



Effectiv HVAC inc.

EFF0122001 : Development Room – PLAY-S - Heating

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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
Theoretical 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

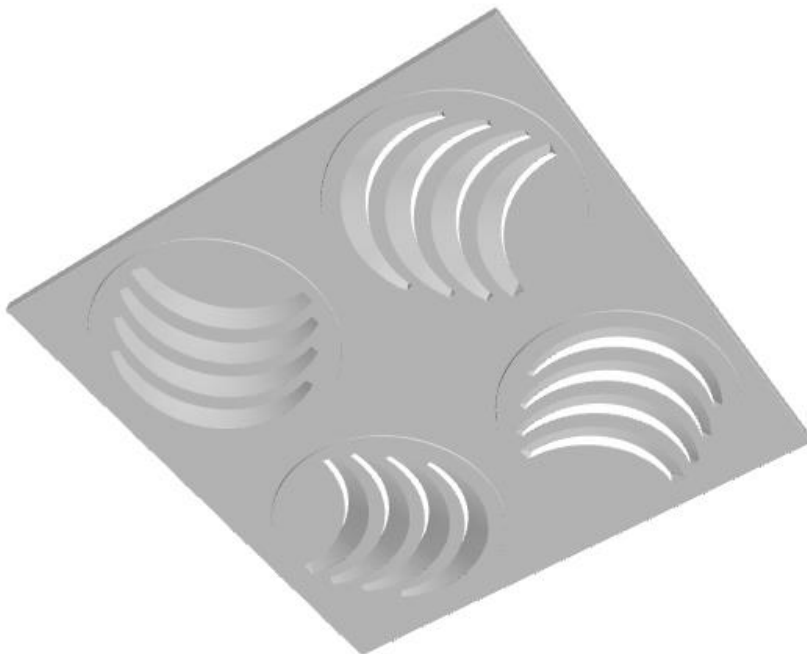
The air diffuser requires a mesh small enough so that flow directions and velocities represent reality

Air diffuser mesh validation

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

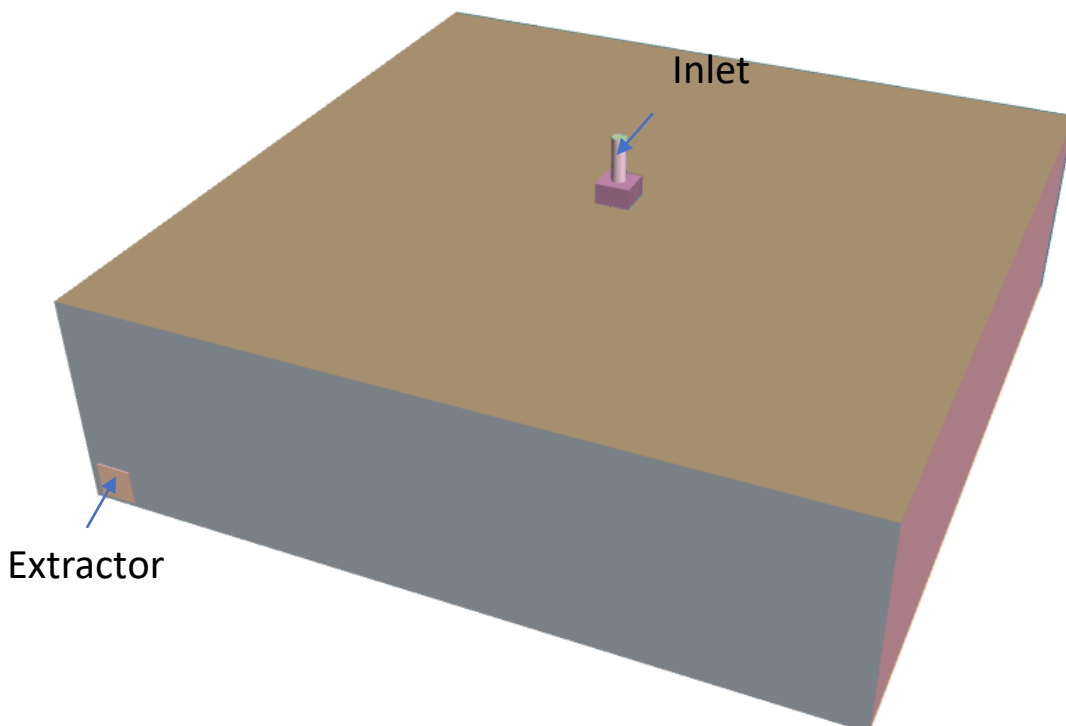
This diffuser incorporates small features that need to be resolved correctly in order to obtain the correct performances.

PLAY-S 24



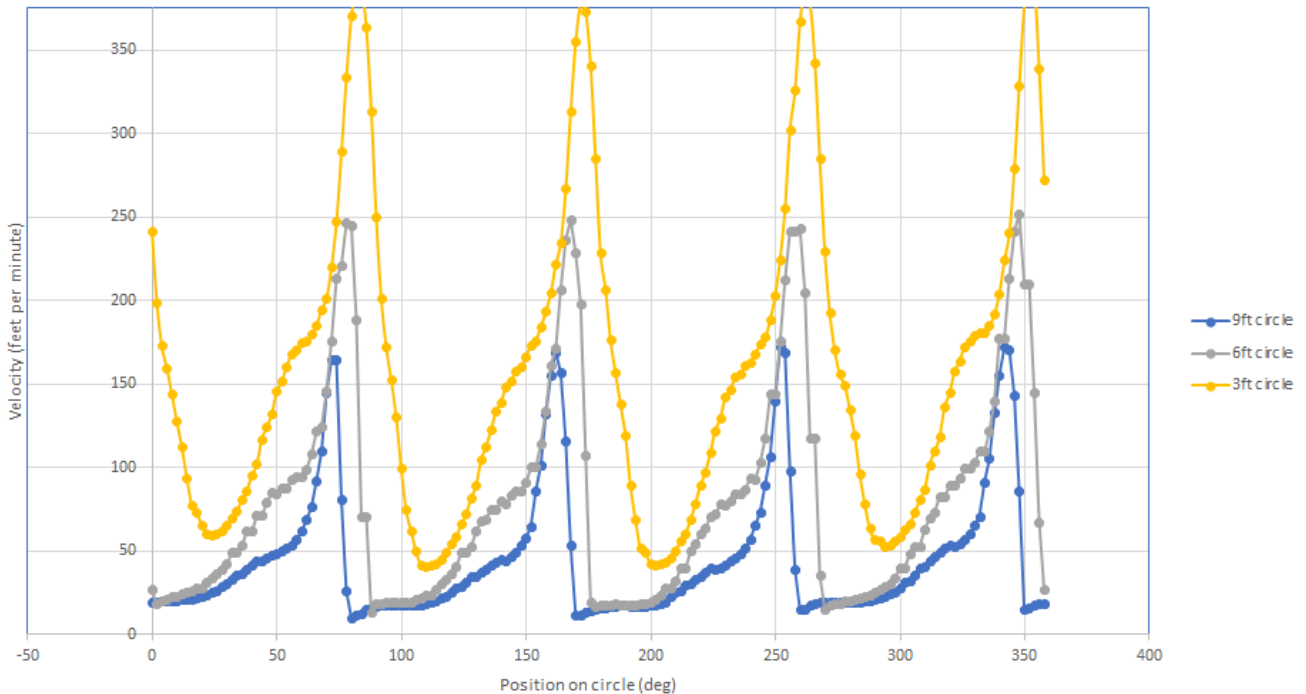
Neck Size (inches)	Neck (fpm) Velocity	200	300	400	500	600	700	800	1000
	Velocity Pressure (H ₂ O)	0.002	0.006	0.01	0.016	0.022	0.031	0.041	.062
6	CFM				98	118	137	157	196
	Pressure Loss (in.w.g.)				0.01	0.014	0.019	0.024	0.037
	NC				< 15	< 15	< 15	< 15	16
	Throw (ft) - Coanda Effect				2-2-4	2-3-4	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 the 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 are 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

PLAY-S 24 CFD Measured throw at 244 CFM



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:

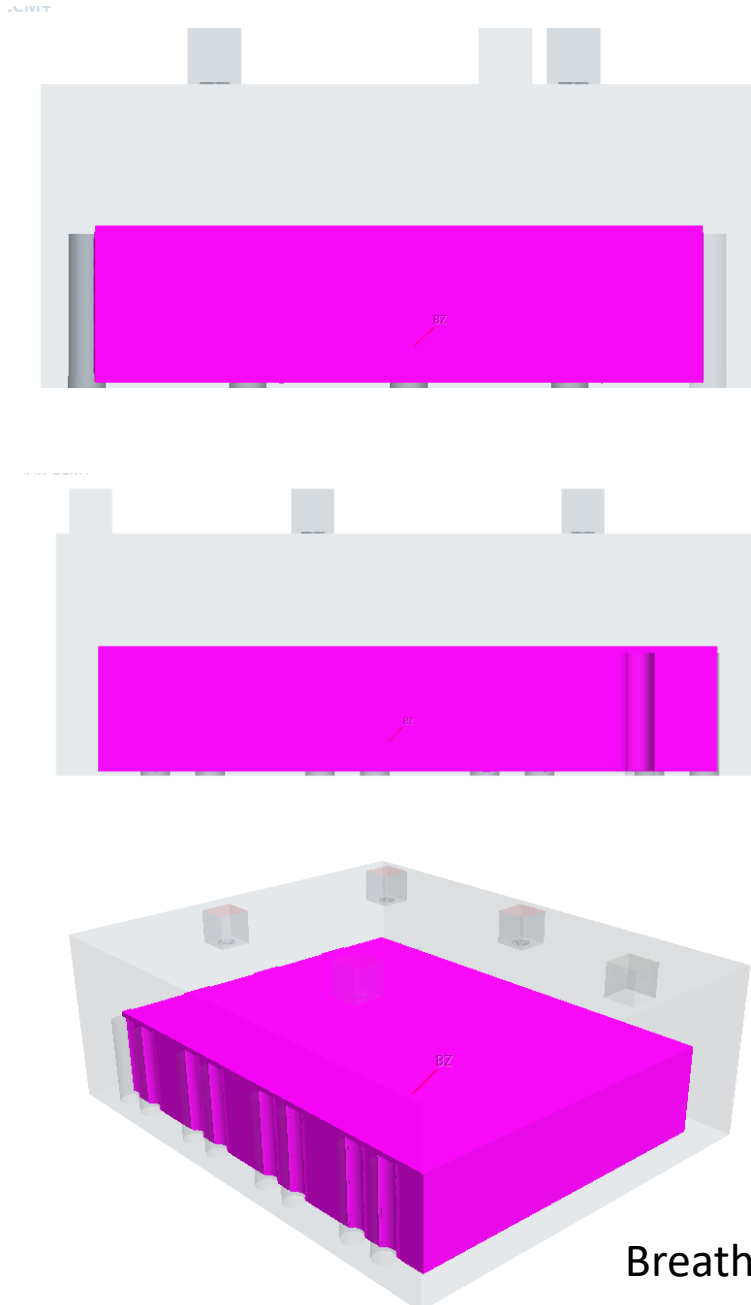
- Steady state approach
- Turbulence modeling active
- Energy and gravity activated
- Species transport
- Surface to surface radiation is modeled

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 theoretical 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 species 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

Generally 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*ft ² *F)
SHGC	0.27

- Ceiling

Properties	
U-factor	0.053 BTU /(h*ft ² *F)

