FA_Equipment_for_Beginners(ProcessControlSystem)_ENG

MITSUBISHI ELECTRIC
Changes for the Better

FA Equipment for Beginners (Process Control System)

This is a quick overview of Process Control System for beginners.

Introduction Purpose of the Course

An instrumentation system enables production control by measuring and controlling various physical quantities. For instance, flow rate, temperature, pressure and liquid level.
This course is intended to equip beginners with the basic knowledge required before performing actual instrumentation control.

Introduction Course Structure

The contents of this course are as follows.
We recommend that you start from Chapter 1.

Chapter 1 - Instrumentation System

Learn the basics of instrumentation systems.

Chapter 2 - Feedback Control

Learn the basics of feedback control (ON/OFF control, proportional (P) action, integral (I) action, PI control, differential (D) action, PID control).

Chapter 3 - Control Loop

Learn about the detection section and operation section in the control loop block diagram.

Final Test

Passing grade: 60% or higher.

Introduction How to use this e-Learning Tool

Go to the next page		Go to the next page.
Back to the previous page		Back to the previous page.
Move to the desired page	TOC	"Table of Contents" will be displayed, enabling you to navigate to the desired page.
Exit the learning		Exit the learning. Window such as "Contents" screen and the learning will be closed.

Introduction Precautions for Use

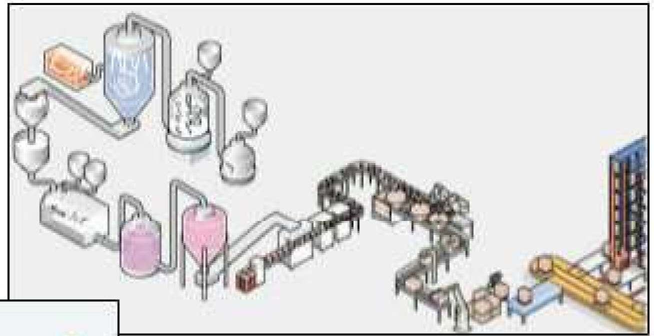
Safety precautions

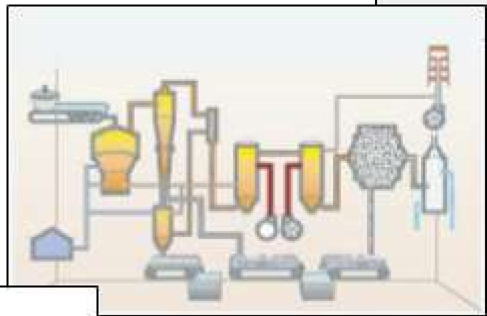
Before using the physical hardware, please read the Safety Precautions in the corresponding manuals and follow the relevant safety information contained therein.

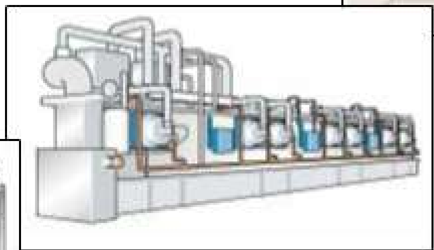
1.1 Instrumentation System

Instrumentation system is used in production facilities to perform measurement and control operations. It is widely used in various industries.

- Ironworks
- Chemical factories
- Environmental facilities
- Water and wastewater treatment equipment
- Air conditioning
- Semiconductor factories
- Food factories
- Pharmaceutical factories
- Paper factories
- Power plants, etc.


Fine chemical plant


Waste disposal facility


Industrial furnace

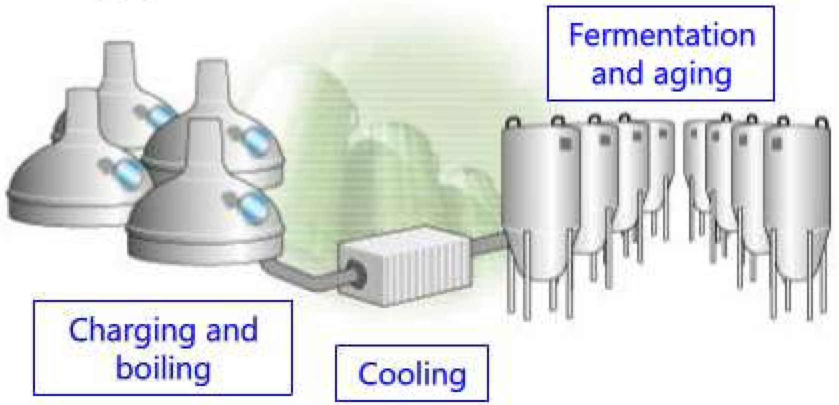

Food machinery

1.2 Control of Instrumentation System

Production facilities in a factory can be classified roughly into the instrumentation system that mainly handles feedback control and the FA system that mainly handles sequence control.
Here are examples of feedback control and sequence control in a beer factory.

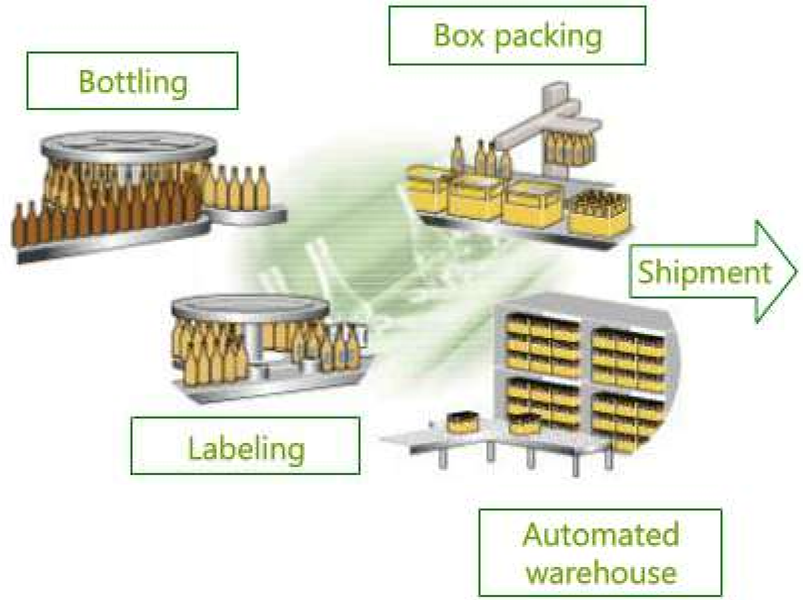
Feedback control

In feedback control, processing is controlled by comparing the target value with the measurement value obtained by feedback and deciding an amount of operation required to make these two values match.
It is used to control temperature, flow rates, and pressure in such processes as charging, fermentation, and aging.



