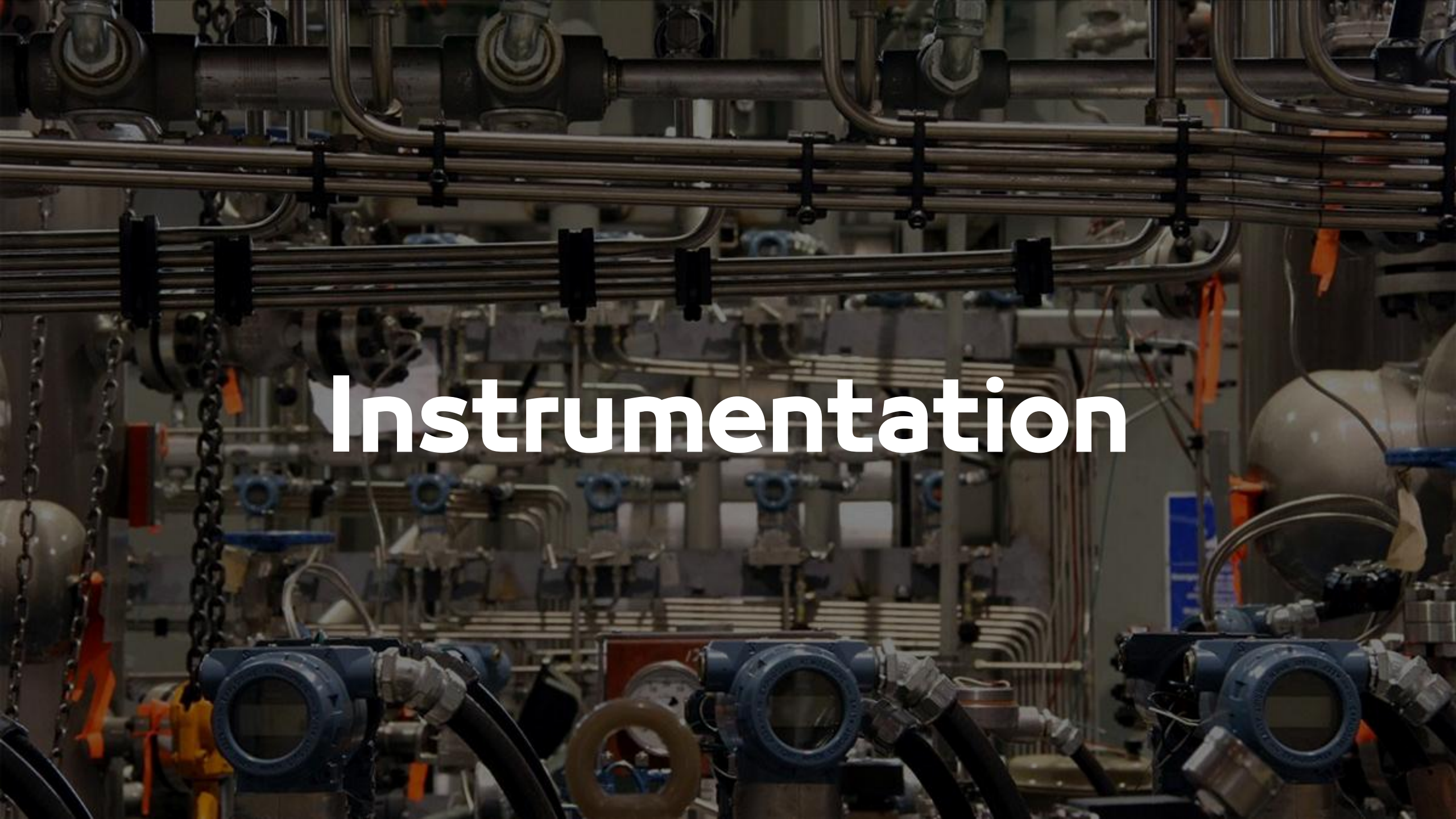
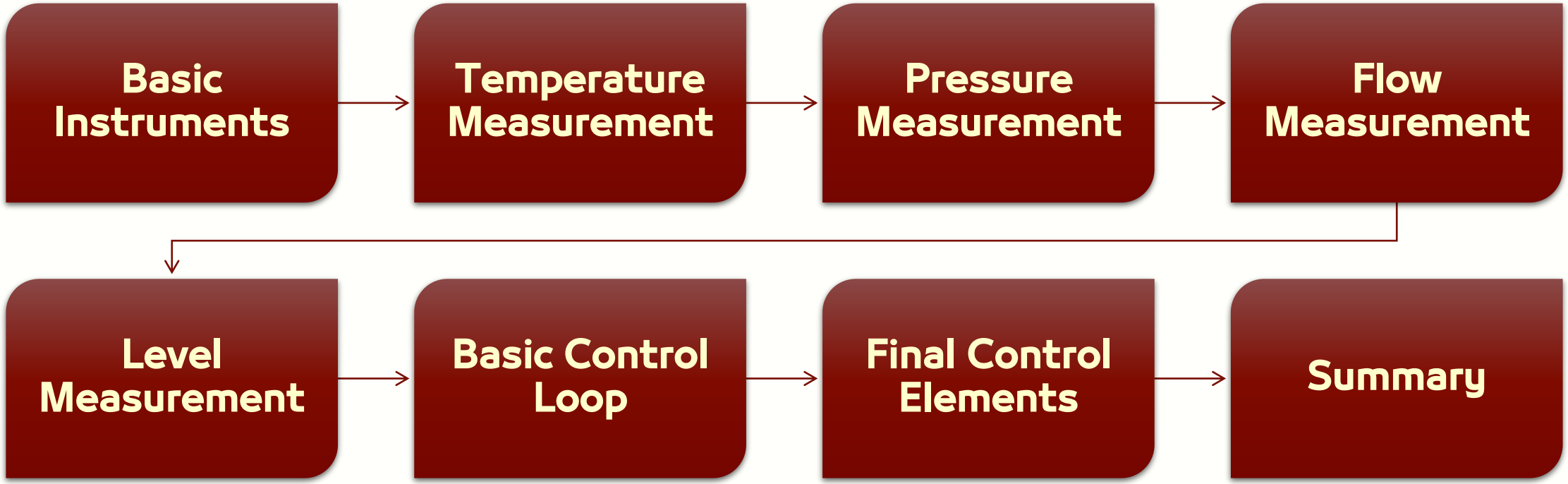
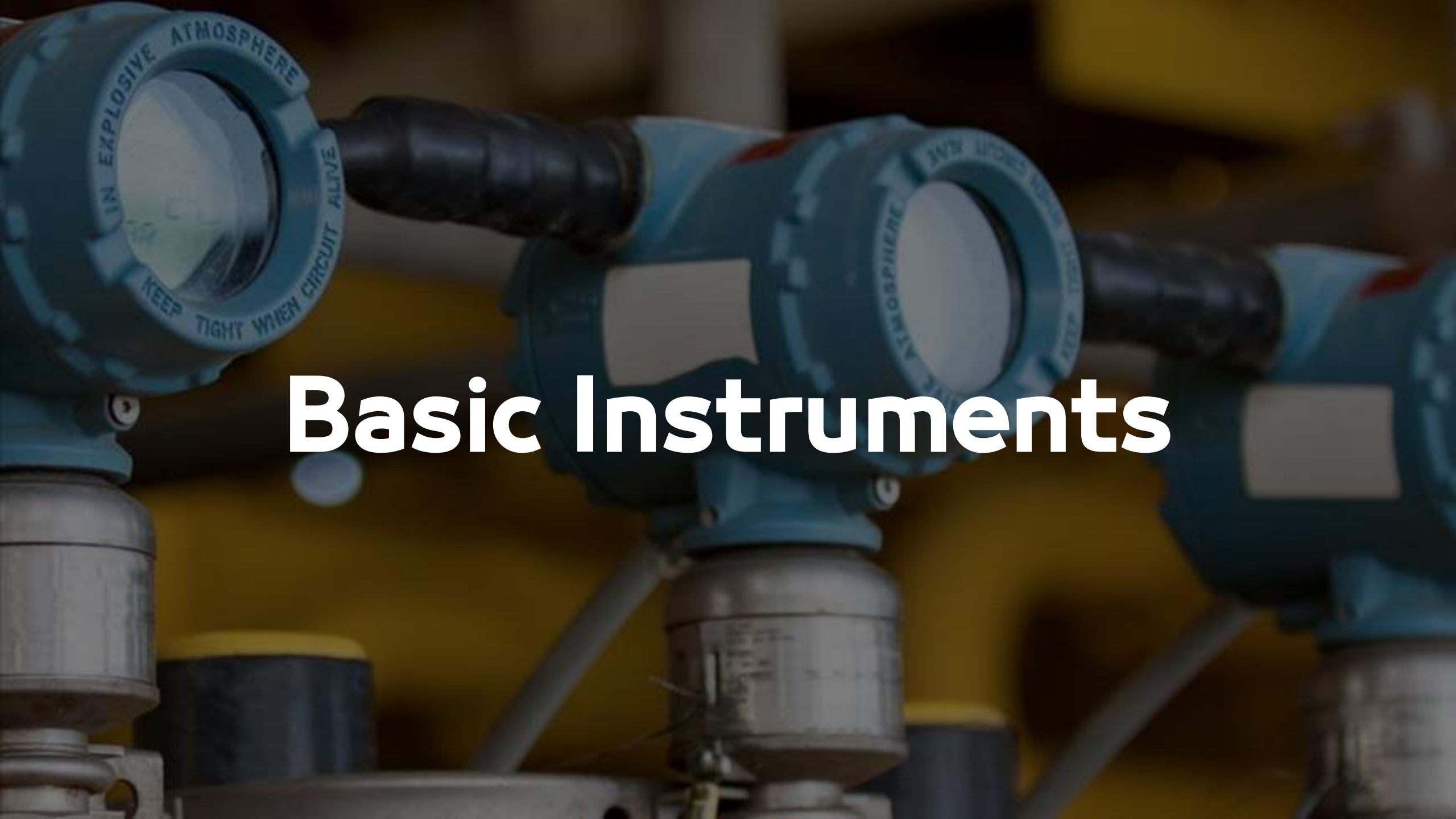

Instrumentation

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Basic Instruments

Basic Instruments



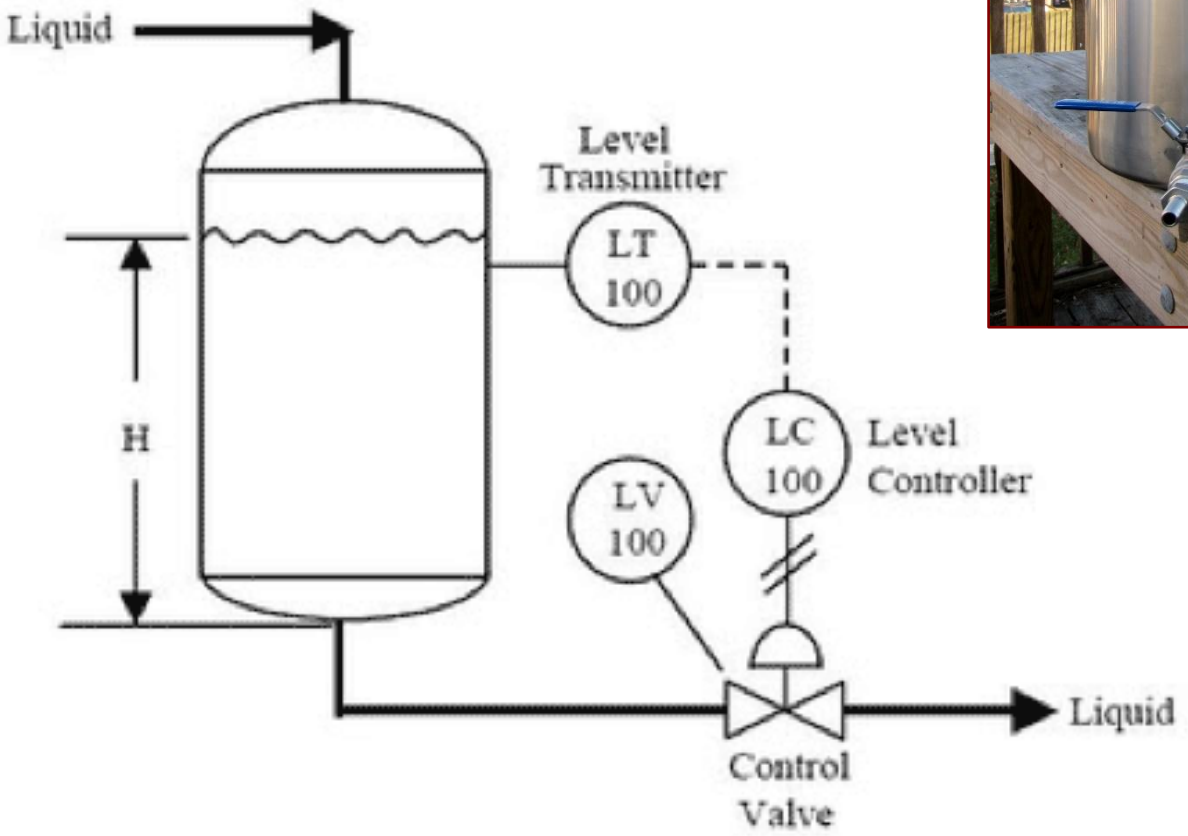
Automatic Control:

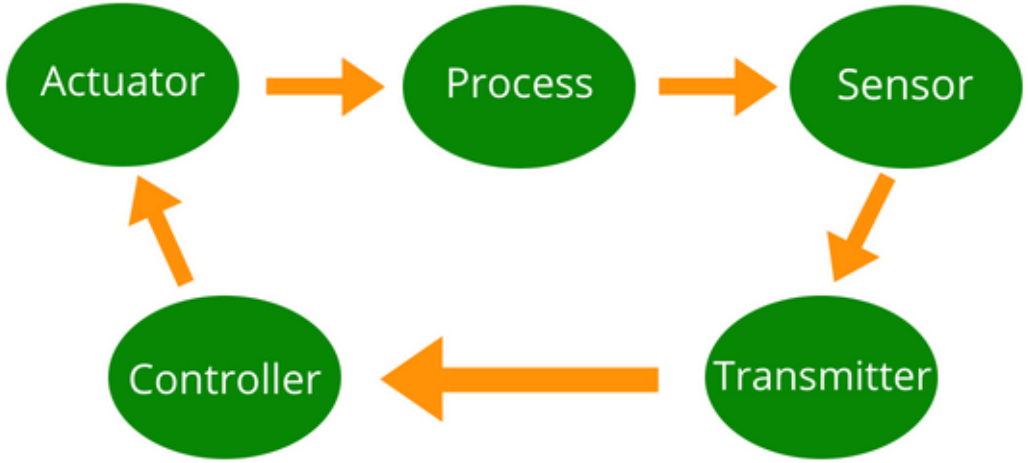
- Foundation for efficient continuous flow processes.
- **Manual Control:**
  - Historically, processes were controlled manually.
  - "Valve intensive" process required technicians to open and close valves manually.
- **Modern Instrumentation:**
  - Advances enable automation of industrial processes.
  - Instruments and computers can:
    - Control opening, closing, and positioning of valves.
    - Start and stop equipment.
    - Measure process variables.
    - Respond automatically.
- **Benefits:**
  - Allows a single process technician to monitor and control large, complex process networks from a single control center.

Control Loop





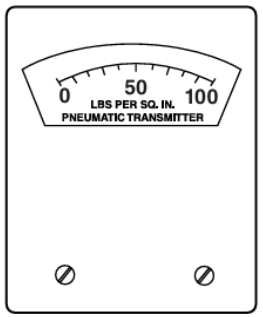




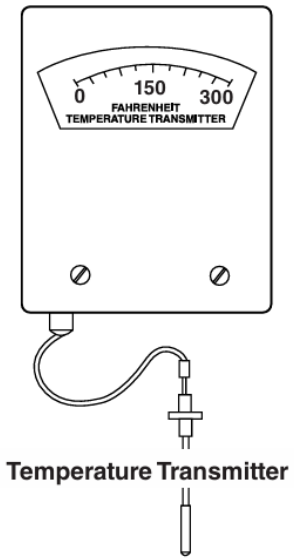
Basic Process Instrumentation

Components:

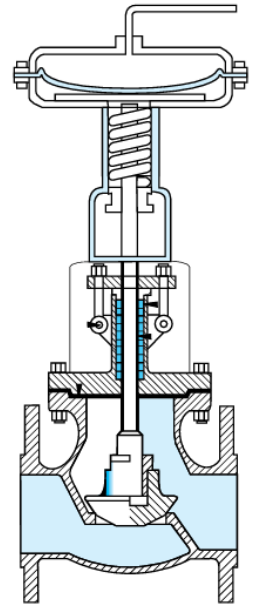
- Primary elements and sensors
- Gauges
- Transmitters
- Controllers
- Computers
- Transducers
- Control valves
- Other final control elements



Pressure Transmitter

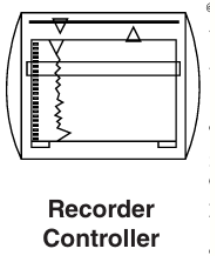


Temperature Transmitter

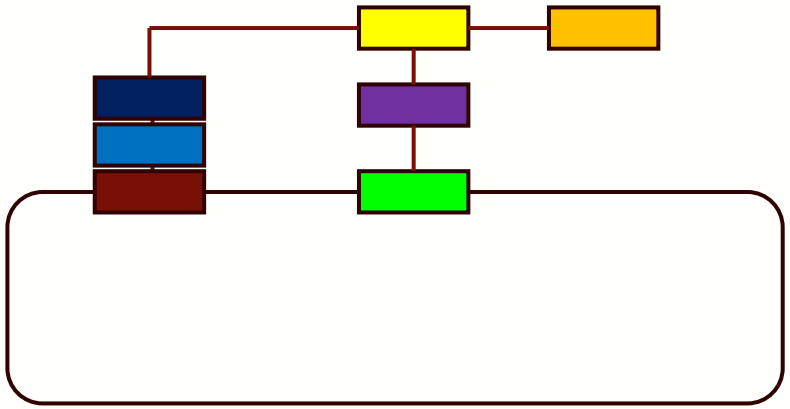

Control Valve



Gauge


Recorder
Controller

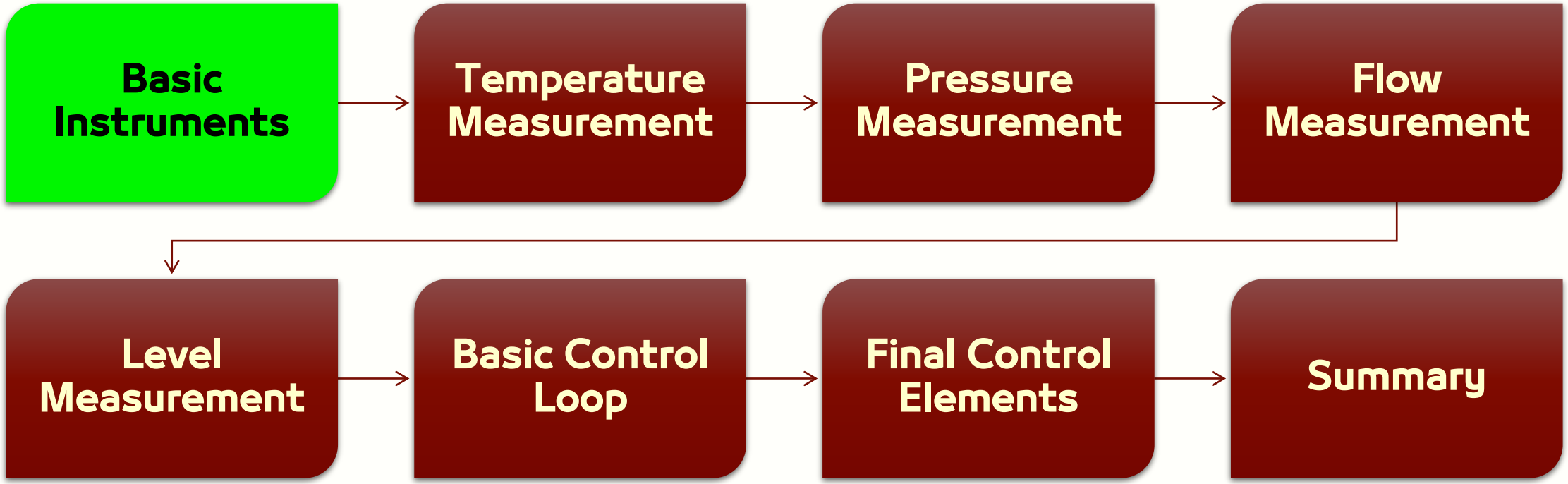
Basic Process Instrumentation

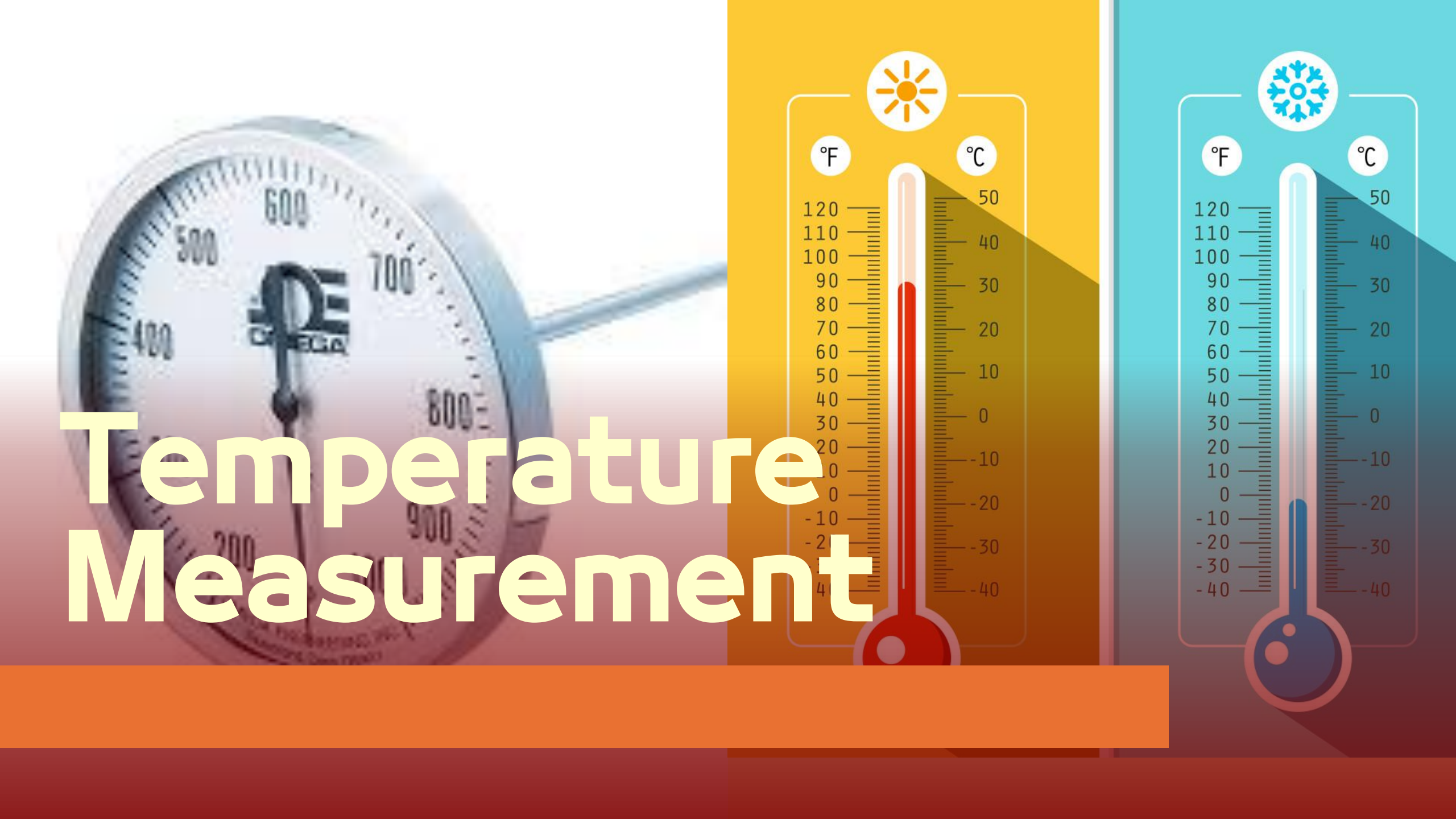


- Computer
- Controller
- Transmitter
- Guage
- Sensor or Element
- Transducer
- Control Valve & Final Control Element

- Primary elements and sensors
- Gauges
- Transmitters
- Controllers
- Computers
- Transducers
- Control valves
- Other final control elements

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Temperature Measurement
°F
°C
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
50
40
30
20
10
0
-10
-20
-30
-40

Temperature Measurement

Monitoring Temperature in Process Streams

- Process technicians closely monitor the temperatures of process streams.
- When heat energy is applied:
  - Molecular activity increases.
  - Energy is transferred from molecule to molecule.
  - Pressure and temperature increase in an enclosed environment.
  - Materials expand.
  - Density changes.

Temperature Definition and Scales

- Temperature: Degree of hotness or coldness of an object or environment.
- Commonly used scales:
  - **Fahrenheit:**
    - 32°F: Freezing point of water.
    - 212°F: Boiling point of water.
  - **Celsius:**
    - 0°C: Freezing point of water.
    - 100°C: Boiling point of water.
- Process operators use Fahrenheit and Celsius thermometers to measure temperature.

Temperature Measurement

Local Temperature Indicators

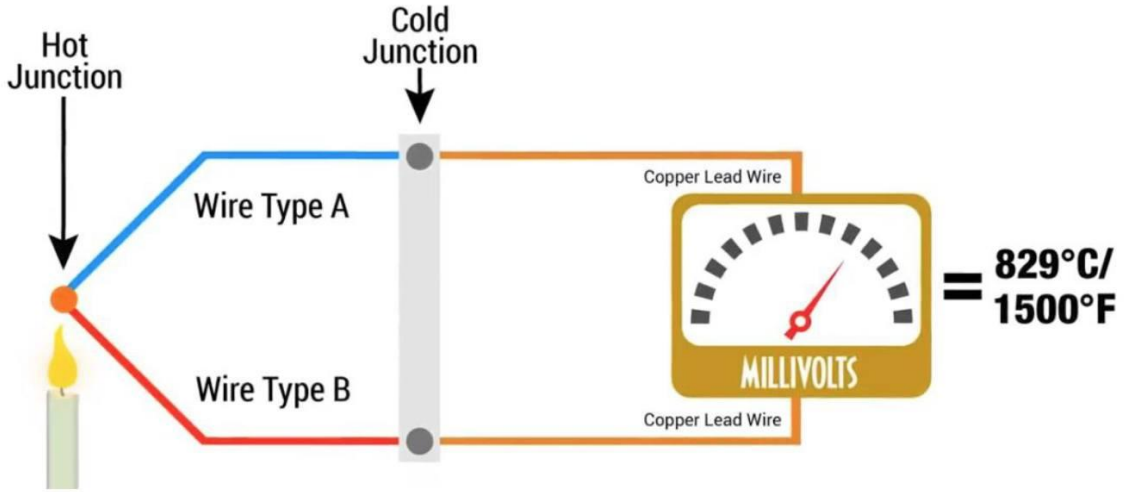
- Typically contain a bimetallic strip that expands differentially with increasing temperature.
- This expansion causes a deflection correlated with temperature.
- Bimetallic thermometers (thermocouples) range from –300° to 800°F.

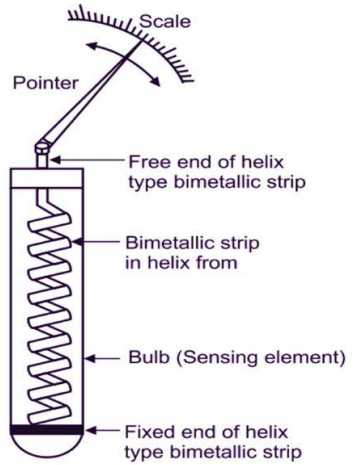
Types of Thermometers

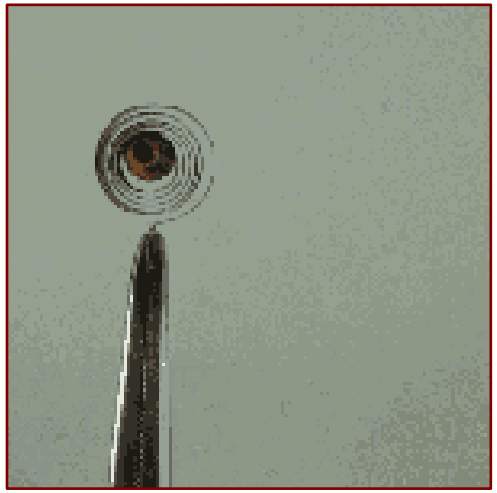
- Some thermometers have a primary element or sensor that includes:
  - A filled thermal bulb and capillary tubing.
  - Resistance bulb.
  - Thermocouple.

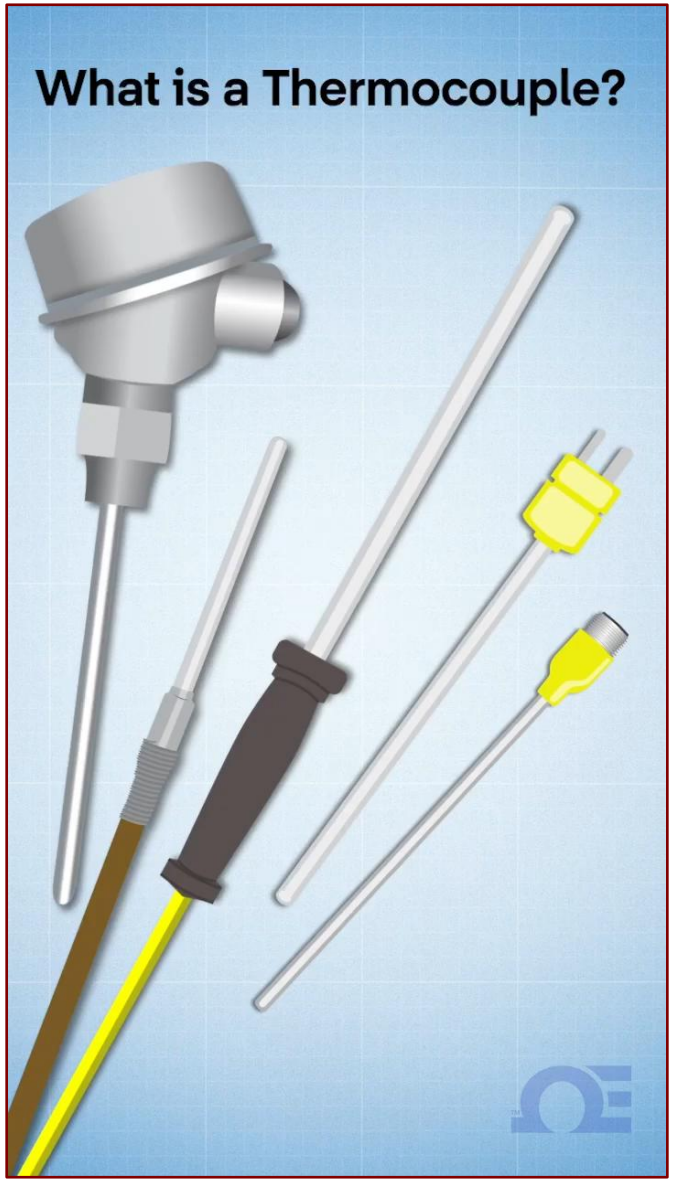
Industrial Use

- Mercury is not used in thermal bulbs or capillary tubing in the industry.
- The most common temperature-measuring devices in the chemical processing industry are thermoelectric.








What is a Thermocouple?

ATO.com | Thermocouple

Thermodynamics

Bimetallic Strip Thermometer

10
15
20
25
30
35
40
45
50
60
70
80
90
100
110
120



مبين الحرارة مزدوج المعدن



Bi-metallic Temperature Gauge

دورة الأجهزة الدقيقة
إعداد/عصام حكم

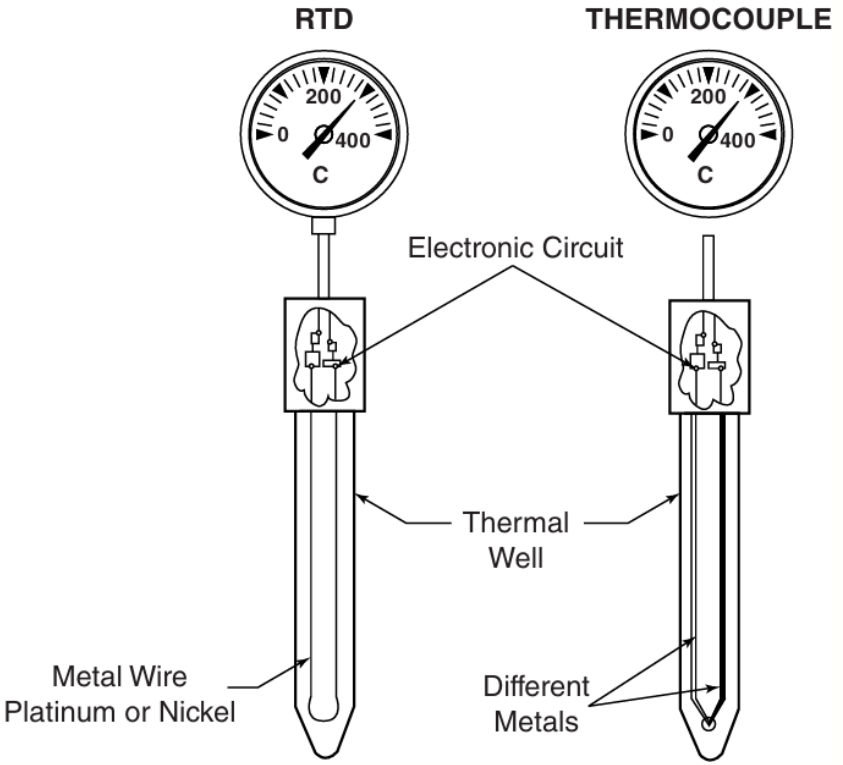
Thermoelectric Temperature-Measuring Devices

Thermoelectric Temperature-Measuring Devices

- **Types:**
  - Resistance Temperature Detectors (RTDs)
  - Thermocouples
- **Common Characteristics:**
  - Both are held in a thermowell, a chamber installed in vessels or piping.

Resistance Temperature Detectors (RTDs)

- Composed of a small platinum or nickel wire encased in a rugged metal tube.
- The electrical resistance in the wire is influenced by changes in temperature.
- Temperature changes are sensed by an electronic circuit and directed to a temperature indicator.

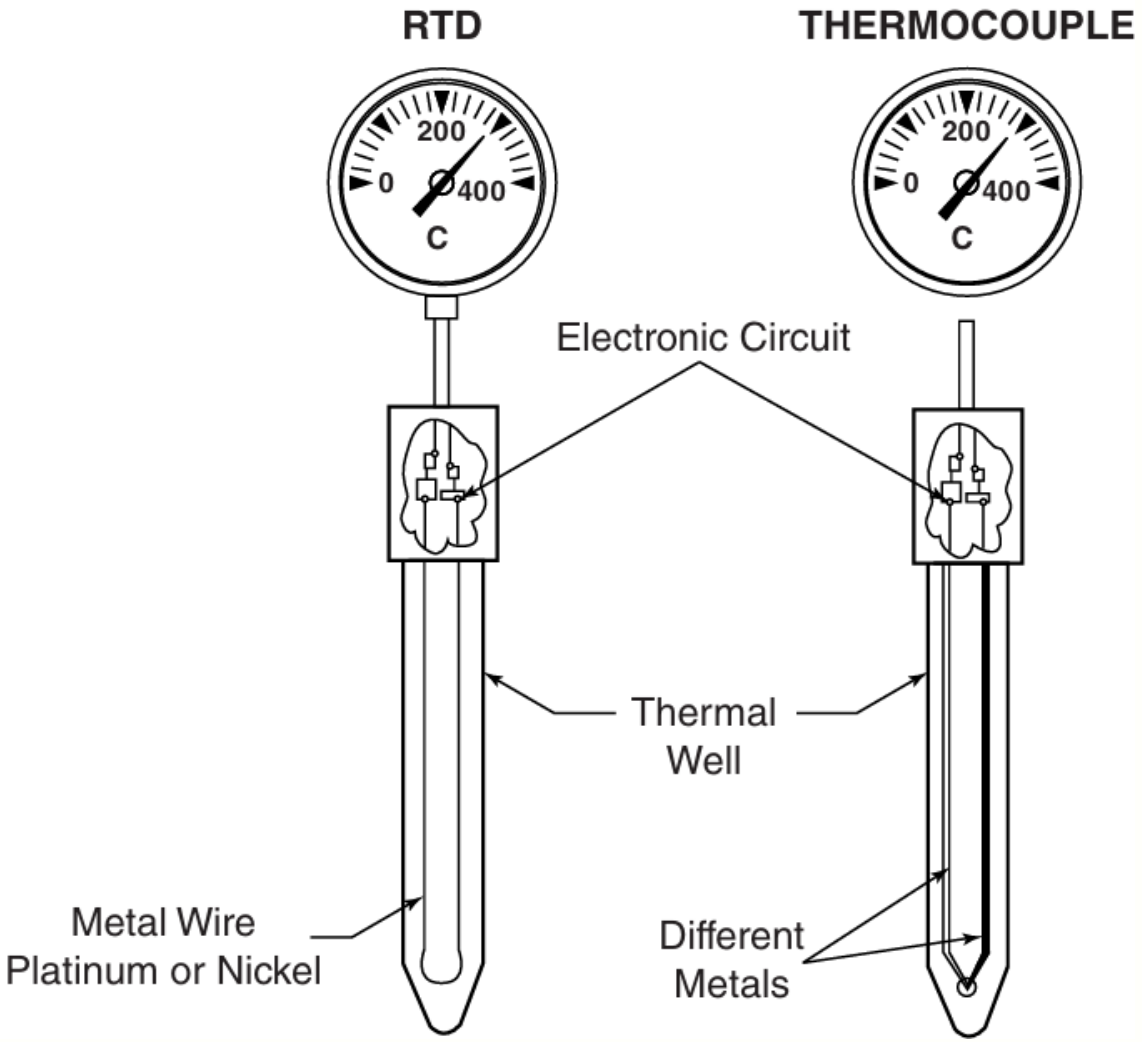




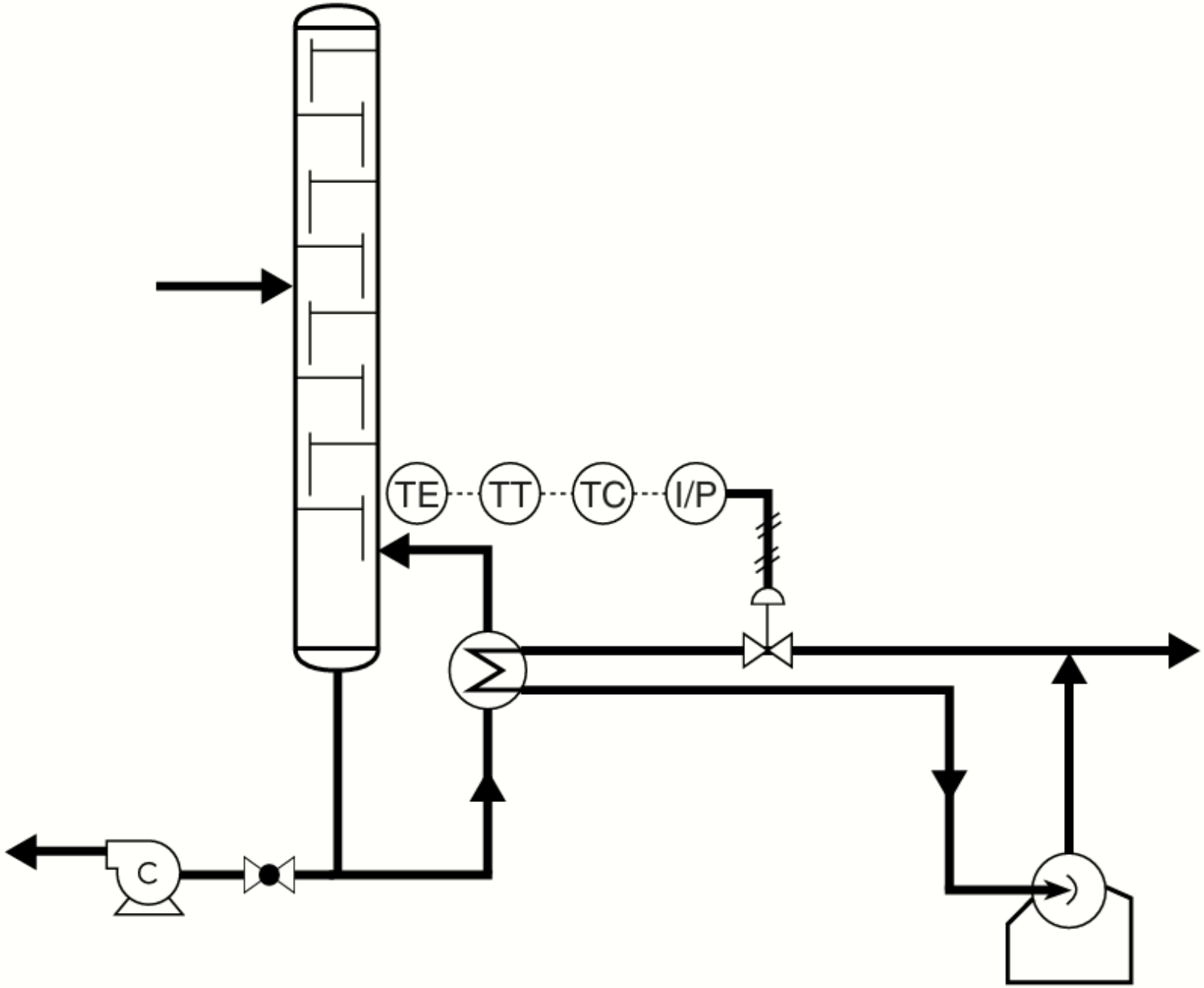
Thermocouples

Thermocouples

- Composed of two different types of metal.
- Designed to convert heat into electricity.
- When heat is applied to the connected ends, a low-level current is generated.
  - The higher the temperature, the greater the current generated.
- Electric current is detected by the associated electronic circuit and converted to a corresponding temperature scale.
- Types:
  - **J-type**
  - **K-type**
    - Preferred for higher temperature measurements.



Temperature Control Loop



Temperature Control Loop

Temperature Control Loop

- **Measurement**
  - Taken at the furnace or from the exiting charge in large fired heaters.
  - Primary sensors: Thermocouples or RTDs (temperature elements).
- **Components**
  - **Temperature Elements**
    - Linked to transmitters.
    - Transmitters sense a process variable and produce a signal for a controller, recorder, or indicator.
  - **Signal**
    - A 4- to 20-mA (milliamp) signal is sent to a controller.
    - The controller compares the signal with a set point (desired value of a process variable).
  - **Controllers**
    - Designed to initiate a change to return a process to its set point if a variance exists.
    - May be located in the field near the equipment or in a remote location.
  - **Transducer**
    - Located near the valve to eliminate process lag.
    - Converts the electric signal to a pneumatic signal of 3 to 15 psi.
  - **Control Valve**
    - Opens and closes depending on the signal received.
    - Controls temperature by reducing or increasing fuel flow to the burners.

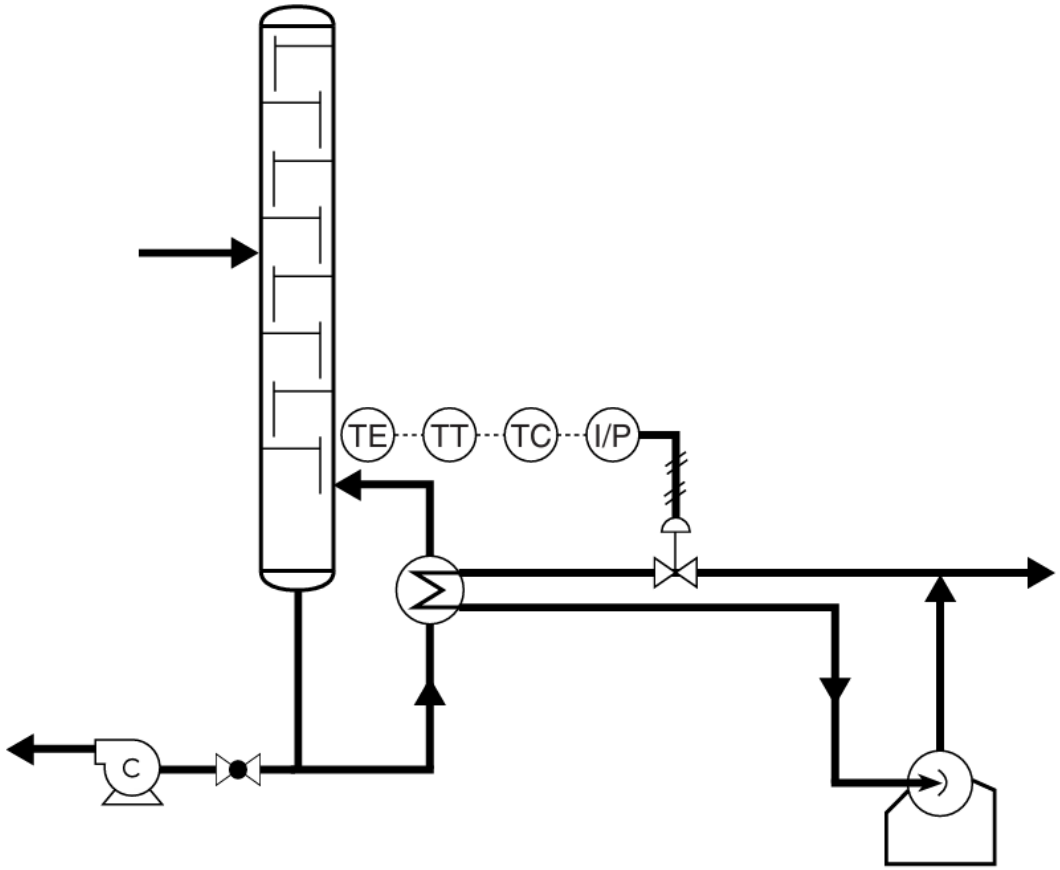
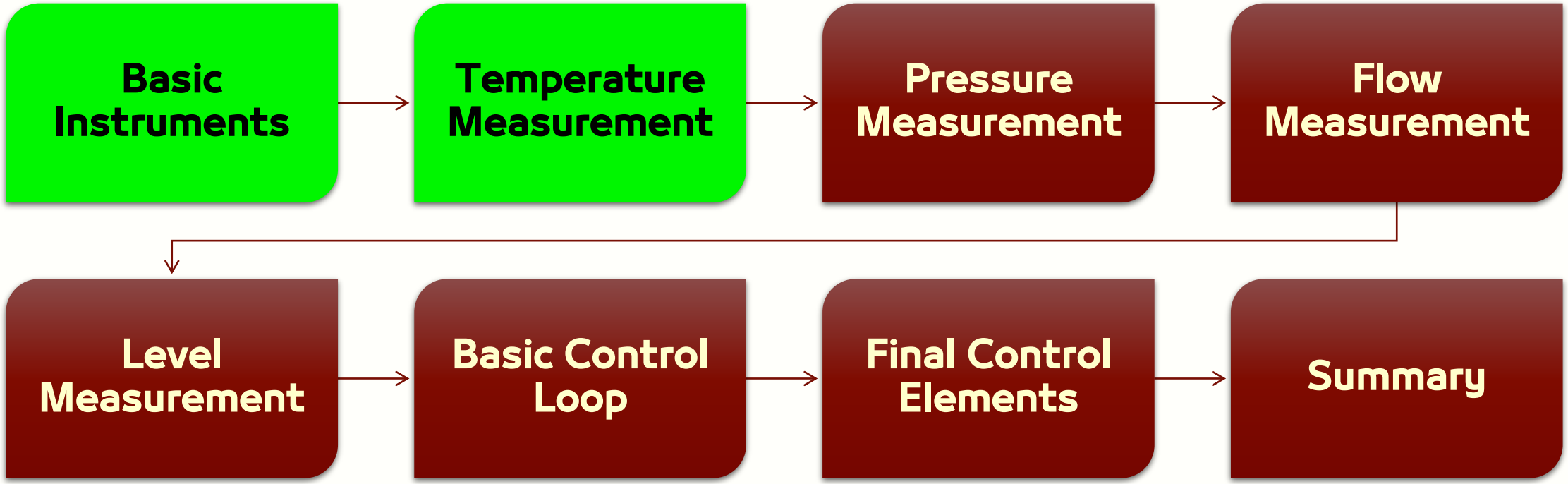
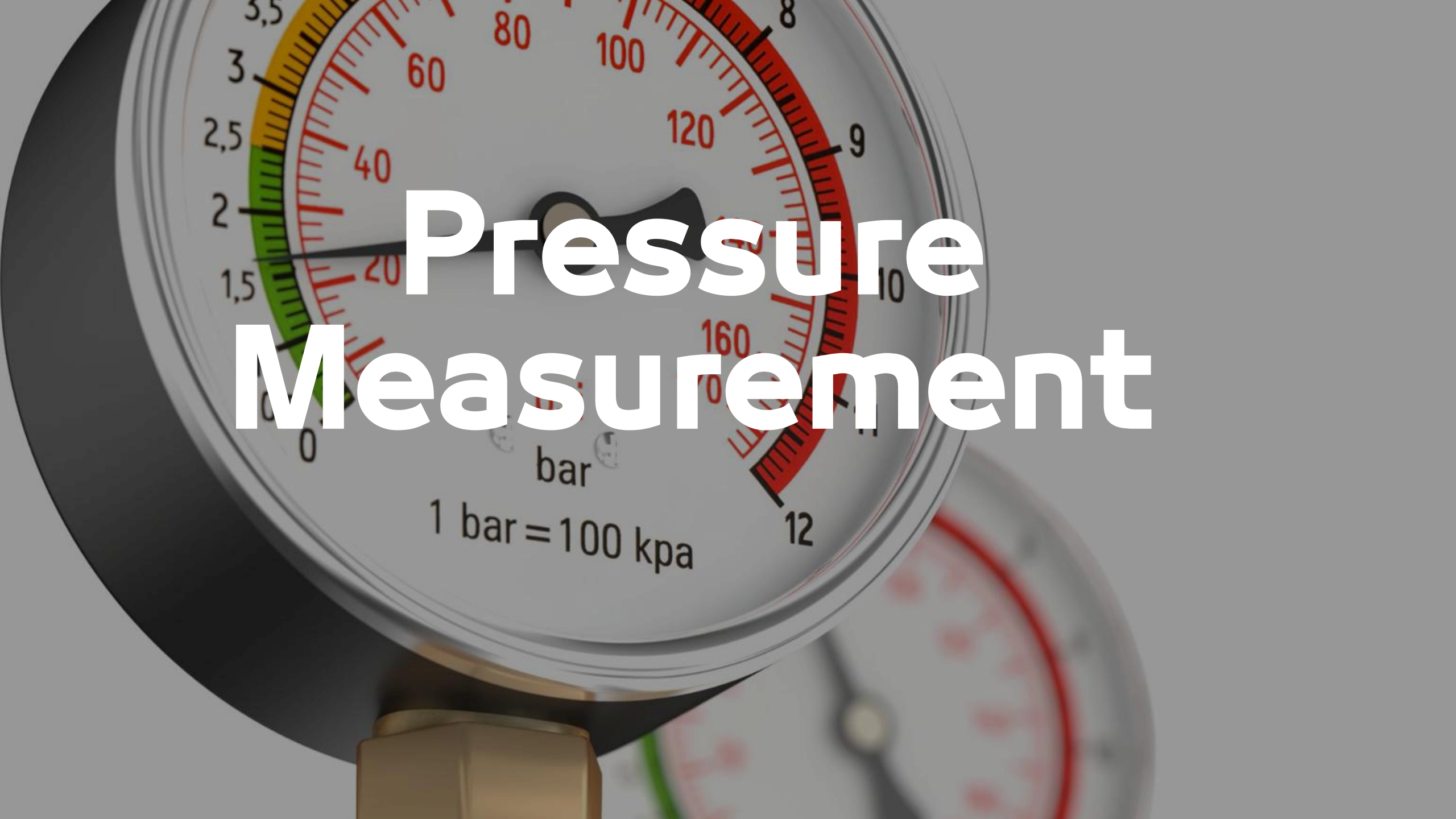


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Pressure Measurement

Pressure Measurement

Pressure in Industrial Environments

- **Definition**
  - Force per unit area exerted by fluid on the equipment.
  - Applicable to fluids (gases or liquids).

