# LEGIONNAIRES' DISEASE:

## Philadelphia Revisited

***The likely Source and***
***how to eliminate it, at any site***

*Warren Trent, PE, CEO*
*and*
*Curtis Trent, Ph.D.*

***Trent Technologies, Inc., Tyler, TX***
***www.TrentTech.com***

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### BACKGROUND

More than two decades have passed since 34 persons died from Legionnaires' disease allegedly contracted in a Philadelphia hotel. In an effort to find the cause of this catastrophe, federal, state and local agencies launched one of the most extensive investigations in medical history. The best public documentation of what went on during the investigation is provided in the records of U.S. Senate and U.S. House of Representatives Hearings[1,2] on Legionnaire's disease.

Somewhere between 100 and 200 medical professionals participated in this investigation, for a period of several months. Because most of the investigative effort went into searching for what infected the victims, that is what was found. About five months after the outbreak in Philadelphia, the culprit was identified. It was a very tiny bacterium discovered, in pathologic specimens taken from victims, by Dr. Joseph McDade of the U.S. Center for Disease Control (CDC), Atlanta. The bacterium was named *Legionella* and legionellosis became the medical name of the disease.

It was also determined that *Legionella* causes illness only when it penetrates to the deep portion of the human lungs. For this to happen, it was concluded that the bacteria must be airborne in an aerosol, likely in very small water droplets.

From the viewpoint of medical science, the discovery of *Legionella* was clearly a brilliant achievement and a major success for the medical profession. Unfortunately, in the Philadelphia investigation, **the source of the *Legionella* was never determined and the spreading mechanism was not identified.**

Thus, a remarkable research effort and discovery has done little in terms of human health benefits and lives saved. The following statement from the January 1997 issue of the *ASHRAE Journal*[3] well summarizes the current situation:

*"Despite two decades of ever increasing information about many aspects of legionellosis, the disease seems to be as common as ever producing tens of thousands of cases and thousands of deaths each year."*

In outbreaks of legionellosis—following the discovery of *Legionella*—of which there have been many, the bacteria have been found somewhere at most of the affected sites. Cooling towers and potable water systems, because they are frequently contaminated with legionellae, are often alleged to be the source of the bacteria. However, how the bacteria are spread from these sources to the victim's lungs is not at all clear. In some instances, it has been postulated that *Legionella* aerosolized in cooling towers was airborne for several hundred meters, where it resulted in human illnesses and deaths. Still, other observers contend that the aspiration of water from potable water systems is the primary mode by which legionella is spread. Neither of these arguments is very convincing.

### MISSING INFORMATION

In the Philadelphia investigation, little attention was given to the role of the air handlers, as the possible source of the bacteria and as the mechanism for spreading them. Reports of the investigation defined only the location of the air handlers, type of refrigerant used in the systems, type of air filters in each unit, location of the water chilling equipment and the source and approximate percentage of outside air used by each unit.

The details necessary for assessing how the air handlers could contribute to the growth and spread of the disease causing agents were not sufficiently defined, or at least not in public documents. For example, nothing was reported regarding the following important factors: Type and size of air handlers; geometry of the cooling coils; the geometry, condition and contents of the drain pans; and the type of drain traps (seals), if any. Although samples of water for testing were taken from the chiller system, potable water system and cooling towers, there is no evidence that condensate samples were taken from the drain pans of the air handler.

### HINDERING MYTHS

Despite the obvious potential for contamination inside an air handler, two industry myths have hindered critical investigation of air handlers as the source of legionellosis outbreaks. These myths are (1) the conditions inside air handlers, including the condensate drain pan, will not support the growth and proliferation of *Legionella* and (2) there is no mechanism for creating the aerosol necessary for transporting the bacteria. Contrary to these myths, examination of available information suggests that air handlers were indeed the likely source of legionellosis outbreaks in Philadelphia, as well as at other locations.

## MYTH #1: Legionella Cannot Grow and Proliferate in Condensate Drain Pans

The first myth is that Legionella cannot grow and multiply in a condensate drain pan because the water temperature is too low. While the growth rate of *Legionella* is found to be greatest in water where the temperature is near 98.6°F[4], it survives at much lower temperatures. In fact, legionella has been found, in water at temperatures varying between 42°F to 145°F[5 (p.168)] and it will grow and multiply at temperatures as low as 60°F[5 (p. 300)].

