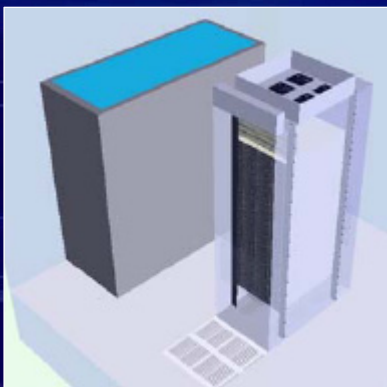
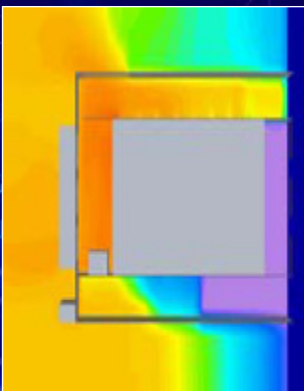


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**CASE STUDY: KlingStubbins**  
Simulation Saves Energy in Data Center by  
Improving Server Rack Efficiency



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## Simulation Saves Energy in Data Center by Improving Server Rack Efficiency

KlingStubbins' goal was to improve energy efficiency of an existing server rack product and provide more Uninterruptible Power Supply (UPS) system capacity for IT equipment instead of rack fan trays, while ensuring the safety of mission-critical computing and communications equipment. The question was whether the integral rack fans could be disconnected and removed, and what other modifications to the server racks were required for improved airflow management in the data center. Physical testing would not have been a viable approach, since it was obvious that a large number of design alternatives would have to be investigated to achieve acceptable server inlet temperatures without rack fans.

KlingStubbins addressed these issues by simulating airflow in and around the rack with FloVENT Computational Fluid Dynamics (CFD) software from Mentor Graphics Mechanical Analysis Division (formerly Flomerics). The simulation evaluated 11 different design scenarios. The simulation results demonstrated that placing blanking panels at various locations within the cabinet, covering the front cabinet door and rearranging the plastic inserts in the rear door made it possible to disconnect the fans while reducing all server inlet temperatures below existing values. The potential energy savings is significant, since the racks are used in large numbers in some of KlingStubbins' client's data centers.

### **Design challenge**

The existing server rack is a fan-assisted enclosure that is designed for installation in existing data centers, where underfloor pressure is not adequate for delivery of full cooling airflow. The rack can receive cooling air from both the room and directly from the underfloor plenum. The integral rack fans impose an additional electrical load on the facility UPS systems as well as a thermal burden. Thus the main goal of the study was to quantify the benefit provided by the fans and determine whether or not modifications can be made to the cabinet to allow the fans to be disconnected, as well as allow for cooling airflow in the computer

room to be tailored to the specific load for air-handler fan energy savings.

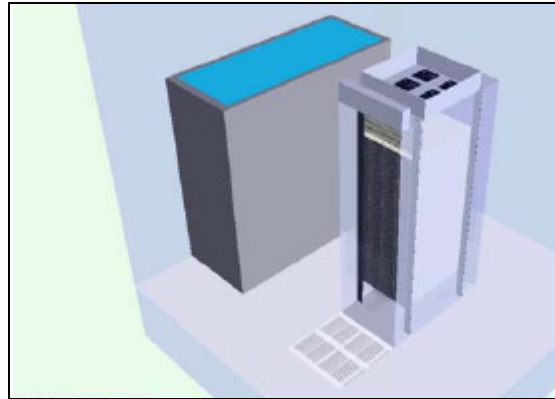


Figure 1: Model of rack server in test chamber

## CFD modeling and simulation

Michael Schwarz, Mechanical Engineer and an Associate at KlingStubbins, realized that he would need to investigate a large number of different design alternatives in order to quantify and optimize thermal performance of the server rack. “It would have been very expensive and time-consuming to investigate these design alternatives by building prototypes and evaluating their performance in a live data center,” Schwarz said. “Instead, we used CFD modeling to simulate the operation of virtual prototypes whose performance closely matches the equivalent hardware prototypes. I selected FloVENT because it is widely used, well-validated, fast, and dependable. It is also important to note that Mentor Graphics' support engineers have extensive experience in CFD modeling techniques and thermodynamics.”

In order to model the rack in its raised floor environment as accurately as possible, the rack geometry was simulated in a virtual test chamber, consisting of a 10 x 10 foot raised floor with a 25 foot ceiling height. A downflow computer room air conditioning (CRAC) unit delivering only the cooling airflow associated with one server rack also occupied the test chamber. One perforated tile or six rotating airflow baffles underneath the rack, or a combination of both, were used to supply cold air to the servers, depending on the scenario being tested. A supply air temperature of 62°F was used

in all scenarios studied, and was based on an average of measurements taken using an airflow capture hood.

