DESIGN AND EXPERIMENTAL STUDY OF A MINIATURE VAPOUR COMPRESSION REFRIGERATION SYSTEM FOR CPU COOLING

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ABSTRACT

The chip power continuously increases traditional passive heat dissipation techniques used in the old version but now new active cooling techniques are arising. Various new active cooling techniques, the Vapor Compression Refrigeration (VCR) system is the leading technology use in CPU. This project presents a miniature VCR system for CPU cooling. The dimension of the system is 300 × 230 ×70 mm3and its cooling capacity is 300 W. It includes a commercial miniature compressor, a capillary tube, a condenser, and an evaporator. The system is tested systematically by experiments. The results indicate that the temperature of the evaporator can be maintained at about 10℃ for hours as required in CPU cooling. A small refrigeration VCR system for cooling computer system components CPU is evaluated. The refrigeration system uses a miniature reciprocating vapor compression compressor system. Due to space limitations in some high-performance computer servers, a miniature refrigeration system composed of a compressor; capillary tube, compact systems are used. In addition, reliability, availability, and serviceability discussion of the proposed CPU-cooling refrigeration solution is presented. The results show that the new technology not only overcomes many shortcomings of the traditional fan-cooled systems but also has the capacity of increasing the cooling system's coefficient of performance COP.

Keyword: - *VCR, Compressor, Evaporator, Refrigerant etc*.

1. INTRODUCTION

As the number of transistors in integrated circuits has rapidly increased to provide greater functionality and computational power, removing the heat dissipated from electronic chips has become a serious challenge in the design of portable device and other space-limited electronics systems. According to the International Technology Roadmap for Semiconductors 2003, the heat dissipation from a single chip package will rise to 170 W in 2005 for high-performance systems. The maximum junction temperature, meanwhile, must continue to be maintained at or below 85 0C. Conventional air cooling techniques are no longer expected to meet the required heat dissipation needs. These methods include heat pipes, liquid immersion, jet impingement and sprays, thermoelectric, and refrigeration. The available alternatives, refrigeration is one of the only methods which can work in high-temperature ambient, and even result in negative values of thermal resistance. The advantages of refrigeration cooling include maintenance of low junction temperatures while dissipating high heat fluxes, potential increases in microprocessor performance at lower operating temperatures, and increased chip reliability. These advantages must be balanced against the increased complexity and cost increase in the cooling system, possible increases in cooling system volume, and uncertainties in the system reliability due, for instance, to moving parts in the compressor.[4]

2. PURPOSE OF THE PROJECT

The refrigeration system uses a miniature reciprocating vapor compression compressor. Due to space limitations in some high and overall efficiency of system are studied. In addition, a reliability, availability and serviceability discussion of the proposed CPU-cooling refrigeration solution is presented. Passive cooling methods, such as heat sink, heat pipe, insulators and vapor chamber, are widely used. These methods are advantageous because it dissipating the heat quickly and hence, their cooling capability is limited. It is estimated that when the chip power reaches 180W, the passive cooling methods would become incompetent. Therefore, new active cooling methods are needed. In a recent study, various active cooling methods, such as vapor compression refrigeration (VCR), thermoelectric refrigeration, Sterling, pulse tube, and absorption refrigeration, are compared. Many problems are yet to resolve including heat capacity, efficiency, reliability, size and cost. However, it is believed that among all these methods, VCR is the best.

3. VAPOR COMPRESSION REFRIGERATION SYSTEM

Vapor Compression Refrigeration (VCR) is a sufficiently compact, low cost, and power efficient technology for reducing the junction temperature of microprocessors below ambient, while removing very high heat fluxes via phase change. The current study includes a scaling analysis of single- and multiple-stage VCR systems for electronics cooling and an experimental investigation of small-scale, two-stage cascaded VCR systems. In the scaling analysis, a method for estimating the size of single- and multiple-stage VCR systems is described, and the resulting trends are presented. The compressor and air-cooled condenser are shown to be by far the largest components of the system, dwarfing the evaporator, expansion device, and inter-stage heat exchanger.[5]

It is well known that the VCR systems, such as refrigerators and air conditioners, are widely used. For electronics cooling, however, two additional requirements are demanded:

- Small refrigeration capacity (less than 500 W); and
- Compact in size (ideally, it should be small enough to be packed into two standard slots in a PC computer case).

