SURVEY OF THE ELECTRICAL SYSTEM OF THE POWER PLANT AT THE UNIVERSITY OF TENNESSEE

by

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I. STATEMENT OF PROBLEM.

This survey of the University of Tennessee power plant was made to determine the exact distribution of power which was generated or purchased.

There is no meter on the auxiliary feeder circuit, but there are wattmeters on all the 2300 volt feeders leaving the plant, and on the generators supplying the bus bars. The wattmeters are read every hour, and the difference between generated kw. and distributed kw. is charged to the auxiliary circuit. According to this method, the power consumed by the auxiliaries is not always a reasonable value. In fact the readings are very inconsistent, and in many cases the variations are unduly large. This leads to the belief that the power is not correctly measured, or else that the auxiliaries are consuming two much power. In order to determine the source of error it seems necessary to check the distribution of power to the 2300 volt feeders and to each branch of the auxiliary circuit.

II. GENERAL INFORMATION ABOUT THE POWER PLANT.

There are, at present, two 625 kv-a. (500 kw. at 0.8 power factor) alternators in the power plant at the University of Tennessee. The older unit is a Westinghouse machine, while the other is a General Electric product. The power demands of the University in the past have not required the use of both machines in parallel. Thus one machine is used as a "stand-by" for use in case of breakdown. The

capacity factor on one machine for the first four months of this year has been approximately 60 percent. The capacity factor for the plant is, therefore, approximately 30 percent. The load factor was approximately 40 percent during this test.

The switchboard is equipped with a synchroscope which may be used when parallel operation becomes necessary. This synchroscope has not been used in the past when changing from one machine to the other. It has not been convenient to use the synchroscope because the motor which operates the governor of the Westinghouse machine has not been connected.

The frequency regulation is rather poor due to errors in meters and lack of a frequency regulator. There are frequency meters and tachometers on both units. The Westinghouse unit has a reed type tachometer, while the General Electric unit has a frequency meter calibrated in percent speed both above and below normal.

There is a Tirrill voltage regulator on the switchboard. It is connected so that, by means of double-throw switches, it can be made to regulate the voltage of either machine. It regulates by varying the resistance in the main field of the machine to which it is connected. The voltage regulator has cone bearings on the contactor arms. It is necessary that these bearings be kept clean and properly adjusted in order for the regulator to operate satisfactorily. The regulator should be examined periodically in order to keep

the bearings and contactors properly adjusted.

The switch-board consists of eight panels. There is a panel for each generator, and a panel for the city oil switch and meters. The other panels are for the five three phase, 2300 volt feeders which supply the campus. There is an automatic oil switch on each panel.

The Strong Hall line has two circuits, one overhead, and one under-ground. The underground circuit is ordinarily used. The overhead line is used in case it becomes necessary to repair the underground line. The transfer is made by means of double-throw switches at the power plant and at the Strong Hall substation.

The five circuits supplying the campus are named according to the first buildings supplied by them. For instance, the Estabrook circuit supplies both Estabrook Hall and Ferris Hall. Home Economics circuit supplies the Home Economics building, New Library, Humes Hall, and other buildings. The Science and Geology circuit supplies Morrill Hall, Barbara Blount Dormitory, Carrick Hall, Science Hall, and the new Physics building.

There are wattmeters on all except the "city" panel. There are watthour meters on both generator circuits supplying the bus bars. There is also a watthour meter on the city line. The Farm circuit is the only feeder which has a watthour meter. There are ammeters and voltmeters in each phase of both alternators. The exciter field and main field

rheostats for each machine are on the alternator panels along with dc. ammeters and voltmeters for each. The alternator panels are also equipped with frequency control switches, but the one on the Westinghouse unit cannot be operated because the governor motor is not connected.

The auxiliary circuit is tapped off behind the Westinghouse alternator panel on the switchboard, and it supplies the power plant substation which is under the turbine floor. This substation supplies six motor circuits, the station lights, and also the campus lights. The motor circuits include the following: a 25 hp. motor on the coal conveyor, a 3 hp. motor on the coal hoist, a 5 hp. motor on the sump pump, a 30 hp. motor which drives the condensate and circulating pumps for the General Electric turbine, a 3 hp. motor which drives the Westinghouse condensate pump, and also a 15 hp. motor which drives the Westinghouse circulating pump. These are all 220 volt, three phase motors. The station lights are on a three wire 110/220 volt circuit. The connected load on this circuit is approximately 5 kw. The street lights are on a two wire 110 volt circuit which has approximately 3 kw. demand.

III. DESCRIPTION OF THE METHOD AND APPARATUS USED.

In order to locate definitely the trouble at the power plant, it seemed desirable to use watthour meters in preference to wattmeters. Thus it was decided to put watthour meters in all circuits - those supplying the bus bars as well as those supplying the campus load. It also seemed necessary

to read these meters daily for at least a month in order that the errors in reading the meters might be as small a percentage of the total as possible. The constants on the meters were large, so evidently the error in readings for a short period of time might be very large in comparison to the total readings. It was thought a good policy to read these meters daily at the same hour and check to see that they were indicating the true power. This was especially important, at first in order to be sure that the meters were properly connected and were giving correct registration. This was advantageous in another way in that it gave an indication of the progress that was made in determining the exact distribution of the power. These readings were taken daily for one month. Calculations were made showing the percentage of the power which was unaccounted for by each day's readings. This was found to be helpful because it afforded a means of quickly detecting discrepancies, and this resulted in their immediate correction. For instance, on Saturday April 4 the daily "check up" revealed a large error. Apparently several hundred kw-hrs. could not be accounted for by the meters in the distribution system. Upon investigation, it was found that a lightning storm on the previous night had blown a fuse in a potential transformer in one phase of the Strong Hall line. Thus the meter measured only part of the power which was actually consumed on that line. The fuse was replaced immediately and only a few hours of the test were in error so far as this one line was concerned.

All the 2300 volt circuits, with the exception of the auxiliary circuit, had potential and current transformers already installed. The leads from these transformers were brought out to their corresponding panels. So that it seemed that there would be very little trouble in the installation of the watthour meters. A sub-panel board was built in front of the main switchboard, and on this board the watthour meters were temporarily hung. Seven wires were brought out on each panel for the wattmeters. These were brought out through conduit when the switchboard was installed, so it was impossible to trace the connections. There were three potential leads which were brought out from two transformers in open delta. The four current leads came from two current transformers which were connected in two phases. Thus there were seven leads on the board to go with eight terminals on the meters. In making the connections it was found that even after a distinction was made between the current and potential leads, there was left quite a variety of possible combinations. It was found by calculation that there were 24 possible combinations for connecting the four current leads. Likewise, there were six possible combinations with three potential leads. This made it possible to connect the leads in 144 combinations, only 8 of which were correct. If these eight leads had been brought out in such a way that no distinction could have been made between current and potential leads, there would have been 40,320 possible combinations of connecting these leads to an eight terminal polyphase watthour meter. It was very advantageous, therefore, to be able to identify the current,

potential and common leads. This reduced the possible total to only 144 combinations. Several combinations were eliminated by arbitrarily connecting the common potential lead to one terminal of each potential coil and then connecting the other two potential leads to the two remaining potential terminals. This left only eight possible combinations of connections for the current leads. Considering only one element of the meter, there are four remaining combinations. If the power factor were greater than 50 percent, two of these combinations would produce a torque on the meter which was only a fractional part of that desired. At unity power factor these combinations would give zero torque, and it could be quickly detected that they were not the proper connections. At low power factors, the determination becomes more difficult. The other two possible combinations are made with the two remaining wires. One way of connecting these wires will give negative torque, because the polarity will be wrong relative to the potential coil of that element. When negative torque is produced, the connections on the current coil must be interchanged in order to get proper polarity. The same procedure was followed on the other element, thus obtaining one of the eight correct combinations out of the total of over 40,000.