Each server was modeled with a 7" high x 19" wide X 26.5" deep chassis, occupying 4 rack units (RU) each. Each server unit therefore dissipates 600 total Watts with a cooling temperature difference of 20°F. This assumption was validated by the client's pre-production testing data. The front of each chassis was assumed to be 60% open for inlet airflow, and the rear included six server fans covering approximately 40% of its area. In the scenarios where the rack fans were operating, they were assumed to deliver 225 CFM each, for a total airflow of 1,350 CFM.

### **Simulation results**

Schwarz simulated 11 different design scenarios. For each scenario he looked at key air properties including:

- Server inlet air temperature, 8 locations
- Server exit air temperature, 8 locations
- Rack exhaust fan air temperature, 6 locations
- CRAC unit supply air temperature
- CRAC unit return air temperature

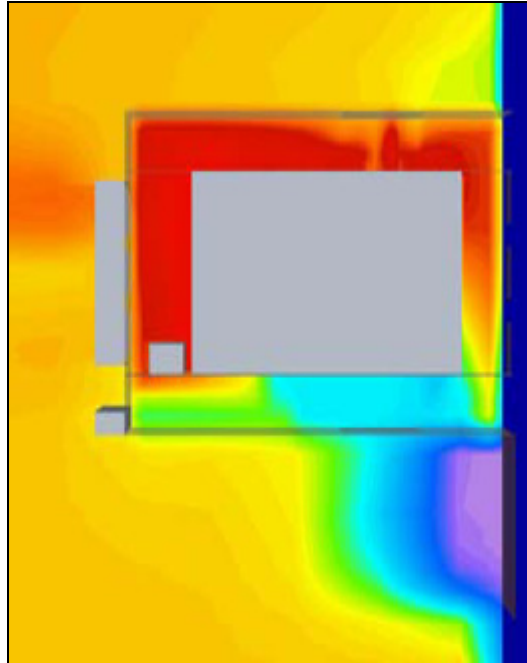


Figure 2: Scenario 1 simulation results

**Scenario 1** models the existing cabinet conditions with fans running at full-speed and 1000 CFM cooling airflow via perforated tiles and floor baffles. The results show that a few of the servers towards the top of the cabinet receive high inlet air temperatures. The average server outlet temperature is approximately 10°F higher than that of the rack exhaust because some hot air recirculation is occurring within the cabinet.

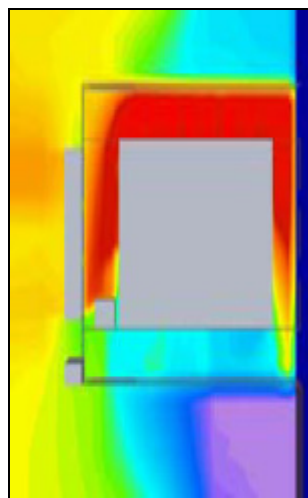


Figure 3: Scenario 2 simulation results

**Scenario 2** is the same as scenario 1 except that the cabinet door plastic inserts are rearranged so that the opening is at the top.

The results show this change provides more consistent cooling of the servers. But since room temperature air is being used for cooling, the cabinet is not utilizing the full cooling capacity of the system by receiving lower temperature cooling airflow.

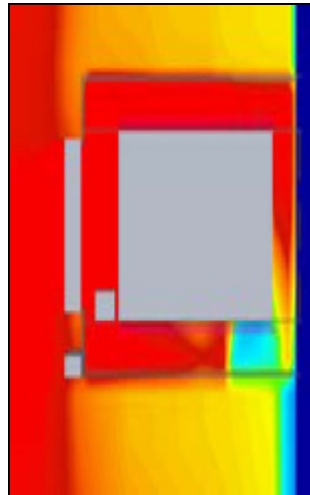


Figure 4: Scenario 3 simulation results

In **scenario 3**, the openings at the cabinet sides are covered, the fan tray is removed and 800 CFM cooling airflow is delivered via floor baffles only in a bottom-to-top rack airflow configuration. The results show that cooling airflow is unevenly distributed within the cabinet so hot air is re-circulated through most of the servers. In this scenario, however, the rack exhaust temperature more closely reflects the cabinet temperatures.

