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The basic principles of the most commonly used lamp types and the circuitry which makes them operate are discussed. The two objectives of this book are to serve as a--(1) guide to economical lighting, and (2) a permanent reference source for troubleshooting. Areas dealt with include--(1) lighting fundamentals, (2) incandescent lamps, (3) incandescent lamp characteristics, (4) fluorescent lamps, (5) fluorescent lamp circuits, (6) fluorescent lamp starters, (7) fluorescent lamp characteristics, (8) mercury lamps, (9) troubleshooting, and (10) cleaning and cleaning methods. (RK)

# Primer of

# SCHOOL LIGHTING

# LAMPS AND MAINTENANCE

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Thanks also are due to Messrs. Samuel and Morris Feldman of Aetna Lighting Service Inc., Allston (Boston), Massachusetts; Mr. Herbert Mendelsohn, Sun Ray Fluorescent Maintenance, Kansas City, Missouri; and Mr. Leon Mendelsohn, Steel City Fluorescent Maintenance, Inc., Chicago. They supplied helpful information for this booklet.

Information on lighting maintenance contractors in a particular community can be obtained from NALMCO (National Association of Lighting Maintenance Contractors), 2120 Keith Building, Cleveland, Ohio.

# Contents

A good lighting system will stay that way only if a good lighting maintenance program is put into effect.

## To the Administrator

Many school systems waste substantial sums of money every year through failure to get all the light they are paying for. Their investment in lighting equipment and electricity to operate it is primarily for the purpose of providing illumination on areas such as desks, chalkboards, and tackboards. Whenever this illumination decreases substantially, money is wasted. The reduction in light output can be as high as 30 to 50 per cent, due to dust and dirt on bulbs, fluorescent tubes and fixtures. Because of the even distribution of the dirt over the fixture, it can go unnoticed.

Of course most school systems wash their lighting equipment each summer, but if this is not done thoroughly, they may start the new season under a handicap. In fact, in some locations it may be desirable to clean the equipment more than once a year.

In addition to the light losses from dust and dirt, there is a loss when over-age bulbs and tubes are not replaced. Some lamps last much longer than their designed life, but do not deliver enough light to justify their continued use. An incandescent bulb with considerable blackening, or a fluorescent tube with very black ends, should be thrown away because it is inefficient and has outlived its usefulness.

The decline in illumination, for whatever reason, is an insidious thing. If a heating unit develops trouble and will only keep the room at 60° F. instead of 70° F., there is no doubt about the need for immediate action. But the illumination in a room can fall off little-by-little without being noticed. Nevertheless, it may take much more effort for the pupils to see quickly and easily.

The Office of Education of the U.S. Department of Health, Education and Welfare says in its booklet "Organizing the Maintenance Program":

"The problem of school plant maintenance begins on the day the school board accepts a building from the contractor and continues throughout the entire life of the building. Experience indicates that in far too many instances school officials fail to recognize this fact. They seem to assume that a new building requires little or no maintenance until it has been in use for several years. It is a mistake, sometimes a costly mistake, for school officials to permit maintenance needs to accumulate before they attempt to develop a planned maintenance program. An adequate school plant maintenance service is vitally important to the pupils, to the educational program, and to the community, because the well-kept school building not only serves as a shelter and a school home for the pupils, but also as a tool of education and, frequently, the center of community life. It is essential that school plants be so operated and maintained that they provide optimum service. Adequately planned, well-built school buildings may be so operated and maintained that they fail to provide this service. On the other hand, average or sometimes mediocre buildings may provide satisfactory service if they are properly operated and maintained."

* * *

"School plant people frequently complain that maintenance is a stepchild of the school district when funds are being allocated for various school services. This complaint is not always without foundation, because school boards are often able to cut appropriations for maintenance without invoking major criticisms such as would be forthcoming if cuts were made in appropriations for other essential school services."

* * *

"In order to stimulate public interest in, and develop a deep concern for, the significance of school plant maintenance it seems appropriate to suggest that school officials might perform an essential service by publicizing the advantages inherent in a long-range, well-planned, adequately financed maintenance program of the school district."

• • •

"Electrical services often become expensive because of wasted current. Inefficient fixtures cause current waste; old, inefficient electric motors consume more current and deliver less power than new motors. Color of ceilings affects illumination levels. If the ceilings do not have the proper reflectance factor, or if they are dirty, they decrease the efficiency of electric lights. In addition, electric lights often replace natural illumination because outside windows are not clean. The atmospheric soiling of glass over a month's period will impede the transmission of light by as much as 25 per cent. This applies not only to window glass but also to glass fixtures used in connection with electric lights. An adequate maintenance program will provide for the replacement of inefficient fixtures and motors, correct ceiling conditions, and keep windows and light fixtures clean, thus eliminating much waste in the use of electric current."

No question about it, the nature of the problem requires that a specific program be followed if the greatest value is to be received for the money spent. It is the purpose of this booklet to suggest some types of maintenance program and then go into some detail about cleaning, relamping, and "trouble shooting." Just enough detail on lamp characteristics and circuitry is included to give custodians and maintenance men an understanding of lamps and their operation.

## Developing the Maintenance Program

While school systems differ widely on their overall maintenance requirements and their maintenance organization, every successful maintenance program must be properly planned and supervised and carried out by trained personnel.

In systems where one crew handles plant operation and another handles maintenance tasks, there is no agreement among school administrators as to which specific duties should be assigned to each crew. Overall efficiency, labor costs, employee morale, size of school system and school board policy must all be taken into consideration. The organization of the work program varies too.

In some systems, one staff assistant may be responsible for both plant operation and maintenance — or separate crew supervisors may be preferable. In other systems, the same versatile crew may perform both operations, with major maintenance jobs handled by outside companies. This of course makes possible a relatively smaller permanent crew.

In any case, the hiring of trained, experienced men is essential if the program is to be carried out properly. If these are not obtainable, good workers should be selected who are willing to serve an apprenticeship to get adequate training on the job.

The volume of work that must be performed will depend on the size of the system — the quality of the original equipment, and its age — the intensity of use by school and non-school groups — and the effectiveness of supervision.

There are three basic types of planned lighting maintenance programs used in school systems. In one type, cleaning, relamping and simple trouble shooting are done by the custodians. Electrical troubles involving ballasts, sockets, or circuits are referred to an electrician who may be either inside or outside the school system.

The second type uses specialized maintenance men employed by the schools who work in teams, going from one school to another in the system. Sometimes a school department electrician also is available.

A few systems use a combination of the first two methods. In the summer, custodians leave their individual schools and become members of teams that travel fro: ‹ school to another. In this case, their maintenance work is nut limited to washing lighting fixtures, but includes floors, windows, furniture and other items.

The third basic type of program is to contract the maintenance of the lightning equipment to an outside lighting maintenance contractor. This is not often done in public schools at present, but the practice is growing. A school system which adopts the practice of doing the work with its own specialized crews is in a position to determine if it would save money by using an outside organization. Information on such organizations can be obtained from the National Association of Lighting Maintenance Contractors, 2120 Keith Building, Cleveland, Ohio.

The influence of voltage on the life and light output of lamps — particularly incandescent — will be discussed later in this book.

However, administrative policy should be involved when lamp life is unduly short or long. (As will be seen, unduly long life means less light per dollar.) Because improper voltage greatly affects life, perhaps the voltage supplied to a school should be changed, overloaded circuits corrected, or lamps of a different voltage rating purchased.

Administrative policy concerning planned maintenance should embrace much more than merely cleaning lamps and fixtures in the summer, if proper results are to be obtained. The administrator will need to lay out work schedules, set relamping policies and prescribe washing methods. Check lists are useful tools in such a program. Table I is an example of such a check list. In addition to such a check list an inventory which would give lamp types and sizes and more detailed descriptions of the fixtures should be kept by the Maintenance Supervisor for ready reference.

## TABLE I
## LIGHTING MAINTENANCE CHECK LIST

Name of School________________________________

| Area | FLUORESCENT FIXTURES | | Incan-descent Fixtures | Mercury Fixtures | CLEANING | |
|---|---|---|---|---|---|---|
| | Metal Shielding | Plastic Shielding | | | Wiped | Washed |
| Classroom No. 1 | x | | | | 12-64 | 7-65 |
| No. 2 | x | | | | 12-64 | 7-65 |
| (etc.) | | | | | | |
| Homemaking | | | x | | 11-64 | 7-65 |
| Art | | x | x | | 10-64<br>2-65 | 7-65 |
| Music | | x | | | 12-64 | 7-65 |
| Gymnasium | x | | | | | 8-65 |
| Parking Lot | | | | x | | 8-65 |

To be of greatest possible help to the custodian, this booklet includes details on lamp characteristics and circuitry. Of course, a custodian may only be concerned with replacing lamps – and perhaps fluorescent lamp starters. On the other hand, his supervisor may need to know about lamp characteristics affected by voltage. An electrician doing maintenance work will be familiar with general circuit problems, but may be in doubt about the differences between various fluorescent lamp and ballast circuits. Consequently, to be generally useful, points will have to be covered which will seem elementary to some readers.

# Chapter 1

# A Short Course in
# LIGHTING FUNDAMENTALS

### Voltage

The *volt* is the electric unit corresponding to pressure if we were talking about water in a pipe instead of electricity in a wire. Household voltage in the United States is most commonly from 115 to 120, but it is sometimes spoken of as "110 volts," because this used to be the common voltage.

Actually, homes with sizeable electric loads have what is known as 115/230 volt service, entering through a 3-wire cable. Between each outside wire and the "neutral" wire the voltage is 115, but between the two "outside" wires, as in Figure 1, the voltage is 230. This permits lamps, electric clocks, small appliances, etc. to operate on 115 volts, while making 230 volts available for large appliances such as electric ranges and air conditioners. Invariably schools are supplied with 115/230 or 120/240 volts unless they have only 3-phase service which will be discussed later.

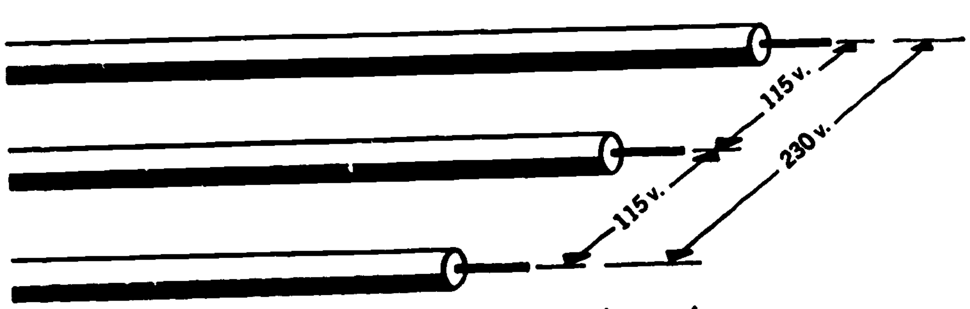



**Fig. 1 Edison 3-wire electric service. Voltages are sometimes 120/240.**

### Current

When voltage is applied to an electric circuit containing any lamp or appliance, a current flows through the circuit and through the device. Current is measured in *amperes,* or amps. for short. It is the current which determines the size of wire necessary to serve a load, because if the current is too great for the size of the wire, the wire will get hot. For example, under most circumstances No. 14 wire should not be required to carry more than 15 amperes, so we put a 15 amp. fuse in the circuit. This contains a soft metal part which will melt and interrupt the circuit if more than 15 amperes flows for more than a moment or two. Sometimes a circuit breaker is used instead of a fuse. This opens an overloaded circuit, but it can be reset when the overload is removed. It does not need to be replaced as does a "blown" fuse.

### Power

Electric power is measured in watts, and 1000 watts = 1 kilowatt (kw). You can easily calculate the power in watts consumed by simple devices such as incandescent lamps and heating coils, by multiplying voltage times current. For example: if the socket voltage is 115 and a heater draws a current of 12 amps., the power is $115 \times 12 = 1380$ watts or 1.38 kilowatts. Kilowatts times hours (kilowatt-hours) are what you pay for on your electric bill.

Incandescent lamps and heating coils are *non-inductive* devices. Fluorescent fixtures and induction motors are inductive devices and, in such cases, power is not voltage times current, because of power factor, as will be explained later.

### Alternating Current

When the starter switch in an automobile is closed, current from the storage battery flows through the wires to the starter motor and back to the battery. It flows in one direction only and is called *direct current* or d-c. There are other direct current devices, such as flashlights and battery-operated radios, but today most electrical devices and apparatus operate on alternating current, or a-c.

In an a-c circuit, the voltage pushes first in one direction and then the other. Each repetition of the process is called a *cycle* and a frequency or 60 cycles per second is almost universal in the United States. This means 120 reversals of direction per second, or the current flowing each way 60 times per second. In most European countries the frequency is 50 cycles.

Edison's first lighting system used d-c, but when a-c was developed, it rapidly supplanted most of the d-c. The principal reason was that transformers can be used on a-c, but not on d-c. A transformer is a simple device with no moving parts, which permits voltages to be "stepped up" and "stepped down" with very little loss in power.

Why do we want to step voltage up or down? Remember that power equals voltage times current, that is, watts = volts × amps. Therefore, for a given amount of power, whenever the voltage goes up, the current comes down. Suppose we have a load of 1,000 kw (1,000,000 watts) at a place a mile away from the power plant . . . if the power were transmitted at 120 volts, the current would be $\frac{1,000,000}{120} = 8330$ amps. Remember also that the amount of current determines the size of wire necessary to carry it. Wires big enough to carry more than 8,000 amps. would be ridiculously and impractically large. On the other hand, if we generate the electricity at, say, 14,300 volts and transmit it to the customer at that voltage, the current will be only $\frac{1,000,000}{14,300} = 70$ amps. This current can be carried by wires smaller than those entering the ordinary home. At the location of the load, a transformer steps the voltage down to 120/240 or some similar useable voltage.

For transmitting power over considerable distances, the voltage from the generators is actually stepped *up*, sometimes to more than 100,000 volts, thus permitting very large amounts of power to be carried by small wires. It is the ability of transformers to step voltages up and down simply and efficiently, that makes much of our industrial development possible.

## Power Factor

Power factor is a difficult subject, and no attempt at a complete explanation can be given here. However, we shall say a little about its effects. As we have mentioned, incandescent lamps and heating devices are non-inductive loads; and the power they require can be calculated quite easily with a formula that is the same for a-c circuits as for d-c circuits. That is:

$$\text{Volts} \times \text{Amperes} = \text{Watts}$$

However, this is not the case in a-c circuits with *inductive* loads such as induction motors and fluorescent lamps and their ballasts. The reason – in circuits serving inductive loads, the reversals in direction of voltage and current do not occur at the same time. (They are not in phase.) This results in a loss of power. The power formula then becomes:

$$\text{Volts} \times \text{Amperes} \times \text{Power Factor} = \text{Watts}$$

Rearranging the formula:

$$\text{Amperes} = \frac{\text{Watts}}{\text{Volts} \times \text{Power Factor}}$$

For example, suppose we have a load of 1800 watts with a power factor of 60% (or .60), on a circuit of 120 volts. The current will be:

$$\text{Amperes} = \frac{1800}{120 \times .60} = 25$$

If the power factor were 100% (or 1.00), that is, if the current and voltage were in phase, the current would be:

$$\text{Amperes} = \frac{1800}{120 \times 1} = 15$$

Thus, it requires larger wires to serve the same load if the power factor is low. It might be better to by-pass the difficult subject of power factor in a book of this type, except that it has an important bearing on ballasts for fluorescent lamps. These come in both high power factor and low power factor types, although high power factor ballasts are used in leading makes of fixtures. To use low power factor ballasts in a fluorescent installation would require substantially larger wires. An inductive load tends to throw the current and voltage out of phase by making the current alternations or reversals *lag* behind the voltage alternations. A capacitor tends to make the current *lead* the voltage in the timing of their alternations. Therefore, a capacitor can be used to balance an inductive load in the same circuit, and result in a high power factor for the combination. In the case of a high power factor ballast, the condenser is built into the ballast.