New and tested meters were obtained from the Tennessee Public Service Company for use on this test. Current and potential transformers were installed in the auxiliary, Estabrook, and Strong Hall circuits. The Estabrook and Strong Hall circuits had 40:1 current transformers already installed,

but they were much too large for the load on those circuits. It seemed that much more accurate results could be obtained by using 5:1 current transformers. The manufacturers guarantee their current and potential transformers not to be in error more than 1 percent. Allowing 1 percent error in the meter, the allowable error for the test would be 3 percent. The actual average error for the whole test was less than 1 percent.

Figure 1 on the next page shows the layout of 2300 volt circuits and meters. "W" is used to indicate wattmeters and "W.H." for watthour meters. The solid lines show permanently installed meters and the dotted lines are temporary test meters.

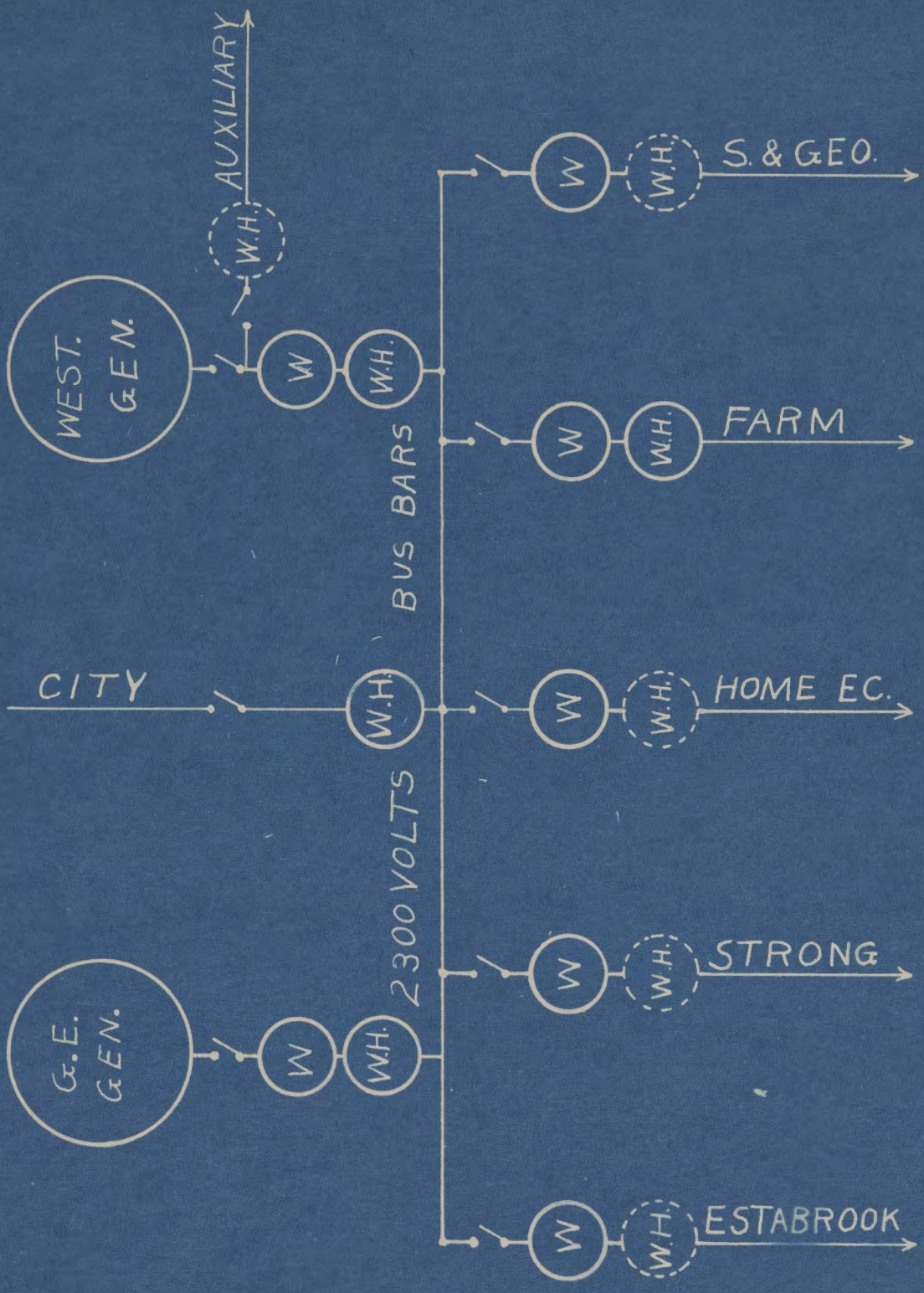

AUXILIARY
W.H.
WEST. GEN.
W
W.H.
S. & GEO.
FARM
BUS BARS
CITY
HOME EC.
2300 VOLTS
G.E. GEN.
STRONG
ESTABROOK

FIG. 1

IV. DATA AND RESULTS.

Reading Number	Date	Esta. kw-hrs.	Strong kw-hrs.	Home Eco. kw-hrs.	Farm kw-hrs.	S. & G. kw-hrs.	Aux. kw-hrs.	Total Distr. kw-hrs.	Total Gen. kw-hrs.	Percent Error
1	Mar. 15	325	775	300	125	180	463	2178	2263	3.75
2	16	250	725	330	175	240	444	2164	1994	-8.53
3	17	450	875	510	250	240	469	2794	2844	1.76
4	18	350	825	480	250	180	481	2566	2656	3.40
5	19	675	725	450	225	240	475	2790	2725	-2.38
6	20	500	700	360	225	180	475	2440	2475	1.42
7	21	475	775	510	225	180	469	2634	2669	1.31
8	22	250	600	360	150	180	463	2003	1863	-7.50
9	23	175	575	360	125	180	469	1884	1944	3.08
10	24	525	785	612	300	324	463	3009	3028	0.63
11	25	540	740	600	260	288	463	2891	2893	0.07
12	26	570	720	576	230	288	478	2862	2858	-0.14
13	27	460	750	516	220	240	526	2736	2746	0.36
14	28	670	830	792	270	312	610	3484	3640	4.28
15	29	270	660	300	130	240	593	2193	2110	-3.94

Reading Number	Date	Esta. kw-hrs.	Strong kw-hrs.	Home Eco. kw-hrs.	Farm kw-hrs.	S. & G. kw-hrs.	Aux. kw-hrs.	Total Distr. kw-hrs.	Total Gen. kw-hrs.	Percent Error
16	30	210	580	384	160	192	585	2111	2130	0.89
17	31	420	730	1008	210	312	607	3287	3360	2.17
18	Apr. 1	660	810	1068	290	384	578	3790	3880	2.32
19	2	590	730	984	220	360	575	3459	3570	3.10
20	3	450	790	924	240	312	565	3281	3300	0.58
21	4	580	850	912	250	288	560	3440	3510	1.99
22	5	460	680	408	140	144	554	2386	2350	-1.53
23	6	480	660	516	180	192	562	2590	2680	3.36
24	7	710	780	960	270	336	582	3638	3680	1.14
25	8	550	760	816	210	216	552	3104	3210	3.30
26	9	590	730	876	220	288	550	3254	3350	2.86
27	10	570	710	828	200	192	585	3085	3120	1.12
28	11	650	700	876	280	288	610	3404	3550	4.11
29	12	170	670	324	140	96	560	1960	2010	2.49

