NLPIP Lighting Answers
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T5 Fluorescent Systems

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Abstract

This publication answers commonly asked questions about T5 systems, including T5 lamps, ballasts, and luminaires. Lighting Answers: T5 Fluorescent Systems contains three parts: physical characteristics, economic issues, and design and application. The first section, physical characteristics, addresses questions on dimensions and performance of lamps, ballast, and luminaire performance. The second section, economic issues, focuses on the monetary benefits of T5 systems. The third section, design and application, discusses proper applications of T5 lamps and the advantages and disadvantages of T5 systems versus T8 systems in lighting design.

Introduction

The T5 lamp is an increasingly popular development in fluorescent lighting. In 1995, T5 fluorescent lamps entered the market in the United States. Today, the three major lamps manufacturers aggressively market T5 lamps. Luminaire manufacturers create innovatively designed compact luminaires using up-to-date optical materials. Recently, lighting designers have begun to specify such T5 luminaires for high-end new construction. The marketing and innovative design of T5 systems have left many end users wondering whether they should consider T5 luminaires instead of T8 luminaires, especially in new construction and retrofitting of T12 magnetic systems. End users are confused by the 10°C (18°F) difference in optimal temperature and the small difference in **system efficacy** between T5 and T8 systems. This section focuses on physical characteristics of T5 systems compared to T8 systems. This publication discusses T5 systems—including T5 lamps, ballasts, and luminaires—to answer commonly asked questions.

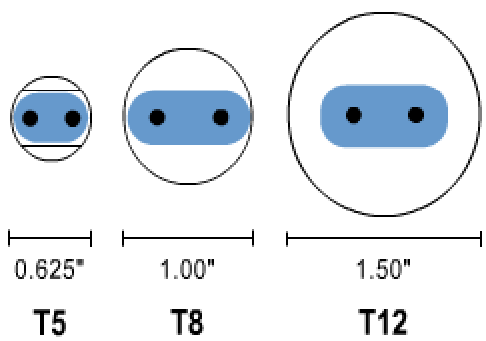
What are T5 lamps?

T5 lamps are fluorescent lamps that are 5/8" of an inch in diameter. This report discusses only linear T5 lamps. Differences in length and socket pin design versus conventional fluorescent lamps prevent any problems with electric circuits or human factors. This section focuses on the physical characteristics of T5 systems compared with T8 systems.

What does T5 mean?

The "T" in lamp nomenclature represents the shape of the lamp-tubular. The number following the "T" usually represents the diameter of the lamp in eighths of an inch (1 inch equals 2.5 centimeters). T5 lamps have a diameter equal to 5 times an eighth of an inch, or 5/8". These lamps are approximately 40% smaller than T8 lamps, which are one inch in diameter, and almost 60% smaller than T12 lamps, which are 1½" in diameter. Figure 1 shows diagrams of lamp ends of T5, T8, and T12 lamps. Figure 1 also shows that pin base type of T5 lamps is different from that of T8 and T12 lamps. T5 lamps have a miniature bi-pin base while T8 and T12 lamps use a medium bi-pin base.

Figure 1. Lamp Ends



Are T5 lamps the same length as T8 lamps?

T5 lamps are slightly shorter than T8 lamps and therefore cannot be used as replacements for the larger lamps. Some luminaires, however, can be made to accept either T5 or T8 lamps by changing the sockets and ballasts. Table 1-1 compares lengths of T5 lamps with T8 and T12 lamps.

Select the measurement(s) to be displayed: ◉ Metric ○ English

Table 1-1. Linear Lamp Lengths

Nominal Length (ft)	Actual Length T5 (mm)	Actual Length T8 and T12 (mm)
2	549	590
3	849	895
4	1149	1199

What T5 lamps are available?

T5 lamps are available for standard output and high output. The wattages for standard T5 lamps are 14, 21, 28, and 35 watts. The high-output T5 (T5 HO) lamps are available in 24, 39, 54, and 80 watts (49-watt T5 HO lamps are also available from GE Lighting). Table 1-2 summarizes the features of the standard T5 and T5 HO lamps available in the United States. A four-foot long, 54-watt version that delivers 5,000 lumens is popular in the United States. The high light output allows fewer luminaires to achieve the same **illuminance** levels as when using other fluorescent lamps. As Table 1-2 shows, however, T5 HO lamps are slightly less efficacious than standard T5 lamps.

Table 1-3 illustrates features of four-foot standard T8 and T12 lamps. Standard T5 and T5 HO lamps have a rated average **lamp life** of 20,000 hours, the same as most standard T8 and T12 lamps. New prolonged-life T8 and T12 lamps have lives of 4,000 to 10,000 hours longer than T5 lamps. (Table 1-3 excludes these lamps.) The lamps in Table 1-2 all use RE80, a rare earth phosphor with a **color rendering index** (CRI) value of 85.

Table 1-2. T5 and T5 HO Lamps

(From manufacturers' catalogs; Philips Lighting 2001/2002; GE Lighting 2001/2002)

Lamp Type	Nominal Length (in)	**CCT** (K)	Light Output* (lm) Initial	Light Output* (lm) Mean	**Lamp Efficacy**** (lm/W)
T5 14W	22	3,000-6,500	1,350	1,269-1,275	96
T5 21W	34	3,000-6,500	2,100	1,974-2,000	100
T5 28W	46	3,000-6,500	2,900	2,726-2,750	104
T5 35W	58	3,000-6,500	3,650	3,431-3,450	104
T5 HO 24W	22	3,000-6,500	2,000	1,880-1,895	83
T5 HO 39W	34	3,000-6,500	3,500	3,290-3,320	90
T5 HO 54W	46	3,000-6,500	5,000	4,700-4,740	93
T5 HO 80W	58	3,000-6,500	7,000	6,580-6,650	88

* Light outputs are measured during lamp operation on reference ballasts under standard laboratory conditions. T5 lamps are operated at 35°C (95°F) compared to T8 and T12 lamps, which are operated at 25°C(77°F). Mean light output means lamp light output at 40% of rated lamp life.

** Lamp efficacies are calculated based on the initial light output data.

Table 1-3. Four-Foot T8 and T12 Lamps

(From manufacturers' catalogs; Philips Lighting 2001/2002; GE Lighting 2001/2002)

Lamp Type	Nominal Length (in)	Phosphor*	CCT (K)	CRI	Light Output** (lm) Initial	Light Output** (lm) Mean	Lamp Efficacy** (lm/W)
T12 40W	48	RE70	3,000-6,500	70-75	3,050-3,250	2,775-2,950	81
	48	RE80	3,000-5,000	80-82	2,200-3,400	1,775-3,090	85
T12 34W	48	RE70	3,000-6,500	70-75	2,650-2,800	2,430-2,520	82
	48	RE80	3,000-5,000	80-82	2,025-2,900	1,775-2,610	85
T8 32W	48	RE70	3,000-6,500	75-78	2,700-2,850	2,550-2,710	89
	48	RE80	3,000-5,000	86	2,800-2,950	2,660-2,800	92

* RE70 designates rare-earth phosphor with CRI values from 70 to 79. RE80 is rare-earth phosphor with CRI values of 80-89.

** Light outputs are measured during lamp operation on reference ballasts under standard laboratory conditions. T8 and T12 lamps are operated at 25°C (77°F), and T5 lamps are operated at 35°C (95°F). Mean light output means lamp light output at 40% of rated lamp life.

*** Lamp efficacies are calculated based on the maximum initial light output data.

What are T5 HO lamps?

"HO" stands for high output. T5 HO lamps deliver more light than standard T5 lamps and are available in higher wattages. HO lamps have the same diameter and length as standard T5 lamps. Table 1-2 compares characteristics of T5 and T5 HO lamps (also see What are T5 lamps?).

Can a T5 lamp replace a T12 or T8 lamp?

T5 lamps cannot replace T12 or T8 lamps because of differences in physical and electrical characteristics. T5 lamps come in different lengths than T8 and T12 lamps. A nominal 4-foot T5 lamp is actually shorter than an equivalent T8 lamp [1149 millimeters (45.23 inches) in total]. Miniature bi-pin sockets fit T5 lamps, while T8 lamps need medium bi-pin sockets. These differences in dimension prevent T5 lamps from being used as replacements for T8 lamps (see What are T5 lamps?). T5 lamps need special ballasts to operate (see Do T5 lamps need special ballasts?).

Do T5 lamps need special ballasts?

T5 lamps need special ballasts to operate. In most cases, the T5 ballasts will not work with T12 or T8 lamps, although at least one manufacturer offers electronic ballasts that can operate either T5 or T8 lamps with appropriate wiring. T5 lamps operate at frequencies greater than 20 kilohertz. **Instant start**, **rapid start**, and **programmed start** electronic ballasts are available for T5 lamp operation.

