

# Dimming Hot Cathode Fluorescent Lamps

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IT HAS long been the desire on the part of lighting engineers to find a method for controlling the brightness of fluorescent lamps over a wide range. It is the purpose of this article to describe a system of brightness control which increases the many advantages of fluorescent lighting while retaining circuit simplicity and ease of installation.

## Filament Lamps

Methods for dimming filament lamps appeared soon after the lamp was introduced because a change in the applied voltage was the only fundamental requirement. Early methods included the water rheostat, iron wire rheostat and the step control using tapped resistors. Improvements in the smoothness and efficiency of the control were gradually made with the introduction of variable autotransformers and thyatron tubes. The amount of light emitted is directly related to the temperature of the filament so with voltage control the range of brightness can be considered infinite.

## Fluorescent Lamps

Due to the complex characteristics of electric discharge lamps, and associated auxiliary equipment, a relatively narrow range of brightness change is practical with line voltage control. Since the fluorescent lamp has a negative resistance characteristic, it requires a ballast in series to control the current. For stable operation the voltage drop across the conventional reactor ballast should be about equal to the lamp operating voltage. When line voltage control is used to dim the fluorescent lamp the voltage drop across the ballast decreases and lamp voltage increases with reduction in current. For this reason only a limited decrease in lamp current can be accomplished before the circuit becomes unstable and the lamp are extinguishes. This generally occurs at a point where lamp brightness is still 50 per cent of normal.

Even with this limited range of two to one it is doubtful whether the lamp will start at the low brightness point because starting voltage is reduced in direct ratio.

In applications where it is desirable to have some control of lamp brightness it is possible to operate one lamp on two ballasts of different current rating. For example, a slimline lamp could be operated at 120, 200 and 320 milliamperes by switching between single lamp 120 and 200 milliamp ballasts or by operating the two ballasts in parallel. Since fluorescent lamps become more efficient at low current levels, brightness changes are not in proportion to lamp current so this system produces steps of 100 per cent, 75 per cent and 50 per cent lamp lumens.

One brightness control method<sup>1</sup> which has been used to some extent in England makes use of individual matching transformers with primaries connected in series with the line and a common variable resistor. This is an arrangement whereby a fixed number of lamps can be operated from one control unit. Any addition or reduction in the number of lamps per circuit requires a change in the value of the control resistor or the line voltage.

A dimming system for fluorescent lamps,<sup>2</sup> employing thyatron tubes is now being used in Europe. The circuit is designed for a special lamp which contains an inside conducting stripe to aid in starting and re-ignition. The control unit uses a rectifier to supply grid voltage to each tube and a separate peaking transformer for phase shift. This system is capable of providing a brightness range of 100 to 1 or better.

Cold cathode fluorescent lamps can be successfully dimmed by operating a number of lamps in series on a high voltage, high reactance transformer. Dimming is accomplished by varying the voltage to the primary of the transformer. This arrangement does not produce as wide a range of brightness as can be produced with hot cathode lamps, because of the relatively low maximum cold cathode lamp current. The high voltage required to start lamps in series makes it necessary to provide special lampholders to insure safety during maintenance. It also has the disadvantage of poor

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starting at very low levels of current since voltage available to start the lamps is inadequate.

### Circuit and Lamp Requirements

When current supplied to hot cathode lamps is reduced, a point is reached where arc current is inadequate to keep the electrodes at a satisfactory electron emitting temperature. The emission for very low current is then supplemented by ion bombardment. This action strips the cathodes of active material and short lamp life results. In view of this, lamp electrodes must be heated continuously at a temperature which will produce sufficient electron emission at any point in the dimming range.

In order to provide smooth operation, the circuit should produce sufficient voltage to start the lamps quickly at minimum as well as maximum brightness. Sufficient voltage must also be available to re-ignite the arc each half cycle to avoid flickering.

### Theory of Operation — Electronic Dimming Control

Control of the lamp brightness is accomplished by adjusting the interval of current conduction during each half cycle of the 60-cycle voltage. Two thyratrons are connected back to back so that the pair of tubes will conduct current for both polarities of the a-c voltage. These tubes act together as a synchronous switch which closes the circuit at a predetermined point in the a-c voltage each half cycle and opens at the end of each half cycle. In this way voltage is applied to the lamp for any desired fraction of the cycle. Fig. 1a shows the voltage wave applied to the entire lamp load when the interval of conduction is set for 90° or half of each cycle.

The abrupt rise in voltage at the leading edge of applied voltage is used to insure re-ignition of the fluorescent lamp on each cycle. The ballast for each lamp contains a choke which is in series with the lamp to limit the lamp current. Across the lamp is a small capacitor which suppresses radio interference and resonates the sharp voltage rise at the leading edge of the applied voltage to a higher peak value to start and re-ignite the lamp on each cycle. The oscillogram in Fig. 1b illustrates this voltage condition.

