CFD on Dilution Ventilation & Infectious Disease Control

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Dilution Ventilation applications

1. Dilution of contaminated air with uncontaminated air for the purpose controlling potential air borne health hazards, fire and explosives conditions, odors, and nuisance type contaminants (vapors, gases, and very fine particulates).

2. Control of indoor atmospheric conditions associated with hot industrial environments (foundries, laundries, bakeries, any non-air-conditioned facility in Puerto Rico.

- **Both operate based on the principle of mixing clean air with contaminated air**

Dilution Ventilation For Health

- Four limiting factors, ACGIH IVM 31st ed:
  1. Quantity of contaminant generated not too great, otherwise air flow rate for dilution impractical.

  2. Workers must be far enough away from contaminant source, or the evolution of contaminant must be in sufficiently low concentrations so that workers will not have an exposure in excess of the established OEL (TLV).

  3. The toxicity of the contaminant must be low (TLV ≥ 100 ppm).

  4. The evolution of the contaminant must be reasonably uniform

Traditional View
General Dilution Ventilation Equation

- “The ventilation rate needed to maintain a constant concentration at a uniform generation rate”

- Based on material balance and assuming no contaminant in air supply

Traditional View
General Dilution Ventilation Equation

- Generation of Contaminant in gaseous/vapor state:

$$G = \frac{0.7609\ x\ T\ x\ SG\ x\ ER}{P\ x\ MW}$$

- Where:

  G :rate of generation of contaminant in vapor or gaseous state, acfm

  SG: specific gravity of contaminant in liquid state, dimensionless (referenced to water)

  ER: Evaporation rate of contaminant, pints/min

  MW: Molecular weight of contaminant, lbm/lbmol

  T : Absolute temperature of contaminant in vapor or gaseous state, °R

  P : Barometric pressure, atm

General Dilution Ventilation Equation

- Accumulated Cont. = Cont. Generation – Cont Removal

$$V_r dC_g = Gdt - Q'C_g dt$$

- Where:

  V_r: volume of the room, ft^3

  G: rate of generation of contaminant in vapor or gaseous state, ft^3/m

  Q': effective volumetric flow rate, acfm

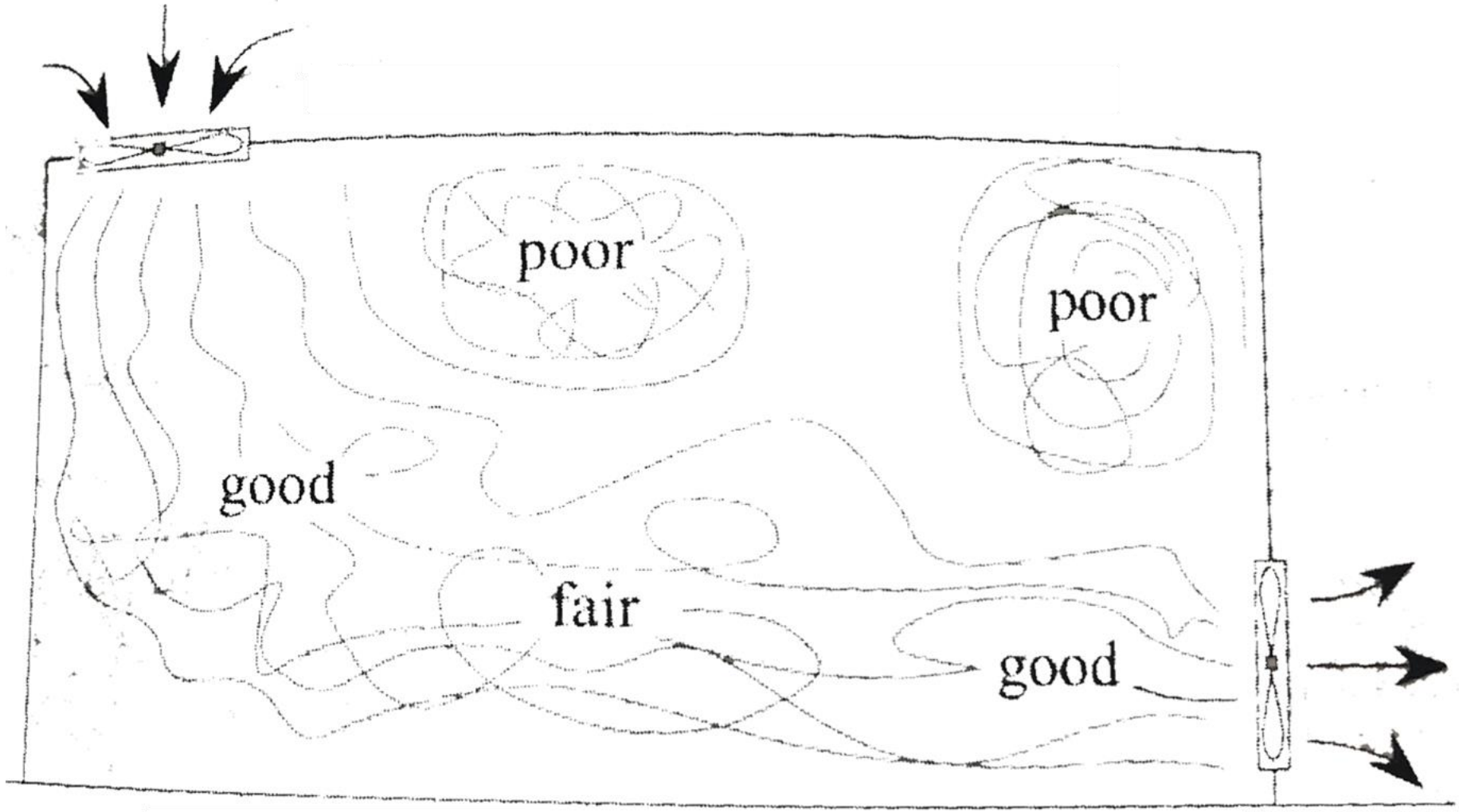
  C_g: concentration of gas or vapor at time t, $ppmx10^{-6}$

  t: time, min

Traditional View
General Dilution Ventilation Equation

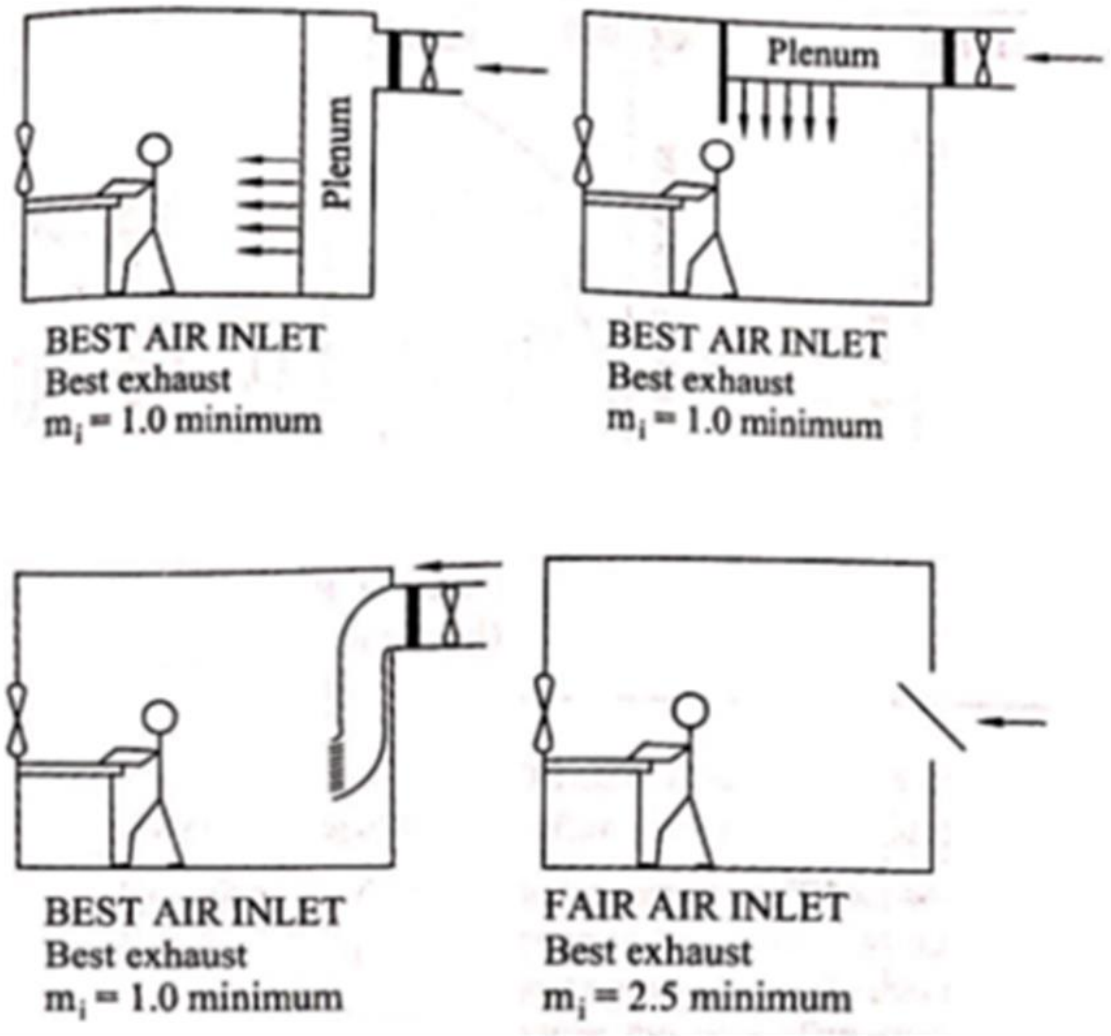
- Three main phases:
  - Steady state, $C_2 = C_1$
  - Generation, $C_2 > C_1$
  - Purge, $C_2 < C_1$
- $T_2 = T_1 + \Delta T$
- All of the phases consider “mixing index”, m_i
- Actual Flow Rate (Q) versus Effective Flow Rate (Q’)
  - $Q = Q' \times m_i$

General Dilution Ventilation Equation



ACGIH Industrial Ventilation Manual

General Dilution Ventilation Equation



ACGIH Industrial Ventilation Manual

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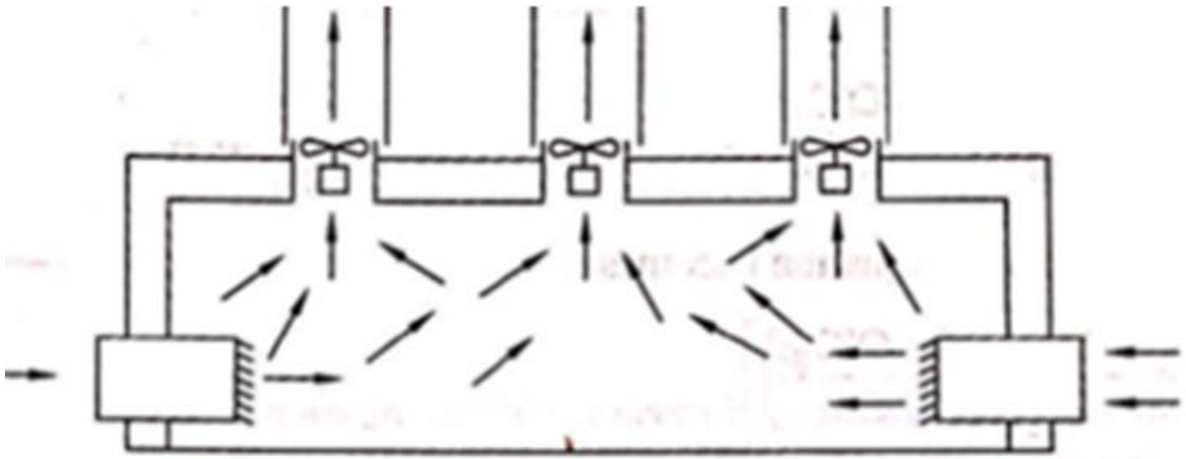
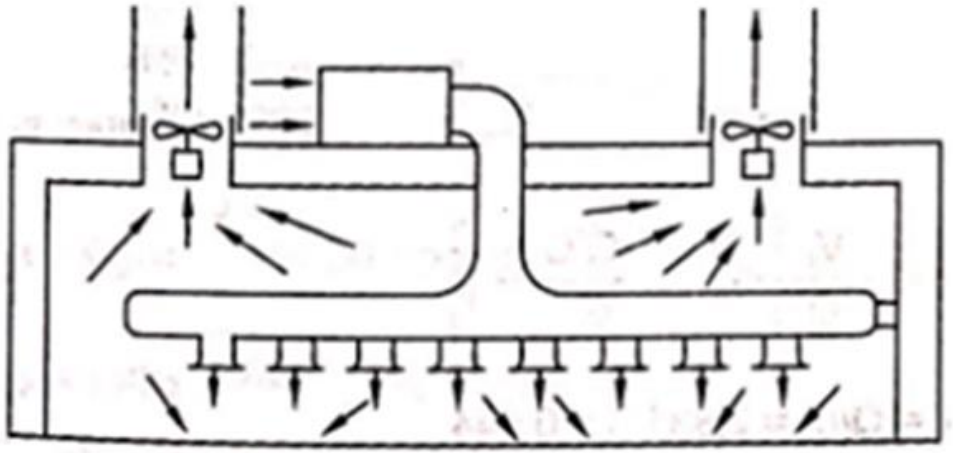


