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NUMERICAL INVESTIGATION OF THE AIR FLOW INSIDE A DATA CENTER

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ABSTRACT

Data centers nowadays consume vast amounts of energy due to high density computational capabilities. Efficient energy consumption is a must to face the increased thermal dissipation of such modern data centers. Energy consumption can be addressed at multiple levels that include cooling requirements. Data center cooling represents a large portion of the energy consumed which can be minimized if best practices are applied in relation to the design of the data center. CFD simulations are the best tools to evaluate such practices in relation to the individual design of each data center. A simple raised floor data center was created using CFD software and two curtains were placed above the floor diffuser opening. The inlet air velocity was changed multiple times as well as the curtains heights. The results showed that: adding two curtains improves the temperature profile of the higher racks at the mid-plane, at low inlet velocities.

Keywords: data center, air flow, partial load, curtains, cold aisle, CFD.

Nomenclature:	
CFD	Computational Fluid Dynamic
DC	Data Center
CRAC	Computer Room Air Conditioner
CRAC	Computer Room Air Conditioner

INTRODUCTION

Data centers (DCs) are energy intensive computing facilities. The utilization of high heat-load computer racks in high density configurations resulted in an increase in the consumed energy. The electrical energy of the data center is finally turned into heat (Ebrahimi K. *et al*, 2014); this escalated the thermal challenges in today's data center systems. Cooling consumes about 40% of the energy provided to a data center (Dai J. *et al*, 2014). DCs require cooling during the whole year regardless of the weather. Also, the increased heat generation by the new equipment can create 'hot spots', this caused the DC managers to over-cool the facility. Over cooling contributed to the increase in the DC power consumption at a rate of 12% per year (Koomey J.K., 2008).

Minor changes in the operating conditions or the configuration of cooling equipment can result in saving large quantities of lost energy. Computer Room Air Conditioning (CRAC) is the main components of an air-cooled data center. In large scale DCs, a computer room air handling (CRAH) unit is used. Efficient control of the CRAC units can improve energy usage in data center in many ways. A motor speed control to ramp down the rate of flow rate contributes to a reduction of about 12.6 % of IT load. Also, 8.1% can be reduced on shutting down un performing CRAC units. On the other hand, if the chilled water set point temperature was raised, this reduces 3.6 % of IT load cooling energy (Iyengar M. *et al*, 2010).

Energy efficient data centers usually use containment system (i.e. cold aisle/hot aisle configuration, in which there are raised floors, perforated tiles and lowered ceilings) (Rasmussen N., 2003) to minimize mixing between the cold air and the hot air (hot air recirculation). Gondipalli *et al.* concluded that this can result in a 15-40% reduction in rack inlet temperature (Gondipalli *et al,* 2008) and cooling savings of 22 % (Muralidharan B. *et al*, 2013). A limitation in the enclosed systems is the leakage in the form of the seams on the wall surface and a rail carrying the racks (Alkharabsheh *et al*, 2015). Another limitation is that the accumulated cold air inside the cold aisle can cause an increase in the static pressure across the cooling units. This leads to a reduction in the flow rate and an increase of the blower's power consumption (Patankar S. V, 2010). Solid tiles are placed in the hot-aisles while the perforated tiles form the floor of the cold-aisles. The perforated tiles open area might range from 25% (the most prevalent) to 56% (for excessive quantities of airflow). The flow through a Perforated tile is determined by the different geometrical characteristics such as size of the tile, pore size and shape, if the edged are blocked (where perforations are absent), and anterior structures (such as flow guiding fins or dampers) (Abdelmaksoud W.A., 2010). In this paper the effect of adding two curtains in front of a floor diffuser opening was tested under different operating conditions.

CFD (Computational Fluid Dynamics) is a set of numerical methods and algorithms that are used to solve the equations governing fluid dynamics. CFD provides a virtual data center environment to try out various configurations. CFD can predict optimal operational conditions of cooling (Patel C.D. *et al,* 2001); predicted airflow patterns (Erden H.S., 2013) and can calculate the time needed before the critical threshold. CFD simulations also help in choosing the optimum position for cooling units and new assets (Moore J. 2006).

MATERIAL AND METHODS

This paper evaluated the effect of adding containment curtains in a cold aisle of a raised floor data centre using CFD simulation. Initially, the software (ANSYS FLUENT version 15.0) was validated. Then, a

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basic data centre room was generated using the software. The sizes of the elements in the mesh were further refined by performing a mesh independency test.

Three parameters were studied; the inlet air velocity (1m/s, 0.9 m/s, 0.8 m/s, 0.7 m/s and 0.6 m/s), the height of the curtains (50% and 37.5% of the rack height), and the operating loads of the server racks (90%, 80%, 70% and 60% of the full load). So, fifty-five configurations were simulated and the results were analysed. The temperature profiles and values as well as the air velocity profiles and vectors were used to compare between the different configurations to point out the effect of each parameter. Velocity fields and temperature contours were obtained in three planes; in the middle plane perpendicular to the length of the rack and parallel to the raised floor at the height of 0.7m and 1.5m.

Software Validation

To validate the CFD model, the results were compared with the results of the experimental model of Qifei Jian *et al*. [14]. The temperature and velocity values obtained from the simulation were compared to the values obtained by Qifei Jian *et al*. at Six measurement points set at the heights (0.3 m, 1 m, and 2 m). Measurement points were at a distance of 0.2 m from the front and back of each rack as shown in Figure-1. The temperature and velocity distribution comparisons are illustrated in Chart 1 to Chart 14. On comparing the simulated model in this paper and the experimental values measured by Qifei Jian *et al.,* the difference in temperature values ranged from +2.4 °C to -1.9 °C and the difference in velocity values was observed to be within ± 0.9 m/s.

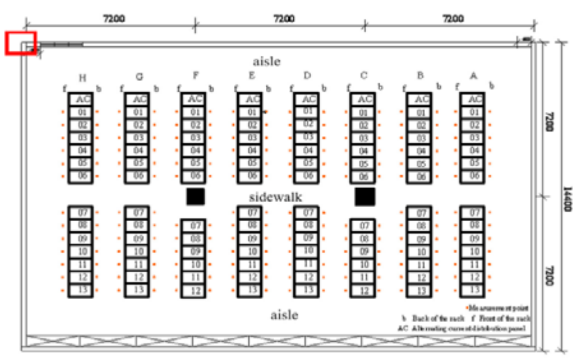

Figure-1. Schematic of the measurement points [14].

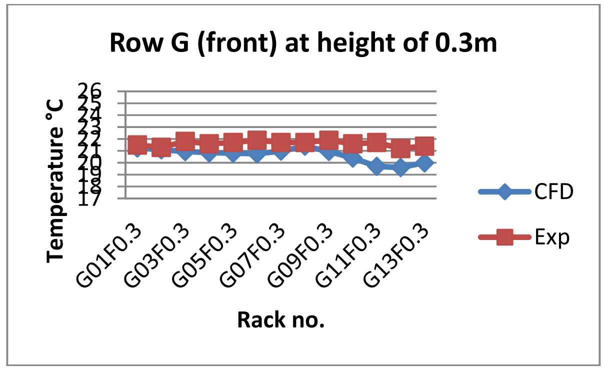

Chart-1. Numerical and experimental temperature values in Row (G) measured at the front of the racks at height of 0.3 m.

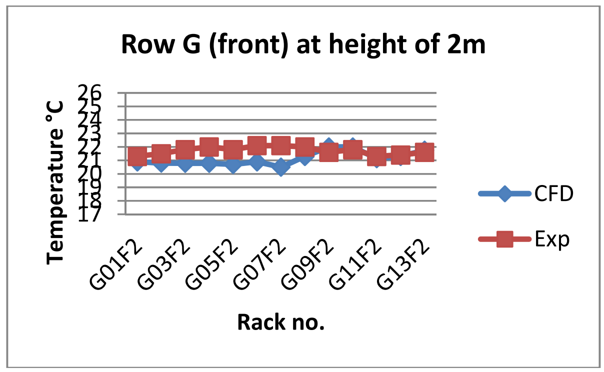

Chart-2. Numerical and experimental temperature values in Row (G) measured at the front of the racks at height of 2m.

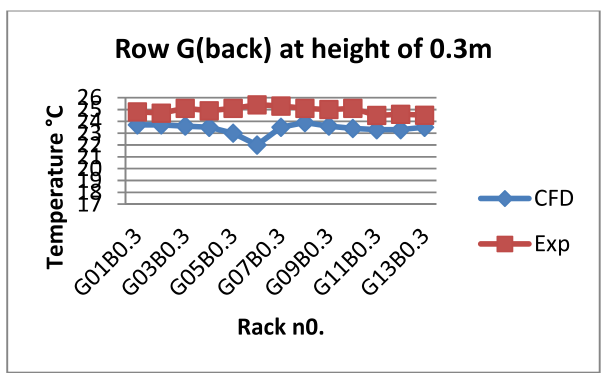

Chart-3. Numerical and experimental temperature values in Row (G) measured at the back of the racks at height of 0.3m.

