CASE STUDY

Sensicast Chiller Monitoring Application Reduces Cost

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SensiNet® Chiller Plant Monitoring System Reduces Operating Costs and Predicts Equipment Failure

Summary

This real world application of Sensicast's SensiNet® wireless sensor network demonstrates the performance improvements that can result once additional data is available. The ease and flexibility in the deployment of the iWSN delivered real value in the monitoring of the exhibit temperatures, saving the cost of unnecessary construction through a greater understanding of the thermal performance of the penguin exhibit. Assessment of air chiller systems performance was made possible by the ease with which monitoring could be accomplished using the SensiNet wireless sensor network – allowing data-driven assessment and action.

About the System

The application of technology to bio- and life sciences often involves proactive monitoring that may improve or sustain life. Such is the case at the Pittsburgh Zoo & PPG Aquarium where a particular species of penguins thrives in temperatures of 50º F. If the temperature becomes too hot, the birds may succumb to heat stress, a condition that increases their susceptibility to disease and associated costs of care.

Figure 1 -Spectator View of Penguin Exhibit at the Pittsburgh Zoo & PPG Aquarium

When outside summer temperatures exceed 90º F, air chillers in the penguin habitat suffer a significant increase in workload. Identifying performance issues and predicting failure for these air chiller systems and associated power supplies – before they become critical – provides valuable corrective action time. Rather than rely on visual temperature observations, temperature and humidity are electronically monitored in various locations within the exhibit. Since intrusion into and disruption of the exhibit would compromise the structure and stress the inhabitants, wireless temperature sensors provide the only realistic solution.

Reliable Monitoring Amid Piping, Pumps, and Penguins

To create the natural environment for the penguins, the exhibit consists of masonry block and concrete walls, fiberglass-reinforced plastic scaffolding and walkways, metal railings, piping and pumps for water circulation, and metal and wire under-layment within the artificial rock and brick. These surroundings provide a fairly harsh environment for common, low-power radio frequency (RF) communication.

For ease of deployment, simplicity in configuration, and reliability in communication, IntelliSensor chose to utilize components from the Sensicast SensiNet wireless sensor network instead.

As in any real world application of intelligent wireless system networks (iWSNs), cost and reliability are major concerns. At the Pittsburgh Zoo & PPG Aquarium, cost scrutiny and limited access mandated limited intrusion and the most efficient and reliable system possible. IntelliSensor performed an engineering evaluation of the site that determined that the placement of just six wireless temperature and humidity sensors would provide reliable data acquisition and adequately measure the temperature profiles necessary (**Figure 2**).

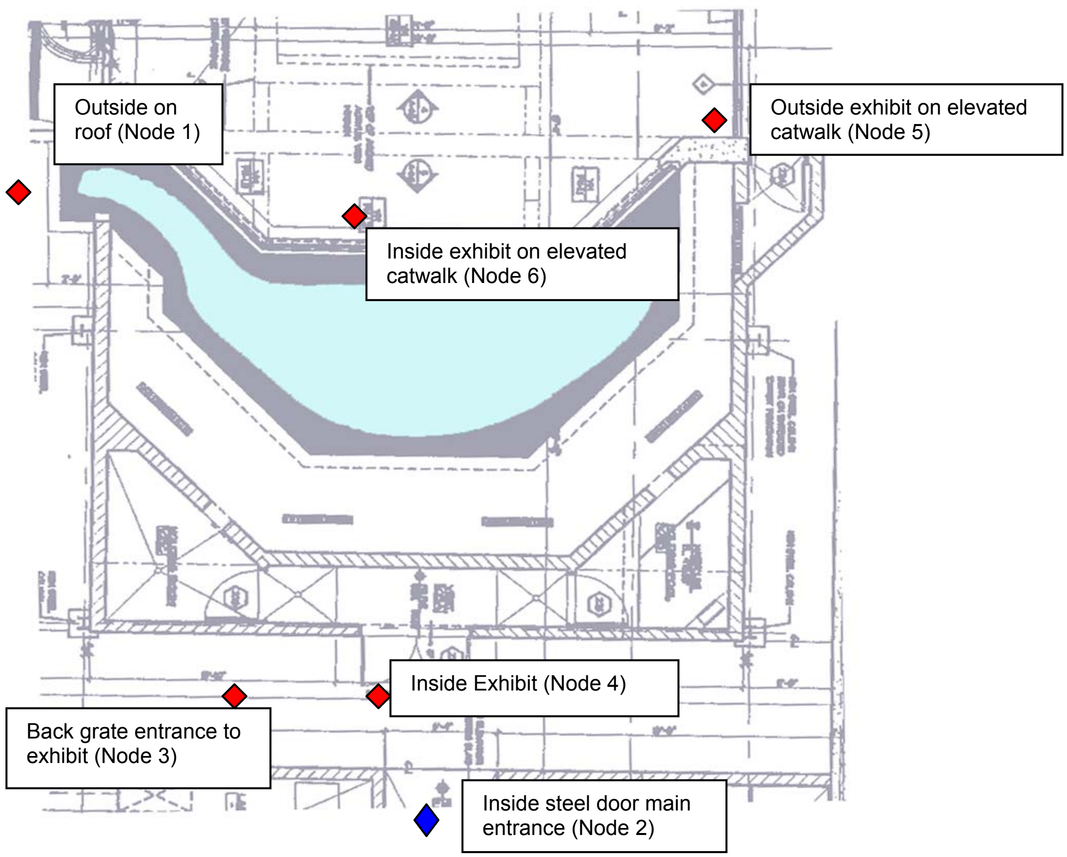
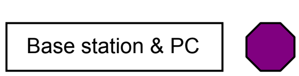


