

SYLVANIA

**Fluorescent
Lamps**

GTE

**Engineering
Bulletin 0-341**

0285

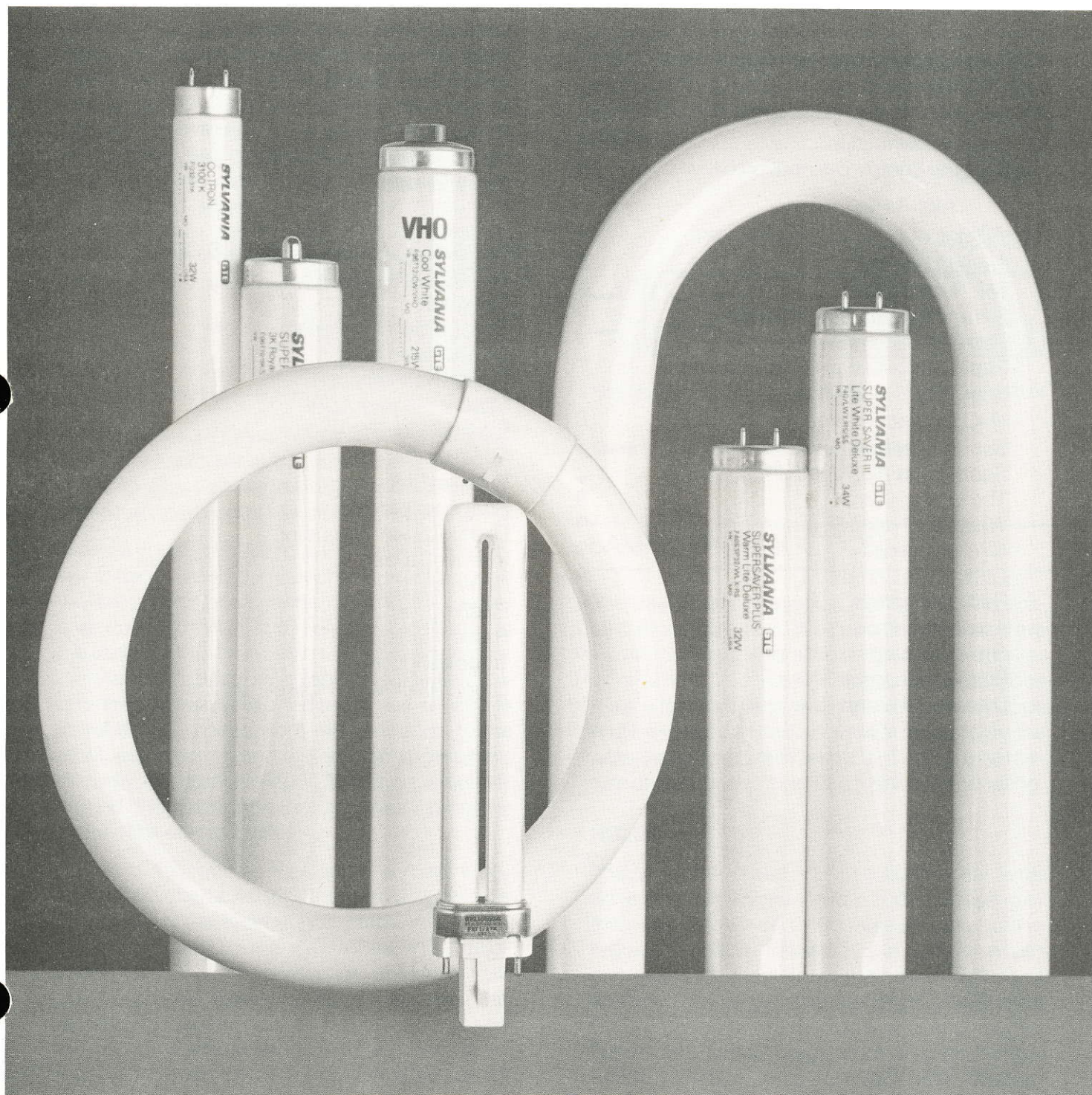


TABLE OF CONTENTS

THEORY OF OPERATION	1	OPERATING CIRCUITS FOR FLUORESCENT LAMPS	10
LAMP CONSTRUCTION	1	Ballasts	12
Bulbs	1	Class P Ballasts	13
Phosphors	2	Electronic Ballasts	13
Electrodes	3	Preheat Circuits	13
Bases	3	Starters	14
ILLUMINATION CHARACTERISTICS OF LAMPS	3	Glow-Switch Starters	14
Efficacy	3	Manual-Reset Cutout Starters	14
Energy Distribution	4	Automatic-Reset Starters	15
Spectral Energy Distribution Curves	4	Instant Start Circuits	15
TYPES OF FLUORESCENT LAMPS	6	Trigger Start Circuits	16
Preheat Lamps	6	Rapid Start Circuits	16
Twin Tube Lamps	6	Interchangeability of 40 Watt Lamps	16
Slimline (Instant Start) Lamps	7	Lampholders	17
Rapid Start Lamps	7	OPERATING CHARACTERISTICS OF FLUORESCENT LAMPS	18
Rapid Start — High Output Lamps	7	Lamp Life	18
Rapid Start — Very High Output Lamps	7	Effect of Burning Periods on Life	18
VHO Outdoor Lamps	8	Group Relamping	19
SuperSaver Lamps	8	Lumen Maintenance	19
SuperSaver <i>Plus</i> Lamps	8	Effect of Temperature	19
The Octron Lamp	9	Effect of Humidity	20
Weather-Shielded Lamps	9	Effect of Voltage	20
Circline Lamps	9	Effect of Frequency	21
Curvalume Lamps	9	Stroboscopic Effect	21
Reflector Lamps	9	Direct Current Operation	21
Aperture Lamps	10	Inverter Ballast	22
Gro-Lux Lamps	10	Dimming	22
Blacklight Lamps	10	Flashing	22
Germicidal Lamps	10	Radio Interference	23
		Troubleshooting	23
		Other Bulletins on Fluorescent Lamps	23

THEORY OF OPERATION

The principle of light production in the fluorescent lamp was known to science for many years before it was applied in a practical light source, just as the principle of the incandescent lamp was known for many years before the invention by Thomas Edison of a practical lamp of that type. The first practical fluorescent lamp was introduced in 1938.

The fluorescent lamp is an electric discharge device which utilizes a low pressure mercury vapor arc to generate ultra-violet (plus a little visible) energy. The ultra-violet energy is absorbed by a phosphor coat on the inside of the glass tube and converted by the phosphor to visible wavelengths; the wavelengths of the light generated are determined by the composition of the phosphor. In addition to the small amount of mercury vapor, the fluorescent tube contains an atmosphere of an inert gas, usually argon, krypton, neon, or a mixture of two or more of these gases.

The pressure of the gases contained in the lamp is very low, usually from 2 to 3 torr. Atmospheric pressure is 760 torr.

A tungsten coil (cathode) coated with an electron emissive material is sealed into each end of the lamp. Fig. 1 shows the construction and illustrates the operation of a typical fluorescent lamp.

When a fluorescent lamp is first turned on, starting voltage passing an electric current through the electrodes heats them, causing their emissive coating material to release electrons. In addition to the thermally released electrons, there are also electrons released by the field difference between electrodes. These electrons travel at high speed from one electrode to the other, establishing an electric discharge or arc through the mercury vapor. The lamp is quickly heated, increasing the mercury vapor pressure to the most efficient value.

An arc of this nature, enclosed in a glass tube, has certain characteristics that vary with the type of gas used, the internal gas pressure and the voltage applied to the electrodes. The major characteristic is the production of visible light and ultra-violet energy. Collisions between the fast-moving electrons from the electrodes and the mercury atoms knock mercury atom electrons out of their orbits. Part of these displaced

electrons settle back to their normal orbits and release energy they have absorbed in the collision. The energy released is primarily in the form of ultra-violet radiation at a wavelength of 253.7 nanometers. Small amounts of blacklight plus visible wavelengths of violet, blue green and yellow are also released.

This ultraviolet energy is converted into visible light by the phosphors, which have the ability to absorb the ultraviolet energy and re-radiate it at longer wavelengths that can be seen as visible light. In other words, the phosphors are excited to fluorescence by ultraviolet energy of the proper wavelength. The color of the visible light produced depends on the chemical composition of the phosphor coating on the inside of the glass tube.

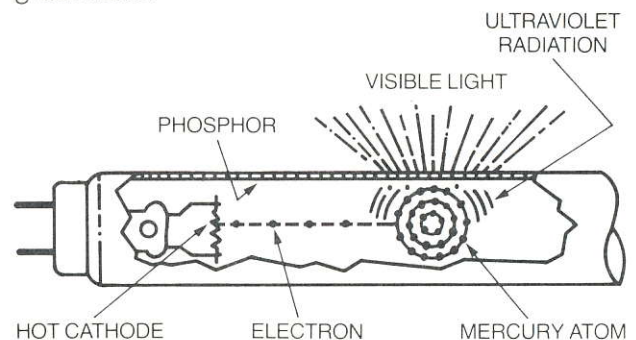


Figure 1. How light is produced in a typical hot cathode fluorescent lamp.

LAMP CONSTRUCTION

The basic parts of a typical hot cathode fluorescent lamp are shown in Figure 2. Although there are many sizes and several shapes of fluorescent lamps, the most commonly used types have a tubular glass envelope with an electrode and base at each end. In addition to mercury, the tube contains a small amount of argon or a mixture of inert gases, and has a phosphor coating.

BULBS

The bulb shape and size of a fluorescent lamp are expressed by means of a code consisting of the letter "T" (which designates that the bulb is tubular in shape) followed by a number which expresses the diameter of the bulb in eighths of an inch. They vary in diameter from T-5 ($5/8$ inch) to T-17 ($2\frac{1}{8}$ inches). In nominal overall length, fluorescent lamps range from 6 to 96 inches, which is always measured from back of lamp-

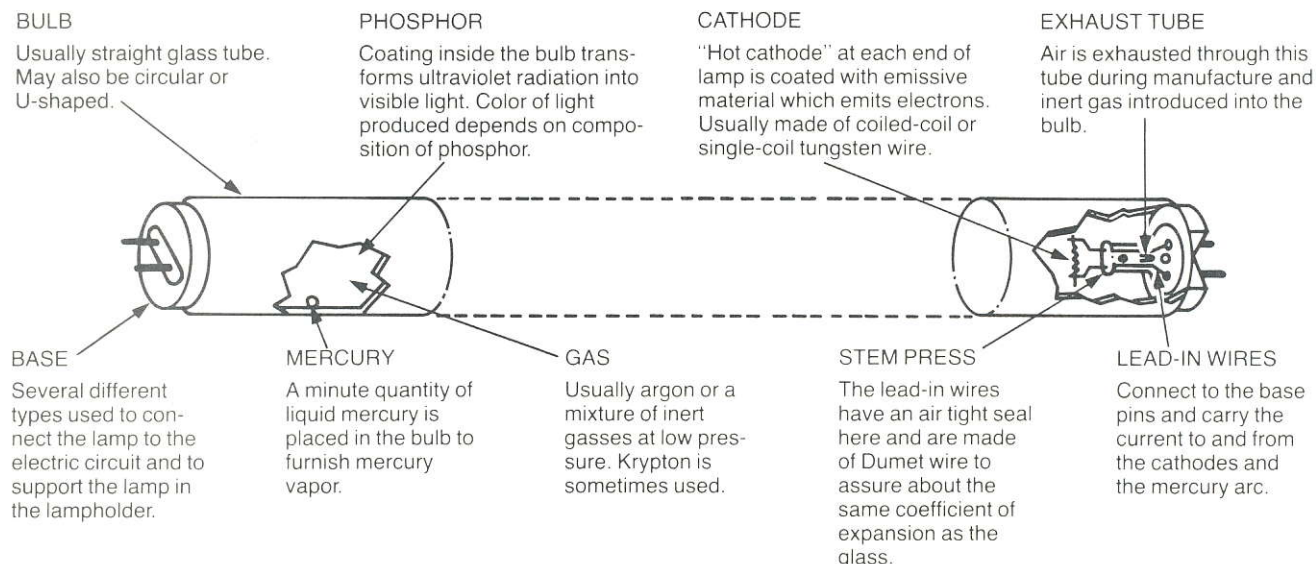


Figure 2. Basic parts of a typical hot cathode fluorescent lamp.

holder to back of lampholder. For example, the actual overall length of the 40-watt rapid start T-12, 48 inch lamp is 47³/₄ inches. Circline lamps, which are circular, are available in five sizes: 6¹/₂ inches, 8 inches, 10 inches, 12 inches and 16 inches outside diameter. There are also U shaped fluorescent types (Curvalume™) with T-8 and T-12 tubes. U shaped types are measured for the distance between the ends. The overall length is measured from the face of the bases to the outside of the glass bend.

