COMPARATIVE TESTS

of

SINGLE AND THREE PHASE MOTORS.

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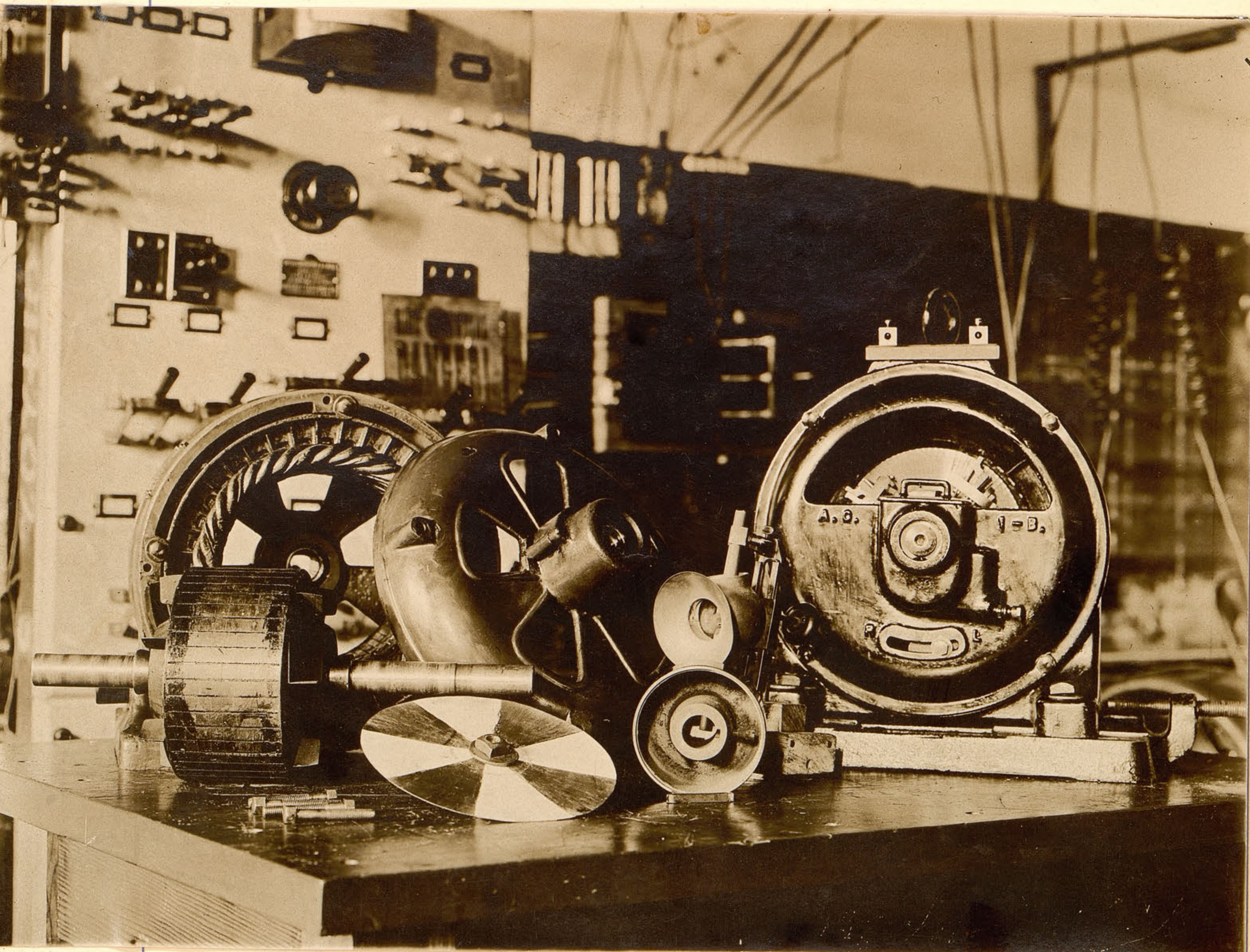
C.I. Weaver.

Outline.

1. Construction.
2. Theory.
3. Advantages.
4. Curve Discussion.
5. The Heyland Diagram.

THE MOTOR DISMANTLED.



COMPARATIVE TESTS OF SINGLE AND THREE PHASE INDUCTION MOTORS.

2 HP Three Phase Induction Motor,
No. 83362, Type 1,
Form K.
1800 R.P.M., 110 Volts, 60 Cycles,
12 amperes.

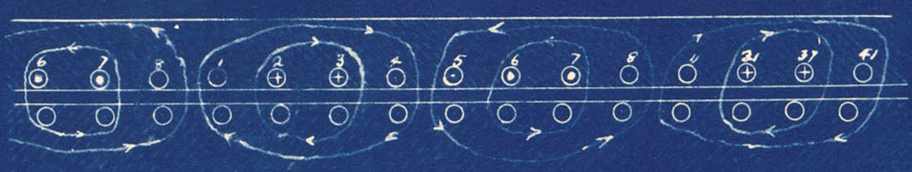
The primary or rotor of the motor is mounted in a hollow cylindrical frame of cast iron. This frame also forms the base of the machine and supports two end plates which contain the rotor bearings. The bearings consist of brass boxes arranged to be lubricated by two rings in each bearing. These rings revolve as the shaft turns carrying the oil from a chamber below the bearings.

The primary consists of an iron core which is built up of sheet steel stampings. The core is firmly bolted to the frame. The conductors, which are copper wires or bars, depending upon the size of the machine, are placed in grooves in the core. These coils are insulated from the core and from each other where more than one conductor is placed in a slot. The windings, which are (y) connected, are held in the slots by thin wedges of tough wood, to protect the winding from mechanical injury, and also from the mechanical pull due to the reaction of the flux in the rotor.

The secondary member or rotor is built up of laminated sheet steel. The laminae are insulated from each other by sheets of tissue paper or by a coating of japan, in order to reduce the loss by eddy currents which are induced by the flux. The conductors in this member are heavy copper bars which are short circuited at the ends of the rotor by heavy copper plates. These conductors are imbedded in nearly closed slots in the core, from which they are insulated by thin strips of mica. There are no electrical connections between this member and the primary member. This form is called the squirrel cage motor, an induction motor having a squirrel cage rotor, requires from three to four times the normal full load current at starting to produce a torque equal to that developed when running at full load. For this reason it is undesirable where large motors are to be used, but on the other hand its simplicity and its ability to carry enormous currents without injury compensates in a degree for the disadvantage it has of drawing excessive currents from the line when starting.

PLATE. I.

Fig. 1.



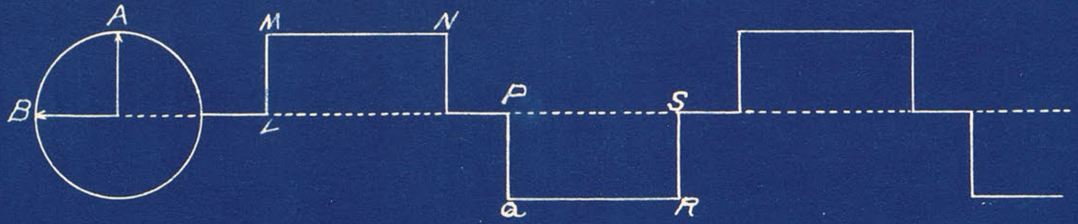
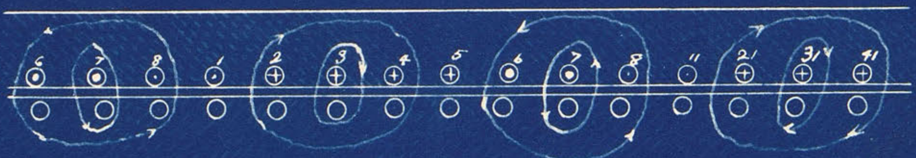


Fig. 2.



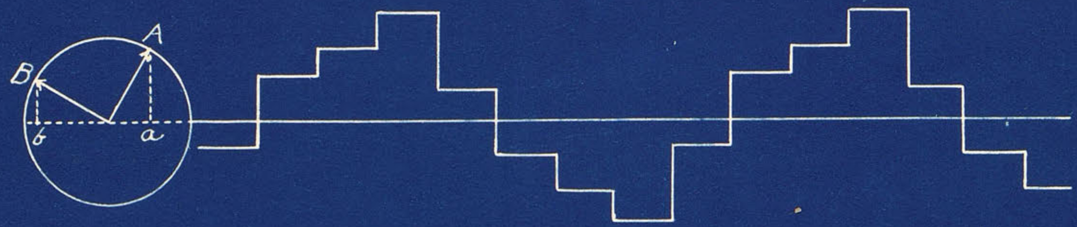
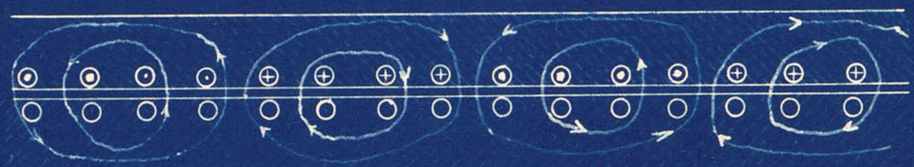


Fig. 3.



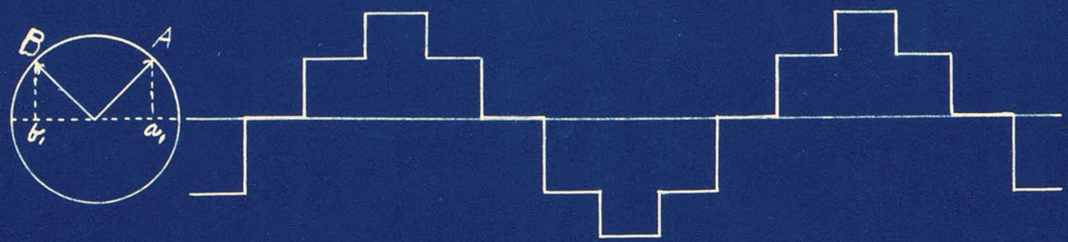
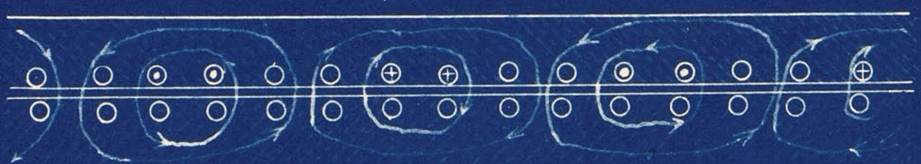


Fig. 4.



