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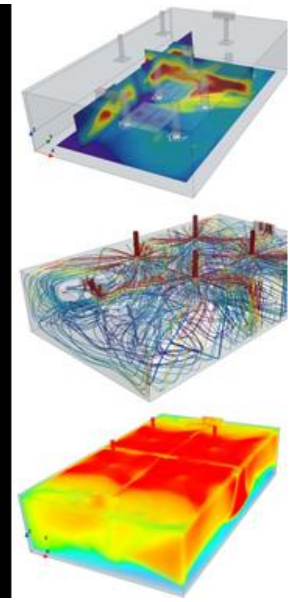

Energy Efficiency Report

Project: Shared Office Space, PLAY Diffusers

January 23, 2023

Client: Mechanical Engineers Ltd.

Provided by: EffectiV HVAC Inc.

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Air Distribution Design - Energy Efficiency Analysis Data

Office Space - PLAY Diffusers

January 23, 2023

Application/Room	
Application Type	Shared Office
Room Dimensions	40 ft x 24 ft x 9 ft
System Type	VAV
Nb of Diffusers/Inlets	4
Nb of Returns/Outlets	2
Nb of Occupants	6
Nb of Computers	6
Nb of Desks	6
Other furniture	N/A
Separators	No

Heating Conditions	
Outside Temperature	13.5 F
Air Supply Temperature	80 F
Setpoint	75.2 F
Maximum Air Volume	N/A
Minimum Air Volume	N/A

Heating Results	**Normalized Design**	**PLAY Diffusers**	**PLAY vs Normalized Design**	
Energy Efficiency				
Average air volume (cfm)	1078	950	-128	-11.9%
Avg. Outlet Temperature (ºF)	76.5	75.9	-0.6	
Ez Factor	0.654	0.76	0.106	+16.2%
IAQ				
CO_2 PPM Breathing Zone	963	981	18	+1.9%
Thermal Comfort				
PPD*	5.18%	5.24%		+0.06%

PPD: Predicted Percentage of Dissatisfied occupants, must be less than 20%

Cooling Conditions	
Outside Temperature	90 F
Air Supply Temperature	55 F
Setpoint	75.2 F
Maximum Air Volume	N/A
Minimum Air Volume	N/A

Cooling Results	**Normalized Design**	**PLAY Diffusers**	**PLAY vs Normalized Design**	
Energy Efficiency				
Average air volume (cfm)	1325	1335	10	+0.8%
Avg. Outlet Temperature (ºF)	77.3	77.7	0.4	
Ez Factor	1.05	0.91	-0.14	-13.3%
IAQ				
CO_2 PPM Breathing Zone	790	797	7	+0.9%
Thermal Comfort				
PPD*	20.50%	14.70%		-5.80%

PPD: Predicted Percentage of Dissatisfied occupants, must be less than 20%

Air Distribution Design - Energy Efficiency Analysis

Shared Office Space – PLAY Diffusers Design

Introduction

The purpose of this air distribution design's energy efficiency analysis of one room is to quantify its energy efficiency performance as well as its positive or negative impact on indoor air quality and occupants' thermal comfort.

When analyzing the energy efficiency of a new design to be implemented in an existing building, a simple approach is to compare the forecasted energy consumption of the new design with the current building's energy consumption.

When designing a new building, however, we do need to set a reference which we can use to compare the energy efficiency of the proposed design. One of the techniques proposed in *ASHRAE Standard 105-2021 - Standard Methods of Determining, Expressing and Comparing Building Energy Performance* when trying to establish a new building's energy performance is to compare its performance with a "normalized building".

This is the method we're using in this efficiency analysis. There isn't a *normalized design* for the number and location of inlets of outlets, therefore it can't be considered in our analysis. When it comes to the ceiling supply and return of conditioned air, however, a few models of diffusers are used in the majority of the designs. In North America, the most commonly used diffusers are cone diffusers (2-Cone, 3-Cone or 4-Cone), plaque diffusers, directional diffusers and perforated diffusers and with 3-Cone diffuser being the most common diffuser, this is the diffuser model that we used in our *normalized building design*.

By comparing a design with high performance diffusers with a normalized design using standard diffusers, where all operation conditions are exactly the same except for the diffusers, we can establish the impact of the type of diffuser on the room's air distribution effectiveness and the building's energy consumption.

Another benefit of using a *normalized design* to compare energy efficiency instead of building code constants is that we can compare both solutions on the same basis, in this case using the same CFD simulation conditions. Thermal comfort is a good example of why this is important. If we were to use the 80% comfort ratio objective as suggested in *ANSI/ASHRAE Standard 55-2017 - Thermal Environmental Conditions for Human Occupancy* as a reference point for our comparison, any design with a better comfort ratio would be considered a good design regardless of the operating conditions. For instance, it is much easier to achieve thermal comfort when heating a small room with low ceilings and no heat loss than it is to heat a large room with high ceilings and large windows. Achieving 81% comfort ratio in such a room may not be a good design. Using a comparison with a *normalized design* gives us a contextual performance ratio. 80% satisfaction ration, or 20% PPD (Predicted Percentage of Dissatisfied), becomes the minimum thermal comfort ratio that must be achieved, and the *normalized design* is now our reference point for the analyzed design's thermal comfort performance.

Another good application of using the *normalized design* approach this is the Ez factor value used in *ASHRAE Standard 62.1 – 2022 – Ventilation and Acceptable Indoor Air Quality*. The *Table 6-4 Zone Air Distribution Effectiveness (Ez)* provides factors for various Air Distribution Configurations. The Ez Factor is used in equations in order to calculate the minimum ventilation rates intended to provide indoor air quality (IAQ) that is acceptable to human occupants and that minimizes adverse health effects. Ez Factor represents the Zone Air Distribution Effectiveness, or in other word the air mixing effectiveness in the room. Inefficient room air mixing will result in a lower Ez value. A lower Ez value will increase the minimum ventilation rates required in order to compensate for inefficient air mixing, to ensure that enough outside air is provided to occupants in the room. Treating outside air (filtration, heating and cooling, humidification or dehumidification) requires a lot of energy. Consequently, a design with a lower Ez Factor will consume more energy in order to maintain the same overall indoor air quality as a system with a higher Ez Factor.

In addition to the default values presented in its Table 6-4, ASHRAE Standard 62.1 – 2022 provides, in its *Normative Appendix C - Zone Air Distribution Effectiveness: Alternative Procedures*, directions on how to calculate a more accurate Ez Factor for a given application by using computer fluid dynamics (CFD) simulations.

Although ASHRAE Standard 62.1 - 2022 provides a table with default values to use in the absence of CFD simulations, we noticed significant variations in Ez factor values between applications in the various simulations that we conducted in the past few months. More specifically, when heating with "ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return", the Ez factor value calculated from advanced simulations was consistently much lower than the default value of 0.8 suggested in Table 6-4. This could have a significantly negative impact on occupants' health.

In this case, comparing a design's simulated Zone Air Distribution Effectiveness to an unrealistic default value could lead us to believe that the design is not performant. It is therefore more accurate to use both Ez Factor values resulting from simulations and to compare a studied design with a *normalized design*. Not only is this approach more accurate in order to quantify a design's efficiency, but it is also safer than using the same default value to calculate minimum ventilation rates for all applications, regardless of the room size, ceiling height, air temperature, type of diffuser, total air volume, etc.

By using CFD simulations to calculate a more accurate Ez Factor value, we are able to quantify a design's real efficiency while ensuring that we are more accurately defining the minimum ventilation rates required to provide indoor air quality (IAQ) that is acceptable to human occupants and that minimizes adverse health effects.

Test Application

The application analyzed in this document is a shared office space with six desks, occupants and laptops. It has one wall with a large window. The room configuration and operating conditions are presented in each report.

We compared the results using different diffusers with the same operating conditions, in both heating and cooling. In both scenarios, we supplied and extracted air from the ceiling. Both scenarios used the same ceiling return grilles. The position of inlets and outlets, the room dimensions, configuration and objects are exactly the same. In the first scenario, we provide air mixing through four PLAY-S or PLAY-UV diffusers by EffectiV HVAC. Both diffusers have exactly the same configuration and throw values, the only difference is that PLAY-UV treats the air before entering the room and has a higher pressure drop, which has no impact on room air distribution effectiveness for a given air volume. In the second scenario, we provide air mixing through four 3-Cone diffusers, considered as a standard product in the industry. That second scenario is what we consider the *normalized design*.

The CFD simulations were conducted by a third party CFD engineering firm following *ASHRAE Standard 62.1 - 2022, Appendix C* guidelines to test Zone Air Distribution Effectiveness in a room using Computer Fluid Dynamics.

Simulations were conducted in both heating and cooling for each diffuser. In this analysis, we compare the results to quantify the design's Energy Efficiency and its impact Indoor Air Quality and Occupants' Thermal Comfort.

Energy Efficiency

Both scenarios used a VAV system with the same supply air temperature and room temperature setpoints. When heating the room with a supply temperature of 80ºF, the PLAY diffusers required 950 cfm to reach the desired temperature, while the standard 3-Cone diffusers required 1078 cfm. PLAY diffusers therefore provided 11.9% direct energy savings compared to standard diffusers in order to reach and maintain the desired room temperature. When cooling with 55ºF supply temperature, the difference is only 0.8%, 1325 vs 1335 cfm, at the advantage of standard diffusers.

The second value to analyze for energy efficiency is the Ez Factor value, described in the introduction. In this study, the design with PLAY diffusers required 16.2% less minimum ventilation rate in heating and 13.3% more minimum ventilation rate in cooling than the *normalized design*.

A noteworthy fact is that these simulations consider extreme scenarios in heating and cooling, where a maximum volume of air will be required in both modes. Since more air volume is normally required in cooling than heating due to the presence of more sources of heat gain (outside temperature in cooling, sun rays, occupants, computers) than heat loss (outside temperature in heating) in most buildings, the cooling simulation represents the most cfm per diffuser that we can expect in this room. More air volume per diffuser results in longer throws, and we can see in the reports that PLAY diffusers in swirl airflow pattern configuration have a longer diagonal throw when supplying 1335 cfm of air through four diffusers. In some cases, we can observe cold air jets reaching the air outlets at high velocity, creating some bypass and loss of air mixing efficiency. A different placement of the diffusers could help reduce that effect. Also, because we don't see this effect as much when supplying 950 cfm of air in heating, it is logical to assume that when operating at lower air volumes than 1335 cfm, this effect will gradually disappear, which will positively affect air mixing efficiency and energy consumption.

Indoor Air Quality

The CFD simulation reports track the Mean Age of Air as well as CO2 Parts per Million (PPM).

The differences between both scenarios are not significant, only 1.9% in heating and 0.9% in cooling. In both cases the CO2 accumulation was below 1,000 PPM, providing acceptable indoor air quality.

It is worth noting that in heating, the design with PLAY diffusers only had 1.9% more CO2 Particles Per Million than the *normalized design* despite using 11.9% less outside air at maximum air volume.

Thermal Comfort

Both types of diffusers provide excellent thermal comfort in heating. The Predicted Percentage of Dissatisfied (PPD) is near 5% in both cases, well below the acceptable limit of 20%.

In cooling, however, there is a significant difference of 5.80% PPD between both diffusers. PLAY diffusers provided 14.70% PPD, which is still within the acceptable range. 3-Cone diffusers, however, provided a 20.50% PPD, which is above the acceptable limit for occupants' thermal comfort.

Thermal comfort issues will likely have to be addressed when cooling with standard diffusers. Using PLAY-S or PLAY-UV diffusers will significantly improve occupants' thermal comfort.

Conclusion

In this application, the design using PLAY diffusers (PLAY-S or PLAY-UV) provided 11.9% direct energy savings when heating at maximum air volume when compared to the *Normalized Design*. When cooling at maximum air volume, there was a loss of efficiency of 0.8%.

The design with PLAY-S and PLAY-UV diffusers also provided 16.2% energy savings in heating when it comes to setting the minimum required ventilation rate for indoor air quality. In cooling, PLAY-S and PLAY-UV diffusers required a minimum ventilation rate which was 13.3% higher. Because of the air bypass due to the longer throw when supplying maximum air volume in cooling, it is reasonable to assume that the 13% extra value will decrease gradually when operating at lower air volumes. Further simulations in minimum or average heating and cooling conditions should also be considered.

CO2 PPM concentrations and IAQ were similar in heating and cooling with both designs.

Thermal comfort PPD values were similar in heating, however the PPD value of 20.50% when cooling with standard diffusers is above the acceptable level. PLAY-S and PLAY-UV diffusers significantly helped improve thermal comfort in cooling with a PPD value of 14.70%.

EffectiV HVAC inc.

EFF0122001 : Development Room – 3-Cones – Heating VAV

January 17th 2023

Yannick Sirois, ing., M.Sc.A.,Ph.D. No OIQ : 130045

Lx Sim Inc.
400 rue Shefford, local 117
Bromont. Québec
J2L 3E7. Canada
Tel. : 450.919.1714
info@lxsim.com
www.lxsim.com

Simulation Summary

Diffuser Configuration

Inlets	Type
4	3-Cones 24

Heating Conditions

Property	Value
Outside temperature	13.5°F
Air supply temperature	80°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	1.0 CLO (pants, sweater, t-shirt underneath)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

Heating Results

Properties	Value
Outlet air temperature	76.5°F
Average flow rate	1078 CFM
Theoritical air age at outlet	478 s
Real air age at outlet	484 s
Ez Factor	0.654
CO2 PPM	963
PMV	-0.06
PPD	5.18

Mandate

Lx Sim has the mandate to analyze the performance of the ventilation system inside a room using a CFD approach

Ventilation system performance is quantified in terms of:

- Mean Age of Air measured at the extraction
- Zone Air Distribution Effectiveness (Ez Factor)
- Occupants thermal comfort (Predicted Mean Vote and Predicted Percentage of Dissatisfied)

Methodology

Each CFD simulation is performed in Simcenter STAR-CCM+ from Siemens

General modeling is based on:

- CFD best practices
- ANSI/ASHRAE Standard 62.1-2019 (Air quality)
- ANSI/ASHRAE Standard 55-2017 (Thermal comfort)

CAD

- The simulation is performed using a 3D representation of the room to be studied
- The room is built according to plans provided
- The model includes the following features and surfaces:
    - Walls
    - Windows
    - Air diffusers
    - Air diffusers feed ducting (if necessary)
    - Air room extractor
    - People (if necessary)
    - Other major obstacles (if necessary)

Mesh

In order to solve fluid mechanics transport equations, the 3D geometry must be discretized in small elements

Element size must be small enough that numerical diffusion does not occur and that all physical effects in the fluid are modeled appropriately

In the ventilation simulation, the most restrictive geometric feature is the air diffuser

The air diffuser requires a mesh small enough so that flow directions and velocities represent reality

General CFD physics modeling

Simulations is in accordance with ANSI/ASHRAE Standard 62.1-2022 - Normative Appendix C.

The following modeling options are used:

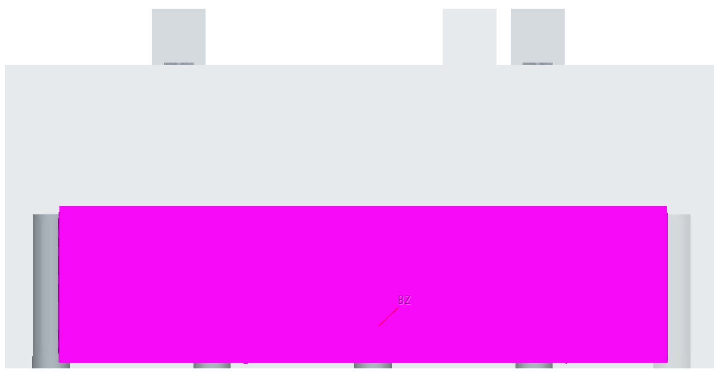
- Steady state approach
- Turbulence modeling active
- Energy and gravity activated
- Species transport
- Surface to surface radiation is modeled

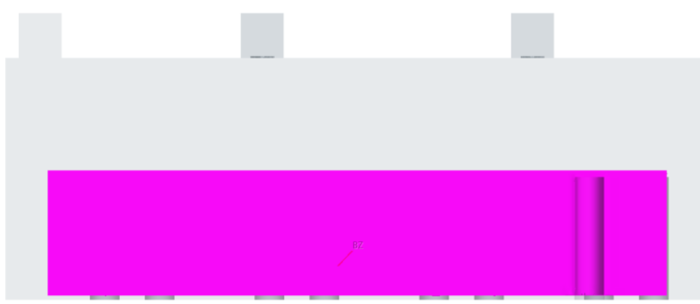
Breathing Zone

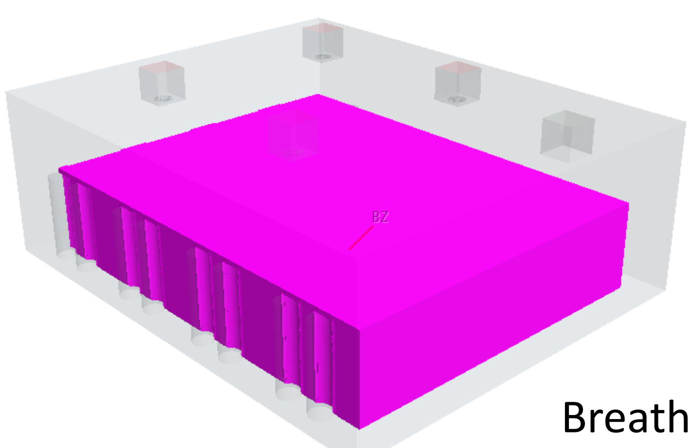
For multiple calculations in this simulation, the breathing zone is used

The breathing zone is defined as per ANSI/ASHRAE Standard 62.1-2022 - Section 3

> ***breathing zone:*** the region within an occupied space between planes 3 and 72 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment.







Breathing zone example

Imposed Flow

- Flow rate in CFM is imposed at each inlet
- Temperature is imposed at each inlet
- Depending on the choice, a proportional error correction is implemented on either the flow rate or the temperature in order to reach the specified setpoint for the temperature in the room
- The temperature in the room to be compared to the setpoint is measured in each cell of the breathing zone and averaged over it
- Since the simulation is in steady state, the final flow rate and air inlet temperature represent an average value corresponding to a continuously running heating or cooling system

Operating conditions

- External conditions
    - External temperature is specified for heat transfer through walls, windows and radiation through the windows
- Walls and windows isolations is specified using U-Factor or R-Factor
- Human heat sources
    - Heat flux through a simple human shape
    - Heat flux defined using the Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2022

Air Age at Extraction

- To measure air age, the simulation uses a transported passive scalar
    - Does not affect flow in any way
    - Increases with time between the inlets and the outlets
- Average age is measured at the outlets using mass average procedure and is compared to the theoritical value

Zone Air Distribution Effectiveness (Ez Factor)

- All Ez Factor calculations are made in accordance with ANSI/ASHRAE Standard 62.1-2022 – Normative Appendix C
- A mass source of a tracer gas species, such as CO_2 is introduced inside the breathing zone volume and uses the specied transport equations
- A mass averaged measure of the molar concentration of the tracer gas at the inlet and exhaust are taken

- The Ez Factor is measured for each mesh cell inside the breathing zone
- The global Ez Factor value is then the volume average of the Ez Factor values inside the breathing zone
- All other requirements for CFD modeling are respected in the model

Thermal Comfort

- Thermal comfort is evaluated with the values of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)
- All calculations are made according to ANSI/ASHRAE Standard 55-2017
- The CFD model implements the code proposed in Appendix B of said standard
    - Values are computed on each cell of the mesh and are available in the complete simulation for visualization and post-processing

Thermal Comfort – Required information

Clothing value

The clothing value describes the types of clothes worn by the occupants.

- Data must be provided in ''clo'' units
- Typical values are shown in Table 5.2.2.2A – Clothing Insulations Icl values for typical ensembles in ANSI/ASHRAE Standard 55-2017

Metabolica rate

The metabolic rate of occupants

- Depends on occupation
- Must be provided in ''met'' units
- Typical values are shown in Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2017

External work

Also in ''met'' units

Generaly around 0 except in very physical action by the occupants

Air temperature

Provided in each cell by the cfd model

Air velocity

Provided in each cell by the cfd model

Mean radiant temperature

Average wall surface temperature provided by the CFD model

Relative humidity

Provided in %

Case Study Presentation

CAD

- Room Dimensions:

Side	Dimension
Length	40 ft
Width	24 ft
Height	9 ft

- 1 window (west)

Properties	
U-factor	0.24 BTU /(h*ft2*F)
SHGC	0.27

- Ceiling

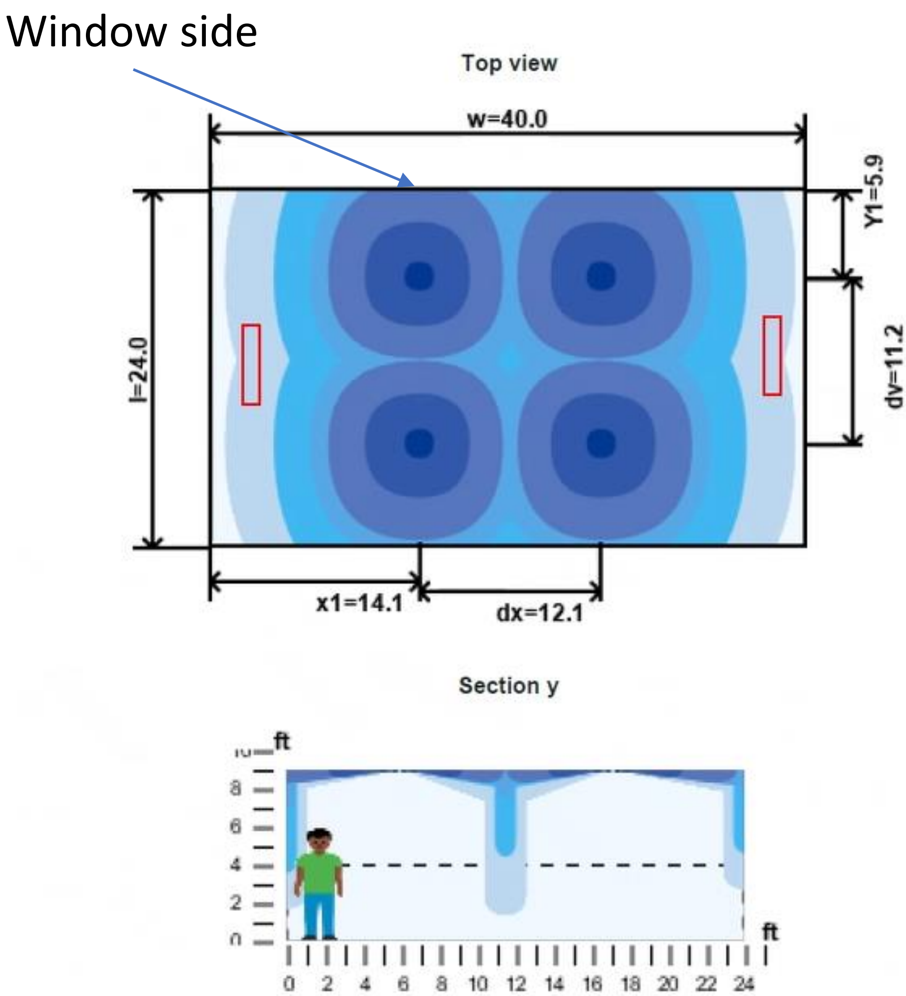
Properties	
U-factor	0.053 BTU /(h*ft2*F)

- Outside wall (west)

Properties	
U-factor	0.044 BTU /(h*ft2*F)

- Inlets and outlets positioned as follows

- Inlets and outlets positioned as follows

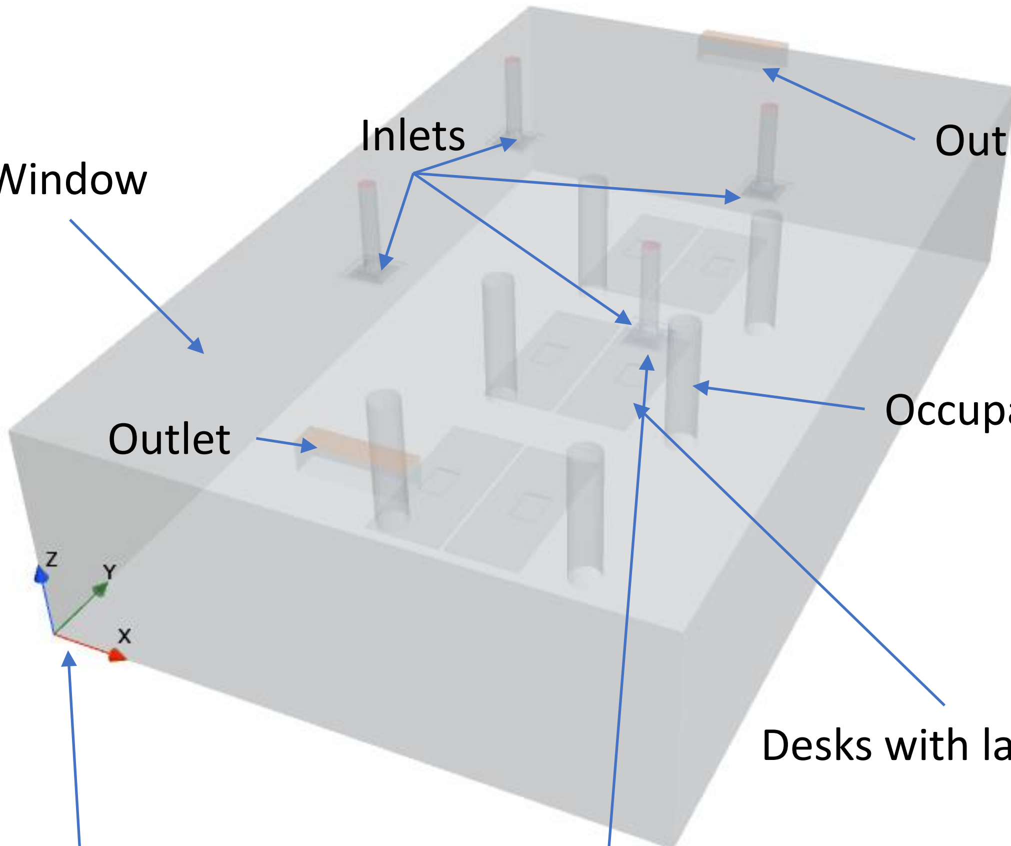


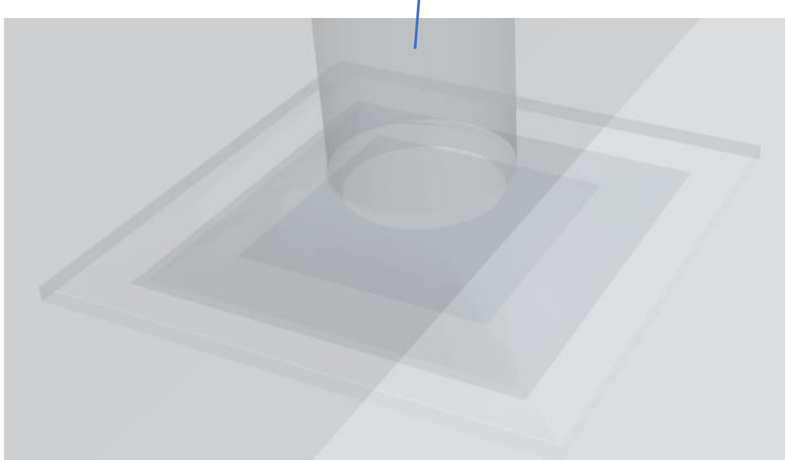
Section x

Diffusers

- 4 3-CONES 24

Resulting model





Diffuser example

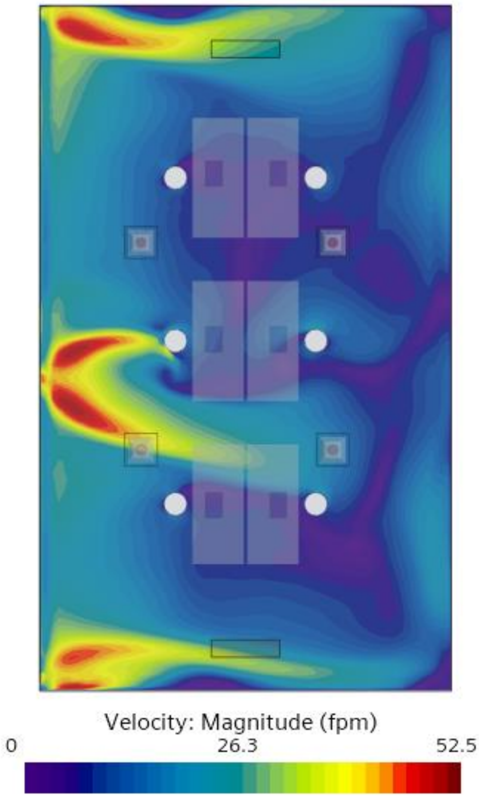
Heating Conditions

Property	Value
Outside temperature	13.5°F
Air supply temperature	80°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	1.0 CLO (pants, sweater, t-shirt underneath)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

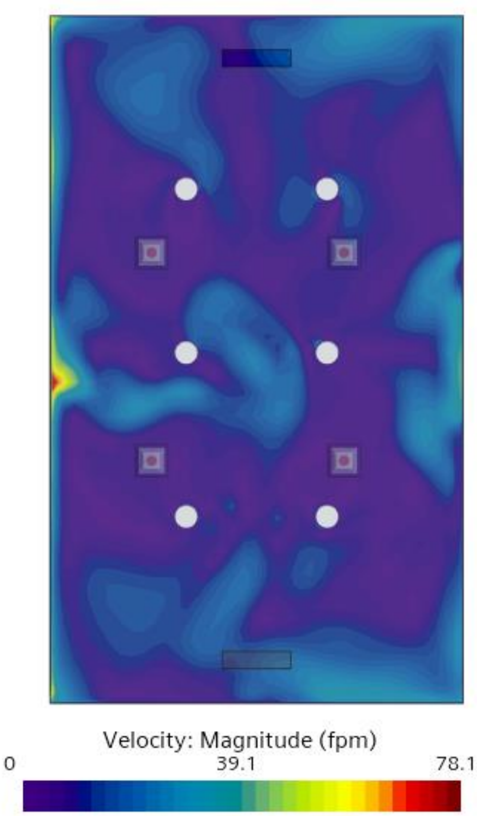
Heating Results

Properties	Value
Outlet air temperature	76.5°F
Average flow rate	1078 CFM
Theoritical air age at outlet	478 s
Real air age at outlet	484 s
Ez Factor	0.654
CO2 PPM	963
PMV	-0.06
PPD	5.18

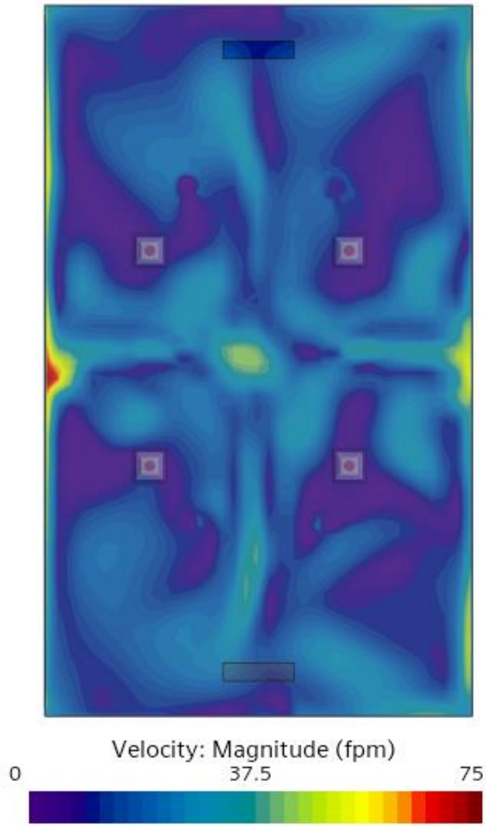
Air Velocity



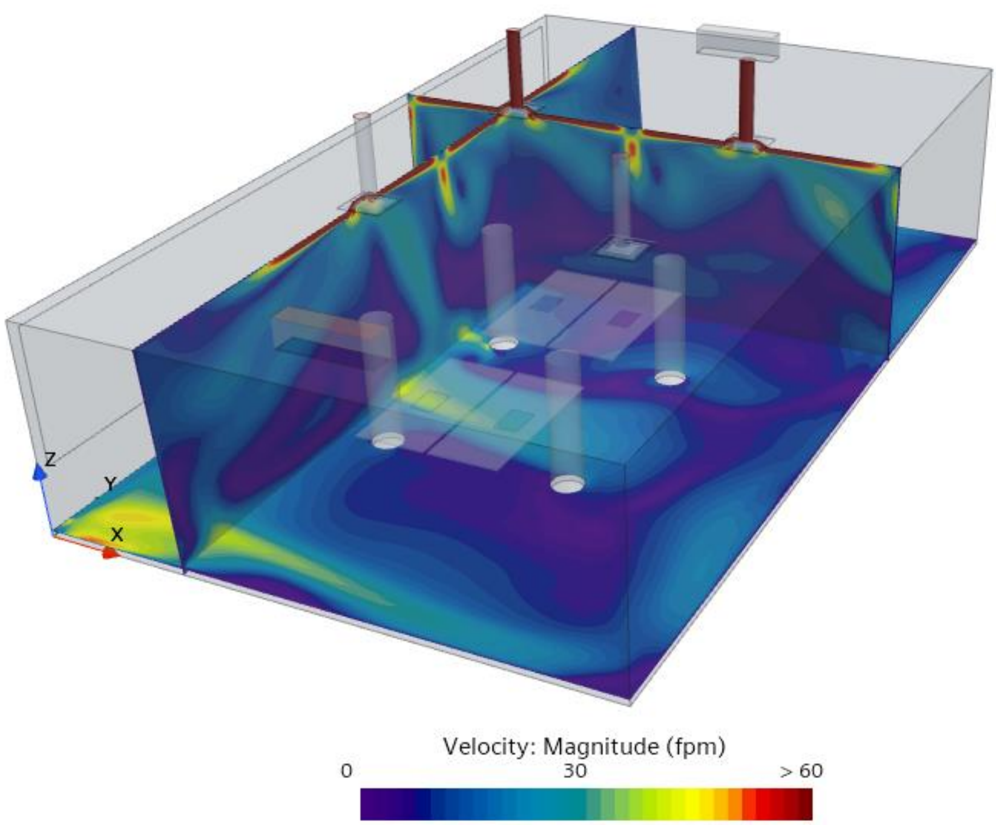
3in from the floor
Average at 17.5 fpm



4ft from the floor
Average at 12.5 fpm



6ft from the floor
Average at 17.8 fpm



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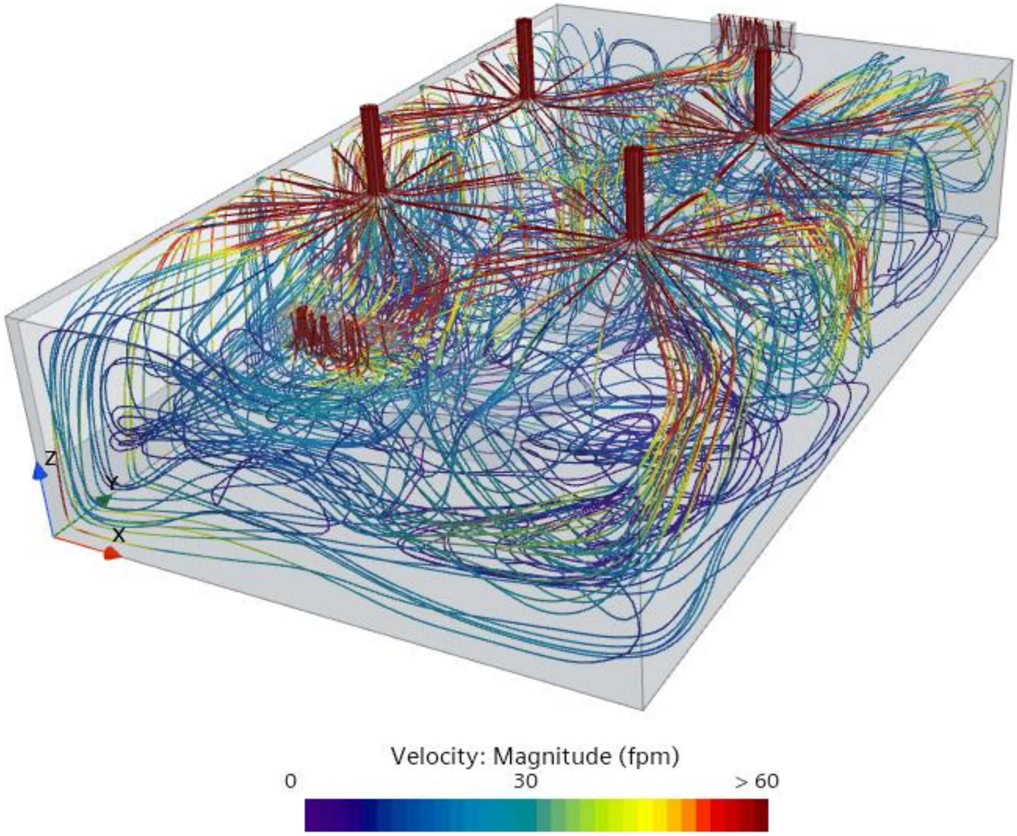
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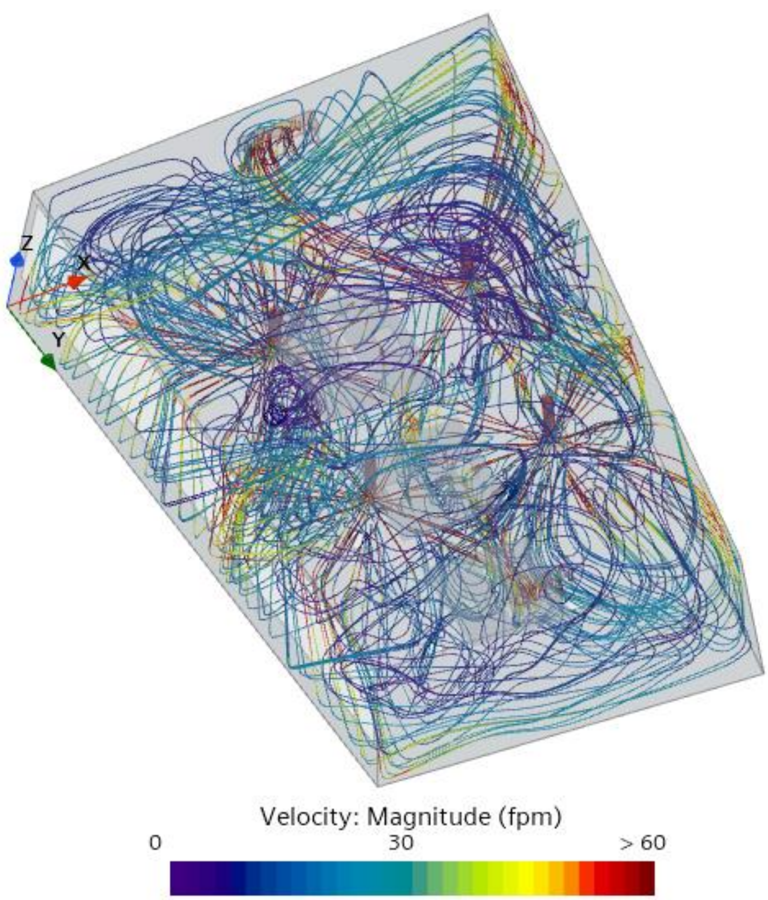
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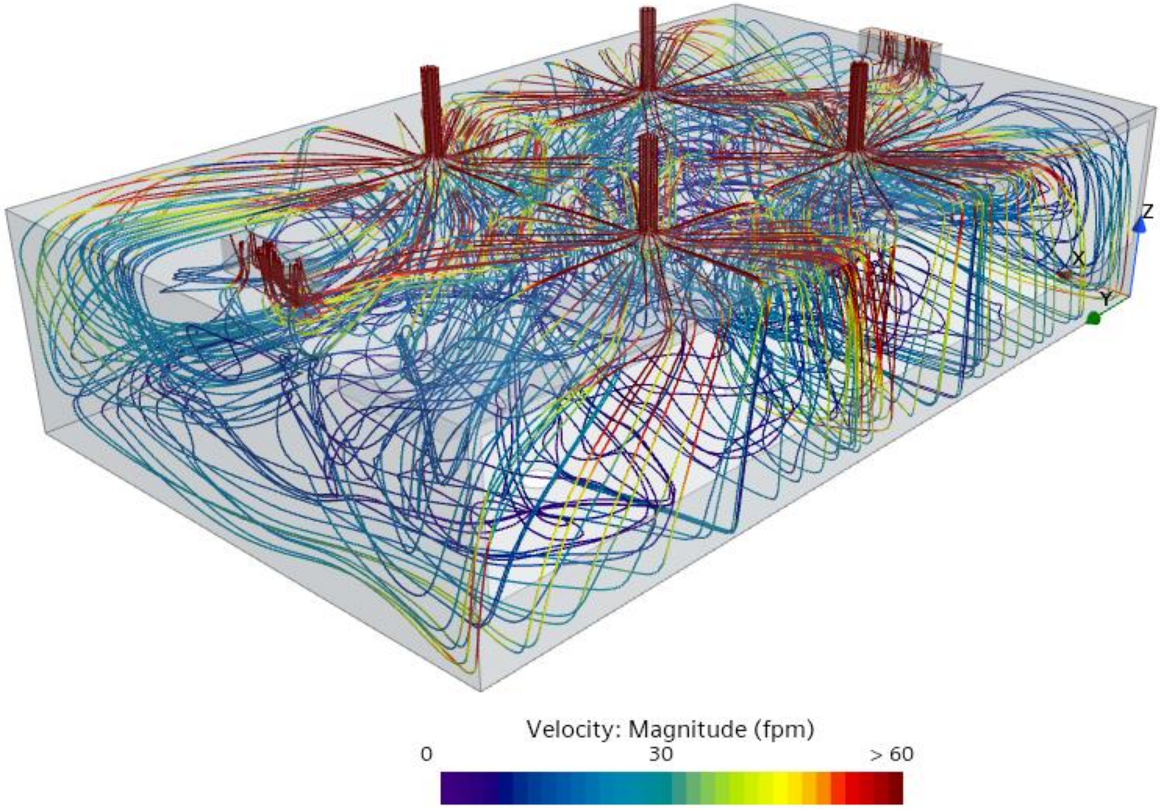
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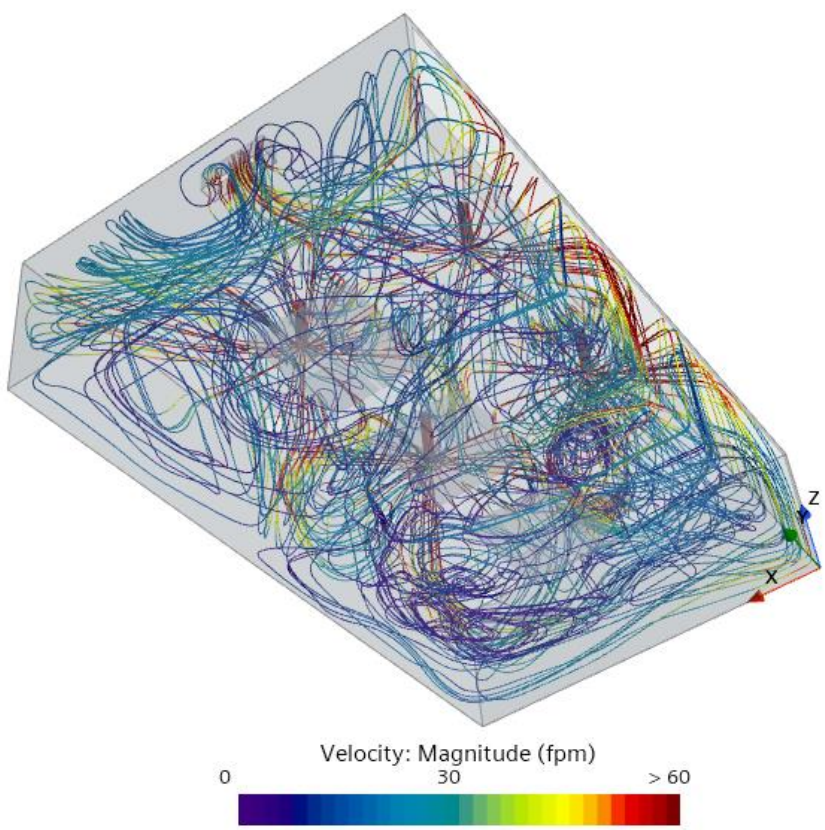
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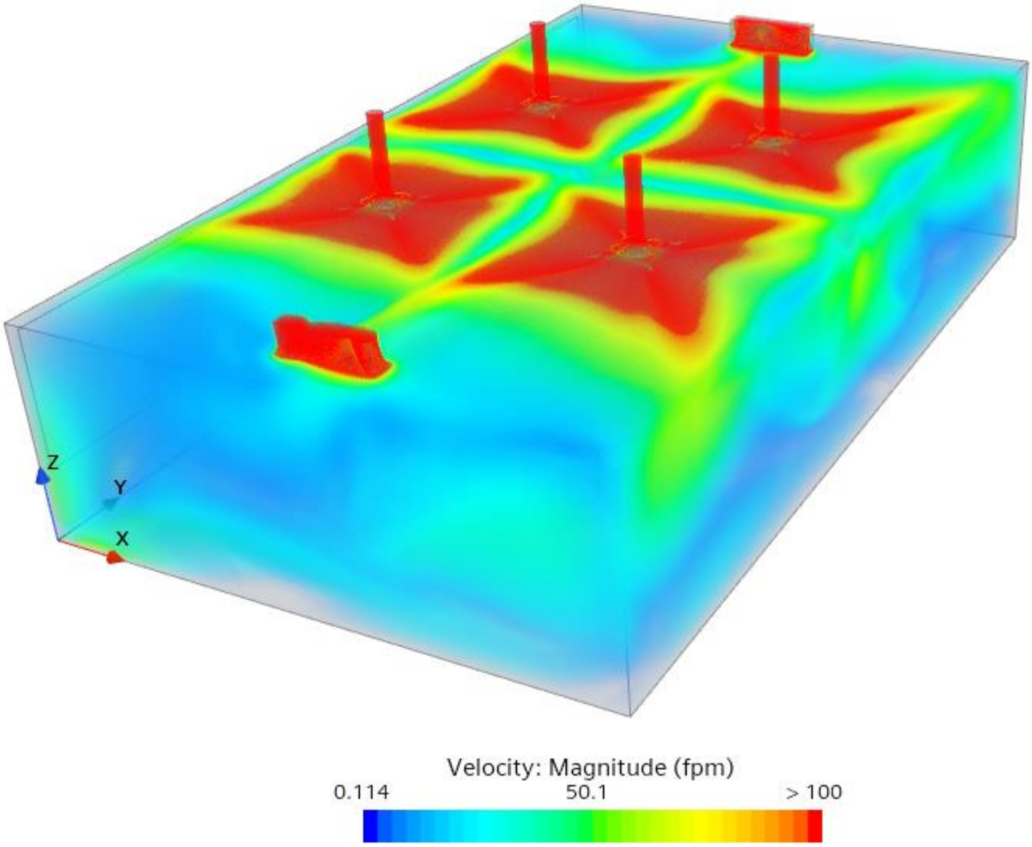
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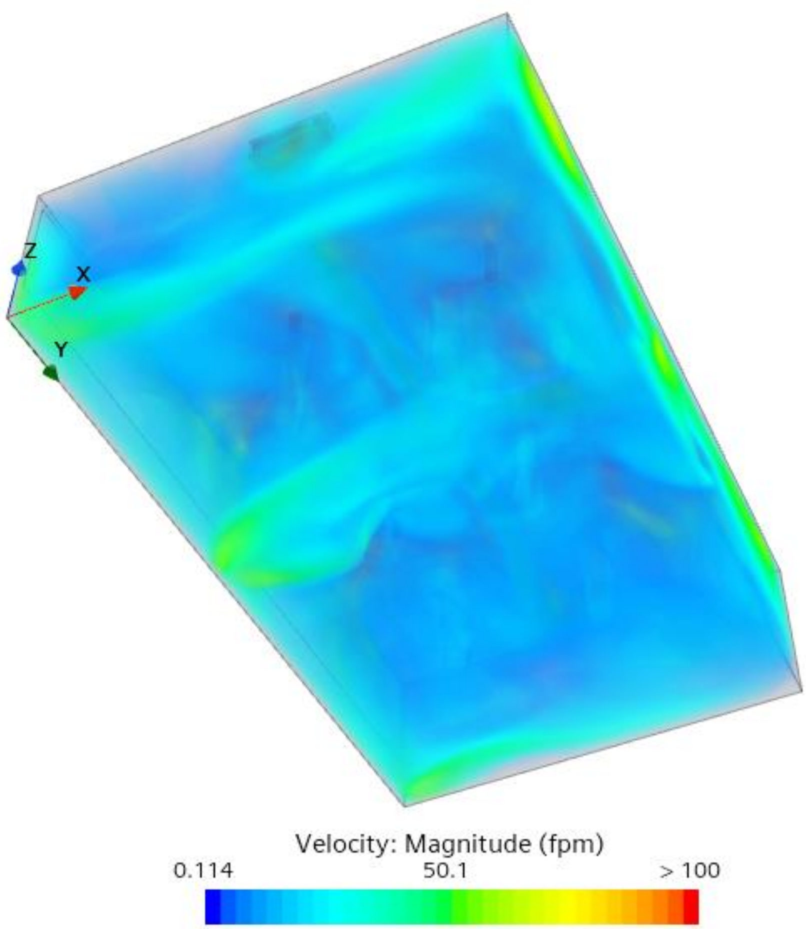
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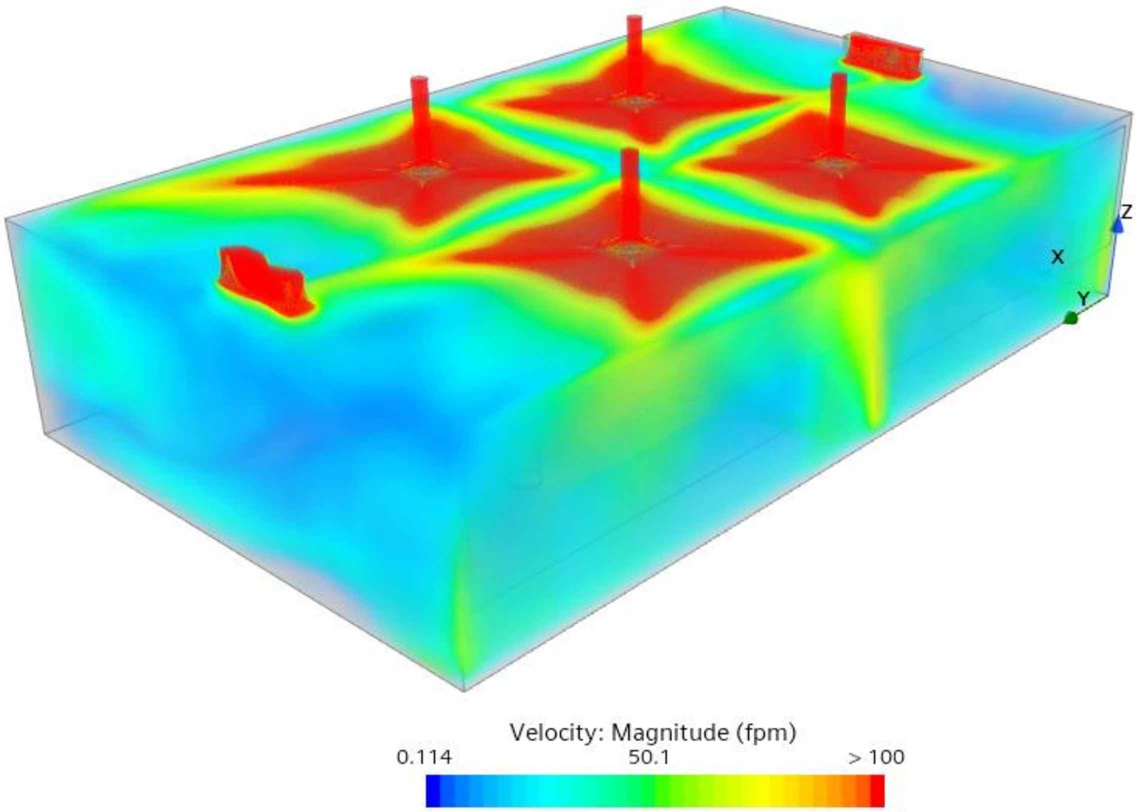
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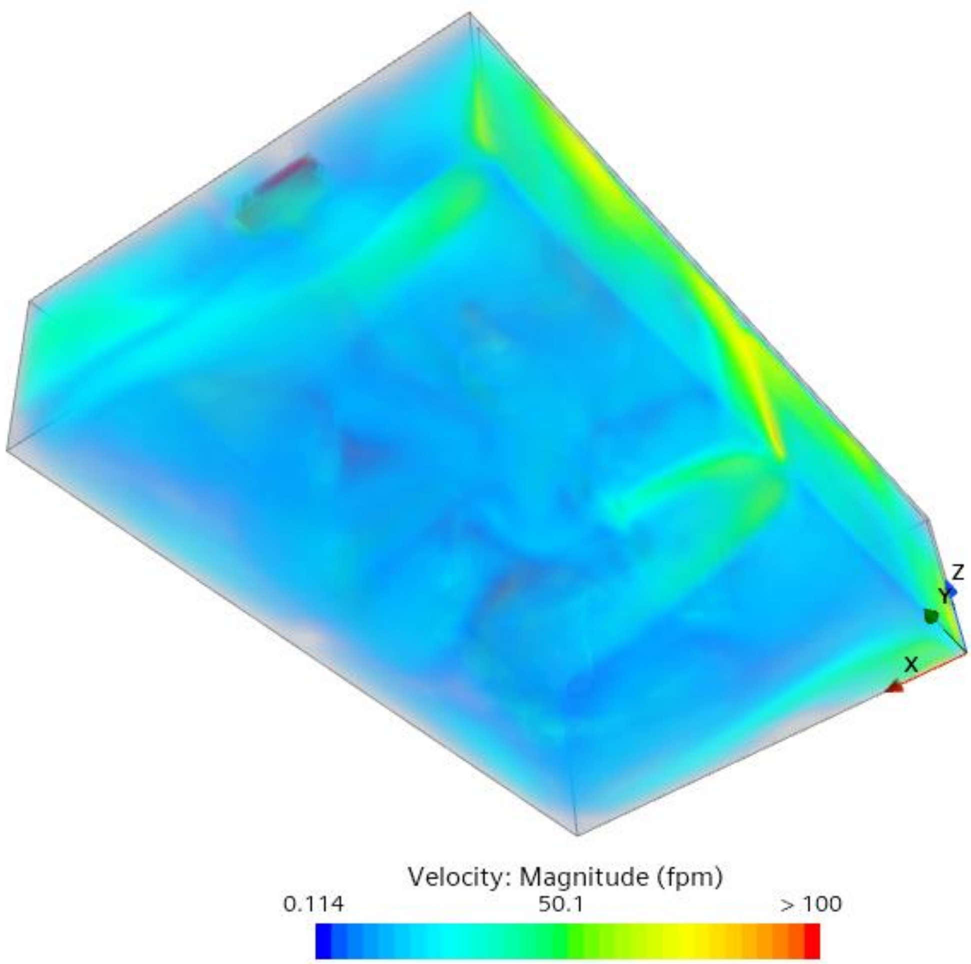
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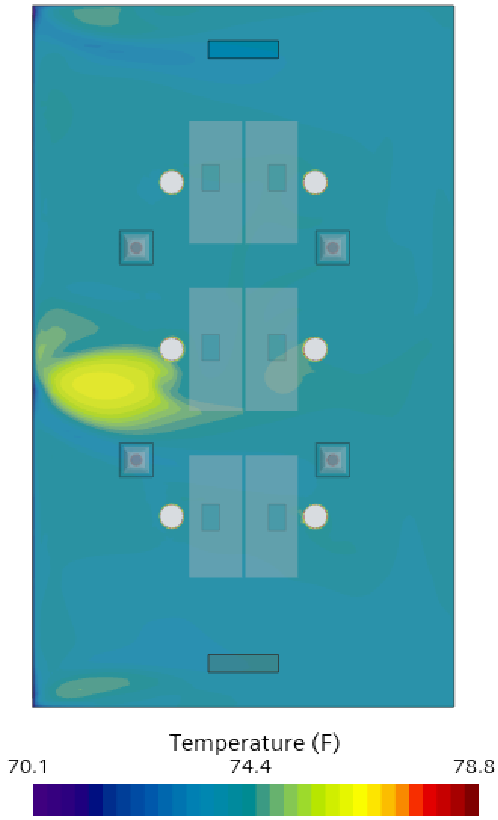
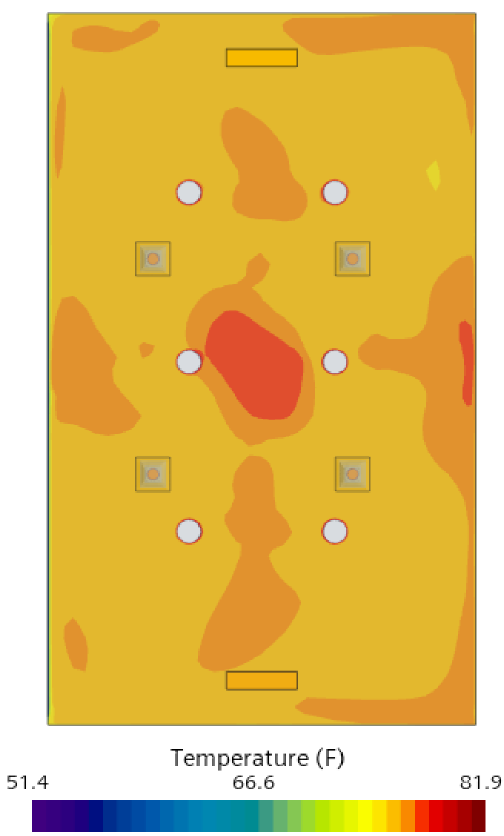
Velocity: Magnitude (fpm)
0.114
50.1
> 100

