

Considerations for temperature sensor deployment in critical environments

How understanding how home heating and refrigeration monitoring can provide insight into deciding how many and where to place temperature sensors in server and telecom rooms, refrigerators and freezers, and other temperature sensitive spaces.

ASHRAE is known for its setting of operating standards for all kinds of industries. Formally known as the American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE recently updated its recommendations for one of the most temperature sensitive environments, namely data and telecommunication centers. Companies and entire industries rely on huge rooms filled with electronic equipment to conduct business. When there is a problem in data centers and telecommunication equipment rooms, companies can come to a complete standstill.

The issue with data centers and any environment with sufficient volume is the uniformity of the temperature around the room. Data centers are equipped with extensive heating and cooling systems and sensor networks to help prevent not only massive outages across the facility but local problem areas that over time would mean individual or local equipment performance issues or failure. To that end, data centers are equipped with multiple temperature sensors and a host of others, and often employ extensive, costly security systems and the associated personnel to keep things running.

Small companies with closets that have become server rooms face the same challenges, and many do not have the resources for costly monitoring systems or the budget to hire outside security firms to monitor and alert them of problems. Likewise, food distribution and service, medical, and even individual homeowners have requirements to monitor room, refrigerator, or storage cabinet temperatures to insure the contents are not damaged by elevated or freezing temperatures. Temperature@lert has heard from many hundreds of such customers about the need for cost-effective temperature and humidity monitoring systems. Recently we introduced our latest generation devices in our WiFi Edition and Cellular Edition product offerings to address these concerns.

Even in small rooms in your home, temperature variations occur according to repeatable cycles. The thermostat is turned down at night and turned up in the morning, either manually or automatically, to meet the needs of the occupants. What does this look like in terms of temperature changes? A WiFi220 was set up with two temperature sensors with a one (1) minute reporting interval. Data was collected over several days to see what the results would look like.

Figure 1 shows one nighttime and morning cycle in a small, second story bedroom room and prompts some observations. Port 1 Temperature is taken at the floor, Port 2 Temperature is taken at an elevation of 5.5 feet. The bedroom has east and south facing windows so gets a lot of morning sun. Outside conditions were cloudless with bright sunshine, temperatures in the upper 50's and low 60's.

The two sensor readings are nearly identical until the heating system turns on at 6:30 a.m. The furnace is controlled by a digital thermostat with a set point of 69°F and a 2 degree differential setting.

The thermostat in the hallway 10 feet away and between 4.5 and 5.0 feet off the floor, the hallway connects to similar bedroom on the west side of the house. The overnight readings are essentially equal; the heating system has been off since 9:00 p.m. the previous evening and the room is unoccupied during the night with the door closed, providing little outside influence except through normal convection from cool walls, floors and windows.

When the heating system comes on the warm air naturally rises and stays near the 8.5 foot high ceiling. This provides the dramatic rise in the yellow line, the sensor at eye-level, followed by a much slower rise in the green line, the sensor near the floor. The temperature in the bedroom overshoots the 69°F set point until sufficient warm air reaches the thermostat. The normal cycling of the heating system is shown through two cycles and a slow rise in the floor level sensor as the room comes to equilibrium.



Figure 1: Temperature@lert WiFi220 with two temperature sensors monitoring the floor level (green) and eye level (yellow) in a small bedroom during the night and morning hours.



Figure 2: The same Temperature@lert WiFi220 with two temperature sensors showing the effect of a ceiling fan mixing the room air, making floor and eye level temperatures more equal.

Figure 2 tells a similar but interestingly different story. At 11:00 a.m. a ceiling fan was switched on, fan speed at low, fan direction blowing upward toward the ceiling, what some call “winter mode”. This has the effect of mixing the warmer air at the ceiling level with the cooler air at the floor. Within one hour the temperature difference has gone from 5.1 degrees to 2.6 degrees, showing the effect of the mixing. So more warm air is nearer the floor where people live, and not at the ceiling. The results show the value of ceiling fans, even in the winter to help reduce heating bills in rooms with tall ceilings.

