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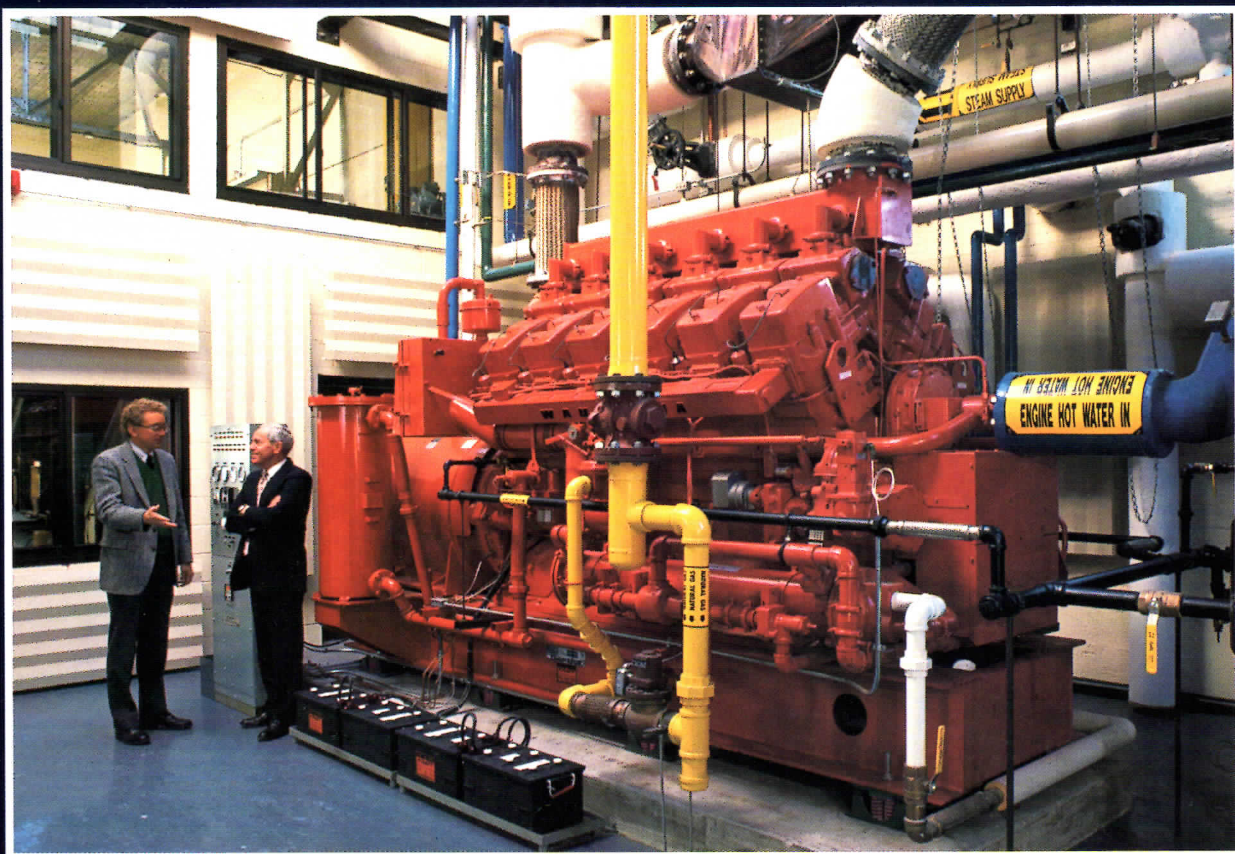

PRACTICAL APPLICATIONS FOR INNOVATIVE HVAC/R SYSTEMS ENGINEERS

CONSIDERATIONS IN DESIGNING DRIER, CLEANER HVAC SYSTEMS

A look at the problems that produce wet hvac systems, and possible solutions.

BY WARREN TRENT, P.E. AND CURTIS TRENT, PH.D.

The number of wet, corroded, and contaminated hvac systems in this country has reached alarming proportions. There are so many deficiencies in the design of existing systems that it is impossible to maintain them in a dry, clean, and healthy condition.

We have examined hundreds of hvac systems throughout the southeastern U.S., during the past two cooling seasons. Of the systems examined, most were wet inside, corroded, and rife with molds and other fungi. These observations are consistent with those reported by others from other parts of the country during the past five to 10 years.[1,2,3]

Maintenance efforts, equipment damage, and surrounding property damage associated with these wet hvac systems is extensive and costly.