Ballasts for T5 lamps are available for 120-, 277-, 240-, and 347-volt operations. Most T5 ballasts are more compact than T8 ballasts, although the dimensions vary depending on manufacturer and lamp type. For instance, the height, width, and length of a T5 ballast are 2.5, 3.00, and 36.20 centimeters (1.0, 1.18, and 14.25 inches) (Universal Lighting Technologies); or 3.18, 3.18, and 48 centimeters (1.25, 1.25, and 19 inches) (OSRAM SYLVANIA, Inc.). These small cross-section sizes allow luminaire designers to create thinner luminaires. Most manufacturers claim that their T5 ballasts have **total harmonic distortion** (THD) of less than 15%. This small amount of THD avoids potential imbalances in electrical lines that would damage wiring, transformers, or other equipment. Manufacturers claim these ballasts have highly efficient power factor values of more than 0.95. Most T5 ballasts carry class "A" sound ratings, so they are very quiet. The small diameter of the T5 lamp bulbs results in an increase in temperature, leading to cracks in the bulb. New ballasts for T5 lamps, therefore, are required to have "end of life" circuitry that ensures that power is shut off to the lamp when its functioning becomes impaired. The National Lighting Products Information Program's (NLPIP's) Specifier Reports: Electronic Ballasts gives more details of performance characteristics and physical features of T5 ballasts.

Table 1-4 lists major North American manufacturers of T5 ballasts and their contacts.

Table 1-4. T5 Ballast Manufacturers and their Contacts in the United States

Manufacturer	Telephone	Web Site
Advance Transformer, Co.	800-322-2086	www.advancetransformer.com
EBW Electronics, Inc.	800-787-0575	www.ebw-electronics.com
Energy Savings, Inc.	847-925-8400	www.esavings.com
Fulham, Inc.	800-238-5426 323-779-2980	www.fulham.com
Future Wave, Inc.	604-990-5325	
K-Tronik International Corporation	888-458-7664 201-488-4600	www.k-tronik.com
Universal Lighting Technologies, Inc.	800-225-5278 615-316-5100	www.universalballast.com
OSRAM SYLVANIA, Inc.	800-654-0089 847-726-6200	www.sylvania.com
Robertson Worldwide	800-323-5633 708-388-2315	www.robertsonww.com

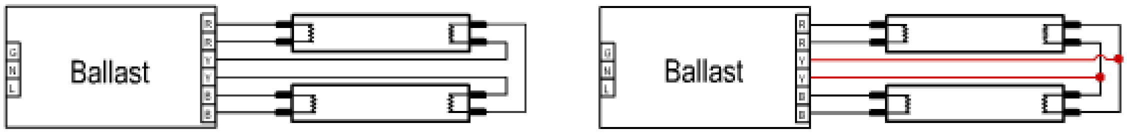
Is it possible to dim T5 lamps?

It is possible to dim T5 lamps with dimming ballasts. In the United States, several dimming ballasts for T5 high output (T5 HO) lamps are available. At least two ballast manufacturers—OSRAM SYLVANIA, Inc., and Energy Savings (see Do T5 lamps need special ballasts?)—produce analog dimming ballasts for T5 HO lamps, and at least one manufacturer—TRIDONIC, Inc., 866-874-3664 or 770-717-0556, www.tridonic.com—provides digital dimming ballasts for T5 HO lamps. Few dimming ballasts for standard T5 lamps are available, however. Analog dimming ballasts use a standard 0- to 10-volt direct-current (VDC) dimming control signal. Digital dimming ballasts use digital communication technology that is controllable through switch DIM®, Digital Serial Interface (DSI), or Digital Addressable Lighting Interface (DALI). The manufacturers claim that these ballasts can dim from 100% to 1% of full light output.

Is there any difference in wiring between T5 and T8 ballasts?

Wiring methods vary for both T5 and T8 ballasts, depending on the starting methods the ballasts use. Wiring for **instant start** ballasts differs from that for **rapid start** ballasts and programmed start ballasts. In addition, the rapid and **programmed start** ballasts have two options for wiring when being connected with more than two T5 lamps (see figure 6). Figure 6 illustrates the two wiring methods of T5 ballasts. In series wiring, electrodes of two lamps are connected in series, while electrodes are connected in parallel in the other method. OSRAM SYLVANIA, Inc., and Universal Lighting Technologies mainly use the series wiring method. On the other hand, Advance Transformer Co.; EBW Electronics; Future Wave Technologies, Inc.; K-TRONIK International Co.; and Robertson Worldwide use the parallel wiring method. Energy Savings' ballasts can be wired by either way. Incorrectly wiring any ballast may hasten end darkening of lamps and/or shorten **lamp life**. Always verify the wiring method with the manufacturer's recommendations.

Figure 6. Wiring Methods for T5 Ballasts



(a) Series Wiring **(b) Parallel Wiring**

Does a T5 lamp give as much light as a T8 lamp?

T5 high output (T5 HO) lamps have greater **luminous flux** per unit length than standard T8 lamps, but the light output of standard T5 lamps per unit length is almost identical to the standard T8 lamps. If, however, this question requires a more precise answer and **lamp efficacy** needs to be taken into account, several factors affecting the light output-and therefore efficacy—should be considered.

One of the most significant factors affecting lamp light output is **ambient temperature**. Table 1-7 summarizes light outputs and efficacies of nominal four-foot standard T5, T5 HO, and standard T8 lamps. Manufacturers usually provide light output data at the optimal temperature for each lamp type in their catalogs: 35°C (95°F) for the standard T5 and T5 HO lamps and 25°C (77°F) for the T8 lamps. Light output data for T5 lamps at 25°C (77°F) and for T8 lamps at 35°C (95°F) are also available from manufacturers, however. Table 1-7 shows that, at 25°C (77°F), the light output of T8 lamps is higher than the standard T5 lamps. At 35°C (95°F), however, the standard T5's light output is higher than that of the T8 lamp. With respect to lamp efficacy, the standard T5 lamps are more efficacious than the standard T8 lamps at 35°C (95°F), but the two types of lamps are nearly identical at 25°C (77°F). The lamp efficacy of T5 HO lamps is higher than the T8 lamps but lower than the standard T5 lamps at 35°C (95°F), and it is the lowest at 25°C (77°F).

Ballast losses are another important factor. Table 1-7 compares lamp-ballast system efficacies for T5 and T8 systems from two ballast manufacturers. The data on lamp efficacy are quoted from manufacturers' catalogs (Philips Lighting 2001/2002; OSRAM SYLVANIA 2002). Although the lamp-ballast system efficacy varies among manufacturers, the maximum **system efficacy** at the optimal temperature for each of the three lamp-ballast systems (standard T5, T5 HO, and T8 systems) appears to be nearly identical on average.

Table 1-7. Lamp Efficacies and System Efficacies of T5, T5 HO, and T8 Lamps
(All lamps are nominally 4 feet. Lamp efficacy is calculated based on initial lamp lumens)

Lamp Type	Lamp Efficacy				Lamp-Ballast System Efficacy					
					Manufacturer A**			Manufacturer B**		
	Lamp Power (W)	Temperature (°C)	Initial Light Output* (lm)	Efficacy (lm/W)	Input Power (W)	Ballast Factor	Efficacy (lm/W)	Input Power (W)	Ballast Factor	Efficacy (lm/W)
F28T5	28	25	2,610	93	63	0.90	75	62	1.00	84
		35	2,900	104	63	0.90	83	62	1.00	94
F54T5HO	54	25	4,400	81	117	1.00	75	117	1.00	75
		35	5,000	93	117	1.00	85	117	1.00	85
F32T8	32	25	2,950	92	59	0.88	88	59	0.90	90
		35	2,714	85	59	0.88	81	59	0.90	83

* Initial lamp lumens are based on the Philips Lighting Company catalog, "SILHOUETTE T5, T5 HO & T5 Circular Fluorescent Lamp Technology Guide."

** Manufacturers A and B are Universal Lighting Technologies and OSRAM SYLVANIA, Inc., respectively. The input powers and ballast factors (BF) are from their catalogs.

