Cold Plates and Recirculating Chillers for Liquid Cooling Systems

ATS cold plates and recirculating chillers can be used in closed loop liquid cooling systems for high-powered electronics.

The miniaturization of high-powered electronics and the requisite component density that entails have led engineers to explore new cooling methods of increasing complexity. As a result, there is a growing trend in thermal management of electronics to explore more liquid cooling systems and the reintroduction, and re-imagining, of cold plate technology, which has a long history that includes its use on the Apollo 11 space shuttle. [1]

Thermal management of high-powered electronics is a critical component of a design process. Ensuring the proper cooling of a device optimizes its performance and extends MTBF. In order for a system to work properly, engineers need to establish its thermal parameters from the system down to the junction temperature of the hottest devices. The use of cold plates in closed loop liquid cooling systems has become a common and successful means to insure those temperatures are managed.

Cold plate technology has come a long way since the 1960s. At their most basic level, they are metal blocks (generally aluminum or copper) that have inlets and outlets and internal tubing to allow liquid coolant to flow through. Cold plates are placed on top of a component that requires cooling, absorbing and dissipating the heat from the component to the liquid that is then cycled through the system.

In recent years, there have been many developments in cold plate technology, including the use of microchannels to lower thermal resistance [2] or the inclusion of nanofluids in the liquid cooling loop to improve its heat transfer capabilities. [3]

An article from the October 2007 issue of Qpedia Thermal eMagazine detailed the basic components of a closed loop liquid cooling system, including:

- A cold plate or liquid block to absorb and transfer the heat from the source
- A pump to circulate the fluid in the system
- A heat exchanger to transfer heat from the liquid to the air
- A radiator fan to remove the heat in then liquid-to-air heat exchanger

The article continued, “Because of the large surface involved, coldplate applications at the board level have been straight forward…Design efforts for external coldplates to be used at the component level have greatly exceeded those for PCB level coldplates.”

Exploring liquid cooling loops at the board or the component level, according to the author, requires an examination of the heat load and junction temperature requirements and ensuring that air cooling will not suffice to meet those thermal needs. [4]

Chillers provide support for liquid cooling loops

In order to increase the effectiveness of the cold plate and of the liquid cooling loop, recirculating chillers can be added to condition the coolant before it heads back into the cold plate. The standard refrigeration cycle of recirculating chillers is displayed in Fig. 1.

Several companies have introduced recirculating chillers to the market in recent years, including ThermoFisher, PolyScience, Laird, Lytron, and ATS. Each of the chiller lines has similarities but also unique features that fit different applications.

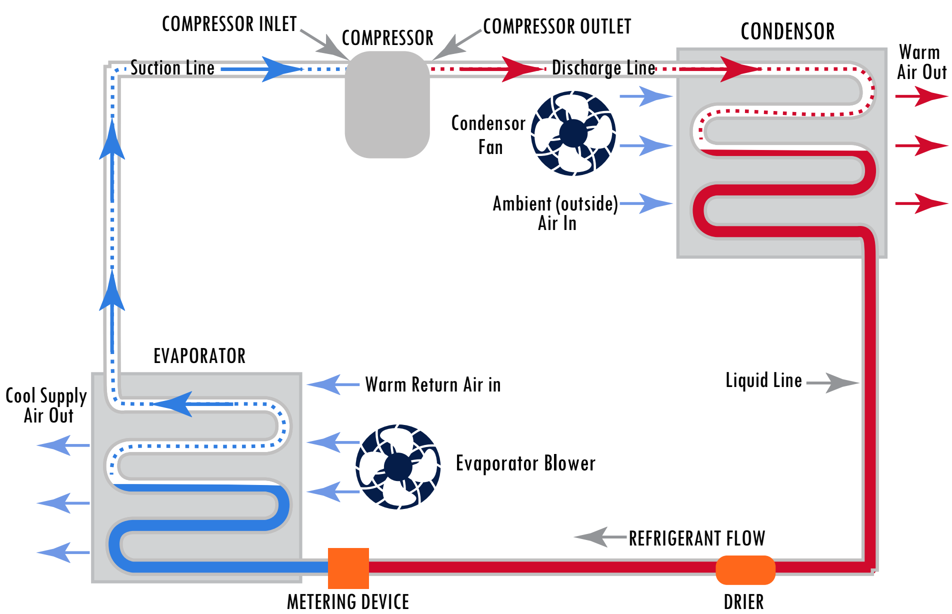

Fig. 1. The standard refrigeration cycle for recirculating chillers.

In order to select the right chiller, Process-Cooling.com warns that it is important to avoid "sticker shock" because of testing conditions that are ideal rather than based on real-world applications. The site suggests a safety factor of as much as 25% on temp ranges to account for environmental losses and to ensure adequate cooling capacity. [5]

The site also noted the importance of speaking with manufacturers about the cooling capacity that is needed, the required temperature range, the heat load of the application, the length and size of the pipe/tubing, and any elevation changes.

"Look for a chiller with an internal pump-pressure adjustment," the article stated. "This feature enables the operator to dial down the external supply pressure to a level that is acceptable for the application. Because the remaining flow diverts internally into the chiller bath tank, no damage will result to the chiller pump or the external application."

When trying to decide on the right size chiller for your particular application, there are several formulas that can help make the process easier. Bob Casto of Cold Shot Chillers, writing for CoolingBestPractices.com, gave one calculation for industrial operations.

