XXVI. *On the Dynamo-electric Current, and on Certain Means to Improve its Steadiness.*

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[PLATES 40–52.]

ON the 14th February, 1867, I communicated a short paper to the Royal Society, describing the accumulative or dynamo-electrical principle of action, the conception of which I attributed to my brother Dr. WERNER SIEMENS. When the paper was read, another paper followed by Sir CHARLES WHEATSTONE (sent in on the 24th February) also describing this principle of action, thus showing that the same line of thought had occupied that eminent philosopher.

In illustration of my paper I exhibited a machine of my design, embodying the accumulative principle of action, which furnished abundant evidence of the powerful nature of the current that could be thus produced. It consisted of two horseshoe electro-magnets, between the poles of which a SIEMENS armature could be made to rotate, the machine being furnished with a handle or pulley for that purpose. A commutator was provided, by which the alternating currents set up in the rotating coil (after a first impulse had been given) were directed through the coils of the stationary electro-magnets in a continuous manner, and proceeded thence outward to ignite a platinum wire of some 12″ in length, or to perform other work.

This machine, although the first of its kind, has done good service ever since its construction, having been found very efficacious in exciting powerful permanent magnets at the telegraph works of SIEMENS Brothers at Woolwich.

Since 1867 the accumulative principle has been employed in the machines of different makers, and one form of dynamo-electric machine, that of M. GRAMME, differs very materially from the machine above referred to, and has met very deservedly with extensive recognition. M. GRAMME embodied in his machine the principle of Professor PACINOTTI's magnetic ring, which enabled him to produce powerful electric currents without much of the loss of energy caused in previous machines through the heating of the rotating armature.

Another modification of the dynamo-electrical machine is one devised by Mr. Von HEFTNER ALTENECK, an engineer and physicist employed under my brother WERNER SIEMENS, at Berlin. This machine differs from that first submitted by myself in several important particulars. Instead of the WERNER SIEMENS armature, Von HEFTNER ALTENECK adopted a rotating coil of iron wire wound with insulated copper wire in more than one direction, the several coils of wire being connected seriatim

with the commutator, and through it, with the wire surrounding the soft iron bars, and with the electric lamp or other resistance on the outer circuit.

The advantage claimed for this mode of construction is that all the wire forming the rotating coil or helix is brought into the magnetic field, excepting only those portions crossing from side to side of the coil; and in order to reduce this unproductive resistance to a minimum, the rotating coil or helix has been made comparatively long, and the number of electro-magnets has been increased generally to six or more.

The principal advantage of the dynamo-electrical machine over all other current generators consists in its power of producing currents of great magnitude, and of an intensity up to 100 volts, with a small primary resistance, and therefore with a comparatively small expenditure of mechanical energy. It labours, on the other hand, under the disadvantage that the power of the current depends, at a given velocity, upon the magnetic force developed in the electro-magnets. This force depends upon the amount of current passing through the coils of the magnets, which in its turn is dependent in an inverse ratio upon the resistance in the outer circuit. If from some accidental cause the external resistance is increased, the electro-motive force of the machine, instead of rising to overcome the obstruction, diminishes, and thus aggravates the resulting disturbance. If, on the other hand, the resistance of the outer circuit diminishes, as in the case when the carbons of an electric regulator touch one another, the electro-magnets are immediately excited to a maximum, and the electro-motive force of the machine is increased. The power absorbed and its equivalent, the heat generated in the circuit, is equal to the square of the electro-motive force divided by the resistance; hence the work demanded from the engine will be greatly increased, the machine may be dangerously overheated, and powerful sparks may injure the commutator. It is chiefly owing to this instability of the dynamo-electric current that its application to electric illumination has been retarded, and that magneto-electric machines and machines producing alternating currents have been again used, although they are inferior to the dynamo machine in the current energy produced for a given expenditure of mechanical energy.

The properties of dynamo-electric machines have been examined by several observers. Messrs. HOUSTON and THOMSON (Franklin Institute) compared the efficiency of the GRAMME, BRUSH, and WALLACE FARMER machines. Dr. HOPKINSON (Institution of Mechanical Engineers, 25th April, 1879) examined a medium-sized SIEMENS machine, determined its efficiency, and expressed the electro-motive force as a function of the current. Herrn MAYER and ANERBACH (WIEDEMANN'S 'Annalen,' November, 1879) experimented on a GRAMME machine, and obtained a curve very similar to Diagram I. M. MASCART has experimented on the GRAMME machine, and Mr. SCHWENDLER on both GRAMME and SIEMENS machines.

The radical defect of the dynamo machine of ordinary construction, may be inferred from the results of these experiments. The remedy has, however, been in our hands from the time of the first announcement of the principle of these machines before the Royal Society, when Sir CHARLES WHEATSTONE pointed out that "a very remarkable

increase of all the effects, accompanied by a diminution in the resistance of the machine, is observed when a cross wire is placed so as to divert a great portion of the current from the electro-magnet."

Some of the constructors of dynamo machines, namely: Mr. LADD in this country, and Mr. BRUSH in the United States of America, have taken advantage of this suggestion, the latter with the avowed object in view of obviating spontaneous changes of polarity in effecting electro-precipitation of metals, and without perhaps having realised all of the advantages of which this mode of action is capable; others have refrained from doing so on account of difficulties resulting, as I shall endeavour to show, from an insufficient examination into some important physical conditions that require attention in order to realise economical results.

An ordinary medium-sized SIEMENS-ALTENECK dynamo-electrical machine has wound on its rotating helix insulated copper wire of 2·5 m.m. diameter in 24 sections, representing a resistance of ·4014 S. U.* The four electro-magnet coils connected seriatim are composed of copper wire of 5·5 m.m. diameter, presenting a total resistance of 0·3065 S. U.

If (as has frequently been done) the wires of this machine were to be connected as suggested in Sir CHARLES WHEATSTONE'S original paper, thus making the outer circuit not continuous with but parallel to the coil circuit, and if the outer circuit had a resistance of one unit, it would follow that the total resistance to the current set up by the rotation of the armature would be reduced from $\cdot4+\cdot3+1\cdot=1\cdot7$ to $\cdot4+\frac{\cdot3\times1}{1+\cdot3}=0\cdot61$ unit, causing a great increase of current, the major portion (in the proportion of 10 to 4) would flow through the electro-magnets, thus causing a great increase of heating effect. The resistance of the field magnet must therefore be greatly increased, but if it were attempted to increase that resistance simply by reducing the diameter of the wire, and increasing the number of convolutions until the same thickness of coil was obtained, the magnetic excitement and with it the electro-motive force of the current produced at a given velocity of rotation would suffer a material decrease. The current flowing through the helix coil would moreover have to divide itself, and in order to reach the same limit in the outer circuit its intensity in the helix coil would have to be increased, causing it to heat more readily than before. It was necessary, therefore, to raise the effect of the magnet current to the same level as before with as small a proportion of the helix current as possible, in order to leave a maximum proportion of the current for the outer circuit. In order to effect this, the magnet bars had to be increased in length, and placed further apart so as to provide room for

* The resistance coils used in these experiments were graduated according to the mercury system introduced by Dr. WERNER SIEMENS, and adopted by the Telegraphic Convention at Vienna in 1868. The B. A. unit was determined in 1874 by KOHLRAUSCH to be 1·0493 S. U., or combined with LORENZ'S value of the S. U. afterwards adopted, $0\cdot9797\times10^9$ C. G. S. units—as much as 2 per cent. below its ascribed theoretical value. Later determinations by H. F. WEBER (Phil. Mag., March, 1878) makes the S. U. to be equal to $0\cdot955\times10^9$ C. G. S. units, and thus the ohm to be 0·2 per cent. higher than its ascribed value; if this latter value is used, the numerical results must be correspondingly altered.

coils of greatly increased weight and dimensions; at the same time the helix wire had to be increased in diameter to give room for the aggregate current, but in reality I found it advantageous to increase the diameter of the same in a much greater proportion.

These general conditions having been determined by preliminary experiment, Mr. LAUCKERT, electrician engaged at my works, undertook a series of comparative experiments which are given in the appendix attached to this paper, and the results are given numerically and exhibited in curves. On examining the curves it will be remarked:

1. That the electro-motive force instead of diminishing with increased resistance, increases at first rapidly, then more slowly towards an asymptote.

2. That the current in the outer circuit is actually greater for a unit and a-half resistance than for one unit.

3. With an external resistance of one unit, which is about equivalent to an electric arc when 30 or 40 webers are passing through it, 2·44 horse-power is expended, of which 1·29 horse-power is usefully employed: an efficiency of 53 per cent. as compared with 45 per cent. in the case of the ordinary dynamo machine.

4. That the maximum energy which can be demanded from the engine is 2·6 horse-power, so that but a small margin of power is needed to suffice for the greatest possible requirement.

5. That the maximum energy which can be injuriously transferred into heat in the machine itself is 1·3 horse-power, so that there is no fear here of destroying the insulation of the helix by excessive heating.

6. That the maximum current is approximately that which would be habitually used, and which the commutator and collecting brushes are quite capable of transmitting.

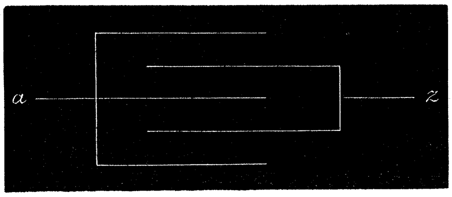
Hence I conclude that the new machine will give a steadier light than the old one, with greater average economy of power, that it will be less liable to derangement, and may be driven without variation of speed by a smaller engine; also that the new machine is free from the objection of having its currents reversed when used for the purpose of electro deposition.

The same peculiarity also enables me to effect an important simplification of the regulator to work electric lamps, to dispense with all wheel and clock-work in the arrangement, as shown in Plate 40. The two carbons, being pushed onward by gravity or spring power, are checked laterally by a pointed metallic abutment, situated at such a distance from the arc itself that the heat is only just sufficient to cause the gradual wasting away of the carbon in contact with atmospheric air. The carbon holders are connected with the iron core of a solenoid coil, of a resistance equal to about fifty times that of the arc, the ends of which coil are connected with the two electrodes respectively. The weight of the core, which has to be maintained in suspension by the attractive force produced by the current, determines the distance between the electrodes, and hence the electric resistance of the arc. The result is that the length of the arc is regulated automatically so as to maintain a uniform resistance, signifying a uniform development of light.

Appendix.

The measurements of the electric currents were made with an electro-dynamometer, the movable part of which consisted of a single turn of 4 m.m. wire, and the stationary coil of nine turns of the same.

To be able to reduce the electrical measurements into absolute power developed, it was in the first place necessary to determine the constant of the instrument in use. This was done in the following manner:—Five copper plates of about 11″ × 8″ were connected as shown in the sketch.



These were carefully weighed and immersed in a solution of sulphate of copper. The machine was previously started, the time of immersion carefully noted, and the readings of the current taken every half minute. The plates were so arranged that the current entering at *a* and leaving at *z* deposited the copper on both sides of the plate at *z*. After a certain time the plates were taken out, quickly rinsed in water, and dried in sawdust. The plates were then carefully weighed again and the deposit calculated per degree reading on the instrument per second of time. Six independent measurements were taken with currents varying from 20 to 40 webers, and gave a mean of ·000779 gramme of copper per second per degree reading. The differences of these measurements from the mean varied from 0·21 per cent. to 6·6 per cent., the mean of the differences being 1·98 per cent.

According to F. Kohlrausch (Pogg. Ann., Bd. cxlix., 1873) the quantity of silver deposited by the C. G. S. unit of electricity is 0·011363 gramme, and since the quantities vary as the equivalents of the metals deposited, we have

$$\frac{\cdot 011363 \times 63\cdot 5}{216} = 0\cdot 003340 \text{ gramme of copper.}$$

One weber being $\frac{1}{10}$ C. G. S. unit, we have to divide by 10 the quantity of copper deposited by a current of one weber in one second, that is ·000334 gramme, and dividing ·000779 by ·000334 we get 2·23323 webers for a degree reading of our instrument.

To be able to compare the machines having the new winding (*i.e.*, the wire on the electro-magnets connected parallel with the outer circuit) with the ordinary machines, it was necessary to experiment on the relation existing between the power expended and the current produced with different resistances in circuit and different speeds.

A medium dynamo machine with 24 part commutator was used, the helix being wound with 336 convolutions of 2·5 m.m. wire, having a resistance of ·4014 S. U. when measured in the machine. The electro-magnets were wound with four layers of

5·5 m.m. wire, each having 32 convolutions, and therefore the four bobbins a total of 512 convolutions with a resistance of ·3065 S. U.

The accompanying Tables Nos. 5, 6, 7, 8, and 9 give the details of the experiments made, which are shown graphically in the diagrams similarly numbered. The current in webers was simply calculated by multiplying the square root of the reading on the electro-dynamometer with the constant of the instrument, *i.e.*, 2·3323.

To be able to calculate the electro-motive force from the current in webers and resistance in SIEMENS' units, it was necessary to convert the S. U. into C. G. S. units by multiplying the same by $\cdot 9337 \times 10^9$. (This figure is given by LORENZ, POGG. Ann., Bd. cxlix., 1873.) By again multiplying this resistance into the current we get, according to OHM's law, the electro-motive force in C. G. S. units, and by dividing by 10^8 we get the E. M. F. in volts.

I have further calculated the total amount of work developed in the following manner:—

Work done $= E \times C \times t$, or, which is the same, $C^2 \times R \times t$, where E is E. M. F; C, current; R, resistance; t, time.

From these calculations t is eliminated as it occurs in all the equations.

$$1 \text{ volt} = 10^8 \text{ C. G. S. units.}$$
$$1 \text{ weber} = \tfrac{1}{10} \text{ C. G. S. unit of current.}$$
$$1 \text{ HP} = 7{\cdot}46 \times 10^9 \text{ C. G. S. units.}$$

Therefore

$$\frac{1 \text{ volt} \times 1 \text{ weber}}{1 \text{ HP}} = \frac{10^8 \times 10^{-1}}{7{\cdot}46 \times 10^9} = \frac{1}{746}$$

and if we multiply the E. M. F. in volts by the current in webers, and divide by 746, we have the actual work developed in horse-power.

To find the actual work done in the outside resistance we use the formula $C^2 \times R$, of course having to reduce the resistance R into absolute C. G. S. units by multiplying by $\cdot 9337 \times 10^9$.

The machine with the new winding had a helix with 24 part commutator wound with 312 convolutions of 2·8 m.m. wire.

The electro-magnets being lengthened by 2″ to take bobbins $10\frac{1}{2}$″, instead of $8\frac{1}{2}$″ as on the ordinary machines, I had three sets of bobbins made, and had the same wound with different sizes of wire, viz.: 2·5 m.m., 2·8 m.m., and 3 m.m., having a respective resistance of 11·26, 7·563, and 4·46 S. U.

The accompanying Tables Nos. 1, 2, 3, and 4 show the experiments made with this machine with electro-magnets of 11·26 S. U. resistance; Nos. 10, 11, 12, and 13 with electro-magnets of 7·563 S. U.; and Nos. 14 and 15 with electro-magnets of 4·46 S. U. The helix in all cases having been wound with 2·8 m.m. wire with a resistance of ·234 S. U. when measured in the machine.

The Tables marked 5, 6, 7, 8, and 9 refer to the dynamo machine wound in the ordinary way.

The Tables marked 16, 17, 18, 19, 20, 21, 22, and 23 show the results obtained with a machine having a helix wound with 288 convolutions of 3 m.m. wire and a resistance of ·173 S. units. The electro-magnets, as before, had a resistance of 11·26, 7·563, and 4·46 S. U.

No. 1.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
500	0·0	..	0·0	..	..	..	..	..	..	·205	..	..	..
,,	·01	·25	·5	..	..	1·63	..	..	·3804	,,	·000831	..	..
,,	·02	·26	·5	..	..	1·63	..	..	·3957	,,	·000864	..	..
,,	·05	·28	1·0	..	..	2·33	..	..	·6091	,,	·00190	..	..
,,	·10	·34	1·5	..	..	2·86	..	..	·9079	,,	·00348	..	..
,,	·25	·48	2·0	..	..	3·30	..	..	1·479	,,	·00654	..	..
,,	·50	·72	14·0	1·0	12	8·80	2·33	8·08	5·915	·714	·0698	·0409	5·73
,,	·75	·94	130·0	1·5	115	26·58	2·86	25·01	23·32	1·43	·881	·587	41·04
,,	1·0	1·16	180·0	2·0	145	31·30	3·30	28·08	33·90	1·83	1·422	·987	53·93
,,	1·25	1·36	145·0	2·0	125	28·08	3·30	26·07	35·65	,,	1·342	1·063	58·08
,,	1·5	1·56	135·0	3·0	115	27·09	4·04	25·01	39·46	,,	1·433	1·17	63·93
,,	1·75	1·75	132·0	3·0	102	26·79	4·04	23·55	43·77	,,	1·592	1·21	66·12
,,	2·0	1·94	120·0	3·5	95	25·55	4·36	22·73	46·28	1·73	1·585	1·29	69·94
,,	∞	..	5·0	4·0	0	5·21	4·66	..	..	·714	..	..	..

