Case Study: Investigating the Effect of Airflow Generated by CerroZone Air Purifier on Laminar Air Supply in Operating Rooms Using Computational Fluid Dynamics

CerroZone White Paper

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Model Overview

ASHRAE/ASHE Standard 170-2017 [1] provides guidelines for design and layout of ventilation system in operating rooms (ORs). This type of environment has strict requirements for sterile zones, especially in and around the surgical table area. Therefore, effect on the laminar air supply from ceiling diffusers is of paramount importance when external device, such as the CerroZone air purifier, is used in such environment. The minimum requirements of the Standard are summarized in **Table 1.**

Table 1. ASHRAE/ASHE Standard 170-2017 minimum requirements

	Notes
Laminar supply diffuser array should be used in ORs	
Coverage area of the primary supply diffuser array should extend a minimum of 12 in. beyond the footprint of the surgical table on each side.	
Sidewall exhaust grilles	Minimum of (2); 8 in. above the floor
Maintain positive pressure	20 air changes per hour (ACH) supplied with 4 ACH outside air
Supply air should be unidirectional, discharge from ceiling	Average velocity 25 to 35 ft/min (fpm)

Fig. 1 shows the overview of the CFD model that resembles the one studied by Khankari [2]. From the minimum requirements outlined in ASHRAE/ASHE Standard 170-2017, the OR model was constructed. **Table 2** shows the geometrical dimensions of major components of the OR model. The dimension CerroZone air purifier is true to scale, i.e., 51 in. (H) x 29 in. (W) x 16.5 in. (D).

Table 2. Geometrical Dimensions

Room Dimension	28 ft. (L) x 20 ft. (W) x 10 ft. (H)
Room Volume	5,600 cu. ft.
Total laminar diffuser area (9)	72 sq. ft.
Total return grilles area (2)	4 sq. ft.
Total Door leakage (2)	0.611 sq. ft.
CerroZone machine	51 in. (H) x 29 in. (W) x 16.5 in. (D)

Fig. 2 shows the top view of the model. The patient and surgical team, except the scrub nurse, are fully covered under the laminar air supply curtain or sterile zone. The figure also shows the position *d* from the CerroZone air purifier intake surface to the nearest exhaust grille.

Set up Conditions

Similar to the work by Khankari, [2], **Table 3** shows the flow conditions for the current OR model. The CerroZone air purifier discharges 220 CFM, which provides 2.36 ACH of clean air. In this report, three different airflow velocities, i.e., 20, 30, and 40 fpm, from air supply ceiling diffusers were investigated, which correspond to 15, 23, and 31 ACH, respectively. Door leakage rate remained at 350 CFM and the exhaust flow rate through return grilles was maintained lower than the supply flow rate. Thus, the OR model was kept at positive pressure.

Table 3. Flow Conditions

CerroZone Machine Volume Airflow	220 CFM
Laminar Diffuser Airflow Velocity	20, 30, 40 FPM
Air Change Per Hour	15, 23, 31 ACH
Door Leakage Volume Airflow	350 CFM

There are totally 5 examining cases in 2 different categories, i.e., varying distance and ACH. Case 1, 2, and 3 have the same ACH but with varying distance *d,* whereas, case 3, 4, and 5 have the same distance *d* but varying ACH as seen in **Table 4**.

Table 4. Studied Cases

Studied Cases	**Distance *d***	***ACH***
Case 1	24 ft.	15
Case 2	10 ft.	15
Case 3	3.6 ft.	15
Case 4	3.6 ft.	23
Case 5	3.6 ft.	31

Results and Discussion

Varying Distance *d*

Fig. 3 shows the velocity profile at the mid plane of the OR model. The laminar air supply curtain remains unaffected at various distance *d*. Both the velocity contour and velocity vector in this figure suggest a strong protective shield from the top surgical table up to the ceiling in the central sterile zone. There is some minimal recirculation from under the surgical table.

Fig. 4 and **5** show the airflow paths from and to the CerroZone machine, respectively. In **Fig. 4**, the air discharge from the machine in all 3 varying distance scenarios is kept away from the central sterile zone and does not interfere with laminar air supply from ceiling diffusers before exiting the OR via return grilles. In **Fig. 5**, the CerroZone machine works with the laminar air supply by sucking the surrounding contaminated air and eliminate airborne bacteria and viruses before discharging it back to the OR.

Varying ACH

Fig. 6 shows the velocity profile at the mid plane of the OR model with various ACHs. Similar to the varying distance study, the sterile zone (laminar air curtain) is protected from any potential interfering air plums caused the CerroZone machine even at the lowest ACH of 15. As the ACH increases, the circulation in the non-sterile zone intensifies but shows no sign of interference with the machine presence. In fact, the stronger laminar air plum acting like an air shield provides stronger protection against any intrusion from non-sterile zones in higher ACH cases.

