A comparison of linear Cold Cathode Lighting and linear Led products

By Mike Hall B.Sc., M.R.S.C.

Contents

Page

M. HALL. 16/02/2010.

Mike Hall is a technical consultant who spent 24 years as a senior member of the technical department of Masonlite (a specialist manufacturer of neon and Cold Cathode Lighting materials). He is Chairmen of the British Sign and Graphics Association Technical Committee and co-Chair of the European Sign Federation Technical Committee. He has sat on both BSI and CENELEC Technical Committees.

INTRODUCTION.

A comparison of the use of LEDs and Cold Cathode Lighting is not straightforward. It is often quite difficult to establish meaningful photometric and other data, particularly on LED systems. Only a few of the manufacturers publish data of value. Below is a table of the main features of LED and Cold Cathode systems.

FEATURE	**LED**	**COLD CATHODE**
GEOMETRY	POINT SOURCE.	LINEAR SOURCE.
EFFICACY	GOOD AT ABOUT 20 TO 40 LUMEN PER WATT.	VERY GOOD AT UP TO 60 LUMEN PER WATT .
COLOUR RANGE	RED, BLUE, GREEN, AMBER, LIMITED RANGE OF WHITES.	VARIOUS SHADES OF RED, ORANGE, YELLOW, GREEN, BLUE, PURPLE, RANGE OF WHITES.
COLOUR QUALITY	COLOURS ARE VERY NARROW BANDWIDTH EMMISSION.	RANGE OF BANDWIDTHS AND SATURATION. FULL RANGE OF WHITES FROM COLD TO WARM.
LIFETIME AND RELIABILITY	VARIOUS FIGURES STATED. VERY DEPENDENT ON QUALITY AND CONDITIONS OF USE.	45,000 HOURS. GOOD RELIABILITY IF OVEN PUMPED AND MADE TO EUROPEAN STANDARDS. EN50107.
TEMPERATURE SENSITIVITY	LIGHT OUTPUT DROPS AS TEMPERATURE RISES.	NOT GOOD BELOW -5 DEGREES CELSIUS. MAXIMUM EFFICACY WHEN LAMP AT 40 DEGREES CELCIUS.
VOLTAGE	LESS THAN 24 V.	LOW (less than 1000 volts) OR HIGH (up to 15000 volts).
TRACK RECORD	GROWING	DECADES IN THE SIGN AND LIGHTING INDUSTRIES.
HAZARD RATING	LOW IF CORRECTLY INSTALLED.	LOW IF CORRECTLY INSTALLED TO EUROPEAN OR US STANDARD.
FIRE HAZARD	LOW VOLTAGE DOES NOT MEAN NO FIRE HAZARD.	LOW IF CORRECTLY INSTALLED TO EUROPEAN OR US STANDARD.
FLEXIBILITY IN LIGHT OUTPUT	CAN BE DIMMED.	CAN BE DIMMED AND LIGHT LEVEL CAN BE SET BY SELECTING RUNNING CURRENT.

APPLICATIONS.

There is no doubt that LEDs have a tremendous potential in the lighting and display industries. In fact they are perfect for message centres, displays and giant TV screens. They can be used to produce very compact, very directional and energy efficient lamps to replace incandescent bulbs. Their colour changing ability has many decorative applications. However, they are a point source. Modifying their output with lenses and diffusers to produce linear light sources will reduce their efficacy, and requires relatively expensive optics to turn them from point to linear sources.

Cold Cathode Lighting, on the other hand is a linear source by definition and, with correct design will create stunning lighting installations in ceiling coves and wall washes, for example. It is second to none in this type of application. Although hot cathode (fluorescent) lamps may have slightly better efficacy they are extremely difficult to produce for custom lighting applications of this type. Cold Cathode Lighting is linear, but not necessarily straight lines. It is available as straight luminaire type fittings, but really comes into its own when custom made to fit almost any architectural geometry.

Whites for Lighting.

LEDs generate white light by combining blue and near UV emitting light from an LED with a yellow phosphor. The resultant spectrum has a large peak in the blue and a broad emission through to the red region.

White Cold Cathode can, for low cost installations where high light output is not required, be based on broadband emission halophosphate phosphors. These range from very blue whites of 8000K or more, through to warm whites of 2800K and also incandescent 2400K.

For longer life, brighter, better lumen maintenance, and higher colour rendition tri phosphor based Cold Cathode lamps are used. Again they range from 6500K to 2800K. These use the same phosphors used in energy efficient, long life hot Cathode and compact fluorescent lamps.

Efficacy calculations are given below.

Coloured lighting.

It is difficult to know where to start comparing the huge range of diameters, colours, light output levels and efficacies of Cold Cathode Lighting.