*Legionella* can be found almost anywhere there is water and suitable nutrients (e.g. dirt and biological growth). Its presence has been reported in numerous places, including the following: cooling towers, humidifiers, evaporative condensers, evaporative coolers, condensate drain pans, water fountains, spas, potable water systems, outdoor ponds, ice makers and many other places.[4,6]

In a typical air handler, operating at design conditions, the temperature of the air leaving the cooling coil is near 55°F. Under these conditions, the temperature of condensate in a free flowing drain pan is about 60°F. However, under part-load conditions, condensate temperatures change markedly. When coolant flow is reduced in response to reduced cooling loads, the temperature of the condensate will increase. Under such conditions, condensate temperatures of 70°F have been measured. *Legionella* is said to proliferate between 68°F and 113°F.[6]

The growth-rate of the *Legionella* bacteria is relatively low in water at temperatures of 60°F to 65°F. However, in the presence of iron (e.g. rusty pans) the growth-rate may increase more than 100 times[5 (p.4)]. Accordingly, even at relatively low temperatures, there is a potential for high growth-rates and great concentrations of *Legionella*, in drain pans of air handlers. Thus, among the millions of HVAC systems in this country, many are undoubtedly infested with high concentrations of legionellae.

## MYTH #2: There is no Mechanism Present to Aerosol and Spread Legionella

The second myth stems from the assumption that the only mechanism present for generating an aerosol inside the air handler is the conditioned air flowing over the surface of the condensate in the drain pan. Typically, this velocity is no greater than 600 feet per minute (fpm). According to the Kelvin-Helmholtz instability limit[5 (p.51)], water will not be aerosolized from the surface until the velocity reaches 7 meters/ second (m/s), or about 1400 fpm. Thus, it can be correctly concluded that the 600 fpm is too low to create an aerosol.

There is, however, another means, not widely recognized, whereby condensate in the drain pan can be and frequently is aerosolized. It is common to draw-through air handlers—the most common type used in public, commercial, and industrial applications. In this type system the static pressure inside the drain pan is always negative. Unless the condensate drain ports are equipped with seals, air will be ingested. And during operation, the level of the condensate will rise in the pan and the velocity of the entering air can entrain and aerosolize the condensate. The negative pressure in condensate drain pans varies among systems. Typically, these pressures range from about -.50 to -5.00 inches of water column (in. wc). Without a seal on the condensate drain line, water will stand in the pan at about .50 and 5.00 inches, respectively. For these conditions, the velocity of the air entering the drain port will vary from about 2000 fpm (23 mph) to about 6200 fpm (70 mph), respectively.

Figure 1 shows how the negative pressure inside the drain pan compartment affects the velocity of the entering air, when no seal is present or when the seal (usually a condensate trap) is dysfunctional. As shown here, for a range of operating pressures, the air velocity in both cases is well above that where aerosolizing begins. Systems operating without adequate drain seals are common, nationwide.

## AEROSOL GENERATION

Condensate in a drain pan of a draw-through HVAC system will usually be aerosolized whenever the system is operated without a drain seal or with a dysfunctional trap. The seriousness of the problems caused by condensate traps is well known to qualified industry professionals. For example, the informative language in the Public Review Draft of the ASHRAE Standard 62-89R[7 (p.5.13)] contains the following comments regarding the condensate trap:

*"Condensate traps exhibit many failure modes that can impact on indoor air quality. Trap failures due to freeze-up, drying out, breakage, blockage, and/or improper installation can compromise the seal against air ingestion through the condensate drain line. Traps with insufficient height between the inlet and outlet* [poor design] *on draw-through systems can cause the drain to back-up when the fan is on, possibly causing drain pan overflow or water droplet carryover into the duct system. The resulting moist surfaces can become sources of biological contamination. Seasonal variations, such as very dry or cold weather, may adversely affect trap operation and condensate removal."*

