Dedicated Outdoor Air Systems

Detecting System Degradation

Preventing dedicated outdoor air system performance degradation requires continuous performance assessment.

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Preventing dedicated outdoor air system (DOAS) performance degradation requires continuous performance assessment. The incentive is providing a healthy and productive work environment while maintaining responsible energy use. The focus here is on early detection and warning.

The DOAS's objective is delivering required outdoor air (OA) to occupants and removing the outdoor air load and the entire building latent load. This is accomplished by cooling and dehumidifying the ventilation air (100% OA) in summer with a cooling coil aided by total energy recovery (TER). It then directly delivers that air to conditioned spaces in a dedicated duct system. In winter, OA is heated and humidified with the help of TER before delivery to each conditioned space.[1,2]

Consequences

This performance assessment need is not unique to buildings served by DOAS systems. In fact, when the entire nonindustrial building stock served by conventional HVAC systems is analyzed, 20% – 30% have problems either with building-related illnesses (5% – 10%) or sick building syndrome (10% – 25%). These facilities began as buildings without known problems and then degraded. In all facilities, early detection and correction is required to avoid disabling problems later.

Woods[3] estimates the consequences of ongoing system performance degradation in the U.S.: 20% of workers are experiencing health related symptoms, 20% of workers are experiencing hampered performance, and 50% of workers have lost confidence in management's ability to deal with the situation.

A major economic investment is needed to mitigate the problem or renovate/replace the facility to recover "goodwill" after system performance degradation. Fisk[4] estimates the economic impact on U.S. businesses is as much as $208 billion per year, including increased respiratory diseases ($6 billion – $14 billion per year), increased asthma and allergies ($1 billion – $4 billion per year), sick building syndrome ($10 billion – $30 billion per year), and reduced worker productivity ($20 billion – $160 billion per year).

Detecting and Intercepting Degradation

Causes of system performance degradation can be divided into three categories: insufficient diagnostic and alarm tools built into the system for early warning of degradation; a lack of awareness of problem buildings' economic consequences; and, indifference.

Degradation of the DOAS performance can occur in three major areas. The supply air quantity can be compromised. The building pressurization function can be compromised. The supply air conditions can be compromised.

Compromised supply air quantity. This could result from failures in the supply fan motor, bearings, or belts. It could also be the result of dirt loading at the filters, enthalpy wheel, cooling coil, or other unintended filters such as grills, diffusers, etc. These could all impact the DOAS's ability to meet the ventilation requirements, latent load duty and its portion of the space sensible load. A failure to deliver in these areas will be immediately noticed by the occupants. Degraded air delivery can be directly monitored with a flow-measuring station in the supply air ductwork, as indicated by FM 1 in *Figure 1*. This flow-measuring device is a must.

Compromised building pressurization. If the magnitude of envelope leakage entering or leaving the building becomes excessive, the enthalpy wheel thermal performance degrades. This adversely impacts the supply air conditions and ability to cool and dehumidify. Positive pressure loss on the building will cause leakage through the envelope, leading to excessive latent loads in the space that may be beyond the DOAS system capacity. Humidity control problems will occur along with the potential for mold and fungi formation. These conditions may be noticed by the building occupants once the situation has become critical. Therefore, the system must have an instrument to monitor building pressurization degradation. While many tools exist to achieve this task, I prefer an envelope flow magnitude and direction sensor. This instrument is labeled FM 2 in *Figure 1*.

Compromised Supply Air Conditions. Degradation in the ability to hold the desired supply air temperature impacts the DOAS's ability to deliver the required space sensible and latent cooling. Such degradation will lead to occupant thermal discomfort, diminished humidity control, and potential microbial growth problems. The supply air condition degradation can be caused by something as simple as enthalpy wheel drive belt or motor failure, deterioration of the enthalpy wheel effectiveness, loss of cooling capacity at the cooling coil (because of insufficient chilled water temperatures or flows, or compromised direct expansion function), or fouling of the cooling coil. It is recommended that the following sensors be installed and programmed to alarm when the values are out of range: sense enthalpy wheel sensible effectiveness (may be compromised by any of the mechanisms discussed earlier) with three temperature measurements, two in the OA stream one before and one after the enthalpy wheel, and a third in the relief air upstream of the EW (identified as T1, T2, and T3 respectively in *Figure 1*); sense the supply air temperature (need for control as well) downstream of the cooling coil and identified as T4 in *Figure 1*; and sense the temperature of the CC inlet fluid temperature (identified as T5 in *Figure 1*).