Units of Measurement

- Pounds per square inch (psi) in the English system.
- Kilograms per square meter (kg/m²) in the metric system.
- Newtons per square meter or pascals (Pa) in the System of International Units (SI).
  - 1 newton = 1 kgm/sec².

Types of Pressure

- **Atmospheric Pressure**
  - Force exerted on the earth by the weight of surrounding gases.
  - At sea level: ~14.7 psi (1.013 Pa).
  - Decreases with altitude due to the reduced height and weight of gas.



Pressure Measurement

Pressure and Altitude

- Atmospheric pressure decreases with altitude due to reduced height and weight of gas.

Hydrostatic Pressure

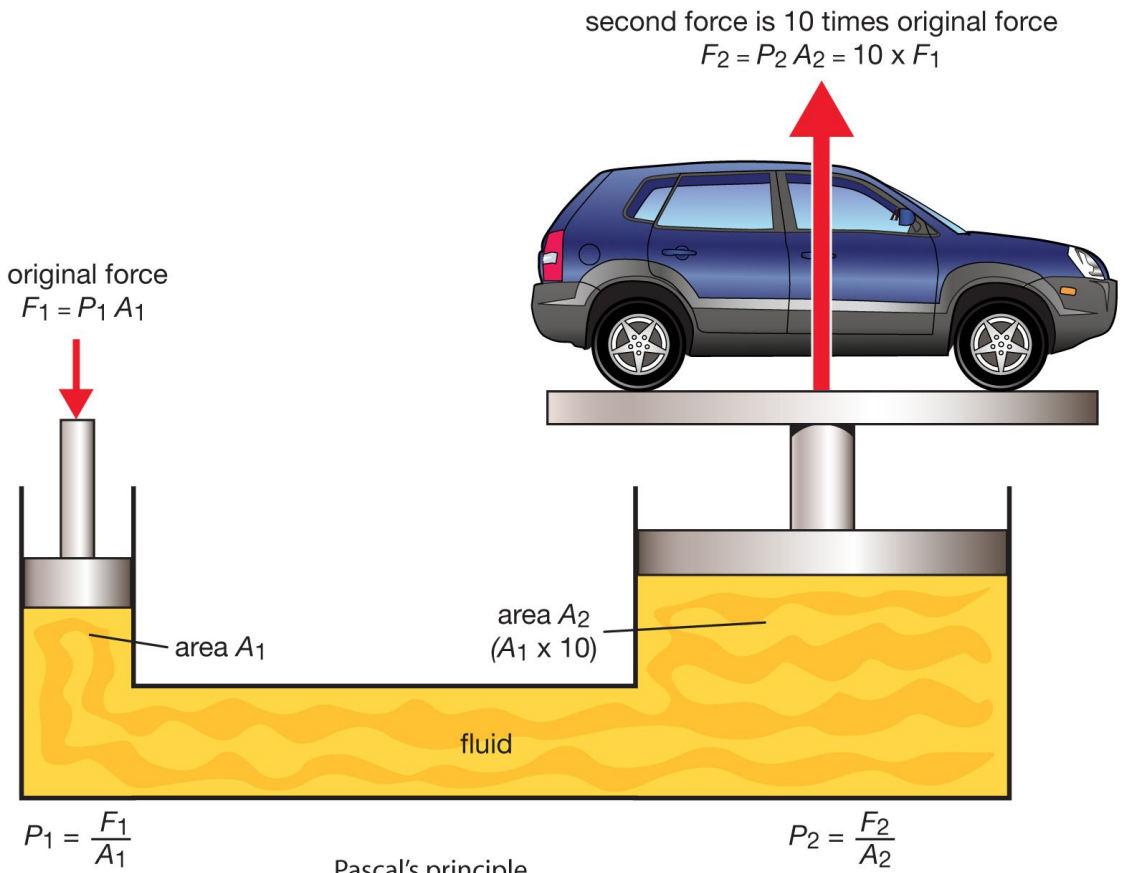
- Pressure exerted on a contained liquid.
- Determined by the depth of the liquid.
- Example: Pressure differences experienced by a swimmer at the surface and bottom of a pool.
  - Causes ears to "pop" when swimming to the bottom of a 10-foot pool.



Pascal Law

Blaise Pascal and Pascal's Law

- Discovered in the 1650s that pressure in fluids is transmitted equally to all distances and directions.
- **Pascal's Law**
  - In a fluid at rest in a closed container, a pressure change in one part is transmitted without loss to every portion of the fluid and the container.
  - Based on the free movement of molecules in fluids.
  - The distance between molecules varies with the state of matter (solid, liquid, or gas).
    - Molecules in gases are much farther apart than in solids.

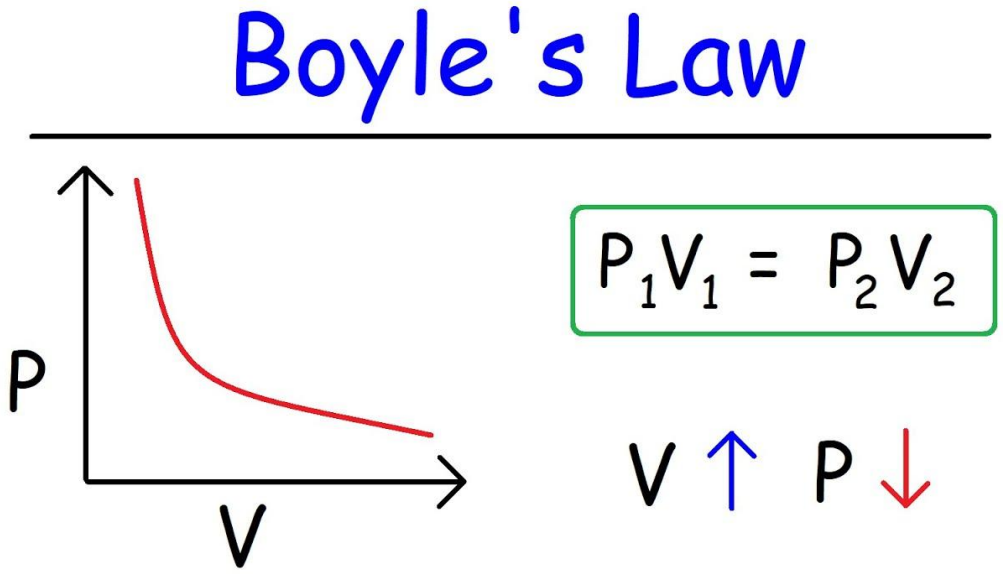


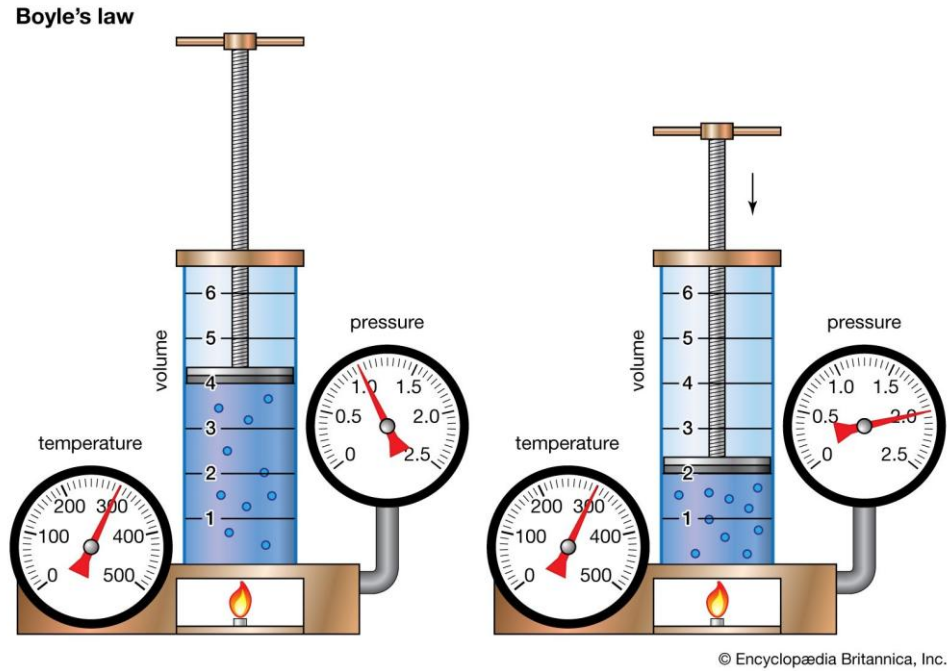
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Boyle's Law

Robert Boyle and Boyle's Law

- Developed laws in the 1650s describing the relationship between pressure and the volume of a gas.
- **Boyle's Law**
  - At constant temperature, the pressure of a gas varies inversely with its volume.
  - Higher gas pressure results in closer gas molecules and a smaller volume.
  - Under ordinary conditions, gas volumes decrease by half when the pressure doubles.
- **Liquids and Solids**
  - Also respond to pressure increases but in much smaller proportions compared to gases.
  - Generally considered noncompressible.

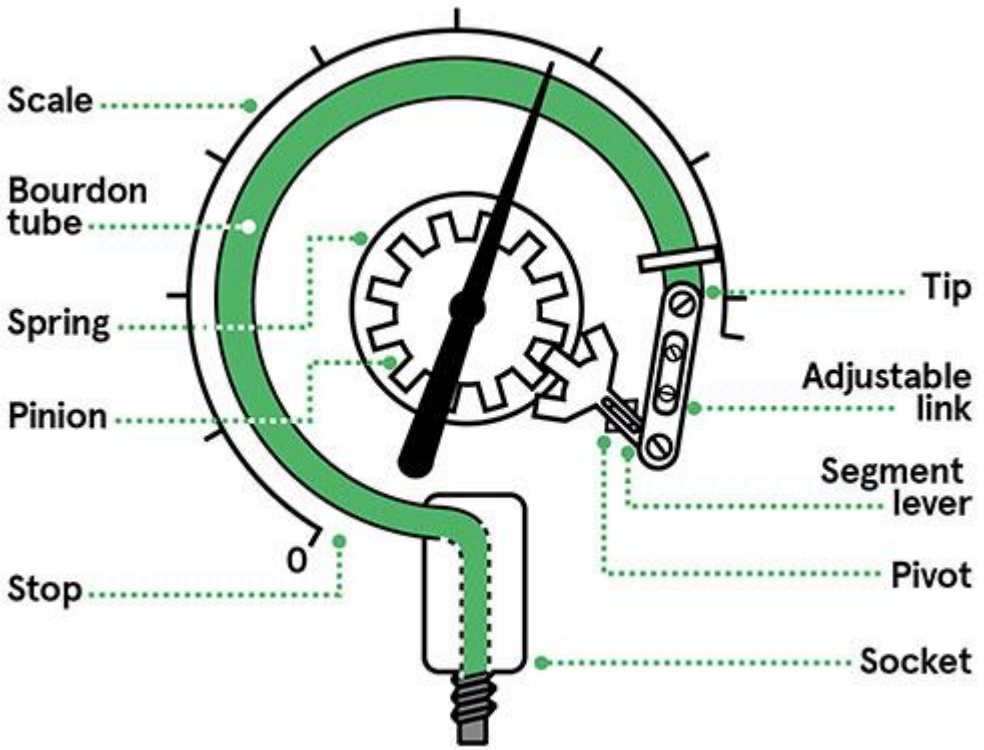


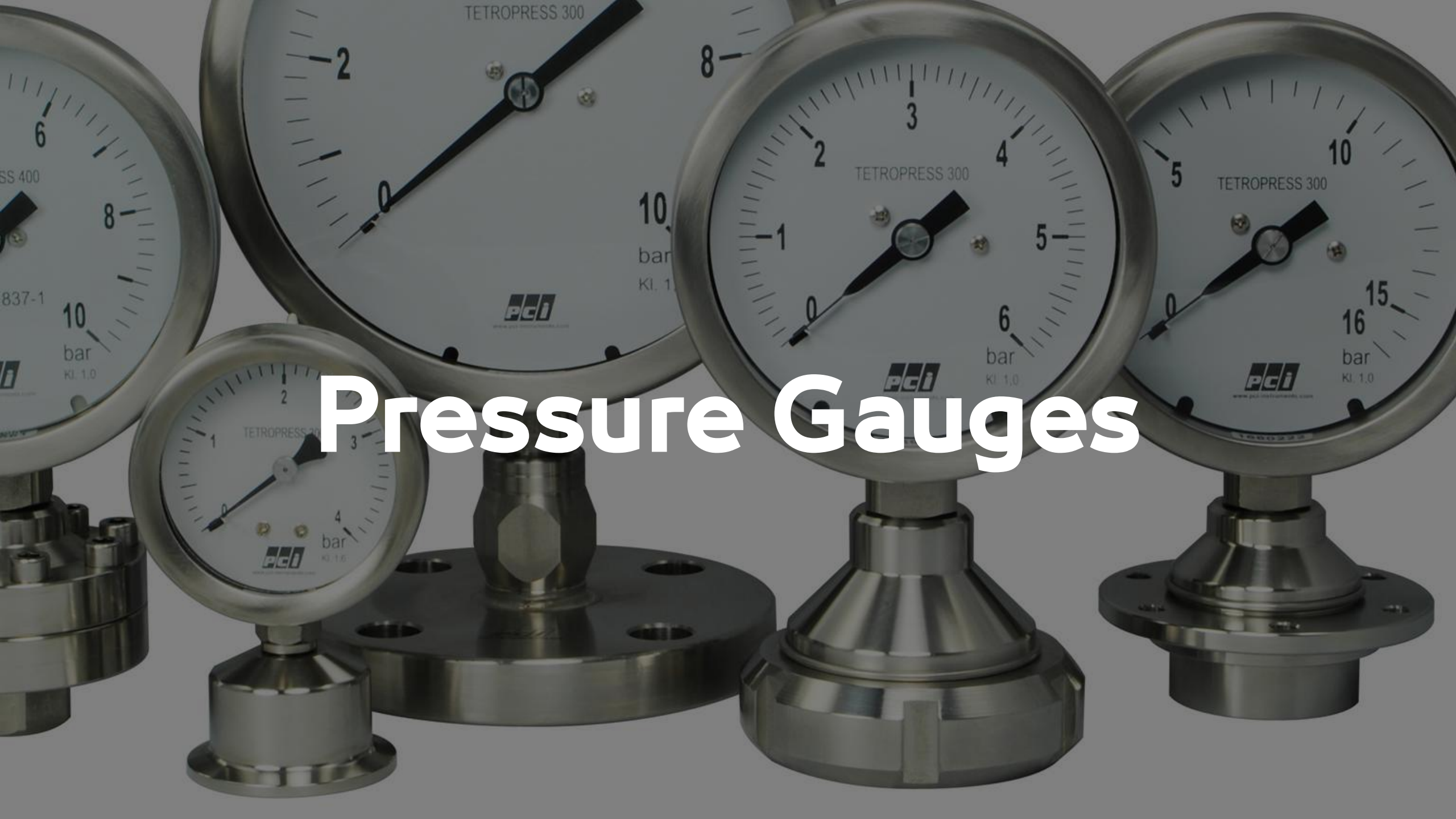


Pressure Measurement

Converse of Boyle's Law

- Pressure can affect temperature.
- Also affects level and flow rate.
- **Impact on Processes**
  - Changes the boiling point of chemicals.
  - Influences reaction rates.
  - Affects the speed at which fluids flow through piping.
- **Importance for Product Quality**
  - These changes can impact product quality.
  - Many instruments (pressure elements) are designed to monitor and control pressure.





Pressure Gauges

Pressure Gauges

Common Pressure Scales in Manufacturing

- **Gauge Pressure Scale**
  - Most commonly used.
  - Values expressed in pounds per square inch gauge (psig).
  - Starts with atmospheric pressure (14.7 psi) as zero and moves up the scale.
- **Absolute Pressure Scale**
  - Starts with a perfect vacuum as zero.
  - Values expressed in pounds per square inch absolute (psia).
  - Takes into account atmospheric pressure.
  - Conversion:
    - From gauge to absolute: Add 14.7 pounds to the psig value.
    - From absolute to gauge: Subtract 14.7 pounds from the psia value.
- **Vacuum Pressure Scale**
  - Refers to pressure below atmospheric pressure, measured in inches of mercury (inHg) or millimeters of mercury (mmHg).



Pressure Gauges

Safety Precautions for Reading a Pressure Gauge

- Do not stand directly in front of the gauge when opening the valve to admit pressure.
- Once the valve is opened:
  - Stand directly in front of the gauge face to take the reading.
- **Parallax Effect**
  - An optical illusion that shifts the gauge reading left or right of the actual value.
  - Caused by the space between the pointer and the face of the gauge.
  - Occurs if you position yourself to the left or right of the gauge face.




3
2
1
0
ODO/TRIP

Vacuum Pressure

Use of Gauges and Vacuum

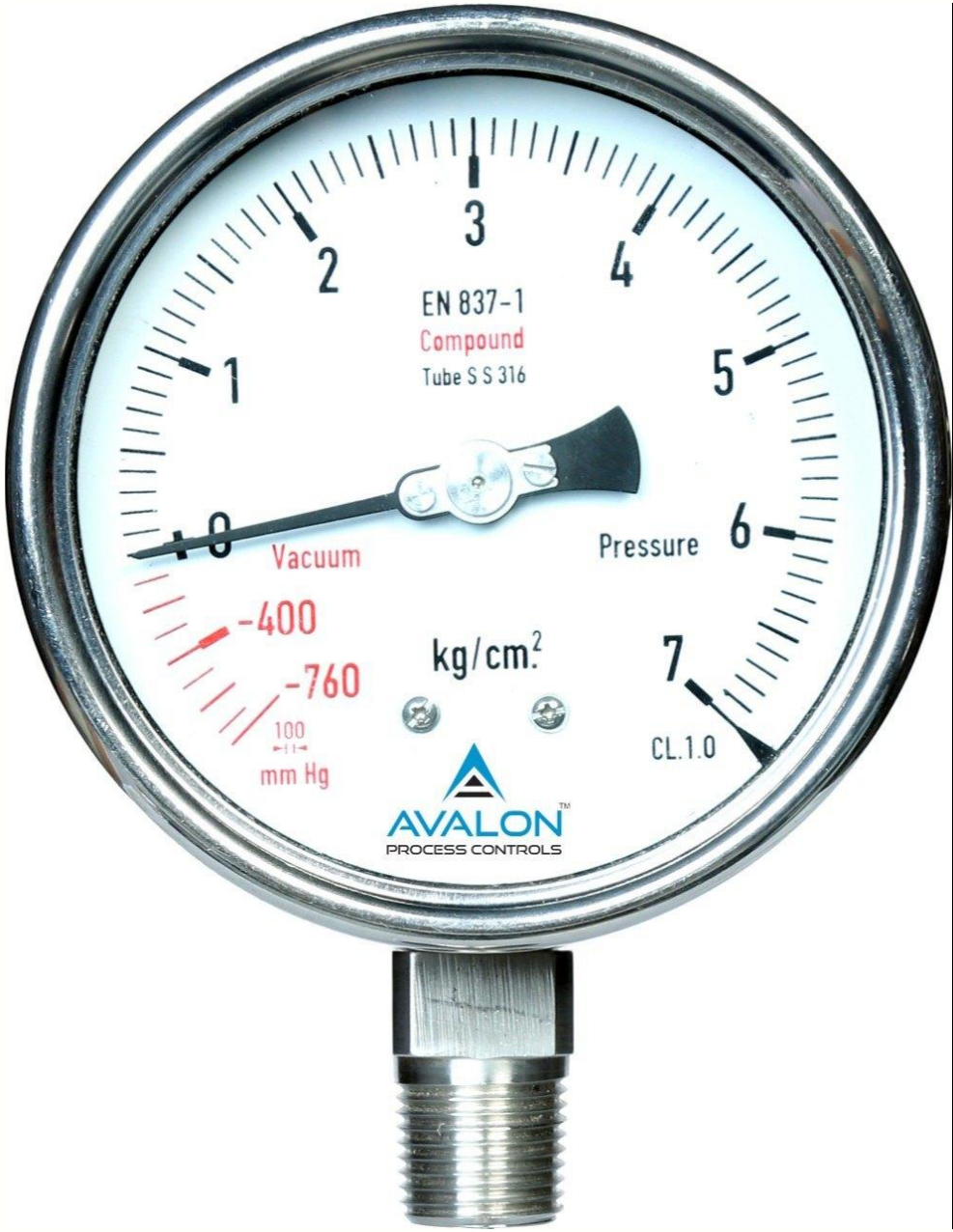
- **PSIG Gauge**
  - Cannot be used with processes operating under a vacuum.
  - Negative pressures can cause primary elements to contract beyond design limits.
  - Accidental encounter with a vacuum compromises the reading scale (shows a low reading).
- **Vacuum Gauges**
  - Designed to operate at pressures less than atmospheric pressure.
  - Express pressure in inches of mercury (Hg).
  - Vacuum is considered anything below atmospheric pressure.
- **Compound Gauges**
  - Can indicate both vacuum and gauge pressure readings.
  - Useful for applications where both positive and negative pressures need to be monitored.



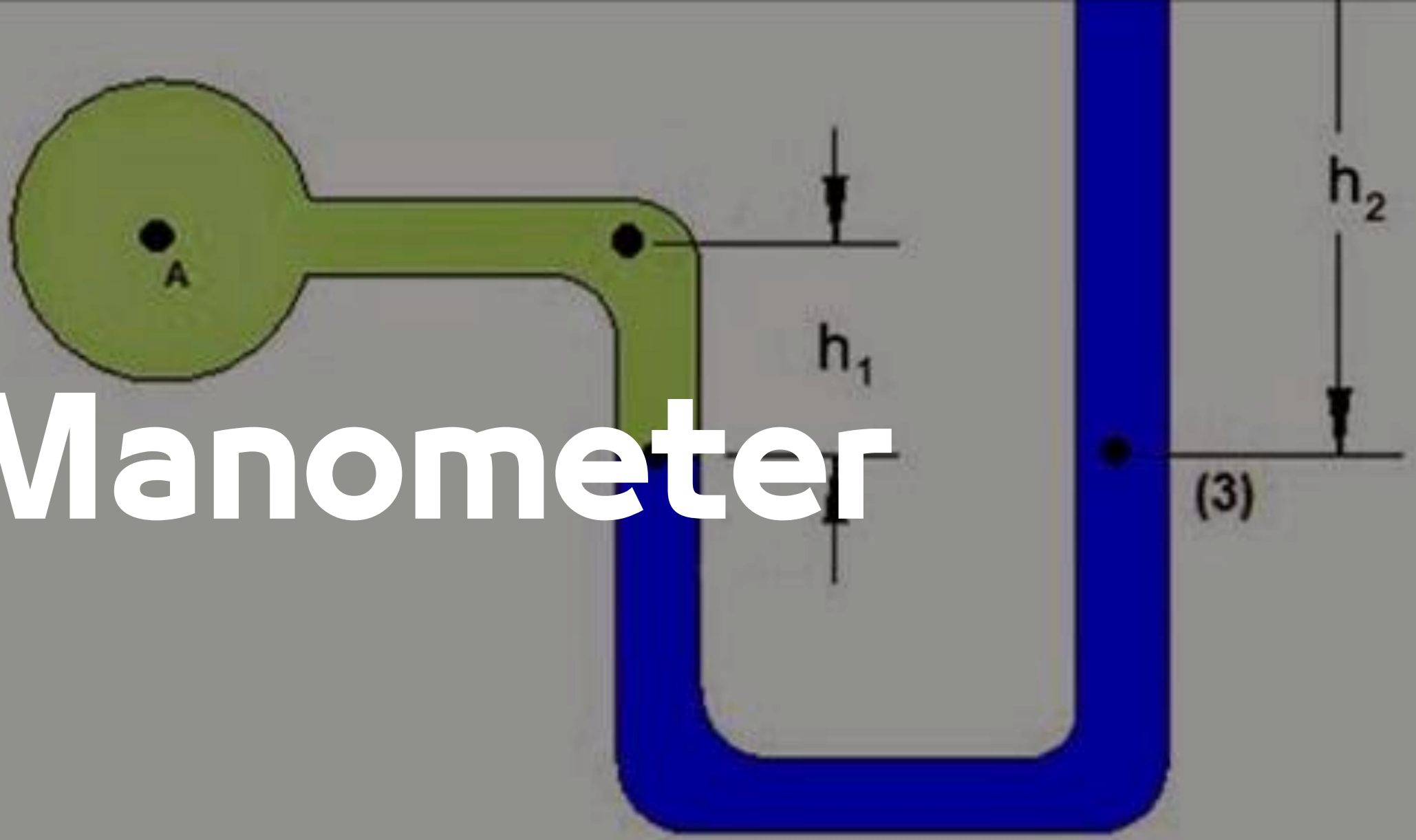


Compound Gauge

- Can indicate both vacuum and gauge pressure readings.
- Useful for applications where both positive and negative pressures need to be monitored

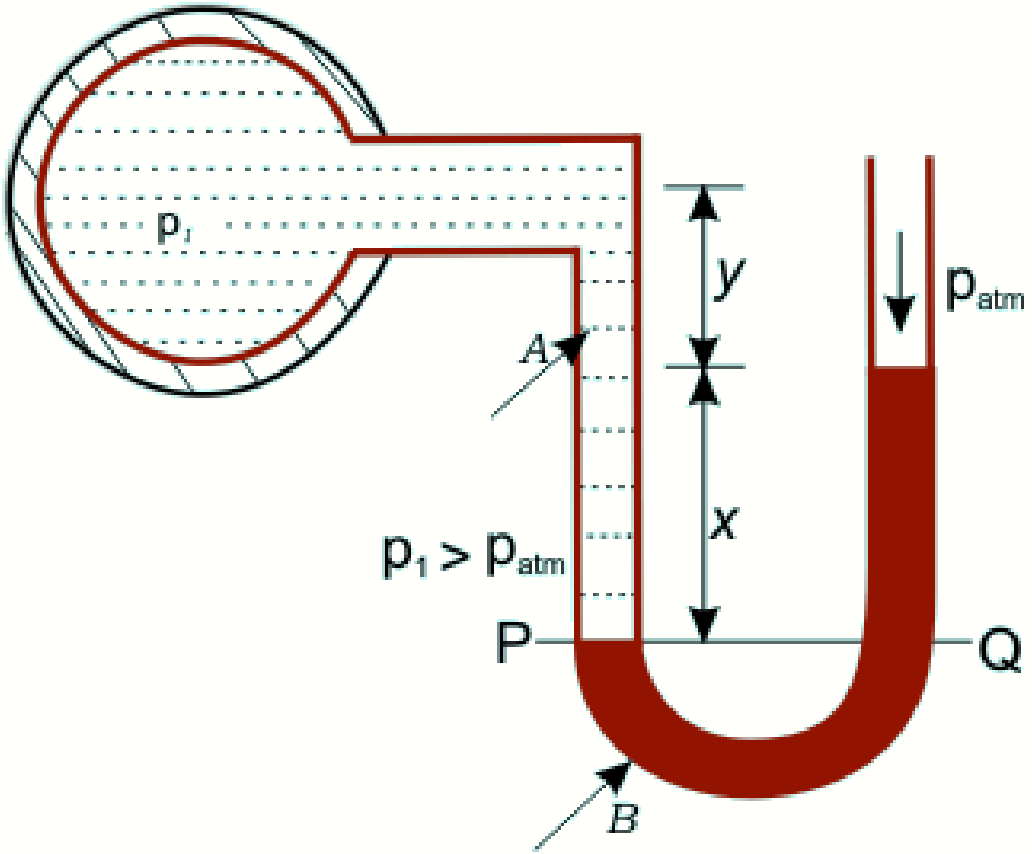


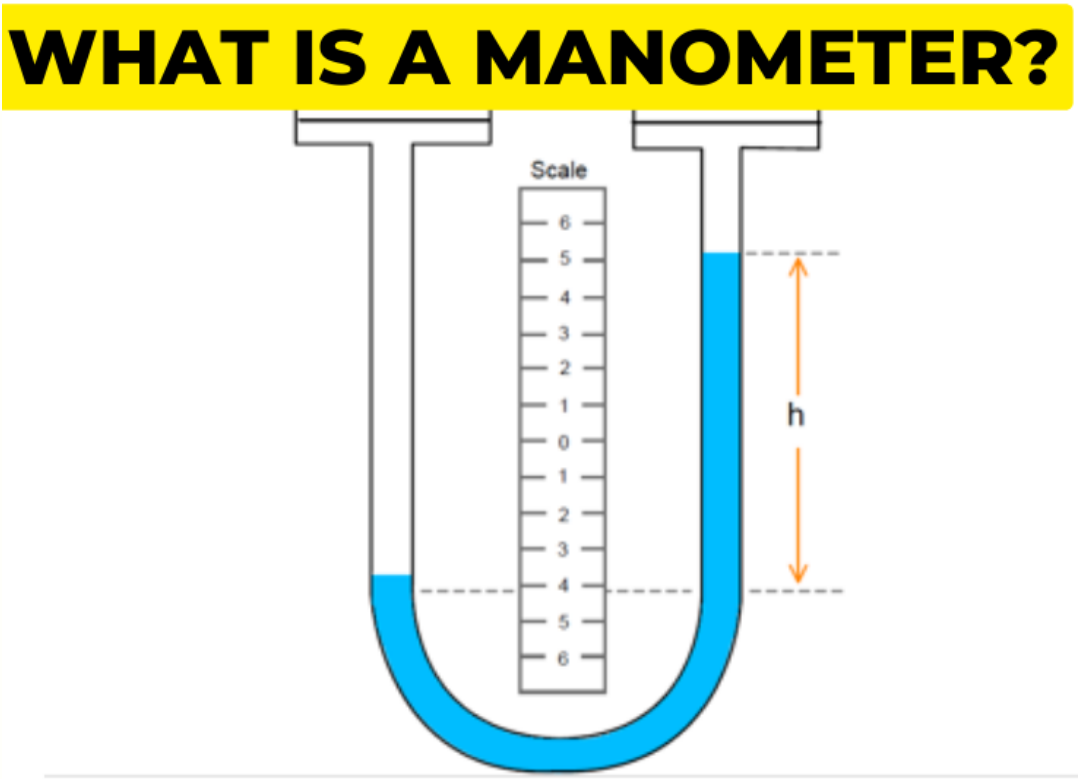
Manometer



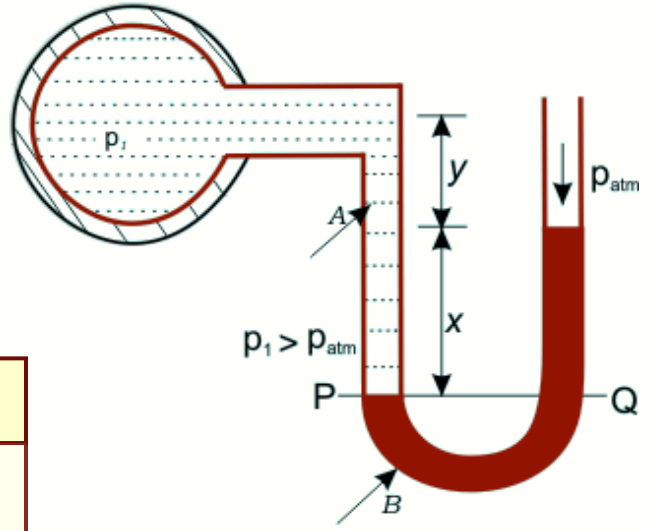
U - Tube Manometer

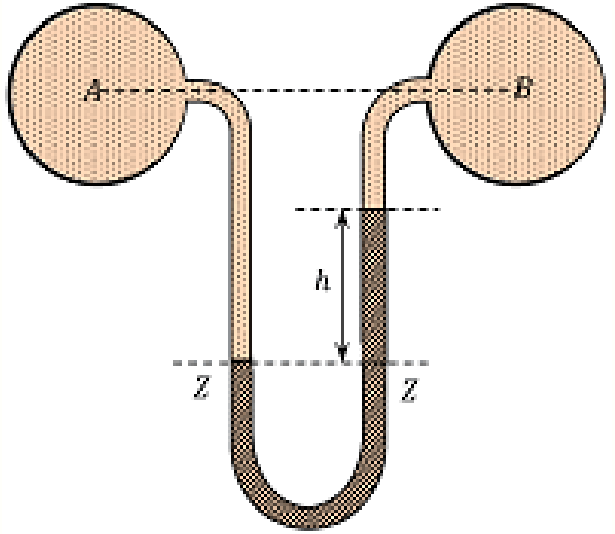
Manometer


p_1
y
A
p_{atm}
$p_1 > p_{atm}$
x
P
Q
B


WHAT IS A MANOMETER?
Scale
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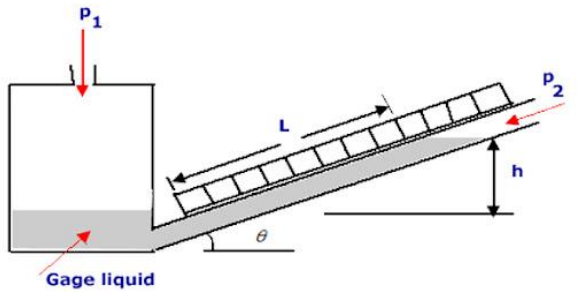
Manometer

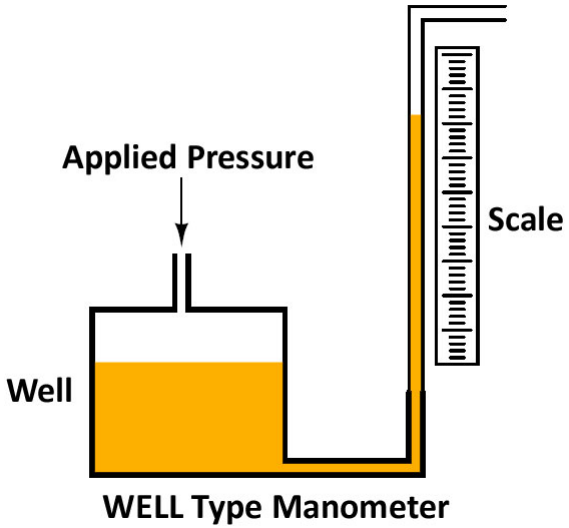




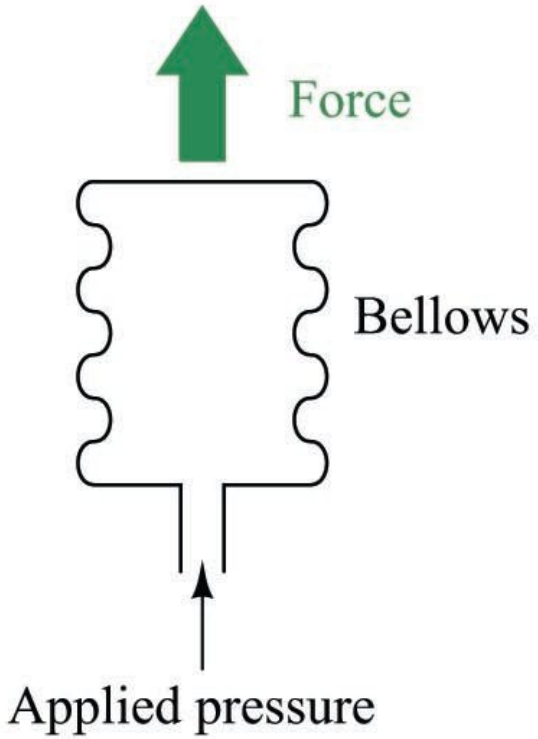
Manometer

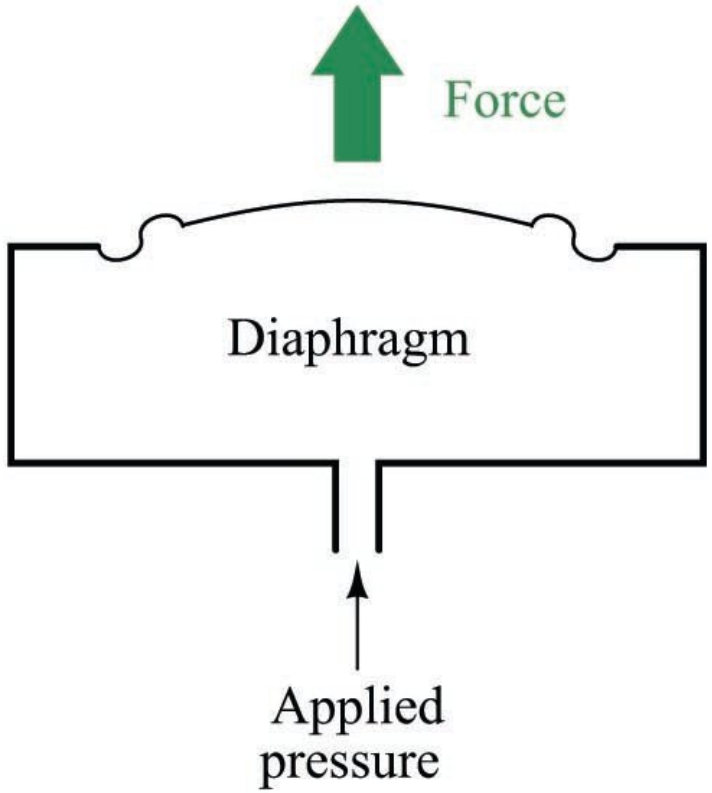
- A device used to measure pressure or vacuum.
- Operates under the hydrostatic pressure principle.
  - A column of water (or other liquid) of a given volume always exerts a specific force.
- **Working Principle**
  - The liquid level in the manometer indicates the pressure.
  - Movement of the liquid in response to pressure changes allows for measurement.
- **Types**
  - **U-tube Manometer:** Measures pressure relative to atmospheric pressure.
  - **Inclined Manometer:** Measures small pressure differences with higher precision.
  - **Differential Manometer:** Compares pressures between two different points in a system.

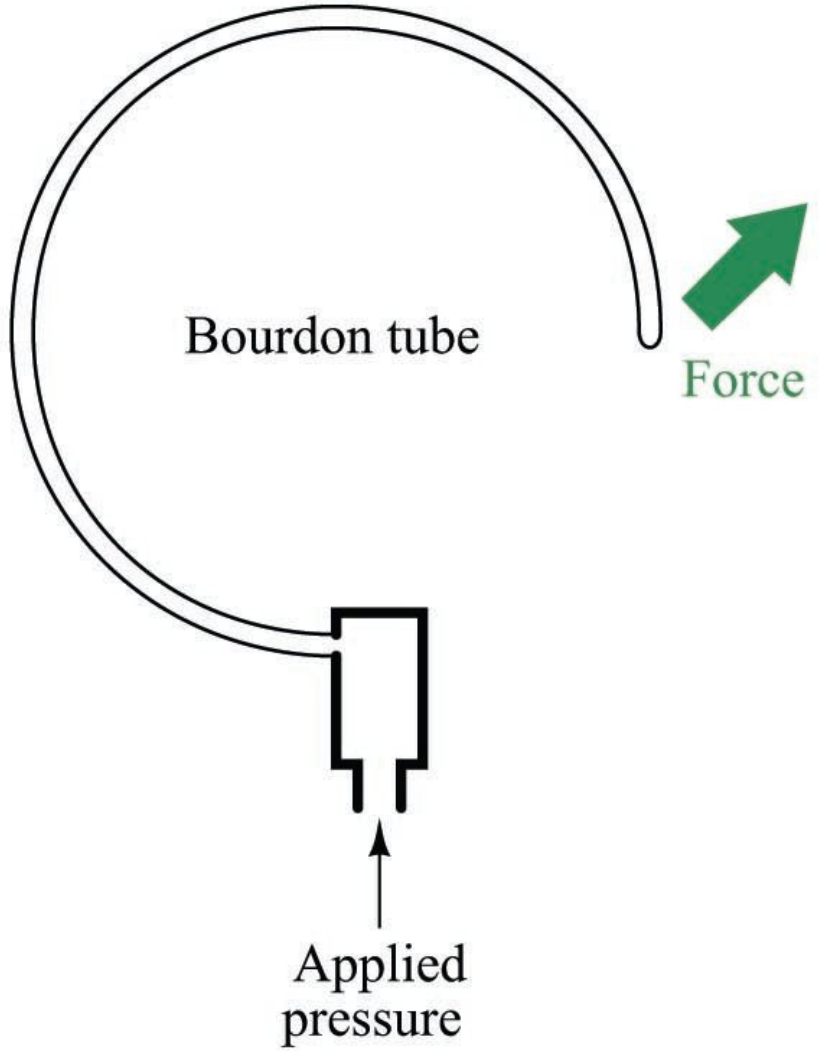




Primary Pressure Elements



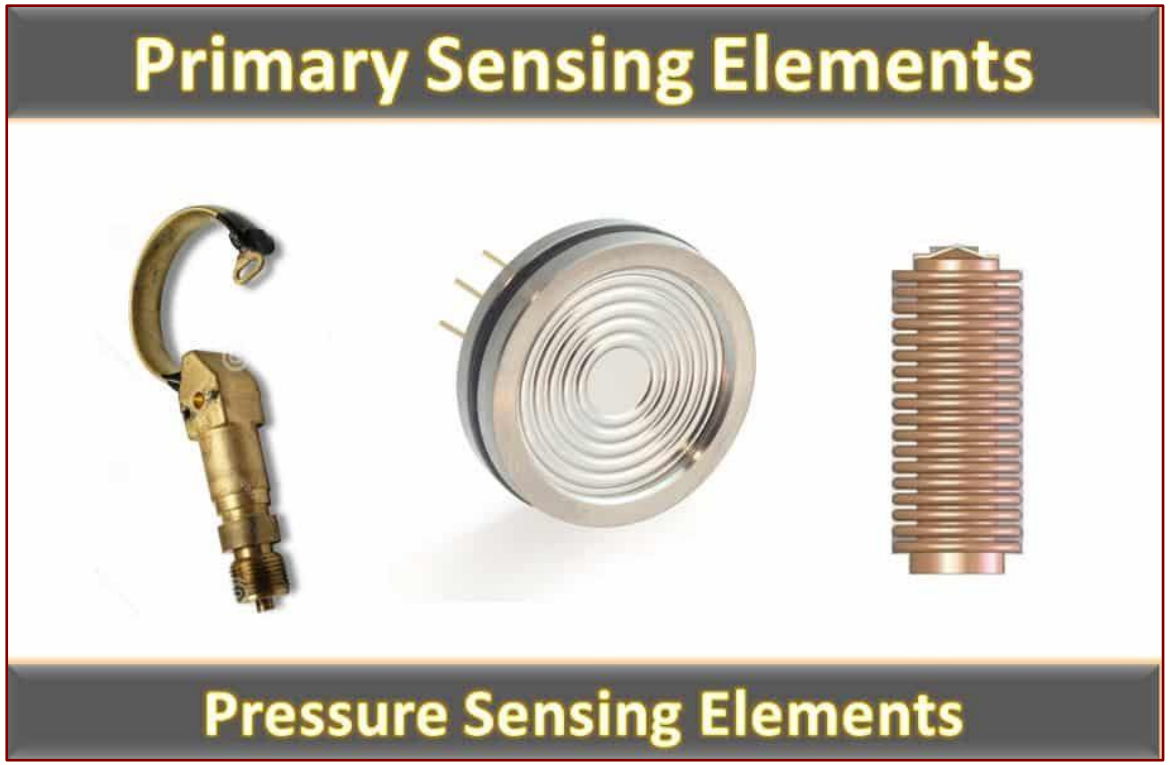


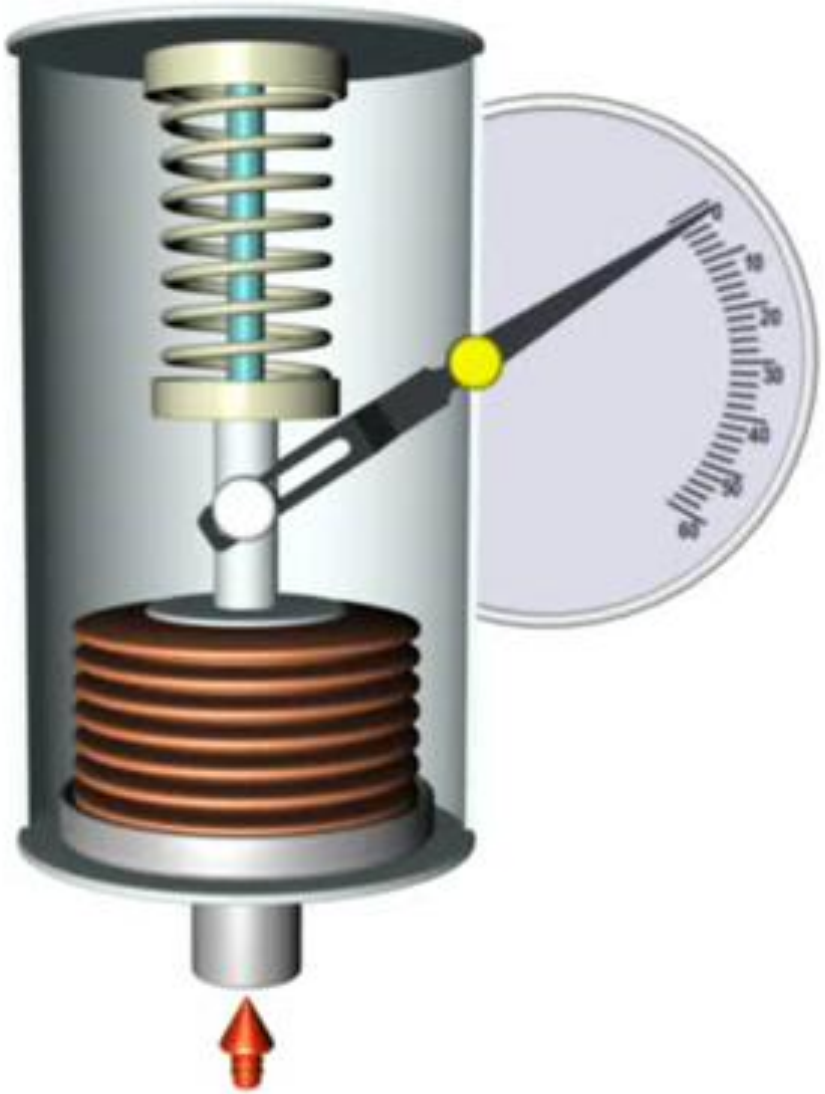


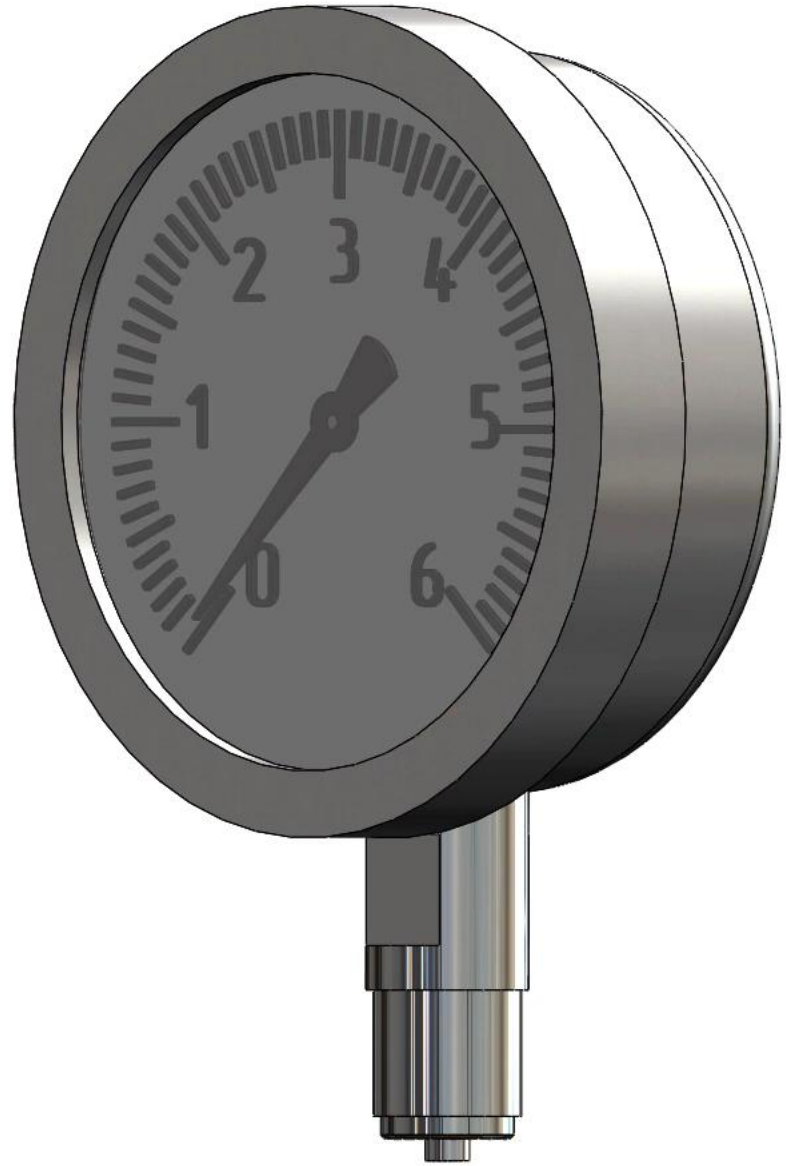
Primary Pressure Elements

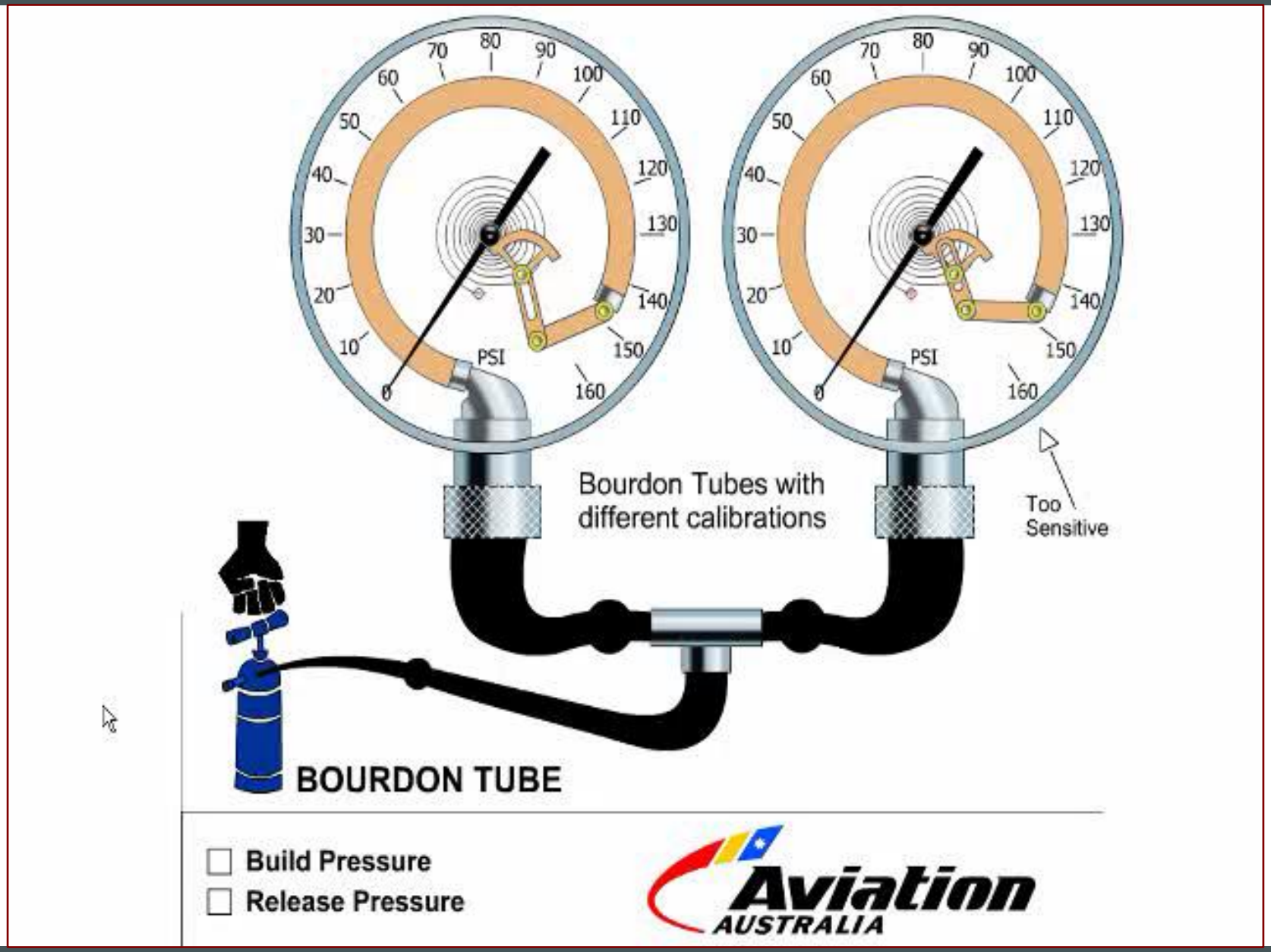
Primary Pressure Elements

- Specifically designed part of a pressure instrument.
- **Function**
  - Sense changes in pressure.
  - Convert pressure changes into mechanical motion.
- **Connection and Operation**
  - Connected to mechanical linkages and scale indicators.
  - Higher pressure results in greater movement by the mechanical linkage.
- **Importance**
  - Essential for accurate measurement and control of pressure in industrial applications.






