LLUMARLITE
Lighting Solutions

What Do I Need From A Light Source?

Part 1 - Colour

Part 2 - Flicker

Part 3 - Lifetime

Part 1 - Colour

Photo by Lønfeldt

What do I need from a light source?

Part 1 - Colour

Many of us knew where we stood with existing lamps – tungsten or halogen at home and for display lighting. Fluorescent lamps in the office. Discharge lamps for factories, warehousing, and outdoor lighting. These had developed to a steady saturation point and we had grown with them, to understand what quality of light we should expect - How much energy they'd use? How often we'd have to clean or replace them? (although despite designing with a suitable maintenance factor, no-one did ever clean them, or 'bulk' replace them!).

Colour Quality

This is measured in two ways. Colour Appearance and Colour Rendering.

Colour Appearance

How 'warm and welcoming' (2700 – 3000K or colour '27 - '30), 'cool and efficient' (4000K or colour '40) or 'cold and stark' (5,000 – 8000K or colour '50 to '80) looks to an occupant. Although, we humans adapt to the colour once we are in an area, as do modern cameras (which are now mainly smartphones of course!). Colour differences are most noticeable when going in and out of different areas. This colour can affect our mood, attitude and as we move towards the 'cold and stark' blue-ey end of the colour spectrum, we are now finding that can affect our sleep patterns and wellbeing in an indoor environment. So, it is unfortunate that much of the earlier and current 'cheaper' LED lighting is often this harsh cold colour that we are being told is 'daylight'.

Colour can affect our mood and attitude

Natural daylight changes colour from warm (dawn) to cool (noon) back to a warm red glow (sunset), so we do not need to be 'blasted' with a poor and unnatural rendition of midday light throughout our working day.

So, to choose a 4000K lamp or LED we are looking for the '_40' part of the colour code.

Personally, my favourite for an office remains "intermediate" 3500K, i.e. '_35, but this colour is less readily available. As lamp and LED businesses became globalised - 4000K gradually became the norm in UK offices to fall in line with the larger markets brought by our European colleagues.

Colour Rendering

How the light source 'renders' or reflects light to the eye. If we were trying to compare cloth samples in a tailor's shop or carpet samples for a home, we would prefer a light source with a full spectrum (all the colours of the rainbow) in it e.g. tungsten or halogen lamps. These have a Colour Rendering Index (CRI) or 'Ra' of 100 i.e. 100% of the spectrum will be generated by the lamp, so any colour not reflected by the sample material is simply because that colour is being absorbed by the said material i.e. 'subtracted'.

At the lower end of lamp quality, maybe an industrial application where colour does not matter to us or what we often see in an LED street lamp application – it does not really matter to us what colours we see, just that we are able to read text on a box label or see obstructions when moving around. In these situation's the CRI or Ra can be as low as 40 i.e. we can only see 40% of the colours reflected (compared to the 100% we would have seen under the tungsten lamp). Hence in these circumstances, poorer colour rendering means we have lost some of the colours of the spectrum from our light source. Anything reflecting light will give a poor or false colour rendition. This is important if buying clothes. If the colours of a shirt or dress looked bright and vibrant in a shop, we'd want them to look the same wherever we went. So, retail lighting should demand a high CRI or Ra close to 100%. In this situation, a compromise maybe required between balancing energy costs and light source production costs. Llumarlite would specify a colour quality 'CRI' or 'Ra' of 90+ (which means 90 or higher).

Anything reflecting light will give a poor or false colour rendition.

The same Ra 90+ is also what Llumarlite would specify for healthcare applications, where comparing patients' complexion or appearance is an important way of recognising an ailment or change.

In an office or other workplaces, we need to recognise people and read their expressions (less critically than in healthcare) as well as being able to carry out paperwork tasks and perhaps read coloured text or graphic designs. So, a slightly lower CRI or Ra is acceptable, 80% is normally specified i.e. Ra 80+.
This colour quality makes up the blank referred to above, so the _40 lamp colour appearance specified above has an added '8' for an office environment needing a CRI/Ra of 80% – i.e. '840'.

There is little written evidence that colour rendering affects our performance, but we can only assume that getting closer to the full colours of the spectrum will be closer to natural light, hence using light sources of CRI/Ra 85 or 90 are likely to make people feel more comfortable in their working environment than the slightly cheaper CRI/Ra 80, but you really want to avoid the lower colour rendering lamps indoors.

