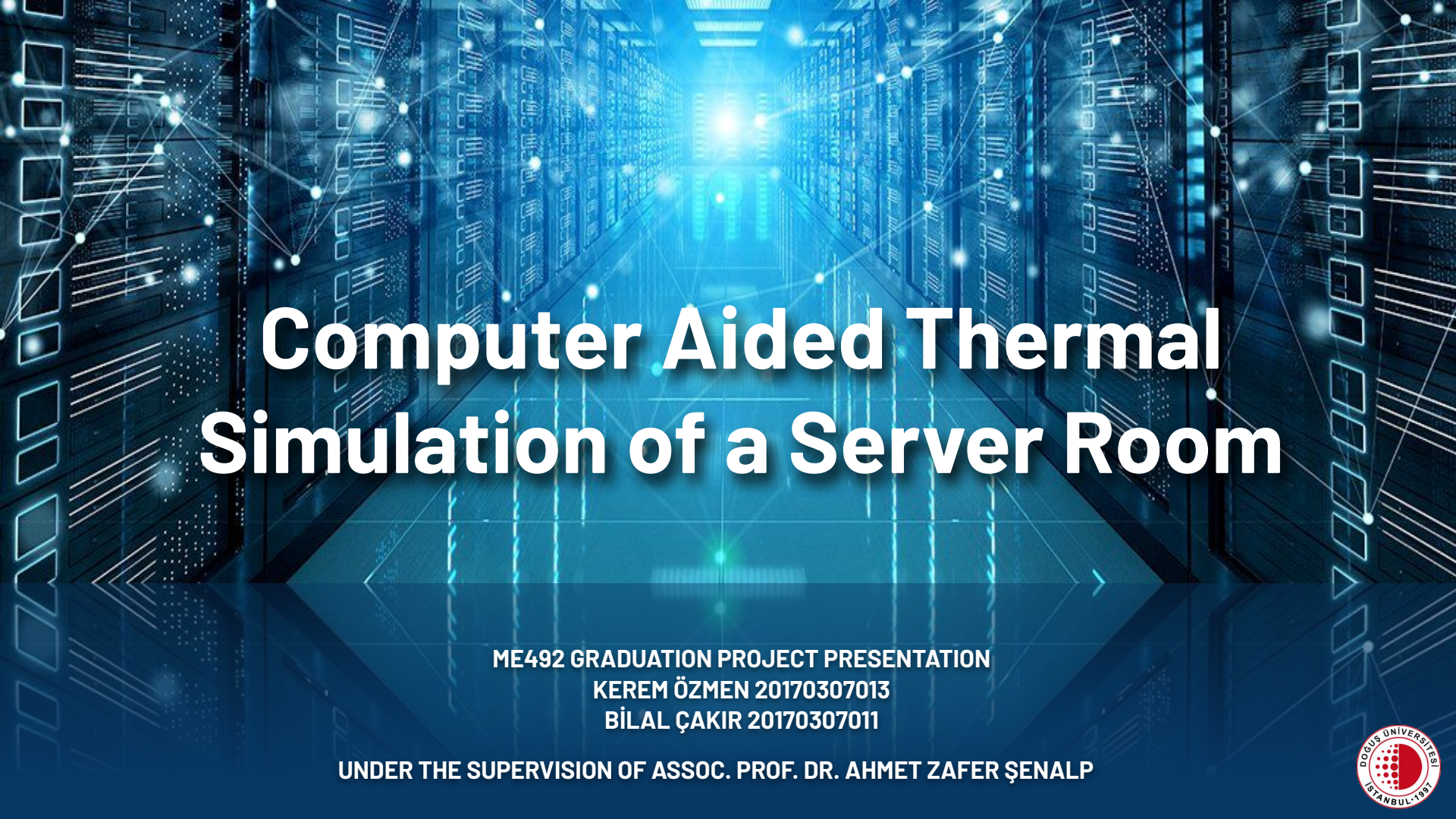


Computer Aided Thermal Simulation of a Server Room

ME492 GRADUATION PROJECT PRESENTATION
KEREM ÖZMEN 20170307013
BİLAL ÇAKIR 20170307011

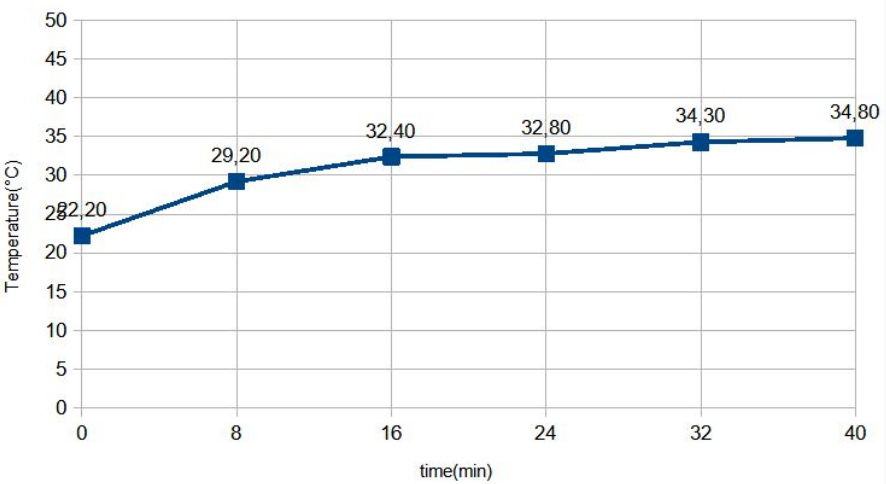
UNDER THE SUPERVISION OF ASSOC. PROF. DR. AHMET ZAFER ŞENALP

Introduction

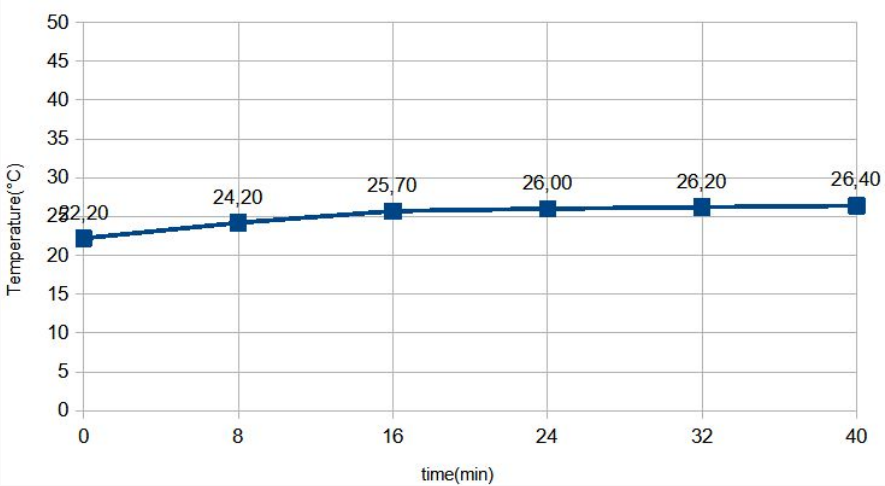
Data centers are the essential element that enables us to communicate with each other. Therefore, stable operation of data centers critically important. Infrastructure services also need to work flawlessly for the continuous operating data centers. Among the infrastructure services, air conditioning and energy are the two main elements. These services need to work more efficiently, both uninterruptedly and economically. Computer aided engineering tools can be used to predict the evacuation of the heat produced in the server rooms in an economical way. With these tools, various situation scenarios can be created and it can be compared how efficient the server rooms in different orientations. ***In this study, it is aimed to find the most thermally efficient server room design by comparing the simulation results created with computer aided engineering tools.***

What we have done in ME491?