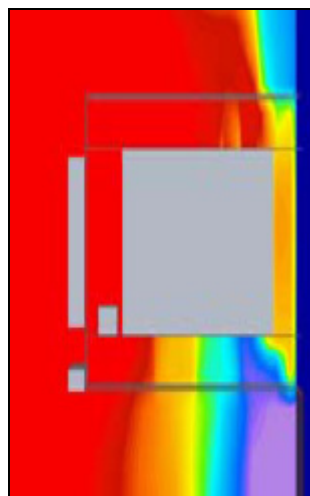


Figure 5: Scenario 4 simulation results

In **scenario 4**, all cabinet door plastic inserts are removed, the rack fans are turned off, the fan tray is covered and 600 CFM cooling airflow is provided via the perforated tile only in a front-to-back rack airflow configuration. The simulation results show that hot air exited re-circulates from the back of the rack to the front. Although this configuration may perform well if located in the middle of a row of racks, it will not if placed at the ends of rows or in a standalone position.

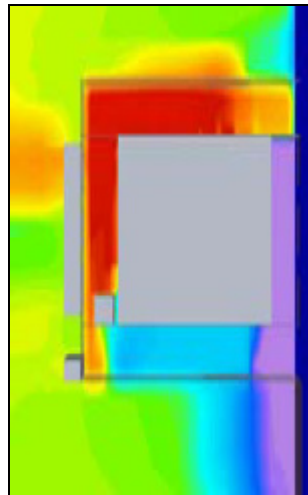


Figure 6: Scenario 5 simulation results

**Scenario 5** is identical to scenario 1 except that a blanking panel is installed between the back of the lowest server and the cabinet bottom in order to direct cooling airflow to the server air inlets. The results show that this scheme directs more cooling airflow to the front of the cabinet, reducing re-circulation of hot air and waste of cooling airflow. This scenario maintains relatively consistent server inlet temperatures.

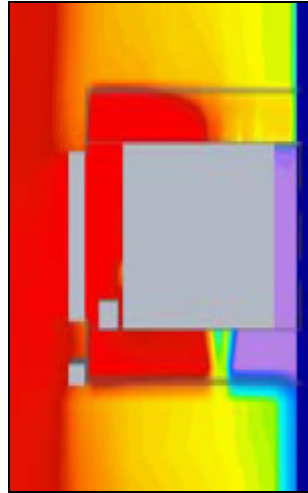


Figure 7: Scenario 6 simulation results

**Scenario 6** is identical to scenario 3 except for the addition of a blanking panel between the back of the lowest server and the cabinet bottom in order to direct cooling airflow to the server air inlets. This scenario combines the bottom-to-top configuration of scenario 3 with the blanking panel used in scenario 5. It shows some improvement over scenario 3, however, inlet temperatures are still too high.

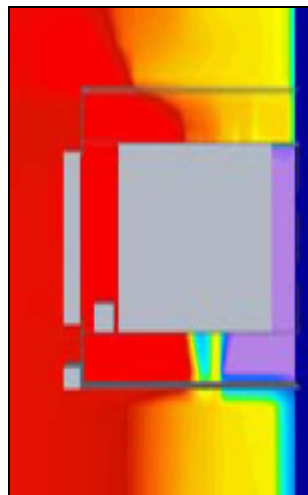


Figure 8: Scenario 7 simulation results

**Scenario 7** is the same as scenario 6 except that plastic inserts are rearranged at the back door, the front door is covered, and additional blanking panels are added between the sides of the lowest server and the mounting rails to prevent short-cycling of cooling airflow. This scheme attempts to allow more hot air to exit the rear of the cabinet to reduce re-circulation and further seals the

bottom openings so that air is not circulated through the space between the sides of the cabinet and the servers. The results show that these changes do not improve inlet temperatures at the higher server locations.

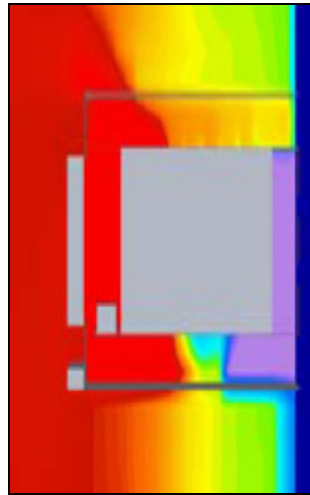


Figure 9: Scenario 8 simulation results

**Scenario 8** is identical to scenario 7 with the addition of two 1U blanking panels at rack units 37 and 42. The simulation shows noticeable improvements in performance although inlet temperatures of the top servers are still too high.

