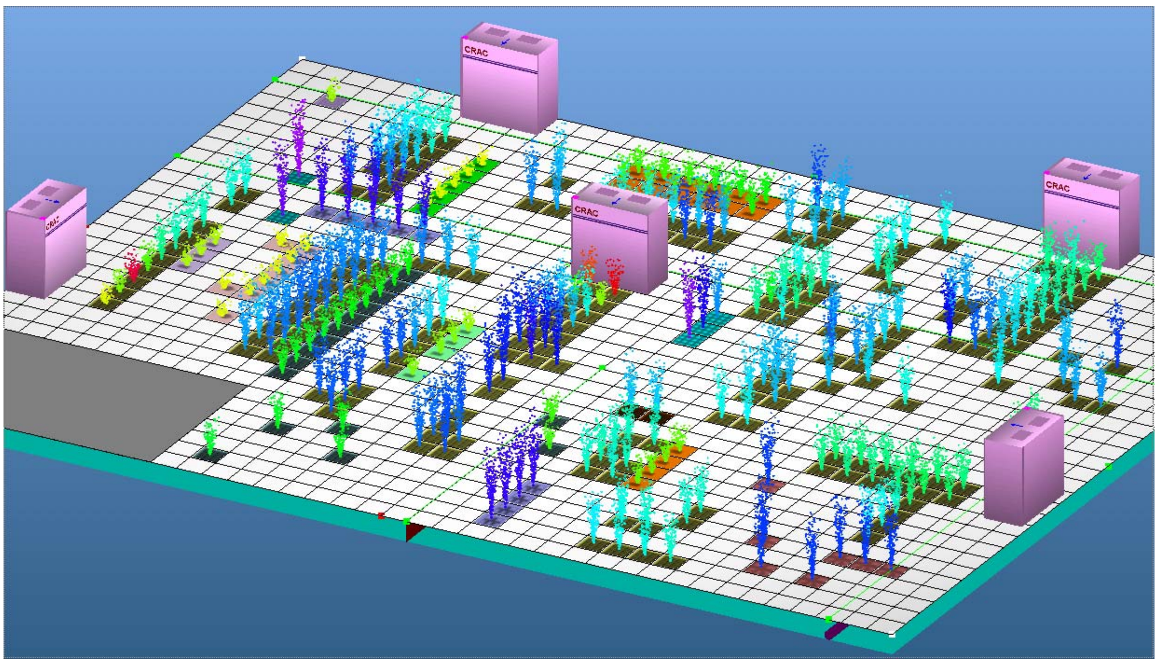
Distributed Leakage Airflow in Raised-Floor Data Centers

White Paper



Innovative Research, Inc.
A Computational Fluid Dynamics Company

3025 Harbor Lane North, Suite 300 • Plymouth, MN 55447 • USA
Tel: 763-519-0105 • E-mail: TileFlow@inres.com • Web: www.inres.com

September 2004

Introduction

In raised-floor data centers, leakage airflow refers to the cooling airflow escaping through unmanaged or extraneous openings on the raised floor and the perimeter walls. Leakage airflow occurs through the gaps between individual panels and around columns on the raised floor, between the raised floor and perimeter walls, between the subfloor and the walls, and around pipes and cables entering the under-floor plenum. Depending on the leakage area, the leakage airflow can be a significant portion of the total airflow entering the plenum. Because the leakage airflow does not participate in direct cooling of the computer equipment in the racks, it represents wastage of the cooling air. (The leakage airflow entering the computer room does provide an indirect benefit by lowering the temperature in the room.)

The leakage area is made up primarily of the gaps between the individual floor panels. Because these gaps are present throughout the raised floor, the corresponding area is referred to as *distributed* leakage area. The importance of distributed leakage area depends on how it compares with the total open area on the raised floor (open area of perforated tiles and cutouts). For a particular raised floor, the distributed leakage area becomes more important as the number of perforated tiles and cutouts is reduced. This reduction causes the leakage airflow to increase and the total amount of cooling air supplied by the perforated tiles to decrease.

In this note, we present a case study to highlight the importance of distributed leakage airflow. This case study is conducted using TileFlow.