However, only coloured glass coated tubing emits light levels as low as some of the LED systems encased in coloured plastic tubes used for architectural lighting. All whites, red, orange, yellows, green, blues, pinks and purples which do not use coloured glass are substantially brighter under most running conditions. See the summary of estimated lumen per metre figures below. Note the ranges depending on the tube diameter at any one current.

COLOUR/PHOSPHOR	LUMENS PER METRE ON 30 mA TRANSFORMER	LUMENS PER METRE ON 60 mA TRANSFORMER	LUMENS PER METRE ON 100 mA BALLAST FOR LIGHTING
STANDARD GREEN	520 TO 750	900 TO 1300	1000 TO 1200
EMERALD GREEN	650 TO 1000	1150 TO 1700	1300 TO 1600
REDS AND PINKS	250 TO 450	200 TO 800	250 TO 800
YELLOWS	200 TO 650	300 TO 1100	350 TO 450

But what about the efficacy? The following table summarises estimated efficacies of various colours at various diameters and typical running currents.

COLOUR/PHOSPHOR	LUMENS PER WATT ON 30 mA TRANSFORMER	LUMENS PER WATT ON 60 mA TRANSFORMER	LUMENS PER WATT ON 100 mA BALLAST FOR LIGHTING
STANDARD GREEN	ABOUT 30	30	40
EMERALD GREEN	40 TO 45	35 TO 40	45
REDS AND PINKS	ABOUT 20	15 TO 20	15 TO 20
YELLOWS	ABOUT 30	ABOUT 25	ABOUT 25

Much is made of the purity of the light from coloured LEDs and this is entirely correct. They emit a very narrow bandwidth of colour. This is great, if that is precisely the colour that you want. However, if your corporate colour is not that specific amber, blue, green or red, you will be forced to use white emitting LEDs which are:-

a) More expensive,
b) Less efficient,
c) Less reliable on colour consistency, than other LEDs.

With Cold Cathode, however, there are a wide range of most colours available, one of which will better suit your corporate colour, if not directly, then will give good colour rendition and brightness when used for backlighting. The wide range of broad emission halophosphate whites, or the high brightness and high colour rendition tri-phosphors give designers a huge choice for either signage or lighting applications.

Control.

LEDs are very versatile and can be switched and dimmed relatively easily.

Cold Cathode can also be dimmed, but step changes in light output can be selected by correct selection of tube diameter and running current. An identical installation running on 60 mA transformers will generate approximately 1.8 times more light than if run on 30 mA transformers. By combining this with the range of tube diameters available, a range of light output levels are available – at the design stage. If you then factor in the range of colours, the possibilities are enormous.

Both LEDs and Cold Cathode can be used in colour mixing systems.

VOLTAGE.

LEDs are driven by low voltage, up to 24 V. However, this does not mean they are risk free. There has been at least one fire caused by an LED installation in the UK (in a petrol station!). Low voltage means high current to achieve a reasonable wattage. High current means high temperatures if things go wrong, and hence the cause of fires. Appropriate protection is essential for safe use. As far as the writer is aware, there is no National or International standard to work to with LED installations.

Cold Cathode lighting can be either high voltage (1000V to 5,000 volts relative to earth (in Europe, higher voltages elsewhere in the world)), or low voltage (less than 1000V). Low voltage installations rarely incur problems.

There have been standards for neon sign installations for many years in many countries. The introduction of an international European Norm involving the requirement for earth leakage protection on the secondary side of the high voltage transformers in1998 has reduced the already low incidence of fires to zero (as far as the writer is aware). Whether high or low voltage, neon and Cold Cathode, correctly installed is safe and reliable especially if the International Standards that exist are worked to.

LIFETIME AND RELIABILITY.

The lifetime data about LEDs is complex. The simple statements often seen of 60,000 or 100,000 hours are misleading, in the writers opinion. Read the detail of the information available from reputable suppliers and it is clear that the lifetime depends on:-

1) The quality of mounting of the LED in a module, which is dependent on the quality of the module manufacturer.
2) The quality of the heat dissipation in the module and from the module to its surroundings. These are dependent on the quality of the module manufacturer, the method of installation, and the installer.
3) The drive current. Set by the manufacturer of the module in most cases. Often set to give maximum light output, which may not be maximum efficacy (lumens per watt). There is also a trade-off between light output and lifetimes with LEDs.
4) The ambient temperature.
5) The resulting junction temperature inside the LED.
6) The type of LED. (InGaN or AlInGap).

Reputable manufacturers use two methods for describing lifetimes. One is based on the percentage of LEDs surviving, and the other on the percentage of the original light output. The latter is less important, in the writer’s opinion, because, in general, the light output of LEDs (whether that be high or low) remains reasonably constant over quite long periods of time.

