Lighting System for the University Campus.

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** Introduction.**

The need of an efficient and artistic lighting system for the University Campus has been in evidence for several years.

There are many different kinds of lighting systems in use at present, but some of them are so inefficient that they need only a slight mention in this article.

The object of this thesis is to discuss comparativelythe different lamps and lighting systems, finally deciding on the most efficient systems, giving their first cost, total cost of installation and total cost of operation.

** Discussion of Arc Lamp Systems.**

The arc lamp is an electric apparatus in which an electric arc is struck and maintained between two or more electrodes, giving a brilliant illumination the color and intensity of which depend upon the composition and diameter of the electrodes, the kind of current applied and the watts consumed.

The first commercial arc light systems for street or park lighting were known as "the open carbon arc system". The arc being formed between two carbon electrodes which were consumed in a few hours. The energy required was high and the efficiency of the system low. The light, about 80% of which was emitted from the crater of the top or positive carbon, was intrinsically brilliant, but unsteady and was thrown on the street at an angle of about 45 degrees below the horizontal, while directly under the lamp the dark shadow was cast.

The commercial introduction of the enclosed arc eliminated many of the objectionable features of its predecessor, the "open arc". Like the open arc, however, the arc stream was established between carbon electrodes, but a small globe, enclosing the arc, was used to exclude the air, thereby increasing

the life of the electrodes. The intrinsic brilliancy was not so great as in the open arc, but the opal enclosing globe became a secondary source of well diffused steady light conspicuous by the absence of shadows in its immediate vicinity.

With the perfection of the enclosed arc, the General Electric Company took up and developed the Magnetite Arc Lamp.

<u>Constant Potential Alternating Current Enclosed Arc Lamp</u>.

This lamp can be operated on circuits ranging in voltage from 95 to 125 volts, either at 60 or 125 cycles. The choke coil is provided with two coils each wound upon a limb of the core. On 60 cycles all of the coils are in use, while on 125 cycles only part of one coil. This coil is provided with a number of taps which permit the cutting in or out of turns, thereby making the lamp adaptable for high or low line pressure.This lamp is not operated in series, and has a power factor of about 70%, with an efficiency of about 80%.

The chief objection to this lamp is unreliability and the amount of care it takes for maintenance. Also the excessive noise and vibration in

starting due to the initial striking of the arc.

Constant Potential Direct Current Enclosed arc Lamp.

This lamp requires 100 to 250 volts at the terminals with 75 to 160 volts at the arc. The minimum amperage is 2 1/2 and the maximum is 6 amperes. Each lamp is fitted with a resistance coil, and is a complete unit for multiple connections on 100 to 125 volts with 75 to 85 volts at the arc, or on 200 to 300 volts with 140 to 160 volts at the arc. This lamp is controlled by a series magnet and has an efficiency of 80%.

This lamp is more reliable than the constant potential alternating current enclosed arc lamp, but has about the same efficiency.

Constant Current Alternating Current Enclosed Arc Lamp.

This lamp requires 75 to 80 volts at the terminals. The arc from 72 to 77 volts. The minimum amperage is 4 and the maximum is 7 1/2. The field control may be either shunt or differential. The lamps operate in series on constant current circuits, usually controlled by constant current transformers, or automatic reactance coils. The system operates on any frequency from 50 to 140 cycles. The efficiency of the complete system is about 80%.

Constant Current Direct Current Enclosed Arc Lamp.

This lamp requires 75 to 80 volts at the terminals. The arc is set for 73 to 78 volts. The amperage is between 5 and 7, depending on the candle power desired. The lamps operate in series on a constant current source of supply, and have an effidiency of about 85%.

Flaming Arc Lamps.

The light from all electric arcs is a result of the phenomena of incandescence, and the problem for illuminating engineers is to increase this property as much as possible. From time to time since 1890 it has been proposed to impregnate carbon electrodes for arc lamps, so as to add metallic vapors to the arc, thereby greatly increasing its size and brilliancy. Several methods of combining metallic salts with the carbon have been tried, but the greatest difficulty has been experienced in securing a uniform mixture which would consume evenly without the formation of a slag which would eventually interrupt the service of the lamp. After several years of extensive practical use the yellow flaming arc has been developed by the Western Electric Company.

