Instrumentation & Process Control Fundamentals

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Goals

- Basic understanding of process control
- Important process control terminology
- Major components of a process loop
- Instrumentation P&ID symbols

Instrumentation Definition

The use of measuring instruments to monitor and control a process variables

+

Variables such as temperature, pressure, flow, level, speed

→

Instrumentation

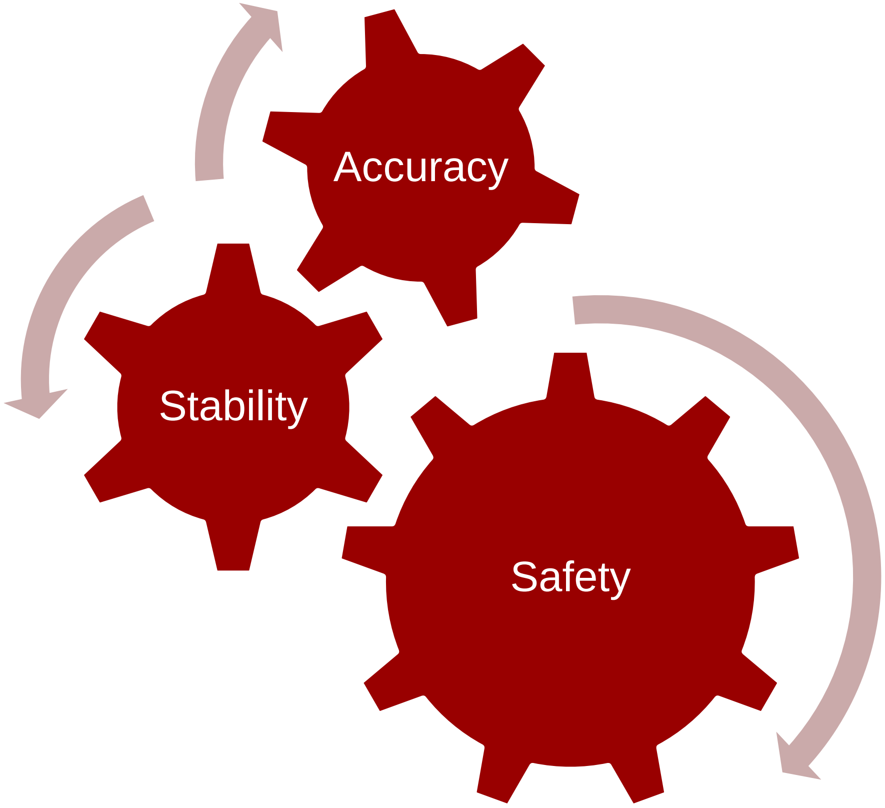
Process Control Definition

Engineering discipline that; deals with architecture and, algorithms for maintaining the output of a specific process with a desired range

Output such as temperature, pressure, flow, level, speed

Process Control

Why Process Control



Process Control Basics and Terminology

Control Loop

It is a cold winter night. You are sitting in front of a small fire but; you feel uncomfortable. You start to throw another log on the fire.

This is a simple example of a control loop where:

- Variable is the Temperature
- Set point is your comfort level
- Action bring the process back into desired condition by adding more fuel to the fire

In industry it works the same and it requires

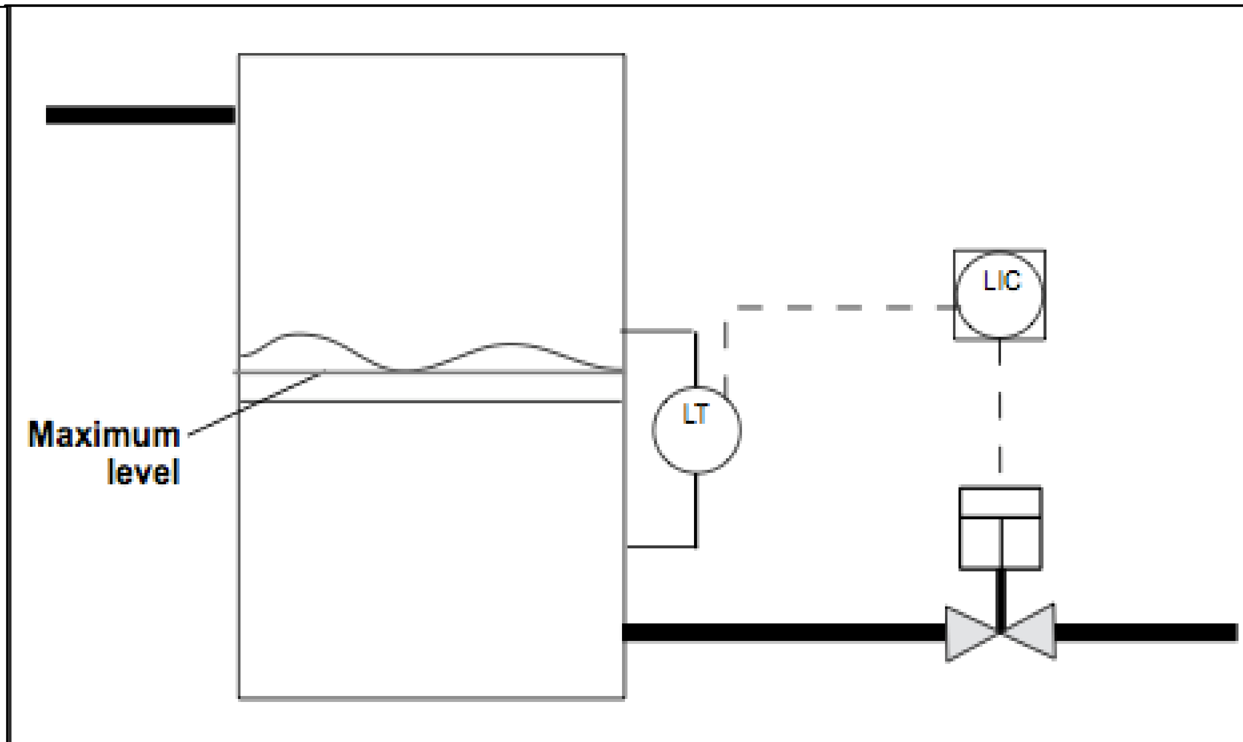
- Measurement
- Comparison
- Adjustment

Simple Control Loop

-In the Figure a level transmitter (LT) measures the level in the tank and transmits a signal associated with the level reading to a controller (LIC).