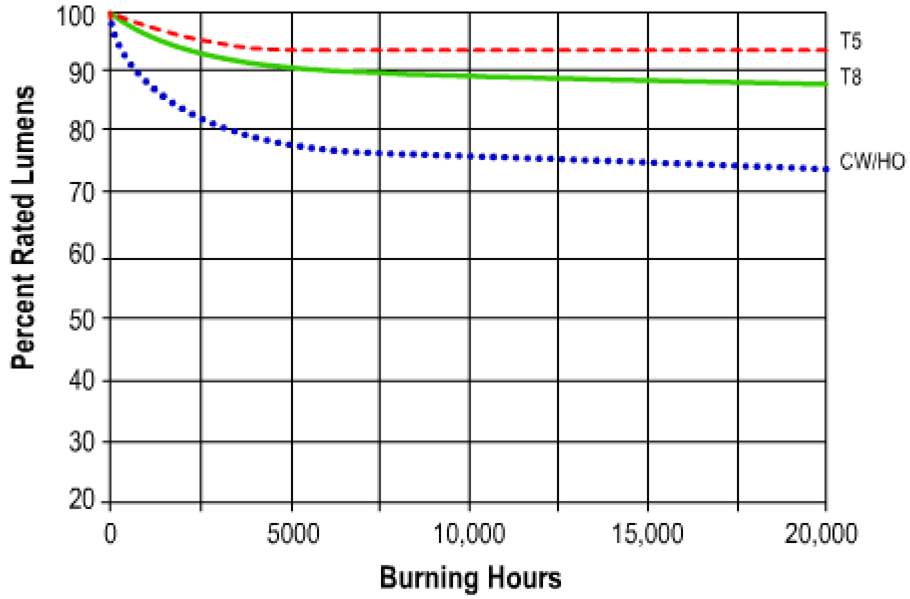
How long do T5 lamps last before they burn out?

Lamp manufacturers claim that T5 and T5 high output (T5 HO) lamps last 20,000 hours (Philips Lighting 2001/2002; OSRAM SYLVANIA 2002; GE Lighting 2001/2002). This average rated **lamp life** is measured at temperatures between 15°C (59°F) and 50°C (122°F) when operated on electronic **programmed start** ballasts on a three-hour switching cycle—3 hours on and 20 minutes off—and designated as the number of hours after which 50% of the lamps fail. The 20,000-hour lamp life of T5 lamps is the same as the lamp life of most T8 lamps, although newly developed prolonged-life T8 lamps have lives of 4,000 or 10,000 hours longer than T5 lamps. Lamps operated on longer burning cycles will have longer life spans. Shorter burning cycles (frequent switching on and off) reduce lamp life. Use of ballasts that do not meet lamp requirements set forth by the lamp manufacturers may also result in reduced lamp life.

Do T5 lamps have better lumen maintenance than T8 or T12 lamps?

Lumen maintenance refers to how a lamp maintains its light output over its lifetime. Both T5 and T5 high output (T5 HO) lamps maintain a higher light output than T12 and most T8 lamps. Manufacturers claim that T5 and T5 HO lamps retain more than 95% of light output at 8,000 burning hours (40% of rated average life). An improved phosphor coating reduces mercury absorption, which is one of the main causes of **lamp lumen depreciation**, leading to a higher lumen maintenance value. Also, because the T5 is smaller in diameter, it has a much smaller surface area. Manufacturers use only **tri-phosphors** in the T5, compared to the T8 and T12, in which there may be a mix of tri-phosphors with **halo-phosphors**. Figure 9 illustrates lumen maintenance curves for T5, T8, and T12 lamps (see How long do T5 lamps last before they burn out?). In Figure 9, T12 lamps are labeled as "CW/HO," which stands for cool white high output.

Figure 9. Lumen Maintenance Curves of T5, T8, and T12 Lamps as a Function of Burning Time



This diagram is based on OSRAM SYLVANIA's catalog, "Product Information Bulletin-PENTRON & PENTRON HO LINEAR T5."

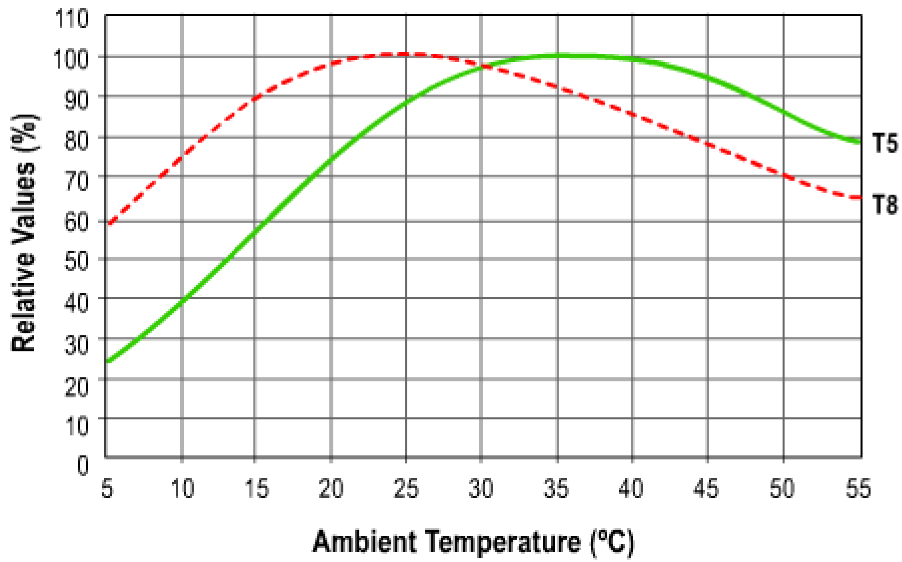
Do T5 luminaires perform better than T8 luminaires?

T5 lamps differ in lamp size and optimal temperature from T8 lamps, and both these factors affect luminaire performance. The smaller lamp diameter of T5 lamps can increase optical control efficiency and flexibility of luminaires. The higher optimal temperature of T5 lamps may allow T5 lamps to perform better in closed luminaires than open luminaires, and the difference in optimal temperature complicates T5 luminaire photometry and other comparisons to T8 lamps.

How does temperature affect the performance of a T5 lamp?

T5 and T5 high output (T5 HO) lamps are designed to produce maximum light output at 35°C (95°F), while the light output of T8 lamps is optimal at a temperature of 25°C (77°F). Figure 10-1 diagrams the performance of T5 and T8 lamps as a function of **ambient temperature**. OSRAM SYLVANIA and GE Lighting also provide similar diagrams in their online catalogs. A recent study (Zhang & Ngai 2001), however, suggested that the difference in light output of T5 lamps between 25°C (77°F) and 35°C (95°F) is often smaller than the difference shown in Figure 10-1. Other uncontrollable factors might also influence the light output of T5 lamps. Figure 10-1 shows that there is roughly a 10% difference in light output for both T5 and T8 lamps between 25°C (77°F) and 35°C (95°F). The 10°C (18°F) difference in optimal temperature between T5 and T8 lamps may affect lamp performance in various types of luminaires.

Figure 10-1. Light Output and Ambient Temperature



This diagram is quoted from SILHOUETTE T5, T5 HO & T5 Circular Fluorescent Lamp Technology Guide, Philips Lighting Company.

How do T5 lamps perform in open and closed luminaires?

Because the performance of T5 and T8 lamps varies as a function of **ambient temperature**, as Figure 10-1 on the previous page shows, T5 and T8 lamps may perform differently in luminaires in which the temperatures are different. The best applications for T5 lamps may differ from those for T8 lamps.

T5 and T5 high output (T5 HO) lamps, designed to produce maximum light output at 35°C (95°F), can take advantage of the heat that often builds up over 25°C (77°F) in compact enclosed luminaires. In such an enclosed luminaire, T5 lamps function better than T8 lamps. In an open luminaire, on the other hand, ventilation may keep the inside temperature lower than 35°C (95°F), and T8 lamps may perform better (see the CASE STUDY).

How does the difference in optimal temperature affect T5 luminaire photometry?

The 10°C (50°F) difference in optimal temperature between T5 and other fluorescent lamps causes a problem when dealing with photometric data, such as **luminaire efficiency**. American National Standards Institute/Illuminating Engineering Society of North America (ANSI/IESNA) standards require an ambient temperature of 25°C (77°F) for photometry. The efficiency of T5 luminaires is determined by dividing the lumen output of the bare lamps by the lumen output from luminaires. The bare lamps would be operating in an ambient temperature of 25°C (77°F) while the ambient temperature in the luminaire could be much higher. This higher temperature causes the lamps to have a higher light output. This procedure often leads to luminaire efficiency values greater than 100%.

In relative photometry, the lumen output from a bare lamp is scaled to rated-lumens provided by the manufacturer using a conversion factor to make the luminaire data independent of the particular lamp used in the test. In T5 and T5 high output (T5 HO) photometric testing, however, the rated-lumen value is obtained at 35°C (95°F), while the bare lamp is tested at 25°C (77°F). Therefore, in order to obtain accurate luminaire efficiency or optical efficiency, the bare lamp lumens and the rated lumens must be at the same temperature.

Table 10-2 shows light outputs of T5 lamps at 25°C (77°F) and 35°C (95°F) provided by a lamp manufacturer. These data may be useful in understanding the range of light outputs until a better solution of photometry procedures for T5 systems is established. As seen in the table, light output at 25°C (77°F) is 10 to 12% lower than it is at 35°C (95°F).

