AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The 48th meeting of the Institute was held at the House of the American Society of Civil Engineers, 127 East 23d street, New York, June 17th, 1890.

THE PRESIDENT, PROF. W. A. ANTHONY :—The meeting will please come to order. Mr. Crocker has a resolution that he desires to offer.

MR. CROCKER :—I offer the following resolution, which has been recommended by the Council, to the Institute for consideration. The idea is that it shall be taken up for action at our next meeting, which will take place in the Fall. With your permission, I will read the resolution :

Whereas, It has been the custom in the nomenclature of electrical units to perpetuate the names of men who have contributed most to electrical science, and

Whereas, In the names thus far adopted the eminent services of Americans have not been recognized, therefore

Resolved, That in the opinion of the American Institute of Electrical Engineers, a just distribution of the honors thus bestowed necessitates a recognition of the splendid contributions to electrical science of one or both of America's great electricians—Benjamin Franklin and Joseph Henry ; and,

Resolved, That this Institute will gladly co-operate with other bodies in this country and abroad to secure the general adoption of these names for electrical units ; and,

Resolved, That the name of Henry should be given to the practical unit of self-induction, since he was the discoverer and greatest investigator of this phenomenon, and because this unit at present time is called a quadrant, which is merely a numerical value, and not a suitable name.

Resolved, That this Institute recommend to electrical societies and electrical engineers the general use of the name “ Henry ” for the unit of induction as being the quickest and surest way to secure its final adoption.

DR. W. E. GEYER : I move that action on this resolution be deferred until the next meeting of the Institute.

MR. MARTIN.—I second the motion.

(Carried.)

THE PRESIDENT.—The next business before the meeting will be a paper on the "Efficiency of Transformers," by Calvin Humphrey and W. H. Powell. This paper will give you the result of some investigations conducted by these gentlemen at Cornell University. The paper will be read by Mr. Powell, and I now have the pleasure of introducing him to the Institute.

MR. POWELL then read the following paper.

EFFICIENCY OF THE TRANSFORMER.

BY CALVIN HUMPHREY AND WILLIAM H. POWELL.

IN pursuing this particular line of investigation it has been our endeavor to throw some light, if possible, upon the general subject of transformers and upon the action of iron when magnetized and demagnetized by an alternating current of high peri-

FIG. 1

odicity. And in order that the results obtained might have a practical bearing, the conditions of working were made to conform as closely as possible to the conditions under which transformer systems are operated in this country.

The question of the economy of the commercial converter as a transformer of energy has been frequently taken up, both from practical and theoretical standpoints, both with widely varying and conflicting results. The losses in the transformer of the

closed circuit type have been considered large and inevitable, so much so, in fact, that Mr. Swinburne has introduced in England a new form of open circuit transformer known as the "hedge-

OPEN CIRCUIT, PLATE I.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.
18.5	21. Volts.	450 Volts.	.104 Amperes.
18.2	9.	190	.102
18.	0.	0	.096
17.8	9.	100	.084
17.6	16.5	310	.074
17.3	28.	545	.036
17.	39.	760	0 ±
16.5	51.5	1020	0 ±
16.	59.	1170	.056
15.	65.	1285	.074
14.	61.5	1223	.094
13.5	57.	1130	.102
13.	47.	925	.104
12.7	40.	780	.104
12.4	27.5	565	.102
12.2	20.	330	.098
12.	9.	245	.096
11.8	0. ±	70	.088
11.6	0. ±	0	.078
11.3	14.	300	.056
11.	27.5	560	.046
10.5	44.	890	0
10.	56.	1105	.03
9.	63.5	1265	.072
8.	63.5	1285	.09
7.5	60.5	1215	.098
7.	53.5	1085	.104
6.7	47.5	945	.110
6.4	40.	810	.110
6.2	29.	610	.108
6.	26.	545	.106
5.8	18	385	.104
5.5	0 +	110	.098
5.	14.	260	.074

hog." It has been Mr. Swinburne's endeavor to obviate the dissipation of energy in hysteresis and Foucault currents in a part of the magnetic circuit, by having that circuit closed through

air. But as will be seen later, the perfection of the transformer is to be met in a better grade of iron, rather than in any radical change in design.

