

Mike Hall Technical Services.

REPORT ON THE USE OF LEDs VERSUS NEON OR COLD CATHODE LIGHTING.

INTRODUCTION.

A comparison of the use of LEDs and neon or 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.

Firstly we need to establish exactly what we mean by the terms used:-

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

Neon. – A linear light source, usually based on fluorescence technology. Most people refer to cold cathode lamps with less than 15 mm diameter as “neon”.

Cold cathode. – The umbrella term for all light sources which rely on “cold” hollow cathodes for their 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 secondary lighting.

Efficiency and efficacy. Efficiency is energy in versus energy out (Watt per Watt).

However, we are interested in efficacy or Lumens per Watt. This measures the amount of light being created per input watt into the drive gear. If we compare efficacies, we are comparing useful light versus energy consumption in a meaningful way.

Below is a table of features comparing LED and Neon or Cold Cathode. We will explore some of these in more detail later in the report.

<u>FEATURE</u>	<u>LED</u>	<u>COLD CATHODE</u>
GEOMETRY	POINT SOURCE.	LINEAR SOURCE.
EFFICACY	GOOD AT ABOUT 20 LUMEN PER WATT.	VERY GOOD AT 30 LUMEN PER WATT OR MORE.
COLOUR RANGE	RED, BLUE, GREEN, AMBER, RANGE OF WHITES.	VARIOUS SHADES OF RED, ORANGE, YELLOW, GREEN, BLUE, PURPLE, RANGE OF WHITES.
COLOUR QUALITY	COLOURS ARE VERY NARROW BANDWIDTH EMISSION.	RANGE OF BANDWIDTHS AND SATURATION. FULL RANGE OF WHITES FROM COLD TO WARM.
LIFETIME AND RELIABILITY	STATED AS 60,000 HOURS PLUS. BUT SEE BELOW.	TYPICALLY 30,000 HOURS. GOOD RELIABILITY IF MADE TO EUROPEAN STANDARDS. EN50107.
TEMPERATURE SENSITIVITY	LIGHT OUTPUT DROPS AS TEMPERATURE RISES.	NOT GOOD BELOW -5 DEGREES CELSIUS. MAXIMUM EFFICACY AT 40 DEGREES CELCIUS.
VOLTAGE	LESS THAN 24 V.	LOW (less than 1000 volts) OR HIGH (up to 15000 volts).
TRACK RECORD	LIMITED IN THE SIGN INDUSTRY	DECADES IN THE SIGN AND LIGHTING INDUSTRIES.
HAZARD RATING	LOW IF CORRECTLY INSTALLED.	LOW IF CORRECTLY INSTALLED TO EUROPEAN OR USA STANDARDS.
FIRE HAZARD	LOW VOLTAGE DOES NOT MEAN NO FIRE HAZARD.	LOW IF CORRECTLY INSTALLED TO EUROPEAN OR USA STANDARDS.
FLEXIBILITY IN LIGHT OUTPUT	CAN BE DIMMED.	LIGHT LEVEL CAN BE SET BY SELECTING RUNNING CURRENT AND CAN BE DIMMED.

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SIGN APPLICATIONS.

Let us look at a specific example of a 2 m by 1 m sign box, with an acrylic face. Let us assume a mixed colour graphic, which requires a 6500 K white coloured back light. We will also specify a light output from the front face (with no graphic) of 400 cd/m².

400 cd/m² is equivalent to 1258 lumens per square metre. For a 2 m by 1 m sign this equates to 2516 lumens in total. With a utilisation factor of 50 % for the acrylic face, the lamps inside the sign need to generate 5032 lumens in total.

Let us compare the lamps and units required for this from LED and neon.

LED.

Using Osram BL04L-W2-865 reels of 240 LEDs each (6500 K white), we would need 10 reels to create 5100 lumens. Total power consumed is 380 Watts.

Neon.

Using triphosphor coated tubing, in 6500 white, we would need about 5.5 metres of 15 mm diameter tubing running on a 60 mA transformer (50 mA running current and at 1000 lumens per metre) to create 5500 lumens. This would normally be three lamps of 1.8 metres each. This could be driven by a standard core and coil transformer of 4000 V output. Total power consumed is 264 Watts. If you were to use a modern electronic driver for the neon, a further 20 % improvement in efficacy would be seen, or 211 Watts.