Air Temperature

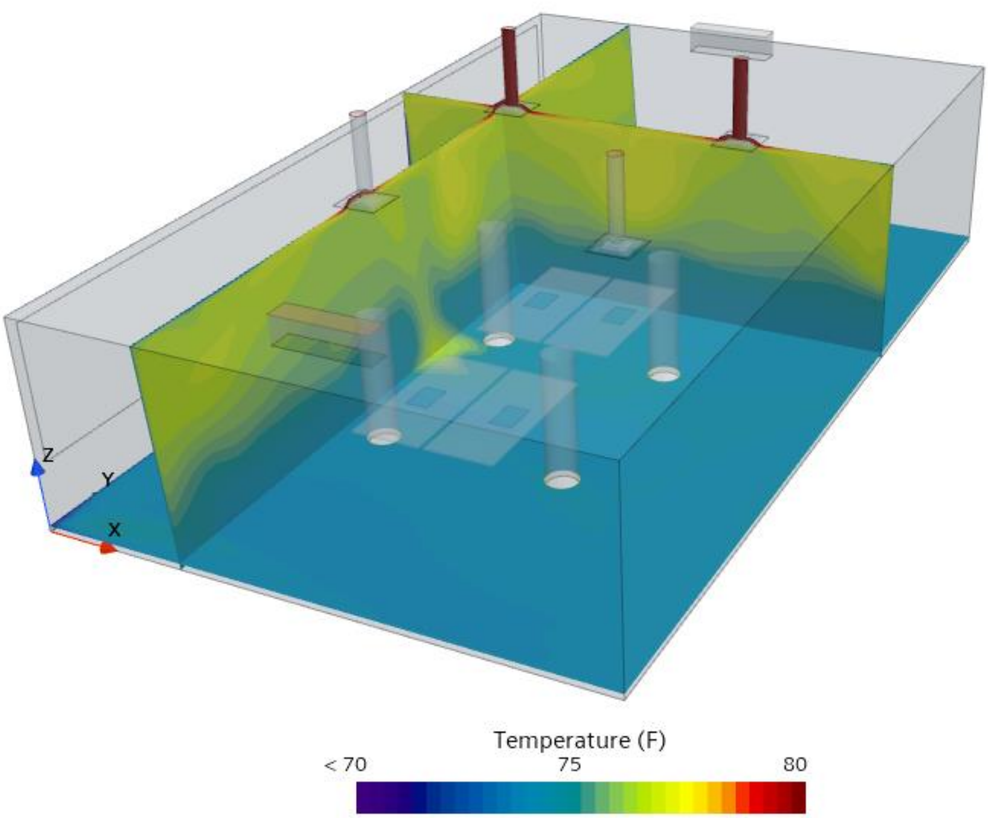


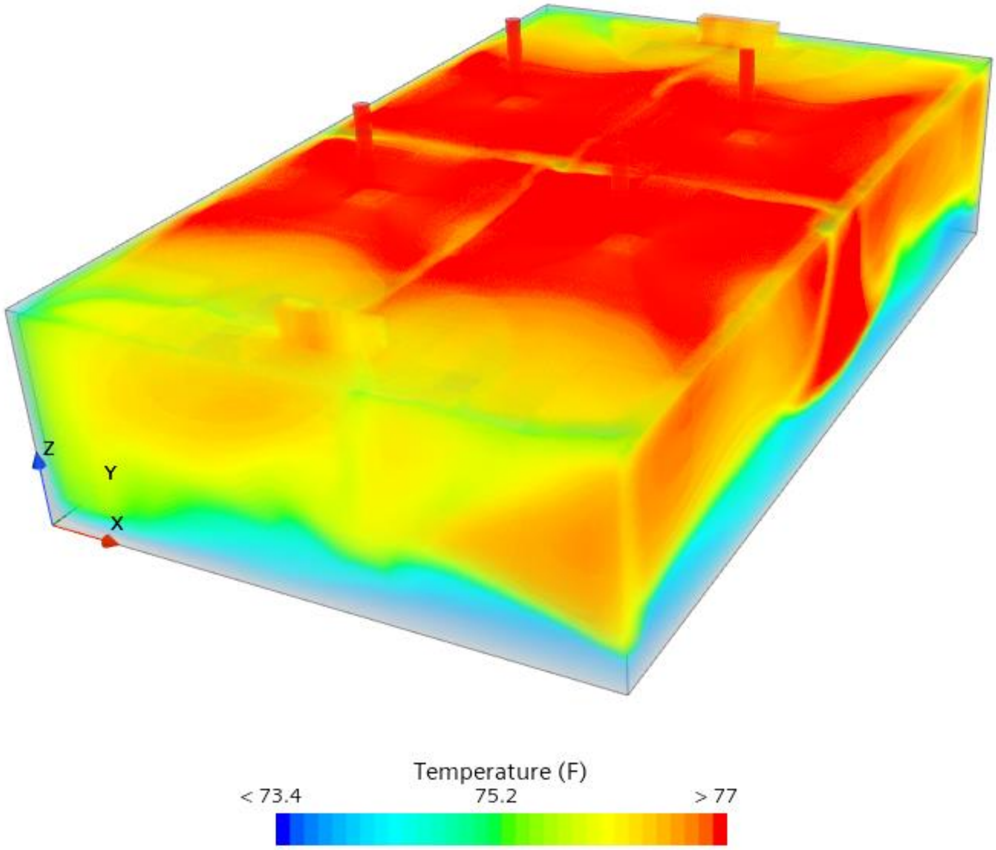
3in from the floor
Average at 74.0°F

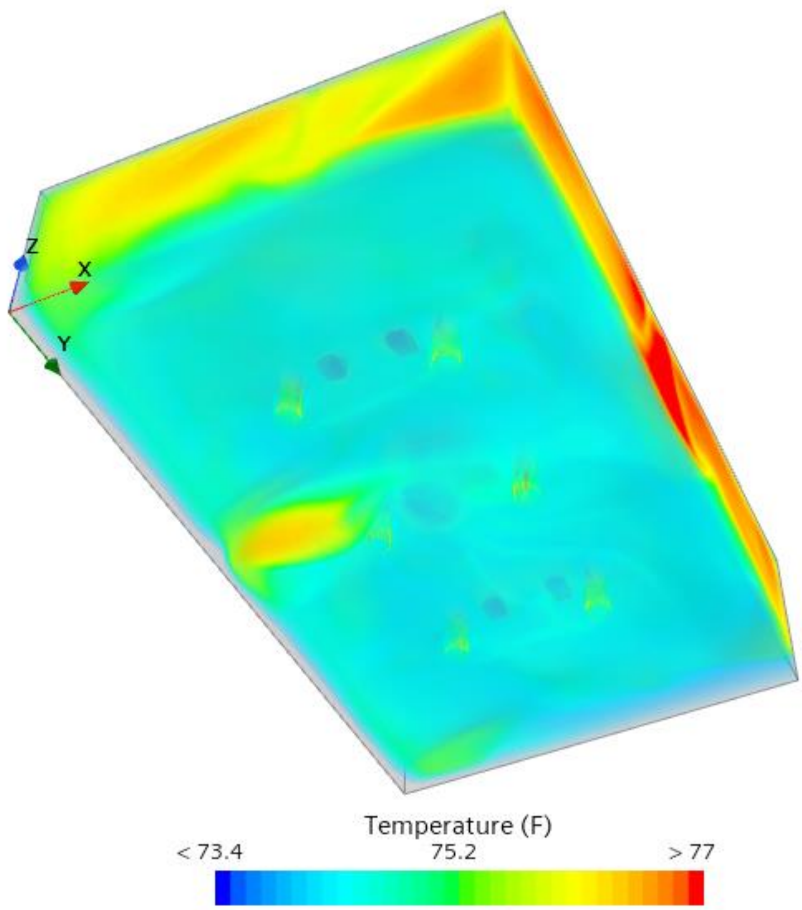


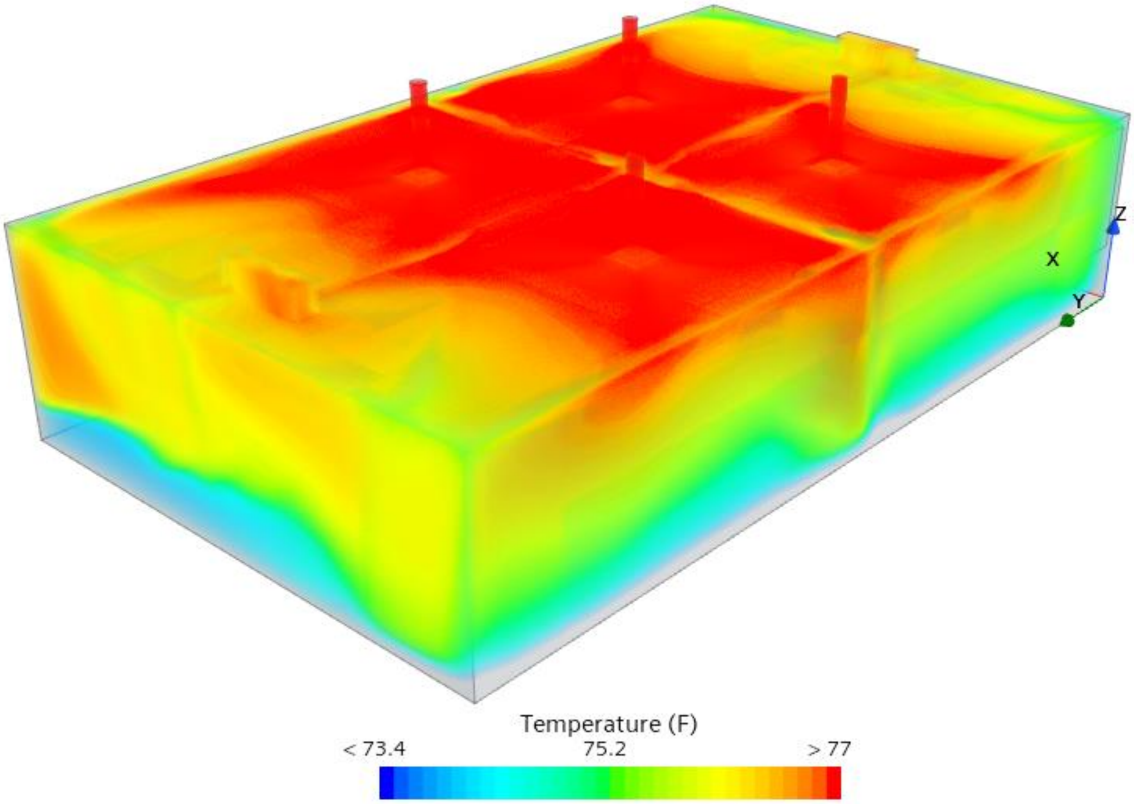
4ft from the floor
Average at 76.0°F

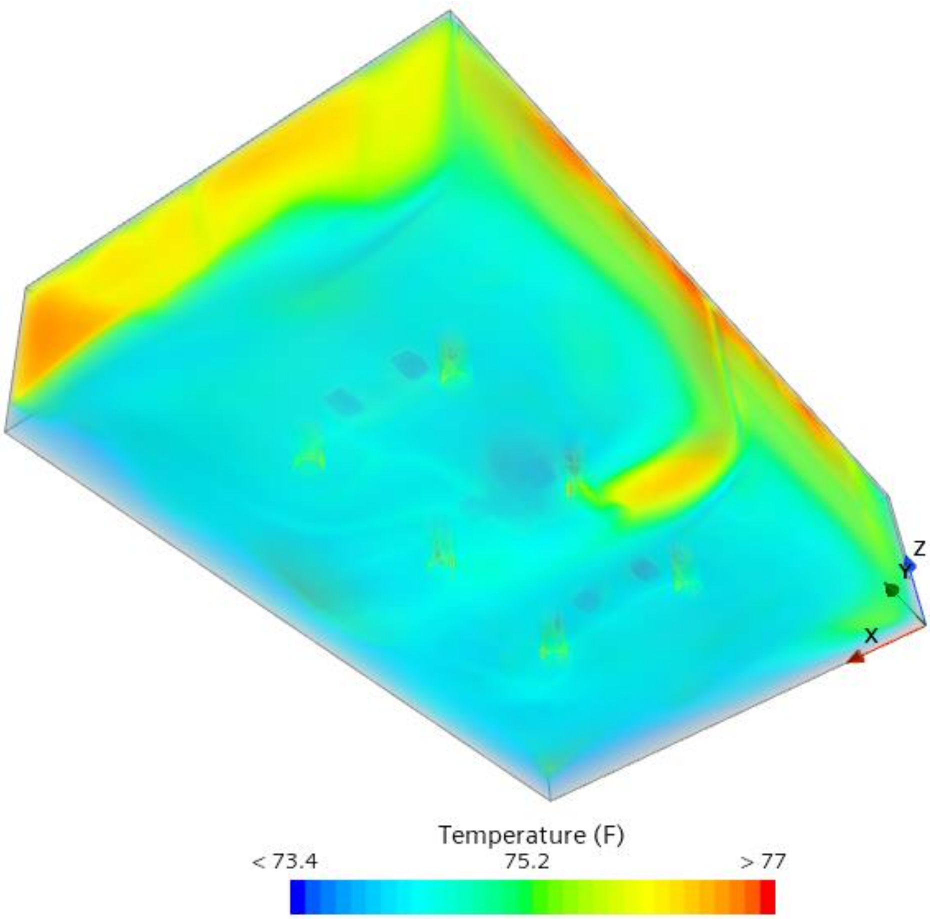
6ft from the floor
Average at 76.5°F



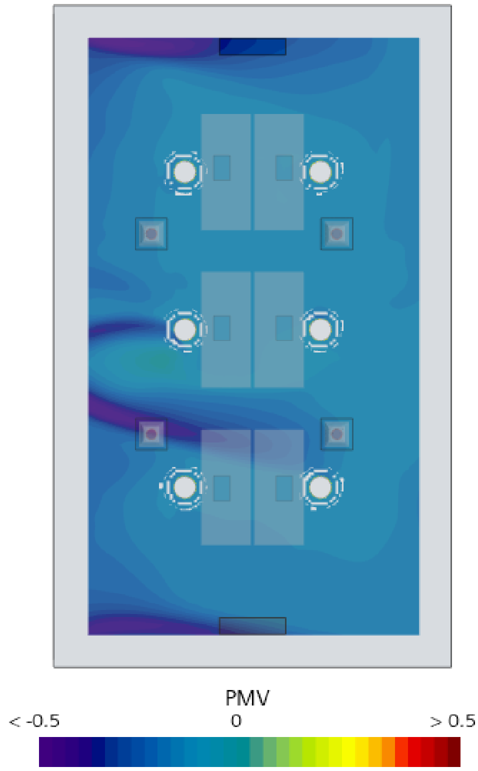

Z
Y
X
Temperature (F)
< 73.4
75.2
> 77


Z
X
Y
Temperature (F)
< 73.4
75.2
> 77

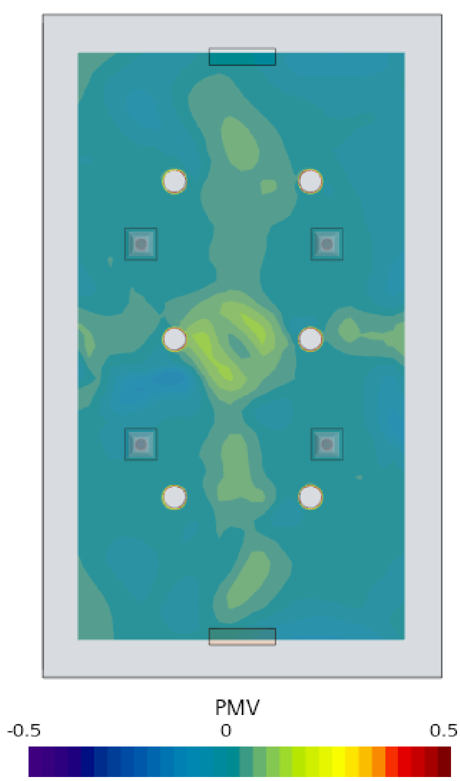

Z
X
Y
Temperature (F)
< 73.4
75.2
> 77


Z
Y
X
Temperature (F)
< 73.4
75.2
> 77

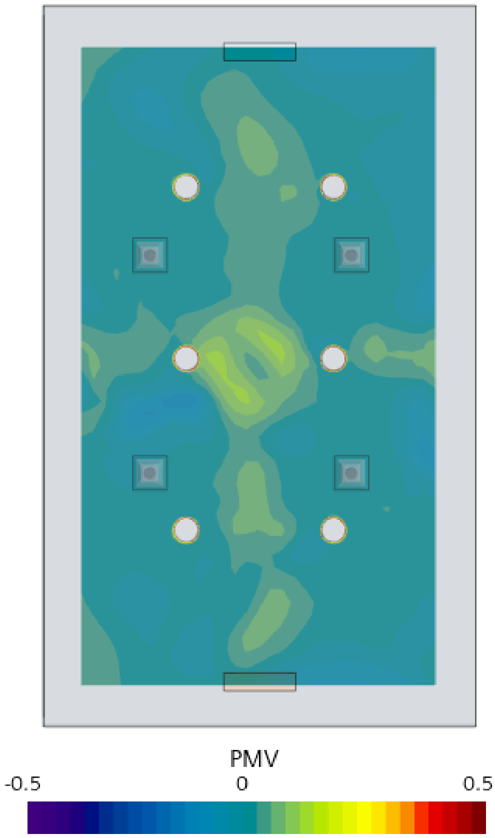
Predicted Mean Vote (PMV)



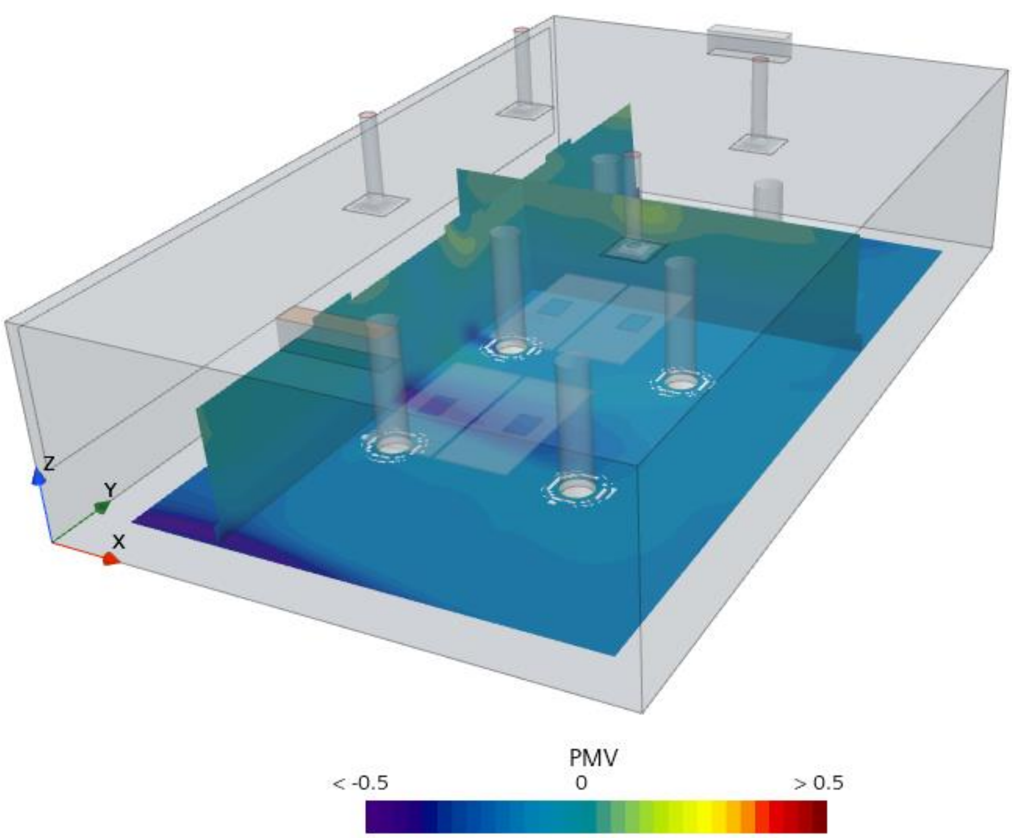
3in from the floor
Average at -0.17



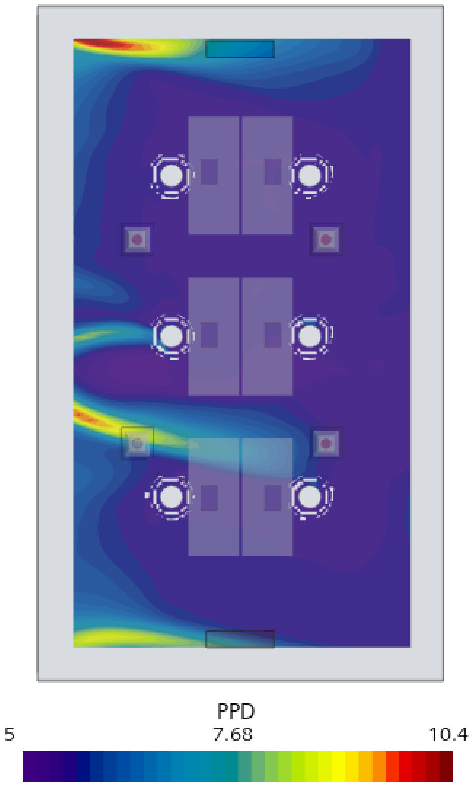
4ft from the floor
Average at -0.02



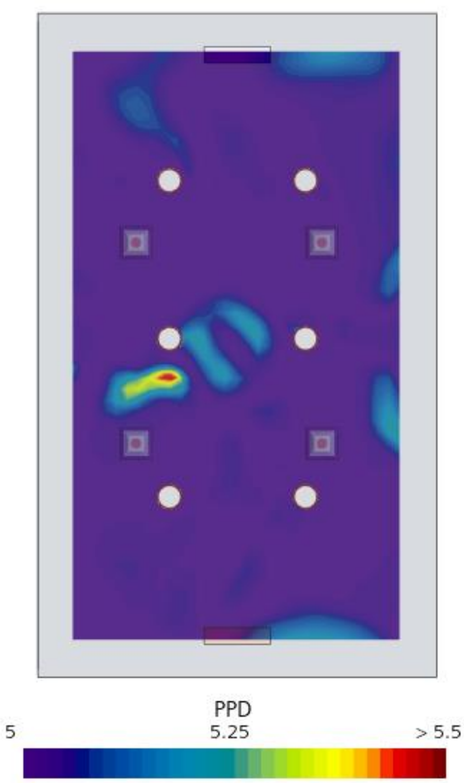
6ft from the floor
Average at 0.001



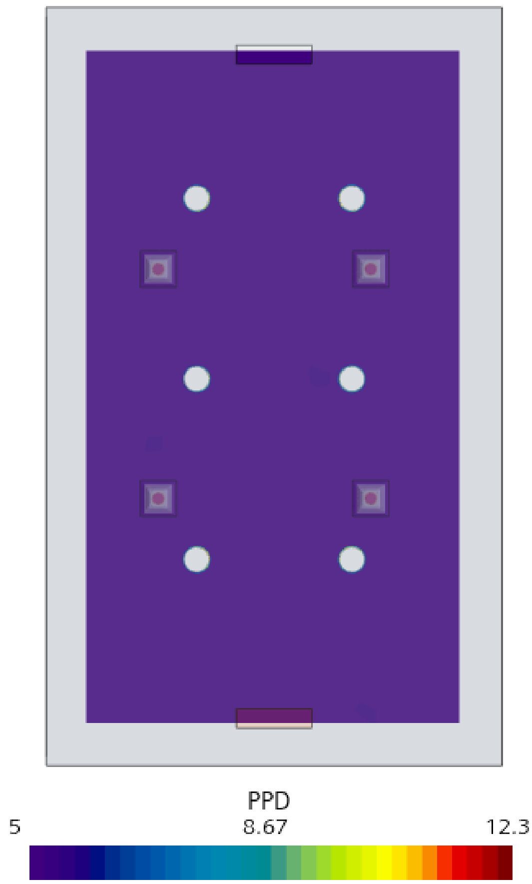
Predicted Percentage Dissatisfied (PPD)



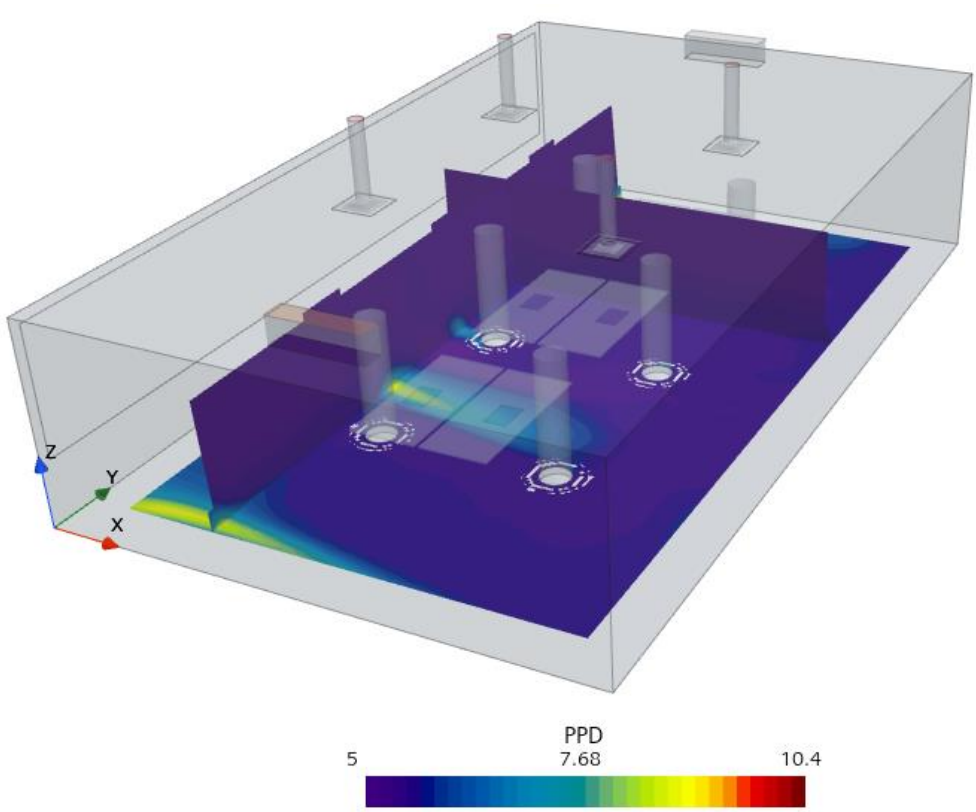
3in from the floor
Average at 5.7%



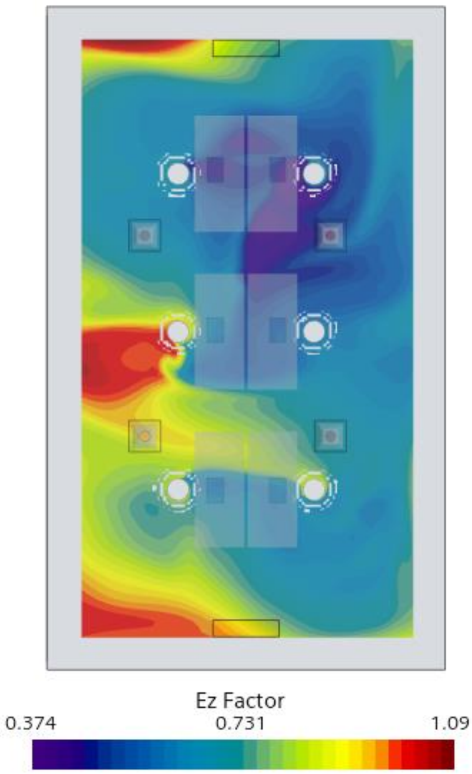
4ft from the floor
Average at 5.0%



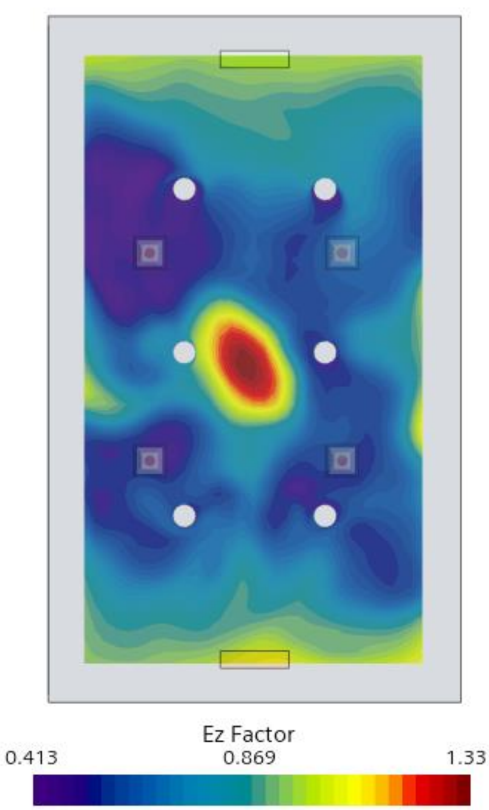
6ft from the floor
Average at 5.0%



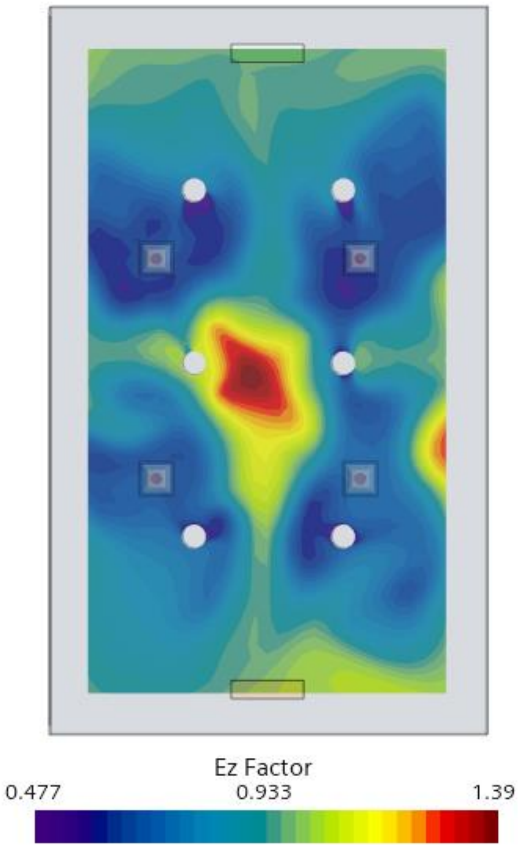
Zone Air change Effectiveness (Ez Factor)



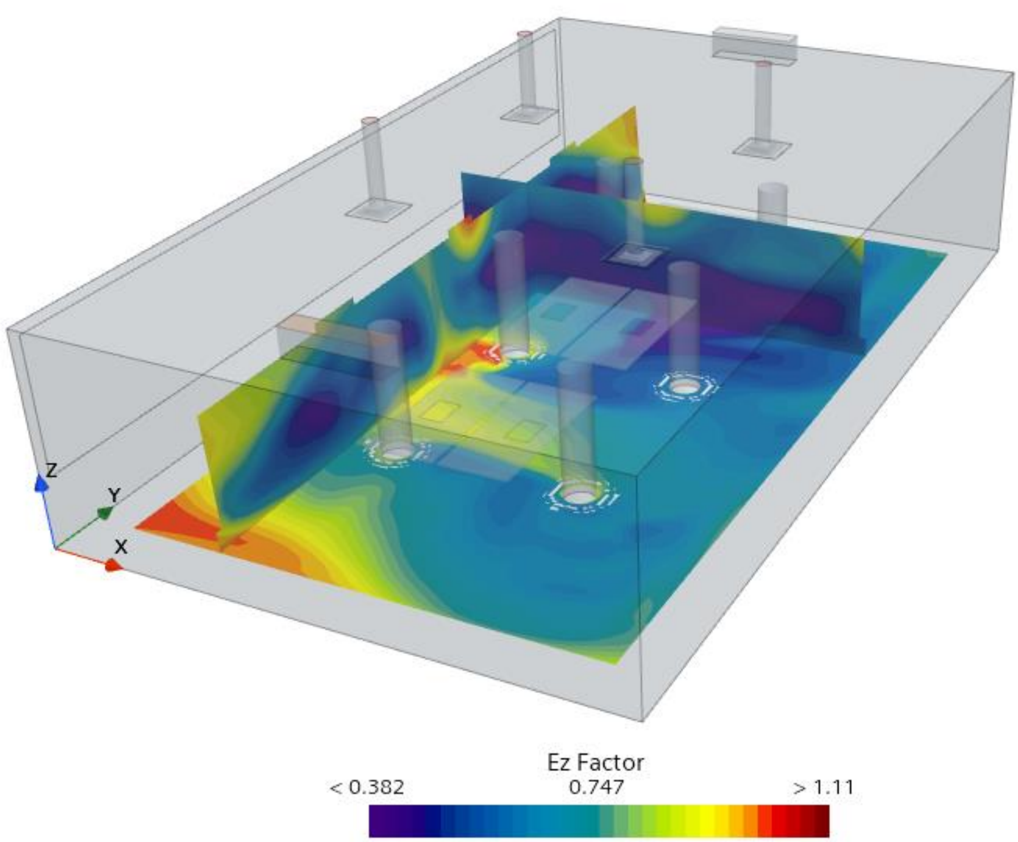
3in from the floor
Average at 0.67



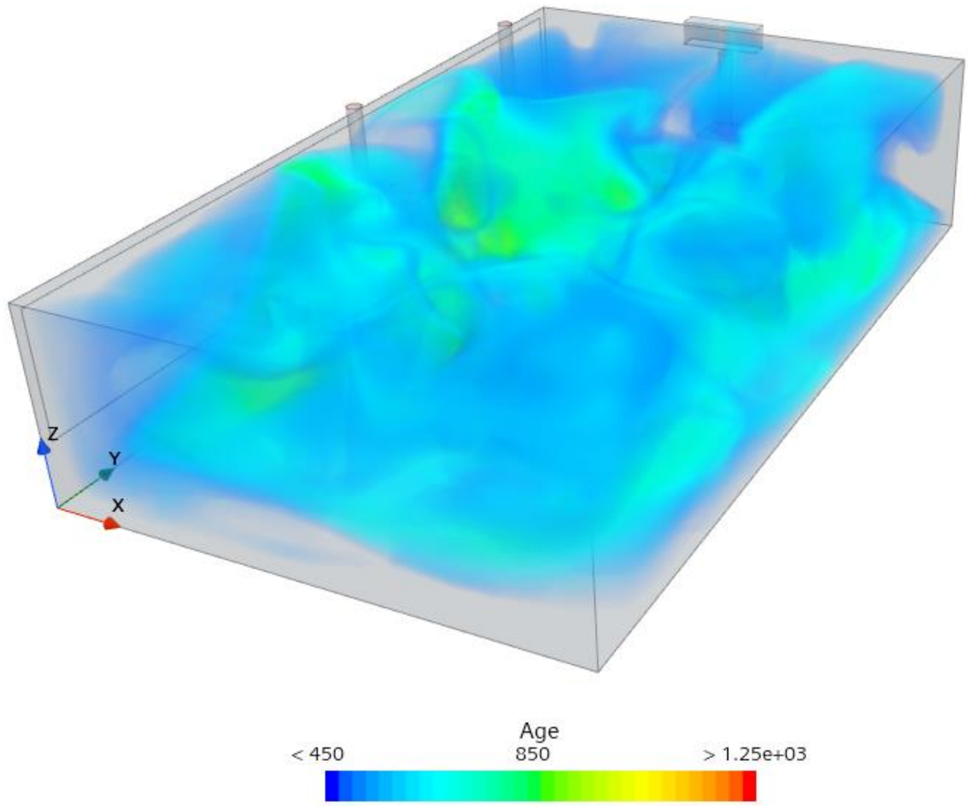
4ft from the floor
Average at 0.73

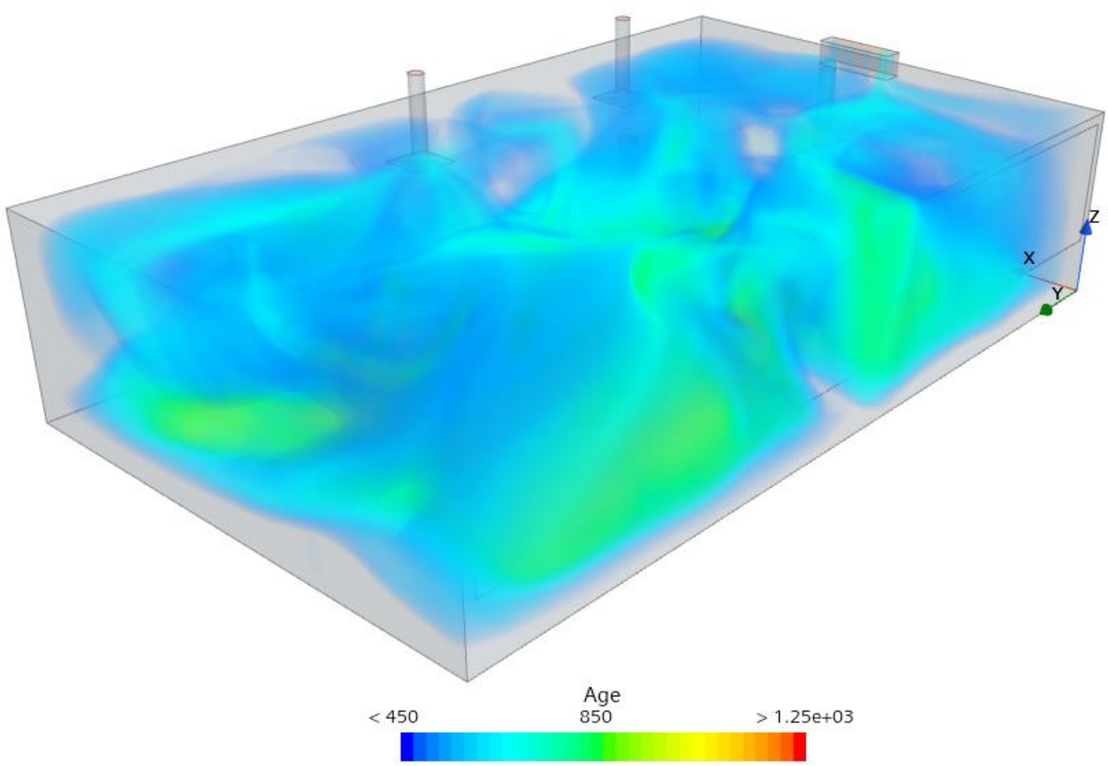


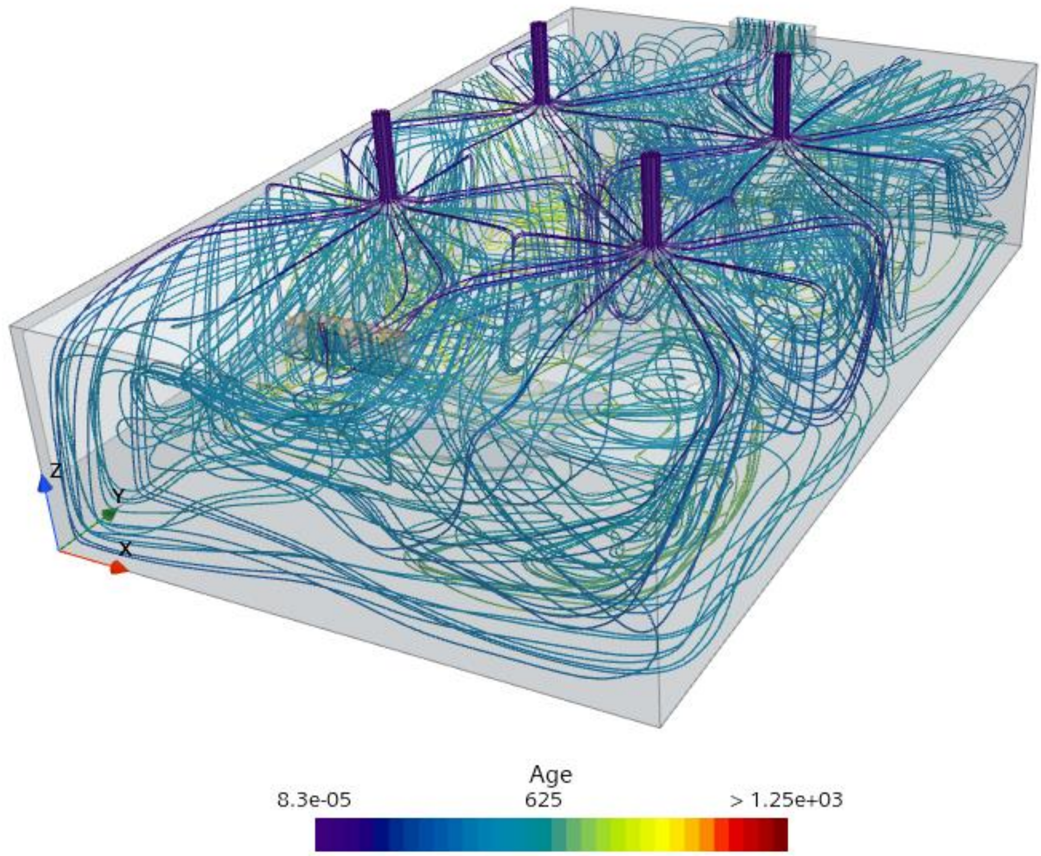
6ft from the floor
Average at 0.83

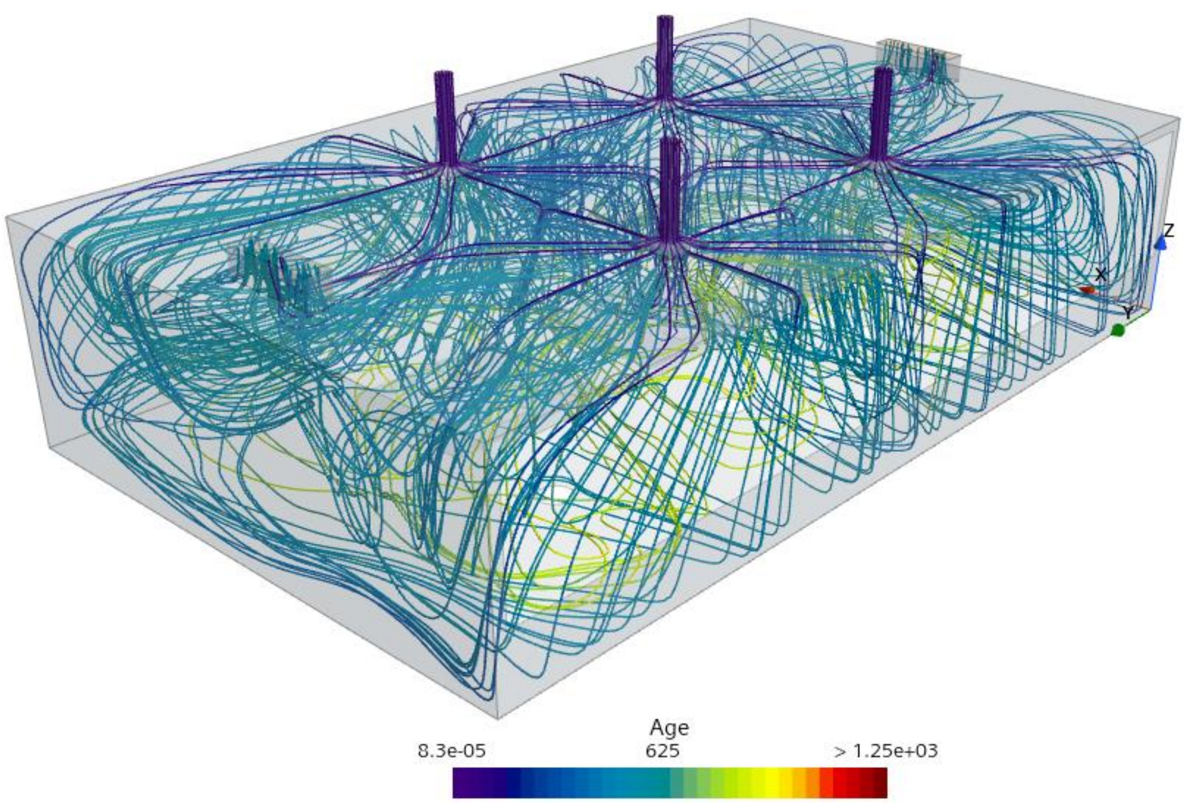


Mean Age of Air



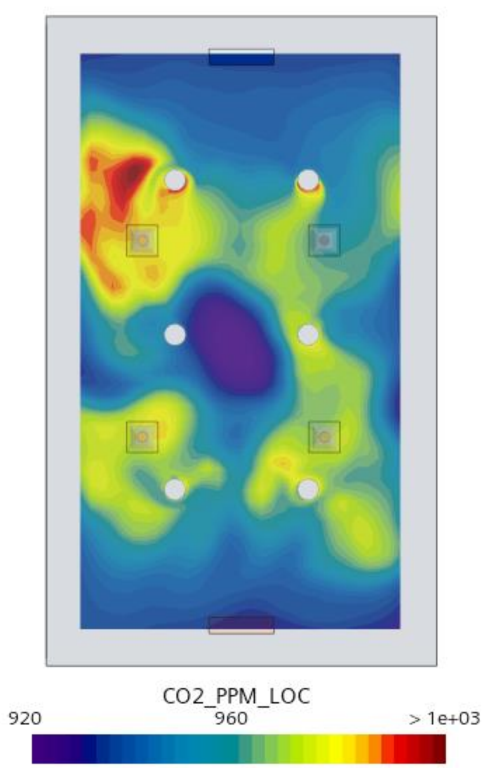



Z
Y
X
Age
8.3e-05
625
> 1.25e+03

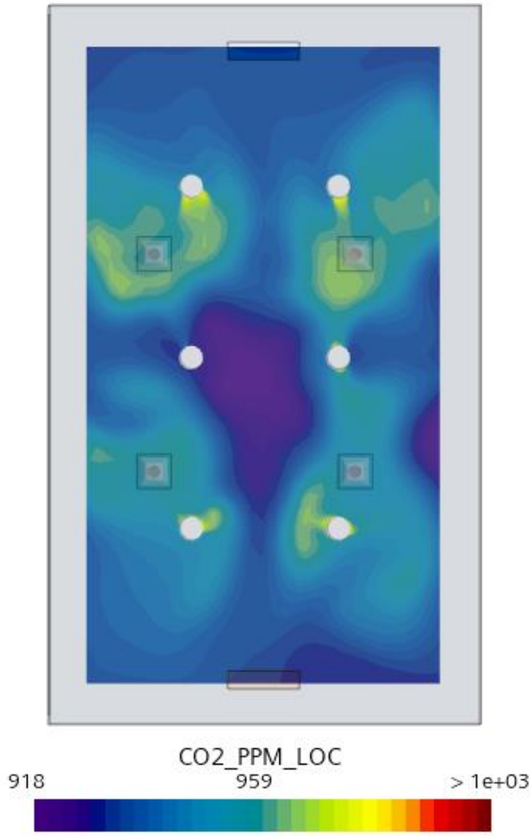

Z
X
Y
Age
8.3e-05
625
> 1.25e+03

CO2 Breathing Zone Concentration (PPM)

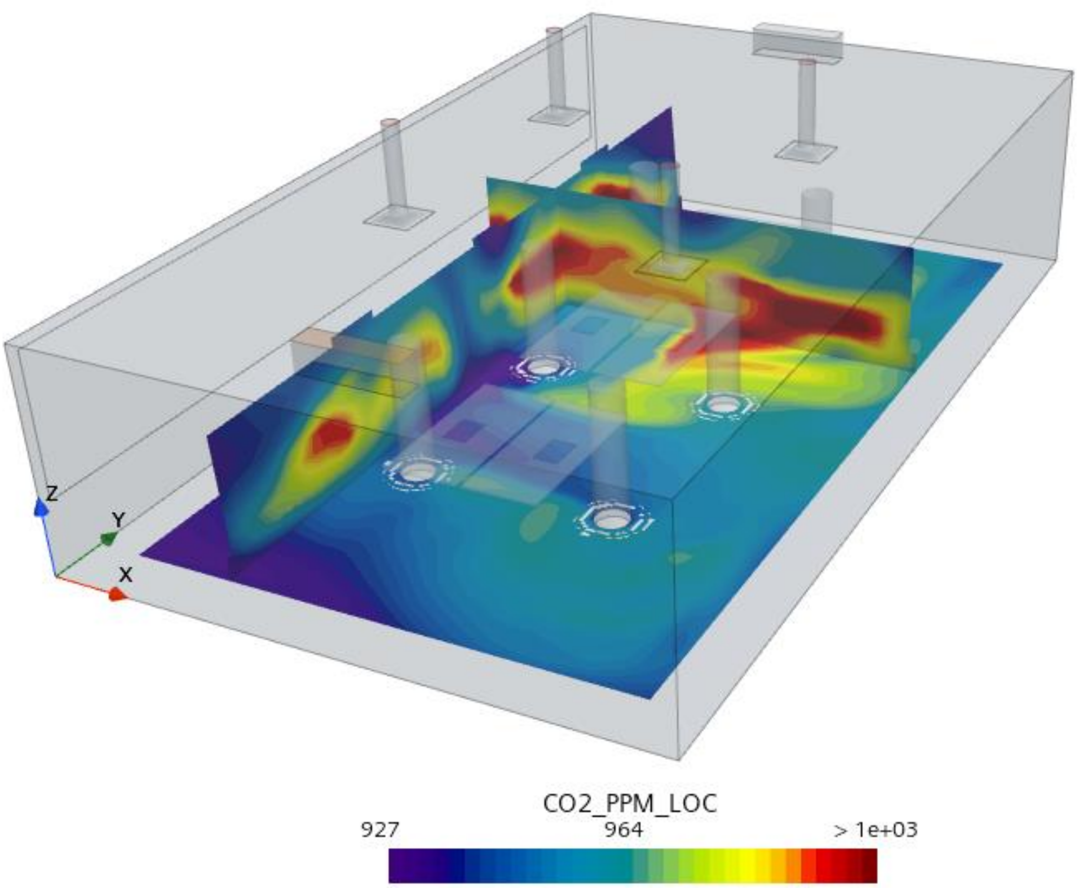
3in from the floor
Average at 959 ppm



4ft from the floor
Average at 954 ppm



6ft from the floor
Average at 943 ppm



EffectiV HVAC inc.