The results presented in this paper are of especial interest as being supplementary to the work of Prof. Ryan and Mr. Merritt in the same line, which was presented to the Institute last De-

PLATE II.

Open Circuit (Old 10-lt Converter.) (40-lt Converter. Bolts Out.)

BRUSH.	P. E. M. F.	P. C.	BRUSH.	P. E. M. F.	P. C.
19	825	.196	19	775	.098
18	0	.225	18	0	.089
17	840	.042	17	845	.0
16	1320	.075	16	1245	.048
15	1420	.117	15	1355	.074
14	1345	.143	14	1290	.09
13	1010	.18	13	965	.09
12	230	.22	12	235	.074
11	630	.1	11	590	.0
10	1115	.058	10	1140	.043
9	1395	.1	9	1325	.074
8	1420	.13	8	1312	.09
7	1195	.17	7	1103	.1
6	570	.217	6	520	.1
5	300	.18	5	318	.058
4	1060	0	4	1014	0

cember.¹ The 10-light transformer which they tested was found to have a remarkably heavy loss on open circuit, which was shown to be due almost entirely to hysteresis in the iron. The transformer gave an efficiency of 86 per cent. at normal load and an "all-day" efficiency of about 40 per cent.

In our work on a 40-light transformer of the same design,—

the two coils placed side by side in a core of laminated plates, Fig. 1,—but of more recent manufacture, the loss on open circuit was found to be about one half as great as in the 10-light transformer. Its efficiency reached 96.2 per cent. at normal load, and the “all-day” efficiency would be about 90 per cent.

The method employed in the work is substantially Prof. Ryan’s method. The instantaneous values were obtained by means of a

PLATE III.
OPEN CIRCUIT, LOW E. M. F.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.
19	24.5	595	.07
18	0.	0	.065
17	27.5	580	0
16	42.	870	.04
15	47.	965	.055
14	45.	950	.07
13	33.	715	.075
12	8.	180	.07
11	19.	420	.04
10	39.	835	.04
9	45.	960	.065
8	46.	945	.07
7	38.	800	.075
6	16.5	395	.07
5	8.	210	.05
4	35.5	755	0

commutating device attached to the alternator. The device consisted of a wooden disc, mounted rigidly on the shaft of the alternator, with a steel contact at one point in its periphery, which made contact with a small piano-wire brush once every revolution. The holder carrying the piano-wire brush was attached to a second wooden disc carrying a pointer which moved over a scale and indicated the position of the brush for a given reading. By means of a clamp screw this second wooden disk carrying the

brush and pointer could be conveniently set at any point. Now since the steel contact in the wooden disc is fixed relatively to the armature, it must share the ever varying E. M. F. of the armature. Then evidently if the brush which completes the circuit

PLATE IV.

SECONDARY CURRENT, 26.8 AMP.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.
18.5	24.5	370	.82
18.	0.	0	.22
17.5	11.	410	.28
17.	30.5	743	.86
16.5	46.	980	1.25
16.	53.	1110	1.55
15.	59.5	1220	1.76
14.	57.5	1145	1.74
13.5	54.	1045	1.64
13.	47.	850	1.43
12.5	34.	565	1.06
12.	13.	200	.16
11.	21.	575	.58
10.5	37.	850	1.06
10.	47.5	1060	1.44
9.	58.5	1215	1.77
8.	59.5	1195	1.80
7.5	56.	1115	1.66
7.	52.5	995	1.58
6.5	42.	780	1.32
6.	27.	390	.9
5.5	10.	0	.34
5.	0.	325	.16

through the contact be altered in position, values can be obtained for different points on the curves of E. M. F. and current.