FAIR
m_i = 2 to 5



GOOD
m_i = 1.5 to 2

ACGIH Industrial Ventilation Manual

General Dilution Ventilation Equation

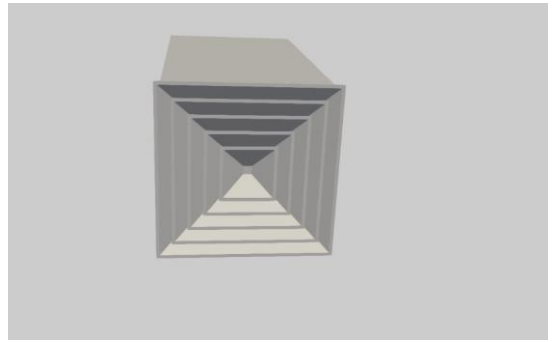
- Bottom line:
  - We only have an average concentration estimate to make our assessment or design
  - We can always increase mi, but....

....we still going to end up with a single average concentration estimate inside the room.

General Exhaust Ventilation under scrutiny of CFD

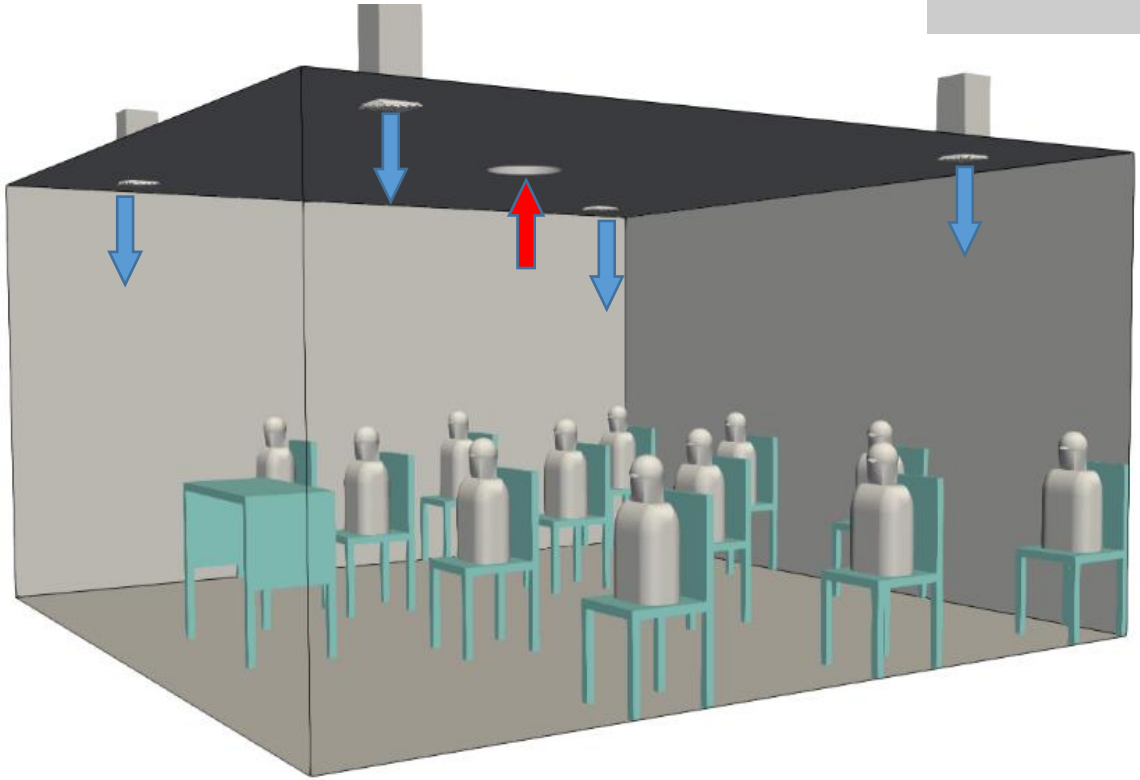
- Let’s assume a school classroom
  - 20 ft x 20 ft x 10 ft
  - Room temperature is 77°F
  - Distance between desks aprox. 5 ft
  - Students are breathing normally
    - 2.4 lpm
    - 4 beaths per minute (5s inhale, 10s exhale)
    - Exhale air velocity (190 - 200 fpm)
  - HVAC with 6 air changes per hour (Q = 400 cfm)
  - 3 different HVAC configurations

General Exhaust Ventilation under scrutiny of CFD



Configuration 1

- 4 inlets (10”x10”)
- 1 outlet (400in^2)
- No air diffusers



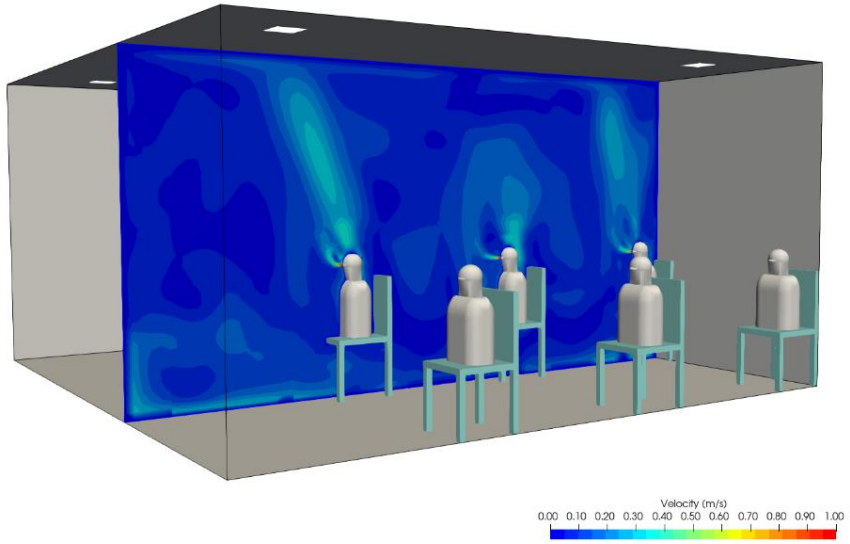
Configuration 2

- 4 inlets (10”x10”)
- 1 outlet (400in^2)
- With air diffusers

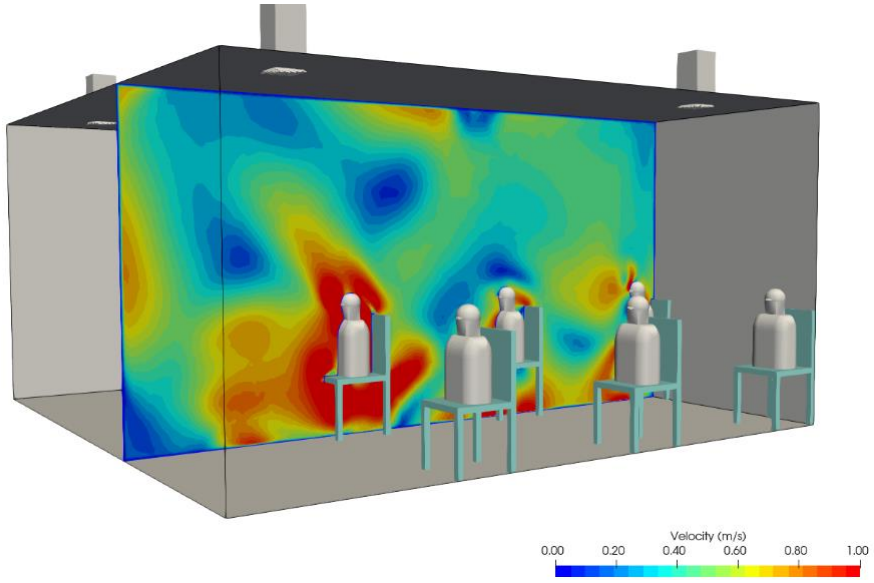
General Exhaust Ventilation under scrutiny of CFD

3D cross section view of air velocity patterns at center of third row of students from left to right of room

Without air diffusers



With air diffusers



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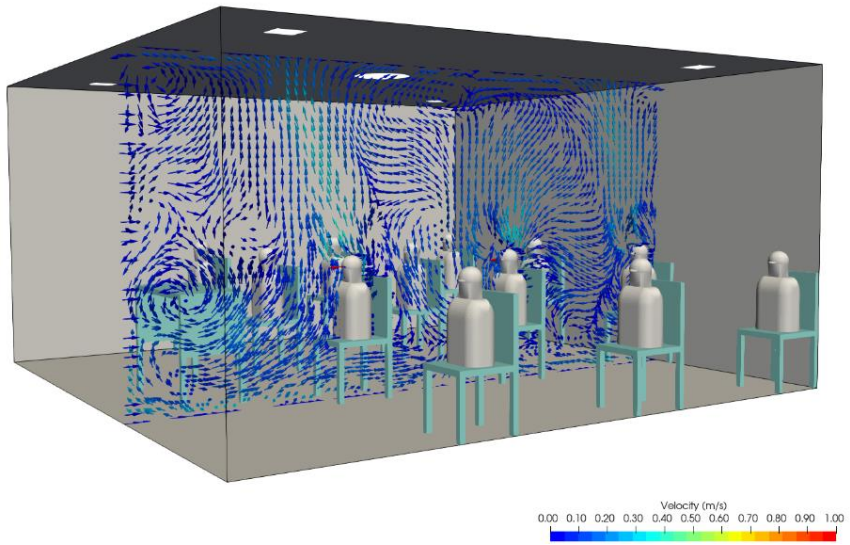

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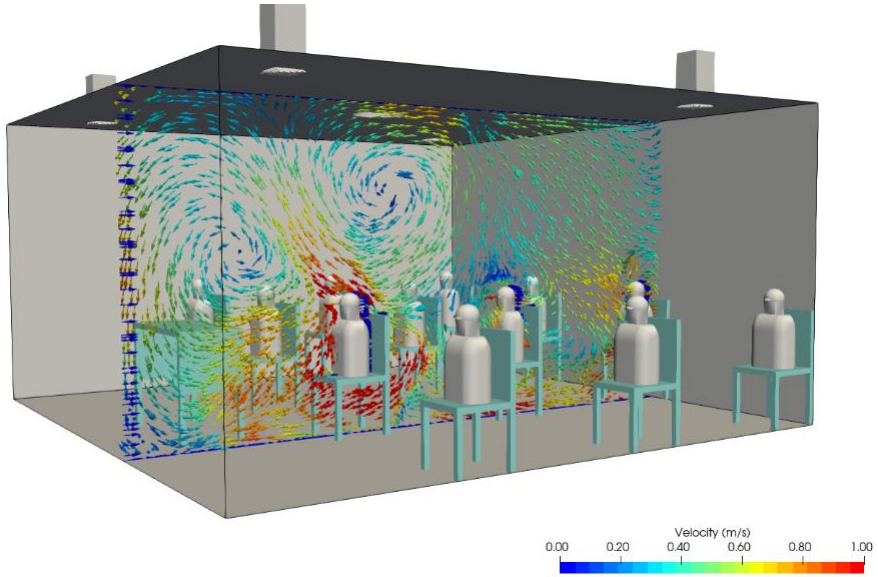