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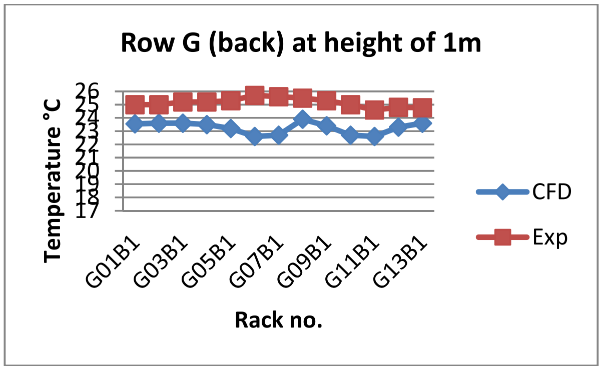

Chart-4. Numerical and experimental temperature values in Row (G) measured at the back of the racks at height of 1m.

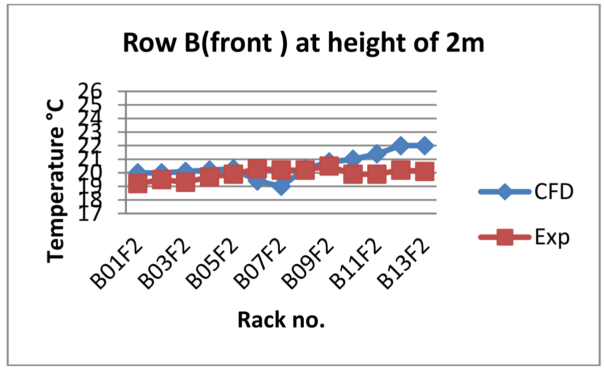

Chart-7. Numerical and experimental temperature values in Row (B) measured at the front of the racks at height of 2m.

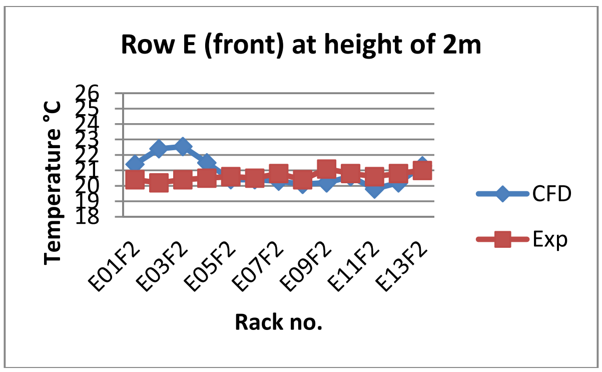

Chart-5. Numerical and experimental temperature values in Row (E) measured at the front of the racks at height of 2m.

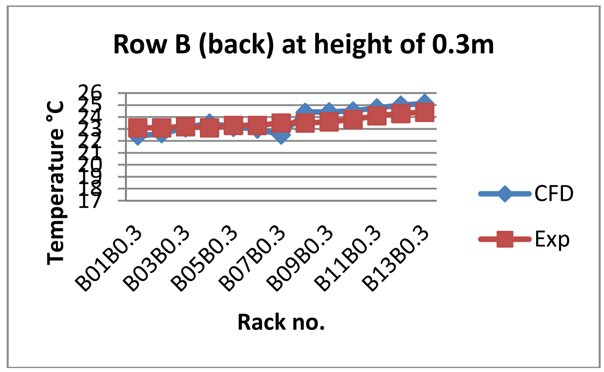

Chart-8. Numerical and experimental temperature values in Row (B) measured at the back of the racks at height of 0.3m.

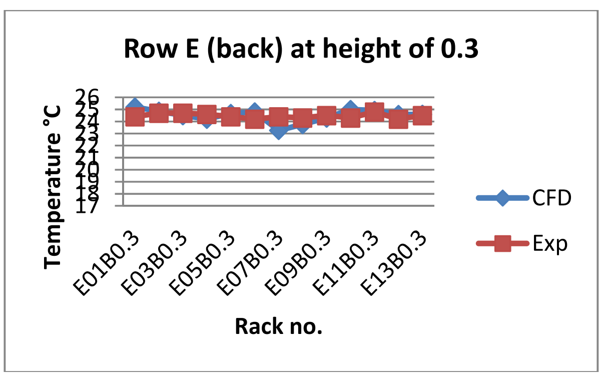

Chart-6. Numerical and experimental temperature values in Row (E) measured at the back of the racks at height of 0.3m.

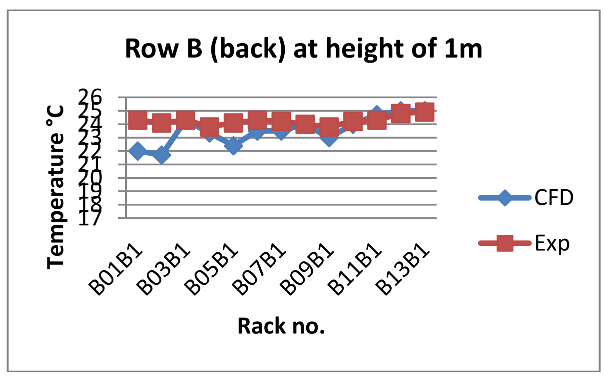

Chart-9. Numerical and experimental temperature values in Row (B) measured at the back of the racks at height of 1m.

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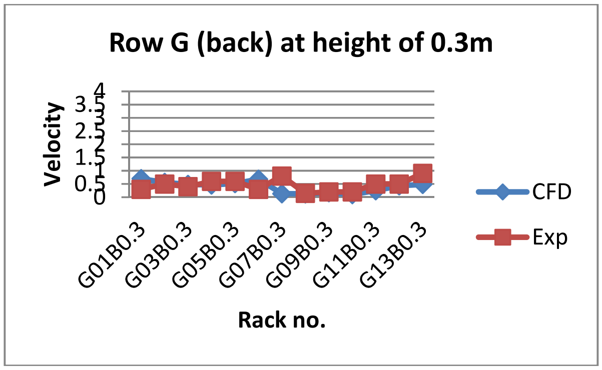

Chart-10. Numerical and experimental velocity values in Row (G) measured at the back of the racks at height of 0.3m.

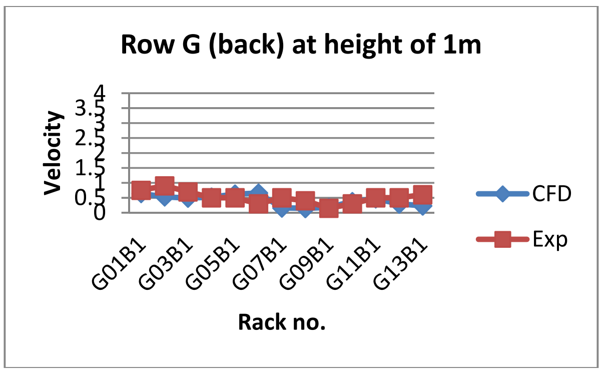

Chart-11. Numerical and experimental velocity values in Row (G) measured at the back of the racks at height of 1m.

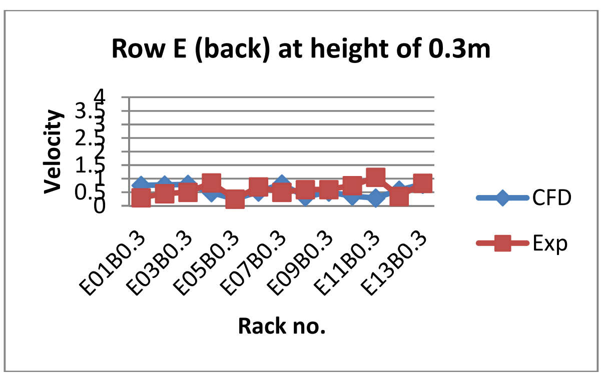

Chart-12. Numerical and experimental velocity values in Row (E) measured at the back of the racks at height of 0.3m.

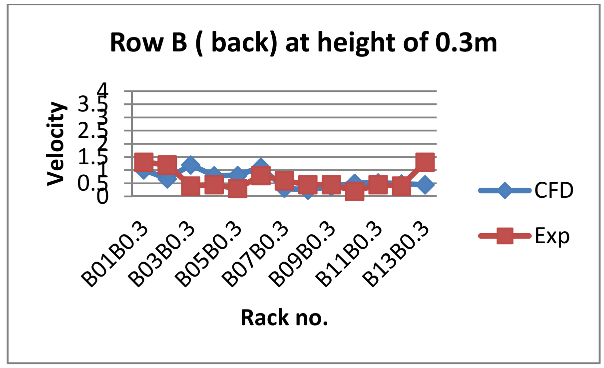

Chart-13. Numerical and experimental velocity values in Row (B) measured at the back of the racks at height of 0.3m.

