

# 7

## Control and Field Instrumentation Documentation

To successfully work with (and design) control systems, it is essential to understand the documents that are typically used to illustrate process control and associated field instrumentation. The documentation of process control and associated field instrumentation is normally created by the engineering firm that designs and constructs the plant. The company that commissioned the plant may have an internal documentation standard the engineering firm will be required to follow.

For an older installation, the plant documentation may only exist as a series of paper documents. Today the documentation created for a new or upgraded plant is produced electronically using automated design tools and software. The tools and software selected by the plant or engineering firm for initial plant design or upgrade will influence the documentation format and how documentation is maintained at the plant site. Also, the selection of the control system determines to what extent the system is self-documenting.

**Self-documenting** – the automatic creation of documents that follow defined conventions for naming and structure.

If the documentation generated by the control system does not follow standards that have been established for process control and instrumentation, then it may be necessary to manually create this documentation.

**Control System** - A component, or system of components functioning as a unit, which is activated either manually or automatically to establish or maintain process performance within specification limits.

In this chapter, we examine four types of drawings that are commonly used to document process control and associated field instrumentation.

In spite of cosmetic differences, the documentation of process control and field instrumentation for a plant are strongly influenced by and, in some cases, are required to follow standards established for the process industry. For example, companies and engineering firms located in North America may follow standards established by ISA. [1] Accredited by the American National Standards Institute (ANSI), ISA has published more than 135 standards, recommended practices, and technical reports. The standards address control and field instrumentation documentation, as well as other areas such as security, safety, batch control, control valves, fieldbus communication, environmental conditions, measurement, and symbols. Many ISA standards were developed through collaboration with the International Electrotechnical Commission (IEC). The IEC is the world's leading organization that prepares and publishes International Standards for all electrical, electronic, and related technologies—collectively known as “electrotechnology.” [2] As previously mentioned in section 2.9, the function block standards, such as IEC 61131 and IEC 61804 (ANSI/ISA-61804), and the batch standards, ANSI/ISA-88 Parts 1-3, have been adopted by many designers of modern control systems for graphics design and documentation of the control system.

## 7.1 Plot Plan

It is often helpful to look at the plot plan to get an overview of how a plant is physically organized. By examining the plot plan, it is possible to get an idea of where a piece of equipment is located in the plant. A typical plot plan is shown in Figure 7-1.

As will become clear in the following chapters, understanding the physical layout of the plant and the distances between pieces of equipment can often provide insight into the expected transport delay associated with material or product flow between pieces of equipment. For example, how long does it take a liquid, gas, or solid material flow to get from one point in the process to another?

**Transport Delay** – Time required for a liquid, gas or solid material flow to move from one point to another through the process.

Physically, if the major pieces of process equipment are laid out far apart, then the transport delay can be significant and in some cases, impact control performance. Also, the physical layout of a plant will impact the length of wiring runs and communication distance from the control sys-

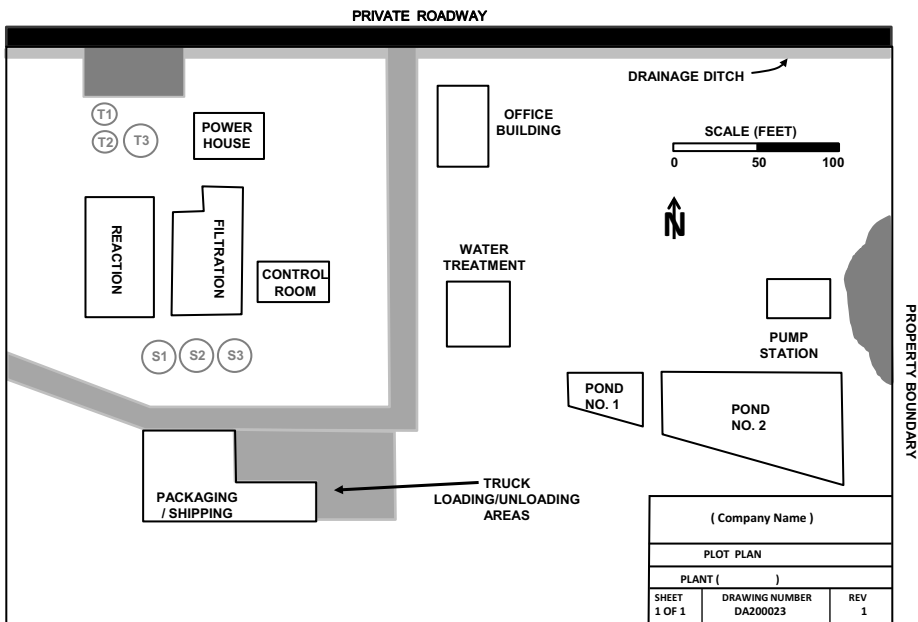


Figure 7-1. Plot Plan

tem to the field devices; thus, it is a good idea to use the plot plan to get a sense of the plant layout and a feel for the location of process equipment and process areas.

## 7.2 Process Flow Diagram

To meet market demands, a company may commission an engineering firm to build a new plant or to modify an existing plant to manufacture a product that meets certain specifications and that can be manufactured at a specific cost. Given these basic objectives, a process engineer will select the type of chemical or mechanical processing that best meets the planned production, quality, and efficiency targets. For example, if the equipment is to be used to make more than one product then the process engineer may recommend a batch process. For example, a batch reactor may be used to manufacture various grades of a lubrication additive. Once these basic decisions are made, the process engineer selects the equipment that will most cost-effectively meet the company's objectives. Based on the production rate, the process engineer selects the size of the processing equipment and determines the necessary connections between the pieces of equipment. The process engineer then documents the design in a process flow diagram (PFD). The process flow diagram typically identifies the major pieces of equipment, the flowpaths through the process, and the design operating conditions—that is, the flow rates, pressures, and temperatures at normal operating conditions and the target production rate.

**Process flow diagram** – Drawing that shows the general process flow between major pieces of equipment of a plant and the expected operating conditions at the target production rate.

Since the purpose of the process flow diagram is to document the basic process design and assumptions, such as the operating pressure and temperature of a reactor at normal production rates, it does not include many details concerning piping and field instrumentation. In some cases, however, the process engineer may include in the PFD an overview of key measurements and control loops that are needed to achieve and maintain the design operating conditions.

**Control Loop** - One segment of a process control system.

During the design process, the process engineer will typically use high-fidelity process simulation tools to verify and refine the process design. The values for operating pressures, temperatures, and flows that are included in the PFD may have been determined using these design tools. An example of a process flow diagram is shown in Figure 7-2. In this example, the design conditions are included in the lower portion of the drawing.

### 7.3 Piping and Instrumentation Diagram

The instrumentation department of an engineering firm is responsible for the selection of field devices that best matches the process design requirements. This includes the selection of the transmitters that fit the operating conditions, the type and sizing of valves, and other implementation details. An instrumentation engineer selects field devices that are designed to work under the normal operating conditions specified in the process flow diagram. Tag numbers are assigned to the field devices so they may be easily identified when ordering and shipping, as well as installing in the plant.