The VCR cycle can be used for server cooling as the temperature generated is high and the conventional methods of cooling like heat sink , etc. can't be so much helpful and the cost of A.C. is too much high so the VCR cycle can be therefore be used as the method and the application for server cooling.

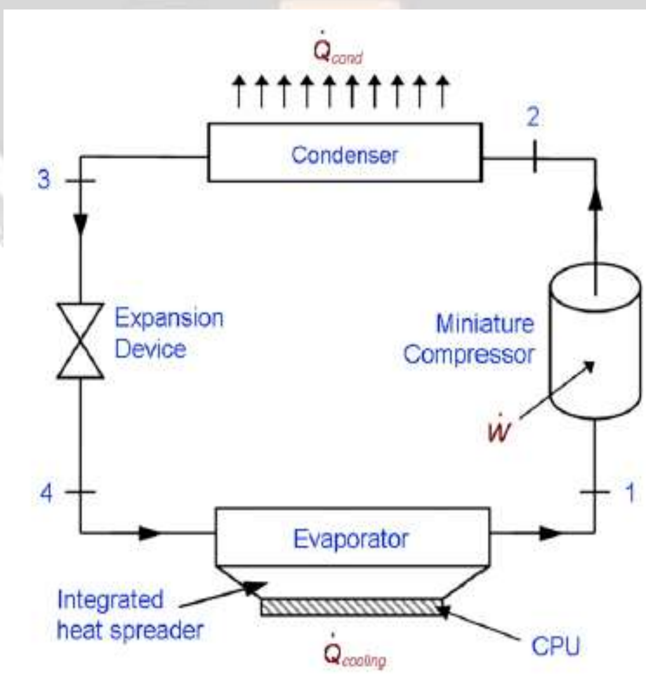

Fig -1 Vapor Compression Refrigeration Cycle

4. MAJOR ELEMENTS OF REFRIGERATION SYSTEM AND THEIR FUNCTIONS:

The main components of a refrigeration system are the condenser, the compressor, the evaporator and the expansion valve

4.1 Compressor:

The compressor's use is to pull the low-temperature and low-pressure vapour from the evaporator, through a suction line. Once the vapour is drawn, it will be compressed. This will cause the vapour temperature to rise. Its main function is to transform a low-temperature vapour in to a high-temperature vapour, to increase pressure. Vapour is released from the compressor into a discharge line. Compressor used in our system is 12V24V48V MAX having capacity of 300W the refrigerant used in this compressor is R134a for portable refrigerator mini air conditioner

- Weight of compressor : 0.72 kg
- Compression rate: Below 8
- Rotary speed : 2000 to 6000 rpm
- Performance : 130 to 400 W
- Evaporation temperature : -18 to 24C
- Maximum discharge temperature : 120C

4.2 Condenser:

Condensation changes gas to a liquid form. Its main purpose is to liquefy the refrigerant gas sucked by the compressor from the evaporator. As condensation begins, the heat will flow from the condenser into the air, only if the condensation temperature is higher than that of the atmosphere. The high-pressure vapour in the condenser will be cooled to become a liquid refrigerant again, this time with a little heat. The liquid refrigerant will then flow from the condenser to a liquid line.