Table 10-2. Comparison of Light Output Data Between 25°C and 35°C
(These data are based on information from the Philips Lighting Company's online catalog: SILHOUETTE T5, T5 HO, & T5 Circular Fluorescent Lamp Technology Guide)

Lamp Type	Lamp Power (W)	Light Output		
		25°C A (lm)	35°C B (lm)	Ratio A/B (%)
T5	14	1,200	1,350	89
T5	21	1,900	2,100	90
T5	28	2,600	2,900	90
T5	35	3,300	3,650	90
T5 HO	24	1,750	2,000	88
T5 HO	39	3,100	3,500	89
T5 HO	54	4,450	5,000	89
T5 HO	80	6,150	7,000	88

Do T5 lamps allow for more optical efficiency of luminaires?

There is no way to answer this question, unless better photometry procedures for T5 luminaires can be established. Luminaire efficiency values in manufacturers' catalogs are unlikely to provide useful information to answer this question because American National Standards Institute/Illuminating Engineering Society of North America (ANSI/IESNA) photometry standards, which were established for conventional fluorescent lamp luminaires, overestimate efficiency for T5 luminaires as discussed in How long do T5 lamps last before they burn out? When, however, lighting designers attempt to use one-lamp indirect luminaires with T5 high output (T5 HO) lamps in place of two-lamp indirect luminaires with T8 lamps (one T5 HO lamp has nearly identical light output to two T8 lamps), they often notice that one-lamp luminaires with T5 HOs provide more uniform **luminaire efficiency**illuminance distributions on the ceiling and floor. This uniformity is because the use of luminaires with fewer T5 HO lamps and the smaller diameter of the T5 lamps result in wider and more uniform beam patterns. Luminaires using one T5 HO lamp may make better use of the light from the lamps than luminaires using two T8 lamps and therefore may assist lighting designers in creating more efficient lighting designs (CASE STUDY).

Does a two-lamp luminaire using T5 HO lamps produce as much light as a three-lamp luminaire using T8 lamps?

In most cases, a two-lamp luminaire using T5 high output (T5 HO) lamps produces more light than a three-lamp luminaire using T8 lamps. Table 11-1 compares nominal system performance between T5 HO and T8 direct/indirect luminaires—a two-lamp luminaire using T5 HO lamps and a three-lamp luminaire using T8 lamps. Table 11-1 suggests that the initial system lumen output from the two-lamp luminaire using T5 HO lamps is higher than the three-lamp luminaire using T8 lamps. This difference means that a two-lamp luminaire using T5 HO lamps can replace a three-lamp luminaire using T8 lamps. This calculation also shows, however, that the two-lamp luminaire using T5 HO lamps may be less efficacious than the three-lamp luminaire using T8 lamps if lamp-ballast **system efficacy** is considered. An absolute measurement appears in the (CASE STUDY)

Table 11-1. Comparison Between a Two-Lamp Luminaire Using T5 HO Lamps and a Three-Lamp Luminaire Using T8 lamps

Ballast No.	Lamp Combination and Type	Lamp Power (W)	Ballast Factor	Input Power (W)	Initial Light Output (lm)	Initial System Efficacy (lm/W)	Temperature (°C)
1	Two-T5 HO	108	1.0	120	8,900	74	25
					10,000	83	35
2	Three-T8	96	0.87	80	7,699	96	25

Ballast 1: QT2*54120PHO 120V 20/CS 1/SKU (OSRAM SYLVANIA, Inc.)

Ballast 2: ES-4/3-T8-32/25/17-UNV-B-IS (Energy Savings)

Are T5 lamps good for the environment?

Although the efficacy of T5 lamps is equivalent to that of T8 lamps, the compact size of T5 lamps reduces the amount of materials used in their manufacture, the potential for toxic substance contamination, and packaging materials needed for shipment and sale. T5 lamps can, therefore, have less impact on the global environment than T8 lamps.

In addition to their smaller dimensions, T5 lamps have an improved phosphor coating that prevents mercury from being absorbed into the phosphor and the bulb glass. This technology allows for reduced mercury content in the lamp, as well as higher **lumen maintenance**. A T5 lamp includes less than 3 milligrams (0.0001 ounces) (Van Vleef 1996) or 5 milligrams (0.0002 ounces) (GE Lighting, T5: Online Video, 2002) of mercury.

Compared to the larger T8 or T12 lamps, T5 lamps save material. The reduced surface area allows manufacturers to use nearly 60% less glass and phosphor material when manufacturing T5 lamps as compared to T12 lamps (Yancey 1998). Manufacturers claim that a T5 lamp requires 38% less glass than a T8 lamp (GE Lighting, New Linear Fluorescent Lamps, 2002). In addition, moving from T12 to T5 lamps can reduce packaging materials by up to 50% (Yancey 1998).

Do T5 lamps start more slowly than T8 lamps?

T5 lamps may appear to start more slowly than T8 lamps for the following two reasons: starting time varies, depending on the starting method, and T5 lamps may take longer to warm up than T8 lamps do. Ballast manufacturers, who use up-to-date technologies for T5 ballasts, developed programmed-start ballasts rather than instant-start ballasts for T5 lamps. These ballasts may make it appear that T5 lamps start more slowly than T8 lamps. For more information on this topic, see Specifier Reports: Electronic Ballasts.

Another factor is that the warm-up time of T5 lamps may be longer than T8 lamps. This difference results from the optimal temperature of T5 lamps being 10°C (50°F) higher than that of T8 lamps. The 10°C (50°F) difference in optimal temperature may extend the warm-up time of T5 lamps.

What are the common trade names for T5 lamps?

Table 14-1 summarizes the trade names and catalog number designations for standard and high-output 4-foot T5 lamps of various color temperatures. Table 14-2 summarizes contact information of manufacturers in the United States.

Table 14-1. Trade Names

Mfg. Name	Trade Name	CRI	Catalog Designation		
			3000K	3500K	4100K
GE Lighting	None	85	F28W/T5/HE/830	F28W/T5/HE/835	F28W/T5/HE/841
		85	F54W/T5/HO/830	F54W/T5/HO/835	F54W/T5/HO/841
OSRAM SYLVANIA, Inc.	PENTRON	82	FP28/830	FP28/835	FP28/841
	PENTRON HO	82	FP28/830/HO	FP28/835/HO	FP28/841/HO
Philips Lighting	Silhouette	85	F28T5/830	F28T5/835	F28T5/841
		85	F54T5/830/HO	F54T5/835/HO	F54T5/841/HO

Table 14-2. T5 Lamp Manufacturers and their Contacts in the United States

Manufacturer	Telephone	Web Site
GE Lighting	800-327-0533	www.gelighting.com
OSRAM SYLVANIA, Inc.	978-777-1900 800-544-4828	www.sylvania.com
Philips Lighting	800-555-0050	www.lighting.philips.com

Do price and availability prevent consumers from buying T5 systems?

A T5 lamp is the newest member of the linear fluorescent lamp family. Newer products tend to cost more and have more limited availability. This section discusses the availability and cost of T5 lamps.

Are T5 lamps readily available to consumers?

T5 lamps are available from distributors that handle lighting products. As of December 2001, most lighting designers have no problems with availability of most T5 systems in most areas of the United States. Some lighting designers still find, however, that dimming ballasts are not readily available, especially for standard T5 lamps and T5 lamps shorter than 4 feet. Because T5 lamps are not presently available at retail stores, lighting designers often order extra lamps at the beginning of the project for their clients.

How do the prices of T5 lamps compare with those of T8 lamps?

The price of T5 lamps is still two to three times (or more) higher than that of T8 lamps. For example, in Troy, New York, in December 2001 a T5 high output (T5 HO) lamp cost approximately $8, while a T8 lamp cost approximately $2.50. T5 luminaires cost approximately 20% more than T8 luminaires when comparing similar type of luminaires. However, the price range of popular T5 luminaires is equivalent to T8 luminaires—$150 to $300 per 4-foot T5 luminaire and $120 to $300 per 4-foot T8 luminaire. To some extent, these price differences can be balanced by reducing the number of lamps in a luminaire and by reducing the number of luminaires in a room. With increasing sales and competition, prices are likely to drop over the next few years.

What is the economic benefit of T5 systems?

The answer to this question may differ from one case to another. As discussed in Does a T5 lamp give as much light as a T8 lamp, T5 lamp-ballast systems are not significantly more efficacious than T8 lamp-ballast systems. Although the smaller lamp size and use of fewer lamps per luminaire (because of the higher light output of T5 lamps) can improve the optical efficiency of T5 luminaires, the temperature issue discussed in Do T5 luminaires perform better than T8 luminaires complicates the photometry of T5 systems. The superiority in optical efficiency of T5 luminaires over T8 luminaires may reduce electric energy use slightly. With respect to initial costs, T5 luminaires may have significant benefits if the higher output of T5 lamps leads to a large reduction in the number of lamps and luminaires per project, especially for large commercial projects (see the CASE STUDY).