Average Error = 0.93 %

Reading Number	Date	Esta. kw.	Strong kw.	Home Eco. kw.	Farm kw.	S. & G. kw.	Estimated Aux. kw.	Total Distr. kw.	Total Gen. kw.	Percent Error
1	Mar. 15	10	35	10	17	11		83	*85	2.3
2	16	30	40	28	30	22		150	**	
3	17	22	40	28	20	12		122	*140	12.8
4	18	10	30	25	22	13		100	*125	20.0
5	19	25	30	25	18	12		110	*125	12.0
6	20	22	25	23	24	12		106	*115	7.8
7	21	20	30	24	25	11		110	*120	8.3
8	22	0	20	8	14	8		50	*60	16.6
9	23	18	30	31	35	15		139	*140	0.7
10	24	18	28	39	21	22		128	*140	8.6
11	25	25	35	45	18	16		139	*150	7.3
12	26	15	25	24	21	15		100	*110	9.1
13	27	25	35	38	26	22	20	166	170	2.4
14	28	30	38	50	18	24	22	182	205	11.2
15	29	0	25	5	17	10	20	67	90	25.6

* W. H. Generator, Aux. not included.
** On City Power.

Reading Number	Date	Esta. kw.	Strong kw.	Home Eco. kw.	Farm kw.	S. & G. kw.	Estimated Aux. kw.	Total Distr. kw.	Total Gen. kw.	Percent Error
16	30	10	20	50	20	20	21	141	165	14.5
17	31	25	40	68	24	30	22	209	220	5.0
18	Apr. 1	27	38	64	26	30	22	207	225	8.0
19	2	20	35	38	15	12	21	131	150	12.7
20	3	20	40	65	24	18	22	189	205	7.8
21	4	30	10	48	20	18	21	147	185	20.5
22	5	10	5	8	5	6	20	54	85	36.5
23	6	25	30	70	27	23	22	197	220	10.4
24	7	20	30	43	15	15	21	144	160	10.0
25	8	18	35	38	18	19	21	149	165	9.7
26	9	40	20	37	15	22	21	155	175	11.4
27	10	23	20	45	27	17	21	153	170	10.0
28	11	20	20	34	18	11	20	123	140	12.1
29	12	0	20	5	17	7	20	69	75	8.0

Average Error = 11.15%

Reading Number	Date	Coal Hoist kw-hrs.	Sump Pump kw-hrs.	Coal Conveyor kw-hrs.	Station Lights kw-hrs.	Street Lights kw-hrs.	W. H. Cond. Pump kw-hrs.	W. H. Circul. Pump kw-hrs.	Total Sum kw-hrs.	Aux. 2300 kw-hrs.	Percent Error
1	Mar. 15	2	29	10	81	43	34	245	448	463	5.7
2	16	2	28	15	93	40	31	223	432	444	2.8
3	17	2	30	0	94	43	34	252	455	469	3.0
4	18	2	29	15	92	40	33	255	466	481	3.1
5	19	2	28	20	88	42	33	253	466	475	1.9
6	20	2	28	15	94	43	34	257	473	475	0.4
7	21	2	29	0	93	40	33	255	450	469	4.0
8	22	2	28	0	94	45	33	243	445	463	4.0
9	23	2	29	0	96	37	34	252	450	469	4.0
10	24	2	28	0	95	43	35	256	459	463	0.8
11	25	5	27	0	97	38	33	256	456	463	1.5
12	26	6	27	17	100	40	33	250	473	478	1.0
13	27	5	28	12	100	42	33	233	533	550	3.0

Reading Number	Date	Coal Hoist kw-hrs.	Sump Pump kw-hrs.	Coal Conveyor kw-hrs.	Cars of Coal Unloaded	Station Lights kw-hrs.	Street Lights kw-hrs.	G. E. 30 H.P. Motor kw-hrs.	Total Sum kw-hrs.	Aux. 2300 kw-hrs.	Percent Error
	Mar.										
14	28	5	29	12		107	44	388	596	610	2.30
15	29	4	29	10		104	46	388	581	593	2.02
16	30	5	28	30	2	97	40	362	562	585	3.94
17	31	4	29	24	2	100	40	382	579	607	4.62
18	Apr. 1	5	29	16	1	104	41	366	561	578	2.94
19	2	5	29	14	1	104	40	372	564	575	1.91
20	3	5	29	0	0	104	43	382	563	565	0.35
21	4	3	29	0	0	101	38	378	549	560	1.96
22	5	4	29	0	0	100	40	362	535	554	3.43
23	6	4	28	12	1	98	43	358	543	562	3.38
24	7	5	31	18	1	96	42	376	568	582	2.40
25	8	4	29	0	0	95	43	366	537	552	2.72
26	9	3	29	0	0	96	40	364	532	550	3.28
27	10	5	29	34	1½	88	40	376	572	585	2.22
28	11	3	29	56	3	84	38	380	590	610	3.28
29	12	4	29	0		88	32	392	545	560	2.68

Average Error = 2.71 %

Total = 350/22 or 15.9 kwh/car

V. ANALYSES OF MOTOR SIZES

General Electric 30 hp. Auxiliary Motor

High reading:

$P = 1.73\ E\ I \cos \theta$

$18800 = 1.73 \times 224 \times 56.8 \times \cos \theta$

$\cos \theta = 0.85$ or .85 power factor

Low reading:

$15200 = 1.73 \times 224 \times 48.4 \times \cos \theta$

$\cos \theta = 0.81$ or .81 power factor

The meters varied from the low to high readings over a period of about 30 seconds and consistently, so simultaneously readings were taken as the meters reached the high point and again at the low point.

$$\frac{18.8}{.746} = 25 \text{ hp.}$$

This seems to indicate that the motor is about the right size for the load.

Coal Hoist Motor (3 hp)

$P = 1.73\ E\ I \cos \theta$

$5400 = 1.73 \times 218 \times 28 \times \cos \theta$

$\cos \theta = 0.5105$ or 0.51 power factor

$\theta = 59.3$

These figures are calculated from a reading taken while the hoist was lifting a full bucket of coal (1000 lbs.)

$\frac{5400}{.746}$ = 7.2 hp. This motor is nearly 250 percent over loaded.

Sump Pump (5 hp. motor)

	I_1	I_2	P
(1)	14.0	6.0	1200
		I_3	
(2)	14.0	7.48	1260

This is a badly unbalanced condition with probably a ground in the motor and, therefore, the power factor cannot be calculated from this data.

Coal Conveyor (25 hp. motor)

There were 22 cars of coal unloaded during the period of the test with a total consumption of 350 kw-hrs. This was an average of 15.9 kw-hrs. per car of coal. The power required seemed to vary from 12 to 20 kw-hrs. per car.

$$\cos \theta = \frac{W}{1.73\ EI} = \frac{6800}{1.73 \times 222 \times 28.8} = 0.615 \text{ power factor}$$

$\frac{6800}{746}$ = 9.12 hp.