However, there is nothing worse than seeing a series of LEDs where a significant number are no longer functioning. And what can you do about it? Very little. The cost of replacing a few LEDs is prohibitive and often impossible due to the often pre-wired modular design of LED systems.

Compare the above with neon or cold cathode. Well processed lamps under normal operating conditions can certainly last 45,000 hours or more. I know of lamps running more than 80,000 hours (but the light output had substantially dropped). In a similar way to LEDs these lamps both drop in light output and occasionally cease to function. Here there is considerable justification for replacing a single failed lamp and returning the installation to a fully functioning state.

Statistically meaningful life data is extremely rare for neon or cold cathode lamps. This is because each lamp maker is slightly different (it is a custom manufacturing industry, after all), and each would have to carry out huge trials to produce meaningful statistical data on their particular lamp efficacies and lifetimes. This is rarely practicable for them to do.

Certainly, by using UL or CE materials and carrying out the installation to recognised standards (e.g. EN50107), the safety and reliability of modern neon and cold cathode installations should be far greater than it used to be. Further, using modern oven pumping systems, processes and materials greatly enhances the reliability and lifetime of neon and Cold Cathode installations.

TEMPERATURE SENSITIVITY.

It is well known that LEDs operate very well in low temperatures. However, they do suffer a drop in light output as temperatures rise. Reliability is also dramatically affected by higher temperatures.

It has been very difficult to establish meaningful data correlating ambient temperature and LED light output, or even LED junction temperature, which is the real measure of an LEDs life expectancy.

We need to consider three temperatures:-

1) Ambient – the temperature of the surroundings of the LED module. Nominally, ambient room temperature is usually quoted as 25 Degrees C.
2) Board temperature – the temperature of the most accessible point adjacent to the LED proper on the module printed circuit board. With many modules even this test point is inaccessible.
3) Junction temperature – the critical temperature inside the LED. This point is always inaccessible.

Unfortunately, the relationship between these three figures is complex. The following is an oversimplification, but is supported by articles in the literature.

In one reported experiment the differences between ambient and board temperatures varied from 3 to 24 Degrees C. This variation was entirely due to the design of the mounting used by the various manufacturers involved.

In many references the junction temperatures are 10 to 15 Degrees above the board temperatures.

So, the junction temperature of an LED can be approximately 15 to 40 Degrees C. above ambient.

If we assume an ambient of 25 Degrees, this means that the junction temperature can be between 40 and 65 Degrees, depending on the LED board and module design.

One study has shown that LED life dropped from the expected 50,000 hours to less than 10,000 hours when the board temperature was varied from 40 to 57 Degrees C. These temperatures are clearly readily achievable.

The junction temperature of the LEDs in the above example will therefore be at least 50 to 72 Degrees C, depending on the quality of the mounting. According to Cree, their XR-E power LED has an expected lifetime (lumen maintenance of greater than 70 % of original) of 50,000 hours as long as the junction temperature does not exceed 80 Degrees C. In a poorly designed module or installation the Cree will therefore not last 50,000 hours.

Many LED modules are designed on the assumption that they will be fitted in a metal letter or box sign to aid heat dissipation. In lighting installations this is rarely the case.

Contrast this with neon and cold cathode where the optimum lamp running temperature is 40 Degrees C., and the drop off in light output (as temperatures rise) is small (and depends on the phosphor in question). Note modern Cold Cathode Lighting lamps use the same phosphors as CCFL and compact fluorescent lamps that run at considerably more than 50 degrees C. Also, the drive gear for neon and cold cathode should be kept relatively cool (less than 40 Degrees C. preferred). However, this is usually relatively easy to achieve by providing adequate ventilation.

