Fluorescent Lamps

Technical Manual

SYLVANIA

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HEADLINES

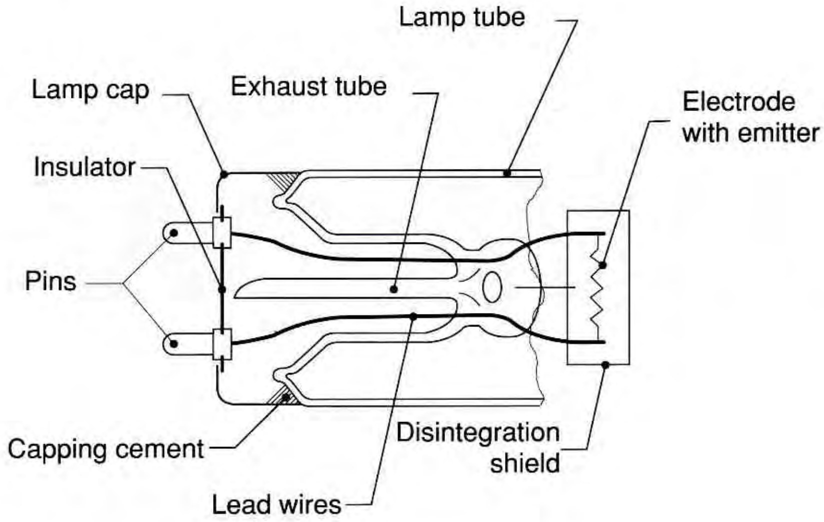
Introduction

Fluorescent lamps are low pressure mercury vapour discharge lamps. The discharge primarily produces ultraviolet radiation of 253.7 nm wavelength which is absorbed by a fluorescent powder coating and converted into longer wavelengths radiations in the visible spectrum. Depending on the choice and mixture of the fluorescent powders, a variety of light colours for general lighting purposes can be obtained, as well as special light sources or radiators with a spectral power distribution for special applications.

Fluorescent lamps are most versatile light sources by the available sizes, power ratings, light colours and luminous performance. More so, they are very efficient in converting electrical energy into light, providing luminous efficacies of up to 100 lumen/Watt. - This, and their long life makes fluorescent lamps very economical lighting solutions.

A variety of external conditions can influence the performance of fluorescent lamps with respect to their light output, life and starting. The recommendations in this technical manual should be followed to obtain optimum performance.

Lamp Construction and Materials



LAMP CONSTRUCTION

Lamp Glass

Standard fluorescent lamps are usually made of lime-soda (soft) glass. This glass quality permits high transmission of radiation in the visible and UV-A spectrum. The transmission declines strongly towards 300 nm, cuts out the major part of UV-B radiation (280-315 nm) and does not transmit UV-C radiation. Infrared is also freely transmitted.

The exceptions are (BLB) Blacklight-Blue lamps which are made with WOOD's filter glass which cuts out any visible radiation above 400 nm.

Germicidal radiators are made with a selected quartz glass which transmits the 253.7 nm UV-C radiation which is produced in the lamp discharge. This glass quality is carefully controlled to cut out any radiation below 200 nm which may cause the formation of ozone (O_3).

Lamp Electrodes

Standard fluorescent lamp types are made with the efficient "stick" coils, which permit to hold the necessary amount of emitter material, important for long lamp life. The coil is made of a tungsten wire surrounded by a fine additional tungsten wire, forming a closely wound tube-shaped electrode, similar to a stick shape which gives it the name.

Construction of STICK COIL

Construction of TRIPLE COIL

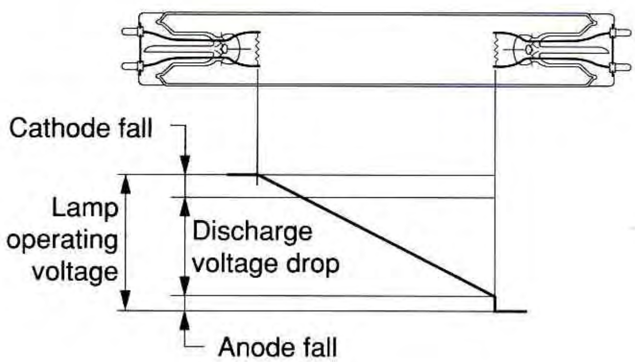
Triple coils are used in some special lamps, particularly for high current types or lamps which are designed for frequent switching as in photocopying machines.

The Emitter Material

It is firmly baked onto the electrode and consists of a mixture of oxides of barium, calcium and other alkaline elements.

Heated to about 800°C these substances have a lower electron affinity and emit freely electrons and help to reduce the electrode losses (also called cathode fall).

This temperature is created on the electrode with the preheating current during lamp starting, and is maintained during lamp operation, partly by the electrode loss and also by the energy of ions returning to the electrode from the discharge.



CATHODE FALL / LAMP VOLTAGE

Electrode Resistance

The electrical resistance and electrode mass is adapted to the preheating conditions which are determined by the control gear.

On starter circuits the preheating current is about 1.5 times higher than the lamp operating current (inductive circuits) or about equal to lamp operating current (overcompensated capacitive circuits). - Minimum or maximum values are to be considered based on choke tolerances and ± 10% line voltage variation. These values are specified in data sheets or by IEC standard Nr. 81 (EN 60081).

On semi-resonant circuits the preheating current is about equal to the lamp operating current.

On rapid start circuits with a preheating transformer for the electrodes, a voltage is applied to the electrodes. Lamps are differentiated, equipped with either:

- low resistance electrodes (mainly USA, Canada and Continental Europe) with a minimum preheating voltage of 3.6 V
- high resistance electrodes (mainly Great Britain) with a minimum preheating voltage of 8 V (see Quick Start)

In all cases the objective is to preheat the electrodes to facilitate lamp starting, and to protect the electrodes (emitter material) from excessive wear (lamp life) during the starting phase.

For circuit design it has to be considered that the electrode resistance (tungsten) increases from room temperature to 800°C by a factor of about 2.5.

The Disintegration Shield

This is a cosmetic element, placed around the electrode to reduce blackening of the lamp ends. It is electrically insulated and has no further function. In lamps with ø 26 mm diameter, its shadow is sometimes falsely interpreted as end blackening.

Fluorescent Powder Coatings

A fluorescent powder coating consists of a mineral matrix substance to which a small percentage of another element is added as activator to obtain an efficient conversion of short wave UV radiation into longer wavelengths radiations in the visible spectrum.

Also called phosphor coatings, the element phosphorus is not found anymore in today's efficient fluorescent lamp powders.

Fluorescent Powder Types

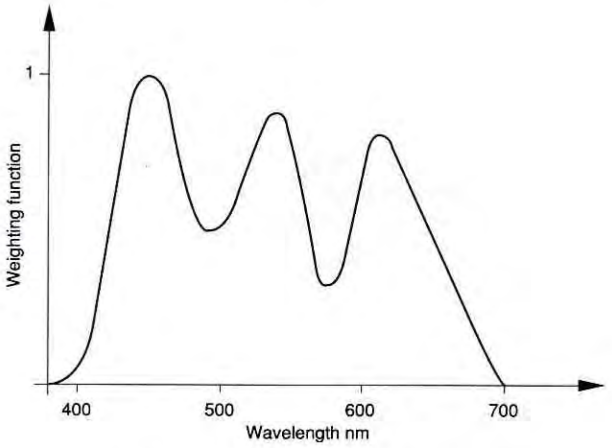
Depending on the chemical composition and the purity, fluorescent powders radiate over a certain band of wavelengths which can be a continuum of several 100 of nanometers, or very narrow emission bands of 10 to 20 nm.

One or several fluorescent powders are mixed to obtain the required total spectral power distribution, the desired luminous flux, correlated colour temperature and colour rendering index.

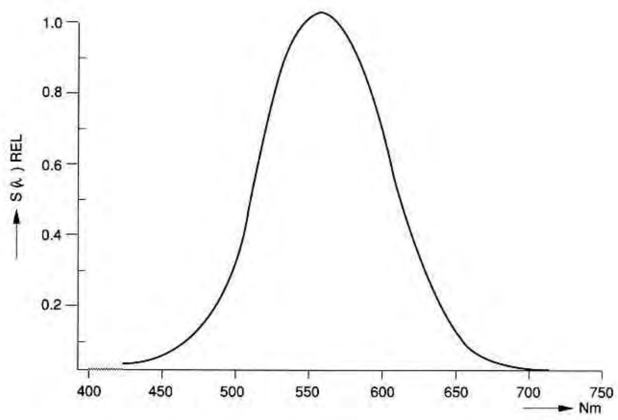
In most cases the spectral lines from the mercury discharge are playing a role in the aspect of the spectral power distribution. These are monochromatic radiations at 404, 435, 546 and 586 nm.

Light and Colour Perception

The choice of fluorescent powders in a mixture depends not only on their efficiency to convert the UV radiation into visible light. Two features of the human eye have to be considered to evaluate the radiation. That is for maximum colour perception, and for brightness perception.



Maximum Colour Perception



Maximum Brightness Perception

- The human eye has maximum colour perceptions at about 450 nm for blue radiations, at 540 nm for green and at 610 nm for red. To obtain a high colour rendering index, the spectral power distribution of the fluorescent powder mix should not deviate at these wavelengths from the spectral line of a black body radiator of the same colour temperature. Narrow band radiating fluorescent powders as used in triphosphor* lamps are particularly adapted to this criterium and efficient to provide both, luminous efficiency and high colour perception / colour rendering index.

* SYLVANIA LUXLINE 180 Series of light colours

- Another advantage of these specific fluorescent powders of the 180 series are their high resistance to the UV-C radiation from the discharge, resulting in high lumen maintenance over lamp life versus the standard (so called) halophosphors.

Yet, halophosphors are still used to produce fluorescent lamps with standard colours like Warmwhite, Coolwhite and Daylight. The reason is mainly the cost of fluorescent powders, and halophosphors are considerably cheaper. More so triphosphor lamps are made with a double coating technique which adds to the cost.

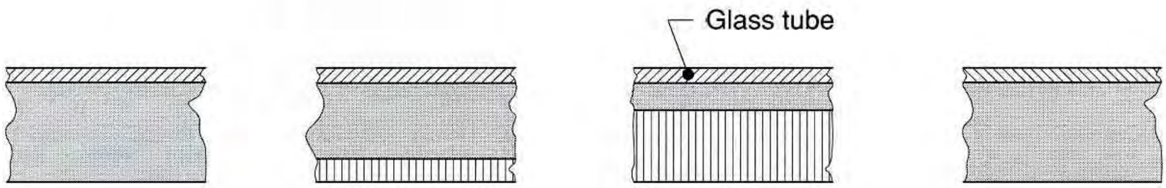
Fluorescent Powder Coating

The tubes are preconditioned by a washing and drying process. - The fluorescent powder is prepared in a water or solvent suspension and applied to the inside of the tube. The tube passes then a baking oven at several hundred degrees to stabilise the coating.

ELITE and LUXLINE Professional Lamps are made with a double coating, first a layer of halophosphor is applied and stabilised, then the triphosphor layer is applied and the lamp tube passes the baking oven.

Families of Fluorescent Lamp Colours

The following shows schematically the 4 families of lamp colours which are offered for general lighting purposes.



Series 100 STANDARD	Series 200 ELITE	Series 180 LUXLINE Professional	Series 190 LUXLINE-PLUS
1 halophosphor coating	1 halophosphor coating plus 1 thin triphosphor coating	1 thin coat of halophosphor plus 1 main triphosphor coating	Single coating of 5 components
Standard light colours	Improved CRI, better lumen maintenance	High CRI High light output Excellent lumen maintenance	Very high CRI Good initial light output and maintenance

The Dimensions of Light Colours

Correlated Colour Temperature

Dimensioned in degrees Kelvin (K). Example: 4000K.
Describes the aspect of light (type of white) in comparison to the light as emitted by a black body radiator at a given actual temperature.

By their correlated colour temperature, light colours can be grouped into:

Warmton (Warm White)	Around 3000K	Dominating radiation in the yellow-red
Neutral White	Around 4000K	Balanced
Daylight	Above 5000K	Dominating radiation in the green-blue

In general lighting applications, light colours with a correlated colour temperature between 2700K and 6500K are utilised.

C.I.E. (x,y) Chromaticity Coordinates

With reference to the colour chart of the C.I.E. (Commission Internationale d'Eclairage) these x,y coordinates allow description of a light colour and its nominal colour point in this chart.

In the chart on the back cover, we find the nominal colour points of the most common light colours, in comparison to the trace of black body temperatures. The tungsten filament of an incandescent or halogen lamp behaves like a black body radiator and the colour points can be found on this curve at the various temperatures.

Colour Rendering Index

Indicated in Ra (8) values or a classification value according to the following table.

Colour Rendering Classification	Ra (8) Values
1a	90 - 100
1b	80 - 89
2a	70 - 79
2b	60 - 69
3	40 - 59
4	20 - 39

The colour rendering index is an indication of the quality of light at a given correlated colour temperature. That is an indication of how natural colours can be seen in comparison to a black body, or perfect full spectrum radiator.

Colour rendering values can only be compared for several light sources if these are all of the same correlated colour temperature.

How to Use the Dimensions of Light

For the choice of the right fluorescent lamp colour proceed as follows, but remember to choose a lamp of high light output, and high lumen maintenance.

1. Choose the Correlated Colour Temperature

The considerations are:

• The ambiance which you want to create		• The colours of the environment which you want to emphasize
• Warm	3000K	• Yellow to red
• Fresh, efficient	4000K	• Balanced
• Cool	6000K	• Yellow to blue

- the influence of natural daylight and the need to harmonise
- the subjective preference of people working in the environment
- established standards for colour temperatures in specific applications

2. Choose the Colour Rendering Index

The considerations are:

- the quality of the environment which you want to create by a natural and enhanced perception of colours in the school, office and commercial environment
- established regulations
- the requirement of high or very high colour rendering index in a variety of specific applications. Examples: hair dressers, graphic arts and print shops, car painting shops, colour matching applications, dyeing processes in the textile, paper or plastic industries, medical and analytical centres, etc.

