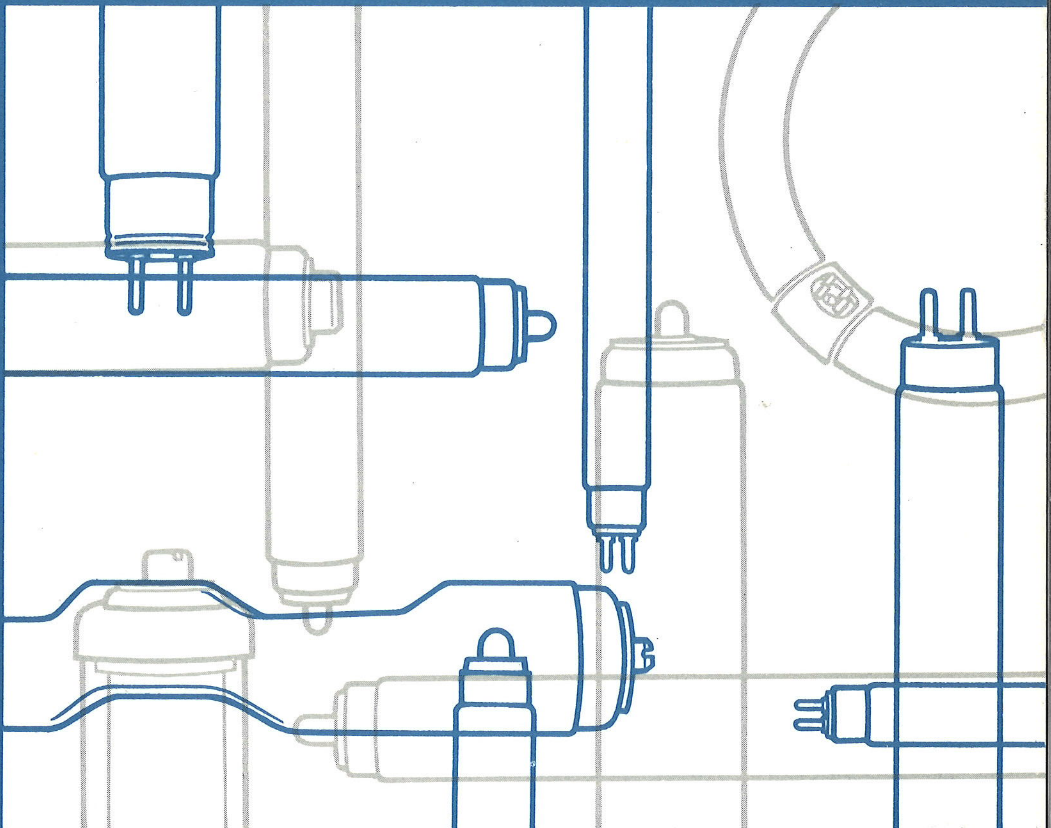
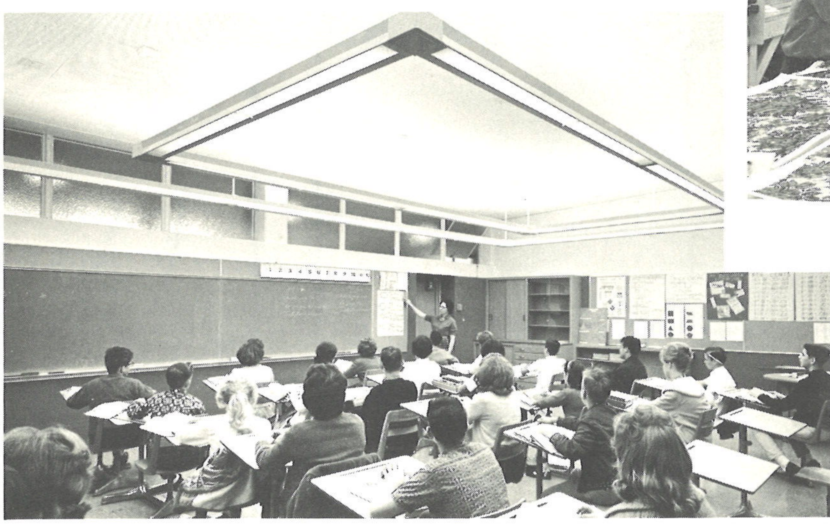
# *fluorescent*
# LAMPS



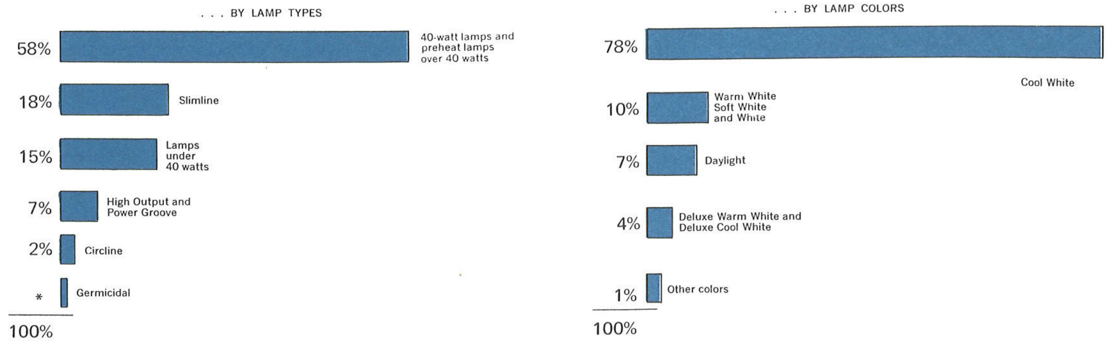
TP-111

LARGE LAMP DEPARTMENT

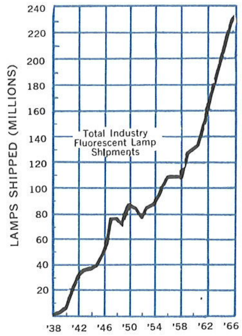
GENERAL ELECTRIC

## 1969 Sales of General Electric Fluorescent Lamps
(in approximate percentages)




* Less than ½%




Millions of fluorescent lamps are used annually in commercial, institutional, industrial, and residential lighting. In fact, for nearly a decade fluorescent lamps have produced more than half of the electric light used in the United States. The main reasons for the popularity and wide application of fluorescent lamps are these:

- High efficiency in producing light, resulting in lower lighting costs.
- Long lamp life and ease of maintenance.
- Relatively low surface brightness and heat content for visual and thermal comfort.
- Wide choice of sizes, shapes, and colors.

Fluorescent lamps were first introduced commercially by General Electric in 1938. Four sizes of 15, 20, and 30 watts were made available in daylight and white phosphors plus several saturated colors. Prior to that time, a number of laboratory models had created interest and were used by research scientists. In fact, Thomas Edison devised a fluorescent lamp in 1896, but it was not a practical device.

# FLUORESCENT LAMPS

From its beginnings in 1938, the fluorescent lamp has undergone amazing changes and improvements. Intensive research work on components, manufacturing methods, and operating systems continues to make significant advances in fluorescent lighting each year.

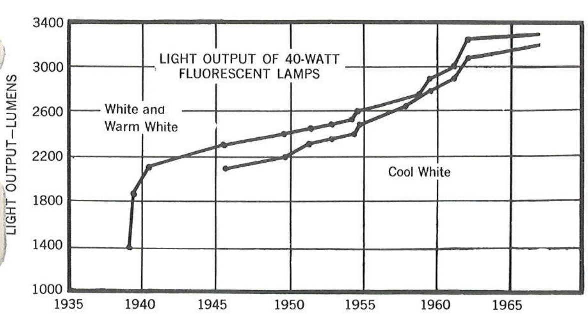
Instead of only four sizes of lamps, there are now available dozens of standard sizes ranging from 6 to 96 inches in length and consuming from 4 to 215 watts. Many sizes are made for special-purpose applications. From a beginning with lines of light, fluorescent lamps are now also made in circular and U-shaped forms.

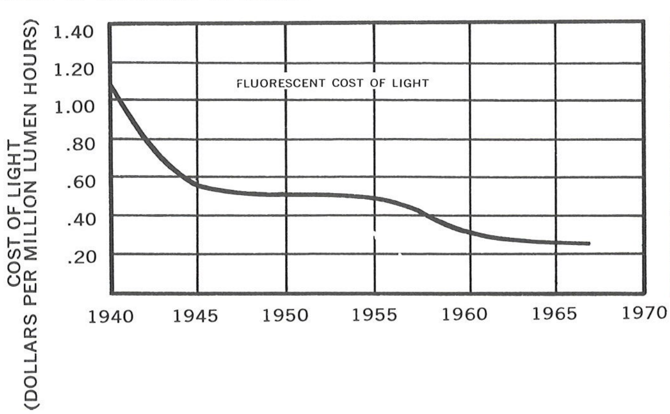
Today, fluorescent lamps are available in eight shades of white light, eight common tints and colors, and several special energy distributions. The most widely used of these are a few of the white shades. In fact, Cool White represents more than three-fourths of all General Electric fluorescent lamp shipments.

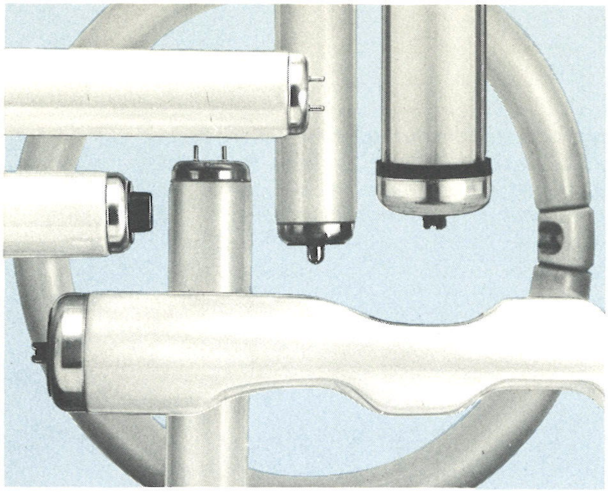
Improvements in fluorescent lamp light and life have been remarkable. Since 1950 alone, the 40-watt Cool White fluorescent lamp has increased 48% in initial light output. This has been coupled with significant improvements in light output through life, and greatly increased average life as well.

Significant changes have been made over the years in the circuits which operate fluorescent lamps, too. The first fluorescent lamps used bulky and relatively complicated auxiliary equipment – ballasts and starters. Modern ballasts are smaller, lighter, and more reliable. For the newer types of lamps the number of auxiliary parts has also been reduced.

This record of constant development and improvement is largely responsible for the remarkable growth curve shown at the upper left. The prospect for future developments is still bright, so the curve can be expected to continue to climb.





# Fluorescent Lamp Parts

Basically, a fluorescent lamp is made up of the following components: 1. A glass tube, or bulb, internally coated with fluorescent material called phosphors. 2. Electrodes supported by a glass mount structure, and sealed at the ends of the tube. 3. A filling gas to aid starting and operation – usually argon, or argon with neon. 4. A small amount of mercury which vaporizes during lamp operation. 5. A base cemented on each end of the tube to connect the lamp to the lighting circuit.

In order to produce fluorescent lamps of high light output, long life, and good maintenance of light output through life, careful control must be maintained over the selection, purity and assembly of all the components of the lamps. Some of the principal characteristics and requirements on the components are these:

**Tube:** Acts as airtight enclosure for the mercury, the filling gas, the cathodes, and the phosphor coating. Glass must be free of structural defects and cleaned before lamp assembly.

**Bases:** Connect the lamp to the electric circuit, and support the lamp. Lamps for preheat and rapid start circuits use two contacts on each end of the lamp. The bipin base is used on all preheat and many rapid start lamps. Some rapid start type lamps, such as high output and Power Groove® lamps, used recessed double-contact bases because of the higher ballast voltage required with lamps longer than 4 feet. Instant start lamps require only one electrical contact on each end of the lamp; thus the single-pin base is most commonly used. Some instant start lamps use bipin bases with the two contacts connected together inside the lamps.

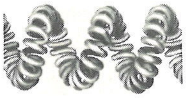
**Mount Structures:** Close off ends of the tube and support each cathode. Wires leading from base are sealed off here. These wires are made of special metal, called Dumet wire, which has virtually the same coefficient of expansion as glass. The mount structure also includes a long glass exhaust tube; during manufacture, air is pumped out of the bulb, and the filling gas and mercury are inserted. The exhaust tube is then cut and sealed off so that it fits inside the base.

**Cathodes:** Cathodes provide terminals for the arc and a source of electrons for lamp current. In some lamps they function alternately as cathodes and anodes, but are commonly called cathodes. In other lamp designs, separate anodes are used because they best fit lamp design requirements. Plate anodes in High Output lamps and wire anodes in Power Groove® lamps are used to reduce the wattage loss at the lamp ends. Cathodes are usually made of coil-coiled, triple-coiled, or stick-coiled tungsten, like an ordinary lamp filament, except coils are filled with alkaline-earth oxides. These oxides emit electrons more freely, thus minimizing losses and keeping efficiency high.

