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ELECTRONICS COOLING TECHNOLOGY BASED ON DIRECT EVAPORATION

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ABSTRACT

Methods and systems, including computer programs, for a cooling system that uses vapor compression, passing refrigerant through a compressor and a condenser and delivering the condensed refrigerant directly to a heat source. Prior to reaching the heat source, the refrigerant is passed through a pressure reduction system that allows for all of the refrigerant to be routed through the system at ambient temperature with no heat loss. After its expansion, the refrigerant drops in temperature and absorbs heat directly from the heat source to evaporate. This is in contrast to contemporary systems which perform vapor compression on a secondary coolant—typically water—that is then used to cool the refrigerant prior to circulation to the heat source. The described direct-contact evaporative cooling solution addresses increasingly critical issues of heat flux in systems such as high-power silicon packages, and allows these systems to operate at optimal efficiency. This cooling system eliminates the need for evaporator and expansion systems of a conventional cooling system, as well as the secondary loop through which the secondary coolant is circulated to the heat source. The improved system also allows a heat source to be cooled to lower than ambient temperatures, which is not feasible through other systems and techniques. Furthermore, the circulation of the refrigerant at ambient temperatures throughout the system reduces the losses in the refrigeration system to ambient heat and lessens insulation and isolation requirements. This feature also reduces the risks of condensation within the cooling distribution structure of the system as well as the risk of damage caused by condensation.

PUBLICATION DESCRIPTION

This document describes techniques for an improved and more streamlined approach to cooling products, such as electronics, on various scales and within different architectures.

Existing cooling systems use the vapor compression principle, where a refrigerant is passed through an evaporator to absorb the heat and evaporate, then directed to a compressor to pressurize vapor and cooled through a condenser. The condensed coolant is then routed back towards the evaporator. Prior to entering the evaporator the refrigerant passes through a pressure reduction valve, and reduced pressure refrigerant passes through the evaporator to absorb heat and evaporate to complete the full cycle. Conventional cooling systems use an evaporator to cool a secondary coolant—typically water—and circulate chilled water through the end heat extraction points (*e.g.*, fan coils or air coolers). FIG. 1 is a diagram that illustrates a conventional cooling cycle.

