CFD Analysis for Comparison of Spread of Infection in Office Room with Mixed Ventilation System and Displacement System.

MECH 5885: Computational Fluid Dynamics

Youngstown State University

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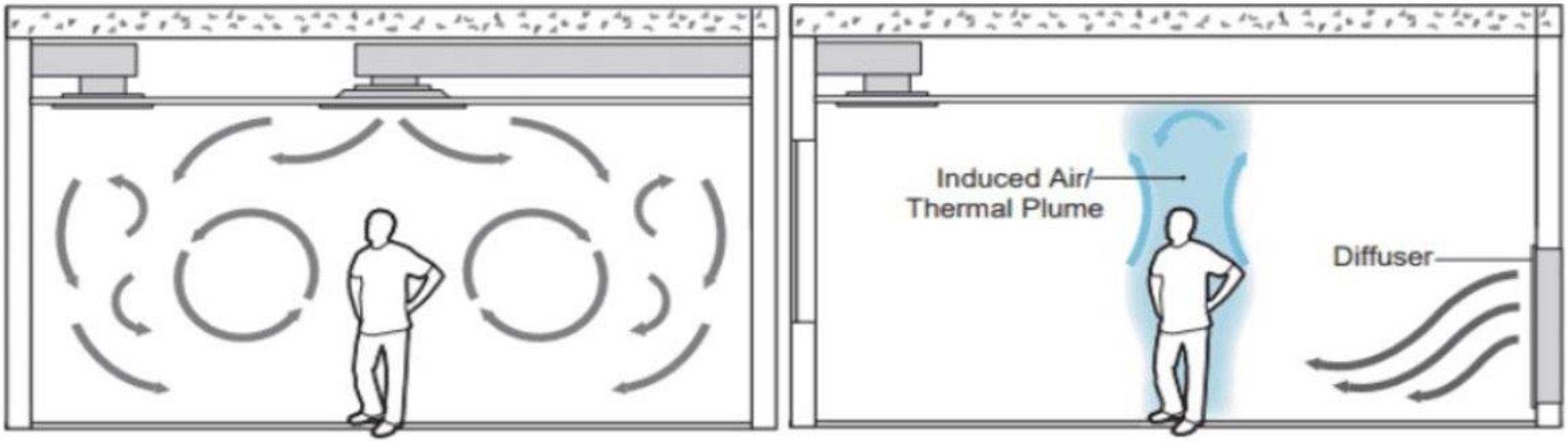
Why this Project?

- According to EPA, roughly 50% of global illness is caused by Indoor air pollution. [1]
- We spent nearly 90% of our lives in building environments. [2]
  - Office buildings
  - Education Buildings
  - Hospitals
- Air borne pollutants spread through the buildings.
- Proper ventilation is necessary in an indoor space to remove aerosol from the room.

Assumption:



Mixed Ventilation (MV)
Supply High, Return High

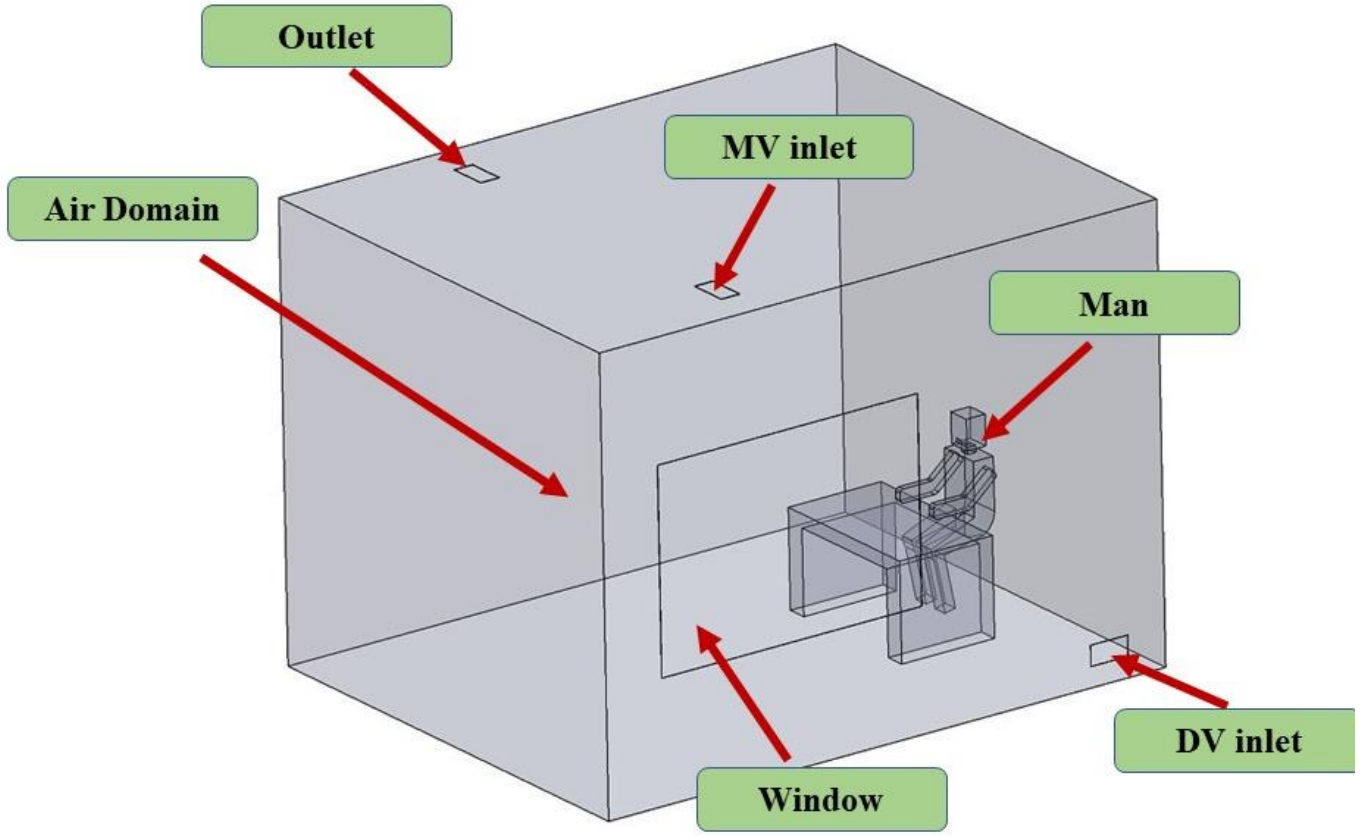
Displacement Ventilation (DV)
Supply Low, Return High

DV better than MV in terms of Infection Control?

Simulation Workflow

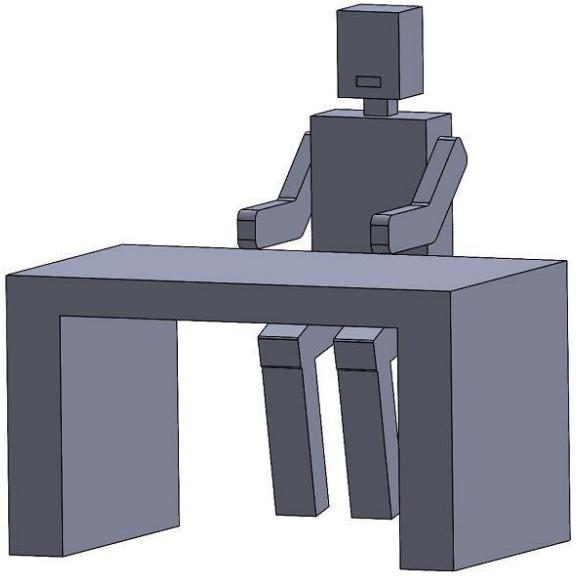
Preprocessing	Solver	Postprocessing
• Designing the Model ▪ Using Solidworks/ ANSYS • Mesh ▪ Using ANSYS Mechanical/ Fluent.	• Fluent ▪ Heat Transfer ▪ Incompressible ▪ Compressible ▪ Multiphase ▪ Combustion	• CFD Post Processing ▪ Contour ▪ Particle track ▪ Animation

Geometry of Sample Office Room



Dimensions:

- Base: 12’x15’
- Room Height: 11’
- Man’s Height: 5’8”



