Automated Process Control Introduction

Alessandro Anzalone, Ph.D.
Hillsborough Community College, Brandon Campus

Agenda

1. Introduction
2. Process Control System
3. Important Terms and Objective of Automatic Process Control
4. Regulatory and Servo Control
5. Transmission Signals, Control Systems, and Other Terms
6. Control Strategies
    1. Feedback Control
    2. Feedforward Control
7. Summary
8. References

Introduction

Automatic process control is concerned with maintaining process variables, temperatures, pressures, flows, compositions, and the like, at a desired operating value. As we will see in this course, processes are dynamic in nature. Changes are always occurring, and if actions are not taken, the important process variables—those related to safety, product quality, and production rates—will not achieve design conditions.

Process Control System

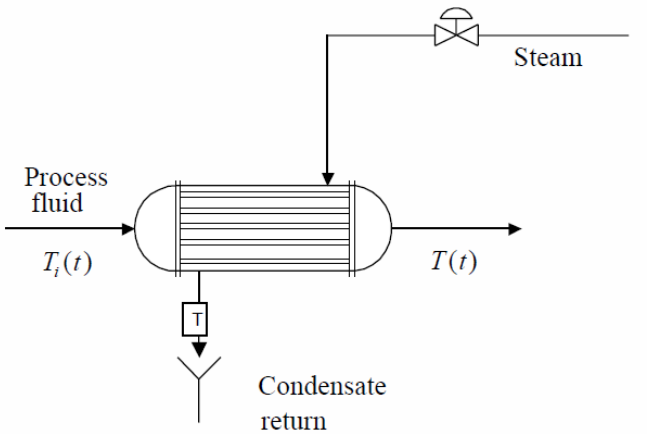


Figure 1-1.1 Heat exchanger.

Process Control System

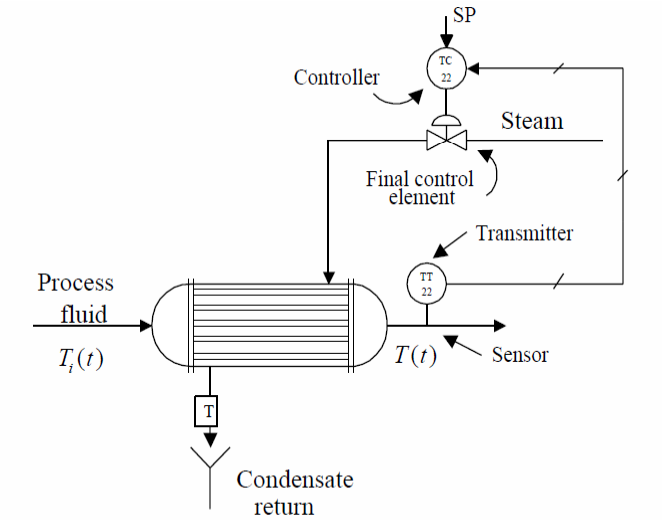


Figure 1-1.2 Heat exchanger control loop.

Process Control System

The preceding discussion presented the three basic components of all control systems:

1. Sensor/transmitter: also often called the primary and secondary elements
2. Controller: the "brain" of the control system
3. Final control element: often a control valve, but not always.

Process Control System

The importance of these components is that they perform the three basic operations that must by present in every control system:

1. Measurement (M). Measuring the variable to be controlled is usually done by the combination of sensor and transmitter.
2. Decision (D). Based on the measurement, the controller decides what to do to maintain the variable at its desired value.
3. Action (A). As a result of the controller's decision, the system must then take an action. This is usually accomplished by the final control element.

Important Terms and Objective of Automatic Process Control

- ✓ The *controlled variable*, which is the variable that must be maintained, or controlled, at some desired value. Process variable and/or measurement are also used to refer to the controlled variable.
- ✓ The *set point* is the desired value of the controlled variable. Thus the job of a control system is to maintain the controlled variable at its set point.
- ✓ The *manipulated variable* is the variable used to maintain the controlled variable at its set point.

Important Terms and Objective of Automatic Process Control

- ✓ Finally, any variable that causes the controlled variable to deviate away from the set point is defined as a disturbance or upset. In most processes there are a number of different disturbances. It is important to understand that disturbances are always occurring in processes. Steady state is not the rule; transient conditions are very common. It is because of these disturbances that automatic process control is needed. If there were no disturbances, design operating conditions would prevail and there would be no necessity of continuously "monitoring" the process.