0
1
2
3
4
5
6


Bourdon Tubes with different calibrations
Too Sensitive
PSI
BOURDON TUBE
Build Pressure
Release Pressure
Aviation AUSTRALIA

Bellows Pressure Element

Bellows Pressure Element

- Consists of:
  - Accordion-type bellows.
  - Spring that resists expansion of the bellows.
  - Pressure inlet.
  - Mechanical linkage.
  - Pointer (gauge indicator).

Operation

- Admits flow into the bellows.
- As the bellows expands:
  - Tension on the spring increases.
  - Mechanical linkage moves, operating the pointer on the gauge.
- If pressure is reduced:
  - The spring forces the bellows back to its original position.

Applications

- Can be used to measure a variety of pressures in different industrial settings.

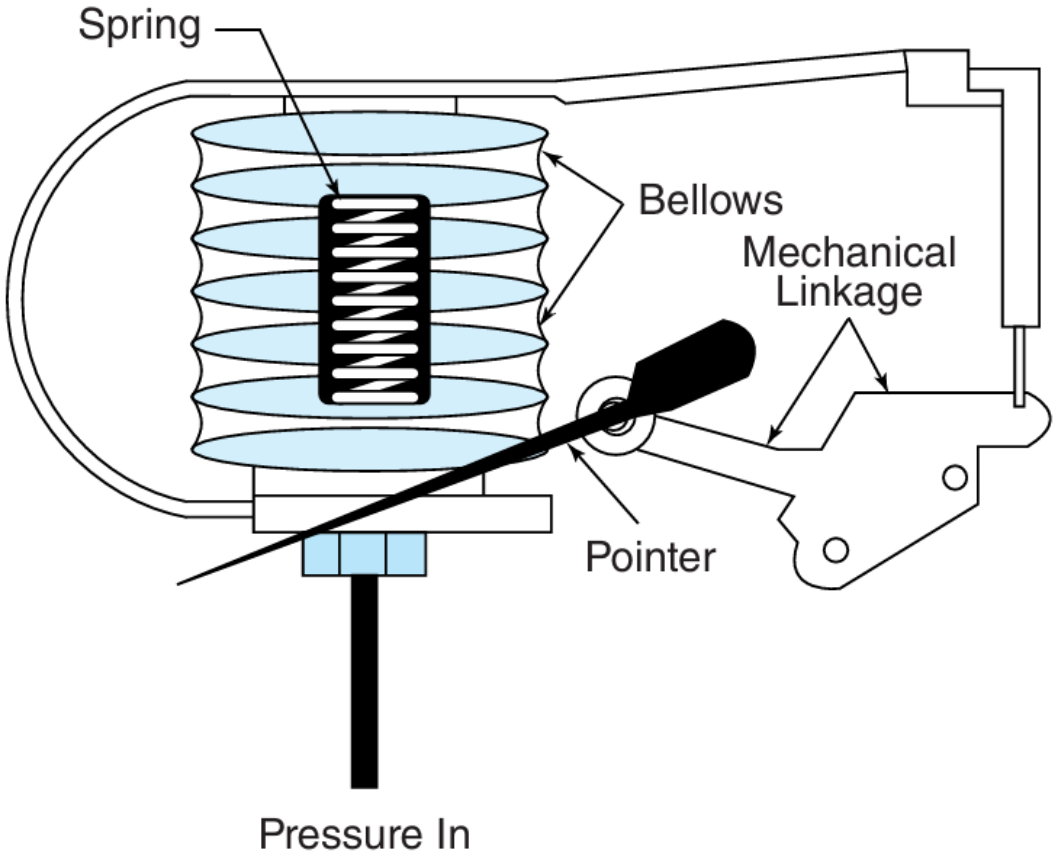


Figure 11.6 *Bellows Pressure Elements*

Bourdon Tubes Element

Bourdon Tube Pressure Element

- Most common type of pressure element.
- Available in various shapes and designs, including:
  - C-type
  - Helical-type
  - Spiral-type

C-type Bourdon Tubes

- Named for their C-shaped, hollow pressure element.
- Components:
  - C-shaped hollow tube.
  - Pressure inlet attached to one end.
  - Mechanical linkage attached to the top.
  - Pointer (gauge indicator).

Operation

- Expands and contracts in response to pressure changes (elastic deformation).
- Movement of the tube drives the mechanical linkage and moves the pointer.

Applications

- Measures a wide variety of pressures, including vacuum.

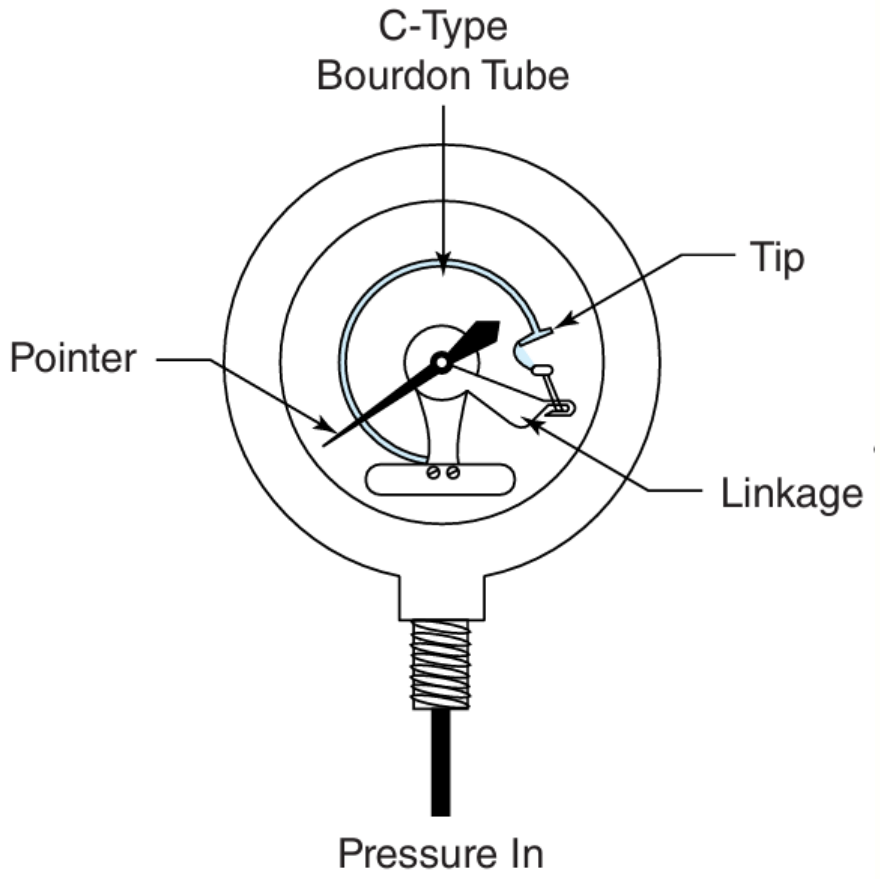
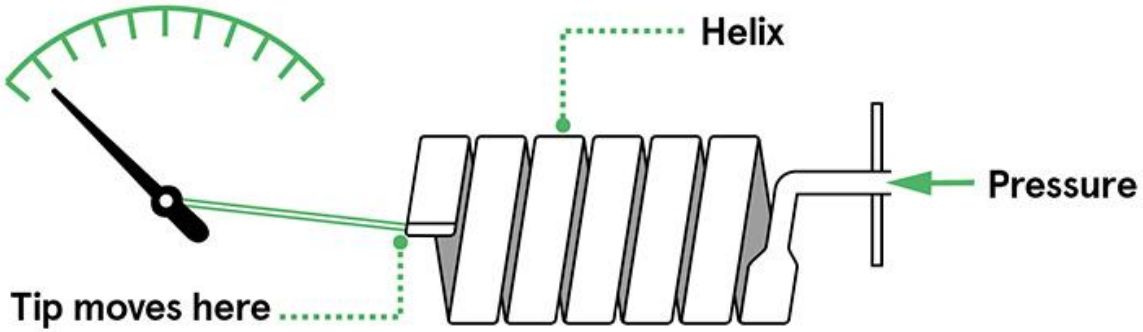


Figure 11.7 *Bourdon Tube–type Pressure Elements*

Bourdon Tubes Element

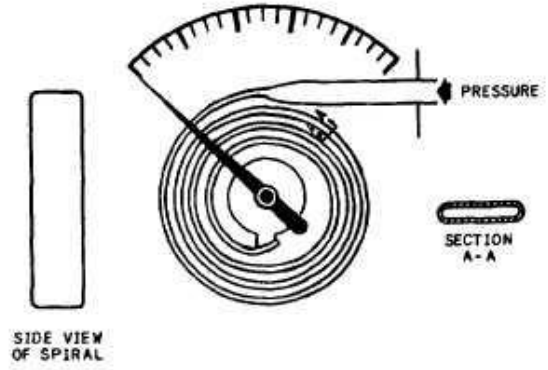
Helical and Spiral-Type Bourdon Tubes

- Operate similarly to C-type Bourdon tubes.
- Main difference lies in the shape of the pressure element.



Applications in Automatic Control Systems

- Spiral-type Bourdon can be connected to a transmitter.
- As the spiral element responds to pressure changes:
  - The transmitter sends a signal to the controller.
  - The controller then sends a signal to the control valve.



Diaphragm Capsule Pressure Element

Diaphragm Pressure Elements

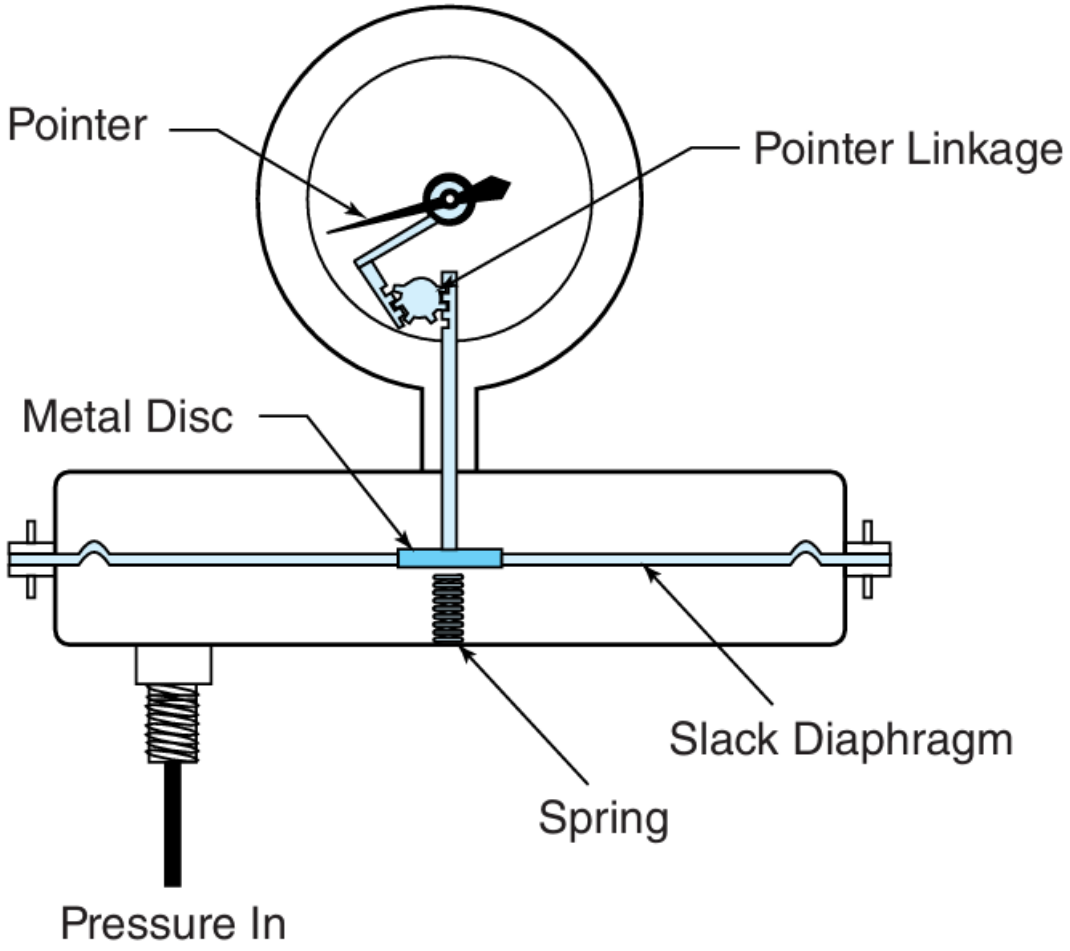
- Two basic types:
  - Diaphragm capsule pressure element.
  - Slack diaphragm pressure element.

Diaphragm Capsule Pressure Element

- Components:
  - Metallic diaphragm capsule consisting of a metal cup covered by a flexible metal plate.
  - Pressure inlet line to the cup.
  - Mechanical linkage.
  - Pointer (gauge indicator).
- **Function**
  - Designed to measure small pressure changes.
  - During operation, the dome of the cup flexes up or down.
  - Movement is transferred proportionally to the pointer, allowing small dome movements to result in significant pointer travel.

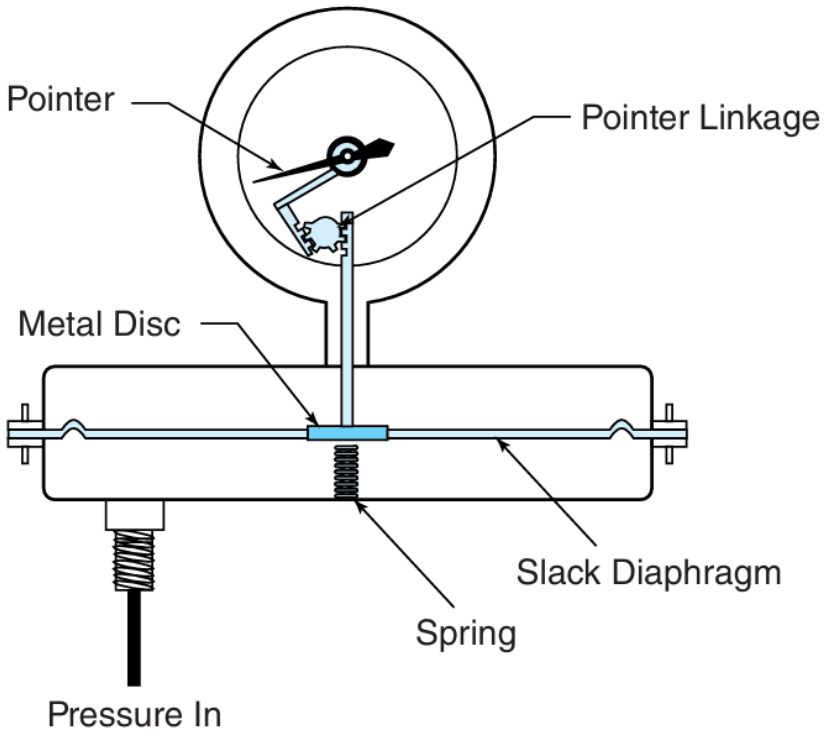
Slack Diaphragm Pressure Element

- Key Components:
  - Flexible diaphragm attached to a spring.
  - Pressure inlet.
  - Mechanical linkage.
  - Pointer.
- **Function**
  - Designed to operate under very low pressures (0 to 0.5 psi).



Diaphragm Capsule Pressure Element

Slack Diaphragm Pressure Element



Diaphragm Capsule Pressure Element



Pressure Transmitter

Pressure Transmitter

- Uses a pressure element to sense pressure.
- Sends a signal to a controller or recorder.

Primary Pressure Elements Used

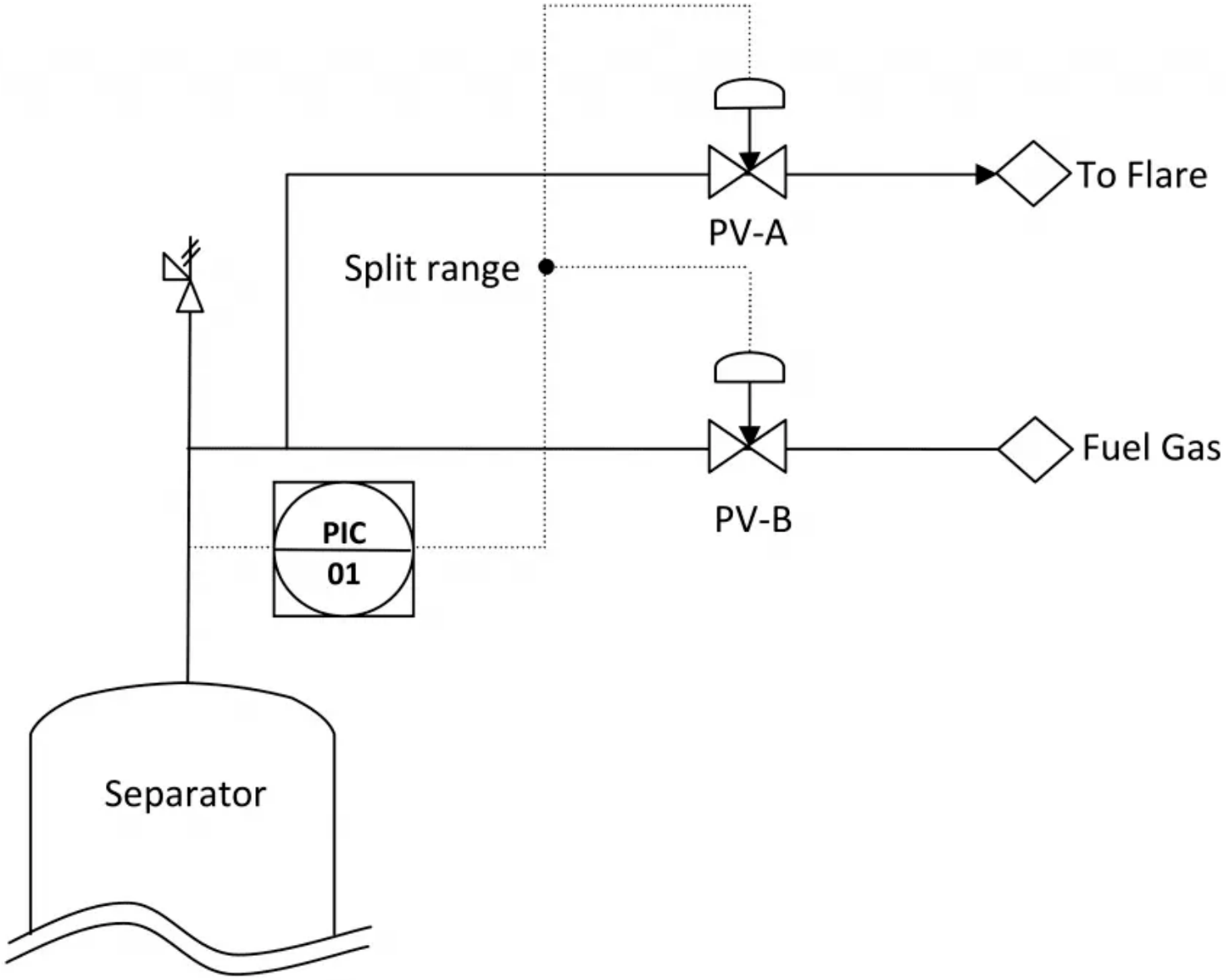
- Includes all previously discussed elements (Bourdon tubes, diaphragms, etc.).

Operation

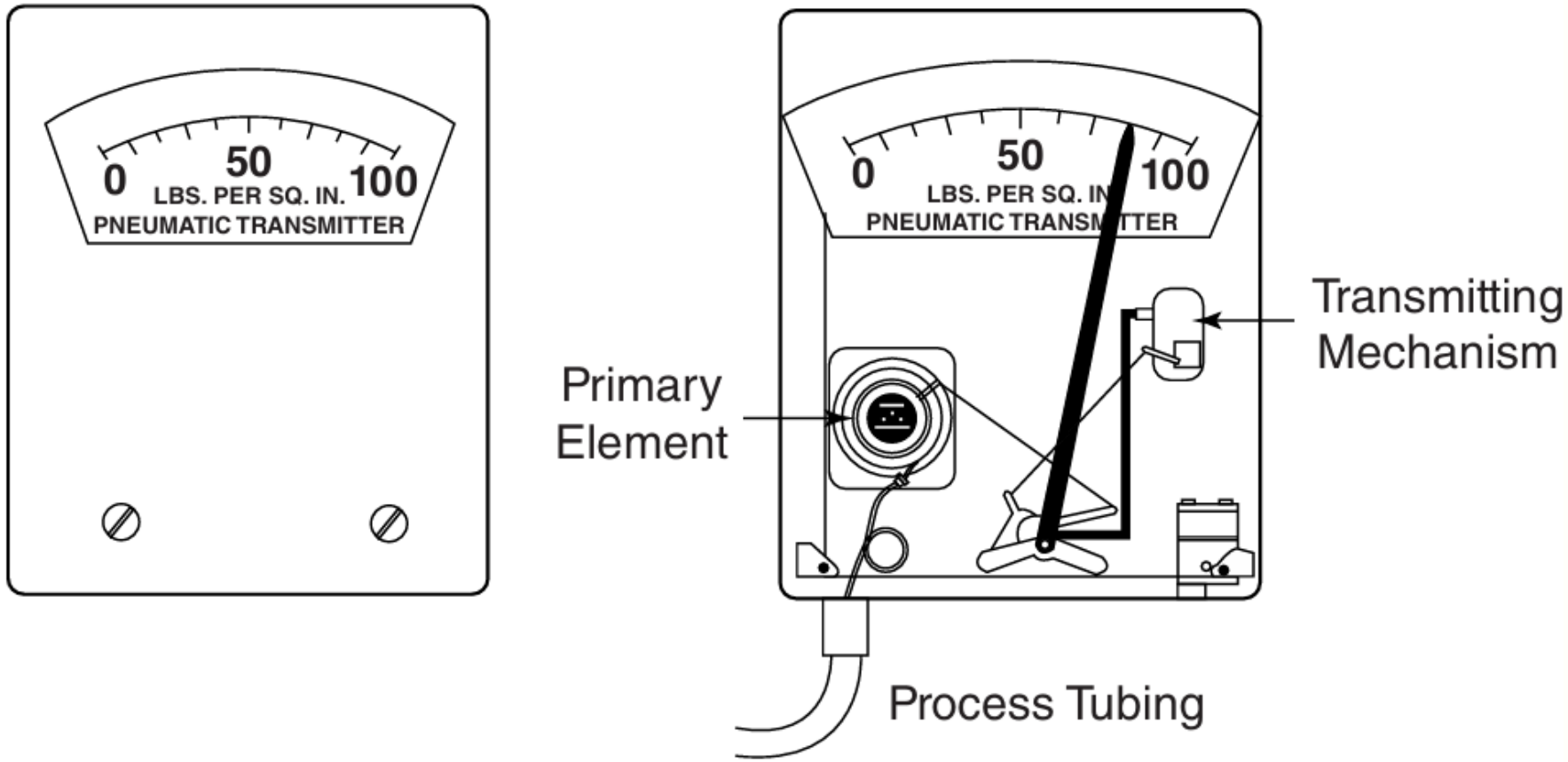
- Linkage movement within the pressure element allows the transmitter to transmit a representative signal of the pressure.
- The controller, based on the received signal, opens or closes control valves.



Pressure Control Loop



Pressure Transmitter



Pressure Controller

Pressure Control Loop Design

- Similar elements to temperature, level, and flow control loops.
- Consistent changes occur in primary elements and sensors.

Primary Elements and Sensors

- Used to detect and respond to pressure changes.
- Typically expansion-type devices.

Components of Pressure Control Loop

- **Pressure Transmitter**
- **Controller**
- **Transducer**
- **Control Valve**

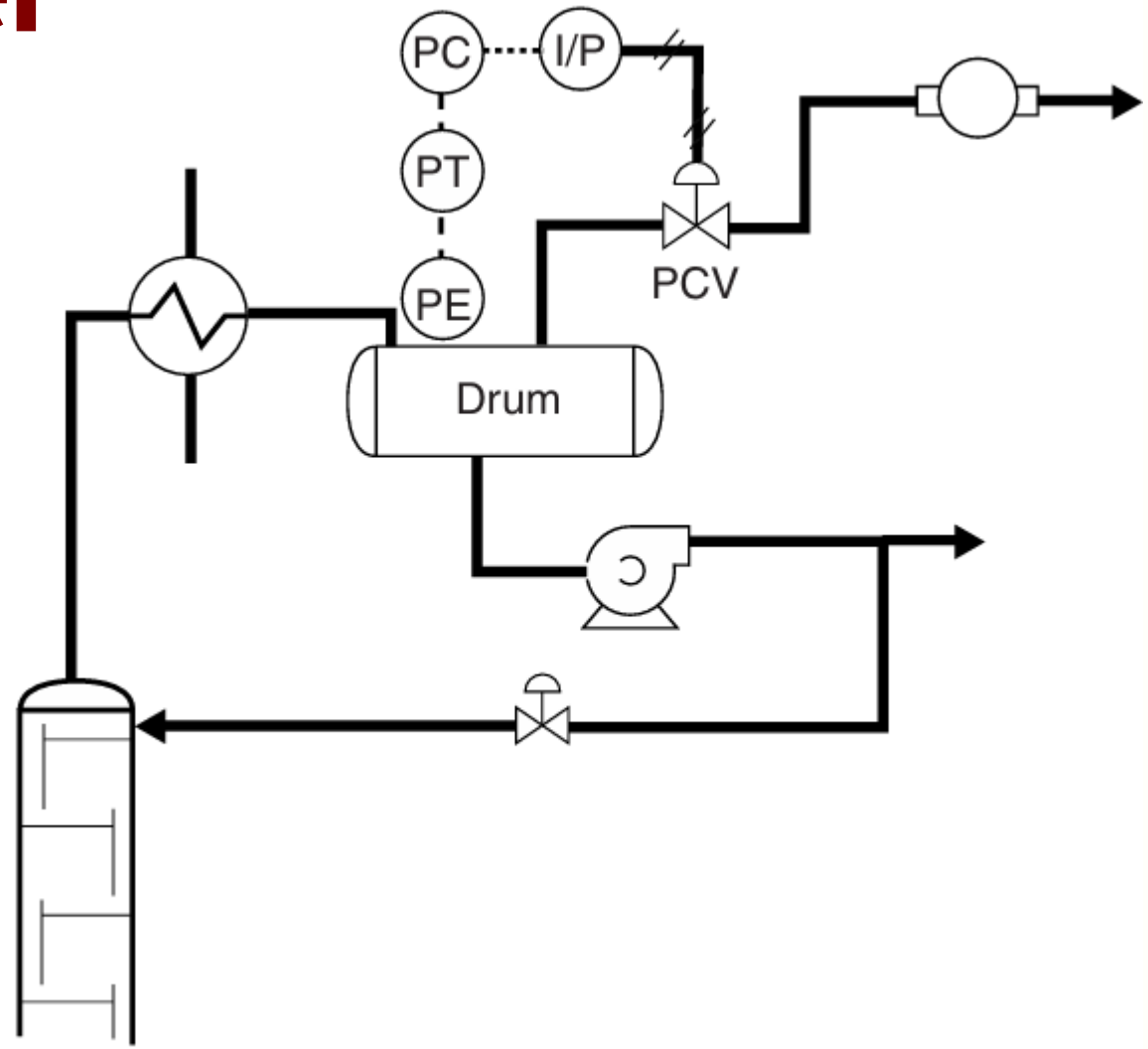
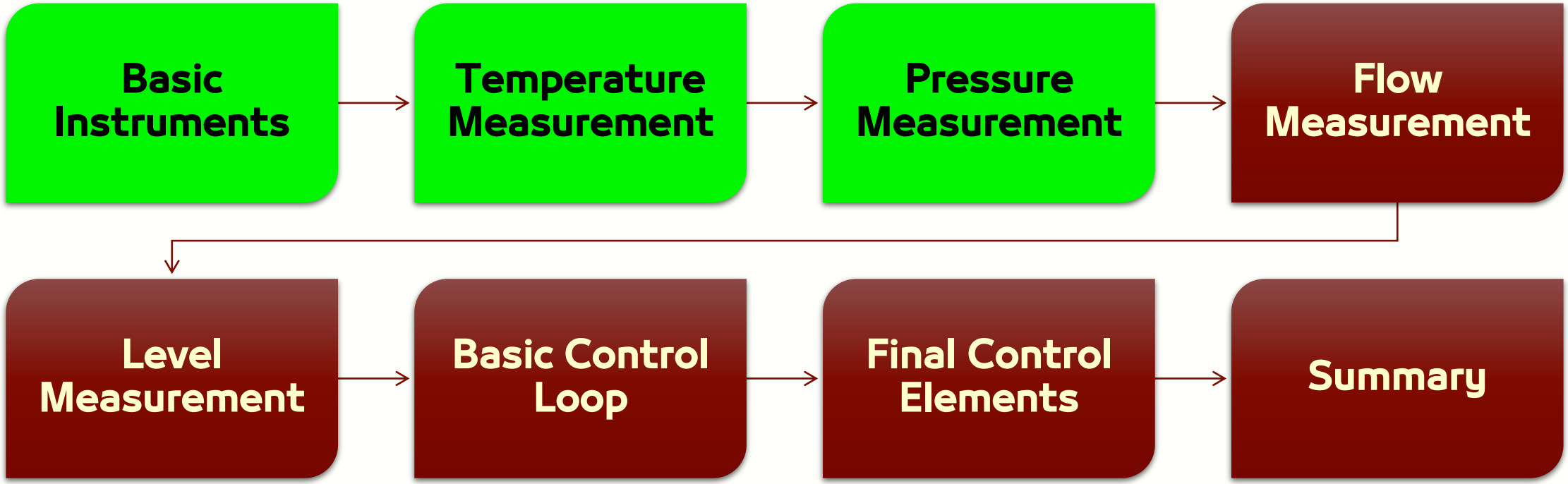
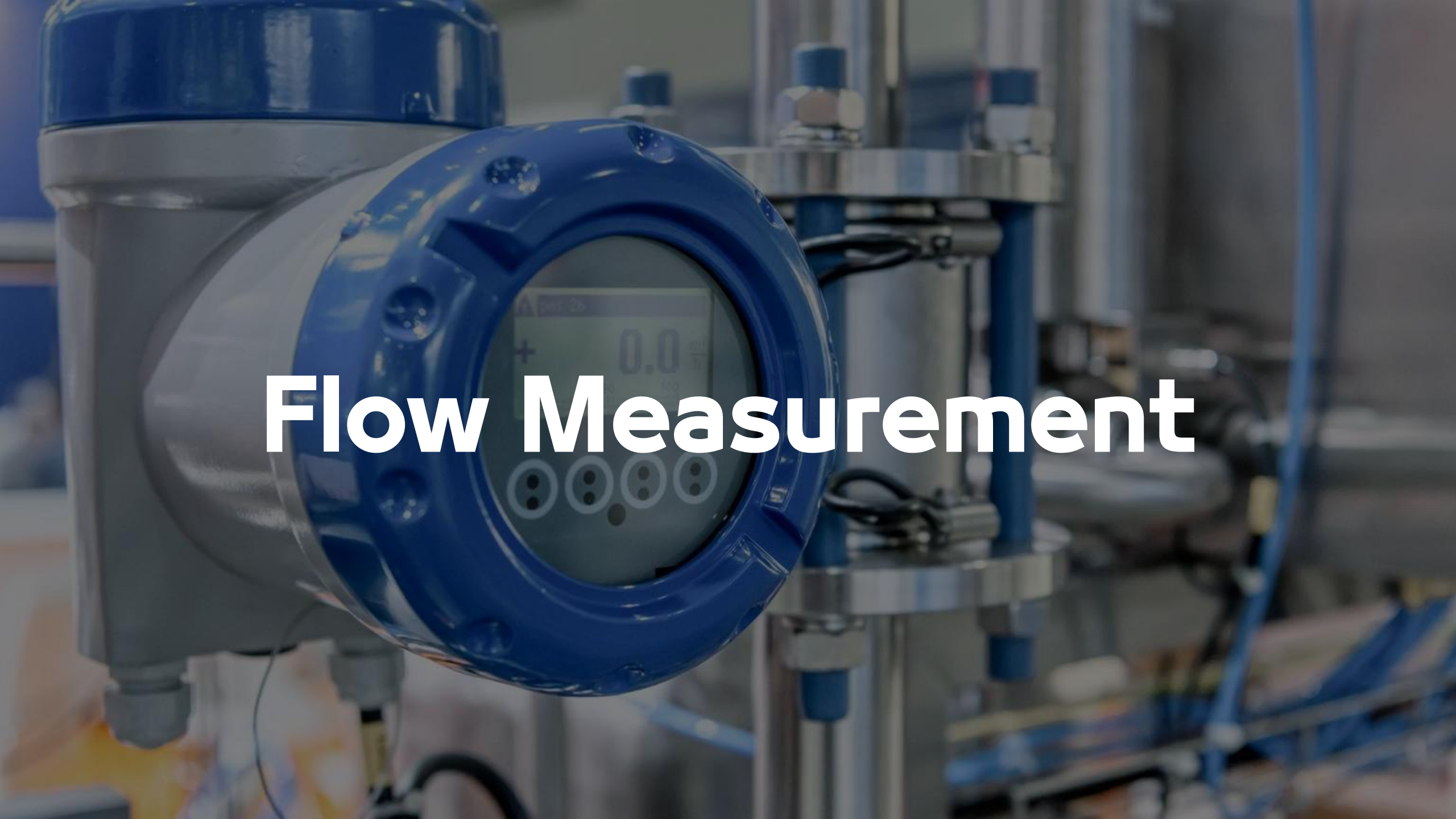
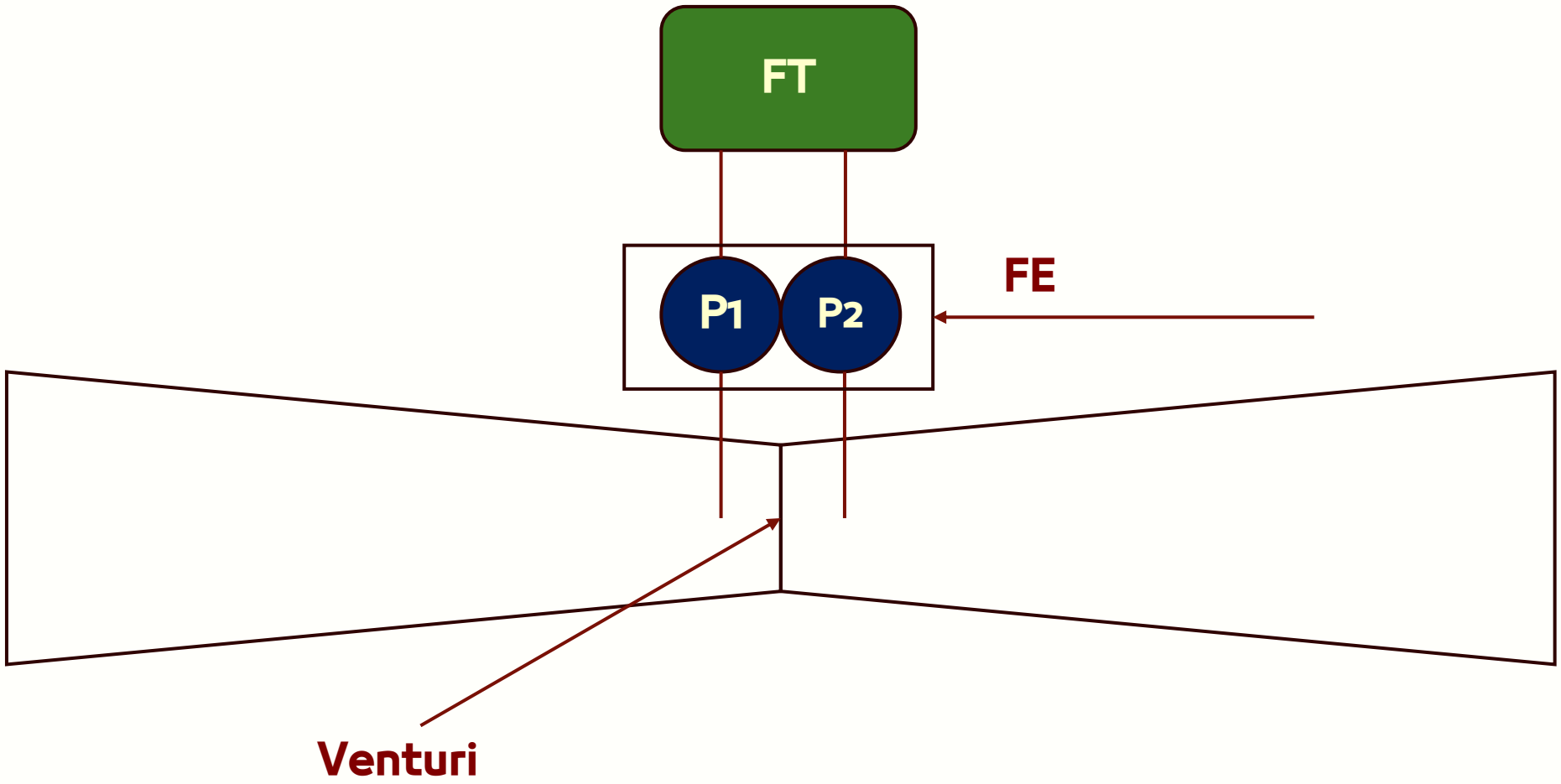


Table of Contents





Flow Measurement


FT
P1
P2
FE
Venturi

Flow Measurement

Fluid Flow in Industrial Processes

- Fluids flow through pipes, valves, pumps, and vessels.
- **Importance of Flow Rate Control**
  - Critical for the operation of the unit.
  - Essential for continuous chemical reactions to ensure proper proportions of reactants.
  - Necessary for accurate control of feed rates and product rates for economic reasons.

Flow Measurement and Control

- **Flow Measurements**
  - Can be taken by various types of flow meters.
- **Flow Control**
  - Typically requires a flow transmitter to accurately monitor and control the process flow.



Flow Measurement

Flow Meters Using Differential Pressure

- **Examples:** Orifice plate meters, venturi meters.

Measurement Principle

- Flow rate is related to pressure differences inside the pipe.
- **Flow-Restrictive Devices:**
  - **Orifice plates.**
  - **Venturi tubes.**
  - **Flow nozzles.**

Operation

- Fluid flow encounters a restriction in the pipe.
- Pressure increases in front of the restriction.
- Fluid velocity increases through the restriction.
- Pressure drops on the other side of the restriction.





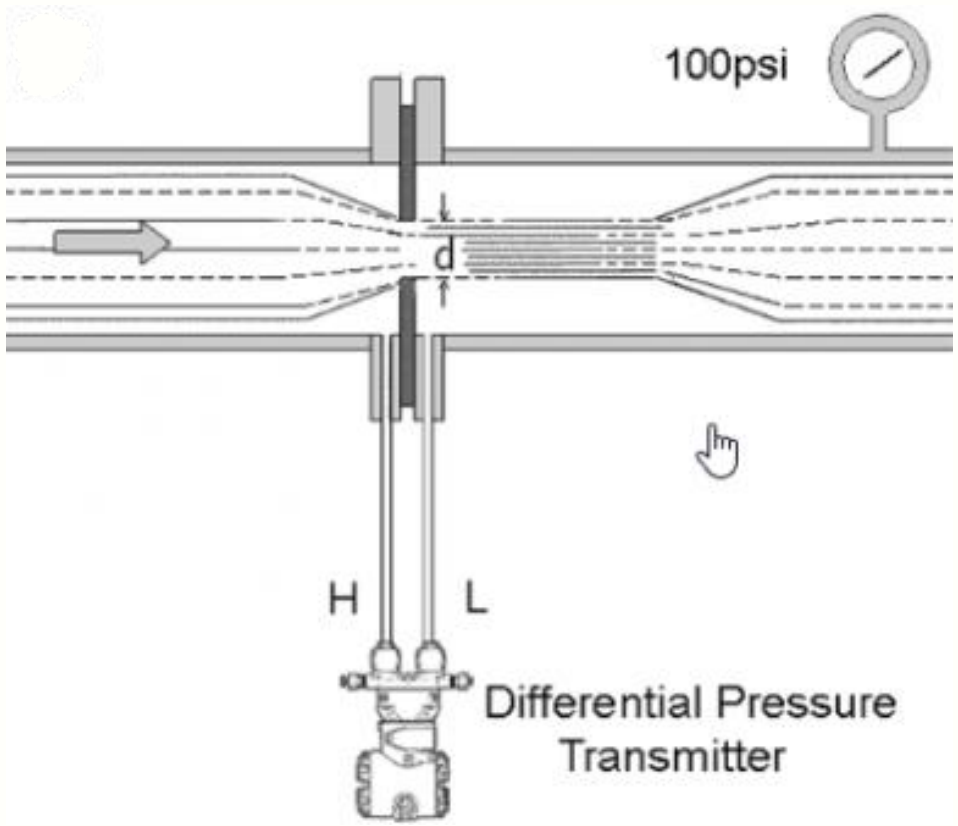
Differential Pressure (DP) Cell

Differential Pressure (DP) Cell

- Measures the pressure difference between the inlet and outlet sides of a restrictive device.
- Connected to a transmitter.

Operation

- **Transmitter:**
  - Sends a signal to a controller.
- **Controller:**
  - Compares the signal from the field with the flow rate set point.
  - Sends signals to control valves to open or close accordingly.



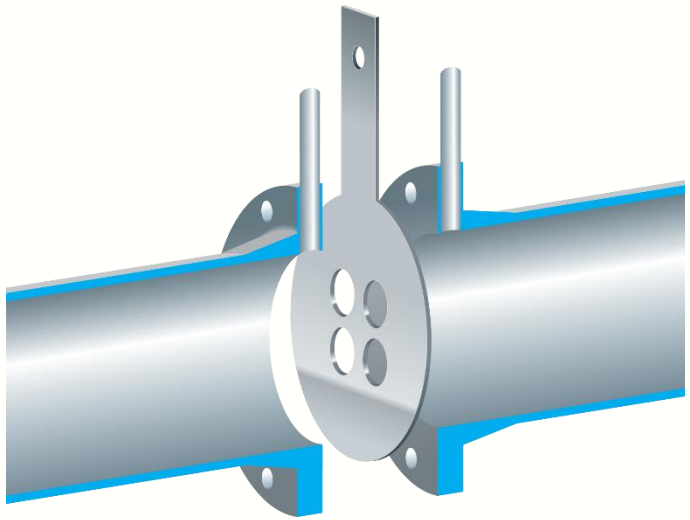
Types of Flowmeter

Orifice Plates	Venturi Tubes	Flow Nozzles	Positive Displacement Meters
Rotameter	Turbine Flow Meter	Weir and Flume Flow-Measuring Devices	Magnetic Flow Meters
Ultrasonic Flow Meters	Vortex Flow Meters	Thermal Flow Meters	The Coriolis Meter

Orifice Plates

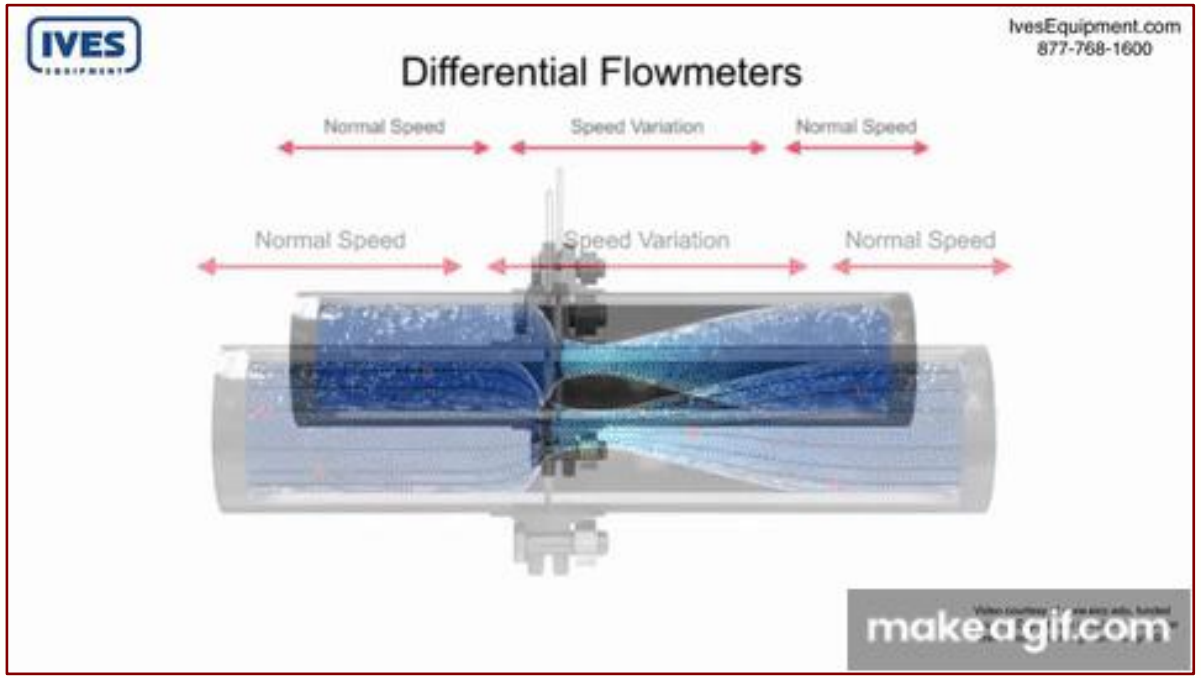


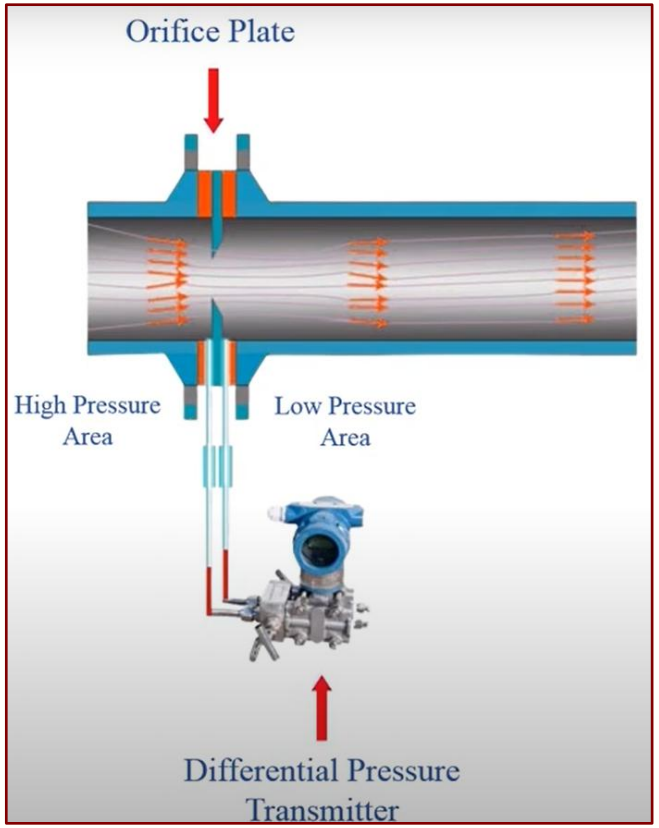




- Orifice plates.
- Venturi tubes.
- Flow nozzles.
- Positive Displacement Meters
- Rotameter
- Turbine Flow Meter
- Weir and Flume Flow-Measuring Devices
- Magnetic Flow Meters
- Ultrasonic Flow Meters
- Vortex Flow Meters
- Thermal Flow Meters
- The Coriolis Meter

Orifice Plates





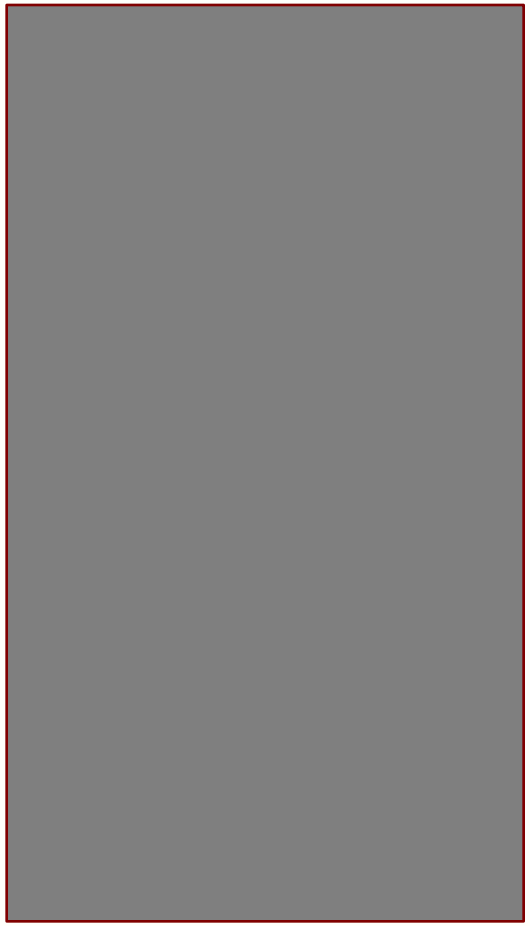
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- Magnetic Flow Meters
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- Thermal Flow Meters
- The Coriolis Meter

Venturi Tubes

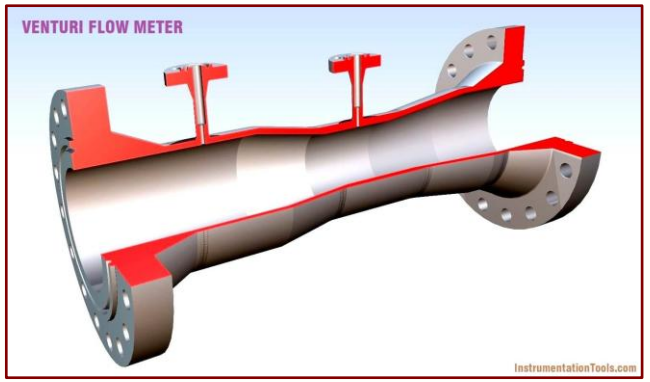


- Orifice plates.
- Venturi tubes.
- Flow nozzles.
- Positive Displacement Meters
- Rotameter
- Turbine Flow Meter
- Weir and Flume Flow-Measuring Devices
- Magnetic Flow Meters
- Ultrasonic Flow Meters
- Vortex Flow Meters
- Thermal Flow Meters
- The Coriolis Meter

Venturi Tubes



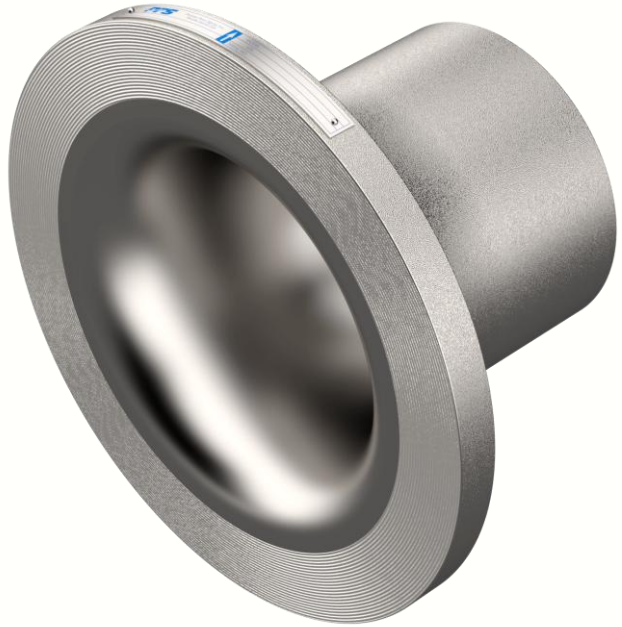


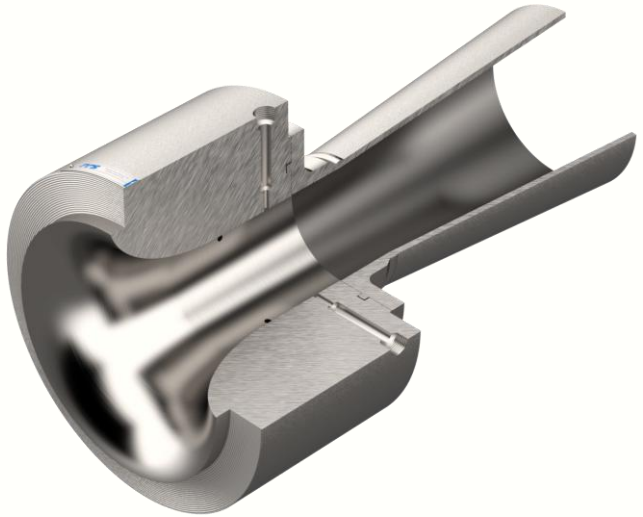




- Orifice plates.
- Venturi tubes.
- Flow nozzles.
- Positive Displacement Meters
- Rotameter
- Turbine Flow Meter
- Weir and Flume Flow-Measuring Devices
- Magnetic Flow Meters
- Ultrasonic Flow Meters
- Vortex Flow Meters
- Thermal Flow Meters
- The Coriolis Meter

Flow Nozzles





- Orifice plates.
- Venturi tubes.
- Flow nozzles.
- Positive Displacement Meters
- Rotameter
- Turbine Flow Meter
- Weir and Flume Flow-Measuring Devices
- Magnetic Flow Meters
- Ultrasonic Flow Meters
- Vortex Flow Meters
- Thermal Flow Meters
- The Coriolis Meter

Positive Displacement Meters

Types of Positive Displacement Meters

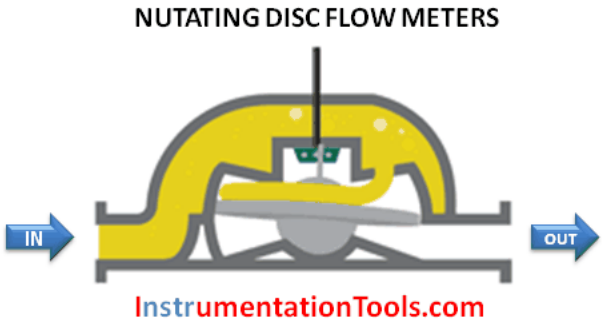
- Nutating disc meter.
- Oval gear meter.

