COMPUTER SCIENCE ICE

DATA CENTER

DIR Barrage Nordx

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RISE Report 2023

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1 Introduction

An upcoming trend in the data center business is liquid cooling, where the waste heat is generated as liquid instead of air, as in traditional cooling. This creates a greater potential of utilizing the excess heat.

Immersion cooling, which involves submerging computer hardware in a non-conductive liquid, is becoming an increasing popular method for cooling high-performance computing equipment, including cryptocurrency mining servers.

The primary advantage of immersion cooling is that it can dissipate heat much more efficiently than traditional air-cooled systems, allowing for higher density computing equipment to be packed into smaller spaces. This results in lower operation costs, as less energy is required to cool the equipment, and potentially higher hash rates, as the hardware can operate at lower temperatures.

Immersion cooling can also enable more efficient heat recovery for district heating compared to air cooling as the cooling liquid used in immersion cooling can reach higher temperatures than air and can transfer heat more efficiently.

In traditional air-cooled systems, the hot air generated by the mining hardware is expelled into the environment and capturing this heat for reuse can be difficult and ineffective. However, with immersion cooling, the heat generated by the mining hardware is transferred directly to the cooling liquid, which can then be circulated to a heat exchanger for recovery.

From previous experiments conducted at RISE ICE in Luleå, it was showed that a single immerse cooled crypto mining server could operate without significant drop in hash-rate or increased power usage in oil-temperatures as high as 69ºC. To further investigate how this could be scaled up and what the potential is for crypto mining servers to support the district heating network, further experiments will be conducted in this project.

There is a large business potential in using immersion cooling for crypto mining servers where more computes can potentially be done for the same amount of power, due to overclocking and power reduced by removing the fans. Another aspect is the work environment, where a quieter data center will be achieved when removing the fans. Furthermore, by using immersion cooling excess heat will be created as liquid which has a higher potential for utilization compared with air.

Barrage is providing sell services and goods in the IT-sector, operations of server hall and development, design and research of software and related activities. They see a need of further development of their data center facilities, to utilize their excess heat.
Barrage wants to be a role model in the field of mining, showing other actors in the same area the positive effects of using immersion cooling and by this pushing the data center industry in an even greener direction creating the 4th generation of data centers.

1.1 Aim

The aim of this project is to continue to investigate immersion cooling for crypto mining servers to develop knowledge how the servers and immersion system behave. Based on the results from the first stage RISE will study the possibility of immersion cooling for mining servers at their Liquid Cooling Testbed (LTC) in their Submer tank, scaling up the testing from the first stage with the objectives:

- Power usage reduction comparison when converting from air to immersion.
- Hash rate comparison when converting from air to immersion.
- Measure the temperature distribution in the tank and the excess heat temperature.
- Investigate potential of heat recovery from crypto mining servers in immersion cooling

2 Experimental setup

The tests were carried out in two phases, first the air tests and then the liquid tests in the Submer Smartpod XL. All tests were performed in RISE ICE facility in Luleå. A further description of the test setup can be seen below.

2.1 Air test

To get a reference test for the immersion cooled miners, they were first tested using traditional air cooling. For this experiment we set up 16 miners as seen in Figure 1. Each miner's internal temperature and hash rate was logged using RISE data-collection system as well as the total power consumption. The miners used are Aladdin Asic Miner: L2–30T with a rated power consumption of 2.4kW.

As the liquid cooling testbed used at RISE has a cooling limit of 40kW, 16 miners were used which should give a theoretical power consumption of approximately 38.4kW. The air-cooled tests were conducted for about 4 hours using all 16 miners, and thereafter a few tests were conducted with fewer miners (12, and 6) to have for reference.

