Camfil Farr

Technical Services Bulletin

Wet Filters in HVAC Systems

Applying Air Filtration in a Humid or Saturated Environment

Many owners, designers and installers have experienced the 'wetting' of air filters in HVAC systems, especially when filter banks are located downstream of cooling coils or humidification equipment. This paper will discuss some of the causes and make some recommendations to assist the designer and building operator in improving the likelihood of filters remaining dry.

While the phenomena of wet filters has been seen in a variety of applications, it is most common in systems employing a high percentage of outdoor air, with blow-through air handling equipment, in regions of the country with high wet bulb design temperatures.

The health and indoor air quality implications of this problem are substantial. Available surplus moisture is the single greatest predictor of mold and microbiological growth. Since filters collect spores and nutrients, and neither coils nor ductwork are assembled in aseptic conditions, the potential for mold growth throughout the HVAC system is present. Although some manufacturers have been proponents of adding biocides to filtration media, studies have shown that a small amount of volatile pesticide applied to air filters is not conducive to solving the long term potential for biological growth, either on the filter surface or, most certainly, throughout the system. This problem should be addressed using a 'whole system' approach and applying principles detailed in ASHRAE Handbooks and publications.

An air filter's design performance characteristics can be compromised when wet; including pressure drop, dust holding capacity, and efficiency. The degree of this compromise will vary with the type of filter and the principle of filtration used. Filters incorporating principles of straining, interception, or diffusion are, less likely to be affected than those incorporating the principle of electrostatic charge. Additional considerations with regard to the applied principles may be found in the ASHR*AE Handbook, HVAC Systems and Equipment*. Further, this wet filter condition, when combined with the various mechanisms promoting condensation, can in many cases, be an early sign signifying that such condensation (and the related increased potential for biological amplification) may also have occurred elsewhere in the system.

Two initial areas should be investigated whenever wet filters are discovered, as the problems may be relatively easy to cure. First, check for improper humidifier operation. Leaking control valves, etc., may create an additional load on the system, leading to the introduction of saturated air to all downstream system components, including filter banks.

Second, check for water carryover from the cooling coils. Although the vast majority of systems are designed at face velocities that will prevent this action (500 feet per minute (fpm) or less), moisture carryover can often result when uneven air distribution across the coil face allow areas of higher velocities to exist. Generally, velocities over 600 fpm may produce moisture carryover. If this condition is suspected, a diffuser section in front of the coil is recommended to provide an even velocity over the face of the coil. This may be complemented in many cases by a moisture eliminator filter section behind the coil and upstream of filter banks. Both components should have appropriate drainage provisions.

Cases of this wet filter phenomenon can still persist despite heeding these precautions. Conditions do exist where a moisture separator drain is bone dry and yet the filters are very wet, as shown in Graphic A. In this example, there is no apparent physical explanation for moisture condensation.

Measurements of the air approaching the filters exhibited 55° F saturated air (100% relative humidity) at a velocity of 300 fpm. There was no carryover from either the coil or the filters. Further, it was reported that considerable quantities of water were dripping from the supply air registers at the duct system terminus.

In cases such as these, the condensation may be caused as follows:

If it is assumed total enthalpy remains constant (there is negligible heat exchange with the surroundings), and that when a gas flow is accelerated, the temperature falls.

It can be shown (Graphic A) when a saturated 55° F air stream is accelerated from 300 to 1800 fpm, the temperature falls approximately 0.03° F and water will condense out of the air. Even a relatively small 12,000 CFM system, will produce 3.4 pounds of water in just eight hours under these conditions.

This moisture is available wherever this acceleration occurs throughout the system. Because the air is still saturated, the water cannot evaporate and the wetness will persist until the thermodynamic conditions change. In affect moisture is squeezed out of the air by compression.

This airflow acceleration **-** temperature depression can occur inside filter elements themselves as well as at any point throughout the system that accelerates flow. Any restriction to flow will cause an air current to accelerate around it (similar to an airplane's wing). Thus, a support strut in ductwork could be wet while surroundings are dry. A diffuser at the terminus may also exhibit condensation because of the vane design incorporated to increase velocity and throw.