With these terms defined, we can simply state the following:

The objective of an automatic process control system is to adjust the manipulated variable to maintain the controlled variable at its set point in spite of disturbances.

Important Terms and Objective of Automatic Process Control

It is wise to enumerate some of the reasons why control is important. They may not be the only ones, but we feel they are the most important.

1. Prevent injury to plant personnel, protect the environment by preventing emissions and minimizing waste, and prevent damage to the process equipment. Safety must always be in everyone's mind; it is the single most important consideration.
2. Maintain product quality (composition, purity, color, etc.) on a continuous basis and with minimum cost.
3. Maintain plant production rate at minimum cost.

Important Terms and Objective of Automatic Process Control

The following additional terms are also important.

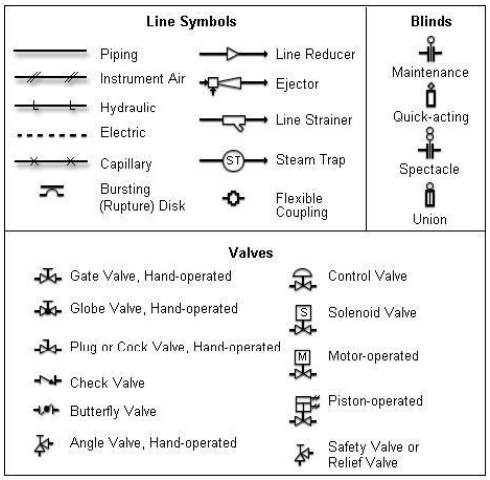
- ✓ *Manual control* refers to the condition in which the controller is disconnected from the process. That is, the controller is not making the decision as to how to maintain the controlled variable at the set point. It is up to the operator to manipulate the signal to the final control element to maintain the controlled variable at the set point.
- ✓ *Automatic or closed loop control* refers to the condition in which the controller is connected to the process, comparing the set point to the controlled variable, and determining and taking corrective action.

Regulatory and Servo Control

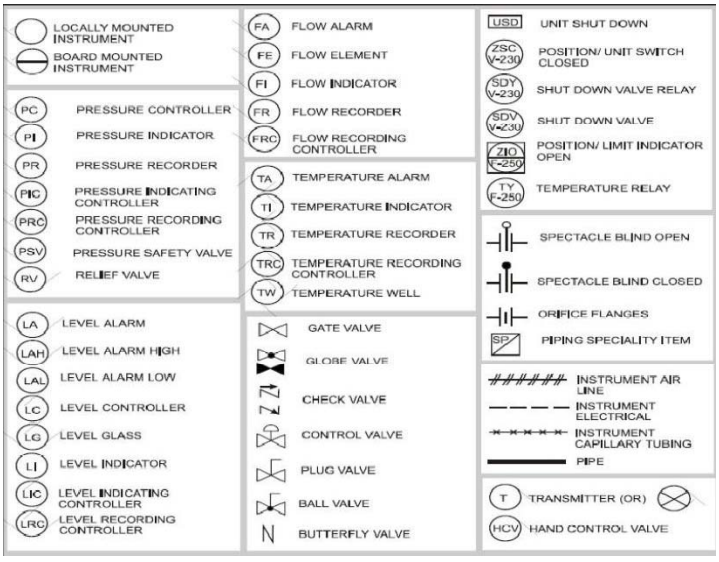
In some processes the controlled variable deviates from the set point because of disturbances. *Regulatory control* refers to systems designed to compensate for these disturbances. In some other instances the most important disturbance is the set point itself. That is, the set point may be changed as a function of time (typical of this is a batch reactor where the temperature must follow a desired profile), and therefore the controlled variable must follow the set point. *Servo control* refers to control systems designed for this purpose.

Regulatory control is far more common than servo control in the process industries. However, the basic approach to designing them is essentially the same. Thus the principles discussed in this course apply to both cases.

Transmission Signals, Control Systems, and Other Terms



Transmission Signals, Control Systems, and Other Terms



Transmission Signals, Control Systems, and Other Terms

It will help in understanding control systems to realize that signals are used by devices (transmitters, controllers, final control elements, etc.) to communicate. That is, signals are used to convey information. The signal from the transmitter to the controller is used by the transmitter to inform the controller of the value of the controlled variable. It is not the measurement in engineering units, but rather, a mA, psig, volt, or other signal that is proportional to the measurement. The relationship to the measurement depends on the calibration of the sensor/transmitter. The controller uses its output signal to indicate to the final control element what to do (i.e., how much to open if it is a valve, how fast to run if it is a variable-speed pump, etc.).