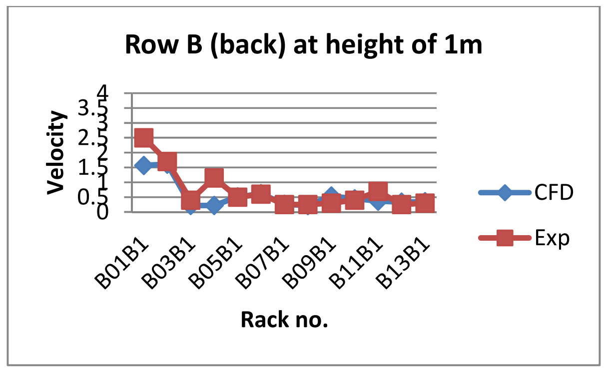

Chart-14. Numerical and experimental velocity values in Row (B) measured at the back of the racks at height of 1m.

Grid Independent Study

Grid sensitivity test was done and the minimum grid size that does not affect the numerical solution was calculated. The used mesh size of 2.055.140 elements each of 50mm in the DC room and 10mm near the diffuser, inlets and outlets of the servers, and the room outlets was compared to a smaller mesh size of 2.577.270 elements each of 45mm and 9mm near the diffuser, inlets and outlets of the servers, and the room outlets as shown in Chart 15 and Chart 16 for temperature and velocity values respectively. Twenty-seven points were used for the comparison. The maximum error in temperature is 0.683°C (less than 1%) and the maximum error in velocity is 0.17m/s as demonstrated in Table-1.

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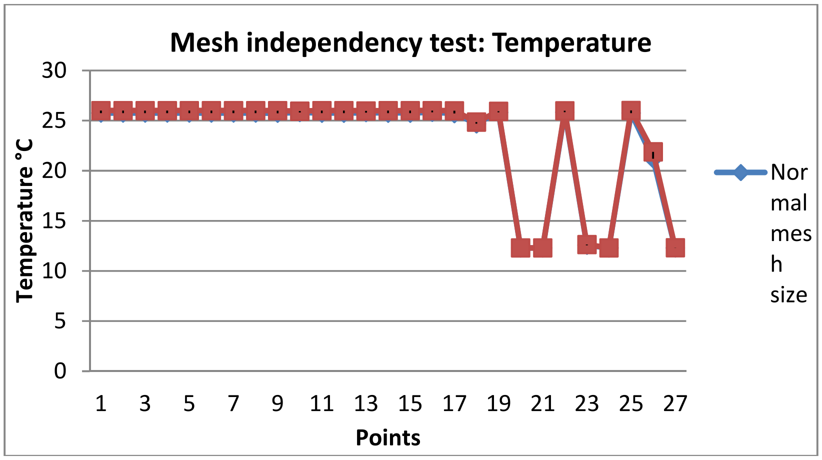

Chart-15. Comparison between temperatures calculated in used mesh size and smaller mesh size.

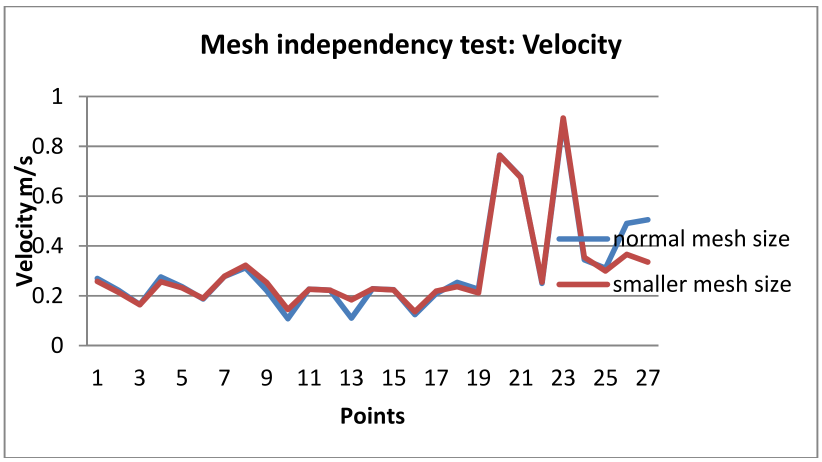

Chart-16. Comparison between velocities calculated in the used mesh and smaller mesh size.

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Table-1. Comparison between temperature and velocity values of the used mesh and the smaller mesh size.

Point	Temperature(K)		Velocity (m/sec.)	
	Used Mesh size	Smaller Mesh Size	Used Mesh size	Smaller Mesh Size
1	298.758	299.003	0.269413	0.257447
2	298.755	299.003	0.221561	0.214209
3	298.755	299.003	0.164327	0.164606
4	298.758	299.003	0.275593	0.256287
5	298.755	299.003	0.236418	0.232055
6	298.755	299.003	0.187593	0.189998
7	298.76	299.003	0.277515	0.278194
8	298.758	299.003	0.31225	0.322578
9	298.745	299.002	0.22128	0.253013
10	298.815	298.948	0.108432	0.14481
11	298.749	299.004	0.227024	0.226203
12	298.748	299.004	0.222099	0.222162
13	298.805	298.971	0.110339	0.183555
14	298.749	299.004	0.228371	0.227522
15	298.749	299.004	0.224359	0.223849
16	298.831	299.005	0.124673	0.136105
17	298.705	298.99	0.20841	0.218987
18	297.681	297.855	0.253591	0.236855
19	298.826	298.932	0.225908	0.211465
20	285.3	285.3	0.765312	0.764146
21	285.3	285.3	0.677118	0.675267
22	298.844	298.993	0.250477	0.255124
23	285.573	285.638	0.906071	0.914132
24	285.3	285.3	0.345178	0.354785
25	298.755	299.019	0.310443	0.299717
26	294.199	294.882	0.491007	0.366313
27	285.3	285.312	0.505	0.335

CFD SIMULATION MODELING

The Data Center Room Model

The simulated model is a raised floor DC room. The room size is 6.71m × 5.49m and height of 3.0 m. The server racks are arranged in 2 rows each of 7 racks. The rack dimensions are 0.610 m width, 0.915m length and 2.0m height. Each rack comprises four server chassis of 0.5m height each. In the servers operating at full load, there is air recirculation inside the server with heat generation equal 875.26W per server.

The rack inlets face each other forming a cold aisle and the exits face the walls forming the hot aisle. The rows are separated by a 1.22m distance occupied by a floor diffuser of width 1.2 m and length 4.2 m. Hot air exits the room through 6 ceiling vents. Figures 2 and 3 show the data center detailed geometry.

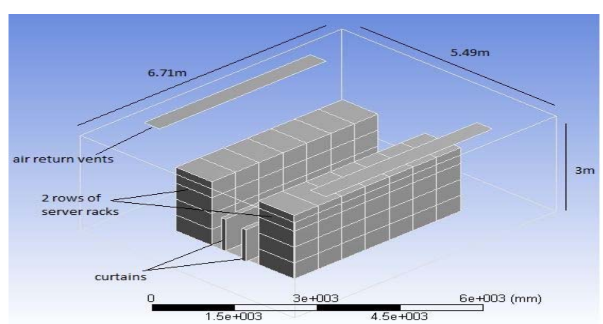

Figure-2. CFD data centre model.

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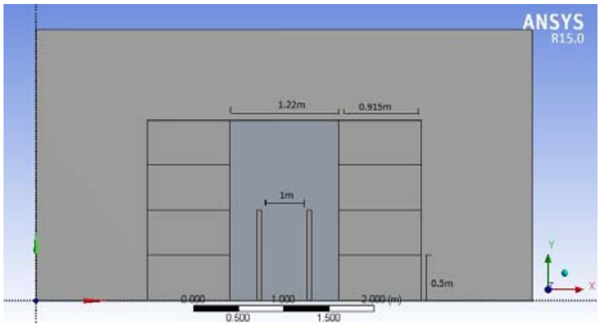

Figure-3. CFD data centre geometry.

Meshing

The geometry was done by using ANSYS FLUENT 15.0. Boundary conditions were specified including server fixed mass flow rate, server heat generation and the inlet air temperature. All simulations were run with the k-ε turbulence model. The element length was 5cm and refined to 2.5 cm near the diffuser, inlets and outlets of the servers, and the room outlets for more accurate calculations. The summary of meshing parameters and boundary conditions are summarized in Table-2 and Table-3.

Table-2. Summary of meshing parameters.

Parameter	CFD
Maximum element size	0.050m
Minimum element size	0.0085m
Diffuser face size (constant)	0.025m
in/out server face size(constant)	0.025m
Room out face size (constant)	0.05m
Total number of the elements	2,055,140
Total number of nodes	373,140

Table-3. Boundary conditions for the CFD model.

