Working with Controllers

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WORKING WITH CONTROLLERS

Lesson One

Introduction to Controllers

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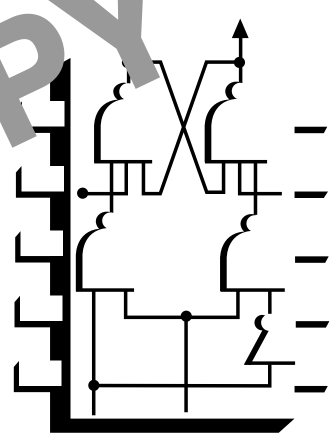

TPC Training Systems

28101

Lesson

1 Introduction to Controllers

TOPICS

- **Development of Controllers**
- **Purpose of Automatic Controllers**
- **Kinds of Controllers**
- **Variables**
- **Process Dynamics**
- **Final Control Elements**
- **Current Proportioning**
- **Position Proportioning**
- **Time Proportioning**
- **Controller Modes and Actions**
- **Controller Terminology**
- **Controller Alarms and Options**
- **Advanced Controllers**
- **Safety in Control Loops**
- **Accuracy in Control Loops**

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OBJECTIVES

After studying this Lesson, you should be able to…

- Describe the kinds of controllers most often used in industrial applications.
- Discuss six important problems of process dynamics that controllers must overcome.
- Compare the actions of current proportioning, position proportioning, and time proportioning.
- Name four kinds of controller alarms.
- Discuss the importance of safety in control loops.

KEY TECHNICAL TERMS

Process variable (PV) 1.05 a signal that represents the actual process value

Setpoint (**SP**) 1.05 the desired value of the process variable

Error (E) 1.05 the difference (positive or negative) between PV and SP

Closed loop 1.06 a system in which any change in controller output appears as a change in controller input

Feedback 1.06 a component of the controller input signal in a closed-loop system

Live zero 1.10 a minimum output other than zero

Root-mean-square (**RMS**) 1.44 a method of estimating overall system accuracy

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This Lesson deals with the individual single-loop automatic control instruments most often applied to industrial processes. It will not discuss the various kinds of specialized controllers—mechanical, hydraulic, fluidic, etc.—sometimes designed into equipment. Other Units deal with the emerging field of computer-based "controllers" that are used in distributed control systems (DCS), and with programmable logic controllers (PLCs). This Lesson presents an overview of automatic controller operation and applications and introduces the terminology to be used in later Lessons.

Development of Controllers

1.01 Until about 1960, virtually all process controllers were pneumatic. Pneumatic controllers use clean, dry compressed air in the range of 3 to 15 psi for both input and output signals. Pneumatic controllers even were designed to provide the proportional, reset, and rate actions that will be described later. Modern pneumatic controllers still are used for special applications, especially where electrically operated equipment might cause explosion hazards.

1.02 In the 1960s, electric/electronic automatic process controllers appeared and rapidly replaced pneumatic controllers, especially in new installations. Early electronic controllers used vacuum tubes, but all controllers are now of solid-state design. Electronic controllers could be made much smaller than their pneumatic counterparts, and wiring was easier and less expensive to install than pneumatic tubing with its connectors, filters, and pressure regulators. These installation considerations, rather than any significant performance benefit, caused electronic controllers to become dominant.

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1.03 In the 1980s, small computer technology became available, and distributed control systems appeared. Microprocessor-based multiloop units and distributed control systems now are displacing electronic controllers. Again, it was installation considerations that led to their growth. Even a large DCS can be installed with a few wires instead of the hundreds or thousands needed by individual electronic controllers. Also, a desktop operator station, similar to a personal computer, can replace hundreds of cubic feet of control room panels.

1.04 An early pneumatic controller, a miniature electronic controller, and a DCS seem to have little resemblance to each other if compared in a control room. However, if a control loop is observed in the plant, using only its primary and final elements for analysis, it may be impossible to determine what kind of automatic process controller is at work. The basic principles discussed in this Lesson apply to all kinds of controllers.

Purpose of Automatic Controllers

1.05 The purpose of any automatic controller is to bring a process variable to a desired value and keep it there. The instruments vary widely in design and construction, but they all operate on the same principle—a controller compares its *process variable* (PV) input, which represents the actual value of the process, with its *setpoint* (SP), which is the desired value. Any difference, positive or negative, is called *error* (E), and error is the basis for calculating the controller output needed to make PV equal to SP.

1.06 Any change in controller output causes a change in the PV value and a resulting change in the controller input. This kind of system, shown in Fig. 1-1 on the following page, is a *closed loop* with *feedback*. An open-loop process does not measure the PV value and feed it back to the instrument. A lamp dimmer in your home is an example of an open loop. A dial setting should produce a certain brightness, but the dimmer cannot correct for an aging bulb, because the actual light produced is not measured. Open-loop processes are seldom found in industry.

1.07 All of the controllers of interest to process control are used in closed loops and have feedback, a setpoint, and a control output. Advanced controllers may have some additional features—for example, feedforward, remote or programmable setpoints, and auxiliary outputs.

