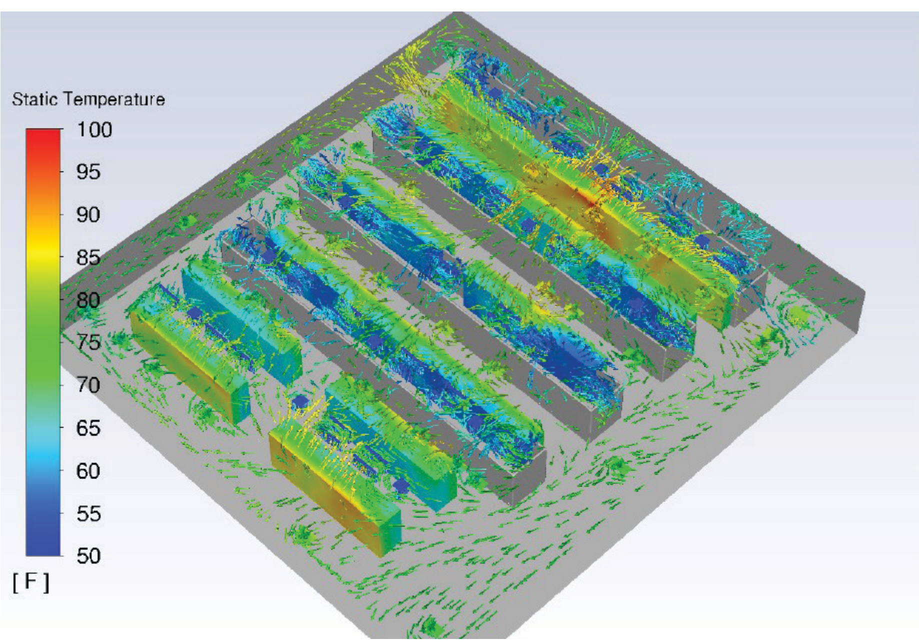
Service Spotlight

6 Reasons Why Your Data Center May Need a CFD Model

SUMMARY

Swanson Rink uses computational fluid dynamics (CFD) analysis to simulate how air behaves in the built environment. With a particular focus on data centers, and how air behaves both inside the data center and around the exterior of the building. CFD modeling is utilized to simulate airflow conditions that otherwise could not be accurately predicted with conventional engineering means.

Models can predict airflow and thermal gradients within the indoor space, identifying problem areas of air stagnation or air recirculation, and calculating air pressure for the sizing of equipment. They can also simulate the conditions of the outdoor space, using local weather data including wind profiles and directions, and predicting the worst case environment that outdoor equipment may experience and exert on other nearby equipment.



Not all data centers will require CFD analysis. In this post we will look at 6 reasons why a CFD model may be valuable for your data center.

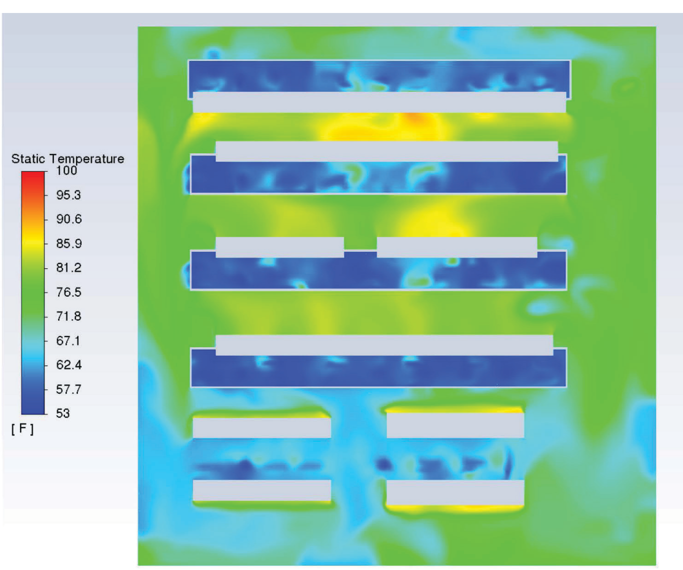
1. Data Center Hot Spots
2. Failure Scenarios
3. Air Static Pressure Calculations
4. Building Effects on Natural Wind Patterns
5. Tracking the Dispersion of Heat and Humidity
6. Tracking the Dispersion of Exhaust Fumes

