Responsible HVAC Design for Hotel and Multi-Family Projects

Summary

Over the last two decades, "green" design has been incorporated into building codes in such a manner that the sum of the prescriptive requirements sometimes don't add up as a "whole." It seems as if many singular components, like envelope design and equipment efficiency, have been optimized, but seemingly no one has thought through all of the consequences of full implementation.

The provision of a tight, energy efficient envelope has a very direct consequence on HVAC design within the dwelling unit. The reduction of sensible loads, while ventilation loads remain constant, increases dehumidification challenges. Finally, manufacturers have not responded with equipment that is correctly sized for today's energy code compliant buildings.

This white paper explores some of the challenges that an HVAC designer faces on a hotel or multi-family project.

Fresh Air Ventilation

An occupant within a residential dwelling unit (i.e. hotel room/suite, apartment, or condo) can be viewed as a "polluter." Carbon dioxide, perspiration, body odors, and other physiological traits are a result of that occupant. When cooking occurs in the unit, similar pollution occurs. In order to avoid the buildup of these contaminants, dilution air is necessary. A modest quantity of fresh air is needed to dilute the space air volume with clean air. This need is sometimes referred to as "fixing pollution by dilution."

Direct provision of outside air is required when the envelope is tight!

Fresh air ventilation supply is especially important to a residential dwelling unit. For units that are constructed to present codes, the unit envelope is tight and cannot "breathe," so direct introduction is a necessity. In the past, most residential dwellings were exempt from a requirement to provide direct, mechanical ventilation to the space. The presence of operable windows (in sufficient quantity) and semi-permeable envelopes was enough to avoid that requirement.

Whether those were wise tradeoffs is arguable, but codes have now evolved such that operable windows will not meet requirements when the building envelope is constructed or renovated to meet the leakage/infiltration requirements of current energy codes.

So, it is fair to say that direct provision of outside air is required for residential dwelling units when they are constructed or renovated under recent building, mechanical, and energy codes.

Ventilation rates will vary by area, occupancy, and volume of the dwelling unit but a common one-bedroom apartment will require, by code, about 20-30 cfm of continuous fresh air flow. Some projects recognize ASHRAE Standard 62.2 as a requirement, alongside mechanical code requirements. This requirement is similar to code, but different enough to warrant review if required by a governing authority on a project. If both code and ASHRAE 62 compliance is required, then usually the most stringent will apply.

It should be noted that, in some cases, intermittent ventilation can be provided; however, those quantities must be sufficiently higher than the continuous values such that the average value is similar. Specific formulas are offered by mechanical codes and ASHRAE to prove a specific value for design.

From a design standpoint, providing an exact quantity of say, 45 cfm is difficult. Air balance techniques for residential style ductwork are not that precise. However, one device seeing implementation is the self-balancing air regulator. This is a device, usually 4-inches in diameter, that will limit airflow through it as long as a minimum upstream pressure (0.1 to 0.2-inches water gage) is provided. While low ventilation flow is undesirable, so is overventilation - it increases utility cost and upsets the optimal operation of the air handling unit.

Exhaust

Some contaminants within a dwelling unit are required to be exhausted before they "pollute" the unit. Toilet fumes are the most specific example of this; it is simple to understand. Cooking vapors are also an example, although a bit less intuitive. Direct exhaust is generally preferred when the vapor's content is so strong that dilution would not be effective.

Exhaust requirements, like fresh air requirements, are prescribed by mechanical codes, ASHRAE Standard 62 (.1 or .2) will also apply. The International Mechanical Code (IMC) requires 20 cfm of continuous exhaust per toilet room, or 100 cfm of intermittent exhaust. (for R-2, R-3, and R-4 occupancies). The continuous value should be used in most cases; this will be further discussed under the topic "Air Balance" next in this paper. The IMC also requires 25 cfm of continuous exhaust for kitchens, or 100 cfm of intermittent exhaust. Again, intermittent exhaust is difficult to provide as there is generally not a makeup air path to support it when construction is tight.