Fluorescent Lamp Colours for General Lighting Purposes

Colour Rendering Index Classification					Colour Temperature (K) / TYPE	2700	3000	3500	3800	4000	4300	5000	6000	6500	LAMP EFFICACY lm/W		
1a	1b	2a	2b	3											HIGH	GOOD	LOW
●					ø 16 ø 26 ø 38 (Argon Lamps)	IF											●
				●			WW									●	
		●					WWX										●
				●				W								●	
	●								CWX								●
		●								UW							●
			●								CW					●	
		●												D			●
				●	ø 26 ES Standard Series 100		129									●	
				●				135								●	
		●							125								●
			●								133					●	
		●												154			●
		●			ø 26 ES ELITE Series 200						233					●	
	●				ø 26 ES LUXLINE Professional Series 180	182									●		
	●						183								●		
	●									184					●		
	●												186		●		
●					ø 26 ES LUXLINE PLUS Series 190	192											●
●							193										●
●									194								●
●												195		172			●

Series 180, LUXLINE Professional Designations

To facilitate the choice of these most efficient light colours, for the various applications, additional designations are indicated

Colour 182	**SATIN**	2700 K, incandescent-like light, for the lighting in home, restaurant and similar applications, to create a warm and welcoming atmosphere.
Colour 183	**DECOR**	3000 K Warm White Deluxe light, for the commercial applications where a warm and efficient light is required to underline the quality of the environment or of exhibited goods. DECOR harmonises perfectly with modern 3000 K tungsten halogen accent lighting.
Colour 184	**BURO**	4000 K Cool White Deluxe light, to create a fresh and modern atmosphere and to stimulate activities. Offices, schools, sport facilities, hardware shops and exhibitions of white ware are typical applications. Also for contrast lighting of dairy products in a general DECOR lighting atmosphere of a supermarket.
Colour 186	**STUDIO**	6000 K Daylight, to extend the natural daylight into the interior. A cool, clean and fresh atmosphere. Ideal for studios, graphic arts and textiles.

Other Colour Designations

WW	.....	Warm White (129)
WWX	.....	Warm White Deluxe
W	.....	White (135)
CWX	.....	Cool White Deluxe
UW	.....	Universal White (125)
CW	.....	Cool White (133)
D	.....	Daylight (154)

Special fluorescent lamps

These light colours are usually not made for general lighting purposes. Their spectral power distribution is designed to obtain specific effects.

Lamp Type	Technical Aspect	Application
Coloured light Blue, Green, Red	Non technical, decorative	Light colour effects, decorative lighting, advertising
GRO Gro-Lux	Blue and red radiation adapted to the plant requirements for photo-and chlorophyll synthesis.	Plant lighting Aquaria
GRO-WS Gro-Lux Wide Spectrum	As above but added far red spectral emissions for outdoor plants used to higher levels of red and infrared	Plant lighting, outdoor species
AQUASTAR Colour 174	Modified GROLUX version for better colour appearance in the yellow-green.	Aquaria
GOURMET Natural-Super Colour 175	A 3800 K neutral white colour with high CRI (88 Ra), for excellent, natural display of meat produce. Low power emission in the critical 500-600 nm spectrum to reduce myoglobin photo-chemistry	Lighting of meat produce
BL 350 Blacklight	Principal emission at 350 nm in the UV-A, some mercury lines in the visible spectrum	Various technical, bug-traps, mineral detection.
BLB Blacklight -Blue	Same fluorescent powder as above. Lamp tube made of WOOD's glass, cutting out all visible radiation	As above discos and theater effects, detection of document and bank note falsification.
ACTIVA Colour 172	Closely controlled 6500 K phosphor mix providing a CRI of 98 Ra. Permits high illuminance in accordance with the Kruithof diagram.	Critical colour work, at daylight correlated colour temperature. Medical, psychological lighting.
G GERMICIDAL	No fluorescent powder is used. The quartz glass lamp tube transmits the 253.7 nm UV-C radiation from the discharge. Any radiation below 200 nm is absorbed by the tube.	Sterilisation of air, gases, liquids and surfaces of solids. Fluorescent effects. Mineral detection. Erasing EPROM memories.

UV Radiators

Definition:

UV-C 100-280 nm
UV-B 280-315 nm
UV-A 315-400 nm

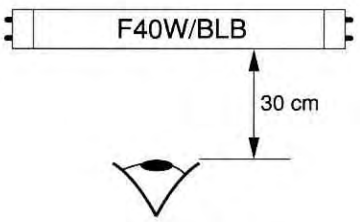
Exposure times

The shorter the wavelength in the UV radiation spectrum, the higher is the energy and the more damaging and harmful (or effective) the radiation can be.

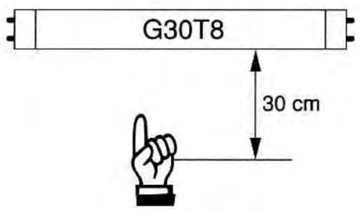
The end result always depends on the intensity of radiations (mW/cm^2) multiplied with the exposure time.

Maximum Permissible Exposure Times (MPET) can be established for the exposure of the skin or eyes for a given range of wavelengths.

Examples



MPET : 1.33 h/day

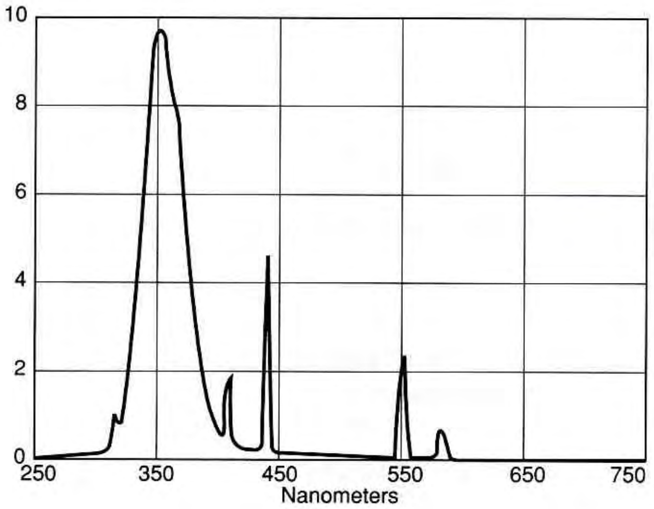


MPET : 1 minute/day

Protection against UV radiation:

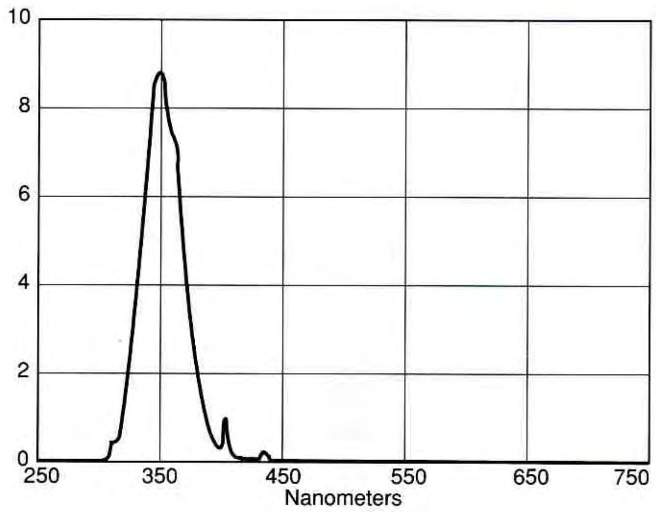
See the diagrams on page 36 for transmission values of various materials for UV radiation. Standard window (soft) glass protects efficiently against UV-C radiation and largely against UV-B. Polycarbonate with a cut-off at about 390 nm protects efficiently against any UV radiation.

UV-A Radiators



BL ... BLACKLIGHT

Lamp: Standard Glass
Max. output: at 350 nm



BLB ... BLACKLIGHT-BLUE

Lamp: Wood's Glass
Max. output: at 350 nm

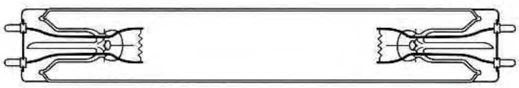
Data	**Ee (250-800 nm)*** µW/cm2	**Flux e (300-500 nm)** W
F15 T8/BL	67.4	2.3
F15 T8/BLB	71.7	2.65
F20 T12/BL	104.5	4.50
F20 T12/BLB	77.6	3.70
F30 T8/BL	123.5	8.40
F30 T8/BLB	98.3	7.00
F40 T12/BL	127.7	12.00
F40 T12/BLB	88.3	10.00

* 25 cm center section

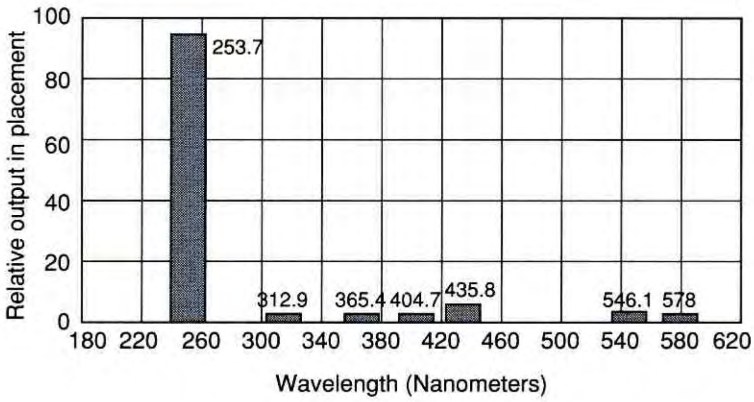
UV-C Radiators

Definition:

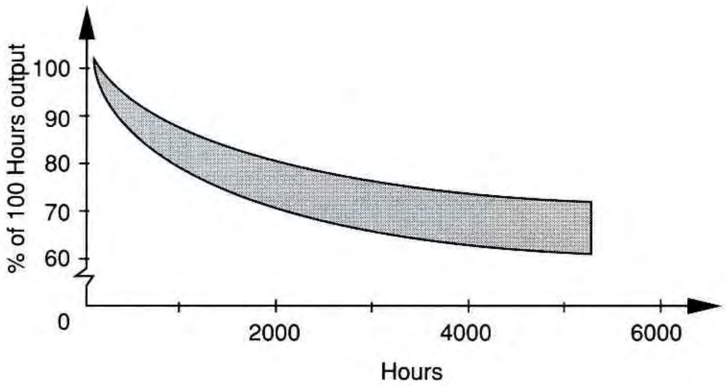
100-280 nm Main output at 253.7 nm.



Germinal Lamps
Quartz glass bulb
200 nm. cut off (no 185 nm. radiation)



Spectral Power Distribution



Output Maintenance

Output Data

	253.7 nm. Radiation in Watt at 100 h	253.7 nm. Radiation Power Density at 1m in micro-Watt/cm^2
G8 T5	1.4	15.0
G15 T8	3.3	35.0
G30 T8	8.4	80.0

UV-C Radiation

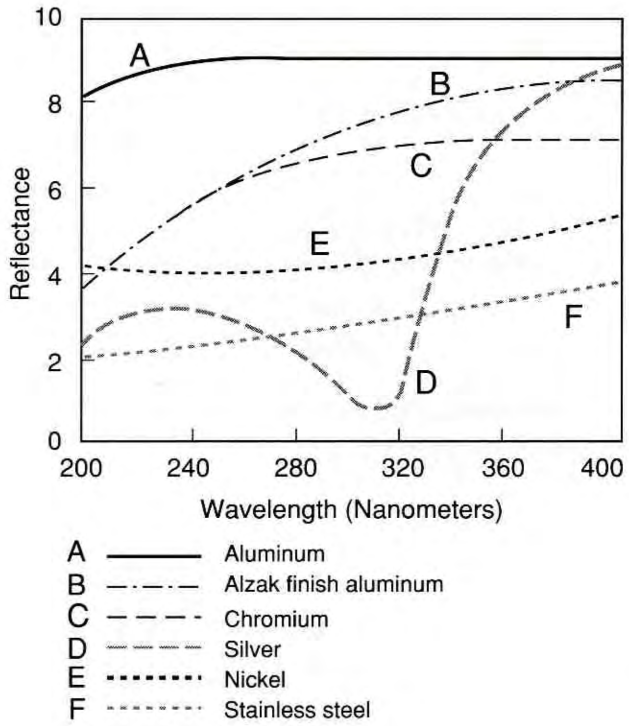
Germicidal Energy (253.7 nm) required to destroy common micro-organisms.

