T H E S I S

ON

TESTING A 7.5 K.W. GENERATOR

AS A SYNCHRONOUS MOTOR

Submitted to the Faculty

of the

O R E G O N   A G R I C U L T U R A L   C O L L E G E

for the degree of

BACHELOR OF SCIENCE

in

ELECTRICAL ENGINEERING

by

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and

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APPROVED:

Redacted for privacy

Department of Electrical Engineering.

Redacted for privacy

Dean of School of Engineering.

The fundamental theory of the electromagnetic phenomena which takes place in the armature of a synchronous motor under load is as follows: Alternating currents flowing through the armature constitute a magnetomotive force which modifies the flux produced by the field winding. This magnetomotive force is known as the "armature reaction". The same armature currents produce stray fluxes in the slots and around the end connections of armature coils; these fluxes induce electromotive forces in the armature winding. The effect of these stray fluxes upon the voltage drop in the armature winding is measured by what is called the "armature reactance".

When the revolving field machine under test is being run as a polyphase synchronous motor, the wave of the resultant magnetomotive force of the armature travels along the air-gap synchronously with the field poles, notwithstanding the fact that the armature windings themselves are stationary in space. This is explained by the fact that the armature currents reach their maxima in different points along the air-gap, at successive moments of time. This fact is expressed briefly by saying that the magnetomotive force travels along the air-gap. Since the armature currents pulsate synchronously with the revolving field, the magnetomotive force of the armature also travels synchronously, moving by two-pole pitches each cycle.

While if the machine under test is being runas a single-phase synchronous motor; the armature reaction is pulsating and is stationary in space. This pulsating magnetomotive force can be resolved into two equal magnetomotive forces of constant magnitude, one revolving synchronously with the field poles, the other revolving synchronously in the opposite direction. The effect of the latter component is considerably weakened by the double-frequency eddy currents induced in the revolving part of the machine.

The magnetomotive force of the polyphase armature winding can be resolved into two components, each of which revolves synchronously with, and in the same direction as the field. One component is in space phase with the field, the other in space quadrature with the field. These reactions are sometimes referred to as the demagnetizing and the cross-magnetizing actions of the armature upon the field.

The foregoing discussion is given in order that we might understand the armature reaction which takes place in a synchronous motor when loaded. These conditions exist in the following experiments.

Plates"A" are the no-load saturation curves of the machine when run as a single phase, three phase both delta and Y connected, quarter phase and six phase synchronous alternator. These curves are to be used in obtaining the Vector Diagrams of the synchronous motor when running as above explained. They show the values of the counter e.m.f. when running with any given field excitation. They are obtained by running the machine as an alternator with open armature circuit and varying the field excitation from zero current to its maximum; reading the field amperes which are plotted as abscissae and volts across one phase of the armature which are plotted as ordinates.

Plates "B" are the phase characteristics or the V curves of a synchronous motor. To determine them the apparatus is connected according to diagrams "A". The field of the synchronous motor is seperately excited by a motor generator set in order that it might be varied within wide limits. The motor was brought up to speed by means of running the D.C. generator as a D.C. motor. When its voltage was the same and its speed was in synchronism with the rotary converter, which was told by the use of voltmeters and synchronizing lamps, the switch was closed, the D.C. supply to the D.C. Generator which was operating as a motor was then also cut out; thus now running the synchronous machine as a synchronous motor, its armature being supplied from the rotary converter and being loaded by the D.C. generator which was supplying current through a water box.

As heavy a load as practicable was first thrown upon the moter and its field excitation so adjusted as to have a power factor of 100% upon the motor. The field current was then gradually reduced, keeping the load constant, until the motor fell out of step. The motor was then again started, the field adjusted as before and this time gradually increased the field current to the practicable limit. In each of the afore said runs the armature amperes and watts; also field current and volts; the loaded generator volts and amperes and the speed were read. Two similar runs were then taken with a decreased load upon the motor and finally a run taken with merely the generator armature open circuited as a motor load. These runs were taken with the synchronous motor operating as a single-phase, three-phase both delta and Y connected and as a quarter phase synchronous motor.

From this data the phase characteristics or V curves were plotted, with field amperes as abscissae and armature amperes as ordinates. These curves give information about the performance of the synchronous motor, and in this respect take the place of the voltage characteristics of an alternator. They permit one to determine, in particular;

(1) Fluctuations of the armature current and of the power factor with a varying load, the field current being kept constant.

(2) Range of variations of the field current necessary in order to maintain a prescribed value of the reactive power input, when the motor is used for improving

the power factor of a system.

(3) Maximum reactive kilovolt-amperes obtainable with the highest permissible field current; or the field amperes necessary to produce a specified amount of reactive kilovolt-amperes in addition to the required mechanical load.

Assume first that the motor is running at a light load, merely revolving the unloaded generator, with its field considerably over-excited, so that the motor draws a large leading current from the line. The energy component of the armature current is small, being just sufficient to overcome the iron loss, friction and the copper loss in the armature with a slight additional load upon the belt. The leading reactive component demagnetizes the field and reduces the induced e.m.f. to a value consistant with the line voltage. With the field over excited the current used by the motor must be such as to weaken the field in order to anable the motor to take energy from the line. A current in order to weaken the field must lag 90 degrees behind the induced electromotive force of the machine. Hence, this current must be leading with respect to the line voltage, because the latter has a direction approximately opposite to that of the induced e,m.f. It is for this reason that an over-excited synchronous motor takes a leading current from the line. This means that in a motor the ficitious cross-magnetizing poles lead the actual poles by 90 degrees, and the flux is distorted so as to be crowded in the direction of rotation of the poles.

In an under-excited synchronous motor the conditions are such that the direct reaction must strengthen the field, the current being leading with respect to the induced e.m.f. (or lagging with respect to the line voltage). The energy component is the same as in the preceding case, so that the flux is again crowded in the direction of rotation of the poles.

In other words, in a synchronous motor the energy component of the armature current creates distortion of the poles 90 degrees ahead of the actual poles. A lagging reactive component of the input current strengthens the field, while a leading component weakens it.

We found that when the synchronous motor was carrying a certain load its field current might be varied within comparatively wide limits, without throwing the motor out of step. The armature current which the motor takes varies with different values of excitation, as shown by the V curves. With a certain value of field current ,the armaturecurrent was a minimum,and the power factor was 100 per cent, Reducing the field current increases the armature current, and draws current from the line, having a lagging component. Increasing the excitation also increases the armature current, but it makes it leading instead of lagging. Beyond a certain limit of excitation, the motor fell out of step. It was impossible to throw the machine out of step by giving it a leading power factor, but if heavily loaded would not operate with but a very slight lagging one.

The vector diagram shown on plate C explains the shape of the V curves. OE is the vector of the applied voltage at the terminals of the motor, and is taken for the values of the voltage as near the same as possible. This voltage is partly balanced by the induced counter e.m.f., EA_1 (which is taken directly from plate 1 for values of field current corresponding to the current at this given power factor and given set of readings) and partly absorbed by the impedance drop OA_1 in the motor armature. Oi_1 be the current taken by the motor and lagging behind the voltage OE by an angle ϕ. The vector OA_1 may be constructed as a resultant of the vectors of ohmic and inductive drop. But the ohmic drop is usually small as compared to the inductive drop, and the total drop may usually be assumed to consist of the inductive drop only. The vector of this drop is, as usual, perpendicular to the direction of the current producing the drop.

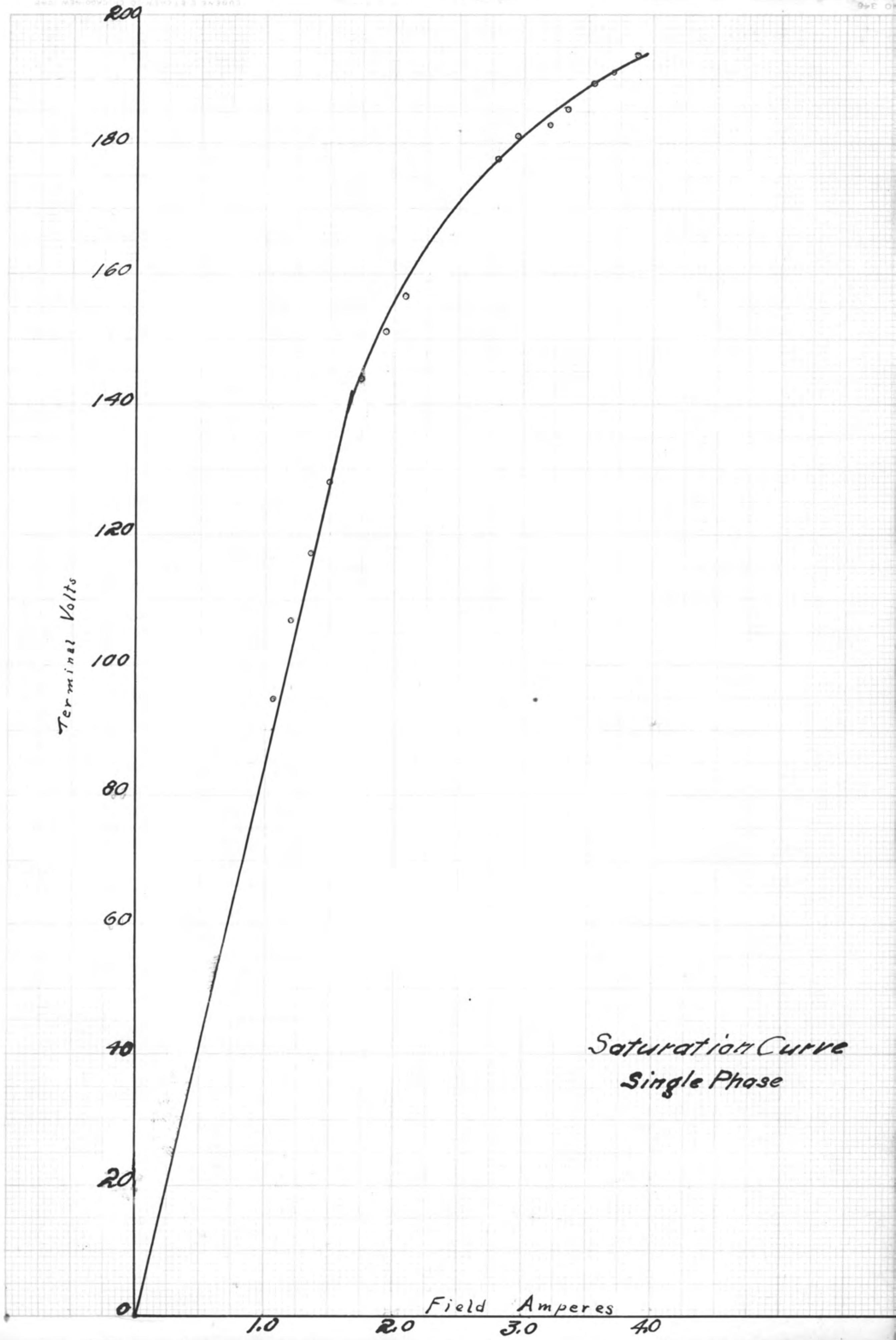
Increasing the excitation increases the counter e.m.f. EA_1 induced in the armature; at a certain value of the field current the triangle EA_1O is converted into EA_2O. The vector of the armature current, being perpendicular to OA_2, now assumes the position Oi_2, and is leading, instead of being lagging, as before. The currents Oi_1 and Oi_2 are so drawn in the diagram, that their working component Oi, in phase with the line voltage, is the same; this is because the output, or the load, being the same in both cases, the true input is also essentially the same. By adjusting the excitation so as to have a counter -e.m.f. equal to EA, the total current is reduced to Oi, in phase with the applied voltage; this corresponds to the lowest point upon the V curves. The vector diagrom shows that either reducing or increasing the field current beyond this value increases the armature current.