The Floor Layout

The case study considers a section of a large data center arranged in hot and cold aisles, shown in Figure 1. The floor size is 26 ft × 14 ft and the plenum height is 12 inch. There are no under-floor obstructions. There are two rows of perforated tiles (open area = 25%), fed by a CRAC unit with a rated flow rate of 5,650 cfm. The size of the CRAC unit footprint is 74 in × 35 in. For the results presented here, the CRAC flow rate is assumed to be constant at the rated value, independent of the pressure in the plenum. As we will see later, the plenum pressure is very reasonable even when there are only a few perforated tiles on the raised floor. Thus, the assumption that the CRAC flow rate remains constant can be justified.

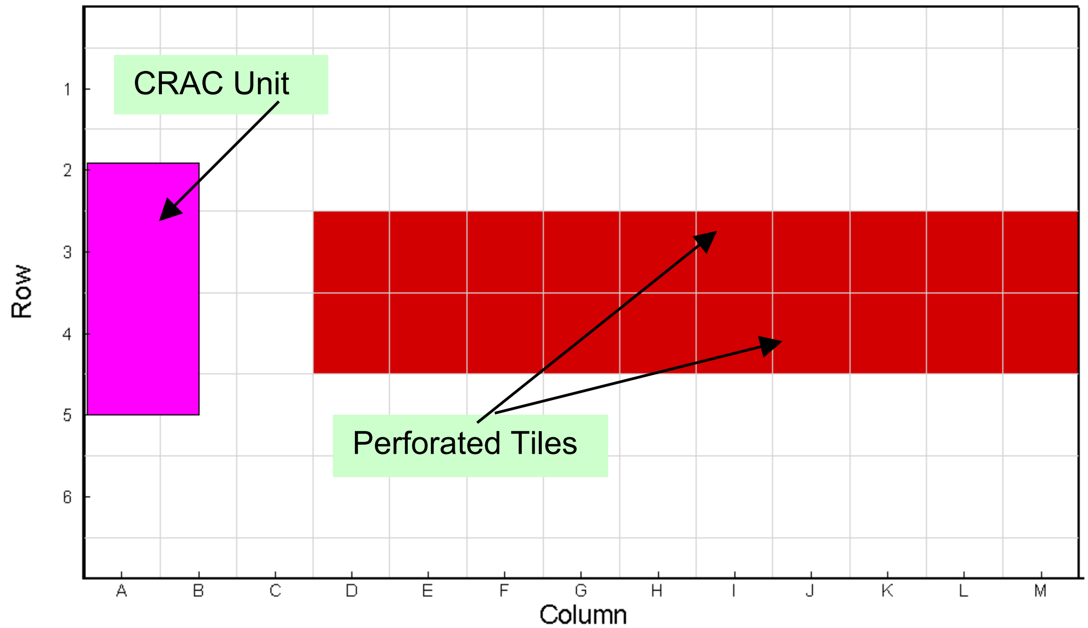


Figure 1. Floor layout for the case study.

Distributed Leakage Area

The distributed leakage area is taken as 0.5% of the exposed floor area (area that is not covered by the footprints of the CRAC units). For the floor considered here, the exposed floor area is

$$\text{Floor Area} - \text{Area of CRAC Unit Footprint} = 26 \times 14 - (74 \times 35) / (12 \times 12) = 346 \text{ sq ft}$$

Thus, the distributed leakage area is

$$346 \times 0.5 / 100 = 1.73 \text{ sq ft}$$

This area corresponds to a gap of about one-eighteenth of an inch (or about 1.4 mm) between two floor panels.

Cases Considered

As stated earlier, the importance of the leakage airflow depends on how the leakage area compares with the open area on the raised floor. In this study, the floor size and the leakage area are kept fixed, and the open area is varied by changing the number of perforated tiles, from 20 to 2. For different number of perforated tiles, the total open area is given in Table 1. The open area is calculated by multiplying the total area of perforated tiles by 0.25 (the perforated tiles are 25% open). (Note that the distributed leakage area is 0.5% of the exposed floor area.)

Table 1. Total open area on the raised floor.

Number of perforated tiles	20	16	12	8	4	2
Total area occupied by perforated tiles (% of the exposed floor area)	23.1	18.5	13.9	9.2	4.6	2.3
Total open area on the raised floor (% of the exposed floor area)	5.8	4.6	3.5	2.3	1.2	0.6

It may appear that the layouts with only 2, 4, or 8 tiles are unrealistic. We emphasize that the quantity of interest is not the number of perforated tiles, but the total open area on the raised floor in relation to the exposed floor area. Thus, the results for 8 perforated tiles in this study would be valid for any raised floor where the open area on the raised floor is approximately 2.3% of the exposed floor area.

