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Whitepaper

Liquid Cooling in Rear Projection Cubes
Ver 1.0

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Continued miniaturization of electronic systems has resulted in a dramatic increase in the amount of heat generated per unit volume. Unless properly designed and controlled, high rates of heat generation result in high operating temperatures for electronic equipment, which jeopardizes its safety and reliability.

The recent advancements in technology for illumination has led to the use of **L**ight **E**mitting **D**iodes (**LED**'s) in projection devices. The LED's are preferred over conventional lamp-based illumination due to their ability to provide more vibrant colors, having significantly longer lifetimes than lamps, reliability and low form factor.

The Rear Projection Industry has been the Early Adopters of the LED Illumination technology, and quickly migrated from conventional Lamps to the use of LED's given the requirements of the mission critical applications in which were Rear Projection Cubes (RPC's) were deployed.

The illumination based on LED is based on the principle of passing high current through Red, Green & Blue LED's respectively for generation of images by employing an alternating sequence of the red, green, and blue LED's.

However the process of passing current through the Tiny LED's for small time fraction not lasting more than a few milliseconds, causes a rapid heating of the LED junction's(The narrow band where two different regions of a semiconductor (such as the p-type and n-type regions) come in contact is called a junction.) and generation of large amount of heat. The junction temperature at the must be brought down very quickly, almost instantaneously to avoid burning out of LED's. Research shows that the temperature of an LED directly impacts the lifetime of the LED's and inversely its luminous flux .

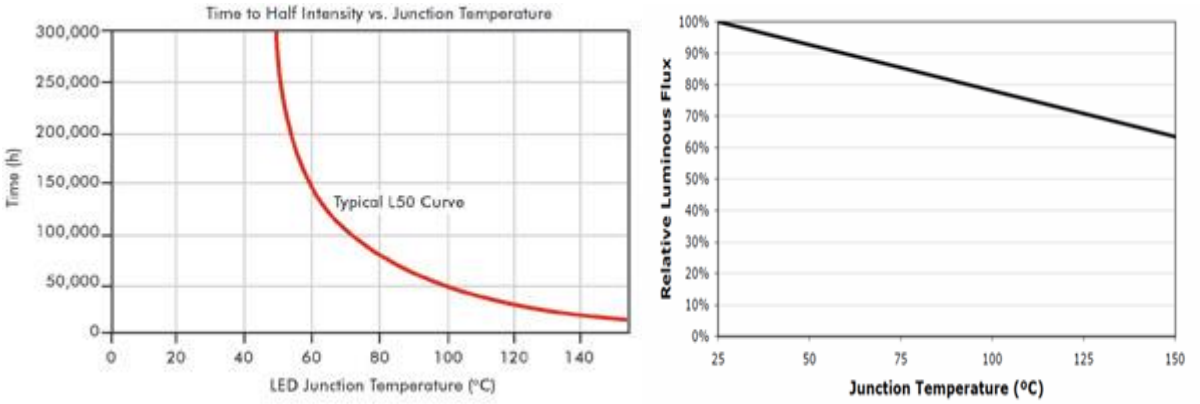

Fig1. Impact on Lifetime & Brightness due to increase in Junction Temperature

A host of methods are employed to bring about a special focus on the cooling of the LED's in order to cool down the LED's, but are broadly classified into two distinct categories viz., Air Cooling and Liquid Cooling.

Air Cooling: Air Cooling typically involves two approaches. In the first case, often a rudimentary adaptation cooling mechanisms used in low end computing devices like Pc's and laptops, air is blown over the heated part to take away heat resulting in lowering of temperature in a given area through the use of pumps. The heated air is then passed overheat sinks that are essentially metallic structures comprising of parallel columns of metal

structures that absorb heat as hot air passes through them, thereby lowering the temperature to a certain extent.

In the second approach also known as passive cooling, the heat is transferred from the source by making use of metal tubes called " heat pipes" that transport the heat away to a cooling device or mechanism located in another part that maybe a part of the illumination unit or could be an external device or subsystem.

In both the above approaches the surrounding temperature of the heated structure is restricted to a range of 10 to 12 Degrees above the ambient(measured in the space immediately surrounding the LED's) temperature.

The following tables shows the relative performances of air cooled based systems.

Parameter	Fan Based Systems	Heat Pipes Based Systems
Principle	Blows Air through fans and makes use of Heat Sinks	Transfers Heat by making use of Metal pipes to Cooling Blocks or Radiators.
Effectiveness	**Lowest in All Cooling Approaches**, air blows over a cross section, hence the source of heat generation is not focused. Leading to wastage of energy and higher operating costs as fans have to run at a faster rpm to bring down the temperature.	Better Than Fan Based Systems. Improved transfer of heat due to customized designs for enhancing cooling and can address the need for small areas.
Noise Levels	Noisy in Comparison due to usage of larger and multiple fans	Lower due to absence of multiple fans but makes use of pumps.
Structural flexibility	Very Poor	Relatively Better due to ductility of metal pipes allowing development of custom paths.

