An experimental investigation on the effects of mineral oil flow rate on CPU immersion cooling

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Abstract. The aim of this research is to analyze the effect of using immersion cooling with different flow rate and fan rotation on decreasing the temperature on CPU. The study used three variables of flow rate: 0.5, 1 and 1.5lpm. in addition, three other variables of fan rotation, 400, 600, and 800 rpm, were used as well. Data collection was by means of benchmark software to load the CPU to work maximum and the logging software to record the temperature. The results show that the immersion cooling could potentially be utilized as the new and more effective cooling system. The most optimum variable to decrease the temperature was 1, 5 lpm with fan rotation at 800 rpm. It decreased the maximum temperature from 60 °C to 47 °C, a deviation of 13 °C lower compared to the conventional fan cooling system with air as a medium. The study established that the higher the flow rate and the fan rotation, the higher temperature can be decrease. Therefore, immersion cooling can be the solution to decrease the consumption of energy on IT sector on a bigger scale.

1. Introduction
The developments in the IT field has triggered high internet usage. Precisely, it has accelerated and facilitated the delivery of information on a global scale. In 2014, The International Telecommunications Union (ITU) reported that as many as 3.7 billion people in the world use the internet. This figure was greater than the previous year which recorded 2.7 billion users. This great of internet user is proportional to the energy consumption. In IT equipment, 40% of energy use for cooling system [1]. Therefore it is necessary to trim the energy usage by means of the data center to maximize global energy consumption and minimize the negative impacts to the environment. One way to overcome the problem is reducing energy within the cooling system of the data center. Within this equipment, it has various units of component such as CPU, motherboard and power supply. The CPU consists of chips as the data processing core. The maximum temperature for the operation of this device is 70 °C [2]. Any rise of 2 °C from the maximum operating temperature will reduce the chip's efficiency by 10% [2]. For this reason, an effective and efficient cooling system is needed to overcome this problem. The two main technical challenges in cooling systems are sufficient heat transfer from heat changes and uneven disappearance of power. The data center cooling method is cooling utilize air and liquid mediums [3].
The cooling process generally used is cooling air medium. The increasing of efficiency and ability of heat transfer from cooling methods to air medium is an issue of concern.

Heat from IT hardware is absorbed by air and carried to the environment, mixed with lower temperature air or cooled through refrigerants [4]. As data centers increase and develop over time, energy consumption escalates [5]. This trend leads to high heat density IT equipment, a factor that causes high energy consumption and costs. The device is sensitive to temperature changes and has the higher risks of failing due to overheating. Furthermore, the equipment is also required to work continuously, 24 hours a day throughout the week [6].

A cooling system is used to prevent overheating from the data center devices, especially the CPU and PSU. These have various types, i.e. Free Convection, Forced Convection Air-cooling, Forced Convection Liquid Cooling, and Liquid Evaporation [7]. One of efficient and new cooling systems for the data center is immersion cooling. It is a method of cooling a computer device through immersing a data center device into a dielectric liquid. In the cooling process, Immersion cooling is applied a pump to circulate cooling liquid (mineral oil) to reduce heat.

Heat transfer at immersion cooling occurs through convection in liquid and gases. This heat transfer happens when there is a temperature difference between the surface of a solid object and liquid. In its displacement, this mechanism involves the transfer of the medium and when translocating heat. There are two types of convection, natural and forced displacements. Mineral oil is a medium capable of providing cooling to electronic devices. The immersion cooling technique with mineral oil media has a heat capacity of 1.150 times greater than conventional cooling which utilize air as a medium [4]. Therefore, the objective of this study was to investigate the immersion cooling on computer equipment, including CPU, motherboard and power supply. Mineral oil is used as a medium in immersion cooling system.

2. Research method

Immersion cooling is a system that submerges an IT device in a dielectric liquid that serve as mineral oil. There are requirements for the medium coolant on immersion cooling that could differ depending on the type of cooling system applied and the electronic equipment used. The chemical nature of medium coolant for electronic devices has special requirements such as: it must be non-flammable, non-toxic and affordable. Furthermore, the coolant medium must have good and high thermophysical properties, including high heat type, thermal conductivity, and heat transfer coefficient. The medium ought to be good in chemical and thermophysical properties, also suitable with the material of the cooling system components and electronic equipment.