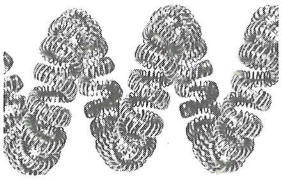
**Mercury Vapor:** Droplets of liquid mercury are placed in the fluorescent tube during manufacture. During lamp operation, the mercury vaporizes to a very low pressure (about 1/100,000th of atmospheric pressure). At this pressure, the current through the vapor causes the vapor to radiate energy most strongly at one specific wavelength in the ultraviolet region (253.7 nanometers). Higher mercury pressures tend to reduce the production of this ultraviolet line. The mercury pressure during operation is regulated by the temperature of the bulb wall.

**Filling Gas:** Besides mercury, the tube also contains a small quantity of a highly purified rare gas. Argon and argon-neon are most common, but sometimes krypton is used. The filling gases ionize readily when sufficient voltage is applied across the lamp. The ionized filling gas quickly decreases in resistance allowing current to flow and the mercury to vaporize.

**Phosphor Coating:** Transforms 253.7-nanometer radiation into visible light. The fluorescent lamp gets its name from the fact that the phosphor coating fluoresces. The chemical make-up of the phosphor determines the color of the light produced. Phosphor particles in fluorescent coatings are extremely small – approximately 0.0007 inch in diameter. Careful control of phosphor particle size is necessary to obtain high lamp efficiency.

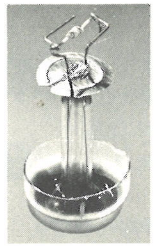


Coiled Coil

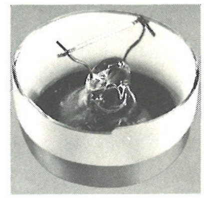


Triple Coil

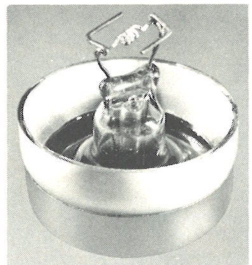
Stick Coil



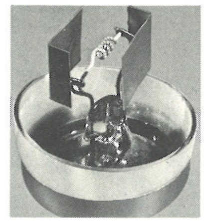
T-12 1500 Miliampere



Rapid Start without Anodes

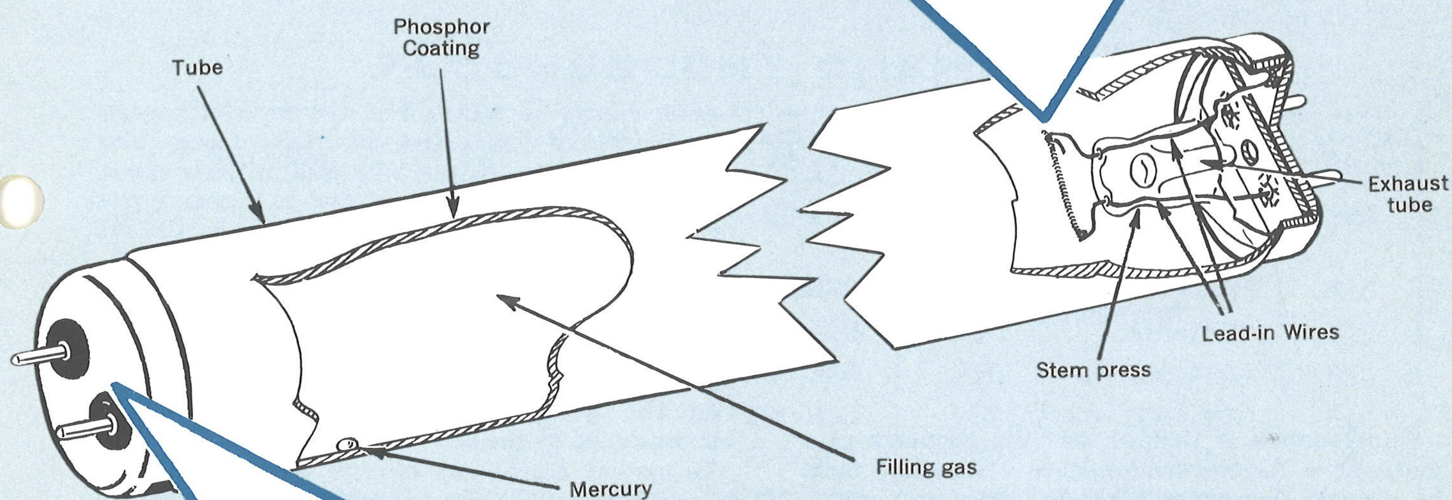


Power Groove with Wire Anodes

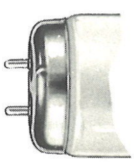


High Output with Plate Anodes

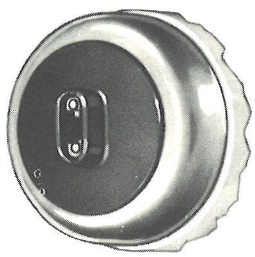
## CATHODE



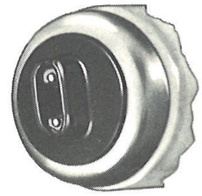

## BASE



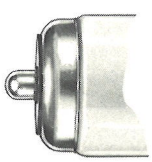
T-12 Med. Bi-Pin



PG-17 Recessed Double Contact

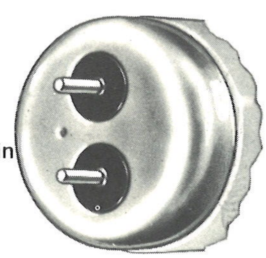


T-12 Recessed Double Contact



T-12 Single Pin

T-10 All Weather Recessed Double Contact

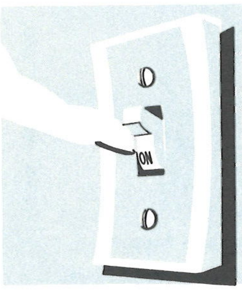


T-17 Mogul Bi-Pin

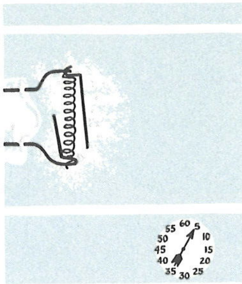

T-5 Min. Bi-Pin

# How Fluorescent Lamps Work

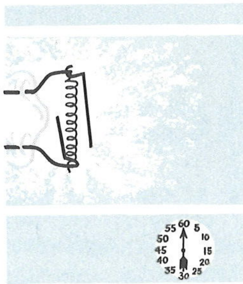
Circuit is energized.



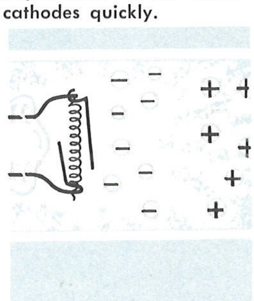

Electrons released from cathode by one of three means:



Preheat circuit heats cathodes slowly.

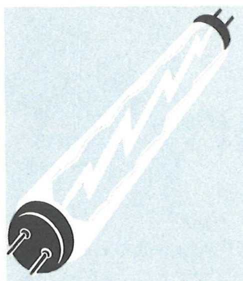


Rapid start circuit heats cathodes quickly.

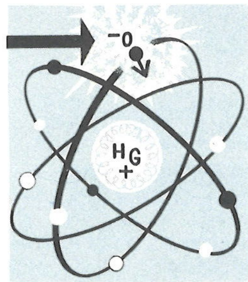


Instant-start circuit voltage draws electrons from cathodes.

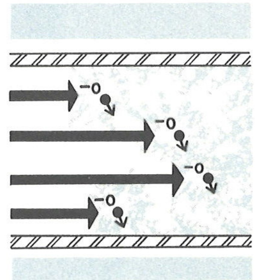
Excess electrons ionize starting gas, reducing tube resistance; arc strikes.



Flow of electrons in arc disturbs electrons in mercury atoms; they shift, giving off radiation.




Radiation from electron collisions is absorbed by phosphor, causing it to glow.



**Fluorescence** is defined as "the property of a material to become self-luminous when acted upon by radiant energy, such as ultraviolet or X-rays." This definition pinpoints the two essential elements required in a fluorescent lamp: 1. A source of radiant energy. 2. A material that will fluoresce.

Many natural and synthetic materials exhibit fluorescence. In fluorescent lamps, the fluorescent powder is applied to the inner surface of the bulb, which is usually tubular in shape. The selection of the phosphors and additives, called activators, determines the characteristics of the emitted radiation, e.g. ultraviolet, colored light, or various shades of white light.

The source of radiant energy to act upon the fluorescent material is an electric arc which passes through mercury vapor within the glass bulb (or tube as it is often called). A fluorescent lamp starts when the voltage difference between the cathodes is sufficient to strike an arc in the filling gas. As the arc current passes through the vapor, it causes changes in the energy levels of electrons in the individual mercury ions. As the electrons change levels, energy is released in the form of several wavelengths of visible and ultraviolet energy. This energy is radiated to the tube wall, where some of it causes the fluorescent material to fluoresce and emit light. Less voltage is needed to strike the arc if the cathodes are heated.

In preheat circuits, current is permitted to pass through the cathodes for several seconds before voltage is applied between the cathodes. This voltage is supplied by the ballast (more on ballasts on Page 15). During operation the cathode temperature is maintained by the arc.

In instant start lamp circuits, sufficient voltage is applied to strike the arc without preheating the cathodes. Preheat and rapid start lamps could be started in this manner by simply applying sufficient voltage, but life would be reduced drastically because the cathodes sputter emissive material. Instant start lamps have cathodes specially designed to withstand starting while cold. After starting, the cathodes in instant start lamps are heated by the arc.

The rapid start circuit is utilized in all of the important new fluorescent developments. The rapid start circuit combines the features of the preheat and instant start circuits. Separate windings in the ballast heat the cathodes continuously; the lamps start almost instantly after the switch is turned on, but less voltage is required for starting than with instant start lamps of comparable length. Result: The annoying time delay of preheat systems is essentially eliminated and rapid start ballasts are less expensive, smaller, and have lower losses than if instant start circuits were used for similar lamps.

# Phosphor Materials and Color

The inside of a fluorescent lamp is coated with a mixture of phosphors. Many compounds fluoresce when exposed to ultraviolet radiation, but for maximum efficiency the phosphors used should have maximum response near 253.7 nanometers because this is the wavelength most efficiently generated by the mercury arc.

Phosphors for use in fluorescent lamps have been selected with maximum sensitivity as near 253.7 nanometers as possible. The range 250-260 nanometers is considered ideal. The most commonly used phosphors (see table below) have their peak sensitivity very near this ideal range.

Calcium halophosphate is the basic phosphor used in white fluorescent lamps. Although the maximum sensitivity of calcium halophosphate occurs at 250 nanometers, this material is also highly responsive to 253.7-nanometer radiation. The maximum sensitivity of magnesium tungstate, which produces bluish-white light, occurs at about 285 nanometers; energy at 253.7 nanometers yields only about 80% as much light as the same amount of energy at 285 nanometers.

Suitable phosphors are available to produce a variety of shades of white and a number of colors of light. For some saturated colors, red, gold and deep blue, a pigment is applied to the tube before the phosphor coating.

**CONVERSION TABLE FOR FREQUENTLY USED WAVELENGTH UNITS**

| Unit | Equals | Exponential Notation |
|---|---|---|
| 1 millimeter (mm) | one thousandth of a meter | $10^{-3}$ |
| 1 micrometer ($\mu$m) | one millionth of a meter | $10^{-6}$ |
| 1 nanometer (nm) | one billionth of a meter | $10^{-9}$ |

NOTE: current engineering practice favors the use of the units shown for dimensions. Some older terms superseded by this practice are: **micron** (equivalent to micrometer); **millimicron** (equivalent to nanometer); and **Angstrom unit** (equivalent to 1/10 of a nanometer).

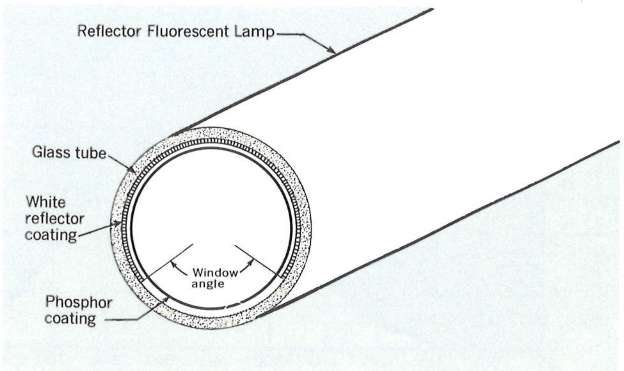
## FLUORESCENT CHEMICALS

| Phosphor | Lamp Color | Exciting* Range | Sensitivity Peak* | Emitted Range* | Emitted Peak* |
|---|---|---|---|---|---|
| Barium Silicate | Black Light | 180–280 | 200–240 | 310–400 | 346 |
| Barium — Strontium — Magnesium Silicate | Black Light | 180–280 | 200–250 | 310–450 | 360 |
| Cadmium Borate | Pink | 220–360 | 250 | 520–750 | 615 |
| Calcium Halophosphate | White | 180–320 | 250 | 350–750 | 580 |
| Calcium Silicate | Orange | 220–300 | 253.7 | 500–720 | 610 |
| Calcium Tungstate | Blue | 220–300 | 272 | 310–700 | 440 |
| Magnesium Tungstate | Blue-White | 220–320 | 285 | 360–720 | 480 |
| Strontium Halophosphate | Greenish-blue | 180–300 | 230 | 400–700 | 500 |
| Strontium Ortho Phosphate | Orange | 180–320 | 210 | 450–750 | 610 |
| Zinc Silicate | Green | 220–296 | 253.7 | 460–640 | 525 |

*nanometers

## DIRECTIONAL FLUORESCENT LAMPS

Several sizes of fluorescent lamps are available with an internal white reflector on part of the inner surface to provide built-in light control. The unreflectorized portion of the tube is called "the window." Candlepower in the direction of the window is significantly increased; however, total light output is reduced. Except in applications with special requirements, regular lamps with an efficient fixture will usually provide better performance. For certain applications, special fluorescent lamps are made with both the reflector and the phosphor coating removed from the window aperture.