Sequence control

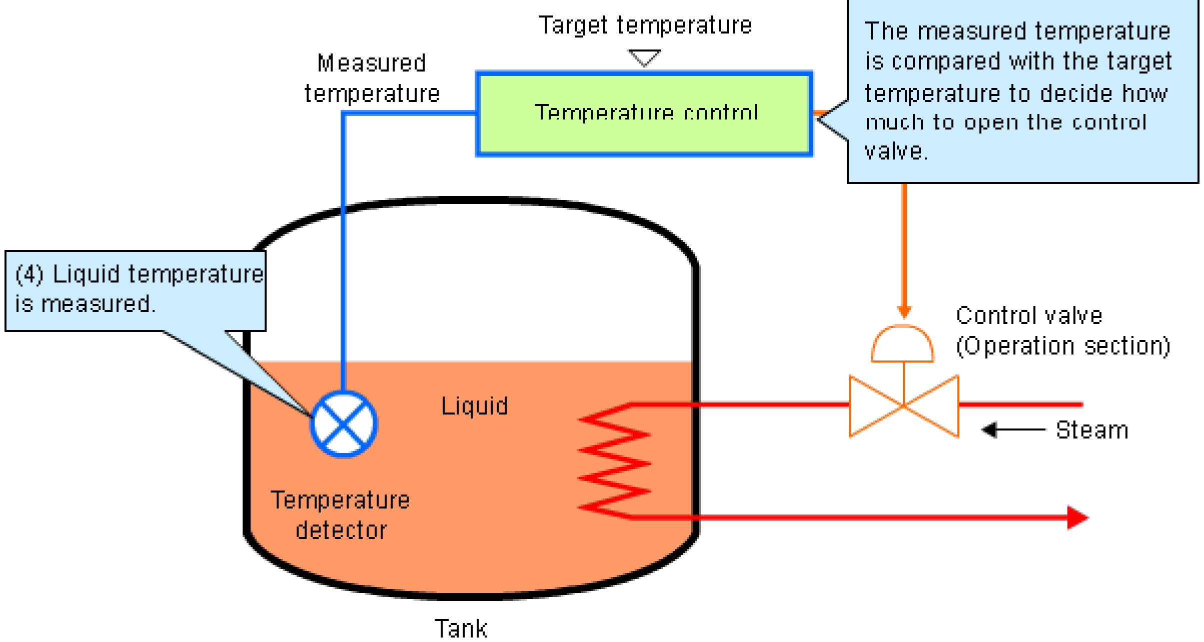
In sequence control, step-by-step processing is controlled according to a given sequence or procedure.
It is used in processing for box packing, conveying and so on.



1.3 Feedback Control

This example shows how feedback control is used to keep the liquid in a tank at a specified temperature.

(1) The temperature detector measures the temperature of the liquid in the tank.
(2) The measured temperature is compared with the target temperature, and the opening of the control valve (amount of operation) is decided according to the difference (deviation) between the two values.
(3) The control valve is operated to control the amount of steam which warms the liquid in the tank.
(4) Feedback control involves repeating steps (1) to (3) to eliminate the difference between the liquid temperature and target temperature.



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This type of control, which compares a measured value with a target value and performs an operation to make them match, is called feedback control.

1.3 Feedback Control

The feedback control of liquid temperature in the tank shown in Figure 1.3-1 can be represented by the following block diagram, Figure 1.3-2.

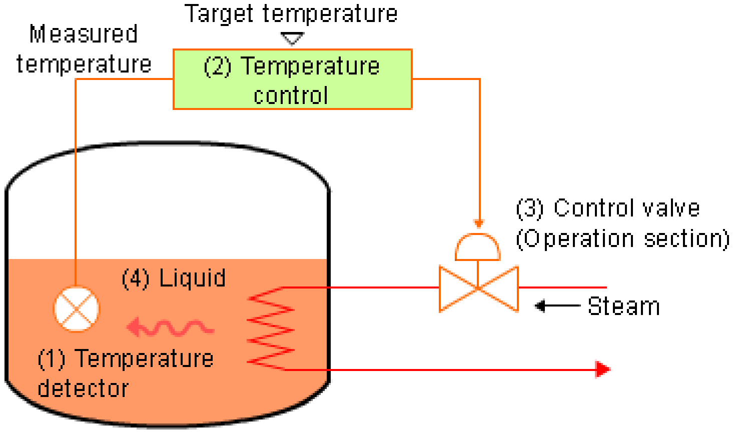

Figure 1.3-1

(1) The target temperature and measured temperature are compared at the comparator.
(2) The steam regulator calculates the amount of operation according to the deviation and sends the operation signal to the control valve.
(3) The control valve is operated according to the operation signal to send steam to the tank.
(4) The liquid temperature in the tank is changed by the steam, and the temperature detector measures the liquid temperature again.

Steps (1) to (4) are then repeated.

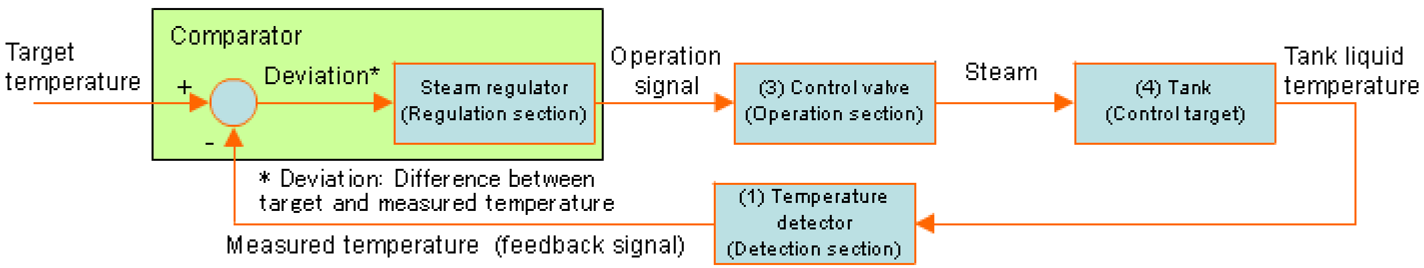

Figure 1.3-2

According to this block diagram, feedback control works as follows.

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1.3 Feedback Control

Feedback control is also used to control flow rate, pressure, and liquid level in addition to temperature.
Figure 1.3-3 shows a general block diagram for feedback control and Table 1.3-1 explains the individual terms.