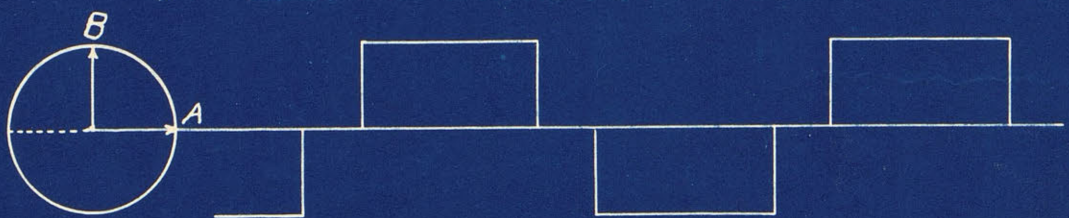
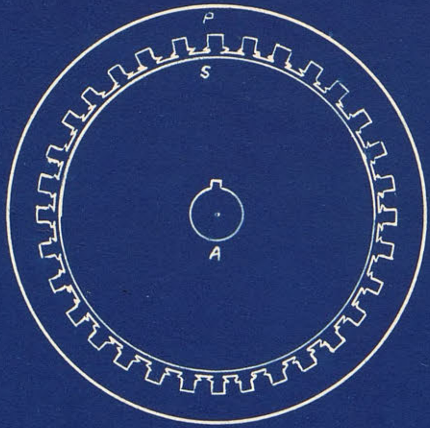
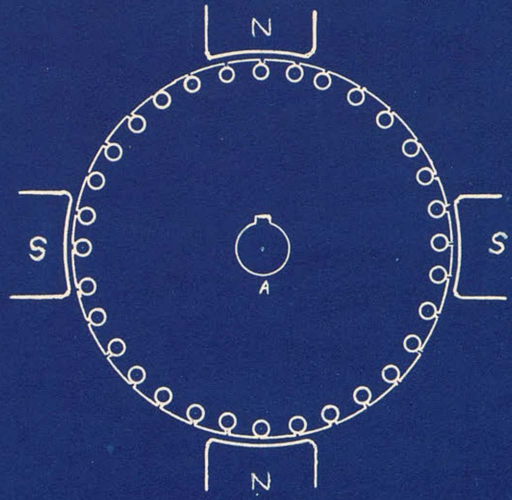


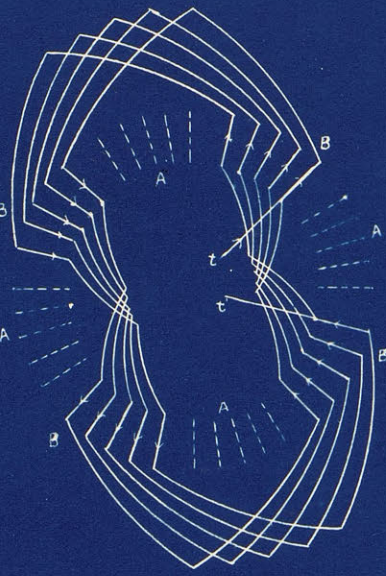
PLATE 2



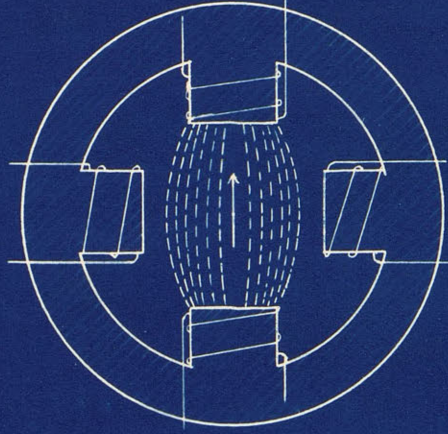
F/G. 1



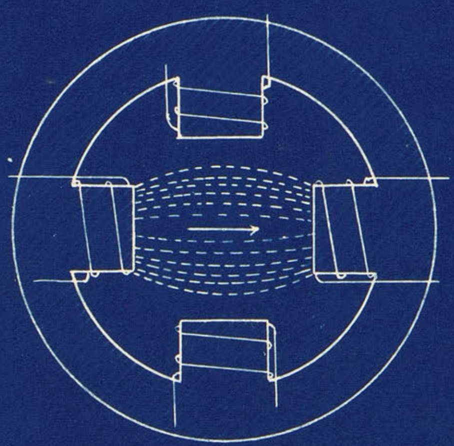
F/G. 2



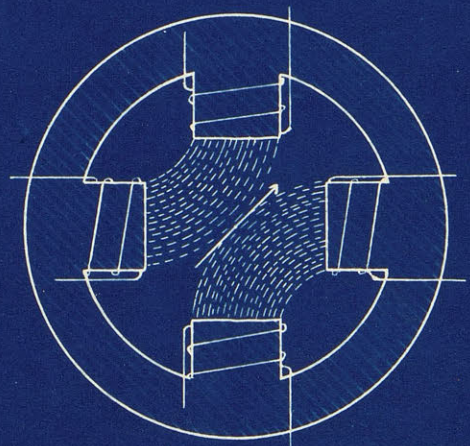
F/G. 3



F/G. 4



F/G. 5



F/G. 6

C.I.W.

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TWO HORSE POWER WAGNER SINGLE PHASE MOTOR,

No. 7038.

Type A.C. 1, Model B, 60 Cycles,

104 Volts, 1800 R.P.M.

This motor has a four pole stator. The poles are composed of laminated sheet steel, upon which the windings are placed instead of being wound in slots as in the polyphase machines. The rotor of this machine is an ordinary direct current drum wound armature, but is provided with a disc commutator having radial bars.. The brushes are held against the commutator by means of a centrifugal governor, so that when the machine reaches full speed the brushes are thrown out from the commutator and a solid copper bar pressed against the commutator segments. Thus short circuiting all of the armature conductors and the rotor becomes a squirrel cage working from a single phase.

STARTING DEVICES.

Figure 1, Plate III, shows the arrangement and connections of a motor and auto-starter, or compensator, which consists of three auto-transformers, A,B,C, each of which have a number of taps, 1, 2, 3, to any one of which the wires (W) may be connected. A special five pole switch, double throw, is used. The blades of the switch touch only three contact points, when in running position, and five of the contact points when the switch lever is in starting position. This form of starting device is used on three phase motors where the line voltage is high.

Figure 2, Plate III, shows the connections for the single phase induction motor, with its condenser, compensator B. A is an auto step-up-transformer. The main stator winding of the motor D E, and the starting winding C, are connected in the middle of D E.

This forms a three phase motor at starting, and when the motor is running at full speed the winding C, is cut out, after which the windings, D E, operate as a single phase motor.

A single phase motor will run equally well in either direction, depending upon the direction in which it is started. If a phase splitting device is used the direction of rotation may be changed by reversing the connections of the starting windings.

When a polyphase motor is running at full speed, all but one of the phases may be disconnected and the motor will continue to operate carrying two thirds the normal load. An induction motor will not start, however, where one phase only of its primary member is connected to the supply mains, hence, to run a motor by a single phase some device must be used,

There are three methods of starting single phase motors.

1. Hand starting.

A small motor may be started by a vigorous pull on the belt which connects it to the machinery which it drives.

2. Split phase starting.

When the alternating current divides between two branches there is a phase difference between the currents in the branches, if the ratio of the resistance to reactance is different in the two branches. This is eapecially ture if one of the branches contains a condenser. Now a two phase motor will start when the currents in the two branches are 90° apart in phase, although the starting torque becomes less and less as the phase difference decreases.

The diphasing of two parts of a single alternating current in two dissimilar branches of a circuit is called phase splitting, and a single phase induction motor may be arranged to start as a two-phase motor by splitting a single phase current, and using the two parts of the split current as a two phase circuit.