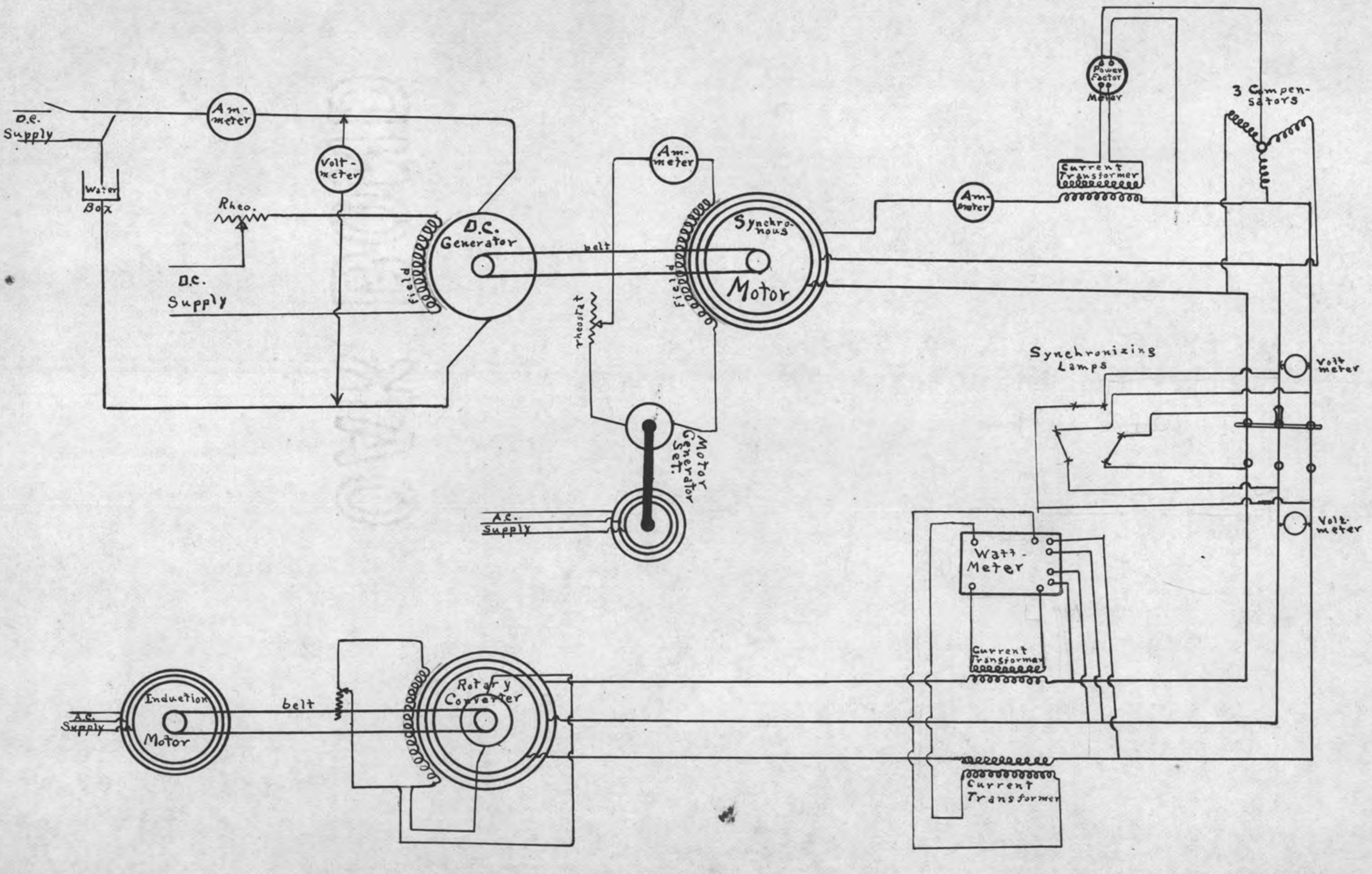
The shape of V-curves depend upon the inductive drop OA in the armature; Increasing the armature inductance makes the curbes more flat; reducing it tends to make the curves sharper. We find that this motor under test has comparatively flat curves, especially so in the single phase, quarter phase and three phase when delta connected; which makes it more stable in operation than one with sharper V-curves, because with flat curves the fluctuations in the armature current and the resulting equalizing currents are less prenounced.

SATURATION CURVE DATA:-

SINGLE--PHASE:-

I_f	E_a
1.055	94.8
1.21	107.
1.35	117.2
1.505	128.
1.66	140.2
1.8	142.
1.95	151.
2.1	156.4
2.275	158.9
2.45	166.
2.625	175.
2.8	177.8
2.95	181.
3.2-	182.7
3.35	185.4
3.55	189.5
3.7	191.
3.875	193.5
3.9	194.5


Saturation Curve
Single Phase
Terminal Volts
Field Amperes
200
180
160
140
120
100
80
60
40
20
0
1.0
2.0
3.0
4.0

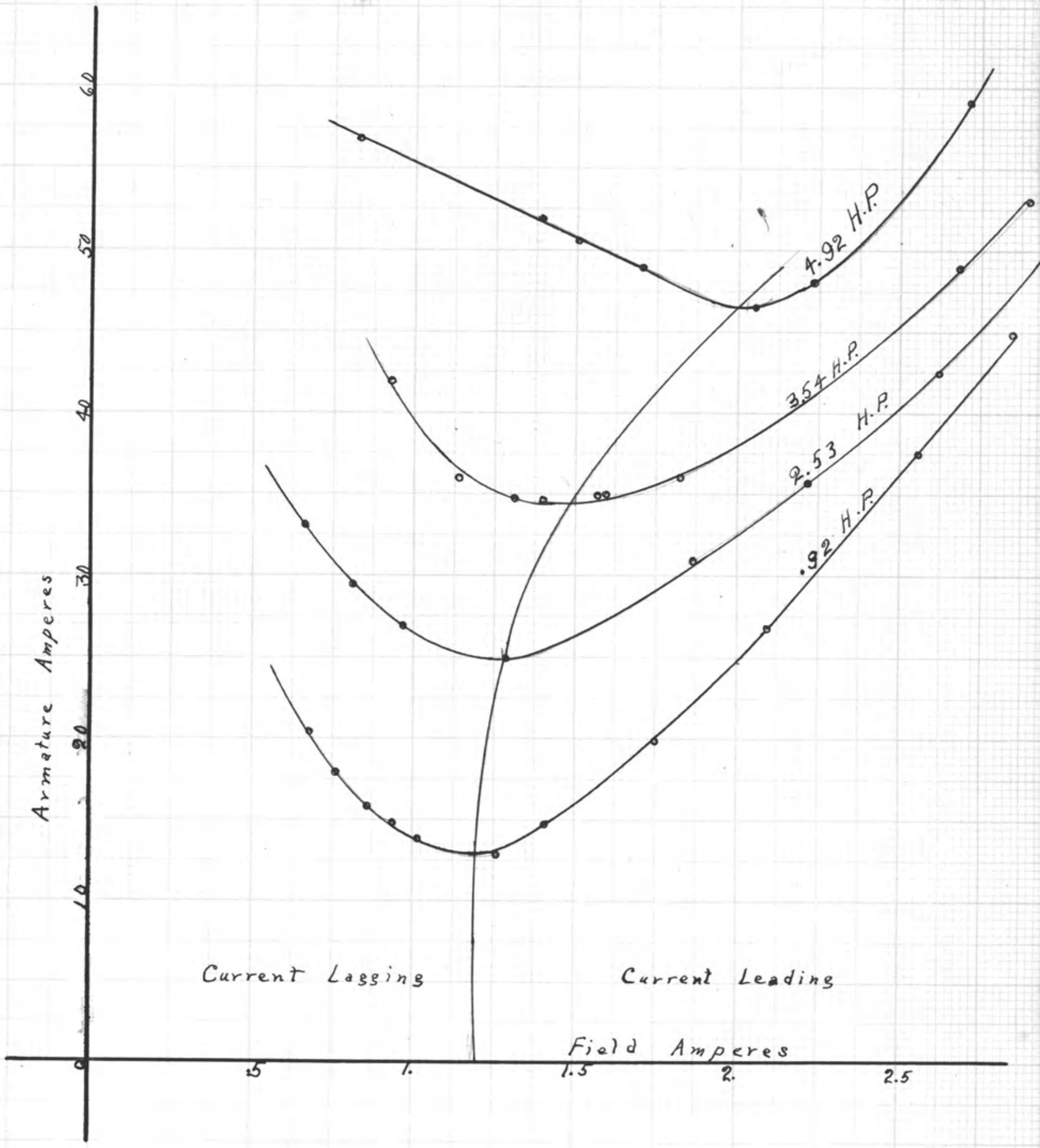


Connections for obtaining "V curves"

DIAGRAM FOR PLATE "B".

SINGLE PHASE " V-CURVES " DATA:-

I_a	E_a	I_f	WATTS	POWER FACTOR	I_a	E_f
24.5	122	1.9	5140	1.000	48.	145
	122	1.7	5060	.985	49.	
	119	1.555	4980	.970	50.	
	119	1.39	4860	.940	52.	
	118	1.825	4620	1.000	45.5	
	119	2.05	4800	.995	46.5	
	117	2.24	4920	.990	48.	
	120	2.42	5040	.980	54.	
	120	2.725	5100	.960	59.	
16.25	121	1.575	3540	1.000	35.	145
	120	1.4	3540	.990	34.5	
	120	1.31	3540	.980	35.	
	119	1.125	3480	.950	36.	
	119	.92	3720	.870	42.	
	119	.825	3780		57.	
	117	1.82	3420	.990	36.	
	118	2.21	3695	.955	42.	
	119	2.69	4020	.990	49.	
	120	2.895	4080	.870	53.	
10.	120	1.29	2472	.990	25.	145
	119	1.175	2530	.970	26.	
	119	.965	2580	.930	27.	
	121	.81	3120	.840	29.5	
	119	.655	2640	.750	33.	
	120	1.855	2615	.955	31.	
	120	2.205	2820	.900	36.	
	120	2.615	3120	.820	43.	
	121	2.96	3420	.800	50.	
		1.26	1200	.995	13.	145
		1.01	1260	.860	14.	
		.945	1296	.780	15.	
		.840	1260	.650	16.	
		.760	1308	.640	18.	
		.670	1403	.600	20.5	
		1.400	1260	.985	15.5	
		1.750	1356	.840	20.	
		2.095	1500	.720	27.0	
		2.560	1620	.610	37.5	
		2.660	1740	.590	49.	
		2.855	1751	.570	45.	

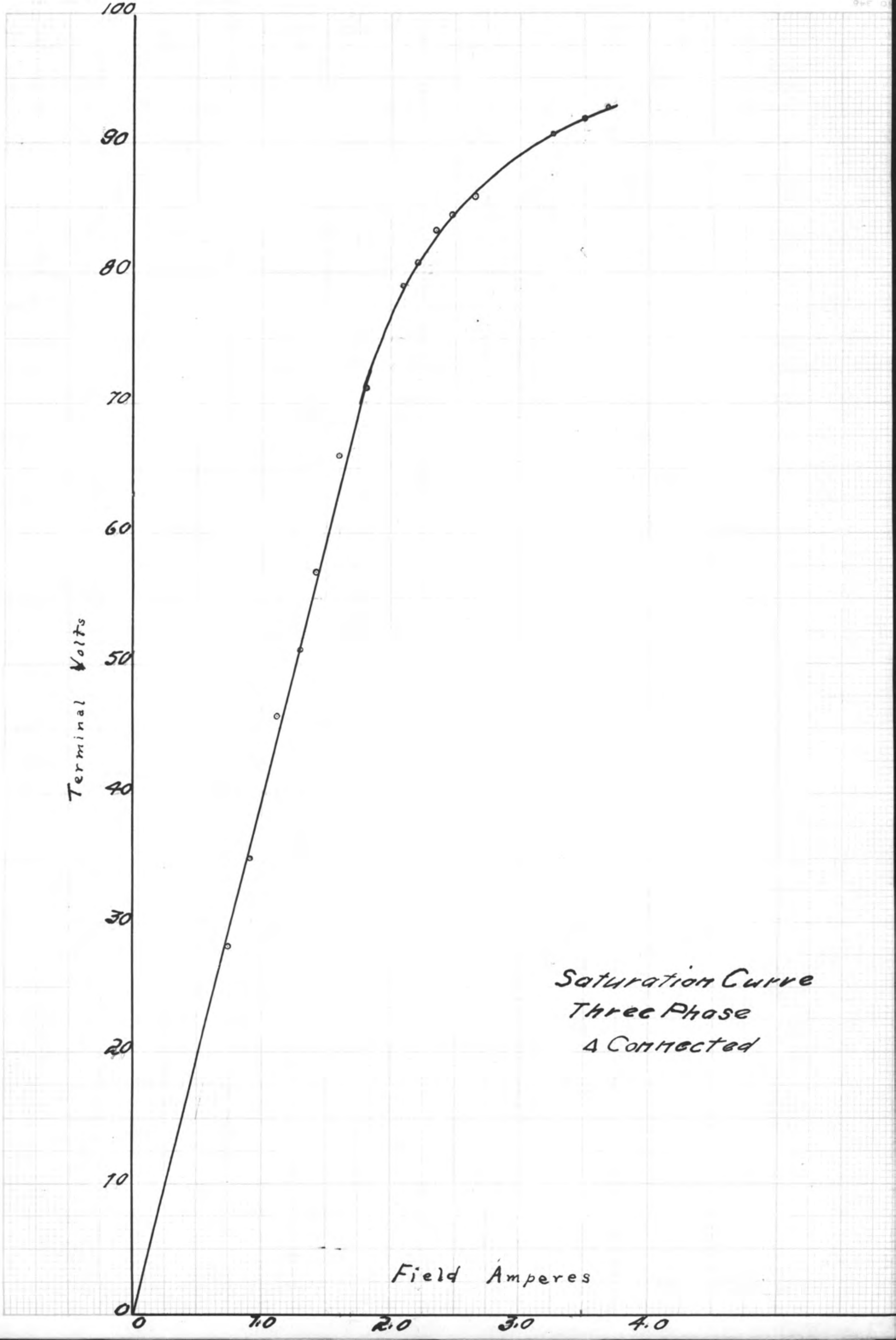


V-Curves For Single Phase.

