ISSN No:-2456-2165

Immersion Cooling for Laptops: Voltage Drop due to Heat, Prototype and Concept Idea

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Abstract:- A typical information technology (IT) system takes around 40% of the total energy used in cooling the system. There are three major classifications of cooling systems and they are water cooling, closed-loop liquid cooling, and immersion cooling systems. Immersion cooling has been observed to be the latest trend in cooling systems for IT devices. It is a cooling procedure that is carried out through the immersion of all computer components in a dielectric coolant. This research examined the cooling process of the circuit board using this immersion method. Mineral oil, because of its high dielectric strength, is used as a medium fluid. Observing voltage drop due to heat produced by circuit and effects of voltage drop in performance of circuit board. A concept idea and design for implementing immersion cooling to laptops.

Keywords:- *Immersion cooling, laptop, motherboard, heat exchanger, coolant, mineral oil, dielectric, air cooling, heating, voltage, efficiency, diluted water.*

I. INTRODUCTION

The main objective of this research is to lower the power consumption of servers and reduce the temperature of all major heat-generating components by using the immersion cooling method as a cooling method for data centre servers. Experiments are used to validate this approach. This chapter gives a brief idea about the data centre, various Cooling systems, high-end servers and their major components.

Despite its importance and widespread use, renewable energy still does not account for a sizable fraction of the energy mix. In 2020, renewable energy amounted to around 10% of global final energy consumption [1]. This percentage, however, is likely to rise in the future as countries lessen their reliance on fossil fuels. Meanwhile, petroleum consumption as a fossil energy source and primary fuel for the world reached around 34.2 percent of global energy consumption in 2017 [2].

Numerous significant events and discoveries worldwide have sped the transition from fossil to renewable energy sources. These factors include growing concern about energy security and climate change, political and social pressures to rein in greenhouse gas emissions, rising and fluctuating oil costs, and a heavy reliance on foreign energy supplies [4].

Therefore, until 2035, the global energy industry's development will be primarily focused on meeting the worldwide demand for energy resources to support economic growth and population increase, as well as strengthening resistance to climate change [5]. Furthermore, dynamic changes are occurring in power systems, as indicated by the development of renewable energy. Numerous developing countries have decided to increase their investment in renewable energy to reduce the sig nificant reliance on fossil fuels. Global investment in clean energy has increased from 18% to 42% since 2004. China, Brazil, and India are the world's first, fifth, and eighth-largest investors in renewable energy, accounting for 37% of worldwide clean energy investment [1]. The distributed energy business and digitization are critical stages toward fossil fuel abolition. To ensure the uninterrupted operation of future decarbonizing power systems, a quantum leap in technology development is necessary.

One of the organizations with huge energy consumption is a data centre, this is a room or building that houses IT (Information technology) equipment, electrical systems, HVAC (Heating, Ventilation, and Air Conditioning) systems, and other related infrastructure, as well as providing critical services that ensure the equipment is kept secure and reliable [3,8]. Between 2000 and 2005, the amount of electricity consumed by data centres worldwide doubled, then rose by around 56% between 2005 and 2010. According to recent energy figures, the data center business accounts for 1.3 percent of global and 2% of US electricity usage. Indeed, the United States consumes between 25% and 35% of global data center electricity consumption [6]. According to a congressional report from the Environmental Protection Agency (EPA), data centres consumed 1.5 percent of America's electricity in 2006 [7,9]

Air cooling systems were later developed to take the role of liquid cooling due to their reliability and feasibility in comparison to liquids. From a digital standpoint, the constant growth of electronic products causes the heat density of information technology equipment to rapidly increase [10], necessitating the development of liquid cooling systems. Liquid cooling technology improves the efficiency of data centres and enables heat to be reused [11,12]. It is possible to provide electricity to a large-capacity immersion cooling system in particular [13].