**Tag number** – Unique identifier that is assigned to a field device.

The decisions that are made concerning field instrumentation, the assignment of device tags, and piping details are documented using a piping and instrumentation diagram (P&ID). A piping and instrumentation diagram is similar to a process flow diagram in that it includes an illustration of the major equipment. However, the P&ID includes much more detail about the piping associated with the process, to include manually operated blocking valves. It shows the field instrumentation that will be wired

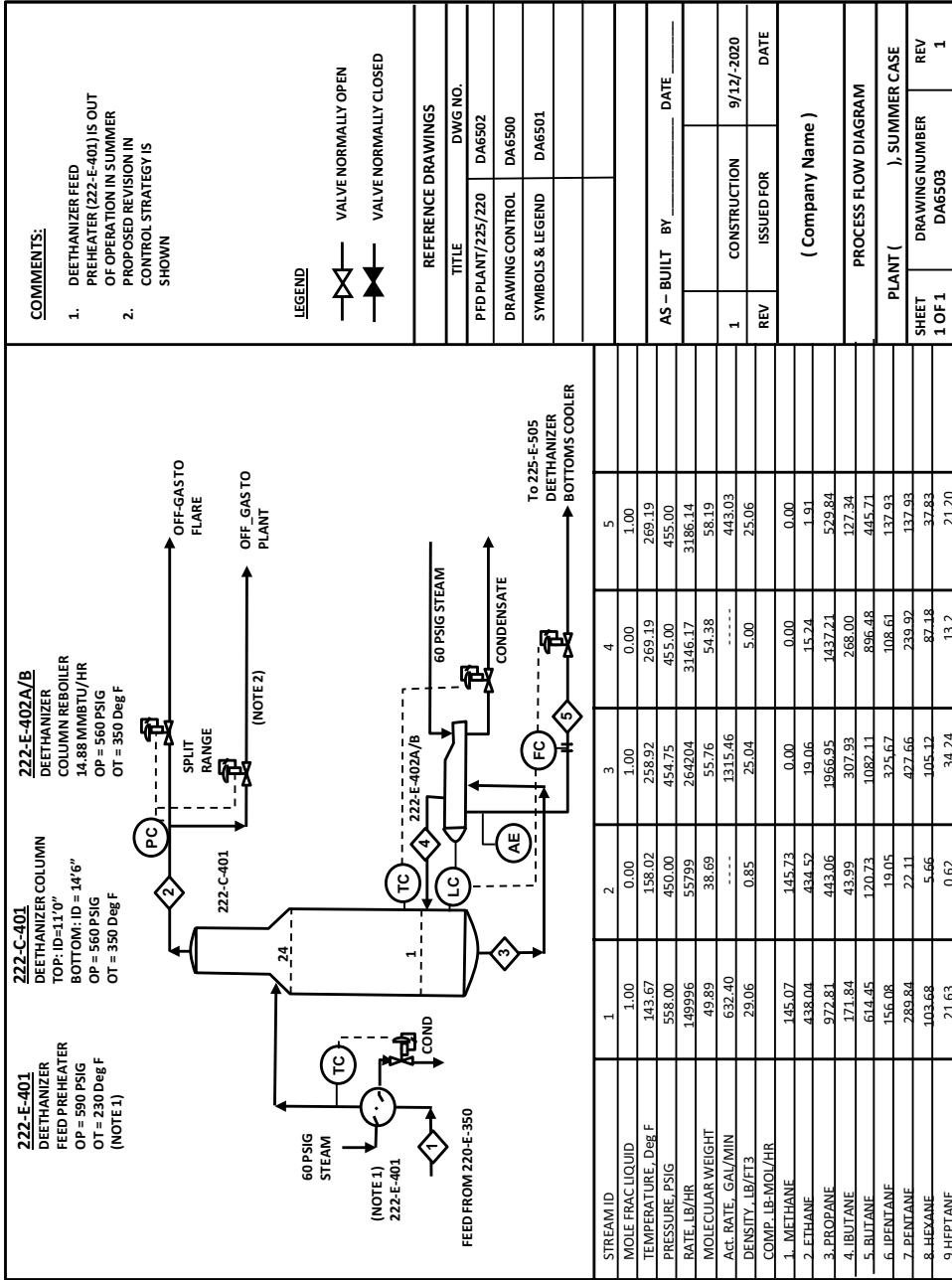


Figure 7-2. Process Flow Diagram

into the control system, as well as local pressure, temperature, or level gauges that may be viewed in the field but are not brought into the control system.

As mentioned earlier, the engineering company that is creating the P&ID normally has standards that they follow in the creation of this document. In some cases, the drawing includes an overview of the closed loop and manual control, calculations, and measurements that will be implemented in the control system.

**Closed loop control** - Automatic regulation of a process inputs based on a measurement of process output.

**Manual control** – Plant operator adjustment of a process input.

However, details on the implementation of these functions within the control system are not shown on the P&ID. Even so, the P&ID contains a significant amount of information and in printed form normally consists of many D size drawings (22 x 34 inches; 559 x 864 mm) or the European equivalent C1 (648 x 917mm). The drawings that make up the P&ID are normally organized by process area, with one or more sheets dedicated to the equipment, instrumentation, and piping for one process area.

**Piping and Instrumentation Diagram** – Drawing that shows the instrumentation and piping details for plant equipment.

The P&ID acts as a directory to all field instrumentation and control that will be installed on a process and thus is a key document to the control engineer. Since the instrument tag (tag number) assigned to field devices is shown on this document, the instrument tag associated with, for example, a measurement device or actuator of interest may be quickly found. Also, based on the instrument tags, it is possible to quickly identify the instrumentation and control associated with a piece of equipment. For example, a plant operator may report to Maintenance that a valve on a piece of equipment is not functioning correctly. By going to the P&ID the maintenance person can quickly identify the tag assigned to the valve and also learn how the valve is used in the control of the process. Thus, the P&ID plays an important role in the design, installation and day to day maintenance of the control system. It is a key piece of information in terms of understanding what is currently being used in the plant for process control. An example of a P&ID is shown in Figure 7-3.



When you are doing a survey of an existing plant, obtaining a copy of the plant P&IDs is a good starting point for getting familiar with the process and instrumentation. Unfortunately, the presentation of process control on the P&ID is not standardized and varies with the engineering firm that creates the plant design. In some cases, process control is illustrated at the top of the drawing and its use of field instrumentation is indicated by arrows on the drawing that point from the field instrumentation to the control representation. Another common approach is to show control in the main body of the drawing with lines connected to the field instrumentation. Using either approach complicates the drawing and its maintenance since process control design may change with plant operational requirements.

For this reason, the P&ID may only show the field instrumentation, with other documentation referenced that explains the control and calculations done by the control system. For example, when the process involves working with hazardous chemicals, then a controller functional description (CFD) may be required for process safety management (PSM). Standards have been established by OSHA for controller functional descriptions. [3]

## 7.4 Loop Diagram

The piping and instrumentation diagram identifies, but does not describe in detail, the field instrumentation that is used by the process control system, as well as field devices such as manual blocking valves that are needed in plant operations. Many of the installation details associated with field instrumentation, such as the field devices, measurement elements, wiring, junction block termination, and other installation details are documented using a loop diagram. ISA has defined the ISA-5.4 standard for Instrument Loop Diagrams. [4] This standard does not mandate the style and content of instrument loop diagrams, but rather it is a consensus concerning their generation. A loop diagram, also commonly known as a loop sheet, is created for each field device that has been given a unique tag number. The loop diagrams for a process area are normally bound into a book and are used to install and support checkout of newly installed field devices. After plant commissioning, the loop Diagrams provide the wiring details that a maintenance person needs to find and troubleshoot wiring to the control system.

**Loop Diagram** – Drawing that shows field device installation details including wiring and the junction box (if one is used) that connects the field device to the control system.

The loop diagram is a critical piece of documentation associated with the installation of the control system. As has been mentioned, the engineering



company that is designing a process normally has standards that they follow in the creation of a loop diagram. These standards may be documented by the creation of a master template that illustrates how field devices and nomenclature are used on the drawing.

The loop diagram typically contains a significant amount of detail. For example, if a junction box is used as an intermediate wiring point, the loop diagram will contain information on the wiring junctions from the field device to the control system. An example of a loop diagram is shown in Figure 7-4.

As is illustrated in this example, junction box connections are shown on the line that shows the division between the field and the rack room. The loop diagram shows the termination numbers used in the junction box and the field device and for wiring to the control system input and output cards. Also, the Display and Schematic portions of the loop diagram provide information on how the field input and output are used in the control system.

Figure 7-4 shows installation details for a two-wire level transmitter that is powered through the control system analog input card. Also, connections are shown between the control system analog output card and an I/P transducer and pneumatic valve actuator. Details such as the 20 psi air supply to the I/P and the 60 psi air supply to the actuator are shown on this drawing. Based on information provided by the loop diagram, we know that the I/P will be calibrated to provide a 3–15 psi signal to the valve actuator. In addition, specific details are provided on the level measurement installation. Since the installation shows sensing lines to the top and bottom of the tank, it becomes clear that the tank is pressurized and that level will be sensed based on the differential pressure.