	LIGHT OUTPUT COMPARISON		
	3000K EXAMPLE	**OSRAM LINEARLIGHT POWERFLEX 3000K**	**KEMPS 3000K 20 MM DIAMETER COLD CATHODE LOW VOLTAGE LAMPS RUNNING AT 100 mA.**
1	DRIVE GEAR	OPTOTRONIC OT 75	LEXABOX TWIN 2x990/100
2	INPUT WATTS	86	120
3	LIGHT OUTPUT PER UNIT OF DRIVE GEAR	1900	6240
	MADE UP FROM	2.8 METRES CONTAINING 120 LEDS	2 X 1.95 METRE LAMPS AT 1600 LUMEN PER METER
4	TOTAL LIT LENGTH (METRES)	2.8	3.9
5	**LUMEN PER WATT (3/2)**	**22**	**52**
6	**LUMEN PER METRE (3/4)**	**679**	**1600**
	HIGHEST LIGHT OUTPUT LED EXAMPLE	**OSRAM LINEARLIGHT POWERFLEX 5400K**	**KEMPS 6500K 20 MM DIAMETER COLD CATHODE LOW VOLTAGE LAMPS RUNNING AT 200 mA.**
1	DRIVE GEAR	OPTOTRONIC OT 75	LEXABOX TWIN 2x990/200
2	INPUT WATTS	86	178
3	LIGHT OUTPUT PER UNIT OF DRIVE GEAR	3600	10920
	MADE UP FROM	2.8 METRESW CONTAINING 120 LEDS	2 X 1.95 METRE LAMPS AT 2800 LUMEN PER METER
4	TOTAL LIT LENGTH (METRES)	2.8	3.9
5	**LUMEN PER WATT (3/2)**	**42**	**61**
6	**LUMEN PER METRE (3/4)**	**1286**	**2800**
	WARM WHITE BORDER TUBE EXAMPLE	**OSRAM LINEARLIGHT POWERFLEX 2700K (NOTE: NOT SUITABLE FOR OUTDOOR USE)**	**KEMPS 2800K 20 MM DIAMETER COLD CATHODE LOW VOLTAGE LAMPS RUNNING AT 50 mA.**
1	DRIVE GEAR	OPTOTRONIC OT 75	LEXABOX TWIN 2x990/50
2	INPUT WATTS	86	70
3	LIGHT OUTPUT PER UNIT OF DRIVE GEAR	1900	3276
	MADE UP FROM	2.8 METRESW CONTAINING 120 LEDS	2 X 1.95 METRE LAMPS AT 840 LUMEN PER METER
4	TOTAL LIT LENGTH (METRES)	2.8	3.9
5	**LUMEN PER WATT (3/2)**	**22**	**47**
6	**LUMEN PER METRE (3/4)**	**679**	**840**
	APPEARANCE	SERIES OF DOTS	CONTINUOUS LINE

GLOSSARY OF TERMS.

BLACK BODY. A full radiator. A thermal radiator obeying Planck's radiation Law.

BLACK BODY LOCUS. The curved line on chromaticity diagrams representing the chromaticities of black body radiators.

CANDELA. Unit of luminous intensity. Equal to 1 lumen per Steradian.

CHROMATICITY. Colour defined by either by coordinates on a plane diagram, or by dominant wavelength and purity. Most commonly used are x and y chromaticity coordinates as defined by CIE 1931. Also used are u' and v' as defined by CIE 1974.

CHROMATICITY DIAGRAM. Plane diagram showing positions of points of different chromaticity, and hence colour. CIE 1931 is the most used and is the rounded triangle shape graph.

COLD CATHODE. – The umbrella term for all light sources which rely on "cold" hollow cathodes for there operation. This is in contrast to hot cathode technology which is commonly referred to as fluorescent lamps. It includes neon signs and Cold Cathode Lighting.

COLD CATHODE LIGHTING. Most people refer to larger diameter (20 or 25 mm), higher current (100 mA or greater) cold cathode lamps as Cold Cathode Lighting. They are often used for architectural lighting.

COLOUR RENDERING INDEX. A means of comparing light sources for the degree to which coloured objects appear compared to a reference light source. Used to compare light sources for their ability to illuminate objects such that the objects appear with the "correct" colour.

COLOUR TEMPERATURE. Temperature of a full radiator which emits radiation of the same chromaticity as the radiator considered. This is often wrongly used as an abbreviation of CORRELATED COLOUR TEMPERATURE.

CORRELATED COLOUR TEMPERATURE. The colour temperature corresponding to the point on the black body locus which is nearest to the chromaticity coordinates of the lamp in question, on the CIE 1960 (u,v) diagram. On the CIE 1931 (x,y) diagram the correlated colour temperatures are often shown as a series of lines crossing the black body locus. Contrary to popular opinion, CCT is not a precise definition of lamp colour.

EFFICACY. Lumens per Watt. Sometimes used just for the lamp. More meaningful is to include the drive gear efficiency also. This allows us to compare the amount of light being created per input watt into the drive gear. If we compare efficacies including drive gear, we are comparing useful light versus energy consumption in a meaningful way.

EFFICIENCY. Efficiency is energy in versus energy out (Watt per Watt). This is not very useful when considering light sources.

ILLUMINANCE. Luminous flux falling on a surface element divided by the element area. Lumens per square metre or, more commonly, Lux.

LED. – Light Emitting Diode. A solid state light source.

LUMINANCE. The flow of light in a given direction. Usually stated in candela per square metre. Cd/m2. Often used to express the light coming off a diffuse surface.

LUX. Unit of illuminance. I.e. light falling on a surface. 1 Lux equals 1 lumen per square metre. 1 l/m2.

NANOMETRE. Unit of length equal to 10 to the power minus 9. Convenient unit for wavelengths of light.

M. HALL. 16/02/2010.