VI. GRAPHS.



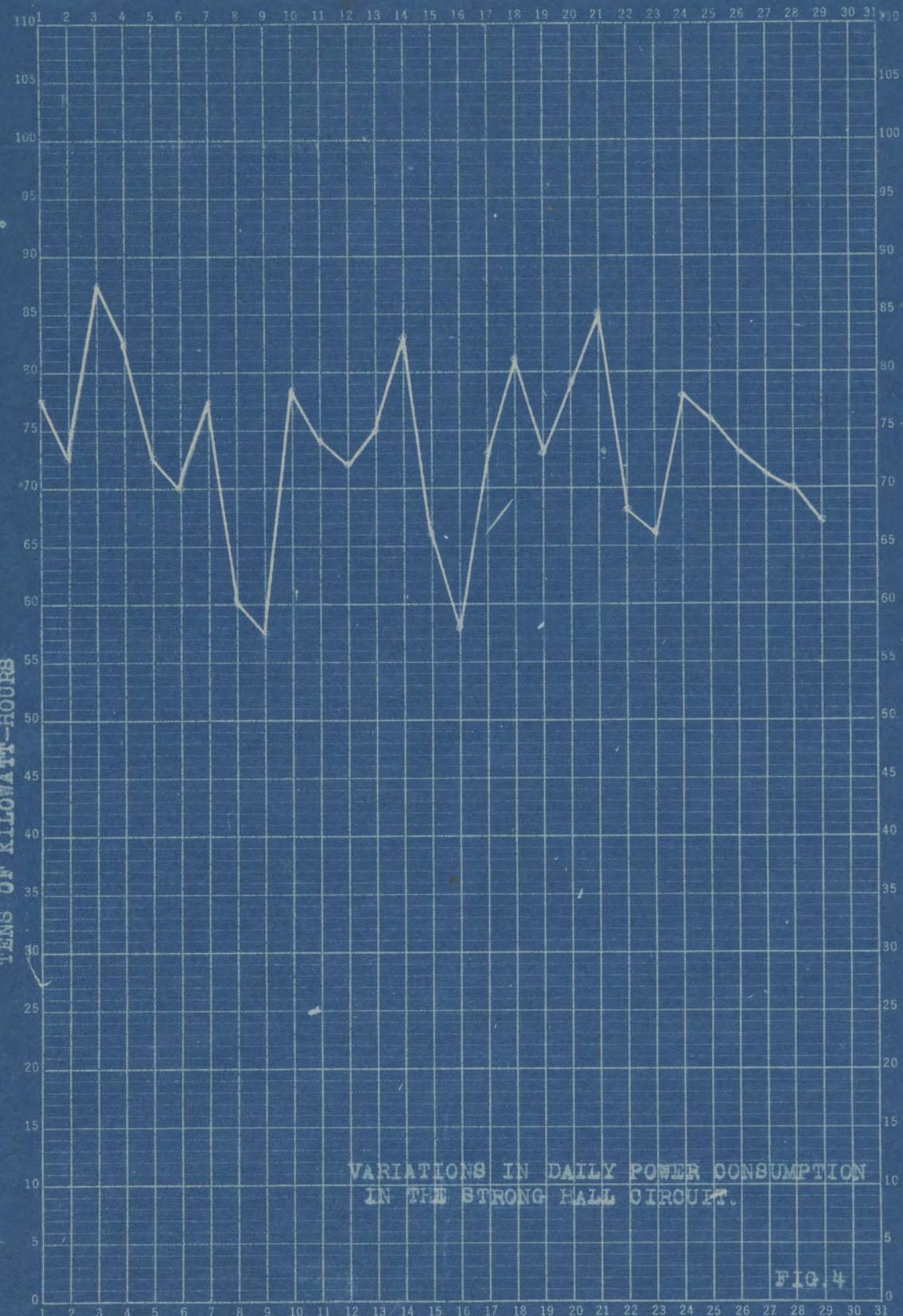
VARIATIONS IN DAILY GENERATED POWER.

FIG. 2



VARIATIONS IN DAILY POWER CONSUMPTION IN THE ESTABROOK CIRCUIT.

FIG. 3



KEUFFEL & ESSER CO., N. Y. NO. 365-134
One Month by Days.

VARIATIONS IN DAILY POWER CONSUMPTION
IN THE STRONG HALL CIRCUIT.

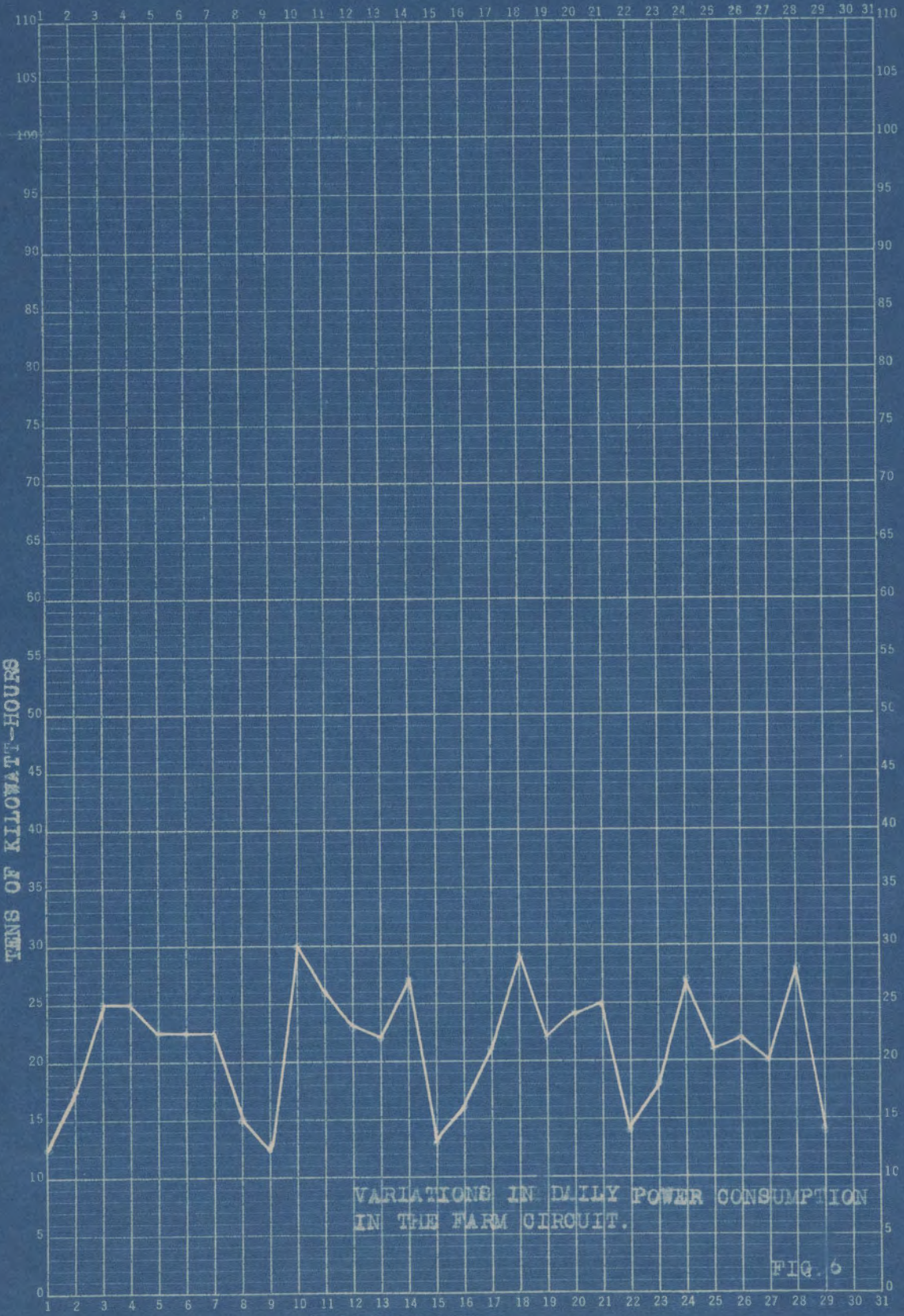
FIG. 4



KEUFFEL & ESSER CO., N. Y. NO. 359-124
One Month by Days.