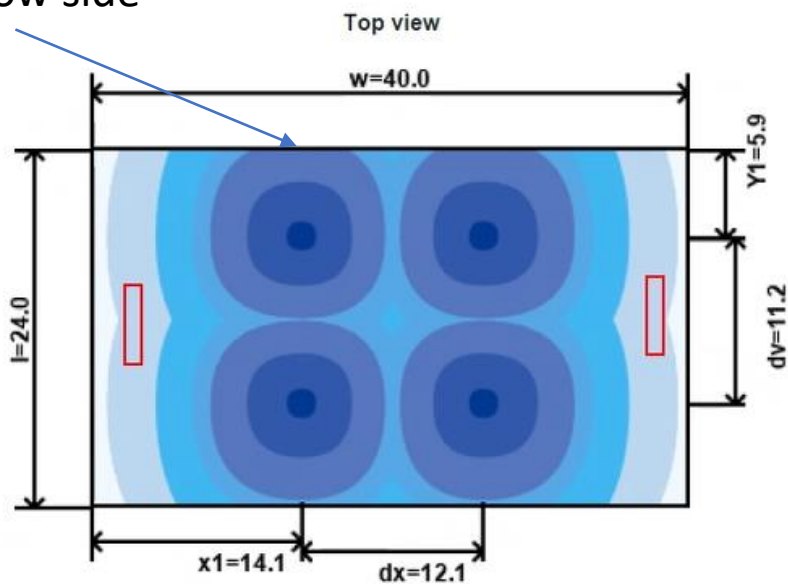
- Outside wall (west)

Properties	
U-factor	0.044 BTU /(h*ft ² *F)

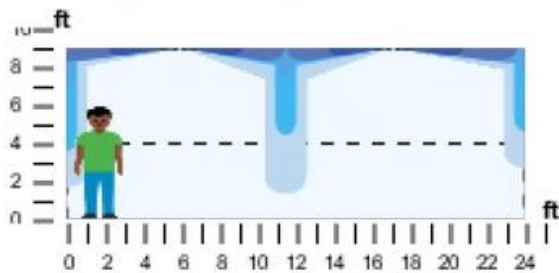
- Inlets and outlets positioned as follows

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Window side



Section y

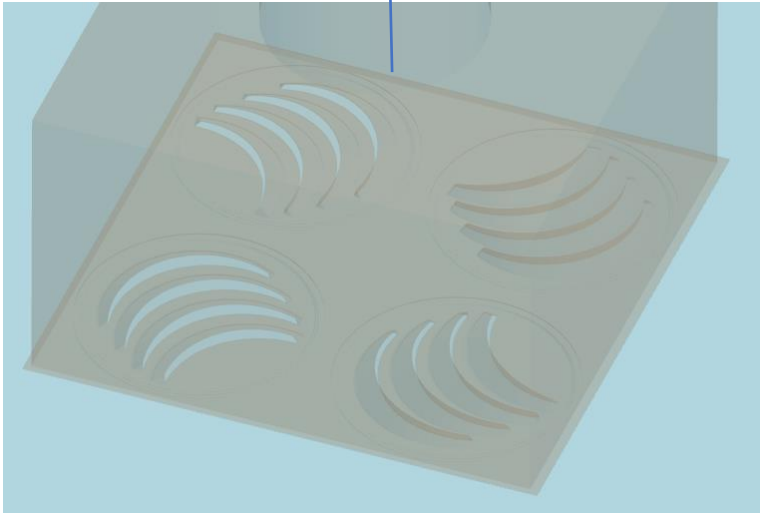
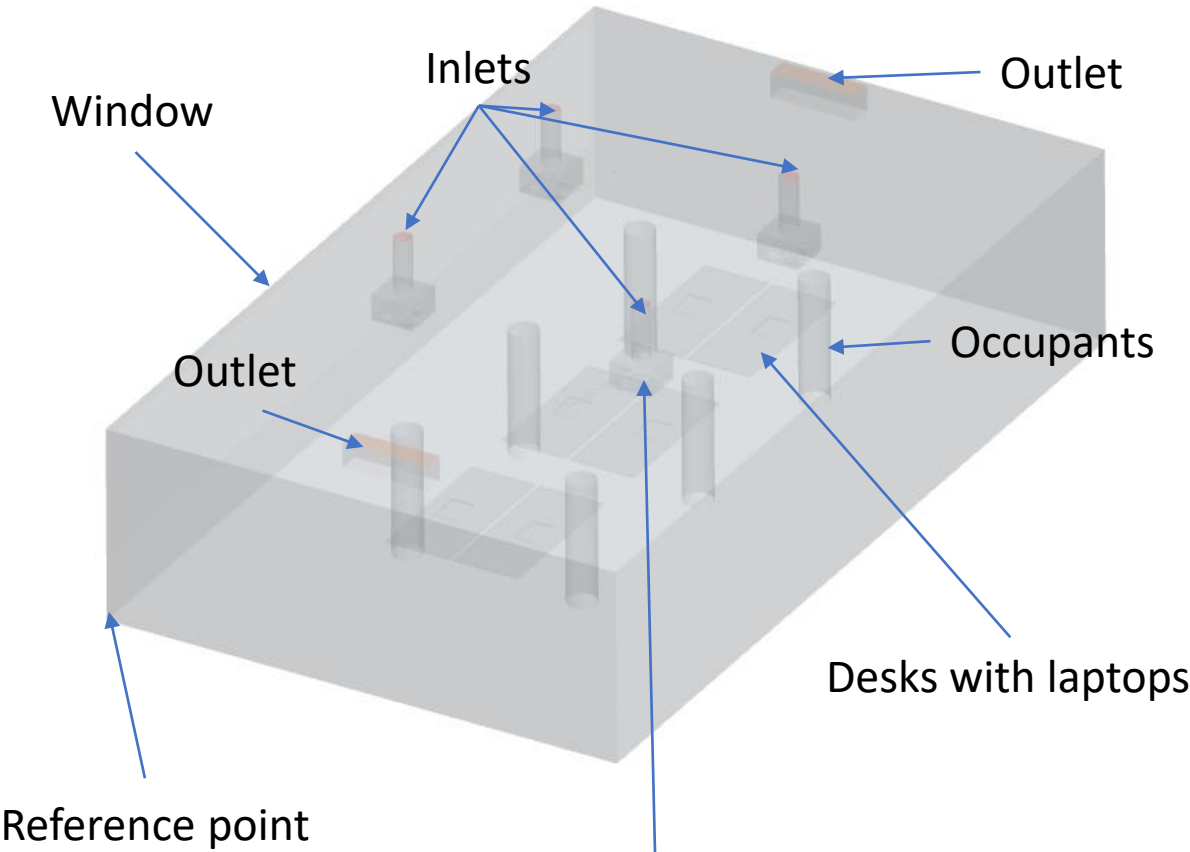


Section x

Diffusers

- 4 PLAY-S 24

Resulting model



Diffuser example

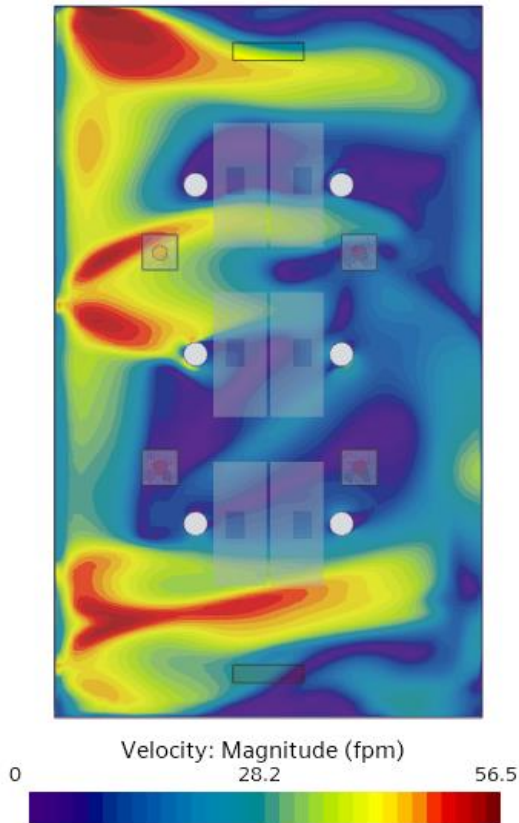
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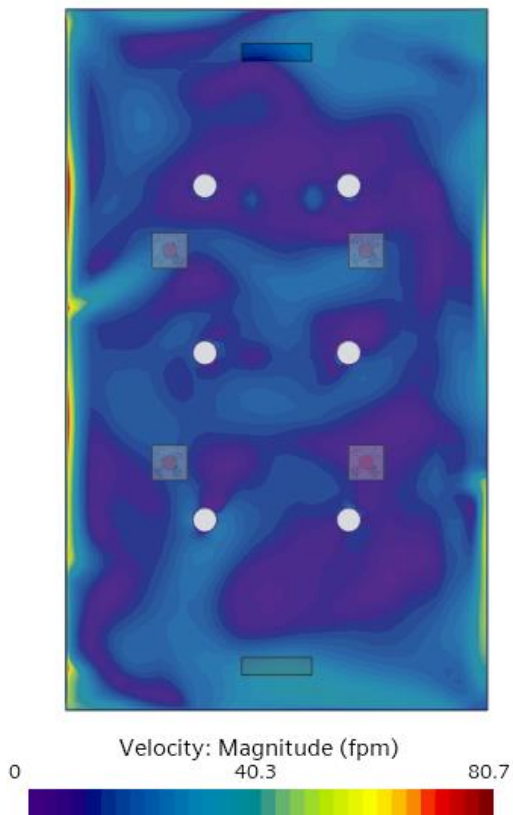
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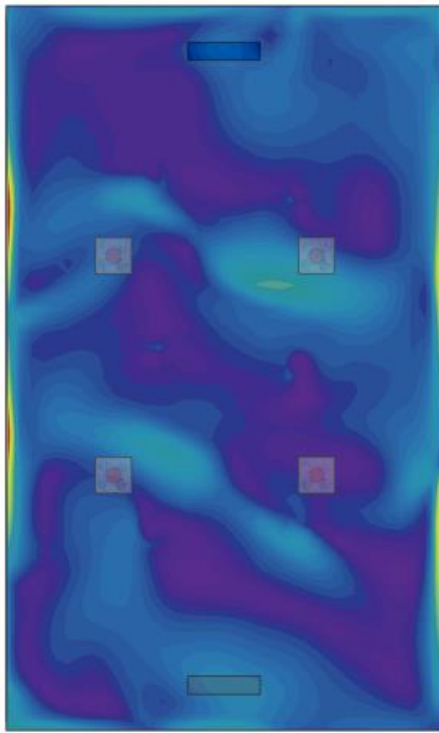
Air Velocity



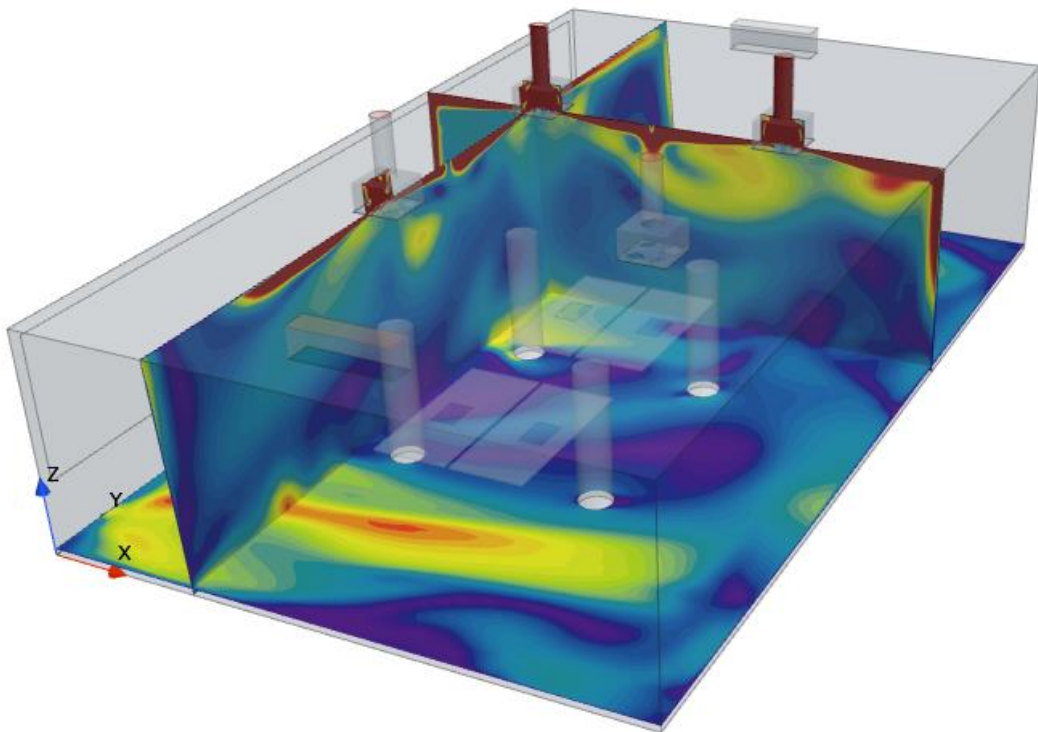
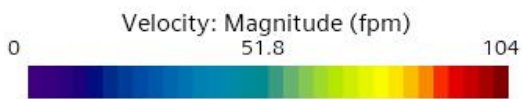
3in from the floor
Average at 23 fpm