SATURATION CURVE DATA:-

THREE PHASE DELTA:-

I_f	E_a
.75	28
.92	35
1.115	46
1.3	51
1.41	57
1.6	66
1.815	71.2
2.08	79.1
2.205	80.9
2.355	83.8
2.47	84.4
2.64	85.8
3.25	90.8
3.4	92.
3.51	91.8
3.675	92.8
3.725	93.5

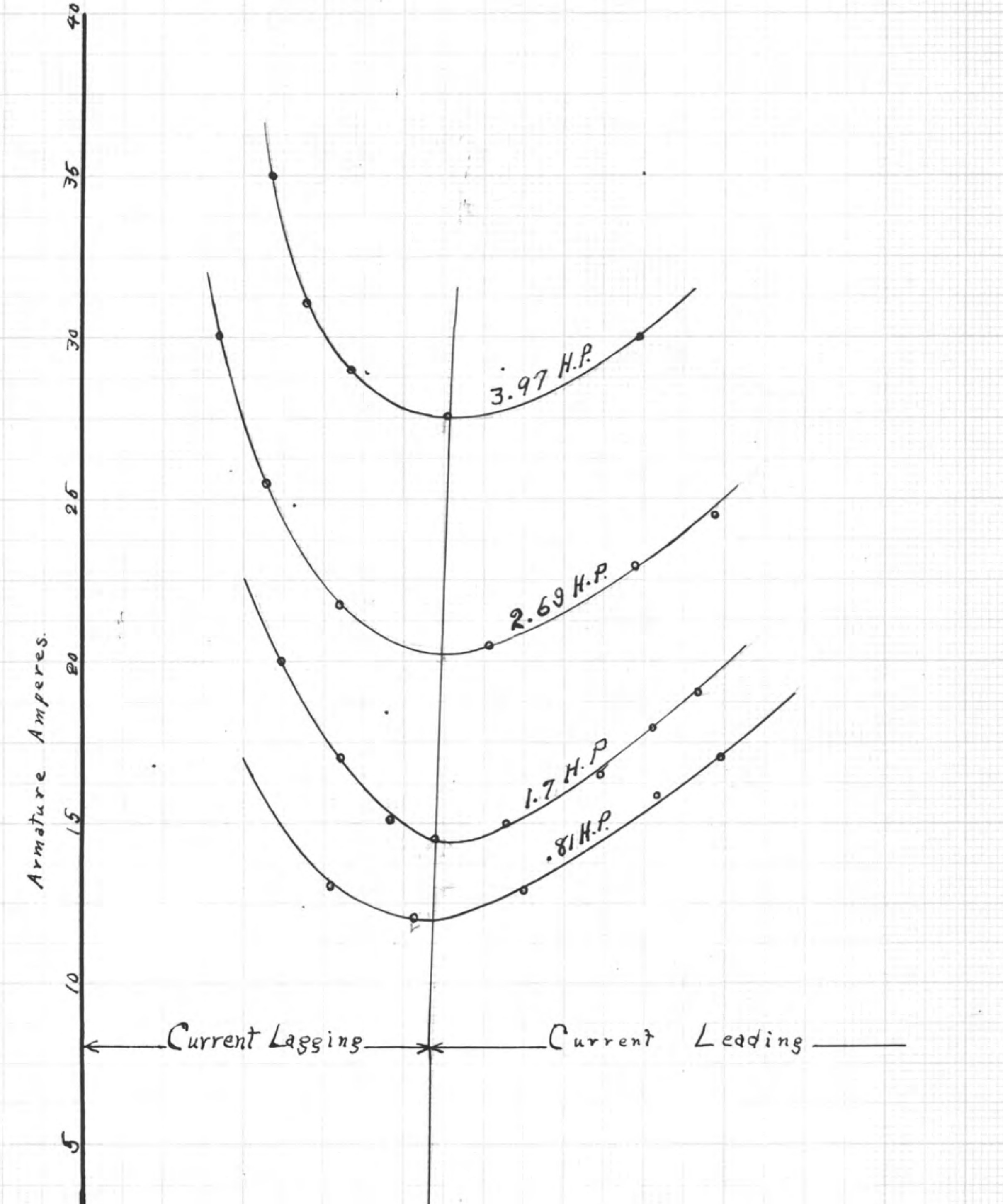

100
90
80
70
60
50
40
30
20
10
0
Terminal Volts
0
1.0
2.0
3.0
4.0
Field Amperes
Saturation Curve
Three Phase
Δ Connected

THREE PHASE DELTA CONNECTED "V-CURVES" DATA:-

GENERATOR			MOTOR					
I_a	E_a	Stray P	H.P. Output	E_a	I_a	I_f	% Power factor	Input Watts.
25	95	586	3.97	86	30	3.49	95	3840
				80	27.5	2.265	100	3810
				68	29	1.675	97.5	3530
				62	31	1.4	96	3600
				50	35	1.2	95.5	3420
15.2	93.5	586	2.69	94.2	24.5	3.9	88	2760
				91.8	23	3.45	95	2670
				85	20.5	2.54	99.7	2700
				74	21.5	1.6	93	2460
				59	25.5	1.15	86	2520
				45	30	1.35	70	2460
7.5	91	586	1.7	95	19	3.85	85	1920
				93.5	18	3.55	90	1825
				92	16.5	3.25	96	1825
				88.5	15	2.65	100	1800
				84	14.5	2.2	96	1800
				81.5	15	1.925	89	1740
				75.5	17	1.63	80	1740
				68	20	1.25	70	1740

THREE PHASE DEETA CONNECTED "V-CURVES" DATA:-

GENERATOR			MOTOR					
I_a	E_a	Stray P.	H.P. Output	E_a	I_a	I_f	% Power factor	Input Watts.
0	100	602	.81	76	17	4	75	1080
				72	16	3.33	90	1140
				67	14	2.75	97	1140
				59	13	2.09	100	1020
				50	14	1.3	96	900
				49	14	1.25	95	840

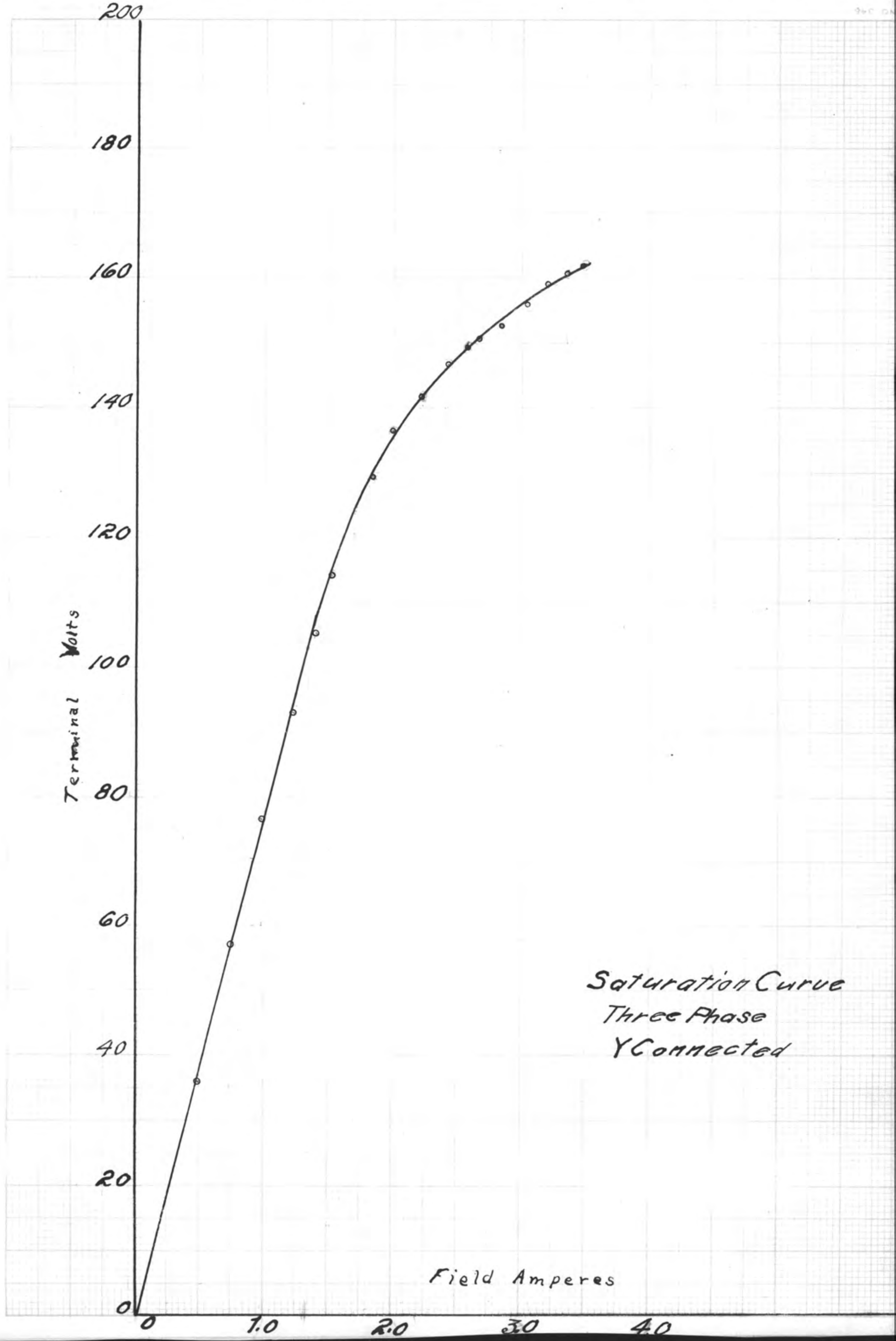


V-Curves For 3 Phase Delta connected

SATURATION CURVE DATA:

THREE PHASE "Y" Connected:-

I_f	E_a
.5	36
.75	57
.99	76.8
1.225	93.
1.405	105.1
1.555	114.6
1.7	120.4
1.85	128.75
2.025	135.6
2.23	141.5
2.42	145.75
2.56	149.1
2.675	150.5
2.85	152.8
3.03	156.8
3.2	159.2
3.35	160.4
3.48	161.75
3.6	179.8
3.705	185.2
3.7	184.2