Figure 2 - Deployment pattern used for reliable temperature and humidity monitoring

Six Nodes Send Reliable Signals



Node 1: The first SensiNet Temperature Smart Sensor to measure temperature and humidity was located in a shaded area on the roof to measure the outside air temperature.

Node 2: The second Temperature Smart Sensor is located just inside and to the left of a steel door which enters the isolation area of the exhibit to facilitate communication with the SensiNet Gateway at the PC data server.

Node 3: Node 3 was located inside the isolation area of the exhibit behind a plastic grate which, when open, permits the penguins to enter the isolation area. This facilitates communication and acts as a redundant temperature and humidity sensor.

Nodes 4, 5 & 6: Node 4 (**Figure 3**) is inside the exhibit hidden from view behind a simulated rock approximately 3 feet above the penguin floor. Node 6 is located inside the exhibit on a reinforced concrete walkway approximately 15 feet above the penguin floor in order to measure temperatures about 10 feet below the roof of the exhibit. SensiNet Smart Sensor Temperature Node 5 is also above the penguin exhibit floor, about six feet higher than Node 6 and at the opposite side of the exhibit.

The SensiNet Smart Sensors were quickly and unobtrusively installed and, as seen in **Figure 1**, not visible to spectators. Since they are battery operated with batteries lasting up to three years, installation was fast and easy. The installation of wired sensors would have required the cutting through the concrete and simulated rock and disruption of the exhibit.

Figure 3 - View from service catwalk shows SensiNet Node 4

Collecting, Viewing and Analyzing the SensiNet Data

IntelliSensor developed custom software that records the measured temperatures and humidity values in a database, prepares reports, and graphs the data for specified intervals. It provides for an alarm to be issued to a pager or telephone if a predetermined level is exceeded. Network administration reports are issued via e-mail at hourly intervals, providing the current temperature, humidity, state of battery charge, and the minimum, maximum, and average temperatures over the previous 24-hour period. A daily management report is also sent by e-mail to select zoo staff. Time snapshots of the data were available remotely on IntelliSensor's website.

The zoo staff utilized the temperature and humidity data from the SensiNet Smart Sensor Temperature nodes to evaluate the thermal performance inside the penguin exhibit to determine if and how thermal performance could be improved. Two performance improvement options were initially considered:

- Installation of additional insulation on the air chiller ductwork, and
- The construction of an isolation barrier.

Figure 4, Phase 1 shows the penguin exhibit daily minimum and maximum temperatures for a three-week period prior to any modifications. The average minimum temperature was 50.9 °F, while the average maximum temperature was 53.7°F. This data was used as a basis for comparing the impact of the changes.

