Process Control Loops

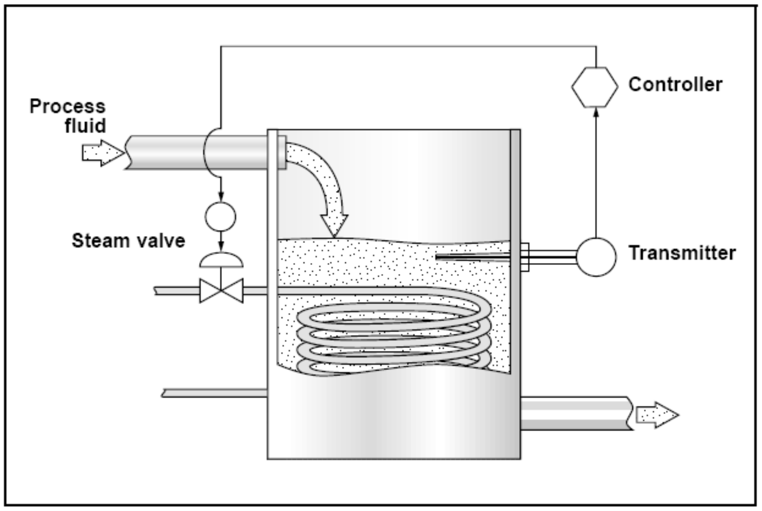
In this section, you will learn about how control components and control algorithms are integrated to create a process control system. Because in some processes many variables must be controlled, and each variable can have an impact on the entire system, control systems must be designed to respond to disturbances at any point in the system and to mitigate the effect of those disturbances throughout the system.

Single Control Loops

Control loops can be divided into two categories: Single variable loops and multi-variable loops.

FEEDBACK CONTROL

A *feedback loop* measures a process variable and sends the measurement to a controller for comparison to setpoint. If the process variable is not at setpoint, control action is taken to return the process variable to setpoint. Figure 7.18 illustrates a feedback loop in which a transmitter measures the temperature of a fluid and, if necessary, opens or closes a hot steam valve to adjust the fluid's temperature.



Feedback Loop

An everyday example of a feedback loop is the cruise control system in an automobile. A setpoint is established for speed. When the car begins to climb a hill, the speed drops below setpoint and the controller adjusts the throttle to return the car's speed to setpoint.

Feedback loops are commonly used in the process control industry. The advantage of a feedback loop is that it directly controls the desired process variable. The disadvantage to feedback loops is that the process variable must leave setpoint for action to be taken.

Activities

1. What type of control loop takes action in response to measured deviation from setpoint?

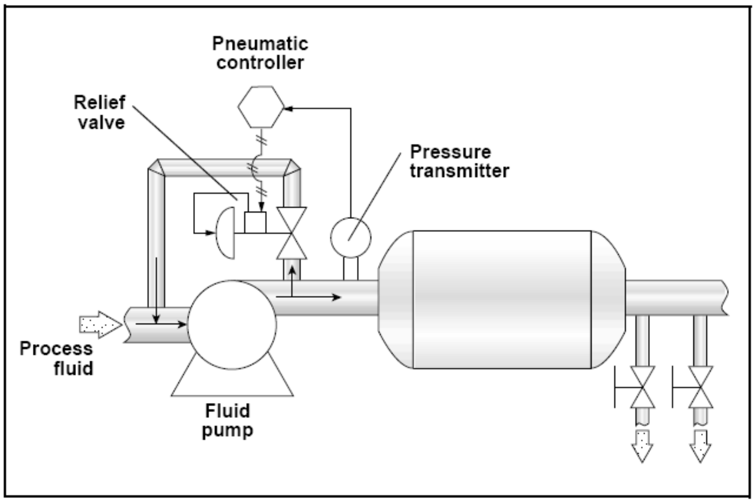
1 Discrete control loop
2 Multi-step control loop
3 Open loop
4 Feedback control loop

Examples of Single Control Loops

While each application has its own characteristics, some general statements can be made about pressure, flow, level, and temperature loops.