Space Air Balance

One concept generally overlooked as the codes have evolved is space air balance. Since the space envelope is tight with little to no leakage, the airflow that is brought into the space must equal the airflow that is exhausted.

Space air balance is critical. Otherwise airstreams will churn or stall.

So, if one chooses to exhaust a certain airflow, there must be a corresponding fresh air flow rate. If not, then the exhaust fan will simply "churn," and little to no exhaust will result. Likewise, if a quantity of fresh air is needed, there must be an exhaust quantity to match. Otherwise, the fresh air will stall, with little to no ventilation occurring. Because of the tightness of the space, these quantities must essentially be equal, as there is no relief path. The space, with all doors closed, will operate at a neutral pressure.

Fortunately, ventilation and exhaust requirements are very similar. Our example one-bedroom apartment may require 45 cfm total exhaust and 30 cfm ventilation. By allowing 45 cfm for both values, the requirements may be met, again at a neutral pressure. While the ventilation requirement is in fact less, failing to provide the equal quantity will starve the exhaust system, as no path for makeup will exist.

The concept of air balance should be remembered by designer and occupant. The scenario of using intermittent exhaust to the outdoors (i.e. a direct exhaust kitchen hood) is not possible, without a source of makeup air. The provision of conditioned makeup air is generally cost-prohibitive for multi-family projects.

Clothes Dryers

We have emphasized the concept that a dwelling unit does not leak air inward or outward. So, what will happen if a clothes dryer is introduced to the unit?

Dryers will generally vent air out the back and to the outdoors. The primary need for a vent is not to discharge lint - that is for the lint filters to catch. A vent is required to exhaust warm moist air out of the space where it would cause excessive heat and humidity. Most residential dryers will exhaust somewhere between 100 cfm and 200 cfm of air flow while in operation, although one should check the manufacturers data when working on a specific design.

Dryers are problematic to space air balance. Innovative solutions are needed.

A traditional dryer will not function well in a tight dwelling unit. The air will not be exhausted, because it cannot be replenished. The dryer will simply churn, without drawing air through itself. This will result in excessively long drying times and perhaps complaints from occupants.

Now, if there was a source of makeup air, this issue could be resolved. Unfortunately, residential dryers do not have makeup connections - they simply draw air from stamped openings in and around the dryer enclosure. Further, attempting to provide some type of makeup air in the intermittent fashion that would be required of it would be futile.

A scenario that may work for some projects is to provide an undercut entry door. Many building codes will allow such an undercut up to 3/4 inches in height, even with fire doors, and this may be just enough to allow sufficient makeup air for a modest dryer, if makeup air is in turn provided to the corridor. Caution should be exercised though, as privacy concerns sometimes exist at entry doors. As always, a complete code study for the project location is needed to confirm.

Most occupants will desire washer/dryer connections within their dwelling unit. What can be provided? In fact, there are "ventless" dryers available on the market. Instead of exhausting their air, they simply recirculate it but through a dehumidifier that cools and dries the air. These dryers have become somewhat more common in recent years but are still unknown to some. They do have additional cost, and they will ultimately require more maintenance. However, they provide a solution within a space that may be otherwise unable to support a dryer.

HVAC

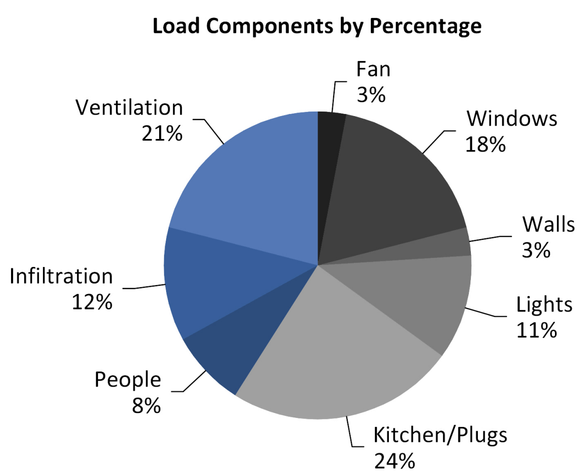
Today, it goes without saying that a dwelling unit will be heated and cooled. In fact the International Energy Code requires both components.