ISSN No:-2456-2165

As stated previously, this paper analyzes the most promising cooling system, immersion cooling, for reducing power use and increasing energy efficiency. Since the first discovery of immersion cooling in the 19th century for usage in transformers until now, it has been developed rapidly for various applications in the latest technology. Initially, the method of immersion cooling with mineral oil only focuses on maintaining the electronic components' temperature to prevent overheating [14,47]. However, current immersion cooling functions to save energy. Therefore, the latest findings need to be presented in a comprehensive literature that can be easily understood by laypeople to practitioners and researchers with a higher level of understanding. To ensure simple literature for the people, this paper begins with an introduction to cooling systems in general, followed by their history, applications, and types. Furthermore, the latest findings on immersion cooling concerning its energy-saving benefits, are reported for the advanced literature

II. GENERAL COOLING SYSTEM

Over the last decade, technological advancements have resulted in the mass manufacture of electronic devices, increasing energy consumption during the manufacturing process and subsequent use of the devices. A nanotechnology approach has also been presented, which reduces the size and cost of the devices but has significant issues in terms of thermal management due to the high-power density, which results in increased heat output. Meanwhile, increased heat generation in the device typically results in decreased productivity and eventual failure. It has been noted that increasing the temperature above 75 °C has the potential to exponentially increase the rate of failure [15]. As a result of the desire to shrink the size of electronic gadgets and boost their productivity, cooling systems have become critical. Numerous solutions have been developed in recent decades as a result of conventional methods' failure to meet the ongoing demand for these devices, with several of them outlined below.

A. Water-cooling system.

The water-cooling system's role in an automobile, which is to circulate water between the heat source and the cooling radiator, is equally applicable to the computer device and data centre. In these systems, coolant is directed to the CPU, which generates the majority of the heat, while the remaining components are cooled by air. For example, in a personal computer, the components that generate the most heat are the central processing unit (CPU) and graphics processing unit (GPU), as demonstrated by the significant heat generated throughout each process. It is critical to highlight that the rapid advancements in technology and communication have increased the growth of data centers and energy consumption globally over the last few years [16]. As a result, it is necessary to place a greater emphasis on data centre cooling systems, which have been claimed to consume more than half of energy via heating, ventilation, and air conditioning operations [17,18]. Additionally, it has been observed that the increasing power density of microprocessors is resulting in a large increase in data centre mechanical cooling requirements [19,20]. Water cooling is a promising cooling technology that has been the primary choice for many data centres when it comes to lowering the temperature of the processor and other components such as graphics cards [21]. This is considered required because the speed of processors used in recent years has increased fast, increasing the amount of heat generated. Water is used to cool these devices because it absorbs heat approximately 30 times faster than air [21], allowing the processor to function at a higher speed and with less noise. Due to the possibility of substituting other liquid substances for water, this water-cooling system is occasionally referred to as a liquid cooling system. Its primary advantage is that it has a larger heat transfer capacity per unit, allowing for a smaller temperature differential between the Central Processing Unit (CPU) and the cooler [8]. Additionally, it has a greater input temperature, which reduces the requirement for active heat rejection equipment and enables the reuse of generated heat [22]. Additionally, the method is efficient and may be applied on high-density servers [23], such as the one shown in the following image.

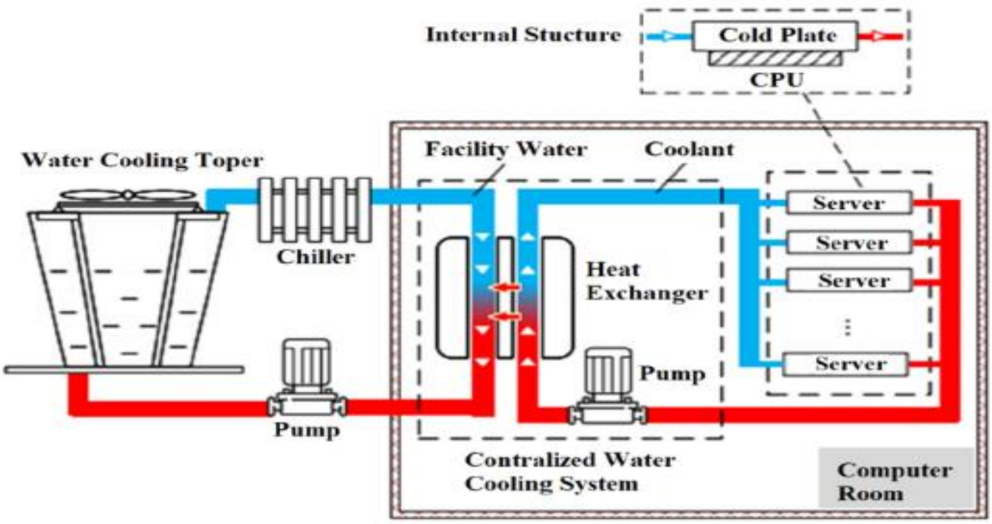

Fig. 1: Water cooling design in the data center [23]

B. Indirect water cooling

Indirect water cooling is the technique of eliminating heat from a source without direct contact with the water. It entails substituting an evaporator or a water-cooled heat sink for the traditional air-cooled heat sink [24]. Additionally, the classic indirect liquid-cooled system is typically equipped with a cooling plate and water-blocking mechanisms. Meanwhile, recent research in this field has tended to focus on microchannel heat sinks and their increased efficiency as a result of their superior heat transfer properties as compared to traditional indirect water-cooling systems [25,26].