PRESSURE CONTROL LOOPS

Pressure control loops vary in speed—that is, they can respond to changes in load or to control action slowly or quickly. The speed required in a pressure control loop may be dictated by the volume of the process fluid. High-volume systems (e.g., large natural gas storage facilities) tend to change more slowly than low-volume systems (Figure 7.21).



A Pressure Loop

Activities

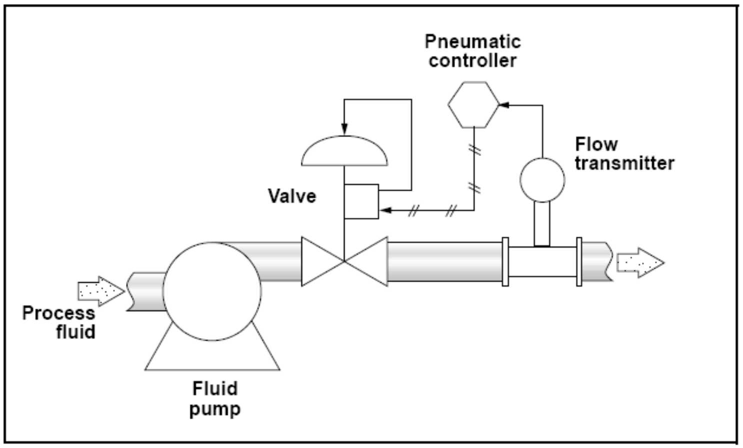
2. How does a high-volume pressure control loop react as compared to a small-volume pressure control loop?

1 Same rate
2 Quicker
3 Slower
4 Extremely fast

Examples of Single Control Loops

FLOW CONTROL LOOPS

Generally, flow control loops are regarded as fast loops that respond to changes quickly. Therefore, flow control equipment must have fast sampling and response times. Because flow transmitters tend to be rather sensitive devices, they can produce rapid fluctuations or noise in the control signal. To compensate for noise, many flow transmitters have a damping function that filters out noise. Sometimes, filters are added between the transmitter and the control system. Because the temperature of the process fluid affects its density, temperature measurements are often taken with flow measurements and compensation for temperature is accounted for in the flow calculation. Typically, a flow sensor, a transmitter, a controller, and a valve or pump are used in flow control loops (Figure 7.22).