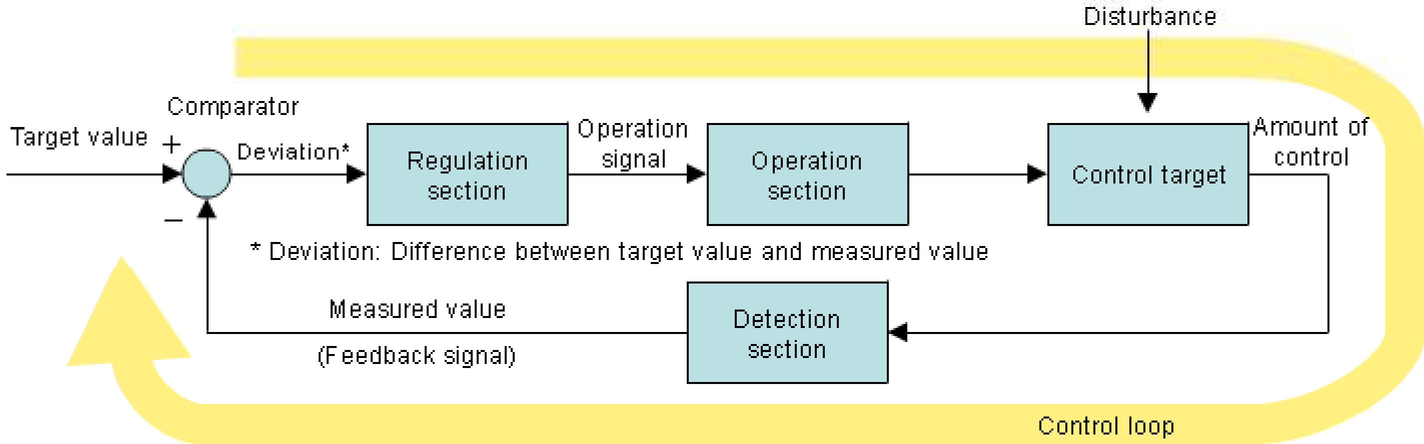


Figure 1.3-3

Term	Explanation
Comparator	Compares the target value and measured value.
Regulation section	Based on the target value and measured value, generates a signal required for the controller to perform intended operations and sends the signal to the operation section.
Operation section	Converts the operation signal received from the regulation section into an amount of operation and acts on the control target to create a change.
Control target	The whole or part of machines, processes, and plants subject to control
Detection section	Extracts the signals required for controlling from control targets such as sensors.
Disturbance	An unexpected change in environment that disturbs the control
Control loop	Returns the operation results to the regulation section. A unit of measurement control

Table 1.3-1

2.1 ON/OFF Control

This section explains ON/OFF control which is the simplest type of feedback control.
ON/OFF control means to turn ON or OFF the control section depending on whether the deviation (target value - measured value) is positive or negative.

Figure 2.1-1 shows how ON/OFF control changes the status of the control valve and liquid temperature.
As shown in Figure 2.1-1 (1), when the temperature of the liquid falls below the target value, the control valve is fully opened (ON) to feed steam.
When steam is fed, the liquid temperature does not rise immediately, but begins to rise after a while and then exceeds the target value as in (2). When the temperature exceeds the target value, the control valve is fully closed (OFF) to stop feeding steam.
However, the liquid temperature does not fall immediately but begins to do so after a while.

Under ON/OFF control, liquid temperature is not constant but varies repeatedly as shown in Figure 2.1-1.
P control (proportional control) was invented to solve this problem as follows.

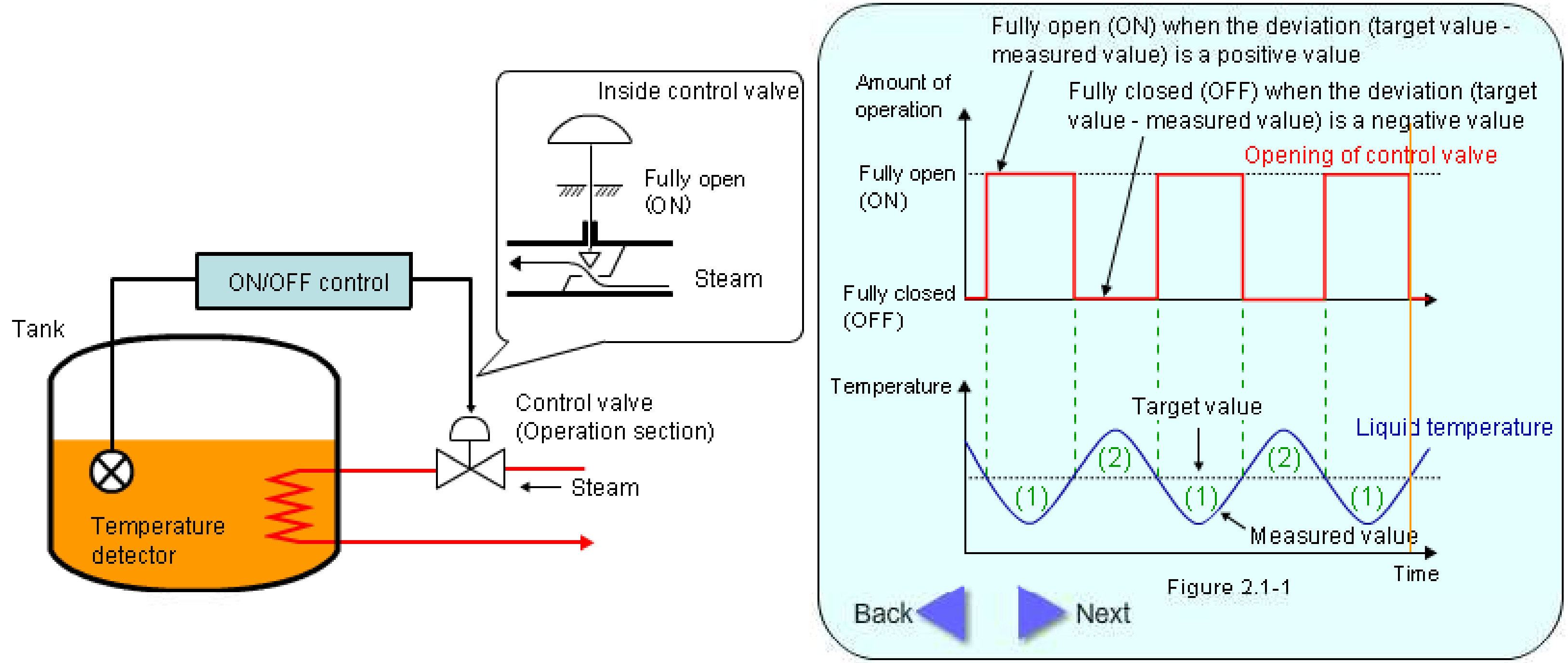


Figure 2.1-1

2.2 Proportional Action

An action that outputs an operation amount proportional to the deviation (target value - measured value) is called proportional action.
Proportional action can reduce fluctuations in liquid temperature by controlling the control valve opening gradually according to the deviation.