Results

Leakage Airflow and Total Airflow Through the Perforated Tiles

The airflow rates for various floor layouts were calculated using TileFlow. For each layout, the leakage airflow and the average pressure under the perforated tiles were recorded. The leakage airflow and the total airflow through the perforated tiles for different open areas are shown in Figure 2. As the total open area on the raised floor is reduced (i.e., the number of perforated tiles is reduced), the leakage airflow increases and the total airflow through the perforated tiles decreases. For 20 perforated tiles (open area of 5.8%), the leakage airflow is only around 7% of the total airflow from the CRAC unit. However, for 8 tiles (open area of 2.3%), the leakage airflow is around 20%; for 4 tiles (open area of 1.2%), it is close to 30%, and for 2 tiles (open area of 0.6%), it is nearly 46%. These results indicate that the leakage airflow is a significant portion of the total inflow when the leakage flow area is comparable to the open area on the raised floor.

A Side Note. A raised floor often has a number of unsealed cable cutouts. The airflow through these cutouts, just like the leakage airflow, does not provide direct cooling to the computer equipment in the racks. The cooling of the computer equipment can be improved by sealing these cutouts, so that more airflow is available through the perforated tiles. By sealing the cutouts, however, we also reduce the open area on the raised floor and increase the prominence of the leakage area. Thus, sealing the cutouts will increase the leakage airflow, and only part of the airflow that was going through the cutouts will be delivered through the perforated tiles.

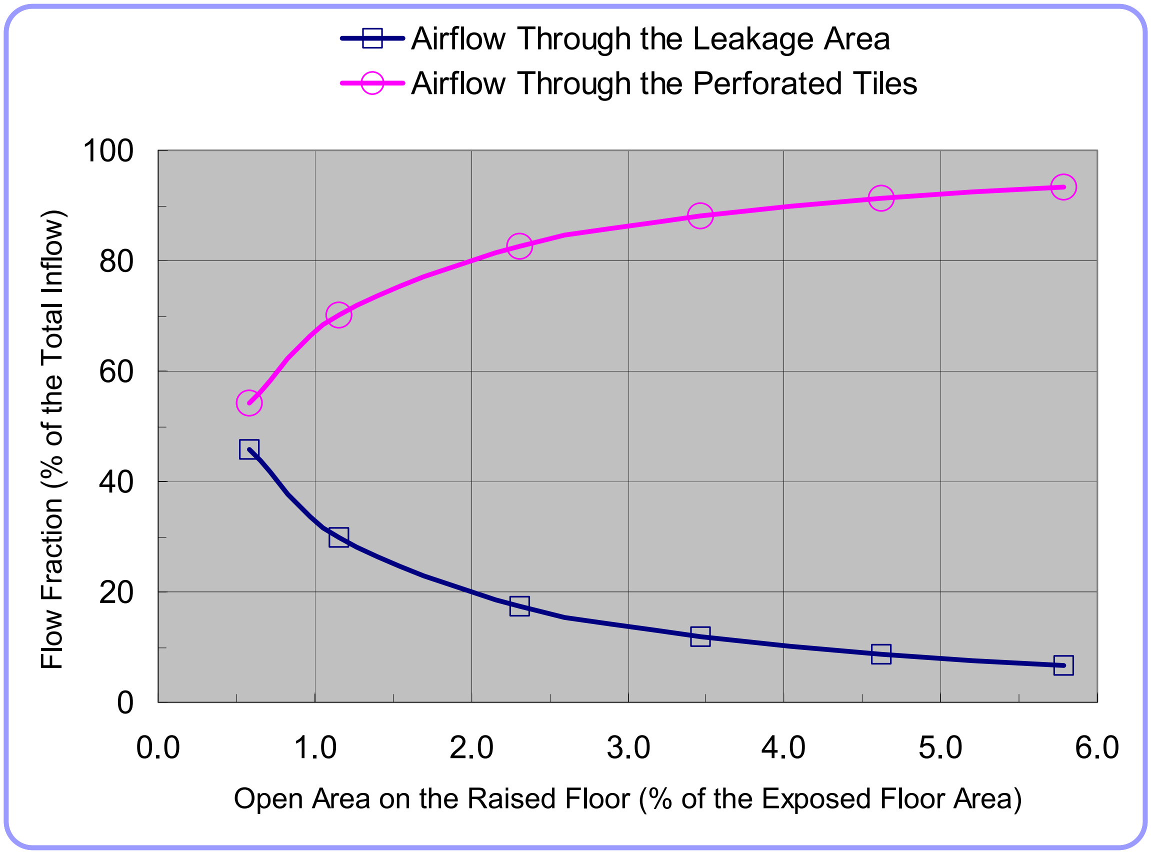


Figure 2. Variation of airflow through leakage area and total airflow through perforated tiles with the open area on the raised floor.

