## **Topics:-**

- Instrument Symbols
- Flow / Pressure measurement
- Control Valve
- Control Valve Accessories
- Temperature measurement
- Level measurement
- Control Loops
- Instruments Calibration
- Codes, standards & Specification
- Safety Instrumented Systems

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# INSTRUMENT SYMBOLS

(1) INSTRUMENT SUPPLY *
OR CONNECTION TO PROCESS

(2) UNDEFINED SIGNAL

(3) PNEUMATIC SIGNAL **

(4) ELECTRIC SIGNAL

(5) HYDRAULIC SIGNAL

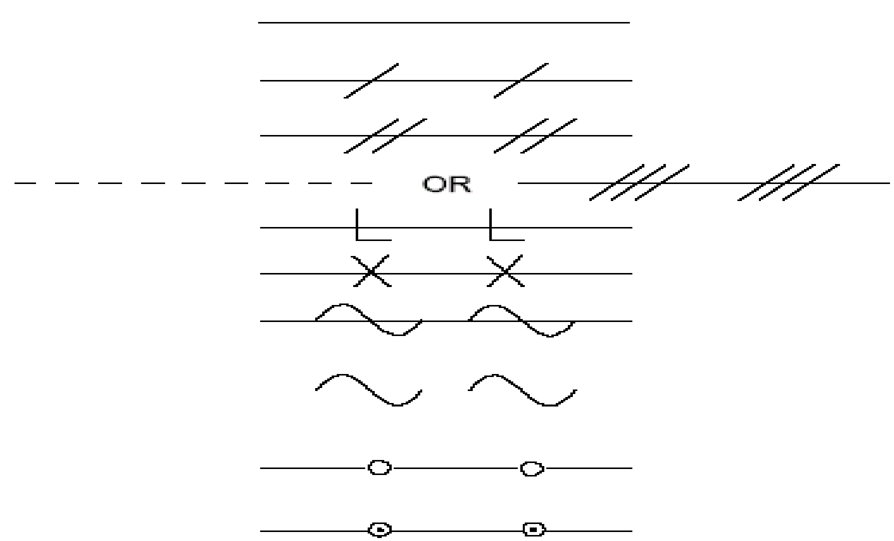
(6) CAPILLARY TUBE

(7) ELECTROMAGNETIC OR SONIC SIGNAL ***
(GUIDED)

(8) ELECTROMAGNETIC OR SONIC SIGNAL ***
(NOT GUIDED)

(9) INTERNAL SYSTEM LINK
(SOFTWARE OR DATA LINK)

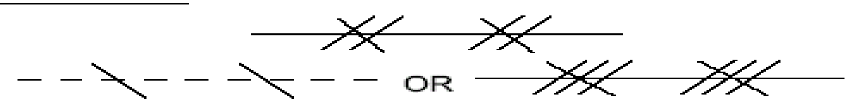
(10) MECHANICAL LINK




OPTIONAL BINARY ( ON-OFF ) SYMBOLS

(11) PNEUMATIC BINARY SIGNAL

(12) ELECTRIC BINARY SIGNAL




NOTE: 'OR' means user's choice. Consistency is recommended.

* The following abbreviations are suggested to denote the types of power supply. These designations may also be applied to purge fluid supplies.

AS - Air Supply
- IA - Instrument Air } Options
- PA - Plant Air } Options

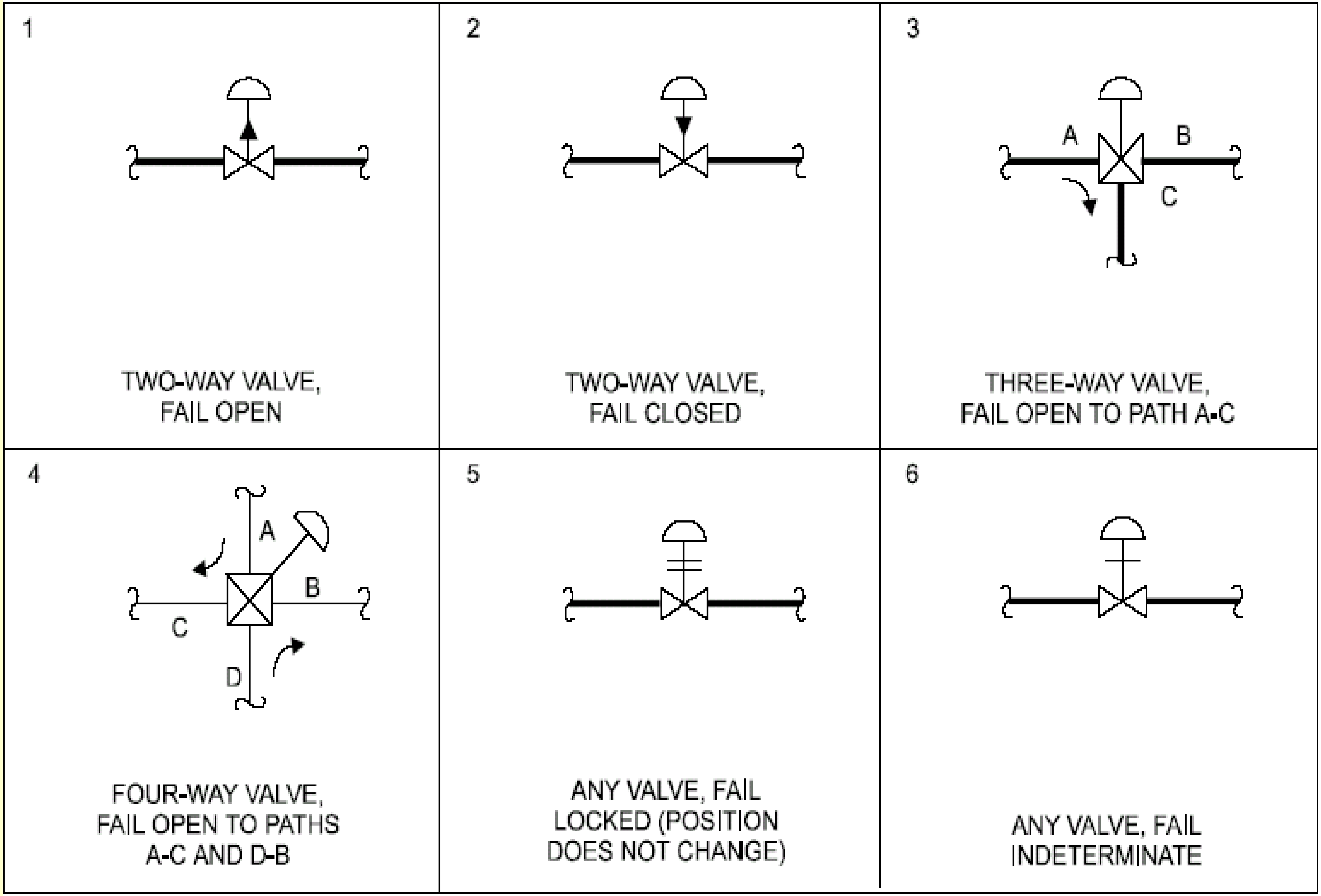
ES - Electric Supply
GS - Gas Supply
HS - Hydraulic Supply
NS - Nitrogen Supply
SS - Steam Supply
WS - Water Supply

The supply level may be added to the instrument supply line, e.g., AS-100, a 100-psig air supply; ES-24DC, a 24-volt direct current power supply.

** The pneumatic signal symbol applies to a signal using any gas as the signal medium. If a gas other than air is used, the gas may be identified by a note on the signal symbol or otherwise.

*** Electromagnetic phenomena include heat, radio waves, nuclear radiation, and light.

# INSTRUMENT SYMBOLS

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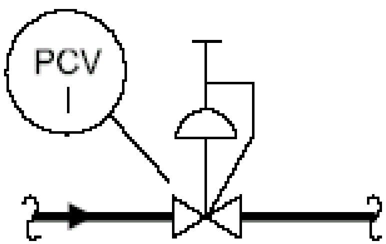
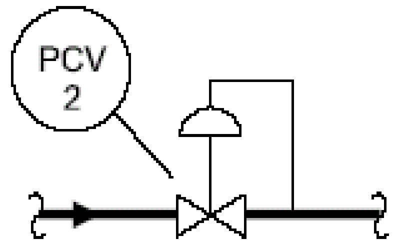
# INSTRUMENT SYMBOLS

1



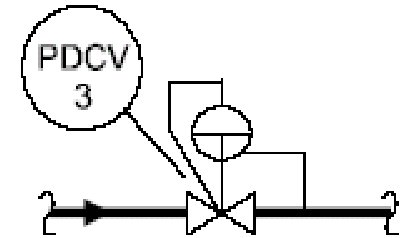

PRESSURE-REDUCING REGULATOR, SELF-CONTAINED, WITH HANDWHEEL ADJUSTABLE SET POINT

2



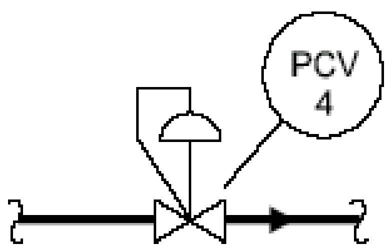

PRESSURE-REDUCING REGULATOR WITH EXTERNAL PRESSURE TAP

3



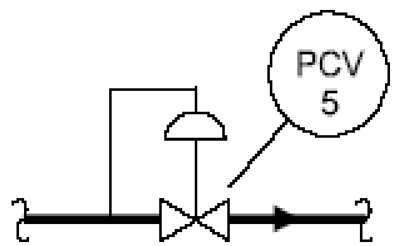

DIFFERENTIAL-PRESSURE-REDUCING REGULATOR WITH INTERNAL AND EXTERNAL PRESSURE TAPS

4



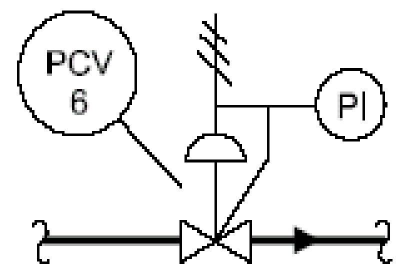

BACKPRESSURE REGULATOR, SELF-CONTAINED

5




BACKPRESSURE REGULATOR WITH EXTERNAL PRESSURE TAP

6




PRESSURE-REDUCING REGULATOR WITH INTEGRAL OUTLET PRESSURE RELIEF VALVE, AND OPTIONAL PRESSURE INDICATOR (TYPICAL AIR SET)

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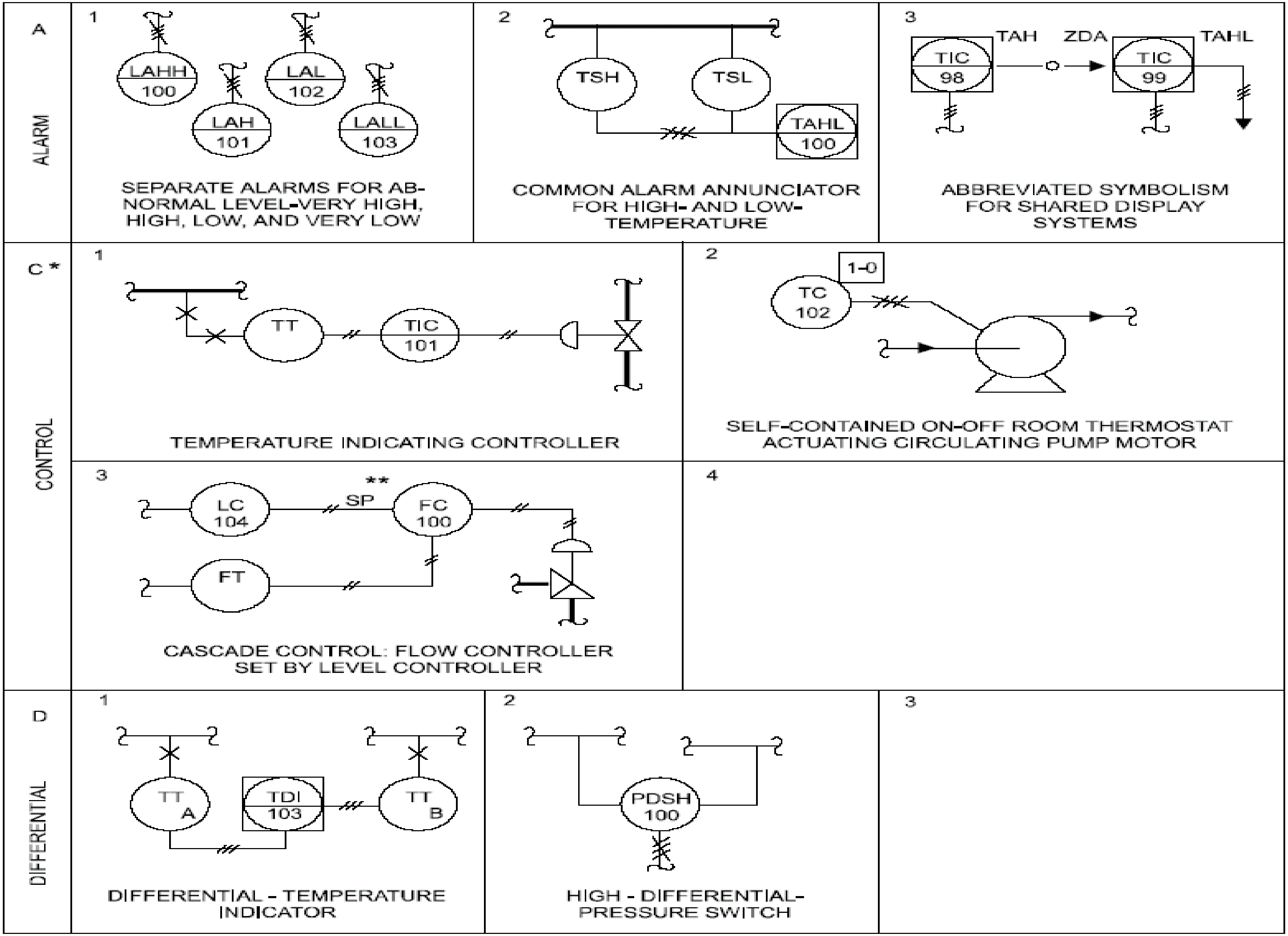
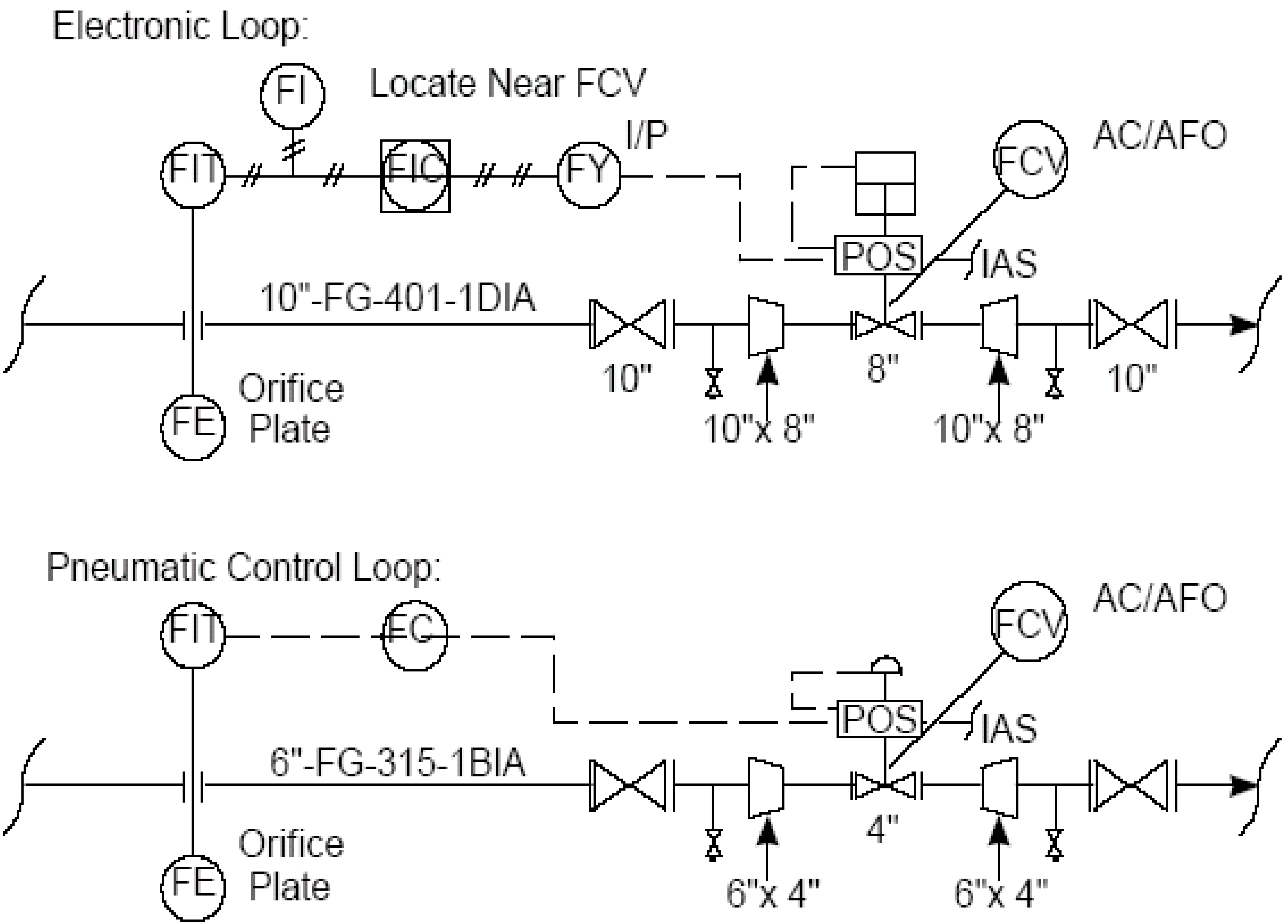
# INSTRUMENT SYMBOLS



# INSTRUMENT SYMBOLS



# FLOW MEASUREMENT

## Flow Rate

Flow rate is an indication of how fast a substance moves through a conduit from one place to another. Flow rate can also be used to determine the distance a substance moves over a period of time. Flow rate is usually expressed as

- Volume flow rate
- Mass flow rate

**Volume Flow Rate** represents the volume of fluid that passes a measurement point over a period of time. An example measurement unit is kg per hour. The volume flow rate can be calculated if the average flow velocity and inside pipe diameter are known. The calculation is based on the formula

$$Q = A \times v$$

where

$Q$ = volumetric flow rate

$A$ = cross-sectional area of the pipe

$v$ = average flow velocity (flow rate)

# FLOW MEASUREMENT

**Mass Flow Rate** represents the amount of mass that passes a specific point over a period of time.

Mass flow rates are used to measure the weight or mass of a substance flowing through a process operation. If the volumetric flow rate and density are known, the calculation is based on the formula

W = Q x r

where

W = mass flow rate

Q = volumetric flow rate

r = density (r = density "rho" )

# FLOW MEASUREMENT

**Laminar Flow:** Streamlined flow of a fluid where viscous forces are more significant than inertial forces, generally below a Reynolds number of 2000.

**Turbulent Flow:** When forces due to inertia are more significant than forces due to viscosity. This typically occurs with a Reynolds number in excess of 4000.

**Volume Flow Rate:** Calculated using the area of the full closed conduit and the average fluid velocity in the form, Q = V x A, to arrive at the total volume quantity of flow. Q = volumetric flowrate, V = average fluid velocity, and A = cross sectional area of the pipe.

**Differential Pressure:** The difference in static pressure between two identical pressure taps at the same elevation located in two different locations in a primary device.

**Static Pressure:** Pressure of a fluid whether in motion or at rest. It can be sensed in a small hole drilled perpendicular to and flush with the flow boundaries so as not to disturb the fluid in any way.