The bad news with LED rather than the traditional lamps, is that we can no longer change the lamp colour appearance, rendering or quality by substituting a relatively cheap replacement lamp. We must make the colour choice initially during luminaire selection, and once installed it is likely to stay that way for the light fitting's lifetime as an integral part of a fixed luminaire. Otherwise, there will be (and is) a major programme of recycling and luminaire replacement to carry out.

The good news with LED is that it is becoming cheaper to make luminaires with variable colour, adjustable tuneable white, by building in LEDs at the warm end of the spectrum along with those of a cooler colour appearance, and control equipment to blend and set or vary these colours. Along with flexibility, and the choice to alter the mood of an area, the addition of more specialist controls can allow us to make the lighting more variable or personal, now called "Human Centric".

Colour can affect our mood and attitude

Now that we can specify a lamp or LEDs colour, we will want to also understand it's flicker and lifetime metrics – these subjects are covered in Part 2 and Part 3.

Part 2 - Flicker

Photo by Fabio Ballasina

What do I need from a light source?

Part 2 - Flicker

Many of us knew where we stood with existing lamps – tungsten or halogen lamps and fluorescent in the office. These had developed in quality to a steady saturation point, and we had grown with them to understand what quality of light we should automatically expect. One thing we have taken for granted is the elimination of flicker with these traditional light sources.

In the conventional light bulb, tungsten lamp filaments continue to remain hot between the 50Hz AC excitation, the resultant glow dampening the 100Hz resultant flicker to an extent.

Recent fluorescent lighting has largely eliminated the flicker, as we found that when operating from the old wire-wound magnetic chokes flicker had adverse effects on many of us, hence 'high frequency' electronic control gear was introduced to operate fluorescent lamps above that noticeable to the eye whilst maintaining efficient energy use in its day.

Then came LEDs and everyone seemed to forget these learnings.

Yes, we'd become so used to automatically expecting high-frequency control gear to come with fluorescent lighting that we simply assumed that LEDs (being better than fluorescent) would automatically tick this box – but it doesn't - unless the driver (control gear) is carefully selected and specified.

What is the problem?

The problem is not the LEDs, but its control gear i.e. the driver. It is cheaper to make an LED driver that operates the LEDs at 50Hz AC, which when rectified becomes 100Hz to coarsely simulate DC, so by default we're back to the flicker problem we had identified in the 80's for fluorescent. A poor default quality is where we often end up, with new technology, when we don't know what to set our expectations against.

Add to this dimming, where the waveform energising the LEDs is often 'cut' which makes flicker more dramatic hence more noticeable, or frequencies and interference can change through the dimming range exacerbating flicker.

What flicker frequency affects people?

Low frequencies below approximately 100Hz are known as visible flicker, we can often notice it. Invisible flicker is frequencies above that which tend to give stroboscopic effect on moving objects, these may otherwise not be noticeable but still have effects on us and how we perceive rotation or the speed of moving objects, this can interfere with filming/video recording and slow-motion replay where flicker is near to a multiple of the frame rate. (Note however, that patterns in video often taken by mobile phones is not a measure of harmful flicker rate, it can be due to the filming frame rate and the display screen refresh rate – hence this must be measured by purpose made specialist equipment). Below is a rough outline of potential flicker frequency issues:

Approximately 3-30 (possibly 70) Hz can cause photo-induced Epilepsy in people

Up to approximately 90 Hz can affect visibility in people

Up to 400 Hz can have an adverse effect on people

1000 – 3000Hz (1-3KHz) could cause other effects on people

Why does flicker effect people?
Humans like most animals have evolved in the wild, the visual environment was daylight from the sun, which essentially is a hot body glowing with little or no flicker. Our eyes have evolved to see detail and colour in the centre but detect changes in light and movement towards the periphery of our vision, to draw our eye to items of interest and look at the detail if we need to.

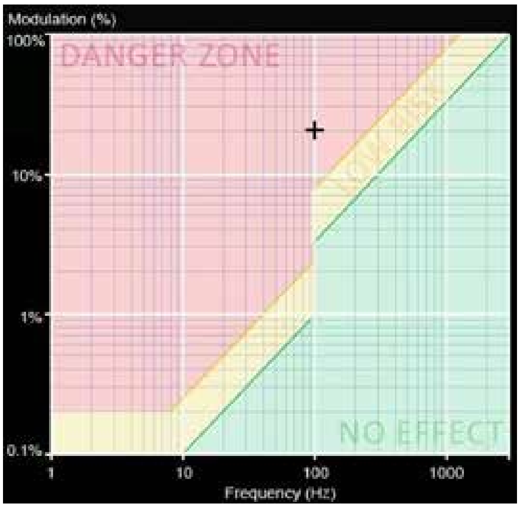
This instinct is probably from hunting or being hunted, invoking the subconscious 'fight or flight' adrenaline and reactions. It is thought that flicker also brings this effect, although the brain and body are unable to fight or flight to get away from the flicker, or even realise it is affecting us. Also, our brain trying to process multiple images could affect us. Both become a subconscious stress upon us potentially leading to fatigue, eyestrain, headaches or worse.

