The Journal of CPRI,
Vol. 9, No. 1, March 2013 pp. 163–168

A Study on Integration of Acetone Charged Copper Pipes (ACCP) to MR16 Indoor Lighting Solutions

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The aim of the present study is to improve the thermal performance of the MR16, 7 W and 9 W LED decorative lighting solutions by integration of acetone charged copper pipe (ACCP) into its aluminum heat sink. With integration of ACCP, the luminary designed for lower wattage can withstand higher wattage and can accommodate more LED's with increased illumination. The heat transfer characteristics of high power LED is analyzed and a novel ACCP cooling device for high power LED is designed. The thermal capabilities of lighting solutions with integration of ACCP and without integration of ACCP for the same load (fixture + heat sink) were investigated experimentally. The experimental results indicate that the given load can accommodate more LED's for higher wattage which can be attributed to improved heat transfer after integration of ACCPs resulting in increased illumination.

Keywords: *LED, Temperature and Heat transfer.*

1.0 INTRODUCTION

Due to the recent low carbon dioxide emission requirement and energy saving movement, high-power light emitting diode (LED) technology has developed rapidly in the last 10 years. Recently, the LED has become widely used in modern indoor/street lights. High brightness LED's are rapidly emerging as a new generation of lighting source for its many distinctive advantages, such as long work-life, low-power consumption, environmental-friendly characteristics and so on [1]. Generally, LEDs conveniently eliminate the limitations of incandescent lamps by providing more light per watt. LEDs do last longer because they do not have filaments that will burn out. Besides, LEDs are known for high efficiency, good reliability, variable colors and low power consumption [2–3]. However, despite the rapid progress of this technology, overheating of these LEDs upon higher input current has become a major drawback [4]. Thus, thermal management of these devices is becoming more and more crucial as poor thermal management would cause excessive rise in the junction temperature and subsequently would either cause a complete thermal runaway of the device or breakdown of the chip [5]. Therefore, effective thermal design of LED packages with low thermal resistance is critical to improve the performance of LED. Currently, fin-heat sink [6–7] is still the mainstream method in industry due to its highest reliability and lowest cost. Meanwhile, Heat Pipe [8] is becoming a good option for emerging high power LED's. As to extremely high flux heat dissipation requirements, water cooling is widely studied. But relatively large system volume, coolant leakage and evaporation problems are the main disadvantages for its practical application in heat dissipation of LED's.

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Phase-change cooling is a promising method for cooling high heat flux devices. Heat pipe is one kind of phase-change heat transfer devices using Phase-change cooling method. There are several reports on thermal characterization of LED packages with the traditional thermal siphon heat pipe [9–10].

In this research work, on the lines of a conventional heat pipe, the temperature mapping of high-power LED luminary is studied with and without integration of ACCP onto the heat sink of MR16 LED luminary (Ø85 × 65 mm, 0.5 kg, Cast aluminum), have been investigated experimentally.

2.0 EXPERIMENTATION

MR16 and 9W LED down light (AVNI) is made up of aluminum extrusion. Suitable MCPCB with LED and lens are mounted at one end face of aluminum extrusion heat sink using thermal adhesive material and the ACCP are at the other end. Figures 1 (a–b) show MR16 and 9 W LED down light with dimensions.

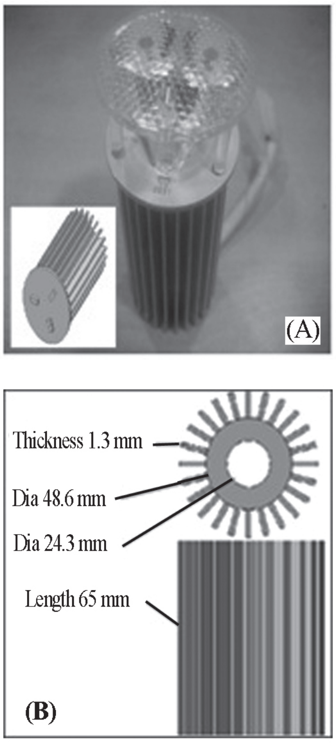


FIG. 1 MR16 AND 9 W DOWN LIGHT (A) IMAGE OF THE LED (B) DIMENSIONS OF THE ALUMINUM HEAT SINK

The specifications of the typical LED luminary are shown in Tables 1(a–b).