PHOSPHORS

The color or wavelengths of the light produced by a fluorescent lamp depends on the chemical composition of the phosphor coating used on the inside of the bulb. By combining different phosphors in varying proportions, it is possible to produce lamps in a wide variety of colors. Lamp colors currently available include many shades of white as well as blue, green, pink and red. Other fluorescent lamps are designed with phosphors that generate the colors of light that are most stimulating to plant growth. Still others have a phosphor known as 350BL which produces near ultraviolet in the blacklight band for activating fluorescent and phosphorescent materials. Similar-size lamps of all colors are basically the same except for the coating, and they all appear white when not lighted. Exceptions: gold, red and incandescent fluorescent lamps which are coated with colored pigments on the inside of the bulbs before the phosphors are applied. Blacklight blue lamps are made with a special glass which filters the visible light that regular blacklight lamps emit.

Some of the newer fluorescent colors are achieved with the use of expensive rare earth phosphors. By blending the primary colors of blue, green and red, one can obtain nearly any desirable shade of "white" with good color rendering and high efficacy. Royal White, Lite White DeLuxe, Warm Lite DeLuxe and the Octron colors are among those using this new technology. In order to utilize these expensive rare earth phosphors economically, Sylvania developed and introduced double-coat phosphor technology, which allows the achievement of desirable characteristics of the rare earth phosphors at a reasonable cost. Figure 3 illustrates these coating methods.

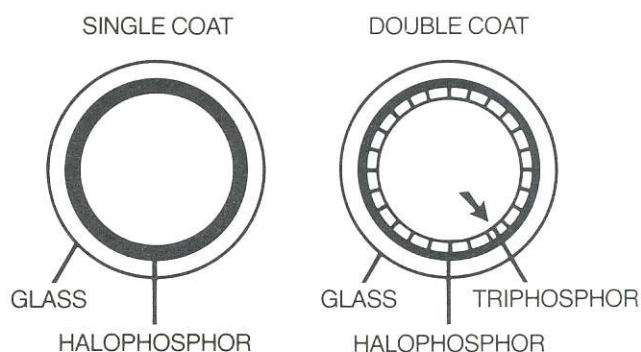


Figure 3. Double Coat Phosphor Technology

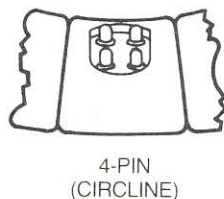
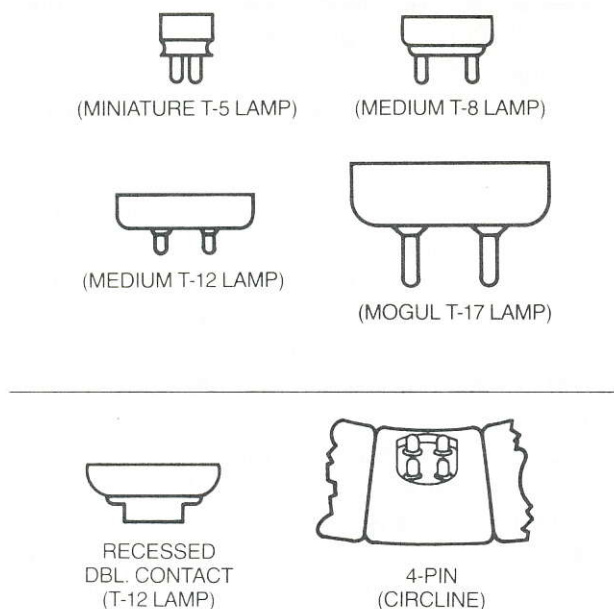
ELECTRODES

The electrode at each end of a fluorescent lamp is generally a coated coiled-coil or triple-coil tungsten wire. The coating on the tungsten wire is an emissive material (barium, strontium and calcium oxide) which emits electrons when heated to an operating temperature of about 950°C. At this temperature electrons are given off freely with only a small wattage loss at each cathode. (See SuperSaver *Plus*) This process is called thermionic emission because the heat is more responsible for the emission of electrons than is the voltage. An electrode of this design is called a "hot cathode" (see Figure 2). This type of cathode lowers the starting voltage required to strike the arc.

SINGLE PIN



BI-PIN



BASES

The bases used on fluorescent lamps are shown in Figure 4. For Preheat and Rapid Start lamps, four electrical contacts are required; two at each end of the lamp. This is accomplished in the standard line of lamps by using a bipin base at each end. There are three sizes: miniature bipin for the T-5 bulbs, medium bipin for the T-8 and T-12 bulbs and mogul bipin for the T-17 bulbs. In Circline lamps, the cathodes are connected to a four-pin base located between the junction of the two ends of the lamp. High Output and Very High Output lamps have recessed double contact type bases. Slimline (Instant Start) lamps require only two electrical contacts, one at each lamp end and have single pin bases.

ILLUMINATION CHARACTERISTICS OF LAMPS

EFFICACY

One of the most important features of fluorescent lamps is their high efficacy. This is the amount of visible light produced (lumens) for every unit of power consumed (watts); it is abbreviated LPW (lumens per watt). It is common practice to compare fluorescent and incandescent lamps in this way, but to make a more accurate comparison, the fluorescent lamp should include ballast wattage. Standard bipin lamps have efficacies (not including ballast losses) that range from 24 to 103 lumens per watt depending on bulb size, color and lamp current frequency. Slimline lamps range from 48 to 84 lumens per watt; High Output types from 40 to 84, and Very High Output from 45 to 75 lumens per watt. For the same color and lamp type, lumens per watt produced are greater for a long lamp than for a short lamp. This is true because the power consumed at the electrodes is the same regardless of the length of the lamp.

Figure 4. Bases for Fluorescent Lamps.

ENERGY DISTRIBUTION

Approximately 60 percent of the input energy in a cool white fluorescent lamp is converted directly into ultraviolet, with 38 percent going into heat and 2 percent into visible light, as shown in Figure 5. The standard phosphor changes about 21 percent of the ultraviolet into visible light with the remaining 39 percent converted to heat. The 23 percent conversion of energy into light for a 40-watt fluorescent lamp is approximately twice the percentage of a 300-watt incandescent lamp, which changes only 11 percent of the input energy into light. The production of 36 percent infrared compares with 69 percent for a 300-watt incandescent.

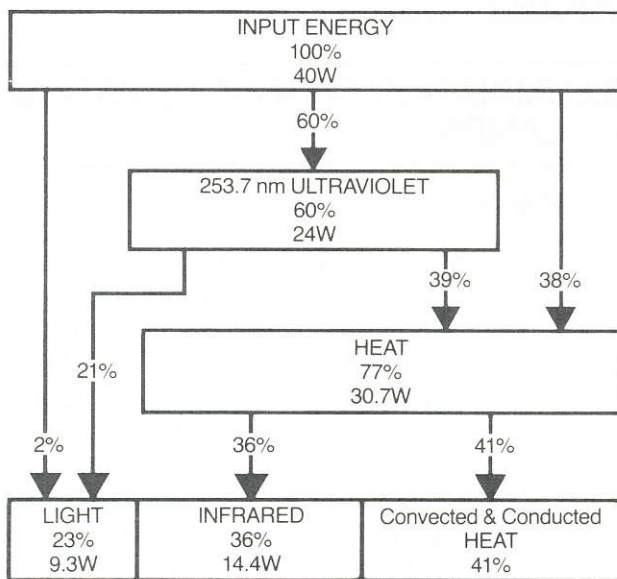


Figure 5. Energy distribution of a typical 40W Cool White Fluorescent Lamp.

SPECTRAL POWER DISTRIBUTION CURVES

The spectral power emission from a fluorescent lamp is of two kinds: (1) the continuous spectrum which is emitted by the fluorescent power and (2) the narrow bands of energy given off by the mercury arc itself at 365.0 (blacklight), 404.7 (violet), 435.8 (blue), 546.1 (green) and 578.0 (yellow).

In Figures 7-12 the power in each 10 nanometer band is shown plotted against wavelength for Sylvania 40-watt fluorescent lamps. For convenience in representation, the power in the mercury lines are shown as bands 10 nanometers wide centered about the actual wavelengths involved. The power in the mercury lines is small compared to that from the continuous radiation. The area under the curves, plus the mercury lines, represent the total power output of the lamps. By dividing the spectrum into arbitrary color bands, as in Table I, the power in each band can be calculated. Mercury lines have been included in this calculation. For spectral power distribution curves for other fluorescent colors, refer to Engineering Bulletin 0-238.

It should be remembered that neither the curves nor Table I indicate how object colors will look when lighted by the various sources. A light source may look white and make white objects look white, yet render colors poorly. Cool White, Warm White, White and Daylight are standard white colors; they have high efficacy and color rendition suitable for most applications in industry, general office areas and schools. Where it is desirable to give colored objects and complexions a more natural and complimentary appearance, Cool White Deluxe, Warm White Deluxe, Natural, Royal White or Octron colors (31K and 41K) should be used. When a close approximation of the incandescent lamp color is wanted, the incandescent fluorescent lamp color is recommended. Since the human eye is less sensitive to red energy, which makes up a higher percentage of the power from Deluxe lamps, such lamps produce about 30 percent less visible light than the standard lamps. A quick reading of Figure 6 (the eye sensitivity curve) shows that the eye is more sensitive, or responds better, to some colors (green, yellow) than others (blue, red); therefore, more energy must be expended to illuminate the color red than to illuminate the color yellow for equal brightness (illumination). This lumen difference, however, does not usually appear as drastic because of the increased vividness of the colors under Deluxe lamps.

TABLE I
Energy Emission of Selected 4-Foot Lamps
in Arbitrary Color Bands in Watts

		34W T-12 Warm Lite Deluxe		34W T-12 Lite White Deluxe		40W T12 Royal White		40W T12 Cool White		40 W T12 Warm White		40W T12 Daylight		32W T8 Octron 31K		32W T8 Octron 41K	
Band	Nanometers	watts	%	watts	%	watts	%	watts	%	watts	%	watts	%	watts	%	watts	%
Ultraviolet	< 380	.24	3.0	.22	2.7	.45	5.2	0.16	1.7	0.13	1.5	0.19	2.1	.25	3.4	.23	2.9
Violet	380-430	.31	3.8	.41	4.9	.29	3.3	0.72	7.6	0.46	5.2	0.87	9.6	.28	3.8	.33	4.2
Blue	430-490	1.07	13.2	1.60	19.3	1.03	11.9	1.98	21.0	1.15	13.1	2.54	28.0	1.04	14.2	1.53	19.6
Green	490-560	1.90	23.5	2.29	27.6	2.23	25.8	2.35	24.8	1.80	20.6	2.49	27.4	1.81	24.7	2.35	30.2
Yellow	560-590	1.11	13.7	1.08	13.0	.80	9.2	1.74	18.4	2.06	23.5	1.32	14.5	.92	12.5	.72	9.2
Orange	590-630	2.66	32.8	2.05	24.8	3.10	35.8	1.69	17.	2.13	24.3	1.20	13.2	2.35	32.0	2.09	26.8
Red	630-700	.81	10.0	.64	7.7	.76	8.8	0.81	8.6	1.03	11.8	0.47	5.2	.69	9.4	.55	7.1
Total		8.10	100%	8.29	100%	8.66	100%	9.45	100%	8.76	100%	9.08	100%	7.34	100%	7.80	100%

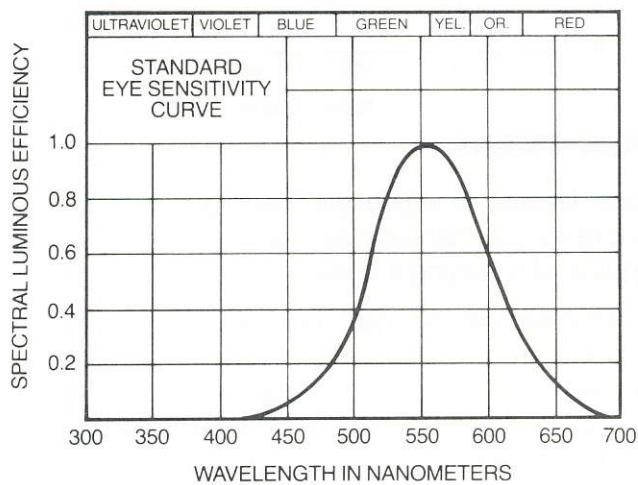


Figure 6. Eye Sensitivity Curve.

