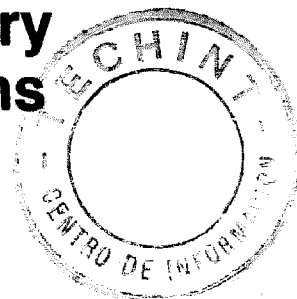


Manual on Installation of Refinery Instruments and Control Systems



Part I—Process Instrumentation and Control Section 5—Controllers and Control Systems

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Part I—Process Instrumentation and Control

SECTION 5—CONTROLLERS AND CONTROL SYSTEMS

5.1 Scope

This section presents recommendations for the application and installation of automatic controllers and control systems. A brief discussion of programmable controllers is also included. Definitions of control terms are provided, and controller types are described. A presentation of distributed control systems, other than user programmable, is included. Computer-based control systems that are user programmable are covered in RP 550, Part I, Section 14.

Modes of control most frequently applied in the refining industry are discussed along with an empirical approach to controller tuning. Special control applications, such as cascade and feedforward, are also discussed, including digital blending systems.

Some of the environmental and safety considerations for the location and mounting of controllers are discussed. Guidelines are provided to aid in the design and installation of both pneumatic and electronic control systems. Finally, some considerations for acceptance testing and check out are reviewed.

5.2 Referenced Publications

The latest edition or revision of the following publications are referenced in this text

ANSI¹

MC85.1M *Terminology for Automatic Control*

ISA²

S51.1 *Process Instrumentation Terminology*

5.3 Terms and Definitions

The following terms are used frequently in this text. The definitions presented are based on ANSI MC85.1M.

An *automatic controller* is a device that operates automatically to regulate a process variable. This is accomplished by comparing a measured process variable with the desired value of the variable, called the set point, and generating an output signal to a control element.

Control action, proportional, provides a continuous linear relationship between the output and the input.

Control action, integral (reset), provides an output that is proportional to the time integral of the input (that is, the rate of change of the output is proportional to the input).

Control action, derivative (rate), is that component of the control action for which the output is proportional to the rate of change of the input.

Control action, proportional plus integral (reset), provides an output that is proportional to a linear combination of the input and the time integral of the input.

Control action, proportional plus derivative (rate), provides an output that is proportional to a linear combination of the input and the time rate-of-change of the input.

Control action, proportional plus integral (reset) plus derivative (rate), provides an output that is proportional to the linear combination of the input, the time integral of the input, and the time rate-of-change of the input.

Control, direct digital, is control performed by a digital device that establishes the signal to the final controlling element.

Controller, direct acting, is a controller in which the value of the output signal increases as the value of the input (measured variable) increases.

Controller, reverse acting, is a controller in which the value of the output signal decreases as the value of the input (measured variable) increases.

A *control system* consists of the hardware and software devices necessary to satisfy functional requirements of an operating facility.

Dead band is the range through which an input can be varied without initiating a response.

A *direct connected controller* receives its inputs directly from the process by electrical, mechanical, or hydraulic means.

Distributed control systems are configurable multiloop control systems in which the user defines the control arrangement within a rigorous format provided by the manufacturer. Distributed control systems are generally not considered user programmable.

Gain, proportional, is the ratio of the change in output due to proportional control action to the change in input.

Gain, derivative action, is the ratio of the maximum gain resulting from proportional plus derivative control action to the gain due to the proportional control action alone (sometimes referred to as rate gain).

¹American National Standards Institute, 1430 Broadway, New York, New York 10017.

²Instrument Society of America, PO Box 12277, Research Triangle Park, North Carolina 27709.

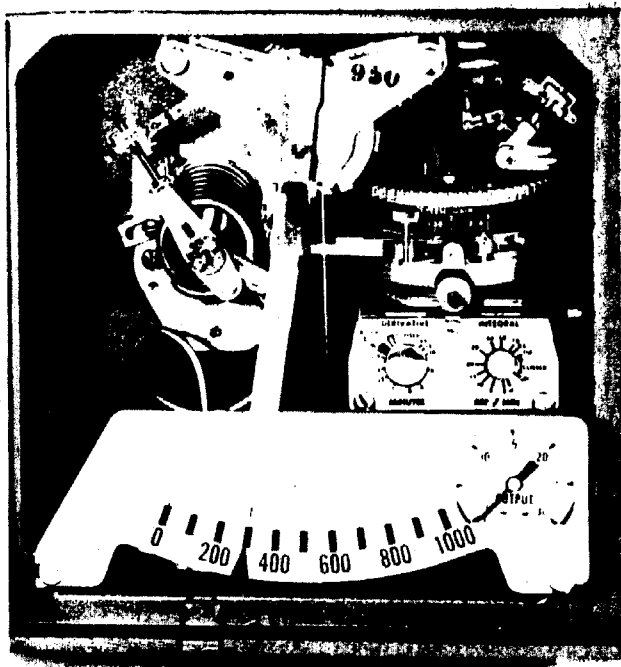


Figure 5-3—Direct-Connected Controller

electronic instruments, which, in the early stages of development, simply duplicated the functions of pneumatic equipment and followed the same packaging concepts very closely. The packaging similarities were intended to provide the process operator with the least possible change in the presentation of information and in the means of changing set points or switching an instrument from automatic to manual.

