THE STREET LIGHTING SYSTEM OF JELLICO, TENNESSEE

and

A DISCUSSION OF THE CHARACTERISTICS OF ILLUMINATION.

by

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Introduction.

The City of Jellico has its own electric power plant. The power is generated by the use of steam from two boilers. Originally each boiler had a capacity of two hundred Horse Power but Dutch ovenss were added and these increased the capacity of each boiler fifty percent, making the total capacity of the plant six hundred horse power.

The plant was first installed about the year 1900 and the equipment has been changed and improved as the need has demanded. At the present time the population is 3000 people and there are several factories located in Jellico and these factories are heavy power consumers. Some of these factories are:

Jellico Brick Corporation
Jellico Raincoat Company
Cumberland Club Company.
Imperial Welding Company.
Elk Lumber Company.
Diamond Hosiery Mills.

These and others with the garages and motion picture house placed a heavy demand on day current.

When the Light Company was first installed none of these heavy consumers were in existence, so the only demands for service were street lights, office, Business and residential illumination. Consequently, all were put on one circuit as the town was small, and they were turned on only at nights and dark days.

When day consuming enterprizes began to make their demand for power the larger street lights had switches placed on the pole, and a young boy was put on the payroll to make

the rounds each morning and night to turn off and on these lights. At first there were nine arc lights only, on the switching route. Then gradually by twos and threes smaller adjacent lights were added until the switching route contained about forty lights.

The company realized that this was a crude method of street lighting and they inspected several street lighting systems. Finally they decided to install a cartridge series system using the General Electric Type R V constant current transformer.

It shall be my effort in this thesis to give,

A description of this system, both general and technical.

How much illumination is furnished by the system.

Discuss illumination both normal and in horizontal plane.

Discuss illumination from the standpoint of new globes and old globes.

Clean reflectors and dirty reflectors.

Clean globes and dirty globes.

As it may be a question to some, I will discuss in part the subject of sufficient illumination. Also graph accompanies this thesis showing the actual illumination of Main Street from the Kentucky State line to Mr. J. E. Austin's home, the distance covered by this graph being 4030 feet. Also, as it may be of interest as a basis of comparison or estimation, I have figured the total cost of the system installed.

Description of System.

The General Electric type R V constant current transformers is located at the power plant beside the main switch board with a separate switch panel for the street lighting system. On this switch panel we have plug switches for the secondary and primary circuits and also an ammeter that range from 0 to 10 amperes. The tranformer is No. 2077003 Type R V Primary Volts 2300 60 Cycle 15 I.W. at 6.6 amperes.

About 300 yards from the plant there is a separation of the line into two circuits, one going to the south part of town and the other to the north part. In the heart of the town there is another separation of the north end circuit, one going up Fifth Avenue. At the end of Main Street there is a loop which takes in the Kentucky Side of town. This makes two main divisions of the system, one of which is divided into three parts. The divisions are:

