Introduction

Control in process industries refers to the regulation of all aspects of the process. Precise control of level, temperature, pressure and flow is important in many process applications. This module introduces you to control in process industries, explains why control is important, and identifies different ways in which precise control is ensured.

The following five sections are included in this module:

- ❑ The importance of process control
- ❑ Control theory basics
- ❑ Components of control loops and ISA symbology
- ❑ Controller algorithms and tuning
- ❑ Process control systems

As you proceed through the module, answer the questions in the activities column on the right side of each page. Also, note the application boxes (double-bordered boxes) located throughout the module. Application boxes provide key information about how you may use your baseline knowledge in the field. When you see the workbook exercise graphic at the bottom of a page, go to the workbook to complete the designated exercise before moving on in the module. Workbook exercises help you measure your progress toward meeting each section's learning objectives.

Performance Objective

After completing this module, you will be able to determine needed control loop components in specific process control applications.

The Importance of Process Control

Refining, combining, handling, and otherwise manipulating fluids to profitably produce end products can be a precise, demanding, and potentially hazardous process. Small changes in a process can have a large impact on the end result. Variations in proportions, temperature, flow, turbulence, and many other factors must be carefully and consistently controlled to produce the desired end product with a minimum of raw materials and energy. Process control technology is the tool that enables manufacturers to keep their operations running within specified limits and to set more precise limits to maximize profitability, ensure quality and safety.

LEARNING OBJECTIVES

After completing this section, you will be able to:

- ❑ Define process
- ❑ Define process control
- ❑ Describe the importance of process control in terms of variability, efficiency, and safety

Note: To answer the activity questions the Hand Tool (H) should be activated.

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The Importance of Process Control

Process

Process as used in the terms *process control* and *process industry,* refers to the methods of changing or refining raw materials to create end products. The raw materials, which either pass through or remain in a liquid, gaseous, or slurry (a mix of solids and liquids) state during the process, are transferred, measured, mixed, heated or cooled, filtered, stored, or handled in some other way to produce the end product.

Process industries include the chemical industry, the oil and gas industry, the food and beverage industry, the pharmaceutical industry, the water treatment industry, and the power industry.

Process Control

Process control refers to the methods that are used to control process variables when manufacturing a product. For example, factors such as the proportion of one ingredient to another, the temperature of the materials, how well the ingredients are mixed, and the pressure under which the materials are held can significantly impact the quality of an end product. Manufacturers control the production process for three reasons:

- ❑ Reduce variability
- ❑ Increase efficiency
- ❑ Ensure safety

Reduce Variability

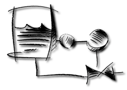
Process control can reduce variability in the end product, which ensures a consistently high-quality product. Manufacturers can also save money by reducing variability. For example, in a gasoline blending process, as many as 12 or more different components may be blended to make a specific grade of gasoline. If the refinery does not have precise control over the flow of the separate components, the gasoline may get too much of the high-octane components. As a result, customers would receive a higher grade and more expensive gasoline than they paid for, and the refinery would lose money. The opposite situation would be customers receiving a lower grade at a higher price.

Activities

1. Process is defined as the changing or refining of raw materials that pass through or remain in a liquid, gaseous, or slurry state to to create end products.

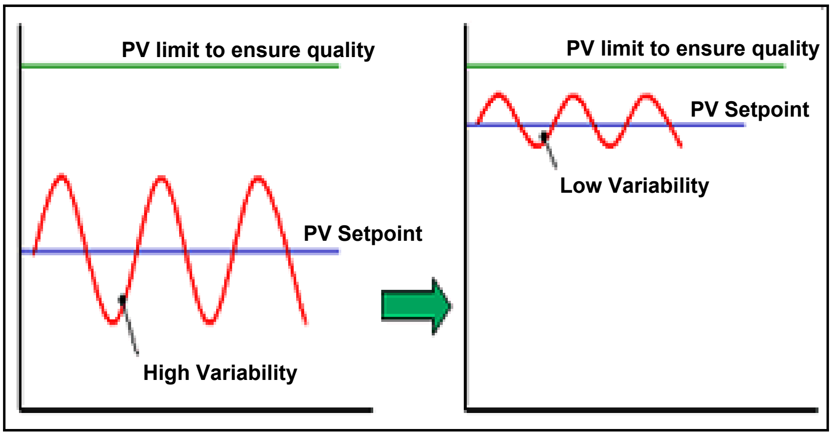
2. Which of these industries are examples of the process industry?
   Select all options that apply.