The operation amount of proportional action is given by: operation amount = proportional gain (Kp) x deviation. Even with the same deviation, as the proportional gain becomes larger, the operation amount becomes larger, which increases the amount of steam supplied.

As the proportional gain becomes smaller, the operation amount becomes smaller and this decreases the supply of steam. (Figure 2.2-1)
The operation amounts of proportional actions for a step-shaped deviation are shown below.

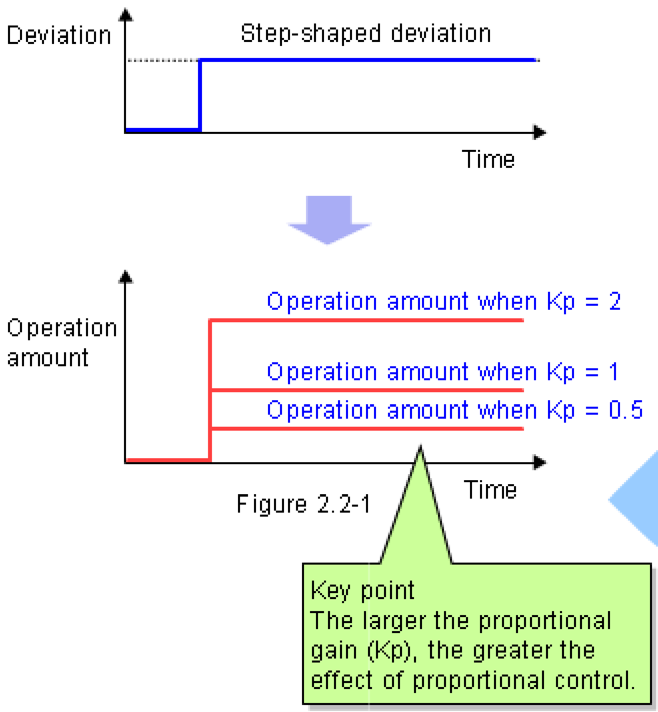
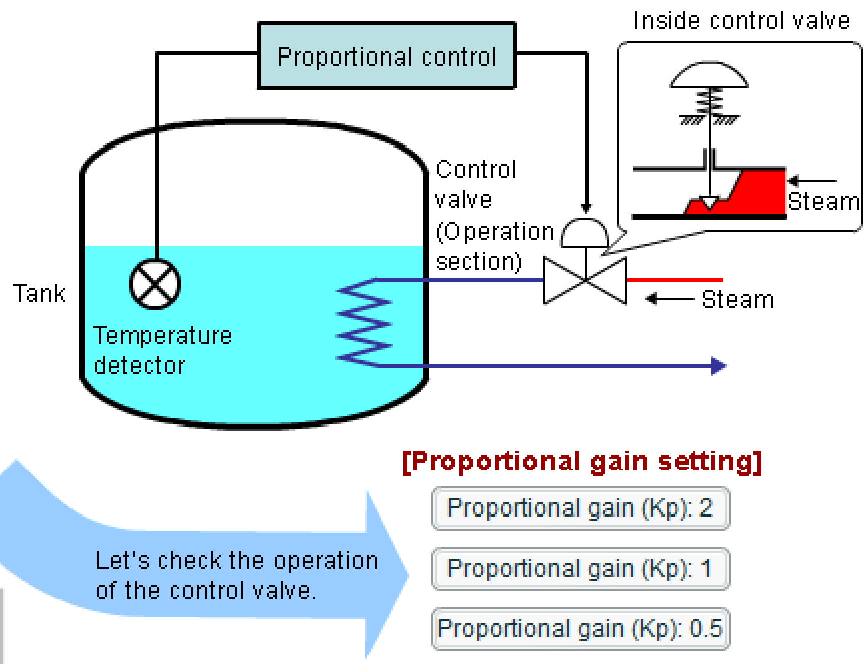
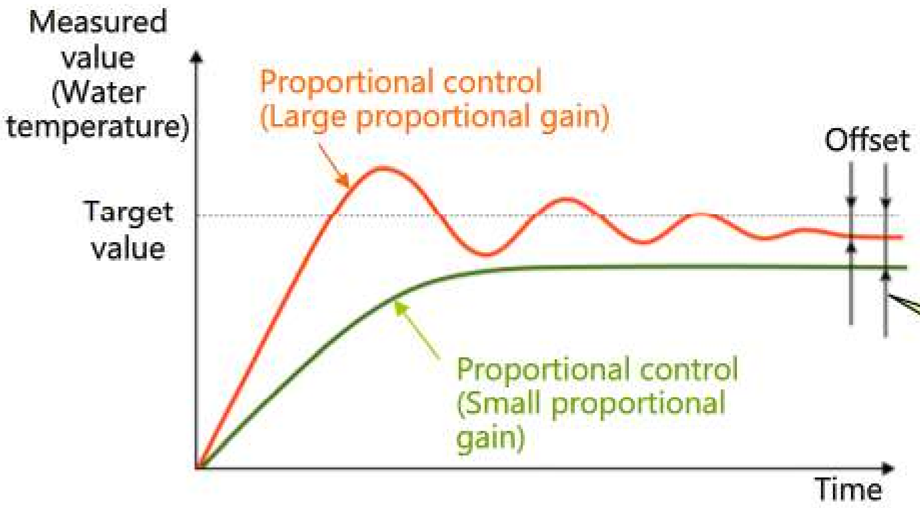


Figure 2.2-1



2.2 Proportional Action

Figure 2.2-2 shows how the control result of proportional actions differs depending on the magnitude of proportional gain. (The control result means the effect of proportional control of liquid temperature in the tank.) Adjusting the control valve little by little reduces liquid temperature fluctuations.



When proportional gain is large	Response becomes slower, but the measured value shifts up and down. (Likely to cause oscillation (also called the Hunting oscillation))
When proportional gain is small	Response becomes slower. (It takes time to reach the target value.)

Key point
Proportional control causes offset and fails to match the target value.

Figure 2.2-2

Proportional action can reduce liquid temperature fluctuations but cannot make the measured value match the target value even after some time, leaving a deviation. This remaining deviation is called offset (steady-state deviation or residual deviation).

2.3 Integral Action and Proportional/Integral (PI) Control

With proportional action, the measured value and target value do not match even after a long time, leaving an offset.
To eliminate this offset, integral action is used.
Integral action eliminates the offset by integrating past and present deviations over time and outputting the result. (Figure 2.3-1)
Integral action is used in combination with proportional action as "PI control".

