Fluorescent Lamps

A Pacific Energy Center Factsheet

Pacific Gas and Electric Company
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Introduction

Fluorescent lamp technology has made tremendous advances over the past few years, with today's products providing greater energy-efficiency, improved color rendition, and a greater selection of color temperatures. These improvements are due in large part to the use of rare earth phosphors replacing older halophosphors used in standard "cool white" lamps. To a lesser degree, efficiency improvements arise from the more widespread use of smaller diameter lamps, which can also increase luminaire efficiency and improve light distribution patterns

Fluorescent Lamp Operation

This page discusses both full-size fluorescent lamps and T-5 compact fluorescent (CF) lamps.

A fluorescent lamp is a glass tube, coated on the inside surface with a phosphor material and filled with argon gas or argon/krypton gas mixture. The lamp also contains a small amount of mercury. When a suitable high voltage is applied across the electrodes located at each end of the sealed tube, an electric arc discharge is initiated, and the resulting current ionizes the mercury vapor. The ionized mercury emits ultra-violet (UV) radiation, which strikes and excites the phosphor coating, causing it to glow or fluoresce, and produce visible light. About 22% of the energy used by the lamp is converted to light. The exact makeup of the phosphor coating determines the color properties of the lamp's light output.

Fluorescent lamps require a ballast to initiate the discharge and regulate the electric current through the lamp. For optimum performance, a particular ballast must match a specific lamp's current requirements. There are three basic types of fluorescent lamp circuits: preheat, rapid start, and instant start. See the fact sheet on ballasts for more information.

Components

- *Electrodes*, also known as the cathode when positively charged and the anode when negatively charged, are located at each end of the lamp. They are coated with an electron-emissive material so that an arc (or stream of electrons) strikes when proper voltage is applied.

- *Low-Pressure Mercury Gas Fill* conducts electricity and ionizes, discharging and then reabsorbing electrons. As a result, ultraviolet (UV) energy is produced.

- *Phosphor Coating* on the inner surface of the bulb emits light when excited by the ultraviolet (UV) energy. The light's color properties depend upon the phospors used.

- *Bulb* is the glass envelope that houses the gas fill and the electrodes. Bulbs come in a variety of shapes: long, straight tubes, grooved tubes, circular, U-shaped, or bent tubes. Bulb sizes are specified in 1/8" increments, e.g., T-12, refers to a 1 1/2" diameter tube.

- *Base* provides a means of electrical connection.

The operating characteristics of fluorescent lamps are summarized below.

Efficacy	Approx. 25-90 lpw
Color Temperature	2500-7500 K
CRI	40-90
Depreciation	10-15%
Life (3 hrs/start)	10,000 - 20,000 hrs

- The *Burning position* of the lamp usually does not affect light output, although some of the lower-wattage compact fluorescent lamps are position sensitive.

- Fluorescent lamps are rated at a 77°F ambient *temperature*. When operated at different ambient temperatures, either above or below 77°F, variations in light output will occur.

- *Dimming* characteristics vary depending on lamp type. For instance, the dimming of compact fluorescent lamps is currently difficult and expensive, although new dimmable products are being developed. Near full-range dimming is possible with 4' T8, T10, and T12 lamps with special ballasts and dimming equipment. The low end of the dimming range is between 1-25% of full light output, depending on lamp type and dimming ballast.

Fluorescent Lamp Types

Manufacturers vary the gas fill, phosphor type, and content, as well as the tube length and diameter, to achieve different lamp characteristics. There is a wide range of commercially available lamps with the smallest being the 6-inch, 4-watt preheat lamp, and the largest and most powerful being the 8-foot, 1500 mA, very high output (VHO), rapid-start lamp.

Standard Fluorescent Lamps

The standard 40-watt (F40T12) lamp is filled with argon gas. Although there are a number of aviants, the most common 40-watt lamp is the "cool white" which uses an older halophosphor technology and is rated at 3050 initial lumens. High demand for the F40T12 lamp over the years has resulted in mass production and low cost. This fact sheet discusses the many opportunities to improve lamp efficacy beyond that of the standard fluorescent lamp.