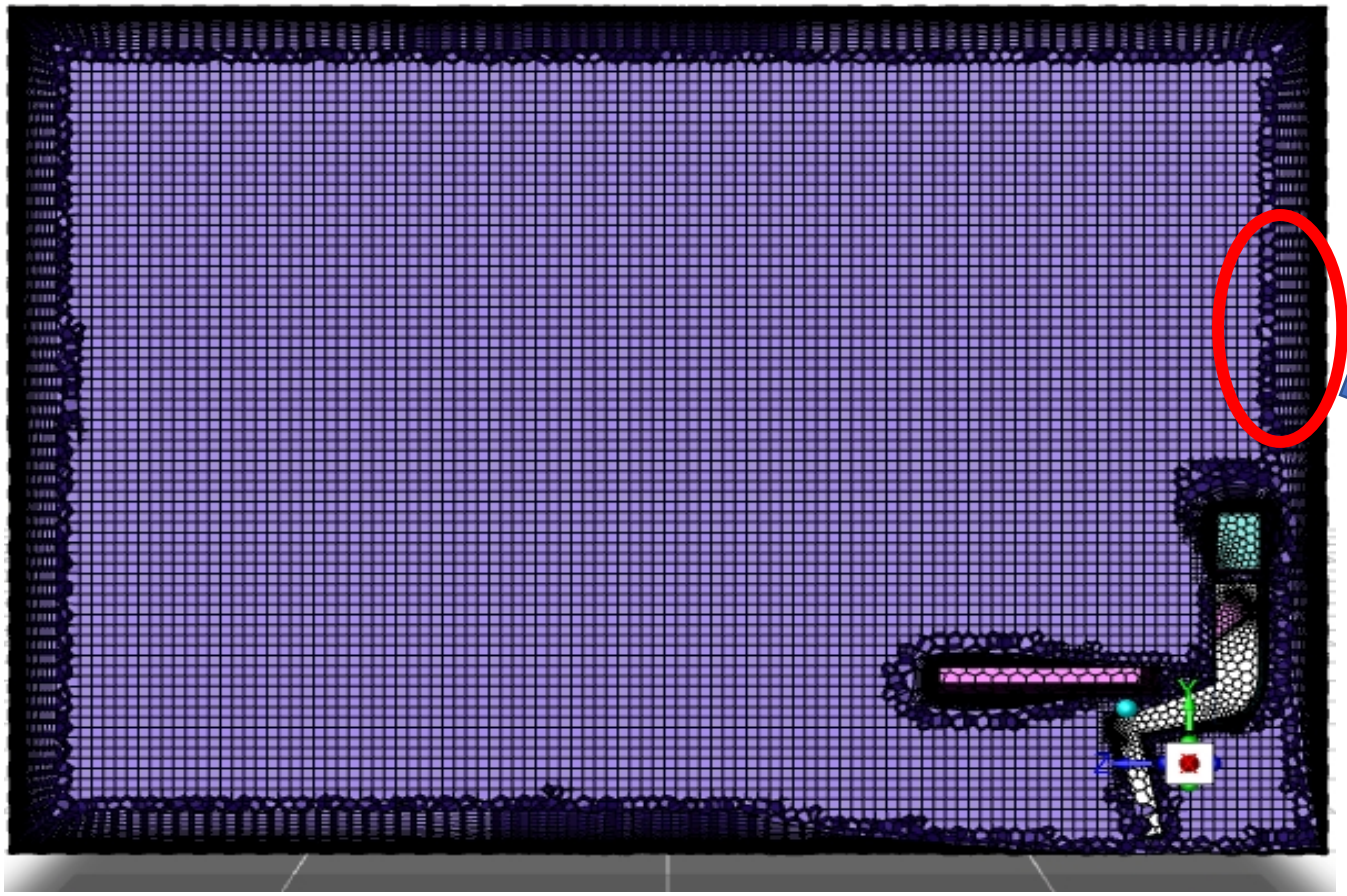
Material Properties

Air	
Density (kg/m3)	1.225
Specific Heat(J/kg-k)	1006.43
Thermal Conductivity (W/m-K)	0.0242
Viscosity (kg/m-s)	1.79E-05
Molecular Weight (Kg/kmol)	28.966