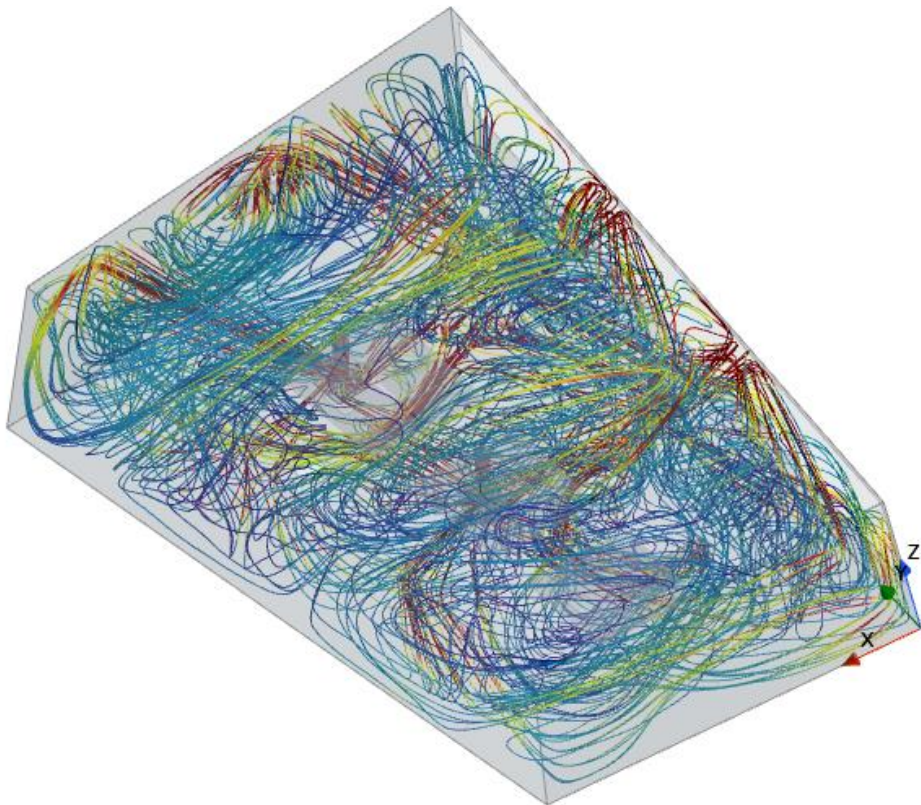
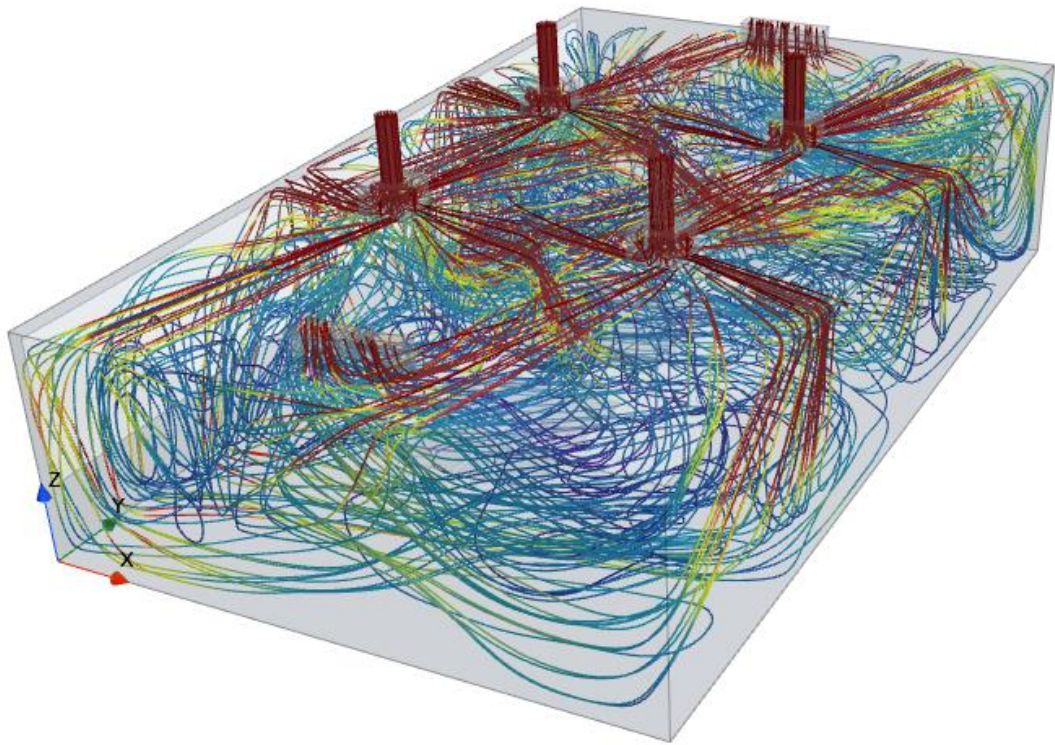


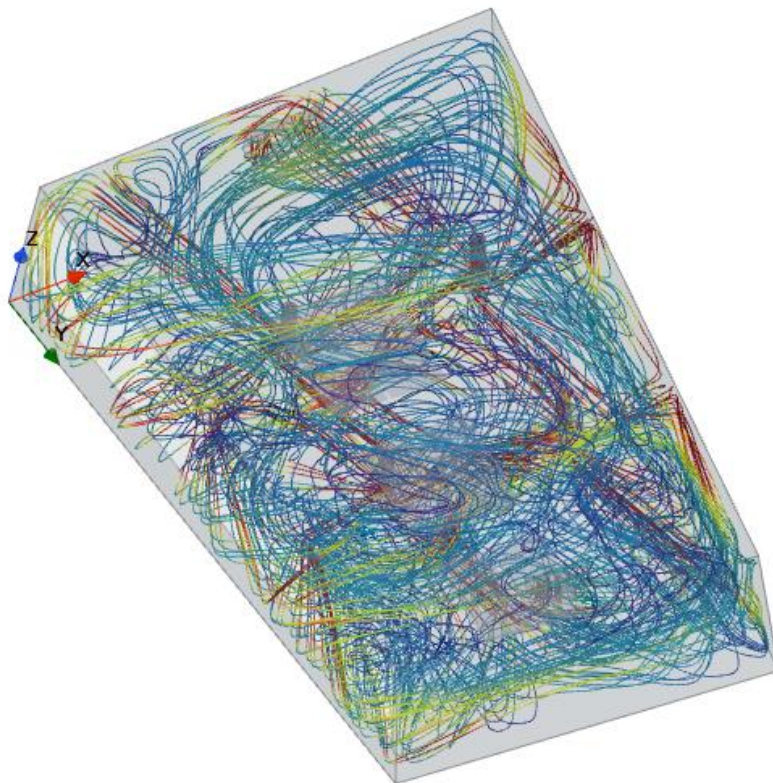
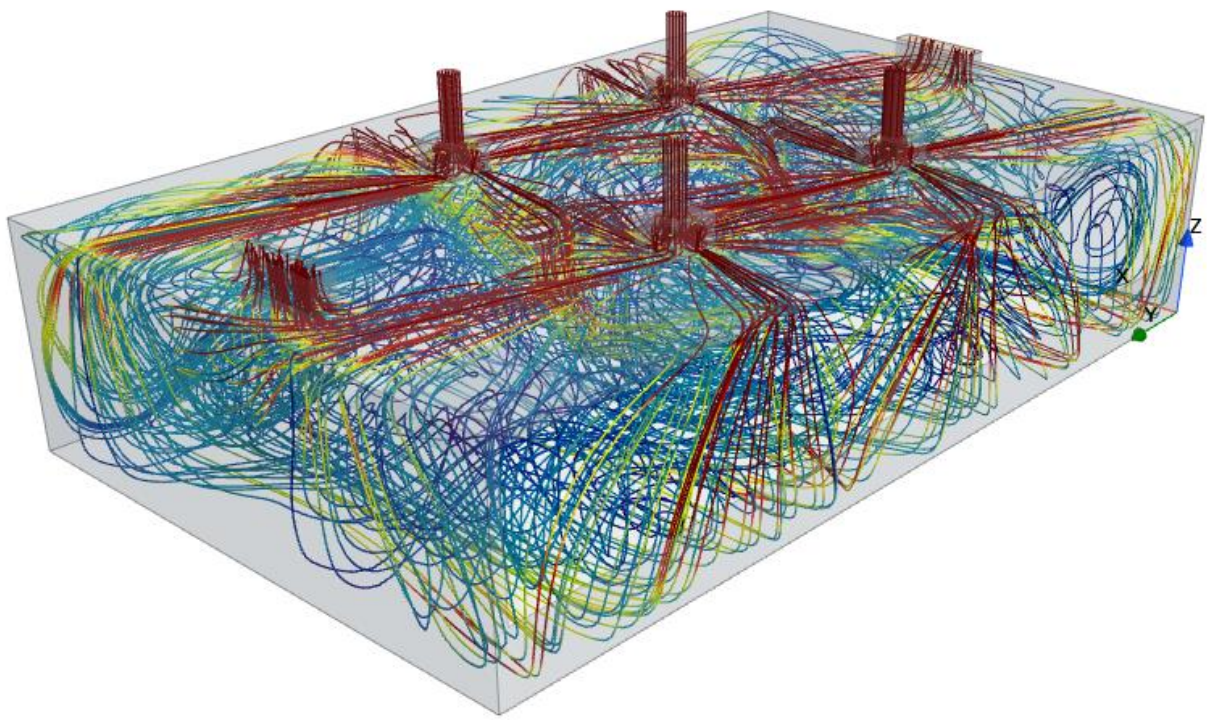
4ft from the floor
Average at 13 fpm

