LightingAnswers

T8 Fluorescent Lamps

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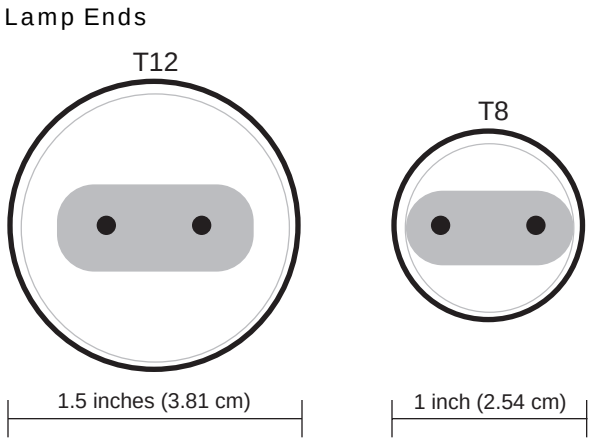
NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

Background

Throughout the 1970s, manufacturers of fluorescent lamps introduced new products that were intended to use less electricity than common 40-watt fluorescent lamps. Initially, these energy-saving lamps also sacrificed light output by about 12 percent. However, new *phosphor** technologies were developed that improved the light output of these energy-saving lamps. Their color rendering properties, as measured by the *color rendering index* (CRI), were also improved.

In 1981, the 32-watt T8 lamp was introduced in the United States, providing further improvements in the *efficacy* of 4-foot fluorescent lamps. Today, the T8 lamp is becoming the standard for new construction and is increasingly popular as a retrofit replacement for 40-watt T12 lamps. All major lamp manufacturers market T8 lamps, and they are readily available in a variety of straight and U-shaped configurations through standard distribution channels. Also available from some manufacturers are T10 fluorescent lamps, a high-wattage, high-*lumen* alternative to T12 lamps. This publication only discusses T8 lamps.

* All terms in italics are defined in the glossary on p. 5.



What does "T8" mean?

The "T" designation in fluorescent lamp nomenclature stands for tubular — the shape of the lamp. The number immediately following the T gives the diameter of the lamp in eighths of an inch. A T12 lamp (on the left in the figure below) is therefore twelve-eighths of an inch, or one-and-one-half inches (3.81 cm), in diameter. A T8 lamp (on the right in the figure below) is eight-eighths of an inch, or one inch (2.54 cm), in diameter. Both T12 and T8 lamps use the medium bi-pin base, which allows T8 lamps to fit into the same *luminaires* as T12 lamps of the same length.

What are the color characteristics of T8 lamps?

T8 lamps have improved color characteristics compared to those of standard T12 lamps. The color characteristics of fluorescent lamps are primarily determined by the phosphor coating inside the lamp. The phosphors used in standard T12 cool white and warm white lamps are *halophosphates*, which usually can only provide either good color quality or high efficacy. For example, a standard cool white T12 lamp has high light output but only a fair *color rendering index* (CRI) of 62. A cool white deluxe T12 lamp has a good color rendering index (CRI of 89) but produces about 28 percent fewer lumens than a standard cool white lamp of the same wattage.

T8 lamps achieve both improved color rendering and high efficacy by employing *rare-earth phosphors*, which are more expensive than halophosphates. To reduce the cost of manufacturing T8 lamps, the glass tube often is coated first with standard halophosphates and then coated with a blend of rare-earth phosphors. Some types of T12 lamps also undergo this dual-coating process to improve color rendering and efficacy. The most expensive lamps use either thicker rare-earth coatings during the dual-coating process or a single thick rare-earth phosphor coating to achieve higher CRI values.

The *correlated color temperature* (CCT) of the lamps is controlled by varying the selection of phosphors and the phosphor blend. Like T12 lamps, T8 lamps are available in a variety of color temperatures, including warm (3000 K), neutral (3500 K), cool (4100 K), and very cool (5000 K).