In this particular installation, the instrumentation engineer has included purge water to keep the sensing line from becoming plugged by material in the tank. Even fine details such as the manual valve to regulate the flow of purge water are included in the loop diagram to guide the installation and maintenance of the measurement device.

In this example, the loop diagram shows the installation of a rotameter. A rotameter consists of a movable float inserted in a vertical tube and may be used to provide an inexpensive mechanical means of measuring volumetric flow rate in the field.

As this example illustrates, the loop diagram provides information that is critical to the installation, checkout, and maintenance of field devices. By examining the loop diagram, it is possible to learn details that may not be

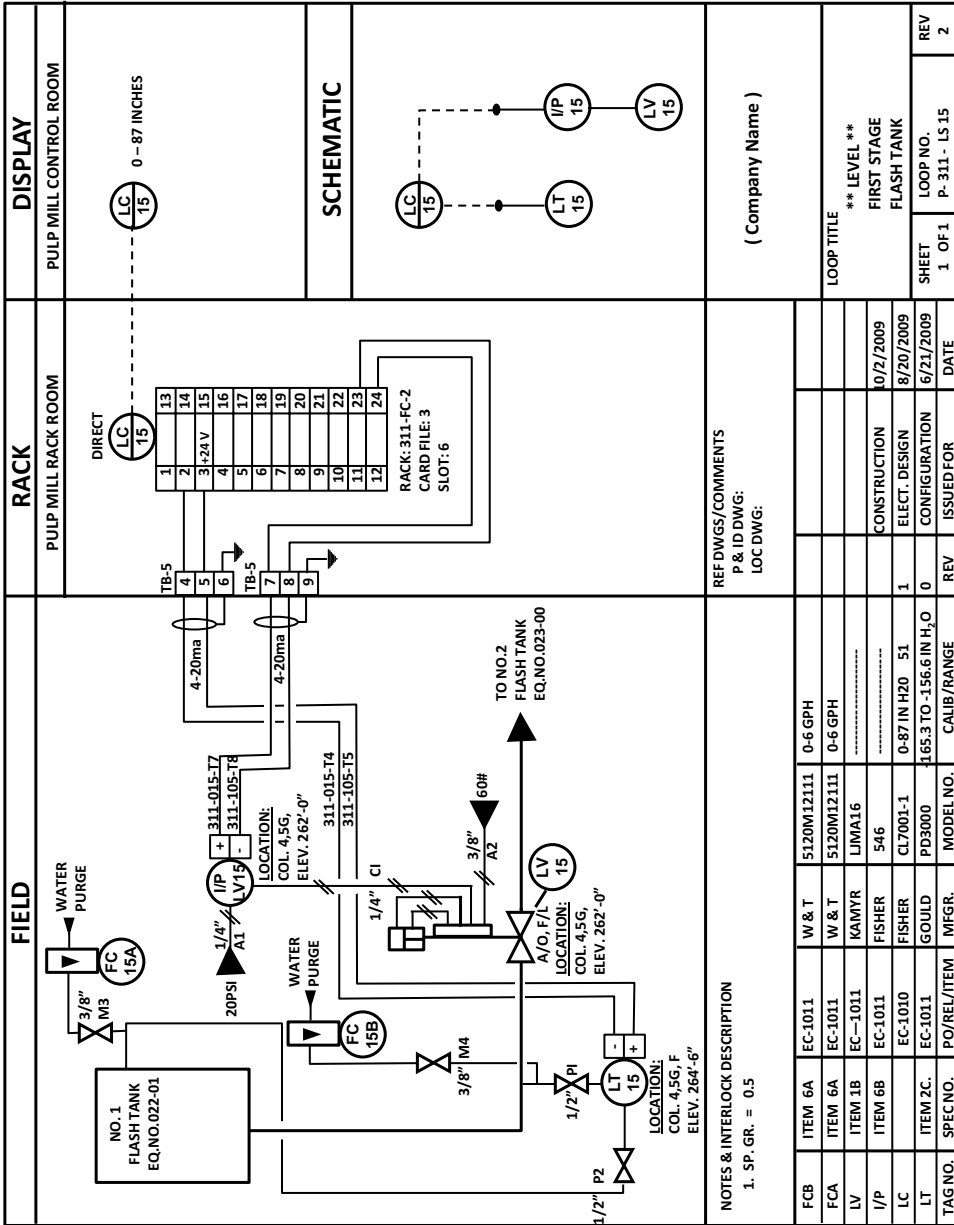


Figure 7-4. Example Loop Diagram—Level Control

obvious when you are touring the plant site. For example, as was previously presented in Chapter 3 on measurement, there are various ways to measure temperature. In the case of a temperature measurement, the loop diagram will provide information on the temperature transmitter, as well as the measurement element that is used. Figure 7-5 shows the loop diagram for a temperature measurement in which a three-wire RTD element is used for the temperature measurement. Details such as the grounding of the shield for the element wire and for the twisted pair going from the transmitter to the control system are noted on the loop diagram.

The process of creating and reviewing loop diagrams is made easier by the fact that many components used to represent measurement and control in similar applications are often repeated. For example, the manner in which the control valve, actuator, and associated I/P transducer were represented in the loop diagram example for a level application is duplicated in other loop diagrams that depict a regulating (control) valve. This is illustrated in the loop diagram shown in Figure 7-6 for a pressure application in which a regulating valve is used in the control of pressure. Also in this example, the pressure measurement is made with a two-wire transmitter. As will be noted by comparing Figure 7-4 and Figure 7-6, the wiring for the pressure transmitter is similar to that used for the level transmitter.

In some cases, the operator uses a process measurement as an indicator or as an input to a calculation that is done in the control system. A loop diagram may be developed for these types of measurement that details the device installation and wiring to the control system. In such cases, the loop diagram will contain no definitions of control. Figure 7-7 shows a flow measurement made by measuring the differential pressure across an orifice plate. As was previously covered in Chapter 3 on measurement, the hole in the orifice plate is sized to give a specific pressure drop at the maximum flow rate that the process is designed to support. As noted in the lower portion of the loop diagram, the orifice plate is sized to provide a differential pressure of 500 inches H<sub>2</sub>O at a flow rate of 750 gpm. Also noted in the loop diagram is the control system is expected to take the square root of this differential pressure to obtain an indication of flow rate.

## 7.5 Tagging Conventions

The tagging conventions that were shown in examples of a P&ID and loop diagrams may be confusing to someone who has not worked with these documents. The naming convention illustrated in the P&ID and loop diagram examples are fairly well standardized in North America. To a certain extent, similar conventions are used in Europe and Asia to document process instrumentation and control. The standard tagging convention used