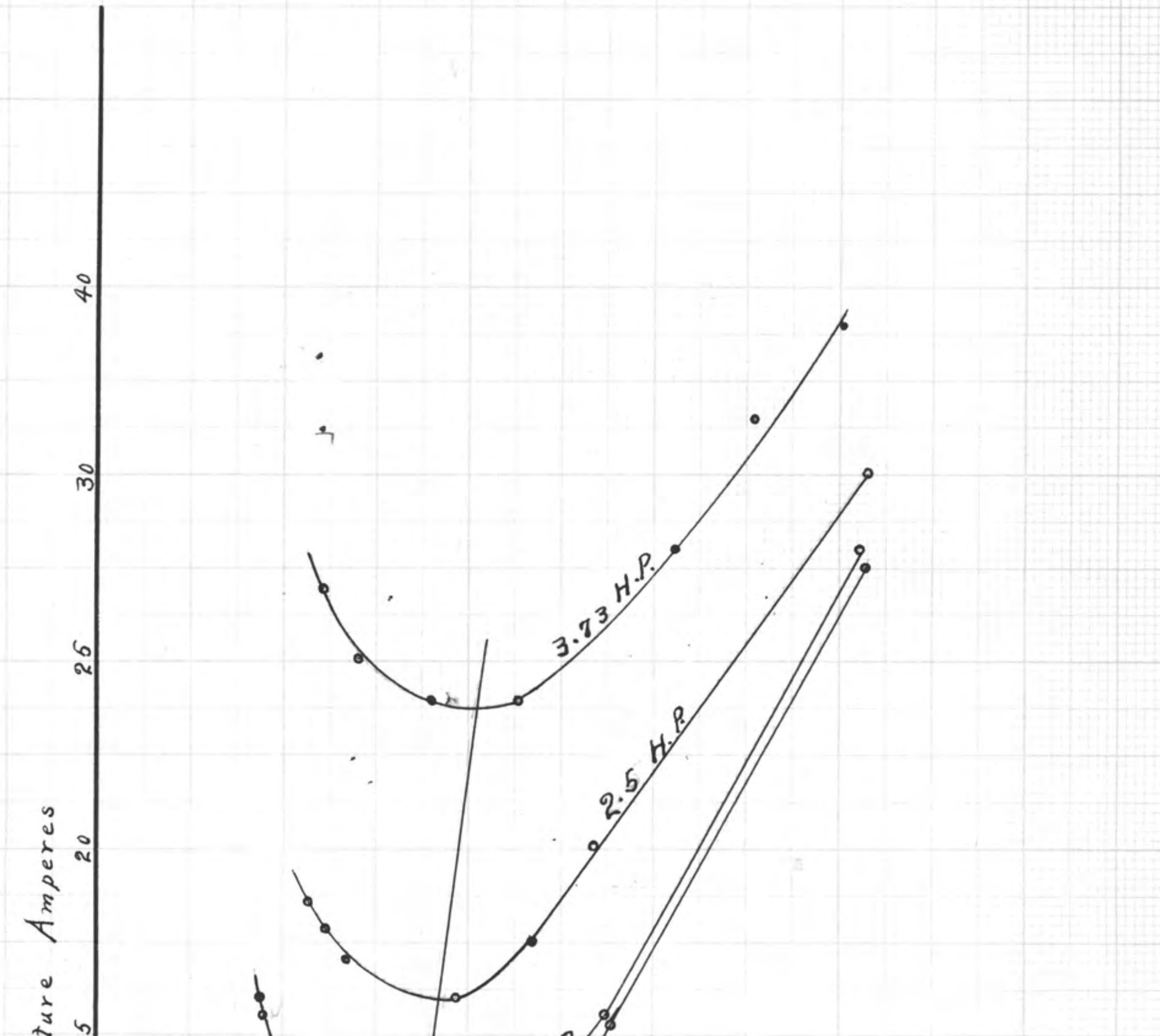

200
180
160
140
120
100
80
60
40
20
0
Terminal Volts
Saturation Curve
Three Phase
Y Connected
Field Amperes
0
1.0
2.0
3.0
4.0

THREE PHASE Y CONNECTED "V-CURVES" DATA:-

GENERATOR				MOTOR				
I_a	E_a	Stray P	H.P. Output	E_a	I_f	I_a	% Power Factor	Input Watts
25	88.5	570	3.73	98.5	4.025	34	80	3560
				98	3.55	31.5	86.5	3540
				97	3.11	28	92.5	3540
				92.7	2.29	24	99.4	3420
				85.8	1.8	24	98.7	3360
				80.8	1.4	25	95.3	3240
				77	1.25	27	91.	3420
17.5	73	586	2.5	102.5	4.15	30	65	2520
				104.	3.75	27.5	68	2580
				99	2.665	20	89.5	2160
				96	2.3	17.5	96.8	2160
				90.2	2.605	16.5	97.3	2280
				87	1.35	17	92.5	2160
				84	1.25	18	88.3	2130
				83.8	1.15	18.6	83	2130
10	60	520	1.5	106.5	4.11	28	48	1680
				98.5	2.325	14	86.5	1260
				96.5	2.1	12	97	1320
				91.8	1.625	11	93	1260
				86.5	1.3	12	79.5	1310
				81.8	1.15	13	75	1250
				85	1.1	14	70.5	1260
				84	1	15	65	1260

THREE PHASE Y CONNECTED "V-CURVES" DATA:-

GENERATOR			MOTOR					
I_a	E_a	Stray P	H.P. Output	E_a	I_f	I_a	% Power Factor	Input Watts.
0	49	520	.7	102	4.15	27.5	68.9	1020
				99.3	2.4	12	71.5	816
				94	2.25	11	80	720
				96.5	2	8.5	96	660
				94	1.7	7	88	684
				90	1.55	7	80	660
				91	1.45	7.5	70	600
				88	1.15	11	60	660

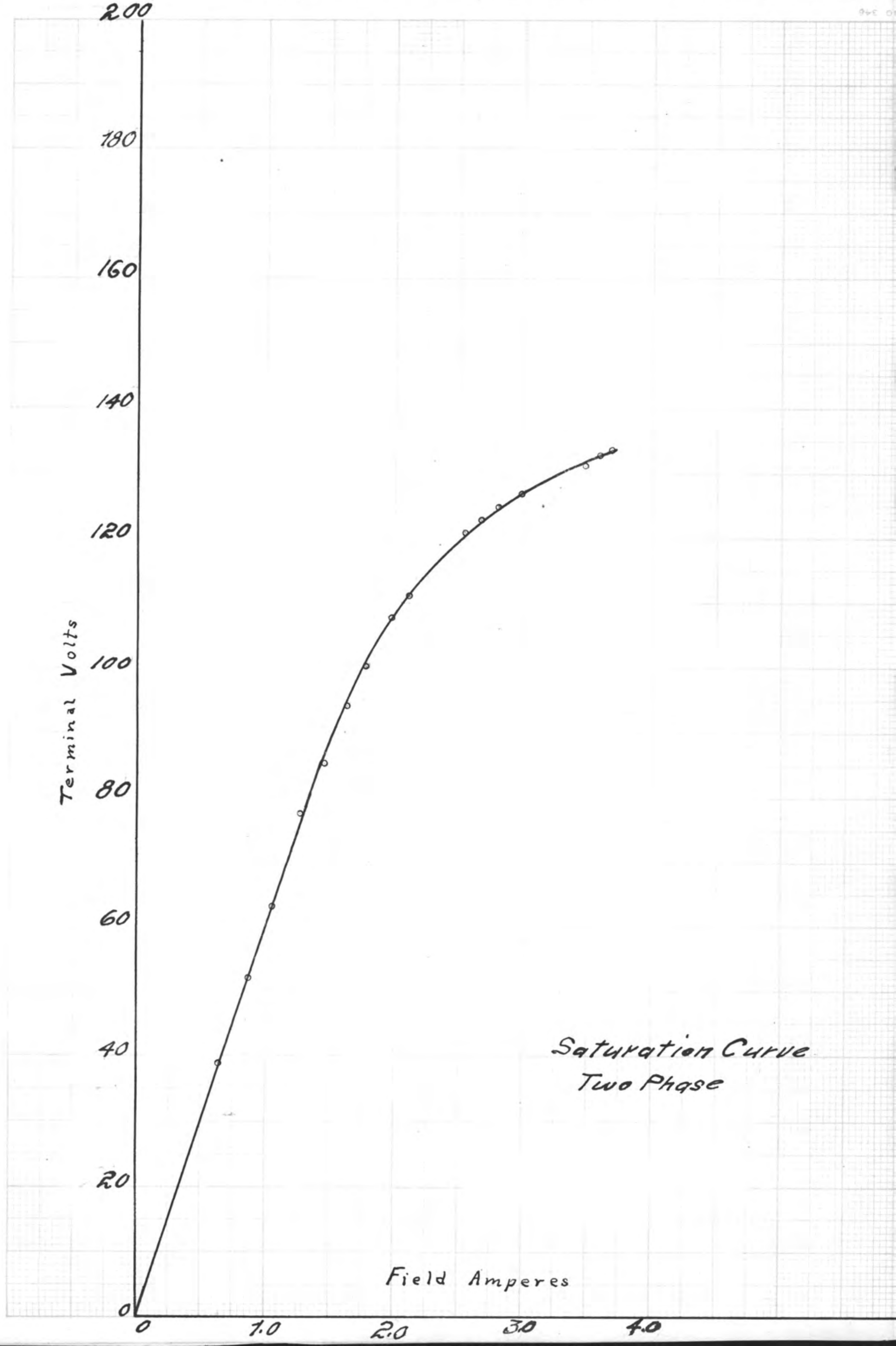


"V-Curves for 3 Phase "Y" Connected

S A T U R A T I O N   C U R V E   D A T A :-

Q U A R T E R   P H A S E :-

I_f	E_a
.655	39
.85	52
1.05	63
1.26	77.8
1.45	85.7
1.66	94
1.765	104.4
1.975	107.7
2.1	111.4
2.325	118.8
2.525	121.5
2.695	123.2
2.825	125.5
2.975	127
3.15	125
3.275	128.3
3.465	131
3.575	133
3.675	133.8

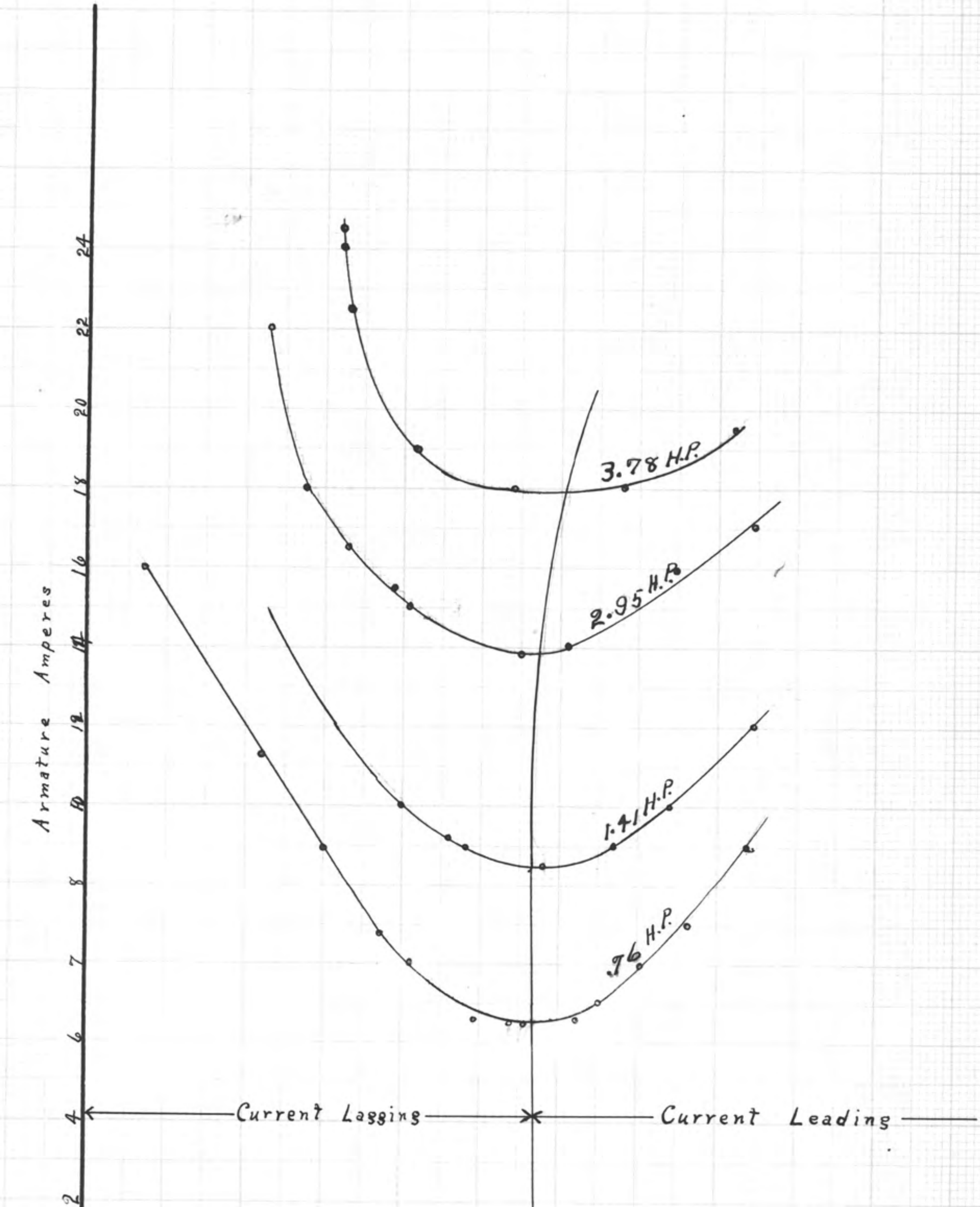

200
180
160
140
120
100
80
60
40
20
0
Terminal Volts
0
1.0
2.0
3.0
4.0
Field Amperes
Saturation Curve
Two Phase