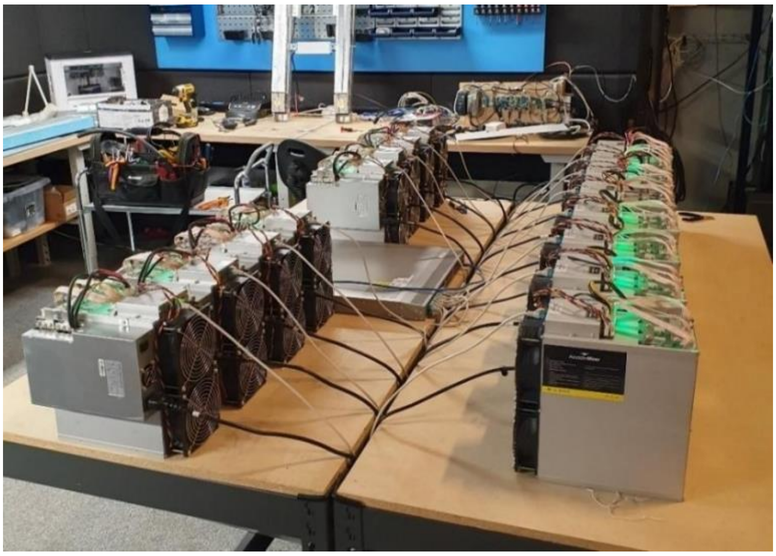

Figure 1. Set up for air tests.

2.2 Liquid test

To test the performance of the immersed cooling miners, a Submer SmartPod XL was used connected to the Liquid Cooling Testbed (LCT) at RISE ICE in Luleå (See Figure 2 and Figure 3). The tank used has a total volume of about 1014 l and was filled with mineral oil, *Submer Smart Coolant*. The cooling capacity of the tank was rated for 50kW with oil temperatures of up to 55ºC.

Figure 2. Submer SmartPod to the left and Liquid cooling testbed (LCT) to the right at RISE ICE T&D.

To cool the SmartPod, the Liquid Cooling Testbed at RISE ICE was used. The SmartPod was connected to the water-cooling loop. In Figure 3 below, a simplified schematic figure of the liquid cooling test bed is presented where the tertiary loop is the water loop connected to the tank. The secondary loop is a water loop that can be coupled to the buildings hot tap water. During these tests, it was not coupled to the hot tap water loop but run as a closed loop. The facility coolant loop is a glycol mixture connected to the facility cooling system for our operational data center.

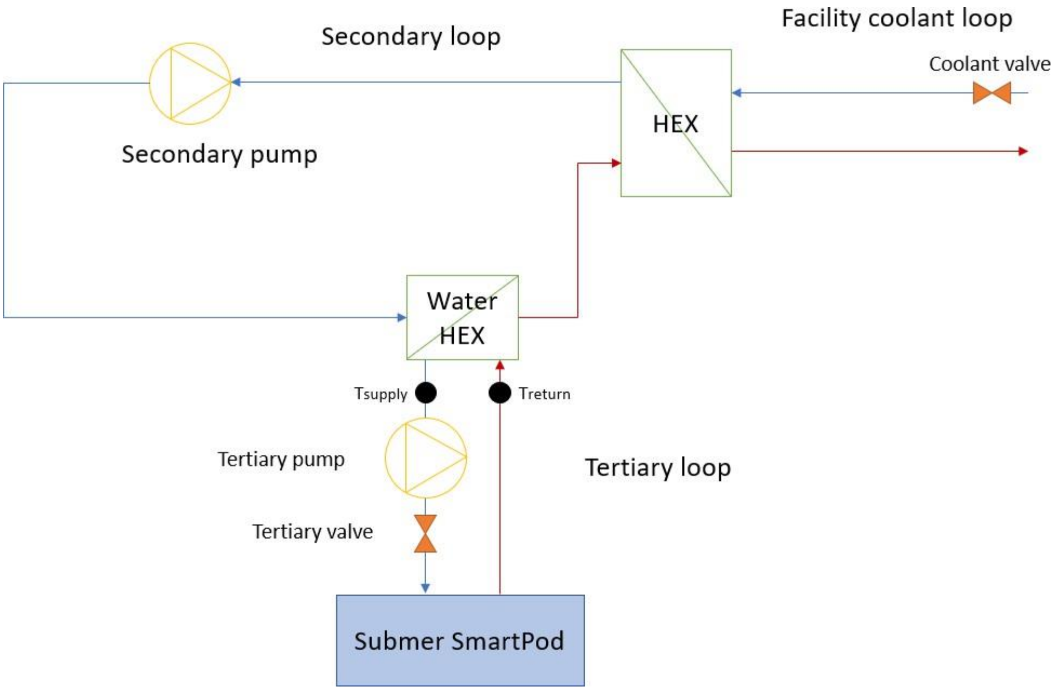

Figure 3. Schematic picture of Liquid Cooling Test Bed (LCT) at RISE ICE T&D.

Before the miners was ready to be submerged, a few modifications were made. The two fans of the miner, as well as the fan of the PSU were demounted. Some miners had a different power supply that would not start unless a fan simulator was installed in its place. These fan simulators were provided by Barrage. The original thermal interface material (TIM) located between the ASIC chips and the heat sinks was left, since no significant differences in performance was shown in previous tests.

