Piping and Instrumentation Diagrams

by

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Course 462
4 PDH (4 Hours)

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Piping and Instrumentation Diagrams

Course Outline:

Overview of P&IDs

Piping and Instrumentation Diagrams (P&IDs) are drawings showing piping and communications as schematic (unscaled) lines and control features as symbols. P&IDs illustrate the functional relationship of piping, instrumentation, equipment, and controllers. They are usually located in the instrumentation drawings in a project drawing set. P&IDs are commonly made by process engineers, controls engineers, and electrical engineers.

The main purpose of a P&ID is to indicate if devices are automatically controlled, and if so, how they are interlocked with instruments. P&IDs convey the interconnectivity of automated components. See Figure 1 for an example in which there is interconnectivity between a pump (P-4-3) and a solenoid valve (FV-4-3) for controlling seal water to the mechanical seals on the pump. To conserve water, the seal water should only flow when the pump is operating. The wiring from the motor starter (MS) to the solenoid (S) allows for the automated control of the seal water.

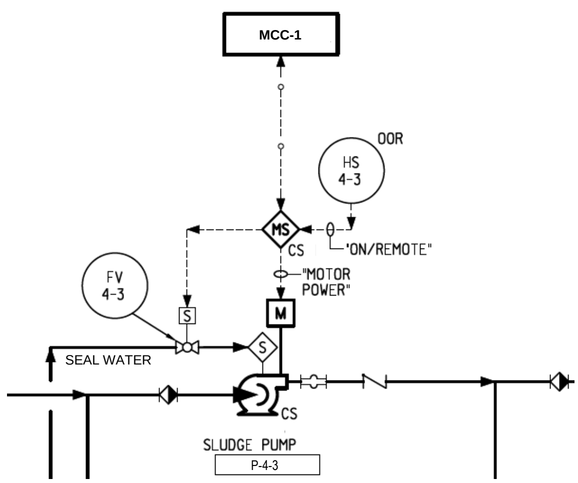


Figure 1: Example P&ID for a pump and a valve.

For Figure 1, the control description is as follows:

Valve FV-4-3 shall <u>open</u> when pump P-4-3 turns <u>on</u>.
Valve FV-4-3 shall <u>close</u> when pump P-4-3 turns <u>off</u>.

Piping and Instrumentation Diagrams

P&IDs are helpful for the following reasons, organized by project phase:

- Design:
  - Helps coordinate instrumentation, controls, and wiring details between process engineers, controls engineers, and electrical engineers.
  - Helps to create detailed control descriptions and control loops.
  - Used to develop Hazard and Operability Studies (HAZOP).
- Procurement:
  - Specifies instrumentation and controls details needed for obtaining quotes.
  - Provides control details needed for estimating programming costs.
- Construction:
  - Specifies details needed for purchasing and installing instruments, electrical devices, and controls components.
  - Provides details needed for the programming of controllers.
  - Helps confirm that communication wires have been terminated correctly.
  - Field changes can be easily recorded on as-built drawings.
  - Utilized during startup and training to understand the function of the system or process.
- Operation:
  - As-built P&IDs provide control details needed for making operation decisions.
  - P&ID format is easy to understand compared to programing code or written descriptions.
  - Operators can read the P&IDs and understand operations options.
  - Helpful for a Job Hazard Analysis (JHA).
  - Helps when preparing for system modifications as part of Management of Change (MOC).

Piping and Instrumentation Diagrams

Typical steps to create a P&ID are as follows:

1. Block flow diagram is created.
2. Process flow diagram (PFD) is created.
3. High-level control descriptions are written.
4. Draft P&IDs are created using process flow diagrams as backgrounds.
5. Areas are drawn at the top of P&IDs for controllers, MCCs (motor control centers), and/or SCADA (supervisory control and data acquisition).
6. Symbols and labels are added to P&IDs for control features.
7. Wiring is drawn on P&IDs to connect electrical devices with controllers, MCCs, and/or SCADA.
8. Detailed control descriptions are completed.
9. Control loops are defined, typically in a table format.
10. Identification numbers on P&IDs are matched with control descriptions and control loops.
11. Quality review performed and corrections made.

Other Types of Diagrams

Piping and Instrumentation Diagrams are also called *Process* and Instrumentation Diagrams since the focus is more on the process than the piping. Both are referred to as P&IDs. P&IDs are related to the following other types of engineering diagrams.

Block Flow Diagram
In the planning stage or early in design, a block flow diagram is commonly made by a process engineer. Block flow diagrams show the main processes as rectangles or circles with lines and arrows for the main flow paths. See Figure 2 for an example of a block flow diagram for a water treatment system.

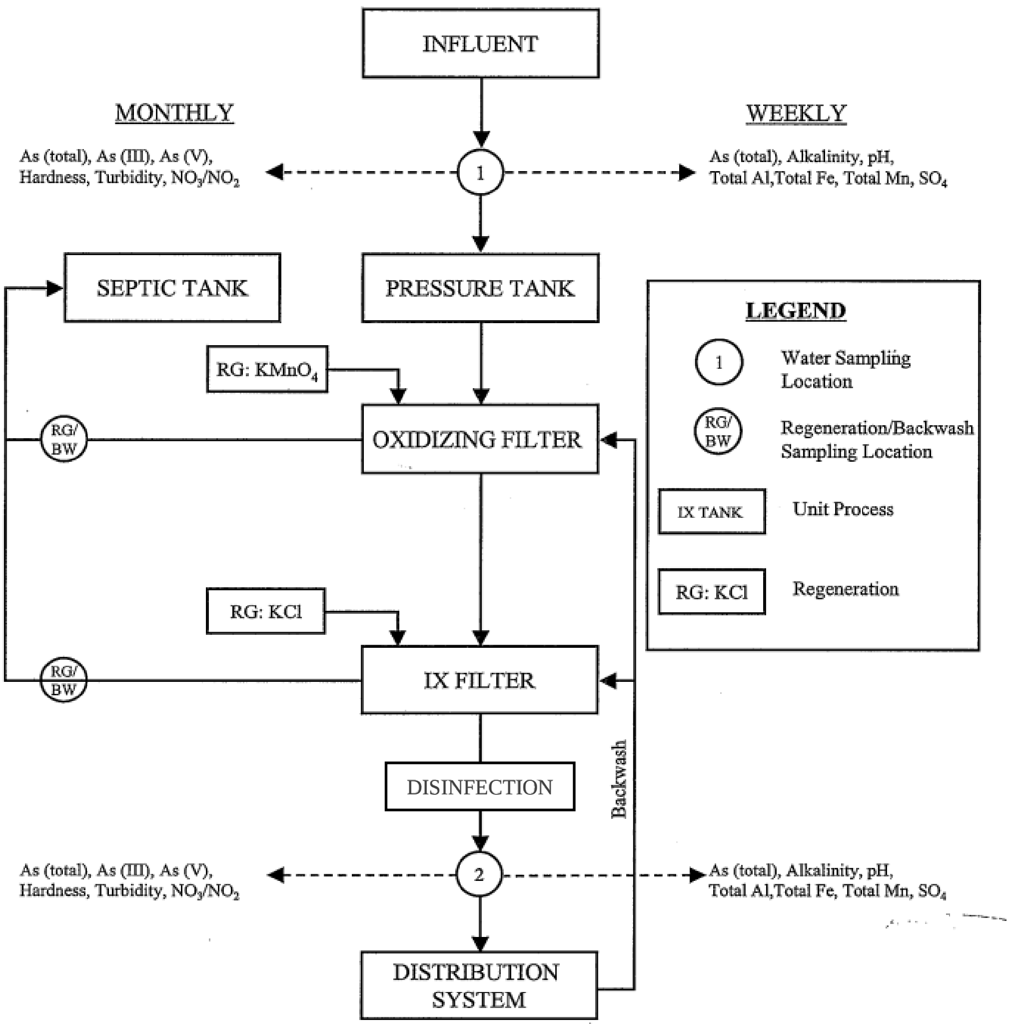


Figure 2: Example of a block flow diagram

Source: “Arsenic Removal from Drinking Water by Ion Exchange and Activated Alumina Plants”, EPA 600/R-00/088

Process Flow Diagram

Process flow diagrams (PFDs) are created by process or mechanical engineers early in the design stage. A PFD is a drawing with lines for piping and symbols for major components such as pumps, tanks, mixers, and flow meters. Ideally, all major components should be identified, including instrumentation. See Figures 3 and 4 for examples.

PFDs are often given to electrical and controls engineers to create P&IDs. PFDs are often used as the background in CAD for creating the P&IDs. Control and communication details are added to the PFD backgrounds to make P&IDs.

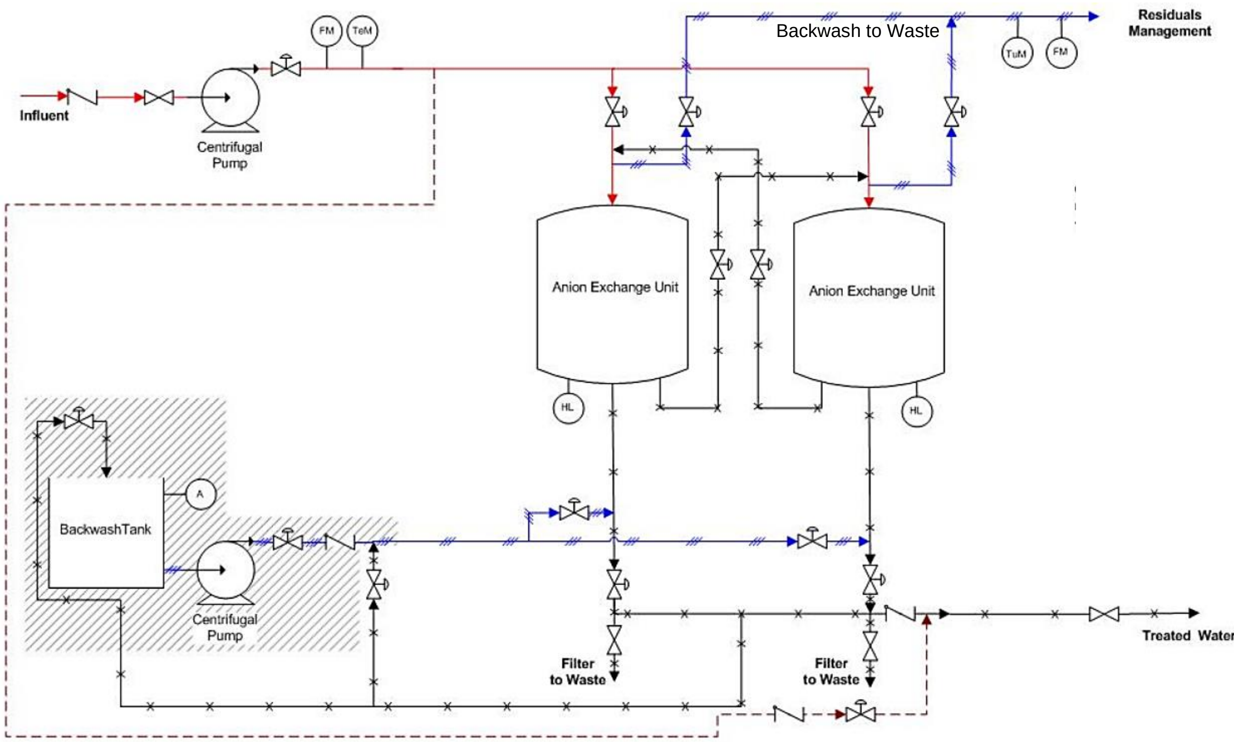


Figure 3: Example PFD with basic features. This drawing could be a starting point for creating a P&ID with control and communication details.

Source: www.epa.gov/sites/default/files/2019-07/documents/wbs-ixclo4-documentation-june-2019.pdf (public domain)

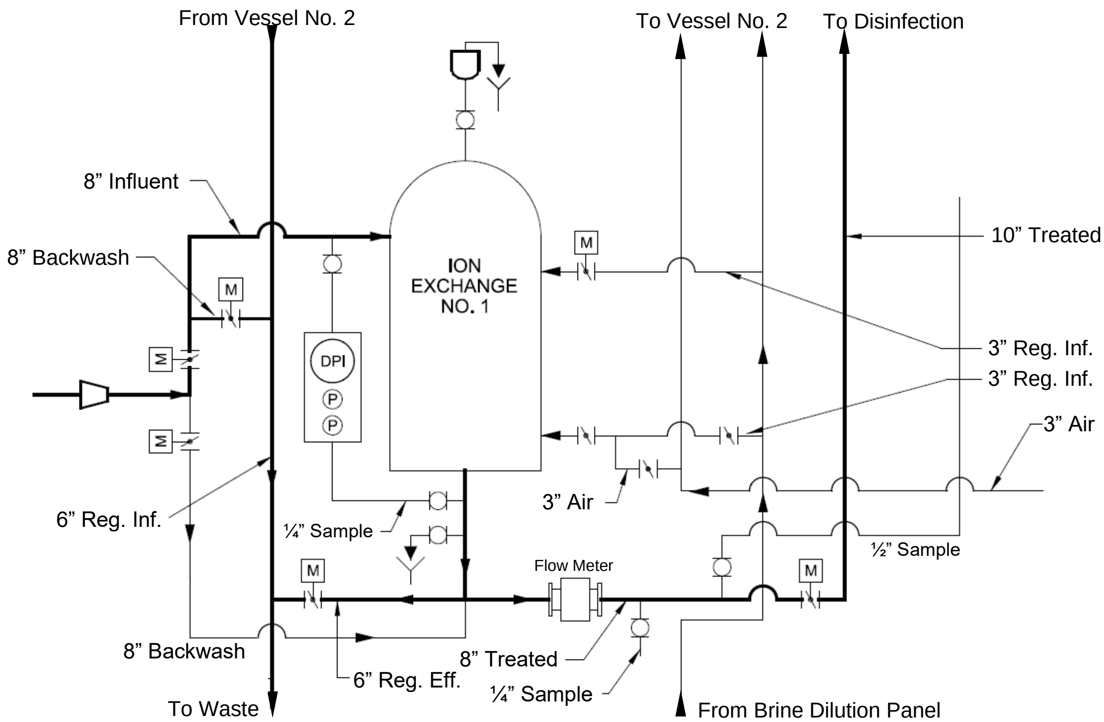


Figure 4: Example PFD with details such as pipe size, fluid type and motorized/automated valves shown with an "M" in a box.

