LightingAnswers

T10 and T9 Fluorescent Lamps

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NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

Introduction

Specifiers who are replacing 4-foot (ft) [1.2-meter (m)], 40-watt (W) T12 lamps or installing new fluorescent lighting systems have several lamp types from which to choose. T8 lamps and energy-saving 34-W T12 lamps are popular options because they require less power. Other options include T10 lamps and T9 lamps (see sidebar on p. 2). In some cases, T10 and T9 lamps offer advantages over T12 and T8 lamps, including higher light output, higher lamp *efficacy**, higher *color rendering index (CRI)* values, a wider selection of *correlated color temperatures (CCTs)*, and compatibility with several ballast types.

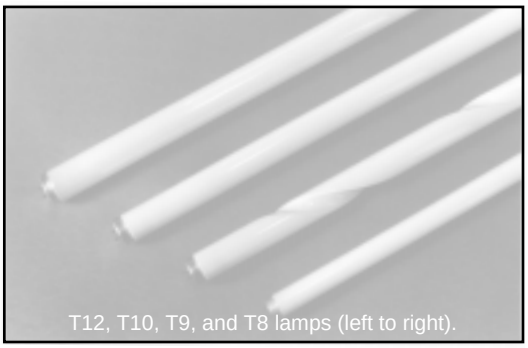
T12 and T8 lamp performance does not vary greatly among different lamp manufacturers, but T10 and T9 lamp performance can vary significantly depending on the manufacturer. The National Lighting Product Information Program (NLPIP) produced this issue of *Lighting Answers* to document the performance of different T10 and T9 lamps and to help specifiers and users identify applications for which these lamps may be suitable.

Duro-Test, Panasonic, and Philips Lighting manufacture 4-ft linear T10 lamps. Only Duro-Test manufactures 4-ft linear T9 lamps. Other lamp lengths are not available, except for specialty T10 lamps that are designed for operation in very cold environments, and circline T9 lamps. This report concerns only linear fluorescent lamps for common architectural applications.

NLPIP requested performance data and lamp samples from all three manufacturers and performed photometric and electrical tests on these samples. For comparison, NLPIP also purchased and tested 4-ft T8 and T12 lamps. Figure 1 shows the four lamp types that NLPIP tested.

* Terms in *italics* are defined in the glossary on p. 7.

Figure 1
Four types of linear fluorescent lamps



T12, T10, T9, and T8 lamps (left to right).

Donna Abbott Vlahos

How do the active power, light output, and system efficacy of T10 and T9 lamps compare with those of T12 and T8 lamps?

The performance characteristics of T12, T8, T10, and T9 lamps are summarized in Table 1 on p. 2. Rated active power (or input power) is 40 W for T10 lamps. T9 lamps are rated at 30 W on T8 ballasts and 34 W on T12 ballasts. By comparison, common T12 lamps are rated at 40 W, energy-saving T12 lamps are rated at 34 W, and T8 lamps are rated at 32 W.

The rated initial light output of 40-W T12 lamps with *rare-earth phosphors* typically is 3200 *lumens* (lm). Rare-earth phosphor T8 lamps and energy-saving T12 lamps typically are rated at 11 to 13% lower light output than 40-W T12 lamps. Depending on the manufacturer and the correlated color temperature (CCT), initial light output ratings for T10 lamps range from 20% less to over 15% more than 40-W T12 lamps. Initial light output ratings for T9 lamps range from 3 to 27% less than 40-W T12 lamps. T12 and T8 rare-earth phosphor lamps also are available in “deluxe” versions that typically produce 50 more lumens per lamp. Manufacturer-reported light output and active power values are reported in Table 2 on p. 4.

NLPIP independently evaluated the performance of T9 and T10 lamps for a variety of parameters; the test methods are described on p. 3 and the results are reported in Table 2 on p. 4. For the reported values of relative system light output and total system power, NLPIP tested two lamps with one ballast of the type shown in Table 2. The resultant values of system light output, power, and efficacy include the interaction effects of the ballast and lamps; these values cannot be directly compared with lamp ratings. To facilitate comparisons among systems, the system light output and system efficacy for two 40-W T12 lamps operating on an energy-efficient magnetic ballast were used as the reference values (100%). The light output and efficacy of all other lamp-ballast systems are expressed as a percentage of this reference combination. NLPIP selected the system using 40-W T12 lamps as the reference because T10 and T9 lamps often are marketed as retrofit alternatives for these lamps.

What types of ballasts do T10 and T9 lamps require?