Organisms	Color	Energy (μW sec/cm²)
Bacillus anthracis		4520
S. enteritidis		4000
B. megatherium sp. (veg.)		1300
B. megatherium sp. (spores)		2730
B. paratyphosus		3200
B. subtilis		7100
B. subtilis spores		12000
Corynebacterium diphtheriae		3370
Eberthella typhosa		2140
Escherichia coli		3000
Micrococcus candidus		6050
Micrococcus sphaeroides		10000
Neisseria catarrhalis		4400
Phytomonas tumefaciens		4400
Proteus vulgaris		2640
Pseudomonas aeruginosa		5500
Pseudomonas fluorescens		3500
S. typhimurium		8000
Sarcina lutea		19700
Seratia marcescens		2420
Dysentery bacilli		2200
Shigella paradysenteriae		1680
Spirillum rubrum		4400
Staphylococcus albus		1840
Staphylococcus aureus		2600
Streptococcus hemolyticus		2160
Streptococcus lactis		6150
Streptococcus viridans		2000
Yeast		
Saccharomyces ellipsoideus		6000
Saccharomyces sp.		8000
Saccharomyces cerevisiae		6000
Brewers' yeast		3300
Bakers' yeast		3900
Common yeast cake		6000
Mold Spores	**Color**	
Penicillium roqueforti	Green	13000
Penicillium expansum	Olive	13000
Penicillium digitatum	Olive	44000
Aspergillus glaucus	Bluish green	44000
Aspergillus flavus	Yellowish green	60000
Aspergillus niger	Black	132000
Rhizopus nigricans	Black	111000
Mucor racemosus A	White gray	17000
Mucor racemosus B	White gray	17000
Oospora lactis	White	5000

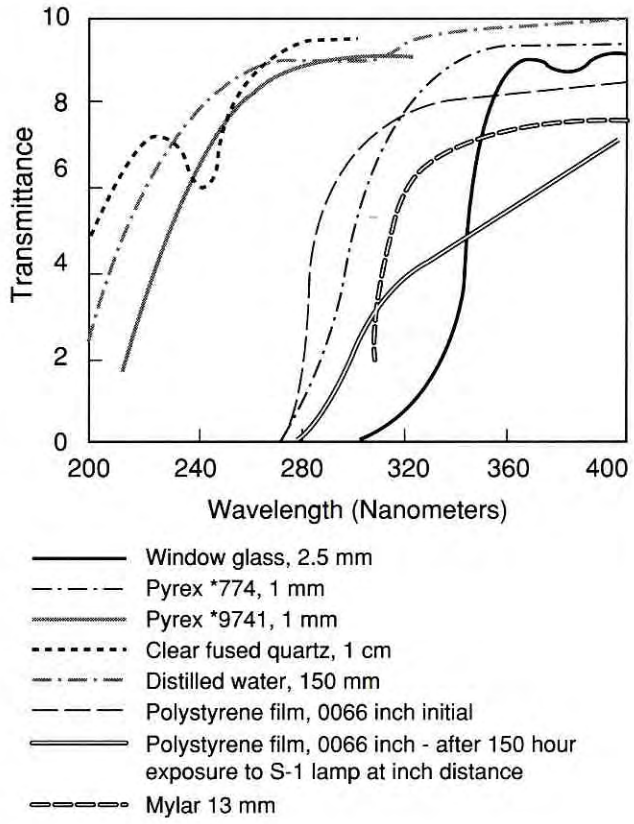
UV-C Radiation Safety

Exposure Time	Max. Irradiance micro-Watt/cm^2
Continuous	0.1
12 h	0.3
7 h	0.5
1 h	3.5
10 Min	20
1 Min	210

Materials, Reflectance/Transmittance



Reflectance Values of Common Materials



Typical Transmittance Curves of Common Materials

Uniformity of Light Colours

Some fluorescent lamp (standard) light colours are internationally standardised by the IEC or CIE with respect to their colour temperature, x,y chromaticity coordinates and colour rendering index.

The major part of Deluxe colours are made to established industry standards. The two important dimensions for production are then the X-Y chromaticity coordinates (see CIE colour triangle) and the related colour temperature. The colour rendering index (CRI) is of course also controlled.

Interchangeability

Based on these standards, fluorescent lamps of the same light colour (see cross references) are interchangeable between the various manufacturers, and should not show noticeable differences.

There is only one restriction:

Lamps by various manufacturers must be new in order to avoid light colour differences due to aging effects.

In installations where lamps are spot-replaced, the new lamps will always look "whiter", for a good part because of the higher light output, and surface brightness (luminance).

Factory Practice

To assure uniform lamp colours according to their standard, test lamps are made and measured. The initial fluorescent powder mix is then, if necessary, corrected to comply with the standard in production.

Applied Tolerances

The x,y coordinates in the CIE chromaticity triangle specify the nominal colour. A manufacturing tolerance is permitted and limited by an ellipse around the nominal value.The limiting line of this ellipse represents the SDCM (Standard Deviation of Colour Matching) which represents 5 SDCM units from the center of the oval.

Light Colour Changes with Aging

The applied powder mix usually consists of various components. These have varying degrees of resistance against degradation by the UV-C radiation.

Accordingly, with the age of the lamp the light colour may shift. - Where light colour uniformity is required, **lamps should be group replaced**.

Lamp Gas and Mercury Fill

Mercury

With continuing efforts to reduce the amount of mercury in a fluorescent lamp, the average for the most common lamp types is a fill of 15 mg today (1991).

After the lamp was evacuated to its low internal fill pressure, a part of the mercury will go into vapour form, to reach under normal operating conditions a partial pressure of about 10^{-3} Torr.

A slight excess of mercury is necessary to compensate for changing conditions regarding the ambient air temperature of the lamp, and for mercury reactions/absorption by other lamp components.

Gas Fill

Traditionally fluorescent lamps use a gas fill of argon (sometimes doped with neon) with a fill pressure of 1.5-3.5 Torr, depending on the lamp type.

An exception are the ø 26 mm energy saver lamps (18, 36, 38 and 58W and some later special types of same diameter) which are filled with a Krypton-Argon gas mix.

This may be used to classify fluorescent lamps into 2 families, Argon filled and Krypton-Argon filled lamps.

Functions of the Gas and Mercury Fill

The gas fill plays a role in the starting phase of the lamp until the discharge in the mercury vapour is firmly established.

Then the gas fill acts as a buffer gas to protect the electrode from mercury ions returning from the discharge.

The mercury vapour is the carrier of the discharge. The produced UV-C resonance radiation of 253.7 nm wavelength is required to activate the fluorescent powder, which then produces light.

Lamp operation

Lamp Starting

With the exception of SLIMLINE lamps (equipped with a single pin Fa8 base) all other lamp types are operated on control gear which provides electrode preheating.

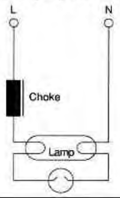
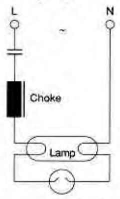
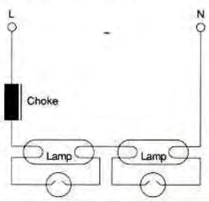
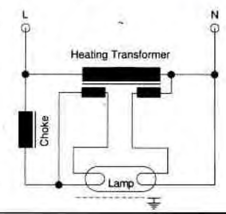
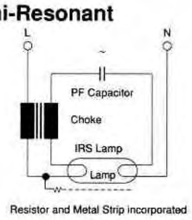
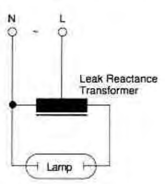
Depending on the type of control gear the preheating of the electrodes is achieved by a defined current or voltage. In all cases the target is to achieve quickly thermionic electron emission from the electrode so that the discharge in the mercury vapour is firmly established, and to obtain long electrode (lamp) life.

Equally important to adequate electrode preheating is the available open circuit voltage at the lamp or the voltage spike, to achieve positive starting in a range of low to high ambient temperatures.

The following table gives an overview of starting and circuit conditions, and a selection of lamp types which are used on the various circuits.

(For the selection of the correct starter see the Technical Manual for Fluorescent Lamp Starters).

Type of Control Gear	Preheating	Starting Voltage	Starter Type ***	Lamp Types	Temperature Range *
Dimmer ballast based on the Rapid Start Circuit	As for Rapid start circuits	Line voltage 220-240 V	None	T12 IRS only	+10 to +40°C
Dimmer ballast electronic/high frequency and General Purpose Electronic High Frequency Ballasts	Depending on ballast design	=	None	Depending on ballast design T8 Argon only or T8 Krypton-Argon	Depending on ballast design

Type of Control Gear	Preheating Method	Starting Voltage	Starter Type ***	Lamp Types	Temperature Range *
Switchstart (inductive) 	Current, Typically 50% higher than lamp current	Voltage spike 600-1000 V	FS-11 FS-22 COP-H20 COP-H46	All T5, T8, T12 CIRCLINE etc. Argon or Krypton lamps	-10 to +50°C
Switchstart (capacitive) 	Current Typically equal lamp current	Voltage spike 600-1000 V	FS-11	All as above	-10 to +50°C
Series (Tandem) 	Current Typically 50% higher than lamp current	Voltage spike 600-1000 V	FS-22	T5, T8, T12 Up to 22W Argon or Krypton lamps	-10 to +50°C
Rapid Start 	Voltage Low volt electrodes Min. 3.6 V ** High Volt electrodes Min. 8 V **	Line voltage 220-240V	None	T12 only Up to 40W Argon lamps only	+10 to +40°C
Semi-Resonant 	Current Typically equal lamp current	Resonance voltage 270-300 V	None	T12-IRS Argon lamps	-10 to +50°C
Instant Start 	No preheating Cold electrode start	450-750 V	None	SLIMLINE only	0 to + 50°C

* for safe lamp starting
** see also page 7 and IEC Specification Nr. 81
*** see also Technical Manual, Fluorescent Lamp Starters

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Starting Aids

Lamp starting can be helped by following means:

1 Sylvania lamps are made with a silicon wax coating on the lamp glass surface which reduces the required starting voltage. The exception are lamps equipped with a metal strip (IRS and MS types) starting aid.

2 A metal strip applied to the lamp will enhance starting particularly on Rapid Start circuits (MS lamps). IRS lamps are recommended for semi-resonant circuits and for Rapid Start based dimmer circuits. The metal strip also helps to stabilise the lamp discharge at reduced light intensities.

The metal strip is a capacitive starting aid making use of the electrical field around the electrodes and the voltage potential between the electrodes.

3 A metal surface parallel to the lamp not further away than 25 mm acts in the same manner. The metal surface (the body of the luminaire) must be earthed.

This is particularly recommended for Rapid Start circuits, but also shows a positive effect for lamps on starter ballast.

Run-up Conditions

The following diagrams show the electrical and light output conditions during lamp stabilisation.

The ambient temperature of the lamp plays a role in the time period until full stabilisation, equally the lamp enclosure or air movements around the lamp.

Krypton lamps usually start with a lower initial light output than Argon lamps and take longer for stabilisation.

During lamp run-up Krypton lamps may show, particularly during the first minute, a slight instability (flicker).

Light output

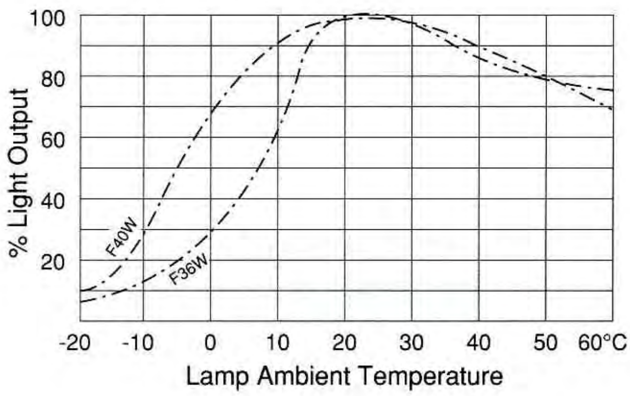
Light Output and Lamp Tube Temperature

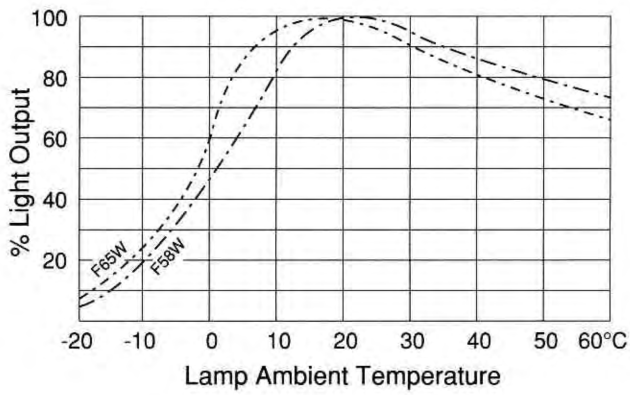
The light output from a fluorescent lamp depends on the mercury vapour pressure, which in turn depends on the coldest spot in the lamp.

In general, the temperature difference between the ambient air and the lamp tube in stable operation is about 20°C, or, a free burning lamp at 20°C air temperature will develop a tube temperature of about 40°C.

Under such conditions, that is in ambient air of 20-25°C, fluorescent lamps will provide the highest light output.

At higher or lower lamp ambient temperatures the light output will be reduced. - There are some exceptions, like so called amalgam lamps as they were produced in the past, with an indium-mercury reservoir for efficient operation at higher ambient temperatures, as in closed luminaires or lamps which are operated at higher current ratings, like HO and VHO types which operate efficiently at lower temperatures as well.





Lamp Ambient Temperature

The ambient air temperature of the lamp will mainly have an influence on the light output as shown in the above diagrams, which also indicate the difference between T12 Argon lamps and T8 Krypton lamps.

Considering the light output drop at low temperatures which may be combined with a reoccurrence of an instable discharge and a disturbing flicker it is recommended to utilise T8 Krypton lamps at temperatures above + 5°C for the F58W and + 10°C for the F36W and F18W type. For lower lamp ambient temperatures it is recommended to utilise Argon lamps.

Closed Outdoor Luminaires

Depending on the luminaire design, the interior lamp ambient temperature may be up to 20°C higher than the exterior temperature because of the thermal losses of the lamp(s) and the ballast.

In such luminaires the recommended limits for outdoor temperatures are - 15°C for the F58W and - 10°C for the F18W and F36W.

Refrigeration Equipment

Depending on the design of such equipment and lamp enclosure, low ambient temperatures for the lamp may determine the choice of Argon lamps to maintain the light output and to avoid disturbing flicker.

This applies to both types of equipment used in commercial display, the open type for fresh milk and meat products and open or closed deep freezing boxes.

Air Movement

Not only the ambient air temperature will determine the lamp tube temperature and consequently the light output but also the air movement to which lamps may be exposed, resulting in a cooling effect for the lamp tube.

This can be air drawn through a luminaire which is integrated into an air conditioning system, or strong air movements created by ventilation systems (cooling in particular) as it can be found in large surface supermarkets, and similar commercial or industrial environments.

While F18W and F36W are considerably affected by this, F58W lamps are not and should be the choice for such conditions.

Luminance

The luminance of fluorescent lamps depends on the lamp dimensions (diameter and length), lamp power or current, the type of phosphor which is used and the angle of view towards the lamp.

It may be influenced by line voltage variation, lamp ambient temperature, and the age of the lamp.

Typical values are 1.0 to 1.5 cd/cm^2.

Lamp temperatures

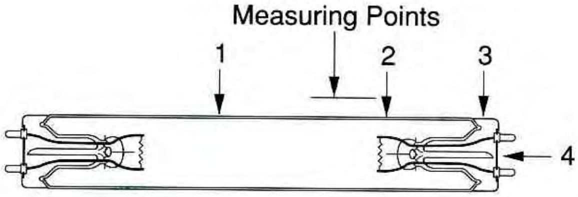
The following table provides measured temperature values for the most common lamp types burning free in ambient air of 25°C at nominal power conditions.