PLATE 3

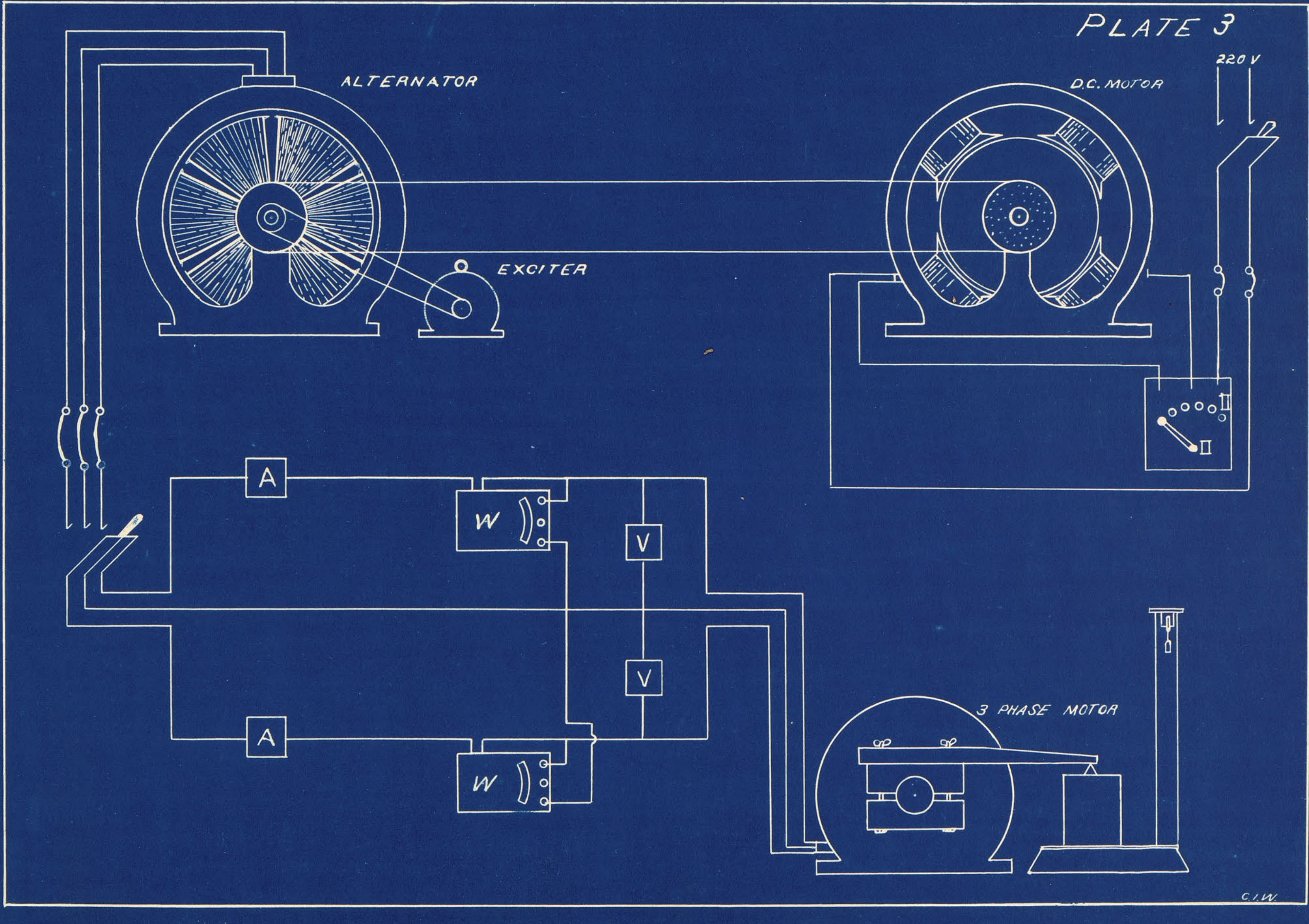

PLATE 4

RUNNING POSITION OF SWITCH

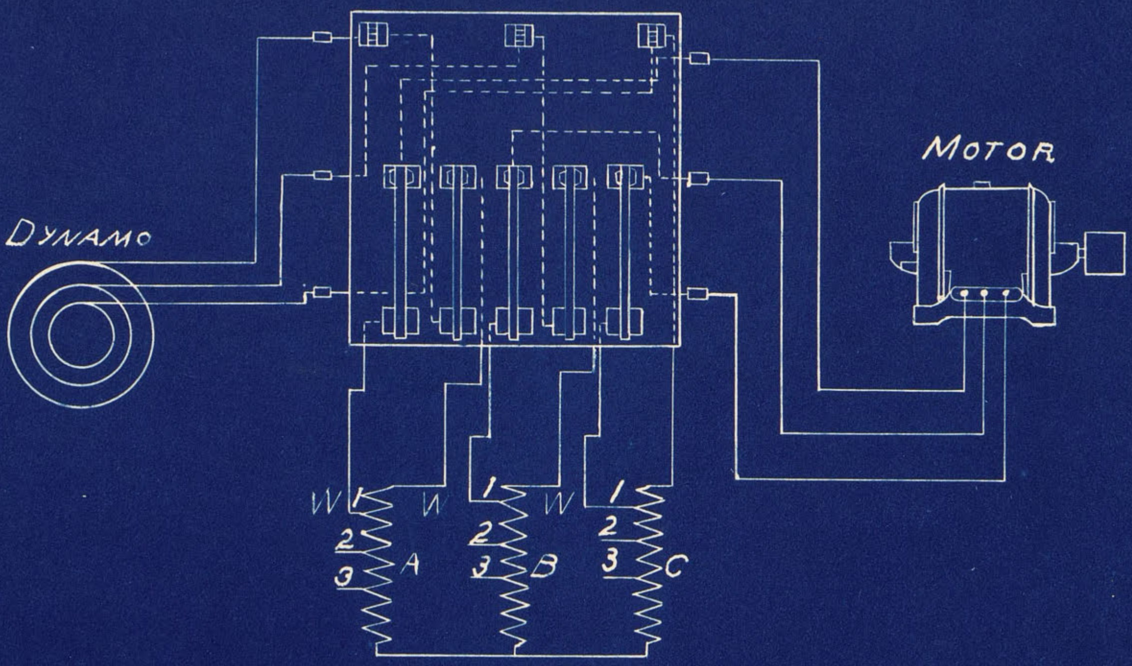

FIG. 1.

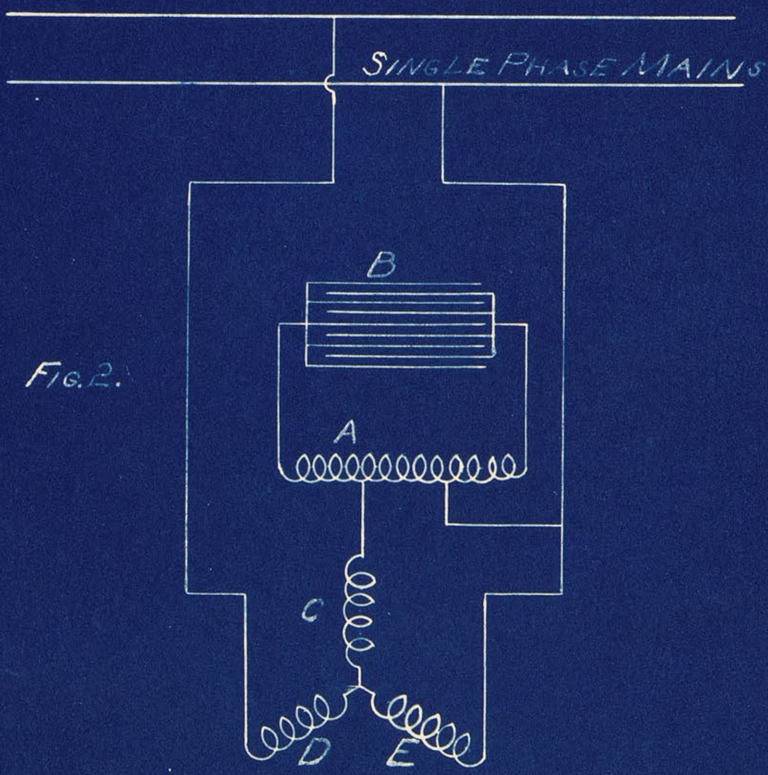

FIG. 2.

Within the last decade the use of alternating currents has demanded a method of converting this current directly into mechanical energy.

The rotary converter was at first used but was not wholly desirable even though the converters did their work admirably and had a fairly high efficiency. The induction motor has the advantage of using the alternating current direct from the source of supply. Plate II shows the stator, rotor, and winding of a two phase induction motor.

The rotating pole theory is one which is widely used among engineers, to explain the action of the machine. Figures 3, 4 and 5, Plate II, show the changes in flux, and the rotation of a magnetic needle which is influenced by the lines of force. This needle may be replaced by the rotor and a load belted to its shaft. In Figure 4, Plate II, the lines of force are passing between two opposite poles and the needle is held in the position shown. This occurs when the current is maximum in the first circuit. As the current in the first circuit begins to decrease and that of the second circuit to grow, we have the lines taking the direction shown in Figure 6, the arrow taking the position of the resultant force of the two fluxes. When the flux from the first circuit has reached zero value, and that of the second circuit has reached maximum, we have the relation shown in Figure 5.

The real difference between the magnetic needle and the squirrel cage rotor is, that there is no slip in the case of the needle, while the rotation of the rotor is developed by means of its slip, the reason for which will be explained later.

Figure 3, Plate II, shows the winding for a two-phase motor. In this figure the straight radial lines represent the conductors, which lie in the slots of the stator; the curved lines represent the end connections. The conductors which constitute one circuit are so connected that the currents flow in opposite directions in adjacent groups of conductors, as indicated by the arrows.

The manner in which the magnetic lines progress along the field of an induction motor is shown in Plate I. The winding considered here is a two phase system, and the machine is shown to be spread out, instead of being circular. In the upper part of the diagram, let one circuit be represented by the heavy circles, (which we will call circuit No.1), the other by light circles. The clock diagram on the right of Figure 1, represents the current relation. In Figure 1, the conductors in circuit No.1 are carrying no current. The magnetic lines will circulate through the iron, in paths similar to those shown by the arrows.

The magneto-magnetic force exerted by the stator coils at each point along the surface of the stator is shown by the square cornered curve below each figure. This is arrived at in the following manner:

In the space between the holes 7 and 2, there is a certain magneto-magnetic force due to the current in the conductors 6,7,2 and 3. Its amount at any moment may be represented by the projector, on a vertical line, of the point A, (the current in the coils being proportional to this projection). We may, therefore, draw the line L M equal to the projection of A. Then the ordinates of M N represent approximately the magneto-magnetic force at each point along the surface between the holes 7 and 2. Between 2 and 3 the magneto-magnetic force is nil, the conductors on one side neutralizing the effect of the conductors on the other. Between 3 and 6, the force is reversed and is represented by the curve P Q R S below the zero line.

In Figure 2, the phase has advanced by 1/16 of a period. If we draw for the coils of circuit No.1, a curve similar to that of the last figure, taking Aa as the magneto-magnetic force, and also a similar curve for the coils of circuit No.2, taking Bb as the magneto-magnetic force, then the sum of these curves is that shown in Figure 2.

In Figure 3, the phase is advanced another 1/16 of a period so that the currents in the two circuits are equal. The sum of their magneto-magnetic forces is shown by the curve in this figure. After another 1/16 of a period, the curve would be of irregular form again like that of Figure 2, but is not shown in the figures. After another 1/16 of a period the current has been reduced to zero, and that in No. 2 is a maximum, so that the curve, (Figure 4,), is similar to that of Figure 1, but is shifted forward through the space of two holes. At a quarter period later it is shifted on past another two conductors, and after another half period has passed all eight holes, and is in the position shown in Figure 1, relative to the next set of coils. The poles, in fact, have gone through a complete cycle.