### Three-Phase Supply

One other explanation which will be attempted, without going into complete detail, is that of a *three-phase* supply. In Figure 2, one circuit is between wires A and B, one between B and C, and

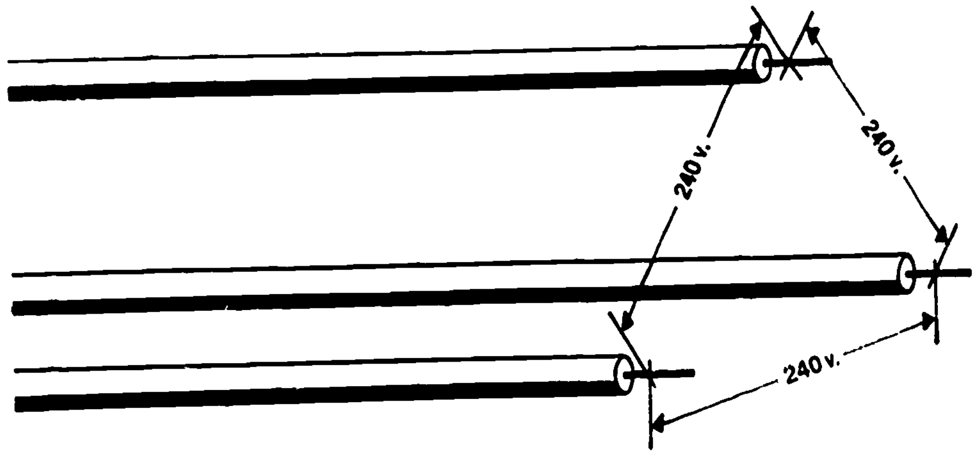



Fig. 2 Three-phase electric service

another between C and A. The important feature is that the alternations of current are not in phase in the three circuits. When the current in one phase is at its maximum, the current in another is at less than half its maximum, and is increasing. The current in the third phase is at less than half its maximum, and is decreasing. Thus, although each wire is a part of two circuits, the current it must carry is never double that of a single circuit. This means a considerable saving in wire for three-phase circuits as compared with single-phase circuits.

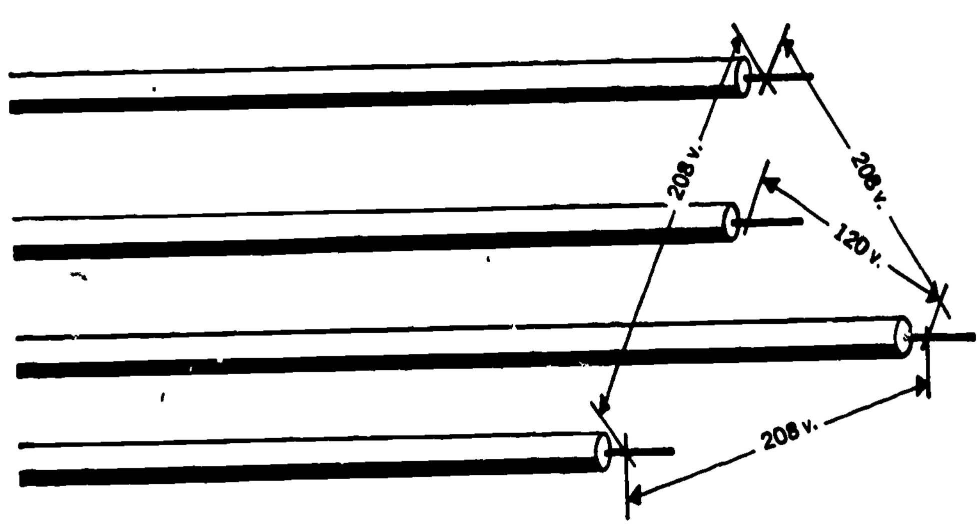



Fig. 3 Three-phase service with neutral. Other voltages can be used, but voltage across phases is always 1.73 times the voltage from phase wire to neutral.

Another type of three-phase circuit is shown in Figure 3. This is known as *3-phase, 4-wire,* the middle wire being the neutral wire. The relative merits of three and four wires are quite technical, but in either case there is a substantial saving in copper as compared with single phase. In industrial zones, both 3-phase *power* circuits and single-phase *lighting* circuits are often brought into large establishments. In such cases, the power circuits need not have as good *regulation* as the lighting circuits; that is, the voltage need not be held as constant by the electric company. In school neighborhoods, where separate circuits may not be available and where the 3-phase power is well regulated, lighting circuits are taken off the power circuits by transformers as indicated in Figure 4.

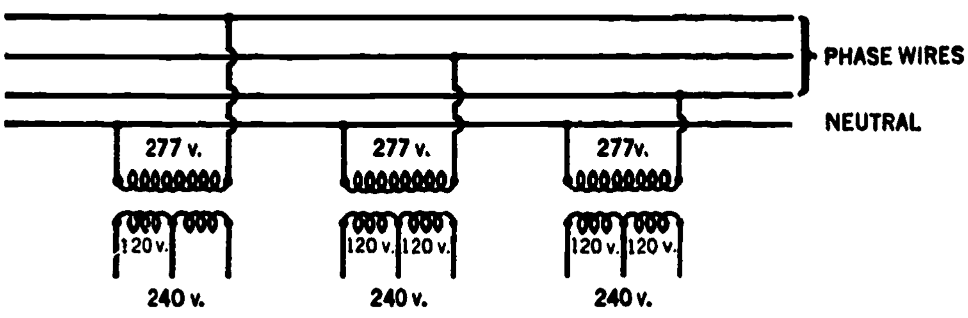



**Fig. 4 Example of lighting transformers connected from phase wires to neutral of a 277/480 volt, 3-phase circuit. Lighting transformers that step the voltage down from 480 to 120/240 volts could be used instead.**

# Chapter 2

# INCANDESCENT LAMPS

### Principles and Construction

When an electric current flows through a wire, the wire becomes warmer. The rise in temperature is only slight if the wire has plenty of capacity to carry the current (that is, relatively little resistance to the current flow). If, on the other hand, the resistance of the wire is somehow increased, the heating can be enough to cause the wire to glow. A familiar example is the electric heater in which the heat comes from a glowing wire.

Such a device has a self-governing effect. With any particular voltage, a current flows through the wire and heats it. The heating, in turn, increases the resistance of the wire, and this tends to reduce the flow of current. Thus a point is reached quickly where no more current will flow unless the voltage is increased. As will be seen later, this is *not* true of a fluorescent lamp, which would "run away with itself" if an outside current-limiting device were not used.

### Basic Principles

The glowing wire in an electric heater would not be very effective as a light source. If more voltage were applied and more current were forced through the coil, it would melt before it became bright enough to give much light. What the inventors of the incandescent lamp did was to seal the filament wire into a glass bulb and pump out the air. In the absence of oxygen, the filament can be operated at a much higher temperature without "burning up."

Many incandescent lamps have an inert gas instead of a vacuum inside the bulb. This enables the filament to be operated at still higher temperatures, because the gas pressure slows down the rate at which the metal slowly evaporates from the filament.

As with the electric heating coil, the incandescent lamp is a self-limiting device and requires no auxiliary equipment. As someone described it years ago, an incandescent lamp is essentially "a piece of wire in a bottle."

Before the introduction of gas-filled lamps in 1913, all lamp filaments were operated in bulbs having a vacuum. In most lamps today, gas is placed inside the bulb to introduce a pressure which reduces filament evaporation and permits a higher filament temperature. The gas first used was nitrogen. Modern lamps use a mixture of argon and nitrogen in amounts that depend on the wattage. Argon and nitrogen are inert gases which do not combine chemically with tungsten. They are introduced into the bulb at about 80 per cent of atmospheric pressure, but the pressure rises to approximately atmospheric when the lamp is operated at normal voltage.

Nearly all lamps smaller than 40 watt and some larger ones are of the vacuum type. The others are gas-filled lamps. Vacuum lamps are designated as Class B, and gas-filled lamps are designated as Class C in catalogs and price schedules.

Figure 5 shows common bulb shapes.

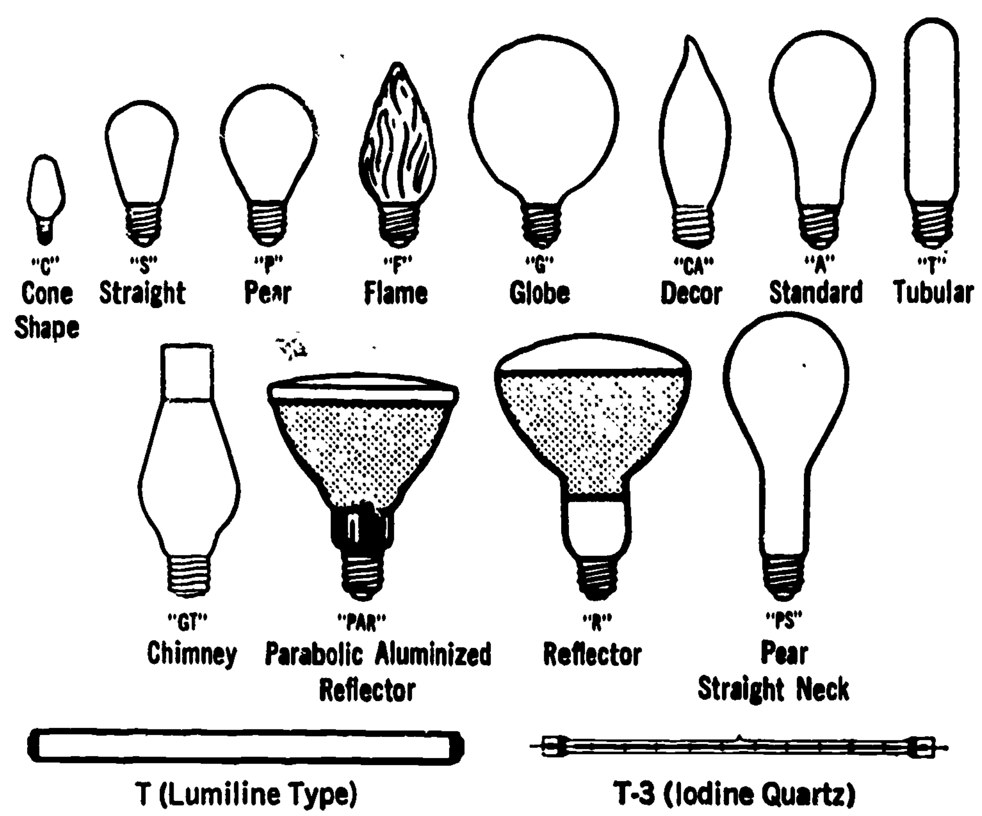



Fig. 5 Common bulb shapes

### Blackening

As a result of normal evaporation of the filament, tungsten particles are deposited on the inner surface of a lamp bulb. The bulb thus becomes blackened. In a vacuum lamp, the blackening occurs rather evenly over the entire inside of the bulb. In a gas-filled lamp, convection currents set up in the hot gas carry the particles of tungsten upward. Thus they are deposited on the bowl when the lamp is burning base down, or on the neck when the lamp is burning base up.

In most vacuum lamps, an active material known as a "getter" is applied to the filament or leads during manufacture to reduce residual gas pressure and to clear up the atmosphere when the lamp is first lighted. In such a vacuum lamp the getter materially reduces blackening. Blackening due to evaporation of the filament is responsible for most of the decline of light output during the life of a lamp. The change in light output (or lumen output) is called "lumen maintenance" or sometimes just "maintenance." Do not confuse it with the maintenance that refers to cleaning lamps and fixtures.

### Built-In Fuse

Few people realize that most of the lamps they buy have built-in fuses. If a filament breaks while a lamp is lighted, an arc could form across the break and draw a much heavier current than the lamp was designed for. The fuse is a part of one lead-in wire. Under an abnormal current such as just described, the fuse will open and protect the lamp and circuit from excessive current.

### Bulb Finishes

The standard bulb finishes are clear, inside-frosted, daylight (clear and inside-frosted), white-bowl, silvered-bowl, inside-reflector, inside-colored, outside-colored, white ceramic, and natural-colored glass.

An inside-frosted finish, which is by far the most common of all bulb finishes, spreads the brilliant filament image and partially diffuses the light. This finish reduces glare when bare lamps are used, and minimizes shadows and bright streaks when lamps are used in lighting fixtures.

Daylight lamps produce a light that is more nearly like daylight in color by the use of blue-glass bulbs which absorb some of the red and yellow wave lengths. This absorption results in a loss in lamp efficiency of approximately 35 per cent. A good rule to remember here is that it takes the next larger wattage size of daylight to supply the same quantity of light as the inside-frosted lamp being replaced. In other words, a 300 watt daylight lamp has approximately the same lumen output as a 200 watt inside-frosted lamp.

White-bowl lamps are made by spraying a white diffusing enamel on the inside of the bowl, opposite the base, to direct about 80 per cent of the light upward and 20 per cent through the bowl. These lamps are often used in open-type industrial reflectors for direct lighting to lessen glare and soften shadows.

