MITSUBISHI ELECTRIC
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White Paper
November 2014

Cooling System Technology for Cube-Based Display Walls

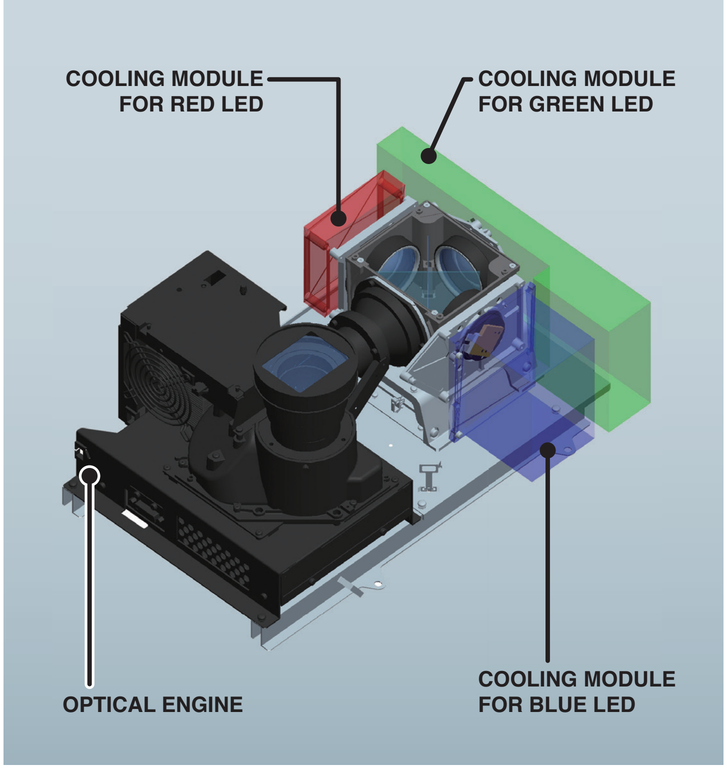
Comparing Air and Liquid-Based Cooling Systems

The cooling system is one of the most crucial parts of any display wall.

The deterioration of electronic components due to high temperatures is, in fact, the main limitation to the useful life of a projection cube. Among other detrimental effects, thermal expansion produces mechanical stresses that cause material fatigue in the metals and silicon wafers used in the LEDs, and thermal cycling causes ongoing changes in their electrical conductivity and resistance.

In an LED light engine, the red LED is the most sensitive to heat. Engineering studies suggest that for every 10 degrees above the optimum temperature, the life of the red LED is reduced by roughly half. A better cooling system thus means longer life for the LED light engine and other key components of the projection cube.

There are two methods used by manufacturers to reduce the temperature inside of their projection cubes: liquid cooling using a pump, coolant and reservoir, and air cooling using a heat sink and fan. In this paper, we will examine the pros and cons of each and the reasons manufacturers may choose one over another. Strong arguments can be made for each.



In the end however, the buyer should examine the results achieved by each system. Each manufacturer has chosen its preferred strategy, yet each has not been able to achieve identical results. We would do well to ask, in a display wall cube of similar resolution and brightness, which has the longest working life? One cooled by air or by liquid?

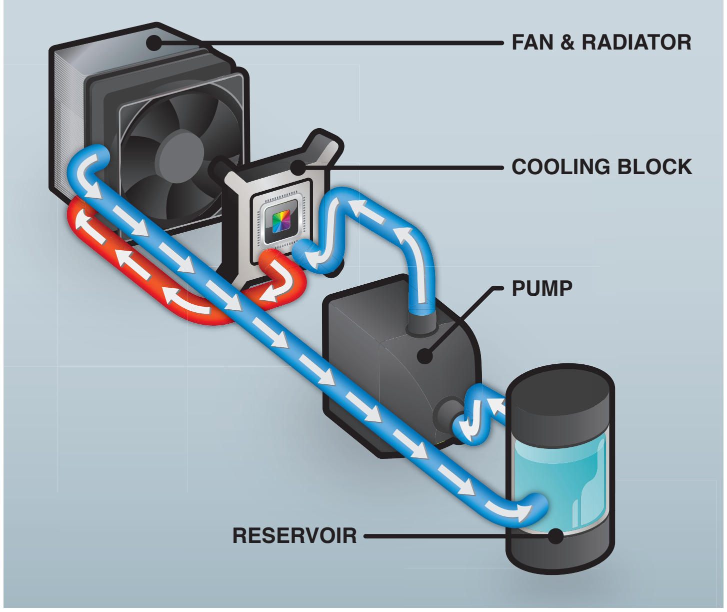
Let's look at each in turn.