According to lamp manufacturers, T10 lamps are compatible with the same ballasts used by T12 lamps, whether magnetic or electronic, including dimming electronic ballasts. Most T12 ballasts are labeled as being compatible with T10 lamps.

The manufacturer of T9 lamps indicates that they can operate on electronic ballasts for T12 lamps and both electronic and magnetic ballasts for T8 lamps. The manufacturer also claims that T9 lamps are compatible with dimming electronic ballasts for either T12 or T8 lamps. NLPIP did not test T10 and T9 lamps with dimming electronic ballasts, nor did NLPIP test long-term lamp-ballast compatibility.

How long do T10 and T9 lamps last?

Depending on the manufacturer, the average rated life of T10 lamps ranges from 20,000 to 24,000 hours (h), compared with 20,000 h for most T12 and T8 lamps. T9 lamps are rated for 20,000 h. The industry-accepted standard for measuring rated life is based on an operating cycle of 3 hours on and 20 minutes off (IES 1987). NLPIP found that at least one manufacturer, Duro-Test, has produced literature that reports lamp life based on a different operating cycle—one start per 10–12 hours. At this operating cycle, lamp life is longer than at the standard operating cycle.

T10 and T9 lamp diameter

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 is therefore twelve-eighths of an inch, or 1.5 inches (in.) [3.81 centimeters (cm)], in diameter. A T10 lamp is ten-eighths of an inch, or 1.25 in. (3.175 cm) in diameter. Technically, T9 lamps should be nine-eighths of an inch in diameter, but actually they are the same size as T10 lamps. The difference is that T9 lamps have an indented groove that winds around the lamp, as shown in Figure 3 on p. 6.

Table 1
Summary of manufacturer-reported data for different lamp types

Lamp Type (4-ft linear)	Active Power (W)	Rated Initial Light Output (lm)	Lamp Efficacy (lm/W)	Compatible Ballast Types	Average Rated Life[a] (h)
T12[b]	40	3200	80	T12 Mag. or Elec.	20,000
T12 (energy-saving)[b]	34	2800	82	T12 Mag. or Elec.	20,000
T8[b]	32	2850	89	T8 Mag. or Elec.	20,000
T10	40	2550–3700	64–93	T12 Mag. or Elec.	20,000–24,000
T9	30	2350–2750	78–92	T8 Mag. or Elec.	20,000
T9	34	2600–3100	76–91	T12 Elec.	20,000

[a] Average rated life is based on 3 hours per start.
[b] Values reported are for rare-earth phosphor lamps with CRI values of 73–75.

What are the color characteristics of T10 and T9 lamps?

The CRI values for T10 and T9 lamps are generally very high. In NLPIP's evaluations T10 and T9 lamps had CRI values ranging from 79 to 90. There is a wide selection of CCTs available for T10 lamps, including 3000, 3500, 4000, 4100, 4200, 5000, 5500, and 7500 Kelvin (K). T9 lamps are available with CCTs of 4200, 5000, and 5500 K.

For both lamp types, the 5500-K lamps are called full-spectrum lamps and are designed to simulate the color appearance of daylight more closely than other fluorescent lamp types. Most rare-earth phosphor lamps contain a mix of three phosphors that produce light in the long-wavelength (red), medium-wavelength (green), and short-wavelength (blue) parts of the visible spectrum. Full-spectrum lamps contain one or two additional phosphors that produce light in the blue-green and, optionally, ultraviolet parts of the spectrum. These lamps have very high CRI values, ranging from 87 to 90 in NLPIP's tests.

How much do T10 and T9 lamps cost?

NLPIP's surveys of manufacturers indicate that T10 and T9 lamps generally are more expensive than T12 and T8 lamps. Prices for T10 lamps range from $9 to $21 (U.S. Dollars) per lamp. T9 lamp prices range from $17 to $18. By comparison T8 lamps with a CRI value of 75 cost $5, and T8 lamps with a CRI value of 85 cost $9. Manufacturers' suggested retail prices are illustrated in Figure 2 on p. 6 and shown in Table 2.

NLPIP's test methods

NLPIP attempted to identify all manufacturers that market linear T10 and T9 lamps for architectural applications in North America, through literature searches, attendance at industry trade shows, and interviews with major lamp manufacturers. NLPIP requested four samples of each T10 and T9 lamp type from the three manufacturers identified; all three manufacturers complied with NLPIP's requests.