QUARTER PHASE "V-CURVES" DATA:-

GENERATOR				MOTOR				
I_a	E_a	Stray P.	Output	E_a	I_a	I_f	% Power factor	Input Watts.
25	92	520	3.78	98.5	21.5	4.1	94.5	2160
				99	21.5	4.1	95	2160
				98	21.5	4	95.5	2040
				95	20	3.4	98.5	1320
				89	20	2.725	100	540
				80.5	21	2 .075	98.2	120
				71	24.5	1.65	96.5	504
				65	26	1.6	96	564
17.5	93	570	2.95	100.5	19	4.225	91.8	2160
				98.5	18	3.775	97	1740
				93.5	16	3.05	99	800
				92	15.8	2.75	99.8	420
				83	17	2.05	97	384
				82	17.5	1.95	96	504
				77	18.5	1.65	93	804
				70	20	1.375	90	1044
8.75	82	536	1.41	104.5	14	4.125	82	1776
				101	12	3.7	82.5	1200
				98	11	3.25	97.7	600
				97	10.5	2.9	100	264
				93	11	2.4	95	240
				92	11.25	2.3	92.5	360
				91	11.25	2.175	89	540
				87.5	12	2	82	768

QUARTER PHASE "V-CURVES" DATA:-

GENERATOR			MOTOR					
I_a	E_a	Stray P.	H.P. Output	E_a	I_a	I_f	% Power factor	Input Watts.
0	85	570	.76	105	11	4.2	68.5	1596
				103.8	9	3.87	78	1068
				102.5	8	3.53	88.5	732
				101.2	7	3.25	98	384
				100	6.5	3.01	99.8	156
				98.6	6.5	2.78	97	60
				97.5	6.5	2.7	95	60
				94.6	6.5	2.46	84	276
				92.5	7.0	2.2	72	640
				91.1	8.0	2.06	61	900
				88.5	8.75	1.875	58	1044
				84.3	11	1.54	50	1404
				74.5	13.25	1.1	44	1800

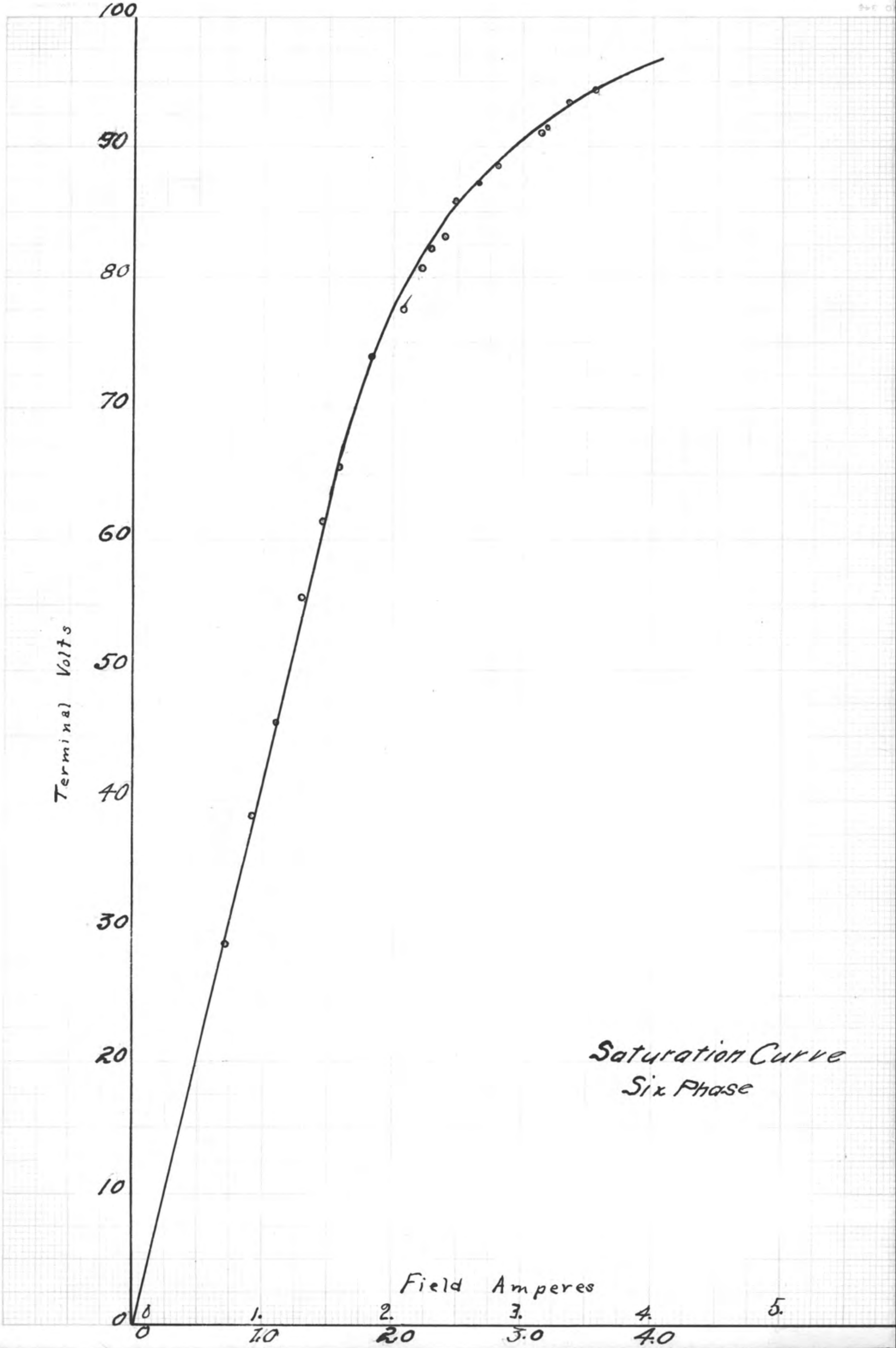


V-Curves for Quarter Phase

SATURATION CURVE DATA :-

SIX PHASE :-

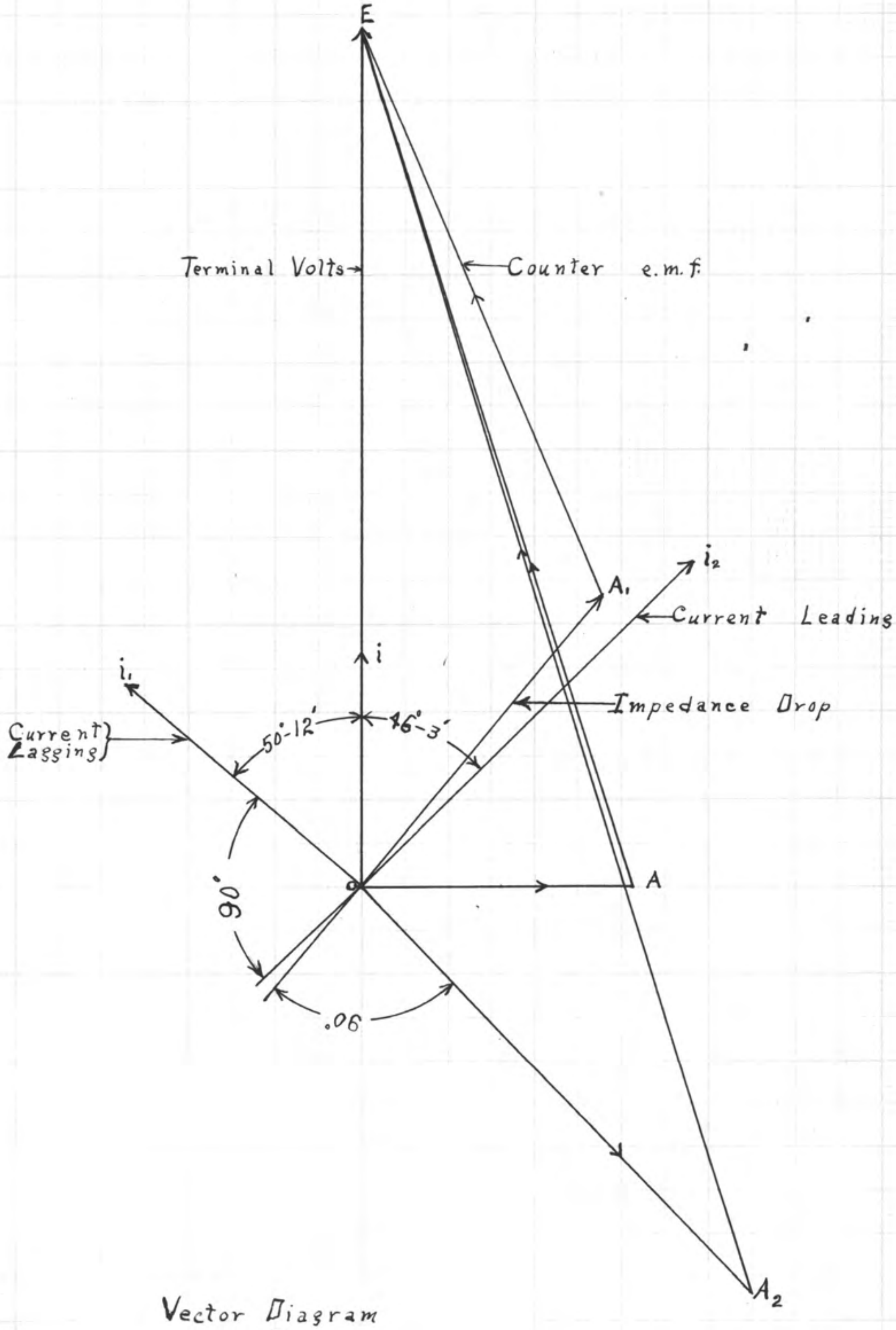
I_f	E_a
.725	29
.902	39
1.105	46.5
1.29	55.5
1.455	61.5
1.6	65.5
1.82	74
2.1	77.5
2.185	80.6
2.305	82.1
2.49	85.7
2.65	87.1
2.81	88.5
3.15	91.
3.175	92.
3.355	93.3
3.58	94.
3.6	97.



100
90
80
70
60
50
40
30
20
10
0
Terminal Volts
Field Amperes
0
1.
2.
3.
4.
5.
0
1.0
2.0
3.0
4.0
Saturation Curve
Six Phase

SINGLE-PHASE " VECTOR DIAGRAM ":

CURRENT			
IN PHASE	LAGGING	LEADING	
1.75	.76	2.095	----- I_f
1.	.64 lag.	.72 lead.	----- Power factor.
0	50° - 12'	46° - 3'	----- angle.
104	71.5	154.	----- counter e.m.f.
32.	43.	66.	----- volts impedance drop.
13.	18.	27.	----- armature current amperes.
24.6	24.5	24.5	----- armature impadance.

