The 6 Most Important Parts of a Temperature Monitoring System

Monitor and Alarm Your Products and Processes

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Increasingly businesses and healthcare organizations are using temperature monitoring systems to safeguard their products and satisfy regulatory demands. You may know that you need a monitoring and/or alarming system but aren't sure how to purchase or use one. To complicate matters this technology comes in the form of many different models with different features. Whether you're a purchasing agent or you're going to be the end user, you can ensure that you're getting the right system by learning a bit about the most important parts to focus on. At **CAS DataLoggers** we've put together this basic tutorial covering the 6 parts to a typical Temperature Monitoring System so you can choose which is best for your application.

Consider each of these six factors when specifying/selecting a temperature monitoring system:

1. **Temperature Probe or Sensor**—The specific probe type will affect the measurement accuracy and the suitable temperature range. Common sensor types include:
    a. Thermocouple
    b. RTD
    c. Thermistor
2. **Thermal buffer**—A buffer helps smooth rapid temperature fluctuations at the sensor due to compressor cycling, door opening, loading/removing products:
    a. Nylon block
    b. Glycol bottle
    c. Glass bead bottle
3. **Measurement device**—Connects to the probe to measure and record the temperature:
    a. Standalone datalogger
    b. Networked/LAN WiFi measurement device
    c. Wireless measurement device and base station or gateway
4. **Data Storage—**Controls how much historical data will be available locally:

a. Internal memory

b. Local base station or gateway

c. Local PC

d. Cloud-based service

5. **Software—**Used to control operation of the system. Functions include:

a. Charting

b. Configuration

c. Data retrieval

d. Alarm management

e. Reporting

6. **Alarming—**Provides immediate notification of temperature excursions. Alarm delivery methods include:

a. SMS—Text message

b. Email message

c. Audible alarm

d. Visual indicator

e. Phone call

Part 1--Probes

Temperature measurements are among the most common data logging applications found across a broad variety of industries including cold chain integrity, medical monitoring, machine/equipment monitoring, environmental monitoring, and in practically every other field. Since temperature monitoring devices are designed for such a wide variety of needs, it's important that you decide on the type of sensors or inputs you'll use.

Dataloggers are able to record temperature data by connecting to sensors such as thermocouple probes, and some have their own internal sensors to log right out of the box. There are 3 main types of temperature sensors that are used with data loggers: thermocouples, thermistors and RTDs.

Thermocouples are the most commonly used, **RTDs** have higher accuracy, and **Thermistors** can offer even more precise measurements. We'll cover each type so you can choose which is best for your application.

Figure 1--Typical thermocouple sensor

1. **Thermocouples** are the most widely used temperature sensor and also one of the least expensive sensors available. They are widely used where cost, simplicity and wide operating range are paramount and where extremely high accuracy is not required. A thermocouple is nothing more than 2 different metal wires of very specific alloys which are fused together at a single point. A thermocouple produces an output voltage (typically at the millivolt level) related to the temperature. The data logger measures the voltage and then applies a calibration equation to convert the voltage to temperature. The data logger also incorporates a cold junction reference to compensate for any offset voltage that occurs at the connections between

the thermocouple wires and the data logger. Because of variations in the composition of the thermocouple wire, typical thermocouple accuracies are on the order of 1-2°F, although special composition wires with reduced errors are also available. Consider thermocouples when you just want a low-cost device that's easy to use.

2. An **RTD sensor** provides a change in resistance that is related to temperature. —they take more accurate readings than thermocouples but have a narrower operating range. The most common RTD consists of a fine platinum wire wound around a cylinder, but nickel and copper wire are also used in some cases. The resistance vs. temperature curve has a very specific slope and the RTD is made so that it has a specific resistance at 0°C, with 100 Ω being the most common value. To measure temperature, the data logger will source a known current through the RTD and measure the resulting voltage from which it can calculate the resistance. Finally, using the slope of the resistance vs. temperature curve and the 0°C resistance, the data logger can calculate the temperature. RTDs are typically more stable and accurate than thermocouples, but at the expense of a more limited operating range. Consider RTD sensors when you need high-precision measurements for a narrow temperature window.