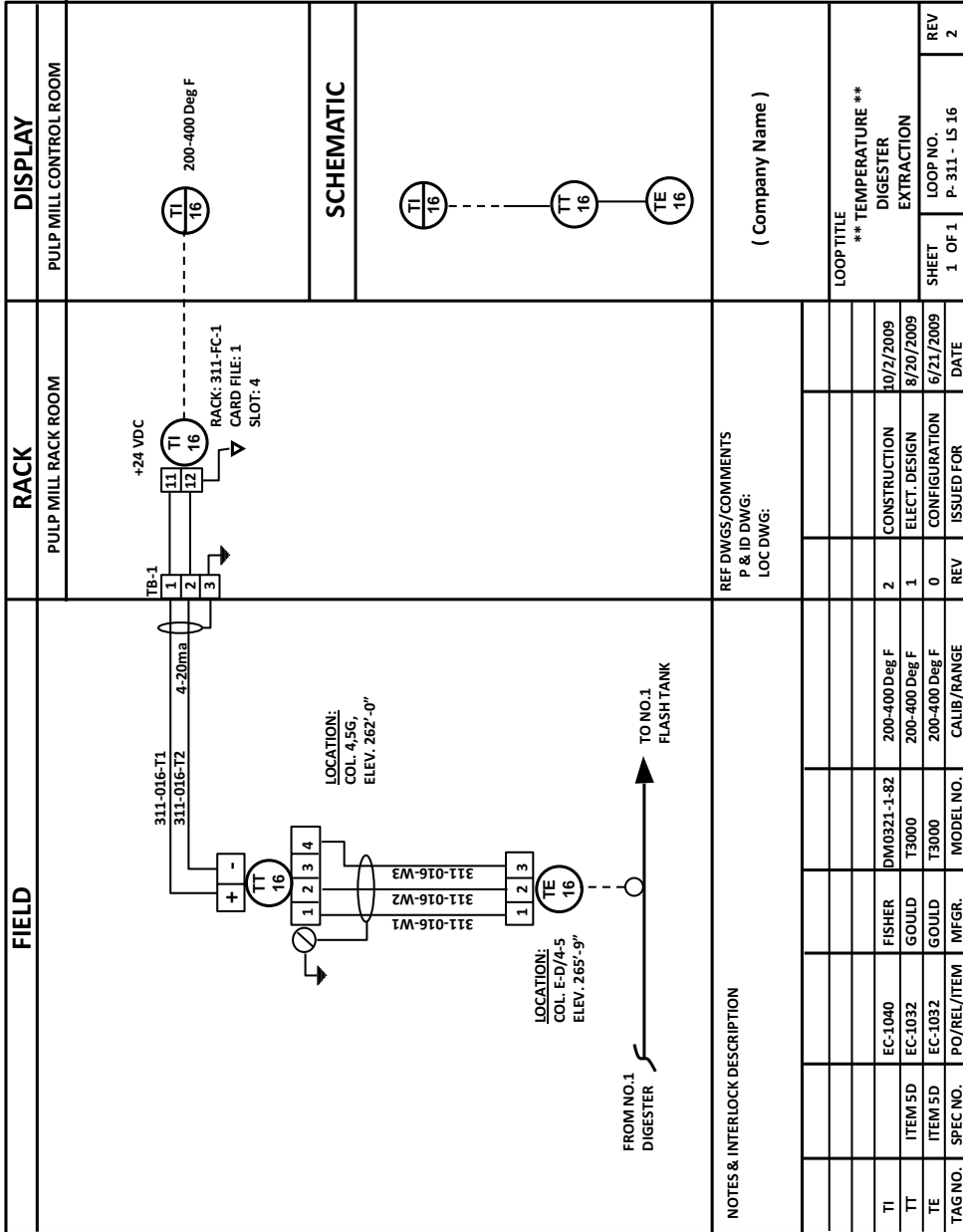


Figure 7-5. Example Loop Diagram – Temperature Control

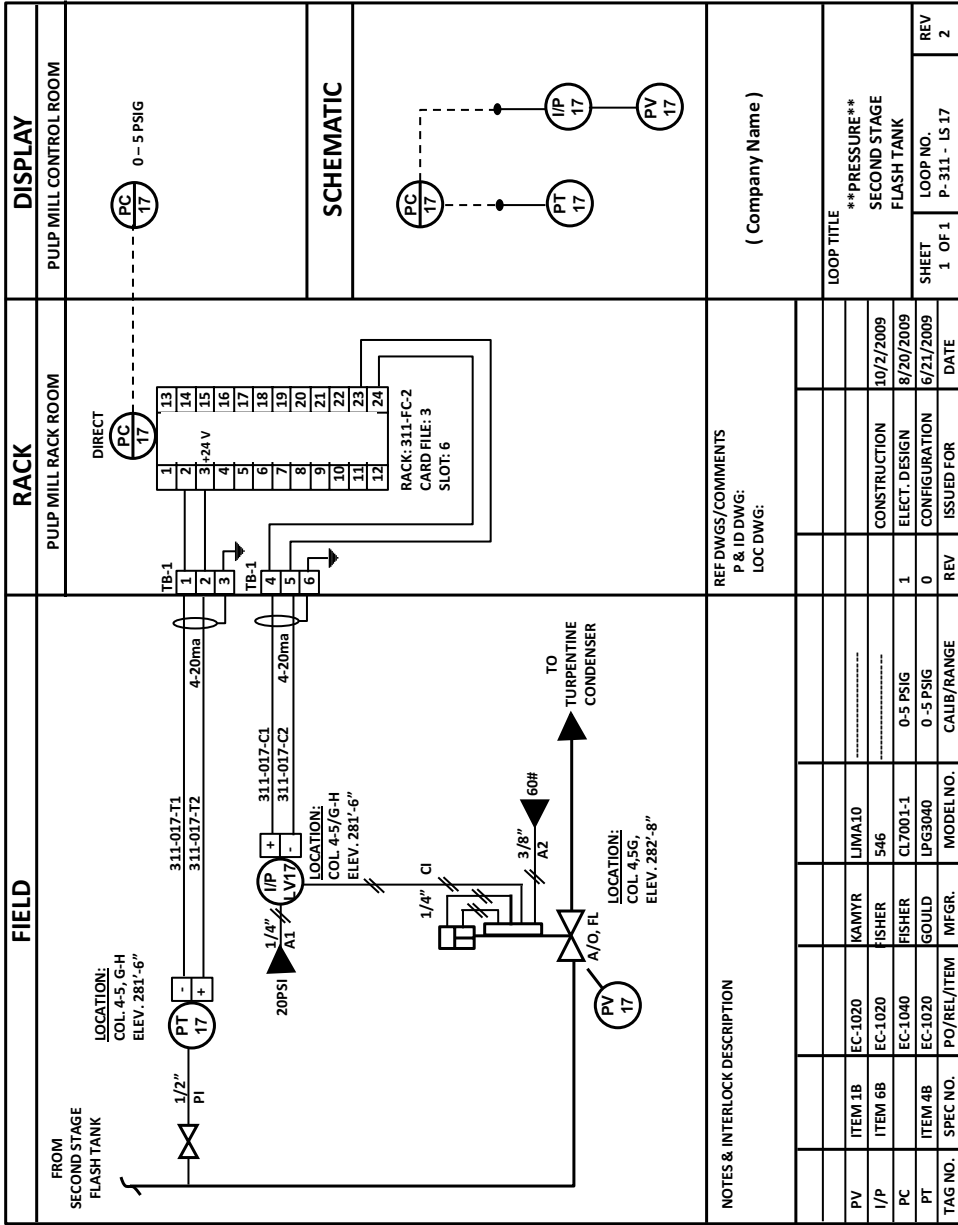


Figure 7-6. Example Loop Diagram – Pressure Control

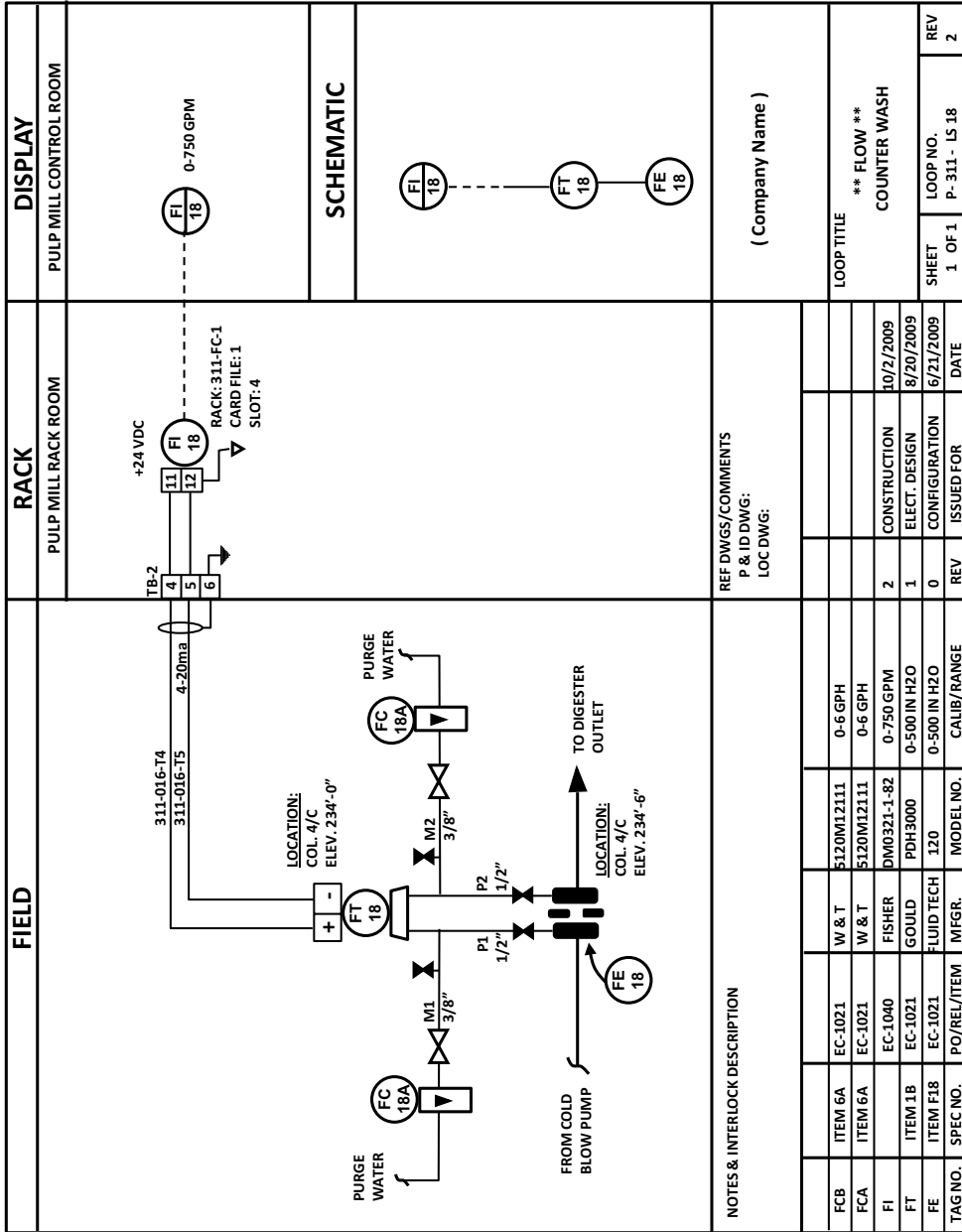


Figure 7-7. Example Loop Diagram – Flow Measurement

in North America has been developed through the efforts of ISA. The format of tags used to identify field devices is defined by ISA-5.1 - Instrumentation Symbols and Identification.

The ISA-5.1 standard defines a standard tag number convention for valves, transmitters, other field devices, and calculation and control functions. In addition, the standard defines expanded tag number conventions that may better meet the documentation requirements of large installations that consist of many process areas or multiple measurements that serve similar functions. The tag number convention defined by ISA-5.1 is summarized in Figure 7-8.

TYPICAL TAG NUMBER	
TIC 103	- Instrument Identification or Tag Number
T 103	- Loop Identifier
103	- Loop Number
TIC	- Function Identification
T	- First-letter
IC	- Succeeding-Letters
EXPANDED TAG NUMBER	
10-PAH-5A	- Tag Number
10	- Optional Prefix
A	- Optional Suffix

Note: Hyphens are optional as separators

**Figure 7-8. ISA-5.1 Tag Number Convention**

The tag number convention established by ISA-5.1 may appear cumbersome, but when examined in detail, it can be easily understood and applied when you are creating new documentation. When first looking at this standard, it is often helpful to consider some examples contained in the standard that illustrate the use of this tagging convention.

The letters that make up the first few characters of a typical tag number (the “leading letters”) are used to identify the function performed by the field device or by the control system. Following these leading letters is a number. The number that appears on the tag is known as the loop number. The loop number is used to uniquely identify one or more field devices that are used to perform a specific function. This combination of function letter and loop number allows a field device in a process area to be precisely identified. Knowing the device tag number is required when filling out a work order to or in discussing a field measurement with an operator or instrument technician. The tag number assigned to a field device is normally stamped on a tag that is attached to the device.

All the devices that are used together to perform a specific function are normally assigned the same loop number. For example, the flow transmitter and regulating valve used to measure and regulate the flow of a process stream may be assigned loop number 101.

The loop number normally has only three digits. Consequently, the number of field devices that can be uniquely identified using the standard tag number convention is very limited. For this reason, an expanded tag number convention, defined by the ISA-5.1 standard, is used in the process industry. The expanded tag number convention allows a number to be inserted in front of the function, and that number is usually the process area number. As discussed in Chapter 2, a plant is divided into process areas that are assigned a number. The combination of the area number, the function letters, and the loop number is unique within a plant.

In some cases, multiple field devices may be used to perform a similar function. For example, in some boiler applications the temperature of each tube in the superheater section of a boiler may have individual temperature measurements. Rather than assigning a loop number to each measurement, the expanded tag number convention assigns a common loop number to all these measurements. When this is done, one or more characters may be added after the loop number to uniquely identify each measurement. For the boiler example, loop number 105 might be assigned to all the superheater temperature measurements and the individual measurements may be identified by adding an A after the loop number for the first measurement, a B for the second measurement, and a C for the third measurement.

