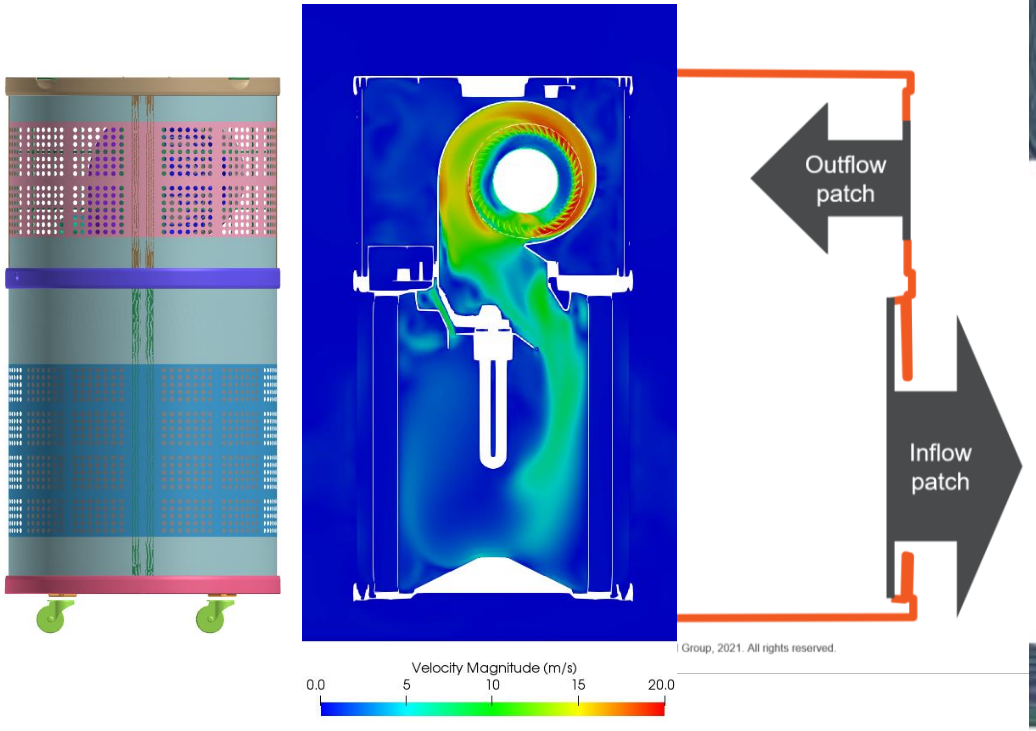
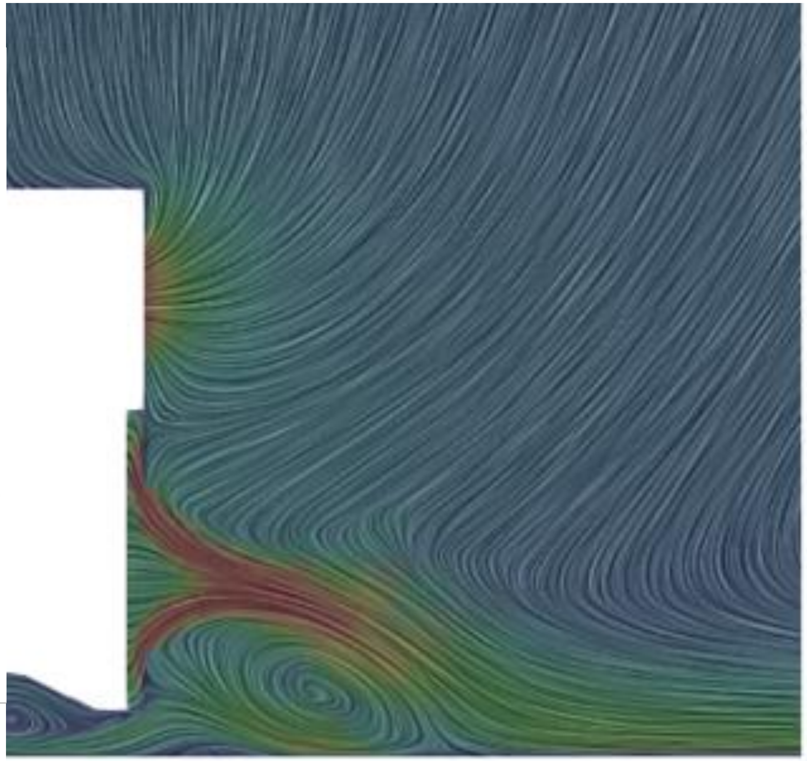
esi
get it right

Rensair





Rensair

WP1: Characterisation of flow through the unit at 300m^3/h (min) and 560m^3/h (max)

WP2: In-situ modelling in the Birmingham Hospital Dental Treatment Room

Final Report 2nd March 2022

Contract: 2021-12-245398 A

Contributors: Ventak Ramana
Reviewed: Pawan Ghildiyal
Approved: Fred Mendonca

Executive Summary

WP1: Characterisation of flow through the unit

- Detailed internal modelling of the unit,
    - Radial fan, UV-reactor volume, HEPA-13 filter and inflow/outflow ventilation holes,
    - Leads to a high level of confidence that the Rensair **device provides a circumferentially and axially uniform air delivery** at the lowest (300m^3/h) and highest flow rates (560m^3/h)
- CFD Modelling confirms the key design characteristics of this unit, namely
    - Upper-unit inflow; **captures the flow hemi-spherically from above and around** it
    - Lower-unit outflow; radial **jet attaches to the floor, enhancing the room penetration and encourages a toroidal-circulation** of airflow in the enclosure
    - This combined effect **assists high-to-low particle precipitation** close to the AGP sources

WP2: In-situ modelling in the Birmingham Hospital Dental Treatment Room

- Air Circulation efficiency (60-65%); When used in isolation, or with the treatment room's mechanical ventilation notionally turned on, the **air circulation efficiency scales with ACH** irrespective of installation location; and rates well in comparison with other commercial portable and wall-mounted units of similar capacity
- P1 is always superior (65%) to P2 (~60%) for circulation efficiency
- AGP log-2 clearance time; **Dental AGP clears to Log-2 reduction within 2.3mins for all scenarios**, and scales with eACH. The larger droplets precipitate very quickly (Stokesian behaviour)

CFD Modelling Summary

Geometry representation, Physics modelling and boundary conditions

WP1: Characterisation of flow through the unit

- Geometry
  - Provided by Rensair, and simplified to remove the fan inlet brackets particular only to USA design and remove the inlet-side filter just downstream of the inlet holes as they are presumed negligible to the flow and pressure resistance
  - Included the full fan blade assembly and volute as this is the main flow driver which determines the inflow and outflow distribution in respect of potential non-uniformities
- CFD Physics and boundary conditions, assumed as
  - Turbulent, isothermal, single phase (airflow only, no particles/droplets)
  - Device through-flow is driven by the modelled fan RPM, tuned to give the desired flow rate

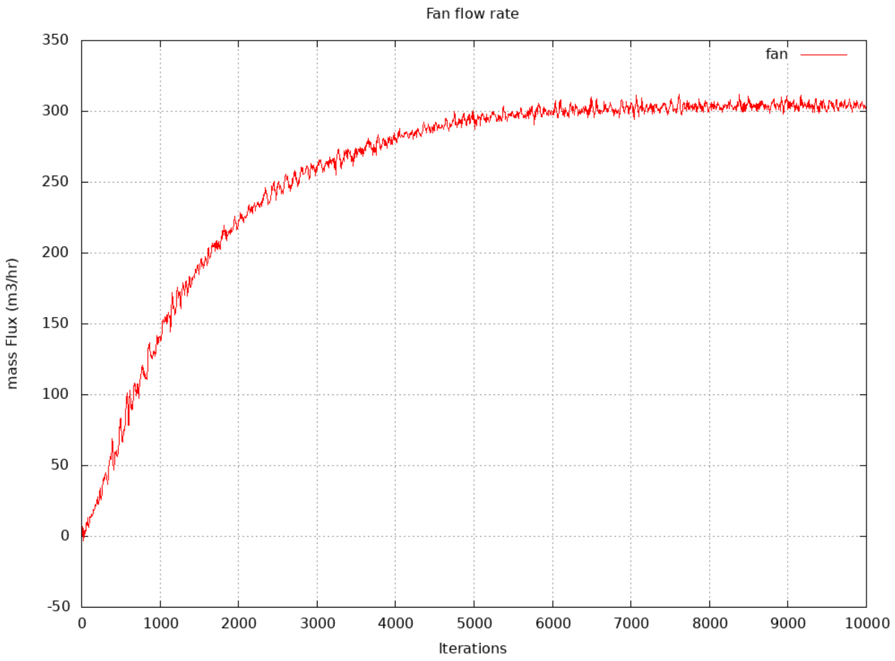
WP2: In-situ modelling in the Birmingham Hospital Dental Treatment Room

- Geometry
  - Geometry is simplified representation of the Rensair device giving the same characteristic inflow and outflow
    - Excludes all internal-to-device components downstream of the inlet holes, and upstream of the outer surface of the HEPA-13 filter
    - Boundary conditions deploy uniform circumferential and axial inflow and outflow distribution
  - Standard geometry for the dental treatment Room 202 at Birmingham Hospital
- CFD Physics and boundary conditions, assumed as
  - Turbulent, isothermal
  - Room mechanical ventilation is based on 5ACH as per measurements in-situ
  - Particulate phase activated in a steady field with one-way coupling (flow influences the particle trajectories) for two types of APG (“Dental” with droplet size predominantly > 10µm)

WP1.1: Flow rates tuning via CFD-corrected RPM

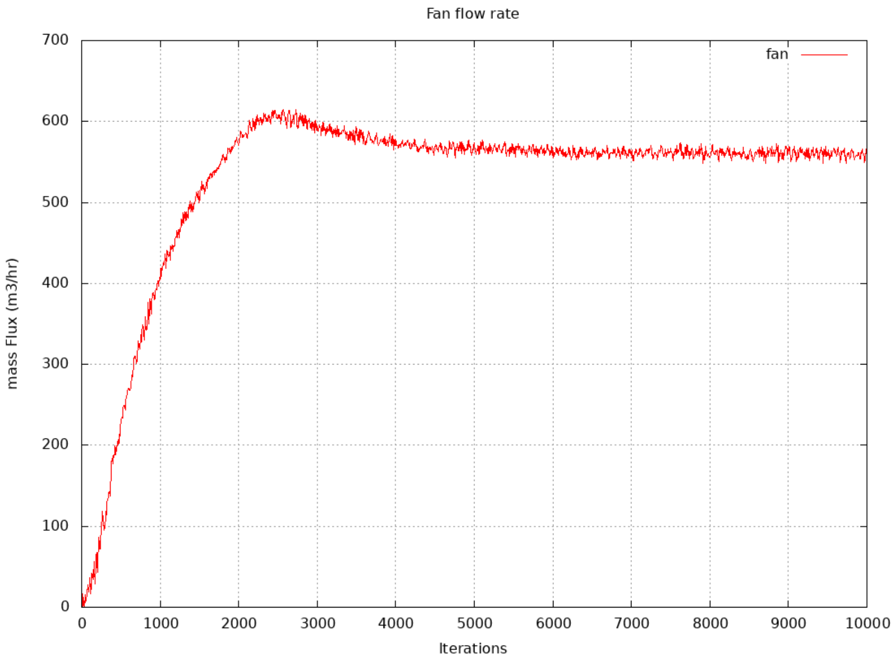
1660 corrected-rpm

	Flow rate (m^3/hr)
CFD monitored	301-304
Expected	300



3050 corrected-rpm

	Flow rate (m^3/hr)
CFD monitored	559-560
Expected	560

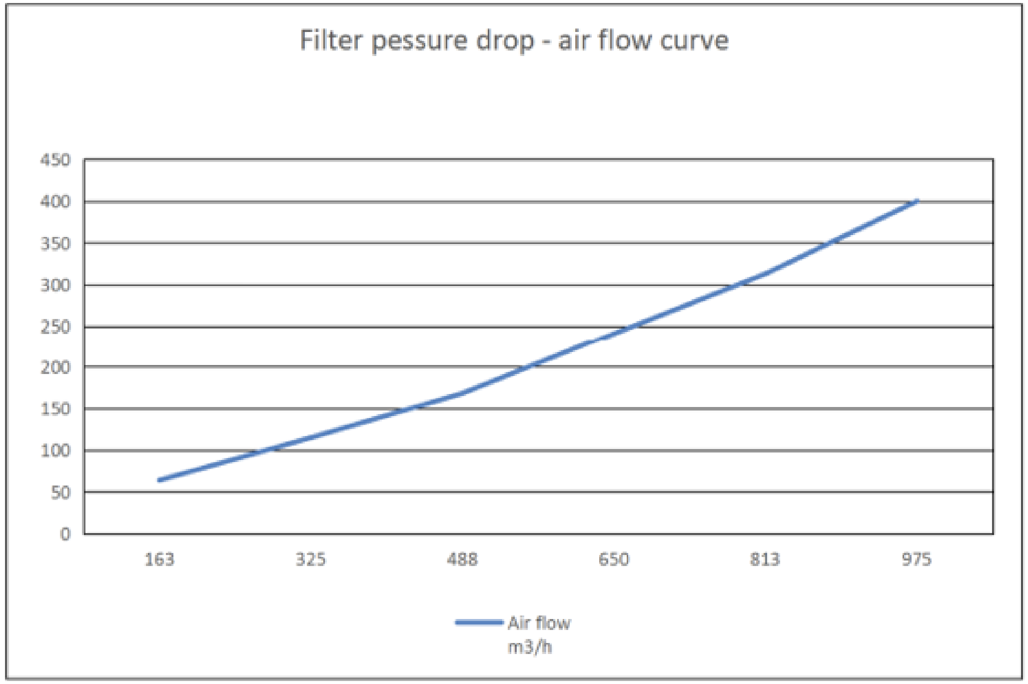


WP1.1: HEPA-13 Filter Pressure drop

	Pressure drop (Pa)
Simulation	110.0 Pa at 301 m^3/hr
From curve	108.0 Pa at 301 m^3/hr

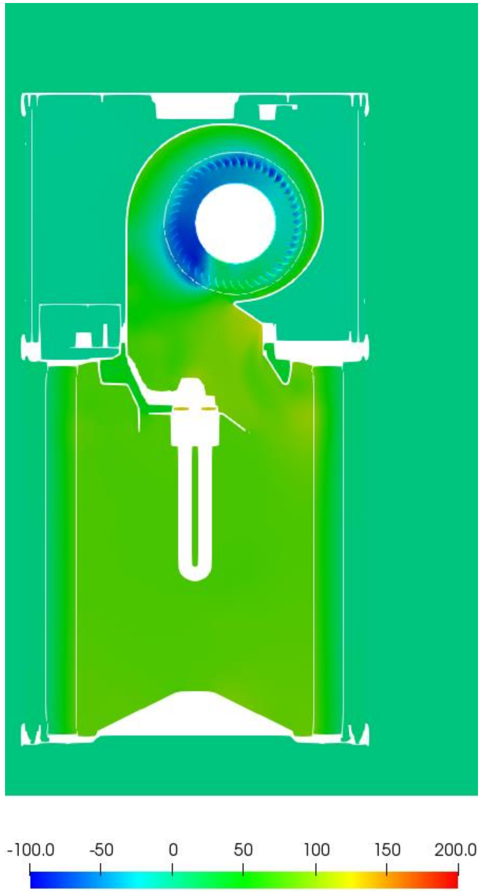
	Pressure drop (Pa)
Simulation	216 Pa at 559 m^3/hr
From curve	208 Pa at 559 m^3/hr

Air flow m3/h	Pressure drop Pa
163	64
325	115
488	168
650	241
813	313
975	400

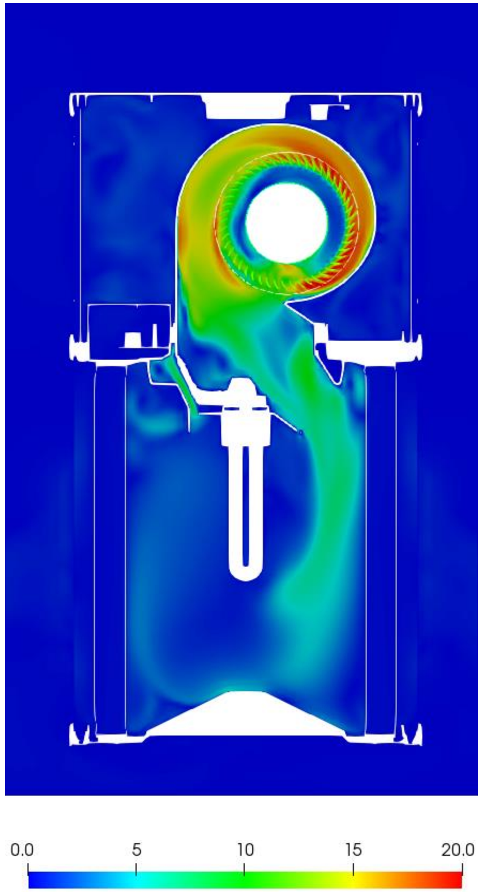


WP1.1: Vertical Planes

300m³/h

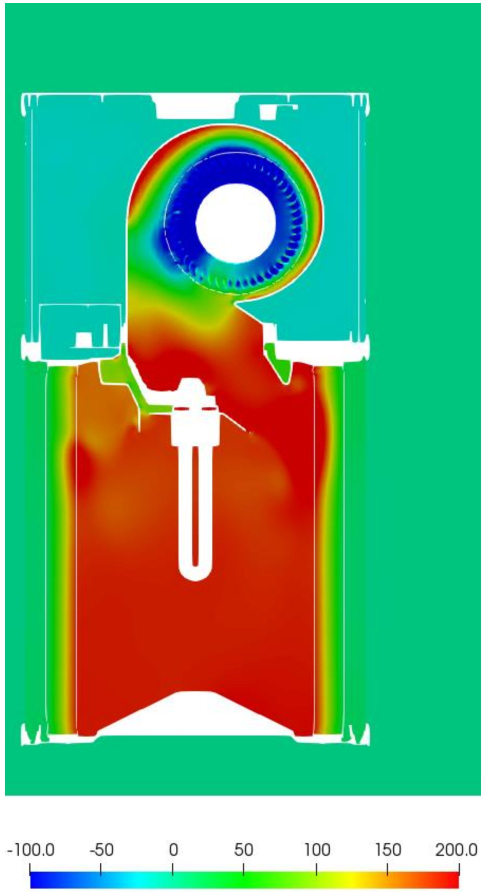


Pressure (Pa)

