Basic Principles of Process Control Systems and Automation – Measuring of Variables Critical to Controlling Processes – Temperature

Your Objectives:

At the end of this lesson, you should be able to be prepared to understand the important factors related to temperature variables.

One of the key variables critical to **controlling processes** is **temperature**, which is why it must be rigorously monitored to ensure both the stability of temperature and along with a consistency of data. And this is basically because a single batch can require rigid temperature control which may include **rapid ramping** across a broad range of temperatures. Single temperature batches, even, can require both heating and cooling throughout the process so as to maintain a stable and accurate temperature, based on the desired reaction.

Cultivation temperatures are commonly monitored within an accuracy range of ± 0.5°C. Temperature measurements are taken using stainless steel Pt100 sensors. The temperature in laboratory bioreactors is controlled in one of two ways:

1. Inside the bioreactor vessel there is a heater. Cooling is ensured by thin-walled pipes, containing cooling water, located inside the vessel's upper cover. Connected to the pipes is an electromagnetic valve.
2. Heating and cooling is expedited inside a thermostat and, with the help of a pump, water circulates through a thermostat in the bioreactor jacket.

Variant 1 is less complex and ensures a more economically, yet constructive, solution. This variant works effectively for smaller bioreactors with a volume of up to approx. 5 litres.

Variant 2 ensures a more evenly distributed volume of heat everywhere inside the bioreactor, which is essential for the cultivation of microorganisms.

The prime cause of a possible lack of uniformity in temperature(s) during the temperature regulation process is incorrectly inputted PID (proportional–integral–derivative controller) parameters. This is displayed on a graph as temperature oscillations. The main challenge faced when attempting to regulate the temperature accurately is that the cooling water's minimal portion may be set too high, causing the need for the valves in the cooling water supply line to be readjusted. Another factor for the regulation accuracy is both area and density of the heat transfer surface because, if the temperature of the inertia is high, greater accuracy is more difficult to reach.

Pt100 sensor working principle

A Pt100 is a sensor used to measure temperatures. It is one of many types of sensors which falls into a group called Resistance Temperature Detectors, or RTDs.

Before explaining how the sensor works, it is worth looking at some of the terminology used as this is vital for identifying and distinguishing (various) sensors.

The sensor type Pt100 identifies two important pieces of information about the sensor. "Pt" is the chemical symbol for Platinum, and so this shows that the sensor is Platinum-based. The second part, "100", relates to the resistance of the device at 0°C. In this case 100Ω. Variations in sensor names involve other materials used, such as Nickel (Ni) and Copper (Cu), as well as different resistance values, (e.g., 50Ω, 500Ω and 1000Ω). In other words, other sensors might be identified as Cu100, Ni120, or Pt1000.

The reason a sensor falls into a category called Resistance Temperature Detectors, including the Pt100, is because "Resistance" denotes the temperature value when applying a change in resistance. For a Pt100, the resistance at 0°C is 100Ω. And at 100°C, it is 138.5Ω. Thus, the change in resistance, with each degree-Celsius change, amounts to 0.385Ω.

Temperature system's continuous control

The purpose of the temperature system is to control the vessel temperature within one (1) degree of the setpoint in order to optimise the environment for cell replication.

The temperature control system consists of two things:

- Temperature **probes**, which provide feedback from within the bioreactor,
- (A) heat **exchanger**(s) that warm(s) or cool(s) the exterior of the bioreactor which, in turn, warm(s) or cool(s) the contents of the vessel.

Temperature probes

The computerised **process controller** receives temperature-input from the temperature probes inside the bioreactor (vessel). If the temperature is too hot, or too cold, the controller signals the heat-transfer exchanger and cooling water then warms, or cools, the vessel accordingly.