# Fluorescent Lamp Spectral

The relative energy output of various types of 40-watt fluorescent lamps is shown. The smooth curves represent only the light resulting from phosphor excitation. Some visible light is generated directly by the mercury arc, and the bars added to the top of each curve show where this energy is concentrated.

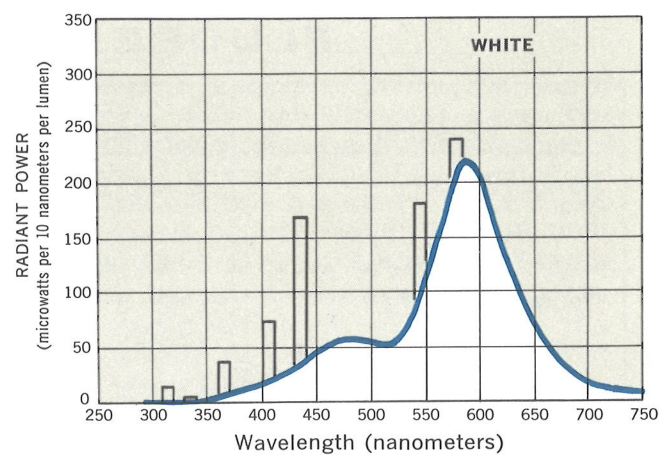
Appearance of the light source alone does not indicate how colors will look when lighted by it. It is possible to make a light source that looks white itself, and makes white surfaces and objects look white, but renders colors poorly. Since their introduction, fluorescent lamps have been greatly improved in color rendition. After many years of research on phosphors, a line of white fluorescent lamps evolved that meets nearly all needs for white light. This line consists of the eight lamp types represented by the curves on this spread.

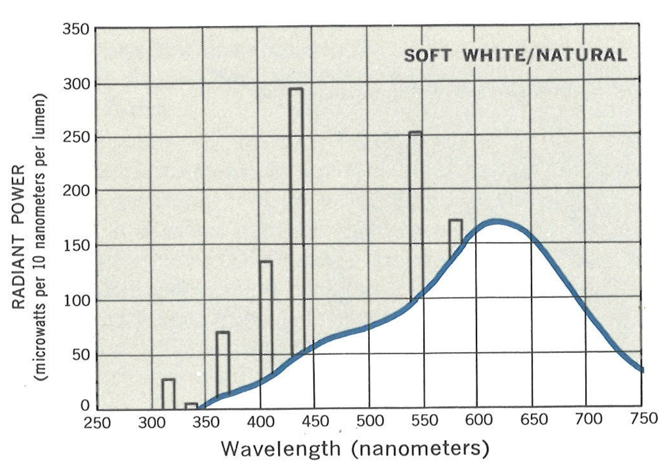
Fluorescent lamp color choice takes into account three elements important in lighting effects: 1. Luminous efficacy (lumens output per watt input), 2. Color rendition; 3. Whiteness. The choice among fluorescent "whites" always involves a compromise among these three items. Obtaining best color rendition necessitates reduction in efficacy. Choice of whiteness affects both efficacy and color rendition for most applications.

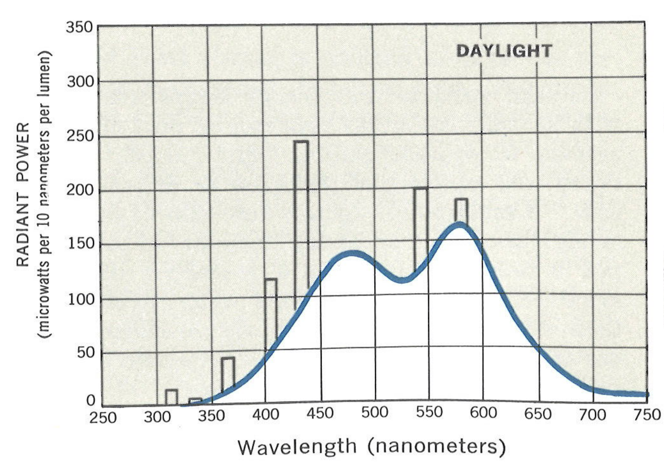
Cool White, Warm White, White, and Daylight lamps are designed for highest efficacy consistent with acceptable color rendition for most applications. These lamps are relatively weak in red rendition.

Deluxe Cool White and Deluxe Warm White lamps are designed to give colored materials and complexions the most natural and complimentary appearance, at reasonable efficacy. In these lamps, the spectrum is given better balance by the addition of red light to the output. The human eye is less efficient in response to red energy, which constitutes a higher proportion of the energy from Deluxe lamps; thus luminous efficacy is reduced. Deluxe lamps give about 30% less light than the standard lamps, but the difference usually does not appear so great because of the increased vividness of colors. Soft White Natural is used where there is a desire for light rich in red and having an overall pinkish cast. Sign White is designed for plastic signs and other applications where a cool, "crisp" white light with good color rendition is desired. It is between Cool White and Daylight in whiteness and provides better color rendition than either.

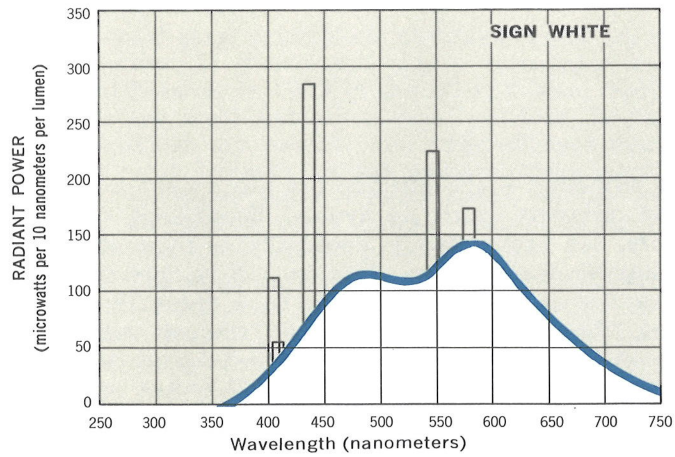
Plant-Light lamps yield greater red and blue light, enriching plants and flowers by accenting blossoms and green foliage.

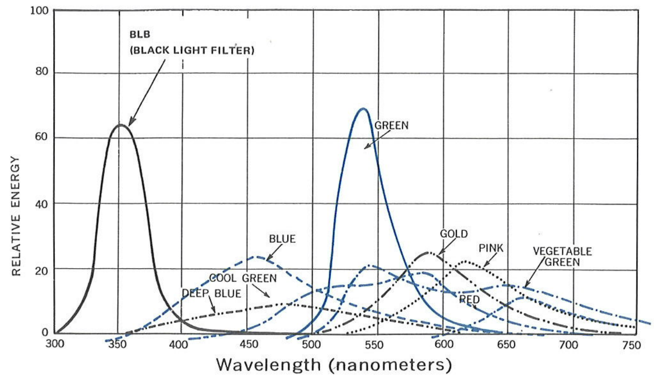


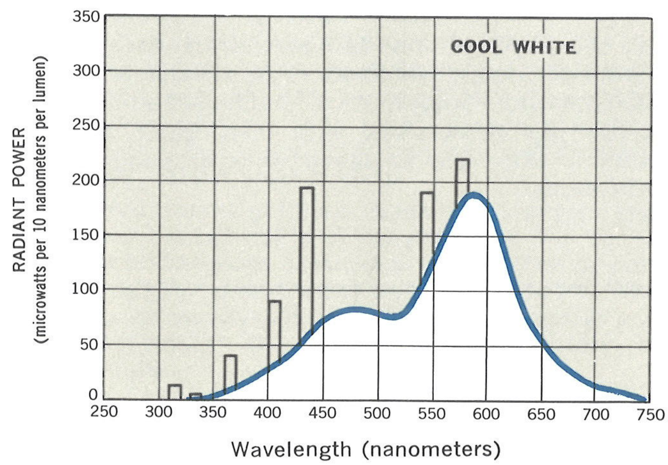



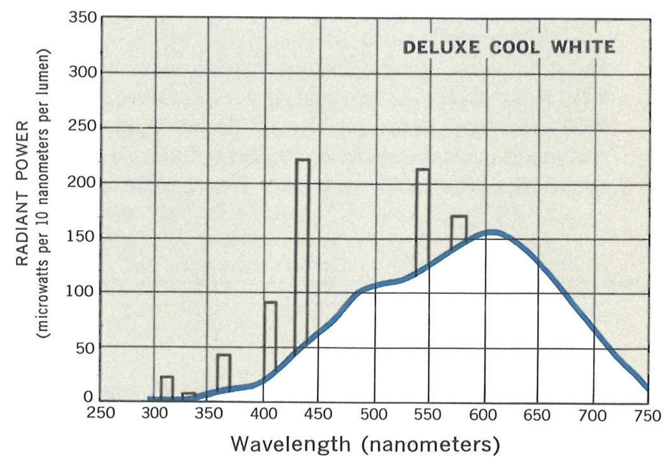
# Data

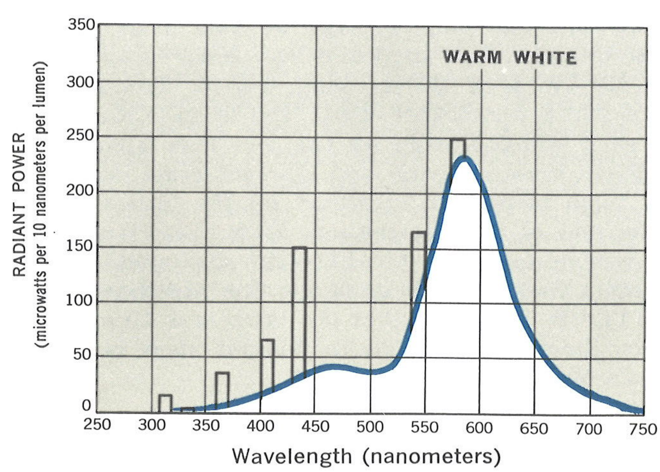


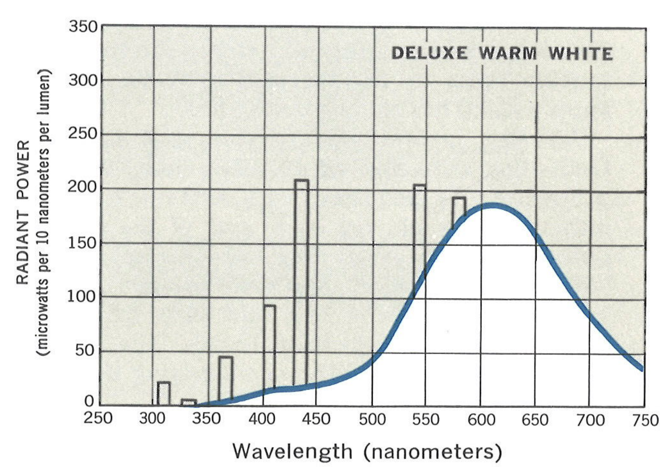




These curves show the relative energy outputs from colored fluorescent lamps of equal wattage. They represent only the energy transferred by phosphor conversion. Some energy generated by the mercury arc source is originally in the visible region. This direct generation of light represents less than 10% of the lumen output, but does influence phosphor composition for final result. This applies to all but the gold and red lamps, in which the colored coatings inside the bulb absorb not only the directly radiated mercury but also the shorter wavelength generated by the phosphors.



# Classes of Fluorescent Lamps

## Preheat Lamps

Early fluorescent systems were all of the preheat type, requiring separate starters. Several seconds of heating time were necessary between the time current to the lamp was turned ON and the time the lamp lighted. Sometimes called general line lamps, the preheat fluorescent types all have bipin bases. Some rapid start lamps and a few of the instant start types are manufactured with bipin bases, also. Sizes of preheat lamps range from 4 to 100 watts, in lengths from 6 inches to 5 feet. The 40-watt size is the most widely used of the preheat types.

The cathodes of the preheat lamp are preheated to emit electrons before the arc strikes; this is where the name "preheat" comes from. This type of lamp operation is also referred to as switch-start or starter-start.