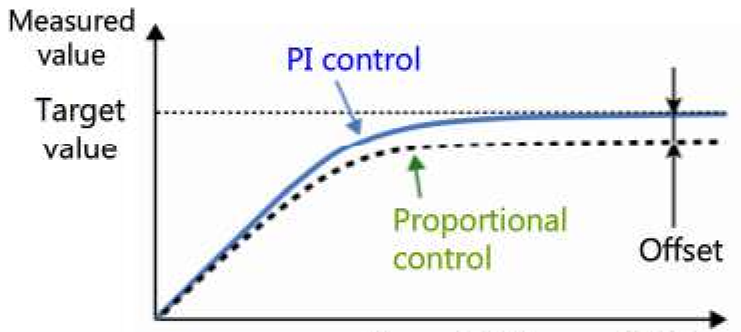


Figure 2.3-1

The smaller the integration time, the faster the offset is eliminated. The greater the integration time, the more time it takes to eliminate the offset.
Figure 2.3-2 shows the differences of integration effects of PI control depending on the length of integration time.

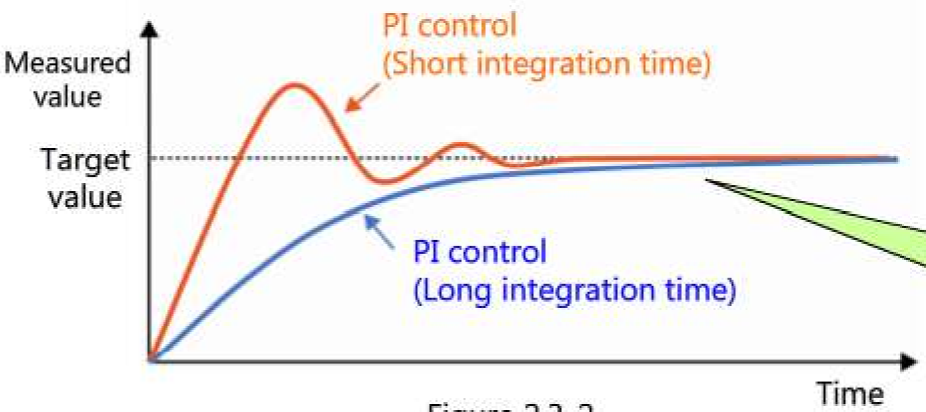


Figure 2.3-2

Short integration time	Eliminates the offset faster but likely to cause oscillation.
Long integration time	Changes measured values smoothly but takes time to eliminate the offset.

Key point
The shorter the integration time, the greater the integration effect.
(The offset is eliminated faster.)

2.4 Differential Action

To minimize the effect of disturbances to the control target, differential action adds an output which is proportional to the rate of change of deviation (deviation differential) to the proportional activation output.
This action is generally used in combination with PI control as "PID control".
Figure 2.4-1 shows the difference in response of the control target with or without differential action used against deviation changes caused by the same disturbance (disturbance A). Adding the differential action reduces the effect of the disturbance.

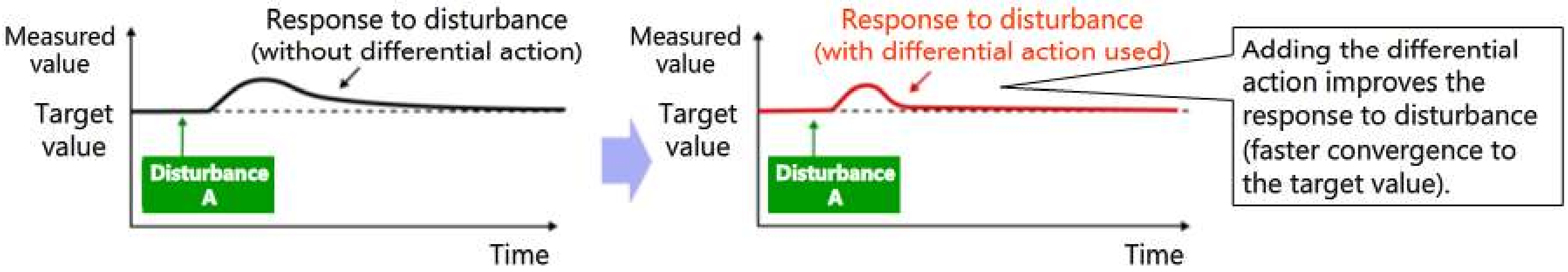


Figure 2.4-1

The longer the differential time, the greater the operation amount by differential action and the larger the differential effect.

Short differential time	Decreases the differential effect.
Longer differential time	Increases the differential effect but is likely to cause oscillation.

Key point
The longer the differential time, the greater the differential effect.

2.5 PID Control

PID control adds the integral action and differential action to the proportional action that outputs an operation amount proportional to the deviation. The integral action eliminates the offset by adding the operation amount obtained by integrating the deviation. The differential action improves the response to disturbances by adding an operation amount according to the rate of change of deviation. Figure 2.5-1 compares the control responses of proportional control, PI control, and PID control.

