From P&ID's to Selection of Instrumentation and Control Valves

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• Loyd Hilliard – Puffer-Sweiven
• Dodd Mize – Emerson Process Management
• Kris Worfe – Emerson Process Management
Outline

• ISA Instrumentation Terminology for P&ID’s
• Control Valves
• Pressure Instruments
• Temperature Instruments
• Level Instruments
• Flow Instruments
• Summary/Additional Questions
Automation Society of America (ISA) P&ID Terminology

- ANSI/ISA-S5.1
- Piping and Instrumentation Diagram – “Drawing that shows the instrumentation and piping details for plant equipment.”
  - A directory to all field instrumentation and control
  - A key document to the control engineer.
Example P&ID
# ANSI/ISA-S5.1 – Identification Letters

<table>
<thead>
<tr>
<th>FIRST-LETTER (4)</th>
<th>MEASURED OR INITIATING VARIABLE</th>
<th>MODIFIER</th>
<th>READOUT OR PASSIVE FUNCTION</th>
<th>OUTPUT FUNCTION</th>
<th>MODIFIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Analysis (5, 19)</td>
<td></td>
<td>Alarm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Burner, Combustion</td>
<td></td>
<td>User’s Choice (1)</td>
<td>User’s Choice (1)</td>
<td>User’s Choice (1)</td>
</tr>
<tr>
<td>C</td>
<td>User’s Choice (1)</td>
<td></td>
<td>Control (13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>User’s Choice (1)</td>
<td>Differential (4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Voltage</td>
<td></td>
<td>Sensor (Primary Element)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Flow Rate</td>
<td>Ratio (Fraction) (4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>User’s Choice (1)</td>
<td></td>
<td>Glass, Viewing Device (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Hand</td>
<td></td>
<td>High (7, 15, 16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Current (Electrical)</td>
<td></td>
<td>Indicate (10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Power</td>
<td>Scan (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Time, Time Schedule</td>
<td>Time Rate of Change (4, 21)</td>
<td></td>
<td>Control Station (22)</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Level</td>
<td></td>
<td>Light (11)</td>
<td>Low (7, 15, 16)</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** ANSI/ISA-S5.1 Standard

**Example:**

- **FIC-101**
<table>
<thead>
<tr>
<th>M</th>
<th>User's Choice (1)</th>
<th>Momentary (4)</th>
<th>Middle, Intermediate (7,15)</th>
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<tbody>
<tr>
<td>N</td>
<td>User's Choice (1)</td>
<td>User's Choice (1)</td>
<td>User's Choice (1)</td>
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<tr>
<td>O</td>
<td>User's Choice (1)</td>
<td>Orifice, Restriction</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Pressure, Vacuum</td>
<td>Point (Test) Connection</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>Quantity</td>
<td>Integrate, Totalize (4)</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Radiation</td>
<td>Record (17)</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Speed, Frequency</td>
<td>Safety (8)</td>
<td>Switch (13)</td>
</tr>
<tr>
<td>T</td>
<td>Temperature</td>
<td></td>
<td>Transmit (18)</td>
</tr>
<tr>
<td>U</td>
<td>Multivariable (6)</td>
<td>Multifunction (12)</td>
<td>Multifunction (12)</td>
</tr>
<tr>
<td>V</td>
<td>Vibration, Mechanical Analysis (19)</td>
<td></td>
<td>Valve, Damper, Louver (13)</td>
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<tr>
<td>W</td>
<td>Weight, Force</td>
<td>Well</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>Unclassified (2)</td>
<td>X Axis</td>
<td>Unclassified (2)</td>
</tr>
<tr>
<td>Y</td>
<td>Event, State or Presence (20)</td>
<td>Y Axis</td>
<td>Relay, Compute, Convert (13, 14, 18)</td>
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<td>Z</td>
<td>Position, Dimension</td>
<td>Z Axis</td>
<td>Driver, Actuator, Unclassified Final Control Element</td>
</tr>
</tbody>
</table>

**Source:** ANSI/ISA-S5.1 Standard
ANSI/ISA-S5.1 – Symbol

6.2 Instrument line symbols
ALL LINES TO BE FINE IN RELATION TO PROCESS PIPING LINES.

ALL LINES TO BE FINE IN RELATION TO PROCESS PIPING LINES.