-The controller compares the reading to a predetermined value, The controller then sends a signal to the device that can bring the tank level back to a lower level

-The valve at the bottom of the tank opens to let some liquid out of the tank.



Process Variables

Is a condition of the process fluid that; can change the manufacturing process in some way.

Process variables such as:

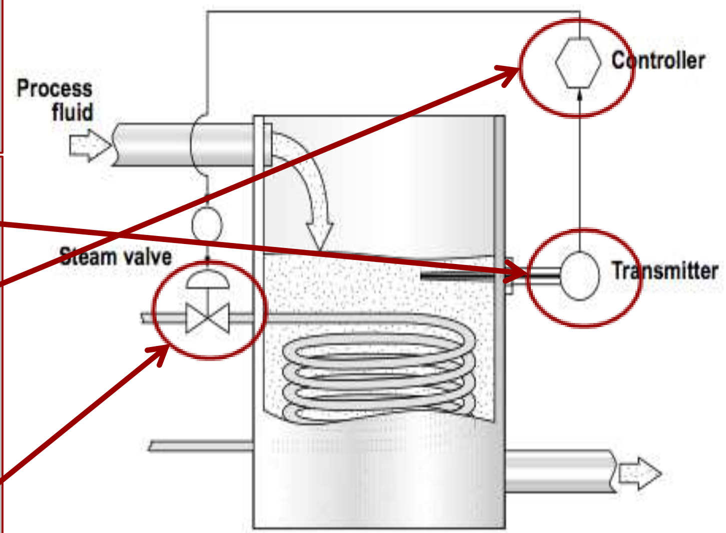
- Pressure
- Flow
- Level
- Temperature
- Density
- pH
- Mass
- Conductivity

Controller

Is a device that receives data from a measurement instrument, compares that data to a programmed set point, and, if necessary, signals a control element to take corrective action.

For example A process fluid tank is to be maintained at a constant temperature 100 °C . The tank is heated by a helical pipe through which steam flows through a control valve.

- A sensor to measure the process temperature
- A controller to compare the temperature reading from the sensor to the set point
- If temperature reaches 110 °C
- The controller determines that, process temperature is above the set point
- The controller signals the control valve to close slightly until process temperature cools to 100 °C



Process Control Basics and Terminology

Set point

Is the value for a process variable is desired to be maintained .

Also known as Reference Variable.

Process Control Basics and Terminology

Measured Variables, Process Variables, and Manipulated Variables

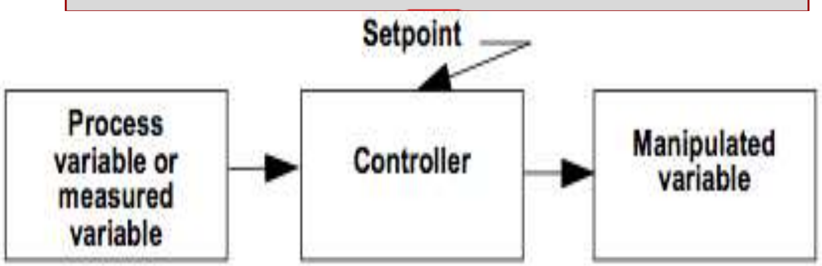
In the previous temperature loop example the measured variable is temperature which must be near to 100 ^oC

The measured variable is also process variable

Measured Variable

is the condition of the process fluid that must be kept at the designated set point.

If we measure the flow into and out of a storage tank to determine tank level



The measured variable (flow) is not process variable (level)

Manipulated Variable

The factor that is changed to keep the process variable at set point. (Flow in this example)

Process Control Basics and Terminology

Error

Is the difference between the measured variable and the set point and can be either positive or negative

Magnitude

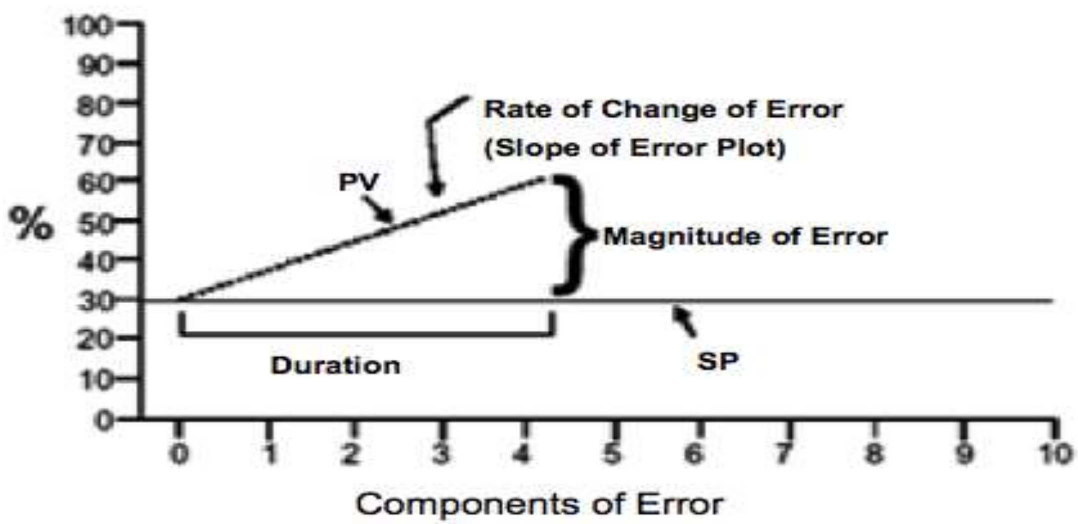
Is the deviation between the values of the set point and the process variable

Duration

Duration refers to the length of time that an error condition has existed.