### Types of Bases

The base of an incandescent lamp performs two very important functions. First, it holds the lamp firmly in the socket in the electrical circuit. Second, it conducts the electricity from the circuit to the lead-in wires of the lamp. For most applications, lamps

**TABLE II**

**VARIOUS INCANDESCENT LAMP BASES**

| BASE TYPE | TYPICAL LAMP USING THIS BASE |
|---|---|
| Mini-can screw .................. | 250-w, T-4, Super Q Iodine Quartz |
| Candelabra ...................... | 7-w, C-7, Night Light |
| Intermediate ..................... | 10-w, S-11, Sign |
| Medium ......................... | 100-w, A-19 |
| Medium skirted (cement) ......... | 300-w, PS-35 |
| Medium skirted (mechanical) .... | 150-w, PAR-38, Projector |
| Three contact medium ........... | 50-100-150-w, PS-25, Three-lite |
| Mogul ........................... | 300-w, PS-30 |
| Three contact mogul ............. | 100-200-300-w, PS-25, Indirect Three-lite |
| Medium prefocus ................ | 500-w, T-10, Projection |
| Mogul prefocus .................. | 1000-w, G-40, Spotlight |
| Double-contact bayonet candelabra | 25-watt, T-8, Home Appliance |
| Disc ............................ | 40-w, T-8, Lumiline |
| Recessed single contact .......... | 300-w, T-4, Iodine Quartz |
| Rectangular recessed single contact ........................... | 1000-w, T-6, Iodine Quartz |

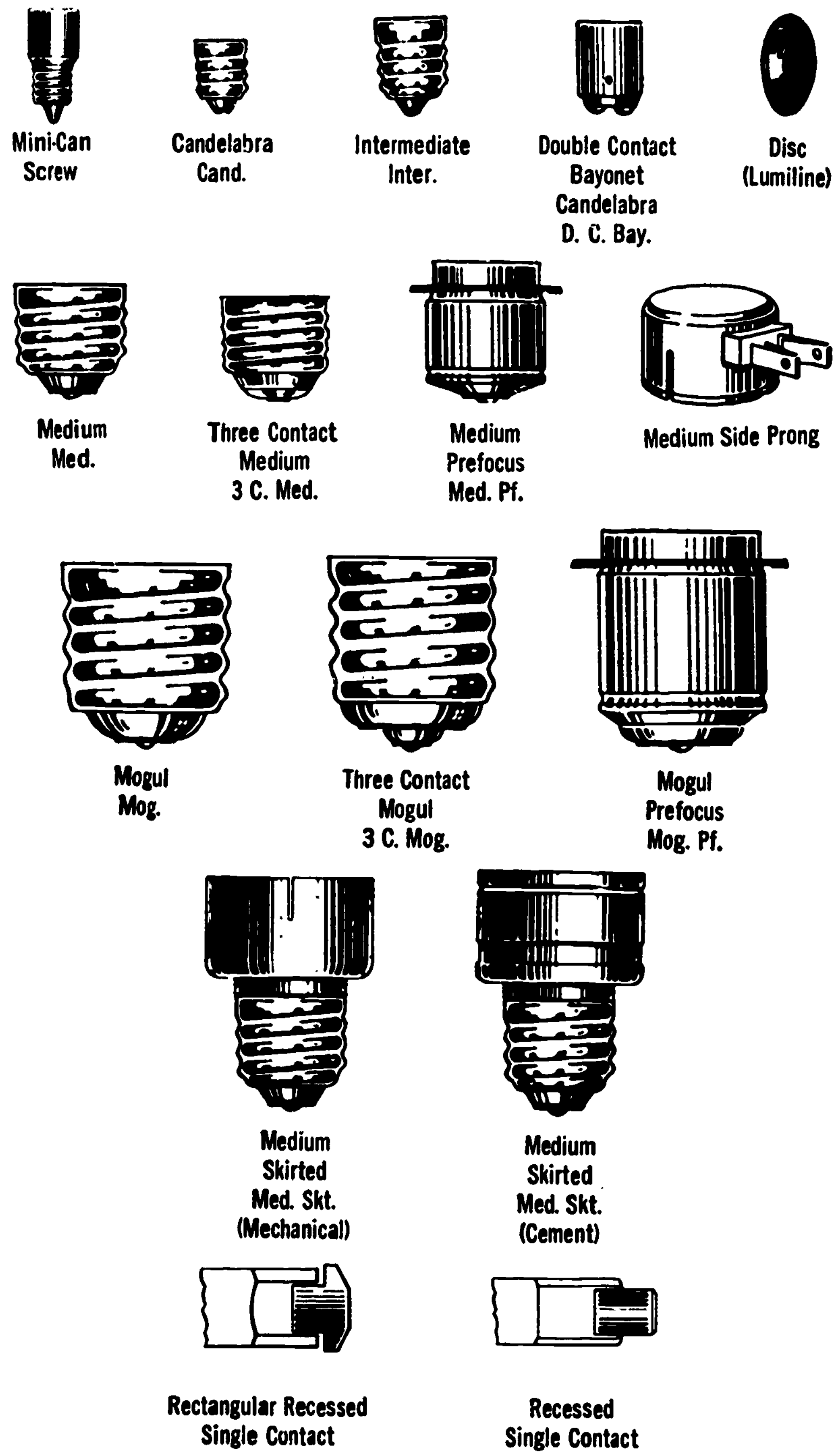



Fig. 6 Incandescent lamp bases

are furnished with one of the various sizes of screw bases shown together with other bases in Figure 6. The bases are described in Table II.

The electrical industry has been converting many of its products, including incandescent lamp sockets, from copper and brass to aluminum. The lamp industry therefore has been changing to aluminum bases, although brass bases are still available on some lamps where users prefer them. During the transitional period, when aluminum bases may be used in brass sockets, it is desirable to prevent electrochemical action between the two metals. A thin coating of sperm oil is provided on most aluminum bases. This coating is invisible and odorless, and gives enough lubrication to prevent sticking.

In most incandescent lamps, a cement holds the glass of the bulb to the metal of the base. On high-wattage lamps (generally those over 500 watt), a silicone basing cement is used in order to withstand the high temperatures involved.

In order that it may fit various types of lighting fixtures, the 300 watt, PS–30 lamp is offered with a choice of two bases: medium skirted and mogul.

When it is necessary that a light source be positioned exactly with respect to a lens or reflector, as in projectors, the medium-prefocus or mogul-prefocus base is used to ensure the proper location of the filament. The pre-focus base consists principally of an inner shell which is attached to the bulb and an outer brass shell which is set in the proper position to ensure an exact light center length. This is the distance from the center of the filament to the bottom of the base. After positioning, the parts are soldered together.

The Lumiline lamp is unique in that it uses two disc bases at opposite ends of the bulb, with each connected to the filament.

# Chapter 3

## INCANDESCENT LAMP CHARACTERISTICS

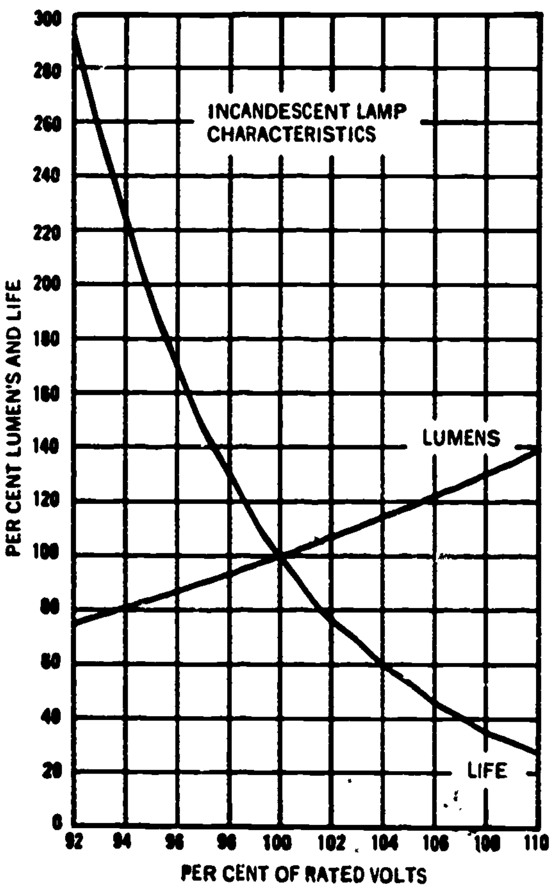



**Fig. 7 Important lamp characteristics as they change with voltage**

Lamp characteristics shown by the curves of Figure 7 are given in *per cent of rated values,* rather than in absolute values, because it is then possible to use one chart for many types of lamps. Although this practice may seem confusing at first, it is believed that this type of chart actually gives a more convenient and valuable aid than the huge assortment of charts which would be necessary if there were an individual one for each lamp and voltage rating. These curves may be used easily as shown in the following example.

Assume that we want to know the light output of a standard 60 watt, 120 volt, A–19 lamp when operated on a 125 volt circuit.

1. The voltage under consideration should be divided by the rated voltage of the lamp to give per cent rated volts. In this case

$$\frac{125}{120} \times 100 = 104\%$$

2. The next step is to determine what percentage of the rated lumens should be expected from a lamp which is operating at 104 per cent of its rated volts. This is done by locating 104 on the "Per Cent Rated Volts" scale at the bottom of the chart and then following a vertical line up to the curve marked "Lumens." At the junction of this vertical line and the curve, a horizontal line should be followed across to the scale on the left. The result will be in per cent of rated lumens. In this example it is 116 per cent.
3. Look up, in a Lamp Price Schedule, the rated light output of the lamp under consideration. For a 60 watt, A–19, standard voltage lamp, the rated light output is 855 lumens.
4. Multiply the rated lumens by the per cent lumens divided by 100 to obtain the expected lumen output. For this example:

$$855 \times \frac{116}{100} = 992 \text{ lumens}$$

Thus, we may expect 992 lumens if we operate a 60 watt, 120 volt, A–19 lamp on a 125 volt circuit.

Other characteristics of a lamp can be found from the chart in like manner. For instance, suppose we want to find the expected life of the lamp in the preceding example. A horizontal line may be carried across from the point where the vertical line for 104 per cent meets the curve marked "Life." This horizontal line will cut the scale on the left at the point indicating the amount of life to be expected. In this case, the figure is about 60 per cent. Since the Lamp Price Schedule gives the normal rated life of a 60 watt lamp as 1000 hours, we may expect 60 per cent of 1000, or 600 hours of life if the lamp is operated on a 125 volt circuit.

### Effects of Voltage on Lamp Operation

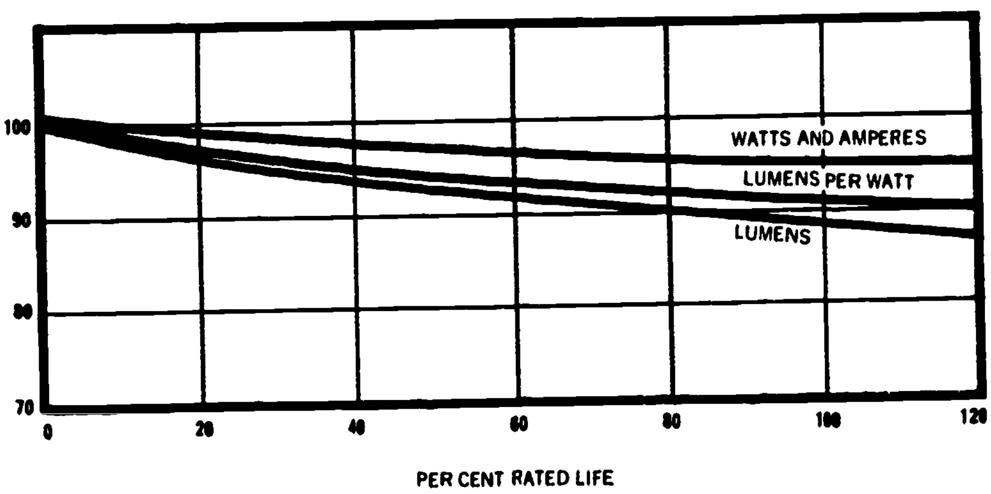



**Fig. 8 Lamp characteristics as they change throughout lamp life.**

The curves on the chart in Figure 8 depict how an incandescent lamp slowly depreciates during life. A lamp produces fewer lumens, at reduced efficiency, as the number of hours of use increases. Therefore, less current is allowed to pass through it and the number of watts consumed by the lamp is reduced. The lumen output falls off because of a lower operating temperature of the filament and increased bulb blackening. The efficiency in lumens per watt does not decrease so rapidly as the lumen output because the number of watts is also decreasing. The iodine-quartz lamp is an exception which will be discussed later.

### Designed Life of Incandescent Lamps

The designer of a particular lamp chooses a length and diameter of filament wire such that a group of these lamps will last for a specified number of burning hours. This number of hours is determined by economic considerations for the user. Figure 7 shows how lumen output goes up when life is shortened. A #2 photoflood lamp is designed to last only 6 hours, in order to get a much higher output. Many domestic lamps are designed for an average life of 750 hours while larger commercial and industrial sizes are usually designed for 1000 hours.

### "Long-Life" Lamps

Sometimes "long-life" or "guaranteed" lamps are offered with claims of very long life. Often a premium price is charged for these lamps. There is no magic about designing a lamp for long life; it is simply a matter of how much efficiency the user is willing to sacrifice. It would be possible to design an incandescent lamp to burn for a million hours, but it would give very little light.

Consider the matter from the standpoint of the housewife. It is true that she is unlikely to be able to measure the illumination in her living room, and it has been argued that a little lower output from a lamp does not matter so long as the lamp lasts much longer. The point is that if the lower light output really doesn't matter to the housewife, she can use the next size smaller lamp and save on electricity. Otherwise she will be paying for light she does not need or does not get.

The following comparison was made between a 100 watt, "long-life" lamp and a 75 watt standard lamp selling for the indicated prices.

| | "LONG-LIFE" | STANDARD |
|---|---|---|
| Rated watts | 100 | 75 |
| Actual measured watts | 110 | 75 |
| Rated lumens | 1,300 | 1,180 |
| Actual measured lumens | 1,185 | 1,180 |
| Rated life in hours | 10,000 | 750 |
| List price of lamp | $0.69 | $0.25 |
| Cost of lamps for 10,000 hr. use | $0.69 | $3.33 |
| Kwh of electricity consumed in 10,000 hours | 1,100 | 750 |
| Cost of electricity @ 3¢ per kwh | $33.00 | $22.50 |
| Lamp cost plus electricity cost | $33.69 | $25.83 |

A similar "long-life" lamp of another brand lists for a still higher price, but it can be seen that the lamp cost is not the important item.

It is true that in industrial plants labor costs for replacing lamps must be taken into account. For hard-to-reach locations, where relamping is difficult or expensive, extended service lamps having a rated life of 2500 hours are available. For traffic signals, where relamping labor cost weighs more heavily than lamp efficiency, lamps of substantially longer life often are used. Another example is the 11-watt sign lamp with a life of 3000 hours, frequently used in exit signs.

### Operation at Other than Rated Voltage

Some uses are not large enough to justify the design of a special lamp, yet the user is willing to sacrifice life to output. In such cases, standard lamps can be operated at higher than rated voltage. An example is the lighting of a field for football or baseball games. Here the lamp cost is small compared to the cost of towers and floodlights. Also the lamps are seldom used for a total of more than 100 to 200 hours per season. They are therefore operated overvoltage in order to increase efficiency and reduce the number of floodlights needed. For example, operating 110 volt lamps at 127 volts will give 140 per cent of rated output, and 28 per cent of the rated number of hours, but this life will be ample if new lamps are installed each year when the installation is cleaned and serviced.

### Group Relamping

When a lamp is rated at 1000 hours, it does not mean that every lamp will operate for exactly 1000 hours and then fail. Such uniformity of life would be impossible, since failure de-

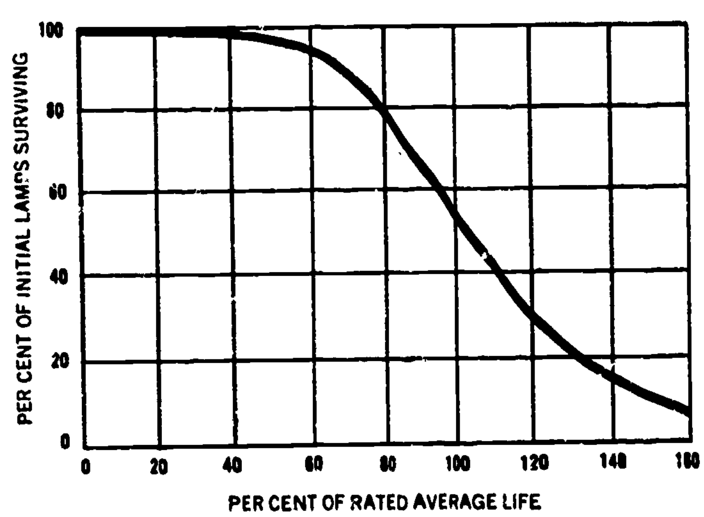



**Fig. 9 Typical mortality or life expectancy curve for incandescent lamps**

pends on wasting away of the filament. What the rating does mean is that in a large group of lamps, the *average* life will be 1000 hours. However, even this meaning is not exactly correct. As shown in Figure 9, about 55 per cent of a large batch of lamps will still be burning at rated life, and 45 per cent will have failed by that time.