Nutating Disc Meter

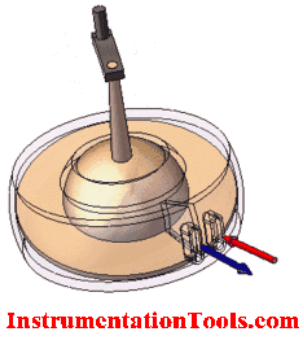
- Components:
  - Counter.
  - Nutating disc (resembles a spinning top).
  - Flow inlet.
  - Flow outlet.

Operation

- Measures fluid flow by counting the rotations of the disc as fluid passes through it.

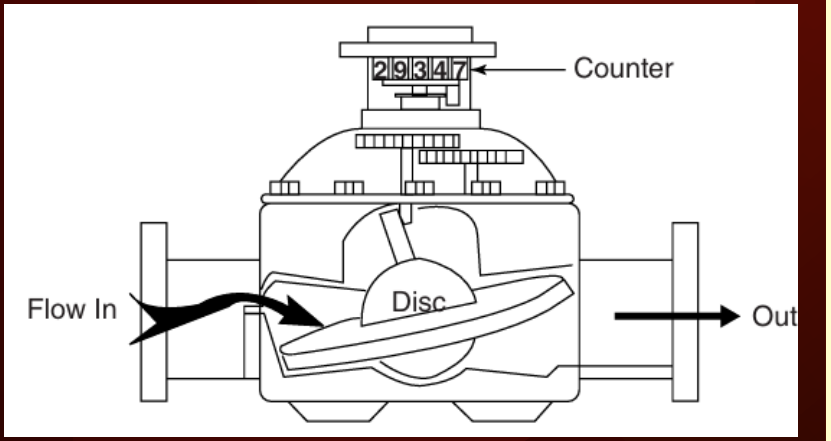


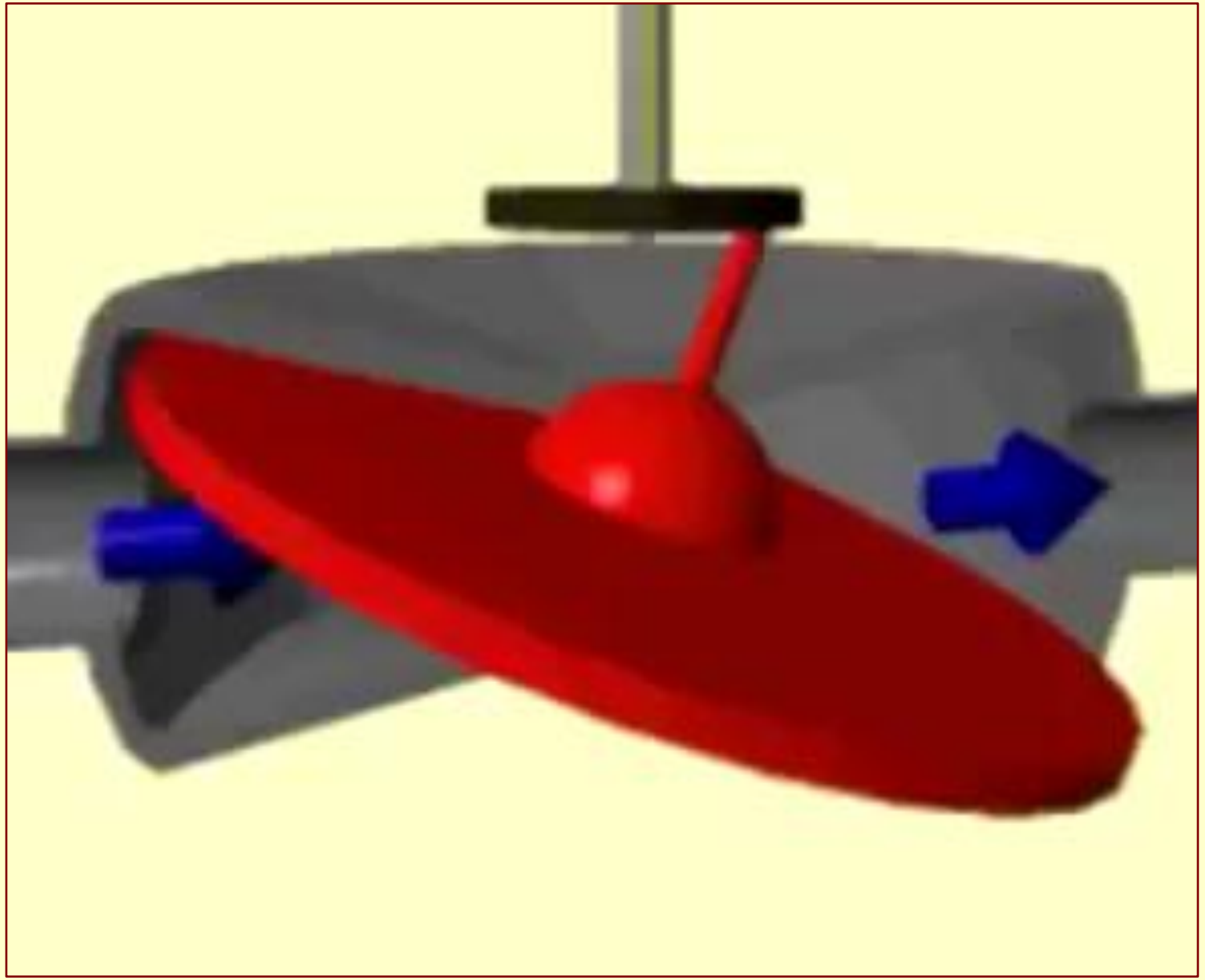




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The Coriolis Meter

Positive Displacement Meters





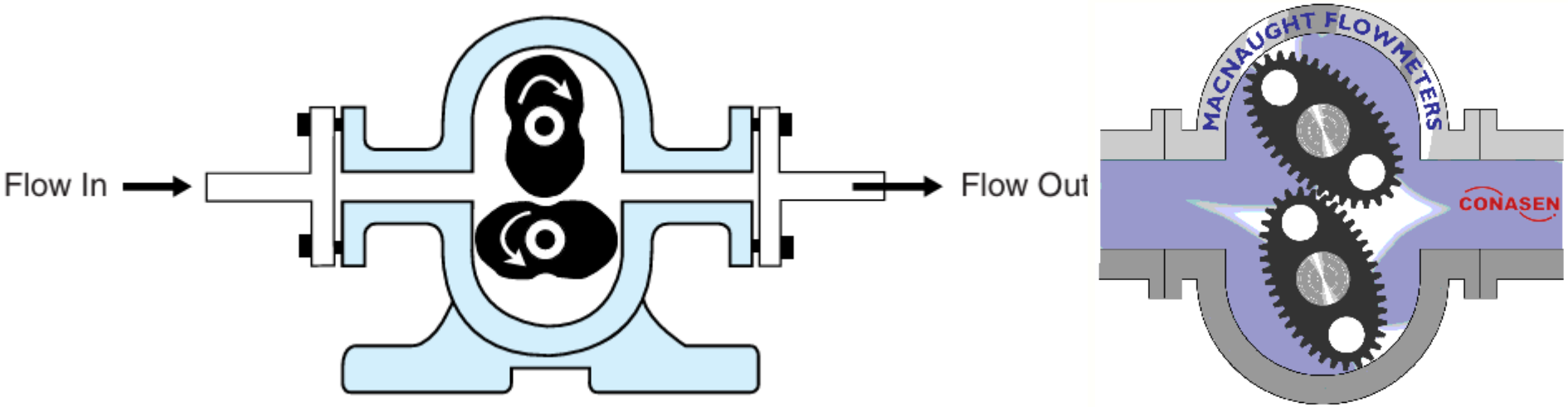
Positive Displacement Meters

Oval Gear Meter

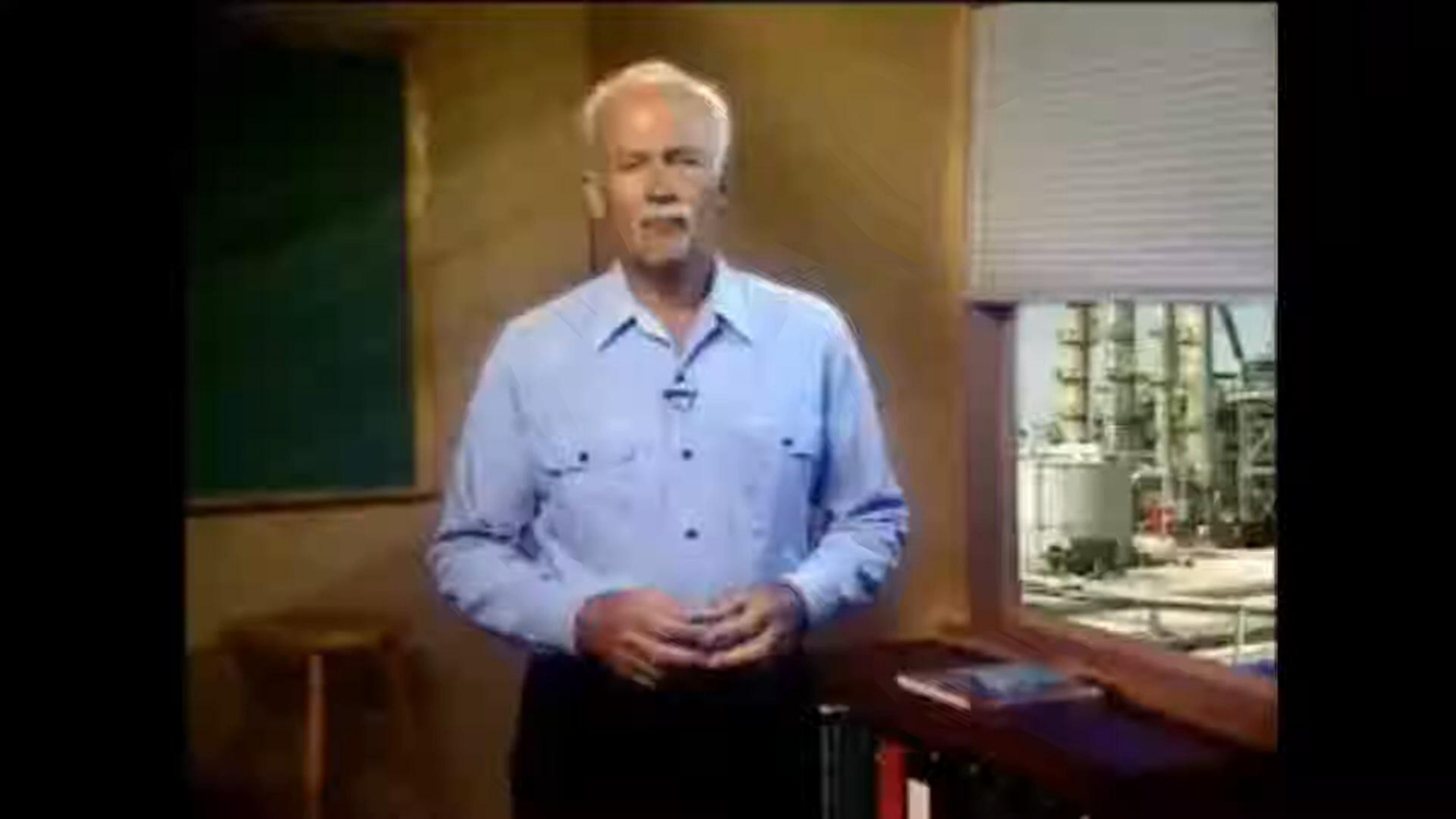
- Internal structure resembles that of a lobe pump.

Operation

- Lobe-shaped elements rotate as fluid passes through the internal chamber.
- The rotation of the gears is used to calculate the total flow rate.



Orifice plates.
Venturi tubes.
Flow nozzles.
Positive Displacement Meters
Rotameter
Turbine Flow Meter
Weir and Flume Flow-Measuring Devices
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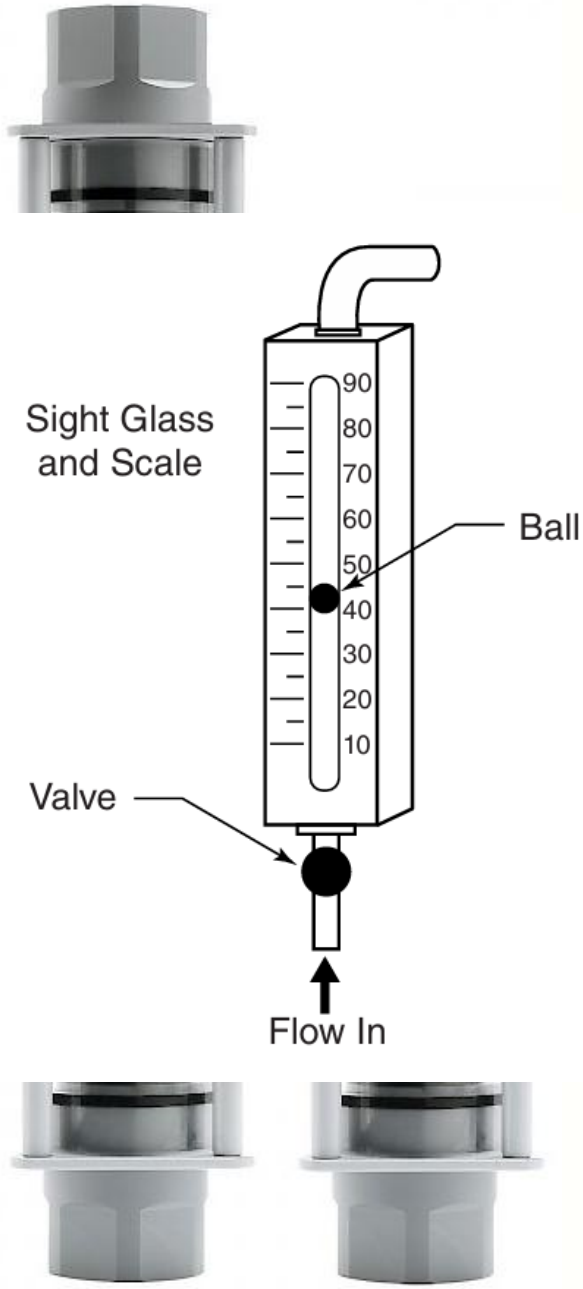
Rotameter

Rotameter

- Components:
  - Tapered tube.
  - Scale.
  - Ball or float.
  - Inlet and outlet.

Operation

- Flow enters the tapered tube at the bottom.
- Flow lifts the ball off its seat.
- The ball provides a constant restriction to the flow.
- The position of the ball corresponds to the flow rate on the scale.
- Higher flow rate causes the ball to rise higher in the tube.
- Fluid flows around the ball and exits at the top.

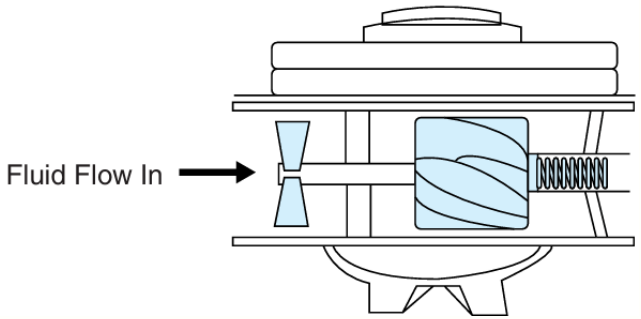


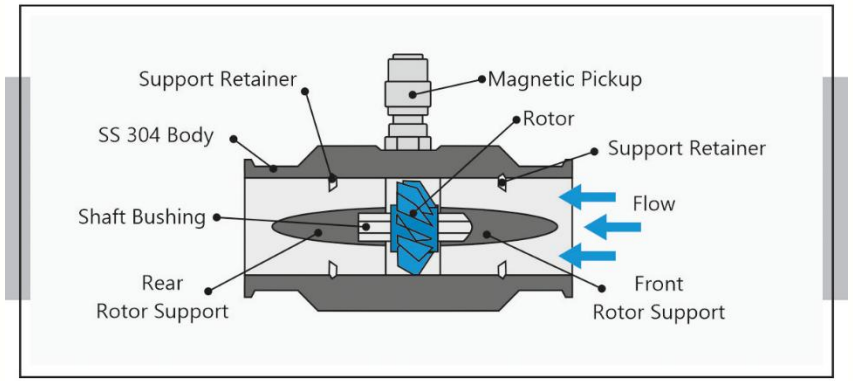
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The Coriolis Meter


KINEMASTER

Turbine Flow Meter

Turbine Flow Meters	Operation	Key Concepts	Characteristics
•Components: •Section of pipe with a rotor mounted inside. •Sensor on the outside of the pipe.	•Fluid enters the turbine flow meter. •Turbine blades begin to rotate. •Speed of rotation is proportional to the velocity of the fluid.	**•Flow Velocity:** •Actual speed of the fluid. •Measured as distance per unit time (e.g., feet per second). **•Flow Rate:** •Total quantity of liquid passing a specific point. •Measured as volume per unit time (e.g., gallons per minute).	•Accurate over a wide range of flows.



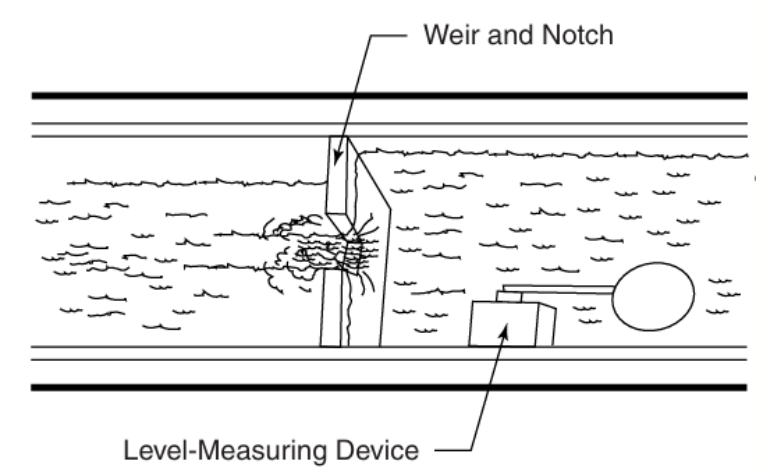


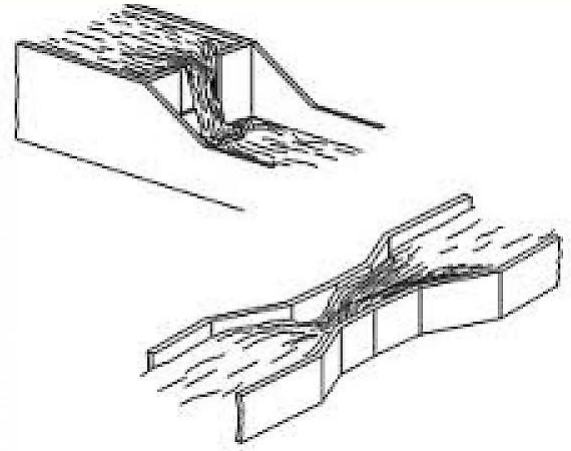
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The Coriolis Meter

Weir and Flume Flow-Measuring Devices

Weir (a dam)
• Placed in a process stream. • Creates a restriction that forces the liquid level to build. • Level is used to calculate flow rate. • Direct correlation: Lower level equals slower flow.

Flumes
• Used for higher flows. • Narrow, sloping pass that funnels flow. • At the inlet, the water level rises. • Level is measured by a level-measuring instrument. • Instrument converts the level to a flow signal.





Orifice plates.

Venturi tubes.

Flow nozzles.

Positive Displacement Meters

Rotameter

Turbine Flow Meter

Weir and Flume Flow-Measuring Devices

Magnetic Flow Meters

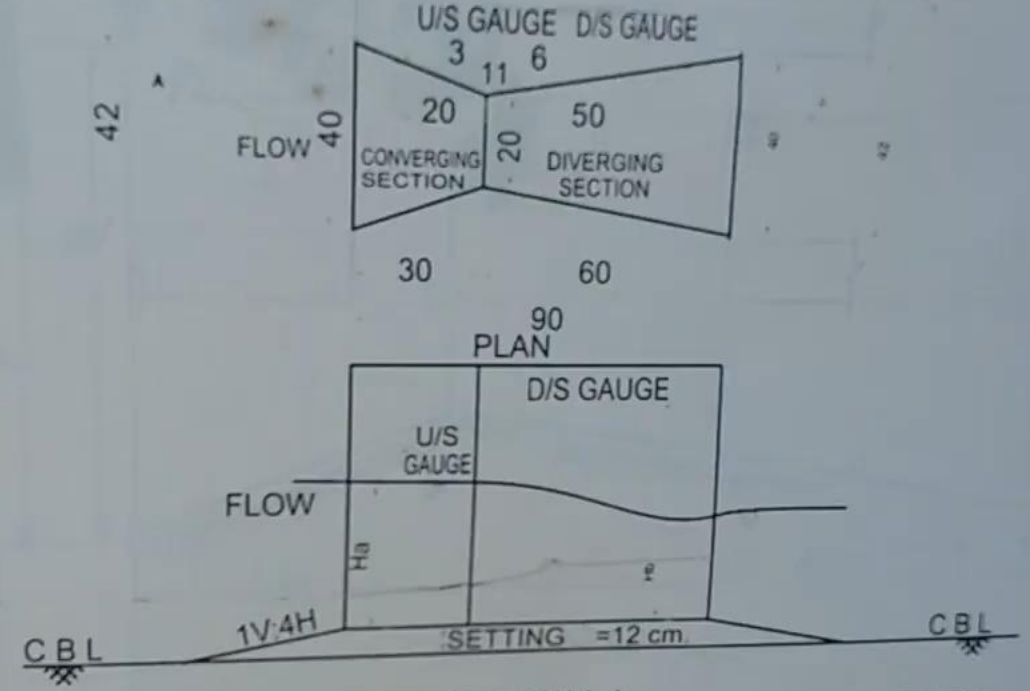
Ultrasonic Flow Meters

Vortex Flow Meters

Thermal Flow Meters

The Coriolis Meter

जल व भूमि व्यवस्थापन संस्था



SECTION A-A

OPERATING LIMIT

$\frac{Ha}{L}$ 0.40

Ha 36 cm.

(For 90 cm LENGTH)

FREE FLOW CONDITION

TRANSITION SUBMERGENCE (St)

$\frac{Hb}{Ha}$ 0.653

CUT THROAT FLUME

(20 cm x 90 cm)

FREE FLOW
DISCHARGE TABLE

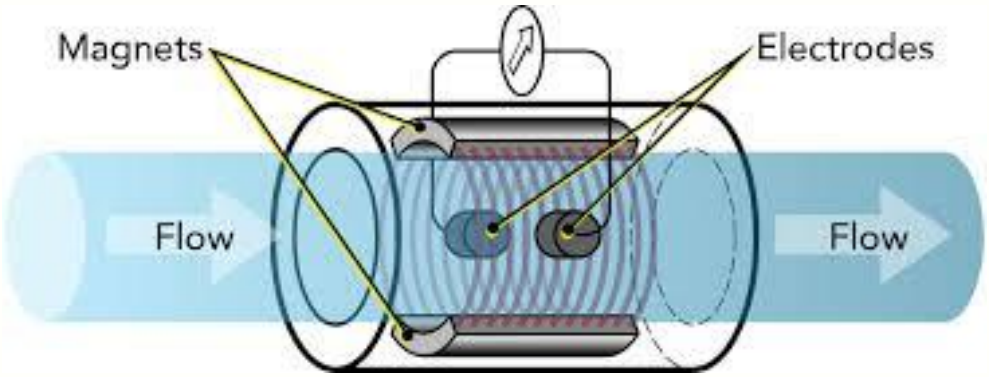
Ha in cm	Discharge (Q) Lit/Sec
10.0	10.7
11.0	12.8
12.0	15.0
13.0	17.4
14.0	19.9
15.0	22.6
16.0	25.5
17.0	28.5
18.0	31.7
19.0	35.0
20.0	38.5
21.0	42.1
22.0	45.9
23.0	49.8
24.0	53.9
25.0	58.1

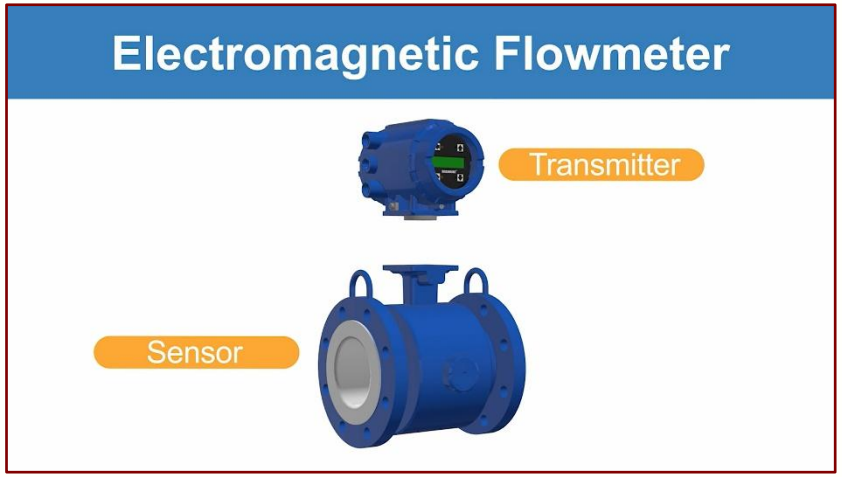
NOTE:- ALL DIMENSION ARE IN CM.

Magnetic Flow Meters

Magnetic Flow Meters

- Measure flow velocity based on the voltage created by fluid flowing through a magnetic field.
- Highly effective for toxic or corrosive fluids.
- Fluid stream does not contact the measurement device.

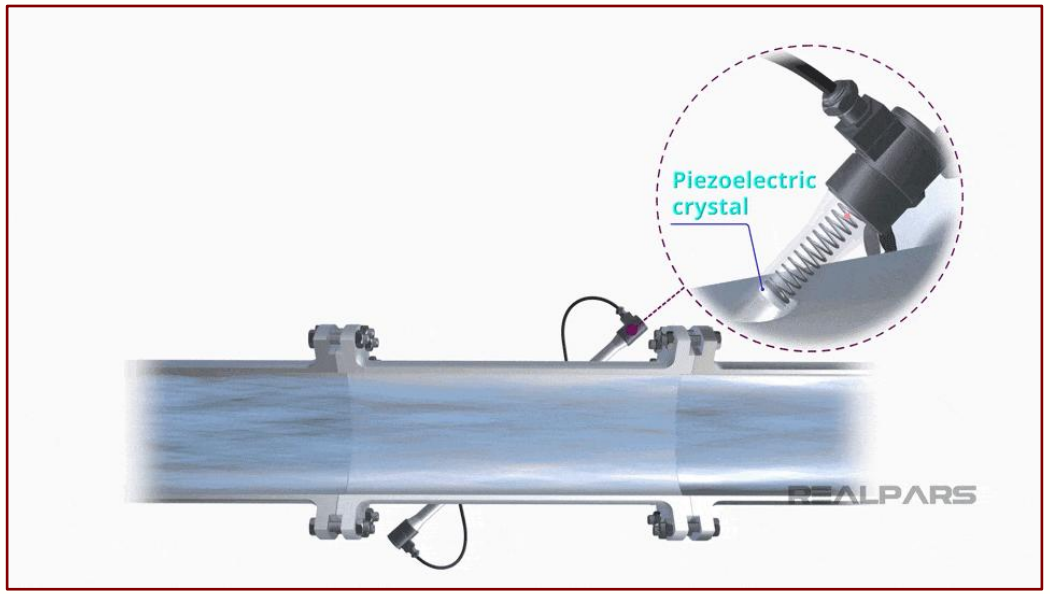




Orifice plates.
Venturi tubes.
Flow nozzles.
Positive Displacement Meters
Rotameter
Turbine Flow Meter
Weir and Flume Flow-Measuring Devices
Magnetic Flow Meters
Ultrasonic Flow Meters
Vortex Flow Meters
Thermal Flow Meters
The Coriolis Meter

Ultrasonic Flow Meters

Ultrasonic Flow Meters
• Measure flow rate based on the Doppler effect. • A sound wave is transmitted to the fluid at a certain frequency. • The frequency of the returned sound wave varies with the fluid velocity. • Not suitable for clean fluids, as they require particles to reflect the sound wave.





Orifice plates.

Venturi tubes.

Flow nozzles.

Positive Displacement Meters

Rotameter

Turbine Flow Meter

Weir and Flume Flow-Measuring Devices

Magnetic Flow Meters

Ultrasonic Flow Meters

Vortex Flow Meters

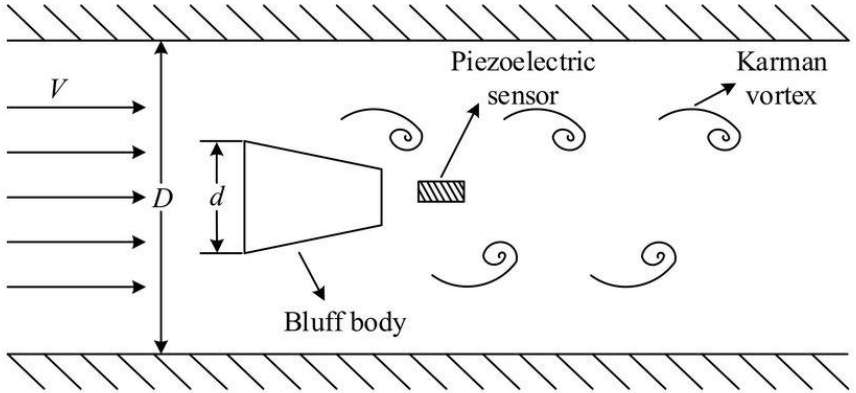
Thermal Flow Meters

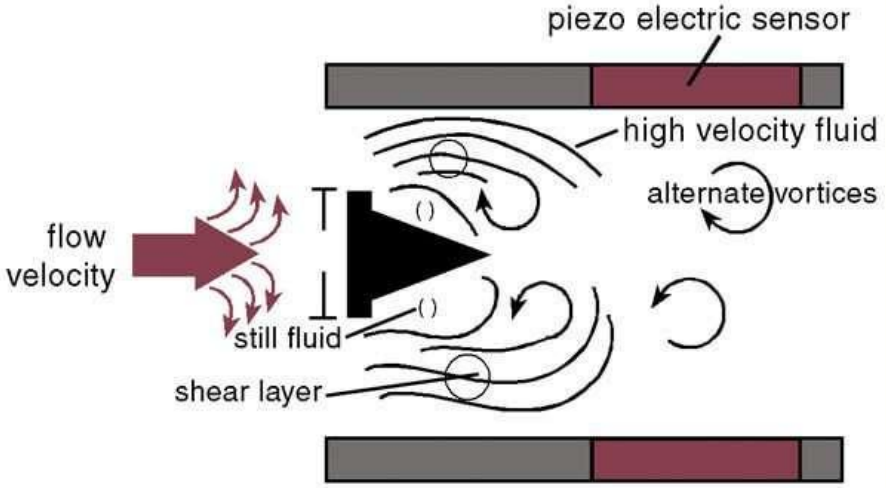
The Coriolis Meter

Vortex Flow Meters

Vortex Flow Meters

- Measure flow rate by creating and measuring vortices in a flow stream.
- Vortices are created by a blunt object in the flow path called a strut bar.





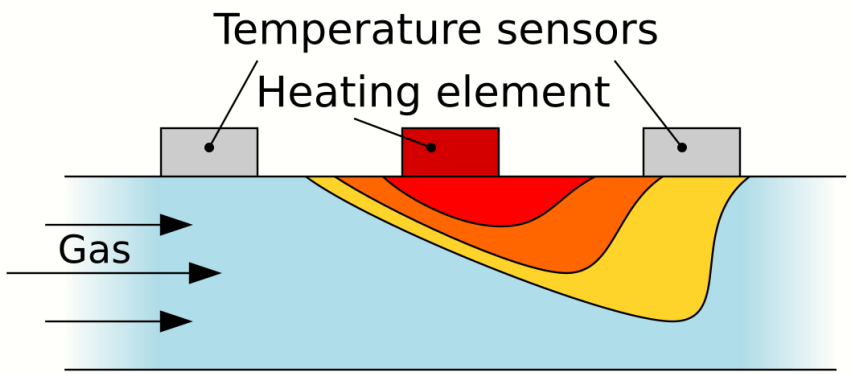
Orifice plates.
Venturi tubes.
Flow nozzles.
Positive Displacement Meters
Rotameter
Turbine Flow Meter
Weir and Flume Flow-Measuring Devices
Magnetic Flow Meters
Ultrasonic Flow Meters
Vortex Flow Meters
Thermal Flow Meters
The Coriolis Meter

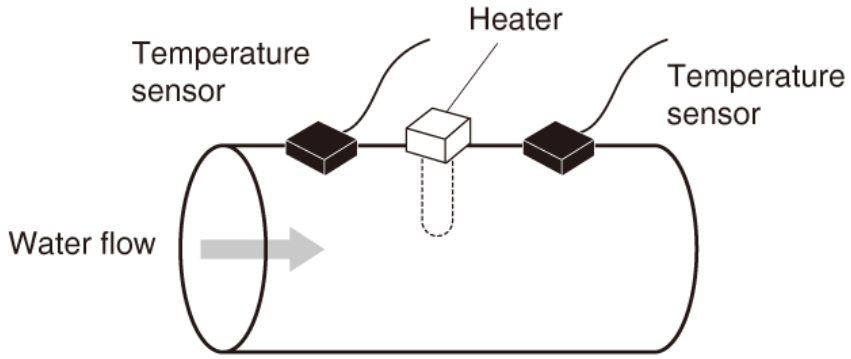


Thermal Flow Meters

Thermal Flow Meters

- Measure flow rate based on changes in resistance due to changes in temperature.
- Thermistors are used to measure the change in resistance.
- Sensitive to the thermal conductivity of the fluid.
- Usually designed for a specific flowing material.

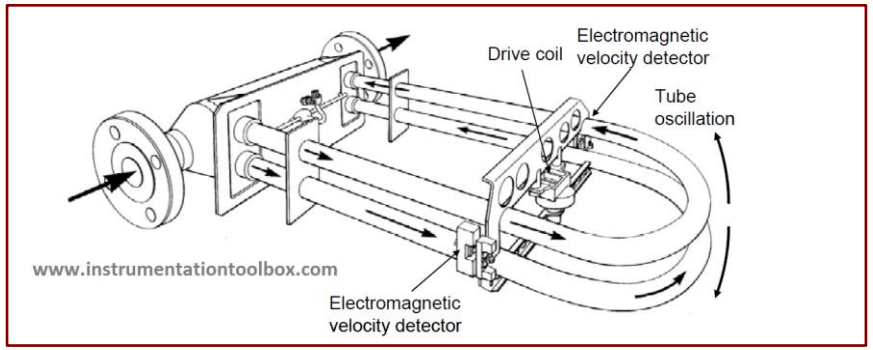




Orifice plates.
Venturi tubes.
Flow nozzles.
Positive Displacement Meters
Rotameter
Turbine Flow Meter
Weir and Flume Flow-Measuring Devices
Magnetic Flow Meters
Ultrasonic Flow Meters
Vortex Flow Meters
Thermal Flow Meters
The Coriolis Meter

The Coriolis Meter

Coriolis Meter
• A true mass flow meter. • Uses a vibrating U-tube to measure changes in momentum (mass flow rate). • Very effective for precise measurements of mass flow rate.









Orifice plates.
Venturi tubes.
Flow nozzles.
Positive Displacement Meters
Rotameter
Turbine Flow Meter
Weir and Flume Flow-Measuring Devices
Magnetic Flow Meters
Ultrasonic Flow Meters
Vortex Flow Meters
Thermal Flow Meters
The Coriolis Meter

Flow Control Loop

Flow Control Loops

- Measurement of flow rate is taken first.
- Flow is then interrupted or controlled downstream.
- Start at the primary element:
  - **Types:** orifice plate, venturi tube, flow nozzle, nutating disc, oval gear, turbine meter.
  - Most common: orifice plate.
  - **Orifice plates** create a pressure differential measured by a DP transmitter.
  - Primary elements typically used with a transmitter.
- Increased velocity across the orifice plate compensates for restriction.
- Transmitted signal is sent to a controller.
- Controller compares incoming signal with desired set point.
- If change is required, controller sends signal to a final control element.

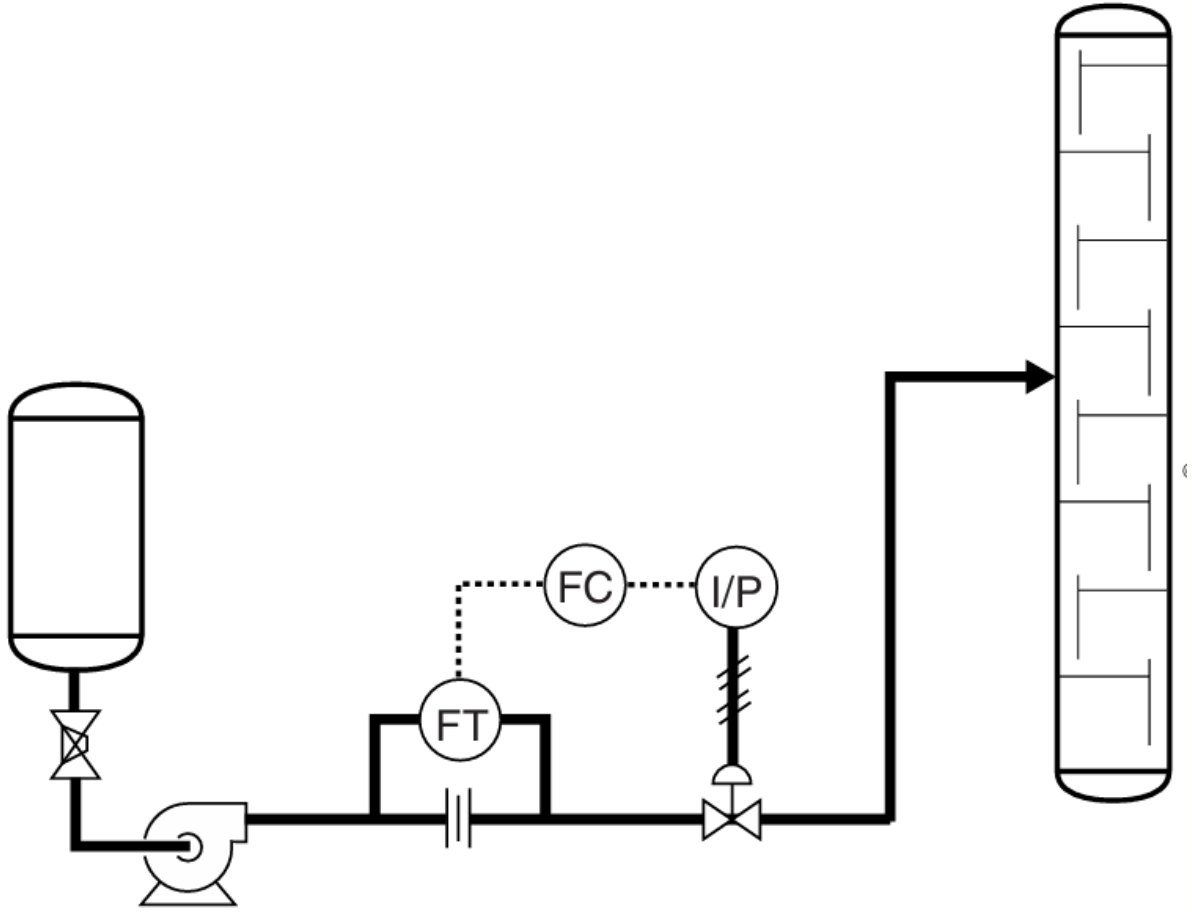
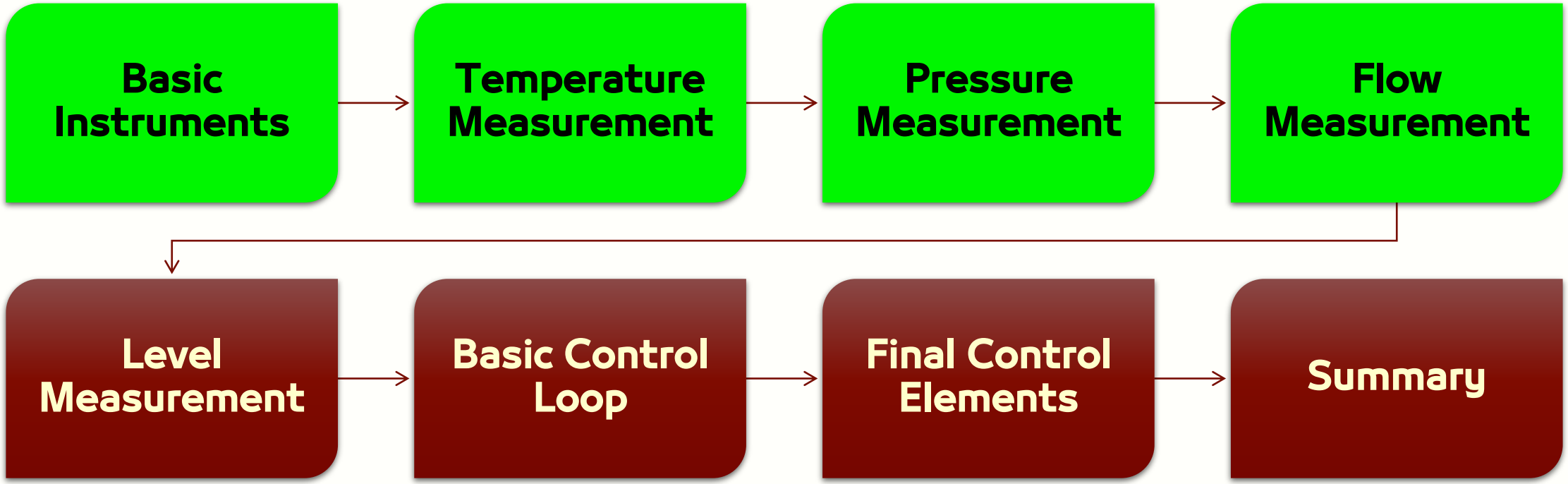
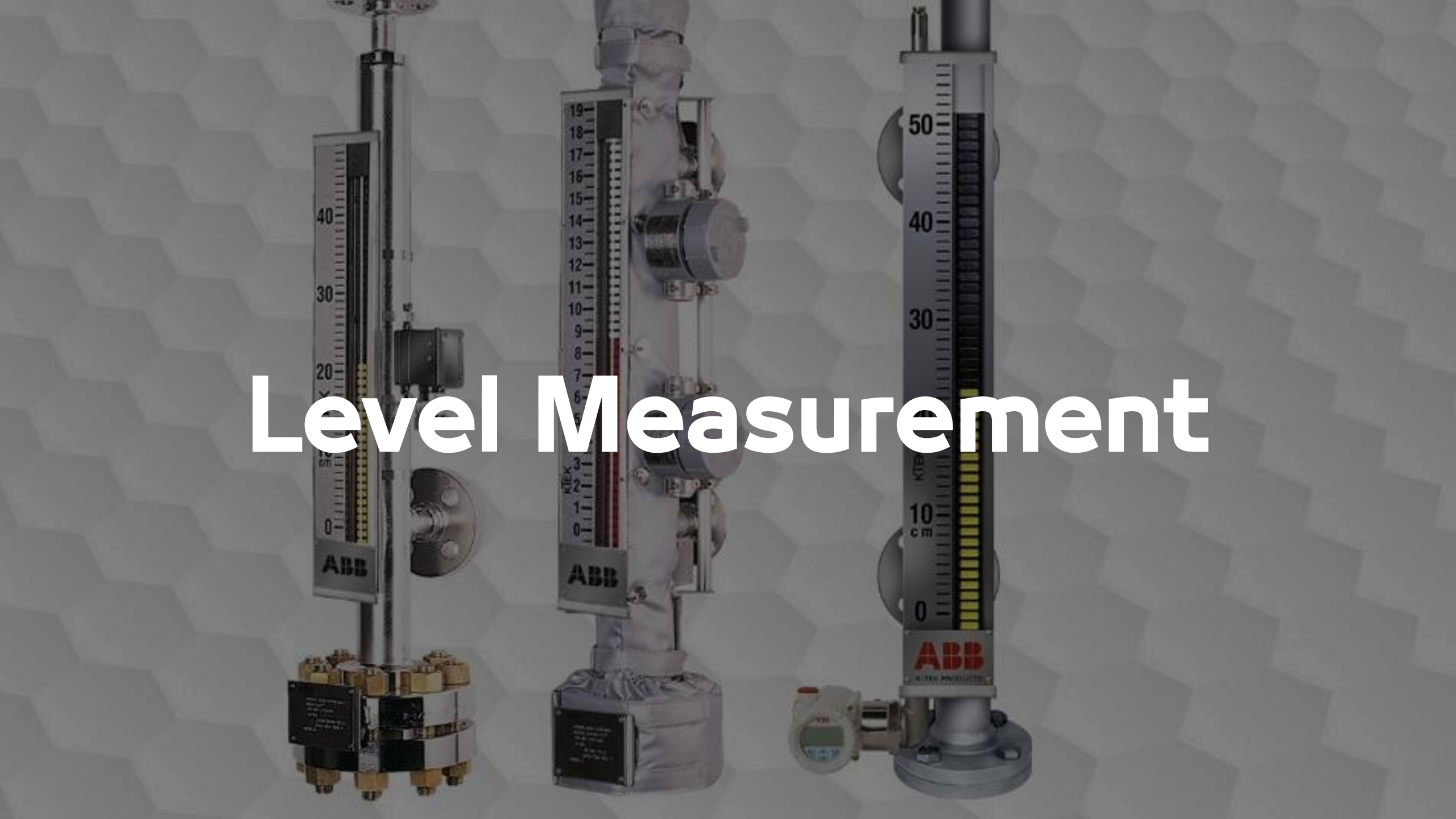