What are good applications for T5 lamps?

T5 lamps differ from T8 and T12 lamps in length and socket size. T5 lamps also require different ballasts than T8 or T12 lamps do. These differences between T5 and T8 lamps make it inappropriate to replace T8 or T12 lamps with T5 lamps. For retrofit applications, the entire luminaire should be replaced with a T5 system. T5 luminaires are usually used in new construction projects. Because T5 lamps have smaller diameters, shorter lengths, and higher **luminances** than T8 and T12 lamps, they are more suitable for indirect lighting, direct/indirect lighting, direct lighting for high-bay applications, and wall-washing applications.

How can T5 lamps be used for indirect lighting?

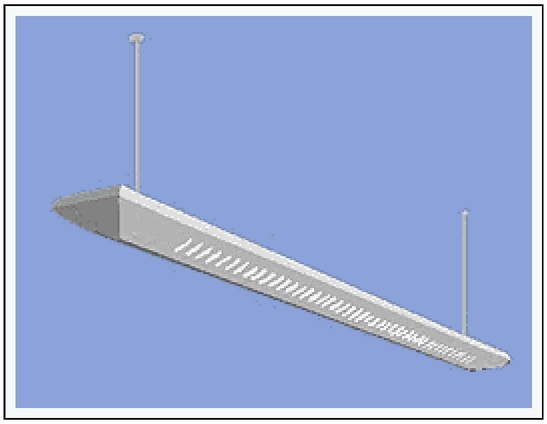
The smaller diameter of T5 lamps allows them to fit in narrow spaces and be easily hidden out of view, making them suitable for indirect lighting for cove, cabinet, and display applications. Using high-output T5 lamps instead of normal T5 lamps for these applications can increase the light output.

How can T5 lamps be used with direct/indirect pendant luminaires?

Pendant luminaires with direct/indirect (including indirect and semi-indirect) luminous intensity distributions are another popular application of T5 lamps (Figure 17-1). Luminaire manufacturers aggressively market these direct/indirect luminaires in a variety of shapes with different optical systems. The percentage of direct (downward) component of these direct/indirect luminaires ranges from 0% to approximately 60% but is usually less than 20%. This reduction in direct downward component reduces glare. The smaller profiles of the T5 lamps and their ballasts versus T8 and T12 lamp systems lead to smaller luminaires with improved optical control. Luminaire designers take advantage of these features and design aesthetically pleasing compact luminaires for high-end luminaire design. These designs include combining computer-designed optical systems such as patented prism panels to induce light softly from the lamps and hemi-cylindrical acrylic diffusers to soften the high luminances of T5 high output (T5 HO) lamps. These direct/indirect T5 luminaires become a viable option for commercial lighting applications where smaller, visually appealing luminaires are in demand. The metric lengths may allow for a better fit into 2x2 and 2x4 ceiling grids.

Luminaire manufacturers often use the same luminaire housings for T5 lamps as T8 (and sometimes T12) systems. Because the lengths, socket sizes, and ballasts of T5 lamps differ from those of T8 or T12 systems, the luminaire housings have two kinds of mountings for sockets: one for miniature bi-pin sockets of T5 lamps and the other for medium bi-pin sockets of T8 and T12 lamps and flexibility of mounting ballasts with different dimensions. In this case, designers use an optimal reflector for each lamp type.

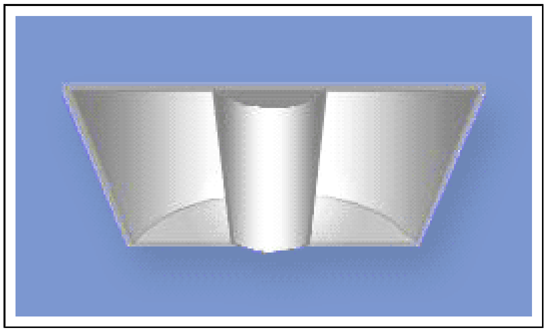
Figure 17-1. Direct/Indirect Pendant Luminaire



How can T5 lamps be used with recessed direct/indirect luminaires?

The thermal characteristics of T5 lamps that optimize their light output at 35° C (95° F) may make small, enclosed luminaires preferable for these lamps. Although small, recessed luminaires with parabolic louvers are popular for commercial lighting in Europe, few luminaires of this type are available in the United States because of their potential to create glare. One recessed T5 luminaire that manufacturers market in the United States is a luminaire with a large semi-cylindrical reflector and a metal mesh filter covering a T5 high output (T5 HO) lamp to soften its high **luminance** (Figure 17-2).

Figure 17-2. Direct/Indirect Recessed Luminaire



How can T5 lamps be used with direct luminaires for high-ceiling applications?

The high luminances of T5 lamps allow designers to use direct luminaires for high-ceiling applications, such as indoor sports facilities, gymnasiums, factories and warehouses, and retail spaces with high ceilings. These high-bay luminaires often have as many as six T5 high output (T5 HO) lamps in a small package with high-efficiency reflectors directing the light downward. Their high location decreases the apparent size of the high-intensity light sources, shields the light sources from the direct view of occupants, and therefore may reduce glare. These luminaires offer an alternative to high-intensity discharge (HID) luminaires. T5 lighting has a number of advantages over HID lighting. T5 lamps are dimmable if used with dimming ballasts, and they flicker less. They also have

- better color rendering
- longer life
- better **lumen maintenance**
- instant restrike capability
- shorter warmup times

Although the initial cost of T5 lamps and luminaires may be higher than HID lamps and luminaires, T5 lighting can use as little as 50% of the energy that HID lighting does, especially if the T5 lamps are used with dimming ballasts, photo sensors, and skylights (Anonymous, T5 Fluorescent Lighting Outshines HIDs, 2000).

Can T5 lamps and luminaires be used for wall washing?

Wall washing with asymmetric luminous intensity distribution may be another application for T5 luminaires. Wall-washer luminaires, featuring luminaire apertures that are shielded by architecture or a low-brightness parabolic louver system from the view of occupants, can avoid causing **glare**.

What are the advantages and disadvantages of T5 systems versus T8 systems in lighting design?

The advantages of T5 lamps over T8 lamps can be summarized as follows:

- The smaller size of T5 lamps allows for smaller luminaires.
- The smaller lamp diameter of T5 lamps makes it easier to design optical systems that distribute light in the intended directions.
- The higher light output of T5 high output (T5 HO) lamps may reduce the number of luminaires per project.

A disadvantage of T5 lamps, if they are inappropriately used, is **glare**. Glare can be prevented, though, by choosing luminaires that shield the light sources from view. Another measure to avoid glare is to decrease the visual size or solid angle of these light sources.

What luminaires are available for T5 lamps?

The smaller diameter of T5 lamps has increased the flexibility of luminaire design and allowed luminaire designers to develop stylish compact luminaires. Figure 18-1 shows examples of such luminaires.

Figure 18-1. Semi-Indirect Pendant Luminaire with One or Two T5 Lamps

Source: Ledalite

Figure 18-2. Direct/Indirect Pendant Luminaire for Two T5 Lamps

Source: Zumtobel Staff

What luminaires are available for T5 lamps? - cont'd

The small diameter of T5 and T5 high output (T5 HO) lamps makes them nearly line sources with high optical controllability. Their quasi-line-source quality allows for a compact optical system that can accurately deliver the light emitted from the light source to where it is needed and therefore achieves a highly efficient optical design.

The higher output of T5 HO lamps may also help increase optical efficiency. Because a T5 HO lamp (5,000 lumens) has nearly 70% more lumen output than a T8 lamp (2,950 lumens), a one-lamp luminaire using T5 HO lamps may replace a two-lamp luminaire using T8 lamps (5,000 lumens) (see Do T5 luminaires perform better than T8 luminaires?). As the number of lamps in a luminaire decreases, the light control generally becomes more efficient and flexible. For instance, a one-lamp luminaire can be built with higher optical flexibility than a two-lamp luminaire. This optical advantage of one-lamp luminaires results in a wider batwing-shaped upward light distribution that can increase **illuminance** uniformity on the ceiling and floor. It also permits a higher mounting height (shorter distance from the ceiling). The ability to achieve high uniformity may let workplane illuminance easily reach IESNA standards.

