Process & instrumentation diagram

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ISA

- ISA stands for the *Instrumentation, Systems, and Automation Society*
- The ISA–5.5–1985 norm is for *Graphic Symbols for Process Displays*
- Scope: The standard is suitable for use in the chemical, petroleum, power generation, air conditioning, metal refining, and numerous other industries. Though the standard may make use of standard symbols now used for piping and instrument diagrams, logic diagrams, loop diagrams, and other documents, the symbols of the standard are generally expected to be used in ways complementing existing types of engineering documents. The symbolism is intended to be independent of type or brand of hardware or computer software.
Automation Engineering

Automation engineering is at the intersection of Control Engineering and Process Engineering

It starts with the idea that no process can work without instrumentation and control. Machines are useless without sensors or actuators. Furthermore, without control loops, no performance can be obtained.

It can be renamed Automated System Engineering where 'automated' means 'autonomous'... capable of working without human intervention.
Historical considerations

First constructions of large (petrochemical) factories were a total failure due to:

- excessive complexity
- excessive number of sensors
- excessive number of actuators
- excessive complexity and length of connection cables

Required: a clear and concise graphical representation of machines, instrumentation, connections.

Note: 5 to 15 % of the total cost of a new factory is related to its automation. In certain cases (e.g. pharmaceutical) the automation cost tends to 100 %. 

Complexity
Unambiguous representation

- unambiguous representation of the process (product flow, air flow, water flow, etc.)
- unambiguous representation of the sensors, actuators and control functions

Question: what is the purpose of a temperature sensor?
Flowsheet & P&ID

- Flowsheet: shows circulation of fluids & products around machines
- Piping and Instrumentation Diagram: show locations and functions of sensors, actuators and control functions

Important: the flowsheet and the P&ID are unambiguous representations of an existing or upcoming process. Hence, it can used at the core of a specification sheet to guarantee the unambiguous design of a future process.
Codification

- first letter: measured variable (e.g. 'T' for temperature)
- second letter: functions (e.g. 'I' for information, 'A' for alarm)
- other letters: depend on second letter

Note: order is important only for first letter
A simple example

Flow indicating controller that performs a square root flow calculation (primary location)

Temperature indicating controller (field mounted)

Temperature transmitter

Pipe

Pneumatically actuated valve

Electrically actuated valve
Sensors in industry

2 main categories

- analogic or numeric
- digital (i.e. on/off). One may speak of detectors

Important: Most of industrial sensors are related to temperature (50%), flowrate, pressure, level, duration. Other specific measures are: Ph, spectro, chromato, etc.

Note: most of sensors are electrical or numerical. In some conditions (e.g. hazardous zones), pneumatic or hydraulic technologies may be preferred.
Signals

PSI: Pounds per square inch

Questions: why 4 mA instead of 0 mA? What is best: voltage or intensity?
1 sensor = 3 or more systems

dotted line: electrical transmission
Always avoid ambiguity

Use LAL, LAH LALH for instance. Note: HH or LL are used when criticity is high and some proper action should be done immediately.
Flowrate measurement

Debit can be estimated through the measure of the pressure drop in the pipe: \( \dot{m}_v = k \sqrt{\Delta P} \)

Note: It is the only case where the 2 first letters are indicating the measured variable.
Don’t forget calibration

It is important to think of the calibration since the beginning. More specifically, how to make the zero?

Note: the sum of all valves is called a manifold.
Note: Physically, the valve LCV1 controls the flowrate while functionally it controls the level.
Introduction

Sensor technologies
Complements

Classification
Signals
Splitting measurement device
Sensor complexity

Proportional Integral Derivative Controllers (front)
Proportional Integral Derivative Controllers (mount)

**Dimensions**

For removing the device from the panel:
- While pressing both sides of the device in direction 1, push it in direction 2.