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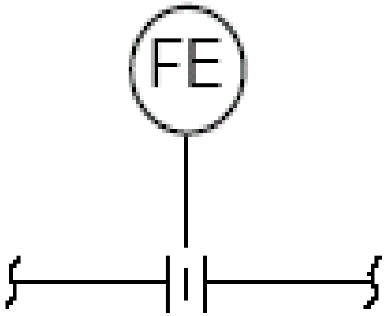
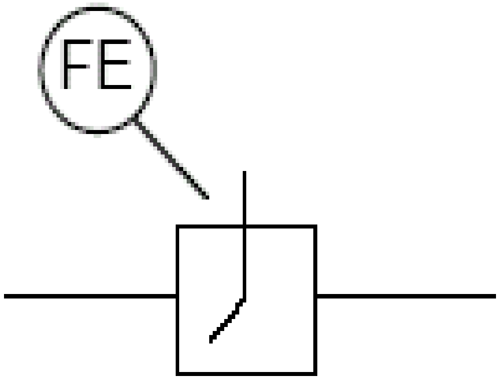
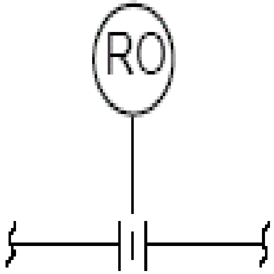
# FLOW MEASUREMENT



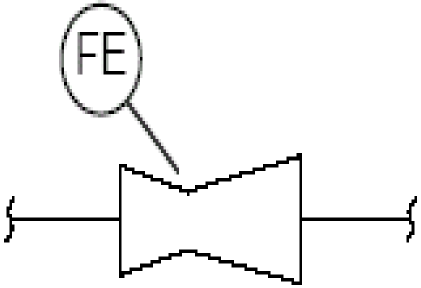

Orifice Plate



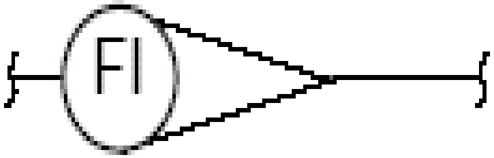

Pitot Tube
Annubar




Restriction Orifice




Venturi




Variable Area Flowmeter (Rotameter)

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# FLOW MEASUREMENT

## Flow Element

### Differential Pressure

- Orifice Plate
- Pitot
- Venturi

**Advantages:**

- Simple, no moving parts

**Disadvantages:**

- Susceptible to wear in dirty services except vertically
- Orifice edge sharpness affects accuracy

### Turbine

Rotor

**Advantages:** Accuracy

**Disadvantages:** Moving parts can wear

### Vortex

Bluff Body

**Advantages:** No moving parts

**Disadvantages:** Bluff body can corrode

Prepared by

# FLOW MEASUREMENT

## Flow Element

### Positive Displacement (PD)

- Oval Gear
- Sliding Vane
- Nutating Disk

**Disadvantages:**

- Many moving parts subject to wear
- Prefilters for dirty service

### Mass • Coriolis • Thermal Mass

**Advantages:**

- Very low maintenance (Coriolis)
- No moving parts, corrosive fluid may effect element (Thermal Mass)

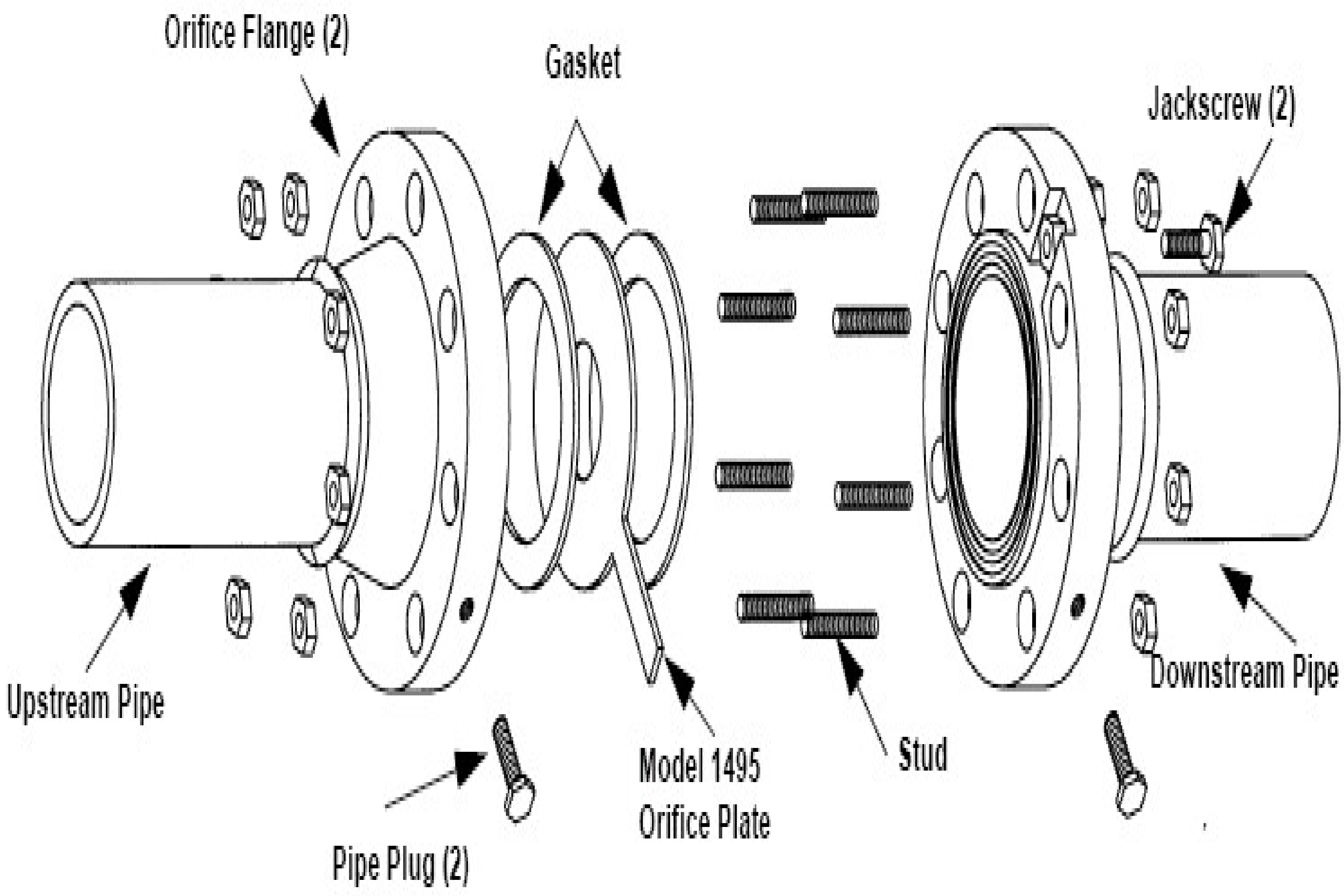
### Magnetic Field (Magmeter)

- AC Field
- DC Field

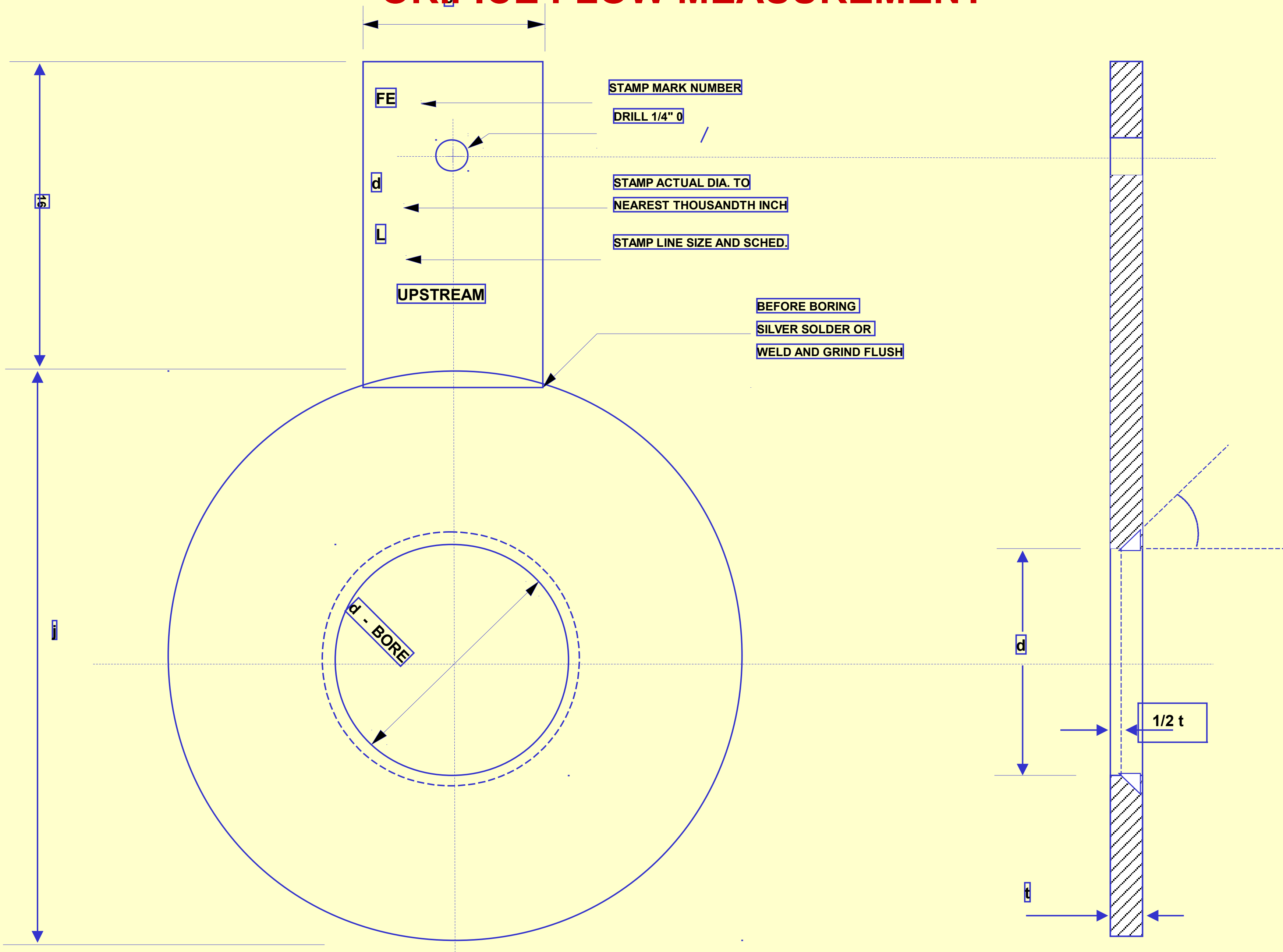
**Advantages:**

- Low maintenance element
- Very low maintenance

# ORIFICE FLOW MEASUREMENT



# ORIFICE FLOW MEASUREMENT

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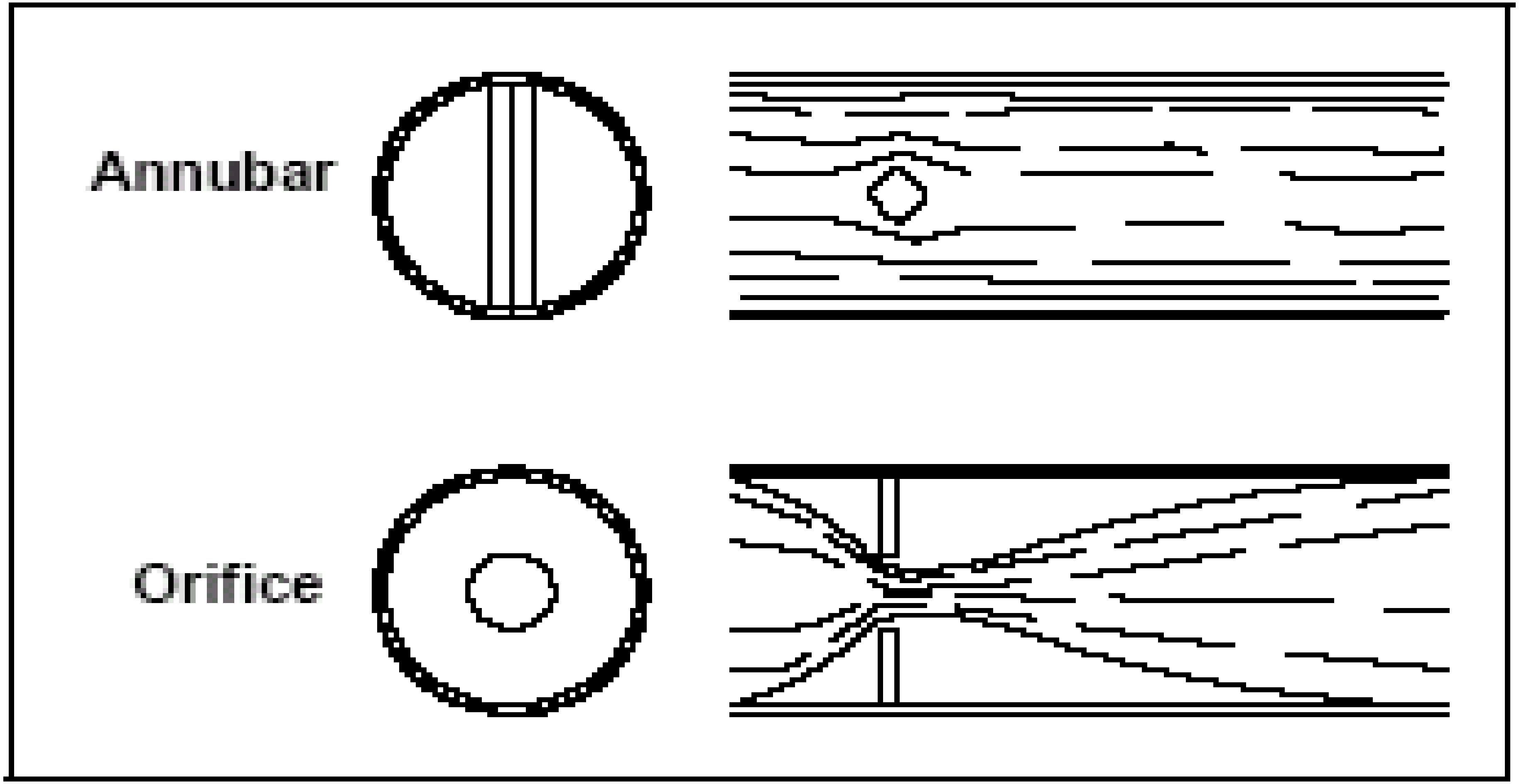
# ORIFICE & ANNUBAR FLOW ELEMENTS

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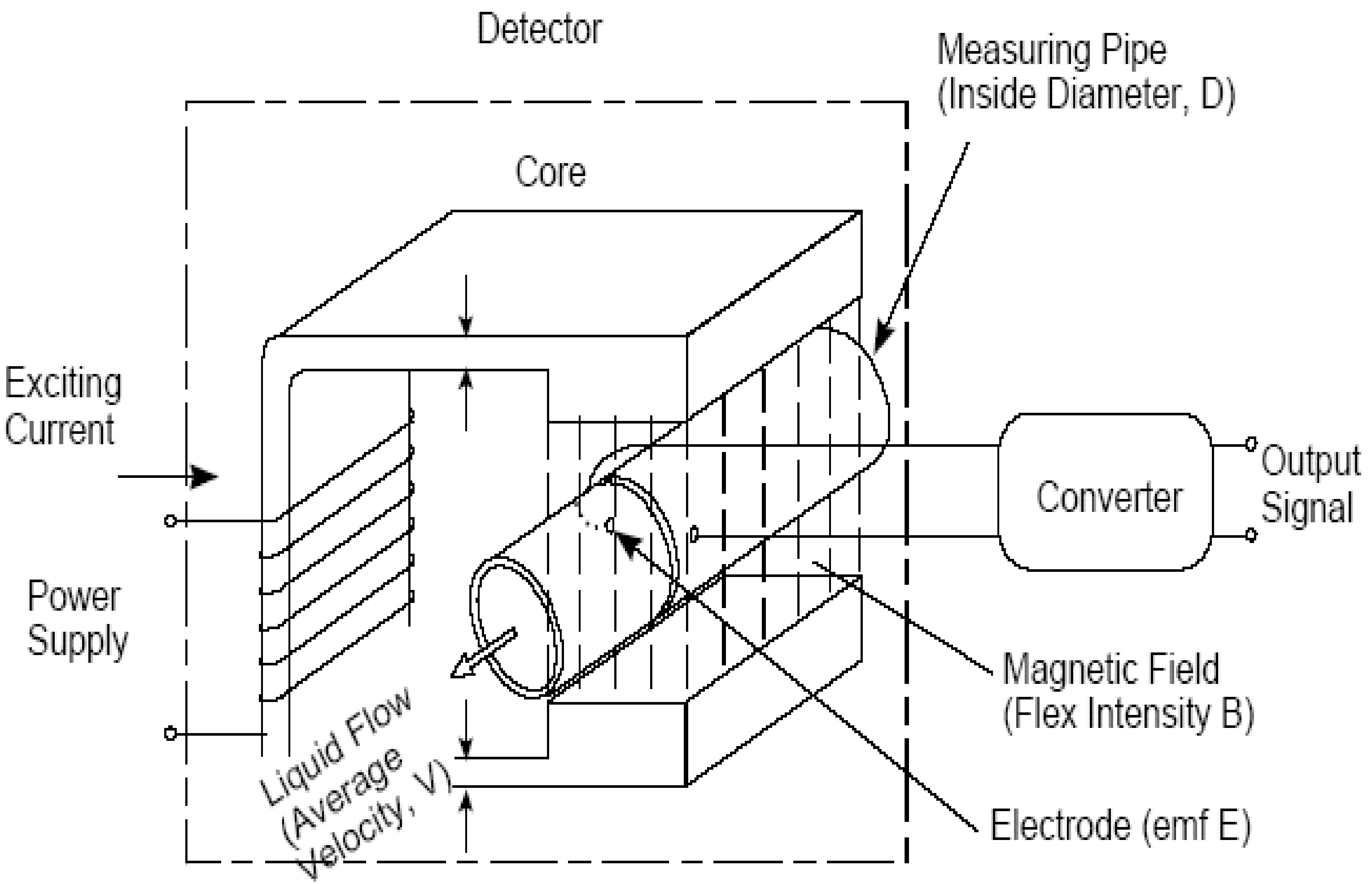
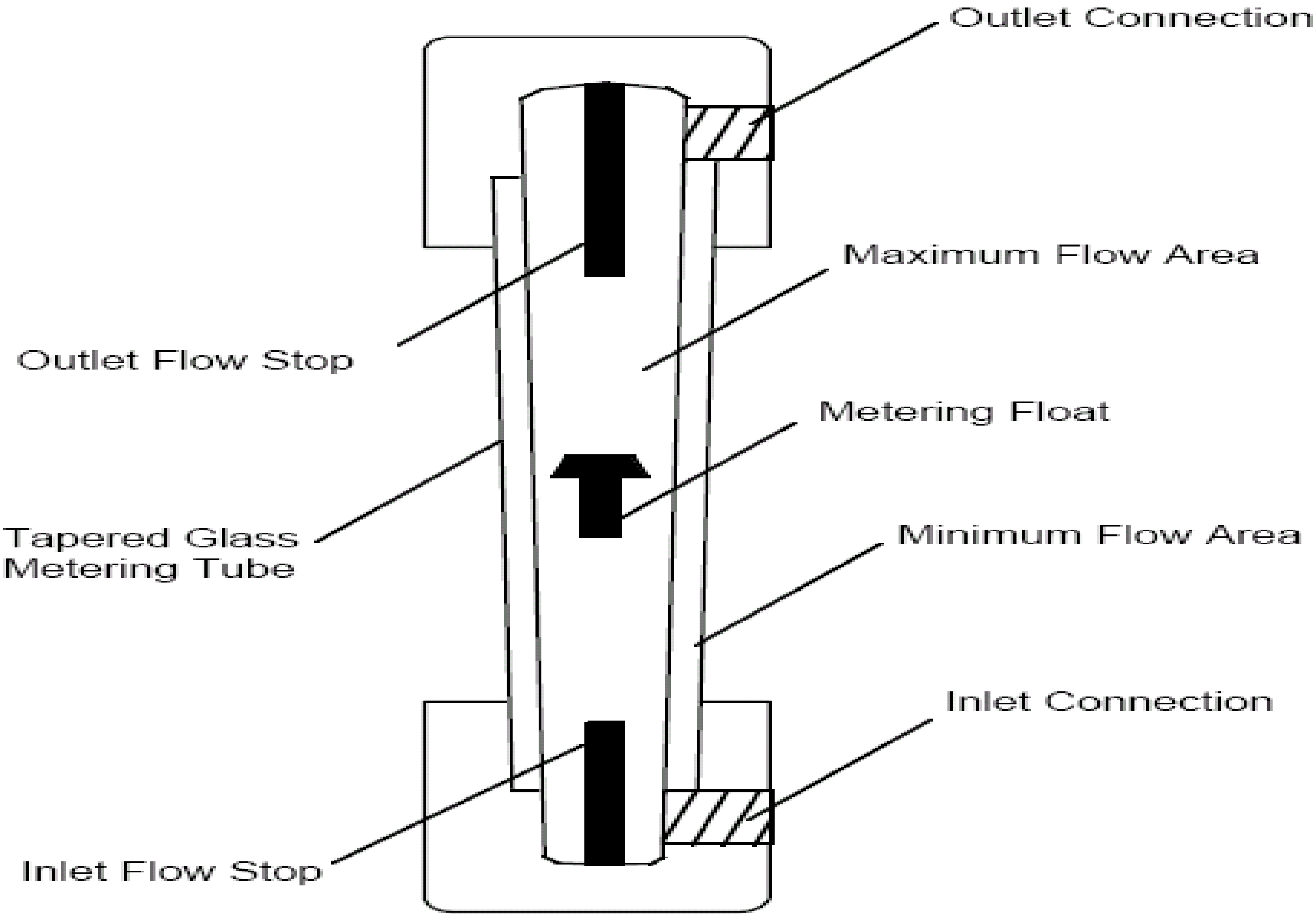
# MAGNETIC FLOWMETER



# ROTAMETER

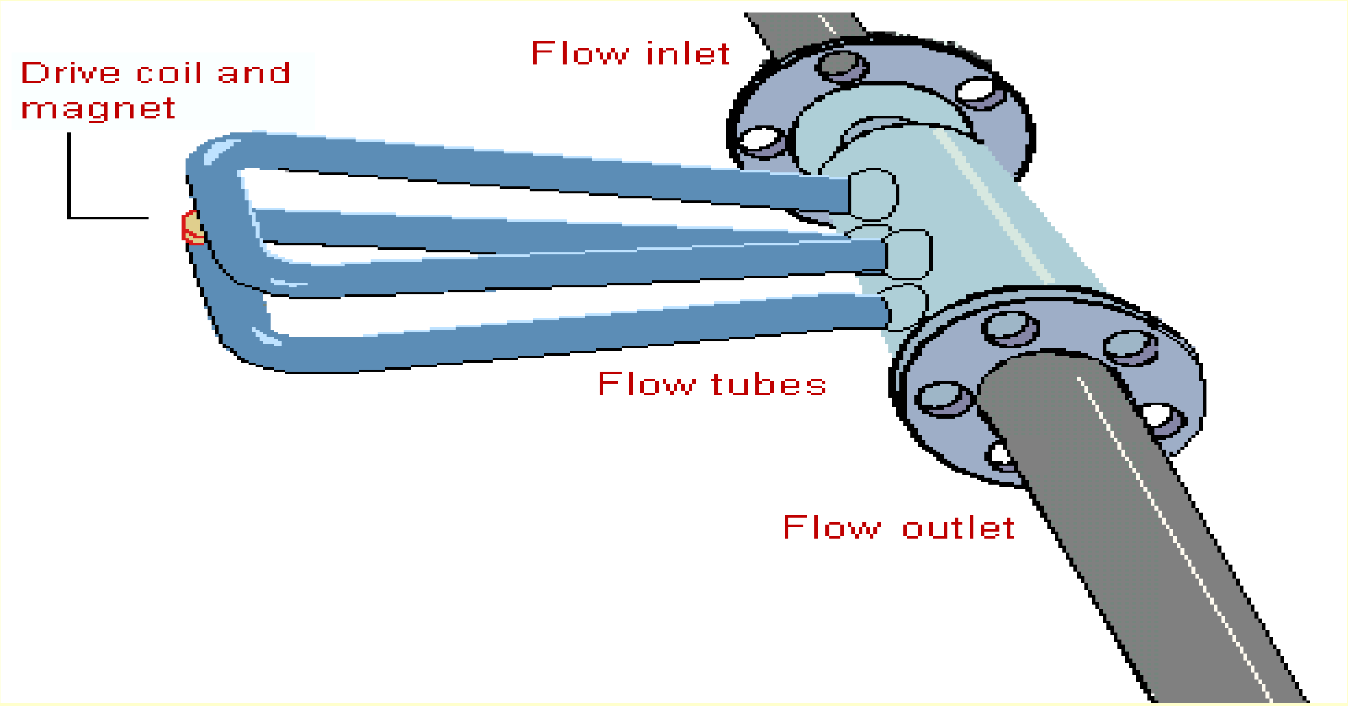

Outlet Connection
Maximum Flow Area
Outlet Flow Stop
Metering Float
Tapered Glass
Metering Tube
Minimum Flow Area
Inlet Connection
Inlet Flow Stop

# Mass Flowmeter : Principles of Operation

## Curved Tube

**Tube Vibration:**

Process fluid entering the sensor is split, half passing through each flow tube. During operation, a drive coil is energized. The drive coil causes the tubes to oscillate up and down in opposition to one another.