EFF0122001 : Development Room – PLAY-S - Heating

November 29th 2022

Yannick Sirois, ing., M.Sc.A.,Ph.D. No OIQ : 130045

Lx Sim Inc.
400 rue Shefford, local 117
Bromont. Québec
J2L 3E7. Canada
Tel. : 450.919.1714
info@lxsim.com
www.lxsim.com

Simulation Summary

Diffuser Configuration

Inlets	Type
4	PLAY-S 24

Heating Conditions

Property	Value
Outside temperature	13.5°F
Air supply temperature	80°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	1.0 CLO (pants, sweater, t-shirt underneath)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

Heating Results

Properties	Value
Outlet air temperature	75.9°F
Average flow rate	950 CFM
Theoritical air age at outlet	544 s
Real air age at outlet	522 s
Ez Factor	0.760
CO2 PPM	981
PMV	-0.08
PPD	5.24

Mandate

Lx Sim has the mandate to analyze the performance of the ventilation system inside a room using a CFD approach

Ventilation system performance is quantified in terms of:

- Mean Age of Air measured at the extraction
- Zone Air Distribution Effectiveness (Ez Factor)
- Occupants thermal comfort (Predicted Mean Vote and Predicted Percentage of Dissatisfied)

Methodology

Each CFD simulation is performed in Simcenter STAR-CCM+ from Siemens

General modeling is based on:

- CFD best practices
- ANSI/ASHRAE Standard 62.1-2019 (Air quality)
- ANSI/ASHRAE Standard 55-2017 (Thermal comfort)

CAD

- The simulation is performed using a 3D representation of the room to be studied
- The room is built according to plans provided
- The model includes the following features and surfaces:
  - Walls
  - Windows
  - Air diffusers
  - Air diffusers feed ducting (if necessary)
  - Air room extractor
  - People (if necessary)
  - Other major obstacles (if necessary)

Mesh

In order to solve fluid mechanics transport equations, the 3D geometry must be discretized in small elements

Element size must be small enough that numerical diffusion does not occur and that all physical effects in the fluid are modeled appropriately

In the ventilation simulation, the most restrictive geometric feature is the air diffuser

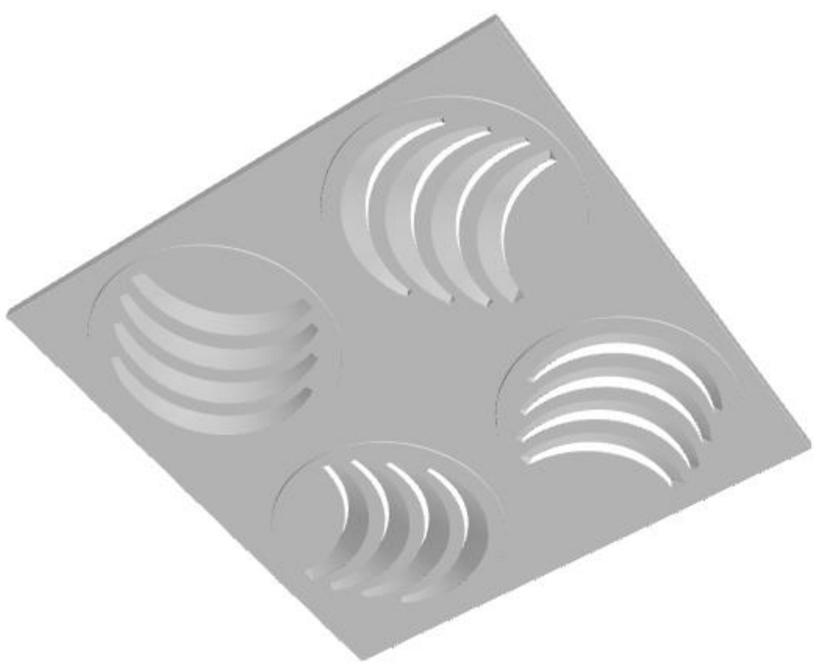
The air diffuser requires a mesh small enough so that flow directions and velocities represent reality

Air diffuser mesh validation

The mesh approach was valided using the PLAY-S 24 diffuser from EffectiV HVAC inc.

This diffuser incorporates small features that need to be resolved correctly in order to obtain the corrrect performances.

PLAY-S 24

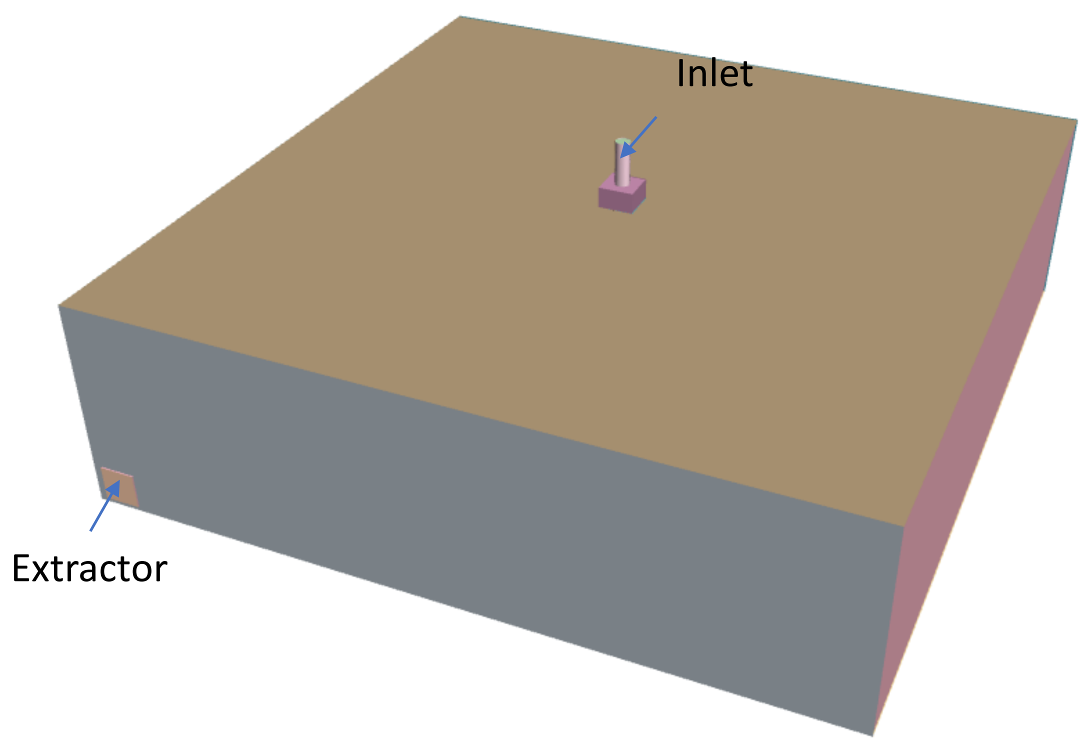


24” x 24” Face, Swirl Effect

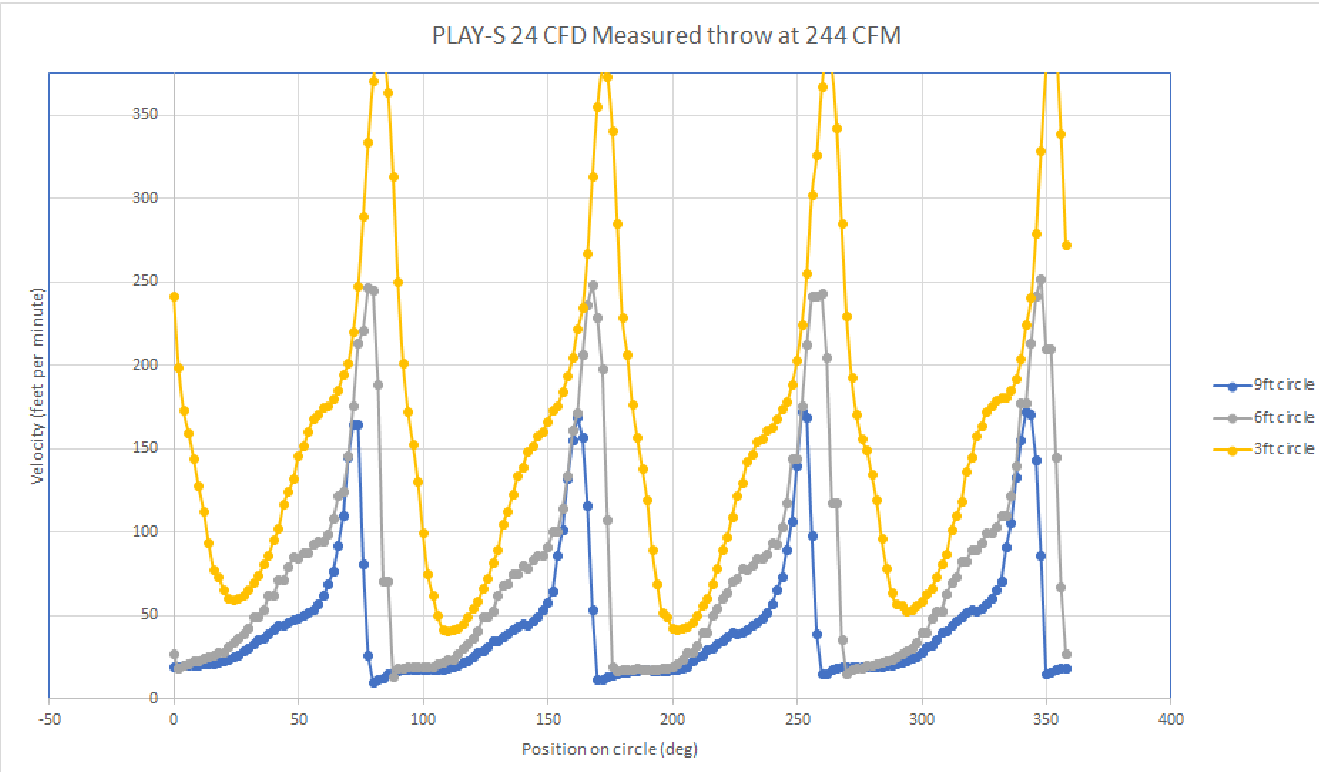
605 mm x 605 mm Face (Metric)

Neck Size (inches)	Neck (fpm) Velocity	200	300	400	500	600	700	800	1000
	Velocity Pressure (H2O)	0.002	0.006	0.01	0.016	0.022	0.031	0.041	.062
6	CFM				98	118	137	157	196
	Pressure Loss (in.w.g.)				0.01	0.014	0.019	0.024	0.037
	NC				< 15	< 15	< 15	< 15	16
	Throw (ft) - Coanda Effect				2-2-4	2-3-4	2-3-5	2-4-6	3-5-7
	Throw (ft) - No Ceiling				1-2-3	1-2-3	2-3-4	2-3-4	2-4-5
8	CFM		105	140	175	209	244	279	349
	Pressure Loss (in.w.g.)		0.011	0.02	0.03	0.041	0.055	0.071	0.107
	NC		< 15	< 15	< 15	18	22	25	31
	Throw (ft) - Coanda Effect		2-3-4	2-3-5	3-4-6	3-5-7	3-6-9	4-6-10	5-8-12
	Throw (ft) - No Ceiling		1-2-3	2-3-4	2-3-5	2-4-6	3-4-6	3-5-7	4-6-9
10	CFM	109	164	218	273	327	382	436	545
	Pressure Loss (in.w.g.)	0.012	0.026	0.045	0.068	0.095	0.127	0.163	0.247
	NC	< 15	< 15	19	25	30	34	37	43
	Throw (ft) - Coanda Effect	2-3-4	2-4-6	3-5-8	4-6-10	4-8-11	5-9-13	6-10-15	9-16-24
	Throw (ft) - No Ceiling	1-2-3	2-3-4	2-4-6	3-5-7	3-6-8	4-6-10	4-7-11	7-12-18
12	CFM	157	236	314	393	471	550		
	Pressure Loss (in.w.g.)	0.024	0.052	0.088	0.134	0.188	0.251		
	NC	< 15	21	29	35	39	44		
	Throw (ft) - Coanda Effect	2-4-6	3-6-8	4-7-11	5-9-13	6-10-16	7-12-18		
	Throw (ft) - No Ceiling	2-3-4	3-4-6	3-5-8	4-7-10	5-8-12	5-9-14		

The diffuser is introduced into a large room with th inlet plenum and an extractor



- A 244 CFM test value is chosen (see performance chart)
- A CFD analysis is performed and the mesh is refined until satisfactory performances a re measured and the changes in mesh do not change the measured values
- To assess validity, samples of velocity are taken in circles at 3, 6 and 9 ft around the diffuser



The results show that average values are very close the expected values of 40fpm at 9ft, 60fpm at 6ft and 100fpm at 3ft

The same mesh strategy is to be used on the full room with multiple diffusers to lead to accurate results

General CFD physics modeling

Simulations is in accordance with ANSI/ASHRAE Standard 62.1-2022 - Normative Appendix C.

The following modeling options are used:

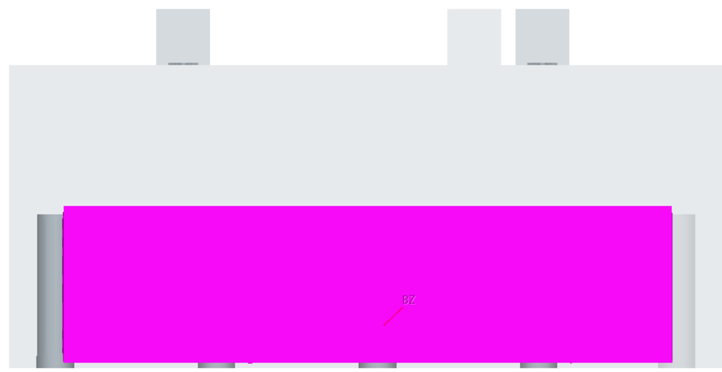
- Steady state approach
- Turbulence modeling active
- Energy and gravity activated
- Species transport
- Surface to surface radiation is modeled

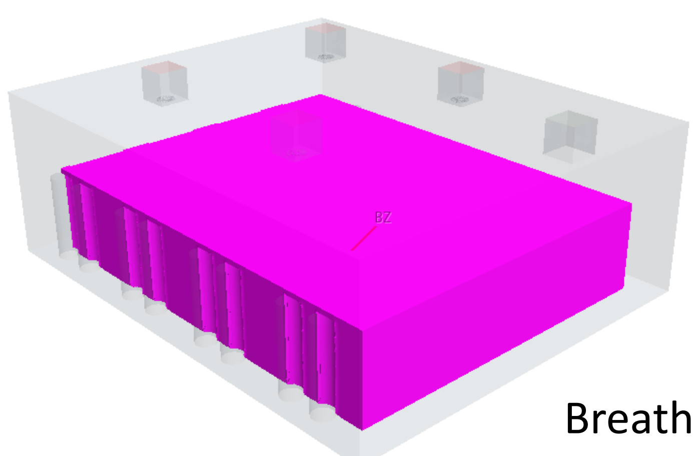
Breathing Zone

For multiple calculations in this simulation, the breathing zone is used

The breathing zone is defined as per ANSI/ASHRAE Standard 62.1-2022 - Section 3

breathing zone: the region within an occupied space between planes 3 and 72 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment.





Breathing zone example

Imposed Flow

- Flow rate in CFM is imposed at each inlet
- Temperature is imposed at each inlet
- Depending on the choice, a proportional error correction is implemented on either the flow rate or the temperature in order to reach the specified setpoint for the temperature in the room
- The temperature in the room to be compared to the setpoint is measured in each cell of the breathing zone and averaged over it
- Since the simulation is in steady state, the final flow rate and air inlet temperature represent an average value corresponding to a continuously running heating or cooling system

Operating conditions

- External conditions
    - External temperature is specified for heat transfer through walls, windows and radiation through the windows
- Walls and windows isolations is specified using U-Factor or R-Factor
- Human heat sources
    - Heat flux through a simple human shape
    - Heat flux defined using the Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2022

Air Age at Extraction

- To measure air age, the simulation uses a transported passive scalar
    - Does not affect flow in any way
    - Increases with time between the inlets and the outlets
- Average age is measured at the outlets using mass average procedure and is compared to the theoritical value

Zone Air Distribution Effectiveness (Ez Factor)

- All Ez Factor calculations are made in accordance with ANSI/ASHRAE Standard 62.1-2022 – Normative Appendix C
- A mass source of a tracer gas species, such as CO2 is introduced inside the breathing zone volume and uses the specied transport equations
- A mass averaged measure of the molar concentration of the tracer gas at the inlet and exhaust are taken

- The Ez Factor is measured for each mesh cell inside the breathing zone
- The global Ez Factor value is then the volume average of the Ez Factor values inside the breathing zone
- All other requirements for CFD modeling are respected in the model

Thermal Comfort

- Thermal comfort is evaluated with the values of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)
- All calculations are made according to ANSI/ASHRAE Standard 55-2017
- The CFD model implements the code proposed in Appendix B of said standard
    - Values are computed on each cell of the mesh and are available in the complete simulation for visualization and post-processing

Thermal Comfort – Required information

Clothing value

The clothing value describes the types of clothes worn by the occupants.

- Data must be provided in ''clo'' units
- Typical values are shown in Table 5.2.2.2A – Clothing Insulations Icl values for typical ensembles in ANSI/ASHRAE Standard 55-2017

Metabolica rate

The metabolic rate of occupants

- Depends on occupation
- Must be provided in ''met'' units
- Typical values are shown in Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2017

External work

Also in ''met'' units

Generaly around 0 except in very physical action by the occupants

Air temperature

Provided in each cell by the cfd model

Air velocity

Provided in each cell by the cfd model

Mean radiant temperature

Average wall surface temperature provided by the CFD model

Relative humidity

Provided in %

Case Study Presentation

CAD

- Room Dimensions:

Side	Dimension
Length	40 ft
Width	24 ft
Height	9 ft

- 1 window (west)

Properties	
U-factor	0.24 BTU /(h*ft2*F)
SHGC	0.27

- Ceiling

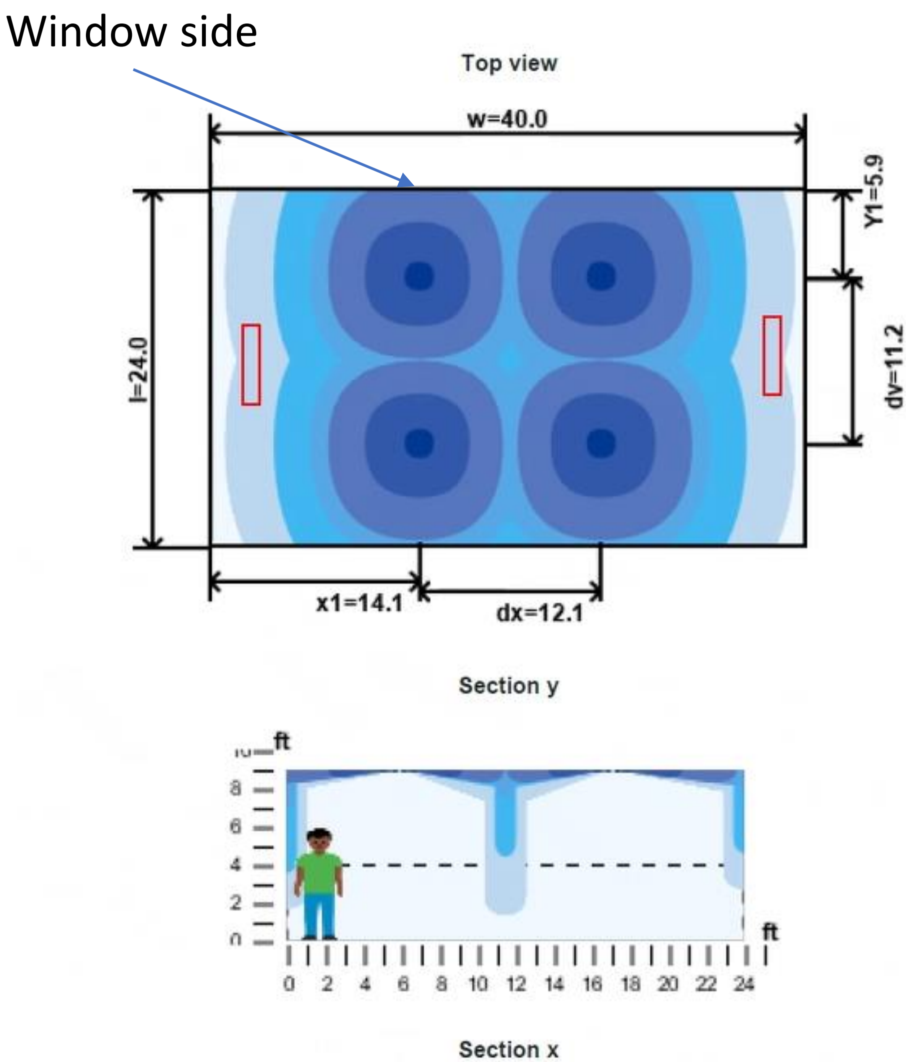
Properties	
U-factor	0.053 BTU /(h*ft2*F)

- Outside wall (west)

Properties	
U-factor	0.044 BTU /(h*ft2*F)

- Inlets and outlets positioned as follows

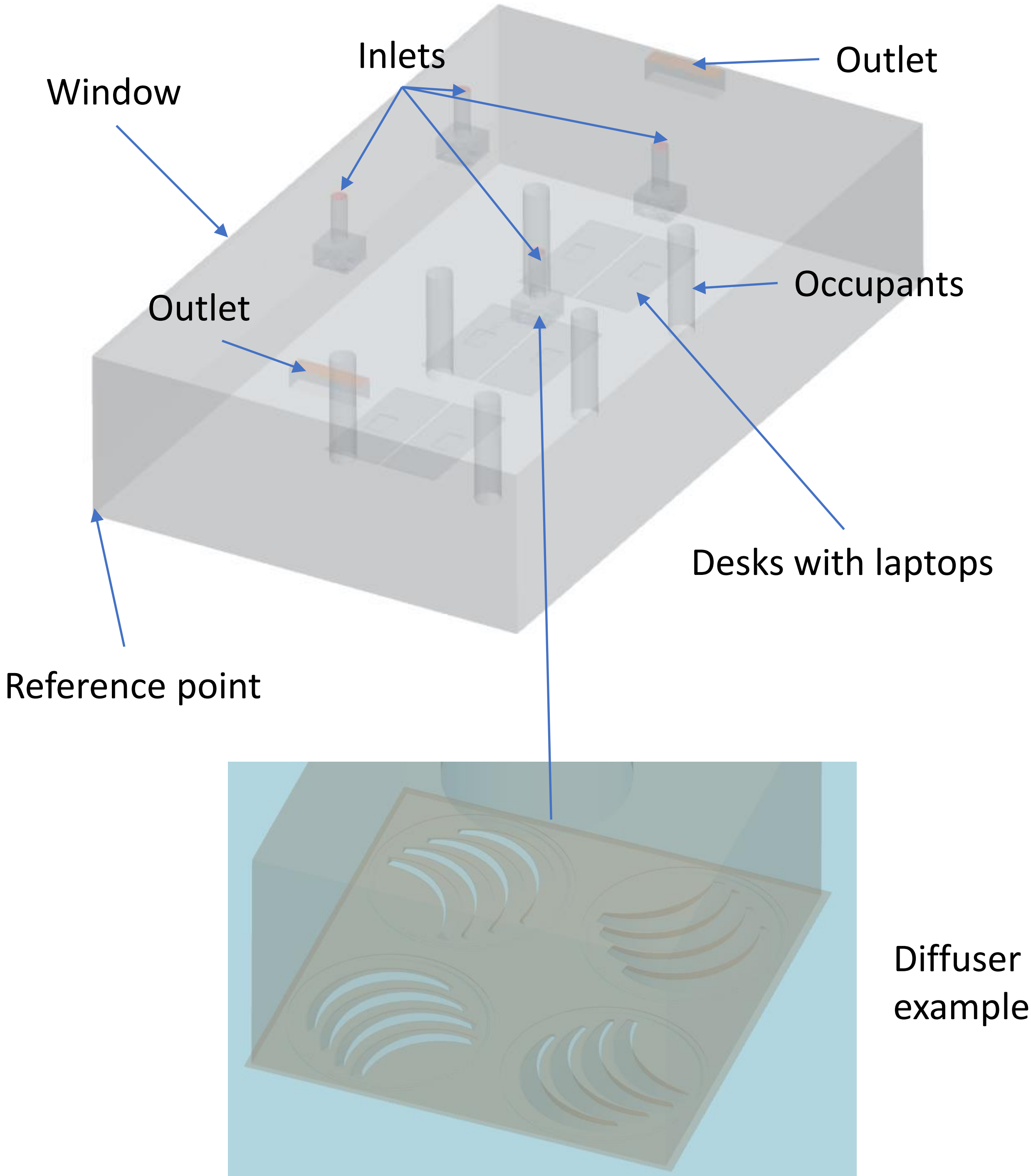
- Inlets and outlets positioned as follows



Diffusers

- 4 PLAY-S 24

Resulting model



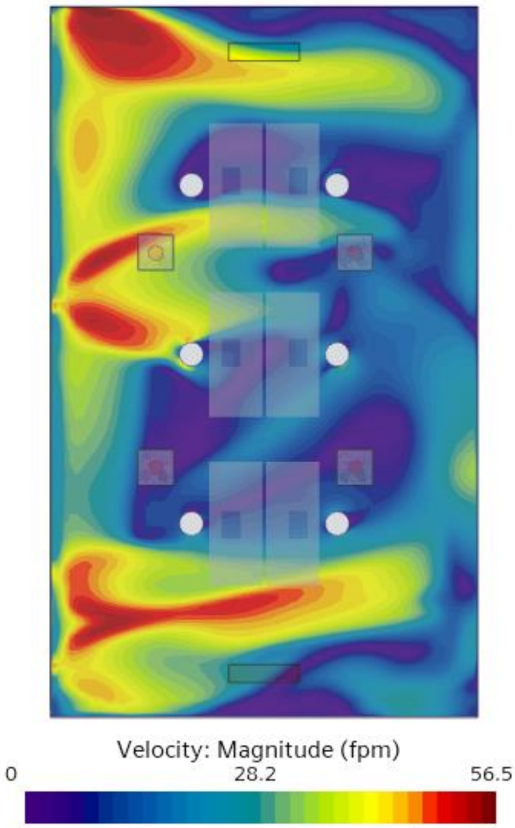
Heating Conditions

Property	Value
Outside temperature	13.5°F
Air supply temperature	80°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	1.0 CLO (pants, sweater, t-shirt underneath)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

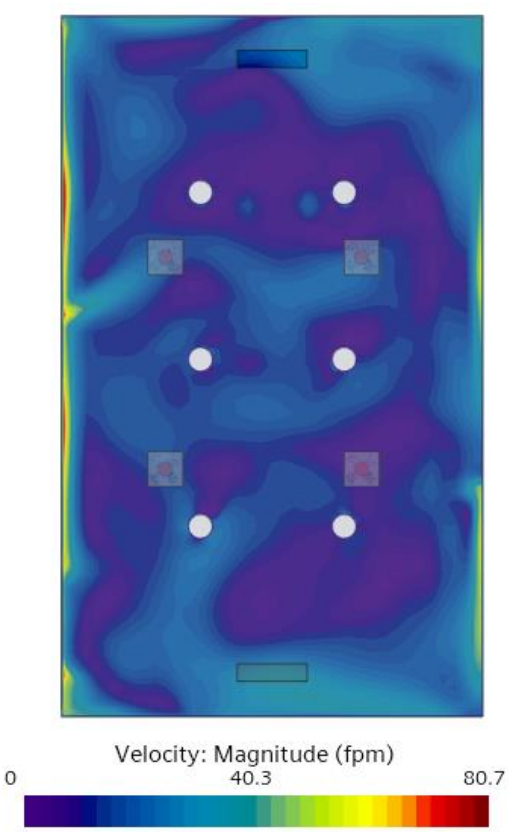
Heating Results

Properties	Value
Outlet air temperature	75.9°F
Average flow rate	950 CFM
Theoritical air age at outlet	544 s
Real air age at outlet	522 s
Ez Factor	0.760
CO2 PPM	981
PMV	-0.08
PPD	5.24

