

Real scale experimental study for performance evaluation of unidirectional air diffuser perforated panels

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Abstract. Nowadays, there is an increasing emphasis on indoor air quality due to technological evolution and the fact that people spend most of the time in enclosed spaces. Also, energy efficiency is another related factor that gains more and more attention. Improving air distribution in an enclosure can lead to achieve these goals. This improvement can be done by adjusting the air terminals position, the dimensions or the air diffuser perforations. The paper presents the study of 8 types of panels with different perforations shapes. The systems were characterized by flow, pressure loss and noise. Usual and special geometries were chosen, all having the same flow surface. The perforated panels were mounted in a unidirectional air flow (UAF) diffuser, also called a laminar air flow (LAF) diffuser, that is placed in a real scale operating room (OR) in our laboratory. The purpose of this study is to determine whether changing the shape in the perforated panels can improve the technical parameters of the diffuser.

1. Introduction

In modern days most of the buildings, whether they are commercial, residential or industrial, have mechanical ventilation systems for improving air quality in their premises [1,2]. The systems, commonly referred to as HVAC systems, have the purpose to improve indoor air quality and thermal comfort. To reach these goals, air parameters and air distribution are adjusted in accordance. Adjusting the air parameters represents an approach that is frequently called as an active method, while modifying the air distribution by changing the geometries in the perforated panels is usually referred as a passive method. Optimizing the air distribution in a space is achieved by adapting the air terminals units to the specifics of the space. This means to choose the optimal position for the air terminals and to select the right dimension and geometry for the diffuser. It is well recognized the fact that air distribution has an influence on thermal comfort, indoor air quality or even energy efficiency [3]. This also influences aerosol distribution, an important parameter in ORs and clean rooms. The paper presents the study of 8 types of panels with different perforations shapes, mounted in an air terminal unit. For each panel, the following technical parameters were determined: flow, pressure loss, noise.

Analysing these technical parameters represents the first step in determining how the geometry of the perforations in panels affects the air distribution in a room. The perforated panels have been mounted on a unidirectional air flow (UAF) [4, 5] or laminar air flow (LAF) [6] diffuser that is installed in the ventilation system of a real scale OR in our laboratory. Future research on

these panels will take into account their performance in terms of thermal comfort. The thermal comfort measurements will be made in the same climatic chamber. The equivalent temperature, PMV and PPD indices will be determined with the help of two humanoid thermal manikins and a ComfortSense equipment.

2. Experimental method

These measurements were made in a climatic chamber that simulates a real scale OR, which has the dimensions of 3.5x3.5x2.5m (LxLxH), temperature control on each wall and air ventilation system with an UAF diffuser. There were 8 types of panels analysed. The geometries selected were common ones, but also some special ones (Fig.1). For an easier reference, the panels were numbered with letters (Fig. 1, Table 1).

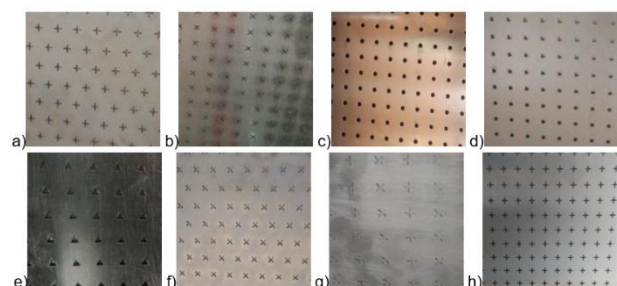


Figure 1. The geometries of the panels

The special geometries were developed in previous studies where it was analysed, by numerical and experimental approaches, the flowing through such shapes [7-9]. The panels are made from an aluminium sheet with the thickness of 1.5mm. A panel dimension is

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1255x635mm. For covering the whole surface of the diffuser, it requires 4 panels, resulting in a total of 32 pieces. The free flow surface for each shape is approximately 19.625 mm² (S_{ff}) and the free flow area for each panel is approximately 0.45m² (A_{ff}). All 4 panels, with the same perforations, were mounted at the same time and measurements were made on the whole surface of the UAF diffuser. In the middle of the UAF diffuser, on the entire length, is a lamp with the width of ≈120 mm. Inside, the plenum is organized as follows: an enclosure at the upper part in which air is supplied, panels with round holes at the lower part of this enclosure for stabilizing the flow, a second enclosure that represents the space for mounting the HEPA (high efficiency particulate air) filters and after the perforated panels are mounted. For these measurements there were no HEPA filters mounted.