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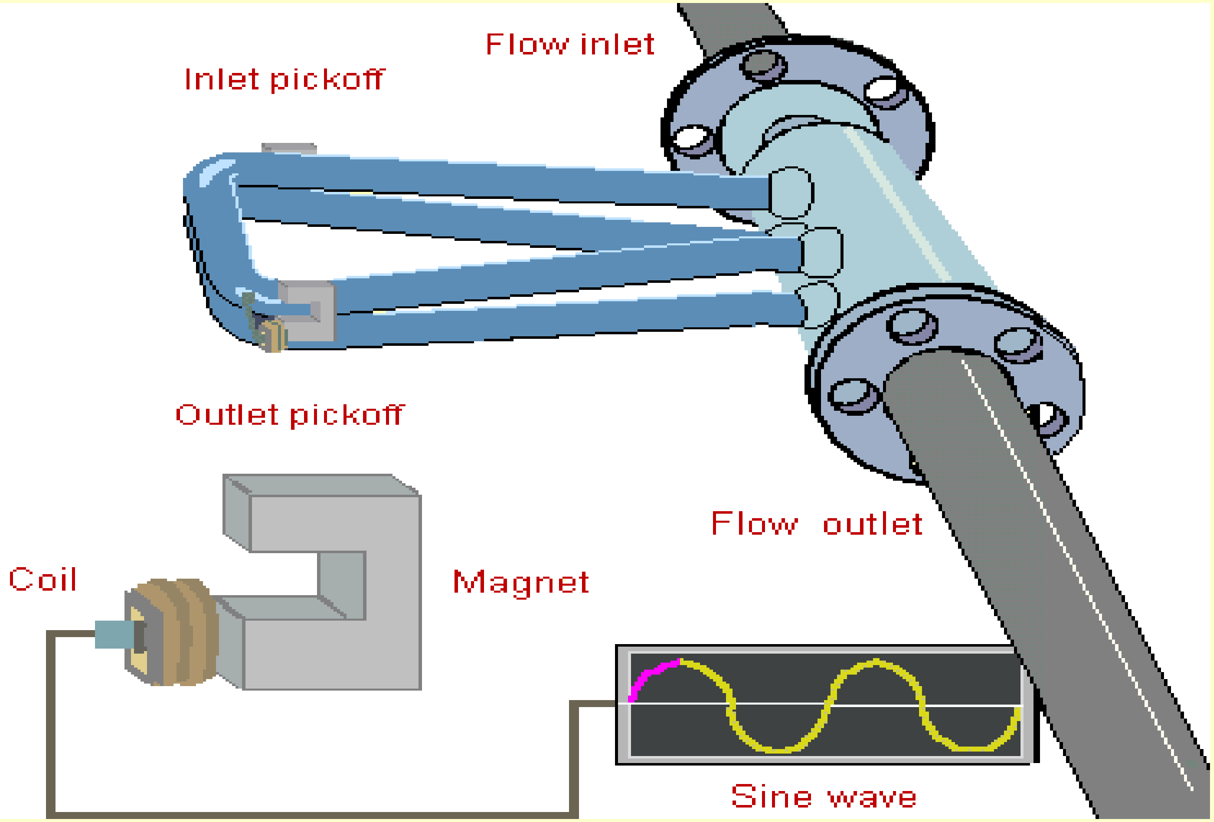
# Signal Generation

Magnet and coil assemblies, called pick-offs, are mounted on the flow tubes. Wire coils are mounted on the side legs of one flow tube, and magnets are mounted on the side legs of the opposing flow tube.

Each coil moves through the uniform magnetic field of the adjacent magnet. The voltage generated from each pickoff coil creates a sine wave. Because the magnets are mounted on one tube, and the coils on the opposing tube, the sine waves generated represent the motion of one tube relative to the other.

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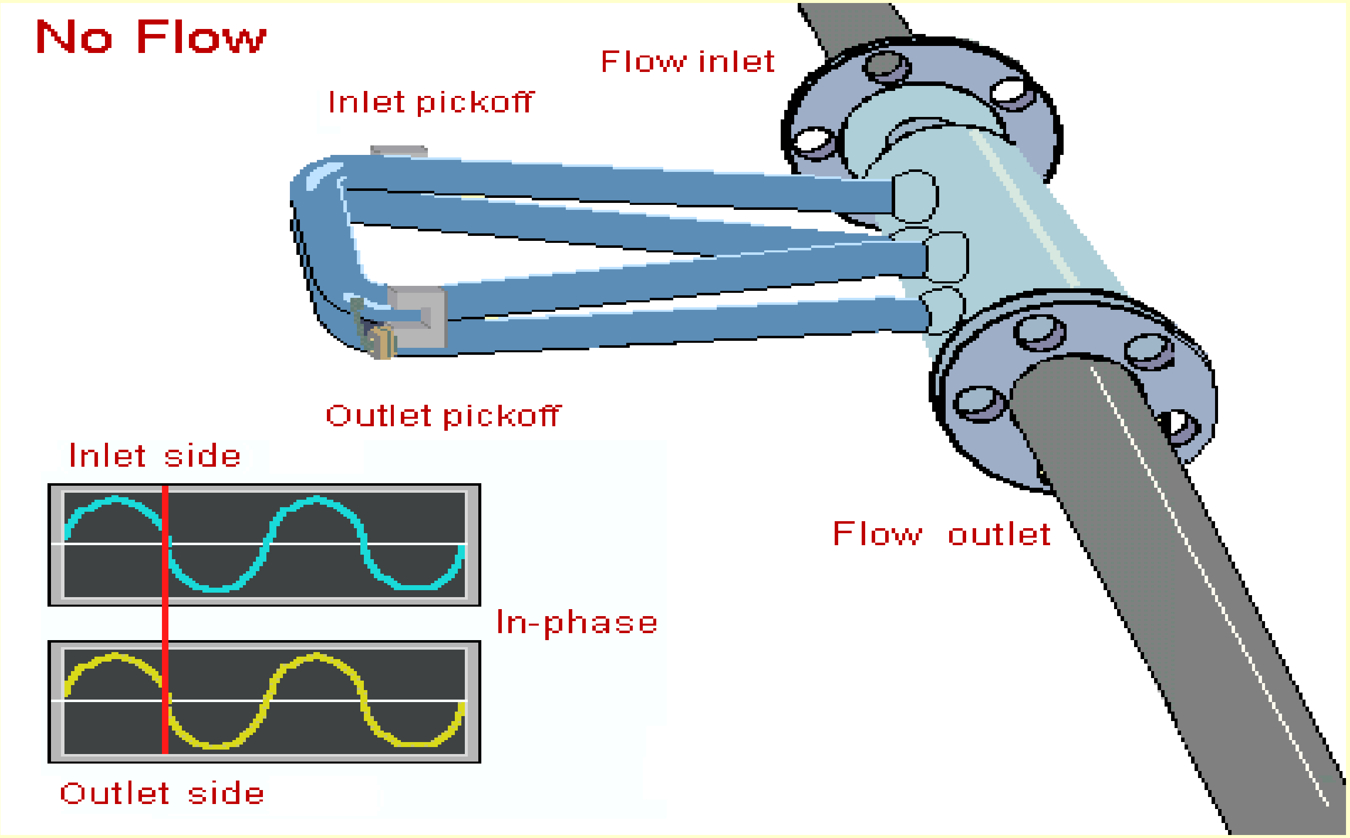
# No Flow - Tube Motion

The flow tubes oscillate 180 degrees in opposition to one another; while one tube moves downward, the other tube moves upward and then vice versa.

Both pickoffs - the one on the inlet side and the one on the outlet side - generate sine wave current continuously when the tubes are oscillating. When there is no flow, the sine waves are in phase.

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# FLOW MEASUREMENT

## Liquid Flow Measurement

- Place taps to the side of the line to prevent sediment deposits on the Transmitter's process isolators.
- Mount the transmitter beside or below the taps so gases can vent into the process line.
- Mount drain/vent valve upward to allow gases to vent.

## Gas Flow Measurement

- Place taps in the top or side of the line.
- Mount the transmitter beside or above the taps so liquid will drain into the process line.

## Steam Flow Measurement

- Place taps to the side of the line.
- Mount the transmitter below the taps to ensure that the impulse piping will stay filled with condensate.
- Fill impulse lines with water to prevent the steam from contacting the Transmitter directly and to ensure accurate measurement at start-up.

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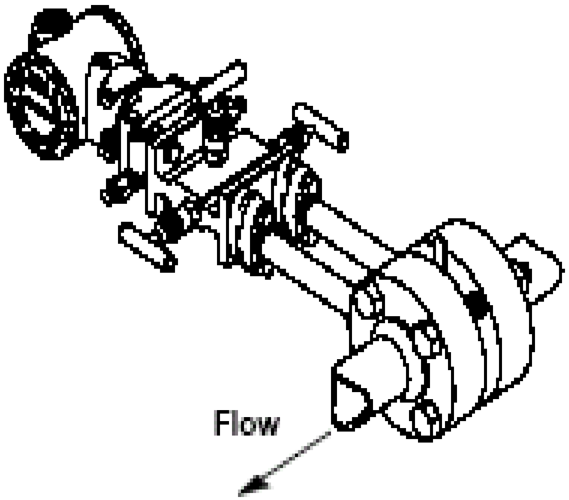
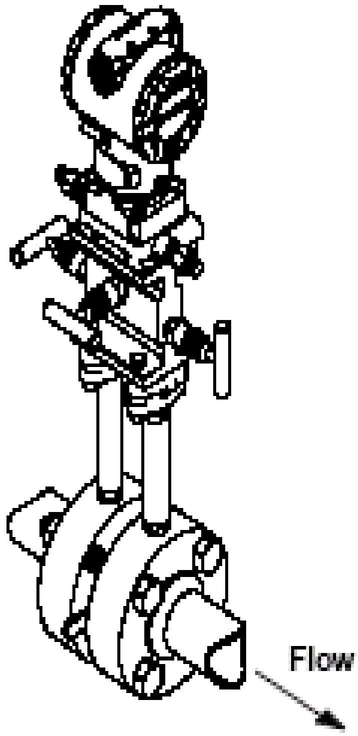
# FLOW MEASUREMENT

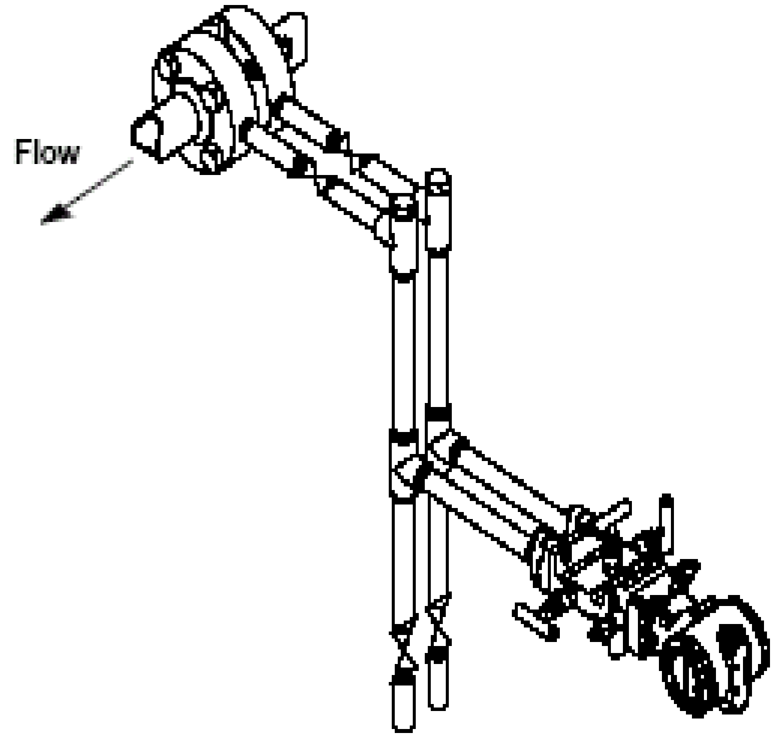
GAS OR LIQUID SERVICE




GAS SERVICE




STEAM SERVICE

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# Pressure Measurement

## Type

1. Pressure Gauges
2. Draft Gauges
3. Pressure Switches
4. Pressure Transmitters
5. Diaphragm seal  transmitters
6. Differential pressure instruments

# INSTRUMENT INSTALLATION-GUIDELINES

- Keep impulse piping as short as possible.

- For liquid service, slope the impulse piping at least 1 inch per foot (8 cm per m) upward from the transmitter toward the process connection.

- For gas service, slope the impulse piping at least 1 inch per foot (8 cm per m) downward from the transmitter toward the process connection.

- Avoid high points in liquid lines and low points in gas lines.

- Make sure both impulse legs are the same temperature.

- Use impulse piping large enough to avoid friction effects and blockage.

- Vent all gas from liquid piping legs.

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# INSTRUMENT INSTALLATION-GUIDELINES

- When measuring a fluid, fill both piping legs to the same level.

- When purging, make the purge connection close to the process taps and purge through equal lengths of the same size pipe. Avoid purging through the transmitter.

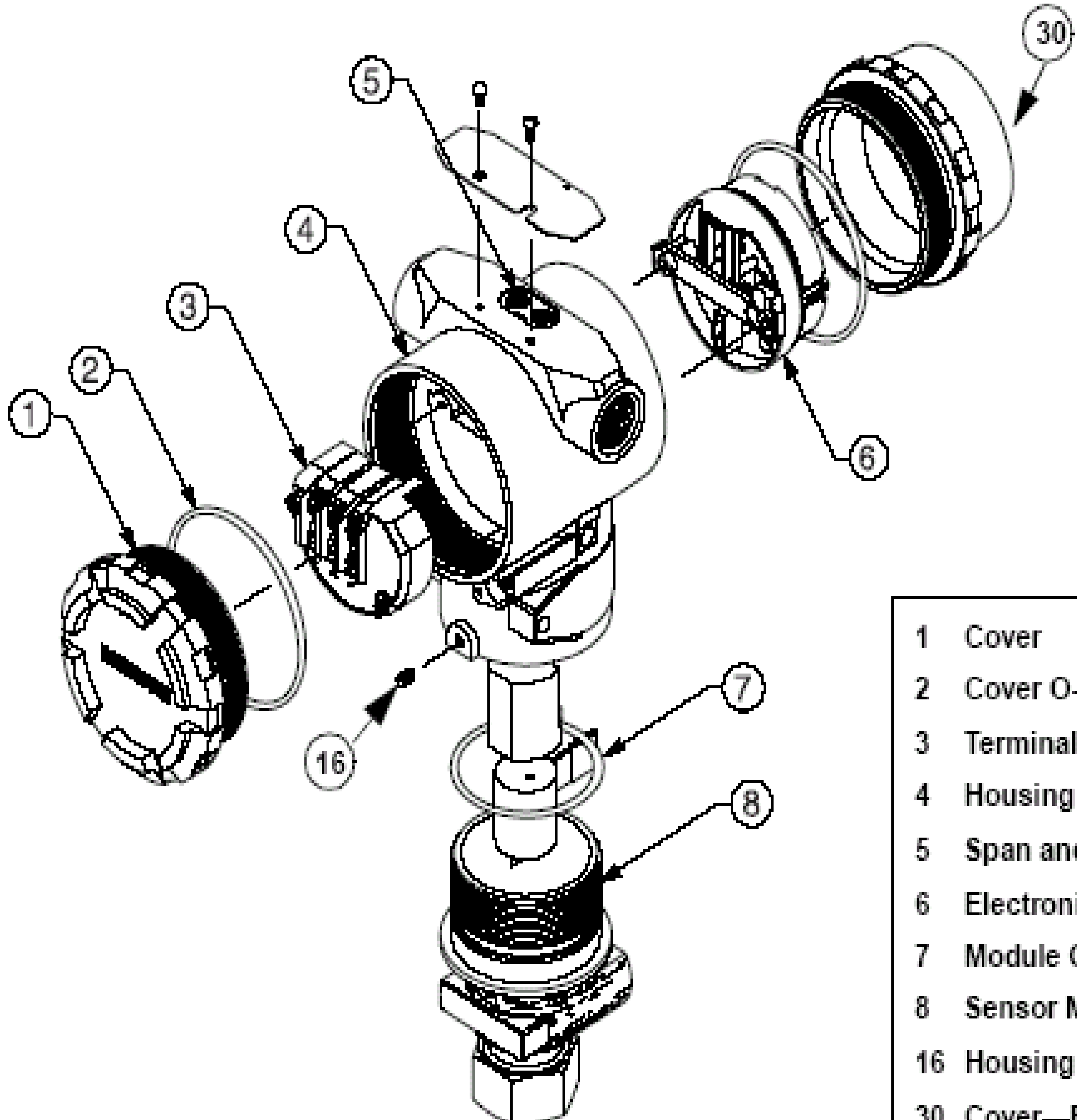
- Keep corrosive or hot (above 250 °F [121 °C]) process material out of direct contact with the sensor module and flanges.

- Prevent sediment deposits in the impulse piping.

- Keep the liquid head balanced on both legs of the impulse piping.

- Avoid conditions that might allow process fluid to freeze within the process flange.

# TRANSMITTER PARTS




| | |
|---|---|
| 1 | Cover |
| 2 | Cover O-ring |
| 3 | Terminal Block |
| 4 | Housing |
| 5 | Span and Zero Adjustment |
| 6 | Electronics Board |
| 7 | Module O-ring |
| 8 | Sensor Module |
| 16 | Housing Rotation Set Screw |
| 30 | Cover—Electronics |

# FLOW MEASUREMENT

## Orifice Meters

Ranges for orifice meters shall be selected from the values shown below

| |
|---|
| **0 --- 625** |
| **0 --- 1250** |
| **0 --- 2500** |
| **0 --- 5000** |
| **0 --- 10000** |

## Rotameters (Variable Area Meters)

Ranges for rotameters shall be selected from the values shown below.

| |
|---|
| **0.1 ---- 1.0 x 10n** |
| **0.12 ---- 1.2** |
| **0.15 ---- 1.5** |
| **0.2 ---- 2.0** |
| **0.25 ---- 2.5** |
| **0.3 ---- 3.0** |
| **0.4 ---- 4.0** |
| **0.5 ----5.0** |
| **0.6 ---- 6.0** |
| **0.8 ---- 8.0** |

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# TYPE OF CONTROL VALVES

**Depends on the construction of the valve the valves are classified in different names. Valves are classified in to two general types based on how the valve closure member is moved: by linear motion or rotary motion. The types of the valves as follows:**

- **Globe valves / Gate valves**
- **Butterfly valves**
- **Ball valves**
- **Angle valve**
- **Diaphragm valves**
- **De-super-heater valves**
- **Slide valves / Diverter valves**

**Valve Operation:-**

1. **Air to Open**
2. **Air to Close**
3. **Air fail to Lock in the same position**

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# DEFINE CV OF A CONTROL VALVE?