These curves only approximately represent the distribution of the magnetic flux, for there are no sharp changes as are shown by the corners in the above curves. The natural spreading of the lines of force tend to round the corners of this curve, and without any great error we may assume the flux density follows a sine curve.

We have considered the manner in which the field is built up. The next to consider is the manner in which the rotary part turns.

In a three phase machine the point of maximum current in the phases occurs at different intervals; such that poles in the stator are in position to act upon the poles induced in the rotor at any moment. Hence, we find the three phase motor is capable of exerting a large torque and will therefore operate under load.

In the case of a single phase machine, however, the poles induced in the rotor are directly under the poles of the stator, and opposed to these, hence the forces act parallel and in the same straight line. Thus there is no couple and no tendency to rotate. If the machine be rotated briskly for a few revolutions, the conductor will cut the lines of force from the stator and poles are produced 90° from the active conductor, which are acted upon by the poles in the stator. When once the torque is established the machine speeds up and operates as beofre, carrying about two thirds of the normal load.

If a three phase machine be running and one terminal be disconnected, the machine will continue to operate as a single phase. Reversing two terminals reverses the direction of the motor. Hence, if the machine be started single phase, and after normal speed has been reached the third terminal is connected, the machine continues to operate as a three phase, or stops, according to its phase relation with the circuit in operation.

The slip of the induction motor is important, for upon this is based the principle of its action. The lines of force from the stator chase around the core, the speed of their revolutions being governed by the frequency of the circuit from the alternator.

If the rotor speed is equal to the speed of the rotating poles in the stator, (and hence the lines of force), there is no cutting of the lines and consequently no current in the rotor and no torque set up. Now, let the speed of the rotor decrease, and lines of force are cut by the conductors on the rotor, and a current is set up which produces the torque required for the given load. Hence, with increase of load there must be an increase of slip.

There are several methods of measuring slip. Any of these have certain disadvantages.

(a) Speed measurement is one of the most common on account of its simplicity, but has the objection of errors in reading the indicator.

(b) Contact methods are those in which contacts are placed on the alternator and motor shafts. So the number of breaks or contacts represents the number of revolutions lost. The apparatud is expensive and complex for this method, although it is accurate.

(c) Frequency of rotor currents is measured by oscillations of an ammeter needle. In this method the resistance of the ammeter is apt to affect the rotor current, and can be used on phase wound motors only.

(d) The stroboscope method is perhaps the simplest and most efficient. In consists of a disc placed on the rotor shaft, bearing a number of black and white sectors, these divisions corresponding to the number of poles of the motor. This disc is illuminated by an arc supplied by current from the main source. If the rotor runs a synchronous speed, a black sector on the disc will have replaced the previous black sector at each flash of the light. Now, if there is slip to the motor, a black sector will not have reached the position of a previous division at the preceding flash, but will have fallen behind. Since the flashes occur with a high frequency the intervals of time cannot be detected, but a shadow is seen to move on the disc in the opposite direction of rotation, and the revolutions of this shadow show the number of revolutions lost per minute.

In many respects the induction motor is precisely like the transformer. The stator of the motor wound on a laminated iron core corresponds to the primary of the transformer, the rotor conductors also wound on a laminated core correspond to the transformer secondary. In most cases the windings on the primary of the motor have the same number of turns as the secondary, and hence the transformation ratio is 1.

When the rotor turns at synchronous speed there are no lines of force cut by the rotor conductor, and hence, no bucking lines.

The stator acts as a choke coil and corresponds to a transformer with open secondary. If the rotor speed decreases, the lines from the primary are acted upon, and by Lenze's Law we find the induced current of the secondary opposing the lines of the primary, and like the transformer, with the secondary loaded, more current is given to the primary to build up the lines which are lost in producing secondary currents.

When the rotary is entirely stopped we have a large torque due to the high electro motive force and current induced in the secondary and this corresponds to the short circuited secondary in the transformer.

If we rotate the armature or rotor in a negative direction the frequency of the rotor current increases above those of the main circuit and we have as a result a frequency changer. In passing through zero space the current and speed torque curves take a backward turn due to the negative torque and speed. By the analytic theory of the polyphase induction motor we get the following:

Let r = resistance per circuit of primary,

r'= " " " " secondary, reduced to primary by square ratio of number of turns = T^2.

d = number of poles,

x = reactance of primary per circuit,

x'= " " secondary " " reduced to primary by square ratio of turns.

S = per cent of slip

I = current per circuit of primary,

E = applied electro motive force per circuit,

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Let Z = impedance of whole motor circuit,

N = frequency of applied electro motive force,

Let the primary and the secondary consist of P circuits on a p phase system,

n = primary turns per circuit,

n' = secondary turns per circuit,

$$t = \frac{N}{n'}, \text{ ratio of transformation.}$$

Now if we neglect the exciting current

$$I = \frac{S\ E}{r' + sr^2 + s^2(x + X')^2}$$

$$\text{Torque } T = \frac{d\ p\ r'\ E^2 S}{4\pi N\ (r' + Sr)^2 + S^2(x' + x^2)}$$

$$\text{Power} = \frac{pr'\ E^2 S(1-S)}{(r' + Sr)^2 + S^2(x' + x)^2}$$

$$\text{Max.Torque} = \frac{d\ p\ E^2}{8\pi NLr + r^2 + (x' + x)^2}$$

$$\text{Starting current} = i = \frac{E}{Z}$$

$$\text{" torque} = t = \frac{d\ p\ E^2}{4\ \pi\ N} \times \frac{r'}{Z^2}$$

It may be said that the principal advantages of the incudtion motor are:

a. Cheap power at a distance from the line.

b. The feeding of the trolley lines and the keeping of the drop within proper limits are cheaply provided for by stationary transformers of high efficiency.

c. Electrolytic troubles cease.

d. Motors more compact, less attention, cost of maintenance less, same or higher efficiency.

e. No sliding contacts, hence no sparks.

To offset these advantages we have:

a. Two trolley wires.

b. Speed control more difficult.

c. Starting not quite so good.

d. Section of mains for same pressure must be greater on account of wattless currents, which increase the load currents about 30%.

e. Possible telephone troubles.

The diagram worked out by Mr. Heyland is perhaps the best method known for finding the relative values of current voltage slip and such. Mr. Heyland pointed out the fact that the locus of point A, Plate A, is a semi-circle, C A R having its center on the line O K.

We may prove this by proving that the perpendicular A K upon A C at the point A, meets the base line O K at a point K, such that the length C K is independent of the length or position of A C, and

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can be simply expressed in terms of the primary flux O C, which is constant, and the coefficients N_1 and N_2, which are also constant.

A,C,K and C_2DO are similar triangles

$$\frac{K\,C_1}{O\,D} = \frac{A_1C_1}{D\,C_2} = \frac{A_1C_1}{B_1C_2 - B_1D}$$

But

$$O\,D = \frac{O\,B_1}{O\,A_1} \times O\,C_1 = N_1 \times O\,C_1 .$$

$$A_1C_1 = O\,B_2 = N_2 \times O\,A_2$$

$$B_1C_2 = O\,A_2$$

$$B_1D = N_1 \times A_1C_1 = N_1N_2 \times O\,A_2$$

Substituting

$$K\,C_1 = O\,C_1 \times \frac{N_1N_2}{1 - N_1N_2} \quad \text{or } K\,C_1 = \text{constant}.$$

The angle P O A_1 measures the power factor of the primary circuit.

The diagram can be seen to resemble the transformer diagram O A_1 = total primary current which is proportional to primary flux, A_1B_1 = primary leakage.

O A_2 represents the secondary current and A_2B_2 the leakage current. Since the angles have been considered in drawing these lines we find O C_1 = primary lines, O C_2 = secondary lines and O C_0 = lines in air gap.

The four principal steps in constructing the diagram are:

Circle of input,

Circle of torque,

Circle of output,

And slip.

The output circle is found by laying off to scale the no load and locked arm currents, and drawing a circle through these points with its center on the line O K.

Other values of current drawn to their respective angles should fall on the curve which can be seen by data plotted on Plate B. The line O P is laid off in watts input. Taking the C^2R loss for a given value of arm current, and subtracting this from the corresponding reading in watts input on the line O P, we find T through which the torque circle passes. The center of the output circle falls on a line with the circles of torque and input and is tangent to C_1k at point K.

The slip may be represented by drawing x_1y_1, Plate A, such that angle Y S K = K T C_1. The triangle S_1SK is similar to triangle C_1TK, so the slip is also proportional to the ratio. $\frac{S_1S}{K\ S}$ of K S being constant the slip is simply proportional to S_1S.

This method is not absolutely correct for small motors, but for all practical purposes it is assumed correct, and the errors introduced are, in most cases, so small as to be negligible.

CURVE DISCUSSION.

The curves on pages show the characteristics of the three phase motor.

1. When under brake load.

2. When pulling a loaded calibrated motor.

These two sets of curves compare very favorably. In the first test the data was obtained with the motor connected as in Plate III.

Curve No.1, page 24 shows the drop in the rotor speed, due to the increase of magnetic leakage, and C^2R loss, as the load is increased. This curve shows the actual speed of the rotor, as explained above.

Curve No.2 is the efficiency curve of the motor as calculated by the following formula from the data obtained.

$$\text{Efficiency} = \frac{\text{Watts output} \times 100}{\text{Watts Input.}}$$

where the watts output are determined by the equation

$$\text{Watts} = \frac{2\pi \times N \times L \times P \times 746}{33000}$$

N = R.P.M.

L = length of brake arm = 18"

P = pounds pull on the scales.

Curve No.3 is the power factor or cos ϕ, which is the quotient of wattmeter readings divided by volt amperes.

$$\cos\phi = \frac{\text{Watts}}{\text{Volt amperes.}}$$

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as obtained by those instruments. The value of cos ϕ as shown by the curve increases with the load, giving a power factor of 74% at full load output.

The apparent efficiency curve as shown is obtained from the apparent input and motor output.

$$\text{Apparent Efficiency} = \frac{\text{Output}}{\text{Apparent input.}}$$

Curves 5, 6, 7 show that the horse power increases directly as the current, for the applied electro motive force being constant. These curves may be said to be plotted to current and horse power as abscissas and ordinates.