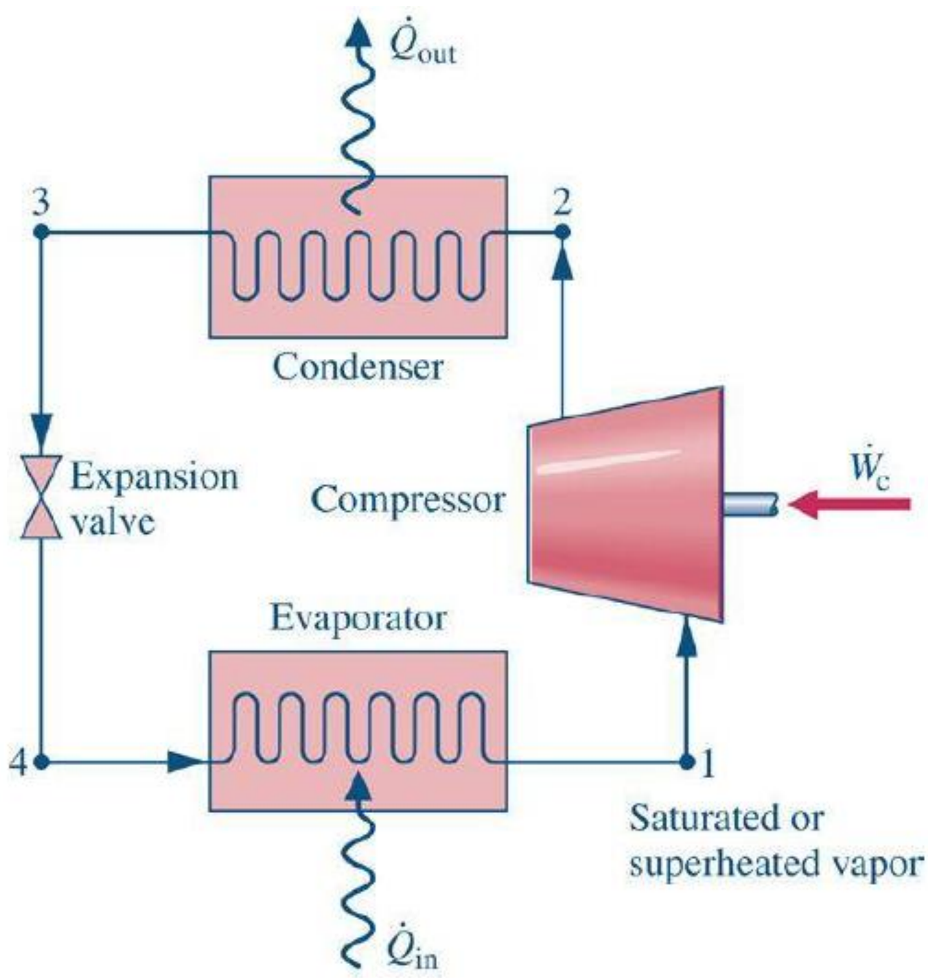

FIG. 1 – Conventional cooling cycle

With heat flux increasing in silicon packages, and with recent developments in machine learning and processor units, there is a rising demand for high-power chips that need to be cooled to provide optimum efficiency. The following system and techniques described provide a cooling solution for high-power silicon packages and other temperature-sensitive devices and operations.

The improved system also utilizes vapor compression, but eliminates the secondary loop and directs the refrigerant directly to the heat source. This is in contrast to the contemporary systems as described above, which perform vapor compression on a secondary coolant that is then used to cool the refrigerant prior to circulation to the heat source. In addition, a compressor and condenser system—similar to those used in current chiller systems—is used in the streamlined cooling system chiller. However, the evaporator and expansion system are eliminated from the chiller. The condensed refrigerant is then routed towards the loads (*e.g.*, server trays, machinery, silicon packages, etc.) through a distribution system and rack manifolds. The refrigerant pressure is then reduced by a pressure reduction system (*e.g.*, an expansion valve) just prior to entering the evaporation area. The evaporator can be similar to a cold plate, and attaches directly to a heat source (*e.g.*, an electronic chip, a motor, etc.). The refrigerant absorbs the heat from the heat source through latent heat of evaporation and turns into saturated vapor. Exhaust refrigerant vapor from multiple heat sources are then collected by a return header and routed back to the chiller to pass through the compressor and condenser to pressurize, and transfer the heat into ambient or a cooling tower circuit.

FIG. 2 is a diagram that illustrates an example of the new cooling cycle as applied at a plant.

