7 Full-Size Fluorescent Lighting

Fluorescent lighting dominates the commercial sector, which makes an examination of this technology's efficiency—and the potential for improvements—particularly compelling. The installation of improved fluorescent lamps, ballasts, fixtures, and controls has been the bread and butter of both utility- and end-user-based energy-efficiency programs for several years. Exciting developments continue to mount in this important category of lighting equipment.

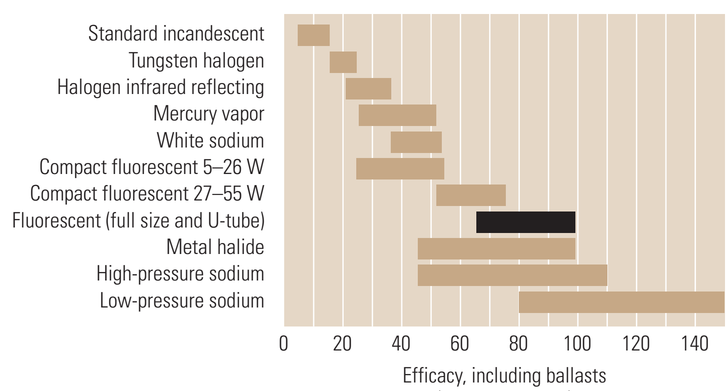
Fluorescent lamps are the primary technology for general area lighting. They combine high efficacy and long life with light quality ranging from acceptable to excellent (**Figure 7-1**). Fluorescent sources generally pose no safety hazards and have few operational limitations. Some of those limitations—such as low beam power; poor operation at low temperatures; expensive dimming controls; and a lack of small, high-brightness light packages—are being erased by ever-improving technology. This chapter covers the basics of fluorescent lighting technology and looks at the performance of noncompact products. Because of their wide variety and special applications, compact fluorescent lamps (CFLs)—including circular lamps and single-ended, high-power T5 lamps—are discussed separately in Chapter **8**. In this chapter, we discuss fluorescent lighting systems in three sections: lamps, ballasts, and fixtures. The last section includes specular reflectors and lenses. Fluorescent lighting controls—including a complete discussion of dimming products—are treated in Chapter **11**.

HIGHLIGHTS

- Modern rare earth, tristimulus phosphors with high efficacy and excellent color rendering are now available for nearly all types and sizes of fluorescent lamps.
- Lamp-ballast efficacies of advanced fluorescent lighting systems now exceed 80 lumens per watt (lm/W); the very best reach about 100 lm/W.
- The reliability and power quality of electronic ballasts have improved, and these ballasts continue to provide the most energy-efficient way to drive fluorescent lamps.
- There are now several dozen models of continuously dimming ballasts for full-size and compact fluorescent lamps on the U.S. market, and prices are slowly dropping. Dimming systems are discussed in more detail in Chapter **11**.
- Reflectors for retrofit and new installations have improved, but they still must be applied carefully.

Figure 7-1: Fluorescent lamp efficacy range

Modern, full-size fluorescent lamps combine efficiency with good light quality and have few limitations.



Note: W = watt.

Source: E SOURCE

EPACT's Impacts on Fluorescent Lighting

The Energy Policy Act of 1992 (EPACT) sets minimum performance standards for the estimated two billion full-size fluorescent lamps (2-foot [ft] U-lamps and 4-ft and 8-ft straight lamps) currently installed in the United States. Lamps covered by the act must meet the specific efficacy and color rendering index (CRI) standards shown in **Table 7-1**. The following fluorescent lamps are exempt from EPACT requirements:

- Lamps with CRIs of 82 or greater
- Lamps with rated power of less than 28 watts
- Four-ft slimline and high-output lamps
- Both 4- and 8-ft very high output lamps
- Eighteen- to twenty-four-inch T12 and T8 lamps
- Two-, three-, five-, and six-ft T12 and T8 lamps
- Any U-lamp shorter than 2 ft (from socket to bend)
- All circline (or circular) lamps
- Specialty lamps, such as those used in plant growth or reprographic applications

Table 7-1: EPACT lamp standards

Lamp group	Wattage	Minimum efficacy (lm/W)	Minimum CRI
4-foot medium bipin	>35	75	69
	≤35	75	45
2-foot U-shaped	>35	68	69
	≤35	64	45
8-foot slimline	65	80	69
	≤65	80	45
8-foot HO	>100	80	69
	≤100	80	45

Notes: CRI = color rendering index; HO = high output; lm/W=lumens per watt.

Source: E SOURCE

Full-size fluorescent systems are most often used for general lighting in commercial, institutional, and industrial spaces with low to medium ceiling height. Until recently, spaces with high ceilings (over 15 feet or so), were generally better served by high-intensity discharge (HID) light sources (Chapter 9), but high-performance fluorescent fixtures incorporating specular reflectors, ballasts with high ballast factors, and multiple high-power T5 or high-performance T8 lamps are increasingly being used in such applications.[1] Residential applications are generally limited to kitchens, workshops, bathrooms, laundry rooms, garages, and other utilitarian areas that require high levels of illumination. The Energy Policy Act of 1992 (EPACT), and subsequent revisions, have had a significant impact on fluorescent systems in the U.S. (see sidebar).