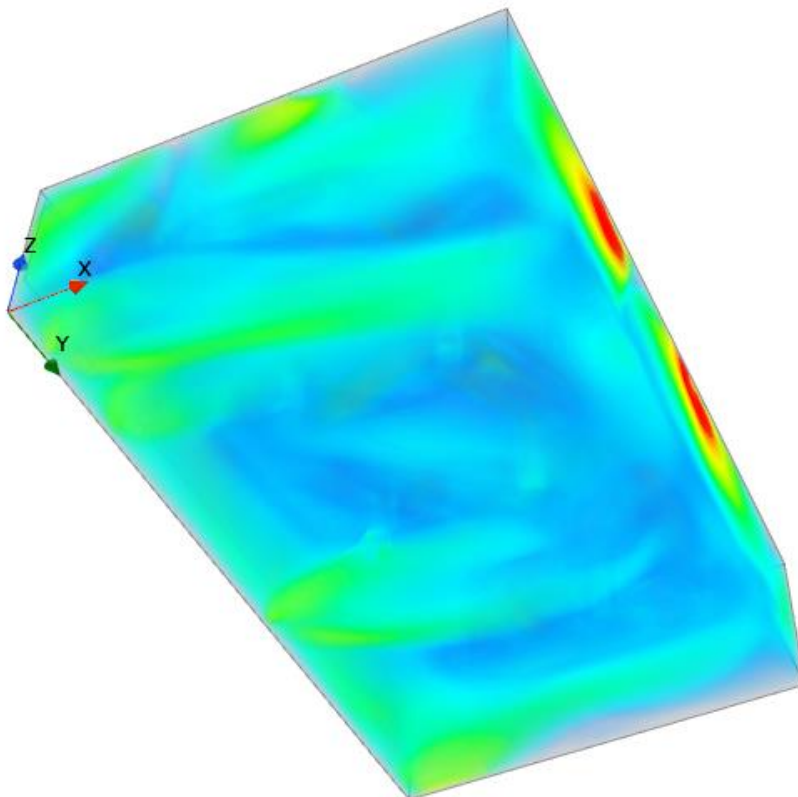
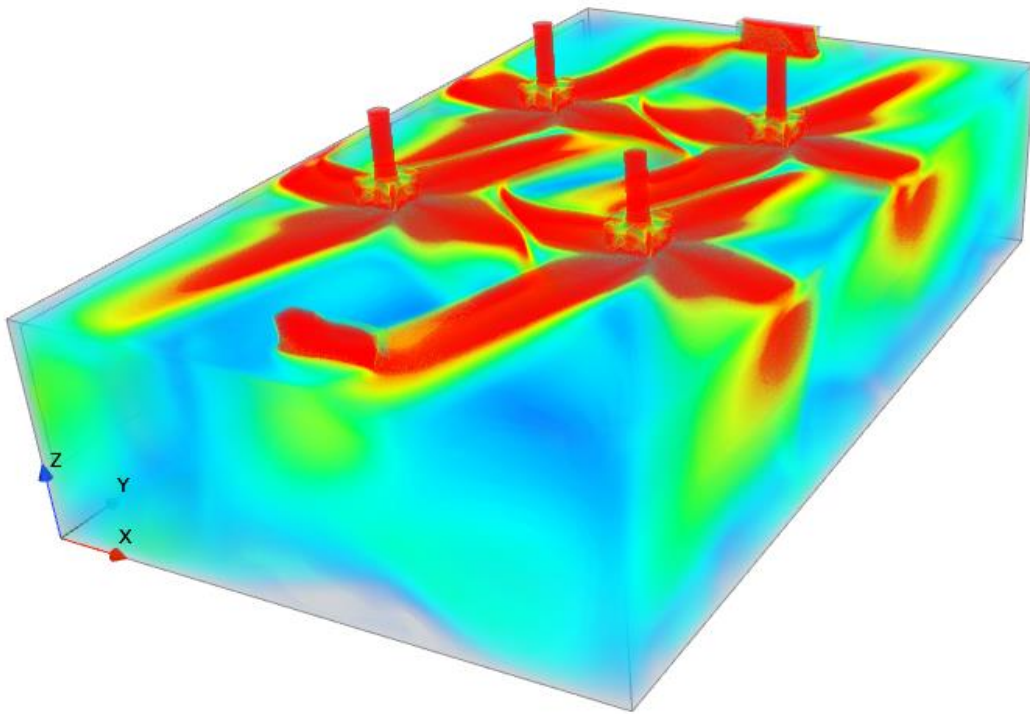


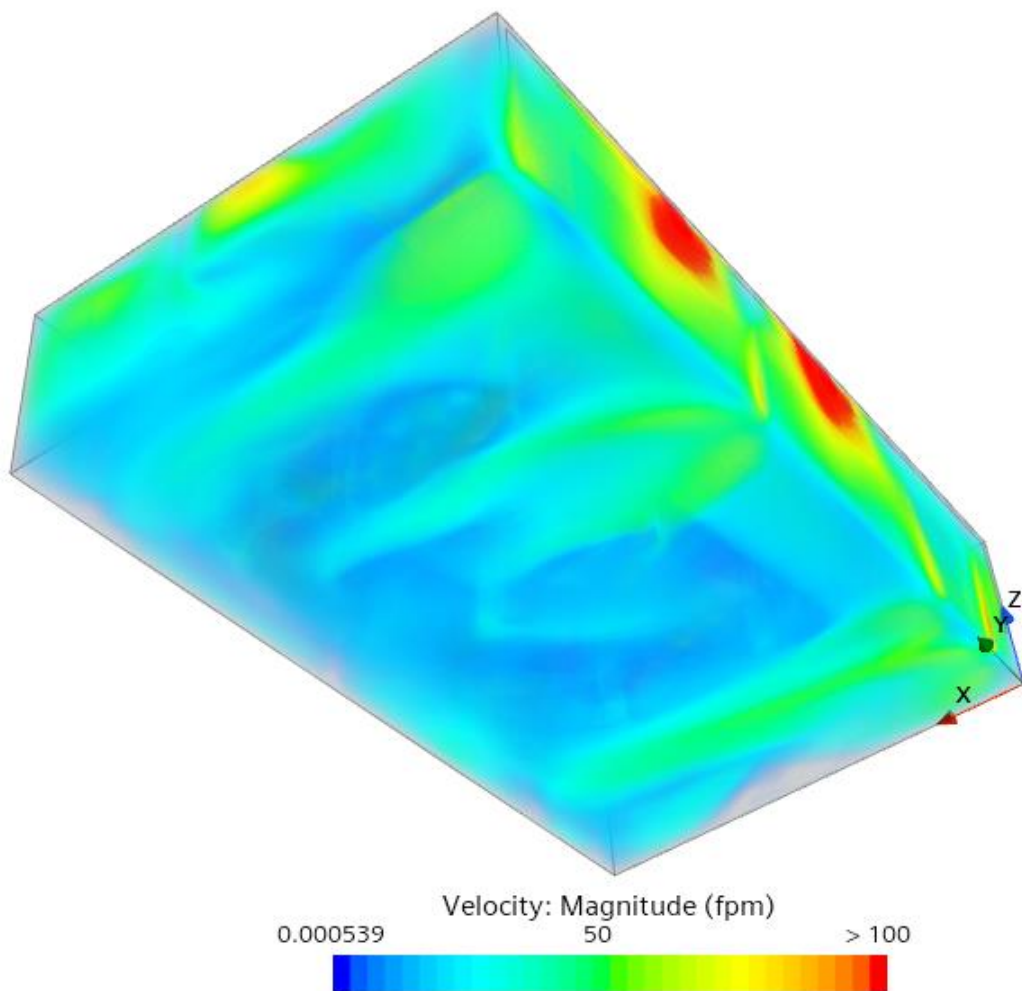
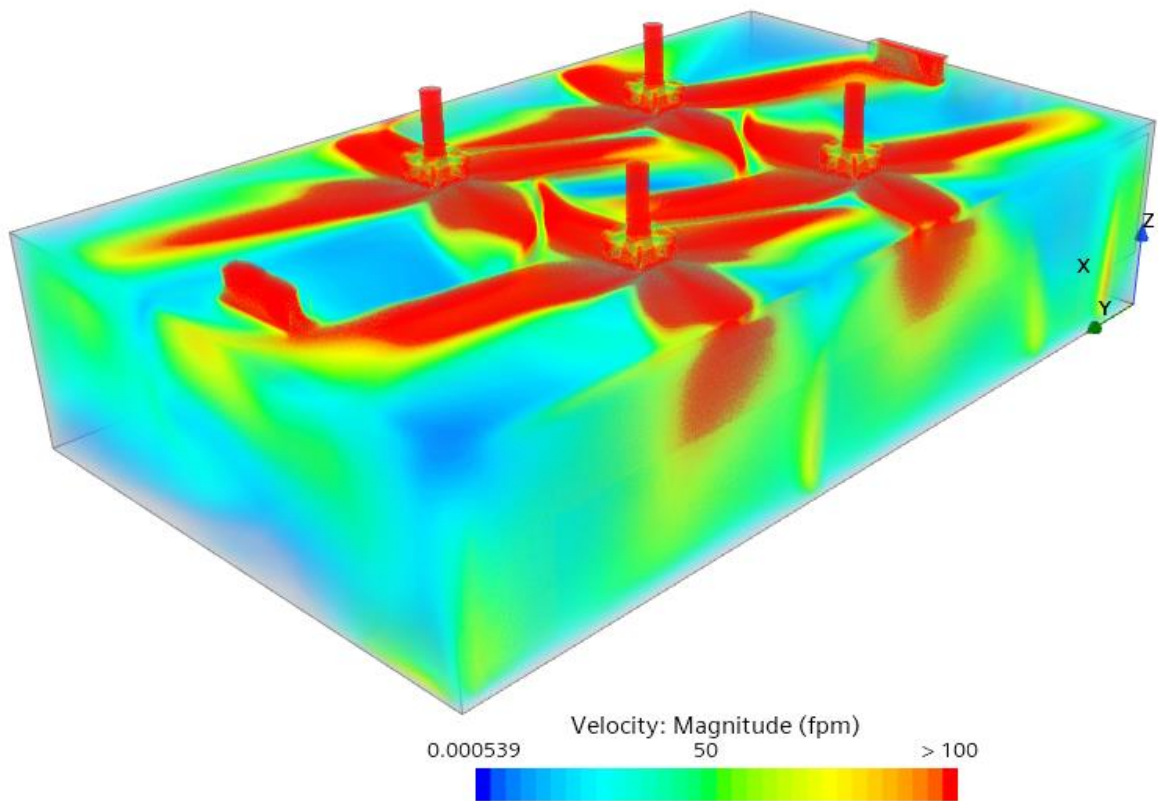
6ft from the floor
Average at 17 fpm