We searched ways to cool down the server's temperature with ***Phase Change Material***. We did experiments to find the best suitable material to absorb and release the heat when it is necessary.



Server cabinet without any PCM



Server cabinet cooling using paraffin wax

Data Center Cooling Technologies

- **Passive cooling ✓**
- **Computer Room Air Conditioner (CRAC) ✓**
- Computer Room Air Handler (CRAH)
- Cold Aisle/Hot Aisle Design
- Calibrated Vectored Cooling (CVC)
- Evaporative Cooling
- Free Cooling
- Liquid Cooling - Chilled Water System
- Liquid Cooling - Immersion System

Computer Room Air Conditioner (CRAC)

It is the most widely used cooling technology in system rooms. The working principle is as follows. A certain gas is liquefied with the help of a compressor and the resulting heat is released to the outside. After this process, the pressure on the liquid is reduced with the expansion valve and the heat is withdrawn from the environment and converted back to gas. The system works with compressors and fan units. It is one of the oldest air conditioning systems that used.

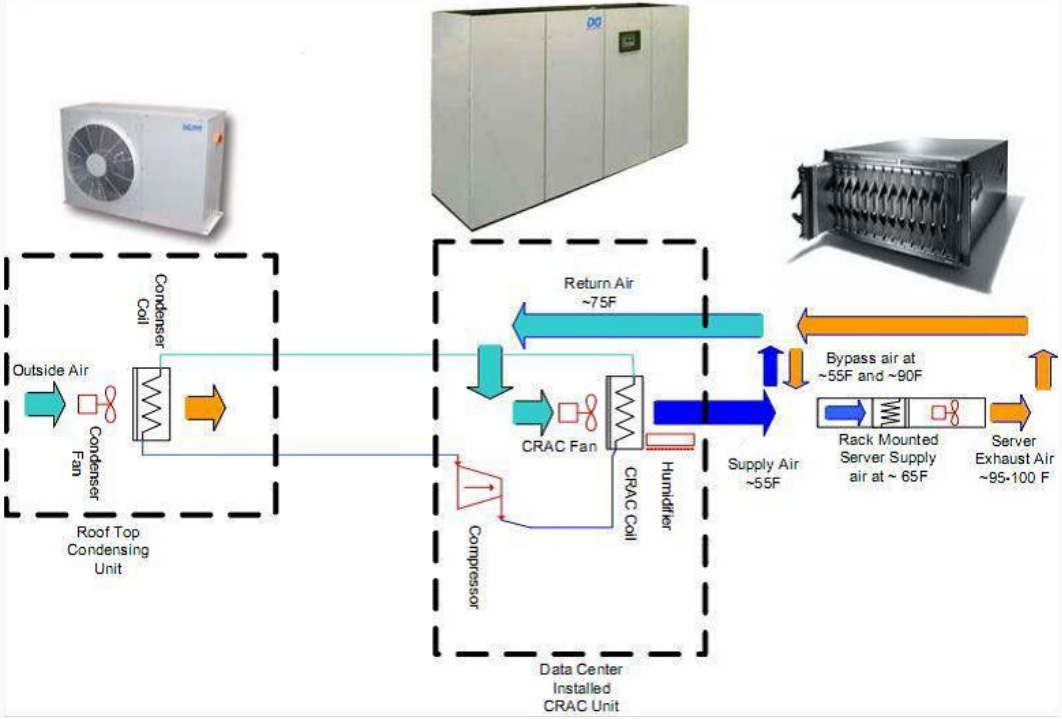


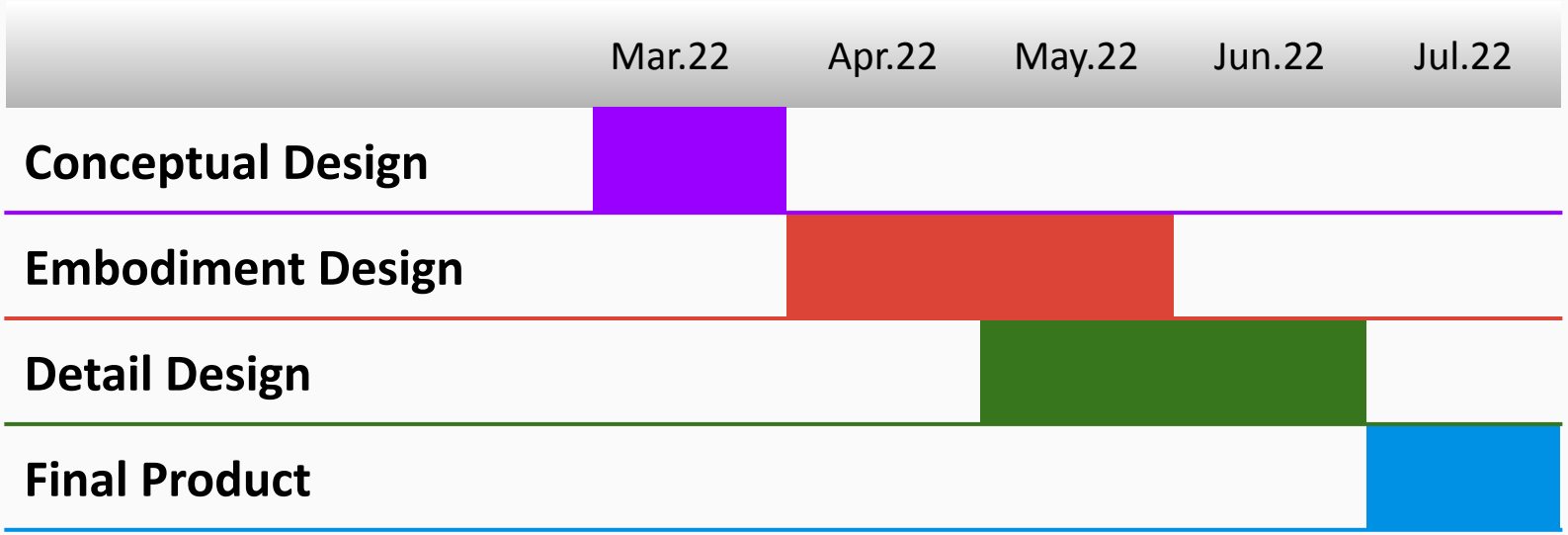
Figure. Working diagram of Computer Room Air Conditioner

Constraints of Study

In this model hot air comes out from the server cabinet. The surface of the server cabinet makes *convective heat transfer* with air. Therefore, the density of the air is an important factor. The air flow velocity and temperature of the hot air is another parameter. The hot air in the room is evacuated from the outlet surface with a pressure. The length of the walls and the volume of the room are also important constraints.