It is common for a legend drawing to be included with a drawing set to define the symbols, abbreviations, line types, shading, etc., utilized on the PFDs and P&IDs. Sometimes there are common legend drawings and sometimes there are separate legend drawings for PFDs and P&IDs.

Instrument Schematic

Instrument schematics (or diagrams) are detailed drawings for particular instruments. They show wiring details with some control logic notes that pertain only to that instrument. See Figure 5 for an example. Instrument schematics differ from a P&ID which shows the interconnectivity of various instruments, equipment, and panels.

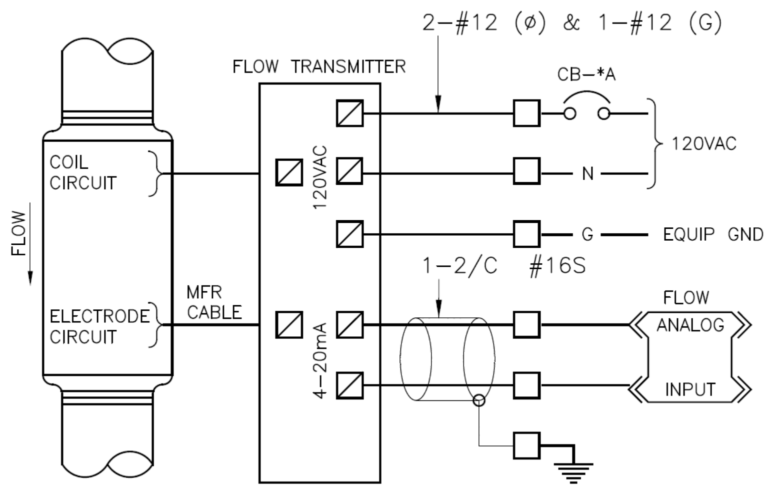


Figure 5: Example instrument schematic for a flow meter.

Wiring Diagram
A wiring diagram shows circuit components as simplified shapes with power and signal wiring between the devices, terminal blocks, and input/output (I/O) cards. See Figure 6 for an example. This differs from P&IDs which show pipes and the relative locations of instruments and equipment.

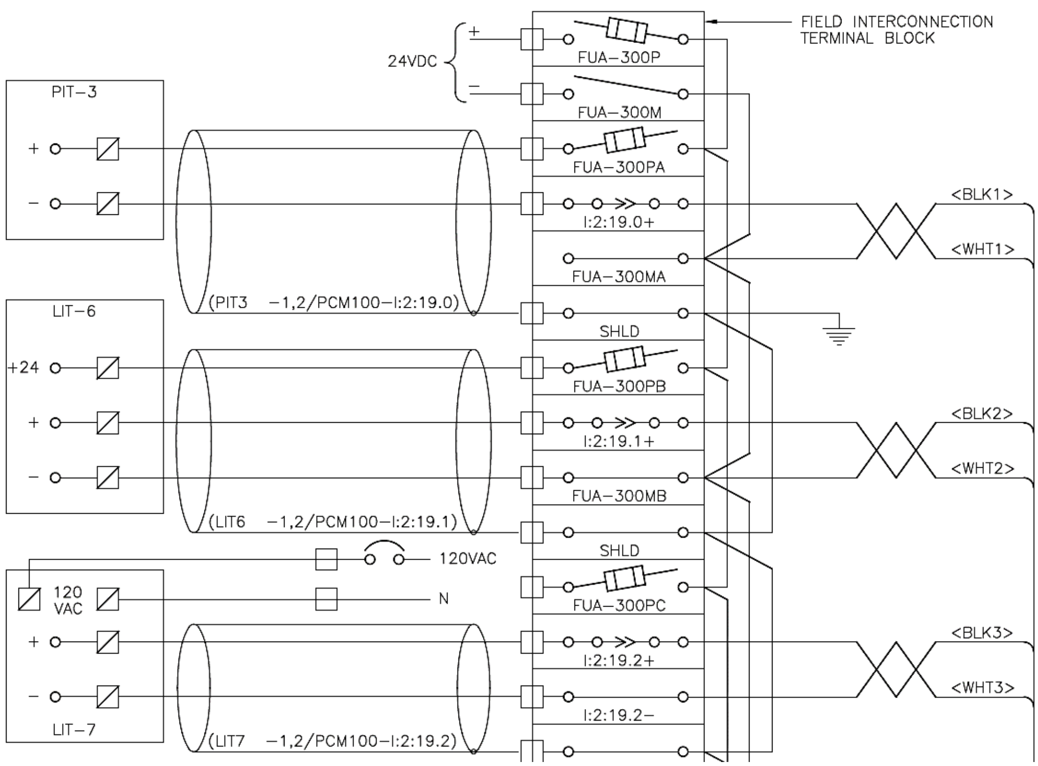


Figure 6: Example wiring diagram for a pressure transmitter (PIT-3),
a 24-volt level transmitter (LIT-6), and a 120-volt level transmitter (LIT-7).

SCADA Network Diagram

A SCADA (supervisory control and data acquisition) network diagram, also called a SCADA architecture diagram, is a block diagram showing the basic SCADA architecture and communication channels between devices, controllers, and computers. This differs from a P&ID because it lacks the locations of instruments on the piping network and it does not indicate control details. See Figure 7 for an example.

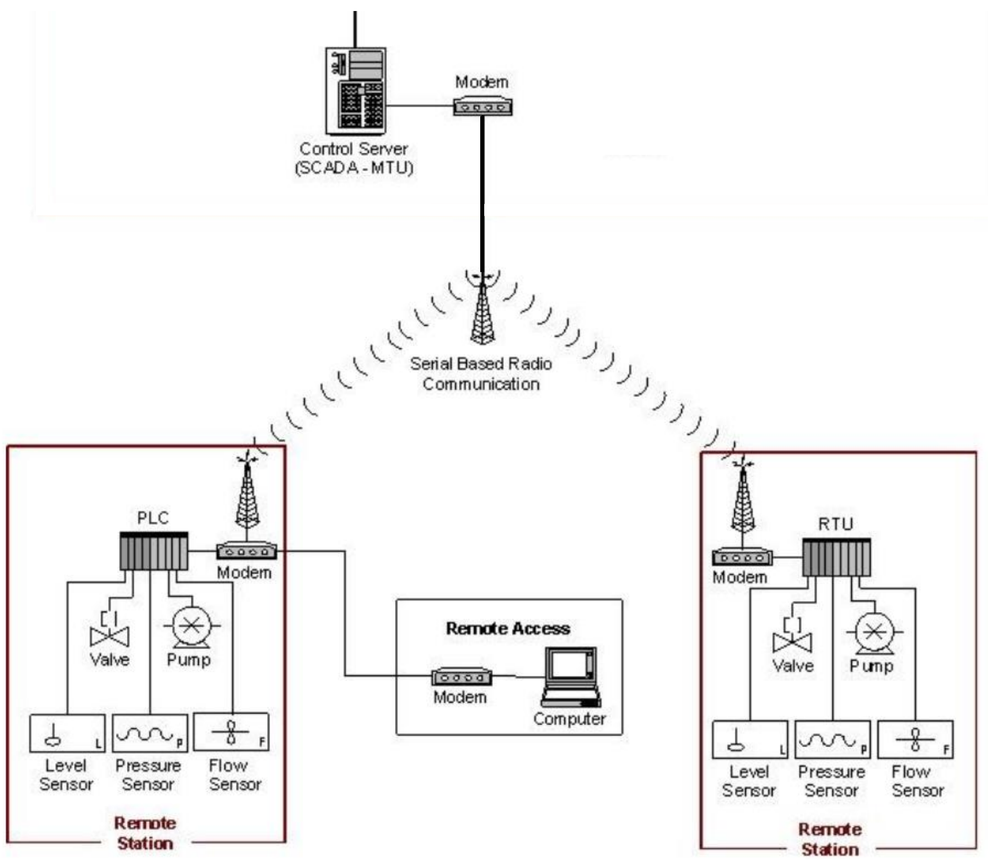


Figure 7: Example SCADA Network Diagram.

Source: https://nvlpubs.nist.gov/nistpubs/specialpublications/nist.sp.800-82r2.pdf

Logic Diagram

Types of logic diagrams included ladder logic diagrams, binary logic diagrams, and Boolean logic diagrams (also called relay logic diagrams). See Figures 8 and 9 for examples. Logic diagrams convey control descriptions pictorially. This differs from a P&ID because it does not show the location of instruments on the piping and does not show communications wiring.

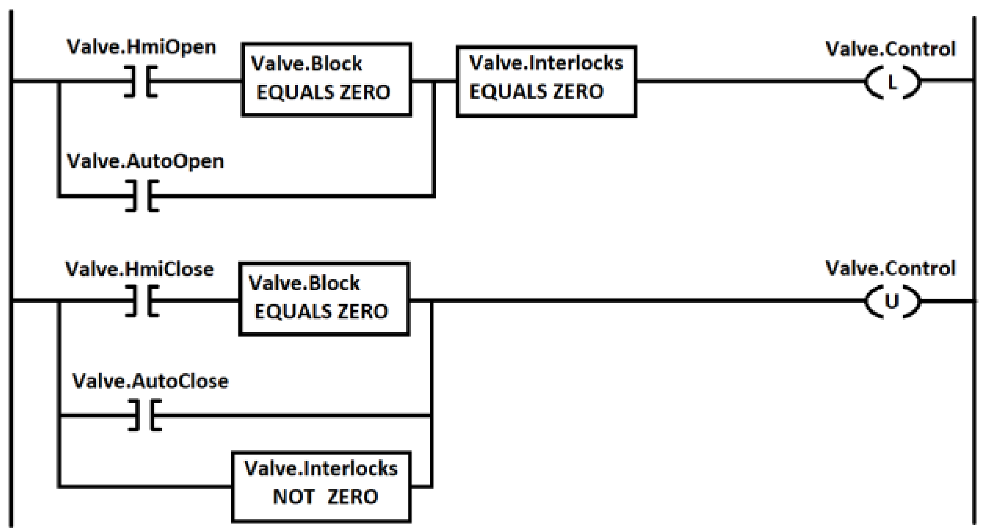


Figure 8: Example Ladder Logic Diagram

Source: https://www.osti.gov/servlets/purl/1468198

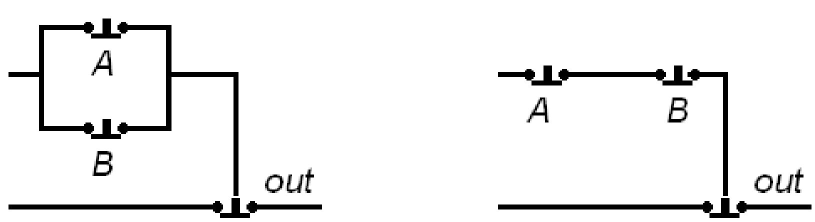


Figure 9: Boolean (or relay) logic diagrams showing alternate **A or B** (left), and alternate **A and B** (right).

https://commons.wikimedia.org/wiki/File:Switch_alternate_and_or.png, Copyright © Dysprosia

Industry Standards

There are numerous standards developed for creating P&IDs. The most common standard is ANSI/ISA 5.1 entitled “Instrumentation Symbols and Identification”. A summary of common standards is provided in Table 1.

Table 1: Summary of Standards for P&IDs

Standard No.	Title	Pages	Sector	Topics Covered
ANSI/ISA 5.1	Instrumentation Symbols and Identification	128	All	Identification Letters Table Graphic Symbols Symbol Dimensions
ISA 5.3	Graphic Symbols for Distributed Control / Shared Display Instrumentation, Logic and Computer Systems	79	Computer SCADA	Symbols Identification Alarms Computer Symbols and Logic
IEC 60617	Graphical Symbols for Diagrams	1900	All	Database of Symbols
ISO 10628	Diagrams for the Chemical and Petrochemical Industry	22	Chemical Petro	Letter Symbols
ISO 14617 Parts 1 to 15	Graphical Symbols for Diagrams	300	All	Functional Links Control Loops Processing Functions Logic Functions
ISO 15519 Parts 1 & 2	Specification for Diagrams for Process Industry	25	Process	Block Diagrams, PFDs, P&ID Layout Connecting Lines Inscription, Scale, Limits
PIP PIC001	Piping and Instrumentation Diagram Documentation Criteria	79	All	Industry Standards Equipment, Piping, Instrumentation, Controls
EN 62424	Representation of Process Control Engineering	175	All	P&ID Software and Controls Interfaces

It is common for companies to have their own library of standard symbols and abbreviations. These unique libraries typically include many symbols from reference standards, but also have unique symbols and abbreviations based on the unique systems being designed.

Letter Designations

P&IDs are busy drawings without a lot of space for lengthy descriptions and specifications. Therefore, letter abbreviations (called letter designations) are used for device labels, control loops, and device functions. See Figure 10 for an example of a P&ID with the letter designations defined in a legend.