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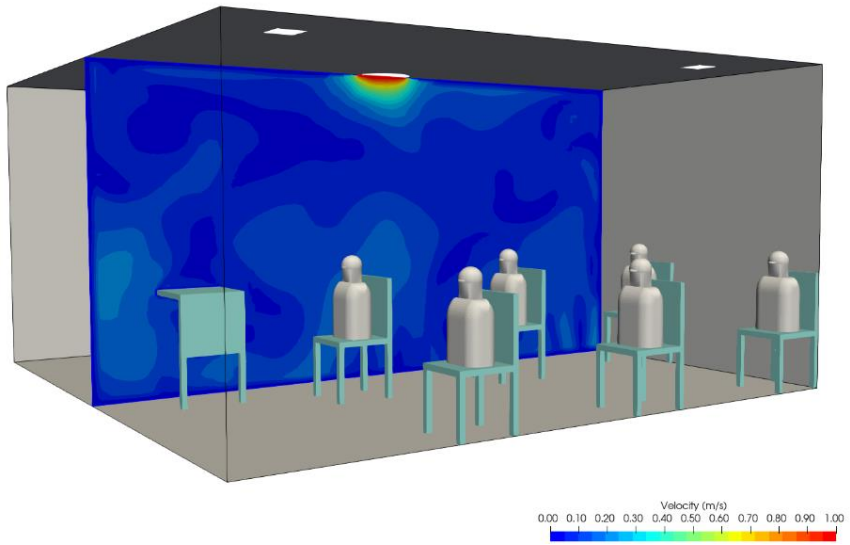
3D cross section view of air velocity patterns at center of teacher table

Without air diffusers



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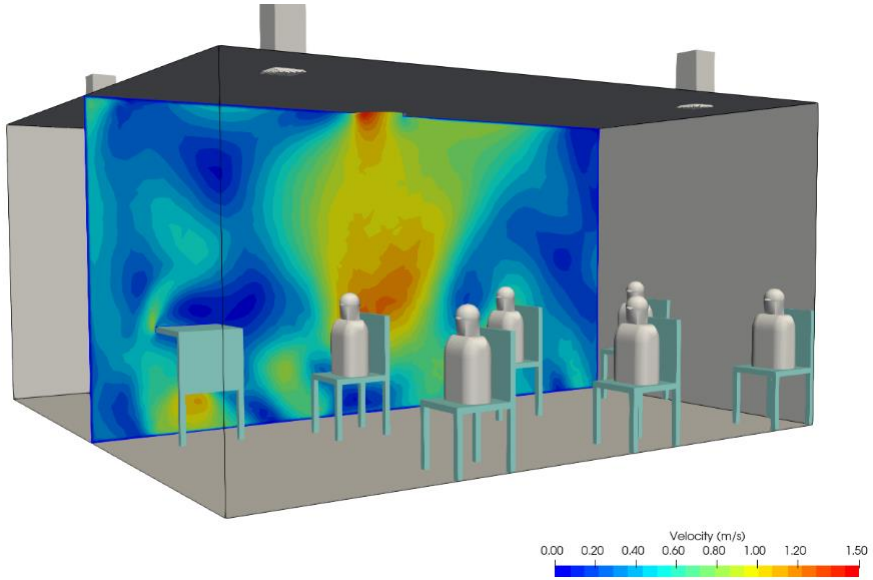

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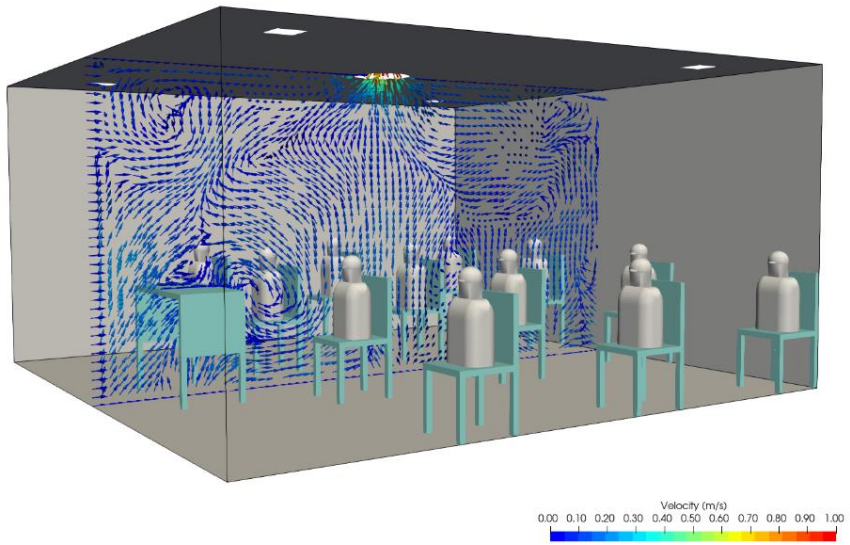

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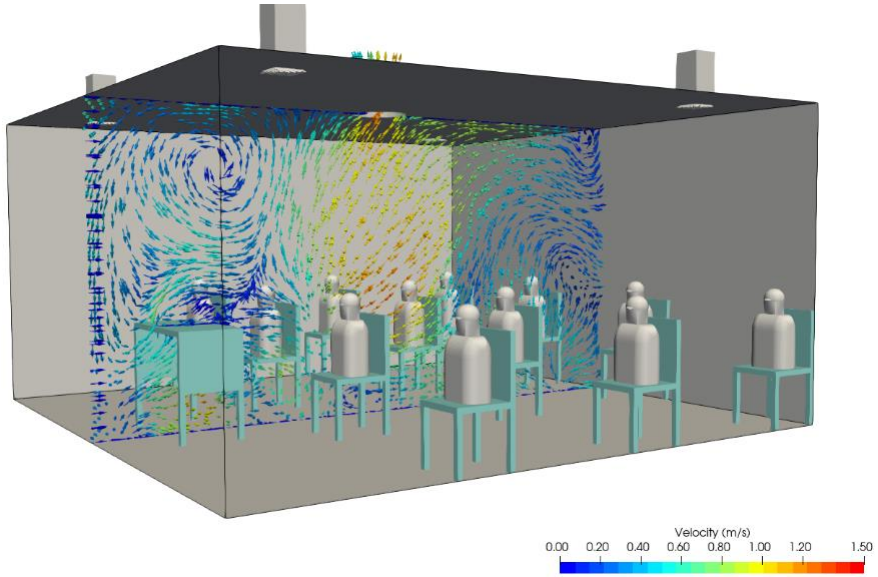
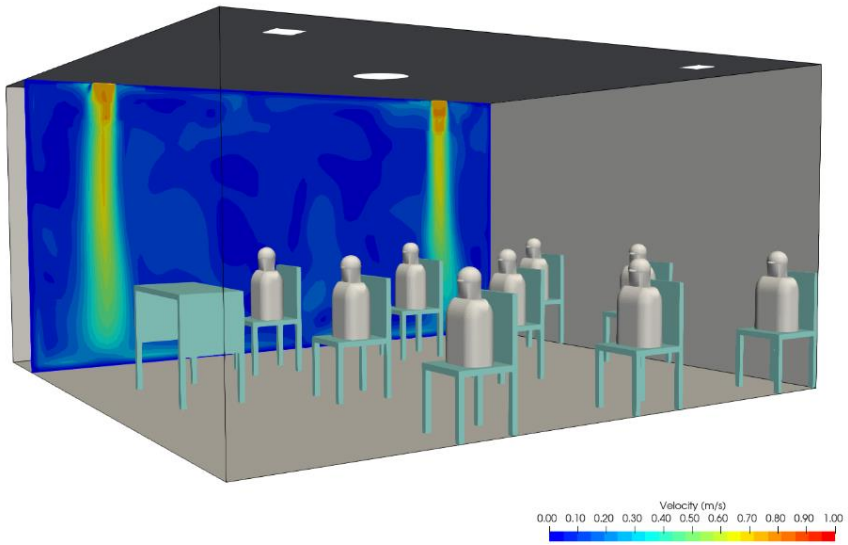


General Exhaust Ventilation under scrutiny of CFD

3D cross section view of air velocity patterns at center of air diffusers in the left side of room

Without air diffusers



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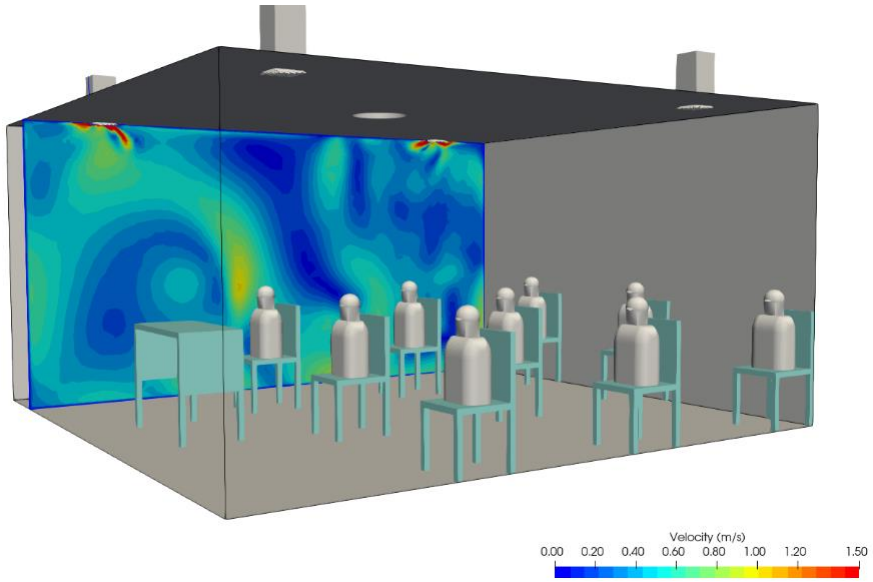

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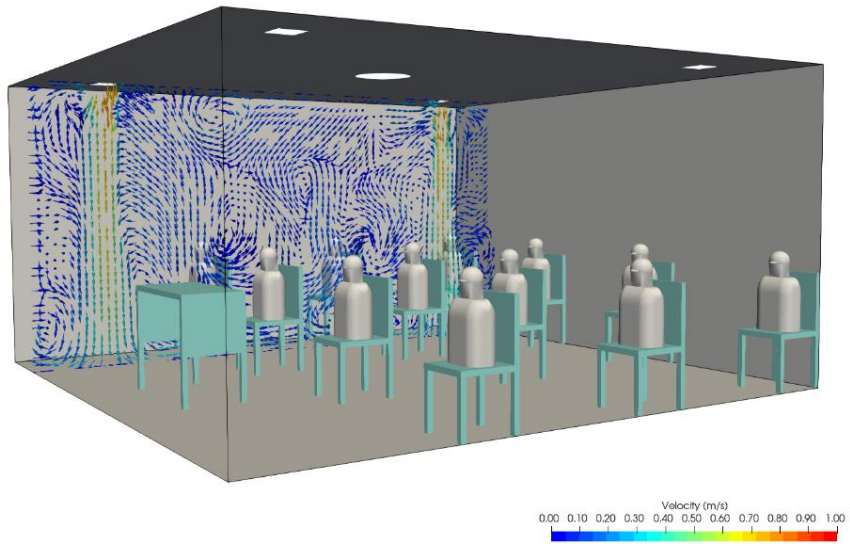