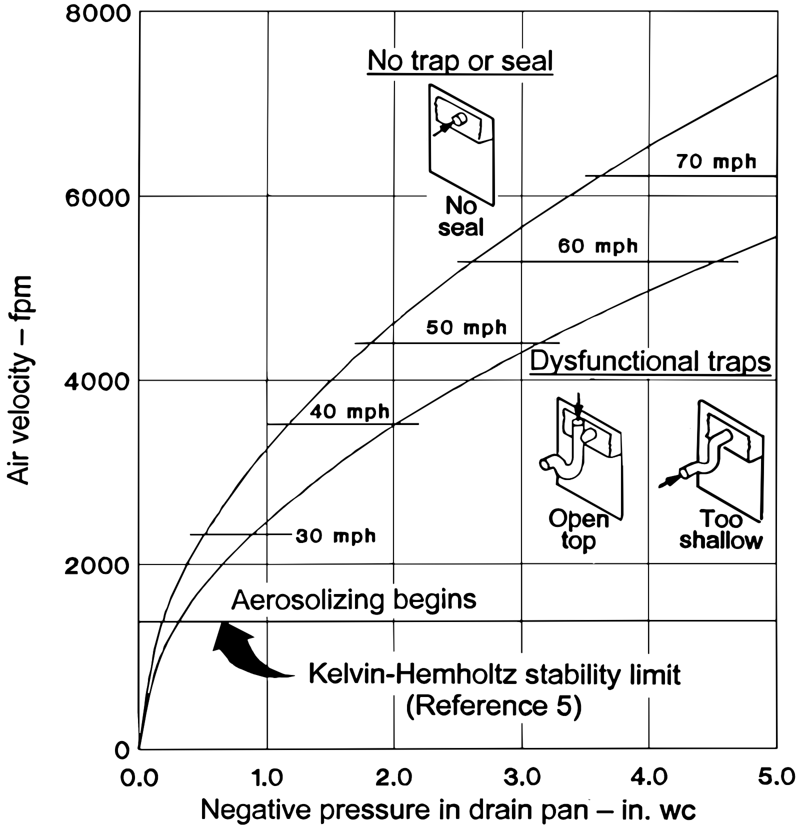


**Figure 1 Velocity of air entering the condensate drain pan through a missing or dysfunctional trap**

(a) Drain pan - large air handler

(b) Drain pan - packaged hvac unit

**Figure 2 Common conditions of drain pans - rusty and contaminated**

These hazardous conditions are readily observable by anyone interested enough to visit and inspect the air handlers in most any public, commercial or industrial facility. Examples of what to expect during such a visit are depicted in Figure 2. Generally, these air handlers will be of the draw-through type, operating without adequate drain seals—no traps or dysfunctional traps—on the condensate drain lines.

During the past eight years we have visited scores of public, commercial and industrial facilities in the central and southern parts of this country. And we have inspected hundreds of HVAC systems during the cooling seasons. With very few exceptions, the systems were of the draw-through type. Most were wet, dirty and visually contaminated inside with various forms of biological growth, due to no seal or a dysfunctional trap. The wetness of internal walls and air supply ducts, which was frequently observed, attests to the fact that air entering the drain port was blowing and aerosolizing the condensate.

Others have reported similar conditions. For example, one report of a NIOSH investigation included the following comment: *"In a building where the air handling units' fans were down-stream from 'chiller' decks,* [draw-through systems] *stagnant water had spawned thick layers of microbial slime."*[8] Almost certainly some of the air handlers in the Philadelphia hotel were in this condition.

Contrary to what many in the industry contend, these conditions are not the result of poor maintenance. They are, instead, the result of system design deficiencies—primarily the use of the condensate trap. Under the most favorable conditions, satisfactory maintenance of a conventional condensate trap is neither realistically feasible nor practical. Under other conditions, satisfactory maintenance is virtually impossible. The maintenance effort required for maintaining a condensate trap is summarized in the McGraw-Hill *HVAC Maintenance and Operations Handbook* (1998)[9] [(p.653)]. Evidently, no such maintenance program was in place at the Philadelphia hotel.

In view of the deplorable conditions of air handler drain systems, which have prevailed in the field for years, the potential for the widespread growth and aerosolizing Legionellae is obvious. Under such conditions, the illnesses and deaths of thousands from legionellosis should surprise no one.