**Cv is numerically equal to the number of U.S. gallons of water at 60°F that will flow through the valve in one minute when the pressure differential across the valve is one pound per square inch.**

**Cv varies with both size and style of valve, but provides an index for comparing liquid capacities of different valves under a standard set of conditions.**

$$Q = C_v \sqrt{\Delta P / G} \qquad (1)$$

where:

$Q$ = Capacity in gallons per minute

$C_v$ = Valve sizing coefficient determined experimentally for each style and size of valve, using water at standard conditions as the test fluid

$\Delta P$ = Pressure differential in psi

$G$ = Specific gravity of fluid (water at 60°F = 1.0000)

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## *Valtek Mark One*
Components

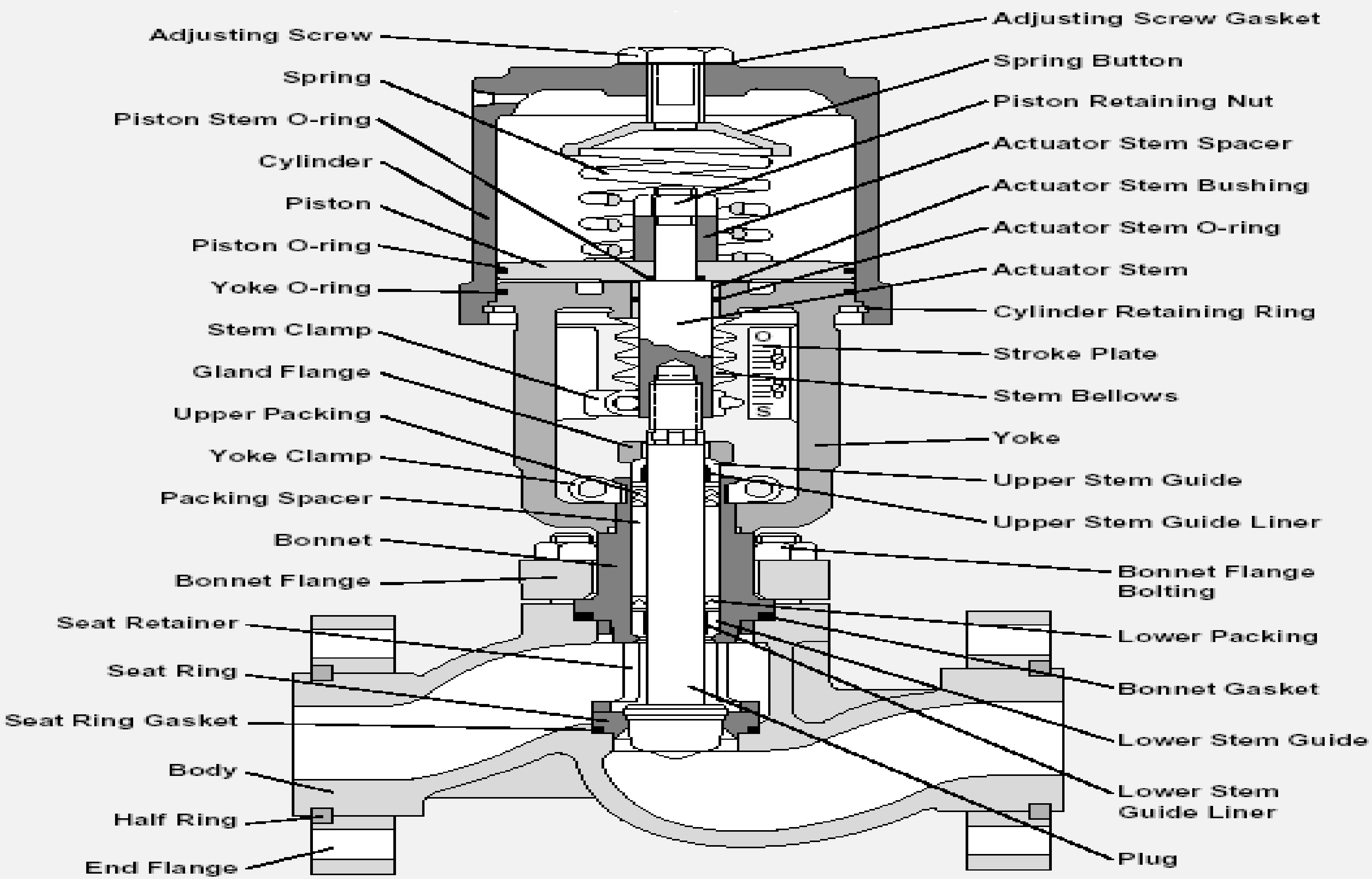
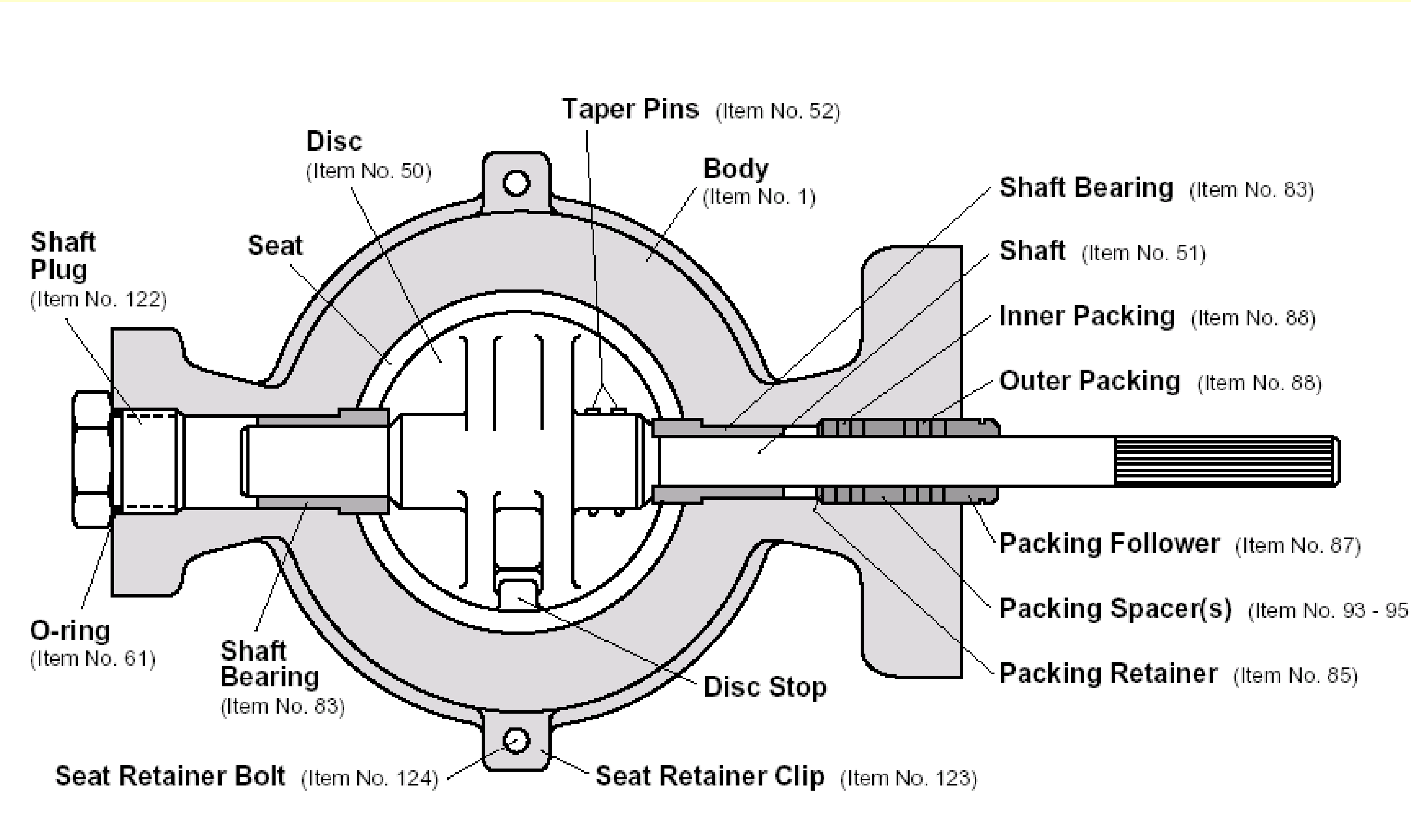



Figure 2: Mark One Control Valve

# Butterfly Valve Body Assembly

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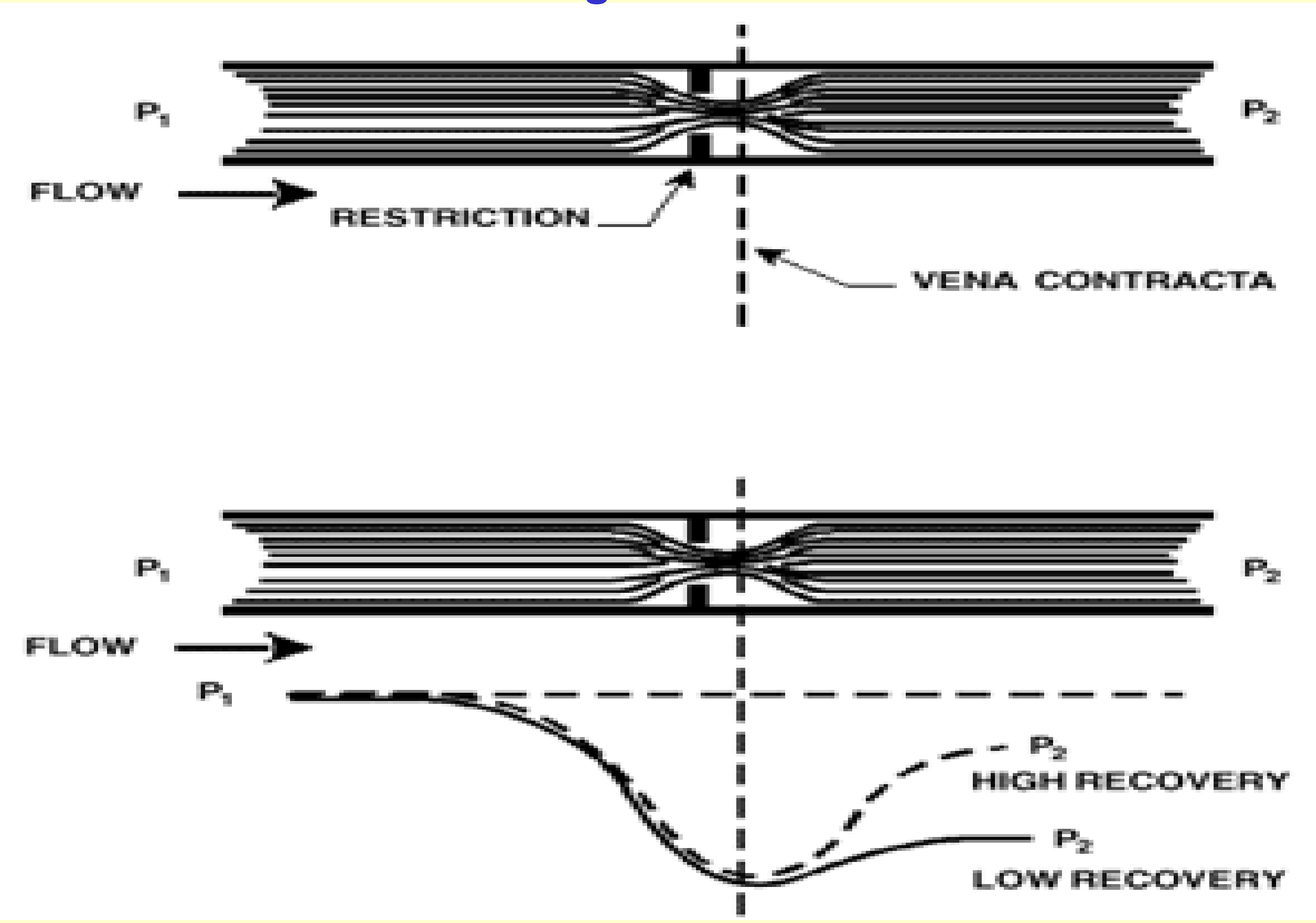
# Flashing and Cavitation

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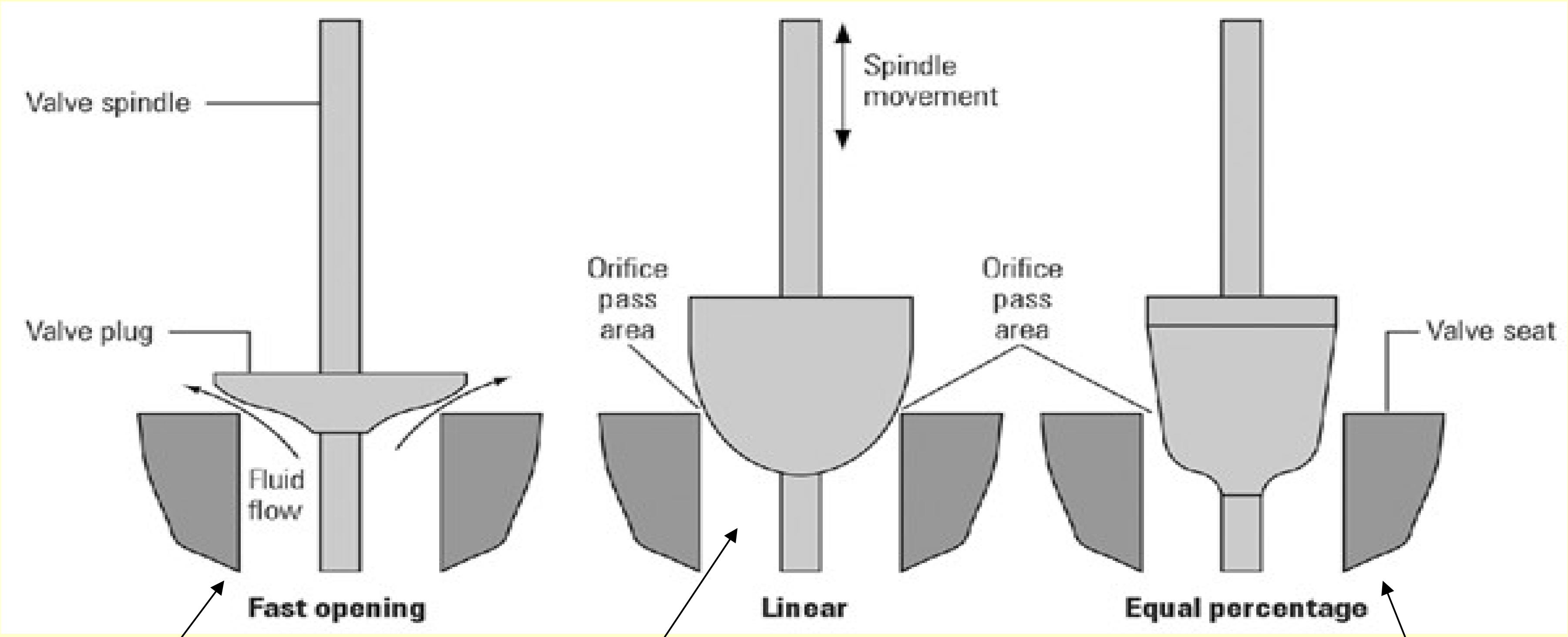
# VALVE PLUGS ACCORDING TO FLOW CHRACTERISTICS




For blow down and vent services

For feed streams services

For Compressor surge controls

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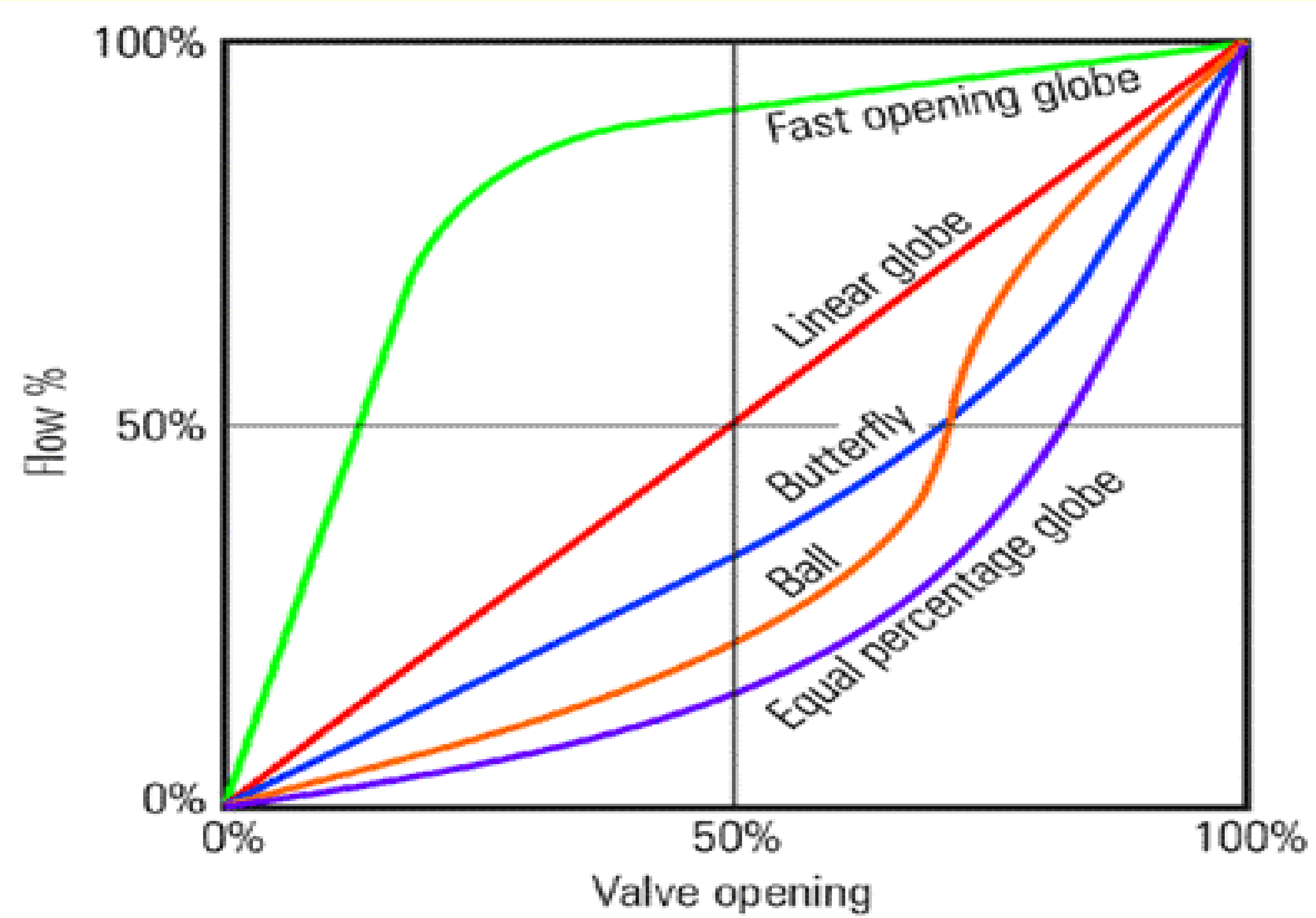
# VALVE FLOW CHRACTERISTICS

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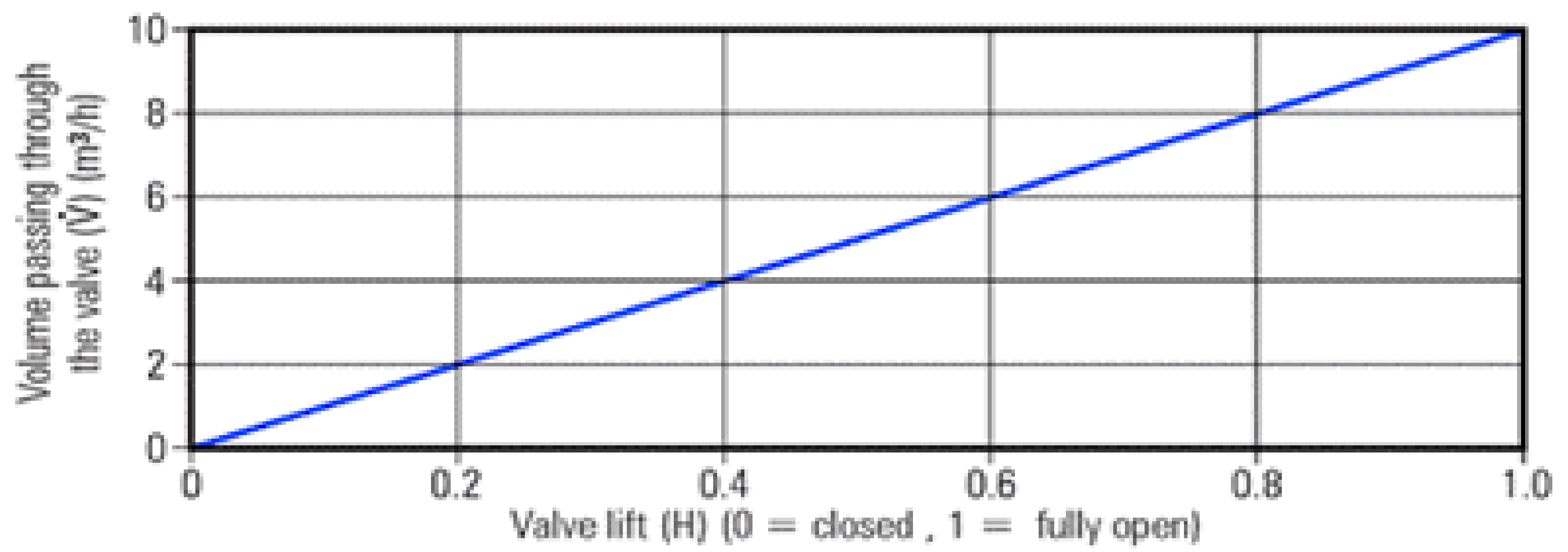
# LINEAR CHRACTERISTICS

The linear characteristic valve plug is shaped so that the flow rate is directly proportional to the valve lift (H), at a constant differential pressure. A linear valve achieves this by having a linear relationship between the valve lift and the orifice pass area (see Figure below).




For example, at 40% valve lift, a 40% orifice size allows 40% of the full flow to pass.

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# EQUAL % CHRACTERISTICS

**These valves have a valve plug shaped so that each increment in valve lift increases the flow rate by a certain percentage of the previous flow. The relationship between valve lift and orifice size (and therefore flow rate) is not linear but logarithmic.**

**Table below shows how the change in flow rate alters across the range of valve lift for the equal percentage valve with a rangeability of 50 and with a constant differential pressure.**

| Valve Lift (H) | Flowrate ($\dot{V}$ $m^3/h$) | Increase in flow from previous increment (%) |
|---|---|---|
| 0.0 | 0.20 * | - |
| 0.1 | 0.30 | 48% |
| 0.2 | 0.44 | 48% |
| 0.3 | 0.65 | 48% |
| 0.4 | 0.96 | 48% |
| 0.5 | 1.41 | 48% |
| 0.6 | 2.09 | 48% |
| 0.7 | 3.09 | 48% |
| 0.8 | 4.57 | 48% |
| 0.9 | 6.76 | 48% |
| 1.0 | 10.00 | 48% |

* Flowrate according to theoretical characteristic due to rangeability. In practice the valve will be fully shut at zero lift.