These lamps are operated two in series on 110 volts on either direct or alternating current. A single direct current lamp can be operated on 110 volts by using a resistance in series with it. A single alternating current lamp can be operated on 110 volts by using a small aototransformer. The transformer is separate from the lamp and can be suspended at a distance from it when desired. The efficiency of a single alternating current lamp when operating from an autotransformer is but little lower than when two lamps are operated in series directly on the mains.

In conclusion, the main disadvantage of the flaming arc lamp are as follows; frequent trimming, high price of carbon, fume deposits on the inside of the lamp and unfavorable light distribution for street lighting.

Magnetite Arc Lamp.

One of the most important factors in the improvement of street and park lighting during the past few years has been the development of the magnetite arc lamp. The high candle power of this type of lamp at slight angles from the horizontal results in nearly as much light between the lamps as in

their immediate proximity provided they are not placed over 100 feet apart.

It is interesting to note that these lamps have been put in in place of the direct current series arc lamps in many places and give much better illumination with a very material reduction in current consumption.

The light from this lamp is of a pure white character and very brilliant. The distribution curve of the magnetite arc lamp has been found to be very nearly ideal for the usual spacing of street and park lamps. There is sufficient light underneath the lamp with the maximum candle power directed at an angle of 15 degrees.This lamp cannot be worked on alternating current because of the fact that no arc can be maintained on alternating current except in the case of electrodes of carbon or some carbides.

This lamp has the magnetite as the negative and a copper rod as the positive terminal. The arc has a nonluminous zone near the positive electrode and an intensely bright luminous zone, composed of volatilized oxides, near the negative electrode and closely resembling in shape an ordinary candle flame. In order to secure the most desirable light distri-

bution as well as to secure simplicity of operating mechanism, the negative electrode is preferably fed from the top. The life of the negative electrode per trim is, for the 4 ampere lamps, about 200 hours.

From a commercial standpoint the magnetite arc lamp is of great interest both to the central station and to the general public. By the use of this type of lamp with its decreased current consumption and increased life per trim nearly twice as much light with greatly superior light distribution can be furnished a given area for the same maintenance and operating costs as with the older arc lamp systems, or an equivalent lighting service can be furnished with only one-half the power consumption.

Constant Potential Magnetite Arc Lamp.

This lamp is not nearly as efficient as the constant current magnetite arc on account of its having to be operated on 110 volt circuits and the arc only requires about 80 volts, so that the remaining volts must be used up by resistance coils, hence it has high resistance losses. These losses

reduce its efficiency to a point much below that of the constant current magnetite arc.

Besides these, there are disadvantages due to the heating of these coils, and the complication of its mechanism, which make it unreliable.

Constant Current Magnetite Arc Lamp.

This lamp as developed by the General Electric Company has been a great advance in the service of illumination.

The distribution of candle power in this lamp is approximately as follows:

Positive crater, 20%; negative crater, 5%; and the arc flame 75%.

This lamp has the following recommendations:

(1) It consumes 30% less energy with 30% additional illumination.

(2) Ideal distribution of light maintained throughout the life of the electrodes, and the position of the arc remains unchanged.

(3) Longer life of electrodes.

(4) Less frequent trimming, hence less cost

for maintenance.

(5) No enclosing globe required.

(6) Its efficiency for the whole system, including rectifier and transformer, is about 88%.

Finally, after a comparative discussion of the different forms of arc lighting, it resolves itself into the choice of the constant current magnetite arc.

From the preceeding comparisons this is obviously the best and most efficient arc lamp to use for a lighting system for our purpose.

** Discussion of Incandescent Lighting.**

In general we have but two kinds of incandescent lamps for street lighting and park lighting; these being the carbon lamp and the tungsten lamp.

The Carbon Lamp.

The carbon lamp is one we are all familiar with. Up to a few years ago it was the only type of incandescent lamp we had on the market.

The ordinary 16 candle power carbon lamps are made in two types: 3.5 watts per candle power and 3.1 watts per candle power (mean horizontal). The 3.5 watt lamp has an average useful life of 850 hours and the 3.1 watt lamp a life of 450 hours.

The tungsten Lamp.