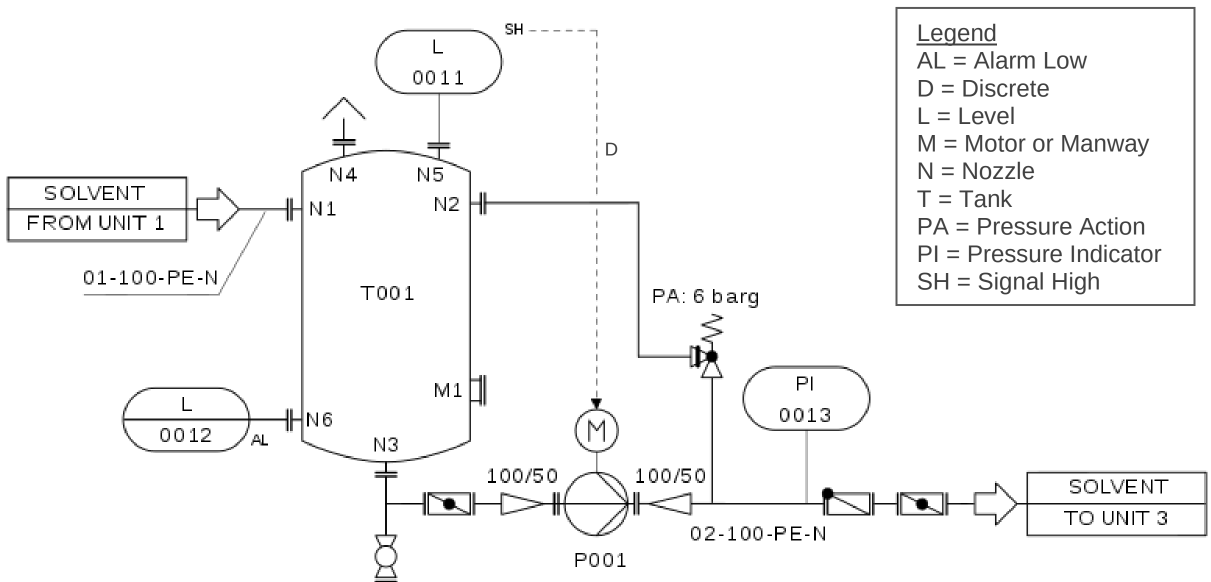


Figure 10: Example P&ID with a legend defining letter designations. The level sensor 0011 sends a discrete signal to start pump P001 when a high level is reached.

Source: https://commons.wikimedia.org/wiki/File:Pump_with_tank_pid_en.svg, modified, Con-struct, CC-BY-SA-3.0

In Figure 10, “M” could mean Motor or Manway. Based on the context, the M1 on the side of the tank is the Manway, and the M in the circle is a Motor for a pump. It is up to the design engineer to make sure any letters used for multiple designations are sufficiently clear on the drawings. Notes can be added to clarify any unclear letter designations.

It is common to utilize a table format for identifying the letter designations for instrument functions (the two or three letters shown inside circles). Table 2 provides the letter designations per ISA 5.1. Many companies develop a standard letter designation table based on common usage. This table can be included with the symbol definitions on a common legend drawing for the P&IDs.

Piping and Instrumentation Diagrams

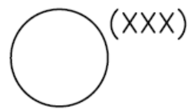
Table 2: Common Letter Designations in P&IDs for Instrument Functions					
Letter	First Letter		Additional Letter(s)		
	Measured Value	Modifier	Readout or Passive Function	Output or Active Function	Function Modifier
A	Analysis		Alarm		
B	Burner, combustion		User choice	User choice	User choice
C	User's choice (usually conductivity)			Control	Close
D	User's choice (usually density)	Difference, Differential			Deviation
E	Voltage		Sensor		
F	Flow rate	Ratio			
G	User's choice (usually gauging)	Gas	Glass/gauge		
H	Hand				High
I	Current	Interlock	Indicate		
J	Power	Scan			
K	Time, time schedule	Time rate of change		Control station	
L	Level		Light		Low
M	User's choice				Middle / intermediate
N	User's choice (usually torque)		User choice	User choice	User choice
O	User's choice		Orifice		Open
P	Pressure		Point/test connection		
Q	Quantity	Totalize/integrate	Totalize/integrate		
R	Radiation		Record		Run
S	Speed, frequency	Safety		Switch	Stop
T	Temperature			Transmit	
U	Multivariable		Multifunction	Multifunction	
V	Vibration, mech. analysis			Valve or damper	
W	Weight, force		Well or probe		
X	User's choice (on-off valve as XV)	X-axis	Accessory devices	Unclassified	Unclassified
Y	Event, state, presence, status	Y-axis		Auxiliary devices	
Z	Position, dimension	Z-axis or Safety Instrumented System		Actuator, driver, or control element	

For additional clarity, instrument tag abbreviations can be defined as shown in Figure 11. The first letter is from the row (measured variable) and subsequent letters are from the columns (instrument function). For example, LS means “Level Switch” in Figure 11, while LS could mean “Level Switch” or “Level Stop” in Table 2.

	MEASURED VARIABLE \ INSTRUMENT FUNCTION	ELEMENT	TRANSMITTER	INDICATING TRANSMITTER	CONVERTER TRANSDUCER, RELAY SPECIAL DEVICES	INDICATOR	RECORDER	CONTROLLER	SWITCH	LIGHT	ALARM
A	ANALYSIS	AE	AT	AIT	AY	AI	AR	AC	AS	AL	AA
B	BURNER FLAME	BE	BT	BIT	BY	BI	BR	BC	BS	BL	BA
C	CONDUCTIVITY	CE	CT	CIT	CY	CI	CR	CC	CS	CL	CA
D	DENSITY	DE	DT	DIT	DY	DI	DR	DC	DS	DL	DA
E											
F	FLOW	FE	FT	FIT	FY	FI	FR	FC	FS	FL	FA
FF	FLOW RATIO				FFY	FFI		FFC	FFS	FFL	
G											
H	HAND (MANUAL)							HC	HS	HL	
I	CURRENT		IT	IIT	IY	II	IR	IC	IS	IL	IA
J											
K	TIME				KY	KI	KR	KC	KS	KL	KA
L	LEVEL	LE	LT	LIT	LY	LI	LR	LC	LS	LL	LA
M	MOISTURE OR HUMIDITY	ME	MT	MIT	MY	MI	MR	MC	MS	ML	MA
N											
O											
P	PRESSURE OR VACUUM	PE	PT	PIT	PY	PI	PR	PC	PS	PL	PA
PD	DIFFERENTIAL PRESSURE		PDT	PDIT	PDY	PDI	PDR	PDC	PDS	PDL	PDA
Q	QUANTITY	QE	QT	QIT	QY	QI	QR		QS		QA
R											
S	SPEED	SE	ST	SIT	SY	SI	SR	SC	SS		SA
T	TEMPERATURE	TE	TT	TIT	TY	TI	TR	TC	TS	TL	TA
TD	DIFFERENTIAL TEMPERATURE		TDT	TDIT	TDY	TDI	TDR	TDC	TDS	TDL	TDA
U	MULTIVARIABLE					UI	UR	UC	US	UL	
V	VISCOSITY	VE	VT	VIT	VY	VI	VR	VC	VS	VL	VA
W	WEIGHT	WE	WT	WIT	WY	WI	WR		WS		WA
X	UNCLASSIFIED	XE	XT	XIT	XY	XI	XR	XC	XS	XL	XA
XV	VIBRATION	XVE	XVT		XVY	XVI	XVR		XVS	XVL	XVA
Y	STATUS					YI				YL	
Z	POSITION	ZE	ZT	ZIT	ZY	ZI			ZS	ZL	

Figure 11: Example Instrument Tag Abbreviations Table from a P&ID legend drawing.

Instrument control abbreviations are shown to the upper right of instrument tags. These can also be defined in a P&ID legend, as shown in Figure 12.



AHC	AUTO/HOLD/CLOSE	OSC	OPEN/STOP/CLOSED
A/M	AUTO/MANUAL		
DEV	DEVIATION	P/P	PUSH/PULL
HOA	HAND/OFF/AUTO	RL	RAISE/LOWER
HOR	HAND/OFF/REMOTE	RSL	RAISE/STOP/LOWER
L/R	LOCAL/REMOTE	S/D	SHUTDOWN
L/O/R	LOCAL/OFF/REMOTE	SEL	SELECT
MOA	MANUAL/OFF/AUTO	S/LOS	START/LOCKOUT STOP
O/O	ON/OFF	SP	SET POINT
OCA	OPEN/CLOSE/AUTO	SR	START/RESET
O/C	OPEN/CLOSE	S/S	STOP/START

Figure 12: Example abbreviations for instrument control functions. These letter designations are commonly placed to the upper right of instrument tag circles, where the (XXX) is shown.

The simplest control device is the O/O (On/Off) switch, as shown in Figure 13.

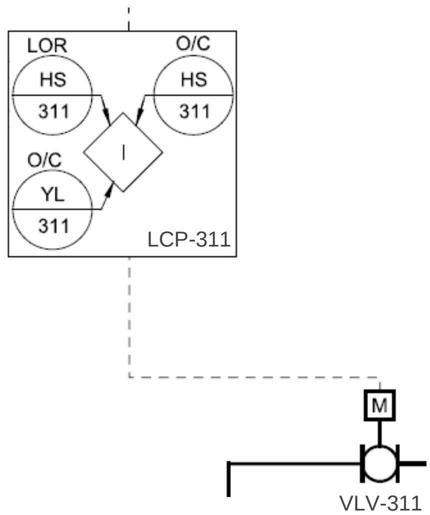
Figure 13: O/O hand switch (HS) on a control panel, with On and Off functions.

HOA stands for Hand/Off/Auto, which is common for a switch that controls equipment with a motor. See Figure 14 for an example of an HOA selector switch. This is similar to HOR (Hand/Off/Remote) in which the device can be controlled remotely (either automatically or by a remote user through a control panel or HMI (Human-Machine Interface) software.

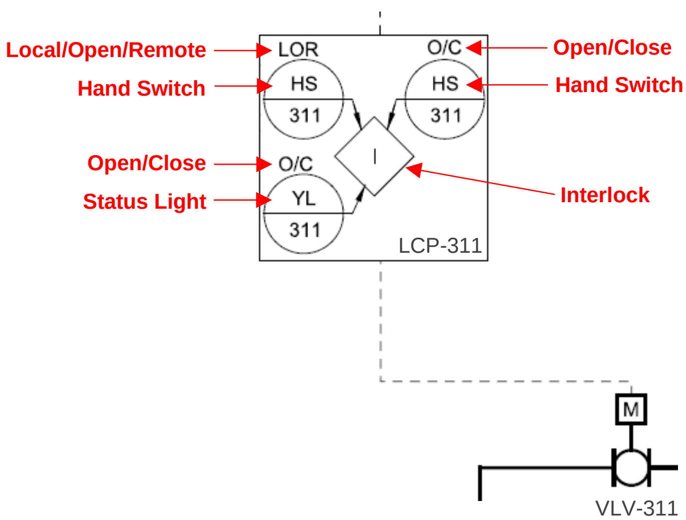
Figure 14: Selector/hand switch with HOA functions:
1) HAND means the device will be on with no automated controls,
2) OFF means the device will be off with no automated controls, and
3) AUTO means the device will be turned on and off through automated controls.

Example Problem 1

Engineer Phelix is reading a P&ID drawing to understand the functions available at the local control panel (LCP) for ball valve VLV-311, as shown below. Help Phelix by writing out the letter designations based on Figures 11 and 12.



Solution:
Letter designations have been spelled out in red in the below diagram.



Note that the “I” could mean Current or Interlock. Based on the context of being in a local control panel with switches, the term interlock is a better fit. An interlock is an electrical device for connecting the function of different components. For example, when the hand switch is set to “Open”, electrical power is sent to the valve motor via an interlock.

Symbols

P&IDs are full of symbols. See Figures 15 to 17 for example P&IDs with various symbols.

Common items that have symbols on a P&ID include:

- Instruments (flow, level, pressure, temperature, weight, pH, chlorine, etc.)
- Control functions (field, panel front, panel rear, SCADA, etc.)
- Interfaces to and from external processes (large arrows are common)
- Valves
- Actuators
- Motors
- Pumps
- Fans, Blowers, and Compressors
- Miscellaneous devices (tanks, mixers, strainer, gate, injection, seal water, etc.)
- Communications wiring (discrete, analog, ethernet, fiber optic, etc.)

These symbols should be defined on a legend drawing.

Figures 18a and 18b show common P&ID symbols for piping, valves, and equipment, per ISO 10628 and ISO 14617.