Liquid Cooled Systems

Liquid cooling is very widely used in mechanical systems, for example in the automotive industry for internal combustion engines, as well as in certain computer systems and LED-based projection cubes.

In this type of setup, there is a coolant circulation system with a pump, hoses, reservoir and radiator. The pump moves the liquid through a coolant block in contact with each LED module, where it absorbs heat energy, then passes it through a radiator composed of number of tubes and fins with a large surface area. A fan blows air from the room through the radiator, where it picks up heat energy from the liquid. The heated air passes out into the room, from which the heat is removed by the building's air conditioning system.

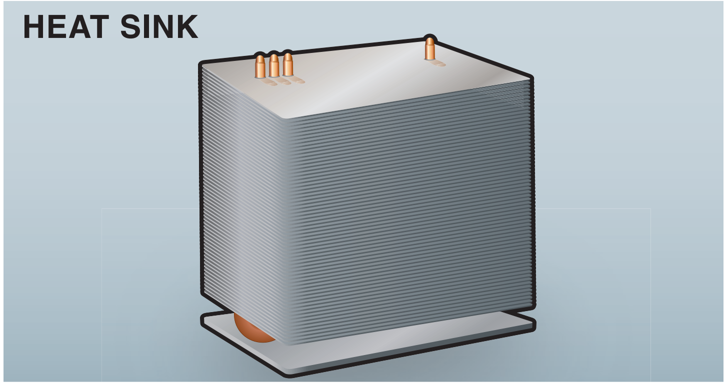
The principles of these systems are very well established. Radiator-based heat exchangers were first used by Roman engineers in 15 AD. Pump-based cooling radiators have been used in modern mechanical systems since 1855.

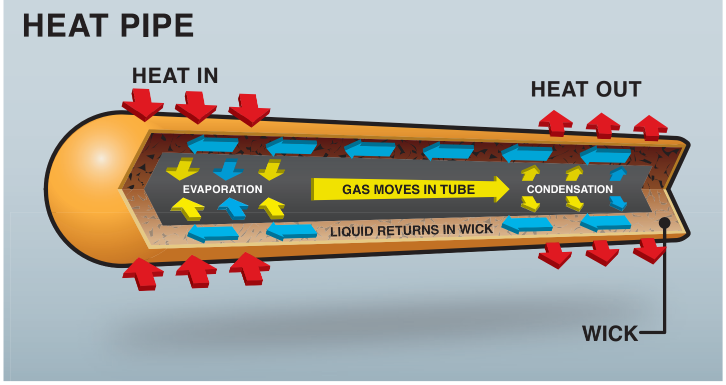


Air Cooled Systems

The air cooled systems used in other projection cubes combine a heat sink, that is, a passive heat exchanger, with a fan-driven air circulation system. This type of air cooling is widely used for electronics, for example in the computer industry to cool the central processing units and graphics processors of faster computer workstations and servers. One heat sink is used for each processor or, in a projection cube, one for each LED module.

A heat sink is a very simple system. The base of the device is in direct contact with the LED module or processor. Heat energy from the module turns water inside the hollow aluminum base into water vapor, which expands via a small copper heat pipe into a radiator, a sealed aluminum structure composed of a large number of fins that increase its surface area. A fan blows room air over the fins, cooling the water vapor and absorbing the heat energy. As the water vapor cools within the radiator, it turns back into liquid. Gravity returns the water to the base via a wick in the heat pipe where it can again be vaporized by heat from the LED module.





Potential Problems

Important considerations in the choice of a cooling system are its need for maintenance and potential for failure.

For example, the mechanical pumps used in liquid cooled projection cubes have a limited lifespan, and their manufacturers recommend replacement of these pumps after as little as 30,000 hours of use. In addition, in these pump-based cooling systems the coolant must stay liquid, and so ethylene glycol, a hazardous substance with a high boiling point, is used rather than water. Ethylene glycol, however, breaks down in time and must also be replaced periodically. The cooling system must normally be drained, then refilled at the same time that the pump is replaced. Because ethylene glycol is caustic and should not be inhaled or come in contact with skin, caution must be observed during maintenance.

Another consideration is that any liquid, whether ethylene glycol or plain water, can damage electronics. There have been incidents where pump-based systems have leaked and caused serious damage to one or more of the cubes that make up a display wall.