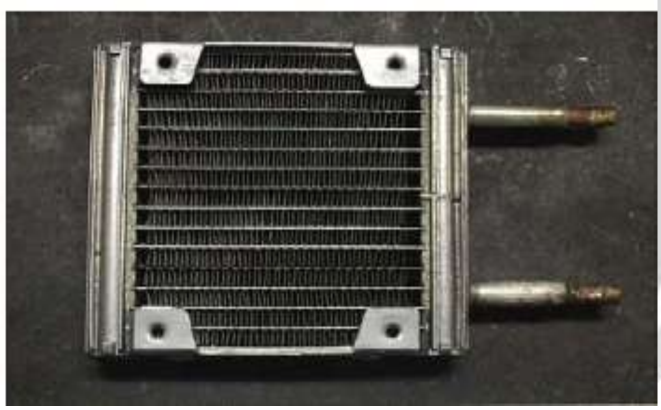

Fig- 2: Micro Channel Condensor

4.3 Expansion Valve:

Commonly placed before the evaporator and at the end of the liquid line, the expansion valve is reached by the liquid refrigerant after it has been condensed. Reducing the pressure of the refrigerant, its temperature will decrease to a level below its atmosphere. This liquid will then be pumped into the evaporator. These refrigerants were commonly used due to their superior stability and safety properties: they were not flammable at room temperature and atmospheric pressure, not obviously toxic as were the fluids they replaced, such as sulfur dioxide. Haloalkanes are also an order of magnitude more expensive than petroleum derived flammable alkenes of similar or better cooling performance. Capillary tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. We have used 0.26mm internal diameter tube. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications varies from 0.5 to 2.28 mm.

Fig -3. Capillary Tube

4.4 Evaporator:

An evaporator is used to turn any liquid material into gas. In this process, heat is absorbed. The evaporator transfers heat from the refrigerated space into a heat pump through a liquid refrigerant, which boils in the evaporator at a low-pressure. In achieving heat transfer, the liquid refrigerant should be lower than the goods being cooled. After the transfer, liquid refrigerant is drawn by the compressor from the evaporator through a suction line. Liquid refrigerant will be in vapour form upon leaving the evaporator

Fig -4. Evaporator

4.5 Refrigerant

A refrigerant is a substance used in a heat cycle to transfer heat from one area, and remove it to another. Usually in gas state at room temperature, found in pretty much everything that cools, and sometimes in things that heat, most commonly air conditioners, fridges, freezers, and vehicle air conditioners. Traditionally, fluorocarbons, especially chlorofluorocarbons (CFC's), were used as refrigerants, but they are being phased out because of their ozone depleting effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane. Most refrigerants found in end of life devices are ozone depleting and global warming inducing compounds.

4.6 R134A

R134a is also known as Tetrafluoroethane (CF3CH2F) from the family of HFC refrigerant. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerant has been widely used as their replacement. It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive. Currently it is also being widely used in the air conditioning system in newer automotive vehicles. The manufacturing industries use it in plastic foam blowing. Pharmaceuticals industry uses it as a propellant. It exists in gas form when expose to the environment as the boiling temperature is -14.9°F or -26.1°C. This refrigerant is not 100% compatible with the lubricants and mineral-based refrigerant currently used in R-12. Design changes to the condenser and evaporator need to be done to use this refrigerant. The use of smaller hoses and 30% increase in control pressure regulations also have to be done to the system.[6]

4.7 Detection of Leaks

When you suspect a leak of R-134a in your air conditioning system, detection can be done by using one of the following 5 methods. The simplest method and cost effective is by the use of soap solution. Workshops may use more sophisticated equipments to do this.

- Fluorescent Dyes
- Soap Solution
- Electronic Leak Detectors
- Halogen selective detectors
- Ultrasonic leak detectors

4.8 Adapter

The adapter is used for the connection purpose. It is the 24 volt AC TO DC power adapter. The DC motors get electric supply through adapter. In electronics, an Analog to Digital Converter (ADC) is a device for converting an analog signal (current, voltage etc.) to a digital code, usually binary. In the real world, most of the signals sensed and processed by humans are analog signals. Analog-to-Digital conversion is the primary means by which analog signal are converted into digital data that can be processed by computers for various purposes.