Table 1. Panel geometries and notations

No.	Panel type	Fig.1	Notation
1	„+” intercalated	a)	A
2	„x” in line	b)	B
3	„O”	c)	C
4	„□”	d)	D
5	„Δ”	e)	E
6	„x” intercalated	f)	F
7	„+” and „x”	g)	G
8	„+”	h)	H

The ventilation system consists in an axial fan, ducts and fittings, air flow regulators, plenum with grilles and an automation system with a frequency converter mounted near the chamber. To have the same flow rate in the system, identical frequencies were selected when each type of panel was measured. The frequencies were selected to provide a minimum flow which the equipment can measure, not smaller than their error of measurement, and to allow at least 6 measurements across the entire range of the converter. The frequencies used for the measurements were 10.3Hz, 19.2Hz, 26.5Hz, 34.5Hz, 40.6Hz, 44.6Hz, 45.3Hz or max, on a Danfoss converter, type VLT HVAC Basic.



Figure 2. a) Ventilation system; b) Frequency converter

The air flow was measured by using a balometer from TSI, type EBT720/EBT721, with a hood of 610x610mm made out of textile. The hood has almost the same width as a panel but only a half of its length. Two types of such balometers were used for verifying if there are any perturbations between the values obtained from measuring with only one equipment and measuring with both at the same time. There were no significant differences between the values obtained, and the ones observed can be due to measurement errors. Also, the balometers were positioned on different areas of the

UAF diffuser surface. These measurements revealed that each panel had almost the same flow rate, regardless of its position in the UAF diffuser. This means that the aerodynamic balancing of the ventilation system was done well. For minimizing air leaks between the panel and the frame of the diffuser, a sealing was made with black duct tape that behaves like a sponge.

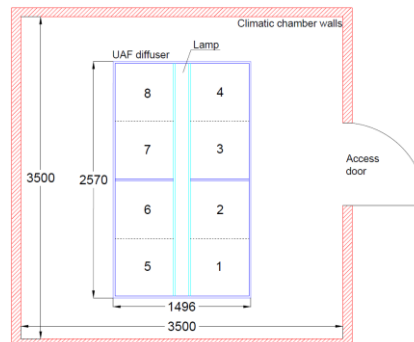


Figure 3. General sketch, top view, at real scale dimensions with the UAF diffuser and climatic chamber

Number notation (from 1 to 8) represents a measurement surface that can be covered by the hood of a balometer. The surface of a panel covers two notations (1 and 2). A total of 8 measurement surfaces for air flow have resulted on the surface of the UAF diffuser.

The pressure loss for each panel was measured by using a differential pressure manometer from Testo, type 521, in which two hoses were connected. For measuring the pressure loss generated by each panel, one of the hoses was mounted before the panel, inside of the plenum, in the space where the HEPA filters had to be mounted. The second hose was mounted after the panel, in the room. The door of the climatic chamber was closed during all measurements.



Figure 4. Equipment used, from left to right: a mounted hose and the manometer, sound meter, balometer

For sound measurements a portable sound meter from Bruel&Kjaer, type 2250-S, was used. The sound measurements were made at a height that corresponds to medical staff, ≈1.8m, and at a height that corresponds to patient, ≈1m. For each height there were four measurement points, each point was placed in the middle of each panel. The acoustic measurements were made also without panels, to determine if they generate or attenuate the sound. The sound measurements were made predominantly in periods without any activity in the laboratory (night or morning), but there were also some that could be done only during the day.

The value obtained for each measurement is an average value over a 10÷20s interval. The measurements were made starting with the lowest frequency, determining the flow, followed by the pressure loss measurement, ending with acoustic measurements. Tests were made for

verifying if there are any differences between the values obtained when going ascending or descending on the frequency converter. No significant differences were observed between the values obtained and the ones observed can be due to reading or measurement errors.

3. Results and comments

Because no attenuation has been implemented to eliminate the noise from the fan, noise levels resulted to be high. Also, due to this fact it will be wrong to assume that the technical characterization refers only to the panels, but rather they would represent the entire system (panel and ventilation system). Each system has been characterized, based on the values obtained, by pressure loss, noise and air flow. Charts for every system with these technical parameters were made. These charts are similar with the ones that can be found in diffusers datasheet. An example of such chart, with noise values for 1.8m and 1m height, can be seen in Fig. 4 and Fig. 5, for the ventilation system with panel type A.