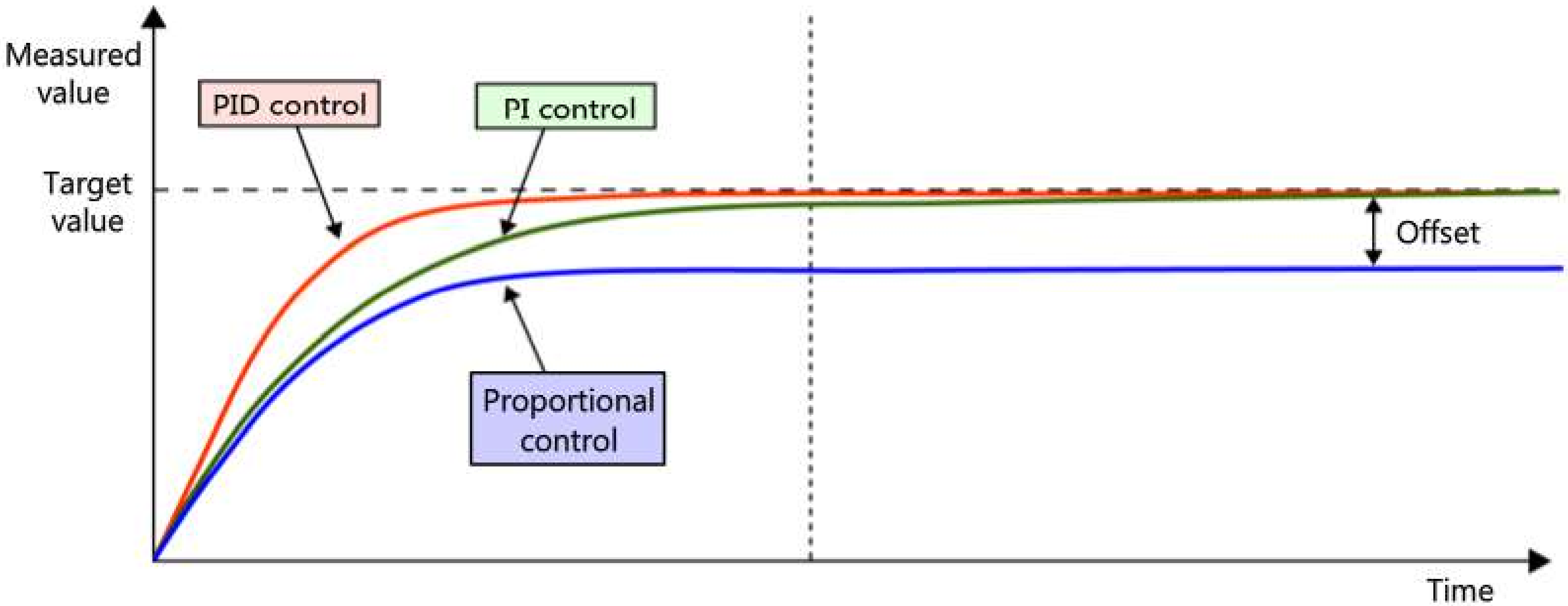


Figure 2.5-1

2.6 Selection of PID Control

PI control is often used for controlling flow rate and pressure because the process responses are fast enough with PID control alone. Besides, differential control may also amplify measurement noise and destabilize processes.
For temperature control, the process responses are generally slow and therefore PID control is often used.

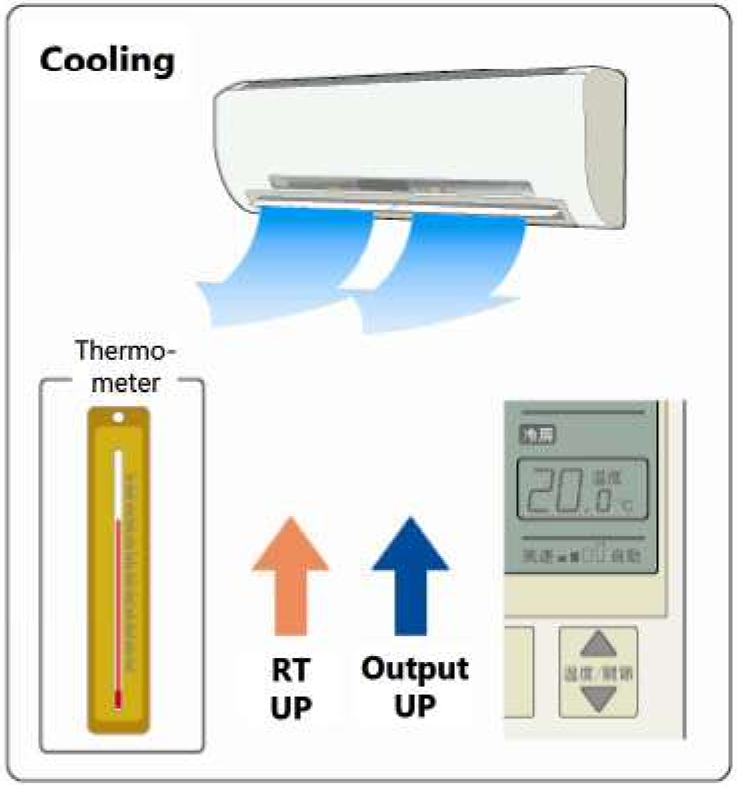
Control target	Control	Considerations
Flow rate, pressure	PI	Flow rate and pressure response fast enough with PI control alone. Differential action may amplify noise and destabilizes process responses.
Temperature	PID	Temperature generally responses slowly.

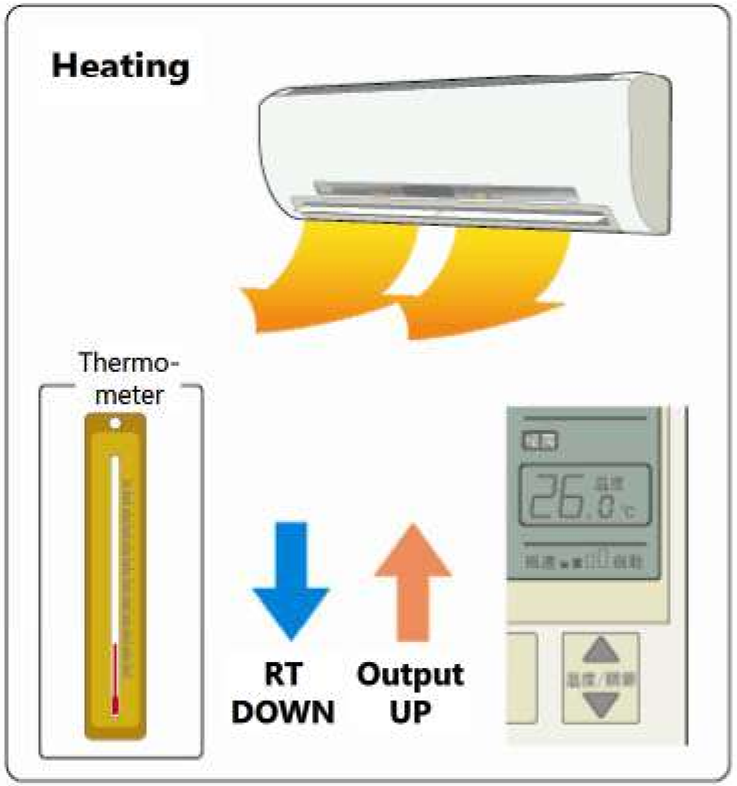
2.7 Normal Action and Reverse Action under PID Control

In PID control, the terms "normal action" and "reverse action" are used depending on the direction in which the operation amount changes according to the changes in measurement values.

The normal action and reverse action are explained below using an air conditioner as an example.

Normal action: Increases the operation amount (cooling output) as room temperature rises when cooling.
Reverse action: Increases the operation amount (heating output) as room temperature falls when heating.





2.8 Constant Control and Tracking Control

Feedback control can be classified into two types of control depending on the target value setting mode: constant control and tracking control.