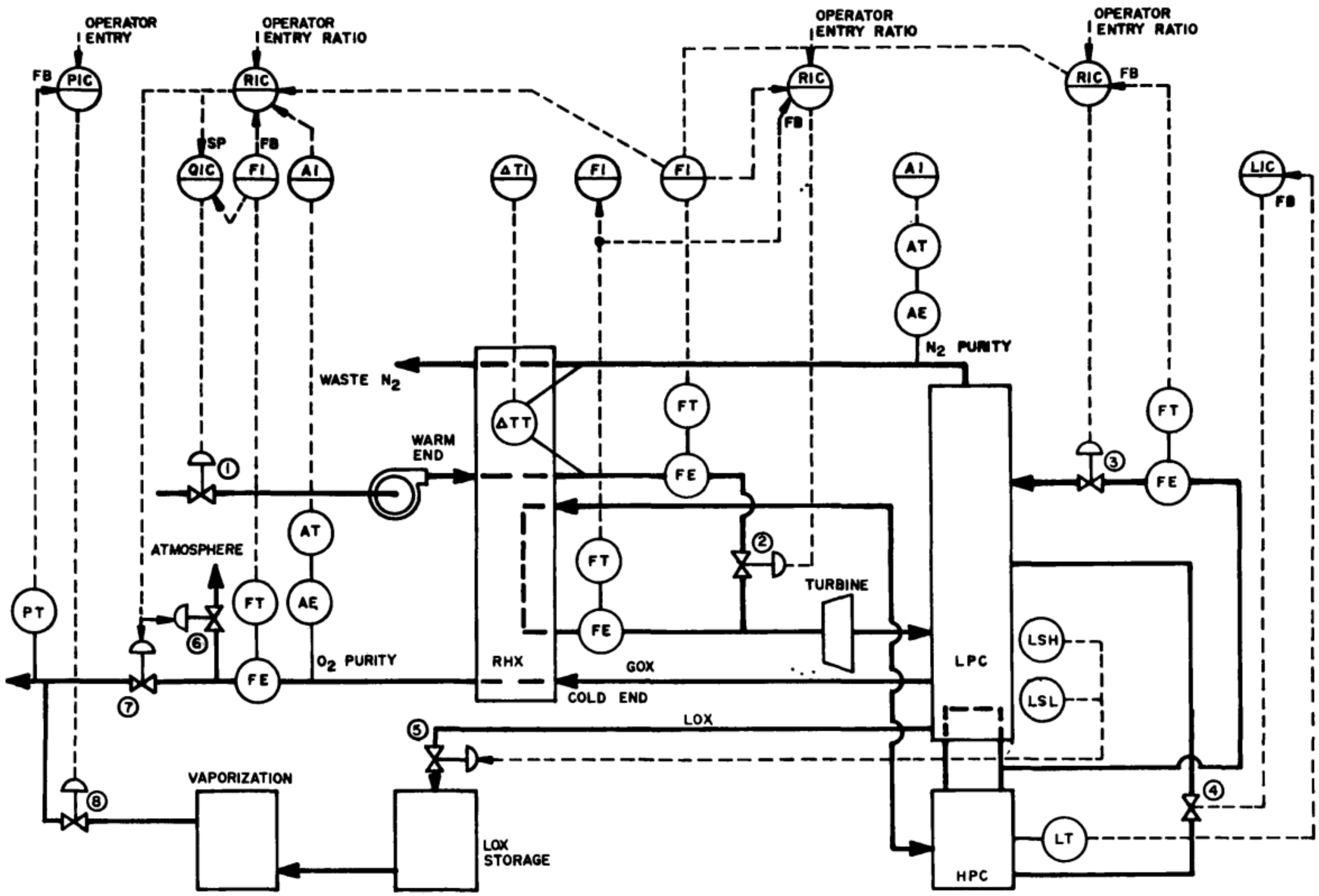


Figure 15: Example P&ID for cryogenic oxygen generation.

Source: EPA-600/8-80-028 (Public Domain)

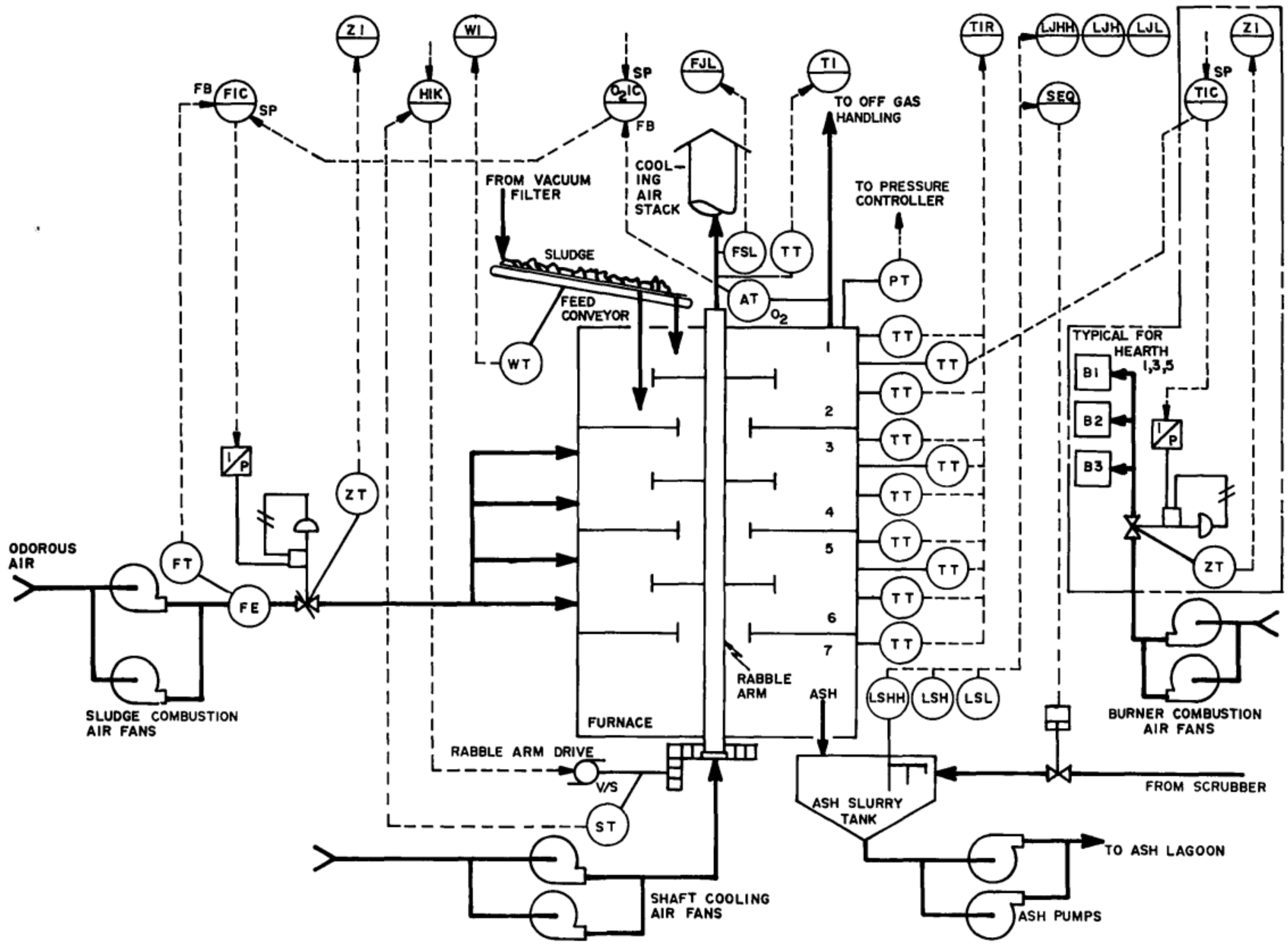


Figure 16: Example P&ID for an incinerator.

Source: EPA-600/8-80-028 (Public Domain)

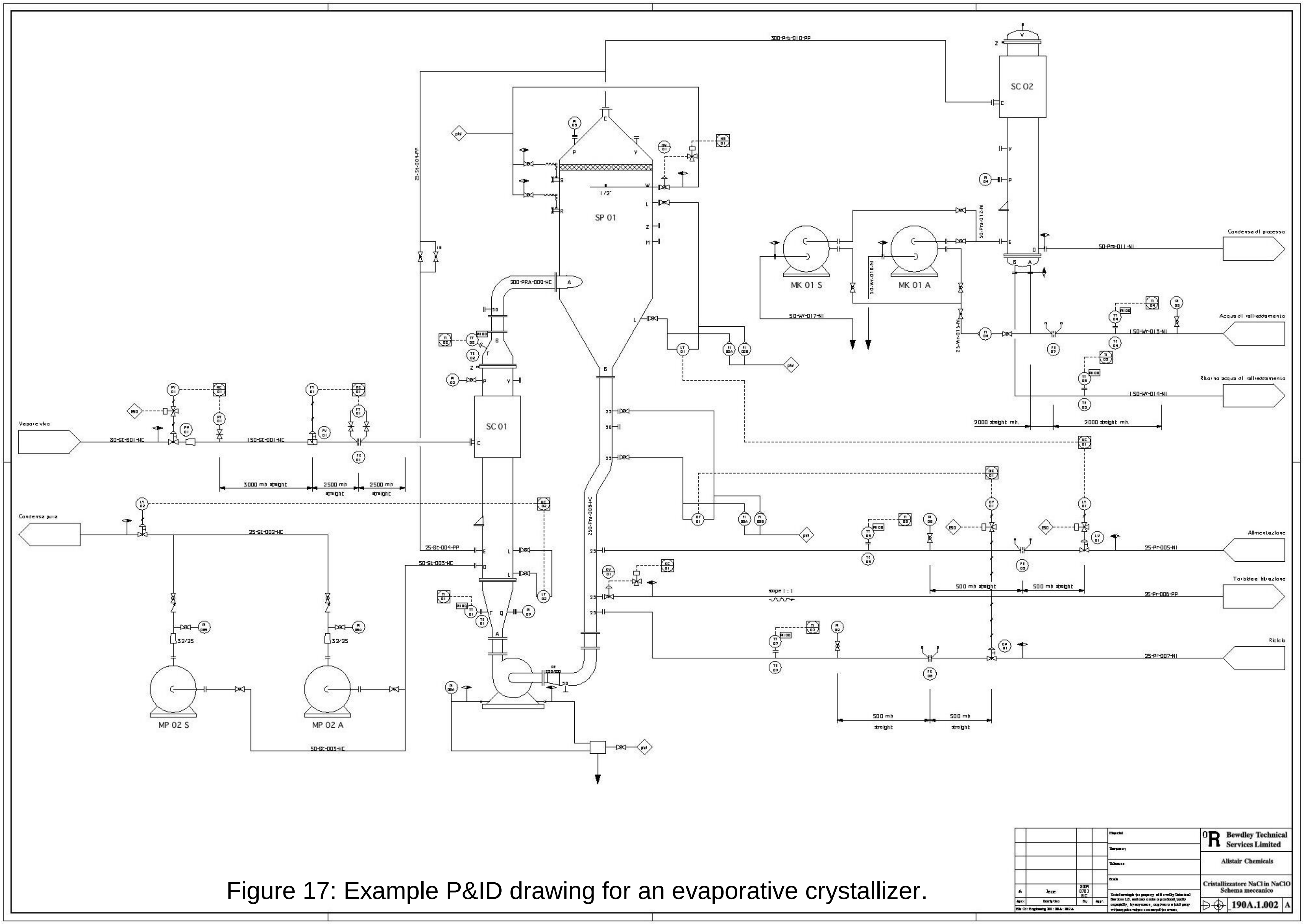


Figure 17: Example P&ID drawing for an evaporative crystallizer.

Piping and Instrumentation Diagrams

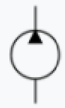
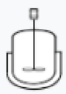
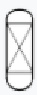
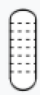
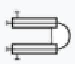
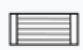
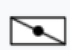
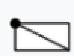
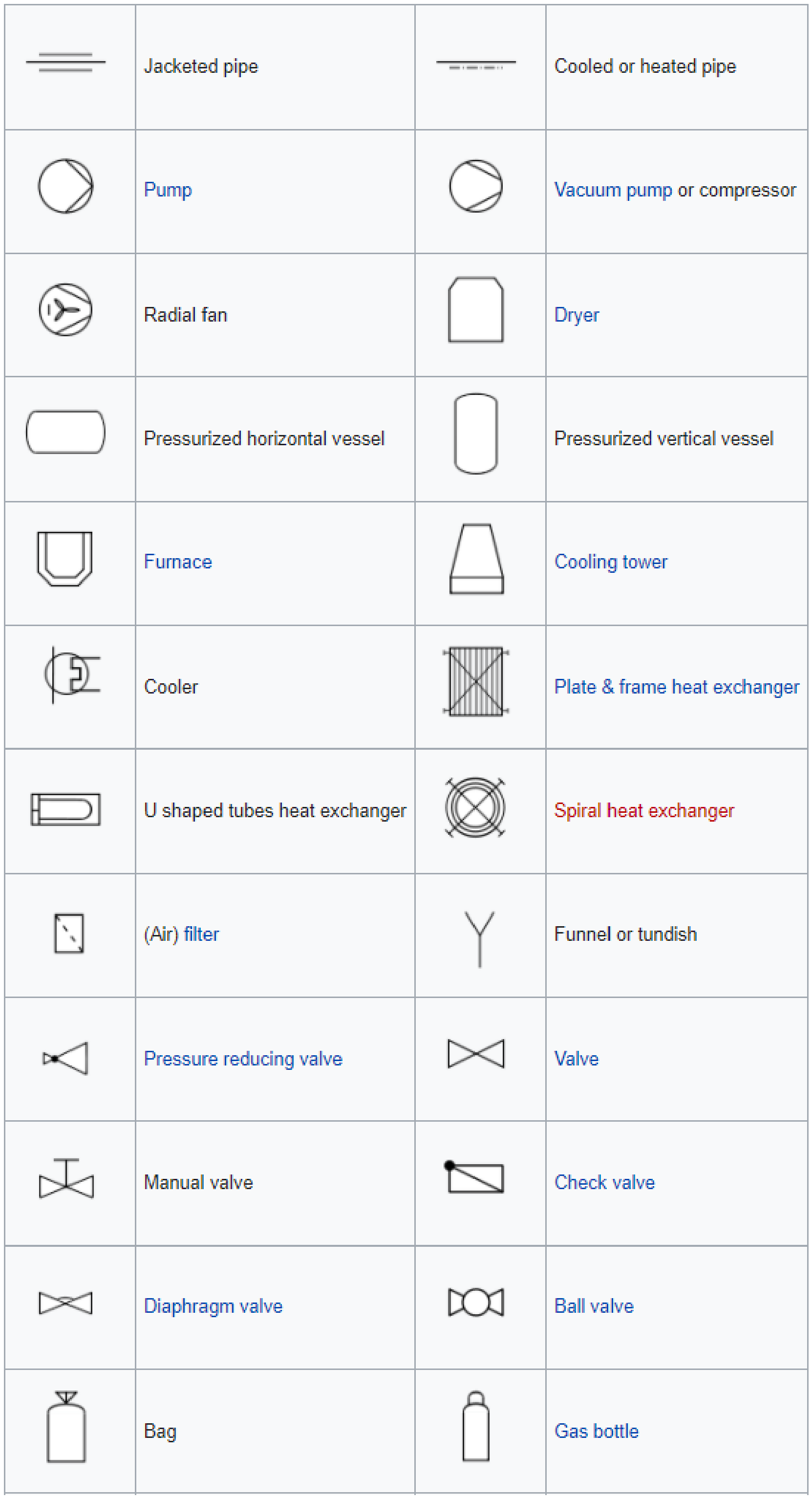
	Pipe		Thermally insulated pipe
	Flexible connection		Hydraulic pump
	Fan		Axial fan, MK,
	Jacketed mixing vessel (autoclave)		Half pipe mixing vessel
	Packed column		Plate column
	Heat exchanger		Coil heat exchanger
	Double pipe heat exchanger		Fixed straight tubes heat exchanger
	Covered gas vent		Curved gas vent
	Steam trap		Viewing glass
	Gate valve		Control valve
	Needle valve		Butterfly valve
	Check valve		Back draft damper

Figure 18a: Common P&ID symbols.