South Division

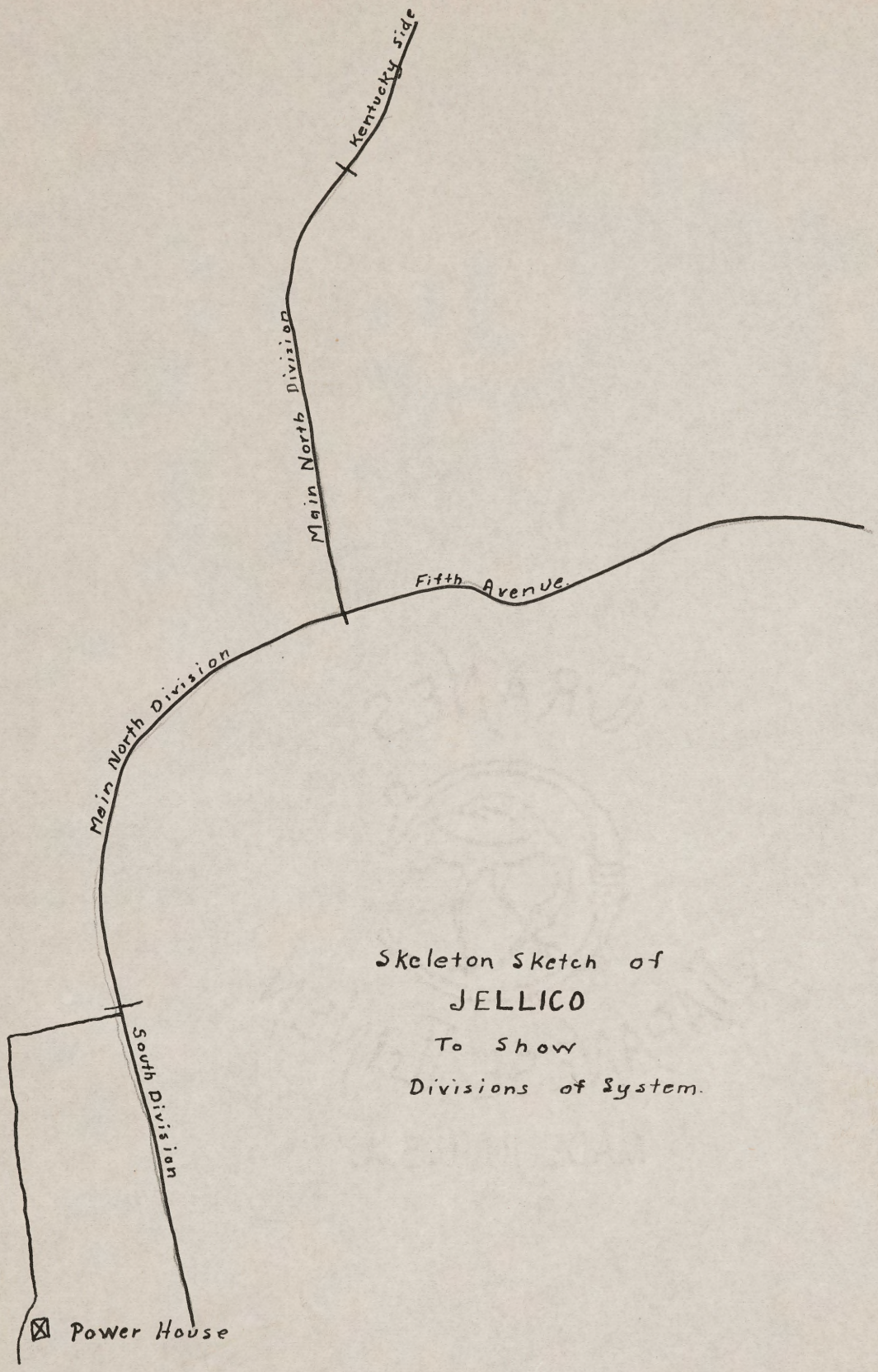
North Division (Main North
(5th Avenue
(Kentucky Side

See sketch of Town in Fig. 1.

In the system there are lights of the following candle power:

6	lights	250	candlepower	
25	"	100	"	
8	"	80	"	
131	"	60	"	making a

Total of 170 lights.



Skeleton Sketch of
JELLICO
To Show
Divisions of System.

Fig. 1

The section for which the graph is plotted contains the following lights:

5 250 C.P. lts, and
19 100 C.P. lts

making a total of 24 lights.

The lights are connected in series and this makes a cartridge cap socket necessary (Fig. 2.). This consists of two flat brass bars "X" and "X^{1}" with a cartridge "C" which is pulled up through the bars at A and B. If the light burns out the current will puncture the cartridge through the holes A and B and in this way one light burning out will not affect the other lights.

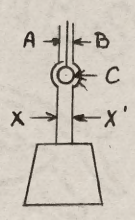


Fig. 2

The lights are hung on arms, four feet long, from the poles on one side of the street at an approximate height of 18 feet. The lights being on one side of the streets have the advantage over the lights in the center of streets because they illuminate the side walks more. At the present day with so much automobile traffic at night very little illumination is needed in the driving part of the street and also Jellico is built all on one side of its main street and there are no sidewalks to be illuminated on the other side.

The Transformer.

The type R V Transformer is designed to give a constant current provided the primary voltage is kept constant.

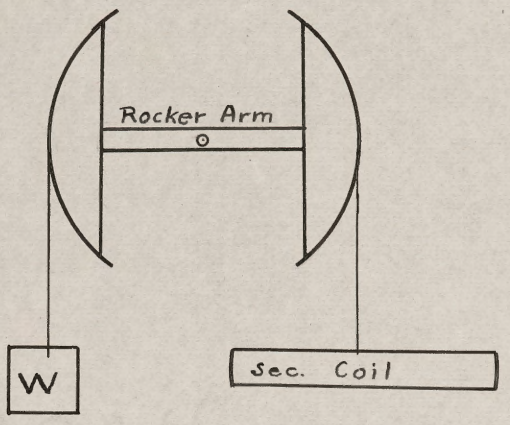


Fig. 3

The rocker arm is mounted on ball bearings and this illiminates practically all of the friction in the movable parts of the transformer. This transformer is air cooled, the windings being subdivided and have vertical ventilating ducts. The coils and core are protected by a heavy wire network which allows free circulation of air, and it is also heavy enough to protect against accidental contact with the live parts or the movement of the coil.

In April 1925 after the transformer had been installed about eight months, some tests were made on its versatility. Instaneously we cut off 33 lights in the Kentucky loop and noted the action of transformer and ammeter. These were cut back in two minutes and the transformer and ammeter action noted again. We repeated both these experiments as a check.