The point in the cycle at which the thyatron tube begins conducting is controlled by the grid voltage. A sine wave, variable in phase relationship to the line voltage is applied to the grid of the tube and the tube will fire or conduct when its plate is positive with respect to the cathode and its

grid voltage is essentially zero. Referring to the circuit diagram of Fig. 2, each grid derives its voltage from two coils in series, one on  $T_1$ , which is constant in voltage and phase, and one on  $T_2$  which is variable in voltage and phase. The sum of these two voltages results in a sine voltage of constant amplitude but variable in phase relationship. In this way the point in the cycle at which the grid is zero volts with respect to the cathode can be controlled.

Fig. 3 represents a vector diagram of the grid circuit. Vector  $AC$  represents the phase of applied line voltage and plate voltage. Vector  $AO$  represents the voltage of one of the secondaries of  $T_1$  and is constant in magnitude and phase. Vector  $BC$  represents the drop across the total resistance in series with the primary of  $T_2$ . Vector  $AB$  is the voltage drop across the primary of  $T_2$  and is variable in magnitude and phase. As the resistance varies, vector  $AB$  varies along the semi-circle  $ABC$ . Vector  $AF$  is the voltage induced in one of the secondaries of  $T_2$ . The turns ratio of the transformer  $T_2$  is such that the maximum magnitude of  $AF$  is twice the magnitude of vector  $AO$ . The voltage applied to the grid of the tube relative to the cathode is the vector sum of  $AO$  and  $AF$ . The dashed lines show the addition resulting in the vector  $AD$ . The voltage  $AD$  is constant in magnitude but lags the plate voltage (vector  $AC$ ) by an angle which varies from 0° to 180° along the semi-circle  $ODE$ .

The control elements of the circuit are resistors  $R_5$  and  $R_6$  one of which can be adjusted so the lamps will not be taken below the minimum brightness and the other selects the brightness at any point in the range. Rotating the control changes the resistance in series with the primary of  $T_2$ . Since both tubes are controlled by the secondaries of  $T_2$  this single control regulates both tubes.

A small capacitor ( $C_1$  and  $C_2$ ) is connected between grid and cathode of each thyatron tube to suppress line surges. Without suppression these surges can cause the tubes to fire prematurely in the cycle giving a flash of light. The resistors  $R_1$  and  $R_2$  are used to limit the grid current to a small value while the grids are positive.  $R_3$  tends to stabilize the lamp operation at very low levels by draining off any residual charge from the yellow line after each pulse of current.

The angle at which the tubes start conduction is a function of the ratio of the sum of  $R_4$ ,  $R_5$ ,  $R_6$  and the primary resistance of  $T_2$  divided by the inductive impedance of the primary of  $T_2$ .

Fig. 4a shows the entire cycle of current wave-shape for five ratios of  $R/X_L$  (.850, 1.08, 1.32, 1.65

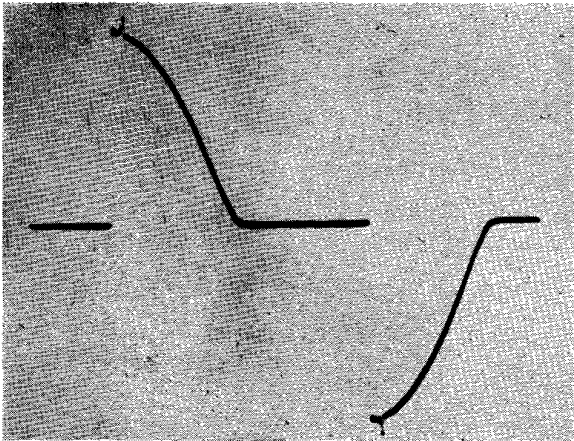


Figure 1a. Operating voltage applied to the lamp circuit for the 90° conduction point.

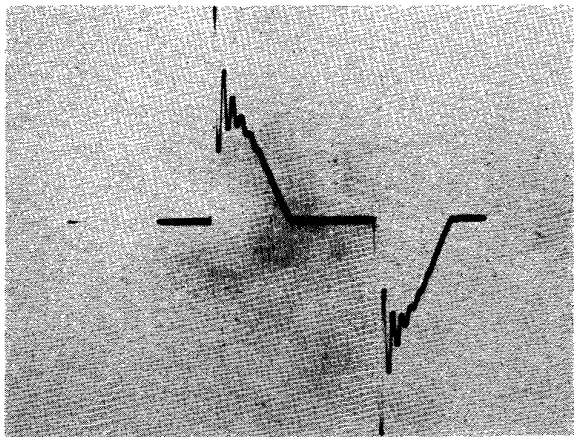


Figure 1b. Open circuit voltage applied to the lamp for the same point as Figure 1a. The high peak voltage is a result of the steep rise on the voltage of Figure 1a, applied to the L-C combination in the ballast. This peak insures starting and re-ignition on each cycle