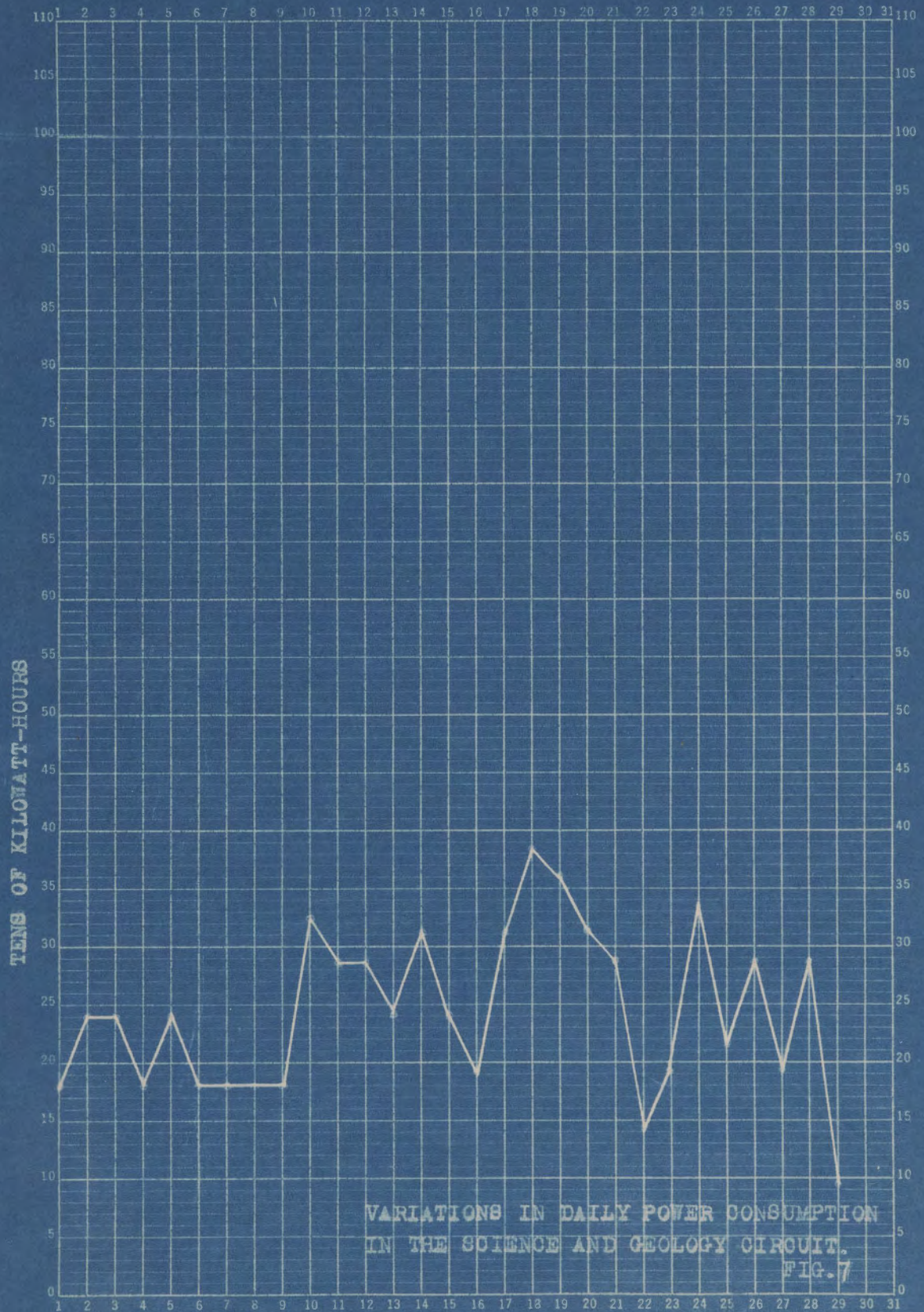
VARIATIONS IN DAILY POWER CONSUMPTION
IN THE HOME ECONOMICS CIRCUIT.

FIG. 5



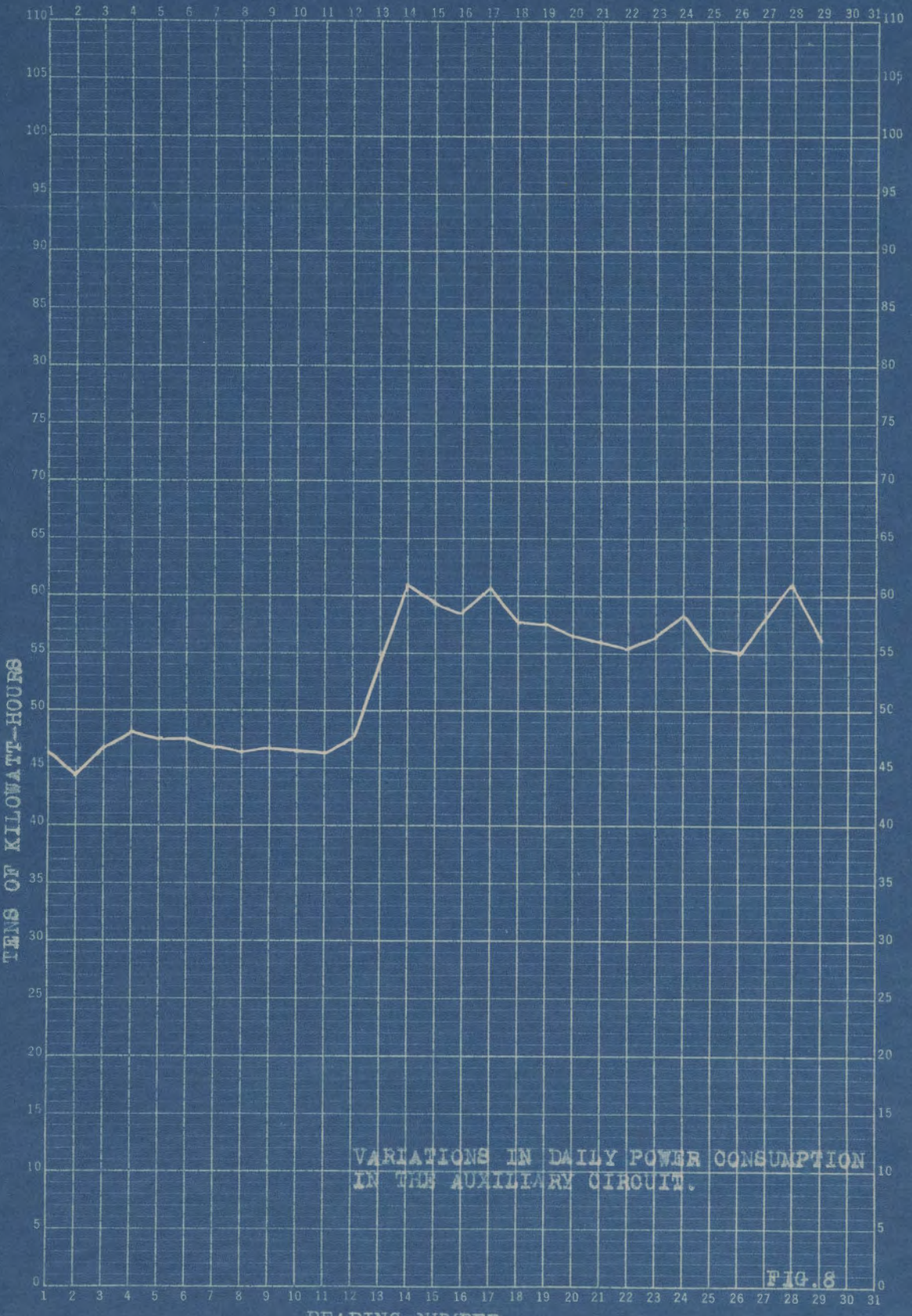
VARIATIONS IN DAILY POWER CONSUMPTION IN THE FARM CIRCUIT.