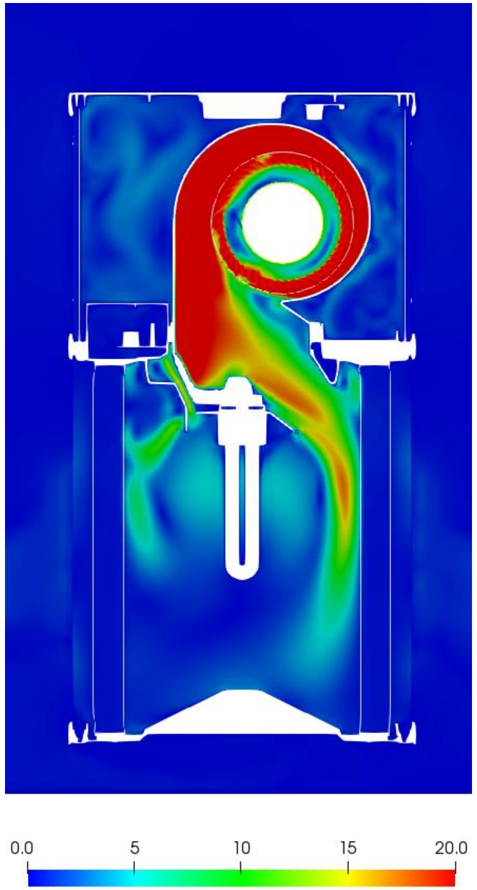


Velocity Magnitude (m/s)

560m³/h



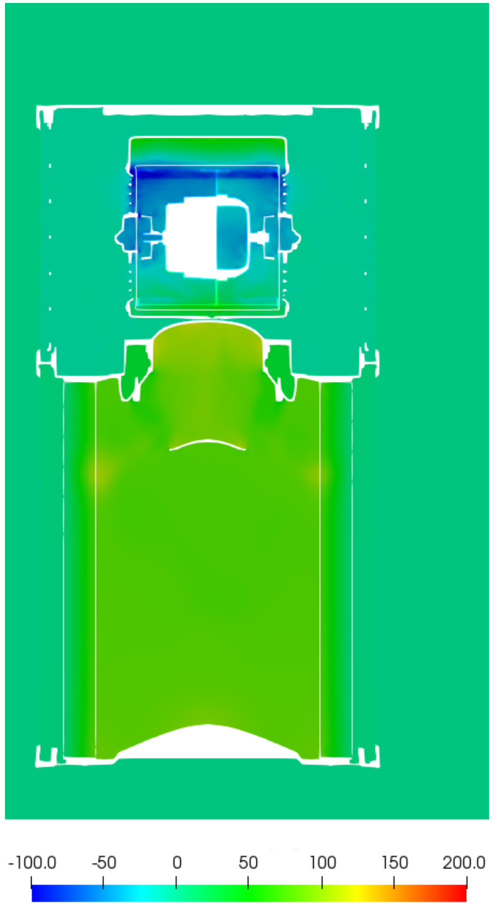
Pressure (Pa)



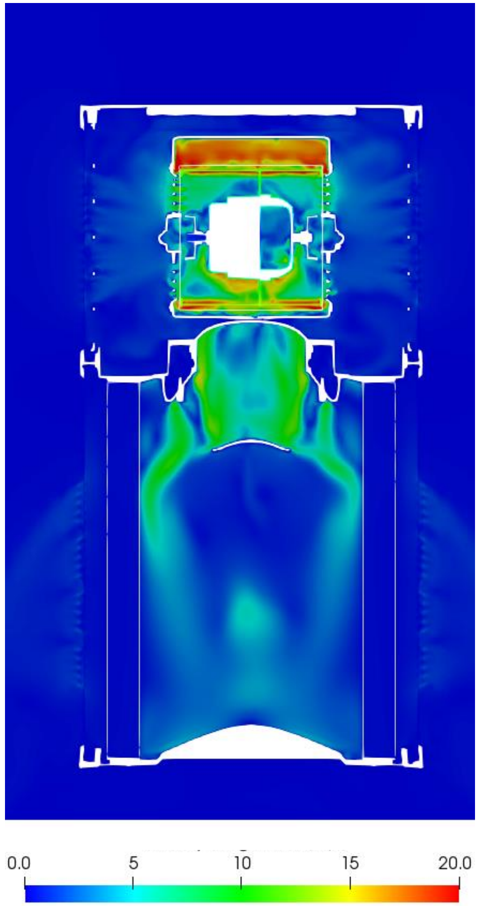
Velocity Magnitude (m/s)

WP1.1: Vertical Planes

300m³/h

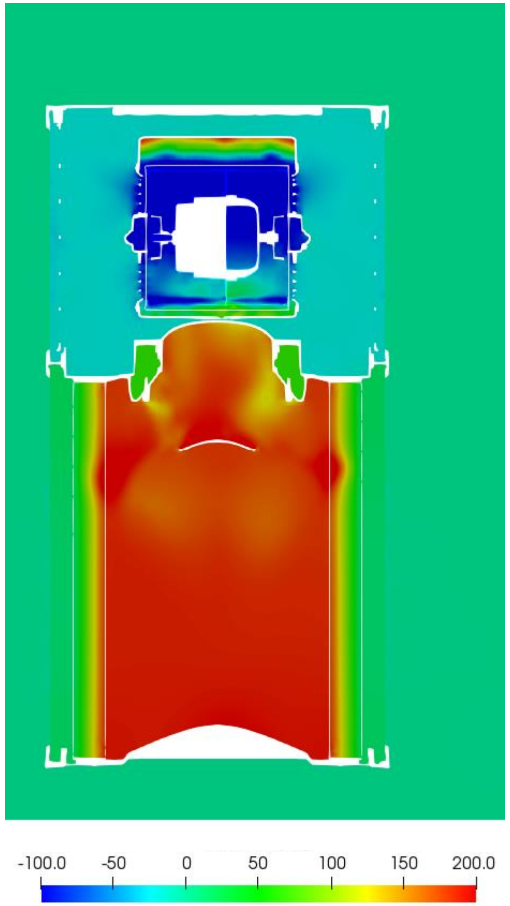


Pressure (Pa)

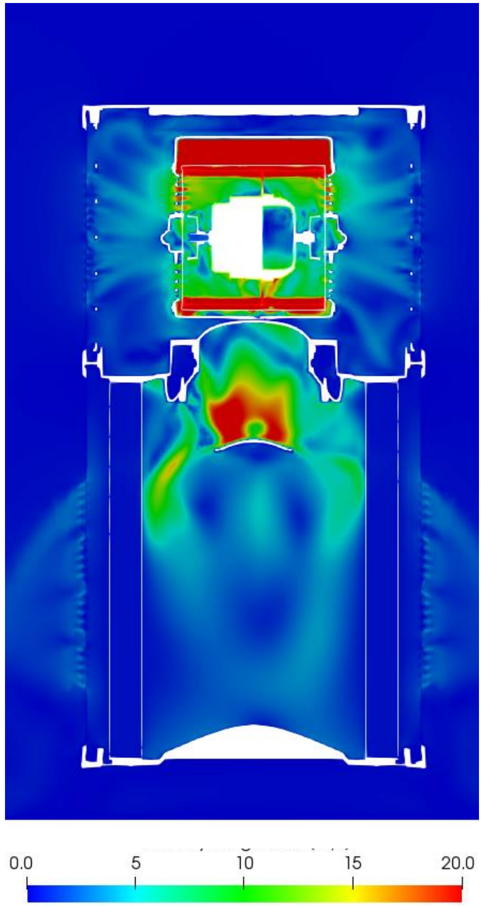


Velocity Magnitude (m/s)

560m³/h

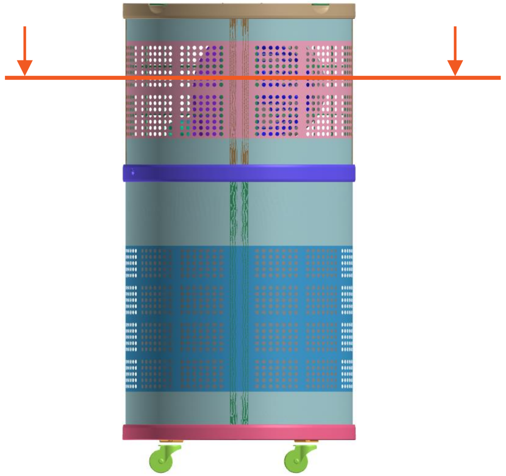


Pressure (Pa)



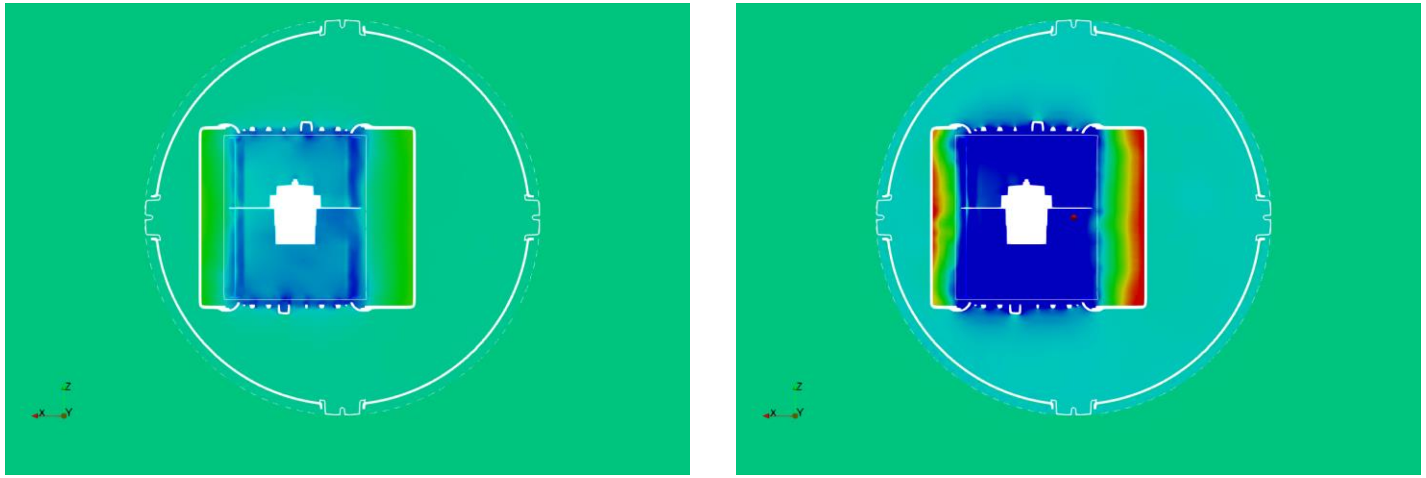
Velocity Magnitude (m/s)

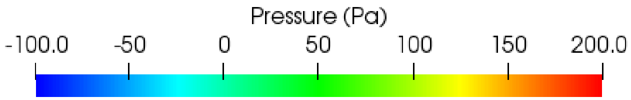
WP1.1: Horizontal Planes

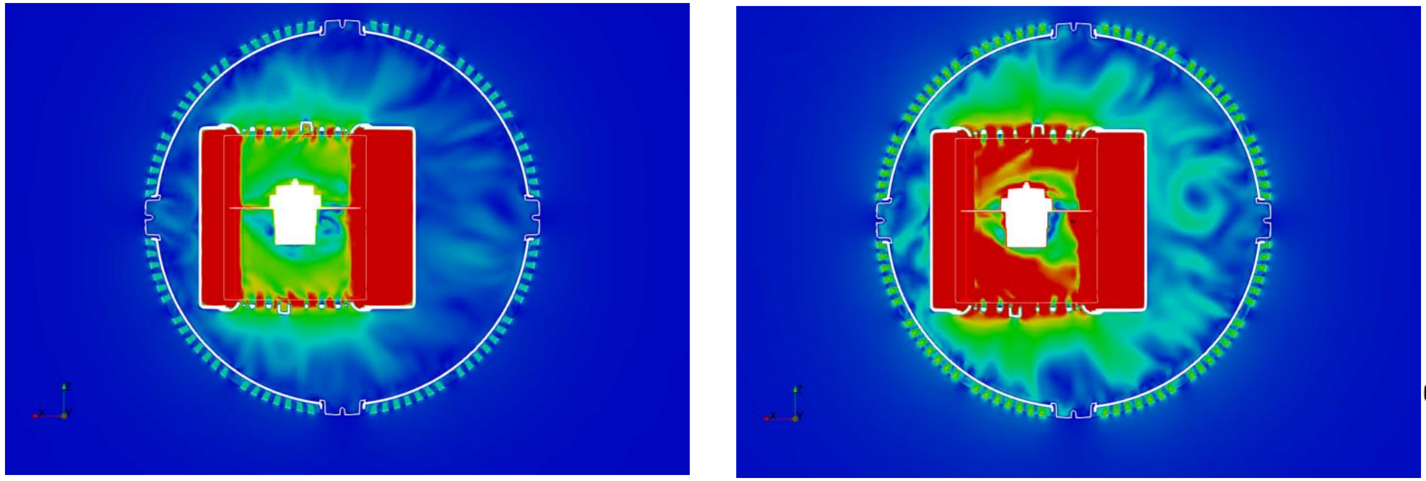


300m³/h

560m³/h

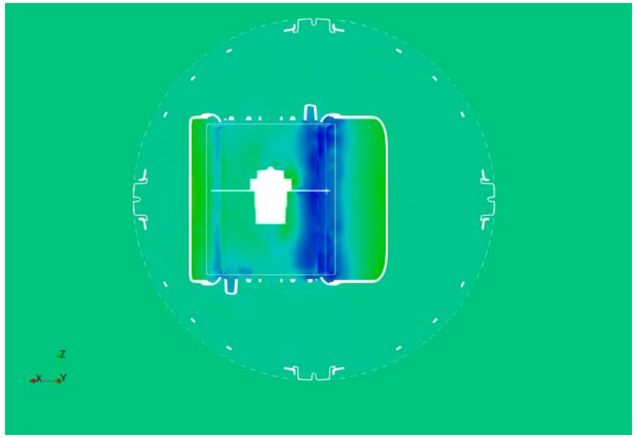
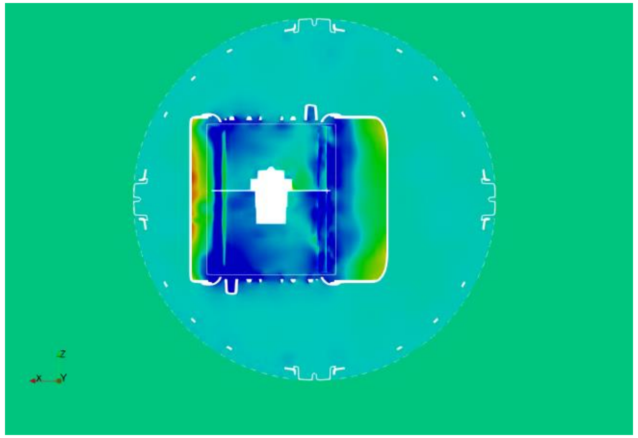
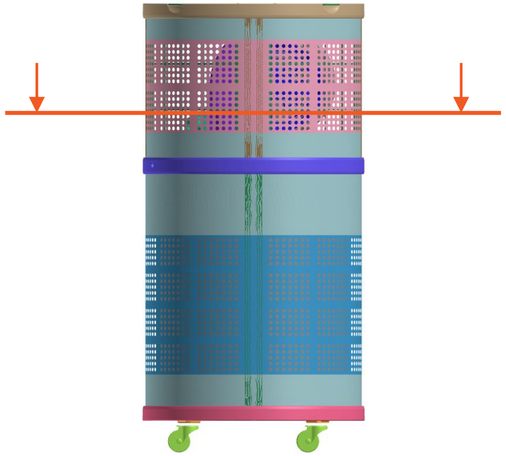
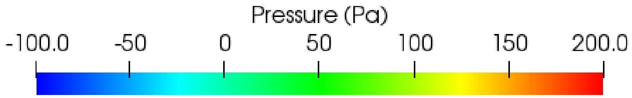


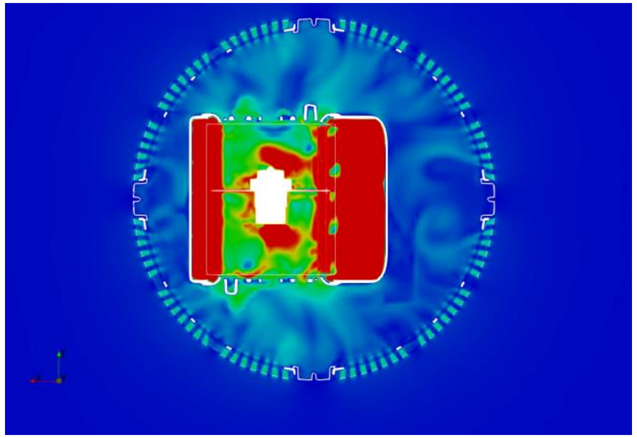
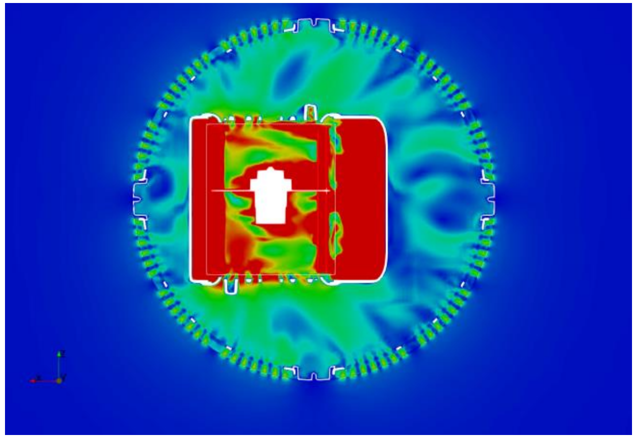