A Flow Loop

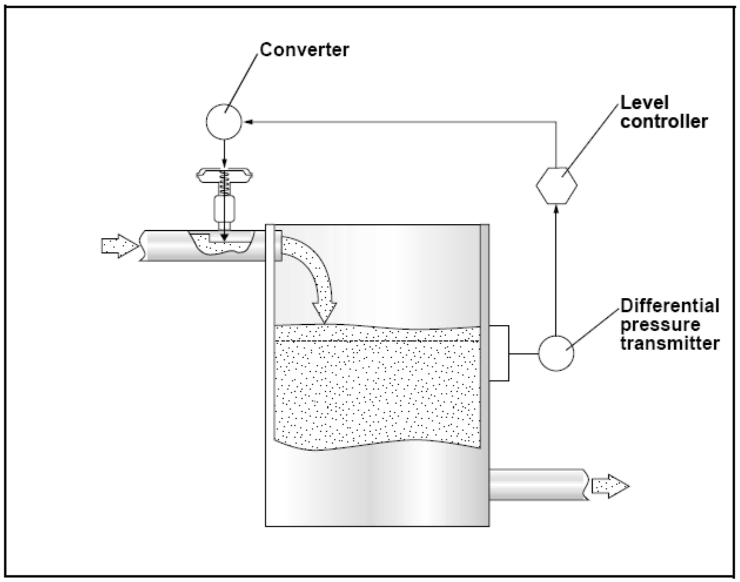
Activities

3. Flow control loops are generally considered to be slow responding loops. Is this statement true or false?

Examples of Single Control Loops

Level Control Loops

The speed of changes in a level control loop largely depends on the size and shape of the process vessel (e.g., larger vessels take longer to fill than smaller ones) and the flow rate of the input and outflow pipes. Manufacturers may use one of many different measurement technologies to determine level, including radar, ultrasonic, float gauge, and pressure measurement. The final control element in a level control loop is usually a valve on the input and/or outflow connections to the tank (Figure 7.23). Because it is often critical to avoid tank overflow, redundant level control systems are sometimes employed.



A Level Loop

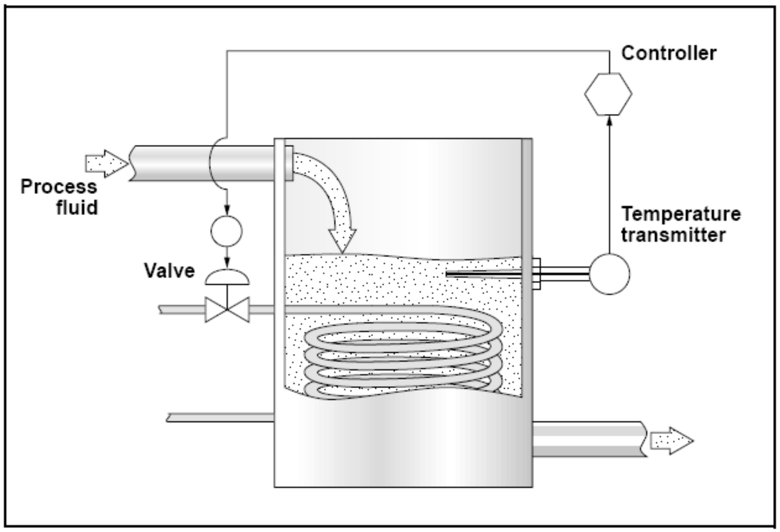
Activities

4. Redundant control systems are sometimes used in level applications because preventing tank overflow is often critically important. Is this statement true or false?

Examples of Single Control Loops

TEMPERATURE CONTROL LOOPS

Because of the time required to change the temperature of a process fluid, temperature loops tend to be relatively slow. Feedforward control strategies are often used to increase the speed of the temperature loop response. RTDs or thermocouples are typical temperature sensors. Temperature transmitters and controllers are used, although it is not uncommon to see temperature sensors wired directly to the input interface of a controller. The final control element for a temperature loop is usually the fuel valve to a burner or a valve to some kind of heat exchanger. Sometimes, cool process fluid is added to the mix to maintain temperature (Figure 7.24).



A Temperature Loop

Activities

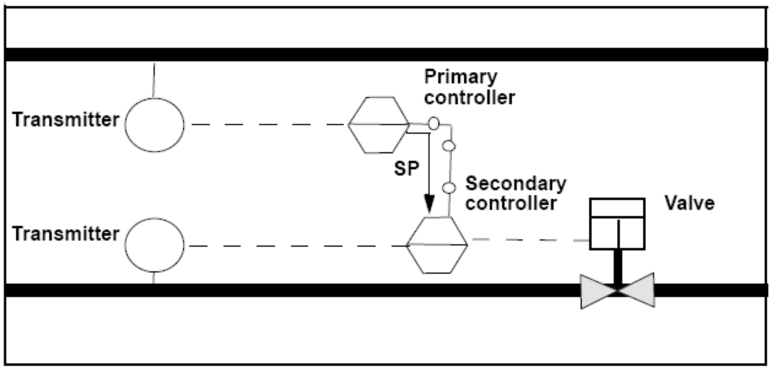
5. What type of control strategy is often used to increase the speed of a temperature control loop?

