

SILHOUETTE

T5, T5HO & T5 Circular
Fluorescent Lamp Technology Guide

*Ultra-Slim Design With
Extraordinary Light Output*



Let's make things better.



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Philips Lighting has transformed the T8 fluorescent lamp, today’s standard, into a slimmer, sleeker, more flexible lamp... the SILHOUETTE T5 offers design flexibility and new aesthetic possibilities... and SILHOUETTE T5 meets or exceeds the technical features of T8 fluorescent lamps, in a 40% smaller package.

Comparison of SILHOUETTE T5 and Standard T8 Fluorescent Lamps

	SILHOUETTE T5	Standard T8 TL80
Efficacy (lpw)	104	92
Lumen Maintenance (%)	95	95
Power (watts)	28	32
Color Rendering Index	85	86
Lumens	2900	2950

Summary of SILHOUETTE T5 Features and Benefits

Features	Benefits
Slim profile lamp and ballast	Improved optical control Smaller luminaires
Variety of sizes and color temperatures	Design and application flexibility
Optimized lamp lengths	Better fit in 2 x 2 and 2 x 4 grid ceilings; Easier relamping
Improved phosphor coating	Higher efficacy—up to 104 lumens per watt; 95% lumen maintenance; 85 CRI
Peak light output at 95°F (35°C)	Better “real world” performance
High frequency electronic ballast with programmed start	High system efficiency Fail/safe operation



I: General Information on Philips SILHOUETTE T5 lamp family: T5, T5HO and T5 Circular

I.1 Introduction

The T5 fluorescent lamp family, all with a 5/8" (16mm) tube diameter, are designed for the highest efficacy and system miniaturization. Both T5 Linear and Circular lamps have excellent color rendering. The T5 lamp family is designed for use with electronic programmed start ballasts (high frequency operation).

The T5 range consists of Linear and Circular lamps (standard output and high output (HO) types).

Standard	High Output	Circular
14W (22in.)	24W (22in.)	22W (9in. OD)
21W (34in.)	39W (34in.)	40W (12in. OD)
28W (46in.)	54W (46in.)	55W (12in. OD) – HO
35W (58in.)	80W (58in.)	

I.2 Lamp technology and operation

The T5 family of low pressure mercury discharge lamps operate by the same principle as other fluorescent lamps. The discharge tube has an electrode sealed into each end and is filled with an inert gas and a small amount of mercury (in both liquid and vapor forms). The inside of the tube is coated with a mixture of fluorescent powders. These powders convert the ultraviolet radiation of the mercury discharge into visible light.

T5 family is designed to operate with electronic programmed start ballasts for optimal performance and life.

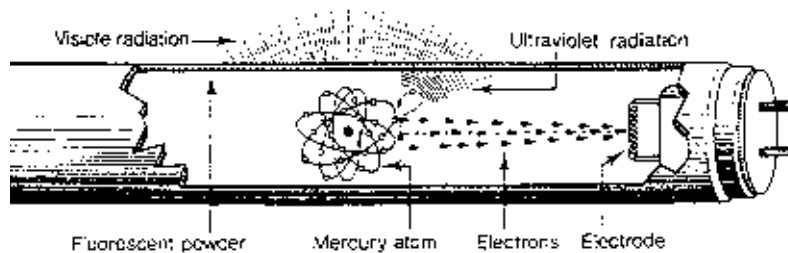


figure 1.1: Exploded view of linear fluorescent lamp

I.2.1 Cold Chamber technology – T5 and T5HO linear lamps

The light output of a low pressure mercury discharge lamp is determined by the mercury vapor pressure which in turn is determined by the temperature of the coolest spot on the discharge tube. In the case of T5 and T5HO lamps, this spot is located on the etched end of the lamp, behind the electrode (cold chamber).

The temperature at the coolest spot on the discharge tube can be influenced by:

- the ambient temperature near the lamps in the fixture
- the power dissipation in the electrodes.



figure 1.2 lamp end with cold chamber – T5 and T5HO lamps



1.2.2 Cold Chamber technology – T5 Circular lamps

In the case of T5 Circular lamps, the cold chamber is located on the etched side of the lamp base.

1.3 Nomenclature

The technical name of the product is: **SILHOUETTET5**, tube diameter of **5/8"** (16mm)

Examples:

F28T5/830: SILHOUETTE T5 lamp
28 Watts
830 color rendering index >80, color temperature **3000K**

F54T5/835/HO: SILHOUETTE T5 **H**igh **O**utput lamp
54 Watts
835 color rendering index >80, color temperature **3500K**

FC9T5/841: SILHOUETTE T5 **C**ircular lamp
outer diameter **9"** (225mm) = 22 Watts
841 color rendering index >80, color temperature **4100K**

FC12T5/830: SILHOUETTE T5 **C**ircular lamp
outer diameter **12"** (300mm) = 40 Watts
830 color rendering index >80, color temperature **3000K**

FC12T5/841/HO: SILHOUETTE T5 **C**ircular lamp, **H**igh **O**utput
outer diameter **12"** (300mm) = 55 Watts
841 color rendering index >80, color temperature **4100K**

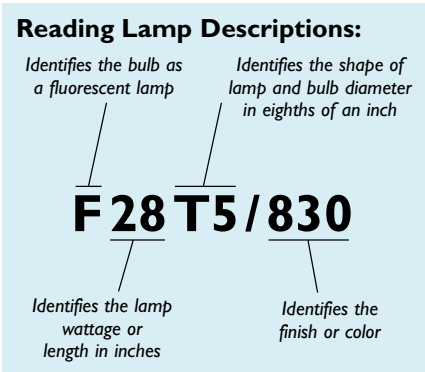


figure 1.2.2 Reading Lamp Descriptions

2: Fixture Design

2.1 Operating temperatures for T5, T5HO and T5 Circular lamps

2.1.1 Maximum temperatures

Fixtures for T5, T5HO and T5 Circular lamps must satisfy the general requirements for fixtures as specified by UL 1598 and, if applicable, comply with the requirements of local standards.

The maximum allowed temperature of the T5, T5HO, and T5 Circular lamp bases is 248°F (120°C).

2.1.2 Effect of fixture design on the lamp temperature

T5 linear lamps will reach maximum light output at 95°F (35°C) ambient temperature in draft-free air. For a given lamp power and ambient temperature, the temperature within the fixture is chiefly determined by:

- the fixture dimensions and type of material
- the position of the ballast
- the degree of ventilation (open, half-open, closed fixture).