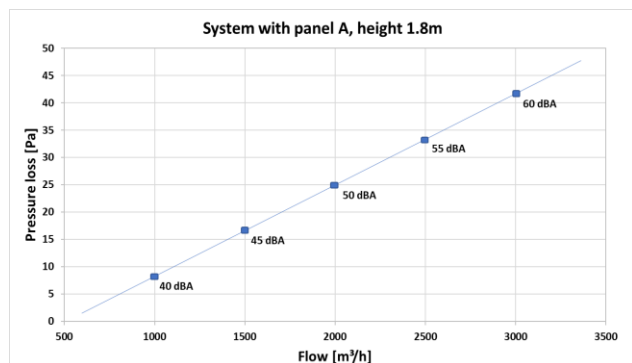


Figure 5. Ventilation system with panel type A, noise 1.8m

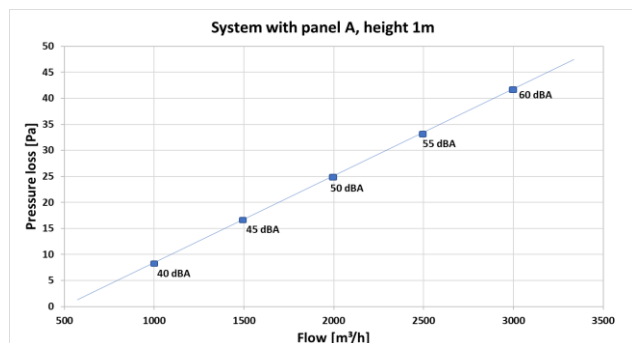


Figure 6. Ventilation system with panel type A, noise 1m

Presenting the data in this manner it's easier to read and allows the user to determine the other two parameters by only knowing one of them. A first comparison regarding the noise level measurements was made between the values obtained at 1.8m and 1m height. All systems have charts with the same allure, that's why only some comparisons are presented here (Fig. 7-10). It was observed that there is only a slight difference between the values measured at these two heights, with a difference of 2dB in average. The peaks that can be observed in the left part of the charts, at low flow rates, are due to environmental disturbances that happened outside. At this flow rates the ventilation system does not generate a lot of noise and any small noises from outside

the climatic chamber, generated in the same time with the measurements, are a disturbing factor.