In April 1926 we did the same with the 33 Kentucky lights.

Also at this time we repeated the same experiment on a larger scale by cutting off and on the 5th Avenue and the Kentucky district together. There were 88 lights in these two loops combined.

At both turns in 1925 and 1926 we noted the action of transformer and ammeter at the time the load was first applied. The results are tabulated in the data on Page A of Data sheets.

At the first application of the full load it took about 4 seconds for the transformer to approximately adjust itself, the ammeter resting at 6.7 amperes. In about two minutes the current had decreased to 6.6 amperes. This two minutes delay was probably due to the transformer coils being cold and it took them that long to heat up. We say this is the probable cause because after completing the tests we cut off the entire system, then we cut them back on and in 4 seconds the ammeter went directly to 6.6 amperes and remained there.

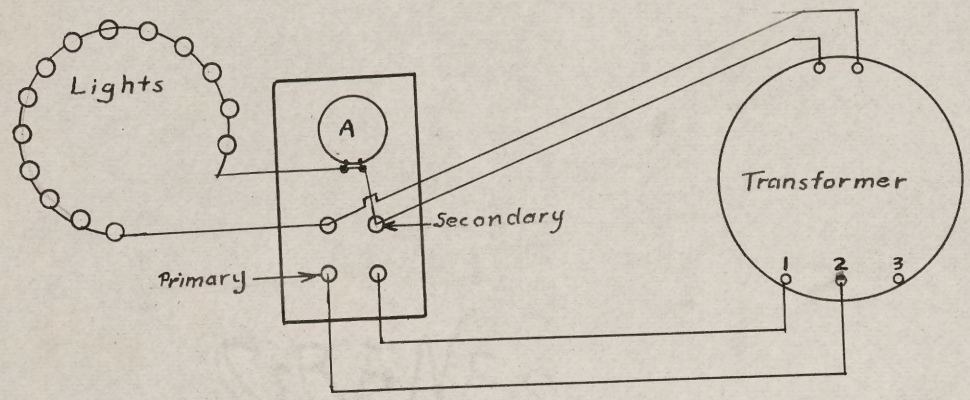
The transformer adjusts itself more quickly to loads being taken off than to loads coming on. When 33 lights were cut off, it took 5 seconds for the transformer to adjust itself to a constant current of 6.6 amperes.

When 33 lights were cut on, it took 10 seconds for the transformer to adjust itself.

When 88 lights were cut on, it took 12 seconds for the transformer to adjust itself.

When 88 lights were cut on, it took 10 seconds for a partial adjustment to 6.55 amperes and 60 seconds for final adjustment to 6.6 amperes.

The transformer, with switch panel and lights are wired in as follows:



Taps 1 and 2 - 100% Load
Taps 1 and 3 - 80% Load

Fig. 4.

When the load is first brought on the coils are latched apart but the load coming on "kicks off" the latches. Then the difference in weight of the coil and the applied weights causes the coil to drop. This drop is slow and the coil is stopped by the force from the primary coil. The amount of constant current may be controlled by the adding or subtracting from the applied weights. It is very necessary that this current be kept constant because if series lamps are given even a small excess of current they are short lived and if the current is slightly low they do not give the illumination specified for them.

The Lights.

There are four sizes of globes used in the system, the 250 c. p., 100 c. p., 80 c. p. and 60 c. p. All the lights are about 18 feet from the street and they hang on a four foot bracket. The poles are set at the edge of the sidewalk.

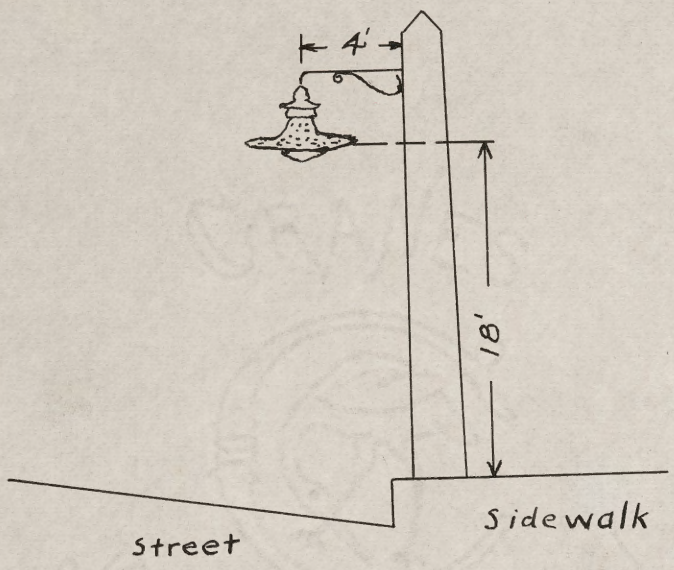


Fig. 5

Tests were made by a small portable foot candle meter of the intensity of the illumination of all the different sizes of lights, of old and new globes, of clean and dirty globes and of clean and dirty reflectors. There are two different types of reflectors with two kinds of each type. They are:

$6\frac{1}{2}$" Holophane prismatic band
$8\frac{1}{2}$" " " "

20" dome radial reflector
20" radial wave reflector flat.