Boundary condition	Value
Inlet air temperature	12.3°C
Server flow rate	$0.0713 m^3 s^{-1}$
Server heat generation on full load conditions	875.26 W

CFD Assumptions

Multiple scenarios were simulated and 2 curtains were added above the diffusers each of 10 cm thickness. Two heights of the curtains (50% and 37.5% of the rack height) were included in the simulations.

Velocity field and temperature contours were plotted in three planes; in the middle plane perpendicular to the length of the rack and parallel to the raised floor at the height of 0.7m and 1.5m. The simulations were run at five different inlet velocities (1m/s, 0.9 m/s, 0.8 m/s, 0.7 m/s and 0.6 m/s), multiple operating conditions (full load, 90%, 80%, 70% and 60% of the full load).

CFD SIMULATION RESULTS AND DISCUSSIONS

The results from the CFD simulations were analyzed at 3 different points (A, B, C) on the inlet of the top most servers. The points were set up at height of 1.75m from the raised floor, and a distance of 2.345m from the wall of the room. The three points A, B, C was set at 1.535m, 2.145m, and 2.755m from the sidewall of the DC room. The measuring points are shown in Figure-4. Comparisons were made on the basis of temperature contour, velocity contour and velocity vectors. The results were obtained plotted in three planes; in the middle plane perpendicular to the length of the rack and parallel to the raised floor at the height of 0.7m and 1.5m. The temperature plot scaled between 10°C and 40°C. while, velocity was plotted with the scale between 0m and 2m.

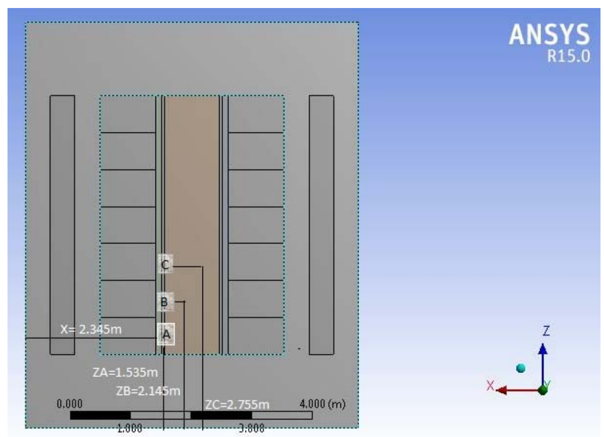

Figure-4. The coordinates of the measuring points.

Point A: X=2.345m, Y=1.75m, Z=1.535m
Point B: X=2.345m, Y=1.75m, Z=2.145m
Point C: X=2.345m, Y=1.75m, Z=2.755m

Parametric Study of the effect of inlet air velocity on temperature and velocity at full load racks

The CFD simulations results at inlet velocity 1m/s were compared to the results at inlet velocity of 0.7m/sec, 0.8m/sec, 0.9m/s and 0.6m/s on the basis of temperature and velocity contours in Figures 5 and 7 and velocity vectors shown in Figures 6 and 8 to study the effect of changing the inlet air velocity on the higher server's temperature at full load conditions.

The results showed that the temperatures of the bottom servers are always lower than the temperature of the upper servers independent of the value of the air flow velocity. On decreasing the inlet velocity, the temperature values at the top servers rises as most of the cold air is delivered to the lower servers. At low inlet velocity, air wakes seen in Figure-8 are also observed at top racks causing hot air to enter the server from the room. This is observed from temperature contour comparison at height of

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1.5m from raised floor level where the temperature values at the top servers ranged from 13.6°C to 12.6°C in the 1m/s model. While, the temperature values at the top servers ranged from 21.3°C to 20°C at inlet velocity 0.6m/sec, from 14.2°C to 12.9 °C at inlet velocity 0.9m/sec and from 18°C to 16.4°C at inlet velocity of 0.7m/sec.

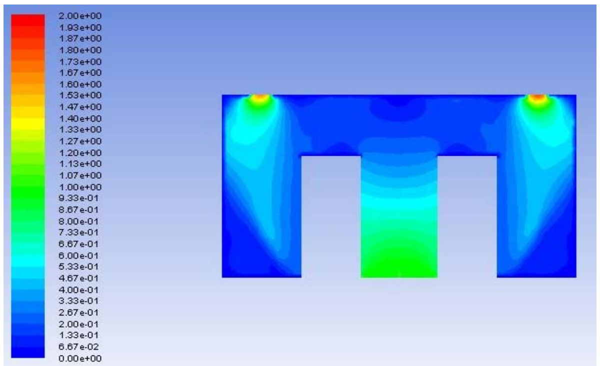

Figure-5. Velocity contour of full load racks at inlet velocity 1m/s.

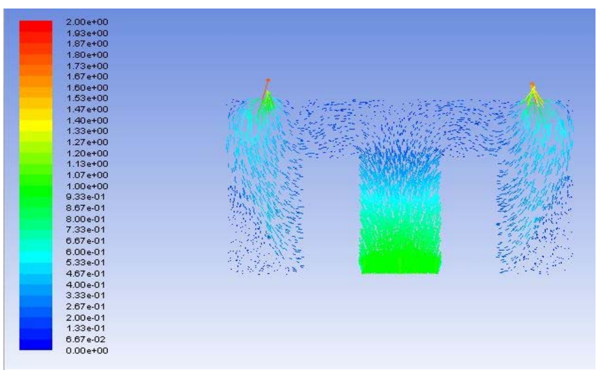

Figure-6. Velocity vector of full load racks at inlet velocity 1m/s.

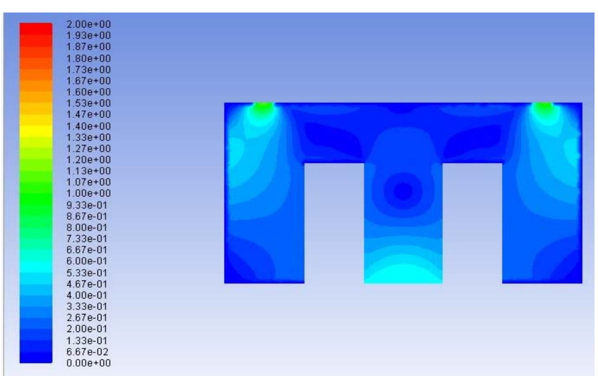

Figure-7. Velocity contour of full load racks at inlet velocity 0.6m/s.

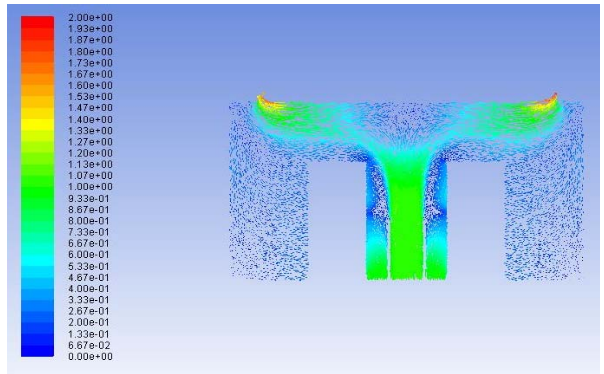

Figure-8. Velocity contour of full load racks at inlet velocity 0.6m/s.

Parametric Study of the effect of using curtains of 1m and 0.75m height (50% and 37.5% of the rack height) at inlet velocity of 1m/s and full load conditions

The CFD simulations results at inlet velocity 1m/s after adding the two curtains were compared to the results at inlet velocity of 1m/s without using the curtains.

From these simulations, it`s observed that Adding the curtains at the high speed (1m/sec) in case of full load operating racks has a bad impact on velocity distribution Figure-9 and velocity vectors in Figure-10. The top server's temperatures that ranged from 13.6°C to 12.6°C in the no curtains model rose to a range of 25.8°C to 12.3°C. This becomes worse with higher curtains i.e. the maximum server temperature was 25.5°C on using shorter curtains and 25.8°C on using the higher ones.

This is because the air contained between the curtains has higher throw and so, get stagnant at the room ceiling. This causes much air passing to the return and by-passing the racks.

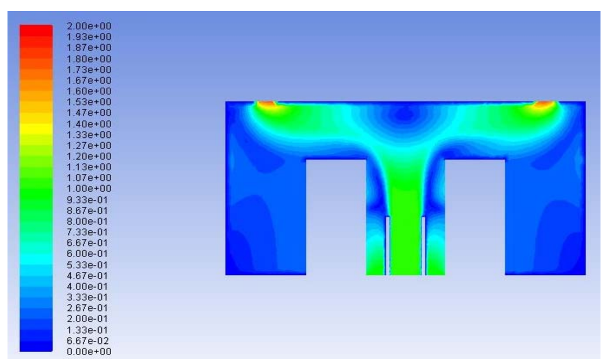

Figure-9. Velocity contour of full load racks at inlet velocity 1m/s using 2 curtains (1m height).