Rate of Change

The rate of change is shown by the slope of the error plot.



Offset

Is a sustained deviation of the process variable from the set point.

Load Disturbance

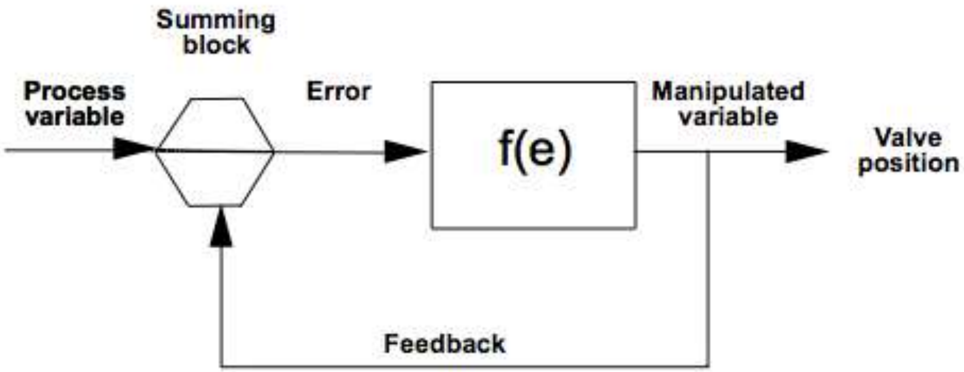
Is an undesired change in one of the factors that can affect the process variable.

Process Control Basics and Terminology

Control Algorithm

Is a mathematical expression of a control function.

Using the temperature control loop example, V in the equation below is the steam valve position, and e is the error. The relationship in a control algorithm can be expressed as:

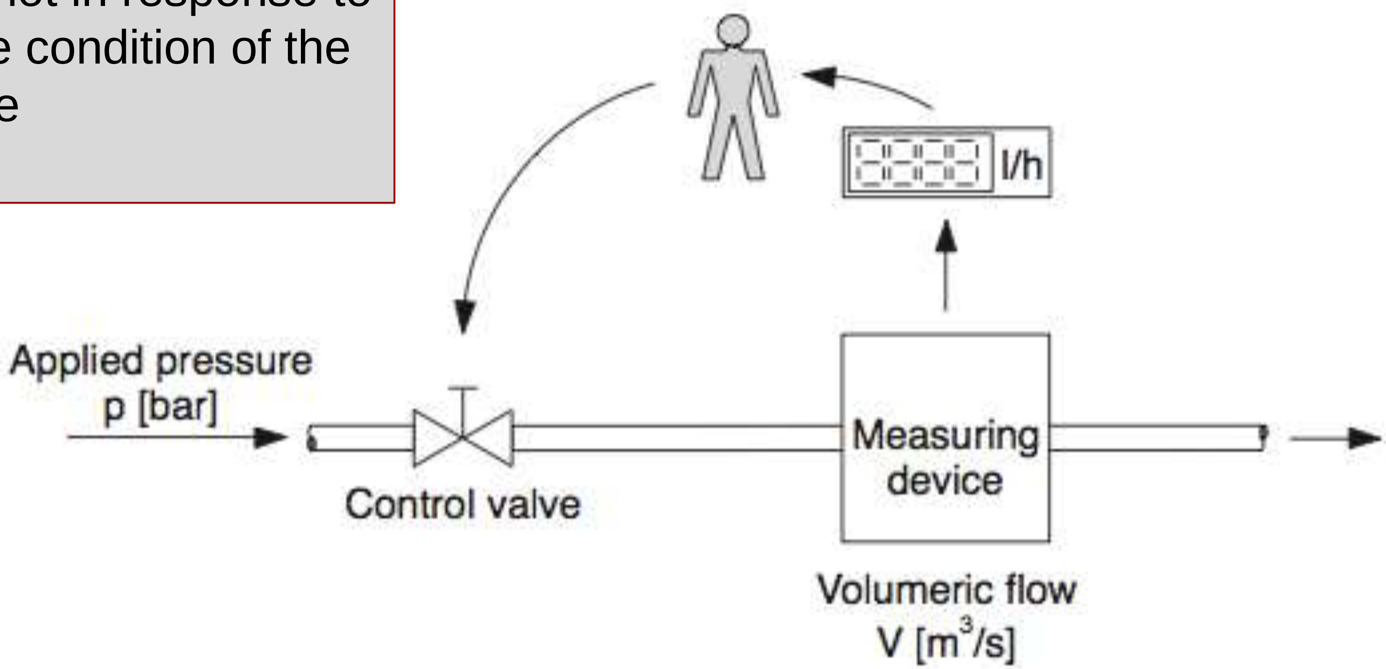


$V = f(\pm e)$

Process Control Basics and Terminology

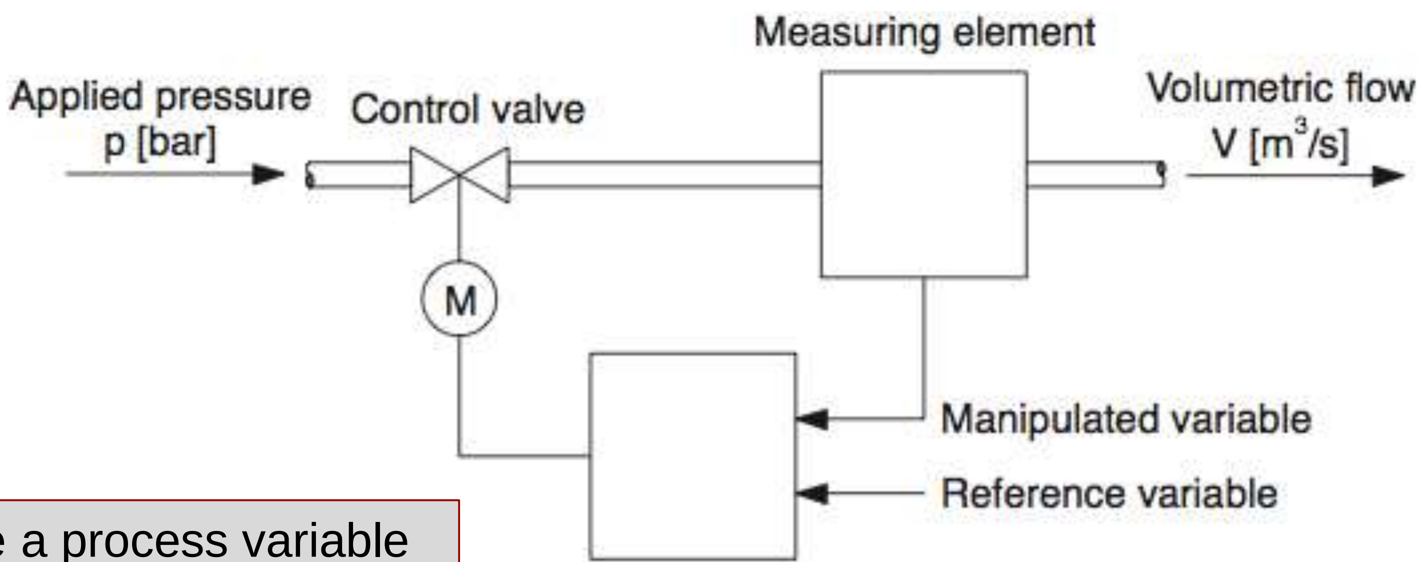
Open Control Loop

Exists where the process variable is not compared, and action is taken not in response to feedback on the condition of the process variable



Process Control Basics and Terminology

Closed Control Loop



Exists where a process variable is measured, compared to a set point, and action is taken to correct any deviation from set point.

Components of Control Loops

Components of Control Loops

Primary Elements (Sensors)

Devices that cause some change in their property with changes in process fluid conditions that can then be measured and, they are the first element in the control loop to measure the process variable

Examples of primary elements include:
-Pressure sensing diaphragms, strain gauges, capacitance cells
-Resistance temperature detectors (RTDs)
-Thermocouples
-Orifice plates
-Pitot tubes
-Venturi tubes
-Magnetic flow tubes
-Coriolis flow tubes
-Radar emitters and receivers
-Ultrasonic emitters and receivers
-Annular flow elements
-Vortex shedder

Components of Control Loops

Transducers

Device that translates a mechanical signal into an electrical signal.

Converters

Device that converts one type of signal into another type of signal.

Transmitters

device that converts a reading from a sensor or transducer into a standard signal and transmits that signal to a monitor or controller.

Transmitter types include:
-Pressure transmitters
-Flow transmitters
-Temperature transmitters
-Level transmitters
-Analytic (O_2 [oxygen], CO [carbon monoxide], and pH) transmitters

Components of Control Loops

Signals

Divided Into Three Types

Pneumatic Signals

Are signals produced by changing the air pressure in a signal pipe in proportion to the measured change in a process variable.
The common industry standard pneumatic signal range is

- 3 psig -------- Corresponds to Lower Range Value (LRV)

- 15 psig -------- Corresponds to Higher Range Value (HRV)

Analog Signals

The most common standard electrical signal is the 4–20 mA current signal.

- 4 mA-------- Represents lowest possible measurement, or zero.

- 20 mA-------- Represents highest possible measurement.

Digital Signals

Are discrete levels or values that are combined in specific ways to represent process variables and also carry other information,

Components of Control Loops

Indicators

Is a human-readable device that displays information about the process like pressure gauge.

Records

Is a device that records the output of a measurement devices.

Components of Control Loops

Controllers

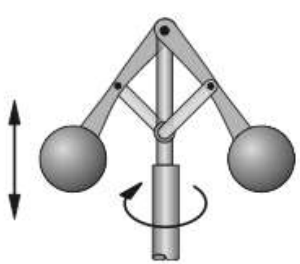
Process variable controller divided Into Two Types

Continuous Action Controller

The manipulated variable of the continuous action controller changes continuously dependent on the system deviation

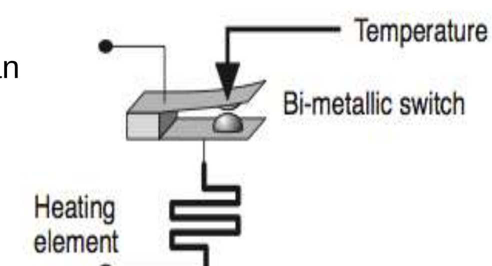
Non Continuous Action Controller

The manipulated variable of a non-continuous-action controller can only be changed in set steps.



Centrifugal Governor

Thermostat of an iron



Components of Control Loops

Controller

Controllers always have an ability to receive input, to perform a mathematical function with the input, and to produce an output signal.

Programmable logic controllers (PLCs)

Are usually computers connected to a set of input/output (I/O) devices. The computers are programmed to respond to inputs by sending outputs to maintain all processes at set point.

Distributed control systems (DCSs)

Are controllers that, in addition to performing control functions, provide readings of the status of the process, maintain databases and advanced man-machine-interface.

