PERCENT OUTDOOR AIR CALCULATION AND ITS USE

APPLICATION NOTE TSI-138

TSI's IAQ instruments calculate Percent Outdoor Air (%OA). In order to take advantage of this feature, it is important to first understand what Percent Outdoor Air is, why it is important, and how to use these instruments to calculate %OA.

The Importance of Fresh Outdoor Air

Perhaps the somewhat infamous quote, "The Solution to Pollution is Dilution," sums up the importance of fresh outdoor air. We may not go as far as to say that indoor environments have "pollution," but we might want to consider the effects of the indoor air components that can't be filtered. These include CO_2, body odors, chemicals from photocopiers and cleaners, and other indoor contaminants. Most of these components alone wouldn't affect someone over short periods of time. However, after long periods of exposure, like in a workplace where 40-hour workweeks are typical, these components have the capacity to make occupants tired, nauseous, and otherwise not as productive.

Volume of Fresh Outdoor Air

One method used to calculate the volume of fresh outdoor air entering a system is to conduct a duct traverse of the outdoor air duct intake. However, this is not always feasible, because there may not be sufficient straight ducting to do a good duct traverse[1] of either the return air or the outdoor air. Often, there is not even a duct for outdoor air, so it is essentially impossible to determine the volume of outdoor air that is entering the system.

An alternative way to determine how much fresh outdoor air is entering a space is to use the following equation:

Volume Fresh Outdoor Air =Volume of delivered air x % Outdoor Air of delivered air

The volume of fresh outdoor air entering a space equals the volume of delivered air (ft^3/min, m^3/hr, m^3/min or L/s) times the % outdoor air. Let's look at each of these items separately.

Total Volume of Delivered Air

The total volume of delivered air is the total volume of both outdoor air and return air entering a space. To determine the total volume of supply air entering a building, do a duct traverse using a TA460 or a PVM620 right after the Air Handling Unit and before the duct branches off. Another method to determine the total volume of delivered air is to use the PH721 capture hood at each supply diffuser and to take the sum of the readings.

Percent Outdoor Air

Percent outdoor air is the % of the total volume of delivered air that is outdoor air. There is more than one way to measure %OA. One method is to use a tracer gas like SF_6. This gas would be used to saturate the system at a set concentration and to record how the concentration decreases over time. Using this information, one can figure out what the %OA is. This can also be done with CO_2 if the concentration is high enough and there are no occupants.

Perhaps a better option is to take three readings of CO_2 concentration and calculate the %OA. The three reading locations include outdoor air, supply air, and return air. Another option is to take temperature readings at those same three locations.

Introducing the Equation

To calculate the %OA, use the following equation for CO_2 or temperature:

$$\%OA = \frac{(X_R - X_S)}{(X_R - X_O)} x100\%$$

Where:

X_R = **Return** air CO_2 concentration OR temperature
X_S = **Supply** air CO_2 concentration OR temperature
X_O = **Outdoor** air CO_2 concentration OR temperature

Some Examples

Let's look at an example. An industrial hygienist takes three samples with the following values:

Outdoor air CO_2 level	= X_O	= 400 ppm
Supply air CO_2 level	= X_S	= 645 ppm
Return air CO_2 level	= X_R	= 823 ppm

Then $\%OA = \frac{(X_R - X_S)}{(X_R - X_O)} x100\% = \frac{(823-645)}{(823-400)} x100\% = \frac{(178)}{(423)} x100\% = 42.1\%$

We can use this equation using temperature measurements too. Let's say that these measurements are taken in cold climates in the winter:

Outdoor air temperature	= XO	= 35ºF
Supply air temperature (before conditioning)	= XS	= 55ºF
Return air temperature	= XR	= 70ºF

Then $\%OA = \frac{(X_R - X_S)}{(X_R - X_O)} x100\% = \frac{(70-55)}{(70-35)} x100\% = \frac{15}{35} x100\% = 42.9\%$

We can use the equation using summer temperature measurements as well:

Outdoor air temperature	= XO	= 93ºF
Supply air temperature (before conditioning)	= XS	= 81ºF
Return air temperature	= XR	= 70ºF

Then $\%OA = \frac{(X_R - X_S)}{(X_R - X_O)} x100\% = \frac{(70-81)}{(70-93)} = \frac{(-11)}{(-23)} = 47.8\%$

Where to Take Measurements

To make sure the %OA measurement is done properly, the readings need to be taken at the appropriate locations. Outdoor air should always be taken away from the building exhaust vents. The location for supply and return may vary if the %OA value you are interested in getting is from using CO_2 or temperature.

For CO_2, the return air reading should be taken inside the return duct or well before the air mixes with the outdoor air. These locations ensure a stable reading. The supply reading should be taken inside the supply duct.