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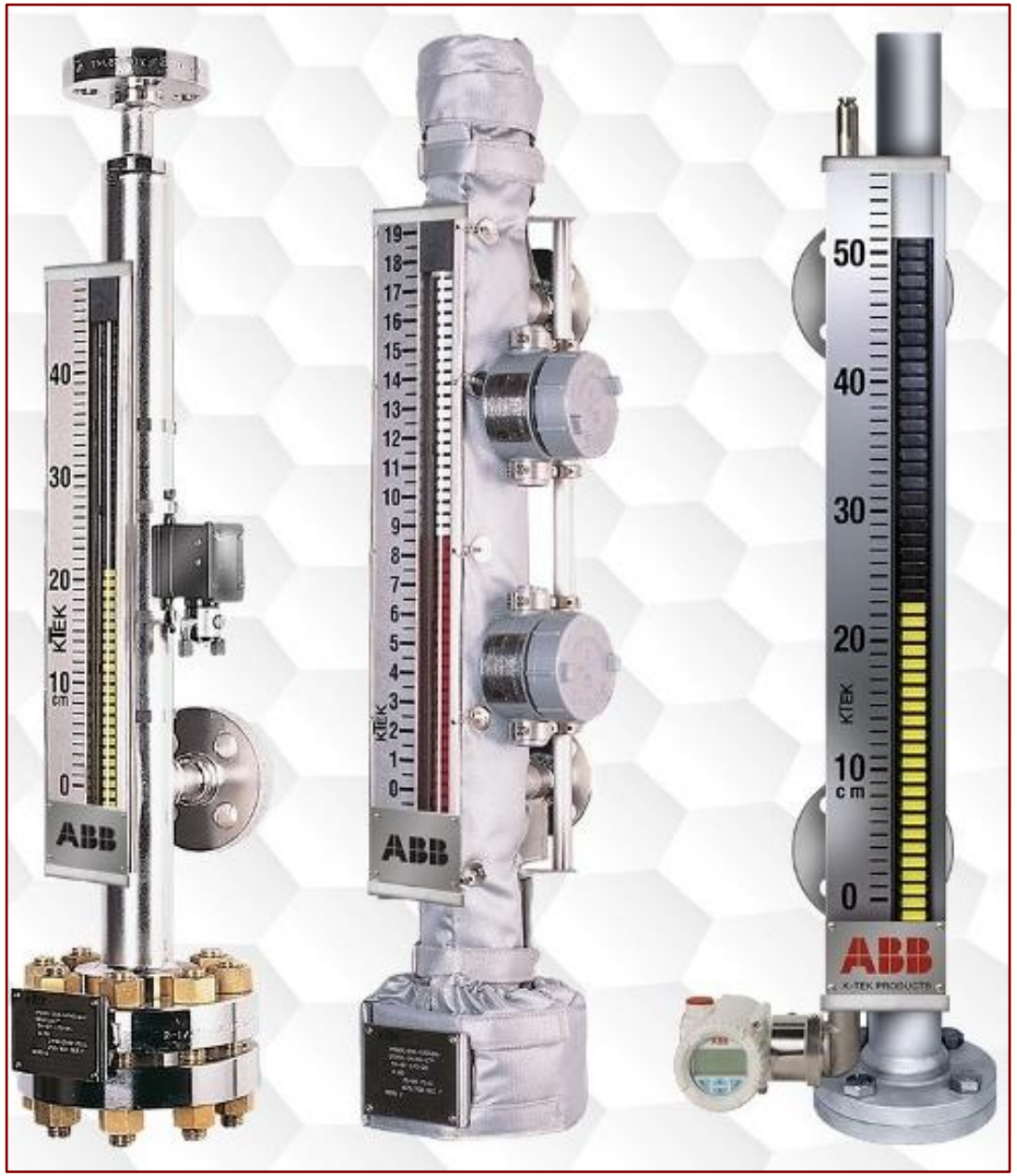


Level Measurement

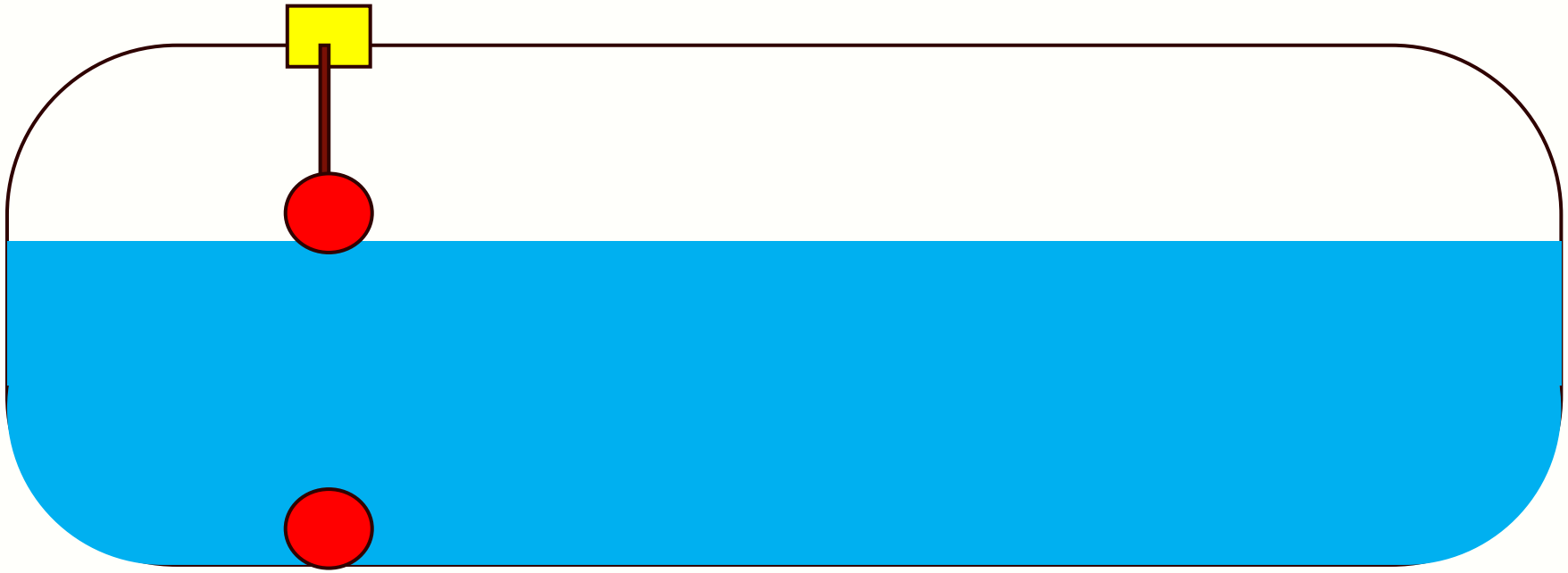
Level Measurement

Level Measurements in Process Control

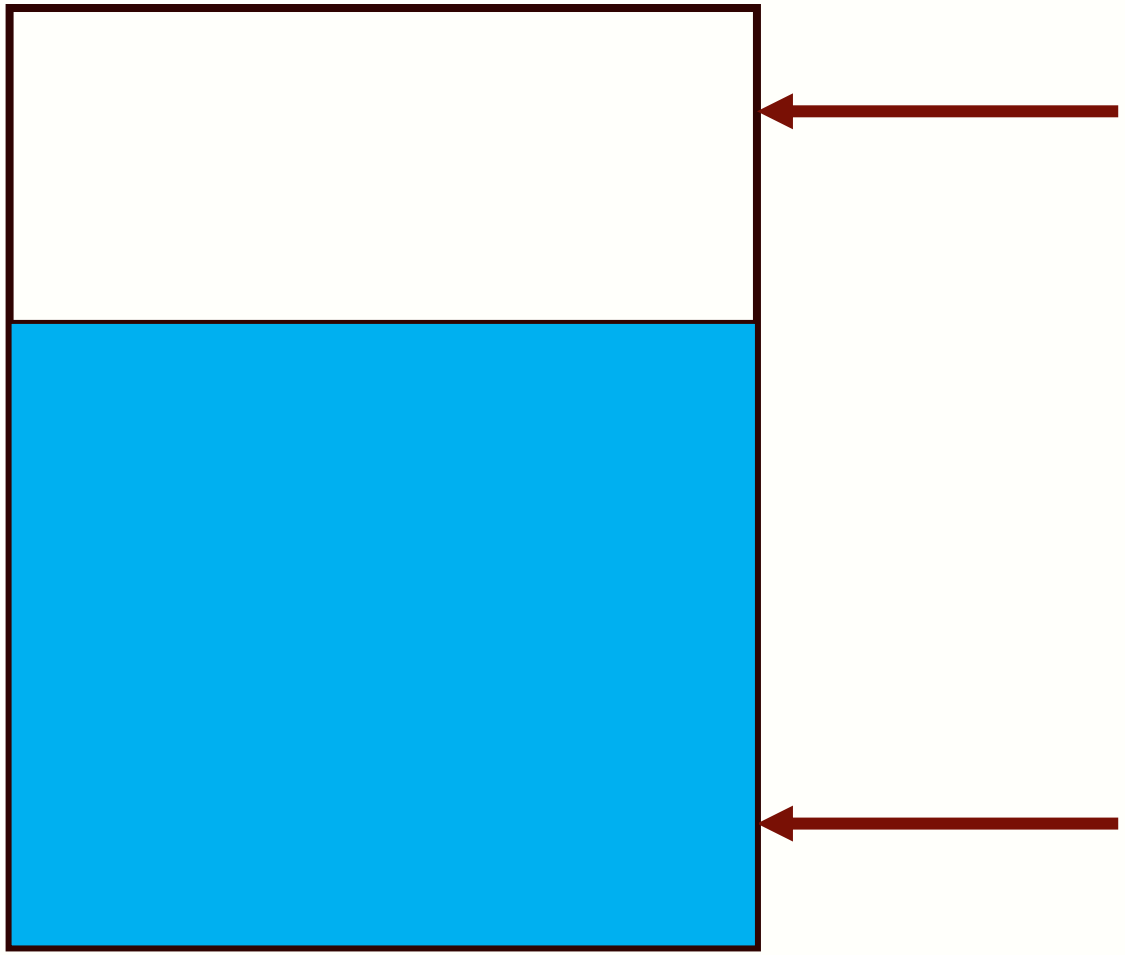
- Fixed reference points used, typically vessel taps.
  - Lowermost tap: zero level.
  - Uppermost tap: 100%.
- Level readings and control are crucial for modern processing.
- **Types of Level Measurements:**
  - **Continuous Measurements:**
    - Levels are monitored continuously.
  - **Single-Point Measurements:**
    - Readings taken from a single point or multiple points on a vessel.
    - Used to turn equipment on/off (e.g., valves, pumps, compressors, motors, alarms).
    - Detect high and low process levels.
- **Classification of Level Measurement Devices:**
  - **Direct Measurements:**
    - Measure the actual level of the substance.
  - **Indirect Measurements:**
    - Measure other parameters to infer the level of the substance.



Lower Tap and Upper Tap



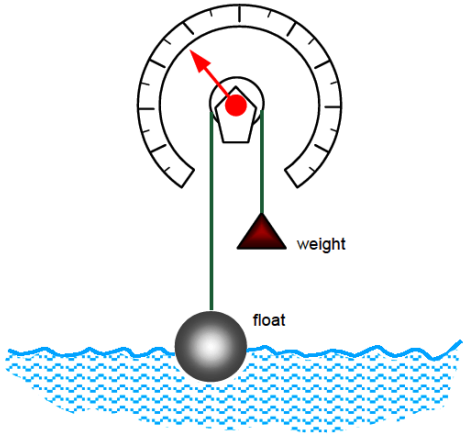
Single Point & Continuous



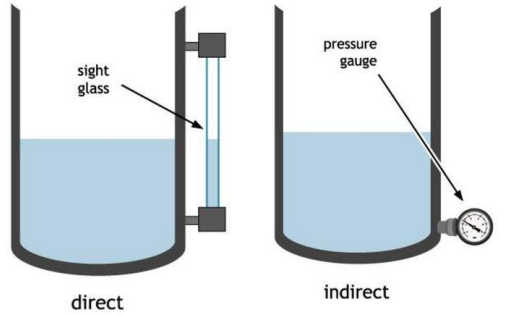
Direct Level-Measurement Instruments

Direct Instrumentation

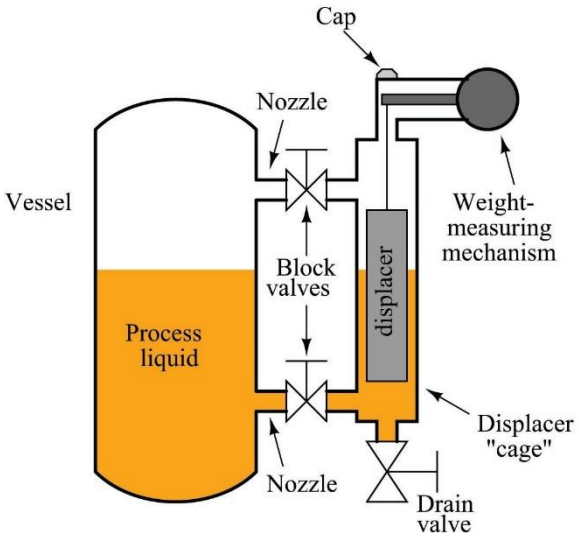
- Physical contact with the fluid surface.
- Calculate product surface level from a reference point.
- **Types of Direct Instruments:**
  - **Sight Glass:**
    - Transparent tube with graduated markings mounted on the side of a tank.
  - **Float and Tape Device:**
    - Float rests on the fluid surface; tape moves up and down with the level.
  - **Displacers:**
    - Buoyancy devices or weights linked to a transmitter to control flow.
  - **Probes:**
    - **Conductivity Probes:**
      - High- and low-level alarms using electricity to complete the circuit.
      - Designed to keep the level between high and low probes, typically for nonflammable materials.
    - **Capacitance Probes:**
      - Radiation devices or load cells.

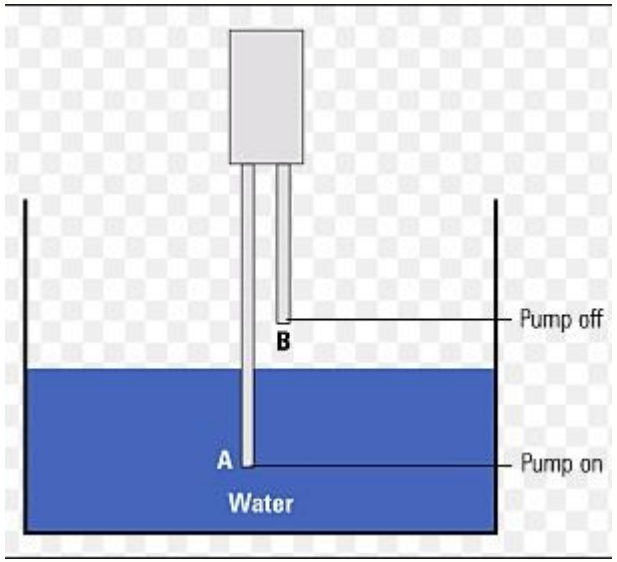


Direct and Indirect Level Measurement



Instrumentation I - Sess





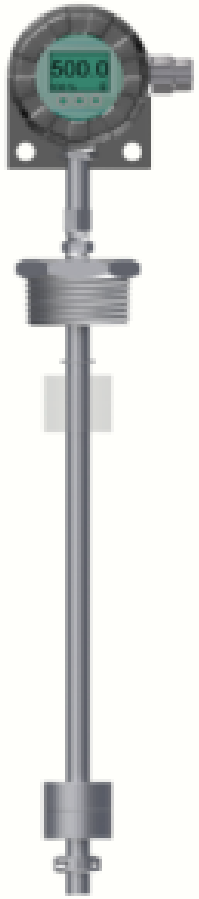
Float Type Level Indicator

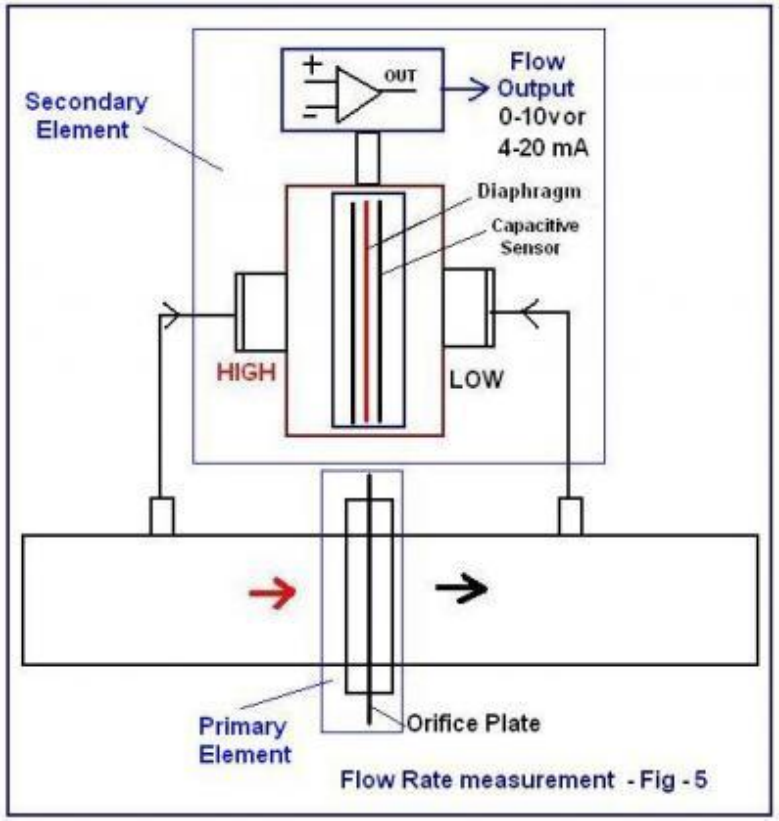

GILL
SENSORS

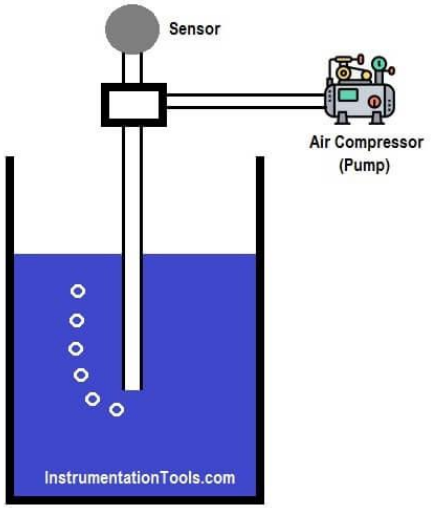
Indirect Instrumentation

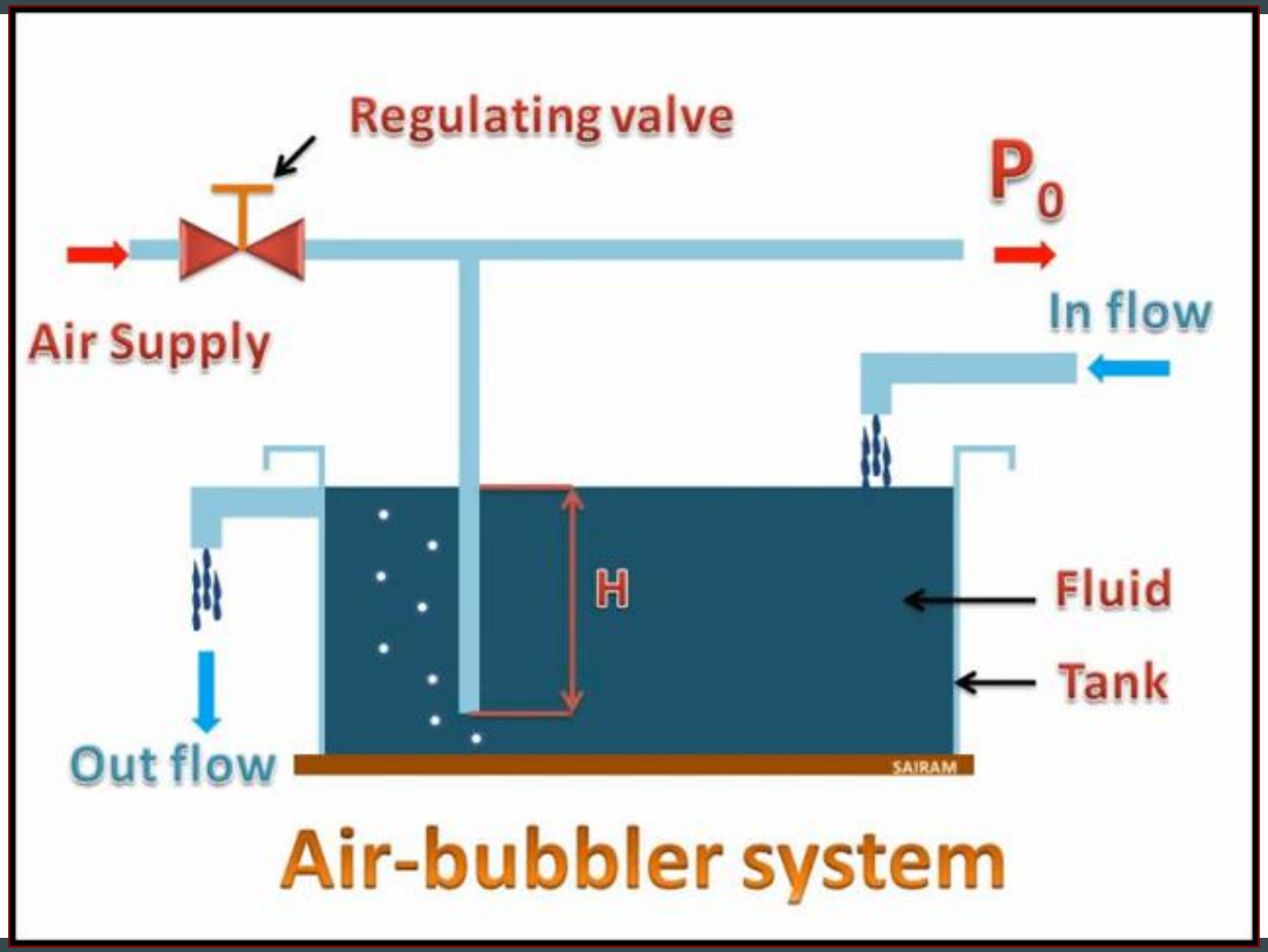
Indirect Instrumentation

- Utilizes pressure changes responding proportionally to level changes.
- **Types of Indirect Instruments:**
  - **DP (Differential Pressure) Cells:**
    - Convert pressure differences to level indication.
    - Measure hydrostatic pressure difference between two points on a pressurized vessel.
  - **Continuous Level Detector Gauge:**
    - Pressure-sensitive instrument.
    - Measures hydrostatic pressure in open vessels and converts it to a level indication.
  - **Bubbler System:**
    - Forces air through a tube positioned in the liquid.
    - The liquid's resistance to flow registers on a pressure-sensitive level gauge, converting the pressure to a level indication.
    - Used to measure levels in open vessels.








Regulating valve
P_0
Air Supply
In flow
H
Fluid
Tank
Out flow
SAIRAM
Air-bubbler system

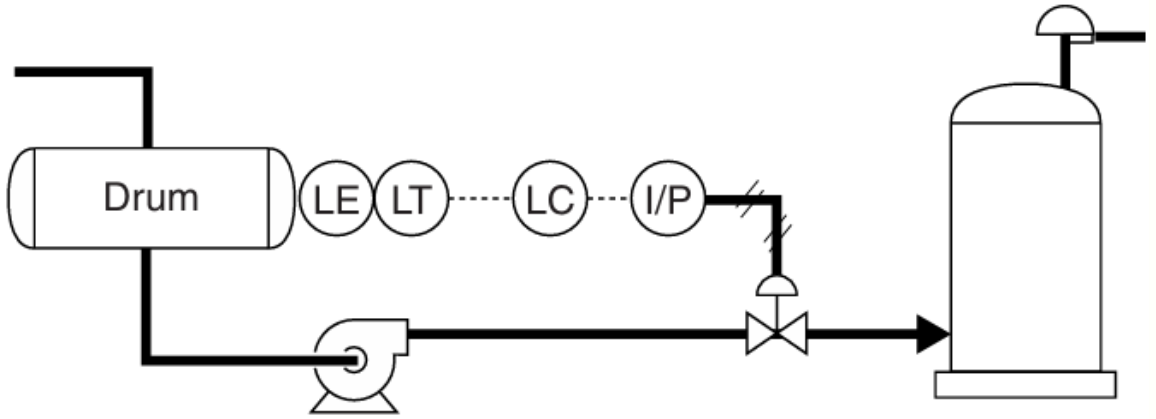
Level Control Loop

Level Control System Components:

- **Primary Element Sensing Device:**
  - Can be direct (floats, displacers) or indirect (differential pressure transmitters).
- **Level Transmitter (LT):**
  - Detects level changes.
  - In systems using a DP cell, the primary element or sensor is inside the transmitter.
- **Controller:**
  - Receives signals from the level transmitter.
- **Transducer:**
  - Converts the signal from the controller.
  - Opens or closes the control valve based on the signal.
- **Control Valve:**
  - Adjusts flow based on the converted signal to maintain desired level.

Figure:

- Uses a DP cell to detect level changes.
- The primary element or sensor is within the transmitter.
- These devices work together to send a signal to the level controller.
- The transducer converts the signal to operate the control valve.

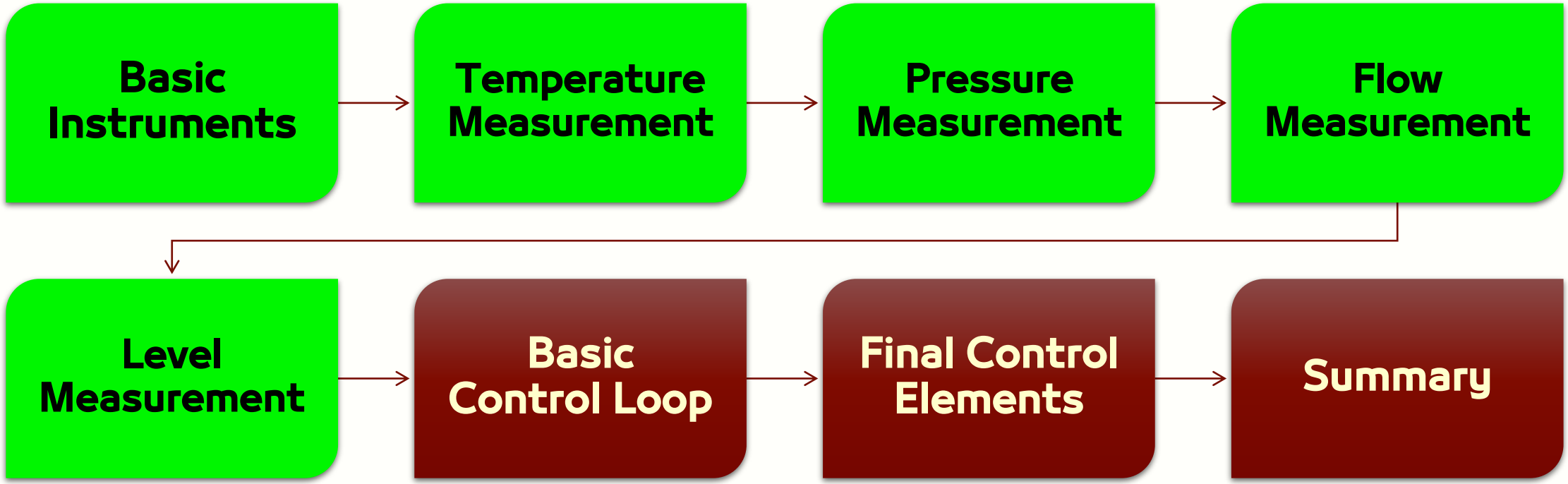


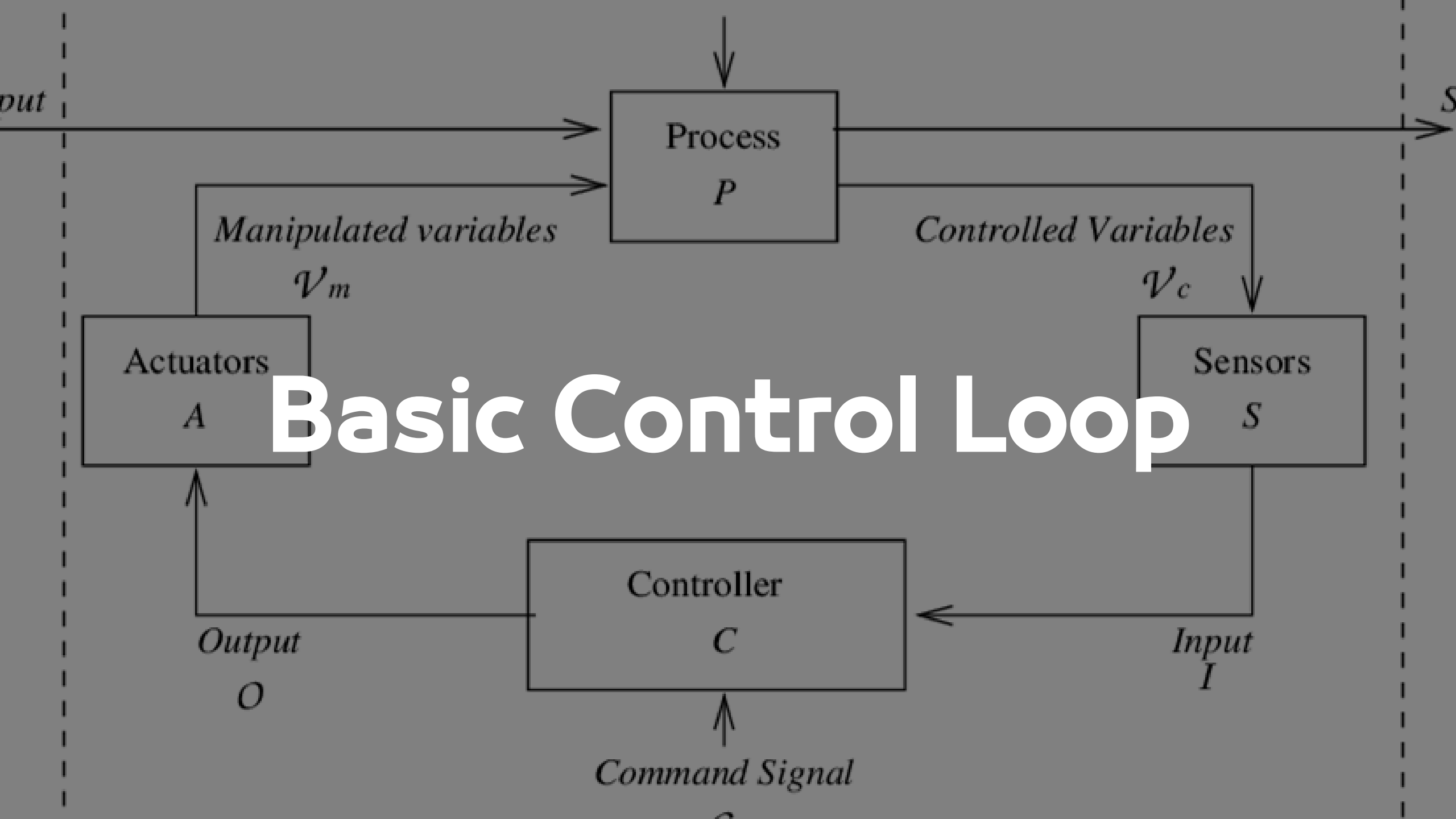
Measurements

Table 11.1 *Primary Elements and Sensors*

	Primary Element	Sensor
Flow	Orifice plate, flow nozzle, DP cell (diaphragm)	DP cell
Level	Float, displacer, DP cell (diaphragm)	DP cell
Pressure	Helix, spiral, bellows, bourdon tube, DP cell	DP cell
Temperature	Capillary tubing, thermal and resistance bulb	Thermocouple, RTD

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Basic Control Loop

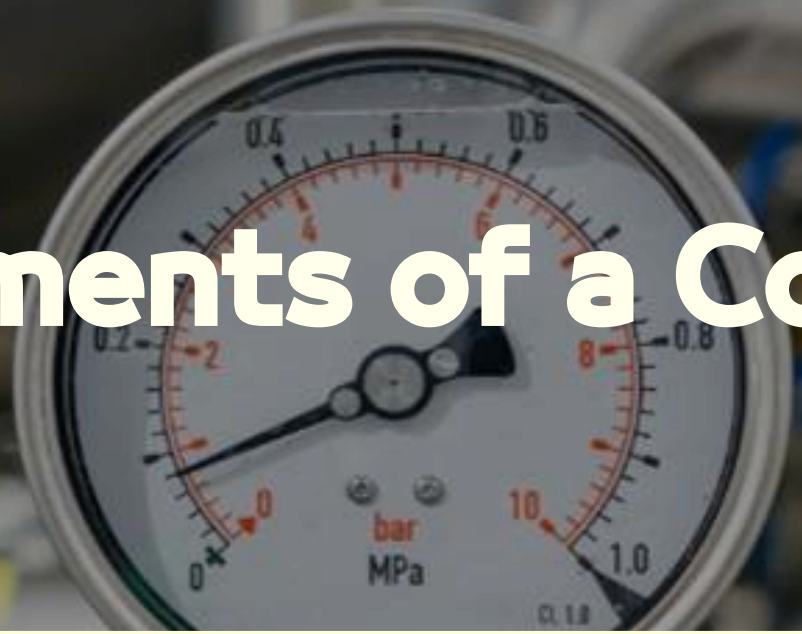
Basic Control Loop

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Instrumentation
Engineering

Automatic Control System:

- **Control Loop**:
  - A group of instruments that work together to control a process.
- **Components:**
  - **Transmitter:**
    - Coupled with a sensing device or primary element.
  - **Controller:**
    - Receives and processes signals from the transmitter.
  - **Transducer:**
    - Converts signals from the controller into actionable outputs.
  - **Control Valve:**
    - Adjusts the flow or other parameters based on the transducer's signals.
- **Applications:**
  - Used to maintain pressure, temperature, flow, level, and composition in process plants.

Basic Elements of a Control Loop



Basic Elements of a Control Loop:

- **Measurement Device:**
  - **Primary Elements and Sensors:** Used to measure variables such as pressure, temperature, flow, and level.
- **Transmitter:**
  - Converts a measurement into a signal for transmission to another instrument.
- **Controller:**
  - Compares the signal with a set point and transmits a signal to a final control element.
- **Transducer:**
  - Converts signals between different types (e.g., air to electric, electric to pneumatic).
  - Also known as I to P (current to pressure) converters or simply converters.
- **Final Control Element:**
  - Makes changes to the process based on signals from the controller.
  - Examples include control valves, dampers, and governors for speed control.
  - Governed by the controller.

Transmitter

0 % → 4 mA

50 % → 12 mA

100 % → 20 mA

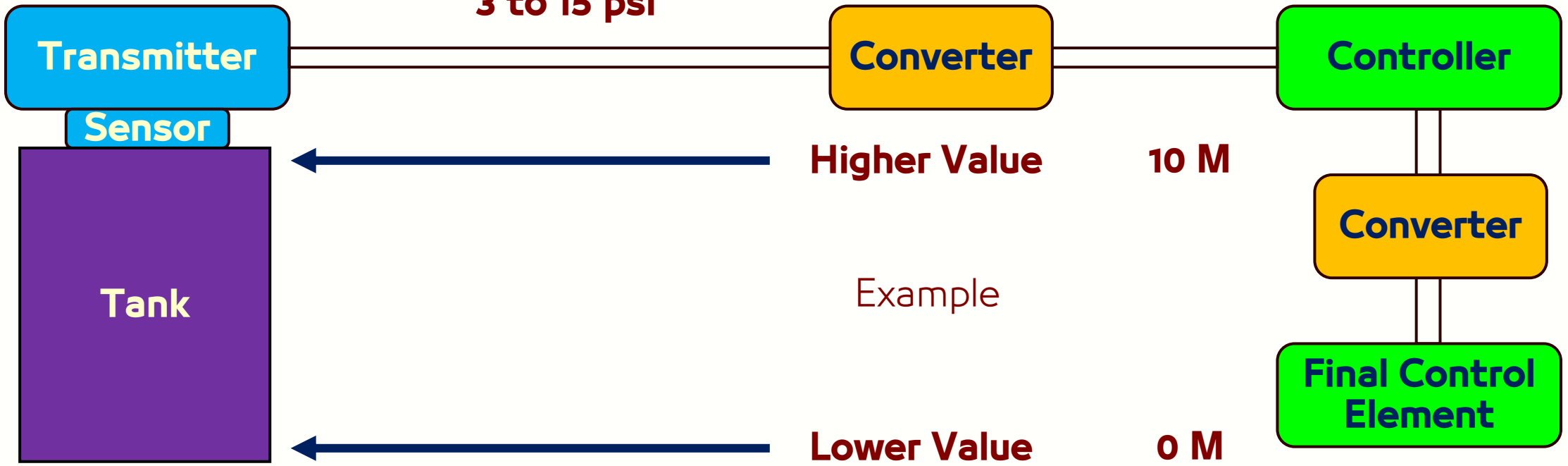
0 M → 4 mA → 3 psi

5 M → 12 mA → 9 psi

10 M → 20 mA → 15 psi

4 to 20 mA

3 to 15 psi



Transmitter

DP Cell Transmitters:

- **Designs:**
  - **Pneumatic**
  - **Electronic**
- **Controller Placement:**
  - Typically mounted 400 (closed loop) to 1,000 (open loop) feet from the transmitter.
- **Electronic Transmitter Signals:**
  - Proportional to the pressure difference between high-pressure and low-pressure legs.
  - Standard output signals:
    - 4 to 20 mA (milliamps)
    - 10 to 50 mA
    - 1 to 5 V (volts)
  - **10 to 50 mA transmitter:**
    - Preferred for higher tolerance to outside interference compared to the 4 to 20 mA transmitter.
- **Pneumatic Transmitters:**
  - Require a 20 to 30 psig air supply.
  - Standard 3 to 15 psig output.



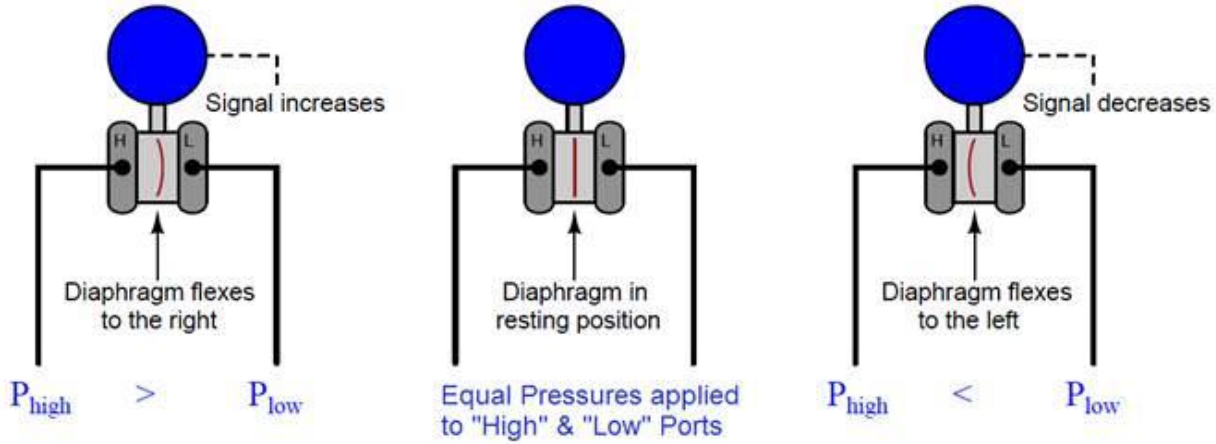
Transmitter

DP Cells:

- **Function:**
  - High- and low-pressure taps connected to each side of an internal twin diaphragm capsule.
  - Pressure changes cause the diaphragms to move, adjusting the signal to the controller.

Smart Transmitters:

- **Reliability:**
  - Do not need constant attention.
  - Equipped with internal diagnostics that warn the operator of potential issues.
- **Versatility:**
  - Used in liquid or gas service to control pressure, viscosity, temperature, flow, and level.
- **Features:**
  - Speed
  - Reliability
  - Internal diagnostics
  - Strong digital signal
  - Remote calibration capabilities





Controllers and Controller Modes

Controllers and Controller Modes

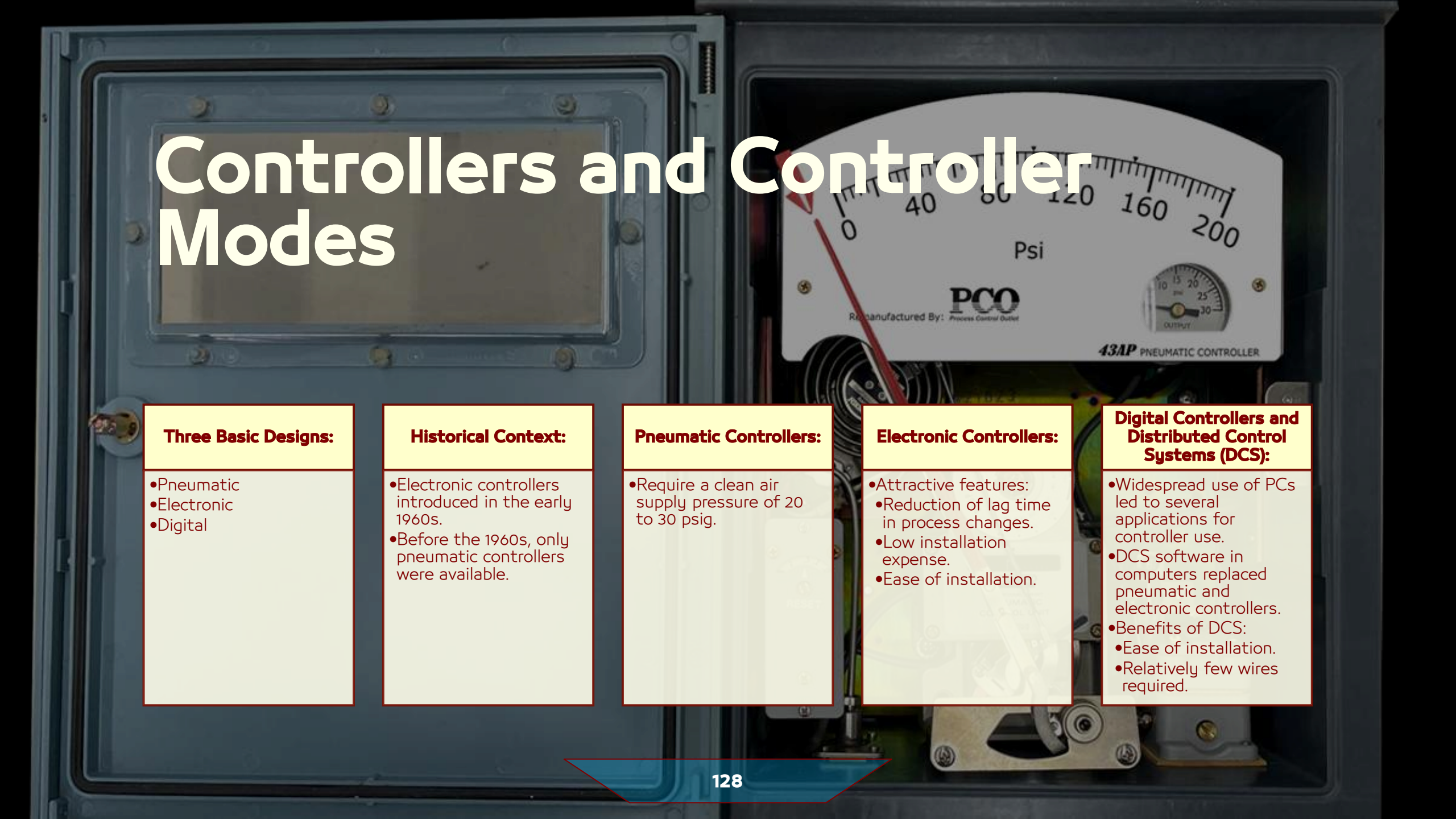
Controller:

- **Primary Purpose:**
  - Receives a signal from a transmitter.
  - Compares this signal with a set point.
  - Adjusts the process (final control element) to stay within the range of the set point.



Figure 11.23 *Field-Mounted Controller*

Controllers and Controller Modes

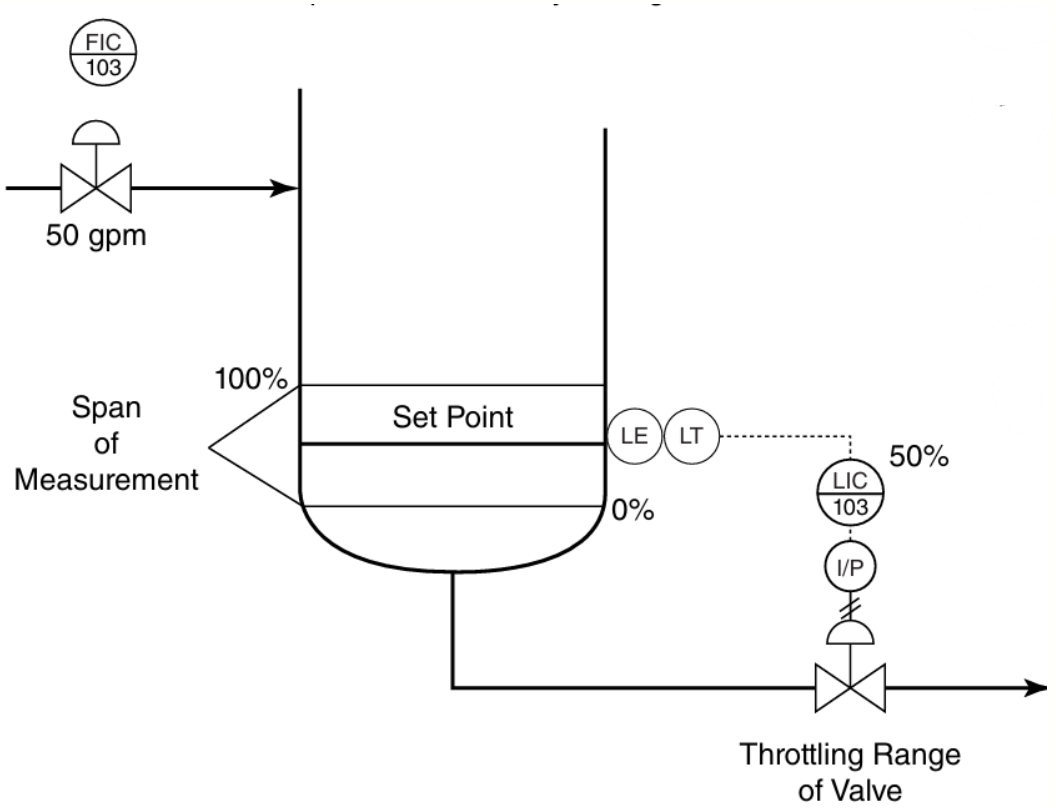


Three Basic Designs:	Historical Context:	Pneumatic Controllers:	Electronic Controllers:	Digital Controllers and Distributed Control Systems (DCS):
•Pneumatic •Electronic •Digital	•Electronic controllers introduced in the early 1960s. •Before the 1960s, only pneumatic controllers were available.	•Require a clean air supply pressure of 20 to 30 psig.	•Attractive features: •Reduction of lag time in process changes. •Low installation expense. •Ease of installation.	•Widespread use of PCs led to several applications for controller use. •DCS software in computers replaced pneumatic and electronic controllers. •Benefits of DCS: •Ease of installation. •Relatively few wires required.

Controllers and Controller Modes

Modern Plants:

- Combination of **pneumatic, electronic, and digital systems**.
- Control loop diagrams identify the type of controller used.
  - Example:
    - Diagonal lines between the transducer and the valve signify pneumatic control.



Controller Operation Modes

Manual Control:

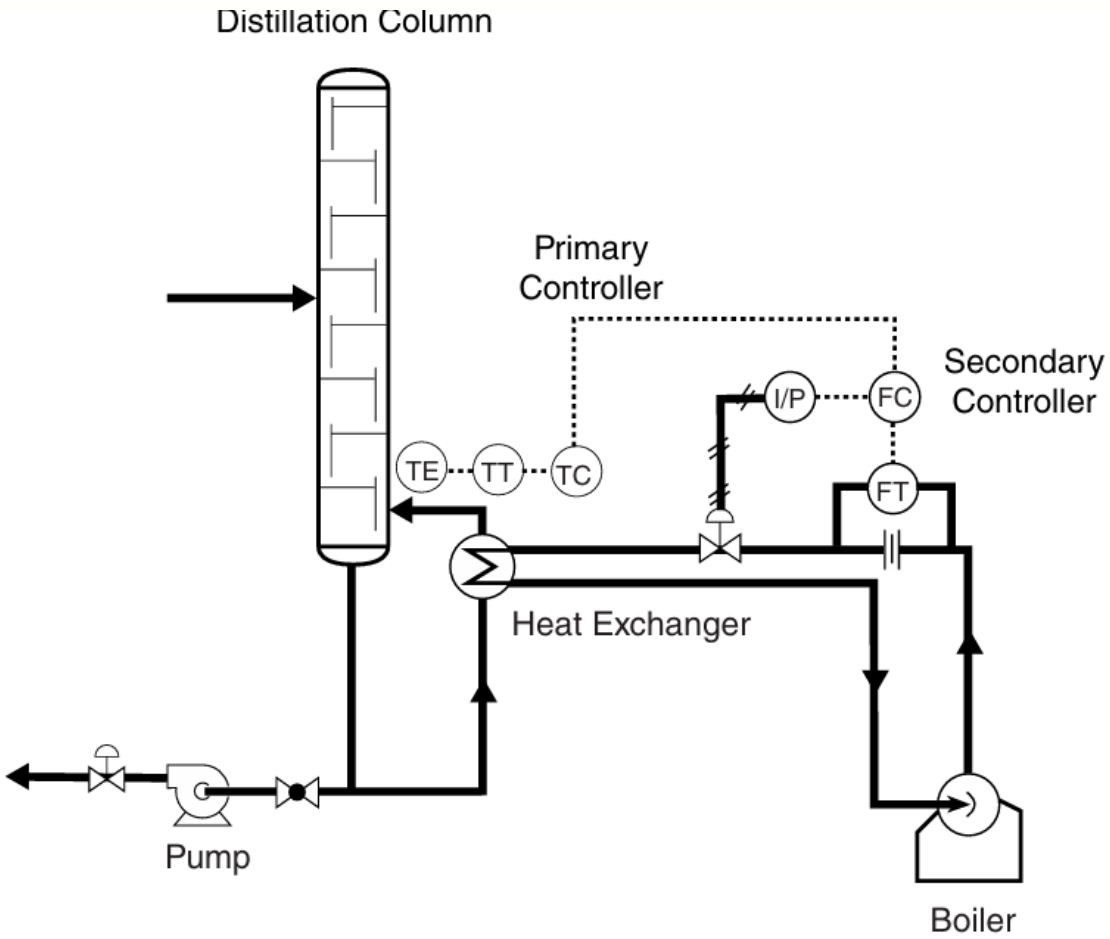
- Used during plant startup until the process is stabilized.
- Controller sends output to the final control element as set by the operator.