Kinds of Controllers

1.08 Virtually all industrial process controllers can be placed in one of three categories, as defined by their output signals:

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- electrical
- electronic
- pneumatic.

Input signals are usually, but not necessarily, of the same form and range as the output signals.

1.09 **Electrical.** Electrical controllers are essentially switches that pass relatively high levels of electric power capable of operating final control elements—for example, valves, motors or heaters—directly or through auxiliary relays. A degree of proportional control can be achieved by varying the time of the switch closure.

1.10 **Electronic.** Electronic controllers produce a small current signal, typically 4 to 20 milliamperes (mA), but sometimes 1 to 5 mA or 10 to 50 mA. This signal is used as a pilot signal for some form of amplifier in the end element. Note that the output signals always have a *live zero*, meaning that the minimum output is other than zero (1, 4, or 10 mA), and note that the output signal range, minimum to maximum, is always in the ratio of 1 to 5 (1 to 5::4 to 20::10 to 50::1 to 5).

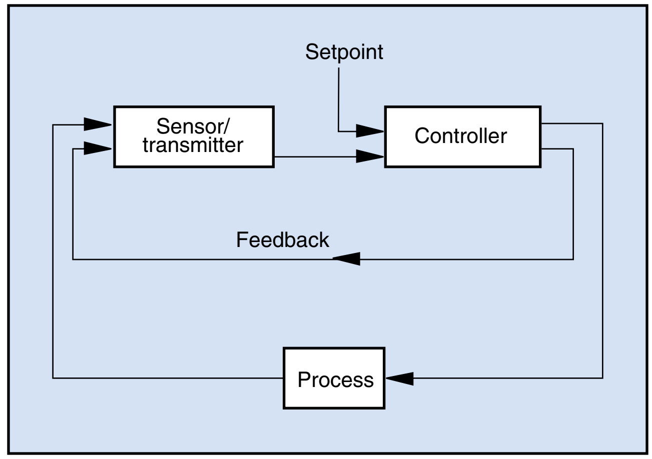
1.11 **Pneumatic.** Pneumatic controllers use compressed air (sometimes nitrogen or another gas) to produce controller output signals of 3 to 15 pounds per square inch (psi) or, sometimes, 6 to 30 psi. Note the live zero and 1:5 range, as in electronic controllers. The controller output has enough pressure to operate many end elements directly—for example, pneumatic diaphragm valves. However, the volume of air passed through the controller is small. Amplifiers often are used to increase the speed of response.

1.12 To understand automatic controllers, you need to understand signal relationships. All automatic controllers are the same in one sense—they are basically signal controllers rather than temperature, level, or pressure controllers. For example, if an electronic controller receives a 3-mA PV input signal when its setpoint calls for a 3.5-mA value, it may produce a 4-mA output signal to correct the error.

Variables

1.13 Typical process control loops include three kinds of values:

Fig. 1-1. Automatic controller and feedback loop



- measured variable
- process variable
- manipulated variable.

The *measured variable*, which sometimes is called the *controlled variable*, is the primary process value—temperature, pressure, flow, etc. This value almost always is converted into another value (mA, for example) by the measuring/transmitting instruments.

1.14 The *process variable* (PV) is a signal that represents the measured variable. For example, a signal of 12 mA might represent a measured variable of 50°F. If the range of the measured variable is 0 to 100°F, a temperature of 50°F would result in a 12-mA input signal to the controller, because the midpoint of a 4- to 20-mA signal is 12 mA.

1.15 The *manipulated variable* is affected by the controller output and may not be the same as the measured variable. For example, suppose water temperature in a tank is the measured variable. The temperature may be controlled by regulating the flow of steam (manipulated variable) through a heat exchanger mounted in the tank. In this example, steam is the control agent, as shown in Fig. 1-2.

Process Dynamics

1.16 The selection of an automatic controller is governed largely by the dynamics of the process to be

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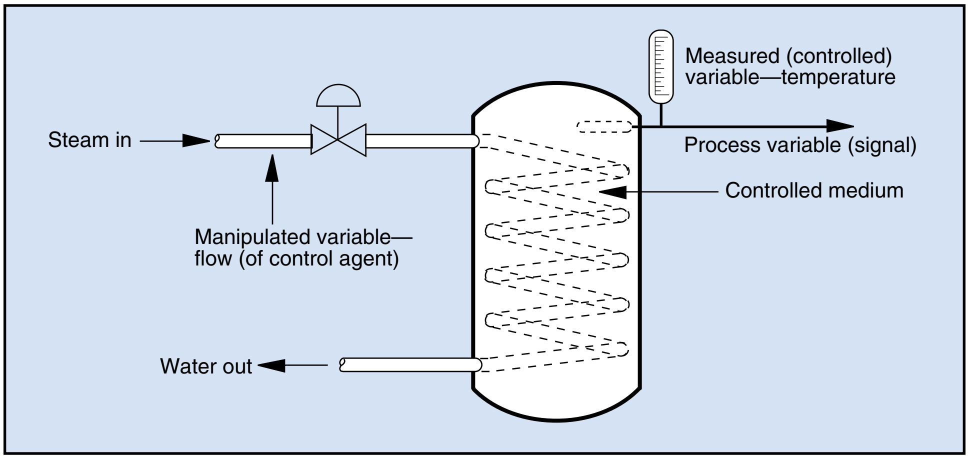
Fig. 1-2. Variables



controlled. The term *process dynamics* refers to the characteristics and behavior of the process and includes the following:

- **Speed of response.** A process may be slow to respond to input energy changes (as in the case of some temperature processes), or it may be so fast that it becomes noisy as it oscillates above and below the setpoint (which happens in some flow processes).