The measurements were taken in

a) normal operation
b) constant preheating conditions (short circuited starter)

Under both conditions the highest temperatures are measured above the lamp electrode.

A variation of these temperatures can be caused by the ambient temperature of the lamp, and by line voltage variation (relative to lamp current).



Operation	Normal				Const. Preheat			
Measuring Points	1	2	3	4	1	2	3	4
F 18 W		72	55	46		76	58	49
F 20 W		64	48	46		72	55	53
F 36 W	45	75	58	47		84	69	55
F 40 W	43	74	50	50		71	53	51
F 58 W	51	108	75	55		124	87	74
F 65 W	48	80	60	55		108	80	74
	Measured Temperatures (°C)							

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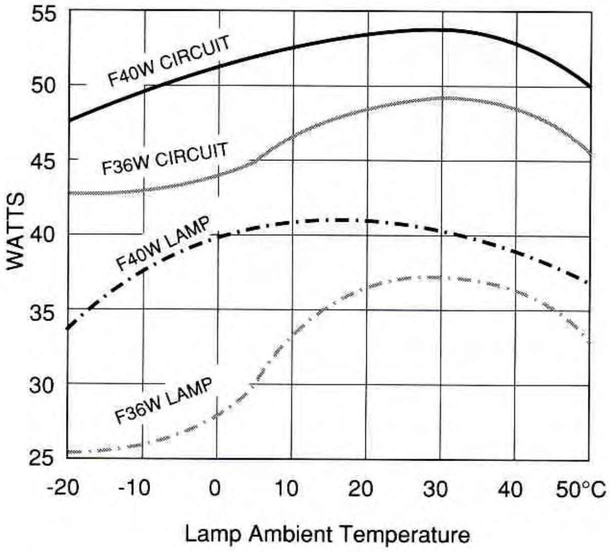
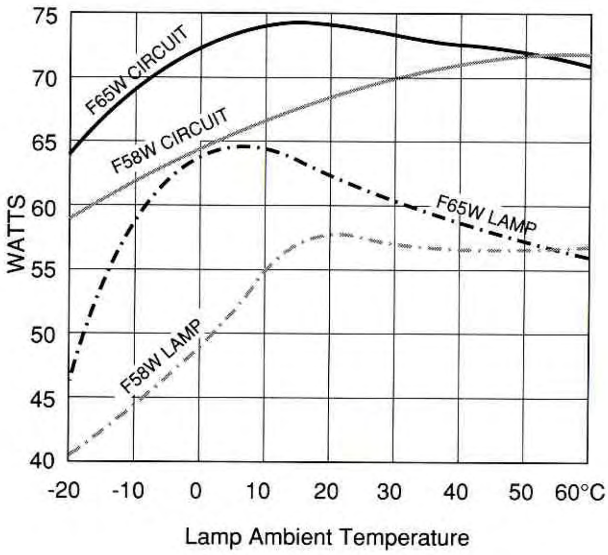
Lamp Wattage and Ambient Temperature

Lamp and circuit wattage vary with the ambient temperature as indicated in the following diagrams.





Lumen Maintenance

Through lamp life the light output will go down due to a slow degradation of the fluorescent powder coating. The rate of light output reduction is faster at the beginning, and depends in general on:

- the type of fluorescent powders as used in a particular lamp family
- the radiation density to which the fluorescent coating is exposed which is a function of the tube diameter and the lamp current.

Nominal values of light output are usually indicated (and measured) after an aging of 100 hours of the lamp on life rack conditions.

Typical lumen maintenance curves are presented on page 43.

Lamp Life

The end of life of a lamp is reached with the exhaustion of the emitter material on the electrode. This will cause the cathode fall to increase and thus the total lamp voltage, until a level of voltage is reached which will not be sustained by the ballast. The lamp will start cycling and will finally not start.

Lamp Life Indications, Terms

All life testing at the factory is done according to industry standards with 8 switchings in 24 hours, which gives a cycle of 2 h 40 minutes on and 20 minutes off.

The lamps are removed after 100, 500, 1000, 2000, 4000 and 8000 hours from the life rack, cleaned and tested in an integrating sphere for their electrical and photometric performance.

On the basis of the developed statistical values for a given lamp type or family of lamps, the following indications can be given for practical purposes:

- a lamp survival curve with its spread of lamp failures at various operating hours
- a lamp survival percentage at a given operating hour limit (example 80 % at 10'000 h)
- a mean, statistical value, relative to a 50% survival rate of a test group.

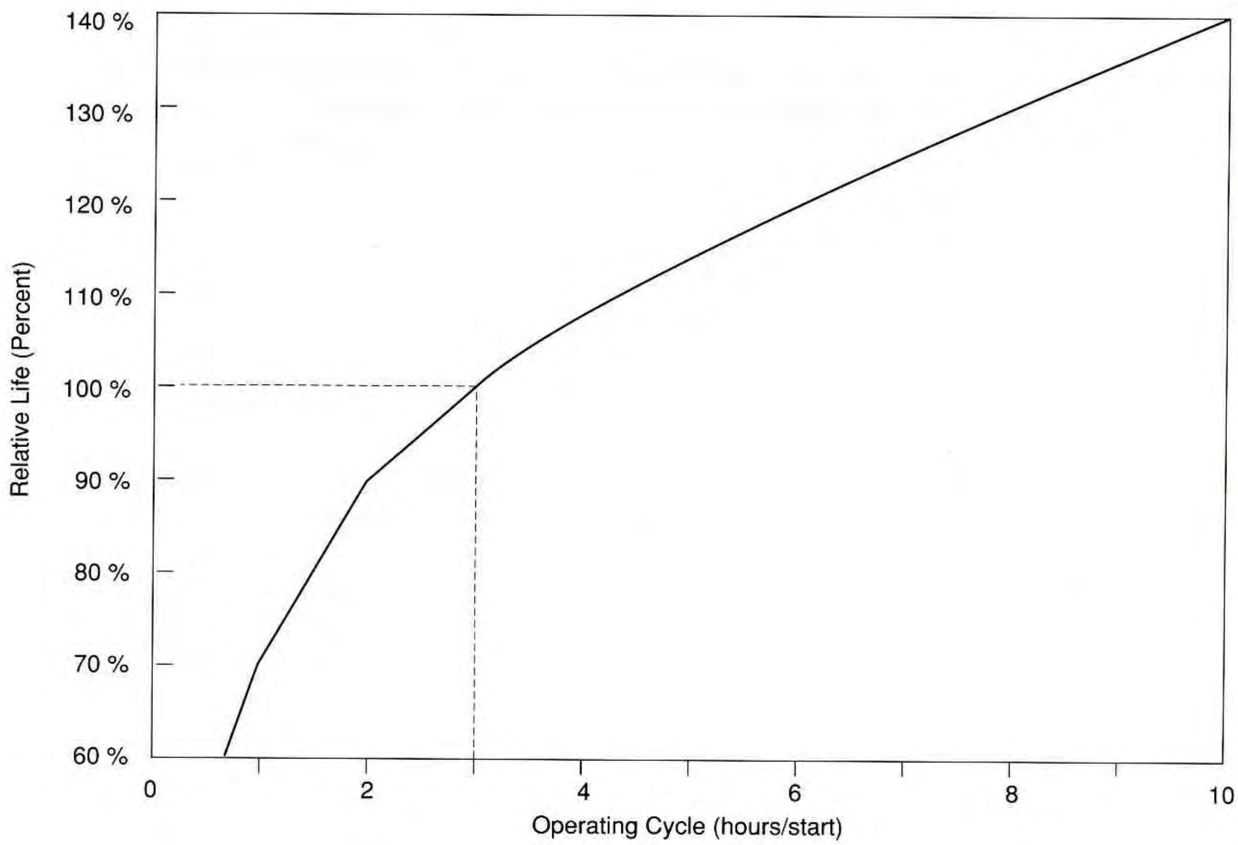
In all cases, the given information is relative to a large number of manufactured lamps over a production period of usually one year, from which lamps have been sampled according to international standards.

What Influences Lamp Life

Switching frequency:

On a standard starter circuit we may consider that each lamp start will reduce lamp life by an average of 2 hours due to the loss of emitter material from the electrode during the starting process.

The following diagram reflects the influence of switching frequency on lamp life.



Ballast type:

The various ballasts provide different starting conditions to the lamp and so the quality of starting varies. The better the preheating and the more positive the starting the less the loss of emitter material from the electrode and lamp life is extended.

Taking the conditions of an inductive starter circuit as a basis for comparison following values could be taken for consideration:
(% lamp life for 8 switchings per 24 h)

• electronic high frequency ballast with good preheating	150%
• inductive starter ballast	100%
• capacitive starter ballast	80%
• electronic high frequency ballast without preheating	70%

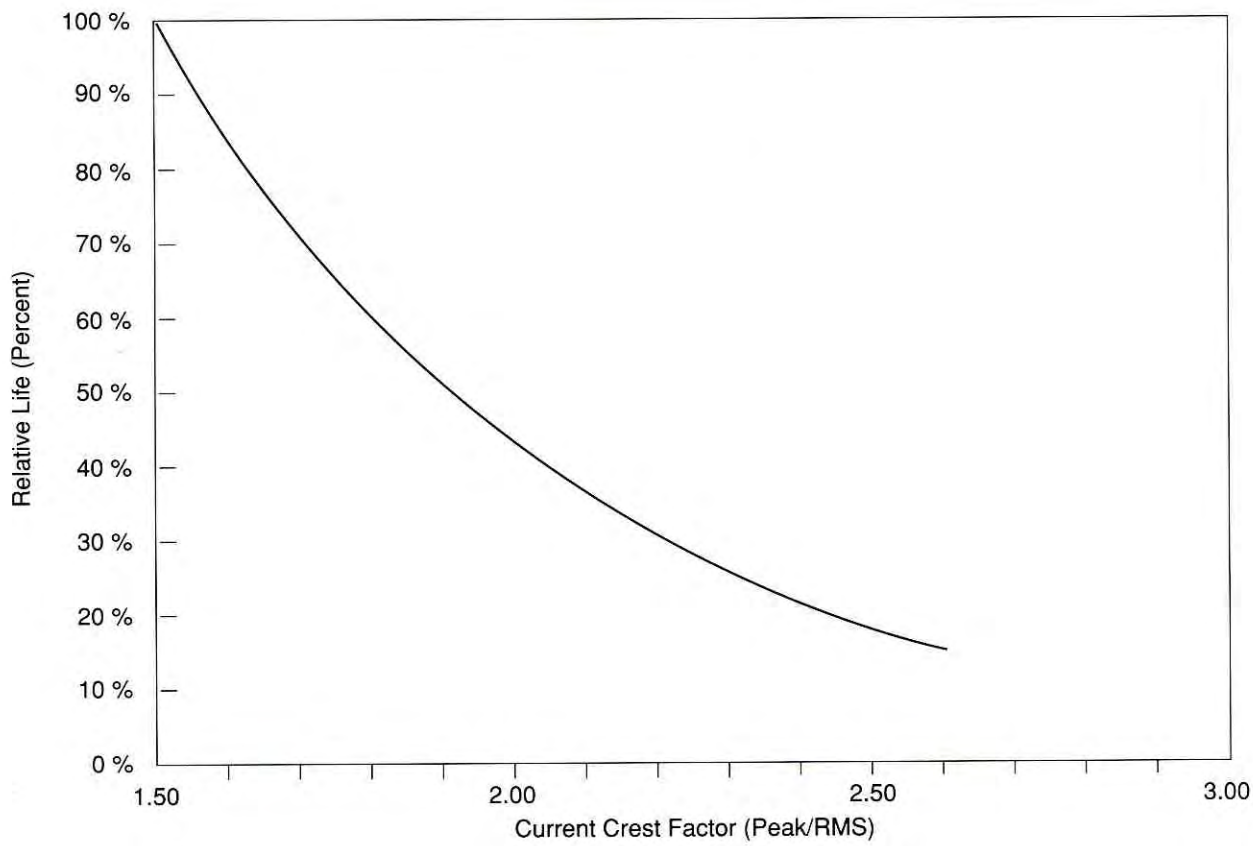
Current Wave Form:

The current wave form is influenced to some extent by the lamp discharge (half wave cycle restriking) but mainly by the ballast.

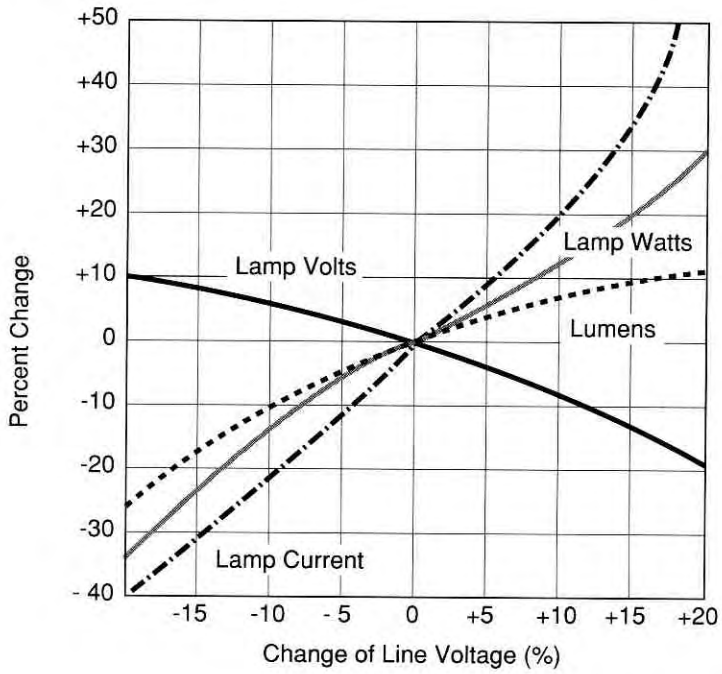
Of importance is the current crest factor, which is the peak current value divided by the r.m.s. (effective) value during the half cycle.

A high current crest factor means that a high current is emitted by the electrodes during a small part of the current wave, which means an accelerated deterioration of the emitter material.