- Constant control

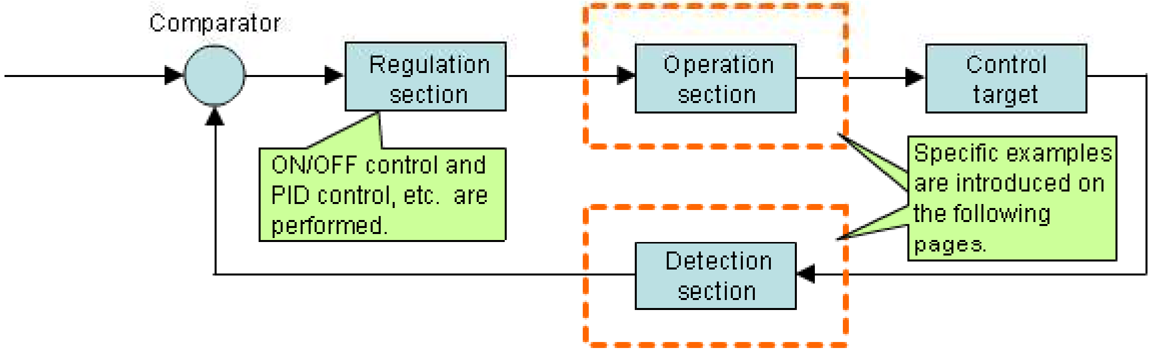
  Control with a constant target value, such as for controlling pressure or temperature to keep it fixed at a given value

- Tracking control

  Control with a target value which changes over time. It is also called follow-up control.
  Tracking control is further classified into two types: program control that changes the target temperature over time according to a specified pattern, and ratio control that keeps ratios constant, such as the air-fuel ratio in combustion and liquid ratio when mixing two or more liquids.

3.1 Detection Section and Operation Section

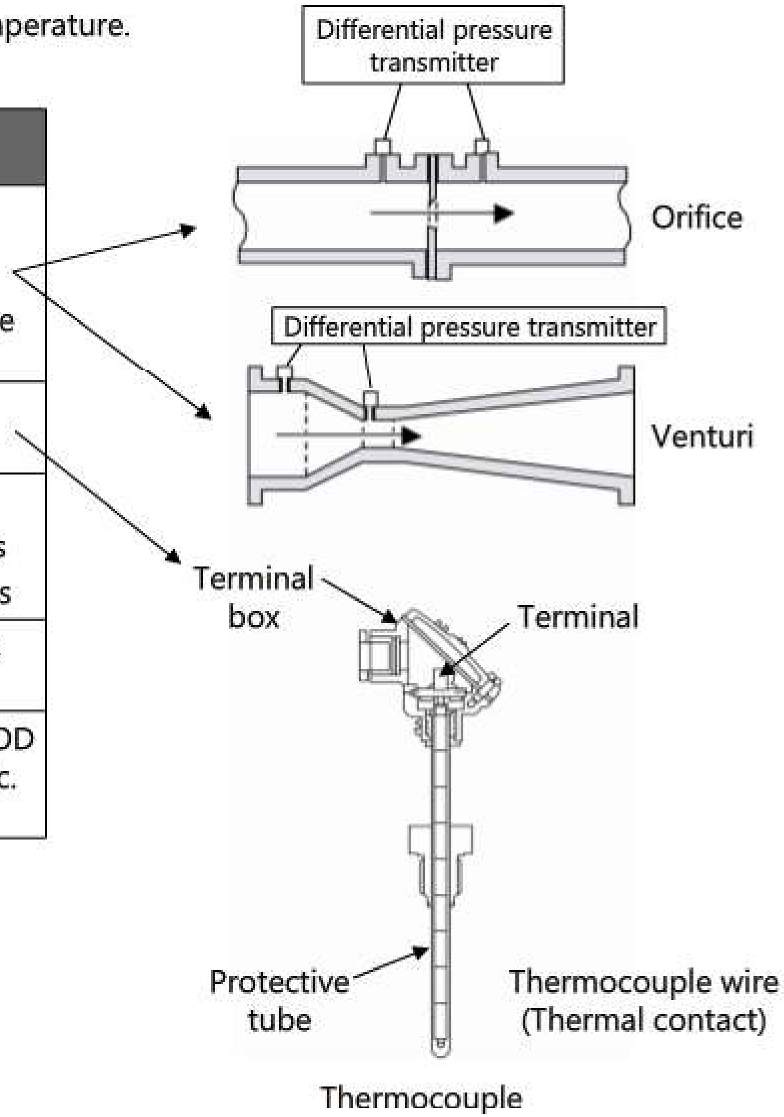
A typical example of the detection section and operation section is explained for the following block diagram of a control loop.



3.1 Detection Section

The table below lists typical sensors used to detect flow rate and temperature.

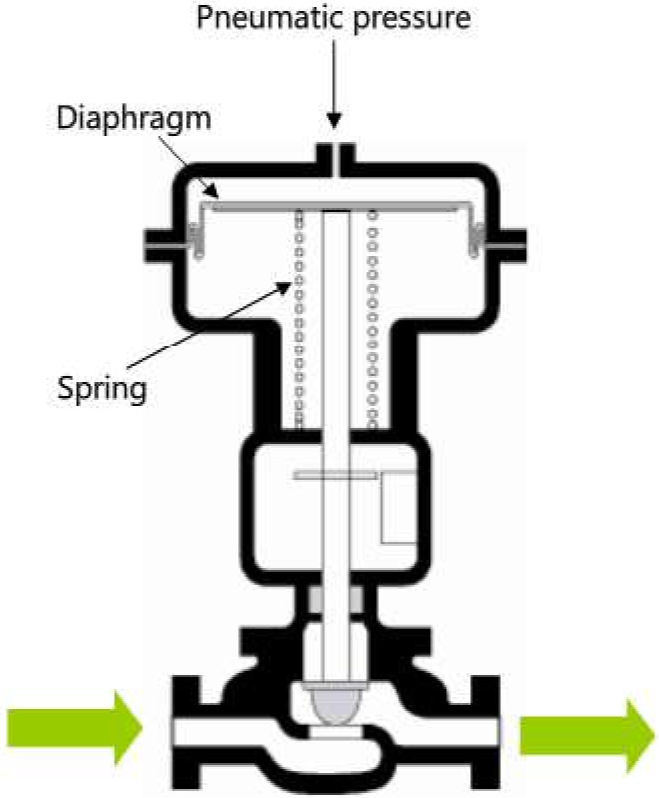
Detection target	Detection method
Flow rate	Differential pressure: Throttle mechanisms (orifice, venturi, etc.) Electromagnetic: Electromagnetic flow meter Positive displacement: Roots type and oval gear type Others (Coriolis, ultrasonic, vortex, etc.)
Temperature	Thermocouple, resistance thermometer, radiation thermometer
Pressure, differential pressure	Electric: Resistance wire and piezoelectric types Elastic: Bourdon tube, diaphragm, and bellows types Liquid column: U-shaped tube and single-tube types
Liquid level	Differential pressure, float, electrostatic capacitance, and ultrasonic types
Chemical compounds	pH meter, oxygen meter, residual chlorine meter, COD meter, H_2 meter, CO_2 meter, gas chromatograph, etc.