Piping and Instrumentation Diagrams



	Jacketed pipe		Cooled or heated pipe
	Pump		Vacuum pump or compressor
	Radial fan		Dryer
	Pressurized horizontal vessel		Pressurized vertical vessel
	Furnace		Cooling tower
	Cooler		Plate & frame heat exchanger
	U shaped tubes heat exchanger		Spiral heat exchanger
	(Air) filter		Funnel or tundish
	Pressure reducing valve		Valve
	Manual valve		Check valve
	Diaphragm valve		Ball valve
	Bag		Gas bottle

Figure 18b: Common P&ID symbols.

Figure 19 shows typical symbols for the location and function of instruments and control devices. For example, a switch may be accessible at the instrument, on the front of the panel next to the instrument, inside the locked panel, or remotely (auxiliary location) at a different panel, MCC, or through SCADA. Defining these details on the P&ID helps ensure the system is constructed as intended during design.

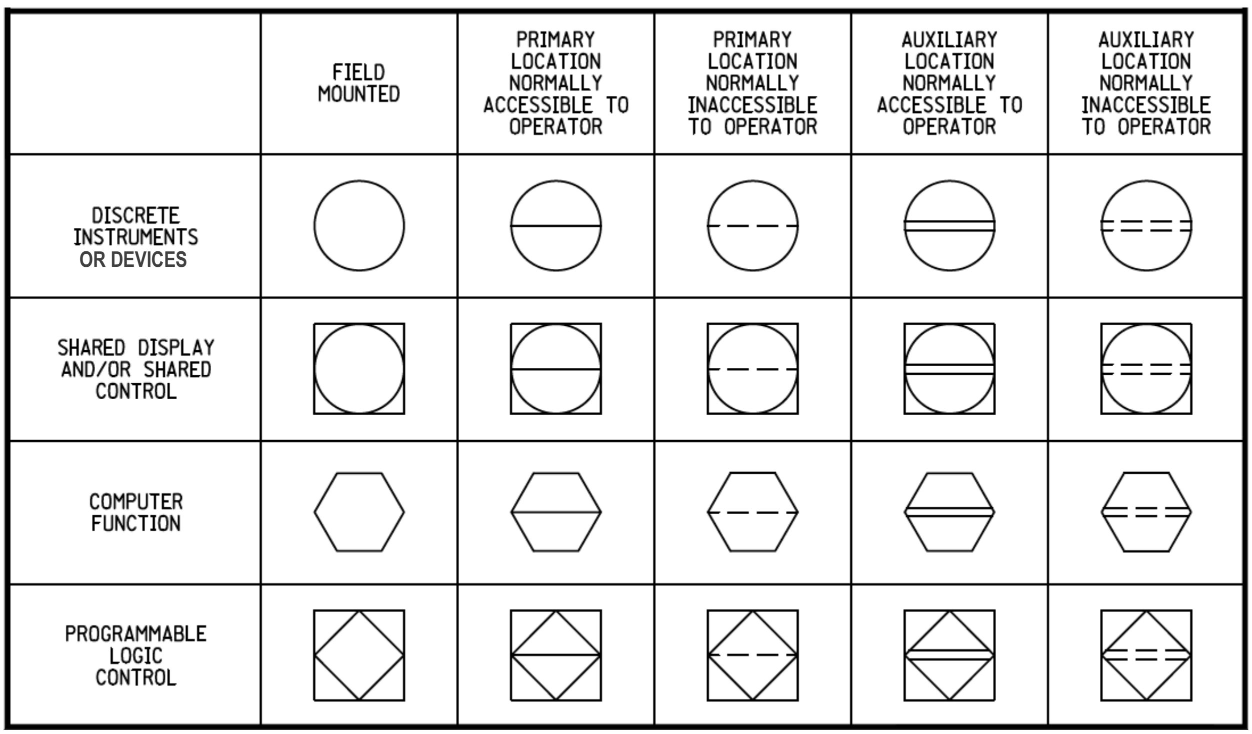
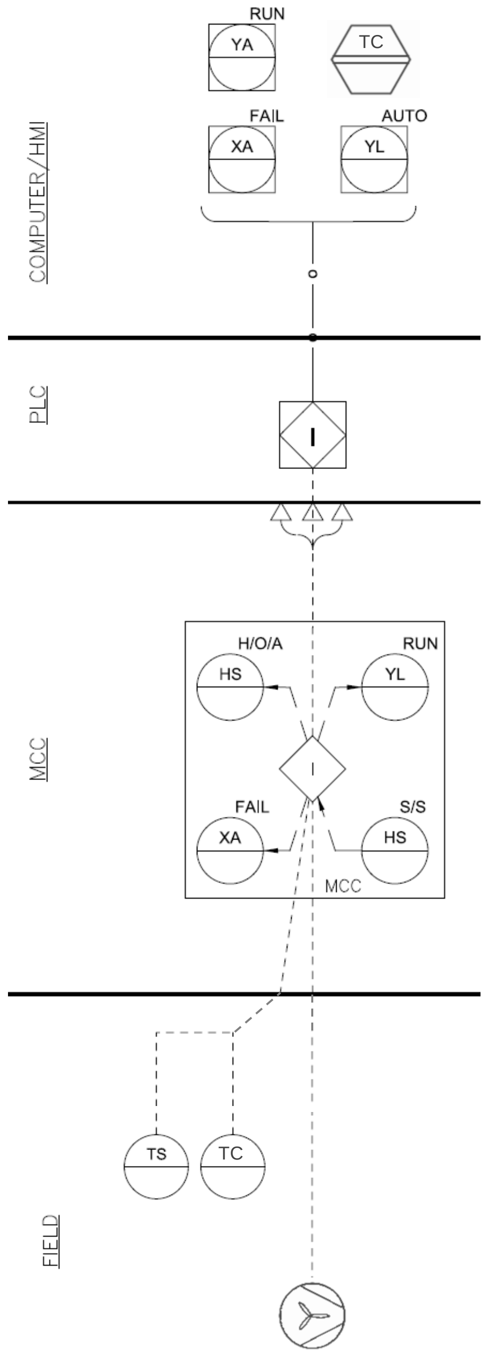


Figure 19: Typical symbols for indicating the location and function of instruments and control devices. Primary location often means at a control panel. Auxiliary location often means in an electrical room, remote/offsite location, or SCADA.

Example Problem 2

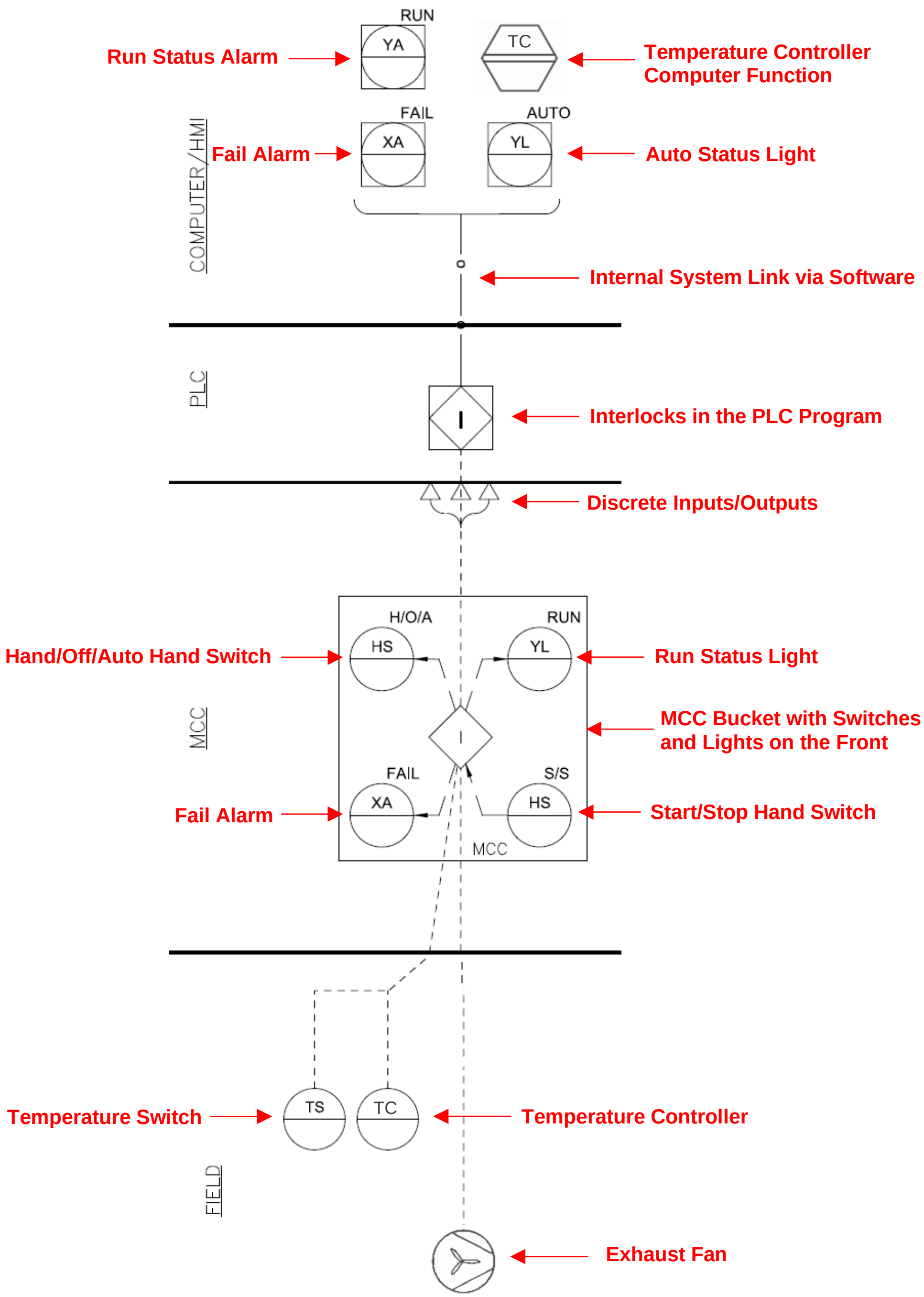
Engineer Nels is struggling to understand the P&ID shown on the right, with are control features for an exhaust fan. Help Nels by describing the symbols and abbreviations.



Piping and Instrumentation Diagrams

Solution:

The below P&ID has notes in red to help explain the symbols and abbreviations. All devices are normally accessible to operators since the symbols have solid horizontal lines in the middle (instead of dashed).



Control Loops

A control loop maintains a process condition at a set value by adjusting devices (i.e. pump speed, valve position, etc.) based on feedback from instruments (i.e. flow meters, level sensors, etc.). Control loops are described in written control descriptions and shown in P&IDs with communications paths/wiring and interlock notes.

For example, a common control loop to maintain flow through a pipe is by adjusting a valve position based on flow meter readings. See Figures 20, 21, and 22 for example flow control P&IDs and an explanation of the control loop.