The tungsten lamp was invented later and has a filament consisting of tungsten alloyed with titanium or thorium or vanadium. The tungsten lamp is capable of an efficiency of 1.25 watts per mean horizontal candle power. Its life is from 1200 to 1600 hours.

The light is pure white, being the nearest approach to daylight yet obtained by artificial illu-

minants.

Due to the high efficiency of the tungsten lamp it is used now almost universally. On account of the shortness of life, fragility of filament, and the voltage drop of distant lights and consequent energy loss the multiple lamps would be out of the question to select as a lighting system for the campus.

However, the series system of tungsten lamps will, on an automatic current transformer, be an ideal form of lighting for streets, parks and similar service.

This lamp shows economy over the ordinary carbon series lamp in two ways:

(1) By requiring one-third of the energy of the carbon lamp, hence, reducing the cost of current two-thirds.

(2) The original central station equipment can be used for three times the number of lamps.

The high efficiency is due to lower voltage required per lamp for a given candle power and current. The increased life of series tungsten lamps over multiple lamps is due to greater cross section of filament. This gives more strength to the fila-

ment and makes it able to stand all ordinary vibrations.

The tungsten series lamp, as compared to the carbon series, is very much more efficient. With the efficiency of the tungsten at 1.25 W.P.C. vs 3.8 W.P.C. of carbon series and a life of 1500 hours vs 1000 hours and cost of $1.35 vs $.60, it is very obvious that there is a greater saving by using tungstens. Also for the same candle power the transformer equipment is cut down by three, or, for the same current, we can put three times as manymlights on the same transformer.

When series lamps are used, it is desirable to use a series socket provided with a film cutout or some compensative resistance device. This series socket is so constructed that when the lamp fails the increased voltage at the lamp terminals punctures, and establishes a circuit through, a thin film of mica or shellaced veiling. This also affords the opportunity of removing the lamp at any time without breaking the circuit.

Comparison of the Series Magnetite Arc and the Series Tungsten Systems.

These systems are the most efficient in their respective classes of lighting. The magnetite arc system is not nearly so flexible a system as the tungsten, on account of being made into larger units. The magnetite also has the disadvantage of having to be trimmed, however, as the life of the electrodes is very long, this is no serious disadvantage.

For park lighting and street lighting, large units are desirable, hence, the magnetite arc is very suitable. By putting several units together in an ornamental cluster, or employing larger units, we can also make a very satisfactory system, for park lighting and street lighting, with the tungsten lamps.

Selection of Posts.

In the tungsten system we do not require as high a lamp post as the magnetite arc. The posts for the tungsten system will be of the same design as those of the magnetite arc system, but about four feet shorter. The cost, however, is the same in both cases. A drawing showing this post is shown later in the discussion.

For a moderate price these were thebest and most artistic posts we could find.

At this point it might be well to say a few words about the concrete post. We were unable to get much cost data on this kind of a post, so, consequently had to confine ourselves to the iron post designs entirely. The concrete standard is admirably adapted to this particular service. It can be moulded and finished to harminize with the outdoor surroundings, buildings, walks, etc. Even among trees and flowers the stone finish seems more in keeping with its environments than any other material.

<u>Selection of Cable.</u>

Both the magnetite arc and the tungsten are 4 ampere series circuits. For a fifty light magnetite arc system 4000 volts is required, which makes it necessary to have a highly insulated cable.

In selecting the size of wire to use for a 4 ampere constant current or series circuit, we used the following method.

For a given size of wire the cost will vary directly as the length and so will the interest on first cost and the energy loss, so it is sufficient

to calculate for any convenient length, say, 1000 feet. The cost of power is three cents per kilowatt hour. The lighting schedule will be approximately 1825 hours per annum. So in considering three cents per kilowatt hour and 1825 hours per annum, we will have 5475 cent-hours per annum.

From the following calculated table we determined the most economical cable to use for our purpose.