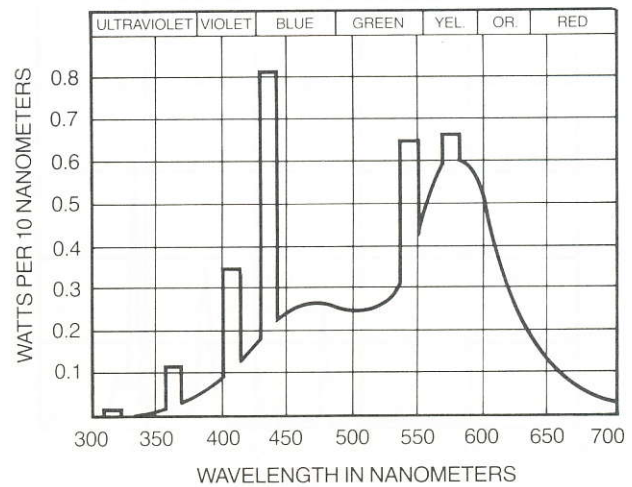


Figure 7. Cool White F40CW.

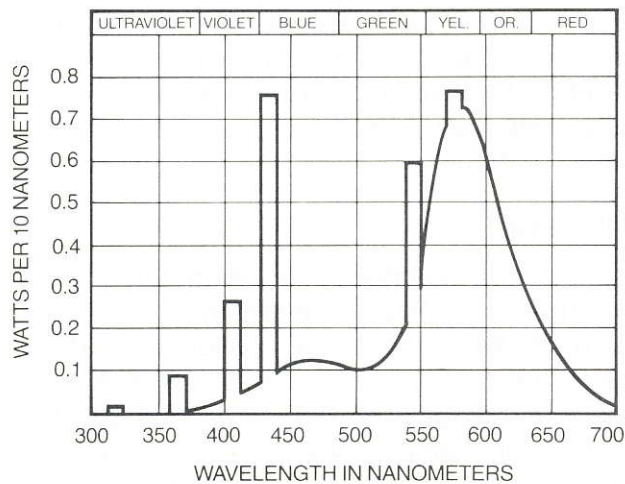


Figure 8. Warm White F40WW.

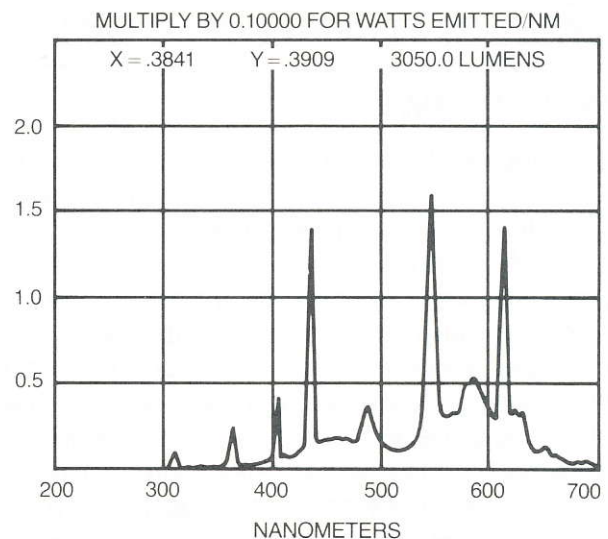


Figure 9. Lite White Deluxe (LWX)

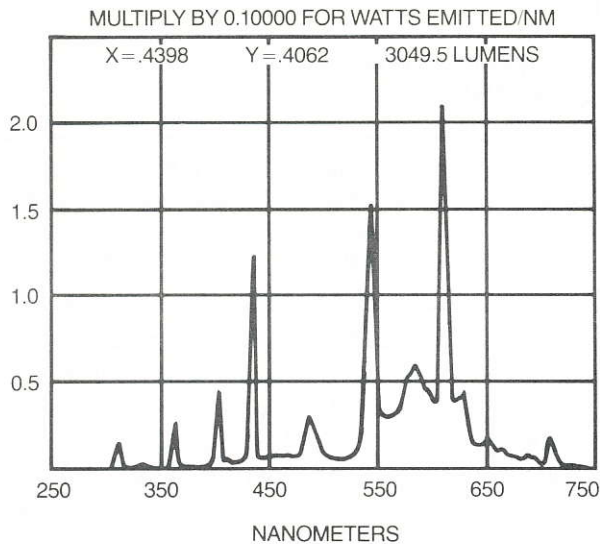


Figure 10. Warm Lite Deluxe (WLX)

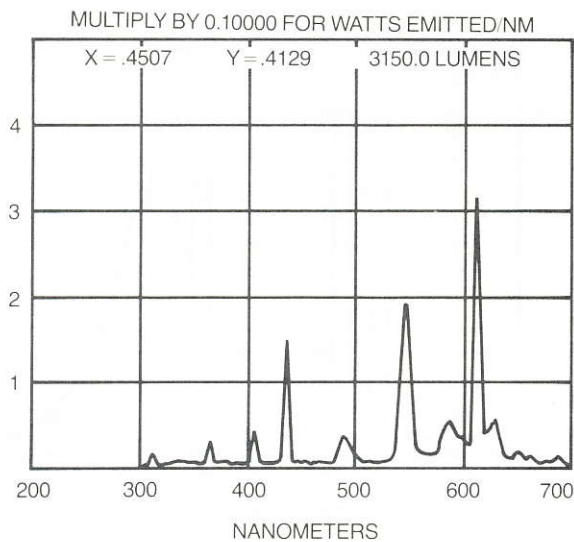


Figure 11. Royal White (3K)

TYPES OF FLUORESCENT LAMPS

PREHEAT LAMPS

The original fluorescent lamps introduced in 1938 were of the preheat type, requiring separate starters. The starter supplies several seconds of current flow through the cathodes to preheat them between the time the lamp is turned on and the time the lamp lights. The cathodes are preheated to emit electrons to aid in the striking of the arc at a lower voltage. The starter is usually of an automatic type which applies current to the cathodes to preheat them; then automatically opens to stop the current flow. This allows full voltage to be applied across the two cathodes, thus striking the arc. There are some preheat systems, such as fluorescent

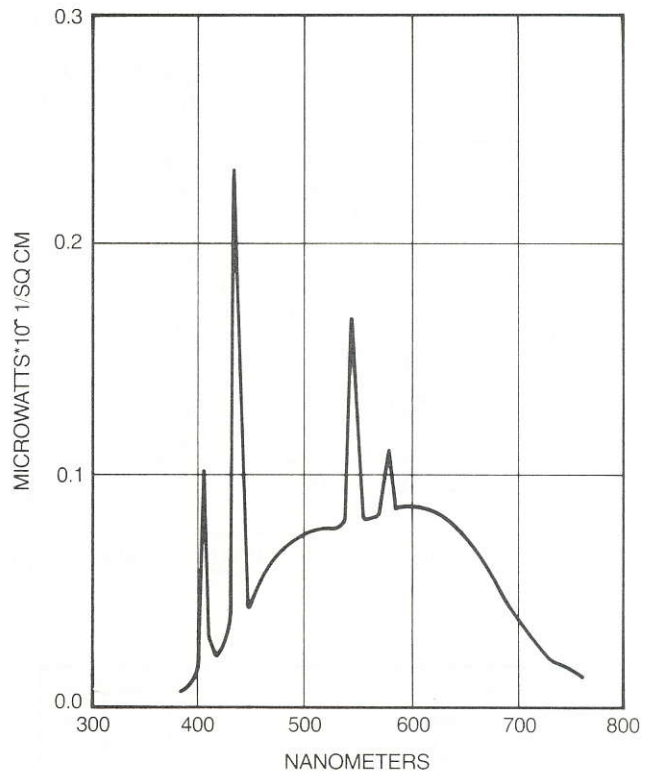


Figure 12. Design 50

desk lamps, in which the starting is done by depressing a manual start button for a few seconds and releasing it to start the lamp.

All Preheat lamps have bipin bases. They range in power from 4 to 90 watts and in length from 6 inches to 60 inches. The lamp ordering abbreviation identifies preheat lamps by wattage, bulb diameter (eighths of an inch) and color. For example, the F20T12/CWX is a 20-watt, 1½ inch diameter Cool White Deluxe lamp.

Miniature types with T-5 bulbs are available in 4-, 6-, 8- and 13-watt sizes. They are used as inspection lights on benches and machines and in make-up mirrors and other applications where small, high-efficacy lamps are desired. Lamps with T-8 bulbs are employed in showcase lighting equipment, portable desk lamps and reprographic systems.

TWIN TUBE

An advanced compact fluorescent lamp, the Twin Tube, is a small single-ended low-wattage type made with a bent tube configuration. This new fluorescent type contains a starter in the base, and is made in 5-, 7-, 9- and 13-watt sizes. The Twin Tube lamp's correlated color temperature of 2700K makes it comparable to low-wattage incandescent types used for the same applications (its color rendering index is 81).

SLIMLINE (INSTANT START) LAMPS

Slimline (Instant Start) lamps were introduced in 1944 to eliminate the slow starting experienced with preheat lamps. These lamps operate without starters. The ballast provides a high enough voltage to strike the arc instantly. Since starters are not required, the lighting system and maintenance are simplified. Because Slimline lamps do not require preheating, only a single pin base is required for each end.

Slimline lamps range in power from 21 to 75 watts and in length from 24 inches to 96 inches. Because Slimline lamps can be operated at more than one current and wattage, the lamp ordering abbreviation identifies them by lamp length instead of wattage. For example, the F96T12/CW is a 96 inch long, 1½ inch diameter Cool White Slimline fluorescent lamp. The fact that it is rated 75 watts for normal operation does not appear in the ordering abbreviation.

The 40-Watt Instant Start lamps use a medium bipin base which has a connection between the pins at each end, giving the same effect as a single pin for each cathode. The instant start lamps with bipin bases will not operate in preheat or rapid start circuits, although they may be inadvertently put into fixtures with ballasts of these types.

Instant start lamps with bipin bases are identified with the letters IS at the end of the ordering abbreviation. For instance, the F40T12/D/IS is a 40-watt, 1½ inch diameter, Daylight Instant Start fluorescent lamp.

RAPID START LAMPS

Rapid Start lamps, which first reached the market in 1952, start smoothly and quickly without starters. They start almost as quickly as Slimline lamps and in a much shorter time than Preheat lamps, using ballasts that are more efficient and smaller than Instant Start ballasts. They depend upon cathode heating, provided by heating windings in the ballast, to reduce the starting voltage requirement below that necessary for Slimline lamps of the same size. This is explained in greater detail in the section on Rapid Start Circuits.

Because of the popularity of the 40-watt lamp in the T-12 bulb size, the ordering abbreviation is simplified by the omission of the bulb size, for example, F40N means a 40-watt, 1½ inch diame-

ter Natural Color Rapid Start lamp. However, the 30-watt Rapid Start lamp has a complete ordering abbreviation, such as F30T12/CWX/RS. Standard Rapid Start lamps are available in 25-, 32-, 34- and 40-watt sizes, with lengths of 36 inches (25-, 30-, 32- and 34-watt sizes) and 48 inches (40-watt size), with specialty lamps available in smaller sizes. A silicone coating is applied to all Rapid Start lamps to provide reliable starting conditions of high humidity.

RAPID START — HIGH OUTPUT LAMPS

Preheat, Slimline and Standard Rapid Start lamps with T-12 bulbs generally operate at 10 watts per foot with a lamp current of 430 ma. High Output lamps for indoor applications generally operate at 800 ma., a loading of about 14 watts per foot. At 800 ma., they provide approximately 45 percent more lumens than Slimline lamps of comparable sizes. For outdoor applications, such as street lighting and floodlighting, High Output lamps are usually operated at 1000 ma. to provide high light output at lower temperatures.

Standard High Output lamps range in power from 32 to 105 watts and in length from 24 inches to 96 inches. The ordering abbreviations, like those for Slimline lamps, indicate lamp length, bulb diameter and color but have the suffix "HO" for High Output, such as F60T12/DSGN50/HO for the 60 inch, 1½ inch diameter, Design 50 High Output lamp. Specialty lamps are available in smaller sizes.

RAPID START — VERY HIGH OUTPUT LAMPS

Very High Output (VHO) lamps operate at 1500 ma. and approximately 25 watts per foot of tube length. When fluorescent lamp current exceeds the 1 ampere (1000 ma.) level, lamp watts per foot become high enough to create a heat problem that requires design ingenuity for proper control. The heat resulting from 1500 ma. in a T-12 bulb, if left uncontrolled, may cause the mercury vapor temperature to run too high with a resulting increase in pressure that will reduce the efficacy. The most efficient operation is obtained with mercury vapor pressure of about 6 to 10 microns, which is the vapor pressure of mercury between 40° and 45°C. This pressure range is obtained in VHO lamps by employing circular metallic reflecting shields mounted

between the electrodes and the lamp ends. These shields break up the convection currents in the heated gas near the cathodes so that proper temperatures are obtained at lamp ends behind the cathodes. This, in effect, produces a "pressure control center" as shown in Figure 13 that operates at the desired 40°C region under lamp rating conditions. The excess mercury condenses in the control center, and optimum mercury vapor pressure is maintained throughout the tube. VHO lamps also use a mixture of rare gases to give long cathode life and high lumen maintenance in the conventional T-12 bulb.