Fig. 7 and **8** show the air flow paths from and to the CerroZone air purifier. In **Fig. 7**, all three various ACH scenarios show the air path does not interfere with the laminar air supply where sterile zone is maintained. With higher ACHs, it shows lesser activity of the moving air originated from the machine in the non-sterile zones. The air path originated from the machine stays in the periphery of the OR model. In **Fig. 8**, it shows the air path leading to the intake of the CerroZone machine. As the ACH increases, more air streams from both sterile and non-sterile zones are sucked into the purifier's intake. This shows that the machine is working with the laminar air supply in the sterile zone to enhance the cleanliness in the OR.

Conclusion

By using CFD modeling, an OR model was constructed to investigate the potential airflow interference of the CerroZone air purifier with the primary HVAC supply. From 5 studied cases in 2 different categories, i.e., varying distance *d* and varying ACH, the CerroZone air purifier shows no interference with the laminar air supply from ceiling diffusers within the sterile zone. In fact, it works with the primary HVAC system to eliminate airborne bacteria and viruses present and enhancing the cleanliness of the OR. Regardless of the variation in ACH and distance *d* in the air purifier machine positioning, the air flow paths from and to the CerroZone machine remain in the non-sterile zone and do not affect the laminar air supply from ceiling diffusers.

References

[1] ANSI/ASHRAE/ASHE Standard 170-2017, Ventilation of Healthcare Facilities.
[2] Khankari, K. (2018). Hospital Operating Room Ventilation Systems. *ASHRAE Journal*, 60(6), 16-26.