(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

6.3 General instrument or function symbols

<table>
<thead>
<tr>
<th>PRIMARY LOCATION ***NORMALLY ACCESSIBLE TO OPERATOR</th>
<th>FIELD MOUNTED</th>
<th>AUXILIARY LOCATION ***NORMALLY ACCESSIBLE TO OPERATOR</th>
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<tbody>
<tr>
<td>DISCRETE INSTRUMENTS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>SHARED DISPLAY BINARY CONTROL</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>COMPUTER FUNCTION</td>
<td>7</td>
<td>8</td>
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<tr>
<td>PROGRAMMABLE LOGIC CONTROL</td>
<td>10</td>
<td>11</td>
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</table>

Source: ANSI/ISA-S5.1 Standard
ANSI/ISA-S5.1 – Instrumentation Symbols

Source: ANSI/ISA-S5.1 Standard
Outline

• ISA Instrumentation Terminology for P&ID’s
  • Control Valves
  • Pressure Instruments
  • Temperature Instruments
  • Level Instruments
  • Flow Instruments
• Summary/Additional Questions
Control Valves

• Primary function: implement control strategy selected by controller (logic solver).

• Secondary function: survive the environment!

• Three predominant styles:
  • Globe
  • Ball
  • Butterfly

• Style selection determined by application.
Control Valves

• Basic assembly includes:
  • Valve body
  • Internal trim
  • Actuator
  • Various accessories
Globe Valves

- Most widely used
- Versatile – a valve for ANY application
  - General, severe and critical service
  - Customizable, characterizable.
Globe Valves
Ball Valves

- High size:capacity ratio
- Slurry, Pulp & Paper applications
- Limited dP and temperature capabilities
Ball Valves
Butterfly Valves

- Economic alternative to globe and ball
- Highest size:capacity ratio
- Primarily used for utility applications
- Not for precise control
Butterfly Valves
Control Valve Construction Options

• Materials of Construction
• Pressure Classes
• End Connections
• Leakage Classes
• Flow Characteristics

• Style selection determined by application.
Control Valve Materials of Construction

- Carbon Steel (WCC, WCB, LCC, LCB, etc…)
- Stainless Steel (316, 304, 321, 410, etc…)
- Chrome Moly (WC6, WC9, C5, C12, C12A, etc…)
- Duplex (CD7MCuN, CD3MN, S31803, etc…)
- High Nickel (Hastelloy C, Monel, Inconel, etc…)
- Exotics (Titanium, Zirconium, Tantalum, Zinc, etc…)

71st Annual Instrumentation and Automation Symposium for the Process Industries
Control Valve Pressure Classes

Number which identifies the pressure retaining ability of a device based on material of construction and temperature.

In accordance with ASME/ANSI B16.34

Table below based on WCC/WCB Carbon Steel

<table>
<thead>
<tr>
<th>Pressure Class</th>
<th>Psig @ 100 deg F</th>
<th>Psig @ 800 deg F</th>
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</thead>
<tbody>
<tr>
<td>150</td>
<td>285</td>
<td>80</td>
</tr>
<tr>
<td>300</td>
<td>740</td>
<td>410</td>
</tr>
<tr>
<td>600</td>
<td>1480</td>
<td>825</td>
</tr>
<tr>
<td>900</td>
<td>220</td>
<td>1235</td>
</tr>
<tr>
<td>1500</td>
<td>705</td>
<td>2060</td>
</tr>
<tr>
<td>2500</td>
<td>6170</td>
<td>3430</td>
</tr>
</tbody>
</table>
Control Valve End Connections
Control Valve Seat Leakage Classes

In accordance with ANSI/FCI 70-2 and IEC 60534-4

Example: 3” globe, max. capacity of 1000 GPM

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Leakage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>No Test Required</td>
<td>---</td>
</tr>
<tr>
<td>II</td>
<td>0.5% Rated Capacity</td>
<td>5 GPM</td>
</tr>
<tr>
<td>III</td>
<td>0.1% Rated Capacity</td>
<td>1 GPM</td>
</tr>
<tr>
<td>IV</td>
<td>0.01% Rated Capacity</td>
<td>0.1 GPM</td>
</tr>
<tr>
<td>V</td>
<td>0.0005 mL/min/in. port dia./psi</td>
<td>0.15 mL</td>
</tr>
<tr>
<td>VI</td>
<td>Bubbles/min by port size</td>
<td>6 Bubbles/min</td>
</tr>
</tbody>
</table>

ALL control valves leak.