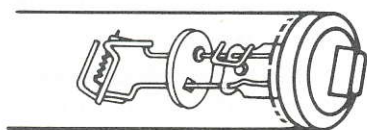


Figure 13. VHO Pressure Control Center.

All VHO lamps have recessed double contact bases. They range in power from 110 watts to 215 watts and in length from 48 inches to 96 inches. Lamp ordering abbreviations are the same as those for High Output lamps except for the suffix "/VHO" instead of "/HO".

SUPERSAVER LAMPS

SuperSaver fluorescent lamps were originally developed to be used to retrofit existing lighting installations in order to reduce energy consumption. Wattage ratings of these lamps are from 10% to 20% lower than the standard lamps they replace. The energy reduction of SuperSaver lamps is accomplished primarily by changing the gas fill to a high percentage of Krypton.

A Krypton lamp has a lower voltage drop when operating at a specified current than one filled with argon. Since typical "lead" type fluorescent ballasts are essentially constant current devices, the voltage of the Krypton filled lamp is actually lower and consequently the voltage is also lower when compared with a standard argon filled lamp. Light output from SuperSaver lamps is reduced by amounts ranging from 12% to 18%.

SuperSaver lamps must be operated at temperatures of 60 degrees F or higher. At lower temperatures, the Krypton-filled lamp becomes unstable and will not only be annoying to occupants of the space, but will give poor service and may in fact damage the ballast on which it is operating (due to current/voltage surges). SuperSaver lamps should always be used with Rapid Start ballasts which meet ANSI specifications. SuperSaver lamps are not intended for use (1) at ambient temperatures below 60°F or in drafty locations, (2) on low power factor ballasts, (3) reduced current/reduced light output ballasts, (4) dimming ballasts, or (5) on inverter operated emergency lighting systems.

SUPERSAVER PLUS

The newest retrofit lamp now available is called the SuperSaver Plus lamp. This energy-saving lamp is basically a SuperSaver lamp as described in the preceding section. Added to this basic product design is a pair of thermally-activated switches which open after the lamp has completed its normal rapid-start starting sequence. Normally each cathode coil dissipates about one watt of power. In all hot cathode fluorescent lamps, this power is consumed during the entire time the lamp circuit is operating. The thermally-activated switches in the SuperSaver Plus lamp provide the means to automatically disconnect the electrical power that heats the coils, thus savings two watts per lamp. In addition the electrical losses within the ballast are reduced by about another half watt. The average total saving is therefore about 2½ watts per lamp more than standard 34-watt energy saving lamps. SuperSaver Plus lamps should only be used on Rapid Start circuits. They should never be used in fixtures equipped with starters. These lamps are not intended for use on high frequency electronic ballasts, nor with Thrift/Mate lamps or other impedance modifying devices.

Because the switches are thermally-activated, they do require a reset time of approximately one minute after the lamp is turned off. During normal operation, the lamp will start just as any rapid start lamp. If a power interruption of less than one minute does occur, however, it may take up to 60 seconds for the switches to reset and the SuperSaver Plus lamp to restart.

The unique bimetal thermal switch which was developed for the SuperSaver *Plus* lamp is inserted into one of the internal lead wires when the lamp is made. Mounts are then sealed into each end of the lamp in the normal manner. Figure 14 shows this construction.

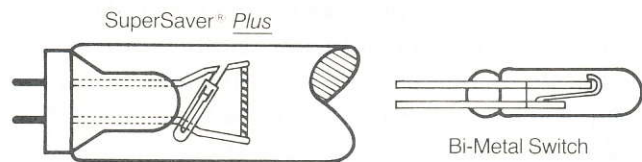


Figure 14. One of two thermally-activated switches in a SuperSaver *Plus* lamp.

THE OCTRON LAMP

Another recent Sylvania engineering development is the Octron fluorescent lamp. As its name implies, the Octron lamp utilizes a T-8 (1") diameter bulb rather than the common T-12 (1½") diameter bulb. This advanced lamp was designed using a system approach. This unique lamp is designed to provide full light output as compared to an F40 fluorescent lamp in the same fixture while consuming 24% less power.

In order to achieve high efficacy, Octron lamps take advantage of the two-coat phosphor technology discussed earlier. An additional benefit of the T-8 diameter is a higher optical efficiency when the luminaire is designed specifically for this lamp.

When operated on the standard 60 hertz power supply, the four-foot Octron 32-watt lamp produces 91 lumens per watt. When operated at high frequency (typical for an electronic ballast), the Octron F032 produces more than 103 lumens per watt on an instant start circuit.

Octron lamps are made in 17-, 25-, 32- and 40-watt sizes, in 2', 3', 4' and 5' lengths, respectively. A new family of Curvalume Octron lamps has also been introduced. This family of lamps has a leg spacing of 1⅝" and are available in 16-, 24- and 31-watt sizes. They are designed to operate on existing Octron ballasts and use standard sockets designed for other Curvalume lamp types. All Octron lamps are available in both a warm 3100K and a cool 4100K color temperature. Refer to Engineering Bulletin O-362 for a complete Octron product description.

WEATHER-SHIELDED LAMPS

Fluorescent lamps encased in glass jackets operate efficiently over a wide range of climatic conditions, including extremes of cold and strong wind, in which unjacketed lamps are inoperable or highly inefficient. Jacketed, weather-shielded lamps are available in several T-12 sizes of Slimline, High Output and Very High Output lamps. The jacket itself is T-14½ (1⅜" Diameter) glass. They are recommended for use in open fixtures in all-weather outdoor applications, and in certain indoor applications such as freezer warehouses, subways and tunnels where cold and/or windy conditions prevail.

CIRCLINE LAMPS

Although Circline lamps are Rapid Start Types for operation on Rapid Start Circline ballasts, they will also operate well on preheat ballasts. Standard sizes range from 22 to 40 watts, with 6½ to 16 inch outside diameters. The 22-watt Circline lamp is also available with a medium base adapter for immediate incandescent retrofit conversion to fluorescent. The lamp's circular design is more suitable for smaller or more symmetrical areas.

CURVALUME LAMPS

Curvalume fluorescent lamps are essentially standard 40 watt lamps bent into a "U" shape with a normal length of 24 inches measured from the pin base face to the outside bend. This curved shape permits the use of two lamps (equivalent to two 48 inch of four 24 inch straight lamps) in a 24 inch square fixture. Curvalume lamps operate on standard 40-watt Rapid Start ballasts. Another advantage is that it allows the wiring and lampholders to be installed at one end of the fixture. This design offers architects and engineers a compact shape to be used in modular ceiling designs.

REFLECTOR LAMPS

These lamps have a partial internal reflective coating between the glass tube and phosphor coating. This reflector provides a directional control with approximately 60 percent more light beneath the lamps than is produced by regular lamps without reflectors. They have the same physical and electrical characteristics as standard lamps and are therefore interchangeable. Reflector lamps are available with reflectors from 135 to 235 degrees in various lamp sizes. These

lamps are especially recommended in dirty locations of industrial applications where the fixtures are difficult to reach for cleaning. Other applications include coves, showcases and other systems in which reflectors are not practical because of space limitations or poor reflectance. In some installations reflector lamps are used for indirect lighting by aiming the light toward the ceiling.

APERTURE LAMPS

The Aperture lamp is similar to the Reflector lamp, but there is a small clear window in the reflective and phosphor coating. This aperture, which runs the full length of the lamp, can have a surface brightness up to eight times that of a standard fluorescent lamp. These lamps are available with apertures ranging from 15 to 60 degrees in various lamp sizes. When used with reflectors or lenses, Aperture lamps provide a very concentrated beam, projected in one direction. Applications include bridge lighting from the rails, aircraft landing strips, highways and approach ramps, billboard and sign lighting, wall washing and reprographic equipment.

GRO-LUX® LAMPS

Gro-Lux fluorescent lamps are designed to produce radiant energy in the wavelength bands that stimulate plant growth. They provide high levels of red and blue radiation, which are beneficial for plant propagation, and enhance vegetative growth of many plants, in home and commercial use. There are basically two types of Gro-Lux lamps; both are made in various sizes. The Standard Gro-Lux lamp, known for its purplish light, promotes plant growth, enhances the appearance of flowers and imparts a dramatic appearance to tropical fish in aquariums. For commercial growers, the type recommended is the Gro-Lux Wide Spectrum fluorescent lamp which is especially tailored to meet their needs. The output of the Gro-Lux/WS lamp is strong in the wavelengths of radiation which promote two major photochemical reactions, photosynthesis and chlorophyll synthesis.

BLACKLIGHT AND BLACKLIGHT BLUE LAMPS

Blacklight fluorescent lamps differ from standard fluorescent lamps in the composition of the phosphor used. This phosphor radiates the major portion of its energy in the near ultraviolet region (peaking at a nominal 350 nanometers)

rather than in the visible range. Since the Blacklight lamp also emits some visible blue radiation, it is often used with an external deep-blue filter to suppress the visible radiation. Blacklight Blue fluorescent lamps are like Blacklight lamps except that they have a special dark-blue bulb which absorbs almost all visible light while freely transmitting ultraviolet radiation, eliminating the need for a separate filter. Both lamp types operate in the same circuits and with the same equipment as equivalent wattage and size standard fluorescent lamps. These are numerous applications for Blacklight lamps in industry as well as a broad range of theatrical and decorative lighting effects. See Engineering Bulletin 0-306 for additional information concerning Blacklight Radiant Energy.

GERMICIDAL LAMPS

Germicidal lamps are included in the fluorescent family although the clear glass bulbs are not phosphor coated. Normal glass used for fluorescent lamps filters out radiation below approximately 280 nanometers. The Germicidal bulb is a special glass that transmits ultraviolet radiation of 253.7 nanometer wavelength generated by the arc. Radiation of this wavelength kills a wide variety of bacteria and molds. It is important that skin and eyes be protected from germicidal ultraviolet radiation, since over-exposure will irritate the eyes and redden the skin. The bare lamps should never be viewed directly. Additional information concerning these lamps may be found in Engineering Bulletin 0-342.

OPERATING CIRCUITS FOR FLUORESCENT LAMPS

Fluorescent lamps, as with all arc discharge lamps, must be operated with a ballast which limits the lamp current and provides the required starting voltage. As the current in the arc increases, the resistance of the arc decreases. Thus the arc in a fluorescent lamp would "run away with itself", drawing so much current that it would destroy the lamp (by burning up the cathodes) if it were not controlled. Limiting the current is the most important function of the ballast, whether it be a choke coil, a reactor, a capacitor or a resistance. Each fluorescent lamp type requires a ballast that is designed especially for its electrical characteristics, the type of circuit in which it operates, and the input voltage and frequency of the power supply.

TABLE II
Reference Data on Sylvania Fluorescent Lamps

Lamp ² Designation	Nominal Watts	Nominal Length (inches) ³	Base	Lamp Operating	
				Amps.	Volts
Preheat					
F4T5	4	6	Min. Bipin	0.170	29
F6T5	6	9	Min. Bipin	0.160	42
F8T5	8	12	Min. Bipin	0.145	57
F13T5	13	21	Min. Bipin	0.165	95
F14T12	14	15	Med. Bipin	0.380	39
F15T8	15	18	Med. Bipin	0.304	56
F15T12	15	18	Med. Bipin	0.330	46
F20T12	20	24	Med. Bipin	0.380	56
F25T12	25	33	Med. Bipin	0.445	64
F30T8	30	36	Med. Bipin	0.350	100
F90T17	90	60	Mog. Bipin	1.500	62
F90T17/SS	85	60	Mog. Bipin		
Rapid Start — Preheat ⁴					
F40	40	48	Med. Bipin	0.430	102
F40T12/RS/SS	34	48	Med. Bipin		
Rapid Start					
F30T12	30	36	Med. Bipin	0.430	78
F30T12/RS/SS	25	36	Med. Bipin		
F025					
F032					
F040					
High Output					
F24T12/HO	32	24	Rec. D.C.	0.800	42
F36T12/HO	44	36	Rec. D.C.	0.800	
F48T12/HO	60	48	Rec. D.C.	0.800	79
F72T12/HO	85	72	Rec. D.C.	0.800	116
F72T12/HO	100	72	Rec. D.C.	1.000	105
F96T12/HO	110	96	Rec. D.C.	0.800	152
F96T12/HO/SS	95	96	Rec. D.C.		
Very High Output					
F48T12/VHO	115	48	Rec. D.C.	1.500	83
F72T12/VHO	165	72	Rec. D.C.	1.500	124
F96T12/VHO	215	96	Rec. D.C.	1.500	161
F96T12/VHO/SS	195	96	Rec. D.C.		
Circline					
FC6T9					
FC8T9	22	8" Diam.	4 — Pin	0.380	60
FC10T9					
FC12T10	32	12" Diam.	4 — Pin	0.430	82
FC16T10	40	16" Diam.	4 — Pin	0.415	108
Curvalume					
FB40/6"	40	24	Med. Bipin	0.430	100
FB40/6/SS					
Instant Start ⁵					
F40T12/IS	40	48	Med. Bipin	0.420	104
F40T17/IS	40	48	Mog. Bipin	0.420	107
Slimline ⁶					
F42T6	25	42	Single Pin	0.200	145
F64T6	38	64	Single Pin	0.200	225
F72T8	38	72	Single Pin	0.200	218
F96T8	51	96	Single Pin	0.200	290
F48T12	39	48	Single Pin	0.425	100
F72T12	55	72	Single Pin	0.425	149
F96T12	75	96	Single Pin	0.425	197
F96T12/SS	60	96	Single Pin	0.440	157

Reference Notes

¹ Rated initial lumens, mean lumens and rated life are not included in this bulletin because frequent improvements in lamp performance continuously obsolesces published data. Refer to other engineering bulletins for current ratings.