Lamps were seasoned for at least 100 hours prior to testing. Two samples of each lamp type were selected at random for evaluation. T10 lamps were tested on both an energy-efficient magnetic ballast for two F40T12 lamps (Advance Transformer Co., cat. no. R-2S40-TP, ballast factor = 0.925–1.000 for 40-W T12 lamps, 0.850–0.925 for 34-W T12 lamps) and an electronic ballast for two F40T12 lamps (Advance Transformer Co., cat. no. REL-2S40-RH-TP, ballast factor = 0.87 for T12 lamps, 0.85 for T10 lamps). For comparison, NLPIP also measured the performance of two 40-W T12 lamps (GE Lighting, cat. no. F40SP35) and two 34-W T12 lamps (GE Lighting, cat. no. F40SP35-WM) with these same ballasts.

Two samples of each T9 lamp type were tested on the electronic ballast mentioned above in addition to an energy-efficient magnetic ballast for two F32T8 lamps (Advance Transformer Co., cat. no. R-2P32-TP, ballast factor = 0.925–1.000 for T8 lamps) and an electronic ballast for two F32T8 lamps (Advance Transformer Co., cat. no. REL-2S32-RH-TP, ballast factor = 0.88 for T8 lamps). For comparison, NLPIP also measured the performance of two 32-W T8 lamps (Philips Lighting, cat. no. TL70) with these last two ballast types.

For all measurements, voltage was maintained at 120 V ±1 V by a conditioned power supply unit. NLPIP tested the lamps inside an integrating sphere 5 ft in diameter, within which the temperature was maintained at 25°C ±2°C. Prior to taking measurements, NLPIP operated the lamps continuously within the sphere for a minimum of 20 minutes.

The following performance characteristics were all measured within 1 minute of each other: relative spectral power distribution, light output, system input current, system input voltage, lamp arc current, lamp arc voltage, cathode current, and cathode voltage. The following performance characteristics were calculated from analysis of the measurements: chromaticity coordinates, CCT, CRI, power factor, reactive power, relative light output, relative system efficacy, system input current total harmonic distortion (THD), system input voltage THD, and total system power.

Table 2 Lamp Performance Data

Lamp Type	Manufacturer	Trade Name	Reported by Manufacturers: CCT (K)	CRI	Lamp Active Power (W)	Rated Initial Light Output (lm)	Light Output at 40% Life (lm)
T12 Magnetic Ballast							
T12	GE Lighting	F40SP35 (40 W)	3500	73	40	3200	2910
		F40SP35-WM (34 W)	3500	73	34	2800	2520
T10	Duro-Test	Aurora III	3000	85	40	3450	2950
		Aurora IV	4000	85	40	3450	2950
		Aurora V	5000	85	40	3450	2950
		Classic-42	4200	82	40	3600	3050
		Vita-Lite Plus	5500	91	40	2750	2350
		ColorClasser 75 Plus	7500	91	40	2550	2150
	Panasonic	Tri-Color F40 EX-30	3000	84	40	3550	3090
		Tri-Color F40 EX-41	4100	84	40	3550	3090
		Tri-Color F40 EX-50	5000	88	40	3550	3090
	Philips Lighting	Advantage X	3000	82	40	3700	3300
		Advantage X	3500	82	40	3700	3300
		Advantage X	4100	82	40	3700	3300
		Advantage X	5000	82	40	3700	3300
T12 Electronic Ballast							
T12	GE Lighting	F40SP35 (40 W)	3500	73	40	3200	2910
		F40SP35-WM (34 W)	3500	73	34	2800	2520
T9	Duro-Test	Classic-42 ULTRA-9	4200	82	34	3100	2650
		Aurora V ULTRA-9	5000	85	34	3060	2600
		Vita-Lite Plus ULTRA-9	5500	91	34	2600	2200
T10	Duro-Test	Aurora III	3000	85	40	3450	2950
		Aurora IV	4000	85	40	3450	2950
		Aurora V	5000	85	40	3450	2950
		Classic-42	4200	82	40	3600	3050
		Vita-Lite Plus	5500	91	40	2750	2350
		ColorClasser 75 Plus	7500	91	40	2550	2150
	Panasonic	Tri-Color F40 EX-30	3000	84	40	3550	3090
		Tri-Color F40 EX-41	4100	84	40	3550	3090
		Tri-Color F40 EX-50	5000	88	40	3550	3090
	Philips Lighting	Advantage X	3000	82	40	3700	3300
		Advantage X	3500	82	40	3700	3300
		Advantage X	4100	82	40	3700	3300
		Advantage X	5000	82	40	3700	3300
T8 Magnetic Ballast							
T8	Philips Lighting	TL70	4100	75	32	2850	2600
T9	Duro-Test	Classic-42 ULTRA-9	4200	82	30	2750	2350
		Aurora V ULTRA-9	5000	85	30	2700	2300
		Vita-Lite Plus ULTRA-9	5500	91	30	2350	2000
T8 Electronic Ballast							
T8	Philips Lighting	TL70	4100	75	32	2850	2600
T9	Duro-Test	Classic-42 ULTRA-9	4200	82	30	2750	2350
		Aurora V ULTRA-9	5000	85	30	2700	2300
		Vita-Lite Plus ULTRA-9	5500	91	30	2350	2000

[a] Average rated life is based on 3 hours per start.