This option to add letters after the loop number allows unique tag numbers to be created for each measurement, even when a large number of similar measurements is made in a process area. A hyphen may be optionally used in the tag number to separate the area number or characters added after the loop number. However, in general, the use of a hyphen in the tag number is not recommended since in many control systems, the length of a tag number is limited to a maximum number of characters (e.g., 12 or 16 characters).

As defined by ISA-5.1, the identification letters used to specify the function of a field device are organized in a specific manner. The meaning of a letter varies depending on whether it is the first letter or a succeeding letter. A table of the identification letters defined by the standard is shown in Figure 7-9. If the first letter of a tag number is an A, this indicates that the primary function of the device is analysis; if the first letter is an F, then the primary function is flow. When the first letter is H, this indicates that a manual or Hand function is to be performed. By reviewing this table of



identification letters, the use of the letters in a tag number can be easily determined.

	First Letters		Succeeding Letters		
	Measured/Initiating Variable	Variable Modifier	Readout/Passive Function	Output/Active Function	Function Modifier
<b>A</b>	Analysis		Alarm		
<b>B</b>	Burner, Combustion		User's Choice	User's Choice	User's Choice
<b>C</b>	User's Choice			Control	Close
<b>D</b>	User's Choice	Difference, Differential			Deviation
<b>E</b>	Voltage		Sensor, Primary Element		
<b>F</b>	Flow, Flow Rate	Ratio			
<b>G</b>	User's Choice		Glass, Gauge, Viewing Device		
<b>H</b>	Hand				High
<b>I</b>	Current		Indicate		
<b>J</b>	Power	Scan			
<b>K</b>	Time, Schedule	Time Rate of Change		Control Station	
<b>L</b>	Level		Light		Low
<b>M</b>	User's Choice				Middle, Intermediate
<b>N</b>	User's Choice		User's Choice	User's Choice	User's Choice
<b>O</b>	User's Choice		Orifice, Restriction		Open
<b>P</b>	Pressure		Point (Test Connection)		
<b>Q</b>	Quantity	Integrate, Totalize	Integrate, Totalize		
<b>R</b>	Radiation		Record		Run
<b>S</b>	Speed, Frequency	Safety		Switch	Stop
<b>T</b>	Temperature			Transmit	
<b>U</b>	Multivariable		Multifunction	Multifunction	
<b>V</b>	Vibration, Mechanical Analysis			Valve, Damper, Louver	
<b>W</b>	Weight, Force		Well, Probe		
<b>X</b>	Unclassified	X-axis	Accessory Devices, Unclassified	Unclassified	Unclassified
<b>Y</b>	Event, State, Presence	Y-axis		Auxiliary Devices,	
<b>Z</b>	Position, Dimension	Z-axis, Safety Instrumented System		Driver, Actuator, Unclassified final control element	

**Figure 7-9. ISA-5.1 Identification Letters**

In some cases, a letter can only be used as a succeeding letter. For example, the letter D would never be used as a first character, but it may be used as a succeeding letter to indicate “differential.” Thus, the combination PD is valid and would indicate the function of the device is “pressure, differential,” that is, differential pressure. The combination HIC would be used to indicate hand indicator controller, that is, manual control. Indication and control based on an analytic measurement would be identified as AIC. The letter combination FIC is quite common and used to indicate a “flow indicating control” function. A control valve used in pressure control would be identified using the letters PV, pressure valve. A temperature



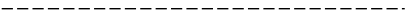
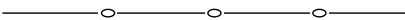
measurement used only for indication would be identified as TI, “temperature indication.” A position transmitter would be identified using the letters ZT.