1 Feedforward control
2 Feedback control
3 Cascade control
4 Ratio control

Multi-Variable / Advanced Control Loops

MULTIVARIABLE LOOPS

Multivariable loops are control loops in which a primary controller controls one process variable by sending signals to a controller of a different loop that impacts the process variable of the primary loop. For example, the primary process variable may be the temperature of the fluid in a tank that is heated by a steam jacket (a pressurized steam chamber surrounding the tank). To control the primary variable (temperature), the primary (master) controller signals the secondary (slave) controller that is controlling steam pressure. The primary controller will manipulate the setpoint of the secondary controller to maintain the setpoint temperature of the primary process variable (Figure 7.17).



Multivariable Loop

When tuning a control loop, it is important to take into account the presence of multivariable loops. The standard procedure is to tune the secondary loop before tuning the primary loop because adjustments to the secondary loop impact the primary loop. Tuning the primary loop will not impact the secondary loop tuning.

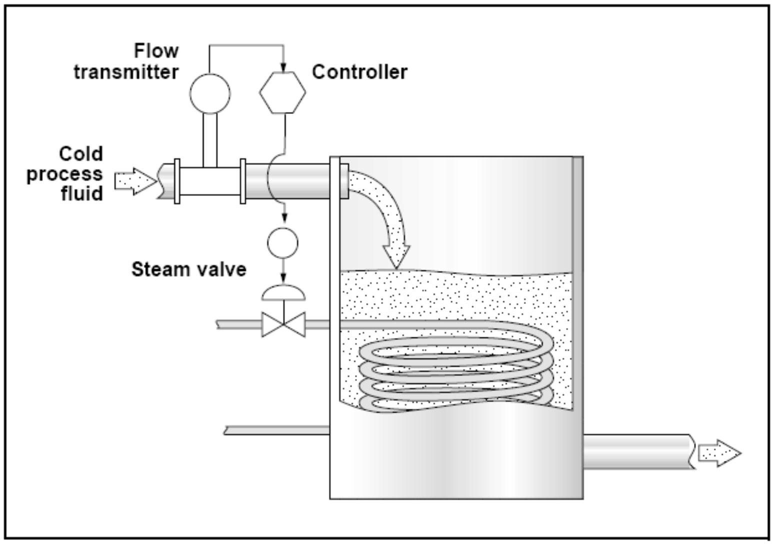
Activities

6. A multivariable control loop contains a primary and secondary controller assigned to different process variables? Is this statement true or false?

Multi-Variable / Advanced Control Loops

FEEDFORWARD CONTROL

Feedforward control is a control system that anticipates load disturbances and controls them before they can impact the process variable. For feedforward control to work, the user must have a mathematical understanding of how the manipulated variables will impact the process variable. Figure 7.19 shows a feedforward loop in which a flow transmitter opens or closes a hot steam valve based on how much cold fluid passes through the flow sensor.



Feedforward Control

An advantage of feedforward control is that error is prevented, rather than corrected. However, it is difficult to account for all possible load disturbances in a system through feedforward control. Factors such as outside temperature, buildup in pipes, consistency of raw materials, humidity, and moisture content can all become load disturbances and cannot always be effectively accounted for in a feedforward system.

In general, feedforward systems should be used in cases where the controlled variable has the potential of being a major load disturbance on the process variable ultimately being controlled. The added complexity and expense of feedforward control may not be equal to the benefits of increased control in the case of a variable that causes only a small load disturbance.