No. 2.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Expended.	Total developed.	Developed in outer circuit.	
600	0·0	·24	0	..	..	..	..	..	..	·245	..	..	..
,,	·25	·48	1	..	..	2·33	..	..	1·044	,,	·0032	..	..
,,	·50	·72	5	..	..	5·21	..	..	3·502	,,	·0244	..	..
,,	·75	·94	125	..	115	26·07	..	25·01	22·87	1·714	·799	·587	34·24
,,	1·0	1·16	215	2·0	175	34·20	3·3	30·86	37·04	2·45	1·70	1·16	47·34
,,	1·25	1·36	195	2·5	153	32·57	3·69	28·84	41·35	,,	1·805	1·3	53·06
,,	1·50	1·56	185	3·5	144	31·72	4·361	27·99	46·20	2·33	1·96	1·47	63·09
,,	1·75	1·75	164	4·0	125	29·87	4·66	26·07	48·80	2·20	1·95	1·49	67·72
,,	2·0	1·94	160	4·0	120	29·50	4·66	25·55	53·43	,,	2·12	1·633	74·22
,,	∞	11·50	6	5·0	0	5·71	5·21	..	65·66	1·10	·503	..	..

No. 3.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
700	0·0	·24	..	..	..	..	..	..	..	·29	..	..	..
,,	·25	·48	4	..	..	4·66	..	..	2·078	,,	·0129	..	..
,,	·5	·72	11	..	..	7·74	..	..	5·203	,,	·0540	..	..
,,	·75	·94	285	5	255	39·37	5·21	37·25	34·56	2·57	1·82	1·3	50·58
,,	1·0	1·18	325	6	280	42·05	5·71	39·03	46·33	3·47	2·61	1·9	54·75
,,	1·25	1·36	300	6	250	40·40	5·71	36·88	51·3	,,	2·77	2·13	61·37
,,	1·5	1·56	276	6	205	38·75	5·71	33·39	55·81	,,	2·90	2·09	60·23
,,	1·75	1·75	230	6	170	35·37	5·71	30·41	57·79	,,	2·74	2·03	58·50
,,	2·0	1·94	215	7	158	34·2	6·17	29·31	61·95	3·28	2·84	2·15	65·54
,,	∞	11·50	11	10	0	7·74	7·37	..	83·11	1·29	·862	..	..

No. 4.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.

Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance (connected parallel to outer circuit).

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
758	12·30	6·11	38	9·0	9	14·38	6·99	6·99	82·03	2·78	1·58	·752	27·26
756	8·90	5·21	49	8·5	14	16·32	6·77	8·88	79·38	2·93	1·74	·878	29·96
734	6·00	4·15	69	9·0	28	19·37	6·99	12·34	75·05	3·0	1·95	1·14	38·00
758	6·00	4·15	72	9·0	28	19·79	6·99	12·34	76·67	3·09	2·03	1·14	36·89
750	4·50	3·43	85	9·0	34	21·50	6·99	13·61	68·85	3·21	1·98	1·04	32·40
756	3·50	2·91	150	7·0	87	28·56	6·17	21·75	77·59	3·86	2·97	2·17	52·07
760	3·00	2·61	185	6·0	107	31·72	5·71	24·12	77·30	3·88	3·29	2·18	56·18
758	2·50	2·28	204	5·0	130	33·31	5·21	26·58	70·91	3·87	3·17	2·21	57·11
750	2·25	2·12	230	..	150	35·37	..	28·56	70·01	3·83	3·32	2·30	60·01
760	2·00	1·94	226	..	157	35·06	..	29·27	63·51	3·88	2·99	2·14	55·15
755	1·75	1·75	252	..	180	37·03	..	31·30	60·50	3·85	3·00	2·14	55·58
754	1·50	1·56	255	..	185	37·25	..	31·72	54·26	3·85	2·71	1·89	49·10
760	1·35	1·44	305	..	240	40·73	..	36·14	54·71	3·72	2·99	2·21	59·41
756	1·25	1·36	310	..	245	41·06	..	36·50	52·14	3·70	2·89	2·08	56·48
764	1·10	1·24	315	..	260	41·20	..	37·61	47·70	3·74	2·63	1·94	51·87
766	1·00	1·16	315	..	264	41·20	..	37·89	44·62	3·59	2·46	1·80	50·01
750	·90	1·07	285	..	238	39·37	..	35·98	39·33	3·06	2·07	1·46	47·71
765	·80	·99	235	..	205	35·75	..	33·39	33·04	2·50	1·58	1·12	44·80
760	·75	·94	208	..	185	33·64	..	31·30	29·52	2·48	1·33	·92	37·09
755	·65	·85	98	..	87	23·09	..	21·75	18·32	1·08	·567	·385	35·64
760	·60	·81	50	..	45	16·49	..	15·64	12·47	1·08	·275	·184	17·03
700	·55	·76	30	..	25	12·77	..	11·68	9·07	·43	·155	·094	21·86
752	·50	·72	12	..	10	8·07	..	7·37	6·36	·46	·069	·034	7·39
..	·40	·65	5	..	4	5·21	..	4·66	3·16	..	·0221	·0109	2·37
..	∞	11·50	12	12·0	..	8·07	8·07	..	86·64	..	·937	..	..

No. 5.

Helix : 24 part commutator, 336 convolutions, 2·5 m.m. wire, ·4014 S. U. resistance.
Electro-magnets : 512 convolutions, 5·5 m.m. wire, ·3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
750	∞	..	..	..	..	·306	..	..	..
„	8·9	9·61	1	2·33	20·90	„	·0653	·0605	19·77
„	6·0	6·71	1	„	14·59	„	·0455	·0408	13·33
„	4·5	5·21	1	„	11·33	„	·0353	·0306	10·00
745	3·5	4·21	7	6·17	24·25	·304	·205	·167	54·93
760	3·25	3·96	16	9·32	34·46	·620	·430	·353	56·90
758	3·0	3·71	26	11·89	41·18	·773	·656	·531	68·70
750	2·75	3·46	40	14·75	47·65	1·224	·942	·749	61·19
740	2·5	3·20	66	18·95	56·62	1·660	1·44	1·12	67·67
756	2·25	2·96	85	21·50	59·42	2·16	1·71	1·30	60·18
774	2·0	2·71	120	25·55	64·65	2·69	2·21	1·63	60·59
768	1·75	2·46	165	29·96	68·81	3·45	2·76	1·97	57·10
736	1·5	2·21	215	34·20	70·57	3·90	3·23	2·20	56·41
710	1·25	1·96	260	37·61	68·80	4·35	3·47	2·21	50·80
724	1·0	1·71	330	42·37	67·65	5·02	3·84	2·25	44·82
736	·9	1·61	520	53·17	79·92	6·16	5·69	3·16	51·29
„	·8	1·51	570	55·67	78·49	6·91	5·86	3·10	44·87
„	·75	1·46	625	58·31	79·48	6·91	6·21	3·19	46·16

No. 6.

Helix : 24 part commutator, 336 convolutions, 2·5 m.m. wire, ·4014 S. U. resistance.
Electro-magnets : 512 convolutions, 5·5 m.m. wire, ·3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
500	3·5	..	..	..	..	·257	..	..	..
496	3·0	3·71	1·5	2·86	9·90	·405	·0379	·0307	7·58
505	2·5	3·21	2	3·29	9·86	·515	·1434	·0338	6·563
516	2·0	2·71	9	6·99	17·68	·579	·165	·122	21·07
520	1·75	2·46	42	15·11	34·70	·796	·702	·500	62·81
490	1·5	2·21	60	18·06	37·26	1·20	·902	·612	51·00
496	1·25	1·96	120	25·55	46·75	1·82	1·61	1·02	56·04
490	1·0	1·71	180	31·30	49·97	2·30	2·09	1·23	53·47
490	·85	1·56	245	36·50	53·16	2·80	2·60	1·42	50·71
504	·75	1·46	280	39·03	53·20	3·08	2·78	1·43	46·42
502	·65	1·36	320	41·72	52·97	3·08	2·96	1·41	45·79
„	·60	1·31	340	43·01	52·60	3·58	3·03	1·39	38·83
„	·55	1·26	355	43·94	51·68	3·58	3·04	1·33	37·15
488	·50	1·21	385	45·76	51·70	3·58	3·17	1·25	34·92
„	·45	1·16	420	47·80	51·77	3·78	3·32	1·29	34·13
„	·40	1·11	491	51·63	53·49	3·98	3·70	1·33	33·42
„	·35	1·06	510	52·66	52·10	4·08	3·68	1·21	29·65
„	·30	1·01	600	57·12	53·89	4·28	4·12	1·22	28·51
„	·25	·96	630	58·54	52·46	4·58	4·11	1·07	23·36

No. 7.

Helix: 24 part commutator, 336 convolutions, 2·5 m.m. wire, ·4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5·5 m.m. wire, ·3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit.	
602	4·5	5·21	..	..	..	·246	..	..	..
„	3·5	4·21	..	..	..	·491	..	..	..
590	3·0	3·71	1	2·33	8·07	·602	·0252	·0203	3·372
602	2·5	3·21	16	9·32	27·93	·676	·349	·2725	40·31
606	2·0	2·71	60	18·06	45·69	1·113	1·106	·816	73·31
602	1·75	2·46	105	23·90	54·89	1·72	1·760	1·25	72·67
600	1·5	2·21	140	27·59	56·93	2·20	2·110	1·429	64·95
590	1·25	1·96	170	30·41	55·65	2·53	2·27	1·45	57·31
600	1·0	1·71	270	38·32	61·18	3·43	3·14	1·84	53·64
620	·85	1·56	378	45·34	66·04	4·43	4·01	2·18	49·21
„	·75	1·46	400	46·64	63·57	4·68	3·97	2·05	43·80
„	·60	1·31	505	52·41	64·11	5·06	4·50	2·06	40·71

No. 8.

Helix: 24 part commutator, 336 convolutions, 2·5 m.m. wire, ·4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5·5 m.m. wire, ·3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended	Total developed.	Developed in outer circuit.	
715	4·5	5·21	..	..	..	·365	..	..	..
698	3·5	4·21	4	4·66	18·32	·427	·114	·095	22·25
700	3·0	3·71	21	10·69	37·03	1·43	·530	·429	30·00
710	2·5	3·21	50	16·49	49·42	1·59	1·09	·682	42·89
680	2·0	2·71	105	23·91	60·50	2·64	1·94	1·43	54·16
690	1·75	2·46	165	29·96	63·11	3·94	2·76	1·98	50·25
708	1·5	2·21	210	33·80	69·75	3·90	3·16	2·14	54·87
685	1·25	1·96	270	38·32	70·13	4·47	3·60	2·30	51·45
686	1·0	1·71	380	45·46	72·58	5·04	4·42	2·59	51·29
720	·85	1·56	550	54·69	79·66	6·46	5·14	3·18	49·22
„	·75	1·46	620	58·07	79·16	6·76	6·16	3·16	46·74
„	·60	1·31	680	60·83	74·41	7·05	6·07	2·78	39·43
„	·50	1·21	900	69·97	79·05	7·72	7·42	3·06	39·63

No. 9.

Helix: 24 part commutator, 336 convolutions, 2·5 m.m. wire, ·4014 S. U. resistance.
Electro-magnets: 512 convolutions, 5·6 m.m. wire, ·3065 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.	Current in webers.	E. M. F. in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.				Expended.	Total developed.	Developed in outer circuit	
450	1	1·71	100	23·33	37·24	1·56	1·16	·681	43·65
500	,,	,,	145	28·08	44·84	2·14	1·69	·987	46·12
550	,,	,,	190	32·14	51·32	2·69	2·21	1·29	47·95
600	,,	,,	235	35·75	57·08	3·43	2·73	1·60	46·65
650	,,	,,	290	39·72	63·42	4·24	3·37	1·97	46·46
700	,,	,,	360	44·25	70·65	5·00	4·18	2·45	49·00
750	,,	,,	420	47·80	76·32	5·81	4·89	2·86	49·22
800	,,	,,	490	51·63	82·44	6·86	5·70	3·34	48·69

No. 10.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2·8 m.m. wire, 7·563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
502	∞	7 8	13	13	..	8·41	8·41	..	61·25	1·33	·69	..	..
513	12·0	4·87	30	12	5	12·77	8·08	5·21	58·07	1·47	·994	·409	27·82
517	10·0	4·54	35	12	7	13·80	8·08	6·17	58·50	1·58	1·082	·476	30·12
520	9·0	4·34	42	12	9	15·11	8·08	7·0	61·23	1·59	1·251	·552	34·72
498	7·5	3·99	40	10	10	14·75	7·37	7·37	54·95	1·42	1·086	·510	35·90
501	6·0	3·51	42	8	15	15·11	6·60	9·03	50·36	1·53	1·020	·612	40·00
500	4·5	3·05	50	7	22	16·49	6·17	10·94	46·96	1·53	1·038	·674	44·05
510	3·5	2·62	75	7	35	20·20	6·17	13·8	49·41	1·77	1·338	·834	47·12
502	3·0	2·38	82	6	42	21·12	5·71	15·11	46·93	1·74	1·329	·857	49·25
507	2·5	2·11	90	6	50	22·12	5·71	16·49	43·58	1·86	1·292	·851	45·75
502	2·0	1·81	120	6	85	25·55	5·71	21·5	43·18	1·95	1·479	1·11	56·92
495	1·75	1·65	140	6	95	27·59	5·71	22·73	42·5	1·92	1·572	1·13	58·85
492	1·5	1·48	160	5	110	29·50	5·21	24·46	40·77	2·01	1·612	1·12	55·72
504	1·25	1·30	190	4	140	32·14	4·66	27·59	39·01	2·16	1·681	1·19	55·09
506	1·1	1·19	205	4	157	33·39	4·66	29·21	37·12	2·27	1·661	1·16	51·10
512	1·0	1·11	200	4	155	32·98	4·66	29·03	34·18	2·09	1·511	1·05	50·23
505	·85	·998	225	4	180	34·98	4·66	31·30	32·60	1·96	1·528	1·04	53·06
510	·75	·917	220	4	183	34·60	4·66	31·55	29·63	1·87	1·374	·934	49·95
507	·6	·790	160	3	120	29·50	4·04	25·55	21·77	1·45	·861	·490	33·79

No. 11.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2·8 m.m. wire, 7·563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
598	·3	·52	3	1	3	4·04	2·33	4·04	1·962	·24	·0106	·00613	2·554
596	·4	·61	4	1	3	4·66	2·33	4·04	2·655	·24	·0166	·00817	3·404
612	·5	·70	30	1	26	12·77	2·33	11·89	8·34	·375	·143	·0884	23·57
,,	·6	·79	180	2	..	31·30	3·30	..	23·08	·87	·968	..	..
620	·6	·79	215	2	180	34·20	3·30	31·30	25·23	1·77	1·16	·736	41·58
615	·7	·87	280	3	240	39·03	4·04	36·14	31·71	2·26	1·66	1·14	50·44
,,	·75	·917	300	4	250	40·40	4·66	36·88	34·59	2·51	1·87	1·28	51·50
600	·85	·998	290	4	245	39·72	4·66	36·50	37·02	2·571	1·97	1·42	55·25
612	1·0	1·11	305	6	235	40·73	5·71	35·75	42·21	2·87	2·30	1·60	55·74
,,	1·25	1·30	290	7	210	39·72	6·17	33·80	48·22	2·86	2·56	1·80	62·93
598	1·5	1·48	230	8	160	35·37	6·60	29·50	48·88	2·81	2·32	1·63	58·00
615	2·0	1·81	195	10	120	32·57	7·34	25·55	55·05	2·89	2·40	1·63	56·40
620	3·0	2·38	130	12	65	26·58	8·08	18·80	59·07	2·66	2·10	1·33	50·00
625	4·5	3·05	85	14	32	21·50	8·88	13·19	61·23	2·30	1·76	·98	42·61
,,	6·0	3·59	70	15	22	19·51	9·03	10·94	65·40	2·16	1·71	·898	41·57
620	7·5	3·99	55	16	16	17·29	9·33	9·33	64·42	1·89	1·49	·817	42·22