Rare Earth (RE) Phosphor Lamps

Rare earth phosphor compounds are selected for their ability to produce visible light at the most sensitive wavelengths of the eye's red, blue and green sensors. When compared with conventional halophosphors, such as cool white (with a CRI of 60-62), RE phosphors produce better color rendering (CRI of 70-89) and higher efficacy, while improving lumen maintenance characteristics. For reasons of lumen maintenance, rare earth materials are required in small diameter lamps, such as compact fluorescents. RE phosphors also raise lumen output up to 8% over conventional halophosphors. RE phosphor lamps are available for most fluorescent lamp configurations and come in a wide range of color temperatures. Two generic types of RE phosphor lamps are offered: RE-70 and RE-80.

RE-70 Lamps

The expression "RE-70" refers to a fluorescent lamp containing phosphor mixes that create a CRI of 70 to 79. These lamps, formerly called "thin coat triphosphor" lamps, contain less of the rare earth phosphors than do the more expensive, high-CRI RE-80 lamps. They increase lumen output of 4-foot lamps by 5% to 6%.

RE-80 Lamps

RE-80 fluorescent lamps, sometimes referred to as "thick-coat triphosphor" or "high CRI" lamps, increase lumen output up to 8% over halophosphor cool white, and increase CRI to 80-89. The additional rare earth phosphor content in these lamps also increases lamp cost.

Energy-Saving (ES) Lamps

In response to the energy crisis of the 1970s, lamp companies introduced "energy-saving" lamps with krypton added to the gas fill. These lamps draw less power than standard F40T12 lamps (usually about 34-35 watts). Because F40T12/ES lamps can be operated by standard

F40T12 ballasts, they can be readily substituted in existing lighting systems. This reduces input wattage by about 12-15%, with a lumen output reduction of 18-20% for a two lamp system. The resulting reduction in light levels is generally acceptable to most users, although lamp color may not be as desirable.

Energy-saving lamps are more sensitive to low temperatures than standard lamps, with minimum starting temperature about 16 °C [60 °F], as opposed to 10 °C [50 °F] for standard 40-watt lamps. Energy-saving lamps are not recommended for dimming applications. Manufacturers offer a range of energy-saving lamps, including rare earth phosphor lamps, slimlines, and high output (HO) lamps.

Heater Cutout Lamps

Heater cutout lamps are rapid-start lamps with an added thermal switch that disconnects the lamp electrode after the lamp has started. This is accomplished with a thermal switch in the lamp. This reduces lamp power by about 2.0 to 2.5 watts per lamp with no reduction of light output. These lamps also are known as "cathode cutout" or "ES+" lamps. While they are suitable for retrofit applications, they are not recommended for use with electronic ballasts or in dimming applications. Disconnecting a lamp's electrode heaters can also be achieved with heater cutout ballasts, used with conventional rapid start-lamps. These ballasts are not recommended for use in conjunction with heater cutout lamps.

A drawback of ES+ lamps is that there is a restrike time of one to two minutes if the lamp is extinguished and then immediately restarted. ES+ lamps are therefore not recommended with occupant sensors or other frequent switching applications. Some manufacturers, but not all, have derated lamp life by 25% for heater cutout lamps.

Extended Output (EO) Lamps

EO lamps are premium versions of standard 40-watt F40T12 lamps which, due to gas fill, redesigned electrodes, thicker or more efficient phosphors, and/or tube diameter, generate more light than standard cool white F40T12 lamps. In some cases, this is accomplished with a slight increase in lamp wattage. Compared to standard F40T12 lamps, they offer higher efficacy, increase both lumen output (up to 21%) and lamp life (20%), and improved lumen maintenance and color rendering. The "EO" nomenclature is not used by any manufacturer; current products use manufacturer-specific trade names or designations.

T-12 EO Lamps

F40T12/EO lamps typically deliver about 11% to 15% more light output than standard halophosphor lamps. Light output is rated at 3400 lumens for the RE-70 lamp and 3500 lumens for the RE-80 version. Color temperatures of 3000 K, 3500 K, and 4100 K are available. Rated lamp life is 24,000 hours at three hours per start.