The Ryan quadrant electrometer was used to measure the primary E. M. F., secondary E. M. F. and primary current. A condenser was connected in multiple with the electrometer. The primary current was measured by the fall of potential through

incandescent lamps placed in series with the primary of the transformer. These lamps were carefully calibrated with the standard instruments of the laboratory in order to know their resistance at different temperatures. Then knowing the resistance

PLATE V.
SECONDARY CURRENT, 44 AMP.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.
19.	22.5	300	1.9
18.	0.	0	.37
17.5	10.	465	.525
17.	26.	745	1.3
16.5	39.	935	1.93
16.	48.5	1075	2.4
15.	55.5	1185	2.77
14.	56.	1150	2.67
13.5	51.	1060	2.58
13.	49.	835	2.3
12.5	47.	625	1.9
12.	35.5	230	1.13
11.5	21.	100	.32
11.	0.	505	.48
10.5	11.	795	1.3
10.	24.5	1015	1.08
9.	40.	1140	2.6
8.	54.	1200	2.84
7.5	57.5	1105	2.77
7.	55.5	1030	2.67
6.5	51.5	805	2.23
6.	45.5	510	1.69
5.5	32.5	130	.97
5.	17.	250	0.

of the lamps, and the potential difference at their terminals, the current flowing at once becomes known.

To measure the E. M. F., twenty-two 50-volt lamps were placed in series across the primaries. The electrometer was connected around two of these lamps, and the whole number calibrated in

order to know just what part of the total impressed E. M. F. was measured. The secondary E. M. F. was measured direct. The secondary current was measured by means of an electro-dyna-

PLATE VI.
SECONDARY CURRENT, 65.2 AMP.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.
19.	45.	745	3.
18.	14.	0	1.08
17.	21.	730	1.23
16.	47.	1120	3.45
15.	58.	1245	4.3
14.	60.	1195	4.35
13.	51.	905	3.8
12.	26.	240	1.85
11.	8.	550	.4
10.	40.	1050	2.9
9.	55.	1225	4.1
8.	59.	1235	4.5
7.	55.	1070	4.25
6.	37.	475	2.83
5.	0.	235	0.
4.	29.	900	2.

meter, which was carefully calibrated both before and after the experiments and was found to be constant. The commutating device was placed in series with the electrometer. Wires

were run from the terminals from which the measurements were desired to a convenient switch-board. (Fig. 2.)

FIG. 2.

It is worthy of mention that this method which gives some thing so definite and fundamental in the treatment of the alter nating current has only come into use within the past year, and

PLATE VII. WATT CURVES.
AMPERES IN SECONDARY

Open-Cir.	9	26.8	44.	65.2	Brush.
—22.1	0	0	180	0	13.
—7.6	148	630	960	1020	17.
30.6	400	1230	1750	2650	16.5
63.8	695	1720	2600	3860	16.
82.	880	2040	3080	4880	15.5
96.	970	2130	3250	5350	15.
105.	960	2160	3300	5520	14.5
116.	850	2020	3170	5250	14.
113.	700	1715	2700	4600	13.5
96.5	480	1220	1950	3440	13.
65.	250	600	1070	1800	12.5
22.8	50	115	253	443	12.
—10.5	0	0	—350	—96	11.5
—25.2		319	2500	220	11.

the task of getting true instantaneous values of the complete waves of E. M. F. and current which has always been considered too tedious for ordinary patience to deal with, was accomplished with ease in this work in forty-five minutes. A calibrated scale for the electrometer readings added very much to the facility with which observations could be taken.

The marked improvement of the 40-light transformer over the 10-light is due, we believe, to an improvement in the magnetic properties of the iron and a fewer number of turns in the coils, made possible by the better grade of iron. In the 10-light transformer Foucault currents were very effectually weeded out by

the interposition of sheets of paper between the laminated sheets of iron; in a 40-light, the oxide of iron on the surface of the plates was the only safeguard against Foucault currents.

The form and extent of the open circuit curves show the loss due to hysteresis and the slight loss also due to the Foucault currents. The presence of Foucault currents is indicated by the fact that the maximum of the primary current wave does not occur simultaneously with the zero of primary E. M. F., but a little before.

The primary current curve was again taken with the laminated plates loose and free to vibrate. The loss was about 10% less than in the former case (Plate II.) This is thought to be brought

about by the decrease in the hysteresis loss, due to the increase of mechanical shock arising from the free vibration of the plates. The vibration was very perceptibly increased. The curve obtained is more regular in form indicating less hysteresis loss.

PLATE IX.
WATT CURVES. OPEN CIRCUIT.