Manufacturers recently adopted a new nomenclature system for lamps that use rare-earth phosphor technology. "RE70" is now to be included at the end of the lamp designation for rare-earth phosphor lamps with CRI values ranging from 70 to 79. "RE80" designates rare-earth phosphor lamps with CRI values of 80 to 89. Color temperature may also be included in the designation by replacing the zero in the new designation with the first two digits of the CCT. For example, "RE741" designates a rare-earth phosphor lamp with a CRI of 70 to 79 and a CCT of 4100 K.

Do T8 lamps require a special ballast?

T8 lamps require a ballast specifically designed to operate lamps at 265 milliamperes (mA), rather than the 430 mA that T12 lamps require. In almost all cases, whenever T12 lamps are replaced with T8 lamps, the ballast must also be replaced. At least one manufacturer offers an electronic ballast that can operate either lamp type; however, T8 lamps have higher input power and higher light output on this ballast than on a ballast that only operates T8 lamps. Ballasts for T8 lamps are available for 120 volt (V), 277 V, 240 V, or 347 V operation. Ballast types include magnetic, which operate the lamps at 60 hertz (Hz), cathode-disconnect (also 60 Hz lamp operation), and electronic.

Electronic ballasts improve the efficacy of T8 lamps by operating them at much higher frequencies than the standard 60 Hz at which magnetic ballasts operate lamps. Fluorescent lamps of a given wattage that are operated at high frequencies (≥ 20,000 Hz) produce 10 to 12 percent more light than the same lamps operated at 60 Hz. Thus, a fluorescent lighting system using high-frequency electronic ballasts requires less electricity to produce

Table 1
Lamp/Ballast Performance Characteristics in Typical 2′ x 4′ Luminaire Types

Four-Lamp Lensed Troffer Luminaire

Lamp Type	Number and Type of Ballasts	Input Power (watts)[1]	Relative Light Output[1]	Annual Energy Costs[2]
40W T12 CRI 52–62	Two Standard Magnetic	179	100	$53.70
	Two Energy-Efficient Magnetic	160	100	$48.00
	Two Electronic	133	94	$39.90
34W T12 CRI 52–62	Two Energy-Efficient Magnetic	137	80	$41.10
	Two Electronic	116	79	$34.80
32W T8 CRI 75–85	Two Energy-Efficient T8 Magnetic	129	95	$38.70
	One T8 Electronic[3]	111	89	$33.30

Three-Lamp Parabolic Louvered Luminaire

Lamp Type	Number and Type of Ballasts	Input Power (watts)[1]	Relative Light Output[1]	Annual Energy Costs[2]
40W T12 CRI 52–62	Two Standard Magnetic	146	100	$43.80
	Two Energy-Efficient Magnetic	123	100	$36.90
	Two Electronic	110	94	$33.00
34W T12 CRI 52–62	Two Energy-Efficient Magnetic	109	82	$32.70
	Two Electronic	90	81	$27.00
32W T8 CRI 75–85	Two Energy-Efficient T8 Magnetic	101	97	$30.30
	One T8 Electronic[3]	87	91	$26.10

1 Input power and relative light output are based on figures from the California Energy Commission. Relative light output is a description of the total light emitted by the luminaire and thus accounts for ballast factor and the optical and thermal effects within the luminaire. A system with standard magnetic ballasts operating 40-watt T12 halophosphate lamps is used as the reference condition for relative light output comparisons. Such ballasts are no longer sold in the United States and frequently are replaced with more efficient ballasts.

2 Annual energy costs assume 3000 operating hours per year and 10 cents per kWh electricity costs.

3 Data are provided for a single T8 electronic ballast operating either three or four lamps, which is the usual T8 system configuration. Two-lamp T8 electronic ballasts also are available but result in lower system efficacies.

the same amount of light as a 60 Hz magnetic ballast system. As shown in Table 1, most commercially available electronic ballasts provide a slight reduction in light output while using significantly less power compared to magnetic ballasts. Many electronic ballasts offer other advantages, such as reduced flicker, less heat, less noise, and the ability to operate as many as four lamps on a single ballast; some offer dimming and better *power quality* characteristics.