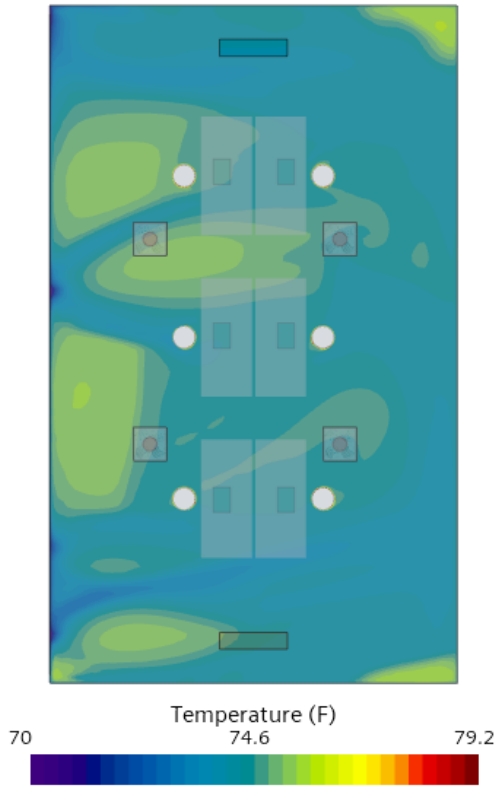




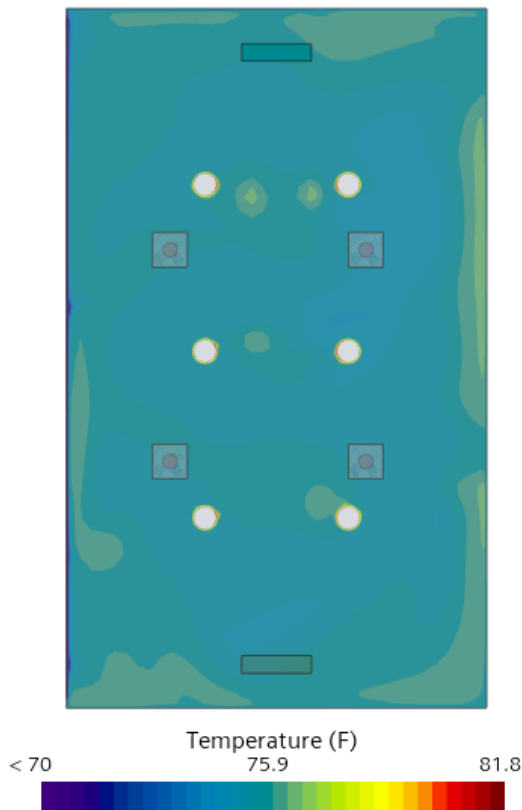




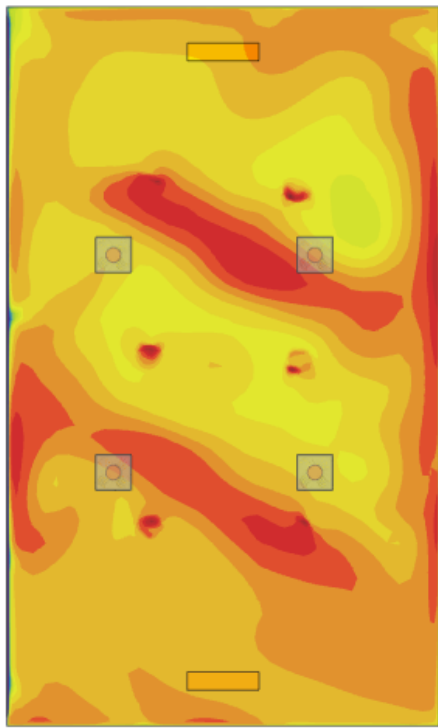
Air Temperature



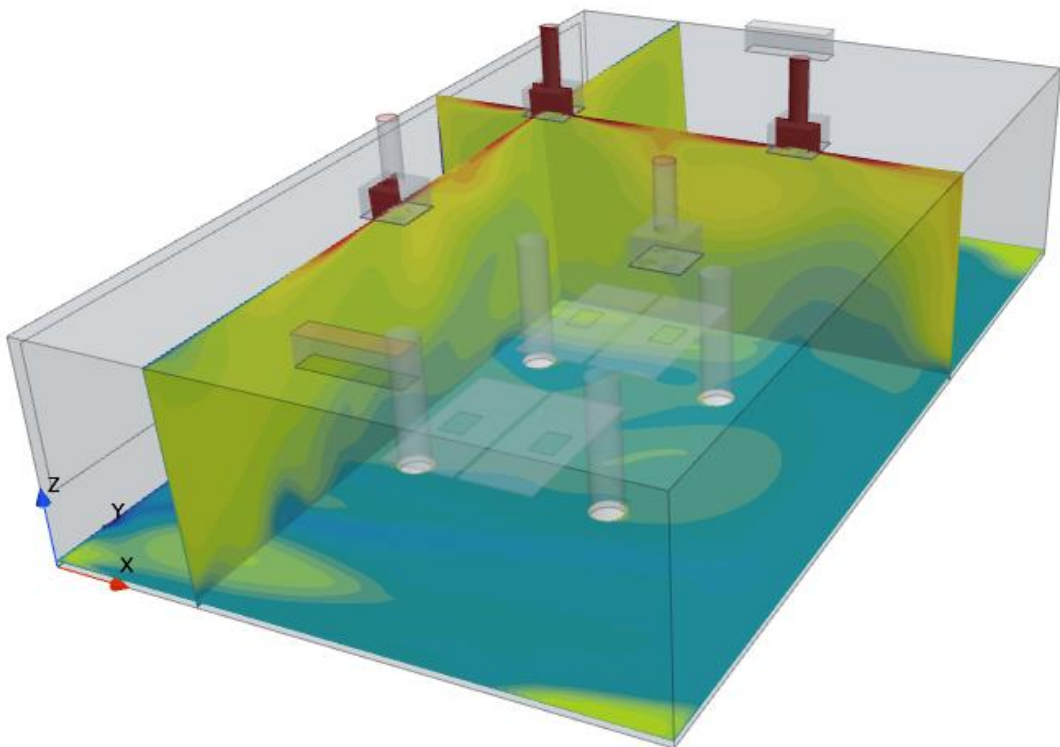
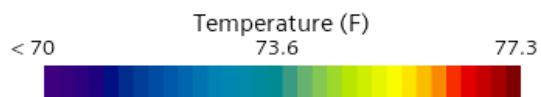
3in from the floor
Average at 74.5°F

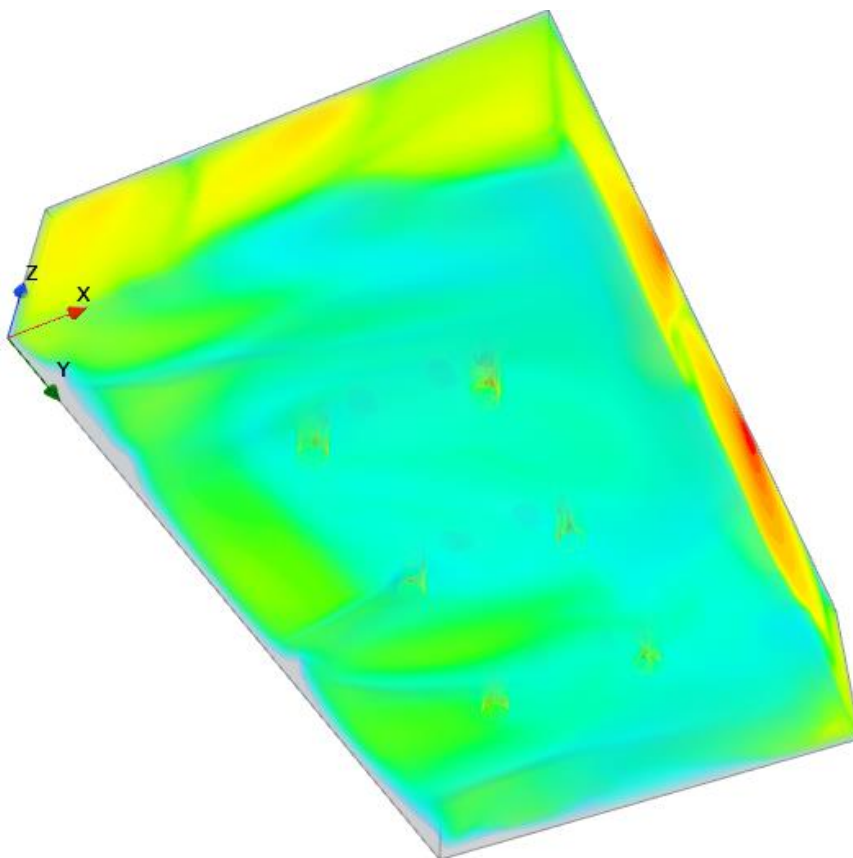
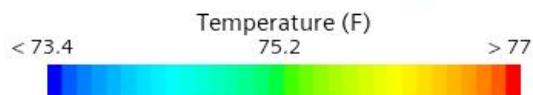
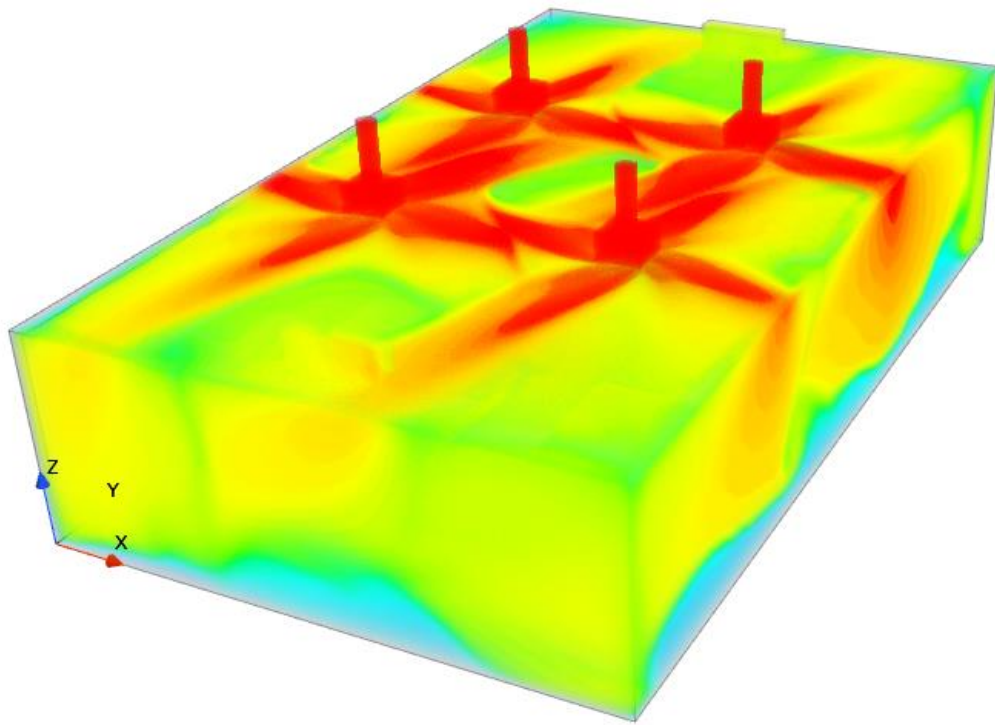