Appendix

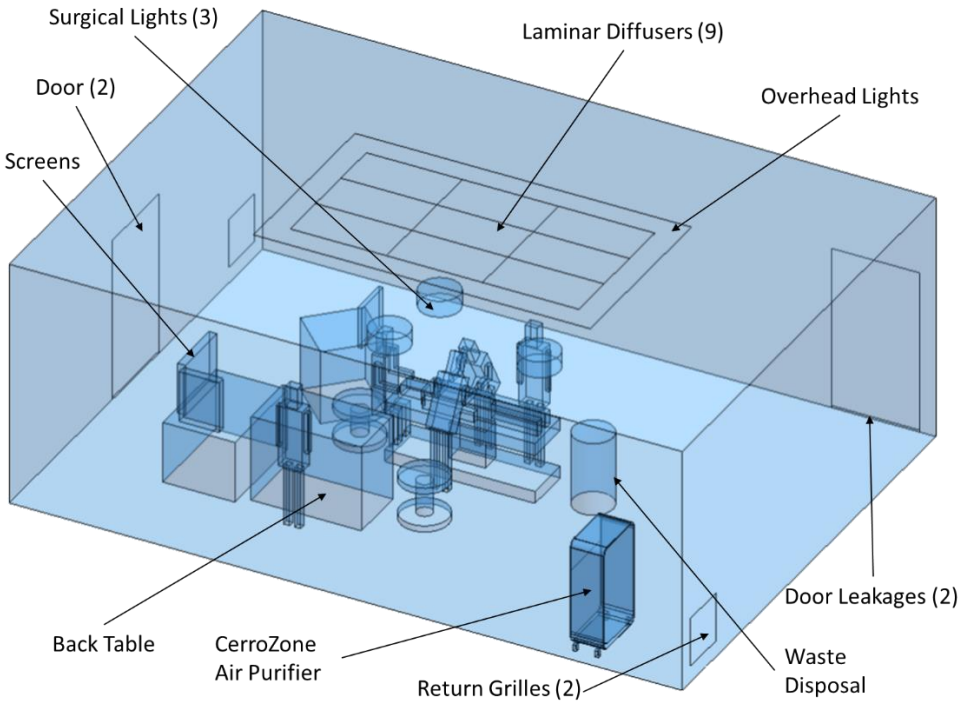


Fig. 1 Overview of the CFD model

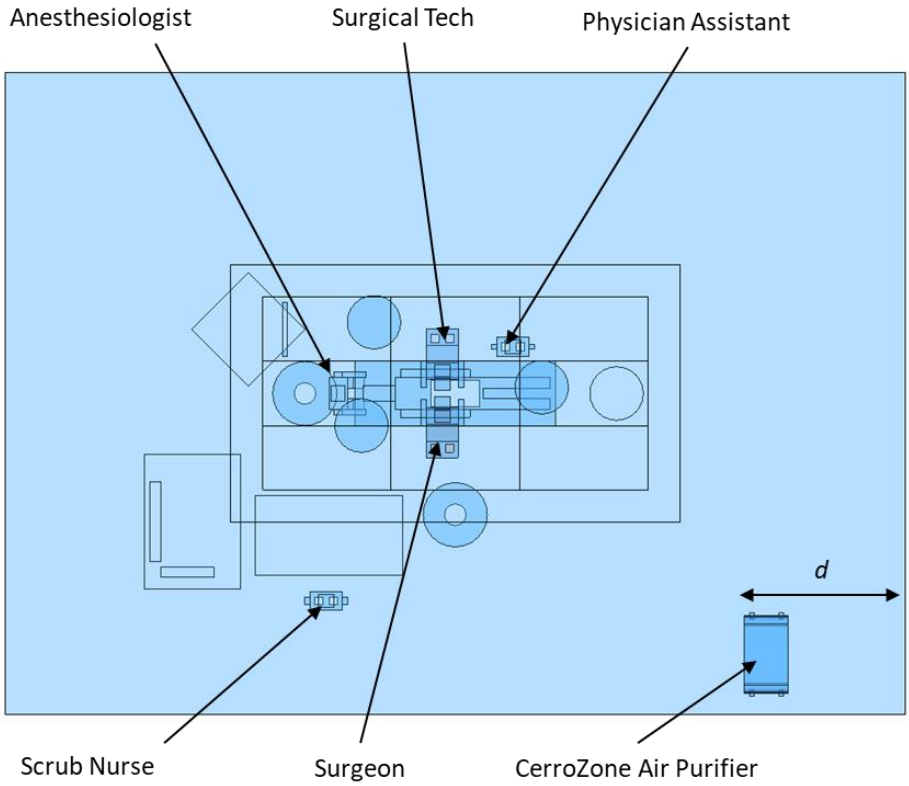
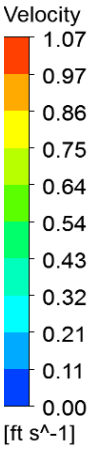
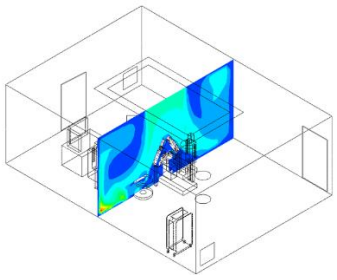


Fig. 2 Top View





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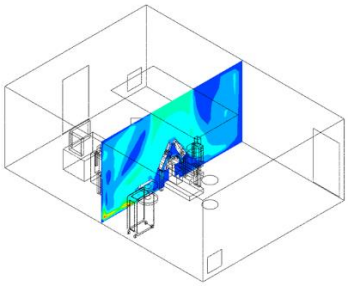

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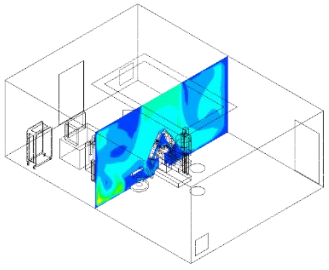

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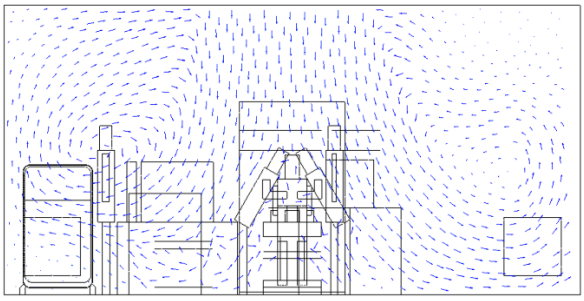
(a)



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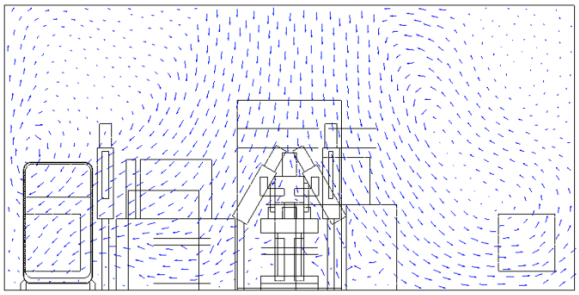

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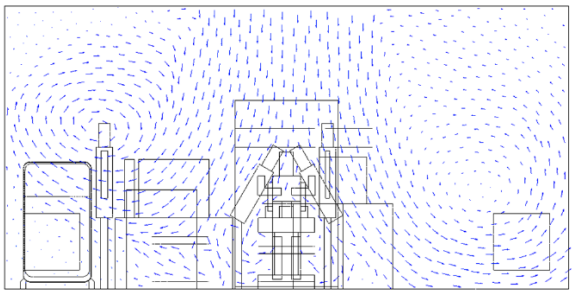

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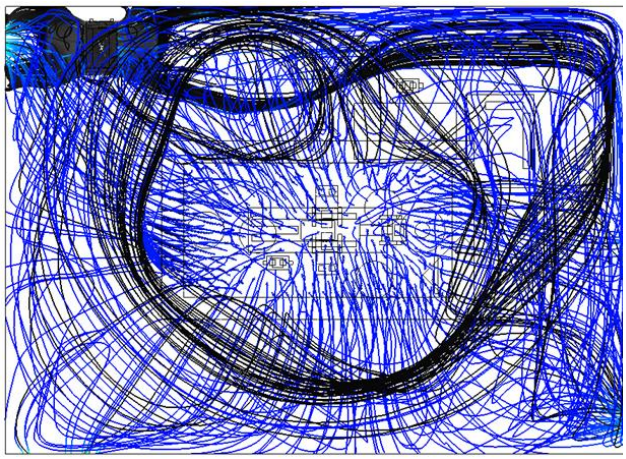
(b)

Fig. 3 Velocity profile at the mid plane: (a) velocity contour; (b) velocity vector