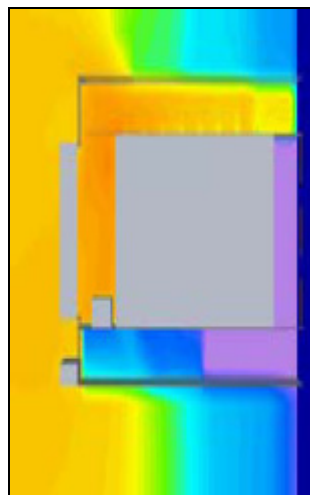


Figure 10: Scenario 9 simulation results

**Scenario 9** is identical to scenario 8 except that the blanking panel at RU 42 is extended to  $\frac{1}{4}$ " from the cabinet top and the front door is covered. Simulation results show extending the top blanking panel to just below the cabinet ceiling provides optimal inlet

temperatures. The  $\frac{1}{4}$ " gap is provided because in actual installations blanking panels will not create a complete seal other than at the mounting rails.

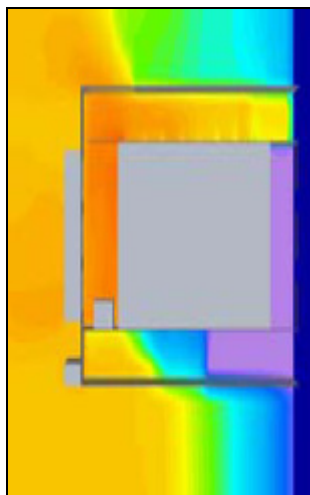


Figure 11: Scenario 10 simulation results

**Scenario 10** is the same as scenario 9 except that the fan tray is left in place but not powered. The fan tray provides resistance to hot air exiting the rack if the fans are not operating. The simulation results show that the average server inlet temperature is 5 degrees lower than with the existing rack arrangement.

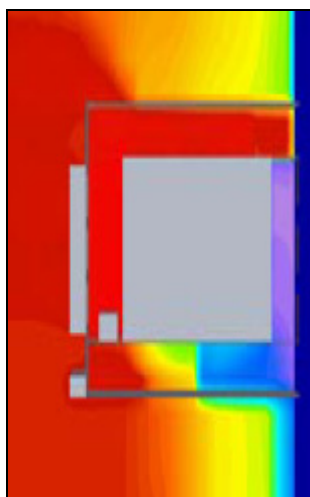


Figure 12: Scenario 11 simulation results

**Scenario 11** is the same as scenario 10 except that the blanking panels between the sides of the lowest server and the mounting rails have been removed. This scenario tests whether the side blanking panels added in scenario 7 are required. The results

show that removing the blanking panels significantly increased inlet temperatures.