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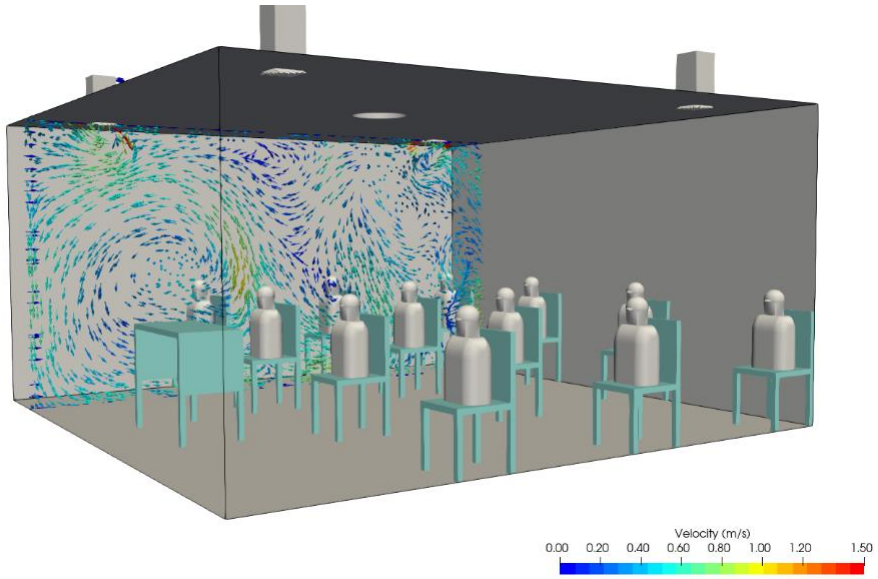
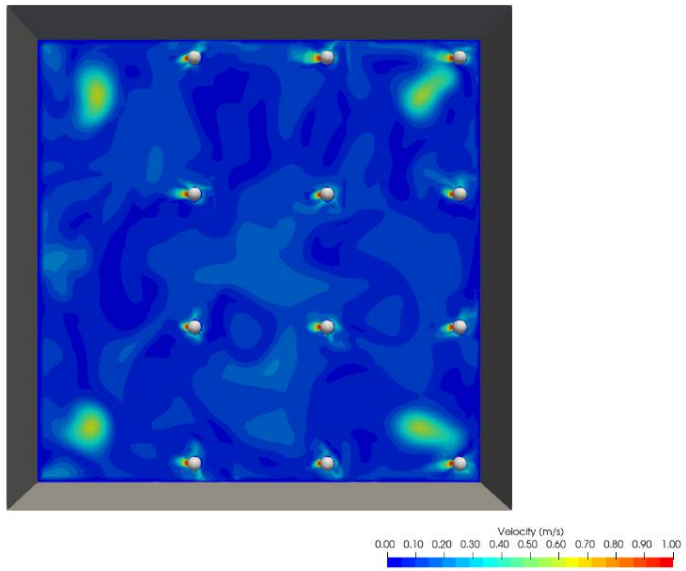


General Exhaust Ventilation under scrutiny of CFD

Top view of air velocity patterns at head height

Without air diffusers



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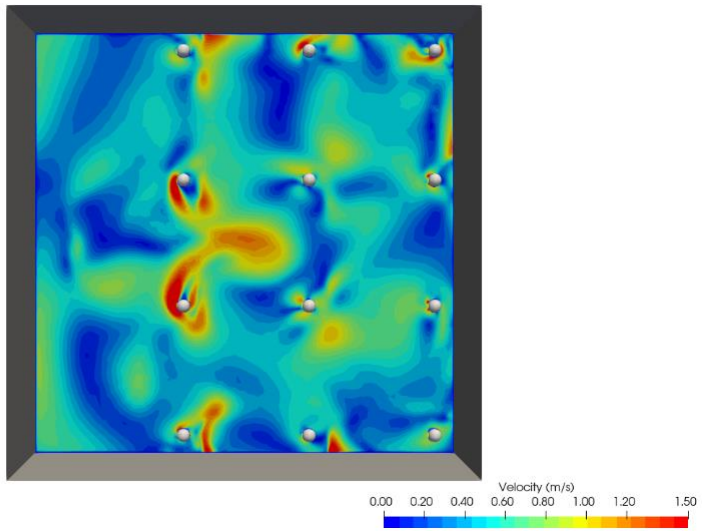

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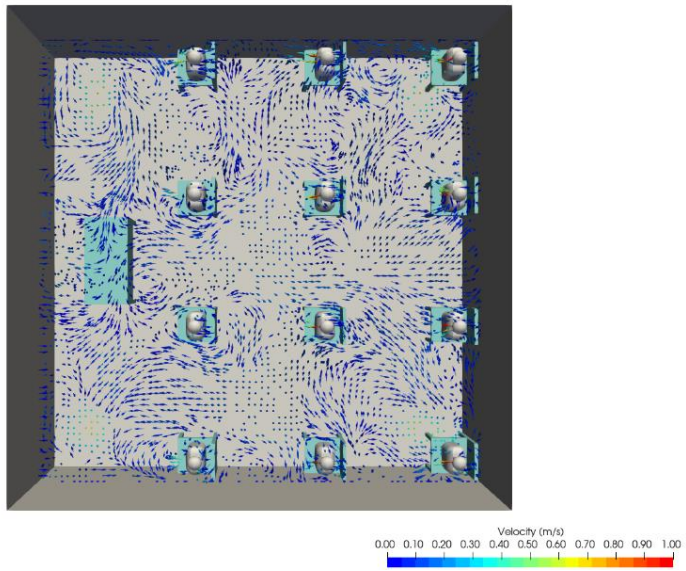

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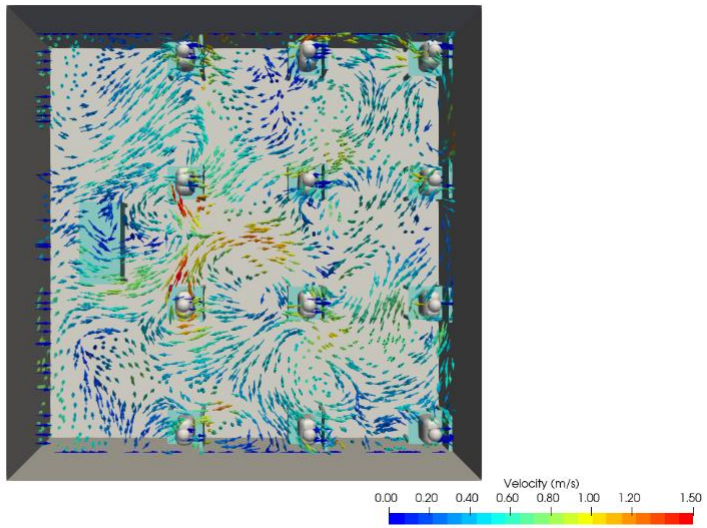
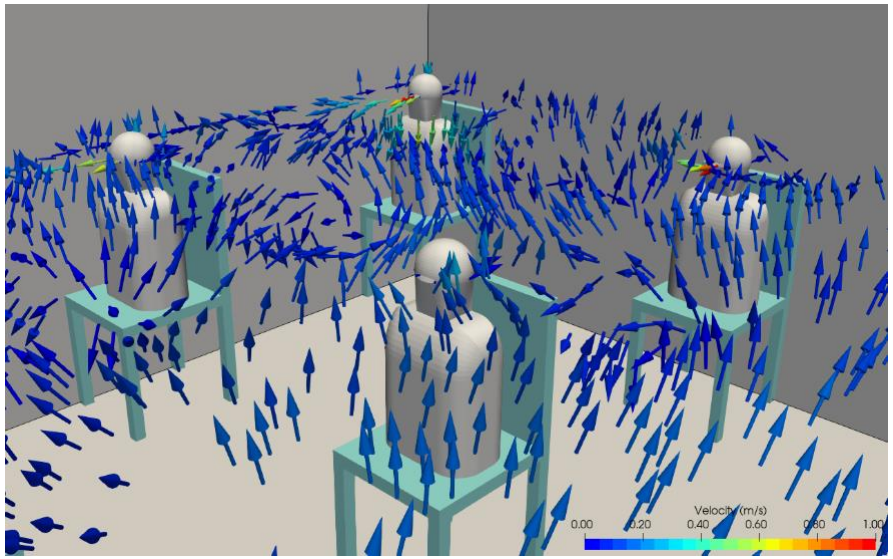


General Exhaust Ventilation under scrutiny of CFD

Closeup in air flow and velocity patterns

Without air diffusers



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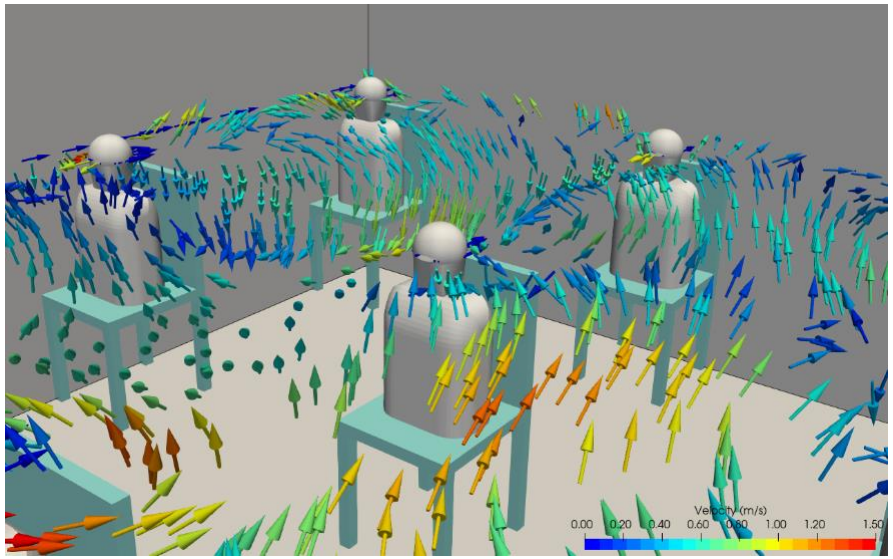
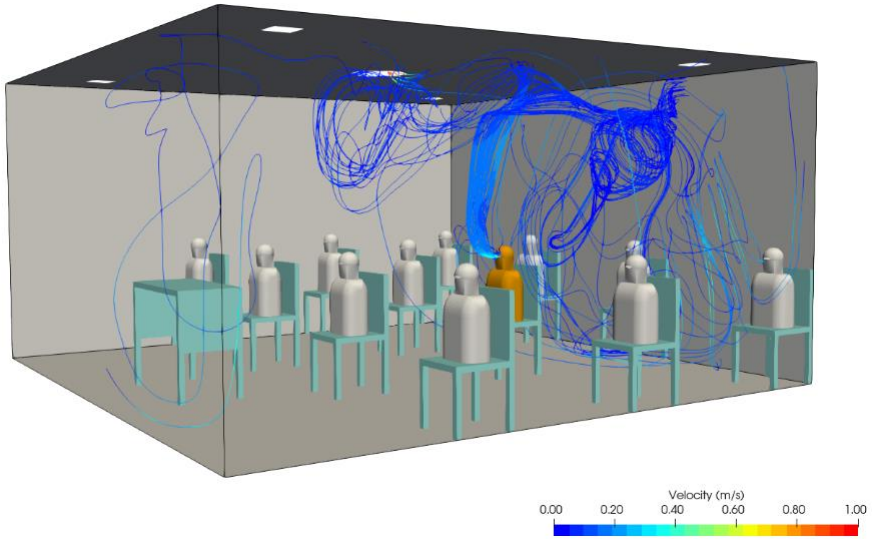