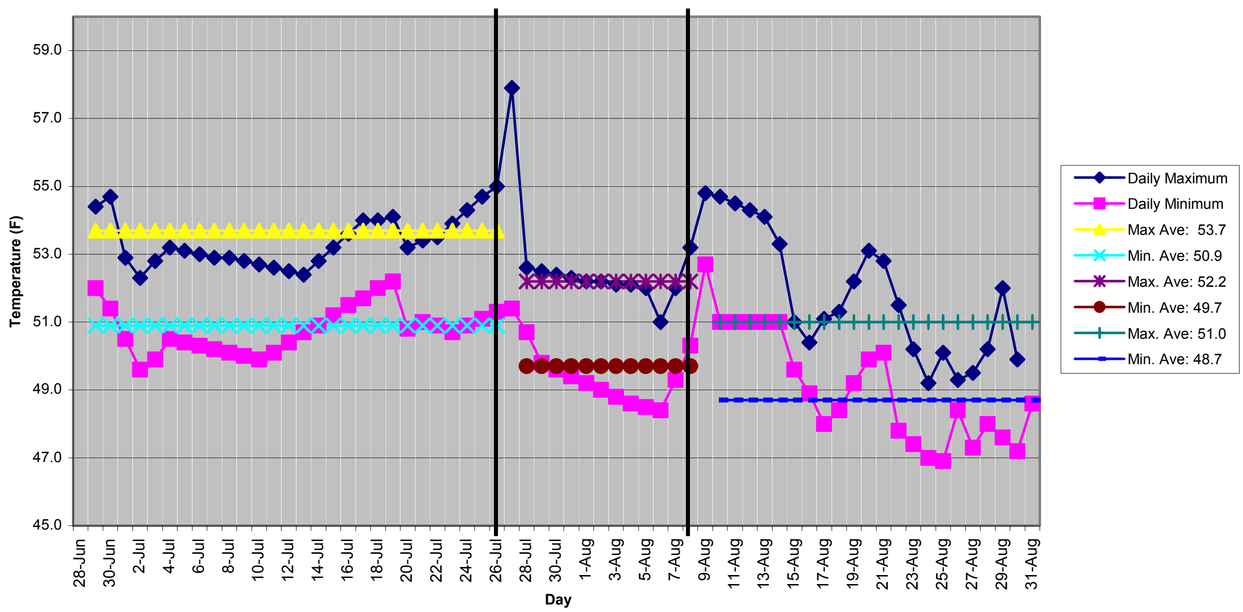


Figure 4 - Daily Temperature Range for Penguin Exhibit through Three Phases of Experiment

Performance Tuning at the Exhibit

First, insulation was added to the ductwork of the air chiller that discharges into the penguin exhibit and the temperature and humidity levels monitored for a two-week period (**Figure 4, Phase 2**). The results: the average daily minimum temperature was reduced by 1.2°F and the average daily maximum temperature was reduced by 1.5°F.

Next, it was noted that a large volume of air above the penguin exhibit was also in contact with the air above another exhibit. A permanent wall was proposed to isolate half of that volume from the penguin exhibit. With construction costs estimated at $5,200 and disruption of the exhibit required, a temporary polypropylene barrier was erected instead. While not providing all of the thermal isolation of a permanent wall, the temporary barrier would confine the cold air from the air chiller system to the penguin exhibit enclosure and allow an assessment of the effect of a permanent wall.

The third phase in **Figure 4** shows the effect of the installation of the barrier over a three-week period. The daily average minimum temperature was reduced by 1°F and the daily average maximum temperature was reduced by 1.2°F. Since confining the chilled air to the penguin exhibit did not significantly enhance the thermal performance, it was concluded that the change in thermal performance did not justify the cost of building a permanent wall.

Performance Evaluation of the Air Chiller

Finally, five additional Sensicast Smart Sensor Temperature and Humidity nodes were temporarily deployed to assess the thermal performance of the air chiller system itself. The air chiller is located on the roof approximately sixty feet from the data server base station. The existing SensiNet Smart Sensor Temperature node measuring the outside air temperature and humidity was moved to a shaded area on the roof just upstream of the air chiller system intake fan. One SensiNet Mesh Router node was installed inside the air chiller system fuse box. The five temporary nodes were installed as follows:

- Node 7: just after the intake fan,
- Node 8: downstream of the enthalpy wheel, just upstream of the air chiller heat exchanger,
- Node 9: just downstream of the air chiller heat exchanger,
- Node 10: placed to measure the temperature of the air returning from the exhibit and,
- Node 11: placed downstream of the enthalpy wheel on the return air side.