3.1 Operation Section

An example of the operation section is shown below.

Type		Mechanism
Control valve	Pneumatic	Pneumatic control valve
	Electric	Electric valve, solenoid valve, etc.
	Others	Hydraulic control valve, etc.
Others		Speed control system (inverter, etc.) Solid state relay, power conditioner, etc.



Pneumatic control valve

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Test | Final Test

Now that you have completed all of the lessons of the FA Equipment for Beginners (Process Control System) Course, you are ready to take the final test. If you are unclear on any of the topics covered, please take this opportunity to review those topics.
There are a total of 9 questions (24 items) in this Final Test.
You can take the final test as many times as you like.

How to score the test

After selecting the answer, make sure to click the **Answer** button. Your answer will be lost if you proceed without clicking the Answer button. (Regarded as unanswered question.)

Score results

The number of correct answers, the number of questions, the percentage of correct answers, and the pass/fail result will appear on the score page.

Correct answers : 3

Total questions : 10

Parcentage : 30%

To pass the test, you have to answer **60%** of the questions correct.

Proceed | Review | Retry

- Click the **Proceed** button to exit the test.
- Click the **Review** button to review the test. (Correct answer check)
- Click the **Retry** button to retake the test again.

Test Final Test 1

Control of instrumentation systems

The production process in the beer factory includes a process centering on sequence control and a process centering on feedback control. Select the applicable option in each box.

Sequence control --Select--

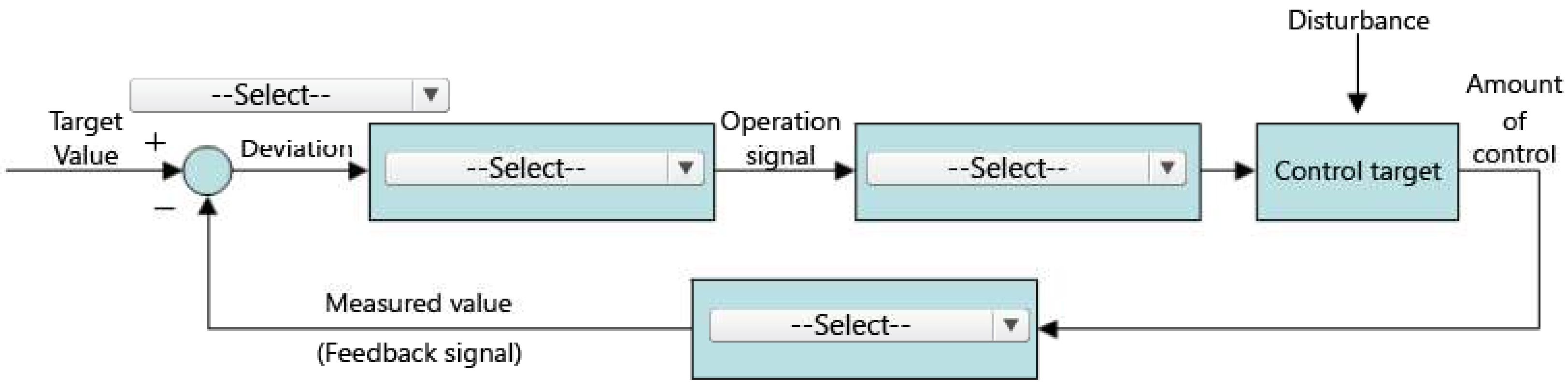
Feedback control --Select--

Answer Back

Test Final Test 2

Feedback control

Select the appropriate option in each box corresponding to Q1 to Q4 in the block diagram of feedback control.



Answer

Back

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Test Final Test 3

Proportional (P) action

Select the appropriate option in each box of the following text to complete the description about proportional action.

In proportional action, as the proportional gain becomes larger, the amount of operation --Select-- ▼ but it is likely to cause --Select-- ▼ .

The proportional action also has the problem that the measured value does not match the target value even after time has passed and --Select-- ▼ remains.

Answer Back

Test | Final Test 4

Integral (I) action

Select the appropriate option in the box of the following text to complete the description about integral action.

Integral action [--Select-- ▼] the integration effect as the integration time becomes longer.

Answer | Back

Test Final Test 5

Differential (D) action

Select the appropriate option in the box of the following text to complete the description about differential action.

In differential action, as the differential time becomes longer, the differential effect --Select-- ▼

but it is likely to cause --Select-- ▼ .

Answer Back

Test Final Test 6

Types of feedback control

Select the appropriate option in each box of the following text to complete the description about the types of feedback control.

Feedback control includes ON/OFF control that turns on or off the operation section depending on the positive/negative deviation, --Select-- combining proportional action and integral action, and --Select-- combining proportional action, integral action, and differential action.

Answer Back

Test Final Test 7

Features of Each Type of Control Target

Select the appropriate option in each box to complete the descriptions about the features of individual types of control targets and the types of control appropriate for them.

Generally, for flow and pressure control, control responses are [▼] and therefore [▼] control is suitable.

For temperature control, control responses are [▼] and therefore [▼] control is suitable.

Answer   Back

Test Final Test 8

Constant control and tracking control

Select the appropriate option in each box of the following text to complete the description about constant control and tracking control.

The type of control over a constant target value is called --Select-- .

The type of control over a target value that varies over time is called --Select-- and is further classified into --Select-- and ratio control.

Answer Back

Test Final Test 9

Components of control loop

Select the appropriate option in each box of the following text to complete the description about the components of a control loop.

Flow meters include --Select-- flow meters having --Select-- and venturi as throttle mechanisms and positive displacement flow meters having the roots type and --Select-- mechanisms.

Answer Back

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Test | Test Score

You have completed the Final Test. You results area as follows.
To end the Final Test, proceed to the next page.

Correct answers :	0
Total questions :	9
Parcentage :	0%

Proceed Review Retry

You failed the test.

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You have completed the FA Equipment for Beginners (Process Control System) Course.

Thank you for taking this course.

We hope you enjoyed the lessons and the information you acquired in this course will be useful in the future.

You can review the course as many times as you want.

Review

Close