The preheating process requires a few seconds. It is usually accomplished by an automatic starter which applies current to the cathodes of the lamp for sufficient time to heat them, and then automatically removes the current from the cathodes causing the voltage to be applied between the cathodes — and striking the arc. In some preheat systems, such as typical fluorescent desk lights, the preheating is accomplished by pushing a manual start button. This button is held down for a few seconds. During this time, the cathodes heat. When the button is released, the arc strikes. Preheat lamps are usually identified by wattage, bulb diameter (in eighths of an inch), and color. Thus a lamp marked F15T8/CW is a 15-watt, 1-in. diameter, Cool White fluorescent lamp. With preheat lamps designed for appliance service, wattage varies widely depending on the ballast. These lamps are identified by length instead of wattage. For example, F26"T8 for a lamp 26 inches long, 1-in. diameter.

Ballasts are available to operate certain preheat lamps without using starters. These ballasts use the rapid start principle of starting and operation. They are designed around the characteristics of the preheat lamps involved. These ballasts are popularly called "trigger start" ballasts. Full rated lamp life will be obtained with these rapid start ballasts if they are designed to meet published specifications.

## Instant Start Lamps

To overcome the slow starting of the preheat system, General Electric introduced instant start lamps in 1944.

In addition to starting as soon as current to the lamp is turned on, instant start lamps also eliminate the need for starters, and thus simplify the lighting system and maintenance.

In instant start lamps, sufficient voltage is applied between the cathodes to break down the resistance of the lamp and strike the arc. The arc quickly heats up the fine wire cathodes, which then supply electrons to sustain the arc.

With the instant start system also came the introduction of lamps up to 8 feet long. Because no preheating is required with instant start lamps, only a single pin on each end of the lamp is required. Lamps with single-pin bases are called "slimline" lamps. A few instant start lamps use bipin bases; however, the lead wires from the pins are connected together inside the lamp. To eliminate the possibility of mistaking these lamps as preheat lamps, the lamps are marked "instant start." Instant start lamps with bipin bases cannot be used in preheat or rapid start circuits and vice versa.

Since slimline lamps can be operated at more than one current and wattage, they are identified by lamp length. The number following the F in the designation is the nominal lamp length in inches, rather than the lamp wattage as with most preheat lamps. For instance, a lamp marked F96T12/WW is a 96-in. long, 1½-in. diameter, Warm White fluorescent lamp. The lamp is identified as a slimline lamp by the fact that it has a single-pin base on each end. Instant start lamps with bipin bases are identified by the letters IS at the end of the designation. With these lamps, the number following the F in the designation is the lamp wattage. For example, the identification F40T17/CW/IS means that the lamp is a 40-watt, 2⅛-in. diameter, Cool White, instant start lamp. It has a bipin base.

# Rapid Start Lamps

The rapid start principle is the most recent basic development in fluorescent types. Introduced by General Electric in 1952 in the 40-watt size, rapid start lamps start quickly without starters. Rapid start ballasts are smaller and more efficient than instant start ballasts for the same wattage lamp. Lamps in rapid start circuits start almost as quickly as instant start lamps, and in a much shorter time than the older preheat lamps.

The rapid start principle utilizes low resistance cathodes which can be heated continuously with very low losses. Today, rapid start systems are the most popular and important fluorescent lighting systems in new installations. The rapid start principle also extends the use of fluorescent lamps into applications that were previously not possible – dimming and flashing.

For many years, General Electric made two 40-watt T12 lamps, either of which could be operated on rapid-start or preheat-start circuits. With advances in technology, both lamps achieved long life on either circuit. The regular lamp produced the highest output and lowest overall cost-of-light, while the alternate lamp produced slightly lower output but consumed less wattage.

Today's GE F40 Mainlighter* combines the advantages of both into a single lamp and gives more light and longer life at a lower operating cost than ever before possible in a single Standard 40-watt fluorescent. The Mainlighter can be used in rapid-start and preheat-start circuits.

The F40 Staybright* solves end-blackening – one of fluorescent lighting's oldest problems. An exclusive electrode design eliminates end-blackening permitting higher initial light output and better lifetime lumen maintenance. Both the Mainlighter and the Staybright are available in a variety of white colors.

Circline lamps are now of the rapid start design. These lamps also work satisfactorily in former preheat and trigger start systems. The high output circline lamp is designed for high current operation and uses a base which permits the connector to be approved for outdoor applications.

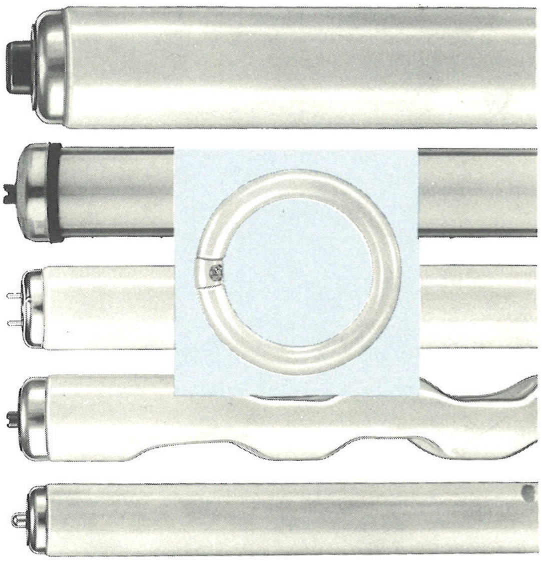
The rapid start principle provided the opportunity to increase fluorescent lamp loading with good system efficiency beyond the level of about 10 watts per foot, which is achieved at lamp current of 430 ma. Previously this was not practical due to the size, cost, and losses in the ballast.

The high output lamp was the first higher current rapid start lamp. High output lamps usually operate at 800 ma, an energy loading of about 14 watts per foot. At 800 ma these lamps produce about 45% more light than slimline lamps of corresponding physical size. For street lighting applications, high output lamps usually operate at 1000 ma to provide high light output at colder temperatures. High output lamps are identified by lamp length, bulb diameter, color, and HO (e.g., F96T12/CWX/HO).

Power Groove lamps also operate on the rapid start principle. Operating at 1500 ma, they are loaded to approximately 25 watts per foot. The unique bulb shape of the Power Groove lamp permits the higher loading without the use of special filling gases which can reduce life. The grooved bulb places a large portion of the phosphor near the arc to minimize internal losses. The double grooves actually increase the length of the arc 1 foot in an 8-foot lamp. Two of the grooves – one on each side near the center – are shaped to operate cooler than the rest of the lamp to keep the internal mercury pressure near the point for maximum output. The Power Groove lamp provides the highest light output of any fluorescent lamp available today. Power Groove lamps are identified by lamp length, bulb designation and color (e.g., F96PG17/CW).

All-Weather fluorescent lamps are rapid start lamps which also operate at 1500 ma. These lamps are designed to provide best performance in specific applications under low temperature conditions. See Page 19.

Newest in the General Electric line of rapid-start fluorescent lamps is the 40-watt Mod-U-Line* fluorescent lamp.† Blending compact, U-shape design with rugged construction, this lamp satisfies growing architectural demands for compact lighting fixtures in today's modular building design. Leg spacing of 3⅝ inches permits two or three lamps per 2-foot by 2-foot fixture, achieving flexible illumination levels while maintaining uniform brightness distribution. Using standard cost-comparing methods, two 40-watt Mod-U-Line lamps yield more light at 30 percent lower cost per footcandle than four 20-watt fluorescent lamps. Further savings are realized because all wiring and lampholders are at one end of the fixture reducing the number of system parts.



* Trademark of General Electric Company

† Made in West Germany

# Fluorescent Lamp Systems

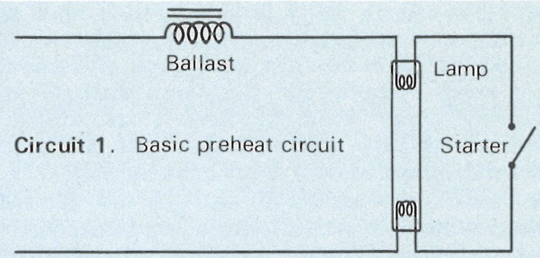
## Preheat Circuits

The components of a preheat fluorescent lamp system include a ballast, starter, starter socket, lamp and lampholders. When power is first applied to the circuit, the starter switch is closed and the lamp cathodes are connected in series with the ballast. The current which flows preheats the lamp cathodes. After sufficient preheat time elapses the starter switch is opened. This causes a high transient voltage between the cathodes which is sufficient to start the lamp.

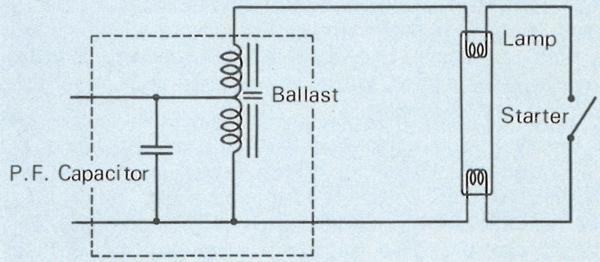
Preheating is used to help ionize gases in the tube, reducing the voltage required to strike the arc. While it is possible to start a preheat lamp without cathode heating by simply applying sufficient voltage, ballasts would be larger and more expensive and lamp life would be short because the cathodes sputter each time the lamp starts.

The starter switch may be manual, as shown in Circuit 1, or automatic. The manual starter is often used with small desk lamps. Three types of common automatic starters are described below.

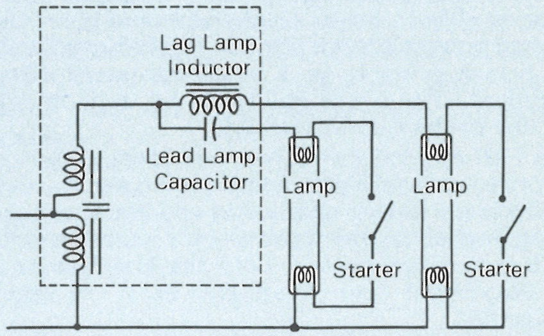
Circuit No. 1 uses only a choke to limit lamp current. Two other representative preheat circuits (No. 2 and 3) are shown at right; these circuits use autotransformers to limit current and increase voltage. The capacitor across the line in Circuit No. 2 corrects the power factor. In Circuit No. 3, a lead-lag system, the lamp circuit controlled by the capacitor has a leading power factor while the lamp circuit controlled by the inductor has a lagging power factor. Together the two circuits result is essentially unity power factor.



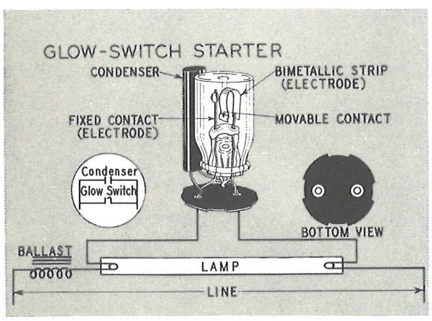

**Circuit 1.** Basic preheat circuit



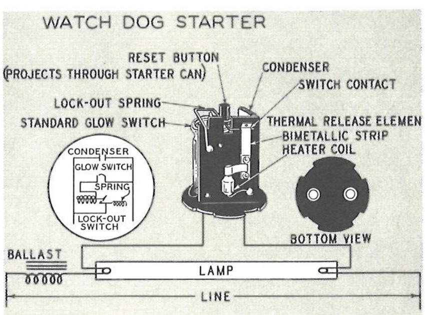

**Circuit 2.** Preheat circuit with autotransformer to step up voltage and capacitor to correct power factor




**Circuit 3.** Lead-lag preheat circuit

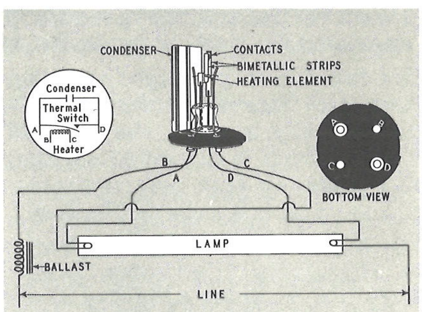



**GLOW-SWITCH STARTERS.** On starting, voltage at the starter produces a glow discharge. Heat from the glow discharge actuates the bimetallic strip, the contacts close, extinguishing the glow, and cathode preheating begins. When the bimetal cools sufficiently due to the elimination of the glow, the contacts open, and the lamp starts. During operation, voltage across the starter is too low to produce further glow; the contacts remain open.




**WATCH-DOG* STARTERS.** This type of starter automatically removes the glow switch from the circuit if the lamp fails to start after 15 or 20 seconds. This eliminates annoying lamp blinking, and conserves the life of the ballast. A new metal glow switch in the G-E FS-400 Watch-Dog starter reduces instant-starting tendencies of the 40-watt lamp on lead circuits. This tends to increase lamp life.

*Registered T.M.




**THERMAL-SWITCH STARTERS.** This type of starter is useful in operating conditions involving low temperature, direct current, or widely varying line voltage. It has a heating coil in series with the ballast and lamp. When voltage is first applied to the circuit, preheating occurs immediately since the thermal switch is closed. The heating coil actuates the bimetallic strip in the starter switch. After sufficient preheat time elapses, the thermal switch opens, and the lamp starts. During lamp operation a small amount of energy is consumed by thermal starters.