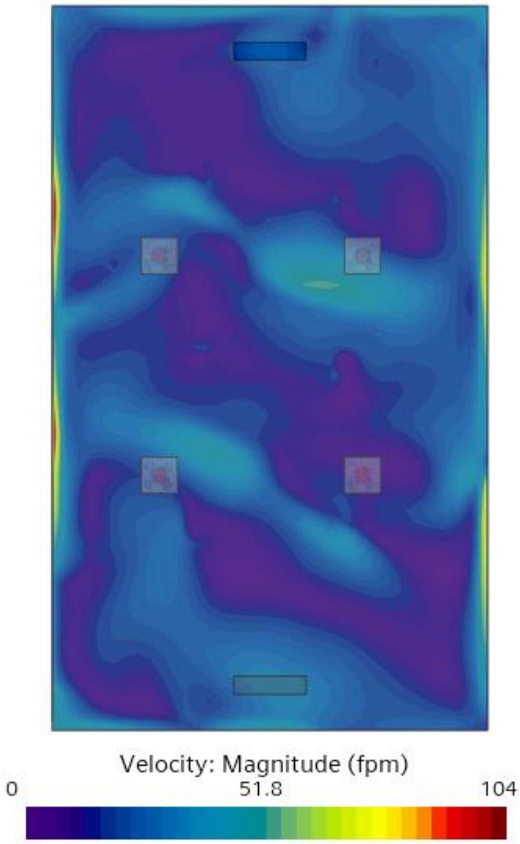
Air Velocity



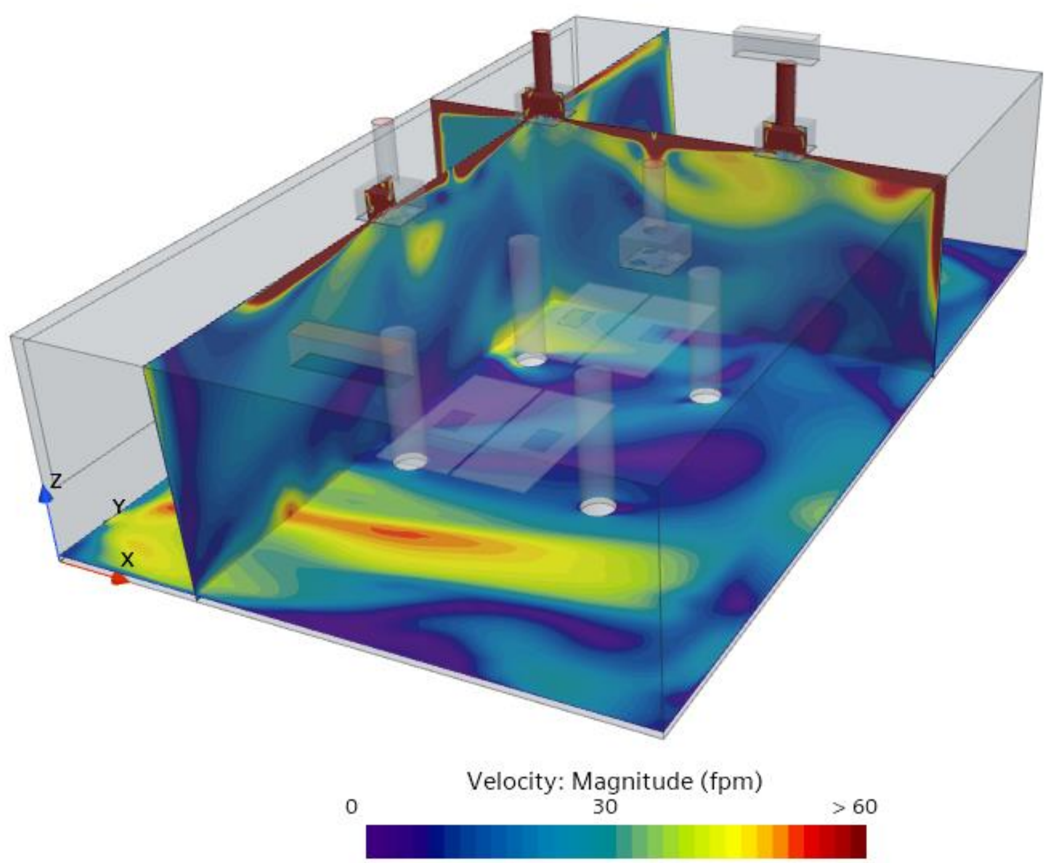
3in from the floor
Average at 23 fpm

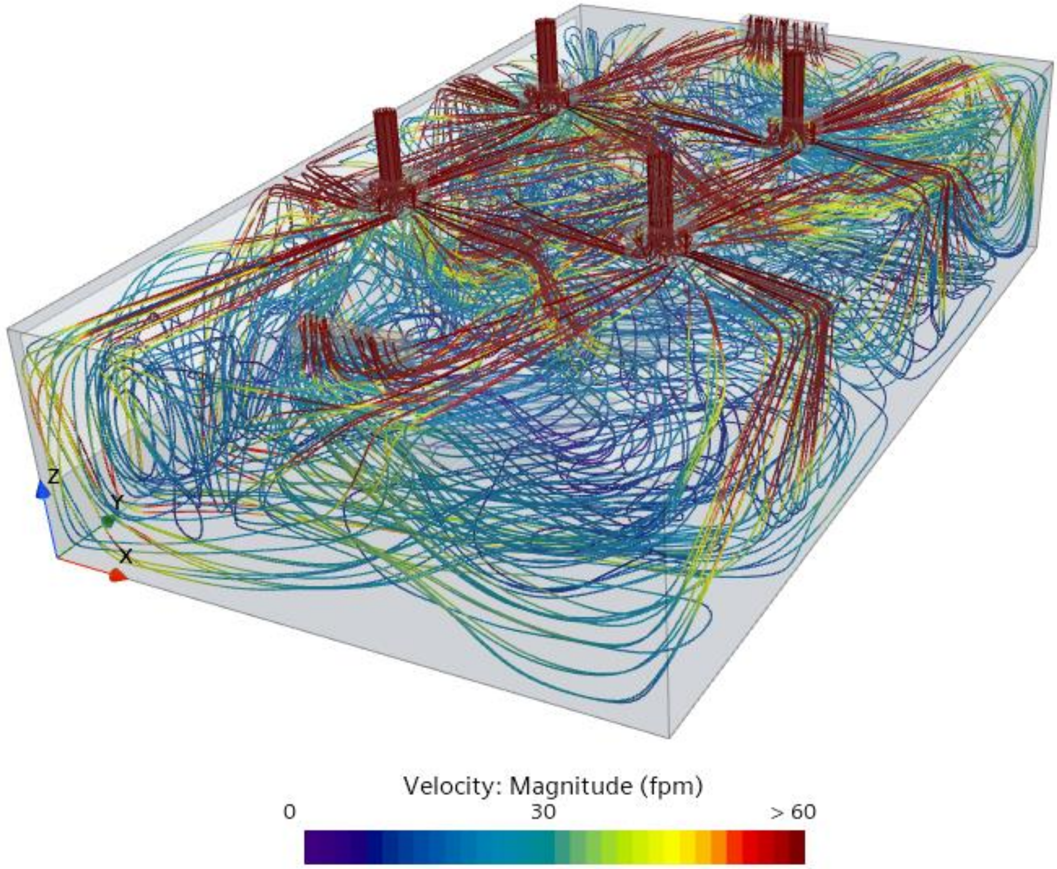


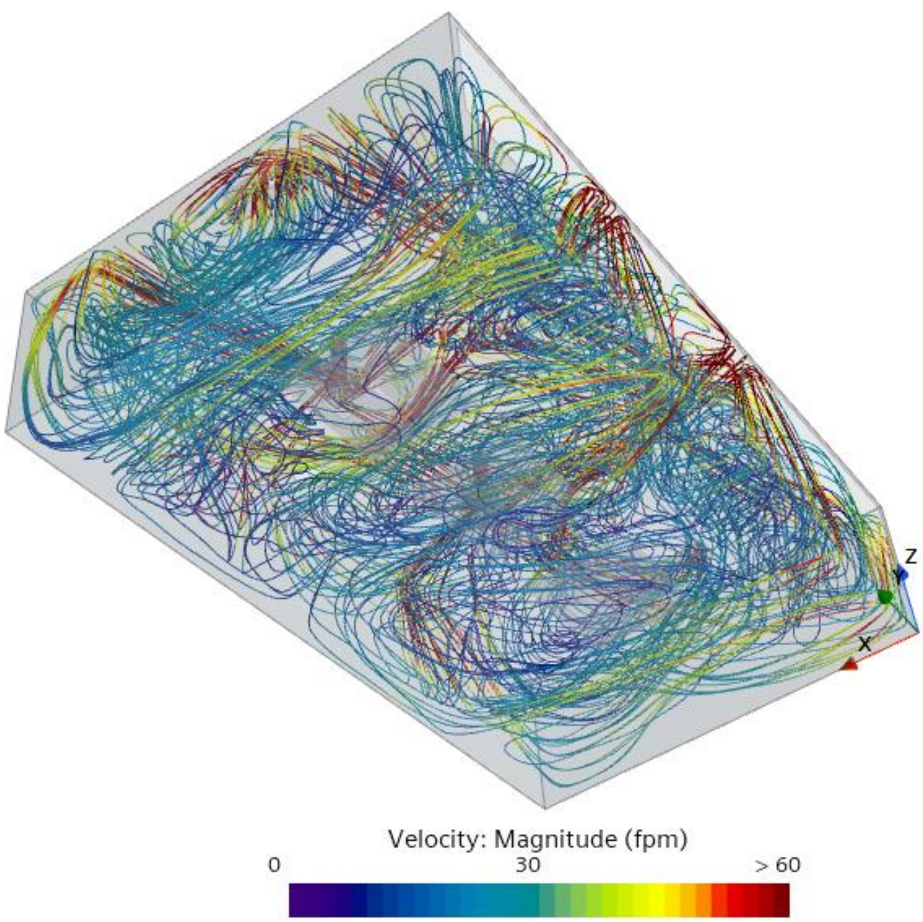
4ft from the floor
Average at 13 fpm

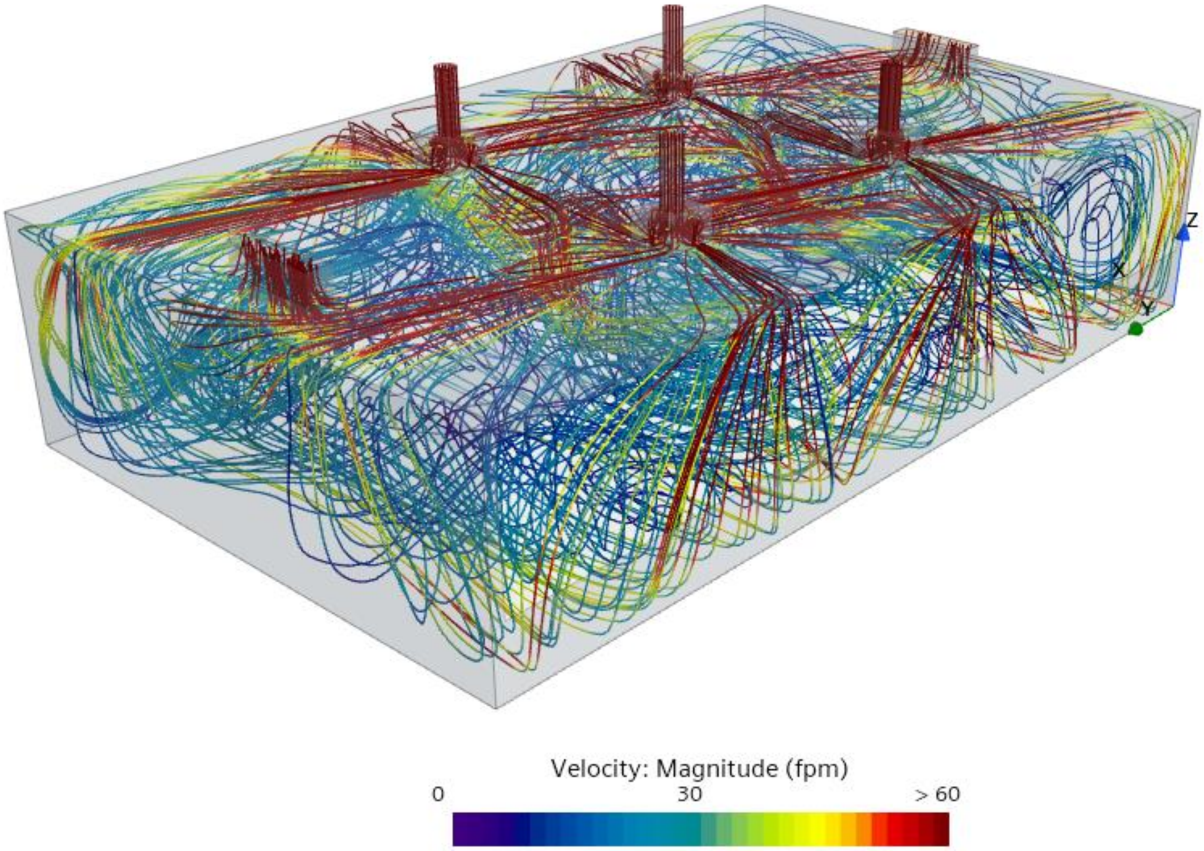


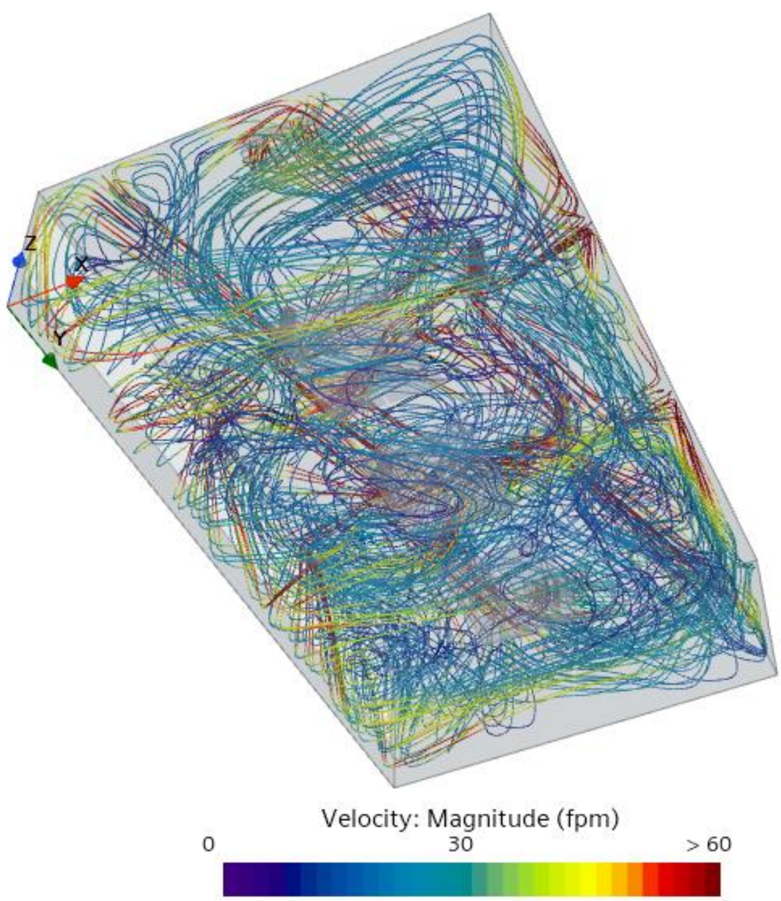
6ft from the floor
Average at 17 fpm

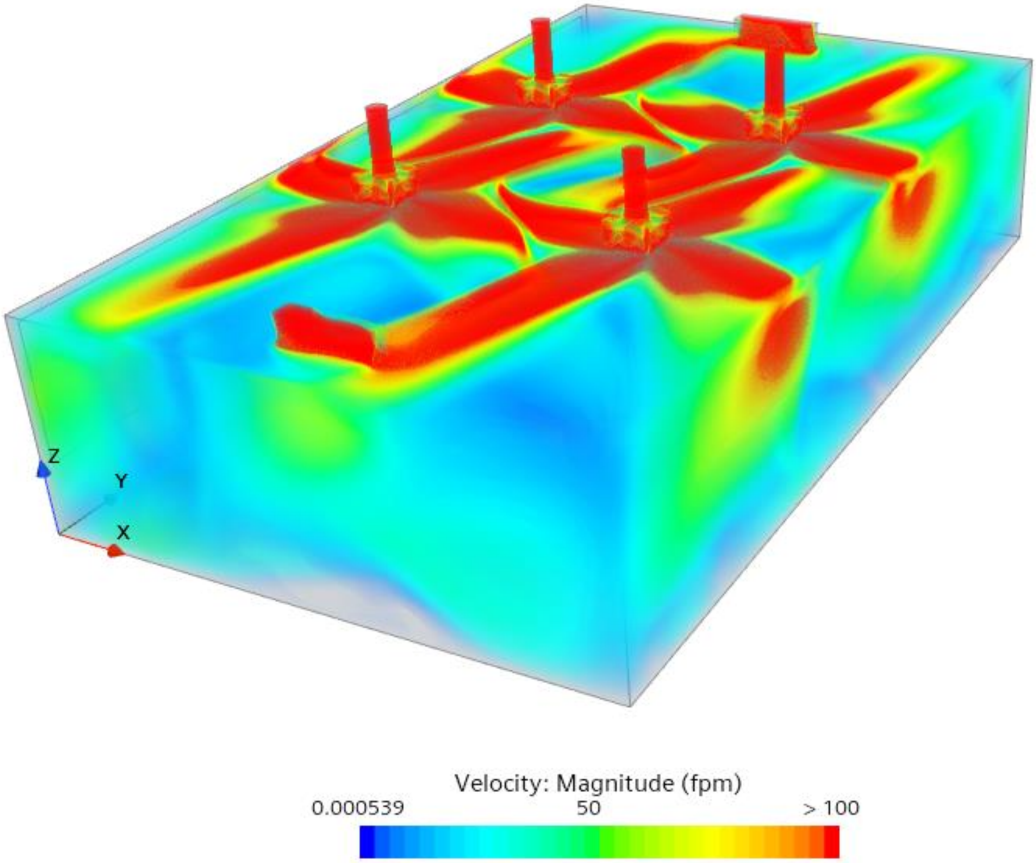


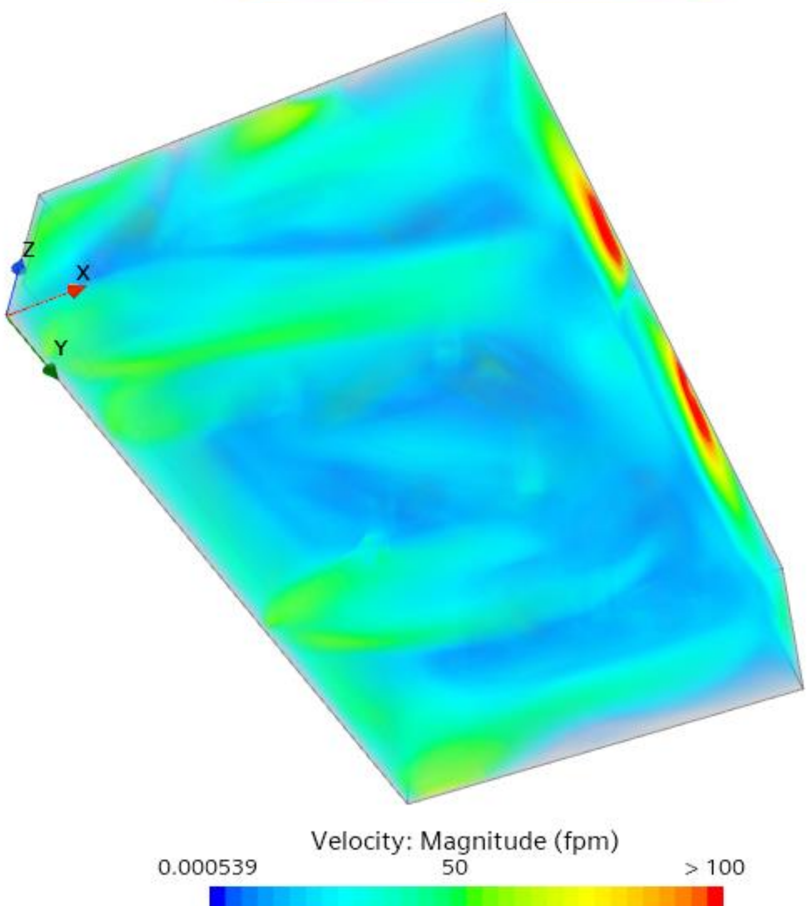

Z
Y
X
Velocity: Magnitude (fpm)
0
30
> 60

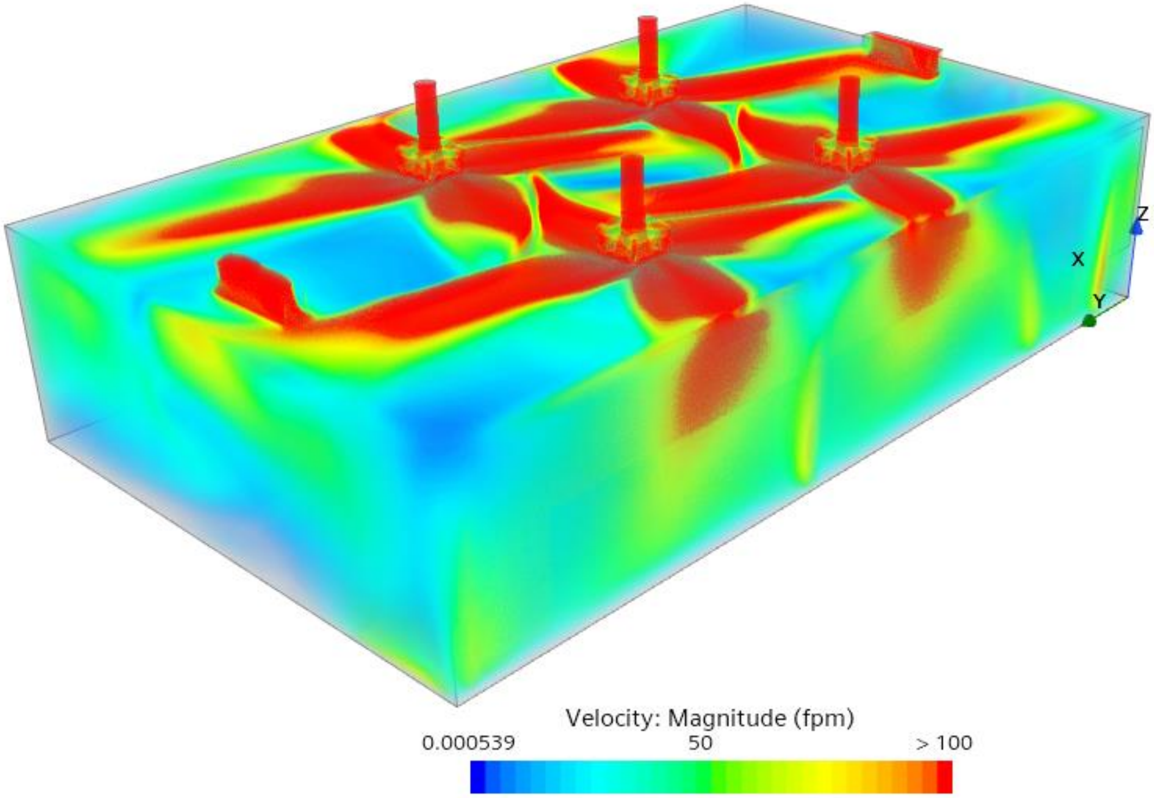

Z
Y
X
Velocity: Magnitude (fpm)
0
30
> 60

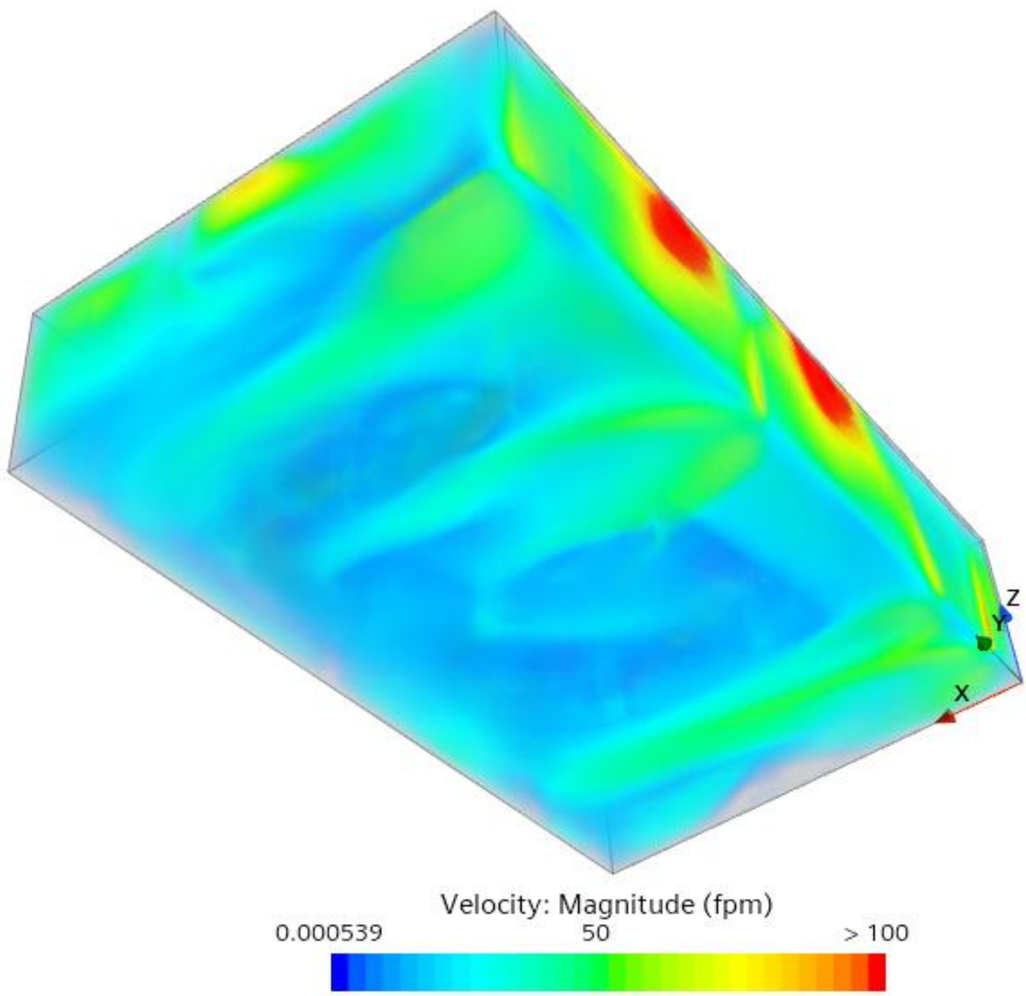

Z
X
Y
Velocity: Magnitude (fpm)
0
30
> 60


Z
X
Y
Velocity: Magnitude (fpm)
0
30
> 60

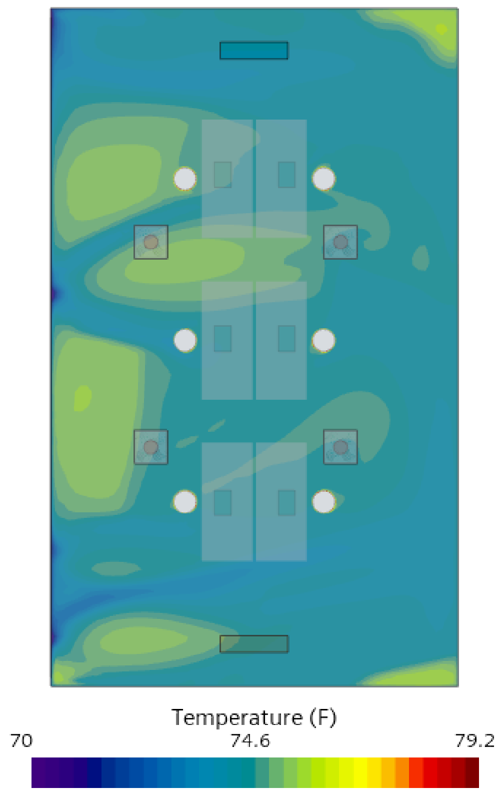

Z
Y
X
Velocity: Magnitude (fpm)
0.000539
50
> 100


Z
X
Y
Velocity: Magnitude (fpm)
0.000539
50
> 100

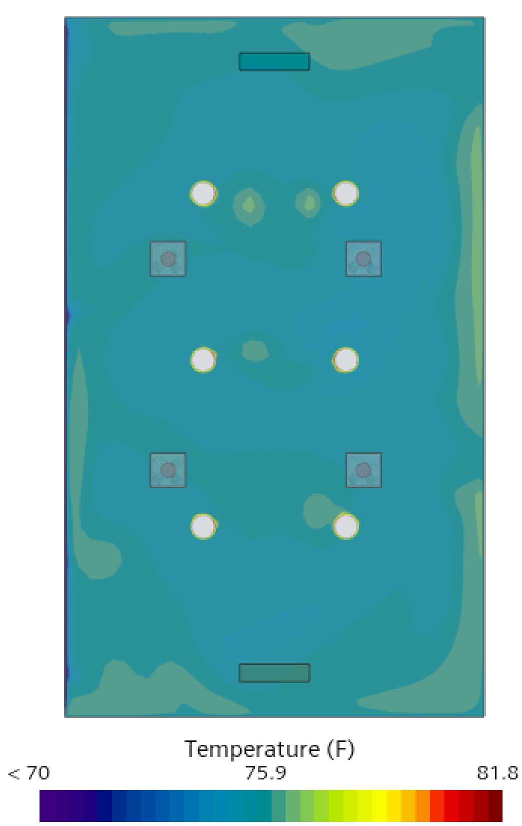

Z
X
Y
Velocity: Magnitude (fpm)
0.000539
50
> 100


Z
Y
X
Velocity: Magnitude (fpm)
0.000539
50
> 100

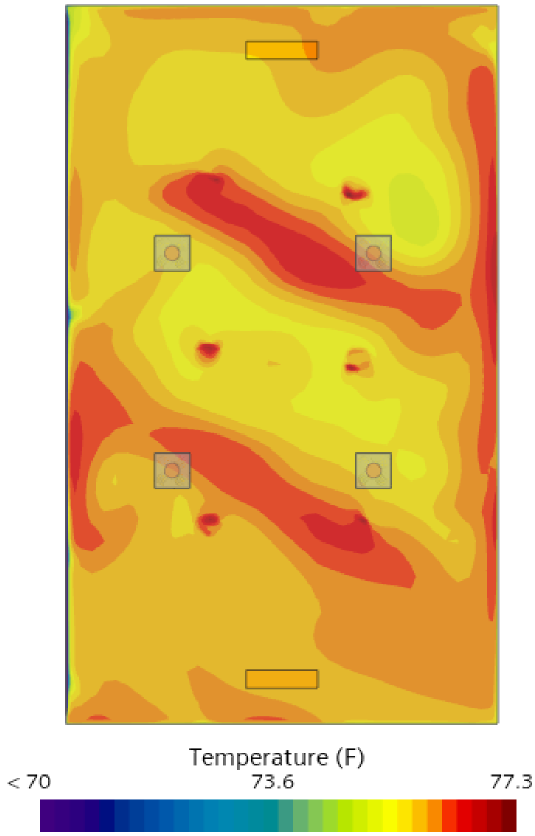
Air Temperature



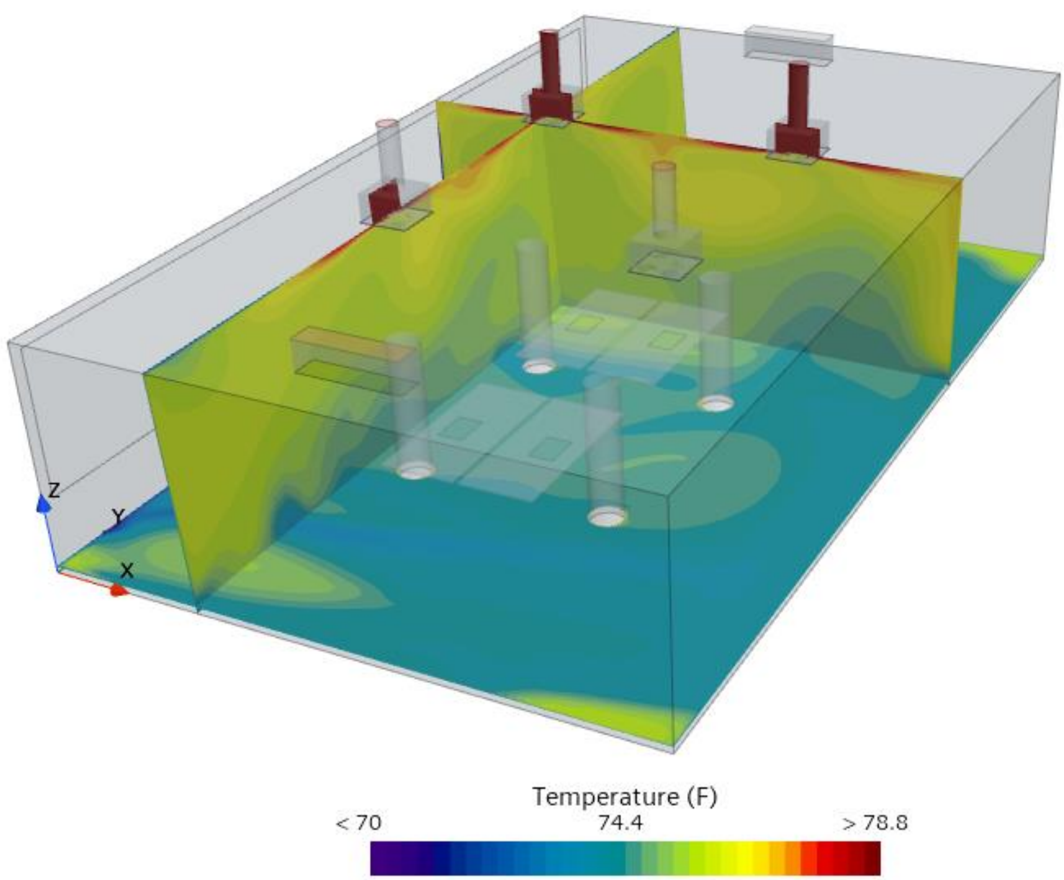
3in from the floor
Average at 74.5°F

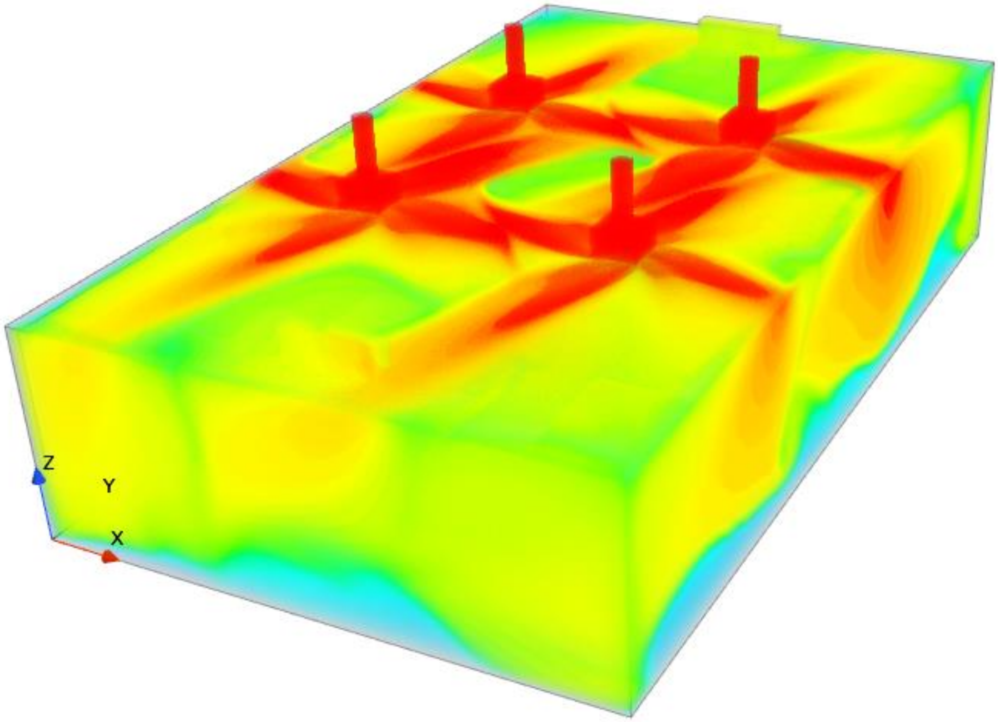


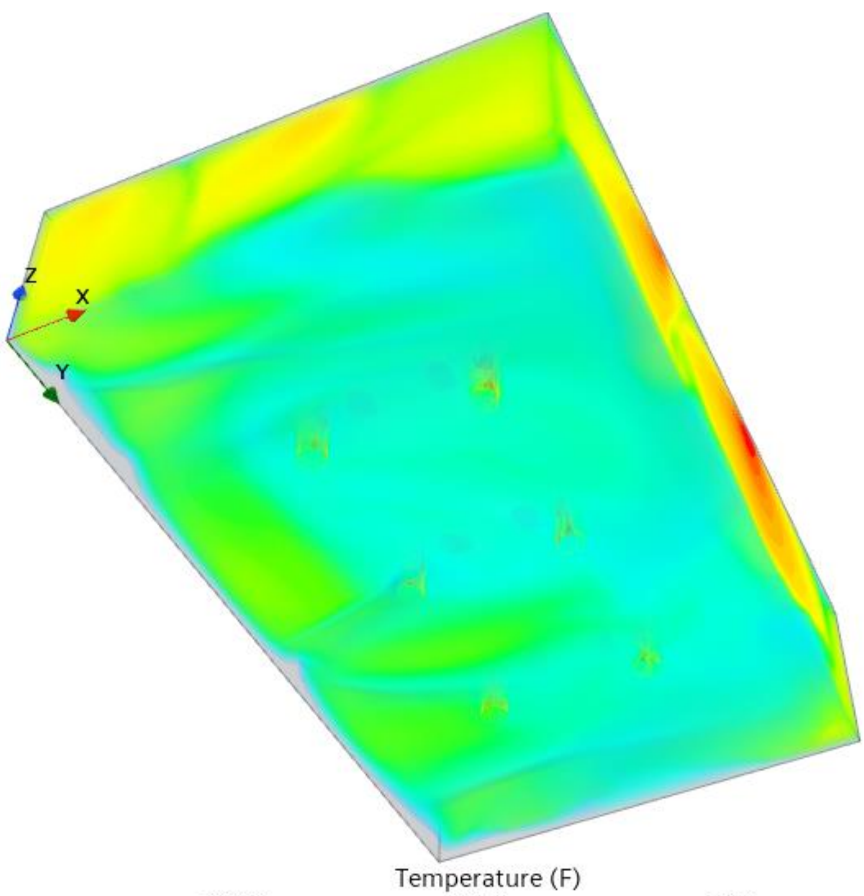
4ft from the floor
Average at 75.4°F

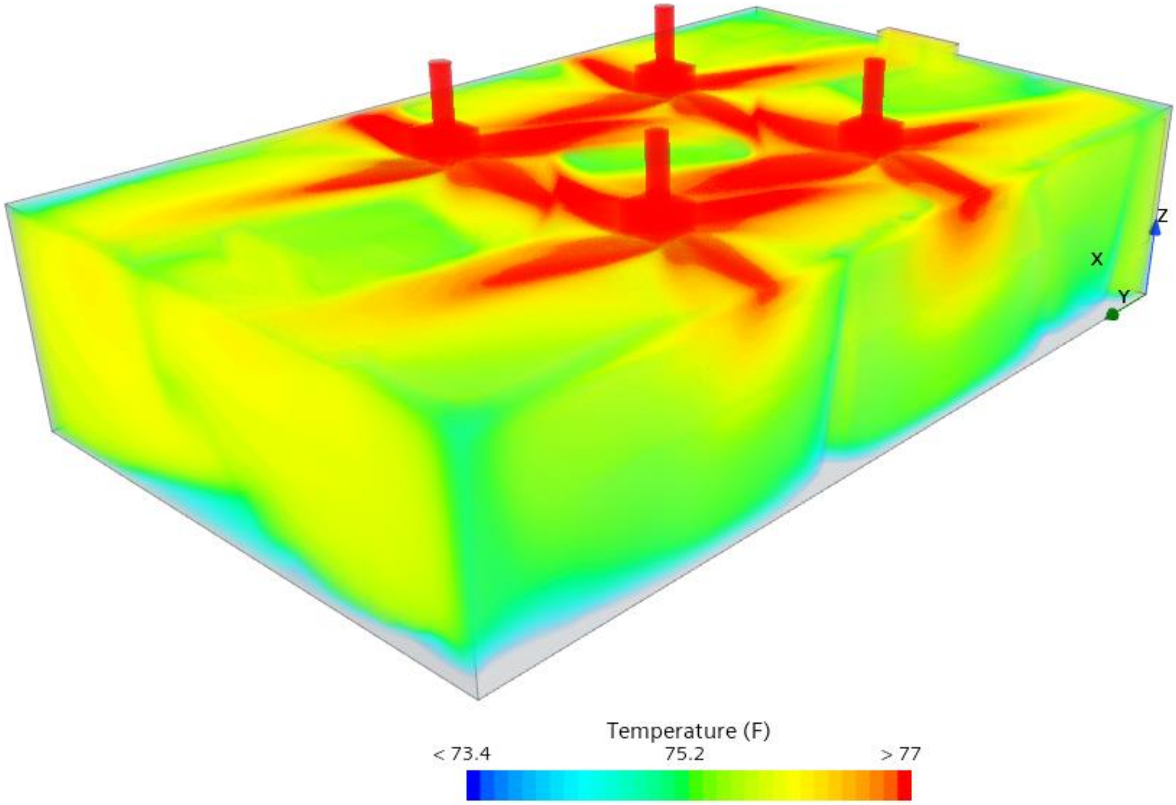


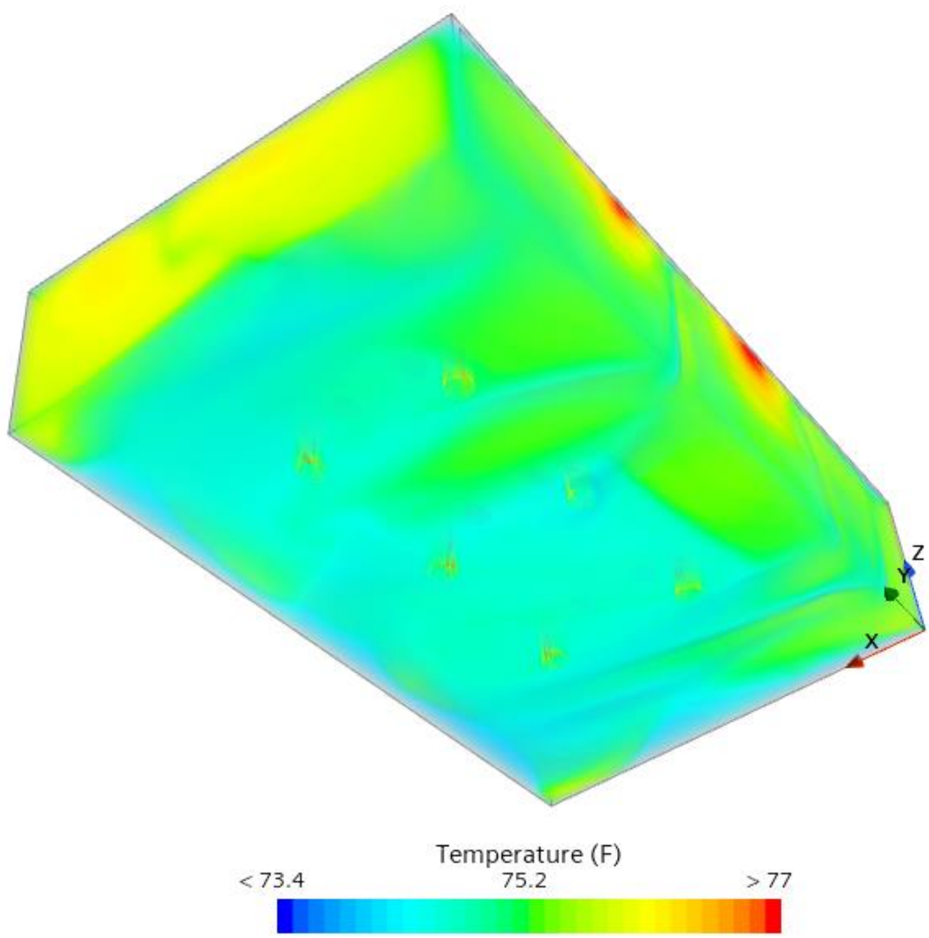
6ft from the floor
Average at 75.7°F



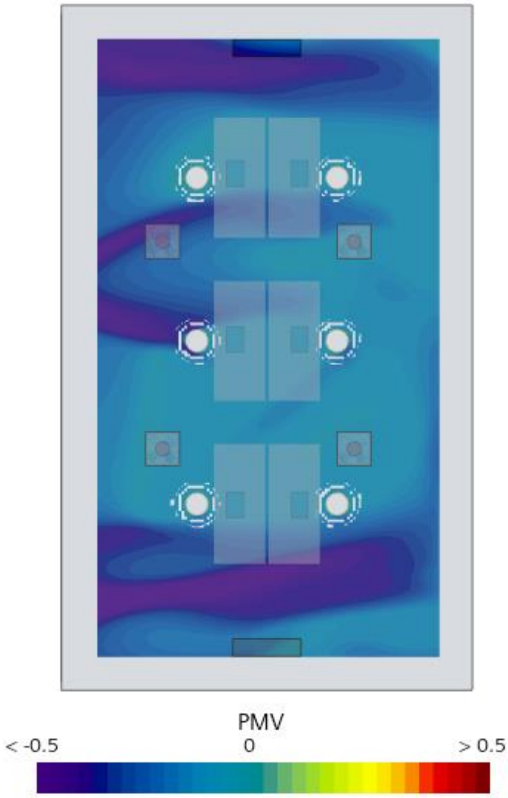

Z
Y
X
Temperature (F)
< 73.4
75.2
> 77


Z
X
Y
Temperature (F)
< 73.4
75.2
> 77

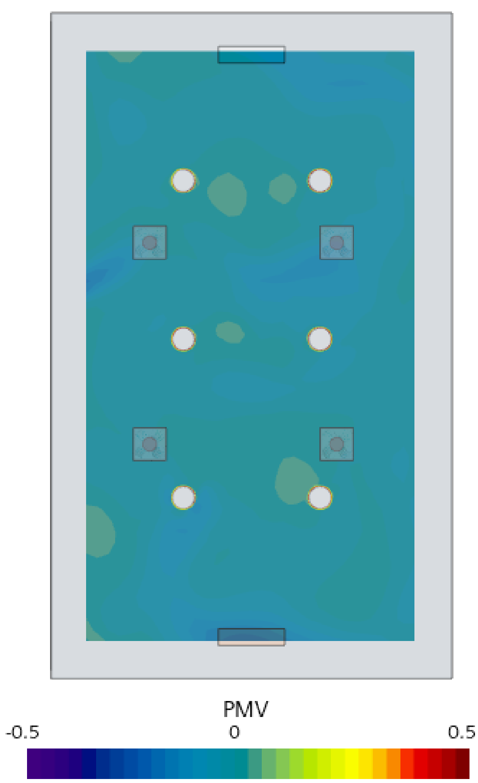

Z
X
Y
Temperature (F)
< 73.4
75.2
> 77


Z
Y
X
Temperature (F)
< 73.4
75.2
> 77

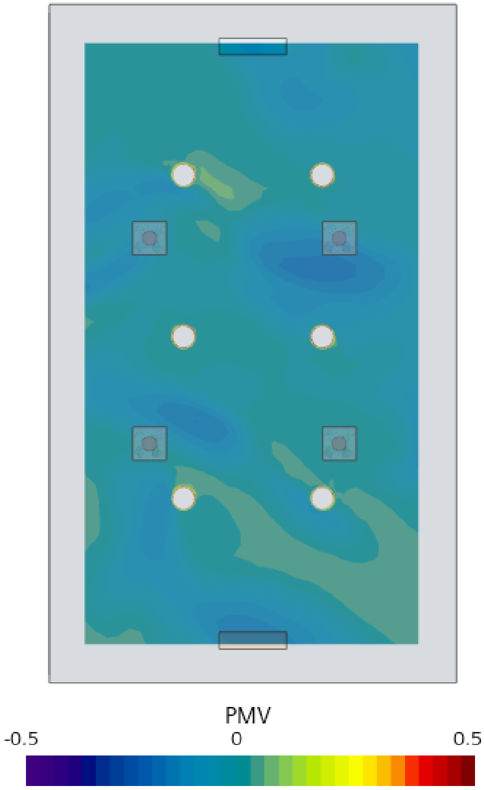
Predicted Mean Vote (PMV)



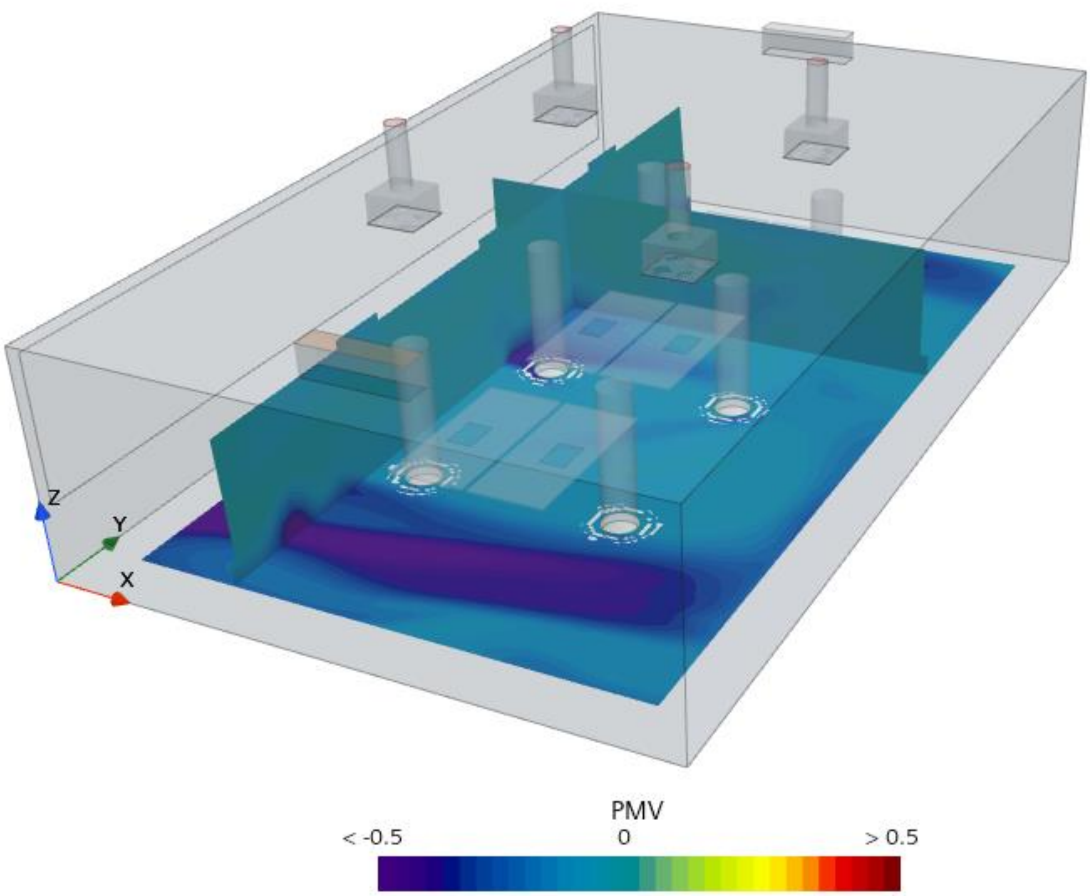
3in from the floor
Average at -0.21



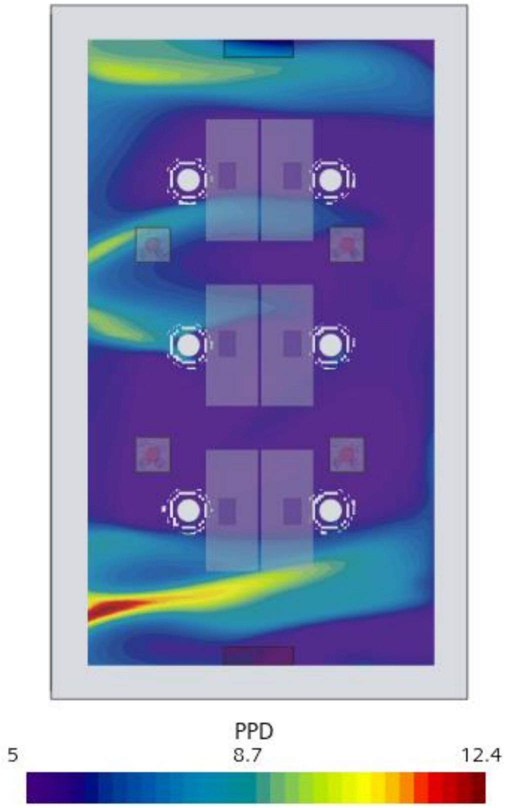
4ft from the floor
Average at -0.05



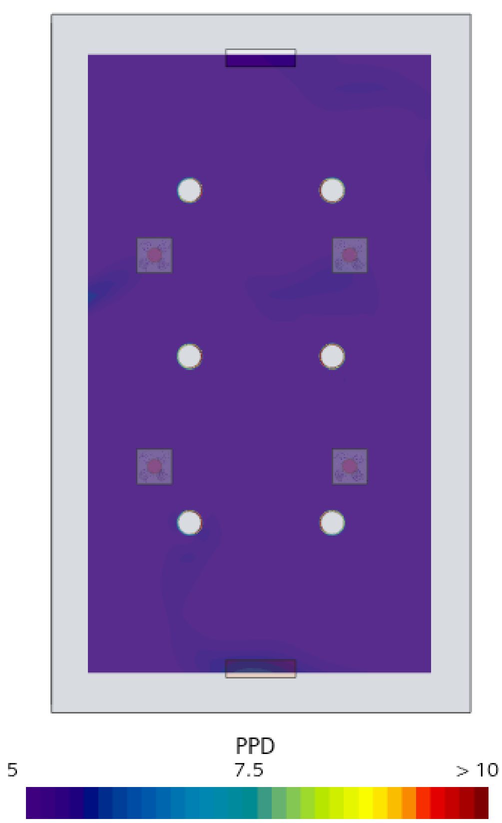
6ft from the floor
Average at -0.05



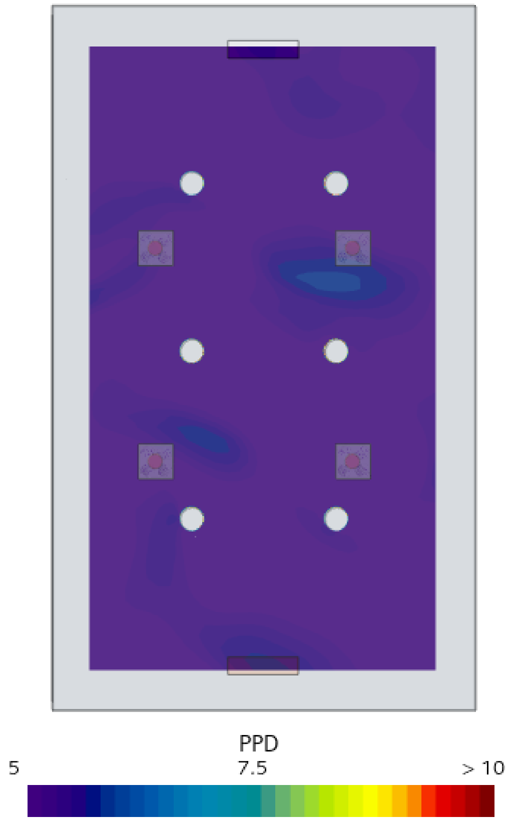
Predicted Percentage Dissatisfied (PPD)



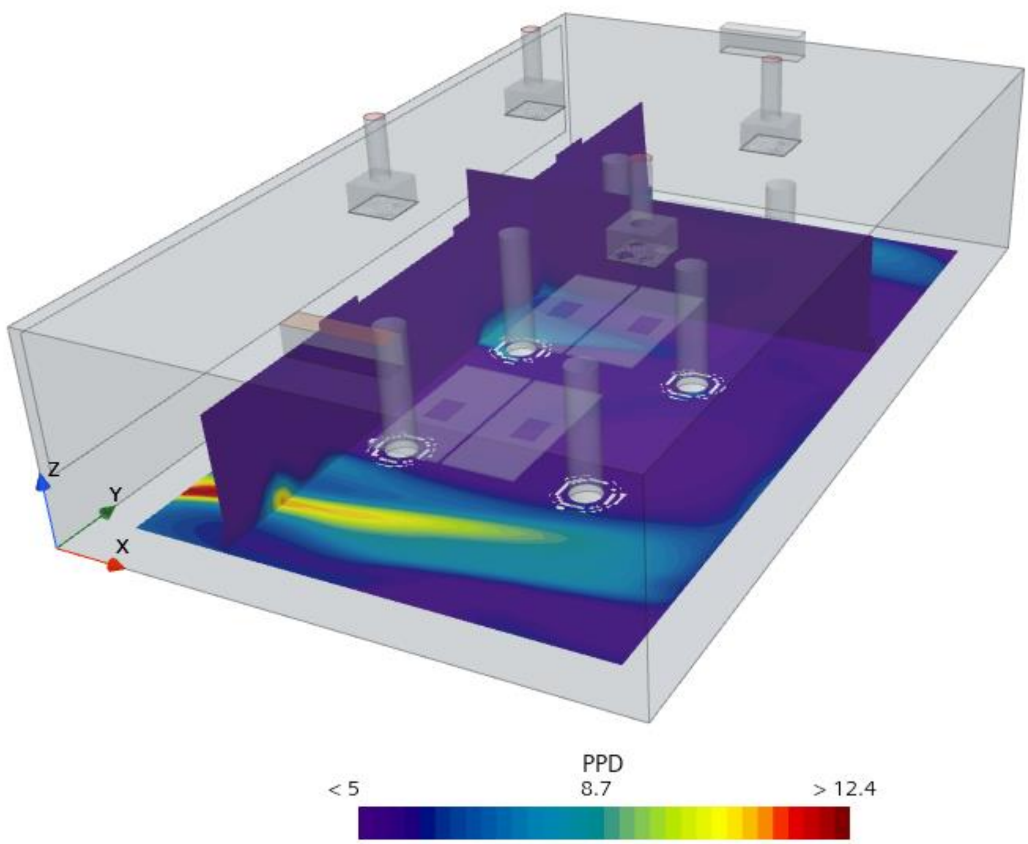
3in from the floor
Average at 6.2%



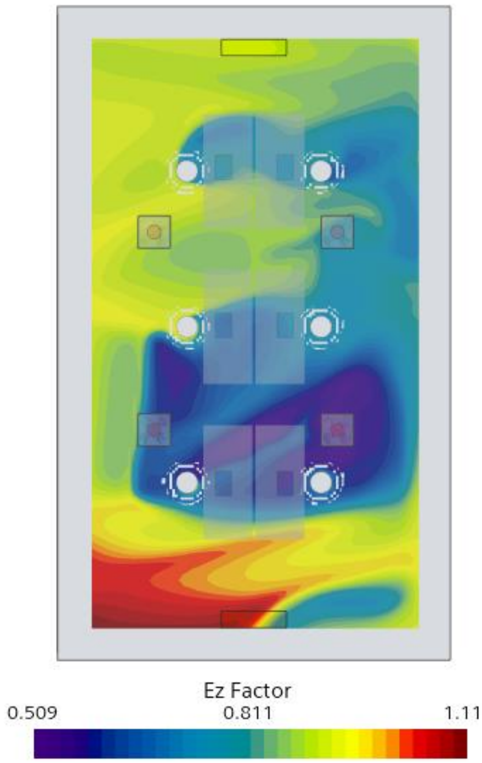
4ft from the floor
Average at 5.1%



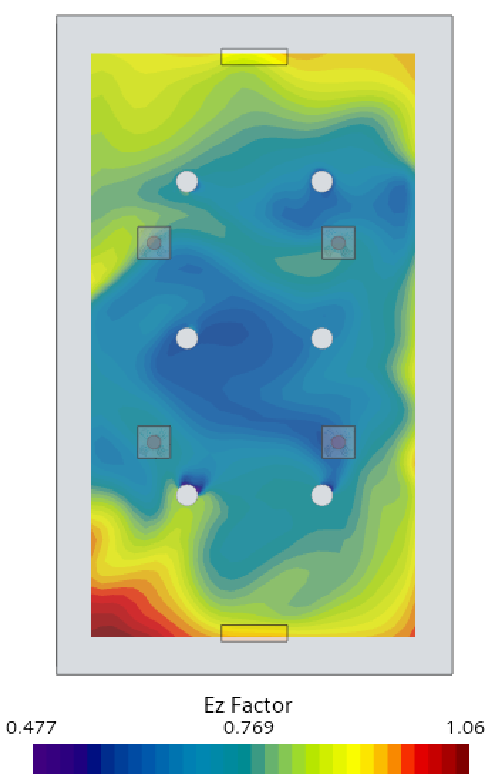
6ft from the floor
Average at 5.1%



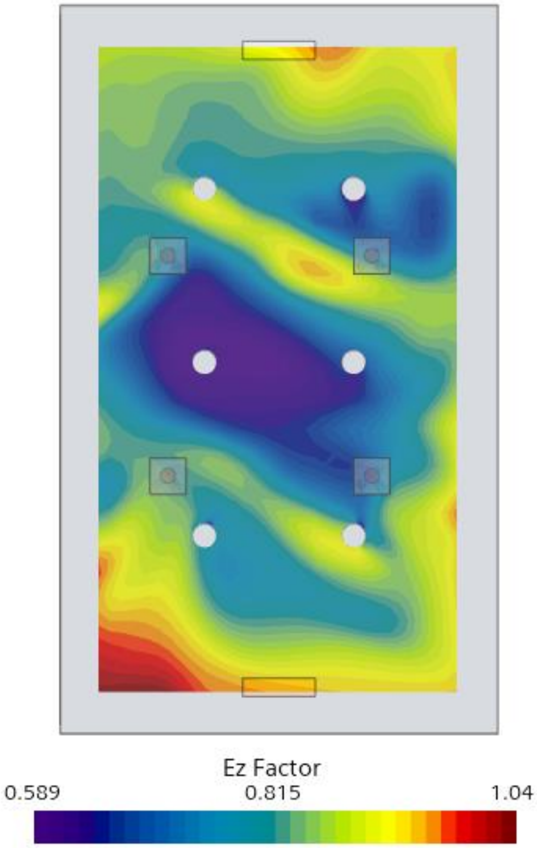
Zone Air change Effectiveness (Ez Factor)



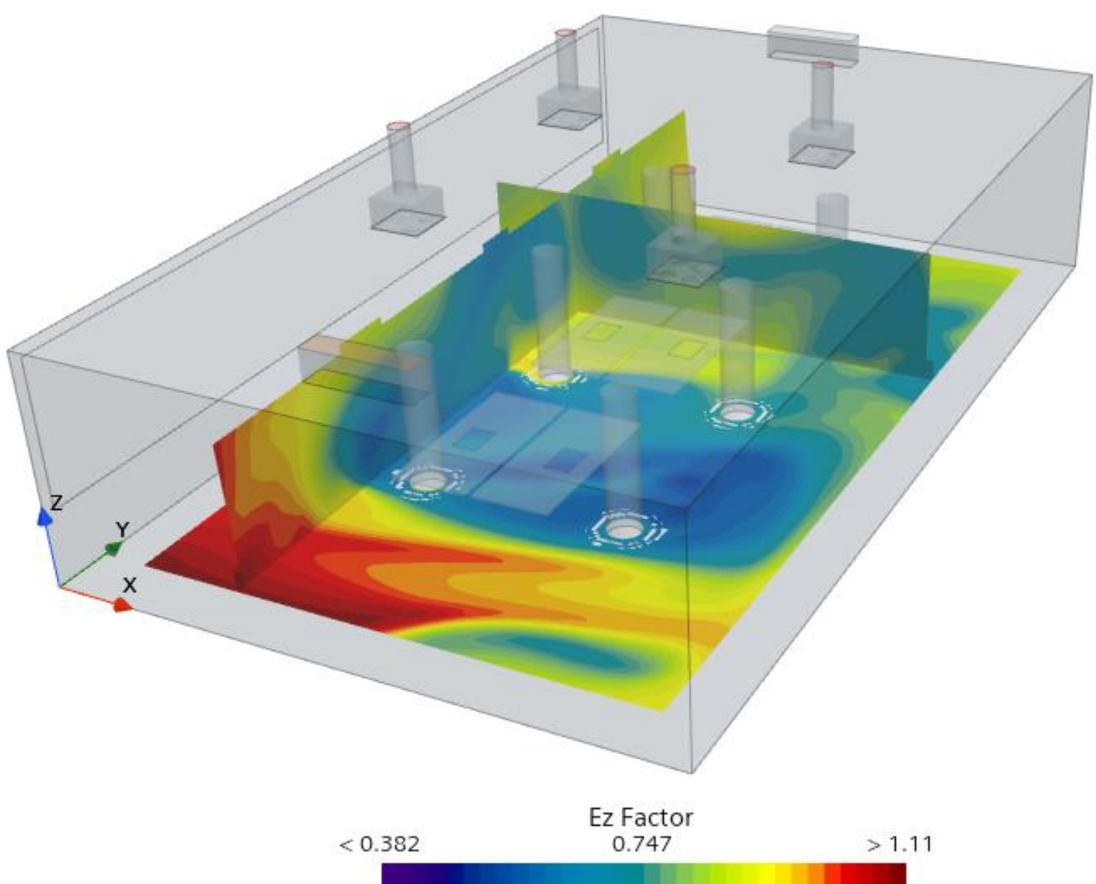
3in from the floor
Average at 0.81



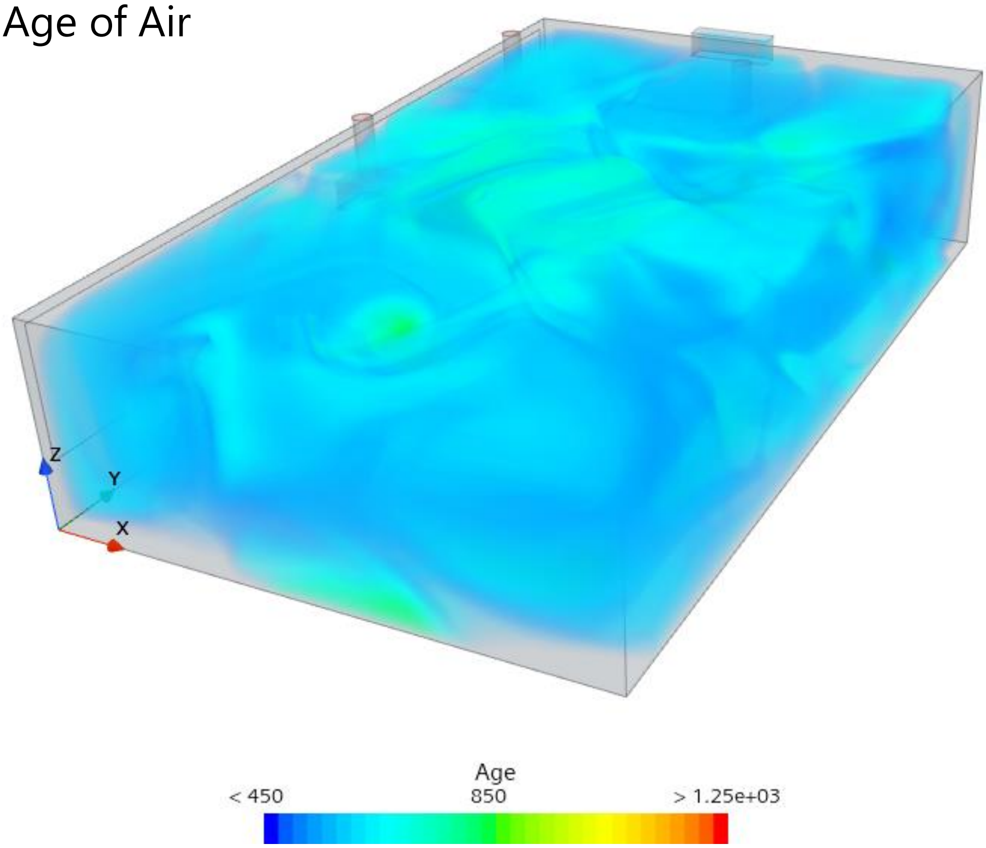
4ft from the floor
Average at 0.77

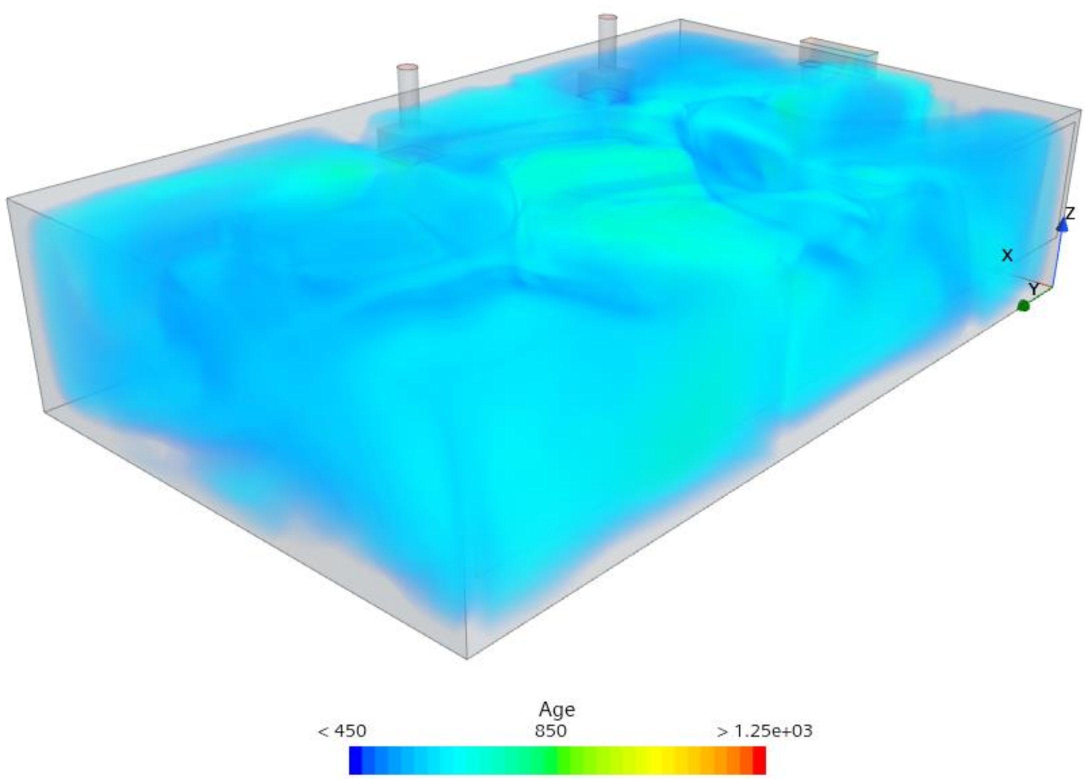


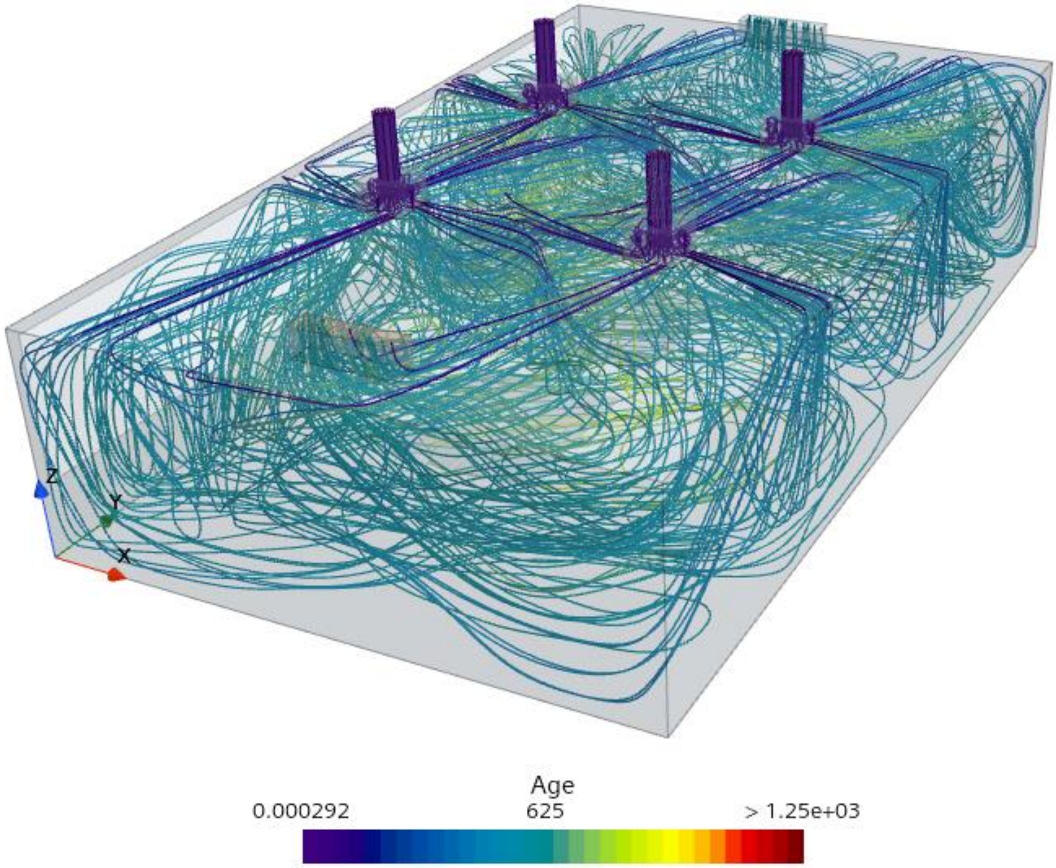
6ft from the floor
Average at 0.76

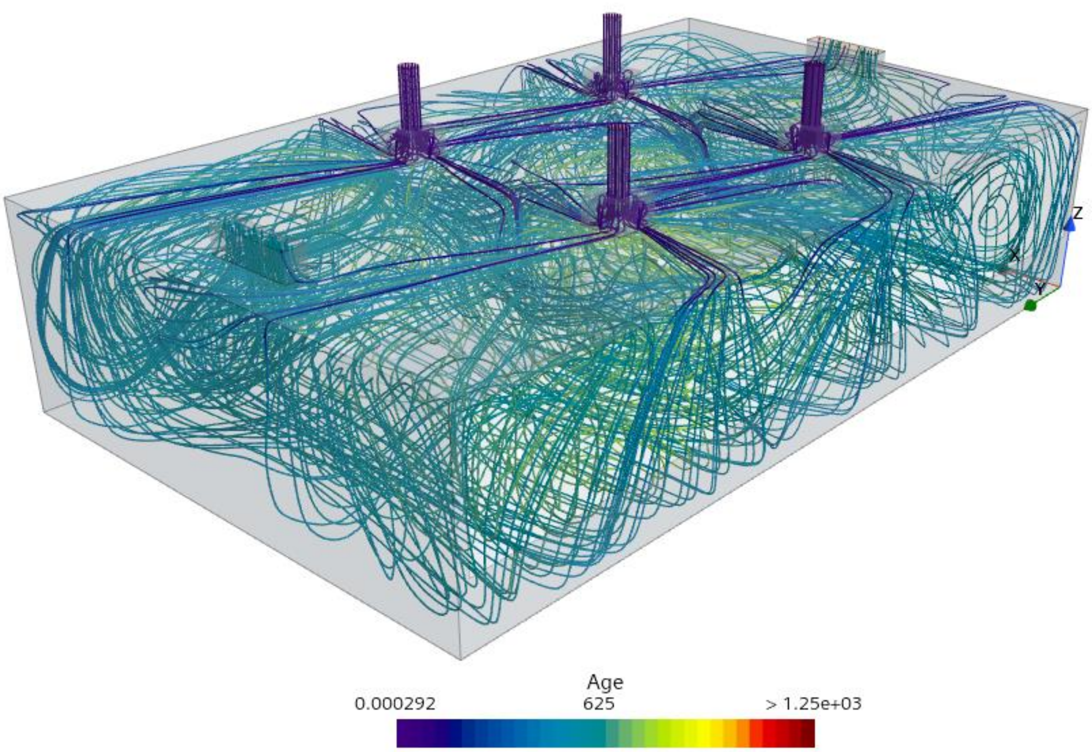


Mean Age of Air

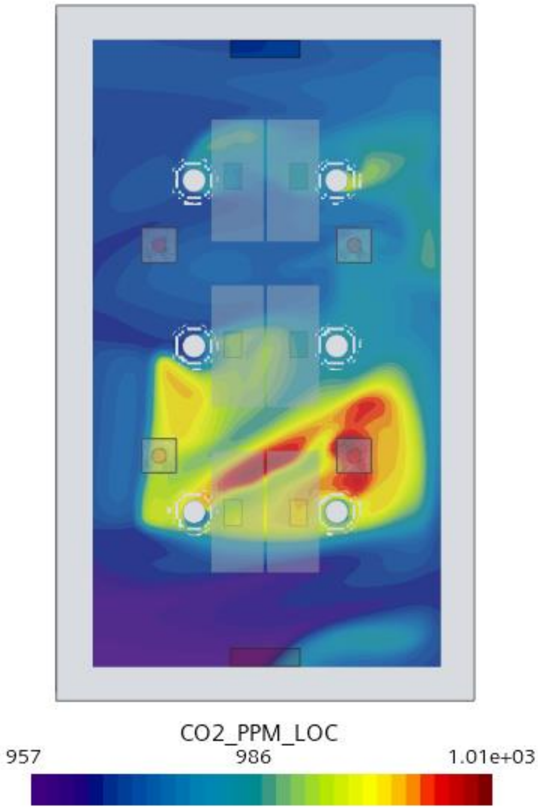





Z
Y
X
Age
0.000292
625
> 1.25e+03

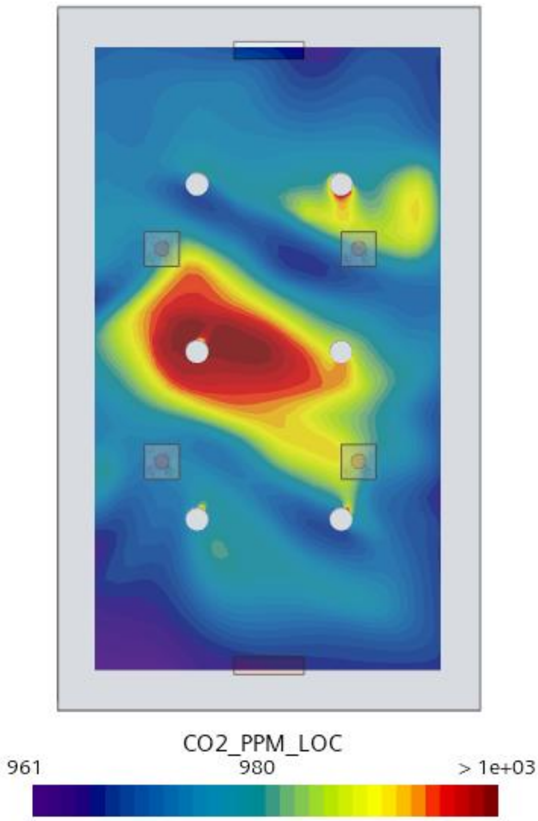

Z
X
Y
Age
0.000292
625
> 1.25e+03

CO2 Breathing Zone Concentration (PPM)

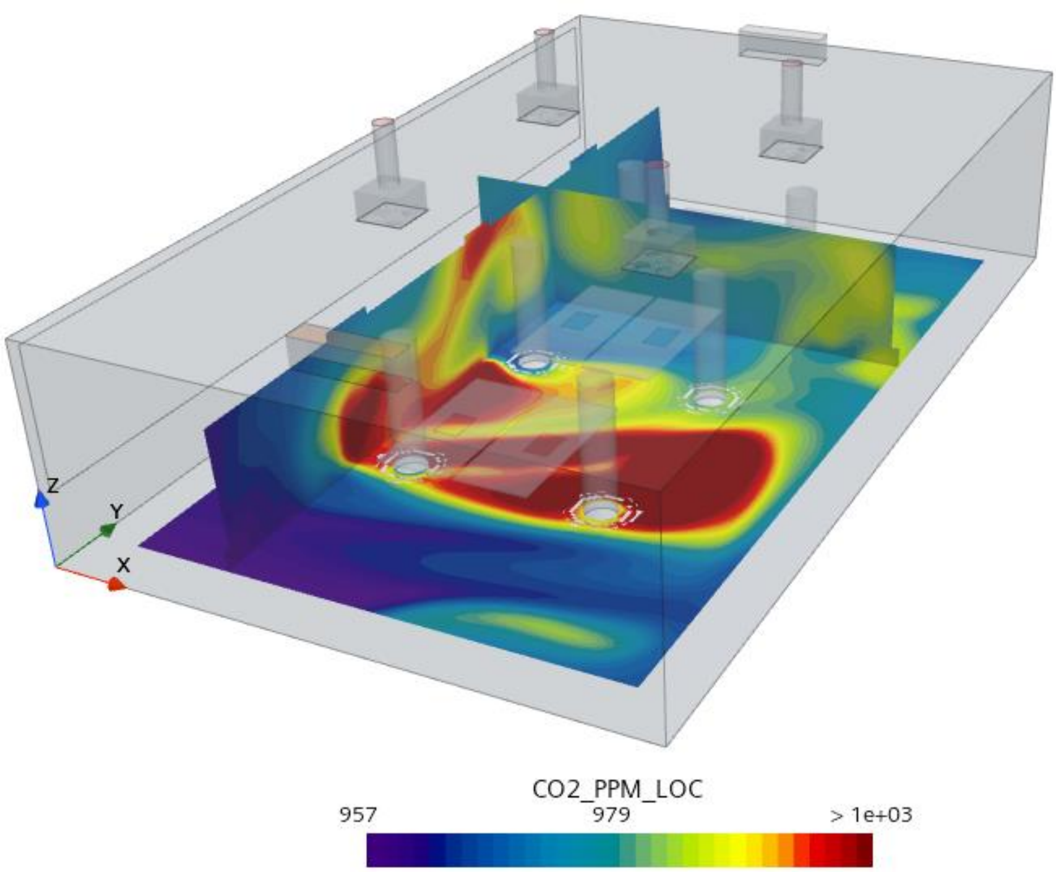


3in from the floor
Average at 978 ppm

4ft from the floor
Average at 980 ppm



6ft from the floor
Average at 977 ppm



EffectiV HVAC inc.