Pressure in the Under-Floor Plenum

As the total open area on the raised floor is reduced, the pressure in the plenum increases. This relationship is shown in Figure 3, where the average pressure under the perforated tiles is plotted as a function of the total open area. It is interesting to note that even when the number of tiles is reduced to 2, the average pressure is only 0.4 inch of water. This pressure value is close to the external static of the CRAC unit. Therefore, even with only two perforated tiles, the airflow supplied by the CRAC unit will be very close to its rated flow rate. This observation is somewhat contrary to our expectation that with only a few perforated tiles the pressure levels in the plenum will become excessively high and dramatically reduce the airflow rate supplied by the CRAC unit. This expectation is based on a sealed raised floor (which is impossible to achieve in reality) and does not consider the leakage airflow. (The precise pressure level is determined by the leakage area and the other open areas available on the raised floor. The results presented here show that the pressure levels in the plenum will become excessively high only under extreme conditions.)

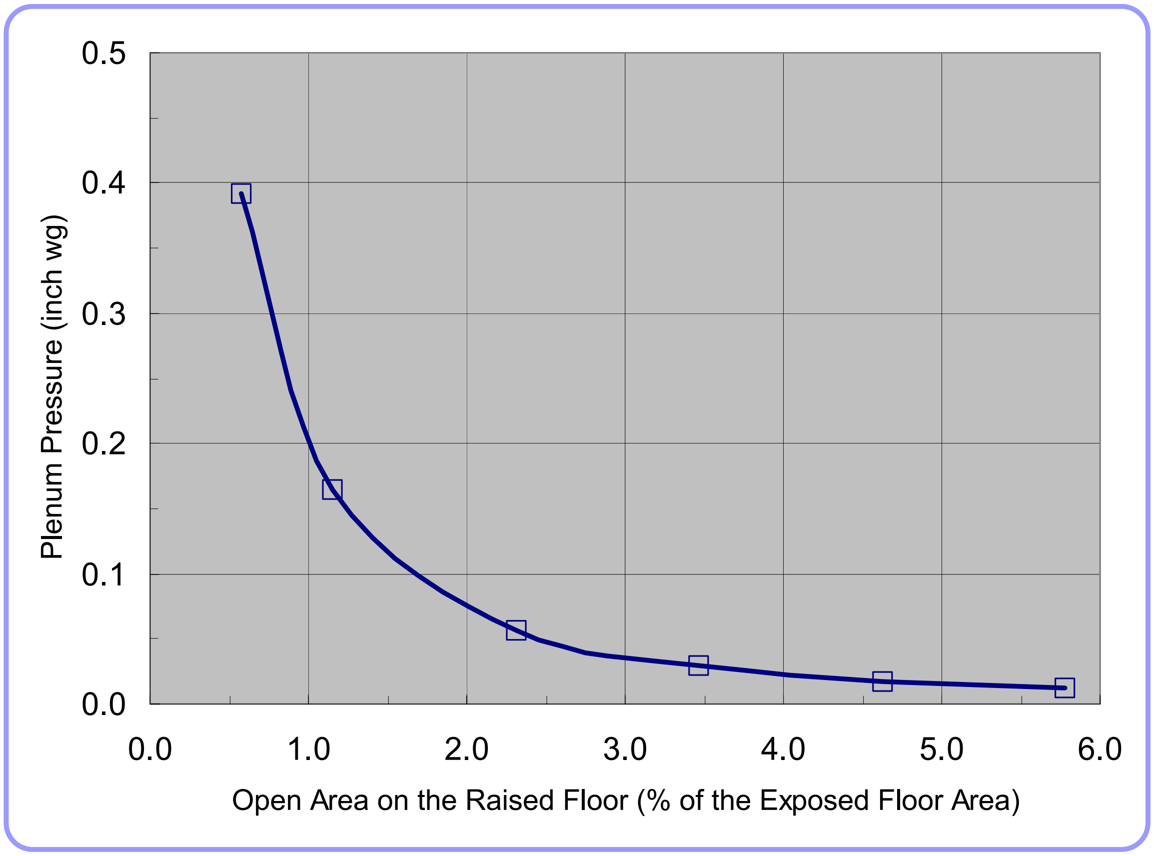


Figure 3. Variation of average pressure under the perforated tiles with the open area on the raised floor.