Do T8 lamps produce as much light as standard T12 fluorescent lamps?

As shown in Table 2, the rated light output (measured in lumens) of a T8 lamp is less than the rated light output of most T12 lamps. However, the light output of a luminaire using T8 lamps can equal or even exceed the light output of a luminaire using T12 lamps, for several reasons.

T8 lamps have an optical advantage over T12 lamps because they have a smaller diameter. When operating in an enclosed luminaire, fluorescent lamps emit much of their light toward the luminaire's internal surfaces and toward each other. Some of that light is reflected out of the luminaire, but some of it is absorbed by the luminaire and the lamps. The smaller-diameter T8 lamps trap less light inside the luminaire.

Another factor that affects a fluorescent lighting system's performance is temperature. Manufacturers' rated light outputs for fluorescent lamps are measured in still air at the industry standard temperature of 25°C. In that environment, the minimum temperature of a T12 fluorescent lamp's bulb wall is about 38°C. Inside an enclosed luminaire, however, the heat generated by the lamps and ballasts results in a minimum bulb wall temperature that is typically higher than 50°C. Light output decreases as the minimum bulb wall temperature increases beyond 38°C, so fluorescent lamps operating in enclosed luminaires typically will produce less light than indicated by their light output ratings. T8 lamps operate at a lower wattage than standard 40-watt T12 lamps and therefore produce less heat, so their performance inside luminaires is closer to their optimal performance. Thus, despite their lower light output ratings, T8 lamps can deliver as much light from a luminaire as T12 lamps can, due to optical and thermal advantages.

T8 lamps also exhibit a slower decline in light output over time, relative to T12 lamps. At 40 percent of their rated life, standard T12 lamps only produce about 88 percent of their initial rated light output, compared to about 90 percent for T8 lamps.

Table 2
Initial Light Output Ratings for 4-Foot Fluorescent Lamps

Lamp Type	Phosphor	Initial Light Output (lumens)
T12 40-Watt	Cool White	3050
	Warm White	3100–3150
	RE70	3200
	RE80	3250–3300
T12 34-Watt	Cool White	2650–2700
	Warm White	2700–2750
	RE70	2800
	RE80	2850–2900
T8 32-Watt	RE70	2850
	RE80	2900–3050

How long do T8 lamps last before they burn out?

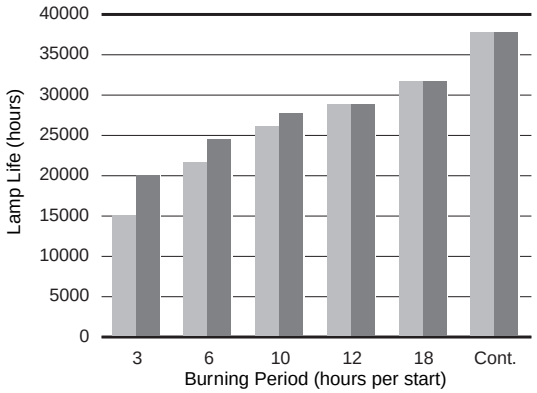
T8 lamps have the same 20,000-hour rated lamp life as standard T12 lamps. The rated life is measured by operating a large sample of lamps on cycles of three hours on and twenty minutes off. The number of hours after which 50 percent of the lamps have burned out is reported as the average rated lamp life. Thus, in a batch of lamps rated for 20,000 hours of life, on average half of them will burn out before 20,000 hours and half will last beyond 20,000 hours.