The holophane reflectors give a more even light than do the dome radial reflectors while the dome radial reflectors give a much brighter apparent cone of light near the light. Evidently it is the glare that causes the cone of light to appear brighter because for different reflectors on the same light the illumination close to the light is the same. It is only for distances within 25 feet of the poles that measurements could be made by the portable foot candle meter.

It is a question whether to measure the illumination on a horizontal plane or to measure it normal to the light rays. Provided the surface were truly a matt surface and only one light were used the horizontal intensity would be the same as the normal intensity multiplied by the cosine of the angle between the rays of light and the horizontal plane. Where the section is between two lights this relationship would not exist, and there is no way to measure the intensity normal to both lights at the same time and provided we could do this we do not know in which way to combine our values of intensity to get the true illumination. We realize that it is not the intensity on a horizontal surface that shows up an object but it is the intensity in a plane normal to the rays of light that illuminates objects. In no case is the horizontal intensity greater than the normal intensity and in the accompanying graph we used the values for nromal intensity. In our observations we measured both normal and horizontal illumination as far as possible within the range of the foot candle meter.

A general impression is that old globes will not give as much illumination as new globes of the same size. Possibly this impression is correct but it is not correct to any marked degree. Our tests for this difference show that when the old globes are washed clean, they give the same intensity at the same point that a new globe gives. There may be some slight difference but it could not be detected with the foot candle meter used.

The ground for this apparently false impression is most probably the fact that old globes are always dirty to some degree and dirty globes will not give out the same amount of light that a clean globe will.

We measured the intensity of some lights and then cleaned the globes and again measured the intensity and there was a marked difference.

A 100 c. p. light at the intersection of Loudon Avenue and South Main Street measured:

Directly beneath it	.036 ft. candles
3 ft. out	.07 ft. candles

The same globe was cleaned and measured:

Beneath it	.05 ft. candles
3 ft. out	.11 ft. candles

A 250 c. p. light at the intersection of Church Street and S. Main Street measured:

Beneath light	.11 ft. candles
3 ft. out	.19 ft. candles

This globe was cleaned and measured:

Beneath light	.20 ft. candles
3 ft. out	.23 ft. candles

From these measurements we learn that if the globes are

washed occasionally the intensity of light on the streets would be greatly increased.

Also we learned that if the reflectors are washed too this will cause a greater intensity out from the lights. This is especially true of the holophane prismatic band reflectors as they completely surround most of the globe.

A 100 c. p. light at the Loudon Avenue crossing of the Southern Railway measured:

Beneath light	.01 ft. candles
12 ft. out	.008 ft. candles

The holophane reflector was washed and the intensity was:

Beneath light	.01 ft. candles
12 ft. out	.015 ft. candles.

The rough indentations on the holophane reflector furnishes regular dust traps and they must be cleaned frequently to give out the maximum illumination.

The Foot-Candle Meter.

The foot candle meter used in the survey was a small portable foot candle meter. By means of a sheostat and a standard bulb we could set the pointer exactly over an arrow. The standard bulb is at one end of the foot candle meter inside of the box. Above this bulb is a very nearly matt surfact. In this matt surface are several holes evenly spaced over which is oiled paper. These holes are about 3/16" of and inch in diameter. There is a scale which reads in foot candles on this matt surface. When the intensity is between 1 and 50 ft. candles there will be one grease spot which is the same brightness as the matt surface andwill seem

to disappear. This means that the same intensity is at that point both inside and outside of the of the box. Then because the scale is graduated to read the intensity at any point due to the light inside, we read the scale at that point and that also is the intensity outside the box at the plane where the foot candle meter is. We read this scale directly when the rheostat pointer is directly over the arrow. For smaller intensities we can set the pointer over a line that reads 1/10. With the pointer thus set we measure intensities by reading the scale and dividing this reading by ten (10). The range for this setting of the pointer is from 0.1 to 5.0 ft. candles. Also for still smaller intensities we can set the pointer over a line marked 1/100 and then we read the scale and divide this reading by 100. The range for this setting is 0.01 to 0.5 ft. candles. It was with this last setting that most of our readings were taken. A plan view of the foot candle meter is shown:

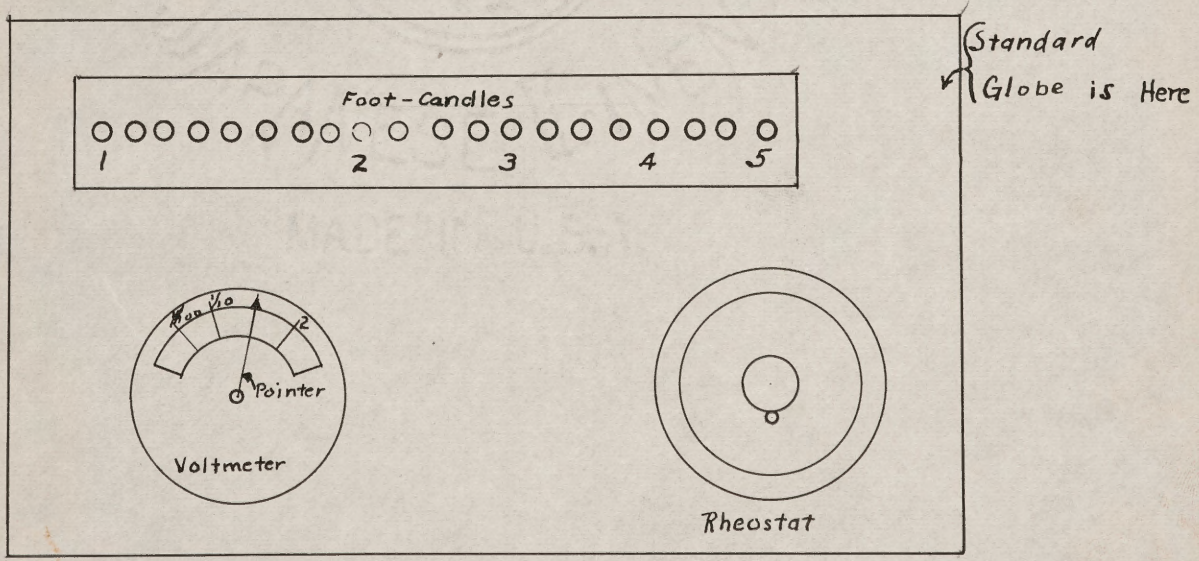


Fig. 6

If as shown, the grease spot at "2" appears not to be, then the intensity on the face of the foot candle meter is two ft. candles or two lumens per square foot. If the pointer were on the mark 1/10 the intensity would be two tenths of a foot candle. If the pointer were on the mark 1/100 the intensity would be two one-hundredths of a ft. candle.

The foot candle meter used is not exactly accurate but its error is small and it is a most convenient instrument for such a survey. Possibly in designing a street lighting system it may become a question as to just how much street illumination is sufficient. We all know that on the brightest of moonlight nights there is sufficient illumination. On a bright moonlight night we measured the intensity of the moonlight. The foot candle meter could not measure this intensity as it was too small, but by an indirect method by measuring the intensity from a light with the moonlight shielded, then removing we found a difference of five to six one-thousandths of a ft. candle. This is a slightly inaccurate method but because the range of the foot candle meter was so small, it was the only method we could use. If we could get an even intensity of from five to seven one-thousandths we would deem this sufficient illumination. But it is impossible to obtain this even intensity. Therefore by noting various intensities that appear to be sufficient we may draw conclusion that may serve or a broad criterion as to what is sufficient illumination.

There is an apparent bright cone of light beneath each light. Actually the points having equal intensities from a circle on the horizontal plane of the street. If the lights are placed about 150 feet apart and each light will illuminate

c circle of twelve feet in radius to .05 of a foot candle, the concentric circle six feet in radius would have about .2 of a foot candle intensity. We would deem this sufficient illumination. The present day tendency is toward a higher illumination and one may desire to obtain greater intensities on the street than are recommended. This may be had by increasing the size of the lights or placing them closer together. Roughly, sufficient illumination will be given by 100 c. p. lights spaced 100 ft. apart or by 250 c. p. lights spaced 150 ft. apart. This illumination is sufficient for a business district as the importance of the streets decreases the illumination of the streets may be decreased. But in no case should there be less illumination than is given by 60 c. p. lights spaced 100 ft. apart. This is relatively poor illumination but it is considered sufficient for cross streets and outlying districts, in spite of the dark spots equidistant from two lights. Some cities have their bright white ways but they are more for the artistic beauty than than for the real practical need.

Cost.

In this system there is about seven miles or about 36,000 feet of number 8 soft drawn weather proof wire. This wire weighs about 390# per mile and the cost of this wire delivered is about 23 cents per pound, making the total wire cost of the system approximately $627.90.

By charging to street lights one-third of the cost of the poles we figure that the cost of installing the fixtures, including labor and the pole cost, is very close to $10.00

per light. As there are 170 lights we shall say that the cost of installation is $1,700.00.

