Topic 7

Professional White Paper on LED Driver Reliability and Fire Risks

1. Failure Rate Baseline and Lifetime Calculation

LED emitters themselves are extremely long-lived, but the overall luminaire lifetime is often limited by the driver (Driver/PSU). The commonly used industry baseline is: Failure rate ≈ 0.2% per 1,000 hours. This is treated as a constant hazard rate $\lambda \approx 2\times10^{-6}$ per hour. The cumulative failure probability after t hours is given by: $F(t) = 1 - e^{(-\lambda t)}$.

Examples:

• 50,000 hours (≈ 5.7 years of continuous operation) → Cumulative failure ≈ 9.5%

• 100,000 hours (≈ 11.4 years of continuous operation) → Cumulative failure ≈ 18.1%

This means that if a luminaire is rated for 50,000 hours, in reality about 10% of drivers may fail within that period unless reinforced design, derating, or screening is applied.

2. Temperature Effects and Lifetime Reduction

Electrolytic capacitors follow the Arrhenius rule: 'For every 10°C increase, lifetime is roughly halved.' At 105°C, compared to the rated 55°C lifetime, service life is shortened by a factor of 32.

Examples:

• At 55°C → Lifetime ≈ 50,000 hours (≈ 5.7 years)

• At 105°C → Lifetime ≈ ~1,600 hours (≈ 0.18 years ≈ 2 months)

• At 105°C, 5,000 hours (≈ 0.57 years) → Cumulative failure ≈ 27%

• At 105°C, 10,000 hours (≈ 1.14 years) → Cumulative failure ≈ 47%

→ In high-temperature industrial environments, most drivers fail within a few thousand hours (often < 1 year).

3. Sources of Fire Risk

Conventional LED drivers are the largest heat and failure sources within luminaires. Main risks include:

1. High-voltage capacitors, MOSFETs, and transformers that fail in heat, causing shorts or smoke/fire.

2. Surge attacks at the input leading to overheating or capacitor explosions.

3. Low efficiency (85–92%), with 10–15% of power dissipated as heat in a small area.

4. Electrolytic capacitor dry-out → ESR increases → hot spots → fire risk.

5. PCB materials (FR-4/FR-2) carbonize above 110–130°C, creating conductive paths and ignition hazards.

4. Official Statistics and Case Studies

NFPA (2015–2019): ~6,600 fires per year linked to wiring/lighting, ~430 deaths, $1.5B in damages.

USFA (2011–2020): ~23,400 electrical fires per year, ~200 deaths, ~975 injuries.

CPSC Case Reports:

• Jul 2024 – Best Lighting: High-bay fixtures, plastic clip failure → 3 fires (no casualties).

• Dec 2024 – NetZero USA: High-bay fixtures, design flaw → 7 fires (no casualties).

• Aug 2025 – Viewrail: Stair-lighting controller overheating → 20 overheating/melting cases (no casualties).

5. Solution – Driverless Architecture

TTL – ParagonLED inside adopts ACCOB solid-state light engines, powered directly by AC, eliminating drivers and high-voltage components, removing ignition sources entirely.

• Multiple gold-wire connections act as micro-fuses: open-circuit on failure, no overheating.

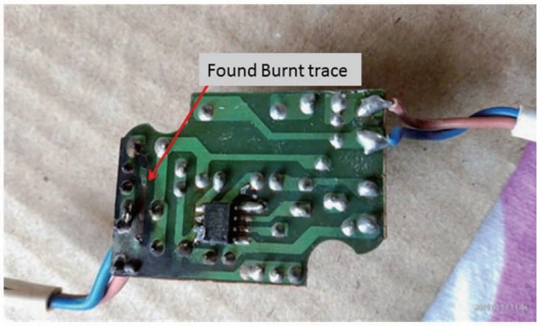
• Verified continuous operation at 100–145°C (tens of thousands of hours).

• Encapsulation with ceramics, quartz, or UL94 5VA materials → no flammable plastics.

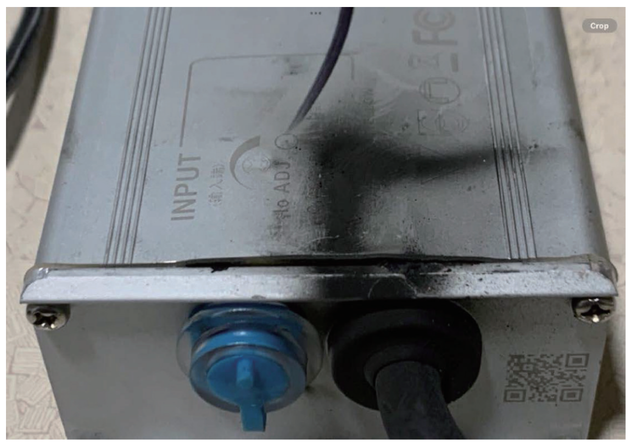
• Provides fail-safe lighting for steel, paper, nuclear, and other high-temperature industries.

6. Conclusion

The driver's inherent failure rate (≈0.2% per 1,000 hours) and accelerated degradation in high temperatures make it the bottleneck for luminaire lifetime and the leading fire hazard. Official data and case studies confirm the vulnerability of traditional drivers in industrial high-temperature conditions. TTL's ACCOB (ParagonLED inside) driverless architecture, with its solid-state design, gold-wire safety fusing, and high-temperature encapsulation, eliminates ignition sources and extends system lifetime, ensuring safer, more reliable operation in extreme environments.



Burnt Mark Under the PCB base cap



The LED driver shown in the image exhibits clear evidence of thermal runaway and internal combustion caused by excessive ambient temperature. The black carbonized residue on the housing indicates an internal flash event, consistent with capacitor venting or PCB carbonization. Such failure modes are characteristic of over-stressed drivers operating beyond their rated thermal limits, posing both electrical short-circuit hazards and ignition risks in industrial environments.