No. 12.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2·8 m.m. wire, 7·563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
700	7·5	4·01	80	18	18	20·86	9·89	9·89	78·10	2·57	2·18	·918	35·72
,,	6·0	3·59	80	17	25	20·86	9·62	11·68	69·92	2·57	1·95	1·02	39·69
707	4·5	3·06	95	16	35	22·73	9·33	13·80	64·94	2·88	1·97	1·07	37·15
710	3·0	2·39	165	14	90	29·96	8·88	22·12	66·85	3·19	2·68	1·84	57·67
704	2·5	2·12	195	12	115	32·57	8·08	25·01	64·47	3·59	2·81	1·96	54·59
716	2·0	1·82	235	9	150	35·75	7·0	28·56	60·75	3·94	2·91	2·04	51·77
723	1·5	1·49	315	7	220	41·40	6·17	34·60	57·60	4·28	3·20	2·25	52·57
715	1·25	1·31	350	6	260	43·64	5·71	37·61	53·38	4·23	3·12	2·21	52·25
722	1·0	1·12	385	5	300	45·76	5·21	40·40	47·85	4·27	2·93	2·04	47·77
705	·75	·92	370	5	305	44·86	5·21	40·73	38·53	3·45	2·31	1·56	45·21
703	·60	·80	300	5	270	40·40	5·21	38·32	30·18	2·29	1·63	1·10	48·03
716	·50	·71	150	4	100	28·56	4·66	23·32	18·94	·292	·725	·34	11·64
710	·40	·62	7	1	7	6·17	2·33	6·17	3·571	·290	·295	·019	6·552

No. 13.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 3200 convolutions, 2·8 m.m. wire, 7·563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
450	1·0	1·12	140	..	105	27·59	..	23·91	28·85	1·47	1·02	·715	48·63
500	,,	,,	185	..	150	31·72	..	28·56	33·16	1·94	1·41	1·02	52·57
550	,,	,,	250	..	195	36·88	..	32·57	38·56	2·47	1·91	1·33	53·85
600	,,	,,	325	..	260	42·05	..	37·61	43·97	3·06	2·48	1·77	57·84
650	,,	,,	400	..	305	46·64	..	40·73	48·77	3·71	3·05	2·08	56·06
700	,,	,,	470	..	350	50·56	..	43·64	52·87	4·43	3·58	2·38	53·72
750	,,	,,	530	..	395	53·69	..	46·35	56·14	5·20	3·91	2·69	51·73
800	,,	,,	640	..	460	58·98	..	50·03	61·69	5·88	4·86	3·13	53·23
850	,,	,,	700	..	510	61·69	..	52·66	64·51	6·42	5·33	3·47	54·05
900	,,	,,	785	..	570	65·33	..	55·67	68·31	6·98	5·98	3·88	55·59
850	,,	,,	700	..	505	61·69	..	52·41	64·51	6·42	5·33	3·44	53·58
800	,,	,,	600	..	440	57·12	..	48·92	59·73	5·71	4·57	2·99	52·36
750	,,	,,	510	..	372	52·66	..	44·98	55·07	4·90	3·89	2·53	51·63
700	,,	,,	440	..	330	48·92	..	42·37	51·15	4·14	3·35	2·25	54·35
650	,,	,,	350	..	270	43·64	..	38·32	45·63	3·45	2·67	1·84	53·33
600	,,	,,	285	..	220	39·47	..	34·60	41·27	2·82	2·18	1·5	53·19
550	,,	,,	240	..	180	36·14	..	31·30	37·79	2·24	1·83	1·23	54·91
500	,,	,,	180	..	135	31·30	..	27·09	32·73	1·73	1·37	·918	53·06
450	,,	,,	135	..	100	27·09	..	23·32	28·33	1·28	1·03	·681	53·20

No. 14.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 2240 convolutions, 3 m.m. wire, 4·46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
505	∞	4·70	23	23	..	11·19	11·19	..	49·01	1·34	·736	..	..
510	7·0	2·96	55	..	9	17·29	..	6·99	47·79	1·77	1·11	·428	24·18
502	6·0	2·8	60	..	12	18·06	..	8·08	47·21	1·74	1·14	·490	28·16
502	5·0	2·6	65	18	14	18·80	9·89	8·88	45·64	1·74	1·15	·493	28·33
492	4·5	2·48	65	16	16	18·80	9·33	9·32	43·53	1·71	1·10	·489	28·60
,,	3·0	2·03	120	15	40	25·55	9·03	14·75	48·43	1·71	1·66	·817	47·78
515	2·5	1·84	125	14	53	26·07	8·88	16·98	44·79	1·99	1·57	·902	45·32
494	2·0	1·62	145	13	7	28·08	8·40	19·51	42·47	1·91	1·60	·953	49·39
,,	1·5	1·36	180	10	100	31·30	7·37	23·32	39·75	2·01	1·67	1·02	50·74
508	1·25	1·22	210	..	130	33·80	..	26·58	38·50	2·18	1·74	1·10	50·46
512	1·0	1·06	260	9	170	37·61	6·90	30·41	32·73	2·40	1·65	1·16	48·33
515	1·0	1·06	280	..	180	39·03	..	31·30	38·65	2·41	2·02	1·23	51·03
506	·9	·99	295	..	205	40·06	..	33·39	36·93	2·37	1·98	1·25	52·74
515	·8	·92	220	7	220	34·60	6·17	34·60	29·72	2·52	1·38	1·20	47·61
,,	·7	·84	295	..	222	40·06	..	34·75	31·42	2·52	1·69	1·05	41·67
498	·3	·52	95	2	75	22·73	3·29	20·20	11·04	0·71	·336	·153	21·55
510	·6	·77	280	5	200	39·03	5·21	32·98	28·06	2·18	1·47	·817	37·48
,,	·5	·69	275	..	210	38·68	..	33·80	24·92	2·42	1·29	·715	29·54

No. 15.

Helix: 24 part commutator, 312 convolutions, 2·8 m.m. wire, ·234 S. U. resistance.
Electro-magnets: 2240 convolutions, 3 m.m. wire, 4·46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
700	..	·24	..	..	..	..	..	..	..	·28	..	..	..
,,	·1	·34	2	..	..	3·29	..	..	1·044	·28	·0046	..	..
,,	·2	·43	3	..	..	4·03	..	..	1·617	·28	·0087	..	..
712	·3	·52	14	..	10	8·88	..	7·37	4·311	·29	·0513	·0204	7·034
698	·4	·61	15	..	12	9·03	..	8·07	5·143	·28	·0622	·0326	11·64
712	·5	·69	370	4	305	44·86	4·66	40·73	28·89	2·61	1·74	1·04	39·84
715	·6	·77	510	6	370	52·66	5·71	44·86	37·86	3·50	2·67	1·51	43·14
,,	·75	·88	570	..	360	55·67	..	44·25	45·74	4·08	3·41	1·83	44·85
720	1·0	1·06	630	15	335	53·69	9·03	42·69	53·14	4·10	3·82	2·28	55·61
714	1·25	1·22	440	18	260	48·93	9·89	37·61	55·73	4·08	3·66	2·21	54·16
708	1·5	1·36	410	21	215	47·23	10·69	34·20	59·97	4·05	3·80	2·20	54·32
700	2·0	1·62	325	25	150	42·05	11·68	28·56	63·60	4·00	3·58	2·04	51·00
712	3·0	2·03	230	32	80	35·37	13·19	20·86	67·04	3·48	3·18	1·63	46·83
,,	∞	4·7	..	50	..	..	16·65	..	..	2·47	..	..	..

No. 16.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
612	0·0	..	..	..	..	..	..	..	..	·25	..	..	..
640	·25	·418	..	..	..	..	..	..	..	·25	..	..	..
625	·5	·652	4	..	..	4·66	..	..	2·84	·25	·018	..	..
620	·75	·876	97	..	90·0	22·97	..	22·12	18·8	·76	·579	·46	60·6
630	1·0	1·09	220	2·0	190·0	34·6	3·3	32·14	35·21	2·44	1·63	1·29	52·86
630	1·25	1·29	225	3·0	190·0	34·98	4·04	32·14	41·13	2·57	1·93	1·61	62·64
635	1·5	1·5	205	3·5	170·0	33·39	4·36	30·41	46·76	2·59	2·09	1·73	66·79
636	1·75	1·69	185	3·5	145·0	31·72	4·36	28·08	50·05	2·46	2·13	1·73	70·32
638	2·0	1·87	165	4·0	120·0	29·96	4·66	25·55	52·3	2·47	2·10	1·63	65·99
628	4·5	3·38	68	6·0	32·0	19·23	5·71	13·19	60·69	2·05	1·56	·98	47·86
624	6·5	4·29	42	7·0	15·0	15·11	6·16	9·03	60·52	1·91	1·22	·66	34·55
635	9·0	5·17	32	7·5	8·5	13·19	6·39	6·8	63·67	1·81	1·13	·521	28·78
610	11·0	5·73	25	7·0	7·0	11·68	6·16	6·16	62·49	1·62	·98	·522	32·22
614	∞	11·43	8	8·0	..	6·6	6·6	..	70·43	1·25	·623	..	..

No. 17.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
665	·25	·42	3	..	3	4·04	..	4·04	1·58	·271	·0085	·0051	1·82
670	·5	·652	30	..	28	12·77	..	12·34	7·74	·547	·132	·095	17·37
665	·75	·875	245	2·0	225	36·50	3·3	34·98	29·85	2·04	1·45	1·14	55·88
660	·85	·963	255	2·5	235	37·25	3·69	35·75	33·49	2·29	1·67	1·36	59·38
640	1·0	1·09	290	3·0	260	39·72	4·04	37·61	40·42	2·61	2·15	1·77	67·81
645	1·1	1·17	272	3·0	230	38·47	4·04	35·37	42·02	2·63	2·17	1·72	65·40
650	1·25	1·29	250	3·5	205	36·88	4·36	33·39	44·42	2·65	2·2	1·74	65·66
645	1·4	1·42	235	4·0	185	35·75	4·66	31·72	47·39	2·63	2·27	1·76	66·92
650	1·5	1·5	228	4·0	180	35·22	4·66	31·3	49·33	2·52	2·33	1·84	73·01
660	1·75	1·69	200	4·5	153	32·98	4·94	28·84	52·04	2·56	2·3	1·82	71·09
660	2·0	1·87	180	5·0	145	31·3	5·21	28·08	54·65	2·42	2·29	1·97	81·40

No. 18.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets: 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
817	1·1	1·17	435	..	360	48·65	..	44·25	53·15	4·67	3·47	2·69	57·6
812	1·0	1·09	465	..	385	50·29	..	45·76	51·11	4·81	3·44	2·61	54·26
815	1·25	1·29	405	5·0	335	46·94	5·21	42·69	56·53	4·82	3·56	2·85	59·12
820	1·5	1·5	370	5·5	290	44·86	5·47	39·72	62·83	4·85	3·78	2·96	61·03
814	1·75	1·69	330	..	250	42·37	..	36·88	66·85	4·82	3·8	2·98	61·82
812	2·0	1·87	300	..	220	40·40	..	34·6	70·54	4·64	3·82	3·00	64·65
824	·9	1·01	450	..	385	49·47	..	45·76	46·65	4·71	3·09	2·36	50·10
820	·8	·92	450	..	390	49·47	..	46·06	42·56	4·35	2·82	2·12	48·73
808	·75	·876	430	..	390	48·36	..	46·06	39·55	4·12	2·56	1·99	48·30
840	·6	·743	220	..	215	34·60	..	34·2	24·00	2·4	1·11	·878	36·58
830	·5	·652	..	..	100	..	..	23·32	..	2·37	..	·34	14·34
820	·5	·652	75	..	70	20·20	..	19·51	12·30	2·34	·333	·238	10·16

No. 19.

Helix : 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets : 3916 convolutions, 2·5 m.m. wire, 11·26 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
480	1·0	1·091	98	..	85	23·09	..	21·5	23·53	1·37	·728	·578	42·19
530	„	„	135	..	123	27·09	..	25·86	27·60	1·73	1·00	·837	48·38
602	„	„	223	..	195	34·83	..	32·57	35·49	2·33	1·66	1·33	57·08
670	„	„	290	..	250	39·72	..	36·88	40·47	3·14	2·15	1·7	54·14
744	„	„	390	..	320	46·06	..	41·72	46·93	3·95	2·89	2·18	55·19
800	„	„	455	..	380	49·75	..	45·46	50·70	4·73	3·38	2·59	54·76
864	„	„	515	..	430	52·92	..	48·36	53·92	5·64	3·82	2·93	51·95
911	„	„	585	..	490	56·42	..	51·63	57·49	6·32	4·35	3·34	52·85

No. 20.

Helix : 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets : 3200 convolutions, 2·8 m.m. wire, 7·563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
716	∞	7·74	26	26·0	..	11·89	11·89	..	85·93	2·04	1·37	..	..
710	2·0	1·75	300	15 0	195	40·4	9·03	32·57	66·01	3·62	3·57	2·66	73·48
706	1·75	1·59	320	13·5	220	41·72	8·57	34·6	61·93	3·74	3·46	2·62	70·05
718	1·5	1·42	360	12·0	255	44·25	8·08	37·25	58·66	3·96	3·48	2·61	65·91
710	1·25	1·25	395	9·0	290	46·35	6·99	39·72	54·10	4·06	3·36	2·47	60·84
708	1·0	1·06	445	7 0	340	49·21	6·16	43·01	48·70	4·04	3·21	2·31	57·18
714	·95	1·02	460	6·0	360	50·03	5·71	44·25	47·65	3·79	3·2	2·33	61·47
706	·9	·977	460	..	370	50·03	..	44·86	45·64	3·75	3·19	2·27	60·53
710	·8	·896	460	5·0	380	50·23	5·21	45·46	41·85	3·62	2·81	2·07	57·18
714	·7	·814	445	4·0	375	49·20	4·66	45·16	37·40	3·35	2·47	1·78	53·13
715	·6	·729	390	..	340	46·06	..	43·01	31·35	2·77	1·94	1·39	50·18
715	·5	·642	..	..	230	..	..	35·37	..	..	..	·875	..
710	·5	·642	205	..	195	33·39	..	32·57	20·02	1·3	·896	665	51·15

No. 21.

Helix : 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets : 3200 convolutions, 2·8 m.m. wire, 7·563 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	Outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
468	1·0	1·06	170	..	130	30·41	..	26·58	30·10	1·34	1·23	·884	65·97
532	,,	,,	235	..	185	35·75	..	31·72	35·38	1·96	1·69	1·26	64·21
610	,,	,,	310	..	240	41·06	..	36·14	40·64	2·61	2·24	1·64	62·83
678	,,	,,	365	..	290	44·56	..	39·72	44·10	3·32	2·63	1·98	59·64
716	,,	,,	430	..	335	48·36	..	42·68	47·86	3·79	3·10	2·28	60·16
788	,,	,,	510	..	385	52·66	..	45·76	52·12	4·35	3·67	2·63	60·46
860	,,	,,	620	..	430	57·14	..	48·36	56·55	5·08	4·33	2·93	57·68

No. 22.

Helix : 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance.
Electro-magnets : 2556 convolutions, 3 m.m. wire, 4·46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
690	∞	4·63	46	46	..	15·82	15·82	..	68·4	2·67	1·45	..	..
702	2·0	1·55	300	24	155	40·4	11·43	29·03	58·47	4·01	3·16	2·11	52·62
694	1·75	1·43	300	22	170	40·4	10·94	30·41	53·94	3·97	2·92	2·03	51·13
698	1·5	1·29	335	20	205	42·69	10·43	33·39	51·42	3·99	2·94	2·09	52·38
696	1·25	1·15	390	18	245	46·06	9·9	36·50	49·46	4·12	3·06	2·08	50·48
696	1·0	·99	395	14	265	46·35	8·88	37·97	42·85	3·98	2·67	1·8	45·22
690	·9	·92	390	9	290	46·06	6·99	39·72	39·56	3·52	2·44	1·78	50·57
649	·8	·85	385	8	290	45·75	6·6	39·72	36·32	3·39	2·22	1·58	46·61
706	·7	·78	360	7	270	44·25	6·16	38·32	32·14	3·02	1·9	1·29	42·71
684	·6	·702	290	..	245	39·72	..	36·50	26·02	2·65	1·38	1·0	37·73
684	·5	·623	..	..	160	..	..	29·50	..	1·26	..	·544	43·18
684	·5	·623	140	..	..	27·59	..	..	16·05	1·26	·594	..	..

No. 23.

Helix: 24 part commutator, 288 convolutions, 3 m.m. wire, ·173 S. U. resistance. Electro-magnets, 2556 convolutions, 3 m.m. wire, 4·46 S. U. resistance.

Revolutions per minute.	Resistance in S. U.		Reading on electro-dynamometer.			Current in webers.			E. M. F. in helix in volts.	Horse-power.			Percentage of energy turned into useful work.
	In outer circuit.	Total in circuit.	Helix.	Electro-magnet.	Outer circuit.	Helix.	Electro-magnet.	Outer circuit.		Ex-pended.	Total developed.	Developed in outer circuit.	
492	1	·99	240	7·0	160	36·11	6·16	29·5	33·41	2·11	1·62	1·09	51·66
528	"	"	282	9·0	185	39·17	6·99	31·72	36·21	2·48	1·9	1·26	50·81
602	"	"	345	12·0	235	43·31	8·08	35·75	40·04	3·07	2·32	1·6	52·12
634	"	"	410	14·0	280	47·23	8·88	39·03	43·66	3·61	2·76	1·9	52·63
722	"	"	450	16·0	300	49·47	9·33	40·4	45·73	4·27	3·03	2·04	47·78
790	"	"	540	18·5	335	54·20	10·03	42·69	50·10	5·0	3·64	2·28	45·60
856	"	"	610	21·0	370	57·60	10·69	44·86	53·24	5·76	4·11	2·52	43·74

Siemens.