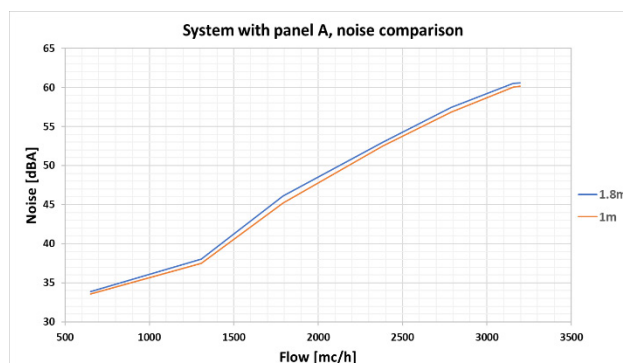


Figure 7. Noise comparison with panel A, 1.8m and 1m

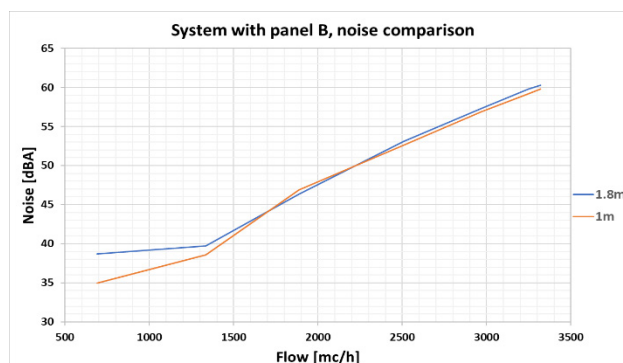


Figure 8. Noise comparison with panel B, 1.8m and 1m

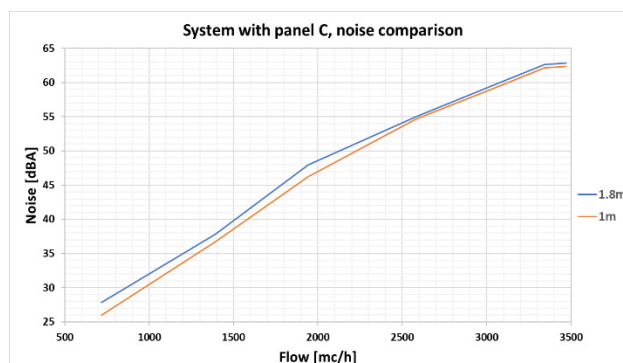


Figure 9. Noise comparison with panel C, 1.8m and 1m

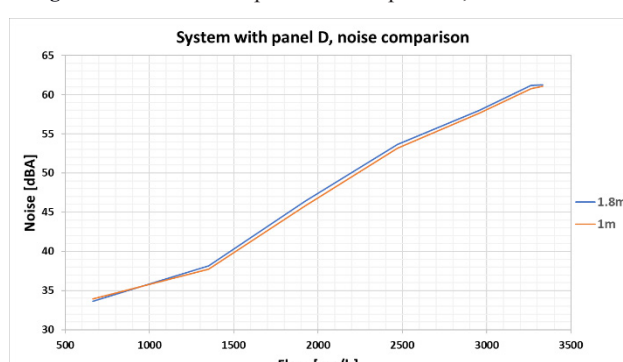


Figure 10. Noise comparison with panel D, 1.8m and 1m

Another interesting comparison was made with the noise level values from all systems, including the values without panels. This comparison can be observed in Fig. 11 and Fig. 12. A first comment here will be regarding the role of the panels in these acoustic measurements. It can be observed that the panels attenuate the noise and

the values are decreasing greatly with them mounted on the UAF diffuser. Here we can see again the influence of the perturbing factors. Despite these perturbations, the measured values are roughly the same for all systems, with slight differences. Also, the differences between the values are almost equal across the entire range of flows. Thus, one can assume that either system will generate almost the same noise and it has no reason to choose one instead of another.

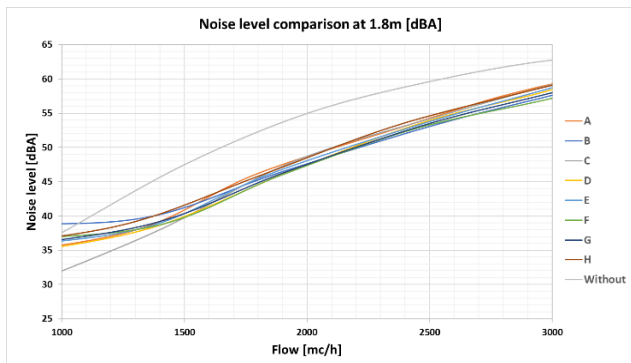


Figure 11. Noise comparison for all systems, 1.8m height

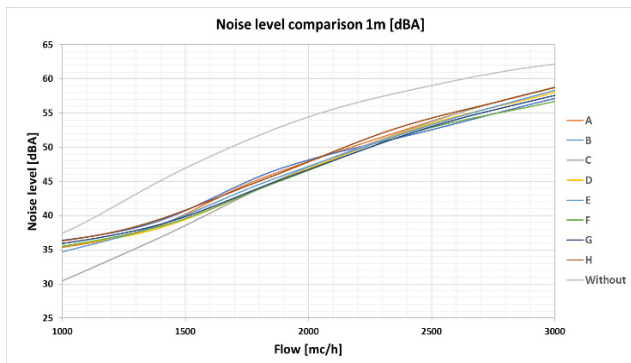


Figure 12. Noise comparison for all systems, 1m height

The pressure loss values obtained for all systems were compared and can be seen in Fig. 13. It can be observed here that there is a threshold around the value of 2000 mc/h. Before this value, there are very small differences between the systems. After this value, the system with panel type E („Δ”) and D („□”) tends to generate more pressure loss than the others. The difference between the system with panel type E, D and the next one, panel type A („+ intercalated”), is around 9-10 Pa.