In the past few years several new approaches have been taken by manufacturers in the architecture or packaging of instrument systems as well as in the design of the operator interface. These variations, generally referred to as distributed control systems, have been made possible by the advances in electronic technology and the lowering costs of digital equipment. Some incentives to use these systems include:

1. Reduced installation costs.
2. Reduced space requirements for control areas.
3. The ability to test the complete system in the vendor's shop.
4. Improved computer interfaces.
5. Improved operator interface.
6. Built-in diagnostics.
7. Improved system reliability.

8. More efficient report generation.
9. Increased flexibility.
10. Improved unit control.

Distributed control systems are defined as those in which the various functions of controlling, indicating, recording, interfacing, and communicating are distributed among a hierarchy of devices that operate both individually and collectively. They have a number of inputs and outputs varying anywhere from a few to several hundred. Instead of the control function being achieved through multiple, stand-alone, self-contained single loop controllers, a distributed control system may take a number of different forms. These systems are intended to simplify installation, improve means of interrelating and extending controller functions, permit the use of common (or shared) devices, or facilitate interfacing a separate computer system. The extent to which these features can be achieved will vary among manufacturers. Because there are so many systems available, it is not possible within the scope of this document to consider all variations. Several forms of distributed control systems that have been applied to refinery processes will be reviewed to emphasize the differences and the available options.

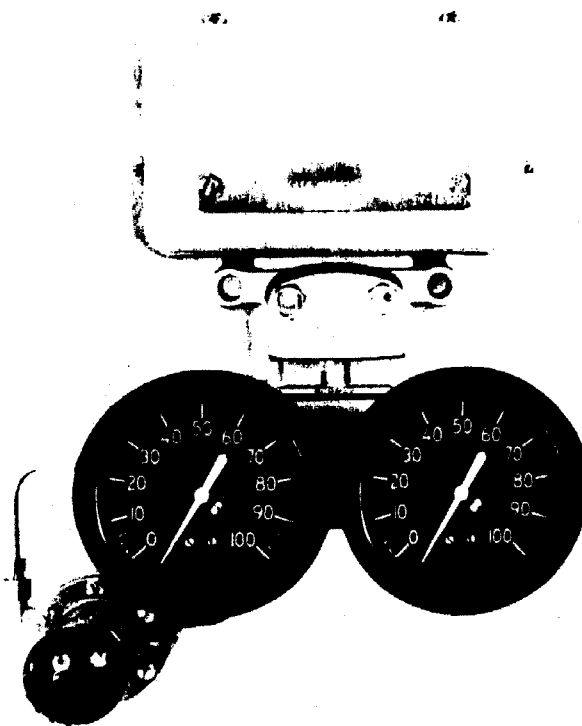


Figure 5-4—Blind Controller with External Gages

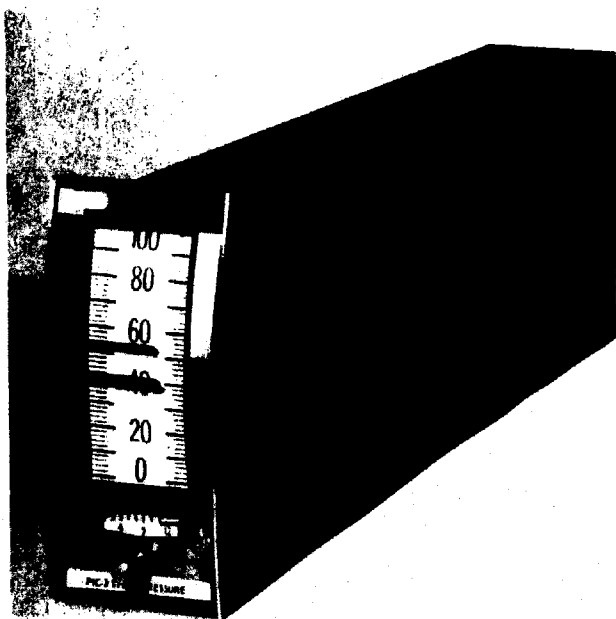


Figure 5-1—Small Case Indicating Controller

A *programmable controller* is a device whose primary function is sequential logic control. A programmable controller accepts binary inputs, generates binary outputs, and in many cases, accepts and generates analog signals.