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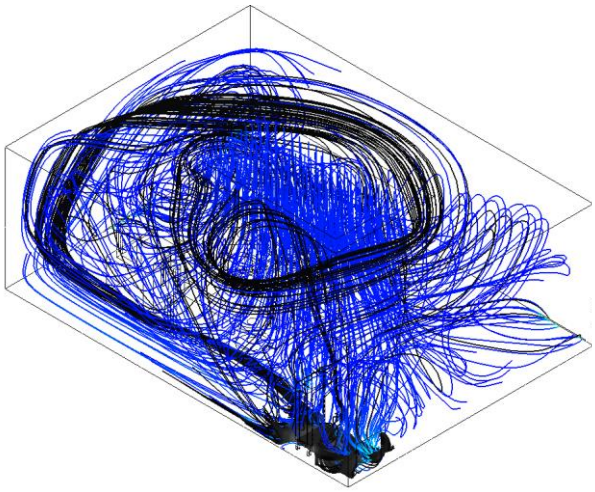

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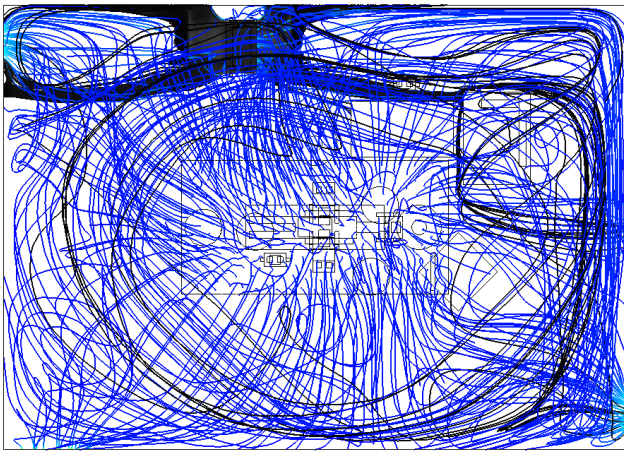

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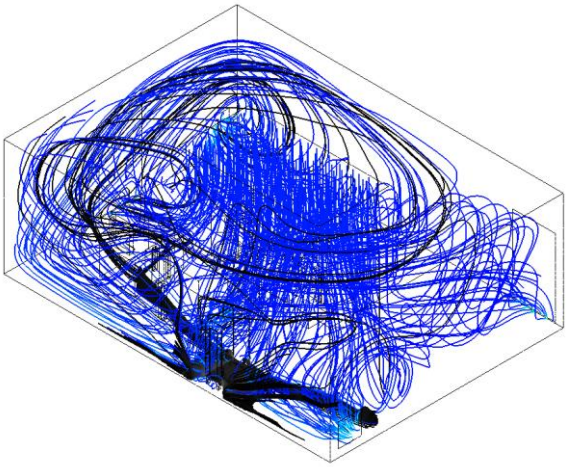

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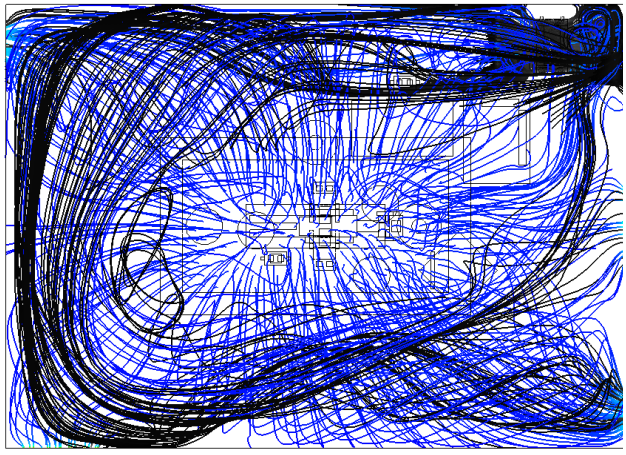

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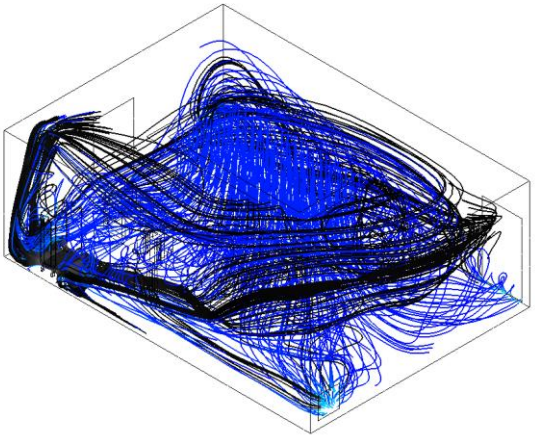
(a)