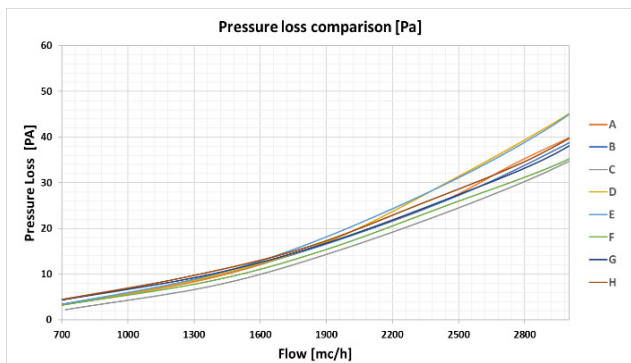


Figure 13. Pressure loss comparison

The other 6 systems tend to keep the same differences between values even after this threshold. For this parameter, one can assume that you should avoid a

system with type E panel, while a better solution will be a system with type C („O”) or F („x intercalated”). A comparison with all the technical parameters was made in Table II and III. For determining the pressure loss and the noise level which corresponds to the 3 flow rates that were chosen, interpolations were made based on the values obtained from measurements. The velocity was calculated for each flow by knowing the free flow surface of a geometry and the total number of geometries in a panel, resulting free flow area.

TABLE I. Technical parameters, same flow, panels A-D

V (m/s)	Q (m³/h)		Panel A („+” i)	Panel B („x” L)	Panel C („O”)	Panel D („□”)
0.43	700	h (Pa)	3.1	3.4	2.3	3.0
		Lp (dBA 1.8m)	33.9	38.7	28.0	33.7
		Lp (dBA 1m)	33.6	35.0	26.2	34.0
0.93	1500	h (Pa)	10.4	11.2	9.7	11.7
		Lp (dBA 1.8m)	40.5	41.7	40.9	40.6
		Lp (dBA 1m)	39.8	41.1	39.5	40.1
1.85	3000	h (Pa)	35.8	38.8	36.7	44.8
		Lp (dBA 1.8m)	57.7	57.6	59.9	58.3
		Lp (dBA 1m)	57.2	57.1	59.5	58.0
Aff (m²) = 0.45		Sff (mm²) =	19.625			

TABLE II. Technical parameters, same flow, panels E-H

V (m/s)	Q (m³/h)		Panel E („Δ”)	Panel F („x” i)	Panel G („+ x”)	Panel H („+” L)
0.43	700	h (Pa)	3.1	3.2	4.2	4.2
		Lp (dBA 1.8m)	35.1	36.4	35.1	35.5
		Lp (dBA 1m)	31.9	33.7	34.2	34.7
0.93	1500	h (Pa)	11.6	10.5	11.9	11.3
		Lp (dBA 1.8m)	40.6	40.7	41.0	41.0
		Lp (dBA 1m)	40.1	40.3	40.4	40.2
1.85	3000	h (Pa)	42.5	35.8	37.2	35.7
		Lp (dBA 1.8m)	57.9	57.4	57.6	57.7
		Lp (dBA 1m)	57.5	57.0	57.3	57.3
Aff (m²) = 0.45		Sff (mm²) =	19.625			

4. Conclusions

This study allowed us to obtain the technical parameters of this panel and the ventilation system and represents a first step in the attempt to research how these geometries influence the air distribution in the enclosure.

Some conclusions can be drawn on the values obtained from the measurement campaign presented in this paper. Regarding the noise measurement values, one can say that no significant differences are between the values obtained at different heights, and the noise produced by the system will be perceived almost the same for both patient (~1m) and surgeon (~1.8m). Another conclusion that can be drawn is that almost no differences were observed for noise levels generated by the different systems. An observation which cannot be overlooked is the fact that any panel attenuates the noise produced by the fan.

Regarding the pressure loss measurements, it was confirmed that some geometries, which were expected to generate high pressure loss („Δ”, „□”), had higher values. Also, it was observed that the special geometries didn't generate high pressure loss at high flow rates, some even getting good results („x” i. or „+” L.).

More research must be done in this field for a better understanding. Future research can study the influences of perforated panels on thermal comfort felt by the occupants, aerosol distribution in the room, energy consumption of the system.

This work was supported by a grant of the Romanian space agency ROSA, QUEST - Advanced air diffusion system of the

crew quarters for the ISS and deep space habitation systems,
STAR-CDI-C3-2016-577

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