The severity of flicker also has an effect, i.e. how much light is there all the time in the background compared to the bright of flashing peaks. This is known as modulation and is measured in % flicker.

Why does flicker effect people?

Plotting flicker frequency against % flicker on a graph can help highlight the potential flicker risk problem. The chart shows that low frequency combined with high % flicker has the highest health risk (highlighted in red), and this improves through a low-risk (amber zone) to a no effect (green zone). It is obvious we should aim our lighting specification for flicker to be in the green zone. The longer or more intensively somebody is working under artificial lighting, the higher the standard employers should offer to minimise health risk, potential mistakes, hence maximising performance and comfort.

This IEEE graph is taken from a random test Llumarlite carried out on a sample 'budget' flat panel LED luminaire and driver. You can see that it has plotted across at 100Hz flicker rate and a modulation of 20%.



This driver and luminaire is clearly not in the 'low-risk' or 'no effect likely' category.

You may also be interested in the fact that, not only does this flicker mean it is unsuitable for office use, it also had very poor colour rendering (Ra64) - which means it would not meet the Ra80 recommended for an office. Meaning people would not be able to recognise colours properly.

What is the lighting industry doing about it?

Unfortunately, regulations follow new technology, but these issues are identified by old and new research and highlighted by people such as myself through the Lighting Industry Associations (LIA) to Lighting Europe and CIBSE/SLL to the various lighting and standards institutes and government bodies. Guidance comes first, the updated Lighting Europe LED Metrics guide is out now and brings this right up to date. Standardisation will follow, but meanwhile you should be aware of the potential problems that already exist across the country where poor-quality or low-cost product has been unwittingly installed, reducing the potential of employees in all sorts of buildings by inadvertently reintroducing the potential health and performance issues of these 'Sick Building Syndrome' problems.

Part 3 - Lifetime

Photo by Ezekiel Elin

What do I need from a light source?

Part 3 - Lifetime

Many of us knew where we stood with existing lamps, here I discuss how to choose LED luminaires to meet your lifecycle needs and helps avoid yet more cheap imported LED products draining our global environment's resources due to their inferior performance against expectations.

Lifetime.

Essentially how long a lamp or LED (now often called 'light source') is expected to last. We should include the whole luminaire as a system now, as often the whole unit may have to be replaced rather than just the light source.

What do they mean by 'last'?

It could be quite simple in terms of older technology – a typical household tungsten lamp (light bulb) would last until the tungsten filament had gradually evaporated itself away, i.e. worn out, and this would have been close to 1000 hours.

A fluorescent lamp would have kept going until the cathode emitter had 'burned off' during starting i.e. by the number of switching cycles in its lifetime. This would have been indicated by the lamp ends becoming black where this had happened over time, and eventually stopped working at approximately 10,000-15,000 hours. If it was never switched off, it could last much longer although it's output would diminish.

Stop working?

The mortality rate (lamp and electronic component life) is measured statistically. The life expectancy of these are expressed as "to 50% failure" i.e. when half of them would be expected to fail. In the home, you'd just change the bulb when it failed, for some commercial or industrial applications where maintenance can be more expensive or disruptive, 'bulk replacement' may be considered more effective, where a statistical survival curve would be followed and as lamps were predicted to start to fail the whole lot would be replaced at once.

> 'Bulk replacement' may be considered more effective

Useful Life?

The light output of a tungsten lamp would not depreciate by any noticeable amount through its life, but most other lamps would. Fluorescent lamps would show end blackening and mercury would soak into the phosphor coating reducing the efficiency of the coating as well as changing the electrical discharge properties within the lamp. High-pressure discharge lamps have aggressive chemicals in them and operate internally at high-temperatures and pressures.

These could eat away at internal cathodes, overheat and damage the Quartz to metal seals, or simply evaporate through the inner envelope of the lamp.

Hence lamps can continue to operate at a reduced output of efficiency, this is called lumen maintenance, and would usually be expressed in a graph or curve. Good lighting design should always make allowances for this figure assuming regular lamp changes. This allowance is called Lamp Maintenance Factor.

You haven't mentioned LEDs yet?
Well in general, a good-quality branded LED operating in a properly controlled microclimate could last more than 100,000 hours.

