Q-RAY™

Not all LED bulbs are created equal

Thermal Analysis of MR-16 under Insulated Environment

Background:

As part of efforts by homeowners to conserve energy, many have installed insulation for their homes. A concern on the use of LED lighting in insulated environment is ability of the LED luminaire to dissipate heat away from the light fixture. An inability to do so might have an impact to the junction temperature and subsequently impact the lifetime of the LED luminaire.

Q-RAY™ MR16 Replacement Lamp

Purpose of Design of Experiment (DOE):

The purpose of this thermal analysis was to study LED junction temperature changes and to predict the lifetime of MR-16 when it is installed in an insulated environment. Simultaneous Thermal Analysis (STA) was used to perform this experiment.

Methodology:

MR-16 lighting fixture was installed in a cavity that was insulated with 8 layers of R40 Insulators. Fig. 1 shows a mock-up of how the MR-16 was installed. This is similar to a typical recess down light ceiling installation. Fig. 2 shows photos of the actual testing box.

FIG. 1 - Mock-up Showing Cross-Section of Testing Box

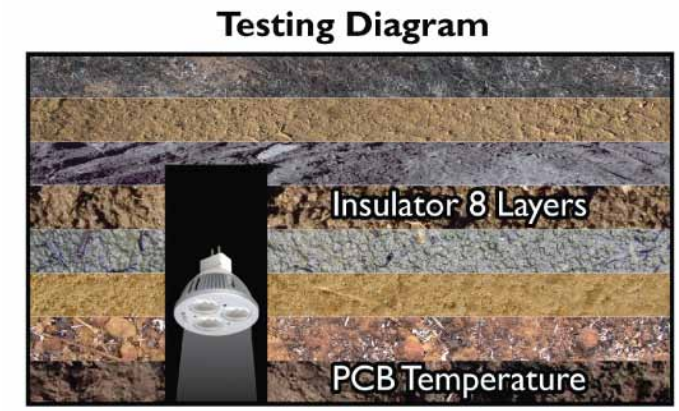

FIG. 2 - Actual Testing Box with Insulator

By using this methodology, we would be able to demonstrate thermal characteristics of the whole device under test (DUT) similar to life application. Data captured from this experiment was used to predict lifetime as well as to analyze the reliability of MR-16 installed.

DUT was placed under fully insulated environment. Then, it was powered up by intended AC voltage source. Temperature measurements were taken at intervals of at least 1 hour, for duration of 32 hours. Ambient Temperatures was controlled at 26°C +/- 1°C with 65% humidity level.

The table in Fig. 3 shows the actual PCB temperature readings captured during the 32 hours of testing period. The lux readings at the beginning and end of the experiment were also captured along with the temperature of the luminaire itself.

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The estimated junction temperature is calculated based on the following formula:

$$Tj = Tsp + (Rj\text{-}sp \times P\ led)$$

where Tj is the Junction Temperature,
Tsp is the Solder Point (or PCB) Temperature,
Rj-sp is the Thermal Resistance between the LED Junction and the Solder Point of the LED lamp,
P led is the Power Consumption of a single LED (the estimated P led of the tested MR-16 is 0.99W).

FIG. 3 - Results of Experiment

Actual Readings Captured

Date	Date (Time)	Hour	PCB Temperature °C	Estimate Junction Temperature °C (Warm White)
4/5/2010	8.30 a.m	0	0	0
	9.30 a.m	1	49	56.97
	12.30 p.m	4	77	84.97
	1.30 p.m	5	83	90.97
	2.30 p.m	6	86	93.97
5/5/2010	9.30 a.m	25	88	95.97
	11.30 a.m	27	85	92.97
	12.30 p.m	28	86	93.97
	1.30 p.m	29	86	93.97
	2.30 p.m	30	85	92.97
	3.30 p.m	31	85	92.97
	4.30 p.m	32	85	92.97

Summary of Experiment

Maximum Reading	88	95.97
Housing Maximum Temperature	70	92.97
Lux (before/after)	550/550	

Nomenclature

Rj-sp - Resistance junction to solder point (°C/W)
P led - Power consumption single led (W)
Tsp - Solder point temperature (°C)

Rj-sp	8
Tj Maximum °C (LED Datasheet)	150

Analysis of Findings:

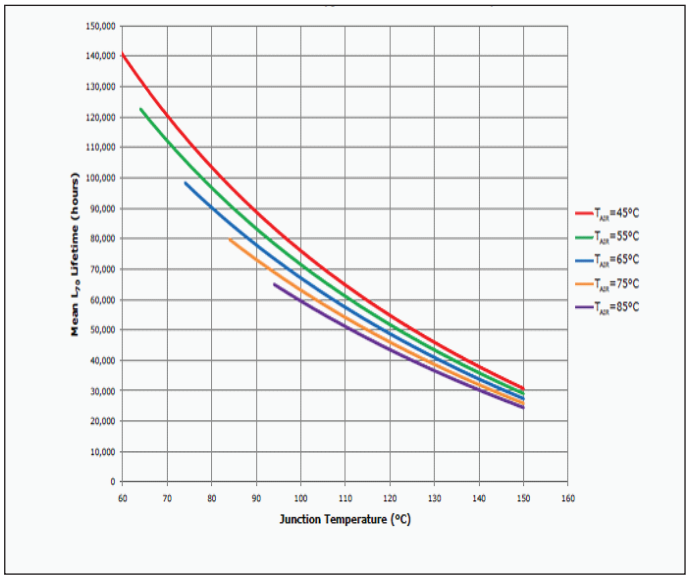
From the actual readings captured, the table shows that the maximum PCB temperature is 88°C, giving an estimated junction temperature of 95.97°C.

The experiment also shows that the maximum temperature of the LED luminaire is 70°C. There is also no degradation of the lux output.

From the results of the experiment, it shows that the maximum junction temperature of the MR-16 is ~96°C. This is below the maximum junction temperature that the LED chip can tolerate, which is 150°C (as given by the LED chip manufacturer).

Fig. 4 shows the L_{70} lifetime prediction graph for the LED chip based on current of 350mA. With maximum junction temperature hitting at less than 100°C, for Tsp of not more than 90°C, L_{70} is estimated to reach 55,000 hours.

FIG.4 – Mean L_{70} Lifetime Curve



Conclusion:

The results of the above experiment show that the Q-RAY™ MR-16 is able to withstand operating in a fully thermal insulated environment. This is due to the fact that that maximum junction temperature falls below the maximum tolerated junction temperature of the LED chip used. The results also concludes that the Q-RAY™ MR-16 is able to achieve lifetime of 50,000 hours when installed in a fully thermal insulated environment.

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