C. Direct water-cooling system.

Direct water cooling differs from indirect water cooling in that the coolant comes into direct contact with electronic components [27]. Difference between direct and indirect water cooling systems in a solar power plant application operated with a supercritical CO_2 cycle [28]. The adaptability of the coolant is one of the primary advantages of this technology since no closed enclosures or pipes are required to guide and sustain fluid flow to the server. Due to latent heat transfer, this system comprises a phase change phenomenon that results in a uniform temperature profile on the surface of the heat source [29,47].

D. Air-cooling system.

Air-cooling is a heat-removing method that works by expanding the surface area and increasing airflow over an object through the addition of cooling fins to the surface and using a fan [31]. It is usually applied to vehicles [32], laptop computers [33], electronics [34], and computer rooms [35,36]. The process of an air-cooled motorcycle engine involves forced convection to release heat into the [37,38]. This occurs through the absorption of the surrounding air by the fan into the fins provided on the outer surface of the engine cylinder block which then transfers the heat from the surface into the air [39]. Meanwhile, the principle of air-cooling in computers involves the absorption of heat from the CPU and keeping it away from the hardware. The heat is transferred from the CPU’s Integrated Heat Spreader (HIS) through a thermal paste to a conductive base plate usually made of copper or aluminium, and later to the heat pipes installed in the electronic cooling system [30].

III. IMMERSION-COOLING HISTORY

The discovery of the immersion system was initiated in the 19th and 20th centuries based on the discovery of electromagnetic induction by Sir Michael Faraday on August 29, 1831, and Joseph Henry. The device invented by Faraday et al. is a primitive transformer because it can only open and close direct current since there was no alternating current at the time. Moreover, C. J. Page manufactured an autotransformer in Washington, D. C in 1836 while the first closed-core transformer was built on September 16, 1884, under the supervision of M. Dery, O.Blathy and K. Zipernovsky at the GANZ Plant in Budapest. This means the immersion of electrical systems, especially transformers, in a dielectric fluid for thermal management was used before 1887 [40].

The first explicit mention of the use of oil as a coolant and insulator was recorded in 1899 in a patent filed for a Constant Current Transformer by Richard Fleming of Lynn, Massachusetts [41,47]. Meanwhile, the first-ever research which specifically used liquid dielectrics to cool ‘‘computers” was conducted in 1966 by Oktay Sevgin of IBM [42] while Richard C. Chu and John H. Seely working for IBM patented an ‘‘immersion cooling system for modularly packaged components” in 1968 [43]. Subsequently, Seymour R. Cray Jr., the founder of Cray Research, LLC. also patented ‘‘Immersion-cooled high-density electronic assembly”[44]. Cooling micro-electronic components with liquids began to attract serious attention in the mid-1980s when IBM, Honeywell, SperryUnivac, Control Data, and Hitachi all introduced indirectly water-cooled mainframe computers [45]. Moreover, Cray T90 was released using a liquid-to-liquid heat exchanger and a one- or two-phase immersion coolant for heat removal in 1995 [46,47]. Meanwhile, the presence of CMOS in the CPU was also reported to have led to significant energy savings which quickly reduces the cooling constraints of high-pressure control (HPC) systems. The immersion systems started gaining attention again in the second decade due to the increased thermal properties of chips.

IV. IMMERSION COOLING IMPLEMENTATION

A. Methodology

As per the design, the focus is to apply a cooling system for laptops and computer motherboards. In the laptop prototype, the base is made up of a transparent material like fibers for plastic. The design mainly consists of 3 chambers.

- **Motherboard compartment (MBC**);**-** Here all circuits and fans [for the motive of the coolant liquid] will be placed with connected wires which will be immersed in the coolant liquid.
- **Heat exchanger compartment (HEC)**;**-** In this chamber, there will be a set of small fans which exchange the heat or cool down the liquid coolant present in the MBC.
- **Input/output cables compartment (IOCC**);**-** Here there will be no flow of coolant and completely sealed from MBC just a few air-sealed wires will be coming out from MBC for input-output data transfers. The further the wires are connected to their pin slots.