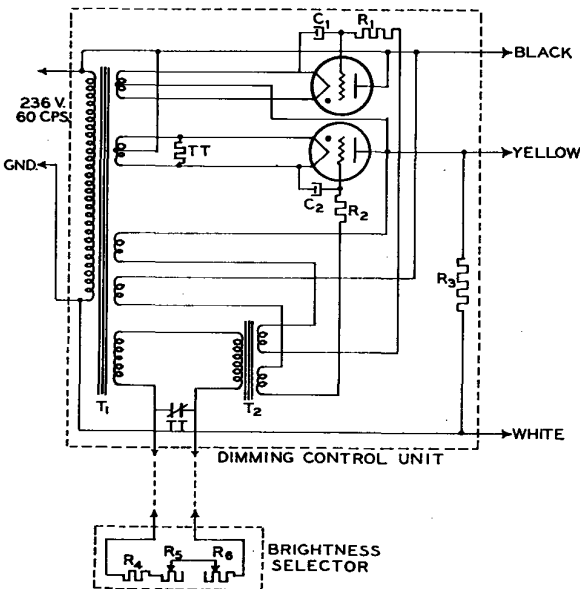


Figure 2. Circuit diagram of the dimming control.

and 1.93). These points correspond to the 20 per cent, 40 per cent, 60 per cent, 80 per cent and 100 per cent light output points. Fig. 4b shows the light output waveshapes for the corresponding ratios of Fig. 4a. The bottom line of this figure is the zero light reference level. Figs. 5a, 5b, and 5c show the relation of R.M.S. lamp current, average light output and conduction angle versus this ratio of  $R/X_L$ .

Lamp<sup>3</sup> flicker at full light output corresponds to single lamp operation with conventional ballasts. The percentage flicker as measured by photo-cell instruments increases as the lamps are dimmed. However, lamp flicker becomes less apparent to the eye as brightness decreases with the result being essentially the same at low brightness on the dimming circuit as conventional operation at full brightness.

### The Distribution System

Referring to Fig. 6 only three wires are required to bring power from the control unit to the lamp load. A nominal 236-volt single phase line supplies power to the control. One common and one control line are needed to supply voltage for lamp arc current. The third wire by-passes the control to provide the cathode preheat transformers in the ballast with line voltage thus maintaining constant cathode temperature over the dimming range.

### The Lamp Ballast

The lamp ballast consists of a series reactor for arc current control and two isolated cathode windings of sufficient voltage to keep electrodes at electron emitting temperature. The lamp load has a power factor of approximately 50 per cent lagging. Correction to over 90 per cent can be made by placing capacitors across the line on the input side

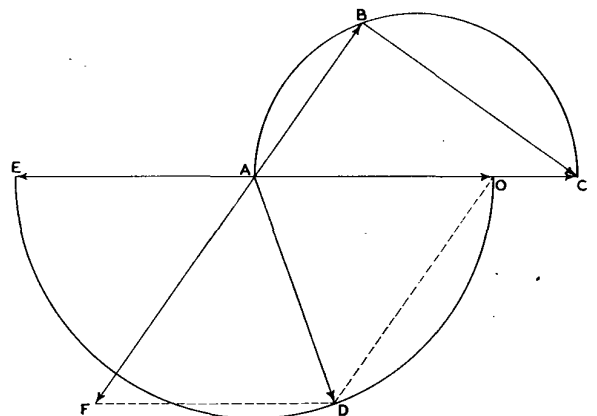


Figure 3. Vector diagram — grid circuit voltages.

of the control. Approximately 4 mfd. per lamp will be required.

### Characteristics of the Dimming System

In order to obtain the maximum range of light output, cathodes must be continuously heated. The instant start lamps such as the slimline group cannot be provided with cathode heat and, therefore, the system was designed for 40-watt preheat lamps only. Early ballasts were designed for either the starter type or Rapid Start lamps when the latter type was not available in colors. Due to the advantages of the Rapid Start lamp which is now listed in colors, it is anticipated that the ballast will be designed exclusively for the Rapid Start lamp.

### Requirements for Starting

It will be noted in the description of Fig. 1b that a peak voltage is supplied to aid in starting the lamps. Since the effectiveness of the peak voltage in starting the fluorescent lamp depends on the capacity coupling from lamp to ground, there should be a grounded metal plate near the lamps; for most applications, fixture bodies or wiring channels will suffice. If open wiring on a wood panel is used there should be a one-inch metal strip running the entire length of the lamp and placed approximately  $\frac{3}{8}$  inch behind the lamp. The strip should then be connected to the grounded line wire through a  $\frac{1}{2}$ -megohm resistor. Under normal conditions the lamps should start quickly and reliably at any point in the dimming range.