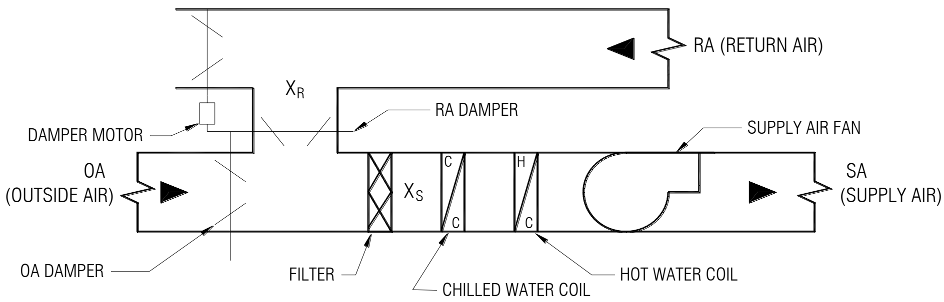

Illustration 1: Air Handling Unit Schematic

If temperature is the measurement used, then the return air value should be taken as close to the air handling unit as possible before the air is mixed with outdoor air. In the illustration given, the return air temperature (X_R) would best be taken in the return air duct just upstream of the return air damper. The supply air should be measured before the air has been conditioned. Temperature measurements should also be taken before any fans, since a fan can increase the temperature up to a few degrees. In the illustration given, the supply air temperature (X_S) would best be taken between the filter and the chilled water coil.

Equation Errors

If the equation results in a negative percentage or a percent above 100%, then this is an equation error. If the supply air value does not fall between the return air value and the outdoor air value, then an error will occur. Typically, if all three measurements are retaken, the issue will resolve itself. If not, then consider which of the following might apply to the situation:

If using temperature to calculate %OA:

- Air has been conditioned before measurement—take measurement closer to the air handling unit.
- Supply air has been mixed with room air—take supply measurement closer to diffuser or inside duct.
- Return air has not been mixed enough—take return air measurement in duct to assure proper mixing.
- Outdoor and inside temperatures are too close to one another—use CO_2 values as a base for %OA calculations.

If using CO_2:

- Supply air is mixing with room air—take measurement closer to diffuser or inside supply duct.
- Return air is not mixed well—take measurement inside return duct.
- Outdoor air measurement is tainted—make sure air entering outdoor air intake is fresh and clean.
- Not enough occupants to generate CO_2—use temperature values as a base for %OA calculations.

When to Use CO_2 or Temperature to Calculate % Outdoor Air

Percent outdoor air can be calculated using either CO_2 or using temperature. There are benefits to both of these methods and it's important to understand when to use one over the other.

Generally, CO_2 should be used when the building that you are interested in has a lot of occupants. This ensures that the CO_2 concentration values of outdoor air and return air are far apart. If there are a sufficient number of occupants then outdoor air should always be the lowest value, and return air should always be the highest. The further these two values are apart, the more accurate the %OA value will be. If there are few or no occupants, then there is little accumulation of CO_2 and the accuracy will not be as good.

Similarly, temperature should be used when the building or room of interest has a big difference in temperature from outdoor air temperatures. This means when it is hot or when it is cold outdoors, then it is a good time to use temperature as a means to calculate %OA. To take a temperature calculated %OA value, take the measurements at the Air Handling Unit. This means that the measurement will indicate the %OA for an entire area of the building, or the entire building depending on what area or areas the air handling unit serves. The reason the measurements need to be taken at the air handling unit is because there are often heating or cooling coils in the ducts or near the diffusers in some buildings which would adversely affect the readings and it is difficult to verify if they are present or not.

What Are Acceptable %OA Values

This is a popular question and it does not have an easy answer. There is no ideal %OA value because it depends on the airflow. If your airflow is high for the number of occupants, you may not need a high %OA. For instance, if you are delivering 1,000 CFM and there are 10 occupants in an office area, you would only need 20% OA to achieve the ASHRAE recommended 20 CFM/person.

(1,000CFM x 20%OA) /10 people = 20CFM/person

However, if you are only delivering 250 CFM in this same scenario with 10 occupants in the same office area, you would need 80% OA to achieve the 20 CFM/person recommendation.

(250CFM x 80%OA) / 10 people = 20 CFM/person

There is no easy answer to this question because the answer varies with the airflow and the maximum number of occupants. The best thing to do is to measure the airflow and find the maximum number of people that will be in the room. Then the following equation can be used to find the %OA that would be needed:

%OA = (CFM/person OA recommended x maximum number of occupants) / airflow

As an example, consider an office space where 20 CFM/person of outdoor air is recommended, where the maximum number of occupants is 30 and the Airflow is 1,800 CFM:

%OA recommended = (20 CFM/person x 30) / 1,800 CFM = 33.3% outdoor air recommended

References

[1]TSI Application Note *Traversing a Duct to Determine Average Air Velocity or Volume*, TI-106

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