1 Identifying Hot Spots

It can be difficult to predict where hot spots might occur in a data center space. While a perfectly uniform data center, with perfect hot/cold aisle containment, should not suffer any concerns of hot spots, real life constraints often force us into a less than ideal design. Examples of some less than ideal design conditions would be not creating full hot/cold aisle containment systems, an unbalanced distribution of air into the room, or the placement of auxiliary electrical heat producing equipment in critical locations. In those cases, a CFD model can be employed to predict room conditions prior to any construction beginning, and test many "what if" scenarios under various room configurations and failure scenarios to find the design that ensures the best performance without over engineering.

Tip: It is important to properly simulate not just the equipment within a data center space, but also to closely recreate and understand the controls systems.

A data center air conditioning unit will typically have pressure and temperature sensors placed in various locations around the space to control its operation. Location of those sensors can have a large impact in simulating the space. For example, duct mounted pressure sensors may meet set-point and begin to modulate down airflow rates before satisfying the room requirements. Causing distant servers to pull air from the closest available source, which is often recirculated hot air. Or, space temperature sensors may control temperature set-points without considering stagnated air around a piece of auxiliary electrical equipment. It is not always necessary to mimic the control system in a CFD model exactly, but it is important to understand the limitations of the controls system when analyzing results.



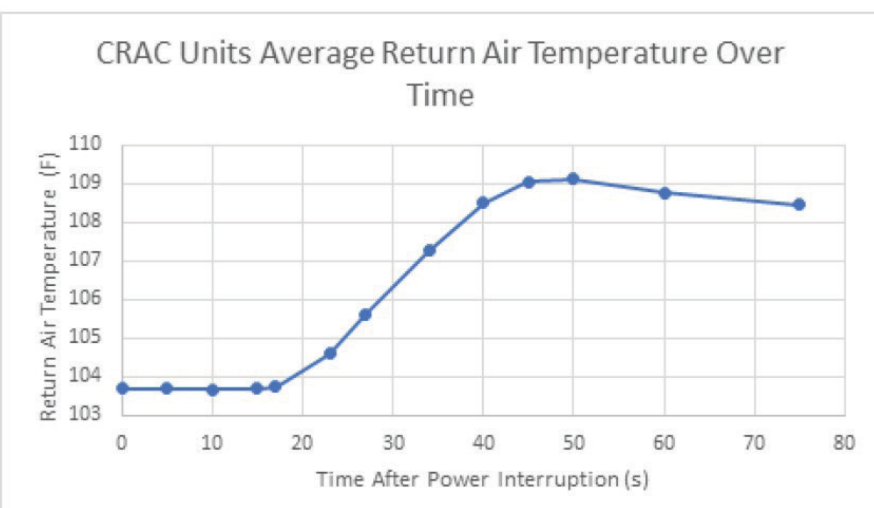
Data Center Hot Spots
The image shows an overhead view of a data center space. This existing space was arranged in less than ideal hot/cold aisle configuration, and space constraints prevented the installation of a full aisle containment system to alleviate temperature issues. A series of CFD models were used to balance new construction costs while vastly improving temperature uniformity and data center operation.

2 Failure Scenarios

It may be inevitable that HVAC systems will experience interruptions to their operation during the lifespan of a data center. Whether the cooling outage is caused by a power interruption, or an equipment failure, a CFD model can be used to simulate how the space will react during that outage. In the case of a power outage, hot air will continue to rise, and systems on uninterruptible power supply units will continue to operate. A CFD model can be used to predict how space air temperatures and pressures will vary over the course of the outage.

Tip: Consider the ramp down and ramp up time of cooling equipment. Systems may take longer than expected to reach full capacity even after power has been returned to the space.