Note that the principle at work in the “liquid cooled” and “air cooled” systems is the same. Heat energy is transferred to a liquid then moved into a radiator where the liquid is cooled by air propelled through the radiator by a fan. Yet the “air cooled” system is much simpler, permanently sealed with no hoses, pumps or other moving parts and no need to ever replace the liquid coolant. Because much less liquid is used, the risk of damage due to a leak is far lower. The simplicity of the air cooled systems results in a rated lifespan far longer than the liquid cooled: 100,000 hours. No maintenance of any kind is required.

In the computer industry, liquid cooling is used only when other methods will not provide adequate heat reduction. The extra complexity and greater potential for failure of these systems is justified only for those very high speed processors that cannot be cooled adequately by fans or a fan/heat sink combination.

Cooling Effectiveness

In the end, the effectiveness of the cooling system can best be judged by the results.

If we were to compare two projection cubes of similar design, similar brightness and similar power consumption, yet with different cooling systems, and we find that one has a significantly longer lifespan, it might be reasonable to conclude that one of the cooling systems is more effective than the other. The other possibility, however, is that one of the LED engines runs hotter and requires more cooling than the other. If this was the case, we’d expect to see greater power consumption and greater thermal dissipation into the room environment.

That is exactly what we do find. If we compare any LED projection cube using a pump-based cooling system with a Mitsubishi 70-Series cube of similar brightness (all Mitsubishi cubes use air cooled, heat sink-based cooling systems), we find that the pump-based projection cubes require at least 50% more electric power to run and dissipate at least 50% more heat energy into the room (measured in BTUs per hour).

One manufacturer makes the advertising claim that its liquid cooling system reduces the temperature inside the LED module by up to ten degrees more than air-cooled systems. That makes sense in this context. It seems they are making a virtue of necessity. Given their specifications for power consumption and thermal dissipation, that claim can only mean they have more heat energy within their LED modules to remove. It does not necessarily mean that the internal temperature, after cooling, is any lower.

We have reason to suspect that the internal temperature is, in fact, higher. Mitsubishi cubes with their air cooled heat-sink systems last 20% - 25% longer than any others. (Mitsubishi 70-Series LED-based cubes are rated at 100,000 hours in Advanced Eco Mode and 80,000 hours in Normal Mode, versus 80,000 hours for other LED-based cubes in Eco Mode and 60,000 hours in Normal Mode.) Since heat is the major cause of deterioration in electronic systems, that would lead us to expect that the Mitsubishi cubes run cooler within each LED module.

(See the accompanying table for brightness, power consumption and lifetime comparisons.)

Power/Thermal Specification Comparison (Air Cooling vs Liquid Cooling)

Model	**VS-50PE78U**				**Comparable 50" Model**		
Manufacturer	Mitsubishi				Competitor		
Cooling System	**Air Cooled**				**Liquid Cooled**		
Resolution	SXGA+ (1400x1050)				SXGA+ (1400x1050)		
Aspect Ratio	4:3				4:3		
Screen Size (diagonal)	50"				50"		
Access	Rear				Rear		
Color Gamut	180% EBU				165% EBU		
Screen Type	Fine Cross				FXS		
Power Mode	**Bright**	**Normal**	**Eco**	**Adv Eco**	**Max**	**Typical**	**Eco**
Brightness (cd/m²)	720	530	360	140	680	*Not Published*	
Power Consumption (watt)	233	147	108	88	350	230	170
Heat Dissipation (BTU/h)	795	502	369	300	1194	785	580
LED Lifetime (hours)	80,000			100,000	60,000		80,000

It's interesting to note that, in most cases, the liquid cooled/pump based projection cubes are not any brighter than the Mitsubishi cubes (in many cases they are considerably less bright). One explanation for this difference would be that Mitsubishi has designed a more efficient light engine: one that produces more brightness with less power and less heat that must be removed with a cooling system. For that reason, Mitsubishi is able to use a mechanically simpler, lower-maintenance, more reliable cooling system and still produce a longer-lasting projection cube.

Conclusion

In comparing cooling systems for LED-based projection cubes, we've looked at the advantages and disadvantages of each.

The "liquid cooling" systems use ethylene glycol pumped from a cooling block in contact with each LED to a radiator similar to those in an internal combustion engine, complete with a coolant reservoir and connecting hoses. It's a relatively complex system that requires periodic maintenance. Of course with complexity comes additional risk of failure.