WP1.1: Horizontal Planes

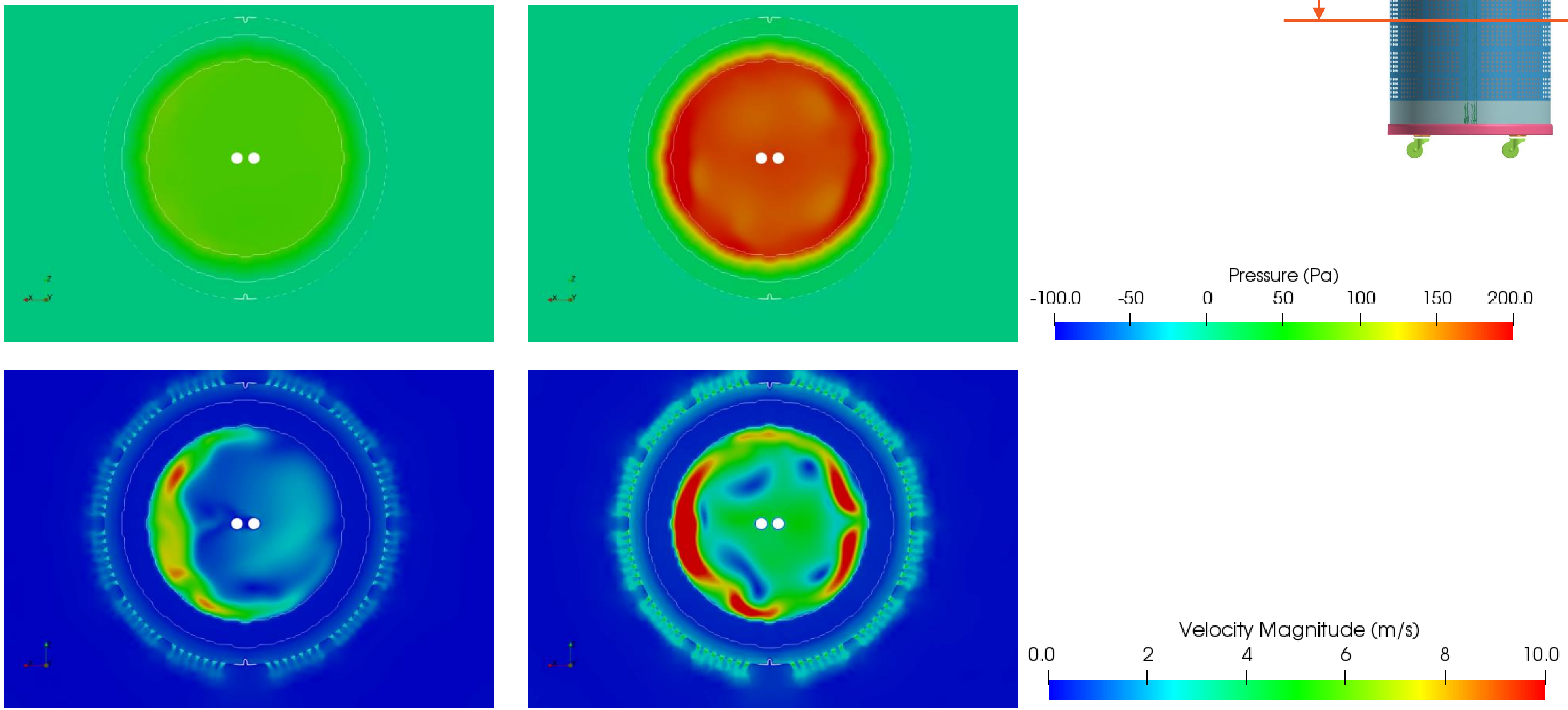
$300m^3/h$ | $560m^3/h$

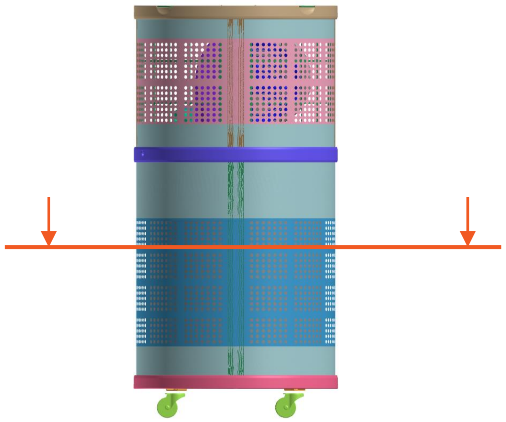






WP1.1: Horizontal Planes

300m³/h | 560m³/h

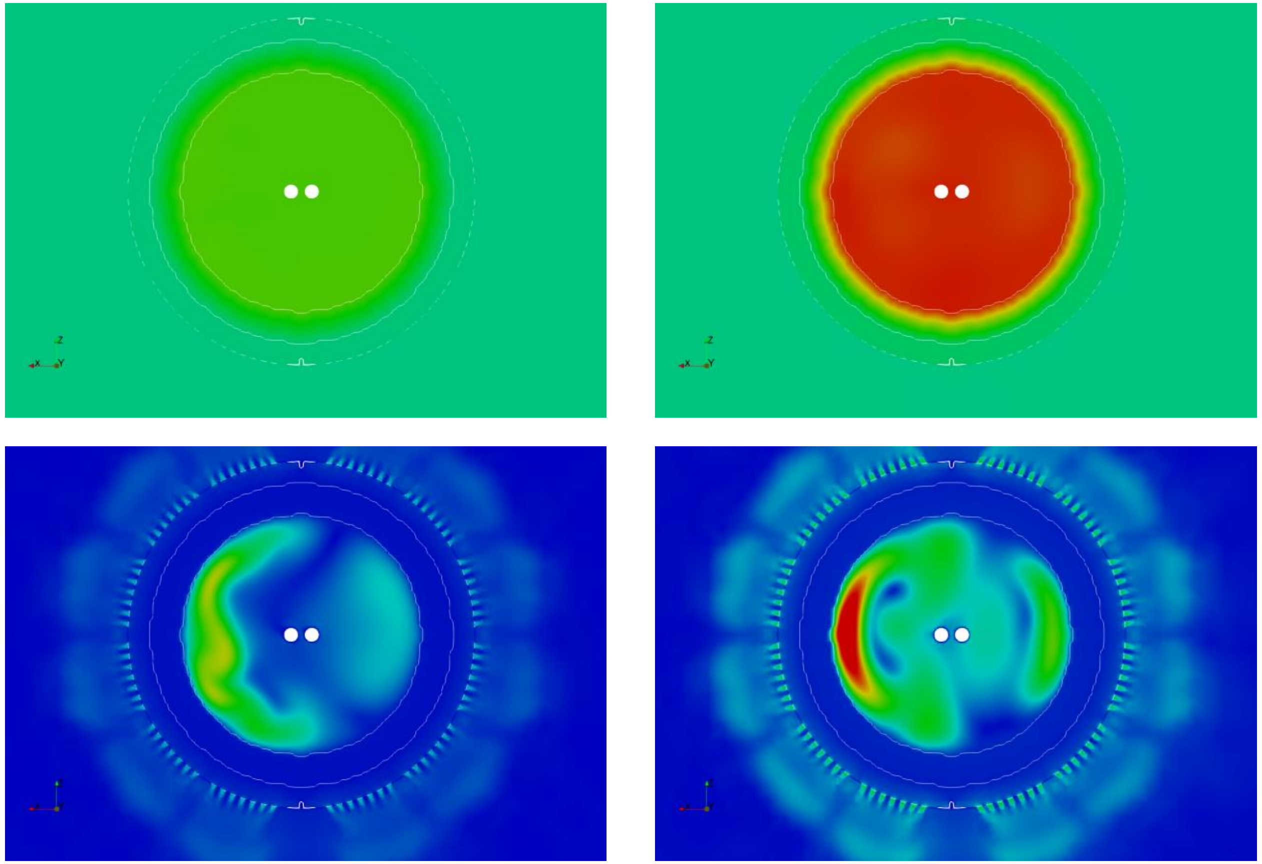


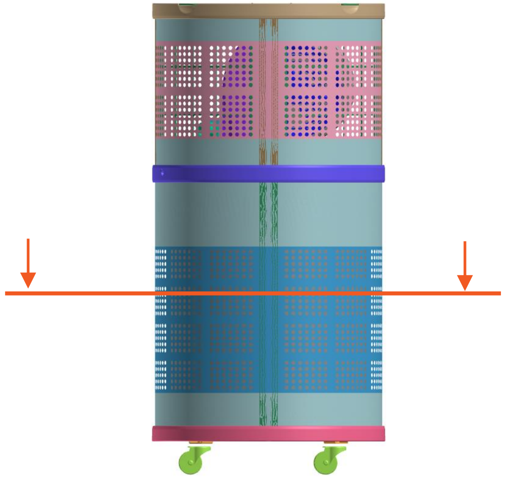


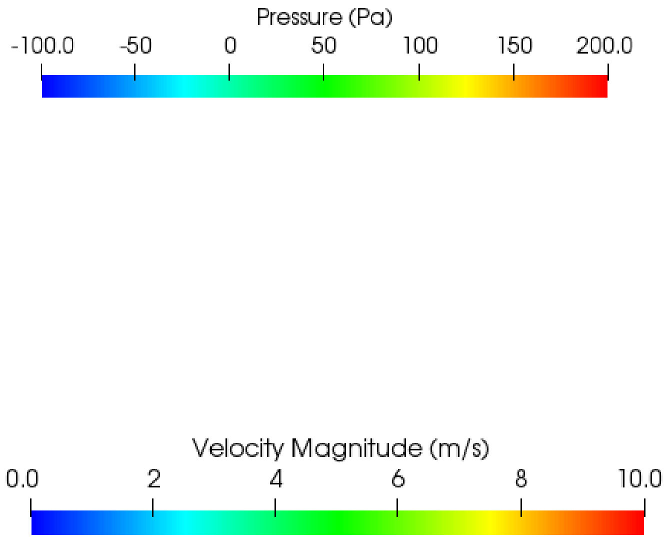
WP1.1: Horizontal Planes

300m³/h

560m³/h



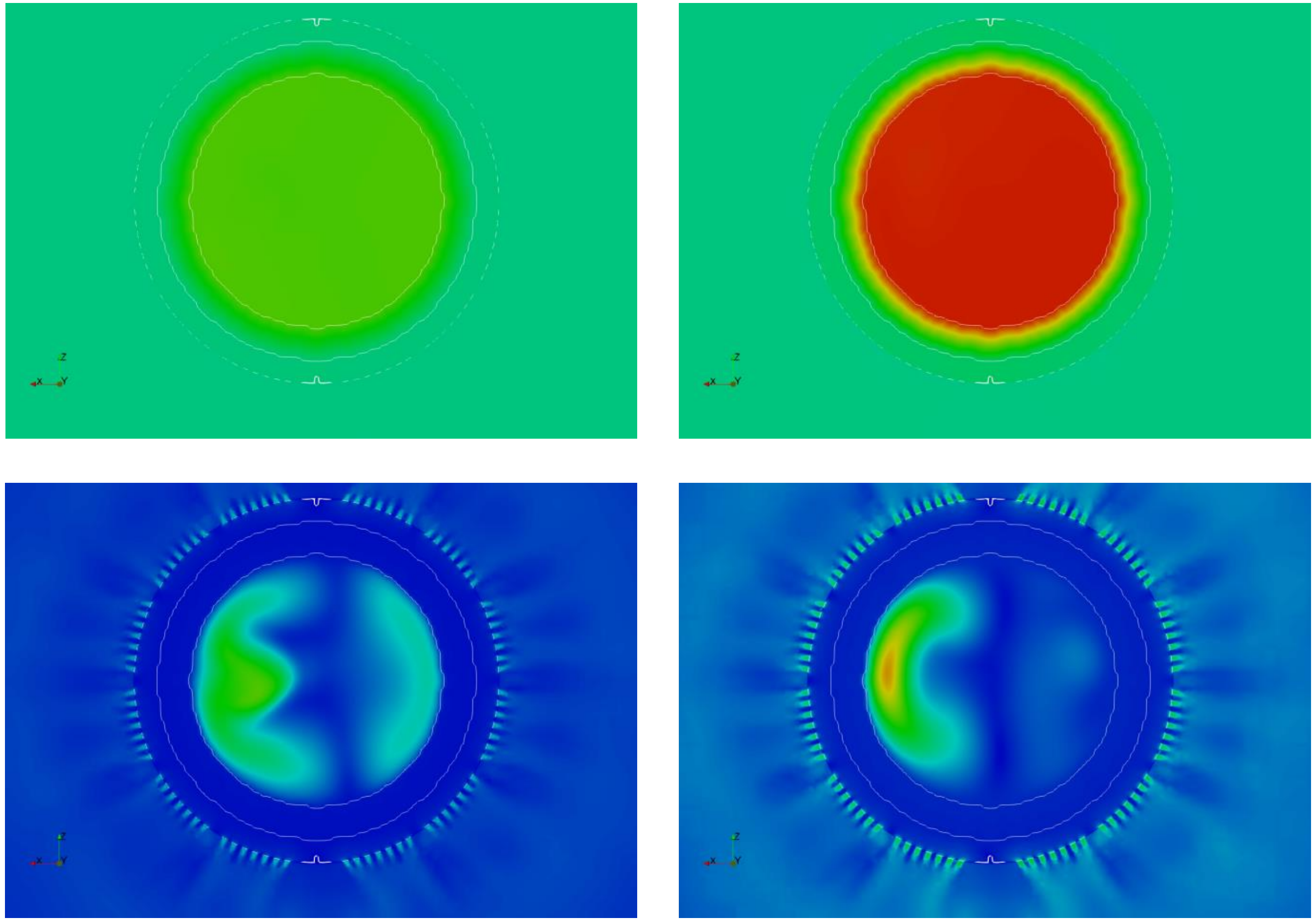


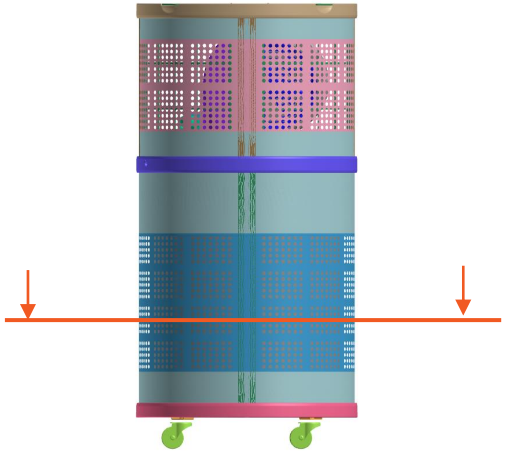


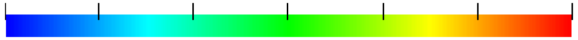
WP1.1: Horizontal Planes

300m^3/h

560m^3/h

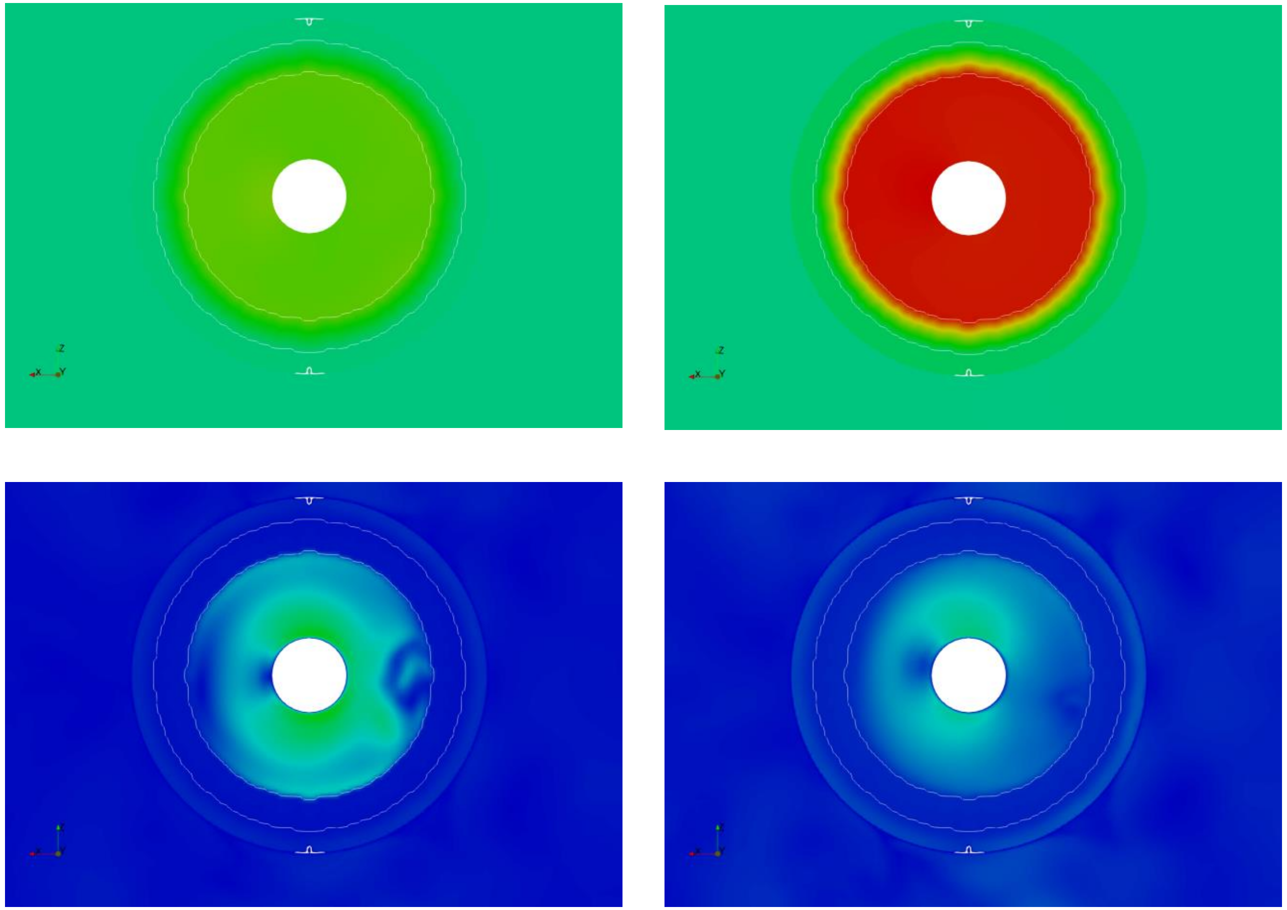


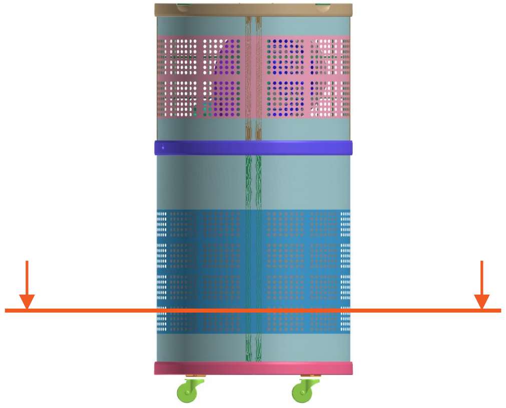


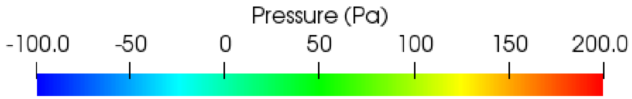


WP1.1: Horizontal Planes

300m³/h | 560m³/h



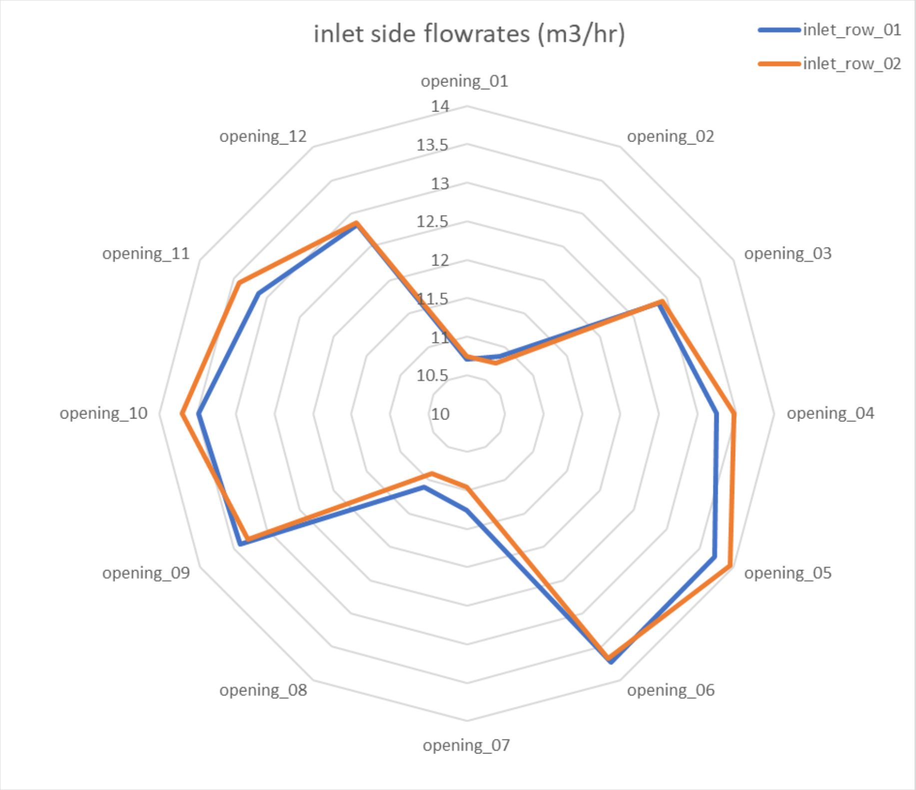


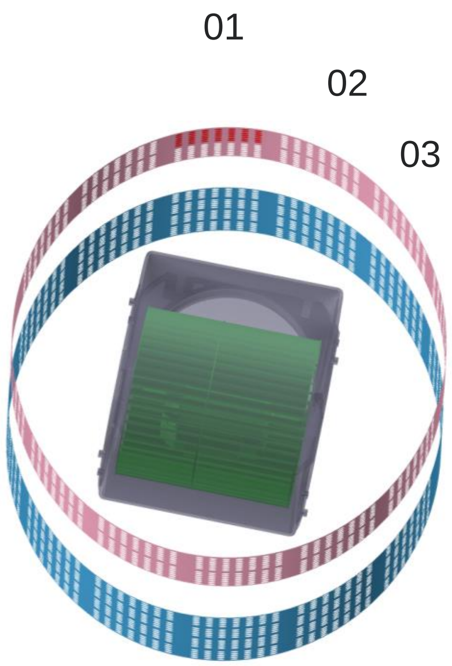


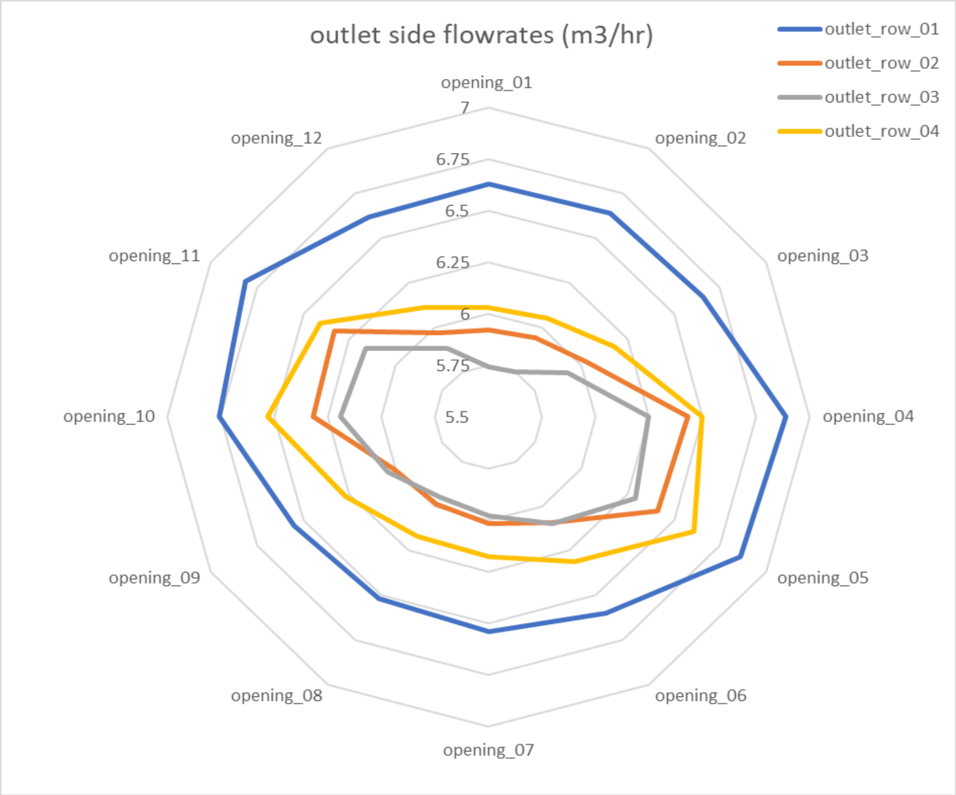
WP1.1: Flow rate distribution 300m³/h

Internal flow Nonuniformity at **300m³/hr;**

- **CIRCUMFERENTIAL:** Non-uniformity quantified 23% inlet and 7-18% outlet side
- **AXIAL:** Non-uniformity quantified 9-13% outlet side



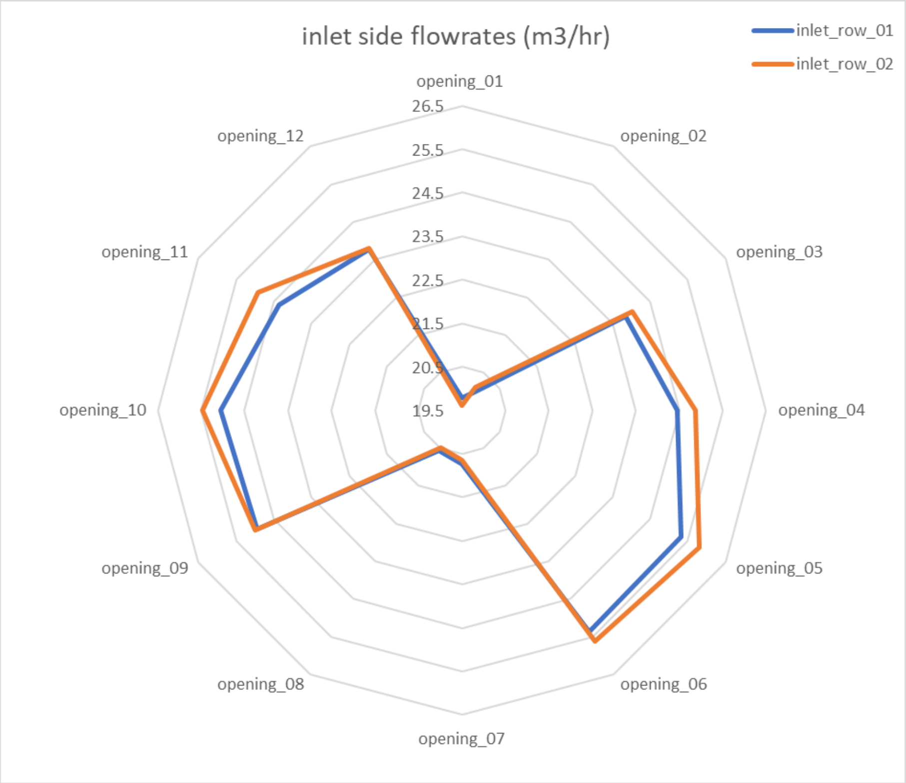


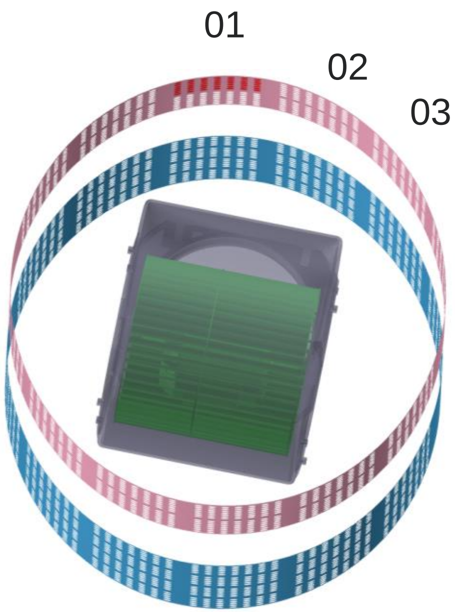