The maximum light output of T5 Circular lamps will be achieved when the ambient temperature is 77°F (25°C).

2.1.3 Non draft free and cold conditions

If the ambient temperature within the luminaire is lower than the optimum temperature of 95°F (35°C) for T5 linear lamps due to "cold" applications, it is recommended to cover the cold spot with an insulating cap to reach optimum light output.



2.1.4 Vertical burning position

As mentioned before the optimum light output with T5 lamps is reached at 95°F (35°C) in draft free air with the lamp in a horizontal position. If the lamp is operated in a vertical position, the upper lamp side will be heated to a slightly higher temperature than the lower lamp side. Therefore, when burning the lamp in the vertical position at cool ambient temperatures, the etched side (location of the cold chamber) should be at the top. At warm ambient temperatures, the etched side should be at the bottom.

2.2 General recommendations for measuring T5 lamps

Before measuring the light output ratio of a luminaire, the T5 lamps should be in a stable condition: the liquid mercury must be in the cold chamber. To reach this condition, the following steps should be taken:

1. To bring the lamp to a stable condition, season the lamp for approximately 100 hours vertically with the cold chamber (located on the etched side) at the lowest point.
2. When the lamp has been off for more than 12 hours, burn the lamp for at least four hours in the above described position before measuring. Transport the lamp in the vertical position with the cold chamber at the lowest point to the measuring system. Gently place the lamp in the (horizontal) lamp holder. Take care to insure that the cold chamber stays at the lowest point.
3. To bring the lamp back to a stable condition, burn the lamp on a nominal ballast for one hour at 77°F (25°C) and check the stability (see note below) by monitoring the luminous flux.
4. Measure the luminous flux of the lamp with the nominal ballast at 77°F (25°C).
5. Gently put the lamp and ballast in the luminaire under test (be careful to keep the cold chamber at the lowest point) and burn the lamp for at least one hour at 77°F and check the stability again by monitoring the luminous flux.
6. Measure the luminous flux of the luminaire at 77°F ambient temperature.

Note: For an additional stability check, the cold chamber can be cooled locally (by air flow, cold spray, etc...). If the light output drops fast after the cold chamber is cooled, the lamp was stable (i.e. the mercury vapor is controlled by the cold chamber). Before this test can be performed, the lamp has to burn in a stable manner for at least 15 minutes before starting the actual measurement.

2.3 Socket and lamp base

T5 and T5HO Linear lamps are fitted with a miniature bi-pin base. G5 sockets for T5 Linear lamps should be rated for 600 volts. The original sockets for T5 miniature bi-pin lamps (i.e. F13T5) are suited for up to 250 volts, which means the applied voltage must be less than or equal to 250 volts to ground. As T5 Linear standard and high output lamps are designed for high frequency operation with electronic programmed start ballasts, the voltage will exceed 250 volts in certain situations. Requirements relating to G5 sockets are standardized in ANSI C81.62 Sheet 2-310, ANSI C81.64 and UL 542.

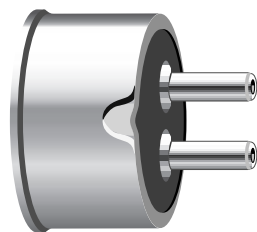


figure 2.1: Lamp end



T5 Circular lamps are fitted with a 2GX13 4 pin base. 2GX13 sockets for T5 Circular lamps should be rated for 600 volts. Requirements relating to 2GX13 sockets will be standardized in ANSI publication C81.62. (Dimensions in mm [Standards pending])

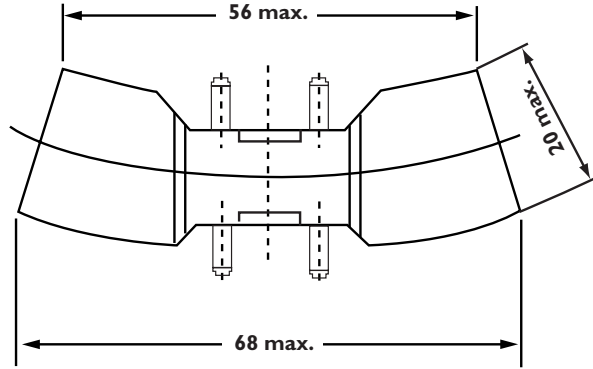


figure 2.1: Detail of lamp base 2GX13

2.4 Guidelines to comply with standards

2.4.1 ANSI Standards

Proposals are under review for non-dimming operation of T5 Linear and T5 Circular lamps with electronic programmed start ballasts. Philips T5 Linear and T5 Circular lamps comply with proposed ANSI standards for high frequency lamp operation.

2.4.2 UV Radiation

T5 Linear and Circular lamps radiate a very low amount of UV. The permitted exposure time (PET value) for these lamps complies with the generally accepted value of 24 hours. See the table below for specific UV values.

Color	UV-A μW/lm	UV-B μW/lm	UV-C μW/lm	UV total μW/lm	D/fc	PET klx•h
830	50.7	11.3	0	62.0	.19	39
835	47.8	9.0	0	56.8	.19	39
841	38.1	6.0	0	44.1	.19	72

2.4.3 IR Radiation

Depending upon the frequency of the lamps, it is possible to have interaction between lamps on electronic high frequency ballasts and IR devices. To avoid infrared interference problems, it is recommended not to use remote controls in the 30-40 kHz range or use electronic ballasts which operate outside of this frequency range.

2.4.4 Explosion Risk

Fluorescent lamps are low-pressure gas-discharge lamps which operate at relatively cool temperatures. These lamps are not subject to specific risks of explosion.



2.5 Optical design

T5 lamps can be used in fixtures of a variety of designs. The choice of material, shape and dimensions can help ensure optimum functioning of the lamp (mechanically, thermally and photometrically).

The T5 Linear lamps with diameter of 5/8" (16mm) is 40% smaller than the existing T8 lamp, which has a diameter of 1" (26mm). SILHOUETTE lamps give fixture designers more freedom in the design of their products, making it easier to build lighting systems which meet customers' needs – offering reduced dimensions, weight and height.

T5 Linear lamps are especially suited for applications with size and space constraints, such as coves, soffits and display cases. SILHOUETTE is ideal for decorative, indirect lighting and general lighting applications in offices and commercial establishments where smaller and more appealing fixture designs are required.