3. **Thermistors** are similar to RTDs (they're sensors whose resistance changes with temperature) but their resistance change is highly non-linear. Like RTD sensors they take more accurate readings than thermocouples. Because of this characteristic, thermistors can offer very accurate temperature measurements, down to an accuracy of 0.01°C, but only over a very limited temperature range (typically 0°C to 100°C). Like RTDs, thermistors are designed to have a specific resistance at 0°C (2252 Ω is a common value) and each family of thermistors has a specific resistance vs temperature characteristic that the data logger must be able to accommodate. Consider using thermistors when you need to record at very high accuracy without worrying about sensor cost.

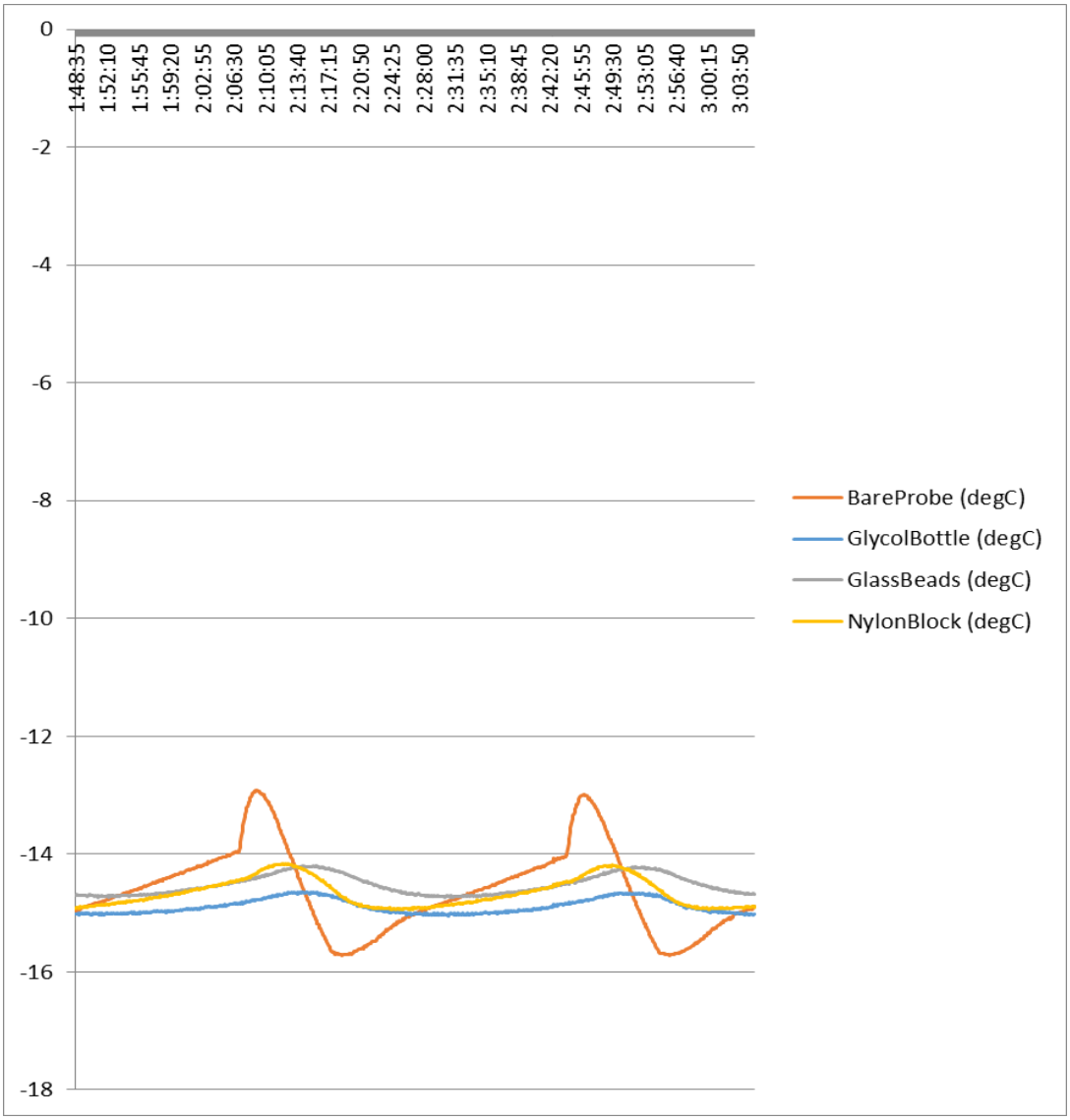
Part 2—Thermal Buffers

Thermal buffers are substances (materials and liquids) used to insulate temperature probes in order to delay the probe's thermal response time. Glycol bottles, nylon blocks and glass beads are common temperature buffers. This has the major benefit of making the **reported** temperature more closely mimic the **actual** temperature of your refrigerated product. This is especially useful in medical monitoring applications including vaccine storage and other drugs/products. Due to CDC recommendations, thermal buffers are becoming standard in hospitals, clinics and pharmacies but also in laboratory and even cold chain settings. By using a buffer you can also eliminate the temperature spikes caused by opening the fridge or freezer door.

In our own experiment detailed in our White Paper **"Comparison of Thermal Buffer Effectiveness,"** the bare probes we used showed extreme temperature fluctuation in all our fridge and freezer test runs. In

fact the compressor cycling of your storage unit will often cause these alarms and pose a major inconvenience along with widely-varying temperature data. As an example of this from our thermal buffer experiment, see **Figure 2** below.

Figure 2: Freezer Cycle Temperature Data



As our data shows, the bare probe's readings were extremely variable compared against the buffered probes. In fact if this had been an actual medical monitoring application, the bare probe could generate false alarms simply due to the normal cycling of the refrigeration compressor. If the limits are set too

tightly, even a small variation in the cycling can trigger an alarm. Since stabilizing your temperature readings is so critical, you can avoid nuisance alarms and get much more accurate data by using temperature buffers on all your probes.