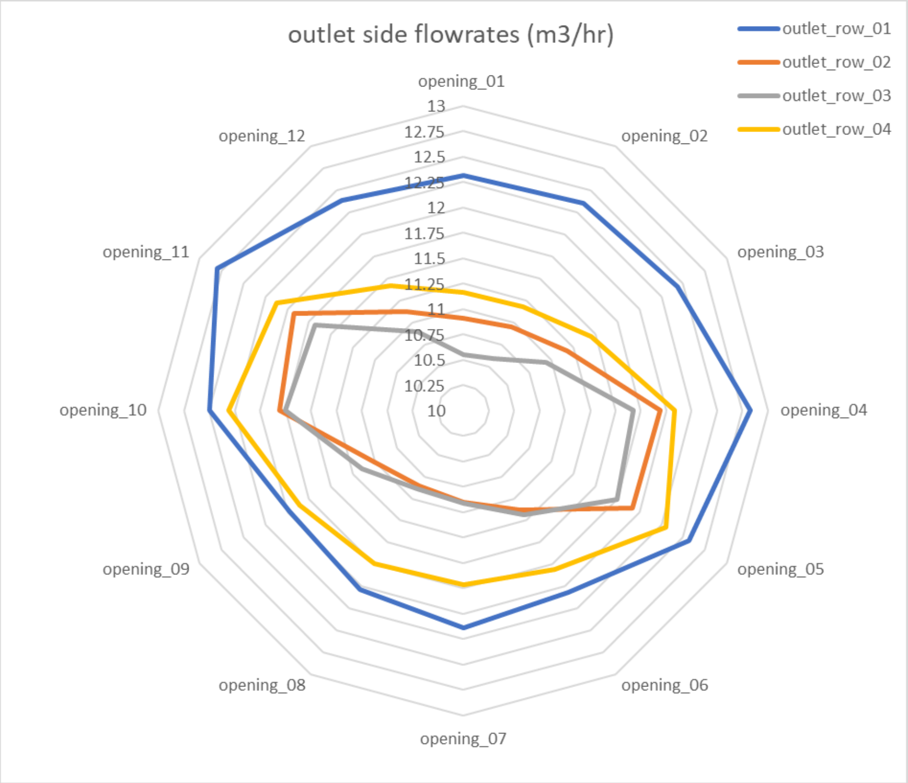
WP1.1: Flow rate distribution 560m³/h

Internal flow Nonuniformity at **560m³/hr;**

- **CIRCUMFERENTIAL:** Non-uniformity quantified 23% inlet and 6-11% outlet side
- **AXIAL:** Non-uniformity quantified 7-12% outlet side





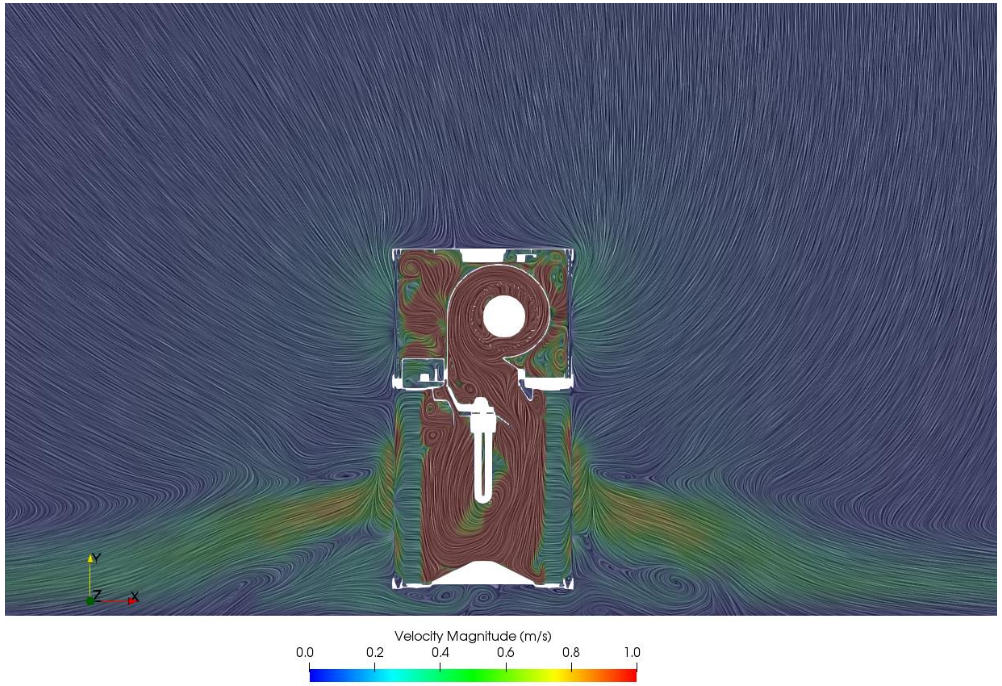


WP1.1: Flow around Device

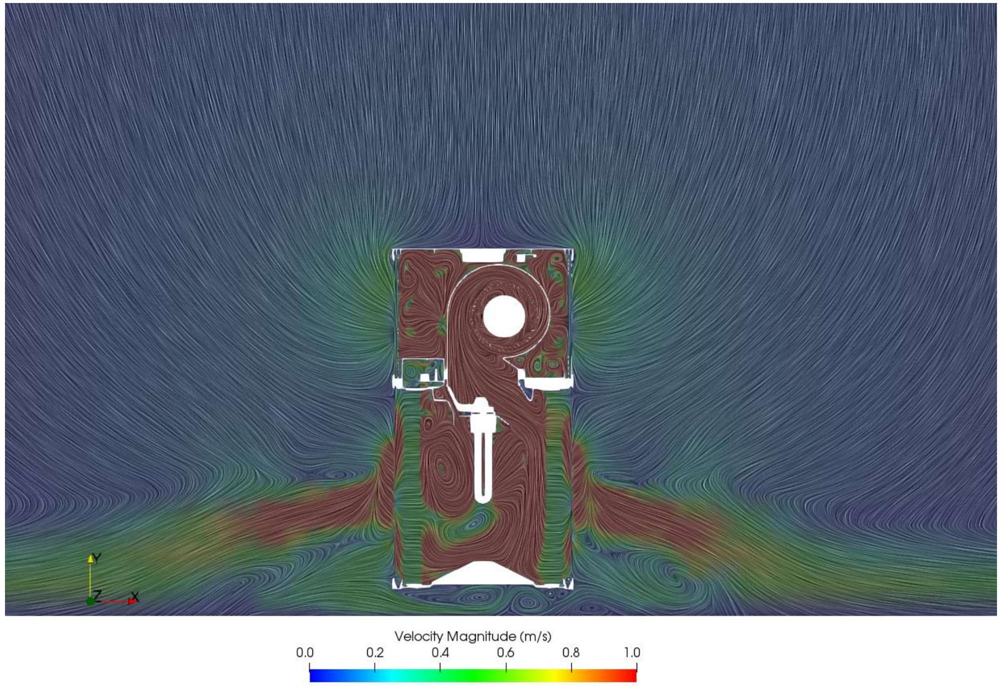
Key design characteristics confirmed:

- Upper-unit inflow; captures the flow in a **hemispherical** fashion from around it
- Lower-unit outflow**; radial jet attaches to the floor**, enhancing the room penetration and encourages a **toroidal-circulation** of airflow in the enclosure
- This combined effect assists **high-to-low particle precipitation** when placed to AGP sources

300m³/h

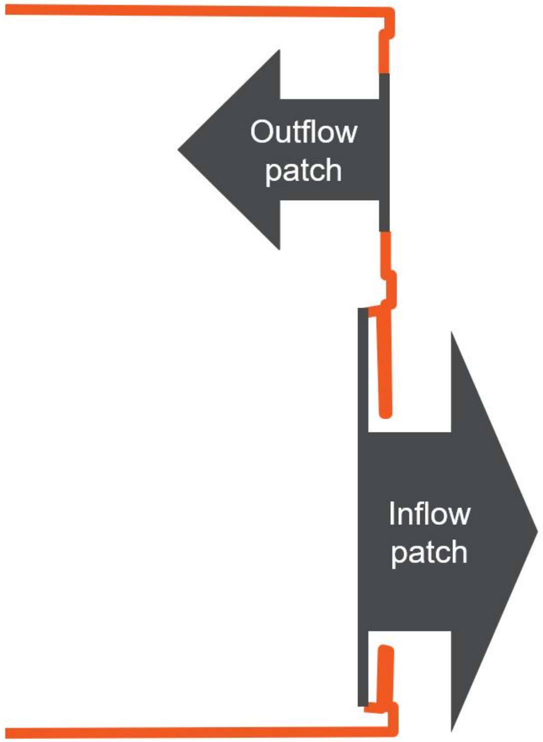


560m³/h



WP1.2: Representative Model

- Geometry detail internal to the device is simplified as uniform inflow / outflow patches
- **Circumferentially and axially uniform** at top-inflow and bottom filter-exit



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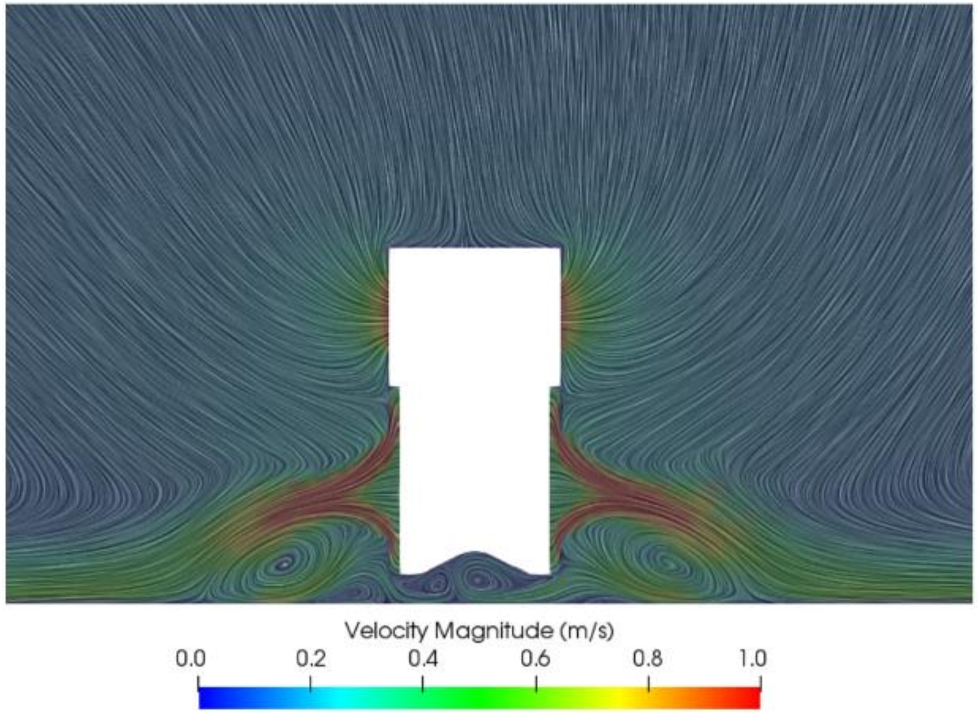
WP1.2: Representative Model