Transmission Signals, Control Systems, and Other Terms

Thus every signal is related to some physical quantity that makes sense from an engineering point of view. The signal from the temperature transmitter in Fig. 1-1.2 is related to the outlet temperature, and the signal from the controller is related to the steam valve position.

Transmission Signals, Control Systems, and Other Terms

It is often necessary to change one type of signal into another type. A transducer or converter does this. For example, there may be a need to change from an electrical signal, mA, to a pneumatic signal, psig. This is done by the use of a current (I) to pneumatic (P) transducer (I/P). The input signal may be 4 to 20mA and the output 3 to 15 psig. An analog-to-digital (A to D) converter changes from an mA or volt signal to a digital signal. There are many other types of transducers: digital to analog (D to A), pneumatic to current (P/I), voltage to pneumatic (E/P), pneumatic to voltage (P/E), and so on.

Transmission Signals, Control Systems, and Other Terms

The term analog refers to the controller, or any other instrument, which is pneumatic, electrical, hydraulic, or mechanical. Most controllers however, are computer based, or digital. By computer-based we don't necessarily mean a mainframe computer but rather, anything starting from a microprocessor. In fact, most controllers are microprocessor-based.

Control Strategies

Feedback Control

The control scheme shown in Fig. 1-1.2 is referred to as feedback control, also called a feedback control loop. One must understand the working principles of feedback control to recognize its advantages and disadvantages; the heat exchanger control loop shown in Fig. 1-1.2 is presented to foster this understanding.

Control Strategies

Feedback Control

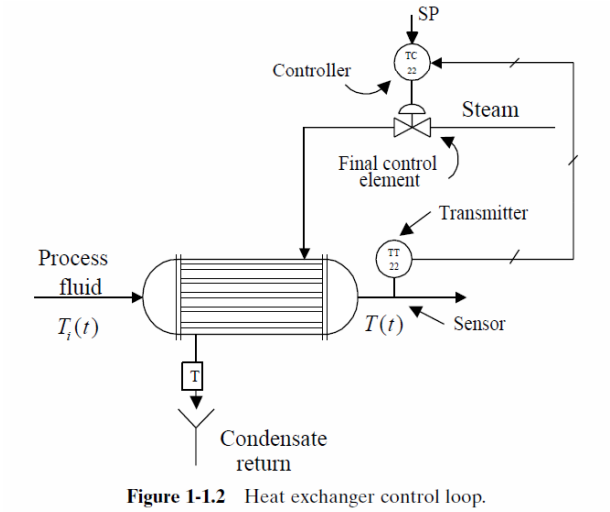


Figure 1-1.2 Heat exchanger control loop.