² "T" stands for tubular bulb; number indicates diameter of tube in eighths of an inch.

³ Indicates length of lamp plus two standard lampholders.

⁴ Electrical values are slightly different for preheat operation.

⁵ Base pins shorted inside base.

⁶ T-6 and T-8 Slimline lamps are also operated at 0.100 amp. and 0.300 amp.

BALLASTS

While limiting the current in a fluorescent lamp is the most important function of a ballast, the ballast must also supply low voltage to heat the cathodes in some systems, and adequate voltage for starting the lamp.

Although fluorescent lamps may be ballasted by inductance, capacitance, or resistance, the most practical and widely used of the three is inductance. In most cases, the fluorescent lamp

ballast includes an inductive device such as a choke coil or an autotransformer to limit the current. Use is also made of the series combination on inductive coil and capacitor.

All magnetic ballasts produce an inherent sound, commonly described as a "hum". This will vary with the type of ballast, from a nearly inaudible sound to a noticeable noise. Most manufacturers give their ballasts a sound rating from A to F, as an aid in the selection of ballasts.

TABLE III
Approximate Watts Loss in Typical Fluorescent Lamp Ballasts

Lamp Designation	Nominal Watts	118 Volts ¹			277 Volts ²		
		Single Lamp	Two — Lamp		Single Lamp	Two — Lamp	
			Series	Lead-Lag		Series	Lead-Lag
Preheat							
F4T5	4	2	—	—	—	—	—
F6T5	6	2	—	—	—	—	—
F8T5	8	2	—	—	—	—	—
F13T5	13	6	—	—	—	—	—
F14T12	14	6	—	—	—	—	—
F15T8	15	5	—	8	—	—	—
F15T12	15	5	—	8	—	—	—
F20T12	20	6	—	10	—	—	—
F25T12	25	6	—	—	—	—	—
F30T8	30	10	—	17	—	—	—
F40T12	40	10	—	16	10	—	16
F90T17	90	20	—	33	—	—	33
Rapid Start							
F30T12	30	52 ³	75 ³	—	52 ³	—	76 ³
F40T12	40	52 ³	94 ³	—	52 ³	—	94 ³
High Output							
F24T12	32	70 ³	100 ³	—	65 ³	100 ³	—
F48T12	60	85 ³	154 ³	—	85 ³	150 ³	—
F72T12	85	135 ³	210 ³	—	135 ³	210 ³	—
F96T12	110	140 ³	246 ³	—	140 ³	246 ³	—
Very High Output							
F48T12/VHO	115	138 ³	247 ³	—	140 ³	247 ³	—
F72T12/VHO	165	200 ³	360 ³	—	200 ³	360 ³	—
F96T12/VHO	215	235 ³	450 ³	—	230 ³	450 ³	—
Circline							
FC8T9	22	29 ³	—	—	—	—	—
FC12T10	32	45 ³	—	—	43 ³	—	—
FC16T10	40	56 ³	—	—	56 ³	—	—
Instant Start							
F40T12/IS	40	20	20	25	23	21	24
F40T17/IS	40	20	20	25	23	21	24
Slimline							
F42T6 ⁴	25	16	—	16	16	—	16
F64T6 ⁴	38	17	—	30	—	—	—
F72T8 ⁴	38	17	—	30	12	—	25
F96T8 ⁴	51	19	—	30	18	—	30
F48T12 ⁵	39	20	20	25	23	21	24
F72T12 ⁵	55	26	27	33	25	26	27
F96T12 ⁵	75	26	27	33	25	26	27

Reference Notes

¹ Ballast range, 110-125 volts.

² Ballast range, 255-290 volts.

³ Total input watts to ballast, including lamp and ballast watts.

⁴ Operating lamp at 200 ma.

⁵ Operating lamp at 425 ma.

An "A" ballast will usually have the least hum and should be used in quiet areas, such as offices and homes. The most audible hum is produced by an "F" ballast, which should be satisfactory for street lighting and noisy factory areas.

Because of the losses within the ballast, they consume a small amount of wattage which must be added to the lamp wattage to obtain the total wattage of the lighting system. Approximate watts loss in typical fluorescent lamp ballasts are listed in Table III.

Increasing energy costs have encouraged the use of energy-saving ballasts. Designed to have lower copper and iron losses, these ballasts operate lamps while consuming less system power.

CLASS P BALLASTS

Class P Ballasts, meeting Underwriters' Laboratories requirements, have a thermal protector in the ballast. This is an automatic resetting (thermostatic) type, designed to remove the ballast from the circuit whenever the ballast case temperature reaches $110^{\circ}\text{C} \pm 5^{\circ}\text{C}$. After the ballast has cooled, the protector recloses the circuit for normal operation, and the lamps will relight.

There are four general types of operating circuits for fluorescent lamps: Preheat, Instant Start, Trigger Start and Rapid Start.

ELECTRONIC BALLASTS

Electronic ballasts are now available to operate some types of fluorescent lamps. These devices substitute solid state circuitry for some of the magnetic components used in conventional ballasts. Electronic ballasts usually operate the lamps at an elevated frequency rather than the 60 hertz available from the utility. Operating fluorescent lamps at higher frequencies may improve lamp efficacy by several percent while reducing internal ballast wattage losses compared with magnetic ballasts.

PREHEAT CIRCUITS

The simple basic preheat circuit is shown in Figure 15. When the lamp on/off switch is closed, the preheat circuit is completed and the heating current flows through the electrodes at each end of the lamp. After the short preheat time (usually about one second) the switch is opened. This impresses a high voltage pulse across the lamp and causes an arc to strike between the cathodes. The switch can be operated manually, as in some desk lamps where a button is pushed to close the starting circuit and then released to open the starting circuit and strike the arc. More commonly, the switch is an automatic switch called a starter. Starters will be described in more detail later in this bulletin.

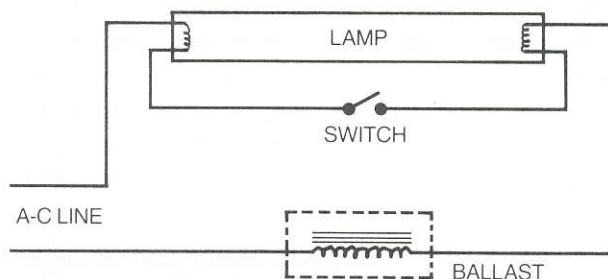


Figure 15. Simple Basic Preheat Circuit.

Preheat lamps may be operated on either single or multi-lamp ballasts. The single lamp ballast has a simple choke coil of choke with autotransformer to supply the voltage required to start and operate the lamp. The two-lamp ballast is usually of the lead-lag type.

Except for a few special applications, pre-heat lamps are now seldom used in sizes over 20 watts (24 inches length). The pre-heat lamp operated on a simple choke type ballast is economically desirable in the small sizes since it is readily started on 120 volts without the necessity for an auto-transformer as a part of the ballast circuit.

Early fluorescent lighting installations made wide use of the four-foot, 40-watt, lead-lag ballast circuit for general lighting. Today, use of this circuit is found only in older installations.

STARTERS

The principal functions of a starter are to close the starting circuit of a preheat lamp while the cathodes heat up, and then to open the circuit to start the lamp. If the arc fails to strike, the starter keeps trying until the lamp starts. A further function in protective starters is to disconnect a lamp from the starting circuit when it fails to start after several attempts. Starters may be of the thermal or the glow-switch type, with the latter being more common.

GLOW-SWITCH STARTERS

A small glowlamp, called a glow switch, is used as the heart of a glow-switch starter. In one type, one electrode is a stiff wire and the other is a bimetal strip, both enclosed in a small glass bottle filled with an inert gas such as argon or neon. When a voltage is applied across the lamp, the same voltage is impressed across the starter, as shown in Figure 16. This causes a glow discharge and a small current flow between the electrodes. The heating effect of the current causes the bimetal strip to expand and to make contact with the other electrode. This momentary delay allows the preheating current to flow through the lamp cathodes for the short time while there is enough residual heat in the switch to keep it closed. As the bimetal strip cools, it bends in the other direction opening the contacts with a resultant high-voltage pulse that should start the lamp.

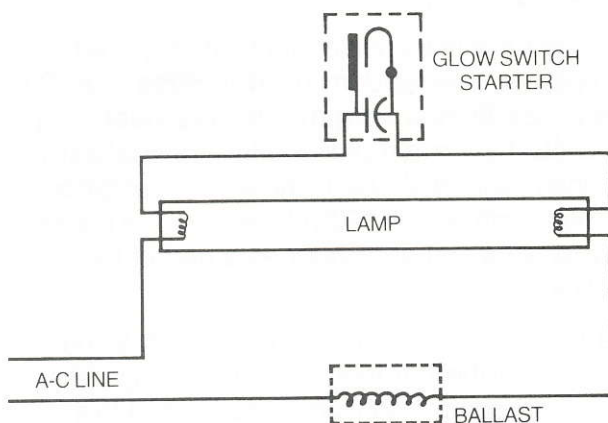


Figure 16. Glow-Switch Starter and lamp circuit.

If the lamp fails to start, the starting cycle is repeated. Once the fluorescent lamp has started, the voltage across the lamp and the starter drops to a point where it is not sufficient to

operate the glow switch. Thus the glow-switch starter consumes no power when the lamp is operating and is available for immediate restarting when the lamp is turned off.

MANUAL-RESET CUTOUT STARTERS

When a fluorescent lamp reaches the end of its life, repeated attempts will fail to start it. With either a thermal-switch starter or a glow-switch starter, the cathodes will continue to flash on and off until the starter fails or the lamp is replaced. This type of operation may also damage the ballast from overheating. A manual-reset starter prevents this repeated cycling. Figure 17 shows a sketch of the mechanism of such a starter, and Figure 18 depicts the circuit diagram.

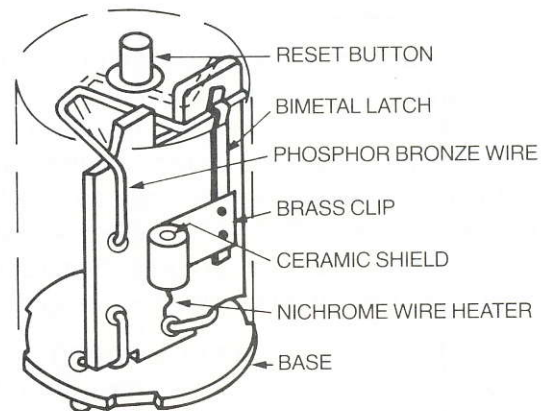


Figure 17. Mechanism of Manual-Reset Starter.