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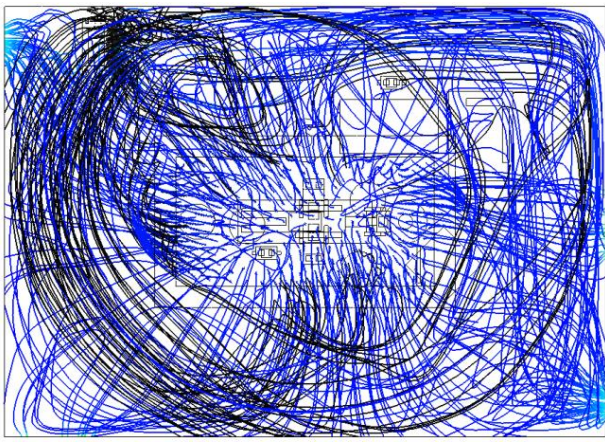
(b)

Fig. 4 Air flow path originated from the CerroZone air purifier: (a) top view, (b) isometric view



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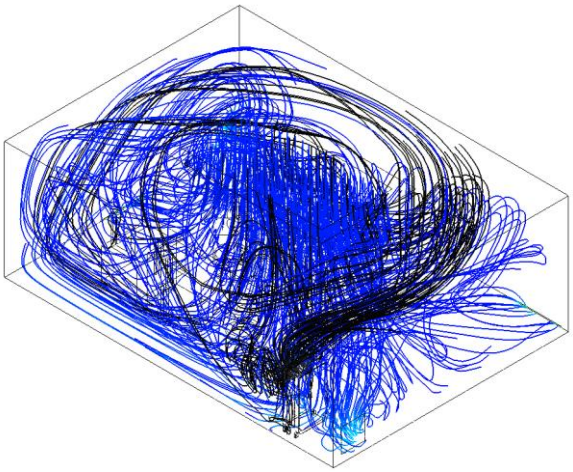

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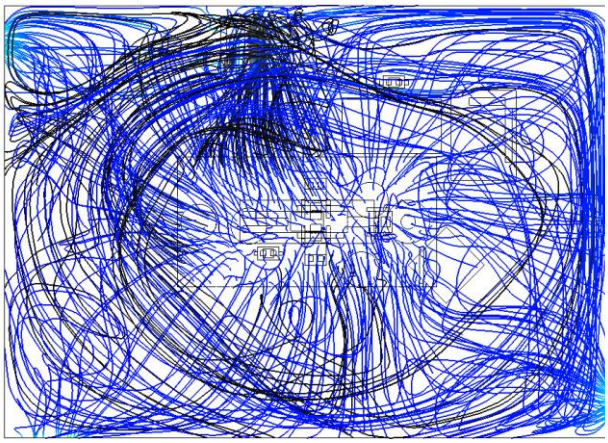

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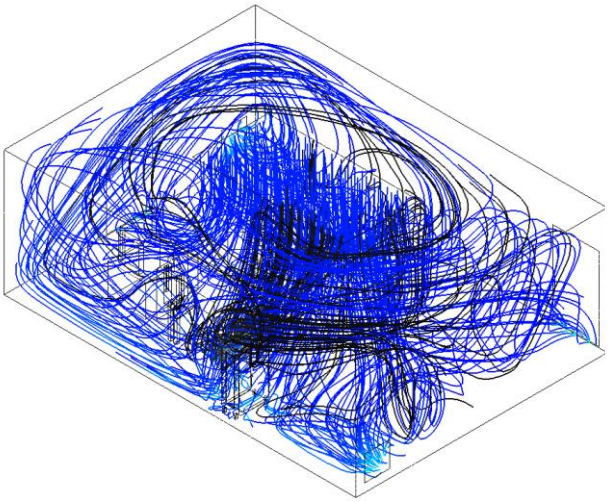

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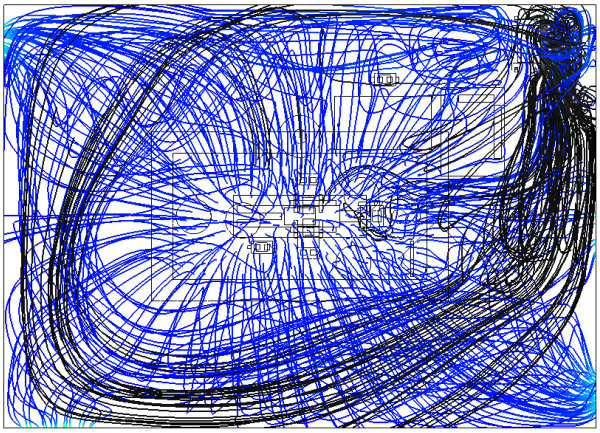

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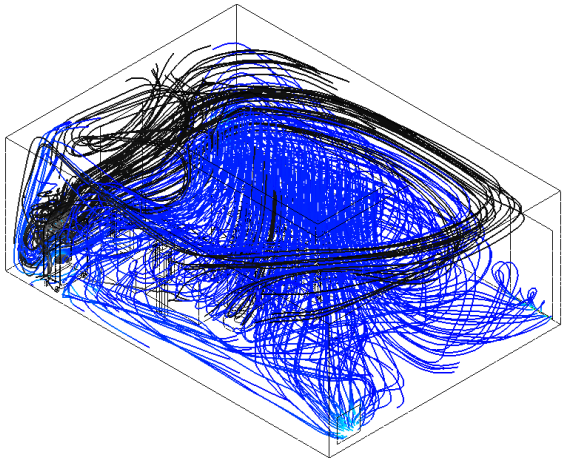