Automatic Control:

- Activated once the process is stable.
- Controller supervises the control loop function, opening and closing the control valve to maintain the set point.

Cascaded (Remote) Control:

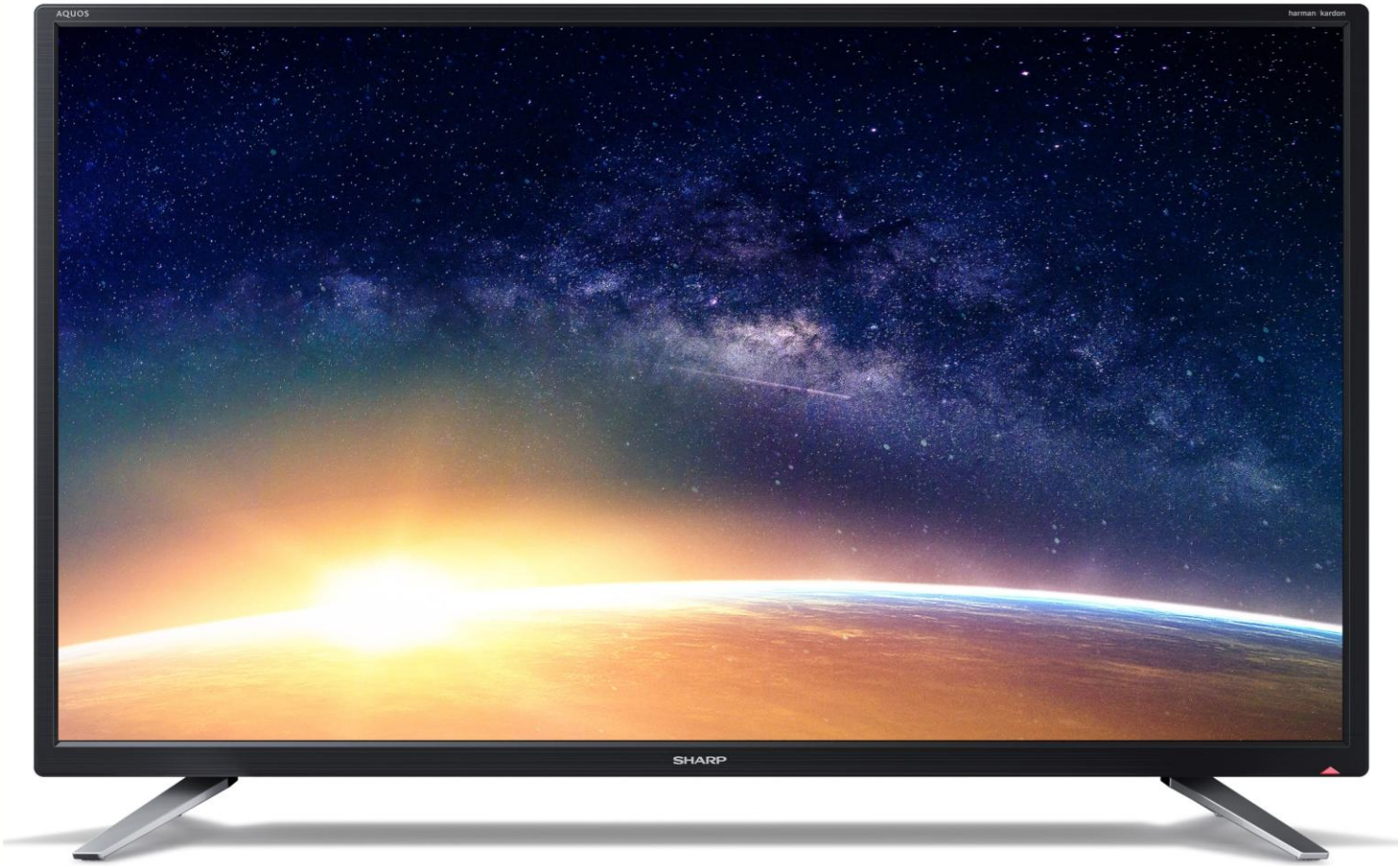
- A second controller resets the primary controller's set point to achieve a desired outcome.



Manual Control

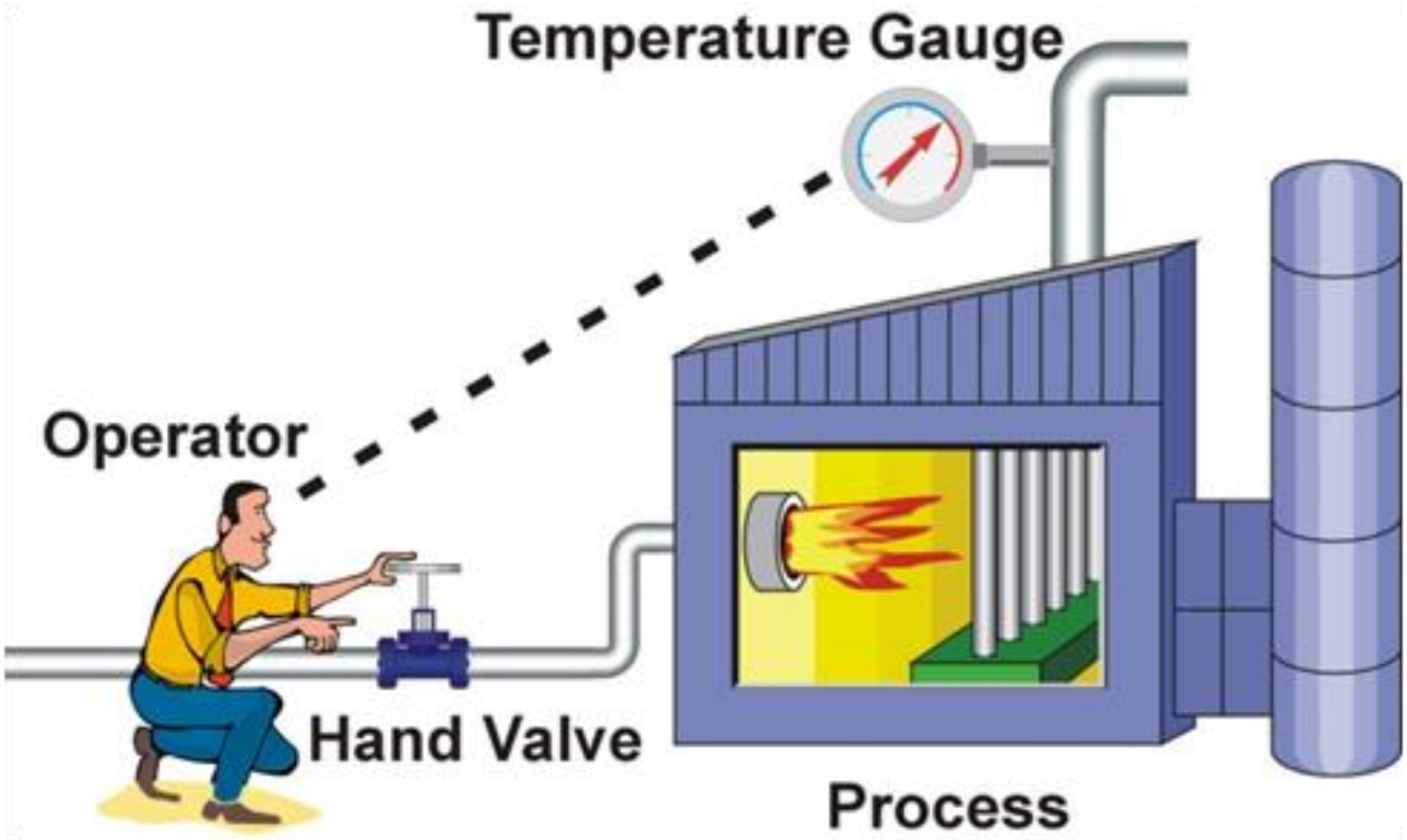


Remote Manual Control

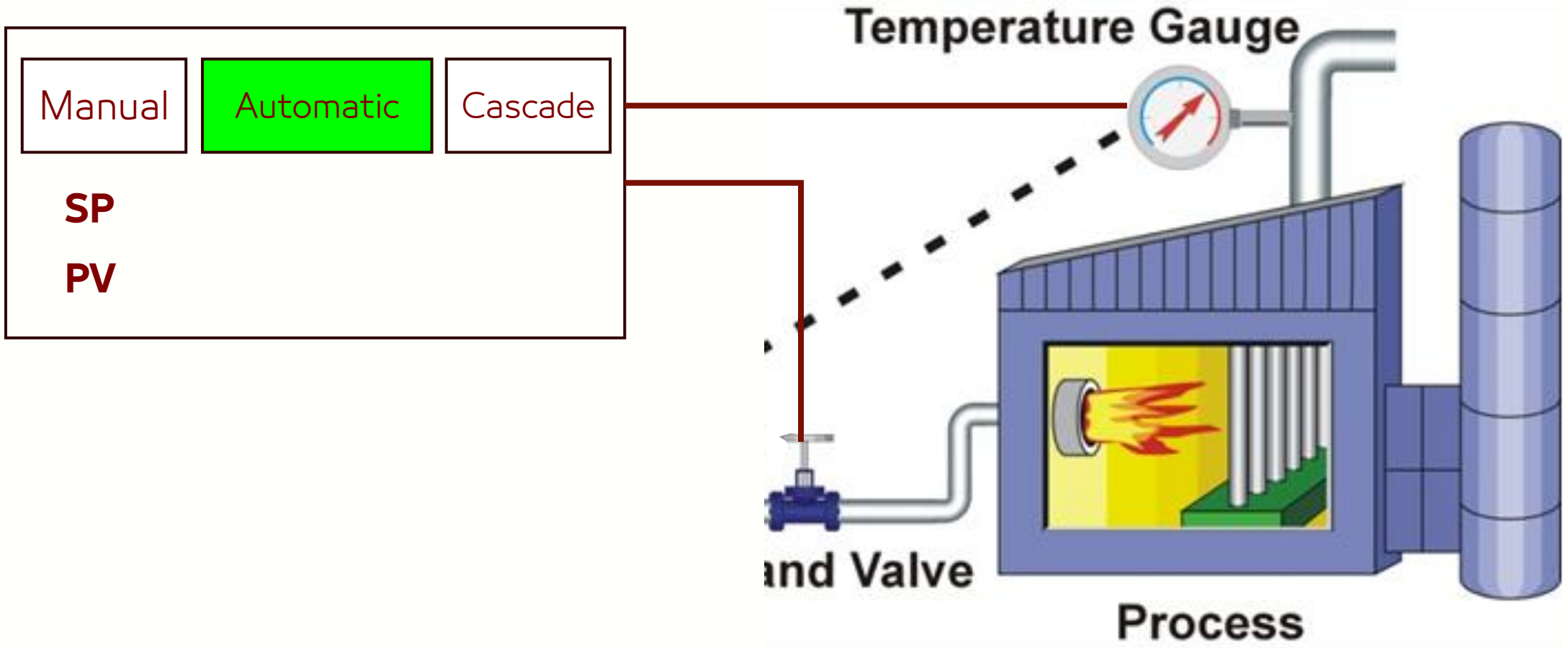




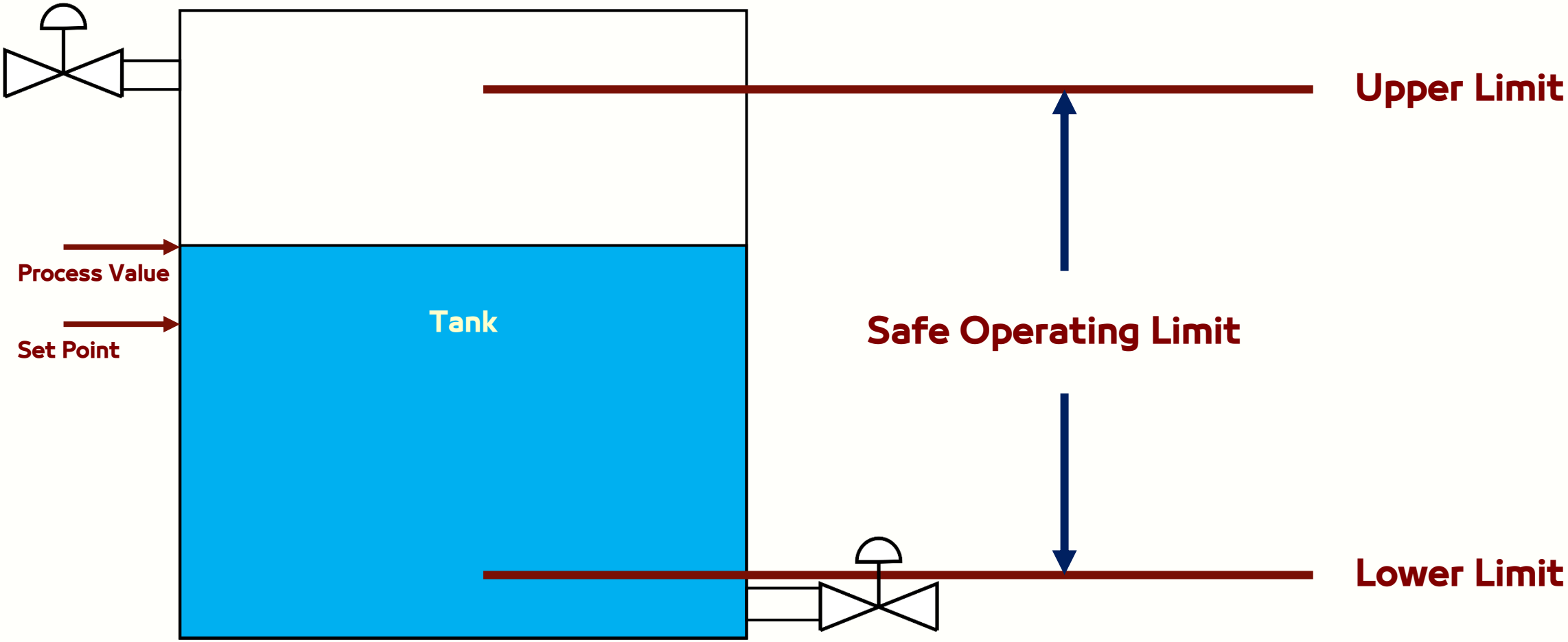
Manual Control



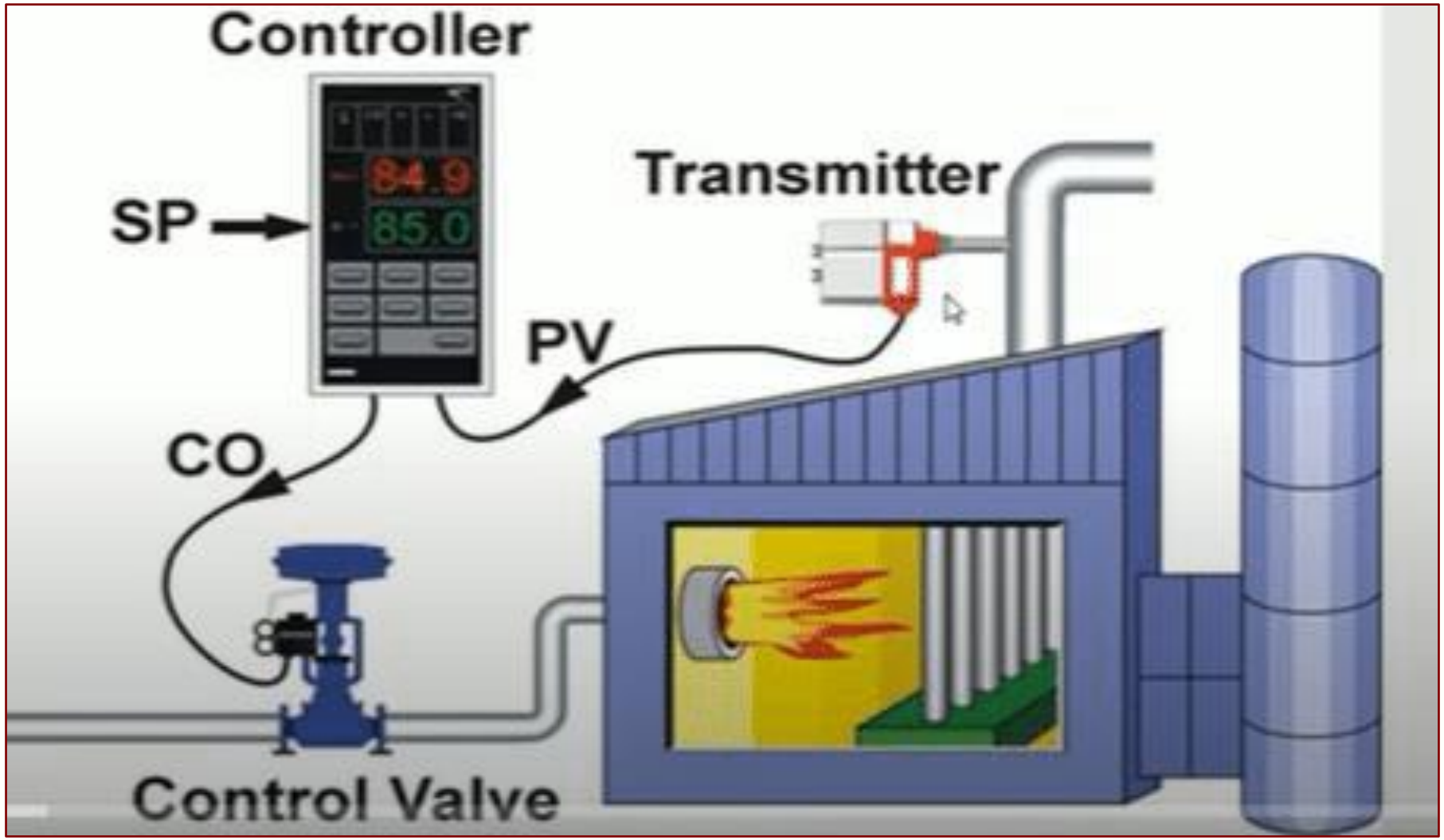
Remote Manual Control



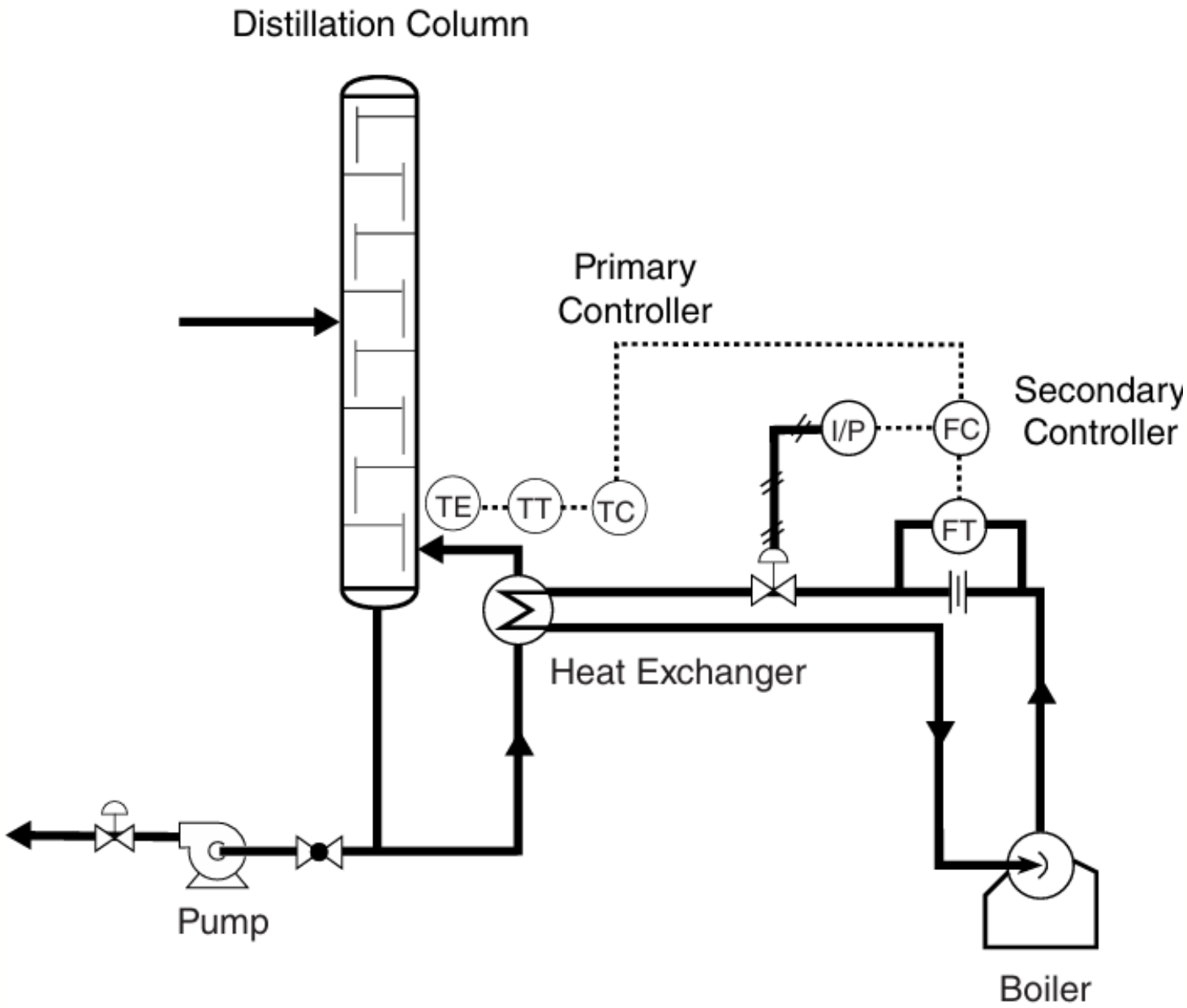
Set Point and Process Value

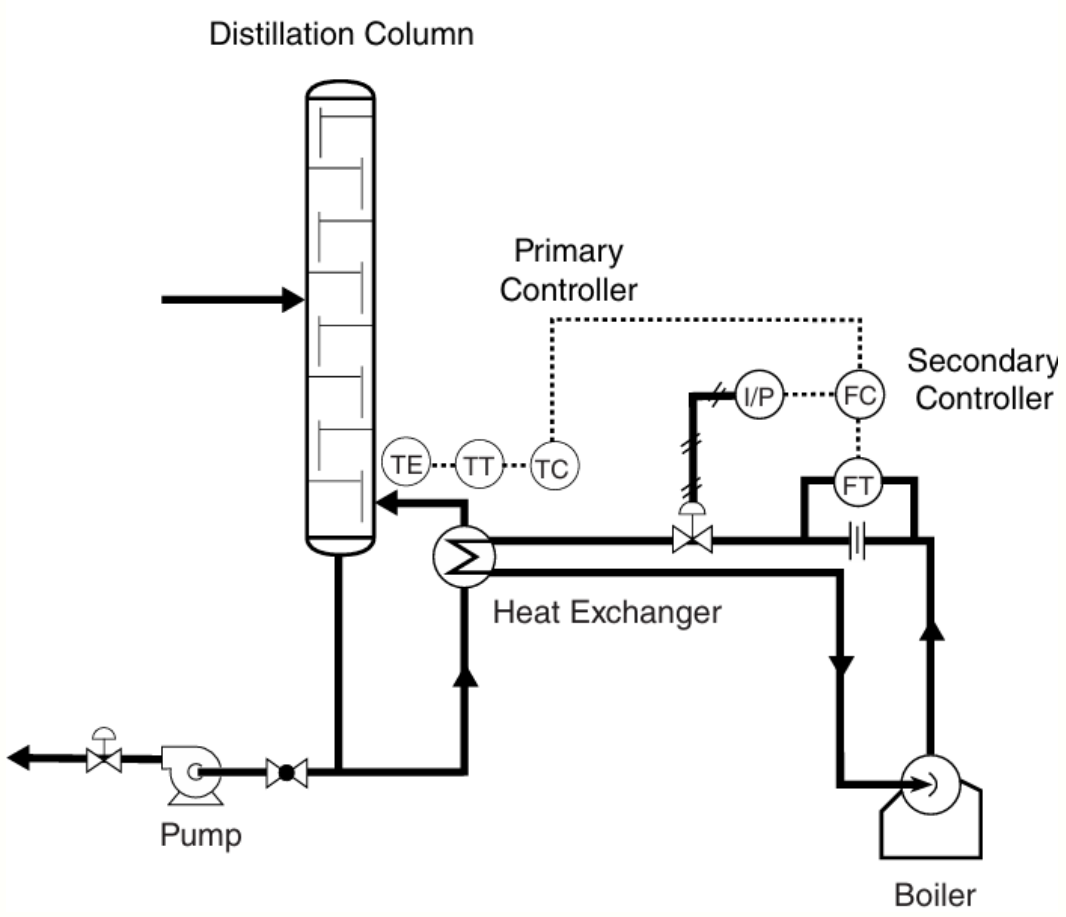


Automatic Control



Cascade Control





Tc ← $T1 = 60^o$ $T2 = 90^o$

Fc →

Input 1 **dT =** 30^o **SP**
Input 2 **F1 =** $100\ l/min$ **PV**
Logic **Rate =** $2\frac{l}{min}/1^o$
Output **F2 =** $160\ l/min$

$T1 = 60^o$ $T2 = 90^o$

dT = 30^o

$F1 = 100\ l/min$ $T1 = 60^o$

$\text{Rate} = 2\frac{l}{min}/1^o$

$F2 = 160\ l/min$ $T2 = 90^o$

Proportional Band

Proportional Band on a Controller:

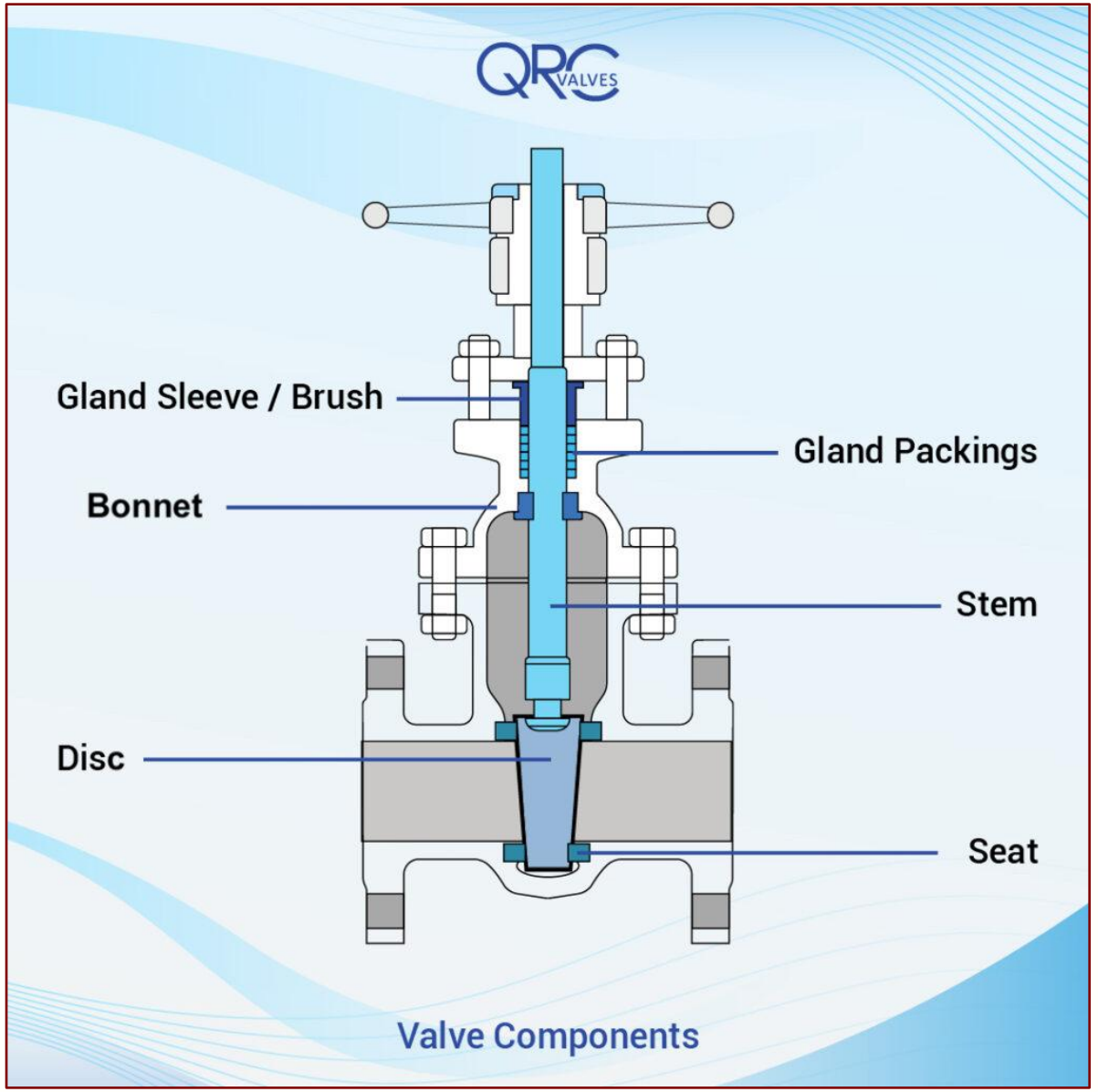
- Describes the scaling factor used to adjust the controller from 0% to 100% output.
- Example: If set at 50% and the final control element (globe valve) has 4 inches of lift, the control valve will open 2 inches.

Range:

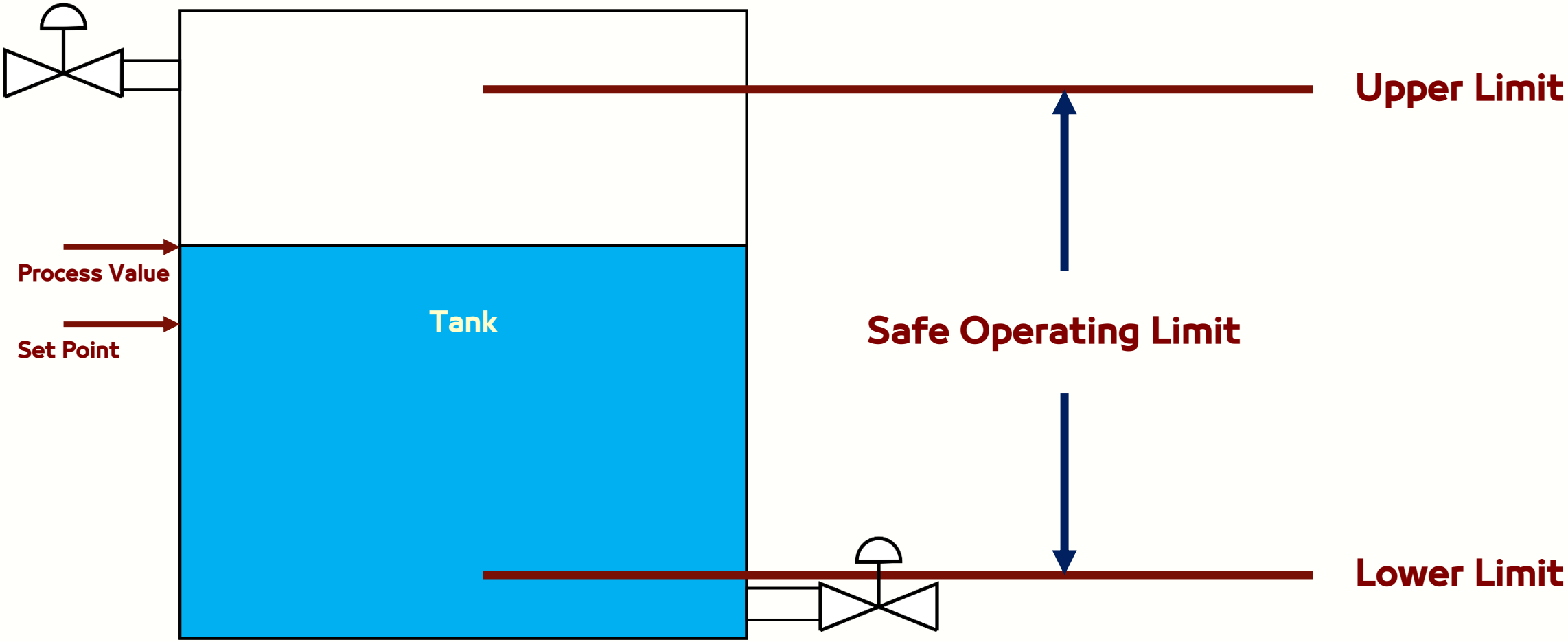
- The portion of the process controlled by the controller.
- Example: A controller might have a temperature range limited to 80 to 140°F.

Span:

- The difference (Δ) between the upper and lower range limits.
- Recorded as a single number.
- Example: The span between 80 and 140 is 60.

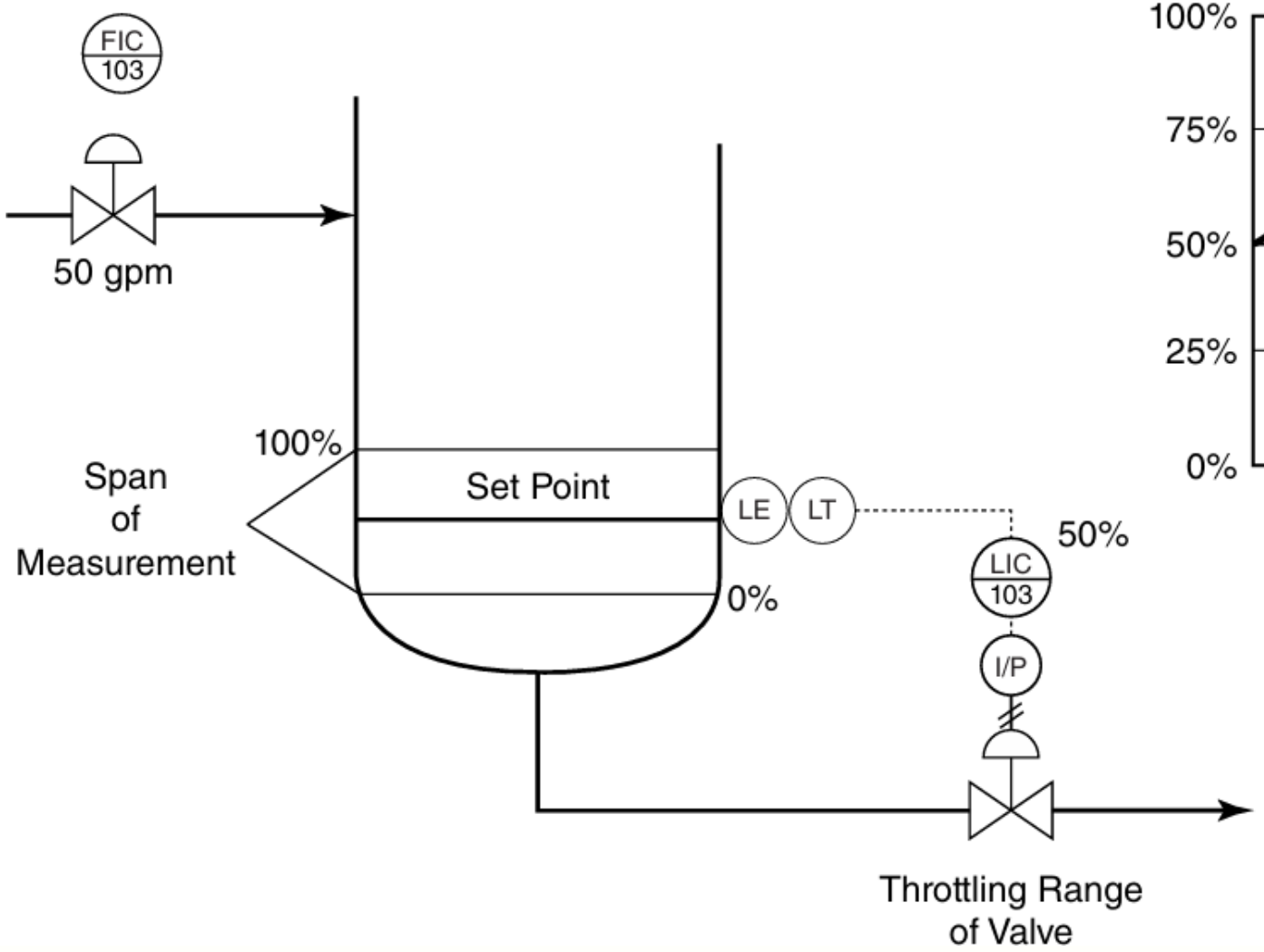


Set Point and Process Value

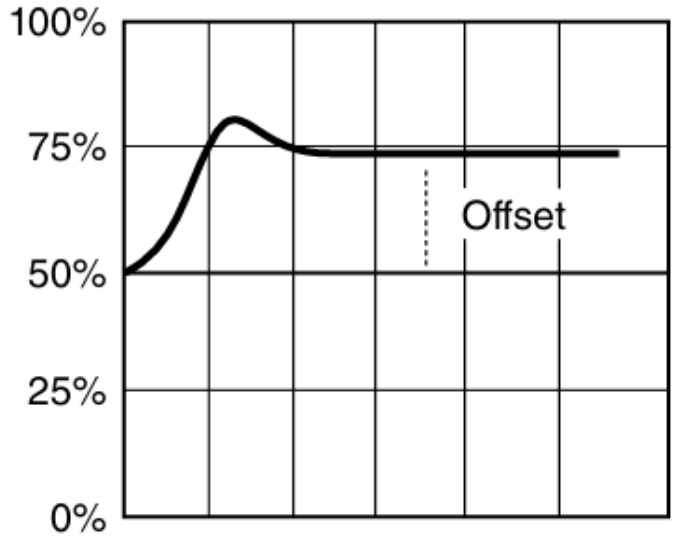


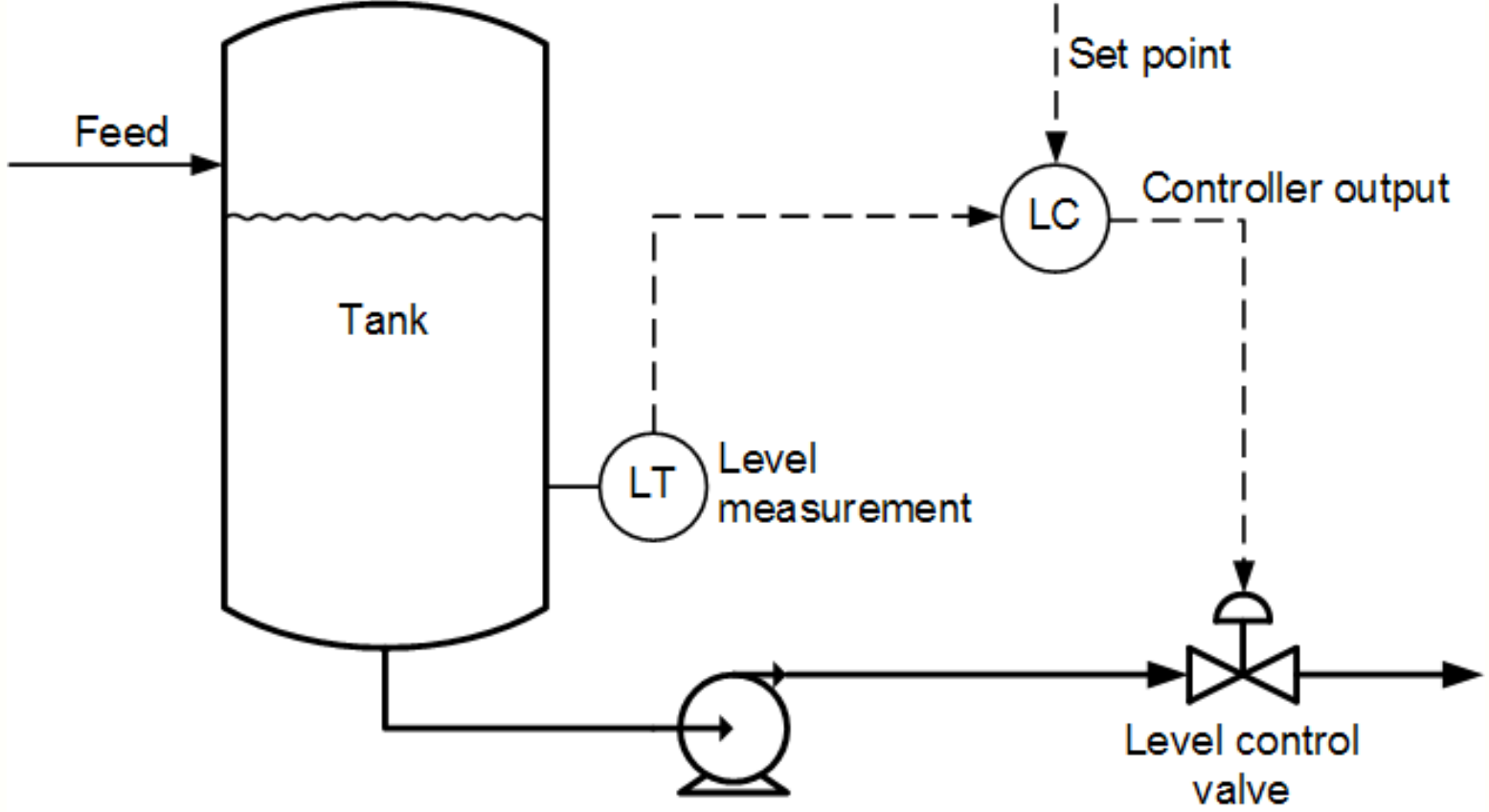
Problems with Proportional Control:

1. Feed Rate Changes
2. Composition Changes
3. Temperature or Density Changes



Flow Rate to Tower Increases 50 gpm–75 gpm



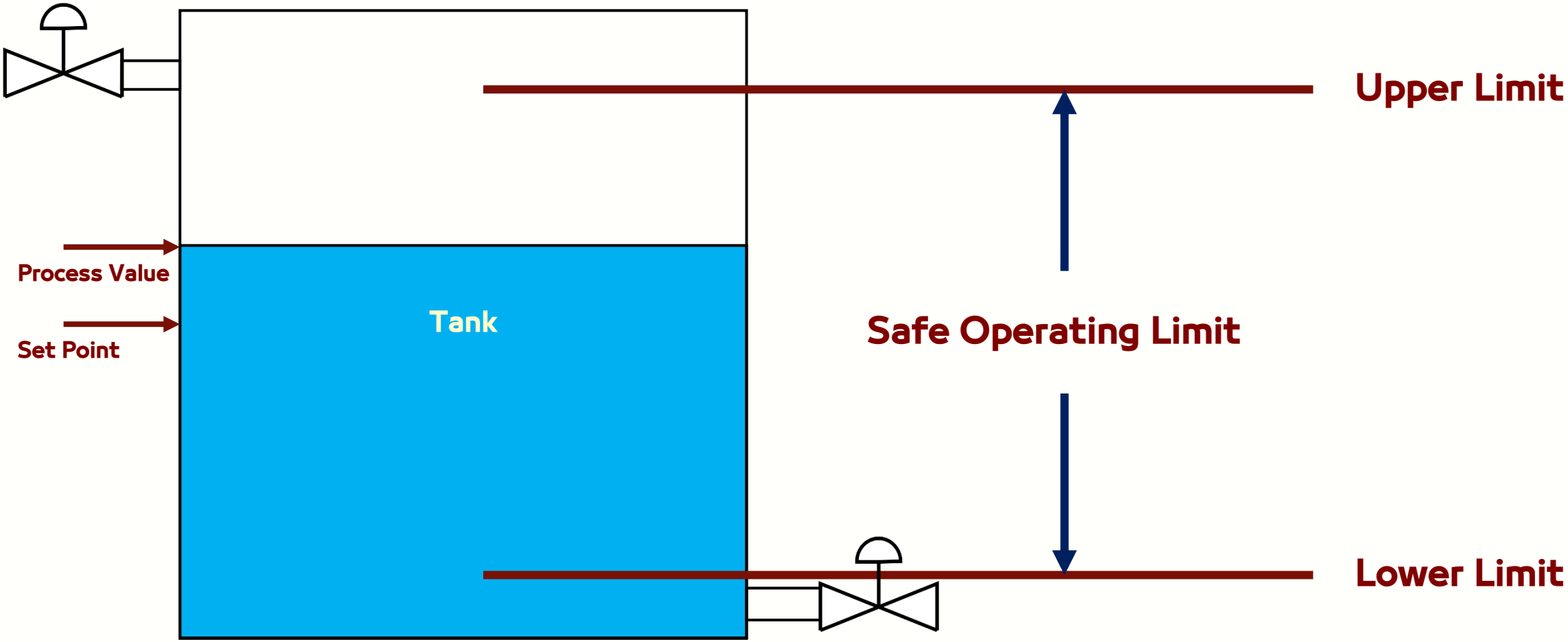


PV = 8 L	Proportional = (SP – PV) / SP %
SP = 8 L	Proportional = 0 %

PV = 5 L	Proportional = (SP – PV) / SP %
SP = 8 L	Proportional = 37.5 %

PV = 0 L	Proportional = (SP – PV) / SP %
SP = 8 L	Proportional = 100 %

Set Point and Process Value



Controller Modes

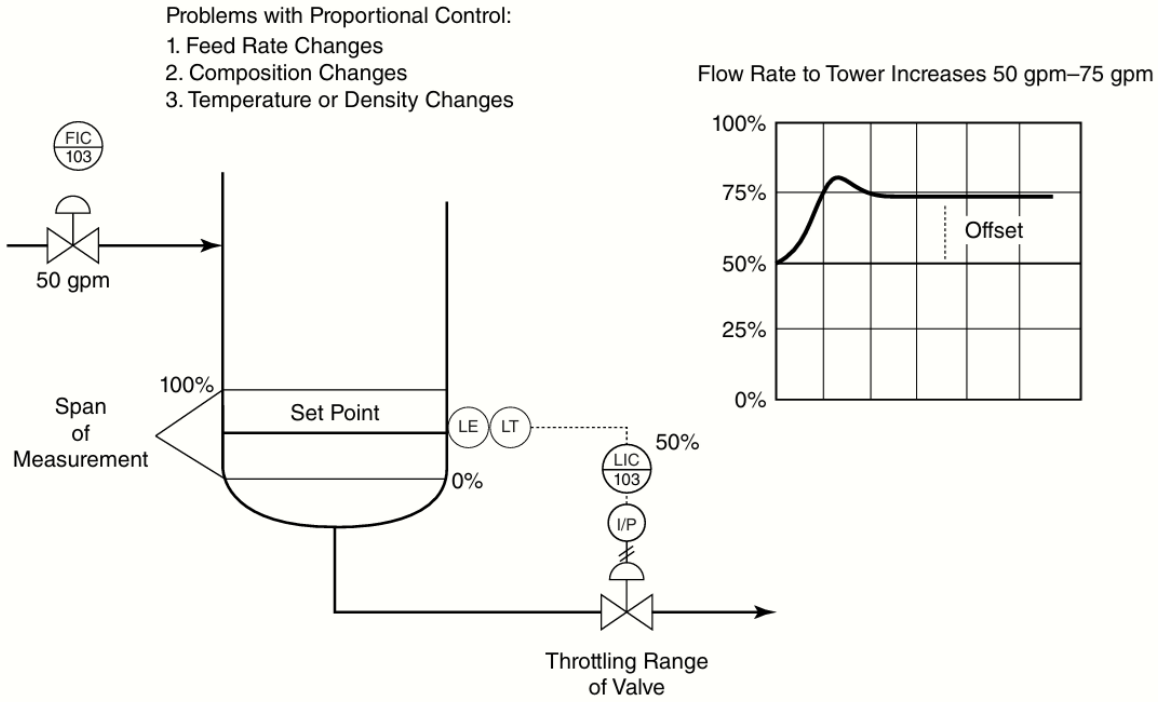


- Gain
- Reset (Integral)
- Rate (Derivative)

Gain "Proportional"

Gain:

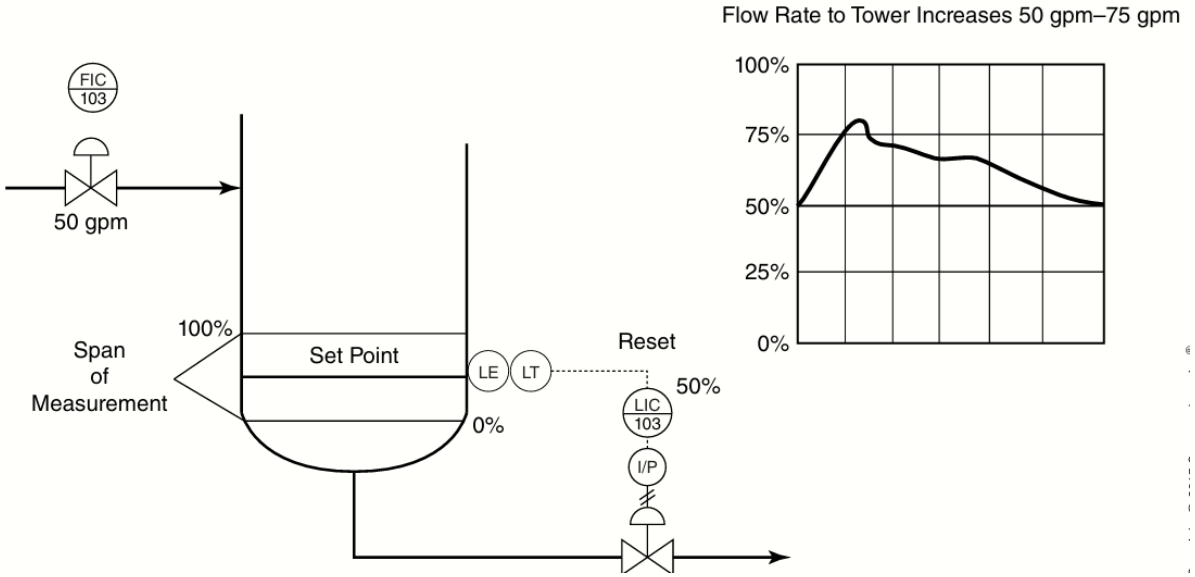
- Used as a tuning constant in modern controllers.
- Defined as the ratio of the output signal from the controller to the error signal (difference between the process variable and set point).
- Reciprocal of the proportional band (PB).
- Example: If PB is 100%, gain = 1.0. If PB is 200%, gain = 0.5 (1/2).
- Gain is rarely used alone, as it only provides a ratio response to a process change.