In the ISA-5.1 standard, several examples are provided that illustrate the correct use of the indication letters within a tag number. Also, the standard covers other letters that may be used in special applications.

The use of tag numbers in a process control system is quite straightforward and must be understood to work with or create documentation for a process control system.

## 7.6 Line and Function Symbols

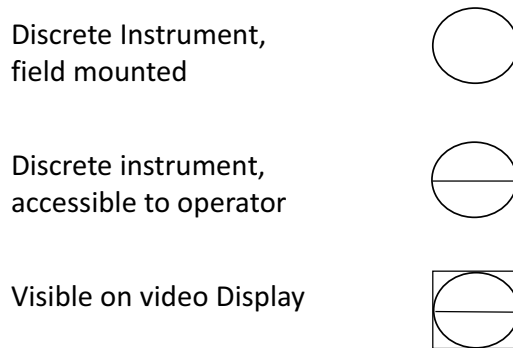
Different types of lines are used in process flow diagrams, piping and instrumentation diagrams, and loop diagrams to indicate the type of connection between field devices and the control system. The ISA-5.1 standard defines the instrument line symbols that are commonly used in control system documentation. As illustrated in Figure 7-10, a solid line is used to represent a physical connection to the process. Two slashes shown as points along a line are used to indicate a pneumatic signal. One of the most common ways to indicate an electric signal is a dashed line as defined in ISA-5.1. Communication links between devices and functions of a distributed control system are indicated by small bubbles along the line as illustrated in Figure 7-10.

- Instrument supply or connection to process 
- Pneumatic Signal 
- Electric Variable or Binary 
- Communication Link 

**Figure 7-10. Excerpt from ISA-5.1 Instrument Line Symbols**

The previous examples of the process flow diagram, piping and instrumentation diagram, and loop diagram contained one or more circle symbols. In these drawings, a circle is used to indicate a discrete instrumentation or control function. A horizontal line drawn through the middle of the circle indicates the function may be accessed by the plant operator. There are many functions, such as those performed by an I/P transducer or valve positioner, that are typically not directly accessible by the operator. Also, some field devices for measurement and actuation may

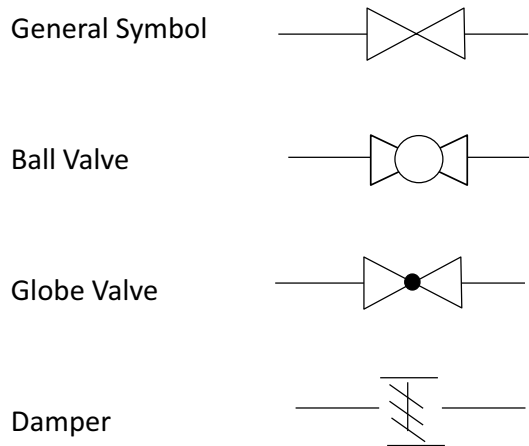
only be accessed by control or calculation functions in the control system and thus would not be shown in the documentation as being directly accessed by the operator. However, the associated control or calculation function that is accessed by the operator would include a horizontal line. As illustrated in Figure 7-11, one of the conventions advocated in ISA-5.1 is to include a square around the circle if the associated function is accessed by an operator through a video display of a distributed control system (DCS). However, in practice, this convention is often not followed.



**Figure 7-11. Excerpt from ISA-5.1 General Instrumentation or Symbol Function**

It is common practice to illustrate the valve body, as well as the valve actuator and positioner function in control system documentation. The ISA-5.1 standard addresses the representation of a valve body. Most types of valves are addressed by this standard. However, the engineering firm that is designing a process plant may have adopted some variation of what is shown in ISA-5.1. In such cases, it is common practice for the engineering firm to provide a drawing that explains the symbol functions included in their documentation. Also, in some cases, a general valve representation is used rather than different representations for a rotary valve or sliding stem valve. [5] Generally, a damper will be shown rather than the general valve symbol to indicate the regulation of air or gas flow to a boiler or a similar process such as a kiln or heater. An excerpt from ISA-5.1 Valve Body and Damper Symbols are illustrated in Figure 7-12.

Since the type of actuator used with a valve body may impact the operation and failure mode of the valve, the type of actuator is normally indicated in control system documentation. The representation of common types of actuators as defined by ISA-5.1 is shown in Figure 7-13. A complete representation of the valve is provided by combining the valve representation with the actuator representation.



**Figure 7-12. Excerpt from ISA-5.1 Valve Body and Damper Symbols**

When a positioner is used with a valve, the diaphragm representation may be combined with a representation of the actuator and the valve body, as is illustrated in Figures 7-16 to 7-19. The failure mode of the valve (i.e., fail open or fail closed) is often indicated by the valve symbol in control system documentation.

A special actuator symbol is defined by the standard for motorized actuators. Motorized actuators are used in some industry segments because upon loss of power, the last valve position is maintained. Also, better resolution may be achieved using a motorized actuator for a specific application, such as the basis weight valve that is used to regulate the thick stock flow to a paper machine in paper manufacturing. [6] Solenoid actuators that are used to automate valves used in on-off service are shown using a special symbol.

Installation details are provided in the loop diagram documentation. Some of details may also be provided in the P&ID. For example, the P&ID and loop diagram may show the orifice that must be installed to measure flow using a differential pressure transmitter. Hand-operated valves that are used to block flow during startup or maintenance are shown since they impact process operation if not properly set up. Also, the installation of inline instrumentation, such as a magnetic flowmeter, is commonly shown in a unique manner in the control system documentation. In addition, measurement elements such as an RTD or a thermocouple are shown since they may be physically installed some distance from the field transmitter or the control system. To provide a consistent means of documenting the physical installation, the ISA-5.1 standard includes symbols for many of these common installation details and field devices. A sample of some of these symbols is shown in Figure 7-14.






- Generic actuator, Spring-diaphragm 
- Spring-diaphragm with positioner 
- Linear piston actuator with positioner 
- Rotary motor operated actuator 
- Solenoid actuator for on-off valve 

Figure 7-13. Excerpt from ISA-5.1 Actuator Symbols

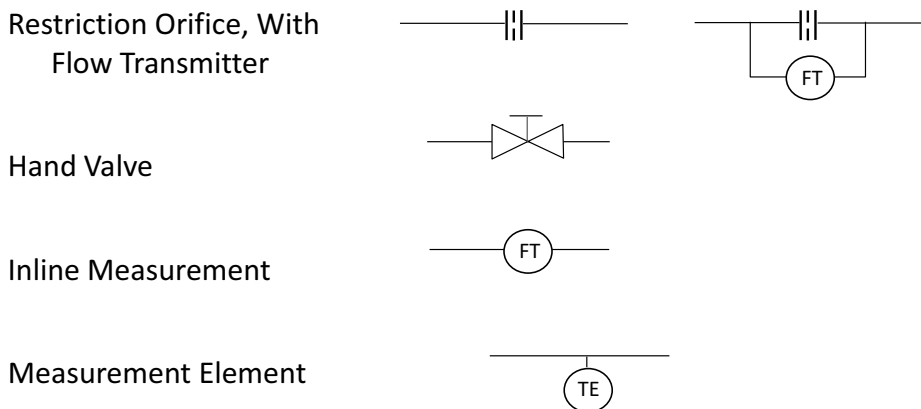
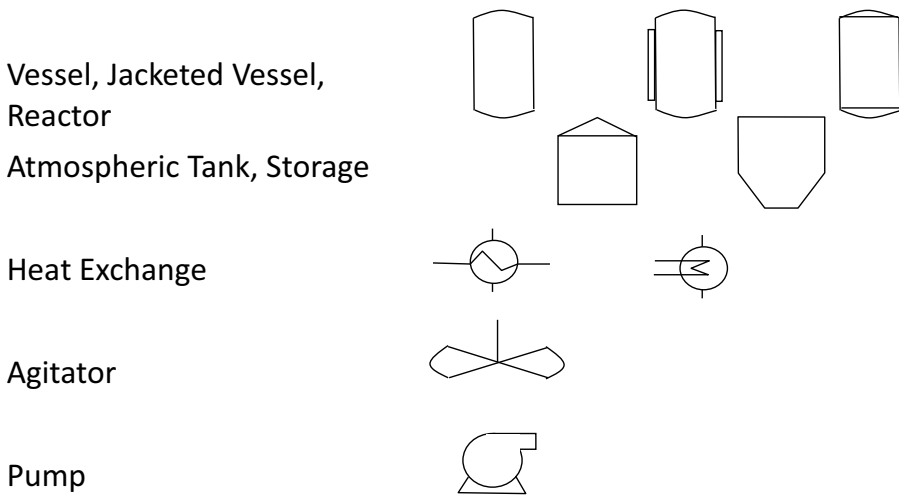