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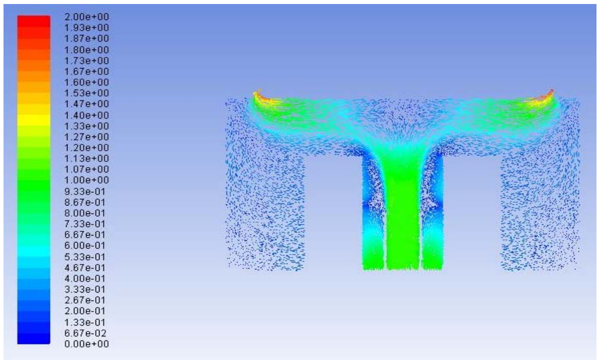

Figure-10. Velocity vector of full load racks at inlet velocity 1m/s using 2 curtains (1m height).

Parametric Study of the effect of using curtains of 1m and 0.75m height (50% and 37.5% of the rack height) at inlet velocity of 0.6m/s,0.7m/sec,0.8m/sec and 0.9m/s and full load conditions

The CFD simulations results at inlet velocity 0.6m/s,0.7m/sec,0.8m/sec and 0.9m/s after adding the two curtains were compared to the results without using the curtains. Adding the curtains improved the temperature and velocity profiles. Curtains enable us to deliver more air higher up the racks to decrease recirculation between ambient air and cold aisle air which make high level server inlet air temperature better for same inlet air velocity. The temperature measured in the mid plane top servers improved from 20^{o}C to 12.3^{o}C after adding the curtains.

On using 2curtains, the inlet velocity (0.7m/sec) is the best for full load Racks at mid plane top servers with drop of the inlet temperature from 16.4^{o}C to 12.3^{o}C. this proves that curtains improve the thermal profile of the top servers at low inlet air velocities. However, at inlet velocity of 0.8m/sec more inlet air passed directly to return without passing to the server. This by pass phenomenon increases with the increase of the velocity at higher curtains seen in Figures 11 and 12 in comparison to lower inlet velocity in Figures 13 and 14.

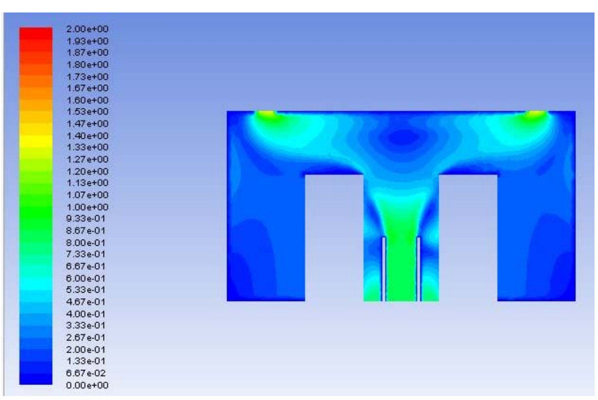

Figure-11. Velocity contour of full load racks at inlet velocity 0.8 m/s using 2 curtains of 1m height.

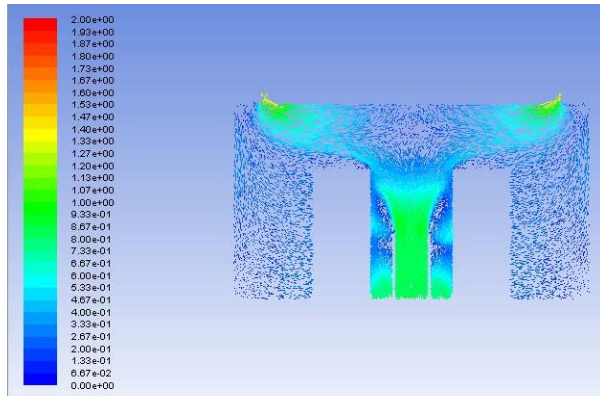

Figure-12. Velocity vector of full load racks at inlet velocity 0.8 m/s using 2 curtains of 1m height.

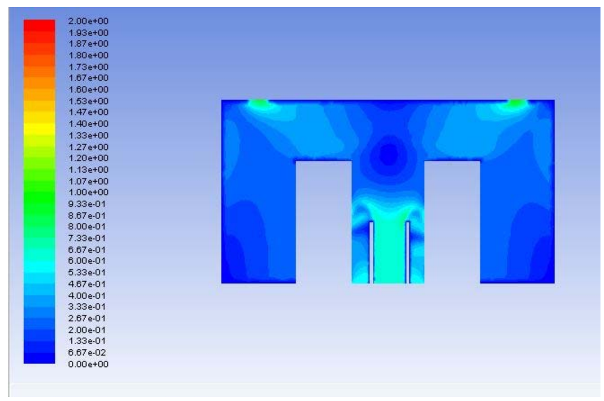

Figure-13. Velocity contour of full load racks at inlet velocity 0.6 m/s using 2 curtains of 1m height.

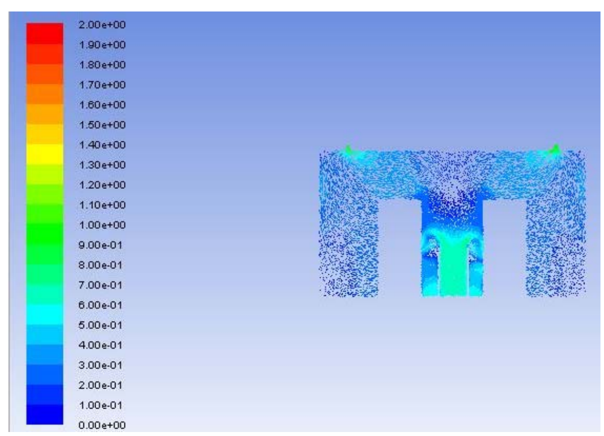

Figure-14. Velocity vector of full load racks at inlet velocity 0.6 m/s using 2 curtains of 1m height.

Parametric Study of the effect of using curtains of 1m and 0.75m height (50% and 37.5% of the rack height) in case of partial load operating conditions of 90%

The CFD simulations results at inlet velocity 0.8m/sec, 0.9m/sec,1m/s after adding the two curtains were compared at the two heights of the curtains, i.e. 50% and 37.5% of the rack height. They were compared on the basis

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of temperature and velocity contours and vectors to study the effect of the different heights of the two curtains on the temperature of the higher servers.

Results showed that the temperature at the return decreases as the height of the curtains increases and also as the inlet velocity increases this is due to increasing the air passing to return without passing to the servers illustrated in Figures 15, 16, 17, 18, 19 and 20. This manifests in the rise of the temperature of the server inlet at measuring point B from 12.3^{o}C to 15.29^{o}C as the inlet velocity is increased from 0.9m/s to 1m/s.

The increased heights of the curtains also results in formation of wakes at the middle servers. This decreases the cold air delivered to the servers in the middle and consequently a rise in temperature of these servers is noticed.

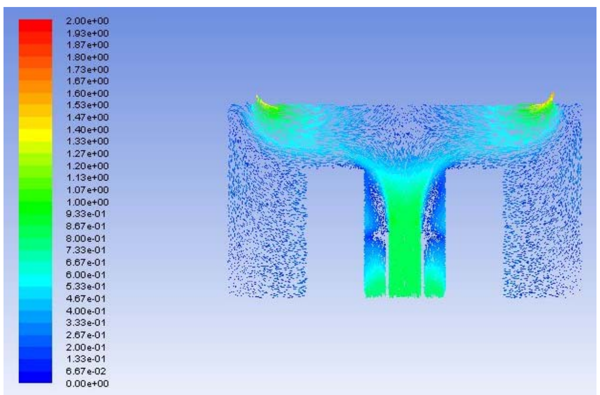

Figure-15. Velocity vector of part load racks (90%) at inlet velocity 0.8 m/s using 2 curtains of 1m height.

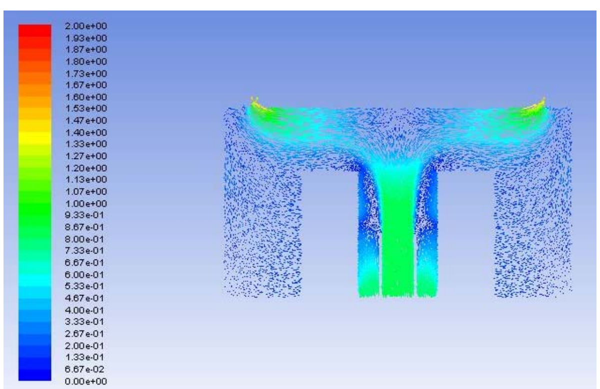

Figure-16. Velocity vector of part load racks (90%) at inlet velocity 0.8m/s using 2 curtains of 0.75m height.