### Brightness Range

The system provides for relative brightness varying at least 100 to 1. Under optimum conditions of line voltage and ambient temperature, and with well seasoned lamps, the brightness range can be increased to 250 to 1. New lamps may not start immediately at the low brightness level and it is recommended that these lamps be seasoned at normal brightness for a short time in order to provide the maximum dimming range for all lamps.

### Color and Efficiency

Fluorescent lamps on dimming circuits offer several advantages over filament lamps: higher efficiency over the dimming range, lower operating costs, and better color control. Filament lamps become increasingly red as they are dimmed; fluorescent lamps change very little in color over their entire brightness range. A comparison of efficiencies of fluorescent and filament lamps appears in

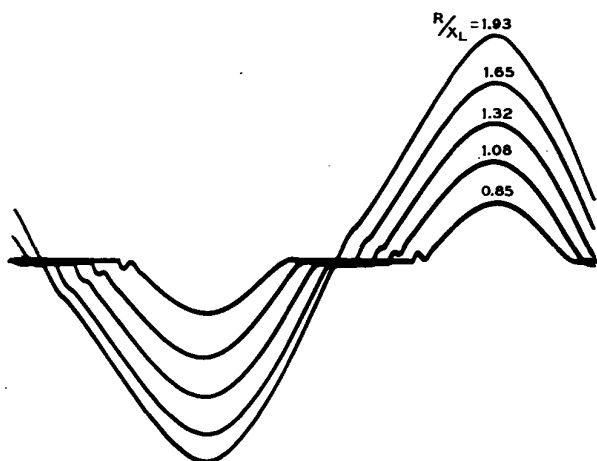


Figure 4a. Current waveshape corresponding to 20%, 40%, 60%, 80% and 100% brightness.

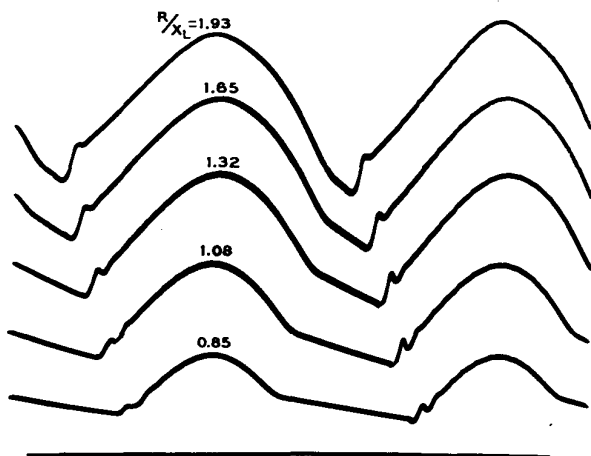


Figure 4b. Light output waveshapes corresponding to the points of Figure 5. The bottom line is the zero light reference line.

Table I; figures are for color of approximately equal chromaticity, with lamps at their normal brightness.

Fig. 7 shows a comparison of the approximate efficiencies of warm white fluorescent and 200-watt filament lamps for a wide range of dimming. No consideration is given to the change in color of the filament lamp as it is dimmed.

Fig. 7 does not include the losses of the ballasts or control equipment for fluorescent lamps. The total loss will vary depending on the number of lamps in the load. However, with 35 lamps on the control unit there will be a nearly constant loss of 4 watts per lamp over the dimming range. The individual ballast will have approximately 8 watts loss at the highest brightness and 2 watts at the lowest brightness. Losses of the control equipment for filament lamp dimming will vary consid-

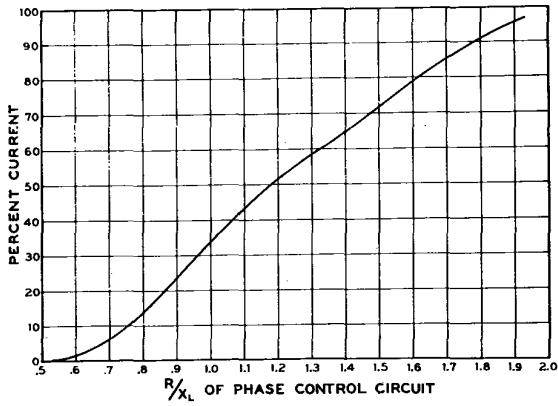


Figure 5a. RMS current versus  $R/X_L$  ratio.