1	Pharmaceutical
2	Satellite
3	Oil and Gas
4	Cement
5	Power



The Importance of Process Control

Reducing variability can also save money by reducing the need for product padding to meet required product specifications. *Padding* refers to the process of making a product of higher-quality than it needs to be to meet specifications. When there is variability in the end product (i.e., when process control is poor), manufacturers are forced to pad the product to ensure that specifications are met, which adds to the cost. With accurate, dependable process control, the *setpoint* (desired or optimal point) can be moved closer to the actual product specification and thus save the manufacturer money.



Increase Efficiency

Some processes need to be maintained at a specific point to maximize efficiency. For example, a control point might be the temperature at which a chemical reaction takes place. Accurate control of temperature ensures process efficiency. Manufacturers save money by minimizing the resources required to produce the end product.

Ensure Safety

A run-away process, such as an out-of-control nuclear or chemical reaction, may result if manufacturers do not maintain precise control of all of the processg variables. The consequences of a run-away process can be catastrophic.

Precise process control may also be required to ensure safety. For example, maintaining proper boiler pressure by controlling the inflow of air used in combustion and the outflow of exhaust gases is crucial in preventing boiler implosions that can clearly threaten the safety of workers.

Activities

3. What are the main reasons for manufacturers to control a process? Select all options that apply.

1 Reduce variability
2 Ensure safety
3 Reduce costs
4 Increase efficiency
5 Increase productivity

Control Theory Basics

This section presents some of the basic concepts of control and provides a foundation from which to understand more complex control processes and algorithms later described in this module. Common terms and concepts relating to process control are defined in this section.

LEARNING OBJECTIVES

After completing this section, you will be able to:

- ❑ Define control loop
- ❑ Describe the three tasks necessary for process control to occur:
  - Measure
  - Compare
  - Adjust
- ❑ Define the following terms:
  - Process variable
  - Setpoint
  - Manipulated variable
  - Measured variable
  - Error
  - Offset
  - Load disturbance
  - Control algorithm
- ❑ List at least five process variables that are commonly controlled in process measurement industries
- ❑ At a high level, differentiate the following types of control:
  - Manual versus automatic feedback control
  - Closed-loop versus open-loop control

Note: To answer the activity questions the Hand Tool (H) should be activated.

The Control Loop

Imagine you are sitting in a cabin in front of a small fire on a cold winter evening. You feel uncomfortably cold, so you throw another log on the fire. This is an example of a *control loop*. In the control loop, a variable (temperature) fell below the setpoint (your comfort level), and you took action to bring the process back into the desired condition by adding fuel to the fire. The control loop will now remain static until the temperature again rises above or falls below your comfort level.

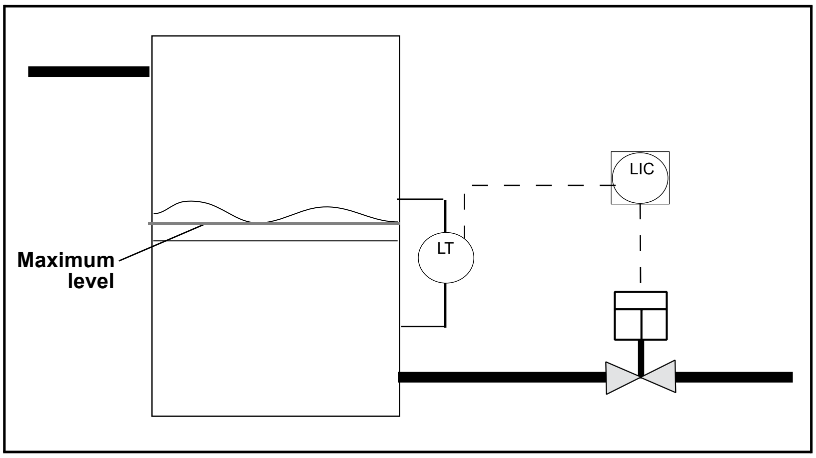
THREE TASKS

Control loops in the process control industry work in the same way, requiring three tasks to occur:

- ❑ Measurement
- ❑ Comparison
- ❑ Adjustment

In Figure 7.1, a level transmitter (LT) measures the level in the tank and transmits a signal associated with the level reading to a controller (LIC). The controller compares the reading to a predetermined value, in this case, the maximum tank level established by the plant operator, and finds that the values are equal. The controller then sends a signal to the device that can bring the tank level back to a lower level—a valve at the bottom of the tank. The valve opens to let some liquid out of the tank.