Typically, the free flow area just inside an air filter's pleat passages may be only 50% of the full-face area. Acceleration occurs around the restriction. Predictably, components of the air filter can become wet. In addition, with supersaturated air conditions, individual media fibers may become nucleation centers for condensing droplets and the filters may again exhibit moisture.

Additionally, moisture is likely to be evident wherever the saturated air stream is in proximity to a colder region, such as near a leaking cold outdoor air stream, a poorly insulated cooler duct, or pipe, etc.

Recommendations

A number of steps can be taken to reduce, but not completely eliminate, the possibility of condensation on filter media.

Certain system design considerations have proven effective in reducing the frequency of condensation occurrence. Each project’s unique requirement will give the designer an indication of which, or all, of the following suggestions to follow.

- Establish routine seasonal inspections of humidifiers to assure they are properly controlled.

- Verify a low percentage of carryover by field demonstration thus assuring that uniform design air distribution over coils is maintained in practice.

- Consider the use of properly drained diffuser sections upstream of moisture producing equipment (cooling coils, humidifiers, etc.) and if necessary, similarly drained moisture eliminators downstream. Water carryover is unacceptable in an HVAC system in that it will damage air filters irrespective of the type or brand that is used.

- Keep a minimum of 1° F, and if possible, 2° F separation between wet bulb and dry bulb temperatures leaving the cooling coil by design. While this strategy will dramatically reduce the incidence of wet filters, it will not guarantee total elimination as part load conditions will likely cause air leaving the coil to be at dew point or saturation.

Design separation of wet bulb and dry bulb temperatures can be accomplished in a number of ways including one or a combination of the following:

- Use reheat. While this method will require additional energy and has traditionally been avoided for reasons of first cost and control difficulties, it is the most certain method to eliminate the problem.

- Consider a draw-through design, locating the fan between the coil and the filter banks. Although the fan generated heat added to the air stream may be undesirable, and may require a diffuser section upstream of the filters for uniform velocity, it might be sufficient to provide the necessary reheat to move the air stream off the saturation line. Serious consideration should be given to proper mixing of air upstream of the coils as well.

- Use separation of wet bulb and dry bulb as prime criteria in coil selection. To do so, evaluate selections with the coil supplier when facing the possibility of near saturation conditions. Suppliers will vary fin spacing, piping arrangements, coil circuiting, control, and flow rates, that impact leaving air conditions. Separation of wet and dry bulb temperatures may be very easily accomplished.

- Include separation of wet bulb and dry bulb as a consideration in the system control strategy. While theoretically possible, this method may prove difficult to achieve in practice, especially when considering it's potential compromising impact on system-wide requirements.

- You can also design the filtration system to resist the high moisture conditions that may occasionally exist. Each of the following methods has been employed with success and should be considered in total when encountering the requirement to mount filter elements in a saturated air stream:

- Reduce filter bank face velocity relative to the coil exit velocity. As a minimum, we recommend a 25% differential (IE: in a saturated air stream, a coil bank designed at 500 fpm should be followed by a filter bank at 375 fpm maximum).