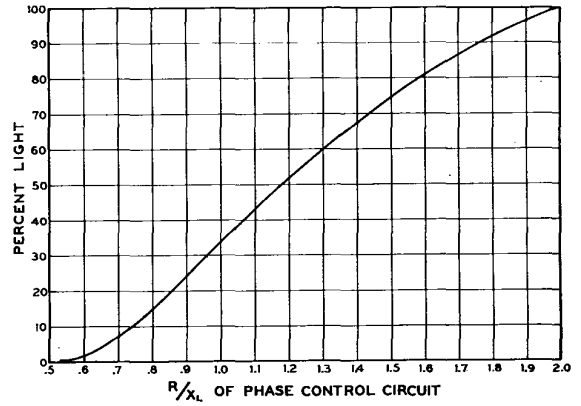


Figure 5b. Light output versus  $R/X_L$  ratio.

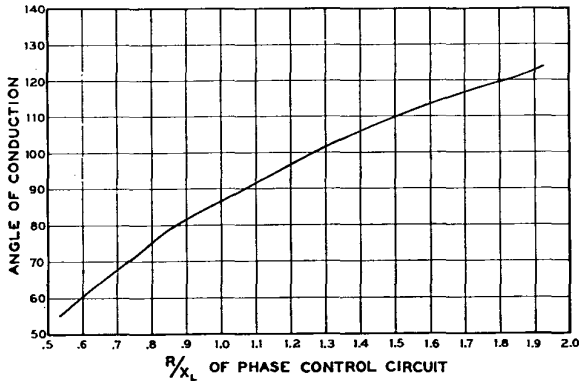


Figure 5c. Conduction angle versus  $R/X_L$  ratio. This angle divided by  $180^\circ$  gives the fraction of the half cycle that voltage is applied to the lamp load.

erably with the type of equipment and the total load.

### Dimming Control and Ballast Design

The General Electric fluorescent lamp dimming control has three parts each of which may be located remote from the other two. The ballast and 40-watt lamp make up one part, the dimming control unit is the second part and the intensity control is the third part.

The ballast, which would be conventionally located in the lamp fixture, has two functions: to limit the lamp current in the usual way and to supply low potential power to heat the lamp cathodes continuously. Only three leads must be brought to the entire group of ballasts from the dimming control unit. The ballasts are connected in parallel, the maximum number depending on the rating of the dimming control unit.

Two models of the dimming control unit are available. One will control 35 (or less) 40-watt fluorescent lamps, and the other will control 8 (or less) 40-watt lamps. Both models operate from 236-volt 60-cycle supply lines. The heart of each unit

TABLE I.

Color	Lumens per Watt 40-Watt Fluorescent	Lumens per Watt 200-Watt Filament (Typical Filters)	Efficiency Ratio Fluor./Filament
White .....	64	18	3.5
Gold .....	33	15	2.2
Pink .....	26	8	3.3
Red .....	4	3	1.3
Medium Green .....	77	3	26.0
Medium Blue .....	27	1.5	18.0
Daylight .....	49	9	5.4

is a pair of industrial thyratron tubes. The principal difference between the two models is the size of these tubes which determines the maximum number of lamps each unit will control. To protect the thyratron tubes in the control unit during initial operation, a time delay device "warms up" the tubes. (T. T. Fig. 2.) Both models are the same size in physical dimensions and may be racked side by side, or panel mounted side by side. Each model has a completely enclosed terminal box built in and provided with standard knock-outs for leads.

The intensity control is essentially a variable resistance. Its purpose is to set the time at which the thyratrons "fire" and pass current to the fluorescent lamps. The variable resistance is rather low in value (less than 1,000 ohms), hence the remote control lines are not likely to pick up stray signals to affect the brightness level of the fluorescent lamps. The intensity control operates at 25 volts or less, and is electrically isolated from the 236-volt supply lines. The intensity control may be used with either model of the dimming control unit. Several units may be controlled by one intensity control, but the variable resistor must be proportionately larger in wattage rating. More elaborate brightness controls using motor driven variable resistances may be devised to suit the needs of special applications.

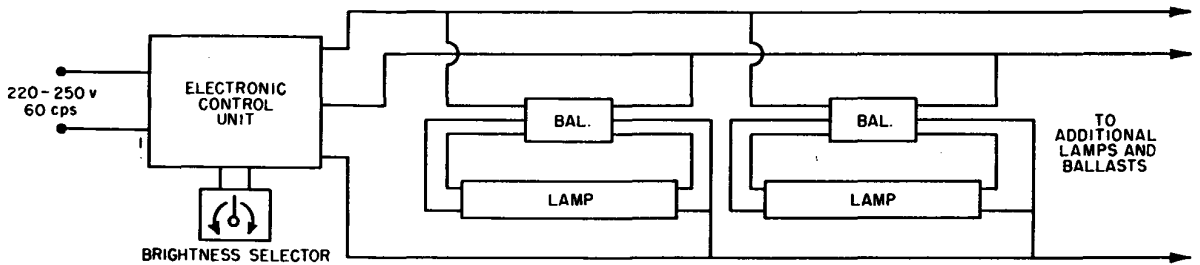


Figure 6. Block diagram of dimming system for fluorescent lamps. The control unit may be placed anywhere and two wires run to the Brightness Selector and only three wires to the lamp load.

