LED Driver and System Reliability

February 3, 2016

Warren Weeks, Director of Innovation & Technology
Doug Hamilton, Director Research & Development
Dennis Carpenter, Principal Reliability Engineer
Chris Bailey, Director of Business Development

Premise

All LED drivers are not created equal and need to be used in their intended applications.

SSL Luminaire Burn-in

- 24 hour burn-in revealed limited driver mortality
- AQL reduced burn-in time
- 100% “Glow-n-Go” may be just as effective

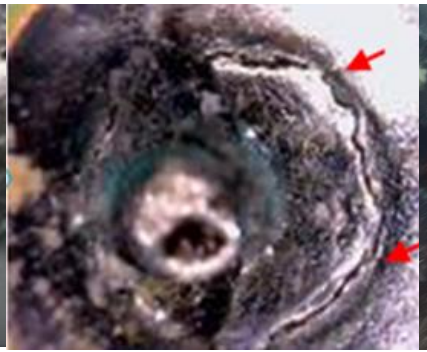


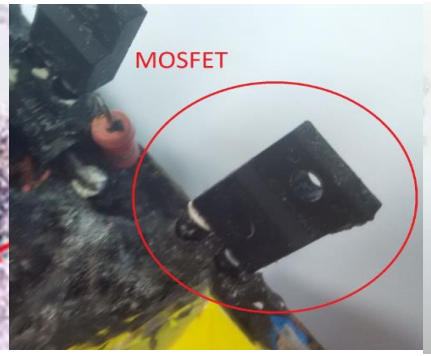
Old school approach that is is expensive.

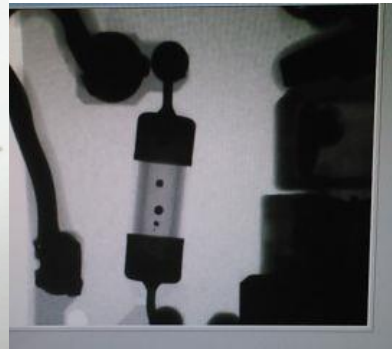
History of LED Driver Mortality (2011–2015)

- Blown fuses
- Blown chokes
- Failed MOVs
- Damaged MOSFETs
- Cracked solder joints
- Damaged 0-10V dimming circuit

Not only electrolytic capacitors

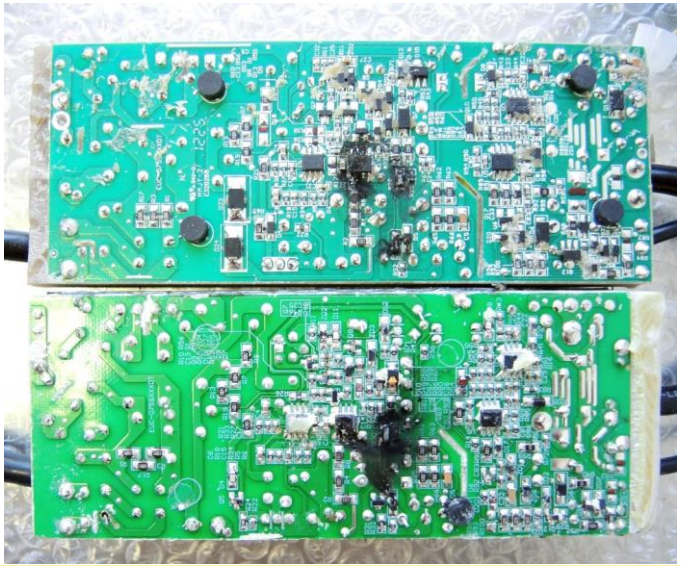






Definition for LED driver / system failure?

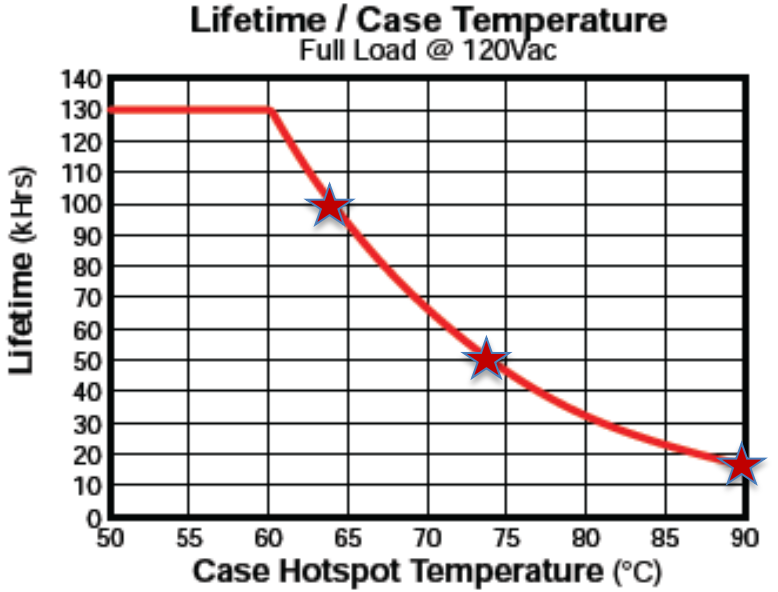
- Only if it generates a warranty claim?
- Falls below DLC, Energy Star, CA Title 24 requirements?
- Efficiency decrease? ROI is reduced?
- Parametric performance drift?
  - Increased ripple or flicker?
  - PF or THD out of tolerance?
- Mortality – no light output



Definition for Lifetime?

