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# L2A CDUS PERFORMANCE AND CONSIDERATIONS FOR SERVER ROOMS UPGRADE WITH CONVENTIONAL AIR CONDITIONING

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## ABSTRACT

*As the online frameworks and services are growing rapidly with the evolution of web-based Artificial Intelligence (AI) applications, server rooms are upgrading in computational capacity and size to keep up with these demands. Enterprise companies with their limited capacity server rooms struggle to keep up with these increasing computational demands. Hence, some of them end up outsourcing their servers to co-located facilities (Co-Lo) and the others choose to upgrade their existing server rooms. Correspondingly, the thermal load associated with such upgrades is typically tremendous. Approximately around 40% of the power consumed by datacentres is dissipated as heat. Conventional HVAC systems fail to satisfy the requirements of such server capacities. Not only do they struggle to fulfil the cooling load, but their maldistribution of cool air into the server room forms a major cause for hotspots formation. To tackle this issue, Liquid-to-Air (L2A) Coolant Distribution Units (CDUs) are being used as a liquid-based cooling solution for rack-level cooling. This type of CDUs provide efficient cooling for servers through liquid coolant that is distributed into cooling loops mounted on top of each server board. The generated heat is curried away using this liquid coolant back to the CDU, which then dissipates it into the surrounding air using dedicated pumps, fans, and heat exchanger, hence the name Liquid-to-Air.*

*In the present work, one of the most popular liquid cooling strategies is explored based on various scenarios. the performance of a 24-kW liquid to Air (L2A) CDU is judged based on cooling effect, stability, and reliability. The study is curried out experimentally, in which a test rack with three thermal test vehicles (TTVs) are used to investigate various operation scenarios. Both liquid coolant and air sides of this experimental setup are equipped with the required instrumentations to monitor and analyse the tests. All test cases were taken in a room with limited air conditioning to resemble the environment of upgraded server rooms with conventional AC systems. Moreover, the impact of using such high-power density cooling unit on the server room environment with restricted HVAC system is also brought to light. Environmental and human comfort parameters such as noise, air velocity, and ambient temperature are measured under various operation conditions and benchmarked against their ranges for human comfort as listed in ASHREE standards. At the end of this research, recommendations for best practice are provided along with areas of enhancement for the selected system.*

Keywords: Electronic Thermal Management, Data Center, Liquid-to-Air CDU, Rack Level Cooling.

## NOMENCLATURE

| | |
|---|---|
| TTV | Thermal Test Vehicle |
| CDU | Coolant Distribution Unit |
| ETM | Electronic Thermal Management |
| L2A | Liquid-To-Air |
| Co-Lo | Co-located |
| HVAC | Heating Ventilation and Air-Conditioning |
| DOE | Design Of Experiment |
| LPM | Letters Per Minute |
| CRAH | Computer Room Air Handler |

## 1. INTRODUCTION

As industries and enterprises expand swiftly, there is an increase in the need for data processing and storage. As the requirement for data processing and storage increases, so does the power density of servers [1].

Liquid-to-air CDUs became a technology of interest among industry and researchers in the past decade. Schmidt [2] installed a L2A heat exchanger (HX) on the side of the server cabinet and was able to efficiently cool a 35-kW server heat load and lessen the effects of hot air recirculation. This method effectively dissipated the heat load without impairing airflow or component temperatures. In another research, Simon [3] created a CFD model for the application of rear door air-to-liquid heat exchangers (RDHx) in data centers lacking additional cooling systems including computer room air handler (CRAH) or computer room air conditioning (CRAC) units.

Various experimental work has been done in this field as well. Gao [4] carried out an experimental investigation on liquid cooled IT rack connected to L2L CDU to determine the effects of changing the secondary fluid temperature, liquid flow rate, and airflow rate on the cooling capacity and GPU temperatures. In a separate study Gao [5], developed a thorough method for transient effectiveness to evaluate and clarify the transient behavior of a HX operating in both cooling and heating applications while taking associated cooling loops or cold plates into mind. He additionally estimated the thermal mass of certain parts using this method.