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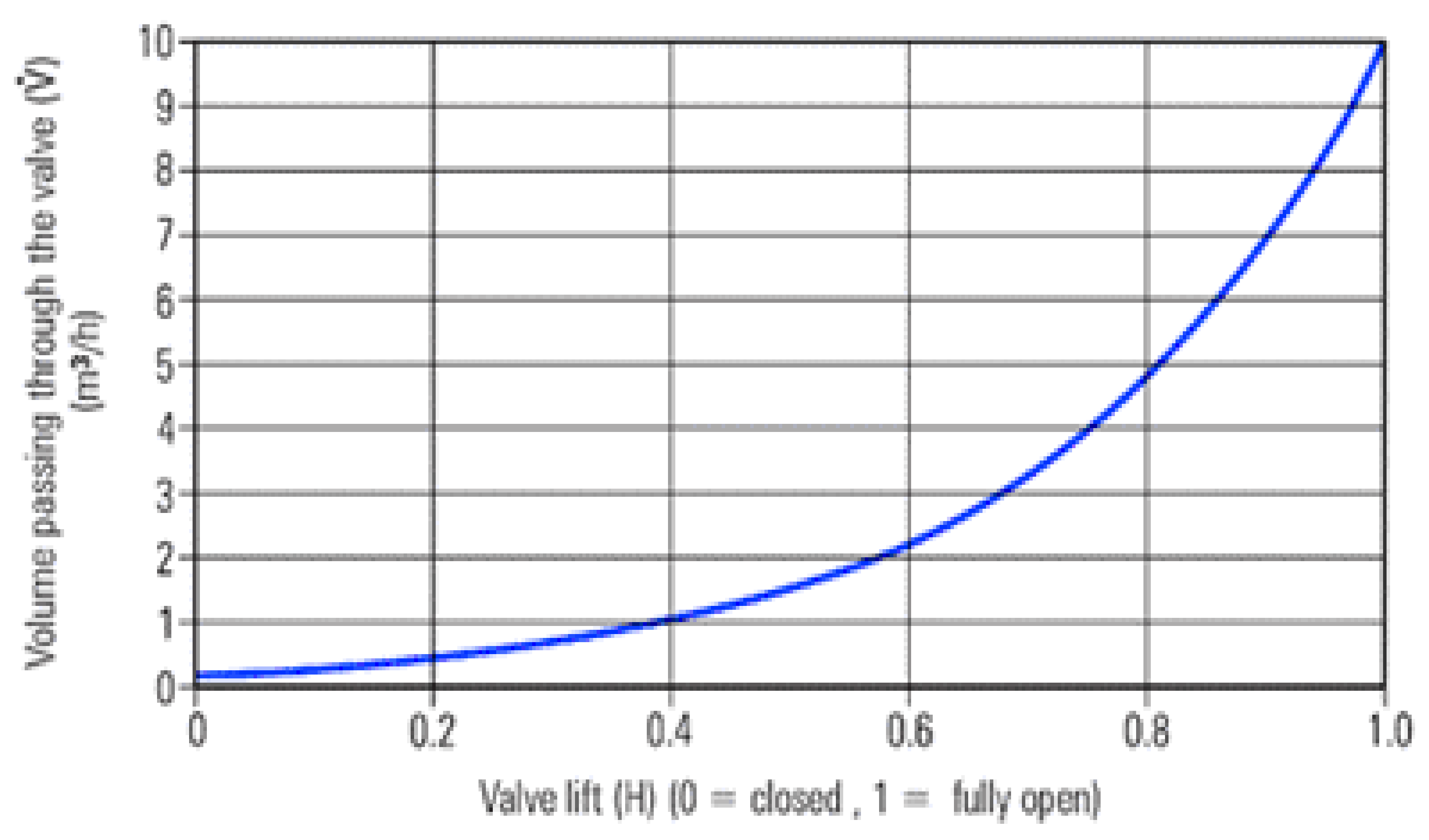
# EQUAL % CHRACTERISTICS

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# Valve Accessories

1. I/P Transducer
2. Positioner
3. Volume Booster
4. Quick Exhaust
5. Lockup Relay
6. Solenoid
7. Limit Switch

## I/P Transducer:

**Transducers convert a current signal to a pneumatic signal. The most common transducer converts a 4-20 mA electric signal to a 3-15 psig pneumatic signal.**

## Volume Booster:

**Volume Boosters are used on throttling control valves to provide fast stroking action with large input signal changes. At the same time, the flow boosters allow normal Positioner air flow (and normal actuation) with small changes in the Positioner input signal. Depending on actuator size, packing set and the number used, boosters can decrease valve stroking times up to 90 percent.**

Prepared by

# Valve Accessories

## Positioner:-

**A valve Positioner is like a proportional controller. The set point is the control signal from the primary controller and the controlled variable is the valve position. The Positioner compensates for disturbances and nonlinearities.**

**The use of Positioner are as follows,**

- **When the signal pressure is not enough to operate the control valve.**
- **To make split range between the valves.**
- **It can be used to reverse the action of the actuator from air to open to air to close and vice versa.**
- **To minimize the effect of hysterisis effect.**
- **To minimize the response time for the valve.**
- **If the actuator is spring less Positioner will be used.**
- **If the valve has high friction.**

# Valve Accessories

**Quick Exhaust:**

- Quick exhaust valves allow the cylinder actuator to quickly vent one side to atmosphere, resulting in an almost immediate full-open or full-closed position. This sudden movement generally limits quick exhaust applications to on/off services where positioners are not used.

## Lockup Relay:

- It is designed to hold the actuator in the last operating position upon air failure.

## Solenoid:

- Used To Open The Valve Or Close it

## Limit switch:

- Limit switches are available to indicate a valve open or closed position.

**Switching Valve:**

- It is used in fail lock up system for to set the air pressure in the required level for lock the valve.

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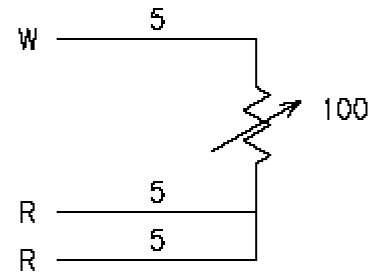
# Temperature Measurement

Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic.

Five types with which the engineer is likely to come into contact are:

- Resistive temperature devices (RTDs and thermistors)
- Thermocouples
- Infrared radiators
- Bimetallic devices
- Liquid expansion devices




$$5\ (w) + 100 + 5\ (r) = 110 - (5\ (w) + 5\ (r)) = 100$$

**Resistive Temperature Devices**

Resistive temperature devices capitalize on the fact that the electrical resistance of a material changes as its temperature changes.
Two key types are the metallic devices

- **RTD:** Resistance temperature detector
- Thermistors

As their name indicates, RTDs rely on resistance change in a metal, with the resistance rising more or less linearly with temperature.

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# Temperature Measurement

**Resistance bulbs** shall be selected in accordance with the following: Resistance bulbs should be used when the working temperature is between -200$^{o}$C and 400$^{o}$C, and precise measurement is required.

Bulbs shall be fitted with platinum resistance elements. And normally $R_0$= 100 ohms

**Thermistors** are based on resistance change in a ceramic semiconductor; the resistance drops nonlinearly with temperature rise.

**Strain Gage:** A measuring element for converting force, pressure, tension, etc., into an electrical signal.

**Wheatstone Bridge:** A network of four resistances, an emf source, and a galvanometer connected such that when the four resistances are matched, the galvanometer will show a zero deflection or "null" reading.

# Temperature Measurement

**Fluid-expansion devices:**

Typically like household thermometer, generally come in two main classifications:

- mercury type
- organic-liquid type

Versions employing gas instead of liquid are also available.

Mercury is considered an environmental hazard, so there are regulations governing the shipment of devices that contain it.

Fluid-expansion sensors do not require electric power, do not pose explosion hazards, and are stable even after repeated cycling.

On the other hand, they do not generate data that are easily recorded or transmitted, and they cannot make spot or point measurements

# Temperature Measurement

**Seebeck Effect:** When a circuit is formed by a junction of two dissimilar metals and the junctions are held at different temperatures, a current will flow in the circuit caused by the difference in temperature between the two junctions.

**Thermocouple:** The junction of two dissimilar metals which has a voltage output proportional to the difference in temperature between the hot junction and the lead wires (cold junction).

**Compensating Lead Wires and Extension Wires**

The compensating lead wires and extension wires shall conform to ANSI MC96.1. Thermocouple extension wire shall be installed in one-continuous length. If intermediate terminating points are required, as in case of multi conductor cables, then the connecting blocks shall be of the same material as the extension wire.

# Temperature Measurement

Wire insulation shall be compatible with ambient temperatures. For ambient temperature up to 100°C, polyvinyl is acceptable. Above 100°C, non-asbestos insulation is required.

| THERMOCOUPLE | | | EXTENSION WIRE | | | | |
|---|---|---|---|---|---|---|---|
| MATERIAL | | ISA | MATERIAL | | COLOR OF INSULATION | | |
| +VE | -VE | SYM | +VE | -VE | +VE | -VE | OVERALL |
| Copper | Constantan | T | Copper | Constantan | Blue | Red | Blue |
| Iron | Constantan | J | Iron | Constantan | White | Red | Black |
| Chromel | Alumel | K | Chromel | Alumel | Yellow | Red | Yellow |
| Chromel | Constantan | E | Chromel | Constantan | Purple | Red | Purple |

| THERMOCOUPLE | | THERMOCOUPLE EXTENSION WIRE REFERENCE JUNCTION 0°C | | | |
|---|---|---|---|---|---|
| TYPE | ISA SYM | TYPE | ISA | JUNCTION TEMP TEMP. LIMIT °C | ERROR °C |
| Copper Constantan | T | Copper Constantan | TX | -60 to +100 | ±1 |
| Iron Constantan | J | Iron Constantan | JX | 0 to 200 | ±2.2 |
| Chromel-Alumel | K | Chromel Alumel | KX | 0 to 200 | ±2.2 |
| Chromel Constantan | E | Chromel Constantan | EX | 0 to 1000 | ±1.7 |

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# Temperature Measurement

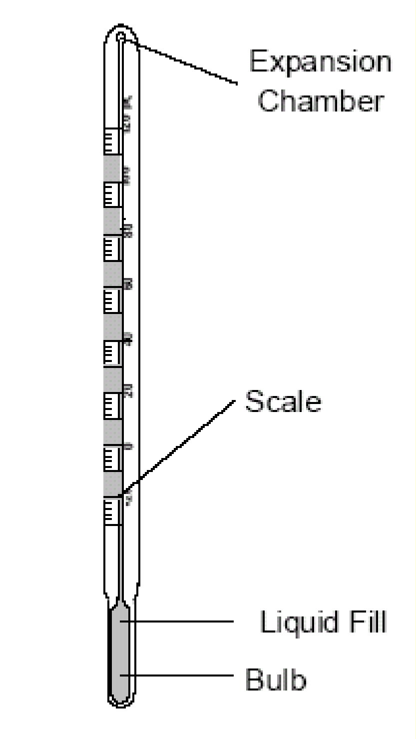
**Infrared sensors,** though relatively expensive, are appropriate when the temperatures are extremely high. They are available for up to 3,000°C (5,400°F), far exceeding the range of thermocouples or other contact devices.

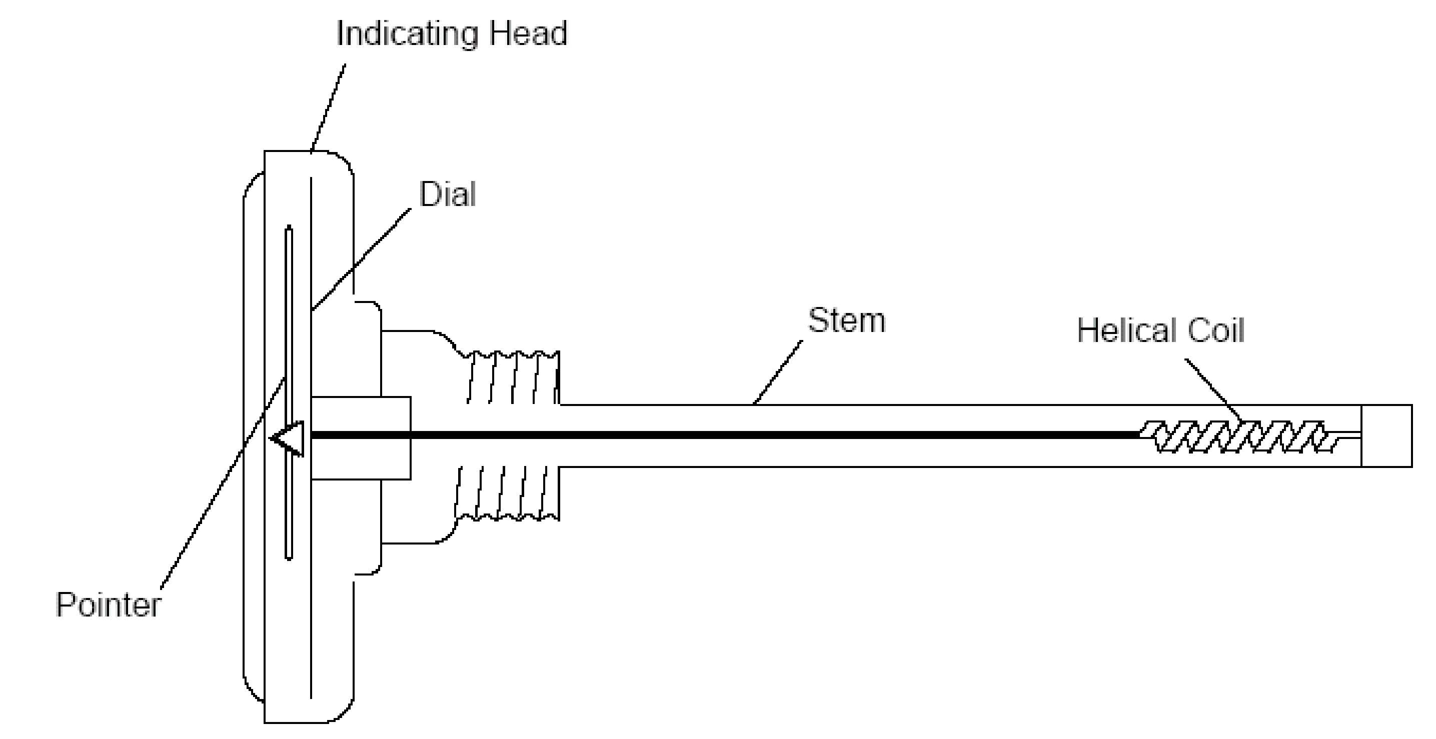
The infrared approach is also attractive when one does not wish to make contact with the surface whose temperature is to be measured.

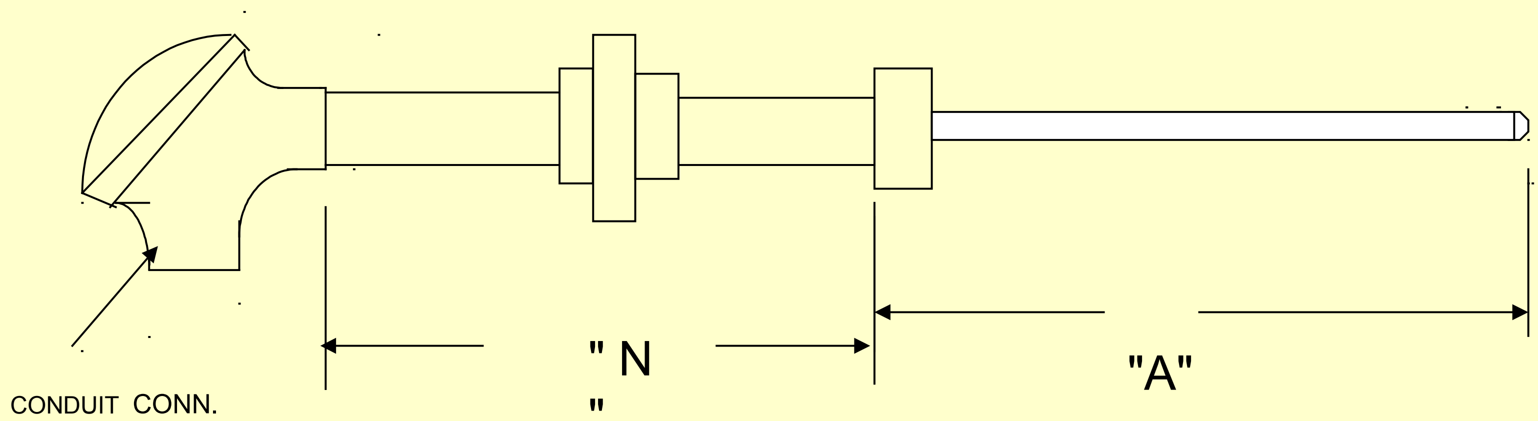
Thus, fragile or wet surfaces, such as painted surfaces coming out of a drying oven, can be monitored in this way. Substances that are chemically reactive or electrically noisy are ideal for infrared measurement.

The approach is likewise advantageous in measuring temperature of very large surfaces, such as walls that would require a large array of thermocouples or RTDs for measurement.

# Temperature Measurement

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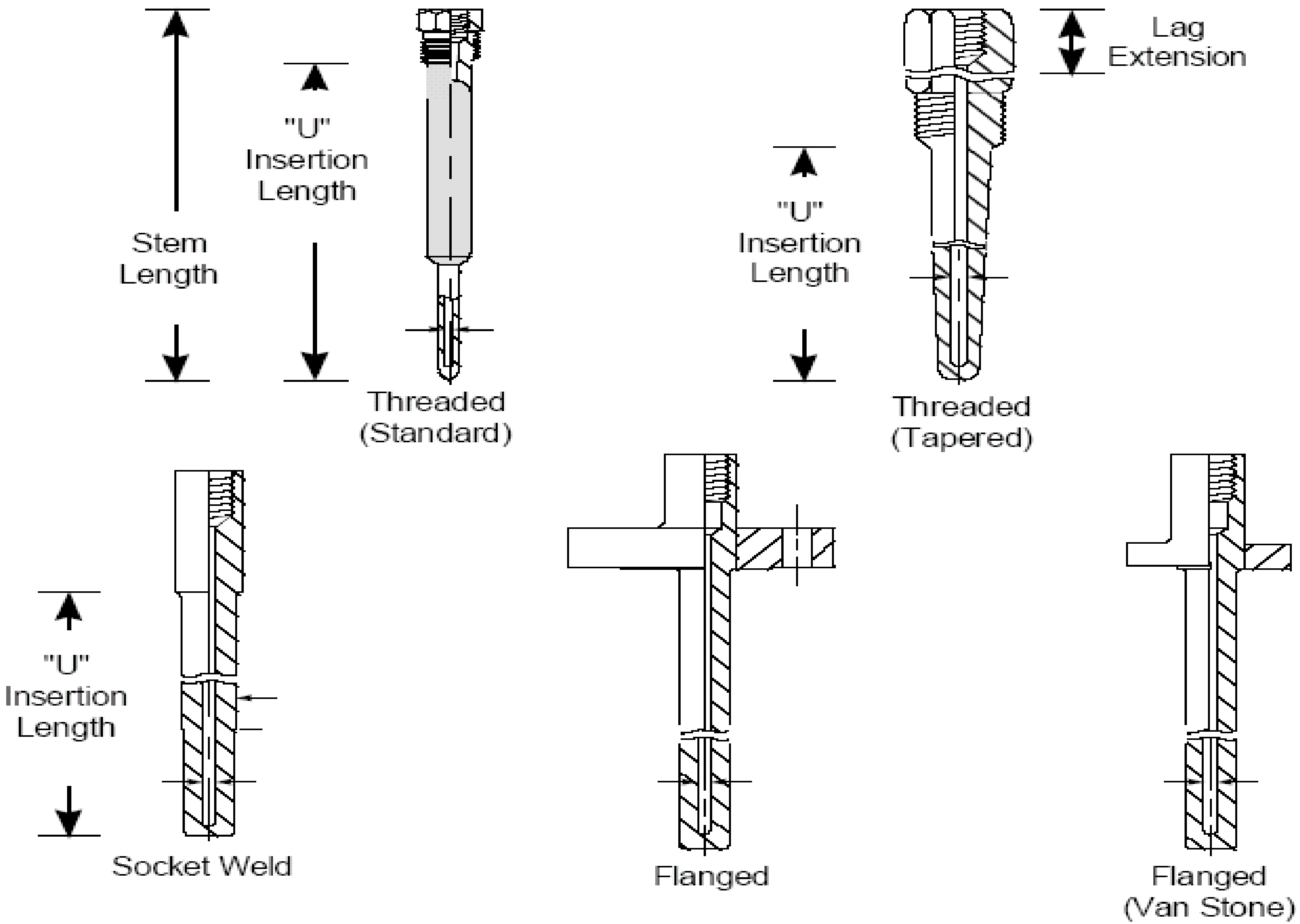
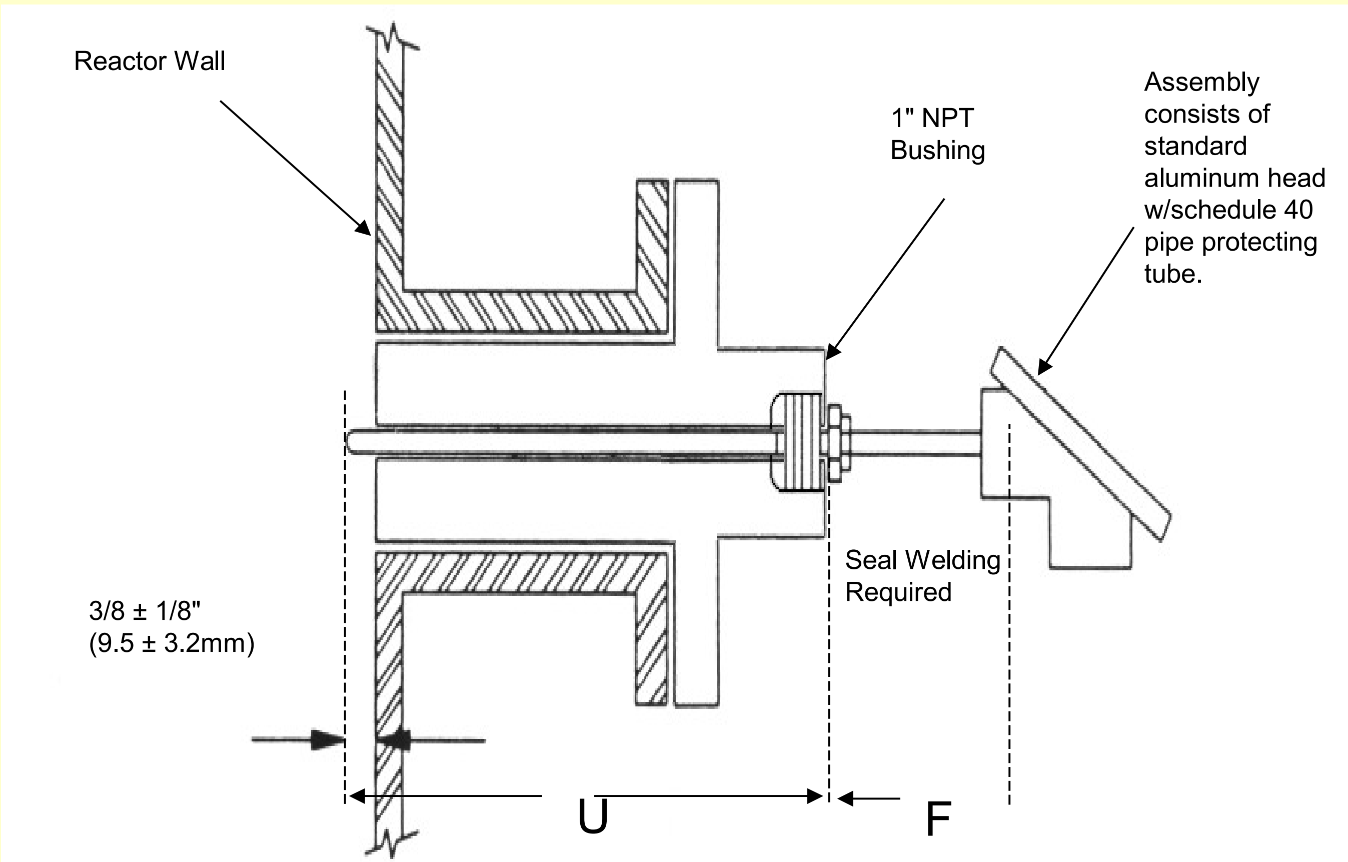
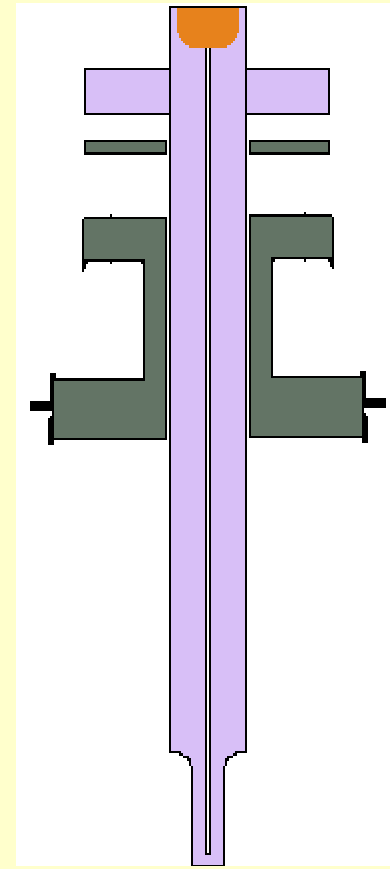
# Temperature Measurement



# Temperature Measurement

## Skin type for Reactors



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# Temperature Measurement

## Field-Mounted Thermometers

Ranges for field-mounted thermometers shall be selected such that normal operating temperature is around 60% of the full scale.