5. PERFORMANCE RESULTS

System performance measurements were conducted under the following operating conditions: evaporator temperatures of 10 to 20°C; refrigerant sub cooling temperature at the condenser outlet of 3 to 10°C; and ambient air temperatures of 25, 27, and 35°C. In general, the measured refrigerant side cooling capacity was lower than the measured heat transfer rate from the CPU. For instance, at an evaporator temperature of 20ºC, the system COP decreased by 20% as the inlet air temperature increases from 25 to 35ºC. Fluctuations in the discrepancies of the evaporator energy balances were due to measurement uncertainties. The cooling capacity of the MSRS for different inlet air temperatures at two different condenser air flow rate. The evaporator heat transfer rate increases with increasing evaporator temperature, at fixed inlet air temperature and air flow rate. This is due to the lower pressure ratio and higher refrigerant mass flow rate. [4]

At a fixed inlet air temperature and constant evaporator temperature, the cooling capacity of the MSRS increases if the air flow rate increases, due to greater heat dissipation from the condenser. The system cooling capacity also increases if the condenser air inlet temperature decreases, probably because of the augmented refrigerant mass flow rate in the system, which leads to lower degrees of sub-cooling and superheat. However, the response of the system is such that the overall product of the refrigerant mass flow rate and the evaporator enthalpy difference increases at lower condenser air inlet temperatures. At a constant air flow rate of 30 CFM, the cooling capacity increases by 28% as the condenser air inlet temperature decreases from 35 to 25ºC. As condenser air inlet temperature decreases from 35 to 27ºC. The overall system performance strongly depends on the compressor efficiency. If the overall compressor isentropic efficiency decreases, the electric power consumption increases and thus, the COP decreases. The compressor used in the experiments was not designed for the given electronics cooling application, can be achieved for small and medium-scale compressors of 3 to 10 kW cooling capacity. It may be noted that with increasing time of compressor usage, both the measured overall isentropic and volumetric efficiencies decreased. [3]

6. CONCLUSIONS

A miniature-scale vapor compression refrigeration system (MSRS) using R-134a as the refrigerant was designed, built, and tested. A commercially available small-scale compressor was installed in the MSRS. After an extensive experimental investigation, the main energy losses of the MSRS were highlighted. The most significant losses occurred in the compressor while the condenser and the evaporator performed to specification. A new compressor design for electronics cooling applications is needed to achieve better performance of the systems. By using this setup COP of the system increases from 2.06 to 8.8 hence the performance of CPU cooling increases while the system is maintained at lower temperature of 10ºC.following are the temperature readings taken during experimentation. from this it is clear that by using VCR cycle for CPU cooling improves the performance.

Temp. Without Heat Sink	Temp. With Heat Sink	Temp. With VCR System
High Temperature [heat supplied]= 98ºc	High Temperature [heat supplied]= 98ºc	High Temperature [heat supplied]= 98ºc
Lower Temperature [heat rejected]=98ºc	Lower Temperature [heat rejected]= 32ºc	Lower Temperature [heat rejected]= 89ºc [maintained]= 10ºc

7. REFERENCES

[1]. Domkundwar & Arora Edition 2005 Refrigeration& Air Conditioning
[2]. R.S. Khurmi & J. K. Gupta Edition 2008 Refrigeration & Air Conditioning
[3]. R. Mahajan, R. Nair, V. Wakharkar, J. Swan, J. Tang, G. Vandentop, Emerging directions for packaging technologies, Intel Technology Journal 6 (2) 2002.
[4]. P.E. Phelan, V.A. Chiriac, T. Yu, Current and future miniature refrigeration cooling technologies for high power micro electronics, IEEE Transactions on Components and Packaging Technologies 25 (3) 2002.
[5]. J.W. Peeples, Vapor compression cooling for high performance applications, Electronics Cooling 7 (3) (2001).
[6]. R.R. Schmidt, B.D. Notohardjono, High-end server low-temperature cooling, IBM Journal Research and Development 2002
[7]. J.G. Maveety, Thermal Management for Electronics Cooling Using a Miniature Compressor. International Microelectronics and Packaging Society, Palo Alto, CA, 2002.
[8]. Zhihui Wu., R. Du. Design and experimental study of a miniature vapor compression refrigeration system for electronics cooling, Applied Thermal Engineering (Science Direct) 2011.