- (U) Velocity
  - Fixed value [m/s]
  - Mean flow rate [kg/s]
- (T) Temperature [K or °C]
- (P) Pressure [Pa]
- (d) Density [g/cm3]
- (cp) Specific Heat Capacity [J/Kg.K]
- (k) Turbulent Kinetic Energy [m2/s2]
- (ε) Dissipation Rate [m2/s2]
- (Ra) Rayleigh Number
- Heat Transfer Coefficient [W/(m²·°C)]
- Time dependency: Steady-state
- Turbulence model: k-epsilon
- Walls: Non-slip and adiabatic

Project Stages



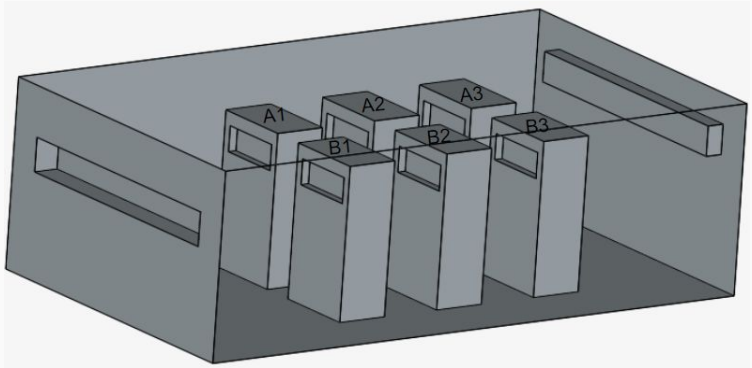
Method of Study

In this study, we performed *steady-state natural convective heat transfer* analysis.

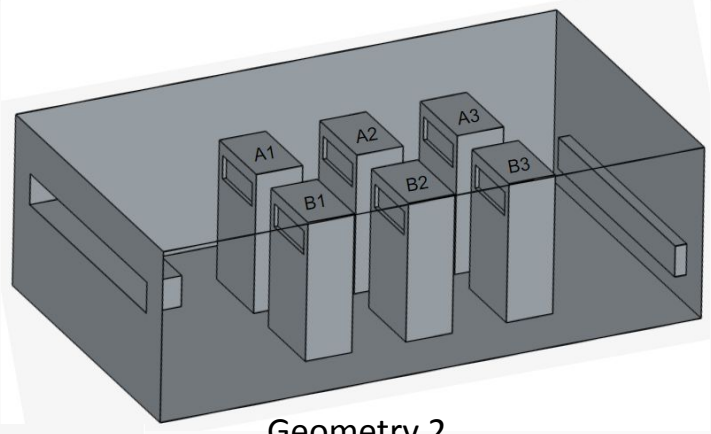
The study was carried out in 2 different analysis programs, *Simscale* and *Ansys Discovery*. 3 different geometries and 2 different boundary conditions were used in the Simscale program. The turbulence model has been chosen as k-epsilon turbulence. In the Ansys Discovery program, 3 different geometries were investigated in the same boundary condition.

The targeted geometry is a server room with 9 server cabinets. In the first stage, thermal analysis was done in the Simscale program. Since the free version of the Simscale program has limited features, a design with 6 server cabinets has been preferred to reduce resource consumption. In the second stage, the design with 9 server cabinets was used in Ansys Discovery.