The curves on pages 28,30 show the performance of the single phase Wagner Motor. When connected as shown in Plate V, to a calibrated dynamo, and also when under brake test. These tests show an efficiency of 81% at full load. This machine uses excessive current when starting, (40 amperes) and will not start under load. As the curves indicate, this machine will not carry a large over load. When the maximum load is reached the motor breaks down and the load must be thrown off. The tests made by the calibrated dynamo method is much more satisfactory than the tests by the prony brake, in fact, it is impossible to obtain first class results from this machine when under a brake test.

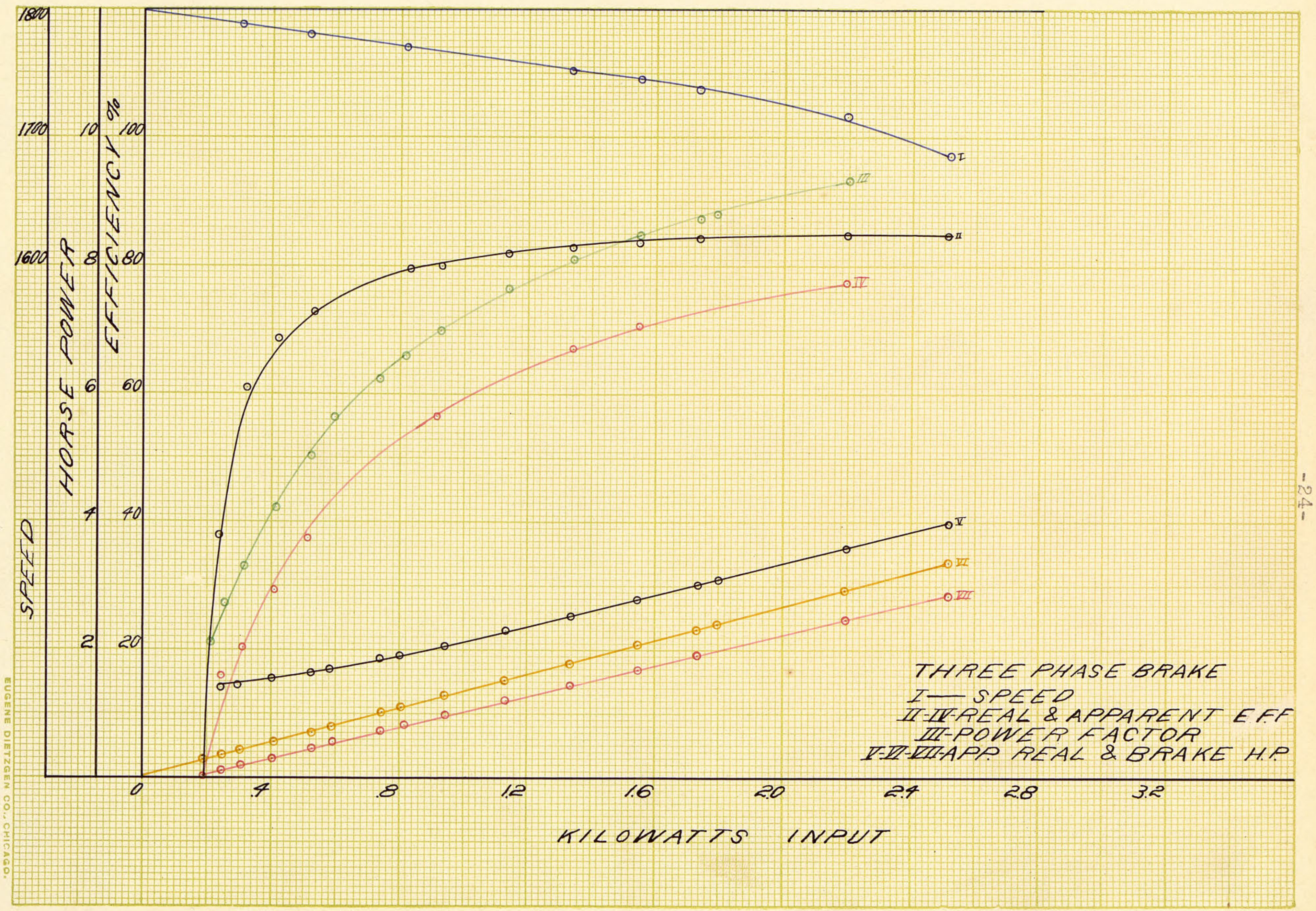
The Heat Test.

The curves on page 32 show the results obtained from a heat test on the single phase motor. In this test both machines were run, and each machine carried 25% over-load for a period of nine and one half hours. During this test the three phase motor seemed much superior to the single phase machine, as it did not become heated above normal, and at the end of the period seemed capable of carrying the load for an indefinite period.

The single phase motor, on the other hand, became excessively hot, as shown by the data, the armature or rotor reaching 70°C., which is above the maximum allowable temperature.

PRONY BRAKE TEST OF THREE PHASE MOTOR.

Apparent Input	Apparent Eff.	Watts Input	Watts Output	% Eff.	Speed	Brake Load	R.Hp	Brake HP	Power Factor
890	0.	190	0	0	1796	0	.254	0	.214
915	15	250	96	38	1793	.25	.335	.127	.274
925	20.8	310	190	61.5	1791	.5	.415	.255	.335
960	29.7	410	285	69	1787	.75	.55	.382	.427
1025	37.	525	380	72.5	1784	1.	.705	.51	.512
1030	46.2	590	476	80	1779	1.25	.79	.64	.572
1200	47.2	750	567	75.6	1774	1.50	1.05	.76	.625
1245	53.	820	660	81	1770	1.75	1.1	.855	.658
1330	56.5	930	750	81	1766	2.	1.25	1.005	.700
1485	62.8	1140	935	82	1753	2.5	1.53	1.25	.766
1645	67.8	1340	1115	83	1744	3.	1.8	1.49	.815
1830	71.	1550	1300	84	1738	3.5	2.08	1.74	.845
2010	72.8	1740	1470	84.5	1728	4.	2.33	1.97	.866
2015	81.5	1790	1640	91	1722	4.5	2.4	2.2	.885
2350	77.5	2200	1830	83.5	1718	5.	2.95	2.45	.935
2530	84.	2520	2140	85.5	1684	6.	3.38	2.86	.99



SPEED
HORSE POWER
EFFICIENCY %
1800
1700
1600
10
8
6
4
2
100
80
60
40
20
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
KILOWATTS INPUT
THREE PHASE BRAKE
I — SPEED
II-IV-REAL & APPARENT EFF
III-POWER FACTOR
V-VI-VII-APP. REAL & BRAKE H.P.
EUGENE DIETZGEN CO., CHICAGO.

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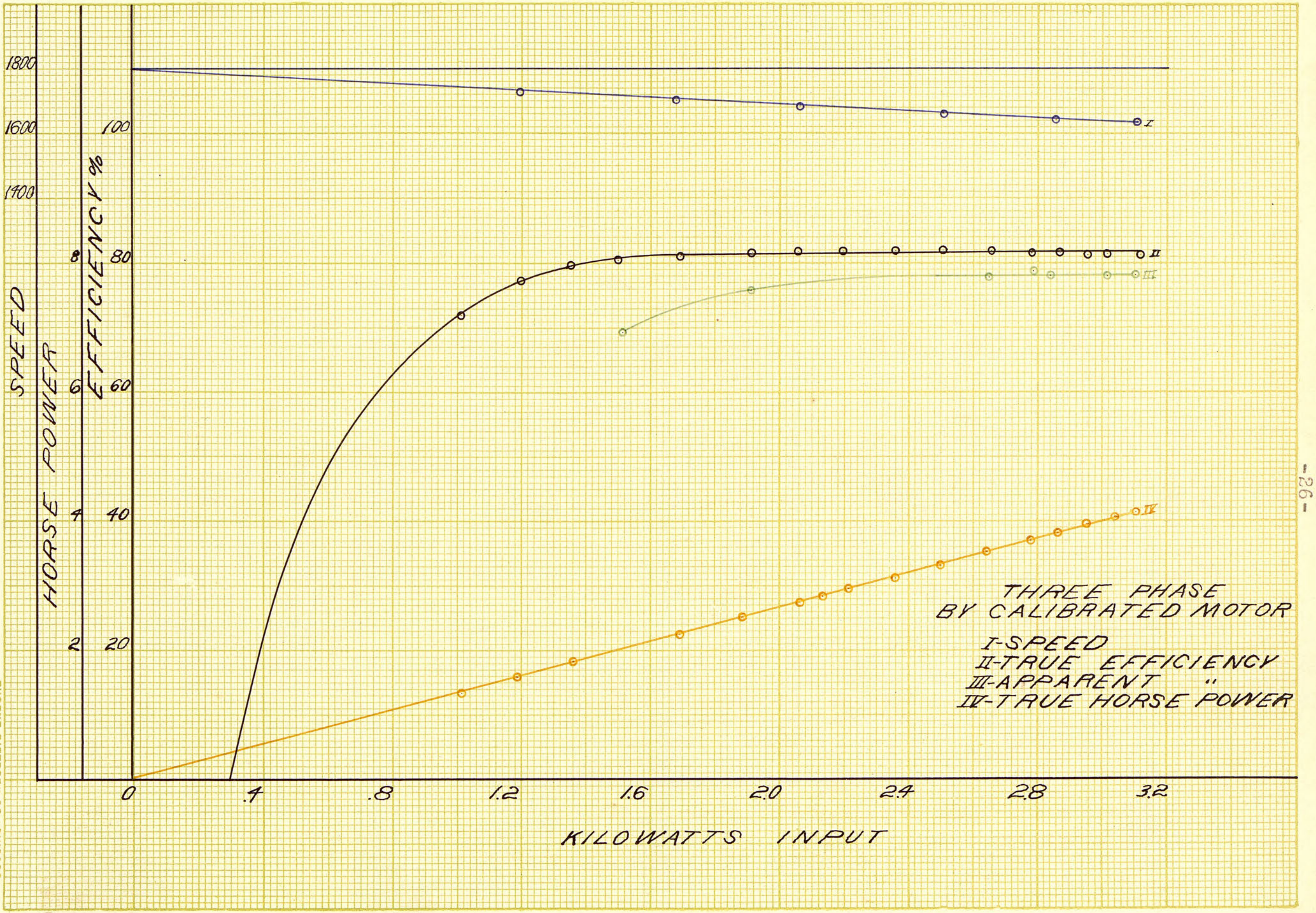
1105

CALIBRATED DYNAMO.