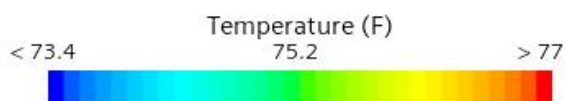
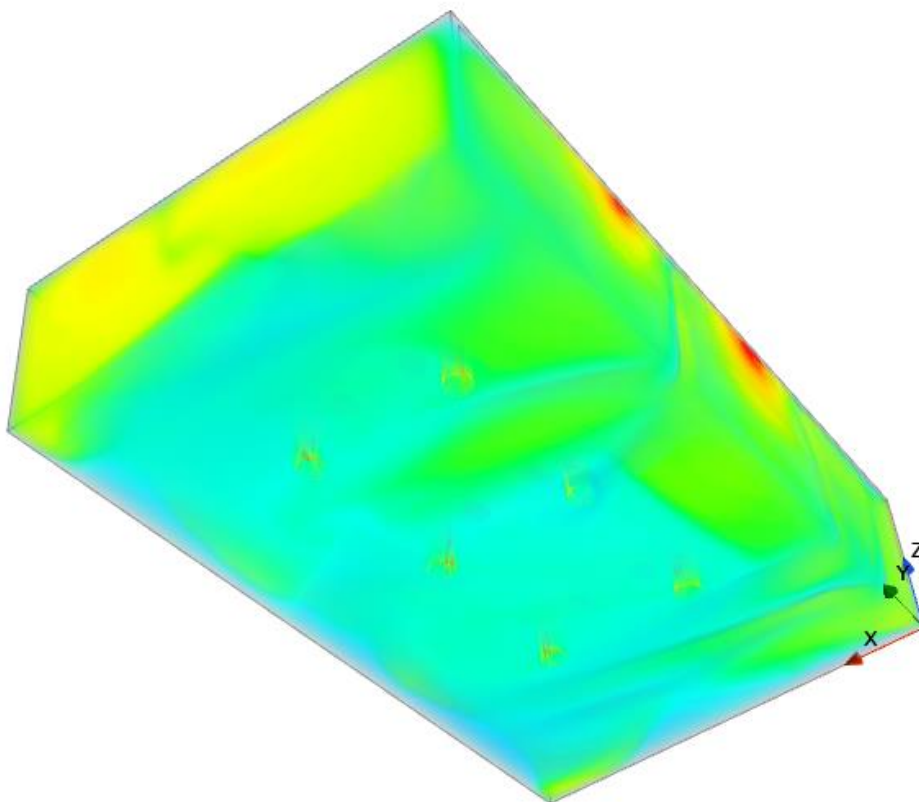
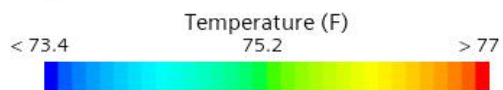
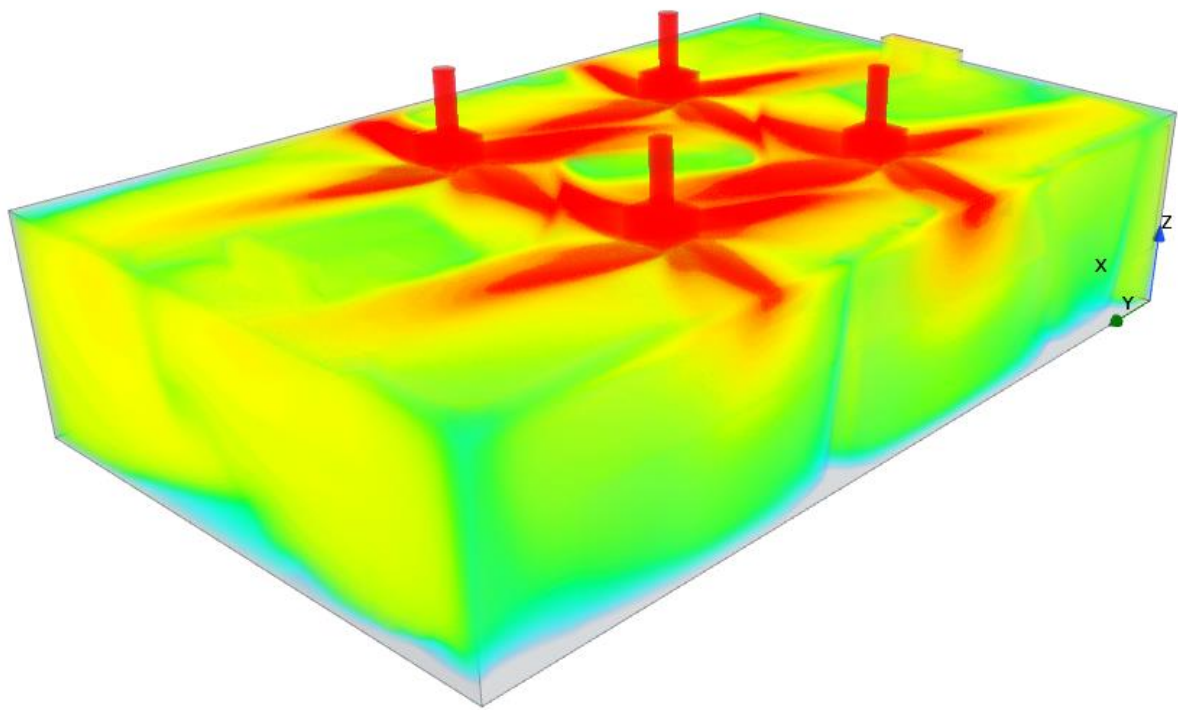
4ft from the floor
Average at 75.4°F



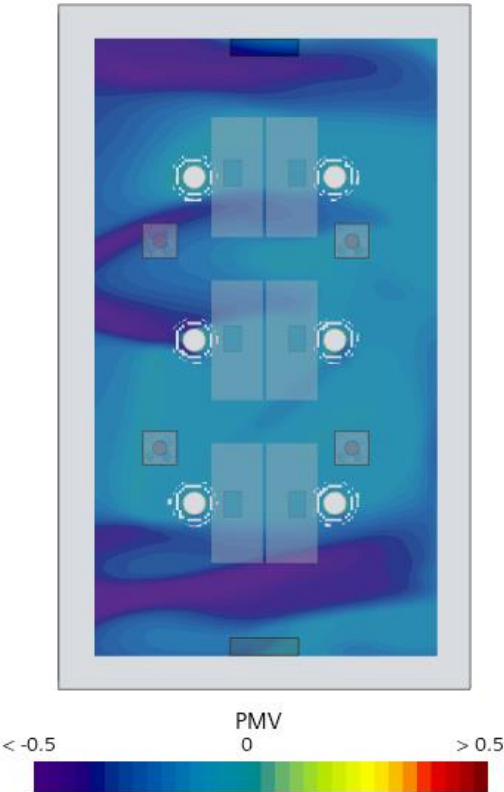
6ft from the floor
Average at 75.7°F



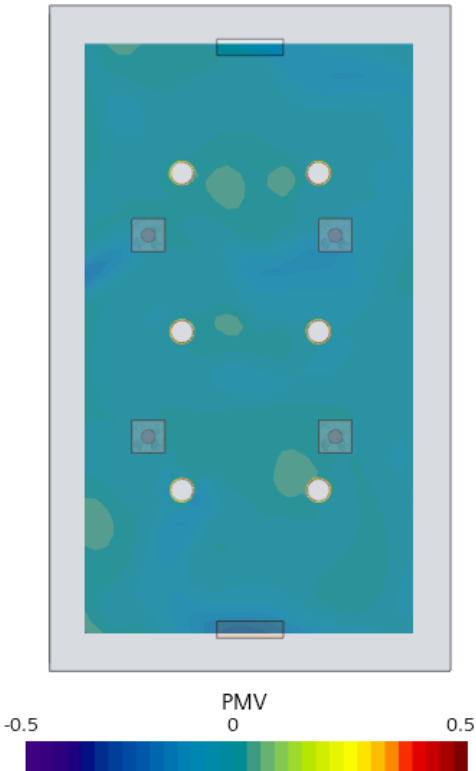




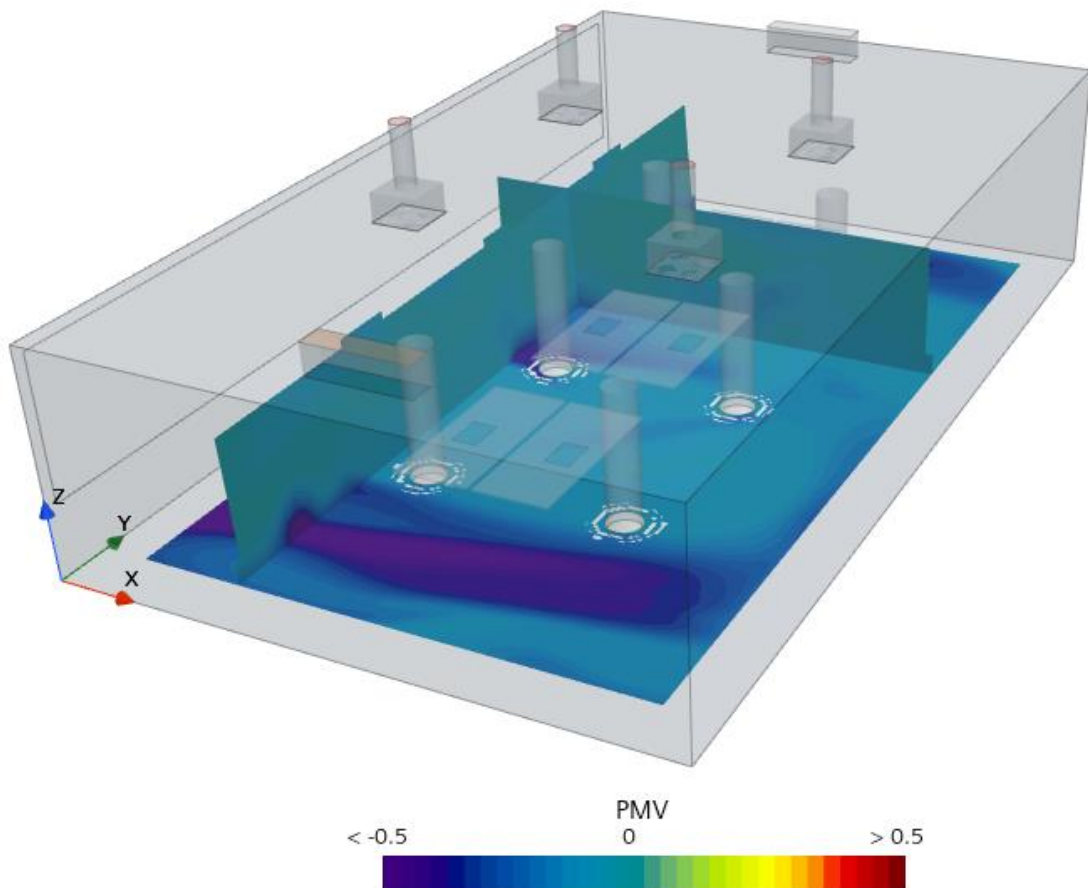
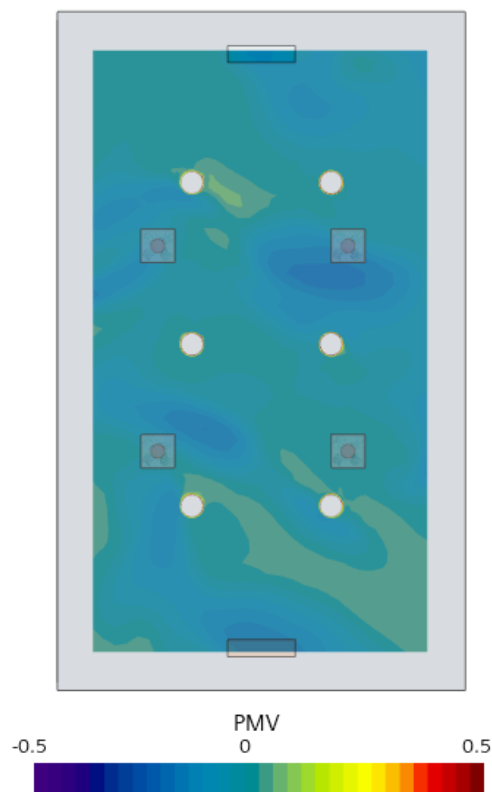
Predicted Mean Vote (PMV)



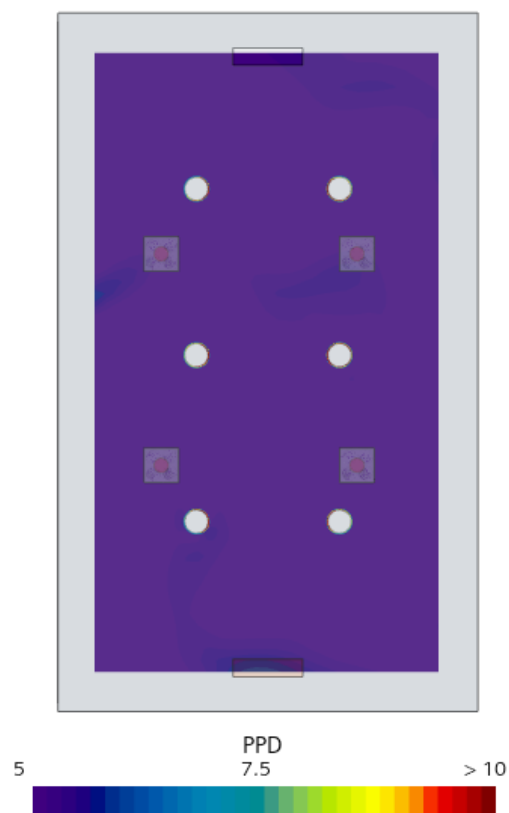
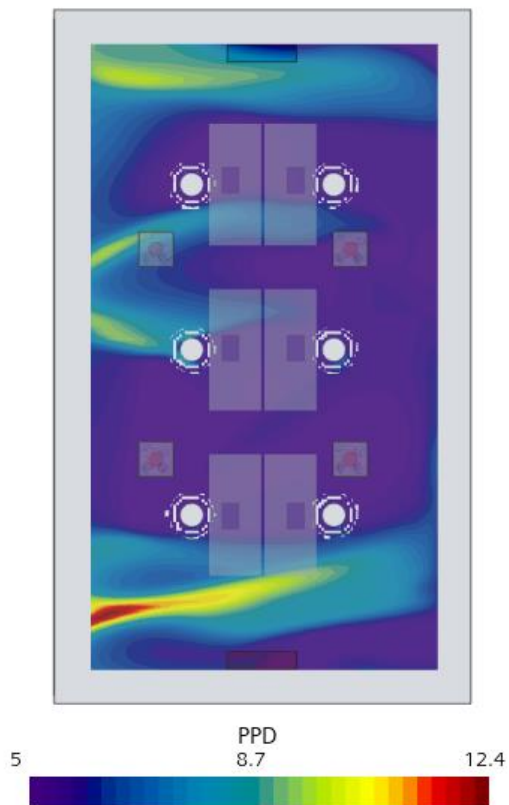
3in from the floor
Average at -0.21