In addition, wet hvac systems are significant contributors to indoor air contamination, which threatens human health and escalates the cost of building ownership. An article in *National Safety and Health News* states:

"Improperly designed and maintained hvac systems have been found to be a major cause of indoor air contamination. Inhalation of microbial contaminates that have been able to enter and breed within a heating, ventilating, and air conditioning system can cause allergic reactions that result in inflammation of the nose (allergic rhinitis), the airways and alveoral spaces (allergic asthma), or alveoli and bronchioles (hypersensitive pneumonitis)."[4]

Within the hvac industry, it is well recognized that wet and contaminated hvac systems are widespread. There is, however, less agreement on the cause of these conditions.

Evidently, OSHA assumes that the cause of wet and contaminated hvac systems is primarily the lack of adequate maintenance. At least its proposed rules on indoor air quality reflect this view.[5] These proposed rules require employers (building owners-users) to define and implement compliance programs in which maintenance is the prime consideration.

In reality, it is probably not economically feasible to keep most existing hvac systems dry inside and free of contaminating biological agents through maintenance alone. In a practical sense, it may even be impossible. Yet the difficulty of maintaining dry and clean hvac systems is not inherent in the hvac system itself. Instead, it is the result of overall system design deficiencies.

FACTORS ESSENTIAL TO DRY AND CLEAN HVAC SYSTEMS

Well-designed hvac systems, which limit the presence of condensate to the surface of the cooling coil and to a small condensate drip pan (that drains well), will remain essentially dry and generally free of contaminating agents.

Unfortunately, today there are few such systems.

Design deficiencies that we have observed, that are largely responsible for wet hvac systems include the following:

- Excessive airflow;
- Deficient airflow;
- Inadequate provisions for ventilating air;
- Non-insulated coolant or refrigerant lines in the airflow path;
- Improper blower (fan) location;
- Inadequate filters and filter holders;
- Highly slanted cooling coils;
- Unsuitable drip pan drain ports position and design;
- Long, undulating, and poorly routed condensate drain lines;
- Unduly large condensate drip pans; and
- Inadequate seals on condensate drain lines.

Excessive airflow. Excessive airflow can cause condensate to be blown from the cooling coil onto internal surfaces of the hvac system. The capacity of cooling coils to resist condensate blow-off varies widely, depending upon the flow area and fin design; that is, number per inch, type of materials, and surface treatment.

Some equipment manufacturers allow coil velocities (based on coil face area) up to 600 fpm. This is near the maximum-tolerable design velocity and should be avoided.

since it provides no margin for operating variations. A velocity of 400 fpm, or 1 sq ft of coil face area per nominal ton of cooling capacity, is a much better value.

Duct design and filter selection are important variables in maintaining suitable air velocity through the coil. Each must be considered and treated in order to avoid excessive airflow.

Deficient airflow. Too little airflow in a unit designed for constant airflow, reduces the temperature of air leaving the coil below the nominal value. If the temperature falls below the dewpoint of the air in the conditioned space, moisture can form on the supply grilles.

Duct design and air filter system selection are critical variables in avoiding deficient airflow. Each must allow for possible variations during normal operation, including increase in pressure loss through a dirty filter.

Inadequate provisions for ventilating air. The ventilating air rates and the maximum indoor humidity of 60% established by ASHRAE Standard 62-1989 place a very high latent heat load on hvac equipment. In humid climates, conventional hvac systems — without reheat provisions — cannot satisfy these requirements.

Providing the required ventilating air without controlling indoor humidity, may create more serious problems related to health and comfort. In some instances, a separate system dedicated to processing ventilating air may be the best choice.[6,7]

The consequences of supplying ventilating air without adequate dehumidification are uncomfortable room humidity and contaminated cooling air supply ducts, room surfaces, and room contents.

In reality, it is probably not economically feasible to keep most existing hvac systems dry inside and free of contaminating biological agents through maintenance alone.

Non-insulated coolant or refrigerant lines. Coolant lines passing through the cooling airflow path condense moisture that can drip onto the floor or onto components inside the hvac unit. Every such line should be covered with waterproof insulation.

Improper blower (fan) location. Improper blower location can result in high-velocity airstreams or vortices that can entrain condensate and blow it onto the surface of internal components.

The flow pattern of air entering the cooling air blower is not uniform. For example, in a squirrel cage blower, there is a core of high-velocity air approaching the blower inlet that extends some distance away.

Hence, if the blower is placed too close to the cooling coil, the high-velocity airstream will carry condensate into the blower. The non-uniform flow field can also develop vortices that entrain condensate from the cooling coil or the condensate pan, and blow it into the system.

The equipment manufacturer and the system designer should be able to assure the customer that no such problems exist. The necessary data can be developed through computational fluid dynamics or properly conducted flow tests.

Inadequate filters and filter holders. The most commonly used air filters (some with arrestance efficiencies above 90%) have an ASHRAE dust spot efficiency so low that they are simply rated as less than 20%.