TABLE 1(A)
TYPICAL SPECIFICATIONS OF A LED LOAD

model no	mr7wa-m1(dat10006)
application (indoor/outdoor)	indoor
luminous flux	> 640 lumens
lamp wattage	7 W
working temperature	–5º C to +50º C
working humidity	10–90% RH
led type	high power led
led make	Philips
lumen efficacy	90–110 lumens/W
dispersion angle	110–120°
colour temperature	2700–3500 K
CRI	> 70

TABLE 1(B)
ELECTRICAL PARAMETERS

input voltage (V)	90 – 265 V_{ac}
input current (A)	0.039 A
input power (W)	7.5 W (±10%)
power factor	>0.7
current (THD)	<100%
output voltage (V)	10.06 V
output current (A)	0.67 A
output power (W)	6.4 W (±10%)
electronics efficiency	>85%
protections provided	surge and over current protection

Coaxial through holes were drilled in to extruded heat sink of MR16, 7 W and 9 W LED down lights. ACCP made out of copper tubes of diameter (5 mm) equal to holes made in heat sinkwere press fit into the holes and acetone liquid was charged into ACCP tubes after evacuation and crimp sealed. The length of ACCP (110 mm) was more than the length of heat sink (65 mm) to make provision for heat rejection to ambient conditions and to accommodate increase in volume due to vaporization.

Figure 2 shows image of LED luminary integrated with ACCP. The properties of the coolant used in the ACCP are presented in Table 2.

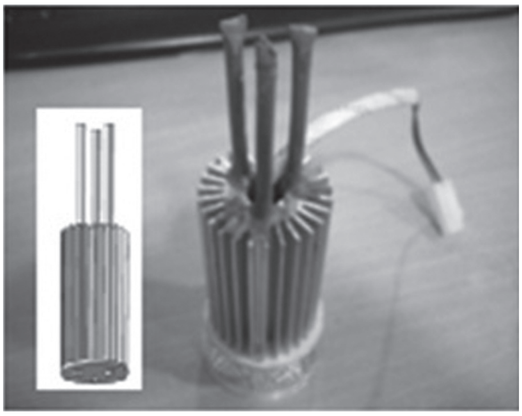
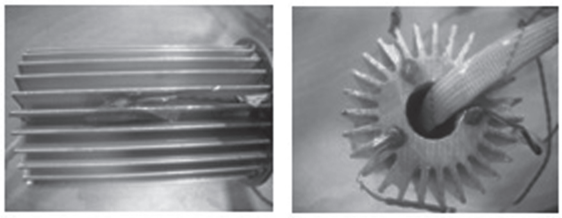


FIG. 2 MR16 LOAD WITH ACCP.

3.0 EXPERIMENTATION

In the experimental set up six thermocouples were employed to data log temperature. Two of them were bonded onto the MCPCB, one thermocouple on side face of heat sink and remaining three thermocouples on end face of heat sink as shown in Figure 3. From the load, all thermocouple were connected to data logger (Agilent make) for acquisition of data. Figure 4 shows the experimental setup.

(A) (B)



(C) (D)

FIG. 3 (A) THERMOCOUPLE LOCATIONS
(B) THERMOCOUPLES ON MCPCB
(C) THERMOCOUPLE ON SIDE FACE OF HEAT SINK
(D) THERMOCOUPLE ON END FACE OF HEAT SINK.

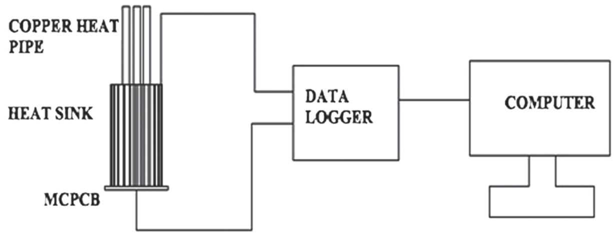


FIG. 4 EXPERIMENTAL SET-UP.

4.0 RESULTS AND DISCUSSIONS

Temperature at various points was logged and the experiment was repeated five times for a given input parameters for accuracy. The average of the temperature data of each thermocouple is drawn and the standard deviation computed. The variation of average temperature as a function of time was drawn with one standard deviation marked on either side of the average value.