Activities

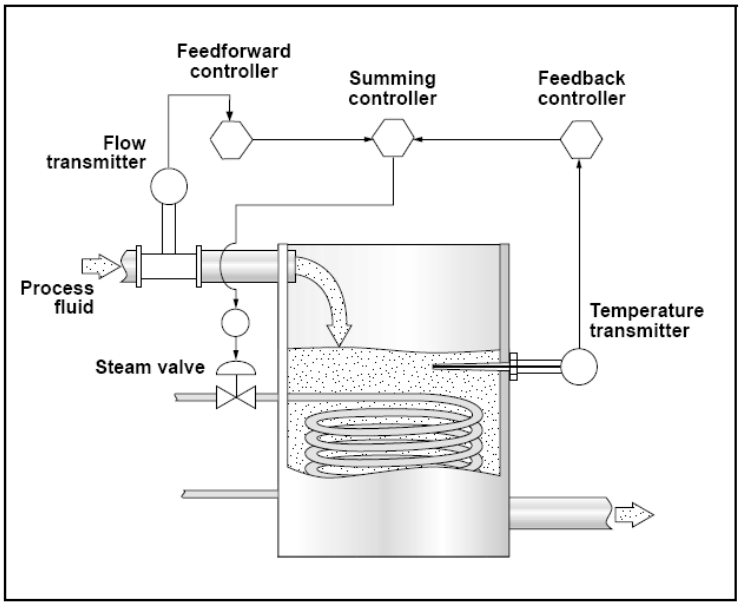
7. What type of control loop anticipates and controls load disturbances before they can impact the process variable?

1 Feedback control loop
2 Feedforward control loop
3 Ratio control loop
4 Single variable loop

Multi-Variable / Advanced Control Loops

FEEDFORWARD PLUS FEEDBACK

Because of the difficulty of accounting for every possible load disturbance in a feedforward system, feedforward systems are often combined with feedback systems. Controllers with summing functions are used in these combined systems to total the input from both the feedforward loop and the feedback loop, and send a unified signal to the final control element. Figure 7.20 shows a feedforward-plus-feedback loop in which both a flow transmitter and a temperature transmitter provide information for controlling a hot steam valve.



Feedforward Plus Feedback Control System

Activities

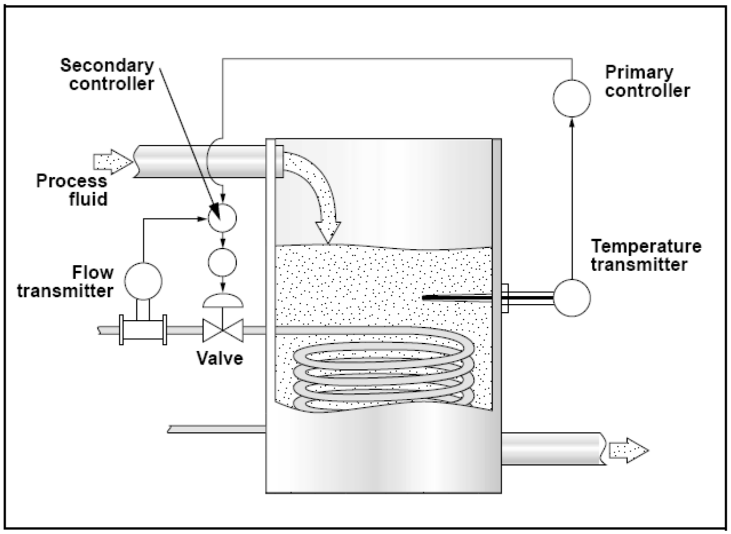
8. A controller with a summing function totals the input from both the feedforward loop and the feedback loop and sends a unified signal to the final control element. This is how a single control signal is sent to the final control element in a feedforward plus feedback system. Is this statement true or false?

Multi-Variable / Advanced Control Loops

This module has discussed specific types of control loops, what components are used in them, and some of the applications (e.g., flow, pressure, temperature) they are applied to. In practice, however, many independent and interconnected loops are combined to control the workings of a typical plant. This section will acquaint you with some of the methods of control currently being used in process industries.

CASCADE CONTROL

Cascade control is a control system in which a secondary (slave) control loop is set up to control a variable that is a major source of load disturbance for another primary (master) control loop. The controller of the primary loop determines the setpoint of the summing contoller in the secondary loop (Figure 7.25).