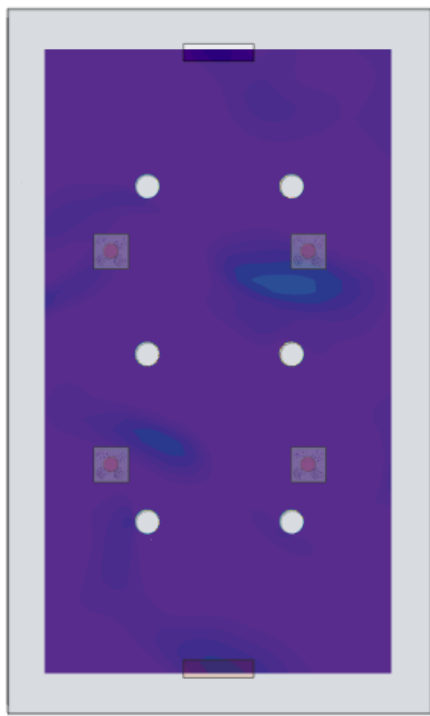


4ft from the floor
Average at -0.05

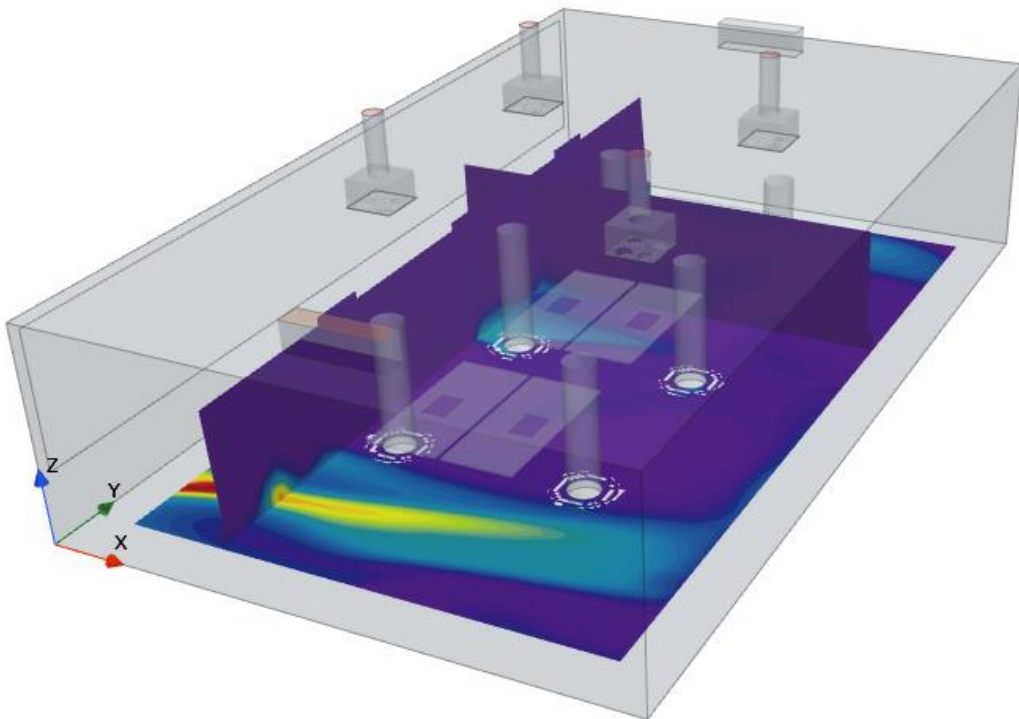


Predicted Percentage Dissatisfied (PPD)

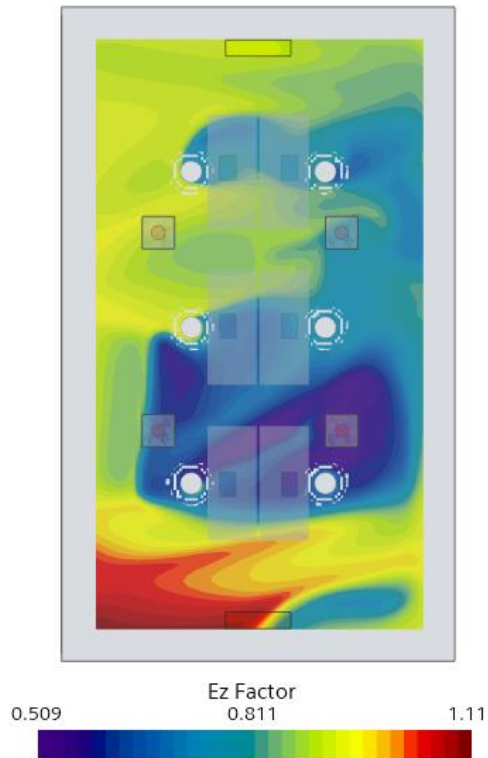




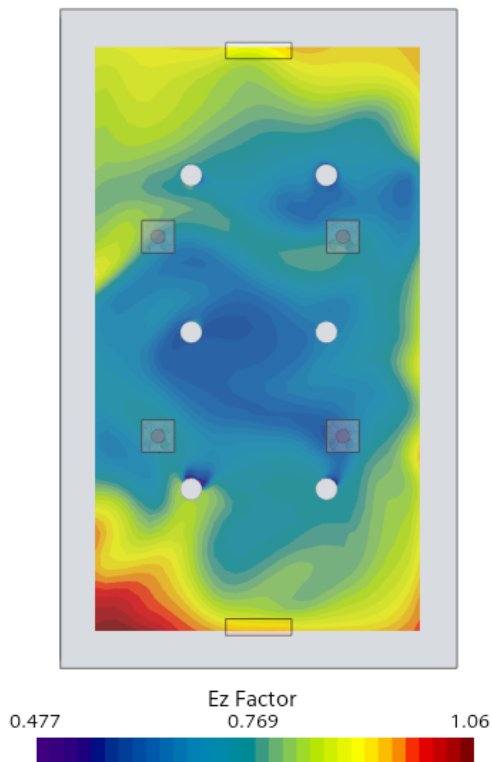
6ft from the floor
Average at 5.1%



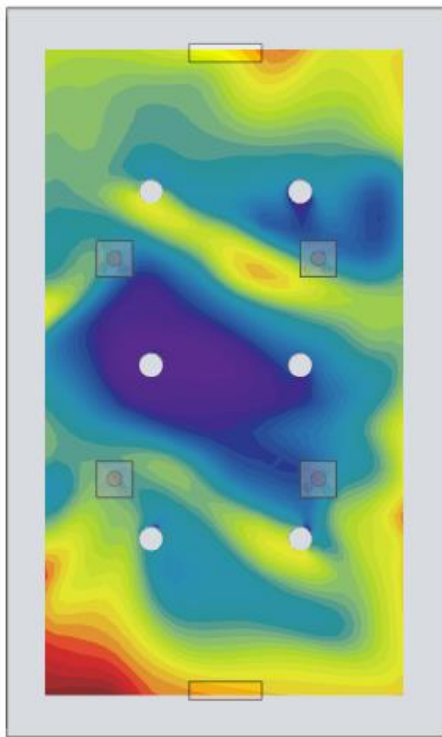
Zone Air change Effectiveness (Ez Factor)