The variation of temperature as a function of time for the MR16, 7 W LED luminary with heat sink (fins) is shown in Figure 5(a) and

TABLE 2

PROPERTIES OF LIQUID ACETONE

Temp (^{o}C)	Latent heat (kJ/kg)	Liquid density (kg/m^3)	Vapor density (kg/m^3)	Liquid thermal conductivity (W/m^{o}C)	Vapor pressure (bar)	Vapor specific heat (kJ/kg^{o}C)	Liquid surface tension (N/m × 10^2)
0	564	812	0.26	0.183	0.1	2.11	2.62
20	552	790	0.64	0.181	0.27	2.16	2.37
60	517	744	2.37	0.168	1.15	2.28	1.86

with both heat sink and integration of ACCP in Figure 5(b).

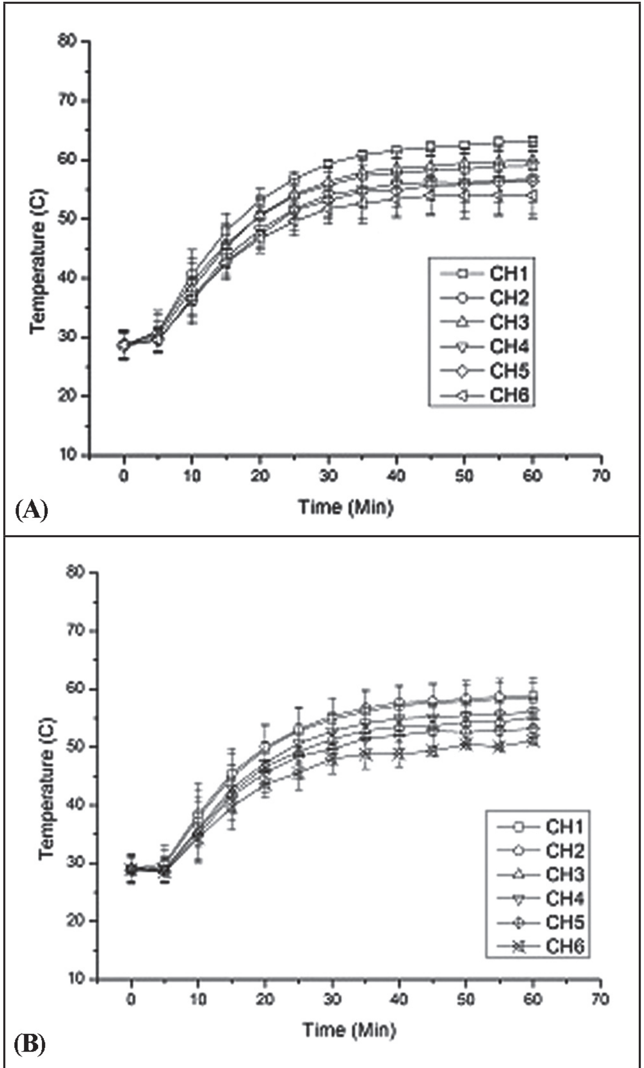


FIG. 5 VARIATION OF TEMPERATURE AS A FUNCTION OF TIME FOR MR16, 7 W LED LUMINARY WITH
(A) HEAT SINK (FIN)
(B) INTEGRATION OF ACCP INTO THE HEAT SINK.

The CH1 recorded a maximum junction temperature and CH_6 nearer to the ACCP recorded a maximum temperature.

Similar experiments were conducted on a MR16, 9 W LED luminary. The variation in temperature as a function of time with fins (Figure 6(a)) and integration of ACCP into the heat sink (Figure 6(b)) are shown below. A comparison of results is shown in Table 3.

For the MR 16, 9 W Load, the junction temperature recorded in heat sink was 70.9 °C whereas when the ACCP was integrated to the same load (heat sink with ACCP) the junction temperature recorded was 67.7° C. This indicates that the ACCP reduces the junction temperature to enhance the life of the Load. The same load can accommodate higher wattage due to improved heat transfer.