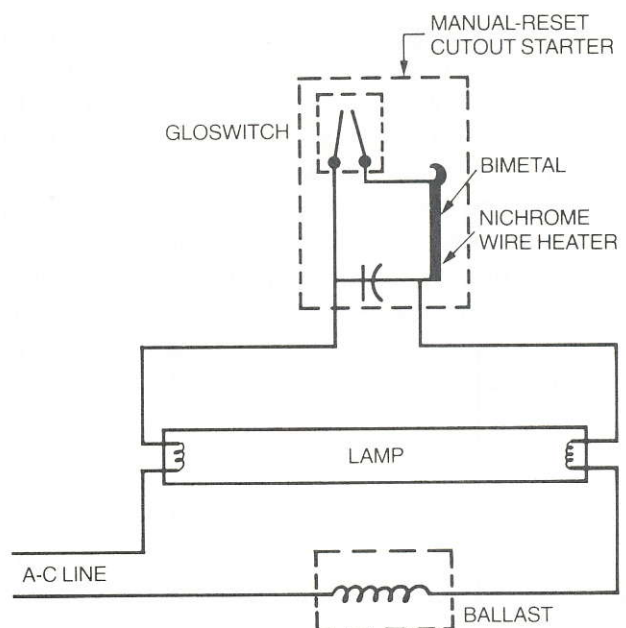


Figure 18. Manual-Reset Starter and lamp circuit.

In addition to a glow switch, the starter circuit includes a small nichrome-wire heater enclosed in a ceramic shield which, in turn, is surrounded by a brass clip. The clip is fastened to a bimetal strip which serves as a latch over a spring. The ceramic shield slows down the transfer of heat from the nichrome-wire to the brass clip, so that the bimetal latch does not receive enough heat to affect it when the starter needs only a few attempts to start the lamp. However, if the lamps fail to start after repeated attempts, enough heat will reach the bimetal strip to pull it away from the latch, thus opening the circuit. The circuit will then remain open and the lamp off until the reset button is pushed. This type of starter not only protects the ballast but prevents the annoyance caused by a cycling lamp.

AUTOMATIC-RESET STARTERS

The manual-reset starter offers protection to the circuit in cutting out a failed lamp, but it is possible for a manual-reset starter to cut out when the lamp has not failed. In an industrial plant, for example, it is possible that 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 will be cut out by manual-reset starters and will not start again until the reset button is pushed. The answer to this type of situation is the automatic-reset starter.

Instead of a manual push button for resetting, the automatic-reset starter has an extra heater which holds the contacts open as long as voltage is supplied to the lamp. The heater draws power on the order of 1 watt. If the lamp has not failed but has been cut out by a condition such as the one just described, the lamp will start again as soon as the starter has cooled. This cooling takes about one minute. In the usual case, however, the lamp would start the next time the circuit was switched on after an off period.

INSTANT START CIRCUITS

If enough voltage is applied across a fluorescent lamp, the arc will strike without preheating of the cathodes. Since no preheating time is required, a circuit with such a high voltage is called an instant start circuit. Because a preheat circuit is not required, Slimline (instant start) lamps have only a single pin base at each end.

A safety circuit is used with instant start lamps to eliminate the possibility of an electrical shock with this circuit design. When the lamp is removed, the base pin acts as a switch, breaking the circuit to the ballast as shown in Figure 19. In order to get a lamp into the lampholders, it must first be pushed into a spring lampholder at the high-voltage end and then inserted into the rigid lampholder at the low-voltage end. Both lamp ends must be in place to close the circuit, permitting the flow of current through the primary winding.

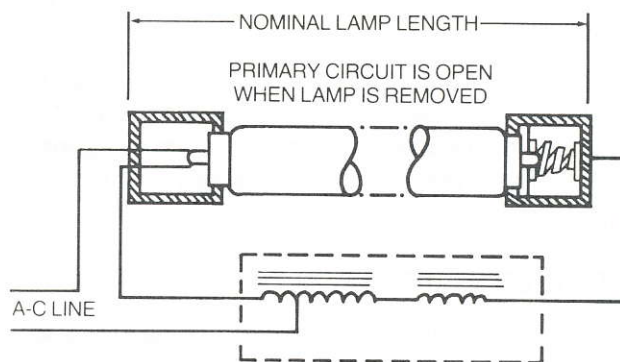


Figure 19. Slimline (Instant Start) lamp, lampholders and circuit.

Most instant start lamps are operated with series sequence ballasts in the circuit shown in Figure 20. The two lamps are actually started in sequence, a few thousandths of a second apart and operate in series.

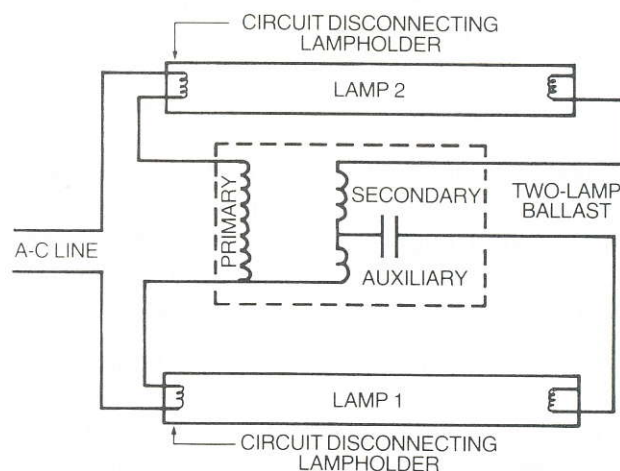


Figure 20. Typical Two Lamp Series — Sequence instant-start circuit.

In the circuit diagram it will be noted that the auxiliary winding supplies the voltage to start Lamp No. 1. Before the first lamp lights, the voltage of the auxiliary winding subtracts from the primary and secondary voltages, thus resulting in insufficient starting voltage for Lamp No. 2. However, when Lamp No. 1 lights, the current flow through the capacitor shifts the phase relationship between the auxiliary winding and the secondary winding, causing the two voltages to add. This causes the voltage to be sufficient to start Lamp No. 2. The lamps then operate in series, with the auxiliary winding contributing nothing to the circuit.

There is also a lead-lag ballast circuit available for special applications. Because it is heavier, and more expensive, its use is generally limited to low temperatures or other special applications.

TRIGGER START CIRCUITS

The trigger start circuit is sometimes used for operating preheat fluorescent lamps up to 20 watts in size. This circuit was developed prior to the rapid start circuit and is quite similar in that it provides continuous heating of the cathodes and does not require a starter. To minimize the power loss of the cathodes during lamp operation, the rapid start circuit was introduced.

RAPID START CIRCUITS

As explained in the section on Rapid Start lamps, ballasts for rapid start circuits have separate windings to provide continuous heating voltage for the lamp cathodes as shown in Figure 21. Unlike the preheat circuit which has no cathode heating after the arc strikes, the rapid start circuit provides the lamp with a small heating current even when the lamp is burning. Under normal conditions, the rapid start ballast will start the lamps in less than one second.

Two lamp rapid start ballasts start the lamps in sequence and then operate them in series. When the circuit is turned on, the first operation is the heating of the cathodes to aid in starting the lamps by reducing the starting voltage requirements. The capacitor shunted across Lamp No. 2 aids in starting Lamp No. 1 first by momentarily applying nearly all of the ballast secondary voltage across Lamp No. 1. Since the voltage drop across Lamp No. 1 is very low after starting, practically all of the ballast voltage is available to

start Lamp No. 2. The two lamps then run in series with rapidly increasing current until stable operation at rated current is achieved. It is essential that proper cathode heat be maintained during lamp operation to insure normal lamp life.

To insure dependable starting, it is important that lamps operated on rapid start ballasts be mounted within one inch of an electrically grounded metal strip extending the full length of the lamp for HO and VHO types and one-half inch for lamps below 500 ma. In most cases, the reflector or the wiring channel serves this purpose.

INTERCHANGEABILITY OF 40-WATT LAMPS

For satisfactory performance, fluorescent lamps should always be operated with the proper ballast type. Table IV describes the lamp performance to be expected when lamps are inadvertently interchanged.

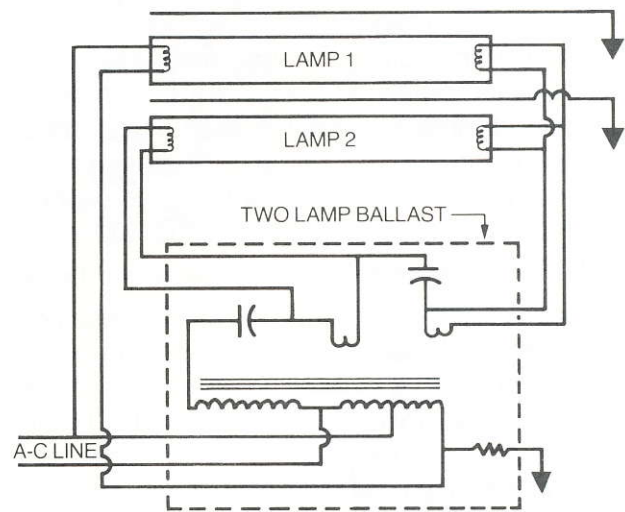


Figure 21. Typical Two Lamp Series — Sequence rapid start circuit.

TABLE IV
Lamp Performance When 40-Watt Bipin
Fluorescent Lamps Are Interchanged with Typical Ballasts

Ballast Type	Bipin-Lamp Type		Lamp Performance
Preheat	Preheat	OK	Normal rated life.
	Instant-Start	NG	Won't start. Filament is short-circuited inside lamp base. Starter will keep trying to strike an arc until failure occurs or the lamp is disconnected.
	Rapid-Start	OK	Normal rated life.
Instant-Start	Preheat	NG	May start. Very short life because primary current flows through one filament, causing early darkening and early failure.
	Instant-Start	OK	Normal rated life.
	Rapid-Start	NG	May start. Very short life because <i>high</i> primary current flows through one filament designed for low heating current.
Rapid-Start	Preheat, only	NG	Not recommended. Might start with best grounding and high line voltage, but starting is doubtful and unreliable under usual field conditions.
	Instant-Start	NG	Will not start. Short-circuited filament across heater winding will overheat ballast and could cause burnout.
	Rapid-Start	OK	Normal rated life.

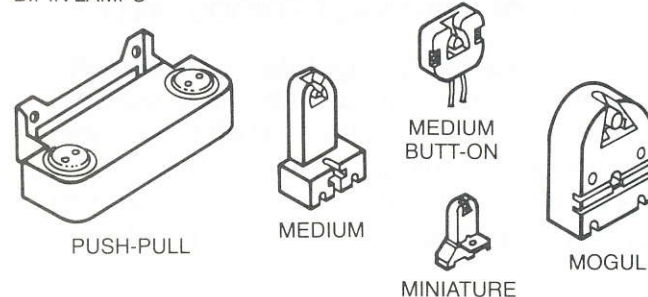
LAMP HOLDERS

Many types of fluorescent lampholders are available for the various types of fluorescent lamp bases and to meet different mounting requirements. Lampholders are required to support fluorescent lamps and to provide electrical connections. The one that is most commonly used for Preheat and Rapid Start bipin lamps is the twist-turn type. Also available for bipin base lamps are spring pressure push-pull lampholders. Special circuit-interrupting bipin lampholders are used with single lamp ballasts and dimming ballasts.

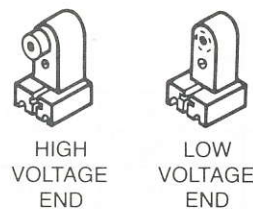
For the support of the Slimline single pin lamp, the spring is in the high voltage lampholder, while the low voltage is rigid and has a circuit-interrupting feature. This type prevents voltage from being applied to the pins of the lamp until the lamp is firmly seated in both lampholders, thus reducing the possibility of shock when the lamp is being installed.

Typical lampholders for fluorescent lamps are pictured in Figure 22.

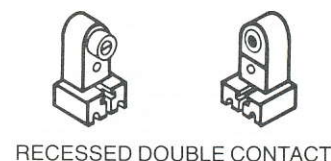
BIPIN LAMPS



SLIMLINE LAMPS



HIGH OUTPUT LAMPS AND VERY HIGH OUTPUT LAMPS



SLIMLINE LAMPS

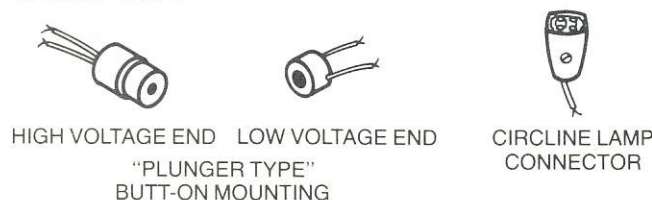


Figure 22. Typical lampholders for fluorescent lamps.

OPERATING CHARACTERISTICS OF FLUORESCENT LAMPS

LAMP LIFE

Compared with incandescent lamps, fluorescent lamps have extremely long average rated lives, but the shape of the life expectancy curve is quite similar, as shown in Figure 23. Because of slight variations in lamp making operations and lamp materials, it is impossible to have each lamp operate for exactly the life for which it was designed. For this reason, lamp life is rated as the average life of a large group of lamps, operated under controlled laboratory conditions. Average rated life is the point at which approximately 50 percent of the lamps in a large test group have burned out and 50 percent remain burning as shown by the life expectancy curve.