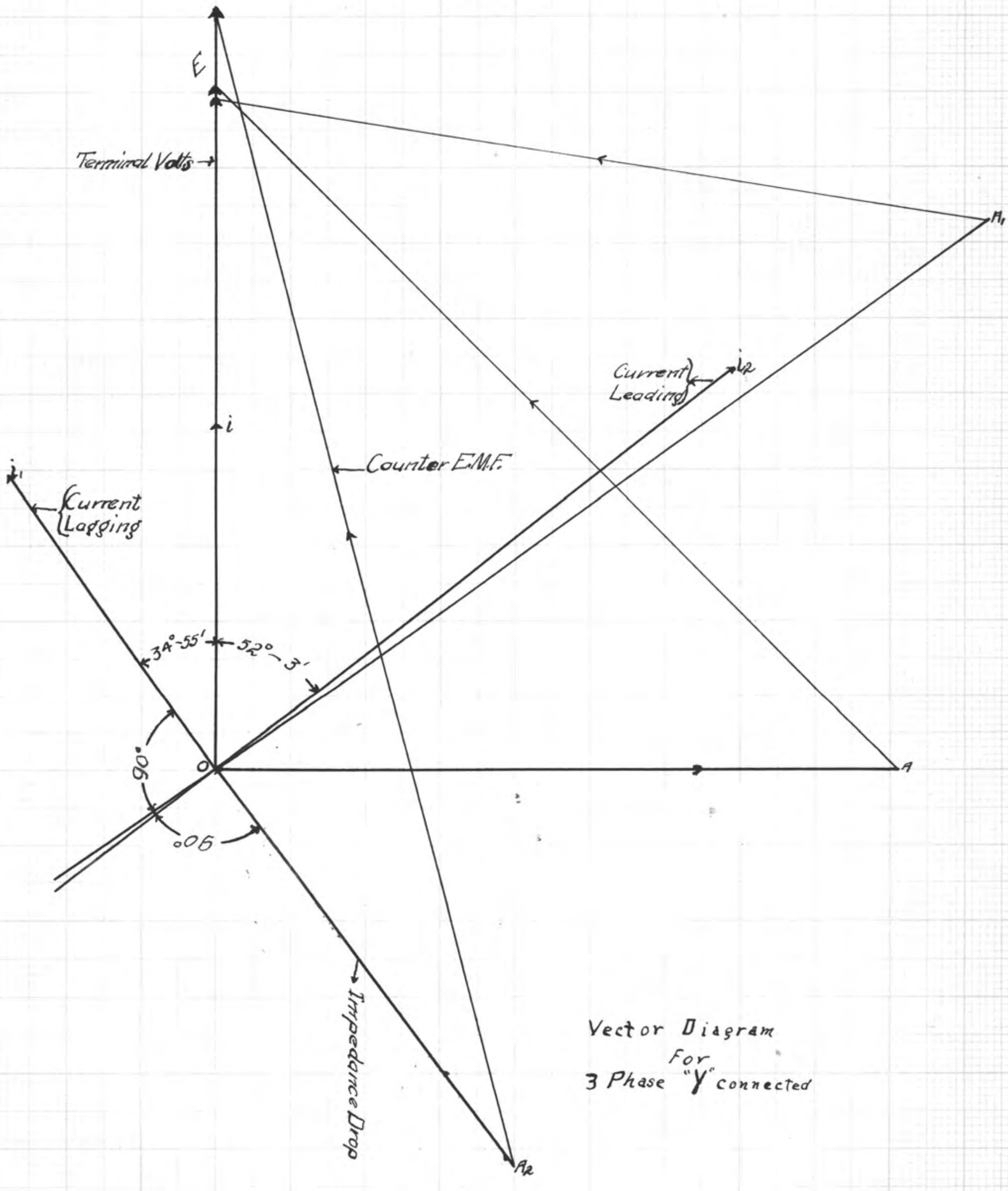


Vector Diagram
For
Single Phase.

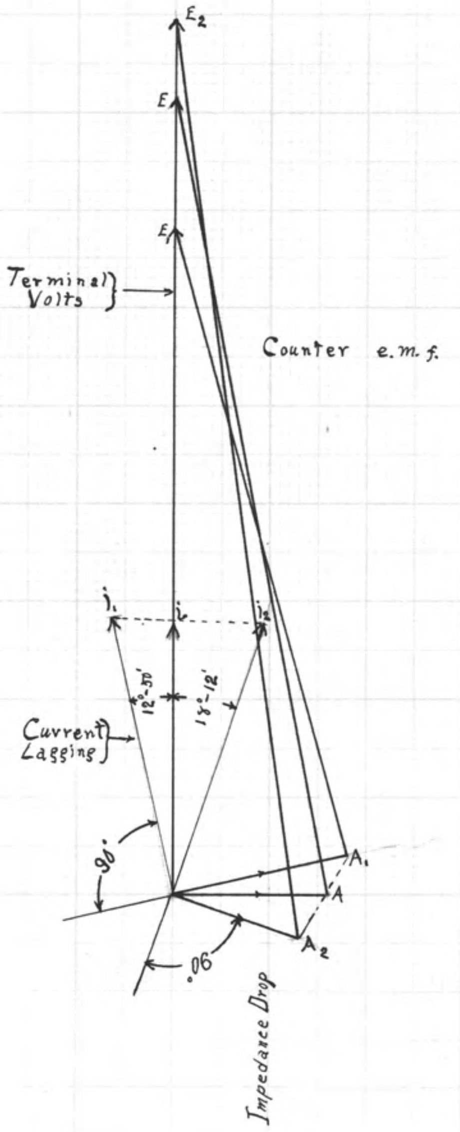
VECTOR DIAGRAM DATA.

Three phase Y connected.

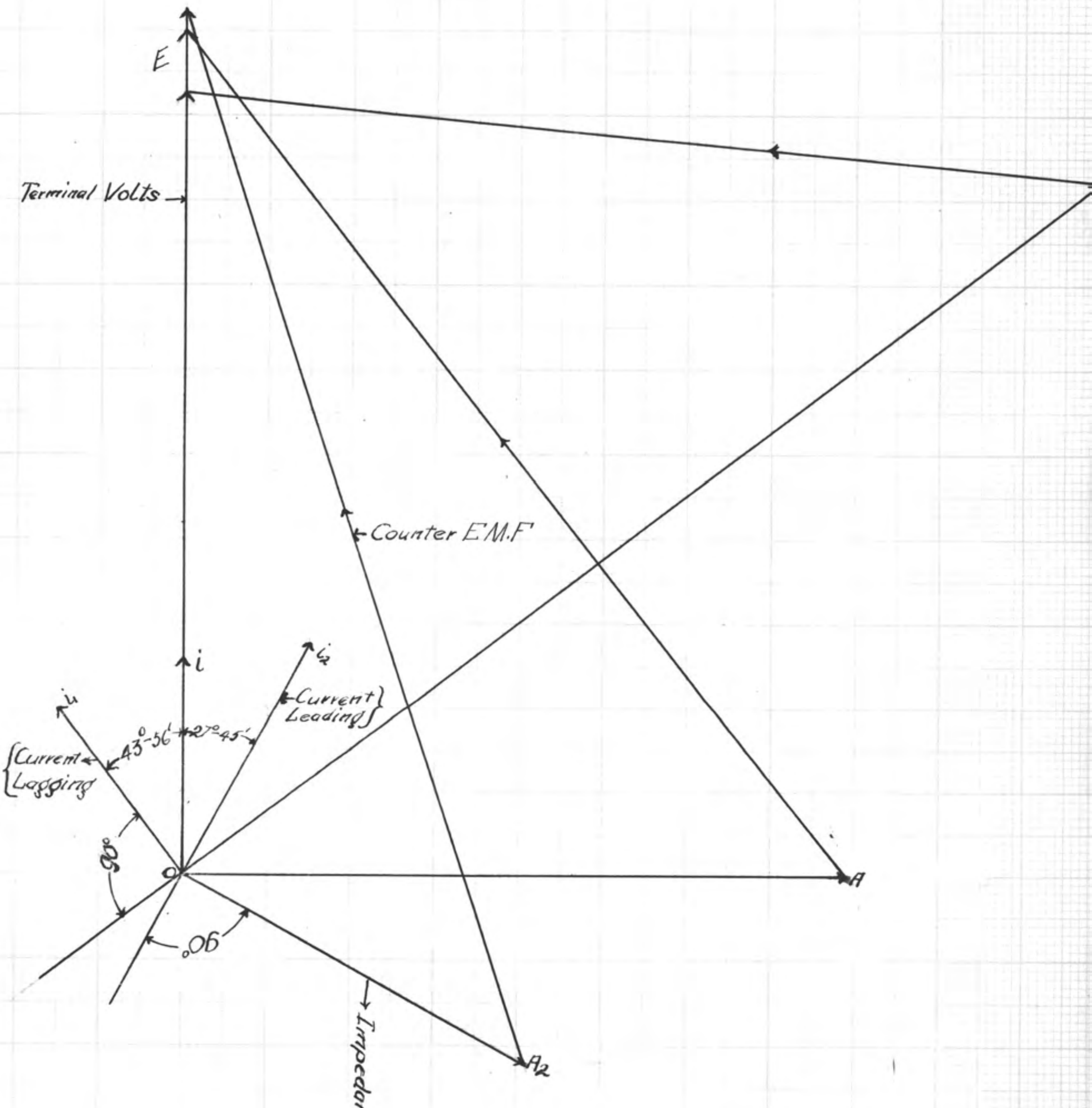
Current	I_f	% Power factor	Angle	Counter E.M.F.	Volts Imped.	Arm. Amps.	Arm. Imped.	Term. Volts.
In phase	1.84	100	0°	129	91	11.5	7.92	91
Reading	1.39	82	34°-55'	105	65.5	12	5.46	89.2
Lagging	3.24	61.5	52°- 3'	159	126.5	22	5.725	101.
Three phase delta connected.								
In phase	2.265	100	0°	81.5	21.	27.5	.764	80.
Leading	1.675	97.5	12°-50'	66	12.5	29	.432	68
Lagging	3.49	95	18°-12'	92	30.5	30	1.015	86
Quarter phase.								
In phase	3.1	99.8	0°	128	79	6.5	12.15	100
Lagging	2.05	72	43°-56'	110	152	7	21.7	92.5
Leading	3.5	88.5	2 7°-45'	132	47	8	5.875	102.5



Vector Diagram
For
3 Phase "Y" connected

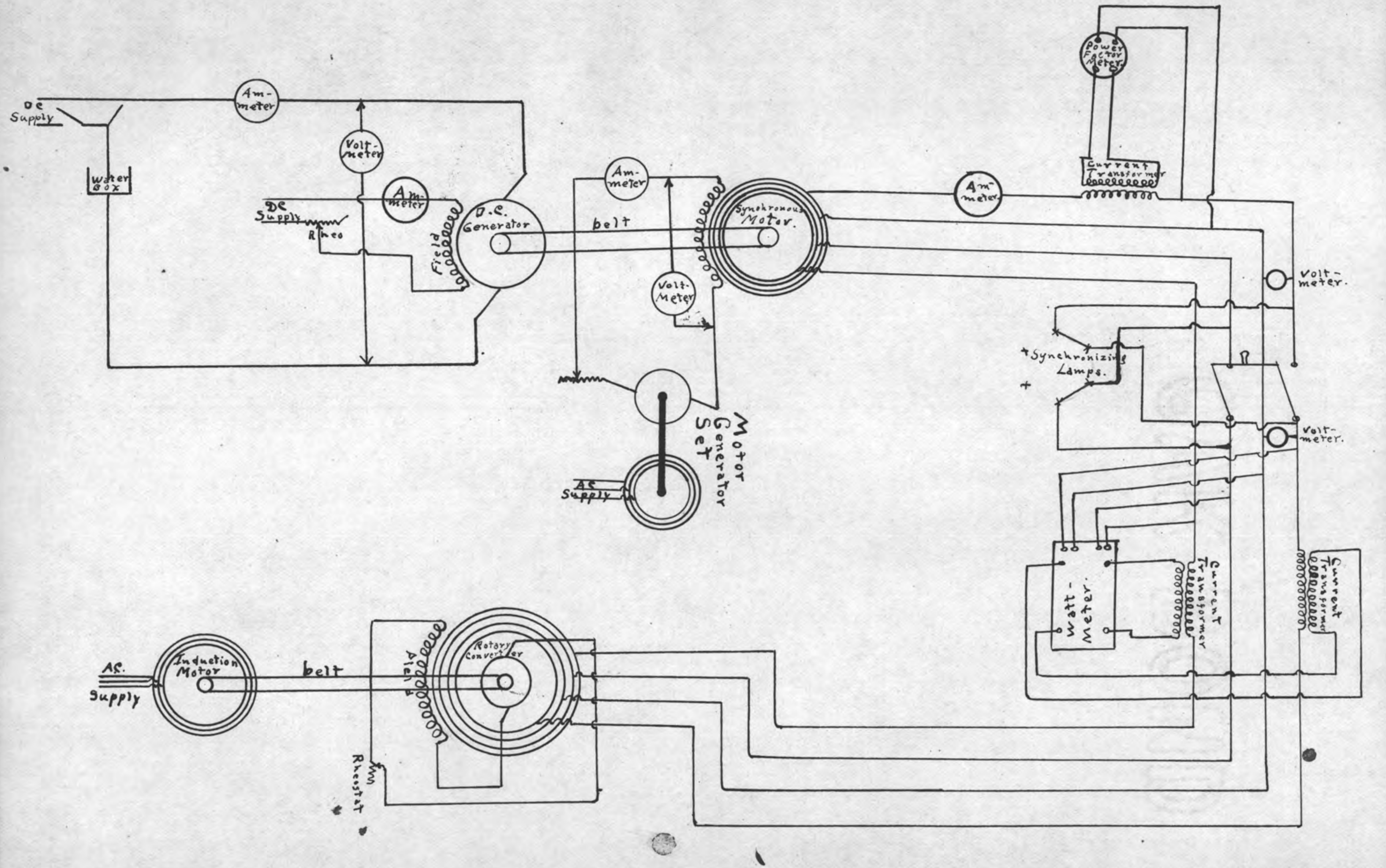


Vector Diagram
For
3 Phase Delta Connected.