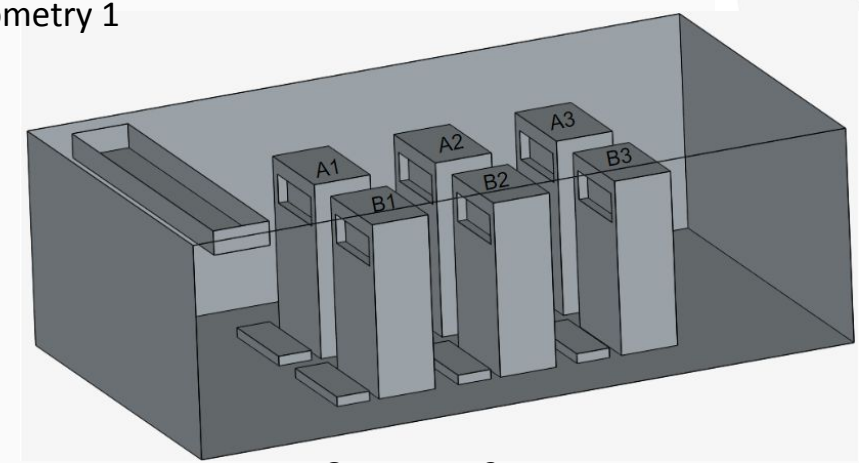
Geometries on Simscale



Geometry 1

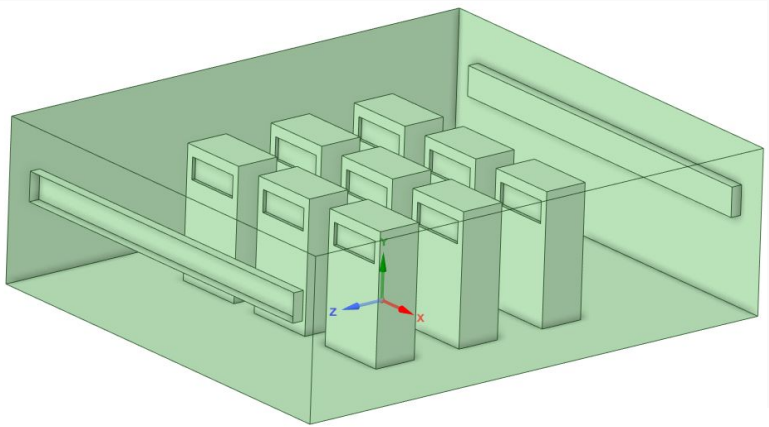


Geometry 2

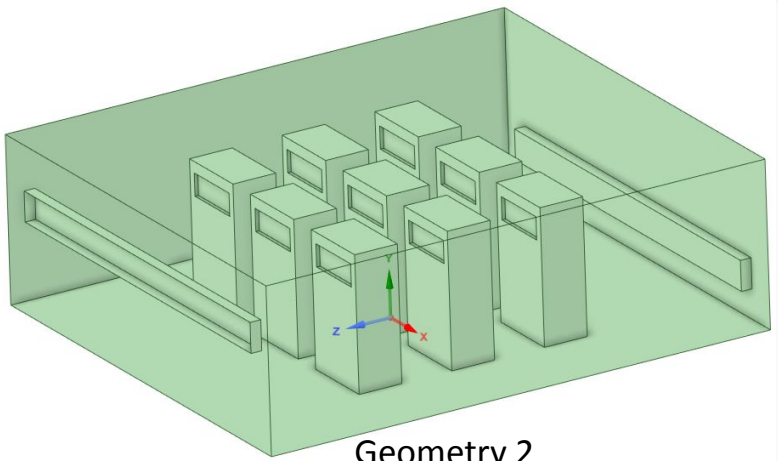


Geometry 3

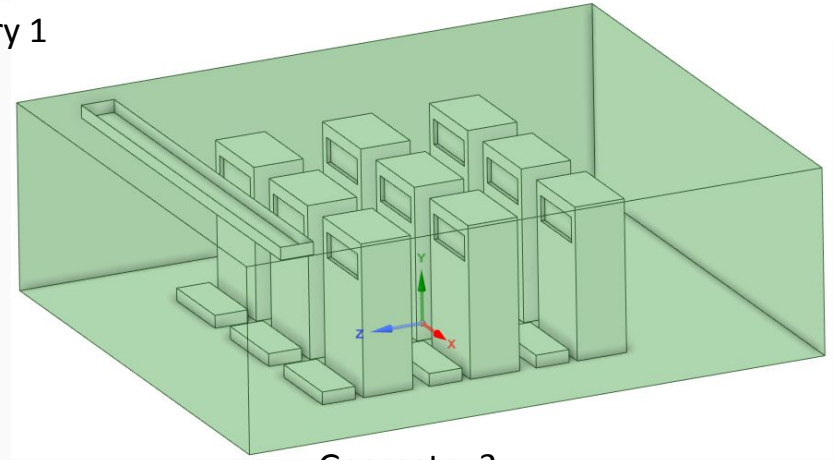
Geometries on Ansys Discovery



Geometry 1



Geometry 2



Geometry 3

Boundary Conditions for Simulation

Boundary Condition 1 for Simscale

Same boundary conditions are determined for geometry 1 and geometry 2.

Inlet velocity: fixed value 0.25 m/s at 17C
Server inlet Velocity: fixed value 0,50 m/s at 55C
Outlet pressure: 100 KPa

Boundary Condition 2 for Simscale

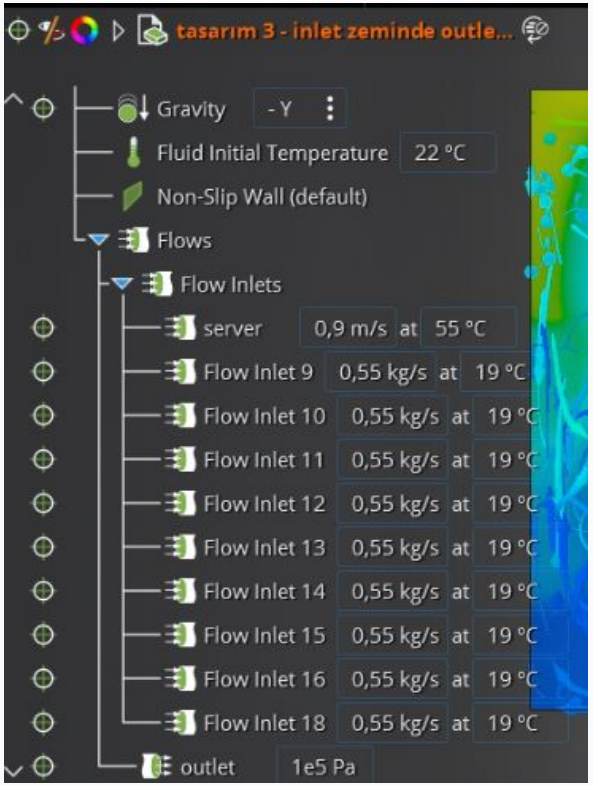
Same boundary conditions are determined for geometry 1 and geometry 3.

Inlet velocity: mean flow rate 3.33 kg/s at 17C (geometry 1)
mean flow rate 0,55 kg/s at 17C (geometry 3) (0,55 kg/s*6=3,33 kg/s)
Server inlet velocity: fixed value 0,50 m/s at 55C
Outlet pressure: 100 KPa

Boundary Conditions for Ansys Discovery

Same boundary conditions were used for all geometries.

Inlet velocity: mean flow rate 5 kg/s at 19C (for geometry 1 and 2)
mean flow rate 0,55 kg/s at 19C (for geometry 3) (0,55 kg/s*9=5 kg/s)
Server inlet velocity: 0,9m/s 55C
Outlet pressure: 100KPa



Ansys Discovery (Geometry 3)

Simulation on Simscale - Boundary Condition 1

Geometry 1. Top Inlet

Temperature Fields

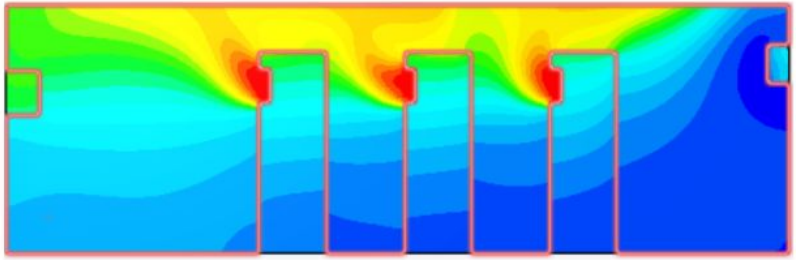


Figure 32. Geometry 1 side view (temperature fields)

Cutting planes: 1	Temperature
Surface Area	12.17 m²
Minimum	17.85 °C *
Average	29.81 °C *
Maximum	54.85 °C *
Integral	3413 (°C)·m² *

*Statistics are based on interpolated data. Learn more

The average temperature value was measured as 29.81 C.

Geometry 2. Lower Inlet

Temperature Fields

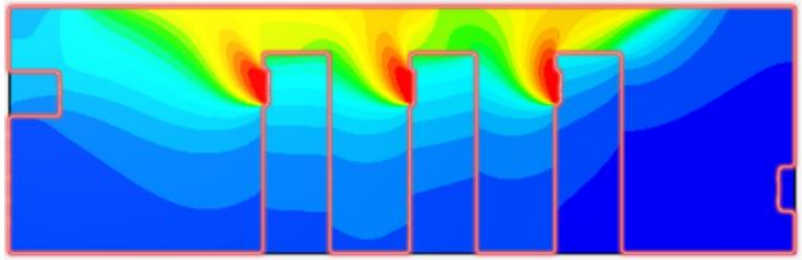
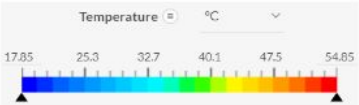


Figure 34. Geometry 2 side view (temperature fields)

Cutting planes: 1	Temperature
Surface Area	12.07 m²
Minimum	17.85 °C *
Average	26.9 °C *
Maximum	54.85 °C *
Integral	3350 (°C)·m² *

*Statistics are based on interpolated data. Learn more



The average temperature value was measured as 26.91 C. Compared to the results in Geometry 1, lower temperature values were obtained with this geometry.

