The condensate trap: A costly failure

by Warren Trent, Ph.D.

The condensate trap is one of the most deceptive, trouble-prone, and costly components in the hvac system.

When installed in a draw-through system, it causes numerous problems which, during the life of the system, may cost owners and users more than the cost of the system itself.

In draw-through systems, air is drawn by the blower, through the return ducts, filters, and cooling coil, creating negative pressure (a vacuum) in the region of the condensate drip pan. Thus, condensate must be discharged from a vacuum.

For successful operation and condensate draining to occur, a seal must be provided which:

- Prevents the inflow of outside air during all operating conditions; and
- Allows condensate to flow freely during cooling operations.

Operating a draw-through-type hvac system without an effective seal will bring about the following consequences:

- The negative pressure, or vacuum, impedes the flow of condensate and frequently causes overflow.
- Inrushing air (often at speeds greater than 30 mph) blows condensate into the system and keeps it wet, providing a fertile place for the growth of contaminating bacteria, mold, yeast, mildew, and other fungi.
- The blowing of condensate also can create an aerosol mist — a known mechanism for spreading legionella (Legionnaires' disease bacteria).
- Outside air, which may be polluted with carbon monoxide, carbon dioxide, and other contaminants, can be drawn into the system and spread throughout the conditioned space.

Despite the seriousness of the need for an effective air-ingestion seal, academia and the air conditioning industry have given little attention to the problem.

Few, if any, university textbooks even refer to the problem. There is no mention of the subject in any of the four ASHRAE Handbooks.

Costly mistake

The condensate trap, although widely endorsed by the industry, does not provide a practical and reliable seal.

The trap exhibits so many failure modes that it is impractical (perhaps even impossible) for most users to service and maintain the device. As a result, too many — perhaps most — draw-through-type air conditioning systems are operating with missing or dysfunctional traps.

Figure 1 illustrates the consequences of operating draw-through-type hvac systems without an effective seal.

The resulting cost to owners and users is excessive. Accurate assessments of these costs are not available. However, it is estimated that the annual cost, in terms of property damage and reduced equipment life, is near $100 per unit per year. Nationwide, this amounts to more than $1 billion annually.

The total cost considering human health is far greater.

Nationally, it has been estimated that annual health care and related costs resulting from indoor air pollution, approaches $100 billion. Of this, it appears that at least 10%, or $10 billion, can logically be attributed to missing or dysfunctional traps.

Failure modes

The numerous failures exhibited by the conventional condensate trap may be categorized as follows:

1. Inherent deficiencies;
2. Design deficiencies; and
3. Common and unwise field practices.

Regardless of its detailed design, the conventional condensate trap, because of its inherent deficiencies, is doomed to failure. Figure 2 depicts some of the inevitable occurrences that result in trap failure and illustrates the predictable consequences.

Flow blockage, illustrated in Figure 2a, occurs in most systems at two- to three-year intervals (sometimes more frequently). Few owners and users have escaped the property damage, maintenance, and air pollution problems resulting from condensate overflow, caused by blocked condensate traps.

As depicted in Figure 2b, traps installed outside are subject to freezing. A ruptured trap can cause the same problems as a missing trap.

During winter months, water seals in many hvac traps literally evaporate, as indicated in Figure 2c. When this happens, pollutants from the condensate disposal, such as carbon monoxide and carbon dioxide, can be drawn into the system, adversely affecting occupants of the conditioned space.