The following diagram indicates the influence of the current crest factor on lamp life. On standard inductive choke circuits, the current crest factor varies from 1.50 to 1.55 which is taken as a basis (100%) for lamp life.



Line Voltage Variation

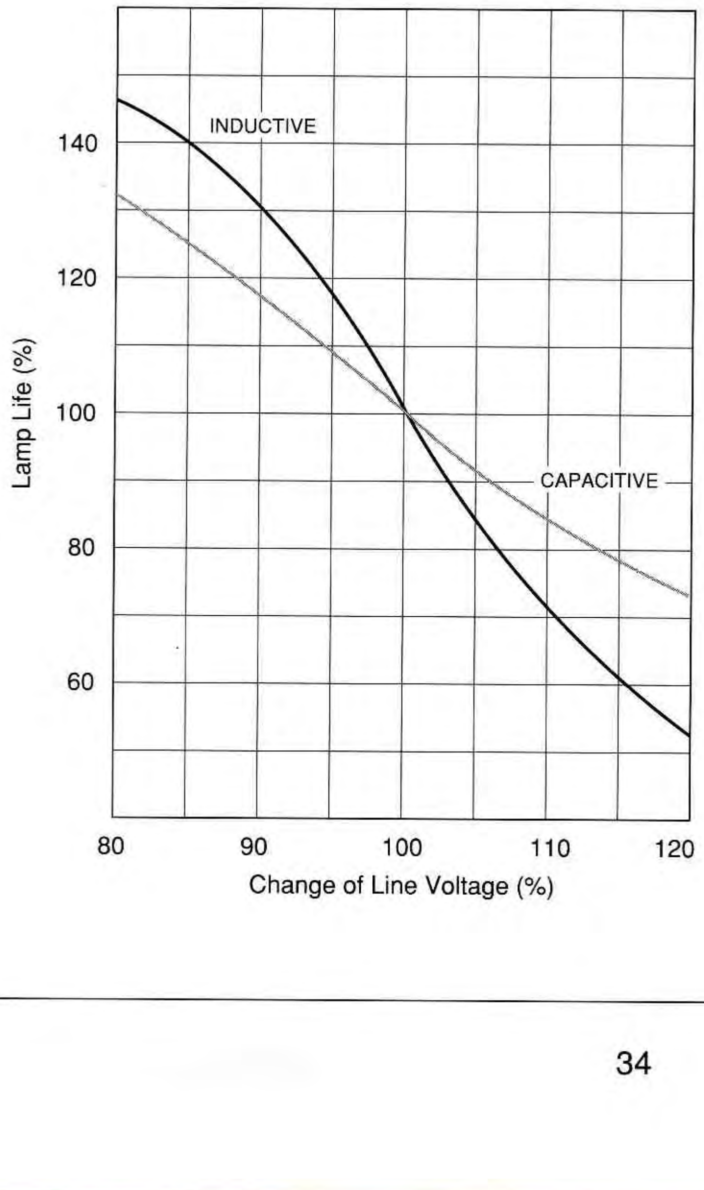


The diagram shows the variations on lamp operating data by line voltage variation.

Lamp life will be reduced with increasing current by about the same percentage.

High line voltage versus the choke nominal voltage will cause an increased lamp current and shorter lamp life.

High ambient lamp temperature will cause an increased lamp current and shorter lamp life. This condition may develop in compact, closed luminaires.



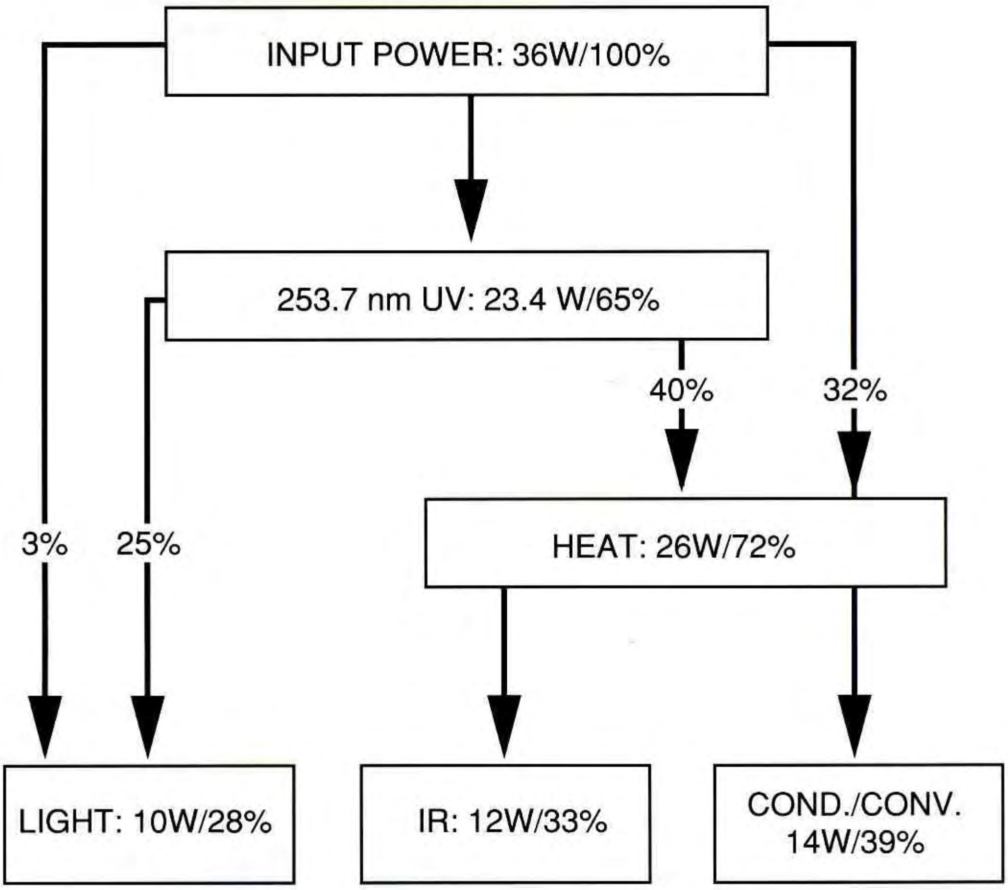
Although lamps on capacitive circuits have a shorter life because of the starting (preheating) conditions and higher current crest factor, lamps on capacitive circuits are less affected by line voltage variation because of a current regulating effect of the series capacitor.

Power Balance of Fluorescent Lamps

The following table shows how a F36W T8 lamp converts the consumed power (36W without ballast) into radiation and heat.

	UV-A + UV-B	VISIBLE	INFRARED RADIATION	HEAT CONDUCTION CONVECTION	TOTAL
WATT	0.2	10.0	12.0	14.0	36.0
% OF LAMP WATTAGE	0.55	27.45	33.0	39.0	100

The type of fluorescent powder coating will influence the power balance slightly for the UV and visible radiation.

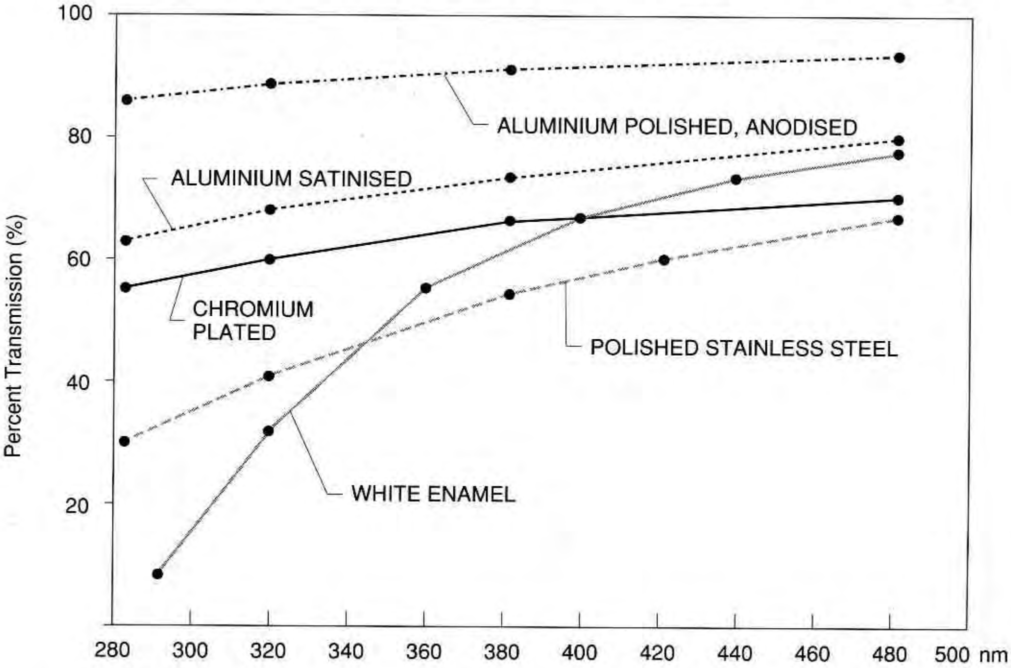


UV Radiation From Fluorescent Lamps

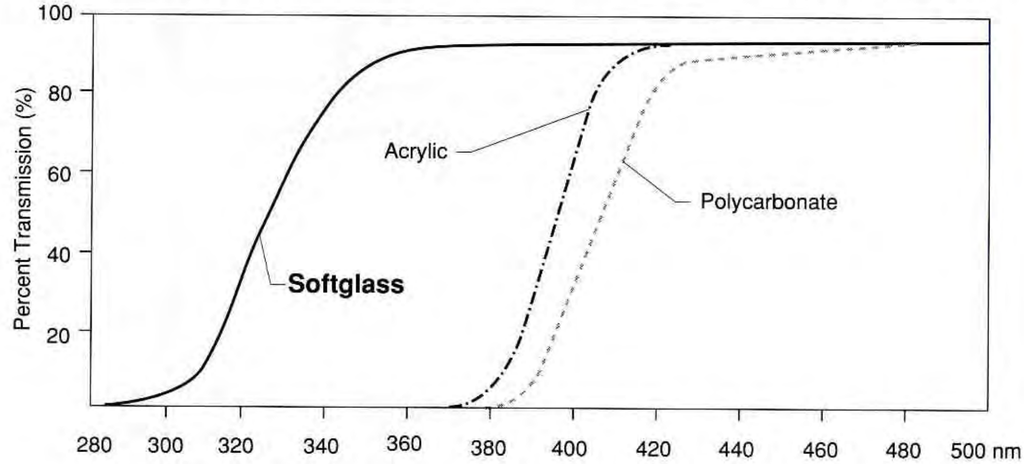
For all general lighting products we can see that no UV-C radiation (below 280 nm) is emitted. The following diagram shows how the glass of the tube absorbs such radiation, in case it is not fully absorbed by the fluorescent powder (softglass).

UV-A radiation (315-400 nm) and UV-B (280-315 nm) represent an average of about 0.8% of lamp wattage. The UV-B part of this radiation is between 15 and 25%, depending on the fluorescent powder coating.

For practical purposes we have to consider that a large part of this radiation is absorbed in the luminaire, particularly in closed designs using polycarbonate or acrylic diffusers.



Reflectance values for various materials in the visible (blue) and ultraviolet



Transmission values for various materials

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Dimming of Fluorescent Lamps

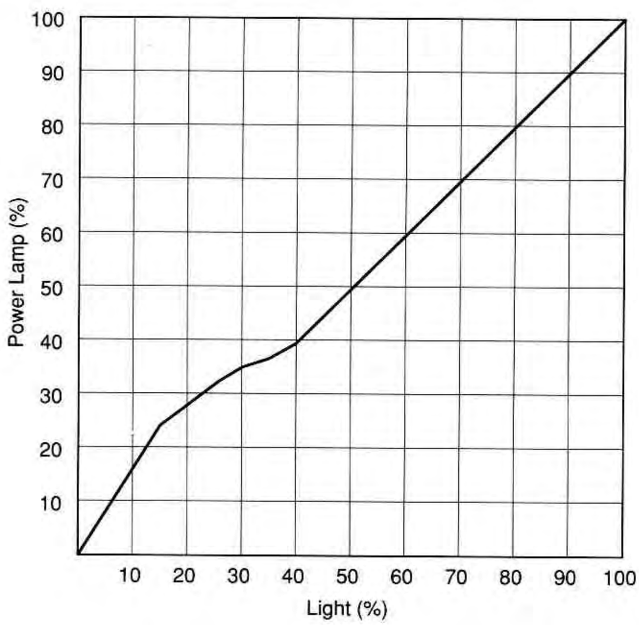
Operated on properly designed control (dimming) gear fluorescent lamps are ideal light sources for either energy management relative to the available natural daylight, or illuminance requirements during the utilisation period of a room or building.

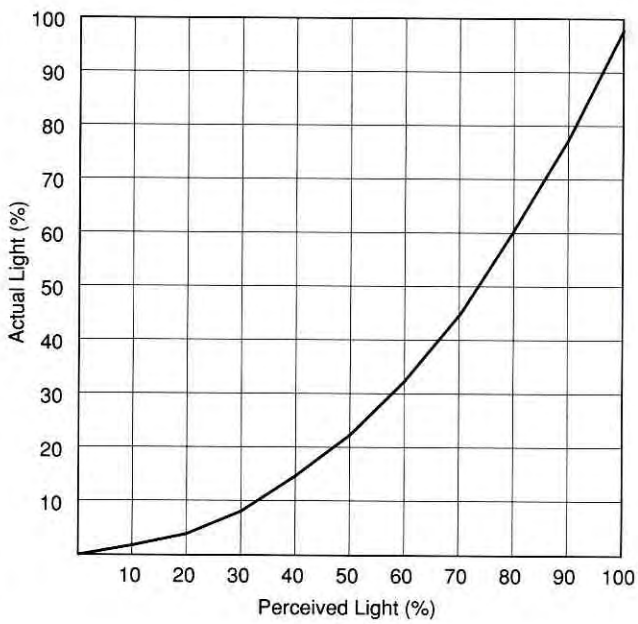
When dimmed, fluorescent lamps

- will not change colour temperature
- maintain their lumen/Watt efficacy throughout the dimming range
- will maintain lamp life
- have instant response to regulation.

