loaded to any desired amount, and there will be established the same phase relations, reactions, and losses that occur in machines driven under the same load conditions in practice with respect to capacity and inductance. The results of the tests show that when two similar machines are equally excited the phase of current and electromotive force obtaining in the circuit corresponds with close approximation to that of

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[1] Philosophical Transactions of the Royal Society, vol. clxxxvii.

[2] *Ibid*, vol. clxxvii. p. 347.

an alternating-current dynamo running on a non-inductive load. The range of the tests, however, is varied considerably, so that the efficiency of the machinery has been determined under conditions corresponding both to a highly inductive load and to a load having a very sensible capacity.

A diagram of the connections is shown in *Fig. 1.* In the main circuit there were two complete self-contained sets of apparatus for the test, one consisting of an ampere-balance, a watt-balance, and an electro-static voltmeter; and the other, which may be called the interrupted-contact set, consisting of a resistance in series with the main circuit and the shunt-resistance across it, an interrupted contact-disk on the end of the shaft, and a quadrant electrometer. The first is the more practical, economical, and direct method. The second method is, on the other hand, susceptible of great refinement and shows the nature of the curves of current and electromotive force and the effect of the reactions in the armature upon the shape of the curves. It, however, entails great labour in observation, plotting, integrating, obtaining constants and calculating tables, yet it is advisable that this method should be used for

Fig. 1.

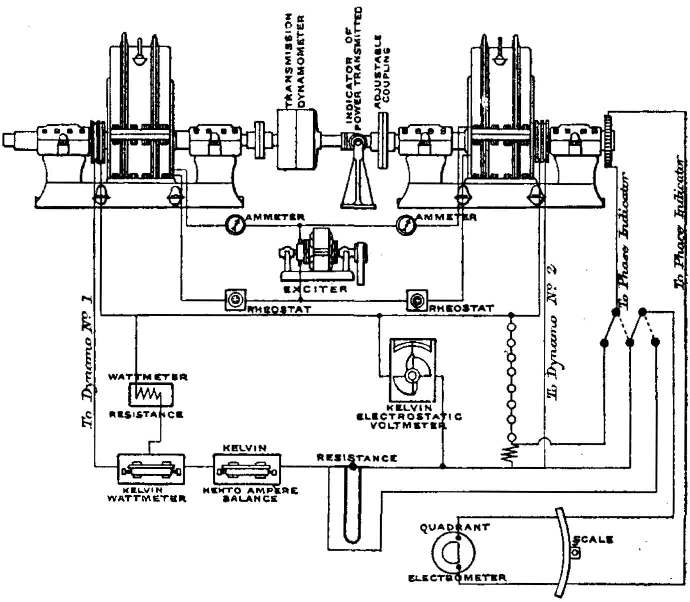
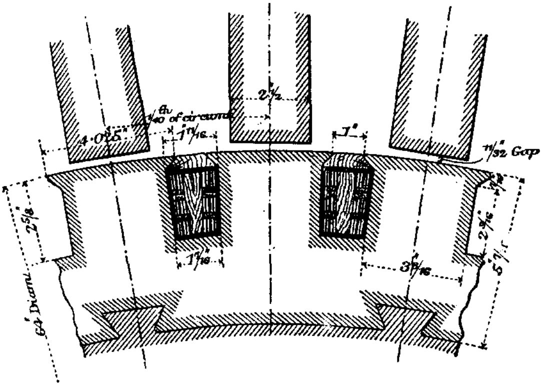


Diagram of the Connections for the Tests.

a new type of machine when the general characteristics, common to all, can be obtained, such as the form of the electromotive-force curve, the influence of the reactions upon the form of this curve, depending in fact upon the ratio of pole-arc to pitch, the number and shape of the tooth or teeth. After that the more direct method will tell all the properties peculiar to the particular machine under test. In this case both methods were used as a check one upon the other.

The two machines tested were constructed by the General Electric Company of the United States for the British Thomson-Houston Company, to be installed in the generating-station of the City of London Electric Lighting Company, Bankside. The output is 385 kilowatts, the speed 300 revolutions per minute, and the potential at full load 2,200 volts. The field-magnet system has forty poles, and consists of a cast-iron yoke holding magnet-cores of laminated sheet-iron, the yoke being cast with the magnet-cores in position. The ratio of the pole-arc to the pitch is 0·5. The coil consists of one hundred and thirty turns and is supported by a brass flange. The coils are arranged in two sets of twenty. The resistance of the two halves of the field in parallel is 1,378 ohms at 20° C. The armature consists of a laminated core of iron 0·014 inch thick fixed on a cast-iron spider. The armature has forty T-shaped projections, each carrying a coil of six turns. Its total resistance is 0·1105 ohm at 20° C. The general arrangement of the armature projections and the poles is shown in *Fig. 2*.

Fig. 2.

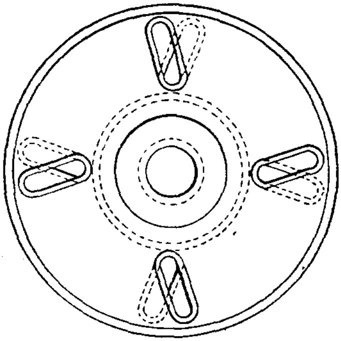


Scale, 2 inches = 1 foot.

CROSS-SECTION THROUGH THE ARMATURE-PROJECTIONS AND POLES.

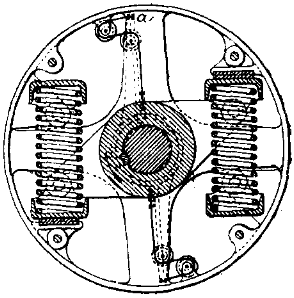
The two machines were carefully aligned upon a large surface-plate and connected by the adjustable coupling. That part of the coupling fixed to the one machine has four slots inclined at an angle to the radial direction, and that fixed to the other machine has corresponding slots inclined by the same amount in the opposite direction. The centre lines of the slots, *Fig. 3*, are tangents to a circle about 8 inches in diameter, having its centre in the axis of the shaft. By this arrangement one armature can be advanced relatively to the other by a distance of 5 inches measured on the periphery, which, as the pitch on the periphery of the armature measured 5 inches, corresponded to a phase variation of 180°, or one-half of a complete period. If, in addition, the field of one is reversed, a total phase relation of one complete period is obtained. The position of one armature relatively to the other was determined by means of scales glued on the peripheries of the armatures and fixed to corresponding points, with respect to the armature-coils, and readings taken with reference to corresponding marks on the field-magnet poles. The scales were long enough to cover five poles, so that a fair average was arrived at. As a check upon these readings and as a convenient reference in setting, parts of the peripheries of the two sections of the coupling were marked in degrees, starting from a common zero obtained by careful alignment of the two armatures, with respect to the field-magnets, and to each other.

Fig. 3.