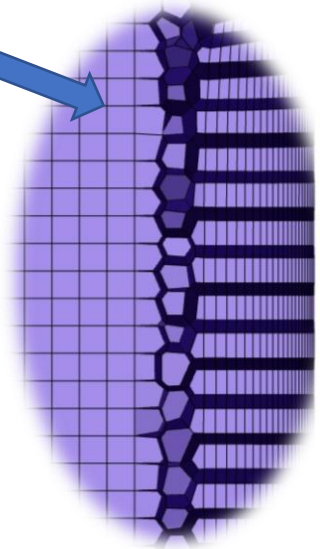
Water Droplets	
Density (kg/m3)	998.2
Specific Heat(J/kg-k)	4182
Latent Heat (J/kg)	2263073
Vaporization Temperature (K)	284
Boiling Point (K)	373

Mixture (Air and Steam)	
Thermal Conductivity(W/m-K)	0.0454
Viscosity (kg/m-s)	4182
Mass Diffusivity (m2/s)	2.88E-05

Mesh



- Created using Fluent.
- Poly-hexacore elements.
- 526518 elements.
- Inflation layers around the boundary.

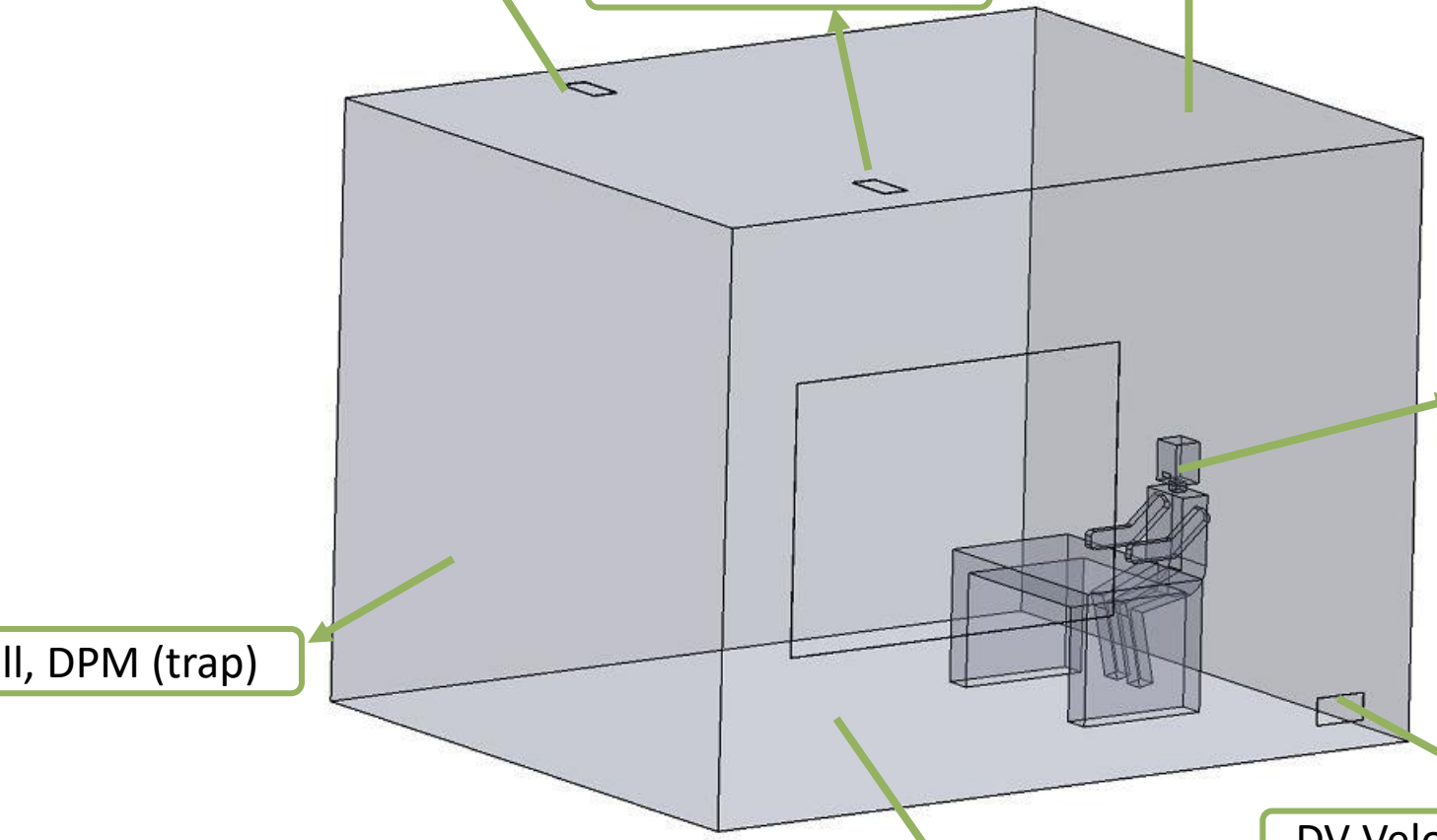


CFD Model Setup

- **Transient analysis**
  - Number of Time Step: 1500
  - Time-Step Size: 0.01 sec.
- **Realizable K-ε model.**
  - Widely used for indoor air flow
  - Improved prediction for spreading rate of round jets. [16]
- **Non-Reactive Species Transport**
  - Mixing and transport of Species (Air and Steam).
- **Discrete Phase Model (DPM)**
  - Inject droplet particles to predict the fate of particles.
  - Coarse droplets and fine droplets.

CFD Model Selection	
Steady/Unsteady	Transient
Dimension	3-D
Turbulance model	Realizable k-e
Multi-component model	Species transport (Air and Steam)
Discrete Phase Model	Two Different Injections

Boundary Conditions



- **Velocity MV: 1m/s**
- **Velocity DV: 0.75 m/s**
- **Fine droplets Velocity: 10m/s**
- **Coarse droplets Velocity:4.2m/s**

Coughing Time: 1 second

Injection Particle

- Particles were water droplets, so Spherical Drag Law was chosen.
- Coarse droplets were variable and followed Rosin-Rammlar Distribution
  - Rosin-Rammlar distribution:
    - Min: 17 μm, Max: 500 μm, Mean: 77 μm

	Injection 1 (Fine droplets)	Injection 2 (Coarse Droplet)
Type	Droplet	Droplet
Size	5 μm	Variable (17 μm - 500 μm)
Injection Type	Surface (mouth)	Surface (mouth)
Injection Velocity	10 m/s	4.2 m/s
Mass flow rate	5 mg/s	5 mg/s

[17] Zang B. (2016)

All the Particle Properties were from literature review.