Components of Control Loops

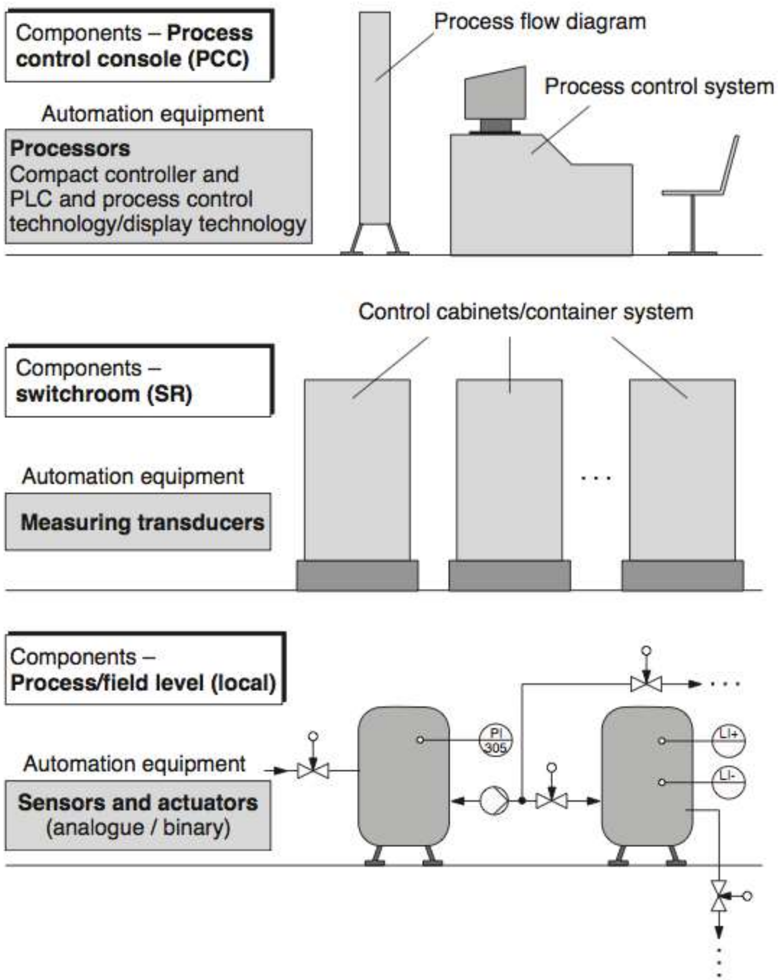
Correcting Elements (Final Control Elements)

Is the part of the control system that acts to physically change the manipulated variable. In most cases, the final control element is a valve used to restrict or cut off fluid flow.

ACTUATORS

Is the part of a final control device that causes a physical change in the final control device when signaled to do so. The most common example of an actuator is a valve actuator

Components of Control Loops

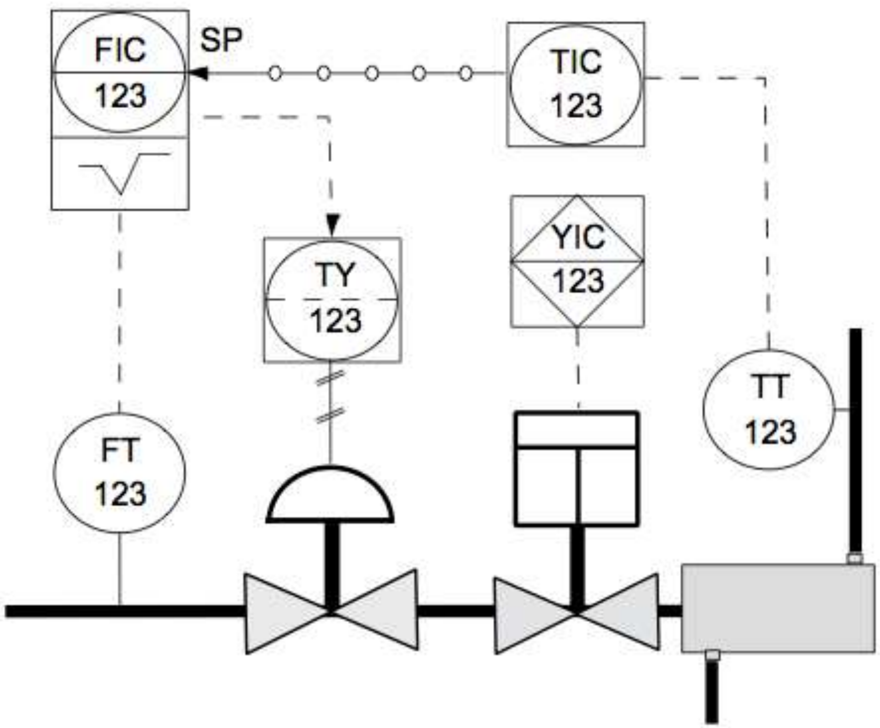


Instrumentation, Systems, and Automation

(ISA) Symbols

Instrumentation, Systems, and Automation

(ISA) Symbols



The figure shows a control loop using ISA symbology. Drawings of this kind are known as *piping and instrumentation drawings* (P&ID).