The dynamometer, *Figs. 4* and *4a*, through which the power was transmitted to the shafting of the two machines coupled together, was designed by the Author in consultation with Dr. Hopkinson, and proved thoroughly reliable and very sensitive. It is a combination of a pulley or sheave, free to rotate on the shaft within the limits of compression of the springs. The power is transmitted from the belt to the shaft through these springs acting on an arm of 12 inches upon a lever fixed to the shaft. The amount of turning of the pulley, with respect to the shaft, is a measure of the compression of the springs, and therefore of the torque applied to the shaft. To indicate this angular position the shaft has fixed to it within the pulley an auxiliary double lever, to the ends of which are fixed the ends of the two steel wires. These first pass from the end of the lever round a small sheave fixed to the inner periphery of the pulley, and then to a sheave on the lever, which deflects the wire radially along this lever towards the shaft. It then passes round a sheave on the hub of the lever, which deflects the wire parallel to the shaft; then on to a collar which is free to travel lengthwise along the shaft, but not free to rotate relatively to the shaft. Upon this collar is mounted another, free to rotate, but not to move longitudinally, with respect to the first collar, and it is thereby constrained to travel backwards and forwards along the shaft with the first collar, according to the angular positions of the pulley and lever or according to the power transmitted. This linear motion along the shaft is converted to a circular motion by attaching wires to the second collar passing around small sheaves mounted on brackets, separate from the machine, the motion being multiplied by means of an index and read off on a degree scale. The scale was graduated by clamping a piece of canvas on the pulley, attaching weights to the free end and reading off the corresponding deflections on the degree scale referred to, which, when plotted to correspond with the weights, formed an equivalent to a stress-strain diagram. A power curve was thus deduced for a speed of 300 revolutions per minute. The two curves, *Fig. 5*, give the activity in horse-power and in kilowatts per degree on the dynamometer-dial for 300 revolutions per minute. During the test all readings were taken as nearly as possible at this speed, as the component losses, of which the dynamometer reading is the sum, are functions of different orders of the speed. It was, however, not found possible to adhere strictly to a uniform speed; still, as the more important loss varies with the speed, the error in correcting proportionally to the speed was not great, say, for a difference of 1 per cent. or 2 per cent. Greater weight was given to those readings which were obtained at a speed of 300 revolutions.

Fig. 4.



Cross section.

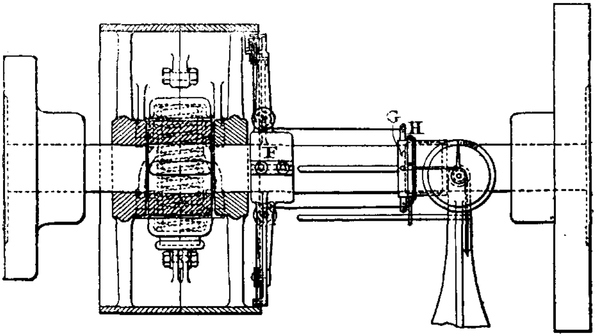
TRANSMISSION DYNAMOMETER.

The first quantity to be measured was the loss through friction of the bearings, and the air-resistance of the coupled machines. At a speed of 300 revolutions per minute, the dynamometer read

40°, which corresponds to a transmitted power of 3,000 watts. This requires care in observing, as the slightest change in speed means a positive or negative inertia factor.

The saturation curves, *Fig. 6*, were next determined for each machine separately, and the dynamometer readings taken at the same time from these observations give also the curves of armature losses with field current, *Fig. 7*, and the armature losses with potential-difference on open circuit, *Fig. 8*, for a speed of 300 revolutions per minute, corresponding to 100 periods per second. The last two sets include 1,500 watts for friction of the bearings and air-resistance, one-half the value obtained in the first observation. This quantity is assumed to be constant, but it is only known when the machine is not excited. The remaining losses consist of hysteresis, eddy current loss and losses incidental to the varying reluctance of the magnetic circuit.

Fig. 4a.

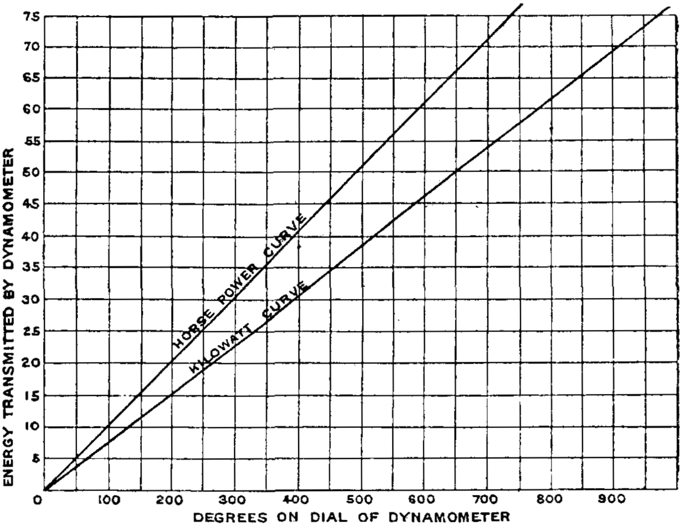


Sectional elevation.

TRANSMISSION DYNAMOMETER.

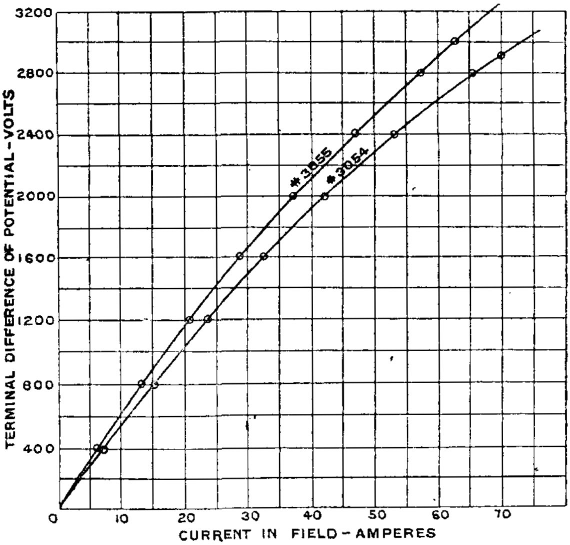
The machines were next coupled together electrically in four different relations corresponding to an exchange of power between the machines equal to full load, three-quarter load, half-load, and quarter-load of either machine; and three sets of observations were taken in each position, one with normal excitation on each machine, another with the excitation of generator above and motor below, and the third with the generator below and motor above, the normal excitation. Readings were taken on the watt-meter, ampere-balance, and voltmeter, and instantaneous values were taken of the current and potential difference on the terminals. In each case about twenty observations were made to construct the curves, Figs. 9–18, Plate 6. In one case only were the open-circuit

Fig. 5.



SCALE OF POWER TRANSMITTED BY THE DYNAMOMETER AT 300 REVOLUTIONS PER MINUTE.