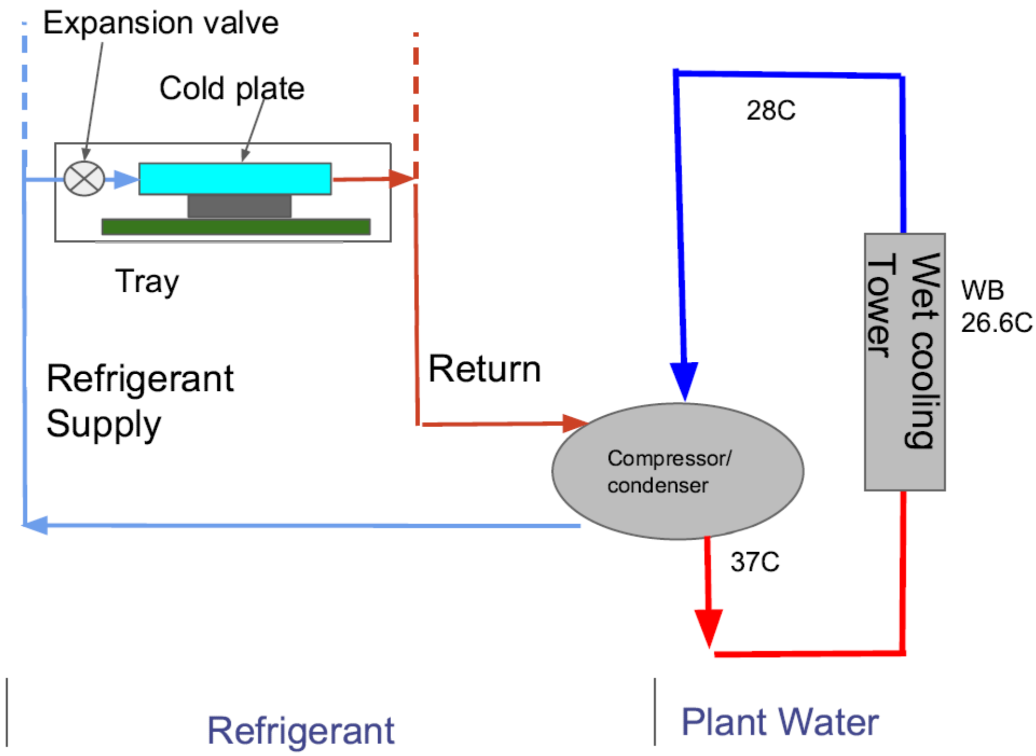

FIG. 2 – New thermal architecture

Advantages of this improved vapor compression system include allowing the heat source to be cooled to lower than ambient temperature, which cannot be accomplished through other technologies. This is critical for high power high heat flux applications where components, such as a silicon package, need to be subcooled to meet the junction temperature requirements of the entire system. Because the refrigerant is expanded prior to evaporation, the refrigerant can be distributed throughout the system at room temperature with no heat loss. Additionally, circulating the refrigerant at room temperature decreases the risks of condensation on cool distribution system and risk of electronics damages caused by condensation. The refrigerant temperature drops only after the expansion, and absorbs heat from the heat source to evaporate, reducing the losses in the refrigeration system to ambient heat and reduces insulation and isolation requirements.

The cooling performance can be tailored to the application for which the cooling system is used. Parameters, such as the cooled temperature of the heat source can be controlled by the pressure reduction system. A higher pressure drop will result in lower evaporation temperature, which may be needed for higher power or higher power density loads. The pressure reduction system, in some examples implemented as an expansion valve, may be operated based on a feedback control loop to control the package temperature at a required level to meet performance or reliability requirements.

This improved cooling system can cool electronics packages to a lower temperature than can be achieved with other cooling technologies, and without performance penalties inherent to such technologies. The system enables coolant temperature within the evaporator (*e.g.*, a cold plate) to drop below the freezing point of water, without the complexities and performance drop of using glycol as the refrigerant in system. Mixtures containing glycol, also known as antifreeze, reduce the thermal performance of a liquid cooling system and result in a substantial drop in evaporator performance. This system can use high performance evaporators, such as evaporative cold plates, with the refrigerant, and allows the evaporators to reach temperatures below 0 ºC without risks of freezing or reducing the evaporation performance. The system absorbs heat in latent heat form, and given that phase change energy absorption per unit mass is much larger than sensible heat, the distribution system can be designed for and used with a much lower flow rate. This can be beneficial in high heat density operations, such as large server racks.

The system can be adapted to be implemented on different scales or within architectures. For example, a localized instance of the water system may be used with a smaller cooling cycle to cool the loads of one tray or one rack of a server room. This refrigeration system can also be used work inside a datacenter and pump the heat out of the heat source at low temperatures to another room at higher temperatures. Computer room air conditioning (CRAC)/computer room air handler (CRAH) units could then absorb the heat and transfer to the outside ambient environment.

In some implementations, the configuration that provides the most efficient and highest performance is using a building level loop, where a compressor-condenser system is used to supply refrigerant to more than one load (*e.g.*, multiple server racks) and the heat is directly transferred to the environment through the condenser or through a cooling tower loop. The pressure reduction system, such as an expansion valve, could be designed as a separate unit from evaporator, or a passive restriction system can be designed within the cold plate, such that as refrigerant passes through the restriction system to enter the evaporative area (e.g., fins of the evaporative cold plate) its pressure would drop.

This system is massively scalable and can be tailored to cool multiple loads at the same or even different pressures and temperatures. Multiple compressor-condenser packages could be designed and utilized in parallel, and/or sequentially used in multistage systems for optimizing the operational performance and cost of the cooling system.

The described techniques also apply to other implementations which may include corresponding systems and computer programs configured to perform the actions and methods described in this document. A computing system that includes multiple computers and hardware circuits can be configured using software, firmware, physical components, or a combination of each of these installed on the system. In operation, these items cause the system to perform the techniques, actions, and methods described in this document.