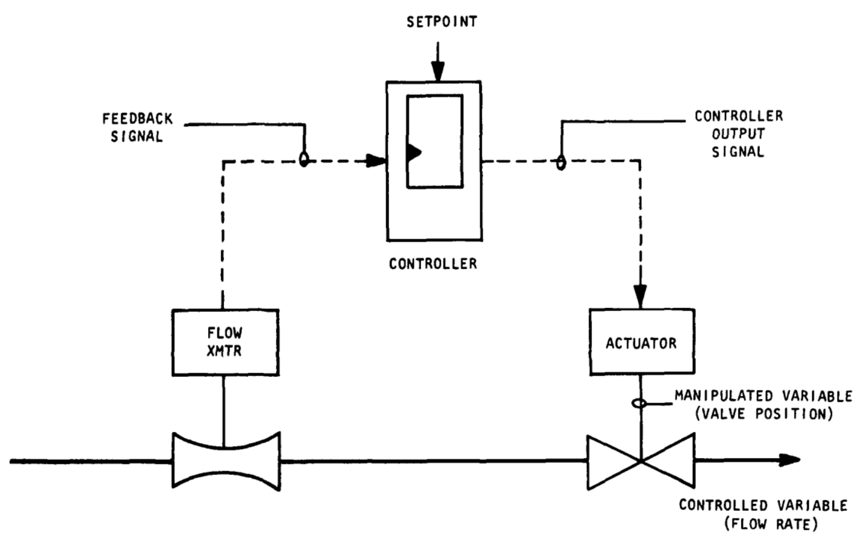
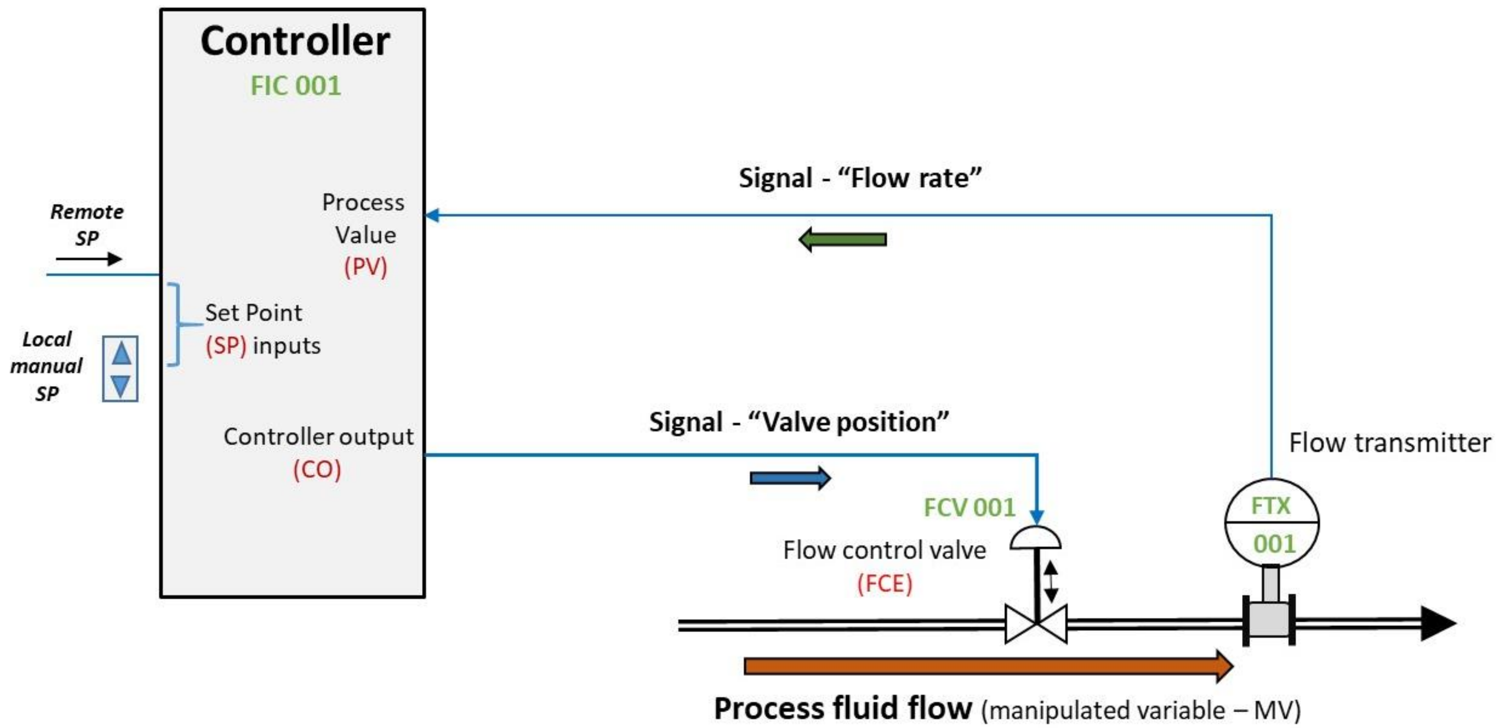


Figure 20: P&ID for a flow control loop. The flow meter is labeled “FLOW XMTR”. The controller can be a local control panel with a programable logic controller (PLC). The communications paths/wiring are the dashed lines labeled as signals.

Source: EPA-600/8-80-028 (Public Domain)



The basic building block of industrial process control systems is the "control loop" which contains all the elements to measure and control a process value at a desired setpoint. The controller may be a discrete piece of hardware, or a function within a large computerised DCS, SCADA or PLC system. Set points can be manually set locally or cascaded from another source.

An example is shown of a flow controller, with a flow transmitter and a control valve. The green text are "tags", which describe the function and identify the equipment. As each loop has a unique number the tags are unique within a plant to prevent confusion. In this case:
FIC = Flow indicating controller, FCV = Flow Control Valve, FTX = flow transmitter.

Standard practical control nomenclature is: SP = process set point, PV = process value, CO = controller output, FCE = final control element, MV = manipulated variable.

Figure 21: Control Loop Explanation

Source: https://commons.wikimedia.org/wiki/File:Industrial_control_loop.jpg, Dougsim, CC-BY-SA-4.0

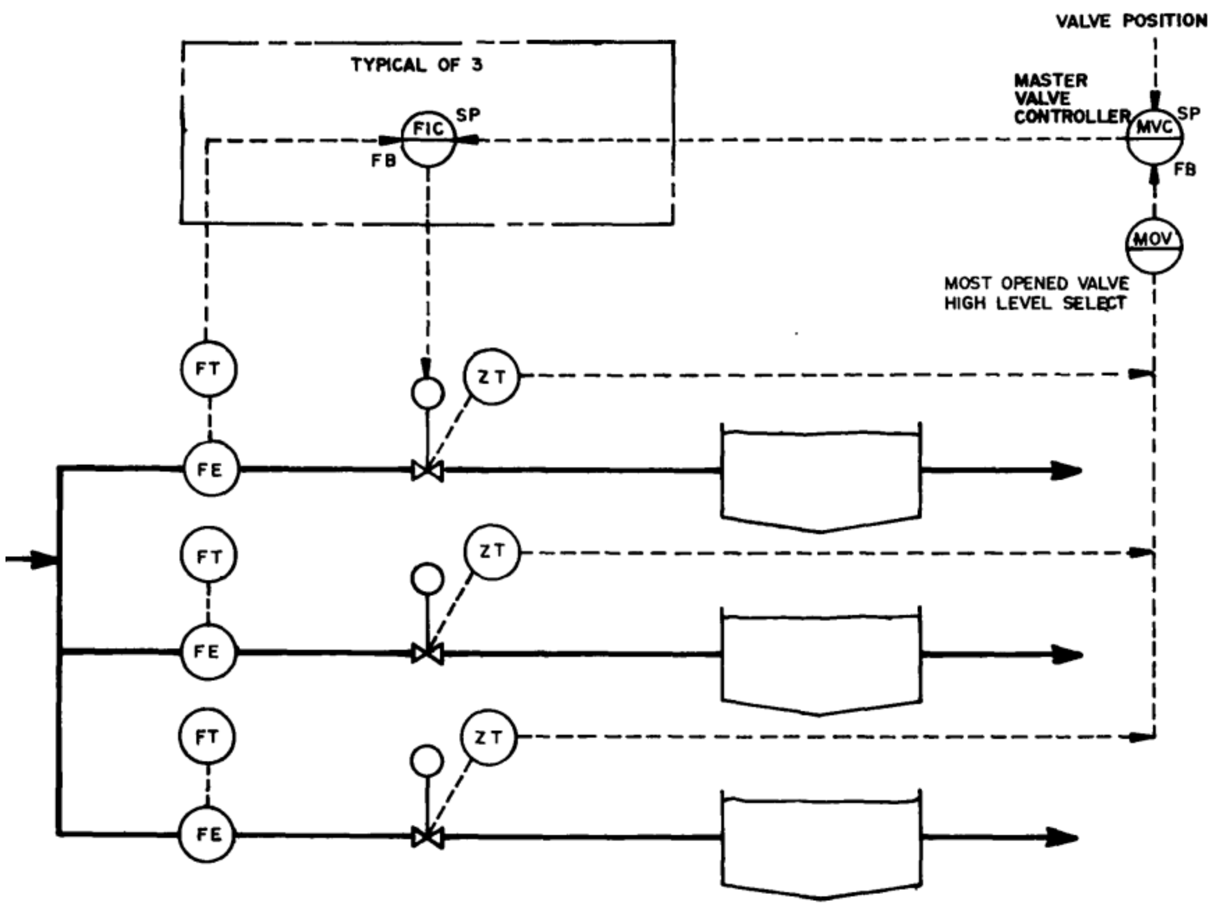


Figure 22: P&ID for a flow control loop to equally divide flow between three tanks. The controller (MVC) receives flow rates from each flow meter (FE & FT) and sends commands to adjust the valve positions. Valve position transmitters (ZT) send current valve position signals back to the controller to help decide which valves to open and close to maintain equal flow with minimal headloss.

Source: EPA-600/8-80-028 (Public Domain)

Additional control loops are shown and explained in Figures 23 to 32.

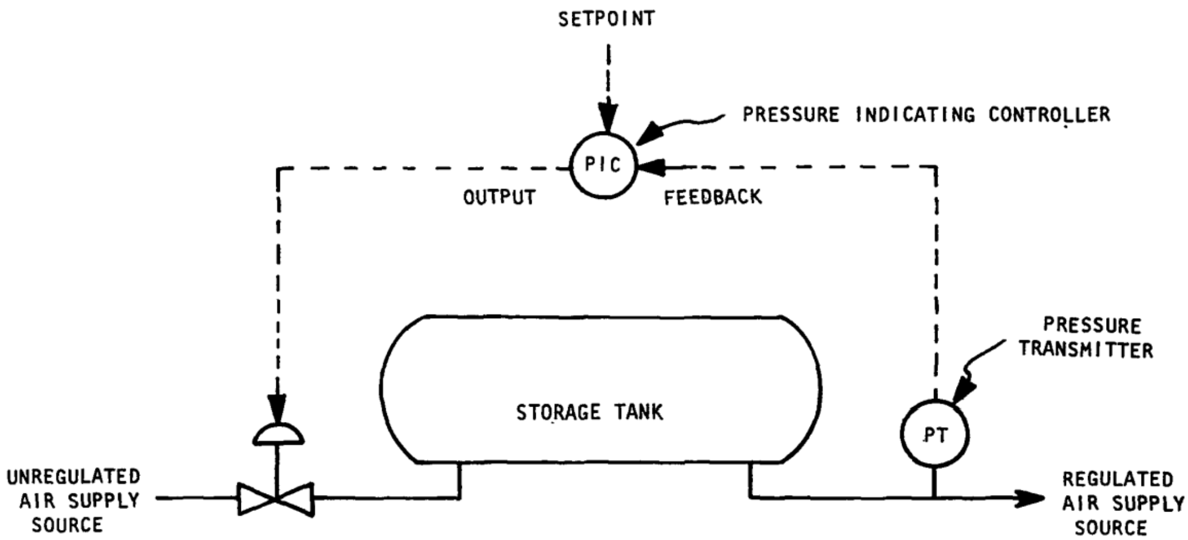


Figure 23: P&ID for a pressure control loop. A controller (PIC) receives pressure transmitter readings (PT) and gives commands to adjust the control valve position to maintain the pressure in the tank outlet pipe.

Source: EPA-600/8-80-028 (Public Domain)

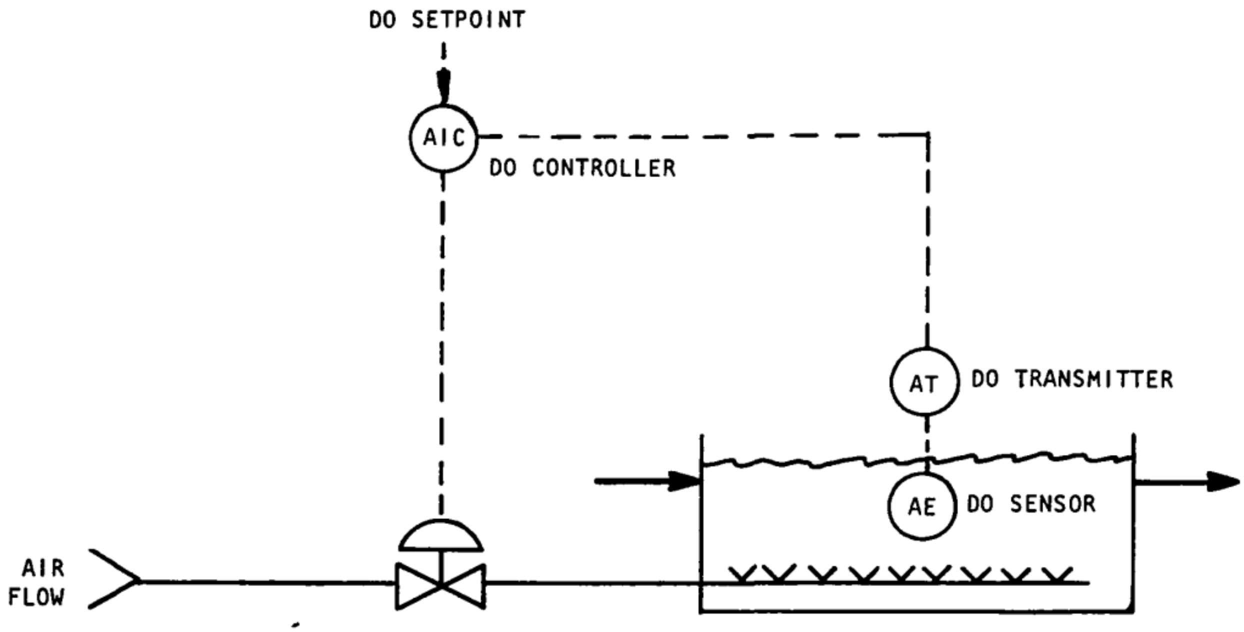


Figure 24: P&ID for a dissolved oxygen control loop. A controller (AIC) receives dissolved oxygen transmitter readings (AT) and gives commands to adjust the control valve position to maintain the dissolved oxygen setpoint in the tank.

