Demand-Controlled Ventilation

The Challenges of Dynamic Reset of Ventilation

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O ver the years, SSPC 62.1 faced and dealt with many technical issues. For example, how to separate ventilation for people-related contaminants from that for building-related contaminants, how to account for both zone and system ventilation efficiency, how to determine intake locations with respect to outdoor contaminant sources, how to deal with environmental tobacco smoke, and how to specify minimum requirements for dehumidification, to name a few. While the committee has resolved most of these issues (at least for now), one big technical challenge remains: dynamic reset of ventilation.

Many refer to this challenge as "demand-controlled ventilation" (which usually addresses zone-level demand), but it's probably more inclusive to call it "dynamic reset" or perhaps "part-load ventilation control." Why? Because it's possible to reset intake airflow in response to the ventilation needs of individual zones for some systems, in response to system ventilation needs for other systems, and in response to both zone needs and overall operation for still other systems. Part-load ventilation control approaches can be used to reset the outdoor airflow requirement at the zone level in response to changes in population-based demand, at the system level in response to changes in system ventilation efficiency, and, in many cases, in response to both zone demand and system ventilation efficiency. Our industry has conducted a treasure hunt of sorts for possible solutions to the part-load ventilation control challenge, as shown in articles[1-5] by Stanke, Taylor, Warden, Persily, Mumma and others over the years, but it's still not clear that the engineering treasure—the solution—actually has been found!

Design Requirements

Most designers know that the Ventilation Rate Procedure (VRP) of Standard 62.1-2007,[6] requires the determination of the minimum breathing-zone outdoor airflow (V_{bz}) based on both people-related and building-related contaminant sources (the sum of the outdoor airflow required per person plus that required per unit area). Zone level calculation requirements are straight forward, easily understood and easily met.

The VRP also requires the determination of the highest minimum outdoor air intake flow (V_{ot}) required at the air handler, based on both breathing-zone outdoor airflow and ventilation system type.

Single-zone systems (one air handler, one zone, local recirculation only)—usually the simplest to design—require the outdoor air intake flow to equal the breathing-zone outdoor airflow requirement. The air handler for each ventilation zone in a building must be designed with enough outdoor air intake flow to properly ventilate the zone at peak population, with no credit for system-level occupant diversity.

Dedicated outdoor-air systems (one 100% OA air handler, more than one zone, no central recirculation)—also simple to design—require the outdoor air intake flow to equal the sum of breathing-zone outdoor airflow requirements. For constant-volume systems, the 100% OA air handler must be designed with enough outdoor air intake flow to properly ventilate all zones, assuming peak population in each zone. Again, no credit for system-level occupant diversity can be taken.

Multiple-Zone Systems

Multiple-zone systems (MZS: one air handler, many zones, central and/or local recirculation), offer the biggest design challenge, since system outdoor air intake flow (V_{ot}) depends on system ventilation efficiency (E_v) and the total outdoor airflow used by all zones in the system (V_{ou}). Using the MZS equations, designers must find E_v based upon both the fraction of outdoor air needed in the discharge air to the critical zone (Z_d) and the average fraction of outdoor air needed in the primary air to all zones in the system (X_s). The fraction Z_d depends on the design population in the critical zone and the fraction X_s depends on the primary airflow at the fan and the outdoor airflow used by all zones (V_{ou}), which depends upon the total number of people in the system. While they add steps to the design process, these equations allow designers to account for system population diversity (D) when finding V_{ou}, which can result in a significant reduction

in intake airflow compared to single-zone and constant-volume 100% OA systems, which must be designed to ventilate all zones at peak population.

So, for design purposes, all zones must be considered to be occupied at peak zone population, but for multiple-zone systems, the system may be considered to be occupied at the expected peak system population—somewhat less than the sum-of-zone peak population.