## THE PHILADELPHIA STORY

Despite the discovery of *Legionella*, the results from the extensive Philadelphia investigation provides little help in determining the source and in reducing the number of persons affected by legionellosis. However, the evidence is strong and the general consensus is that exposure to the bacteria occurred in the hotel lobby and that transmission was by air. Hence, the air handler serving the center of the lobby is strongly implicated.

Comments reported in the senate hearings[1] support this observation. For example, hotel staff members reported periods of *"poor flow of cooling air"* during the investigation. Also in the same document, it was reported that, *"The dysfunction of the air handling system that serves the center of the lobby 2 weeks after the convention might indicate that the system was working imperfectly earlier."*

In addition to the above comments, there are other factors that point to and implicate the air handler serving the lobby. This air handler had been in operation for 22 years. Like air handlers of this vintage, it likely exhibited several characteristics that are conducive to the growth and spreading of legionellae. That is, it almost certainly (1) was the draw-through type; (2) depended upon a condensate trap to prevent air ingestion and permit condensate drainage; and (3) incorporated a large, deep drain pan, constructed of common steel.

Draw-through systems inherently create a negative pressure in the drain pan area. As stated in ASHRAE Standard 62-89R, quoted above, the condensate trap is subject to numerous failure modes, which frequently destroy the drain seal. When there is no seal on the drain line, the negative pressure holds backs the condensate and causes it to stand in the pan. The air rushing through the dysfunctional trap at high velocity entrains and aerosolizes the condensate. The standing and stagnant condensate enriched with iron from a rusty steel drain pan form a fertile place for the growth and proliferation of legionellae. Once the contaminated condensate is aerosolized inside the air handler, the bacteria are swept quickly into the conditioned space. The transmission is thorough and complete, since all the air in a conditioned space, typically, passes through the air handler 5 to 10 times per hour. All these conditions were likely present in the air handler serving the central lobby of the Philadelphia hotel.

Figure 3 shows a sketch of the envisioned air handler configuration, and its location relative to the hotel lobby. It also summarizes the likely conditions of the air handler and the conditioned space. The proximity of the air handler to the lobby ensures that contaminates from the air handler enter the lobby in high concentrations. One could hardly visualize more favorable conditions for spreading the legionellae bacteria.

## ELIMINATING THE SOURCE OF LEGIONELLOSIS

Legionellosis is a serious life threatening disease. The discovery of *Legionella* has done little, or nothing, to reduce the incidence of this terrible malady[3]. It has been estimated that about 9,000 persons[3] in the United States die annually from this disease. Efforts to reduce the number of victims have been remarkably unsuccessfully, ostensibly, because the real sources of legionellosis have not been identified. Even so, there is no concerted effort, within the industry, to find the sources of the disease. An investigative effort comparable to that being devoted to leukemia (about 11,000 deaths annually) or that devoted to investigating airline crashes (an average of much less than 200 causalities annually) could well identify the source and virtually eliminate these deaths in a short period of time. A comprehensive engineering program plan for defining and eliminating sources of legionellosis is long overdue. It is time for the industry and/or government to act.

In the meantime immediate action should be taken, on both new system designs and on systems now in operation, using what is already known. For example, we know that Legionellae are everywhere. They are often present in condensate drain pans. They thrive in standing contaminated water, grow in condensate at temperatures common to drain pans, and their growth is accelerated many fold in the presence of iron (rusty pans).

Drain pans constructed of stainless steel or of other non-corrosive material can virtually eliminate iron as a factor. Sloped drain pans can prevent condensate puddles and local stagnation. But neither is a remedy for standing, stagnant condensate and the