Fixtures with T5 Linear lamps can be made almost half as narrow as existing T8 fixtures. The smaller T5 lamps allow designers to develop optics which have efficiencies comparable to or better than existing ranges.

2.5.1 Luminance

The luminance of T5 standard lamps (14W, 21W, 28W and 35W) is approximately 1.7×10^4 cd/m², which is between the luminance of a T8 and a PL-L lamp.

The luminance of T5 High Output lamps is as follows:

24W	2.5×10^4 cd/m ²
39W	2.8×10^4 cd/m ²
54W	2.9×10^4 cd/m ²
80W	3.3×10^4 cd/m ²

The luminance of T5 Circular lamps is as follows:

22W	2.0×10^4 cd/m ²
40W	2.6×10^4 cd/m ²
55W	3.3×10^4 cd/m ²

Depending on the ambient brightness and the desired degree of comfort, the effect of this luminance has to be reduced to an acceptable level by:

- Selecting a sufficiently large shielding angle. For open ceiling luminaires a shielding angle of at least 30° is recommended.
- Reducing the luminance by means of diffuser material. Since an evenly distributed luminance is often desired, the distance between the lamp and the diffuser must not be too small. With strong diffusers such as opal sheet, a distance of at least 20mm is recommended; with screenings which have less scattering effect the distance should be increased proportionally.



Examples of possible reflector types and the resulting luminous intensity distributions follow.

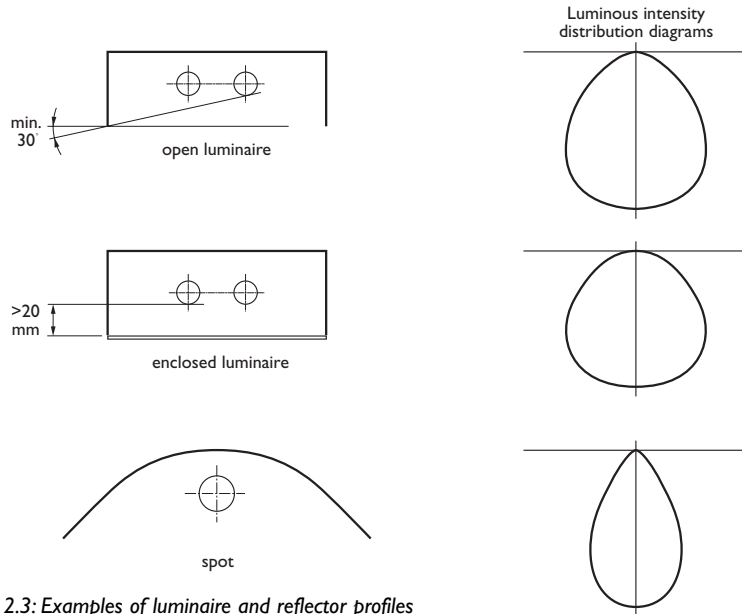


figure 2.3: Examples of luminaire and reflector profiles

3: SILHOUETTE T5 family Specifications

3.1 Range

The SILHOUETTE T5 range consists of Linear (standard output and high output types) and Circular lamps.

Standard	High Output	Circular
14W (22in.)	24W (22in.)	22W (9in. OD)
21W (34in.)	39W (34in.)	40W (12in. OD)
28W (46in.)	54W (46in.)	55W (12in. OD) – HO
35W (58in.)	80W (58in.)	

3.2 Mechanical characteristics

3.2.1 Dimensions T5 Linear

For maximum lamp dimensions see table below. Lamp base: G5 (See ANSI C81.61 Sheet I-310)

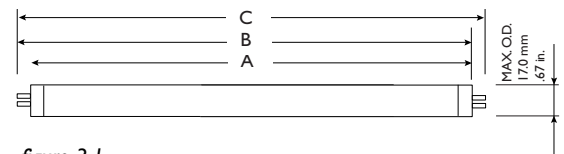


figure 3.1

Lamp Type	A MAX. in/mm	B MIN. in/mm	B MAX. in/mm	C MAX. in/mm
14W, 24W	21.61/549.0	21.80/553.7	21.89/556.1	22.17/563.2
21W, 39W	33.42/849.0	33.61/853.7	33.70/856.1	33.98/863.2
28W, 54W	45.24/1149.0	45.42/1153.7	45.52/1156.1	45.80/1163.2
35W, 80W	57.05/1449.0	57.23/1453.7	57.33/1456.1	57.61/1463.2



**3.2.2 Dimensions
T5 Circular**

For maximum lamp dimensions see table below.
Lamp base: 2GX13 (Standards pending).

Lamp Type	X max. in/mm	X min. in/mm	D in/mm
FC9T5	9.0/231.0	8.6/220.0	0.63/16.0
FC12T5 (40W, 55W)	12.0/306.0	11.4/293.0	0.63/16.0

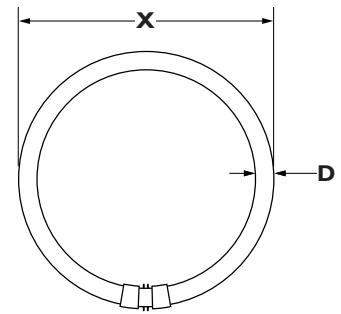


figure 3.2

3.3 Electrical Characteristics

3.3.1 Electrical and lighting characteristics of T5 Linear lamps:

In the following tables, the electrical and photometrical data are given:

Lamp Type	Reference Ballast			Nominal conditions at T _{amb.} = 77° F		
	Rated Voltage V	Calibration Current mA	Resistance Ω	Initial Discharge Luminous Current mA	Lamp Voltage V	Flux lm
T5 14W	167	170	500	165	86 ± 10	1200
T5 21W	246	170	725	165	129 ± 10	1900
T5 28W	329	170	950	165	170 ± 10	2600
T5 35W	413	170	1200	165	215 ± 10	3300

Lamp Type	Nominal conditions at T _{amb.} = 95° F			
	Discharge Current VmA	Luminous Efficacy lm/W	Lamp Voltage V	Initial Luminous Flux lm
T5 14W	170	82 ± 10	1350	96
T5 21W	170	123 ± 10	2100	100
T5 28W	170	167 ± 10	2900	104
T5 35W	170	209 ± 10	3650	104

Note: Data after 100 operating hours.