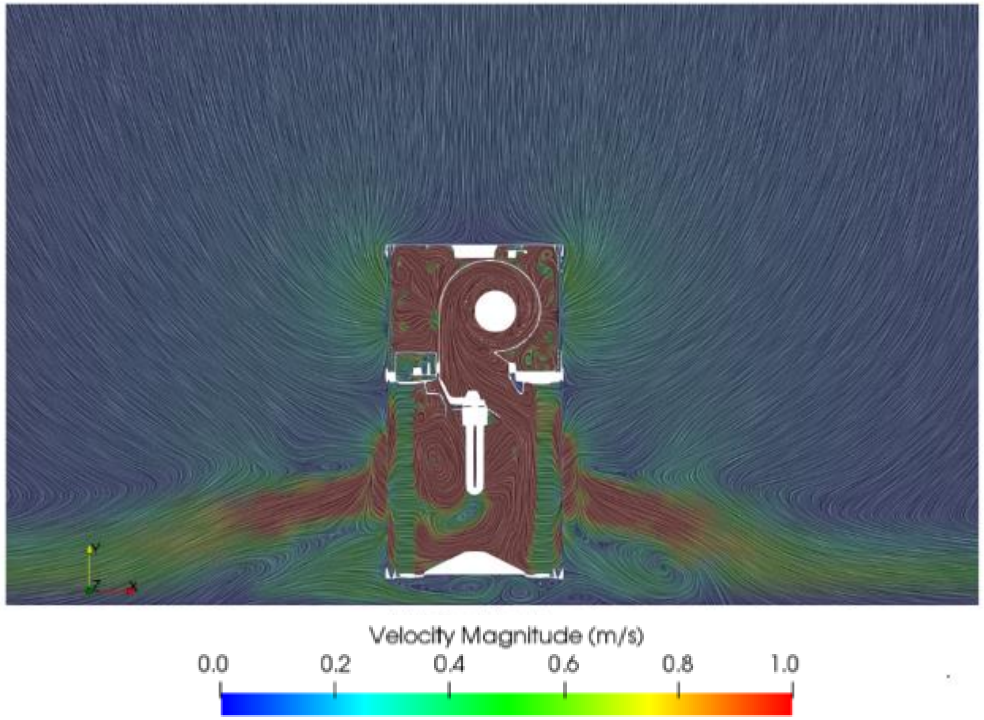
Simplified representation correctly reproduces

- the **hemispherical inflow** capture and
- radial-jet **outflow tendency towards the floor** (Coanda effect)

Representative model



Detailed model



WP1.2: Assessing ventilation for AGPs and fallow Time in Dentistry

Dental Treatment Room – Birmingham Hospital

WP2: Dental Treatment Room – Birmingham Hospital

Open volume is $44.7m^3$

3 occupants and equipment included

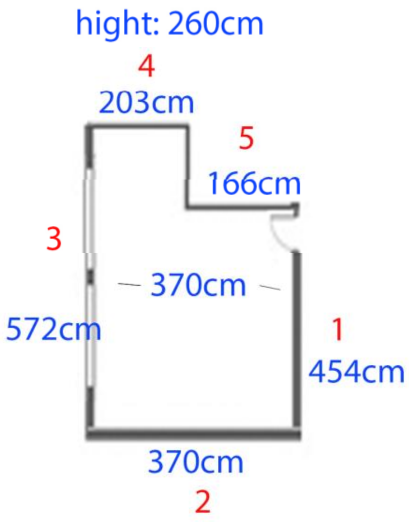
Mechanical Ventilation

- Vent air supply @ 5ACH
- Extract exactly balanced

Windows/door closed

Air supply diffuser

- Louver angle 30º from horizontal



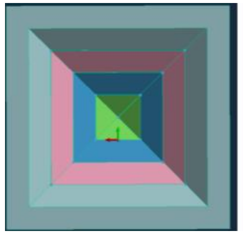
WP2: Dental Treatment Room – Birmingham Hospital

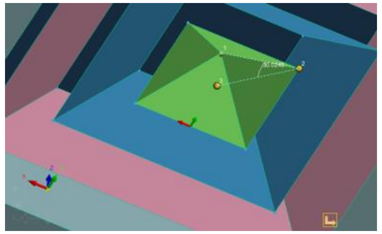
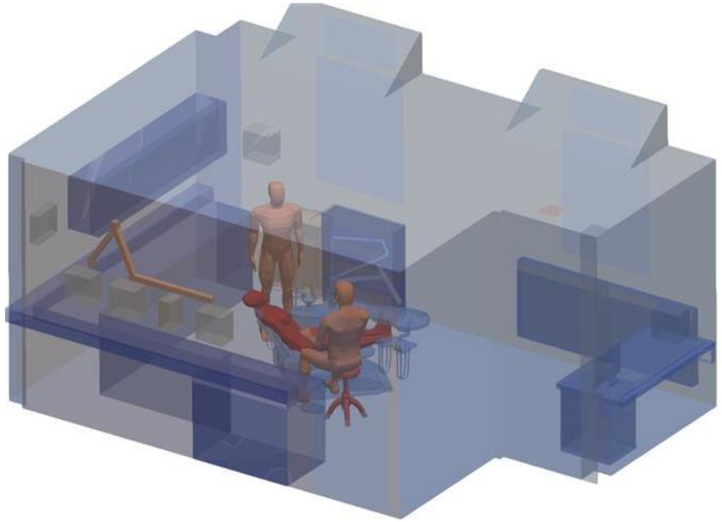
CFD MODEL

- Vent air supply @ 5ACpH
- Extract exactly balanced
- Windows/door closed
- Open volume is 44.7m[3]
- 3 occupants and equipment included

- Air supply diffuser
  - Louver angle 30º from horizontal

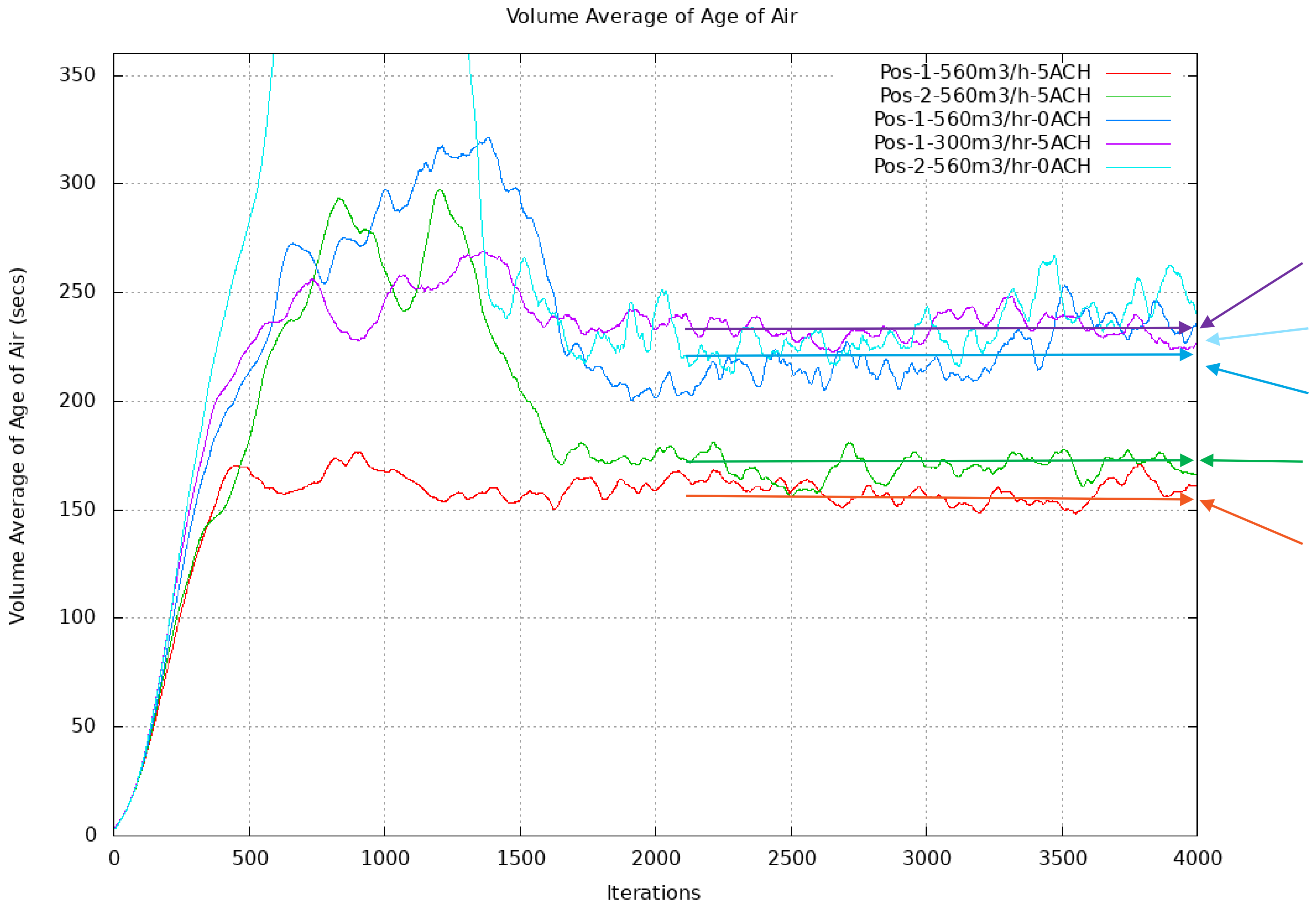
- Rensair device in positions
  - **P1**: Max (560m[3]/h) setting with ventilation ON and OFF
    Min (300m[3]/h) setting with ventilation ON
  - **P2**: Max (560m[3]/h) setting with ventilation ON and OFF




In-situ modelling – AoA: All Positions

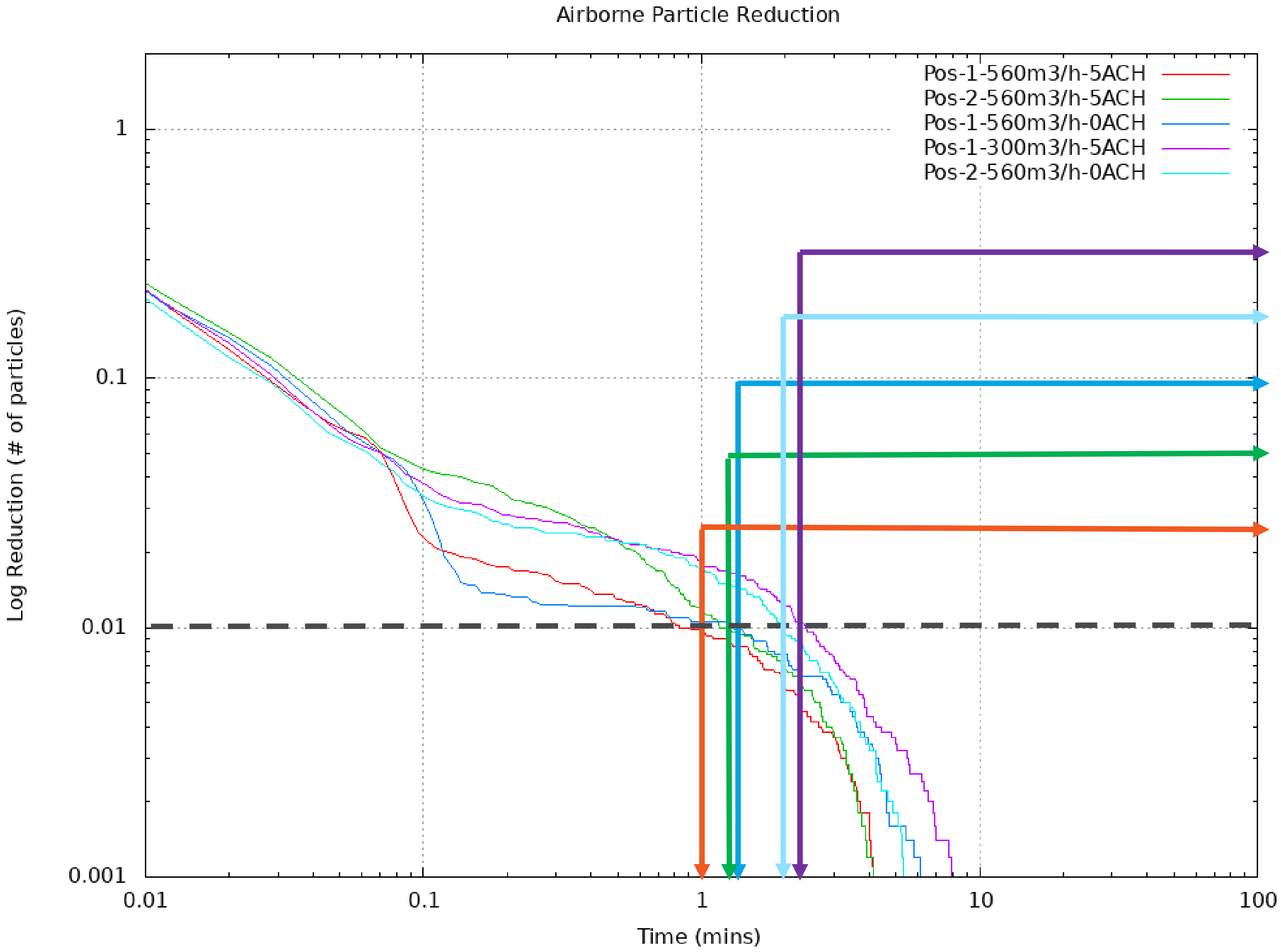
Combinations of 220m³/h mechanical and 300/560m³/h enhanced



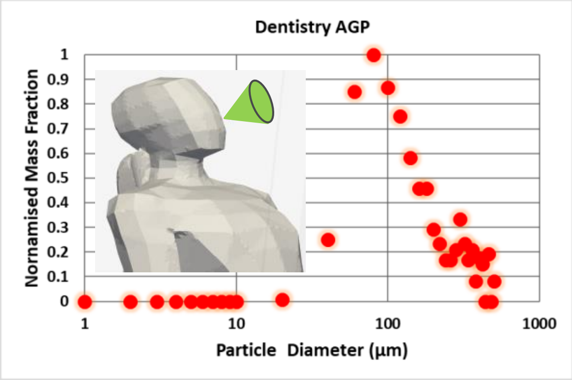
	Average Age Of Air (s)	eACH	Circ.Eff %
Pos-1-300m3-5ACH	**234**	11.8	**65%**
Pos-2-560m3-0ACH	**234**	12.6	**61%**
Pos-1-560m3-0ACH	**221**	12.6	**65%**
Pos-2-560m3-5ACH	**170**	17.6	**60%**
Pos-1-560m3-5ACH	**158**	17.6	**65%**

In-situ modelling – Dental AGP Log-2 (99%) clearance

Combinations of 220m³/h mechanical and 300/560m³/h enhanced



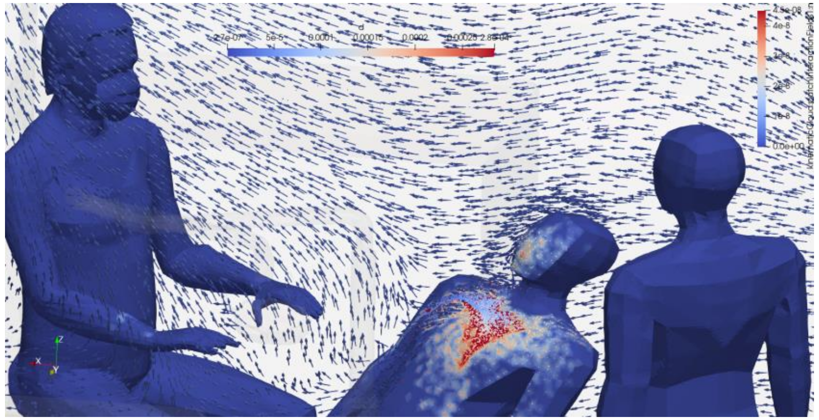
	Average Age Of Air (s)	eACH	Log-2 Clearance time (min)
Pos-1-300m3-5ACH	234	11.8	**2.37**
Pos-2-560m3-0ACH	234	12.6	**1.95**
Pos-1-560m3-0ACH	221	12.6	**1.30**
Pos-2-560m3-5ACH	170	17.6	**1.23**
Pos-1-560m3-5ACH	158	17.6	**0.84**



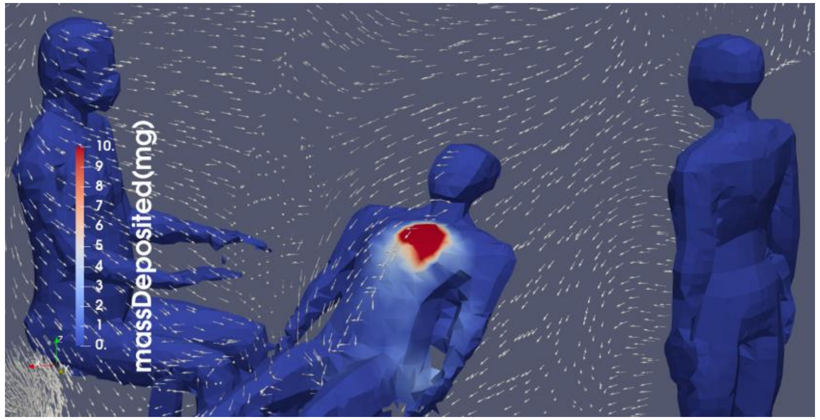
Dental AGP – Deposition and near-patient flow field