Moreover, Chowdhury [6] examined the cooling capability, pros, and cons of combining in-row coolers with external air conditioning units for different IT rack power configurations, as well as the effects of raising the inlet temperature at multiple airflow rates. More recently, Shahi [7] investigated the thermal characteristics and temperature of the core of liquid-cooled computer systems while considering several different variables, such as supply coolant temperature, coolant flow rate, and the heat loads of IT equipment. The results revealed a strong correlation between core temperatures and all the input variables, providing pertinent knowledge for improving the thermal performance of liquid-cooled computer systems.

The hybridization of liquid cooling and air cooling was also a point of interest in the Electronic Thermal Management (ETM) community. Yengar [8] studied hybrid cooled server rack that uses air cooling for low-power equipment and warm water above the ambient as the working fluid for high-power components. The results demonstrated that this approach allowed for higher water supply temperatures to be tolerated, up to 45 °C for water and 50 °C for air, while lowering overall energy consumption by approximately 25 %. Another research conducted by Bhalerao [9] utilized a CFD modeling and second-law analysis to show that the use of hybrid liquid-air cooling methods could decrease overall energy loss and raise energy efficiency. Additionally, the study found that in-row coolers are more effective at removing heat than computer room air handler (CRAH) units.

Recent studies focused on standardizing the methods and procedures of Liquid-To-Air deployment in data centers as well as aspects related to heatsink performance on the liquid side [10,11]. In the present work, we shed light on the most considerations associated with using liquid-to-air CDUs. More specifically, the CDU performance and environmental impact while operating under limited HVAC environment.

## 2. MATERIALS AND METHODS

A well instrumented experimental setup is utilized to investigate the performance of the CDU under various operation conditions. A Design Of Experiment (DOE) was put together to target the required performance indicators in a comprehensible way.

### 2.1 Setup Description.

In this setup, a rack manifold connects to three imperviously mounted Thermal Test Vehicles (TTVs), which are connected to cooling loops on each TTV. The use of three TTVs specifically is justified by the need to conserve space for a data acquiring system as well as to allow for the simultaneous mounting of CDUs of various sizes and the ease of switching between them. Comparisons of the performance of several liquid-to-air CDUs are being conducted using this experimental configuration.

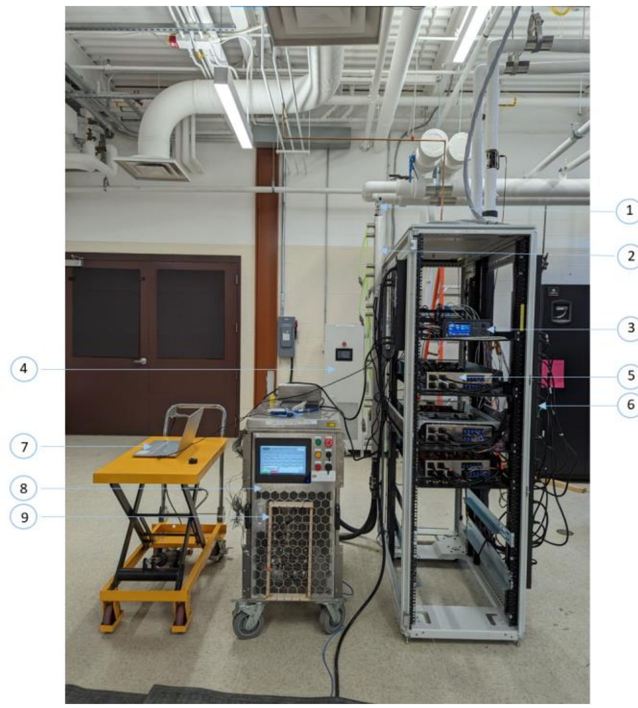

Figure 1: The experimental setup for the Liquid-to-Air CDUs. Components: (1) Rack manifold's air vent, (2) Rack manifold, (3) Data acquisition system, (4) Power supply, (5) TTVs, (6) Power Distribution Unit (PDU), (7) Laptop, (8) liquid-to-air CDU, (9) Thermocouple mesh for air side measurements.

Figure 1 shows the experimental setup including the liquid-to-air CDU standing aside of the test rack. The selected CDU occupies 20U (34.7 inches) and has a maximum cooling capacity 24 kW. More specifications of the CDU are shown in table 1.

Table 1: Experimented CDU specifications.

| Item | Specification |
|---|---|
| Maximum Cooling Capacity | 24 kW |
| Coolant Type | PG25 |
| Power Consumption | 4.1 kW |
| Maximum Coolant Flow Rate | 70 LPM |
| Dimensions (W×D×H) | 17.5" (W), 33.8" (D), 34.7 (H) |

A sketch for the utilized TTVs is shown in figure 2.