During the operation of a fluorescent lamp, the emissive material is gradually depleted from the cathodes. The normal end of life is reached when there is insufficient emissive material remaining on either cathode to strike the arc.

EFFECT OF BURNING PERIODS ON LIFE

Since published average rated life figures are generally based on a three hour burning cycle, these ratings reflect the effects of both starting and burning. Changes in the burning cycle will affect life in service. Shorter burning cycles (more frequent starts) shorten life and

longer burning cycles (less frequent starts) increase life. Figure 24 shows typical mortality curves for the 40-watt rapid start lamp on different burning cycles.

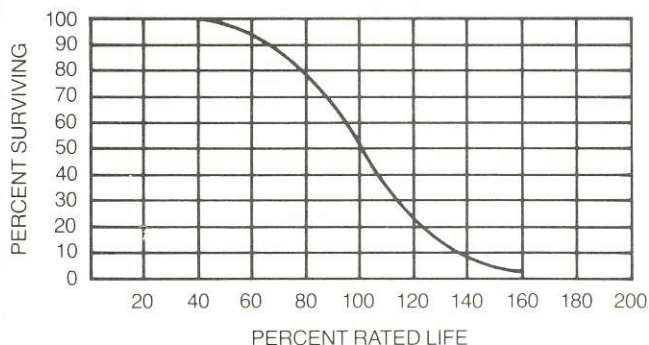


Figure 23. Typical Life Expectancy or Mortality Curve for Fluorescent Lamps.

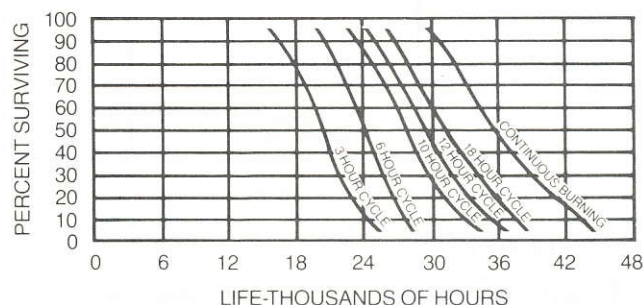


Figure 24. Typical Mortality Curves as a function of burning cycles for 40-watt Rapid Start lamps with a rated life of 20,000+ hours.

Table V lists the average life in hours of fluorescent lamps at various burning cycles.

TABLE V

Average Life in Hours of Fluorescent Lamps at Various Burning Cycles

Lamp Type	Hours Per Start					
	3	6	10	12	18	Continuous
40W Preheat	15,000	17,500	21,250	22,500	25,000	28,125
40W Rapid Start	20,000 +	24,420	27,750	28,860	31,600	37,700
High Output (HO)	12,000	14,000	17,000	18,000	20,000	22,500
Very High Output (VHO)	10,000	12,500	14,990	15,980	17,980	24,980
Slimline (96T 12)	12,000	14,000	17,000	18,000	20,000	22,500

GROUP RELAMPING

Fluorescent lamps in a lighting system can be replaced either individually as they burn out or in a group at one time, thereby saving considerable labor. The mortality curve in Figure 25 indicates that fluorescent lamps begin to fail faster after reaching 70 percent of rated life. In addition, light output falls off as the total burning hours of the lamp increases. For most fluorescent installations, the best time to group relamp is between 65 percent and 75 percent of average service life. However, the most economical relamping schedule should be determined by considering the lamp and labor costs for each specific installation.

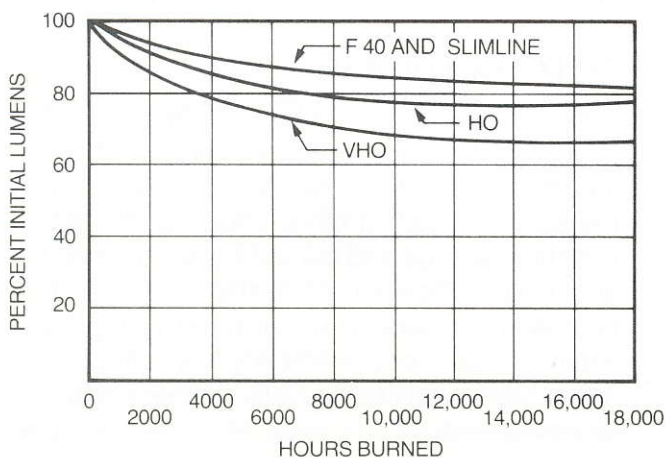


Figure 25. Approximate lumen maintenance of various types of Cool White fluorescent lamps.

LUMEN MAINTENANCE

Since a fluorescent lamp drops in light output much more rapidly during the first 100 hours of life than it does later, the published "initial lumens" value is the figure measured after the first 100 hours of burning. During this 100 hour period the lumen depreciation may be as much as 10 percent. The drop off is much more gradual during the rest of lamp life. The two principal causes of this depreciation are (1) a gradual deterioration of the phosphor coating and (2) a blackening on the inner surface of the bulb from the emissive material given off by the cathodes. This is particularly noticeable at the ends of the

lamp. The smaller diameter lamps, with T-5, T-6 and T-8 bulbs, show greater end darkening because the cathodes are closer to the bulb wall. Lumen maintenance is not appreciably affected by the number of burning hours per start.

The lumen maintenance is better with standard T-12 Rapid Start and Slimline lamps than with High Output and Very High Output types. What's more, some phosphors have better maintenance than others. Figure 25 depicts the lumen maintenance of three types of cool white fluorescent lamps.

EFFECT OF TEMPERATURE

The light output of a fluorescent lamp varies considerably with the temperature of the bulb wall. The temperature affects the mercury vapor pressure, which depends upon the coolest point on the bulb wall. Variations in the mercury vapor pressure change the light output of the lamp. Since changes in ambient temperature are accompanied by similar changes in bulb wall temperature, the light output is affected by variations in ambient temperature, as shown in Figure 26. Rated lumen output values are measured at a standard industry test ambient temperature of 77°F (25°C).

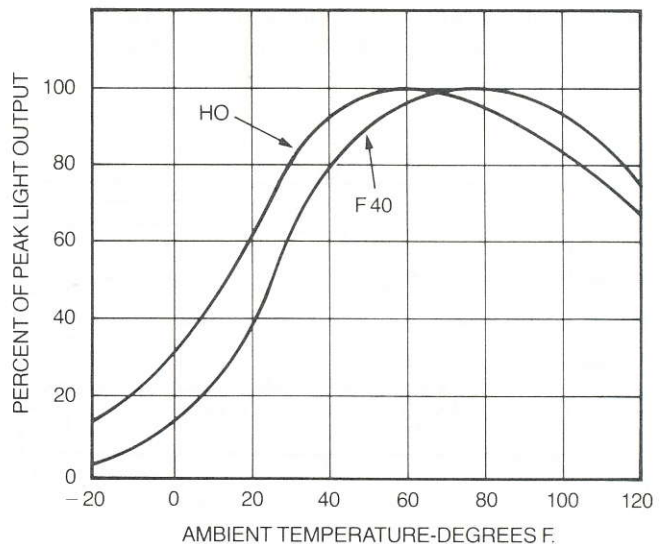


Figure 26. Changes in light output with ambient temperature for bare fluorescent lamps in still air.

Fluorescent lamps used indoors at normal room temperature provide the most light when they are operated in lighting equipment which is designed to allow proper ventilation and to prevent overheating. It will be noted in Figure 26 that the light output decreases as the ambient temperature increases above 77°F. Heat-removal air-handling troffers improve light output by controlling lamp bulb wall temperatures. It should also be noted that bare lamps exposed to excessive cooling from air conditioning may show reduced light output.

When fluorescent lamps are used outdoors, starting may be a problem at low temperatures, and higher starting voltage may be required. Standard ballasts will start lamps reliably down to 50°F. Low temperature ballasts are available for certain lamp types to provide starting down to 0°F and also down to -20°F on others.

After the lamp has been started, the effective light output depends on the temperature the bulb reaches. Since this optimum temperature varies with the lamp type, the selection of the proper lamp for the application (ambient) temperature range to be experienced is quite important. The relative light output versus ambient temperature curves for several types of fluorescent lamps commonly used outdoors are shown in Figure 27. The ambient temperature at which peak light output occurs depends on the lamp type, the design of the fixture and the wind speed.

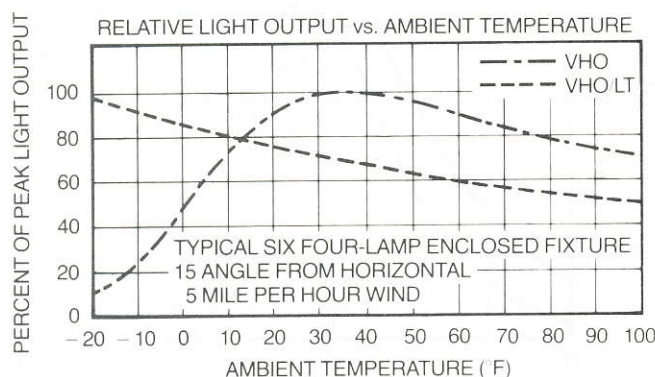


Figure 27. Curves showing relative light output at various ambient temperatures for VHO fluorescent lamps.

EFFECT OF HUMIDITY

To assure reliable starting under conditions of high humidity, the surface of Rapid Start and Instant Start lamps are coated with a silicone material. When the bulb is dry, there is an electrostatic charge on the outside of a fluorescent lamp which reduces the starting voltage requirements. High humidity can produce a film of moisture on the bulb that makes much higher starting voltages a necessity. The silicone coating causes the moisture to form in minute droplets instead of a continuous film, thus ensuring reliable starting even when the humidity is high. With preheat circuits, starting is no problem under any humidity condition since the preheat circuit furnishes a higher starting voltage pulse.

EFFECT OF VOLTAGE

Although the fluorescent lamp is not as sensitive to voltage changes as the incandescent lamp, the voltage at the fixture should be kept within the specified ballast rating shown on the label. Both high voltage and low voltage will shorten life and reduce efficiency. While standard incandescent lamps, operated under rated voltage, will extend life but, reduce efficacy, low voltage may cause starting difficulties with fluorescent lamps as well as reduce efficiency. The effect of variations in line volts on lamp volts, amperes, watts and lumens is shown in Figure 28.

A rule of thumb is that a 1% variation in the line voltage changes the lumen output by about 1%.

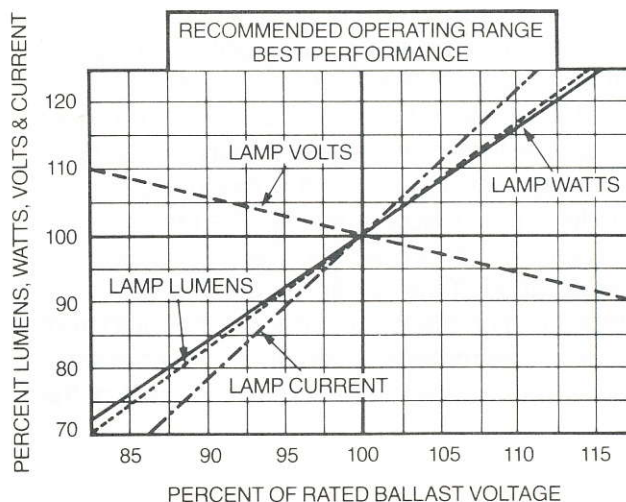


Figure 28. Effect of voltage on lamp volts, amperes, watts and lumens with 2-lamp series rapid start ballast.

Low line voltage may reduce the preheat current with Preheat lamps and this may result in frequent flashing of the lamps during starting. Shorter lamp life will result because more emissive material is driven from the cathodes. Rapid Start lamps operated at low voltage will be bothered with reduced cathode heater current, which can adversely affect starting, increase early end discoloration and shorten lamp life. Even during burning, Rapid Starting lamps must have adequate cathode voltage.

If subjected to a large drop in line voltage, fluorescent lamps may go out, momentarily or longer, depending on the duration of the reduction. The maximum allowable voltage drop varies with the lamp type and the characteristics of the ballast.

Approximate percentage of line voltage drops that will cause 40-watt T-12 lamps to go out are as follows:

Preheat	25%
Rapid Start Series Sequence	20%
Instant Start Series Sequence	50%
Instant Start Lead-Lag	40%

EFFECT OF FREQUENCY

The effectiveness of a ballast in limiting current depends on the frequency of the power supply. For this reason, a ballast should be operated only at the frequency for which it is designed. If a 60 hertz ballast, for example, is used on a 50 hertz circuit, the current to the lag lamp is increased. This causes shorter lamp life and an overheated ballast. A frequency higher than that for which the ballast was designed will reduce the current to the lag lamp. With the lead lamps, changes in frequency have an opposite effect.