SIZE OF B+SG	COST OF 1000 FT. OF LEADED CABLE IN DOLLARS	FIXED CHARGES AT 15% IN DOLLARS	LINE LOSS IN KILOWATTS	TOTAL CHARGES IN DOLLARS CENT-HOURS PER ANNUM 5475
8	$156.00	$23.40	0.016	$24.28
10	130.00	19.50	0.026	20.92
12	130.00	19.50	0.041	21.74

In the above table, it is seen that we use the same cost for 1000 feet of leaded cable for No. 12 B & S as we did for the No. 10 B & S. We were instructed to do this by the manufacturers, who stated thatfor a No. 12 B & S , it would have to be a special order and that the cost would be practically the same as for a No. 10 B & S. They also state

that No. 10 B & S is as small as is usually specified on cable of this kind. The only difference would be a slihgt saving in copper, which is of very slight consequence, and for mechanical reasons it is not practical to make up heavily lead covered cables of smaller wire than No. 10.

Hence, for these reasons and by means of the above table it is evident that No. 10 B & S is the most economical to use.

Rectifying System and Constant Current Transformer.

The magnetite arc requires a rectifying system, as the energy is taken from the A C bus bars. This rectifying apparatus costs considerable more than the constant current transformer required for the tungsten system. However, this extra cost of the magnetite system, as compared to the tungsten system, is somewhat offset due to the fact that in the case of the latter system the lamp renewals cost much more than the renewals of electrodes for the magnetite system. The characteristics of the constant current transformer for the tungsten system especially adapts it for controlling series incandescent circuits. The constant current transformer, besides acting as a controlling device, insulates the generating system from the incandescent circuits, thereby preventing a ground on the entire system is case of a ground on the series circuit.

Detailed Comparison of the Series Tungsten and Magnetite Arc Systems.

Mean Spherical Candle Power per Unit.

Tungsten.

For 100 watt lamp - - 62.6 m.s.c.p.

" 50 " " - - 31.3 m.s.c.p.

Magnetite. - - - - - - - - - - - -216.0 m.s.c.p.

Distribution of Light.

Tungsten.

.0105 foot candles at 150 feet.

Magnetite.

.0270 foot candles at 150 feet.

Consumption of Each Lamp.

Tungsten.

40 c.p.lamp - 50 watts.

80 c.p.lamp - 100 watts

Magnetite. 310 watts.

Watts per Candle Power.

Tungsten. - - - - - - - - 1.25

Magnetite. - - - - - - - .88

Cost per Unit Lamp on Top of Post.

Tungsten.

1 lamp standard -	1 80 c.p. lamp	$1.01
	1 globe	1.00
	1 series socket	.40
		$2.41
3 lamp standard -	1 80 c.p. lamp	$1.01
	2 40 c.p. lamp	1.68
	3 globes	3.00
	3 ser. sockets	1.20
		$6.89

Magnetite. Total outfit - - - - - - - - - $25.00

Total Cost of Lamps on Top of Post

Tungsten.

41 single lamp standards - - -	$98.81
4 three " " - - -	27.56
	$126.37

Magnetite. 45 single lamp standards - $1125.00

Total Cost of Posts.

Tungsten. 45 posts at $43.00 each - - $1935.00 see p 16

Magnetite. 45 " " " " - - $1935.00

Cost of Constant Current Transformer

for Tungsten System - - - - - - $250.00

Cost of Rectifying Apparatus for

Magnetite Arc System - - - - $950.00

Total Cost of Cable Laid. (same for both systems.)

9650 feet of No. 10 B & S 5000 volt

at 13 ¢ per foot - - -$1254.50

9650 feet of Trench at 6¢ per foot for digging

and installation of cable - - - - 579.00

9650 feet of 1/2 tile at 4¢ per foot - - 386.00

$2219.50

Total Cost of Installation of System.

Tungsten.

Lamps and fixtures - - - - - - -	-$126.37
Posts - - - - - - - - - - - - - -	1935.00
Constant Current Transformer - -	250.00
Cable Installation - - - - - - -	-2219.50
	$4530.87

Magnetite.

Lamps - - - - - - - - - - - - - -	-$1125.00
Posts - - - - - - - - - - - - - -	1935.00
Rectifying Apparatus - - - -	- 950.00
Cable Installation - - - - - - -	-2219.50
	$6229.50

Total Cost of Operation per Annum.

<u>Tungsten.</u>

4.9 K W x 1825 hrs. per year - 8942.5 K W H.

8942.5 K W H at 3 cts. - - - - $268.28

I^2R loss = 16 x 9.6 Ohms = 153.6 watts.