All cases, P1/P2 with mechanical ventilation ON/OFF

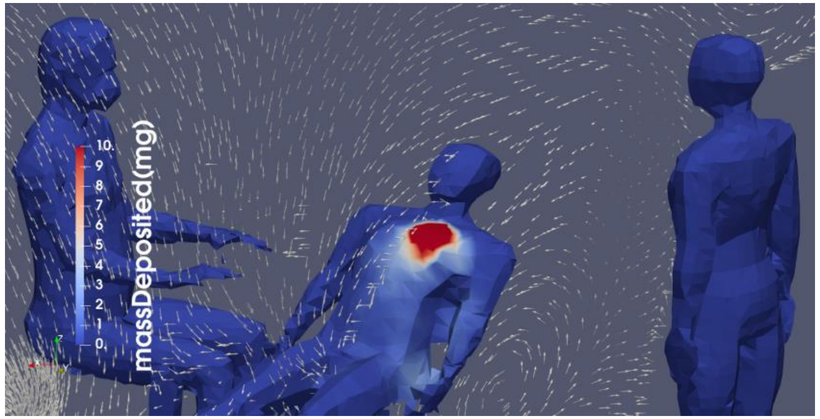
DATUM: **no Rensair** + M_{ON}



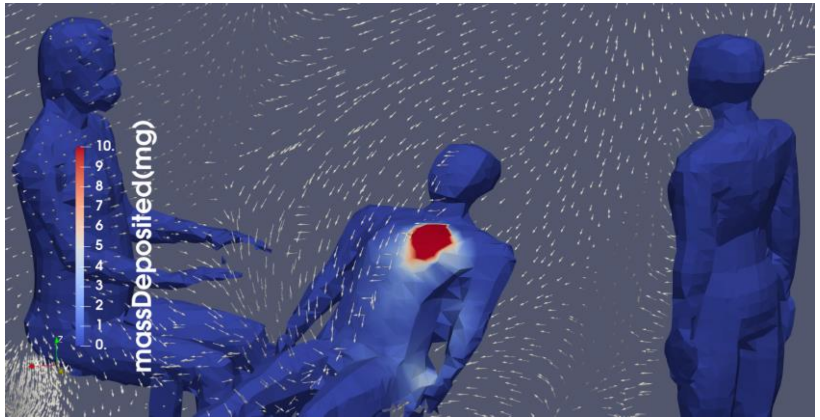
P_1 : 560 + M_{ON}



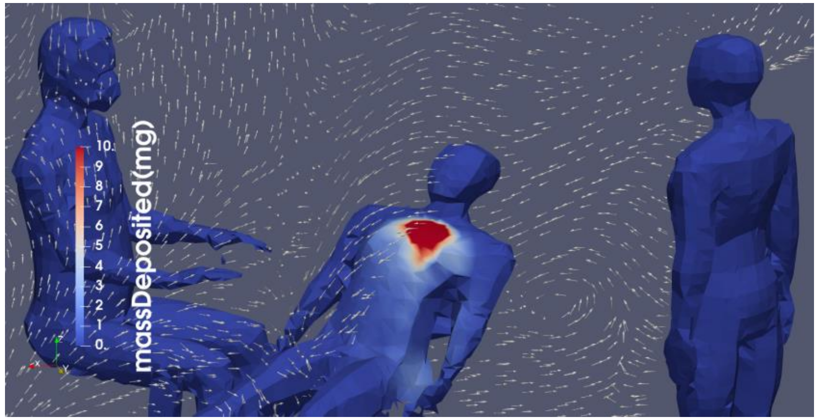
P_1 : 560 + M_{OFF}



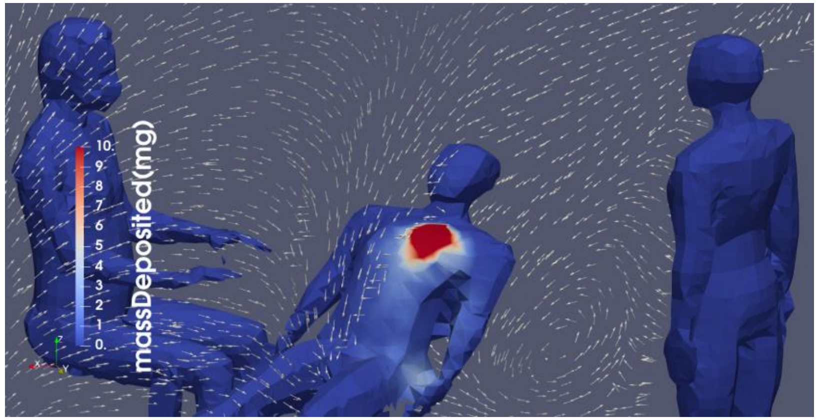
P_1 : 300 + M_{ON}



P_2 : 560 + M_{ON}



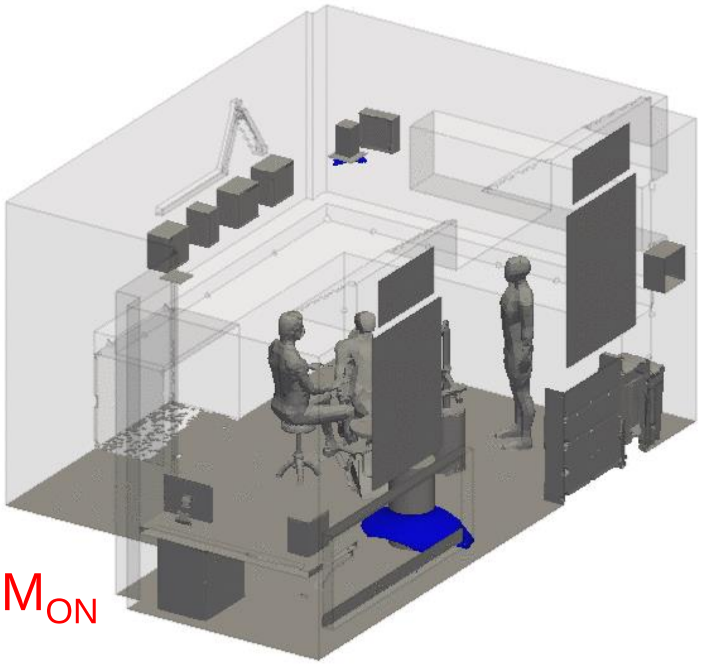
P_2 : 560 + M_{OFF}



In-situ modelling - Positions 1 (desk) and 2 (door);

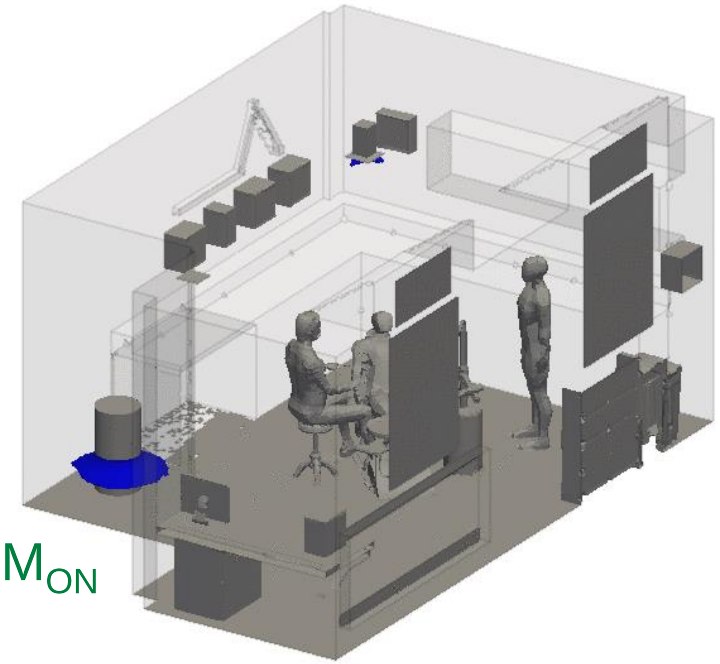
220m³/h mechanical and 560m³/h enhanced (780 m³/h total)

Iso Surface of Age of Air at 3 secs



P_1 - 560+M_{ON}

Iso Surface of Age of Air at 3 secs

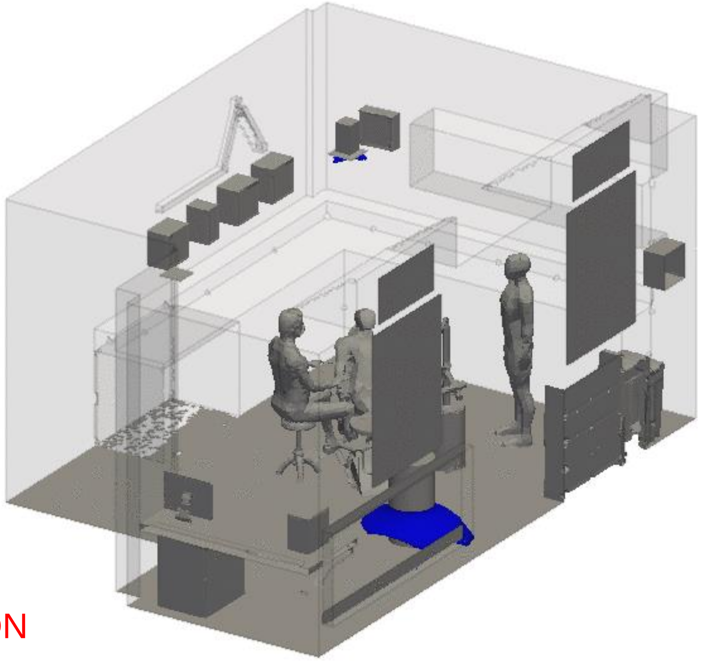


P_2 - 560+M_{ON}

In-situ modelling - Positions 1 (560m³/h vs 300m³/h);

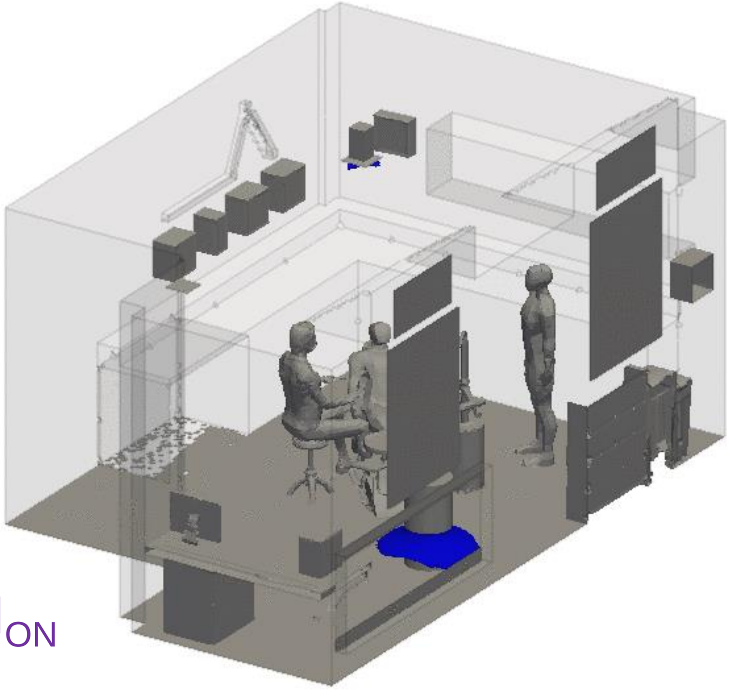
220m³/h mechanical ventilation ON

Iso Surface of Age of Air at 3 secs



P_1 - $560+M_{ON}$

Iso Surface of Age of Air at 3 secs

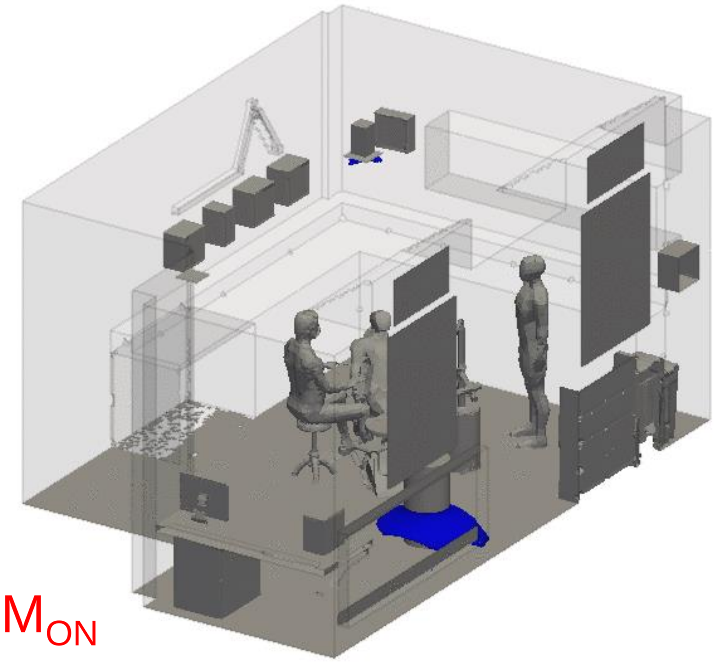


P_1 - $300+M_{ON}$

In-situ modelling - Positions 1 @ 560m³/h

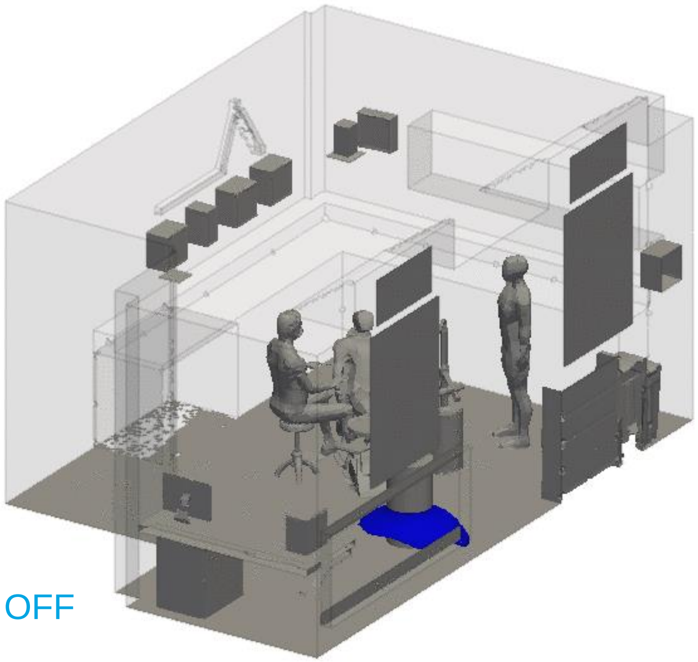
220m³/h mechanical ventilation ON vs OFF

Iso Surface of Age of Air at 3 secs



P_1 - 560+M_{ON}

Iso Surface of Age of Air at 3 secs

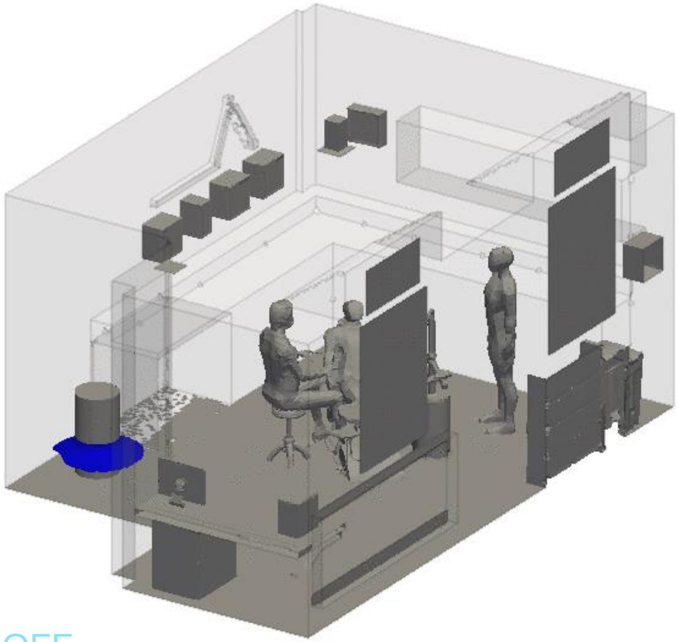


P_1 - 560+M_{OFF}

In-situ modelling - Positions 2 @ 300m³/h

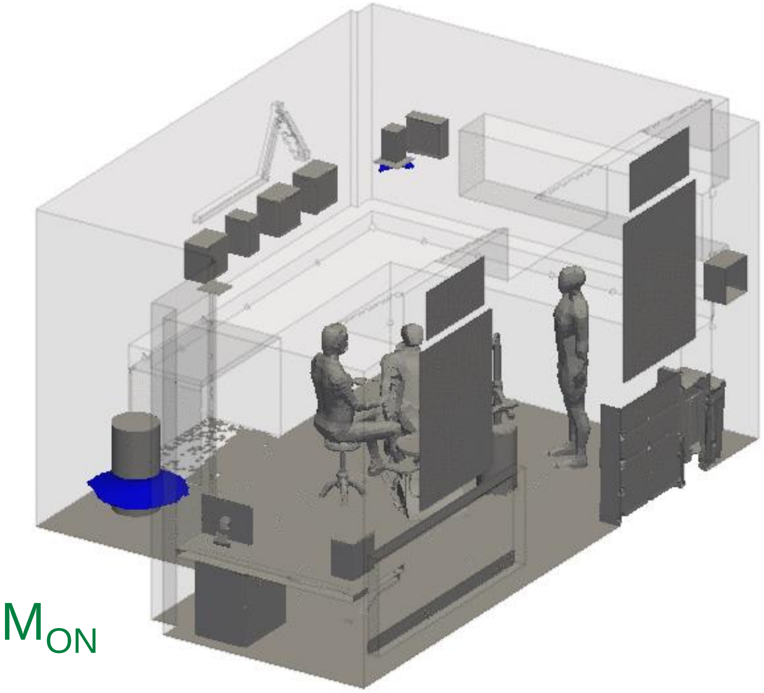
220m³/h mechanical ventilation OFF vs ON