The same is true for refrigerators and freezers, both large and small. Figure 3 shows the same WiFi220 with two temperature sensors after moving it to a 17 cu.ft. household refrigerator. The temperature falls as the sensors come to equilibrium with their new environment and level off. The Port 1 Temperature sensor is on the top shelf toward the rear corner, away from the direct flow of the cooling air inlet. The Port 2 Temperature sensor is on the bottom of the compartment, below the vegetable bin and near the door. The two sensor readings converge to within 1.4 degrees after 30 minutes before they move apart as the refrigerator cycles. The cooling air is introduced to reduce the temperature when the two sensors are 8.1 degrees apart and after ten minutes brings them again to within 1.1 degrees of each other. It is important to note the refrigerator's temperature sensor is on the rear wall above the top shelf, so seeing the same temperatures as Port 2 Temperature sensor. If it were on the bottom of the refrigerator the contents of the top shelf would see temperatures that could lead to early spoiling of the food located there.



Figure 3: The same Temperature@lert WiFi220 with two temperature sensors after moving them to a household refrigerator compartment.

Again, the effects of natural convection, heated air rising and cold air sinking, dictates the temperature profile even in this small, confined space. And while the thermostat is set low enough that we're not throwing out spoiled milk, in some applications such as pharmaceutical and blood storage, being able to account for the temperature profile of the refrigerated storage space can be critical to insure product safety and efficacy. In those cases, two or more temperature sensors may be called for, and indeed are often used.

So how many sensors do you need to monitor a location and insure the temperature is within the range needed to protect valuable equipment, property or data? One would be sufficient if the sensor was located in close proximity to the items to be protected. If the space is large and the heat distribution is not very uniform, two sensors placed in the warmest and coolest points in the space would help give a quicker warning if things started to drift out of range. How efficient is mixing of air in the room? Better mixing will provide better temperature uniformity and require fewer sensors. Understanding the dynamics of the space being monitored can help understand the data from the sensors.

In some applications two sensors would be preferred. In small server rooms for example, one sensor monitoring the room temperature near the ceiling would give a worst-case condition, providing valuable time to help head off potential problems. And a second sensor inside a critical server rack could provide advanced alerting should there be an AC outage that will take time to show up in the room but could have a more immediate effect where the source of heat is located.

The story is similar for refrigeration and freezer applications where there is a need to keep food, vaccines, or other temperature sensitive materials within a defined range to insure safety and efficacy. Temperatures can change quickly when doors are opened, so locating sensors too close to the door could trigger false alerts. Those monitoring such spaces need also be aware that placement of the sensor at a location different from the unit's control system sensor can also lead to questions about whether the sensor is operating properly since the device is showing a different reading than the refrigerator thermometer. Figure 3 can help one understand that sensor placement can have an effect on whether or not two sensor readings match. To get started it may be best to place the sensor near the control system's sensor to see if there is a difference. The two sensors should be in good agreement with each other, all things being equal.

Temperature@lert's latest generation WiFi and Cellular Edition products support one or two sensors, making them very cost effective for multi-point monitoring. And with the optional combination Temperature/Humidity probe, critical electronic equipment and other humidity sensitive products such as pharmaceuticals have an additional level of protection from damage due to condensing moisture, dehydration, or static electricity. And Temperature@lert offers a 10 and 20 sensor expansion module that can support sensor with cable lengths up to 100-feet (30 meters) for larger installations.

So when it comes to the question of how many sensors are enough and where to place them, the best advice is to baseline your space. If you see significant differences from one location to another, especially close to the equipment, materials or products you're trying to protect, placement in the area with poorest control may be best. And based on that information, do you believe one sensor will provide the advanced warning you need? If yes, then one sensor will do the job. If not, more sensors may be needed. The expandability of Temperature@lert's WiFi and Cellular Edition products allows you to start small, automatically collect data and grow your Temperature@lert Sensor Cloud as needed.