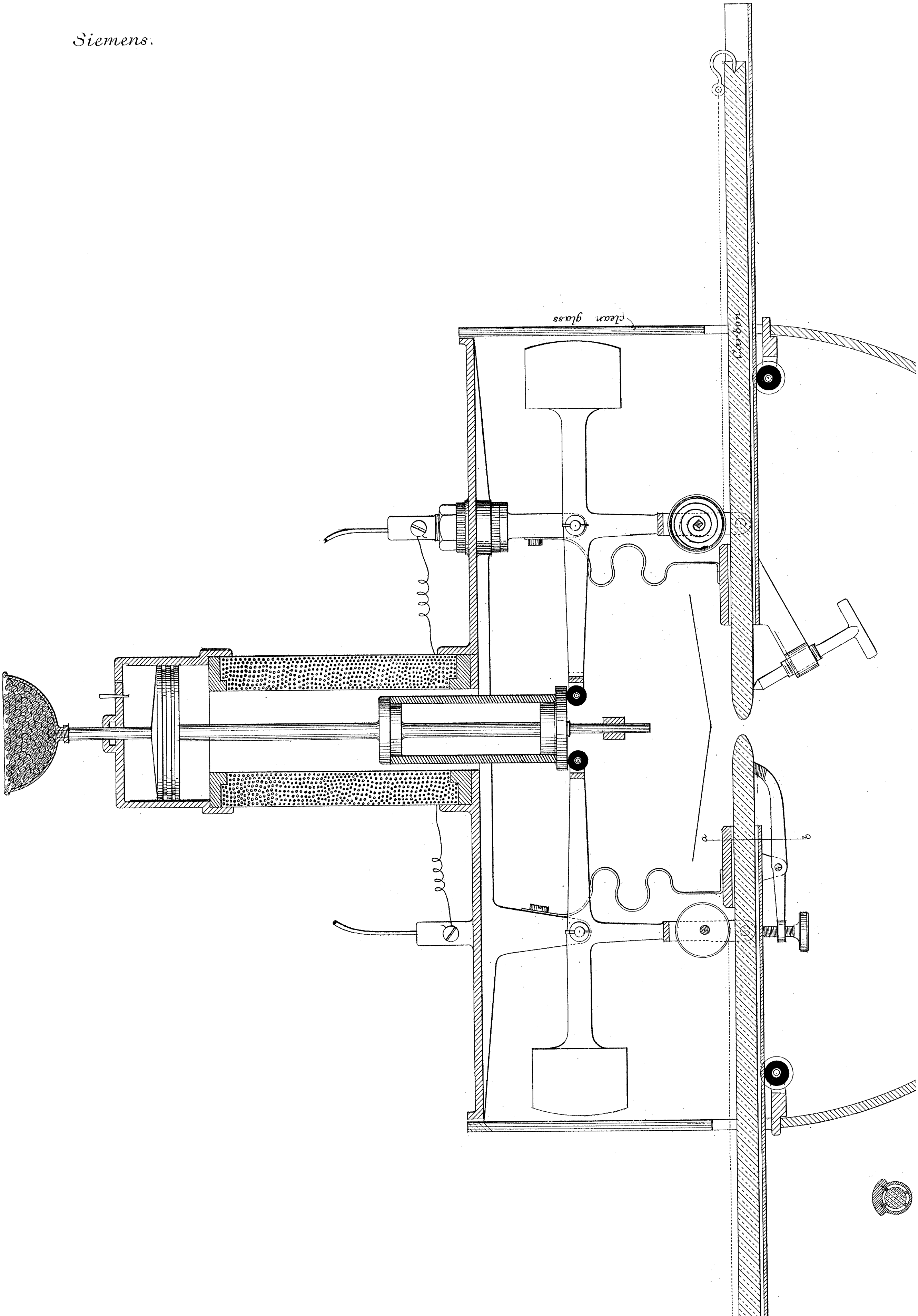
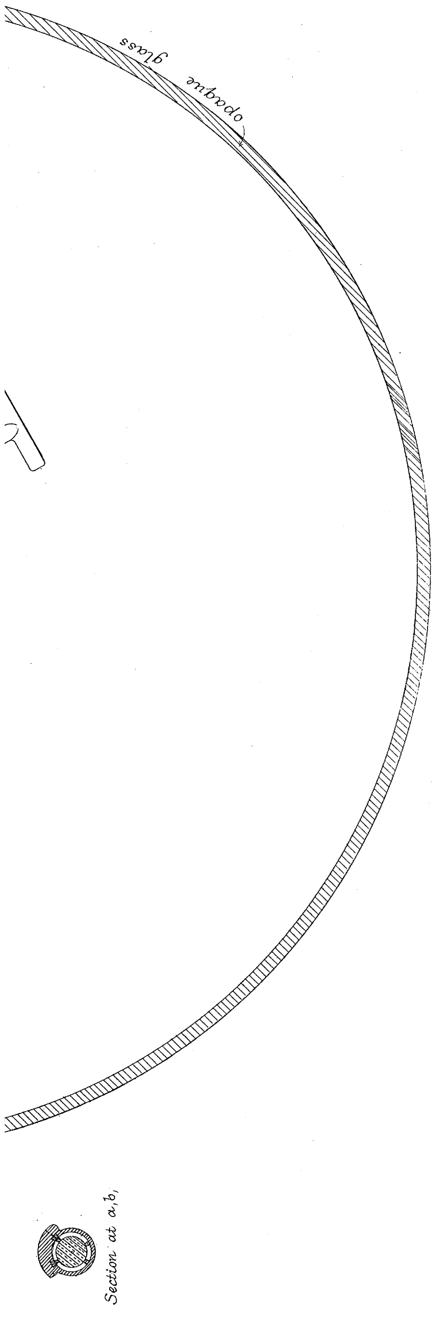
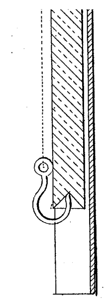


Plate 40.





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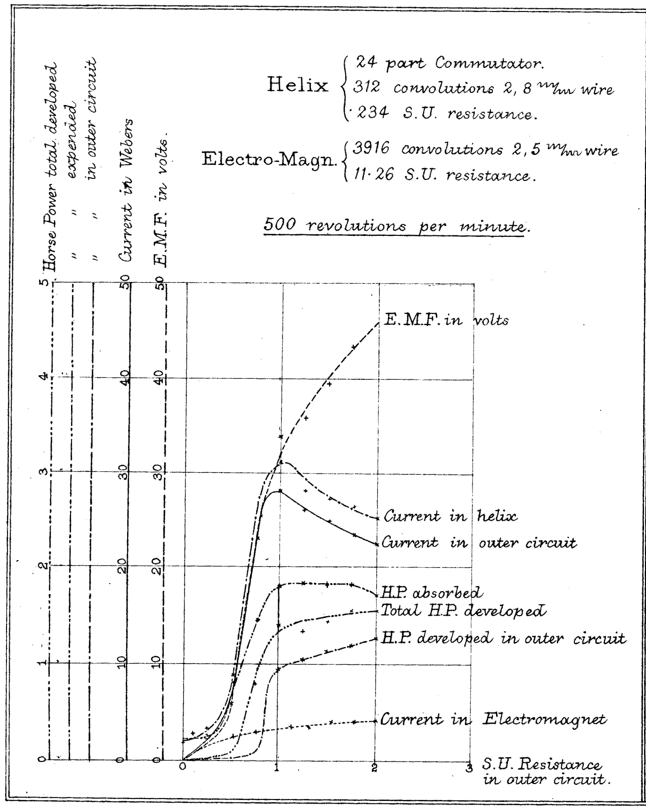
N° 1.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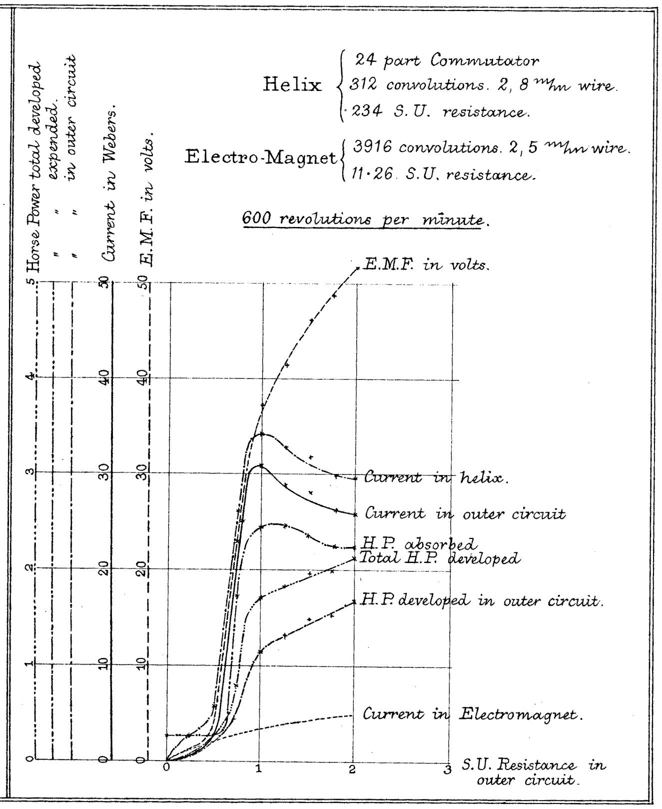
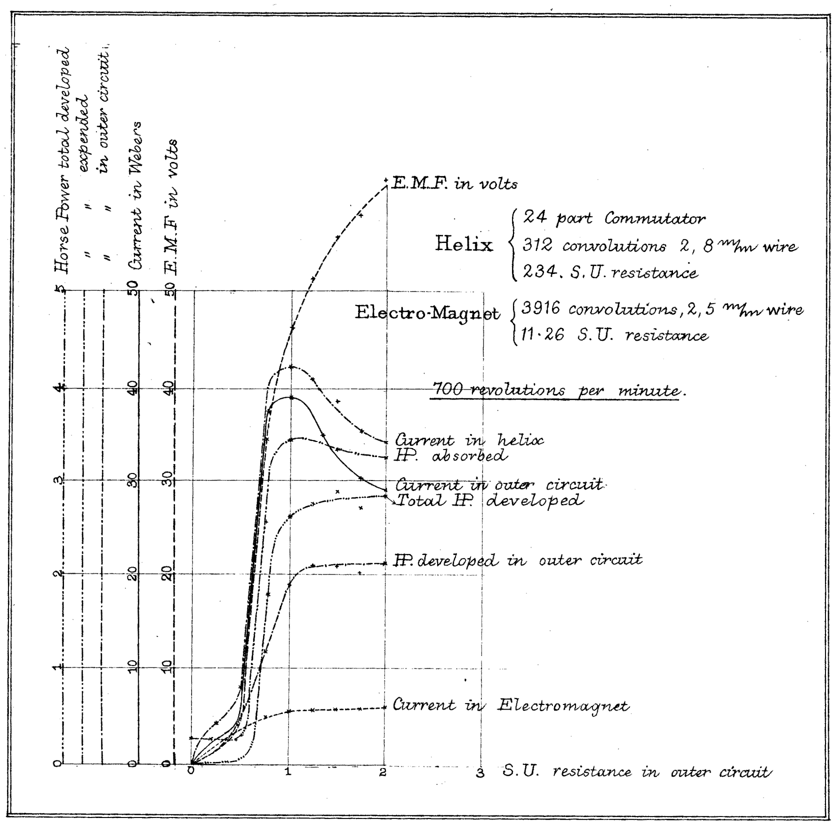
Electro-Magn. { 3916 convolutions 2, 5 m/m wire 11·26 S.U. resistance.
500 revolutions per minute.
Horse Power total developed
" " expended.
" " in outer circuit
Current in Webers
E.M.F. in volts.
E.M.F. in volts
Current in helix
Current in outer circuit
H.P. absorbed
Total H.P. developed
H.P. developed in outer circuit
Current in Electromagnet
S.U. Resistance in outer circuit.

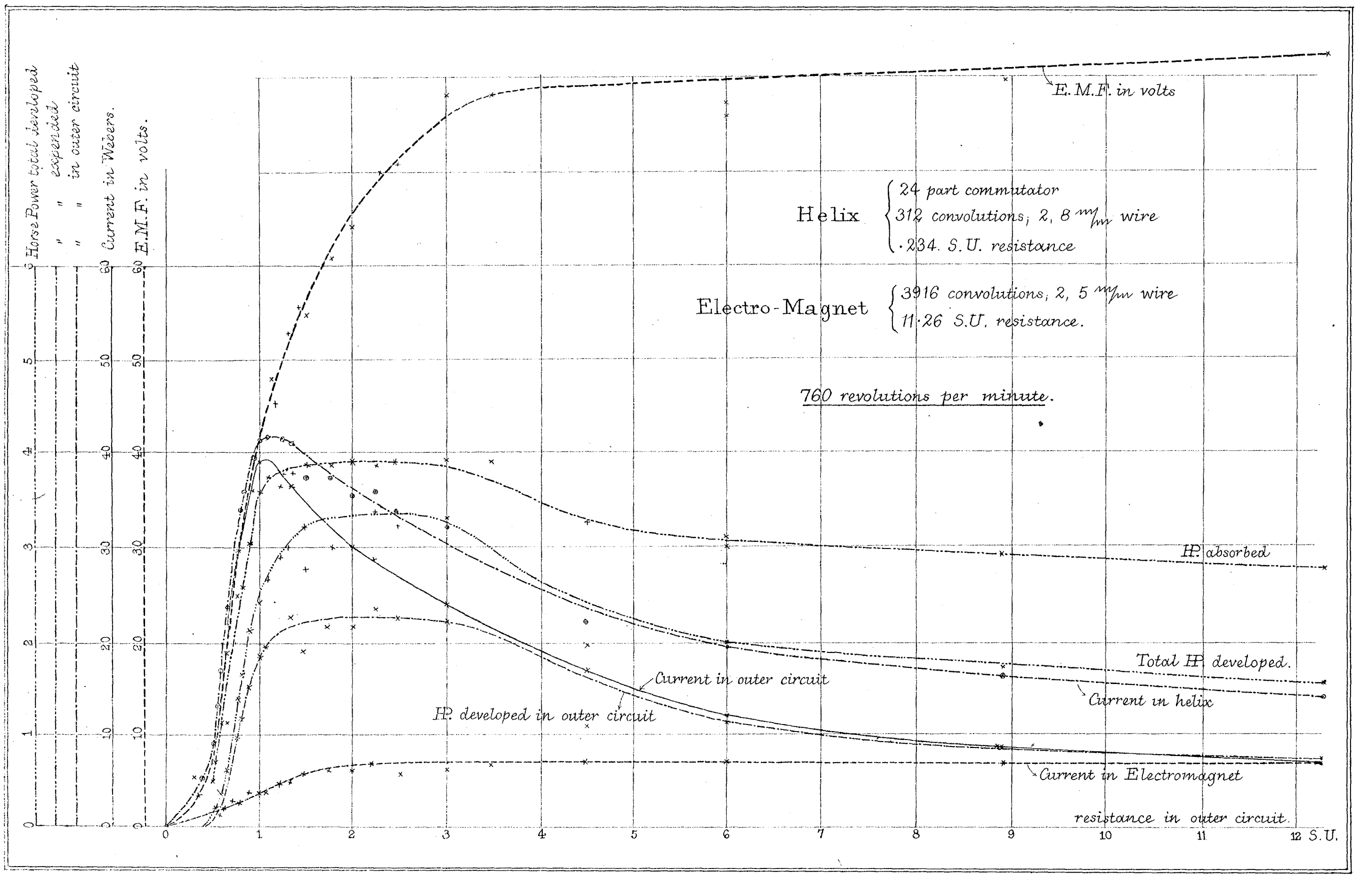
N° 2.


Helix { 24 part Commutator 312 convolutions. 2, 8 m/m wire. ·234 S.U. resistance.
Electro-Magnet { 3916 convolutions. 2, 5 m/m wire. 11·26. S.U. resistance.
600 revolutions per minute.
Horse Power total developed
" " expended.
" " in outer circuit
Current in Webers.
E.M.F. in volts.
E.M.F. in volts.
Current in helix.
Current in outer circuit
H.P. absorbed
Total H.P. developed
H.P. developed in outer circuit.
Current in Electromagnet.
S.U. Resistance in outer circuit.

N° 3.


Horse Power total developed
" " expended
" " in outer circuit.
Current in Webers
E.M.F in volts
E.M.F. in volts
Helix { 24 part Commutator 312 convolutions 2, 8 m/m wire 234. S.U. resistance
Electro-Magnet { 3916 convolutions, 2, 5 m/m wire 11·26 S.U. resistance
700 revolutions per minute.
Current in helix
H.P. absorbed
Current in outer circuit
Total H.P. developed
H.P. developed in outer circuit
Current in Electromagnet
S.U. resistance in outer circuit

No. 4.