The only problem area is discharge stability below a certain degree of dimming, particularly with ø 26 mm Krypton lamps, which may lead to flicker or striation. High frequency control gear is the best solution to overcome such problems to relatively low levels of dimming.

With respect to the performance of the human eye, however, dimming of lamps does provide a factor of increased lighting efficiency as is demonstrated in the following diagram. This, of course, applies to all light sources when dimmed.





For dimming control gear based on the Rapid Start circuit Argon lamps with a diameter of ø 38 mm and equipped with a metal strip are recommended (IRS lamps).

Flicker (Stroboscopic Effect)

With each half cycle of the discharge, 100 times a second on 50 Hz supplies, the light output of the lamp goes from a minimum to a maximum and back to minimum. The output does not go back to zero because of the phosphorescent properties of the fluorescent powder coating.

These "light pulses" or modulation is too fast for the human eye to observe. Furthermore, reflections of light in the environment in which we work and the influence of natural daylight through windows attenuate this effect.

The light pulse frequency may, however, become visible by the reflections on rotating or fast moving objects, depending on their speed. If such stroboscopic effect is disturbing or dangerous, 3 solutions are possible:

- to install lamps on a DUO circuit with the modulations being at a phase angle of about 120°
- to install lamps individually on 2 or 3 phases (2 or 3 modulations with phase angles of 120°)
- to use high frequency control gear which operates the lamps at about 30.000 Hz.

Fluorescent Lamp Efficiency

The various factors which will influence the light output from a lamp were mentioned in the previous chapters, and should be considered for the efficiency of lighting and its economy.

The main factor is then the lumen/Watt efficacy of the lamp under nominal conditions, and the values can be taken from the catalogue.

The lm/W efficacy varies for the various lamp types with the dimensions, lamp power and the type of fluorescent powder coating.

From the following data comparison it is obvious that lamps of 36W and 58W are most efficient particularly with triphosphor coatings of the LUXLINE range and these should primarily be chosen for general lighting purposes.

Lamp Type	**Luminous Efficacy (lm/W)**	
	Standard CW	LUXLINE 180 Series
F4W	38	
F13W	68	
F15W	60	
F18W	64	81
F30W	58	
F36W	83	96
F58W	83	93
F125W	68	
F96 T12/VHO	70	

For lighting design calculations the light output of the lamp and its lumen/Watt efficacy will have a direct influence on the number of luminaires which are required to achieve a required illuminance (lux) on the working plane, and on the consumption of electrical energy which is mainly responsible for the annual operating cost of an installation.

High Frequency Operation

Various types of electronic high frequency control gear is available today for standard lighting applications or dimming purposes. The lamps are then typically operated at a frequency around 30.000 Hz, instead of 50 Hz line frequency.

The main effect on the lamp is a reduction of the cathode fall and an increase in discharge efficiency both permitting a reduction of the lamp power for the same light output.

To maintain or increase the lamp life such systems should provide adequate electrode preheating for lamp starting.

These high frequency systems are designed for the operation of ø 26 mm lamps in general, with either Krypton-Argon gas fill, or Argon gas fill, or for both types. The interchangeability of lamp types has to be checked.

Lamp Types

For a suitable match of lamp and type of control gear see pages 22 and 23.

Criteria for Choice

For normal lighting applications 3 criteria for lamp choice apply:

1. Lumen / Watt Efficacy (lm/W)
   High efficacy leads to an efficient use of electrical energy and low annual operating cost.

2. Correlated Colour Temperature
   The choice will determine the ambiance which we want to create. A choice from colour temperatures between 2700K and 6500K permits to find the right light colour for all applications.

3. Colour Rendering Index (or Group)
   The CRI will determine the quality of light for a chosen colour temperature. It means how natural colours of the environment which we are lighting will look like.

It may be important to note that in the total operating cost of an installation, the annual cost of lamps represents only 5 - 10%. The cost of lamps should therefore not become a determining factor in priority to the above 3 main criteria.

Lamp Types and Designations

SYLVANIA uses a designation system as explained below, for standard tubular lamps.
Example : F15W/T8/CW

F ...	stands for Fluorescent
15W ...	the lamp power (nominal) (see exception USA style lamps)
T ...	stands for TUBULAR
T8 ...	the diameter of the lamp tube. Indicated in 1/8 fractions of an inch T5 ... 5/8 inch ... 16 mm T8 ... 8/8 inch ... 26 mm T12 ... 12/8 inch ... 38 mm
CW or 133 ...	the lamp colour. See lamp colour chart.

Other designations are used to specify special lamp types:

FC ...	CIRCLINE lamp
FR ...	Reflector lamp
FU ...	U-shaped lamp
RS ...	Rapid Start lamp, for RS circuits
MS ...	Metal strip lamp. The strip has no electrical connection.

IRS ... International Rapid Start lamp. Equipped with a metal strip which is connected at one lamp end over a high value resistance to the electrode electrical potential.

There are 4 lamp types of USA style with their particular designations:

F96 T12/CW ... SLIMLINE lamp with single pin Fa8 bases. 96 indicates the nominal lamp length in inches.

F48 T12/HO/CW ... HO (High Output) lamp. Operates with higher current rating (typical 0.8 A). R17d bases. 48 stands for nominal length in inches.

F72 T12/VHO/CW ... VHO (Very High Output) lamp. Operates with high current rating (typical 1.5 A). R17d bases. 72 stands for nominal length in inches.

F48 T12/CW/VHO/LT ... LT (Low Temperature) lamp.
Equipped with a T14 1/2 protection tube (46 mm). For outdoor use, in open luminaires.

Maintenance

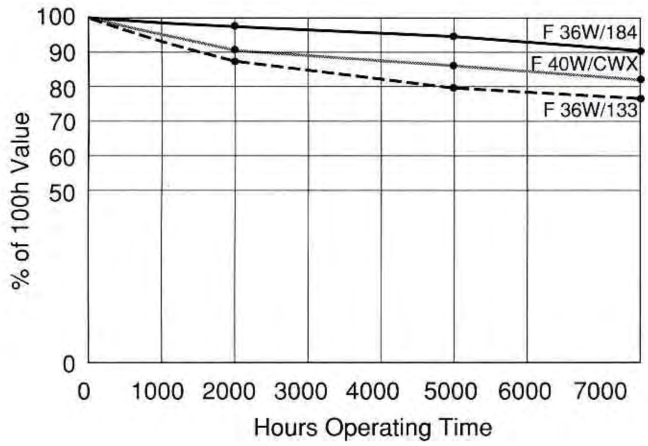
The way maintenance is applied to a fluorescent lighting installation will have a considerable influence on its average performance and annual cost. The objective should be to obtain an optimum of light output.

Light Output Depreciation

Once a new installation is started up, 3 factors will contribute to a light output depreciation:

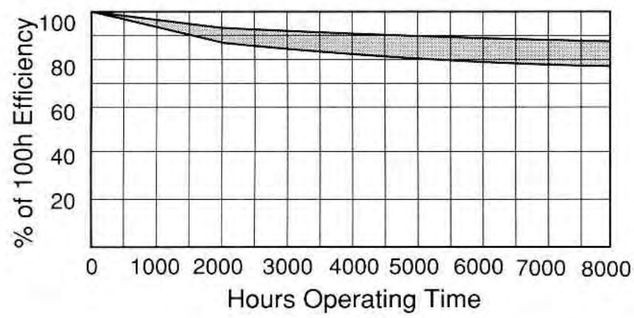
- the lumen depreciation characteristic of the lamp
- the depreciation of the luminaire efficiency because dust and airborne contaminants will reduce the reflectance and transmission of light of the luminaire components
- Lamp failures

Typical diagrams of these effects are given below.



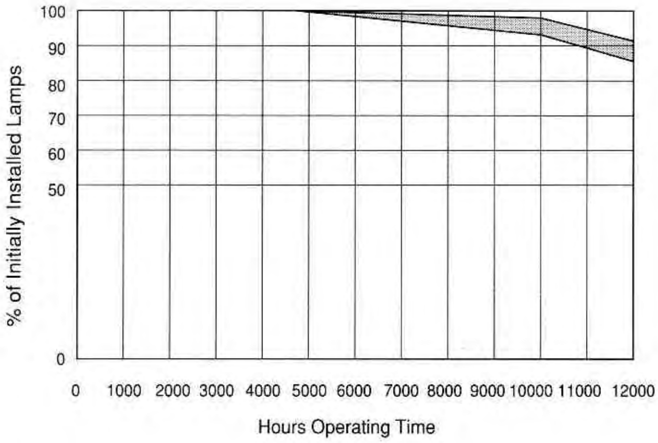
Lamp Lumen Depreciation

Lumen depreciation will depend on the choice of the light colour. Series 180 Lamps show outstanding performance and provide high light output over life.



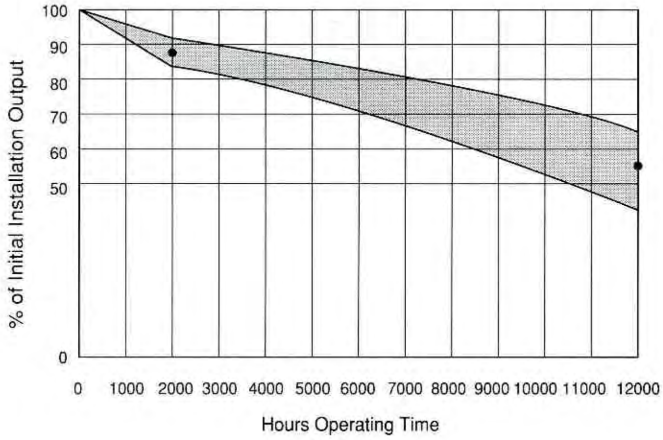
Luminaire Dirt Depreciation

Luminaire dirt depreciation will depend on the cleanliness of the environment (air) and on luminaire design.



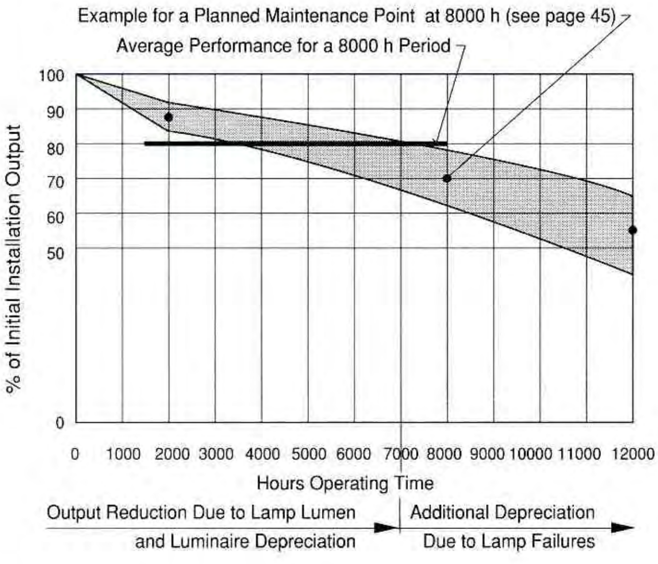
Lamp Failures

The rate of lamp failures will depend on the lamp type, the type of control gear and the operating conditions.



Installation Performance

The overall installation performance will depend on the 3 factors multiplied with each other at any point of operating hours.



Analysis

Lighting Products Choice

It is obvious that the choice of a LUXLINE Series 180 lamp and a luminaire with low light output depreciation will lead to a high light output performance. Low lamp failure rates will be obtained with lamps of the F36W and F58W type.

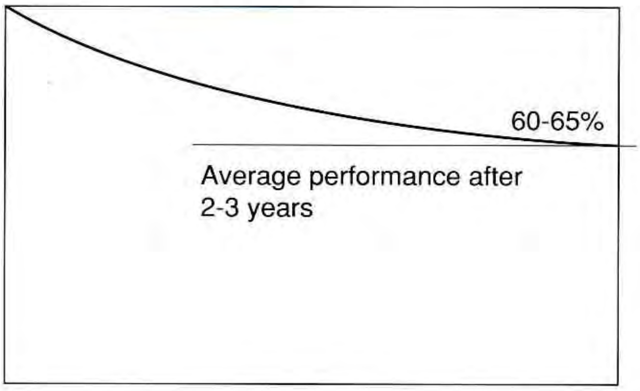
Maintenance Modes

Spot Replacement

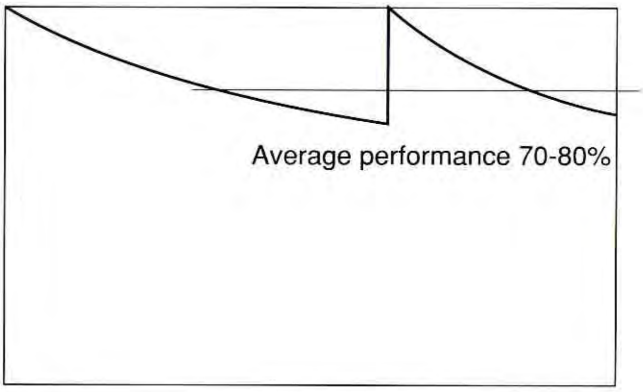
The unsatisfactory performance, and complaints about many lighting installations comes from a widely practised mode: SPOT REPLACEMENT of failed lamps. Usually this is combined with an absence of cleaning cycles for the luminaires.

This is bad practice. Although all lamps are maintained burning, the light output performance of such an installation will depreciate in a typical office environment to 65-60% of the initial output, but annual operating cost (mainly electricity) will remain 100%.

Spot replacement mode



Planned lighting maintenance



Planned Lighting Maintenance

This is a recommended mode of maintenance. Average and minimum light output performance can be analysed on basis of accumulated data, and a maintenance period can be decided on for optimum performance and lowest cost.

This means changing all lamps at the same time, and cleaning the luminaires correctly. The installation will then perform with almost its initial output again.

A typical average performance of an installation in an office environment will then be around 75 to 80%.

Maintenance Planning, Part of Lighting Design

The comparison of installation performance for the two maintenance modes shows that planned lighting maintenance can provide up to 25% more average light output.

This also means that on an average basis 20% less luminaires, lamps and electricity consumption will be required to achieve the required average illuminance.