Receiver controller is a controller that receives its input from a remotely mounted transmitting device such as a process transmitter or transducer.

Set point is an input variable that sets the desired value of the controlled variable. (The input variable may be manually set, automatically set, or programmed. It is expressed in the same units as the controlled variable.)

For additional information see S51.1, *Process Instrumentation Terminology*.

5.4 Single Loop Controllers

Single loop controllers are available in many sizes and shapes but are generally referred to as small case controllers, nominally 6 inches by 6 inches (150 millimeters by 150 millimeters) or smaller, and large case controllers, nominally 8 inches by 10 inches (200 millimeters by 250 millimeters) or larger. While small case controllers are usually mounted in the control room, large case instruments are more commonly used for field installations. There is a large variety of cases available for large-case controllers, including weatherproof, watertight, and explosionproof cases.

There are three basic types of single loop controllers:

1. Blind controllers, having no indication of measured variable, set point, or output.

2. Indicating controllers, generally having a display of the measured variable, set point, and output.
3. Recording controllers, recording the measured variable on a circular or strip chart and usually including a display of the measured variable, set point, and output.

When recording is required with small case controllers, it is usually done with a separate instrument.

Controllers may be either connected directly to the process or receive an input from an external source such as a transmitter. Direct-connected controllers are mechanically, electrically, or hydraulically connected to the measured variable via a pressure element, thermocouple, filled thermal system, or other means. The signal for the receiver-type controller is usually 3 to 15 pounds per square inch gage (20 to 100 kilopascals gage) pneumatic or 4 to 20 milliamperes direct current electronic.

Controller features that must be specified include: required control modes, ability to switch from manual to automatic operation, local or remote set point, and optional functions. Figures 5-1 through 5-4 illustrate typical single loop controllers.

5.5 Distributed Control Systems

The evolution of process control instrumentation has been more rapid in the last few years than ever before. Pneumatic instruments, although still widely used, have given way to

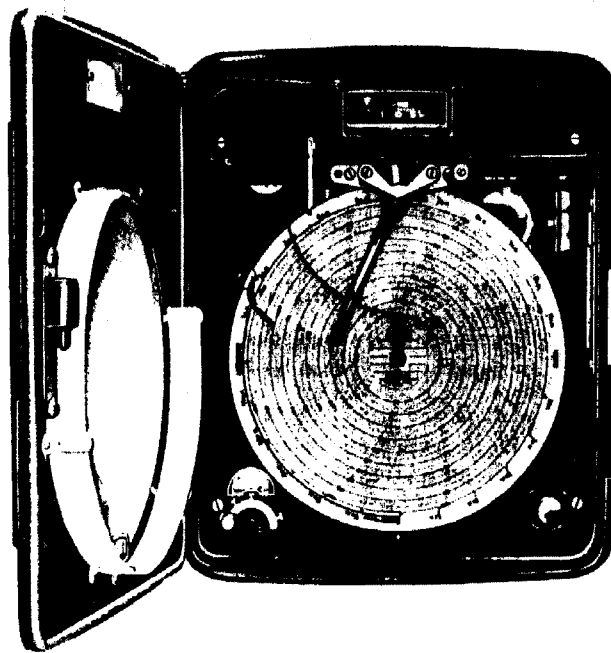


Figure 5-2—Large Case Recording Controller

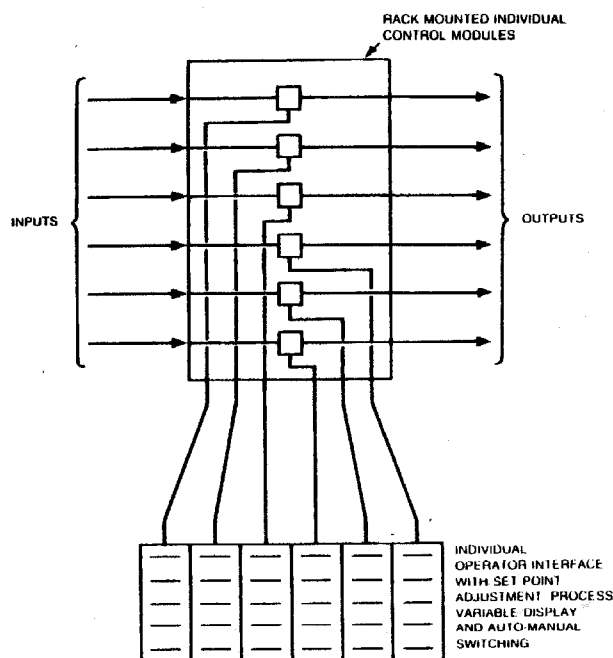


Figure 5-5—Rack Mounted Individual Control Modules with Individual Remote Operator Interfaces