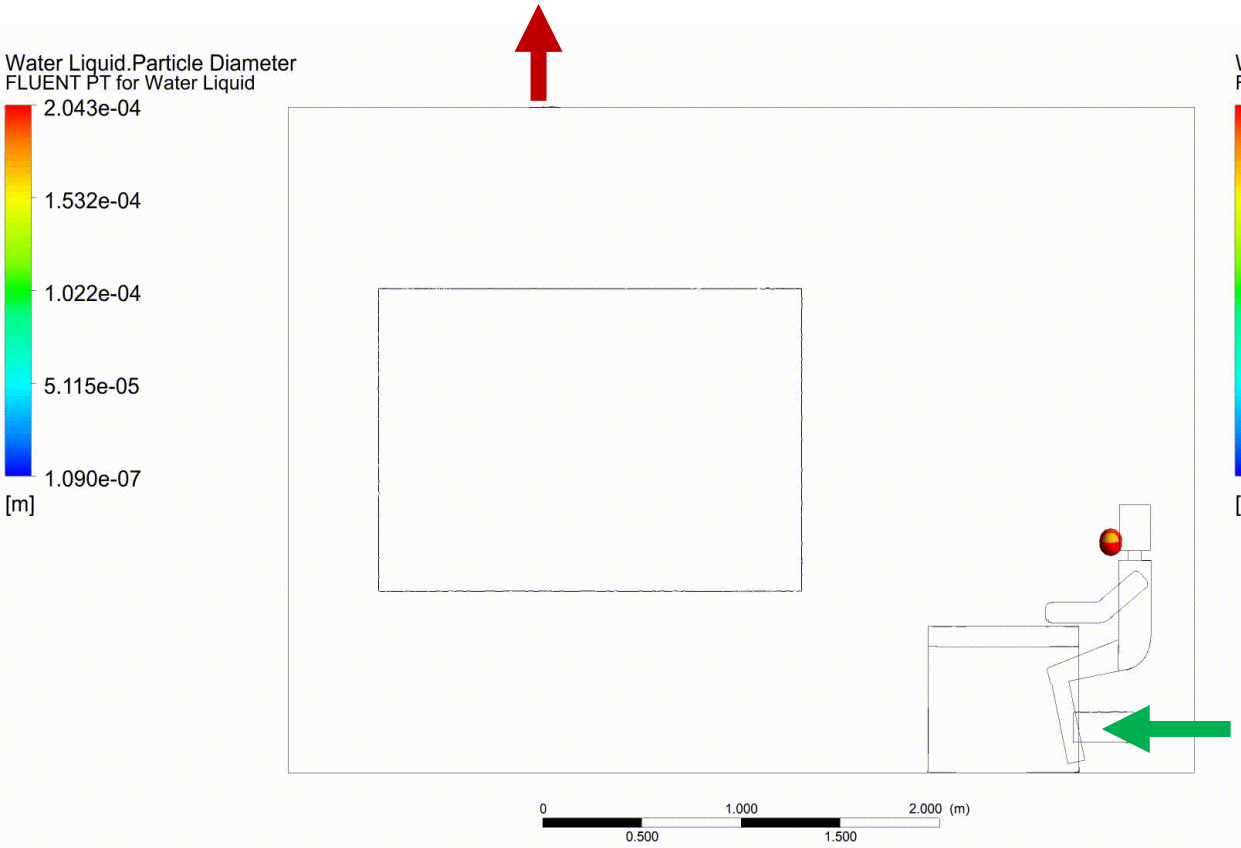
Grid & Time Step Convergence

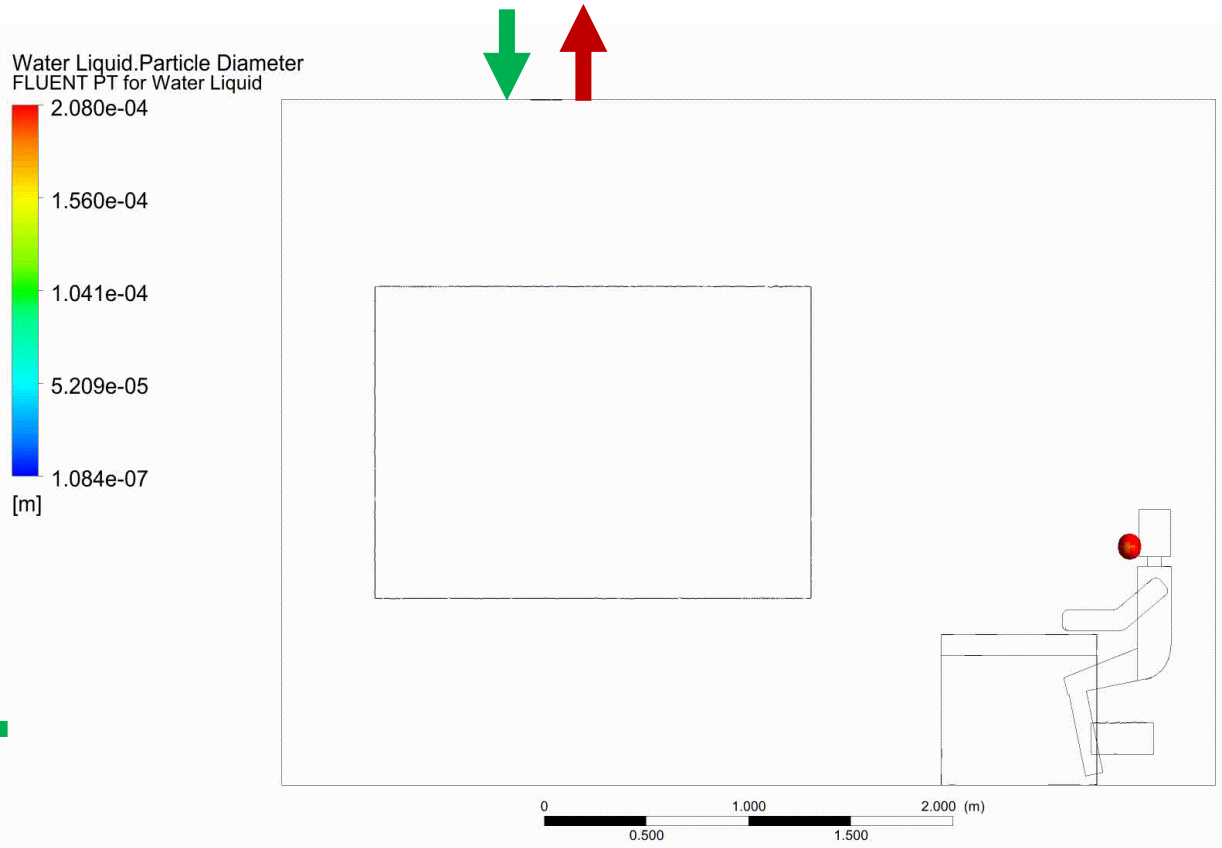
- **Performed to ensure results are not affected by number of elements.**