Measuring conditions:

- Position: free burning, horizontal position
- Operating frequency = 25 kHz
- In a reference circuit, according to IEC standardization

**3.3.2 T5 Linear lamps nominal operation**

Lamp Type T5	Discharge Current mA	Lamp Voltage V	Lamp Power W	Initial Luminous Flux lm	Luminous Efficacy lm/W
14W	130	89	11	1140	104
	170	82	14	1350	96
	220	78	17	1590	94
21W	130	132	17	1770	104
	170	123	21	2100	100
	220	116	25	2470	99
28W	130	178	23	2440	106
	170	167	28	2900	104
	220	156	34	3410	100
35W	130	220	28	3070	110
	170	209	35	3650	104
	220	192	42	4290	102

Measuring conditions for T5 linear lamps:

- Ambient temperature: 35°C (95°F)
- Position: free burning, horizontal position
- Operating frequency: 20–26kHz

3.3.3 Electrical and lighting characteristics of T5 Linear HO lamps:

In the following tables, the electrical and photometrical data are given:

Lamp Type	Reference Ballast			Nominal conditions at $T_{amb.} = 77^{\circ}F$		
	Rated Voltage V	Calibration Current mA	Resistance Ω	Initial Discharge Luminous Current mA	Lamp Voltage V	Flux lm
T5 HO 24W	150	300	250	295	77 ± 8	1750
T5 HO 39W	224	340	330	325	117 ± 10	3100
T5 HO 54W	235	460	255	450	121 ± 10	4450
T5 HO 80W	290	552	260	540	151 ± 15	6150

Lamp Type	Discharge Luminous Current Efficacy VmA		Lamp Voltage V	Initial Luminous Flux lm	
					lm/W
T5 HO 24W	300		75 ± 8	2000	89
T5 HO 39W	340		112 ± 10	3500	92
T5 HO 54W	460		118 ± 10	5000	93
T5 HO 80W	555		145 ± 15	7000	88

Note: Data after 100 operating hours

Measuring conditions:

- Position: free burning, horizontal position
- Operating frequency = 25 kHz
- In a reference circuit, according to IEC standardization



Lamp Type T5HO	Discharge Current mA	Lamp Voltage V	Lamp Power W	Initial Luminous Flux lm	Luminous Efficacy lm/W
24W	260	78	20.0	1800	90
	300	75	22.5	2000	88
	425	79	29.1	2380	81
39W	260	122	31.8	3000	94
	340	115	39.0	3500	90
	425	109	45.8	3960	86
54W	370	139	50.9	4790	93
	460	135	54.0	5000	91
	650	121	77.9	6510	82
80W	295	188	55	5370	98
	555	145	80	7000	88
	600	142	85	7330	86

3.3.4 T5 Circular lamps nominal operation

Measuring conditions for T5 Circular lamps:

- Ambient temperature: 25°C (77°F)
- Position: free burning, base up position
- Operating frequency: 20-26kHz

Lamp Type T5 Circular	Discharge Current mA	Lamp Voltage V	Lamp Power W	Initial Luminous Flux lm	Luminous Efficacy lm/W
22W	300	75	22	1800	82
40W	320	126	40	3300	83
55W	550	101	55	4400	80

Notes:

1. Data after 100 operating hours.
2. A discharge current less than the lowest value given for each lamp type will have a negative effect on lamp life unless extra electrode heating is used to keep the electrode at a sufficiently high temperature.
3. A discharge current of more than the highest value given for each lamp type will have a negative effect on lamp life (even without any electrode heating current).
4. The bold printed values correspond with the nominal lighting characteristics.



3.4 Lighting characteristics 3.4.1 T5 Linear lamps

The normalized polar luminous intensity distribution of T5 Linear lamps is given in the following diagrams. The intensity distribution is not valid for circular lamps.

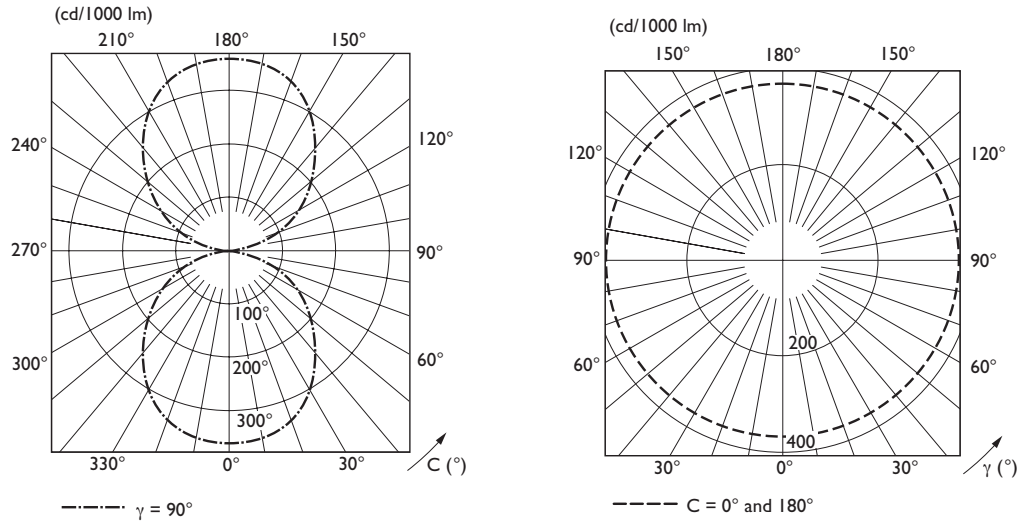


figure 3.3: Luminous intensity distribution of T5 Linear lamps

3.4.2 Spectral power distribution

The normalized spectral power distribution of T5 Linear and Circular lamps is given in the following diagrams.