# Instant Start Circuits

Instant-start systems are composed simply of a ballast, lamp and lampholders. The ballast contains a transformer that provides sufficient open-circuit voltage to attract electrons from the cathodes without preheating. Instant-start lamps are made with cathodes specially designed to reduce the loss of electron-emitting materials caused by this method of starting. During lamp operation, a few turns of wire on each cathode become red hot to continue to provide free electrons efficiently.

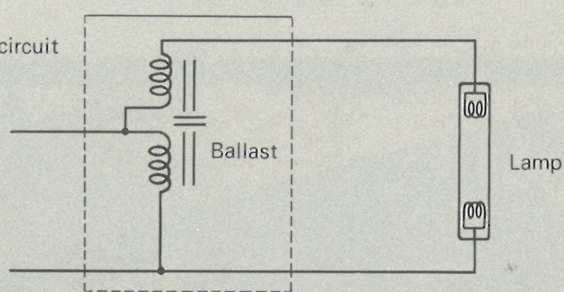
Slimline lamps, with single-pin bases, are the most common instant-start types, although some bipin-based lamps are designed for this service. They may be operated at different lamp currents (and wattages) with appropriately designed ballasts. T-6 and T-8 slimline lamps are usually operated at 200ma lamp current; the T-12 slimlines are usually operated at 425ma. Operation at higher currents usually increases output, while slightly decreasing efficiency. At lower currents, light output is decreased, but efficiency is slightly increased. A minimum current of about 120ma is necessary for sufficient cathode heating to maintain reasonable lamp life. Systems for continuously varying current (dimming) are not practical with instant-start lamps; generally, separate ballasts are required for each level of lamp current desired.

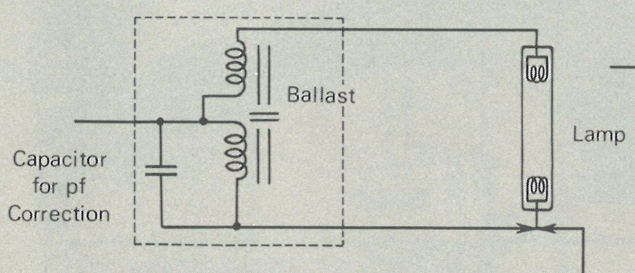
Because slimline lamps require relatively high voltages to start, lampholders are designed to reduce the hazard to maintenance personnel when the lamps are removed and installed. This is generally accomplished by having push-pull lampholders wired in the circuit so that the ballast is disconnected unless both ends of the lamp or lamps it serves are properly seated in position.

Circuit 4 shows the basic instant-start circuit, while Circuit 5 adds the disconnecting lampholder and power factor correction used in most common single-lamp circuits. Circuit 6 shows a two-lamp circuit designed to operate the lamps in series.

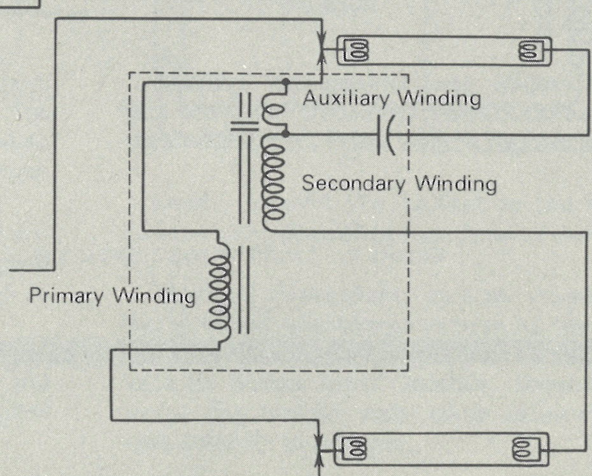
Originally, two-lamp slimline circuits were of the lead-lag type, operating lamps in parallel; one lamp was connected with a reactance having leading power factor, and the other with a lagging reactance, with the combination having a net high power factor. Today, most two-lamp slimline ballasts are designed to start the lamps in sequence a few thousandths of a second apart, and operate the lamps in series with a combination of reactances that has a slightly leading high power factor. The design of series-sequence ballasts has significantly reduced ballast size, cost and sound level, thus improving economics and pleasantness of lighting with instant-start lamps.

**Circuit 4.** Basic instant start circuit




**Circuit 5.** Instant start circuit showing disconnect lampholder




**Circuit 6.** Typical series instant start circuit

# Rapid Start Circuits

Ballasts for rapid start systems have separate windings to heat the lamp cathodes continuously. When the circuit is energized, these windings quickly heat the electrodes, causing sufficient ionization in the lamp for the arc to strike from the voltage of the main ballast windings. The immediate heating of the cathodes reduces the voltage necessary to strike the arc. This reduces ballast size and losses, and thus improves the efficiency of the system. The rapid start circuit eliminates the annoying flicker associated with starting of preheat systems. It also simplifies system maintenance since the starter and its socket are eliminated.

Rapid start circuits are used in the vast majority of new fluorescent installations today. High output, Power Groove, circline, All-Weather™, and the new panel fluorescent lamps are all designed specifically to operate in rapid start systems.

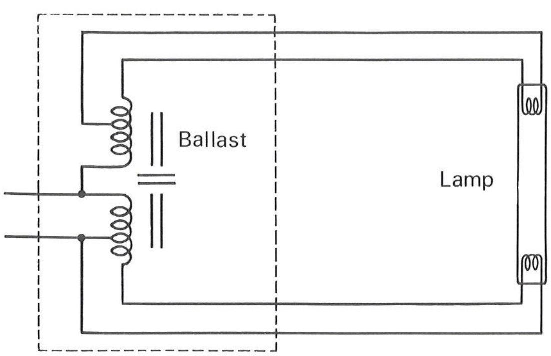
All rapid start lamps are coated with Dri-Film® silicone coating to aid reliable starting under conditions of high humidity.

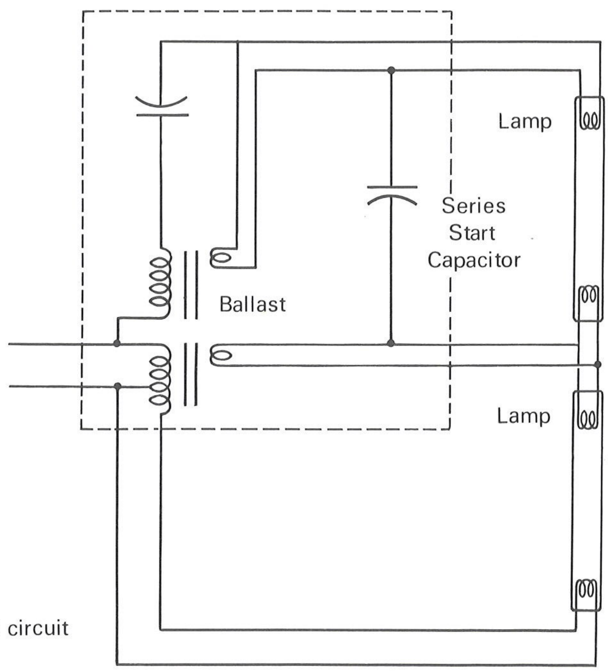
To assure reliable starting of rapid start lamps, an external starting aid is needed, except with the panel fluorescent lamp. This consists of an electrically grounded metal strip extending essentially the full length of the lamp. In most cases, the wiring channel or a reflector is used as the starting aid. The starting aid should normally be within 1 inch of the bulb wall (½ inch for circline). In the panel fluorescent lamp, the starting aid is applied to the back of the lamp during manufacture.

Typical rapid start circuits are shown. Circuit 7 is the simplest; note the tapped windings for heating the electrodes continuously.

The series circuit (Circuit 8) is the most common for multiple lamp ballasts. The capacitor across the top lamp aids in starting the lower lamp first; the voltage drop across the lower lamp after starting is very low; this places virtually the entire ballast voltage across the upper lamp for reliable starting. With this system, the starting voltage for both lamps need be only slightly higher than for one lamp.

**Circuit 7.** Basic rapid start circuit




**Circuit 8.** Two-lamp series lead circuit

# Auxiliary Equipment

## BALLASTS

The principal function of a ballast is to limit current to a fluorescent lamp. A ballast also supplies sufficient voltage to start and operate the lamp. In the case of rapid start circuits, a ballast supplies voltage to heat the lamp cathodes continuously.

A fluorescent lamp is an arc discharge device. The more current in the arc, the lower the resistance becomes. Without a ballast to limit current, the lamp would draw so much current that it would destroy itself.

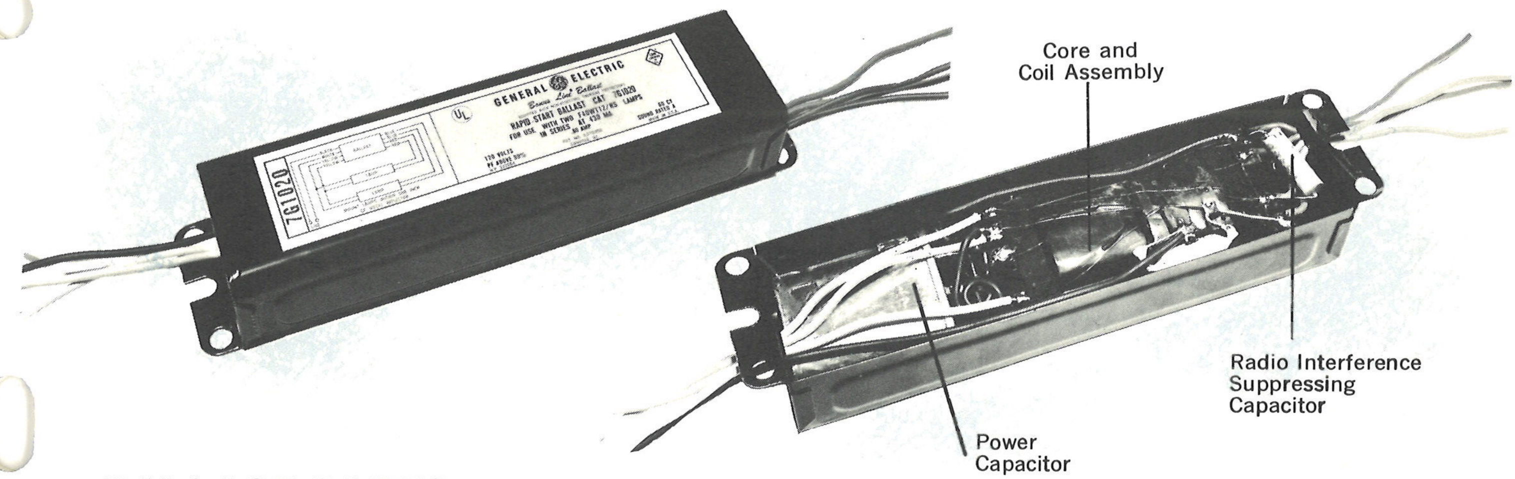
An inductive ballast constitutes the most practical solution to limiting lamp current. The simplest inductive ballast is a coil, inserted into the circuit to limit current. This works satisfactorily for lower wattage lamps. However, for most fluorescent lamps in use today, line voltage must be increased to develop sufficient starting voltage. Also, rapid start circuits require low voltage to heat the electrodes continuously. To meet these requirements, most ballasts today contain transformers.

The light output, life, and starting reliability of a fluorescent lamp depend greatly on the design of the ballast. The United States of America Standards Institute (USASI) specifies the requirements which are needed to provide good lamp performance. Many ballasts on the market today meet these specifications and produce excellent service and good light output from fluorescent lamps. However, some do not.

For these reasons, Certified Ballasts Manufacturers (CBM) was organized by a group of ballast manufacturers to assure the lighting user of obtaining ballasts which meet high performance standards, primarily in the areas of light output, life, and starting reliability. The CBM requirements are generally derived from USASI standards. Ballasts which feature CBM certification meet or exceed minimum specifications.

The National Electric Code requires class P ballasts in new indoor installations except for fixtures using choke ballasts.

The GE Ballast Dept. offers a useful publication on ballast selection, operation, and installation. Ask for publication GEA-7325 "What You Need To Know about Fluorescent Ballasts."




## BALLAST PARTS

**Core and coils** form the heart of the ballast. These parts stabilize operation of the lamp. The coils consist of many turns of insulated copper wire, wound closely together. The core is made of laminated steel.

**Power Capacitor** decreases the load on the distribution system by correcting the power factor. This minimizes current and allows more lamps to be installed on a given electrical system.

**Radio Interference-Suppressing Capacitor** reduces feedback of radio-frequency energy to the power lines. Without this capacitor, excessive noise might develop in nearby radios.

**Potting Compound** (not shown on drawings) fills the space inside the ballast case, improves heat dissipation, and helps reduce ballast sound.

**Leads** connect the ballast to the line and lamp. Color coding identifies functions of the leads.

**Thermal Protectors** detect excessive temperature which sometimes occurs at the end of ballast life, and permanently de-energize the ballast. Available in Bonus Line* models, these protectors remove the ballast only when failure is inevitable and actually in process.