The correct microclimate would be a well-designed luminaire 'system' with heat sinking to maintain the LEDs junction temperature (where the power passes through the semiconductor) correctly and a quality driver regulating the power of the LEDs. This microclimate would also assume the luminaire is installed in the correct environment (ambient temperature) that it was developed and tested in and that there are no contaminants through life due to other materials, vapours, or gases in the environment of the LEDs.

As the LED is a solid-state device, this is unlikely to fail electrically in normal use, but the phosphor that produces light or the silicon than contains it will degrade gradually, this accelerates if overheated or contaminated, but is a gradual failure mode.

LED life is so long when compared to conventional lamps, that life testing to destruction is no longer carried out, it is impractical. So predictive testing and statistical extrapolation are

> LEDs Could last more than 100,000 hours

what classifies the LED, they are now usually tested to 2,000 or 6,000 hours. Hence 'useful life' is, in fact, best judged by the lumen maintenance of the LEDs, the metrics of this are explained below:

'L' The percentage of light output (lumens) anticipated from the LED (or set of LEDs) at the statistical point of measurement.

'B' The percentage of LED (or set of LEDs) anticipated to not meet the above output criteria (i.e. B50 means 50% will be below the 'L' figure, B10 means only 10% will be below the 'L' figure).

The lighting industry is trying to standardise on the L70 B50 figure, and 50,000 hours is what one would expect to be a reasonable life. As B50 is now accepted as the common standard, it will no longer need to be stated hence will be dropped, so we will just see L70 and hours life. In most applications, this lumen output would be expected after 10 years of reasonable use (ie normal use - expected 8 – 10 hours per day) in an office or school application, whereas fluorescent lamps traditionally may have had to be changed 2 or 3 times in a similar application.

As good quality LEDs survive for longer, the most likely cause of system failure (abrupt failure) within a light or luminaire becomes the control gear or driver. This can be a complex electronic device and it's life is greatly affected by temperature ('tc' being the drivers maximum case temperature measurement point – note this is different to the ambient temperature within the luminaire and the ambient temperature environment that a luminaire is guaranteed to operate in). The lifetime of control gear or drivers is based on when 10% failure is anticipated – this may be expressed as 0.2% / 1000 hours. Quality control gear might be expected to last 50, 75, or 100,000 hours, realistically this is the point at which one would expect to consider either luminaire or control gear replacement, as failures are expected to occur more rapidly after this point.

Hence driver lifetime is the weak point in the LED luminaire system, and so the control gear failure time is the likely luminaire failure time, so luminaire lifetime claims should be based on this driver lifetime factor, which would nowadays be expected to fall within the L70 LED useful lifetime period where quality luminaires, LEDs and drivers are used in the correct application and environment.

So, for LEDs the 'useful life' is the light output and the life expectancy of the complete luminaire, L70 50,000H and a 5-year warranty would be a good standard for most applications and would include control gear

For applications which are difficult to access safely, or installations which have high operating hours you may choose to select from products with a longer useful life.

Further information

Evaluating Performance of LED Luminaires
https://www.lightingeurope.org/general-publications
Human responses to lighting based on LED solutions https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I6z6

Definition of Colour Rendering
https://en.wikipedia.org/wiki/

Color_rendering_index
LIA Publication (Control Gear Life)
https://www.thelia.org.uk/sites/default/files/resources/LIA%20TS27%20-%20Lifetime%20of%20electronic%20controlgear.pdf

LIA Publication (Colour)
https://www.thelia.org.uk/sites/default/files/resources/LIA%20TS36%20-%20LIA%20Statement%20on%20Colour%20Rendering%20Quality%20%26%20Comments%20on%20IES%20TM-30.pdf

Institute of Electrical and Electronic Engineers standards regarding flicker and dimming in LED Drivers
https://standards.ieee.org/findstds/standard/1789-2015.html

Human Responses to Light
https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I6z6

SCHEER report – includes preliminary flicker information, requesting further investigation (– for flicker read from page36)
https://ec.europa.eu/health/sites/health/files/scientific_committees/scheer/docs/scheer_o_011.pdf

Where can I get help?

Llumarlite has a team of experts and colour comparator boxes in our office for demonstrations, or we can bring some sample colours and tools to your office to help you compare - what you have now against what you want in the future. Contact us today so that we can help you make the right decisions.

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LLUMARLITE
Lighting Solutions

Designing, sourcing and installing energy efficient lighting solutions for 25 years. Specialising in custom design, source and install retrofit lighting to help your business improve the visual lighting environment, save direct & indirect energy and reduce your carbon footprint

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