Efficiency Test Three Phase Motor.

Apparent Input	Watts Input	Watts Output	Efficiency	True HP	Slip	Apparent Efficiency.
0	320	0	0	.43	1800	0
0	1030	744	73.9	1.3		0
0	1195	932	78	1.6		0
945	1200	935	78	1.6	1765	0
1515	1370	1096	80	1.83		72.2
1795	1525	1235	81	2.04		69.
2080	1700	1394	82	2.28		67.2
2080	1930	1582	82.1	2.58		76.
2270	2070	1676	81	2.77	1712	74.
2270	2205	1830	83	3.05		80.6
2430	2360	1958	83	3.16		80.5
2520	2515	2075	82.4	3.36	1674	83
2715	2655	2105	82.5	3.55		77.5
2860	2795	2290	81.9	3.74		79.8
3023	2865	2350	82	3.84	1666	77.8
3060	2875	2375	82	3.85		77.8
3120	2960	2425	82	3.96		77.7
3215	3035	2490	81	4.06		77.5
3215	3110	2520	81	4.16	1630	78.2



SPEED
HORSE POWER
EFFICIENCY %
1800
1600
1400
100
80
60
40
20
8
6
4
2
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
KILOWATTS INPUT
I
II
III
IV
THREE PHASE
BY CALIBRATED MOTOR
I-SPEED
II-TRUE EFFICIENCY
III-APPARENT "
IV-TRUE HORSE POWER
EUGENE DIETZGEN CO., CHICAGO.

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#2

PLATE 5

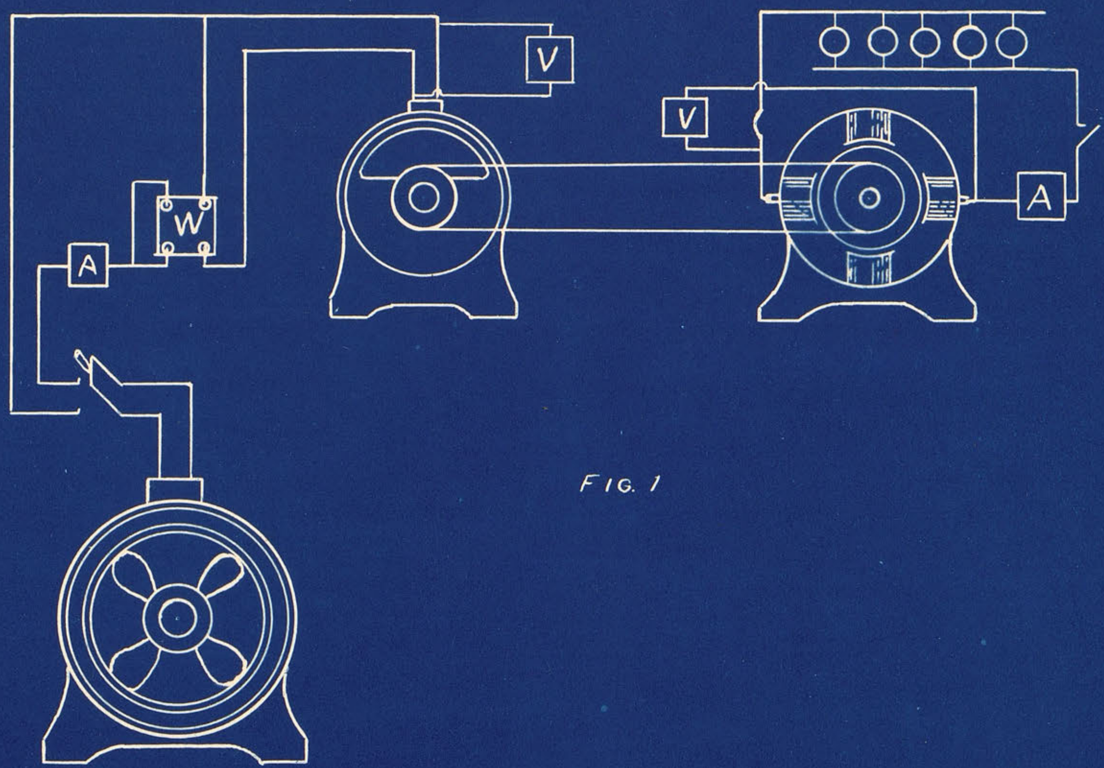


FIG. 1

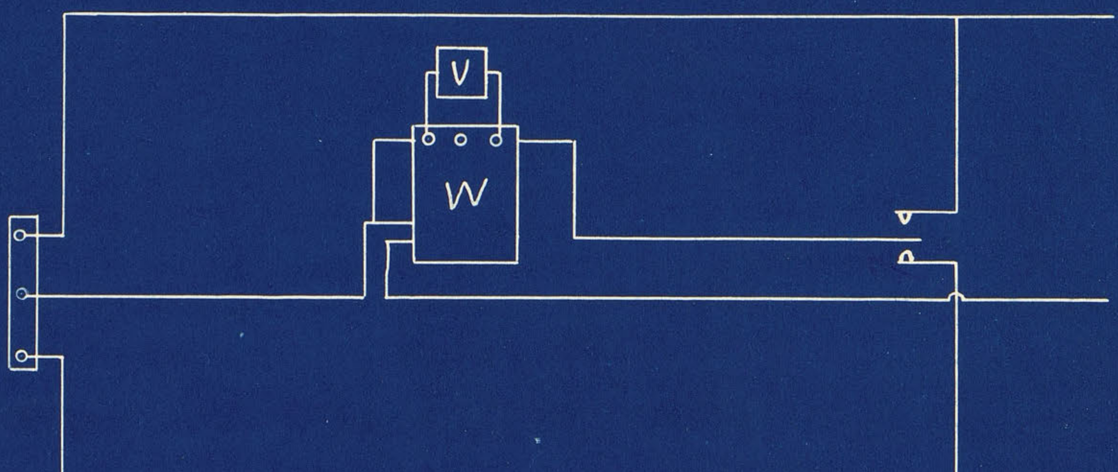
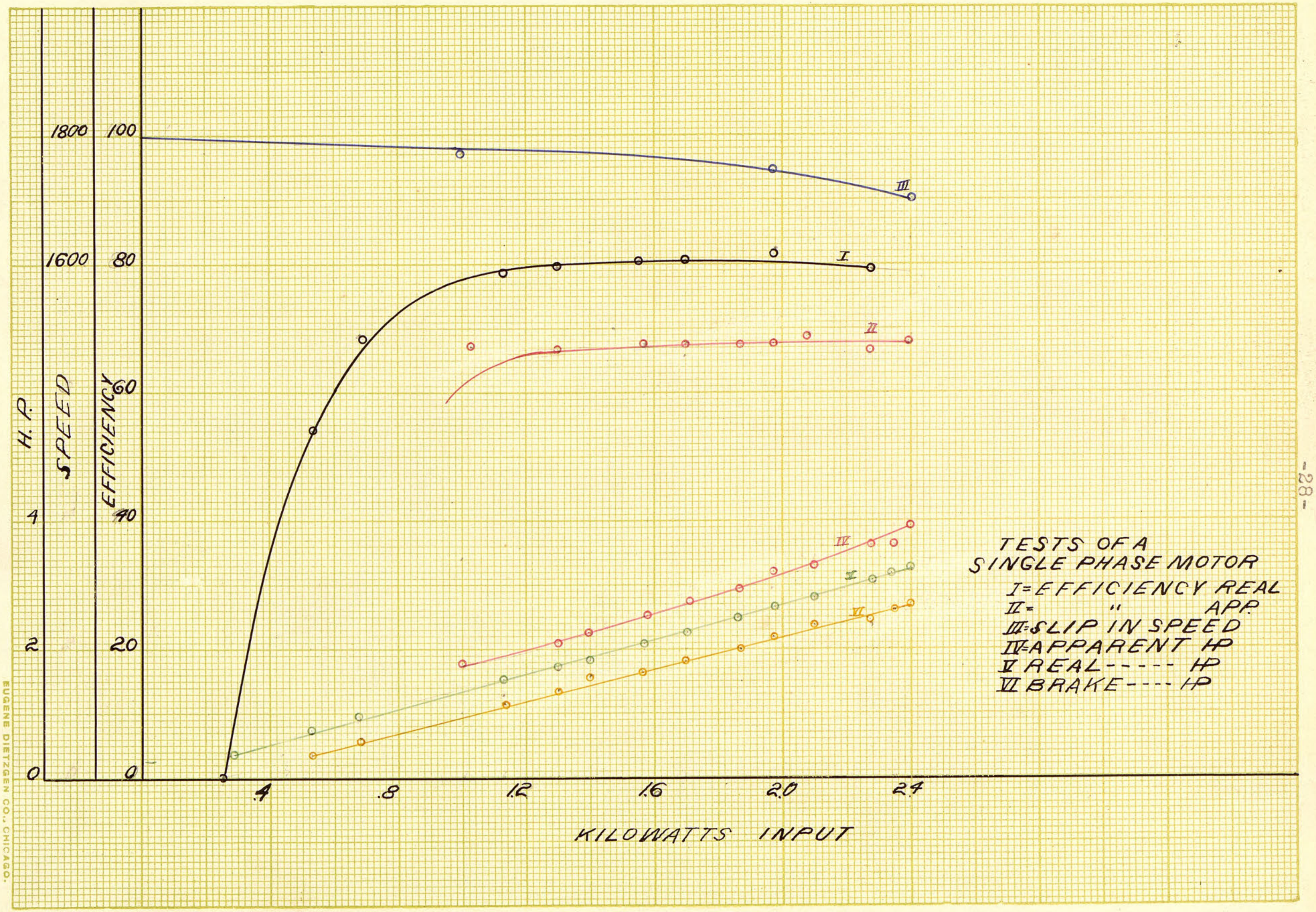


FIG. 2

C.I.W.