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(a) *(b)*

Fig. 5 Air flow path from OR to the intake of the CerroZone air purifier: (a) top view, (b) isometric view

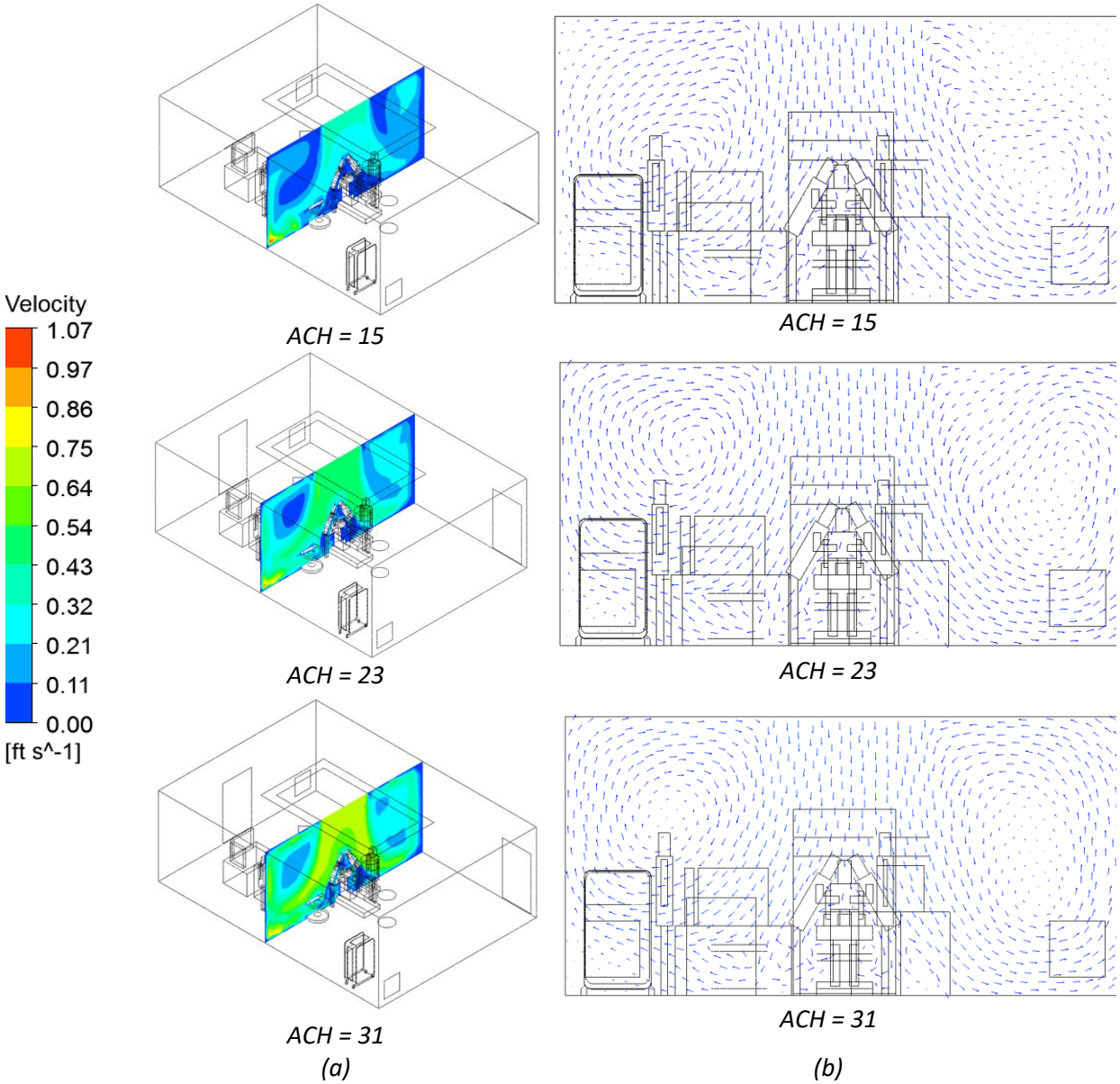
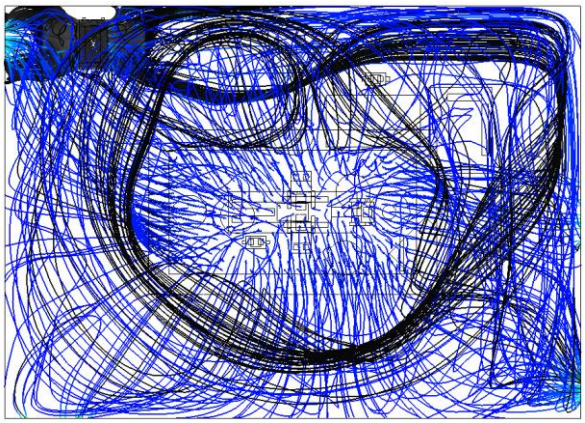