FIG. 6



VARIATIONS IN DAILY POWER CONSUMPTION
IN THE SCIENCE AND GEOLOGY CIRCUIT.
FIG. 7

KEUFFEL & ESSER CO., N. Y. NO. 359-134
One Month by Days.



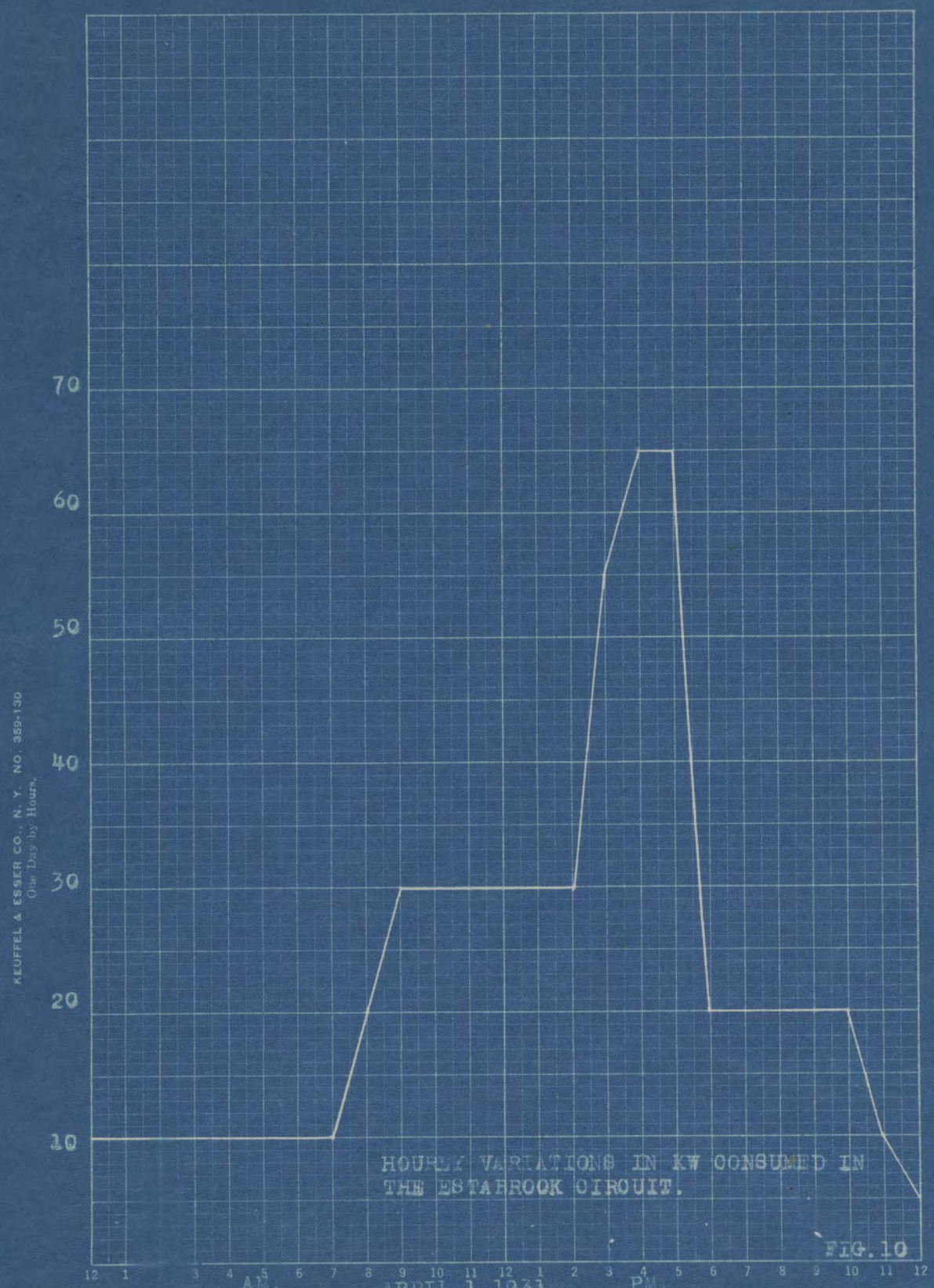
VARIATIONS IN DAILY POWER CONSUMPTION IN THE AUXILIARY CIRCUIT.

FIG. 8

KEUFFEL & ESSER CO., N. Y. NO. 359-134
One Month by Days.


360
320
280
240
200
160
120
80
40
KEUFFEL & ESSER CO., N. Y. NO. 359-130
One Day by Hours.
HOURLY VARIATIONS IN GENERATED KW.
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
A.M.
P.M.
APRIL 1, 1931