EFFICIENCY TEST OF SINGLE PHASE BY CALIBRATED DYNAMO.

Input	Output	Efficiency	App. HP	Real HP	Speed	App.Eff.	App. Input.	HP Output
250	0	0		.33	1800	0		0
530	288	54		.71		0		.38
680	468	69		.91		0		.67
1130	881	78	1.74	1.52	1775	67	1300	1.17
1300	1036	79.2	2.09	1.74		665	1560	1.39
1400	1170	83.5	2.23	1.87		703	1665	1.57
1575	1264	80.2	2.5	2.1		675	1870	1.69
1700	1369	80.5	2.72	2.28		68	2030	1.83
1875	1500	80.5	2.9	2.5		672	2235	2.01
1975	1633	82.5	3.23	2.65	1745	677	2410	2.18
2100	1760	83.9	3.42	2.8		69	2550	2.36
2280	1809	79.2	3.6	3.05		66	2735	2.42
2350	1980	84	3.6	3.15		72	2735	2.67
2400	2018	84	3.9	3.22	1700	692	2910	2.7


1800
1600
100
80
60
40
20
0
4
2
0
H.P.
SPEED
EFFICIENCY
.4
.8
1.2
1.6
2.0
2.4
KILOWATTS INPUT
I
II
III
IV
V
VI
TESTS OF A
SINGLE PHASE MOTOR
I = EFFICIENCY REAL
II = " APP.
III = SLIP IN SPEED
IV = APPARENT HP
V REAL ----- HP
VI BRAKE ---- HP
EUGENE DIETZGEN CO., CHICAGO.

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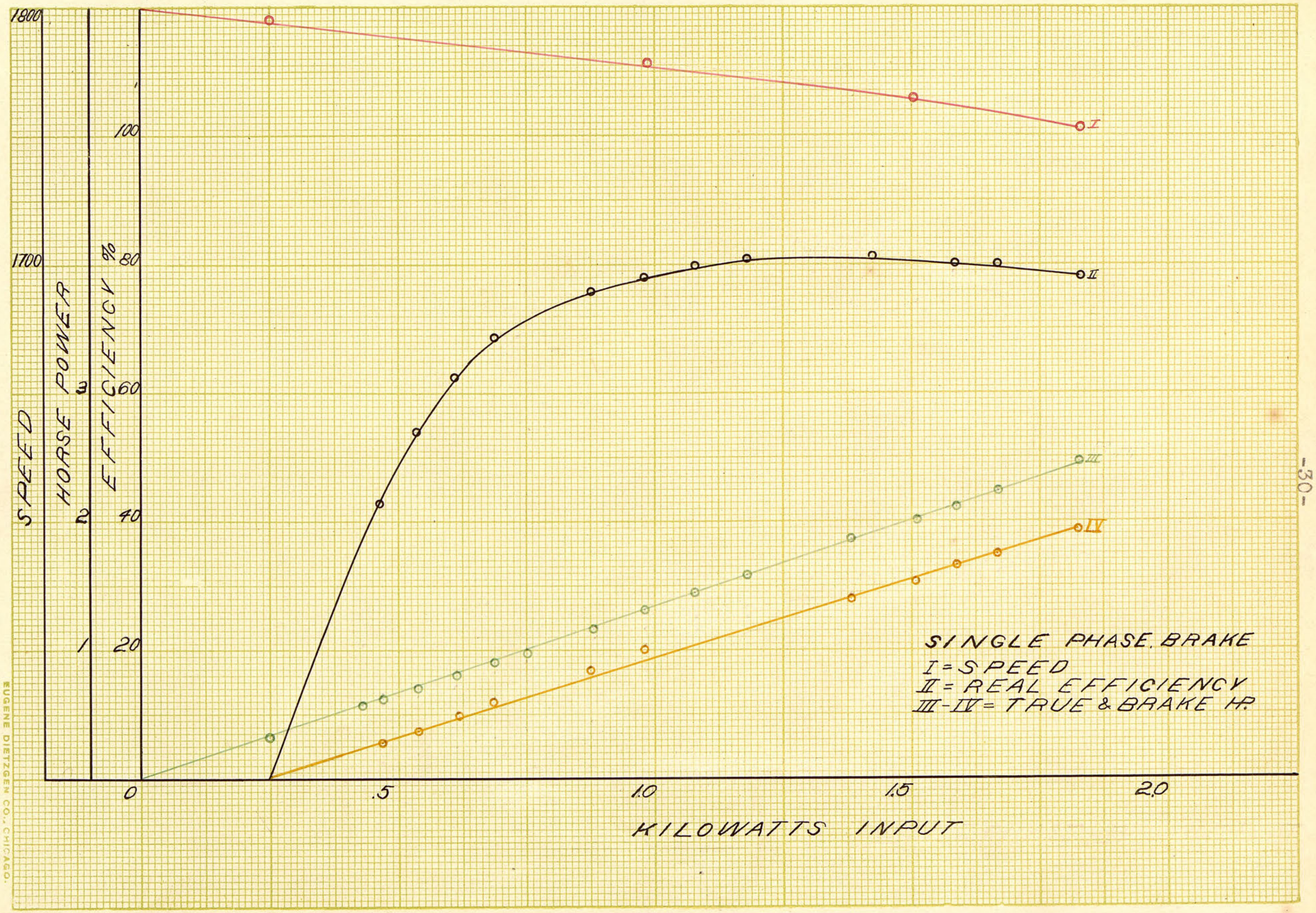
PRONY BRAKE TEST

SINGLE PHASE INDUCTION MOTOR 2 HP.

Watts Input	Watts Output	% Eff.	Brake Load	Real HP	B HP	Slip
250	0	0	0	.33	0	1797
430	96	22	.25	.57	.012	
470	200	42.5	.50	.63	.268	
530	288	44	.75	.71	.386	
610	383	63	1.	.82	.515	
680	468	69	1.25	.91	.625	
750	575	76	1.50	1.	.77	
880	660	76	1.75	1.18	.885	
980	765	78	2.	1.31	1.04	1779
1080	863	80	2.25	1.45	1.15	1776.5
1180	957	81	2.50	1.57	1.28	
1390	1055	76	2.75	1.86	1.44	1764
1510	1150	76	3.	2.02	1.54	1764
1580	1245	79	3.25	2.12	1.67	
1670	1340	80	3.50	2.24	1.79	
1830	1438	78	3.75	2.46	1.93	1753


SPEED
HORSE POWER
EFFICIENCY %
1800
1700
100
80
60
40
20
3
2
1
0
.5
1.0
1.5
2.0
KILOWATTS INPUT
I
II
III
IV
SINGLE PHASE. BRAKE
I = SPEED
II = REAL EFFICIENCY
III-IV = TRUE & BRAKE H.P.
EUGENE DIETZGEN CO., CHICAGO.

SINGLE PHASE

TEMPERATURE.

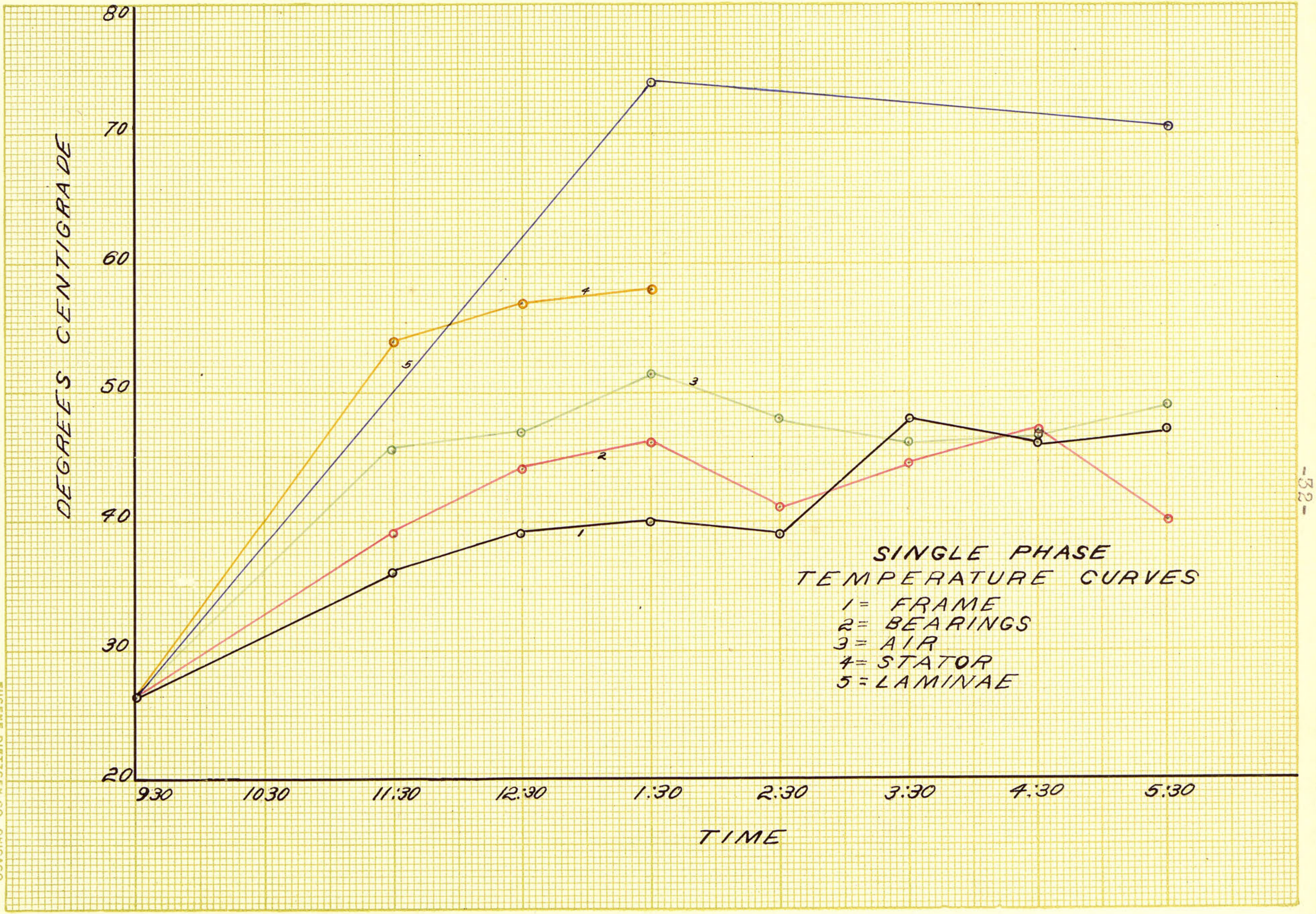
Time	Frame	Air NE	Air SE	Bearings N	Bearings S	Stator	Laminae	Rotor
8:30	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3
11:30	36	39	48	43.5	45	54		
12:30	39	44	44.7	45	47	57		
1:30	40	46	52	49.5	51.5	58	74	68
2:30	39	41	45.5	45	48			
3:30	48	44.6	49	43	46			
4:30	46	47	49.6	43	46			
5:30	47	40	50	53	49		70.5	66.5

THREE PHASE.