Even though a few lamps in a certain batch will operate for considerably longer than rated life, it is not economical to keep them operating, because of their reduced efficiency. Some users recognize the economy of replacing lamps before they even reach rated life. For example, Figure 9 shows that at 70 per cent of rated life, only 10 per cent of the lamps in a large group will have failed. If all lamps in an installation are replaced at some such time, the labor of replacing individual lamps may be reduced greatly. To let all lamps in a large installation burn until they fail means a high labor cost for replacing each lamp on an individual trip. The labor cost per lamp is much lower when all lamps in a group are replaced at the same time.

### Rough-Service and Vibration Lamps

At the sacrifice of some efficiency, it is possible to manufacture lamps which will resist jolts and vibrations to a considerable degree. When deciding which kind of lamp to recommend, one must consider what kind of rough treatment the lamp will get. Shocks and blows, such as might be received by a lamp used on an extension cord in a garage, call for the rough-service lamp.

Vibrations of fairly high frequency, such as would be present

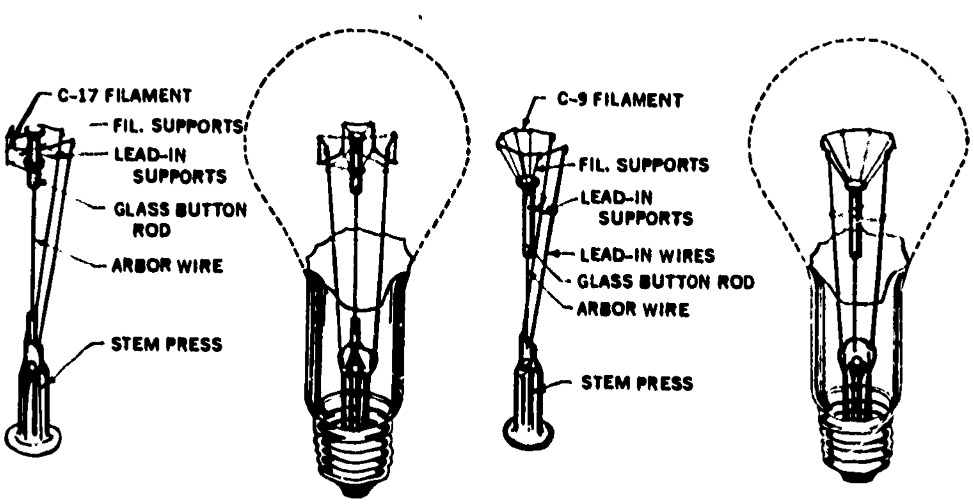



Fig. 10 (left) Typical rough-service lamp
Fig. 11 (right) Typical vibration-service lamp

on a sewing machine or a lathe, call for the vibration lamp. Many types of rotating machines transmit vibrations to their surroundings and make the use of vibration lamps desirable. One of the important features of the 100 watt vibration and the 100 watt, 150 watt, and 200 watt rough-service lamps is the arbor wire shown in Figures 10 and 11. This is made of a type of spring steel commonly known as piano wire, and it acts as a cushion against both shocks and vibrations.

The rough-service lamp shown in Figure 10 has extra filament supports, lead-in supports and the arbor wire. The extra supports diminish the possibility of the filament breaking under a blow, but they also reduce the efficiency, because a cool spot occurs at each point where a support touches the filament.

The vibration lamp shown in Figure 11 uses a more flexible filament of tungsten wire. It will sag when subjected to vibration, but it will not break so easily as will non-sag wire. Since the wire is allowed to sag, more supports are necessary. As with the rough-service lamp, the extra supports reduce the efficiency because of the cool spots. Vibration lamps are not recommended for burning in a horizontal position, since portions of the coil may sag enough to touch each other and short-circuit part of the coil.

## Reflector Lamps

Reflector lamps of the R type are available in sizes from 30 watt, R–20 to 1000 watt, R–52. The PAR lamps, which have much thicker glass, are made in sizes from 75 watt, PAR–38 to 500 watt, PAR–64. In addition, there are PAR–38 and PAR–46 lamps with side prong bases for use in confined spaces. Reflector lamps are made to produce narrow beams for spotlighting and wide beams for floodlighting, with some variations of these in the larger sizes. Lamp manufacturers do not offer identical items in reflector lamps, so a specific Lamp Price Schedule should be consulted for details. There are also the 25 watt and 40 watt T–10 reflector show case lamps in which the reflector is along the side of the lamp.

When R lamps are to be used outdoors or in a location where moisture may splash on them, heat-resistant glass should be chosen. The PAR lamps are made of heavy, molded glass and can be used under adverse weather conditions. They also are used widely indoors because of their rugged construction or because they produce more concentrated beams than do the R lamps. The 150 watt, PAR-38 lamps are available with blue, green, red and yellow lenses; and 150 watt, R-40 lamps are available in blue, blue-white, green, red, pink, and yellow bulbs. In each case, the color is fused into the glass and cannot chip, flake, or check. PAR lamps are also made with dichroic lenses which produce much more brilliant colored light beams by a different and more efficient principle.

### Indirect Reflector Lamps (Silvered-Bowl)

Where incandescent lighting is called for under conditions of minimum glare, particularly in schools and offices, the light is often directed toward the ceiling which reflects it back to the room. The ceiling then becomes, in effect, the light source. This is called indirect lighting. Sometimes the fixture directs the light from an inside frosted lamp upward, but more often a silvered-bowl lamp is used. In this case, the only fixture needed is something to hold the lamp socket and to provide some shielding to hide the neck of the lamp from normal view. Cleaning is not much of a problem, because every time a lamp is replaced it carries its own new reflector with it. Silvered-bowl lamps are available in various sizes from 60 watt, A-19, to 1000 watt, PS-52.

## IODINE QUARTZ LAMPS

Iodine quartz (or IQ) lamps are important members of the incandescent family. They are intensely bright yet small in size (some not much larger than a cigaret) – thus permitting good optical control in spotlights, floodlights and controlled beam fixtures. They are ideal for parking areas, protective lighting and building floodlighting.

Figure 8 shows how lumens (of light output) fall off throughout the life of an ordinary incandescent lamp. This does not happen with an iodine-quartz lamp, Figure 12, due to the principle of the iodine regeneration cycle. The tubular quartz (high silica glass) lamp with iodine vapor sealed in the bulb is a commerical application of this principle. Since quartz has a melting point of 1650° C, it is ideal for both the iodine cycle and for smaller enclosures of high wattage filaments. Ordinarily, tungsten evaporating from a hot filament is carried to the relatively cool bulb wall of standard lamps, where it accumulates and forms a black deposit. However, under temperatures of several

Fig. 12 Typical Iodine Quartz lamp (500T3Q/CL/U)

hundred degrees Centigrade, tungsten vapor and iodine vapor combine with each other to form tungsten iodide.

Operation at bulb wall temperatures well above 250° C is readily achieved in small diameter tubular quartz lamps. When tungsten iodide is formed in the vicinity of the bulb wall, it will not adhere to the wall and is borne by convection currents back to the filament where the temperature is several thousand degrees. The iodide is then reduced, the tungsten redeposits on the filament and the iodine vapor recirculates to continue the regenerative cycle. Thus the bulb walls remain clean throughout life and the filament has a higher efficiency and longer life. Theoretically, the lamp would last forever if the tungsten could be redeposited evenly on the filament. In actual practice, however, the tungsten is not evenly deposited; consequently lamp life is generally an average of 2000 hours. Sylvania general lighting iodine quartz lamps have built-in fuses.

Because of its high temperature, the lamp should not be touched with bare hands while operating, or for several minutes after it has been turned off. Due to the extremely high output, considerable heat is produced, which takes several minutes to dissipate. A characteristic purple hue of the iodine vapor is visible when the lamp is first turned off. Generally, when the purple color is no longer discernible, the lamp is cool enough to handle.

Portions of the bulb wall may reach 600° C in normal operation, hence, sensible precautions must be taken to keep combustible materials away from bulbs. Oil, grease, or any other contamination left on a lighted lamp can cause devitrification (brittleness and eventual failure) of the quartz. Even moisture from hands can cause trouble so it is best to wear clean cotton gloves when inserting a new lamp. Should the lamp become so contaminated, clean with water and/or methanol and dry with a clean soft cloth before using.

# Chapter 4

# FLUORESCENT LAMPS

The principal advantage of the fluorescent lamp is its efficiency, which is nearly three times as great as that of an incandescent lamp. Another advantage is that a considerable range of colors can be had without loss of efficiency. For example, a blue light can be produced with a fluorescent lamp by choosing a blue fluorescing phosphor; whereas with an incandescent lamp, it would be necessary to use a blue bulb or filter, which would absorb part of the light and reduce the over-all efficiency.

## Operating Principles

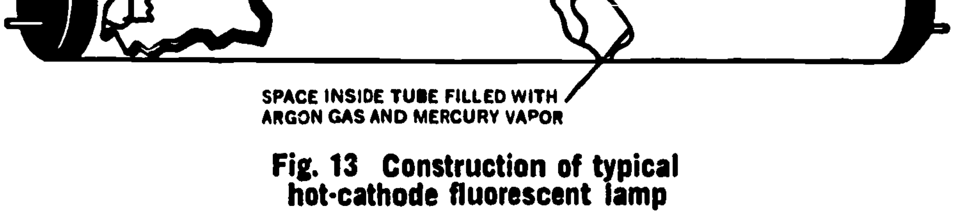



**Fig. 13 Construction of typical hot-cathode fluorescent lamp**

A typical *hot-cathode* fluorescent lamp is illustrated in Figure 13. At each end there is a cathode, sometimes called an electrode. The glass bulb, or tube, contains an inert gas such as argon, and a drop of mercury. The cathode is a tungsten filament similar to that in an incandescent lamp, but its primary purpose is to emit electrons. Any hot wire emits electrons, but one carrying an emissive material, such as a compound of barium, calcium, or strontium, will emit electrons at a much faster rate.

The cathode of a fluorescent lamp is made like a coiled-coil filament of an incandescent lamp, so that it will hold more of the emissive material.

An electric current has been described as a flow of electrons along a wire, but the path need not be a metallic one. If a gas is ionized, it will conduct an electric current, and, in doing so, it radiates energy. The resistance of the path between two electrodes can be broken down and an arc caused to "strike" by applying enough voltage across the path. On the other hand, if the cathodes in a fluorescent lamp are heated first, they will give off a cloud of electrons and permit the arc to strike with a lower voltage. Some fluorescent lamp circuits depend on voltage alone for starting, while some heat the cathodes first.

## Simple Preheat Circuit for Fluorescent Lamps

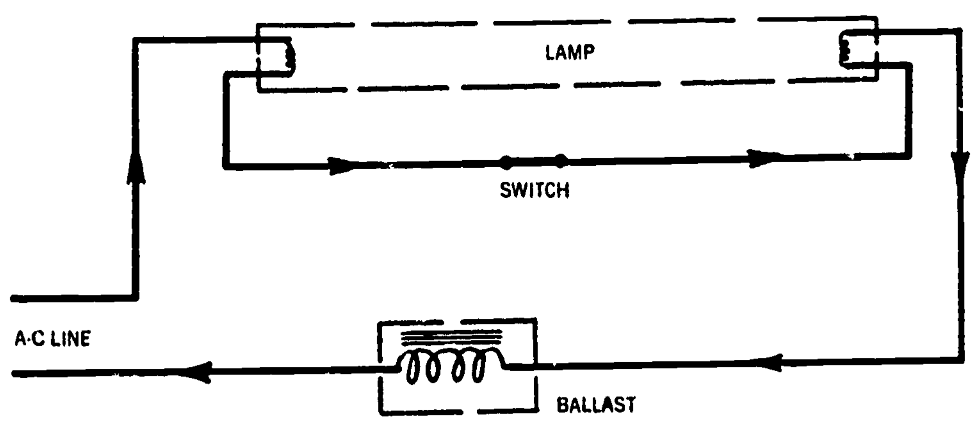



**Fig. 14 Simple preheat circuit with starting switch closed**

The simplest type of circuit for a fluorescent lamp is known as a preheat circuit. As represented in Figure 14, such a circuit includes two cathodes, a switch, and a ballast. When the switch is closed, an electric current flows through one cathode, the switch, the other cathode, and the ballast. Since the current is alternating, it flows through the circuit first in one direction and then in the other. If it has a frequency of 60 cycles, it reverses itself 120 times in each second. In order to show the path of the current, arrows have been included in Figure 14. These arrows show the direction of flow at a certain instant. At an instant 1/120 second later or earlier, the current would be flowing in the opposite direction.

Depending on the length of the lamp and the voltage of the supply circuit, the ballast may be of a transformer or a choke type. In the simple circuit of Figure 14, the ballast is a choke coil. With the current flowing as in the illustration, both cathodes will become incandescent and will give off electrons, helped by the emissive coating. These electrons ionize the argon gas near the cathodes and make it a better conductor of electricity. If you could examine a fluorescent lamp with no phosphor coating at this stage of its operation, you would see a bluish glow surrounding each cathode. This glow indicates the ionization.

When a current flowing through a coke coil is interrupted, there is induced in the coil a momentary voltage greater than the voltage which had been applied. Thus when the switch in Figure 14 is opened, this extra "kick" of voltage is applied across the cathodes of the lamp and causes an arc to strike between the cathodes. The flow of current through the arc is indicated in Figure 15. The heat produced by the argon arc changes the liquid mercury to vapor and the arc becomes a mercury-vapor arc.

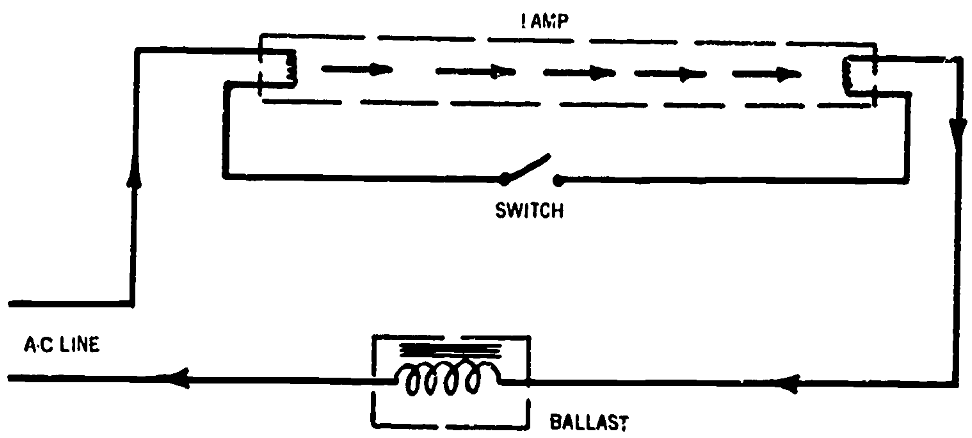



**Fig. 15 Flow of current with starting switch open**

## Behavior of Arc

An arc behaves quite differently than an incandescent filament, in that it is not a self-limiting device. It was explained earlier that a heated filament conducts a given current for a given voltage because its resistance would increase if it got hotter. With an arc, however, the hotter the arc, the lower its resistance, so it would "run away with itself" and destroy the lamp if it were not held back. This is the most important purpose of the ballast, whether it be a choke coil, a condenser, or a resistor.