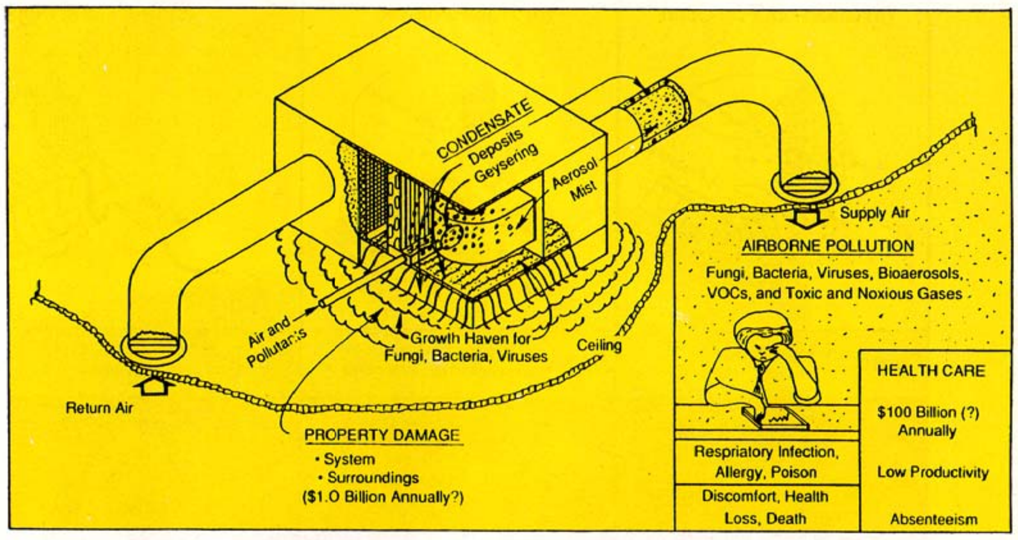

FIGURE 1— Draw-through hvac system without seal.

Figure 2d illustrates the consequences of starting-up an hvac system after the seal has evaporated. When this occurs, condensate will be blown into the hvac unit and ductwork. At the same time, pollutants may be drawn into the system and distributed to the conditioned space.

Bad design

Improper trap design adds to the potential for trap failure.

For a trap to operate properly, under ideal conditions, the geometry must be selected to match the negative pressure inside the hvac unit.

Determining the best geometry for a condensate trap is a simple task for engineers knowledgeable in the fundamentals of fluid mechanics. Yet, the design of many traps found in the field is such that failure is inevitable.

In the most-suitable trap design, trapped condensate must be deep enough to ensure that a seal will be maintained against the most-adverse operating negative pressure. And the discharge port must be sufficiently low, to ensure that water stands in the trap and not in the condensate pan, during all operating conditions.

Figure 3 illustrates common design deficiencies in condensate traps and depicts likely consequences.

The trap represented in Figure 3a is sold at many hvac supply houses. At best, this design causes water to stand too deep in the

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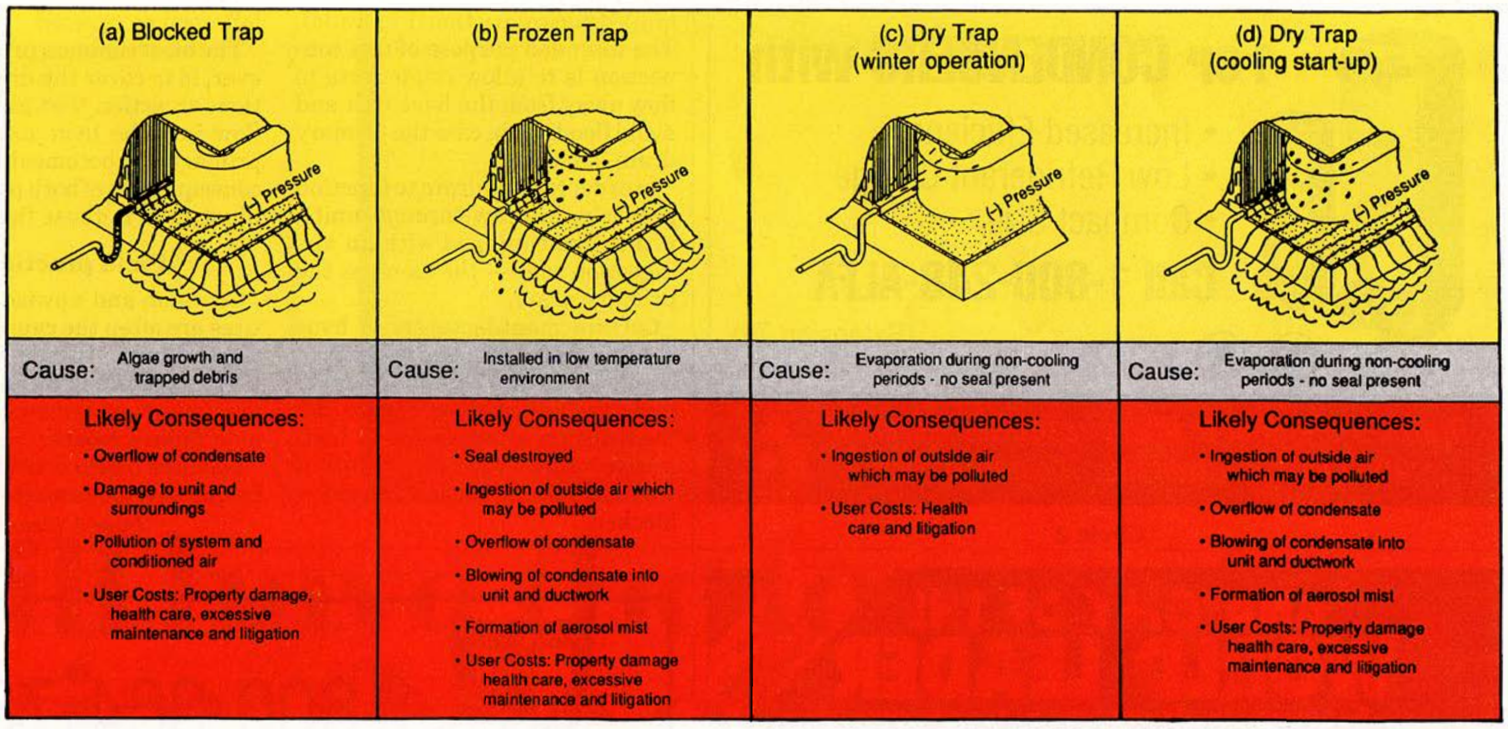