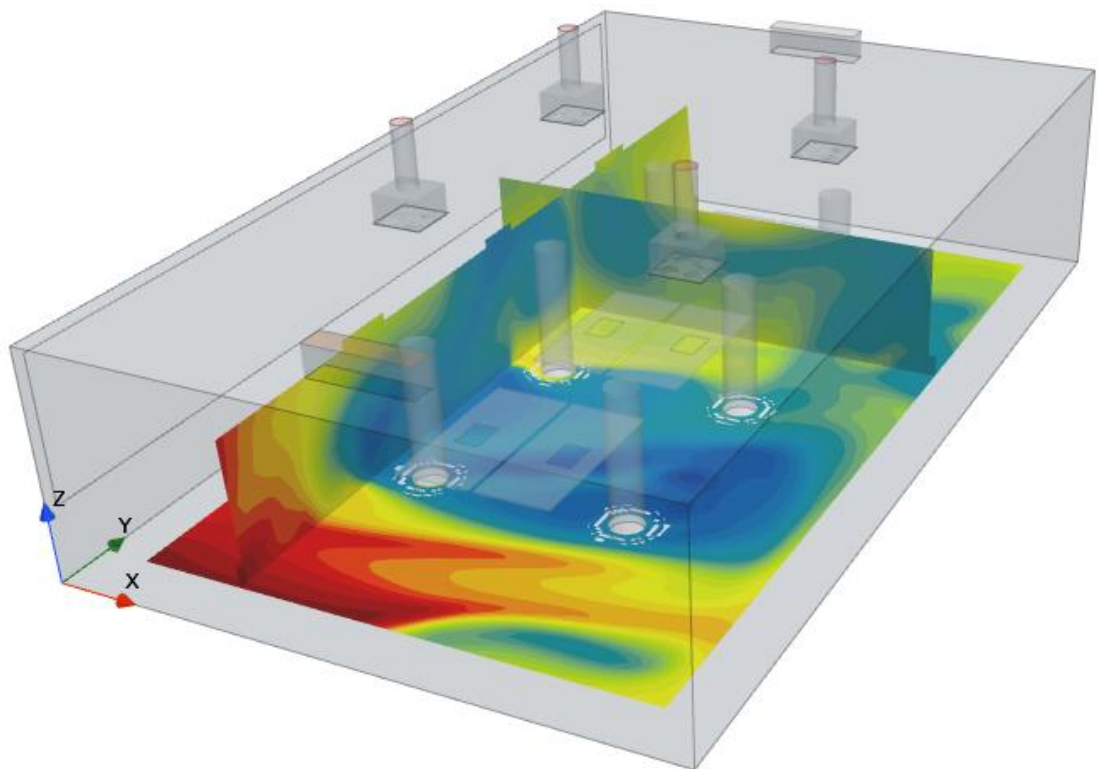
3in from the floor
Average at 0.81



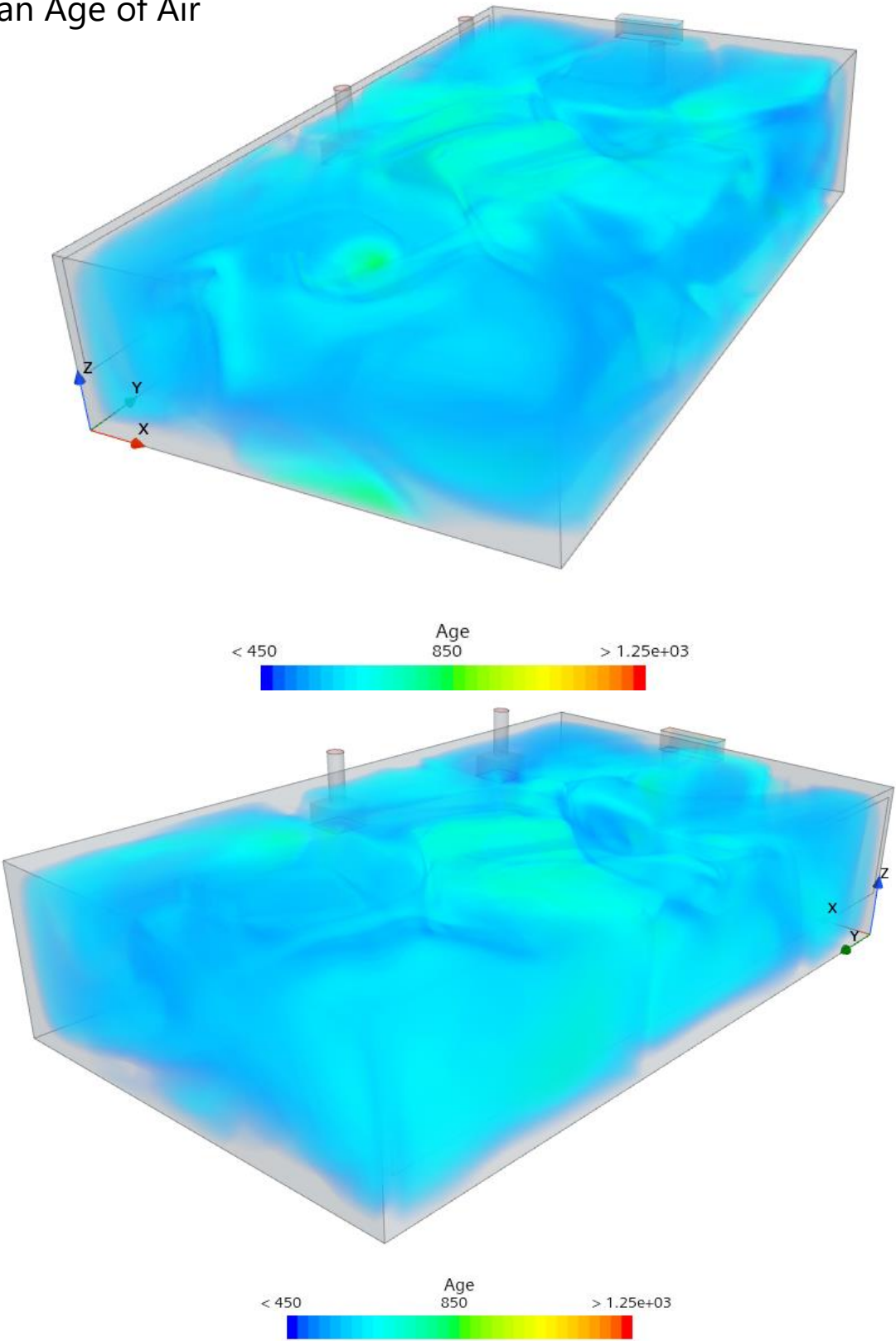
4ft from the floor
Average at 0.77

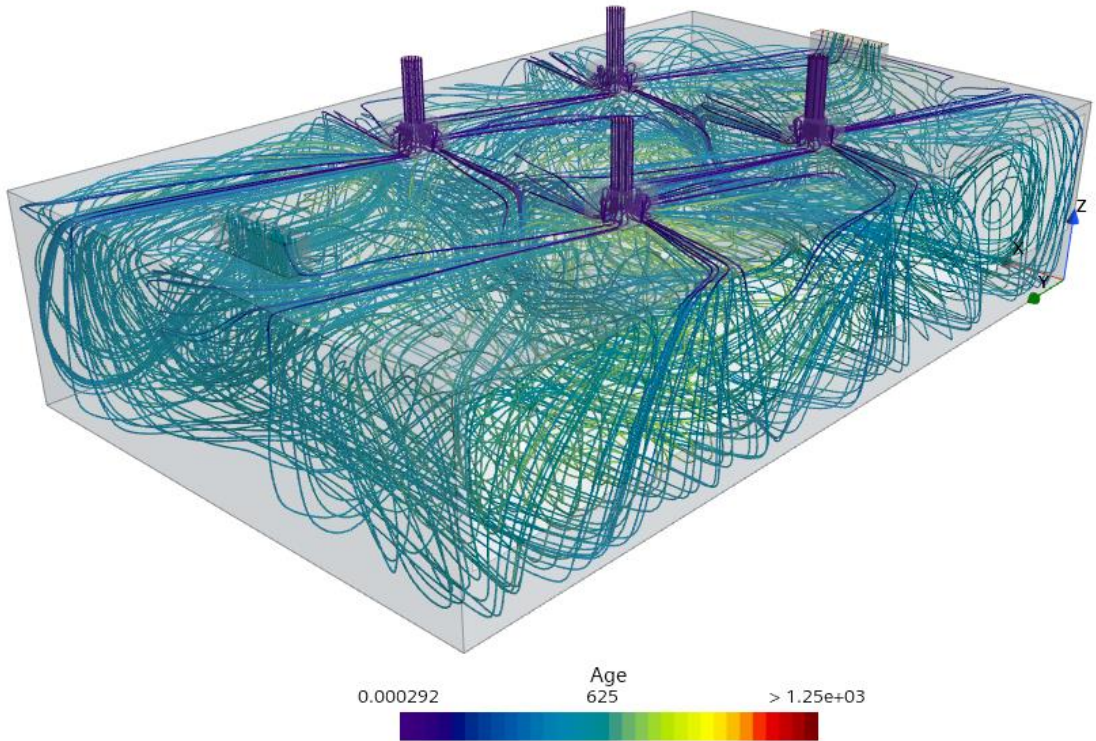
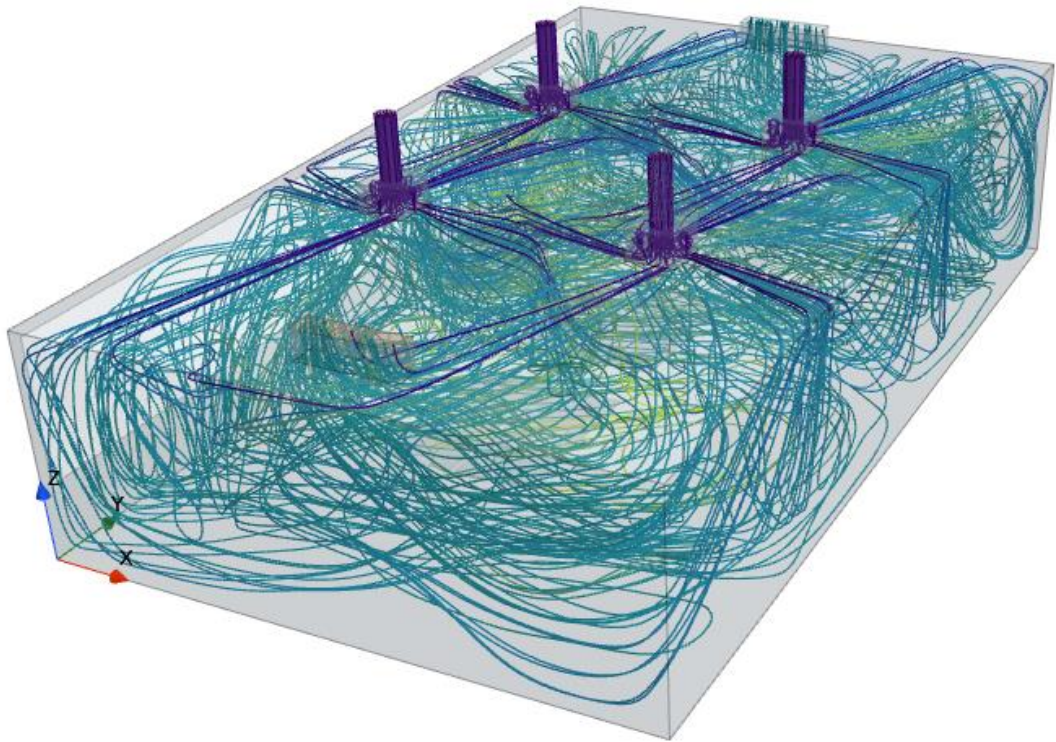


6ft from the floor
Average at 0.76

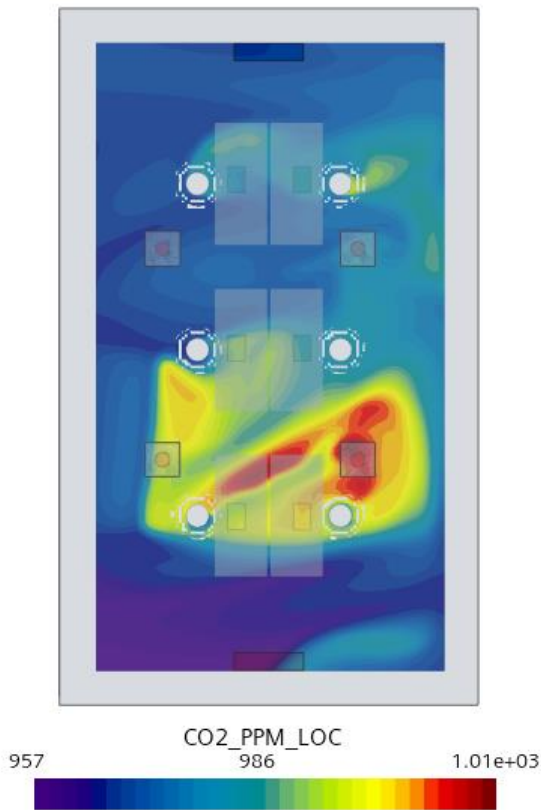


Mean Age of Air

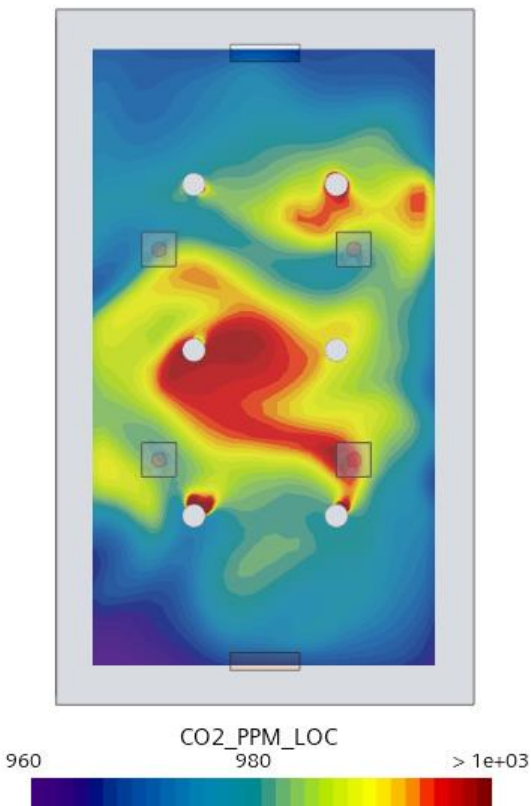




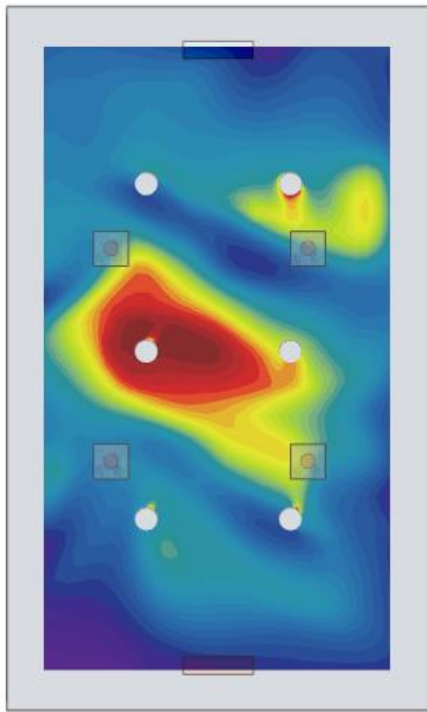
CO2 Breathing Zone Concentration (PPM)



3in from the floor
Average at 978 ppm



4ft from the floor
Average at 980 ppm



6ft from the floor
Average at 977 ppm