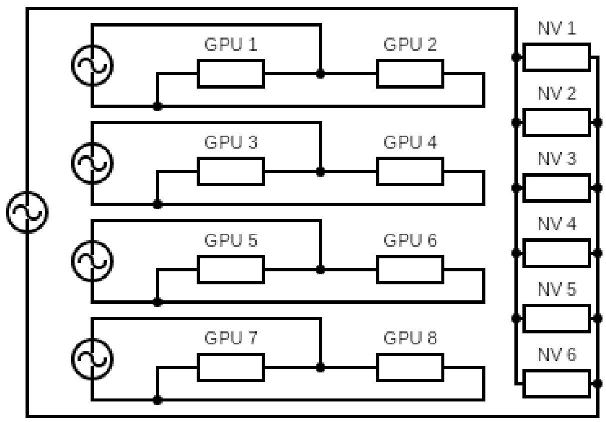


Figure 2: The experimental setup for the Liquid-to-Air CDUs.

### 2.2 Design of Experiment.

Since we are interested in studying the effect of deploying liquid-to-air CDUs on the IT room environment, the following performance indicators are measured/determined under various operation conditions.

1. Room temperature.
2. Room Relative Humidity (ø).
3. Air jet speed.
4. Noise generation.

The study was conducted under the operation conditions listed in table 2.

Table 2: Operation conditions of the conducted tests.

| Heat load (kW) | Percentage of Full Load | Supply Coolant Flow Rate (LPM) | Supply Coolant Temperature (°C) |
|---|---|---|---|
| 6.0 | 25.0% | 18 | 32 |
| 6.0 | 25.0% | 24 | 32 |
| 24.0 | 100.0% | 24 | 32 |
| 24.0 | 100.0% | 24 | 36 |
| 26.0 | 108.3% | 24 | 32 |
| 26.0 | 108.3% | 33 | 32 |

As shown in table 1, The study included various power levels in order to assess the impact of using such CDUs on both the room environment and the cooling effect at various rack-power densities. Moreover, the supply coolant flow rate and the supply coolant temperature are also varied to match different data center standards.

## 3. RESULTS AND DISCUSSION

The results presented in this work encompass both the cooling performance of the CDU and its impact on the IT-room environment and human safety. The case temperature of each heater element on the TTVs serves as the most direct indicator of the cooling performance. However, the focus of the present work lies in examining the changes in ambient conditions, specifically temperature and relative humidity, in a room with limited HVAC capabilities. Additionally, the noise level and air jet speed are also taken into consideration.

### 3.1 TTVs Case Temperatures.

For the low-power test conditions mentioned in table 2, the power level is kept at 25% of the full cooling capacity of the CDU while the coolant flow rate is set at 18 LPM and then changed to 24 LPM. In both cases the CDU showed stable and reliable cooling indicated by the smooth curves of case temperatures shown in figure 3.

It is also shown that as the flow rate is increased to 24 LPM, the case temperatures on both the heater types are reduced. However, the 24 LPM test showed some fluctuations in the case temperature. This observation is directly related to the control settings of the CDU. Nevertheless, the amplitude of this fluctuation is within an acceptable range.

The highest recorded fan duty during the low power test was 60%. However, for most of the test duration, the average fan duty was less than 40%. The associated noise decibels and air jet speed were 63 dB and 5.2 m/s. These values are within the acceptable range for data centers and IT-rooms according to [12].

When it comes to air temperature and room environment, heat loads as low as 6.0 kW had negligible effect on room temperature under the operation of the conventional HVAC system. This case is not the same, however, for higher heat load tests of liquid-to-air ETM systems. For instance, the second and third set of tests presented in table 2 had a significant impact on the room environment in every metric. Air temperature, relative humidity, noise decibels, and air jet speed were all affected by the amount of heat load that is required to be rejected by the CDU.