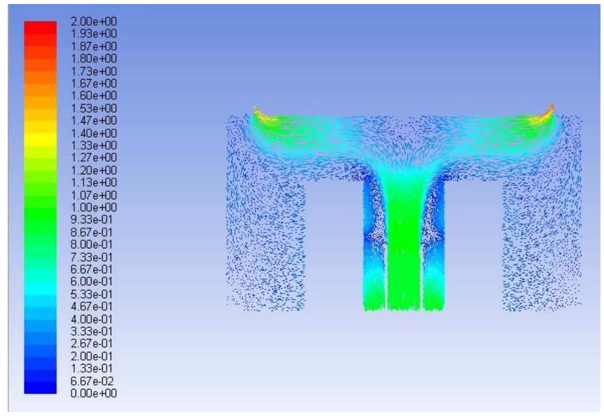

Figure-17. Velocity vector of part load racks (90%) at inlet velocity 0.9m/s using 2 curtains of 1m height.

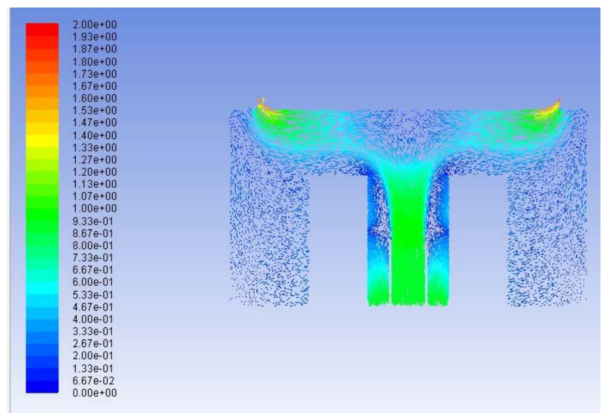

Figure-18. Velocity vector of part load racks (90%) at inlet velocity 0.9m/s using 2 curtains of 0.75m height.

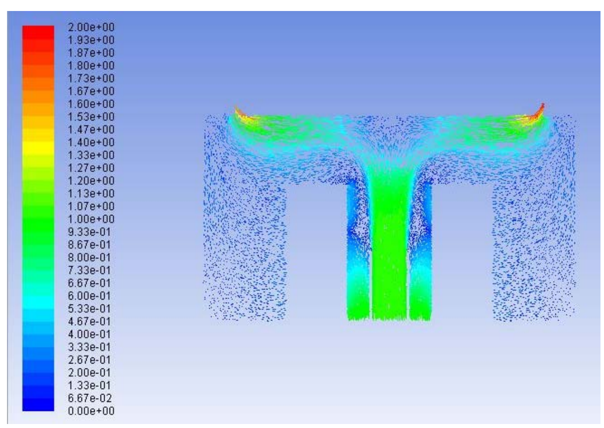

Figure-19. Velocity vector of part load racks (90%) at inlet velocity 1m/s using 2 curtains of 1m height.

VOL. 16, NO. 4, FEBRUARY 2021 ISSN 1819-6608

ARPN Journal of Engineering and Applied Sciences

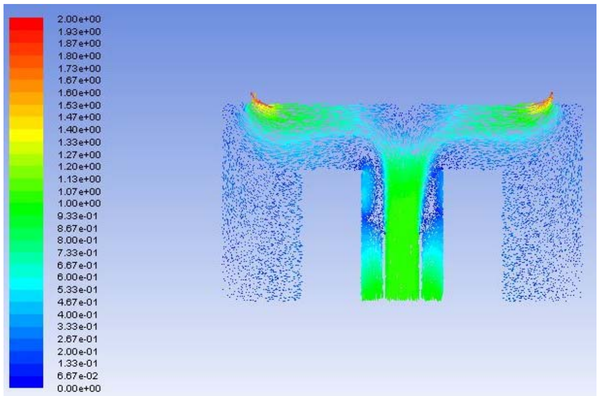

Figure-20. Velocity vector of part load racks (90%) at inlet velocity 1m/s using 2 curtains of 0.75m height.

Parametric Study of the effect of using curtains of 1m and 0.75m height (50% and 37.5% of the rack height) in case of partial load operating conditions of 80%

The CFD simulations results at inlet velocity 0.7m/sec,0.8m/sec,0.9m/s after adding the two curtains were compared at the two heights of the curtains, i.e. 50% and 37.5% of the rack height.

The results illustrated in Figures 21 to 26 showed that in case of racks operating at part load of 80%, the inlet speed of 0.8 m/sec with curtains of 0.75m is the best configuration to provide optimum operating conditions for the top servers. The temperatures of the top servers measuring points were calculated to be 25.78^{o}C, 12.3^{o}C and 12.3^{o}C at the mid plane.

Increasing inlet air velocity or curtains height will increase the air that passes directly to the return as seen in the rise of temperature calculated at point B from 12.3 ^{o}C at inlet velocity 0.8m/s to 15.9^{o}C at inlet velocity 0.9m/s which decreases energy usage efficiency.

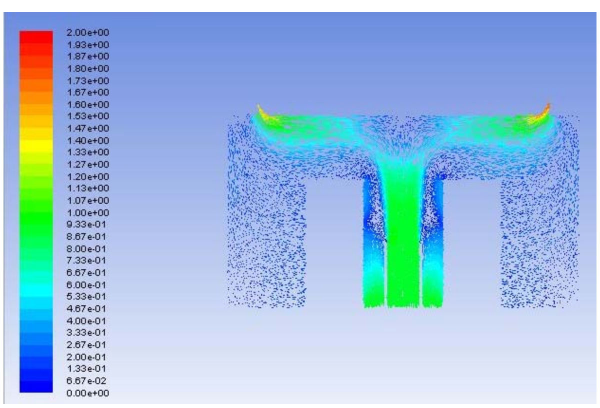

Figure-21. Velocity vector of part load racks (80%) at inlet velocity 0.9m/s using 2 curtains of 1m height.

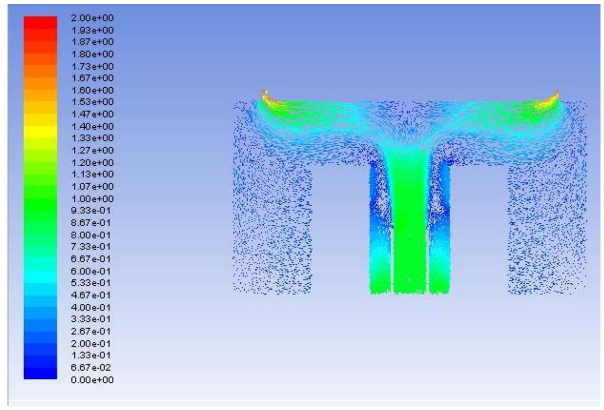

Figure-22. Velocity vector of part load racks (80%) at inlet velocity 0.9m/s using 2 curtains of 0.75m height.

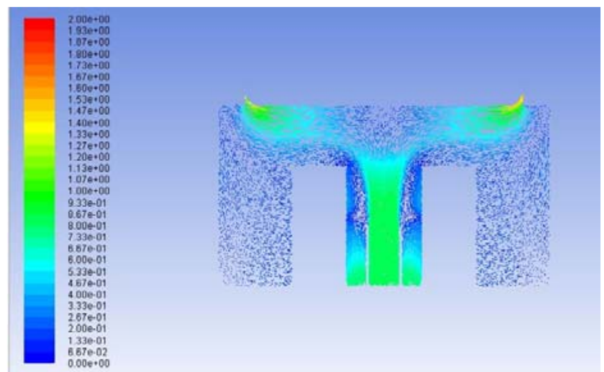

Figure-23. Velocity vector of part load racks (80%) at inlet velocity 0.8m/s using 2 curtains of 1m height.

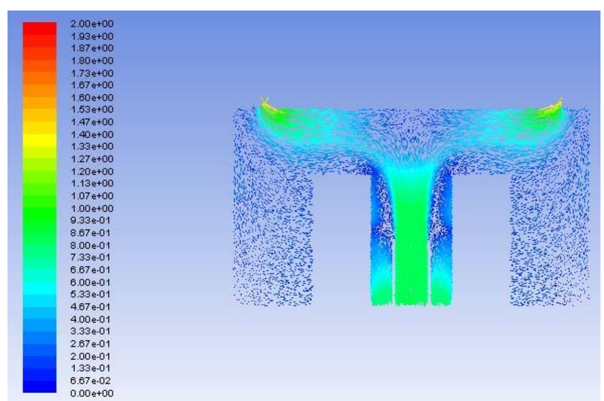

Figure-24. Velocity vector of part load racks (80%) at inlet velocity 0.8m/s using 2 curtains of 0.75m height.