**Note**
1) While panel mounting, additional distance required for connection cables should be considered.
2) Panel thickness should be maximum 9mm.
3) If there is no 100mm free space at back side of the device, it would be difficult to remove it from the panel.
Proportional Integral Derivative Controllers (wiring)

**ENDA INDUSTRIAL ELECTRONICS**
**EUC442-230VAC-RS**
**PID UNIVERSAL CONTROLLER**
**SN: XXXXXXXX**

- **230V AC 10% - 20% 50/60Hz 5VA**
- **RS-485 COM.**
- **AM/SSR OUT**
- **AL1 OUT**
- **AL2 OUT**
- **AC 250V 2A RESISTIVE LOAD**
- **TC**
- **mA (mA imp).**

**ENDA INDUSTRIAL ELECTRONICS**
**EUC442-24VAC**
**PID UNIVERSAL CONTROLLER**
**SN: XXXXXXXX**

- **24V AC 10% - 20% 50/60Hz 5VA**
- **RS-485 COM.**
- **AM/SSR OUT**
- **AL1 OUT**
- **AL2 OUT**
- **AC 250V 2A RESISTIVE LOAD**
- **TC**
- **mA (mA imp).**

**NOTE:**

- **Supply:**
  - 184-251V AC 50/60Hz 5VA
  - **Fuse**
  - **230V or 24V AC**
  - **Supply Cable size: 1.5mm²**

- **Sensor Input:**
  - For J-K-T-T-R type thermocouple:
    - Use suitable compensation cables. Pay attention to the polarities of the thermocouple cables as shown in the figure right are connected to the.
  - For resistance thermometer:
    - When 2 wired Pt 100 is used, terminals 6 and 7 must be short-circuited.

**Order Code:**

- **EUC442-**
  - **1**
  - **2**

1. **Supply Voltage**
   - 230VAC...230V AC
   - 110VAC...110V AC
   - 24VAC....24V AC
   - SM.........9-30V DC / 7-24V AC

2. **Modbus Option**
   - RS.........RS-485 Modbus communication
   - None....Don't support RS-485 Modbus communication

**Logic output of the instrument is not electrically insulated from the internal circuits. Therefore, when using a grounding thermocouple, do not connect the logic output terminals to the ground.**

**Note:**

1. Mains supply cords shall meet the requirements of IEC 60227 or IEC 60245.
2. In accordance with the safety regulations, the power supply switch shall bring the identification of the relevant instrument and it should be easily accessible by the operator.

**Holding screw 0.4-0.5mm**

**Equipment is protected throughout by DOUBLE INSULATION.**
Another example
## Codification of location

<table>
<thead>
<tr>
<th>Central Control Room</th>
<th>Auxiliary Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessible to Operator</td>
<td>Accessible to Operator</td>
</tr>
<tr>
<td>Discrete Instruments</td>
<td></td>
</tr>
<tr>
<td>Behind the panel or otherwise inaccessible to Operator</td>
<td>Behind the panel or otherwise inaccessible to Operator</td>
</tr>
<tr>
<td></td>
<td>Feild Mounted Instrument</td>
</tr>
</tbody>
</table>

| Shared Hardware | | |
|-----------------|-----------------|
| Shared Display, Shared Control | |
| | |

| Software | | |
|----------|-----------------|
| Computer Function | |
| | |

| Shared Logic | | |
|--------------|-----------------|
| Programmable Logic Control | |
| | |
Control Room
In the field
## Codification of sensor letters

