EXECUTIVE SUMMARY

Solid state light sources (LEDs) are characterised by long lifetimes when operated under certain conditions. However, like any other device they gradually lose their performance over time. This means that their useful life is limited in duration despite the fact that they keep operating during the entire lifetime of the application. Hence, for safety critical applications such as emergency lighting, additional performance monitoring remains mandatory to ensure that the application conforms to required norms. To ensure proper functioning at all times and under all circumstances, ETAP emergency lighting products provide an additional level of safety and assurance that is rarely found in emergency lighting products from other manufacturers.
LEDs have a long but not infinite lifetime

High quality LEDs\(^1\) are in general robust devices that can operate well in excess of 100,000 hours, when properly operated. However this can only be guaranteed when drive currents and operating temperatures are kept within certain limits as specified by the LED manufacturer. Also external factors such as moisture ingress in outdoor environments can have a detrimental impact on lifetime. However all of these issues can be solved by proper luminaire design and installation, and the probability of a catastrophic failure of the LED can be reduced to negligible/acceptable levels.

Despite their long inherent life, LEDs gradually lose performance over time. For emergency lighting applications, this performance is directly related to depreciation of lumen output. For white LEDs, lumen depreciation\(^2\) is mainly caused by a discoloration of the chip encapsulate and decreased efficiency of the phosphor coating, while in the longer run the internal efficiency of the die\(^3\) also plays a role.

Early generation and most low power white LEDs typically lose up to 50% of their initial lumen output within the first 8,000 - 15,000 hours. Due to improvements in thermal design and improved materials, high quality power LEDs nowadays can have average lumen maintenance\(^4\) of 50 - 70% after 50,000 hours of operation.

The useful lifetime of a LED is different from the lifetime of the LED component

When talking about LED lifetime in relation to emergency lighting applications, most people make the association with the mean time between failures (MTBF\(^5\)). MTBF marks the point in time at which a LED would fail completely and stop emitting light altogether. However, long before this point is reached in well designed applications, ageing phenomena will reduce the useful operating life of LEDs to a shorter period. Hence different indicators should be used to define the practical lifetime of a LED, as will be explained below.
To obtain the highest possible (optimum) lifetime of the LED light source, the following conditions should be met whilst designing the luminaire:

- LED reliability data as a function of operating conditions must be available. This information can be obtained from the manufacturer or (preferably) be measured by an independent company;
- Drive currents and heat must be carefully managed. More specifically, to achieve a typical lifetime of 50,000 hours with a 50% lumen maintenance, the internal LED die temperature must typically be kept below 80°C - 85°C under the worst possible operating conditions. Because this temperature is dependent on the design of the luminaire, great care should be taken when designing the luminaire;
- The optical system of the luminaire should be designed for the highest system efficiency. Higher initial margin means that greater depreciation can be tolerated before performance targets are impaired, thus longer application lifetime can be achieved.

All ETAP emergency luminaires are designed according to these criteria. Additionally, dimming is adopted in all maintained designs types to further increase lifetime.

To illustrate the lifetime of LEDs in an application, let us consider a practical example:

ETAP K1 and K2 signage luminaires typically reach a maximum die temperature of 85°C in emergency mode and 70°C in maintained mode. This means that according to manufacturers’ data we can expect that at least 50% of the initial performance will be retained after 50,000 hours of continuous operation. Because the initial brightness of K1 and K2 luminaires are in the range of 16 - 20 Cd/m² (while the EN1838 end-of-life level is defined as 2 Cd/m²), we can theoretically tolerate a lumen loss of up to 90% instead of 50%. This indicates that the LED light source in a K1 or K2 signage luminaire will continue functioning well beyond 50,000 hours whilst conforming to required norms. More specifically, from the published graphs we can derive that the projected theoretical average useful life in this case will be well in excess of 100,000 hours.
Understanding ETAP’s published light source lifetime

Care should be taken when interpreting a LED lifetime prediction.

Lifetime predictions are based on averages. E.g. if a LED manufacturer claims that 50% of their LEDs (from any batch) will emit at least 70% of the initial lumens after 50,000 hours of operation, this implies that 50% of the LEDs will not perform to the required levels (which in this case is emitting at least 70% of its initial lumens) after 50,000 hours. Therefore, in all practical terms, the lifetime of the LEDs will depend on the requirement(s) of the application. Also, the distribution around this average is not known, i.e. it is not known how many LEDs will perform to the requirements after, for example, 20 or 30,000 hours of operation.