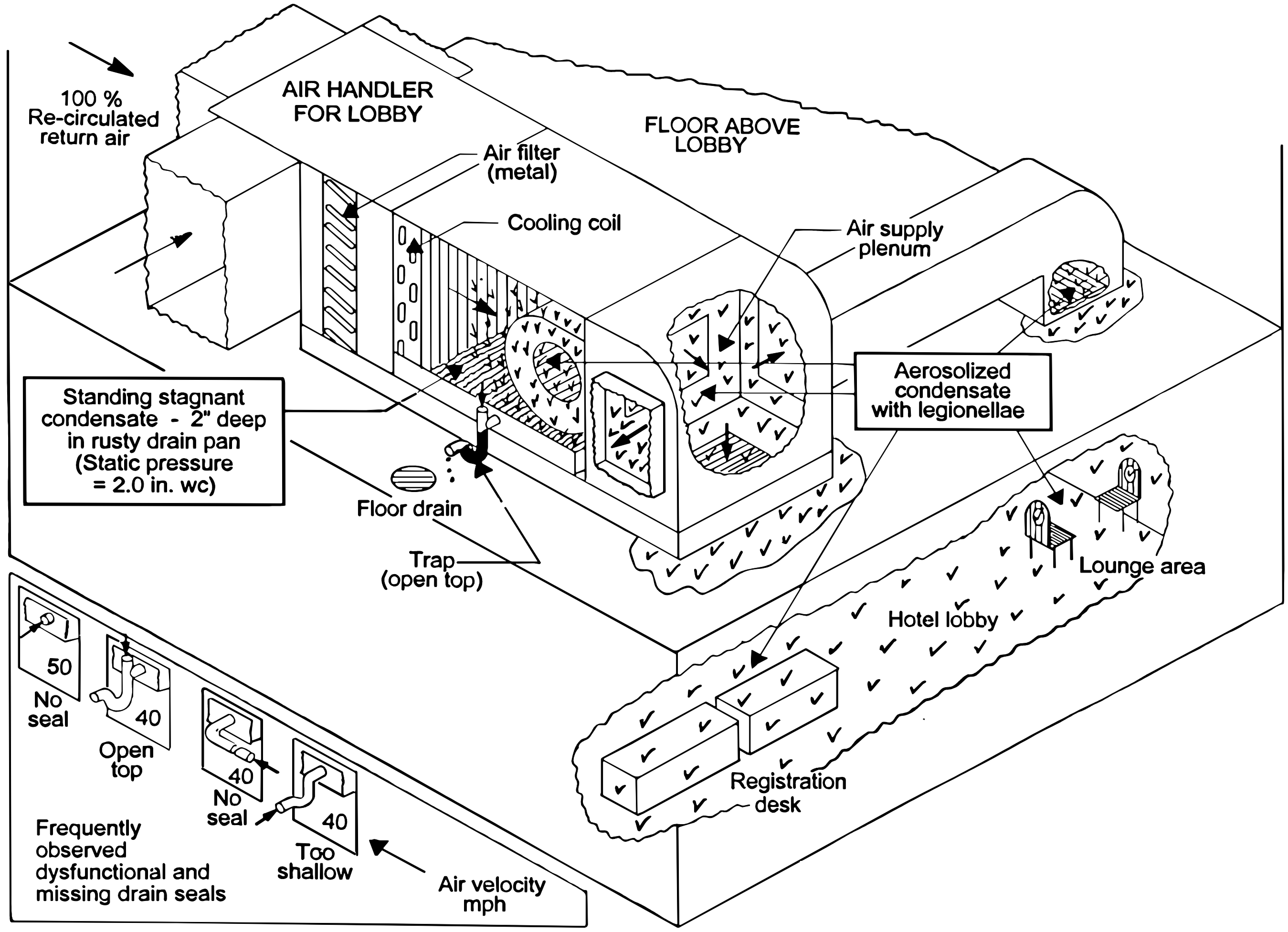


**Figure 3 Envisioned features and condition of the air handler serving the central area of the hotel lobby**

aerosolizing action caused by dysfunctional condensate traps.

Aerosolizing of condensate from drain pans can be prevented in different ways. In the design phase, one way is to select air handlers in which the drain pan is placed under positive pressure, instead of negative pressure (draw-through systems). This, of course, is not possible for the millions of draw-through systems now in service. For these and newly designed draw-through systems the obvious remedy is an effective and reliable condensate drain seal. The commonly used condensate trap meets neither of these criteria. In fact, the condensate trap is the current problem, not the remedy. In some applications, the condensate pump can effect suitable condensate removal and provide a seal against air ingestion. However, it also exhibits many failure modes, which render it unreliable.