Fig. 6 Velocity profile at the mid plane: (a) velocity contour; (b) velocity vector



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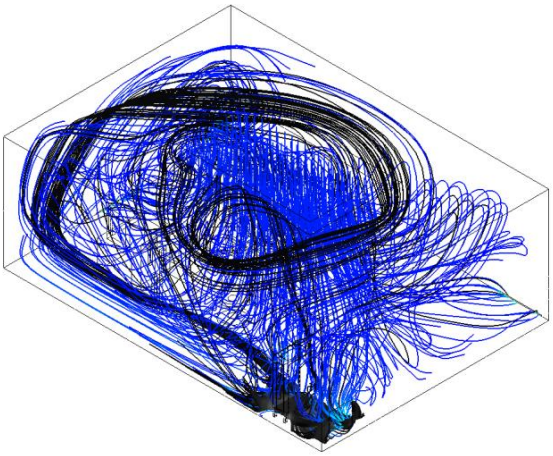

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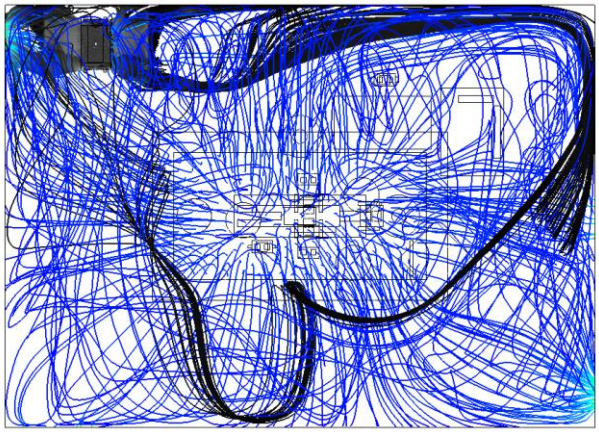

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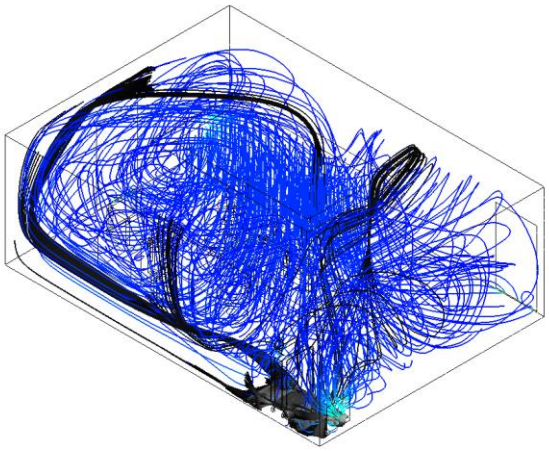

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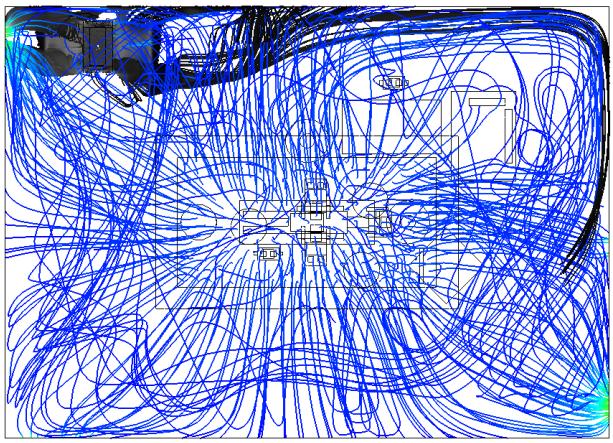

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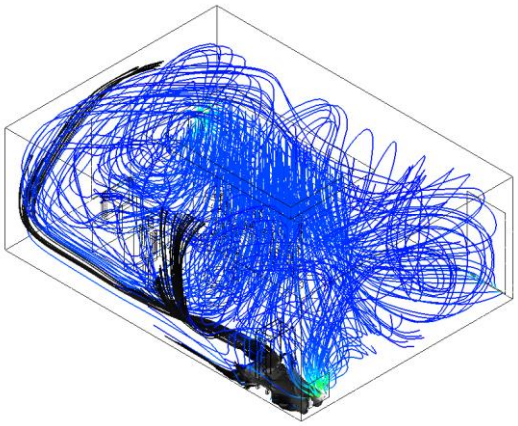

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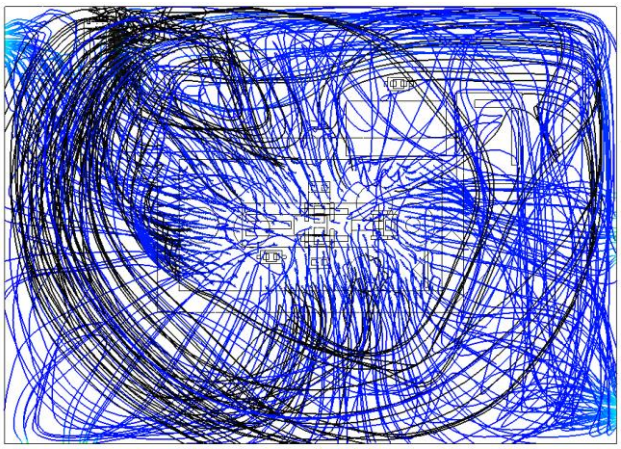
Fig. 7 Air flow path originated from the CerroZone air purifier: (a) top view, (b) isometric view