153.6 x 1825 = 281.05 K W H at 3¢ 8.43

Insurance, Maintenance and Repairs at 5%.

$226.55

Interest - - - - - - at 5% - - - - - 226.55

Depreciation, 10%, - - - - - - - - - 453.10

Total - - - - $1182.91

<u>Magnetite.</u>

13.95 K W x 1825 hrs. per yr. 25458.75 K W H

25458.75 K W H at 3 cts. - - - - - -$763.76

I^2R loss 16 x 9.6 Ohms = 153.6 watts.

153.6 x 1825 = 281.05 K W H at 3¢ 8.43

Insurance, Maintenance and Repairs at 5%

311.47

Interest at 5% - - - - - - - - - - - 311.47

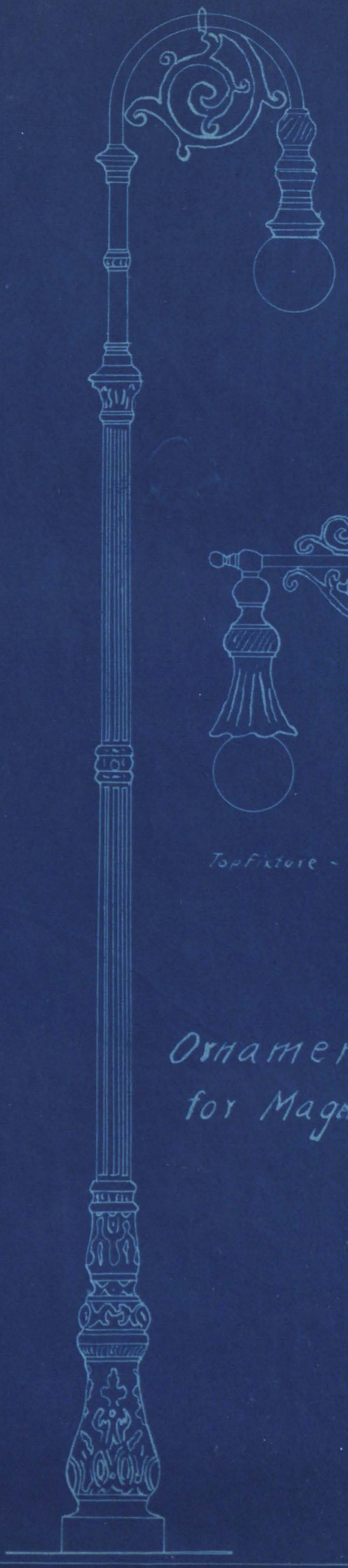
Depreciation at 10% - - - - - - - - 622.94

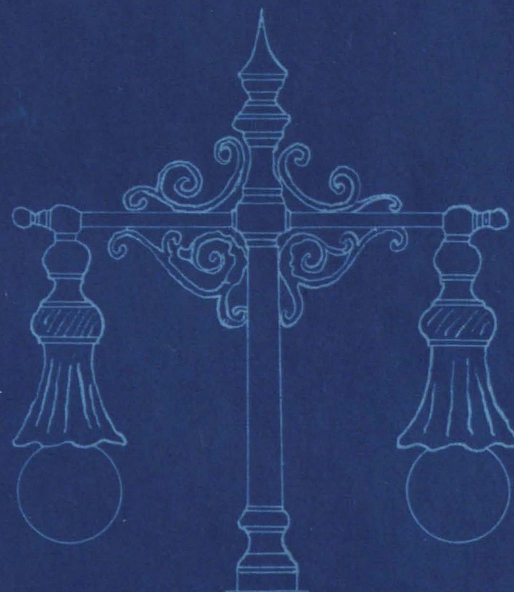
Total - - - - $2018.07

*** Conclusion.***

After considering the advantages and disadvantages of both these systems, and their comparative costs we might suggest that a combination of the two systems using the magnetite where intense illumination is required and the tungsten for outlying points or places where the foliage is thickest.

This would be an ideal system for our purpose.