Figure 7-14. Excerpt from ISA-5.1 Symbols for Other Devices

## 7.7 Equipment Representation

A representation of major pieces of process equipment is normally included in control system documentation. This allows the field instrumentation installation to be shown in relationship to the process equipment. Example process equipment representations are illustrated in Figure 7-15.

A general vessel representation may be appropriate for vessels, agitators, heat exchangers, and pumps that do not play an important role in the control system. For example, an agitator on a tank may not directly impact the control associated with the tank level. A special representation is provided



**Figure 7-15. Examples of Process Equipment Symbols**

for a reactor. A jacketed vessel symbol may be used when a vessel is heated or cooled by circulating liquid through an outside shell. Such a design is commonly used in the batch industry, and permits the vessel's contents to be heated or cooled without coming in contact with the circulating liquid. A symbol is also provided for flat-bottomed and cone-shaped storage tanks that are open to the atmosphere. The examples include a representation of a heat exchanger, which is used to heat or cool a liquid stream. A symbol is defined for an agitator that may be used to ensure good mixing of liquids in a vessel. Also, a pump symbol is shown in these examples.

## 7.8 Documentation Examples

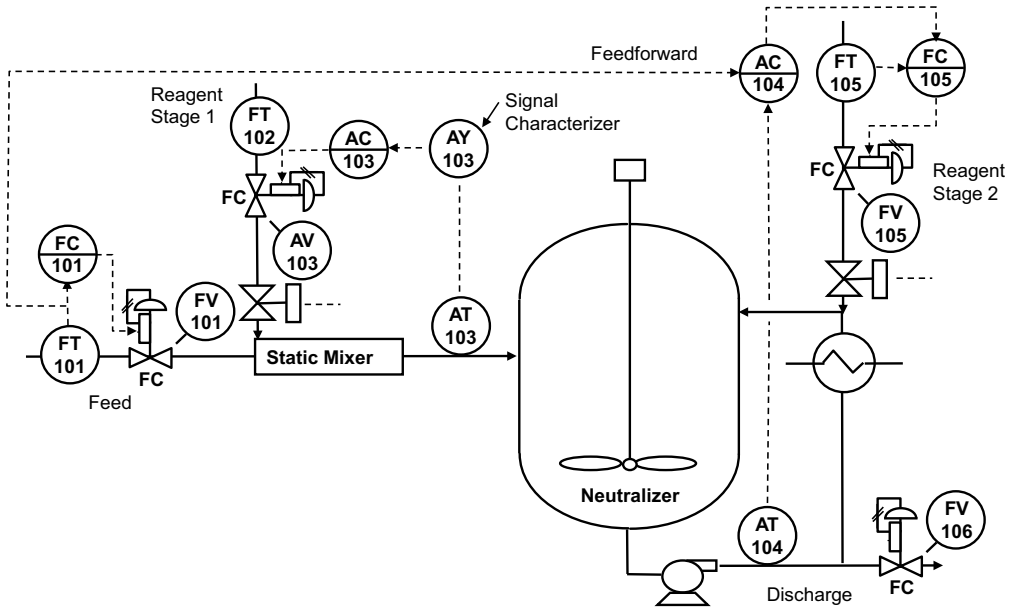
The four examples included in this section are designed to illustrate many of the recommendations of the ISA-5.1 standard. In the first example, questions and answers are used to highlight specific points that have been covered in this chapter. A review of these questions will hopefully serve to reinforce your understanding of concepts and terminology that will be used in later chapters. By studying the control system and field instrumentation documentation, a lot can be learned about the process and the way the control system is designed to work. Such background information can be extremely helpful when you are working with or troubleshooting the control system for a new process.

### 7.8.1 Example – Basic Neutralizer Control System

The neutralizer process may be used to adjust the pH of a feed stream. The field devices and process controls that would typically be provided to this

process are shown in this piping and instrumentation diagram illustrated in Figure 7-16.

After reviewing this diagram, consider the following questions and answers.



**Figure 7-16. Example – Basic Neutralizer Control System**

**Question:** What tag number convention is shown in this example?

**Answer:** The expanded tag number convention, defined by the ISA-5.1 standard, is not used in this example since the tag only contains function letters and a loop number.

**Question:** Flow measurements are made using FT101, FT102, and FT105. What type of measurement technique is used by these field devices?

**Answer:** The field device is shown as installed inline and the liquid is conductive. Thus, a magnetic flowmeter is installed.

**Question:** Do the valves have digital positioners?

**Answer:** Yes, an electric signal is shown going directly to a box located on each valve. The pneumatic line from the

actuator is also tied to this box. Therefore, we can assume that these valves are installed with a valve positioner.

**Question:** What type of valve is being used to regulate flow?

**Answer:** The general valve body symbol is used and thus the type of valve is not indicated in this drawing.

**Question:** Is the plant operator able to access the control functions indicated by AC103, AC104, FC101, and FC105?

**Answer:** Yes, the circle indicating these control functions contains a horizontal line that indicates the operator may access this function.

**Question:** Can the operator access flow measurements FT101, FT102, and FT105, as well as analytic (pH) measurements AT103 and AT104?

**Answer:** No, the circle indicating these measurement functions does not include a horizontal line. In this case, these measurements are not directly accessed by the operator.

**Question:** Are any on-off (blocking) valves used in this process?

**Answer:** Yes, two blocking valves are shown with electric on-off actuators.

**Question:** What function is provided by AC103?

**Answer:** The function letters of the tag number indicate that the function is analytic control.

**Question:** What measurement is used by AC103 in performing its control function?

**Answer:** Since an electric signal line is shown from AT103 to AC103, then control must be based on the measurement AT103 (pH).

**Question:** What is the purpose of the function shown between AT103 and AC103, that is, AY103?

**Answer:** On the diagram, this function is noted as Signal Characterization. When a complex calculation is done, it is often represented by a single function with AY noted inside the circle and a note provided to explain the purpose of this function.



**Question:** Does the vessel have an agitator?

**Answer:** Yes, the figure shows an agitator impeller in the vessel, powered by a motor on top of the vessel.

**Question:** Is the pump fixed speed or variable speed?

**Answer:** Since control of the process is done using a regulating valve, then it may be assumed that the pump is fixed speed.

**Question:** How could the liquid in the vessel be heated?

**Answer:** A heat exchanger is shown in the recirculation line and could be used to heat (or cool) the liquid in the vessel.

**Question:** How is the pH of the incoming stream adjusted?

**Answer:** The output of AC103 and AC104 go to a valve and flow loop, respectively, that regulates the flow of reagent to the inlet stream and recirculation line. Thus, it may be assumed that reagent is used to adjust pH.

## 7.8.2 Example – Basic Column Control

The basic column control system shown in Figure 7-17 is somewhat more complicated than the basic neutralizer control system. However, after studying this example, it will become clear that many of the components that make up the column control system are similar to those used in the basic neutralizer control system. As we have seen, what is learned by working with one process may be often applied to another process. Once you become familiar with a few processes, it becomes easier to work with other processes.