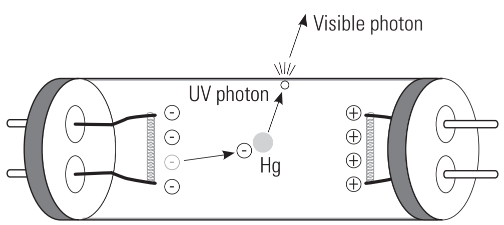
As a result of these rules, standard full-wattage lamps have been replaced by "energy-saving," reduced-wattage lamps. In addition, the color rendering indexes (CRIs) of standard and high-output (HO) cool and warm white lamps have been increased due to a switch to new rare earth phosphor lamps. Among categories covered by EPACT, most lamps being sold today meet the standards, but some older installed lamps in low-use applications may not. "Energy-saving" T12 lamps meet both the efficacy and the CRI standards, but this is only because the CRI standard for these reduced-wattage lamps is so lax. It is possible to purchase "covered" types of lamps that do not meet the EPACT standards. Sales of these lamps are permitted because they are identified as "for export only." It is a violation of the law to install these export-only lamps in fixtures in the United States.

EPACT became effective for 2-foot (ft) U-lamps and 4-ft standard lamps in October 1995, and for 8-ft slimline and HO lamps in April 1994. No lamps manufactured after those dates can be sold in the U.S. unless they meet the standards or are identified as export-only lamps. Any fixtures with old lamps that do not meet EPACT specifications can be brought into compliance by merely being upgraded with lamps that use rare earth phosphors.

It should be noted that the lamp efficacy standard is calculated without ballast losses. Although the 1987 National Appliance Energy Conservation Act (NAECA) ballast-efficacy standard remains in effect, it is now superseded by the Fluorescent Lamp Ballasts Energy Conservation Standards issued by the U.S. Department of Energy (DOE) in 2000 under 10 CFR Part 430. These standards will effectively ban the sale of most magnetic ballasts for fluorescent lamps by 2005.

Figure 7-2: Fluorescent lamp operation

Fluorescent lamps maintain an electric arc through gas, in contrast to the continuous metal filaments used in incandescent lamps.

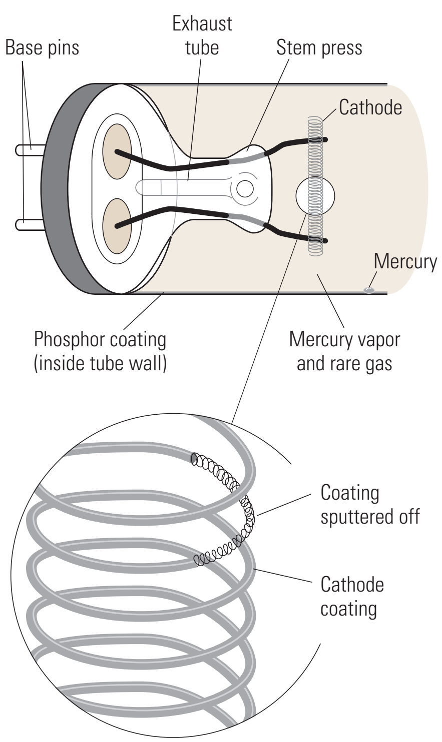


Notes: Hg = mercury; UV = ultraviolet

Source: E SOURCE; adapted from *IESNA Lighting Handbook* [2]

Figure 7-3: Fluorescent lamp electrode construction

Electrode erosion eventually causes lamp failure.



Source: E SOURCE; adapted from *IESNA Lighting Handbook* [2]

7.1 Fluorescent Lamps

The basic fluorescent lamp contains low-pressure mercury vapor and inert gases in a partially evacuated glass tube (**Figure 7-2**). The mercury atoms are energized by collisions with free electrons that have been excited by an electric field. As they descend back to the lower energy state, the mercury atoms emit ultraviolet (UV) photons that then strike phosphors—specially formulated compounds that line the tube. Another round of excitation and de-excitation causes the phosphors to emit visible photons, or to fluoresce. Altering the phosphors produces different qualities of white light.

All fluorescent lamps use a power-conditioning device called a *ballast*. Although ballasts perform various functions, their primary role is to control the operating current of a fluorescent lamp or other type of discharge lamp. Ballasts also typically provide the high voltage necessary to start the lamp, provide power to heat the electrodes in many types of fluorescent lamps, and ensure control and safety in a variety of failure modes. Ballasts and starting methods are discussed in Section **7.2.**

Ballast-conditioned power is supplied through contacts in metallic or plastic end caps (called *bases*), which feed electrodes at each end of the lamp. The electrodes are formed from coiled tungsten wire coated with an electron-emissive material such as barium oxide. When heated, this material releases electrons into the tube to create and maintain the arc. The primary reason for fluorescent lamp failure is the depletion of barium from the electron-emissive material or the erosion of this material on the electrodes (**Figure 7-3**).[2] This depletion or erosion, which occurs more rapidly during lamp ignition, also deposits cathode material onto the lamp walls, creating the familiar lamp-end blackening.