The CDC advises using thermal buffers instead of just relying on a bare probe, and specifically recommends using a **glycol bottle** as a temperature buffer for refrigerator applications. **Glycol bottles** are a great solution for determining fridge and freezer temperature profiles, and in fact we found that glycol bottles had the best performance in our own fridge and freezer tests. Therefore temperature buffers are an inexpensive way to help protect your products and give you meaningful data.

Part 3—Measurement Device

Temperature measurement devices such as **dataloggers** connect to temperature sensors and record readings to their internal memory or to an external storage device, often a USB stick. What is a datalogger? **Data loggers** are electronic devices—usually palm-sized and inexpensive--designed to collect and store specific or universal values, often independently of a PC. This way you can log data anywhere and then come back later to download readings to a computer via USB stick or cable. Data loggers are much more reliable and accurate than manual measurements and also free up employees for other duties. Many models also feature automated alarm capabilities, making them an all-in-one system.

Data loggers are often used to solve a short- or long-term problem, for example when you need a way to alarm tank temperature or graph data to get an accurate temperature profile for a medical freezer. This can be a great way to cut costs otherwise incurred from process delays or inventory loss.

If you’re not sure how to use a data logger, an experienced solutions provider will help by asking you specific questions to help you determine which products are the most suitable including how many inputs are required and what type; how often you need to take a reading; how much data needs to stored; how the data logger will be used; how you'll communicate with the device; and any other requirements the application might have.

Another main reason to use a datalogger is to gather and archive data for regulatory purposes whether it’s for a product, a piece of equipment, or environmental temperatures, say inside a surgery room or residence. We’ll cover a few characteristics of data loggers to help you make the best choice.

Sampling Rate:

After determining what temperature range you need to log and where you need to log it, it helps to decide how often you need the datalogger to take a reading. You might need continual monitoring for

their industrial process or healthcare inventory, or you might only need to take a reading once every 30 minutes or every hour just to keep tabs on a specific product or environment.