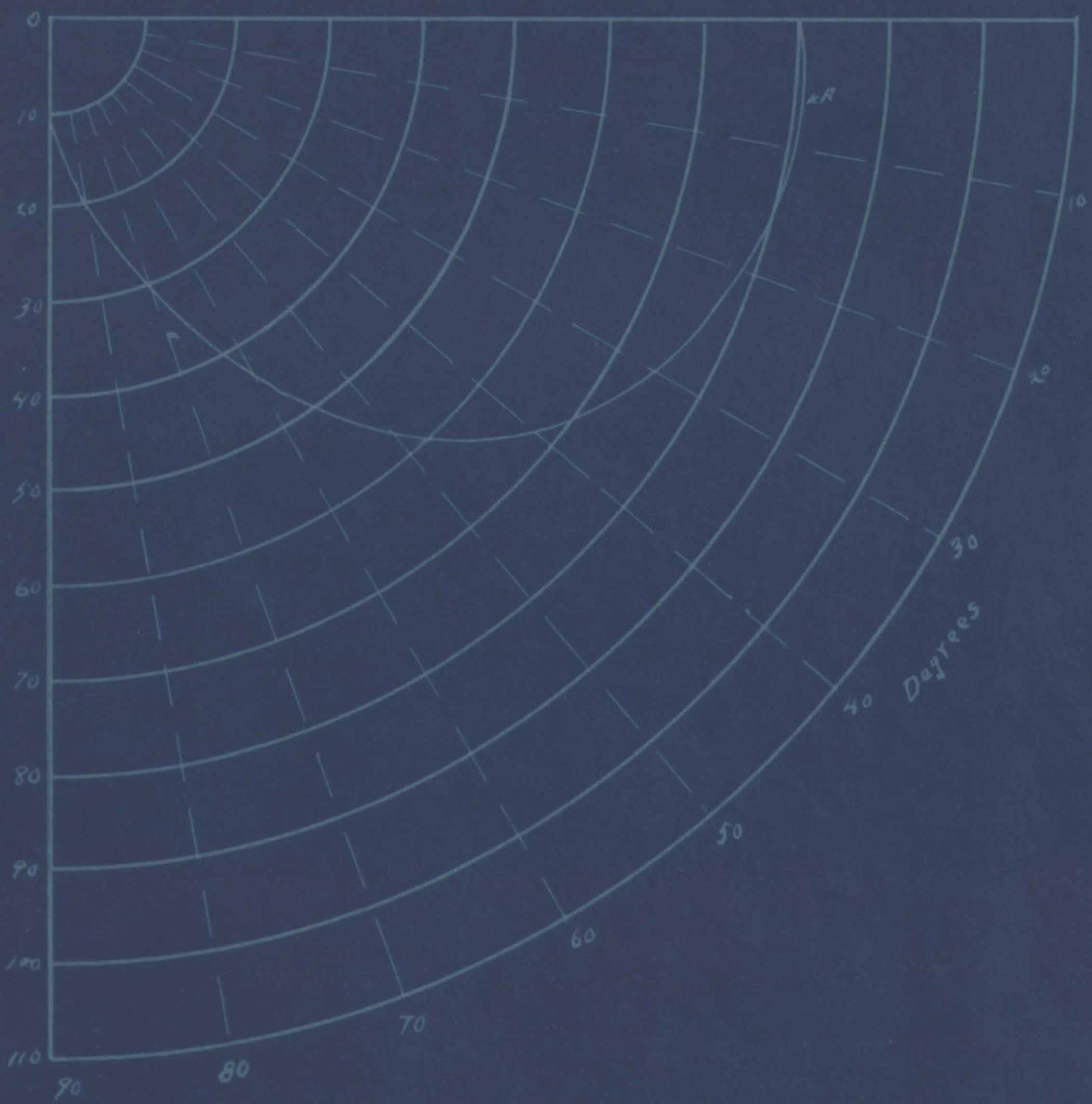


Top Fixture – Can be used with Magnetite
or Tungsten Lamps.

Ornamental Lamp Post for Magnetite Arc Lamp.

A.P.