	Actual flow time: 5 sec (Time-Step Size: 0.05)		
No. of elements	**No. of particles at the end**	**Percentage difference**	**Simulation Time**
8135687	103625	3.04	32 hrs
1885879	100563	0.70	15 hrs
526518	99863		6 hrs

- **Results were not affected by element size.**
- **Therefore, time-step convergence was performed.**

		Actual flow time:5 sec	
No. of Elements	**Time-Step Size (s)**	**No. of particles at the end**	**Percentage difference**
526518	0.1	90657	9.22
	0.05	99863	1.73
	0.01	101621	



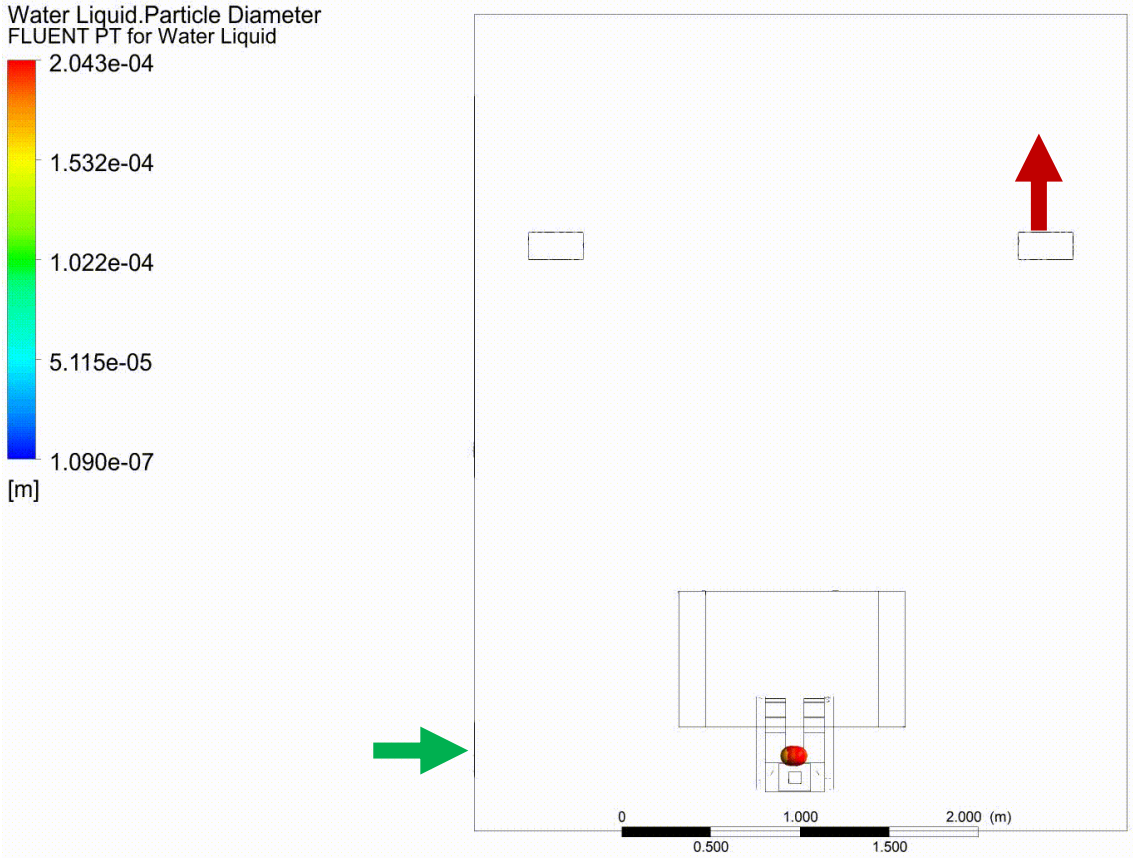


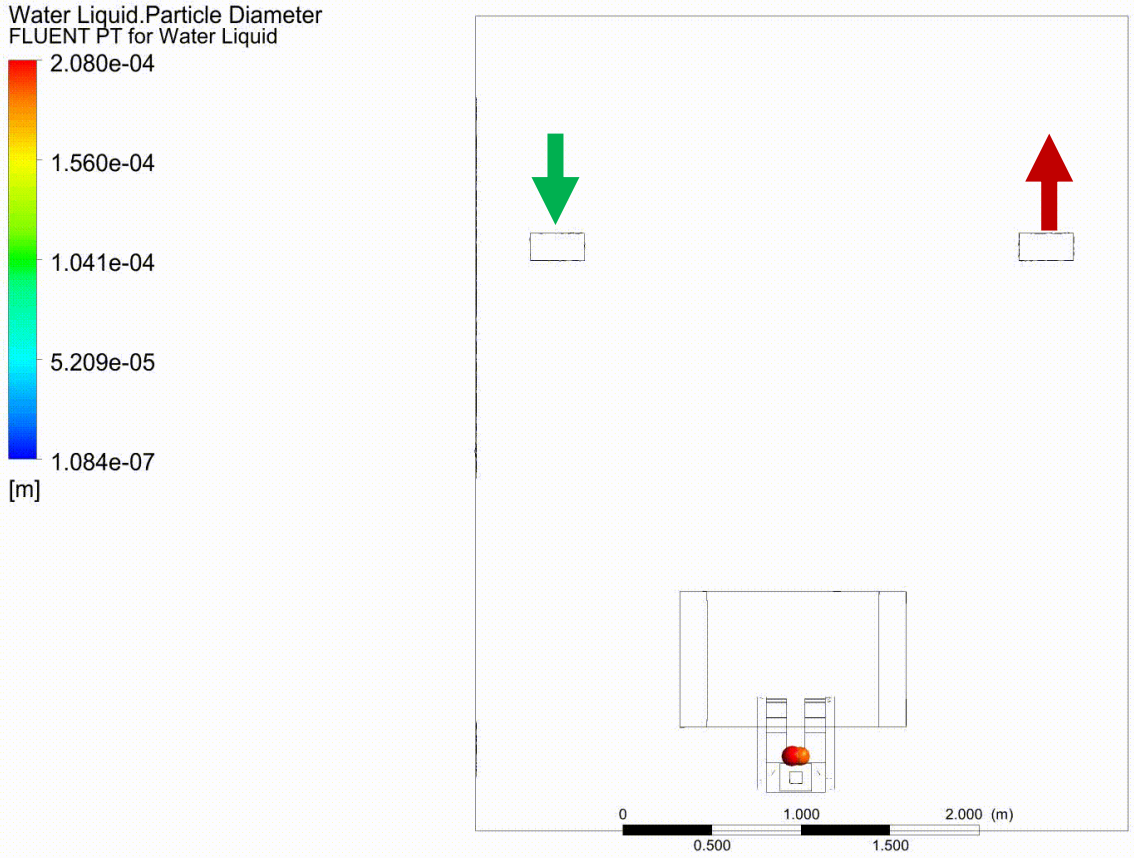
Displacement Ventilation

Less particles at the end of 15 sec

Mixed Ventilation

More particles at the end of 15 sec





Displacement Ventilation

Spread relatively low in the room

Mixed Ventilation

Spread relatively high in the room

CFD Results

- Particles remaining in MV was approx. 3 times greater than in DV.
- Relatively equal number of particles were trapped and evaporated.
- Higher number of Particles were escaped through outlet in DV than in the MV system

AT THE END OF 15 SECONDS		
	Displacement Ventilation	**Mixed Ventilation**
Remaining Particles	5229	15653
Particles Trapped	210256	211536
Particles Escaped	26530	15823
Particles Evaporated	156890	155963

Improvement Needed

- Variable material properties with change in temperature.
- Simulation for more time.
- More than one person on the room.
- Change in Position of inlet and outlet on the room.
- Change in size of the room.

THANK YOU