Simulation on Simscale - Boundary Condition 2

Geometry 1. Top Inlet

Temperature Fields

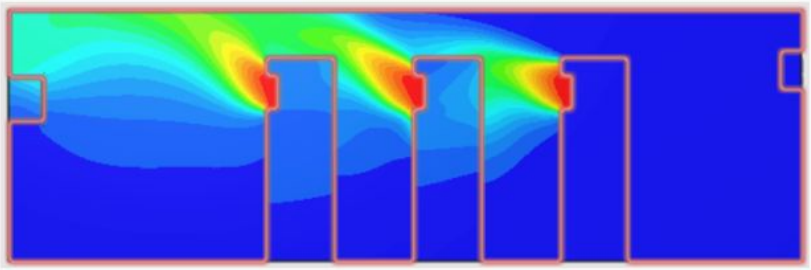
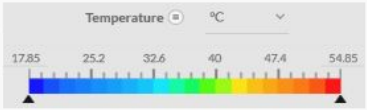


Figure 36. Geometry 1 side view (temperature fields)

Cutting planes: 1	Temperature
Surface Area	12.08 m²
Minimum	17.85 °C *
Average	24.9 °C *
Maximum	54.85 °C *
Integral	3326 (°C)-m² *

*Statistics are based on interpolated data. Learn more



The average temperature value was measured as 24.9 C.

Geometry 3. Raised Floor

Temperature Fields

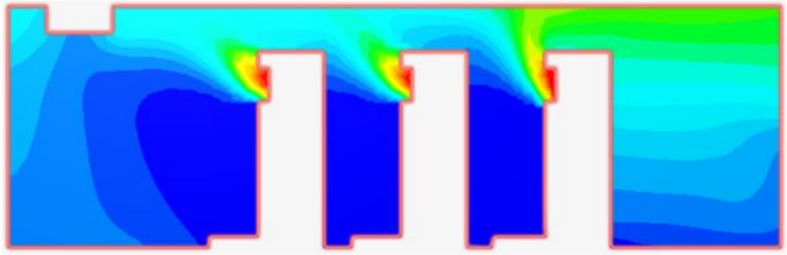
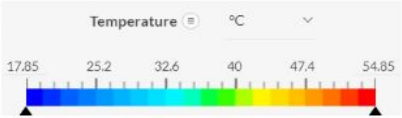


Figure 38. Geometry 3 side view (temperature fields)

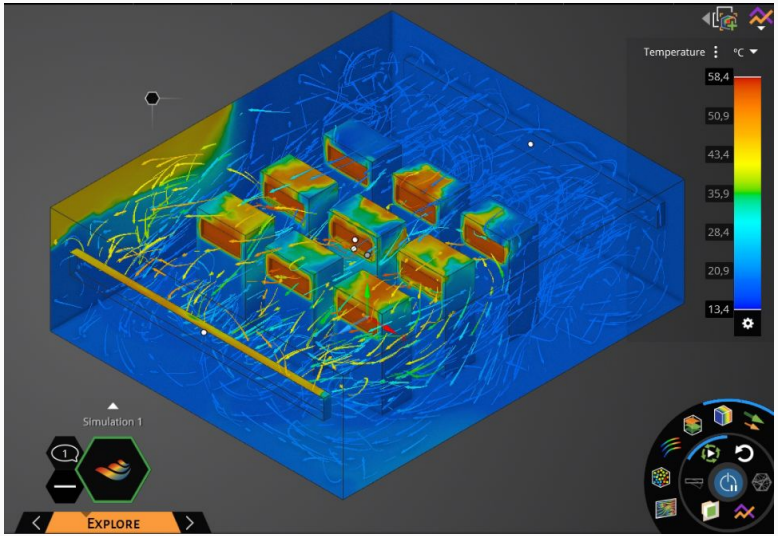
Cutting planes: 1	Temperature
Surface Area	12.17 m²
Minimum	17.85 °C *
Average	23.15 °C *
Maximum	54.85 °C *
Integral	3333 (°C)-m² *

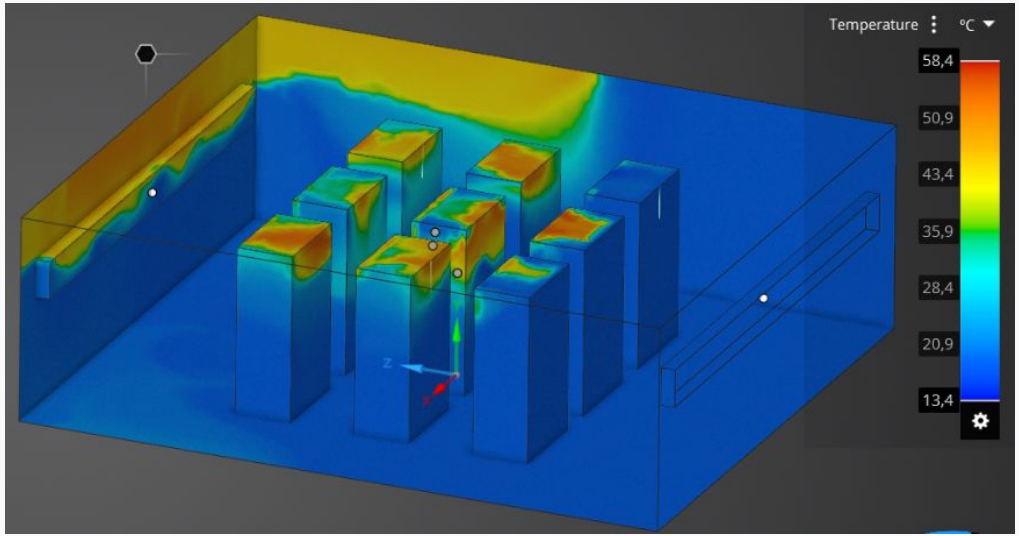
*Statistics are based on interpolated data. Learn more