EFF0122001 : Development Room – 3-CONES - Cooling

January 12th 2023

Yannick Sirois, ing., M.Sc.A.,Ph.D. No OIQ : 130045

Lx Sim Inc.
400 rue Shefford, local 117
Bromont. Québec
J2L 3E7. Canada
Tel. : 450.919.1714
info@lxsim.com
www.lxsim.com

Simulation Summary

Diffuser Configuration

Inlets	Type
4	3-CONES 24

Cooling Conditions

Property	Value
Outside temperature	90.0°F
Air supply temperature	55.0°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	0.57 CLO (trousers, short sleeve shirt)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

Cooling Results

Properties	Value
Outlet air temperature	77.3°F
Average flow rate	1325 CFM
Theoritical air age at outlet	389 s
Real air age at outlet	363 s
Ez Factor	1.05
CO2 PPM	790
PMV	-0.79
PPD	20.5

Mandate

Lx Sim has the mandate to analyze the performance of the ventilation system inside a room using a CFD approach

Ventilation system performance is quantified in terms of:

- Mean Age of Air measured at the extraction
- Zone Air Distribution Effectiveness (Ez Factor)
- Occupants thermal comfort (Predicted Mean Vote and Predicted Percentage of Dissatisfied)

Methodology

Each CFD simulation is performed in Simcenter STAR-CCM+ from Siemens

General modeling is based on:

- CFD best practices
- ANSI/ASHRAE Standard 62.1-2019 (Air quality)
- ANSI/ASHRAE Standard 55-2017 (Thermal comfort)

CAD

- The simulation is performed using a 3D representation of the room to be studied
- The room is built according to plans provided
- The model includes the following features and surfaces:
  - Walls
  - Windows
  - Air diffusers
  - Air diffusers feed ducting (if necessary)
  - Air room extractor
  - People (if necessary)
  - Other major obstacles (if necessary)

Mesh

In order to solve fluid mechanics transport equations, the 3D geometry must be discretized in small elements

Element size must be small enough that numerical diffusion does not occur and that all physical effects in the fluid are modeled appropriately

In the ventilation simulation, the most restrictive geometric feature is the air diffuser

The air diffuser requires a mesh small enough so that flow directions and velocities represent reality

General CFD physics modeling

Simulations is in accordance with ANSI/ASHRAE Standard 62.1-2022 - Normative Appendix C.

The following modeling options are used:

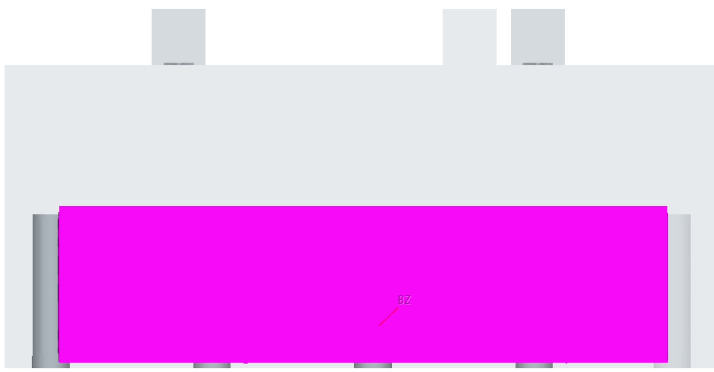
- Steady state approach
- Turbulence modeling active
- Energy and gravity activated
- Species transport
- Surface to surface radiation is modeled

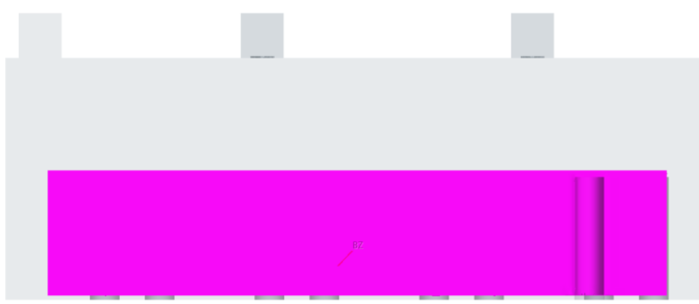
Breathing Zone

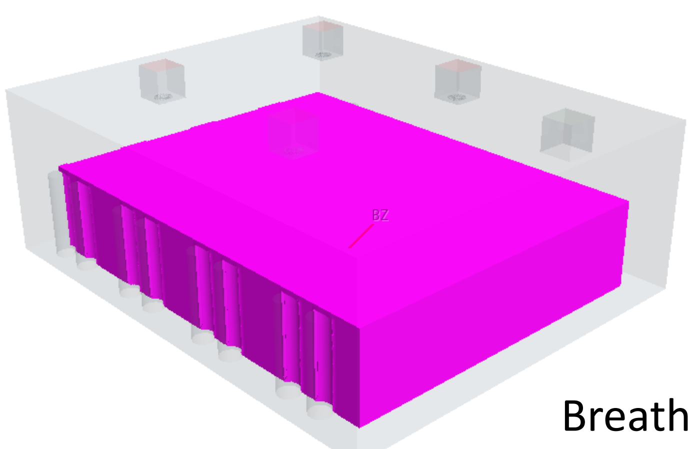
For multiple calculations in this simulation, the breathing zone is used

The breathing zone is defined as per ANSI/ASHRAE Standard 62.1-2022 - Section 3

breathing zone: the region within an occupied space between planes 3 and 72 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment.







Breathing zone example

Imposed Flow

- Flow rate in CFM is imposed at each inlet
- Temperature is imposed at each inlet
- Depending on the choice, a proportional error correction is implemented on either the flow rate or the temperature in order to reach the specified setpoint for the temperature in the room
- The temperature in the room to be compared to the setpoint is measured in each cell of the breathing zone and averaged over it
- Since the simulation is in steady state, the final flow rate and air inlet temperature represent an average value corresponding to a continuously running heating or cooling system

Operating conditions

- External conditions
    - External temperature is specified for heat transfer through walls, windows and radiation through the windows
- Walls and windows isolations is specified using U-Factor or R-Factor
- Human heat sources
    - Heat flux through a simple human shape
    - Heat flux defined using the Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2022

Air Age at Extraction

- To measure air age, the simulation uses a transported passive scalar
    - Does not affect flow in any way
    - Increases with time between the inlets and the outlets
- Average age is measured at the outlets using mass average procedure and is compared to the theoritical value

Zone Air Distribution Effectiveness (Ez Factor)

- All Ez Factor calculations are made in accordance with ANSI/ASHRAE Standard 62.1-2022 – Normative Appendix C
- A mass source of a tracer gas species, such as CO_2 is introduced inside the breathing zone volume and uses the specied transport equations
- A mass averaged measure of the molar concentration of the tracer gas at the inlet and exhaust are taken

- The Ez Factor is measured for each mesh cell inside the breathing zone
- The global Ez Factor value is then the volume average of the Ez Factor values inside the breathing zone
- All other requirements for CFD modeling are respected in the model

Thermal Comfort

- Thermal comfort is evaluated with the values of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)
- All calculations are made according to ANSI/ASHRAE Standard 55-2017
- The CFD model implements the code proposed in Appendix B of said standard
    - Values are computed on each cell of the mesh and are available in the complete simulation for visualization and post-processing

Thermal Comfort – Required information

Clothing value

The clothing value describes the types of clothes worn by the occupants.

- Data must be provided in ''clo'' units
- Typical values are shown in Table 5.2.2.2A – Clothing Insulations Icl values for typical ensembles in ANSI/ASHRAE Standard 55-2017

Metabolica rate

The metabolic rate of occupants

- Depends on occupation
- Must be provided in ''met'' units
- Typical values are shown in Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2017

External work

Also in ''met'' units

Generaly around 0 except in very physical action by the occupants

Air temperature

Provided in each cell by the cfd model

Air velocity

Provided in each cell by the cfd model

Mean radiant temperature

Average wall surface temperature provided by the CFD model

Relative humidity

Provided in %

Case Study Presentation

CAD

- Room Dimensions:

Side	Dimension
Length	40 ft
Width	24 ft
Height	9 ft

- 1 window (west)

Properties	
U-factor	0.24 BTU /(h*ft2*F)
SHGC	0.27

- Ceiling

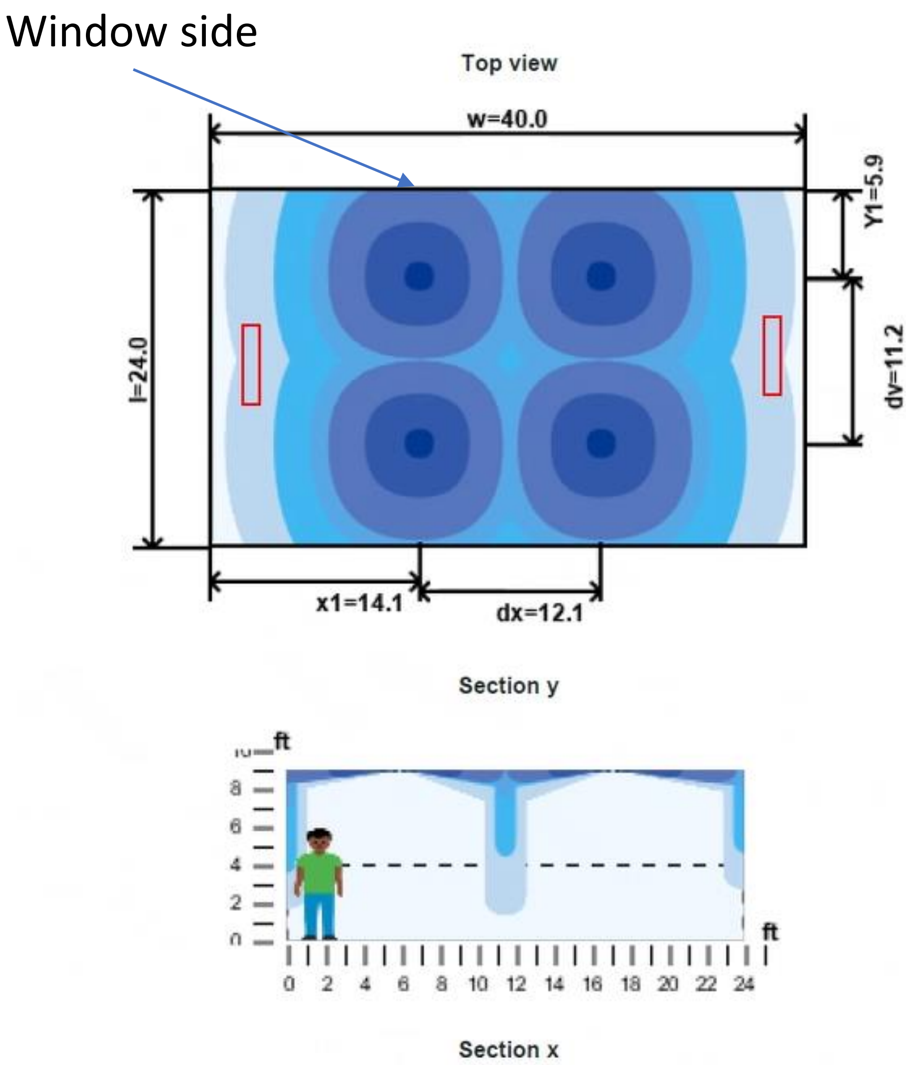
Properties	
U-factor	0.053 BTU /(h*ft2*F)

- Outside wall (west)

Properties	
U-factor	0.044 BTU /(h*ft2*F)

- Inlets and outlets positioned as follows

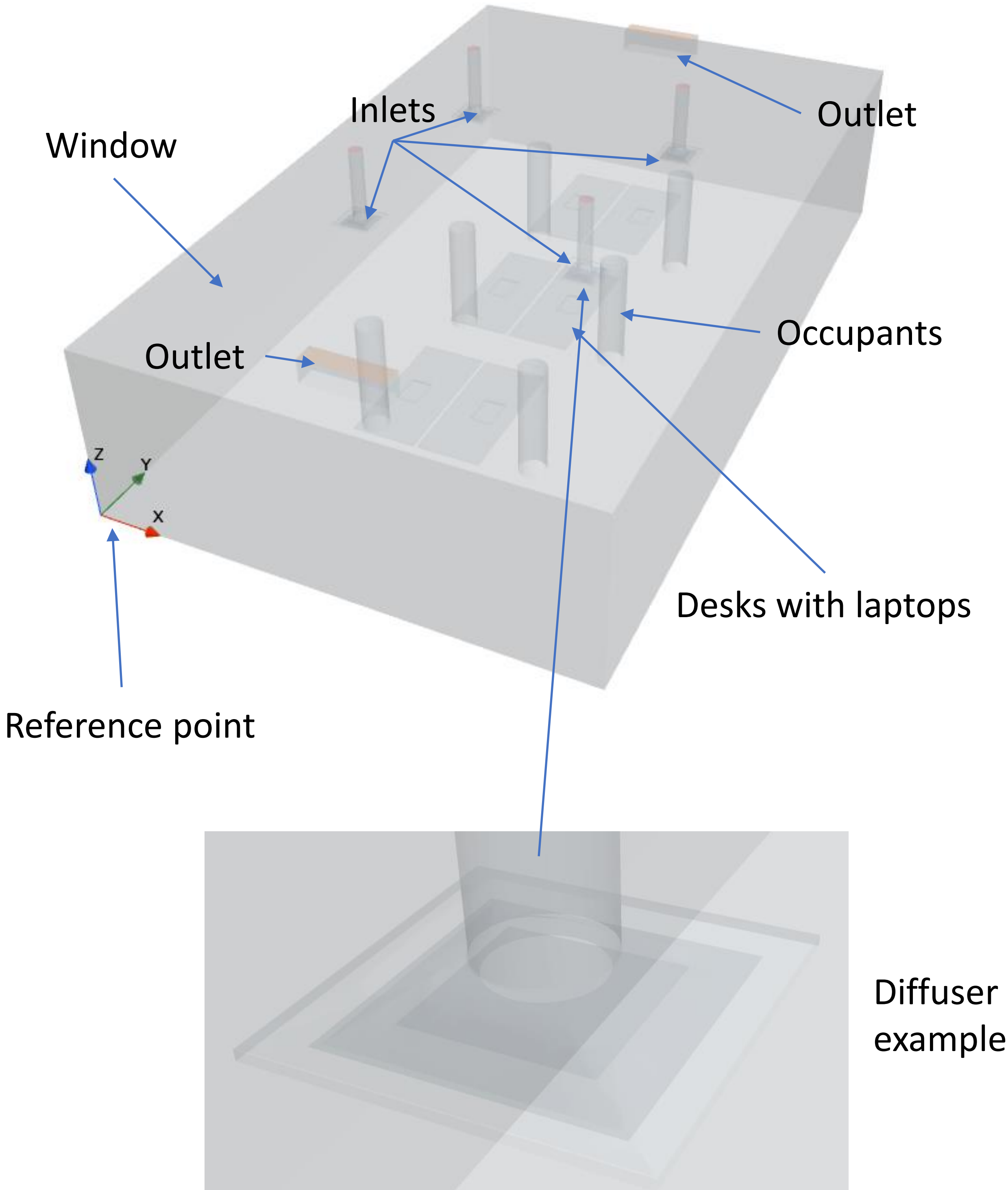
- Inlets and outlets positioned as follows



Diffusers

- 4 3-CONES 24

Resulting model



Cooling Conditions

Property	Value
Outside temperature	90.0°F
Air supply temperature	55.0°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
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Number of occupants	6
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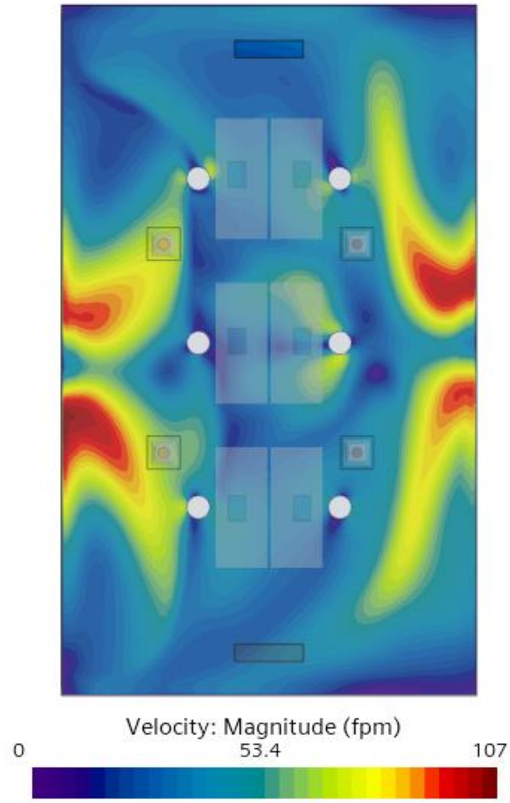
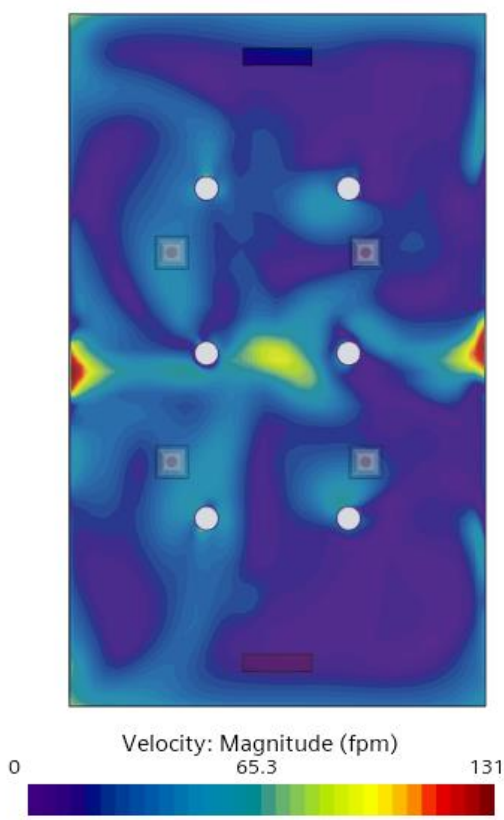
Cooling Results

Properties	Value
Outlet air temperature	77.3°F
Average flow rate	1325 CFM
Theoritical air age at outlet	389 s
Real air age at outlet	363 s
Ez Factor	1.05
CO2 PPM	790
PMV	-0.79
PPD	20.5

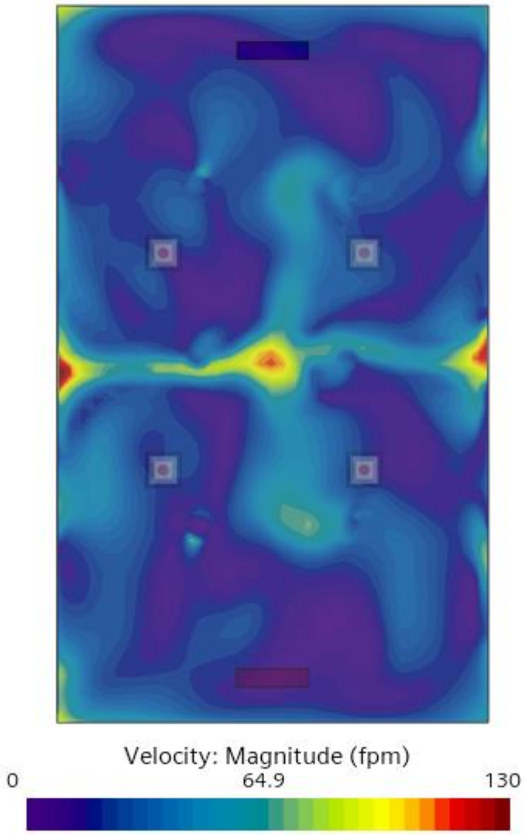
Air Velocity



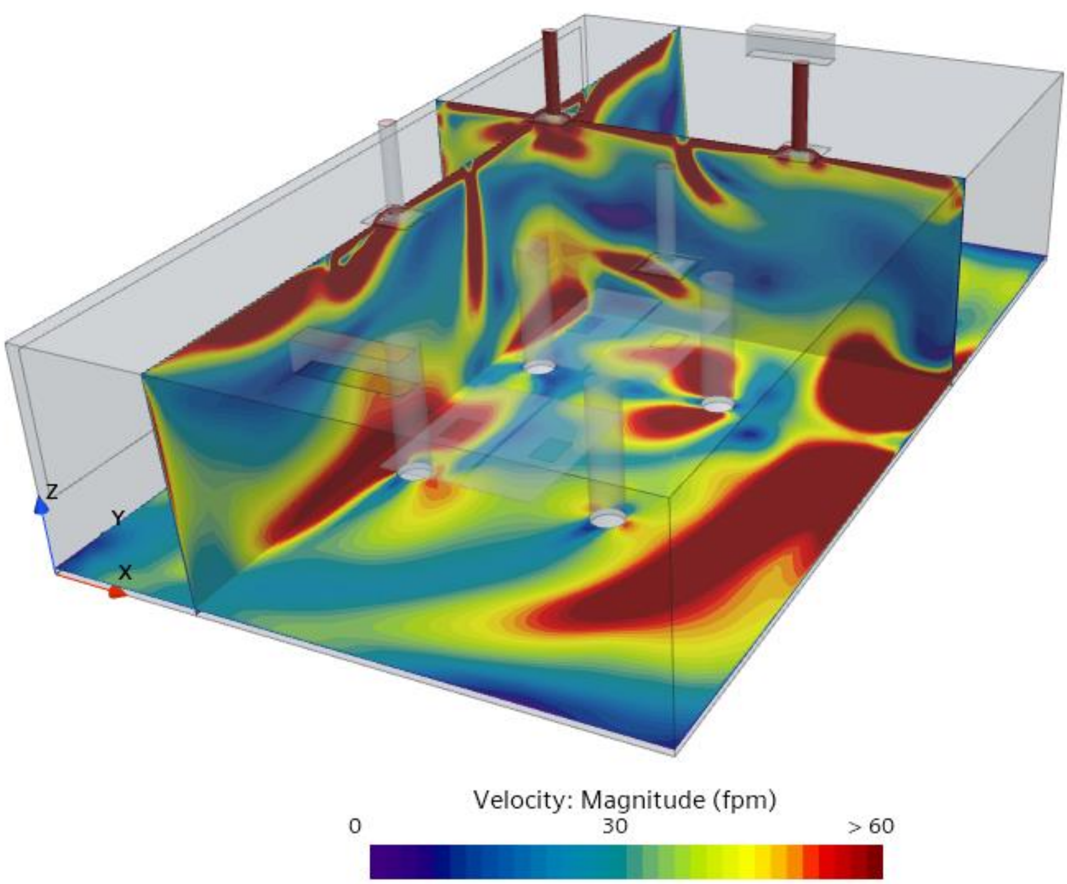
3in from the floor
Average at 45.2 fpm

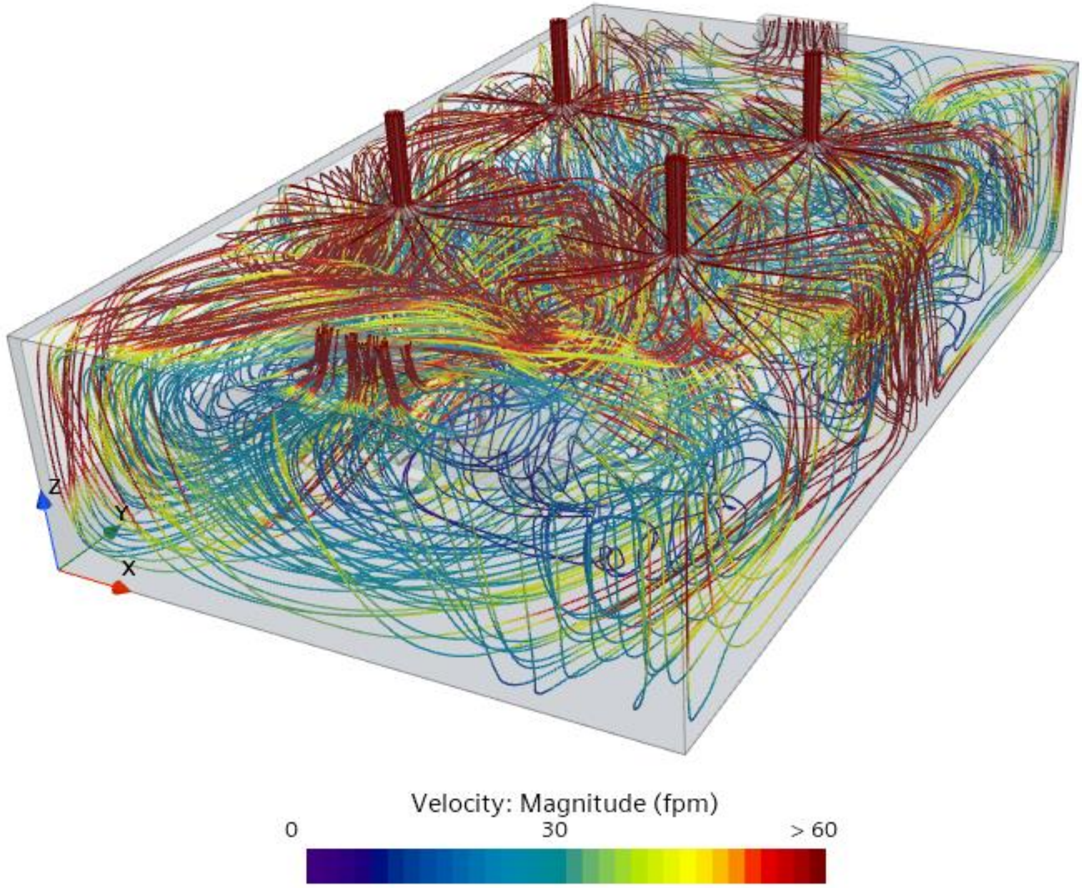


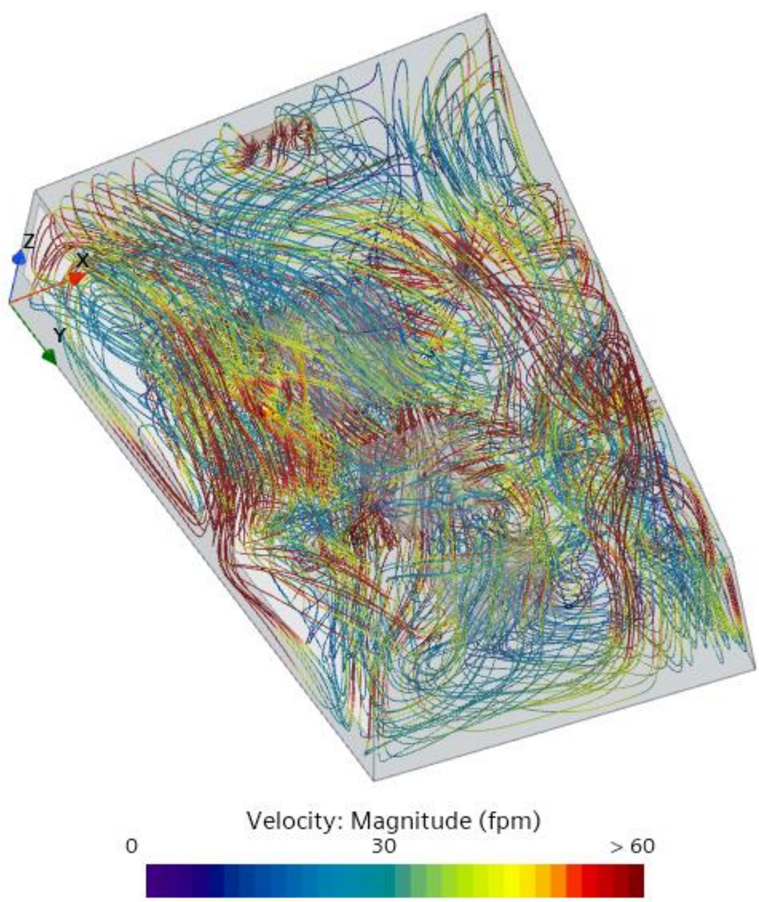
4ft from the floor
Average at 24.7 fpm

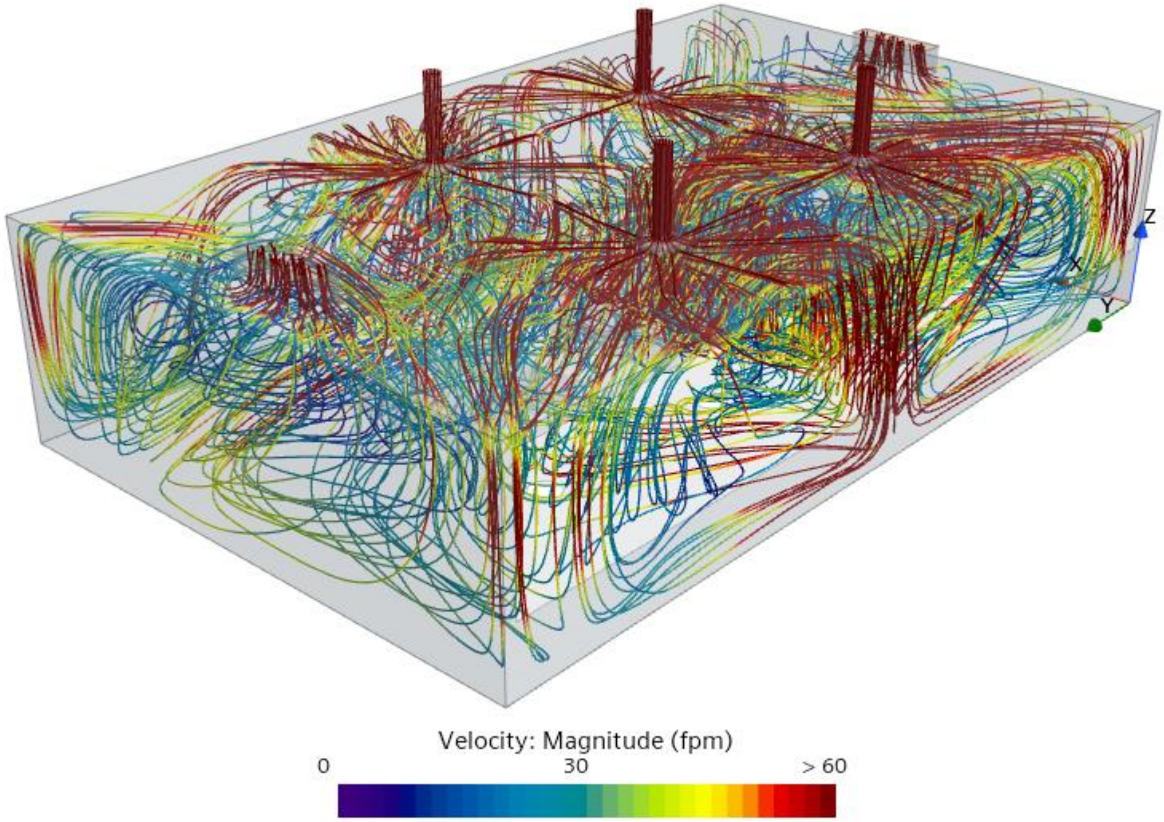


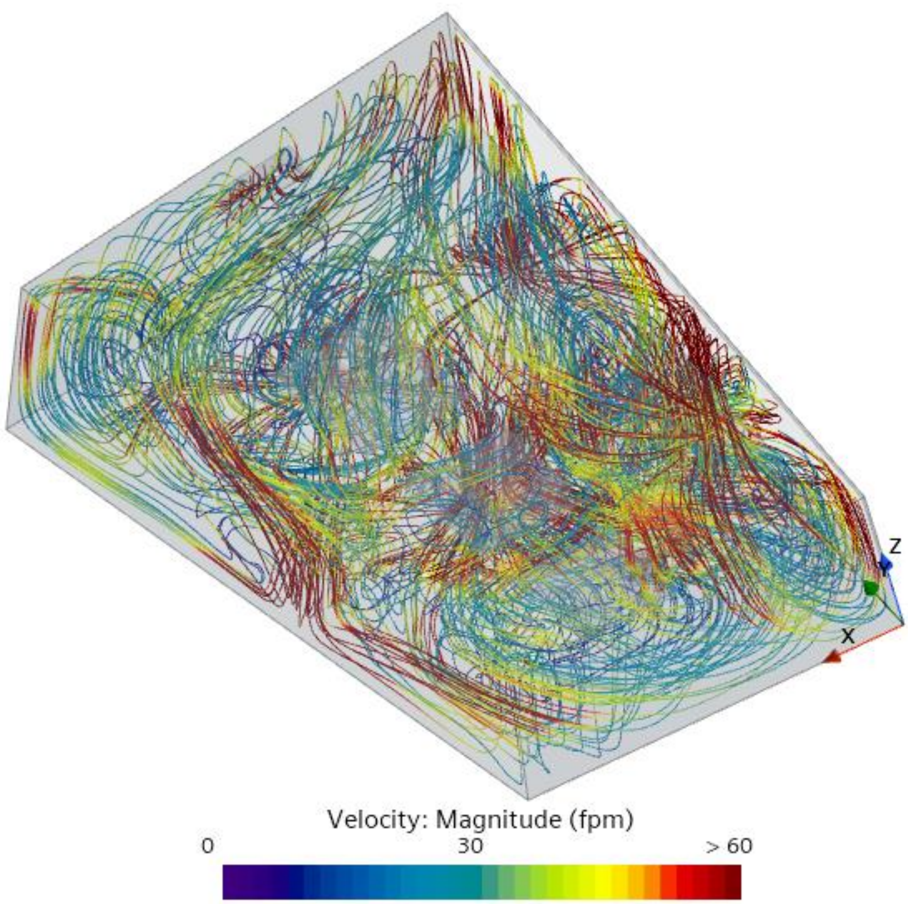
6ft from the floor
Average at 27.3 fpm

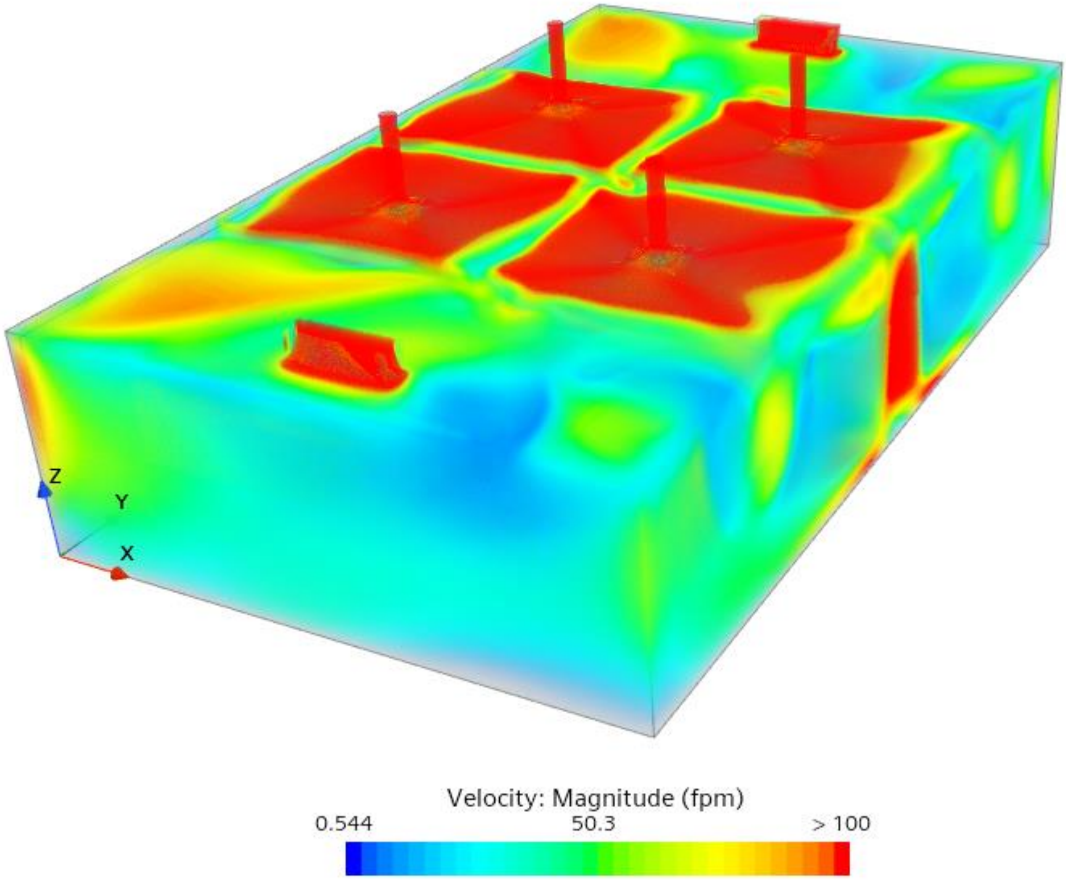



Z
Y
X
Velocity: Magnitude (fpm)
0
30
> 60


Z
X
Y
Velocity: Magnitude (fpm)
0
30
> 60


Z
X
Y
Velocity: Magnitude (fpm)
0
30
> 60


Z
X
Velocity: Magnitude (fpm)
0
30
> 60


Z
Y
X
Velocity: Magnitude (fpm)
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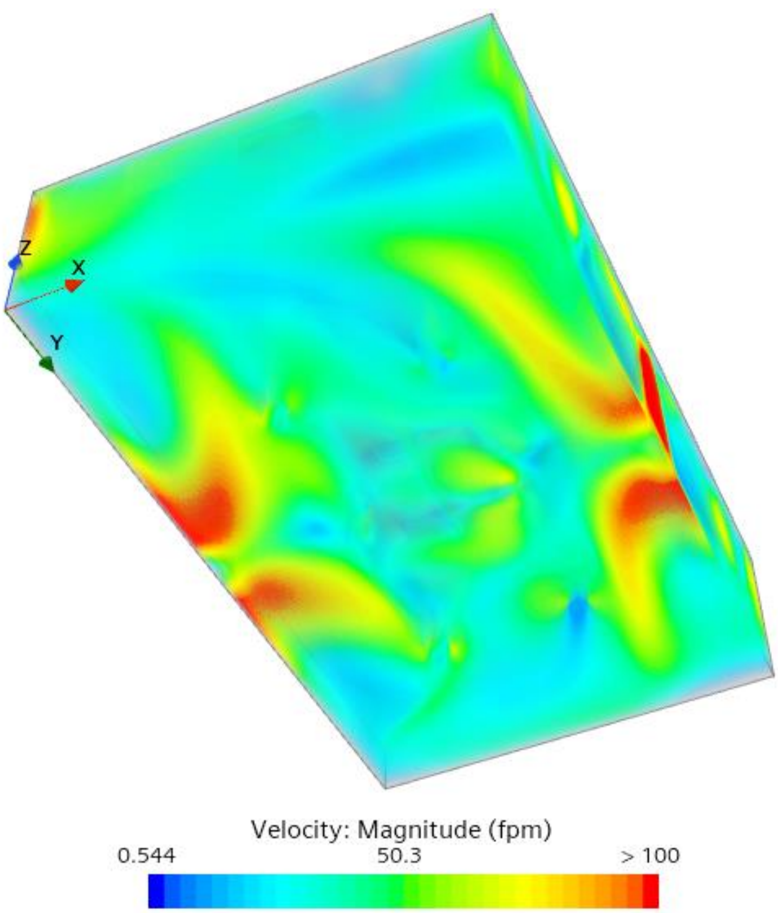
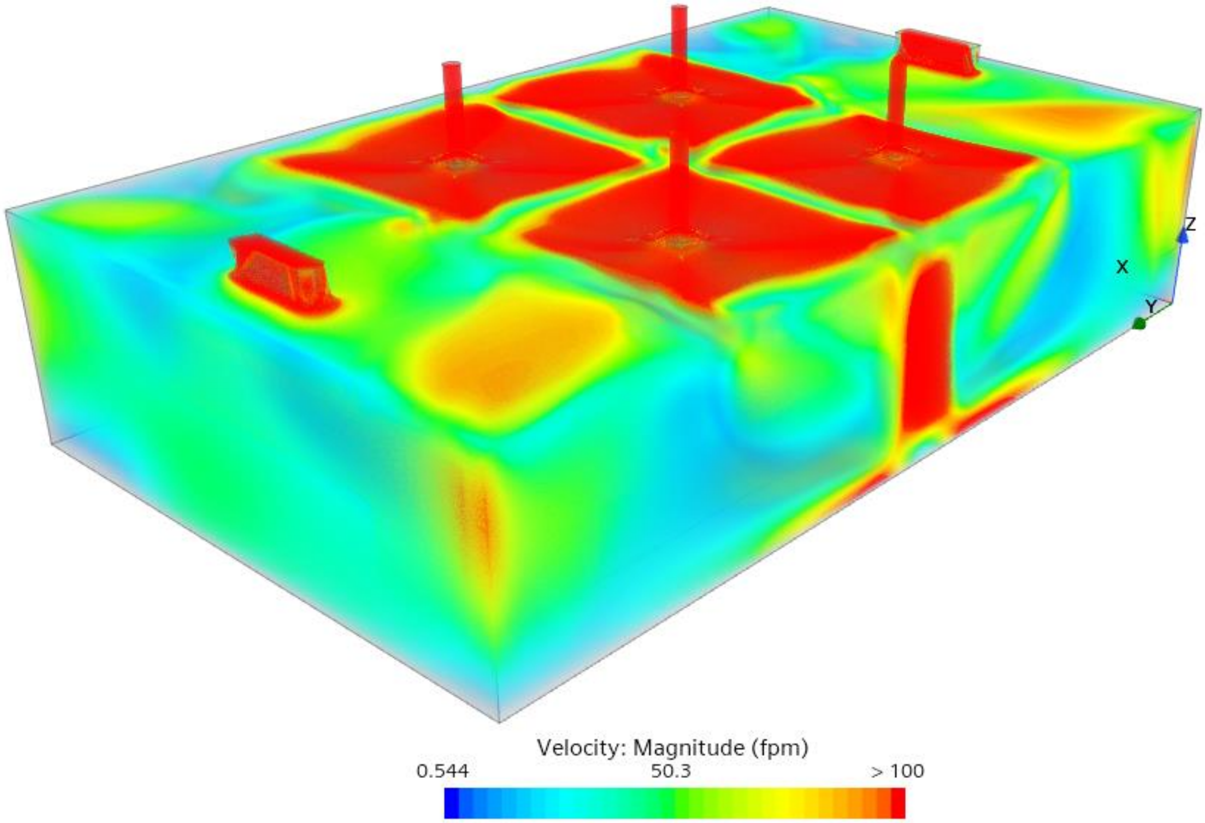
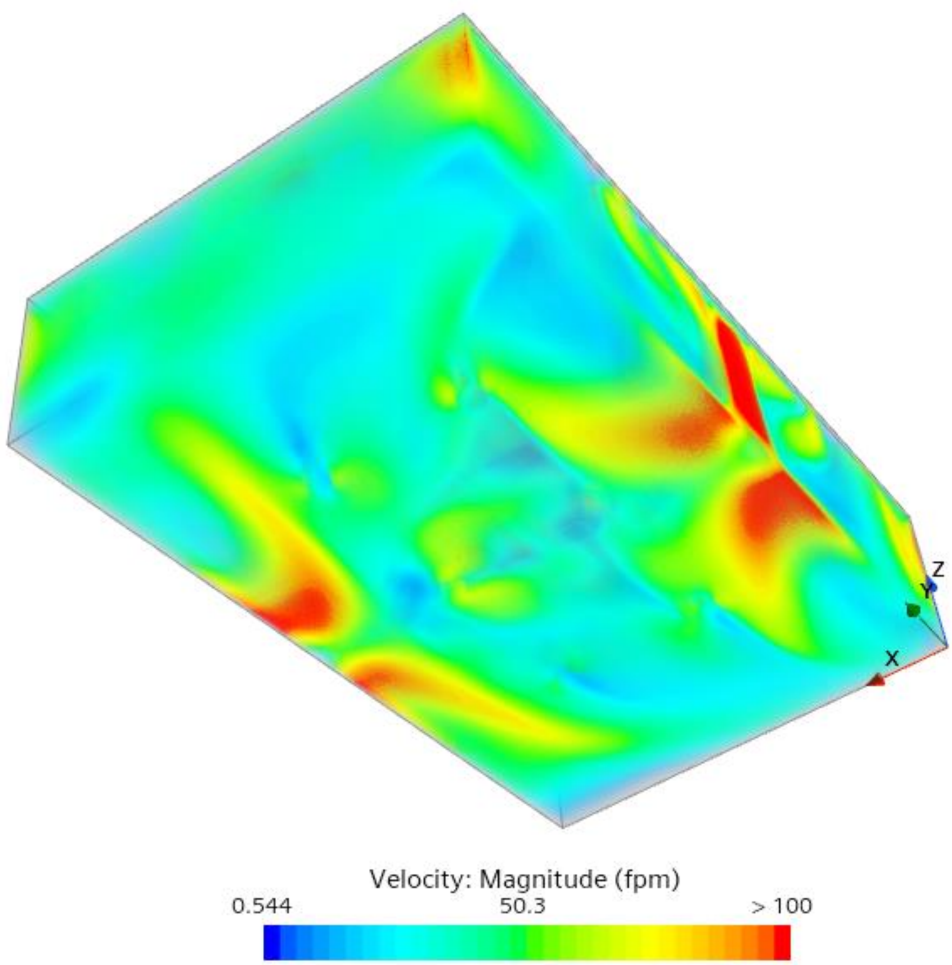
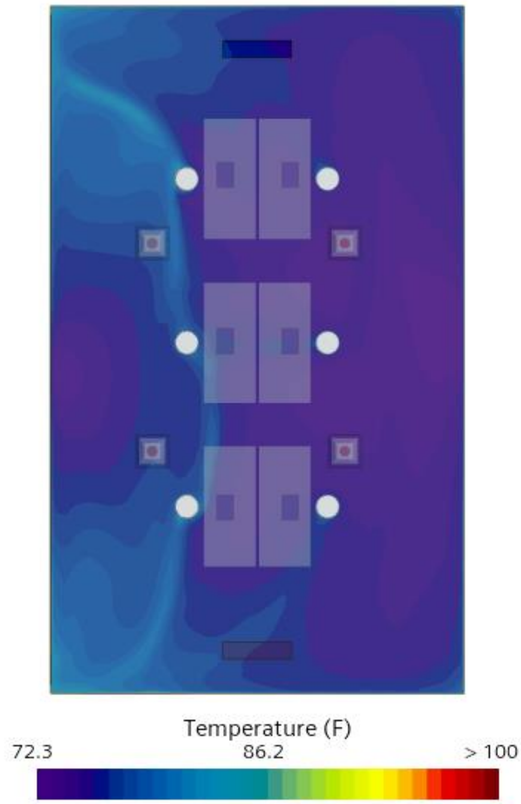
50.3
> 100