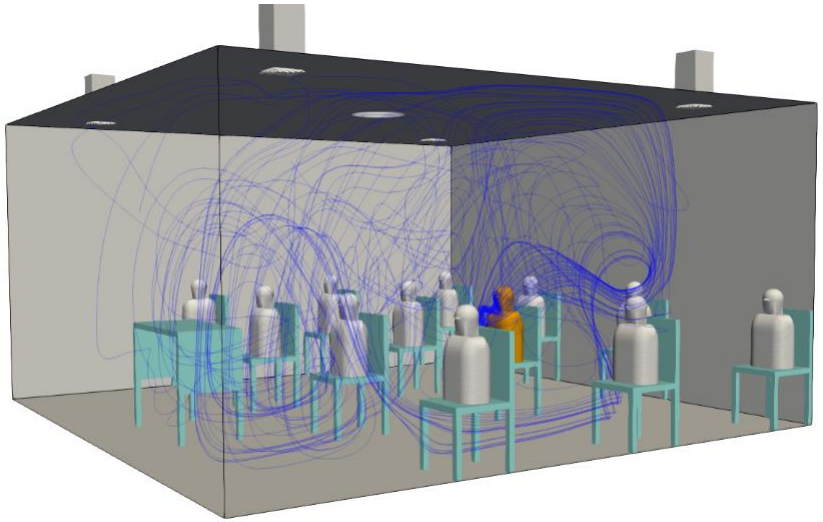
General Exhaust Ventilation under scrutiny of CFD

Following the path of an exhalation for 5 minutes

Without air diffusers



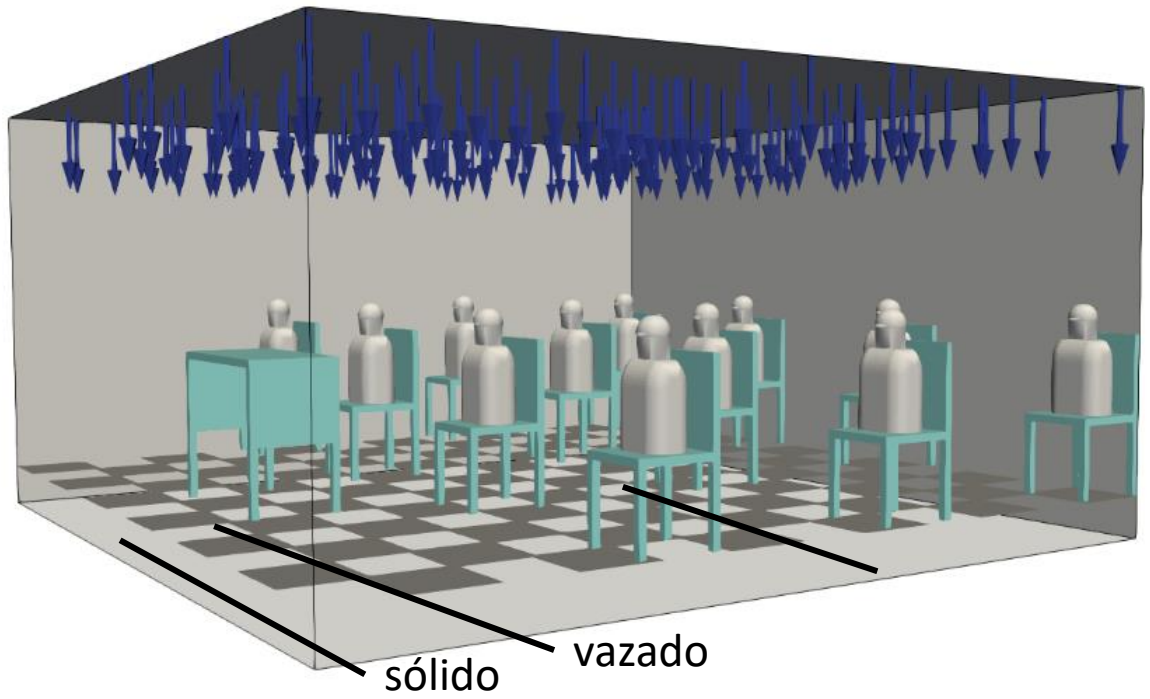
With air diffusers



General Exhaust Ventilation under scrutiny of CFD

Configuration 3

- Down draft Displacement Ventilation
- 25% perforated plate as air diffuser
- Floor raised 1 ft
- 20”x20” welded round bar exhaust grills (white squares)
- Downward air velocity is 4 fpm



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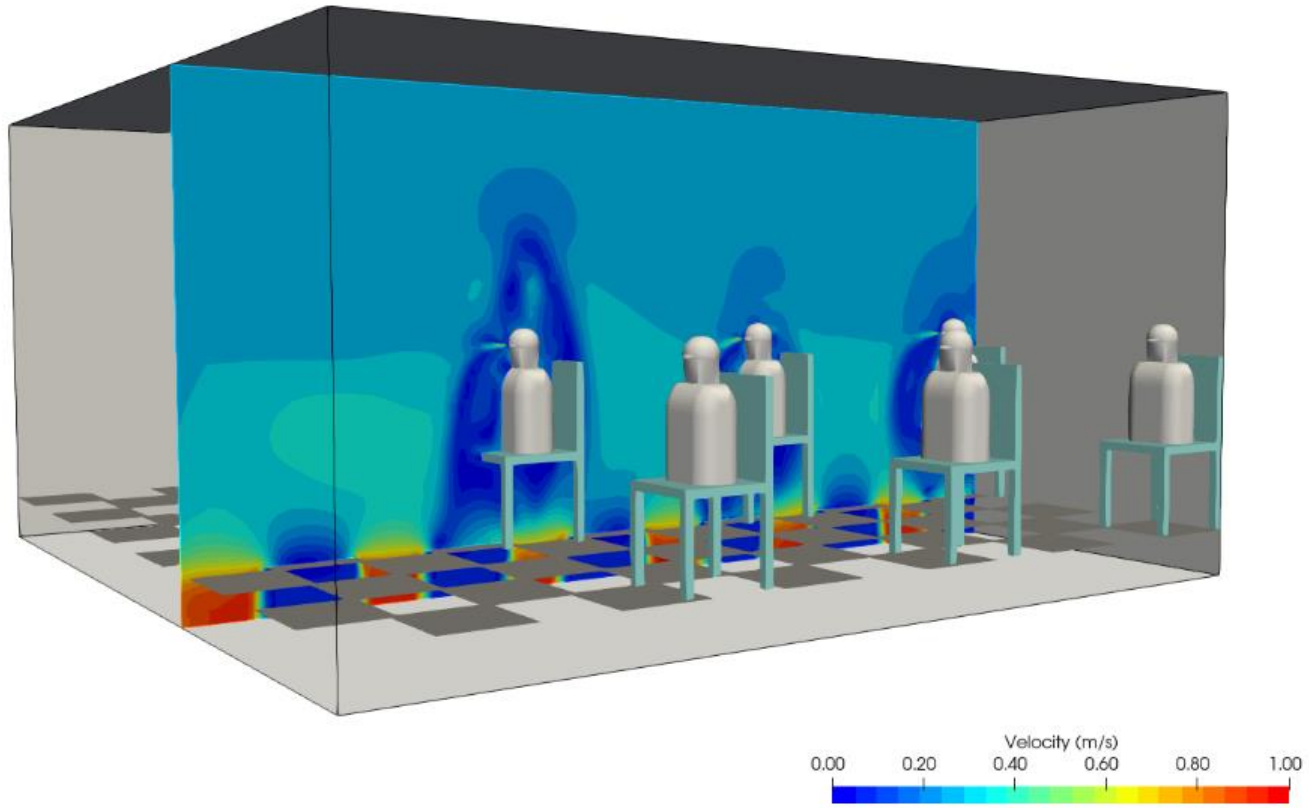
3D cross section view of air velocity patterns at center of third row of students from left to right of room



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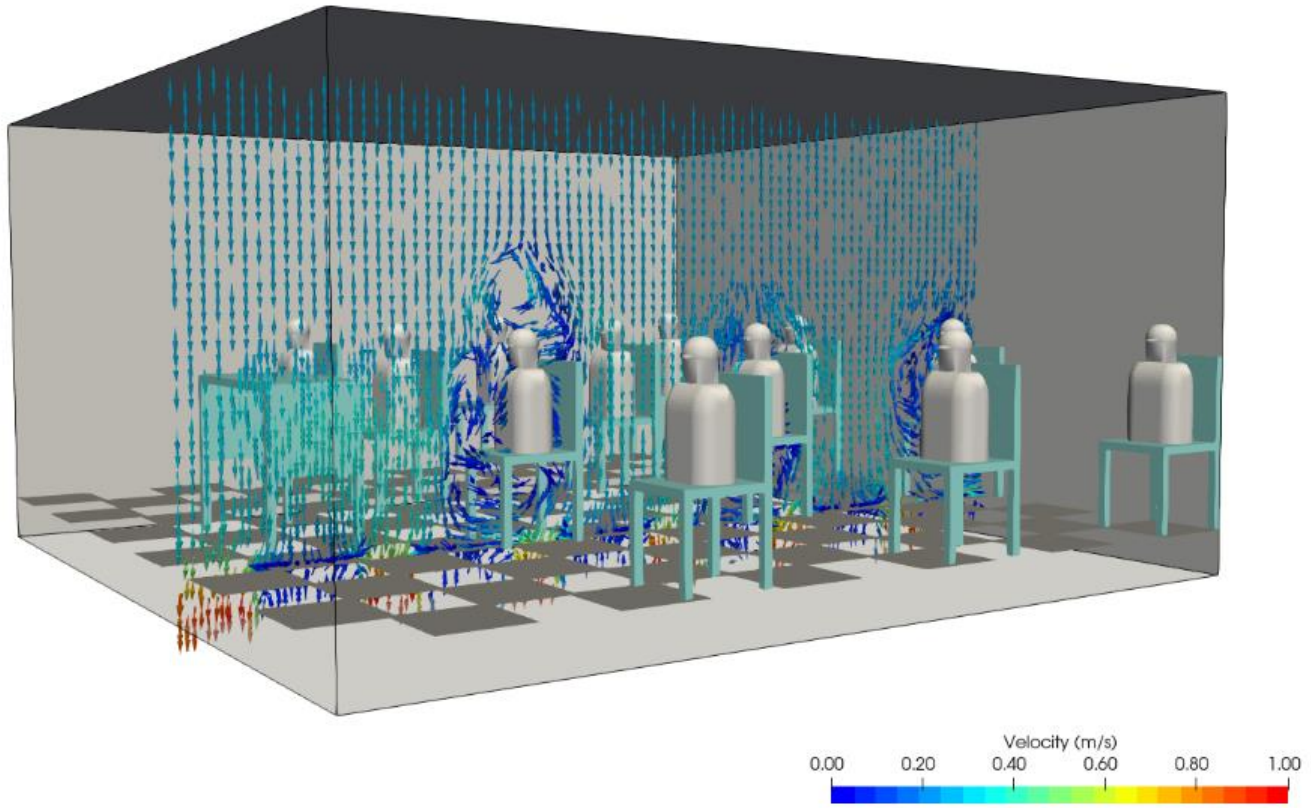