- **Lag.** A process may resist change and lag behind its energy input, not responding promptly when energy is added and overshooting the setpoint after energy input is stopped. Large electrically heated furnaces with heavy loads often exhibit lag. Figure 1-3 shows examples of resistances causing system lag. The wall, the capillary tube, and the resistor *resist* the transfer of energy required for control of the process.

- **Dead time.** There may be a delay between related actions, and a process may appear not to respond at all to changes in energy input. For example, conveyor belts may have empty

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Fig. 1-3. Resistances as cause of system lag

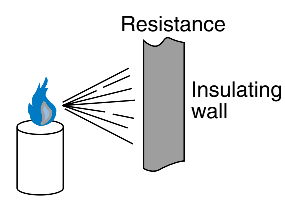
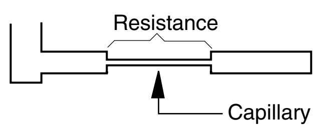
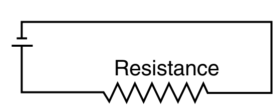
Kind of resistance	Unit	
Thermal	$\frac{\text{degree}}{\text{Btu/hr}}$	
Fluid	$\frac{\text{psi}}{\text{ft}^3\text{/min}}$	
Electrical	$\frac{\text{volts}}{\text{coulombs/sec}}$ = ohms	

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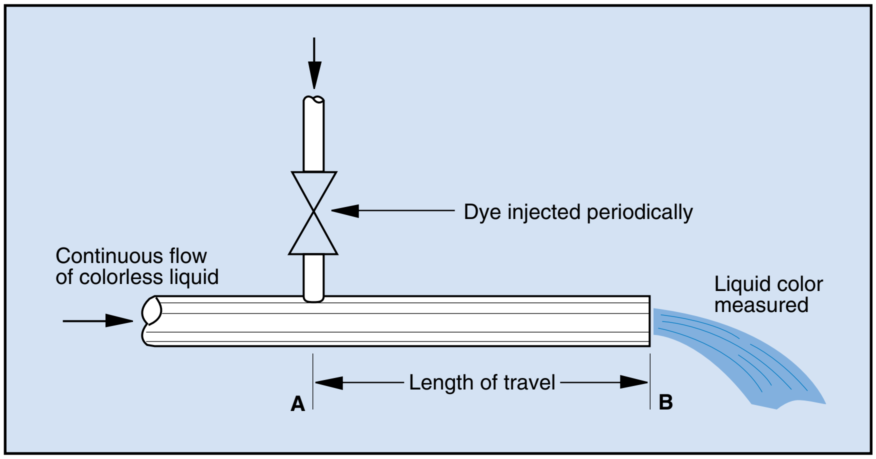
Fig. 1-4. Dead time in fluid flow process



sections and deliver no product when started. Figure 1-4 shows another example, in which the dead time is the time required for a quantity of dye to travel from point A to point B after being injected into a long pipe.

- **Hysteresis.** A process may respond differently when approaching the setpoint from above than it does when approaching from below. For example, a valve that is open a certain percentage as the PV increases to SP may be more or less open, depending on the kind of valve action, as the PV decreases toward SP. Process devices that are subject to hysteresis affect the process dynamics.

- **Capacitance.** In a process, the input of material or energy causes a change in one or more measured values in the system. How much material or energy it takes to produce a change of one unit in one component of the system is called the *capacitance* of that component. For example, Fig. 1-5 shows two tanks identical in size and shape, one standing upright and the other on its side. Compare the volumes of additional liquid required to raise the level in both tanks by the same amount. The tank on its side clearly requires more liquid, because it has a larger base area. Therefore, it has greater capacitance.

- **Nonlinearity.** A process may respond differently to equal increments of energy change, depending on the starting value. Many chemical reactions exhibit nonlinearity, as shown in Fig. 1-6. When the instruments have nonlinear outputs (as thermocouples do), control problems can be created or compounded.

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Final Control Elements

1.17 Process industries use a variety of final control elements (for example, valves) that receive the output signals from controllers. In addition to process dynamics, the kind of final control element employed in a specific application will determine the kind of automatic control instrument to be used.

1.18 Most final control elements are regulated by one of three kinds of proportional action. The controller must change the amplified error signal to one of the following:

- a *current*-proportioning signal (between maximum and minimum)
- a *position*-proportioning signal (between full open and full closed)
- a *time*-proportioning signal (speed or duration, depending on the final control element).