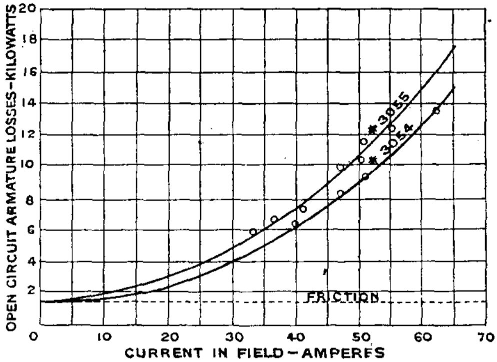
Fig. 6.



SATURATION CURVES AT 300 REVOLUTIONS PER MINUTE.

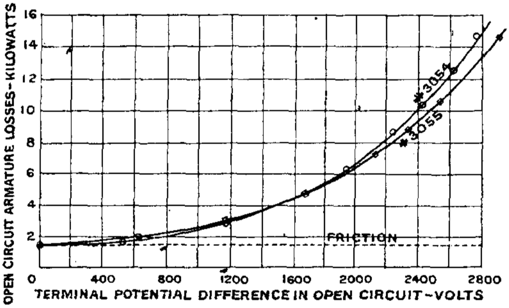
potential-differences taken directly throughout, this being sufficient to establish the form of the curve and to locate the two potential differences, and to compare their determined positions with the measurements on the coupling. How near this was made to accord can be seen by reference to Figs. 16–18, Plate 6, in which the curves E_g, E_m, representing the impressed and counter electromotive-forces of generator and motor, cross the zero line 71° or 72° apart. The angular positions of the armature differed by 2·01 inches on the scales laid on their periphery. The mean difference between the poles was 5·01 inches, corresponding as nearly as possible to 72° difference of phase. The terminal potential-difference curve of each machine on open circuit is plotted separately, *Fig. 19*, so that the characteristic of each may be observed.

Fig. 7.



Curves of Armature Losses with Field-Currents on Open Circuit at 300 Revolutions per Minute.

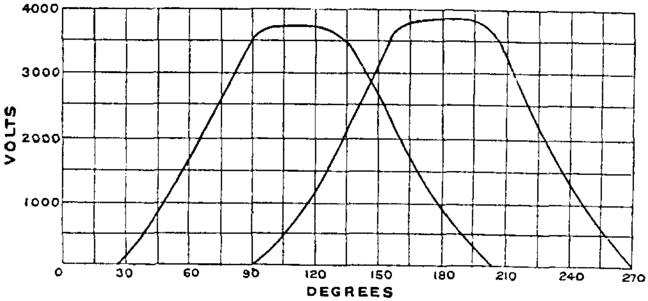
Fig. 8.



Curves of Armature Losses with Terminal Potential Differences at 300 Revolutions per Minute.

In the diagrams, Figs. 9–18, Plate 6, E_g represents the impressed electromotive-force of the generator; E_m the counter electromotive-force of the motor; and "e" represents the effective electromotive-force of both motor and generator. Actually "e" is the curve of instantaneous values of the terminal potential-difference on the generator, but the correction for the generator armature-resistance on the one hand, and for the motor armature-resistance plus the resistance of the connections on the other, are inappreciable, so that the same curve "e" stands for the effective electromotive-force of both machines. The curve marked $\int e\,d\,t$ is the integral curve of "e"; $\int E_g\,d\,t$ the integral curve of E_g; and $\int E_m\,d\,t$ the integral curve of E_m. As shown by Dr. Hopkinson in the Papers referred to, were it not for the effect of the current in the armature, the integral curves should cross at the instant that the current is zero, as implied in the equation for $x = 0$:—

Fig. 19.



Terminal Potential-Difference Curves on Open Circuit, Speed, 300 Revolutions per Minute.

$$\int E\,d\,t = \int R\,i\,d\,t + \int L\,\frac{d\,i}{d\,t}\,d\,t.$$

The difference therefore of the two integral curves at the instant when the current is zero, is a measure of that effect of the armature current upon the field which is not accompanied by a corresponding displacement of current relatively to the electromotive-force. The diagrams afford the means of measuring this effect in percentage of the total flux for various effective current values and various phase relations. They show the nature of the effect of the current in diminishing the effective ampere-turns on the field-magnets, and, to some extent the magnitude of the effect; for instance, in Fig. 16, E_1, the phase relations are nearest those of non-inductive load conditions, the difference between $\int E_g\,d\,t$ and $\int e\,d\,t$ is $0{\cdot}15 \times 10^6$, and the maximum flux is $2{\cdot}55 \times 10^6$. The percentage increase in the flux necessary to overcome the effect of the current of 177·8 amperes in the armature upon the total magnetizing force in the phase relation indicated is approximately 6 per cent. of the maximum value. The E_2 and E_3 curves, Figs. 17 and 18, however, seem to agree that this result is too low, and that the result is nearer 7 per cent., for, in these cases, the percentage is greater, and at the same time the current is more nearly in phase with the impressed electromotive-force. Comparing this group with another group C, say, where the currents in the armature are smaller, the difference is at once apparent. Comparing C, in which the phase relations approximately correspond with group E, it will be seen that the increase necessary in the flux is 3·2 per cent. For this purpose set A is ill-conditioned, as the errors incidental to the plotting are greater than the difference sought for.

The difference in the integral curves at the instant when the current is zero, together with the dynamometer readings, form the basis of the analysis of the reaction of the current, in so far as it affects the core losses in the armature and the field structure. The whole action of the current in the armature may be summarized as follows:—

1. Reaction in the electro-magnetic field accompanied by displacement, expressed by the equation, $E = R x + L \frac{d x}{d t}$.

2. Reaction of current on the field not accompanied by displacement of current, an effect represented by losses through induced current in the field-magnet winding, core and yoke.