Leakage Classes not meant for actual leakage rate prediction.
Control Valve Flow Characteristics

![Graph showing control valve flow characteristics](Image)

- Quick Open
- Linear
- Equal Percent

Percent of Rated Flow Coefficient ($C_v$) vs. Percent of Rated Travel.
## Control Valve Application Comparison

<table>
<thead>
<tr>
<th>Application</th>
<th>Globe</th>
<th>Ball</th>
<th>Butterfly</th>
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</thead>
<tbody>
<tr>
<td>Utility</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Chemical</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Flashing</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cavitation</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosive</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Corrosive</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>3 Way</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Temp/Press</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solids</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Low Flow</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Flow</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Viscous</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Pulp</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
Outline

• ISA Instrumentation Terminology for P&ID’s
• Control Valves
• Pressure Instruments
• Temperature Instruments
• Level Instruments
• Flow Instruments
• Summary/Additional Questions
Why Measure Pressure?

The four most common reasons for measuring pressure are:

- Safety
- Process Efficiency
- Cost savings
- Inferred measurement of other variables
## Pressure Units

### Units of Force Over Area of Fluid

- Pounds per square inch (psi) 68°F
- Kilograms per square centimeter (kg/cm²)
- Grams per square centimeter (g/cm²) (mmH2O)
- Pascals (Pa)
- Kilopascals (kPa) 1 kPa = 1000Pa (mmHg)
- Bar 1 bar-100,000 Pa
- Millibar (mbar) 1 mbar = 1/1000 bar

### Units Referenced to Columns

- Inches of water (in H2O at 68°F)
- Feet of water (ft H2O)
- Millimeters of water
- Inches of mercury (in Hg)
- Millimeters of mercury
- Torr 1 torr = 1 mmHg
- Atmosphere (atm) – The pressure exerted by the earth’s atmosphere at sea level
Why Measure Pressure?

Reference Pressure

- A pressure measurement that is compared to the measured pressure of the process material.
- Pressure-measurement devices differ in what they use as a reference pressure.
- The sensor is the part of a pressure-measurement instrument that physically reacts to pressure input.
- The side of the sensor that measures the pressure of the process material is called the high side of the instrument. The other side, or reference pressure side, is known as the low side of the instrument.
- Pressure-measurement devices can be categorized according to the reference pressure from which they measure.
- The three reference pressures are:
  - Absolute
  - Gage
  - Differential
Why Measure Pressure?

Reference Pressure

- **Absolute** - compares measured pressure to a perfect vacuum.
- **Gage** - uses the pressure of the surrounding atmosphere (approximately 14.7 psi) as a reference pressure.
- **Differential** - A differential pressure measurement uses a second process pressure as a reference pressure.
Why Measure Pressure?

Inferring Non-pressure Variables

There is a known relationship between pressure and density, pressure and level, and pressure and flow of a fluid through pipe.

These non-pressure variables can be inferred from pressure measurements.

- Flow
- Level
- Density
- Interface Measurement
Why Measure Pressure?

Electronic Pressure Transmitters

Electronic transmitters convert input pressure into a digital or electrical signal. Electronic transmitters have two basic parts: Sensor and Electronics.

The sensor of an electronic pressure transmitter physically responds to changes in input pressure. It converts the physical movement into an electrical property, such as capacitance, voltage, inductance, or reluctance.

The electronics part of the transmitter changes the output of the sensor into a standard electronic signal. The output is a 4 mA and 20mA signal that corresponds to process pressures within the operating range.
Why Measure Pressure?

Electronic Pressure Transmitters
Several types of sensors used with electronic pressure transmitters are:

- Variable capacitance
- Piezoresistive
- Piezoelectric
- Variable inductance
- Variable reluctance
- Vibrating wire
- Strain gauge
Electrical Classifications

Product Approvals and Certifications

Approval agencies located throughout the world act as a testing authorities in the design, manufacture, and operation of process control instruments.

Certification ensures expert *conformity with standards* and provides *evidence of compliance* with legal obligations such as safety regulations.

Hazardous areas are those where a risk of explosion exists because flammable atmospheres are likely to be present.

Safety codes are used to designate hazardous area certification for electrical equipment. Example of a North American Safety Code is:

- **Class I** = Hazardous Material in Surrounding Area
- **Div. 1** = Probability of hazardous materials being an ignitable concentration in the surrounding atmosphere.
- **Groups A,B,C,D** = Gas Groups
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• Level Instruments
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Why Measure Temperature?