## 7.8.3 Example – Batch Reactor Control System

Batch processing plays an important role in some industries. In a batch process, a vessel is charged with feed material that is processed in the vessel through mechanical or chemical means (or both). At the end of the process, the product—which may be a finished product or an intermediate product for use in another process—is removed from the vessel. The batch reactor example illustrated in Figure 7-18 is known as “continuous feed batch,” in which feed material is continuously added to the vessel throughout part or all of the batch processing. The reaction takes place, and finally the product is pumped from the vessel. In comparing the basic components to those seen in the previous two examples, the only new element introduced by this example is an eductor (a device that produces vacuum by means of the Venturi effect) that is used to remove gases created by the batch reaction.

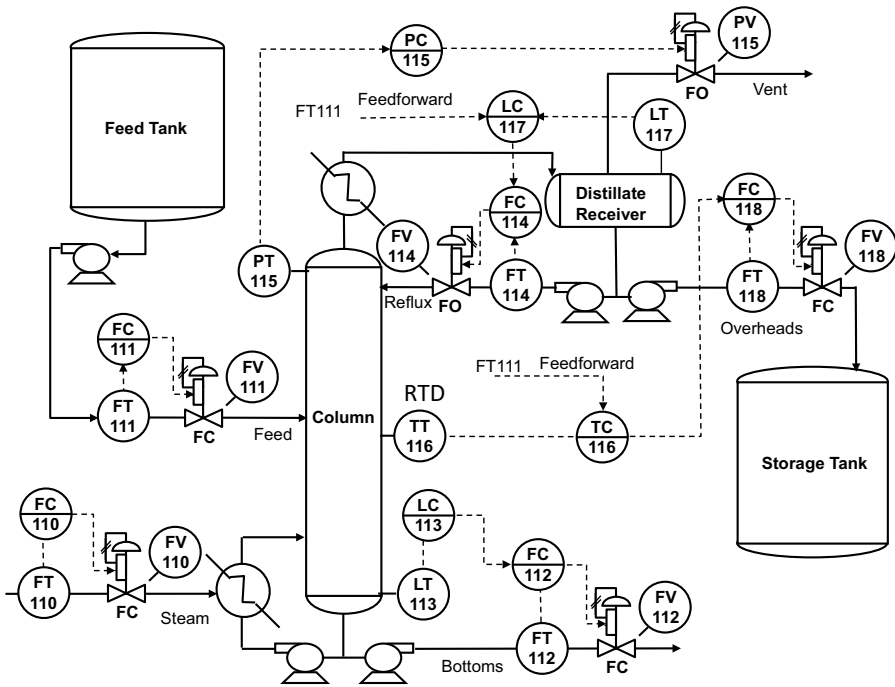


Figure 7-17. Basic Column Control System

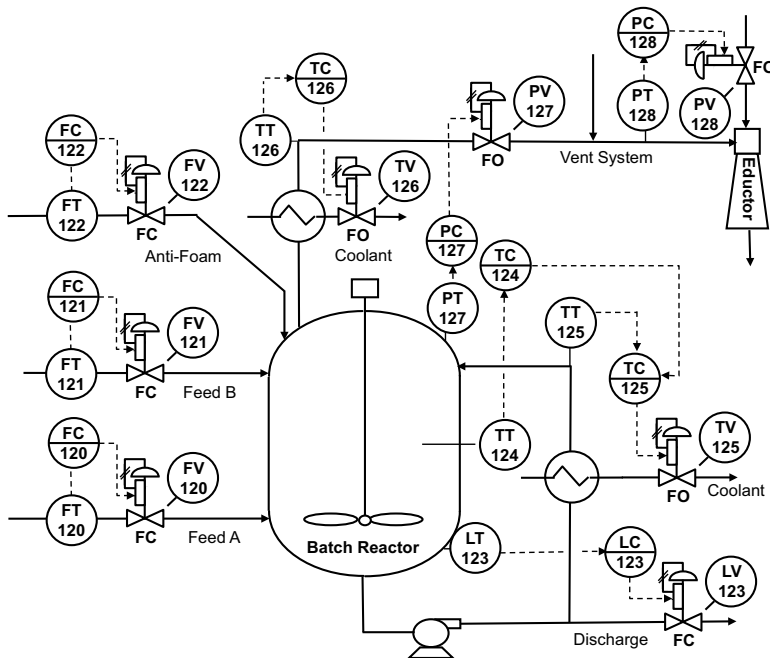


Figure 7-18. Example – Batch Reactor Control

### 7.8.4 Example – Continuous Feed and Recycle Tank

In studying the example of a continuous feed and recycle tank shown in Figure 7-19, you will note that the only new function that was not contained in a previous example is FFC133. The function letters of the tag number indicate that this new function is ratio control. The line connections indicate that the ratio control is implemented using two feed streams to Reactor 1.

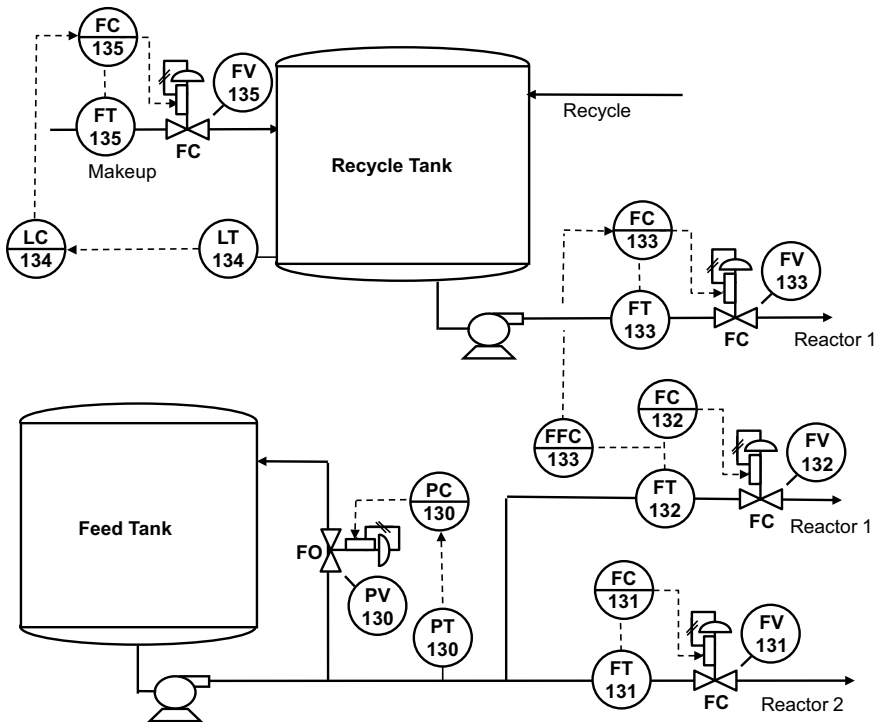


Figure 7-19. Example – Continuous Feed and Recycle Tank

Knowing the tag number and symbols on a P&ID is the first step in understanding which measurement and control functions have been installed on the process. As the examples shown in Figure 7-16 to 7-19 illustrate, a basic understanding of the control and process is possible if you are familiar with the tag number and symbols on the P&ID. Later chapters on control implementation will address how the control functions shown on the P&ID and loops sheet are implemented.

## References

1. The International Society of Automation (ISA). <http://www.isa.org>.
2. International Electrotechnical Commission (IEC). <http://www.iec.ch>.
3. OSHA Standard 29 CFR 1910.119, *Process safety management of highly hazardous chemicals*. <http://www.osha.gov>.
4. ISA-5.4-1991, *Instrument Loop Diagrams*, Research Triangle Park, NC: ISA (ISBN 1-55617-227-3).
5. Skousen, Philip. *Valve Handbook – Second Edition*, Chapter 1.5.1, McGraw-Hill Handbook (ISBN: 0071437738).
6. Lehtinen, Marjaana. More speed and accuracy for basis weight control, pp. 22–24, *Automation* 1, 2004.