Instrumentation, Systems, and Automation
(ISA) Symbols

Signal Lines

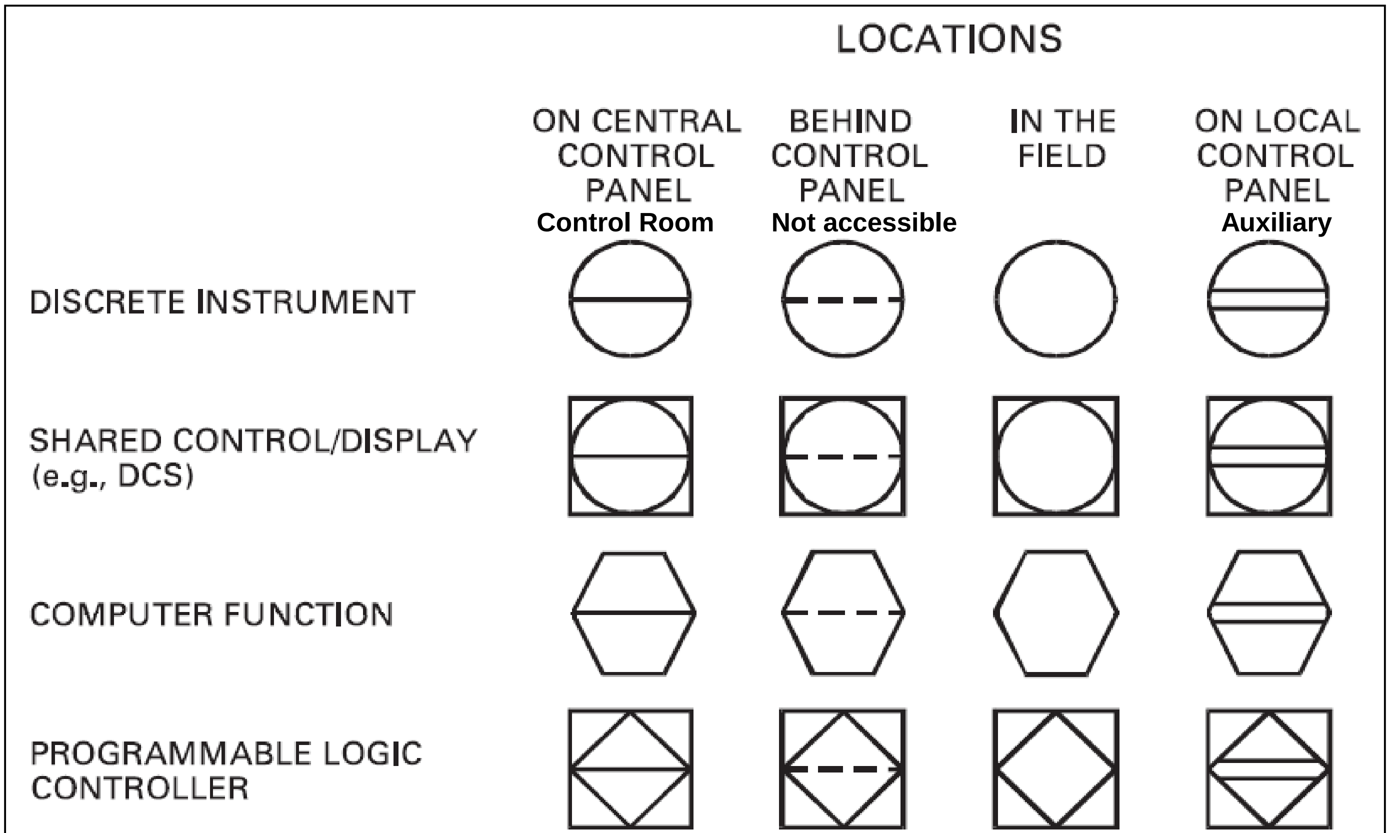
	PROCESS CONNECTION OR INSTRUMENT SUPPLY PIPE
	UNDEFINED SIGNAL
	PNEUMATIC SIGNAL
	ON-OFF PNEUMATIC BINARY SIGNAL
	ELECTRIC SIGNAL
	ELECTRIC BINARY SIGNAL
	HYDRAULIC SIGNAL

	CAPILLARY TUBE
	ELECTROMAGNETIC OR SONIC SIGNAL (NOT GUIDE)
	INTERNAL SYSTEM LINE (SOFTWARE OR DATA LINK)
	MECHANICAL LINK
	SIGNAL TO SUPERVISORY CONTROL SYSTEM
	SIGNAL AND COMMAND FROM SUPERVISORY CONTROL SYSTEM

Instrumentation, Systems, and Automation

(ISA) Symbols

Function

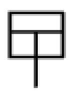
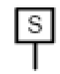
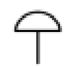


Instrumentation, Systems, and Automation

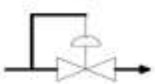
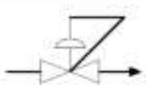
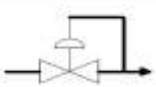
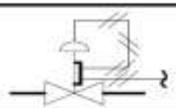
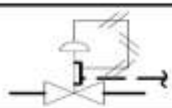
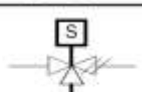
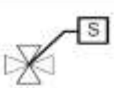
(ISA) Symbols

Control Valves

Actuator Symbols

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	CYLINDER		SOLENOID
	ROTARY MOTOR EL. TYPE		DIAPHRAGM
	HAND		

Self Actuated Regulators

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	BACK PRESSURE REGULATOR SELF CONTAINED		BACK PRESSURE REGULATOR WITH EXTERNAL PRESSURE TAP
	PRESSURE REDUCING REGULATOR SELF CONTAINED		PRESSURE REDUCING REGULATOR WITH EXTERNAL PRESSURE TAP
	CONTROL VALVE WITH PNEUMATIC POSITIONER		CONTROL VALVE WITH ELECTROPNEUMATIC POSITIONER
	3 WAY SOLENOID VALVE (ARROW SHOWS AIR FLOW ON DE-ENERGISATION)		4 WAY SOLENOID VALVE