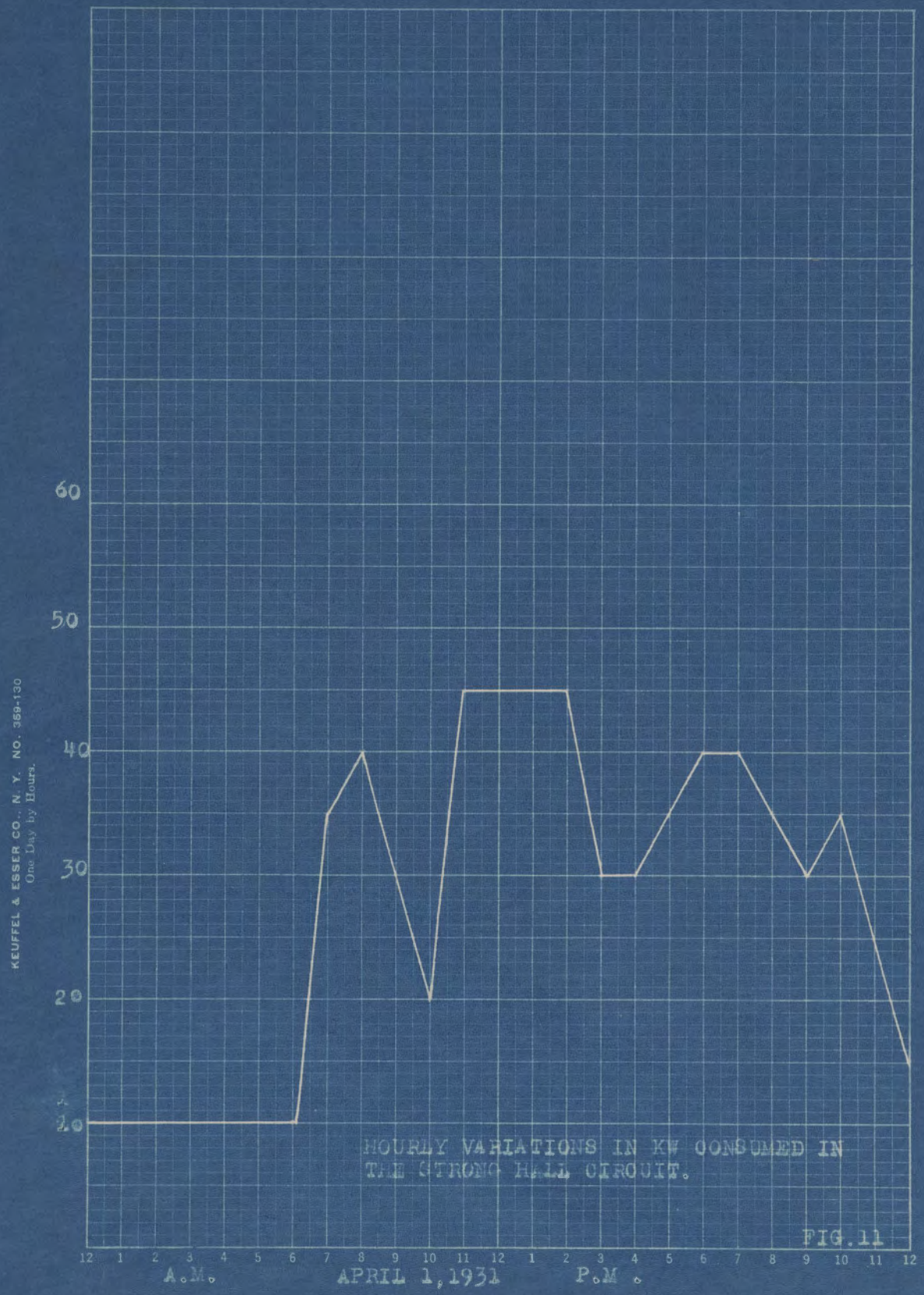
FIG. 9



HOURLY VARIATIONS IN KW CONSUMED IN THE ESTABROOK CIRCUIT.

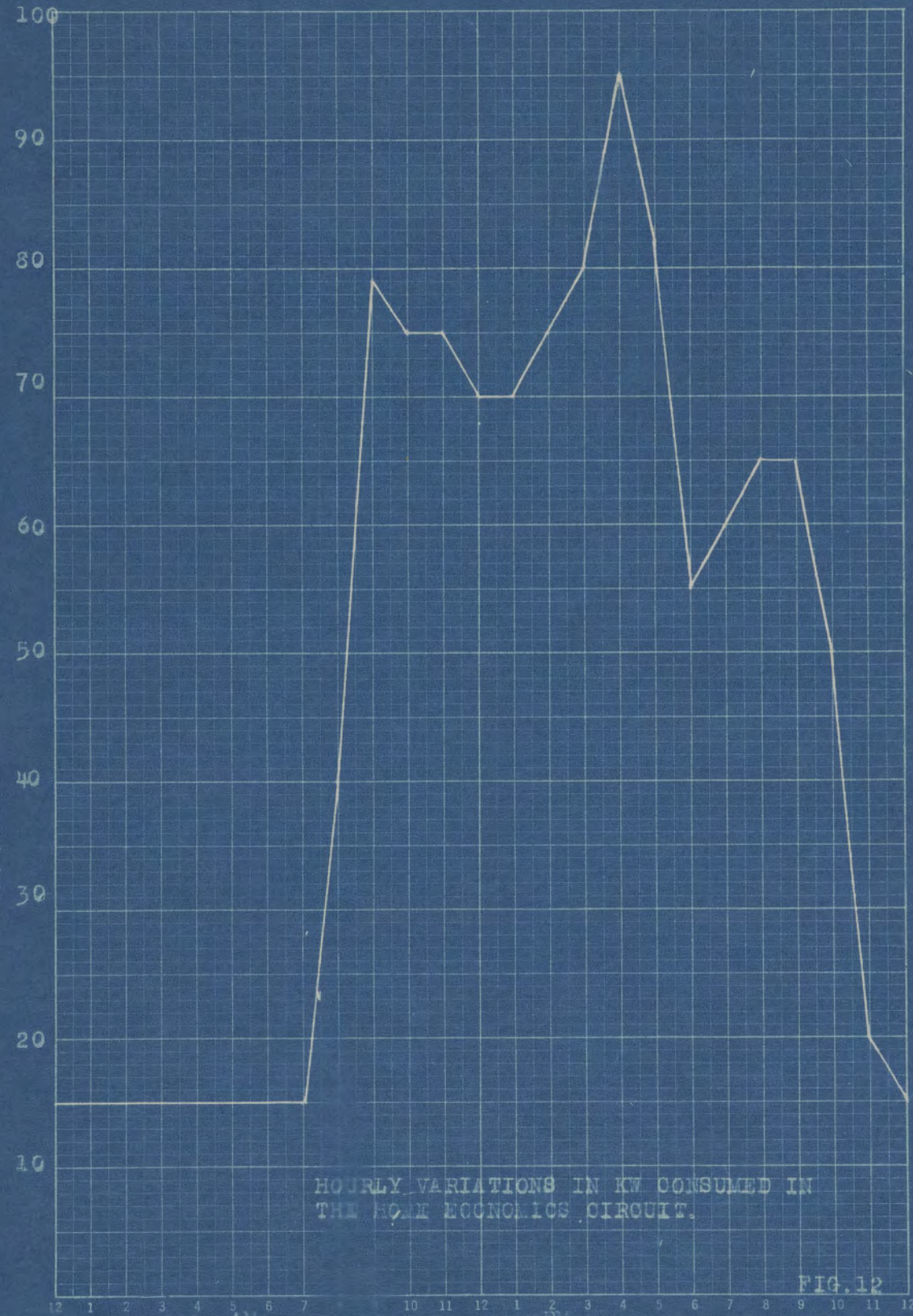
FIG. 10

APRIL 1, 1931



HOURLY VARIATIONS IN KW CONSUMED IN THE STRONG HALL CIRCUIT.