While data loggers usually consume very low power, you'll want to look at the battery life which varies considerably based on the manufacturer, model and how often it's designed to take readings—this is its **sample rate**.

Most data loggers can handle recording at rates up to about 1Hz (once per second). For most typical applications you won't need a high sampling rate, although there are exceptions in academic, life science and research applications. If you need a faster recording frequency, be aware that as the speed of the data logger increases, the price does as well. Make sure that the recording rate you are specifying is appropriate. For example using a K-Type thermocouple, the sensor/sample may take several seconds to register a change in temperature. Recording such a temperature with a data logger at 5Hz would provide redundant or useless data.

As with any type of electronics, there are lots of different manufacturers and models. Typically these devices are available in both indoor and outdoor models. While some of these loggers are dedicated to a certain input or sensor type, others are programmable and scalable for different types.

Many data loggers are more than accurate enough to cover most applications. If you're monitoring product or room temperature, a logger that's accurate within a few degrees should be enough, which will keep the price low, but some applications benefit more from high-accuracy models accurate within one-tenths of a degree.

Communication with the data logger can be done in many different ways, including serial or RS-232 interface, USB or Ethernet interface, wireless capability including Wi-Fi and proprietary RF links, analog telephone (PSTN) modem, cellular, CDMA or GPRS/GSM modem, and satellite modem.

Examples of temperature dataloggers which can read the signals from probes or which take readings themselves include portable standalone models, networked models and wireless models:

a. **Standalone Dataloggers:**

Many data loggers can record in **standalone mode** meaning that they don't require a PC or other devices to take readings, so they're more portable than data acquisition systems which usually require PC connection. These devices commonly have an LCD display showing current temperatures or alert you when they're out of spec.

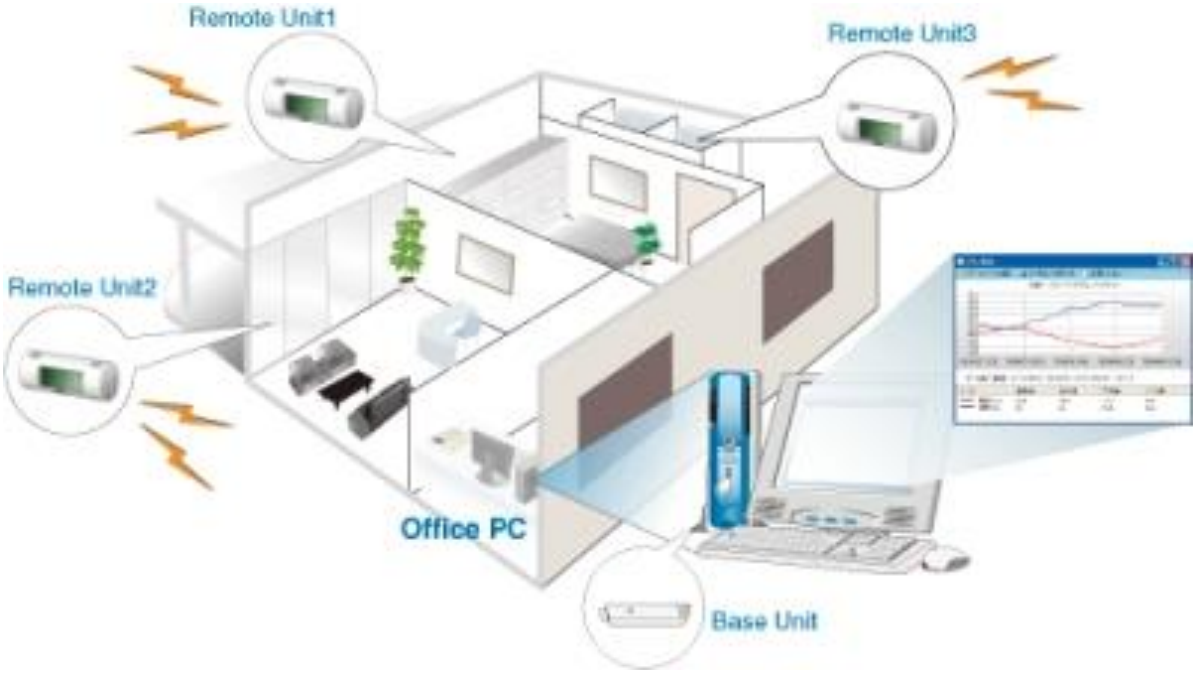
Many data logger models are durable and will continue to reliably operate for at least a few years, although cold chain data loggers are available which do the job for a single trip and a low cost. Most data loggers for industry and individual use are battery-operated, while some models can also be powered externally.