Before submersing the miners, four small screw eyes were attached in the existing holes from the front fan panel, and a thin metal wire was attached between the four hooks. Together with metal rods the miners were hung into the Submer tank at a desired height. (See Figure 4)

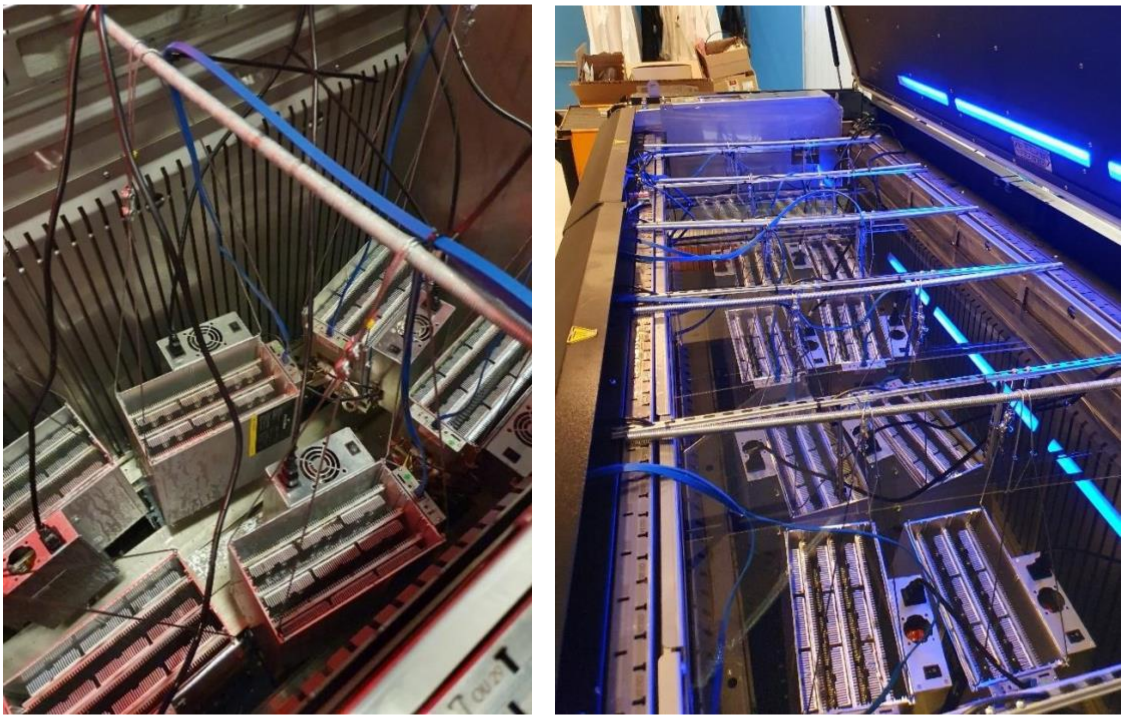

Figure 4. Set up of mounting of the servers.

A set of twelve temperature sensors (DS18B20) was mounted above each server to get an idea of how the heat is distributed in the tank, and to find out if there are any local hotspots. (See Figure 5 and Figure 6) The sensors were immersed around 15cm under the surface. The temperature values were collected and stored using a Raspberry Pi and the RISE ICE Data collection system.