- What is a failure?
- What is the failure rate?
- At what confidence level?
- Ambient vs. case temperature?
- Is max case temp important?
- Is MTBF useful?

No industry consistency at all



MTBF	-	250,000 hours	-	Measured at 120Vac input, 80%Load and 25°C ambient temperature (MIL-HDBK-217F)
Life Time	-	67,200 hours		Measured at 220Vac input, 80%Load, Case temperature=60℃ @ Tc point. See life time vs. Tc curve for the details

ENVIRONMENTAL SPECIFICATIONS	
Ambient Operating Temperature	-35 ºC to 50 ºC
Max. Case Temp. (Tc)	75ºC (50kHrs) 85°C (20kHrs)
Max. Storage Temp.	75ºC

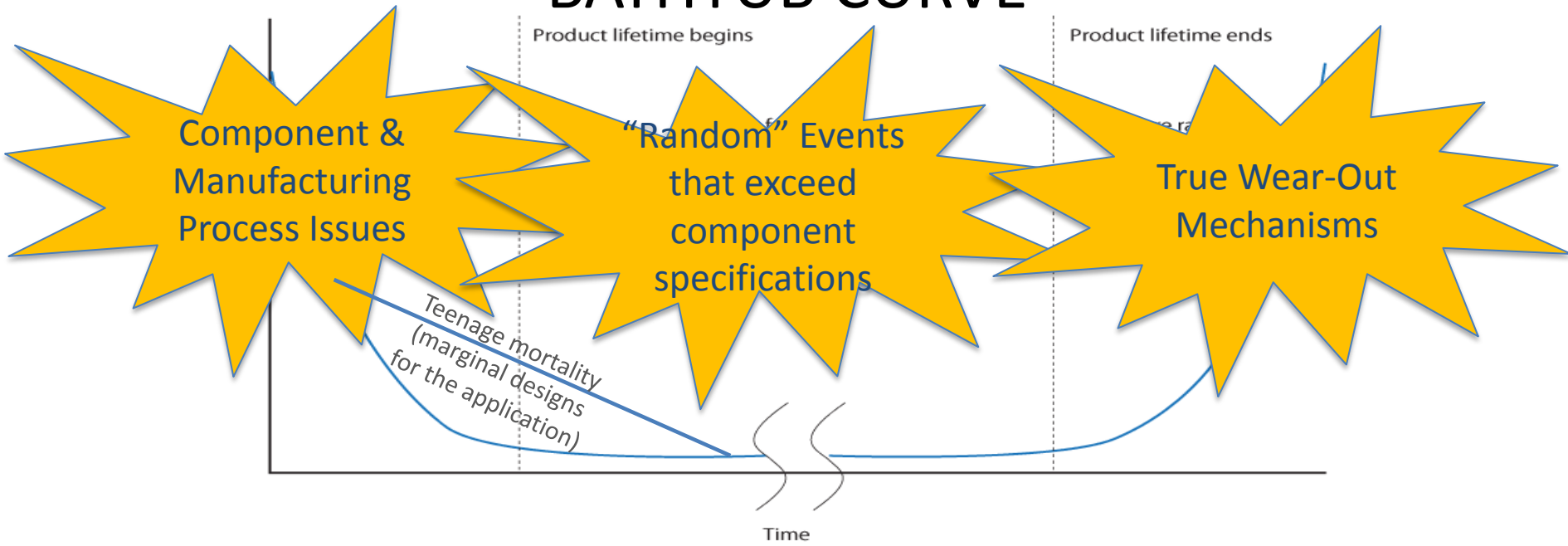
MTBF = Mean Time Between Failure

- Original calculations defined by MIL-HDBK-217F
- Other similar commercial standards have evolved (Telcordia SR-332)
- Assumes constant failure rate for each component which may/is not be true
- For example:
  - A product with MTBF of 50,000 hours will exhibit about 15% failures in the first year (8000 hours)
  - A product with MTBF of 500,000 hours will exhibit about 1.5% failures in the first year (8000 hours)

Over-emphasis on MTBF as a measure of reliability is misleading and dangerous.

Expected Lifetime & Sources of Failures

"BATHTUB CURVE"



4. The "bathtub" curve, which is the most basic illustration of reliability, shows product failure rates at given life-cycle points.