Nowadays data loggers can take a sample every second which is more than enough for most cold chain applications. Sample rate is inversely tied to battery life and the max sample rate depends on the logger chosen. Many data loggers nowadays have non-volatile memory which ensures that recorded data is still safe if the battery fails or power is lost. The logger's software will usually tell you when the battery's getting low but you'll cut down on hassle by choosing a model with a user-replaceable battery life of a year or more.

If you don't mind traveling to the data logger every so often, standalone loggers are a great choice.

b. Networked/LAN/WiFi dataloggers

Figure 3: Networked System in an Office



In contrast to standalone data loggers, more advanced data logger models have the ability to automatically send their data to an office PC. These dataloggers can connect to a LAN or be used over the internet to automatically send data over Ethernet or WiFi interface communication, providing a low-cost way to manage data from long distances. For example you can view current temperatures

anywhere in your building at any time or receive warning emails whenever values go outside safe windows.

These setups often use Remote Units to collect data locally and transmit it to a Base Station. Recorded Data and Current Readings can be automatically downloaded from Remote Unit(s) at a set interval and send downloaded data via e-mail to specified addresses, or by FTP to a server including T&D's WebStorage Service. Moreover, the Unit can be set up to monitor for warnings and send warning reports via e-mail.

Often your selection will already be made for you depending on your facility's wired or wireless setup. If you have or are planning on installing wiring to a central location, this is a quick way to send data from one point of your facility to another. Many data loggers provide their own cabling.

c. Wireless dataloggers

Figure 4: Accsense Wireless Monitoring System

Wireless technology is quickly becoming the standard in many industries and temperature monitoring applications. Many data logger models can also automatically send their readings to a wireless base station or wireless gateway and then to an office PC, even from a distant location for remote monitoring. For example a major market for wireless systems is in healthcare applications. Here, wireless systems are very effective for temperature monitoring and alarming in refrigerators and freezers, storage areas, and incubators. Wireless communication is increasingly popular although there are many other options including Zigbee, Bluetooth and proprietary wireless systems.

Wireless systems are ideal when:

- You have a number of distributed points where you need to measure temperature
- It would be difficult or expensive to run wires from your measurement points back to a central location
- Data needs to be collected and transmitted from a truck or other vehicle while it is in motion, preventing the use of wired sensors
- Data and/or alarms need to be collected from a site that is difficult to access or does not offer regular internet connectivity.

Wireless systems are widely used to automatically transfer their readings to an office PC which saves workers the time and trouble of traveling to each datalogger to retrieve the data or check alarm status. Many of the key features of any wireless system include factors such as wireless range, update rate and cost which are based on the wireless technology that is employed. Wireless range can be anywhere from 5ft with Bluetooth to unlimited range using cellular network transmission. Many dataloggers can act as Repeaters to extend the wireless range so users can 'daisy chain' them together.

Some layouts make wireless system deployment difficult. Consider whether the units would have clear line of sight to a gateway or a repeater or if their communication would be obstructed by walls or objects.

No matter which communications features are best for your application, you can use the same data logger repeatedly for different applications so they can be a great value especially for small businesses. Whether you need a simple single-channel unit to log temperature or a multi-channel system to log several temperature inputs and other parameters at the same time, you can find a data logger to meet your exact needs.

Part 4: Data Storage

Depending on your temperature recording application, you may need to only capture a few minutes' worth of data or you may need to be able to store whole months of readings. You can determine the amount of data storage required by multiplying the number of channels by the sample rate and recording duration:

Total Number of Points = Number of Channels X Sample Rate X Recording Duration

Depending on the data logger, there may be a limit based on the total amount of internal memory, or the logger may offer the option of using external memory such as a USB memory stick to expand the available memory. The most popular cold chain dataloggers use USB data collection.