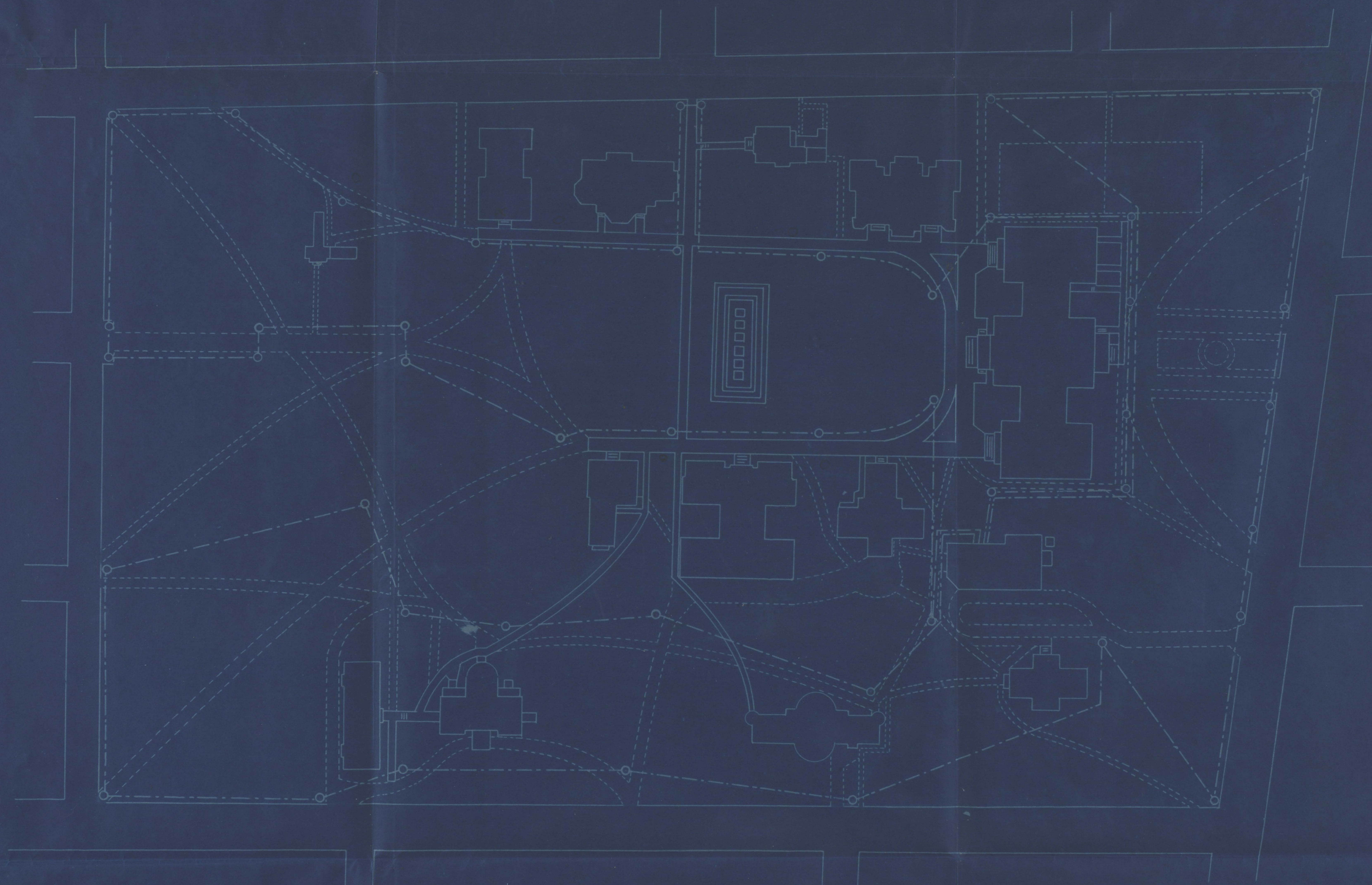
ILLUMINATION CURVES



A- 100 Watt Tungsten Series Lamp

ILLUMINATION CURVES

A - - 4 Amp D.C. Magnetite Arc Lamp



PROPOSED LIGHTING SCHEME OF
THE CAMPUS OF THE UNIVERSITY OF MISSOURI
COLUMBIA, MISSOURI.

○ Position Of Lamps
—·—·— Path Of Circuit

Scale 1" = 100 ft.