The fixtures complete with hanger and reflectors are itemized as follows:

Quantity	Description	Unit Cost	Total Cost
100	20" radial wave reflector	@ $7.88	$788.00
35	20" dome radial reflector	@ 8.33	291.55
26	6½" Holophane prismatic band	@ 13.28	245.28
6	8½ " " "	@ 15.97	95.82
	Total fixture Cost.....		$1520.65

Some of the globes will last as long as three (3) years, while some will burn out in two or three months. We will say that the average life of a globe in the system will be twelve months. The initial cost of globes was very close to $250.00. The catalog price of the transformer plug switch panel is $220.00. There are some discounts on the above prices but these discounts vary; therefore, we are giving the catalog prices on the parts. The total costs itemized are:

Wire Cost	$ 627.90
Installation and Erle Cost	1,700.00
Fixture Cost	1,520.65
Globe Cost	250.00
Transformer Cost	900.00
Switch Panel Cost	220.00
Total Cost of System Installed....	$5,218.55

It would be very reasonable to assume for a city of 2500 to 3500 population, that a suitable street lighting system would cost approximately $5,000 installed.

Data:-

Action of Transformer due to Changes in Load.

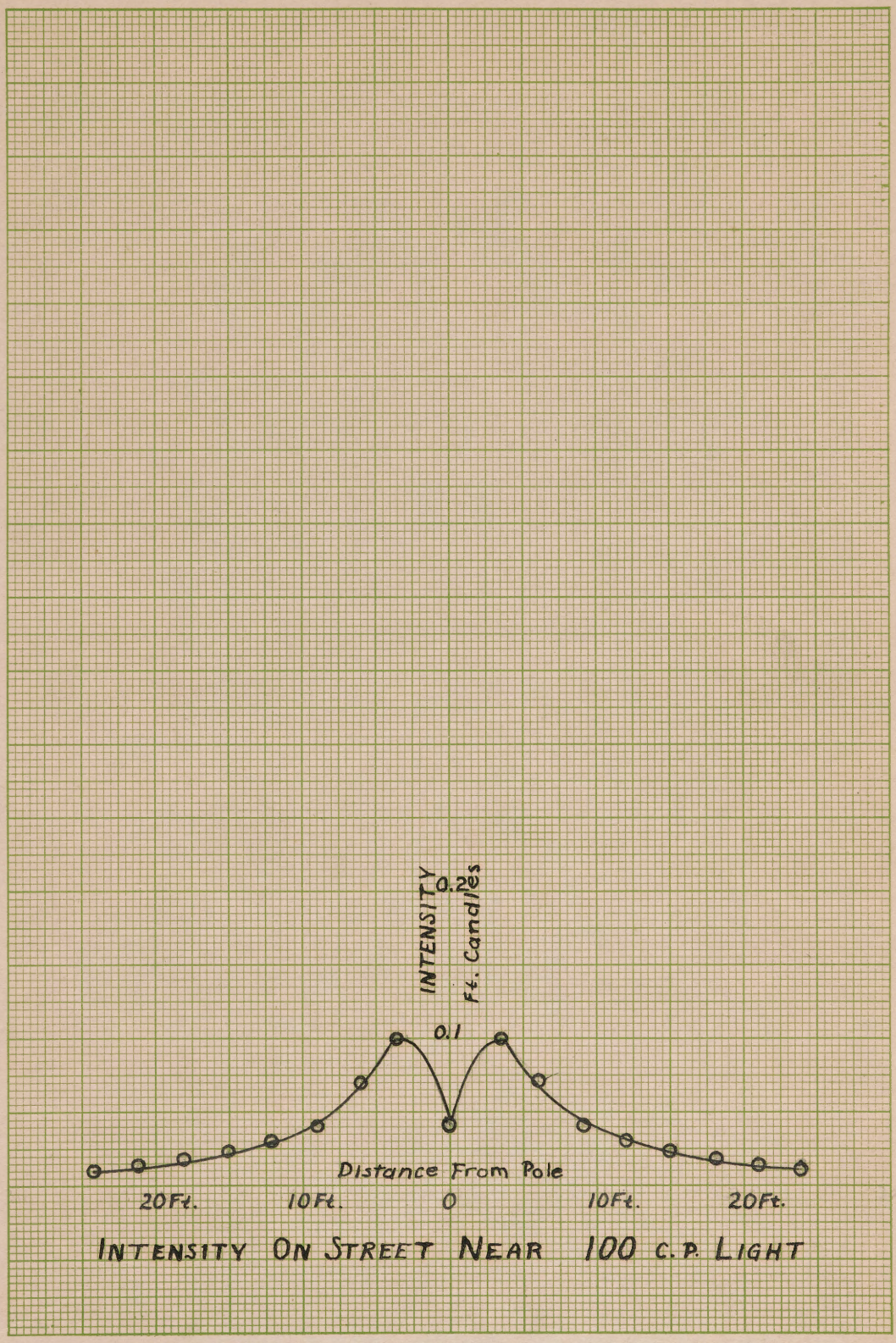
Date	Load	Current Change	Time of Change
April,1925			
	Off		
	Full load	0 - 6.7 amps	4 seconds
		6.7- 6. 6 "	120 "
	33 lts off	6.8 - 6.6 "	5 "
	33 lts on	6.5 - 6. 6"	10 "
	33 lts off	6.8 - 6.6 "	5 "
	33 lts on	6.5 - 6.6 "	10 "
April,1926			
	Off		
	Full load	0 - 6.7 amps	4 seconds
		6.7 - 6.6 "	120 "
	33 off	7 - 6.6 "	5 "
	33 on	6.4 - 6.6 "	10 "
	33 off	7 - 6.6 "	5 "
	33 on	6.4 - 6.6 "	10 "
	Off		
	Full load	0 - 6.7 amps	4 seconds
		6.7 - 6.6 "	120 "
	88 off	9 - 6.6 "	12 "
	88 on	6.2 - 6.55"	10 "
		6.55-6.6 "	60 "
	88 off	9 - 6.6 "	12 "
	88 on	6.2 - 6.55"	10 "
		6.55 - 6.6"	60 "
	Off		
	Full load	0 - 6.6 amps	5 seconds