(Unit: Deg. C.)

| |
|---|
| **-50 --- 50** |
| **-30 --- 50** |
| **0 --- 50** |
| **0 ---100** |
| **0 --- 120** |
| **0 --- 150** |
| **0 --- 200** |
| **0 --- 250** |
| **0 --- 300** |
| **0 --- 400** |
| **0 --- 500** |
| **100---500** |

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# Level Measurement

Type of level Measurements:

- Reflex Flat Gauge Glass
- Transparent Flat Gauge Glass
- Magnetic Float
- Float Switch
- Torque Tube Displacer
- Displacer Switch
- Bubbler Tube
- Hydrostatic Head Example / Differential Pressure
- Ultrasonic
- Nuclear

# Level Measurement

## Stand pipe

A large pipe, usually 4 inches in diameter, mounted on the side of vessel. Level measurement devices, such as sight gauges and pressure transmitters, are attached to the pipe. The standpipe serves to transmit level to more than one device. Also referred to as bridle or stilling well.

## Tappings

Connections to a vessel to which a measurement device's nozzle/flange is attached.

## Interface

The point or location where two phases meet. In a liquid level measurement, two non-mixing liquids of different specific gravities and color establish a boundary that can be viewed as a distinct line.

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# Level Measurement

## Diff Pressure Type

When the LEVEL in vessel is at or below the bottom connection the force on the high pressure leg (the lower vessel nozzle) will see 12" x 1.0 = 12" WC.

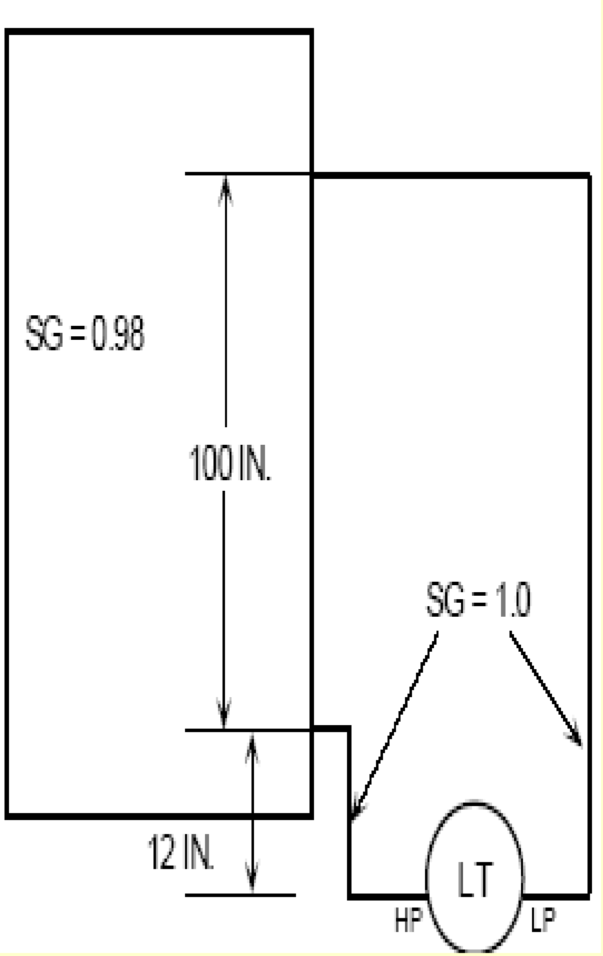
The low pressure leg (the higher vessel nozzle) will see 112" x 1.0 = 112" WC.

The differential is 12" WC - 112" WC = -100" WC.

When the vessel is full, the force on the high pressure leg will be 12" x 1.0 + 100" x 0.98 = 12 + 98 = 110" WC.

The low pressure side will see 112" x 1.0 = 112" WC.

The differential is 110" WC - 112" WC = -2" WC.




**The transmitter should be calibrated for -100 to -2" WC.**

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# Level Measurement

## Diff Pressure Type

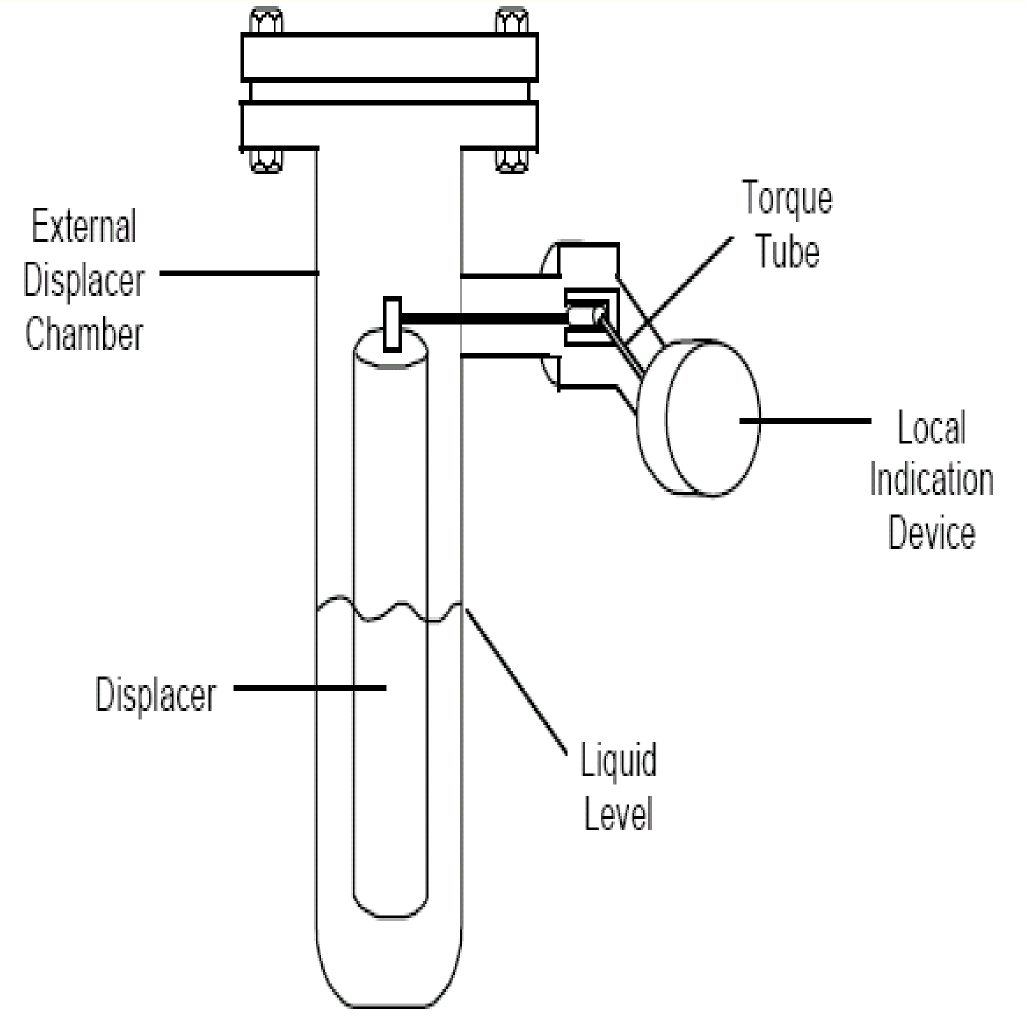
The force of the liquid head is linear with mass if the vessel is vertical with straight sides.

If the readout is calibrated in mass of material (instead of volume of material), the reading will be correct for any specific gravity as long as it is within the live area of calibration and ignoring the small error from the heel of the vessel.

The vessel may not be full at 100% calibration but it will contain the correct amount of mass of material.

# Level Measurement

## Displacer Type




**Displacer dimension**

**0 ---356**
**0 ---813**
**0 ---1219**
**0 ---1524**
**0 ---1829**

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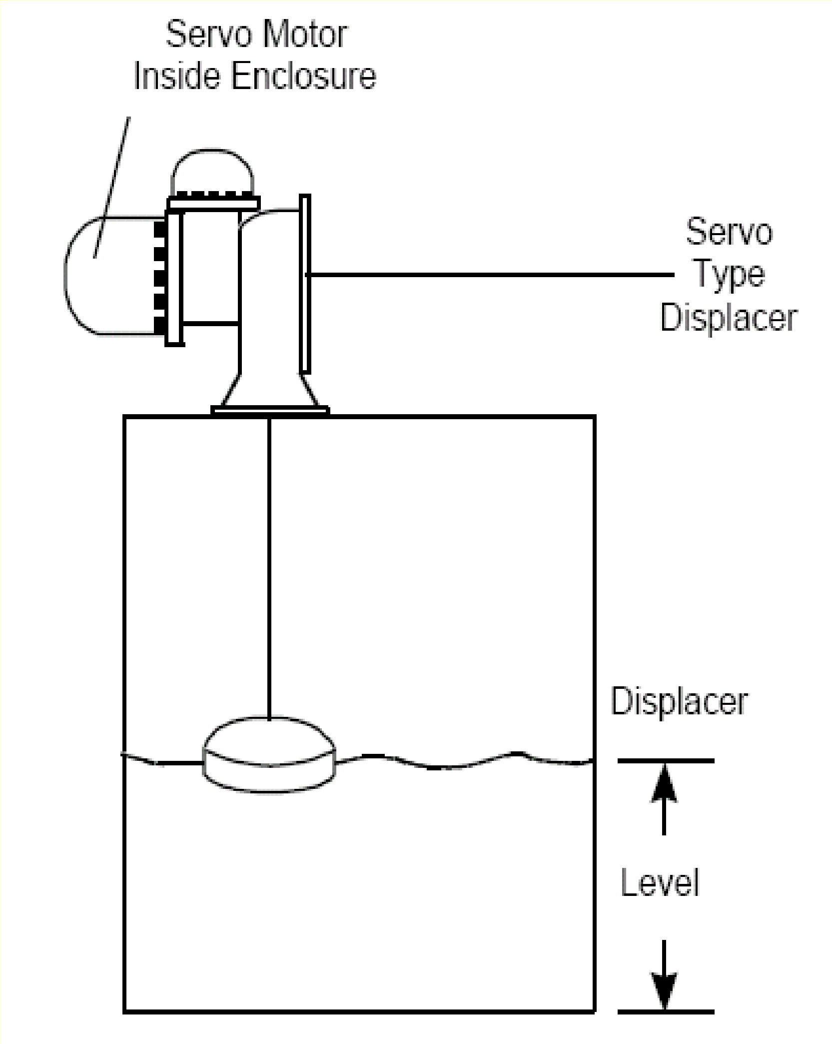
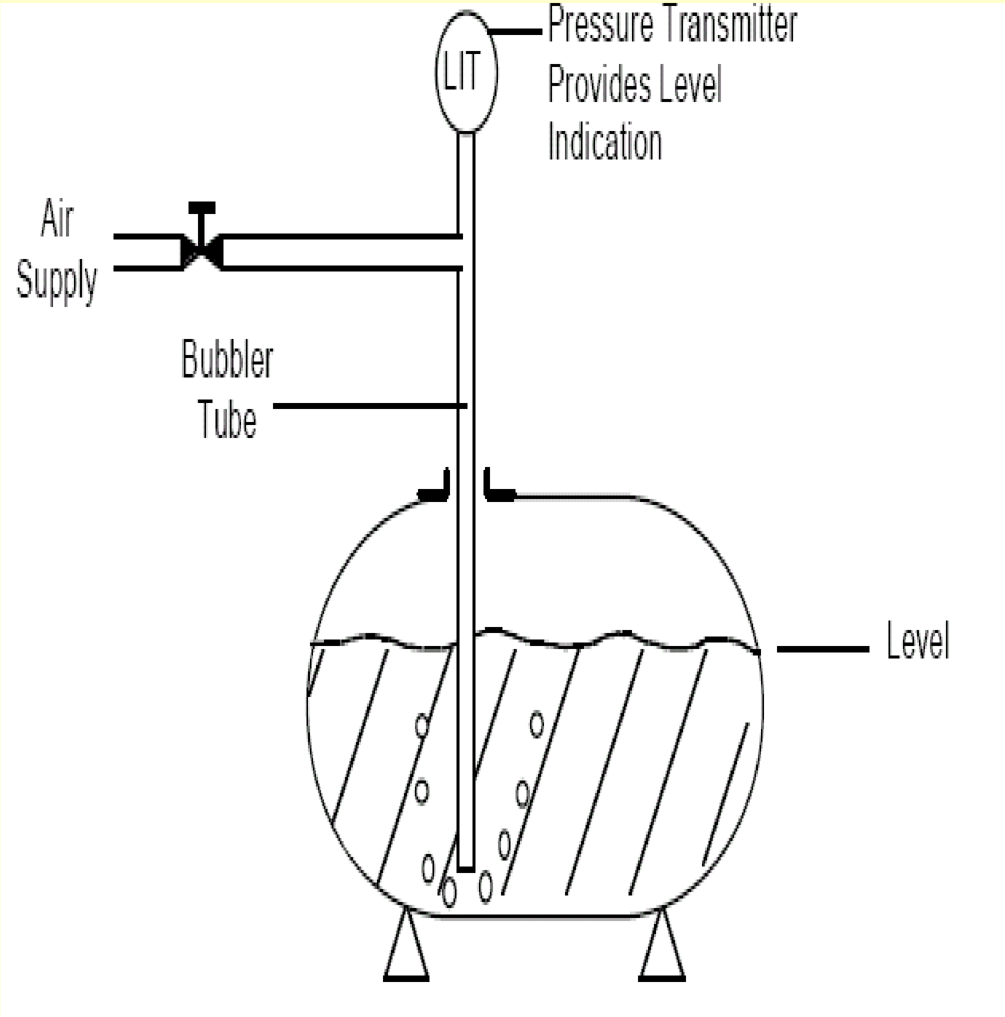
# Level Measurement

## Servo Gauge Type




## Bubbler Type

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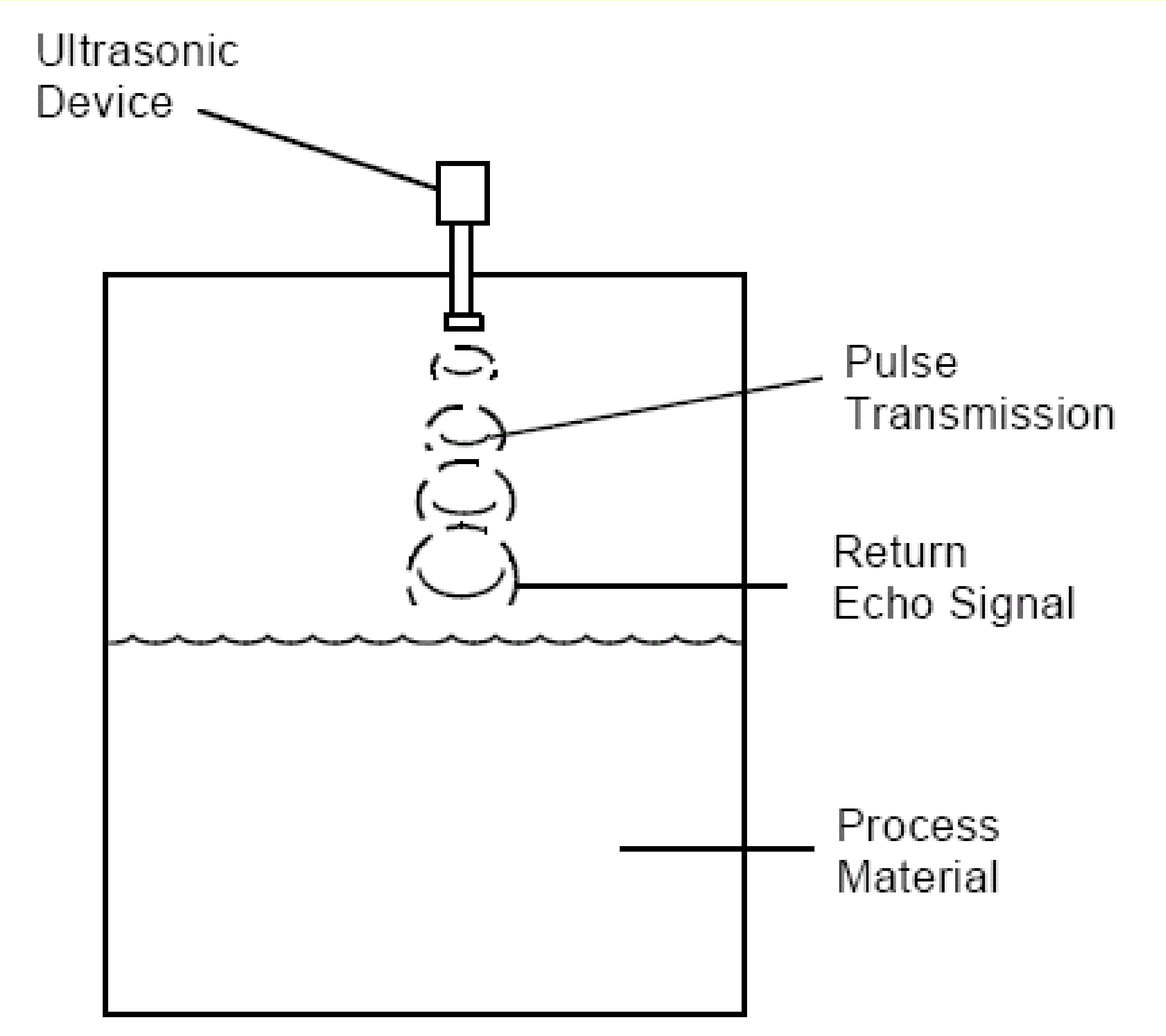
# Level Measurement

## Ultrasonic Type



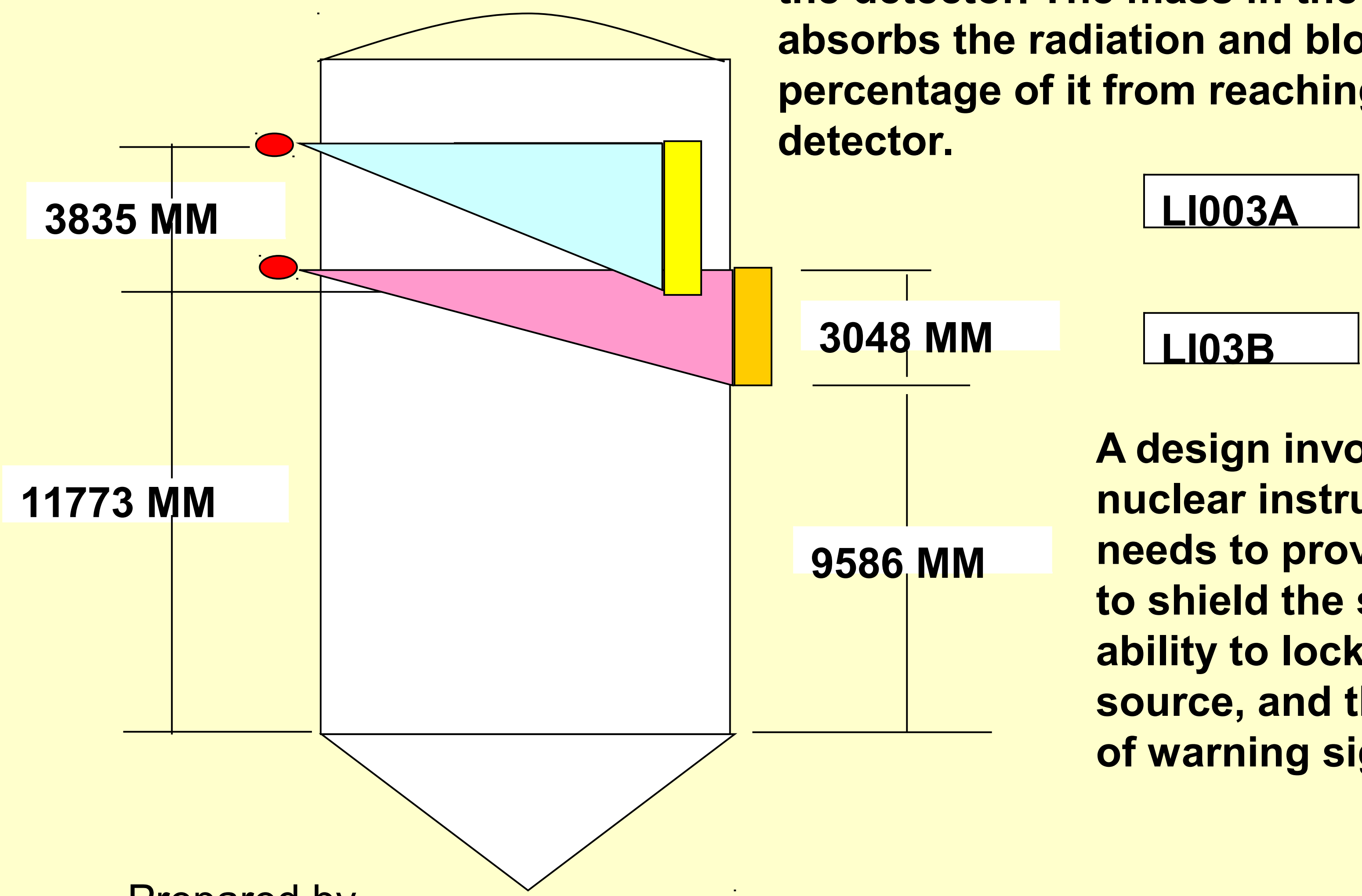

**Use of non-contact instruments should be considered for applications in**

- **corrosive**
- **toxic**
- **highly viscous**
- **slurries & heavy or irregularly shaped bulk materials or where probes can be damaged by the process.**

# Level Measurement

## Nuclear Type

Nuclear instruments have a radiation source and detector. The source radiates the signal through the vessel to the detector. The mass in the vessel absorbs the radiation and blocks a percentage of it from reaching the detector.