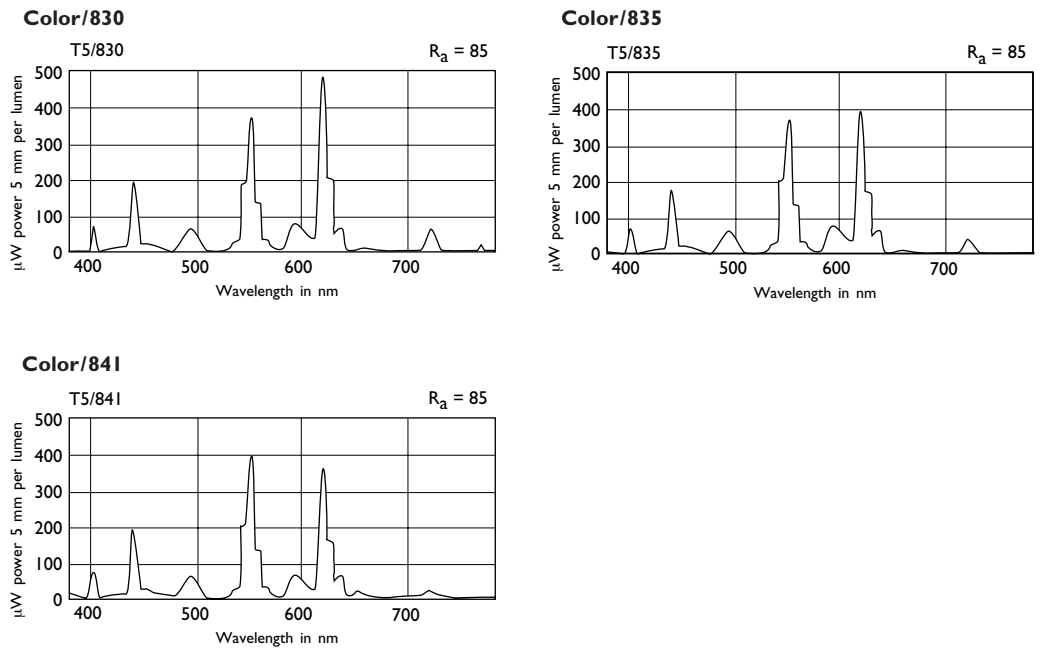


figure 3.4: spectral power distribution of T5 Linear and Circular lamps



3.4.3 Color characteristics

Color rendering index (Ra): 85

Correlated color temperatures:

- 3000K (830, warm)
- 3500K (835, neutral)
- 4100K (841, cool)

Chromaticity coordinates:

	830	835	841
x	0.438	0.409	0.381
y	0.403	0.397	0.379

4: Lamp Operation

4.1 Lifetime performance and lumen maintenance

4.1.1 Lifetime—T5 Linear lamps

If T5 Linear lamps are operated on electronic programmed start ballasts designed according to the correct specifications, at a three hour switching cycle (165 minutes on, 15 minutes off), the lamps will have a rated average lifetime of 20,000 hours. Use of other ballasts that do not meet the provided starting and lamp requirements (i.e. HF/IS), will result in reduced lamp life.

4.1.2 Lumen Maintenance—T5 Linear lamps

Lumen maintenance of T5 Linear lamps is 95% at 8,000 burning hours (40% of rated average life).

4.1.3 Lifetime—T5 Circular lamps

If T5 Circular lamps are operated on electronic programmed start ballasts designed according to the correct specifications, at a 3 hour switching cycle (165 minutes on, 15 minutes off), the lamps will have a rated average lifetime of 16,000 hours.

4.1.4 Lumen Maintenance—T5 Circular lamps

Lumen maintenance of the 22W and 40W T5 Circular lamps is 85% at 6,400 burning hours (40% of rated average life). The lumen maintenance of the 55W is 76% at 6,400 burning hours.

4.2 End-of-life behavior and associated risks

The following possible situations can be identified:

1. The lamp does not start but both cathodes are intact. If, for whatever reason, the lamp does not start, the ballast may continue to supply the preheating current to the cathodes. This may cause overheating of the lamp base. Ballast and fixtures should take care of maximum preheating currents and maximum lamp base temperature (see section 2.1.1) to avoid this overheating.
2. The lamp operates, but one of the cathodes is deactivated (emitter depleted) or broken. The normal end-of-life situation for fluorescent lamps is emitter depletion of one of the cathodes. In most cases the discharge will extinguish and the lamp will not start again, i.e. situation one. However, if the ballast is capable of sustaining the discharge, a new condition arises. The absence of emitter material causes the cathode fall to rise sharply, resulting in extra power dissipation. It is concentrated in a very



small region in front of the cathode and is highly asymmetric. It only occurs in the half cycle when the depleted electrode has to act as cathode and emits electrons. The same applies when the cathode breaks and a lead wire acts as cathode.

This situation of a sustained discharge is more likely to occur with lamps operated on a high frequency instant start electronic ballast. (However, it can occur with other ballast types as well.) The extra power in the cathode fall region may lead again to strong overheating of the base and its surroundings, i.e. the glass and the socket. So the ballast should limit the sum of the power in the cathode fall to a safe level, or switch off.

3. The lamp operates, but with both cathodes deactivated (emitter depleted) or broken. In situation two, the ballast does not have to switch off but might limit the power in the cathode region, for instance by sensing asymmetry in the voltage. The lamp then continues to operate. After some time the emitter of the other cathode will become depleted. Now on both sides an increased cathode fall is present. The situation is symmetric again, with a higher lamp voltage. If the ballast senses asymmetry only and does not switch off, it may return to 'normal' operation, with extra local power dissipation in both cathode falls. Again this will lead to overheating of the cathode regions. So the ballast should switch off at too high values of the lamp voltage.
4. The lamp operates, but with a strongly increased lamp voltage. The lamp voltage may also increase by slow leak-in of impurities. If the ballast is capable of sustaining the discharge, with for instance a constant current, the lamp wattage will increase symmetrically together with the voltage. This higher lamp power is not localized as above, but may still lead to overheating of the lamp and parts of the system. So the ballast should switch off at too high values of the lamp voltage, or limit the power it can deliver to the lamp.

4.3 Relationship of luminous flux to ambient temperature

4.3.1 Temperature Dependency—T5 Linear Lamps

Relative values of luminous flux (Φ), lamp voltage (U), lamp current (I), and lamp power (P) as a function of ambient temperature, measured at constant current.