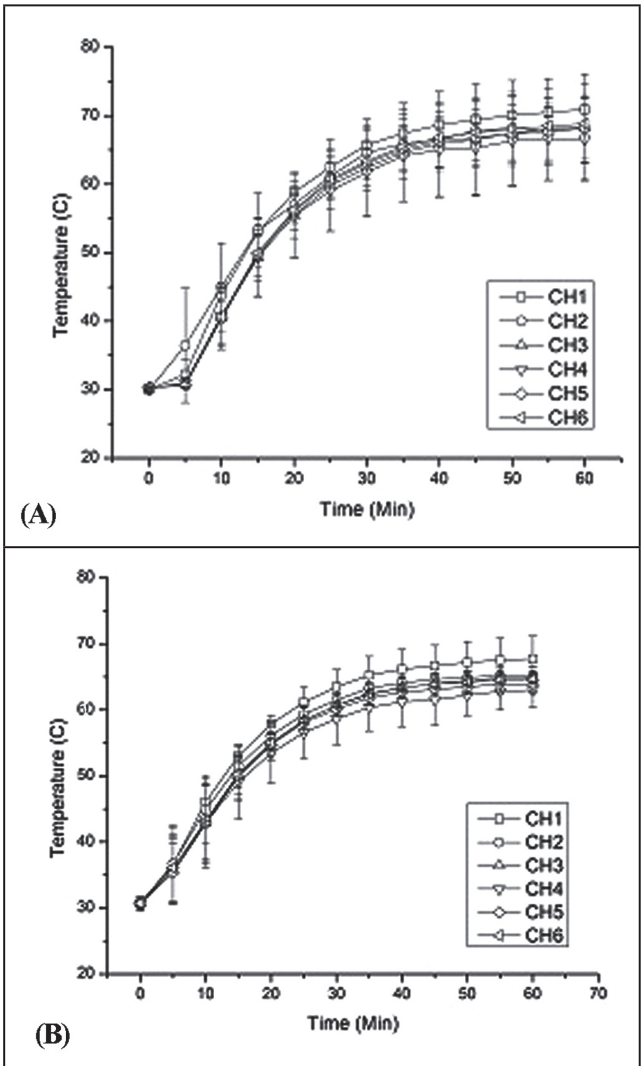


FIG. 6 (A) VARIATION OF TEMPERATURE AS A FUNCTION OF TIME WITH HEAT SINK
(B) WITH INTEGRATION OF ACCP.

For the MR16, 7 W LED load, the maximum junction temperature recorded on the LED side was 63.1^0 C and a maximum temperature on the heat sink side was 56.6^0 C with heat sink alone whereas for the same load integrated with ACCP's the corresponding temperatures were 58.9^0 C and 56^0 C respectively.

TABLE 3 COMPARISON OF RESULTS							
Sl. No.	**Test setup**	**No of LED**	**Input voltage (V_{in}) (V)**	**Input current (I_{in}) (A)**	**Total wattage (W)**	**Maximum Junction tempera-ture (°C)**	**Maximum temp on the heat sink end (°C)**
1	7 W load with heat sink	3	3.2	0.75	7.2	63.1^{0}C	56.6^{0}C
2	7 W load with heat sink and ACCP	3	3.2	0.75	7.2	58.9^{0}C	56.0^{0}C
3	9 W load with heat sink	3	3.2	1	9.6	70.9^{0}C	66.6^{0}C
4	9 W load with heat sink and ACCP	3	3.2	1	9.6	67.7^{0}C	64.6^{0}C

5.0 CONCLUSIONS

The raising junction temperature would decrease the luminous efficiency and affect the reliability once junction temperature rises beyond the working temperature range. Reduction in junction temperatures could be achieved by employing heat sink (aluminum fins) and addition of ACCP improves the performance. Excellent heat sink design with ACCP could meet the cooling need of high-power LEDs also. By incorporating the ACCP in to Heat sink, the power input can be increased by 20–25% thereby enhancing luminescence/light output and life span of the load. By incorporating wick into ACCP the device would become a heat pipe which would enhance the performance even further.

As a thumb rule, with reduction in junction temperature of 5^0 C, the energy saved equivalent to increased life of LED light approximately equal to 300 hrs, would be nearly equal to 2000 W/h average.

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