Instrumentation, Systems, and Automation

(ISA) Symbols

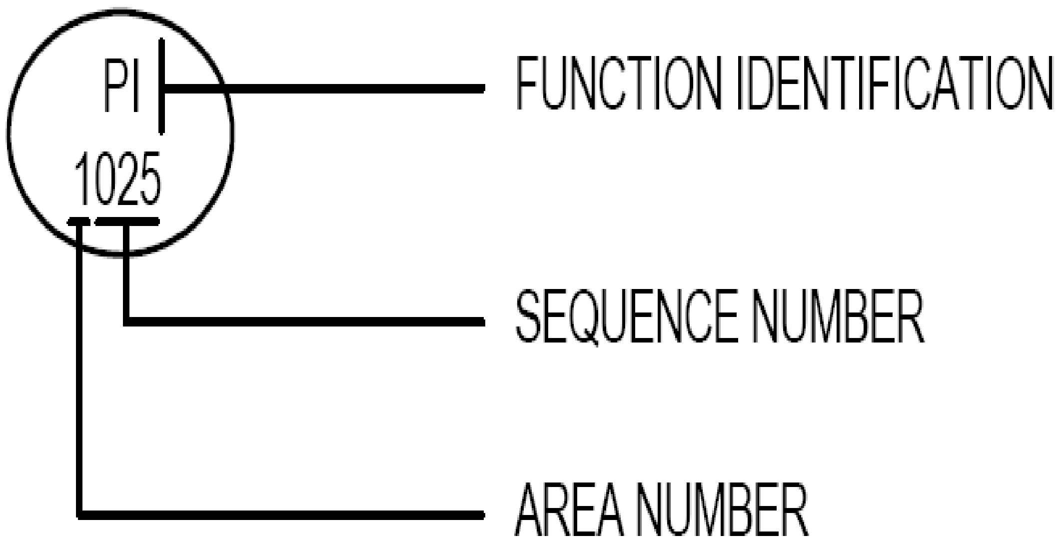
Control Valves

- Status of valves (default position) is shown below the valve symbol:
  - NO = Normally Open
  - NC = Normally Closed
  - LO = Locked Open
  - LC = Locked Closed

- Status of valves (fail position) is shown below the valve symbol:
  - FO = Fail Open
  - FC = Fail Closed
  - FL = Fail Last or Locked
  - FI = Fail Indeterminate

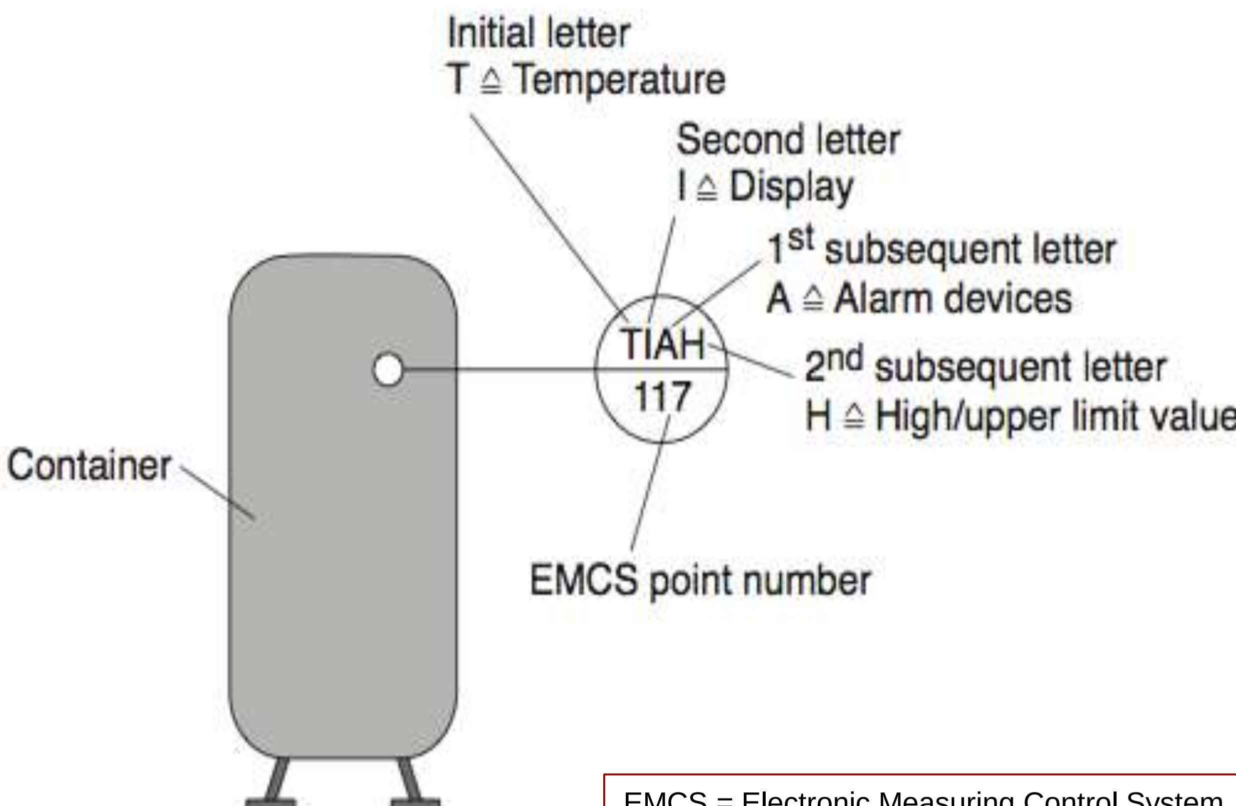
Instrumentation, Systems, and Automation (ISA) Symbols