FIGURE 2 — Inherent trap deficiencies.

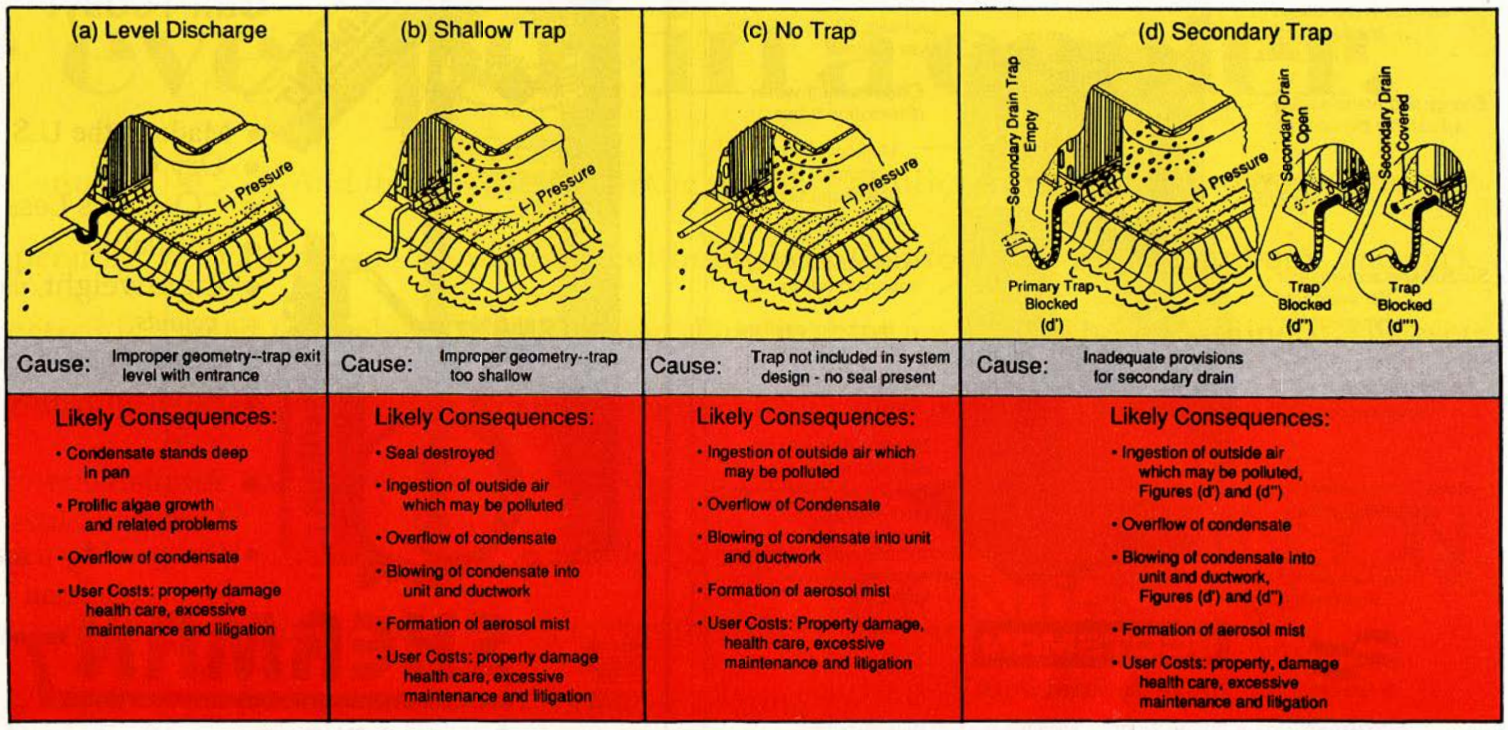

FIGURE 3 — Trap design deficiencies.

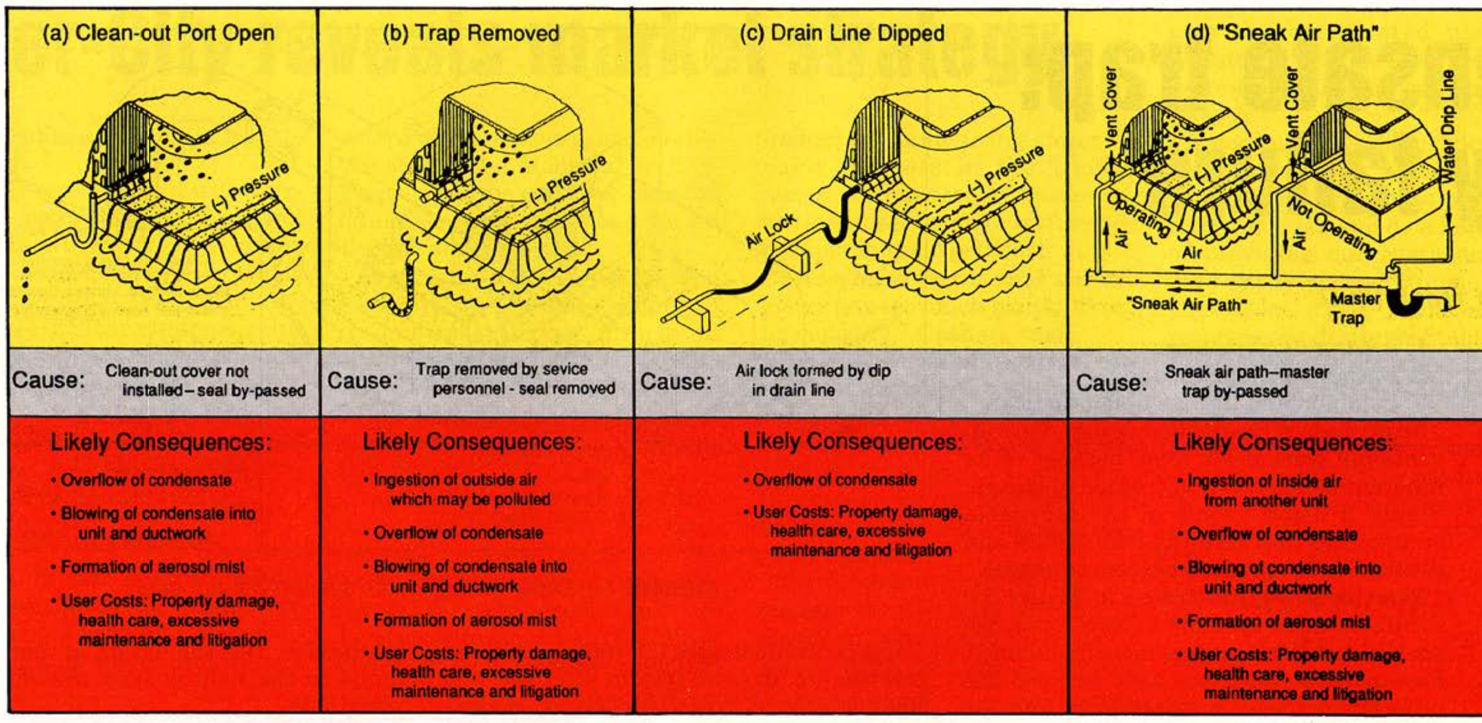

FIGURE 4 — Common and unwise field practices.

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drain pan. At worst, it can cause condensate overflow and flooding.