A design involving nuclear instruments needs to provide a way to shield the source, the ability to lock out the source, and the posting of warning signs.

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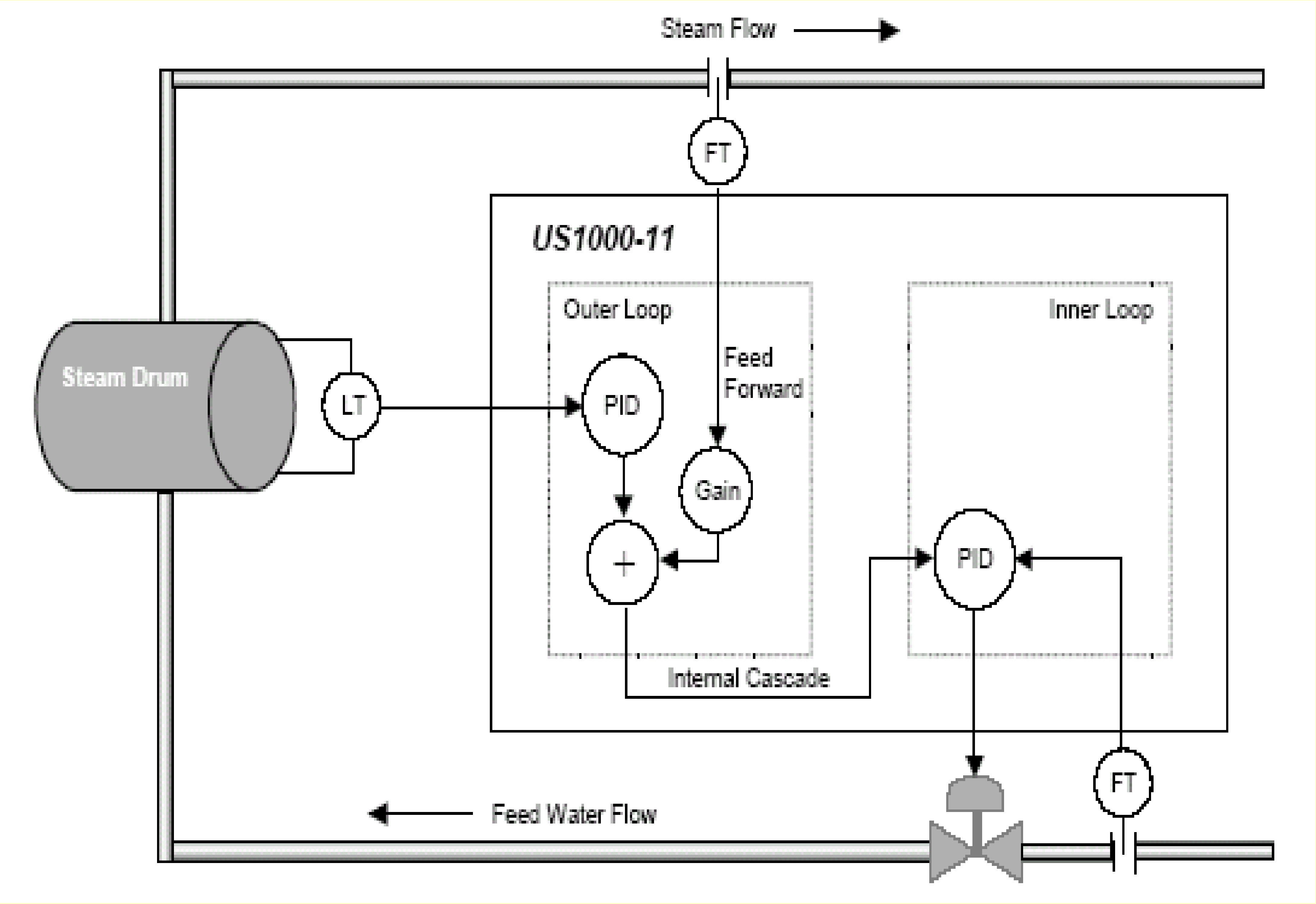
# Steam Drum : Level Control

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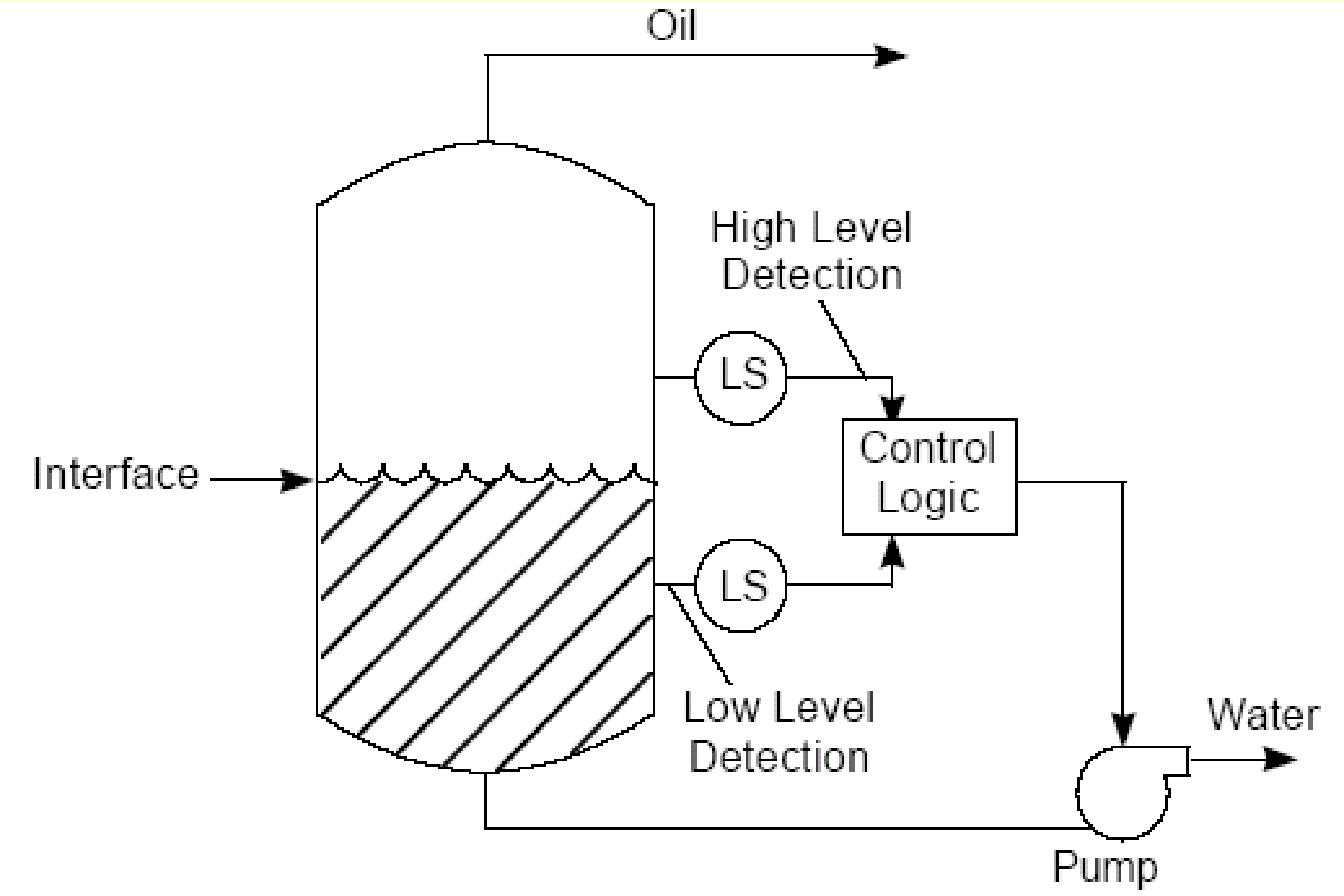
# Level Measurement

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# Level Measurement

## Magnetic Gauges

A magnetic gauge is a metal tube with an internal float magnetically coupled to an indicator on a scale on the outside of the tube.

Magnetic gauges should be considered as an alternative to glass for flammable, corrosive, toxic, high pressure, high temperature, or long visible length service.

The installation of the magnetic level gauge should be the same as for glass level gauges. The exception is that the end connection should be flanged and excess flow ball check valves are not required.

The floats in magnetic level gauges are thin-walled and may collapse from excessive pressure (e.g., hydro testing).

Magnetic gauges should not be used for liquids containing dirt or suspended solids.

Dirt can cause the float to stick resulting in false indications. The float in a magnetic gauge is engineered for a certain range of liquid densities.

# CONTROL LOOP

- **Primary Element:** The measuring element that quantitatively converts the measured variable energy into a form suitable for measurement.

  **Note:** The sensing portion is the primary element for transmitters that do not have external primary elements.

- **Transmitter:** A transducer which responds to a measured variable by means of a sensing element, and converts it to a standardized transmission signal which is a function only of the measured variable.

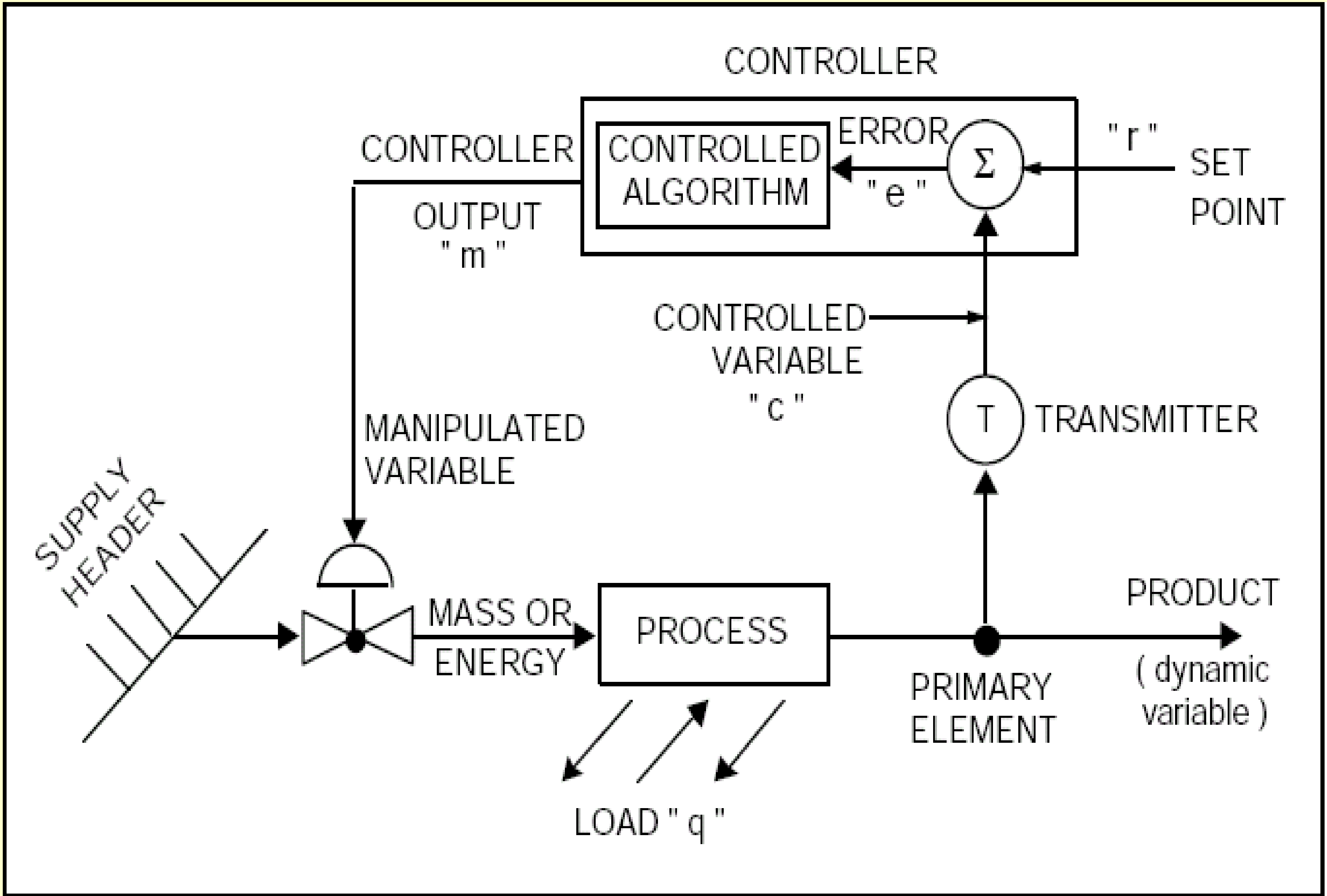
- **Controlled Variable:** A variable the value of which is sensed to originate a feedback signal. (Also known as the process variable.)

- **Controller:** A device which operates automatically to regulate a controlled variable.

- **Controller Algorithm (PID):** A mathematical representation of the control action to be performed.

- **Set Point:** An input variable which sets the desired value of the controlled variable.

# CONTROL LOOP



# CONTROL LOOP

## Error

In process instrumentation, the algebraic difference between the real value and ideal value of the measured signal. It is the quantity which when algebraically subtracted from the indicated signal gives the ideal value.

## Manipulated Variable

A quantity or condition which is varied as a function of the algebraic error signal so as to cause a change to the value of the directly controlled variable.

## Feedback Control

Control action in which a measured variable is compared to its desired value to produce an actuating error signal which is acted upon in such a way as to reduce the magnitude of the error.

## Cascade Control

Control in which the output of one controller is introduced as the set point for another controller.

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# CONTROL LOOP

**Proportioning Band:** A temperature band expressed in degrees within which a temperature controller's time proportioning function is active.

**Proportioning Control plus Derivative Function:** A time proportioning controller with derivative function. The derivative function senses the rate at which a system's temperature is either increasing or decreasing and adjusts the cycle time of the controller to minimize overshoot or undershoot.

**Proportioning Control plus Integral:** A two-mode controller with time proportioning and integral (auto reset) action. The integral function automatically adjusts the temperature at which a system has stabilized back to the set point temperature, thereby eliminating droop in the system.

**Proportioning Control with Integral and Derivative Functions:** Three mode PID controller. A time proportioning controller with integral and derivative functions. The integral function automatically adjusts the system temperature to the set point temperature to eliminate droop due to the time proportioning function. The derivative function senses the rate of rise or fall of the system temperature and automatically adjusts the cycle time of the controller to minimize overshoot or undershoot.

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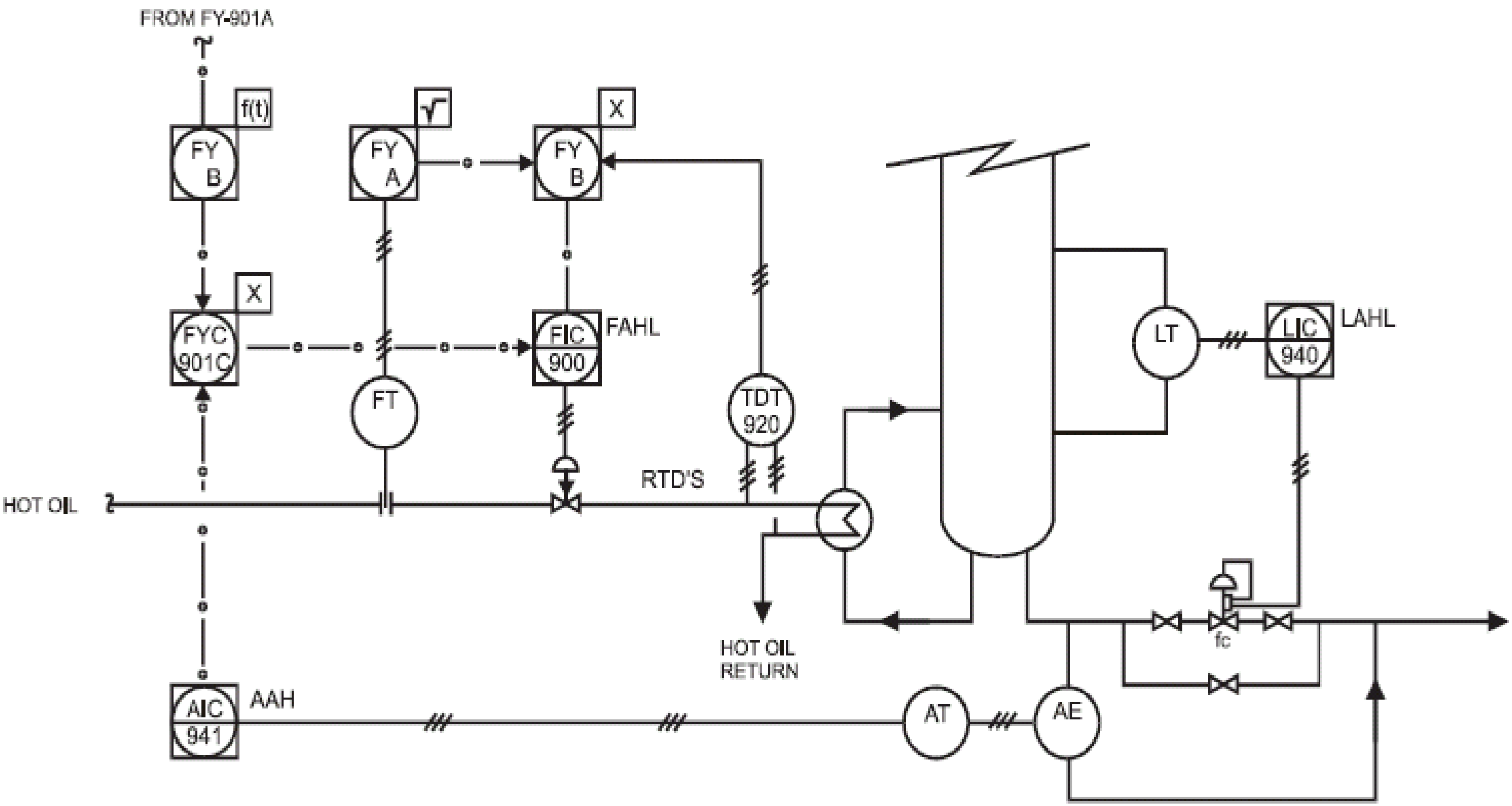
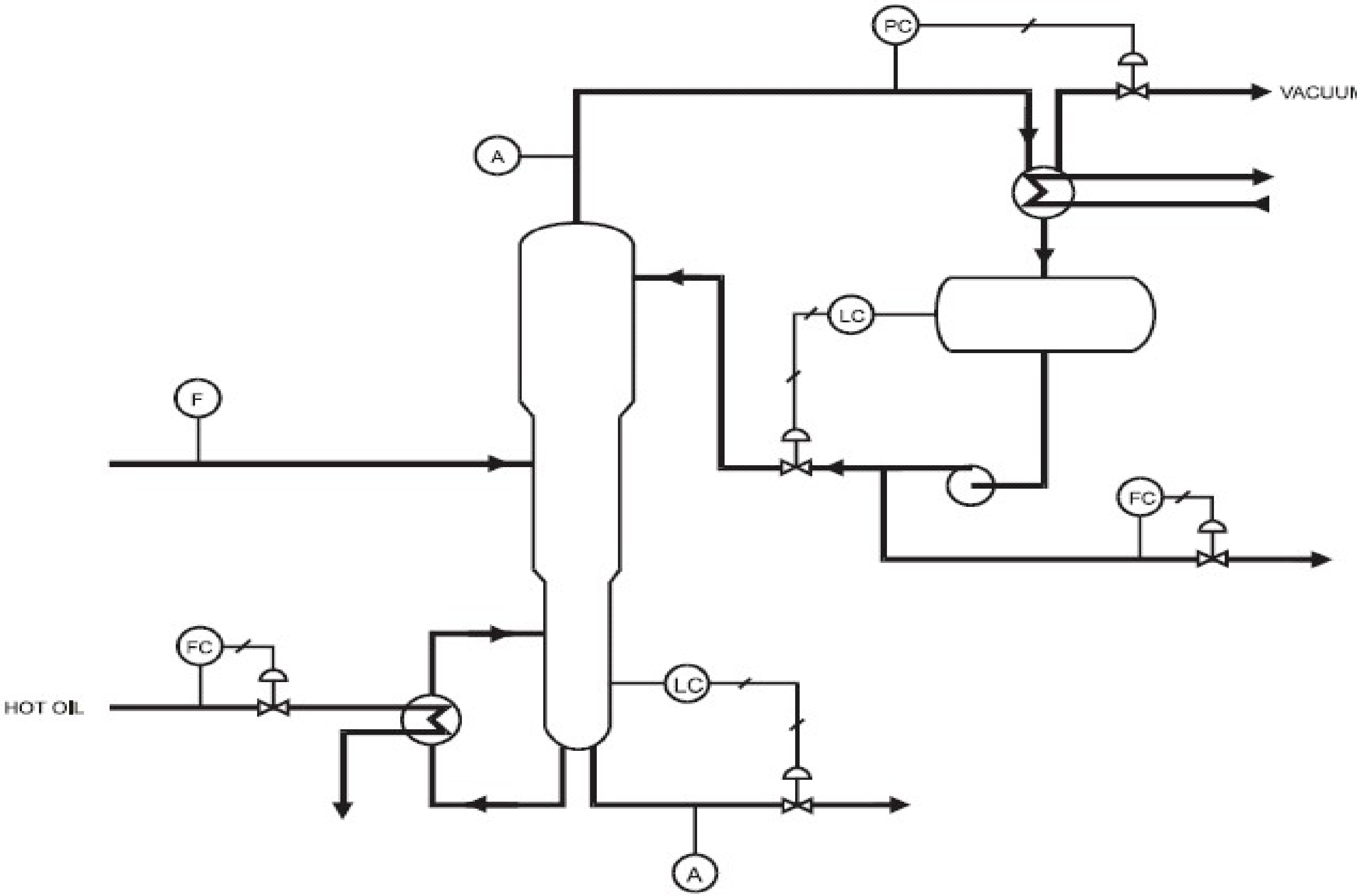
# FEEDBACK CONTROL LOOPS