It's also important to consider what is practical for your application and analysis. Many users initially state that they want to record multiple channels of data at hundreds of Hz. One problem with this is that

this would quickly fill the available memory and need more frequent downloads. Even worse, it becomes impractical to analyze all the data--with a high speed data logger sampling at 100 Hz, users can exceed the maximum number of rows in Excel in just over 10 minutes!

a. **Internal**—Many monitoring systems store recorded data on their internal memory, and there are as many different options for memory size. Note that some dataloggers have no internal memory and require users to buy external memory cards--a good solutions provider will be clear with you about this and other specifics.

b. **Local gateway**—Wireless gateways automatically collect recorder data and transmit it to a network or PC.

c. **Local PC**—PCs remain a popular and inexpensive method for storing data. It's easy to just remove a Flash drive from a USB data logger.

d. **Cloud**—Cloud storage is a relatively recent capability, enabling more advanced monitoring systems to send temperature data directly to the cloud. This is a convenient method when multiple users all need access to the data.

Part 5: Software

Ultimately you have to retrieve the data from the data recorder somehow, so do you plan to bring the logger to a computer to download data, or would you like to handle it remotely? Data logger software handles data display, configuration/setup, alarming, and more. Data recorder software might come included with the logger or cost extra depending on the manufacturer and model. Just as with PC software, some interfaces are more user-friendly than others, so if you're new to datalogging or your staff is required to work with the software, be sure to ask your distributor about it first.

Communication with the data logger for setup of monitoring and downloading data can be done in many different ways, including all the communications methods mentioned above.

a. Charting—Useful for identifying and displaying data trends such as temperature profiles or spikes. Many software packages also generate and print reports.

b. Configuration—This is an area where a user-friendly interface really pays off—you want to be able to quickly move through naming sensors and setting temperature limits and sample rates.

c. Data retrieval—You'll want to be able to retrieve your data as quickly and easily as possible, and an intuitive software really helps here.

d. Alarm management—Here you'll choose who will receive alarms and how they'll be notified, whether over email, text message or even landline phone calls with some models.

e. Report generation—The ability to easily generate compliance reports may be necessary for FDA or other regulatory bodies.

Part 6: Alarms

Many also support alarming capabilities to alert you whenever their user-set limits are exceeded.

Local alarms can consist of anything from bright LED indicators and beeps to loggers with external alarm outputs for connection to sirens, horns etc. More sophisticated models will automatically send you an email or text alarm to your smartphone so you're always on top of potentially critical changes in your product or process. Additionally, some data loggers send your data directly to a secure cloud server and will even give you a phone call at the start of an alarm event.

a. **SMS**—SMS text alerts are a popular way to get an instant heads-up on alarm events. Once configured the data logger automatically sends alarms out to specified personnel.

b. **Email**—Email alerts are equally convenient, although for critical applications you'll want to ensure that you're aware of when you're emailed—many users use their mobile devices to give them an audible when they have an incoming alarm email.

c. **Audible**—If you know that personnel will be in the vicinity or if you're in no danger of losing product, an audible alarm might be enough for your purposes. Just be sure that there are no negative consequences to miss an alarm such as process delays or spoiled food! A good rule of thumb is to assume that someone might not be in the room when the alarm goes off.

d. **Visible**—As with audible alarms, first ensure that the data recorder is located somewhere with high traffic so personnel have a fast response time.

e. **Phone**—Some systems provide dial-out capability to land line or cell phones, enabling immediate notification virtually anywhere.

With this basic understanding of the different parts of a temperature monitoring system, you're now informed enough to think about how you want to get your data and how you want to work with it. This is a great place to start contacting solution providers and seeing products and feature lists. Post-installation you should start seeing the benefits whether in the form of reduced product loss, lower operating process costs, greater vendor reputation, or whatever your specific needs are.