A fluorescent lamp is operated at low pressure and most of the energy of the mercury arc is given off as invisible ultra-violet light. If you have seen a lamp in which the phosphor coating was omitted, you saw a bluish-green arc, but what you saw was only the small part of the total energy radiated in the visible range.

### Phosphors

The important function of the phosphor is to take the invisible ultra-violet energy and convert it to visible energy by lengthening its wave length. This can be compared to the way in which a radio takes inaudible radiated waves and lengthens their wave lengths so they can be heard.

### Circuits

The switch shown in Figure 15 can be hand operated as in some desk lamps where you push a button to close the starting circuit and then release it to open the starting circuit and strike the arc. Much more often the switch is an automatic switch called a starter. Starters will be discussed in more detail later.

Lamps up to 25 watts in size will operate on simple choke ballasts, but lamps of greater length and higher wattage require more than 120 volts for starting. For these, the ballast must serve not only as a choke coil but also as a transformer to step up the voltage, unless the line voltage is higher than 120. In large installations line voltages such as 220 or 250 volts are sometimes used. In these cases, larger lamps may be operated on choke ballasts.

## Chapter 5

# FLUORESCENT LAMP CIRCUITS

The basic types of circuits for large fluorescent lamps are preheat, rapid start and instant start. In a preheat circuit the switch (Figures 14 and 15) is replaced by a starter. This is really an automatic switch . . . it opens after the cathodes are heated, and permits the arc to strike.

In a rapid start circuit, the ballast supplies separate current for the cathodes of the lamp. After the arc strikes, the current through the cathodes drops somewhat, but continues to flow. Cathodes in rapid start lamps are of heavier construction and some makes of preheat lamps cannot be used interchangeably on rapid start circuits. Sylvania lamps can be used interchangeably. For example, the same 40 watt lamp is used on both types of circuit.

### Instant Start Circuits

If enough voltage is applied across a fluorescent lamp, the arc will strike without any preheating of the cathodes. A circuit with such high voltage is called an *instant start circuit.* An instant start lamp must have a larger, heavier, and more expensive ballast. In instant start lamps with bipin bases, the two pins at each end are connected to each other inside the base. Note, therefore, that such lamps should not be placed in a preheat circuit. Neither should a preheat lamp be placed in an instant start circuit.

Slimline lamps are also instant start lamps, but they have only a single pin at each end. The name slimline is not too descriptive, however. It started as a description of T–6 and T–8 lamps up to 8 ft. long, but, in order to round out the line, a certain amount of overlapping has occurred. For example, a 40 watt, T–12 lamp that is 4 ft. long can be preheat or rapid start, instant start, or slimline.

A safety circuit is used with an instant start lamp. If safety precautions were not taken, a workman might touch the pin on one end of an instant start lamp while the switch was on and the other end of the lamp was in the high-voltage lampholder. It would be possible for enough current to flow through the arc space of the unlighted lamp to shock him and perhaps make him fall from a ladder.

For safety reasons, therefore, a lamp must first be pushed into a spring lampholder at the high-voltage end and then allowed to come back into the rigid lampholder at the low-voltage end. Both lamps must be in place to have the circuit closed so that current will flow through the transformer in the ballast.

The rapid start circuit was developed after the instant start circuit, but in the 40 watt (4 foot) lamp it has replaced preheat and most instant start lamps in new work. It requires no starters and the ballasts are smaller, lighter, and less expensive than those in instant start circuits. The lamps do not start as fast as on instant start circuits, but they start in no more than 2 seconds, and usually in less than 1 second.

### High Output and Very High Output Circuits

High output and very high output lamps operate on rapid start circuits, but are not interchangeable with other rapid start lamps, because they operate on higher currents. Because of the higher currents, lampholders for rapid start lamps should have silver-plated contacts.

### Grounding

Reference has been made to a three-wire circuit, sometimes called an Edison three-wire circuit. The middle wire, called the *neutral,* is grounded at the power station. That is, it is connected to the earth. In present-day systems, the neutral wire is also grounded on the consumer's premises, and there is no fuse in the neutral wire. It is also customary to ground major appliances for safety reasons. Portable devices would be safer if they were grounded, but such grounding is not too common.

If trouble develops with a grounded system and a grounded appliance or lighting fixture, and the line wire touches the metal of the structure or housing, a current will flow through the neutral wire to the ground, and the fuse in the line wire will blow. If the appliance is not grounded, its housing will be "hot," and anyone touching it may receive a shock. In fluorescent lighting fixtures, grounding has another advantage. When a lamp is near a metal surface which is grounded, an electric charge, like the effect described in a condenser, is set up between the lamp and the metal. This helps the arc to strike under difficult conditions, such as low line voltage or high humidity.

### Cold-Cathode Lamps

All the lamps we have described thus far are known as hot-cathode lamps. In the types called *cold-cathode* lamps, the cathode is a thimble-shaped cylinder of soft iron instead of a filament. The names hot-cathode and cold-cathode are poorly chosen, because a cold-cathode lamp emits more heat than a hot-cathode lamp of the same wattage.

As in an instant start, hot-cathode lamp, the arc in a cold-cathode lamp is struck by applying a high voltage across the cathodes. Cold cathodes have been used for many years in neon sign tubing. In fact, if argon and mercury are substituted for neon in such tubing, and a phosphor is used inside the tube, the result is a cold-cathode fluorescent lamp.

Cold-cathode lamps have a very long life, but they are less efficient than hot-cathode lamps, and they provide less light per foot of length. They are particularly suited for use in signs, where there is need for small tubing which will be brighter and whiter than neon and which can be used in small diameters and bent into various shapes. Cold-cathode lamps are seldom used in schoolrooms nowadays, but are sometimes used in decorative cove lighting installations where they can be bent to follow the contour of curved surfaces.

### Sizes of Fluorescent Lamps

There are fewer variations in types and diameters of fluorescent lamps than of incandescent bulbs. Fluorescent lamps are either straight or circline. Both forms are designated as Type T.

Straight lamps come in six diameters: T–5, T–6, T–8, T–10, T–12, and T–17. Circline lamps are of two tube diameters: T–9 and T–10. The three sizes of slimline lamps are T–6, T–8, and T—12. The number after the T is the diameter in eights of an inch. Lengths of fluorescent lamps range from 6 in. to 8 ft.

### Bases

The bases used on fluorescent lamps are shown in Figure 16, and Lamp Price Schedules tell what kind of base is used for each kind of lamp. Slimline lamps have single-pin bases.

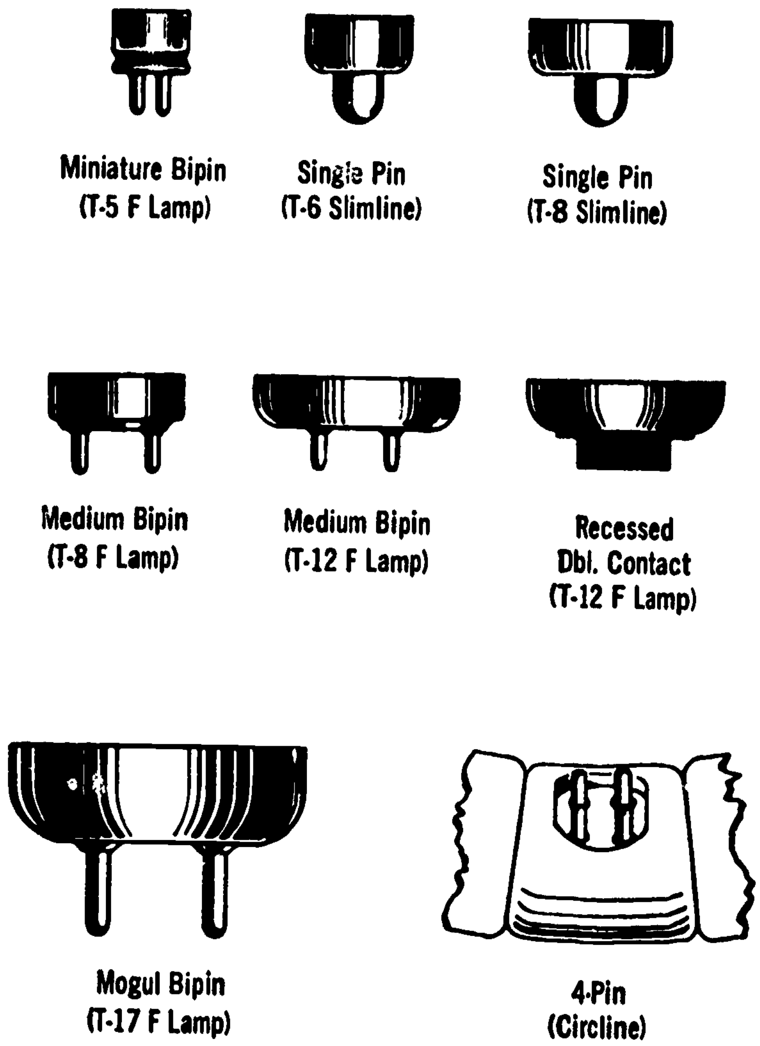



**Fig. 16 Fluorescent Lamp Bases.**

# Chapter 6

# FLUORESCENT LAMP STARTERS

The internal construction of starters differs in various types and makes, but we shall be concerned here only with their behavior in a circuit.

The simplest type of starter opens the starter circuit a short time after the fixture is turned on. If the lamp does not light, the starter will close and, after a pause, open again. One or two tries are usually sufficient, but if the lamp has reached the end of its life (when most of the cathode coating material is gone from the cathodes), the arc will not strike. As current is intermittently supplied to the cathodes, the ends of the lamp will light up from the cathode glow. This continual flashing on and off will not only shorten the life of the starter; it may damage the ballast.

A *manual-reset cutout starter* cuts itself out of the circuit if the lamp fails to light after repeated attempts. The starter switch will then remain open until a reset button on top of the starter is pushed. This type of starter not only protects the ballasts, but prevents the annoyance caused by a flashing lamp. However, it is possible for a cutout starter to cut out when the lamp has not failed. For example, a period may occur when the line voltage is abnormally low or the voltage is somewhat low and the humidity is high, and some lamps will not start. These lamps would be cut out by manual-reset cutout starters and would not start again until the reset button was pushed.

A further development is the *automatic reset starter*. Instead of a push button for resetting, it has an extra feature which holds the switch open as long as voltage is supplied to the lamp. If the lamp has not failed, but has been cut out by some condition such as just described, the lamp will start again after about a minute when the line voltage returns to normal. Table

III lists the types of starters recommended for use with specific standard start preheat fluorescent lamps.

## TABLE III

## STANDARD START PREHEAT LAMPS AND STARTERS THAT GO TOGETHER

| LAMP | RECOMMENDED STARTERS |
|---|---|
| F4T5 | FS-5 |
| F6T5 | FS-5 |
| F8T5 | FS-5 |
| F13T5 | FS-4 |
| F14T8 | FS-2 |
| F15T8 | FS-2, COP-20, M-2(DC) |
| F15T12 | FS-2, COP-20, M-2(DC) |
| F20T12 | FS-2, COP-20, ROBOT COP FS2-NA, M-2(DC) |
| F20T12/26" | FS-2, FS-25 |
| F22T8 | FS-12 |
| F25T12/28" | FS-25 |
| F25T12/30" | FS-25 |
| F25T12/33" | FS-25 |
| F30T8 | FS-4, COP-30 |
| F40T12 | FS-4, ROBOT COP FS4-NA, COP-40, FS4-TG, COP 40/400 |
| F90T17 & F100T17 | FS-6, COP-6, COP-64, ROBOT COP FS6-NA, FS-64, ROBOT COP FS64-NA |
| **Circline** | |
| FC8T9 (22W) | FS-25 |
| FC12T10 (32W) | FS-12 |
| FC16T10 (40W) | FS-4 |
| **Appliance** | |
| F18T8/K/24" | FS-25 |
| F18T8/K/26" | FS-25 |
| F18T8/K/28" | FS-25 |
| F18T8/K/30" | FS-25 |

# Chapter 7

# FLUORESCENT LAMP CHARACTERISTICS

### Factors Affecting Performance

Factors which affect the performance of fluorescent lamps are line voltage, ballast quality, starter type and quality (for preheat lamps), temperature, humidity, and frequency of starting.

### Effect of Variation in Voltage

Voltage fluctuations have less effect on the operation of fluorescent lamps than on the operation of incandescent lamps. But the voltage to a fluorescent lamp cannot be ignored entirely. Standard ballasts for fluorescent lamps are designed to operate on a line voltage of 118, but lamps with these ballasts will operate satisfactorily over a range in line voltage from 110 to 125. If the voltage is below 110 or above 125, the situation should be corrected. Usually the best way of making the correction is to have the line voltage adjusted. In case it is not feasible to do so, it may be possible to obtain ballasts designed for the line voltage provided.

When the voltage delivered to the lamp is too low, it may be difficult to start the lamp, particularly if the humidity is high. Also because of the smaller amount of energy in the mercury arc, the output of visible light is less. When the voltage delivered to a preheat lamp or a rapid start lamp is higher than it should be, the lamp will sometimes operate as an instant start lamp. As a result, the cathode coating will deteriorate more rapidly. With any fluorescent lamp, operation of the arc at higher than rated current has an objectionable effect on the cathode coating. Also lumen maintenance suffers somewhat.

The characteristics of fluorescent and incandescent lamps are affected differently by changes in voltage. A fluorescent lamp suffers somewhat when operated either undervoltage or overvoltage. An incandescent lamp has a different relationship between output and life.

### Effect of Starting on Life

It is a good idea to cut down the number of times fluorescent lamps are turned off and on each day. In fact, it is even advisable to leave lights on until floors are swept and rooms are cleaned and let the custodians turn the lights off – rather than have the teachers turn them off and custodians turn them on to clean up. By cutting the number of starts in half, the useful life of the lamps may even be doubled.

The reason for this is that more of the cathode-coating material is used up when a lamp starts than is used in several minutes of operation. This is true whether the lamp is preheat, instant start or rapid start. Therefore, the actual average life of a group of lamps depends on how often they are started.

A period of three hours of continuous operation used to be considered a fair average in business and industry, so it became the custom to base rated average life on three hours per start. Lamps being tested for length of life in the laboratory are burned for three hours, then turned off for 20 minutes, then put on again for three hours, and so on.