The four most common reasons for measuring temperature:

• Product quality and yield
• Efficiency
• Safety
• Custody Transfer
Why Measure Temperature?

The four most common reasons for measuring temperature:

Temperature is a measure of a material’s internal molecular activity. As the level of molecular activity rises, the temperature of a substance increases. Hot and cold are subjective, qualitative descriptions of the rise in molecular activity.

The three temperature measurement scales in use today are:

- Fahrenheit
  - \[ C = \frac{(F - 32) \times 5}{9} \]
- Celsius (also called Centigrade)
  - \[ F = 1.8 \times C + 32 \]
- Absolute (Kelvin and Rankine)
Why Measure Temperature?

Temperature Sensors

RTD’s and T/C’s have several construction characteristics in common which are:

• Sensing element – located at tip of the temperature sensor on an RTD and the entire length of the T/C wires

• Sensor sheath – or the cable housing is constructed of metal and holds most of the component parts of the temperature sensor. Typically (MgO) sensor packing (also called a mineral insulated (MI) cable) surrounds the sensing element and is contained within the sensor sheath. The packing decreases the impact of process vibration on the sensing element for more accurate measurement. The end of the sensor sheath is sealed with a fill (e.g., epoxy) that keeps moisture out of the sheath and away from the sensing element.

• Lead Wires – Lead Wires connect the sensing element either directly to a distributed control system (DCS) or to a temperature transmitter connected to a DCS.

• Threaded adaptor (optional) – is welded over the rear housing of the sensor sheath.
Why Measure Temperature?

Resistance Temperature Detectors (RTD)

RTDs operate on the principle that the electrical resistance of a metal increases as temperature increases. This phenomenon known as thermoresistivity.

The three types of resistance metals most commonly used to construct RTD’s are:

- Platinum
- Copper
- Nickel

RTD elements are available in several designs; the two most common designs are:

- Wire –wound
- Thin-film
Why Measure Temperature?

Thermocouples (T/C)

A T/C consists of two wires of dissimilar metals (e.g., iron and constantan) that are joined at one end of to form a *hot injunction* (or sensing element).

The temperature measurement is made at the hot junction of the T/C, which is in the process.

The other end of the T/C lead wires, when attached to a transmitter or volt meter, form a cold or reference junction.

Several types of T/C’s are available, each differing by the metals used to construct the element, wide ranges of temperatures, applications and accuracies.
Why Measure Temperature?

Transmitting the Temperature Sensor Signal

To be useful for control, safety, or monitoring applications, a temperature measurement signal must be relayed from the point of measurement to the DCS of the process. The signal is relayed back to the DCS in one of many ways. The two most common ways are transmitters and wiring direct.

Transmitters – The sensor is wired a short distance to the transmitter, where its signal is converted to a digital or 4-20 mA signal. The converted signal output is then communicated back to the DCS through transmitter wire or a wireless network.

Wiring direct – The sensor’s lead wires are wired the entire distance to the DCS. No signal conversion takes place along the route.
Outline

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Why Measure Level?

Common Level Technologies:

• Ultrasonic
• DP & Hydrostatic
• Steam-Water Interface Level
• Vibrating Fork & Float Switch
• Guided Wave Radar
• Non-Contacting Radar
• Inventory Tank Gauging
Ultrasonic

An ultrasonic pulse launched into the tank is reflected back from the liquid surface. The level is derived from the time difference between when the pulse was sent and received.

- For simple tanks, open air levels and open channel flow
- Top mounted and non-contacting
- Unaffected by fluid density, viscosity, dirty coatings and corrosiveness

See page 20
DP & Hydrostatic

- Atmospheric tank
- Capillary Tubing
- Remote capillary seals
- “Electronic Remote Sensors”
Steam-Water Interface Level

A controller determines the steam-water interface level by measuring the electrical resistance of electrodes mounted in a water column connected to a boiler steam drum.

- Also ideal for condensate detection and turbine water induction protection
- Highly reliable steam drum level
- Side mounted and fault tolerant

See page 27
Vibrating Fork and Float Switch

The vibrating fork oscillates at its natural frequency in air. When liquid covers the fork, reducing the frequency, it triggers an alarm. With the float switch, when liquid rises to lift the float, the device’s magnetic coupling triggers an alarm.

- Flexible mounting
- High and low alarms, overfill protection and pump control
- Suitable for wide pressure and temperature requirements for most liquids, including hygienic applications
- Immune to changing process conditions

See page 22
Guided Wave Radar

Measurement is based on the time difference between sending and receiving a microwave pulse that was sent down a probe and reflected back at the product surface.