LED 380 Watts and high capital cost.

Neon 211 Watts and lower capital cost.

LIGHTING AND DISPLAY 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 and energy efficient lamps to replace incandescent bulbs and their colour changing ability has many decorative applications. However, they are a point source. Modifying their output with diffusers to produce linear light sources must greatly reduce their efficacy.

Cold cathode lighting, on the other hand is a linear source by definition and, with correct design will create stunning secondary lighting installations in ceiling coves and wall washes, for example. It is second to none in this type of application. The more efficient hot cathode lamp is extremely difficult to produce for custom lighting applications of this type.

So let us compare LED and Cold Cathode Lighting, in terms of efficacy.

KingLED White Jade tubing produces between 176 and 202 lumens per metre long lamp, depending on the colour. Power consumption is quoted at 10 Watts per metre long lamp. This is equivalent to 17.6 to 20 Lumens per Watt.

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 the above lamps. All whites, red, orange, yellows, green, blues, pinks and purples which do not use

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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
TRIPHOSPHOR WHITES	500 TO 900	1000 TO 1500	1300 TO 1500
HALO WHITES	350 TO 850	650 TO 1250	700 TO 1300
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
YELLOW	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
TRIPHOSPHOR WHITES	35 TO 40	30 TO 35	30 TO 35
HALO WHITES	30 TO 35	20 TO 30	20 TO 30
STANDARD GREEN	ABOUT 30	30	30
EMERALD GREEN	40 TO 45	35 TO 40	35 TO 40
REDS AND PINKS	ABOUT 20	15 TO 20	15 TO 20
YELLOW	ABOUT 30	ABOUT 25	ABOUT 25

COLOUR RANGE, QUALITY AND FLEXIBILITY.

Much is made of the purity of the light from 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 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 neon and 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 designs a huge choice for either signage or lighting applications.

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

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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.

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 writer's 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 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).
- 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 (if it were even feasible given module designs) is prohibitive.

Compare the above with neon or cold cathode. Well processed lamps under normal operating conditions can certainly last 30,000 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 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 reliability of modern neon and cold cathode installations should be far greater than it used to be. Further, using modern pump systems, processes and materials greatly enhances the reliability and lifetime of neon and cold cathode installations.

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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 can also be affected. 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.
- 3) Junction temperature – the critical temperature inside the LED.

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.

Sign boxes, particularly south facing, can achieve temperatures in excess of 50 Degrees C. The board temperatures of the LEDs in the sign box will be 55 to 75 Degrees C.

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.

Temperatures easily achieved in a sign box.

The junction temperature of the LEDs in that sign box will therefore be at least 65 to 90 Degrees C, depending on the quality of the mounting. A Cree 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 poor fitting the Cree will not last 50,000 hours in a sign box running at 50 Degrees C.

Contrast this with neon and cold cathode where the optimum 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. To prevent mercury vapour pressure from becoming excessively high, provision of a “cold spot” on a lamp is advantageous. 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 fitting the drive gear outside the sign box, and/or providing adequate ventilation.

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

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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.

Neon signs and 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 in 1998 has reduced the already low incidence of fires to (as far as the writer is aware) zero. 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.

TRACK RECORD.

LEDs in signs and lighting have only recently become commercially viable. They have little track record.

Neon and cold cathode installations have been carried out since the 1920s. There is much in the way of instruction and Standards to work with and to.

CONCLUSIONS.

LEDs certainly have their place in displays, message centres and giant TV screens, and as replacements for incandescent lamps in lighting applications.

Their use as an alternative to neon or Cold Cathode Lighting is less clear. Light output, efficacy and lifetimes can be compromised by inadequate design and installation. The environmental conditions can actually preclude their use in extremes of temperature. E.g South facing installations in hot climates.

LEDs are point sources which have plenty of significant applications. When a linear source is required, such as in architectural lighting, then there is still nothing better than neon or Cold Cathode Lighting.

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