Although all the new SensiNet Smart Sensor Temperature nodes were located inside the metal compartments of the air chiller system – a significant distance from the data server base station – this deployment was completed fairly quickly and reliable communication established.

Temperature/humidity sampling intervals of one- to two-minutes were easily set using the SensiMesh® software to correspond with the sampling rate inside the exhibit. During the two-day sampling period, the outside air temperature varied from a minimum of 40.2º F to a maximum of 72.5º F. The temperature after the intake fan is typically 4°F to 7°F higher than the outside air due to heat from the fan motor in the compartment. The temperature after the

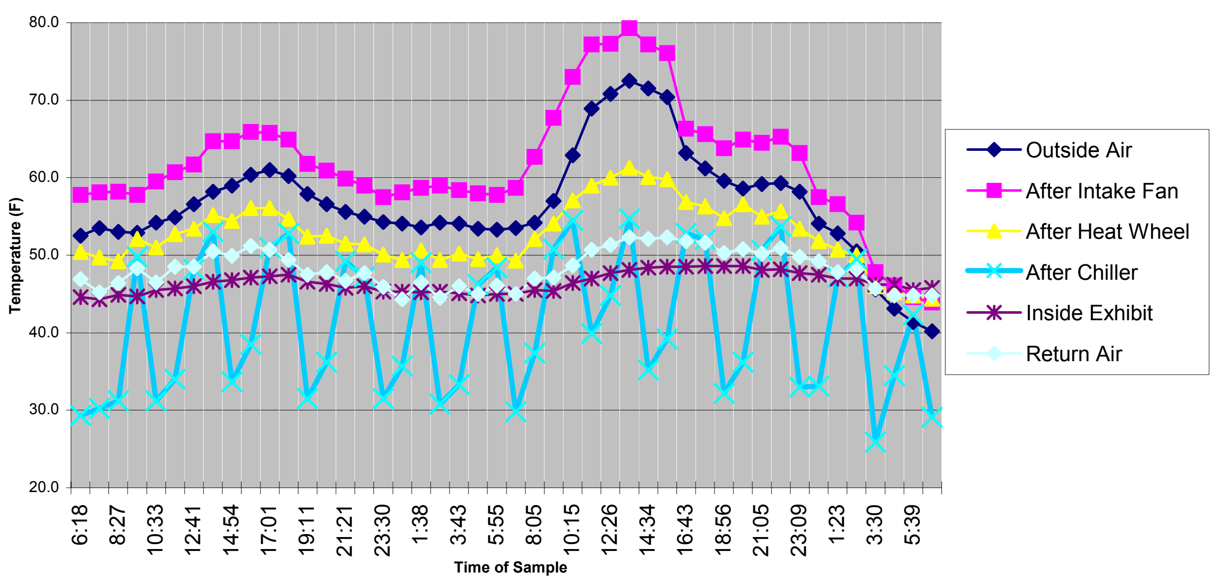


Figure 5 – Sample of Thermal Performance of Air Chiller from Two-Day Period

enthalpy wheel shows that as the outside temperature increases, the temperature drop across the enthalpy wheel increases. The exhibit temperature varied from a minimum of 44.3º F to a maximum of 48.6º F.

The most interesting response was shown by the temperature in the compartment just downstream of the air chiller heat exchanger.

The air chiller heat exchanger is divided into an upper and a lower section. For two hours, airflow doors are opened to the upper heat exchanger and coolant flows to cool the air. Then the upper airflow doors close, the lower airflow doors open and cold coolant flows to cool air through the lower heat exchanger. This process is used to preclude the buildup of ice during periods of high humidity

This led to the examination of the detailed data collected every two minutes. Temperature indications from the SensiNet Temperature node indicated that for two hours the temperature of air around the wireless sensor was approximately 30º F lower than the temperature reading in the upstream compartment when the upper chiller air flow doors were open. However, during the next two-hour period, when the lower compartment air flow doors are open, the temperature at the SensiNet Temperature node was only approximately 12º F lower than the temperature reading in the upstream compartment**.**

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