Current Proportioning

1.19 Current in a control loop usually ranges from 4 to 20 mA DC. Current outputs are used to modulate various final control elements. Many final control elements operate directly from the current output of the

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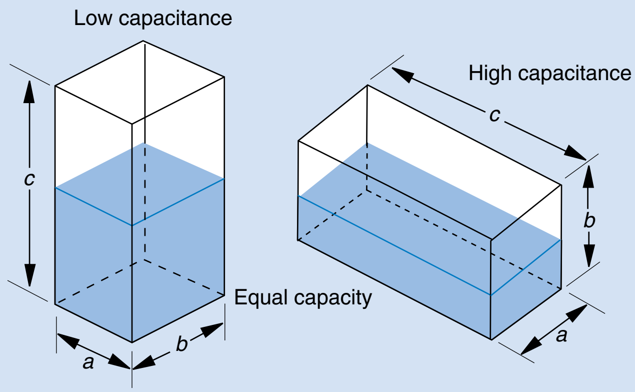
Fig. 1-5. Volume capacitance



Dimensional units for capacitance in control applications	
Kind of process	**Unit**
Thermal	$\frac{\text{Btu}}{\text{degree}}$
Volume	$\frac{\text{ft}^3}{\text{ft}}$
Weight	$\frac{\text{lb}}{\text{ft}}$
Electrical	$\frac{\text{coulomb}}{\text{volt}}$ = farad

controller while others require a transducer to transform the current signal into some form that the final control element can use. Two common transducers are the following:

- current-to-pneumatic (I/P or mA/psi)
- current-to-voltage (I/E or I/V or mA/mV).

1.20 Current-to-pneumatic transducers convert the 4- to 20-mA DC controller output to a proportional 3- to 15-psig pneumatic signal. Most industrial control valves are pneumatic devices in which a spring opposes a diaphragm. Pneumatic signals are easily amplified to obtain the speed and power needed by the final control element. Pneumatically operated final control elements do not cause sparks and are resistant to the severe conditions inherent in their locations directly on process equipment.

1.21 Large diaphragms on pneumatic control valves provide amplification of the controller signal pressure at the cost of slow speed of response. Where pressure and speed are both required, a *positioner* is used between the I/P transducer and the valve. The positioner is actually a smaller pneumatic control valve that uses the controller output to control the flow of air to the final control element.

1.22 Current-to-voltage transducers are used to provide the required power for electrically operated final control elements. (A controller output of 20 mA at 24 V is only 480 milliwatts.) As shown in Fig. 1-7 on the following page, electrically operated heaters often are used as final control elements for large furnaces and ovens that require current proportioning.

1.23 A silicon-controlled rectifier (SCR) is one kind of I/E transducer. The SCR acts as a solid-state switch or gate, allowing current in one direction only. A current output from the controller, applied to the gate of the SCR, is used to modulate the amount of AC voltage applied to the load. As the gate current increases, the SCR gate is turned on more fully and, in turn, the AC voltage applied to the load increases. SCRs can handle heater voltages from 120 V AC for small ovens to 240 or 480 V AC for large furnaces

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Fig. 1-6. Nonlinearity in a chemical reaction

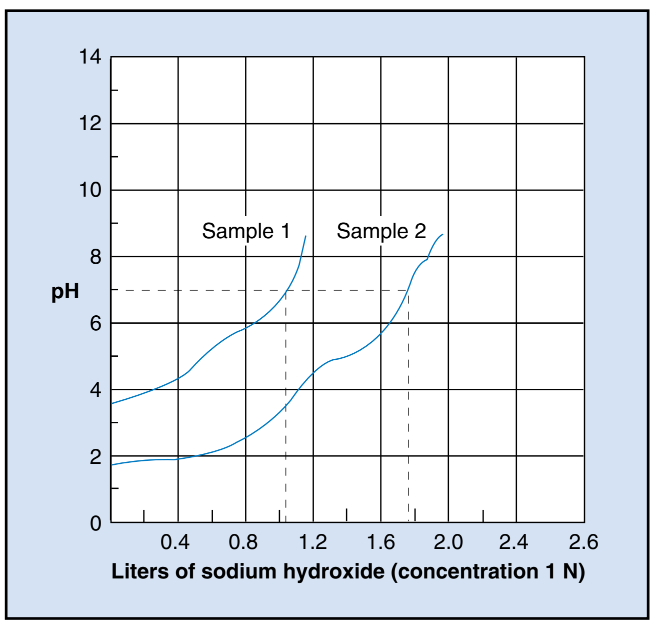

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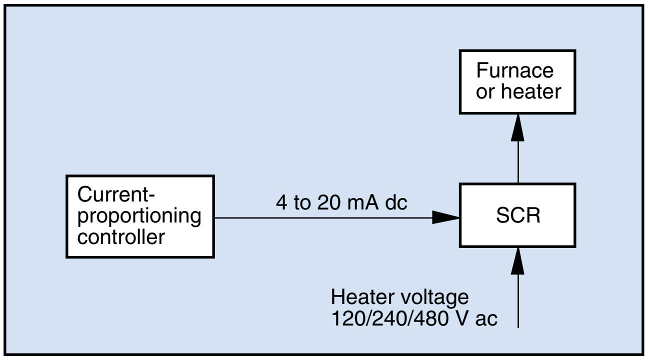
Fig. 1-7. Current proportioning with SCR



used to heat-treat steel. These voltages are too large for direct switching by a controller.