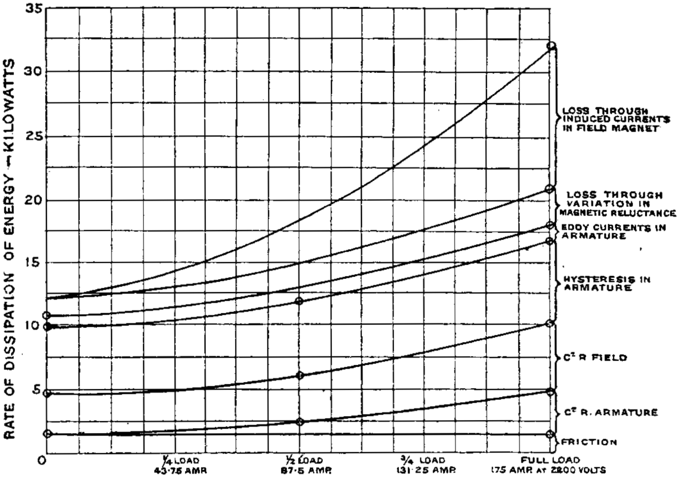
The following is the method of analyzing the second effect. It will be sufficient to refer to one set of curves only, thus, take Fig. 16, E_1, the total flux in the armature of the generator necessary to fulfil the conditions 1 and 2 over that necessary to fulfil the conditions in 1 is greater by 6 per cent.; the density is greater and therefore the increase in hysteresis loss and eddy currents may be calculated. Further, from these two values of the total flux is obtained two impressed electromotive-force values, one of which must fulfil condition 1 and can be verified by a polar diagram, and then by referring to *Fig. 8* the corresponding losses are obtained, and the difference gives the increased losses accompanying the increased flux-density. A further reference to the saturation curves and the corresponding field current, together with the resistance of the field-coils, gives the increased $C^2 R$ losses in the field winding. Next the power absorbed is compared with the open-circuit loss for the corresponding impressed electromotive-force of the generator, the difference giving the losses through induced current in the field-magnet structure, in this instance due to a current of 177·8 amperes in the armature with a phase difference of 28°. The loss from increased flux-density, hysteresis and eddy currents, is 11 kilowatts and the loss through induced currents is 10 kilowatts. The magnitude of this quantity is readily understood when it is borne in mind that a current of a certain periodicity in a revolving armature induces currents of twice that period in a stationary field; in fact, the whole effect of the current, as regards the field-magnet, may be regarded, for practical purposes, as that of a fixed vector, which when compounded with the field ampere-turns gives the effective ampere-turns and a vector of equal magnitude rotating at double periodic turns of the current. The amount of compounding in the first case depends upon the phase relation of current and electromotive-force; the effect of the phase relation upon the latter does not seem to be of so much importance.

The following Table gives the total loss by induced currents in the field-magnet, in the coupled generator and motor in different phase relations, and for different currents the result varying approximately as the square of the current. The results of the tests are shown in Table I of the Appendix, and give the losses at about quarter, half, three-quarters and full load under three conditions of phase relation of current and electromotive-force indicated by the relative values of the energy dissipated in the fields. Those values which correspond to the higher power factor in the Table, or to coincidence of current and electromotive force in the Figs., may be taken as corresponding to a non-inductive load. It will be seen that the phase relation of armatures, and consequently impressed and counter electromotive-force, remains unaltered under any one letter, such as A, B, &c. The phase relation of the potential-difference terminal D P and current is altered by varying the field-current to an extent indicated by item (*b*). The three conditions are placed under headings such as A_1, A_2 and A_3 for Table I. In item 10, an average value is obtained for both generator and motor by the method of taking half the total number of watts absorbed by the system, less half the known number of watts. This is obviously not always the case, as the impressed electromotive-force of the generator need not be equal to the counter electromotive-force of the motor, neither are they equal in any of these tests.

Curves.	Current in System.	Loss by Induced Currents in Generator and Motor.
	Amperes.	Kilowatts.
E_1	177·8	21
C_1	126·4	10·56
B_1	84·2	5·82

The result of halving the total losses, other than the armature-winding and field-winding losses, affects the efficiencies of the generator and motor, making the motor efficiency less than the generator efficiency, in spite of the fact that the effect of the current in the field, in these cases, is such as to diminish the $C^2 R$ losses in the field for the same counter electromotive-force. In Table II, which is a summary of this analysis, and also in the curves, *Fig. 20,* this has been done by halving that part of the total loss which is approximately the same for two equal machines, and apportioning the rest in proportion of the impressed and counter electromotive-force. Bearing and wind friction is in this case assumed constant for all loads. Table II gives the allocation of the losses in alternator No. 3,054 in percentage for full non-inductive load, three-quarter load, half load and quarter load, and one-tenth load. These have been deduced not only from the coupled tests but in part from direct observation of instantaneous values of current and potential difference on a water rheostat. By means of this Table the curves of efficiency can be predicted with fair accuracy for this type of dynamo. The definition of type must cover the shape and number of armature projections, the ratio of the pole arc to the pitch, and the maximum armature reaction, upon which the items 8 and 10 principally depend.

Fig. 20.



Potential-difference, 2,200 volts; speed, 300 revolutions per minute.

ALLOCATION OF LOSSES IN MACHINE No. 3054, ON NON-INDUCTIVE LOAD.

The Paper is accompanied by twenty-one drawings, from which Plate 6 and the *Figs.* in the text have been prepared.

APPEN

TABLE I.—GENERATOR AND MOTOR COMBINATION TEST, SHOWING ALLOCATION OF

——	A_1	A_2	A_3
a. Phase-difference between armatures . degrees	17·7	17·7	17·7
b. Power-factor	0·9723	0·6691	0·8910
1. Power given out by generator in kilowatts (by watt-meter)	93·73	89·22	93·03
2. Power given to motor . . . . . . kilowatts	93·5	89·00	92·8
3. ,, dissipated in generator-armature ,,	0·21	0·298	0·37
4. ,, ,, ,, motor-armature . . ,,	0·21	0·298	0·37
5. ,, ,, ,, generator magnet-winding ,,	2·93	2·35	3·9
6. ,, ,, ,, motor ,, ,, ,,	2·58	3·19	1·81
7. ,, ,, ,, connections . . . ,,	0·23	0·22	0·23
8. ,, absorbed by combination through belt ,,	22·7	21·9	22·6
9. Total electrical power developed in generator = Nos. 1 + 3	93·94	99·52	93·4
10. Half power absorbed by system, less half known power = $\frac{1}{2}$ {No. 8 − (Nos. 3 + 4 + 7)} . . .	10·90	10·49	10·81
11. Total power given to generator = Nos. 5 + 9 + 10	107·85	102·36	108·12
12. Percentage efficiency of generator = $\frac{\text{No. 1}}{\text{No. 11}}$ . .	87·04	87·25	86·11
13. ,, loss in generator-armature	0·194	0·291	0·340
14. ,, ,, generator magnet-winding . .	2·72	2·29	3·61
15. ,, sum of all other losses in generator .	10·05	10·17	9·94
16. ,, efficiency of generator-armature = $\frac{\text{No. 1}}{\text{Nos. 9} + 10}$	89·52	89·21	89·20
17. ,, ,, motor = $\frac{\text{Nos. 9} + 10 - 8}{\text{Nos. 2} + 6}$ . .	85·6	84·83	86·27
18. ,, loss in motor-armature	0·22	0·323	0·39
19. ,, ,, motor magnet-winding . . .	2·68	3·46	1·93
20. ,, sum of all other losses in motor . .	11·68	11·39	11·43
21. ,, efficiency of motor-armature = $\frac{\text{Nos. 9} + 10 - 8}{\text{No. 2}}$	88·0	87·83	87·95

DIX.

Losses in the Two Machines (No. 3,054 as Generator and No. 3,055 as Motor).