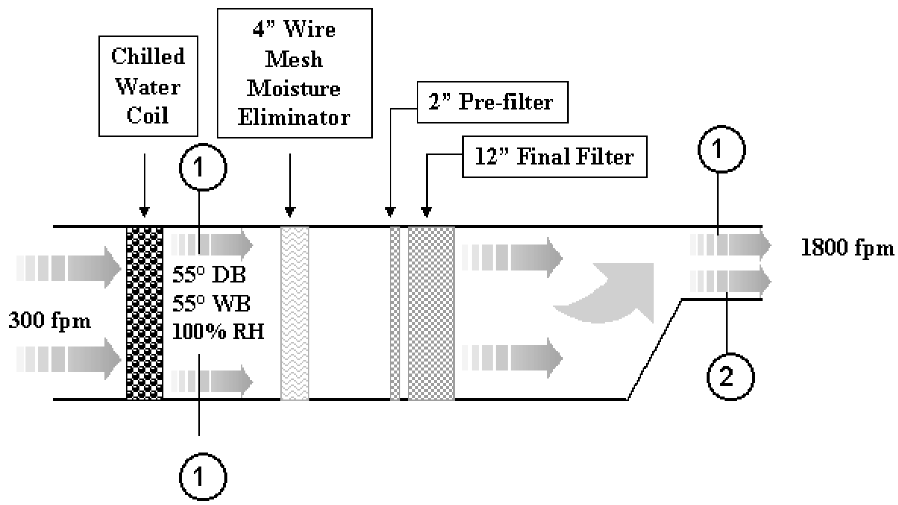
- Certain filter elements exhibit preferable characteristics based upon the use of different types of media. Filter elements employing wet-laid media may exhibit improved performance when operated continuously above the saturation line. Camfil Farr's Aeropac and Durafil are constructed using wet-laid media.

While independent tests suggest that lower pressure drop filters absorb less moisture, there are many factors at play when filters are operated in a wet or saturated air stream. It is inappropriate to conclude that lower pressure drop alone is the reason for these observed differences. Media velocity, difference in fiber size, as well as fiber distribution also contribute to overall performance when operating under these conditions.

The use of filters that retain most of their specifications when returning to normal operating conditions after saturation is highly recommended. Cartridge type filters will suffer less damage after drying out than non-supported bag type filters, while retaining their superior structural integrity. This may be a critical product requirement should this saturation situation be anticipated. As a filter absorbs moisture, it's pressure drop can increase significantly. Additionally, after prolonged dampness on partially caked filters, sedimentation or a cementing process can occur which may substantially raise the air filter's pressure drop. Should this occur, the filters need to be replaced.

Follow ASHRAE guidelines to maintain adequate distance upstream of filter banks to insure uniform design velocity at the face of the filter bank. In a blow-through design, locating a filter bank 18" downstream of equipment that accelerates the air to twice the coil velocity is certain to create problems. Absolute minimum separation of the filter bank from other system components should be 20 to 40" if only to allow for service access. In cases where the fan is located directly upstream of the filter bank assure that a minimum of 2 ½ duct diameters is incorporated to promote uniform airflow across the filter bank. The duct section before the filter should be at least the same duct diameter as the filter bank face area. For additional protection, or in areas of limited space, install an air diffuser section to correct airflow.

Because Mother Nature is so unpredictable, it's probably impossible to permanently eliminate wet filters in all circumstances. We believe the aforementioned suggestions will reduce the frequency of its occurrence and unquestionably result in a better indoor environment.



For the following please reference ASHRAE Handbook of Fundamentals (1997, Chapter 6:

$$\dot{m}\ {}_1q_2 = rh_a [(h_1\text{-}h_2) - (W_1\text{-}W_2)hw_2] + KE_1\text{-}KE_2 = 0; \quad @\ KE = rh_a \frac{V^2{}_2\text{-}V^2{}_1}{2gJ}$$

$$\dot{m}\ [(h_1\text{-}h_2) - (W_1\text{-}W_2)h_{w2}] = \frac{V^2{}_2\text{-}V^2{}_1}{2gJ}$$

For acceleration from 300 fpm to 1800 fpm:

$$\frac{V^2{}_2\text{-}V^2{}_1}{2gJ} = 0.01746 \frac{\text{Btu}}{\text{1b D.A.}}$$

Using linear interpolation, and numerical iteration from 55° F and saturation; this increase in kinetic energy gives a temperature depression of 0.029° F and water condensation (w_1-W_2) of 7.627-06 lb H_2O/1b D.A. for a small 12,000 CFM system. This equals 3.4 pounds of liquid water in 8 hours.

<u>Document References</u>

1997 ASHRAE Handbook of Fundamentals, Chapter 6
1995 ASHRAE Handbook of HVAC Applications