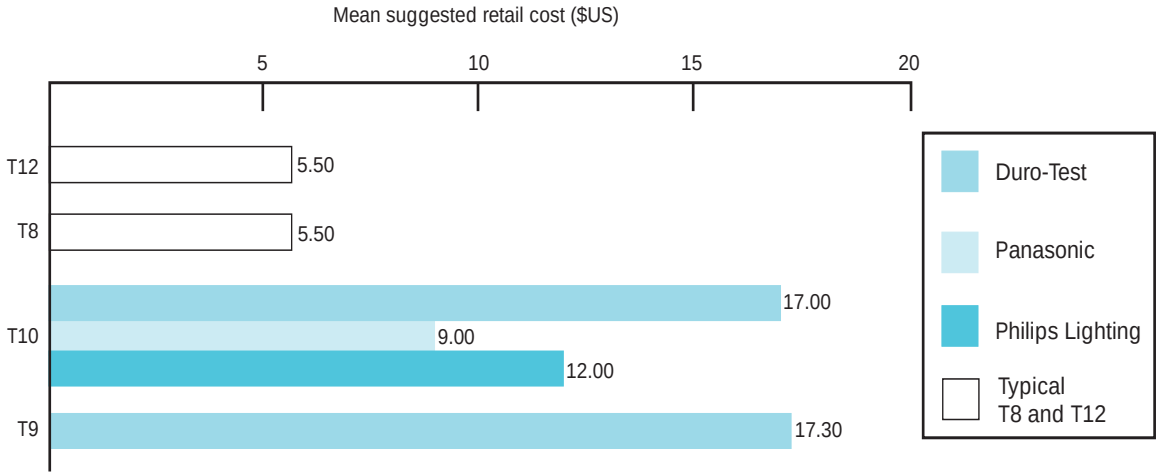
[b] NLPIP's test methods are described on p. 3.

Reported by Manufacturers		Measured by NLPIP[b]				
Avg. Rated Life[a] (h)	Sugg. Retail Cost ($US)	CCT (K)	CRI	Relative System Light Output[c] (%)	Relative System Efficacy[c] (%)	Total System Power[d] (W)
20,000	5	3300	69	100	100	86
20,000	6	3400	69	79	92	74
20,000	16	2800	85	90	85	91
20,000	16	4100	80	102	97	91
20,000	16	4800	82	101	96	90
20,000	16	4300	80	105	98	92
20,000	17	5700	87	100	93	92
20,000	21	7600	88	90	84	92
20,000	9	2900	86	117	109	93
20,000	9	4000	86	116	107	93
20,000	9	4800	87	110	102	92
24,000	12	(Samples not received from manufacturer in time for testing)				
24,000	12	3500	82	115	108	91
24,000	12	4100	80	113	106	91
24,000	12	4900	81	109	103	91
20,000	5	3200	70	91	109	72
20,000	6	3400	70	78	105	64
20,000	17	4300	79	96	106	78
20,000	17	4800	82	92	100	79
20,000	18	5700	90	82	90	79
20,000	16	2800	86	80	92	75
20,000	16	4000	81	92	106	75
20,000	16	4800	83	91	105	75
20,000	16	4300	81	95	108	75
20,000	17	5700	88	88	100	76
20,000	21	7600	89	80	92	75
20,000	9	2900	86	104	119	75
20,000	9	3900	86	101	116	75
20,000	9	4800	88	97	111	75
24,000	12	(Samples not received from manufacturer in time for testing)				
24,000	12	3500	83	104	120	75
24,000	12	4100	81	101	116	75
24,000	12	4900	82	98	113	75
20,000	5	3900	73	87	93	81
20,000	17	4400	79	85	93	79
20,000	17	4900	81	81	85	81
20,000	18	5800	89	75	79	82
20,000	5	3900	74	75	104	62
20,000	17	4300	79	69	103	58
20,000	17	4900	82	66	95	60
20,000	18	5800	90	61	86	61

[c] Relative system light output and relative system efficacy are expressed as a percentage of the values for two 40-W T12 lamps operating on a magnetic ballast.