T-10 EO Lamps

F40T10/EO lamps produce significantly more light output than standard F40T12 halophosphor lamps. Rated initial lamp lumen output for premium T-10 lamps is 3700 lumens, made possible by increased power and RE-80 phosphor coatings. The only available T-10 lamp size at this time is the 4-foot replacement for the standard F40T12. It actually consumes about 42 watts, but due to its higher voltage, it draws slightly less current (about 400 mA), and ballast losses are lower. A typical energy-efficient magnetic ballast for two F40T10 lamps will draw about 92 watts, with a ballast factor of 0.95, and a system efficacy of about 76 lumens/watt. Some T-10 lamps are sensitive to variations in voltage input and may not start properly with the 40-watt T-12 ballast over the entire voltage input range. One manufacturer makes a ballast to match the T-10 lamp. T-10 lamps also have a rated lamp life of 24,000 hours. At present, T-10 lamps are premium-priced products.

U-Tube Lamps

Another popular version of the standard 40-watt F40T12 fluorescent lamp is a U-shaped configuration, usually referred to as a "U tube" or "U-bent lamp." They are available with both 6-inch and 3-5/8-inch leg spacing, and have an overall length of about 22 inches. U-tubes are also available in 34-watt ES versions and with RE phosphors.

U-lamps are used mostly with square luminaires, such as 2' x 2' troffers or surface mounted luminaires. U-lamps are rated for an effective life of up to 18,000 hours at three hours per start.

Slimline Lamps

Slimline fluorescent lamps are recognizable by their single pin bases. While slimlines are available in T-6, T-8, and T-12 diameters, and in lengths ranging from 24'' to 96'', the following discussion focuses on the 425-mA F96T12 configuration, popular in many commercial applications.

Slimline lamps use a lamp designation code different from most other fluorescent lamps: the number following the "F" designates the lamp length in inches, not the wattage. For example, F96T12 refers to a slimline lamp, 96 inches long and 1.5 inches in diameter. Lamp wattage must be determined from lamp catalogs. The F96T12 lamp, for instance, is actually 75 watts. Slimline lamps are popular in many commercial applications using open luminaires. Eight-foot slimline lamps are more efficacious than standard F40T12 rapid-start lamps, due to instant start operation. In addition, the greater length of the F96T12 creates a higher lumen package, due to reduced lamp end losses as a percentage of the total lamp wattage (end losses are constant, so increasing the length of the tube reduces their impact).

Slimline lamps are available in standard, 60-watt ES, and RE versions. Instant start operation means that the rated lamp life of slimline lamps is significantly shorter than in rapid-start lamps. The F96T12 slimline lamp, for instance, is rated at 12,000 hours, at three hours per

start. It is also worth noting that magnetic ballasts for slimline lamps have a lower (i.e. noisier) sound rating than standard magnetic ballasts.

High Output (HO) Lamps

High output (HO) rapid-start fluorescent lamps have a recessed double contact base, and require a special ballast. HO lamps use the same designation terminology as slimline lamps. Thus, an 8-foot HO lamp uses the designation F96T12/HO. They are available in lengths ranging from 18" to 96". The most popular configurations, the 110-watt F96T12 and 85-watt F72T12, are commonly used in many commercial and industrial applications. HO lamps are available with rare earth phosphors and in reduced-wattage, ES versions.

A standard 8-foot HO lamp has a rated lamp output of 8900 lumens and a lamp life rating of 12,000 hours (three hrs/start operation). RE-70 and RE-80 phosphor coatings raise the light output to 9200 and 9350 lumens, respectively. HO lamps increase lumen output significantly by drawing considerably more power than standard fluorescent lamps. For example, a cool white 4-foot HO lamp (F48T12/HO) produces about 4300 lumens and draws about 60 watts, not including ballast losses. A standard F40T12CW lamp, by comparison, produces 3050 lumens and uses 40 watts.

Very High Output (VHO) Lamps

The most powerful fluorescent lamp is a 1500 mA lamp, known as a very high output (VHO) lamp. An F96T12/VHO lamp uses conventional halophosphors and produces 13,500-15,700 initial lumens, while consuming 215 watts, not including ballast losses. Some reduced wattage, ES versions of VHO lamps are available.

Although HO and VHO lamps are more efficacious than standard fluorescent lamps, they generally can not compete with T8 and T5, alternatives in terms of efficacy and total system performance.

T-8 Lamps

The 265 mA T-8 fluorescent lamp-ballast system is a relatively recent energy-efficient lighting product. Introduced to the American market in 1982, these lamps are now made by all major U.S. lamp manufacturers.

Smaller lamp diameters and the exclusive use of rare earth phosphors increase the efficacy of these lamps over standard F40T12 lamps.