B_1	B_2	B_3	C_1	C_2	C_3	E_1	E_2	E_3
36·2	36·2	36·2	51·9	51·9	51·9	71·6	71·6	71·6
0·9890	0·8090	0·9659	0·9877	0·8481	0·9877	0·9903	0·9336	0·9613
171·13	159·3	175·82	266·1	258·24	266·97	382·0	376·0	372·0
170·7	158·9	175·4	265·5	257·6	266·3	381·0	375·0	371·0
0·78	0·89	0·93	1·77	1·91	1·92	3·5	3·52	3·36
0·78	0·89	0·93	1·77	1·91	1·92	3·5	3·52	3·36
3·2	2·25	4·52	3·98	2·8	5·57	5·25	4·175	4·37
2·58	3·6	2·11	3·14	4·55	2·44	3·66	5·13	4·3
0·43	0·40	0·42	1·00	0·64	0·67	1·00	1·00	1·00
25·9	26·2	26·35	36·4	37·1	37·25	54·6	54·25	50·75
171·91	160·19	176·75	267·87	260·15	268·89	385·5	379·52	375·36
11·96	12·01	12·04	16·13	16·32	16·37	23·3	23·11	21·52
187·07	174·45	193·31	287·98	279·27	290·83	414·05	406·81	401·25
91·48	91·32	90·95	92·5	92·5	91·75	92·2	92·4	92·75
0·42	0·51	0·48	0·62	0·68	0·66	0·845	0·866	0·837
1·71	1·29	2·34	1·38	1·00	1·99	1·27	1·028	1·09
6·39	6·88	6·23	5·5	5·82	5·60	5·685	5·706	5·32
93·07	92·51	93·13	93·7	93·4	93·68	93·4	93·4	93·7
91·16	90·00	91·51	92·1	91·31	92·2	92·00	91·4	92·3
0·45	0·55	0·52	0·659	0·771	0·714	0·91	0·922	0·896
1·49	2·22	1·19	1·176	1·73	0·908	0·952	1·342	1·145
6·90	7·23	6·78	6·065	6·19	6·18	6·14	6·34	5·66
92·54	91·89	92·61	93·2	92·9	93·23	93·00	93·00	93·3

TABLE II.—LOSSES IN ALTERNATOR NO. 3,054, WORKING ON A NON-INDUCTIVE LOAD.—PERCENTAGES OF TOTAL POWER.

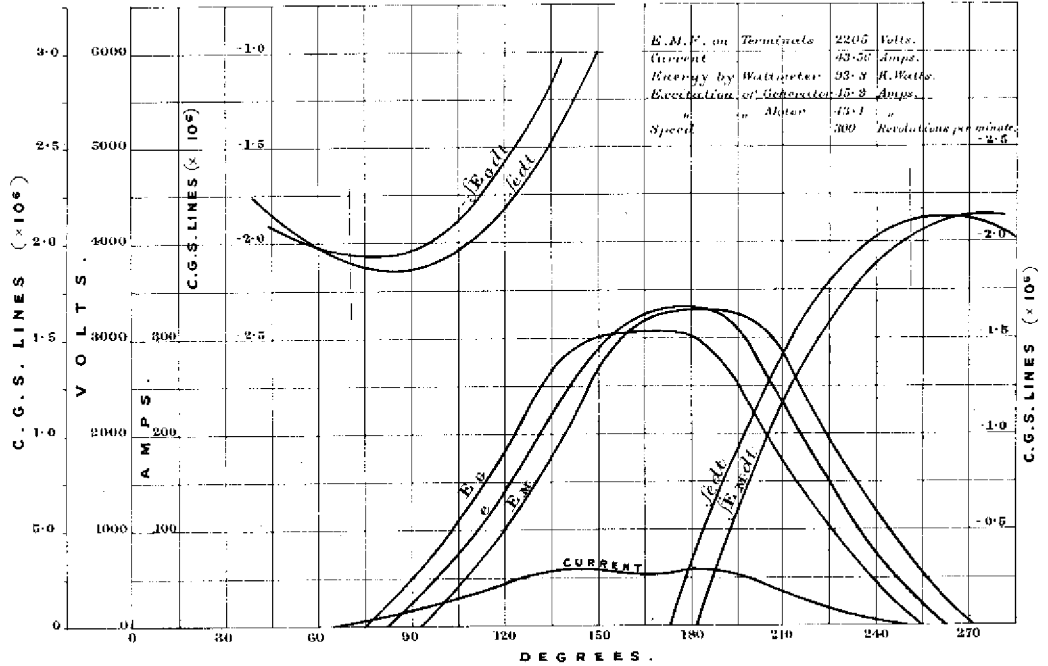
——	Full Load.	Three-quarter Load.	Half Load.	Quarter Load.	One-tenth Load.	No Load.
Total power delivered at terminals . . kilo-watts	385·0	288·75	192·5	96·25	38·5	0
Current . . . amperes	175·0	131·25	87·5	43·75	17·5	0
Potential difference on terminals . . volts	2,200	2,200	2,200	2,200	2,200	2,200
Friction (all sources) per cent.	0·36	0·48	0·71	1·36	2·94	12·5
Field winding . . „	1·272	1·375	1·66	2·98	6·26	25·9
Hysteresis in armature . . . . „	1·62	2·015	2·8	4·98	10·37	44·0
Eddy in armature . „	0·288	0·415	0·544	0·905	1·75	5·85
Variation of magnetic reluctance . . . „	0·696	0·767	0·946	1·45	2·64	11·75
Armature winding . „	0·816	0·608	0·426	0·226	0·196	0
Reaction of current in armature on magnet frame . . „	2·645	2·11	1·66	1·175	0·88	0
	7·697	7·71	8·746	13·076	25·026	100·0
Efficiency of generator . . . . „	92·31	92·29	91·25	86·93	74·97	0
Total power given to generator . . . kilo-watts	417·0	313·0	211·0	110·5	51·1	12·0

ALTERNATING-CURRENT DYNAMO TESTS.

PLATE 6.

Fig: 9.