1.24 Electrically operated final control elements, particularly resistance heaters, can create difficult control problems. Heater elements have low resistance when cold and draw very large currents, but produce little heat at start-up. As the elements themselves heat up, they draw less current but deliver more heat to the process. The SCR allows current to flow to the heaters at a level corresponding to the instructions it receives from the controller.

1.25 In addition to these controller output transducers, process control loops may require controller input transducers. Pneumatic-to-current (P/I), voltage-to-current, and other similar transducers are widely used.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

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1-1. The purpose of an automatic controller is to make ________ equal to ________.	1-1. PV; SP Ref: 1.05
1-2. Feedback means that a change in controller output affects the process and causes a change in ________.	1-2. CONTROLLER INPUT Ref: 1.06
1-3. Most electronic controllers produce an output signal in the range of ________.	1-3. 4 to 20 mA Ref: 1.10
1-4. The process variable (PV) is a signal that represents the ________ variable.	1-4. MEASURED Ref: 1.14
1-5. Process ________ refers to the characteristics and behavior of a process.	1-5. DYNAMICS Ref: 1.16
1-6. A process that responds differently to equal increments of change is said to be ________.	1-6. NONLINEAR Ref: 1.16
1-7. An I/P transducer changes a(n) _______ signal to a(n) ________ signal.	1-7. CURRENT; PNEUMATIC (PRESSURE) Ref: 1.19
1-8. An SCR is one kind of ________ transducer.	1-8. I/E Ref: 1.23

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Position Proportioning

1.26 A process controller that provides a position-proportioning output allows variable positioning of the final control element. The advantages of a controller with this flexibility include precise modulation, smoother control, and a more consistent PV value.

1.27 Pneumatic systems often use control valves as final control elements. The controller output is sent to the valve, which may include a valve positioner. The purpose of the positioner is to modulate the valve more precisely and to amplify the signal to overcome friction and hysteresis in the valve. The positioner can be compared to the SCR used in the electrical current-proportioning system. The controller signal actually controls a mechanism which, in turn, controls the final control element.

1.28 As in the current-proportioning arrangement, the SP and PV are compared. If an error signal is generated, it is conditioned as needed and sent to the valve positioner where it is compared with the valve positioner feedback signal. The resulting signal modulates the positioner output signal, and this signal actually modulates the valve to increase or decrease the flow of the control medium—for example, steam.

Time Proportioning

1.29 A control system that uses time proportioning modulates the output on and off with varying frequency. The ability to modulate the output ON time and OFF time provides control over the responsiveness of the system.

1.30 Varying the ON and OFF times modulates the value of the PV over the range of control. Depending on the system, more ON time may cause the value of the PV to decrease, while more OFF time may cause it to increase—or the opposite may be true.

Controller Modes and Actions

1.31 Automatic controllers can be classified as either on/off (two-position) or continuous. An *on/off controller*—for example, your home thermostat—operates at a control point. When heat is needed, the furnace is turned on. When the control point is reached, the furnace is turned off. A deadband may be added between the ON and OFF temperatures to

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Application 1-1

Ollie enjoyed working in his modern control room. His control panel had many permanently installed controller cases, and any controller chassis could be slid into any case to make plug-in connections to the wiring. He knew that his controllers were interchangeable, because they all used 4- to 20-mA inputs and outputs and had the same adjustments, although the adjustment settings were different. There were various scales on the controllers' indicating meters, but they could be changed simply by slipping a preprinted scale tape behind a plastic window.

So, when FIC-27 (the flow-indicating controller for loop 27) failed, Ollie felt confident in replacing it with TIC-32 (the temperature-indicating controller for loop 32), which wasn't being used at the time. He exchanged the scale tapes and carefully set the tuning adjustments and forward/reverse action of TIC-32 to be the same as FIC-27. He slid the replacement controller into the FIC-27 case on the panelboard and switched from manual to automatic.

Sure enough, flow loop 27 (which Ollie had held quite steady under manual control) quickly stabilized under automatic control. However, curiously, the controller's position-indicating meter showed the valve position to be about 25% open. Before it had always been about 75% open.

Ollie called the instrument shop to find out how the loop could be working so well when the valve position was so far off. The instrument engineer didn't have to think long before realizing the FIC-27 was forward-acting, but TIC-32 was reverse-acting. Ollie had switched to the correct output action, but he wasn't aware that the position meter was driven by a signal from the valve positioner, not by the controller output.

