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INCREASING THE VENTILATION EFFECTIVENESS OF MULTIZONE AIR-HANDLING UNITS THROUGH IMPROVED OUTSIDE AIR DUCT DESIGN

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ABSTRACT

Multizone air-handling units were popular for nearly 25 years and many are still in service today. The degree of mixing of outside air and return air in these units depends to a great degree on the manner in which the outside air is ducted into the return air system. Tests conducted during this study demonstrate that there can be a 600% variation in outdoor air quantity from one zone to another. This can result in very uneven outside air distribution within the building, which can be bad or good, depending on the requirements of the individual zones.

INTRODUCTION

Prior to the widespread adoption by the HVAC industry of variable-air-volume systems, multizone air-handling units were a very popular design choice in schools, hospitals, and office buildings when the number of temperature zones was limited to less than 16 per floor. The advantage of the multizone unit was that the temperature control dampers were accessible in the mechanical room rather than above the ceiling in a double-duct terminal unit. Although the early coil control strategies often allowed for simultaneous heating and cooling, the energy efficiency of these units has been improved through better coil control strategies and, in some cases, converting the units to variable air volume. Although energy efficiency is a major issue with multizone units, the purpose of this paper is to describe how control of the distribution of outside air in a multizone unit can be increased through careful design of the outside air ducts.

MULTIZONE SYSTEM GEOMETRY

One of the major design advantages of a blow-through air-handling unit, of which the multizone unit is an example, is that the supply ducts and the return duct are shallow and wide. The shallowness of the ducts minimizes the depth of the ceiling plenum, which allows for higher ceilings or a reduced floor-to-floor building dimension.

The location of the multizone unit in one- or two-story buildings is often on the roof or along an outside wall at the rear of the building. In many instances, the unit is positioned parallel to the outside wall. The physical arrangement of the multizone unit and the geometry of the return air duct often result in a mechanical room configuration whereby the outside air duct is teed into one side of the return duct, as shown in Figure 1. The problem with this seemingly innocent design results from the fact that the outside air does not mix uniformly with the return air, and several zones may receive little or no outside air. Thus, while the total volume of outside air may meet current ventilation standards, the effectiveness of the system to provide uniform ventilation to all zones is highly questionable.

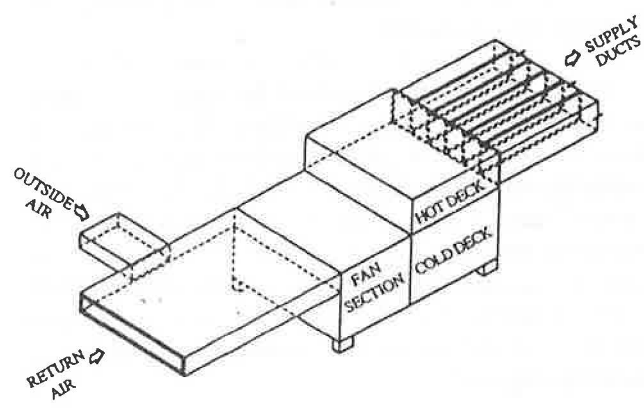

Figure 1 *Multizone system layout.*

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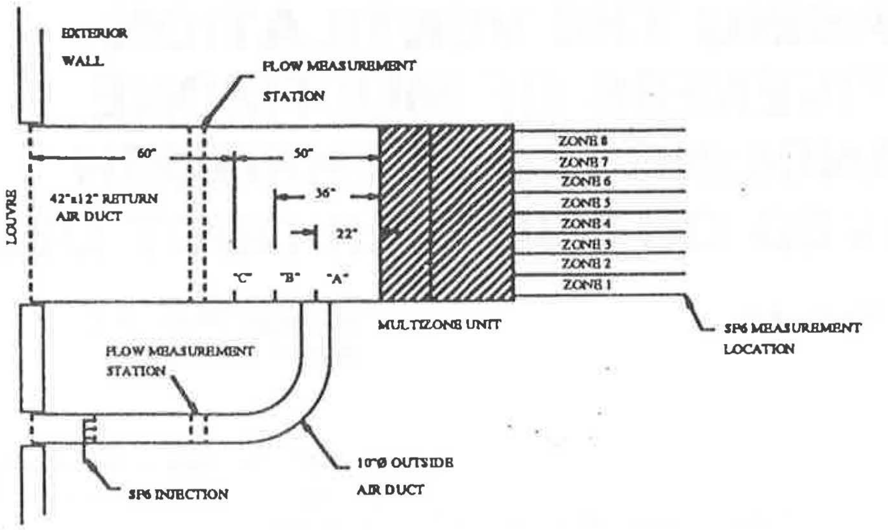

Figure 2 Test configuration (top view).

DETERMINING VENTILATION EFFECTIVENESS

In order to test the hypothesis that a duct arrangement similar to that shown in Figure 1 will result in a non-uniform distribution of outside air, two architectural engineering graduate students set up an experiment using a commercially available multizone unit. A sketch of the layout is shown in Figure 2. The unit has a wide return air duct with a outside air duct teed into one side. The multizone unit draws outside air through both the return duct and the outside air duct. SF_6 is injected into the "outside" air duct and the concentrations measured in each of the supply ducts. Actual room return air was not used because the concentration of SF_6 would continue to increase as the test continued, thus making steady-state measurements impossible.