Vector Diagram
Quarter Phase

The purpose of this experiment is to investigate the performance of the synchronous motor when running as a single-phase, three phase connected both delta and Y also when running as a quarter phase synchronous motor, mainly in regard to its efficiency and power factor under various loads. The apparatus was connected according to diagram "C". The motor being brought up to speed by a similar method as was used in the foregoing experiments. The armature of the synchronous motor again being supplied from the rotary converter. The field current was so set as to have a power factor of 100% atas heavy a load as practicable, and kept constant through out the run. In thisrun the load upon the motor was gradually decreased by decreasing the load upon the generator which it was running. Readings were taken of Motor (armature volts, armature amperes, field volts, field amperes, armature watts and power factor). At the same time readings of Generator (armature volts, armature amperes and field amperes). This test was preformed when the machine was running as a single phase, three phase connected both delta and Y also when running as a quarter phase synchronous motor. The machine was running at synchronous speed which at the beginning of each run was read. However, there might have been a slight variation from this speed throughout the run owing to the variation of the frequency of the supply current; yet it was considered to be constant throughout each separate test. From this set of data to K.W. OUTPUT as abscissae the power factor, efficiency, Apparent K.W. input, true K.W. input, K.W. output, and the synchronous speed of the motor was plotted as ordinates.



Connections For Obtaining Performance Curves For Quart[illegible]

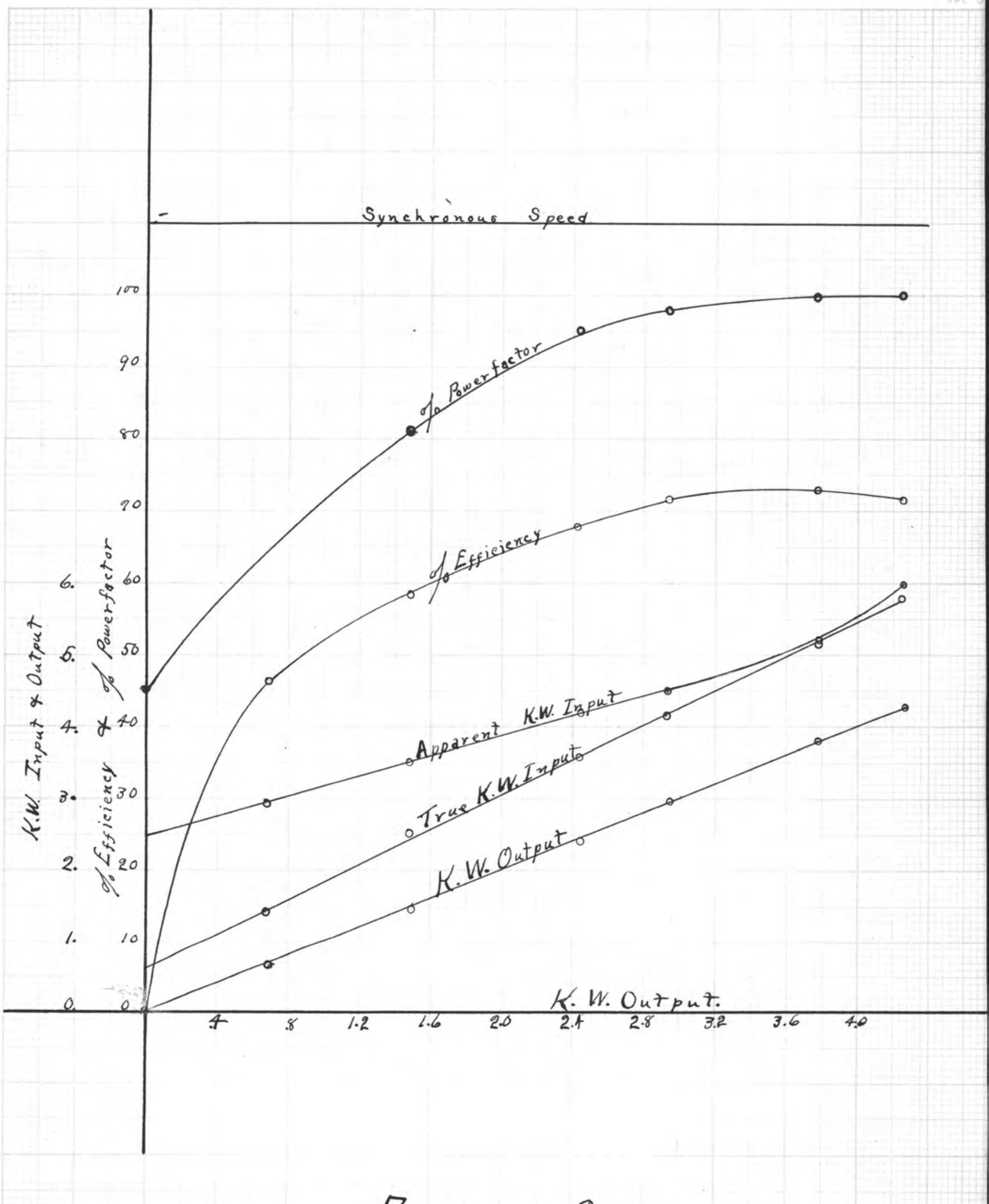
Diagram For Plate "D"

PERFORMANCE CURVES SINGLE PHASE:- DATA:-

MOTOR:-						GENERATOR:-		
E_a	I_a	E_f	I_f	armature input Watts	% Power factor	E_a	I_a	I_f
102	54.	145	1.95	5700	100	118	29.	2.5
105.8	46.5	145	1.925	4920	99.5	119	25.	2.5
109.5	38.5	145	1.95	3840	98.	118	18.5	2.45
113.5	34.5	145	1.95	3300	95.	121.5	13.75	2.48
113.7	28.5	145	1.95	2280	81.	121.	6.5	2.425
116.5	23.	145	1.95	1200	65.	121	0.	2.4

GENERATOR					MOTOR			
E_aI_a	STRAY POWER	OHMS resis-tance	I_a^2R	OUTPUT Watts	Armature Input Watts	I_fE_f	Total Input	% Effici output/input
3422	690	.175	147.3	4259.3	5700	282.8	5982.8	71.3
2975	690	.19	119.	3784.	4920	279.1	5199.1	72.85
2184	690	.212	72.7	2946.7	3840	282.8	4122.8	71.4
1685	690	.24	45.3	2420.3	3300	282.8	3582.8	67.5
786.5	690	.295	12.5	1489.	2280	282.8	2562.8	58.2
00.	690	.---	0.	690.	1200	282.8	1482.8	46.5

MOTOR		
E_aI_a	E_fI_f	INPUT apparent
5510	282.8	5792.8
4918	279.1	5197.1
4214	282.8	4496.8
3914	282.8	4196.8
3241	282.8	3523.8
2580	282.8	2962.8



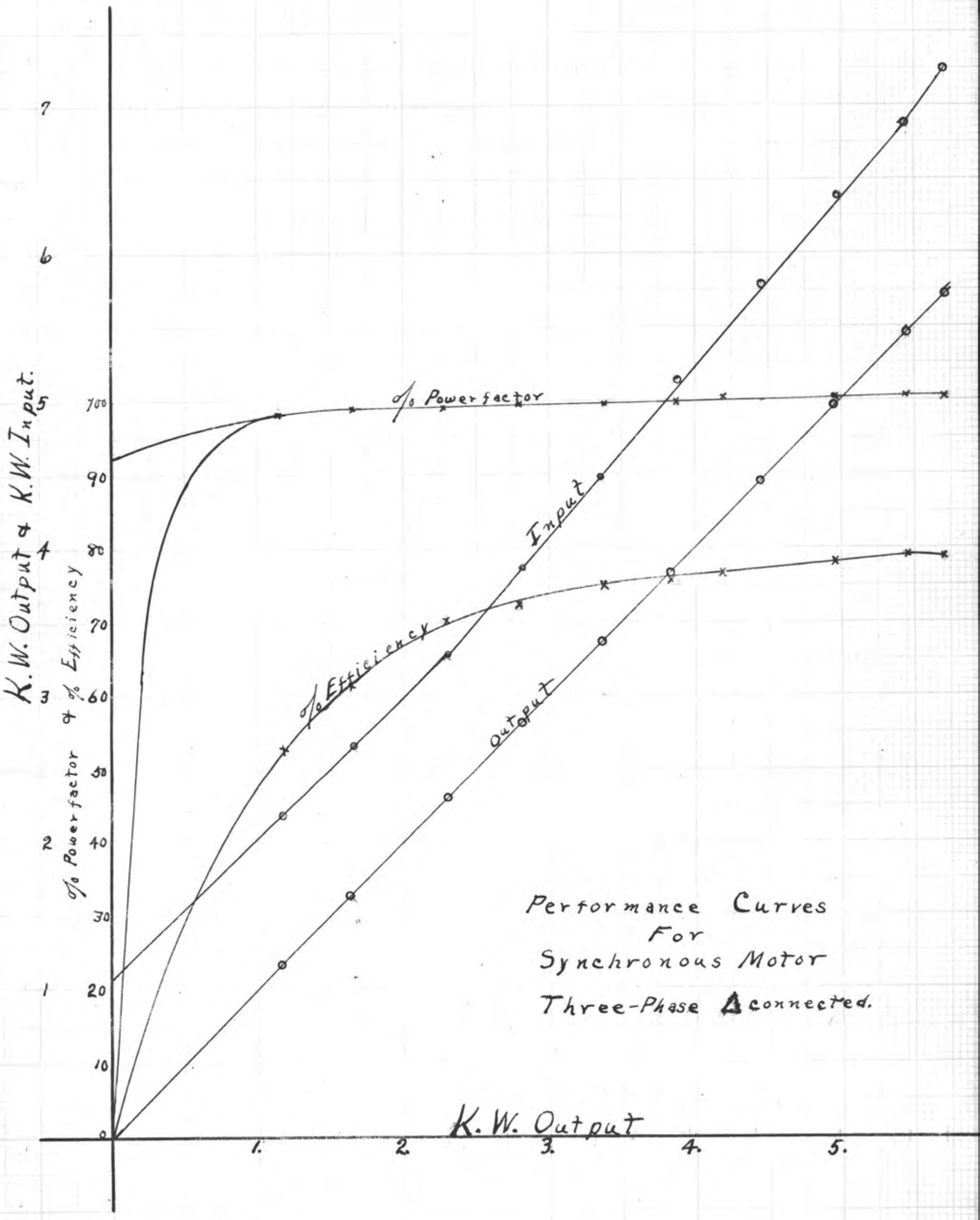
Performance Curves of A synchronous Motor SINGLE-PHASE.

PERFORMANCE CURVE DATA.

Three phase delta connected.