The instrument shop offered three solutions. Ollie could replace the 0 to 100% meter tape with a 100 to 0% tape, the instrument shop could switch the meter leads, or the feedback element of the valve positioner could be reversed. Ollie said thanks, hung up, and headed for the envelope full of scale tape in his desk drawer.

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prevent unwanted cycling. Also, you can vary the ratio of ON time to OFF time to achieve a degree of proportioning of output to error, but this does not alter the basic kind of control. On/off controllers are all-or-nothing devices, sometimes called "bang-bang" controllers.

1.32 *Continuous* controllers always have some output. This output is made larger or smaller in proportion to the error to be corrected. The size of the output is calculated from the error and the controller actions. A controller may have one or more actions, and is referred to as a one-mode, two-mode, or three-mode controller, accordingly.

Controller Terminology

1.33 This Unit covers many concepts in process control. Although you are not yet expected to understand all of the following terms in detail, a familiarity with basic controller terminology will be helpful in this and later Lessons:

- *SP* (*setpoint*) is the desired value of a process expressed in engineering units (°F, psi, gpm, etc.) set into the controller by the operator.
- *RSP* (*remote setpoint*) is a setpoint set into a controller from a remote source—the output of another controller, for example—rather than by the operator.
- *E* (*error*, or *deviation*) is the difference between the process variable and the setpoint. Error may be positive or negative and may be caused by a change in either PV or SP.
- *Forward/reverse action* describes the direction of output change compared to the direction of input change. Most controllers can be switched between the two actions.
- *P* (*proportional action*) is a component of the output signal whose value is related to the size of the error.
- *I* (*integral action*, or *reset*) is a component of the output signal whose size is related to the length of time the error has persisted. This action, if present, is added to the proportional component.
- *D* (*derivative action*, or *rate*) is a component of the output signal whose size is related to the speed at which the error is changing. This action, if present, is added to the P or P and I components.
- *Bias* is a fixed component of the output signal. Bias is present even when the error is zero, and is always added to the P, I, and D components.
- *PB* (*proportional band*) is a scaling factor (a multiplier) defined as the percentage change in measured variable needed to cause a 100% change in controller output. Electronic controllers usually express PB as *gain* (*K*). Gain is the reciprocal of proportional band. That is: $K = 1/PB = 100\%/PB$ and $PB = 1/K = 100\%/K$.
- *Approach* is a component in the output for processes (typically temperature processes) that have large initial errors and a tendency to overshoot as they near the setpoint.
- *Cascade control* describes an arrangement of two or more controllers in which the output of one controller becomes the PV or RSP input to another controller rather than going to an end element, which receives only the output signal from the final controller.
- *Feedforward control* is a form of cascade control in which an output from one controller is sent to a second controller.
- *Ratio control* is a form of cascade control, often used in flow applications, in which several controllers combine to maintain a specified quantity made up of several components in controlled ratio to one another.

Controller Alarms and Options

1.34 Automatic controllers often are equipped with a variety of alarms to enhance their usefulness and improve the safety of the processes they control.

- *Input alarms* monitor PV and operate switches when PV is above or below a set value. Some instruments provide multiple alarm points—low/low, low/high, high/high, for example.

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- *Output alarms* are similar to input alarms, but they monitor the controller's output signal.

- *Deviation alarms* provide a contact closure when PV differs from SP by a set value (above or below). This deviation band moves with SP. For example, if the trip value is +10°F, the trip point will be 130°F when SP is 120°F, and 190°F when SP is 180°F.

- *Rate-of-change* alarms provide a contact closure when a value is increasing or decreasing faster than a set rate. These alarms are independent of the size of the change and can be applied to any of the controller's signals.

1.35 Controllers also can be equipped with other optional features to increase their usefulness. In addition to the control output, auxiliary outputs can be included to operate recorders or to provide remote setpoints to other controllers. Other optional features include output limiting and rate-of-change control on output and/or setpoint changes.

Advanced Controllers

1.36 Certain processes and control problems recur frequently, and designers have added special features to create advanced automatic controllers. The recent use of microprocessors makes it possible to increase the sophistication of these instruments, and this trend certainly will accelerate.

1.37 Advanced controllers may include many features. The following features, all of which are discussed in Lesson Four, are representative of the many special capabilities that can be provided:

- self-tuning to eliminate the trial-and-error tuning process

- adaptive tuning to lessen the compromise of tuning adjustments

- error-squared calculation to increase response speed

- anti-reset windup for stability in slow processes

- setpoint tracking for bumpless auto/ manual transfers

- setpoint rate limits and clamping to increase stability.

It is in the implementation of complex control strategies that microprocessor-based controllers and distributed control systems offer their greatest benefits. Figure 1-8 illustrates the many functions available with a microprocessor-based controller. Many of these can be incorporated, selectively, into analog controllers.

Safety in Control Loops

1.38 Pneumatic controllers are inherently quite safe for people and property. The constant flow of air minimizes accumulation of moisture, dust, and dirt. They do not generate electric sparks, and the pressure and volume of air that they pass are low. However, air supplies to these instruments may be at higher pressures and caution should be used.