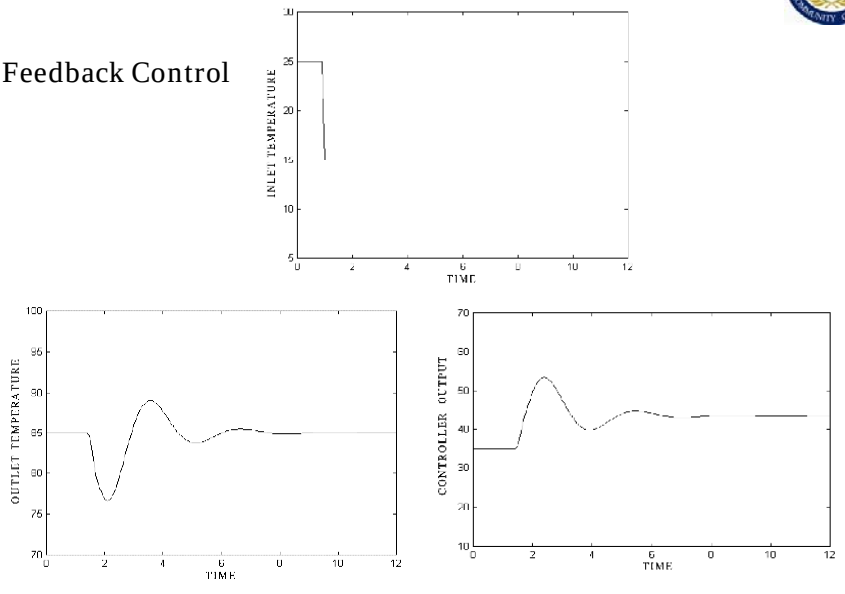
Control Strategies

Feedback Control

If the inlet process temperature decreases, thus creating a disturbance, its effect must propagate through the heat exchanger before the outlet temperature decreases. Once this temperature changes, the signal from the transmitter to the controller also changes. It is then that the controller becomes aware that a deviation from set point has occurred and that it must compensate for the disturbance by manipulating the steam valve. The controller then signals the valve to increase its opening and thus increase the steam flow. Figure 1-5.1 shows graphically the effect of the disturbance and the action of the controller.

Control Strategies

Feedback Control



Control Strategies

Feedback Control

The *advantage* of feedback control is that it is a very simple technique that compensates for all disturbances. Any disturbance affects the controlled variable, and once this variable deviates from the set point, the controller changes its output to return the controlled variable to set point. The feedback control loop does not know, nor does it care, which disturbance enters the process. It only tries to maintain the controlled variable at set point and in so doing compensates for all disturbances. The feedback controller works with minimum knowledge of the process. In fact, the only information it needs is in which direction to move. How much to move is usually adjusted by trial and error. The *disadvantage* of feedback control is that it can compensate for a disturbance only after the controlled variable has deviated from the set point. That is, the disturbance must propagate through the entire process before the feedback control scheme can compensate for it.

Control Strategies

Feedforward Control

Feedback control is the most common control strategy in the process industries. Its simplicity accounts for its popularity. In some processes, however, feedback control may not provide the control performance required. For these processes, other types of control may have to be designed. Later in the course we present additional control strategies that have proven to be profitable. One such strategy is *feedforward control*. The objective of feedforward control is to measure the disturbances and compensate for them before the controlled variable deviates from the set point. If applied correctly, the controlled variable deviation would be minimum.

Control Strategies

Feedforward Control

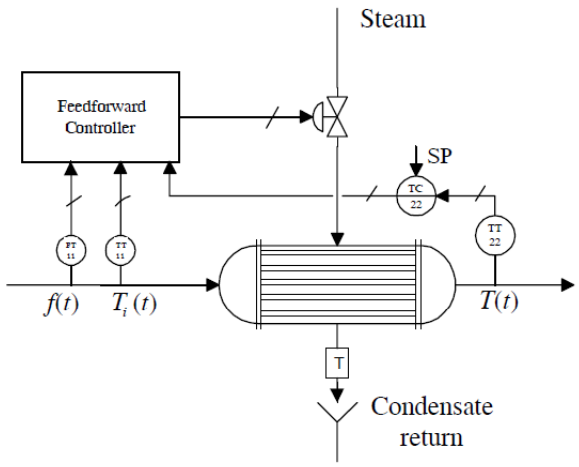


Figure 1-5.3 Feedforward control with feedback compensation.

Control Strategies

Feedforward Control

The advanced control strategies are usually more costly, in hardware, computing power, and personnel necessary to design, implement, and maintain, than feedback control. Therefore, they must be justified (safety or economics) before they can be implemented. The best procedure is first to design and implement a simple control strategy, keeping in mind that if it does not prove satisfactory, a more advanced strategy may be justifiable. It is important, however, to recognize that these advanced strategies still require feedback compensation.

Summary

- ✓ The working principles of a control system can be summarized with the three letters M,D, and A: M refers to the measurement of process variables, D to the decision to be made based on the measurements of the process variables, and A to the action to be taken based on the decision.
- ✓ The basic components of a process control system were also presented: sensor/transmitter, controller, and final control element. The most common types of signals—pneumatic, electrical, and digital—were introduced along with the purpose of transducers.
- ✓ Two control strategies were presented: feedback and feedforward control. The advantages and disadvantages of both strategies were discussed briefly.

References

1. Automated Continuous Process Control, Carlos A. Smith, 2002, Wiley-Interscience, ISBN: 978-0471215783.
2. http://www.egpet.net/vb/images/imported/2008/10/Basic20Piping2026 20Instrumentation20Symb-1.jpg
3. http://1.bp.blogspot.com/-NbmlW7nmwrM/Tc_LuuQa15I/AAAAAAAAAKI/euYRzMUYyK8/s1600/P%2526ID+Symbols.jpg