Many different instruments and devices may or may not be used in control loops (e.g., transmitters, sensors, controllers, valves, pumps), but the three tasks of measurement, comparison, and adjustment are always present.



A Simple Control Loop

Activities

1. The three tasks associated with any control loop are measurement, comparison, and adjustment. Is this statement true or false?

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Process Control Terms

As in any field, process control has its own set of common terms that you should be familiar with and that you will use when talking about control technology.

PROCESS VARIABLE

A *process variable* is a condition of the process fluid (a liquid or gas) that can change the manufacturing process in some way. In the example of you sitting by the fire, the process variable was temperature. In the example of the tank in Figure 7.1, the process variable is level. Common process variables include:

- ❑ Pressure
- ❑ Flow
- ❑ Level
- ❑ Temperature
- ❑ Density
- ❑ Ph (acidity or alkalinity)
- ❑ Liquid interface (the relative amounts of different liquids that are combined in a vessel)
- ❑ Mass
- ❑ Conductivity

SETPOINT

The *setpoint* is a value for a process variable that is desired to be maintained. For example, if a process temperature needs to kept within 5 °C of 100 °C, then the setpoint is 100 °C. A temperature sensor can be used to help maintain the temperature at setpoint.
The sensor is inserted into the process, and a contoller compares the temperature reading from the sensor to the setpoint. If the temperature reading is 110 °C, then the controller determines that the process is above setpoint and signals the fuel valve of the burner to close slightly until the process cools to 100 °C. Set points can also be maximum or minimum values. For example, level in tank cannot exceed 20 feet.

Activities

2. A process variable is a condition that can change the process in some way.

3. Imagine you are in a cabin in front of a small fire on a cold winter evening. You feel uncomfortably cold, so you throw another log into the fire. In this scenario, the process variable is temperature. Is this true or false?

4. If the level of a liquid in a tank must be maintained within 5 ft of 50 ft, what is the liquid's setpoint?

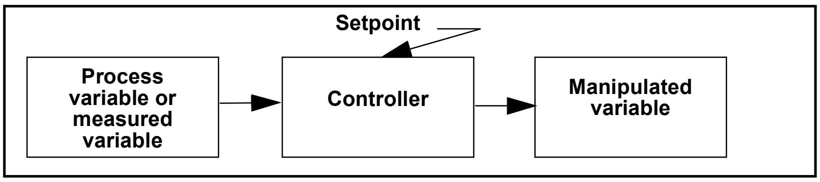
1 45 ft
2 55 ft
3 5 ft
4 50 ft

Process Control Terms

Measured Variables, Process Variables, and Manipulated Variables

In the temperature control loop example, the measured variable is temperature, which must be held close to 100 °C. In this example and in most instances, the measured variable is also the process variable. The *measured variable* is the condition of the process fluid that must be kept at the designated setpoint.

Sometimes the measured variable is not the same as the process variable. For example, a manufacturer may measure flow into and out of a storage tank to determine tank level. In this scenario, flow is the measured variable, and the process fluid level is the *process variable.* The factor that is changed to keep the measured variable at setpoint is called the *manipulated variable*. In the example described, the manipulated variable would also be flow (Figure 7.2).



Variables

Error

Error is the difference between the measured variable and the setpoint and can be either positive or negative. In the temperature control loop example, the error is the difference between the 110 °C measured variable and the 100 °C setpoint—that is, the error is +10 °C.

The objective of any control scheme is to minimize or eliminate error. Therefore, it is imperative that error be well understood. Any error can be seen as having three major components. These three components are shown in the figure on the folowing page

Magnitude

The magnitude of the error is simply the deviation between the values of the setpoint and the process variable. The magnitude of error at any point in time compared to the previous error provides the basis for determining the change in error. The change in error is also an important value.

Activities

5. ____________________ is a sustained deviation of the process variable from the setpoint.