Data:-

Costs of System Installed.

Quantity	Item		Unit Cost	Total Cost
2730#	No. 8 W.P Wire	@	$ 0.23	$ 627.90
170	Poles and Labor	@	10.00	1,700.00
100	20" radial wave reflector	@	7.88	788.00
35	20" dome radial reflector	@	8.33	291.55
26	6½" Holophane "	@	13.28	345.28
6	8½ " "	@	15.97	95.82
	Globes			250.00
1	R V Transformer			900.00
1	Plug switch Panel			220.00
	Total Cost Installed			$5,218.55

FormE-5



INTENSITY ON STREET NEAR 100 C.P. LIGHT

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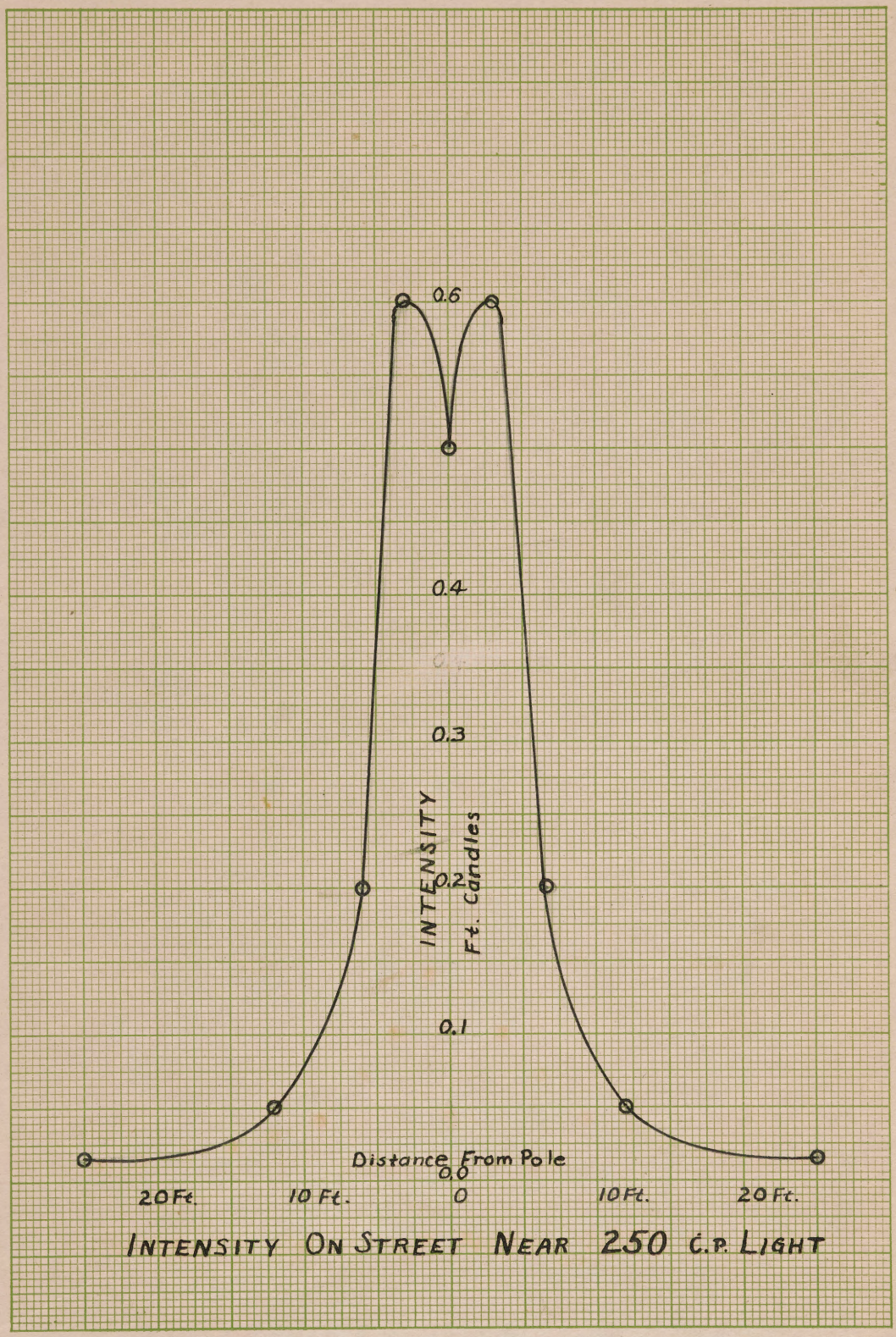