If the optical system is well designed, the light output from a one-lamp luminaire using a T5 HO lamp can exceed that from a two-lamp luminaire using T8 lamps. As discussed in Do T5 luminaires perform better than T8 luminaires?, a two-lamp luminaire using T5 HO lamps often has more light output than a three-lamp luminaire using T8 lamps. When lighting designers specify these T5 HO luminaires instead of T8 luminaires, they can often use fewer luminaires per project, especially for large commercial projects.

How do luminaire manufacturers prevent glare?

The smaller bulb diameters and higher light outputs of T5 lamps increase the light emitted per unit area—or the **luminance**—of the lamp bulb walls. A T5 or T5 high output (T5 HO) lamp has 60% of the surface area of a T8 lamp. Because, however, a standard T5 lamp has nearly identical light output to a T8 lamp (2,900 lumens versus 2,950 lumens), the surface luminance of a standard T5 lamp is 1.64 times as much as a T8 lamp. Further, the light output of a T5 HO lamp is 5,000 lumens, so the surface luminance is 2.83 times as high as a T8 lamp (see the CASE STUDY). The higher surface luminance, without any shields or diffusers, results in more glare and discomfort for room occupants. Unless the lamps are properly shielded, these high-luminance light sources may also annoy workers by reflecting off of computer screens or other visual display units.

To avoid glare from the high-luminance bulb walls of T5 lamps, luminaire manufacturers design indirect and direct/indirect luminaires that keep the lamps out of sight. Acrylic guide panels [see Figure 18-2.], parabolic louvers, and metal mesh filters are often used with these luminaires. Direct luminaires with parabolic louvers, metal mesh filters, or diffusers may be able to reduce glare. When using louvers, shielding angles must be at least 30° in open ceiling luminaires in order to be effective. A recent study suggests that even a luminaire overhead can cause discomfort glare when the luminance of the luminaires is high enough, such as bare T5 or T5 HO lamps (Ngai & Boyce 2000). If a typical diffuser is used, a distance of at least 20 millimeters (0.8 inches) is needed between the lamps and the diffuser in order to obtain effective diffusion (Philips 2001/2002). Designers should realize, though, that indirect lighting and most glare control filters or diffusers reduce the amount of light delivered to the workplane compared to unshielded direct fixtures.

Another measure to avoid glare is to decrease the apparent size of high-luminance light sources. For example, in high-bay applications, such as factories and warehouses, even high-luminance luminaires using T5 HO lamps may be acceptable because the apparent size of the luminaires near the high ceiling is small to the observer.

Glossary Terms

Ambient temperature	The temperature of the surrounding air that comes into contact with the lamp and ballast. Ambient temperature affects the light output and active power of fluorescent lamp/ballast systems. Each fluorescent lamp-ballast system has an optimum ambient temperature at which it produces maximum light output. Higher or lower temperatures reduce light output. For purposes of lamp/ballast tests, ambient temperature is measured at a point no more than 1 meter (3.3 feet) from the lamp and at the same height as the lamp.
Ballast	A device required by electric-discharge light sources such as fluorescent or HID lamps to regulate voltage and current supplied to the lamp during start and throughout operation.
Ballast factor (BF)	The ratio of the light output of a fluorescent lamp or lamps operated on a ballast to the light output of the lamp(s) operated on a standard (reference) ballast. Ballast factor depends on both the ballast and the lamp type; a single ballast can have several ballast factors depending on lamp type.
Color rendering	A general expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.
Color rendering index (CRI)	A measure of the degree of color shift that objects undergo when illuminated by a lamp, compared with those same objects when illuminated by a reference source of comparable correlated color temperature (CCT). A CRI of 100 represents the maximum value. A lower CRI value indicates that some colors may appear unnatural when illuminated by the lamp. Incandescent lamps have a CRI 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 a 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 are usually considered warm sources, whereas those with a CCT above 4000 K usually considered cool in appearance.
Dimming ballast	A device that provides the ability to adjust light levels by reducing the lamp current. Most dimming ballasts are electronic.
Direct luminaire	A luminaire that emits light in the general direction of the task to be illuminated. The term usually refers to luminaires that emit light in a downward direction.
Electronic ballast	A ballast that uses electronic components instead of a magnetic core and coil to operate fluorescent lamps. Electronic ballasts operate lamps at 20 to 60 kHz, which results in reduced flicker and noise and increased efficacy compared with ballasts that operate lamps at 60 Hz.
Flicker	A rapid and continuous change in light levels caused by the modulation of the light output from fluorescent lamps.
Glare	The sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance and visibility.
Halo-phosphors	Also referred to as halophosphates. Phosphors are the white powder inside fluorescent lamps that fluoresces (emits visible light) when excited by the ultraviolet radiation produced by the mercury vapor that is energized by the electric arc sustained inside the lamp. Phosphors are used to achieve high efficacy, good color rendering, and low lamp lumen depreciation. Halo-phosphors, however, are limited in their ability to provide a high color rendering index without sacrificing light output and are often mixed with other phosphors.
Illuminance	The amount of light (luminous flux) incident on a surface area. 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.
Instant start	A method of starting fluorescent lamps in which the voltage that is applied across the electrodes to strike the electric arc is up to twice as high as it is with other starting methods. The higher voltage is necessary because the electrodes are not heated prior to starting. This method starts the lamps without flashing. It is more energy efficient than rapid or preheat starting, but results in greater wear on the electrodes during starting. The life of instant-start lamps that are switched on and off frequently may be reduced by as much as 25 percent relative to rapid-start operation. However, for longer burning cycles (such as 12 hours per start), there may be no difference in lamp life for different starting methods.

Lamp efficacy	The ratio of the light output of a lamp (lumens) to its active power (watts), expressed as lumens per watt (LPW).
Lamp life	The median life span of a very large number of lamps (also known as the average rated life). Half of the lamps in a sample are likely to fail before the rated lamp life, and half are likely to survive beyond the rated lamp life. For discharge light sources, such as fluorescent and HID lamps, lamp life depends on the number of starts and the duration of the operating cycle each time the lamp is started.
Lamp lumen depreciation (LLD)	The reduction in lamp light output that progressively occurs during lamp life.
Light power density (LPD)	Sometimes referred to as power density. A measurement of the ratio of light output in an area and the electric power used to produce that light. LPD is determined by dividing the total light output by the total wattage consumed and is measured in lumens per watt.
Lumen maintenance	The ability of a lamp to retain its lumen output over time. Greater lumen maintenance means a lamp will remain brighter longer. The opposite of lumen maintenance is lumen depreciation, which represents the reduction of lumen output over time. Lamp lumen depreciation factor (LLD) is commonly used as a multiplier to the initial lumen rating in illuminance calculations to compensate for the lumen depreciation. The LLD factor is a dimensionless value between 0 and 1.
Luminaire	A complete lighting unit consisting of a lamp or lamps and the parts designed to distribute the light, to position and protect the lamp(s), and to connect the lamp(s) to the power supply. (Also referred to as fixture.)
Luminaire efficacy	The ratio of the measured light output of a luminaire to its active power, expressed in lumens per watt (LPW).
Luminaire efficiency	The ratio, expressed as a percentage, of the light output of a luminaire to the light output of the luminaire's lamp(s). Luminaire efficiency accounts for the optical and thermal effects that occur within the luminaire under standard test conditions.
Luminance	The photometric quantity most closely associated with the perception of brightness, measured in units of luminous intensity (candelas) per unit area (square feet or square meter).
Luminous flux	The rate of flow of light, measured in lumens. The overall light output of a lamp
Medium Bi-Pin	A type of connector commonly used on T-8 and T-12 fluorescent lamps. Two small pins protrude from the lamp ends, which are inserted into a socket in the fixture.
Miniature bi-pin	A type of connector commonly used on T-5 lamps. Similar in design to but smaller than medium bi-pin connectors, it uses two small pins that protrude from the lamp ends and are inserted into a fixture socket.
Phosphors	The white, powdered material coating the inside of the glass tube of a lamp. The phosphors fluoresce (emit visible light) when excited by the ultraviolet radiation produced by the mercury vapor that is energized by the electric arc sustained inside the lamp.
Photosensor	A device used to integrate an electric lighting system with a daylighting system so lights operate only when daylighting is insufficient.
Power factor (PF)	The ratio of active power (in watts) to apparent power (in rms volt-amperes), power factor is a measure of how effectively an electric load converts power into useful work. Power factor (PF) is calculated using the equation PF = (active power) / [(rms voltage) x (rms current)]. Phase displacement and current distortion both reduce power factor. A power factor of 0.9 or greater indicates a high power factor ballast.
Preheating time	Also referred to as preheat time and lamp preheat time. The length of time that a ballast heats a lamp's electrodes before initiating the lamp arc. Rapid start ballasts preheat a lamp before initiating the arc in order to ease starting. Too short or too l
Programmed	Refers to a type of rapid start ballast that optimizes the starting process by waiting until the lamp's electrodes have been