Reset "Integral"

Reset:

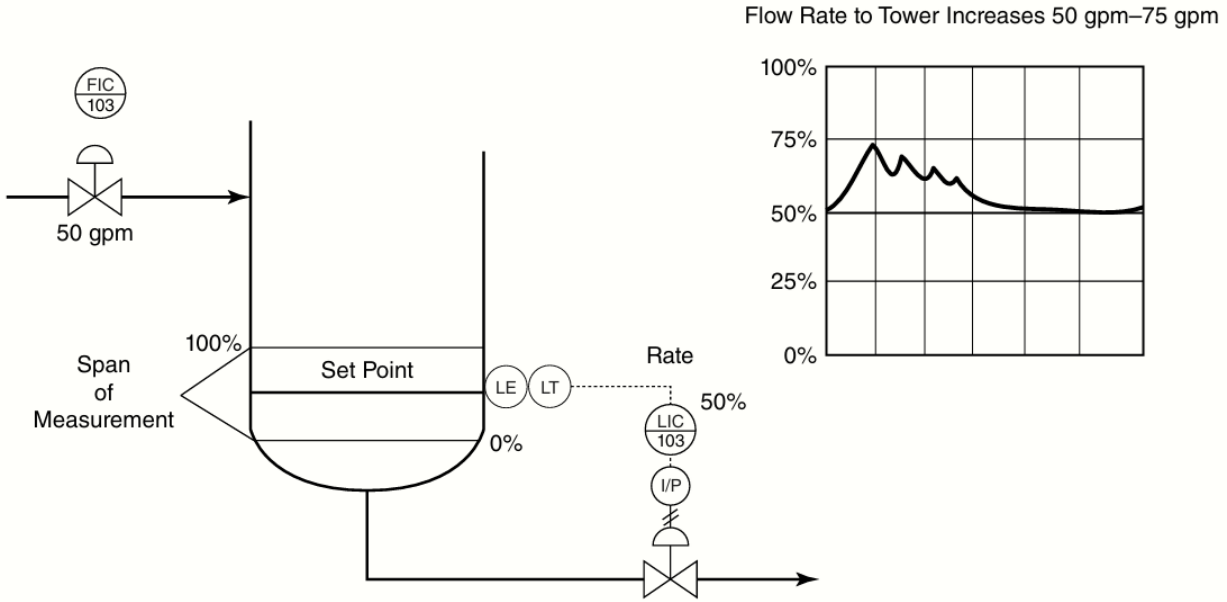
- A control mode that calculates a slope, in repeats per minute, back toward the set point in response to a process change.
- Designed to reduce the difference between the set point and process variable.
- Adjusts the controller's output continuously until the offset is eliminated.
- Responds proportionally to the size of the error, the length of time it lasts, and the reset gain setting.



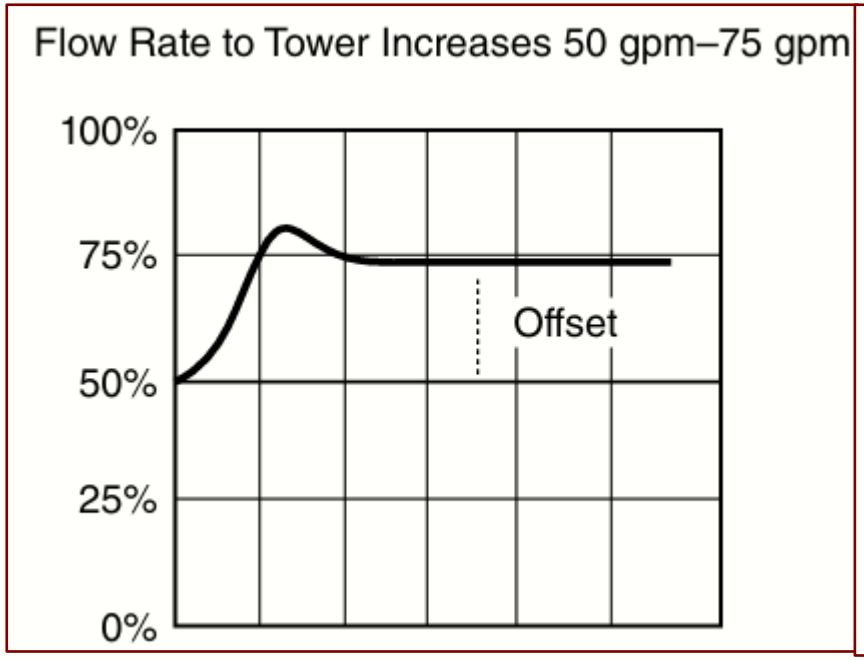
Rate "Derivative"

Rate Mode:

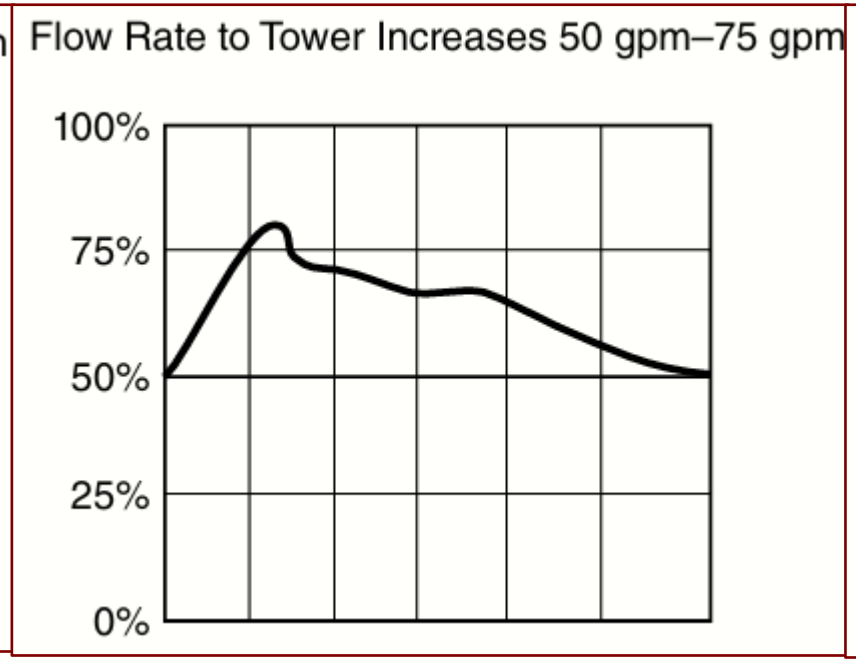
- Enhances controller output by increasing the output in relation to the changing process variable.
- Provides a braking action as the process variable approaches the set point, preventing overshooting.
- Responds aggressively to rapid changes and passively to smaller changes in the process variable.



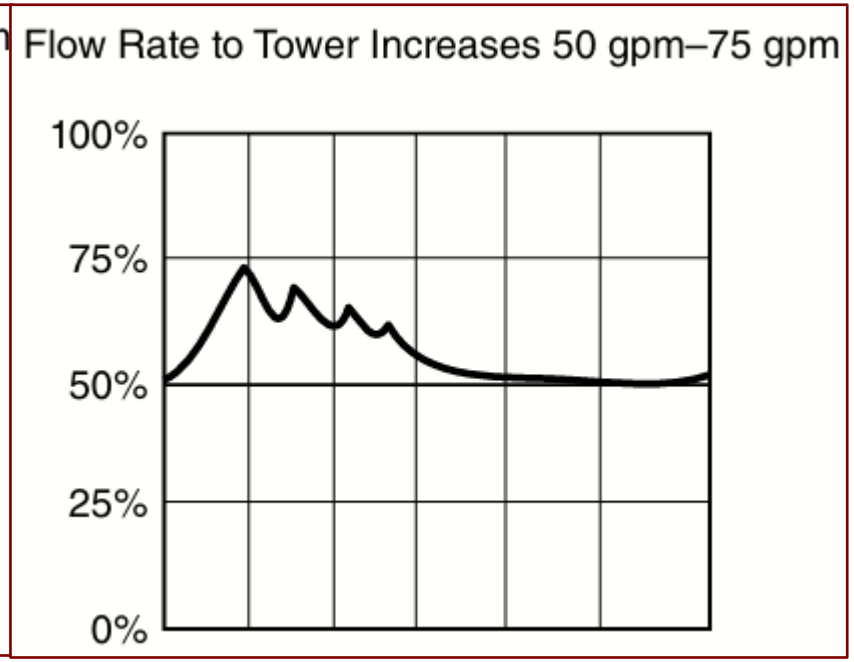
Proportional

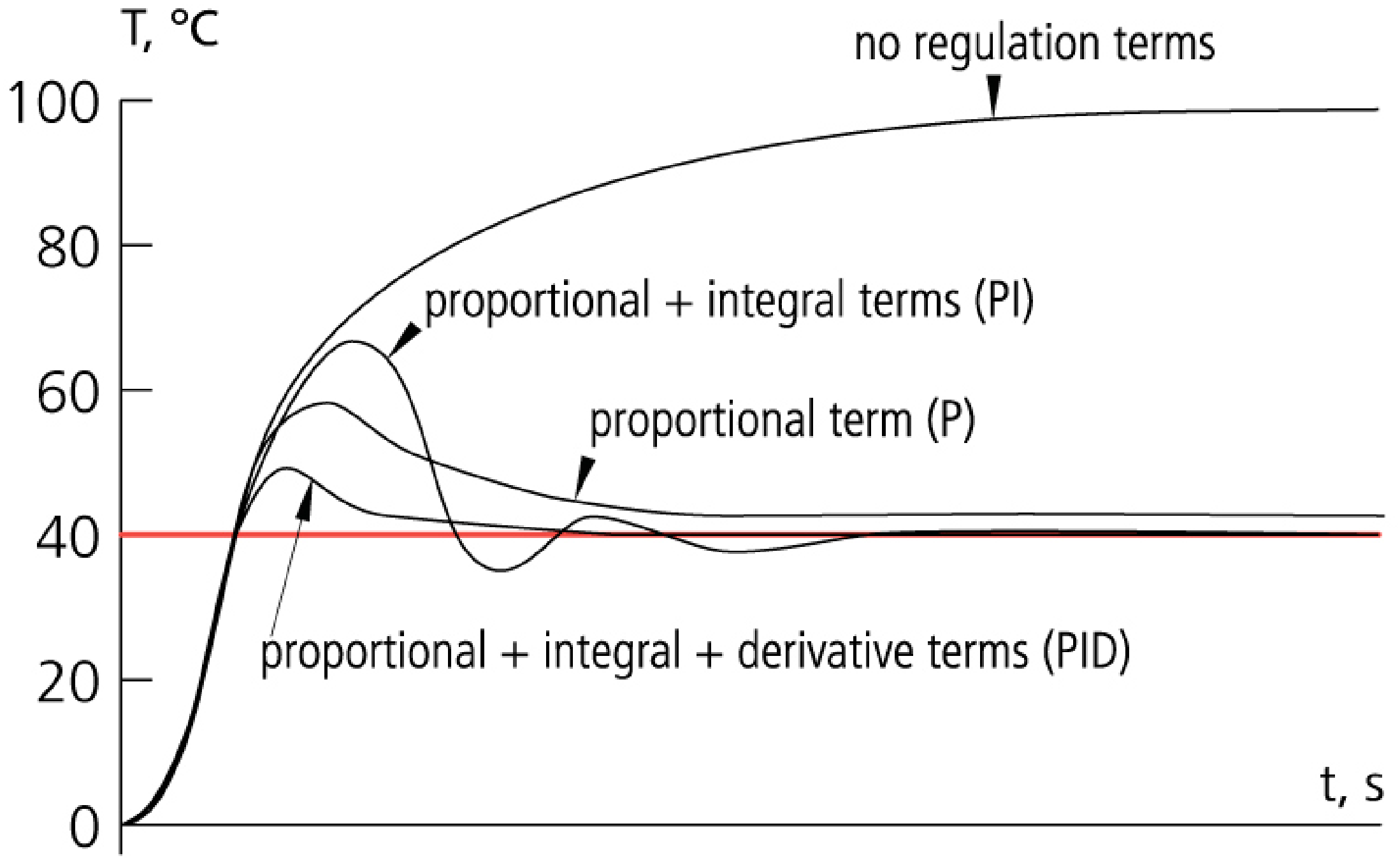


Integral



Derivative




T, °C
100
80
60
40
20
0
no regulation terms
proportional + integral terms (PI)
proportional term (P)
proportional + integral + derivative terms (PID)
t, s

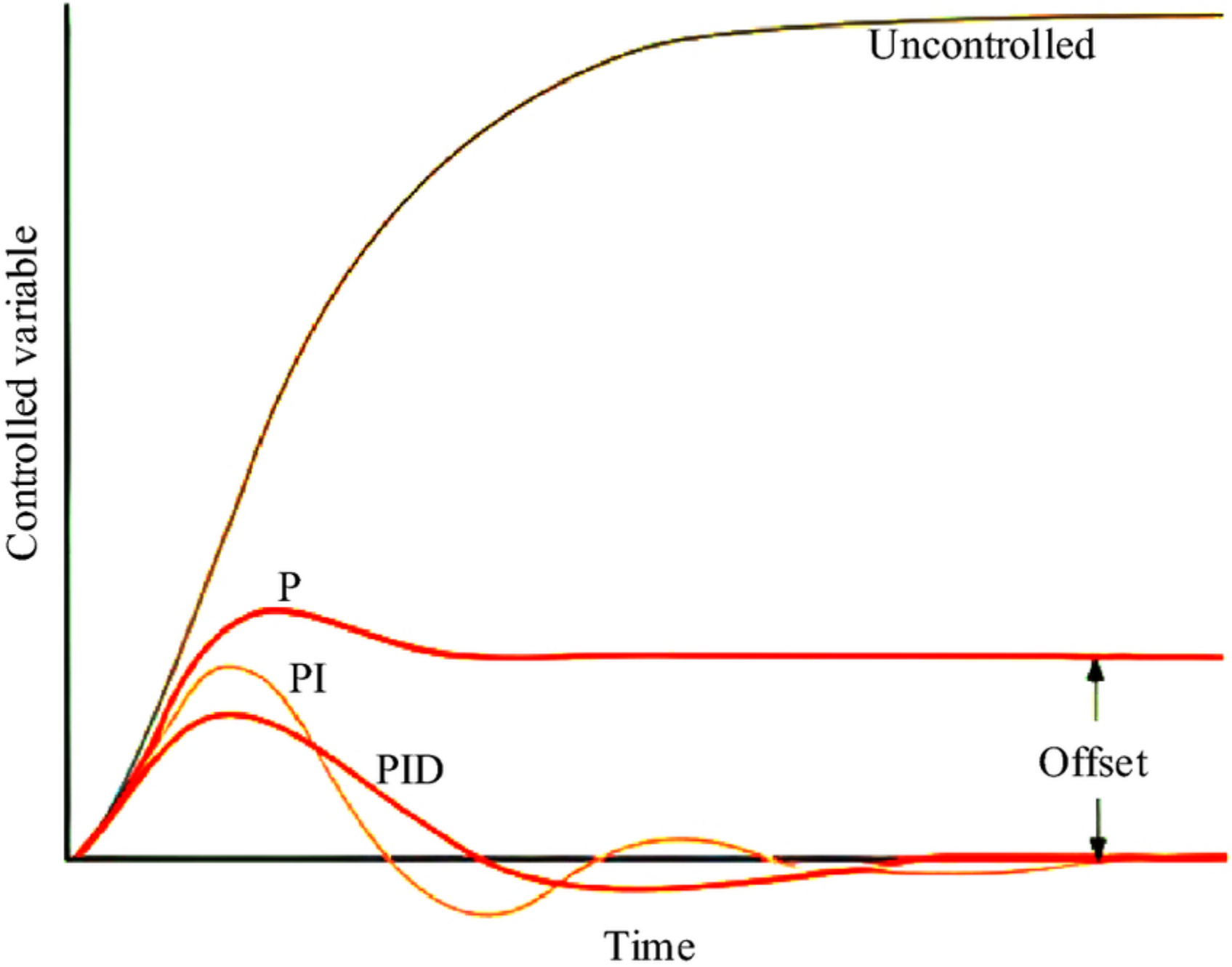
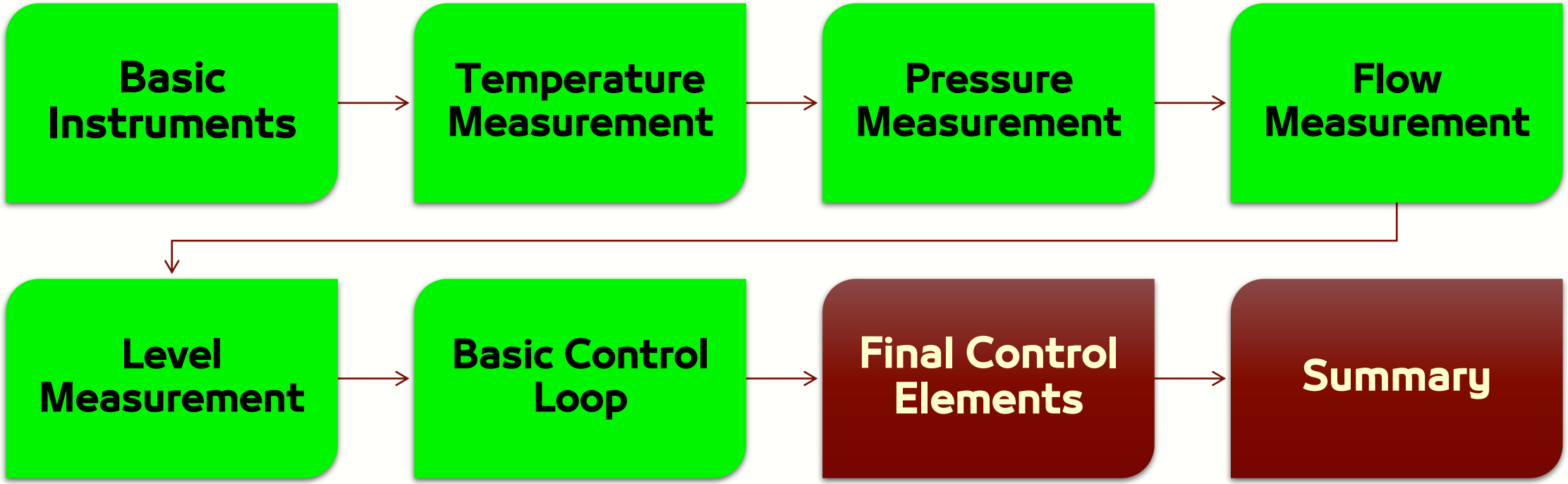

Uncontrolled
Controlled variable
P
PI
PID
Offset
Time

Table of Contents





Final Control Elements

Final Control Elements

Final Control Elements:

- Typically, automatic valves, but can also be motors or other electric devices.
- Last link in the control loop; they make the actual changes in the process.
- Automatic valves regulate the process by opening or closing.
- Invaluable in modern processing due to remote control capabilities.
- **Actuator:**
  - Device that automates a valve.
  - Controls the position of the flow control element by moving and controlling the valve stem.



Automatic Valves



Automatic Valves

Control Loop Components:

- Control loops consist of several components:
  - Sensing device
  - Transmitter
  - Controller
  - Transducer
  - Automatic valve

Role of Automatic Valves:

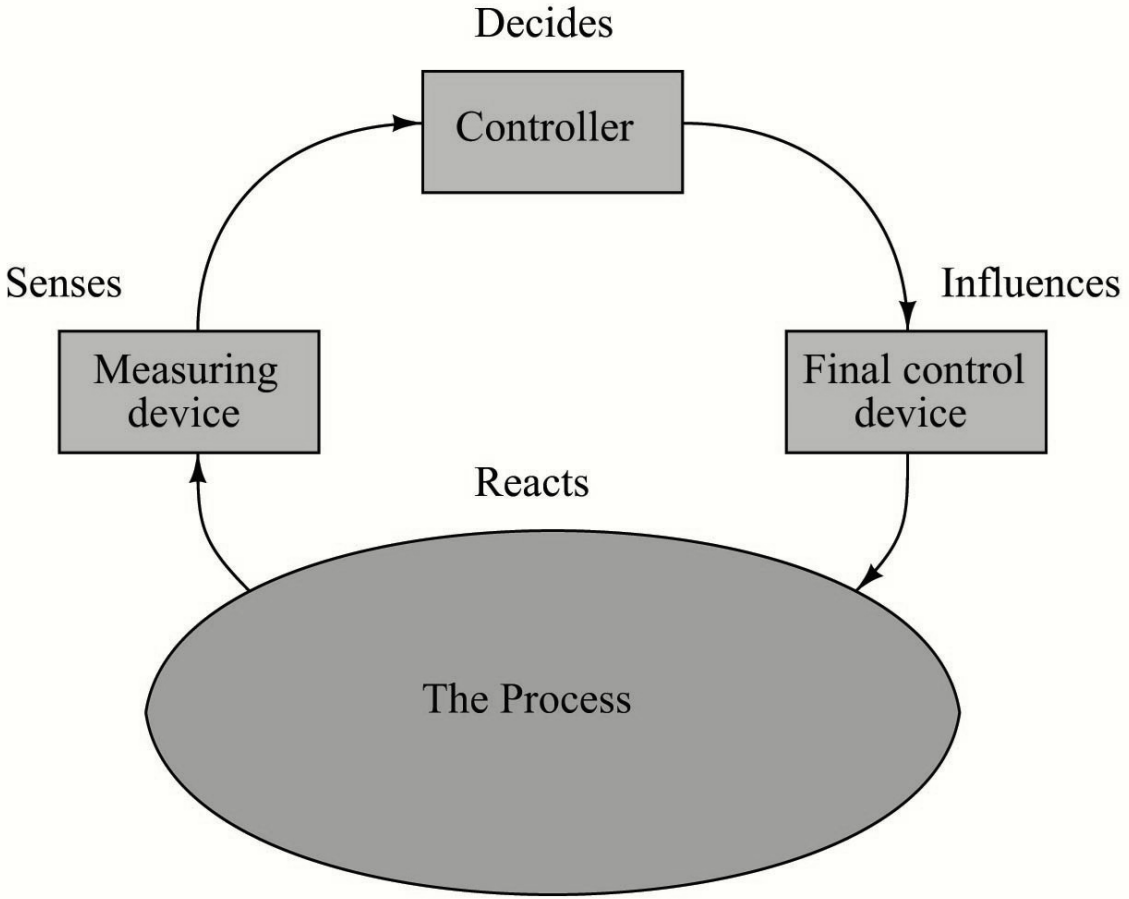
- Automatic valves play a crucial role in automated instrument systems by allowing control from remote locations.
- They are essential in processing industries due to their ability to regulate fluid flow.

Common Type of Automated Valve:

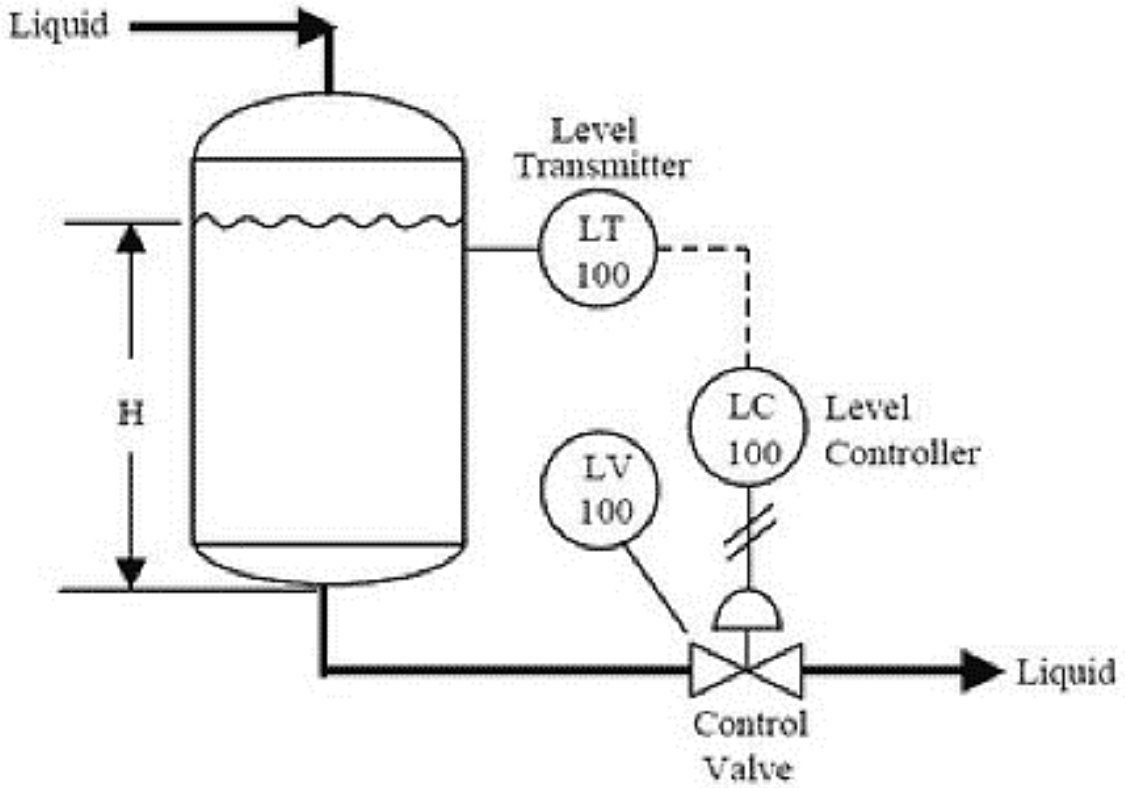
- The most common type of automated valve is the globe valve.
- Globe valves are preferred for their versatile capability to handle on/off or throttling functions.

Functionality:

- Control loops utilize on/off or throttling type valves to regulate fluid flow in and out of a system.
- Automatic valves can control various parameters such as pressure, temperature, flow, or level in industrial processes.



Process Control





Automatic Valves

Categories of Automatic Valves:

- Automatic valves are classified into two main categories:
  - **Control valves**
  - **Spring- or weight-operated valves**

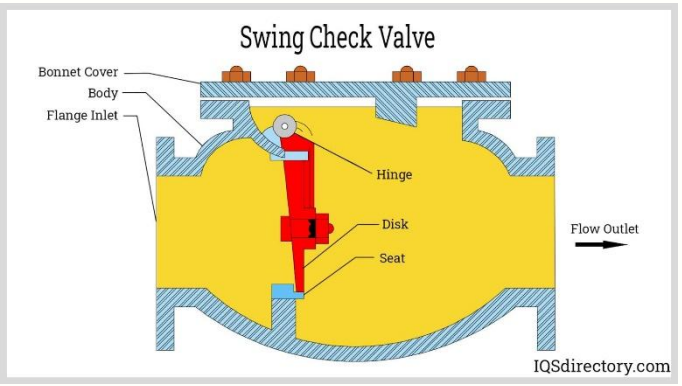
Types of Control Valves:

- Control valves can be operated by:
  - **Air**
  - **Electricity**
  - **Hydraulics**

Spring- or Weight-operated Valves:

- These valves hold the flow-control element in place until the pressure from under the disc becomes strong enough to lift the element from the seat.
- Check valves fall into this category.





Automating Valves

Automating Valves:

- Any valve discussed in this chapter can be automated by installing **an actuator**.
- The actuator controls the **position of the flow-control element** by moving and controlling the position of the valve stem.

Types of Actuators:

- **Pneumatically (air) operated**
- **Electrically operated**
- **Hydraulically operated**

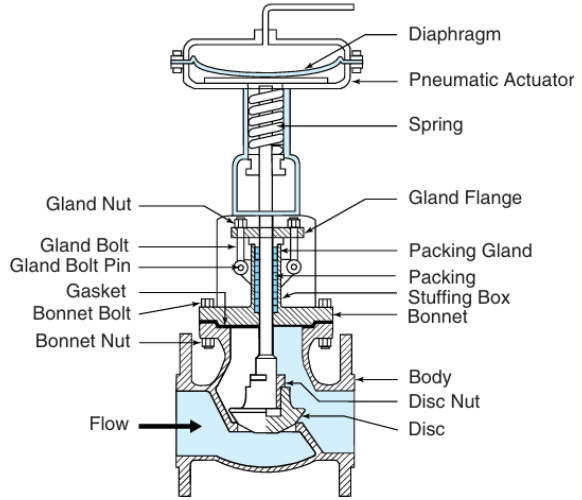


Figure 2.26 *Pneumatic Automatic Valve Components*

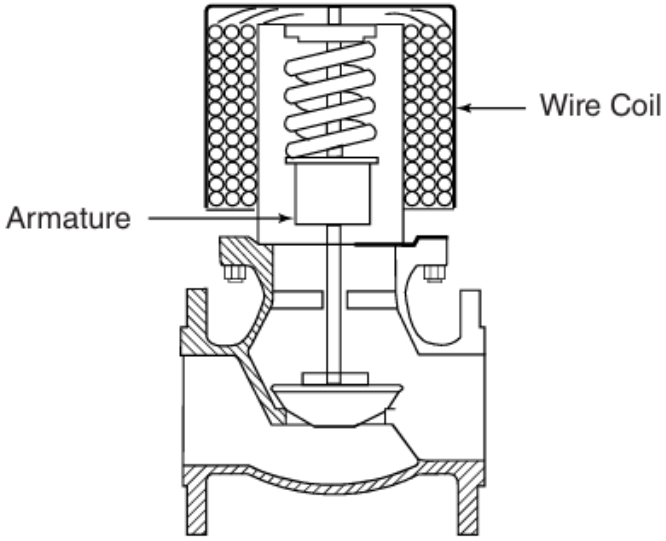
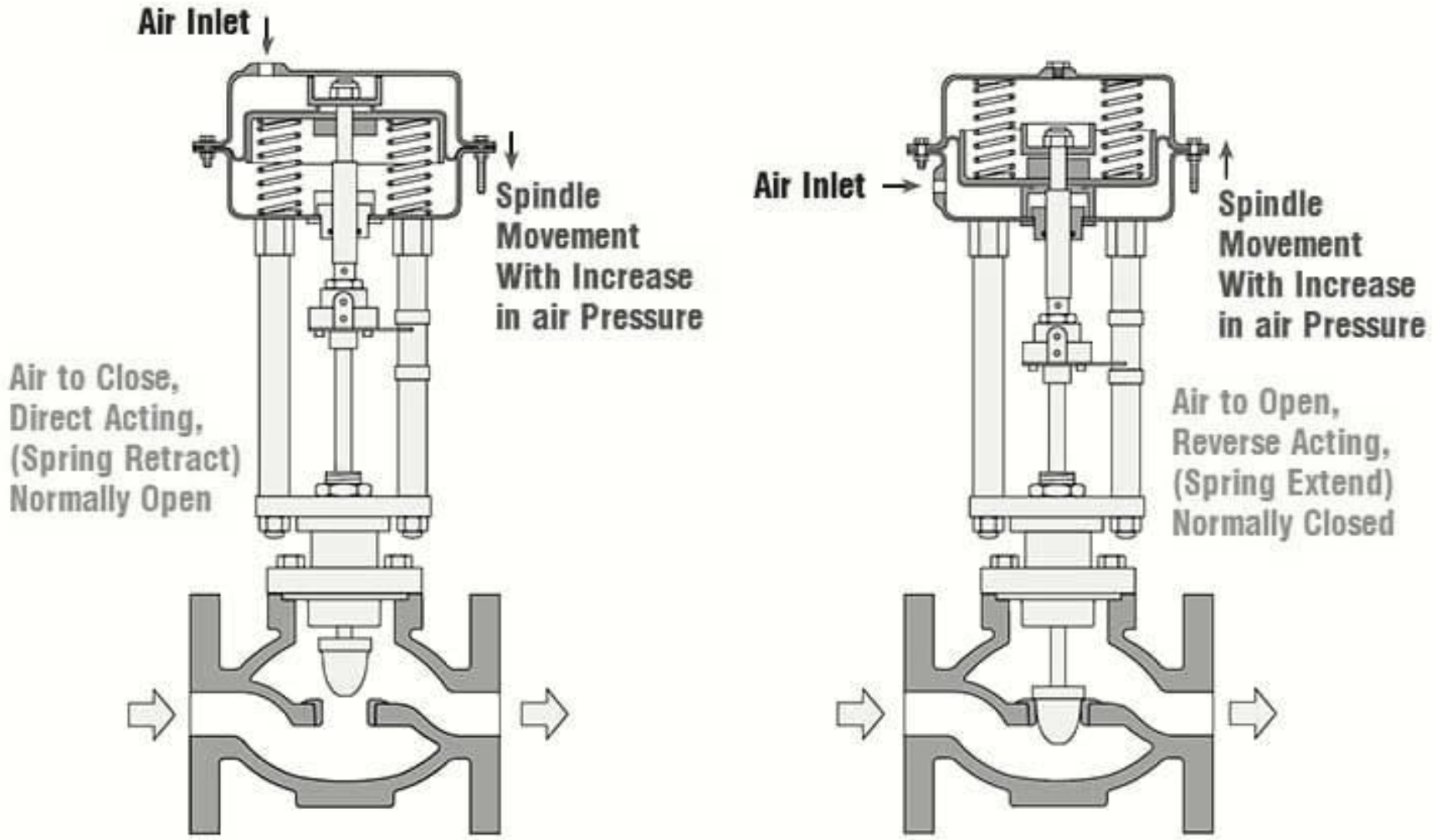


Figure 2.27 *Solenoid Valve*

Pneumatic Actuators



Pneumatic Actuators

Most common type of actuator.

Three designs:

- Diaphragm
- Piston
- Vane

Diaphragm Actuator:

- Dome-shaped device with a flexible diaphragm running through the center.
- Typically mounted on the top of the valve.
- Valve position (on or off) is held by a powerful spring.
- Air enters the dome on one side of the flexible diaphragm, controlling the valve.

Piston Actuator:

- Uses an airtight cylinder and piston to move or position the stem.
- Commonly used with automated gate valves or slide valves.
- Used where a lot of stem travel is needed.

Vane Actuators:

- Direct air against paddles or vanes.
- Frequently used on quarter-turn valves.

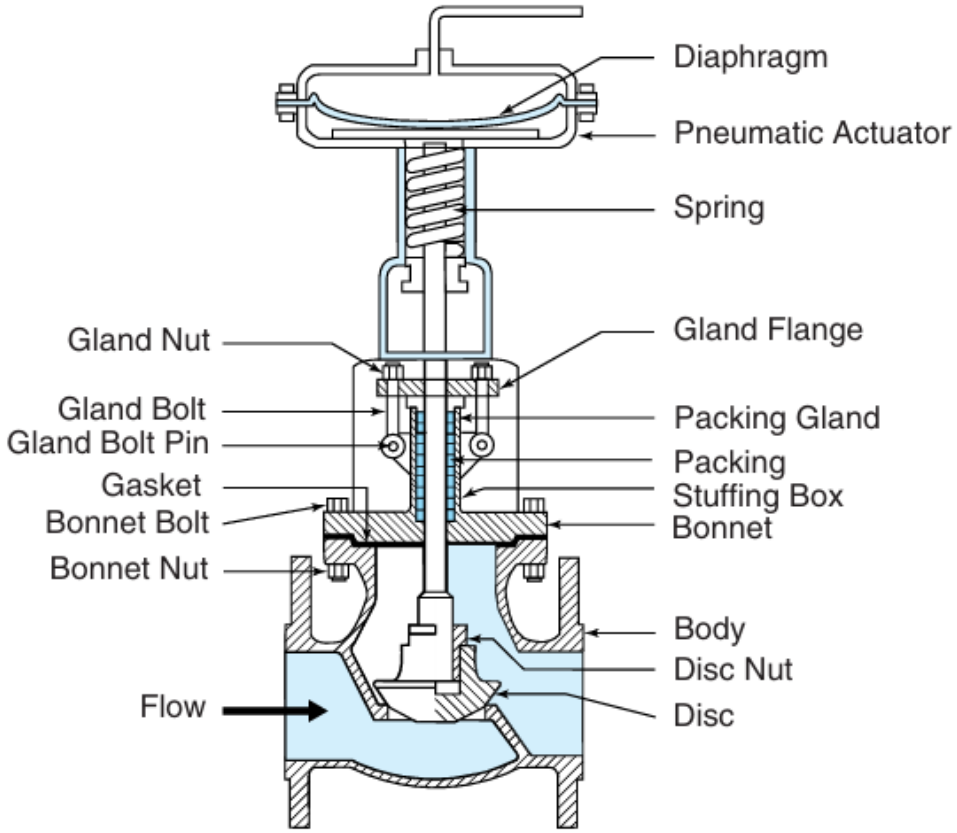


Figure 2.26 *Pneumatic Automatic Valve Components*

Diaphragm Actuator

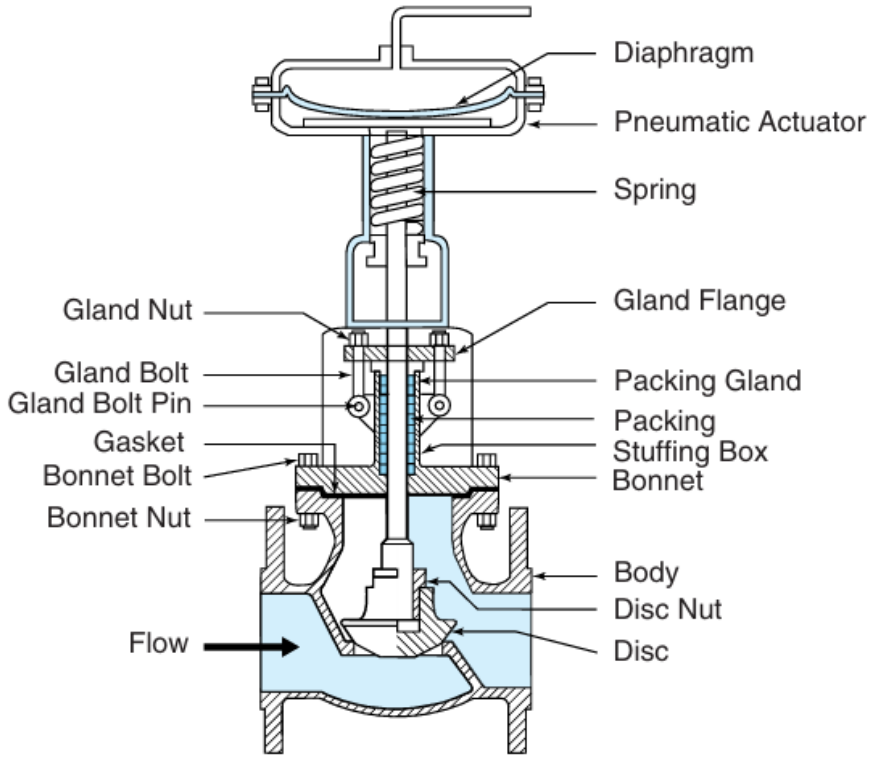
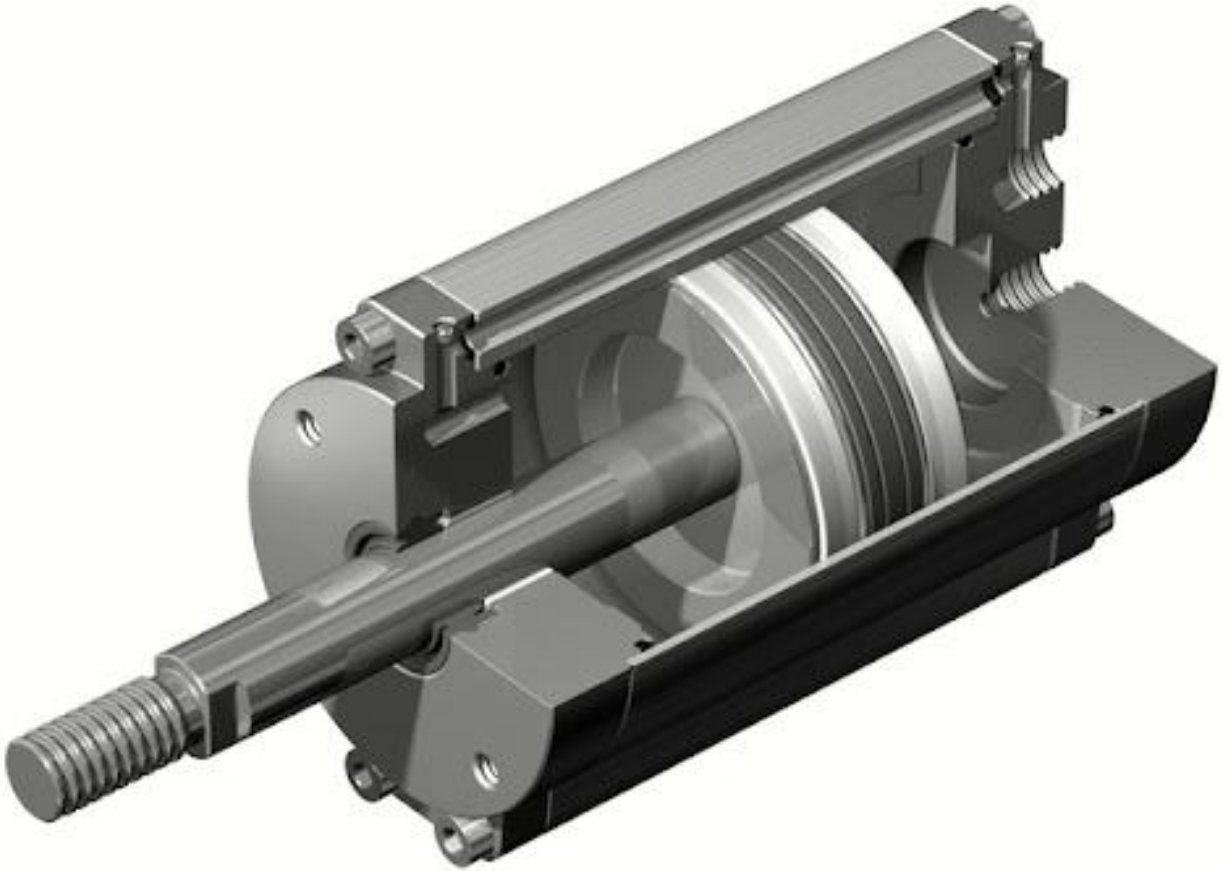


Figure 2.26 *Pneumatic Automatic Valve Components*

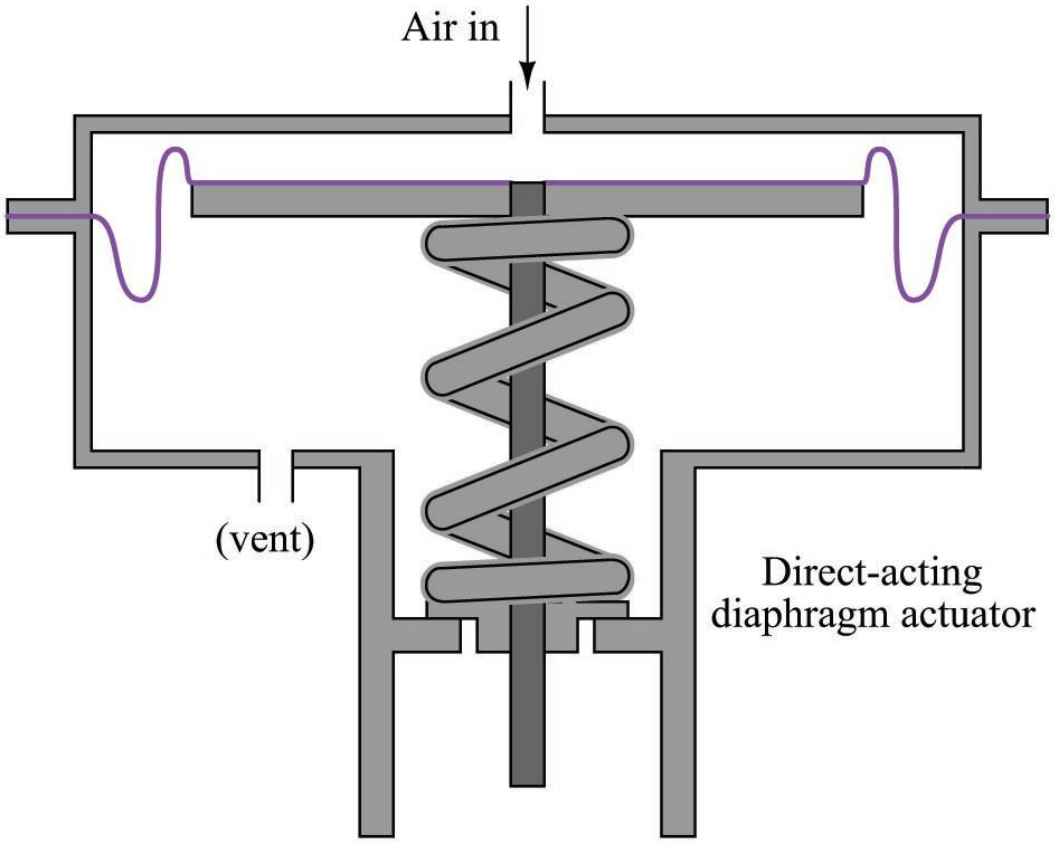
Diaphragm Actuator

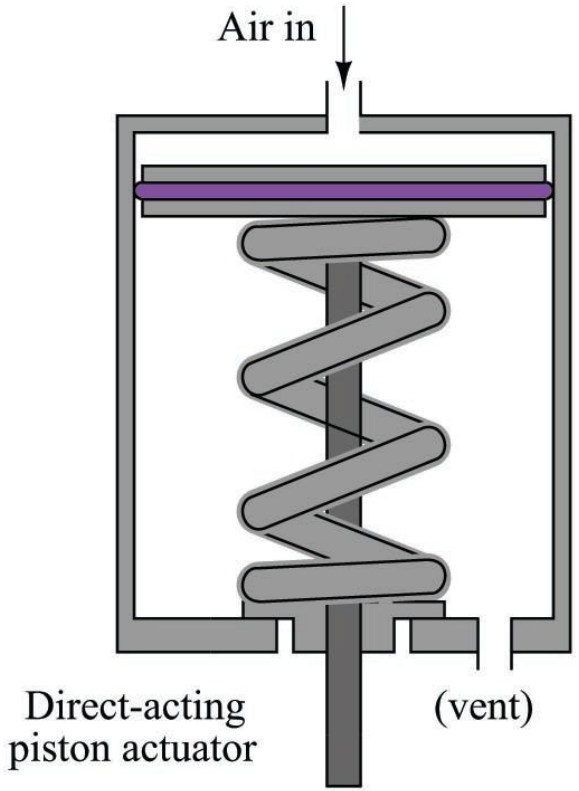


Piston Actuator



Piston Actuator





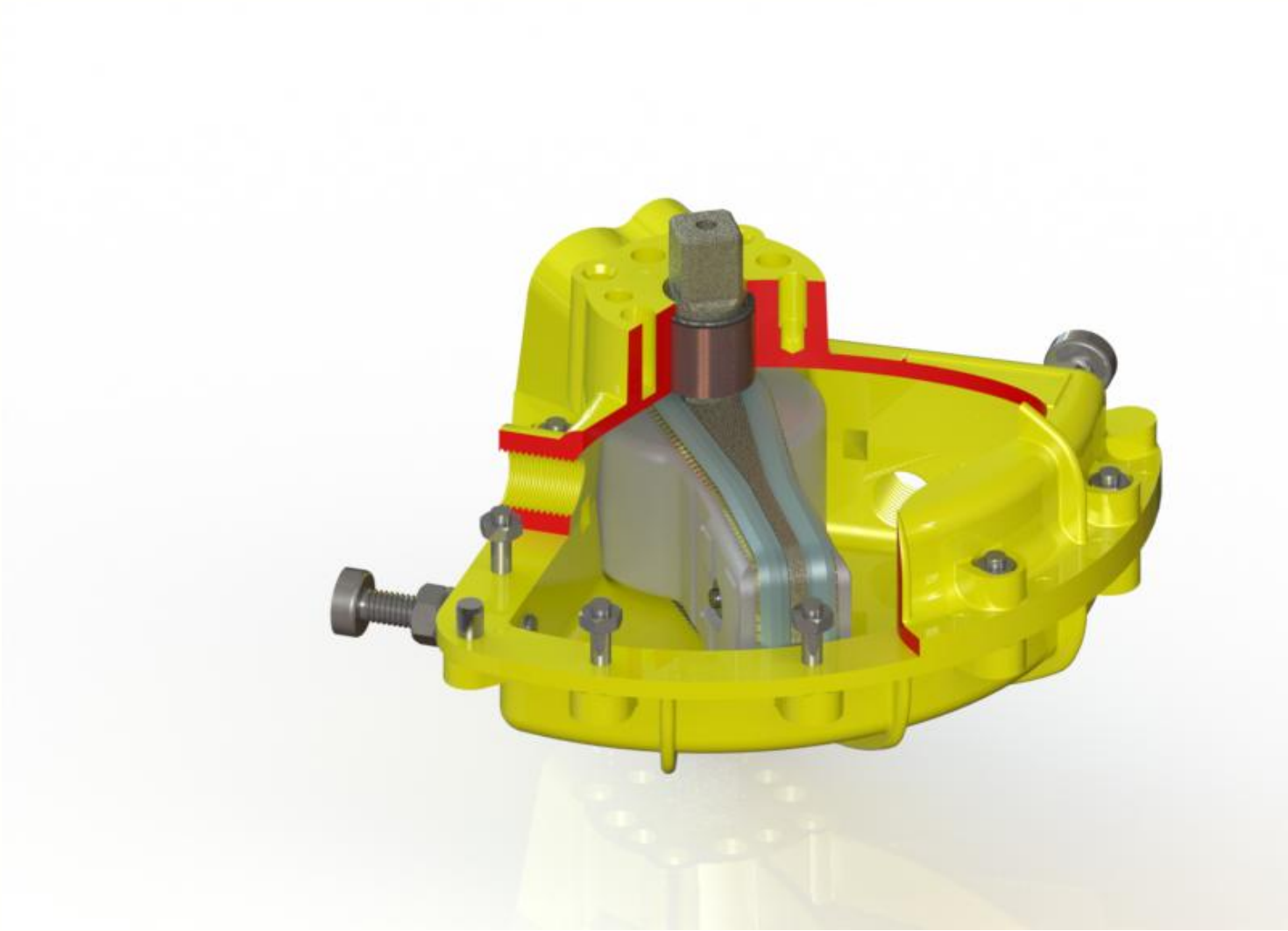
Piston Actuator



Piston Actuator



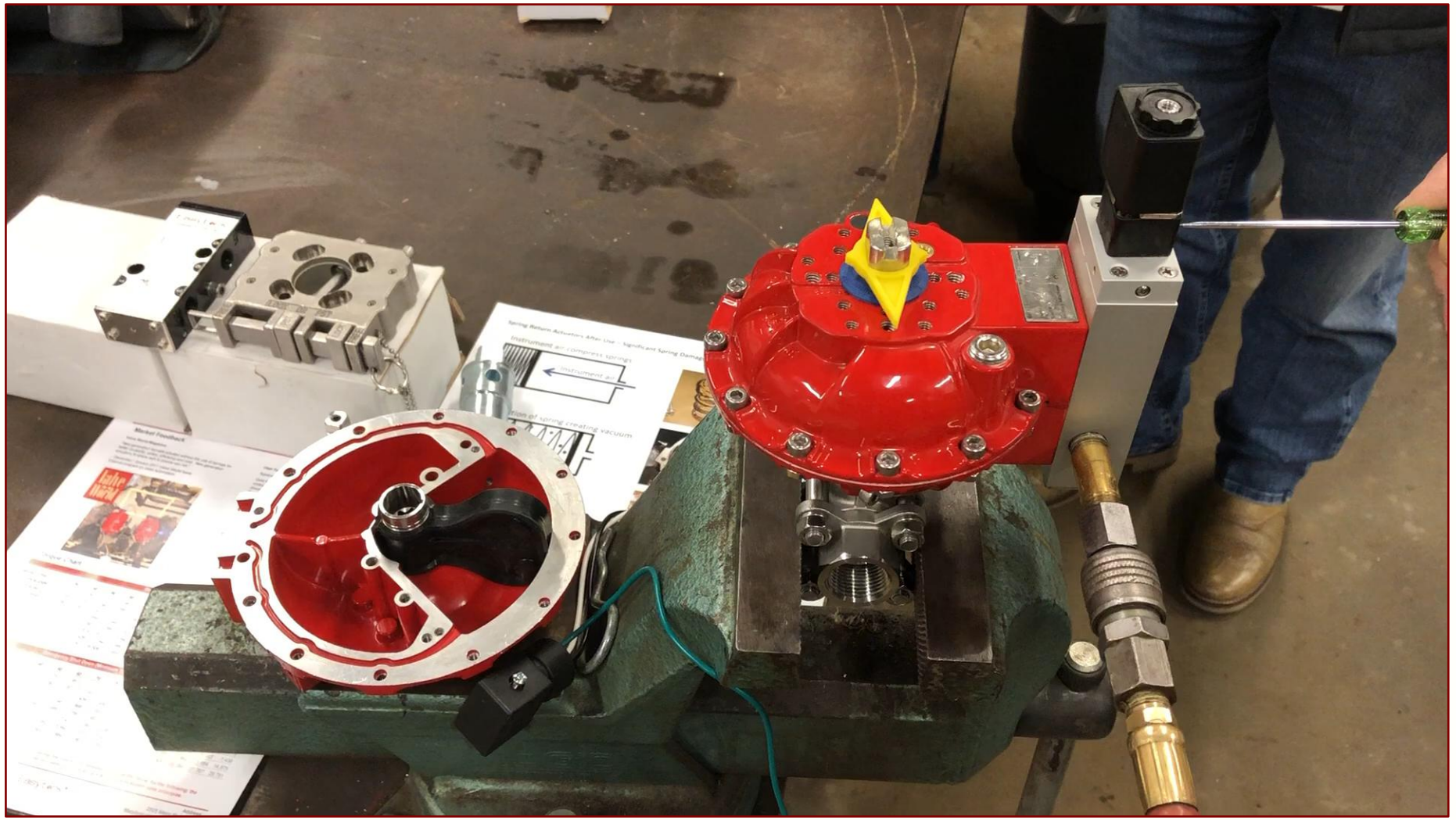
Vane Actuators



Vane Actuators



Vane Actuators



Common Terms for Pneumatic Actuators

Air to Open; Spring to Close:

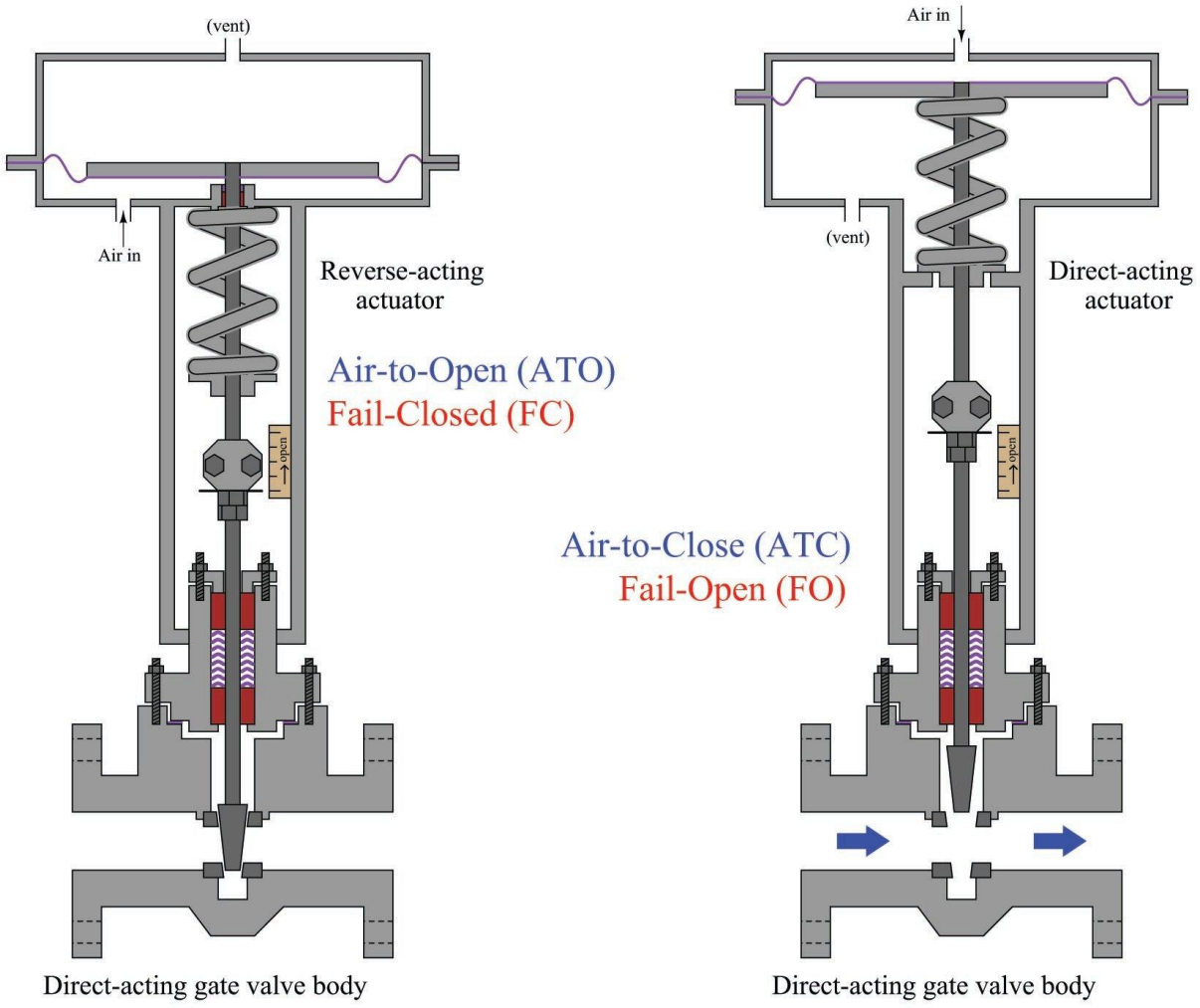
- Valve fails in the closed position if the air system goes down.
- Air line typically located on the bottom of the dome.