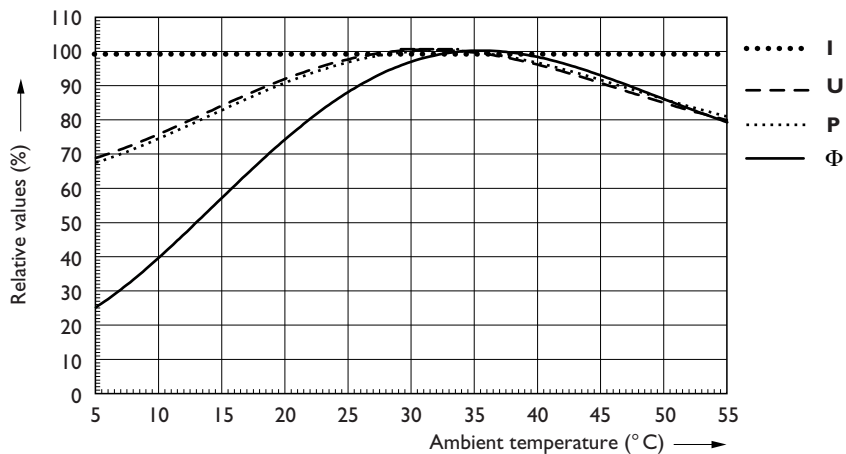


figure 4.3: Temperature dependency, T5 linear lamps

Relative values of luminous flux (Φ) as a function of the ambient temperature. T5 Linear lamps are designed for 95°F (35°C) ambient temperature by means of a cold chamber at nominal settings without heating.



Lamp position: free burning (measured with constant current)

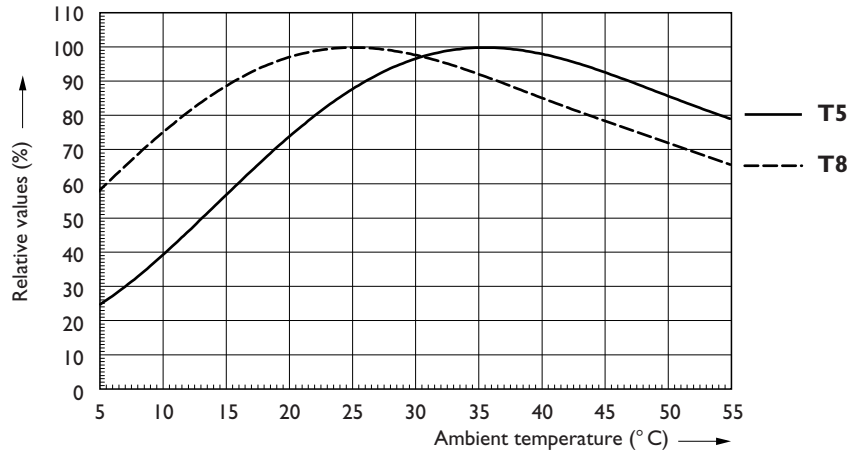
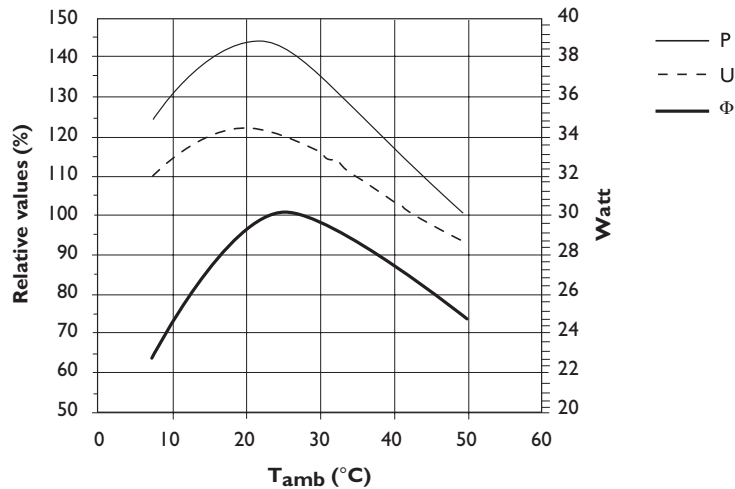


figure 4.3: Ambient temperature, T5 linear lamps

4.3.2 Temperature dependency—T5 Circular lamps

Relative values of luminous flux (Φ), lamp voltage (U), and lamp power (P) at constant current as a function of ambient temperature.



40W lamp, 320mA constant current

4.4 Radio Interference—Electronic Operation

The T5 family of lamps, like all high frequency operated gas discharge lamp systems, generate spurious radio frequency energy in the radio spectrum. For trouble free operation of other electrical/electronic equipment, the following instructions should be followed.

- The operating frequency of a fluorescent lamp is determined by the ballast driving the lamp. The electronic programmed start ballasts do operate the lamps within the lower end of the radio frequency, however, proper grounding and positioning of lamps and fixtures should prevent any serious interference issues.



–If lamps are used in plastic fixtures, a metal reflector connected to the grounded case of the ballast is advised for EMI shielding and a starting aid.

–If the lamps are used in metal fixtures, the ‘hot’ lamp wires should be as short as possible. All metal parts of the fixture should be well connected to the grounded case of the ballast. Always keep the mains wires away from the lamp wires.

Note: Some ballast cases are plastic. The metal reflectors or fixtures should not rely on the ballast case for grounding but directly to the grounded (green) conductor.

Emission limits: Ballasts shall comply with the Federal Communications Commission (FCC) Title 47, Part 18 Subpart C Non-Consumer Equipment, for conducted and radiated EMI.

5: Ballast design for SILHOUETTE T5 lamp family

5.1 Introduction

The optimum performance of fluorescent lamps largely depends on the properties of the ballast used. Like all gas discharge light sources, fluorescent lamps cannot function when they are operated directly on the mains supply voltage. Certain electrical and/or electronic devices have to be built into the lamp circuit, either in the lamp itself or externally in the form of a ballast.

The ballast performs a number of functions:

- it limits and stabilizes the lamp current, a necessary measure in view of the negative resistance characteristic of gas discharge lamps (i.e. when the lamps current increases, the lamp voltage will decrease),
- it provides the ignition voltage (higher than the normal operation voltage) for the initial lamp starting,
- it supplies controlled energy to heat the lamp electrodes during ignition as well as normal operation.

In addition to these basic functions, the ballast must fulfill a number of other equally important requirements:

- it must ensure a sufficiently high power factor,
- it must limit the harmonic distortion of the mains current,
- it must offer adequate suppression of any electromagnetic interference (EMI) that might be produced by the lamp/ballast system and that could otherwise interfere with other electronic equipment,
- it must limit the short-circuit current and/or the current during running-up of the lamp, to protect the lamp electrodes from overloading,
- it must prevent over heating of the lamp bases or tubes if the lamps fail to ignite or are operated abnormally (as outlined in section 4.2),
- it must limit the lamp voltage, lamp current and the lamp power within the specifications during mains voltage variations.