In recent years, adopted energy codes have prescribed building features (independent of HVAC) that help minimize energy use. While acceptance and enforcement has moved slowly, the market is now finally delivering buildings with continuous insulation, improved window performance, vapor barriers, and LED lighting. Appliances like televisions and water heaters are more efficient. Cooking occurs more often in a microwave than it does on a range.

A result of these energy saving measures is that the required heating and cooling capacity is much less. Initially, this sound like good news - until an exact unit selection is pursued. A modest one-bedroom apartment, depending on orientation, will have a peak cooling load as low as 6,500 Btuh. A 350 square foot hotel room may be as low as 5000 Btuh, even in a moderately humid southeastern location.

Right-sized HVAC units are crucial for a dwelling unit. Unfortunately, they are not available!

Available equipment is sorely lacking in this range. Commercial split systems are widely available only down to 18,000 Btuh. A few 1-ton units are available, but most don't meet current efficiency requirements. Units that use variable refrigerant flow (VRF) technology are available, but the are not well-suited for applications that require fresh air ventilation. Nor do they perform well in humid climates, especially at part load conditions. PTACs are available down to 7,000 Btuh, but are less than optimal for multi-room units, and they sometimes lack precise outside air control.



Further, as the unit sensible loads have been reduced, the fresh air loads have stayed constant, if not increased. As a result, the fresh air component is now a much greater percentage of the overall load that must be addressed. The chart above illustrates that that over 40% of a typical apartment load has a latent load component.

While the load profile has been significantly reduced, available equipment has not changed to match the market demand. VRF, a poor solution for humid areas, does represent new technology but can only accomplish sensible cooling. It cannot effectively condition the "humid" side of the load. Dedicated outside air (DOA) systems are often suggested, but they are expensive and require fire rated chases for most multi-story buildings. Further, they must be metered separately from discreet dwelling units, so they won't qualify under many housing development guidelines. Water-source heat pumps (WSHP) perform similar to split systems, they just use a cooling tower for heat rejection. Four-pipe systems, using chilled water and hot water, perform best, but rarely seem to fit in the budget of a multi-family project.

Improvement is most needed in the small split-system market area.

There is a need for equipment to be designed and available for these smaller loads, while also having adequate latent heat performance. Sadly, the opposite has occurred. HVAC equipment should have good part-load performance as well. This second statement is equally important to the first. Improvement is most needed in the small split-system area. Units smaller than 1.5 tons are sorely needed to satisfy small apartment needs.

Dehumidification Cycles

Reheat is an acceptable option by code!

One method of ensuring adequate dehumidification of an over-sized air conditioner is to continue operating the compressor, over-cooling the space, while also heating (or re-heating) the air to maintain comfort. This is of course wasteful, as one is simultaneously heating and cooling. However, it may be the last resort when no reasonable option exists. Reheat has long been discouraged, even within energy codes and standards; however, this unfortunate result may actually be acknowledged, if not endorsed by recent versions of ASHRAE Standard 90.1. The 2016 version of that standard allows reheat in individual systems that are less than 40,000 Btuh, which includes virtually all dwelling unit systems. The IECC has no provision that would prevent the use of reheat.

Conclusion

Today's HVAC design for residential dwelling units is especially challenging. A fundamental principle is that the building envelope is now tight - it doesn't leak and will not support ventilation airflow that "just leaks through the cracks."

Fresh air and exhaust requirements must now be established through code and standard research and then be balanced with each other. Fresh air must be provided by mechanical means; operable windows are no longer a code compliant solution. Clothes dryers are now a real challenge to support within a dwelling unit, unless a more costly ventless dryer is used.

Finally, HVAC equipment is not being provided in right-sized capacities and with part-load performance that will allow it to be correctly applied to modest-sized residential dwelling units. This paper has attempted to shed light on this discrepancy and encourage manufacturers to create optimal and innovative equipment designs.

applied
engineering

405 Erin Drive
Knoxville, TN 37919
www.appeng.com

For more information:
Contact: Jack Hopkins, P.E. Principal