Z
X
Y
Velocity: Magnitude (fpm)
0.544
50.3
> 100

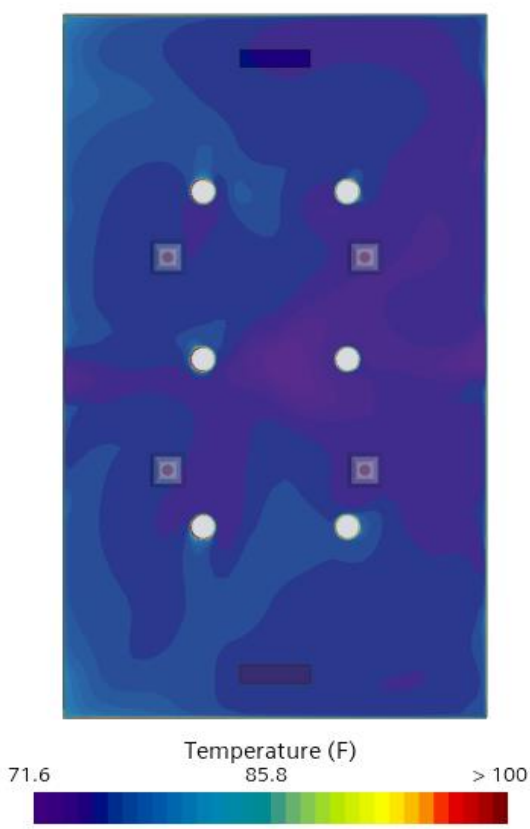

X
Y
Z
Velocity: Magnitude (fpm)
0.544
50.3
> 100


Z
Y
X
Velocity: Magnitude (fpm)
0.544
50.3
> 100

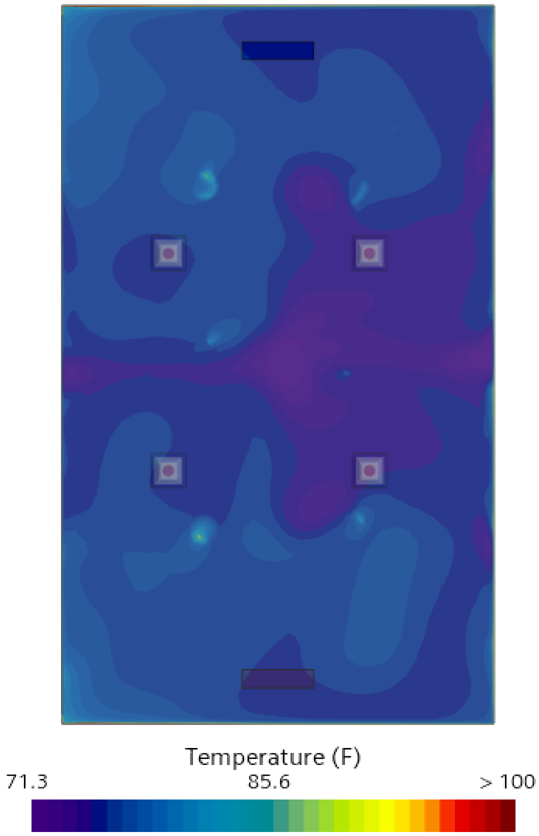
Air Temperature



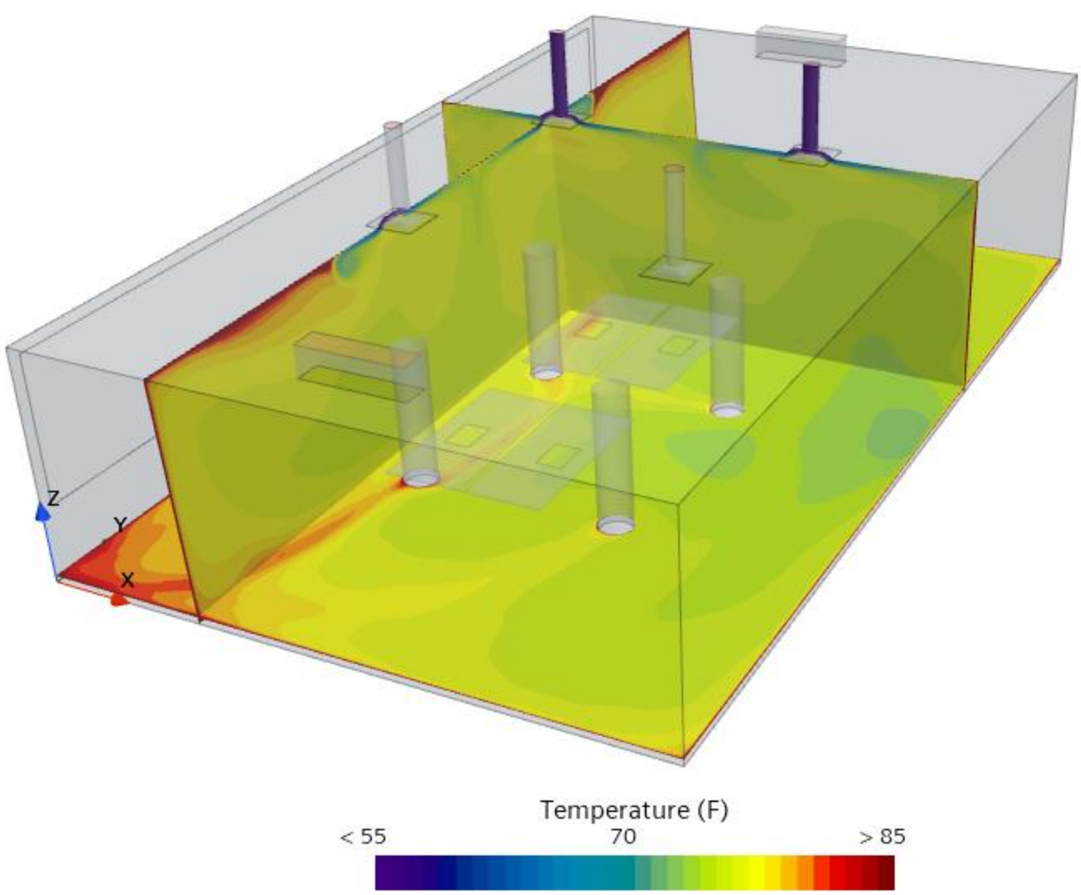
3in from the floor
Average at 75.9°F

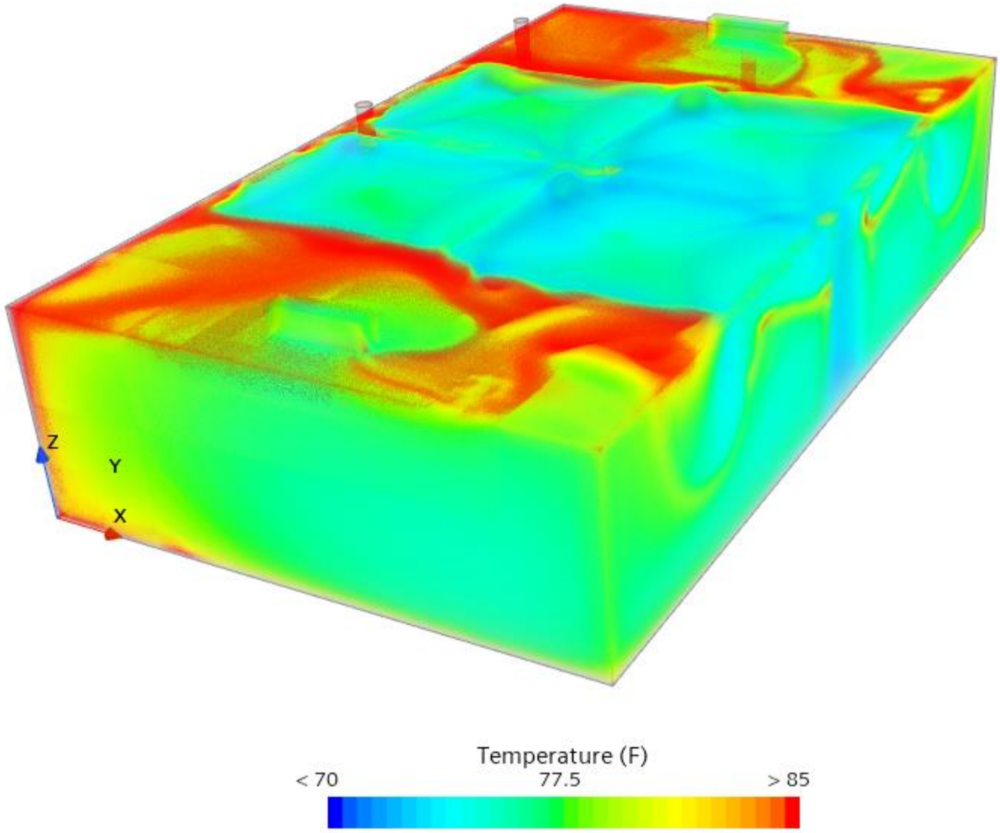


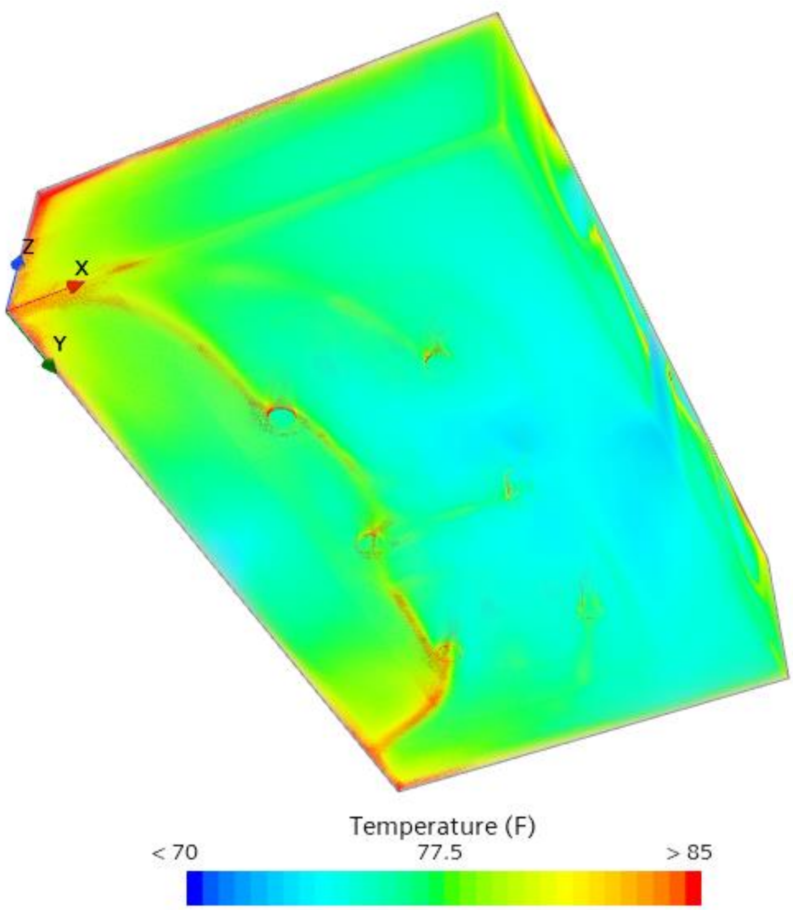
4ft from the floor
Average at 75.5°F

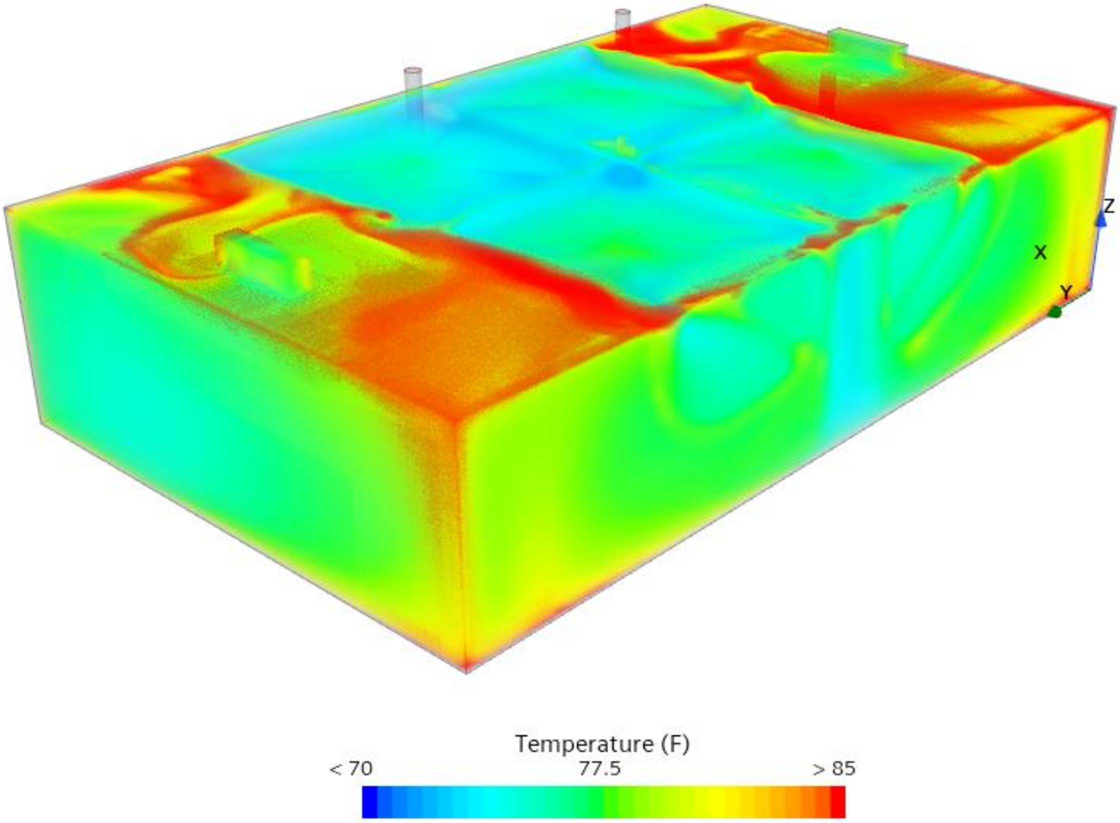


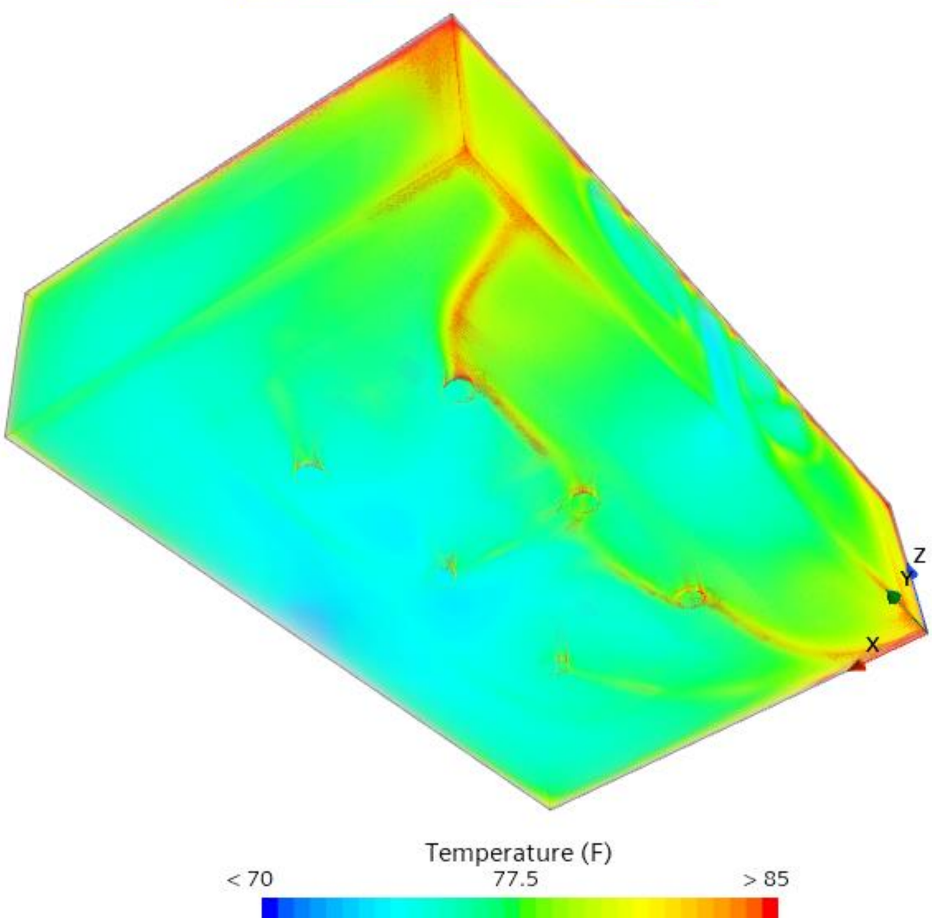
6ft from the floor
Average at 75.8°F



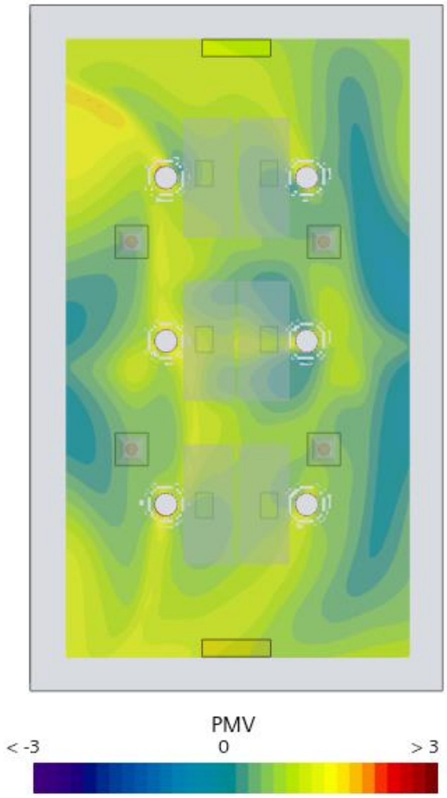

Z
Y
X
Temperature (F)
< 70
77.5
> 85


Z
X
Y
Temperature (F)
< 70
77.5
> 85

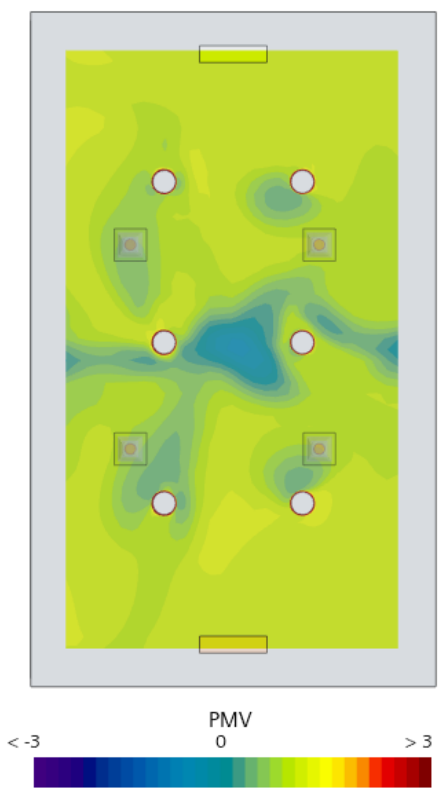

Z
X
Y
Temperature (F)
< 70
77.5
> 85


Z
Y
X
Temperature (F)
< 70
77.5
> 85

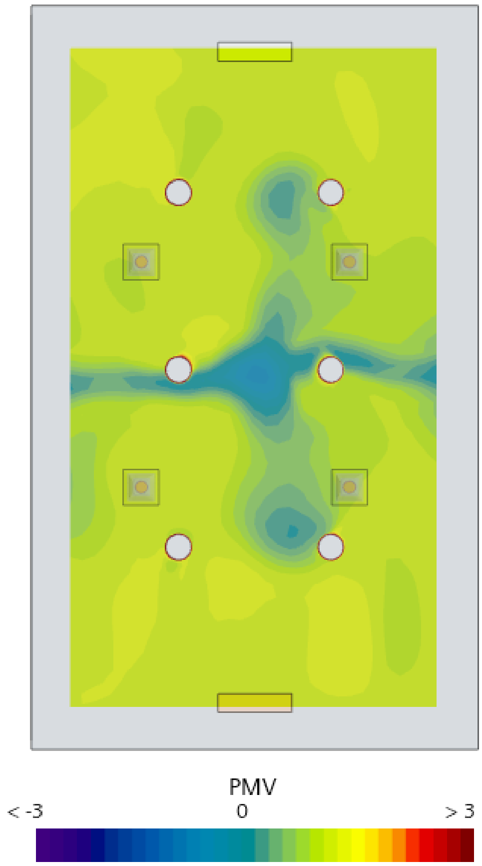
Predicted Mean Vote (PMV)



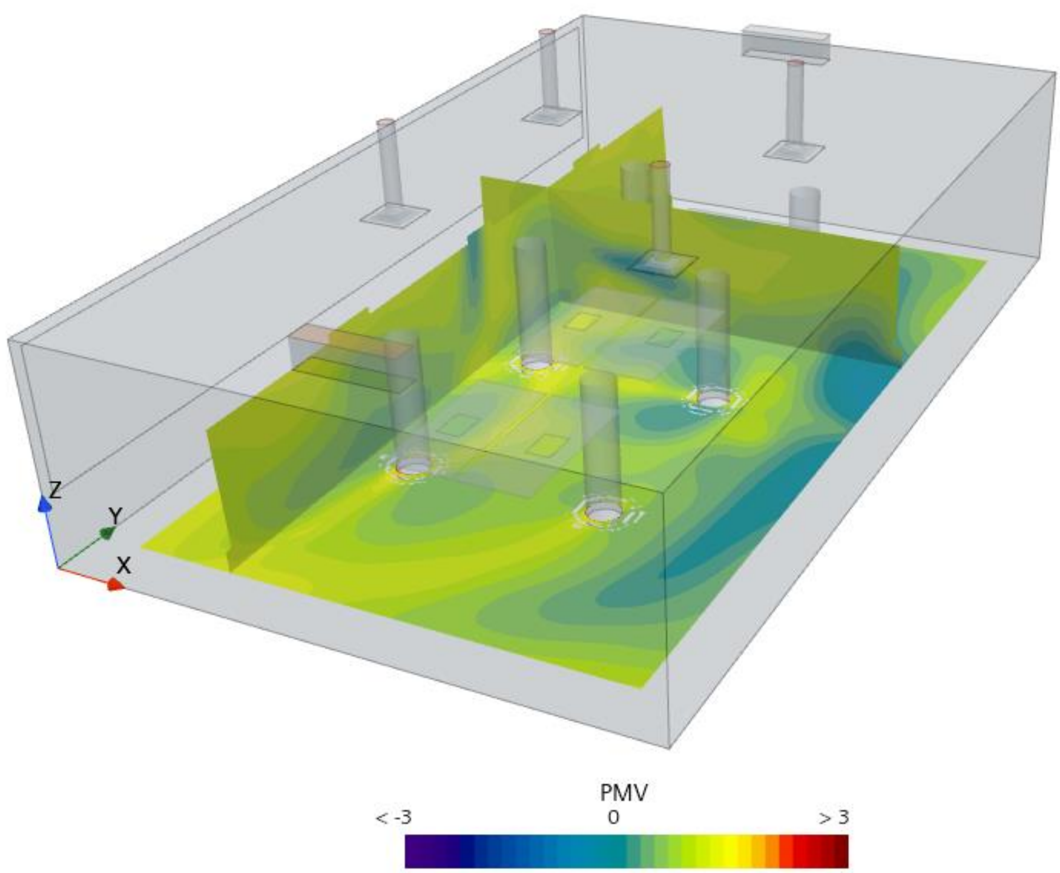
3in from the floor
Average at 0.58



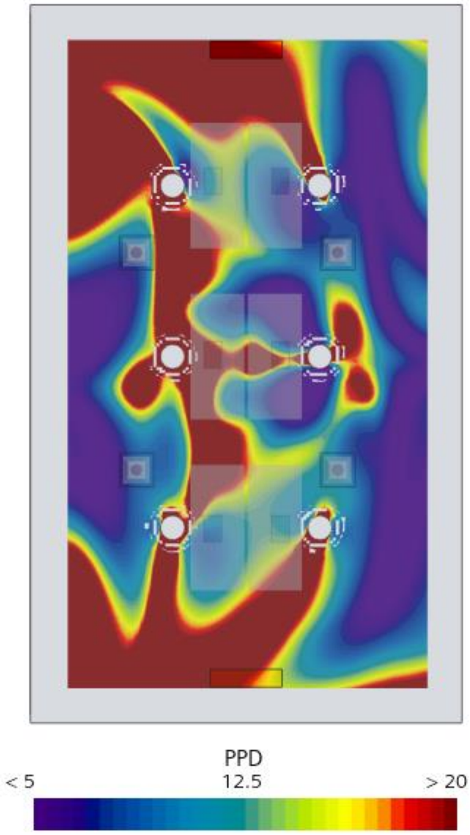
4ft from the floor
Average at 0.87



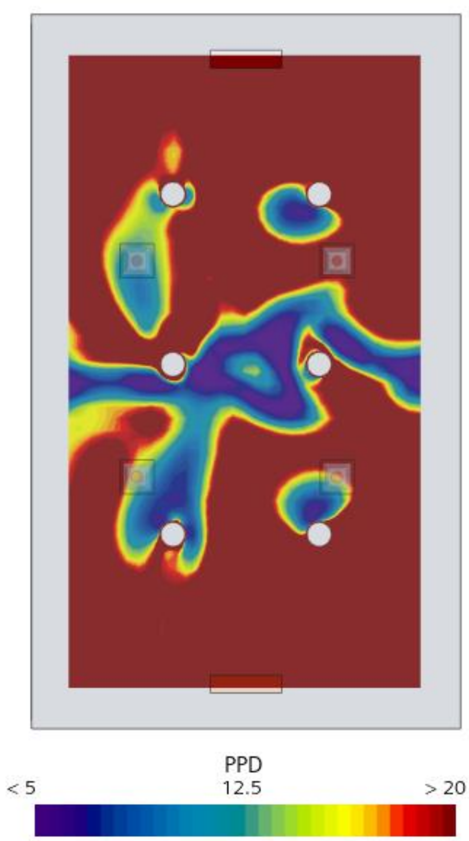
6ft from the floor
Average at 0.91



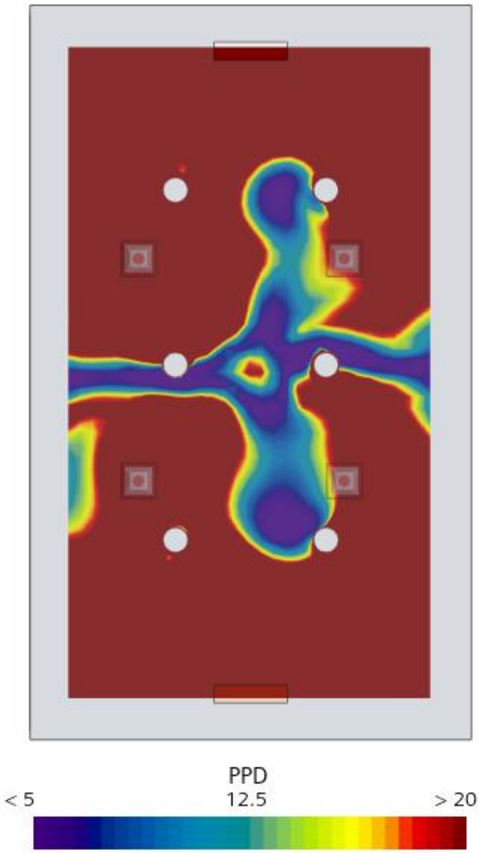
Predicted Percentage Dissatisfied (PPD)



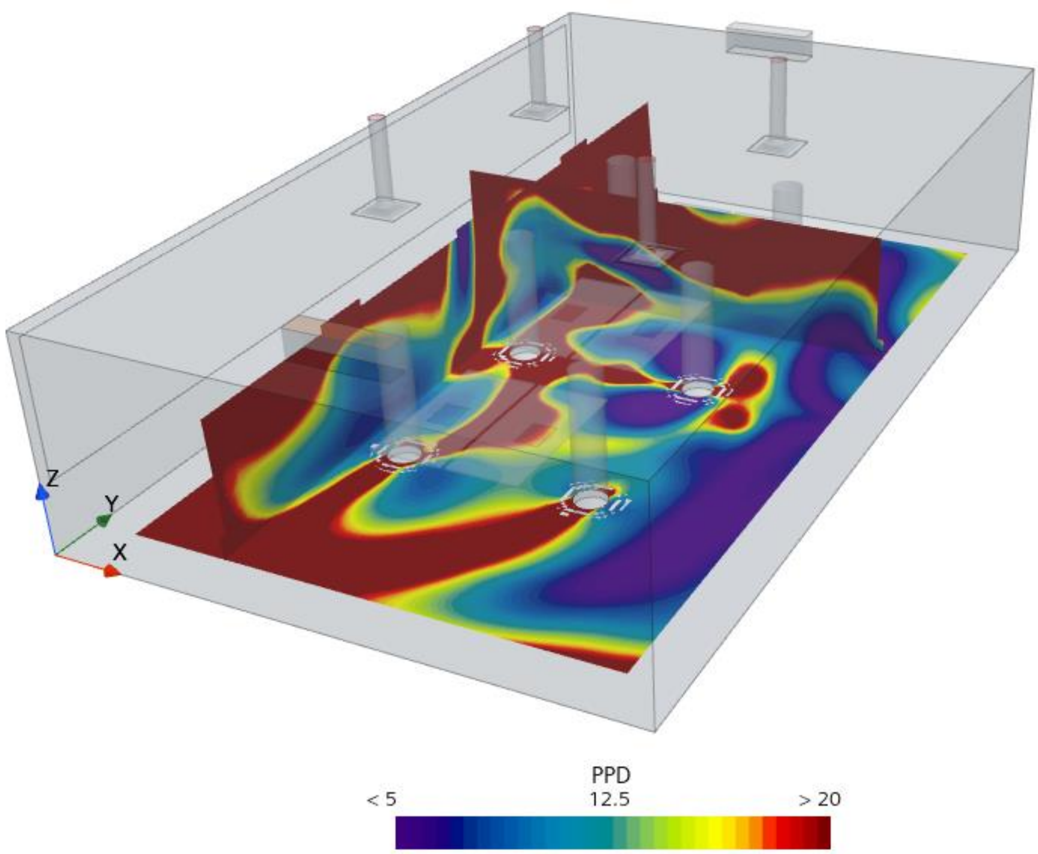
3in from the floor
Average at 14.8%



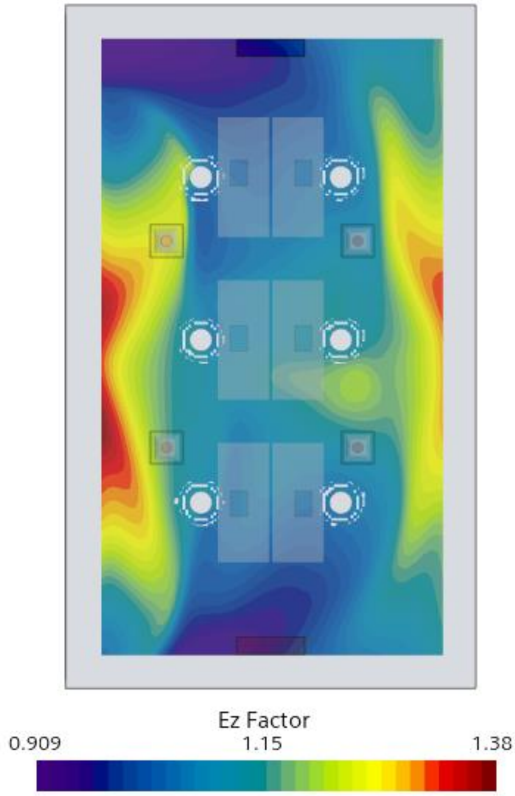
4ft from the floor
Average at 22.2%



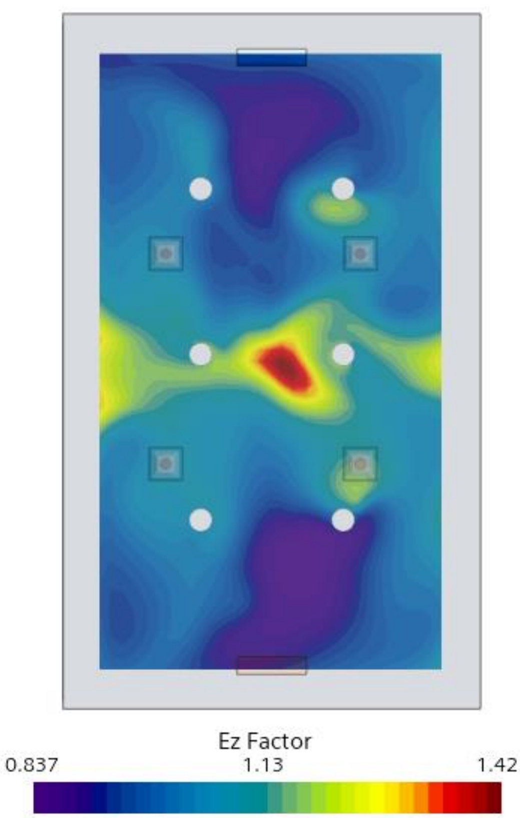
6ft from the floor
Average at 24.6%



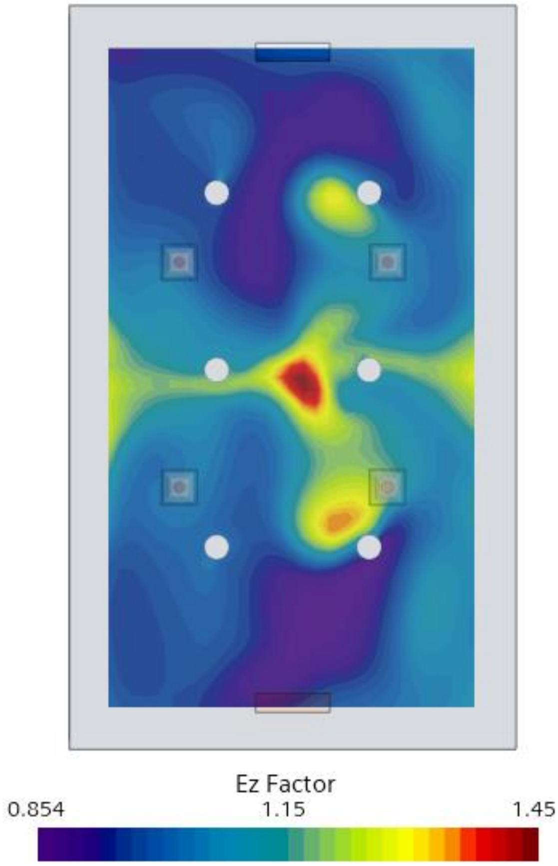
Zone Air change Effectiveness (Ez Factor)



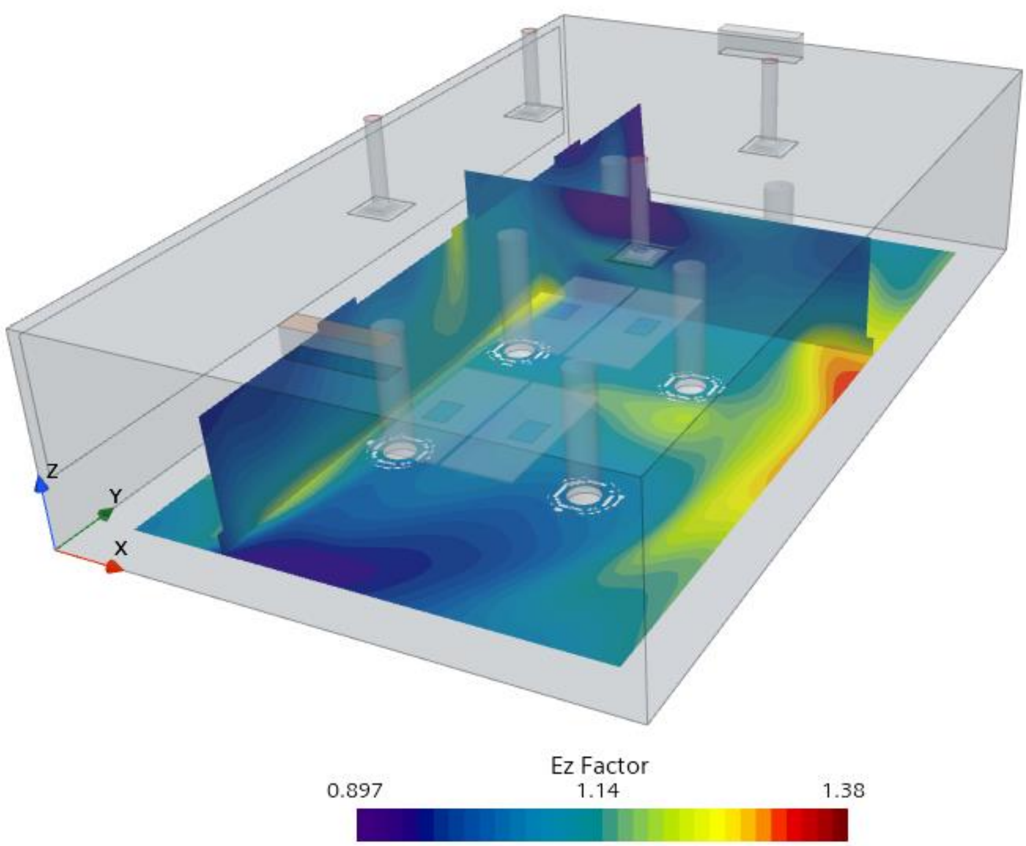
3in from the floor
Average at 1.11



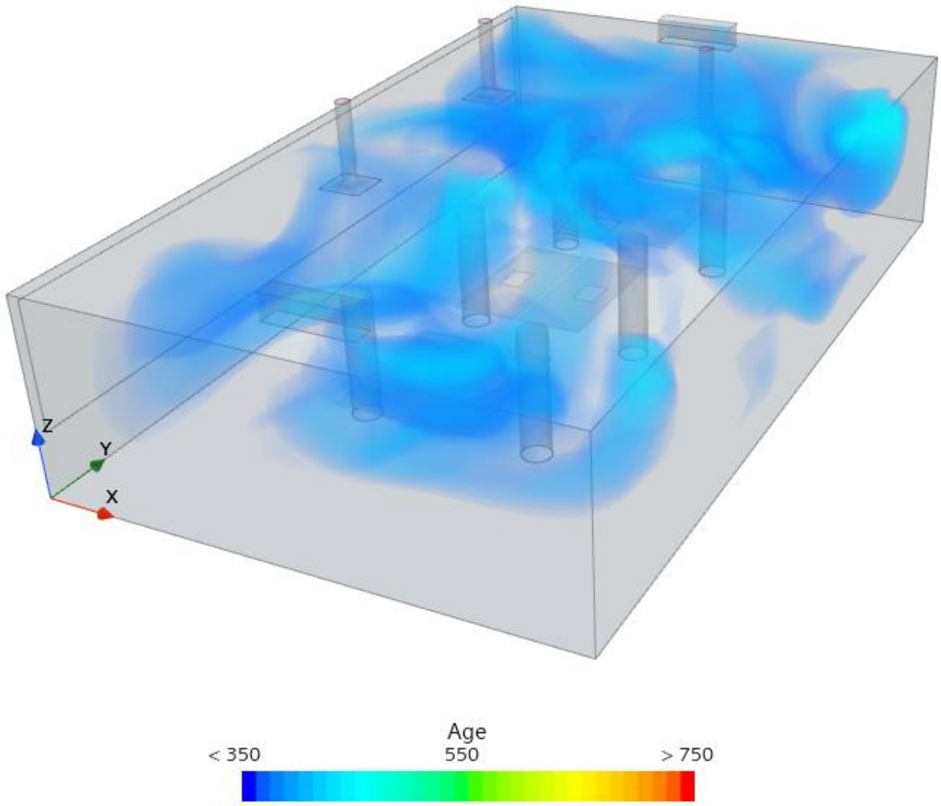
4ft from the floor
Average at 1.02

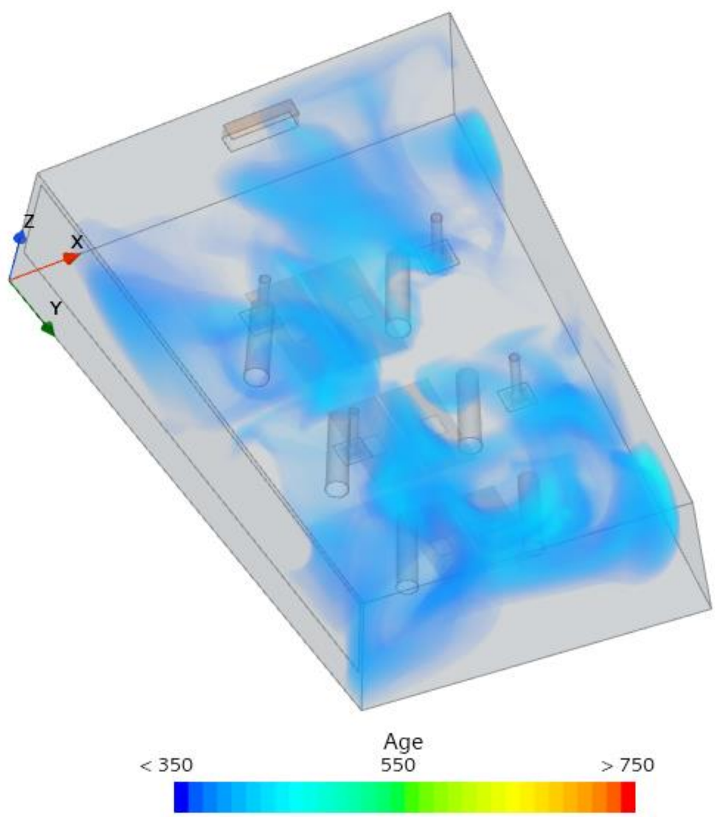


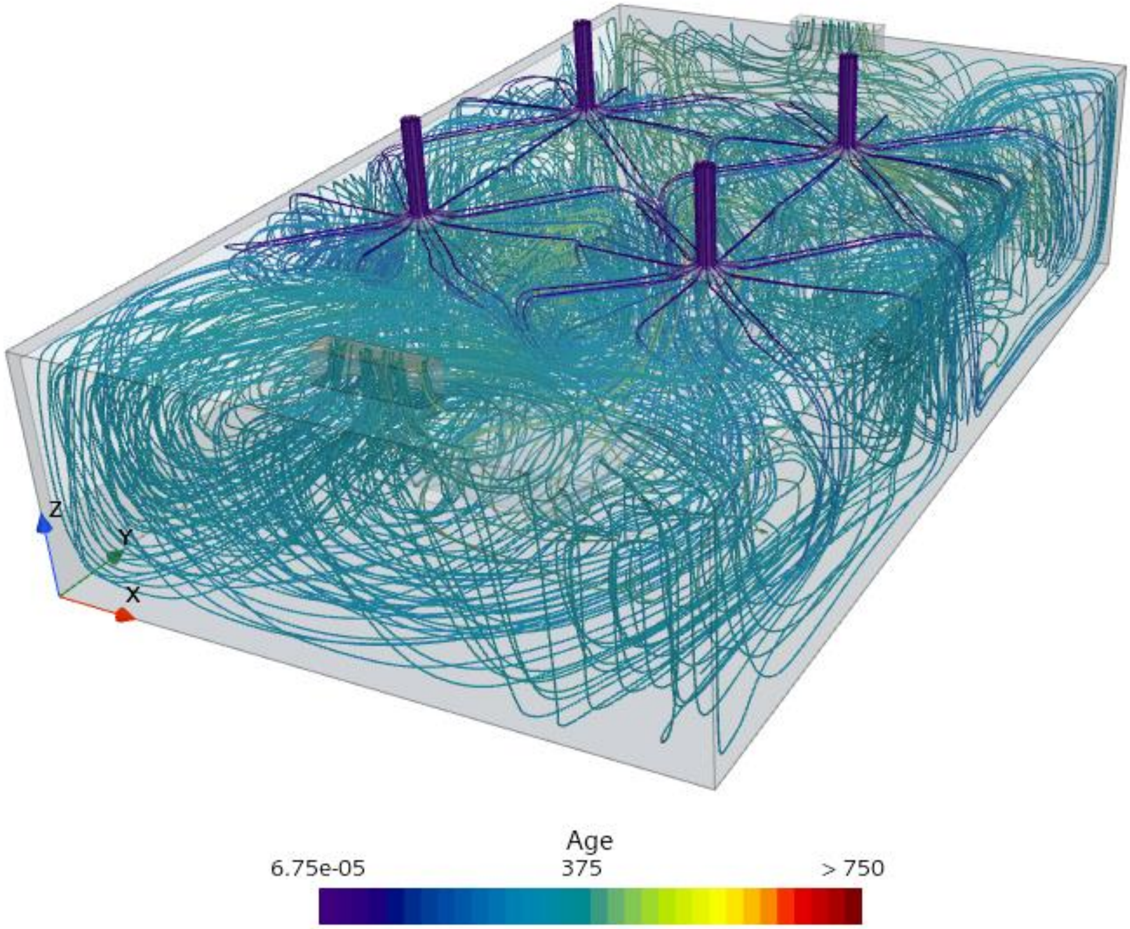
6ft from the floor
Average at 1.02

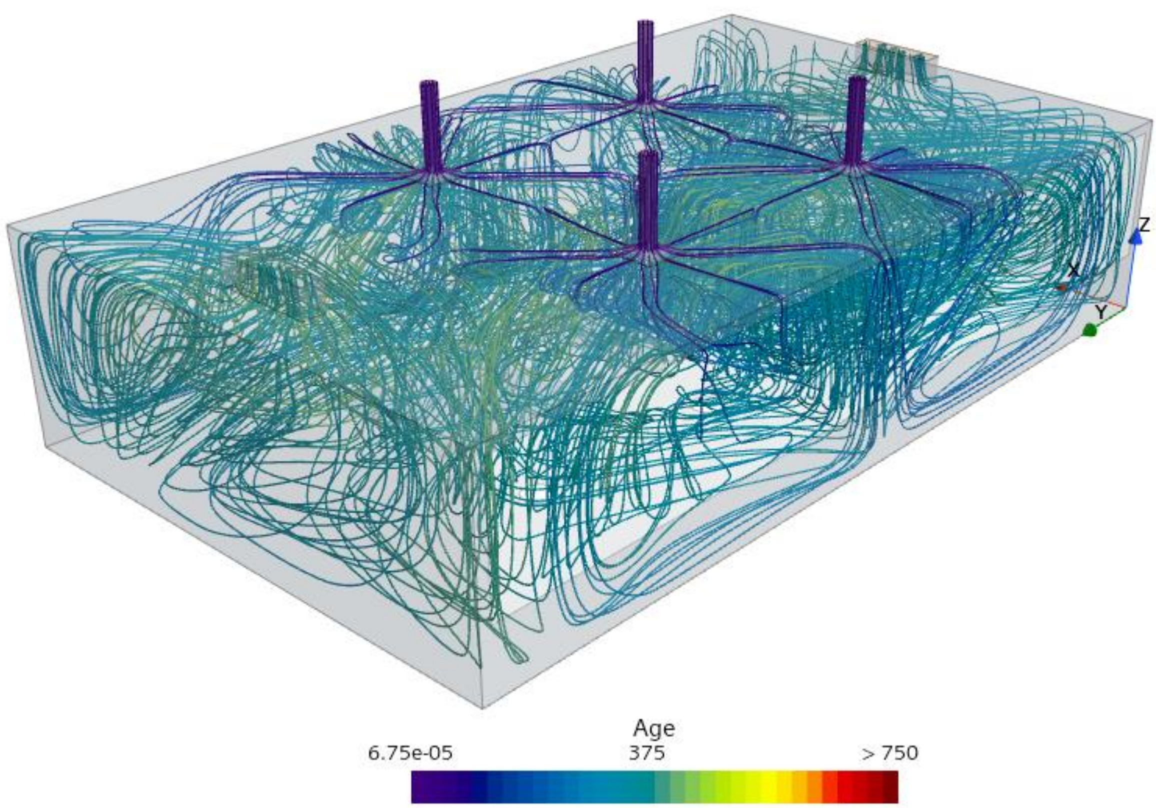


Mean Age of Air

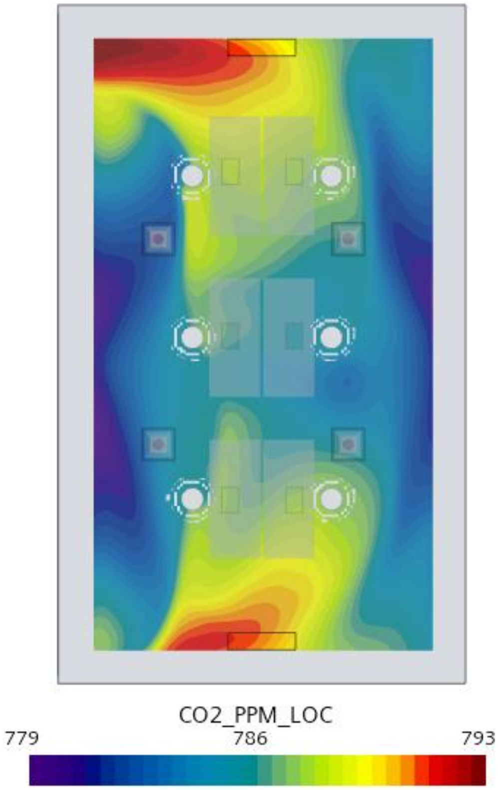




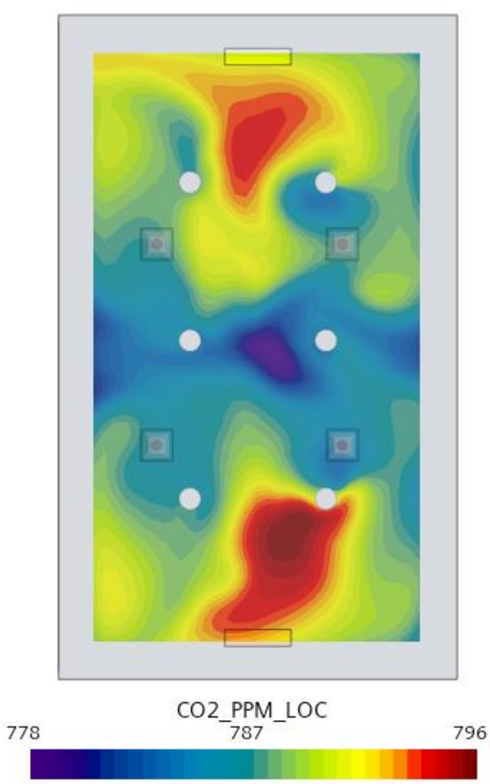

Z
Y
X
Age
6.75e-05
375
> 750


Z
X
Y
Age
6.75e-05
375
> 750

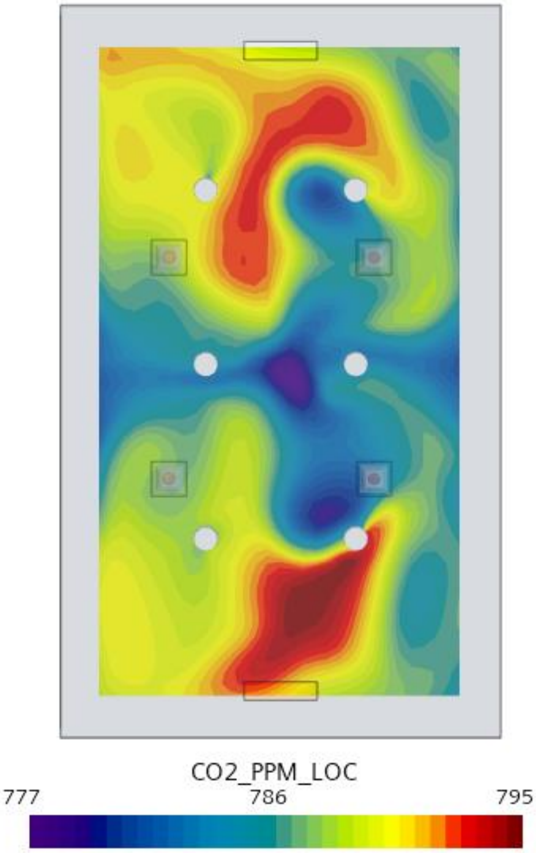
CO2 Breathing Zone Concentration (PPM)



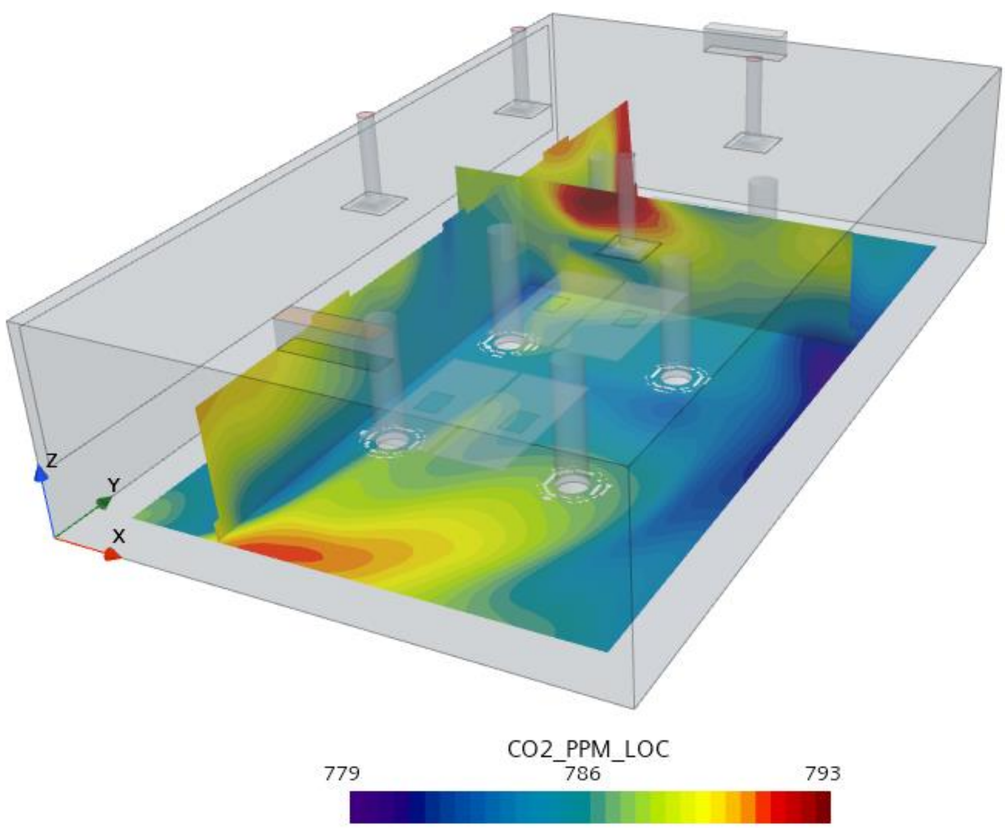
3in from the floor
Average at 785 ppm



4ft from the floor
Average at 789 ppm



6ft from the floor
Average at 788 ppm



EffectiV HVAC inc.