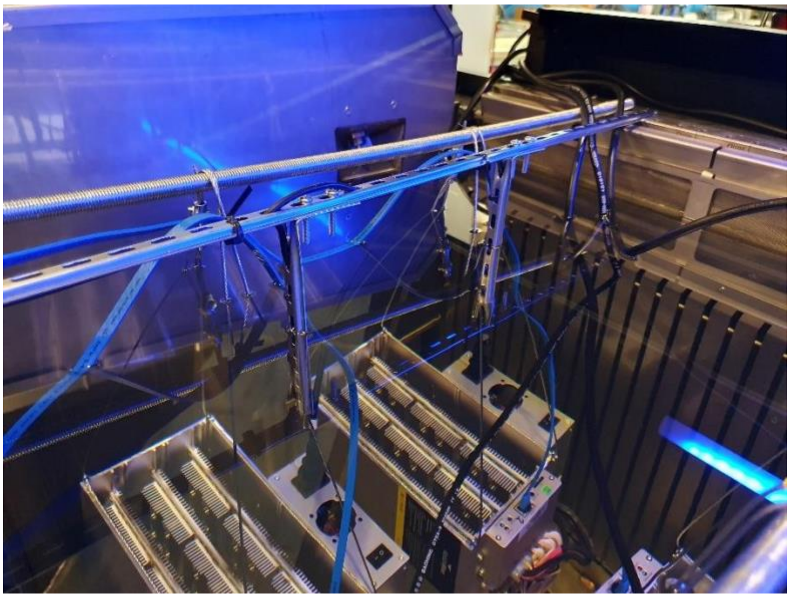

Figure 5. Mounting of temperature sensors in tank.

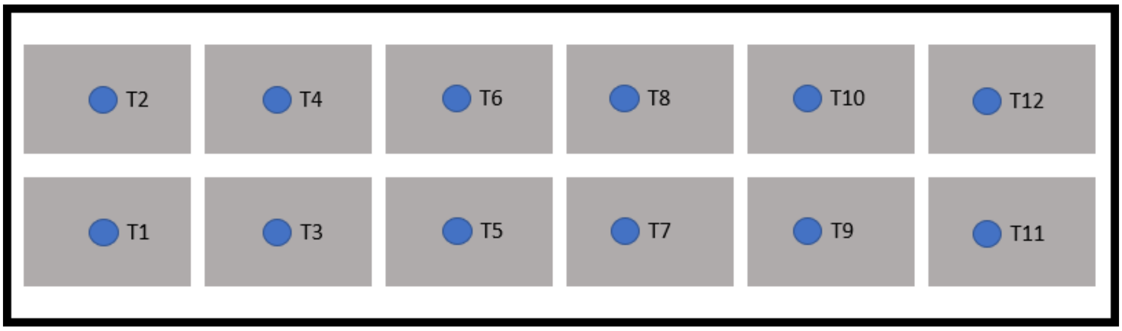

Figure 6. Schematic over the sensors mounted in the tank.

The rejected heat for the water-cooling loop was calculated using the equation below

$$Q = \dot{m} \cdot c_p \cdot \Delta T \quad [W]$$

Where the mass flow is calculated with the volume flow, V, and the density, ρ, for the water.

$$Q = V \cdot \rho \cdot c_p \cdot \Delta T \quad [W]$$

The constants for density and specific heat capacity for the water at 40ºC was used, 992 kg/m^3 and 4.186 kJ/kg K, respectively. It was calculated with the water supply and return temperature sensors near the pump at the LCT.

3 Result and discussion

In this chapter the results from the air and liquid cooled tests are presented. Due to limitations in the Submer tank's operation temperature and LCT's cooling capacity, the liquid test could only be carried out with 11 miners.

In Figure 7 below the average temperature of all servers is presented for the air and liquid cooled tests. The temperature for the air test was around 68°C and around 69.5°C for the liquid test. During the air-cooled test, the air temperature in the lab was 20.4°C.

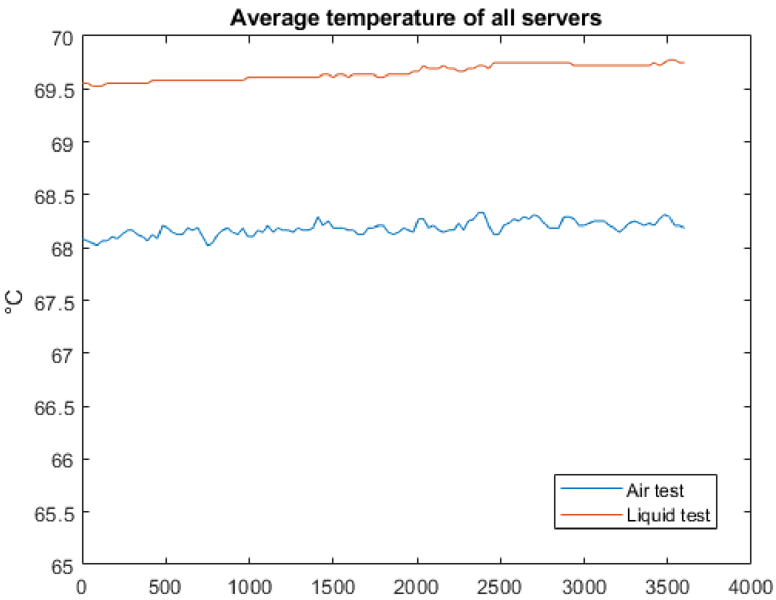

Figure 7. Average temperature of all servers for air (blue) and liquid (red) cooled tests.