According to Ottney, a filter must have a dust spot efficiency rating of about 25% to prevent dust from adversely affecting the cooling coil.[8] Dust deposited on cooling coils affords a breeding ground for biological contaminants, reduces the airflow area, and increases the potential for condensate blow-off.

A leaky filter holder can greatly reduce or even destroy the effectiveness of the most efficient air filter. This is a weak feature in most systems.

Highly slanted cooling coils. Highly slanted coils tend to drip condensate onto the floor of the hvac unit, beneath the coil. Extension of the condensate drip pan to handle this situation creates an even greater problem, as discussed below.

In addition, drip pans under slanted coils usually extend upstream of the coil. In this arrangement, condensate stands at the base of the coil at a level equal to the pressure differential across the coil. This standing water creates a growth haven for algae and other organisms.

Unsuitable drain port locations. Proper drain port location is essential for adequate condensate drainage. Acceptable drainage requires that drain ports be located flush with the lowest point in the bottom of the pan. In addition, the pan should be slanted toward the drain port, or the hvac unit should be tilted toward the drain exit.

Side drain port connections must be the male type, since female connections require an internal fitting that prevent complete drainage and cause condensate to stand in the pan. Bottom drain ports are preferred over side ports.

Long condensate drain lines. Long condensate drain lines are synonymous with condensate flooding problems. Dips, common in long lines, form water traps. Condensate caught in these traps supports the growth of algae that can block the flow. Also, double traps form air locks that prevent condensate flow. In addition, the fittings required for rapid turns in drain lines catch debris and block condensate flow.

If it is absolutely necessary to use long drain lines, give careful attention to supports that ensure a suitable drain slope without dips, and line routing that avoids abrupt turns.

Unduly large condensate drip pans. The large condensate pan is a major source of contaminants.

In systems with 20 tons of capacity and larger, the condensate pan often covers the entire floor beneath the cooling coil and the blower. Pan areas in excess of 50 sq ft are not uncommon.

A condensate control device for draw-through hvac systems

Controlling the flow of condensate from the drip pan of a hvac system is essential to avoiding a wet, corroded, and contaminated interior. This requires a reliable seal in the condensate drain line — a seal that will prevent the ingestion of outside air, through the drain connection, and allow condensate to flow unimpeded from the drip pan.

Current practice is to use a condensate trap to form the required drain-line seal. Despite this practice, the trap is unequivocally unsuitable for this purpose. It is far too failure-prone and unreliable. In fact, dysfunctional condensate traps account for most wet, corroded, and contaminated hvac systems.

A condensate control device, which is free of all the problems that plague the condensate trap, is available from Trent Technologies.

The "CostGard" provides a simple and reliable seal that meets all the requirements of the 1994 Standard Mechanical Code.[11]

The 1994 Standard Mechanical Code page 36, section 304.8.2 states:

"The condensate drain system shall provide a seal that prevents ingestion of air or other gas, through the condensate drip pan drain and overflow connections, from all outside sources, including the condensate disposal place, during all operating conditions."

CostGard is applicable to draw-through hvac systems up to 100 tons of cooling capacity. Installed in the condensate drain line, it ensures unimpeded flow of condensate from the drip pan. And it prevents the ingestion of outside air under all operating conditions. It has no moving parts.

The device applies hydraulic and pneumatic forces, readily available in the hvac unit. Each of the critical features of the device was established through analyses and development testing, over a period of more than six years.

One key feature is that CostGard uses air for a seal instead of water. Thus, it negates the condensate (water) problems associated with the condensate trap. Every aspect of the device is covered by patent claims.

Operating principles are illustrated in Figure 1.

During both heating and cooling operations, the air seal is formed as follows:

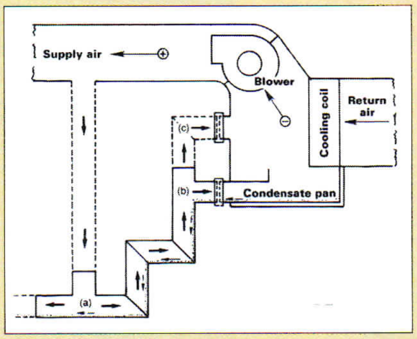

Figure 1

Figure 2

Fresh air from the blower discharge is supplied to point (a) at a pressure slightly above atmospheric. Some of the air flows away from the hvac unit, thus preventing ingestion of outside air. A portion of the fresh air returns to the hvac unit, passing through points (b) and (c). The quantity of air returning to the unit is minimized by the high pressure loss in the mitered elbows. This pressure loss, plus the air flowing through the bypass connected at point (c), ensures that air entering the condensate drip pan does not produce blowing, geysering and an aerosol mist.