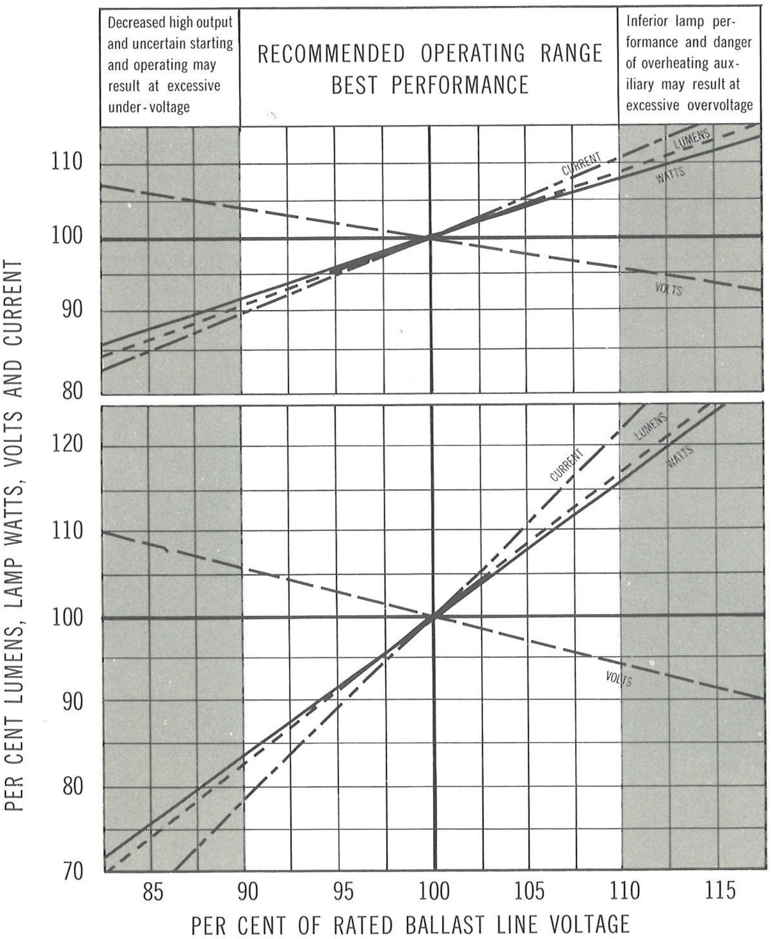
*Trademark

## BALLASTS (Continued)

Because fluorescent lamps are not connected directly to an electric power line, but are connected to a ballast, there is no specific voltage associated with any fluorescent lamp.

A ballast, however, does connect to the electric power line during operation. Therefore, ballasts carry specific voltage range ratings. Variable voltage conditions are encountered on most lighting circuits; thus ballasts and lamps must perform satisfactorily over a reasonable range of circuit voltage. Line voltage is also a factor in starting reliability. Therefore, voltage lower than recommended may cause unsatisfactory starting.

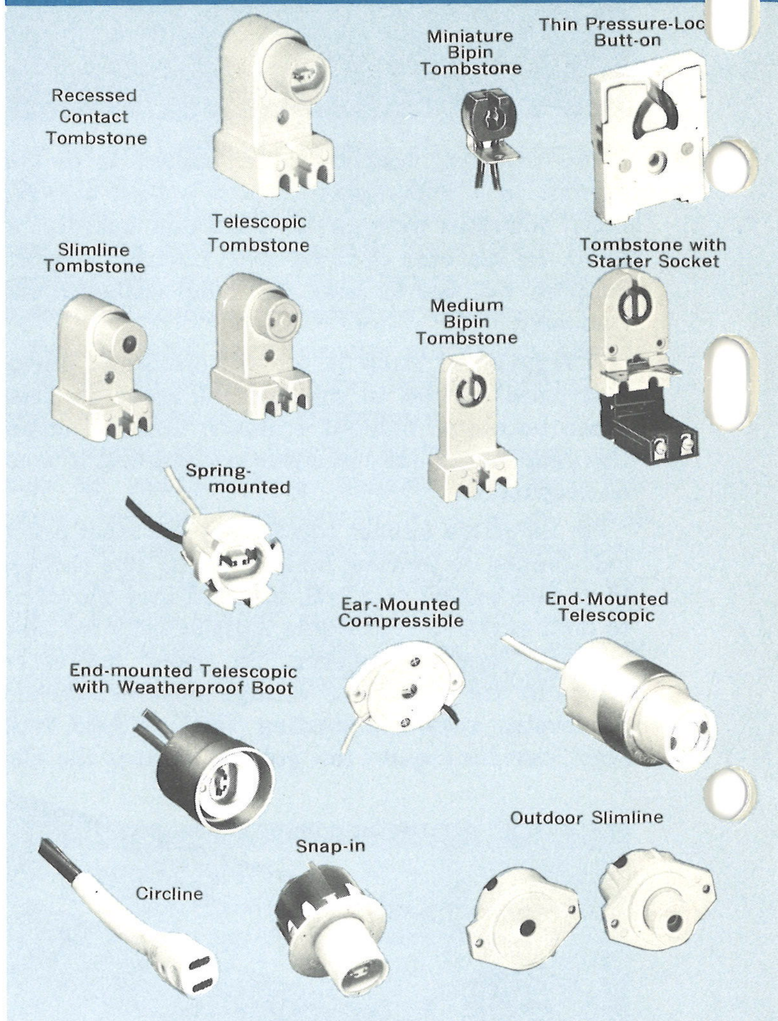
The changes in lamp characteristics with variations in circuit voltage are given in the accompanying charts. Generally, 1% variation in line voltage changes the lumen output only about 1%.




Characteristics of fluorescent lamps as voltage applied to the ballast changes from design voltage. Top curves are for series instant-start circuits, series rapid-start circuits, the lead lamp of lead-lag preheat circuits, and most high power factor single lamp circuits. Bottom curves are for the lag lamp of lead-lag preheat circuits and most low power factor single lamp circuits.

# Auxiliary Equipment

## LAMPHOLDERS




In fluorescent lamp systems, except Circline systems, the lampholders have two functions: 1. Support the lamp. 2. Electrically connect the lamp to the system. (In the Circline fluorescent lamps, the lampholders serve only to bring power to the lamp.)

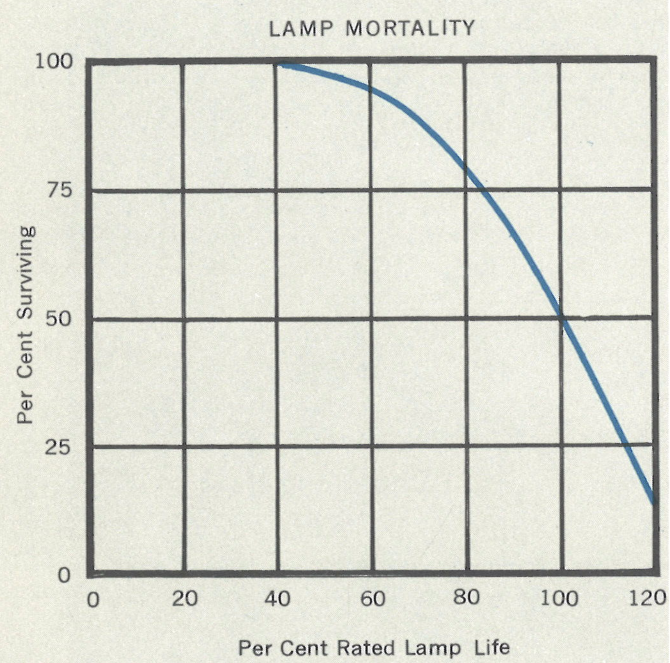
Many different types of lampholders are available to satisfy various mounting requirements. There are several different types of lampholders to accommodate each of the different types of bases used on fluorescent lamps. It is beyond the scope of this publication to show all lampholders available. However, the ones shown above are typical of the types available. The more popular types include tombstone, telescopic, compressible, turret, and weatherproof lampholders.

Some lampholders are available with a circuit-interrupting feature. With this type, no voltage is applied to the pins of the lamp until the lamp is completely seated in both lampholders. This reduces the possibility of shock when the lamp is being installed.

# Lamp Mortality

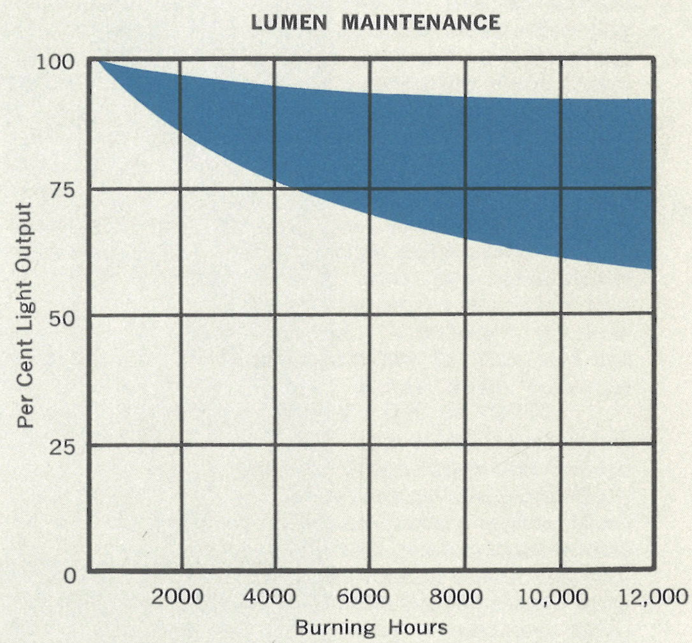
Fluorescent lamp life is influenced to a great degree by operating conditions. For example, operation with frequent starts shortens life appreciably. On the other hand, operation with many burning hours per start lengthens lamp life. For this reason, lamps have several different life ratings, based on the number of hours per start.

The curve below shows Per Cent Burnouts of fluorescent lamps plotted against Per Cent Rated Lamp Life. This curve is valid for all popular fluorescent lamps, under most operating conditions. Average life ratings for the various lamps and operating conditions can be obtained from General Electric fluorescent lamp data sheets.




# Lumen Maintenance

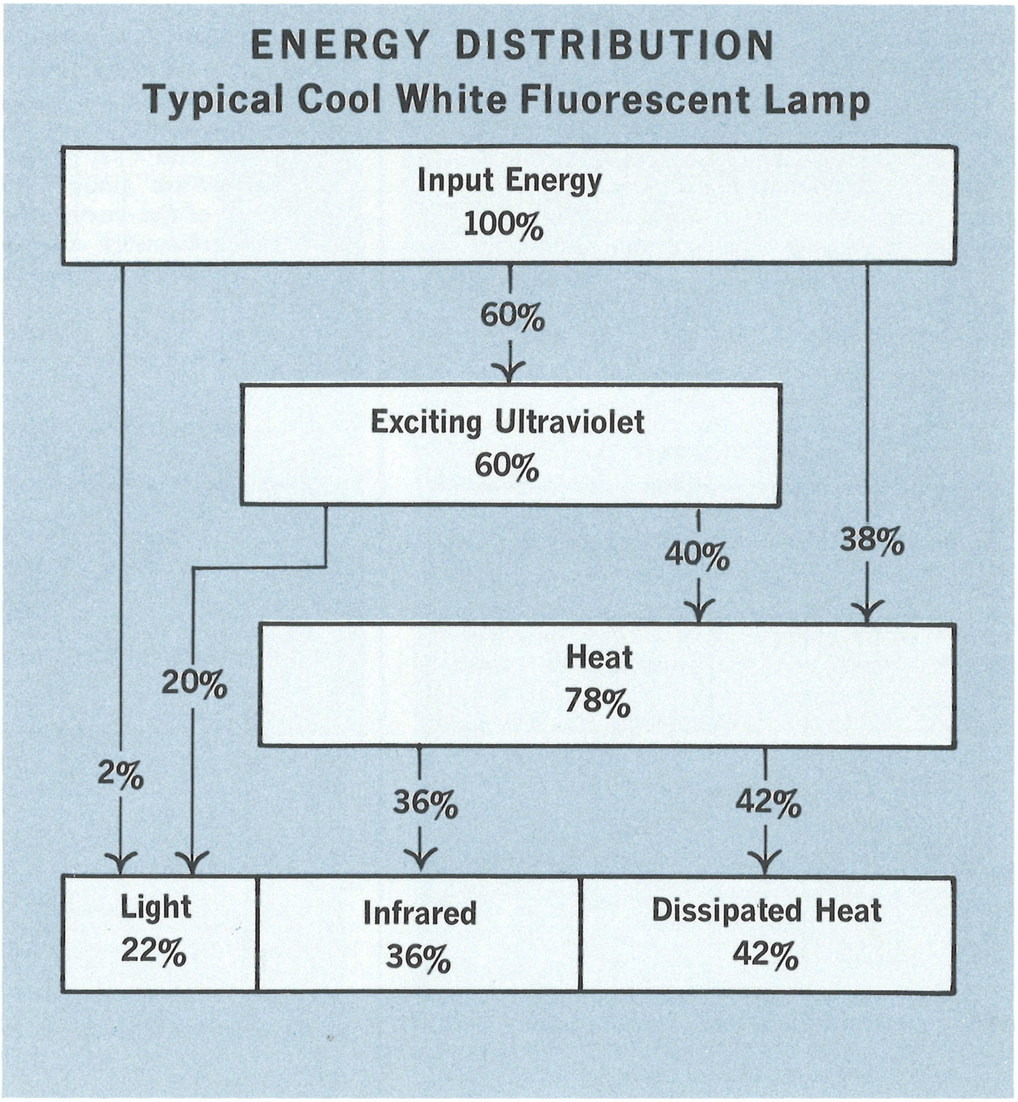
Like other types of lamps, fluorescent lamps depreciate in light output as they age. The initial light output is variable from lamp to lamp, and this value may decrease rapidly during the first 100 hours of operation. The lumen depreciation may amount to as much as 10%. For rating purposes, the 100-hour value is used as the initial value. The curve below shows typical range of fluorescent lamp depreciation in light output vs time. The vast majority of lamp types depreciate along a line near the upper limit of the curve. Light depreciation is not noticeably affected by the number of burning hours per start.