[d] Total active power for two lamps operating on the indicated ballast.

Figure 2
Lamp cost comparison
These costs are the mean cost of a single lamp of a particular type, for each manufacturer. For each type, the mean of the costs for various CCTs and active power values is reported. See Table 2 for a full listing of suggested retail costs. For comparison, the typical costs of T12 and T8 lamps (with rare-earth phosphors) are shown.



When should specifiers consider using T10 and T9 lamps?

The main advantages of most T10 lamps are their high CRI values and high light output. However, they do not reduce power compared with 40-W T12 lamps. They are suited for applications where color rendering or high *illuminance* is important, including retail spaces, inspection areas, bathrooms, medical examination rooms, restaurants, print shops, and graphic design offices.

In retrofit applications, four T12 lamps frequently are replaced by two T10 lamps. With the addition of a specular reflector, two T10 lamps can provide an illuminance that more closely approaches that of the old four-lamp system than two T8 lamps can. Despite higher lamp costs than T8 lamps, *simple payback* for such a retrofit may be faster with T10 lamps because they do not require a new ballast. Additionally, some T10 lamps have a rated life of 24,000 h, or 20% longer than most T12 lamps, which may further reduce life cycle costs. However, long-term savings may be less with T10 lamps than with T8 lamps or energy-saving T12 lamps because T10 lamps require more power than those lamp types.

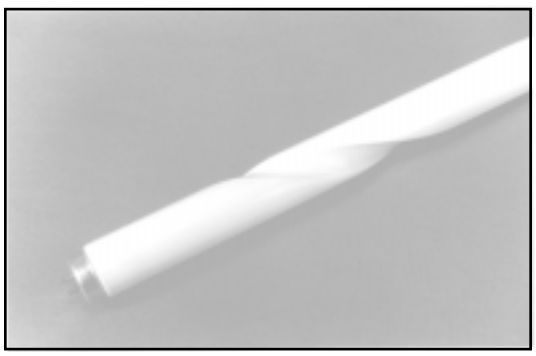
T10 lamps' high light output also may make them a good candidate for use with dimming electronic ballasts. Using T10 lamps with dimming electronic ballasts for T12 lamps can result in a system with a higher maximum light output than either a T8 or a T12 lamp dimming system can provide.

T9 lamps offer good color rendering, plus flexibility in ballast compatibility. If several ballast types are in use in a facility, a single lamp type can be stocked for replacement, possibly reducing inventory and saving storage space. However, NLPIP's tests indicate that T9 lamps require much more power when operated on T12 electronic ballasts than when operated on T8 electronic ballasts, and they have a higher suggested retail cost than most other lamps.

For applications where the lamp is exposed, a T9 lamp's groove may give it a novelty appeal (see Figure 3).

The full-spectrum (5500-K) versions of both T10 and T9 lamps may also have specialty applications: their high CCT and excellent color rendering may make them suitable for applications such as inspection areas, video studios, and teleconferencing rooms.

Figure 3
T9 lamp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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. Cool white fluorescent lamps have a CRI of 62.

correlated color temperature (CCT) A specification of the apparent color of a light source relative to the color appearance of a reference source, 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 are usually considered "warm" sources, whereas those with a CCT above 4000 K are usually considered "cool" in appearance.

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

illuminance The density of luminous flux (lumens) incident upon a surface; it is the luminous flux divided by the area of the surface when the surface is illuminated uniformly. Illuminance is measured in footcandles (lumens/square foot) or lux (lumens/square meter). One footcandle equals 10.76 lux, although for convenience 10 lux commonly is used as the equivalent.

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 emitted in all directions per unit time. Ratings of initial light output provided by manufacturers express the total light output after 100 hours of operation. A new fluorescent lamp initially may burn up to 10% 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 by as much as 20% in a phenomenon known as lamp lumen depreciation.

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.

simple payback The period of time required for an investment such as an energy-efficient lighting system to earn back initial costs through energy savings. Simple payback is limited because it does not account for the time value of money, maintenance and replacement costs, or other economic factors.

Resources

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Lighting*Answers*

Lighting Answers complements the National Lighting Product Information Program's (NLPIP) other serial, *Specifier Reports*. Each issue of *Lighting Answers* presents educational information about a specific topic or a particular technology. For this issue of *Lighting Answers*, NLPIP has summarized information about T10 and T9 lamps and performed limited testing.