5.2 Electronic ballasts

5.2.1 Starting conditions

Like all fluorescent lamps, T5 Linear and Circular lamps have electrodes coated with emissive material which facilitates lamp ignition (and operation) by providing a continuous flow of electrons. This can only occur efficiently if the electrodes are heated to a temperature commonly referred to as the emission temperature by the proper auxiliary electrode heating supplied by the ballast (rapid start or programmed start ballasts) or by preheat current provided during the ignition phase (preheat system).



The programmed start ballast is recommended for the T5 lamps. With programmed start operation, once the preheating time has passed and the electrodes are at or above their emission temperature (te), the OCV is raised from a low voltage level (Vmax during preheating, when t < or = te) to a high voltage (Vmin when t > te for the desired ambient temperature) for ignition. When the electrode and ballast combination are designed properly, this system provides far superior normal cycle and switching life versus the other systems identified.

The following information is intended to help electronic ballast manufacturers in designing ballasts for maximum system performance.

5.2.2 Electrode preheating

The following tables include minimum and maximum preheating data for T5 Linear and Circular lamp electrodes at five different preheating times: 0.5s, 1.0s, 1.5s, 2.0s, and 3.0s.

Some preceding remarks:

1. Preheating times <0.4s are discouraged
2. Preheating currents at intermediate times can be found by interpolation
3. The values given are presumed to be constant during the preheating time
4. Varying currents or voltages give an integrated preheating effect and the rms of the preheating applied must satisfy the requirements given in the Tables.
5. Frequent use of heating currents or voltages outside the mentioned limits will cause accelerated end-blackening and will have a negative effect on lamp life.

T5 standard linear lamps—Current controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating current within the following limits:

For 14W, 21W, 28W and 35W standard lamps:

Lamp Type	Preheating Current mA	Preheating time					Rsub
		0.5s	1.0s	1.5s	2.0s	3.0s	
14, 21, 28, 35W	min. mA (r.m.s.)	290	235	210	200	185	30.0 Ω
	max. mA (r.m.s.)	385	310	280	265	245	30.0 Ω

T5 standard linear lamps—Voltage controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating voltage within the following limits:

For 14W, 21W, 28W and 35W standard lamps:

Lamp Type	Preheating Voltage V	Preheating time					Rsub
		0.5s	1.0s	1.5s	2.0s	3.0s	
14, 21, 28, 35W	min. V	8.8	7.0	6.4	6.0	5.6	30.0 Ω
	max. V	11.6	9.3	8.4	7.9	7.4	30.0 Ω

**T5 standard linear lamps—Energy controlled preheating**

Depending on the available time for preheating, the ballast should provide a preheating energy within the following limits:

For 14W, 21W, 28W and 35W standard lamps:

Lamp Type	Preheating Energy J	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
14, 21, 28, 35W	min. J	1.30	1.65	2.05	2.40	3.15	30.0 Ω
	max. J	2.25	2.90	3.55	4.20	5.50	30.0 Ω

T5HO linear lamps—Current controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating current within the following limits:

Lamp Type	Preheating Current mA	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
24W	min. mA (r.m.s)	700	550	485	450	420	8 Ω
	max. mA (r.m.s)	925	725	645	600	555	8 Ω
39W	min. mA (r.m.s)	700	550	485	450	420	8 Ω
	max. mA (r.m.s)	925	725	645	600	555	8 Ω
54W	min. mA (r.m.s)	1060	815	715	660	600	4.8 Ω
	max. mA (r.m.s)	1405	1080	950	875	795	4.8 Ω
80W	min. mA (r.m.s)	1095	845	740	685	620	4.5 Ω
	max. mA (r.m.s)	1450	1115	980	905	820	4.5 Ω

T5HO linear lamps—Voltage controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating voltage within the following limits:

Lamp Type	Preheating Voltage V	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
24W	min. V (r.m.s)	5.6	4.4	3.9	3.6	3.4	8.0 Ω
	max. V (r.m.s)	7.4	5.8	5.2	4.8	4.4	8.0 Ω
39W	min. V (r.m.s)	5.6	4.4	3.9	3.6	3.4	8.0 Ω
	max. V (r.m.s)	7.4	5.8	5.2	4.8	4.4	8.0 Ω
54W	min. V (r.m.s)	5.1	3.9	3.4	3.2	2.9	4.8 Ω
	max. V (r.m.s)	6.7	5.2	4.6	4.2	3.8	4.8 Ω
80W	min. V (r.m.s)	4.9	3.8	3.3	3.1	2.8	4.5 Ω
	max. V (r.m.s)	6.5	5.0	4.4	4.1	3.7	4.5 Ω

**T5HO linear lamps—Energy controlled preheating**

Depending on the available time for preheating, the ballast should provide a preheating energy within the following limits:

Lamp Type	Preheating Energy J	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
24W	min. J	1.95	2.40	2.85	3.30	4.40	8.0 Ω
	max. J	3.40	4.20	5.00	5.75	7.35	8.0 Ω
39W	min. J	1.95	2.40	2.85	3.30	4.40	8.0 Ω
	max. J	3.40	4.20	5.00	5.75	7.35	8.0 Ω
54W	min. J	2.70	3.20	3.70	4.20	5.20	4.8 Ω
	max. J	4.70	5.60	6.45	7.35	9.10	4.8 Ω
80W	min. J	2.70	3.20	3.70	4.20	5.20	4.5 Ω
	max. J	4.70	5.60	6.45	7.35	9.10	4.5 Ω

T5 Circular lamps—Current controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating current within the following limits:

Lamp Type	Preheating Current mA	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
22, 40W	min. mA (r.m.s)	700	550	490	455	420	8.0 Ω
	max. mA (r.m.s)	925	725	645	600	555	8.0 Ω
55W	min. mA (r.m.s)	1095	845	740	685	620	8.0 Ω
	max. mA (r.m.s)	1450	1115	980	905	820	8.0 Ω

T5 Circular lamps—Voltage controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating voltage within the following limits:

Lamp Type	Preheating Voltage V	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
22, 40W	min. V (r.m.s)	5.6	4.4	3.9	3.6	3.3	8.0 Ω
	max. V (r.m.s)	7.4	5.8	5.2	4.8	4.4	8.0 Ω
55W	min. V (r.m.s)	4.9	3.8	3.3	3.1	2.8	4.5 Ω
	max. V (r.m.s)	6.5	5.0	4.4	4.1	3.7	4.5 Ω



T5 Circular lamps—Energy controlled preheating

Depending on the available time for preheating, the ballast should provide a preheating energy within the following limits:

Lamp Type	Preheating Energy J	Preheating time					
		0.5s	1.0s	1.5s	2.0s	3.0s	R _{sub}
22, 40W	min. J	1.95	2.4	2.85	3.3	4.2	8.0 Ω
	max. J	3.4	4.2	5.0	5.8	7.35	8.0 Ω
55W	min. J	2.7	3.2	3.7	4.2	5.2	4.5 Ω
	max. J	4.7	5.6	6.5	7.4	9.1	4.5 Ω

5.2.3 Lamp ignition

Depending on the preferred ambient temperature range, the electronic ballast should generate the following open circuit voltages.

T5 standard linear lamps:

Lamp Type, Ambient Temp. Range		50° F to 140° F 10° C to 60° C	-4° F to 140° F -15° C to 60° C
14W			
max. during preheat period	V (r.m.s)	130	130
min. for ignition	V (r.m.s)	230	275
21W			
max. during preheat period	V (r.m.s)	200	200
min. for ignition	V (r.m.s)	340	390
28W			
max. during preheat period	V (r.m.s)	240	240
min. for ignition	V (r.m.s)	425	530
35W			
max. during preheat period	V (r.m.s)	275	275
min. for ignition	V (r.m.s)	530	700

T5HO linear lamps

Lamp Type, Ambient Temp. Range		50° F to 140° F 10° C to 60° C	-4° F to 140° F -15° C to 60° C
24W T5HO			
max. during preheat period	V (r.m.s)	130	130
min. for ignition	V (r.m.s)	280	350
39W T5HO			
max. during preheat period	V (r.m.s)	175	175
min. for ignition	V (r.m.s)	350	390
54W T5HO			
max. during preheat period	V (r.m.s)	240	240
min. for ignition	V (r.m.s)	520	620
80W T5HO			
max. during preheat period	V (r.m.s)	250	250
min. for ignition	V (r.m.s)	580	750



T5 Circular lamps

Lamp Type, Ambient Temp. Range		50° F to 140° F 10° C to 60° C	-4° F to 140° F -15° C to 60° C
22W T5C			
max. during preheat period	V (r.m.s)	170	170
min. for ignition	V (r.m.s)	350	400
40W T5C			
max. during preheat period	V (r.m.s)	150	150
min. for ignition	V (r.m.s)	280	430
55W T5C			
max. during preheat period	V (r.m.s)	150	150
min. for ignition	V (r.m.s)	280	430

Note: The open-circuit voltages are valid for:

- sinusoidal voltages (crest factor 1.4), frequency 20-26 kHz,
- applications with a grounded starting aid plane at a distance of 6mm (.24 in.)
- properly preheated coils.

5.3 Dimming

In a burning lamp at least part of the emissive material has to be kept at a sufficiently high temperature for good lamp performance. Above a certain limit value, the discharge current itself can take care of this. Below this limit, an additional electrode current has to be applied.

For good lamp performance, $I_{discharge}$, I_{heat} , and I_{total} have to be kept between limits. For T5 Linear and Circular lamps the following tables describe these limits and their mutual relationships.

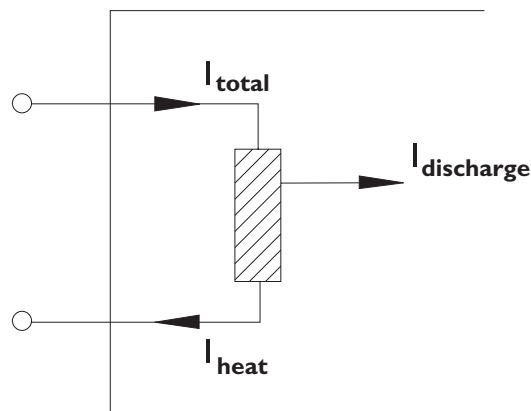


figure 5.1 Lamp electrode

5.3.1 Running and dimming conditions

T5 standard linear lamps

14, 21, 28, 35W	$I_{discharge}$ 1)	I_{heat} 2)	I_{total} 3)
nominal operation (r.m.s)	130-205 mA	< 165mA	130-240 mA
dimming operation (r.m.s)	15-130 mA	< 165mA	140-240 mA



T5HO linear lamps

24WT5HO	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	270-435 mA	< 365mA	270-450 mA
dimming operation (r.m.s)	30-270 mA	< 365mA	310-450 mA
39WT5HO	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	270-435 mA	< 365mA	270-450 mA
dimming operation (r.m.s)	30-270 mA	< 365mA	310-450 mA
54WT5HO	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	370-625 mA	< 525mA	370-650 mA
dimming operation (r.m.s)	50-370 mA	< 525mA	370-650 mA
80WT5HO	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	440-715 mA	< 575mA	440-770 mA
dimming operation (r.m.s)	55-440 mA	< 575mA	480-770 mA

T5 Circular lamps (values under consideration)

22WT5C	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	260-425 mA	< 355mA	260-480 mA
dimming operation (r.m.s)	30-260 mA	< 357mA	305-480 mA
40WT5C	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	260-425 mA	< 365mA	260-480 mA
dimming operation (r.m.s)	35-260 mA	< 370mA	315-480 mA
55WT5C	I_{discharge 1)}	I_{heat 2)}	I_{total 3)}
nominal operation (r.m.s)	440-610 mA	< 575mA	440-610 mA
dimming operation (r.m.s)	50-440 mA	< 575mA	485-610 mA

Notes:

1. Discharge currents during dimming operation require additional electrode heating (I_{heat}). Discharge currents > I_{discharge max} will have a negative effect on lamp life.
2. Heating currents > I_{heat} will cause accelerated end-blackening.
3. I_{total} has a maximum value to avoid local overheating of the electrodes.
For I_{discharge} < I_{discharge min}, when extra electrode heating is applied, the minimum electrode heating is covered by the lower limit set to I_{total}.

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