Iso Surface of Age of Air at 3 secs



P_2 - 560+M_{OFF}

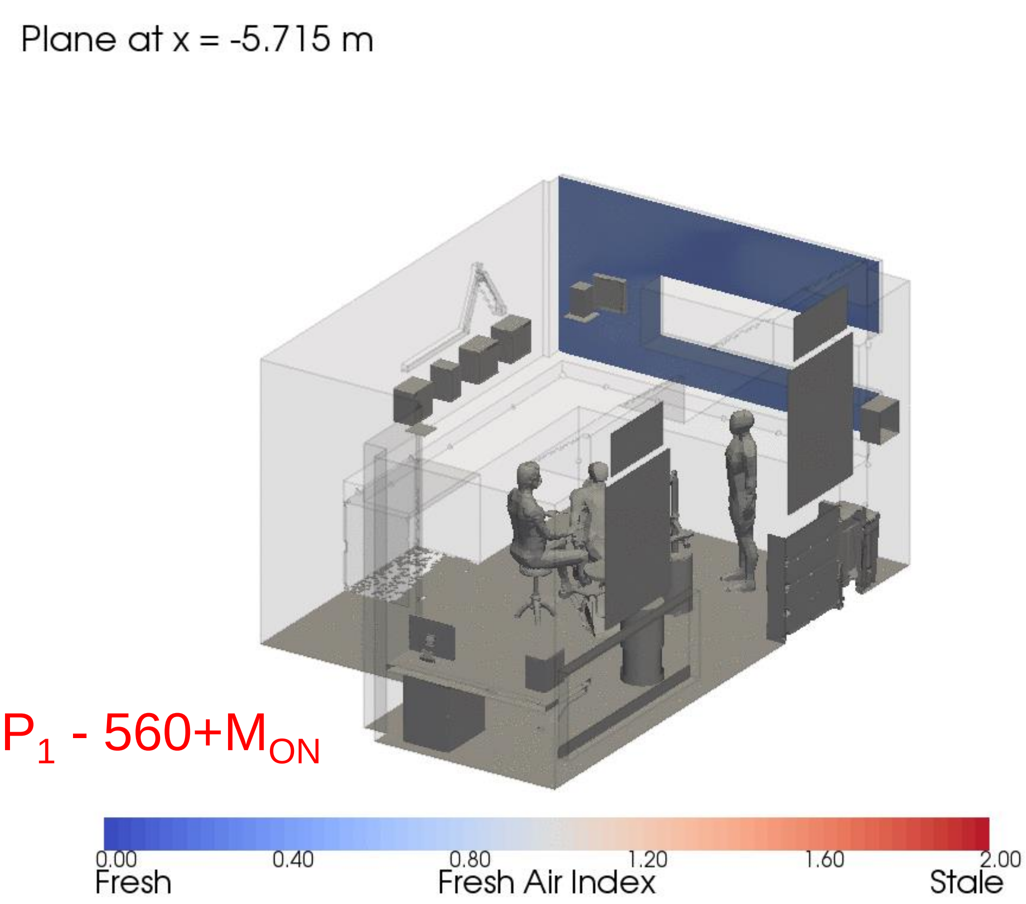
Iso Surface of Age of Air at 3 secs



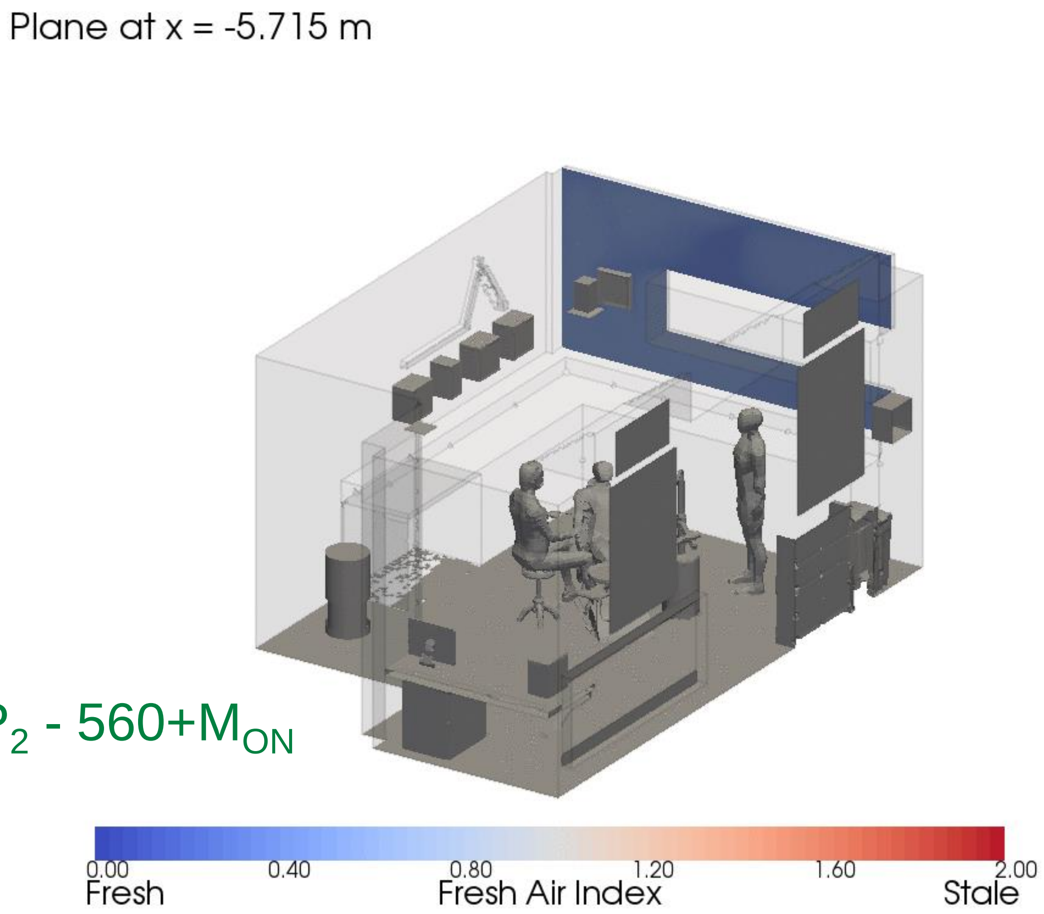
P_2 - 560+M_{ON}

In-situ modelling - Positions 1 (desk) and 2 (door);

220m³/h mechanical and 560m³/h enhanced (780 m³/h total) – FAI_{10}



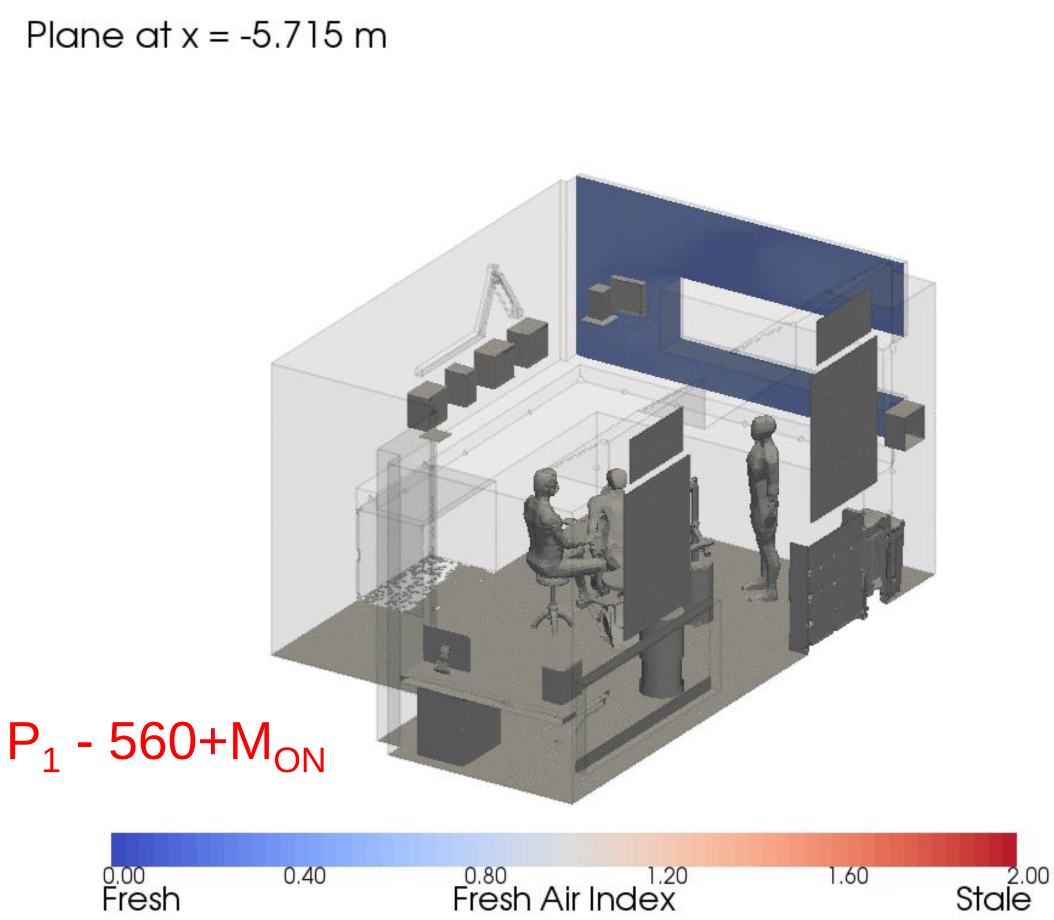
P_1 - 560+M_{ON}

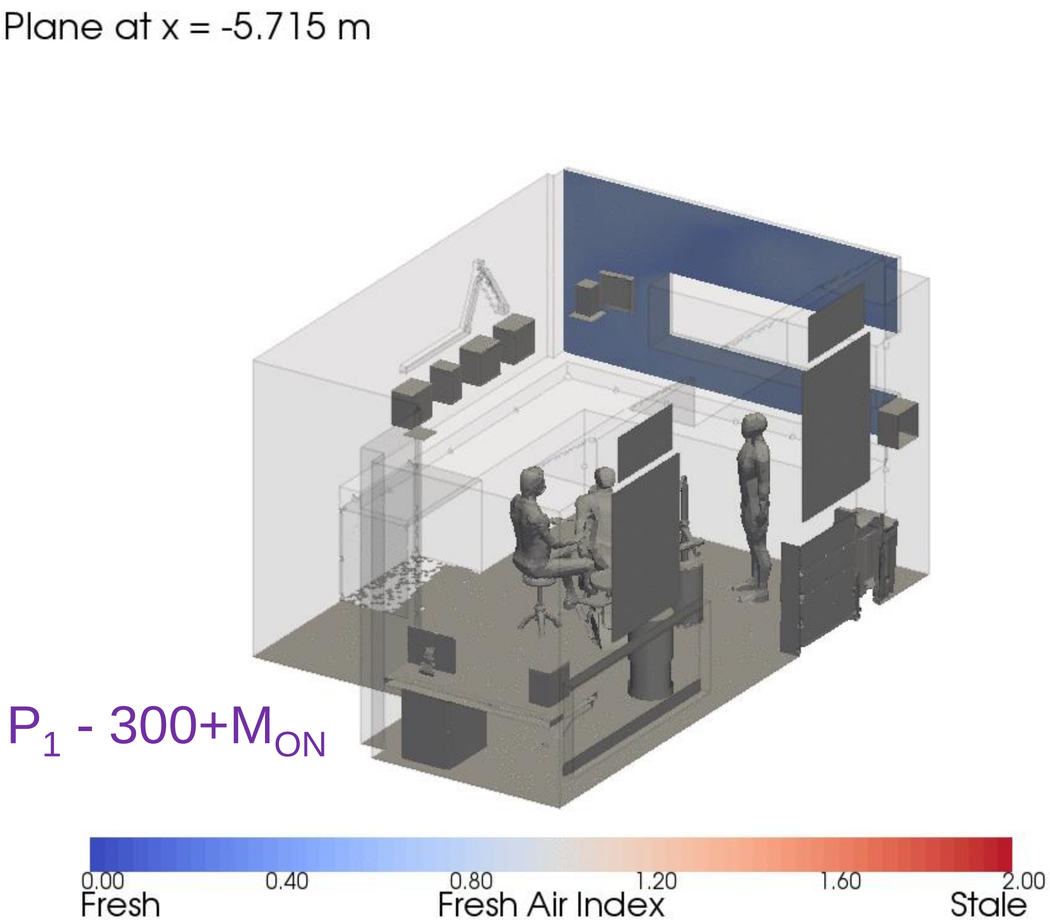


P_2 - 560+M_{ON}

In-situ modelling - Positions 1 (560m³/h vs 300m³/h);

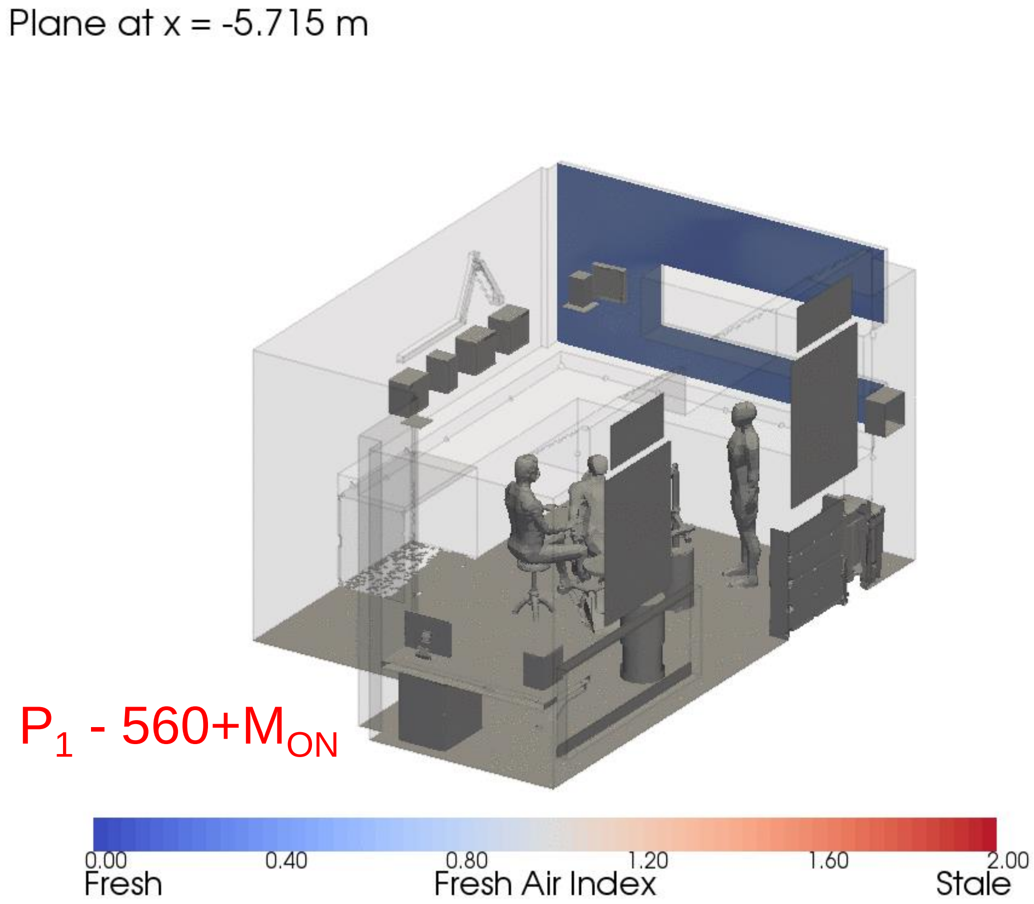
220m³/h mechanical ventilation ON – FAI_{10}

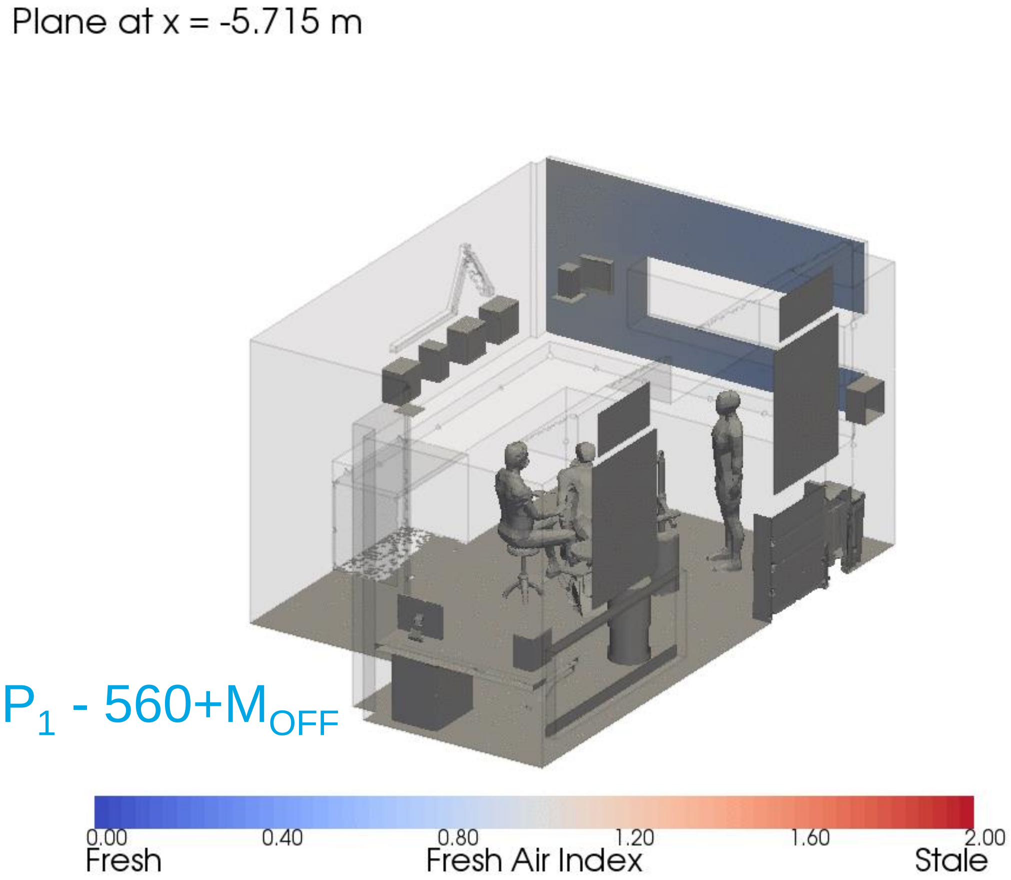




In-situ modelling - Positions 1 @ 560m^3/h

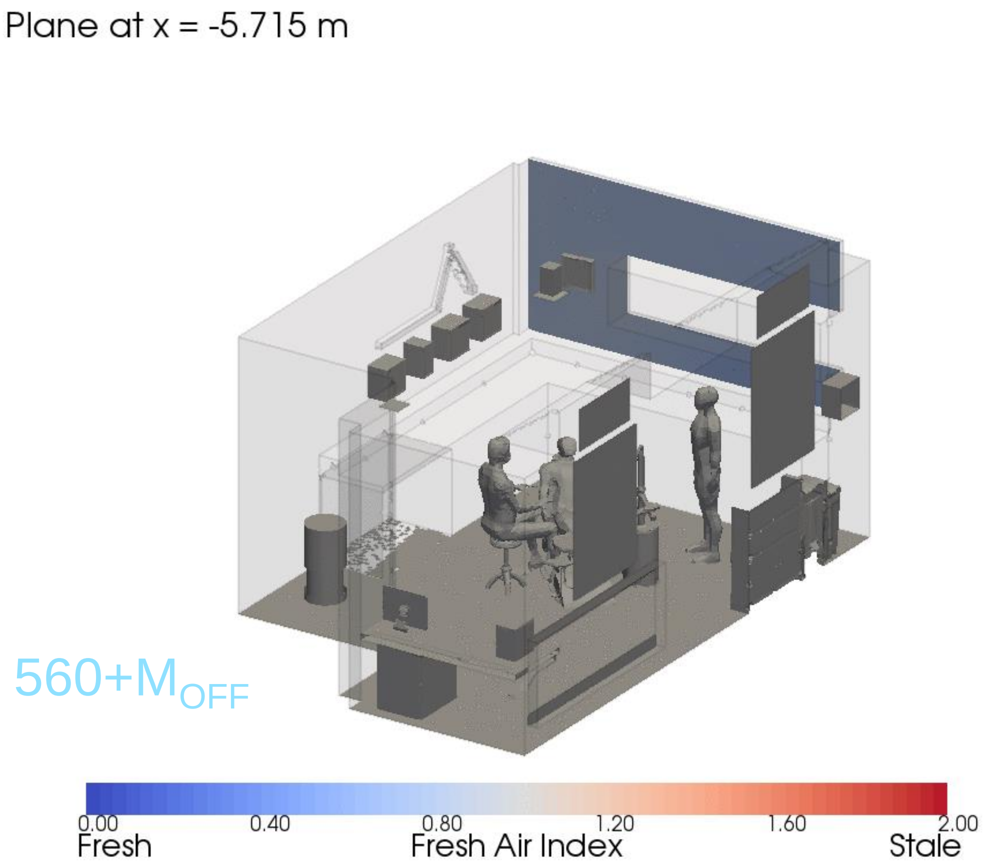
220m^3/h mechanical ventilation ON vs OFF – FAI_{10}