EFF0122001 : Development Room – PLAY-S - Cooling

December 13th 2022

Yannick Sirois, ing., M.Sc.A.,Ph.D. No OIQ : 130045

Lx Sim Inc.
400 rue Shefford, local 117
Bromont. Québec
J2L 3E7. Canada
Tel. : 450.919.1714
info@lxsim.com
www.lxsim.com

Simulation Summary

Diffuser Configuration

Inlets	Type
4	PLAY-S 24

Cooling Conditions

Property	Value
Outside temperature	90.0°F
Air supply temperature	55.0°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	0.57 CLO (trousers, short sleeve shirt)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

Cooling Results

Properties	Value
Outlet air temperature	77.7°F
Average flow rate	1335 CFM
Theoritical air age at outlet	384 s
Real air age at outlet	363 s
Ez Factor	0.910
CO_2 PPM	797
PMV	-0.58
PPD	14.7

Mandate

Lx Sim has the mandate to analyze the performance of the ventilation system inside a room using a CFD approach

Ventilation system performance is quantified in terms of:

- Mean Age of Air measured at the extraction
- Zone Air Distribution Effectiveness (Ez Factor)
- Occupants thermal comfort (Predicted Mean Vote and Predicted Percentage of Dissatisfied)

Methodology

Each CFD simulation is performed in Simcenter STAR-CCM+ from Siemens

General modeling is based on:

- CFD best practices
- ANSI/ASHRAE Standard 62.1-2019 (Air quality)
- ANSI/ASHRAE Standard 55-2017 (Thermal comfort)

CAD

- The simulation is performed using a 3D representation of the room to be studied
- The room is built according to plans provided
- The model includes the following features and surfaces:
  - Walls
  - Windows
  - Air diffusers
  - Air diffusers feed ducting (if necessary)
  - Air room extractor
  - People (if necessary)
  - Other major obstacles (if necessary)

Mesh

In order to solve fluid mechanics transport equations, the 3D geometry must be discretized in small elements

Element size must be small enough that numerical diffusion does not occur and that all physical effects in the fluid are modeled appropriately

In the ventilation simulation, the most restrictive geometric feature is the air diffuser

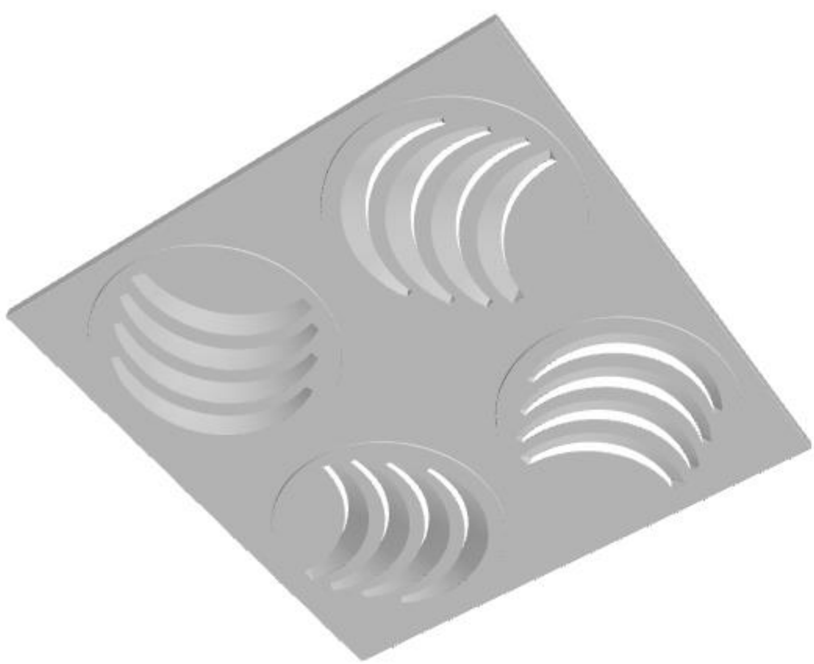
The air diffuser requires a mesh small enough so that flow directions and velocities represent reality

Air diffuser mesh validation

The mesh approach was valided using the PLAY-S 24 diffuser from EffectiV HVAC inc.

This diffuser incorporates small features that need to be resolved correctly in order to obtain the corrrect performances.

PLAY-S 24

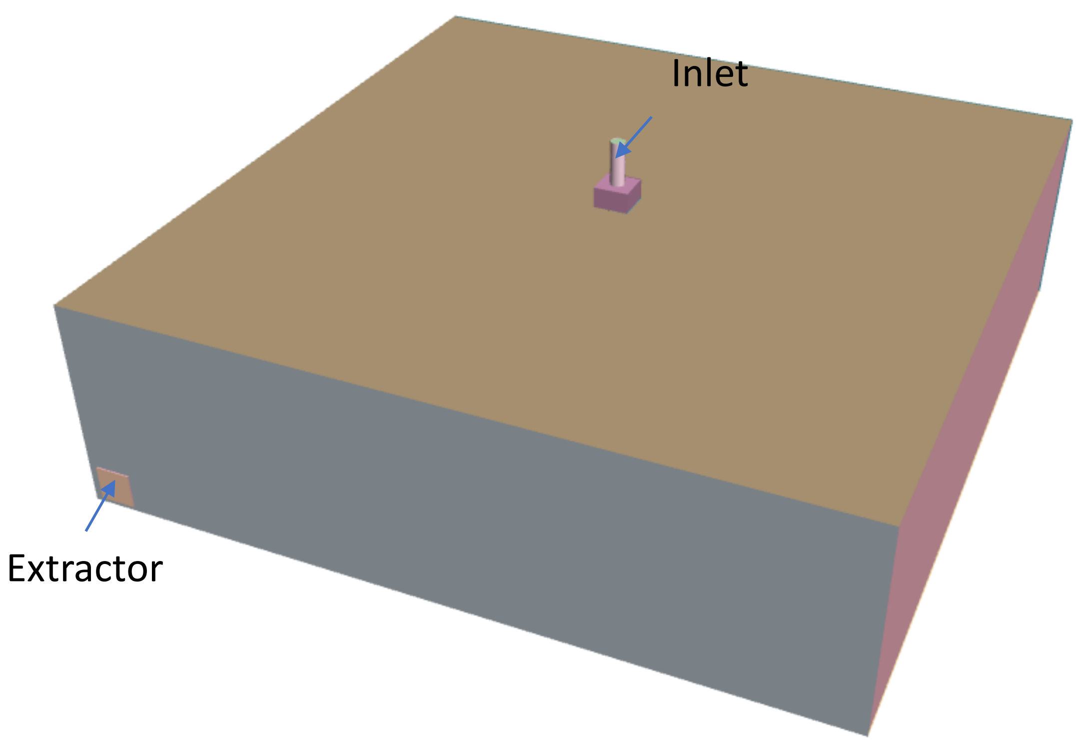


24" x 24" Face, Swirl Effect

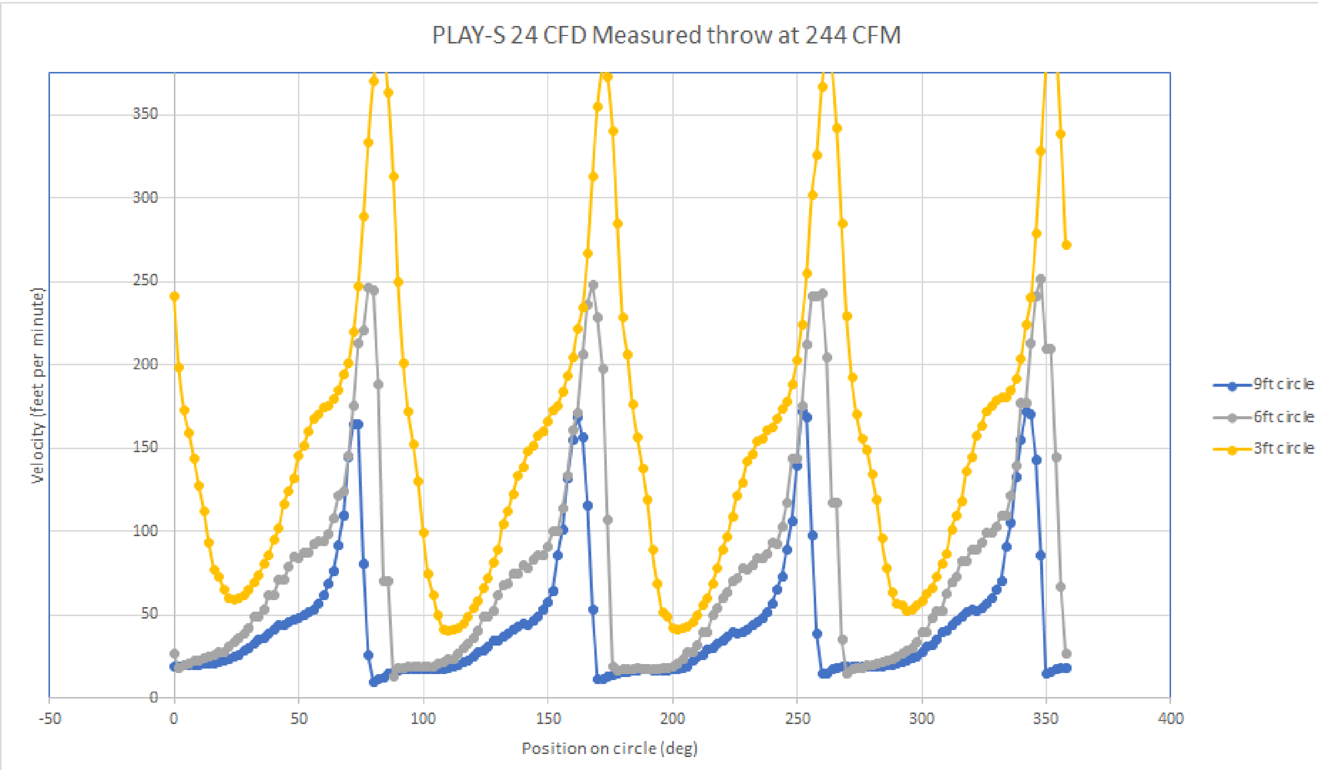
605 mm x 605 mm Face (Metric)

Neck Size (inches)	Neck (fpm) Velocity	200	300	400	500	600	700	800	1000
	Velocity Pressure (H_2O)	0.002	0.006	0.01	0.016	0.022	0.031	0.041	.062
6	CFM				98	118	137	157	196
	Pressure Loss (in.w.g.)				0.01	0.014	0.019	0.024	0.037
	NC				< 15	< 15	< 15	< 15	16
	Throw (ft) - Coanda Effect				2-2-4	2-3-4	2-3-5	2-4-6	3-5-7
	Throw (ft) - No Ceiling				1-2-3	1-2-3	2-3-4	2-3-4	2-4-5
8	CFM		105	140	175	209	244	279	349
	Pressure Loss (in.w.g.)		0.011	0.02	0.03	0.041	0.055	0.071	0.107
	NC		< 15	< 15	< 15	18	22	25	31
	Throw (ft) - Coanda Effect		2-3-4	2-3-5	3-4-6	3-5-7	3-6-9	4-6-10	5-8-12
	Throw (ft) - No Ceiling		1-2-3	2-3-4	2-3-5	2-4-6	3-4-6	3-5-7	4-6-9
10	CFM	109	164	218	273	327	382	436	545
	Pressure Loss (in.w.g.)	0.012	0.026	0.045	0.068	0.095	0.127	0.163	0.247
	NC	< 15	< 15	19	25	30	34	37	43
	Throw (ft) - Coanda Effect	2-3-4	2-4-6	3-5-8	4-6-10	4-8-11	5-9-13	6-10-15	9-16-24
	Throw (ft) - No Ceiling	1-2-3	2-3-4	2-4-6	3-5-7	3-6-8	4-6-10	4-7-11	7-12-18
12	CFM	157	236	314	393	471	550		
	Pressure Loss (in.w.g.)	0.024	0.052	0.088	0.134	0.188	0.251		
	NC	< 15	21	29	35	39	44		
	Throw (ft) - Coanda Effect	2-4-6	3-6-8	4-7-11	5-9-13	6-10-16	7-12-18		
	Throw (ft) - No Ceiling	2-3-4	3-4-6	3-5-8	4-7-10	5-8-12	5-9-14		

The diffuser is introduced into a large room with th inlet plenum and an extractor



- A 244 CFM test value is chosen (see performance chart)
- A CFD analysis is performed and the mesh is refined until satisfactory performances a re measured and the changes in mesh do not change the measured values
- To assess validity, samples of velocity are taken in circles at 3, 6 and 9 ft around the diffuser



The results show that average values are very close the expected values of 40fpm at 9ft, 60fpm at 6ft and 100fpm at 3ft

The same mesh strategy is to be used on the full room with multiple diffusers to lead to accurate results

General CFD physics modeling

Simulations is in accordance with ANSI/ASHRAE Standard 62.1-2022 - Normative Appendix C.

The following modeling options are used:

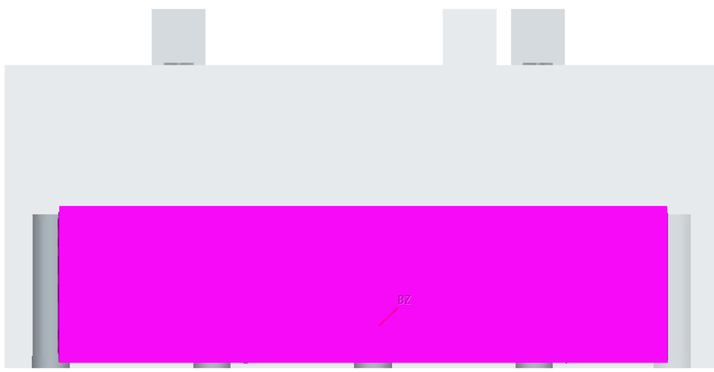
- Steady state approach
- Turbulence modeling active
- Energy and gravity activated
- Species transport
- Surface to surface radiation is modeled

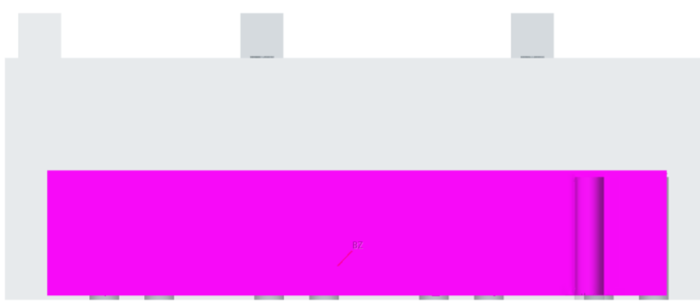
Breathing Zone

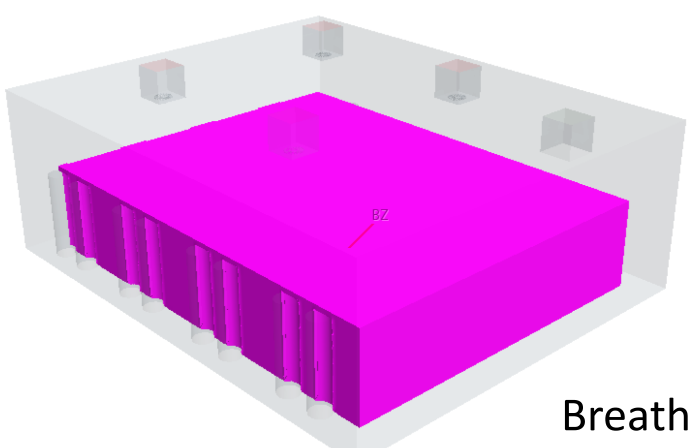
For multiple calculations in this simulation, the breathing zone is used

The breathing zone is defined as per ANSI/ASHRAE Standard 62.1-2022 - Section 3

breathing zone: the region within an occupied space between planes 3 and 72 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment.







Breathing zone example

Imposed Flow

- Flow rate in CFM is imposed at each inlet
- Temperature is imposed at each inlet
- Depending on the choice, a proportional error correction is implemented on either the flow rate or the temperature in order to reach the specified setpoint for the temperature in the room
- The temperature in the room to be compared to the setpoint is measured in each cell of the breathing zone and averaged over it
- Since the simulation is in steady state, the final flow rate and air inlet temperature represent an average value corresponding to a continuously running heating or cooling system

Operating conditions

- External conditions
    - External temperature is specified for heat transfer through walls, windows and radiation through the windows
- Walls and windows isolations is specified using U-Factor or R-Factor
- Human heat sources
    - Heat flux through a simple human shape
    - Heat flux defined using the Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2022

Air Age at Extraction

- To measure air age, the simulation uses a transported passive scalar
    - Does not affect flow in any way
    - Increases with time between the inlets and the outlets
- Average age is measured at the outlets using mass average procedure and is compared to the theoritical value

Zone Air Distribution Effectiveness (Ez Factor)

- All Ez Factor calculations are made in accordance with ANSI/ASHRAE Standard 62.1-2022 – Normative Appendix C
- A mass source of a tracer gas species, such as CO_2 is introduced inside the breathing zone volume and uses the specied transport equations
- A mass averaged measure of the molar concentration of the tracer gas at the inlet and exhaust are taken

- The Ez Factor is measured for each mesh cell inside the breathing zone
- The global Ez Factor value is then the volume average of the Ez Factor values inside the breathing zone
- All other requirements for CFD modeling are respected in the model

Thermal Comfort

- Thermal comfort is evaluated with the values of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)
- All calculations are made according to ANSI/ASHRAE Standard 55-2017
- The CFD model implements the code proposed in Appendix B of said standard
    - Values are computed on each cell of the mesh and are available in the complete simulation for visualization and post-processing

Thermal Comfort – Required information

Clothing value

The clothing value describes the types of clothes worn by the occupants.

- Data must be provided in ''clo'' units
- Typical values are shown in Table 5.2.2.2A – Clothing Insulations Icl values for typical ensembles in ANSI/ASHRAE Standard 55-2017

Metabolica rate

The metabolic rate of occupants

- Depends on occupation
- Must be provided in ''met'' units
- Typical values are shown in Table 5.2.1.2 Metabolic Rates for typical Tasks taken in ANSI/ASHRAE Standard 55-2017

External work

Also in ''met'' units

Generaly around 0 except in very physical action by the occupants

Air temperature

Provided in each cell by the cfd model

Air velocity

Provided in each cell by the cfd model

Mean radiant temperature

Average wall surface temperature provided by the CFD model

Relative humidity

Provided in %

Case Study Presentation

CAD

- Room Dimensions:

Side	Dimension
Length	40 ft
Width	24 ft
Height	9 ft

- 1 window (west)

Properties	
U-factor	0.24 BTU /(h*ft2*F)
SHGC	0.27

- Ceiling

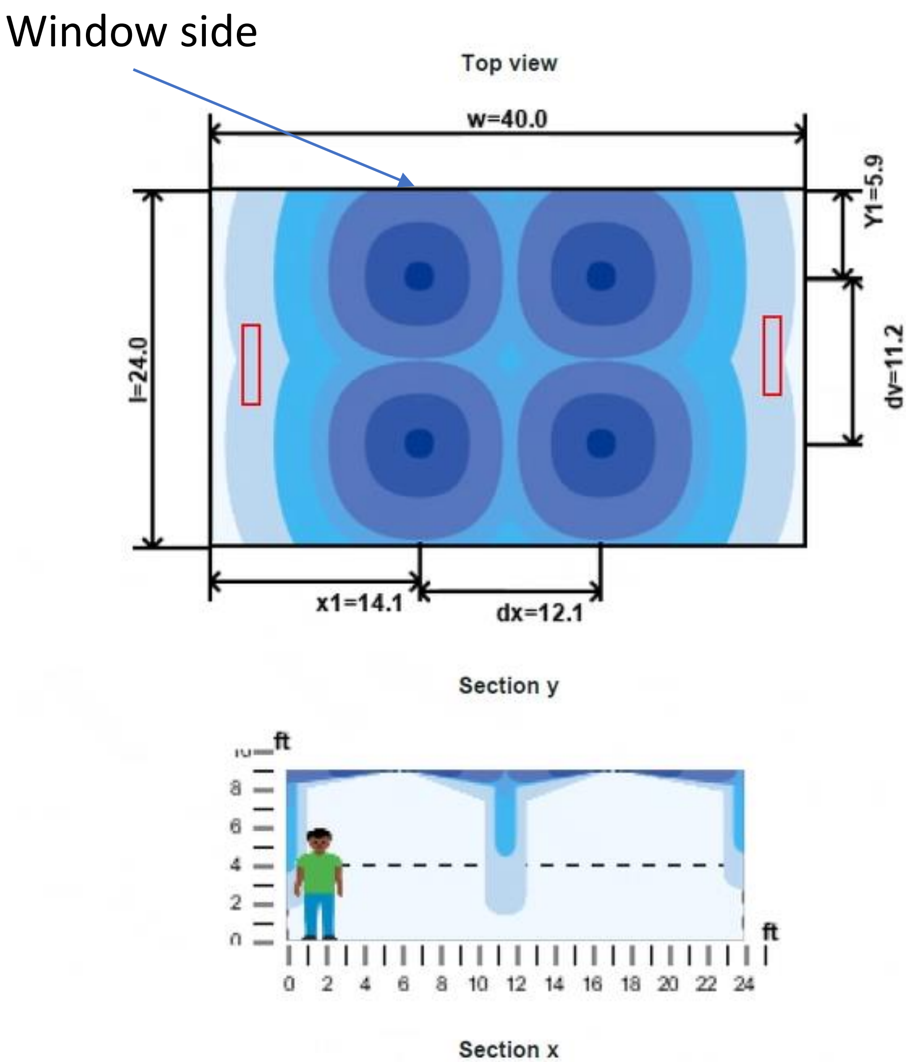
Properties	
U-factor	0.053 BTU /(h*ft2*F)

- Outside wall (west)

Properties	
U-factor	0.044 BTU /(h*ft2*F)

- Inlets and outlets positioned as follows

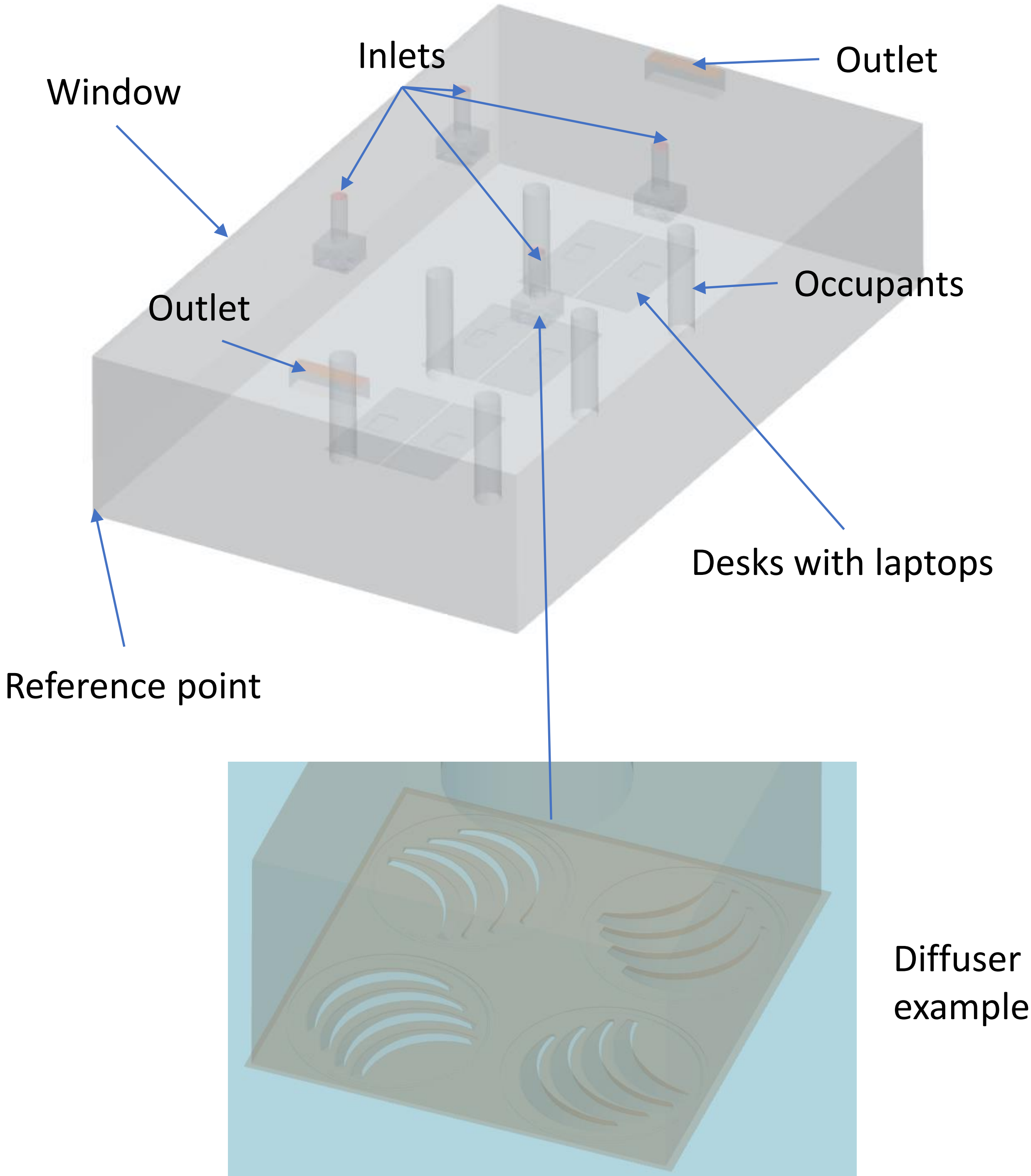
- Inlets and outlets positioned as follows



Diffusers

- 4 PLAY-S 24

Resulting model



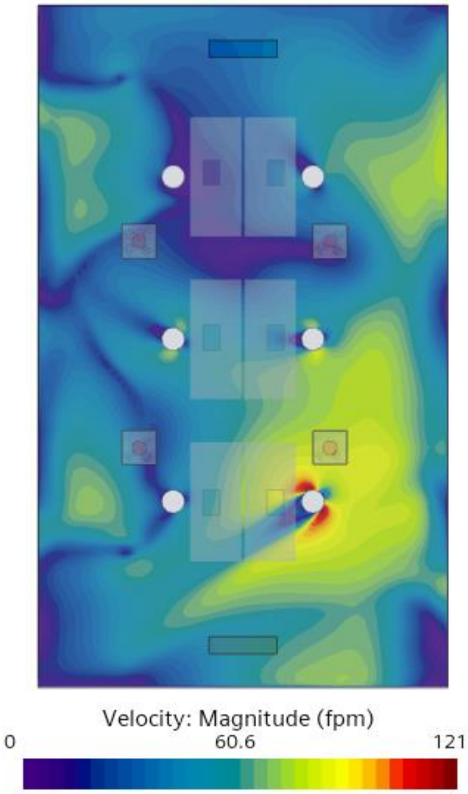
Cooling Conditions

Property	Value
Outside temperature	90.0°F
Air supply temperature	55.0°F
Setpoint	75.2°F
Relative humidity	30%
Inlets flow rate	Variable (VAV)
Occupants metabolism rate	1.0 MET (regular desk work)
Occupants clothing index	0.57 CLO (trousers, short sleeve shirt)
Number of occupants	6
Heat release by occupant	60 W
Number of laptops	6
Heat released by laptop	36 W
Outside Air	10%

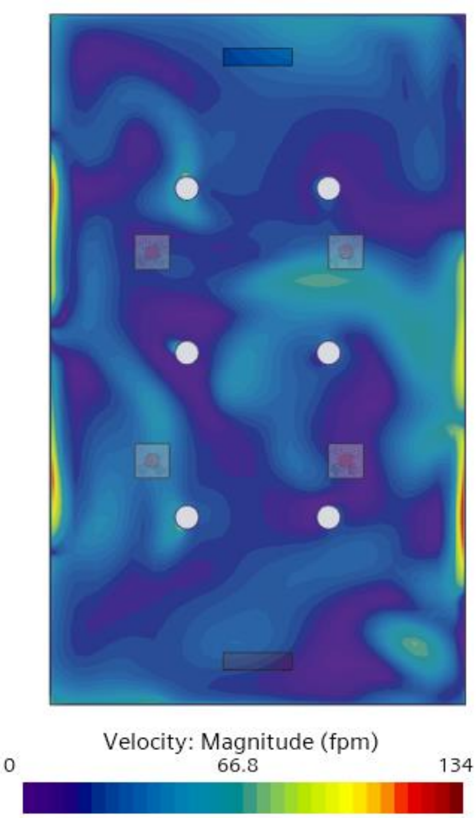
Cooling Results

Properties	Value
Outlet air temperature	77.7°F
Average flow rate	1335 CFM
Theoritical air age at outlet	384 s
Real air age at outlet	363 s
Ez Factor	0.910
CO_2 PPM	797
PMV	-0.58
PPD	14.7