Lamp manufacturers publish the lifetime of their lamps by lighting them for hours in a controlled environment. The same is true for LED manufacturers, apart from the fact that LEDs have only recently found their place in lighting and they do last longer than other light sources. The longest lifetime measurements for LEDs available today cover a time span of 30,000-50,000 hours. Hence, although the LEDs still may operate beyond 50,000 hours, it is not possible to state an accurate lifetime for LEDs without a great deal of uncertainty. Phenomena not detected today might play an important role in the longer run. For this reason, LED suppliers typically limit their lifetime predictions to 50,000-60,000 hours.

Each new generation of LEDs uses new improved materials and packaging technology. Therefore, reliability/lifetime measurements should be restarted from scratch.
ETAP ensures product performance

Because of these uncertainties, even though we can predict average lifetimes, we cannot guarantee it for each and every luminaire. For this reason additional monitoring of the actual performance is mandatory. Every maintained ETAP LED emergency luminaire is fitted with a light sensor (as standard) that monitors the light source’s performance over time. When the required performance level can no longer be achieved, a lamp fault signal is raised alarming that the LED should be replaced. This is a unique characteristic of ETAP luminaires to ensure maximum reliability.

The figure below shows the relationship between ETAP’s published lifetimes and the actual lifetimes that might be expected within a given emergency lighting application. The solid blue curve denotes the typical lifetime derived from LED manufacturers’ data. The shaded blue area on both sides of this curve indicates the performance deviation over different LEDs. This deviation might be attributed to LED flux binning, batch differences, differences in ageing conditions and so on. Also note that the average curve is accurate only up to the measurement timeframe (30,000-50,000) – the right side of it is based on extrapolation into the future.
The horizontal red curve marks the application specific useful end-of-life limit. When the blue LED depreciation curve crosses the target limit (the red line) the light source is considered as end-of-life. This point corresponds to the average expected lifetime which is published in the ETAP emergency lighting documentation.

Because of the aforementioned performance spread, and the limited precision of the performance measurements (marked by the shaded area around the theoretical end-of-life limit), the end-of-life is in fact not really a well defined point but rather a fuzzy area around the life expectancy, as indicated in the graph. Therefore, end-of-life could be defined as a range rather than by a single number. For this reason we are only able to declare typical end-of-life expectations, and not minimum guaranteed values.

The figure also makes it clear that when the initial performance level of the application (left) lies more closely to the end-of-life level, extreme fluctuations in actual life time may arise; in fact, some luminaires might even be end-of-life immediately after installation.
Conclusion: ETAP guarantees reliability

When comparing ETAP published lifetime figures with other published data, it is imperative to take the following considerations into account:

- All ETAP lifetime publications are based on stringent application dependent EN 1838 conformity levels, and not on opportunistic MTBF figures or performance data of the LED only.
- ETAP lifetime projections are all based on well documented component reliability data, complemented by thermal and performance measurements carried out on the actual luminaires.
- Claiming a warranty of the emergency lighting luminaire based on the warranty or expected lifetime of the LED light source does not make sense. ETAP guarantees the reliability of the entire application.
- Given the fact that the LED technology in emergency lighting has only been in use for a couple of years, it is not technically correct for manufacturers to claim their luminaire are “maintenance free” or have lifetimes exceeding 10 years without having a periodic test system. In all ETAP LED luminaires, a unique follow up system is included.

With regard to average lifetime expectations of LED luminaires, ETAP products are designed using a unique philosophy: ETAP guarantees that its luminaires perform according to the (legally) required performance levels for their entire lifetime.
Glossary

1 LED (Light Emitting Diode) – a semiconductor device that emits light when current is passed through it

2 Lumen depreciation – the gradual loss in light output of a given light source over time

3 Die – fragment of semiconductor material cut out of a larger wafer, and constituting a single device

4 Lumen maintenance – the property of a light source to keep its initial performance level in terms of lumen output over time

5 MTBF (Mean Time between Failure) – a statistical measure defining the time at which 50% of the components out of a large population have failed. For LEDs, which have low probability of failure and exhibit slow performance degradation, the tendency is to redefine MTBF as the time at which 50% of a large population/batch still have a minimum predefined performance level (typically 50% or 70% of the initial value such as lumen output)

6 LED package – the assembly that houses and protects the LED die. It also serves to disperse the internally generated heat and contains a primary optical system to direct the generated light out of the device

7 LED binning – process of sorting LEDs into groups according to a given performance measure. LEDs can thus be classified according to their lumen output (flux binning), colour (colour binning) or forward voltage (voltage binning)