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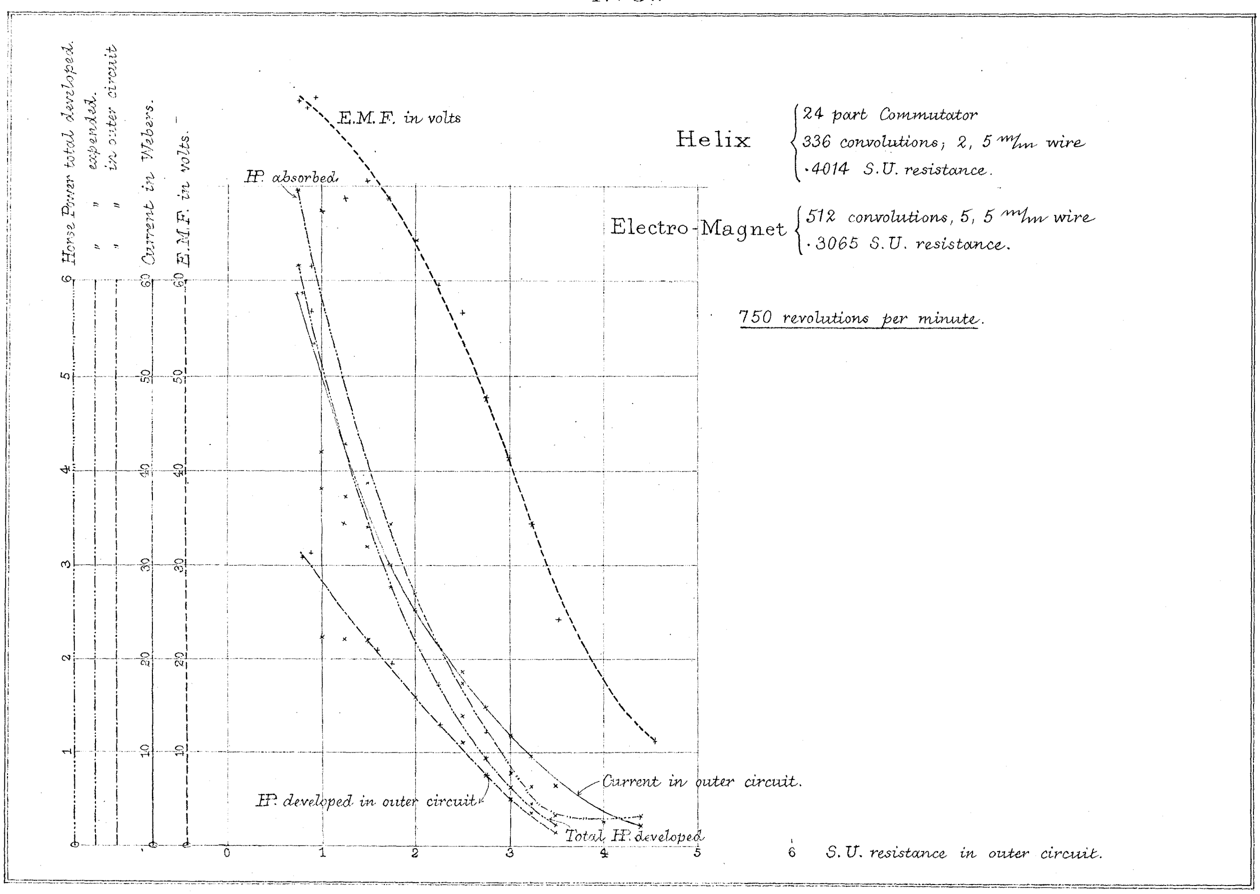

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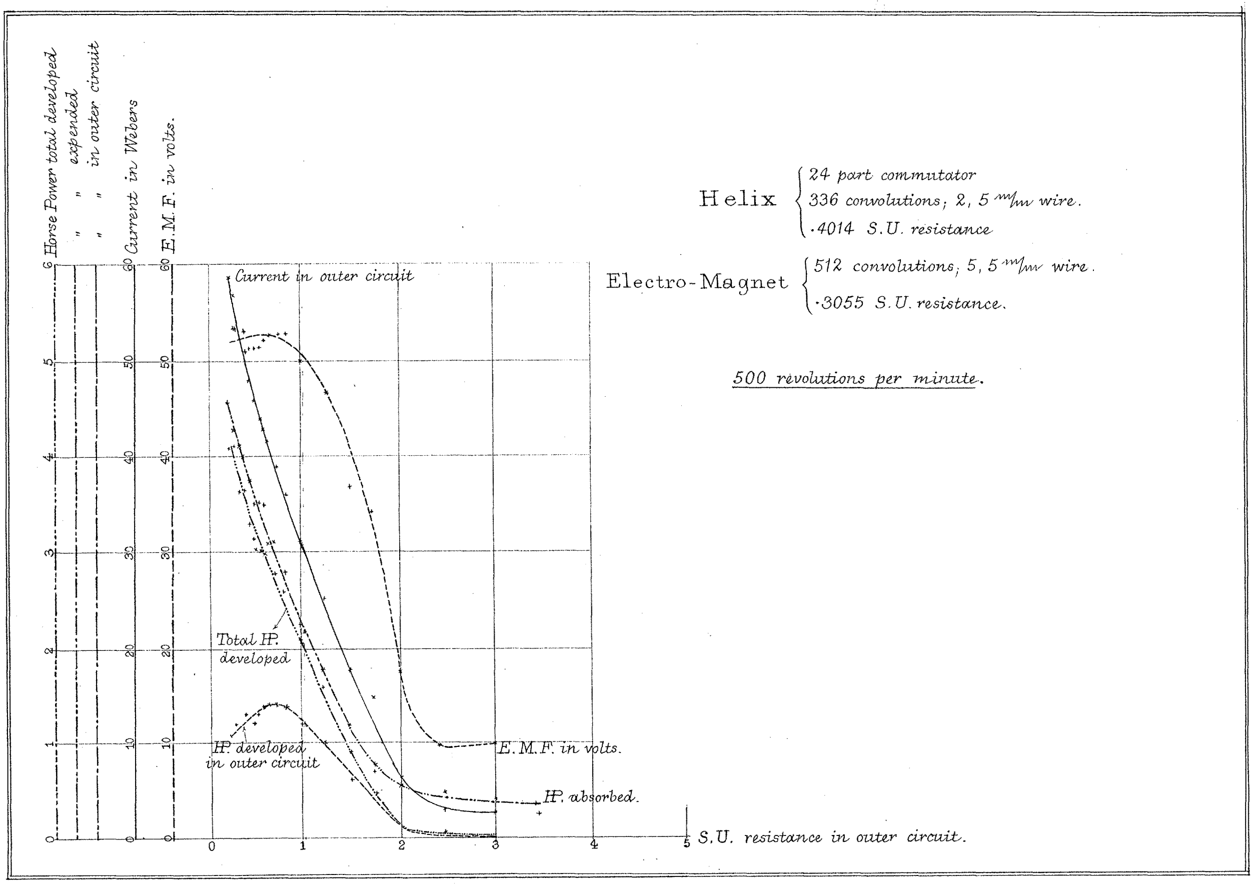

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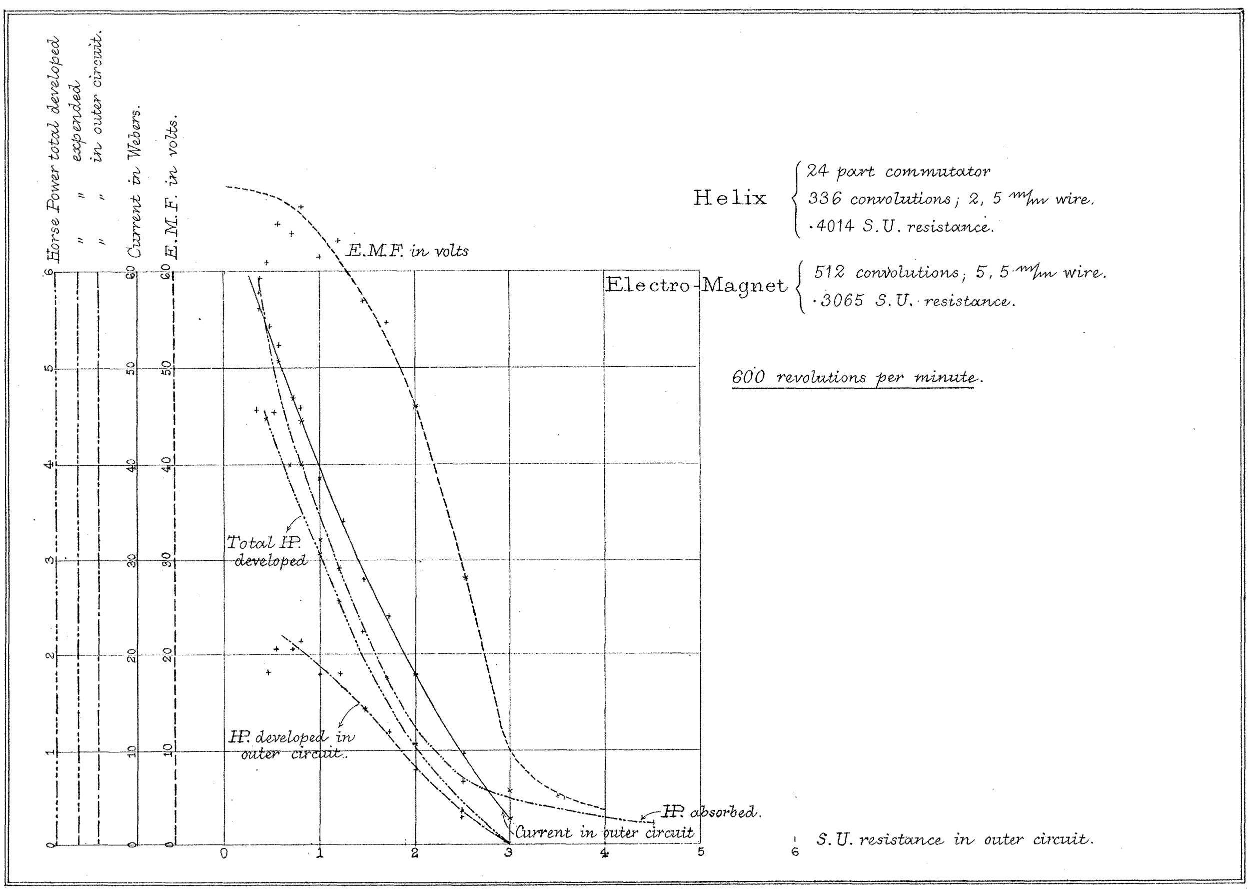

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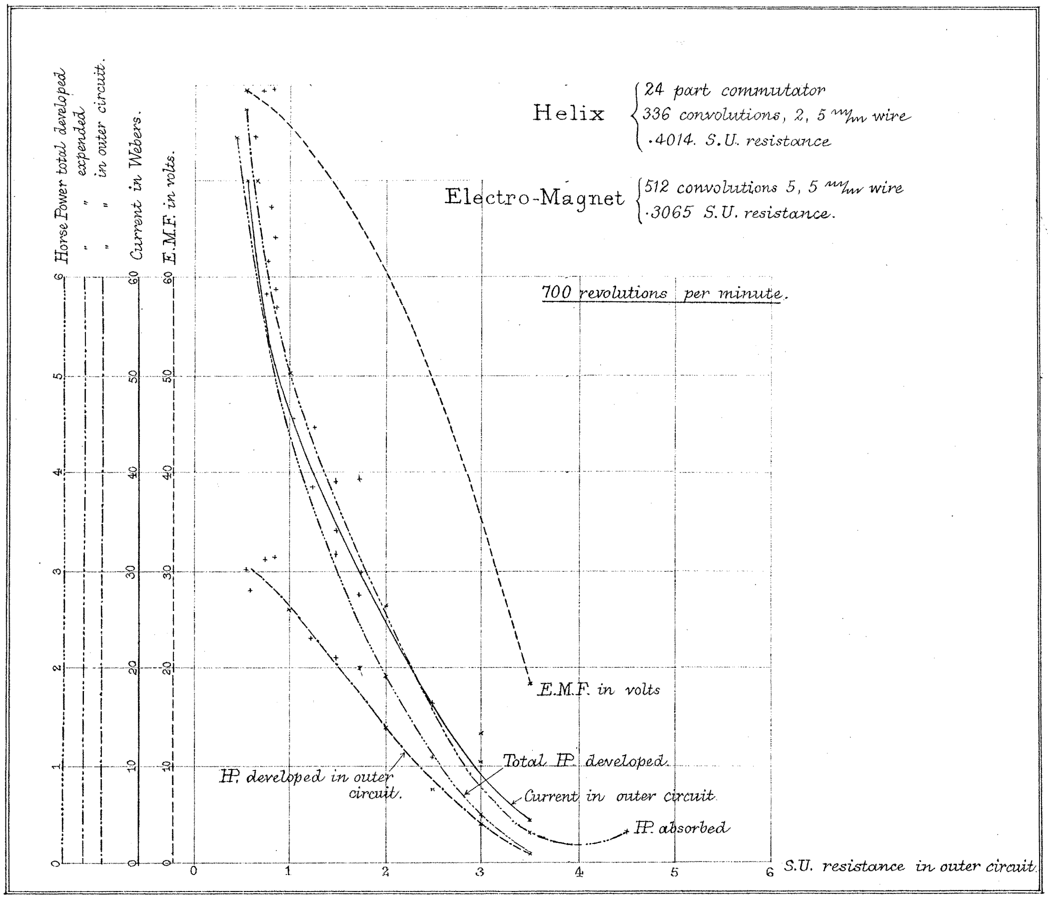

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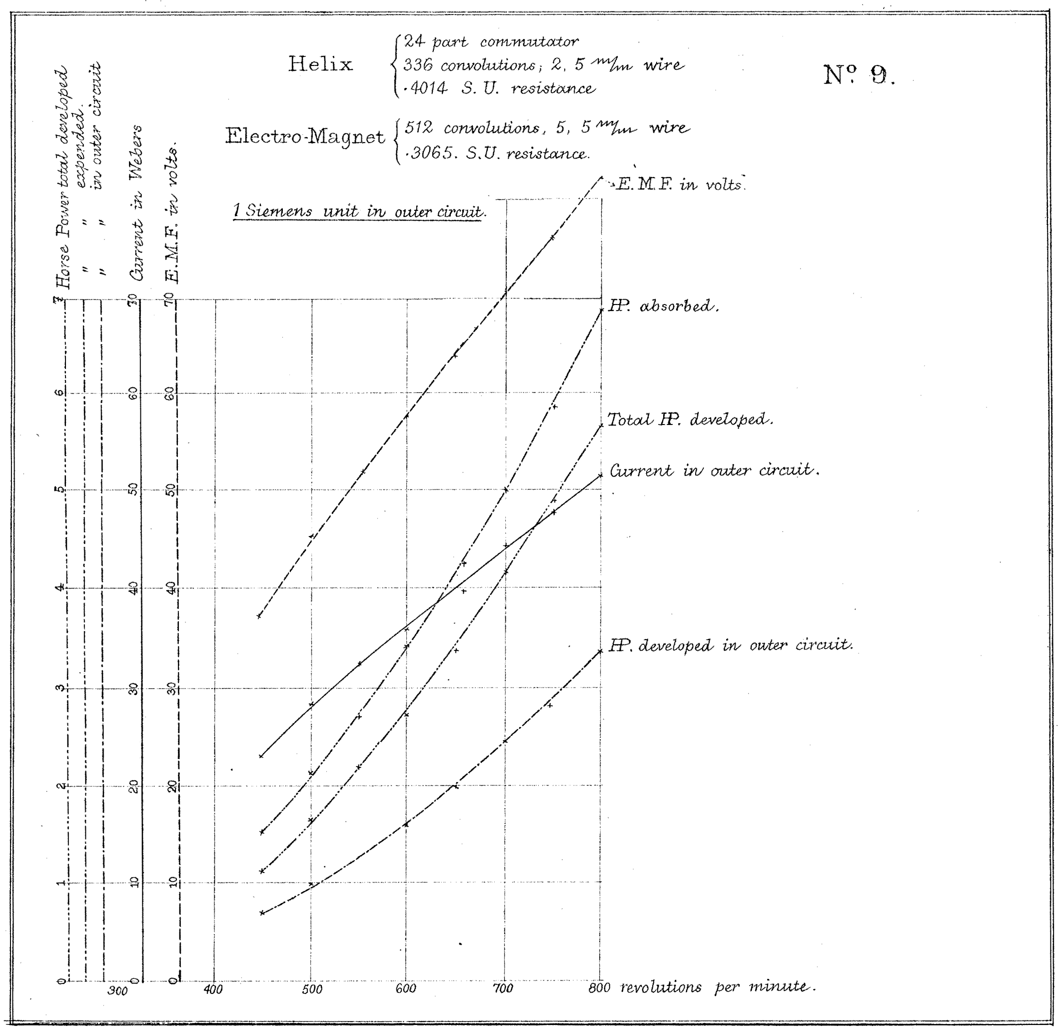