MOTOR						GENERATOR		
a	I_a	E_f	I_f	Arm. Input Watts	% Power Factor	E_a	I_a	I_f
6	50			6360	99.4	98.9	46.75	2.05
7	52	77.75	68	6730	99.5	97.0	50.0	2.04
7	47			5880	99.7	101.	41.5	2095
7	42			5280	99.8	101.5	36.45	2075
8	38			4625	100.	103.5	30.55	2.065
9	34			3960	99.9	105	25.5	2.075
9	26			2760	99.5	105.5	16.	2.06
0	29.5			3360	99.7	106.	20.25	2.06
0.5	21			2160	99.	109.	9.6	2.0575
1.0	17.5			1680	99.	110.	5.25	2.06

GENERATOR			MOTOR			
$_aI_a$	Stray Power	$I_a{}^2R$	Input Watts	E_fI_f	Total Input	% Effic.
850	518	345	5713	527	7257	78.8
630	526	306	5462		6887	79.5
180	534	270	4984		6407	78.4
700	550	215	4465		5807	77.0
150	566	158	3874		5152	75.2
680	574	118	3372		4487	75.1
670	574	56	2300		3287	70.2
150	574	82	2806		3887	72.4
045	574	24	1643		2687	61.3
578	574	8	1160		2207	52.8

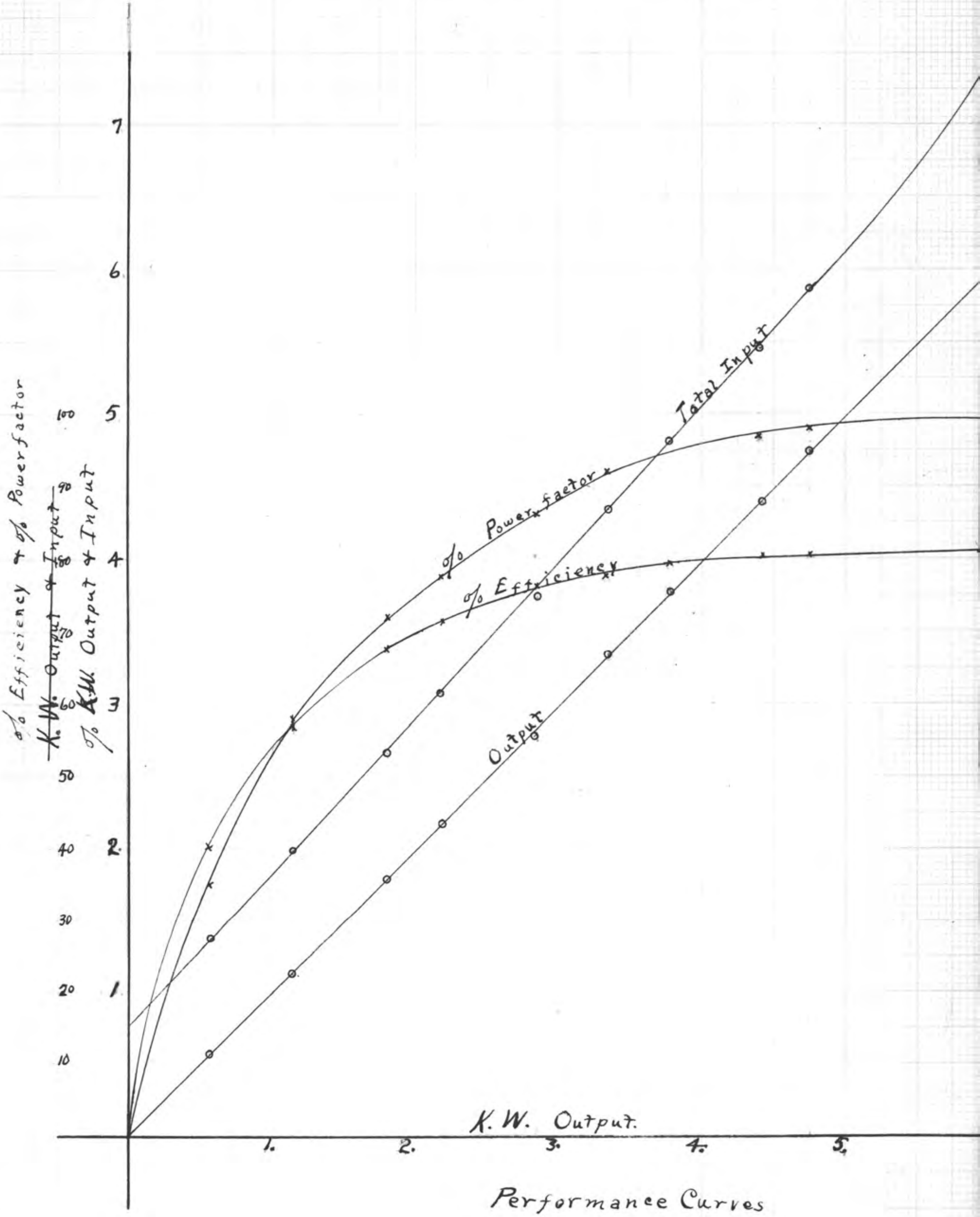

Performance Curves
For
Synchronous Motor
Three-Phase Δ connected.
K.W. Output & K.W. Input.
% Power factor & % Efficiency
% Power factor
% Efficiency
Input
Output
K.W. Output
1. 2. 3. 4. 5.
1 2 3 4 5 6 7
10 20 30 40 50 60 70 80 90 100

PERFORMANCE CURVE DATA.

Three Phase Y Connected.

MOTOR						GENERATOR		
E_a per θ	I_a per θ	E_f	I_f	Arm. input watts	% Power factor	E_a	I_a	I_f
87	30	139	3.15	2640	77.5	106	14.9	2
87	29	139	3.15	2220	72.	107	11.2	2
82	44.5	135	3.15	6960	99.6	97 .2	52.4	2.04
81.9	39.5	134	3.15	5460	98	99	40	2.01
83.7	38	137.5	3.15	5030	96.6	100.5	36	2.005
84.9	36	138	3.15	4375	95.5	102.2	30	2.03
84.5	34.5	138	3.15	3900	92	102.9	26	2.01
86	32	138.5	3.15	3300	86	105	21	2.00
88	27	139.5	3.15	1560	58	109.5	5.1	2.04
88.5	26.5	139.5	3.15	960	35	111.5	0	2.04

GENERATOR			MOTOR			
E_aI_a	Stray power	I^2R	Output watts	I_fE_f	Total input	% Eff.
5090	520	372	5982	425	7385	81
3960	538	249	4747	422	5882	80.7
3620	547	209	4376	433	5463	80.3
3068	561	155	3784	434	4809	79.2
2678	555	122	3355	434	4334	77.3
2205	555	86	2846	437	3737	76.2
1198	563	32	1793	438	2658	67.55
1579	555	50	2184	438	3078	68.75
559	570	8	1137	439	1999	56.9
0	570	0	570	439	1399	40.8



Performance Curves
of
Synchronous Motor

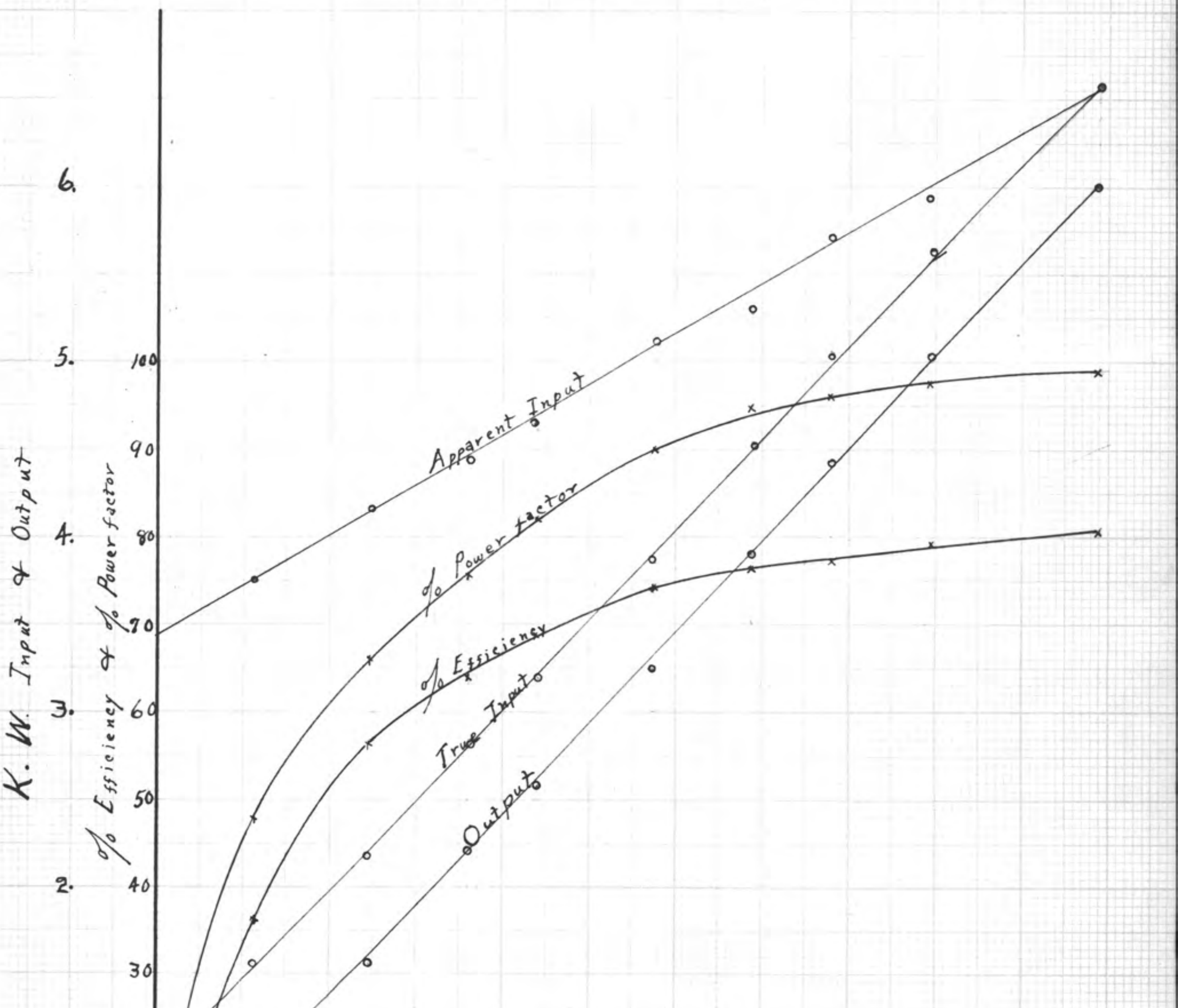
THREE-PHASE "Y" connected.

PERFORMANCE CURVE DATA.

Quarter Phase.

MOTOR						GENERATOR		
E_a	I_a	E_f	I_f	Amp. Input Watts	% Power Factor	E_a	I_a	I_f
91	66	160	3.6	6000	99	99	46.5	2.06
90.2	59	169	3.6	5040	97.5	101.3	36.5	2.065
91.2	56	171	3.6	4440	96	102.5	31	2.075
90	52	168	3.6	3900	95	102.6	26.8	2.065
92	49	173	3.6	3240	90	105.	21.2	2.06
91	44	171	3.6	2580	82	105.2	15	2.065
93	41	173	3.6	2220	75	108.	11.1	2.055
91	39	172	3.6	1560	66	108.	6 .	2.05
93	33.6	174	3.6	960	48	112.5	0	2.05

GENERATOR						MOTOR		
E_aI_a	Stray Power	I_a^2R	Output Watts	I_fE_f	Total Input	% Effic. output/input	E_aI_a	Apparent Input
4615	544	303	5462	575	6575	80.9	6010	6585
3705	567	213	4485	608	5648	79.4	5320	5928
3176	567	163	3906	616	5056	77.2	5100	5716
2750	567	128	3445	605	4505	76.5	4680	5285
2227	567	88	2882	623	3863	74.6	4510	5133
1580	567	50	2197	616	3196	68.8	4010	4626
1200	575	31	1806	623	2843	63.5	3812	4435
648	575	11.	1234	619	2179	56.7	3548	4167
0	575	0	575	627	1587	36.3	3125	3752



Performance Curves of
A Synchronous Motor
Quarter-Phase.