No.	990 VOLTS.	740 VOLTS.
16.9	0.	0.
16.7		
16.5	30.5 Watts.	11.5
16.	64.	34.
15.5	82.	46.5
15.	96.	53.5
14.5	111.5	61.
14.	116.	66.
13.5	113.5	64.
13.	97.	54.
12.5	65.	35.5
12.	23.	12.5
11.7	0.	0.
11.5	-10.5	-7.5
11.	-25.	-17.
10.5	0.	7.
10.3		0.

The lag of the primary current behind the primary E. M. F. is seen to be greatest when the secondary circuit was open and decreases as a non-inductive load is introduced into the secondary circuit. This tendency of the lag of the primary current to de-

crease with increase of load, continues until the curve of primary current comes into unison with the curve of secondary E. M. F.

The secondary E. M. F. is in unison with the primary E. M. F. on open circuit and gradually falls behind as the load increases on the secondary. This is doubtless due to the leakage of lines of force arising from the enormous magnetizing forces at work in

PLATE X.

SMALL ALTERNATING CURRENT MOTOR ON SECONDARY.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.	S. C.
19	30.	780	.53	7.36
18	0.	0	.35	4.48
17	40.	790	0	0.
16	60.	1195	.25	3.52
15	64.	1310	.43	6.2
14	61.	1240	.53	7.5
13	46.	930	.54	7.5
12	11.	140	.42	5.76
11	26.	570	.12	0.
10	55.	1115	.14	2.89
9	63.5	1305	.375	4.47
8	63.5	1310	.50	7.20
7	53.	1095	.55	8.32
6	27.5	560	.49	7.20
5	14.	290	.25	3.52
4	47.	950	0	0.

opposition to one another in the primary and secondary circuits.

When an inductive resistance is introduced into the secondary circuit, the lag of the primary current is greatly increased, as shown by the set of curves in Plate X. The inductive resistance used in this case was due to a small alternating current motor. The curve of secondary current was also taken and found to lag

behind the secondary E. M. F. and to be in unison with the primary current. About 5.5 amperes flowed in the secondary and yet the lag of primary current is as great as on open circuit.

Plate XI shows the relation of primary current and primary E. M. F. when the secondary was closed through the secondary of a 20-light transformer whose primary remained open. The current

PLATE XI.

INDUCTIVE RESISTANCE OF SECONDARY.

BRUSH.	S. E. M. F.	P. E. M. F.	P. C.
19	39.	790	.147
18	0.	0	.126
17	40.	770	0
16	61.	1185	.066
15	67.	1310	.108
14	63.5	1245	.126
13	48.5	950	.135
12	11.	290	.135
11	26.	515	.06
10	56.	1105	.05
9	66.	1315	.099
8	65.5	1295	.12
7	56.	1105	.126
6	26.	545	.126
5	14.	260	.108
4	48.	500	0

curve shows a distinctive lag from the inductive resistance and is altered in form to a great extent.

In Plate IX will be seen the watt curves for open circuit loss, one for 990 volts and the other for 740 volts. From the value of the mean ordinates it is seen that the loss varies strictly as the square of the impressed E. M. F.

In Plate II is plotted to the same scale the current which flowed on open circuit in the case of the 10-light transformer and the 40-light transformer.

Plates IV, V, and VI show the curves of primary E. M. F. and current and secondary E. M. F. for different loads, from which the watt curves of Plate VII. are computed by taking the product of corresponding ordinates of primary E. M. F. and current.

The efficiency curve shown in Plate VIII. is the ratio between the energy of the primary circuit as indicated by the mean ordinate of the watt curve, and the energy of the secondary circuit as expressed by the product of the $\sqrt{\text{mean}^2}$ readings for E. M. F. and the current. The coercive force is equal to .8 c. g. s.

These considerations go to show that the loss due to the reversal of polarity of the iron, which perhaps must always be present may be reduced almost indefinitely by a proper study of the magnetic properties of the iron used.

THE PRESIDENT.—As the next paper touches upon the same subject we will have it read before any discussion takes place. The paper is by Prof. Harris J. Ryan, of Cornell University. It is in continuation of the work which the Professor gave to you last winter.

PROF. RYAN then read the following paper :