5.5.1 TYPES OF DISTRIBUTED CONTROL SYSTEMS

5.5.1.1 Individual Control Modules

As indicated in Figure 5-5, this configuration consists of rack-mounted individual control modules and individual remote operator interfaces. The physical features of such a system are primarily the rack mounting of equipment, the provision of common power supplies, prewired termination facilities, and prewired positions into which additional printed circuit cards can be plugged. Interwiring between modules can be done at the factory. With the use of plug-in connectors to the individual operator interfaces, the installation wiring is essentially reduced to inputs from and outputs to the field devices. Factory wiring permits the use of automated equipment, reducing wiring errors.

Individual control modules lend themselves to the addition of features that permit interfaces to a communications network and the use of shared devices, such as a central computer and the operator interface shown in Figure 5-6.

Individual control modules provide continuous control of each individual loop.

5.5.1.2 Microprocessor-Based Multiloop Control Modules

Some manufacturers provide a microprocessor-based system (as shown in Figures 5-7 and 5-8) that accommodates

a number of control loops with individually selectable control algorithms. Such systems allow control relationships between variables to be programmed. Many advanced control strategies can be devised without requiring additional equipment or wiring changes. With some systems, a separate programming or configuration device is required.

The operator interface can consist of individual modules, as indicated in Figure 5-7, or an interface can be provided, as shown in Figure 5-8. Through an interface, a communication network can transmit information to a computer or a shared operator display.

The microprocessor-based multiloop system is a shared controller that scans inputs and updates its outputs in cycles. In effect, the control loop whose "turn" it is to function, consults its memory for current process value, set point, control program, and the last output value and "connects" itself to the common controller. There it selects the required algorithm or algorithms and computes a new output value. The process is then repeated for the next loop.

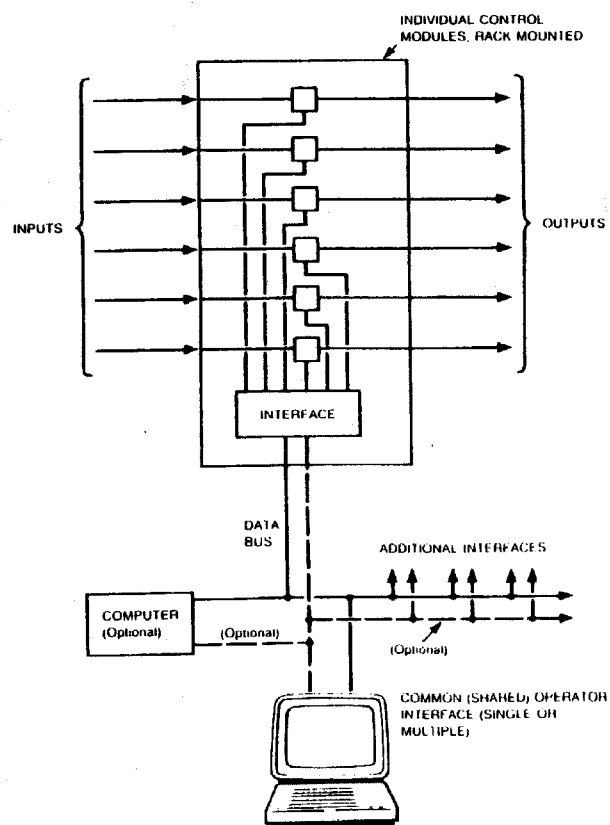


Figure 5-6—Rack Mounted Individual Control Modules with Common Remote Operator Interface and Optional Computer Interface