 ISSN 1819-6608

ARPN Journal of Engineering and Applied Sciences

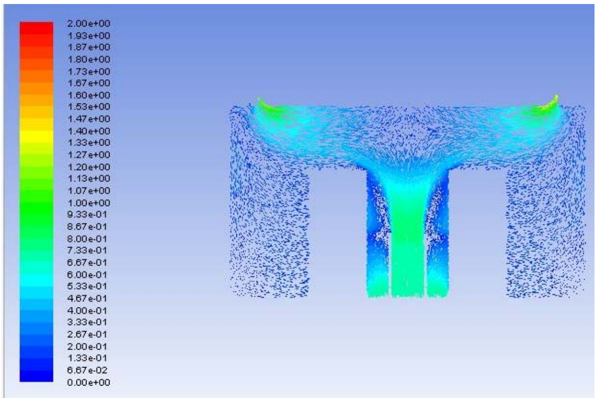

Figure-25. Velocity vector of part load racks (80%) at inlet velocity 0.7m/s using 2 curtains of 1m height.

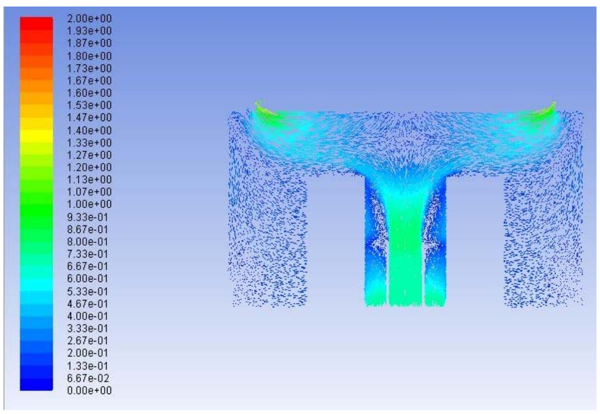

Figure-26. Velocity vector of part load racks (80%) at inlet velocity 0.7m/s using 2 curtains of 0.75m height.

Parametric Study of the effect of using curtains of 1m and 0.75m height (50% and 37.5% of the rack height) in case of partial load operating conditions of 70%

The CFD simulations results at inlet velocity 0.6m/sec,0.7m/sec,0.8m/s after adding the two curtains were compared at the two heights of the curtains, i.e. 50% and 37% of the rack height. The simulations were run using Servers operating at partial load of 70% are illustrated in Figures 27 to 32.

The curtains of 1m height provide the most uniform velocity contour in comparison to configurations involving shorter curtains.

Moreover, air inlet velocity of 0.7m/s can provide optimum cooling to the racks if 1m height curtains are used.

Low height curtains combined with low inlet air velocity results in more recirculation where hot air enters the cold aisle which affects the cooling of high level servers.

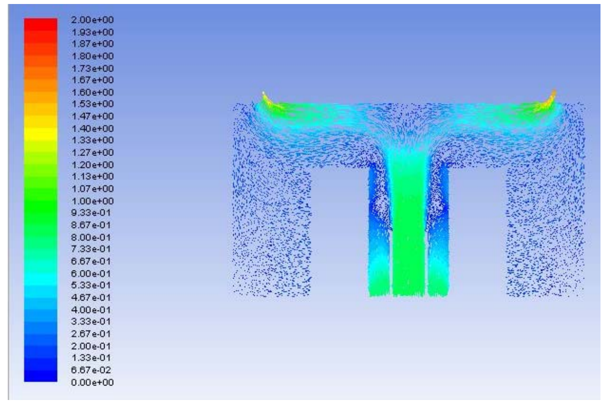

Figure-27. Velocity vector of part load racks (70%) at inlet velocity 0.8m/s using 2 curtains of 1m height.

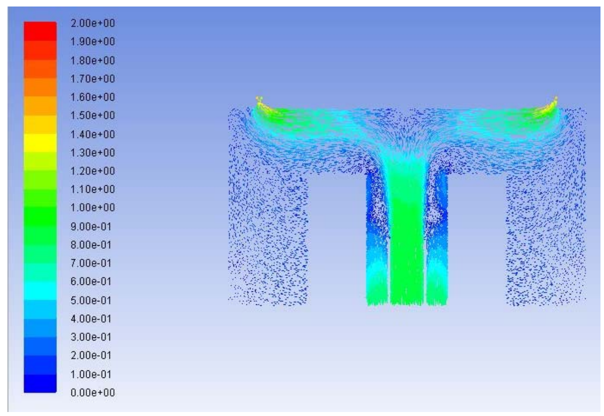

Figure-28. Velocity vector of part load racks (70%) at inlet velocity 0.8m/s using 2 curtains of 0.75m height.

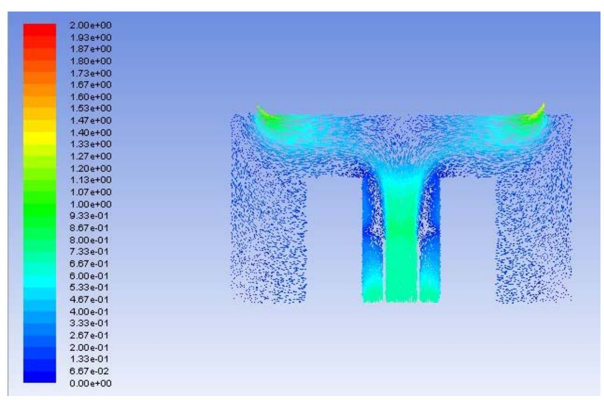

Figure-29. Velocity vector of part load racks (70%) at inlet velocity 0.7m/s using 2 curtains of 1m height.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

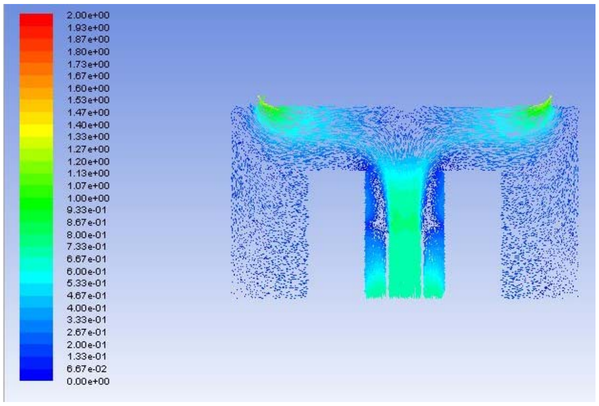

Figure-30. Velocity vector of part load racks (70%) at inlet velocity 0.7m/s using 2 curtains of 0.75m height.

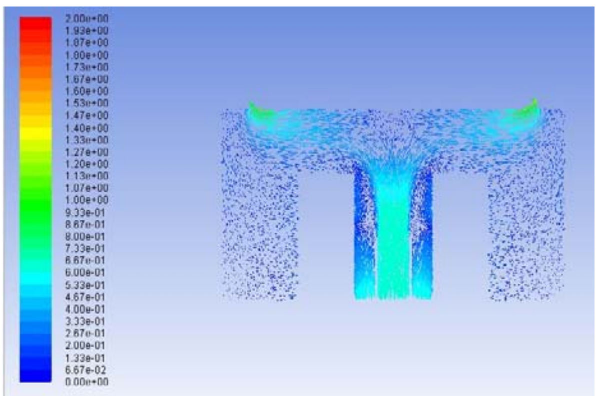

Figure-31. Velocity vector of part load racks (70%) at inlet velocity 0.6m/s using 2 curtains of 1m height.

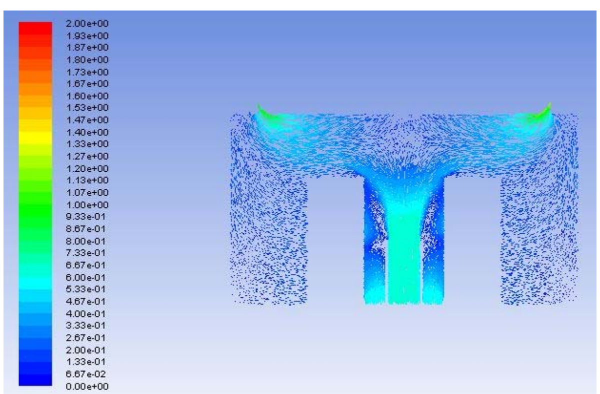

Figure-32. Velocity vector of part load racks (70%) at inlet velocity 0.7m/s using 2 curtains of 0.75m height.

Parametric Study of the effect of using curtains of 1m and 0.75m height (50% and 37.5% of the rack height) in case of partial load operating conditions of 60%

The CFD simulations results at inlet velocity 0.6m/sec,0.7m/sec,0.8m/s after adding the two curtains were compared at the two heights of the curtains, i.e. 50% and 37% of the rack height. The simulations were run using Servers operating at partial load of 60%.

Curtain of 1m height provide optimum cooling at air inlet velocity of 0.8m/s as the recirculation problem is at top servers disappeared as shown in Figures 33 to 37.