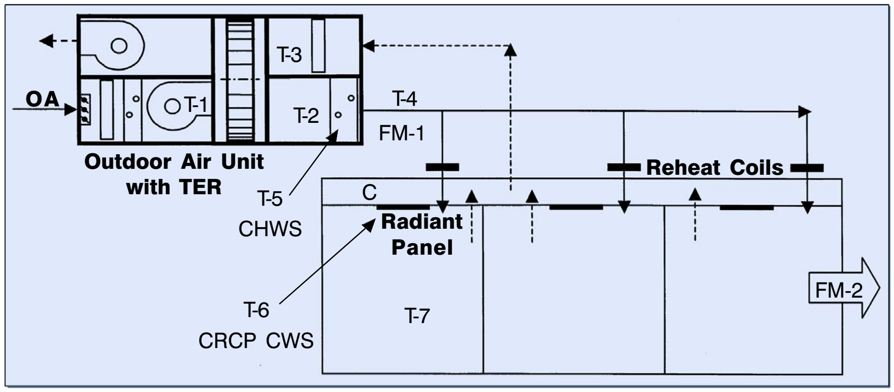

Figure 1: DOAS with parallel radiant cooling.

Ceiling Radiant Cooling Panels

The industry has several options for parallel sensible cooling, including conventional VAV systems, fan coil units, unitary equipment, water source heat pumps, or ceiling radiant cooling panels (CRCP). Any of these choices can provide acceptable to excellent system performance. U.S. industry is quite familiar with all these choices with the possible exception of radiant cooling. So, the parallel system discussion of early detection and warning in this column will be limited to CRCPs.

Operating characteristics and design procedures for CRCPs are detailed in ASHRAE literature.[5] When used in parallel with DOAS, which maintains the space dew-point temperature (DPT) at or below design conditions and bears a portion of the design space sensible load, the CRCP is controlled via the room thermostat to remove the balance of the space sensible loads. CRCP capacity control can be achieved with either constant volume variable temperature or variable volume constant temperature cooling fluid. In either case, the cool panel fluid temperature is held slightly above the space DPT.

Should the panel fluid temperature control fail to perform correctly, passive fail safe condensate sensors hard-wired into the zone control valve power circuit cause the zone control valve to close under spring return power if condensation forms. This fluid temperature control failure action isolates the panels from the source of cooling, avoiding damaging condensation. Should the passive fail-safe sensor isolate the panels from the source of cooling, it means that the CRCP sensible cooling has been turned off and the occupants of the space will be aware of a thermally uncomfortable situation. Such an event signals something is wrong with the system, and needs immediate attention.

Condensation can occur only when either the panel water temperature is too low, or the room DPT control has been lost either by a failure in the DOAS equipment or unplanned changes in the latent loads in the space. The condensation causes must be identified and corrected before manually resetting the passive fail-safe condensate sensor. Instrumentation necessary to provide early detection and warning pertaining specifically to the CRCP include: panel supply water temperature, indicated as T6 in *Figure 1*, space temperature, T7, and the condensate sensor C.

System Sizing and Degradation Detection

Some in the HVAC design community have sized the chiller large enough to meet the load if the enthalpy wheel malfunctions. Consequently, any degradation or failures with the enthalpy wheel part of the system easily could go undetected without detection and warning equipment. Even the detection and warning equipment would not need to be acted on expediently to maintain health and comfort. But, any degradation of the energy recovery components would have serious operating cost consequences. However, if the chiller is properly downsized because of the enthalpy wheel, and it degrades below an easily detected point, comfort cannot be maintained, so expedient, corrective action will be demanded. Only indifference would allow this to occur when early detection and warning instrumentation is available.

Modest oversizing of the DOAS flowrates or CRCP areas are recommended safety factors, and should not adversely impact energy use or early detection.

Conclusions

Detecting and intercepting HVAC system degradation is important in ensuring the long-term performance of systems. When properly designed and implemented, a high level of performance can be expected. Unfortunately, most HVAC systems do not give early and continuous indications of degradation to occupants or management until the situation has progressed too far.

References

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