FIG. 11

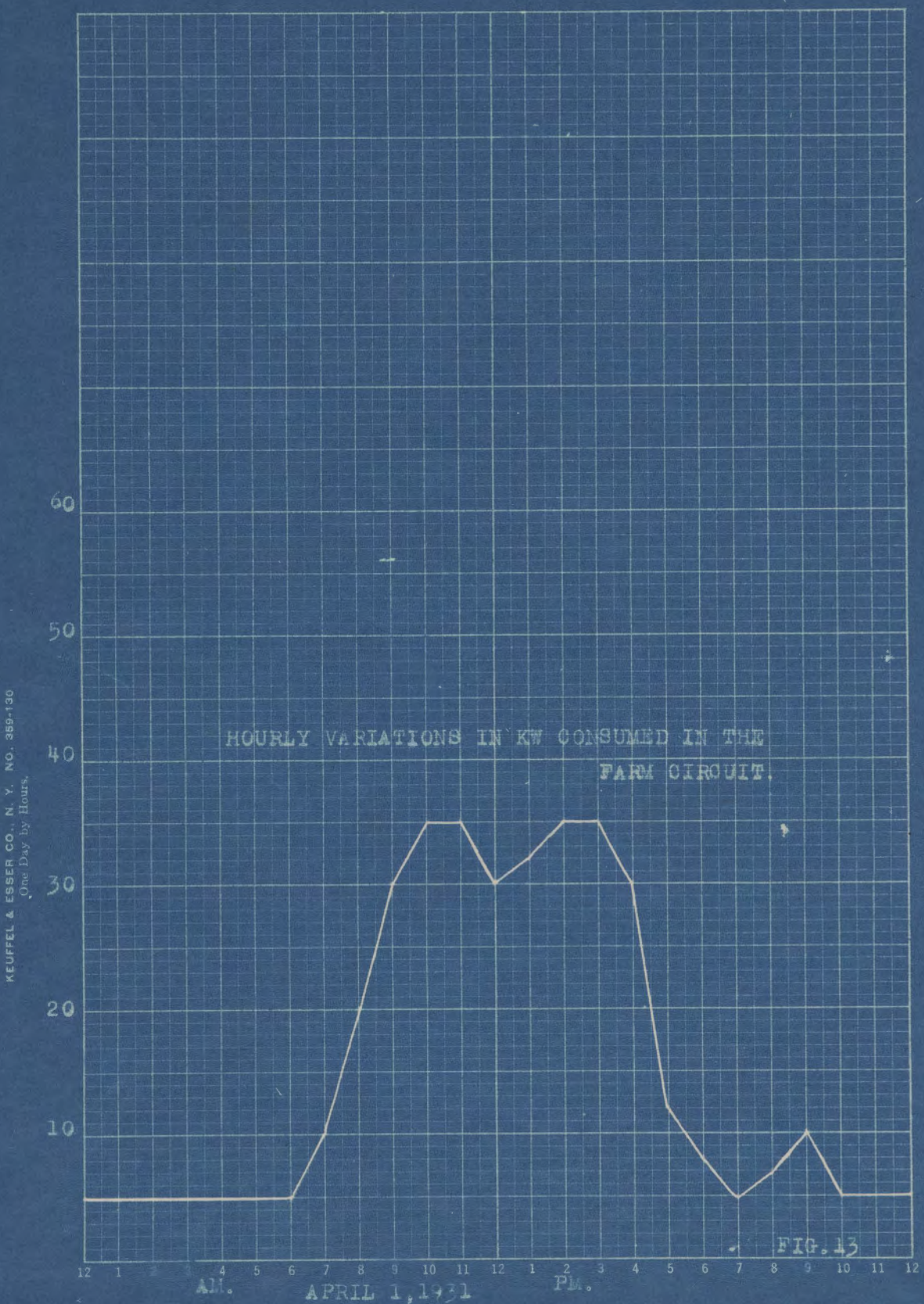


KEUFFEL & ESSER CO., N. Y. NO. 359-130
One Day by Hours.

HOURLY VARIATIONS IN KW CONSUMED IN THE HOME ECONOMICS CIRCUIT.

FIG. 12

APRIL 1, 1931



KEUFFEL & ESSER CO., N. Y. NO. 359-130
One Day by Hours.

FIG. 13


HOURLY VARIATIONS IN KW CONSUMED IN THE SCIENCE AND GEOLOGY CIRCUIT.
50
40
30
20
10
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
AM.
PM.
APRIL 1, 1931
KEUFFEL & ESSER CO. N. Y. NO. 359-130
One Day by Hours

FIG. 14

VII. FINDINGS.

In checking over the circuits behind the switchboard, it was found that the auxiliary 2300 volt circuit was tapped to the leads coming from the Westinghouse generator as shown in Figure 1. They were tapped to the generator side of the current transformers, and therefore the wattmeter on the Westinghouse generator did not read the total kw. generated, but read only the total generated less the amount used by the auxiliaries. The wattmeter on the General Electric unit read the total generated when that unit was running. This accounts for part of the wide variations in the "unaccounted for" power. This would tend to indicate that when the Westinghouse unit was operating, the meters should check with none left for the auxiliaries. This was not the case, so it was necessary to look for other sources of trouble.

After the watthour meters had been installed, it was found that the watthour meter on the Home Economics line showed more kw. than was indicated by the wattmeter. The connections to the wattmeter were checked, and it was found that the switchboard wattmeter had the potential leads interchanged. The meter indicated 5 kw. at the time, while the true power was found to be 35 kw. At unity power factor the current in the current coil was 90° out of phase with the voltage on the potential coil, and the registration was zero regardless of the load. When the power factor was less than unity, one element of the meter gave a negative torque, and the other gave a positive torque. Thus if the power factors

of the two phases had been identical, the resultant torque on the meter would have been zero. But as it happened, the element which tried to produce positive torque was connected to the phase with the poorest power factor, and the resultant torque was ordinarily positive. Thus the meter indicated a very erratic value of power. Since this was a heavily loaded line, it accounted for the large amount of power which had been generated at times when the distribution meters did not indicate where it was used.

Other sources of error seem rather small in themselves, but they produce considerable error when combined. The scales on the Estabrook and Strong Hall wattmeters are too condensed to read accurately - especially at small loads of less than 10 kw. when the error may easily be 50 percent or more. The transformer ratios on these two circuits are out of proportion to the load on the circuits. The maximum load is less than 100 kw., while the full scale deflection is 800 kw. It was found that most of the wattmeters were in error at least 10, or even 15 percent. There were errors also due to the incorrect reading of the meters.

It was found that the street lights were on the auxiliary circuit. This resulted in the consumption of approximately 3 kw. at night which should not be charged to the auxiliaries themselves.

Miscellaneous findings around the plant might include that the frequency meters were indicating 1 cycle slow. The

Westinghouse turbine tachometer indicated 3800 revolutions per minute when the machine was actually running less than 3600. The General Electric speed meter indicated 2 percent fast when the turbine was running 3600 r.p.m. The voltage regulator had a badly pitted bearing. This hampered its action so that it gave very poor regulation. The power factor meter on the General Electric generator does not indicate properly - it shows a leading power factor when it should be lagging.

VIII. SUGGESTIONS.

It is suggested that the auxiliary tap be changed so that it feeds directly from the bus bars. This will result in the elimination of confusion because the wattmeter on the Westinghouse generator can then indicate the true load on the machine and the total generated power.

The Home Economics meter should be properly connected. This can be done by merely interchanging two of the potential leads on the back of the switchboard. This would also help in making the wiring on this panel conform to the wiring of the other panels. In fact the wiring on the whole switchboard should be standardized. It is almost impossible to trace out the circuits as the wiring is at the present time. This makes it very difficult to install new instruments, and this accounts, in all probability, for the improper connections on the Home Economics meter.

If correct registration is desired, smaller ratio current

transformers should be used in the Estabrook and Strong Hall circuits. The full scale deflection on the wattmeters for these circuits should be approximately 250 instead of 800 kw.

The voltage regulator is badly in need of adjustment. At present it is almost a complete failure as a regulator, but it probably could be repaired and adjusted so as to give fair regulation.

The power plant is very much in need of a frequency regulator. It happens that the University plant is in an exceptionally good position to have almost perfect frequency regulation at a very low cost. The city line, which has a regulated frequency, is used as a "stand-by". It is suggested that two Telechrone clocks be installed on the switchboard, - one on the city, the other on the power plant, and that the one on the city be used as the master clock. The frequency of the power plant could then be so adjusted that the clocks always indicated exactly the same time. This is the method used by the power plants with regulated frequency where automatic frequency control has not been installed. It would take a little practice and skill to keep the clocks together at first, but fair regulation should be obtained by setting the clock once an hour. This would certainly be an improvement over the present situation.

It is suggested that the Westinghouse governor control motor be connected so as to permit the use of the synchroscope when changing from one unit to the other. This would prevent the interruption of service due to the change. It is very

unsatisfactory at present for motors, out on the lines which are running on tests, to fall out due to failure to synchronize when changing generators. If these motors were not equipped with voltage releases they would be burned up after the change from one generator to the other.

The power factor meter on the General Electric generator should be properly connected. It seems that some of the leads have been interchanged so that it reads leading when it should show a lagging power factor.

A fire extinguisher for the switchboard might be a good investment. The 2300 volt plug jacks behind the switchboard frequently arc when they are opened or closed, especially when there is a load on the line. These jacks are dangerously near the switchboard wiring so that it seems that some precautions should be taken against fire.

The General Electric 30 hp. motor does not have fuse protection except some 200 ampere fuses in the main lines. These fuses do not give the motor adequate individual protection. The overload temperature relay for this motor has the temperature trip blocked so that it cannot operate even under conditions of very heavy overload. It is suggested that more ample protection of some kind be installed in this motor circuit.

IX. APPROVAL.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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