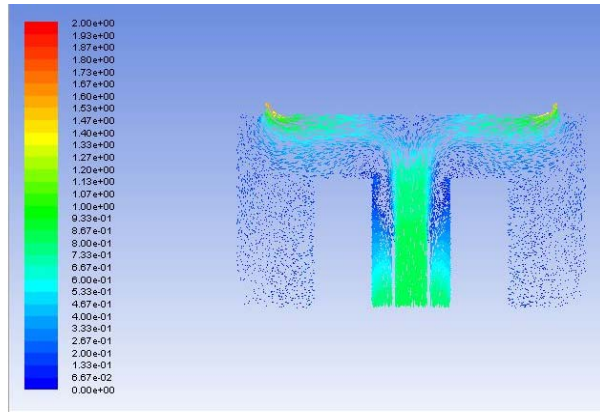

Figure-33. Velocity vector of part load racks (60%) at inlet velocity 0.8m/s using 2 curtains of 1m height.

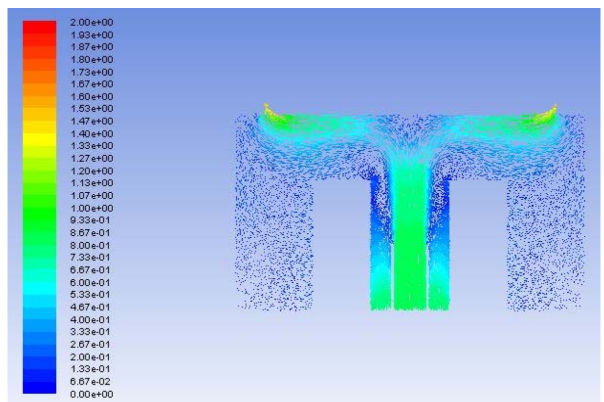

Figure-34. Velocity vector of part load racks (60%) at inlet velocity 0.8m/s using 2 curtains of 0.75m height.

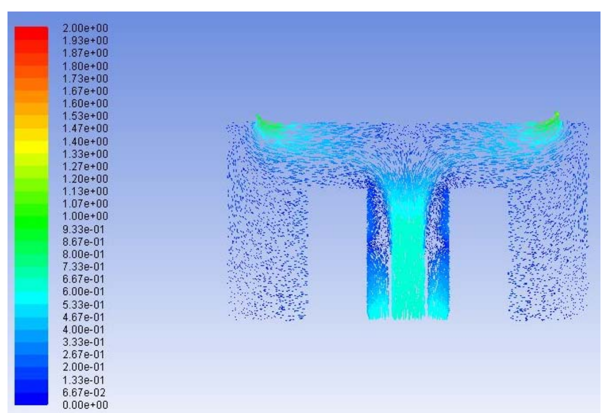

Figure-35. Velocity vector of part load racks (60%) at inlet velocity 0.6m/s using 2 curtains of 1m height.

ARPN Journal of Engineering and Applied Sciences

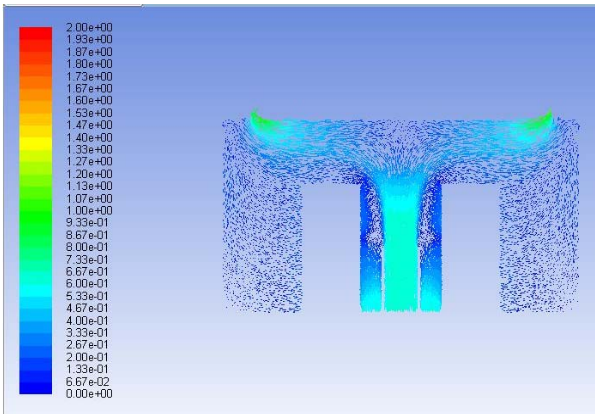

Figure-36. Velocity vector of part load racks (60%) at inlet velocity 0.6m/s using 2 curtains of 0.75m height.

SUMMARY AND CONCLUSIONS

CFD simulations of multiple configurations were studied, and their results were compared regarding temperature contour and air flow velocity contours and vectors. The simulations were conducted at inlet air velocities of 1 m/s, 0.9m/s, 0.8 m/s, 0.7m/s and 0.6 m/s. Then, two curtains were placed above the diffuser of two different heights (50% and 37.5% of the rack height). The simulations were run once more but using part load operating conditions. Simulations were analyzed at three different points A, B, C at the inlet of the top most servers. Temperature and velocity profiles were plotted in three planes; in the middle plane perpendicular to the length of the rack and parallel to the raised floor at the height of 0.7m and 1.5m. According to the previously discussed parametric study:

- Placement of containment curtains would improve the thermal profile of higher servers at low inlet air velocity 0.6m/s

- In case of High load and high inlet air velocity it is better not to use air Curtains. This is because the air contained between the curtains has high throw which if combined with high inlet velocity, this leads to increase in the volume of cold air by-passing the top servers.

- Adding the curtains generally improved the thermal profile of mid plane servers (point C). But the thermal profile of the top servers furthest from the mid plane (point A) and the middle servers became worse due to increased recirculation.

- As the height of the curtains decrease, the temperature and velocity profiles improve. This is due to increased air by passing the servers in case of higher curtains.

REFERENCES

Ebrahimi K., Jones G.F. & Fleischer A.S. 2014. A review of data center cooling technology, operating conditions and the corresponding low-grade waste heat recovery opportunities. Renewable and Sustainable Energy Reviews. DOI: 10.1016/j.rser.2013.12.007

Dai J., Ohadi M. M., Das D. & Pecht M.G. 2014. Optimum cooling of data centers. New York, Springer. DOIhttps://doi.org/10.1007/978-1-4614-5602-5

Koomey J. K. 2008. Worldwide electricity used in data centers. Environmental Research Letters, 3(3). 034008IP Address: 128.3.13.162

M. Iyengar, R. Schmidt and J. Caricari. 2010. Reducing energy usage in data centers through control of Room Air Conditioning units. 2010 12th IEEE Intersociety Conference on Thermal and Thermo mechanical Phenomena in Electronic Systems, Las Vegas, NV, pp. 1-11. doi: 10.1109/ITHERM.2010.5501418

Rasmussen N. 2003. Avoidable mistakes that compromise cooling performance in data centers and network rooms. White Paper 49, Revision 1, American Power Conversion, Washington.

S. Gondipalli, S. Bhopte, B. Sammakia, M. Iyengar, R.R. Schmidt. 2008. Effect of isolating cold aisles on rack inlet temperature, in: Proceedings of the 11th IEEE ITHERM Conference, pp. 1247-1254, Orlando, FL, USA.

Muralidharan B., Ibrahim M., Shrivistava S., Alkharabsheh S. & Sammakia B. 2013. Impact of Cold Aisle Containment on Thermal Performance of Data Center. Proceedings of the ASME 2013 International Technical Conference and Exhibition on Packaging and Integration of Electronic and Photonic Microsystems. Volume 2: Thermal Management; Data Centers and Energy Efficient Electronic Systems. Burlingame, California, USA. July 16-18, V002T09A016. ASME. https://doi.org/10.1115/IPACK2013-73201

Alkharabsheh S., Bahgat G., Sammakia and Shrivastava. 2015. Experimentally Validated Computational Fluid Dynamics Model for a Data Center with Cold Aisle Containment. Journal of Electronic Packaging, 137137(2): 021010 DOI: 10.1115/1.4029344

Patankar S. V. 2010. Airflow and Cooling in a Data Center. ASME J Heat Transfer, 132(7): 073001. https://doi.org/10.1115/1.4000703

Abdelmaksoud W.A., Khalifa H.E., Dang T.Q., Elhadidi B. 2010. Experimental and Computational Study of Perforated Floor Tile in Data Centers. 12th IEEE Intersociety Conference on Thermal and Thermo mechanical Phenomena in Electronic Systems, Las Vegas, NV, 2010, pp. 1-10, doi: 10.1109/ITHERM.2010.5501413.

ARPN Journal of Engineering and Applied Sciences

Patel C.D., Bash, C.E., Belady C., Stahl L. & Sullivan D. 2001. Computational fluid dynamics modeling of high compute density data centers to assure system inlet air specifications. Proc. The Pacific Rim/ASME International Electronics Packing Technical Conference and Exhibition. Corpus ID: 15356299.

Erden H.S. 2013. Experimental and Analytical Investigation of the Transient Thermal Response of Air Cooled Data Centers. Dissertations - ALL. Paper 43.

Moore J., Chase J.S. & Ranganathan P. 2006. Weatherman: Automated, online, and predictive thermal mapping and management for data centers. IEEE International Conference on Autonomic Computing, Dublin, Ireland, 2006, pp. 155-164, doi: 10.1109/ICAC.2006.1662394.

Qifei J., Qiaoli W. and Zheng Z. 2012. Comparison between Numerical and Experimental Results of Airflow Distribution in Diffuser Based Data Center. Journal of Electronic Packaging, 134(1): 011006. DOI: 10.1115/1.4005912