The average hashrate for the tests can be seen in Figure 8, where the results are quite similar for both the tests with the air test around 0.3 TH/s higher.

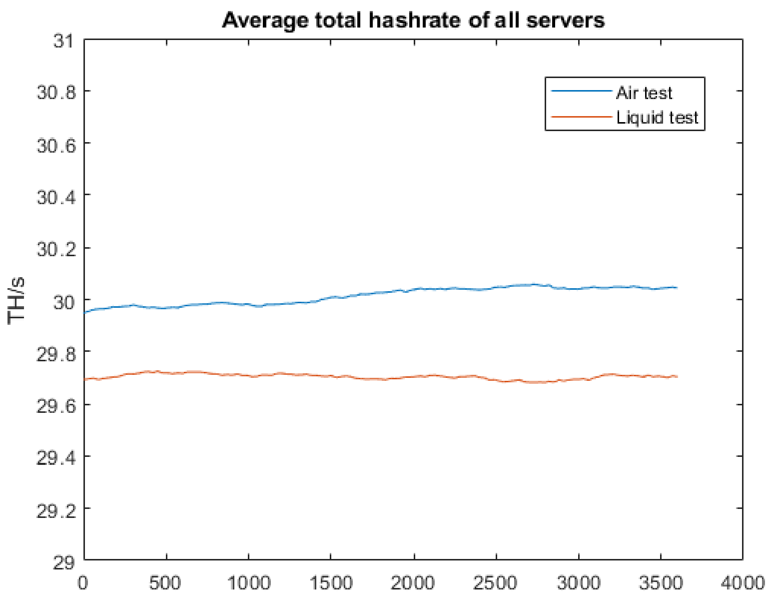

Figure 8. Average hashrate of all servers for air and liquid cooled tests.

Since we discovered the limitation in the Submer tank and LCT, and could only run 11 miners, the average IT power for one server was calculated to be able to compare the tests. The results are showed in Figure 9 below and show a lower power of around 2.44 kW for the liquid test compared to slight above 2.49 kW for the air test. This is a decrease of around 2%. This power drop was expected as the fans draw around 60W at full power.

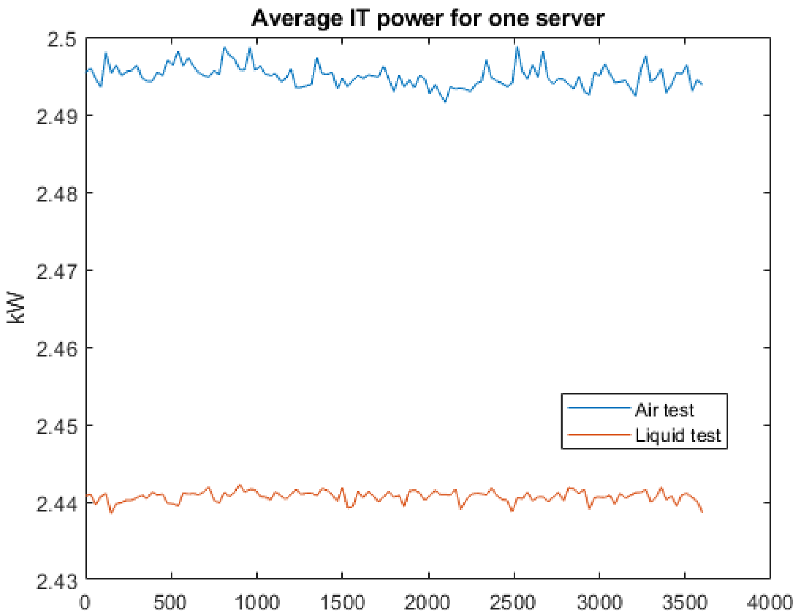

Figure 9. Average IT power for a server for air (blue) and liquid (red) cooled tests.

The rejected heat from the tank and the total IT power are presented in Figure 10 below. The total IT power was about 0.5 kW higher than the rejected heat due to thermal losses to the environment. This shows a good potential to recover heat from the crypto miners, since nearly all electrical power input can be extracted as thermal energy, compared with air-cooled solutions where heat recovery is a greater challenge.