Average Flow Rate per Perforated Tile

As the number of perforated tiles is reduced, the increase in the plenum pressure causes an increase in the *average* flow rate through a perforated tile. This relationship is shown in Figure 4. For 20 perforated tiles, the average flow is about 260 cfm per tile. For 8 tiles, the average flow becomes 580 cfm; for 4 tiles, it is 990 cfm.

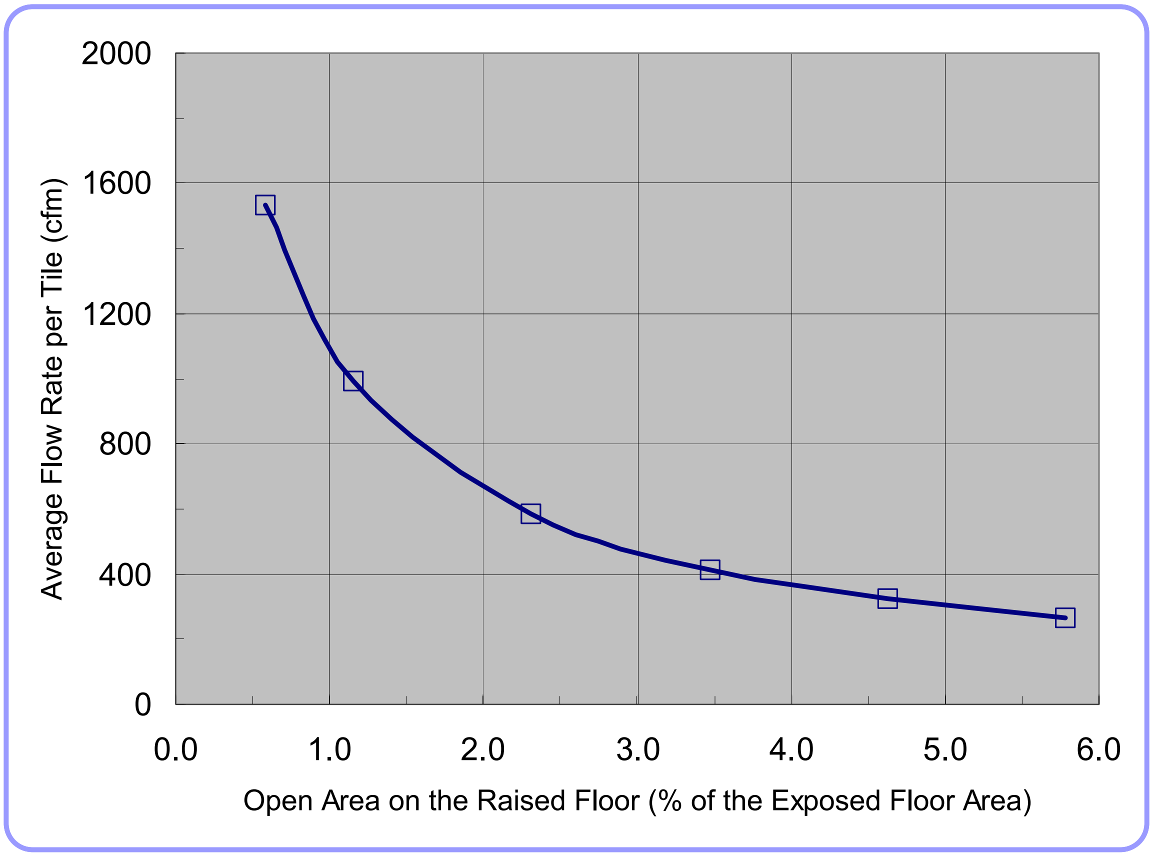


Figure 4. Variation of average flow rate per perforated tile with the open area on the raised floor.

Summary

This case study shows that attention must be paid to the leakage airflow when the leakage area is comparable to the total open area of the perforated tiles and cutouts on the raised floor.