+ For level and interface measurement of liquids or solids
+ Suitable for wide temperature and pressure requirements
+ Top mounted and unaffected by media density, viscosity, conductivity, turbulence and dust
Inventory Tank Gauging

Complete tank gauging system solutions for tank terminals and refineries.

+ Reliable, non-contacting radar gauges with custody transfer accuracy
+ Suitable for a wide range of applications and tank types
+ Integrated tank instrumentation for high-performance results
### Application Considerations for Level

**Measurement**
- Level
- Interface (liquid/liquid)
- Volume
- Density
- Mass
- Open channel flow

**Process medium characteristics**
- Changing density
- Changing dielectric
- Wide pH variations
- Pressure and temperature changes
- Condensing vapors
- Bubbling/boiling surfaces
- Foam
- Coating liquids
- Viscous liquids
- Crystallizing liquids
- Solids, granules, powders
- Sludges and slurries

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Guided wave radar</th>
<th>Non-contacting radar</th>
<th>Dip level / void meter</th>
<th>Ultrasonic</th>
<th>Vibrating fork</th>
<th>Float</th>
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<tbody>
<tr>
<td>Level</td>
<td>●</td>
<td>●</td>
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<td>Wide pH variations</td>
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<tr>
<td>Bubbling/boiling surfaces</td>
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<td>●</td>
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### Application Considerations for Level

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<tr>
<th>Tank environment considerations</th>
<th>Guided wave radar</th>
<th>Non-contacting radar</th>
<th>DIP level / floatomatic</th>
<th>Ultrasonic</th>
<th>Vibrating fork</th>
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<td>Small tank ≤ 40 in (1 m)</td>
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1. Clamping dielectric has no impact on level measurements but it will have some impact on interface measurements.
2. Position instrument where it will not be in contact with agitator blades.
Outline

• ISA Instrumentation Terminology for P&ID’s
• Control Valves
• Pressure Instruments
• Temperature Instruments
• Level Instruments
• Flow Instruments
• Summary/Additional Questions
Flowmeter Selection Process

- Tendency to stay with what’s worked in past
- Gathering information often difficult
- Not an Exact Science
  - Usually more than one answer
- Bottom line – Faster growing Flow solutions deliver CAPEX & OPEX improvements
Why Measure the Flow?

To measure -

• the raw materials that are purchased.
• the finished products are produced?
• how much is used internally to produce finished product.
• what utilities are being used in the process.
• the ratios needed in order to blend final products accurately.
• what is occurring in your process for proper control.
Flowmeter Selection Process

Application → Performance → Fluid Properties → Installation → Economic Factors

Application:
- Control
- Monitor
- Indicate
- Batch
- Custody Transfer

Performance:
- Accuracy
- Repeatability
- Temperature Effect

Fluid Properties:
- Liquid, Gas, Steam Conductivity
- Multi-phase Viscosity
- Pressure
- Temperature

Installation:
- Line Size
- Vibration
- Pipe Runs
- Submergence

Economic Factors:
- Cost
- Installation
- Reliability

Environmental & Safety:
- Emissions
- Hazardous Waste
- Disposal
- Leak Potential
- Shut Down System?

Meter Selected:
- Coriolis
- DP
- Mag
- Vortex
- Ultrasonic
- Turbine
- Thermal
- PD
- ?

To Vendors
Industrial Flowmeter Types

- **Head Producing (DP)**
  - Orifice
  - Nozzle
  - Venturi
  - Wedge
  - Annubar/Pitot tube
  - Elbow tap
  - Target meter
  - Variable area/Rotameter

- **Velocity**
  - Turbine
  - Electromagnetic
  - Vortex
  - Ultrasonic

- **Mass**
  - Coriolis
  - Thermal

- **Positive Displacement**
  - Diaphragm seal
  - Mechanical seal
Straight Pipe Requirements Per Flow Technology

0.65β Ratio for DP Primary Elements

- Orifice
- Averaging Pitot Tube
- Wedge
- V-Cone
- Conditioning Orifice
- Magmeter
- Venturi
- Ultrasonic
- Nozzle & Venturi Nozzles
- Vortex w/o K-factor correction
DP is One Piece of the Flow Solution Puzzle

<table>
<thead>
<tr>
<th></th>
<th>Clean Gases</th>
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</table>
DP Flow - Theory of Operation