The trap illustrated in 3b is seen frequently on rooftop hvac units. In this configuration, the depth of the water seal is often too shallow to withstand the internal negative pressure. In this case, condensate flow will be impeded and air entering the unit through the drain pipe can blow condensate into the system and ductwork.

The worst-possible design is depicted in Figure 3c, where no trap is provided. Here, the blowing of condensate into the system and ductwork is continuous and overflow is likely.

The condensate drain pan in some hvac units is equipped with a "secondary" drain connection, located at a level above the primary drain connection (Figure 3d). The intended purpose of this connection is to allow condensate to flow away from the hvac unit and avoid flooding, in case the primary drain is blocked.

In order for this drain to function properly, in draw-through units, it must be equipped with an air-ingestion seal — the same as the primary drain.

Certain manufacturers of hvac equipment recommend that a trap be placed in the secondary drain line, as indicated in Figure 3d. Such design arrangement is ineffective unless the trap is full of water when the primary drain is blocked.

Unless special design provisions are made to keep water in the trap, which is seldom the case, the conditions illustrated will result.

The effects are the same as for cooling start-up with an empty trap. Moreover, since the secondary drain connection is near the top of the pan, overflow is likely.

Because the conventional trap is suitable for use in a secondary drain, the system designer may not specify that a trap be installed. In this case, the drain line may be left open or covered.

The most common practice, however, is to cover the drain connection, an action that assures overflow into the hvac unit once the primary trap becomes blocked. The consequences of both practices are illustrated in these figures.

Field practices

Common and unwise field practices are often the cause of serious trap failures. Although not inevitable, they occur frequently. Figure 4 summarizes some of the common failure modes.

Because blocked traps occur so frequently, they are often equipped

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with a cleaning port at the top of the trap. If this port is left open as indicated in Figure 4a — a common occurrence — the consequences are the same as if no trap is installed.

When traps become blocked to condensate flow, service and maintenance personnel often remove the trap as illustrated in Figure 4b. This is done, according to one service person, "to let the water run out."

The results are, of course, just the opposite. Water will stand in the pen at a depth equal to the negative pressure in inches of water. The consequences again are the same as those for a missing trap.

Figure 4c illustrates another common and costly situation. The second trap formed by a dip in the drain line creates an air lock, which frequently stops condensate flow and causes flooding and associated problems.

Often, two or more hvac units are connected to a common condensate disposal line equipped with a master trap, as depicted in Figure 4d.

Even if the master trap is functioning properly, if one of the units is shut off or cycles off, a "sneak air path" is created. As shown in the figure, air can then enter the drain line through the non-operating unit and cause blowing of condensate into the operating unit.

Assessment summary

The conventional condensate trap is unsuitable for use in the drain line of draw-through-type hvac systems. It exhibits so many failure modes that frequent and costly failures are inevitable.

These burdensome failures have plagued owners and users of hvac systems since the inception of the draw-through hvac system, more than a half century ago.

With the proliferation of draw-through units over the past couple of decades, trap failures and associated problems have reached epidemic proportions. Society cannot afford, nor should it tolerate, the excessive costs of property damage and human health care brought on by those common and recurring trap failures.

So far, academia and the hvac industry have given little attention to this serious and costly problem. Few, if any, university textbooks even refer to the problem.

Discussion of this subject in most professional technical publications is conspicuous by its absence.

The greatest awareness of condensate trap problems is among owners, users, and their maintenance personnel, who generally assess the situation as a necessary evil. Efforts to address the problem have been feeble.

For example, in order to keep the trap filled with water, some have attached a water-supply pipe that allows water to drip continuously into the trap, to ensure that a seal is present during all operating conditions. Others have installed heating elements on traps to prevent freezing in outside locations.

Considering that these efforts apply to only two of more than a dozen common failure modes, their effects on the overall trap failure problem are inconsequential.

In a few instances, where the consequences of trap failure are too great to risk, some users have opted for replacing the condensate trap with a condensate pump. A pump is evidently more dependable than the trap. However, it is expensive, has moving parts, and introduces a new set of failure modes.

Fortunately for frustrated owners and users, today there is a reliable condensate control device available which exhibits none of the failure modes common to the condensate trap and the condensate pump.

(The features and characteristics of this device were discussed in the Oct. 19, 1992 issue of The News. *Announcements of the availability of the device were included in the "Product Profile" section of the November/December, 1993 issue of* Engineered Systems *and in the "What's New section of the Dec. 6, 1993 issue of* The News.*)*