Actually nowadays, lamps are usually burned longer than three hours in most applications, including schools. Figures 17 and 18

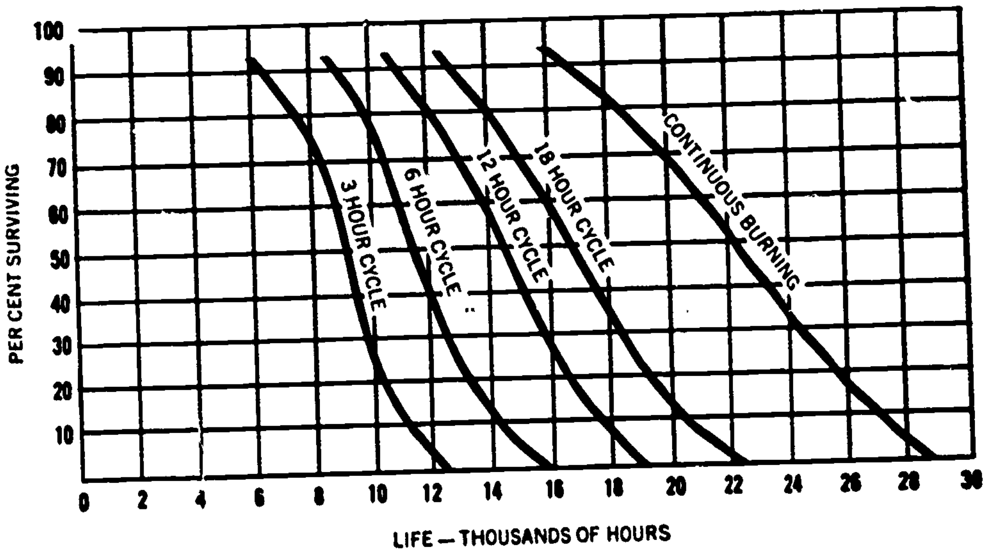



**Fig. 17 Mortality curves of 40 watt preheat lamps.**

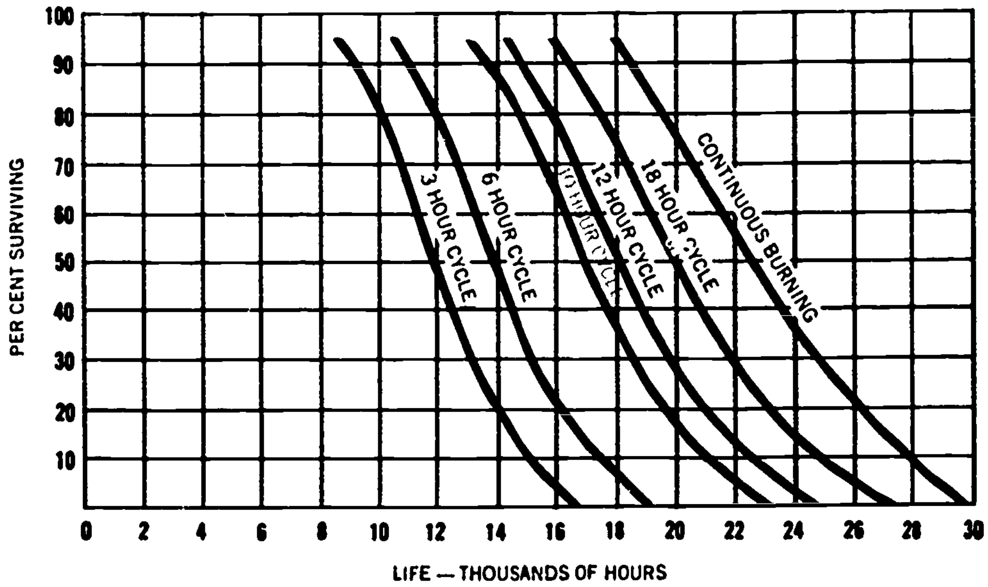



**Fig. 18 Mortality curves of 40 watt rapid start lamps.**

show rated mortality curves of preheat and rapid start lamps for various burning periods. The rated average life in each case is where the curve crosses the 50% line. For example, on a 3-hour cycle, the rated average life of a preheat lamp is 9,000 hours, while that of a rapid start lamp is 12,000 hours. A rapid start lamp has a rated average life of 18,000 hours on a 12-hour cycle and more than 22,000 hours when burned continuously.

Instant start lamps are affected somewhat more by frequency of starting and therefore have somewhat shorter lives.

## Lumen Maintenance

As indicated in Figure 19, there is some falling off of lumen output as a fluorescent lamp is used. It is believed that this happens because the phosphors slowly lose some of their ability to convert ultra-violet radiation into visible light.

## Group Replacement

Group replacement of fluorescent lamps is being used more and more widely in business and industry because of the overall savings.

In most large installations of fluorescent lamps, there are areas of considerable size where all lamps are turned on and off at the same time. In such areas, if all lamps operated for exactly 12,000 hours and then failed, they logically would be replaced

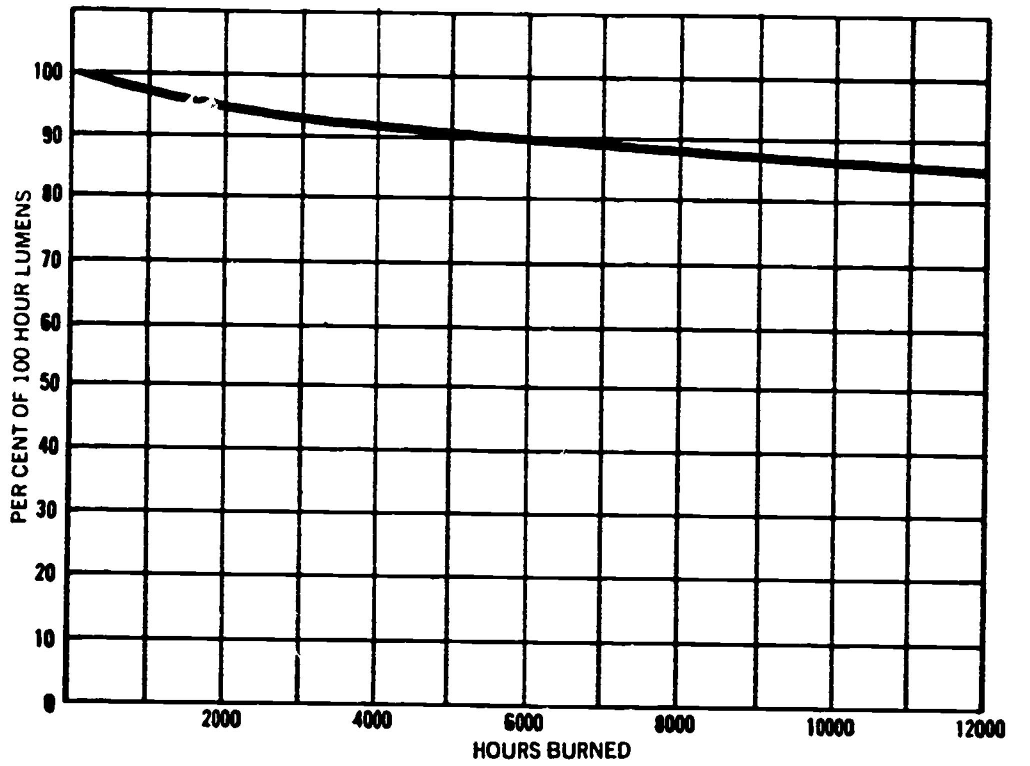



**Fig. 19 Lumen maintenance of 40 watt, T-12 lamps.**

in one large-scale operation. Of course, this does not happen. Instead, the lamps will fail according to one of the mortality curves in Figure 17 or 18, if the number used is large enough to be representative.

When a single lamp is replaced, it usually is necessary for someone to report the failure, then for someone to get a ladder and a new lamp and travel to the location. The man must climb the ladder and the lamp must be installed. The ladder must then be returned to its storage place, and the old lamp must be disposed of. Where the installation is large enough to keep at least two men busy, the labor cost of replacing lamps on an individual basis is even higher.

A much better plan for replacing lamps is to use group relamping. In this plan, some point, such as 85% of rated life, is chosen, and all lamps are replaced at once by a trained crew using equipment specially designed for the job. For example, stagings on wheels, and ladders with racks for holding lamps, are used. Further savings can be made by combining the group replacement of lamps with the periodic cleaning of fixtures and by use of special washing equipment.

In a spirit of false economy, some users hesitate to remove and throw away lamps which will still burn. When labor costs are considered, however, removing such lamps is actually cheaper in the long run. Furthermore, lamps which burn beyond their rated life do not give as much light per dollar spent for electricity, because of their lower efficiency.

When a group replacement plan is used and an individual lamp which fails early is replaced prematurely, say after 2000 or 3000 hours, it is not necessary to throw the new lamp away after the next group replacement. The new lamp can be marked with a grease pencil when installed, and removed with the others, but can be saved when the others are thrown away. Then it can be used to replace another early burnout in the next group.

Instead of replacing all lamps at 85% of rated life, another method is to keep a count of early replacements and make the group replacement when early replacements have reached 20% of the total number of lamps in service. This method automatically makes allowance for any deviation from average rated life caused by more or less frequent turning on and off.

A school system cannot show the same savings as an industrial plant if no additional labor cost is required for replacing individual lamps as they fail. However, in a large system, particularly if lamps are replaced by electricians rather than by custodians, important savings are possible.

### Lamp Color

There are eight shades of fluorescent "white" lamps: Standard Cool White, Deluxe Cool White, Natural, Standard Warm White, Deluxe Warm White, White, Daylight, and Soft White. Deluxe Cool White, Natural, and Deluxe Warm White have more red radiation than the others, at the sacrifice of some light output. Standard Cool White is the color most commonly used in classrooms, although White and Warm White are occasionally used. The light from Warm White lamps is similar to that from incandescent lamps except that it has less red output. Where fluorescent lighting is used in an art room the preferred color is Deluxe Cool White.

### Reflector Lamps and Aperture Lamps

Reflector and Aperture lamps are not commonly used in schools, but are included here for the sake of completeness.

As shown in Figure 20, a reflector lamp has a reflective coating around part of its circumference. When used in a school it would most likely be found in display cases or other small interiors where there is no room for separate reflectors.

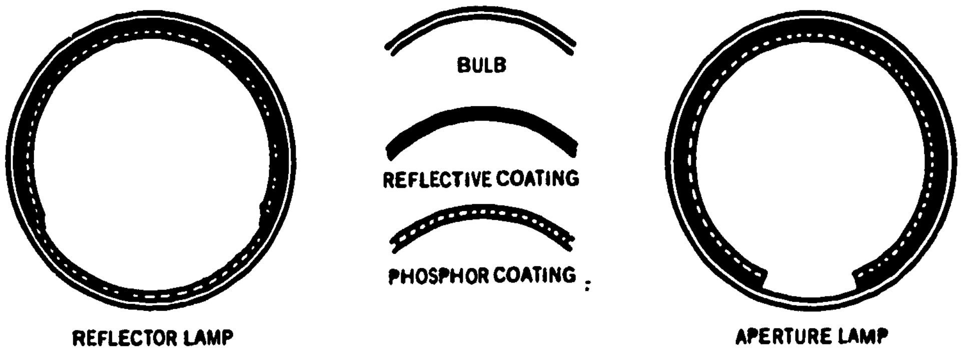



**Fig. 20 Cross section of fluorescent reflector and aperture lamps.**

An aperture lamp has a clear area with no phosphors and the rest of the lamp has a reflective coating. The lamp has very high brightness as seen through the uncoated portion. Aperture lamps are generally used with reflectors of special design, as shown in Figure 21.

In replacing such a lamp, it is important to note that the main direction of light from the lamp is toward the reflector, not toward the room. In schools, aperture lamps may be used in chalkboard lighting fixtures and for "wall washing" with light in a lobby or an auditorium.

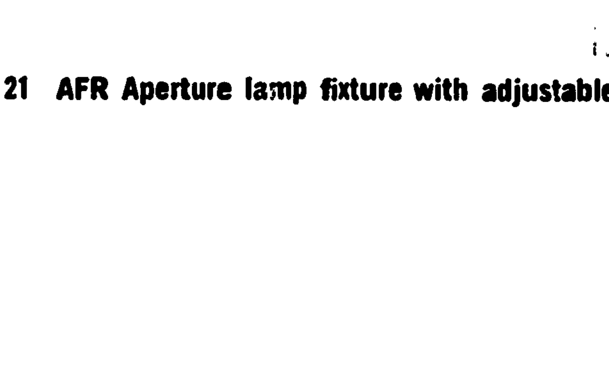


**Fig. 21 AFR Aperture lamp fixture with adjustable reflector.**

# Chapter 8

## MERCURY LAMPS

Mercury lamps are not used widely in schools, but their occasional use in gymnasiums and frequent use in parking areas makes some mention of them desirable. The arc in a mercury lamp operates at a higher pressure than the one in a fluorescent lamp, and in the case of a clear mercury lamp, the visible light comes from the arc itself. The light is of a bluish-green color, with a complete absence of red, with the result that it makes red objects look black.

A color improved mercury lamp has a phosphor which converts some of the energy to various colors of light, including red.

Still better color rendition is provided by lamps which use the vapors of several metals to provide light of good color-quality from clear bulbs. An example is the new Sylvania Metalarc lamp.

Both mercury lamps and Metalarc lamps require several minutes to arrive at full brightness. After an interruption of current supply, there is a delay before the arc re-strikes and for another warm-up period before full output is reached. Therefore, in indoor installations some incandescent or fluorescent lighting also is usually used with mercury or Metalarc lamps, so that a momentary interruption in supply will not leave the area in total darkness.

# Chapter 9

# TROUBLE SHOOTING

There is no sharp dividing line between the things a custodian might do to chase down electrical troubles and the things which should be left for an electrician to investigate. This section is directed to both.

## INCANDESCENT LAMPS

### Causes of Short Life

Most complaints about incandescent lamps are concerned with alleged short life. The first question to answer is whether or not the lamps are lasting for substantially shorter lengths of time than their rated *average* life. Are enough lamps involved for failures to be significant — for example, 100 or more? As shown in Figure 9, page 17, the rated life represents the average of the lamps in a group. In a large group, a few lamps could burn out early. A small group may, by chance, have more than its share of these.

Another thing which can happen involves a new installation of considerable size in an area where all of the lamps are burned for the same number of hours per day. For the first few weeks there will be only an occasional burnout. Then, as the end of rated life approaches, large numbers of lamps will burn out, and the user will feel that he is having to replace too many lamps.

If careful records are kept on a large installation, and the average life appears to be too short, it is possible that the socket voltage is higher than the lamp voltage. Plugging a voltmeter into the socket momentarily will not answer this question completely, because the voltage may be higher at some times of the day than at others. However, most electric light companies have recording voltmeters which they are willing to install in circuits where voltage conditions are suspect.

If the average life is shorter than the mortality curve predicts, and if the failed lamps show considerably less than the usual amount of blackening, look for service conditions which would account for the result. Are the lamps subject to shocks or blows which would call for rough-service lamps? Are the lamps exposed to vibrations which would indicate the need for vibration lamps?

Cracking or breaking of bulbs can occur when high-wattage lamps are exposed to a drop of water or a piece of cold metal. Evidence may be discoloration of the glass to a blue-black color, or the color may approach a yellow. Heat-resistant glass should be used in exposed locations and outdoors, except where low-wattage vacuum lamps are involved.