Bonus Tip: Depending on space set-points, providing UPS power only to the fan portion of cooling units, and not the compressorized cooling portion, may be a cheaper way to ride through power interruptions. Volumes of cold air accumulated in the space could be a buffer for maintaining proper space temperatures during the outage. When using cold aisle containment, air static pressure issues (in the form of servers not being provided adequate airflow from the cooling units) may occur much more rapidly than temperature issues during a power outage.



Failure Scenarios
The graph shows the return air temperature to computer room air conditioning units over time, after a power supply issue interrupted their operation. A CFD model was used to determine how space temperature would react during this outage and if the data center systems could return cooling before temperatures became critical.

3 Air Pressure Calculations

Traditional engineering techniques allow for the calculation of air static pressure losses to properly size HVAC fans. However, those calculations often struggle to account for ‘system effects’, where changes in airflow direction in rapid succession lead to a higher than expected static pressure drop. A CFD model can give more confidence that system effects are properly accounted for in complicated duct and HVAC system design.

Tip: Complicated duct systems can be split into many different segments for evaluation. Areas with more traditional duct designs can use standard calculated duct static pressure loss values, and only unique areas where system effects are predicted to be high will full CFD analysis be required.

4 Building Effects on Natural Wind Patterns

Buildings act as large disruptors to natural wind patterns causing swirling eddies that can trap exhaust and prevent fresh air from reaching building and equipment air intakes. This is an effect that cannot be predicted by equipment manufacturers in their design guidelines, as it is so specific to each unique site. Placing equipment in vulnerable locations around a building, where swirling eddies may trap hot air, can cause conditions that far exceed worst case conditions that would be predicted with conventional engineering means.

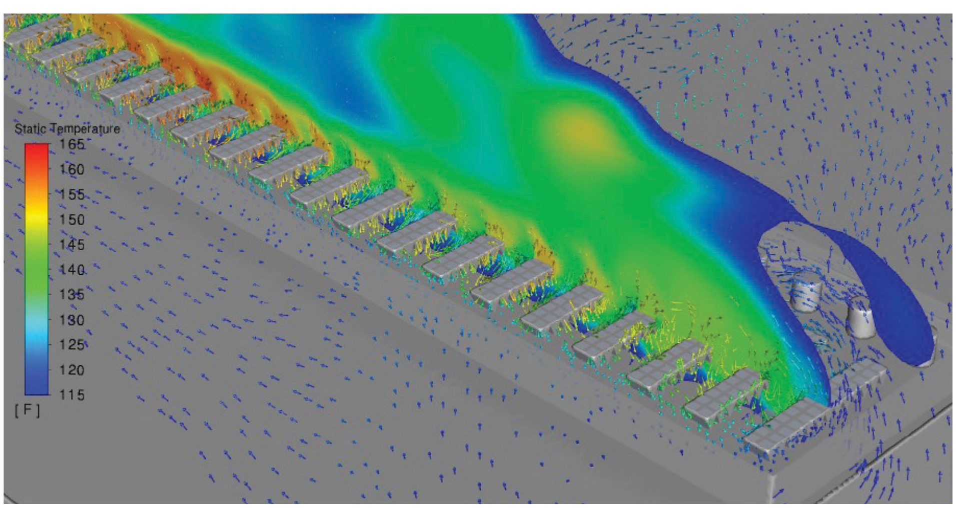
Tip: The location and intensity of these swirling eddies change depending on the prevailing wind direction and speed. Local wind data should be analyzed to identify worst case conditions for critical equipment or at building air intakes. Results should be collected in multiple wind directions, at multiple speeds, to have confidence in the results.

Bonus Tip: Obtaining steady state results may not be realistic when analyzing the large area of turbulent airflow surrounding the building. Careful CFD meshing parameters and an appropriate turbulence model for the application should be chosen. Even so, the chaotic nature of turbulent eddies means close monitoring of critical equipment should occur during CFD solving to ensure results are accurate and converging properly.