Tag Number



Instrumentation, Systems, and Automation (ISA) Symbols

Tag Number



EMCS = Electronic Measuring Control System

Instrumentation & Process Control Fundamentals Summary

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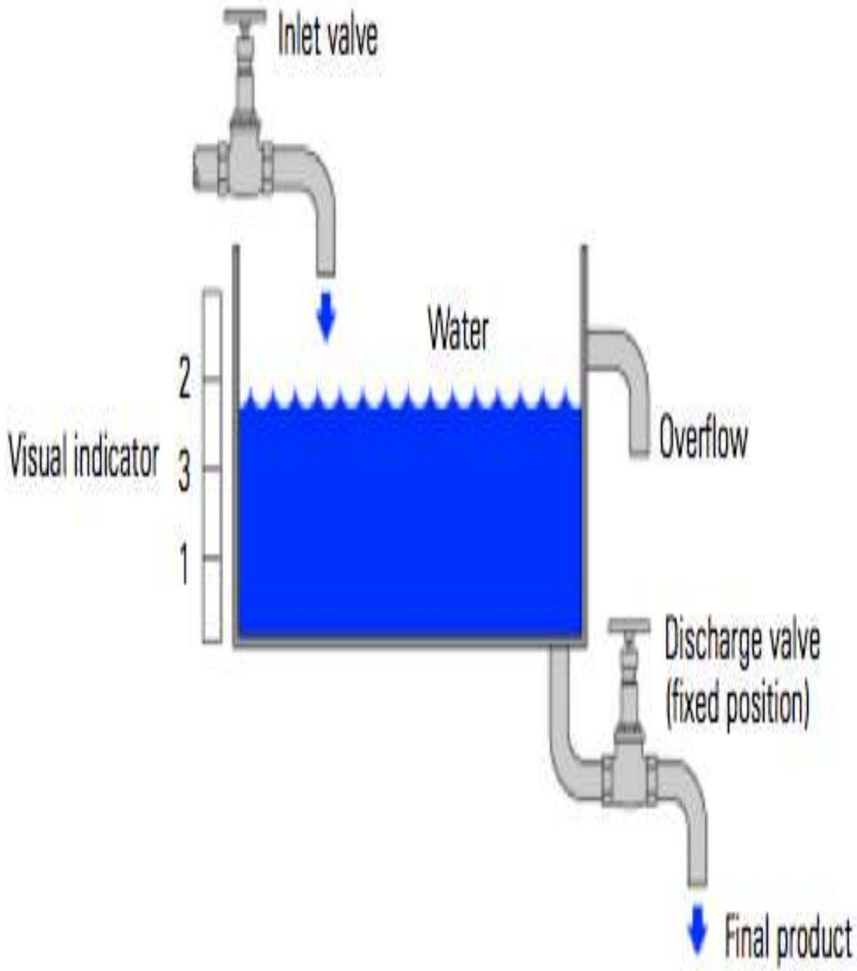
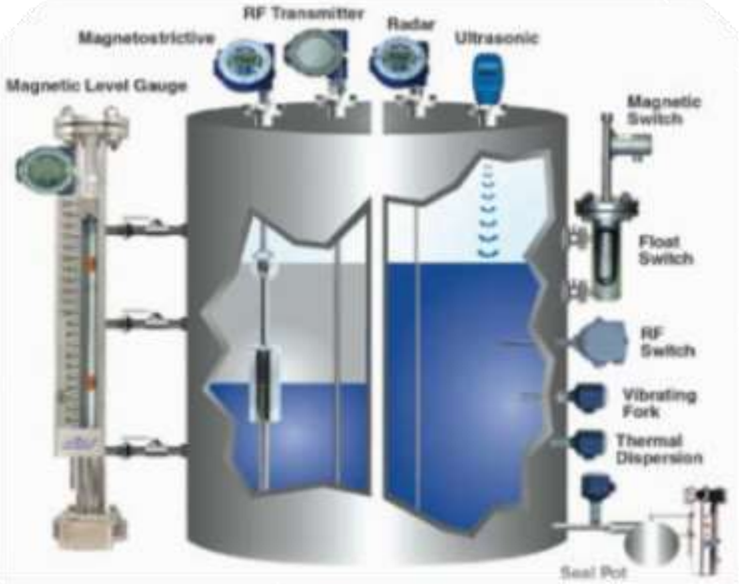


In the process example shown (Figure5.1.1), the operator manually varies the flow of water by opening or closing an inlet valve to ensure that:
-The water level is not too high; or it will run to waste via the overflow.
- The water level is not too low; or it will not cover the bottom of the tank.
The outcome of this is that the water runs out of the tank at a rate within a required range. If the water runs out at too high or too low a rate, the process it is feeding cannot operate properly.
At an initial stage, the outlet valve in the discharge pipe is fixed at a certain position.
The operator has marked three lines on the side of the tank to enable him to manipulate the water supply via the inlet valve. The 3 levels represent:
1. The lowest allowable water level to ensure the bottom of the tank is covered.
2. The highest allowable water level to ensure there is no discharge through the overflow.
3. The ideal level between 1 and 2.

Instrumentation & Process Control Fundamentals Summary

1. The operator is aiming to maintain the water in the vessel between levels 1 and 2. The water level is called the **Controlled condition**.
2. The controlled condition is achieved by controlling the flow of water through the valve in the inlet pipe. The flow is known as the **Manipulated Variable**, and the valve is referred to as the **Controlled Device.**
3. The water itself is known as the **Control Agent**.
4. By controlling the flow of water into the tank, the level of water in the tank is altered. The change in water level is known as the **Controlled Variable**.
5. Once the water is in the tank it is known as the **Controlled Medium**.
6. The level of water trying to be maintained on the visual indicator is known as the **Set Point**.
7. The water level can be maintained at any point between 1 and 2 on the visual indicator and still meet the control parameters such that the bottom of the tank is covered and there is no overflow. Any value within this range is known as the **Desired Value**.
8. Assume the level is strictly maintained at any point between 1 and 2. This is the water level at steady state conditions, referred to as the **Control Value or Actual Value**.
Note: With reference to (7) and (8) above, the ideal level of water to be maintained was at point 3. But if the actual level is at any point between 1 and 2, then that is still satisfactory. The difference between the Set Point and the Actual Value is known as **Deviation**.
9. If the inlet valve is closed to a new position, the water level will drop and the deviation will change. A sustained deviation is known as **Offset**.

Instrumentation & Process Control Fundamentals



The End of The Session

QUESTIONS??