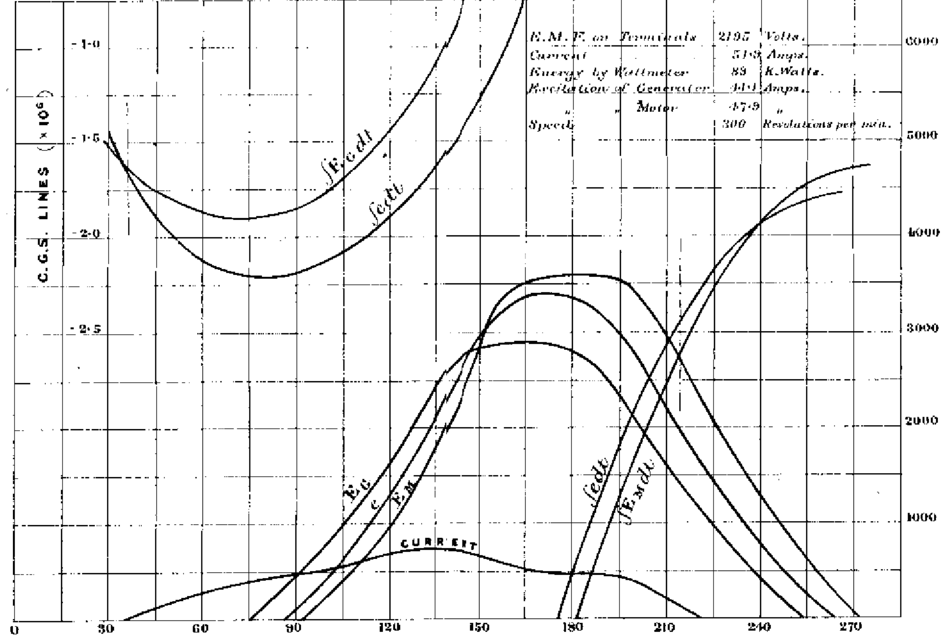
A₁ Curves.



E.M.F. on Terminals	2205	Volts.
Current	43·56	Amps.
Energy by Wattmeter	93·8	K.Watts.
Excitation of Generator	15·9	Amps.
" " Motor	43·1	"
Speed	300	Revolutions per minute.

Fig: 10.

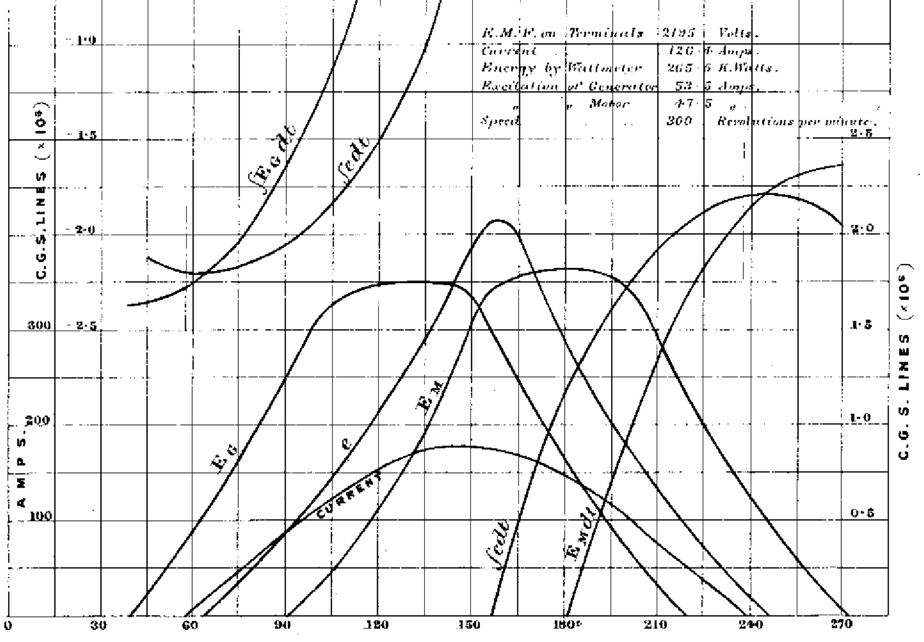
A₂ Curves.



E.M.F. on Terminals	2195	Volts.
Current	51·3	Amps.
Energy by Wattmeter	89	K.Watts.
Excitation of Generator	44·1	Amps.
" " Motor	47·9	"
Speed	300	Revolutions per min.

Fig: 13.

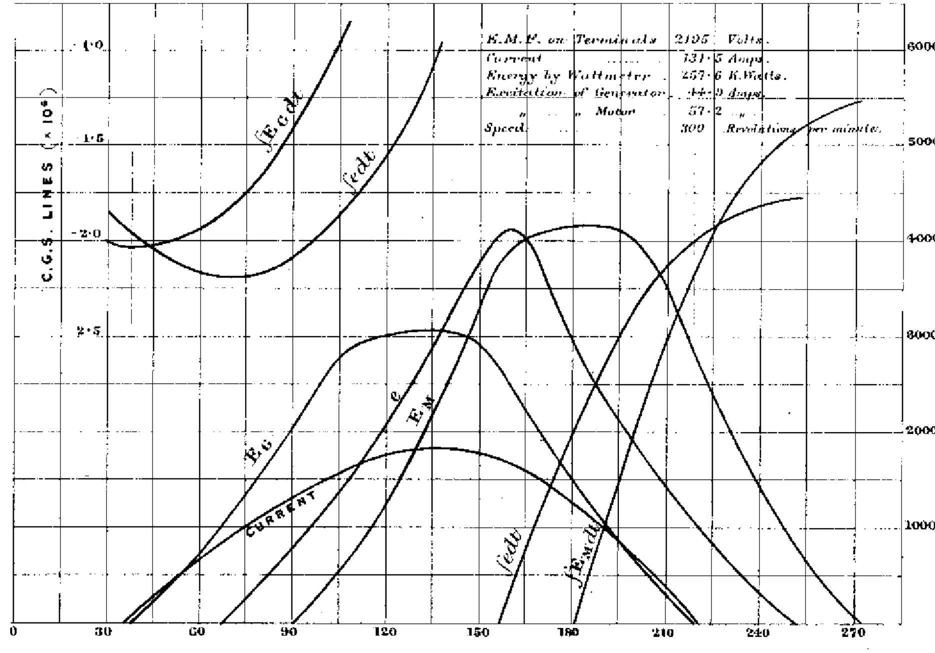
C₁ Curves.



E.M.F. on Terminals	2195	Volts.
Current	126·4	Amps.
Energy by Wattmeter	265·5	K.Watts.
Excitation of Generator	53·5	Amps.
" " Motor	47·5	"
Speed	300	Revolutions per minute.

Fig: 14.