Table 1: Comparison Between Fan Based & Heat Pipe Based Cooling Mechanisms

Liquid Cooling:

The use of liquids for cooling has been ***de-facto*** option for high performance equipment and systems, for guaranteeing the best efficiency in heat transportation and cooling. The liquid cooling mechanism is based on the principle of convection-cooling based on Newton's Law of Cooling that states the rate of heat loss of a body is proportional to the difference in temperatures between the body and its surroundings*. Convection involves the transfer of heat by the motion and mixing of macroscopic particles of a fluid(flow of liquid past a solid boundary).

The two specific parameters that give liquid-based systems unique edge are

1. **Thermal Conductivity** : A measure of the ability of a material to transfer heat.
2. **Specific Heat Capacity** : The Ability to Absorb heat.

Refer to the table on next page..

Parameter	Air	Water	Ethylene Glycol
Thermal Conductivity@25 º Degrees Celsius	0.024	0.58	0.25
Specific Heat Capacity at Constant Pressure(kJ/kg º C	0.001004	1.07	2.42

Table 2: Comparison Between Various Media used for Cooling.

From the above table it can be seen that the use of fan-based systems does not meet the performance objectives of cooling that are needed in LED based RPS's. Most manufacturers make use of either heat pipe-based systems to accommodate the needs from customers for highly constrained budgets or make use of liquid cooling-based systems for offering truly **S**tate-**o**f-**A**rt Cooling Systems that meet high performance objectives.

In addition, the following advantages are attributable to Liquid Based Cooling Systems" over air-based systems.

Parameter	Liquid Cooling Based Systems	Heat Pipes Based Systems	Fan Based Systems
Principle	Transfer of Heat Through Liquid Circulation	Transfer of Hot Air through Heat Pipes.	Blows Air through fans over a Cross Section.
Contact With Source of Heat (LED Junction)	Yes	No	No
Focussed Part Cooling	Yes	To an Extent	No
Effectiveness	Very High	Medium	Very Low
Noise Levels	Silent	Silent	Noisy In Comparison
Structural flexibility	Very High	Medium	Low

Barco's Liquid Cooling Technology:

Several years of experience and focused development have enabled Barco to develop one of the most efficient cooling mechanisms by employing liquid cooling, giving customers high efficiency and functionality. Barco's Liquid Cooling based RPC's run up to ***10 Degrees cooler*** and focus on rapid and almost instantaneous cooling of the LED junction that is the main source of heat and needs directed cooling. surrounding temperature of the heat source is restricted to 3`4 Degrees above the ambient temperature. Thereby significantly improving the performance and lifetime of the LED's.

Through its dedicated R&D Effort Barco is able to further optimize the Liquid Cooling Mechanisms by employing special Liquids that help in faster heat transfer and exceed significantly the heat carrying capacity of water-based systems. Thereby ensuring high performance and long-term reliability.

End User Benefits

Barco's Liquid Cooling Based RPC Cubes Provide customers unique benefits that are unmatched by any other solution in the industry.

- **Faster & Effective Cooling**: As the liquid is in direct contact with the source of the heat i.e. the LED Junction.
- **No wastage of Energy**: As the liquid is focusses to cool only the desired part, less energy wastage implies lower running costs.
- **High Flexibility**: Due to the inherent nature of the flexibility of the cooling mechanism, changes in design can be brought about easily to accommodate specific customer needs.
- **Corrosion Proof**: To do away with the corrosive nature of water based cooling systems, Barco uses a special polymer that is noncorrosive and has specially added corrosion inhibitors. Additionally, the entire cooling system makes use of special hoses that are dually reinforced to provide and occurrences of leakage. Additionally special care is taken to secure the hoses through the use of additional clamps to reinforce the seating of the hose on the system parts.
- **Immune to Changes in Ambience**: Since the efficiency of air-based systems can be severely impacted by the ambient air conditions of the installation site, there is an extra burden on the end customer to deploy systems that regulate air properties.
- **Universal Deployment:** Unlike water cooled systems, Barco's special liquid filled systems can operate a wide variety of environments does not crystallize (provides for frost resistance) in very cold environments or evaporates in hot conditions.
    1. **Freezing Point: -50 º C**
    2. **Boiling Point: 150 º C**
- **User Friendly:** Due to its high Boiling Point of 198 Degree**,** no evaporation takes place eliminating the risk of accidental fumes inhalation by service technicians or end customer technical teams.

References:

1. www.researchgate.net
2. www.engineeringtoolbox.com
3. www.onlinelibrary.wiley.com