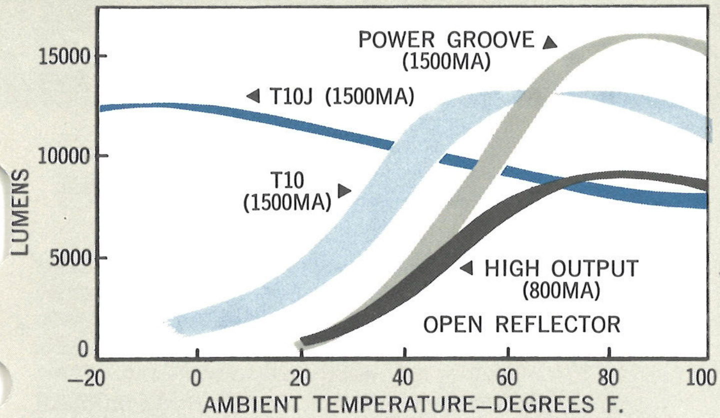


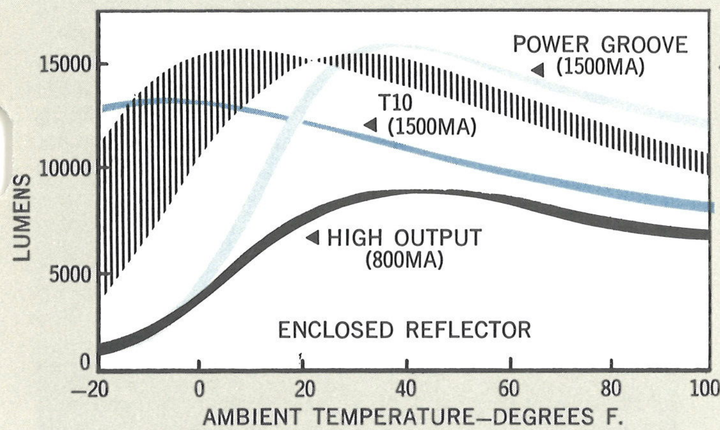
# Energy Distribution

Fluorescent lamps, with efficacy ranging up to 75 or 80 lumens per watt, are among the most efficient commercially available sources of electric light. In addition to light, several other forms of energy are emitted by fluorescent lamps. Near ultraviolet radiation accounts for a small part (0.5%) of the lamp input. About one-third of the input (35.7%) is infrared energy due, principally, to the temperature of the lamp's bulb wall. This is a low-temperature long wavelength form of energy as contrasted with the shorter wavelength, near infrared energy produced by the higher temperature of tungsten filaments in incandescent lamps. The remaining energy (41.8%) is dissipated by conduction and convection.

Fluorescent lamps produce much less radiated heat per lumen of light than incandescent lamps. For example, the 40-watt rapid start fluorescent lamp radiates about 58% of its energy as light, infrared and ultraviolet and produces (as of this writing) 3200 lumens. In contrast, a 150-watt general service incandescent lamp radiates about 80% of its energy as light and infrared and produces 2800 lumens. Obviously, the luminous efficacy of fluorescent lamps is much higher than that of incandescent lamps (75 to 80 lumens per watt for fluorescent, compared with 16 to 22 lumens per watt for general service incandescent lamps). Thus fluorescent lamps have a definite advantage when light with low radiant energy content is important.





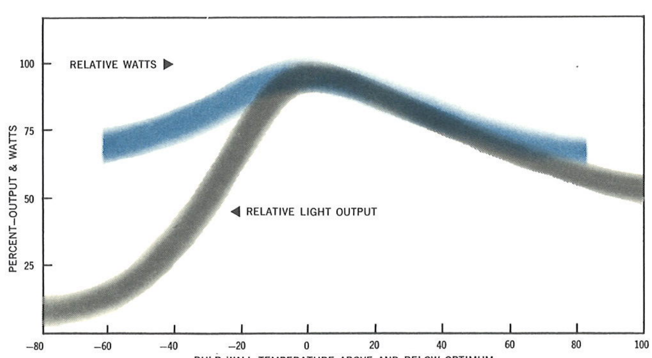




# Temperature Characteristics

Under the exposed operating conditions of the test, the T10J is the only lamp that maintains output in sub-freezing conditions. The other lamps produce satisfactory results if temperature does not drop below 30 F (T10), 40 F (high-output), or 50 F (Power Groove).

The T10 lamp in an enclosed fixture performs much like the T10J when all fixture openings are sealed. The effect of luminaire design on output is shown by the shaded curve which includes several types of multi-lamp, enclosed units, designed for Power Groove lamps. The general shapes of the curves are the same. Curves shift right or left depending on the degree of protection provided by the luminaire.

The light output of any fluorescent lamp depends on the mercury vapor pressure inside the lamp. Optimum pressure for maximum light output for most fluorescent lamps occurs when the coolest spot on the bulb is about 100 F. Bulb wall temperature is affected by lamp wattage and bulb diameter, by the design of the luminaire, and by the ambient temperature and draft conditions. As the bulb wall temperature is raised above 100 F., the mercury vapor pressure within the tube increases and the light output and lamp wattage slowly drop. At lower bulb-wall temperatures, the mercury condenses on the tube, pressure drops, and light output falls sharply. The wattage drops slowly. This characteristic is common to all fluorescent lamp designs. With some 8-foot lamps, the drop in light output at lower temperatures can be observed as gradual dimming from the ends to the center of the tube.




Light output and wattage of fluorescent lamps vary as bulb wall temperature varies from the optimum of 100° F.

**Lamp Characteristics**: Each lamp type has specific operating characteristics. The 1500-ma Power Groove lamp has the highest light output of any fluorescent type. It is designed with two special shaped grooves in the center which operate cooler than the rest of the lamp. These make it possible to operate the lamp efficiently in typical indoor ambient temperatures or in enclosed multi-lamp outdoor luminaires.

The T-10 All-Weather lamp is smaller in diameter; it purposely has no mercury control points, and operates about 30 degrees hotter than the Power Groove lamp at the same current rating. The T-14 jacket of the T-10J All-Weather lamp protects the bulb from drafts and it operates warmer than if it were exposed.

**Indoor Operation**: For indoor use at normal room temperatures, lamps operate most efficiently in luminaires designed to prevent overheating. Such designs may include ventilation slots, incorporation into the air-handling system of the room, or localized cooling. Excessive cooling may reduce output and cause unstable operation.

**Outdoor Operation**: The problems encountered in using fluorescent lamps outdoors or at low temperatures indoors fall into two categories: 1. Starting. 2. Operating. Fluorescent lamps become harder to start when cold. "Outdoor" or low-temperature ballasts compensate for this and are designed to reliably start lamps down to some specified temperature, usually 0 F. or –20 F.

Once started, successful operation depends on how hot the lamp becomes. Each lamp and fixture combination exhibits approximately the same characteristic light output vs temperature curve. However, the temperature at which peak output occurs depends on the lamp, the luminaire design and the wind speed and direction. These curves shown were taken under specific laboratory conditions, time, temperature, wind, and luminaire type; changing any of these conditions changes the curves.

## Dimming

The light output of rapid start fluorescent lamps may be adjusted or dimmed by a number of special circuits. All of these circuits incorporate one essential principle: The ballast must keep the cathodes of the lamp energized at the proper voltage regardless of the amount the lamp may be dimmed.

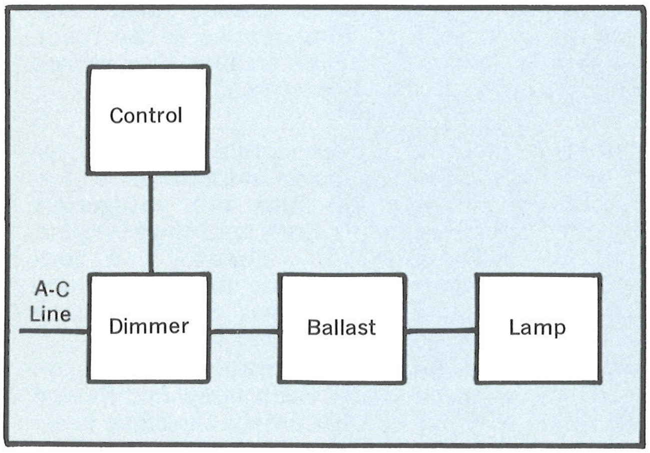
Current passing through the lamp or lamps in the dimming system may be controlled by a number of methods. The methods used include thyratrons, silicon-controlled rectifiers and other solid-state devices, variable inductors, autotransformers, saturable core reactors, magnetic amplifiers, etc.

Dimming systems vary widely in performance. Some systems can dim lamps no lower than 20% of normal full output, while others can dim lamps as low as 0.2%.

The limitations of some dimming systems cause undesirable operating characteristics toward the lower end of the dimming range which should be expected. Lamps may flicker or go out entirely. Marked non-uniformity in output from one lamp to another may be observed. On the other hand, the better systems produce a wide range of dimming without exhibiting any of these less desirable performance features.

In most dimming systems, the lamp can be started at any setting of the dimmer control. However, in some systems it is necessary to turn the control to nearly full brightness to start the lamp; once started, the brightness can again be reduced.

Dimming systems for 40-watt fluorescent lamps are made commercially by several manufacturers. Many systems can dim either 30-watt rapid start or 40-watt lamps with the same ballast. However, 30-watt and 40-watt lamps should not both be used on the same dimmer control.



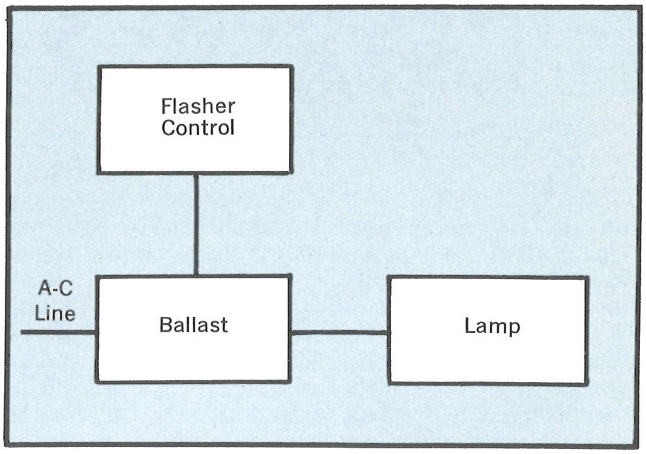
Block diagram of a fluorescent lamp dimming system. The ballast heats the cathodes of the lamp to the proper operating temperature; the control and dimmer, in conjunction with the ballast, vary current in the arc.

## Flashing

The life of fluorescent lamps is seriously reduced by turning them ON and OFF frequently when ordinary ballasts are used. However, it is possible to flash rapid start type lamps and maintain satisfactory life by using a special flashing ballast.

Similar to dimming ballasts, the flashing ballasts heat the lamp cathodes continuously even when the lamp arc is in the off portion of the flashing cycle. Flashing is accomplished by interrupting current to the arc only. One-, two-, and three-lamp flashing ballasts are available for most high output lamps. In addition, "Hi-Low" two-level flashing ballasts are available for certain lamp lengths.

In addition to the special ballast, a flasher designed for this specific application is also required. Plastic sign manufacturers utilize flashing fluorescent lamps of various colors to create many interesting and attractive advertising effects.



Block diagram of a fluorescent lamp flashing system. The flasher interrupts arc current without affecting cathode heating.

## High-Frequency

Any fluorescent lamp may be operated at frequencies higher than 60 Hz if proper ballasting is used. In general, light output and lamp efficiency increase at higher frequencies; however, some lamps react more favorably than others. The curves below show Relative Efficiency plotted against Frequency. The efficiency at 60 Hz is taken as the 100% value.