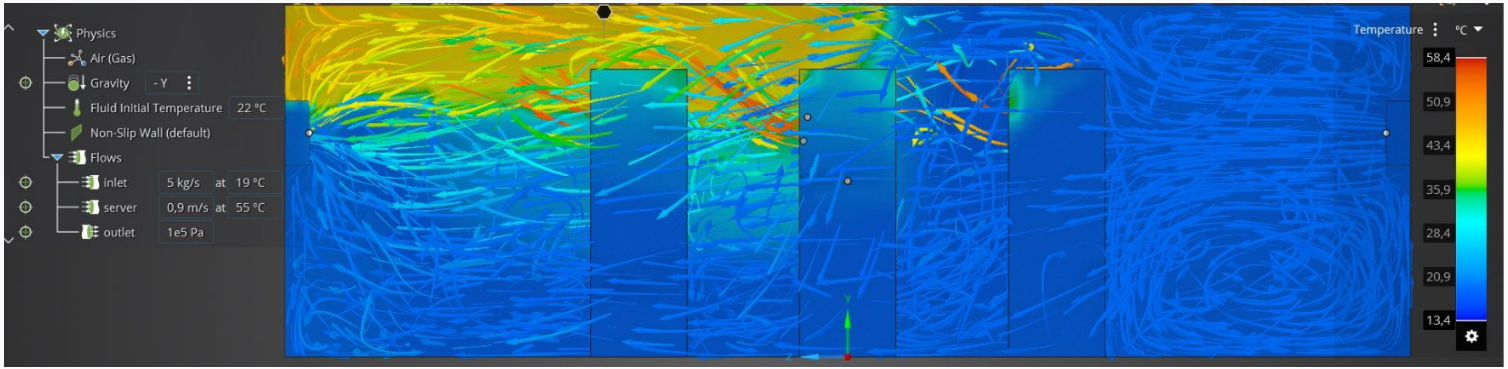


The average temperature value was measured as 23.15 C. Compared to the results in Geometry 1, lower temperature values were obtained with this geometry.

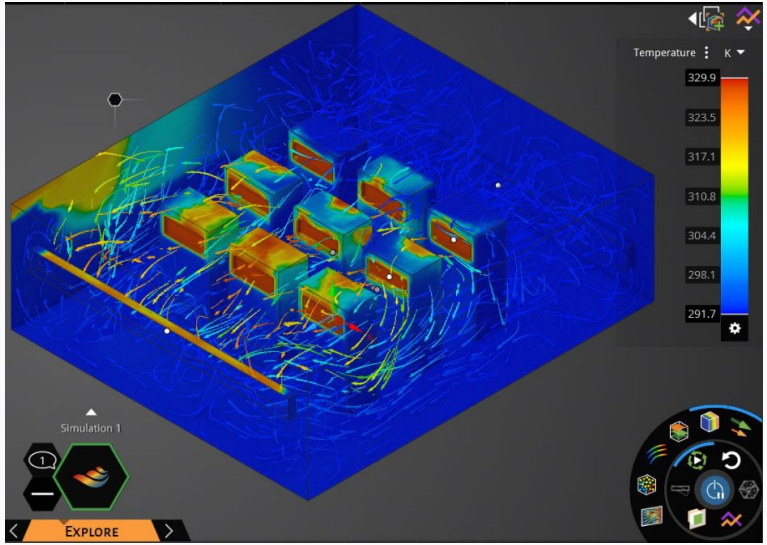
Simulation on Ansys Discovery - Geometry 1

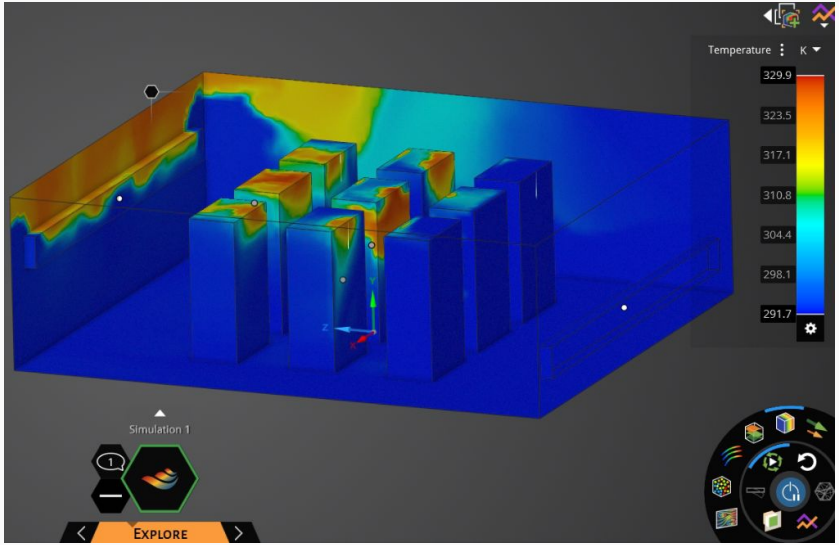


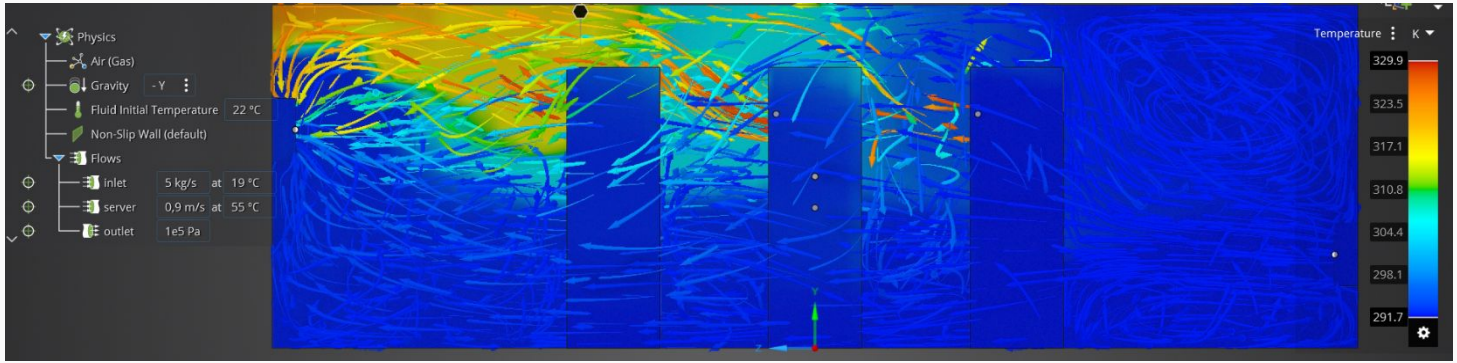




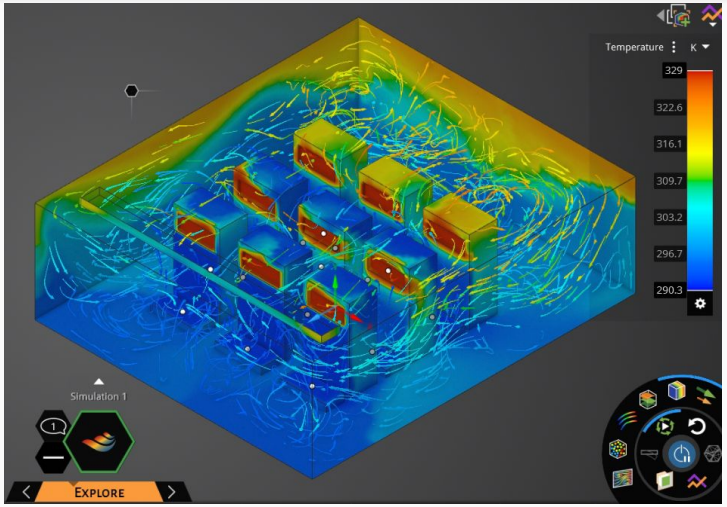
Simulation on Ansys Discovery - Geometry 2