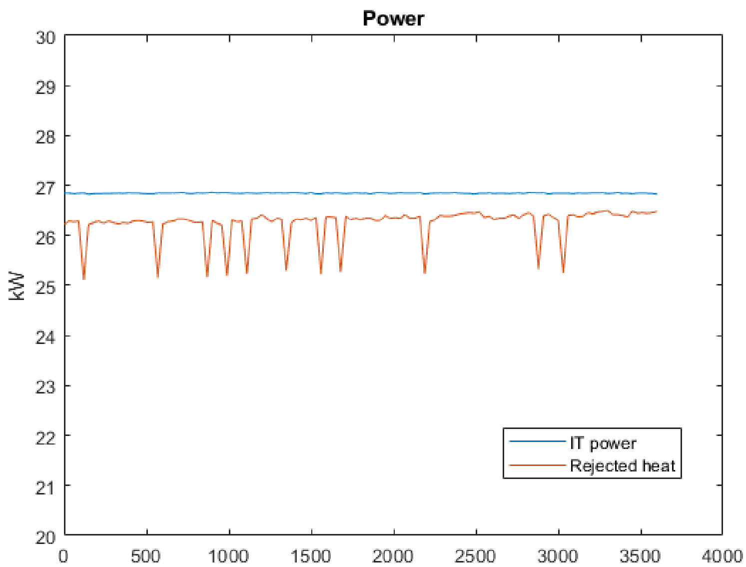

Figure 10. Total IT power (blue) and rejected heat (red) for the liquid cooling test. The spikes in the rejected heat are due to the sampling resolution of the pump.

The average oil flow in the tank was 6.6 m³/h and around 52.5°C. The average water flow in the cooling loop was 2.39 m³/h and the supply and return temperatures were around 41°C and 51°C respectively, see Figure 11. Since the return water temperature and the oil temperature is close to each other, this shows low losses in the heat exchanger.

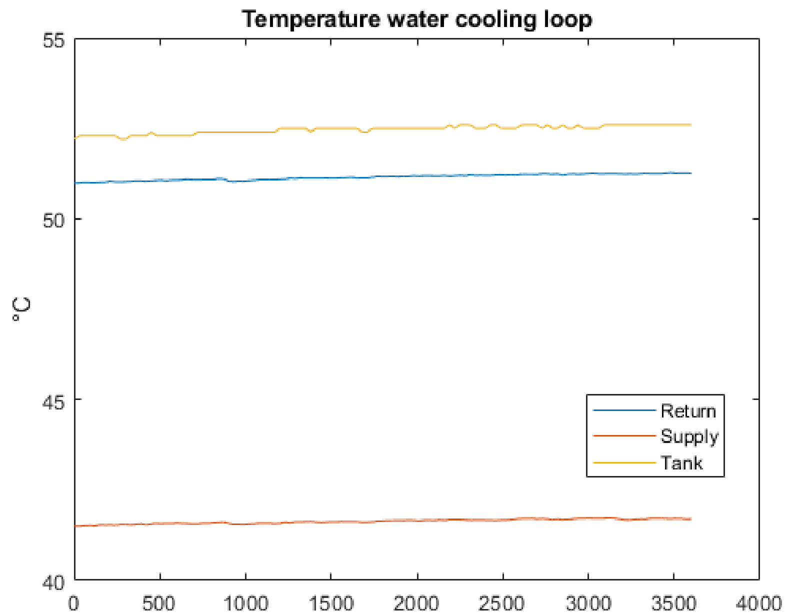

Figure 11. Supply and return temperature in the water-cooling loop and the oil temperature in the tank.

The temperature sensors mounted to see the heat distribution in the tank shows a rather similar result throughout the tank, with less than 1 °C in difference, see Figure 12.