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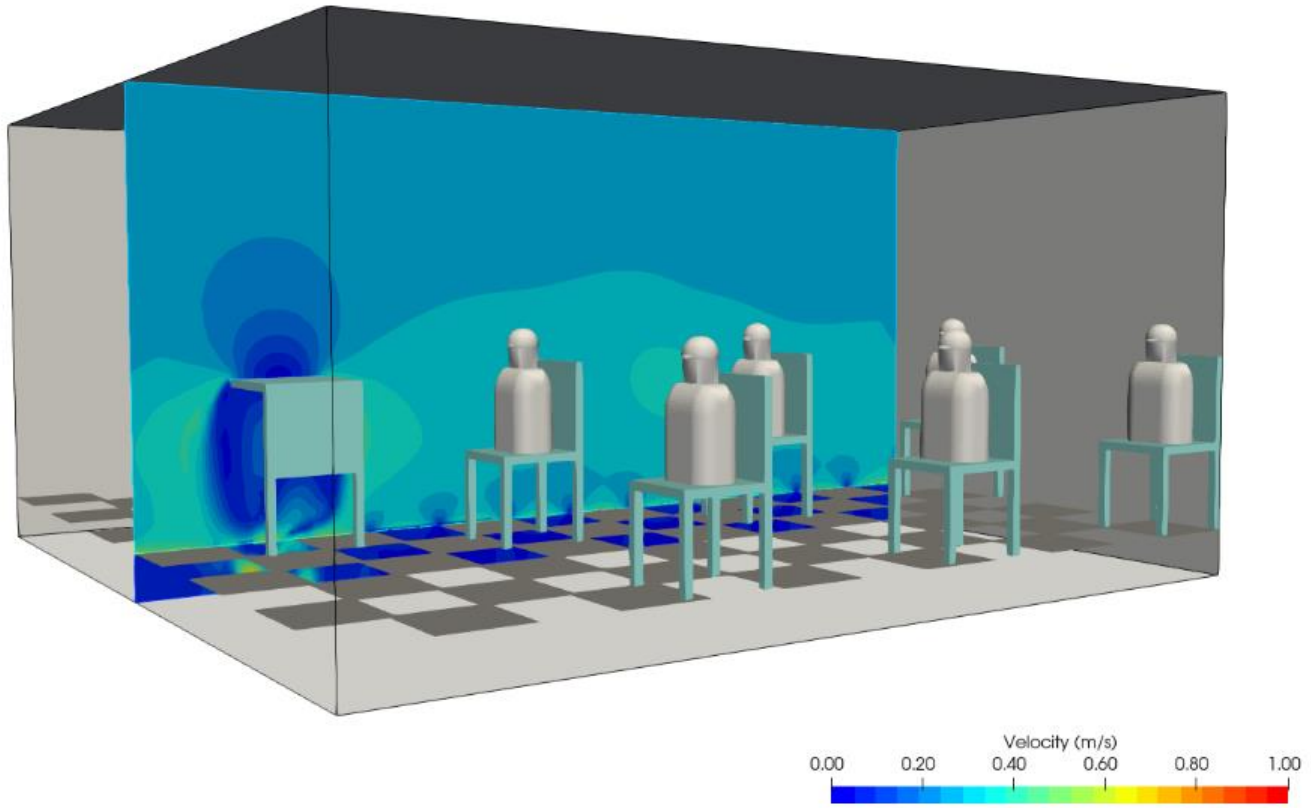
3D cross section view of air velocity patterns at center of teacher table



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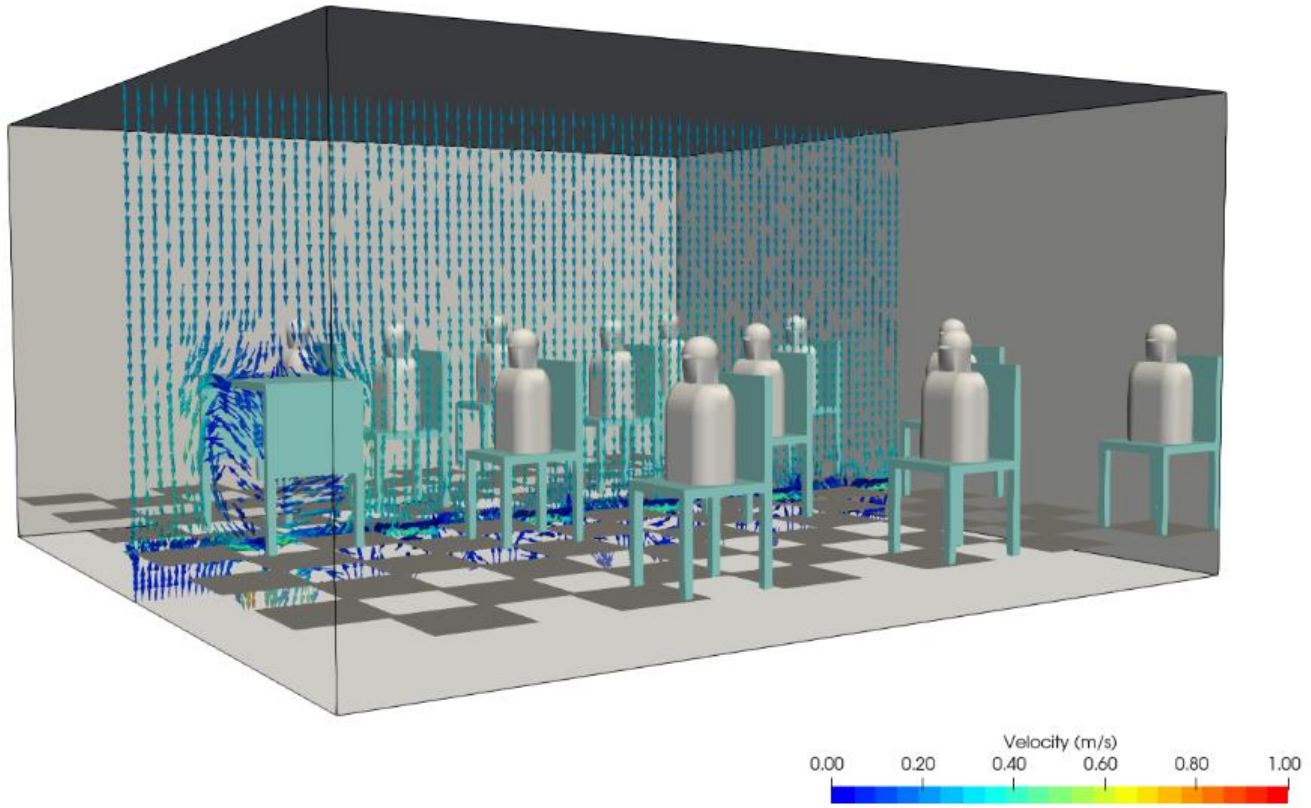

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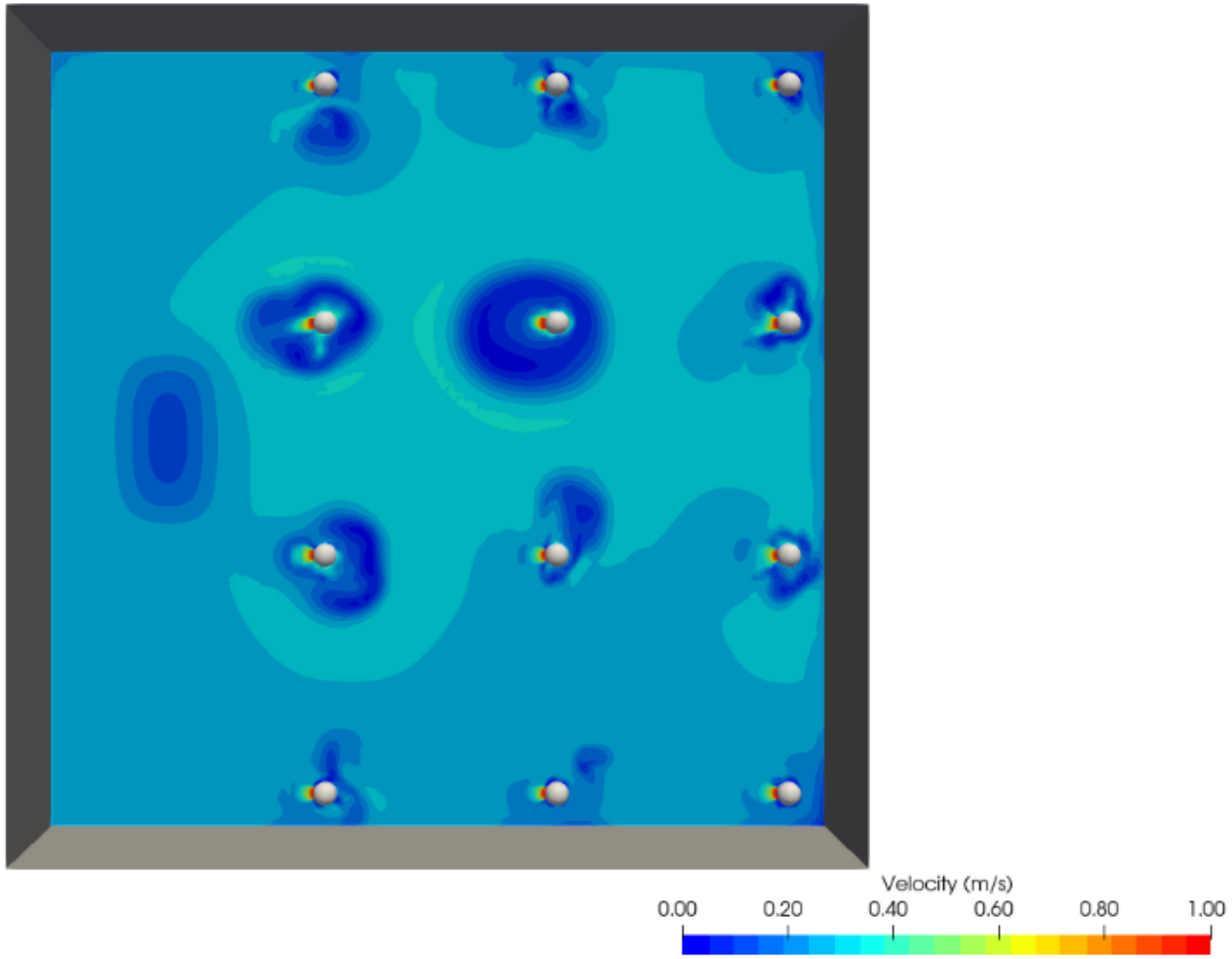
Top view of air velocity patterns at head height



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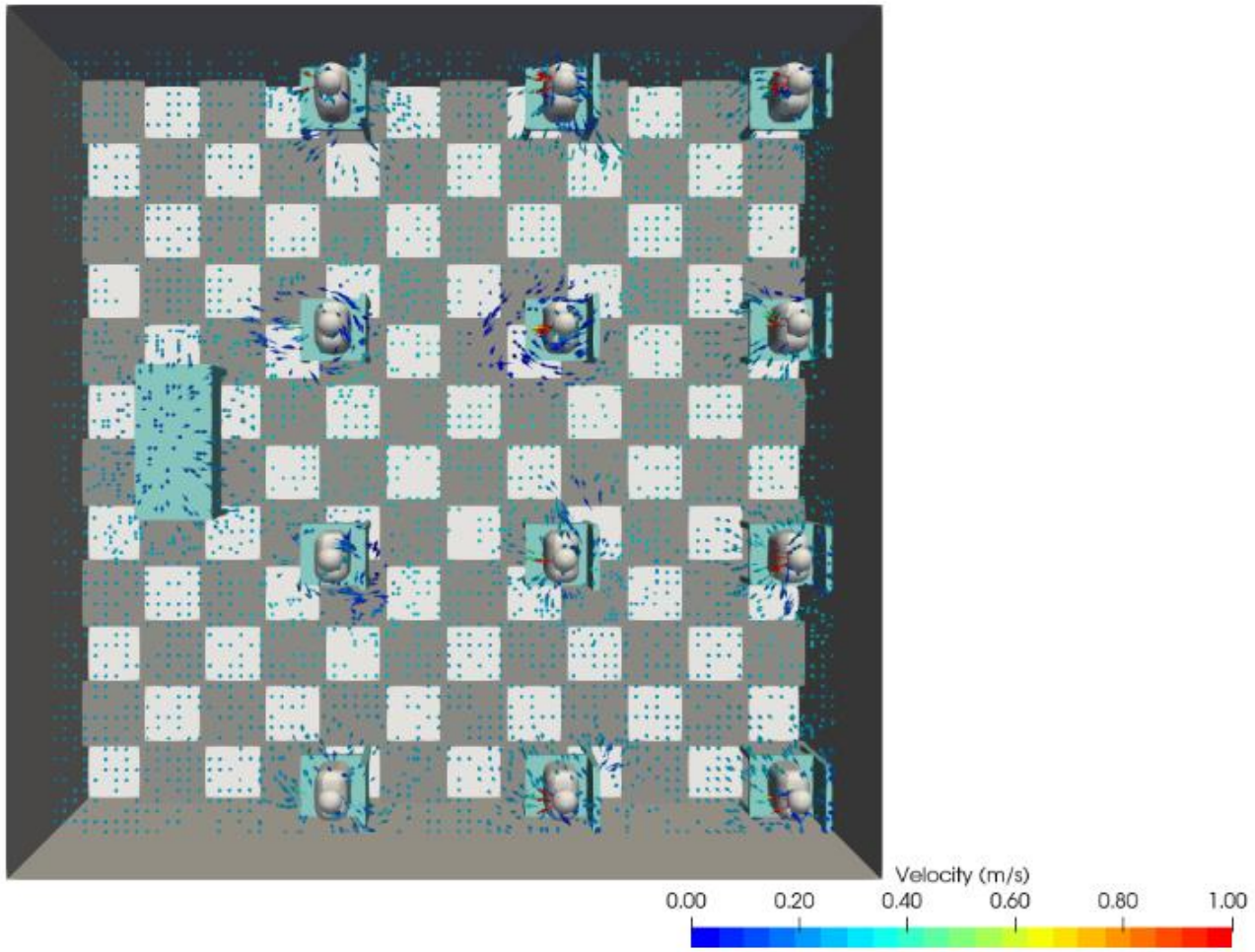