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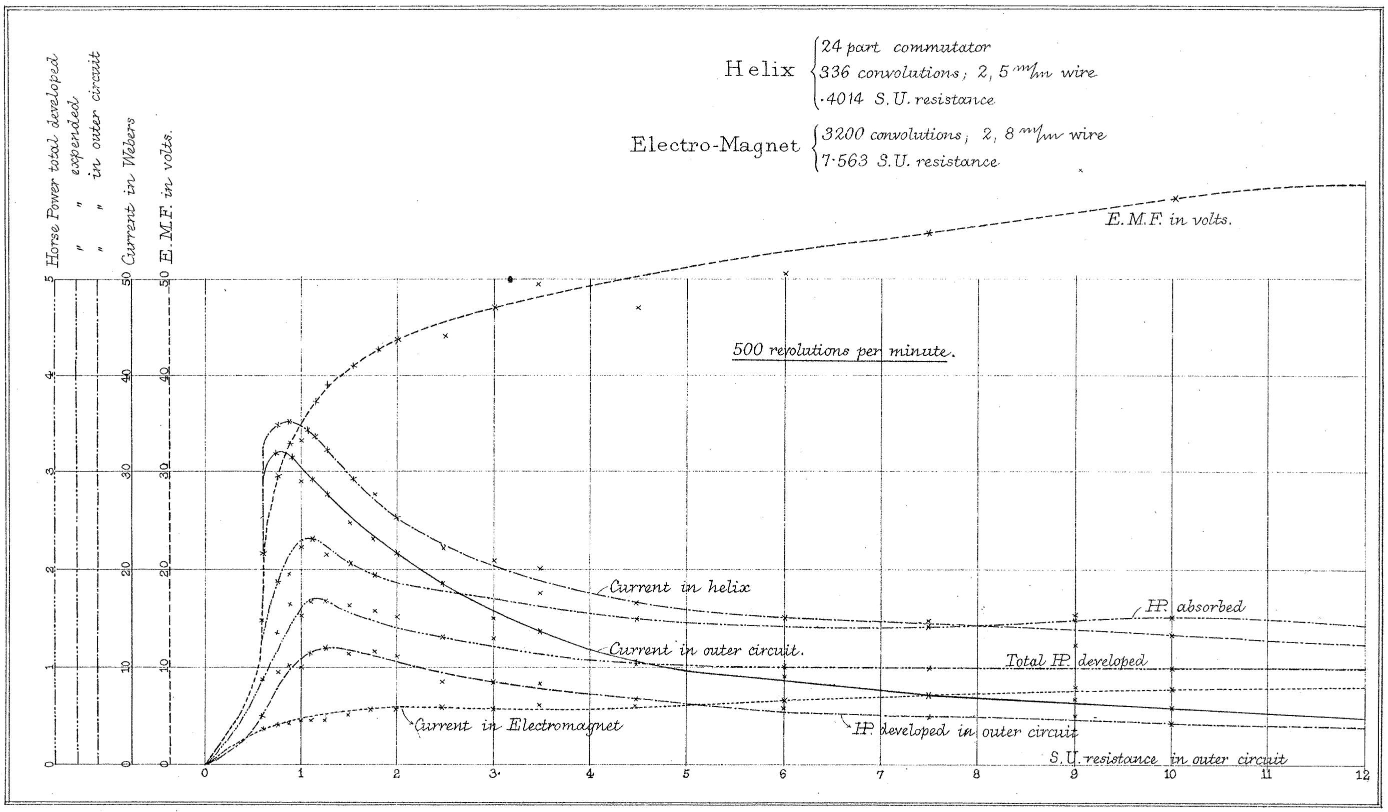

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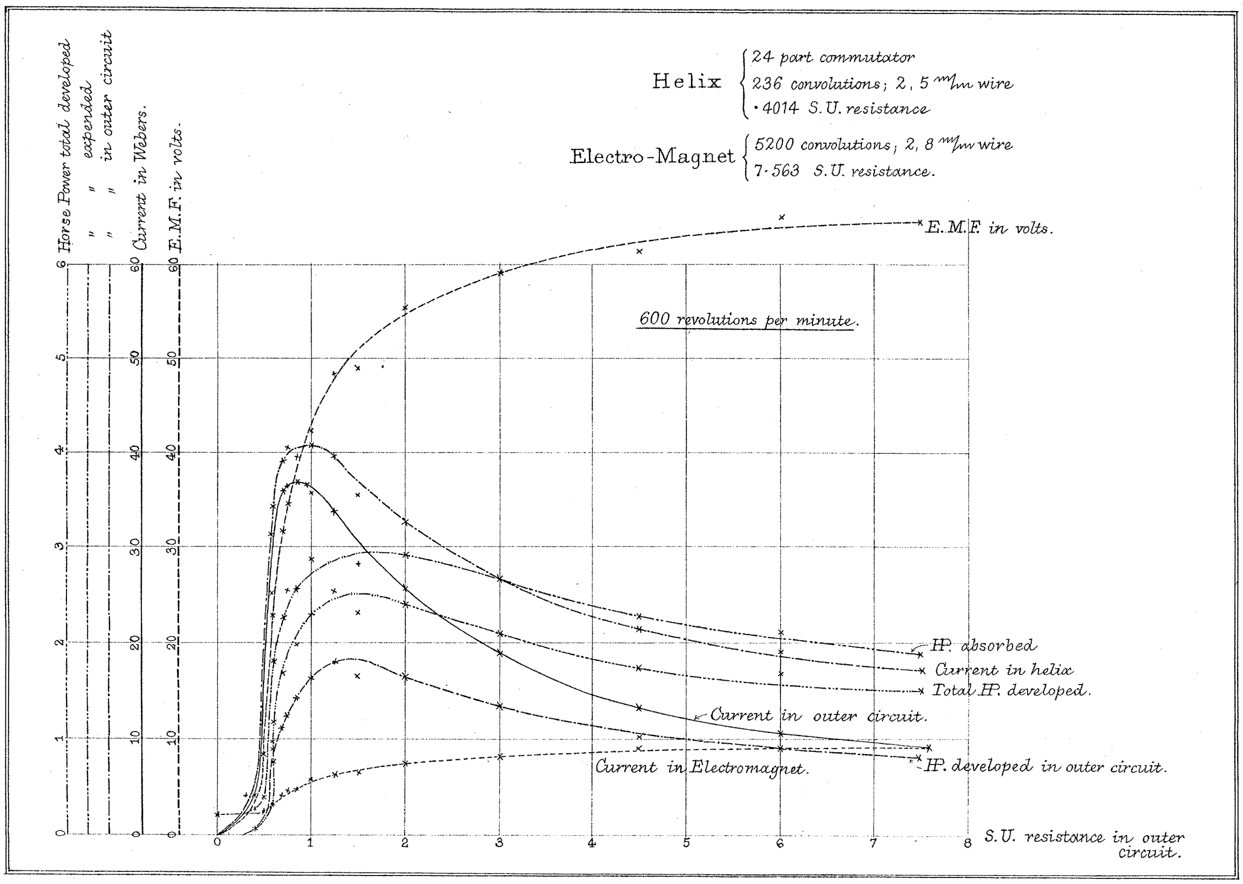

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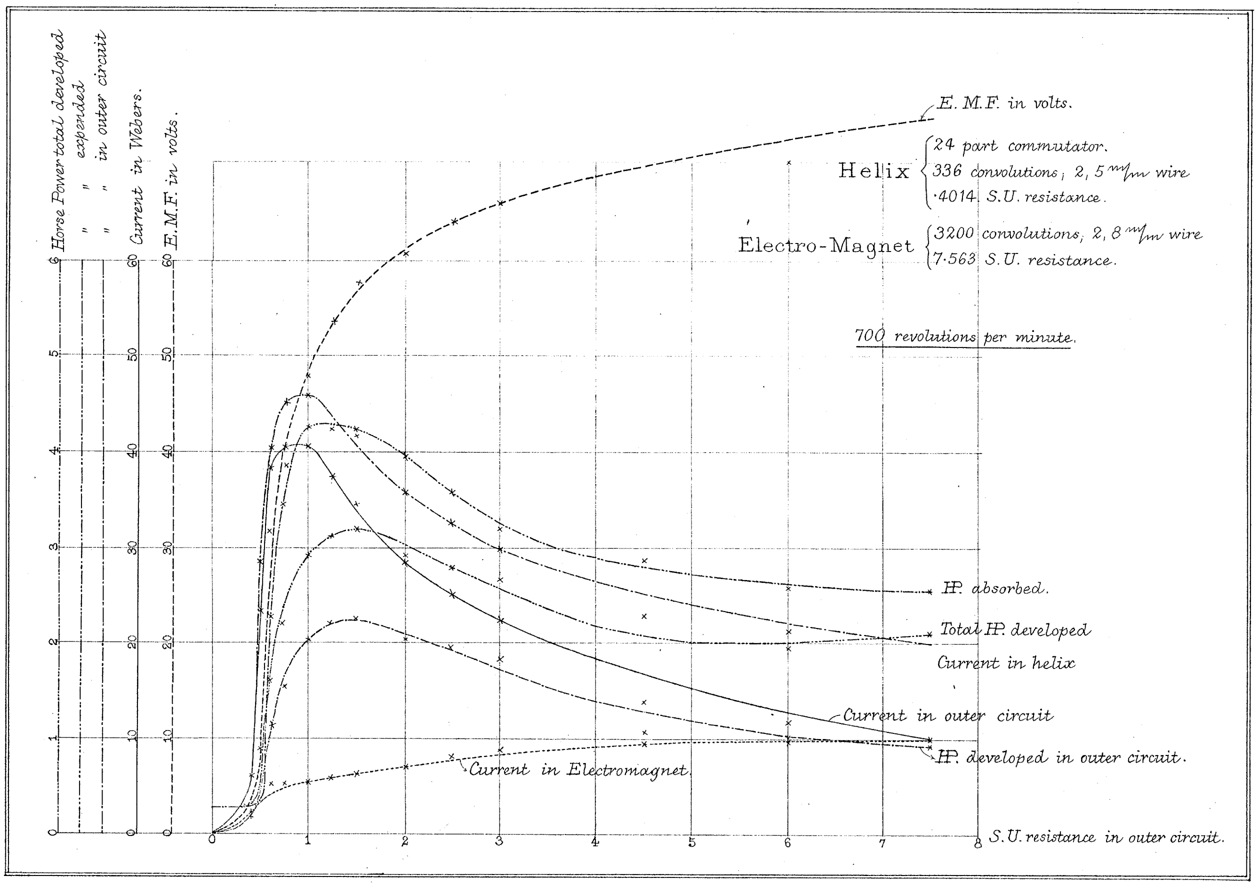

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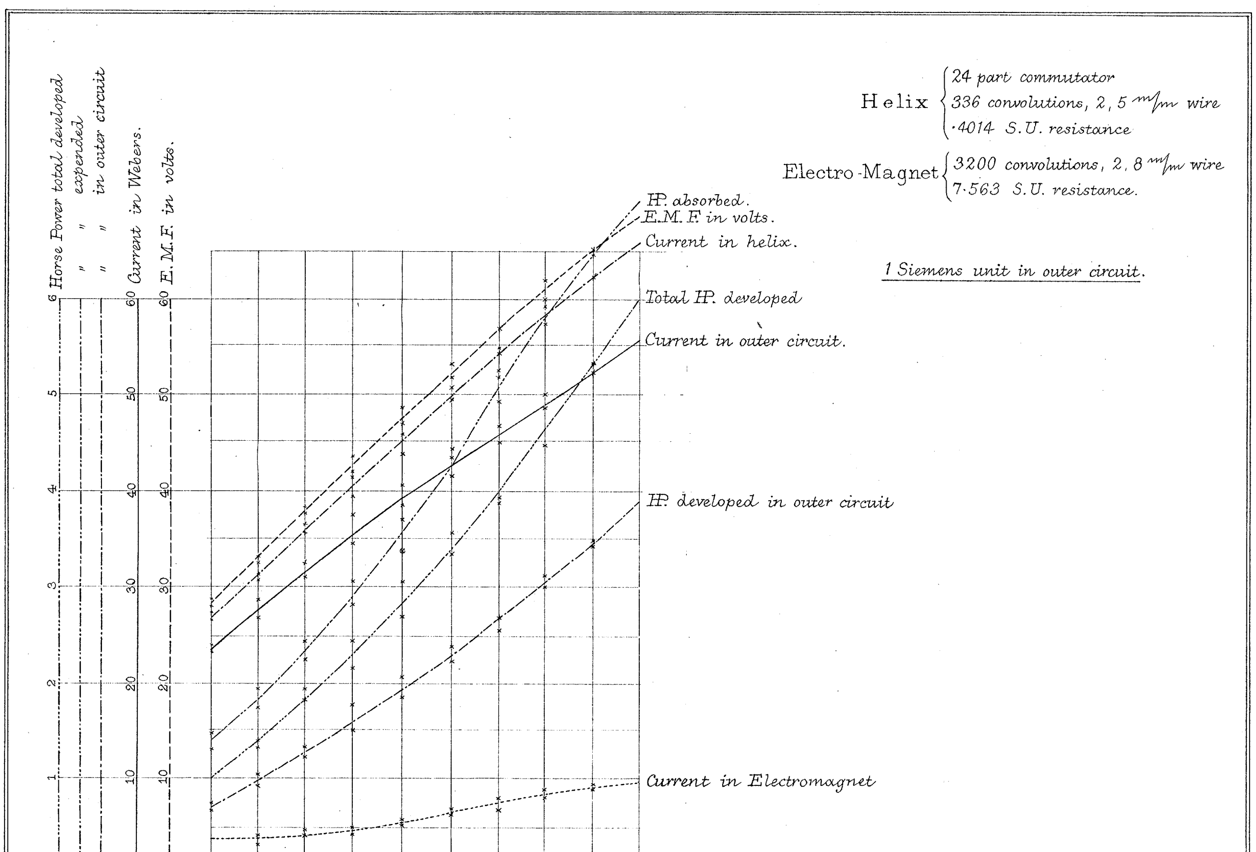

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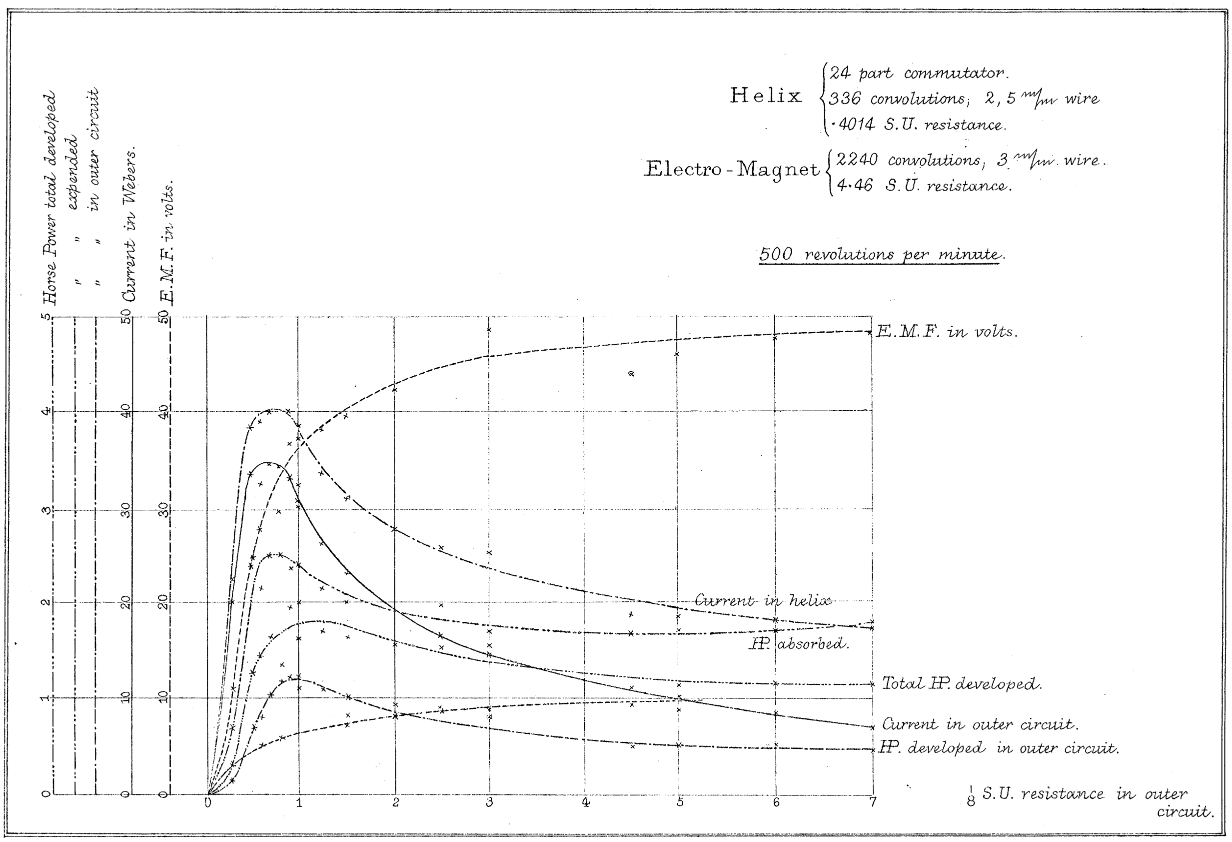