Lamps that are operated on a longer burning cycle, for example, in an office where they are left on all day, will have longer average lifespans. Lamps that are operated 24 hours a day can have an average life of nearly 38,000 hours. Conversely, shorter burning cycles will shorten lamp life. For instance, fluorescent lamps that are switched frequently, as can occur if they are controlled by occupancy sensors, may burn for less than their rated 20,000 hours. However, it usually is economical to switch fluorescent lights off whenever the spaces they are lighting are unoccupied, because both labor and electricity costs can be reduced by routinely switching off lights in unoccupied spaces. (See the articles by Higgins and Tichy, and Carrière and Rea listed in the "Resources" section for more information on this issue.)

Average rated life of fluorescent lamps is based on three-hour burning cycles on a *rapid-start* circuit. Many electronic ballasts for T8 lamps utilize an *instant-start* circuit. Lamps that are operated on an instant-start circuit consume less power than those on a rapid-start circuit but experience a reduction in lamp life of as much as 25 percent for three-

hour burning cycles. However, at least one lamp manufacturer states that the difference in lamp life between these two starting methods decreases with longer burning cycles, as shown in the figure below. Some electronic ballasts are available that utilize a rapid-start circuit to achieve 20,000-hour lamp life.

Effect of Burning Periods on T8 Lamp Life



Average lamp life in hours versus hours on during burning cycle (number of hours on, 20 minutes off).

Instant-Start Electronic Ballast

Rapid-Start Energy-Efficient Magnetic Ballast

Where should T8 lamps be used?

T8 lamps generally require ballasts designed specifically for their operating characteristics, so they are appropriate for new construction projects and for retrofit applications in which ballasts are being replaced. In a recessed, enclosed luminaire, replacing four T12 lamps and two standard magnetic ballasts with four T8 lamps and one electronic ballast can yield energy savings of as much as 40 percent with little or no reduction in maintained light output. T8 lamps also are appropriate for use with specular reflectors, which can minimize wasted light by redirecting it down and out of the luminaire. In some cases, existing four-lamp luminaires can be fitted with reflectors that enable the luminaire to provide well over half as much light with two new T8 lamps as it can with four new T12 lamps. However, reflectors also alter the light distribution of luminaires, which may affect the illuminance uniformity.

For new construction, T8 lamps are appropriate for recessed parabolic luminaires and for indirect lighting systems, where the smaller diameter of the T8 lamp provides improved optical control and the opportunity to design more compact luminaires. The surface of a T8 lamp is brighter than the surface of a T12 lamp and may therefore produce more glare when the lamp is exposed to view.

What are the common trade names for T8 lamps?

Each major lamp manufacturer has a different trade name for T8 lamps. Table 3 gives the trade names and catalog number designations for several popular 4-foot, 32-watt T8 lamps of various color temperatures and color rendering index values. In addition to the common 4-foot length, T8 lamps are also available in 2-, 3-, 5-, and 8-foot lengths and in several U-shaped sizes. For applications where high light output is necessary, T8 lamps are also available in 4-foot, 36-watt versions that produce about 20 percent more light than standard 32-watt T8 lamps. These higher-wattage lamps require different ballasts than other T8 lamps.

Table 3
Manufacturers, Trade Names, and Catalog Designations for 4-Foot 32W T8 Lamps

CRI Designation	CCT	GE Lighting Trimline	OSRAM* Trichrome	Philips TL70/TL80	Sylvania* Octron
RE70	3000 K	F32T8/SP30	FO32/730K	F32T8/TL730	
	3500 K	F32T8/SP35	FO32/735K	F32T8/TL735	
	4100 K	F32T8/SP41	FO32/741K	F32T8/TL741	
RE80	3000 K		FO32/830K	F32T8/TL830	FO32/30K
	3500 K		FO32/835K	F32T8/TL835	FO32/35K
	4100 K		FO32/841K	F32T8/TL841	FO32/41K
	5000 K				FO32/50K

* OSRAM and Sylvania have merged into a new company named OSRAM SYLVANIA INC. Product names and availabilities may change as product lines are merged.