Lamp bases contain contacts designed to control their compatibility with different starting methods and power loadings. In general, a design with two pins or recessed contacts on each end implies rapid start or preheat start, whereas a single electrical contact indicates instant start. There is an important exception: All manufacturers offer T8 lamps with bipin bases that can be rapid-started *or* instant-started. For operation with instant-start ballasts, the socket contacts at each end of these lamps must be wired together within 4 inches (in.) of the lamp holder to act as one.[3]

Fluorescent lamps differ primarily in their size, type of phosphor coating, fill gas, and base/cathode design. By varying these four characteristics, manufacturers create lamps that span a wide range of wattages, light outputs, colors, and lifetimes. Diameters range from 0.250 to 2.125 in. and lengths from 6 to 96 in. Nominal power consumption (without ballasts) ranges from under 20 watts to over 200 watts, and light output also spans an order of magnitude: from under 1,500 lumens (lm) to over 15,000 lm. Lamp-only efficacy covers a smaller range: from 60 to 100 lumens per watt (lm/W). As shown in **Figure 7-4**, lamps are designated primarily by their wattage or length and tube diameter.

7.1.1 Lamp Families

Linear fluorescent lamps can be divided into "families" based on the three basic ways in which they are started: preheat start, instant start, and rapid start. Preheat start is sometimes called switch start, and there are a number of variations of rapid start, which will be discussed later. The design of the ballast determines the starting mode used for any fluorescent lamp, but the lamp must be compatible with the starting mode of the ballast. This has led to the development of families of fluorescent lamps that are matched to the three basic starting modes.

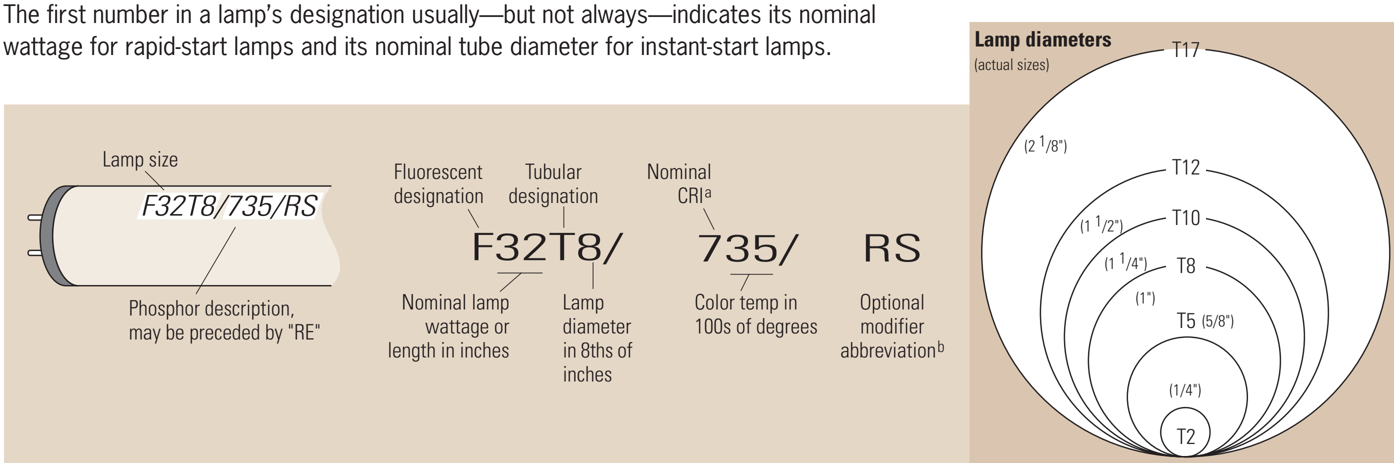
The large selection of fluorescent lamps available has a sometimes confusing array of names and features. The majority of older full-size fluorescent fixtures use rapid-start 40-watt or 34-watt F40T12 lamps. However, since at least 1997 the majority of new installations have used T8 lamps operating on instant-start electronic ballasts (see **Figure 7-5**).[4] **Figure 7-6** shows the fluorescent lamp family tree, and the sections below discuss the pros and cons of each of the family members.

Preheat lamps. Preheat lamps designed for 120-volt (V) power systems are generally relatively short lamps (6 to 36 inches in length) and typically use low-cost, low-performance phosphor. However, new versions with good color rendering are available. Preheat starting degrades lamp electrodes more rapidly than other starting methods, so preheat lamps have relatively short lifetimes. They are typically used only with magnetic or resistive ballasts.

Due to preheat lamp systems' short length and low-quality phosphor, and

Figure 7-4: Lamp designations

The first number in a lamp's designation usually—but not always—indicates its nominal wattage for rapid-start lamps and its nominal tube diameter for instant-start lamps.



Notes: a. Nominal color rendering index (CRI) range (7 = 70–79, 8 = 80–89, 9 = 90–99).
b. For example, RS = rapid start, ES = energy saving, and HO = high output.

Source: E SOURCE