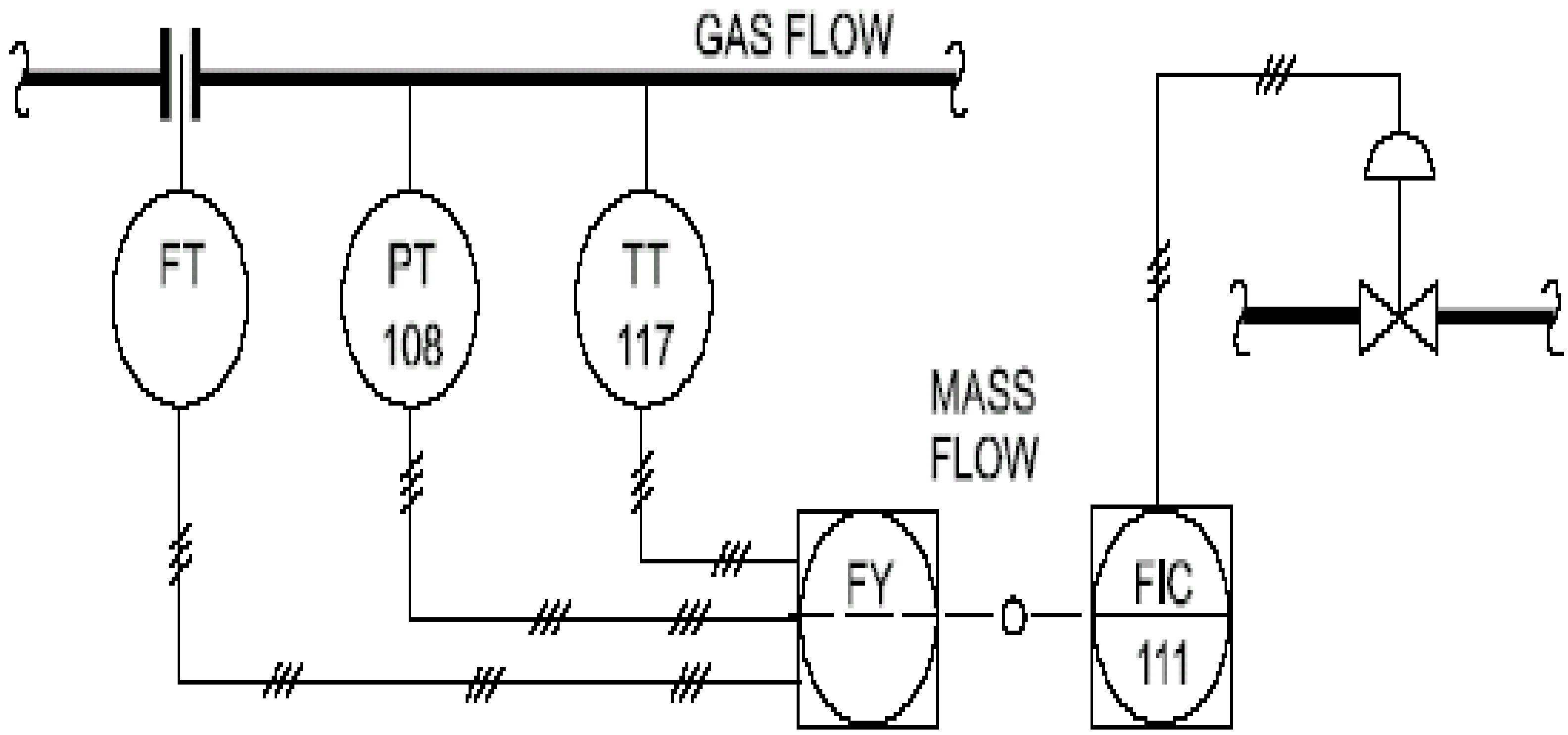



DETAILED SYMBOLISM AND MORE COMPLETE IDENTIFICATION USED TO DESCRIBE THE CONTROL SYSTEM WHEN TYPE OF HARDWARE AND KINDS OF SIGNALS HAVE BEEN CHOSEN.

# FEEDBACK CONTROL LOOPS



# MASS FLOW CONTROL LOOP




MASS-FLOW COMPUTATION PERFORMED BY MASS-FLOW COMPUTING RELAY FY-111 HAVING LINEAR INPUTS FOR PRESSURE AND TEMPERATURE AND A NON-LINEAR INPUT FOR FLOW

Prepared by

# TRANSMITTERS - CONTROL LOOPS

## What is HART?

HART ("Highway Addressable Remote Transducer") is a communication protocol designed for industrial process measurement and control applications.

It's called a **hybrid** protocol because it combines analog and digital communication.

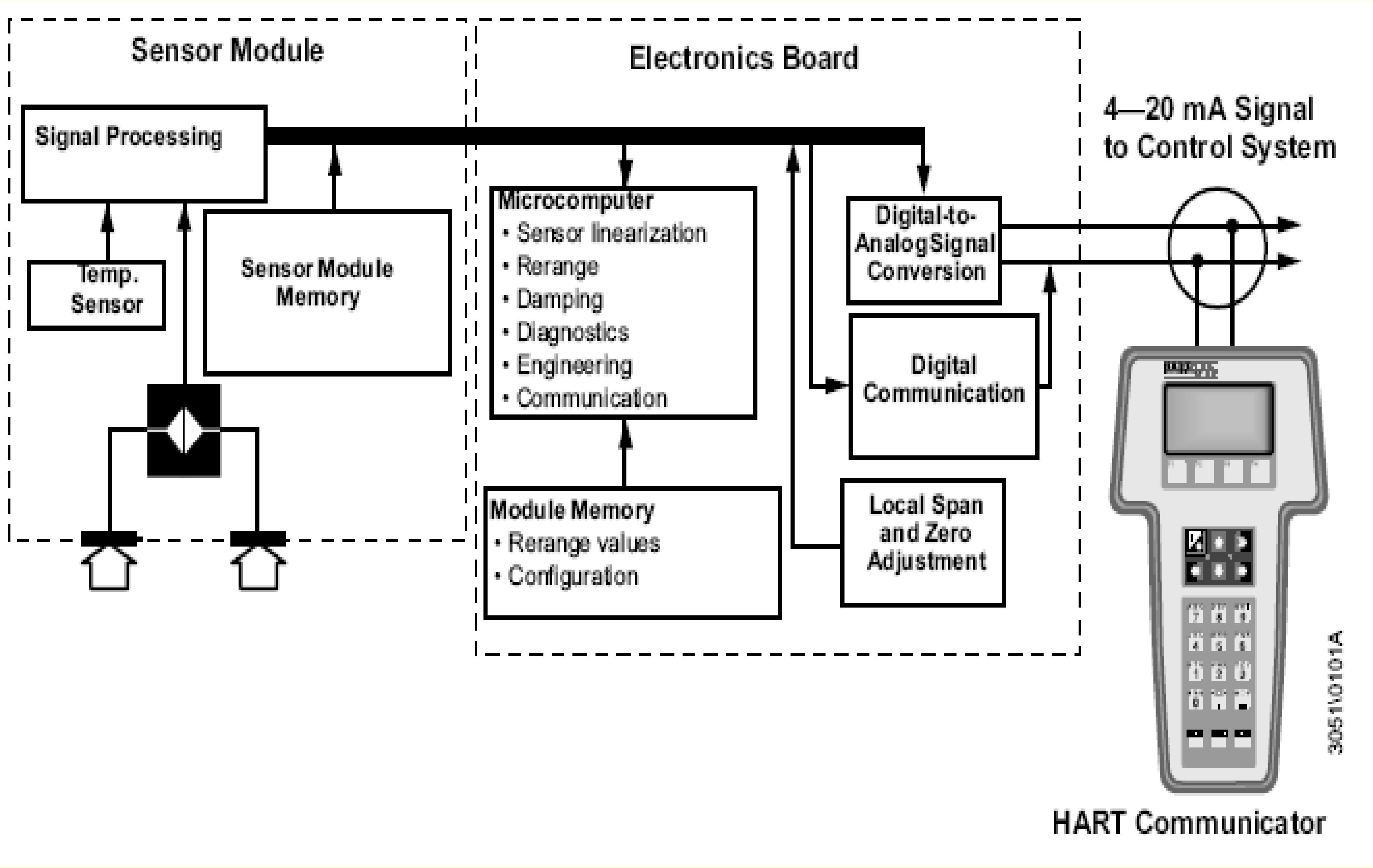
It can communicate a single variable using a 4-20 ma analog signal, while also communicating added information on a digital signal. The digital information is carried by a low-level modulation superimposed on the standard 4-to-20 mA current loop.

The digital signal does not affect the analog reading because it's removed from the analog signal by standard filtering techniques.

The ability to carry this added digital information is the basis for HART's key benefits

# Transmitters - Calibration

## How to use HART?

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# INSTRUMENT CALIBRATION

**Calibration:** The process of adjusting an instrument or compiling a deviation chart so that its reading can be correlated to the actual value being measured.

**Accuracy:** The closeness of an indication or reading of a measurement device to the actual value of the quantity being measured. Usually expressed as ± percent of full scale.

**Error:** The difference between the value indicated by the transducer and the true value of the measurand being sensed. Usually expressed in percent of full scale output.

**Repeatability:** The ability of a transducer to reproduce output readings when the same measurand value is applied to it consecutively, under the same conditions, and in the same direction. Repeatability is expressed as the maximum difference between output readings.

**Range:** Those values over which a transducer is intended to measure, specified by its upper and lower limits.

# INSTRUMENT CALIBRATION

**Span:** The difference between the upper and lower limits of a range expressed in the same units as the range.

**Rangeability:** The ratio of the maximum flowrate to the minimum flowrate of a meter.

**Duplex Wire:** A pair of wires insulated from each other and with an outer jacket of insulation around the inner insulated pair.

**Excitation:** The external application of electrical voltage current applied to a transducer for normal operation.

**Explosion-proof Enclosure:** An enclosure that can withstand an explosion of gases within it and prevent the explosion of gases surrounding it due to sparks, flashes or the explosion of the container itself, and maintain an external temperature which will not ignite the surrounding gases.

**Intrinsically Safe:** An instrument which will not produce any spark or thermal effects under normal or abnormal conditions that will ignite a specified gas mixture.

Prepared by

# INSTRUMENT CALIBRATION

| Field Instrument | Output Signal generated by | Check Points | Remarks |
|---|---|---|---|
| D/P Instrument, Low Pressure Instrument | Hand operated air pump or regulated air, and manometer or precision type test indicator | 0, 50, 100% of span, both increasing and decreasing | Check output signal against receiver instrument indication |
| Variable Area Meter type Transmitter | Transmitting mechanism actuated by hand | 0,50,100% of span, both increasing and decreasing | Check output signal against receiver instrument indication |
| Pressure Instrument | Dead weight tester, or regulated air and precision type test indicator | 0, 50, 100% of span, both increasing and decreasing | Check output signal against receiver instrument indication |
| Pressure Switch | Dead weight tester, or regulated air and precision type test indicator | Set point only & differential | Check alarm light, solenoid valve, sequence and interlock etc. |

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# INSTRUMENT CALIBRATION

| Field Instrument | Output Signal generated by | Check Points | Remarks |
|---|---|---|---|
| Pressure Gauge, Draft Gauge | ----- | Atm. Pressure | ----- |
| Field Temperature Transmitter (mV/E, R/E etc.) | mV source, resistance source and precision type test indicator | 0, 50, 100% of span both increasing and decreasing | Check output signal against receiver instrument indication |
| Thermometer | Temperature bath | Amb. Temperature Thermometer shall be checked with a temp. bath and a standard thermometer. | ------ |
| Displacer Type Level Instrument | Immersing the displacer in water | 0,50, 100% of span both increasing and decreasing | Check output signal against receiver instrument indication |
| Ball Float Type Level | Actuating the switch mechanically | ----- | Check alarm light, solenoid valve, sequence and interlock, etc. |

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# INSTRUMENT CALIBRATION

| Field Instrument | Output Signal generated by | Check Points | Remarks |
|---|---|---|---|
| Tank Gauge | Raising the float mechanically or electrically | (1) Zero point<br>(2) Smooth flat movement | (1) Check receiver instrument indication<br>(2) Prior to checking, the tank level must be confirmed as zero |
| Control Valve (Controller Output) | Controller manual output | 0, 50, 100% of the valve stroke, both increasing and decreasing | (1) Check the valve stroke against the travel indicator<br>(2) Check the valve action at air failure<br>(3) Check that the valve accessories, limit switch, AFR, function correctly.<br>(4) Confirm the closing point of control valve stroke<br>(5) Check alarm light, solenoid valve, sequence and interlock etc. |

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# INSTRUMENT PROCESS CONNECTIONS

| TYPE | PROCESS CONNECTIONS / SIZE | | |
|---|---|---|---|
| Pneumatic Signals | NPT 1/4 in female / 6mm / 8 mm | | |
| Electronic Signals<br>(Weatherproof or Explosion proof | NPT 1/2 in female | | |
| Differential Pressure Instruments<br>(Pressure Connection) | NPT ½ in female<br>Diaphragm 2 or 3 in; Flanged | | |
| Thermowell | Flanged | General Service | 1 in |
| | | High Velocity Service | 1 1/2 in |
| | Welded | General Service | 1 in |
| | | High Velocity Service | 1 1/2 in |
| | Screwed | | 3/4 in (male) |
| | Vessel | | 2 in |
| Pressure Instruments | --- | NPT 1/2 in female | |
| | Diaphragm | 2” Flanged | |
| Pressure gauges (Bourdon) | --- | NPT 1/2 in female | |
| | Diaphragm | 2” Flanged | |
| Draft Gauges | | NPT 1/4 in female | |

Prepared by

# INSTRUMENT PROCESS CONNECTIONS

| TYPE | PROCESS CONNECTIONS / SIZE | | |
|---|---|---|---|
| Level Instruments | Flange Type Differential Pressure Instrument | Diaphragm | 2” Flanged |
| | DP Transmitters | | NPT 1/2 in female |
| | Displacer | External<br>Internal | 2” Flange<br>4” Flange |
| | Gauge Glass | | 3/4 in |

Prepared by

# CABLE CONTINUITY TESTING

Step 1. Continuity and identification of each wire and continuity of shield wire shall be inspected between the field instrument terminals and the control cabinets terminals by using a battery powered phone.

Step 2. Insulation resistance test shall be performed by using a 500V or 100V megger. In this case, the wire shall be disconnected from the terminal both at the field and in the control cabinets.

The minimum resistance value shall be as follows:

a) Line to line 10M OHM at 20 Deg. C
b) Line to ground 10M OHM at 20 Deg. C
c) Line to shield 10M OHM at 20 Deg. C

If this test (megger) is required, close supervision will be required to prevent damage to the instruments. Temperature compensation will be made using compensating curves prepared by the cable manufacturers.

Step 3. The electricity charged in the wire by the insulation resistance test shall be discharged by grounding the wire and then the wire shall be connected firmly to its terminal.

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# CODES, STANDARDS AND SPECIFICATIONS

The following codes and standards, to the extent specified herein, form a part of this Design Criteria. When an edition date is not indicated for a code or standard, the latest edition in force at the time shall apply.

1. International Electrical Commission (IEC)
2. National Electrical Code (NEC)
3. National Electrical Manufacturer's Association (NEMA)
4. American National Standard Institute, Inc. (ANSI)
5. Instrument Society of America (ISA)
6. Institute of Electrical and Electronic Engineers (IEEE)
7. International Standards Organization (ISO)
8. American Petroleum Institute (API)
9. API RP550: Installation of Refinery Instruments And Controls Systems
10. API Standard 670:Vibration, Axial-Position and Bearing Temperature Monitoring systems

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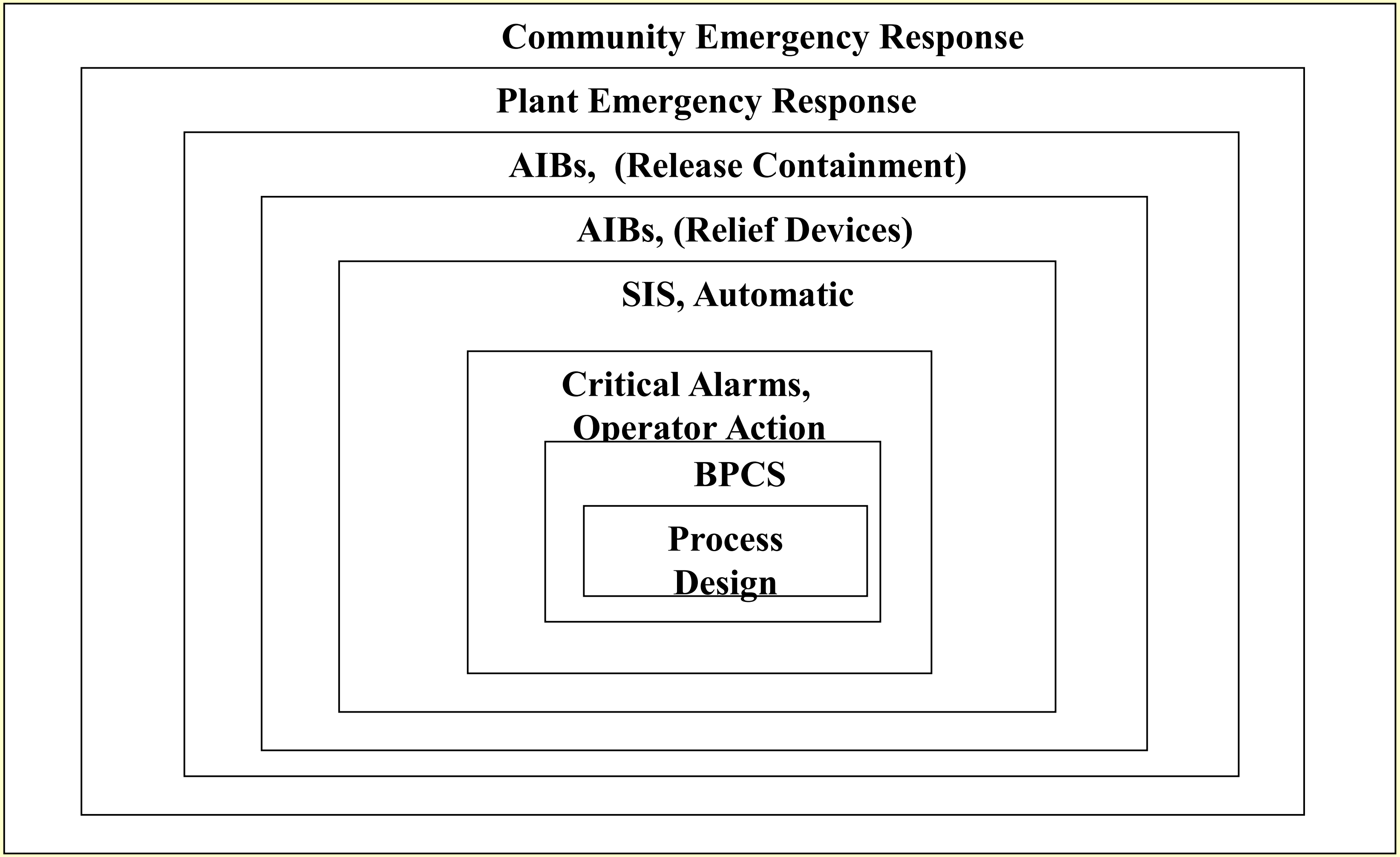
# LAYERS OF PROTECTION

(LINES OF DEFENSE AGAINST HAZARDOUS EVENTS)




BPCS: Basic Process Control System, dynamic – active

AIB: Approved Independent Backup

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# FAILURE DISTRIBUTION OVER THE SIS COMPONENTS

- SENSORS 42%
- LOGIC SOLVER 8%
- FINAL ELEMENTS 50%
- USUALLY THE LOGIC SOLVERS (PLCs) RECEIVE GREATER ATTENTION, WHEREAS THE FIELD DEVICES ARE RESPONSIBLE FOR OVER 90% OF THE FAILURES

## SEPARATION OF SIS AND BPCS

- "Normally, the logic solver(s) are separated from similar components in the BPCS.

  Furthermore, SIS input sensors and final control elements are generally separate from similar components in the BPCS."

  "Provide physical and functional separation and identification among the BPCS and SIS sensors, actuators, logic solvers, I/O modules, and chassis."

# SEPARATION OF SIS AND BPCS

## International Electro-technical Commission (IEC)

- "The separation of the safety related functions and the non safety related functions should be done whenever possible". "highly recommended"

## ANSI / ISA

- "Sensors for SIS shall be separated from the sensors for the BPCS". "The logic solver shall be separated from the BPCS".

# SEPARATION OF SIS AND BPCS

## API

- “The safety system should provide two levels of protection.. The two levels of protection should be independent of and in addition to the control devices used in normal operation.”

## NFPA

- “Requirement for Independence: The logic system performing the safety functions for burner management shall not be combined with any other logic system”.

# SEPARATION OF SIS AND BPCS

## IEEE

- “The safety system design shall be such that credible failures in and consequential actions by other systems shall not prevent the safety system from meeting the requirements”.

## UK Health and Safety Executive

- “It is strongly recommended that separate control and protection systems are provided.”

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