Lamp Testing

Nominal Lamp Data

Indicated product data apply to lamps aged for 100 hours on a standard switching cycle of 2 h 40 Min. ON and 20 Min. OFF.

In the UK it is also practice to indicate values for the light output at 2000 hours (lighting design lumens).

Test Methods

SYLVANIA lamps are made to standards as specified in IEC Nr. 81 (EN 60081) and the test methods as described in these standards apply.

Electrical Measurements

Due to the non-sinusoidal current and voltage wave forms only TRUE-RMS multifunction meters can be used. The crest factor capability should be 2.5 or better.

When setting up circuits for measurements care should be taken that high voltage spikes created by the starter/choke during lamp starting will not damage the instruments. These spikes may be of up to 1200V.

Lamp Power Factors

Depending on the lamp and ballast type, lamp power factors between 0.8 and 0.9 can be measured.

Trouble Shooting

Refer also to the Technical Manual, Fluorescent Lamp Starters.

If lamps do not perform to standard the control should cover the complete system, that is

- the lamps, and starters
- lamp holders, starter holders
- the control gear
- the luminaire and wiring
- line voltage conditions, switching cycles
- environmental conditions, like temperature, moisture etc... .

It should also be considered that often several factors combined will lead to unsatisfactory performance.

Refer also to the Trouble Shooting section in the STARTERS Technical Manual

Symptom	Possible Cause	Remedy
No lamp starting, no visible function, no preheating	No line voltage at luminaire	Check fuses, line switch, luminaire connection
	Wiring defect in luminaire	Control wiring and luminaire, ballast connections
	Bad contacts in lamp or starter holders	Control, change holders
	COP starter not reset	Reset
	Starter or Lamp defect/or end of life	Change starter or lamp
	Wrong lamp, T8 Krypton lamp on Rapid Start or Semi-Resonant ballast	Change to T12/RS or T12/IRS lamp
	Preheating circuits on Rapid Start ballast defect, or luminaire earthing missing	Control preheating voltage on lamp holders, control earthing connection
	T8 Krypton lamp on electronic ballast made for T8 Argon lamps	Change to T8 Argon lamps
No lamp starting, lamp ends glow continuously	Defective starter	Change starter
	Wiring defect in luminaire	Control wiring and starter connections
No lamp starting, continuous starting attempts	Lamp defect or at end of life	Change lamp
	Defect or bad starter	Change starter
	FS-11 starter or COP type on Series (Tandem) ballast	Change to FS-22
Long starting time, continuous starting attempts	Bad starter	Change starter
	Unfavourable combination of capacitive circuit and low line voltage	Change to inductive circuits and parallel compensation. Or change from T8 to T12 lamps

Symptom	Possible Cause	Remedy
Lamp starts with a flash then no further function	Wiring defect in luminaire, or choke is short-circuited	Control wiring and choke
Lamp discharge is snaking	Impurities in lamp	Operate lamp for 15 minutes then switch-off and let cool down. Repeat if necessary, or change lamp.
Lamp shows flicker, unstable operation	T8 Krypton lamps during stabilisation time	Will usually disappear within one minute
	T8 Krypton lamp at too low ambient temperature or in heavy air (cooling) draft	Use close fixture. Divert air current. Or change to T12 lamps (recommended for refrigeration equipment)
Lamp is cycling	Bad starter (combined with low line voltage)	Change starter
	Lamp end of life	Change lamp
	Lamp with high reignition spike (combined with low line voltage)	Change lamp
Lamps in installation show colour differences	Different lamp colours installed	Control lamp stamps. If lamps of different manufacturers are installed refer to cross reference chart
	Lamps are of different age in the installation. Old lamps trend to look warmer.	If critical, group replace lamps
	Effect of different reflector or enclosure materials or colours. Different age of luminaires	Apply cleaning cycle to all luminaires. If possible change parts which are different

Symptom	Possible Cause	Remedy
Lamps show end blackening	Lamp goes towards the end of life	Change lamps if disturbing
	Bad preheating for starting (particularly on capacitive circuits)	Starter ballasts: preheating current should be about 50 % higher than normal lamp cur-rent on inductive circuits, equal normal lamp current on cap-acitive circuits. Rapid Start ballast: For RS lamps the pre-heating voltage should be min. 3.6 V but typically 4.0 - 4.5 V. See special instructions for HO and VHO lamps.
	Shadow of electrode shield in T8 lamps	This is normal
Dark spots on downward side of lamp	Mercury condensation because of cooling effect from air draft	Turn lamps 180°. If spots re-occur, reduce air movement through luminaire.
Short lamp life (Early failures may occur due to rare developmental glass defects, air leakers)	High line voltage versus nominal ballast voltage	Control line voltage and ballast data.
	High lamp ambient temperature in closed and compact luminaires	Improve ventilation of luminaire
	Ballast defect	Control wiring and lamp current.
	Bad starting conditions, insufficient preheating	Control line voltage, preheating current
	Refer also to pages 31-34	
Ballast noise, humming	Bad choke or loose and vibrating parts. Choke end of life.	Tighten ballast and/or luminaire parts. Change ballast if necessary
Main fuse blowing	Defect wiring in luminaire. Choke at end of life and short circuited	Control wiring and choke. Change choke if necessary

Lamp Reference Data

Fluorescent

Lamp Rating W	Dimensions: Diameters nominal (IEC) mm	Dimensions: Length max. (IEC) mm	Electrical Characteristics (IEC nominal): Lamp Current A	Electrical Characteristics (IEC nominal): Lamp Voltage V	Recommended Lamp Ballast: Starter Ballast	Recommended Lamp Ballast: Rapid Start Ballast (starterless low resistance electrode)	Recommended Lamp Ballast: Semi-Resonent Dimming Circuit (low resistance electrode)
4	16	136	0,17	29	•		
6	16	212	0,16	42	•		
8	16	288	0,145	56	•		
13	16	517	0,165	95	•		
14	26	361,2	0,34	46	•		
15	26	437	0,31	55	•		
16	26	720	0,20	95	•		
18	26	590	0,37	57	•		
20	38	590	0,37	57	•	•	
20 IRS	38	590	0,37	57	•	•	•
22	29	216*	0,40	62	•		
25/28"	26	691,4	0,38	80	•		
25/30"	26	742,2	0,36	84	•		
25/33"	26	818,4	0,34	90	•		
25	38	970**	0,30	94	•		
30	26	895	0,365	96	•		
30	38	895	0,405	81	•	•	
32	32	311*	0,45	81	•		
36	26	1200	0,43	103	•		
38	26	1047	0,44	104	•		
40	38	1200	0,43	103	•	•	
40 IRS	38	1200	0,43	103	•	•	•
40	38	970**	0,56	81	•		
40/2ft	38	589,8	0,88	47	•	•	
40	32	413*	0,42	110	•		
42	38	1047	0,535	89	•		
60	32	413*	0,75	92	•		

* Circline Lamp max. Outer Diameter

** 1 Meter lamp

Lamp Rating W	Dimensions Diameters nominal (IEC) mm	 Length max. (IEC) mm	Electrical Characteristics (IEC nominal) Lamp Current A	 Lamp Voltage V	Recommended Lamp Ballast Starter Ballast	 Rapid Start Ballast (starterless low resistance electrode)	 Semi-Resonent Dimming Circuit (low resistance electrode)
58	26	1500	0,67	110	•		
65	38	1500	0,67	110	•		
65 IRS	38	1500	0,67	110	•		•
70	26	1763,8	0,70	128	•		
80	38	1500	0,87	99	•		
85	38	1764	0,80	120	•		
100	38	2375	0,96	125	•		
125	38	2375	0,94	149	•		

Lamp Reference Data

US Style Lamps (HO and VHO with R17d cap)

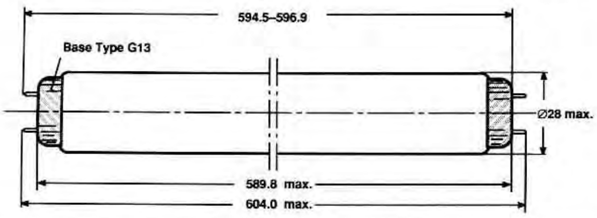
Lamp Rating W	Type Description	Dimensions: Diameter Nominal mm	Dimensions: Length Nominal inch	Dimensions: Length Max. mm	Electrical Characteristics: Lamp Current A	Electrical Characteristics: Lamp Voltage V
HO High Output Lamps						
35	F24 T12/../HO	38	24"	557	0.8	42
42	F30 T12/../HO	38	30"	708.9	0.8	50
45	F36 T12/../HO	38	36"	861	0.8	59
55	F42 T12/../HO	38	42"	1013.7	0.8	68
60	F48 T12/../HO	38	48"	1166	0.8	79
70	F60 T12/../HO	38	60"	1471	0.806	95
76	F64 T12/../HO	38	64"	1573	0.8	102
85	F72 T12/../HO	38	72"	1776	0.8	116
100	F84 T12/../HO	38	84"	2081	0.785	132
110	F96 T12/../HO	38	96"	2385	0.8	152
VHO Very High Output Lamps						
74	F24 T12/../VHO	38	24"	557	NA	NA
115	F48 T12/../VHO	38	48"	1166	1.5	83
135	F60 T12/../VHO	38	60"	1471	1.5	108.5
160	F72 T12/../VHO	38	72"	1776	1.5	124
195	F96 T12/../VHO/SS	38	96"	2385	1.55	145
215	F96 T12/../VHO	38	96"	2385	1.5	161
SLIMLINE (Fa8 Cap)						
21	F24 T12/..	38	24"	541	0.42	52
25	F42 T6/..	19	42"	998	0.2	145
30	F36 T12/..	38	36"	863.6	0.42	76
36	F42 T12/..	38	42"	998	0.42	91
38	F64 T6/..	19	64"	1557	0.2	225
38	F72 T8/..	26	72"	1760	0.2	218
39	F48 T12/..	38	48"	1151	0.425	100
50	F60 T12/..	38	60"	1473.2	0.425	127
51	F96 T8/..	26	96"	2370	0.2	290
52	F64 T12/..	38	64"	1557	0.420	136
55	F72 T12/..	38	72"	1760	0.425	149
70	F84 T12/..	38	84"	2082.8	0.420	179
75	F96 T12/..	38	96"	2370	0.425	197

100 h Lumen Data

Lamp		Light Colours										
		WW	W	UW	CW	D	SATIN	DECOR	BURO	STUDIO		
(W)	(Type)	129	135	125	133	154	182	183	184	186	193	194
4	T5	145	145		140	115						
6	T5	290	290		280	240						
8	T5	400	400		380	340	420	420				
13	T5	880	880		860	750	950	950				
14	T8	700			700	650						
15	T8	900	900		900	750	950	1000		1000		
16	T8	1100	1100	1050	1100							
18	T8	1150	1150	1050	1150	1050	1350	1350	1350	1300	1000	1000
20	T12	1200	1200	1050	1200	1050						
22	FC	1100	1100	1000	1100	1000	1300	1300	1300			
25	T8 28"				1700	1500						
25	T8 30"	1800			1800							
25	T8 33"				1900	1700						
25	T12 1m	1800			1800	1450						
30	T8	2200	2200		2200	1900						
30	T12	2360	1900		2300	1950						
32	FC	2000	2000	1700	2000	1700	2200	2200	2200			
36	T8	2850	2850	2500	2850	2500	3350	3350	3350	3250	2350	2350
38	T8			2600				3300	3300			
40	T12	3000	3000	2500	3000	2500						
40	T12 1m	2800	2800	2300	2800	2100						
40	T12 2'	2000	2000		1900							
40	FC	2800	2800	2300	2800	2400	3200	3200	3200			
42	T12	3200		2500	3200							
58	T8	4600	4600	4000	4600	4000	5200	5200	5200	5000	3750	3750
60	FC	3650			3650	2900						
65	T12	4800	4800	4000	4800	4200						
70	T8	5400	5400		5300							
100	T12	8200	8200		8200							
125	T12	9500	9500		9500							

FLUORESCENT LAMP F18W/T8

OUTLINE: Dimensions in mm



ELECTRICAL DATA:		Nominal Value	Min.	Max.
Lamp Wattage	(W) :	18.0	16.6	19.4
Lamp Voltage	(V) :	57.0	50.0	64.0
Lamp Current	(A) :	0.370		

OPERATING CONDITIONS :		Ballast Type	Starter
Single Lamp Circuit	:	20W	FS-11, FS-22, COP/H-20, COP/H-46
Tandem Circuit	:	40W	FS-22

PHOTOMETRIC DATA:

COLOUR		CODE	Luminous flux lm	CRI Class	Colour Temp. (K)
UNIVERSAL WHITE	UW	125	1050	2A	4100
WARM WHITE	WW	129	1150	3	3000
COOL WHITE	CW	133	1150	2B	4300
WHITE	W	135	1150	3	3500
DAYLIGHT	D	154	1050	3	6500
PROFESSIONAL	ACTIVA	172	1000	1A	6500
PROFESSIONAL	GOURMET	175	650	1B	3700
PROFESSIONAL	SATIN	182	1350	1B	2700
PROFESSIONAL	DECOR	183	1350	1B	3000
PROFESSIONAL	BURO	184	1350	1B	4000
PROFESSIONAL	STUDIO	186	1300	1B	6200
WARM WHITE DELUXE	PLUS	193	1000	1A	3000
COOL WHITE DELUXE	PLUS	194	1000	1A	3800

APPLICATION: For further lamp data refer to IEC 81 / EN 60081, most recent edition.

ATTENTION: The product must be used with suitable operating equipment and in accordance with the specified data.

Issued by : ERLANGEN Date : 05.83 Revision date: 29.04.91	DATA SHEET	Specification Nbr : 4510C Supersedes : 4510B 08.11.90 Page 1 of 2

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FLUORESCENT LAMP F18W/T8

PHOTOMETRIC DATA:

COLOUR		CODE	Luminous flux lm	CRI Class	Colour Temp. (K)
UNIVERSAL WHITE	UW	225	1100	2A	4200
WARM WHITE	WW	229	1250	2B	3000
COOL WHITE	CW	233	1250	2A	4100
WHITE	W	235	1250	2B	3500
DAYLIGHT	D	254	950	2B	6300
WARM WHITE DELUXE	WWX	232		2B	3150
COOL WHITE DELUXE	CWX	234		1B	3900
AQUASTAR		174	850	3	10000
GRO LUX	GRO		not suitable for lighting applications		

APPLICATION: For further lamp data refer to IEC 81 / EN 60081, most recent edition.