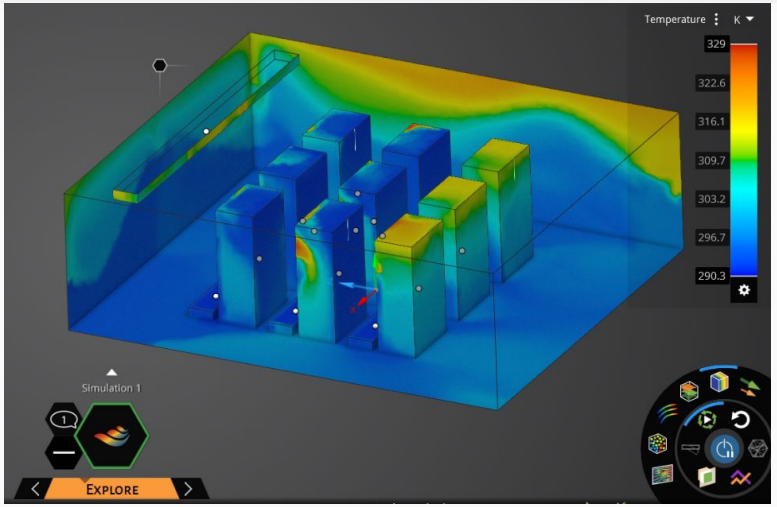


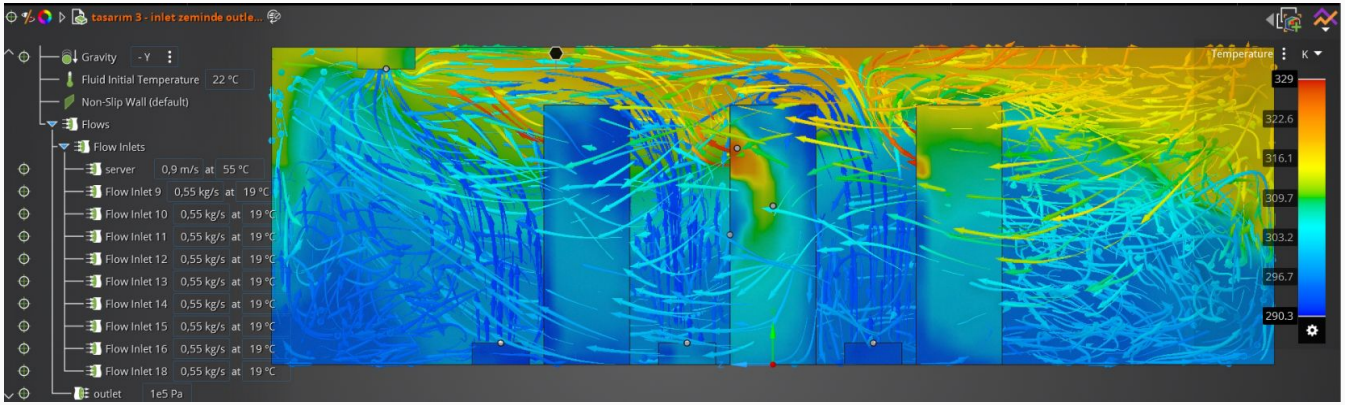




Simulation on Ansys Discovery - Geometry 3

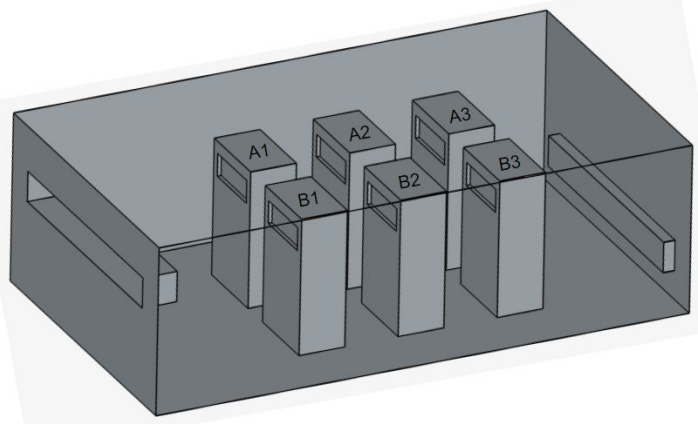


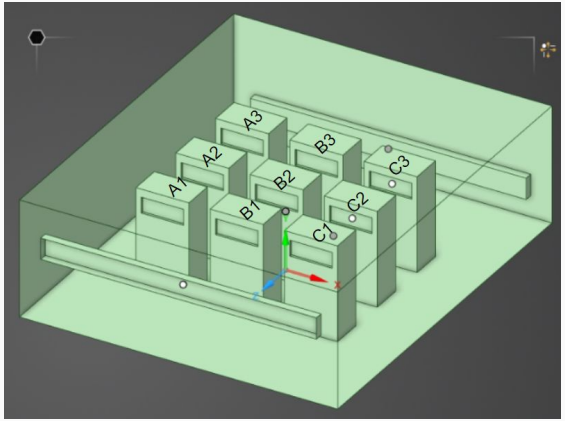




Measuring the Temperatures of the Cabinets

3 server cabinets were selected in each geometry. A point is set at the rear of the cabinet which is 350mm below the top. Measurements were made from this point. A1, B2 and A3 points were determined in the Simscale program. A1, C2 and A3 points were determined in the Ansys Discovery program.





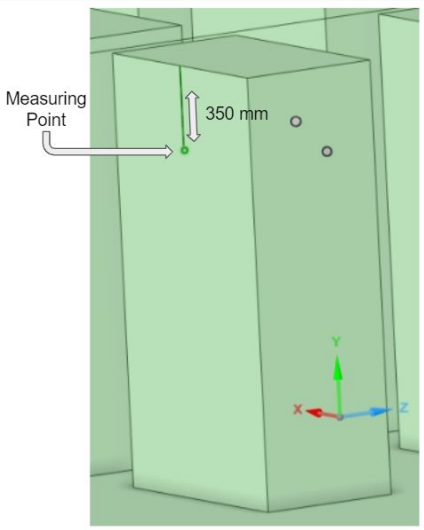
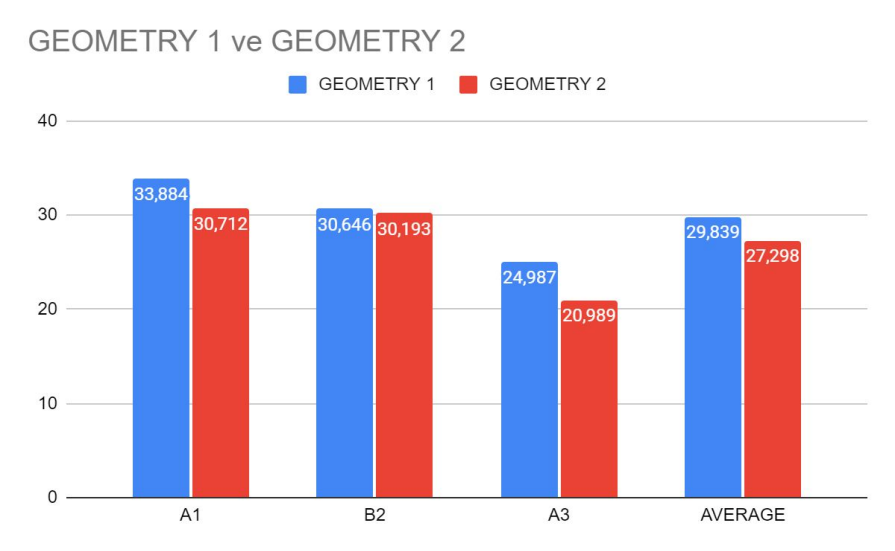