The straight T-8 lamps have the same medium bi-pin bases as T-12 lamps, allowing them to fit the same sockets. However, T-8 lamps have different electrical characteristics, so they do not use a standard F40T12-type lamp ballast designed for 430 milliampere operation. The standard T-8 lamp family operates at 265 mA, but T-8 lamps are also being designed to operate with special ballasts at substantially higher power levels. There is only a minor cost

difference between a standard T-8 lamp-ballast system and a standard F40T12 lamp-ballast configuration.

T-8 lamps are available in several straight tube and U-bent configurations. Generally, they are available in color temperatures of 3000 K, 3500 K and 4100 K, and have either RE-70 or RE-80 phosphor coatings. Rated power ranges from 16 to 59 watts.

Like standard F40T12 lamps, T-8 lamps are rated at 20,000 hours for 60 Hz rapid start operation. However, for highest efficacy, they are often matched with an electronic ballast that operates the lamps in an instant start mode and at 25 KHz (electronic ballasts for rapid-start operation are also available). Instant start operation of T-8 lamps reduces rated lamp life by 25% (based on three hours per start operation), but lamp efficacy is increased by more than 10% when compared with rapid-start operation. In most commercial applications, where lamps are on for a period of 10 hours between starts, lamp life is only slightly less than that of rapid-start operation. Like T-12 lamps, T-8 lamps may be dimmed, but they require specialized dimmers and ballasts to work properly.

T-8 lamps offer several advantages over standard (non-RE phosphor) T-12 lamps:

- The two-lamp F32T8 system with an energy-efficient magnetic ballast has an efficacy of 78 lumens/watt, as compared to 68 lumens/watt for a standard two-lamp F40 T12/RE70 lamp system.
- The two-lamp F32T8 system with an instant start electronic ballast can achieve an efficacy of up to 90 lumens per watt. Given optimum electronic ballast designs, a representative efficacy for an electronically ballasted two-lamp F40T12/RE70 system is only about 78 lumens/watt.
- All T-8 lamps contain rare earth phosphors. RE phosphor coatings give T-8 lamps improved color rendering and lamp lumen maintenance over T-12 halophosphor lamps.
- T-8 lamps purchased in large quantities are not much more expensive than halophosphor T-12 lamps, and are actually less expensive than either 34-watt or 40-watt T-12 lamps with RE phosphors. Additionally the cost of T-8 lamp system installations is often subsidized by utilities in the form of rebates or incentives. Overall, on a life-cycle cost basis, a T-8 lamp-ballast system is usually a better investment than any 4-foot T-12 system.

T-5 Compact Fluorescent Lamps

High wattage versions of T-5 compact fluorescent lamps range in length from 10.5 inches to 22.5 inches. As such they are particularly effective in applications calling for smaller, more compact luminaires. Lamps of up to 55 watts are available, allowing for nearly any general/ambient lighting application.

Despite their small sizes, T-5 lamps have high lumen output, excellent color rendering, and good efficacy, due to the use of RE phosphor coatings. T-5 lamps use RE-80 high color rendition phosphors and are available in color temperatures of 3000, 3500, and 4100 K. High wattage T-5 lamps, available in 18, 27, 39, 40, 50, and 55 watts, operate at currents ranging

from 250 to 550 mA and are configured with four-pin 2G11-type bases. In general, they require dedicated ballasts.

Low wattage versions of T-5 compact fluorescent lamps rise in popularity as an energy-efficient, long-lasting substitute for the incandescent lamp, consuming on average one-quarter to one-third as much energy as its incandescent counterpart and lasting up to ten times longer. For example, a 10,000 hour, 13-watt compact fluorescent lamp (about 17 watts with the ballast) will provide about the same illumination as a 60-watt incandescent lamp that has a life of approximately 1000 hours.

Low wattage T-5 compact fluorescent lamps are available in a wide range of color temperatures, from 2700 K to 5000 K. They have very good color rendering properties, and they are available in a variety of sizes, shapes, base configurations, and wattages. The increasing availability of luminaires designed for compact fluorescent lamps – in both new and remodel applications – means that compact fluorescent lamps can meet many design requirements for general lighting applications.

For More Information

Contact your PG&E representative or call 1-800-468-4743 for more information about PG&E's energy efficiency programs and other services.