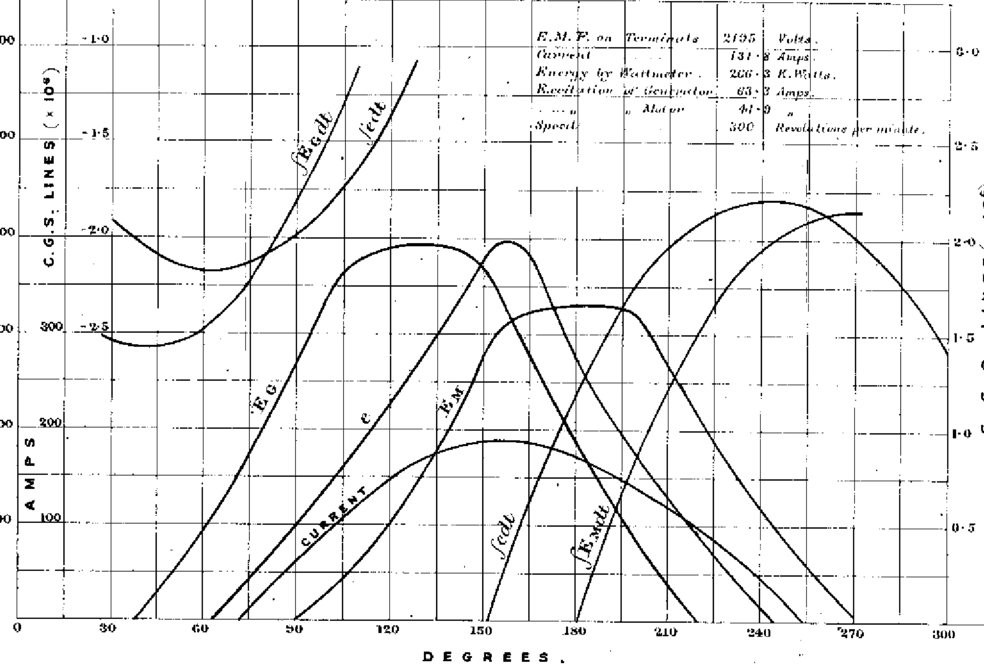
C₂ Curves.



E.M.F. on Terminals	2195	Volts.
Current	131·5	Amps.
Energy by Wattmeter	257·6	K.Watts.
Excitation of Generator	44·9	Amps.
" " Motor	57·2	"
Speed	300	Revolutions per minute.

Fig: 15.

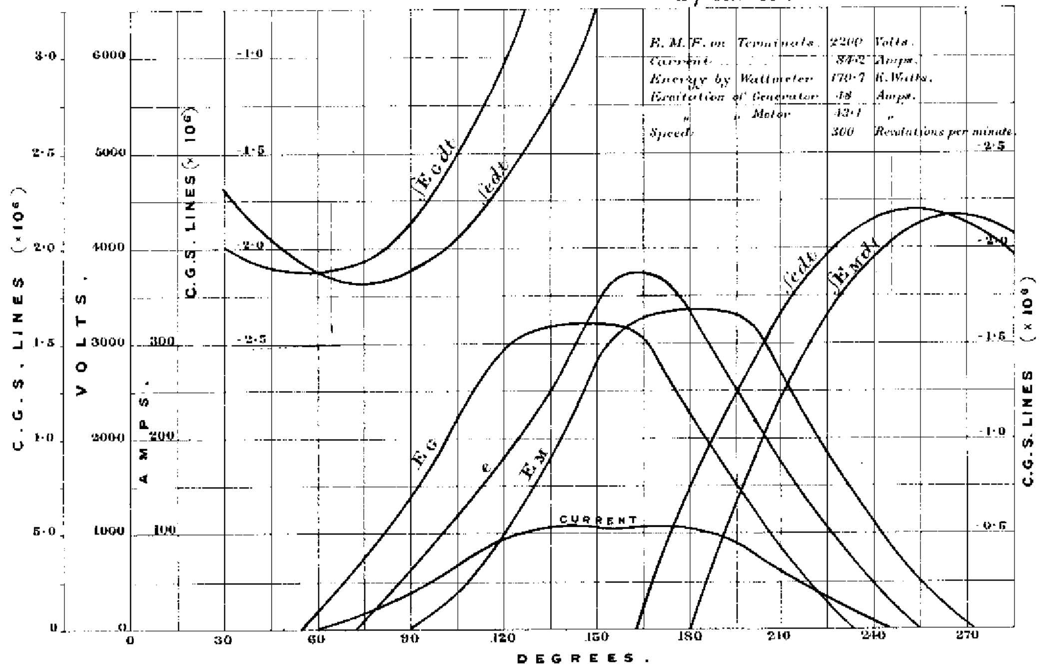
C₃ Curves.



E.M.F. on Terminals	2195	Volts.
Current	131·8	Amps.
Energy by Wattmeter	266·3	K.Watts.
Excitation of Generator	63·3	Amps.
" " Motor	41·9	"
Speed	300	Revolutions per minute.

Fig: 11.

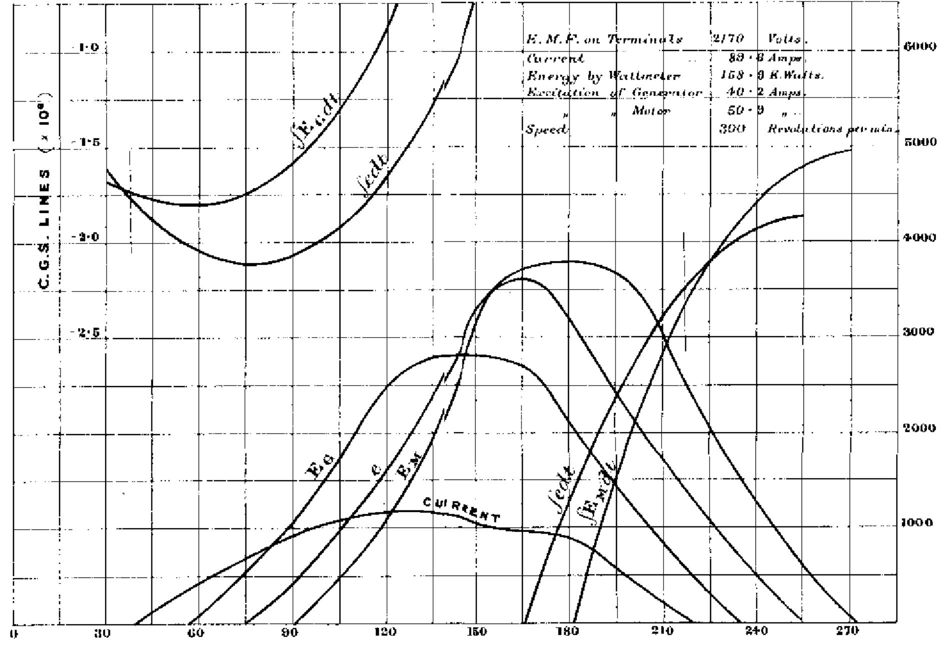
B₁ Curves.



E.M.F. on Terminals	2200	Volts.
Current	84·2	Amps.
Energy by Wattmeter	170·7	K.Watts.
Excitation of Generator	48	Amps.
" " Motor	43·1	"
Speed	300	Revolutions per minute.

Fig 12.