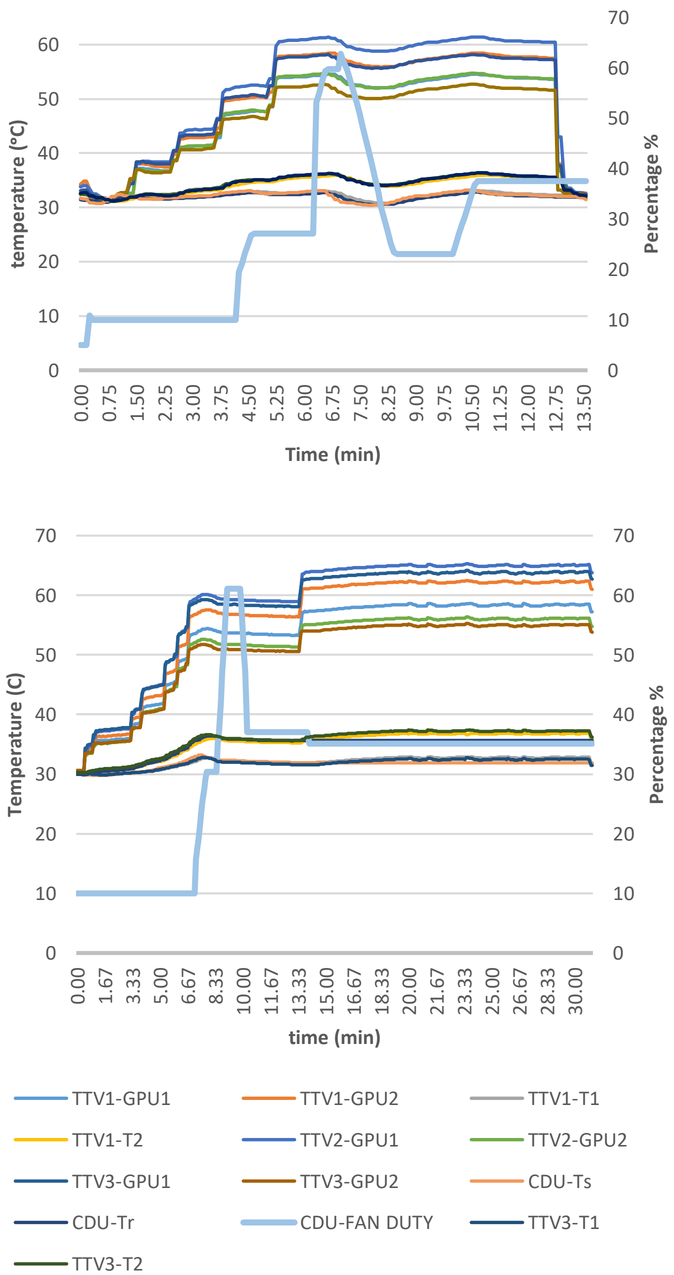


Figure 3: TTVs case temperatures under low heat load operation (Upper chart shows the results at 24 LPM supply coolant flow rate and lower chart is generated at 18 LPM).

The second set of tests conducted using this liquid-to-air CDU is at the full heat capacity of the unit (24 kW). The only parameter that is changed here is the supply coolant temperature in which it is increased from 32 °C to 36 °C. These values are typically the standard values used in liquid based ETM systems whether they are liquid-to-air or liquid-to-liquid.

To investigate the performance of this CDU even further, the heat load was pushed beyond the maximum heat capacity of the CDU. In the third set of testing, the CDU was subjected to 26 kW of thermal load using three TTVs connected to the power supply shown in figure 1. The response of the CDU for both the 24 kW and the 26 kW tests along with the case temperatures of the TTVs are all shown in figure 4.