### ISA SYMBOLS AND LETTERING

<table>
<thead>
<tr>
<th>MEASURED VARIABLE</th>
<th>MODIFIER</th>
<th>READ OUT</th>
<th>DEVICE FUNCTION</th>
<th>MODIFIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Analysis</td>
<td>Alarm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Burner, Combustion</td>
<td>User’s choice</td>
<td>User’s choice</td>
<td>User’s choice</td>
<td></td>
</tr>
<tr>
<td>C User’s choice</td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D User’s choice</td>
<td>Differential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Voltage</td>
<td>Sensor (Primary element)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Flow rate</td>
<td>Ratio (Fraction)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G User’s choice</td>
<td>Glass, viewing device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H Hand</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I Electrical Current</td>
<td>Indication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J Power</td>
<td>Scan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K Time, time schedule</td>
<td>Time rate of change</td>
<td>Control station</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L Level</td>
<td>Light</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M User’s choice</td>
<td>Momentary</td>
<td>User’s choice</td>
<td>User’s choice</td>
<td></td>
</tr>
<tr>
<td>N User’s choice</td>
<td>User’s choice</td>
<td>User’s choice</td>
<td>User’s choice</td>
<td></td>
</tr>
<tr>
<td>O User’s choice</td>
<td>Orifice, restriction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P Pressure, vacuum</td>
<td>Pressure, vacuum Point, test connection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q Quantity</td>
<td>Integrate, totalizer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R Radiation</td>
<td>Record</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S Speed, frequency</td>
<td>Safety</td>
<td>Switch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T Temperature</td>
<td>Transmit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U Multivariable</td>
<td>Multifunction</td>
<td>Multifunction</td>
<td>Multifunction</td>
<td></td>
</tr>
<tr>
<td>V Vibration, Mechanical analysis</td>
<td>Multifunction</td>
<td>Valve, damper, louver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W Weight, force</td>
<td>Well</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X Unclassified</td>
<td>X axis</td>
<td>Unclassified</td>
<td>Unclassified</td>
<td>Unclassified</td>
</tr>
<tr>
<td>Y Event, state, or presence</td>
<td>Y axis</td>
<td>Relay, compute, convert</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z Position, dimension</td>
<td>Z axis</td>
<td>Driver, actuator</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Equipments

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Icon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td><img src="image" alt="Compressor Icon" /></td>
</tr>
<tr>
<td>Reciprocating compressor</td>
<td><img src="image" alt="Reciprocating Compressor Icon" /></td>
</tr>
<tr>
<td>Compressor silencers</td>
<td><img src="image" alt="Compressor Silencers Icon" /></td>
</tr>
<tr>
<td>Centrifugal</td>
<td><img src="image" alt="Centrifugal Icon" /></td>
</tr>
<tr>
<td>Rotary compressor</td>
<td><img src="image" alt="Rotary Compressor Icon" /></td>
</tr>
<tr>
<td>Liquid ring compressor</td>
<td><img src="image" alt="Liquid Ring Compressor Icon" /></td>
</tr>
<tr>
<td>Centrifugal compressor</td>
<td><img src="image" alt="Centrifugal Compressor Icon" /></td>
</tr>
<tr>
<td>Mixing reactor</td>
<td><img src="image" alt="Mixing Reactor Icon" /></td>
</tr>
<tr>
<td>Jacketed mixing vessel</td>
<td><img src="image" alt="Jacketed Mixing Vessel Icon" /></td>
</tr>
<tr>
<td>Half pipe mixing vessel</td>
<td><img src="image" alt="Half Pipe Mixing Vessel Icon" /></td>
</tr>
<tr>
<td>Vertical vessel</td>
<td><img src="image" alt="Vertical Vessel Icon" /></td>
</tr>
<tr>
<td>Horizontal vessel</td>
<td><img src="image" alt="Horizontal Vessel Icon" /></td>
</tr>
<tr>
<td>Column</td>
<td><img src="image" alt="Column Icon" /></td>
</tr>
<tr>
<td>Pump</td>
<td><img src="image" alt="Pump Icon" /></td>
</tr>
<tr>
<td>Centrifugal pump</td>
<td><img src="image" alt="Centrifugal Pump Icon" /></td>
</tr>
<tr>
<td>Centrifugal pump 2</td>
<td><img src="image" alt="Centrifugal Pump 2 Icon" /></td>
</tr>
<tr>
<td>Centrifugal pump 3</td>
<td><img src="image" alt="Centrifugal Pump 3 Icon" /></td>
</tr>
<tr>
<td>Vertical pump</td>
<td><img src="image" alt="Vertical Pump Icon" /></td>
</tr>
<tr>
<td>Rotary gear pump</td>
<td><img src="image" alt="Rotary Gear Pump Icon" /></td>
</tr>
<tr>
<td>Proportioning pump</td>
<td><img src="image" alt="Proportioning Pump Icon" /></td>
</tr>
<tr>
<td>Vacuum pump</td>
<td><img src="image" alt="Vacuum Pump Icon" /></td>
</tr>
<tr>
<td>Screw pump</td>
<td><img src="image" alt="Screw Pump Icon" /></td>
</tr>
<tr>
<td>Turbine pump</td>
<td><img src="image" alt="Turbine Pump Icon" /></td>
</tr>
<tr>
<td>Pump 2</td>
<td><img src="image" alt="Pump 2 Icon" /></td>
</tr>
<tr>
<td>Bag</td>
<td><img src="image" alt="Bag Icon" /></td>
</tr>
<tr>
<td>Gas bottle</td>
<td><img src="image" alt="Gas Bottle Icon" /></td>
</tr>
<tr>
<td>Selectable fan</td>
<td><img src="image" alt="Selectable Fan Icon" /></td>
</tr>
</tbody>
</table>
Heat exchangers
Valves