First, determine the change in temperature (ΔT), then the BTU/hour (Gallons per hour X 8.33 X ΔT), then calculate the tons of cooling ([BTU/hr]/12,000), and finally oversize by 20 percent (Tons X 1.20). [6]

Not every application will require industrial capacity, so for smaller, more portable chillers, Julabo.com had a secondary calculation for required capacity (Q).

$$Q=[(rV\ cp)_{material}+(rV\ cp)_{bath\ fluid}]\Delta T/t$$

In the above equation, r equals density, V equals volume, cp equals constant-pressure specific heat, ΔT equals the change in temperature, and t equals time. "Typically, a safety factor of 20-30% extra cooling capacity is specified for the chilling system," the article continued. "This extra cooling capacity should be calculated for the lowest temperature required in the process or application." [7]

Comparison of Industry Standard Recirculating Chillers

	ATS-CHILL150V	ATS-CHILL300V	ATS-CHILL600V	Lytron Kodiak® RC006	Thermo Fisher ThermoChill II	PolyScience LS Series	Laird MRC300
Temp. Range	0-40°C	5-35°C	5-35°C	5-35°C	5-30°C	-20°C- +40°C	2-40°C
Temp. Stability	±0.1°C	±0.1°C	±0.3°C	±0.1°C	±0.1°C	±0.1°C	±0.10°C
Cooling Capacity (Q_{max} at 20°C)	150W	300W	600W	820W	700W	980W	290W
Pump Pressure	0.4 BAR	0.6 BAR	0.6 BAR	n/a	n/a	<3.43 PSI	n/a
Water Tank Capacity	3.0 L	4.5 L	8.5 L	4.9 L	9.5 L	2.65 L	0.45 L
Overall Dimensions (W x D x H)	236 x 260 x 380 mm (9.3 x 10.2 x 14.9")	235 x475 x 450 mm (9.3 x 18.7 x 18.0")	235 x 475 x 450 mm (9.3 x 18.7 x 19.2")	318 x 483 x 309 mm (12.5 x 19.0 x 22.6")	605 x 356 x 585 mm (23.8 x 14.0 x 23.0")	607 x 254 x 483 mm (23.9 x 10 x 19")	213.43 x 337.83 x 345.49 mm (8.40 x 13.30 x 13.60")
Weight	10 kg (22.1 lbs.)	23 kg (50.7 lbs.)	23 kg (50.7 lbs.)	44 kg (97.0 lbs.)	40.8 kg (90.0 lbs.)	46.3 kg (102.0 lbs.)	13.6 kg (29.9 lbs.)
Power Failure Mode	Protects against over pressure and compressor overload	Protects against over pressure and compressor overload	Protects against over pressure and compressor overload	Pressure relief factory-set at 90 PSI (6.2 BAR)	Temperature alarms	Low flow shutoff and alarm	n/a
Power Supply Required	AC 220V	Switch Selectable 120/220Vac	Switch Selectable 120/220Vac	Varies per customer choice	230Vac	120/240VAC	100-240Vac

Applications for liquid cooling systems with chillers

Recirculating chillers offer liquid cooling loops precise temperature control and coupled with cold plates can dissipate a large amount of heat from a component or system. This makes chillers (and liquid cooling loops in general) useful to a wide range of applications, including applications with demanding requirements for temperature range, reliability, and consistency.

Chillers have been part of liquid cooling systems for high-powered lasers for a number of years to ensure proper output wavelength and optimal power.viiiix To ensure optimal performance, it is important to consider safety features, such as the automatic shut-off on the ATS-Chill 150V that protects against over-pressure and compressor overload. Other laser-related applications include but are not limited to Deep draw presses, EDM, Grinding, Induction heating and ovens, Metallurgy, Polishing, Spindles, Thermal spray, and Welding. [10]

Machine hydraulics cooling and semiconductors also benefit from the inclusion of chillers in liquid cooling loops. Applications include CVD/PVD, Etch/Ashing, Wet Etch, Implant, Inductively Coupled Plasma and Atomic Absorption Spectrometry (ICP/AA), Lithography, Mass Spectroscopy (MS), Crystal Growing, Cutting/Dicing, Die Packaging and Die Testing, and Polishing/Grinding. [11]

One of the most prominent applications for liquid cooling, heat exchangers, cold plates, and chillers is in medical equipment. As outlined in an ATS case study,xii medical diagnostic and laboratory equipment requires cyclic temperature demands and precise repeatability, as well as providing comfort for patients. For Harvard Medical School, ATS engineers needed to design a system that could maintain a temperature of -70°C for more than six hours. Using a cold plate with a liquid cooling loop that included a heat exchanger, the engineers were able to successfully meet the system requirements.

Liquid cooling with chillers are also being used for medical imaging equipment and biotechnology testing in order to provide accurate results.

Conclusion

Closed loop liquid cooling systems are not new but are gaining in popularity as heat dissipation demands continue to rise. Using cold plate technology with recirculating chillers, such as the ATS-Chill150V, ATS-Chill300V, and the ATS-Chill600V, to condition the coolant in the system can offer enhanced heat transfer capability.

Portable and easy to use, ATS vapor compression chillers are air-cooled to eliminate costly water-cooling circuits and feature a front LED display panel that allows users to keep track of pressure drop between inlet and outlet and the coolant level. They each use a PID controller.

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