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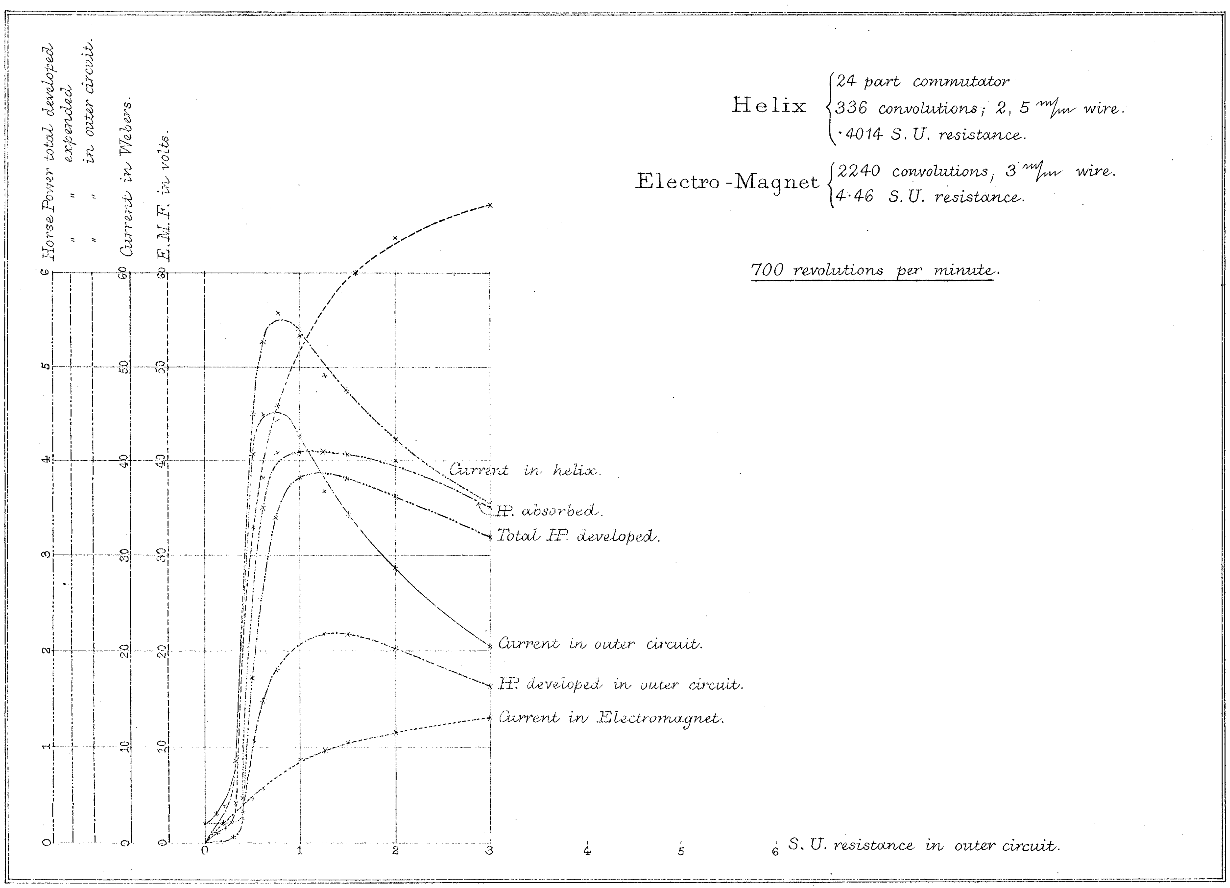

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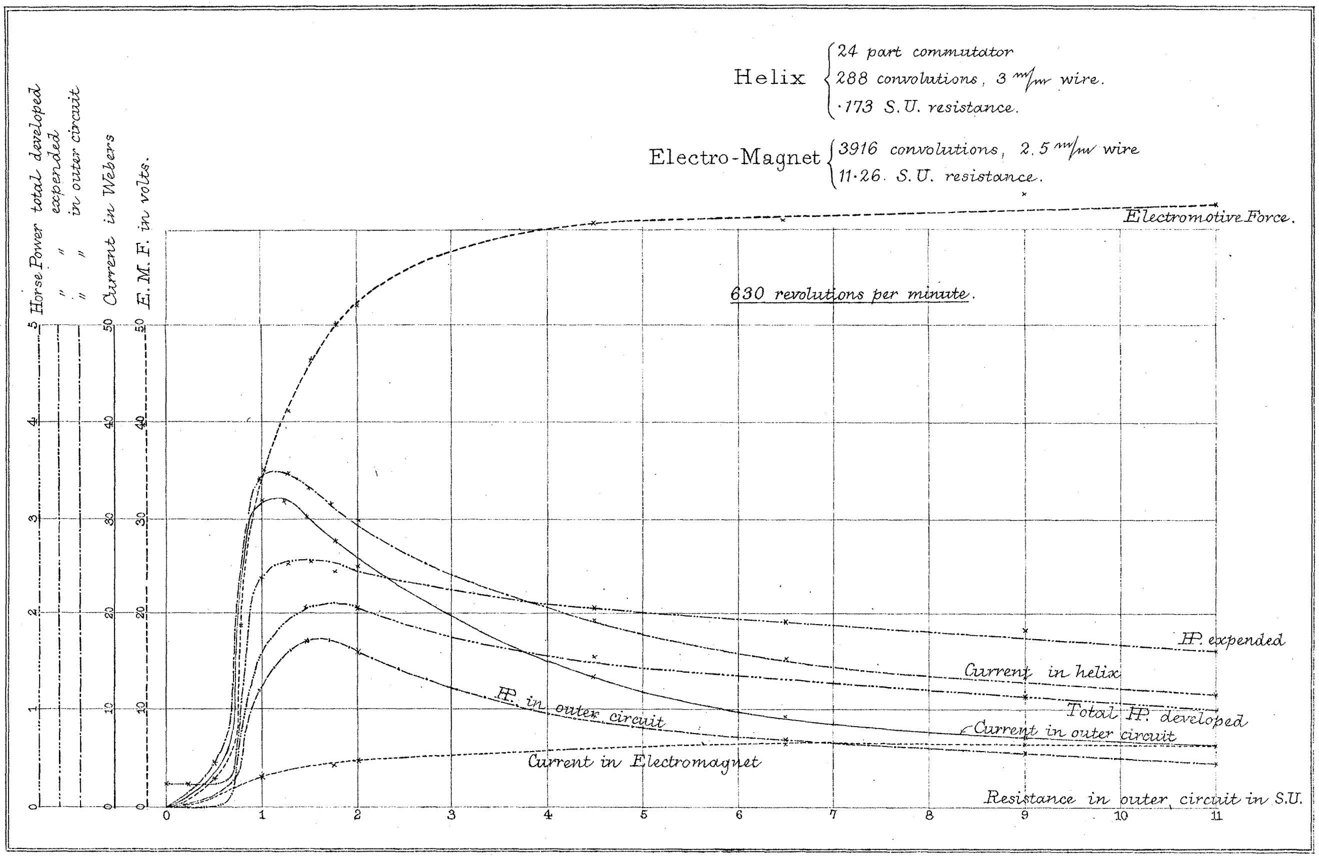

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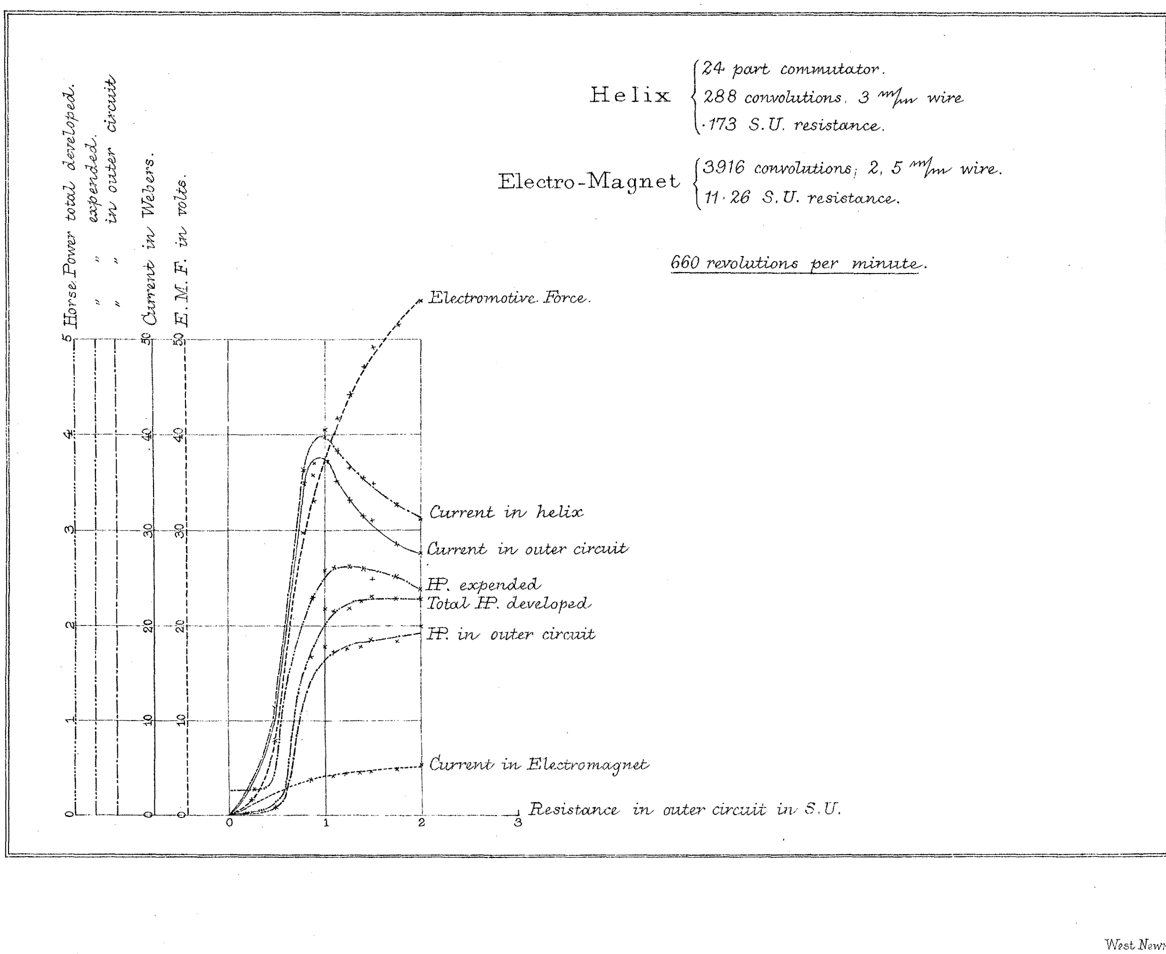

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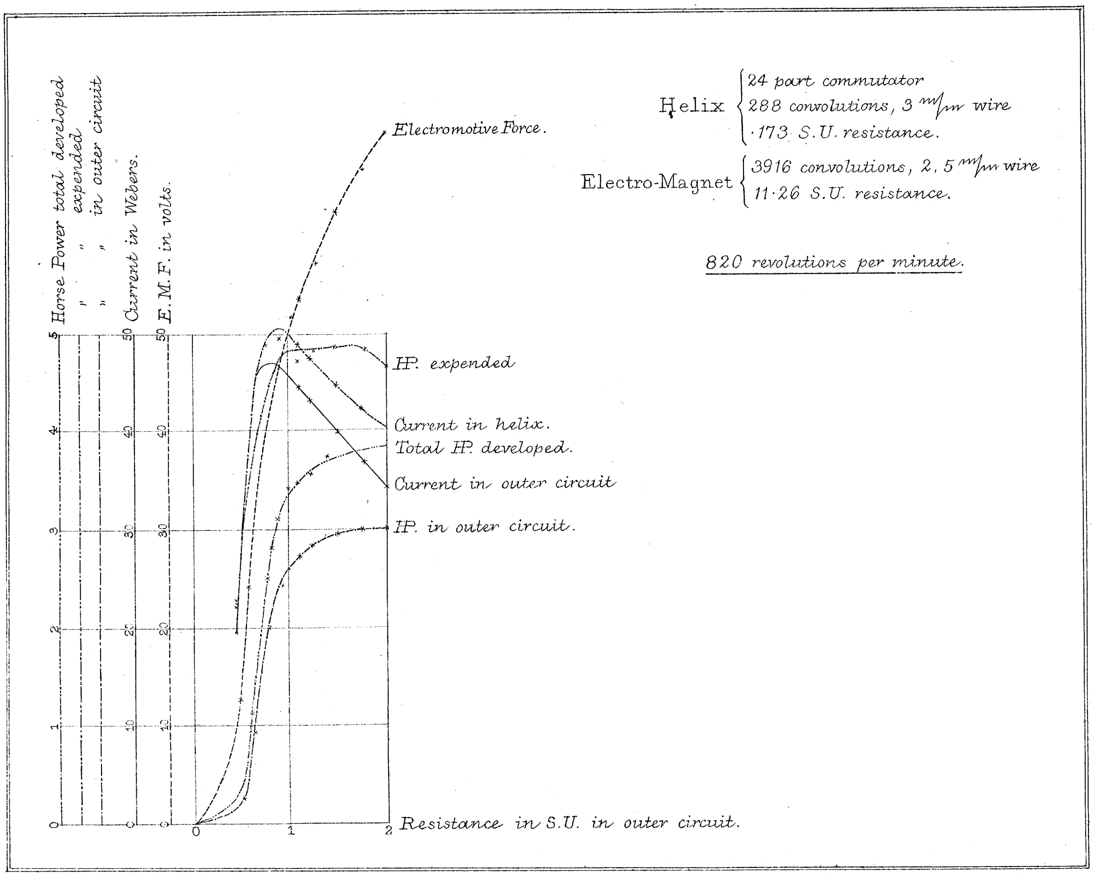

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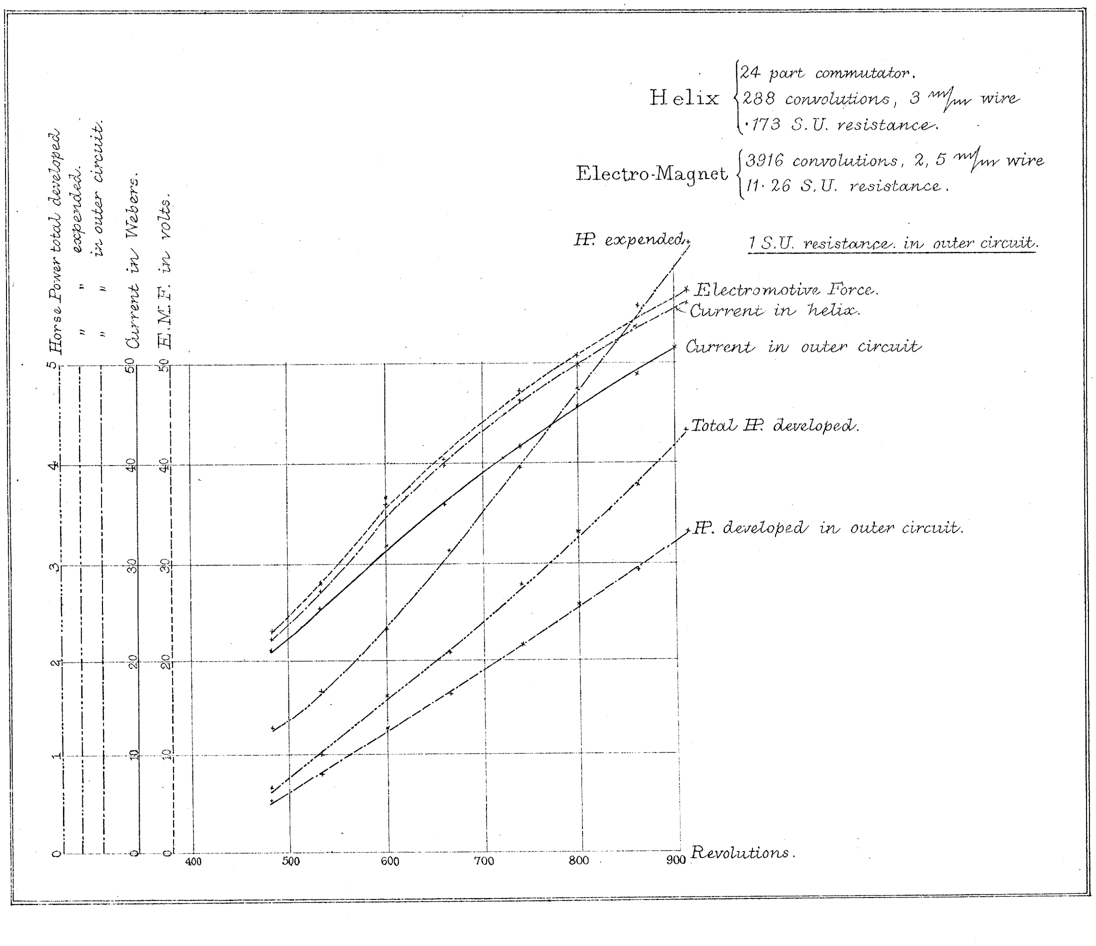