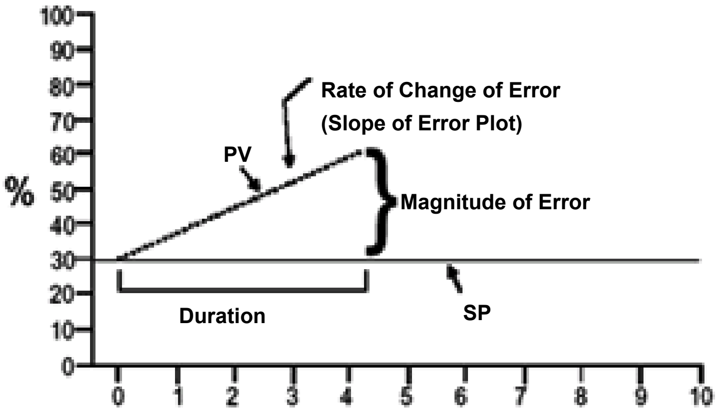
6. A load disturbance is an undesired change in one of the factors that can affect the setpoint. Is this statement true or false?

Process Control Terms

Activities

Duration
Duration refers to the length of time that an error condition has existed.

Rate Of Change
The rate of change is shown by the slope of the error plot.



Components of Error

OFFSET

Offset is a sustained deviation of the process variable from the setpoint. In the temperature control loop example, if the control system held the process fluid at 100.5 °C consistently, even though the setpoint is 100 °C, then an offset of 0.5 °C exists.

LOAD DISTURBANCE

A *load disturbance* is an undesired change in one of the factors that can affect the process variable. In the temperature control loop example, adding cold process fluid to the vessel would be a load disturbance because it would lower the temperature of the process fluid.

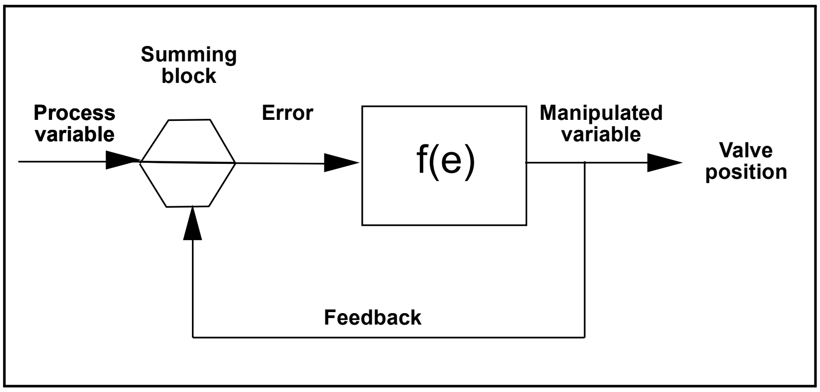
CONTROL ALGORITHM

A *control algorithm* is a mathematical expression of a control function. Using the temperature control loop example, V in the equation below is the fuel valve position, and e is the error. The relationship in a control algorithm can be expressed as:

Process Control Terms

$$V = f(\pm e)$$

The fuel valve position (V) is a function (f) of the sign (positive or negative) of the error (Figure 7.3).



Algorithm Example

Control algorithms can be used to calculate the requirements of much more complex control loops than the one described here. In more complex control loops, questions such as “How far should the valve be opened or closed in response to a given change in setpoint?” and “How long should the valve be held in the new position after the process variable moves back toward setpoint?” need to be answered.

MANUAL AND AUTOMATIC CONTROL

Before process automation, people, rather than machines, performed many of the process control tasks. For example, a human operator might have watched a level gauge and closed a valve when the level reached the setpoint. Control operations that involve human action to make an adjustment are called *manual control* systems. Conversely, control operations in which no human intervention is required, such as an automatic valve actuator that responds to a level controller, are called *automatic control* systems.

Activities

7. Automatic control systems are control operations that involve human action to make adjustment. Is this statement true or false?

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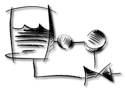

Process Control Terms

CLOSED AND OPEN CONTROL LOOPS

A *closed control loop* exists where a process variable is measured, compared to a setpoint, and action is taken to correct any deviation from setpoint. An *open control loop* exists where the process variable is not compared, and action is taken not in response to feedback on the condition of the process variable, but is instead taken without regard to process variable conditions. For example, a water valve may be opened to add cooling water to a process to prevent the process fluid from getting too hot, based on a pre-set time interval, regardless of the actual temperature of the process fluid.

Activities

8. Under what circumstances does an open control loop exist?
   Select all options that apply.

1 Process variable is not measured
2 Process variable is not compared
3 Process variable is measured and compared to a setpoint
4 Action is taken without regard to process variable conditions
5 Action is taken with regard to process variable conditions