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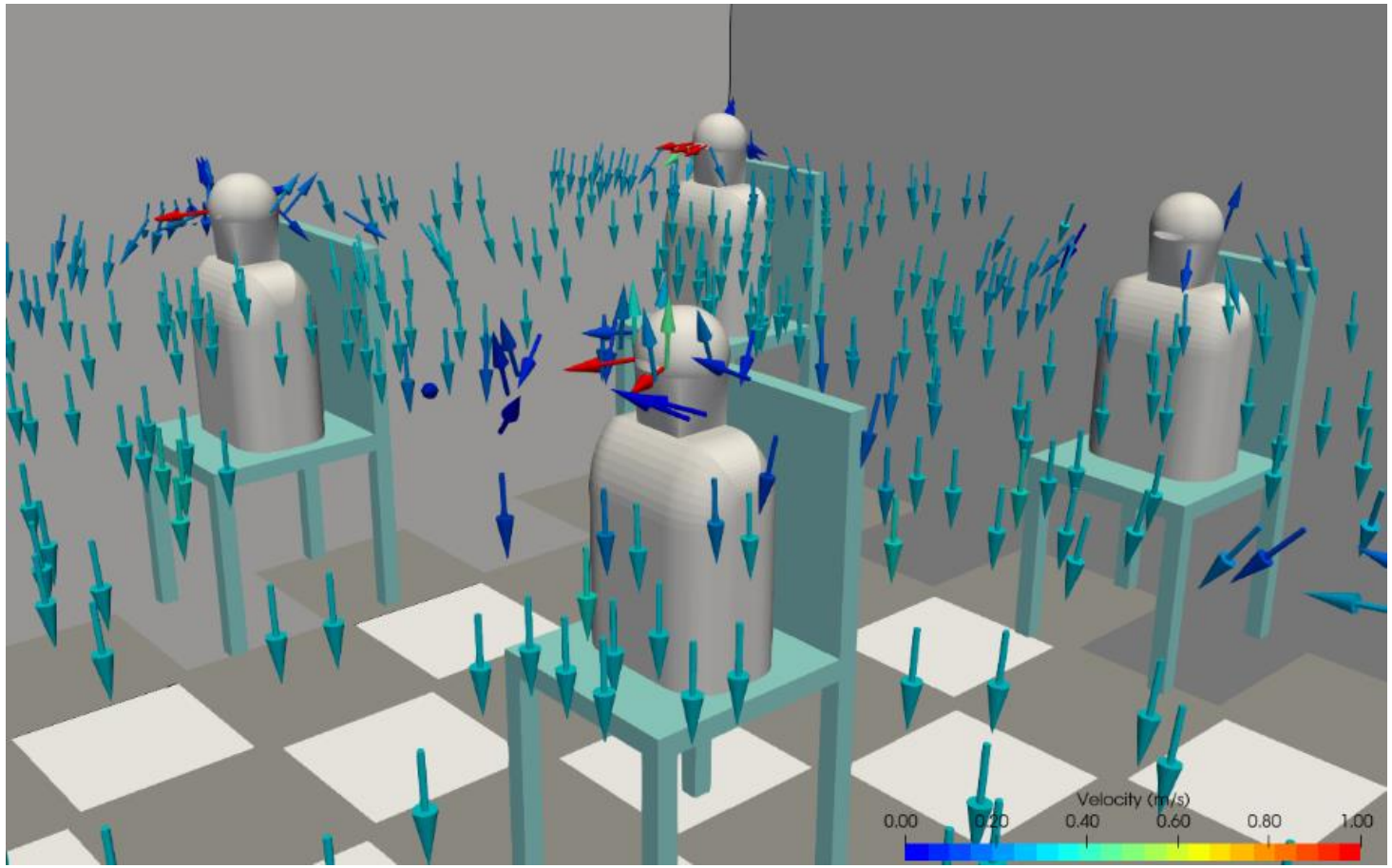
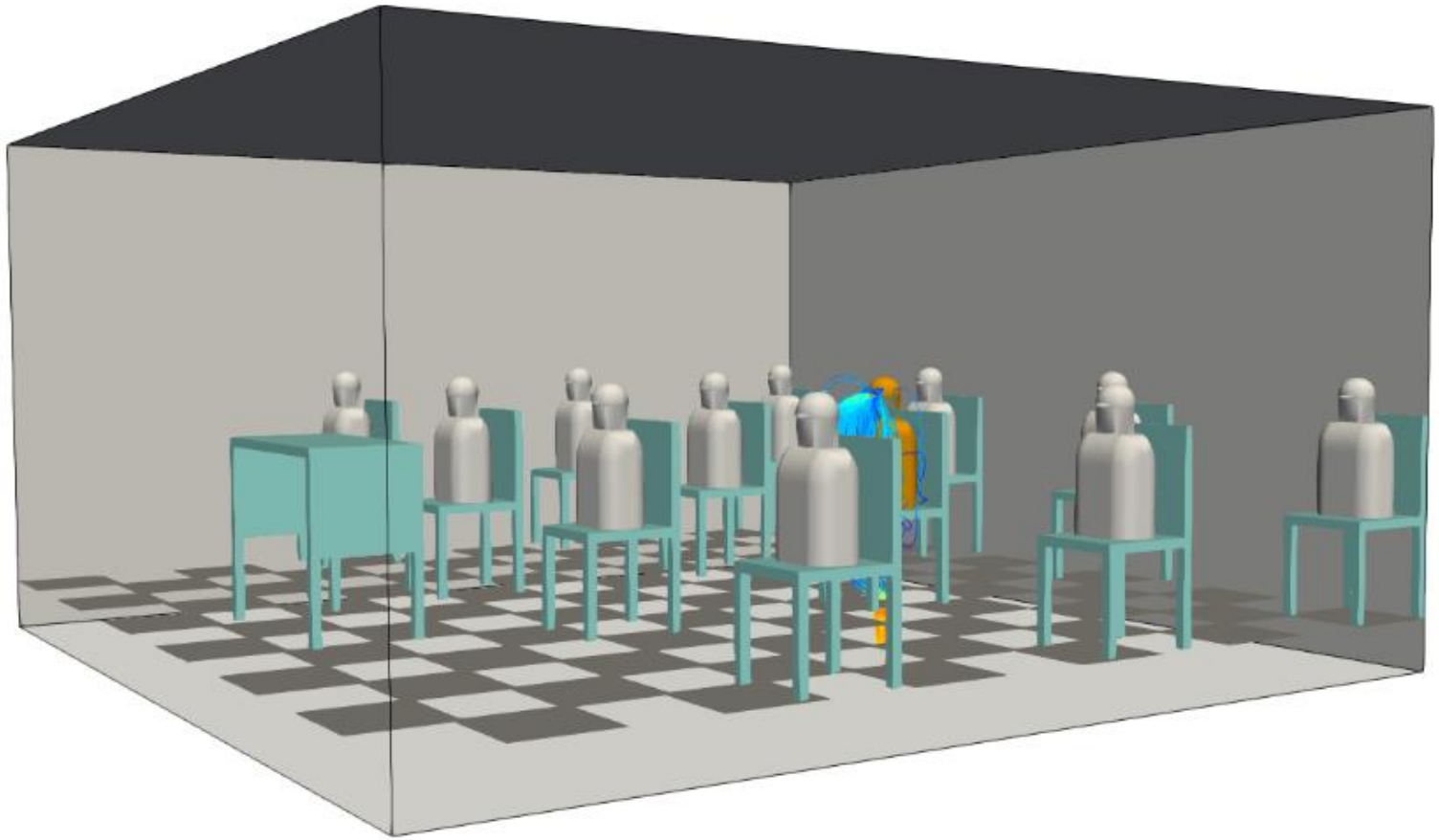
Closeup in air flow and velocity patterns