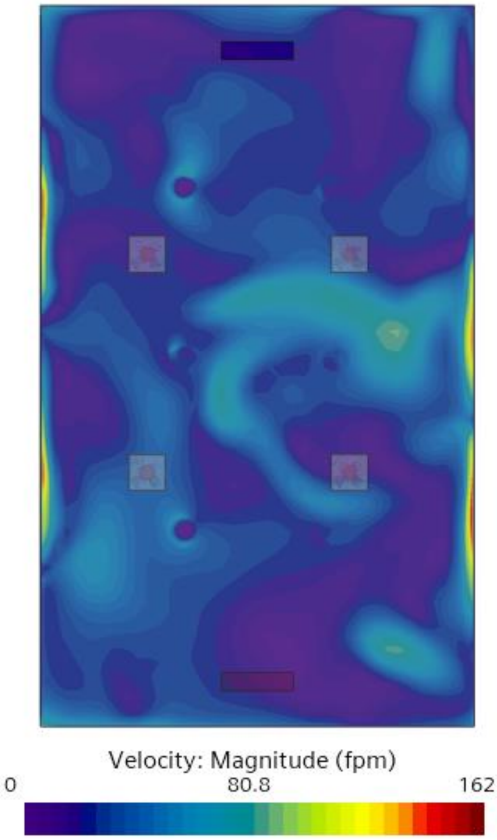
Air Velocity



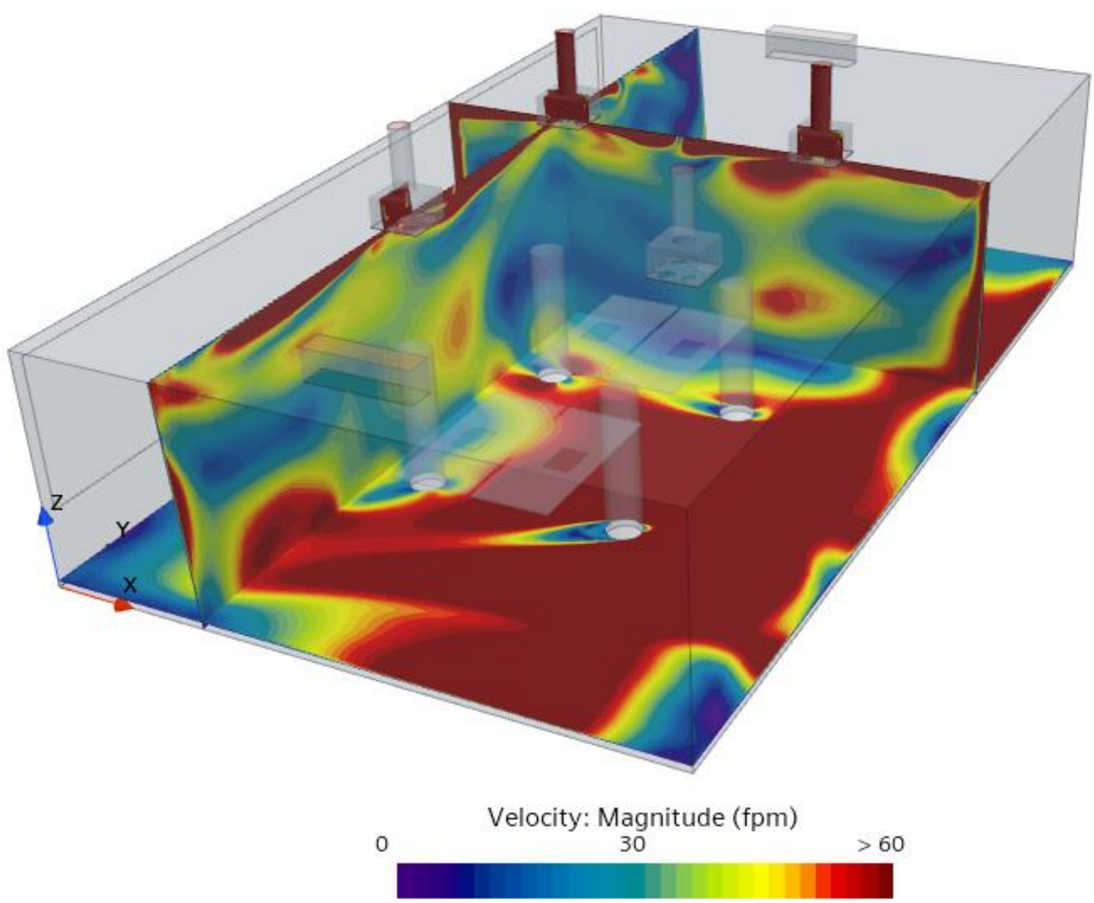
3in from the floor
Average at 48.4 fpm

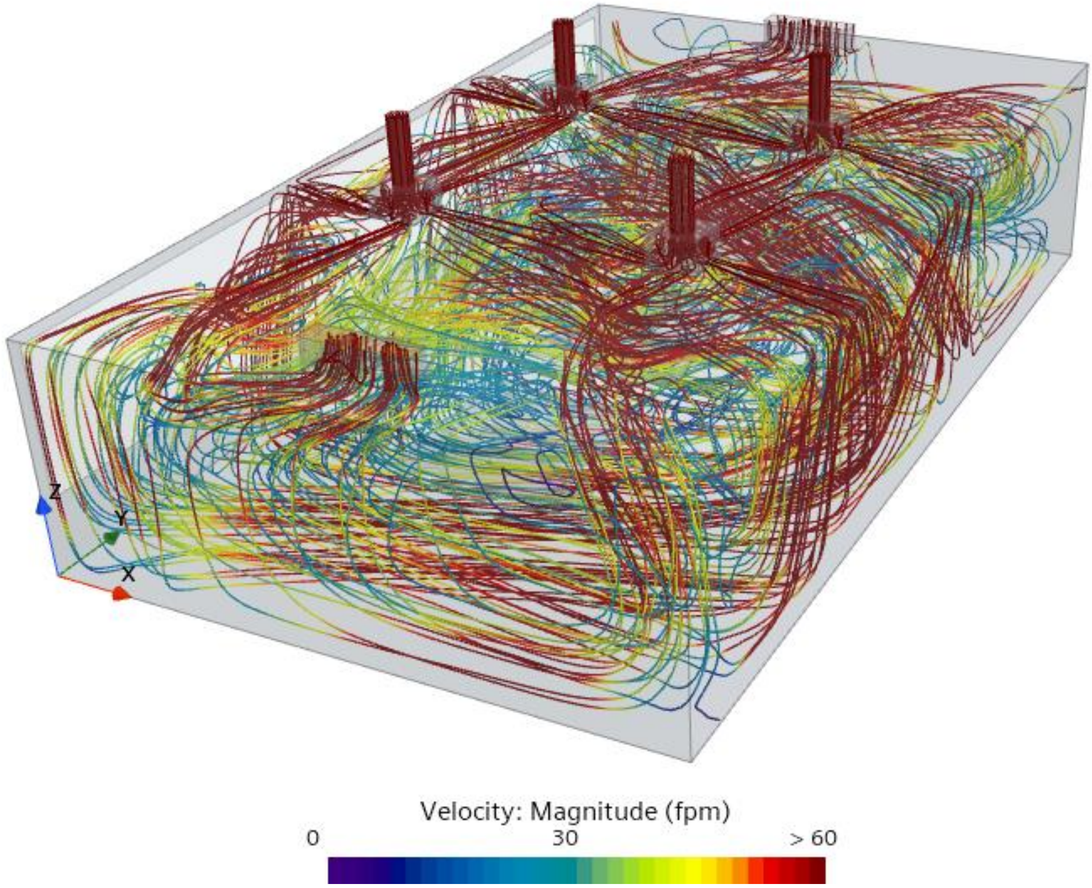


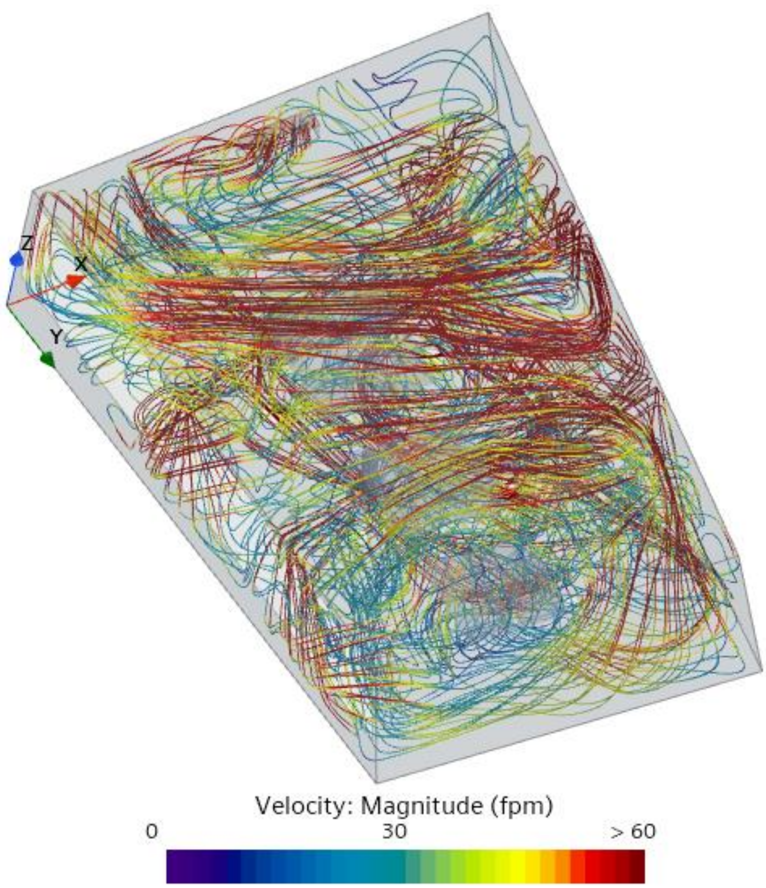
4ft from the floor
Average at 28.6 fpm

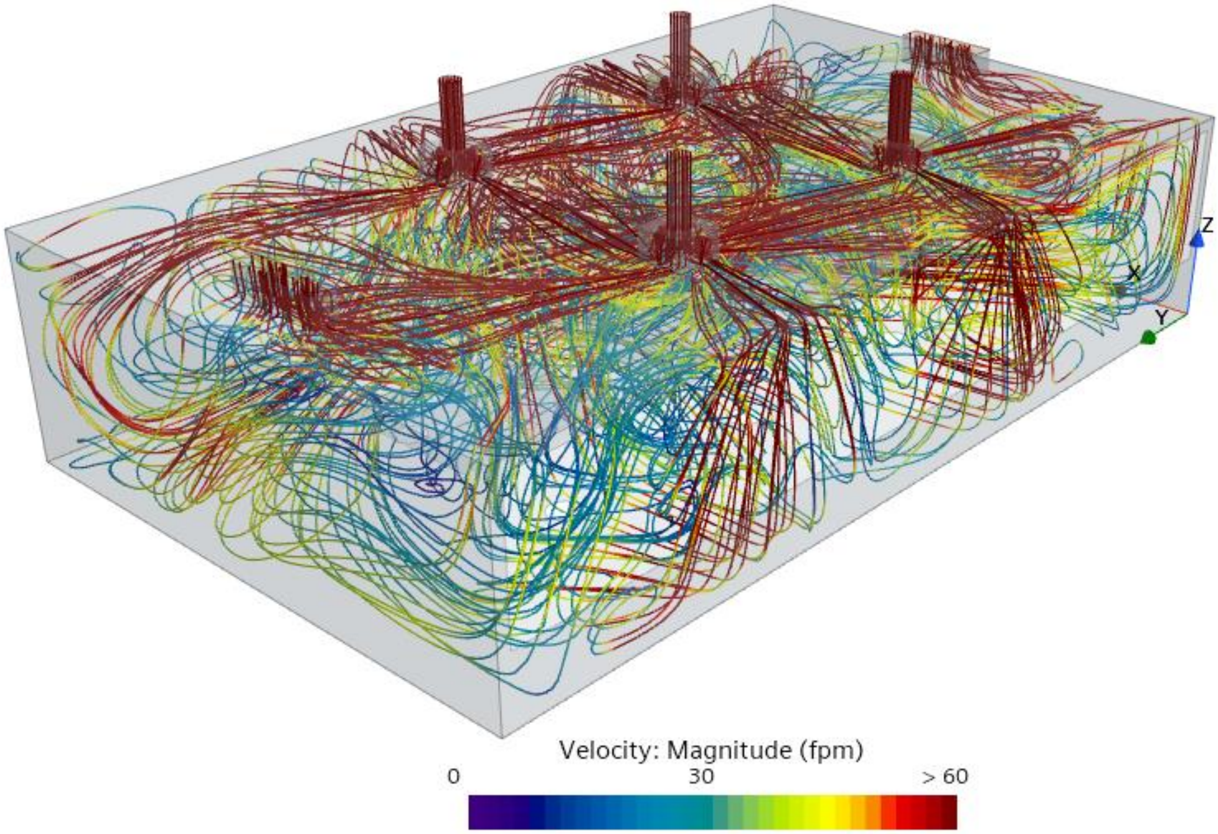


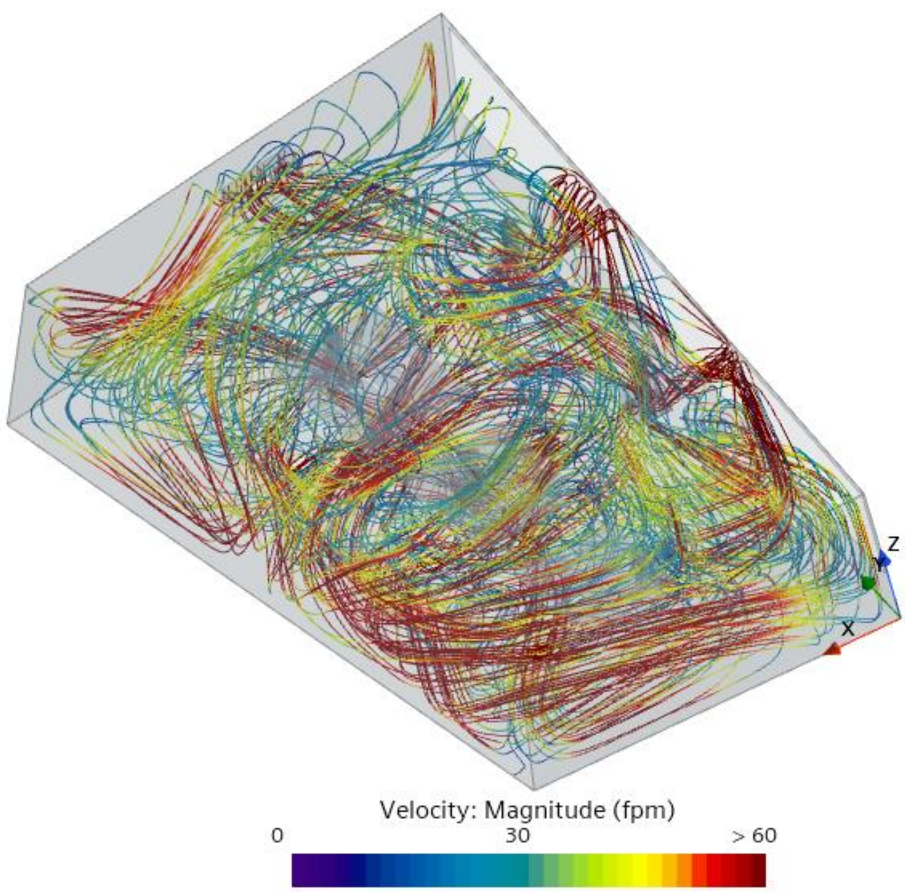
6ft from the floor
Average at 31.0 fpm

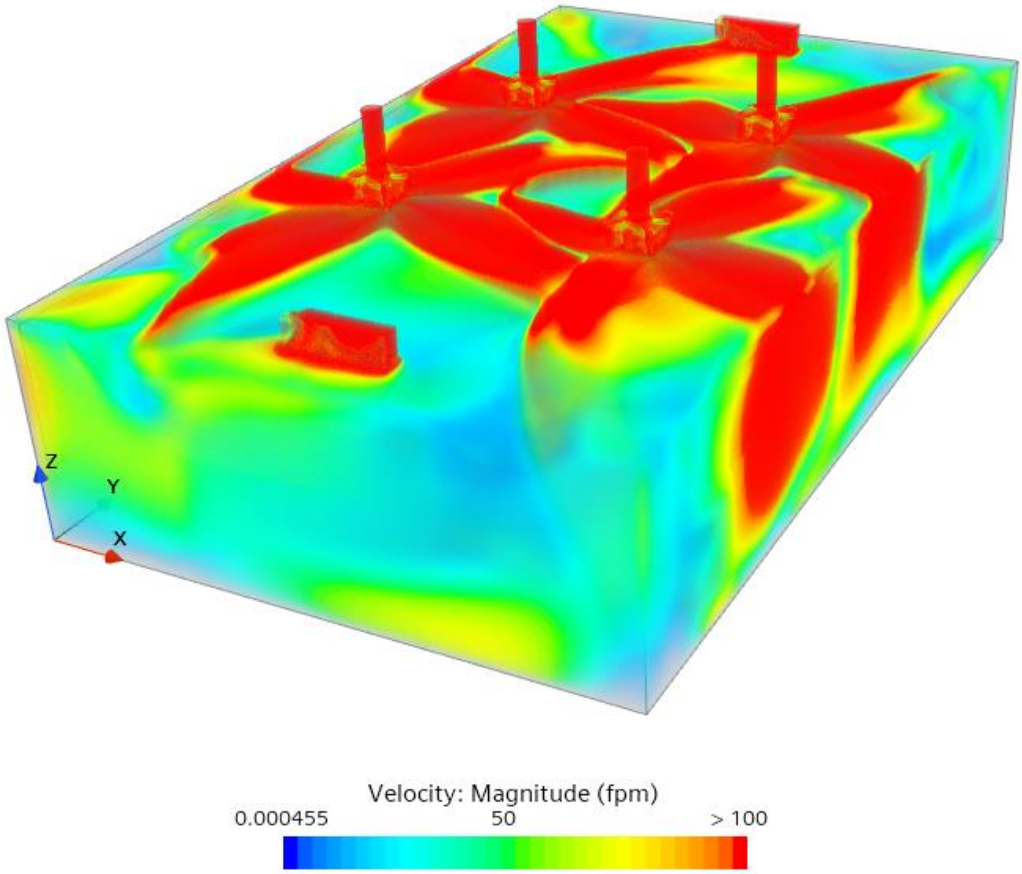


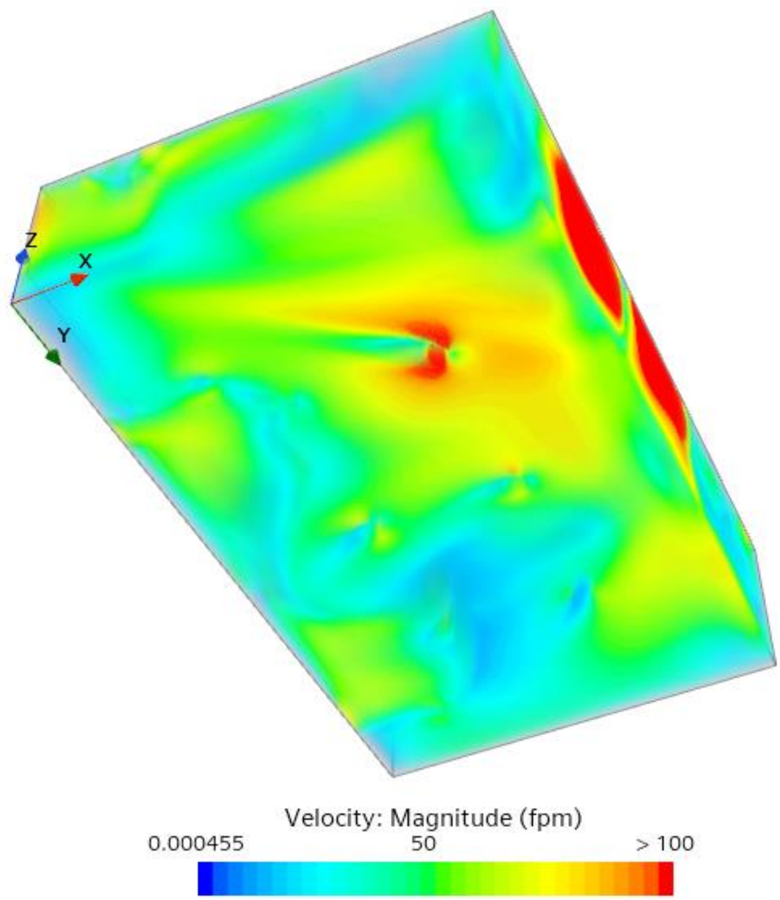

Z
Y
X
Velocity: Magnitude (fpm)
0
30
> 60

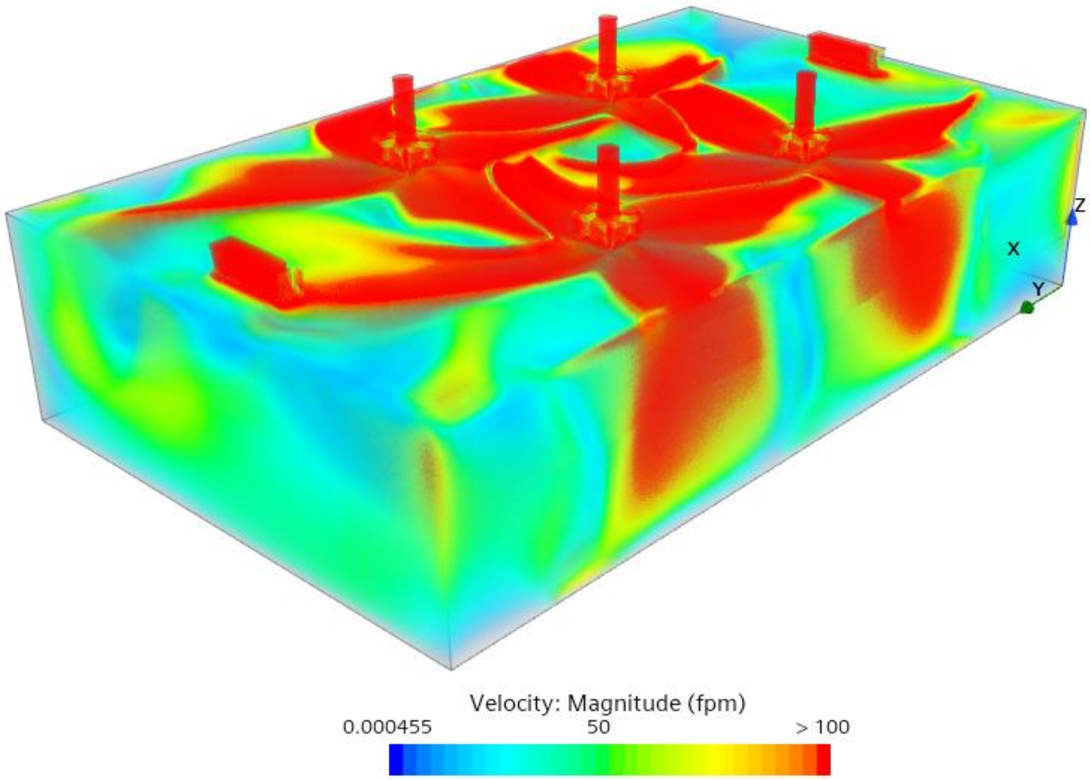

Z
X
Y
Velocity: Magnitude (fpm)
0
30
> 60

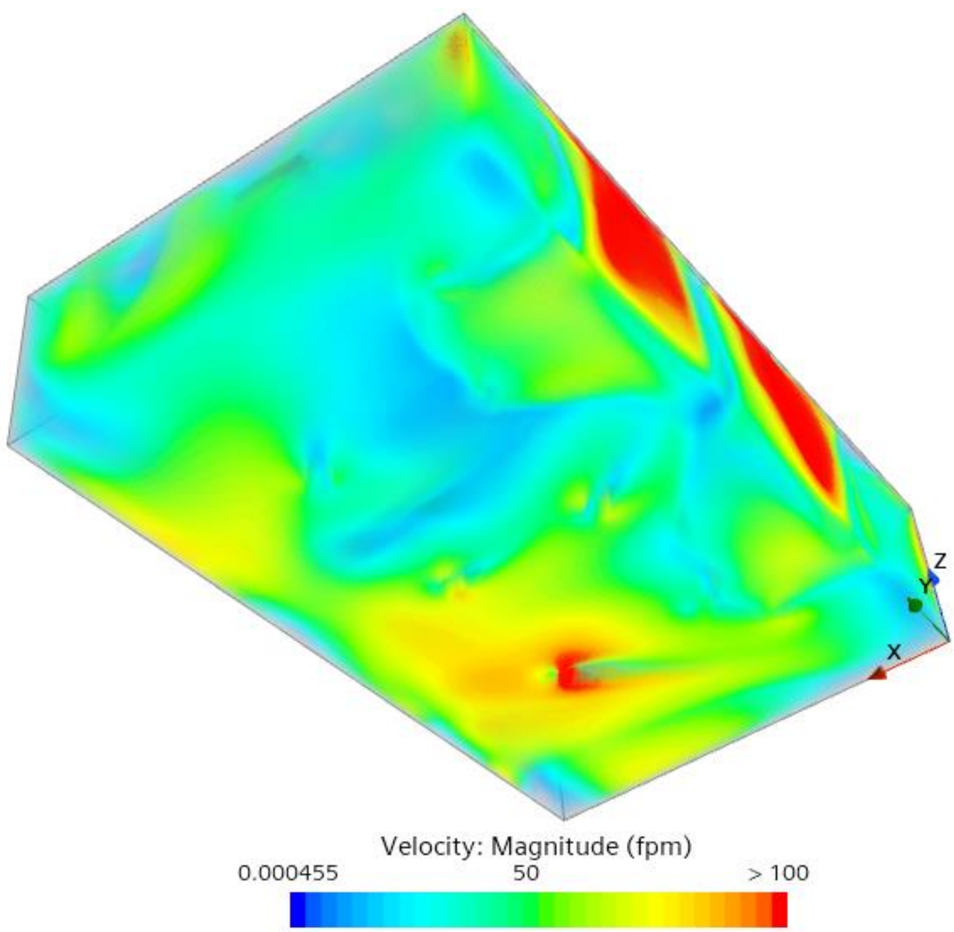

Z
X
Y
Velocity: Magnitude (fpm)
0
30
> 60


Z
Y
X
Velocity: Magnitude (fpm)
0
30
> 60

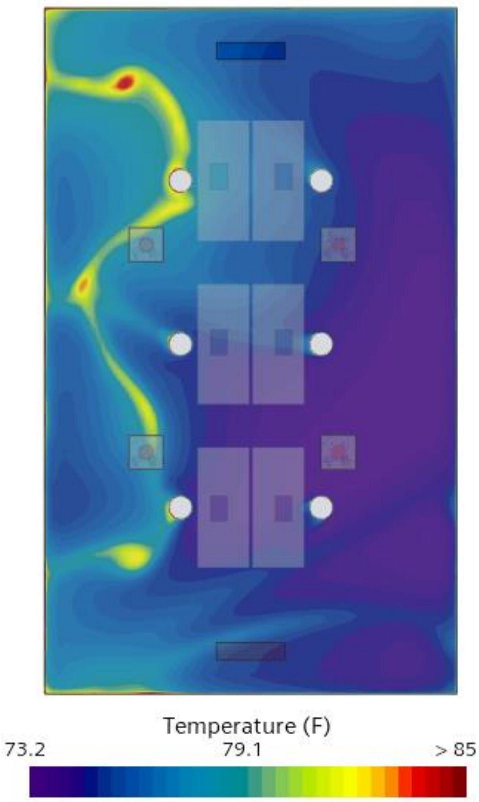

Z
Y
X
Velocity: Magnitude (fpm)
0.000455
50
> 100


Z
X
Y
Velocity: Magnitude (fpm)
0.000455
50
> 100

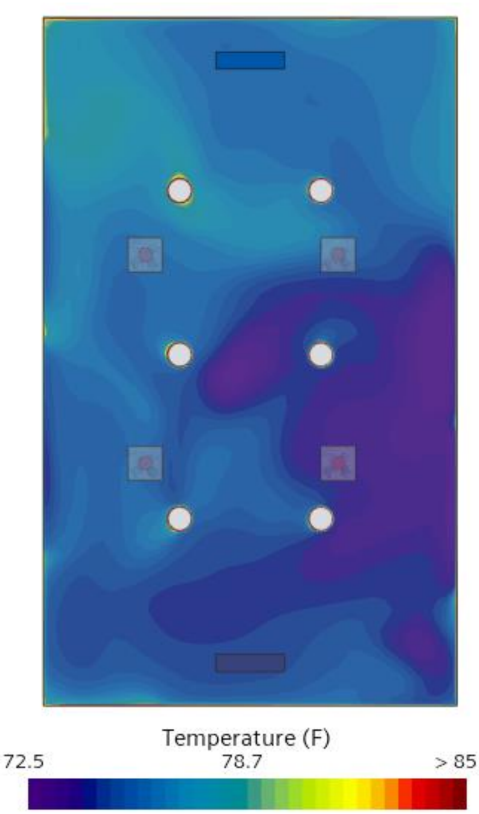

Z
X
Y
Velocity: Magnitude (fpm)
0.000455
50
> 100


Z
Y
X
Velocity: Magnitude (fpm)
0.000455
50
> 100

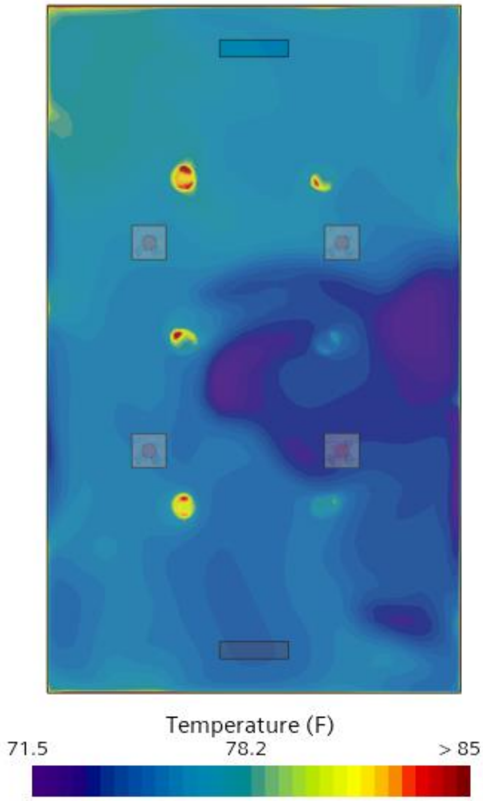
Air Temperature



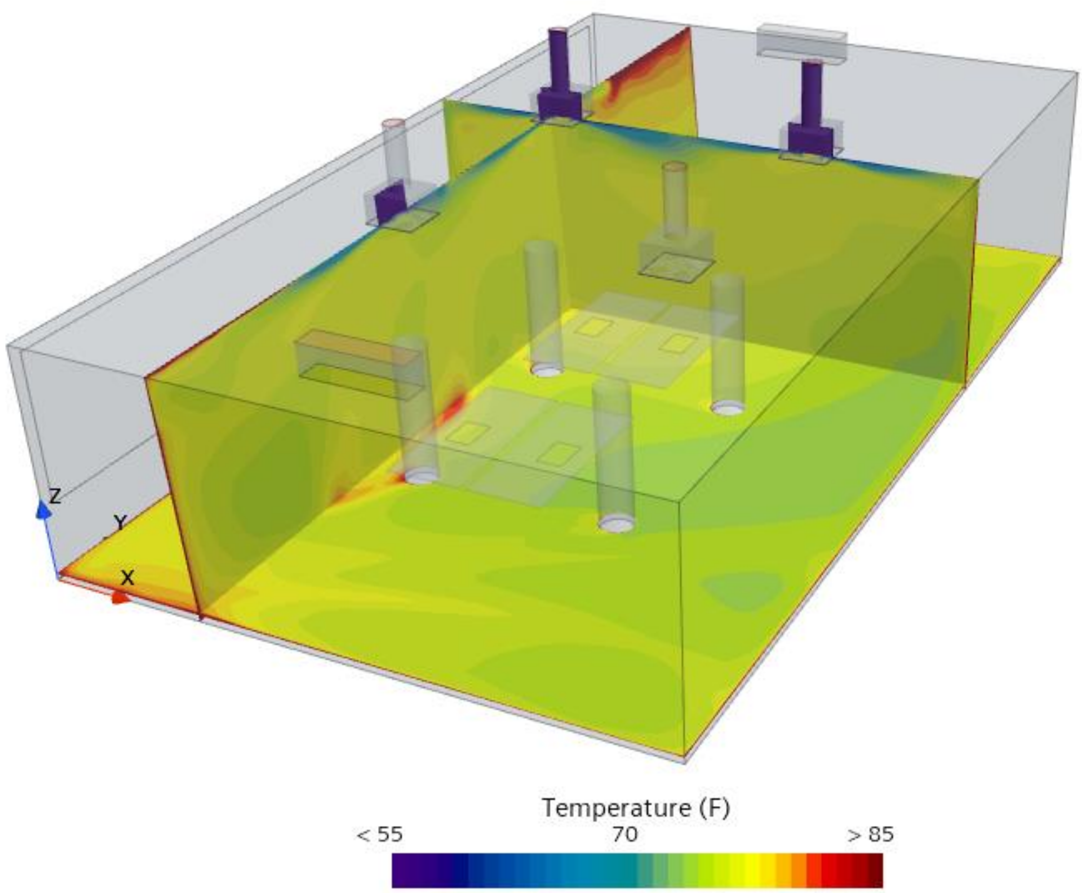
3in from the floor
Average at 75.9°F

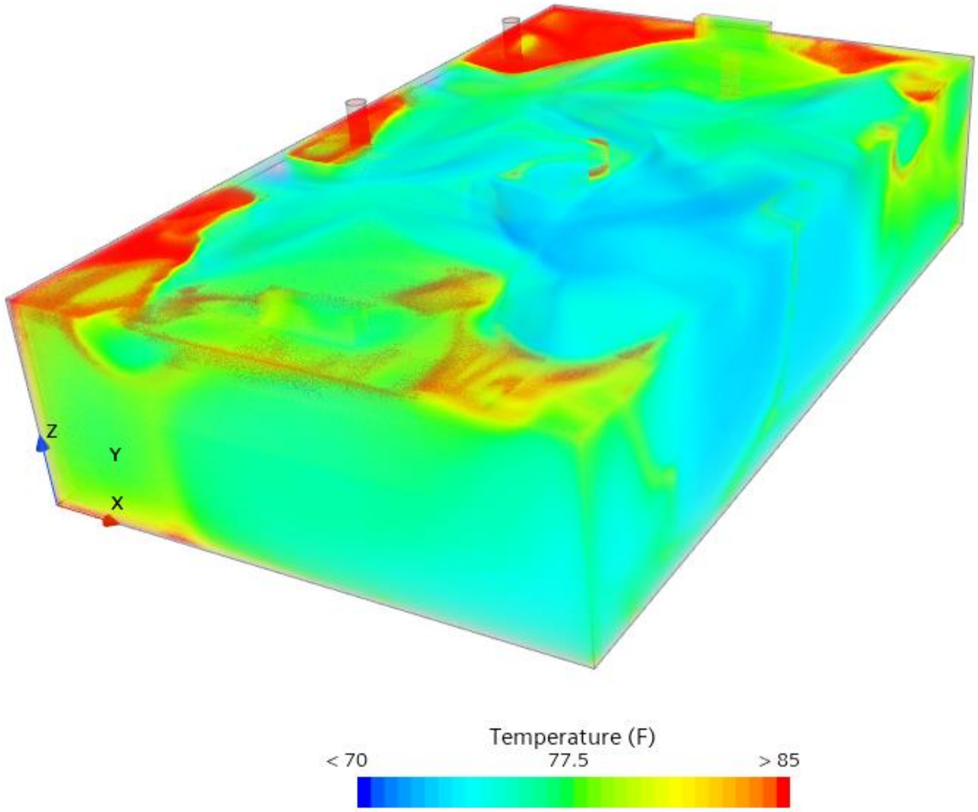


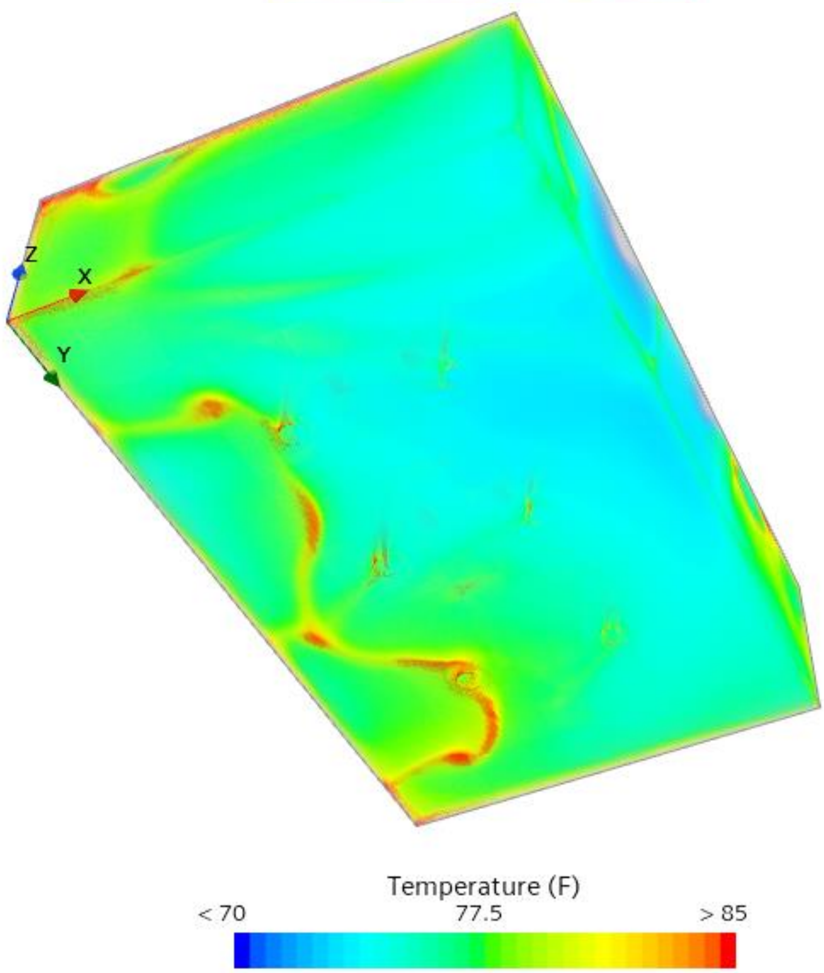
4ft from the floor
Average at 75.3°F

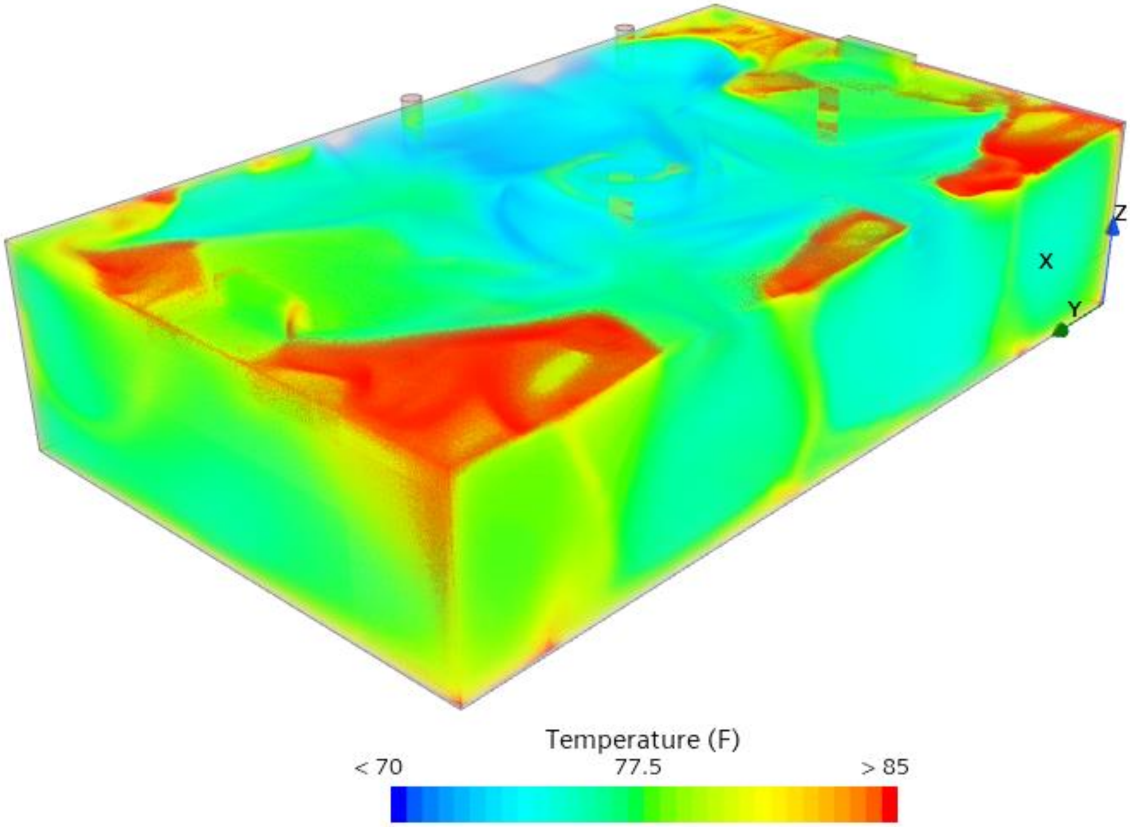


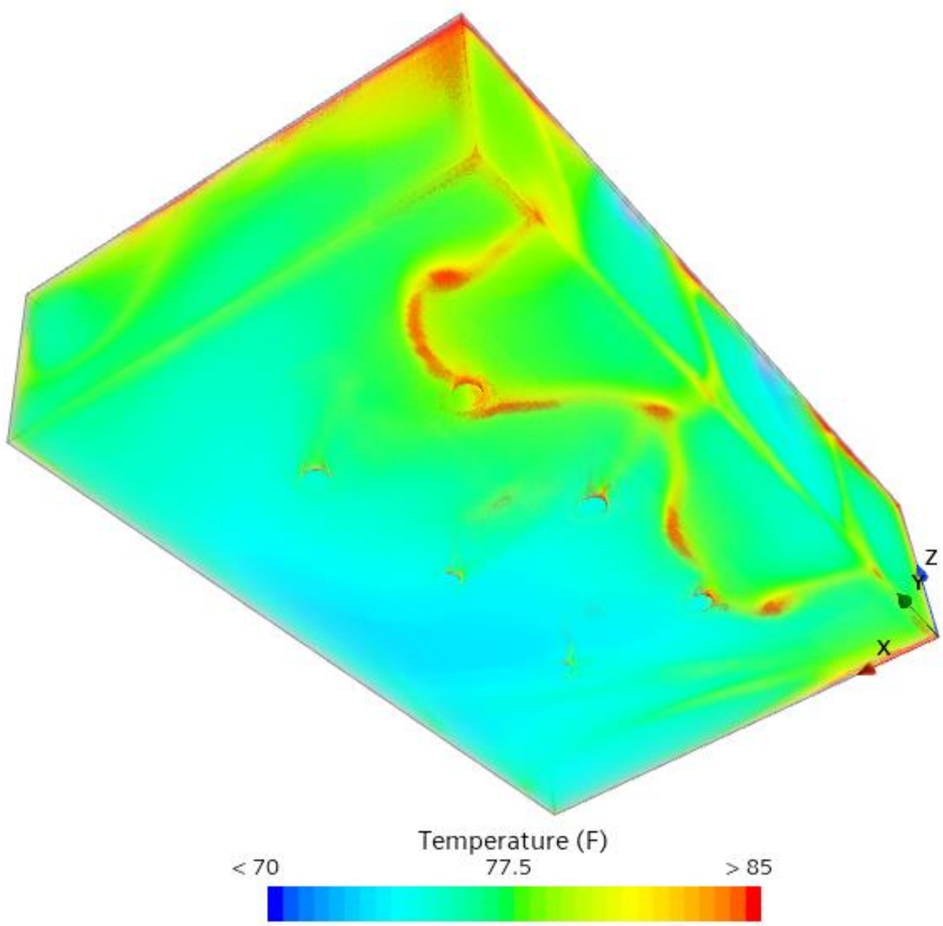
6ft from the floor
Average at 75.6°F



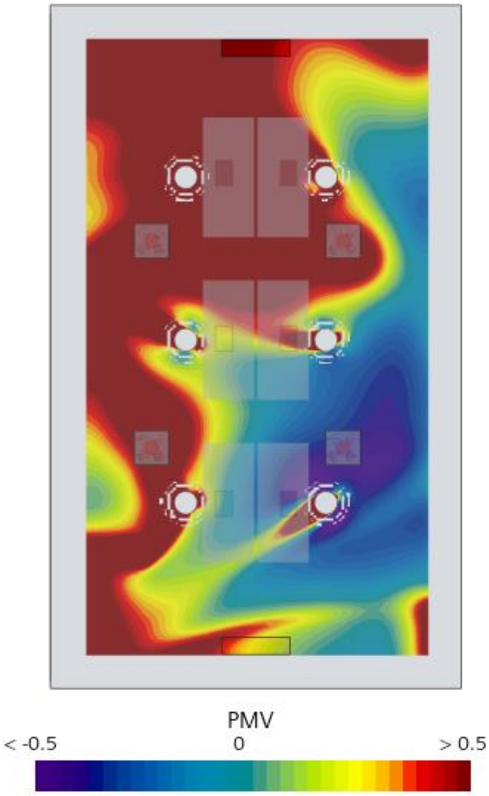

Z
Y
X
Temperature (F)
< 70
77.5
> 85


Z
X
Y
Temperature (F)
< 70
77.5
> 85

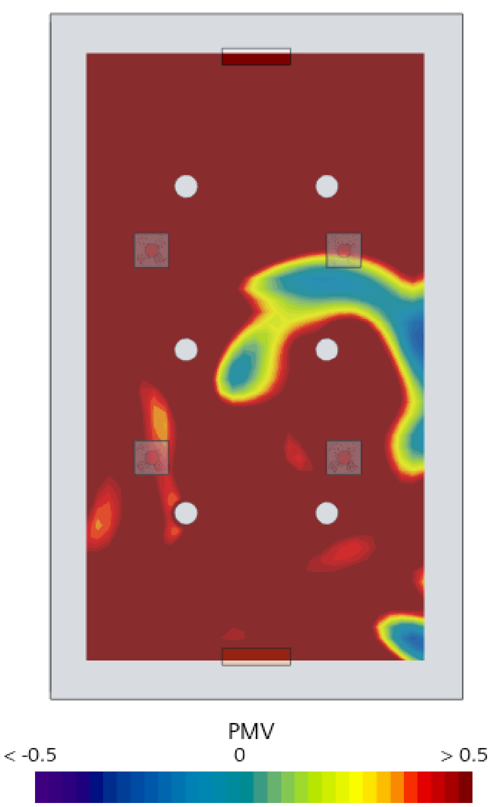

X
Y
Z
Temperature (F)
< 70
77.5
> 85


Z
Y
X
Temperature (F)
< 70
77.5
> 85

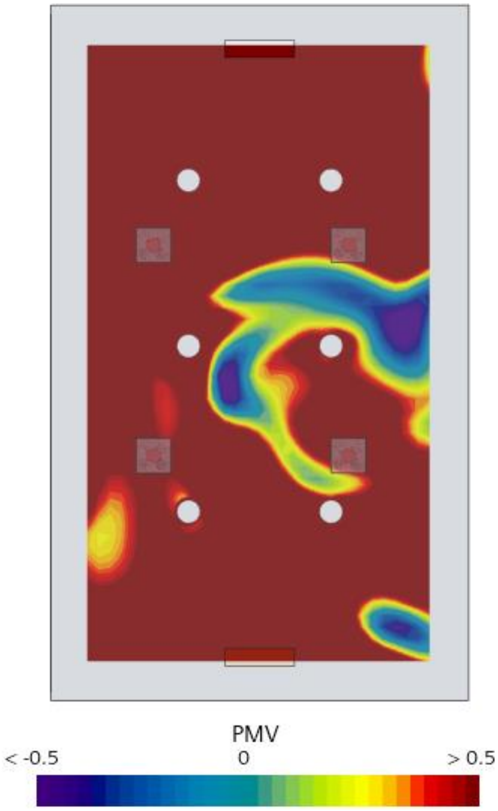
Predicted Mean Vote (PMV)



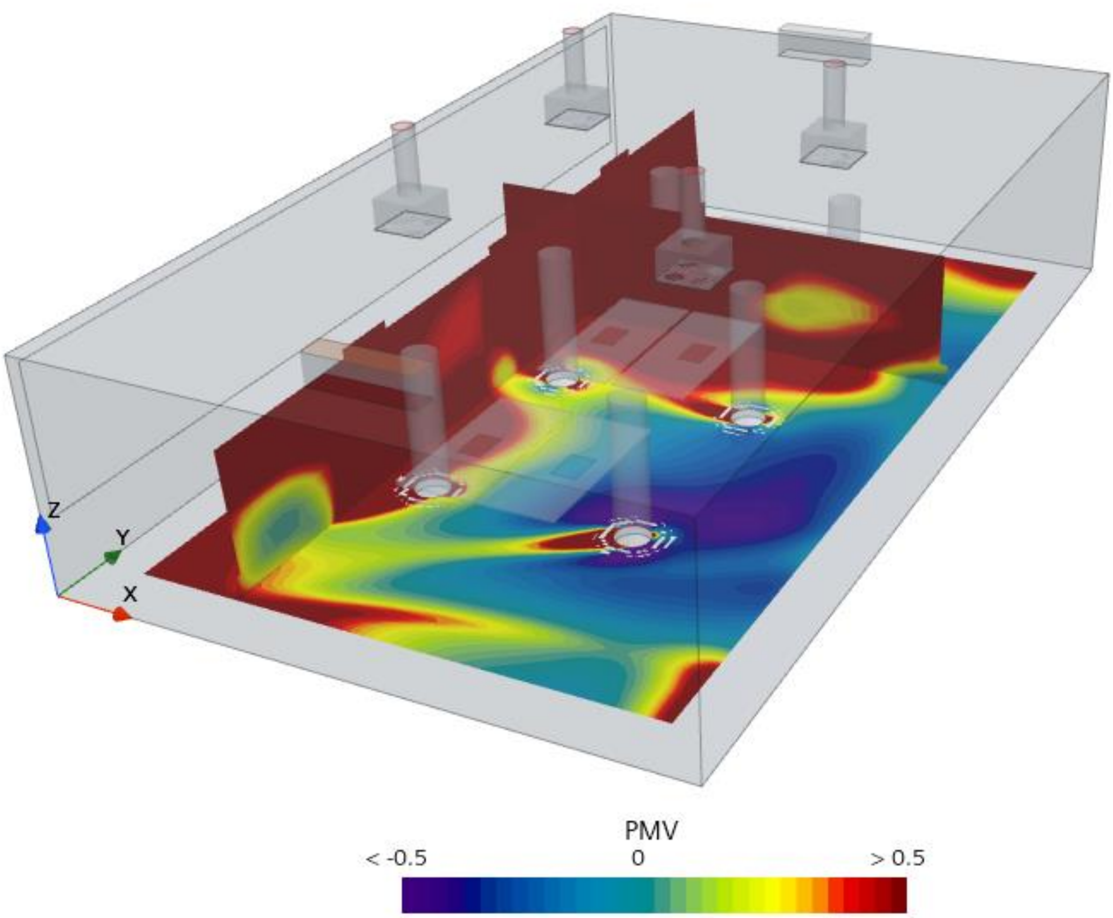
3in from the floor
Average at 0.31



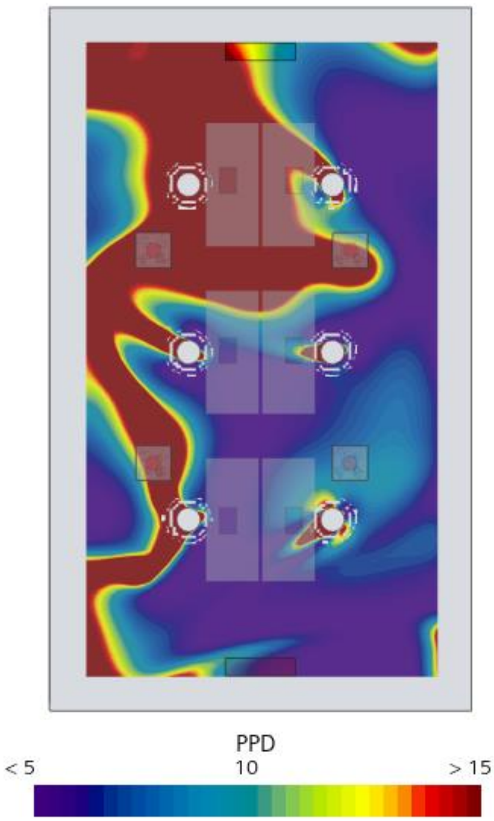
4ft from the floor
Average at 0.69



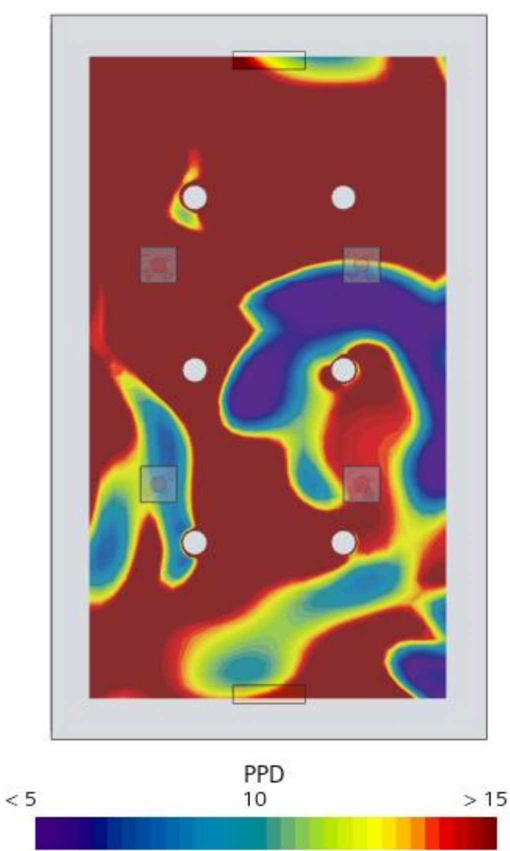
6ft from the floor
Average at 0.68



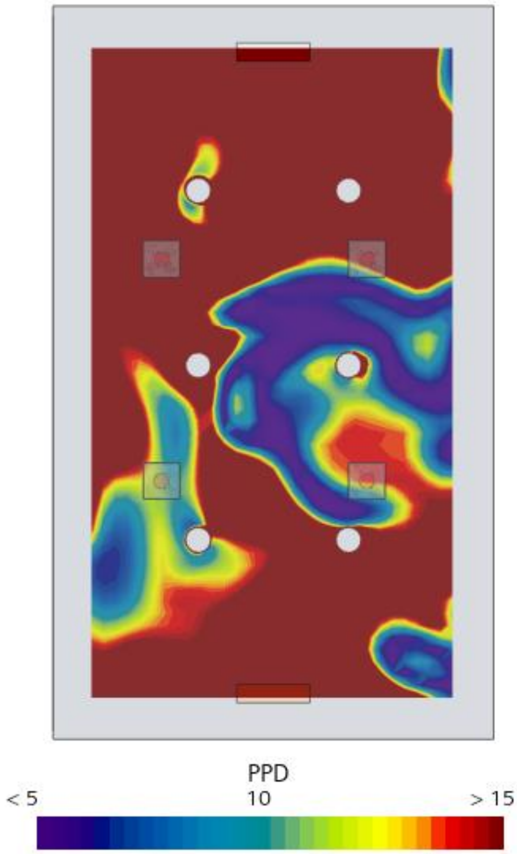
Predicted Percentage Dissatisfied (PPD)



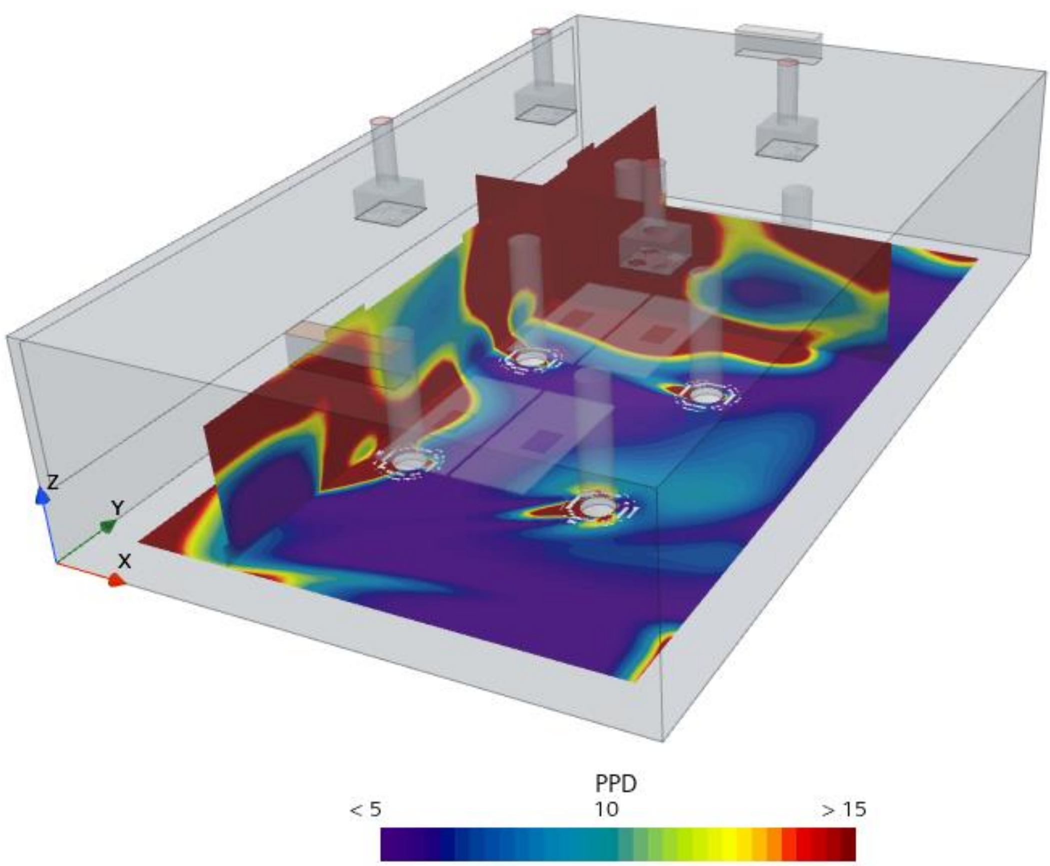
3in from the floor
Average at 11.4%



4ft from the floor
Average at 16.5%

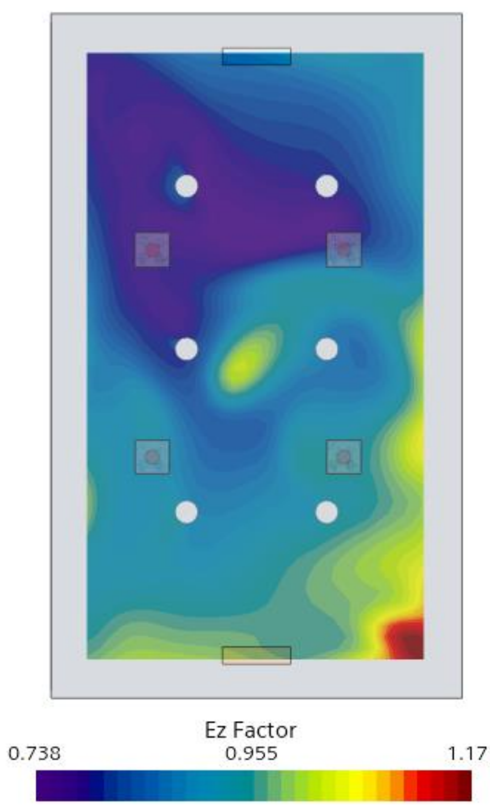


6ft from the floor
Average at 16.9%

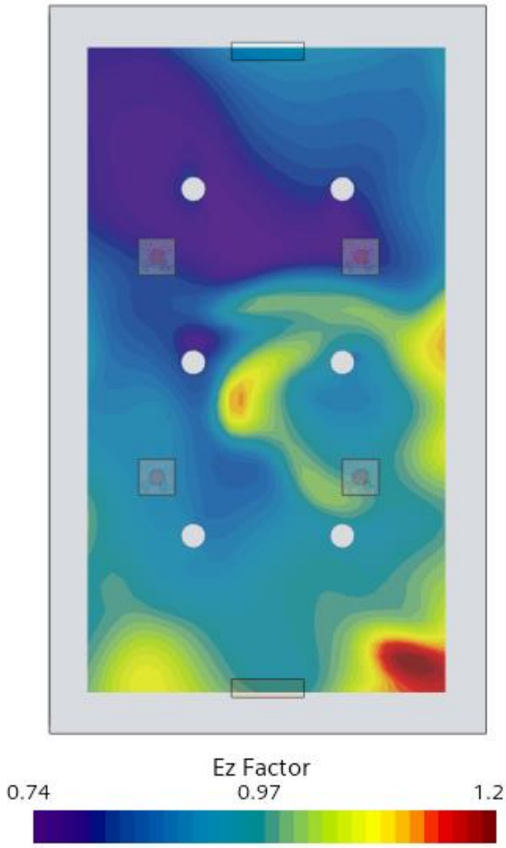


Zone Air change Effectiveness (Ez Factor)

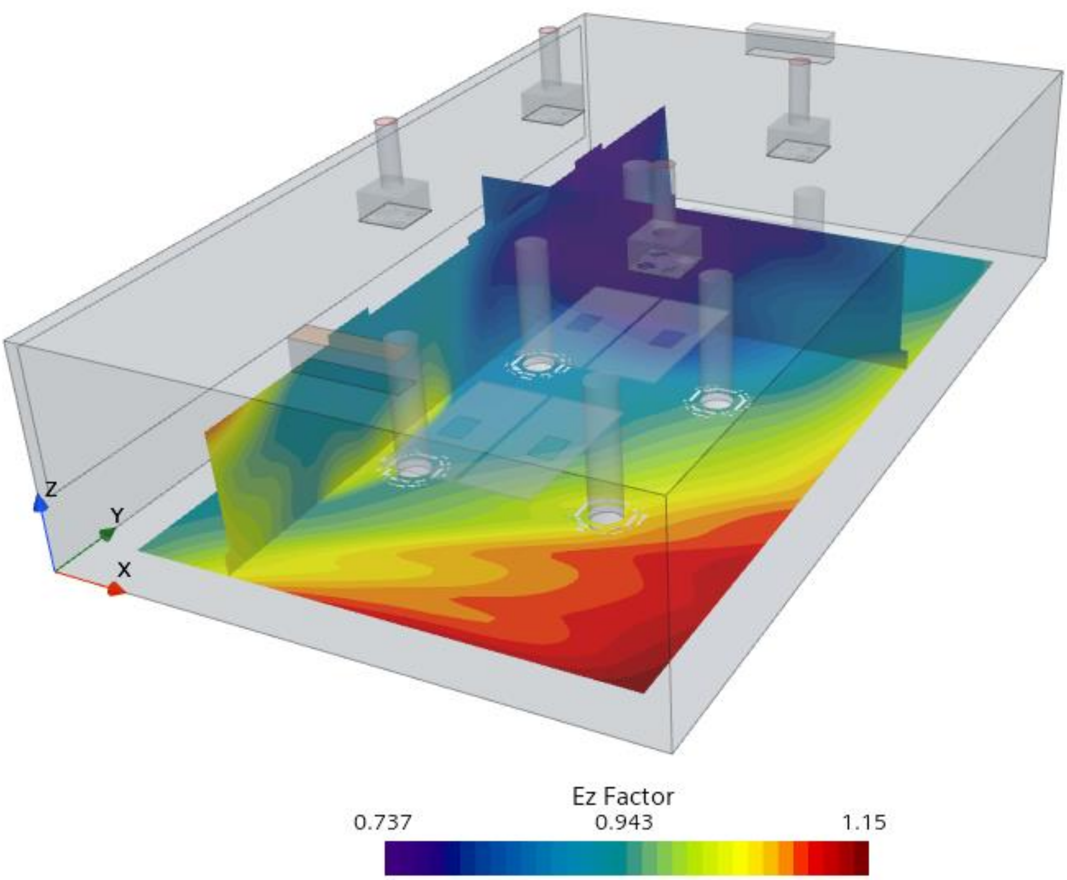
3in from the floor
Average at 0.93



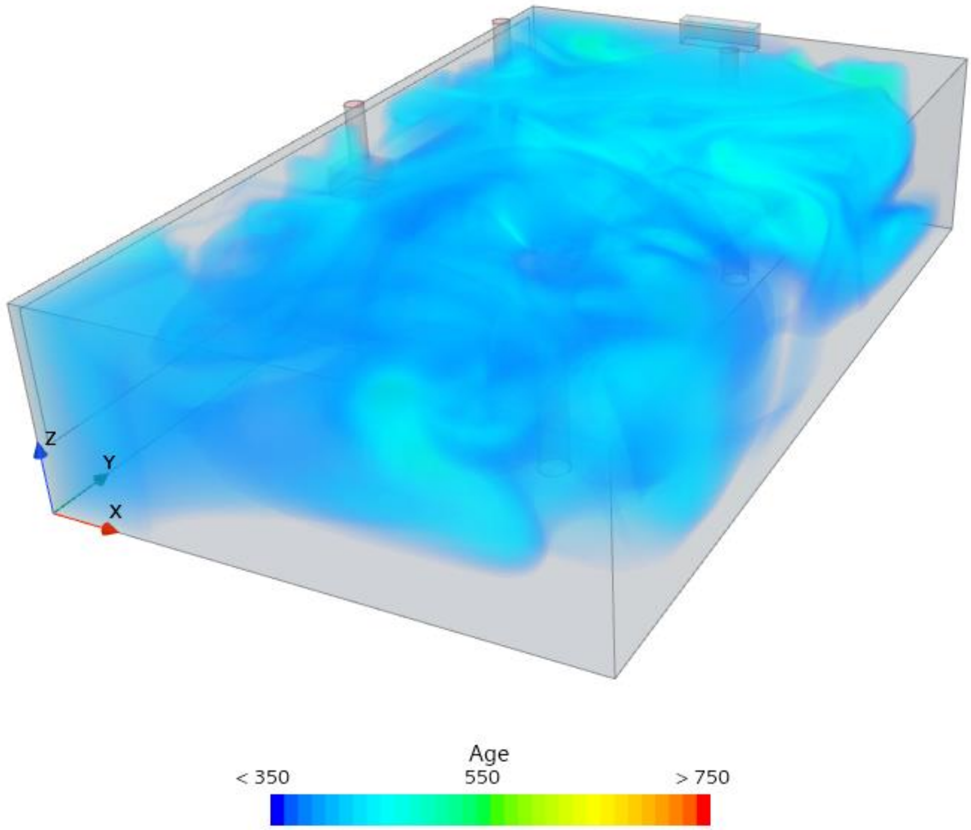
4ft from the floor
Average at 0.90

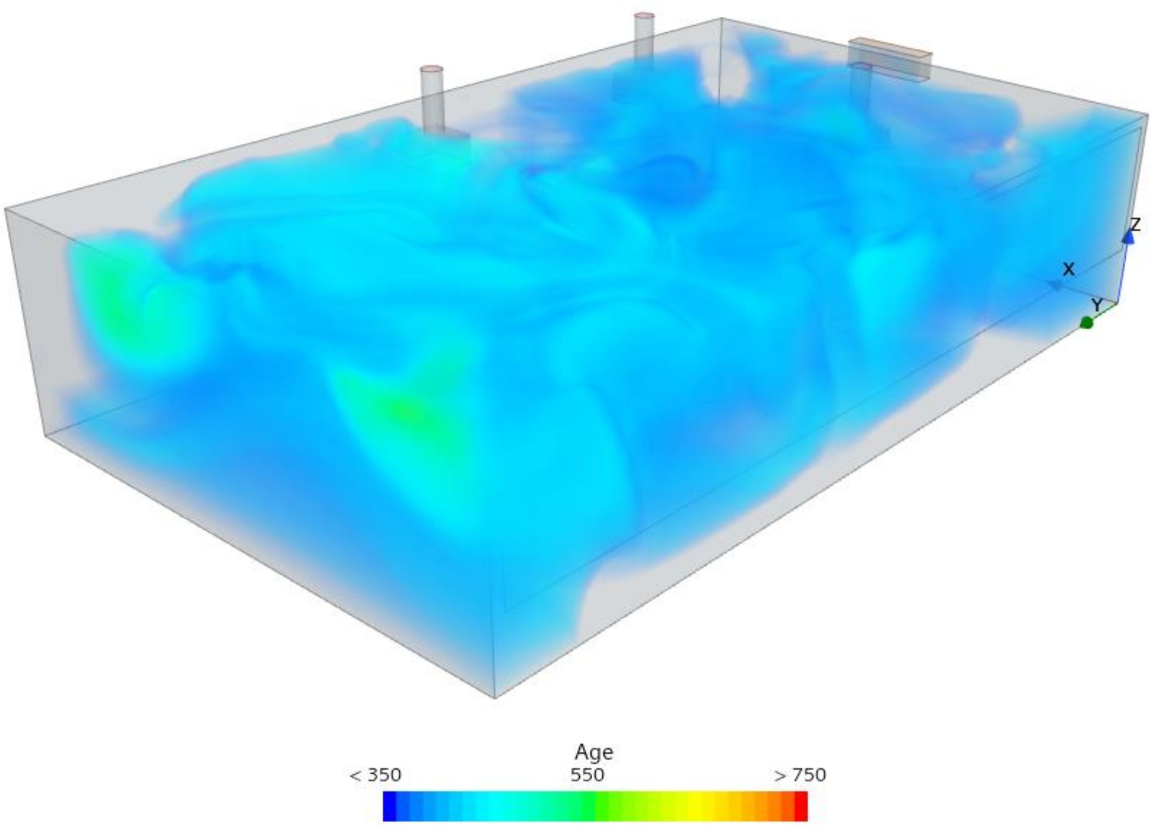


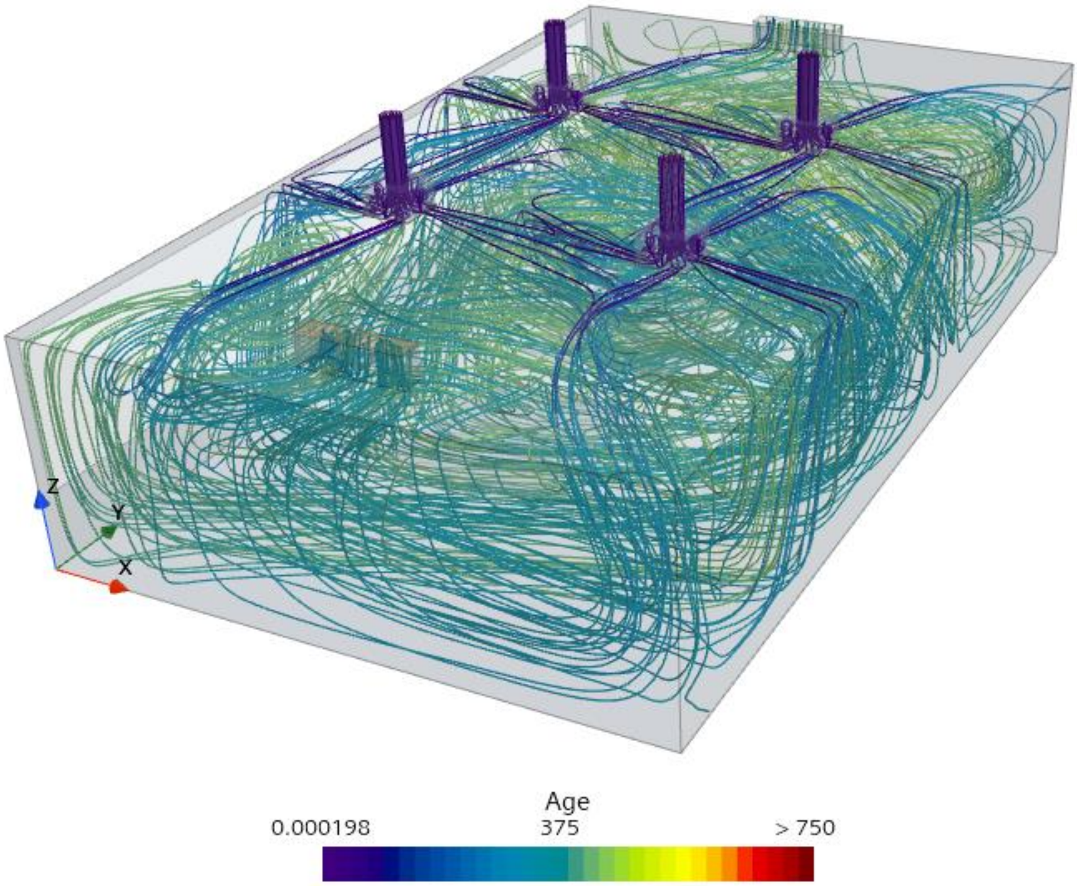
6ft from the floor
Average at 0.76

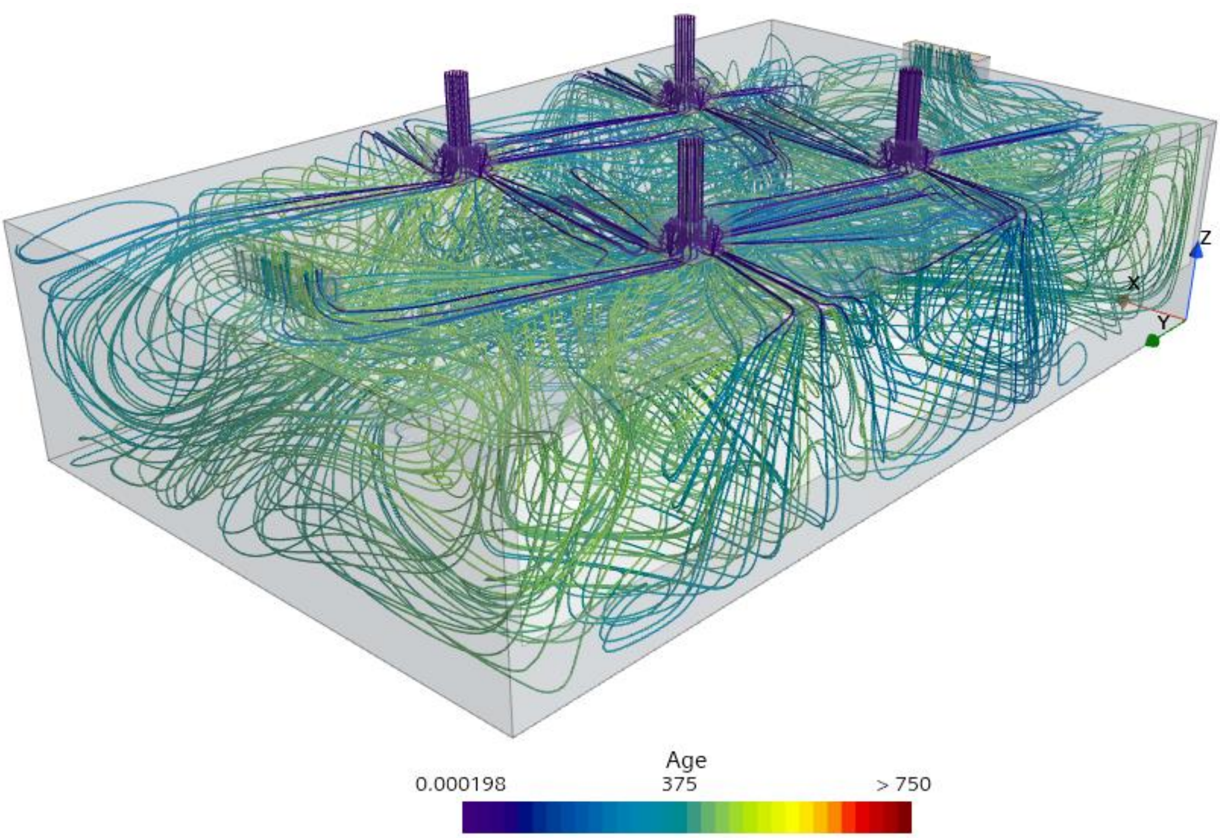


Mean Age of Air





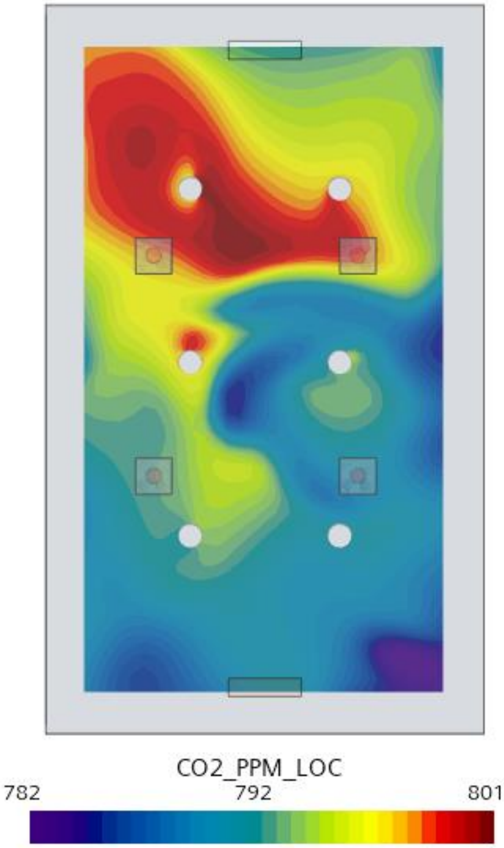

Z
Y
X
Age
0.000198
375
> 750


Z
X
Y
Age
0.000198
375
> 750

CO2 Breathing Zone Concentration (PPM)

3in from the floor
Average at 791 ppm

4ft from the floor
Average at 794 ppm



6ft from the floor
Average at 793 ppm