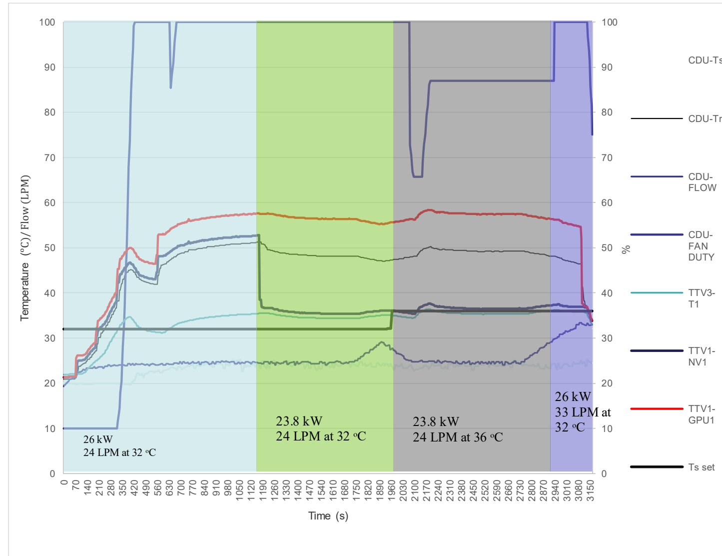


Figure 4: TTVs case temperatures under full heat load operation and 108.3% of full load operation (Upper chart shows the results at 24 LPM supply coolant flow rate and lower chart is generated at 18 LPM).

It can be seen in figure 4 that the fan duty is kept almost at its higher limit throughout the entire test. The only case in which the fan duty went down to 88% is the case that had a thermal load of 24 kW and a supply coolant temperature of 36 °C. any case other than this one, whether it includes higher thermal load, lower supply coolant temperature, or higher coolant flow rate, will cause the fan duty to increase to its higher limit (100%). The reason why investigating these cases is important is because the higher the fan duty the higher the energy consumption as well as the noise associated with the CDU operation. Moreover, reducing the fan duty is also beneficial in which it reduces the recirculation of hot air to the intake side of the CDU and improves its cooling performance.

The noise generated by this CDU at full fan speed reached a value of 96 dB. Noise values higher than 70 dB are dangerous to human beings and can cause hearing damage. Additionally, the room temperature was also recorded before and after the full power tests. Figure 5 shows a comparison between the hot spots' intensity inside the room before and after the full load tests.

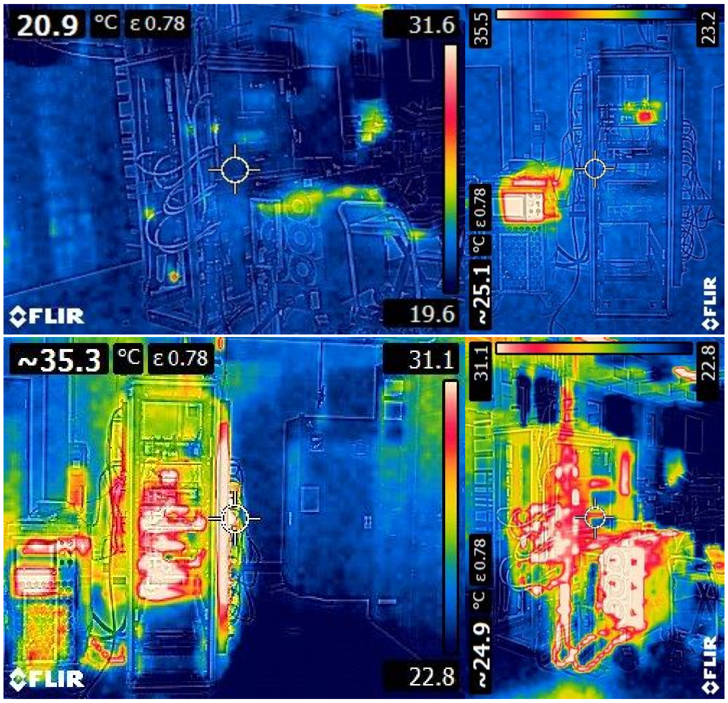

Figure 5: IR-Imaging of the test environment before and after the high heat load tests (Upper pictures were taken before the test and lower pictures were taken after).

As indicated by figure 5, the room temperature was significantly increased at the end of the test due to overloading the HVAC system with heat loads above its cooling capacity. This observation is significant and worth taking into consideration when upgrading IT-rooms that has conventional or limited HVAC systems.

## 4. CONCLUSION

The present work addresses a critical issue associated with upgrading IT-rooms that have limited HVAC systems. The use of liquid-to-air CDUs is one of the most convenient approaches due to the ease of deployment. This study showed the impact of deploying such ETM system on the room environment and human comfort. The results showed that the stressing liquid-to-air CDUs to their limits under limited HVAC environments can cause auditory danger and significant increase in room temperature. Moreover, the performance of the CDU itself is also affected due to the hot air recirculation. The studied cases showed that using proper values for supply coolant temperature and setting up the limit for the heat load can help solve this problem.

## ACKNOWLEDGEMENT
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