Recommended Levels of Surge Protection

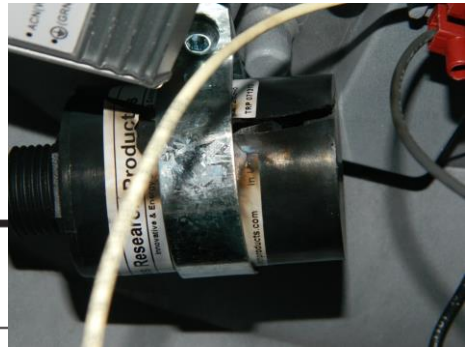


TABLE 2. IEEE C62.41 CURRENT/VOLTAGE WAVEFORMS FOR VARIOUS EXPOSURE LOCATIONS

CAT.	LEVEL	VOLTAGE (KV)	0.5μs X 100 KHZ RING WAVE CURRENT (A)	1.2 X 5μs (V) 8 X 20μs (A) COMBINATION WAVE CURRENT (KA)
A1	Low	2	70	—
A2	Medium	3	130	—
A3	High	6	200	—
B1	Low	2	170	1
B2	Medium	4	330	2
B3	High	6	500	3
C1	Low	6	—	3
C2	Medium	10	—	5
C3	High	20	—	10

120V only applications

120-277V light commercial
Primarily 277V industrial
347/480V indoor

347/480V outdoor

Usually requires added surge protector device

Solid State Light Sources Used in Roadway and Area Lighting

(ANSI C136.37-20xx)

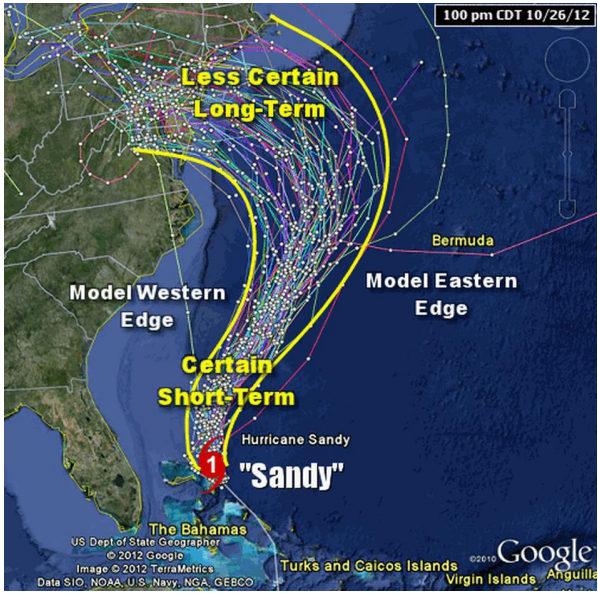
Exposure	Test Level
Typical	6kV / 3kA
Enhanced	10kV / 5kA
Extreme	20kV / 10kA

Driver/System Reliability Methodology

- What causes system failures?
  - Elevated temperatures
  - Thermal cycling
  - Surge / transient events
  - Repeat switching
- How to mimic this in “reasonable” amount of time to create failure distribution?

Driver Reliability Test Procedure

- 24 drivers and LED loads in environmental chamber
- Powered at maximum voltage: 277V, 347V, or 480V
- Cycled for 2 sec ON, 12 sec OFF
- 80°C to -20°C to 80°C (repeat)
  - 3°/min ramp time
  - Relative Humidity ranges from 85% to 20%
  - 1 hour dwell time at temperature
- Demonstrate 99% reliability at 90% confident level
  - Exponential distribution (constant failure rate) used to model zero (or low) failures
  - Weibull analysis for failure distribution when sufficient failures occur
  - 2 to 3 week test depending on number of failures



Luminaire System Reliability Test Procedure

- 8 “Production” Luminaires
- Thermal Cycling (1 hour dwell time)
  - Outdoor fixtures: -20°C to 60°C
  - Indoor fixtures: 15°C to 60°C
- Electrical Cycling
  - Fixtures powered as temp is raised, de-energized as temper is lowered
  - Minimum energized time of 1½ hours each cycle
- Humidity Cycling
  - 30% to 85% R.H., saturation period across multiple thermal cycles
  - Promotes saturation and drying, accelerate potential aging of susceptible materials
- Single failure constitutes failure to meet requirements
  - Corrective action necessary to improve design or manufacturing process

Parametric Performance

- Chroma C8000 automated system
  - 120V, 277V, 347V and 480V testing
- Full parametric pre-stress testing
  - Sets performance baseline
  - Keep LED driver suppliers honest
- Repeat post-stress testing
  - Parametric out-of-spec “failure”

LED Driver Selection – Rules of Thumb

- LED driver selection should be very early in NPD process, not last
- Forget max case temperature; design to desired lifetime case temp
- Design surge protection for Location Category of worst environment
  - Surge matters! And designs should be tested!
- Limit number of drivers per fixture
  - Failure rates are additive
  - FCC Title 47 CFR Part 15 troubles (remember to test)
  - How many LED drivers will be on sole dimming circuit?
  - Uses isolated electrical components
- Ask for driver manufacturers' reliability test data and quality plan

Thank you!

Warren Weeks
wweeks@hubbell.com
864-678-1050