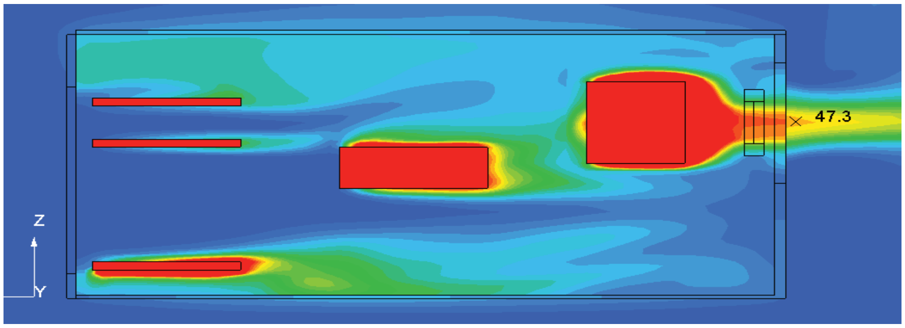
The "air cooled" systems use a separate heat sink for each LED module consisting of an aluminum base plus copper heat tubes and an aluminum radiator. While "air cooling" also uses a coolant (water), it is a far less complex system that's permanently sealed, with no pumps, no moving parts and no required maintenance.

Which system offers greater cooling power is an open question. Although one manufacturer claims their liquid-cooled system is more effective, none of the projection cube manufacturers publishes specifications for the internal temperatures of its LED modules.

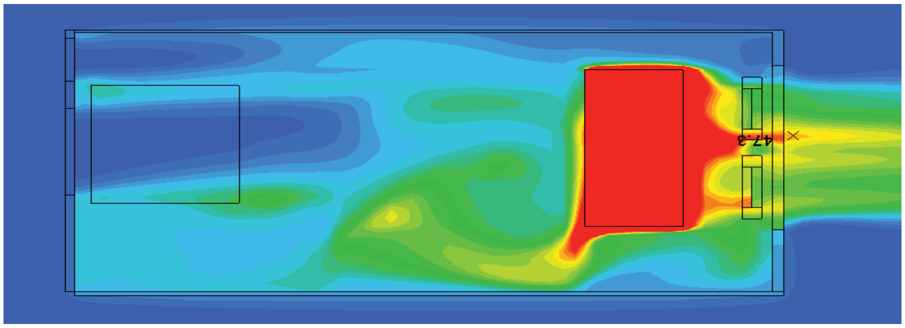
Still, given the published specs for power consumption, heat dissipation and longevity, it appears that liquid cooling is at best a necessary evil. Given its simplicity and reliability, air cooling is an obvious choice, and one integral, at least in the case of Mitsubishi, to a projection cube design with an LED lifetime at least 20% longer than any other.

70 Series Cooling System

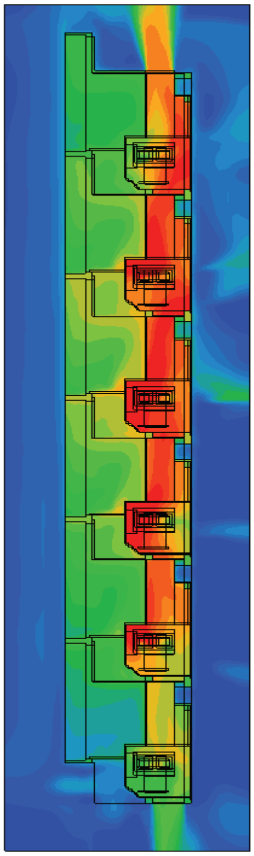
Engine Box (Top view)

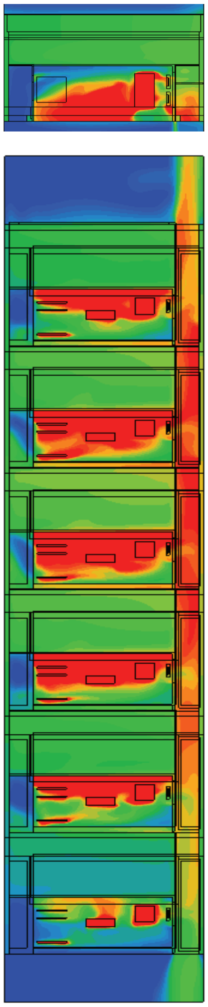


Engine Box (Backside view)



Multi Layer Stacking (6-layer)





Report Information

This report has been created by Mitsubishi Electric US Visual & Imaging Systems Division (www.me-vis.com) and Mitsubishi Electric Sales Canada (www.mitsubishielectric.ca).

Mitsubishi Electric is the global leader for command and control display wall products, with a wide variety of rear-projection DLP display wall cubes and LCD display wall panels. This report has been created agnostically to compare the two technologies and for certain specifications, is based on Mitsubishi Electric products.

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