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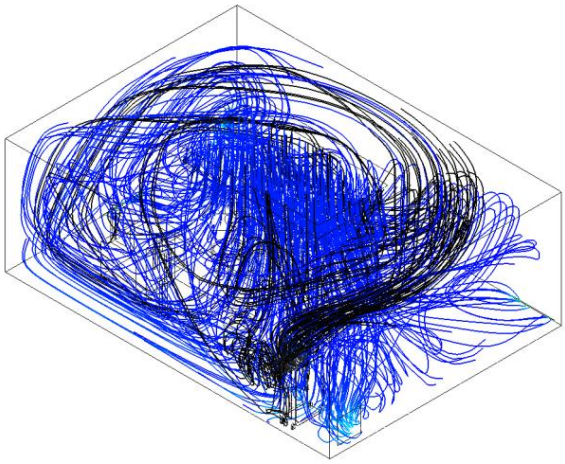

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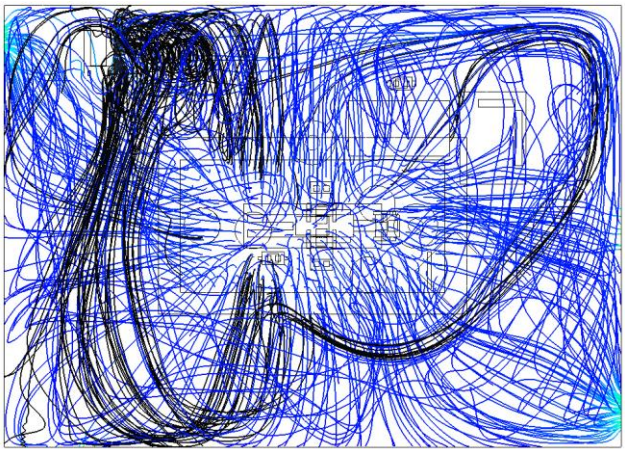

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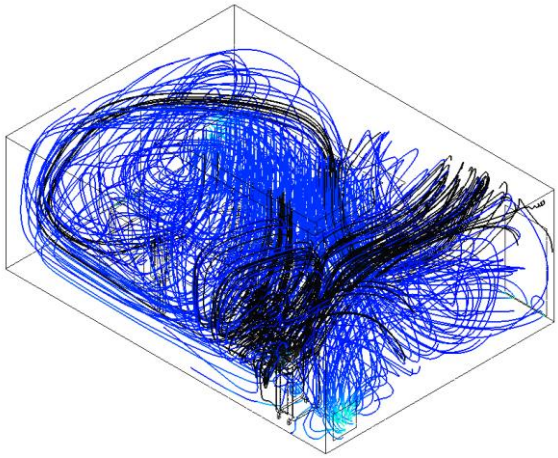

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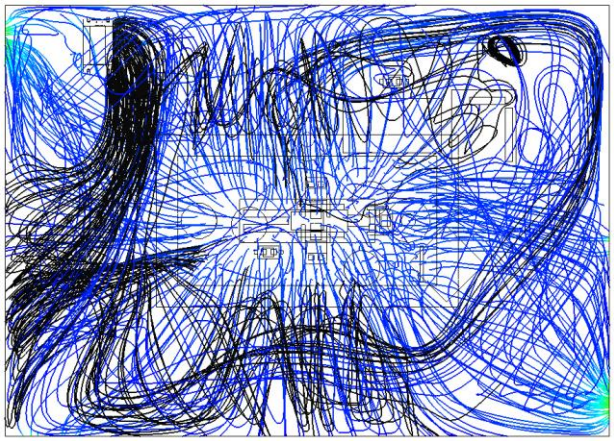

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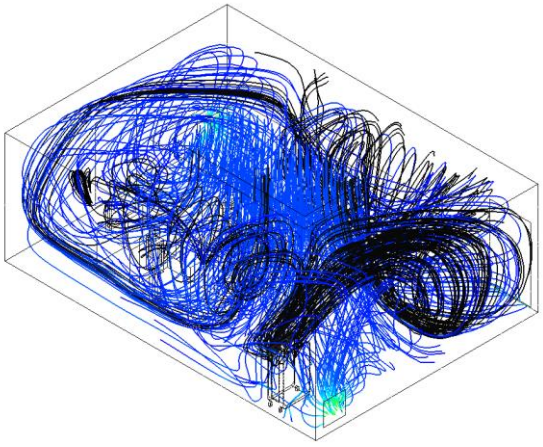

ACH = 31

(b)

Fig. 8 Air flow path from OR to the intake of the CerroZone air purifier: (a) top view, (b) isometric view

Contact Information

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