Source: EPA-600/8-80-028 (Public Domain)

Piping and Instrumentation Diagrams

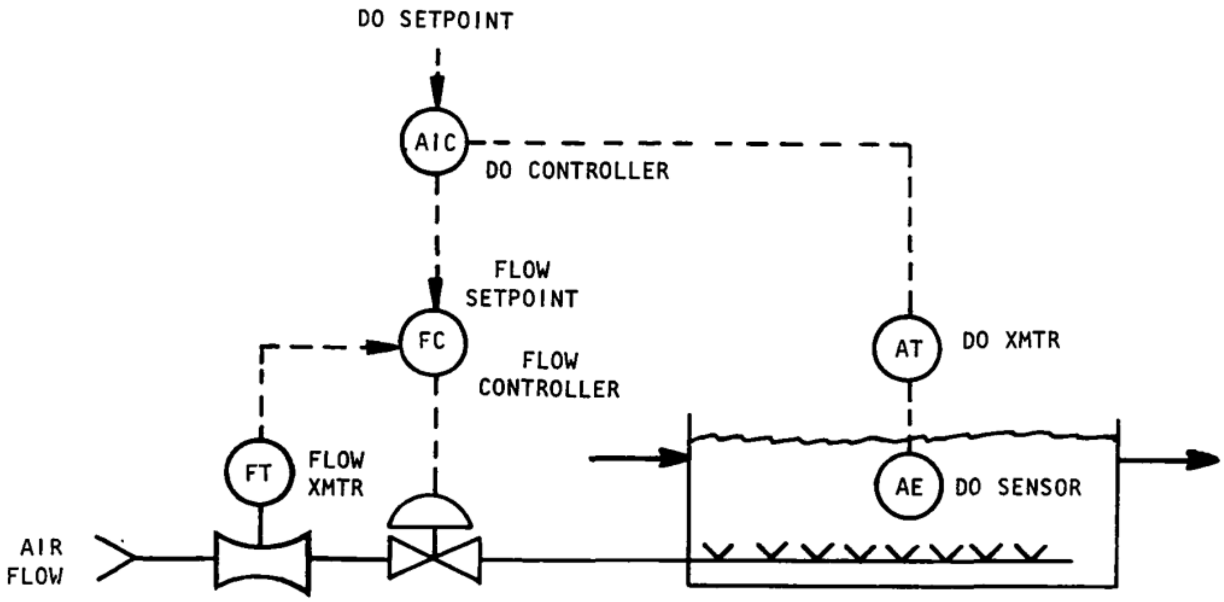


Figure 25: P&ID for a dissolved oxygen control loop with cascade control, meaning there are two controllers. In this case, the dissolved oxygen controller (AIC) provides output to the flow controller (FC), which sends the commands to adjust the valve position. The flow controller takes into account the current air flow rate which helps to avoid overfeeding or underfeeding of air.

Source: EPA-600/8-80-028 (Public Domain)

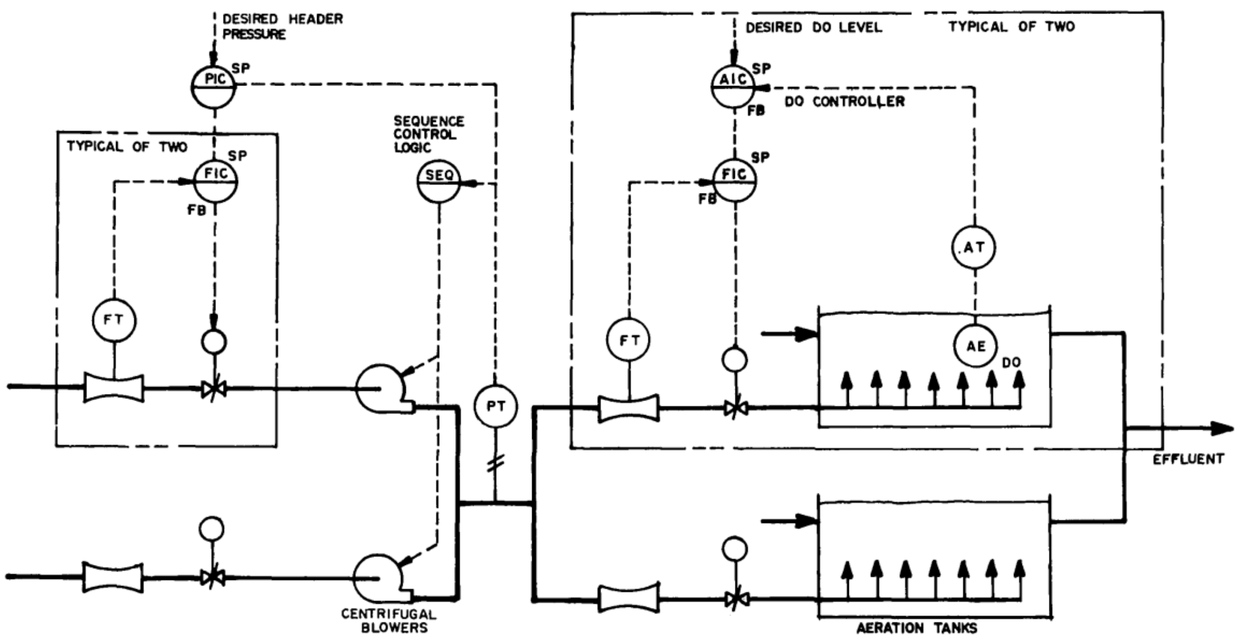


Figure 26: P&ID for a blower speed control loop (left) and a dissolved oxygen control loop (right), both with cascade control. The blower speeds are adjusted based on the inlet and outlet pressures and the air flow rates, with the goal of maintaining the desired header pressure while keeping the blowers within an efficient operating range. The dissolved oxygen control is the same as Figure 25.

Source: EPA-600/8-80-028 (Public Domain)

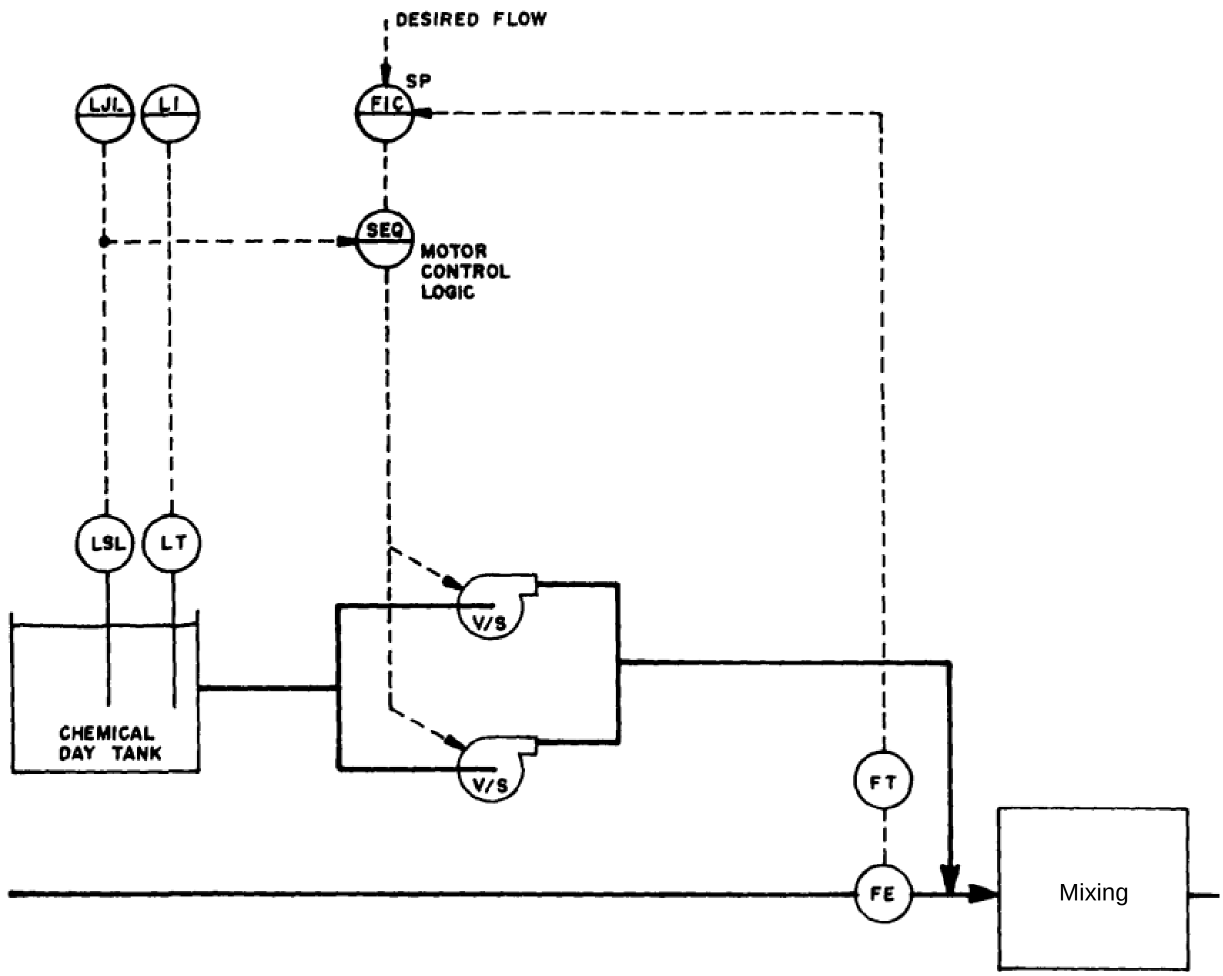


Figure 27: P&ID for a chemical feed control loop. The controller adjusts the chemical pump speed based on the water flow rate readings to achieve a set dosage (5 mg/L for example). This is called flow pacing.

Source: EPA-600/8-80-028 (Public Domain)

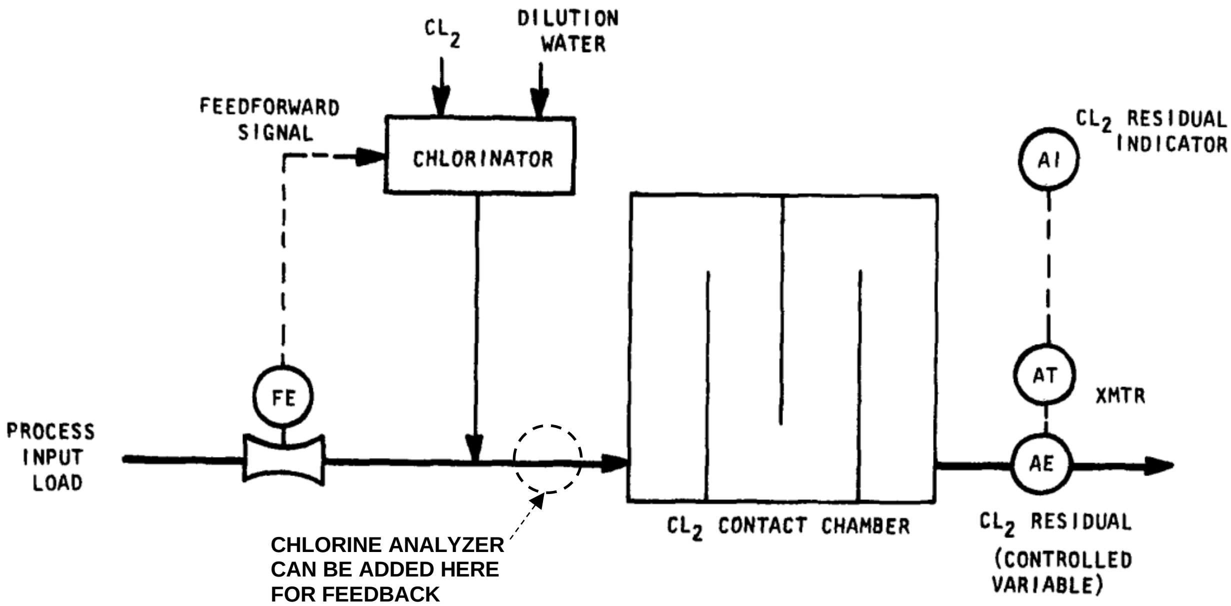


Figure 28: P&ID for a chlorination control loop. The chlorinator feeds chlorine into the process water. Like the controller in Figure 27, the chlorinator adjusts the chlorine feed based on the process flow rate to achieve a set dosage (5 mg/L for example). This is called feedforward control (or ratio control) since the controller only uses upstream readings to control the feed rate.

The chlorine level is measured at the discharge but does not influence the controller. If it were to influence the controller, it would be called feedback control instead of feedforward control, since it uses downstream readings.

A chlorine analyzer can also be added upstream of the contact chamber (shown in dashed) with an additional feedback control for adjusting the chlorine feed.