![Figure 1. Experimental diagram of immersion cooling.](image)
Immersion cooling is included in Forced Liquid Convection. The heat transfer occurs due to the movement of dielectric fluid by a pump flowed in and out through the radiator. The motherboard was inserted into a vessel. Liquid is flowed through the pump to the vessel containing the motherboard. After the motherboard perfectly enters the vessel, mineral oil is inserted. The volume of mineral oil used in this study was 10 liters. The variables were flow rate (lpm) and time (hours) with the data collection ratio as 0.5 lpm: 1 lpm: and 1.5 lpm: Benchmark software and data logging were used for computers capable of working optimally and recording temperature.

The initial step in the practical aspect of the study involved turning on the computer and waiting for half an hour to stabilize its condition. The flow rate was then controlled using a ball valve to the variables 0.5 lpm, 1 lpm and 1.5 lpm. Flow rates measured using a flow meter were again quantified manually with a measuring cup for accuracy.

Variable fan rotation used several fans in different turns. The flow rate and fan rotation were suited to fit the variables and thereafter, the computer started benchmarking and logging data to get a temperature increase data on immersion cooling. Data retrieval was taken for 24 hours for each variable. After one variable was examined, the computer was rested for about 1-2 hours.

3. Results and discussion

3.1. Temperature

The temperature achieved using immersion cooling indicated that the method is better than conventional cooling. The temperature achieved using conventional cooling was 60 °C, but with immersion cooling, the results obtained are shown in Figure 2.

![Figure 2. CPU temperature with different flow rate.](image)

In Figure 2, it can be seen that the maximum working temperature decreased with the flow rate. These results indicated that heat transfer occurring can reach the optimal value with the increase in flow rate. The most optimal reduction in working temperature was achieved through a variation in the flow rate of 1.5 lpm with the lowest temperature of 47 °C compared to other variations. This temperature was 13 °C lower than the temperature achieved through conventional cooling systems of air medium. This shows that the flow rate and fan rotation have a significant role in reducing the maximum temperature.

3.2. Temperature on inlet channels

Measurements on the inlet channel was carried out to determine how high the fluid temperature increased absorbs heat directly from the CPU component. This provided an environmental view of immersion cooling, a fluid that directly immerses the CPU component. The inlet temperature consisted of three results from each variation in the flow rate. The results of inlet temperature measurements were as shown in Figure 3.
In light of above, it is evident that the highest inlet temperature was at a variation of the flow rate of 0.5 lpm. The lowest inlet temperature was at a 1.5 lpm. This showed the absorbed environmental heat was affected by the variable flow rate and fan rotation.

3.3. Temperature on outlet channels
Temperature measurement on the outlet channel was carried out after the fluid passed through the radiator. The results of the measurements on the outlet were as follows:

The results showed the fluid temperature on the outlet decreased. The heat exchange occurring on fan-assisted radiators posted the best results at a variation of 1.5 lpm, implying that the flow rate helped in heat transfer in the radiator. Moreover, the lowest temperature after passing through the radiator was attained was 32.7 °C. This proved that immersion cooling applying mineral oil had a higher heat absorption capacity that affects maximum CPU working temperature. It was capable of reducing 13 °C on 1.5 lpm. The data obtained shows more than 50% of students agreed that geothermal is environment-friendly energy, 20% did not know while the remaining disagreed. The second question on the development of geothermal energy has a higher positive impact than a negative one with 60% in agreement, 22% did not understand, while the remaining disagreed.

4. Conclusions
Immersion Cooling is a system which by means of immersing CPU components employ the principle of convection heat transfer. The heat generated from the CPU is absorbed by the mineral oil and then pumped to be cooled in the radiator before being poured back into the vessel. The results of this study
indicates that heat loss occurring is 13 °C lower than conventional cooling with air. This is because the heat absorption capacity of mineral oil is greater than air. The effect of the flow rate and rotation has a large influence on temperature reduction. The lowest temperature can be achieved with the highest flow rate and fan rotation variable of 1.5 lpm and 800 rpm. For energy consumption or PUE was 1.4 for conventional coolers and 2.04 for immersion cooling. In this study CPU components were immersed for 5 months. Throughout the immersion period there were damages (delaminating, warpage, and swelling). This shows that immersion cooling is an appropriate cooling system and meets the demands of technological development and progress.

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