Condensate flows through the device without being trapped. At the same time, the counterflow of condensate and air creates a pulsing action that ensures free passage of debris. Hence, the potential for freeze-up and flow blockage, common problems with traps, is nil.

A typical field installation of the device is shown in Figure 2.

Installation of this device alone does not ensure that draw-through hvac systems remain dry, clean, and uncontaminated. But used in conjunction with known and accepted design practices, it makes it possible for architects and engineers to design and specify such hvac systems.

If the condensate pan is nearly level (as is often the case), stagnant water will always stand in the pan during the cooling operation. Even in the absence of internal negative pressure, flow will not occur until condensate covers the entire pan and reaches a level necessary to effect flow.

Depending upon system size and location of drain connections, the water level necessary for flow to occur varies from about $^1/_8$ to $^3/_8$ in. Regardless of its depth, stagnant water in the condensate pan affords an ideal environment for the proliferation of algae and contaminating biological agents. It is not surprising, therefore, that most large condensate pans are filled with potentially contaminating organisms.

Building owners-users are concerned about this situation, as they should be. In the past six years, we have visited numerous facilities and inspected scores of large hvac systems. None of these systems with large condensate pans was free of stagnant water, algae, and biological contaminants.

Exactly why manufacturers and designers incorporate large condensate pans is not entirely clear. Some possible reasons are to catch condensate blown from the cooling coil, to catch condensate that drips from non-insulated coolant line in the airflow path, or to catch condensate entrained and spread by blower-generated vortices.

In draw-through systems, however, the real purpose of the large condensate pan seems to be for protecting the floor of the unit and the surrounding property from damage caused by blowing condensate entrained by air drawn in through the condensate drain line.

How to provide an adequate air seal and essentially negate the need for large condensate pans is covered here.

INADEQUATE SEALS ON CONDENSATE DRAIN LINES

All the system design deficiencies listed here, except the inadequate seals on condensate drain line for draw-through systems, can be remedied by applying known design practices.

The large pan problems discussed above represent only some of many problems associated with an inadequate condensate drain seal. The current industry practice of using a condensate trap on the drain line to form the required seal has been a dismal failure. In fact, the practice is responsible for most wet and contaminated hvac systems.

From reviewing hundreds of operating hvac systems, we have defined more than a dozen failure modes exhibited by the conventional condensate trap. Typical and common trap failures include:

- Blockage of condensate flow;
- Damage by freezing;
- Empty from condensate evaporation;
- Unsuitable design; and
- Service-induced deficiencies.

These and other failure modes common to the condensate trap, are discussed in detail in references 9 and 10. Among those familiar with hvac operations and maintenance, there is no question about whether any particular condensate trap will fail. The only questions are, how will it fail; how soon will it fail; and, what damage will it cause?

Obviously, therefore, the design of a reliable hvac system that will remain dry and clean inside must include a seal that is free of all the failure modes and problems that plague condensate traps. More specifically, a reliable seal must exhibit the following features:

- Prevents outside air from being drawn into the system during both heating and cooling operations;
- Allows condensate to flow freely from the hvac unit;
- Prevents condensate in the drain pan from being blown into the hvac unit and ductwork;
- Eliminates condensate overflow caused by trap blockage and negative pressure inside the hvac system;
- Is not affected by algae growth;
- Is not affected by condensate evaporation;
- Is not damaged by freezing temperatures;
- Has no moving parts;
- Is self-cleaning; and
- Is self-regulating.

CONCLUSIONS

Every one of the hvac system deficiencies discussed herein has been observed in the field. Moreover, one or more of these deficiencies, accompanied by internal wetness, corrosion, and contamination, were found in most systems.

The maintenance effort, equipment damage, surrounding property damage, and human health problems associated with wet and dirty hvac systems are extensive, and the cost to building owners-users both excessive and unnecessary.

The most prevalent and detrimental is inadequate seals on condensate drain lines.

The current industry practice of depending upon a condensate trap to provide a drain line seal is the problem. Because the trap is so unreliable, most existing draw-through hvac systems operate without a seal or with a dysfunctional seal on the condensate drain line.[9,10]

The seriousness of the problems caused by inadequate seals has led to the development of at least one effective and reliable seal for draw-through hvac systems. (The "CostGard" condensate control device is defined and discussed in the accompanying sidebar.)

We don't know why there are so many deficiencies in existing systems. The engineering knowledge and technology to remedy all but one of the deficiencies discussed here, has been available for years. And with the advent of a reliable condensate drain seal, there is no reason for building owners-users to accept wet and dirty hvac systems and the accompanying high costs. **ES**

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