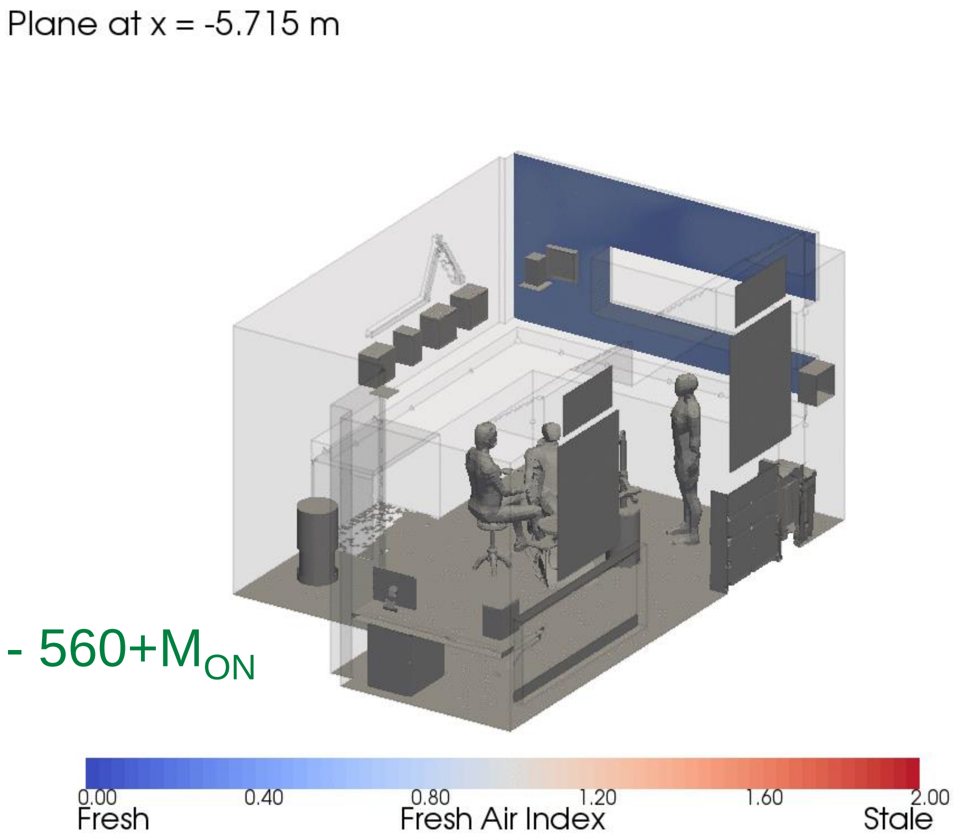
In-situ modelling - Positions 2 @ 300m³/h

220m³/h mechanical ventilation OFF vs ON – FAI_{10}



P_2 - 560+M_{OFF}

P_2 - 560+M_{ON}



Conclusions

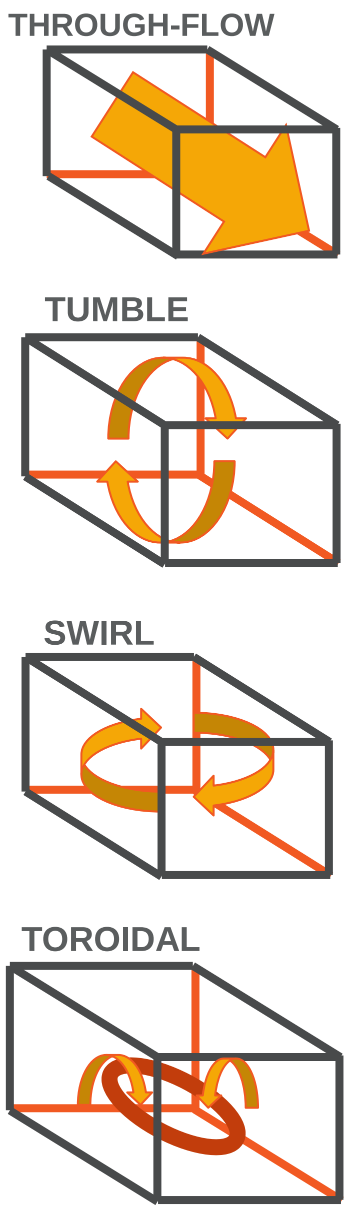
WP1: Characterisation of flow through the unit

- Detailed internal modelling of the unit,
  - Radial fan, UV-reactor volume, HEPA-13 filter and inflow/outflow ventilation holes,
  - Leads to a high level of confidence that the Rensair **device provides a circumferentially and axially uniform air delivery** at the lowest (300m^3/h) and highest flow rates (560m^3/h)
- CFD Modelling confirms the key design characteristics of this unit, namely
  - Upper-unit inflow; **captures the flow hemi-spherically from above and around** it
  - Lower-unit outflow; **radial jet attaches to the floor, enhancing the room penetration and encourages a toroidal-circulation** of airflow in the enclosure
  - This combined effect **assists high-to-low particle precipitation** close to the AGP sources

WP2: In-situ modelling in the Birmingham Hospital Dental Treatment Room

- **Air Circulation efficiency (60-65%)**; When used in isolation, or with the treatment room's mechanical ventilation notionally turned on, the **air circulation efficiency scales with ACH** irrespective of installation location; and rates well in comparison with other commercial portable and wall-mounted units of similar capacity
- P1 is always superior (65%) to P2 (~60%) for circulation efficiency
- **AGP log-2 clearance time**; Dental AGP clears to Log-2 reduction **within 2.3mins for all scenarios**, and scales with eACH. The larger droplets precipitate very quickly (Stokesian behaviour)

General Recommendations and Findings

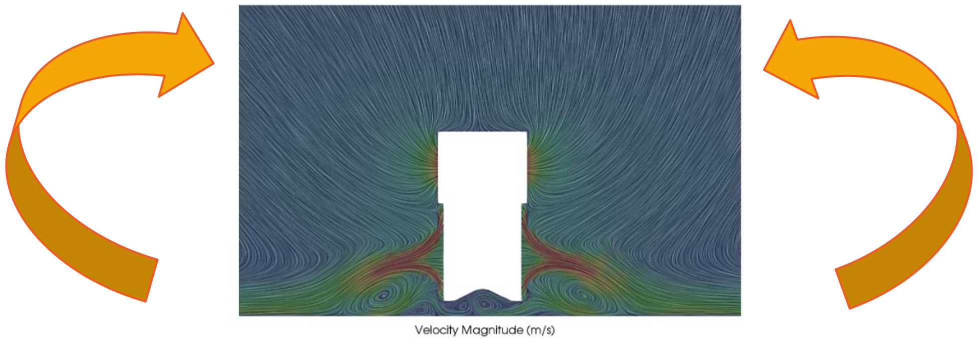


Room ventilation

- Encourage stable flow patterns; corridor/wind-tunnel, swirling, tumbling, toroidal
- Encourage downward flow so as to precipitate aerosols in the proximity of AGPs
- Avoid generating dead-recirculation pockets

Rensair device

- stimulates a **TOROIDAL** ventilation pattern
- in-situ demonstrates precipitation of aerosols from AGPs
- demonstrates a stable floor-wise room penetration, avoiding ground particulates (dust/carpet) ingestion into the device which may prematurely block the filter



Thank you

Rensair

Any Questions?

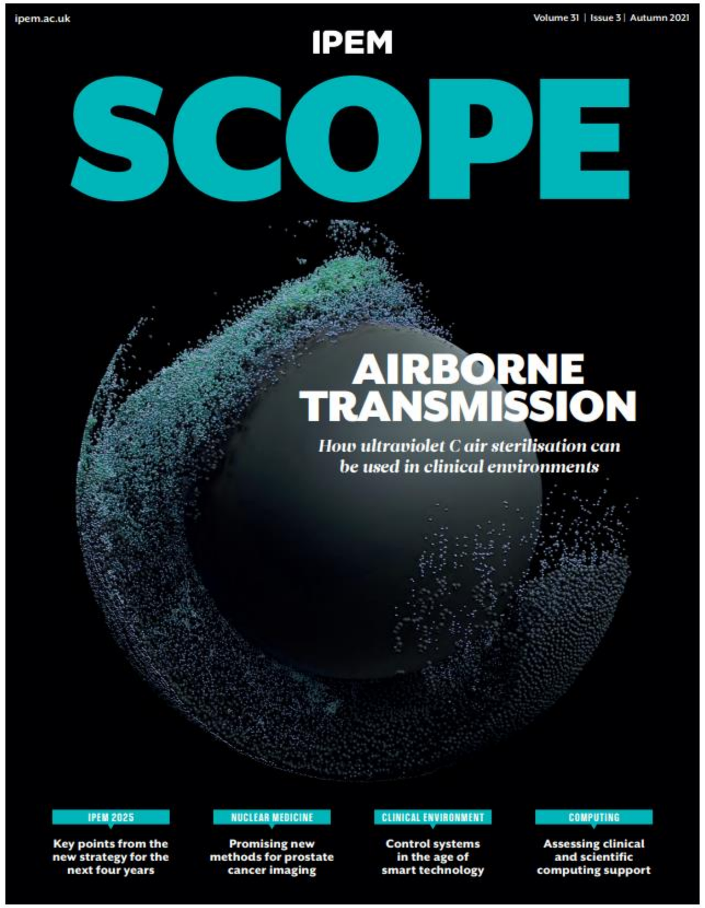
Deliverables:

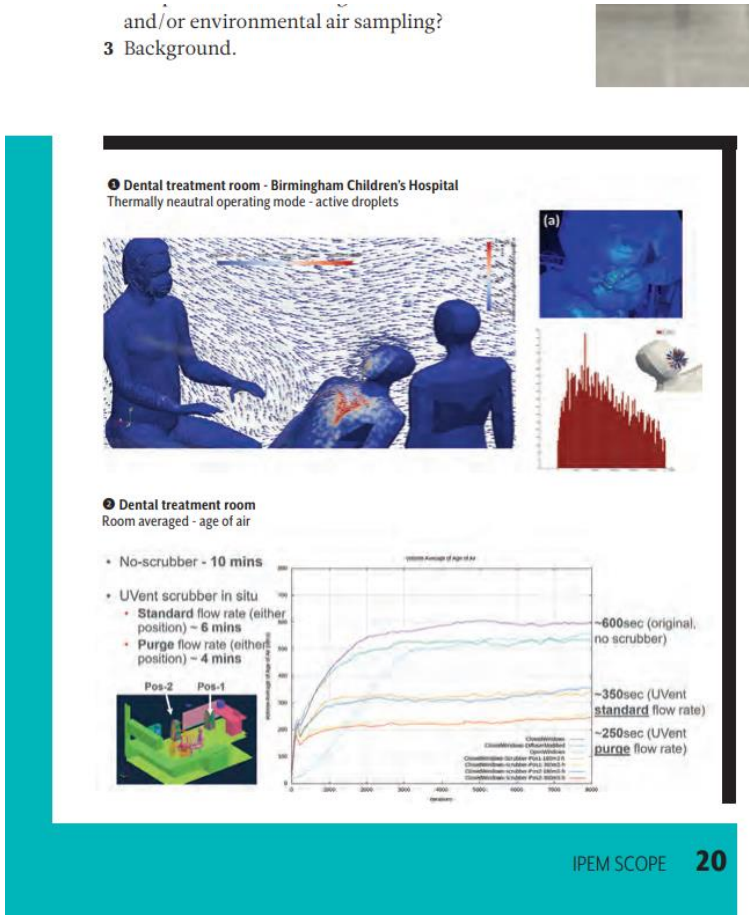
- This report (final communication 15th March 2022)
- CAD modelling files (via electron link communicated 15th March 2022):
  - STL for the detailed device (CFD ready)
  - STL for the representative model (CFD ready)

Appendices

Comparison from publication

	Average Age Of Air (s)	eACH	Circ.Eff%
Pos-1-560m3-5ACH	158	17.59843	65%
Pos-2-560m3-5ACH	170	17.59843	60%
Pos-1-560m3-0ACH	221	12.59843	65%
Pos-1-300m3-5ACH	234	11.74916	65%
Pos-2-560m3-0ACH	234	12.59843	61%
published			
no scrubber -5ACH	600	5	60%
UVent-180-5ACH	340	9.049494	59%
UVent-360-5ACH	230	13.09899	60%





Underlying Flow Regimes: Aerosols/droplets

Contamination sources - Dentistry AGP

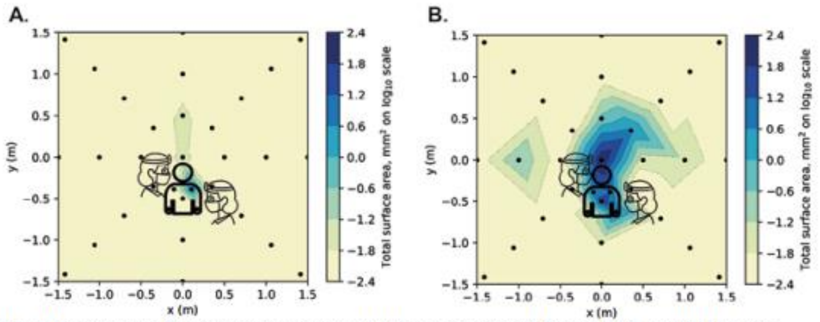
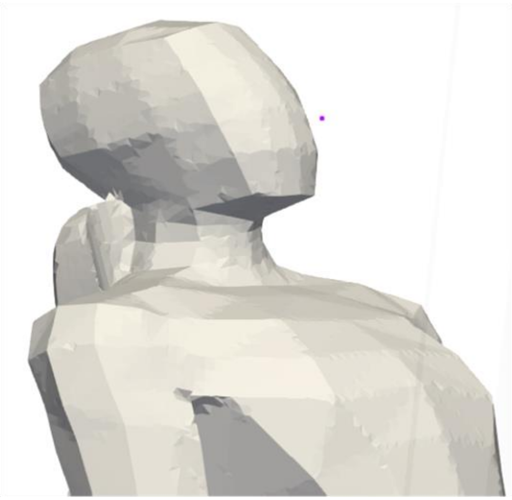
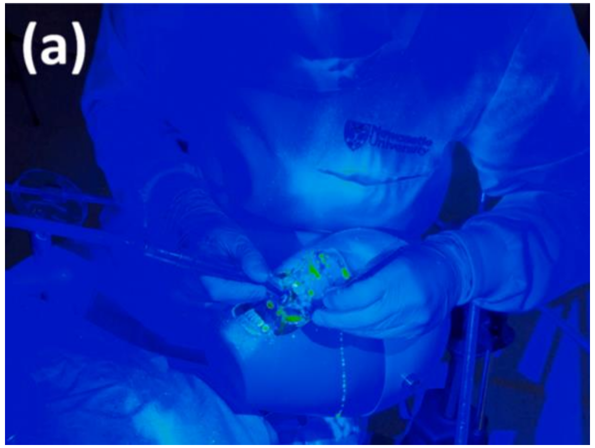


Fig. 2 Heat maps showing contaminated surface area (mm²) from photographic image analysis. a) Orthodontic debonding procedure. b) Positive control (anterior crown preparation). For each coordinate, the maximum value recorded from three repetitions of each clinical procedure was used. Logarithmic transformation was performed on the data (Log_{10}). Note the scale is reduced to remove areas showing zero readings

Evaluating splatter and settled aerosol during orthodontic debonding: implications for the COVID-19 pandemic

Hayley Llandro,[1] James R. Allison,[1,2] Charlotte C. Currie,[1,2] David C. Edwards,[1,2] Charlotte Bowes,[1,2] Justin Durham,[1,2] Nicholas Jakubovics,[2] Nadia Rostami[2] and Richard Holliday*[1,2]





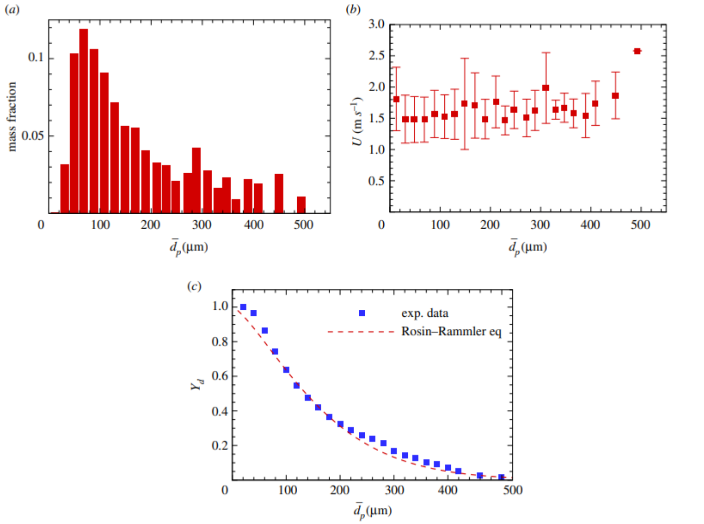


Figure 7. (*a*) Histogram of the droplet size distribution. (*b*) The velocity distribution of the droplets. (*c*) The Rosin–Rammler curve fitted for our obtained experimental droplet size data with a 29.5 ml min^{-1} flow rate.

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Aerosol formation due to a dental procedure: insights leading to the transmission of diseases to the environment

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[2]School of Environmental Sciences, University of Liverpool, Liverpool, UK

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