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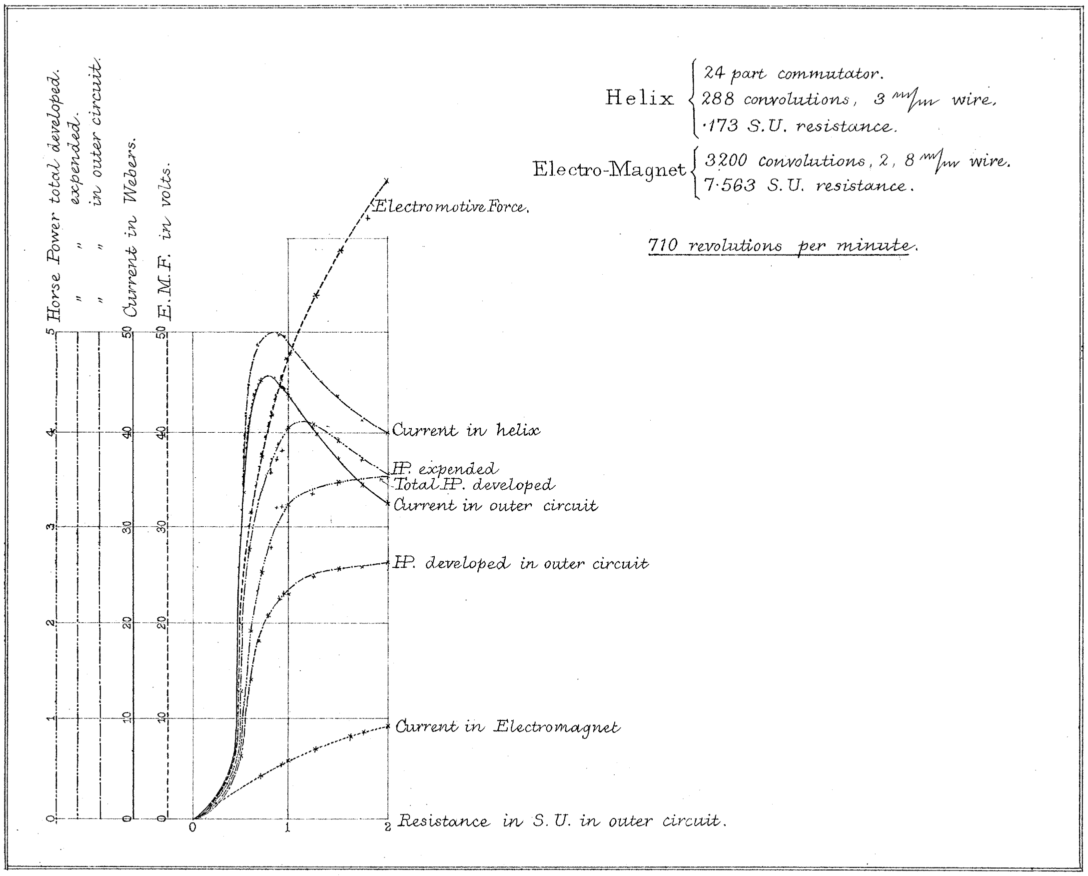

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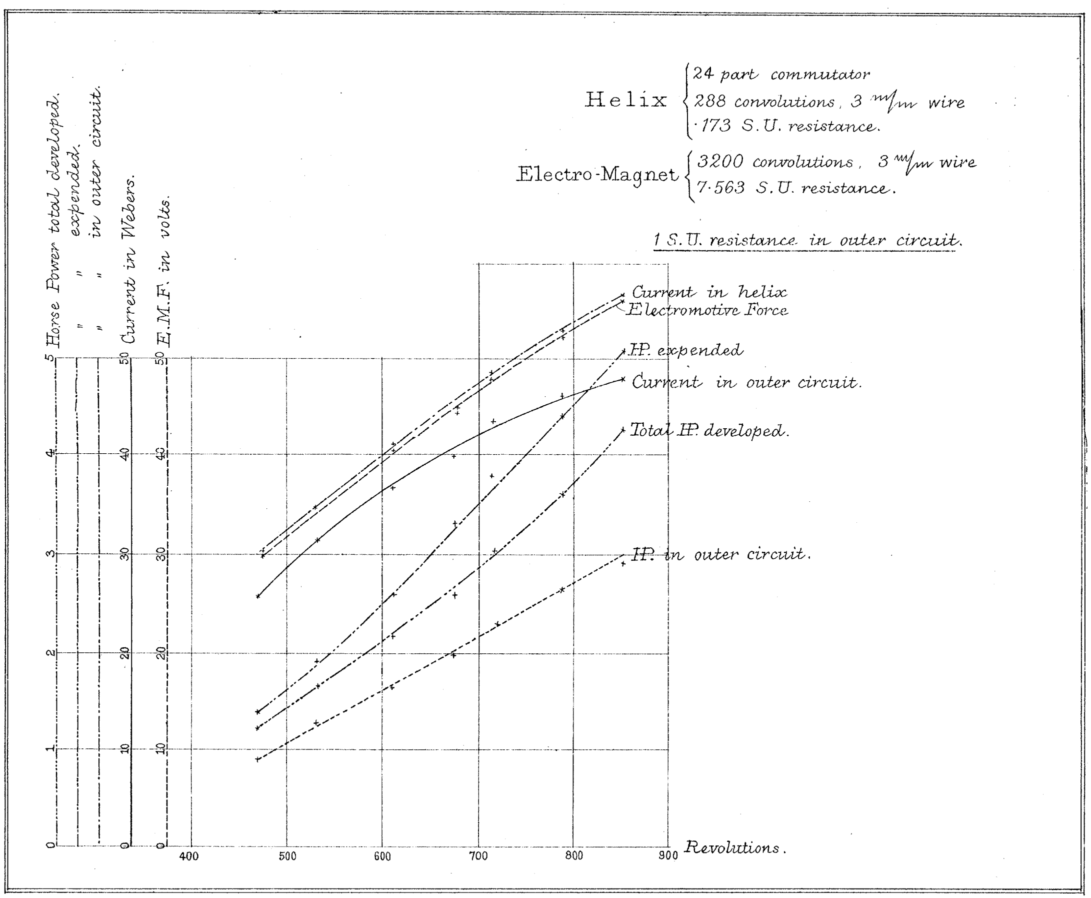

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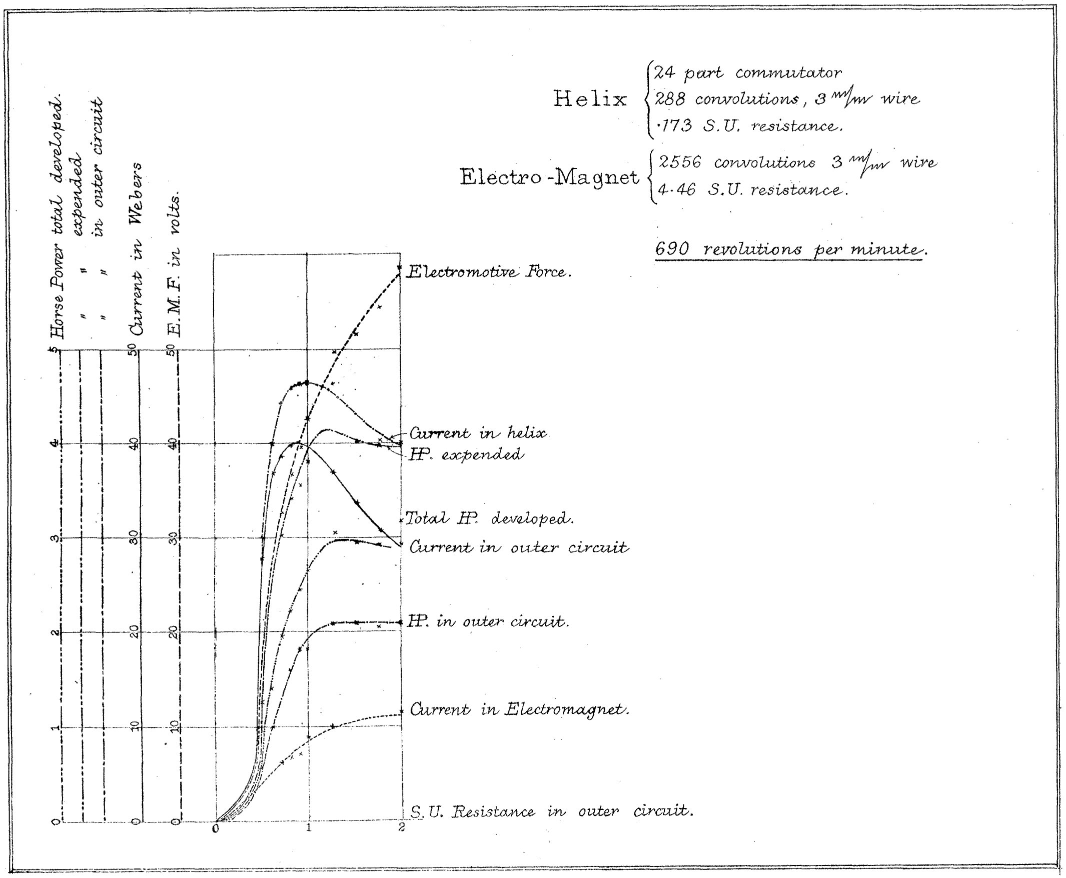

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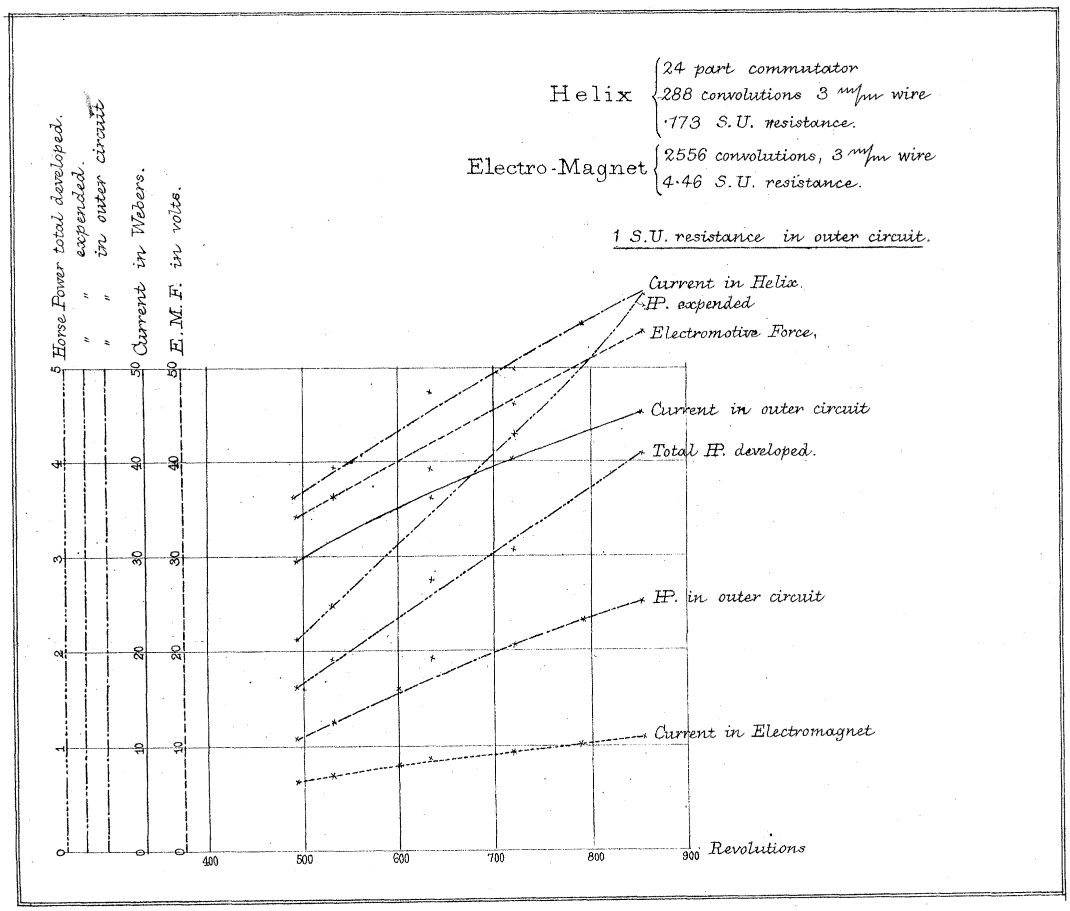

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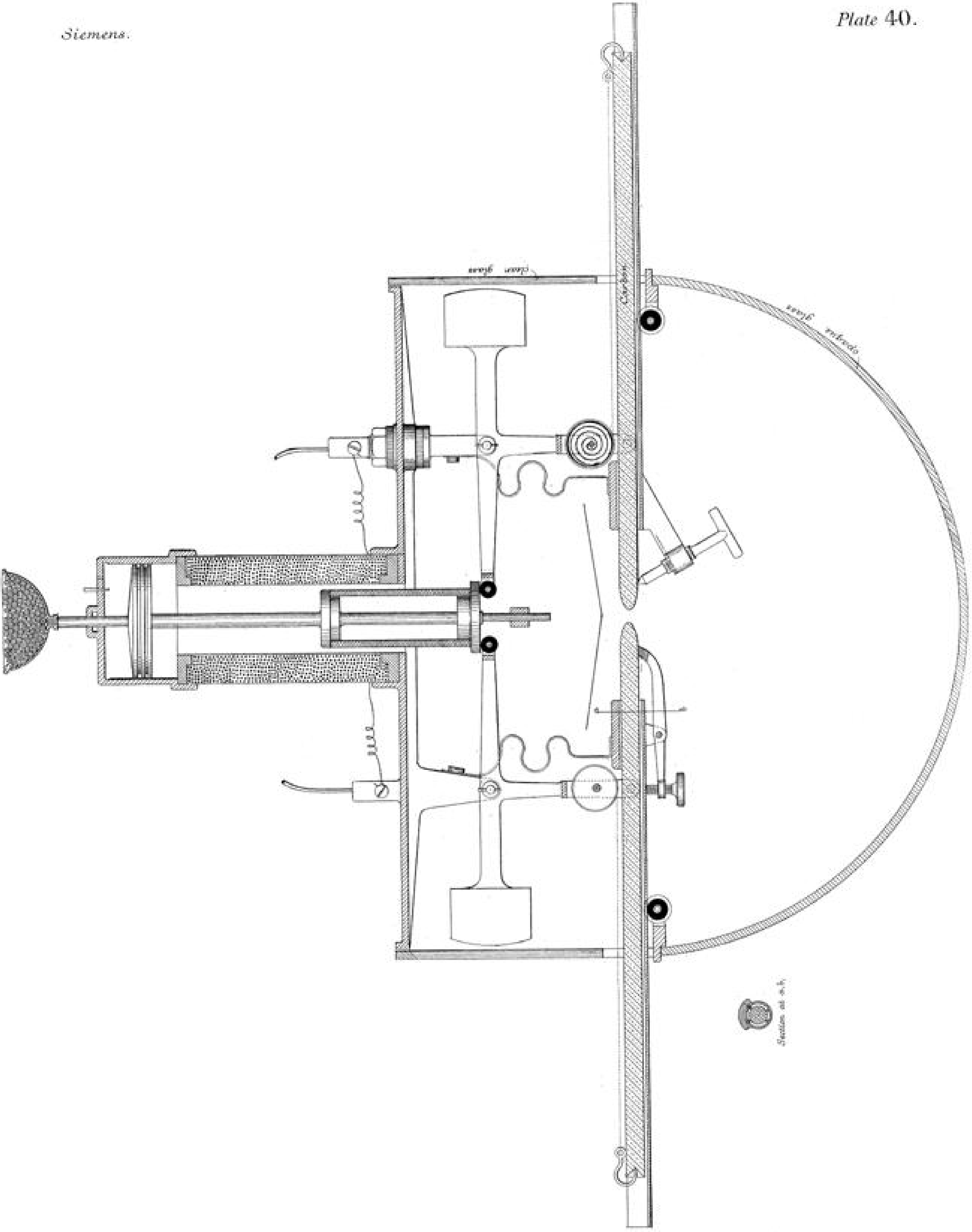
LIST OF ILLUSTRATIONS.

ERRATUM.

Page 1071, *for* Plates 40–52, *read* Plates 40–51.

Siemens. Plate 40.



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