5 Tracking the Dispersion of Heat and Humidity

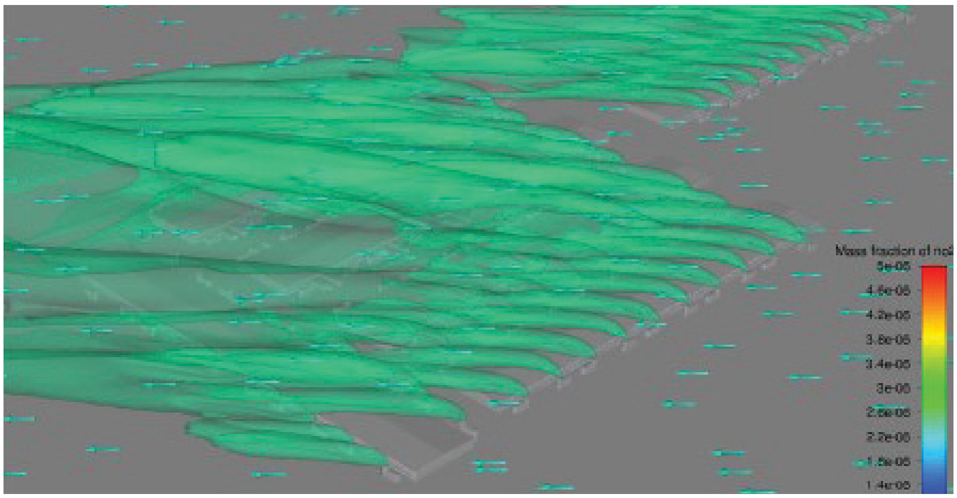
Mechanical and electrical equipment, as well as solar heat load from a roof, can greatly increase the air temperature and/or humidity levels around a data center. It is important to track where that heat and humidity travels to ensure it is not impacting any critical equipment. Equipment manufacturers' minimum clearance guidelines do not account for the specific conditions of your project. They do not consider the impact of other nearby equipment from separate manufacturers, which combine with the swirling wind eddies present around the building to create conditions more extreme than the manufacturer envisioned.

Tip: For this analysis to be valuable, great care should be taken to ensure equipment modeled in CFD will closely simulate the operation of its real life counterpart. Heat generation of equipment should be based off manufacturers' equipment performance data under various operating conditions, using deltaT's or wattages, and not constant input or outlet temperatures. Equipment outlet air velocities should closely match expected values, even while balancing CFD computational resources which can make modeling small surfaces difficult. Additionally, fan speed operation will often fluctuate as the equipment experiences different intake air conditions, which the CFD model should take into account.



Air Cooled Chillers Heat Accumulation
Roof mounted air cooled chillers modeled at left. Although the chillers are spaced at a distance exceeding manufacturer's recommendations, the large number of them nearby cause an accumulation of heat down the line. Because they are also placed on top of a roof, there are extreme wind eddies that the manufacturer may not have anticipated.

6 Tracking the Dispersion of Exhaust Fumes



Generator Exhaust Fume Tracking
The model tracks generator exhaust at a large data center campus. The accumulation of Nitrogen Dioxide emitted from the generators increases as we reach each building further downwind.

Generator exhaust includes gases and particulate matter that can be harmful to humans and detrimental to the operation of a building. Some engineering techniques seek to estimate exhaust fume concentrations based on formulas which predict exhaust plume travel path and dilution. Those techniques are very valuable and often code required, but are generally not adequate for analysis with multiple buildings or multiple exhaust sources. CFD gives a visual depiction of how fumes travel around the building, which can be invaluable in troubleshooting and problem solving. CFD provides the tools to analyze systems with multiple buildings, complicated wind patterns, and challenging intake and exhaust locations, to ensure that harmful gas exposure limits are not breached.

Tip: Whenever possible, analysis should include the data centers as well as any adjacent buildings or topographical features. Exhaust fumes avoiding building air intakes are largely dependent on tall exhaust stacks gaining height above the data center buildings, but they are also greatly impacted by low pressure zones or eddies which require the inclusion of nearby structures to accurately predict.