There are some installations which operate fluorescent lamps at frequencies higher than 60 hertz, such as 400 hertz or 840 hertz. These use a special ballast which is smaller in size and has less wattage loss than a 60 hertz ballast. The efficacy and light output of most fluorescent lamps increases when the frequency is increased. Installations of high frequency systems are limited primarily by the cost and efficiency of the equipment required to convert 60 hertz power into higher frequencies. Some of the high frequency systems currently in use have a centralized static-converter power supply and operate at frequencies of 3000 hertz or more.

STROBOSCOPIC EFFECT

The mercury arc in a fluorescent lamp operated on a 60 hertz alternating current goes on and off 120 times per second (every half cycle). The light from the lamp would go out completely except that the phosphors have some phosphorescent or "carry-over" action. That is, they continue to glow for a short period of time after the existing radiations are cut off. However, there still is a rapid variation in light output which is unnoticed by the human eye, except possibly as flicker at the ends of the lamp. Under some circumstances, this variation in light output may produce what is called stroboscopic effect. Because of the stroboscopic effect, an object that is moving at a uniform speed may appear to move jerkily. Under the most extreme conditions, a rotating object, such as a fly wheel, may seem to be standing still or even rotating in a reverse direction. Today, stroboscopic effect rarely causes any difficulty with fluorescent lamps because modern phosphors have relatively long carry-over periods. Should this stroboscopic effect be a problem, the staggered use of ballasts on three phase circuits will reduce the stroboscopic effect by operating the lamps out of phase, so that they reach their maximum light output at different times.

DIRECT CURRENT OPERATIONS

Fluorescent lamps can be operated on direct current, provided a resistance is used in series with an inductive ballast and there is a sufficiently high voltage. A single lamp d-c circuit is shown in Figure 29. The choke type of ballast must still be used in a d-c circuit to supply the inductive "kick" needed to start the lamp when the starting switch is opened. Since the choke has no limiting effect on the direct current flowing through the arc, a resistance must be used in series with the lamp and choke to limit the current. The number of ohms resistance depends on the size of the lamp and the circuit voltage. The efficacy is reduced, as compared with alternating current operation, because the resistance consumes approximately as much energy as the lamp. Lamp life will also be reduced.

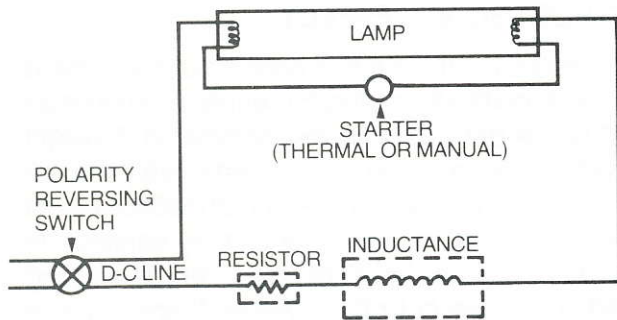


Figure 29. Typical circuit for direct current operation of fluorescent lamps.

Another problem results from the steady flow of direct current in one direction. This causes the mercury to drift toward the negative end of the tube. As a result the positive end becomes dim after several hours of operation. A polarity-reversing switch is recommended for all lamps of 6 watts and over to reverse the functions of the electrodes every few hours and thus eliminate the tendency to burn dim at one end. For the shorter lamps, which are not bothered with mercury migration, it is a good idea to use a reversing switch to even the wear on the cathodes by reversing the direction of the current. The control switch should be the type that will automatically reverse the current each time the lamp is turned on.

INVERTER BALLASTS

Sometimes it is desirable to convert direct current to alternating current for using fluorescent lamps with battery powered equipment, such as automobiles, boats, campers, hand lanterns and other portable applications. This can be done with an inverter ballast, which is a compact, solid-state device that converts low voltage d-c to high frequency a-c. Its use opens up a field to fluorescent lamps that was formerly reserved exclusively for incandescent lamps.

DIMMING

The dimming of Rapid Start fluorescent lamps is practical when they are operated on dimming ballasts and specifically designed circuits. The dimming ballast keeps the lamp cathodes supplied with the proper heating current regardless of the extent to which the lamp may be dim-

med. The dimming element that controls the arc current may be either a variable voltage auto-transformer, adjustable reactor, thyatron, silicon-controlled rectifier or other solid-state device. Some dimming systems offer smooth control without flicker from full brightness to nearly total darkness with a dimming ratio of approximately 500 to 1. Rated lamp life is not usually affected by normal dimming service, provided the lamp current crest factor is not increased or coil heater voltage is not decreased. Figure 30 shows a typical dimming circuit for a 40-watt Rapid Start lamp.

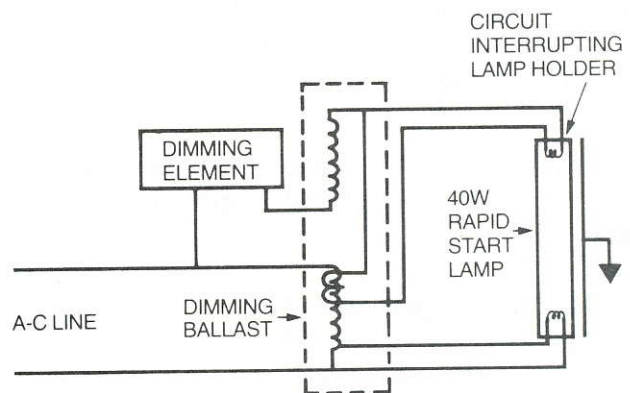


Figure 30. Typical dimming circuit for 40-Watt Rapid Start Lamp.

FLASHING

When fluorescent lamps on ordinary ballasts are switched on and off frequently, the life is greatly reduced (Refer to Effect of Burning Periods on Life, page 18). However, the use of a special flashing ballast permits Rapid Start lamps to be flashed millions of times with normal life expectancy. Flashing ballasts are similar to dimming ballasts in that they provide continuous heating current for the lamp cathodes, even when the lamp is in the off section of the flash cycle. The flashing does not turn off the entire circuit but opens the lamp arc circuit only. The flashing circuit is like the dimming circuit in Figure 30 except that the dimming element is replaced with a special flashing device. Flashing fluorescent lamps are widely used by plastic sign manufacturers.

RADIO INTERFERENCE

Electromagnetic radiation that may cause a buzzing sound in nearby radio receiving sets is emitted by the mercury arc of a fluorescent lamp. This interference is usually limited to the standard AM broadcast band because of the frequencies generated by the arc. Radio interference is greatly suppressed by the use of capacitors in rapid start and instant start ballasts and in starters for preheat circuits.

It is possible for a fluorescent lamp to cause radio interference in three ways:

- 1) through "broadcasting" radiation directly from the lamp to the radio
- 2) through radiation from the electric wires near the fixture and
- 3) through "feedback" along the electric wires to the radio.

If the radiation is direct, moving the radio at least 10 feet away from the lamp will generally eliminate the noise. Interference that is conducted to the radio may be suppressed by connecting a filter in the line at the fixture. This type of filter is available from radio parts stores.

TROUBLESHOOTING

Since this bulletin is not intended to be a service manual, it does not include any troubleshooting procedures. For complete information on this, see Engineering Bulletin 0-330, Troubleshooting Fluorescent Lighting.

OTHER BULLETINS ON FLUORESCENT LAMPS

For more detailed information on some of the types of fluorescent lamps described in this bulletin, see the following engineering Bulletins:

- 0-262 The Standard Gro-Lux Fluorescent Lamp
- 0-285 Gro-Lux Wide Spectrum Fluorescent Lamp
- 0-315 Sylvania 96" VHO Lifeline Lamps
- 0-328 VHO Outdoor Fluorescent Lamp
- 0-333 Fluorescent Lamp Performance Data
- 0-338 Controlled Fluorescent Lighting
- 0-342 Germicidal Lamps
- 0-362 Octron Lamps

SYLVANIA**GTE****Location****Sales
Offices**(TO OBTAIN SALES AND
TECHNICAL INFORMATION)**Distribution
Centers**(TO ORDER LAMPS AND TO OBTAIN SHIPPING
INFORMATION) WAREHOUSE STOCKS
MAINTAINED IN THESE LOCATIONS

Zip Code

Zip Code

Atlanta, Ga.	2115 Sylvan Rd., S.W. 404-762-1781	30344	2115 Sylvan Rd., S.W. 404-762-1781	30344
Boston, Mass.	60 Boston Street, Salem, MA 617-777-1900 — X3473	01970	105 Andover Street, P.O. Box 377, Danvers, MA 617-777-1900 — X2866	01923
Buffalo, N.Y.	25 Dewberry Lane, Gardenville Ind. Park 716-668-7559	14224	25 Dewberry Lane, Gardenville Ind. Park 716-668-7555	14224
Charlotte, N.C.	3811 North Davidson St., P.O. Box 5246 704-334-4671	28225	3811 North Davidson St., P.O. Box 5246 704-334-4671	28225
Chicago, Ill. (Elk Grove Village)	800 Devon Ave., Elk Grove Village, Illinois 312-593-3400	60007	800 Devon Ave., Elk Grove Village, Illinois 312-593-3400	60007
Cincinnati, Ohio	5480 Creek Road 513-793-6440	45242	5480 Creek Road 513-793-6440	45242
Cleveland, Ohio	4848 West 130th Street 216-267-6800	44135	4848 West 130th Street 216-267-6800	44135
Dallas, Texas (Carrollton)	2040 McKenzie Dr., P.O. Box 5018, Carrollton, TX 214-247-7800 75011-5018		2040 McKenzie Dr., P.O. Box 5018, Carrollton, TX 214-247-7800 75011-5018	
Denver, Colorado	4675 Holly Street 303-399-1760	80216	4675 Holly Street 303-399-1760	80216
Detroit, Michigan (Dearborn)	10800 Ford Road, Dearborn, MI 313-582-8754	48126	10800 Ford Road, Dearborn, MI 313-582-8754	48126
Hartford, Conn.	100 Constitution Plaza 203-249-5823	06103	105 Andover Street, P.O. Box 377, Danvers, MA 617-777-1900	01923
Honolulu, Hawaii	770 Kapiolani Blvd. Suite 513 808-536-5267	96813	1811 Adrian Road, Burlingame, Calif. 415-697-3500	94010
Houston, Texas	1440 Greengrass Dr. 713-869-8671	77008	1440 Greengrass Dr. 713-869-8671	77008
Kansas City, Kansas	450 Funston Road 913-371-3773	66115	450 Funston Road 913-371-3773	66115
Los Angeles, Calif.	6505 East Gayhart Street, P.O. Box 2795 213-726-1666	90051	6505 East Gayhart Street 213-726-1666	90040
Minneapolis, Minn. (Fridley)	5330 Industrial Blvd. N.E., Fridley, Minn. 612-571-9400	55421	5330 Industrial Blvd. N.E., Fridley, Minn. 612-571-9400	55421
New Orleans, Louisiana	5510 Jefferson Highway 504-733-6970	70183	5510 Jefferson Highway 504-733-6970	70183
New York, New York	237 Park Avenue, 9th Floor 212-503-1010	10017	1000 Huyler Street, Teterboro, N.J. 212-244-8820	07608
Orlando, Florida	7492 Chancellor Drive, P.O. Box 13327A 305-859-6220	32859	7492 Chancellor Drive, P.O. Box 13327A 305-859-6220	32859
Philadelphia, Penn. (Devon)	465 Devon Park Drive, P.O. Box 500, Devon, PA 215-293-9330	19333	465 Devon Park Drive, P.O. Box 500, Devon, PA 215-293-9330	19333
Pittsburgh, Penn.	450 Butler Street, P.O. Box 9544 412-781-4533	15223	450 Butler Street, P.O. Box 9544 412-781-4533	15223
St. Louis, Missouri (Hazelwood)	5656 Campus Parkway, Hazelwood, MO 314-731-5515	63042	5656 Campus Parkway, Hazelwood, MO 314-731-5515	63042
San Francisco, Calif. (Burlingame)	1811 Adrian Road, Burlingame, Calif. 415-697-3500	94010	1811 Adrian Road, Burlingame, Calif. 415-697-3500	94010
Seattle, Washington	750 So. Michigan Street 206-763-2660	98108	750 So. Michigan Street 206-763-2660	98108
Teterboro, New Jersey	1000 Huyler Street 201-288-9484	07608	1000 Huyler Street 201-288-9484	07608
Washington, D.C. (Springfield, Va.)	6610 Electronic Drive, Springfield, VA 703-354-3100	22151	6610 Electronic Drive, Springfield, VA 703-354-3100	22151

GTE Products Corp.
Lighting Center
 Danvers, Massachusetts 01923
 617-777-1900