Figure. Temperature measuring on the server cabinet

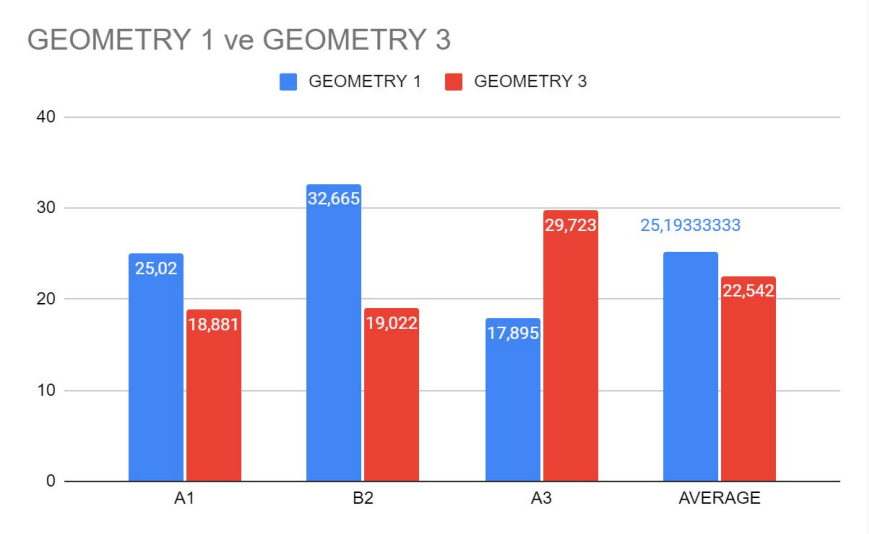
Results on Simscale - Boundary Condition 1

When measurements are made under the same conditions, the temperature of A1, B2 and A3 servers is lower in Geometry 2. On average, a temperature of 27,298 C was measured. According to geometry 1, a temperature difference of 2 °C has occurred. According to this analysis, the most efficient geometry was determined as geometry 2.



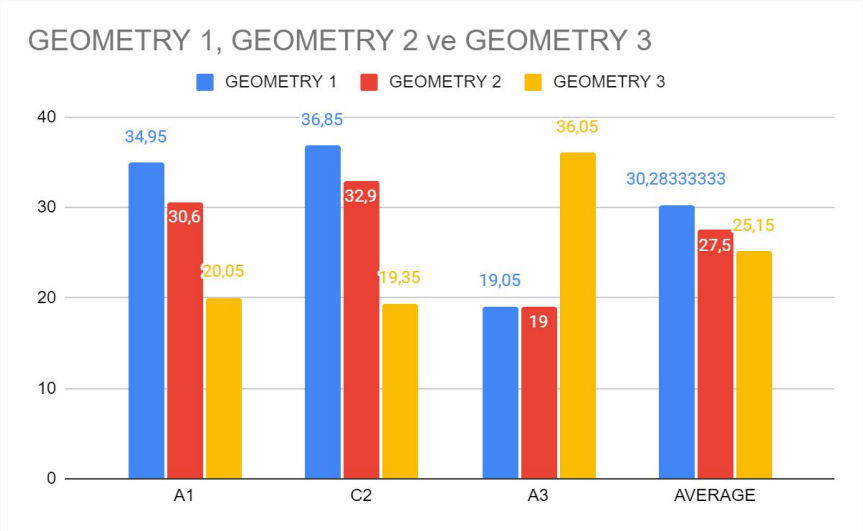
Results on Simscale - Boundary Condition 2

When measurements are made under the same conditions, the temperature of A1, B2 and A3 servers is lower in Geometry 3 according to the results. The temperature of servers A1 and B2 is lower in geometry 3, while the temperature of server A3 is lower in geometry 1. This result is related to the positioning of inlets in different regions. In Geometry 3, an average temperature of 22,542 C was measured. According to geometry 1, a temperature difference of 3 °C has occurred. According to this analysis, the most efficient geometry was determined as geometry 3.



Results on Ansys Discovery

The temperature values on the A1, C2 and A3 cabinets in 3 different geometries were measured under the same conditions. When these values are compared with Simscale results, similar results are obtained. Especially in the A3 cabinet, the temperature is at the highest level in geometry 3. Because there is no rear cooling in geometry 3. However, on average, the lowest temperature values are observed in geometry 3. The average value of cabinet temperatures in Geometry 3 was measured as 25,15 C.



Comparison of Ansys Discovery and Simscale

Ease of use: Ansys Discovery stands out in terms of ease of use. Meshing is done manually in Simscale, while in Ansys Discovery, this process is done automatically (in Explore mode).

Analysis time: Analyzes made in Simscale vary according to the size of the mesh. The analysis process took about 1 hour due to the usage restrictions of the program. In Ansys Discovery, results are available within minutes.

Modeling environment: Ansys Discovery has includes the SpaceClaim program, so the modeling tools are more complex. On the other hand, Simscale's built-in geometry modeling environment has more basic features, it is simple.

Analysis results: Temperature and velocity fields can be observed according to the results in Simscale and Ansys Discovery. Detailed analysis results are available in both programs.

Conclusion

With computer aided engineering programs, temperature and velocity fields in a server room can be determined. In this study, steady-state natural convective heat transfer analysis was performed. Comparing the results of the simulations that were made in Simscale and Ansys Discovery, the direction and location of the inlet and outlet openings leads to different server cabinet temperatures. In order for the servers to work efficiently and cost-effectively, the temperature values measured on the cabinets must be low. Geometry 3 provides the lowest temperature values on the cabinets according to both simulation programs. ***According to the results of the analysis, it has been determined that the optimum and most efficient solution is raised floor design for the cooling of server rooms.***

References

- Ashrae, “Design Considerations for Datacom Equipment Centers, ASHRAE, 2009
- Ashrae, “Thermal Guidelines for Data Processing Environments”, ASHRAE, 2012
- Ashrae, “2021 ASHRAE Handbook: Fundamentals”, ASHRAE, 2021

Thank you for your attendance.

Do you have any questions?

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