Monitor point	Scenario										
	1	2	3	4	5	6	7	8	9	10	11
Server 1 inlet temp.	69.9	71.0	71.5	68.1	69.7	62.1	62.1	62.2	62.1	62.1	69.1
Server 2 inlet temp.	70.7	71.9	77.0	70.4	71.9	67.4	63.1	64.5	62.1	62.1	71.0
Server 3 inlet temp.	70.7	72.2	88.3	74.6	71.9	74.7	78.9	73.0	62.2	62.6	70.9
Server 4 inlet temp.	70.8	74.1	85.7	78.4	71.9	92.2	73.6	72.6	65.2	68.2	73.9
Server 5 inlet temp.	70.9	73.8	88.0	82.2	72.0	91.3	95.6	82.0	66.0	69.7	76.8
Server 6 inlet temp.	73.3	74.3	91.9	84.3	71.8	91.5	96.4	96.4	65.8	69.6	77.8
Server 7 inlet temp.	78.9	74.0	92.1	92.3	71.4	90.3	98.5	97.2	66.4	74.4	81.0
Server 8 inlet temp.	83.6	74.1	94.3	105.0	72.3	90.3	100.0	97.2	69.6	78.6	87.6
Average inlet temp.	<b>73.6</b>	<b>73.2</b>	<b>86.1</b>	<b>81.9</b>	<b>71.6</b>	<b>82.5</b>	<b>83.5</b>	<b>80.6</b>	<b>64.9</b>	<b>68.4</b>	<b>76.0</b>
Server 1 outlet temp.	90.0	92.4	93.5	92.3	84.5	80.9	81.1	81.1	81.0	81.0	91.7
Server 2 outlet temp.	90.3	93.3	94.4	87.2	90.0	82.2	81.4	81.5	81.2	81.1	92.6
Server 3 outlet temp.	89.2	92.5	97.3	92.7	90.9	87.8	85.1	83.5	81.1	81.1	91.6
Server 4 outlet temp.	89.9	92.9	99.3	94.4	90.9	97.2	87.1	83.5	81.5	82.2	91.1
Server 5 outlet temp.	90.1	93.4	98.6	99.1	91.0	101.5	96.8	85.2	82.0	83.5	91.9
Server 6 outlet temp.	90.5	93.4	101.0	102.6	90.9	105.9	101.9	99.6	82.9	83.3	91.8
Server 7 outlet temp.	92.2	93.4	106.9	108.4	90.8	106.5	110.1	109.7	83.5	83.8	97.7
Server 8 outlet temp.	93.0	93.3	107.0	120.0	91.0	106.0	113.1	112.7	85.3	87.3	95.2
Average outlet temp.	<b>90.7</b>	<b>93.1</b>	<b>99.8</b>	<b>99.6</b>	<b>90.0</b>	<b>96.0</b>	<b>94.6</b>	<b>92.1</b>	<b>82.3</b>	<b>82.9</b>	<b>93.0</b>
Rack fan 1 outlet temp.	87.4	87.3	100.3	97.6	87.3	94.1	95.7	92.2	82.6	83.1	91.1
Rack fan 2 outlet temp.	83.7	87.6	96.8	97.3	84.3	88.7	91.3	88.8	81.7	82.2	90.1
Rack fan 3 outlet temp.	73.8	75.6	95.5	97.7	70.3	94.5	97.2	93.6	82.9	84.0	90.4
Rack fan 4 outlet temp.	73.6	75.8	90.2	97.4	68.7	86.5	91.2	88.7	82.1	82.8	89.7
Rack fan 5 outlet temp.	80.0	83.3	93.7	97.9	79.5	95.1	97.3	95.5	83.1	84.5	92.1
Rack fan 6 outlet temp.	79.1	83.1	90.5	97.9	79.4	85.7	91.7	88.9	82.8	84.1	90.8
Average fan outlet temp.	<b>79.6</b>	<b>82.1</b>	<b>94.5</b>	<b>97.6</b>	<b>78.3</b>	<b>90.8</b>	<b>94.1</b>	<b>91.3</b>	<b>82.5</b>	<b>83.5</b>	<b>90.7</b>
CRAC supply	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0
CRAC return	79.4	80.2	81.4	93.8	78.2	82.0	83.6	85.9	81.7	81.9	83.8

Figure 13: Summary of simulation results



Figure 14: This shows the inside of the rack, looking up at the fan tray before modifications



Figure 15: Essentially the same view as in Figure 14, but with the blanking panels in place. Also note the temperature sensors at the inlets of the highest server that were used during the validation testing

Figure 13 summarizes the results from all 11 scenarios. “Scenario 9 delivers the best results by eliminating the fan tray while reducing average server inlet temperatures from 73.6°F in the base case to 64.9°F,” Schwarz said. “However, scenario 9 requires that the fan trays be removed, which might be a difficult operation to perform on live equipment. As a result, in most cases scenario #10 will be used. In this scenario, average inlet temperatures at 68.4°F are still considerably lower than scenario 1.” Once the design was identified, the required parts were obtained from the rack manufacturer and the CFD results were validated by taking air temperature measurements before and after the modifications were completed and with the total server power load. The data center is currently being retrofitted rack-by-rack. Schwarz added, “Overall, the design improvements developed through the simulation make it possible to turn off both the fan trays and specific CRAC fans for substantial energy savings while

maintaining server inlet temperatures below the previous design. The key is improving airflow management in the data center.”

### **About KlingStubbins**

KlingStubbins provides professional services in all major disciplines within the realm of architecture, engineering, interiors, planning, and landscape architecture. The firm consists of more than 450 professionals in its Philadelphia, PA; Cambridge, MA; Raleigh, NC; San Francisco, CA; Washington, DC; and Beijing, China offices. Its areas of market focus and specialization include Corporate/Commercial, Government, Science + Technology, Higher Education, Hospitality/Entertainment, Institutional/Civic, Mission Critical, and Health Care. The company is a nationally recognized leader in sustainable design and an innovator in project delivery. KlingStubbins can be found online at [www.klingstubbins.com](http://www.klingstubbins.com).

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The Mechanical Analysis Division of Mentor Graphics Corporation (formerly Flomerics) is a world leader in the computer simulation of engineering design processes involving heat transfer and fluid flow. Our customers eliminate mistakes, reduce costs, and accelerate and optimize their designs by applying our simulation software and consultancy services before building physical prototypes. Using our advanced Computational Fluid Dynamics (CFD) software, we help increase efficiency in the mechanical design process, saving valuable time and money.

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