Where a lamp is made only for certain burning positions, the blackened area may indicate that the lamp was burned in an improper position, and its life was thus shortened. For example, suppose a 3-way 100–200–300 watt, PS–25 lamp has a blackened neck and very little blackening on the face of the bulb. Since the blackening occurs above the filament in a gas-filled lamp, the lamp probably was burned base up. If a Lamp Price Schedule is referred to, a footnote may be found which says, "Burn base down." Thus the lamp was operated improperly.

When the inner surface of a lamp is covered with a white powder, the lamp is called a *leaker*. The usual cause of the deposit is a very tiny air leak which did not admit enough air to prevent the lamp from lighting in the quality control check at the factory. However, the air slowly worked its way in thereafter, and when the lamp was lighted by the user, the filament burned out and a coating of tungsten oxide was deposited inside the bulb.

Sometimes, clearances or ventilation arrangements in a fixture are such that the lamp operates hotter than it should. An indication of this is often a dark-brown discoloration of the base. Another result of overheating can be a loose base.

### Complaints of Low Output

Most complaints involve short life. Occasionally, however, low output is mentioned. Low output may mean that the socket voltage is too low or that some of the lamps have lasted far beyond their expected life. The latter condition would be indicated by an excessive amount of bulb blackening.

## FLUORESCENT LAMPS

Occasionally you will hear someone say that fluorescent lighting bothers his eyes. Actually there is nothing in fluorescent lighting which is harmful or which should cause annoyance when good engineering practices have been followed. As far as physical effects are concerned, the American Medical Association gave fluorescent lighting a "clean bill of health" in 1945. Psychological reactions are harder to deal with, because people tend to use their eyes as scapegoats. If someone has a headache, he is likely to feel that his eyes are bothering him; and if there is anything new about the lights or the lighting system, it is likely to be blamed. As each new light source came along – the gas flame, the Welsbach gas mantle, the incandescent lamp, the fluorescent lamp – some people felt that it bothered their eyes. Then, as the new source became universally accepted, this feeling was forgotten.

### Lamps Failing To Start

When a lamp is out and the ends are not glowing, the first thing to look for is improper seating of the lamps in the lampholders. Bipin lamps have small raised spots or positioning nubs on each base to indicate the position of the pins when they are not visible. For lampholders mounted vertically in the fixture, the nub should be pointing straight down. If it is not, twist the lamp until it is, and the lamp should light. Figure 22 shows right and wrong position of the nub.

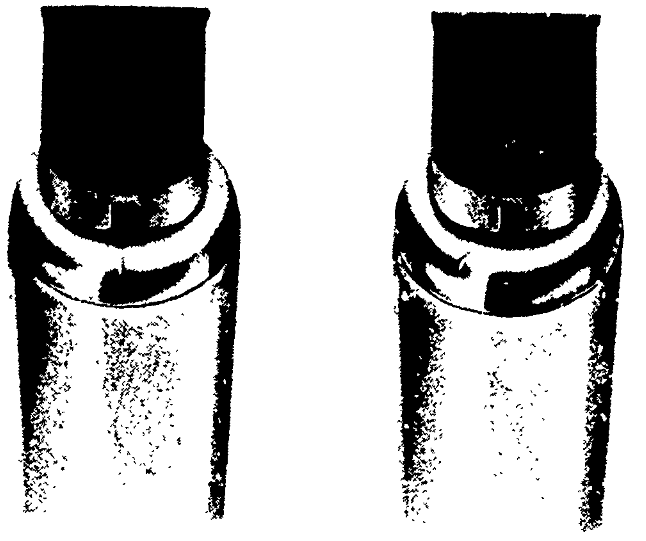


Fig. 22 Right position of nub (left). Wrong position of nub (right).

When the cathodes of a preheat lamp flash on and off, but the lamp does not start, look for a sign that the lamp has reached the end of its life. This would be indicated by dark ends, as shown in Figure 23. If the lamp appears to be new, it may be defective.

Starters for 90 or 100 watt lamps carry the following instructions: "For optimum results try reversing position of this starter in the socket." This means to remove the starter, turn it 180° and replace it. It may start the lamp more easily in one position than the other.

If a preheat lamp is neither lighted nor trying to light, check the type of starter. A manual-reset starter merely may need to have the reset button pushed. If the starter is an automatic reset, you will have to wait approximately a minute for it to reset itself when you try a new lamp in the fixture. A glow starter may need replacing, or the trouble may be with the lamp.

When an instant start lamp fails to start, and it does not appear to be near the end of its life, look for poor contact because the lampholders are spaced too far apart. Also, the contacts of some lampholders may have become corroded under damp conditions. Rapid start lamps in particular are dependent on good contact. For this reason, contacts in the lampholders should be made so as to resist corrosion. The best lampholders have silver-plated contacts.

The line voltage may be low, and this condition can affect the starting and operation of any type of lamp.

### Short Life

As with incandescent lamps, customers sometimes think that the life of a fluorescent lamp has been shorter than it actually was, or they may base their conclusion on too few samples. On the other hand, it seems evident that if a sizeable group of fluorescent lamps is showing short life, the most likely cause is frequent starting. Remember that rated life figures are based on 3 hours of operation per start.

### End Darkening

End darkening is of three types, which are shown in Figure 23. The blackening on the upper lamp is of the type which is characteristic of a lamp near or at the end of its life. It is fairly dense and extends along the bulb for 2 or 3 inches.

A dark spot such as that on the middle lamp is not an indica-

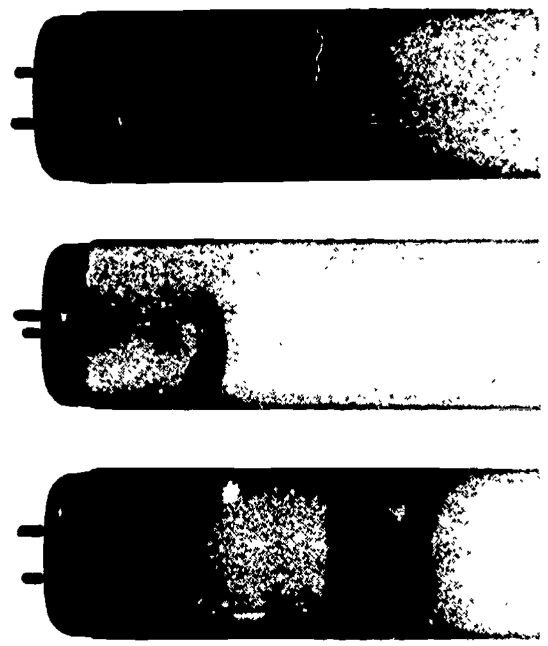


**Fig. 23 End darkening and discoloration spots and bands on fluorescent lamps.**

tion of the end of the life of the lamp. It is condensed mercury, which sometimes appears on new lamps but usually evaporates after the lamp has been lighted for a while. Mercury may condense on the bulb at other times, where one part of the bulb is cooler than the rest. This condensation may show as streaks along the lower part of the lamp, or as spots where louvers are close to the lamp.

Once in a while gray or brownish bands may occur, as shown on the lowest lamp in Figure 23. They will be about 2 inches from the lamp base, and the edge of each band on the side toward the base will be sharper. While such bands may detract a little from the appearance of the lamp under some circumstances, moderately dark bands have no significance in regard to the life or performance of the lamp.

### Snaking

Sometimes the arc in a fluorescent lamp may swirl and twist within the bulb. When this occurs, it is usually in a new lamp, and the effect will disappear after the lamp has been turned on and off a few times or reversed in position in the lampholders. If the trouble persists, it may be due to a defect in the lamp. If other lamps snake in the same fixture, the ballast is probably at fault.

An instant start lamp occasionally may snake at the end of its normal life.

## Ballast Noise

The ballast for any fluorescent lamp produces a slight hum, which is caused by the action of the alternating current on the iron cores of the coils. The loudness of the hum depends on the design of the ballast and the quality of construction. It is usually rather faint, but a defective ballast can be quite noisy. When you walk into a schoolroom in a quiet location, you can hear the total hum of the ballasts in the fluorescent fixtures. Normally, however, you will not notice this hum when the room is occupied. It is surprising how, even in a quiet schoolroom, the hum is masked by the faint noises the children make in breathing and stirring in their seats.

A noisy ballast can be located by turning off fixtures until you find the row or group in which it is located. Take out lamps until you find the exact fixture which has the noisy ballast.

## Failed Ballasts

An occasional ballast will fail after several years' operation. The ballast must be designed for the specific size and type of lamp used, as well as for the voltage and frequency of the electrical system. It is necessary to use the correct type of ballast to prevent filament damage which may cause burnout. In making a replacement, check the ballast being removed.

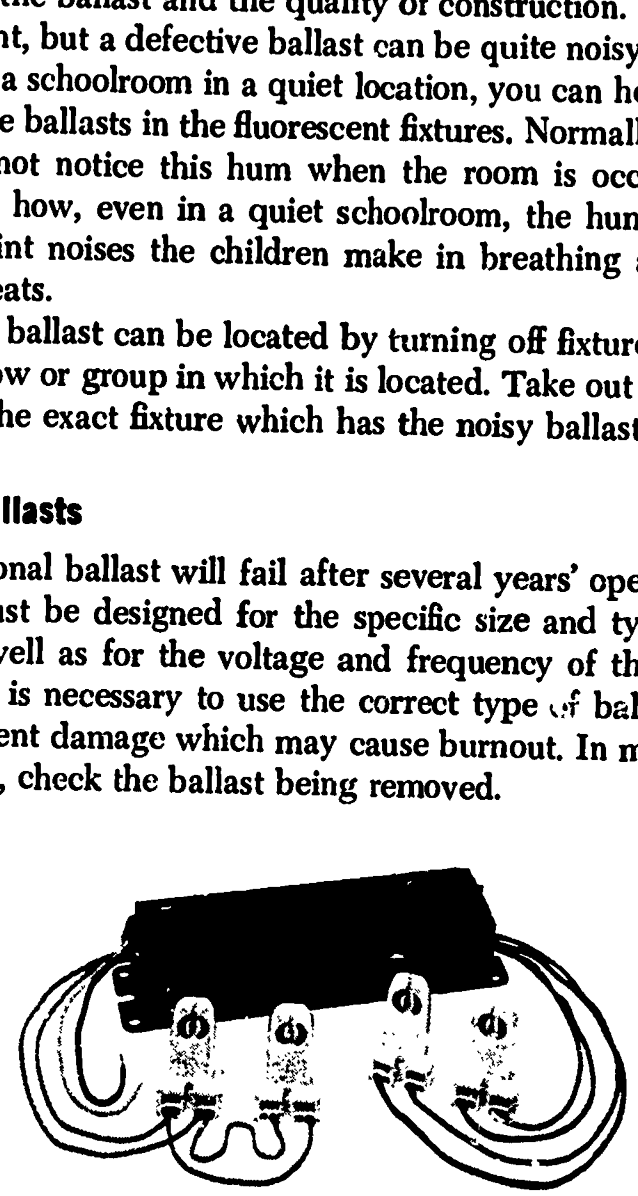


**Fig. 24** New ballast and socket kits make it easy to modernize old-fashioned 40 watt preheat fixtures, converting them to fast rapid start operation. These kits eliminate separate starters and replace old sockets. They also cut maintenance time. Kits are made by leading manufacturers and available at most electrical dealers.

### Ballast Socket Kits

Leading manufacturers offer ballast socket kits for 40 watt rapid start lamps as shown in Figure 24. Lampholders are already wired to the ballasts, so replacement is easy. If the ballast being replaced is preheat, it is still wise to use rapid start, since Sylvania Universal 40 watt lamps operate on either type of circuit, and starters will not be needed on the new circuit.

## MERCURY LAMPS

As with incandescent and fluorescent lamps, complaints of short life should be considered in terms of whether the installation is large enough to give a true picture. Note also the possibility of early failures mentioned in discussing mortality curves.

If the arc tube of a failed lamp is blackened, it is likely that the lamp has reached the end of its normal life.

A destroyed arc tube can mean that the lamp was operating on a defective ballast. If the arc tube appears to be all right but the lamp will not light, look for broken connections in the external circuit and inside the lamp. The ribbon connectors should look bright even after long life. If they have a blue or gray color, there is a leak in the outer jacket.

A crescent-shaped crack on a soft-glass bulb means that, while the bulb was hot, a drop of water struck the bulb at that point. All Sylvania mercury lamps are made of hard glass which minimizes this problem.

The usual practice of cleaning when relamping does not necessarily apply to mercury because of their exceptionally long life. In high bays where dirt accumulation is rapid and cleaning difficult, reflector lamps may be the wisest choice.

Simple records of lamp replacements should be kept to check lighting costs and operation. The "recording base" on all Sylvania mercury lamps makes this convenient.

When disposing of mercury lamps, break a few at a time, avoiding shattered glass. Break large numbers of lamps outdoors or under a well-ventilated exhaust hood to prevent breathing mercury vapors. Protective glasses should be worn.

# RECOMMENDED QUICK-REFERENCE TROUBLE-SHOOTING CHART

## FLUORESCENT LAMPS

When a fluorescent lamp fails to operate properly, it may be due to the lamp or trouble elsewhere in the lighting system. A check-up should be made to correct the trouble and possibly save the cost of a new lamp.

### IF LAMP DOES NOT START . . . Cause May Be:

**Poor contact** Twist lamp gently in lampholder with current on. If lamp flashes, there is probably a loose lead-wire or lampholder part.

**Defective starter** If using preheat lamps, replace starter. If the lamp still doesn't light, the socket contacts, wiring or ballast may be at fault.

**Burned-out lamp** Try a new lamp. If lamp was burned out, check service record to see if length of service approximates rated life. Early failure of rapid start lamps occurs usually where filaments have not been properly heated. Also defective starters shorten life by causing slow or rapid preheating, or repeated flashing.

**Faulty fixture** Try lamp in an operating fixture. If it lights, the fault was in the fixture from which it came. Check for the following:

**Dirty lampholders** Check for dust and dirt accumulation which attracts and holds moisture. It can slow or prevent starting of rapid start and slimline lamps. Prevent by regular cleaning of lamps and fixtures.

**Worn lampholder contacts** Replace with new lampholders.

**Defective ballast** If previous tests don't reveal the trouble, perhaps the ballast needs replacement. Check label to make sure it is the right type.

### IF LAMP BLINKS, FLASHES OR FLICKERS . . . Cause May Be:

**End of lamp life** Darkened ends and reddish glow indicate lamp needs replacement.

**Start of lamp life** New lamps sometimes flicker, swirl or "snake." This usually clears up after the lamp has operated for a while or has been turned off for a few moments. If it doesn't, check starter and ballast.

**Defective starter** Try a new lamp in place of the flickering lamp. If trouble persists replace with a new starter. If the new lamp still flickers, circuit and ballast should be checked for proper electrical characteristics.

### IF LAMP IS DISCOLORED . . . Cause May Be:

**Normal end darkening** This occurs late in life of any fluorescent lamp so it should be replaced.

**Early end darkening** If lamp is fairly new, check for a defective starter, wrong ballast, or incorrect circuit voltage, and correct the condition. A temporary condensation of mercury within the tube may also be responsible. This will correct itself when lamp is operated at proper temperature.