Air to Close; Spring to Open:

- Valve fails in the open position if the air system goes down.
- Air line typically located on the top of the dome.

Double-Acting, No Spring:

- Air lines are located on both sides of the dome.



Electric Actuators

Solenoid Valve:

- Designed for on/off service.
- Wire coil surrounds the upper spring and stem.
- When the wire coil is energized, a magnetic field causes the armature to lift and compress the spring.
- Armature is held in place until the current stops.

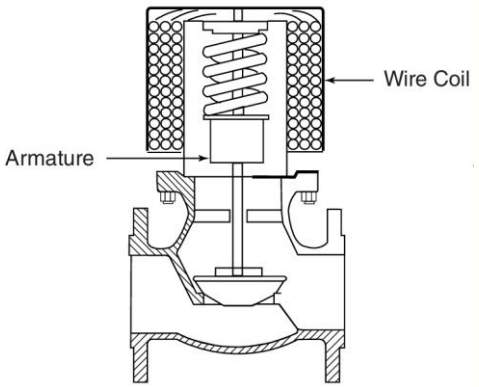


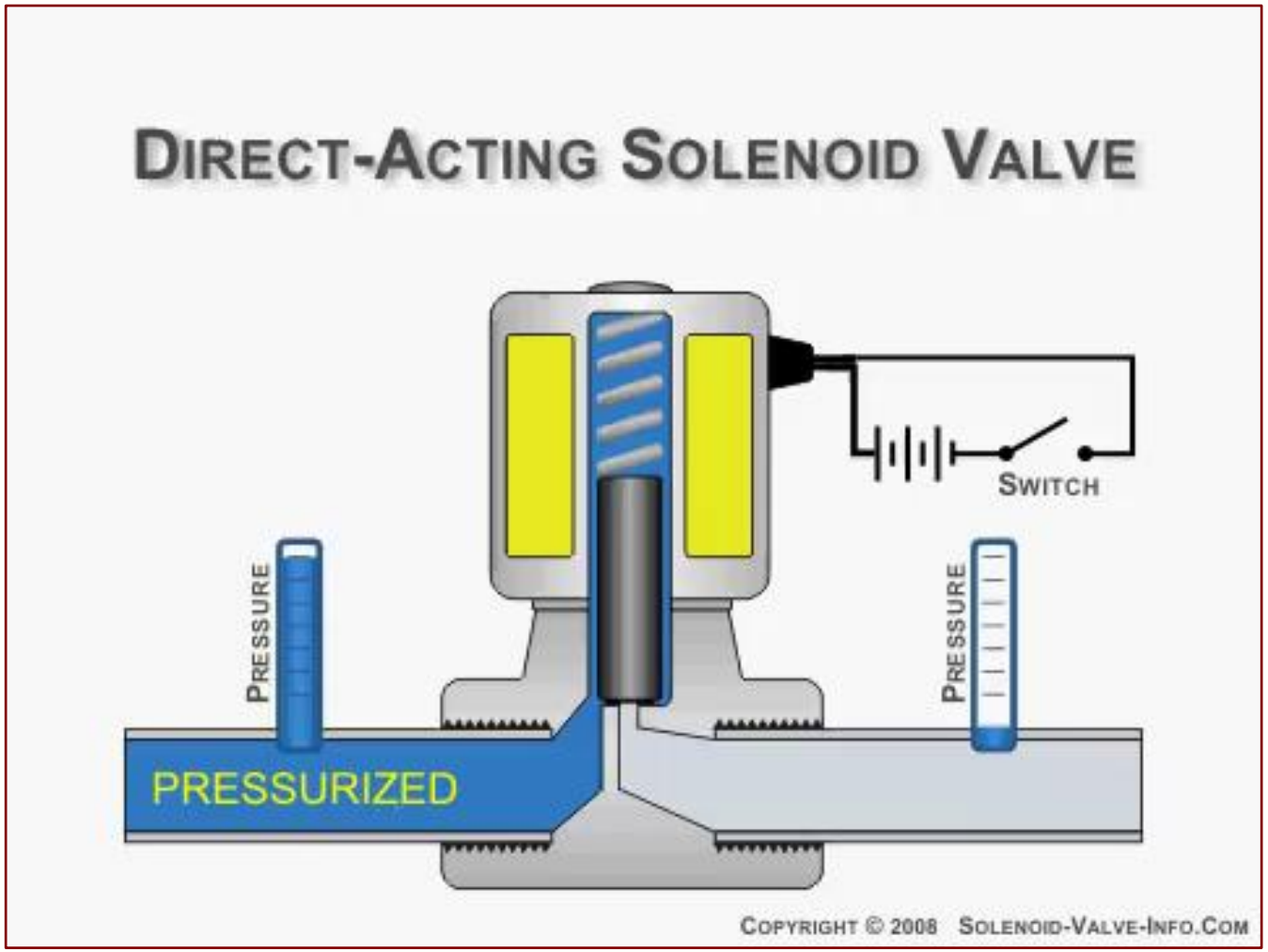
Figure 2.27 *Solenoid Valve*

Motor-Driven Actuator:

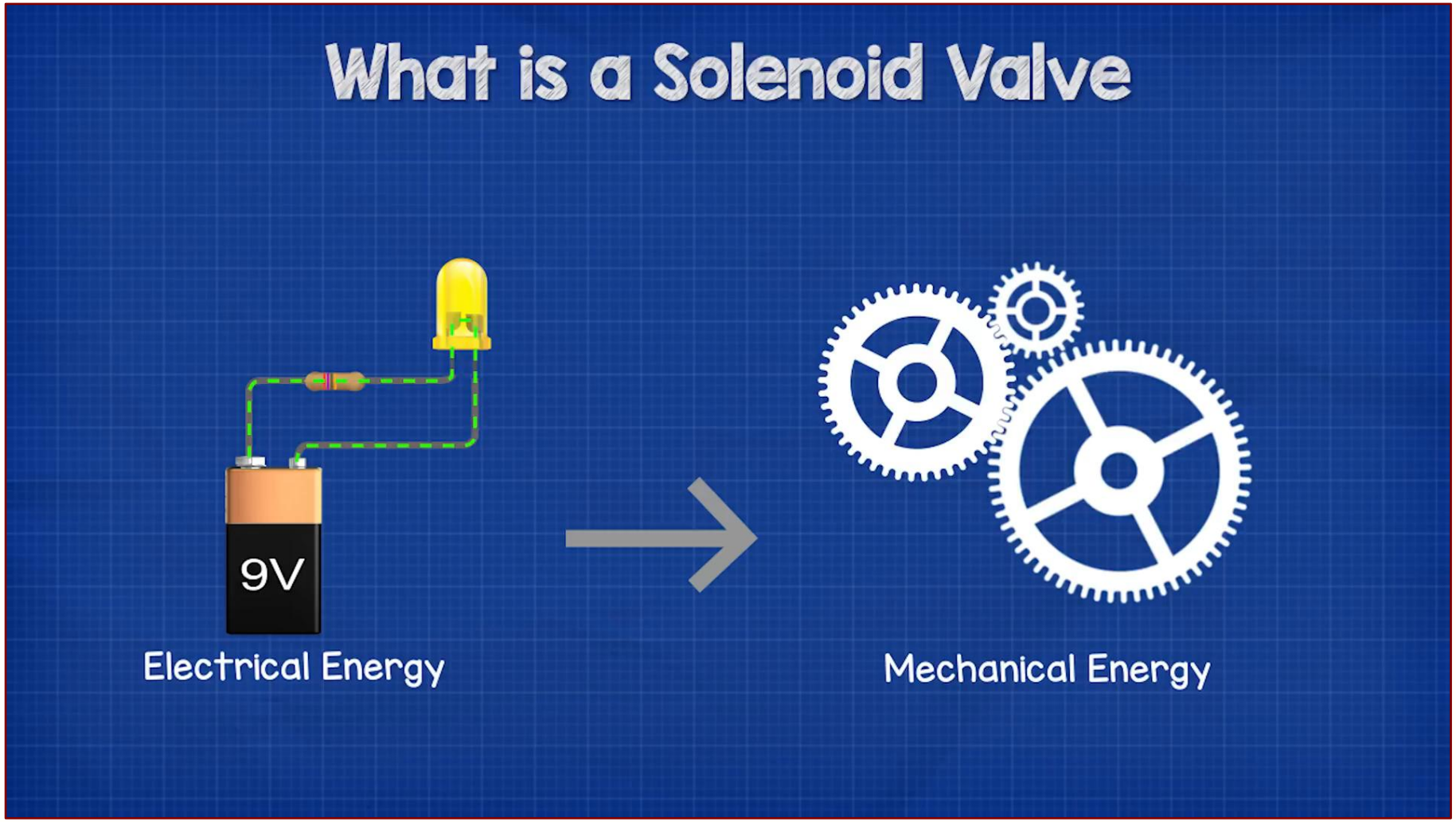
- Attached to the valve stem by a set of gears.
- Gear movement controls the position of the stem.
- Mechanical devices limit the movement of the stem by stopping the motor when the valve is open or closed.



Solenoid Actuators

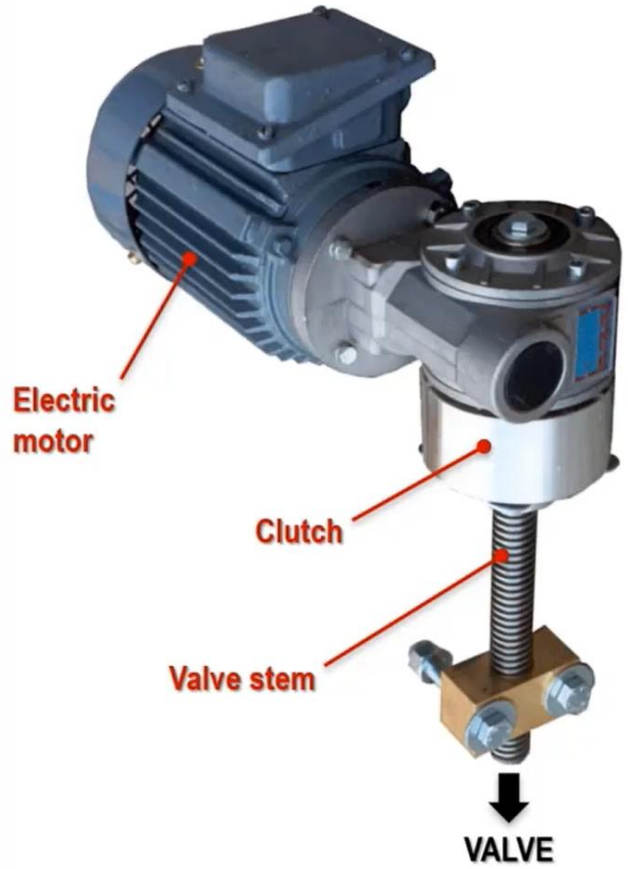


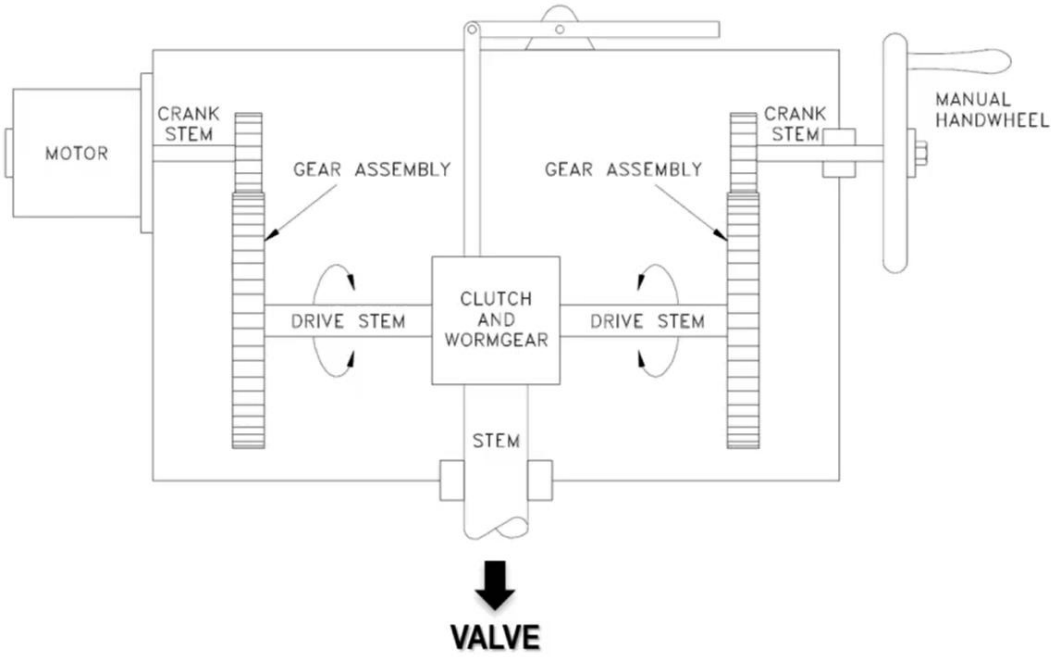
Solenoid Actuators



Electric Motor Actuators

VALVE ACTUATORS



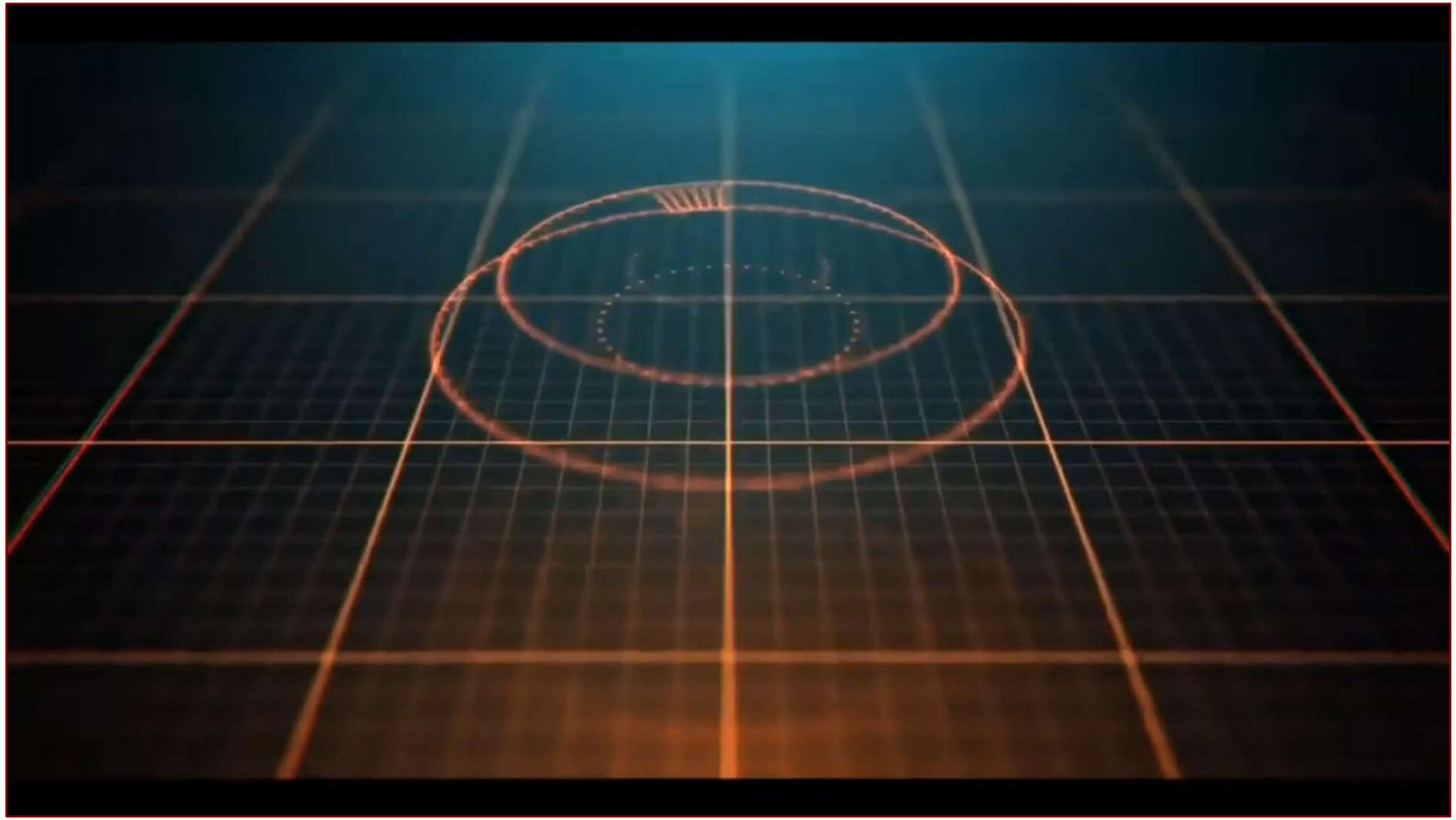


Mr. Engineer

Electric Motor Actuators



Electric Motor Actuators



Hydraulic Actuators

Strength: Very strong, capable of handling high force requirements.

Mechanism: Convert liquid pressure to mechanical energy.

Components: Utilize a liquid-tight cylinder and piston to move or position the valve stem.

Common Applications:

- Automated gate valves.
- Slide valves.





Interlocks and Permissive

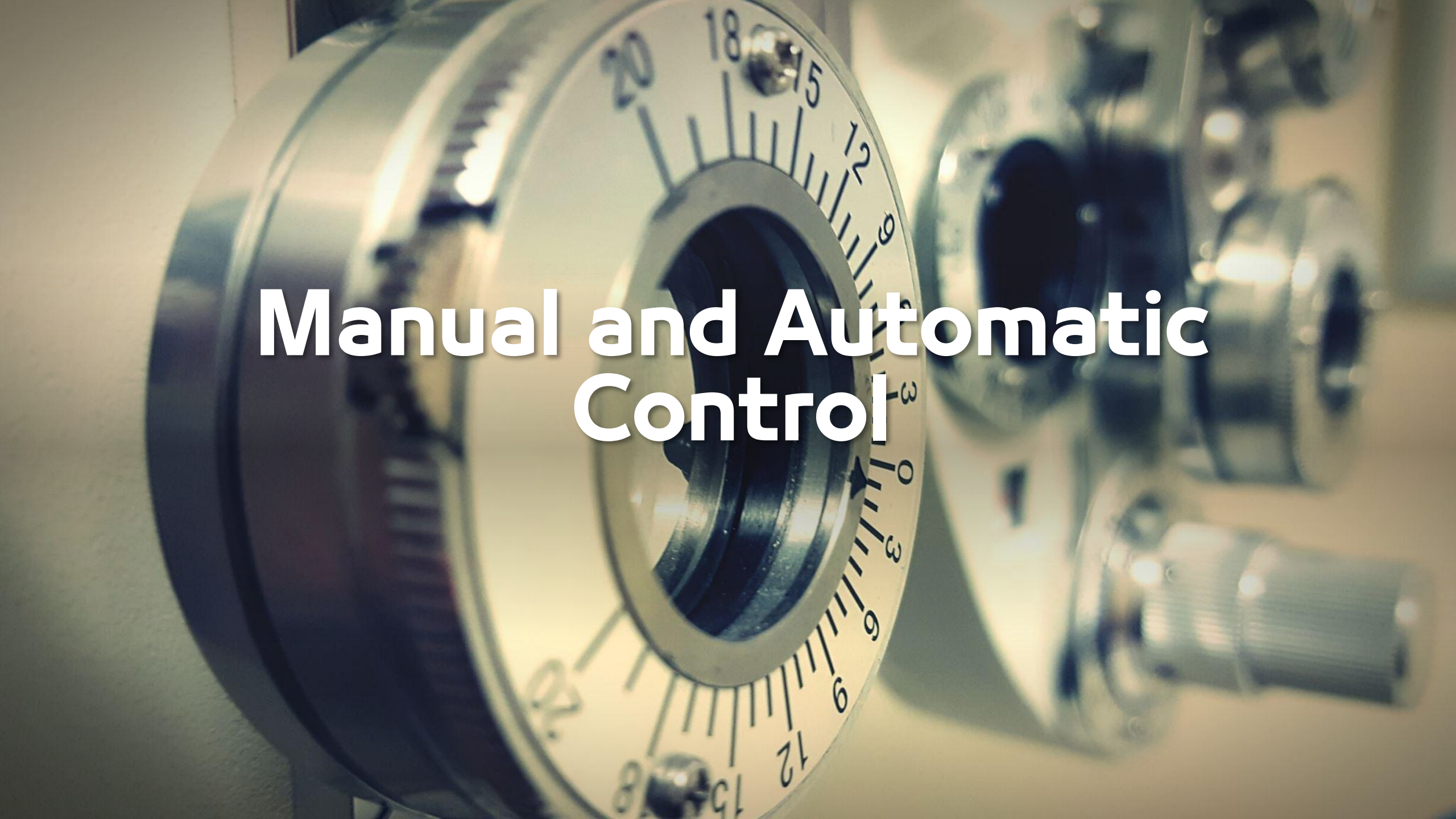
Interlocks:

- **Purpose:**
  - Designed to prevent damage to equipment and personnel.
  - Stop or prevent the start of certain equipment if preset conditions are not met.
- **Types:**
  - **Softwire Interlocks:**
    - Contained within the logic of a programmable computer.
  - **Hardwire Interlocks:**
    - Physical arrangement involving electrical relays.
    - Operate independently of the control computer.
    - Usually run side by side with computer softwire interlocks.
    - Cannot be bypassed and must be satisfied before the associated process can proceed.

Interlocks and Permissive

Permissives:

- **Purpose:**
  - Control a set of conditions that must be satisfied before a piece of equipment can be started.
  - Deal with startup items.
- **Difference from Hardwire Interlocks:**
  - Hardwire interlocks deal with shutdown items.
- **Characteristics:**
  - Controlled by the DCS (Distributed Control System).
  - Do not necessarily shut down the equipment if conditions are not met.
  - Prevent the equipment from starting up if conditions are not satisfied.



Manual and Automatic Control

Manual and Automatic Control

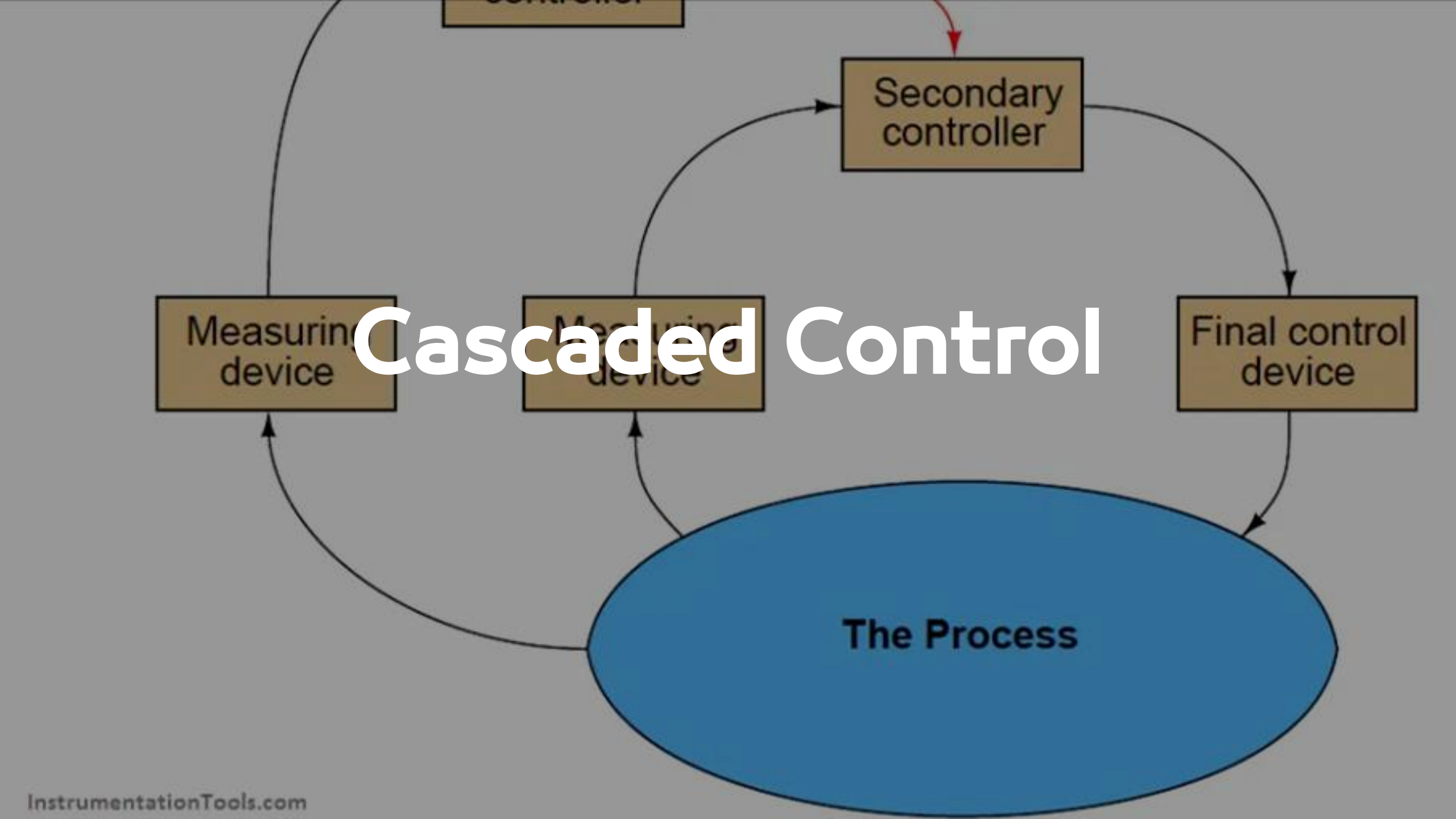
Startup Procedure:

- **Manual Control:**
  - Console operators use manual control to establish a steady state flow initially.
  - Helps reduce process variations.
- **Control Loop Adjustment:**
  - New processes will cause control loops to swing high and low as they attempt to match the set point.
  - Experienced technicians understand the operating valve percentage for steady-state operation.
- **Switch to Automatic Control:**
  - Once the system is stable, the console technician will set the set point on the controller and place it in AUTO.
  - This procedure helps achieve steady-state operation faster and ensures high-quality product output.

Manual and Automatic Control

Automatic Control:

- Utilizes all five elements of the control loop in a dynamic system.
  - Measurement device
  - Transmitter
  - Controller
  - Transducer
  - Final control element
- Functions:
  - Measures, compares, and attempts to control specific processes.
- **Control Loops:**
  - Process units may have hundreds of control loops.
  - Controls various aspects like level, pressure, temperature, flow, and analytical processes.
- **Benefits:**
  - Enables process technicians to manage larger and more complex process systems.



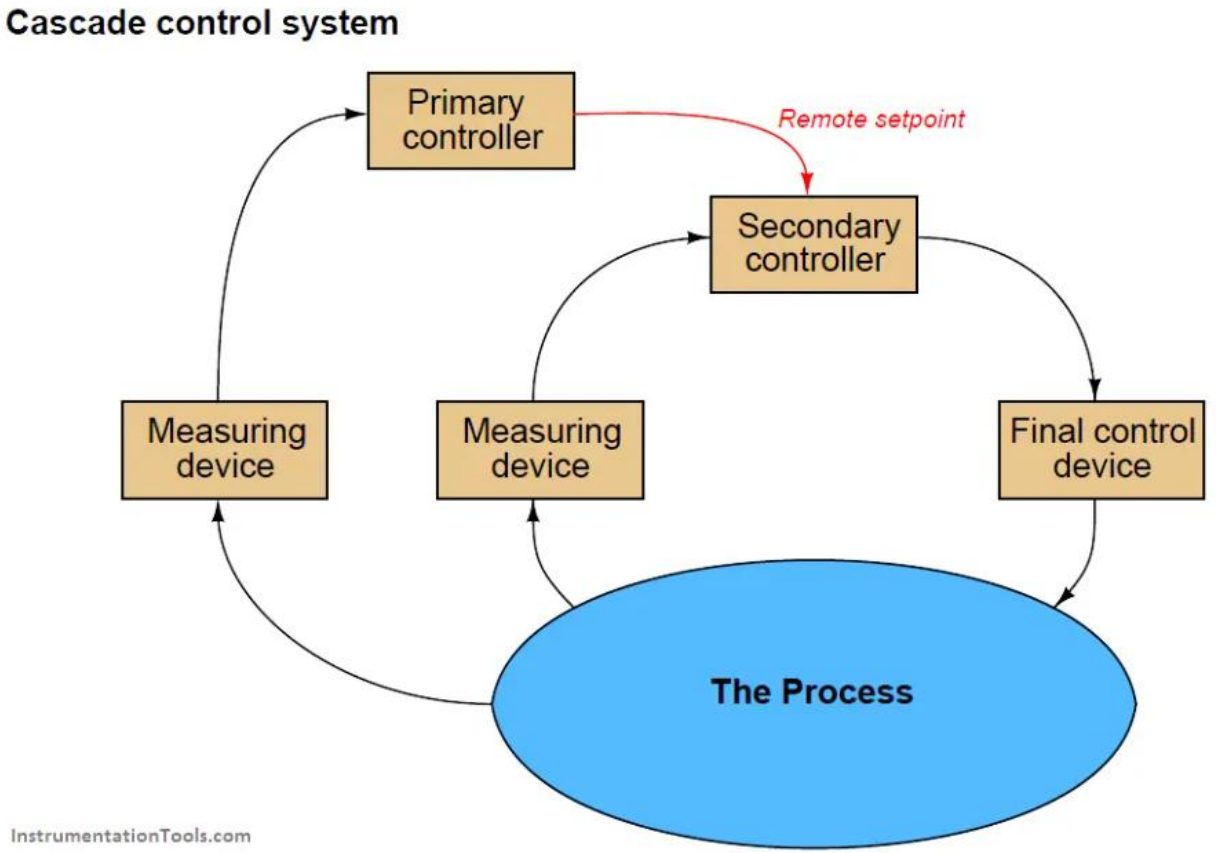
Cascaded Control

InstrumentationTools.com

Cascaded Control

Cascade Control:

- Uses elements from two separate control loops.
  - Primary controller **(Master)**
  - Secondary controller **(Slave)**
- **Function:**
  - The primary controller regulates the overall process.
  - The secondary controller manages a specific part of the process under the primary controller's supervision.
- **Communication:**
  - Controllers in a cascade system communicate exclusively with each other.



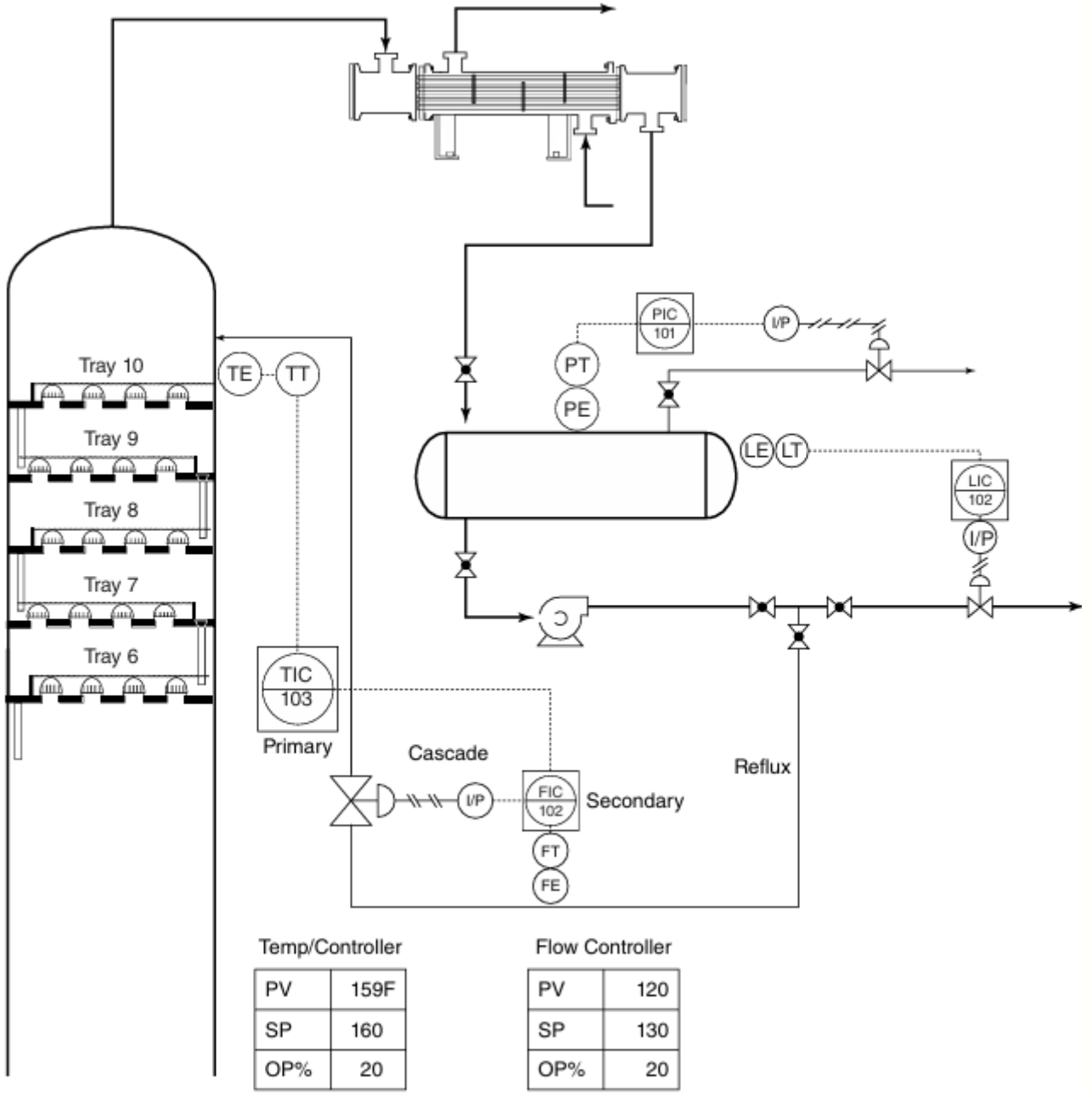


Figure 11.27 *Cascaded Control Loop*

Cascaded Control



Process Systems:

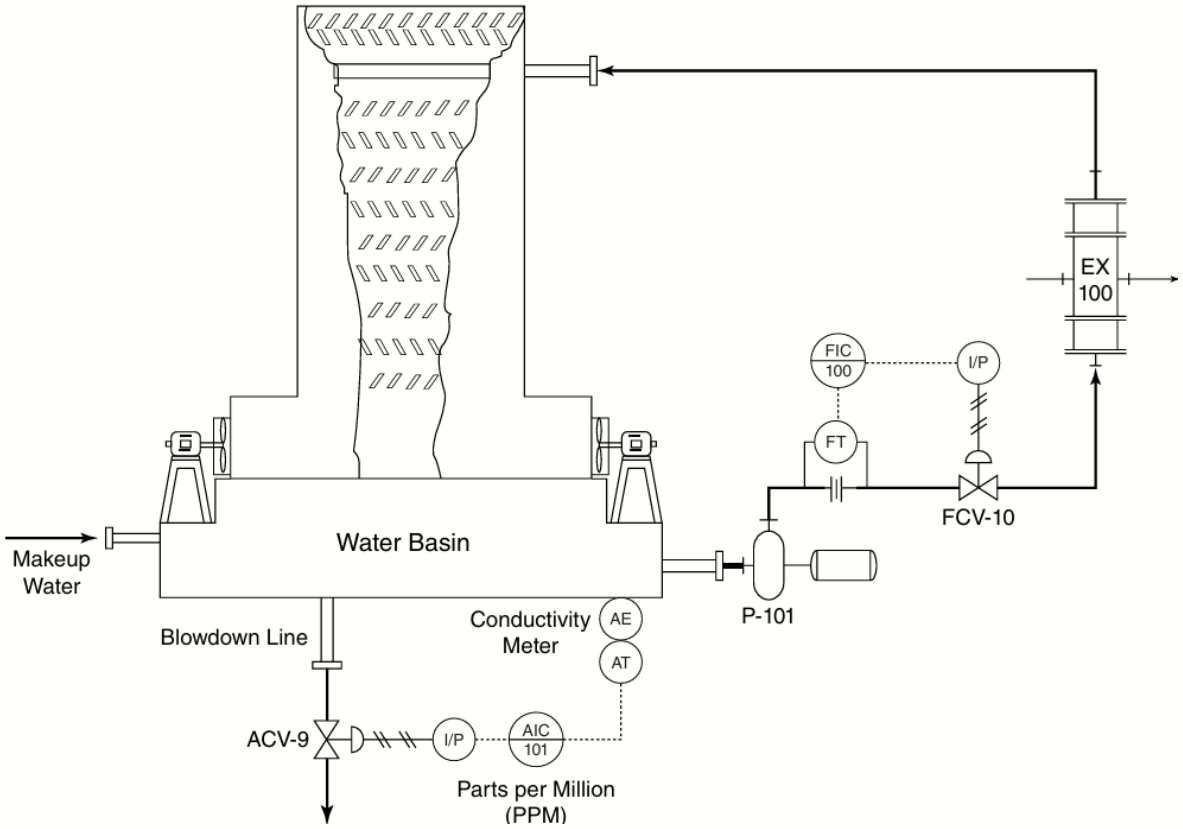
- Can achieve multiple similar objectives simultaneously.
- **Example: Distillation System:**
  - Reflux used to control temperature and improve product purity.
  - Flow control loop ensures steady flow.
  - Temperature control is the most crucial factor.
- **Temperature Control in Distillation:**
  - Temperature element placed on the top tray.
  - Connected to a transmitter, controller, transducer, and control valve on the reflux line.
  - **Conflict Resolution:**
    - Flow control valve and temperature control valve may conflict.
    - By selecting temperature as the primary controller, both flow and temperature control can work together to achieve operational objectives.


Analytical Control

Analytical Control

Analytical Control Loop:

- Used to control process variables like pH, PPM (parts per million), and product concentrations.
- Example: Cooling Towers:
  - Require close control of pH and PPM.
  - Shifts in these variables can cause serious problems.
  - Control systems are used to manage these analytical variables.



Analytical Control

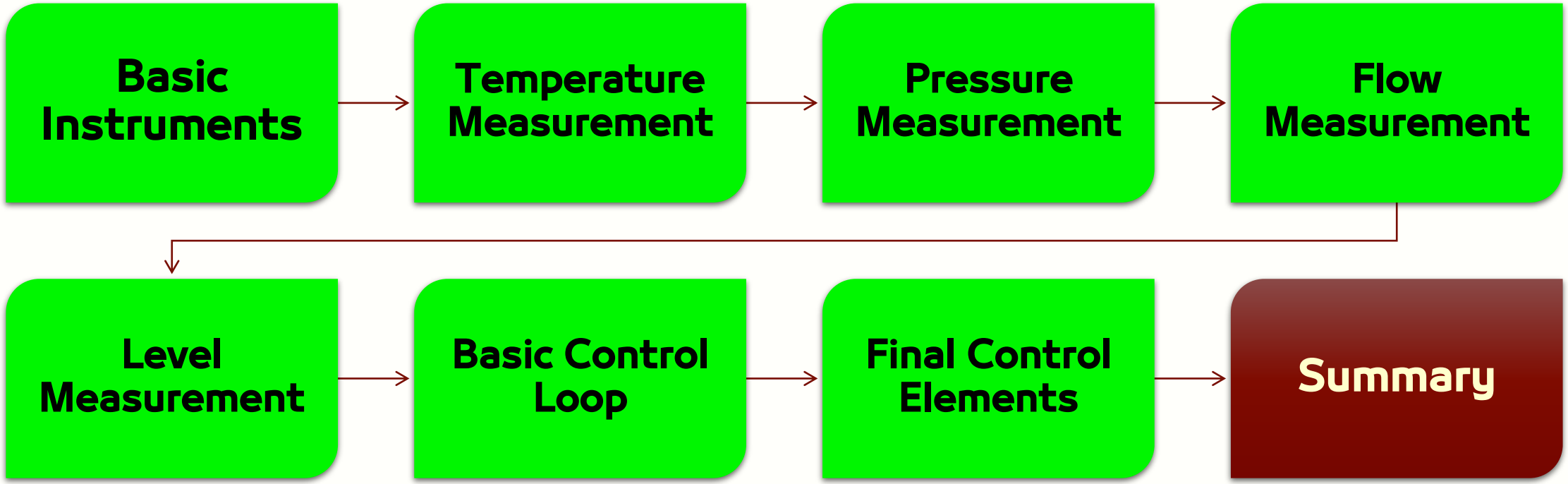
Definition:

- Analytical control involves monitoring and controlling specific **chemical compositions, properties, or other analytical parameters** of a process stream. It ensures that the desired product quality and process efficiency are maintained.

Key Aspects:

- **Measurement:**
  - Uses analytical instruments to measure chemical or physical properties such as **pH, conductivity, concentration of specific components, moisture content**, etc.
- **Control:**
  - Adjusts the process parameters (**like flow rates, temperatures, pressures)** based on the analytical measurements to maintain the desired conditions.

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Summary

Automation in Process Control:

- Enhances operators' ability to manage large and complex networks.
- Basic instruments include:
  - Gauges (pressure, level, temperature, flow)
  - Differential pressure (DP) cells
  - Transmitters (pressure, level, temperature, flow)
  - Controllers (pneumatic, electronic)
  - Transducers
  - Control valves
  - Primary elements and sensors (displacer, buoyancy float, thermocouples, orifice plates, etc.)
  - Computers

Pressure Measurement:

- Most common type: bourdon tube.
- Common pressure scales:
  - Gauge scale (psig)
  - Absolute scale (psia)
  - Vacuum scale (Hg)

Flow Measurement Devices:

- Flow transmitter
- Nutating disc meter
- Oval gear meter
- Rotameter
- Turbine flow meter
- Weir
- Flume

Level Measurements:

- Identified by a fixed reference point (zero) above or below a product.
- Devices classified as direct or indirect:
  - Direct: Physical contact with fluid surface.
  - Indirect: Pressure changes proportional to level changes.

Control Loop:

- Group of instruments working together to control a process.
- Typically includes:
  - Transmitter coupled with a sensing device or primary element
  - Controller
  - Transducer
  - Control valve

Controller:

- Receives a signal from a transmitter, compares it with a set point, and adjusts the final control element to maintain the set point.
- Designs: pneumatic, electronic, digital.

Final Control Elements:

- Typically, automated valves but can include motors or other electrical devices.
- Last link in the control loop, making the actual process change.

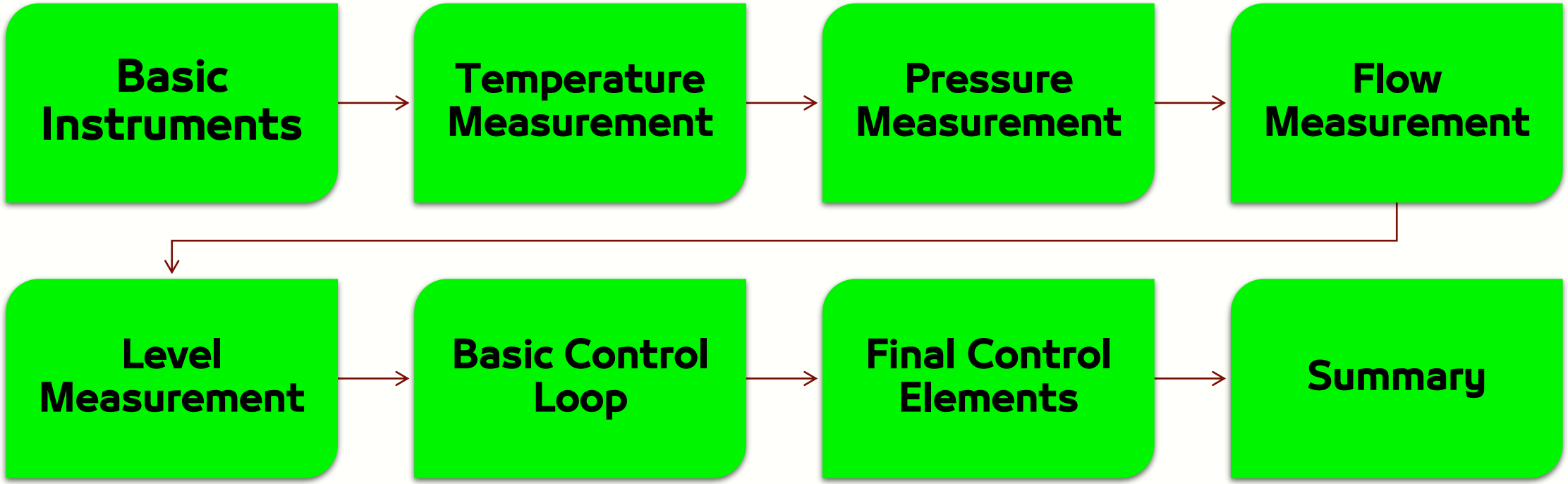
Interlocks:

- Designed to prevent damage by stopping or preventing equipment start-up if conditions aren't met.
- Types:
  - Hardwire: physical arrangements, can't be bypassed.
  - Softwire: contained within programmable logic.

Permissive:

- Special interlocks that control conditions required for equipment startup.
- Deal with startup items, while hardwire interlocks deal with shutdown items.

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Thank You