start	heated to apply the starting voltage, thus easing the load to the electrode and extending lamp life. Standard rapid start ballasts heat the electrodes during the starting process to allow quicker starting without flicker.
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. Heating the electrodes before starting the lamps reduces the voltage required to strike the electric arc between the electrodes. A rapid-start system starts smoothly, without flashing.
Rated average lamp life	Also referred to as lamp rated life. Lamps are tested in controlled settings and the point at which 50% of a given sample burns out is listed as the lamps' rated average lamp life.
Rated lumen	Also referred to as rated light output from lamp in lumens. Lumen refers to 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. Manufacturers rate their lamps' initial light output after 100 hours of operation.
Skylight	A device similar to a window that is placed in a roof, allowing sunlight to enter a structure, thus reducing the need for electric lighting. Skylights can be used to reduce peak load demand by taking advantage of sunlight during the peak demand time of the day.
Sound Rating	Magnetic ballasts sometimes produce a humming noise caused by vibration of the magnetic core. Electronic ballasts operate at high frequencies and are usually less noisy. Ballasts are rated from "A" to "F" based on their noise levels. Ratings define the range of ambient sound levels in which people will not notice the ballast noise. The higher the rating, the more noise that will be required to mask the ballast hum.
System efficacy	Also referred to as relative system efficacy, system efficacy is a measurement of a system''s ability to convert electricity into light. Measured in lumens per watt (LPW), system efficacy is the ratio of the light output (in lumens) to the active power (in watts).
Total harmonic distortion (THD)	A measure of the degree to which a sinusoidal wave shape is distorted by harmonics, with higher values of THD indicating greater distortion.
Tri-Phosphors	Tri-phosphors are a blend of three narrow-band phosphors (red, blue, and green) that provide improved color rendition and higher light output versus some other types of phosphors.
Uniformity	The degree of variation of illuminance over a given plane. Greater uniformity means less variation of illuminance. The uniformity ratio of illuminance is a measure of that variation expressed as either the ratio of the minimum to the maximum illuminance or the ratio of the minimum to the average illuminance.
Wall-washing	The practice of illuminating vertical surfaces, such as walls. Wall-washer luminaries are designed to illuminate vertical surfaces.

How do T5 lamps perform in open and closed luminaires?

The Lighting Research Center measured temperatures in four direct/indirect pendant (open) luminaires and four direct recessed (closed) luminaires. In the direct/indirect luminaires, researchers measured temperatures at 16 to 20 locations at 1-centimeter (0.4 inch) intervals across cold spots of the lamp. In the direct recessed luminaire, researchers measured temperatures at two to size locations at 1-centimeter (0.4 inch) intervals across cold spots the lamp. The cold spot for a T5 high output (T5 HO) lamp is located on the metallic end cap of label side within 2 millimeters (0.08 inches) of the glass across the end caps of lamps. The cold spot for a T8 lamp is located around the center of the lamp. During the measurements, the room was at a temperature of 25°C (77°F). Table 10-1 illustrates the results of the temperature measurements in those open and closed luminaires. Temperature distribution within the luminaires was relatively even, except within the immediate surroundings of lamps.

Table 10-1. Temperature in Open and Closed Luminaires

Luminaire					Temperature	
Type	No.	Lamp Combination and Type	Optics Type	Input Power (W)	Average (°C)	Range (°C)
Direct/indirect luminaire (open)	1	Three-T8	Louver	83	36	32-43
	2	Two-T5 HO	Louver	120	32	29-38
	3	Two-T8	Louver	54	34	30-42
	4	One-T5 HO	Louver	60	29	28-35
Direct luminaire (closed)	5	One-T8	Louver	27	38	35-39
	6	One-T8	Flat panel	27	40	39-42
	7	One-T5 HO	Louver	55	46	38-52
	8	One-T5 HO	Flat Panel	55	46	42-51

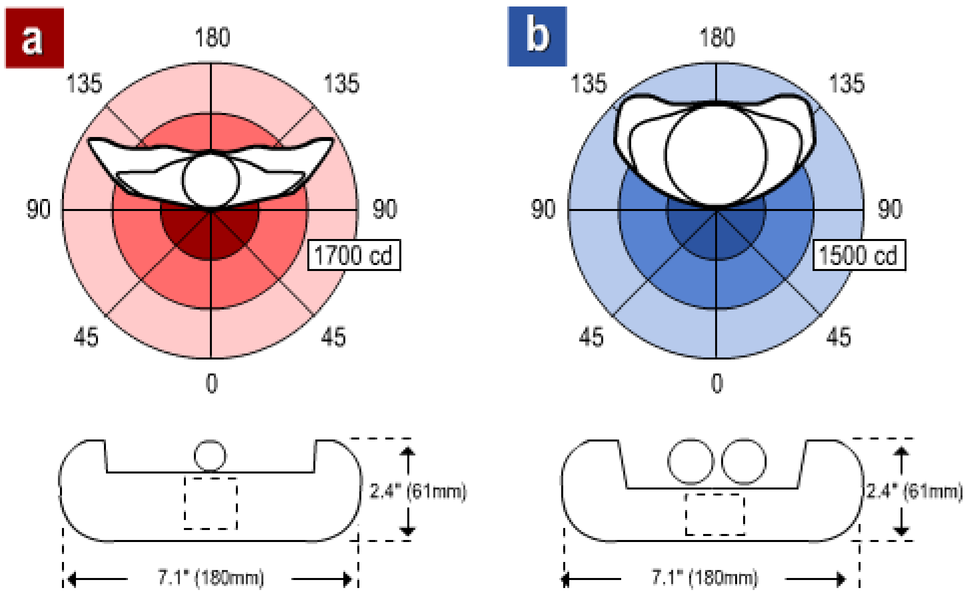
This data may vary depending on selection of lamps, ballasts, and luminaires.

Comparison of the temperature values in Table 10-1 with the lamp performance data as a function of **ambient temperature** in Figure 10-1 may suggest that in the direct/indirect (open) luminaires, where temperatures are lower than 35°C (95°F), T5 lamps emit less light than under the optimal condition of 35°C (95°F). In the direct recessed (closed) luminaires, where the temperatures are much higher than 35°C (95°F), T5 lamps function better than T8 lamps.

Do T5 lamps allow for more optical efficiency of luminaires?

Figure 10-2 illustrates luminous intensity distribution of a one-lamp indirect pendant luminaire using a T5 highg output (T5 HO) lamp as compared with an indirect pendant luminaire using two T8 lamps. Because these two luminaires use the same housing, they appear similar from the outside, but each reflector is optimized for each lamp type.

Figure 10-2. Luminous Intensity Distribution of T5 HO and T8 Luminaires



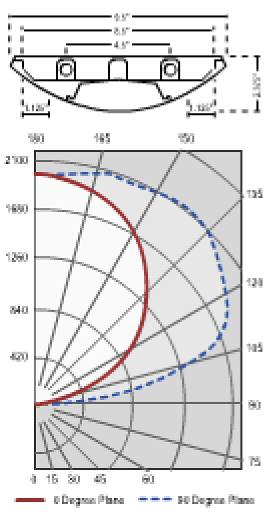
(a) 1 T5 HO luminaire (8213H01) **(b) 2 T8 luminaire (8213T02)**

Quoted from Specification Sheets of Minuet from Ledalite

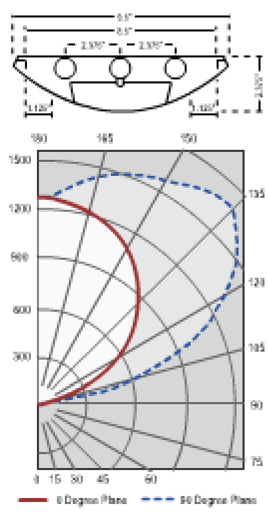
Does a two-lamp luminaire using T5 HO lamps produce as much light as a three-lamp luminaire using T8 lamps?

No absolute light output data are available from manufacturers, so the Lighting Research Center measured light outputs of two two-lamp luminaires using T5 high output (T5 HO) lamps and two three-lamp luminaires using T8 lamps. Figure 11 illustrates the four luminaires and their luminous intensity distribution diagrams. Luminaires 1 and 2 in Figure 11 are the same as Luminaires 1 and 2 in Table 11-1. Luminaires 1 and 2 are indirect pendant luminaires and Luminaires 3 and 4 are direct/indirect pendant luminaires. Table 11-2 shows the results of light outputs obtained by the absolute measurements. Although the sample number is small, these measurements also suggest that a two-lamp luminaire using T5 HO lamps could replace a three-lamp luminaire using T8 lamps, but a two-lamp luminaire using T5 HO lamps may need more electrical energy than a three-lamp luminaire using T8 lamps. Because the measurements show that lumen output from the two-lamp luminaire using T5 HO lamps is higher than that from the three-lamp luminaire using T8 lamps, lighting designers could potentially reduce the number of luminaires per project compared to the number required when specifying three-lamp luminaires using T8 lamps, thus reducing first cost and total power density of the installation.