An effective drain seal, for draw-through systems, is essential to preventing stagnant condensate and to eliminating aerosolizing as a source of legionellosis. But an effective drain seal does much more for indoor air quality. It precludes the ingestion of outside air or other gases, when the trap is dry, and therefore prevents contaminates such as sewer gas and carbon monoxide from being drawn into the system. It also prevents flooding at start-up for cooling, when the trap is empty. In addition, by preventing the aerosolizing of condensate, an effective drain seal removes the primary source of internal system wetness. In so doing, it eliminates the accompanying biological growth, which contaminates HVAC components and supply air ducts. This virtually removes the draw-through HVAC system as a contributor to Sick Building Syndrome and Building Related Illness.

In the interest of their clients and building occupants as well as themselves, system designers would be well advised to place increased emphasis on finding an effective and reliable drain seal for draw-through HVAC systems. Clearly, providing an effective drain seal is as important, if not more important, as is providing suitable air ventilation and acceptable humidity control. It therefore warrants equal consideration by the designer.

The mechanics of fluid flow associated with draining condensate from the drain pan of a draw-through air handler are not simple. Nevertheless, system designers should have the basic technical understanding needed to evolve or select a suitable drain seal for the draw-through systems they design. The conventional condensate trap is simply not an acceptable option.

The design and selection of condensate drain seals is treated in The McGraw-Hill *HVAC Systems and Components Handbook* (1998)[10 (p.2.3.18)]. It reviews traps, condensate pumps, and defines one new drain seal, which is effective, reliable and suitable for draw-through systems. Ingenious designers may, of course, evolve other equally suitable drain seals.

## CONCLUSIONS

There is a critical need for effective and reliable condensate drain seals for draw-through HVAC systems. In fact, it is safe to say that the spread of legionellosis will not be diminished, nor will Sick Building Syndrome and Building Related Illnesses be reduced appreciably until draw-through HVAC systems are equipped with effective and reliable drain seals. Moreover, until then, we cannot be assured that another outbreak of legionellosis, like the one in Philadelphia, will not occur.

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## BIOGRAPHICAL SKETCH OF AUTHORS

**Warren C. Trent**, M.S. Purdue University, is a Registered Professional Engineer and CEO of Trent Technologies, Inc., Tyler, Texas. He is a member of the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) and a Fellow in the American Institute of Aeronautics and Astronautics (AIAA).

He is a co-author of chapters on “Condensate Control” for two McGraw-Hill Handbooks: *HVAC Systems and Components Handbook*, and *HVAC Operations and Maintenance Handbook.*

He has had more than 30 years experience in fluid flow research and development, including pioneering work in the development and application of the geothermal heat pump. He served as Director of Engineering Technology for the McDonnell Douglas Corporation where, among other projects, he directed the design and development of the propulsion system for the F15 fighter aircraft.

As an Evaluator for the Accreditation Board for Engineering and Technology (ABET), from 1983 to 1989, he visited and evaluated 12 university Mechanical Engineering Programs for academic accreditation.

He is a patentee and is listed in *Who’s Who in Science and Engineering* and *Who’s Who in America.*

Since 1993 he has been the CEO of Trent Technologies, Inc.

**C. Curtis Trent**, M.S. Ph.D. University of Wisconsin, formerly the President of Trent Technologies, Inc. of Tyler, Texas. He has held tenured professorships and department head positions at Kansas State University, Washington State University, and North Carolina State University. He has directed the research of 22 Doctoral candidates.

He is a co-author of chapters on “Condensate Control” for two McGraw-Hill Handbooks: *HVAC Systems and Components Handbook*, and *HVAC Operations and Maintenance Handbook.*

He is the author or co-author of six books, numerous monographs and the author of 30 refereed journal articles.

He has served as a consultant to the governments of Nigeria, Malawi, Botswana, and Gambia.

**Trent Technologies, Inc.**
*Engineering Research & Development*

*15939 Old Jacksonville Highway*
*Tyler, TX 75703*

**www.TrentTech.com**

*(903) 509-4843*