- Gate valve, Hand-operated
- Check valve
- Check valve 2
- Butterfly valve
- Flanged valve
- Flanged valve 2
- Angle valve, Hand-operated
- Relief valve
- Angle valve, Hand-operated
- Ball
- Diaphragm
- Solenoid valve
- Hydraulic valve
- Motor-operated valve
- Powered valve
- Float-operated valve
- Needle valve
- 3-way plug valve
- Four-way valve
- Gauge
- Bleeder valve
Piping lines

- Major pipeline
- Connect pipeline
- Major straight line
- Straight line pipe
- Process connection
- Side by side
- Top-bottom
- One-to-main
- Multi-lines
- Mid arrow
- Multi-lines elbow
- Top to top
- Electrical signal
- Sonic signal
- Nuclear
- Pneumatic
- Hydraulic signal line
- General joint
- Butt weld
- Mechanical Link
- Soldered/Solvent
- Double Containment
- Flange
- End caps
- End caps 2
- Breather
- Flange
- Electrical Bounded
Automation Engineering procedure

Chain list: electrical links between instruments (caution with impedances), mounting docs: specific competences are required.

More and more, engineering is not in charge of the installation → documents are of utmost importance!
Legal and security issues

- P&ID is a legal document (associated with contracts)... it should be signed
- Schematics of loops: polarities, shielding, etc. are depicted... Essential for the electricians... and maintenance.
Examples
Drum dryer

- Longitudinal cut
  - Steam
  - Condensate

- Side view
  - Liquid
  - Scraper
  - Powder
  - Stirrer
Air lift fermenter
A.7 Symbols for Use in Drawing Food Engineering Process Equipment

- Belt conveyor
- Blower
- Centrifuge
- Centrifugal pump
- Closed tank
- Drain
- Trap (e.g., condensate release)
- Batch dryer

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*Symbols for Use in Drawing Food Engineering Process Equipment*
Appendices

- Fluidized bed dryer
- Spray dryer
- Electric motor
- Belt (continuous tunnel) dryer
- Rotary dryer
- Elbow
- Elevator
- Evaporator (barometric type)
Symbols for Use in Drawing Food Engineering Process Equipment

- Feeder
- Basic heat exchanger
- Double pipe type heat exchanger
- Hopper
- Hopper with vibrator
- Shell and tube heat exchanger
- Plate heat exchanger
- Filter
- Gear pump
- Double pipe type heat exchanger
Appendices

- Mixer
- Open tank
- Positive displacement pump
- Screen with one under-product
- Screw conveyor
- Pressure vessel
- Pipes
- Flexible pipe or hose
- Jacketed pipe
- Major flow lines
- Fall 1:50
- Multi evaporator
- Screen with one under-product
- Screw conveyor