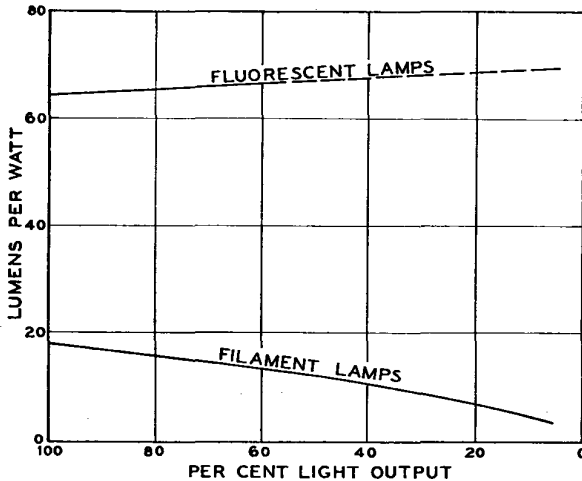


Figure 2. Comparison of lamp efficiency for the fluorescent and incandescent lamps over the dimming range for white light.

### Applications

There are many applications for brightness control of fluorescent lamps. The greatest demand for this added flexibility of fluorescent lighting has come from the theatre and stage lighting field. However, many others can now make use of the advantages of fluorescent lamps with controlled light output. Television studios, auditoriums, restaurants, night clubs, hotels, display areas, show windows and experimental laboratories are included in the list of lighting fields for which this system is expected to serve a useful purpose.

### References

1. Strange, J. W.: "Dimming of Fluorescent Lamps," *British Kinematography*, p. 183 (June 1952).
2. Hess, K. W., and deJong, F. H.: "Controlling the Luminous Intensity of Fluorescent Lamps with the Aid of Relay Values," *Philips International Review*, Vol. 12, No. 3, p. 83 (September 1950).
4. Eastman, A. A., and Campbell, J. H.: "Stroboscopic and Flicker Effects from Fluorescent Lamps," *ILLUMINATING ENGINEERING*, Vol. XLVII, No. 1 (January 1952).

### DISCUSSION

W. P. CARPENTER\*: This paper was informative and new to me. Certainly the combination described fulfills a requirement for control of hot cathode fluorescent lamps.

I would like to ask the following questions:

1. Early in the paper there is mentioned "relatively low cold cathode lamp current." What is meant by this?
2. A time delay is incorporated, presumably for thyatron protection. What is its warm-up time from cold start? What is its recycling time when hot?
3. Are the ballasts the same as used for any other non-dimming fluorescent applications?
4. Does the thyatron dimmer have Underwriters' approval?
5. It was mentioned that the brightness ratio is approximately 100 to 1, and in some cases 250 to 1 with seasoned lamps. Please describe what this ratio means with reference to eye sensitivity with respect to blackout. Does a brightness ratio of 100:1 on the 40-watt fluorescent lamp take the lamp down to apparent blackout?

HERBERT S. GLICK\*\*: In addition to applications mentioned by the authors, I think that there might be some applications in controlling lighting in darkrooms in the photographic manufacturing industry. I would like to add the following:

Lighting working areas for the manufacture of sensitized photographic material is a highly specialized task for several reasons:

1. The lighting level is extremely subdued.
2. Fixtures are specially designed to be light-tight and to hold filters and to meet other special requirements.
3. Lamp replacements must be made in extreme subdued light with a maximum of safety to film and personnel.

At Kodak Park, which is the largest photographic sensitized materials manufacturing plant of Eastman Kodak Company, our present practices and methods have been established over a period of many years and are based on the use of tungsten filament lamps. For darkroom lighting we are more interested in long lamp life than in high lumen output. Because fluorescent lamp life is now so much longer than filament lamp life we are now investigating the possibility of using fluorescent lamps in our darkrooms.

Although dimming is by no means one of our major requirements, we do have numerous applications where a

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simple and safe dimming control would open the way for us to replace tungsten filament with fluorescent lamps.

J. W. STRANGE\*: The reference to the English use of a cascade dimming circuit in dimming fluorescent lamps gives a rather false impression of the early application in England. The first application was some years earlier in 1949 and the original intention was to meet stage requirements for a range of at least 400 to 1 in brightness and instantaneous striking at any point of this range. This was easily met by the combination of continuous cathode heating, adjacent earth and separate impedance control. Although the cost was about 25 per cent up on equivalent incandescent systems, it offered great advantages, in efficiency particularly, and found immediate application to cyclorama lighting and other theatre uses.