Glossary

color rendering index (CRI) A measure of the accuracy with which a light source of a particular CCT renders different colors in comparison to a reference light source of the same CCT. The highest CRI attainable is 100. Incandescent lamps have CRIs above 95. The cool white fluorescent lamp has a CRI of 62; fluorescent lamps containing rare-earth phosphors are available with CRI values of 80 and above.

correlated color temperature (CCT) A specification of the apparent color of a light source relative to the color appearance of an ideal incandescent source held at particular temperature and measured on the kelvin (K) scale. The CCT rating for a lamp is a general indication of the "warmth" or "coolness" of its appearance. As CCT increases, the appearance of the source shifts from reddish white toward bluish white; therefore, the higher the color temperature, the cooler the color appearance. Lamps with a CCT rating below 3200 K usually are considered "warm" sources, whereas those with a CCT above 4000 K usually are considered "cool" in appearance.

efficacy The ratio of light output (lumens) of a lamp to input power (watts).

halophosphates The class of phosphors commonly used in fluorescent lamps. Halophosphates are limited in their ability to provide a high color rendering index without sacrificing light output. Standard T12 lamps containing halophosphates are the most common, and least expensive, fluorescent lamps. However, new United States federal regulations require that by October 1995 all fluorescent lamps must meet minimum efficacy and CRI standards; 40-watt T12 halophosphate lamps do not meet these standards. T8 lamps usually contain both halophosphates and rare-earth phosphors.

instant-start A method of starting fluorescent lamps without preheating the electrodes. Instant-start ballasts cause the electric arc to strike between the lamp's electrodes by supplying a high initial voltage to the lamps.

lumen A unit measurement of the rate at which a lamp produces light. A lamp's light output rating expresses the total amount of light that the lamp emits in all directions per unit time. Light output ratings provided by manufacturers express the total light output after 100 hours of lamp operation. A new fluorescent lamp initially burns up to 10 percent brighter than indicated by the light output rating, and over the first 100 hours the light output will decrease rapidly to the light output rating. After 100 hours, the light output will slowly decrease over the life of the lamp in a phenomenon known as lumen depreciation.

luminaire A complete lighting unit consisting of a lamp or lamps and the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

phosphors The white, powdered material coating the inside of the glass tube; the phosphors fluoresce (emit visible light) when excited by the ultraviolet radiation produced by the mercury vapor, which is energized by the electric arc sustained inside the lamp.

power quality The degree to which current and voltage wave forms conform to a sinusoidal shape and are in synchronous phase with each other. Poor power quality results when the wave forms are distorted and/or out of phase and can interfere with data communications, cause inefficient operation or failure of other electrical equipment on the same supply line, and result in excessive current in electrical distribution lines. Other NLPIP publications listed in the "Resources" section discuss the power quality characteristics of specific technologies in detail.

rapid-start A method of starting fluorescent lamps in which the electrodes are heated prior to starting, using a starter that is an integral part of the ballast. By heating the electrodes before starting the lamps, the voltage required to strike the electric arc between the electrodes is reduced.

rare-earth phosphors A group of phosphors containing rare-earth elements. Rare-earth phosphors are used in fluorescent lamps to achieve high efficacy and better color rendering. They produce light in very narrow wavelength bands.

Resources

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With this issue, the National Lighting Product Information Program (NLPIP) is pleased to introduce a second serial publication, *Lighting Answers*, designed to complement NLPIP's other serial publication, *Specifier Reports.* In each issue of *Specifier Reports* NLPIP invites manufacturers to participate, performs extensive testing and reporting, and reports manufacturer-specific data. Each issue of *Lighting Answers* presents information about lighting technology in one of three formats: some issues present a summary of available information about a particular technology in an educational format with no testing; some issues present educational information about a specific topic that is of concern for lighting professionals; and other issues present information about a new or special technology on which NLPIP has performed some limited testing. For this issue of *Lighting Answers*, NLPIP has summarized available information on T8 fluorescent lamps; no testing was conducted.