Temperature.

Time	Frame	Air NE	Air SE	N.Bear.	S.Bear.	Stator	Lam.	Rotor
8:30	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3
11:30	35.5	32	30	32.5	32.5	35		
12:30	34.5	34.9	34.8	36.	33.2	33		
1:30	35	36	35	34.2	34.3	33.5	37.5	39
2:30	35	35	35.5	36.3	33.5	34		
3:30	36	37.5	36.8	36	36.5	35.2		
4:30	37.5	38	37	37	36.2	35		
5:30	38	38	37	37.6	37.2	35.4	70.5	66.5

Air NE = Air in north end of machine,
" SE = " " south " " "
N Bearings = Bearing in north end of machine.


DEGREES CENTIGRADE
80
70
60
50
40
30
20
9:30
10:30
11:30
12:30
1:30
2:30
3:30
4:30
5:30
TIME
SINGLE PHASE
TEMPERATURE CURVES
1 = FRAME
2 = BEARINGS
3 = AIR
4 = STATOR
5 = LAMINAE
1
2
3
4
5

DATA FOR HEYLAND DIAGRAM.

Locked Armature.

Watts 1100,

Volt amperes 2157.5

Amperes 44.5

Cos ϕ = .5093 = 59° 23'

No Load (Running Light.)

Amperes 9.5

Volt amperes 1035.

Watts 190

Cos ϕ = .1835 = 79° 25'

Amperes 13.1

Watts 820.

Volt amperes 1447.8

Cos ϕ = .5663 = 55° 30'

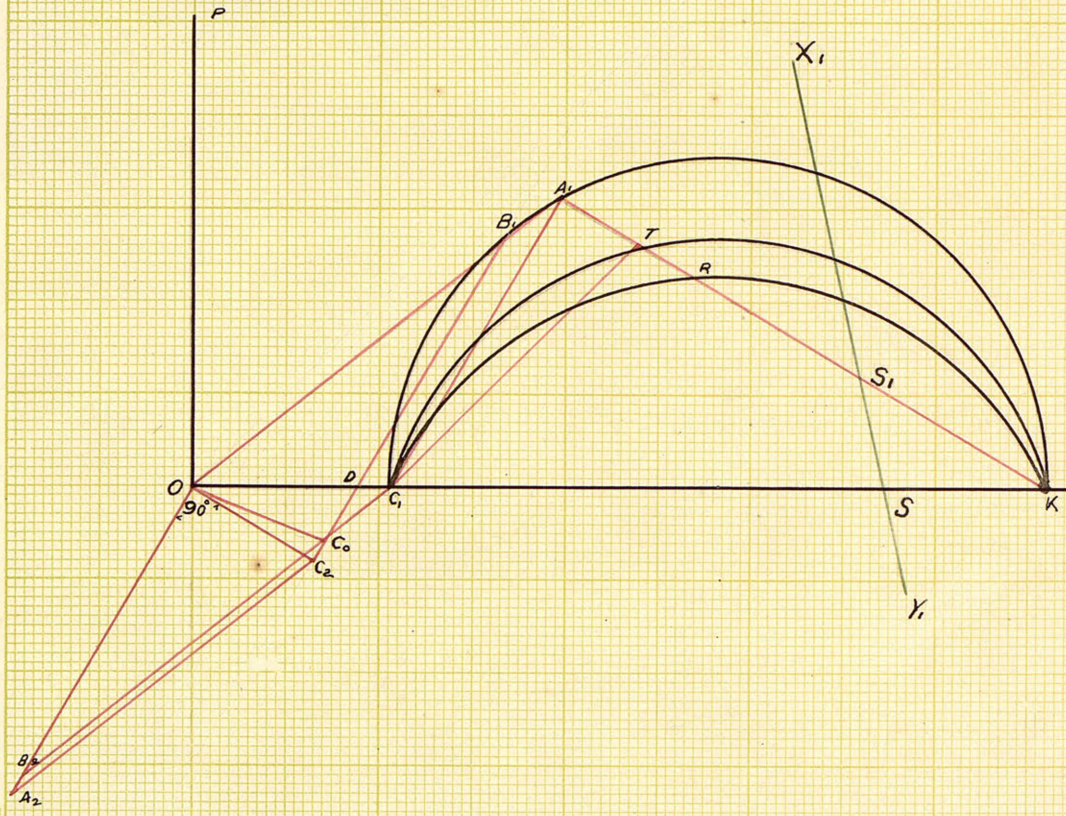
Amperes 19.5

Watts 1550.

Volt amperes 2136.

Cos ϕ = .725 = 43° 32'

PLATE A



HEYLAND DIAGRAM

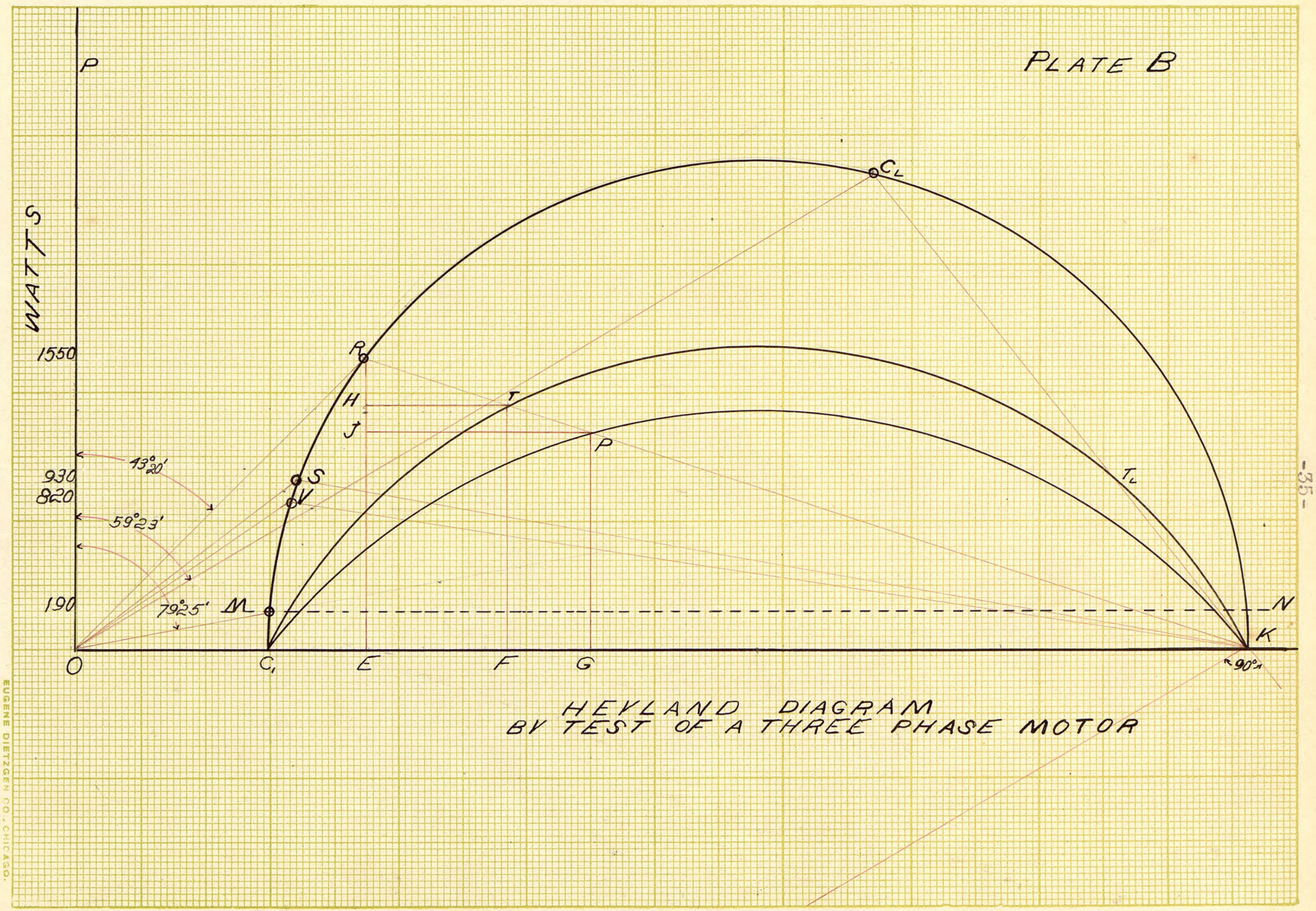


PLATE B
WATTS
P
1550
930
820
190
0
43°20'
59°23'
79°25'
M
N
K
90°
R
S
V
H
J
T
P
C_L
T_L
C_1
E
F
G
HEYLAND DIAGRAM
BY TEST OF A THREE PHASE MOTOR