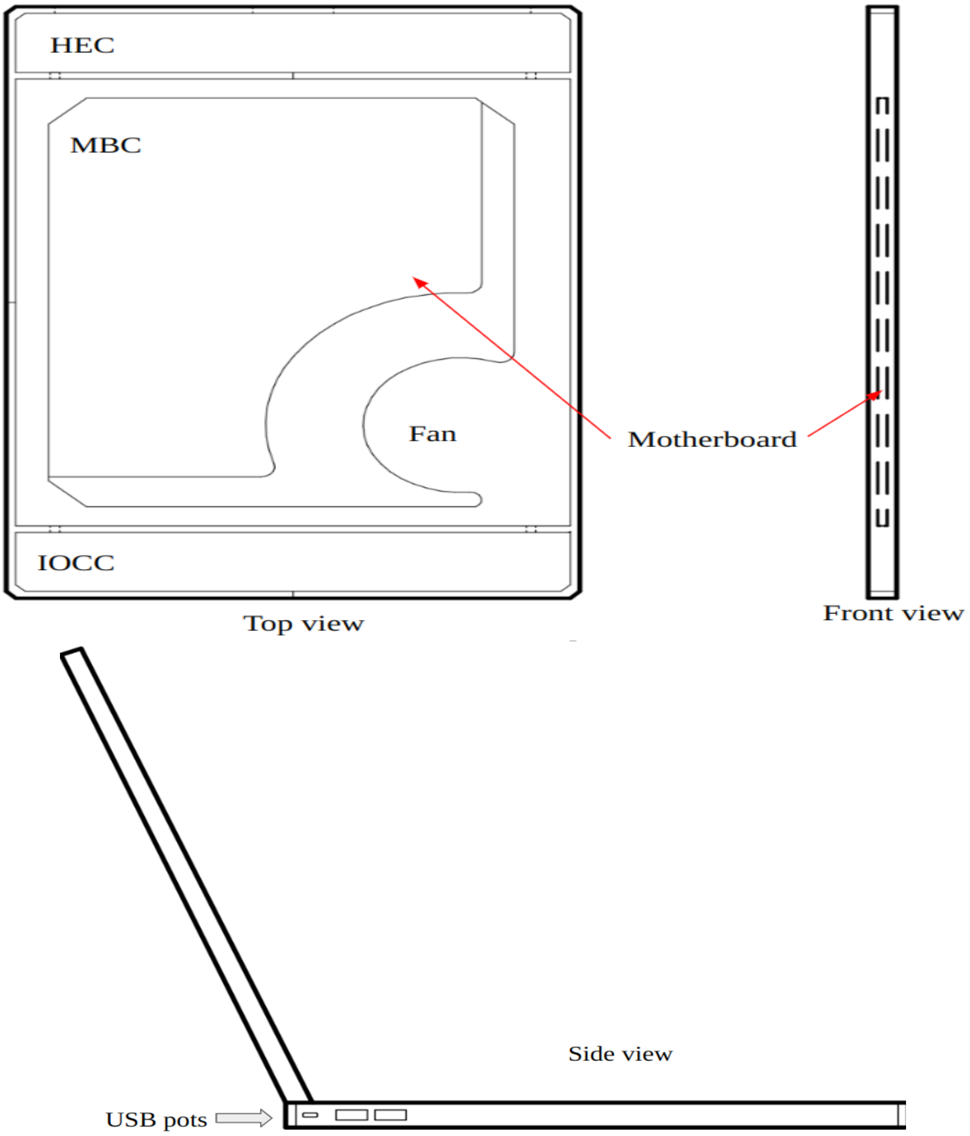

Fig. 2: Prototype design

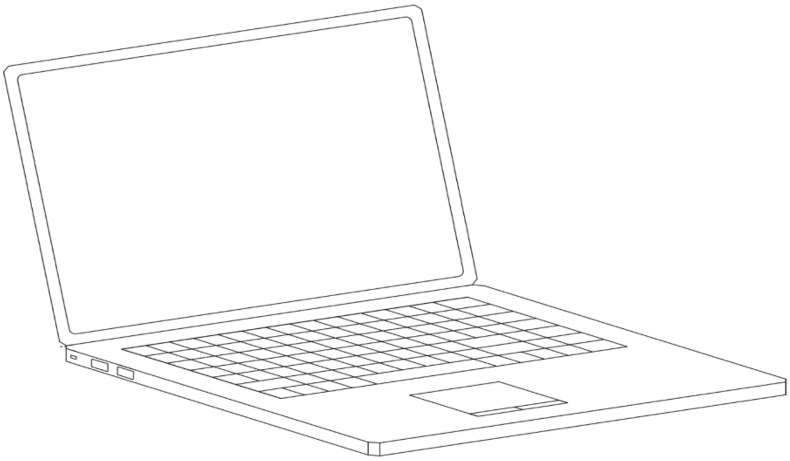

Fig. 3: Overall concept design

B. Working Model

In the working model, a normal phone charging circuit is used which converts AC / DC to DC 8v. It is made from acrylic sheets and the circuit is placed in a cube. And filled with mineral oil only input-output cable connections are taken out. Then the whole model is sealed with adhesive. Make it leak proof.

ISSN No:-2456-2165

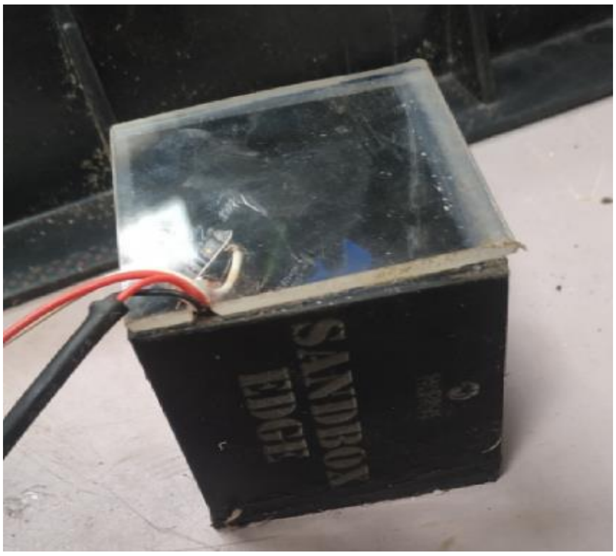

Fig. 4: Working Model

C. Non-Working model

The non-working model has been tried to mark models as concept design MBC and IOCC. Here a motherboard and fan of the computer are used. A plastic base tray in their motherboard is placed and the selection of cable slots is separated for an acrylic sheet. Connection wires are connected and collected then they are air sealed. Later the tray is filled with coolant. Then an acrylic sheet is used to close the top of the tray in that acrylic sheet a fan is placed correctly at top of a processor for the motion of the coolant. Then the acrylic sheet was closed and sealed at the top of the tray.


Fig. 5: MBC housing

Fig. 6: Non-working model immersed in diluted water.

V. RESULTS AND DISCUSSION

The table shows how the immersed cooling system is 30% more effective than the different cooling systems. Two key aspects must be considered when comparing the demonstrated technology to alternate existing cooling technologies: their ability to provide high energy efficiency, and their ability to cool high-heat density equipment. For example, free-air cooling is energy efficient but may not be able to provide the cooling required. Several types of fluid can be used for cooling and the use of liquids is one of the most prominent and efficient methods that can be directly or indirectly