Cascade Control

Activities

9. Ratio control is the term used to describe a system in which the controller of the primary loop determines the setpoint of a secondary loop. Is this statement true or false?

Multi-Variable / Advanced Control Loops

BATCH CONTROL

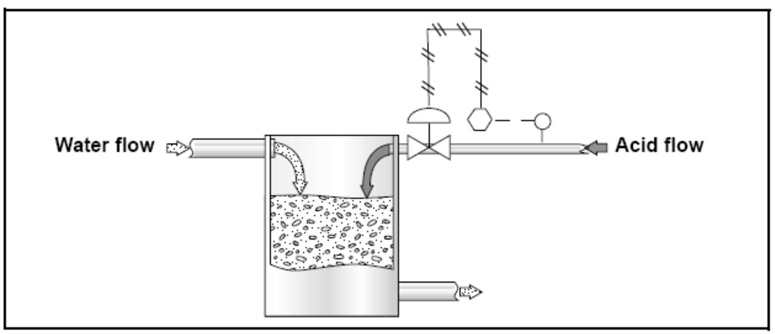
Batch processes are those processes that are taken from start to finish in batches. For example, mixing the ingredients for a juice drinks is often a batch process. Typically, a limited amount of one flavor (e.g., orange drink or apple drink) is mixed at a time. For these reasons, it is not practical to have a continuous process running. Batch processes often involve getting the correct proportion of ingredients into the batch. Level, flow, pressure, temperature, and often mass measurements are used at various stages of batch processes.

A disadvantage of batch control is that the process must be frequently restarted. Start-up presents control problems because, typically, all measurements in the system are below setpoint at start-up. Another disadvantage is that as recipes change, control instruments may need to be recalibrated.

RATIO CONTROL

Imagine a process in which an acid must be diluted with water in the proportion two parts water to one part acid. If a tank has an acid supply on one side of a mixing vessel and a water supply on the other, a control system could be developed to control the ratio of acid to water, even though the water supply itself may not be controlled. This type of control system is called *ratio control (*Figure 7.26). Ratio control is used in many applications and involves a contoller that receives input from a flow measurement device on the unregulated (wild) flow. The controller performs a ratio calculation and signals the appropriate setpoint to another controller that sets the flow of the second fluid so that the proper proportion of the second fluid can be added.

Ratio control might be used where a continuous process is going on and an additive is being put into the flow (e.g., chlorination of water).



Ratio Control

Activities

10. Which term describes a control system in which controlled flow is added proportionately to an uncontrolled flow?

1 Selective control
2 Cascade control
3 Ratio control
4 Fuzzy control

Multi-Variable / Advanced Control Loops

SELECTIVE CONTROL

Selective control refers to a control system in which the more important of two variables will be maintained. For example, in a boiler control system, if fuel flow outpaces air flow, then uncombusted fuel can build up in the boiler and cause an explosion. Selective control is used to allow for an air-rich mixture, but never a fuel-rich mixture. Selective control is most often used when equipment must be protected or safety maintained, even at the cost of not maintaining an optimal process variable setpoint.

FUZZY CONTROL

Fuzzy control is a form of adaptive control in which the controller uses fuzzy logic to make decisions about adjusting the process. *Fuzzy logic* is a form of computer logic where whether something is or is not included in a set is based on a grading scale in which multiple factors are accounted for and rated by the computer. The essential idea of fuzzy control is to create a kind of artificial intelligence that will account for numerous variables, formulate a theory of how to make improvements, adjust the process, and learn from the result.

Fuzzy control is a relatively new technology. Because a machine makes process control changes without consulting humans, fuzzy control removes from operators some of the ability, but none of the responsibility, to control a process.

Activities

11. In which type of control system will the more important of two variables be maintained?

1. Fuzzy control
2. Cascade control
3. Ratio control
4. Selective control

12. ______________ control is the term used to describe a control system in which the controller uses computer logic to make decisions about adjusting the process.