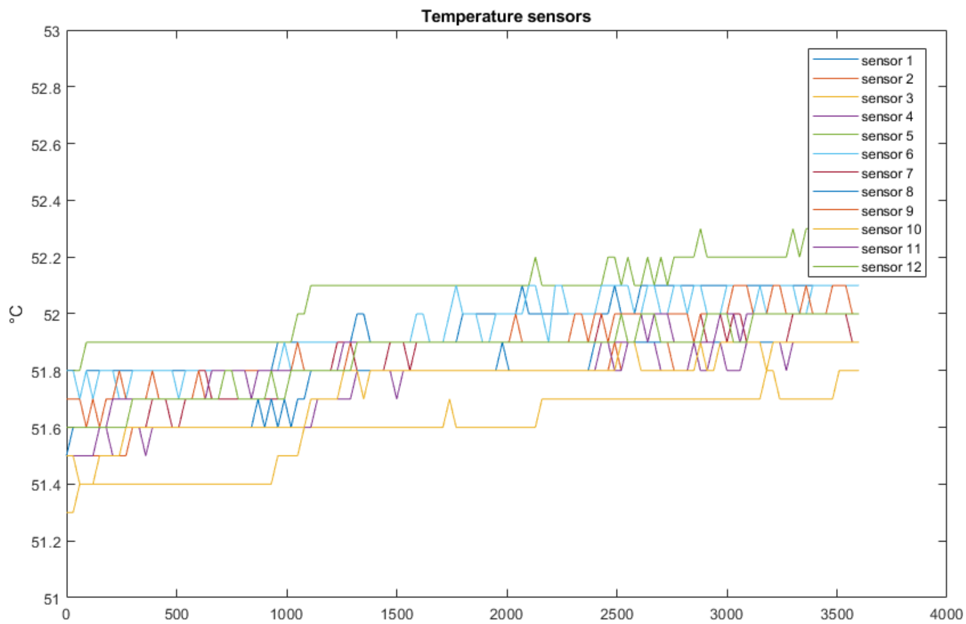

Figure 12. Temperature sensors mounted in the tank over each server.

There were two limiting factors in this project, the first was the Submer SmartPod that couldn't achieve the high temperatures we were expecting without the cooling system shutting off. Since crypto mining servers can withstand high work temperatures without significant losses in performance, some modifications should be considered to the tank in order to increase the output temperature to make it easier to reuse the excess heat. The second limiting factor was in the LCT, where the heat rejection we could achieve with the current flows and temperatures was 26.4 kW. This limited us to run 11 miners instead of 16 as we were expecting.

A great benefit of immersed cooling compared to traditional air cooling is the reduced noise level from the fans. When we ran air-cooled tests using 16 miners, the noise level got so loud it was hard to work in the lab. Once the miners were submerged however, only a very low buzz from the pump could be heard.

It should however be mentioned that working with oil has its challenges. It easily gets all over the place, and each time a piece of hardware is lifted from the oil, it needs it's time to drip off before you can start working with it. It is also very hard to get rid of all oil, so once the hardware has been exposed to it, it is hard to reverse it into air-cooled again.

4 Conclusion

The results show that the air-cooled servers have a higher hashrate and was running cooler than the immersed miners, however the difference was quite small, 30 TH/s at around 68.1°C compared to 29.7 TH/s at 69.6 °C. Further tests should be performed before concluding if this decrease is due to the lower operation temperature or not.

The power was reduced with 2% for the liquid test compared to the air tests. However, if the power required for the pumps in the cooling loop is included, the power consumption is rather close. The biggest difference is however that, using immersion cooling, the heat is ready for heat recovery without any significant modifications.

The result from the temperature sensors mounted in the Submer SmartPod XL shows that it has a good heat distribution throughout the tank, with no obvious hot-spots due to a good distribution of the coolant.

The rejected heat from the results shows that a mining data center can heat up a facility or tap water. Combining the results from previous experiments, where high temperatures were achieved and these tests where the heat recovery was performed, it shows potential for new applications. For example, it could be used for fourth generation district heating.

Since the tank has a big volume, the tank also works as a thermal heat storage in case of a short power-outage due to thermal inertia. This could be important if the excess heat is used for temperature sensitive facilities such as a greenhouse where a rapid temperature drop could stress the plants or in worst case kill them off.

4.1 Future work

Due to the limitation of the tank temperature and LCT we could only run tests with 11 miners, which resulted in a lower power density than desired. It would be interesting to perform test with higher power density through e.g., stacking or modification of the servers.

Since the potential of high efficiency in the heat rejection with higher temperatures, it would be interesting to investigate a mining datacenter that could be connected to fourth generations district heating.

Other improvements of an immersion cooling tank that would be of interest to look into is:

- Adjust the tank to withstand higher temperature to be able to reject as efficient as possible.
- A controllable pump that can control the heat rejection from the tank with the flow.
- If the heat will be recovered, the tank could be insulated to minimise the losses to the environment.
- Mount the PLC outside of the CDU so that it doesn’t overheat due to heat conduction from the oil in the heat exchanger.
- Safety measure that will shut off IT if the cooling loop fails or tank is overheating.

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