INTENSITY ON STREET NEAR 250 C.P. LIGHT

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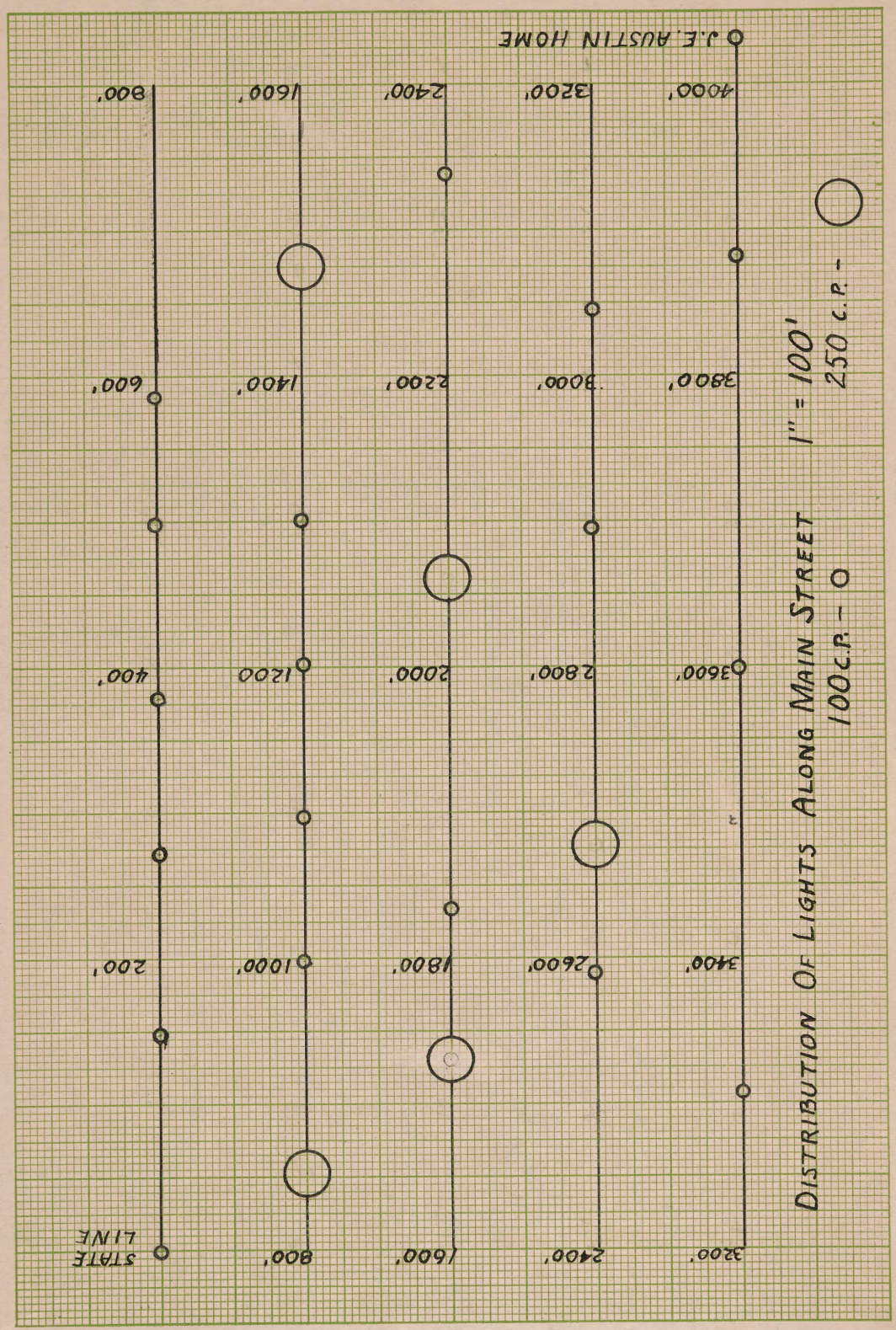
FormE-5



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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 conslusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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