implemented. For the direct method, the fluid must be non-conductive material because the fluid is in contact with electronic devices. Mineral oils are used as the main liquid insulating medium because of their good electrical neutralizing and cooling properties. Many of these oils are used as cooling fluid as they provide a much higher capacity of heat transfer than air with the same volume.

Tests Conditions	Temperature of the circuit (C)	Before immersed cooling (V)	After immersed cooling (V)	Voltage loss (V)	Percestage of voltage loss (%)
Output voltage at room temperature on load.	29	8.58	8.65	0.07	-0.8%
Output voltage at room temperature with the load.	29.4	7.59	7.99	0.40	-5.27%
Output voltage at heat supplied to the circuit on load.	38	6.53	7.95	1.42	-17.86%
Output voltage at heat supplied to the circuit with the load.	44	5.02	7.54	2.52	-33.42%

Table 1: Test conditions and results

VI. CONCLUSION

This period has witnessed a high rate of advancement in IT. This development decreases the energy consumption used in cooling electronic components, increases the performance of electronic circuits and increases efficiency, therefore an effective cooling system is needed to reduce the level of energy consumption. Immersion cooling is one of the recent and trending cooling systems. This method uses a dielectric fluid that does not conduct electric current so as to reduce heat effectively This review gives a superior technique to cool a laptop and computers utilizing the immersion cooling method, which is not a new technology as numerous researches have been recorded. For the laptop and computers however, more investigation is needed to exploit the capabilities of electronic devices and the effects this approach will have on them as well as its comprehensive impact on the environment.

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