General Exhaust Ventilation under scrutiny of CFD

Following the path of an exhalation for 5 minutes



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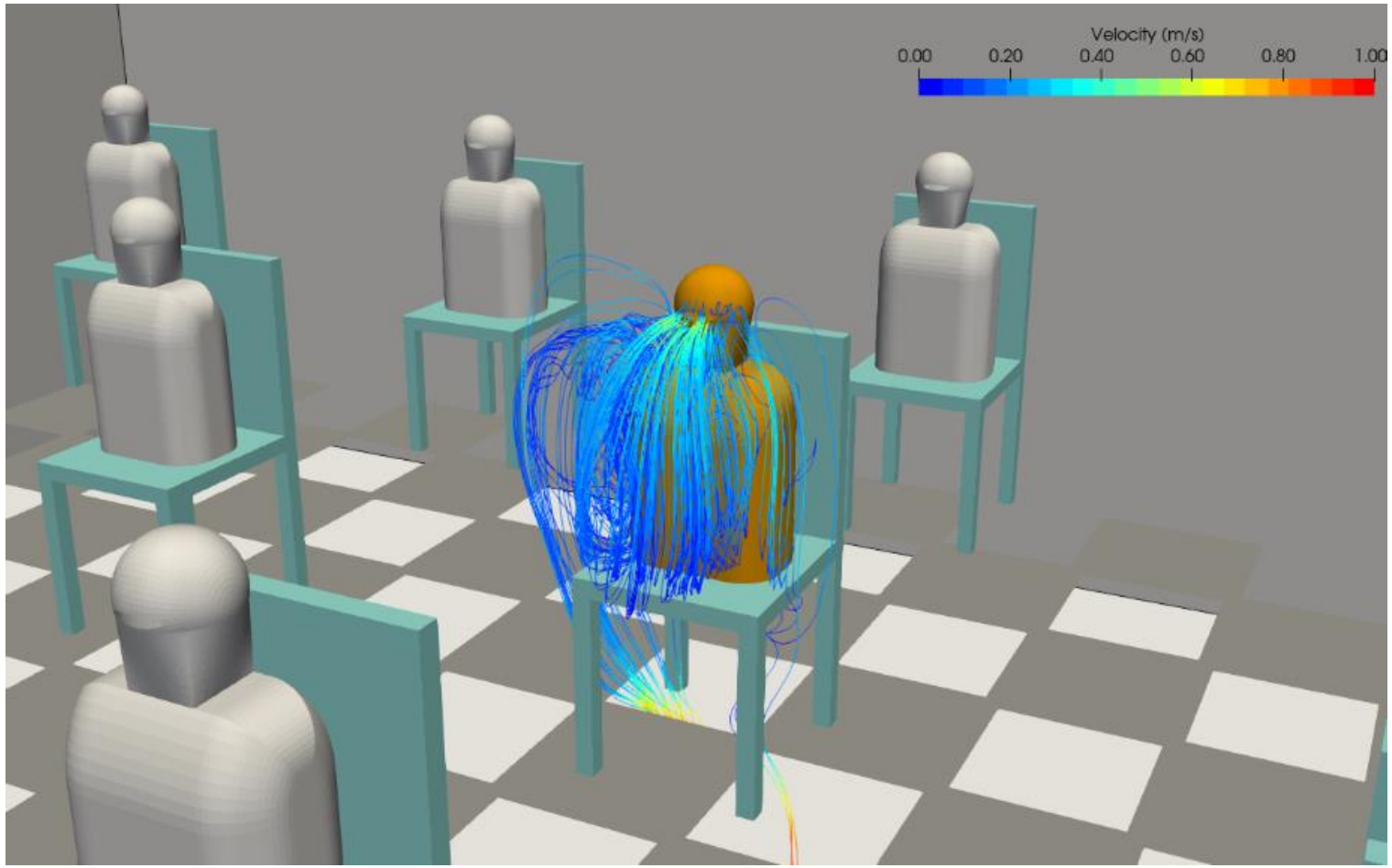
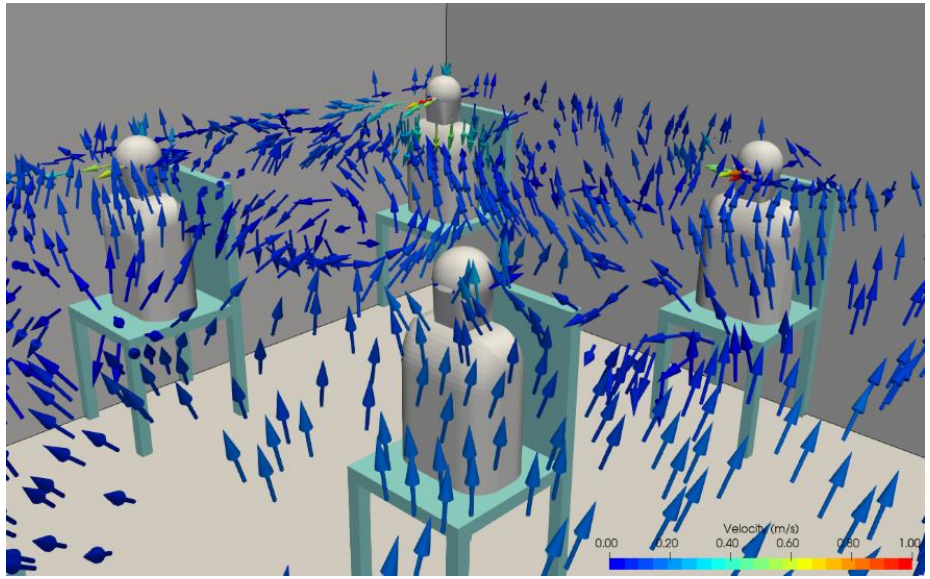
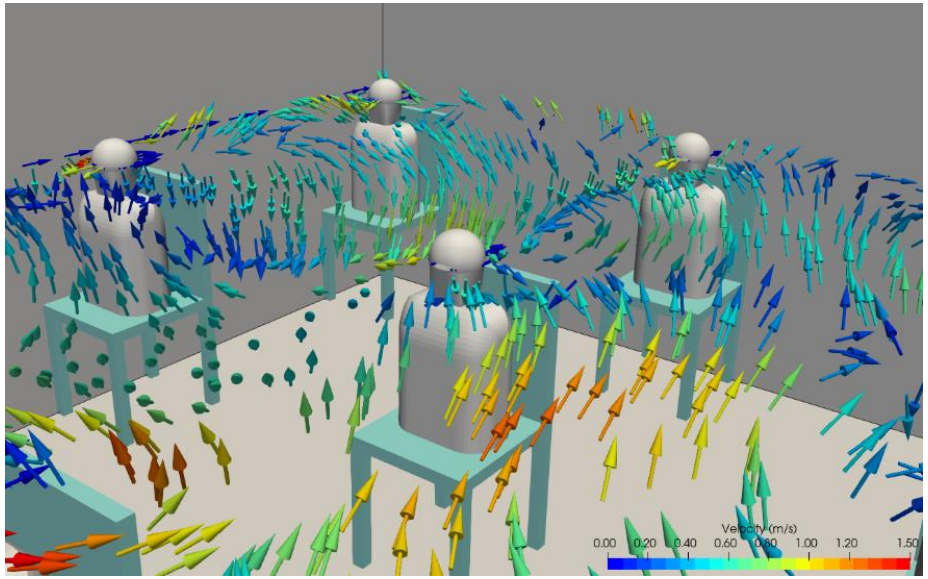


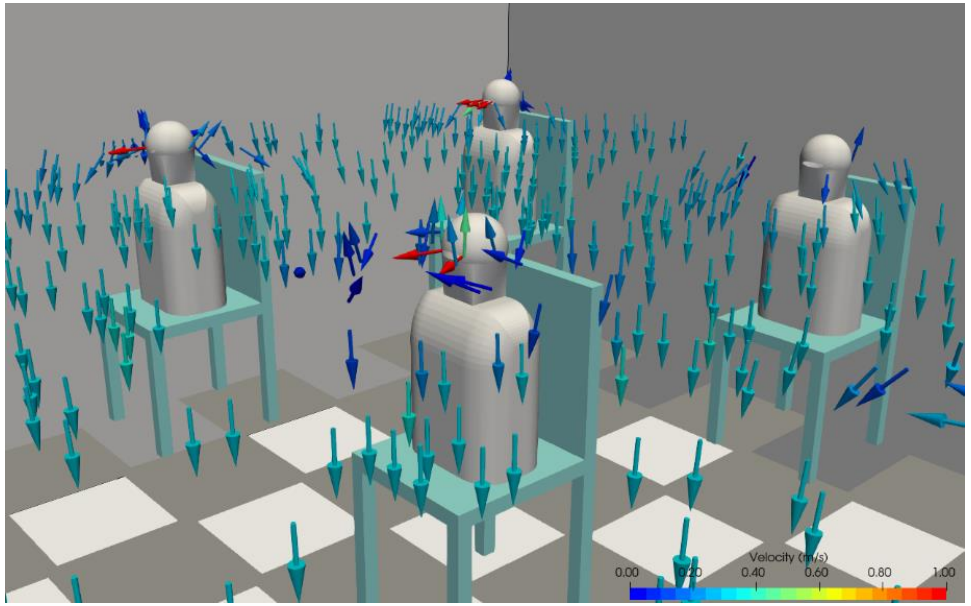
Dilution ventilation without air diffusers



Dilution ventilation with air diffusers

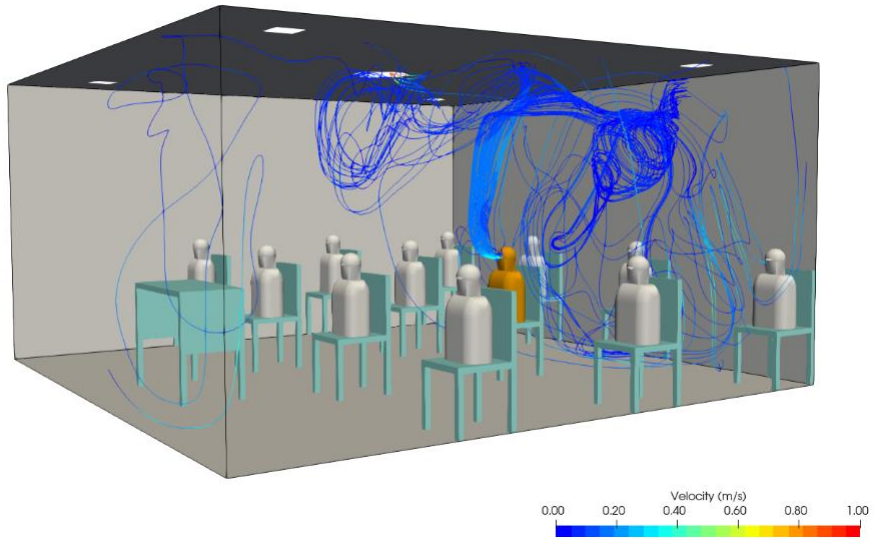


All three at 6 air changes per hour



Displacement ventilation

Dilution ventilation without air diffusers



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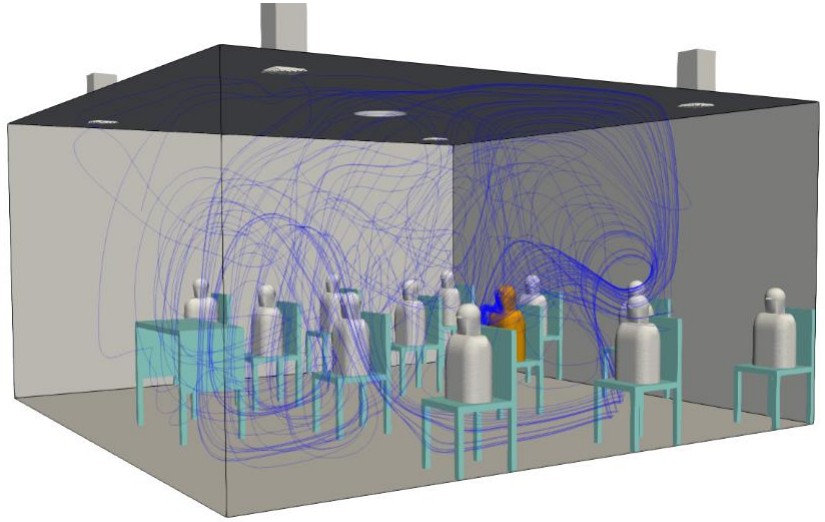

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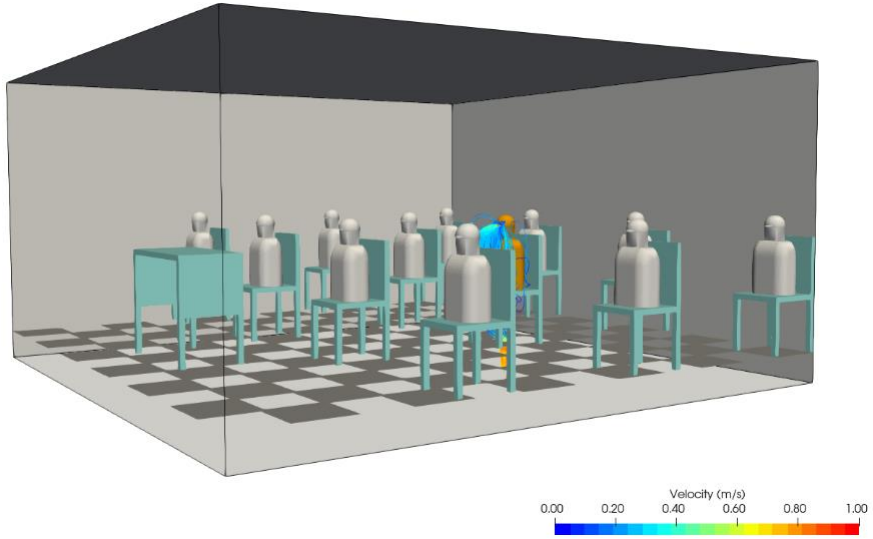

Displacement ventilation

Acknowledgments

- Dr. Rafael Sartim
  - Course development and coordination
  - Professor and Researcher
  - ACGIH Committee Member
  - UFES and Arcelomittal Global R&D
  - Espirito Santo, Brazil

Acknowledgments

- André Palmiro Storch
  - CFD simulation and animation
  - Process Research Engineer
  - ArceloMittal Global R&D
  - Espirito Santo, Brazil

Thank You!

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Any Questions