Flow = $K \sqrt{DP}$

$Q = N \cdot C_D \cdot Y_1 \cdot E \cdot d^2 \sqrt{DP \cdot \rho}$
Coriolis is One Piece of the Flow Solution Puzzle

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</table>
Coriolis Multi-Variable Capability

Three process variables measured independently:

- Direct Mass Flow
- On-Line Density
- Temperature
In a Coriolis meter, the inertial force is provided by vibrating the flow tubes. The tube twist or angle of deflection from the vibration plane is measured and converted into a mass flow measurement.
Magmeters is One Piece of the Flow Solution Puzzle

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</table>
Magnetic - Theory of Operation

Faraday’s Law: $E = kBDV$

- $k$ = Proportionality constant
- $B$ = Magnetic field strength
- $D$ = Length of conductor
- $V$ = Velocity of conductor
- $E$ = Induced voltage (linear with velocity)

Diagram showing conductive process medium, field coils, sensing electrodes, SST tube, flange, and magnetic field.
## Ultrasonic is One Piece of the Flow Solution Puzzle

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</table>
Ultrasonic - Theory of Operation

- Measures transit times of ultrasonic pulses
- Transducer locations placed for optimum measurement accuracy
- Transducers act alternately as transmitter and receiver
- Downstream pulses traverse stream more quickly than upstream pulses

\[ Q = V_{\text{average}} \cdot A \]

where

- \( Q \) = flow rate
- \( V_{\text{average}} \) = mean velocity of the fluid in the pipe
- \( A \) = area of the pipe

For Multipath USM

\[ V_{\text{average}} = \sum_{1}^{n} W_i V_i \]
Ultrasonic – Theory of Operation

- **Time-of-flight**
  - Single-path and Multi-path
  - Generally used in clean liquids, Natural Gas

- **Doppler**
  - Relies on small particles in the flow
  - Good for dirty flows
## Vortex is One Piece of the Flow Solution Puzzle

<table>
<thead>
<tr>
<th></th>
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</table>
Vortex - Theory of Operation

• Based on the von Karman Effect
  – Fluid alternately separates from each side of the shedder bar face
  – Vortices form behind the face and cause alternating differential pressures (DP) around the back of the shedder bar
  – The frequency of the alternating vortex development is linearly proportional to flow rate
Thermal Mass is One Piece of the Flow Solution Puzzle

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</table>
 Thermal Mass – Theory of Operation

- Heats one probe
- Measures fluid temperature with other probe
- Mass flow rate is computed based on the amount of electrical power required to maintain a constant difference in temperature between the two temperature probes.
Turbine is One Piece of the Flow Solution Puzzle

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Turbine - Theory of Operation

- A rotor is positioned in the flow stream
- The rotational velocity is proportional to fluid velocity
Positive Displacement is One Piece of the Flow Solution Puzzle

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<tr>
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<td>Low/Medium</td>
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<td>X</td>
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<td>Turbine</td>
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<td>PD</td>
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Positive Displacement - Theory of Operation

- Differential pressure across the flowmeter causes the oval gears to rotate (in opposite directions)
- A known quantity of liquid is entrapped and “metered” with each rotation of the rotors
- Flow is proportional to the speed of rotation
Outline

• ISA Instrumentation Terminology for P&ID’s
• Control Valves
• Pressure Instruments
• Temperature Instruments
• Level Instruments
• Flow Instruments

• Summary/Additional Questions
Summary

• P&ID’s are a key reference for instrumentation and control
• ANSI/ISA-S-5.1 provides guidelines
• There are an immense array of choices for instrumentation and control valves
• Other information:
  – Contact us for more detailed information
  – “The Three ‘-actions’ of Process Instrumentation” (Wed. 10:00)
  – “The Anatomy of a Reliable Instrument Loop” (Wed. 1:45)
  – “Instrument Engineering Experiences in 50+ Years,” (Wed. 3:30)
  – “Flow Technology Overview and Selection” (Thurs. 1:30)
Speakers

- James Beall - Principal Control Consultant, Emerson Process Management, james.beall@Emerson.com

- Loyd Hilliard – Severe Service Business Manager, Puffer-Sweiven, Inc., loyd.hilliard@puffer.com

- Dodd Mize – Regional Sales Manager, Emerson Process Management, dodd.mize@emerson.com

- Kris Worfe – Account Manager, Emerson Process Management-Flow Division, kris.worfe@emerson.com