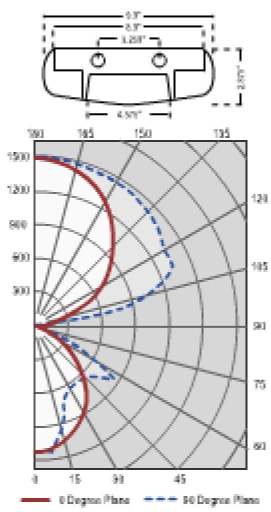
Figure 11. Cross-sections and Measured Luminous Intensity Distribution for the Absolute Measurements



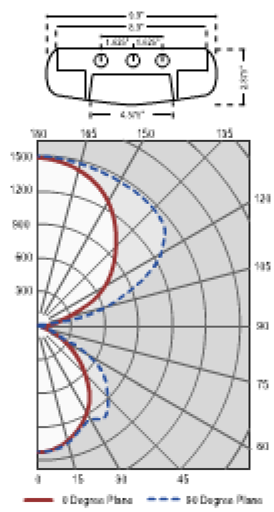
Luminaire 1
see larger view



Luminaire 2
see larger view



Luminaire 3
see larger view



Luminaire 4
see larger view

Table 11-2. Measured Light Output Data
(Measured by Luminaire Testing Laboratory, Inc. at an **ambient temperature** of 25°C)

Luminaire Type	No.	Lamp Combination and Type	Input Power (W)	Light Output (lm)	Luminaire Efficacy (lm/W)
Indirect luminaire	1	Two-T5 HO	121.6	8,552	70.3
	2	Three-T8	83.4	5,892	70.6
Direct/indirect luminaire	3	Two-T5 HO	121.3	8,390	69.2
	4	Three-T8	90.3	6,153	68.1

This data may vary depending on selection of lamps, ballasts, and luminaires

Figure 11

What is the economic benefit of T5 systems?

To investigate the economic impact of T5 systems, the Lighting Research Center conducted simple calculations for a typical small office room using T5 and T8 luminaires. Table 16 uses these calculations to answer common questions about the economics of T5 wnd T8 systems

- How many lamps and luminaires are needed to provide **illuminance** greater than 300 lux (30 footcandles)?
- How many lamps and luminaires are needed to provide appropriate uniformity (maximum/minimum illuminance ratio less than 3)?
- What are the initial costs of the installations?
- What are the energy costs of the installations?

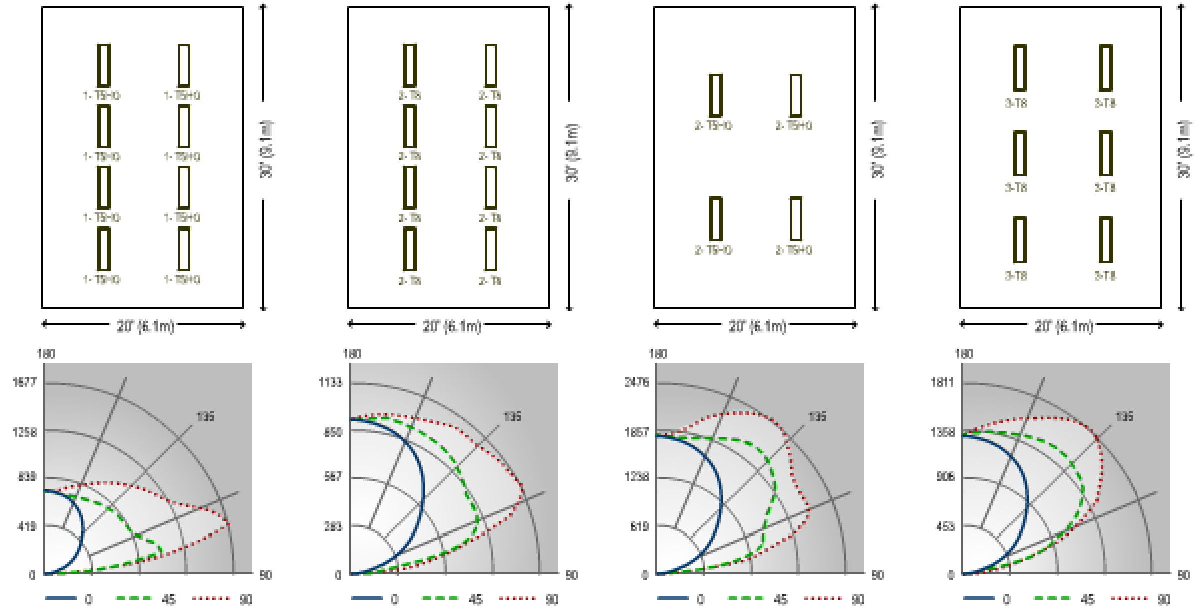
Layouts 1 and 2 compare installations using one-lamp luminaires with T5 high output (T5 HO) lamps and those using two-lamp luminaires with T8 lamps. Layouts 3 and 4 compare the use of two-lamp luminaires with T5 HO lamps and three-lamp luminaires using T8 lamps. Figure 16 shows luminaire layouts for all four cases. In this calculation, **luminaire efficiency** data in catalogs were used.

Table 16. Economic Comparisons Between T8 and T5 Systems

Layout	A	B	C	D
Luminaire type	Indirect	Indirect	Indirect	Indirect
Lamp type	One-T5 HO	Two-T8	Two-T5 HO	Three-T8
E average-workplane (lx)	359 (33fc)	348 (32fc)	370 (34fc)	385 (36fc)
Uniformity (Max/Min)	2.5	2.5	2.7	2.8
Input power (W)	62	59	120	87
Power density (W/m^2)	8.9 (0.83 W/ft^2)	8.5 (0.79 W/ft^2)	8.6 (0.80 W/ft^2)	9.4 (0.87 W/ft^2)
Number of lamps	8	16	8	18
Lamp cost	$64	$39	$64	$44
Number of luminaires	8	8	4	6
Luminaire cost	$2,456	$2,064	$1,052	$1,764
Initial cost	$2,520	$2,103	$1,116	$1,808
Energy costs*	$149	$142	$144	$157

*Energy costs calculated based on 10 cents per kWh and 3000 hours of operation per year.

Figure 16. Luminaire Layouts and Luminaires



Luminaire 1	**Luminaire 2**	**Luminaire 3**	**Luminaire 4**
see larger view	see larger view	see larger view	see larger view

This data may vary depending on selection of lamps, ballasts, and luminaires

Between Layouts 1 and 2, T5 systems offer no advantages over T8 systems. The higher output T5 lamps reduce the number of lamps needed but cannot decrease the number of luminaires per project. Because the average illuminance level in Layout 1 is slightly higher than in the Layout 2, however, if the one-lamp luminaire using the T5 HO lamp succeeds in reducing the number of luminaires per project, especially in large office areas, the T5 luminaire may save initial cost.

In Layouts 3 and 4, the two-lamp luminaires using T5 HO lamps succeed in reducing both initial cost and energy costs. The smaller number of T5 luminaires lowers initial cost. As the scale of projects becomes larger, the economic benefit with respect to initial cost may increase. The slightly higher optical efficiency and slightly lower illuminance level of T5 luminaires in Layout 3 reduce power density for the T5 installation.

Using T5 luminaires will usually provide an economic benefit by reducing initial cost if the project is large enough to allow the number of luminaires to be reduced. By selecting optically efficient T5 luminaires, building owners may reduce electrical energy consumption slightly as well.

Figure 16

How do luminaire manufacturers prevent glare?

The Lighting Research Center compared bulb wall **luminances** of T5 and T5 high output (T5 HO) lamps with T8 and T12 lamps. Researchers measured luminances at three points—center of bulb, 30 centimeters (12 inches) to the left, and 30 centimeters (12 inches) to right—for each lamp using a luminance meter (LS 110, Minolta) under the standard temperature of 25°C (77°F). These measurements used eight T5 HO lamps, eight T5 lamps, three T8 lamps, and three T12 lamps. During the measurements, the T8 and T12 lamps were in a horizontal position, but the T5 and T5 HO lamps were in a vertical position. Table 18-1 shows the results of the measurements.

Table 18-1. Bulb Wall Luminances of Fluorescent Lamps

Lamp Type	Luminance (cd/m^2)	Ratio to T8 (%)
T5 HO	37,000	300
T5	22,500	180
T8	12,500	100
T12	4,600	40

Resources

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