Source: EPA-600/8-80-028 (Public Domain)

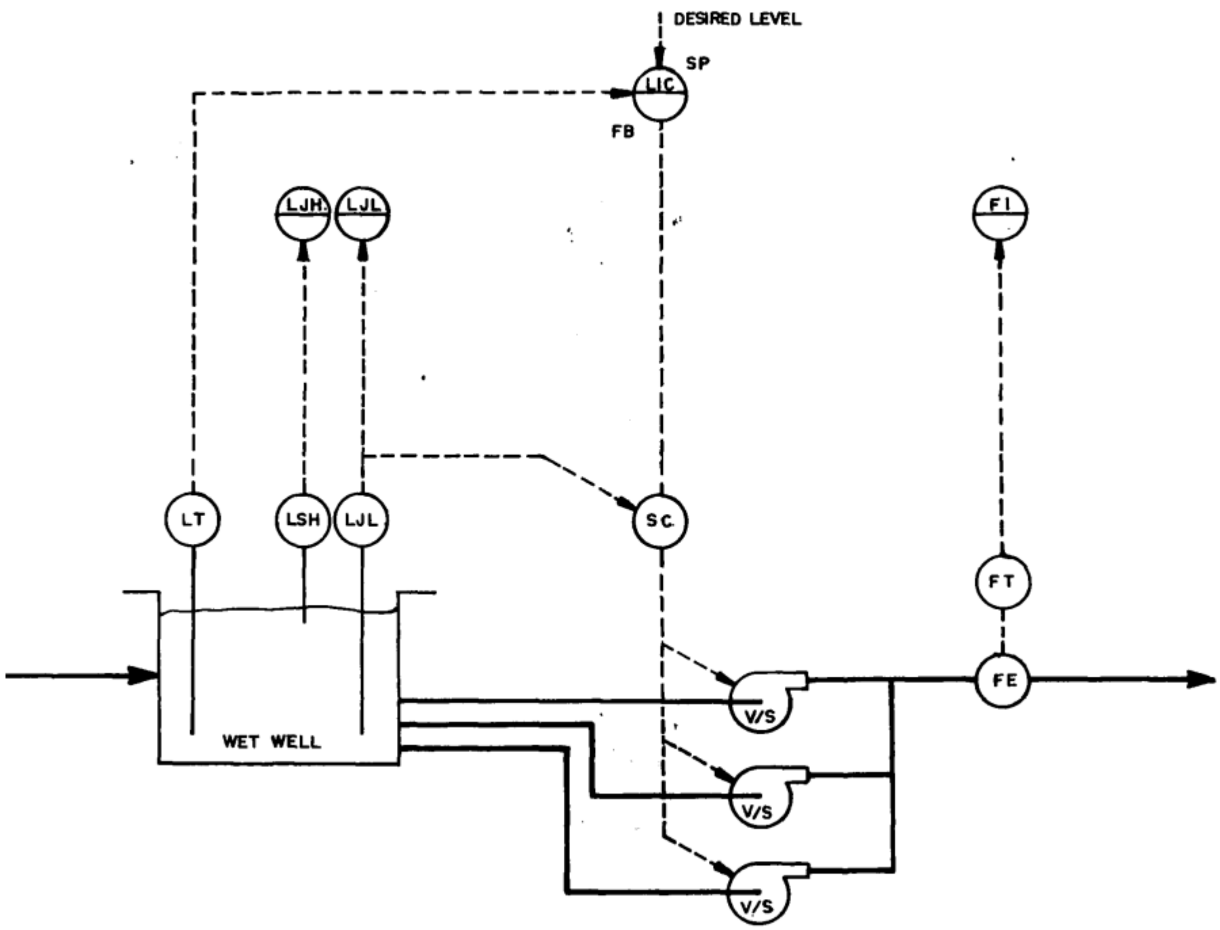


Figure 29: P&ID for a pump station control loop with level control. There is a desired water level in the wet well, which is often a setting on the HMI screen. The number of pumps in operation and the pump speeds are adjusted to maintain the water level. If the high-level switch (LSH) is triggered, pump speeds are increased. If the low-level switch (LJL) is triggered, pumps are turned off. These level switches act as a backup in case the level transmitter (LT) malfunctions. In this case, the flow meter readings are not utilized in the control loop. However, flow readings can be utilized to keep the pumps operating within the efficient operating range.

Source: EPA-600/8-80-028 (Public Domain)

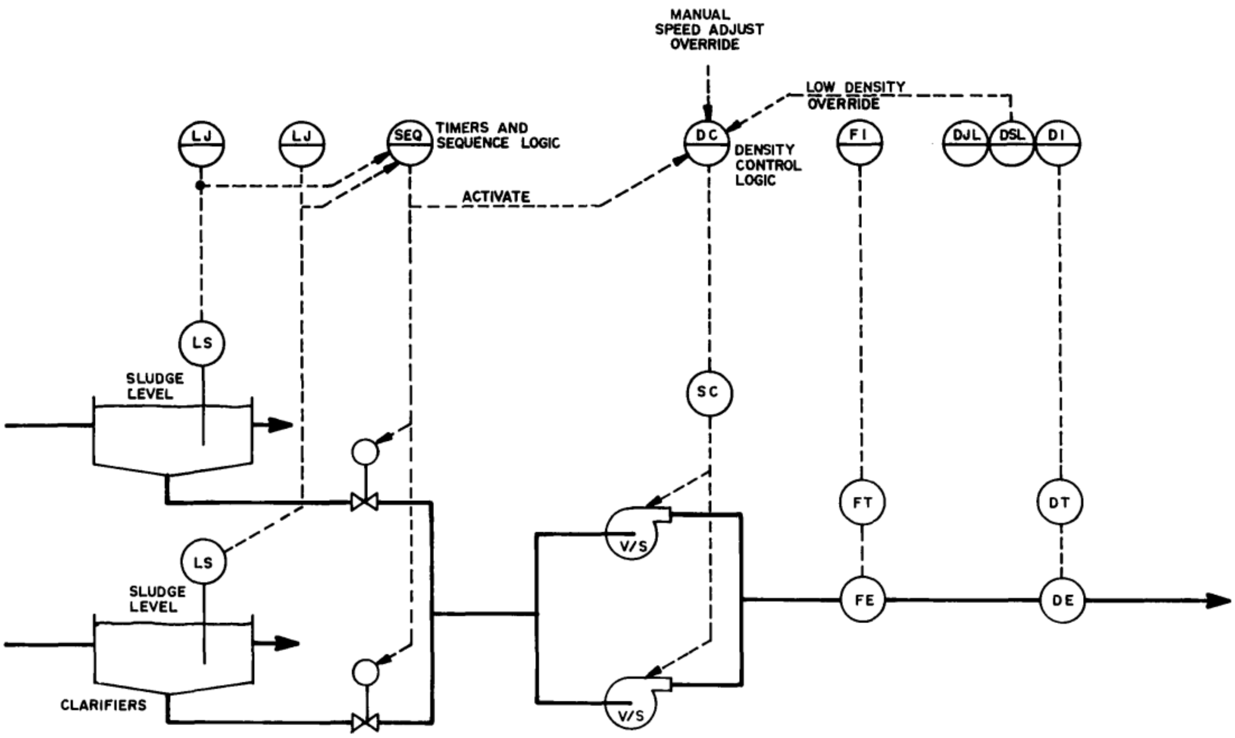


Figure 30: P&ID for a clarifier sludge pumping control loop. Sludge is withdrawn from the bottom of the clarifiers by control valves (by gravity) or with pumps. Often the withdrawal is based on a timer, such as 10 minutes of withdrawal every hour. In this case, the valves will open for 10 minutes, then close for 50 minutes, and repeat. The sludge blanket level (LS) and the sludge density (DE) can be monitored to adjust the timer settings and/or the pump speed.

Source: EPA-600/8-80-028 (Public Domain)

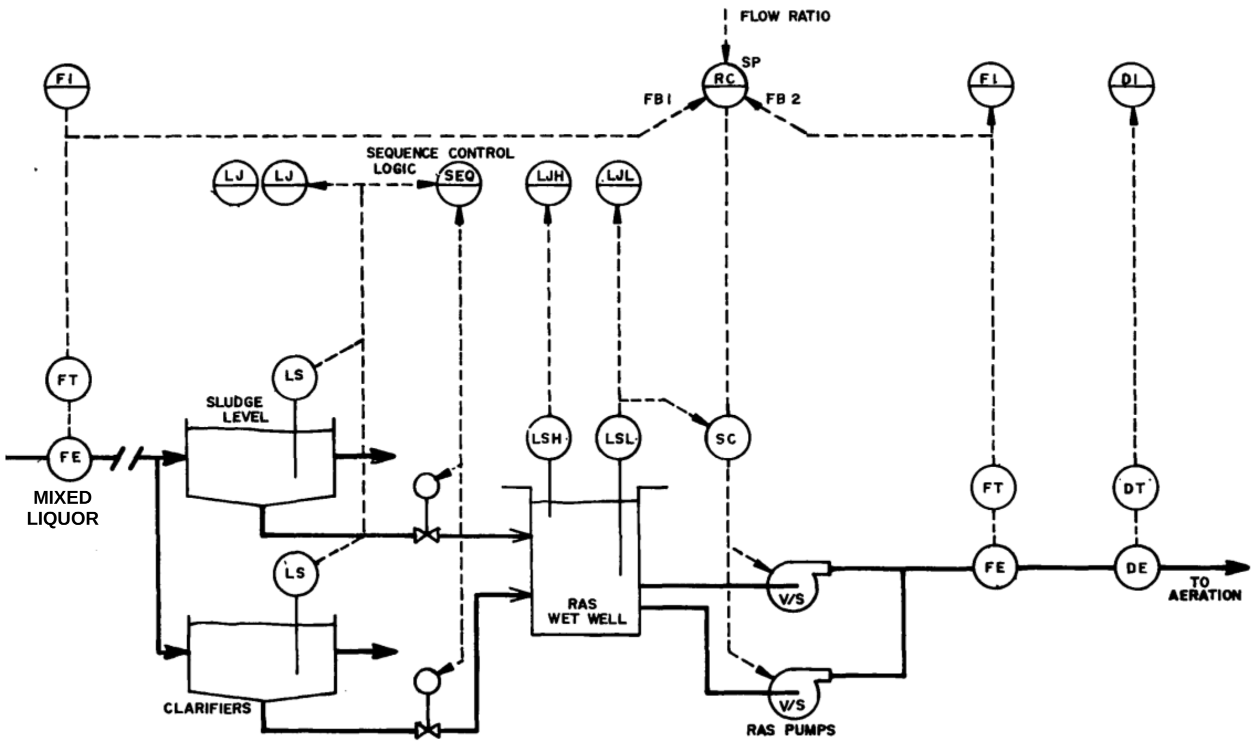


Figure 31: P&ID for a return activated sludge (RAS) pumping control loop. This is similar to Figure 27 with the following additions:

1) The RAS WET WELL collects the sludge by gravity. Sludge flow from the clarifiers is adjusted by the control valves. The wet well has high- and low-level switches (LSH and LSL) for pump control. A level transmitter is common for redundancy.
2) The RAS flow rate should be proportional to the mixed liquor flow, called the flow ratio set point. This ratio is achieved by adjusting the pump speeds.

Source: EPA-600/8-80-028 (Public Domain)

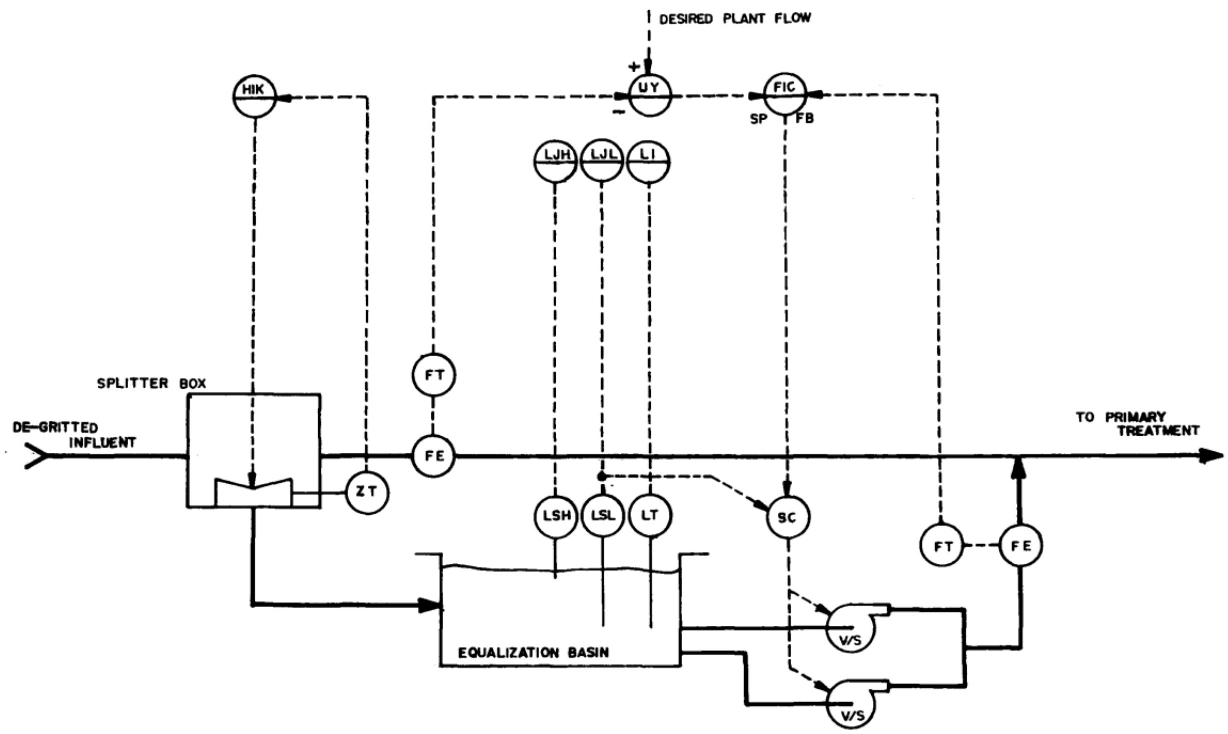


Figure 32: P&ID for a flow equalization control loop. When influent flow rates are higher than average (above desired plant flow), the excess flow is diverted to the equalization basin through an adjustable weir-type slide gate (HIK). A pump or control valve could also be used. When flows are below average, make-up flow is pumped out of the equalization (EQ) basin and mixed with the influent. The goal of the flow controller (FIC) is to maintain a consistent flow rate. The level in the EQ basin needs to be monitored to ensure the basin is brought back to a low level before the next high flow period begins. The volume of equalization needs to be large enough to handle the volume of flow that is in excess of the average flow.

Source: EPA-600/8-80-028 (Public Domain)

Helpful References

American National Standard (2009) “Instrumentation Symbols and Identification”. ANSI/ISA-5.1-2009.

Baldwin, K.M., et al. (2018) “A Novel Framework for Control System Safety Interlock Design and Implementation”. ISA Power Industry Division.

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