There are a number of variants of this early circuit, of which the cascade circuit is one, which found application where other limitations such as length of wiring are more important than range of dimming. Thyatron control is an example of one circuit which has commercial application only to relatively large installations where the range of dimming is not so critical. The cost of the control gear makes it prohibitive for smaller numbers than about 8 or 10 lamps.

There are a number of points in the paper which are not quite clear. No indication is given of the size and rating of the control resistance but one estimate would indicate that it would have to carry a fairly heavy current. It also appears that the circuit is limited to supplies in the region of 236v. The authors, in preparing Table I have fallen into the common error of not including ballast losses of the fluorescent lamps, and have also taken initial and not average values. This gives an over-optimistic picture.

When dimming circuits are used for such purposes there is a marked relative improvement of the fluorescent lamp compared with the incandescent lamp when this is "on check." This may be as much as 2/300 per cent. This does not necessarily apply to the present circuits which are more suitable for auditorium lighting where the lamps are either full up or out.

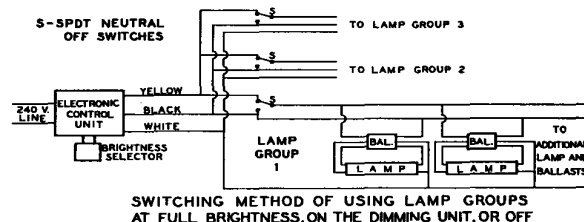
One of the major disadvantages of thyatron circuits is that leading circuit ballasts cannot be used and even with separate power factor correction a factor of only 90 per cent can be achieved. In our experience, mercury vapour valves are unsatisfactory due to the long warm-up period, and their sensitivity to temperature; for this reason we prefer the gas-filled type.

J. H. CAMPBELL, H. E. SCHULTZ and W. H. ABBOTT\*\*: The authors wish to thank Mr. Carpenter for his comments and the questions he raised regarding the fluorescent dimming system. It is hoped the following comments may provide the answers.

1. The relatively low current referred to in connection with cold cathode lamps applies to a lamp design limitation. Because of the nature of the electrodes in cold cathode lamps the lamp current is limited to a maximum of about 200 milliamps, the most common rating being 120 milliamps. Hot cathode lamps of the 40-watt rapid-start design used in the dimming circuit have a maximum rating of 425 milliamps.

2. The time delay relay period is 20 seconds for the 8-lamp dimmer model and 60 seconds for the 35-lamp dimmer model. After the main power switch has been opened, 20

minutes must elapse before reclosure, to allow cooling to recover the above time delays. However, it is not necessary or desirable to turn the dimmer off when complete blackout is needed. This can be accomplished by means of a switch in the control line, thus allowing the thyatron tubes in the dimmer to remain heated so the brightness selector can be operated without delay. If it is desired to turn the lamps on at full brightness without waiting for the dimmer control relay, the thyatron output can be short circuited by means of a simple switch. The illustration shows how both conditions can be satisfied by means of a single pole double throw switch with a neutral position.



Groups of lamps operating on the same dimming control may be switched independently to any one of the three positions without affecting the control or other groups of lamps.

3. No. A ballast for the 40-watt rapid-start lamp, designed to match the characteristics of the dimming control is needed.

4. The dimmers have been submitted for Underwriters Laboratory consideration. Only preliminary examination has been made at this date.

5. We could not say that 1 per cent of maximum brightness represents blackout. However, in cases where complete blackout is needed, the brightness selector when turned to the minimum position can be arranged to operate a switch to turn the lamp load off. Most dimming cycles are short enough in time so the eye cannot become dark adapted sufficiently to detect a marked change from 1 per cent brightness to zero.

The authors wish to thank Mr. Glick for presenting his idea on the use of the dimming circuit for the photographic manufacturing industry. This appears to be another application where fluorescent lamps are preferred to filament lamps when methods are available to control brightness of both sources.

This transfer of information helps the application engineer to understand the problems involved in special lighting installations and to adapt new equipment to meet the requirements.

The authors wish to thank Dr. Strange for his discussion, and hasten to assure him that our reference to one method of dimming employed in England was intended to give credit for development work accomplished there on a somewhat different approach to the problem. Space allotted to this paper did not allow for a complete review of the many circuit combinations developed here and abroad for dimming fluorescent lamps.