**Bands, rings, spots** These occasionally appear near lamp ends. They are usually small and have no effect on life or performance. Same is true of thin mercury condensation streaks along the bottom of lamp.

**Dark areas** If lamp ends remain lighted, but with long dark streaks along the tube, usually lamp is in path of cold air from air conditioning source, causing mercury condensation. Cold air stream should be diverted.

### IF LIGHTING FIXTURE HUMS . . . Cause May Be:

**Ballast** A certain amount of hum is normal. Unusually loud humming can often be corrected by making sure ballast mounting and attachments are rigid. If noise persists, replace ballast to prevent shortening lamp life.

## MERCURY LAMPS

### IF LAMP DOES NOT START . . . Cause May Be:

**Normal end of lamp life** Check service record to see if length of service reasonably approximates rated hours of life. If so, replace the lamp.

**Faulty circuit** Check wiring for open circuit, incorrect wiring, or inadequate voltage due to poor connections or improper wire size.

**Defective socket** Check socket for proper lamp seating and contact. Socket may show indication of arcing. Lamp base may be pitted or solder on base may be melted. Replace socket, and lamp if necessary.

**Low temperature at lamp** If lamp is operating at low temperature, and ballast is not rated for low-temperature operation, change the ballast.

**Lamp not adequately cooled** This only occurs on relighting. Lamp will relight when sufficiently cooled (4–7 minutes).

**Insufficient voltage** Increase supply voltage. If using tapped ballast, match ballast tap connection to supply voltage.

### IF LAMP FAILS PREMATURELY . . . Cause May Be:

**Lamp damage** Check for small cracks in the outer jacket from transportation or handling. Failure may not occur for several hundred hours.

**Bulb touching fixture or other object** Correct this. A socket extension may provide a temporary solution. Check effect of extension on optics and output.

### IF OPERATION IS INTERMITTENT . . . Cause May Be:

**Loose wiring, incorrect ballast, variable voltage** Check for loose connection. See if the ballast is correct. To eliminate voltage variation, separate the lighting from the power circuit. Provide voltage regulators.

**High-voltage lamp** Lamp not matched to ballast — replace with correct lamp.

### IF ARC TUBE IS CRACKED, BLACKENED OR SWOLLEN IN EARLY LAMP LIFE . . . Cause May Be:

**Overwattage operation** Check ballast, correlate with lamp type.

**Excessive current** See if lamp operated on unballasted circuit. Check for possibility of over-current or over-voltage which can shatter arc tube or its ends, or burn up connecting ribbons inside outer jacket. Check for over-wattage operation which can cause premature backening.

## INCANDESCENT LAMPS

Because incandescent lamps are more simple in operation than any other light source, they usually give satisfactory service with little attention. However, certain conditions may cause unsatisfactory performance.

**Lamp out** If there is considerable blackening, the lamp has reached the end of its normal life. The normal life can be shortened however, by over-voltage operation. If there is little or no blackening, consider whether the conditions call for a rough service or a vibration lamp.

**Low light output** Bulb may be blackened but lamp may be continuing to operate after normal failure point. Replace with new lamp. If there is little or no blackening, lamp may be operating under voltage. Check socket voltage.

**Short life** If a considerable number of lamps fail to average their rated life, they may be operating over-voltage. Check socket voltage.

**Blistered bulb** May occur in high-wattage lamps when used in fixtures which concentrate too much heat at the bulb.

**Cracks or checks** Can be caused by water or contact with cold metal. Hard-glass lamps should be used in exposed locations or outdoors.

## Chapter 10

# CLEANING AND CLEANING METHODS

Your lighting system will continue to deliver all the light it was designed to give only if it receives proper maintenance. This not only includes replacing burnouts but periodic cleaning too. Dirty lamps, fixtures, walls and ceilings lead to a gradual loss of light — as high as 50%. Meanwhile you continue to use and pay for the same amount of electricity.

A lighting maintenance program will prevent this. It should include periodic light meter checks of lighting levels to help schedule cleaning frequency . . . maintenance of the proper line voltage to avoid lighting inefficiency and damage to equipment . . . and prompt replacement of dead lamps.

Lamps should be wiped, fixtures washed, and walls and ceilings cleaned or repainted at scheduled intervals. Clean, light-colored walls and ceilings reflect and spread the light. Dark dirty ones absorb and waste it.

Use of labor-saving methods and equipment, plus a stock of spare lamps and parts, also helps cut maintenance time and costs to a minimum.

Methods of cleaning lighting equipment necessarily differ in different schools, depending upon available equipment and size and skills of crews. Except in very large school systems, it is probably not feasible to duplicate the methods of the professional maintenance organizations. Nevertheless, their methods offer a good basis for study and comparison; and many specific details are applicable to any school system.

Surfaces to be washed include plastic, glass, aluminum, and painted or enameled steel. Lamps, diffusing panels and louvers should be removed and washed at floor level. Where reflecting surfaces are fixed, they must be washed in place.

Use detergents to avoid rinsing. Do not use ammoniated prod-

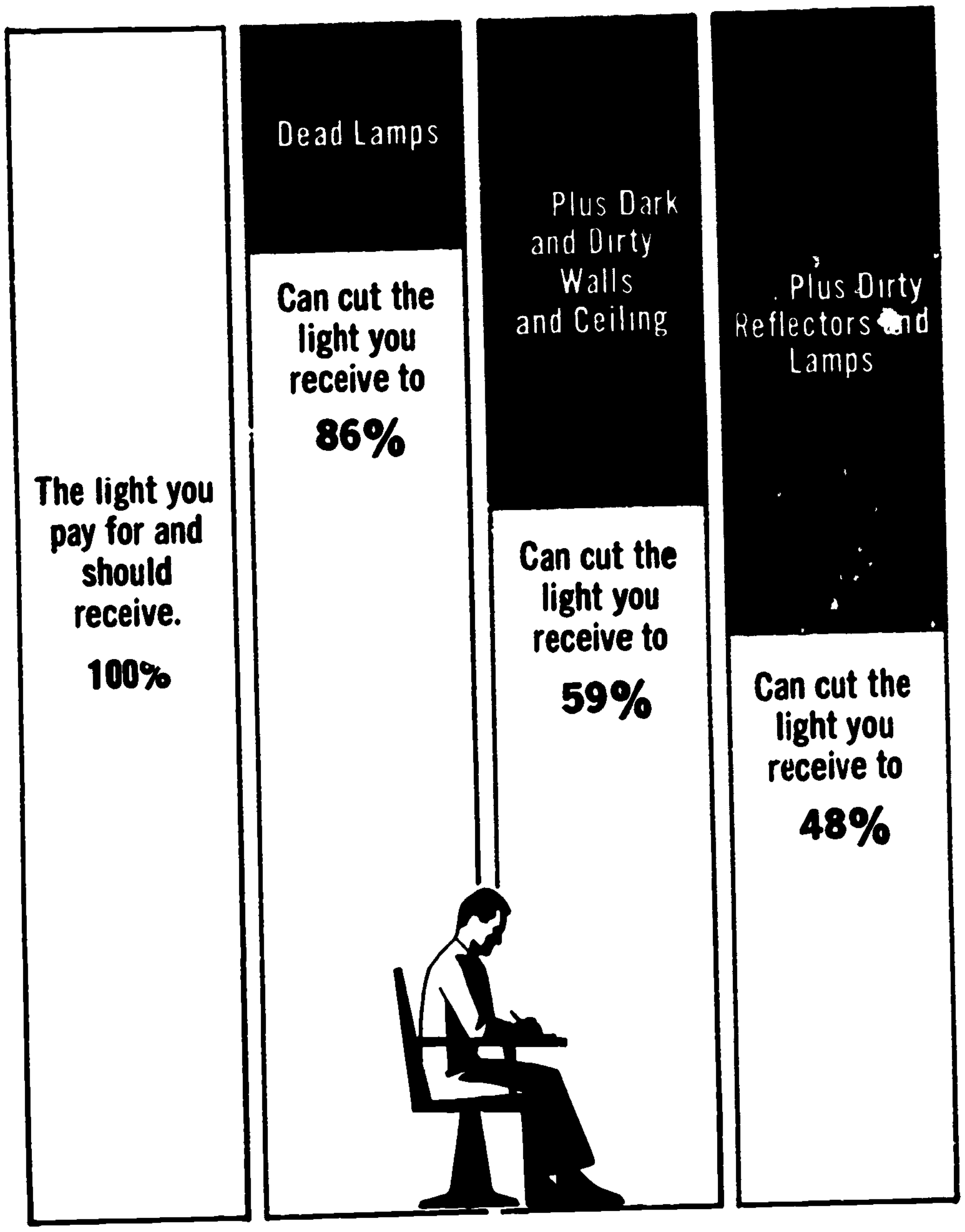



Fig. 25 Light Loss Chart for a typical lighting installation after 5000 to 6000 hours of operation.

ucts on painted surfaces. The most important ingredient is "elbow grease." Water softeners, wetting agents and destaticizers may be added where conditions indicate their desirability. The parts should be washed in one tank, then, if desired, rinsed in another, then air dried. For washing use lint-free cloths such as shop towels or turkish towels. For plastic panels, the final rinse water should contain a destaticizer, so the panels will not accu-

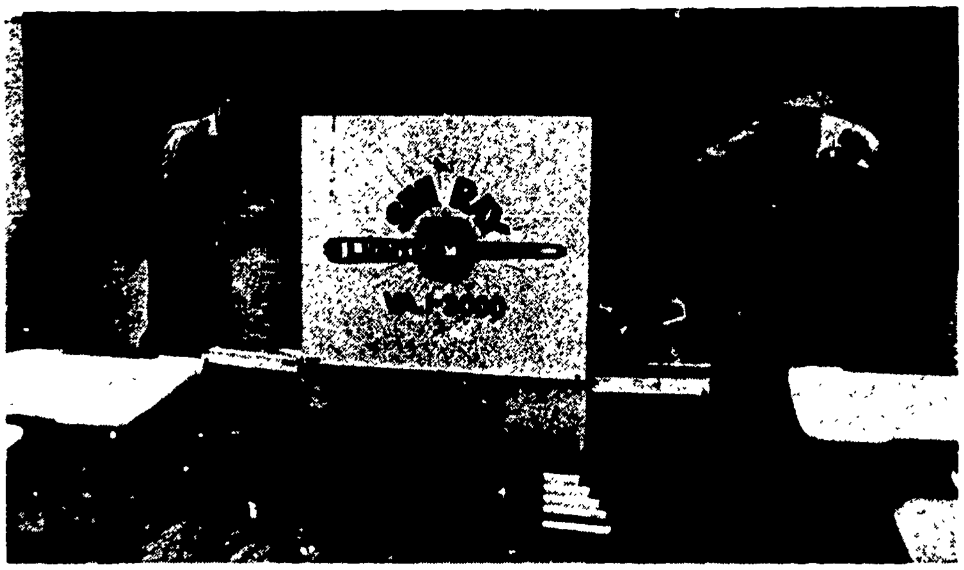


Fig. 26 Maintenance crew machine-washing fluorescent fixture louvers.

mulate static electricity and thereby attract dust. Do not under any circumstance dry wipe or rub plastic parts since this creates static electricity.

Some professional maintenance organizations use machines especially designed for washing fluorescent parts, but it is unlikely that these would be of value to a school system doing its own cleaning, unless the system was very large and used a trained crew on a year-round cleaning program, or where in the case of multiple locations, full utilization of the device could be obtained on a rotation basis.

Another method used by many professionals, but probably not appropriate for school department crews, involves the use of stilts, as shown in Figure 27. (They would certainly appeal to the imagination of the school children, however.)

Where a few widely spaced incandescent fixtures light a classroom, the use of a stepladder is common, but a day of going up and down a ladder can be quite tiring. Where fluorescent fixtures are involved, the use of a rolling scaffold or staging is recommended, as in Figure 28.

If a school has modern lighting, it is also likely to have furniture which is not fastened to the floor. When the furniture is pushed aside or stacked in the summer, there is a good opportunity to use an efficient type of rolling scaffold or staging. However, the advantage of a rolling scaffold is that it can straddle desks and chairs so they need not be removed.

**Fig. 27 Cleaning lighting fixtures from stilts.**

**Fig. 28 Cleaning fixtures with rolling scaffold.**

The size of crew is subject to variation, but at least one man in each crew should know all of the jobs. Tables IV and V show combinations which have been used successfully. Figure 29 shows a suggested work pattern for a two-man crew with one stepladder.

If the fixtures are unusually dirty, a professional maintenance organization will sometimes strip a considerable area at once in assembly-line fashion, wash the parts, and then reassemble them.

Any lamps which appear to be near end of life, should be replaced at time of cleaning.

**TABLE IV**

**POSSIBLE CREWS FOR CLEANING FIXTURES WITH 4-FOOT LAMPS**

| Total Crew | Equipment | Men Up | Passing Lamps & Moving Staging | Washing |
|---|---|---|---|---|
| 2 | 1 Stepladder | 1 | 0 | 1 |
| 3 | 2 Stepladders | 2 | 0 | 1 |
| 3 | 1 Rolling Stage | 1 | 1 | 1 |
| 4 | 2 Rolling Stages | 2 | 1 | 1 |

**TABLE V**

**POSSIBLE CREWS FOR CLEANING FIXTURES WITH 8-FOOT LAMPS**

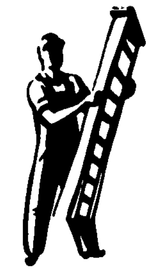
| Total Crew | Equipment | Men Up | Passing Lamps & Moving Staging | Washing |
|---|---|---|---|---|
| 3 | 2 Stepladders | 2 | 0 | 1 |
| 3 or 4 | 1 Rolling Stage | 1 or 2 | 1 | 1 |
| 4 | 2 Rolling Stages | 2 | 1 | 1 |

## SUGGESTED WORK PATTERN FOR 2-MAN CREW WITH ONE STEPLADDER

1 Man on ladder removes lamps and passes them down to man on floor.

2 Man on ladder removes reflectors and/or glass parts and passes them down to man on floor, who in turn passes up spare fixture parts previously cleaned.

3 Man on ladder secures clean fixture parts in place. Meanwhile man on floor wipes off the lamps which he passes back to man on ladder.



4 Man on ladder reinstalls lamps and sees that the fixture is working properly. He has a pocketful of starters to replace defective starters in case the lamps do not start promptly.

5 Man on ladder descends and puts ladder under next fixture.

6 Meanwhile man on floor washes and dries the fixture parts from the first fixture and has them ready to replace the soiled parts in the second fixture.

7 This procedure is repeated throughout the entire area.

If you'd like more information on how to get better performance from your present school lighting system – get in touch with the Sylvania District Sales Office in your area. A helpful free booklet: "How Group Relamping Slashes Lighting Maintenance Costs" (FL-709) is yours on request.

You may also wish to send for the booklet, "Organizing the Maintenance Program," published by the Department of Health, Education and Welfare. The price is 50¢. Write to Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

For additional information on lighting maintenance contractors in your area, write to the National Association of Lighting Maintenance Contractors, 2120 Keith Building, Cleveland, Ohio.