Operating (Part-Load) Requirements

During operation, when the population in a zone is less than the peak design population, it may make sense to reduce the outdoor airflow to the breathing zone, in an effort to match the current outdoor airflow to that needed by the actual (or estimated) population. In other words, it may make sense to dynamically reset breathing-zone outdoor airflow based on people-related demand. We call this kind of zone-level dynamic reset "demand-controlled ventilation." Several methods for zone-level DCV have been discussed in the Users Manual[7] and by Taylor[2] and Stanke.[1] These methods include time-of-day (TOD) scheduling, binary occupancy sensing (OCC), people counting (COU), and various approaches based on CO_2-sensing (CO_2). These methods may be implemented to control intake airflow directly (intake airflow controlled in proportion to CO_2 level, for instance) or indirectly (intake airflow controlled to a set point, calculated based on current estimated population, for instance). In any case, zone-level DCV has been used in the past and may continue to be used in the future.

But What About System-Level Dynamic Reset?

For single-zone systems, where outdoor air intake flow equals zone outdoor airflow, any of the zone-level DCV methods mentioned above can be used to reset intake airflow directly.

For dedicated outdoor air systems, things get more interesting. These systems typically use a constant-volume (CV) air handler to deliver the outdoor air directly to the occupied zones. For CV systems, no dynamic reset of intake airflow is possible, even when zone-level demand can be determined. However, for systems using a VAV air handler and local zone outdoor-airflow controls (sensors and dampers), any of the zone-level DCV methods mentioned above can be used to adjust zone outdoor airflow. The intake airflow at the air handler can be controlled to satisfy the outdoor airflow requirements for all zones, usually by maintaining the pressure in the ventilation-air supply duct.

For multiple-zone systems, things get even more interesting. In fact, so interesting (and perhaps so elusive) that Standard 62.1 includes no definitive requirements for the design and operation of systems using dynamic reset control approaches, nor does its Users Guide. Section 6.2.7 of the standard allows dynamic reset controls, but it doesn't prescribe approaches or limitations. Our industry needs more work in this area.

What are the problems? Here's a list of items to consider:

- People either come and go to/from the system (variable system population) or they merely move from zone to zone (relatively constant system population). So, what system population must be used for design purposes, that is, to find both D and V_{ou}? And what system population must be used for calculations during part-load operation?
- The VRP allows credit for occupant diversity (D) when finding the outdoor air used by the system (V_{ou}) at design conditions. In a sense, this diversity credit allows the design population in each zone to be reduced to a system average population. This makes sense, but what is the system occupant diversity at design when the system includes some (or all) DCV zones? Do these zones qualify for population diversity or must they be fully occupied for design calculations?
- Can designers spread the design system population among the zones in a worst-case fashion for design calculations, and ignore occupant diversity (use $D = 1.0$ in all zones) both for design and part-load calculations?
- Although the system may be designed using system occupant diversity, can the same diversity factor be used to solve the MZS equations for the intake airflow required at part-load? Does part-load diversity apply to all zones or just those zones with no DCV capability? After all, the part-load population in DCV zones might be lower than design population but higher than diversity population.
- How can the MZS equations be used to find required intake airflow at part-load conditions?
- Can part-load intake airflow be determined directly from DCV zone conditions, without using the MZS equations?
- How accurately must CO_2 sensors sense zone CO_2, or how close must TOD schedule estimates match actual population to ensure adequate part-load ventilation?
- How low can zone-level and system-level outdoor airflow be reset without adverse impact on zone-to-zone or indoor-to-outdoor pressure relationships?

Designers may already know or can easily find the answers to some of these questions, but answers to the others may prove more difficult. In any case, dynamic reset of outdoor air intake flow at part-load conditions clearly offers some technical challenges for designers.

Are there solutions to these problems? Yes. But, the committee, with help from both the research and design community, needs to study the problems carefully and determine reasonable solutions. In the meantime, designers can apply their imagination and control creativity to comply with the standard, since it offers neither definitive nor prescriptive requirements for dynamic reset control options.

Conclusions

So, dynamic reset of ventilation presents a technical challenge. SSPC 62.1 is stepping up to this challenge and has begun the process of addressing it via Addendum 62.1g (2007). But, the committee, along with the design and research community, has more work to do.

The more people thinking about this challenge the better. Be sure to review and submit comments on current and possible future addenda related to dynamic reset requirements. If you have ideas, please contact us by e-mail or via a change proposal or a

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research proposal. Or, if you think you can help more directly, apply for committee membership. One way or another, join the hunt for the dynamic reset treasure and the energy savings it promises!

References

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