The current carried by the control resistance is comparatively light, since it is only 125 milliamperes at maximum and 31 milliamperes at minimum. The brightness control is a 500-ohm potentiometer rated at only 5 watts. The small size of this unit together with the low voltage applied to the grid phasing circuit of the thyatron tubes (24 volts), makes it convenient for location anywhere in the lighted area.

Dimmers were designed for 236-volt operation in order to

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\*\*Authors.

operate the maximum number of lamps on a pair of thyatron tubes. Where 236-volt circuits are not available, a single autotransformer can be used to step-up the voltage from either 208 or 120 volts.

With regard to the omission of ballast losses Table I, it is the custom here to show efficiencies of fluorescent lamps and losses of ballasts separately because overall efficiency will vary depending on the make and type of ballast employed. Approximate ballast losses are discussed in a subsequent paragraph. Initial lumens for both filament and fluorescent lamps are the same as the published values. In the case of fluorescent lamps, published lumens are 100-hour figures. An average figure would be difficult to assign since depreciation with life will vary considerably depend-

ing on the number of starts the lamp receives. A filament lamp also depreciates during life on a curve similar to that of a fluorescent lamp. The ratios of Table I are conservative for lamps operating below normal brightness due to the decrease in efficiency of the filament lamp while fluorescent lamps increase in efficiency as brightness is reduced. (See Fig. 7.)

The primary circuit power factor can be corrected to 90 per cent lagging at full output. Power factor at minimum output will be leading.

Thyatron tubes of the type used in this device are gas filled for the 35-lamp dimmer and mercury vapor for the 8-lamp dimmer. In each case the warm-up time is approximately one minute.

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## Street Lighting Photocell Control Calibration Cabinet

Discussion of paper by W. N. Lindblad and L. C. Edwards

(Published October 1953 issue of ILLUMINATING ENGINEERING, p. 509)

R. J. PALMER\*: This paper is very timely, at least so far as the Detroit Edison is concerned. We have recently given some thought to improving our own method of photoelectric control calibration and so any ideas such as those contained in this account are welcomed for consideration.

There are approximately 600 photoelectric control units on the company lines in street lighting service. This does not include the photoelectric controls which are integral with luminaires and control approximately 400 individual lamps.

At present there are but two test sets in operation on the system. Our Meter Department has one, and that group is charged with the responsibility for acceptance testing of all controls as received from vendors. The other test set is in the company Radio Laboratory and that group has the responsibility for routine testing and maintenance of electronic type controls. Footcandle measurements are made to determine the illumination level of both turn off and turn on. This is to check against trouble reports that come in from the field. Quite often photocell controls are blamed when other equipment is at fault.

Both of the test sets are equipped with constant-voltage transformers and footcandle meters having "Viscor" filters. Beyond this, different principles of operations are employed.

That which is in the Meter Department has a 50-watt projection type lamp enclosed in a lamp house. The light is directed through an aperture to a relatively large diffuser and from there to the photo control location. The projection lamp is used because its higher lumens per watt provide a better color temperature than does the standard incandescent lamp. The light intensity is controlled by varying the aperture with an iris diaphragm. This results in no change of color temperature. The other test set uses a standard 100-watt incandescent lamp, and the intensity is controlled by varying the lamp voltage. This does vary the color temperature.

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\*Detroit Edison Co., Detroit, Mich.

The experience gained from these two units has shown that it is not especially desirable to vary color temperatures during the test of photo sensitive devices particularly when making acceptance tests. Also, the procedure does not lend itself to satisfactory testing of mixed groups of photo sensitive controls incorporating both blue and red sensitive tubes. We have found that to obtain uniformity of control action it is necessary to establish what might be termed "equivalent" footcandle intensities of incandescent light energy. These are the incandescent light intensities which will have the same energizing influence on the photo tube as does an arbitrarily established daylight intensity. The variations because of color temperature differences between daylight and artificial light are as much as 25 per cent as read on the footcandle meter, if only the blue sensitive tube is considered. If the red sensitive tube is added, the variation becomes as much as 75 per cent.

It is with the foregoing in mind that we question the use of resistors in series with the calibrating lamp as a means of varying light intensities. Also, when it comes to acceptance testing, we believe that the values of 1.3, 1.5, 1.7 footcandles are too limited.

The instructions for use of the calibrating box raise three other questions.

1. Is anything of value gained by having a thirty-minute preheat period for the control devices over, say a three- to five-minute warm up period? The half hour time implies the need for a moderately elaborate pre-heat rack to accommodate the various designs of control units, or else much testing time is lost because of preheating in the calibration cabinet.

2. The use of an auxiliary bright lamp to provide 150 footcandles, and then suddenly by switching, dropping the intensity to 1.5 plus or minus .2 footcandle does not simulate the rate of decrease in daylight intensities. Because of the delay and feed back characteristics of controls, it seems that more reliable results might be had if the auxiliary