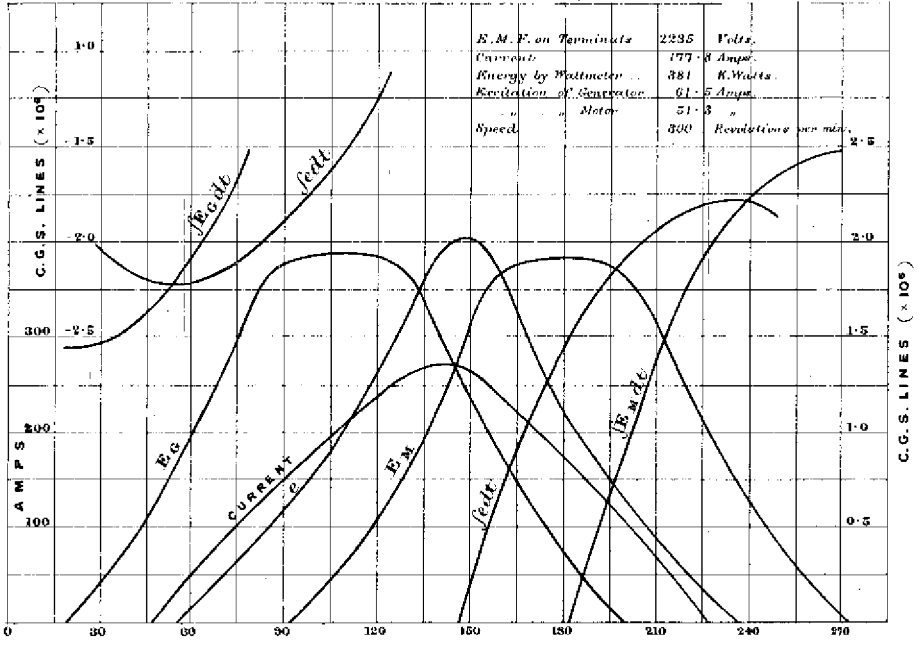
B₂ Curves.



E.M.F. on Terminals	2170	Volts.
Current	89·8	Amps.
Energy by Wattmeter	158·9	K.Watts.
Excitation of Generator	40·2	Amps.
" " Motor	50·9	"
Speed	300	Revolutions per min.

Fig: 16.

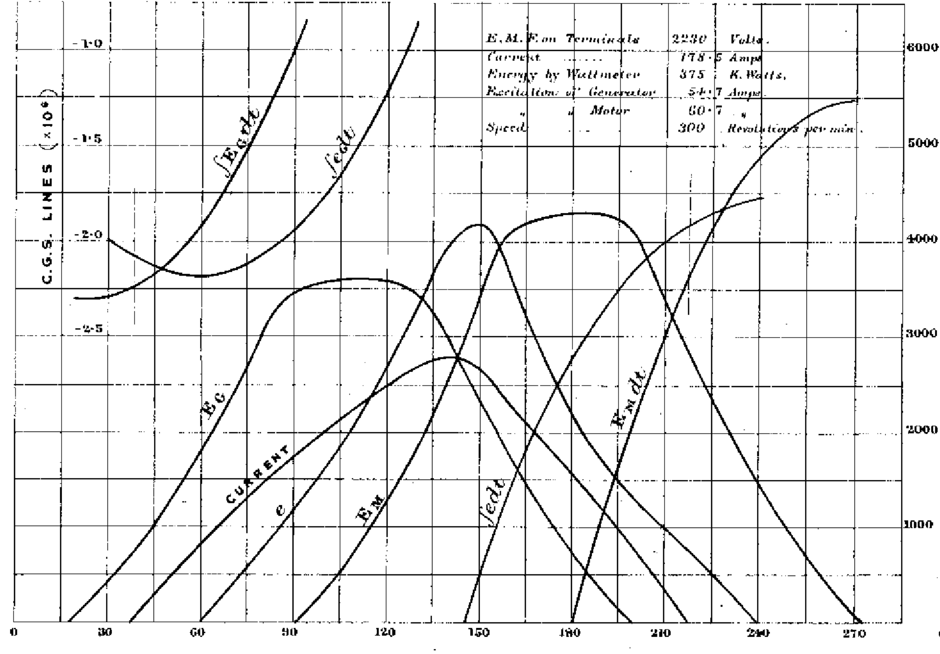
E₁ Curves.



E.M.F. on Terminals	2235	Volts.
Current	177·8	Amps.
Energy by Wattmeter	381	K.Watts.
Excitation of Generator	61·5	Amps.
" " Motor	51·3	"
Speed	300	Revolutions per min.

Fig: 17.

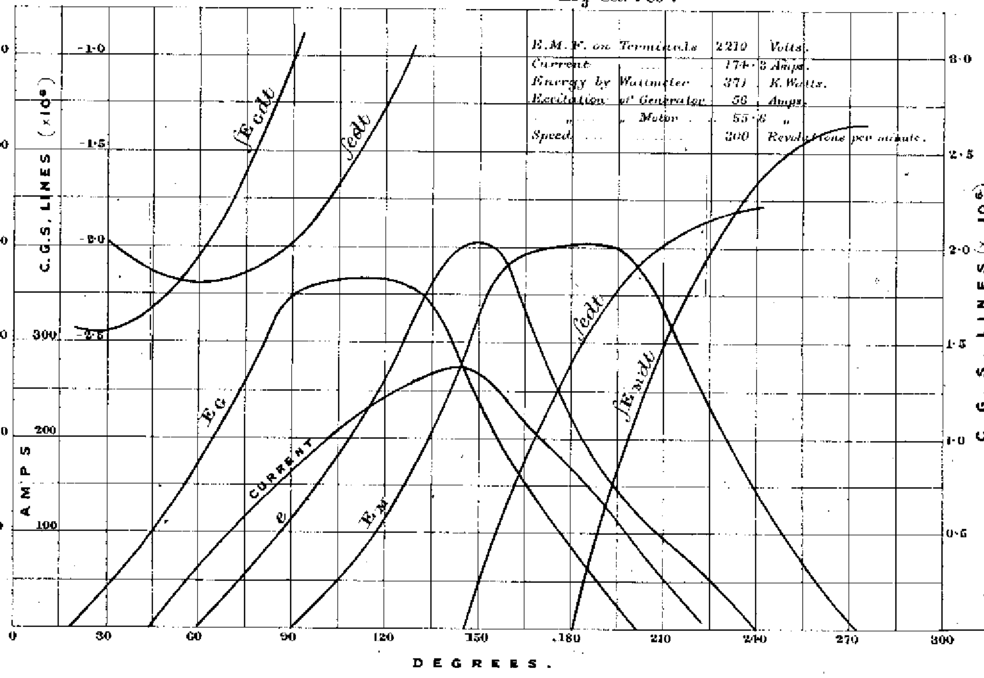
E₂ Curves.



E.M.F. on Terminals	2230	Volts.
Current	178·5	Amps.
Energy by Wattmeter	375	K.Watts.
Excitation of Generator	54·7	Amps.
" " Motor	60·7	"
Speed	300	Revolutions per min.

Fig: 18.

E₃ Curves.



E.M.F. on Terminals	2210	Volts.
Current	174·3	Amps.
Energy by Wattmeter	371	K.Watts.
Excitation of Generator	56	Amps.
" " Motor	55·6	"
Speed	300	Revolutions per minute.

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