The concentration of SF_6 was measured in the "outside" air duct and at each of the eight supply ducts using a general-purpose gas analyzer. SF_6 was injected into the "outside" air duct using three nozzles, and the uniformity of the mixture was checked. The volume of "return" and "outside" air was monitored using flow-measuring stations. After each test, mass balance calculations were performed in order to confirm the accuracy of the measurements. The "outside" air duct was teed into the "return" air duct at locations A, B, and C, as shown in Figure 2.

RESULTS

Figures 3, 4, and 5 show the results of the three different experiments. With the outside air tee in position "A," the concentration of outside air in zone 1 is 5.9 times that in zone 8. With the outside air tee in position "B," the concentration of outside air in zone 1 is 4.5 times that of zone 8. Even when the outside air tee is in

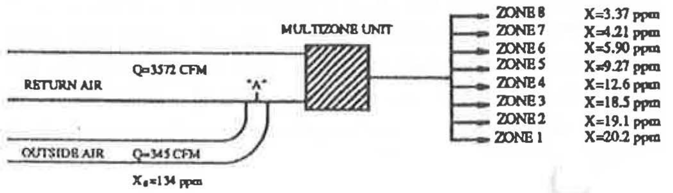

Figure 3 Results with outside air at "A."

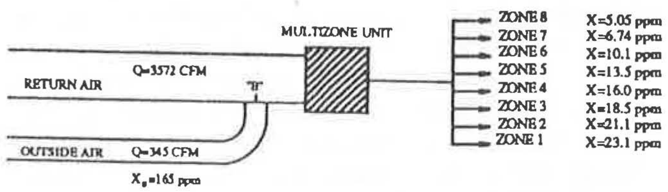

Figure 4 Results with outside air at "B."

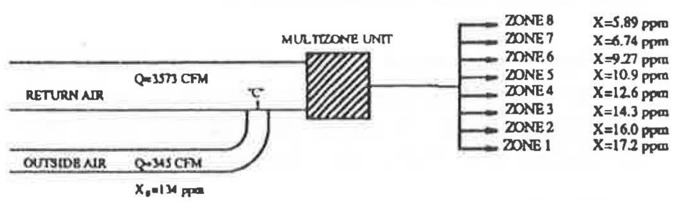

Figure 5 Results with outside air at "C."

position "C," the outside air concentration in zone 1 is 2.9 times that in zone 8. For position "C," the average outside air concentration of zones 1, 2, 3, and 4 is 1.3 times the average concentration in zones 5, 6, 7, and 8. This variation was expected because the fan is a double-inlet design and the majority of the fresh air goes into one side of the fan. The result that was not expected was the variation in outside air concentration for the zones served by the same fan inlet. For example, zones 1, 2, 3, and 4 are served by one side of the fan and yet the SF_6 concentration varies from 17.25 ppm (zone 1) to 12.64 ppm (zone 4). This phenomenon is consistent for each test, and it indicates that there is not complete mixing of the outside air and the return air in the fan.

It is quite obvious from the data that the outside air distribution throughout this building would be very non-uniform, which could result in poor indoor air quality in several zones in the building. This situation could be improved by relocating the outside air tee farther from the multizone unit, but this is usually impractical because most mechanical rooms are too small. A more practical approach is to tee the outside air duct into the return air duct at two locations, as shown in Figure 6. Based on the concept of superposition and using data from Figure 3, the outside air distribution would be at least as uniform as that shown in Figure 7.

However, a uniform distribution of outside air is not always the goal, and if by chance the zones that receive the most outside air have requirements that exceed those of the other zones, then the HVAC system could be considered very effective. Thus, the return air/outside air duct arrangement for a multizone system allows the engineer to have some control over how ventilation air is distributed throughout the building. Smoking lounges, for example, require a lot of outside air, and these areas should be served from zone 1 (in our experiment) rather than zone 8.

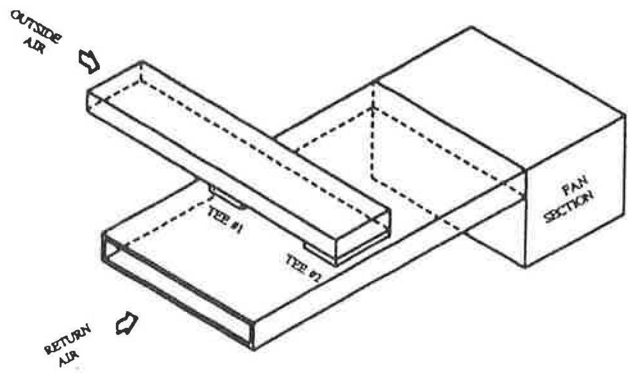

Figure 6 *Ducting for uniform outside air distribution.*

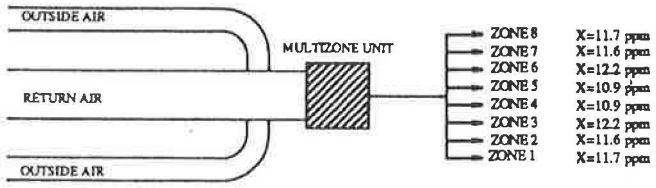

Figure 7 *Outside air distribution based on superposition.*

SUMMARY

The results of this study indicate that certain return air/outside air duct arrangements can result in a very non-uniform distribution of ventilation air throughout a building. On the other hand, the engineer can take advantage of this phenomenon in order to improve the outside air distribution by the multizone system.