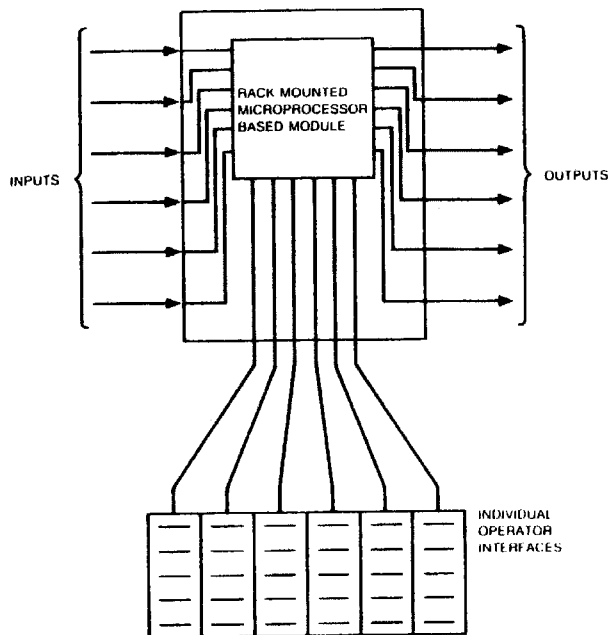


Figure 5-7—Microprocessor-Based System for Multiloop Control with Individual Remote Operator Interfaces

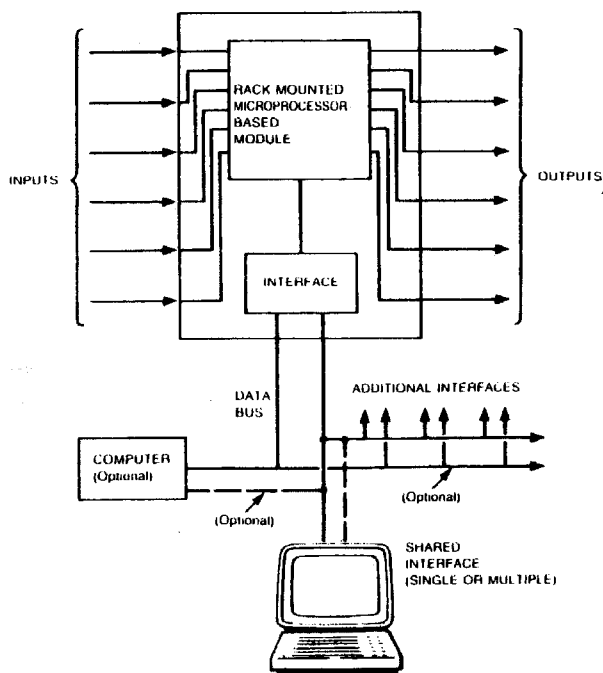


Figure 5-8—Microprocessor-Based System for Multiloop Control with Shared Remote Operator Interface and Optional Computer Interface

5.5.1.3 Computer-Based Process Controller

Some process control systems utilize a single computer (see Figure 5-9) dedicated to a number of loops sufficient for one or more process units. While this computer may have some features that are software selectable, it is generally a self-contained package with both the software and hardware determined by the manufacturer and dedicated to process control.

These process controllers may use microprocessor technology. They have memories, use digital communications, and usually have cathode ray tube displays and a keyboard for communications. As with microprocessor-based control modules, these computer-based controllers can provide some very intricate control systems, including logic and calculation capability, without the need for additional equipment or wiring modifications. They are usually limited to control systems having up to a few hundred loops because they are not modular but monolithic in design.

5.5.2 FLEXIBILITY OF DISTRIBUTED CONTROL SYSTEMS

Most of the features of distributed control systems have been and are available through the use of individual components mounted and wired on a conventional upright panel or console. Such arrangements, however, have limited flexibility and expandability because equipment must be added or wiring changed to add or modify control strategies. The benefits of a computer control system that could add loops,

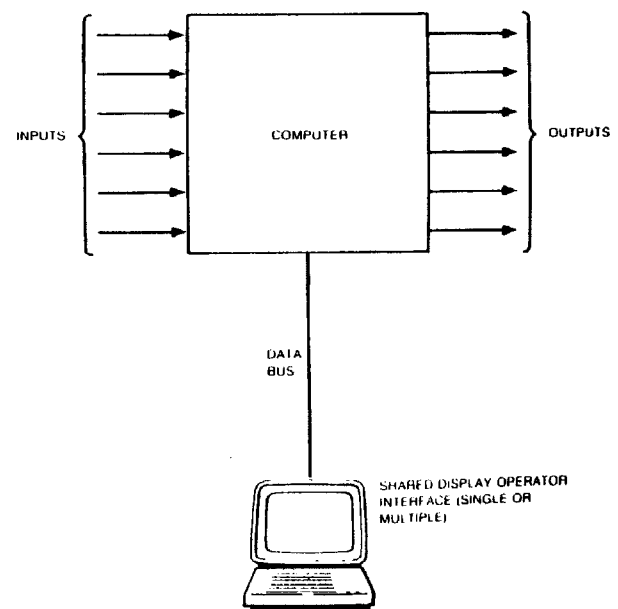


Figure 5-9—Computer-Based Process Controller for Multiloop Control with Shared Display Operator Interface