1.39 Electrical controllers handle dangerously high levels of power and must be treated with extreme care. If they are used in a potentially explosive environment, special installation procedures must be used. It is critically important that safety equipment be maintained to original specifications at all times.

1.40 Electronic controllers handle lower power levels than electrical controllers, but they are equally dangerous. Remember:

- A 20-mA current can kill you!

- A 20-mA current can blow up your plant!

Electronic controllers can be installed and maintained to the standards used for electrical controllers. However, the concept of *intrinsic safety* for explosion prevention can be applied to electronic instruments and is more convenient, reliable, and cost-effective.

1.41 Intrinsically safe installations require that the controllers be located in a nonhazardous location—for example, a control room isolated from the plant operations. The signals to and from the controllers pass through *intrinsic safety barriers* that are designed to prevent any dangerous level of electric power from reaching the hazardous area of the plant. This eliminates the need for special enclosures for the transmitters and transducers in the plant.

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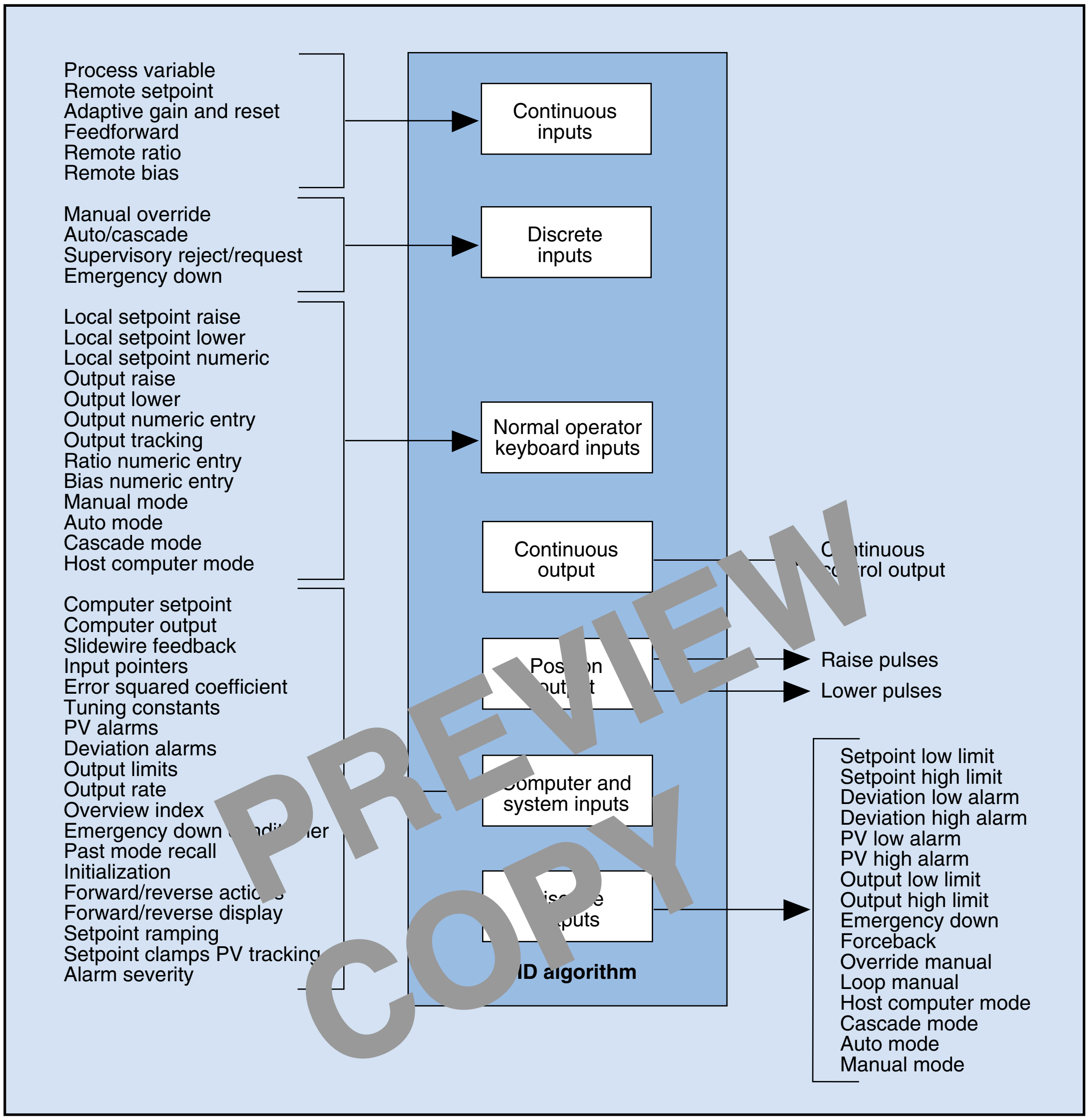
Fig. 1-8. Microprocessor-based controller functions



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1.42 An intrinsically safe installation is *not* safe for personnel. All proper precautions must be used when handling such equipment.