ATTENTION: The product must be used with suitable operating equipment and in accordance with the specified data.

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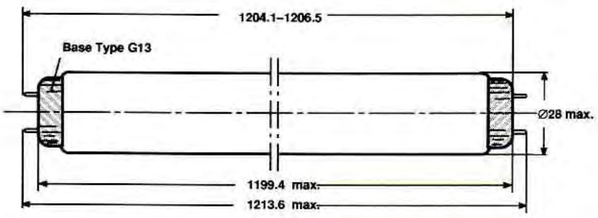
FLUORESCENT LAMP F36W/T8

OUTLINE: Dimensions in mm



ELECTRICAL DATA:		Nominal Value	Min.	Max.
Lamp Wattage	(W) :	36.0	33.7	38.3
Lamp Voltage	(V) :	103.0	93.0	113.0
Lamp Current	(A) :	0.430		

OPERATING CONDITIONS :		Ballast Type	Starter
Single Lamp Circuit	:	40W	FS-11, COP/H-20, COP/H-46
Tandem Circuit	:		

PHOTOMETRIC DATA:

COLOUR		CODE	Luminous flux lm	CRI Class	Colour Temp. (K)
UNIVERSAL WHITE	UW	125	2500	2A	4100
WARM WHITE	WW	129	2850	3	3000
COOL WHITE	CW	133	2850	2B	4300
WHITE	W	135	2850	3	3500
DAYLIGHT	D	154	2500	3	6500
PROFESSIONAL	ACTIVA	172	2300	1A	6500
PROFESSIONAL	GOURMET	175	1500	1B	3700
PROFESSIONAL	SATIN	182	3350	1B	2700
PROFESSIONAL	DECOR	183	3350	1B	3000
PROFESSIONAL	BURO	184	3350	1B	4000
PROFESSIONAL	STUDIO	186	3250	1B	6200
WARM WHITE DELUXE	PLUS	193	2350	1A	3000
COOL WHITE DELUXE	PLUS	194	2350	1A	3800

APPLICATION: For further lamp data refer to IEC 81 / EN 60081, most recent edition.

ATTENTION: The product must be used with suitable operating equipment and in accordance with the specified data.

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FLUORESCENT LAMP F36W/T8

PHOTOMETRIC DATA:

COLOUR		CODE	Luminous flux lm	CRI Class	Colour Temp. (K)
UNIVERSAL WHITE	UW	225	2500	2A	4200
WARM WHITE	WW	229	3000	2B	3000
COOL WHITE	CW	233	3000	2A	4100
WHITE	W	235	3000	2B	3500
DAYLIGHT	D	254	2500	2B	6300
WARM WHITE DELUXE	WWX	232		2B	3150
COOL WHITE DELUXE	CWX	234		1B	3900
AQUASTAR		174	2000	3	10000
GRO LUX	GRO		not suitable for lighting applications		

APPLICATION: For further lamp data refer to IEC 81 / EN 60081, most recent edition.

ATTENTION: The product must be used with suitable operating equipment and in accordance with the specified data.

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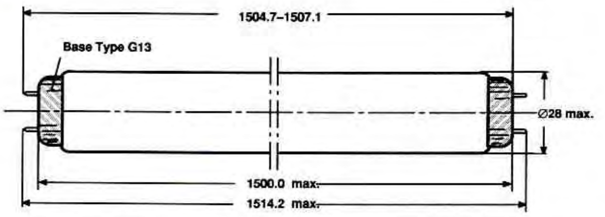
FLUORESCENT LAMP — F58W/T8

OUTLINE: Dimensions in mm



ELECTRICAL DATA:			Nominal Value	Min.	Max.
Lamp Wattage	(W)	:	58.0	54.6	61.4
Lamp Voltage	(V)	:	110.0	100.0	120.0
Lamp Current	(A)	:	0.670		

OPERATING CONDITIONS :	Ballast Type	Starter
Single Lamp Circuit :	65W	FS-11, COP/H-46
Tandem Circuit :		

PHOTOMETRIC DATA:

COLOUR		CODE	Luminous flux (lm)	CRI Class	Colour Temp. (K)
UNIVERSAL WHITE	UW	125	4000	2A	4100
WARM WHITE	WW	129	4600	3	3000
COOL WHITE	CW	133	4600	2B	4300
WHITE	W	135	4600	3	3500
DAYLIGHT	D	154	4000	3	6500
PROFESSIONAL	ACTIVA	172	3700	1A	6500
PROFESSIONAL	GOURMET	175	2400	1B	3700
PROFESSIONAL	SATIN	182	5200	1B	2700
PROFESSIONAL	DECOR	183	5200	1B	3000
PROFESSIONAL	BURO	184	5200	1B	4000
PROFESSIONAL	STUDIO	186	5200	1B	6200
WARM WHITE DELUXE	PLUS	193	3750	1A	3000
COOL WHITE DELUXE	PLUS	194	3750	1A	3800

APPLICATION: For further lamp data refer to IEC 81 / EN 60081, most recent edition.

ATTENTION: The product must be used with suitable operating equipment and in accordance with the specified data.

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FLUORESCENT LAMP — F58W/T8

PHOTOMETRIC DATA:

COLOUR		CODE	Luminous flux (lm)	CRI Class	Colour Temp. (K)
UNIVERSAL WHITE	UW	225	4000	2A	4200
WARM WHITE	WW	229	4800	2B	3000
COOL WHITE	CW	233	4800	2A	4100
WHITE	W	235	4800	2B	3500
DAYLIGHT	D	254	3900	2B	6300
WARM WHITE DELUXE	WWX	232		2B	3150
COOL WHITE DELUXE	CWX	234		1B	3900
AQUASTAR		174	3500	3	10000
GRO LUX	GRO		not suitable for lighting applications		

APPLICATION: For further lamp data refer to IEC 81 / EN 60081, most recent edition.

ATTENTION: The product must be used with suitable operating equipment and in accordance with the specified data.

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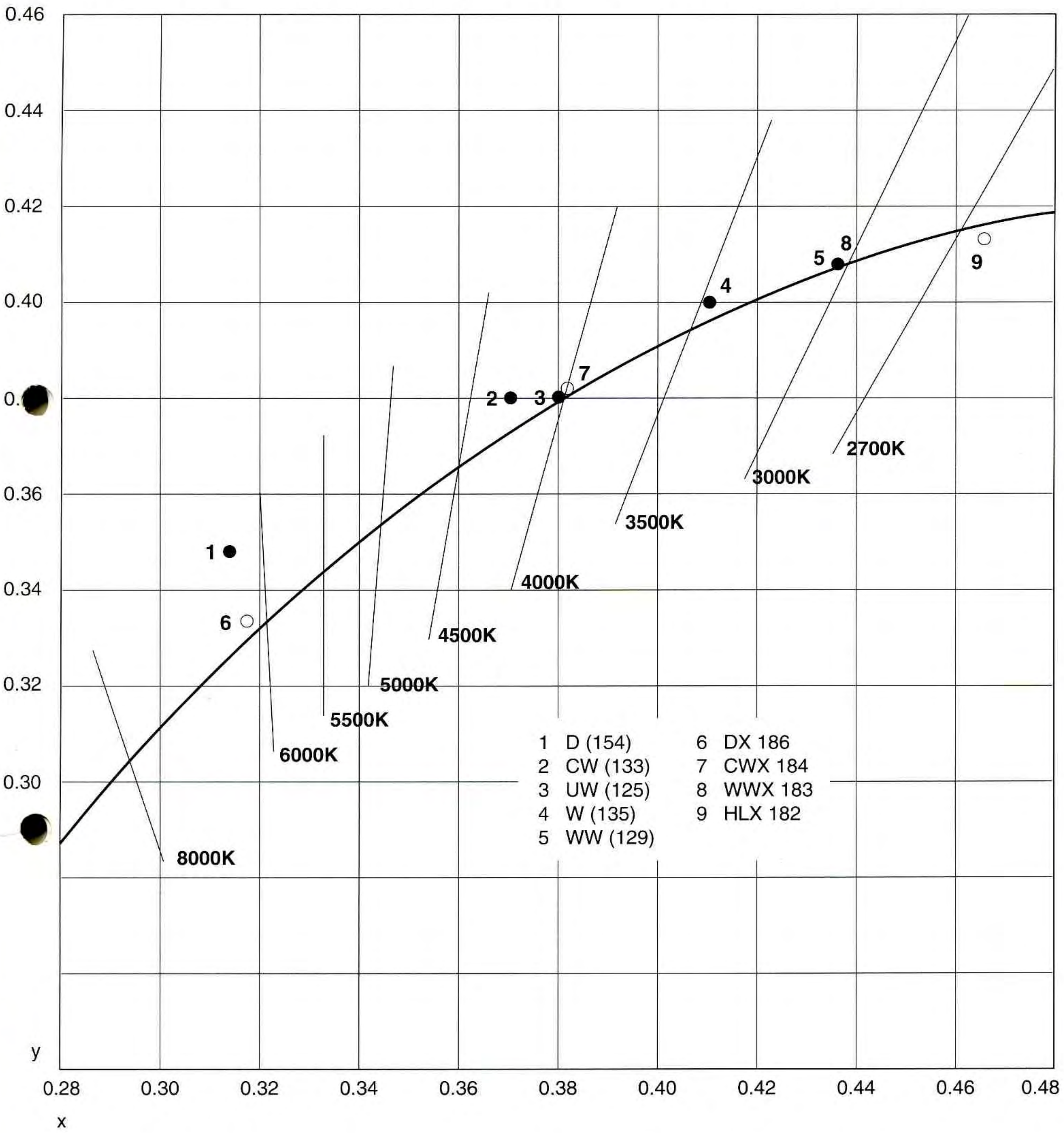
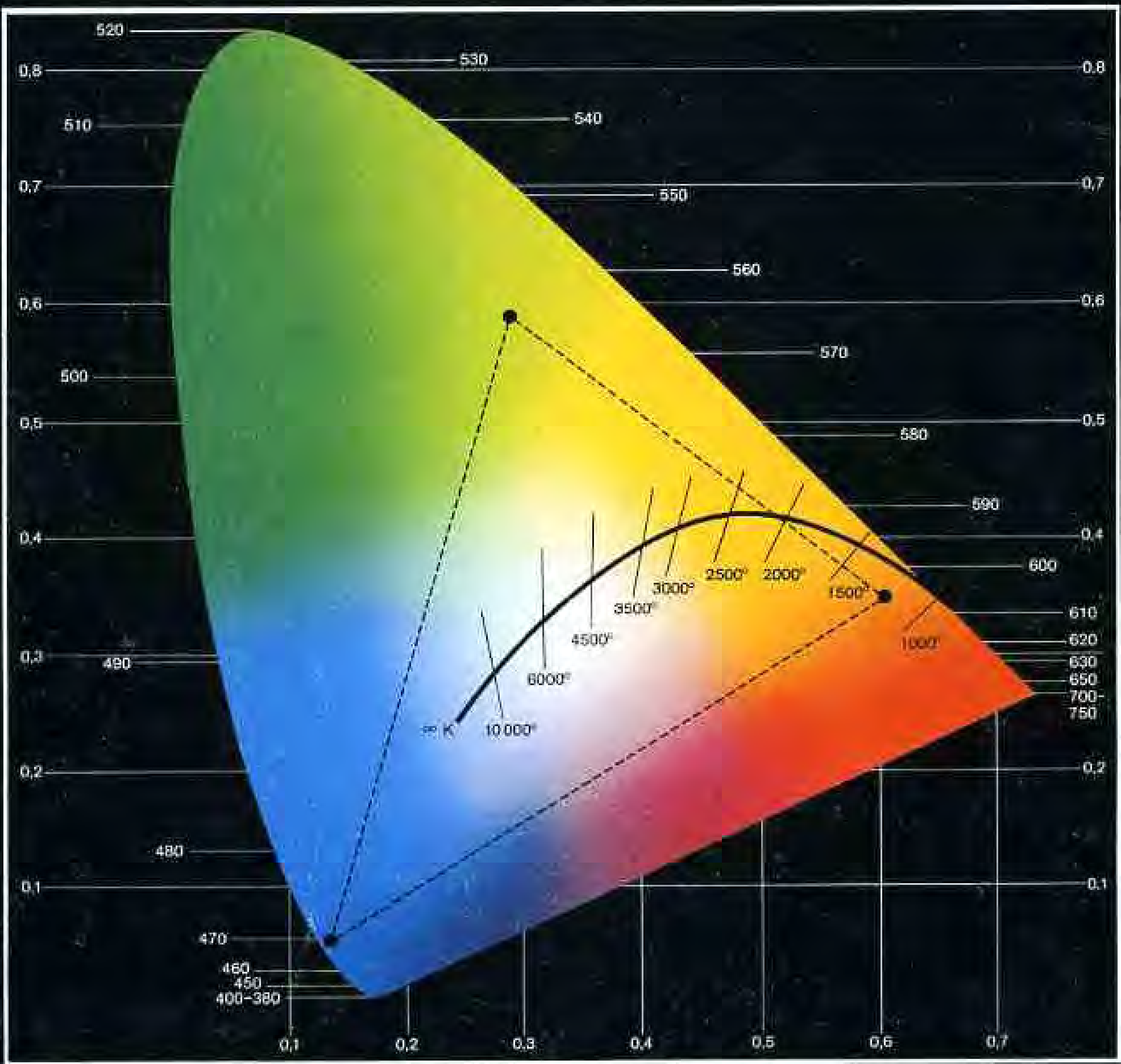
The most Common Fluorescent Lamp Colours in the C.I.E. Chromaticity Chart



Series 180, LUXLINE
Phosphor Colorimetrics



The CIE Chromaticity Chart shows the X - Y location of these 3 phosphors. Basically, depending on the proportions used in the phosphor mix, any lamp colour can be made within the triangle between the 3 single phosphors.

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