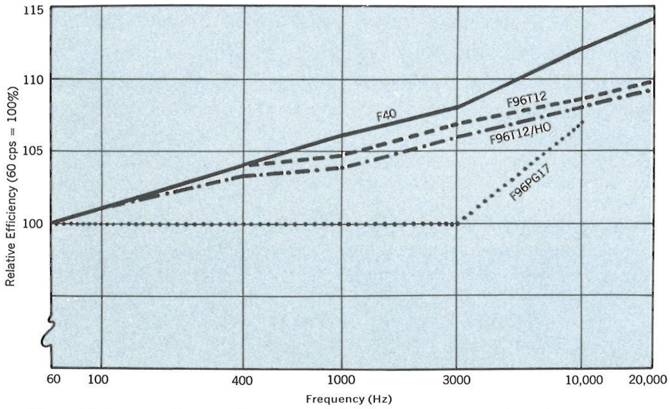
The highest gain in efficiency occurs in the 40-watt lamp. Power Groove lamps do not exhibit increased efficiency until the frequency exceeds 3000 Hz.

At higher frequencies, ballasts are smaller because the number of turns and the amount of iron required in the ballast decrease. This is true because inductive reactance, which is resistance to the flow of ac current, increases in proportion to frequency. Thus, operation at higher frequencies reduces the size, weight, and internal losses of the ballast.

The primary limitations to high-frequency systems are the cost and efficiency of the equipment required to convert 60-Hz power into higher frequencies. Present high-frequency systems usually use a centralized static-converter power source and operate at 3000 Hz or higher.

### Inverter Ballast

Another completely new field of high-frequency lighting has been entered with the introduction of the inverter-ballast. These are compact solid-state devices which convert low voltage dc to high frequency ac. Their use permits high efficiency, low brightness fluorescent lighting where formerly only incandescent was possible. Typical applications are boats, automobiles, campers, hand lanterns, and portable applications of all kinds. Inverter-ballast circuitry and components are now available commercially.




The efficiency of most fluorescent lamps increases when frequency increases. Power Groove lamps remain constant in efficiency until the frequency exceeds 3000 Hz; at higher frequencies, Power Groove lamps are also more efficient. On this curve, the efficiency at 60 Hz is taken as the 100% value.

## Direct Current

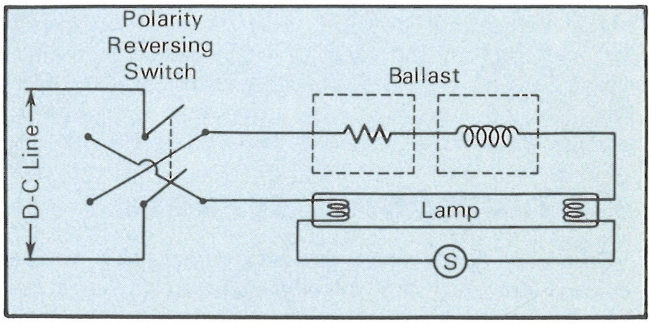
Fluorescent lamps are intended primarily for use on ac circuits; however, operation on dc circuits is possible with proper auxiliary equipment. For dc operation, two components make up the ballasting equipment:

1. A resistor to limit current to the desired value.

2. A choke type ballast to supply an inductive voltage "kick" for starting the lamp.

When a fluorescent lamp is operated in an ac circuit, an inductive ballast limits current to the lamp without consuming an appreciable amount of power. This is possible because of characteristics exhibited by inductance in an ac circuit. However, the resistance ballast used for dc operation consumes about the same amount of power as the lamp. Therefore, over-all efficiency of fluorescent lamps operated on dc circuits is much lower than for operation on ac circuits.

When operated on direct current, the longer fluorescent lamps have a tendency to become dim at one end after several hours' operation. This is caused by the fact that the current flows continuously in one direction, causing the mercury to accumulate at the negative (cathode) end of the lamp. A line-reversing switch is often used to reverse the electrode functions periodically (every few hours of operation), thus overcoming the tendency to dim more at one end. Even for the shorter lamps, which do not exhibit this mercury migration, a reversing switch is recommended. Reversing the current flow from time to time evens the wear in the cathodes, resulting in longer life. A ratchet relay, which reverses current each time the lamps are lighted, is a good device for the purpose. Lamp life ratings are based on ac operation. When lamps are operated on dc, life may be somewhat reduced.




Typical circuit for direct-current operation of fluorescent lamps. The resistor limits current to the lamp, and the inductor provides a surge of high voltage to aid in starting the lamp.

# Special Lamp Characteristics

Fluorescent lamps are highly reliable in their operation. However, they have certain unusual characteristics which may be observed from time to time.

## SPIRALING AND FLICKERING

Early in life, fluorescent lamps occasionally exhibit a condition called spiraling, i.e., the brightness varies from end to end. This condition is often caused by loose materials being knocked off the cathode. Normally, this condition disappears after the lamps have been burned for a few hours.

On 60-Hz operation, fluorescent lamps all develop a 120-Hz fluctuation. However, this is not perceptible to the human eye. Sometimes a lamp flickers at lower frequencies (which is perceptible) when the lamp is first turned ON or when it is cooled to too low temperature by a draft. Ordinarily, this type of flicker stops when the lamp warms up.

## UNDER AND OVERVOLTAGE

Ballasts are usually designed for operation on 120-volt circuits. In general, operation is satisfactory with voltage as low as 110 volts, or as high as 125 volts. Similarly, ballasts for 208-volt service operate satisfactorily from 200 to 215 volts; 240-volt service from 220 to 250 volts; 277-volt service from 250 to 290 volts; and 480-volt service from 440 to 500 volts.

If the circuit voltage is too high, operating current is excessive. This overheats the ballast, and causes premature ballast failure. If lower than rated voltage is applied, current may be too low for satisfactory heating of the cathodes, causing unreliable or delayed starting, and reduced lamp life. Curves on Page 16 show how varying line voltage affects typical lamp characteristics.

## STROBOSCOPIC EFFECTS

When a fluorescent lamp is operated on alternating current, the current passes through zero twice each cycle and reverses in direction. As this occurs, the light from the lamp dips momentarily to a low value. On 60-Hz power this occurs 120 times per second. No flicker is visible since the eye does not respond to a frequency this high. However, an interesting phenomenon called stroboscopic effect may sometimes be observed on rapidly moving or rotating objects. Instead of a uniform blur, evenly spaced shadows along the path of the moving object may be observed. These occur at the points occupied by the object when the current in the lamp is passing through zero.

The stroboscopic effect from fluorescent lamps may occasionally be useful to judge the speed of an object moving at synchronous or near synchronous speed. However, fluorescent lamps will not produce the sharp stroboscopic images obtained on moving pictures or television or with a special stroboscopic light made for the purpose. The characteristic blur of motion is always plainly visible. There is no danger of mistaking a rotating object for a stationary one.

## RADIO INTERFERENCE

Fluorescent lamps produce detectable radio interference on the standard AM broadcast band (500-1700 kHz). Although radiation can be detected in the 2-200 MHz region, interference with broadcasting services in this frequency range (FM radio, TV, etc.) is rare.

Most modern radios have built-in antennas. Moving the radio a short distance away from fluorescent lamps and associated electric supply lines (see table) is helpful. If the radio cannot be moved, install an outdoor antenna with shielded or twisted lead-in. Also, grounding the radio is often helpful.

Radio noise may also enter the receiver from the fluorescent lamps through a common power supply circuit. The wiring supplying the fluorescent lamps can act as an antenna to broadcast the noise where non-metallic cable or knob-and-tube wiring is used. Line filters placed in the fluorescent fixtures can relieve these problems. Such filters are available from radio parts suppliers.

For special laboratory, military, and industrial applications, fluorescent fixtures may be equipped with appropriate metal louvers or conducting glass lenses. In this way, the radio noise may be almost completely screened and prevented from leaving the fixture. Equipped with high quality commercial line filters, such fixtures have tested below the noise limitations of the most stringent military specifications.

**Recommended Distance from Lamp to AM Radio Antenna**

| LAMP SIZE | DISTANCE (feet) |
|---|---|
| 14, 15, 20-watt | 4 |
| 32-watt circline | 5 |
| 30-watt | 6 |
| 40-watt | 8 |
| 90 and 100-watt; 72 and 96-in. slimline | 10 |

# Trouble Shooting

Although this publication is not intended to be a service manual, a few basic trouble-shooting procedures are worthy of mention. For more complete trouble-shooting procedures, see Maintenance Guide for Fluorescent Lighting, General Electric publication No. 302-5019R. The following procedures will restore most systems to operation.

## PREHEAT CIRCUITS

Lamp blinks ON and OFF. Usually this is a normal end-of-life lamp failure. However, if the lamp has not been in service long, a number of factors should be considered as possible causes. The starter may be defective, and it should be replaced. The lamp may be at fault. Lamp replacement is the next logical step.

Changing the lamp and starter may correct the trouble only temporarily if there is a borderline cause of the difficulty for some other reason. Low circuit voltage, low ballast rating, low temperature, and cold drafts can cause difficulty of this nature. Also, several of these conditions may be contributing factors. With two-lamp ballasts, the starter leads from the two pairs of lampholders may be criss-crossed. When this happens, the lamps start promptly if both starters open at the same time. However, if one lamp starts, the other may blink on and off for a long time before starting, or it may not start at all.

Lamp makes no starting effort or starts slowly. Be certain that the lamp makes proper contact in the lampholders. The lamp can be checked by testing it in another circuit. The starter may have reached the end of life; if so, it should be replaced. Also, the ballast may be open-circuited.

Ends of lamp remain lighted. In a new installation, the circuit may be wired incorrectly. If the installation has been in operation, the trouble may be a shorted capacitor in the starter, or the switch contacts may be welded together. In either case, the starter must be replaced.

## INSTANT START CIRCUITS

Because instant start and rapid start circuits do not use starters, there are fewer components to cause trouble. Virtually the only thing that goes wrong with these circuits is that the lamps fail at normal end of life, and occasionally ballasts fail.

To assure starting under high humidity conditions, instant start lamps are coated with Dri-Film.

The ballast open-circuit voltage is about three times the normal lamp voltage. Therefore, on some ballast designs, these lamps may start and operate even when one cathode is completely de-activated at the end of normal life. In this condition, the lamp may spiral violently; sometimes orange-colored flashes occur. Such lamps or any lamps which become quite black at one end should be replaced promptly because there is little life left. The end of life spiraling results in abnormally high peak voltages and ballast overheating; if the lamp is not replaced, the ballast may fail.

## RAPID START

Completely reliable starting in rapid start circuits depends on the presence of a suitable starting aid. The starting aid is an electrically grounded metal strip extending essentially the full length of the lamp, connected so there is a proper potential difference between it and the high-voltage end of the ballast circuit. The wiring channel or a reflector is sufficient; however the starting aid should be within an inch of the bulb wall in most cases.

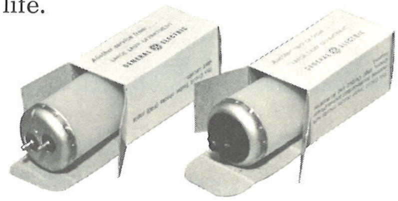
If, under high humidity conditions, rapid start lamps start slowly or do not start at all although the cathodes are properly heated, this may be due to dirt on the lamp which is off-setting the Dri-Film coating. In this case, the lamps should be cleaned.

Satisfactory starting and lamp life of lamps in rapid start circuits depend on proper heating of both cathodes when lamps start. With heating current at only one cathode, either the lamp fails to start or the lamp starts slowly (about 5 seconds). In either case, lamp life is reduced drastically.

Heating current at only one cathode can be caused by improper contact in the holder, broken holder, open cathode, shorted leads in the lamp base, corroded or dirty base pins or holder contacts, defective ballast, improper wiring, etc. Inexpensive testers are available to check cathode heating voltage in rapid start circuits.

Lamps started many times without being operated for reasonable periods of time become hard to start. This situation can be corrected by operating hard-to-start lamps for several hours.

On most two-lamp 40-watt ballasts, if one lamp fails both go out or are quite dim. The good lamp is not damaged because heating current still flows through the cathodes. At normal failure, lamps simply fail to start, and are black at one or both ends. There usually is no flashing, spiraling, or ballast overheating at the end of lamp life.



Rapid start tester for bipin fixtures, another for Power Groove, High Output and All-Weather fixtures. Help locate fixture troubles.

## FLUORESCENT DISPOSAL

Since June of 1949, the basic phosphor used in the manufacture of GE fluorescent lamps has been an inert phosphate found to be safe in the ordinary handling of either an intact or broken lamp; however, as with any product containing glass and chemicals, reasonable care should be observed in the disposal of fluorescent lamps. As in the case with any fine dust, excessive inhalation of the phosphor dust should be avoided.

Since fluorescent lamps are filled with a very low gas pressure (almost a vacuum), implosions may occur during the breaking of the lamps. Proper equipment should be worn by the operator to protect the eyes and skin from flying glass. For this reason too, unbroken lamps should not be thrown into incinerators or other fires. If lamps are to be broken, break them outdoors, or in a well-ventilated indoor area. The use of a waste container and local exhaust ventilation will minimize the dispersed dust and mercury vapor. Adequate protection should be taken against flying glass.

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GENERAL ELECTRIC

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TP-111
Revised SEPTEMBER, 1970