Accuracy in Control Loops

1.43 Automatic controllers do not require accuracy specifications as individual components in a control loop, because they produce an unpredictable, continuously variable output that has whatever value is required to bring error to zero. It may be paradoxical, but it should be evident that a controller requires an error in order to function.

1.44 Other components in the loop do affect overall accuracy. A good method for estimating overall accuracy is the *root-mean-square* (RMS) of the component accuracies. RMS is the square root of the average of the squares. It can be calculated by squaring the accuracy specification of each component, adding these squared values together, dividing by the number of values, and taking the square root of the result.

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1-9. In a pneumatic system with a controller and a valve positioner, the signal from the ________ actually modulates the valve.	1-9. POSITIONER Ref: 1.27
1-10. A time-proportioning system uses ________ control.	1-10. ON/OFF Ref: 1.29
1-11. Continuous controllers always have some ________.	1-11. OUTPUT Ref: 1.32
1-12. Proportional action is related to the size of the ________.	1-12. ERROR Ref: 1.33
1-13. The action that is related to the length of time the error has persisted is called ________ action.	1-13. INTEGRAL (RESET) Ref: 1.33
1-14. The action that is related to the speed at which the error is changing is called ________ action.	1-14. DERIVATIVE (RATE) Ref: 1.33
1-15. The deviation band in a deviation alarm moves with the ________.	1-15. SETPOINT (SP) Ref: 1.34
1-16. To be safe, remember that a 4- to 20-mA current can ________ you!	1-16. KILL Ref: 1.40

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Answer the following questions by marking an "X" in the box next to the best answer.

1-1. All automatic controllers

- ☐ a. are microprocessor-based
- ☐ b. compare a PV to an SP
- ☐ c. have about the same construction
- ☐ d. include advanced features

1-2. The ratio of minimum to maximum output signal of a proportional controller is 1 to

- ☐ a. 2
- ☐ b. 5
- ☐ c. 8
- ☐ d. 10

1-3. The process variable signal represents the

- ☐ a. control agent
- ☐ b. error
- ☐ c. manipulated variable
- ☐ d. measured variable

1-4. Large diaphragms on pneumatic valves

- ☐ a. amplify pressure
- ☐ b. improve linearity
- ☐ c. increase sensitivity
- ☐ d. increase speed of response

1-5. A silicon-controlled rectifier is a kind of ________ transducer.

- ☐ a. E/I
- ☐ b. I/E
- ☐ c. I/P
- ☐ d. P/E

1-6. A two-position controller always

- ☐ a. has some output
- ☐ b. is on or off
- ☐ c. provides forward and reverse action
- ☐ d. provides integral or derivative action

1-7. Gain is the ________ proportional band.

- ☐ a. opposite of
- ☐ b. reciprocal of
- ☐ c. same as
- ☐ d. square root of

1-8. A cascade control system with four controllers sends ________ control output(s) to the final control element.

- ☐ a. one
- ☐ b. two
- ☐ c. three
- ☐ d. four

1-9. Which of the following alarms is independent of the size of PV change?

- ☐ a. Deviation
- ☐ b. Input
- ☐ c. Output
- ☐ d. Rate-of-change

1-10. The root-mean-square method is used to calculate

- ☐ a. integral and derivative action
- ☐ b. proportional band or gain
- ☐ c. system accuracy
- ☐ d. transducer bias

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SUMMARY

An automatic controller has a process variable (PV) input and a setpoint (SP). Any difference, positive or negative, between PV and SP is called error. A controller must have an error in order to operate, but its purpose is to make the error as small as possible.

On/off controllers turn on when there is an error and turn off when there is no error (or vice versa). Continuous controllers always have some output that increases and decreases in proportion to error. In both cases, the output may be electrical, electronic, or pneumatic.

The effect of controller output on a process is determined by process dynamics—that is, the characteristics and behavior of a process in reaction to changes in energy input. Various kinds of controllers and final control elements are available to meet the demands imposed by process dynamics.

Standard controllers can be equipped with one to three or more modes or actions, which represent mathematical terms in the calculation that determines controller output as a function of error. Each mode can be adjusted (tuned) for the best operation with a particular process. These controllers also can be fitted with a variety of alarms and optional features to suit application requirements. Advanced controllers, especially microprocessor-based instruments, can provide even more capabilities for complex processes.

An automatic controller is one of many components in a control loop. The overall performance and safety of the process depend on proper installation, operation, and maintenance.

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Answers to Self-Check Quiz

1-1. b. Compare a PV to an SP. Ref: 1.05

1-2. b. 5. Ref: 1.10

1-3. d. Measured variable. Ref: 1.14

1-4. a. Amplify pressure. Ref: 1.21

1-5. b. I/E. Ref: 1.23

1-6. b. Is on or off. Ref: 1.31

1-7. b. Reciprocal of. Ref: 1.33

1-8. a. One. Ref: 1.33

1-9. d. Rate-of-change. Ref: 1.34

1-10. c. System accuracy. Ref: 1.44

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